

Privacy Act Statement: The filing of this document is required by the Foreign Agents Registration Act of 1938, as amended, 22 U.S.C. § 611 *et seq.*, for the purposes of registration under the Act and public disclosure. Provision of the information requested is mandatory, and failure to provide this information is subject to the penalty and enforcement provisions established in Section 8 of the Act. Every registration statement, short form registration statement, supplemental statement, exhibit, amendment, copy of informational materials or other document or information filed with the Attorney General under this Act is a public record open to public examination, inspection and copying during the posted business hours of the Registration Unit in Washington, DC. Statements are also available online at the Registration Unit's webpage: <http://www.fara.gov/>. One copy of every such document, other than informational materials, is automatically provided to the Secretary of State pursuant to Section 6(b) of the Act, and copies of any and all documents are routinely made available to other agencies, departments and Congress pursuant to Section 6(c) of the Act. The Attorney General also transmits a semi-annual report to Congress on the Administration of the Act which lists the names of all agents registered under the Act and the foreign principals they represent. This report is available to the public in print and online at: <http://www.fara.gov/>.

Public Reporting Burden. Public reporting burden for this collection of information is estimated to average 1.5 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Chief, Registration Unit, Counterespionage Section, National Security Division, U.S. Department of Justice, Washington, DC 20530; and to the Office of Information and Regulatory Affairs, Office of Management and Budget, Washington, DC 20503.

1. Name of Registrant

2. Registration No.

Fenton Communications

5803

3. This amendment is filed to accomplish the following indicated purpose or purposes:

☐ To give a 10-day notice of change in information as required by Section 2(b) of the Act.

☒ To correct a deficiency in

☐ Initial Statement

☒ Supplemental Statement for the period ending October 31, 2007

☐ Other purpose (specify): _____

☐ To give notice of change in an exhibit previously filed.

4. If this amendment requires the filing of a document or documents, please list -

Supplemental Statement attached

5. Each item checked above must be explained below in full detail together with, where appropriate, specific reference to and identity of the item in the registration statement to which it pertains. (If space is insufficient, a full insert page must be used.)

It was brought to our attention that the original supplemental statement filed 12/17/07 was filed for an incorrect period end date. This amendment ~~is~~ is to change that date from 12/31/07 to the correct date of 10/31/07.

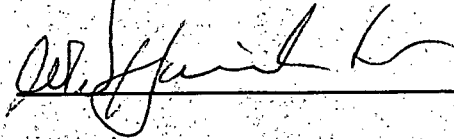
EXECUTION

In accordance with 28 U.S.C. § 1746, the undersigned swear(s) or affirm(s) under penalty of perjury that he/she has (they have) read the information set forth in this registration statement and the attached exhibits and that he/she is (they are) familiar with the contents thereof and that such contents are in their entirety true and accurate to the best of his/her (their) knowledge and belief, except that the undersigned make(s) no representation as to the truth or accuracy of the information contained in the attached Short Form Registration Statement(s), if any, insofar as such information is not within his/her (their) personal knowledge.

(Date of signature)

March 26, 2005

(Type or print name under each signature¹)



William W. Hamilton

¹ This statement shall be signed by the individual agent, if the registrant is an individual, or by a majority of those partners, officers, directors or persons performing similar functions, if the registrant is an organization, except that the organization can, by power of attorney, authorize one or more individuals to execute this statement on its behalf.

For Six Month Period Ending

10/31/07
(insert date)

I - REGISTRANT

1. (a) Name of Registrant

Fenton Communications

(b) Registration No.

5803

(c) Business Address(es) of Registrant

1000 Vermont Ave, NW, Suite 200
Washington, DC 20005

2. Has there been a change in the information previously furnished in connection with the following:

(a) If an individual:

(1) Residence address(es) Yes ☐
(2) Citizenship Yes ☐
(3) Occupation Yes ☐

No ☒
No ☒
No ☒

(b) If an organization:

(1) Name Yes ☐
(2) Ownership or control Yes ☐
(3) Branch offices Yes ☒

No ☒
No ☒
No ☐

(c) Explain fully all changes, if any, indicated in items (a) and (b) above.

Address change from 1320 18th St. NW to
1000 Vermont Ave, NW, Suite 200
Washington, DC 20005

2009 MAR 30 PM 5:18
CRM/ISS/REGISTRATION UNIT

IF THE REGISTRANT IS AN INDIVIDUAL, OMIT RESPONSE TO ITEMS 3, 4 AND 5(a).

3. If you have previously filed Exhibit C¹, state whether any changes therein have occurred during this 6 month reporting period.

Yes ☐ No ☒

If yes, have you filed an amendment to the Exhibit C? Yes ☐ No ☐

If no, please attach the required amendment.

¹ The Exhibit C, for which no printed form is provided, consists of a true copy of the charter, articles of incorporation, association, and by laws of a registrant that is an organization. (A waiver of the requirement to file an Exhibit C may be obtained for good cause upon written application to the Assistant Attorney General, National Security Division, U.S. Department of Justice, Washington, DC 20530.)

4. (a) Have any persons ceased acting as partners, officers, directors or similar officials of the registrant during this 6 month reporting period? Yes ☐ No ☒

If yes, furnish the following information:

Name	Position	Date connection ended
------	----------	-----------------------

- (b) Have any persons become partners, officers, directors or similar officials during this 6 month reporting period? Yes ☐ No ☒

If yes, furnish the following information:

Name	Residence address	Citizenship	Position	Date assumed
------	----------------------	-------------	----------	-----------------

5. (a) Has any person named in item 4(b) rendered services directly in furtherance of the interests of any foreign principal? Yes ☐ No ☒

If yes, identify each such person and describe his service.

- (b) Have any employees or individuals, who have filed a short form registration statement, terminated their employment or connection with the registrant during this 6 month reporting period? Yes ☐ No ☒

If yes, furnish the following information:

Name	Position or connection	Date terminated
------	------------------------	-----------------

- (c) During this 6 month reporting period, has the registrant hired as employees or in any other capacity, any persons who rendered or will render services to the registrant directly in furtherance of the interests of any foreign principal(s) in other than a clerical or secretarial, or in a related or similar capacity? Yes ☐ No ☒

If yes, furnish the following information:

Name	Residence address	Citizenship	Position	Date assumed
------	----------------------	-------------	----------	-----------------

6. Have short form registration statements been filed by all of the persons named in Items 5(a) and 5(c) of the supplemental statement? Yes ☒ No ☐

If no, list names of persons who have not filed the required statement.

II - FOREIGN PRINCIPAL

7. Has your connection with any foreign principal ended during this 6 month reporting period?

Yes ☒ No ☐

If yes, furnish the following information:

Name of foreign principal

Date of termination

Royal Norwegian Embassy

June 7, 2007

8. Have you acquired any new foreign principal² during this 6 month reporting period?

Yes ☐ No ☒

If yes, furnish the following information:

Name and address of foreign principal

Date acquired

9. In addition to those named in Items 7 and 8, if any, list foreign principals² whom you continued to represent during the 6 month reporting period.

Corporacion de Promocion de Exprtacion e Inversiones
(CORPEI) through Foley Hoag, LLP

10. EXHIBITS A AND B

(a) Have you filed for each of the newly acquired foreign principals in Item 8 the following:

Exhibit A³ Yes ☒ No ☐
Exhibit B⁴ Yes ☒ No ☐

If no, please attach the required exhibit.

(b) Have there been any changes in the Exhibits A and B previously filed for any foreign principal whom you represented during the 6 month period? Yes ☐ No ☒

If yes, have you filed an amendment to these exhibits? Yes ☐ No ☐

If no, please attach the required amendment.

² The term "foreign principal" includes, in addition to those defined in Section 1(b) of the Act, an individual organization any of whose activities are directly or indirectly supervised, directed, controlled, financed, or subsidized in whole or in major part by a foreign government, foreign political party, foreign organization or foreign individual. (See Rule 100(a) (9).) A registrant who represents more than one foreign principal is required to list in the statements he files under the Act only those principals for whom he is not entitled to claim exemption under Section 3 of the Act. (See Rule 208.)

³ The Exhibit A, which is filed on Form NSD-3 (Formerly CRM-157), sets forth the information required to be disclosed concerning each foreign principal.

⁴ The Exhibit B, which is filed on Form NSD-4 (Formerly CRM-155), sets forth the information concerning the agreement or understanding between the registrant and the foreign principal.

III - ACTIVITIES

11. During this 6 month reporting period, have you engaged in any activities for or rendered any services to any foreign principal named in Items 7, 8, and 9 of this statement? Yes ☒ No ☐

If yes, identify each such foreign principal and describe in full detail your activities and services:

Royal Norwegian Embassy - media relations ending June 7, 2008
CORPEI - media relations

Embassy of the Republic of Bolivia (ERB) - Activities for this foreign principal did not occur during this period, but rather in the six month period ending April 30, 2008.

12. During this 6 month reporting period, have you on behalf of any foreign principal engaged in political activity⁵ as defined below? Yes ☒ No ☐

If yes, identify each such foreign principal and describe in full detail all such political activity, indicating, among other things, the relations, interests and policies sought to be influenced and the means employed to achieve this purpose. If the registrant arranged, sponsored or delivered speeches, lectures or radio and TV broadcasts, give details as to dates and places of delivery, names of speakers and subject matter.

CORPEI - See Attached

Royal Norwegian Embassy - See Attached

13. In addition to the above described activities, if any, have you engaged in activity on your own behalf which benefits any or all of your foreign principals? Yes ☐ No ☒

If yes, describe fully.

⁵ The term "political activities" means any activity that the person engaging in believes will, or that the person intends to, in any way influence any agency or official of the Government of the United States or any section of the public within the United States with reference to formulating, adopting or changing the domestic or foreign policies of the United States or with reference to the political or public interests, policies, or relations of a government of a foreign country or a foreign political party.

IV - FINANCIAL INFORMATION

14. (a) RECEIPTS - MONIES

During this 6 month reporting period, have you received from any foreign principal named in Items 7, 8, or 9 of this statement, or from any other source, for or in the interests of any such foreign principal, any contributions, income or money either as compensation or otherwise? Yes ☒ No ☐

If no, explain why.

If yes, set forth below in the required detail and separately for each foreign principal an account of such monies⁶.

Date	From whom	Purpose	Amount
6/1/07	Royal Norwegian Embassy	Communication Services	\$10,000
5/4/07	Foley Hoag, LLP	Communication Services	\$10,000
5/4/07	Foley Hoag, LLP	Communication Services	\$20,000
6/10/07	Foley Hoag, LLP	Graphic Design & Ad Placement	\$77,421
6/30/07	Foley Hoag, LLP	Communication Services	\$20,000
10/31/07	Foley Hoag, LLP	Communication Services	\$122,500
		Total	\$359,921.00

(b) RECEIPTS - FUND RAISING CAMPAIGN

During this 6 month reporting period, have you received, as part of a fund raising campaign⁷, any money on behalf of any foreign principal named in items 7, 8, or 9 of this statement? Yes ☐ No ☒

If yes, have you filed an Exhibit D⁸ to your registration? Yes ☐ No ☐

If yes, indicate the date the Exhibit D was filed. Date _____

(c) RECEIPTS - THINGS OF VALUE

During this 6 month reporting period, have you received any thing of value⁹ other than money from any foreign principal named in Items 7, 8, or 9 of this statement, or from any other source, for or in the interests of any such foreign principal?

Yes ☐ No ☒

If yes, furnish the following information:

Name of foreign principal	Date received	Description of thing of value	Purpose
---------------------------	---------------	-------------------------------	---------

6, 7 A registrant is required to file an Exhibit D if he collects or receives contributions, loans, money, or other things of value for a foreign principal, as part of a fund raising campaign. (See Rule 201(e).)

8 An Exhibit D, for which no printed form is provided, sets forth an account of money collected or received as a result of a fund raising campaign and transmitted for a foreign principal.

9 Things of value include but are not limited to gifts, interest free loans, expense free travel, favored stock purchases, exclusive rights, favored treatment over competitors, "kickbacks," and the like.

15. (a) **DISBURSEMENTS - MONIES**

During this 6 month reporting period, have you

(1) disbursed or expended monies in connection with activity on behalf of any foreign principal named in Items 7, 8, or 9 of this statement? Yes ☒ No ☐(2) transmitted monies to any such foreign principal? Yes ☐ No ☒

If no, explain in full detail why there were no disbursements made on behalf of any foreign principal.

If yes, set forth below in the required detail and separately for each foreign principal an account of such monies, including monies transmitted, if any, to each foreign principal.

Date	To whom	Purpose	Amount
------	---------	---------	--------

CORPEI - See attached invoices

Royal Norwegian Embassy - No disbursements were made on behalf of this foreign principal, as it was not necessary for the project.

Approximately \$55,480.⁰⁰
Total

(b) DISBURSEMENTS - THINGS OF VALUE

During this 6 month reporting period, have you disposed of anything of value¹⁰ other than money in furtherance of or in connection with activities on behalf of any foreign principal named in Items 7, 8, or 9 of this statement?

Yes ☐No ☒

If yes, furnish the following information:

Date disposed	Name of person to whom given	On behalf of what foreign principal	Description of thing of value	Purpose
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(c) DISBURSEMENTS - POLITICAL CONTRIBUTIONS

During this 6 month reporting period, have you from your own funds and on your own behalf either directly or through any other person, made any contributions of money or other things of value¹¹ in connection with an election to any political office, or in connection with any primary election, convention, or caucus held to select candidates for political office?

Yes ☐No ☒

If yes, furnish the following information:

Date	Amount or thing of value	Name of political organization	Name of candidate
------	--------------------------	--------------------------------	-------------------

^{10, 11} Things of value include but are not limited to gifts, interest free loans, expense free travel, favored stock purchases, exclusive rights, favored treatment over competitors, "kickbacks" and the like.

V - INFORMATIONAL MATERIALS

16. During this 6 month reporting period, did you prepare, disseminate or cause to be disseminated any informational materials¹²?
 Yes ☒ No ☐

IF YES, RESPOND TO THE REMAINING ITEMS IN SECTION V.

17. Identify each such foreign principal.

Royal Norwegian Embassy
 CORPEI

*Materials attached

18. During this 6 month reporting period, has any foreign principal established a budget or allocated a specified sum of money to finance your activities in preparing or disseminating informational materials? Yes ☐ No ☐

If yes, identify each such foreign principal, specify amount, and indicate for what period of time.

Royal Norwegian Embassy - Contract was for \$10,000 5/24/07 - 6/7/1
 CORPEI - Contract for \$20,000/month, plus expenses 4/16/07 - 6/30

19. During this 6 month reporting period, did your activities in preparing, disseminating or causing the dissemination of informational materials include the use of any of the following:

- | | | | |
|---|--|---|---|
| ☐ Radio or TV broadcasts | ☒ Magazine or newspaper articles | ☐ Motion picture films | ☐ Letters or telegrams |
| ☒ Advertising campaigns | ☒ Press releases | ☒ Pamphlets or other publications | ☐ Lectures or speeches |
| ☒ Internet | ☐ Other (specify) _____ | | |

20. During this 6 month reporting period, did you disseminate or cause to be disseminated informational materials among any of the following groups:

- | | | |
|---|---|---|
| ☐ Public officials | ☒ Newspapers | ☐ Libraries |
| ☒ Legislators | ☒ Editors | ☐ Educational institutions |
| ☐ Government agencies | ☐ Civic groups or associations | ☐ Nationality groups |
| ☐ Other (specify) _____ | | |

21. What language was used in the informational materials:

☒ English

☒ Other (specify)

Spanish

22. Did you file with the Registration Unit, U.S. Department of Justice a copy of each item of such informational materials disseminated or caused to be disseminated during this 6 month reporting period? Yes ☐ No ☒

*Please see attached materials

23. Did you label each item of such informational materials with the statement required by Section 4(b) of the Act? Yes ☐ No ☒

¹² The term informational materials includes any oral, visual, graphic, written, or pictorial information or matter of any kind, including that published by means of advertising, books, periodicals, newspapers, lectures, broadcasts, motion pictures, or any means or instrumentality of interstate or foreign commerce or otherwise. Informational materials disseminated by an agent of a foreign principal as part of an activity in itself exempt from registration, or an activity which by itself would not require registration, need not be filed pursuant to Section 4(b) of the Act.

VI - EXECUTION

In accordance with 28 U.S.C. §1746, the undersigned swear(s) or affirm(s) under penalty of perjury that he/she has (they have) read the information set forth in this registration statement and the attached exhibits and that he/she is (they are) familiar with the contents thereof and that such contents are in their entirety true and accurate to the best of his/her (their) knowledge and belief, except that the undersigned make(s) no representation as to the truth or accuracy of the information contained in the attached Short Form Registration Statement(s), if any, insofar as such information is not within his/her (their) personal knowledge.

(Date of signature)

(Type or print name under each signature¹³)

Mar 23, 2009

William W. Hamilton Jr

2009 MAR 30 PM 5:18
CRM/ISS/REGISTRATION UNIT

¹³ This statement shall be signed by the individual agent, if the registrant is an individual, or by a majority of those partners, officers, directors or persons performing similar functions, if the registrant is an organization, except that the organization can, by power of attorney, authorize one or more individuals to execute this statement on its behalf.

Supplemental Statement

Section III – Activities

12. Norwegian Royal Embassy: Fenton Communications was engaged by the Norwegian Embassy to provide communications strategy and public relations outreach around World Environment Day 2007. Fenton conducted media outreach promoting an event held on June 5, 2007 at 1 PM at the National Geographic Headquarters (17th and M Streets, NW in Washington, DC) that featured: 1) the public release of an analysis showing the extent of melting ice caused by climate change; 2) insights from the Norwegian government as it has struggled first hand with the impacts of climate change; and 3) the personal experience of world-famous polar explorers Liv Arnesen and Will Steger, who discussed melting ice at the top of the world. The event also featured Bill Mansfield, United Nations Environment Program; Dr. Robert Corell, Global Change Director, The H. John Heinz III Center for Science, Economics and the Environment; Terry D. Garcia, Executive Vice President, National Geographic Society; and Michael Rosenfeld, President of National Geographic Television. It was followed by an afternoon of panel discussions on climate change.

CORPEI: We were hired to design a communications strategy to promote the renewal of the Andean Trade Preferences and Drug Eradication Act (ATPDEA) by the U.S. Congress. We did this through a series of media briefings, individual interviews for Ecuadorean businesspeople and government officials, paid advertising and the distribution of fact sheets on the positive aspects of the trade agreement for both countries.

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FOR CORPEL

MEDIA SIGN-IN SHEET:

Foreign Minister Espinosa and CORPEI Investors- 6-7-07

[illegible]

MEDIA SIGN-IN SHEET:
Attorney General Garaicoa – ICSID-10-25-07

[illegible]

Congressional Contacts on behalf of CORPEI

DATE	NAME/OFFICE/POSITION	METHOD	TOPIC	Client
27-Jun-07	Daniel Brito, Office of Congressman Raul Grijalva (D-AZ), Legislative Assistant	email	ATPDEA	CORPEI
1-Jun-07	Chelsea Thomas, Senate Finance Committee, Democratic Staffer	email	ATPDEA	CORPEI
1-Jun-07	Chris Slevin, Office of Senator Sherrod Brown (D-OH), Legislative Assistant	email	ATPDEA	CORPEI
27-Jun-07	Daniel Brito, Office of Congressman Raul Grijalva (D-AZ), Legislative Assistant	email	ATPDEA vote timing	CORPEI
27-Jun-07	Daniel Brito, Office of Congressman Raul Grijalva (D-AZ), Legislative Assistant	email	ATPDEA	CORPEI
22-Jun-07	Daniel Brito, Office of Congressman Raul Grijalva (D-AZ), Legislative Assistant	email	AP article	CORPEI
12-Jun-07	Peter Quilter, House of Representatives Committee on Foreign Relations, Democratic	email	ATPDEA	CORPEI
13-Jun-07	Chris Slevin, Office of Senator Sherrod Brown (D-OH), Legislative Assistant	email	ATPDEA	CORPEI
25-Jun-07	Alan Tennille, Office of (former) Congressman Jerry Weller (R-IL), Legislative Director	email	op-ed timing	CORPEI

Supplemental Statement

Section IV – Financial Information

15. (a) Detailed invoices attached for disbursements made on behalf of CORPEI.

2009 MAR 30 PM 5:18
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FENTON COMMUNICATIONS

1320 18th Street, NW, 5th Floor • Washington, DC 20036

TEL: (202) 822-5200 • FAX: (202) 822-4787

INVOICE

Invoice Number: 4-17556

Invoice Date: 08/20/07

Page: 1

Bill To: Foley Hoag, LLP
Attn: Paul Reichler
1875 K Street NW
Suite 800
Washington, DC 20006

For Job G/Ecuador Ad (6-00313)

Expenses

Photography & Design

630.00

Subtotal Expenses	630.00
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Total Fees	0.00
Total Expenses:	630.00
Total Due:	630.00

Balance Due is Payable by: 09/19/07

Please remit payment to:

Fenton Communications, Inc.
1320 18th Street, NW
5th Floor
Washington, DC 20036

ATTN: Accounts Receivables

Job Billable Expenses Detail

Fenton Communications, Inc.

Account Manager: 3-01156

Job: No.: 6-00313, Date Filter: 06/01/07..06/30/07

August 20, 2007 2:49 PM

Page 1

JAC

6-00313 G/Ecuador Ad

G/L Acct #	Trx Date	Vendor Name	Invoice No.	Description	Total Price
70120		Photography & Design			
	06/25/07	American Express 1009 B	11009-JUN/07ADJ	GettyImages, Immigration Ad Photo S.Bodiker6/11/	630.00
		Subtotal	Photography & Design		630.00
		Report Total			<u>630.00</u>

Fenton Communications, Inc.

Page 1

JAC

Invoice U 4-18515

Ship-to Code

Ship-to

Foley Hoag, LLP

Attn: Paul Reichler

1875 K Street NW

Suite 800

Washington, DC 20006

Salesperson Code WILLIAM

Cust./Item Disc. Gr.

Payment Terms Code	30
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Document Date 08/20/07

Posting Date 08/20/07

Tax Liab No

Tax Area Code

Type	No.	Description	Departm Code	Project Code	Job No.	Unit Price	Amount
Account (G/L)	70120	Photography & Design	DC	5-10150	6-00313	630.00	630.00
					Total		630.00
					Tax Amount		0.00
					Total Incl. Tax		630.00

FENTON COMMUNICATIONS

1320 18th Street, NW 5th Floor ■ Washington, DC 20036

TEL: (202) 822-5200 ■ FAX: (202) 822-4787

INVOICE

Invoice Number: 4-17258

Invoice Date: 08/02/07

Page: 1

Bill To: Foley Hoag, LLP
Attn: Paul Reichler
1875 K Street NW
Suite 800
Washington, DC 20006

For Job Ecuador (5-20997)

Expenses

Meeting / Press Conferences	544.71
Courier / Messenger Services	10.29
Copies	23.79
Local Travel	182.00
Electronic News Service	7.95
Miscellaneous Billable	1.48

Subtotal Expenses 770.22

Total Fees	0.00
Total Expenses:	770.22
Total Due:	770.22

Balance Due is Payable by: 09/01/07

Please remit payment to:

Fenton Communications, Inc.
1320 18th Street, NW
5th Floor
Washington, DC 20036

ATTN: Accounts Receivables

08/07/07

Job Billable Expenses Detail

Fenton Communications, Inc.

Account Manager: 3-01103

July 31, 2007 1:11 PM

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JAC

5-20997 Ecuador

G/L Acct #	Trx Date	Vendor Name	Invoice No.	Description	Total Price
80125	Meeting / Press Conferences				
	06/15/07	Connex International	354043	Conference call P.Favian 06/07/07 12.00pm	355.64
	06/25/07	American Express EV	23008-JUN/07	Cosi ,Ecudor Press Breafast 6/7/07 P.Fabian	189.07
			Subtotal	Meeting / Press Conferences	544.71
80130	Courier / Messenger Services				
	06/30/07	Apple Courier	151704	Apple Courier 1	10.29
			Subtotal	Courier / Messenger Services	10.29
80140	Copies				
	06/20/07	Rosario Rivera - Petty cash	062007	Newsroom, copies for Roll Call-CORPEI Ad 6/14/0	23.79
			Subtotal	Copies	23.79
80160	Local Travel				
	06/20/07	Rosario Rivera - Petty cash	062007	Taxis (7) T.Gerson,P. Favian 6/13 & 14/07	76.00
	06/26/07	William Hamilton J.	062607	Taxi & Parking 5/4 &18/07	28.00
	06/30/07	Timothy K. Gerson	063007	Taxis (5) 6/14-6/27/07	78.00
			Subtotal	Local Travel	182.00
80185	Electronic News Service				
	06/25/07	American Express 1009 B	11009-JUN/07	Paypal, A.Sobel Foreign Policy Mag. Article 6/18/0	7.95
			Subtotal	Electronic News Service	7.95
80950	Miscellaneous Billable				
	06/30/07	Abby Brabec	063007	Newspaper for client T.Olumide 6/22/07	1.48
			Subtotal	Miscellaneous Billable	1.48

Report Total 770.22

Invoice U 4-18239

Sell-to Customer No. 2-27036

Ship-to Code

Sell-to

Foley Hoag, LLP
Attn: Paul Reichler
1875 K Street NW
Suite 800
Washington, DC 20006

Ship-to

Foley Hoag, LLP
Attn: Paul Reichler
1875 K Street NW
Suite 800
Washington, DC 20006

Your Reference

Customer Posting Group DC

Payment Terms Code 30
Due Date 09/01/07
Pmt. Discount Date 08/02/07
Payment Discount % 0
Payment Method Code
Shipment Method Code

Salesperson Code WILLIAM

Cust./Item Disc. Gr.
Invoice Disc. Code 2-27036

Document Date 08/02/07
Posting Date 06/30/07
Tax Liable No
Tax Area Code

Type	No.	Description	Departm Code	Project Code	Job No.	Unit Price	Amount
Account (G/L)	80125	Meeting / Press Conferences	DC	5-10125	5-20997	272.355	544.71
Account (G/L)	80130	Courier / Messenger Services	DC	5-10125	5-20997	10.29	10.29
Account (G/L)	80140	Copies	DC	5-10125	5-20997	23.79	23.79
Account (G/L)	80160	Local Travel	DC	5-10125	5-20997	60.66667	182.00
Account (G/L)	80185	Electronic News Service	DC	5-10125	5-20997	7.95	7.95
Account (G/L)	80950	Miscellaneous Billable	DC	5-10125	5-20997	1.48	1.48
						Total	770.22
						Tax Amount	0.00
						Total Incl. Tax	770.22

INSERTION ORDER – PLEASE CONFIRM RECEIPT BY RETURN EMAIL

TO: Jenna Golden, 202-266-7163, jgolden@nationaljournal.com

FROM: Abby Brabec, Fenton Communications, abrabec@fenton.com

PUBLICATION: Congress Daily

CLIENT: CORPEI

BILLING ADDRESS: Fenton Communications
1320 18th Street NW #500
Washington, DC 20036
202-822-5200

FENTON PROJECT NUMBER: 6-00313

SIZE: Full Page, Full Color – No Bleed

LOCATION: Right Hand Page, Far Forward

RUN DATE: Wednesday, June 20 and Monday, June 25

CHECK DATES: Upon Receipt of Invoice

PRICE: \$16,150.00 net grand total (\$19,000.00 gross grand total)

NOTE: Please mail tear sheets to billing address.

#

INSERTION ORDER – PLEASE CONFIRM RECEIPT BY RETURN EMAIL

TO: Alison Friedrich, (202) 628-8563, afriedrich@thehill.com

FROM: Abby Brabec, Fenton Communications, abrabec@fenton.com

PUBLICATION: The Hill

CLIENT: CORPEI

BILLING ADDRESS: Fenton Communications
1320 18th Street NW #500
Washington, DC 20036
202-822-5200

FENTON PROJECT NUMBER: 6-00313

SIZE: Full Page, Full Color – No Bleed (10" x 13 1/2")

LOCATION: Directly across from Sen. Grassley's Trade Report

RUN DATE: June 20, 2007

MATERIAL CLOSING: Please use ad from previous run on 6/14

CHECK DATES: Upon Receipt of Invoice

PRICE: \$8,381.00 net (\$9,860.00 gross)

NOTE: Please mail tear sheets to billing address.

#

INSERTION ORDER – PLEASE CONFIRM RECEIPT BY RETURN EMAIL

TO: Madonna Overby, 202-824-6818, madonnaoverby@rollcall.com

FROM: Abby Brabec, Fenton Communications, abrabec@fenton.com

PUBLICATION: Roll Call

CLIENT: CORPEI

BILLING ADDRESS: Fenton Communications
1320 18th Street NW #500
Washington, DC 20036
202-822-5200

FENTON PROJECT NUMBER: 6-00313

SIZE: Full Page, Full Color – No Bleed (9 7/8" x 14")

LOCATION: Right Hand Page, Far Forward

RUN DATE: June 20, 2007 (Second run of ad from June 14)

CHECK DATES: Upon Receipt of Invoice

PRICE: \$10,144.75 net (\$11,935.00 gross)

NOTE: Please mail tear sheets to billing address.

#

FENTON COMMUNICATIONS

1320 18th Street, NW 5th Floor ■ Washington, DC 20036

TEL: 202/522-5200 ■ FAX: 202/522-4787

INVOICE

Invoice Number: 4-16948

Invoice Date: 06/19/07

Page: 1

Bill To: Foley Hoag, LLP

Attn: Paul Reichler

1875 K Street NW

Suite 800

Washington, DC 20006

For Job Ecuador (5-20997)

Expenses

Publications

203.69

Meeting / Press Conferences

6.27

Local Travel

83.00

* Meals *Press breakfast - sign in sheet included in*

291.50

section III.

Subtotal Expenses

584.46

Total Fees 0.00
Total Expenses: 584.46

Total Due: 584.46

Balance Due is Payable by: 07/19/07

Please remit payment to:

Fenton Communications, Inc.

1320 18th Street, NW

5th Floor

Washington, DC 20036

ATTN: Accounts Receivables

07/23/07
N

Job Billable Expenses Detail

Fenton Communications, Inc.

Account Manager: 3-01103

June 14, 2007 4:59 PM

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RER

5-20997 Ecuador

G/L Acct #	Trx Date	Vendor Name	Invoice No.	Description	Total Price
80110	Magazines				
	05/26/07	American Express EV	23008-MAY/07	EV Financial Times, Online subscription 5/12/07	203.69
			Subtotal	Magazines	203.69
80125	Meeting / Press Conferences				
	05/21/07	Connex International	340657	Conference call T.Gerson 5/18/07 1200pm	6.27
			Subtotal	Meeting / Press Conferences	6.27
80160	Local Travel				
	05/31/07	Rosario Rivera - Petty cash	053107	Taxis (1) P.Favian 5/24/07	12.00
	05/18/07	Rosario Rivera - Petty cash	051807-1	Taxi (6)P.Favian/T.Gerson/ Mtg. 5/1,4 & 8/07	58.00
	05/31/07	William Hamilton J.	060707	Taxi to Mtg. Ecuador's Ambassador 5/29/07	13.00
			Subtotal	Local Travel	83.00
80220	Meals				
	05/26/07	American Express EV	23008-MAY/07	Old Evvitt Grill., Deposit Svcs.Breakfast, 5/2/07	100.00
	05/26/07	American Express EV	23008-MAY/07	Old Evvitt Grill., Balance/Svcs.Breakfast, 5/2/07	191.50
			Subtotal	Meals	291.50
				Report Total	584.46

Fenton Communications, Inc.

June 15, 2007 11:20 AM

Page 30

RER

Invoice U 4-17928

Sell-to Customer No. 2-27036

Ship-to Code

Sell-to

Foley Hoag, LLP

Attn: Paul Reichler

1875 K Street NW

Suite 800

Washington, DC 20006

Ship-to

Foley Hoag, LLP

Attn: Paul Reichler

1875 K Street NW

Suite 800

Washington, DC 20006

Your Reference

Salesperson Code WILLIAM

Customer Posting Group DC

Cust./Item Disc. Gr.

Payment Terms Code 30

Invoice Disc. Code 2-27036

Due Date 07/18/07

Document Date 06/18/07

Pmt. Discount Date	06/18/07
--------------------	----------

Posting Date 05/31/07

Payment Discount %	0
--------------------	---

Tax Liab. No

Payment Method Code

Tax Area Code

Shipment Method Code

Type	No.	Description	Departm Code	Project Code	Job No.	Unit Price	Amount
Account (G/L)	80110	Magazines	DC	5-10125	5-20997	203.69	203.69
Account (G/L)	80125	Meeting / Press Conferences	DC	5-10125	5-20997	6.27	6.27
Account (G/L)	80160	Local Travel	DC	5-10125	5-20997	27.66667	83.00
Account (G/L)	80220	Meals	DC	5-10125	5-20997	145.75	291.50
					Total		584.46
					Tax Amount		0.00
					Total Incl. Tax		584.46

INSERTION ORDER – PLEASE CONFIRM RECEIPT BY RETURN EMAIL

TO: Beth Tray, 202-628-8519, btray@thehill.com

FROM: Abby Brabec, Fenton Communications, abrabec@fenton.com

PUBLICATION: The Hill

CLIENT: CORPEI

BILLING ADDRESS: Fenton Communications
1320 18th Street NW #500
Washington, DC 20036
202-822-5200

FENTON PROJECT NUMBER: 6-00313

SIZE: Full Page, Full Color – No Bleed (10" x 13 1/2")

LOCATION: Right Hand Page, Far Forward

RUN DATE: June 14, 2007

MATERIAL CLOSING: June 13 by NOON

CHECK DATES: Upon Receipt of Invoice

PRICE: \$8,381.00 net (\$9,860.00 gross)

NOTE: Please mail tear sheets to billing address.

#

INSERTION ORDER – PLEASE CONFIRM RECEIPT BY RETURN EMAIL

TO: Eric Richardson, 202-824-6815, ecr@rollcall.com

FROM: Abby Brabec, Fenton Communications, abrabec@fenton.com

PUBLICATION: Roll Call

CLIENT: CORPEI

BILLING ADDRESS: Fenton Communications
1320 18th Street NW #500
Washington, DC 20036
202-822-5200

FENTON PROJECT NUMBER: 6-00313

SIZE: Full Page, Full Color – No Bleed (9 7/8" x 14")

LOCATION: Right Hand Page, Far Forward

RUN DATE: June 14, 2007

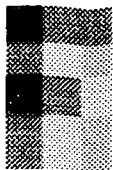
MATERIAL CLOSING: June 13 by NOON

CHECK DATES: Upon Receipt of Invoice

PRICE: \$10,144.75 net (\$11,935.00 gross)

NOTE: Please mail tear sheets to billing address.

#



FENTON COMMUNICATIONS

1320 18th Street, NW, 5th Floor • Washington, DC 20036

TEL: (202) 822-5200 • FAX: (202) 822-4787

INVOICE

Invoice Number: 4-16639

Invoice Date: 05/17/07

Page: 1

Bill To: Foley Hoag, LLP
Attn: Paul Reichler
1875 K Street NW
Suite 800
Washington, DC 20006

For Job Ecuador (5-20997)

Expenses

Publications
Local Travel
Internet Services

52.77

41.00

200.00

Subtotal Expenses

293.77

Total Fees 0.00

Total Expenses: 293.77

Total Due: 293.77

Balance Due is Payable by: 06/16/07

Please remit payment to:

Fenton Communications, Inc.
1320 18th Street, NW
5th Floor
Washington, DC 20036

ATTN: Accounts Receivables

ns/20k

Job Billable Expenses Detail
Fenton Communications, Inc.
Account Manager: 3-01103

May 11, 2007 2:42 PM
Page 75
RER

5-20997 Ecuador

G/L Acct #	Trx Date	Vendor Name	Invoice No.	Description	Total Price
80110	Magazines				
	04/26/07	American Express EV	23008-APR/07	The Ecomista, subscription 4/26/07	52.77
			Subtotal	Magazines	52.77
80160	Local Travel				
	04/30/07	William Hamilton J.	043007	Taxi (2) Ecuador's Embassy 4/25/07	29.00
	04/30/07	William Hamilton J.	043007	Taxi (1) to Lawyers office to meet Procurador 4/3	12.00
			Subtotal	Local Travel	41.00
80170	Internet Services				
	04/26/07	American Express EV	23008-APR/07	IWP Newsletters,World trade Online subscription 4	200.00
			Subtotal	Internet Services	200.00
				Report Total	293.77

Invoice U 4-17598

Sell-to Customer No. 2-27036

Ship-to Code

Sell-to

Foley Hoag, LLP
Attn: Paul Reichler
1875 K Street NW
Suite 800
Washington, DC 20006

Ship-to

Foley Hoag, LLP
Attn: Paul Reichler
1875 K Street NW
Suite 800
Washington, DC 20006

CRM/ISS/REGISTRATION UNIT
2009 MAR 30 PM 5:18

Your Reference

Salesperson Code WILLIAM

Customer Posting Group DC

Cust./Item Disc. Gr.

Invoice Disc. Code 2-27036

Payment Terms Code 30

Due Date 06/13/07

Pmt. Discount Date 05/14/07

Payment Discount % 0

Payment Method Code

Shipment Method Code

Document Date 05/14/07

Posting Date 04/30/07

Tax Liable No

Tax Area Code

Type	No.	Description	Departm Code	Project Code	Job No.	Unit Price	Amount
Account (G/L)	80110	Magazines	DC	5-10125	5-20997	52.77	52.77
Account (G/L)	80160	Local Travel	DC	5-10125	5-20997	20.50	41.00
Account (G/L)	80170	Internet Services	DC	5-10125	5-20997	200.00	200.00

Total 293.77
Tax Amount 0.00
Total Incl. Tax 293.77

Supplemental Statement

Section V - Informational Materials

Attached are copies of informational materials disseminated on behalf of CORPEI.

* Materials disseminated to entire Latin American press list (attached) unless otherwise noted.

2009 MAR 30 PM 5:19
CRM/ISS/REGISTRATION UNIT

Master Latin American Press List

Outlet	First Name	Last Name	Job Title	E-mail Address
Agence France-Presse	Mauricio	Rabuffetti	Bureau Chief	mauricio.rabuffetti@afp.com
Agence France-Presse	Hector	Velasco	Director	hector.velasco@afp.com
Agence France-Presse	Jordi	Zamora	Bureau Chief	jordi.zamora@afp.com
Al Jazeera	Will	Stebbins	Washington Bureau Chief	william.stebbins@aljazeera.net
Al Jazeera	News	Desk	Latin America desk	latinamerica@aljazeera.net
Al Punto	Marcela	Salazar	Washington Producer	masalazar@univision.net
Alternet	Joshua	Holland	Staff Writer	joshua.holland@alternet.org
ANSA Italian News Agency	Marcelo	Raimon	Correspondent	marceloraimon@hotmail.com
Associated Press	Jeannine	Aversa	Economics Reporter	javersa@ap.org
Associated Press	Sally	Buzbee	Assistant Washington Bureau Chief	sbuzbee@ap.org
Associated Press	News	Desk	General Newsdesk	apquito@ap.org
Associated Press	Harry	Dunphy	International News Reporter	hdunphy@ap.org
Associated Press	Nestor	Ikeda	Spanish Language Reporter	nikeda@ap.org
Associated Press	Matthew	Lee	Trade Reporter	mvlee@ap.org
Associated Press	Gonzalo	Solano	Correspondent	gsolano@ap.org
Associated Press	Edwin	Tamara	Editor	etamara@ap.org
Associated Press	Jeanneth	Valdivieso	Reporter	jvaldivieso@ap.org
BBC	Bruno	Garcez		bruno.garcez@bbc.co.uk
BBC World News	Carlos	Chirinos	Spanish Language Reporter	carlos.chirinos@bbc.co.uk
BBC World Service	Lourdes	Heredia	Latin America Correspondent	lourdes.heredia@bbc.co.uk
BBC/Guardian	Greg	Palast		gregpalast@gregpalast.com
Bloomberg	Steven	Bodzin	Correspondent	sbodzin@bloomberg.net
Bloomberg	Daniel	Cancel	Reporter	dcancel@bloomberg.net
Bloomberg	Alex	Emery	Spanish Language Economics Reporter	aemery1@bloomberg.net
Bloomberg	Bill	Faries	Correspondent	wfaries@bloomberg.net
Bloomberg	Stephan	Kueffner	Reporter	skueffner@bloomberg.net
Bloomberg	Indira	Lakshmanan	Foreign Affairs/Diplomacy Reporter	ilakshmanan@bloomberg.net
Bloomberg	Helen	Murphy	Correspondent	hmurphy1@bloomberg.net
Bloomberg	Karla	Palomo	Reporter	kpalomo@bloomberg.net
Bloomberg	Marisela	Riveros		mriveros@bloomberg.net
Bloomberg	Chris	Swan	Correspondent	cswann1@bloomberg.net
Bloomberg	Viola	Gienger	International News Reporter	vgienger@bloomberg.net
Bloomberg	Matthew	Walter	Bureau Chief	mwalter4@bloomberg.net
Bloomberg	Laura	Zelenko	International Editor	lzelenko@bloomberg.net
Bloomberg	Mark	Dragem	Trade/Investment Reporter	mdragem@bloomberg.net
Bloomberg TV	Marisela	Riveros	Reporter	mriveros@bloomberg.net

BNA	Rosella	Brevetti	Int'l Trade Reporter	rbrevetti@bna.com
Boston Globe	Alan	Berger	Editorial Writer	berger@globe.com
Boston Globe	Foreign	Desk		
Boston Globe	James "Jim"	Smith	Foreign Editor	smith@globe.com
Cable News Network (CNN)	Igor	Krotov	Foreign News Assignment Editor	igor.krotov@turner.com
Cable News Network (CNN)	Caleb	Silver	News Desk	caleb.silver@turner.com
Cable News Network (CNN)	Thomas	Watkins	News Desk Editor	thomasgwatkins@yahoo.com
Cable News Network International (CNNI)	Tomas	Etzler	Assignment Editor	tomas.etzler@turner.com
CBS News Network	Christopher	Hulme	Foreign News Editor	
CBS News Network	Maria	Mercader	Foreign News Producer	
CBS News Network	Ana	Real	Foreign News Producer	
CBS News Network - Washington Bureau	Lois	Dyer	Assignment Editor, Planning Editor	ldx@cbsnews.com
Chicago Tribune	Gary	Marx	International News Correspondent	gmarx@tribune.com
Christian Science Monitor	Sara	Llana	Latin American Correspondent	llanas@csmonitor.com
Clarín	Ana	Baron	Spanish Language Reporter	Abaron8789@aol.com
CNN en español	Willie	A. Lora	Bureau Manager	
CNN en español	Liliana	Gonzalez	Spanish Language Washington Correspondent	liliana.gonzalez@cnn.com
CNN en español	News	Desk	Newsdesk	espanol.mesa@turner.com
CNN en español	Robert	Lenz	Latin America Assignment Editor	robert.lenz@turner.com
CNN en Español Radio	Flavia	Colombo-Abdulla	Supervising Producer	flavia.colombo@turner.com
CongressDaily	Peter	Cohn	Trade Reporter	pcohn@nationaljournal.com
Deutsche Presse-Agentur (DPA)	Gonzalo	Espariz Nieto	US Correspondent	espariz.gonzalo@dpa.com
Diario Hoy	Thalía	Flores y Flores	International Editor	tflores@hoy.com
Diario Hoy	Johani	Ponce	Reporter	poncepress@gmail.com
Dow Jones Newswires	Mercedes	Alvaro	Correspondent	mercedes.alvaro@dowjones.com
Dow Jones Newswires	Elizabeth	Price	International Business Reporter	elizabeth.price@dowjones.com
DPA	Laura	Barros	Reporter	laurabarros37@yahoo.com
Economist	Peter	David	Foreign Editor	peterdavid@economist.com
Economist	Lane	Greene	Correspondent, The Global Agenda	lanegreene@economist.com
Economist	Brooke	Unger	Bureau Chief	brookeunger@economist.com
EFE News Services	Fernando	Arroyo	Correspondent	eferedaccion@andinet.net
EFE News Services	Maria	Azpiazu	Bureau Chief	azpiazum@efeamerica.com
EFE News Services	Elvira	Palomo		epalomo@efeamerica.com
EFE News Services	Jorge A.	Bañales	Correspondent	jabanales@aol.com
EFE News Services	Teresa	Bouza	Economics Correspondent	tbouza@efeamerica.com

EFE News Services	Isabel	Conde		isabelcra@gmail.com
EFE News Services	Victor	Martin	NYC bureau	vmartin@efeamerica.com
EFE News Services	César	Muñoz	Correspondent	cmunoz@efeamerica.com
EFE News Services	Maria	Peña	Congress Correspondent	mpena@efeamerica.com
EFE News Services	Macarena	Vidal	Deputy Bureau Chief	mvidal@efeamerica.com
El Diario - La Prensa	Javier	Castano	Managing Editor	jcastano@eldiariolaprensa.com
El Diario - La Prensa	Umberto	Garcia	News Assignment Editor	ugarcia@eldiariolaprensa.com
El Diario - La Prensa	Judith	Torrea	NYC bureau	judith.torrea@eldiariony.com
El Diario - La Prensa	Ricardo	Vasconcellos	Latin America Editor	rvasconcellos@eldiariony.com
El Nuevo Herald	Carlos	Castaneda	Publisher/Editor in Chief	
El Nuevo Herald	Humberto	Castello	Executive Editor	hcastello@herald.com
El Pais	Antonio	Caño	Correspondent	elpais1@nationalpress.com
El Pregonero	Alex			alex@elpreg.org
El Tiempo Latino	Alberto	Avendaño	Associate Publisher	avendano57@yahoo.com
El Tiempo Latino	Milagros	Vela	Spanish Language Editor	MILAGROSVE@aol.com
Expansion	Alberto	Bello	Spanish Language Editor	abello@expansion.com.mx
Financial Times	Ted	Alden	DC Bureau Chief	edward.alden@ft.com
Financial Times	Richard	Lapper	Editor	richard.lapper@ft.com
Financial Times	Naomi	Mapstone	Andean Correspondent	naomi.mapstone@ft.com
Financial Times	Quentin	Peel	International Affairs Editor	quentin.peel@ft.com
Financial Times	Jude	Webber	Argentina Correspondent	jude.webber@gmail.com
Financial Times	Hal	Weitzman	Chicago/Midwest Correspondent	no longer covers Latin America
Financial Times/TIME/Bloom	Stephan	Küeffner Andrade	Correspondent	skueffner@gmail.com
Folha de Sao Paulo	Sergio	Davila		sdavila@folhasp.com.br
Folha de Sao Paulo	Fabiano	Maisonave	Sao Paulo	fmaisonave@folhasp.com.br
Forbes	Andrew	Gillies	Associate Editor	agillies@forbes.com
Freelance Journalist	Lucy	Hood		lahood5@aol.com
Freelance Journalist	Frank	Smyth		smyth.frank@gmail.com
Global Finance	Daniel	Keeler	Web Site Editor	dan@gfmag.com
Houston Chronicle	Tracey	Eaton	Latin America Editor	tracey.eaton@chron.com
Houston Chronicle	John	Otis	South America Bureau Chief	john.otis@chron.com
Hoy - Los Angeles Edition	Jesse	Linares	News Editor	jlinares@hoyllc.com
Inside U.S. Trade	Luke	Engan	Reporter	luke.engan@iwpnews.com
Inside U.S. Trade	Jamie	Strawbridge	Reporter	jamie.strawbridge@iwpnews.com
Institutional Investor	Lucy	Conger	Editor	lucy_conger@yahoo.com
IPS Latin America	Humberto	Marquez	Correspondent	hmarquez@ipslatam.net
Journal of Commerce	Alan	Field	Associate Editor	afield@joc.com

La Jornada	Jim	Cason	Spanish Language Washington Bureau Chief	
La Opinion	Maria Luisa	Arrendondo	Latin America News Editor	maria.arrendondo@laopinion.com
La Opinion	Maribel	Hastings	Washington Correspondent	maribel.hastings@laopinion.com
La Opinion	Pedro	Rojas	Executive Editor	pedro.rojas@laopinion.com
La Opinion	Hugo	Valicente	Editor	
La Vanguardia	Joaquin	Ibarz		jibarz@attglobal.net
La Vanguardia	Alfred	Reixach	Reporter	jibarz@attglobal.net
Los Angeles Times	Foreign	Desk	Foreign Desk	foreign@latimes.com
Los Angeles Times	Mike	Faneuff	Foreign Desk	mike.faneuff@latimes.com
Los Angeles Times	Chris	Kraul	Reporter	cwkraul@aol.com
Los Angeles Times	Patrick	McDonnell	Reporter	patrick.mcdonnell@latimes.com
Los Angeles Times	Marjorie	Miller	Foreign Editor	marjorie.miller@latimes.com
Los Angeles Times	Lisa	Richardson	Editorial Page Staff Writer	lisa.richardson@latimes.com
Los Angeles Times "La Plaza"	Deborah	Bonello	Blogger	dbonello@gmail.com
Los Tiempos USA			Spanish Language	lostiemposusa@aol.com
Lou Dobbs Tonight (CNN)	Bill	Tucker	Correspondent	bill.tucker@turner.com
Miami Herald	Tyler	Bridges	Latin America Correspondent	tbridges@MiamiHerald.com
Miami Herald	Jane	Bussey	International Business/Trade Reporter	jbussey@miamiherald.com
Miami Herald	World	NewsDesk		worldnews@herald.com
Miami Herald	Andres	Oppenheimer	International News Columnist	aoppenheimer@miamiherald.com
Miami Herald	Juan	Tamayo	Foreign Editor	jtamayo@herald.com
Miami Herald	Juan	Vasquez	Op-ed Editor	jvasquez@miamiherald.com
Miami Herald	John	Yearwood	World Editor	jyearwood@miamiherald.com
National Journal	Bruce	Stokes	Trade/Economics Correspondent	bstokes@nationaljournal.com
NBC News Network	Mark	Potter	Correspondent	mark.potter@nbc.com
NBC News Network	Andrea	Mitchell	Foreign Senior Correspondent	andrea.mitchell@nbc.com
New York Times	Ed	Andrews	Trade/Int'l Business Reporter	eandrews@nytimes.com
New York Times	Foreign	Desk		foreign@nytimes.com
New York Times	Paul	Krugman	Columnist	krugman@nytimes.com
New York Times	Andres	Martinez	Foreign Editor	martinez@nytimes.com
New York Times	Eduardo	Porter	Editorial Writer	porter@nytimes.com
New York Times	Simon	Romero	Correspondent	romeros@nytimes.com
New York Times	Maggy Ayala	Sarmiento	Reporter	
New York Times	David	Unger		unger@nytimes.com
New York Times	Steven	Weisman	Chief Economic Correspondent	weisman@nytimes.com
New York Times Syndicate	Marcela	Sánchez	Washington Columnist	nyts-sanchez@nytimes.com
Newsweek	Joe	Contreras	Foreign Editor	joe.contreras@newsweek.com

Noticias Caracol	Vanessa	de La Towe	Spanish Language Reporter	vanedelatowe@gmail.com
Notimex	Ruben	Barrera	Correspondent	nanche@aol.com
Notimex	Jose Lopez	Zamorano	Bureau Chief	joseloz12@gmail.com
NPR	Julie	McCarthy	South American Correspondent	jmccarthy@npr.org
NPR - Marketplace	Caitlan	Carroll	Producer	ccarroll@marketplace.org
NPR - Marketplace	Mary	Stucky	Freelancer	mstucky@roundearthproductions.com
NPR/National Public Radio	Ted	Clark	Deputy Senior Foreign Editor	tclark@npr.org
NPR/National Public Radio	Anne	Hawke	Associate Producer	ahawke@npr.org
NPR/National Public Radio	Loren	Jenkins	Senior Foreign Editor	ljenkins@npr.org
NPR/National Public Radio	Angela	Maldonado	Producer (NPR's Latino USA)	amaldonado@kut.org
NPR/National Public Radio	Didi	Schanche	Latin America Editor	dschanche@npr.org
NY Daily News	Juan	Gonzalez	Columnist	jgonzalez@nydailynews.com
O Estado de Sao Paulo	Roberto	Lameirinhas	Reporter	roberto.lameirinhas@grupoestado.com.br
O Estado de Sao Paulo	Patricia	Mello	Correspondent	patricia.mello@gmail.com
Plain Dealer	Pete	Krouse	Business Reporter	pkrouse@plaind.com
Proceso	Jesus	Esquivel	Correspondent	je77car@aol.com
RadioFranceInternationale	Éric	Samson	Correspondent	esamson@ecnet.ec
Reuters	Hugh	Bronstein	Correspondent	hugh.bronstein@thomsonreuters.com
Reuters	Allister	Bull	Washington Correspondent	alister.bull@thomsonreuters.com
Reuters	Michael	Christie	Bureau Chief U.S. Southeast & Caribbean	MICHAEL.CHRISTIE@REUTERS.COM
Reuters	News	Desk (Quito)	News Desk	quito.newsroom@reuters.com
Reuters	Adriana	Garcia	Reporter	adriana.garcia@reuters.com
Reuters	Kieran	Murray	Bureau Chief	kieran.murray@thomsonreuters.com
Reuters	Doug	Palmer	International Trade Correspondent	doug.palmer@reuters.com
Reuters	Missy	Ryan	Agriculture Trade Correspondent	missy.ryan@reuters.com
Reuters	Alonso	Soto	Correspondent	alonso.soto@reuters.com
Reuters	Alexandra	Valencia	Correspondent	alexandra.valencia@reuters.com
San Francisco Chronicle	Rob	Collier	World News Reporter	rcollier@sfchronicle.com
San Francisco Chronicle	Jack	Epstein	Latin America Editor	jepstein@sfchronicle.com
South Florida Sun-Sentinel	William	Gibson	Bureau Chief	wgibson@sun-sentinel.com
South Florida Sun-Sentinel	Doreen	Hemlock	International Business Reporter	dhemlock@sun-sentinel.com
Telemundo	Julio	Aliaga	News Director	jaliaga@zgsgroup.com
Telemundo	Fran	Sevilla		correo@telemundo.com
Telemundo Internacional	Berta	Castañer	News Director	bxcastaner@telemundo.com
Telemundo Network	Sevilla	Fran	Reporter	correo@telemundo.com
Telemundo TV	Wendy	Thompson	Spanish Language Vice President	wthompson@zgsgroup.com
TeleSur	Chris	Belcher		cbelcher@telesurtv.net

TeleSur	Maria	Luciana Reos	Spanish Language Reporter	telesurtv@aim.com
TeleSur	Sarai	Peña		apena@telesurtv.net
TeleSur	Nitza	Perez	Spanish Language DC Bureau	nsoledad@telesurtv.net
TeleSur	Roselena	Ramirez	Spanish Language Reporter	rosramir@hotmail.com or rramirez@telesurtv.net
Telesur	Francisco			telesurtv.dc@gmail.com
The Hill	Ian	Swanson	Trade/Immigration Reporter	
Time Magazine	Stephan	Kuffner		
Time Magazine	Tim	Padgett	Latin America Editor	tim_padgett@timemagazine.com
Time Magazine	Adam	Zagorin	Correspondent	asked to be removed from this list
Times of London	James	Hider	Correspondent	jameshider@yahoo.co.uk
TV5 (France)	Frederic	Groll-Bourel	Reporter	TV5latina@tv5.org
Univision	Rafael	Tejero		rtejero@univision.net
Univision Network	Deborah	Durham		ddurham@univision.net
Univision Network	Jamie	Garcia		jgarcia@univision.net
Univision Network	Maria	Lopez-Alvarez	News Director	mlopezalvarez@univision.net
Univision Network	Maria	Martinez-Henao	Assignment Editor	mhenao@UNIVISION.NET
Univision Network	Fernanado	Pizarro	Assignment Editor	fpizarro@univision.net
Univision Network	Roberto	Pons	Assignment Editor	rpons@univision.net
Univision Network	Leticia	Pradera	Assignment Editor	lpradera@univision.net
Univision Network	Sylvia	Rosabel-Ley	News Director	srosabel@univision.net
Univision Network	Rafael	Tejero	International Assignment Manager	rtejero@univision.net
Univision Network	Elizabeth	Valdes	Assignment Desk Manager	evaldes@univision.net
Univision Radio	Monica	Delta	Spanish Language Reporter	monicadelta@gmail.com
Univision TV	Ernesto	Clavijo	Spanish Language News Director, Washington	eclavijo@entravisiondc.com
USA Today	Jim	Cox	International News Editor	jcox@usatoday.com
USA Today	Darlana	Craig-Jackson	Editor	djackson@usatoday.com
USA Today	Barbara	Hagenbaugh	Economics Reporter	bhagenbaugh@usatoday.com
USA Today	David	Jackson		dmjackson@usatoday.com
USA Today	Jim	Michaels	Deputy Editor	jmichaels@usatoday.com
USA Today	Elisa	Tinsley	World Editor	etinsley@usatoday.com
USA Today	Bill	Nichols	Diplomatic Correspondent	bnichols@usatoday.com
USA Today	Barbara	Slavin	Foreign Affairs Reporter	bslavin@usatoday.com
Voice of America News	Gonzalo	Abarca	Spanish Language Producer	gabarca@voanews.com
Voice of America News	Patricia	Dalmasy	Correspondent	pdalmasy@voanews.com
Voice of America News	Alejandro	Tarre	Reporter	atarre@voanews.com
Wall Street Journal	Mike	Allen	Foreign Editor	mike.allen@wsj.com

Wall Street Journal	Bob	Davis	Int'l Economics Correspondent	bob.davis@wsj.com
Wall Street Journal	Jose	DeCordoba	Correspondent	jose.decordoba@wsj.com
Wall Street Journal	Greg	Hitt	Trade Reporter	greg.hitt@wsj.com
Wall Street Journal	David	Luhnow	Latin Amer. Bureau Chief	david.luhnow@wsj.com
Wall Street Journal	Matt	Moffett	South America Correspondent	matthew.moffett@wsj.com
Wall Street Journal	Michael	Phillips	Reporter	michael.phillips@wsj.com
Wall Street Journal	John	Lyons	Reporter	john.lyons@wsj.com
Wall Street Journal	David	Luhnow	Reporter	davidluhnow@wsj.com
Wall Street Journal	Jose	De Cordoba	Reporter	josedecordoba@wsj.com
Wall Street Journal	Ricardo	Millan	Reporter	ricardo.millan@wsj.com
Washington Hispanic	Nely	Carrion	Spanish Language Directora Editor	nellycarrion2001@yahoo.com
Washington Post	Phil	Bennett	Assistant managing editor for foreign news	bennettp@washpost.com
Washington Post	Bill	Booth	Mexico Correspondent	boothb@washpost.com
Washington Post	Foreign	Desk	Foreign Desk	foreign@washpost.com
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Washington Post	Lori	Montgomery	National Economic Policy Reporter	montgomeryl@washpost.com
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Washington Post	Josh	Partlow	Latin America Correspondent	partlowj@washpost.com
Washington Post	Jason	Ukman	Latin America Editor	ukmanj@washpost.com
Washington Post	Jonathan	Weisman	Business Reporter	weismanj@washpost.com
Washington Post and NPR	Juan	Forero	Foreign Correspondent	jmforero@yahoo.com
Washington Tariff & Trade L	Samuel	Gilston	Editor/Publisher	sgilston@comcast.net
Washington Tariff & Trade L	Elayne	Gilston	Managing Editor	tgilston@comcast.net
Washington Times	Kelly	Hearn	World & Nat'l Security Desk	khearn@washingtontimes.com
Washington Times	Steve	Hirsch	International Business Reporter	shirsch@washingtontimes.com
Washington Trade Daily	James	Berger	Co-Editor	trigtrig@aol.com
Washington Trade Daily	Mary	Berger	Co-Editor	trigtrig@aol.com
Washingtonpost.com	Jefferson	Morely		jeff.morley@wpni.com
RCN TV	Natalia	Orozco	Correspondent	nataliao@gmail.com
Notimex	News	Desk	Tijuana bureau	Ntx_tj@hotmail.com

MEDIA ADVISORY

For Friday, May 4, 2007

Contact:

Paco Fabian
Fenton Communications
(202)822-5200
pfabian@fenton.com

Ecuador Attorney General To Host Breakfast Briefing Dr. Xavier Garaicoa to Discuss Developments on a Host of Issues

Washington, DC – Recent U.S. media coverage of the Ecuadorian elections, the referendum and constitutional assembly have been inconsistent and in many cases, inaccurate. Dr. Xavier Garaicoa, recently appointed Attorney General of Ecuador, is in Washington this week, and will host an invitation-only press breakfast briefing with members of the media to discuss the constitutional assembly, Andean Trade Preferences and the Occidental Petroleum arbitration case that Ecuador has pending before the World Bank.

**WHO: Dr. Xavier Garaicoa,
Attorney General of Ecuador**

WHEN: Friday, May 4, 9:00 AM

**WHERE: Old Ebbitt Grill
Cabinet Room
675 15th St., NW
Washington, DC
Tel. (347) 4800**

TO RSVP, PLEASE CONTACT: Paco Fabian, Fenton Communications, 202 822-5200,
pfabian@fenton.com

#

PRESS RELEASE
MINISTRY OF FOREIGN AFFAIRS OF THE REPUBLIC OF ECUADOR

For Immediate Release

DC)

May 11, 2007

Contact: Jorge Icaza, Embassy of Ecuador (Washington,

234-7200 / jicaza@mmrree.gov.ec

**Ecuadorean Foreign Minister Describes Meeting with
Negroponte as “Cordial and Informative”**

QUITO. After a meeting between Ecuadorean President Rafael Correa and the U.S. Deputy Secretary of State, John Negroponte, Ecuador’s Minister of Foreign Affairs, María Fernanda Espinosa, stated that Ecuador “does not agree with the format and content of free trade agreements” but added that, “we do agree on mutually beneficial commercial agreements upon which we are willing to start conversations with the United States. Of course the results will be very different from what Ecuador was negotiating in the past.”

Minister Espinosa said that she talked to Deputy Secretary Negroponte about Ecuador’s interest in establishing a dialogue with the United States as well as the framework for long term trade relations. The extension of the Andean Trade Promotion and Drug Eradication Act (ATPDEA) was also discussed.

“ATPDEA will be in effect until June and then we trust it will be extended for two additional years; therefore we have two years to start a discussion about trade agreements,” Minister Espinosa noted.

She added, “The president has opposed traditional ‘free trade’ because in the past it has been very detrimental to the livelihoods of poor farmers.”

Espinosa said that the meeting with the Deputy Secretary of State was very “cordial”, and that Mr. Negroponte “left very pleased” and “insisted on excellent relations between our nations.”

“Leadership with Clean Hands”

Espinosa stated that the president had a productive and pleasant conversation with Negroponte regarding the constituent assembly process, the September 30th elections and the demand by Ecuadorean citizens for the country’s transformation through a new constitutional framework.

President Correa spoke about the country’s transformation process under his administration, and emphasized that “political democracy cannot exist without economic democracy.” The President told Mr. Negroponte that the United States has nothing to fear from new leaders arising in the continent, especially in Ecuador, because they are leaders with “clean hands.” Correa added that Ecuador loves and admires the American people.

Finally, Correa explained his government’s economic plan and strategic proposals on social issues and economic production.

###

MEMORANDUM TO THE PRESS
May 22, 2007

JUST THE FACTS: Opposition Legislators and the Constitutional Assembly in Ecuador

The process of strengthening a democracy can be complicated and messy. The new Correa administration in Ecuador is trying to fix a polarized and broken system that has seen the Andean country go through 8 presidents in 10 years, struggling under a flawed constitution that lacks an efficient system of checks and balances.

Recent erroneous reports by the *Economist* and AP from Quito suggest that the democratic process taking place constitutes a “power grab” by the executive, suggesting that President Correa is seeking to centralize power. In fact, there is systemic disorder, from which the president is seeking – with considerable public support – to create a working government.

The Supreme Elections Tribunal (TSE), the highest court on electoral matters, erroneously interpreting the current constitution, sent the President’s decree calling for a constitutional assembly to the Congress (needs an approximate date), which was not a required step. The Congress, in turn, amended the decree -- eliminating the requirement that candidates obtain signatures in order to participate in the election of delegates to the assembly. Without such a requirement, the likelihood of thousands of candidates could have resulted in chaos.

Seeking to prevent problems, the president filed a new decree requiring signatures for all candidates, and the TSE called a referendum for April 15 on the creation of a constitutional assembly. That referendum went forward and 82% of the voting electorate endorsed the creation of a new constitution.

The Congress again questioned the tribunals binding decision, and violated the constitution by removing the president of the TSE. In response, and within its right as the highest authority regarding electoral matters, the TSE removed the legislators who voted to replace the president of the SET, for “[I]nterfering in the functionality of electoral bodies, which will result in the dismissal and the suspension of political rights for a period of one year.” (Art. 57 of the Law of Constitutional Control).

The removed legislators engaged in a prolonged appeals process that was rejected by three courts based on Article 57, and ratified by the attorney general. However, the Constitutional Court, without jurisdiction over the case, decided to reinstate the removed legislators. TSE appealed the ruling, which made the reinstatements impossible under the law. Ultimately, the Congress, with 57 replacement legislators appointed by the affected political parties, resolved to substitute the members of the Constitutional Tribunal, a step that by law should have been taken in January 2007, when their terms expired.

This tumult was the inevitable product of an unworkable and imbalanced government structure. In the referendum, 82% of Ecuadorians voted to set in motion the creation of, a new constitution to harmonize government functions. That vote was overseen and ratified by the OAS and other international bodies. The next step is the orderly selection of delegates to the assembly.

For more information, please see the timeline and in-depth analysis attached or contact Paco Fabian or Timi Gerson at 202-822-5200.

INGLÉS ABAJO

Invitación a los Medios para:
Viernes, 1 de junio, 2007

Contact: Comandante Jaime Davalos
(443) 254-1102

*******RUEDA DE PRENSA MAÑANA (VIERNES)*******

**EMBAJADOR ECUATORIANO LLEGA A SAN JUAN PARA ACOMPAÑAR LA PRIMERA
PARADA DEL BUQUE-ESCUELA ECUATORIANO GUAYAS**

*La decisión de empezar gira mundial del buque en Puerto Rico
afirma la amistad, vínculos militares entre los Estados Unidos y Ecuador*

QUÉ: Rueda de prensa

CUANDO: Viernes, 1 de junio a las 9:30am
(El buque llega al puerto a las 8:00am)

DONDE: Camara de Oficiales en el Buque Escuela Guayas
Muelle 1 de Turismo, San Juan, PR

QUIEN: Embajador Luis Gallegos

El Buque Escuela Guayas ha sido una parte clave de la formación académica y militar de los alferes ecuatorianos, que cuando terminen esta gira mundial en el buque se graduaran y se conviertiran en oficiales de marina.

Media Advisory for:
Friday, June 1, 2007

Contact: Comandante Jaime Davalos
(443) 254-1102

******PRESS CONFERENCE TOMORROW (FRI)******

**ECUADOREAN AMBASSADOR TO U.S. JOINS ECUADOR'S OLDEST NAVAL SHIP -
BUQUE ESCUELA GUAYAS - IN SAN JUAN, PUERTO RICO**

*Choice of U.S. as first stop on global tour touts friendship between two countries,
strengthens military relations following UNITAS controversy*

WHAT: Press conference on the Ecuadorean Buque Escuela Guayas.

WHEN: Friday, June 1, 2007 at 9:30am

WHERE: Camara de Oficiales del Buque Escuela Guayas
Muelle 1 de Turismo, San Juan, PR

WHO: Ambassdor Luis Gallegos, Ecuadorean Ambassdor to the United States

The historic Guayas School boat has been a crucial part of the academic and military preparation for Ecuadorean sailors, who will graduate to become officials in the Ecuadorean navy following their world tour.

//

*******MEDIA AVAILABILITY/ADVISORY*******

Media Advisory For:
Monday, June 4, 2007

Contact: Timi Gerson, 202-822-5200

**AS TRADE TREATY FACES JUNE 30 DEADLINE, ECUADOR
FOREIGN MINISTER TO MEET WITH SECRETARY RICE**

***One-on-one meeting at OAS Summit to focus on trade
preferences renewal, need for swift action in U.S. Congress***

On Monday, June 4th at the Organization of American States (OAS) annual meeting in Panama, the Ecuadorean Foreign and Commerce Minister, Maria Espinosa, will meet with U.S. Secretary of State Condoleezza Rice. The top item for discussion is the fast approaching June 30 expiration of the **Andean Trade Preferences and Drug Eradication Act (ATPDEA)**. This trade preferences treaty covers Bolivia, Colombia and Peru as well as Ecuador and is a critical policy instrument in the fight against narco-trafficking.

The ATPDEA program provides trade preferences for key Ecuadorean products, such as flowers and tuna, entering the United States. In the five years it has been in effect, 350,000 rural jobs have been created in rural Ecuador and U.S. investment in the country has risen 30 percent. American companies in Ecuador include Bechtel, Citibank, Del Monte Foods, Exxon-Mobil, Dole/Standard Fruit and General Motors.

**ECUADOREAN AMBASSADOR TO THE UNITED STATES
LUIS GALLEGOS IS AVAILABLE FOR COMMENT ON
ATPDEA & THE OAS MEETING**

To contact Ambassador Gallegos,
please call or email Timi Gerson at 202-822-5200 x210 or tgerson@fenton.com

///

MEDIA ADVISORY

FOR THURSDAY JUNE 7, 2007

CONTACT: Paco Fabián or Timi Gerson
(202) 822-5200 pfabian@fenton.com

ON THE RECORD PRESS BREAKFAST WITH ECUADOR FOREIGN MINISTER MARIA ESPINOSA

Focus on Andean Trade Preferences and Drug Eradication Act (ATPDEA), which will expire June 30 without Congressional action

WHAT: Press breakfast with the Ecuadorean Foreign Minister Maria Espinosa

WHEN: Thursday, June 7 at 9:00am EST

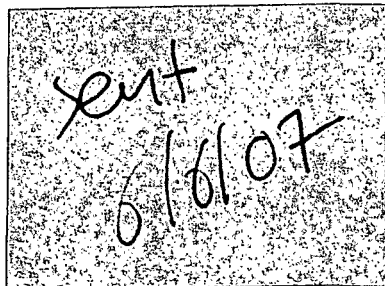
WHERE: Offices of Fenton Communications
1320 18th Street, NW, Fifth Floor
Washington, DC 20036

The Foreign Minister of the Republic of Ecuador, María Fernanda Espinosa, will be in Washington, DC this week to lobby on behalf of extension of the Andean Trade Preferences and Drug Eradication Act (ATPDEA). She is joined by American investors based in Ecuador as well as representatives of the Ecuadorean private sector.

ATPDEA, which covers Bolivia, Colombia, Ecuador and Peru, is set to expire on June 30th if Congress does not act in the next few weeks to renew the preferences program. Minister Espinosa met with Secretary of State Condoleezza Rice about this issue on Monday in Panama at the OAS annual meeting.

For more information, contact:
Paco Fabián or Timi Gerson at 202-822-5200

//



PRESS CALL ADVISORY

FOR THURSDAY JUNE 7, 2007

CONTACT: Paco Fabián or Timi Gerson
(202) 822-5200 pfabian@fenton.com

ON THE RECORD PRESS CALL WITH ECUADOR FOREIGN MINISTER MARIA ESPINOSA

**Focus on Andean Trade Preferences and Drug Eradication Act
(ATPDEA), which will expire June 30**

WHAT: Press Call with Ecuador Foreign Minister Maria Espinosa

WHEN: Thursday, June 7 at 9:00am EST

CALL IN: 1- 800-862-9098 (*Inside the United States*)
1- 785-424-1051 (*International*)

CONFERNECE ID: 7ATPDEA

The Foreign Minister of the Republic of Ecuador, María Fernanda Espinosa, will be in Washington, DC this week to lobby on behalf of extension of the Andean Trade Preferences and Drug Eradication Act (ATPDEA). She is joined by American investors based in Ecuador as well as representatives of the Ecuadorean private sector.

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**For more information on the press call, contact:
Paco Fabián or Timi Gerson at 202-822-5200**

//

INSERTION ORDER – PLEASE CONFIRM RECEIPT BY RETURN EMAIL

TO: Eric Richardson, 202-824-6815, ecr@rollcall.com

FROM: Abby Brabec, Fenton Communications, abrabec@fenton.com

PUBLICATION: Roll Call

CLIENT: CORPEI

BILLING ADDRESS: Fenton Communications
1320 18th Street NW #500
Washington, DC 20036
202-822-5200

FENTON PROJECT NUMBER: 6-00313

SIZE: Full Page, Full Color – No Bleed (9 7/8" x 14")

LOCATION: Right Hand Page, Far Forward

RUN DATE: June 14, 2007

MATERIAL CLOSING: June 13 by NOON

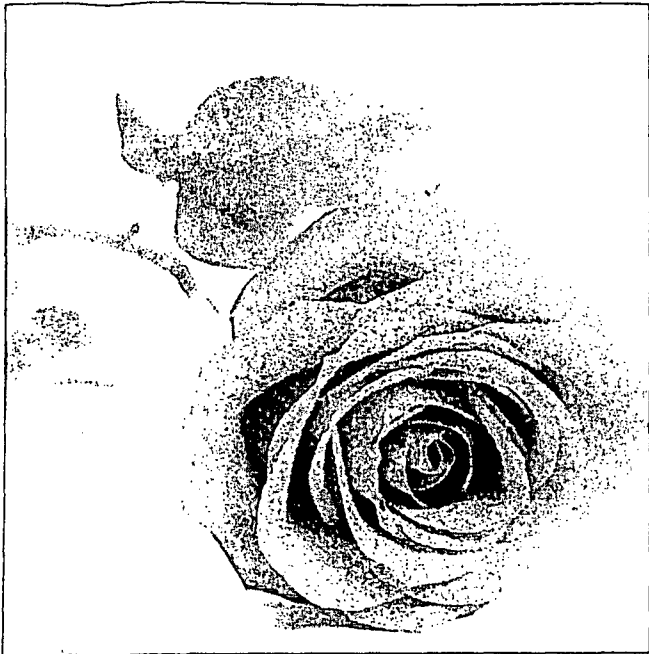
CHECK DATES: Upon Receipt of Invoice

PRICE: \$10,144.75 net (\$11,935.00 gross)

NOTE: Please mail tear sheets to billing address.

#

Don't let this... turn into this.



Vote yes to extend ATPDEA

A rose is a rose, except when it is all that stands between the US and the illegal drug trade.

Thanks to the Andean Trade Preferences and Drug Eradication Act (ATPDEA), Ecuador is the only country in the region with zero coca cultivation. That is because Ecuadorians enjoy something that most poor countries lack—jobs.

Since 1991, ATPDEA in Ecuador alone has created 350,000 jobs in thousands of local businesses that export legal agricultural products like vegetables and, yes, roses to the US, benefiting not just the local economy but the more than 100 American companies that work and invest in Ecuador.

Without ATPDEA, these rural workers could be forced into a far less savory enterprise—coca farming—rolling back the advances against drug-trafficking.

ATPDEA is the most effective weapon in the war on drugs. It's a big deal to Ecuador and a good deal for the United States. We urge Congress to move quickly to extend this Act.

ATPDEA. Good for us. Good for the US.

FOR PROMOTION OF EXPORTS AND INVESTMENTS

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CORPORATION FOR THE PROMOTION OF EXPORTS AND INVESTMENTS

www.corpei.org

INSERTION ORDER – PLEASE CONFIRM RECEIPT BY RETURN EMAIL

TO: Beth Tray, 202-628-8519, btray@thehill.com

FROM: Abby Brabec, Fenton Communications, abrabec@fenton.com

PUBLICATION: The Hill

CLIENT: CORPEI

BILLING ADDRESS: Fenton Communications
1320 18th Street NW #500
Washington, DC 20036
202-822-5200

FENTON PROJECT NUMBER: 6-00313

SIZE: Full Page, Full Color – No Bleed (10" x 13 1/2")

LOCATION: Right Hand Page, Far Forward

RUN DATE: June 14, 2007

MATERIAL CLOSING: June 13 by NOON

CHECK DATES: Upon Receipt of Invoice

PRICE: \$8,381.00 net (\$9,860.00 gross)

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REPRESENTATIVE

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INSERTION ORDER – PLEASE CONFIRM RECEIPT BY RETURN EMAIL

TO: Madonna Overby, 202-824-6818, madonnaoverby@rollcall.com

FROM: Abby Brabec, Fenton Communications, abrabec@fenton.com

PUBLICATION: Roll Call

CLIENT: CORPEI

BILLING ADDRESS: Fenton Communications
1320 18th Street NW #500
Washington, DC 20036
202-822-5200

FENTON PROJECT NUMBER: 6-00313

SIZE: Full Page, Full Color – No Bleed (9 7/8" x 14")

LOCATION: Right Hand Page, Far Forward

RUN DATE: June 20, 2007 (Second run of ad from June 14)

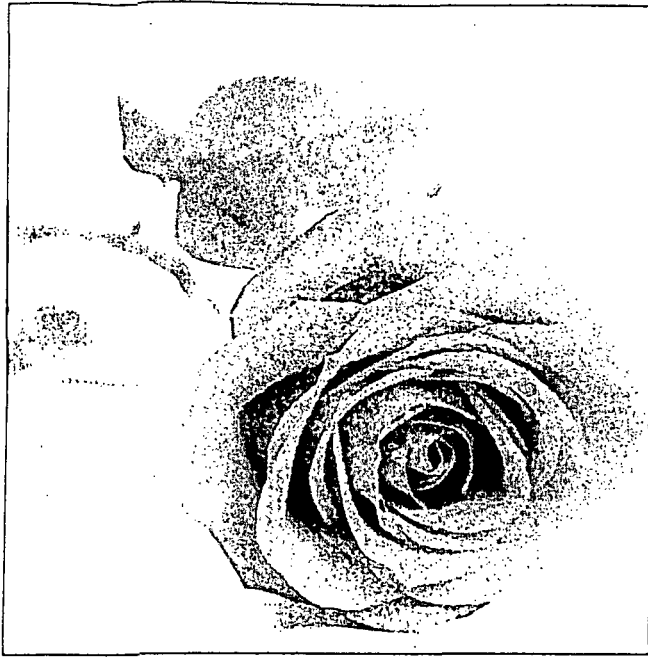
CHECK DATES: Upon Receipt of Invoice

PRICE: \$10,144.75 net (\$11,935.00 gross)

NOTE: Please mail tear sheets to billing address.

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INTERNATIONAL

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CORPORATION FOR THE PROMOTION OF EXPORTS AND INVESTMENTS

www.corpei.org

INSERTION ORDER – PLEASE CONFIRM RECEIPT BY RETURN EMAIL

TO: Alison Friedrich, (202) 628-8563, afriedrich@thehill.com

FROM: Abby Brabec, Fenton Communications, abrabec@fenton.com

PUBLICATION: The Hill

CLIENT: CORPEI

BILLING ADDRESS: Fenton Communications
1320 18th Street NW #500
Washington, DC 20036
202-822-5200

FENTON PROJECT NUMBER: 6-00313

SIZE: Full Page, Full Color – No Bleed (10" x 13 1/2")

LOCATION: Directly across from Sen. Grassley's Trade Report

RUN DATE: June 20, 2007

MATERIAL CLOSING: Please use ad from previous run on 6/14

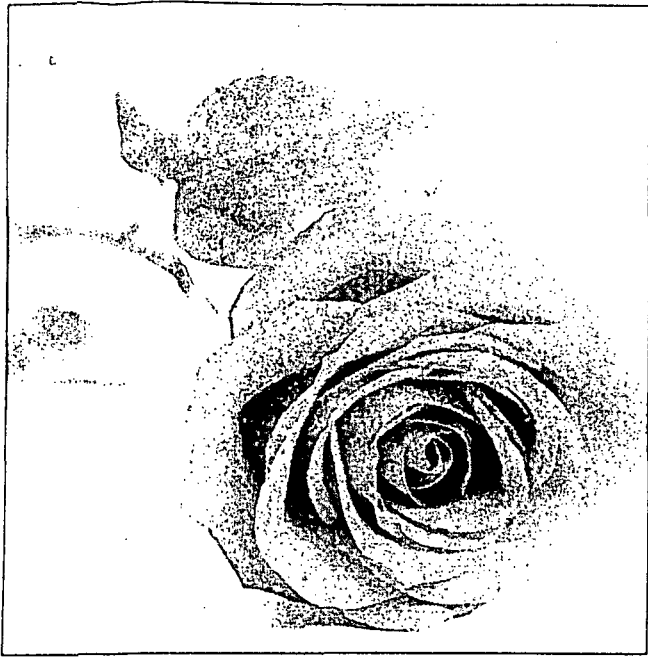
CHECK DATES: Upon Receipt of Invoice

PRICE: \$8,381.00 net (\$9,860.00 gross)

NOTE: Please mail tear sheets to billing address.

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LET IT ALL BE GOOD

CORPEI

CORPORATION FOR THE PROMOTION OF EXPORTS AND INVESTMENTS

www.corpei.org

INSERTION ORDER – PLEASE CONFIRM RECEIPT BY RETURN EMAIL

TO: Jenna Golden, 202-266-7163, jgolden@nationaljournal.com

FROM: Abby Brabec, Fenton Communications, abrabec@fenton.com

PUBLICATION: Congress Daily

CLIENT: CORPEI

BILLING ADDRESS: Fenton Communications
1320 18th Street NW #500
Washington, DC 20036
202-822-5200

FENTON PROJECT NUMBER: 6-00313

SIZE: Full Page, Full Color – No Bleed

LOCATION: Right Hand Page, Far Forward

RUN DATE: Wednesday, June 20 and Monday, June 25

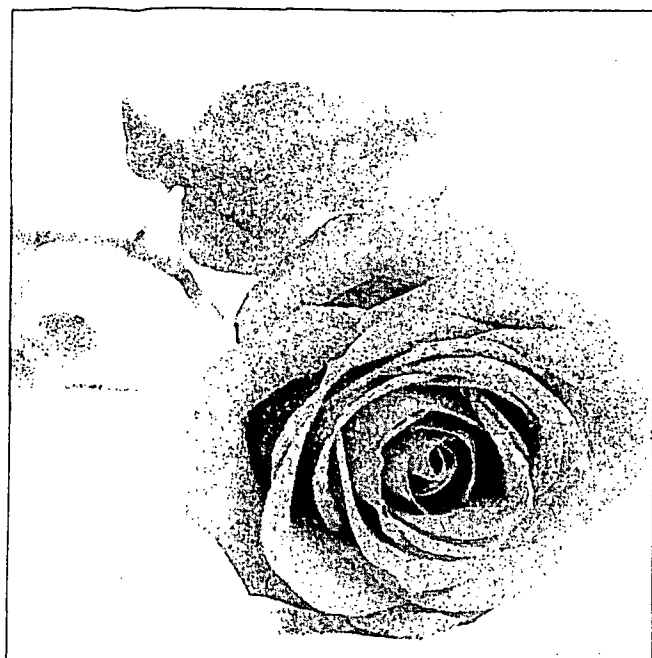
CHECK DATES: Upon Receipt of Invoice

PRICE: \$16,150.00 net grand total (\$19,000.00 gross grand total)

NOTE: Please mail tear sheets to billing address.

#

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www.corpei.org



PRESS RELEASE
FROM THE EMBASSY OF THE REPUBLIC OF ECUADOR

For Immediate Release:
June 20, 2007

Contact: Timi Gerson
202-360-7801

**CONGRESSIONAL ACTION ON ATPDEA EXTENSION APPLAUDED
AS CLOCK TICKS TOWARD JUNE 30 DEADLINE**

Washington, DC. The U.S. Congress took the first step in extending trade preferences to Bolivia, Colombia, Ecuador and Peru today. Proposed legislation was marked up by the House of Representatives' Ways and Means Committee. Following mark-up, the Andean Trade Preferences and Drug Eradication Act can move out of committee and onto the full House floor for a vote. Without Congressional action, ATPDEA will expire in less than two weeks, on June 30.

Below is the statement of Ecuador's Ambassador to the United States.

STATEMENT OF AMBASSADOR LUIS GALLEGOS

The government of Ecuador is pleased to see action by the U.S. Congress to extend the trade preferences before the June 30th deadline. By moving forward with a mark-up of the proposed ATPDEA legislation, the Ways & Means Committee is sending a clear signal that it understands the importance of this program and the urgency of its renewal.

Jobs created by ATPDEA support more than 1.4 million people in rural Ecuador by providing 350,000 heads of household with employment in areas that otherwise would be susceptible to the drug trade. Ecuador remains the only country in the region with zero cocoa cultivation thanks to the alternative industries that have flourished under the preferences program. ATPDEA has also provided opportunities for the more than 100 American companies with operations and investments in Ecuador and created thousands of jobs in U.S. port cities and companies that supply seeds, machinery and packaging for Ecuadorean exports.

This program strengthen the ties between our two nations, helping us work together to secure the Americas and jointly face the threats of the 21st century.

###

EMBASSY OF ECUADOR

For Immediate

Release:

Contact: Timi Gerson, 202-360-7801

June 27, 2007

STATEMENT OF AMBASSADOR LUIS GALLEGOS **ON 8-MONTH EXTENSION OF ANDEAN TRADE PREFERENCES**

The government of Ecuador is pleased that the United States Congress has recognized the critical importance of the Andean Trade Preferences and Drug Eradication Act (ATPDEA) to our country and to the Andean region as a whole.

While we are disappointed that ATPDEA was not extended for the full two years and three months contained in the original legislation, we are relieved that commerce will continue to flow smoothly between our two countries for the next eight months. The extension will also permit us to continue our successful fight against drug trafficking.

We look forward to ongoing dialogue with our counterparts here in Washington to create a long-term economic framework for Ecuador-U.S. relations.

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The ATPDEA Is a Win-Win for Both Ecuador and the U.S.

June 27th, 2007

The Andean Trade Promotion and Drug Eradication Act (ATPDEA) is the commercial basis of the relationship between Ecuador and its biggest trade partner, the United States. Recently, this trade program has been mischaracterized as “one-way” trade by individuals who ignore the benefits that it provides for U.S. commercial and foreign policy interests. As a Congressional vote looms likely this week, let’s review how ATPDEA works for both countries.

Drug trafficking is a problem that plagues not only the Andean region, but the U.S. with its estimated 25 million drug consumers — but it is in precisely this area that we find the greatest ATPDEA success story. Ecuador is a strong partner in the war on drugs, seizing close to 40 tons of illicit narcotics last year alone. But many people are not aware that we are also the only country in the region with zero coca cultivation. Agricultural export industries provide rural jobs for Ecuadoreans who might otherwise have few options outside coca cultivation. The largest coca fields in the world are just over the Colombian border, less than 40 miles from Ecuador’s flower fields. If ATPDEA disappears, we fear that the 1.4 million people dependent on these jobs would become prime recruits for the drug trade.

U.S. businesses would also lose out without ATPDEA. American seed, fertilizer and farm equipment providers, distribution and transportation companies and retailers all benefit from the ATPDEA production chain. Roughly 75 cents of every dollar spent on Ecuadorean roses stays in the U.S. economy and more than 50,000 U.S. jobs have been created in the floral sector alone.

Upwards of 100 American businesses invest and operate in Ecuador. Without ATPDEA, American companies will lose opportunities to do business in Ecuador — and your country’s greatest export, American entrepreneurship, will slow to a trickle in the region. There have been concerns raised regarding treatment of American investments in Ecuador, but let me set the record straight by stating the reality: Ecuador will continue to honor its Bilateral Investment Treaty (BIT) with the United States as we enter into talks to update that agreement. My government is committed to resolving disagreements through the appropriate and agreed upon channels and we also recognize the importance of a long-term, permanent pact on trade and investment issues. That is why we are excited to have begun the first stage

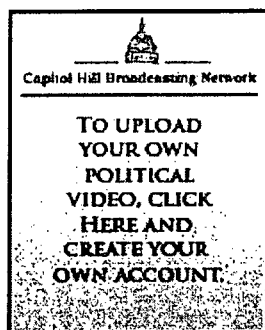
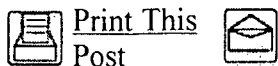
of bilateral talks with our U.S. counterparts about an economic framework for our two nations.

Ecuador wishes to maintain and deepen its ties with the United States. ATPDEA renewal is a vital component of this ongoing process. We urge the U.S. Congress to look at the real life results of ATPDEA and vote yes to this "win-win" trade deal.

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By **Ambassador Luis Gallegos, Republic of Ecuador**

This entry was posted on Wednesday, June 27th, 2007 at 8:38 am and is filed under [Politics](#), [Economy/Budget](#), [Foreign Policy](#) .



QUESTIONS & ANSWERS

- This section is a Q&A slot featuring interviews with members of Congress and sometimes with senior aides, selected lobbyists and policy experts. The Hill will ask the questions, but we welcome your input; to help us shape the discussion please [send your comment](#).

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The Miami Herald

Trade benefits U.S., Ecuador

By BERNARDO TRAVERSARI

Quick, name the one Andean country with zero coca cultivation. You didn't even know that there was one? I'm not surprised.

As the executive director of the Ecuadorean-American Chamber of Commerce, I frequently find myself explaining Ecuador's unique status and how we got that way. Heavy policing of our borders and freedom from the internal violence that has plagued neighboring Colombia and Peru are factors. But the biggest reason Ecuador remains drug-free is also the simplest: jobs.

Flowers instead of coca

Less than 20 miles from the flower farms of rural Ecuador lie the illicit coca fields of Colombia, whose produce finds its way to American streets as cocaine and crack. But our Ecuadorean flower workers earn more money than Colombian coca farmers. The story of how Latin America's most successful anti-drug program was implemented at zero cost to U.S. taxpayers comes down to six letters: ATPDEA.

The Andean Trade Preferences and Drug Eradication Act was enacted in 1991 between the United States and Bolivia, Colombia, Ecuador and Peru. In Ecuador, it is the lifeblood of the 1.4 million people whose families depend on

the jobs it creates, the thousands of businesses in the export production chain and the more than 100 American companies with investments and operations in Ecuador. They ship flowers, tuna, vegetables and other products to the United States, creating badly needed work in rural Ecuador.

It would be difficult to overestimate the political, economic and social instability that could result if the U.S. Congress does not renew ATPDEA before its June 30 expiration.

- It would roll back advances against drug-trafficking as 350,000 workers find themselves with few employment options outside the coca industry.

- It would wipe out much of the Ecuadorean private sector, harm U.S. companies exporting from Ecuador and increase anti-American sentiment in the region.

Preferences programs such as ATPDEA are out of vogue in some circles, which decry them as "one-way trade." The Andean trade pact turns this notion on its head. It creates tens of thousands of U.S. jobs -- 50,000 in Florida alone. For every \$1 spent on Ecuadorean roses, 75 cents remains in the U.S. economy. The seeds, soil, machinery and packaging for Ecuadorean exports are imported duty-free from U.S. companies, while many

Ecuadorean farms and factories are owned by U.S. investors. More than 90 percent of cotton for Ecuadorean textiles comes from the United States, generating jobs on American farms and in the port cities of Miami, Long Beach, Houston, New Orleans, Charleston and Savannah.

It is a virtuous cycle that sidesteps the polarized trade debate. No other agreement enjoys the strange bedfellow support of labor unions, multinational corporations, Latin American social movements and the Bush administration.

You are no doubt asking yourself why renewal of this arrangement isn't sailing through Congress. Unfortunately, politics and common sense are often at odds. Arguments opposing ATPDEA belong firmly in the "cut off your nose to spite your face" camp of economic relations.

- One is that Ecuador should be "punished" for not negotiating a free trade agreement with the United States -- but this approach primarily punishes the American and Ecuadorean businesspeople who are the most ardent advocates of open markets and free trade.

- Another is that Ecuador denounced the Bilateral Investment Treaty with the United States -- but last week Foreign Minister María Espinosa declared publicly that Ecuador will not denounce the treaty but instead will analyze investment issues in a bilateral economic dialogue that both countries have committed to begin immediately.

The chamber has worked closely with the Correa government on this issue because it is a matter of national interest that transcends partisan politics. ATPDEA renewal is our top priority. It may be small potatoes in the United States but a big deal in Ecuador and the other countries affected by it.

Long friendship

It is no secret that the United States is struggling for the hearts and minds of Latin Americans. Supporting ATPDEA underscores U.S. commitment to economic and human development as well as anti-drug efforts in the region.

Ecuador and the United States have a long-standing friendly relationship. For the sake of that relationship, Congress should move quickly to extend ATPDEA.

Bernardo Traversari is executive director of the Ecuadorean-American Chamber of Commerce in Quito, Ecuador. He can be reached at btraversari1@ecamcham.co.m

This opinion piece was published on June 22, 2007.

*****INVITATION: PRESS BREAKFAST *****

Media Advisory For:
Thursday, October 25, 2007

Contact: Paco Fabian, Fenton Communications
(202) 822-5200, paco@fenton.com

PRESS BREAKFAST BRIEFING WITH ECUADOREAN ATTORNEY GENERAL DR. XAVIER GARAICOA

Ecuadorean Attorney General Will Discuss Developments on International Arbitration, Constituent Assembly

Dr. Xavier Garaicoa, Attorney General of Ecuador is in Washington this week, and will host an invitation-only press breakfast briefing with members of the media to discuss international arbitration cases that Ecuador has pending before the World Bank's International Centre for the Settlement of Investment Disputes (ICSID) as well as the process to reform the Ecuadorean constitution, including the recent election of a constitutional assembly.

WHO: Dr. Xavier Garaicoa, Attorney General of Ecuador

WHEN: Thursday, October 25 at 9:00 AM EST

WHERE: Fenton Communications
1320 18th St. NW, 5th Floor
Washington, DC 20036

International and National Call-In Number (For Media Outside Washington, D.C.):
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Media Contacts:

Paco Fabian 202.412.9969, Fenton PR

Amanda Brasier, 864.940.7311, CBM US

CBM Presents Vision Award To Ecuadorian Ambassador Luis Gallegos

(Washington, D.C., Oct. 11, 2007) —CBM (Christian Blind Mission), presented His Excellency Luis Gallegos, the Ambassador of Ecuador, with the organization's highest honor—the 2007 CBM Vision Award in appreciation of the ambassador's advocacy on behalf of people with disabilities. This national award was presented during a World Sight Day celebration held Oct. 11 at the Ecuadorian Embassy.

CBM is the largest international development organization dedicated to improving and sustaining a higher quality of life for people with disabilities who are living in extreme poverty. The Vision Award is given to a person or organization that has made a significant impact in assisting people with disabilities. Ambassador Gallegos was honored for his advocacy and public policy work on behalf of individuals with disabilities.

"Ambassador Gallegos' energy and passion in educating the world about the plight of persons with disabilities is unsurpassed," says Ron Nabors, CEO of CBM. "He has traveled the world advocating for those individuals who often have no voice."

Ambassador Gallegos is a career Diplomat for the Ministry of Foreign Affairs, and has served in several countries and the United Nations for more than 30 years. For three years, he chaired the ad-hoc committee on the Comprehensive and Integral International Convention to Promote and Protect the Rights and Dignity of Persons with Disabilities. He has been the vice president of UNICEF's executive board. Ambassador Gallegos has traveled the globe—going to Japan, London, Tunisia and the United States—to lead discussions related to persons with disabilities.

The Ambassador's native country serves as an international model for its partnerships to eradicate river blindness, or onchocerciasis. In the Esmeralda's region, the government has partnered with CBM and Merck Pharmaceuticals to treat 400,000 with Mectazin®, a solution that prevents river blindness. The province has treated 85 percent of its population and is on the path to stop the transmission of river blindness.

"I accept this award with utmost humbleness on behalf of the millions of persons with disabilities who lack the voice to be heard," Ambassador Gallegos. "I am deeply committed to be their voice and their eyes in this unwavering commitment to remove the tangible and intangible barriers that society has placed in the path of these persons."

In 2006, the Vision Award was given to Merck on behalf of the company's contribution of Mectazin to CBM for distribution in developing countries.

CBM provides prevention, treatment, rehabilitation and microloans to people worldwide living with disabilities in the poorest of countries.

About World Sight Day:

World Sight Day is an annual day of awareness to focus global attention on blindness and vision impairment. Seventy-five percent of blindness is avoidable by treatment or prevention.

Every minute a child goes blind. In developing countries, 50 percent of those children die within two years. The leading cause of blindness in children is Vitamin A deficiency, which can be prevented by an annual dose of Vitamin A, which costs just 60 cents.



EMBASSY OF ECUADOR
Washington, D.C.

Minister of Economic Policy and Production Mauricio Dávalos is an economist with a long career of public service. He has served in the Ecuadorean government as Minister of Agriculture, Minister of Natural Resources and Energy, General Manager of the Central Bank of Ecuador, Governor of Ecuador for the International Monetary Fund (IMF), President of the National Investment Bank Steering Committee, the Ecuadorean Representative to the Bank of the Andes and Spain, a Representative of the Christian Democratic Party in the First Commission for the Legal Restructuring of State that developed the current Ecuadorean Constitution and a Member of the Constitutional Assembly.

Minister Dávalos was the Director of the Institute of Economic Research at the Catholic University of Ecuador and President of the Center for Latin American Monetary Studies. His experience in the private sector includes positions as President of Florisol, Ltd. Quito, President of the Association of Producers and Exporters of Flowers of Ecuador and the Executive Director of Queenroses. He is a graduate of the Catholic University of Ecuador.

Minister for National and International Security Policy Fernando Bustamante has served extensively in both the public and private sector as a national policy expert on security issues. He was the sub-director for the Armed Forces and Democratic Governance project for the U.S. National Endowment for Democracy, a member of the Work Group on Andean Security, a risk assessment analyst for the London-based firm Jane's Country Risk and a government advisor on the negotiation of the Ecuador-Peru security treaty (*Tratado de Seguridad y Medidas de Confianza Mutua*). Minister Bustamante was a member of the Study Group on Constitutional Reforms for the Government of Ecuador in 1997 and has consulted extensively with United Nations ranging from the UN Development Program (UNDP), the UN Food and Agriculture Organization (FAO) and UNICEF.

He has published on the topics of democracy and the role of the military, security threats in the Western Hemisphere, militarization in the region and U.S. military and counter narcotics policy in Latin America. Minister Bustamante is an accomplished academic and has taught at universities in Argentina, Chile and Ecuador. He received his undergraduate degree in Sociology from the Catholic University of Chile and has done postgraduate work in Public Administration and Political Science at Harvard University and the Massachusetts Institute of Technology (MIT) respectively.

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H. Josef	Hebert	Associated Press	Reporter - energy	(202) 641-9472	jhebert@ap.org
Deb	Riechmann	Associated Press	Reporter	(202) 641-9494	driechmann@ap.org
Liz	Sidoti	Associated Press	Reporter - politics	(202) 641-9827	lsidoti@ap.org
Matt	Yancey	Associated Press	Congress and enviro News Editor	(202) 641-9403	myancey@ap.org
Bob	Kemper	Atlanta Journal-Constitution	Reporter -Congressional	(202) 331-0900	bkemper@ajc.com
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James	Efstathiou	Bloomberg	Energy Reporter	(202) 654-1224	jefstathiou@bloomberg.net
Kim	Chipman	Bloomberg News	Reporter - environment/ politics	(202) 624-1927	kchipman@bloomberg.net
Tina	Seeley	Bloomberg News	Energy Reporter	(202) 624-1965	tseeley@bloomberg.net
Daniel	Whitten	Bloomberg News	Energy Reporter	(202) 624-1956	dwhitten2@bloomberg.net
Bill	Small	Bloomberg Radio	Reporter - Business, WHouse	(202) 624-1929	BSMALL@BLOOMBERG.NET
Audrey	Hipkins	BNA's Environmental Compliance Bulletin	Executive Editor	(202) 452-4412	ahipkins@bna.com
John	Donnelly	Boston Globe	Reporter - Enviro. & International	(202) 857-5141	donnelly@globe.com
Susan	Milligan	Boston Globe	Reporter -Congressional	(202) 857-5143	s_milligan@globe.com
John	Carey	Business Week	Reporter - Environment/ Science	(202) 383-2214	john_carey@businessweek.com
Steve	LeVine	BusinessWeek	Foreign affairs and energy Correspondent	(202) 383-2216	steve_levine@businessweek.com
Teri	Okita	CBS - Newspath	Reporter	(202) 457-4577	newspath@cbs.com
Bette	Hileman	Chemical & Engineering News	Senior Editor - climate change/ environmental tech	(202) 872-4583	b_hileman@acs.org
Jeffrey	Johnson	Chemical & Engineering News	Senior Editor - energy/ biofuels/ nuclear	(202) 872-6072	j_johnson@acs.org
Bill	Neikirk	Chicago Tribune	Reporter -Congressional	(202) 824-8214	wneikirk@tribune.com
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Scott	Carlson	Chronicle of Higher Education	Senior Reporter - Green Planning and Sustainability	(202) 466-1704	scott.carlson@chronicle.com
Rich	Monastersky	Chronicle of Higher Education	Senior Writer - Science	(202) 466-1729	rich.monastersky@chronicle.com
Kevin	Braun	ClimateWire	Editor in Chief	(202) 628-6500	kbraun@eenews.com
Robin	Bravender	ClimateWire	Reporter	(202) 737-4340	rbravender@eenews.net
John	Fialka	ClimateWire	Editor	(202) 737-4340	jfialka@eenews.net
Lauren	Morello	ClimateWire	Reporter	(202) 737-4340	lmorello@eenews.net
Karen	James	CNBC Cable Network	Coordinating Producer, Energy and Conservation	(202) 776-7408	karen.james@nbcuni.com
Steve	Redisch	CNN/Cable News Network	Deputy Washington Bureau Chief	(202) 898-7911	steve.redisch@turner.com

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Matthew Hoyer	CNN-Washington Bureau	Executive Producer	(202) 515-2293	matthew.hoyer@turner.com
Peter Gardett	Coal Daily	Editor	(202) 349-2862	peter.gardett@argusmediagroup.com
Marcin Skomial	Coal Outlook	Associate Editor	(202) 383-2000	marcin_skomial@platts.com
Charlotte Wright	Coal Outlook	Managing Editor	(202) 383-2190	charlotte_wright@platts.com
Darren Goode	CongressDaily	Energy & Environment Reporter	(202) 550-6619	dgoode@nationaljournal.com
Keith Koffler	CongressDaily	Reporter	(202) 347-7187	kkoffler@nationaljournal.com
Doug Podolsky	Consumer Reports	Senior Editor Health and Science	(202) 462-6262	pododo@consumer.org
Marcus Stern	Copley News Service	Editor	(202) 737-7685	marcus.stern@copleydc.com
Linda Cartwright	CQ Green Sheets	Reporter	(202) 546-2929	lcartwright@cq.com
Coral Davenport	CQ Green Sheets	Reporter	(202) 419-8572	cdavenport@cq.com
Leslie Duncan	CQ Green Sheets	Reporter	(202) 419-8487	lduncan@cq.com
Toni Johnson	CQ Green Sheets	Reporter	(202) 419-8577	tjohnson@cq.com
Marcia Clemmitt	CQ Researcher	Staff Writer - health/ environment	(202) 729-1351	mclemmitt@cqpress.com
Avery Palmer	CQ Today	Environment Reporter	(202) 419-8332	apalmer@cq.com
Catherine Richert	CQ Today	Reporter - agriculture	(202) 419-8468	crichtert@cq.com
Rebecca Adams	CQ Weekly	Reporter - energy/ environment	(202) 419-8308	radams@cq.com
Steve Cook	Daily Environment Report	Reporter - air pollution	(202) 452-4331	scook@bna.com
Larry Evans	Daily Environment Report	Managing Editor - environment	(202) 452-4367	levans@bna.com
Mike Ferullo	Daily Environment Report	Reporter - nuclear/ mining	(202) 452-4237	mferullo@bna.com
Audrey Hipkins	Daily Environment Report	Executive Editor - global warming	(202) 452-4417	ahipkins@bna.com
Gloria Onley	Daily Environment Report	Editorial Assistant	(202) 452-4620	gonley@bna.com
Pat Phibbs-Rizzuto	Daily Environment Report	Reporter - chemicals	(202) 452-4106	prizzuto@bna.com
Amena Saiyid	Daily Environment Report	Reporter	(202) 452-5358	asaiyid@bna.com
Dean Scott	Daily Environment Report	Reporter - climate change	(202) 452-4130	dscott@bna.com
Jim Landers	Dallas Morning News	International Business Columnist	(202) 661-8407	jlanders@dallasnews.com
Jim Landers	Dallas Morning News	Reporter - Energy	(202) 661-8407	jlanders@dallasnews.com
Dave Michaels	Dallas Morning News	Energy, enviro and transportation Correspondent	(202) 661-8425	dmichaels@dallasnews.com
Donna Block	Deal, The	Reporter-Business/ energy	(202) 429-2993	dblock@thedeal.com
Justin Hyde	Detroit Free Press	Reporter - energy/environment	(202) 906-8204	jhyde@freepress.com
Siobhan Hughes	Dow Jones Newswires	Energy, Oil and Climate Reporter	(202) 862-6654	siobhan.hughes@dowjones.com
Ian Talley	Dow Jones Newswires	Energy Reporter	(202) 862-9285	ian.talley@dowjones.com
Campion Walsh	Dow Jones Newswires	Energy/economics reporter	(202) 862-9291	campion.walsh@dowjones.com
Monica Trauzzi	E & E TV	reporter - environment/energy	(202) 737-4340	mtrauzzi@EandE.tv
David Heath	Environment	Assistant Editor	(202) 296-6267	dheath@heldref.org
Melanie Papasian	Environment	Assistant Editor	(202) 296-6267	mpapasian@heldref.org
Megan Petty	Environment	Editorial Assistant	(202) 296-6267	mpetty@heldref.org
Barbara Richman	Environment	Managing Editor	(202) 296-6267	brichman@heldref.org
Mary O'Driscoll	Environment & Energy Daily	Reporter - Congressional	(202) 737-4340	modriscoll@eenews.net
Rachel Jean-Baptiste	Environmental Law Reporter	Senior Editor	(202) 558-3101	jean-baptiste@eli.org
Kellyn Betts	Environmental Science & Technology	Editor - Senior Associate	(202) 872-4582	k_betts@acs.org
Barbara Booth	Environmental Science & Technology	Assistant Editor	(202) 872-4582	est@acs.org
Kris Christen	Environmental Science & Technology	Editor - Assistant	(202) 872-4582	est@acs.org

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Catherine	Cooney	Environmental Science & Technology	Editor - Environment	(202) 872-4582	est@acs.org
John	Crittenden	Environmental Science & Technology	Associate Editor	(202) 872-4582	est@acs.org
David	Dzombak	Environmental Science & Technology	Associate Editor	(202) 872-4582	est@acs.org
Britt	Erickson	Environmental Science & Technology	Managing Editor	(202) 872-4545	b_erickson@acs.org
Janet	Herring	Environmental Science & Technology	Associate Editor	(202) 872-4582	est@acs.org
Ronald	Hites	Environmental Science & Technology	Associate Editor	(202) 872-4582	est@acs.org
Naomi	Lubick	Environmental Science & Technology	Associate Editor	(202) 872-4582	est@acs.org
Armistead	Russell	Environmental Science & Technology	Associate Editor	(202) 872-4582	est@acs.org
Gary	Sayler	Environmental Science & Technology	Associate Editor	(202) 872-4582	est@acs.org
Mitchell	Small	Environmental Science & Technology	Associate Editor	(202) 872-4582	est@acs.org
Joseph	Suflita	Environmental Science & Technology	Associate Editor	(202) 872-4582	est@acs.org
Maria	Recio	Fort Worth Star-Telegram (Washington Bureau)	Reporter - Environmental Business	(202) 383-6000	mrecio@krwashington.com
Faith	Bremner	Gannett	Reporter - Congressional	(202) 906-8106	fbremner@gns.gannett.com
Erin	Kelly	Gannett	Reporter - NE environment	(202) 906-8120	ekelly@gns.gannett.com
Diana	Marrero	Gannett	DC Reporter	(202) 906-8112	dmarrero@gns.gannett.com
Laura	Rehrmann	Gannett News Service	Editor - Congressional	(202) 906-8147	lrehrmann@gns.gannett.com
Larry	Wheeler	Gannett News Service	Florida enviro Correspondent	(202) 906-8135	lwheeler@gns.gannett.com
Bill	Holland	Gas Daily	Associate Editor	(202) 383-2286	bill_holland@platts.com
Rodney	White	Gas Daily	Associate Editor	(202) 383-2143	rodney_white@platts.com
Emily	Rabin	GreenBiz.com	Senior Writer	(202) 833-2933	editor@greenbiz.com
Dan	Berman	Greenwire	Reporter	(202) 737-4340	dberman@eenews.net
Eric	Bontrager	Greenwire	Enviro and Public Lands Reporter	(202) 628-6500	ebontrager@eenews.net
Katherine	Boyle	Greenwire	EPA and Water Reporter	(202) 737-4340	kboyle@eenews.net
Allison	Freeman	Greenwire	Reporter - Enviro / oceans	(202) 737-4340	afreeman@eenews.net
Eryn	Gable	Greenwire	Reporter	(202) 737-4340	egable@eenews.net
Sara	Goodman	Greenwire	Green technology/business and green media	(202) 628-6500	sgoodman@eenews.net
Alexei	Kaplun	Greenwire	Energy Reporter	(202) 737-4340	akaplun@eenews.net
Kate	Ling	Greenwire	Energy Policy Reporter	(202) 628-6500	kling@eenews.net
Jenny	Mandel	Greenwire	Green biz and energy tech Reporter	(202) 628-6500	jmandel@eenews.net
Jenny	Mandel	Greenwire	Reporter	(202) 737-4340	jmandel@eenews.net
Lauren	Morello	Greenwire	Science/Technology/ Oceans reporter	(202) 737-4340	lmorello@eenews.net
Patrick	Reis	Greenwire	Environment & Conservation Reporter	(202) 737-4340	preis@eenews.net
Darren	Samuelsohn	Greenwire	Reporter	(202) 737-4340	dsamuelsohn@eenews.net
Josh	Voorhees	Greenwire	Environment & Conservation Reporter	(202) 628-6500	jvoorhees@eenews.net
Manu	Raju	Hill	Senate Reporter	(202) 628-8503	mraju@thehill.com
Betsy	Rothstein	Hill, The	Reporter - Congressional	(202) 628-8516	betsyr@thehill.com
Jim	Snyder	Hill, The	Reporter-Energy	(202) 628-8540	jsnyder@thehill.com
David	Ivanovich	Houston Chronicle	Reporter - Energy/Oil/Gas	(202) 263-6500	david.ivanovich@chron.com
Jean	Chemnick	Inside Energy	Policy Reporter	(202) 383-2243	jean_chemnick@platts.com
Brian	Hansen	Inside Energy	Associate Editor	(202) 383-2242	brian_hansen@platts.com
David	Jones	Inside Energy	Editor - Energy Management	(202) 383-2242	david_jones@platts.com
Michael	Schmidt	Inside Energy - climate change	Managing Editor	(202) 383-2269	mike_schmidt@platts.com

MASTER Environmental Press List

Bill	Loveless	Inside Energy - energy/ congress	Editor	(202) 383-2240	bill_loveless@platts.com
Michael	Schmidt	Inside Energy/with Federal Lands	Managing Editor	(202) 383-2269	mike_schmidt@platts.com
Steven	Dolley	Inside NRC	Associate Editor	(202) 383-2166	steven_dolley@platts.com
Helen	Hausmann	Inside NRC	Assistant Editor	(202) 383-2170	helen_hausmann@platts.com
Daniel	Horner	Inside NRC	Associate Editor	(202) 383-2164	daniel_horner@platts.com
Jenny	Weil	Inside NRC	Managing Editor	(202) 383-2161	jenny_weil@platts.com
Jim	Ostroff	Kiplinger Letter	Associate Editor - energy	(202) 887-5414	jostroff@kiplinger.com
Mark	Willen	Kiplinger Letter	Senior Editor	(202) 887-6462	mwillen@kiplinger.com
Kevin	Braun	Land Letter	Editor in Chief	(202) 628-6500	kbraun@eenews.net
Aaron	Zitner	Los Angeles Times	Assistant National News Editor	(202) 824-8394	aaron.zitner@latimes.com
John	Dimsdale	Marketplace	Bureau Chief,	(202) 223-6699	dimsdale@marketplace.org
Mike	Bold	McClatchy	Editor - News	(202) 383-0017	mbold@mcclatchydc.com
Robert	Boyd	McClatchy	Reporter - Science	(202) 383-6007	rboyd@mcclatchydc.com
Sean	Reilly	Mobile Register/Newhouse (Washington Bu	DC Reporter / environment	(202) 383-7815	sean.reilly@newhouse.com
William	Greider	Nation, The	Reporter	(202) 546-2239	
Karen	Front	National Geographic		(202) 828-6695	kfont@ngs.org
Margaret	Kriz	National Journal	Reporter	(202) 739-8428	mkriz@nationaljournal.com
Alexis	Simendinger	National Journal	Staff Correspondent	(202) 739-8490	asimendinger@nationaljournal.com
Gwen	Arnold	National Wetlands Newsletter	Editor	(202) 939-3800	arnold@eli.org
Colin	Macilwain	Nature	Editor	(202) 737-2510	c.macilwain@naturedc.com
Leslie	Sage	Nature	Senior Editor	(202) 737-2511	l.sage@naturedc.com
Alexandra	Witze	Nature	Senior News and Features Editor	(202) 626-2525	a.witze@naturedc.com
Jay	Blackman	NBC	Reporter - National News	(202) 885-4734	jay.blackman@nbc.com
Tom	Costello	NBC	Reporter	(202) 885-4200	tom.costello@nbc.com
John	Broder	New York Times	Reporter - environment	(202) 862-0359	broder@nytimes.com
Matt	Wald	New York Times	Reporter - Energy/Transportation	(202) 862-0363	mattwald@nytimes.com
Daniel	Stone	Newsweek	Enviro Reporter	(202) 626-2075	Daniel.stone@newsweek.com
Sue	Goodwin	NPR - Talk of the Nation	Executive Producer	(202) 513-2340	sgoodwin@npr.org
Elizabeth	Arnold	NPR/National Public Radio	Reporter - Science/Enviro - Alaska	(202) 513-2256	earnoldnpr@gmail.com
Alison	Aubrey	NPR/National Public Radio	Reporter - Science	(202) 513-2000	aaubrey@npr.org
Nell	Boyce	NPR/National Public Radio	Technology/ Science Reporter	(202) 513-2432	nboyce@npr.org
Daniel	Charles	NPR/National Public Radio	Science Contributing Editor	(202) 513-2200	dcharles@npr.org
Rebecca	Davis	NPR/National Public Radio	Science Producer	(202) 513-2438	rdavis@npr.org
Anne	Gudenauf	NPR/National Public Radio	Science Desk Senior Editor	(202) 513-2787	agudenauf@npr.org
Christopher	Joyce	NPR/National Public Radio	Science Desk Correspondent	(202) 513-2789	cjoyce@npr.org
David	Malakoff	NPR/National Public Radio	Editor--Science/Environment	(202) 513-2435	dmalakoff@npr.org
Joe	Neel	NPR/National Public Radio	Editor - Deputy Senior	(202) 513-2785	jneel@npr.org
John	Nielsen	NPR/National Public Radio	Environmental Correspondent	(202) 513-2781	jnielsen@npr.org
Joe	Palca	NPR/National Public Radio	Reporter - Science	(202) 513-2776	jpalca@npr.org
Elizabeth	Shogren	NPR/National Public Radio	Environmental Reporter	(202) 513-2243	eshogren@npr.org
Brenda	Wilson	NPR/National Public Radio	Science Desk Editor & Senior Correspondent	(202) 513-2783	bwilson@npr.org
Steven	Dolley	Nuclear Fuel	Associate Editor	(202) 383-2166	steven_dolley@platts.com

MASTER Environmental Press List

Elaine	Hiruo	Nuclear Fuel	Managing Editor	(202) 383-2163	elaine_hiruo@platts.com
Daniel	Horner	Nuclear Fuel	Associate Editor	(202) 383-2164	daniel_horner@platts.com
Barbara	Lewis	Nuclear Fuel	Assistant Editor	(202) 383-2169	barbara_lewis@platts.com
Margaret	Ryan	Nuclear Fuel	Editorial Director -Nukes	(202) 383-2170	margaret_ryan@platts.com
Gregory	Couturier	Oil Daily	Assistant Editor	(202) 662-0736	gcouturier@energyintel.com
Robert	Dillon	Oil Daily	Associate Editor	(202) 662-0723	rdillon@energyintel.com
Larry	Pearl	Pesticide & Toxic Chemical News	Managing Editor	(202) 887-6320	larry.pearl@informa.com
Elizabeth	Auster	Plain Dealer	Reporter - political columnist	(202) 638-1366	eauster@plainsd.com
Sabrina	Eaton	Plain Dealer	Reporter - political	(202) 638-1366	seaton@plainsd.com
Marty	Coyne	Platts	Reporter-Enviro	(202) 737-4340	x248
Daniel	Goldstein	Platts Global Alert	Senior Energy Reporter	(202) 383-2250	daniel_goldstein@platts.com
Gerald	Karey	Platts Oilgram News Bureau	Bureau Chief-Washington	(202) 383-2250	gerry_karey@platts.com
Bart	Jansen	Portland Press Herald	Reporter - political	(202) 488-1119	bjansen@pressherald.com
Chris	Baltimore	Reuters	Reporter - Energy/Oil & Gas	(202) 898-8316	chris.baltimore@reuters.com
Russ	Blinch	Reuters	Editor - Commodities and Energy	(202) 898-8415	russ.blinch@reuters.com
Chris	Doering	Reuters	Reporter - commodities	(202) 310-5683	christopher.doering@reuters.com
Deborah	Zabarenko	Reuters	Reporter- climate/ environment	(202) 898-8388	deborah.zabarenko@reuters.com
Tom	Doggett	Reuters	Reporter - Utilities	(202) 898-8320	tom.doggett@reuters.com
Robert	Gehrke	Salt Lake Tribune	DC Reporter	(202) 662-8925	gehrke@sltrib.com
Finlay	Lewis	San Diego Union-Tribune	Reporter	(202) 737-7687	finlay.lewis@copleydc.com
Zach	Coile	San Francisco Chronicle	Reporter - Enviro, Energy, Congress	(202) 263-6565	zcoile@sfchronicle.com
Carolyn	Lochhead	San Francisco Chronicle	Washington Correspondent - Congress, energy and tech	(202) 263-6565	clochhead@sfchronicle.com
Eli	Kintisch	Science	Staff Writer - congress/ science policy	(202) 326-6446	ekintisc@aaaas.org
Eric	Stokstad	Science	News Writer - environment	(202) 326-6500	estoksta@aaaas.org
Ben	Harder	Science News	Environment & Policy Writer	(202) 785-2255	bharder@sciserv.org
Susan	Milius	Science News	Life Sciences Writer	(202) 785-2255	smilius@sciserv.org
Sid	Perkins	Science News	Earth Science Writer	(202) 785-2255	sperkins@sciserv.org
Janet	Raloff	Science News	Senior Editor	(202) 785-2255	jraloff@sciencenews.org
James	Brosnan	Scripps Howard News Service	Reporter-Energy	(202) 408-2708	brosnanj@shns.com
Michael	Sprengelmeyer	Scripps Howard News Service	Reporter - Colorado focus/environment	(202) 408-2729	sprengelmeyerm@shns.com
Charles	Pope	Seattle Post-Intelligencer	Reporter - Washington	(202) 263-6461	charliepope@seattlepi.com
Bill	Lambrecht	St. Louis Post-Dispatch	Reporter - Environment & Conservation	(202) 429-9126	blambrecht@post-dispatch.com
Sue	Goodwin	Talk of the Nation	Executive Producer - environment	(202) 513-2340	sgoodwin@npr.org
Bill	Walsh	Times-Picayune	Reporter	(202) 383-7817	bill.walsh@newhouse.com
Kent	Garber	U.S. News & World Report	Reporter	(202) 955-2010	kgarber@usnews.com
Liz	Halloran	U.S. News & World Report	Senior Editor	(202) 955-2318	lhalloran@usnews.com
Danielle	Knight	U.S. News & World Report	National News Editor	(202) 955-2227	dknight@usnews.com
Jim	Pethokoukis	U.S. News & World Report	Senior Writer - Science and Business	(202) 955-2524	jpethokoukis@usnews.com
Bret	Schulte	U.S. News & World Report	Associate Editor - Environment	(202) 955-2009	bschulte@usnews.com
Krishnadev	Calamur	United Press International	Energy Correspondent	(202) 898-8000	kcalamur@upi.com
Carmen	Gentile	United Press International	Energy Correspondent	(202) 898-8000	cgentile@upi.com
Carmen	Gentile	United Press International	Energy Correspondent	(202) 898-8000	cgentile@upi.com

MASTER Environmental Press List

Kushal	Jeena	United Press International	Reporter - Energy	(202) 898-8000	energy@upi.com
Ben	Lando	United Press International	Reporter - energy	(202) 898-8000	blando@upi.com
Barbara	Hagenbaugh	USA Today	Reporter- Economy/Economic Issues, Energy	(202) 906-8150	bhagenbaugh@usatoday.com
Traci	Watson	USA Today	Reporter - climate/ space	(202) 906-8156	twatson@usatoday.com
Bill	Triplett	Variety	DC correspondent	(202) 659-3805	bill.triplett@variety.com
Rosanne	Skirble	Voice of America Radio Network	Reporter - Environment	(202) 619-2806	rskirble@voanews.com
Stephen	Power	Wall Street Journal	Energy and Environmental Policy	(202) 862-9269	stephen.power@wsj.com
Jonathan	Weisman	Wall Street Journal	Reporter	(202) 862-9200	jonathan.weisman@wsj.com
Joe	White	Wall Street Journal	Senior Editor - environment, energy and transportation	(202) 862-9200	joseph.white@wsj.com
Bill	Sammon	Washington Examiner	Senior Politics Correspondent	(202) 459-4943	bsammon@dcexaminer.com
Nils	Bruzellius	Washington Post	Editor - Science/Health/Enviro	(202) 334-7410	bruzelliusn@washpost.com
Jon	Cohen	Washington Post	Reporter	(202) 344-7410	cohenj@washpost.com
Juliet	Eilperin	Washington Post	Reporter - Enviro	(202) 334-7774	eilperinj@washpost.com
David	Fahrenthold	Washington Post	Reporter - Enviro	(202) 334-7550	fahrenthold@washpost.com
Michael	Fletcher	Washington Post	Reporter	(202) 334-7443	fletcherm@washpost.com
Steve	Mufson	Washington Post	reporter- energy	(202) 334-6414	mufsons@washpost.com
Kathy	Belyeu	Wind Energy Weekly	Editor	(202) 383-2500	kathy_belyeu@awea.org
Wendy	Rieger	WRC-TV	Environmental Reporter	(202) 885-4000	wendy.rieger@nbc.com



NORWEGIAN EMBASSY

MEDIA ADVISORY FOR
Tuesday, June 5, 2007

CONTACT: Joel Finkelstein or Kate Geller: 202.822.5200
Trude L. Paulsson: 202.944.8925

MELTDOWN!

New U.N. Study on Melting Ice and Global Warming to Show IPCC Just the Tip of the Iceberg

*Norwegian Embassy, UNEP and National Geographic Society to Host Launch of
New Study, Afternoon of Briefings with Key Voices in Debate*

WASHINGTON, DC --On TUESDAY, June 5, 2007, the Norwegian Embassy, the United Nations Environment Programme (UNEP) and the National Geographic Society will host an event presenting new evidence of the grave threat posed by melting ice from climate change – with findings that update and extend the work of the recent international report on global warming.

June 5th is World Environment Day, the main international observance of which is in Tromsø, Norway. The Washington, D.C. event will feature insights from the Norwegian government as it has struggled first hand with the impacts of climate change; as well as the personal experience of world-famous polar explorers Liv Arnesen and Will Steger, who will discuss melting ice at the top of the world.

A new peer-reviewed UNEP report to be released at the event will include:

- New evidence showing that permafrost in polar areas is already melting, releasing the potent greenhouse gas methane into the atmosphere with such force that it is opening holes in ice-covered lakes even during sub zero winter months.
- Other possible feedback effects where global warming actually causes more global warming – including recent science not included in the IPCC.
- The latest understanding of the dynamics of melting ice sheets, and what that means for future sea level rise.
- Other impacts of the decline in snow cover, sea ice, glaciers, permafrost and lake ice caused by global warming.

An afternoon program of panel discussions following the press event will focus on the politics, policies and technology of global warming. The full agenda is available online at <http://www.norway.org/wed>.

WHAT: World Environment Day 2007, featuring a landmark new analysis showing that the extent of melting ice caused by climate change

WHO: Bill Mansfield, United Nations Environment Program
Liv Arnesen and Will Steger, Polar Explorers
H.E. Knut Vollebaek, Ambassador of Norway
Dr. Robert Corell, Global Change Director, The H. John Heinz III Center for Science, Economics and the Environment.
Terry D. Garcia, Executive Vice President, National Geographic Society
Michael Rosenfeld, President of National Geographic Television: Presentation of Polar Bear movie
Additional speakers will take part in afternoon panel discussions.

WHERE: National Geographic Headquarters
Grosvenor Auditorium
17th and M Streets NW, Washington, D.C.

WHEN: 1.00 P.M.: Press Event and Report Release
2:30 P.M. – 6:00 P.M.: Panel Discussions on the politics, policies and technology of climate change.

CONTACT: Joel Finkelstein or Kate Geller | 202.822.5200
Trude L. Paulsson | 202.944.8925

#

World Environment Day - June 5, 2007

Melting Ice – A Hot Topic? Conference Program

Venue:

National Geographic Headquarters
Grosvenor Auditorium
17th and M Streets NW, Washington, D.C.

Time: 1.00 p.m. - 6.00 pm

Followed by a reception

1.00 – 1.30 p.m.: Opening:

- 1.00 p.m.: Introductions:
Terry D. Garcia, Executive Vice President, National Geographic Society (confirmed)
H.E. Knut Vollebaek, Ambassador of Norway (confirmed)
Video greeting from the Norwegian Minister of Environment Ellen Bjoernoey (confirmed)
- 1.05 p.m.: Video transmission from World Environment Day opening in Tromsø, Norway
Video greeting from CEO Fredrik Halvorsen, Tandberg, *Reducing carbon footprints by teleconferencing* (tbd)
- 1.10 p.m. Bill Mansfield, Senior Advisor to the Executive Director, UNEP:
Opening remarks and visual evidence of Global Climate and Eco. System Change (confirmed)
- 1.15 p.m. Dr. Robert Corell, Global Change Director, The H. John Heinz III Center for Science, Economics and the Environment (confirmed)

1.25 - 2.20 p.m.: Reporting from the Poles

Michael Rosenfeld, President of National Geographic Television (confirmed)
Ice Bear. Screening of clip from National Geographic's film from Svalbard, Norway
Liv Arnesen, Polar Explorer: *Exploring the impacts on the Arctic environment* (confirmed)
Will Steger, Polar Explorer: *Report from latest expedition, Global Warming 101* (confirmed)

2.20 – 2.40 p.m.: Break

2.40 – 3.15 p.m.: Panel 1. Melting Ice – A Hot Political Topic?

Moderator: Juliet Eilperin, Washington Post Staff Writer (confirmed)

Key note remarks:

Representative from U.S. Administration (tbc)
Representatives from US Congress (tbc)

3.15 – 3.30 p.m.: Q&A

3.30 - 3.50 p.m.: Dennis Dimick, Executive Editor National Geographic Magazine: *"Global Warming: Bulletins from a Warmer World and the current June 2007"*. (confirmed)

3.50 - 4.00 Erik Assadourian, World Watch Institute: *Moving beyond the consumer society* (confirmed)

4.00 – 5.15 Panel 2. Reducing Emissions - What Are the Options?

Moderator: David Hales, President of the College of the Atlantic (confirmed)

Bill Wehrum, Acting Assistant Administrator for Air and Radiation, EPA (confirmed)

Lasse Nord, Norwegian Commission on Low Emissions, *How Norway can reduce its emissions by 50-80% by 2050* (confirmed)

Silje Schei Tveitdal, Political Advisor on Energy and Environment; Norwegian Parliament: *From oil economy to renewable energies* (confirmed)

Carbon capture and storage:

William Christensen, Norwegian Ministry of Energy: *CCS- The Norwegian Perspective* (confirmed)

Svend Soeyland, Bellona (confirmed): *CO2 sequestration – bridging technology towards a renewable future*

Arve Thorvik, Vice President, EU Affairs, STATOIL: *Carbon Capture and Storage: Industrial solutions in the making* (confirmed).

Q & A

5.15 – 6.00 Panel 3. Technological Solutions

Moderator: Dr. Joseph Romm, Center for Energy and Climate Solutions: *The Low Carbon Car of the Future* (confirmed)

Alden Meyer, Director of Strategy Policy, Union of Concerned Scientists: *Technological solutions to global warming* (confirmed)

Scott Sklar, President, Stella Group: *Market Trends for Renewable distributed Generation and Smart Grids* (confirmed)

Peter Repinski, UNEP: *Energy efficiency: Green buildings* (confirmed)

Siir Kilgis, Honors Graduate, Science, Technology and International Affairs, Georgetown University: *Reducing CO2 Emissions with Rational Exergy Management* (confirmed)

Q&A

Closing remarks by Congressman Earl Blumenauer , (D-3rd OR), Member of Select Committee on Energy Independence and Global Warming (confirmed)

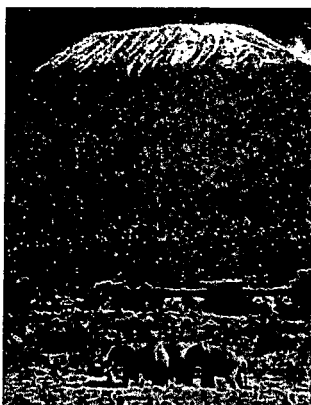
Closure 6.00 pm

Followed by reception offered by the Royal Norwegian Embassy (at National Geographic Society)

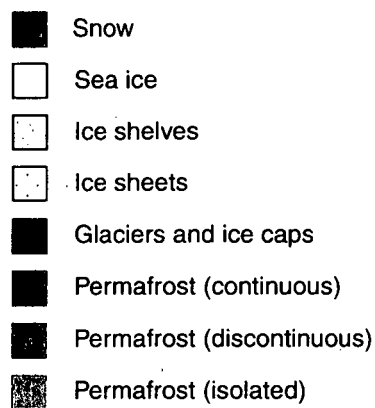


GLOBAL OUTLOOK FOR

ICE & SNOW



The Cryosphere



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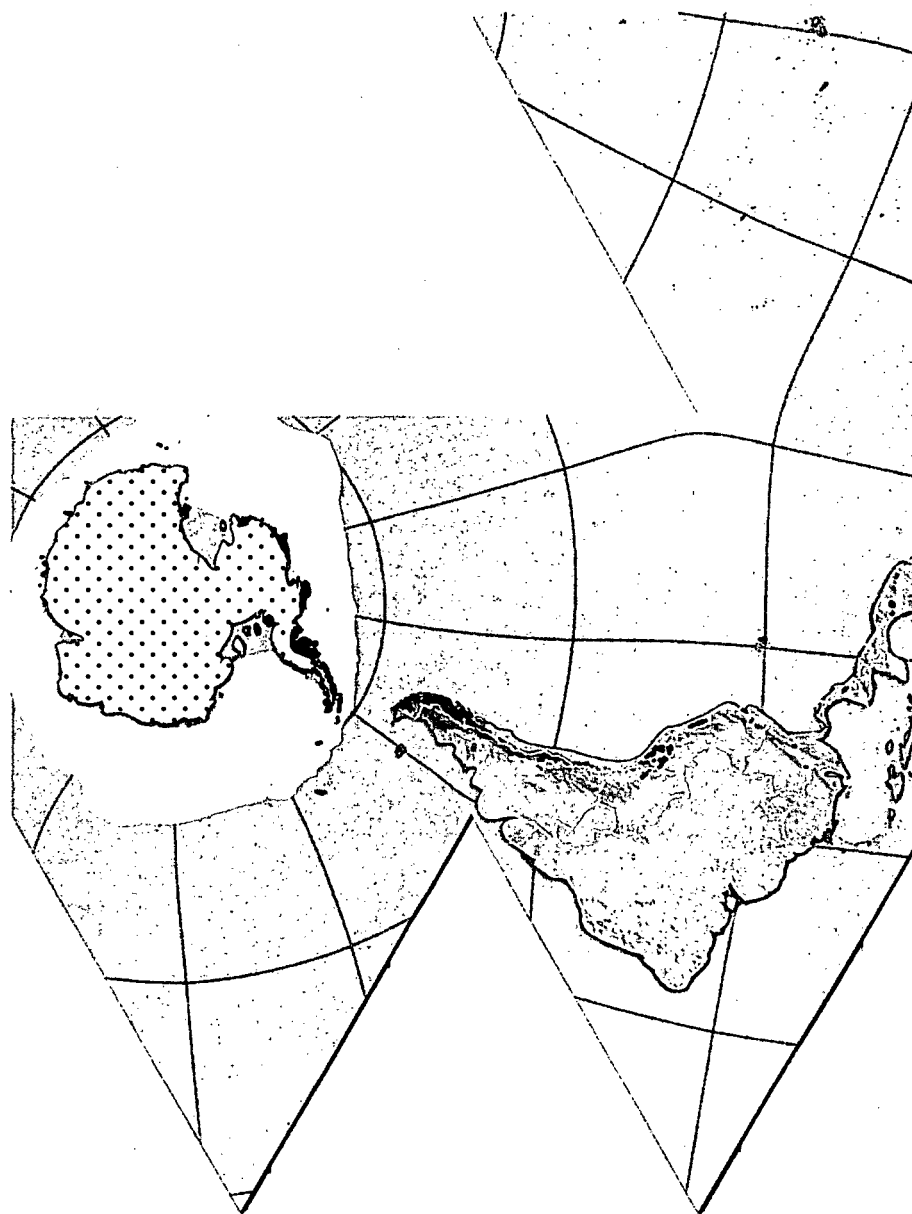
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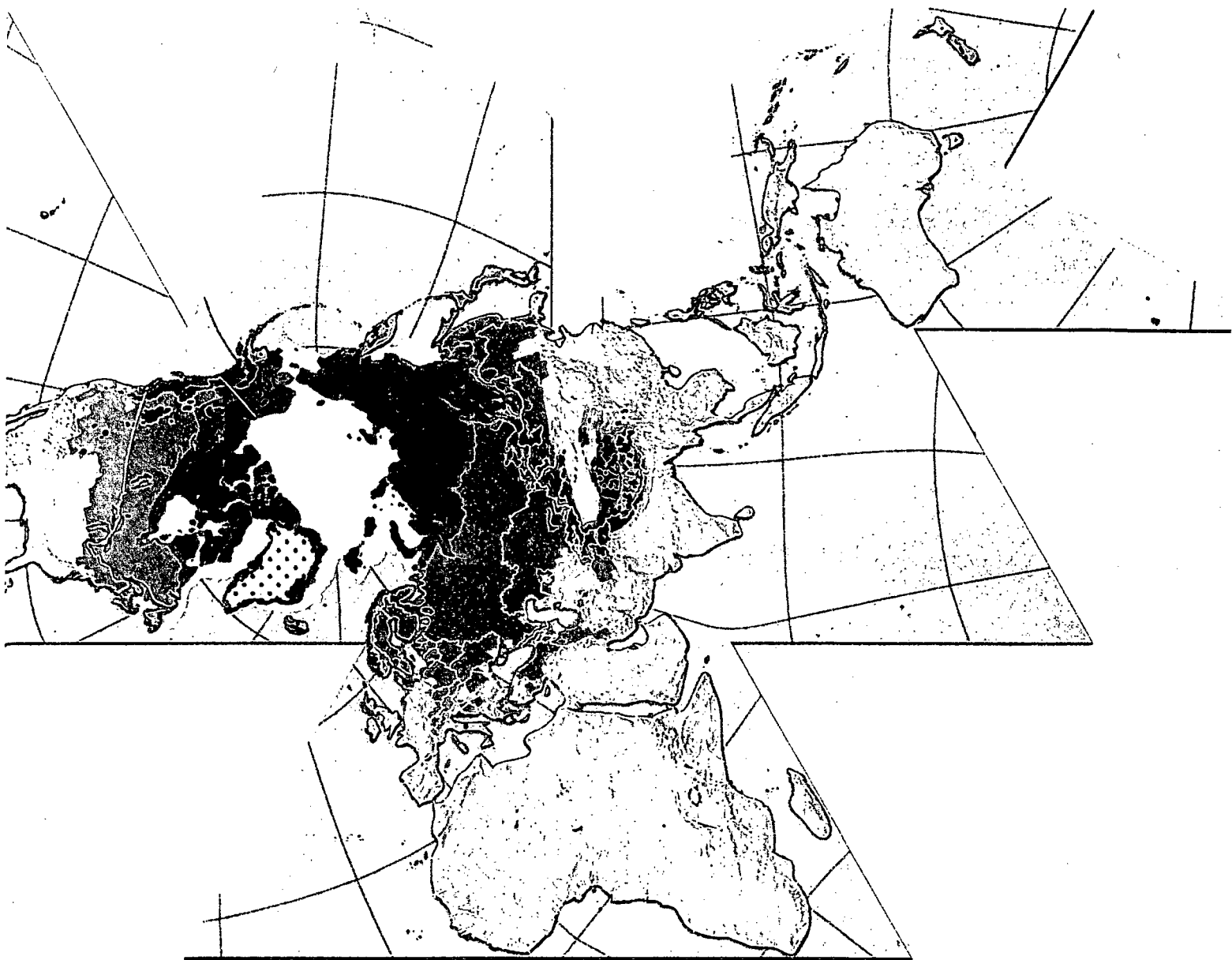


Notes:

Snow cover extent for Northern Hemisphere is represented by the 1966–2005 February average, for Southern Hemisphere by the 1987–2003 August average.

Sea ice extent for Northern Hemisphere is represented by the 1979–2003 March average, for Southern Hemisphere by the 1979–2002 September average.

Permafrost data for mountain areas and for the Southern Hemisphere are not represented in this map.



GLOBAL OUTLOOK FOR
ICE&SNOW

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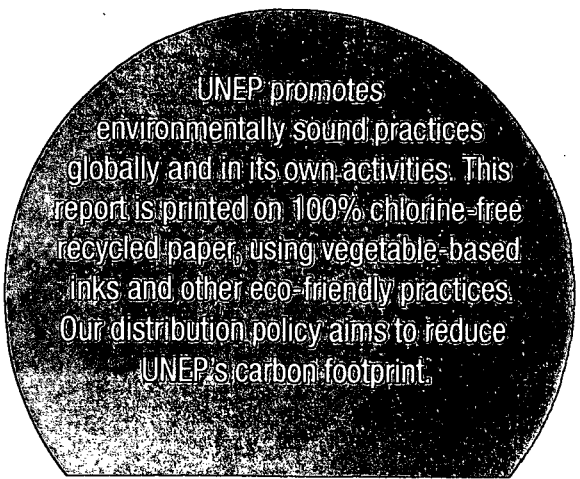
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Division of Early Warning and Assessment (DEWA)
United Nations Environment Programme
P.O. Box 30552
Nairobi 00100, Kenya
Tel: (+254) 20 7623562
Fax: (+254) 20 7623943
E-mail: dewa.director@unep.org
Web: www.unep.org

Editing and production by UNEP/GRID-Arendal, Norway
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Components of the Cryosphere		Area Covered (million square km)	Ice Volume (million cubic km)	Potential Sea Level Rise (cm) 6C
Snow on land (Northern Hemisphere) (annual minimum ~ maximum)	4	1.9 ~ 45.2	0.0005 ~ 0.005	0.1 ~ 1
Sea ice, Arctic and Antarctic (annual minimum ~ maximum)	5	19 ~ 27	0.019 ~ 0.025	0
Ice shelves	6A	1.5	0.7	0
Ice sheets (total)	6A	14.0	27.6	6390
Greenland		1.7	2.9	730
Antarctica		12.3	24.7	5660
Glaciers and ice caps (lowest and [highest] estimates)	6B	0.51 [0.54]	0.05 [0.13]	15 [37]
Permafrost (Northern Hemisphere)	7	22.8	4.5	~7
River and lake ice	8	(n/a)	(n/a)	(n/a)

Source: IPCC (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M.C. Marquis, K. Averyt, M. Tignor and H.L. Miller). Intergovernmental Panel on Climate Change, Cambridge and New York

Foreword



Ice, snow and climate change are closely linked. The *Global Outlook for Ice and Snow* investigates those connections, the current situation of ice and snow and the global significance of changes, now and in the years to come. The book was prepared for World Environment Day 2007 to provide an up-to-date assessment on this year's theme: Melting Ice – A Hot Topic? The *Global Outlook for Ice and Snow* is the second thematic assessment report in UNEP's Global Environment Outlook series.

It was written by teams of experts from different disciplines and many countries and has included leading research organizations in the preparation and the reviewing of the book.

Ice and snow on land, in the seas, and in the ground, collectively known as the cryosphere, are defining components of ecosystems in the northern part of the Northern Hemisphere, in Antarctica and in the world's mountain regions. Changes in ice and snow alter the distribution of Earth's heat and water, and influence regional and global ocean circulation.

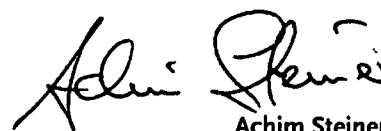
Many plants and animals such as the polar bear have evolved to live on, in and around ice and cannot survive without it. Traditional cultures are intimately tied to ice and snow in the far North and in mountain areas. For many people in northern and mountain regions, ice and snow are part of daily winter life, a resource for recreation and income generation, and an important part of national and regional identity.

In high mountain areas, particularly in the Himalayas and Andes, ice and snow are important sources of water for billions of downstream users; frequently maintaining

river flows and the recharge of aquifers in dry seasons. Glaciers are melting, sea ice is shrinking, permafrost is thawing. These changes have widespread impacts, from collapsing infrastructure in the Arctic to increased flooding of small islands in the South Pacific.

Reports of the Intergovernmental Panel on Climate Change (IPCC), founded by UNEP and the WMO, reflect our best understanding and knowledge on climate change, and identify uncertainties and research needs. March 1 of this year marked the start of International Polar Year (IPY) 2007–2008, the largest-ever international polar research programme. Much IPY research is directed to answering questions and resolving uncertainties about the cryosphere and climate change.

The IPCC's 4th Assessment reports underline the far reaching implications of changes in ice and snow. For example a total loss of Himalayan glaciers could happen within the lifetimes of many alive today affecting the water supplies of hundreds of millions of people. Climate change has indeed moved to the top of the global sustainable development agenda. The *Global Outlook for Ice and Snow* will serve as a reference publication in the debate, contribute to effective decision-making and ultimately the action so urgently needed.



Achim Steiner

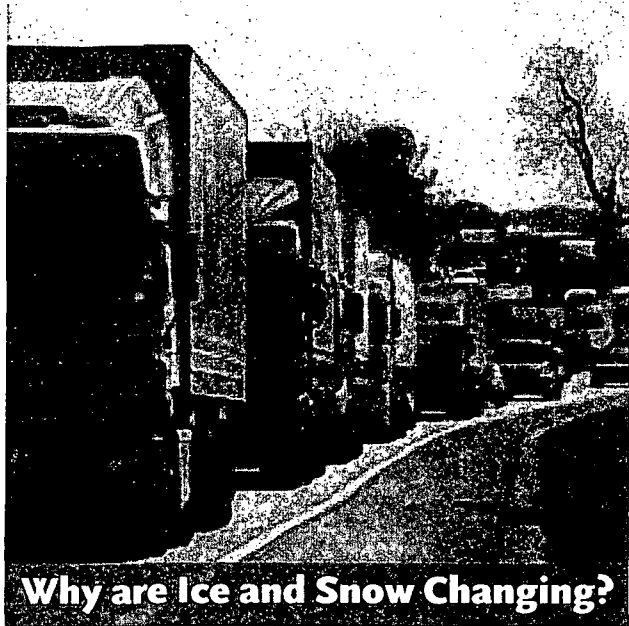
United Nations Under-Secretary-General
and Executive Director,
United Nations Environment Programme

Highlights

Ice and snow are important components of the Earth's climate system and are particularly sensitive to global warming. Over the last few decades the amount of ice and snow, especially in the Northern Hemisphere, has decreased substantially, mainly due to human-made global warming. Changes in the volumes and extents of ice and snow have both global and local impacts on climate, ecosystems and human well-being.

Snow and the various forms of ice play different roles within the climate system. The two continental **ice sheets** of Antarctica and Greenland actively influence the global climate over time scales of millennia to millions of years, but may also have more rapid effects on, for example, sea

level. **Snow** and **sea ice**, with their large areas but relatively small volumes, are connected to key interactions and feedbacks at global scales, including solar reflectivity and ocean circulation. Perennially **frozen ground** (permafrost) influences soil water content and vegetation over continental-scale northern regions and is one of the cryosphere components most sensitive to atmospheric warming trends. As permafrost warms, organic material stored in permafrost may release greenhouse gases into the atmosphere and increase the rate of global warming. **Glaciers and ice caps**, as well as **river and lake ice**, with their smaller areas and volumes, react relatively quickly to climate effects, influencing ecosystems and human activities on a local scale. They are good indicators of climate change.



Why are Ice and Snow Changing?

- A main conclusion of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report of 2007 was that it is very likely that most of the global warming during the last 50 years is due to the increase in human-made greenhouse gases.
- The largest recent increases in annual temperatures for the planet are over the North American Arctic, north central Siberia and on the Antarctic Peninsula.
- The climate system is influenced both by natural variability and external factors such as greenhouse gases and the sun. During the 21st century the most important external influence on snow and ice will be the increase in greenhouse gases.
- Overall Arctic temperatures have been increasing at almost double the global rate. Climate model simulations for the Arctic project further increases in average temperatures plus a trend to warmer high and low temperature extremes.
- In Antarctica the recent warming has not been widespread, but model projections for the end of the 21st century indicate a broader pattern of warmer surface temperatures.
- Ongoing changes to ice and snow have a predominantly positive feedback effect which will result in accelerating rates of change.

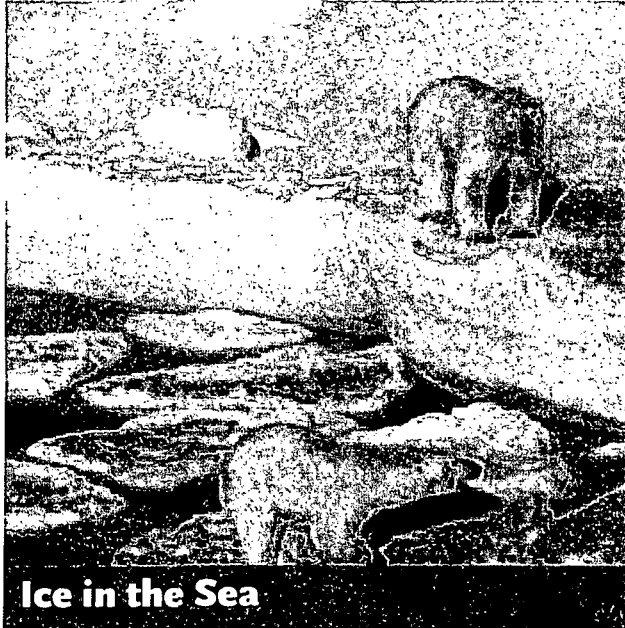


- ▣ Mean monthly snow-cover extent in the Northern Hemisphere has declined at a rate of 1.3 per cent per decade over the last 40 years with greatest losses in the spring and summer.
- ▣ Major reductions in snow cover are projected for mid-latitudes by the end of this century. Parts of the Canadian Arctic and Siberia are projected to receive increased snow fall.
- ▣ Air temperatures are projected to continue increasing in many mountainous regions, which will raise snow lines and cause other changes in mountain snow cover.
- ▣ Snow is an important ecological factor. Increased frequency of snow thaw due to rise in air temperatures changes the properties of snow cover, with implications for plants and animals that interact with snow.

Projected changes in amount of snow cover will affect the structure of ecosystems.

- ▣ Snow cover is a major influence on climate due to its high reflectivity of sunlight and its insulating properties. Decreases in snow-cover extent will act as a positive feedback to global warming by changing the reflectivity of the land surface.
- ▣ Changes in snow cover have a dramatic impact on water resources. Snow in mountain regions contributes to water supplies for almost one-sixth of the world's population.
- ▣ Changes in snow cover affect human well-being through influences on water resources, agriculture, infrastructure, livelihoods of Arctic indigenous people, environmental hazards and winter recreation.

Photo: Jon Aars/NPI



Ice in the Sea

- In the last three decades there have been declines in the extent of Arctic sea ice of 8.9 per cent per decade in September and 2.5 per cent per decade in March. The retreat of sea ice is particularly noticeable along the Eurasian coast. Sea-ice thickness has declined in parts of the Arctic since the 1950s and both the extent and the thickness of Arctic sea ice are projected to continue to decline with the possibility of a mainly ice-free Arctic Ocean in summer by 2100 or earlier.
- Antarctic sea ice is projected to decline in extent at a similar rate as in the Arctic, but it is not expected to thin as much.
- Declines in the extent of sea ice accelerate the rate of melting because more sunlight is reflected by the bright surface of snow and sea ice than by the dark surface of open water. This is the same feedback process that results from decline of snow-cover extent on land. This feedback process affects climate globally.
- Melting sea ice may influence global patterns of ocean circulation; increasing melting of sea ice in combination with increased freshwater influx from melting glaciers and ice sheets may result in major changes to ocean circulation.
- Sea ice is vital habitat for organisms ranging from tiny bacteria, algae, worms and crustaceans to sea birds, penguins, seals, walrus, polar bears and whales. Some sea-ice dependent animals are already at risk and the predicted declines in sea ice may lead to extinctions.
- Shrinking sea ice is forcing coastal Arctic indigenous people to adopt different methods of travel and to change their harvesting strategies. Further loss of sea ice threatens traditional livelihoods and cultures.
- Increasing extent of open water in polar regions will provide easier access to economic activities such as exploration and exploitation of petroleum resources, and ship-borne tourism, with accompanying benefits and risks.
- The Northern Sea Route along Russia's Arctic coast is currently navigable for 20–30 days annually. Predictions are that by 2080 the navigable period will increase to 80–90 days. This, combined with the potential of future opening of the Northwest Passage through Canada's waters, will likely have a major impact on world shipping.

Photo: Konrad Steffen



Ice on the Land

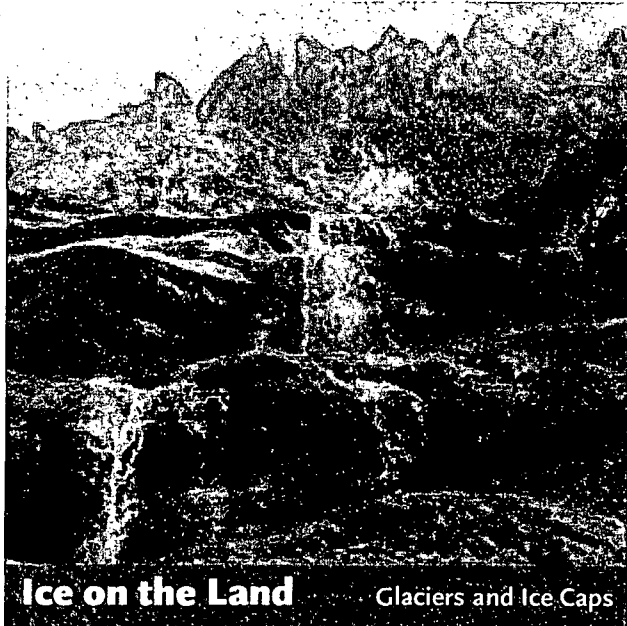
Ice Sheets

- Annual total loss of mass from the Greenland Ice Sheet more than doubled in the last decade of the 20th century and may have doubled again by 2005. This is related to more melting and also to increased discharge of ice from outlet glaciers into the ocean. Warmer Greenland summers are extending the zone and intensity of summer melting to higher elevations. This increases both meltwater runoff into the ocean and meltwater drainage that lubricates glacier sliding and potentially increases ice discharge into the ocean.
- There is uncertainty concerning recent overall changes in ice mass in the Antarctic Ice Sheet but there is probably an overall decline in mass with shrinking in the west and addition in the east due to increased snowfall. Ice shelves are thinning and some are breaking up. Gla-

ciers that feed the ice shelves are observed to accelerate, as much as eight-fold, following ice-shelf break-up.

- Observations made over the past five years make it clear that existing ice-sheet models cannot simulate the widespread rapid glacier thinning that is occurring, and ocean models cannot simulate the changes in the ocean that are probably causing some of the ice thinning. This means that it is not possible now to predict the future of the ice sheets, in either the short or long term, with any confidence.
- The Greenland and Antarctic ice sheets hold about 99 per cent of the world's freshwater ice (the equivalent of 64 m of sea level rise) and changes to them will have dramatic and world-wide impacts, particularly on sea level but also on ocean circulation.

Photo: Igor Smichkov/Stock



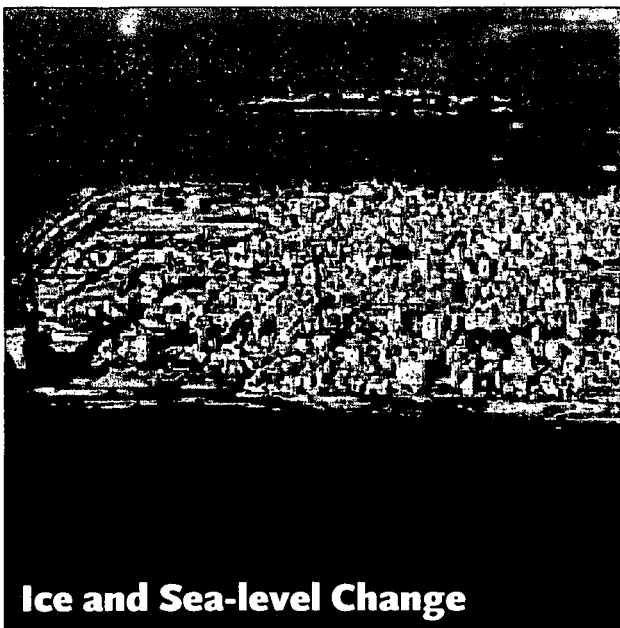
Ice on the Land

Glaciers and Ice Caps

- Over the past 100 years, and particularly since the 1980s, there has been worldwide and dramatic shrinkage of glaciers. This shrinking is closely related to global warming.
- Projected increases in global air temperatures will ensure the continuing shrinkage of glaciers and ice caps and may lead to the disappearance of glaciers from many mountain regions over the coming decades.
- Disappearance of glaciers will have major consequences

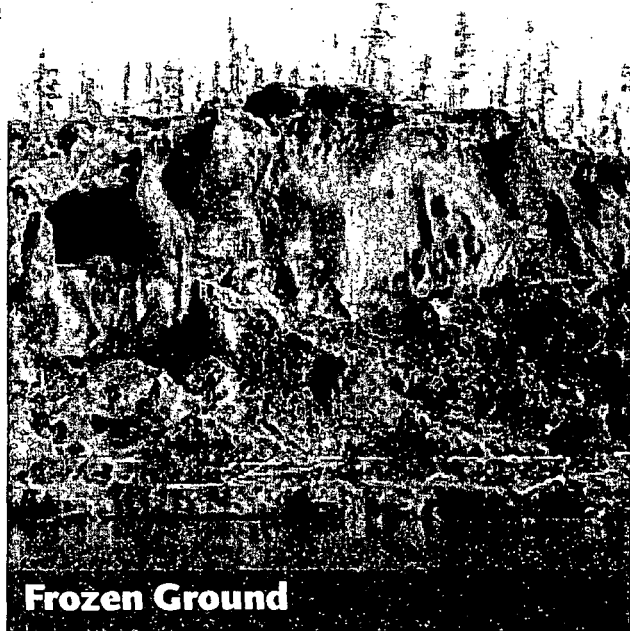
on water resources, especially in regions such as the Himalayas–Hindu Kush, the Andes, Rocky Mountains and European Alps, where many dry-season river flows depend on glacier meltwater.

- Shrinkage of glaciers leads to the deposition of unstable debris, the formation of ice and debris dammed lakes and it increases instability of glacier ice. These conditions pose increased risk of catastrophic flooding, debris flows and ice avalanches.



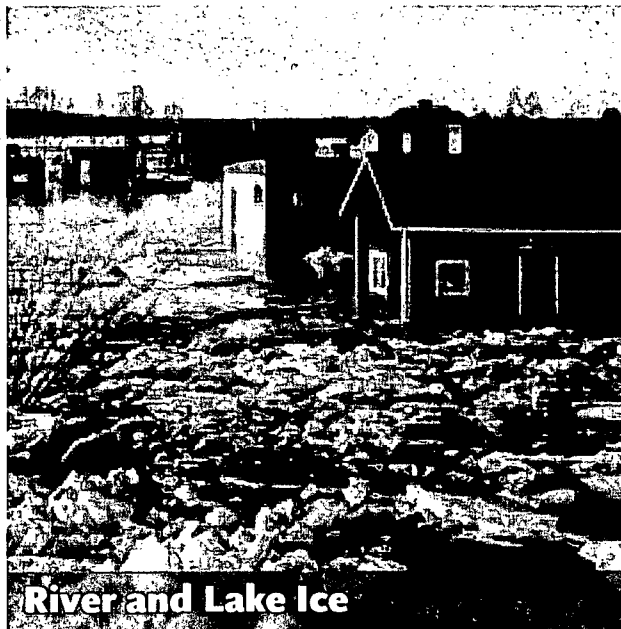
Ice and Sea-level Change

- Sea level is rising at an increasing rate which is associated with global warming. The rate of sea-level rise is now 3.1 mm per year; the average for the 20th century was 1.7 mm per year.
- More than a third of sea-level rise is from meltwater from glaciers and ice sheets with most of the remaining rise being due to thermal expansion of the oceans. The contribution of meltwater to sea-level rise can be expected to continue and accelerate as more land ice melts. Over the long term the ice sheets of Greenland and Antarctica have the potential to make the largest contribution to sea-level rise, but they are also the greatest source of uncertainty.
- For the next few decades, the rate of sea-level rise is partly locked in by past emissions and will not be strongly dependent on 21st century greenhouse gas emissions. However, sea-level projections closer to and beyond 2100 are critically dependent on future greenhouse gas emissions.
- The IPCC Fourth Assessment Report projects a global sea level rise over the 21st century in the range of about 20 to 80 cm. However, the upper bound of this projection is very uncertain.
- Climate change is also projected to increase the frequency and severity of extreme sea-level events such as storm surges. This will exacerbate the impacts of sea-level rise.
- The impacts of sea level rise in any region will depend on many interacting factors, including whether the coastal region is undergoing uplift or subsidence, and to what degree development has altered natural flood protection such as coastal vegetation.
- Rising sea levels will potentially affect many millions of people on small islands and at and near coasts worldwide. A wide range of adaptation and mitigation measures will be required to assist people to cope with the consequences; these will require cooperation among nations as well as among all levels of government, the private sector, researchers, non-government organizations and communities.



Frozen Ground

- Permafrost temperatures have increased during the last 20–30 years in almost all areas of the Northern Hemisphere. Warming of permafrost is also reported from areas of mountain permafrost. This warming has not yet resulted in widespread permafrost thawing.
- Climate changes are projected to result in permafrost thawing across the subarctic by the end of this century, with the most significant thawing occurring in North America.
- Permafrost stores a lot of carbon, with upper permafrost layers estimated to contain more organic carbon than is currently contained in the atmosphere. Permafrost thawing results in the release of this carbon in the form of greenhouse gases which will have a positive feedback effect to global warming.
- Thawing of ice-rich permafrost results in the formation of thermokarst, land forms in which parts of the ground surface have subsided. Thermokarst affects ecosystems and infrastructure and can accelerate permafrost thawing.
- The construction and everyday use of existing infrastructure can result in permafrost thawing, with subsequent effects on infrastructure. Increases in air temperatures may accelerate this ongoing permafrost degradation associated with infrastructure.
- Thawing of permafrost has significant impacts on ecosystems, with the potential to completely change habitats, for example, from boreal forest to wetlands.
- In mountainous areas thawing permafrost may increase slope instability, raising the risk of natural hazards such as landslides and rock falls.



River and Lake Ice

- Changes that have largely mirrored rising air temperatures are affecting river and lake ice, mainly seen as earlier spring break up and, to a lesser extent, later autumn freeze up.
- The trend to longer ice-free periods is projected to continue. Details are uncertain but strong regional variation is expected, with the amount of change depending on the degree of warming that is forecast.
- Ice formation on rivers and lakes is a key factor controlling biological production and changes in the length and timing of ice cover have ecosystem effects.
- In remote areas frozen rivers and lakes are used as trans-

port corridors and longer ice-free periods mean reduced or more expensive access to communities and industrial developments. Many northern indigenous people depend on frozen lakes and rivers for access to traditional hunting, fishing, reindeer herding or trapping areas.

- Spring break up often causes damming of rivers by ice, resulting in costly flooding. Lowered temperature gradients along north-flowing rivers in the Northern Hemisphere may lead to reductions in ice-jam flooding. This has potential negative ecological consequences for deltas where annual flooding is needed to maintain ponds and wetlands.



Policy and Perspectives

Changes in ice and snow raise policy issues at global, regional and local scales.

Global

- Ice, snow and climate change are closely linked. Mitigating climate change by reducing greenhouse gases emissions is the main global policy response to mitigate changes in ice and snow.
- The IPCC Fourth Assessment Report concluded that, to avoid further and accelerated global warming with major negative consequences, greenhouse gases must stop increasing and start decreasing no later than 15 to 25 years from now. Economic assessments indicate that this is achievable without significant welfare losses.

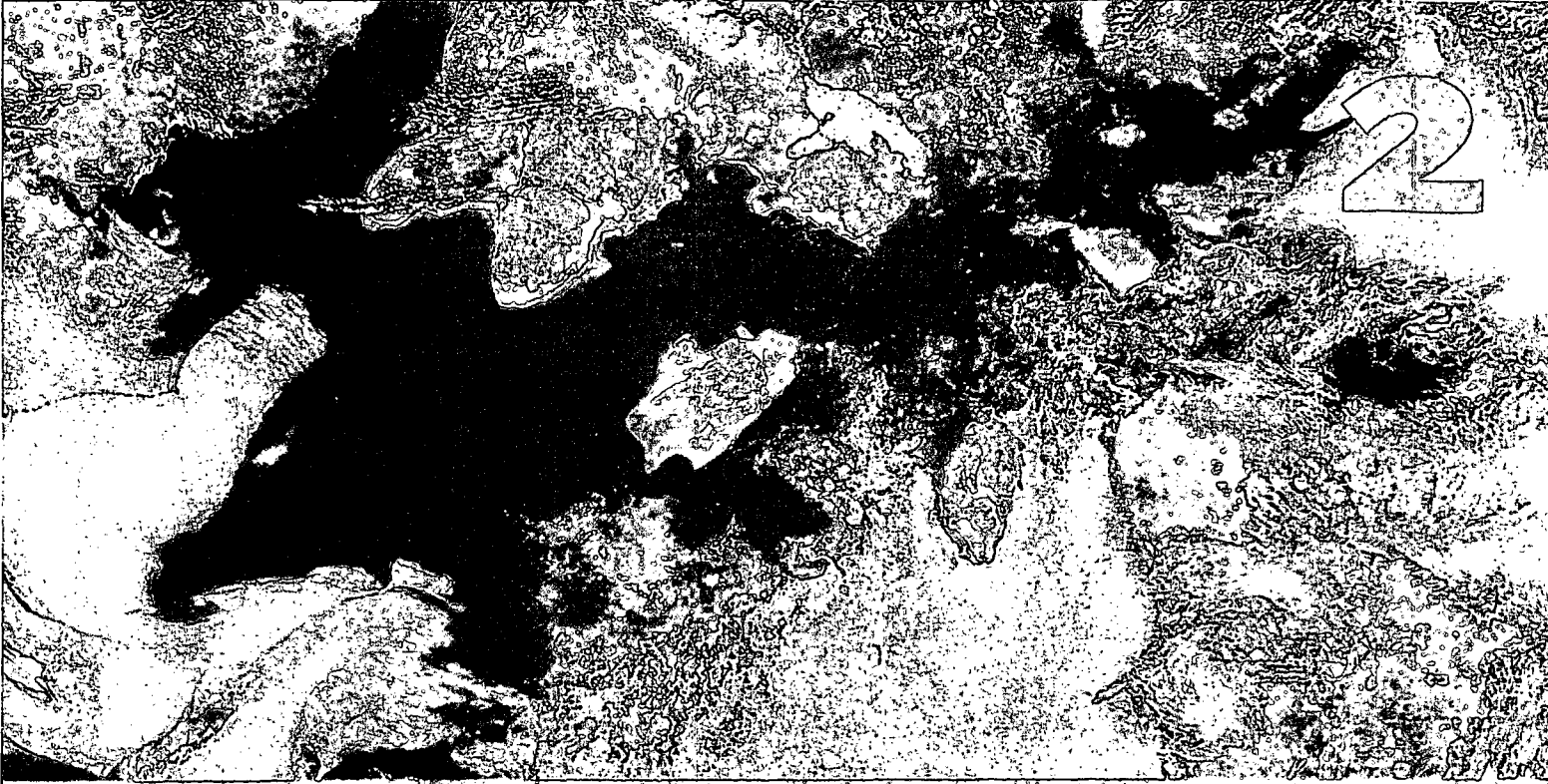
Regional

- Adaptation policy must be tailored to regions and requires regional scientific knowledge and assessment of impacts of climate change.

- In the Arctic, key policy issues centre on the prospect of retreating sea ice and the implications for shipping and exploitation of oil and gas reserves. This raises issues of jurisdiction and of regulatory regimes in the Arctic marine environment.
- In Antarctica, the projected decrease in sea-ice extent is likely to contribute to an already rapid expansion of the tourism industry with potential impacts on the environment and on the value of Antarctica in research. This points to the need for a regulatory framework for Antarctic tourism.
- In the Himalayas–Hindu Kush region, projected changes in snowfall and glacier melt are expected to increase risks of both floods and water shortages, potentially affecting hundreds of millions of people. Strategies for water management and land-use planning are needed to reduce vulnerability to the impacts of global warming.

Local

- Impacts of changes in ice and snow are already major concerns in many Arctic communities. Examples of local impacts are damage to coastal infrastructure from thawing permafrost and increased storm surges, and loss of access to subsistence resources for indigenous people. Expansion of shipping and oil and gas development will bring both local opportunities and potential for negative economic and social effects. Most individual communities currently lack the capacity to cope effectively with these stresses. Responses to these challenges are likely to reflect differences in political and legal systems among Arctic states.



2

Why are Ice and Snow Important to Us?

Pål Prestrud (Center for International Climate and Environmental Research, Oslo, Norway)

Why are Ice and Snow Important to Us?

This report demonstrates how we are affected by ice and snow, whether we live in the northern regions or tropical climates or in between. Ice and snow are important components of the Earth's climate system and are particularly vulnerable to global warming. Ice and snow are important parts of northerners' identity and culture, especially for indigenous people, whose cultures have adapted to a world in which ice and snow are not only integral parts of the ecosystem but also support a sustainable way of life. Reduction of ice and snow damages the ecosystems that support these cultures and livelihoods.

*"As our hunting culture is based on the cold, being frozen with lots of snow and ice, we thrive on it," says Sheila Watt-Cloutier, former Chair of the Inuit Circumpolar Council. "We are in essence fighting for our right to be cold."*¹

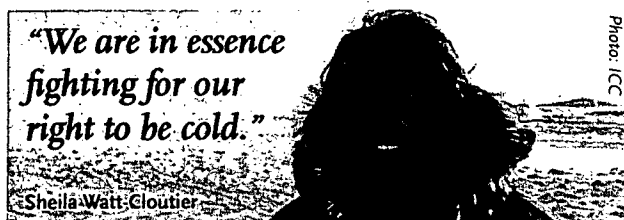
Ice and snow are also important in temperate and tropical areas. Hundreds of millions of people are affected by the ice and snow that accumulate in mountain regions. The slow melt from glaciers provides water to rivers supporting agriculture, domestic water supplies, hydroelectric power stations, and industry. If the glaciers disappear, people distant from these mountains, in the

lowlands and big cities of Asia and South America, will suffer from the loss of this dry-season water flow.

The global significance of ice and snow is profound. Less ice, snow and permafrost may amplify global warming in various ways. Melting glaciers and ice sheets in Greenland and Antarctica will raise the mean sea level. The retreating sea ice, in combination with increased supply of fresh water from melting glaciers and warmer ocean temperatures, could affect the strength of major ocean currents.

Over the last few decades, the amount of ice and snow, especially in the Northern Hemisphere, has decreased substantially^{2,3}. The primary reason for this decrease is the ongoing global warming that the WMO/UNEP Intergovernmental Panel on Climate Change³ (see Chapter 9) attributes mainly to human activities. This trend will accelerate if the global warming continues.

This book looks at the forces driving this unprecedented change (Chapter 3), and at the current state and outlook for the components of the cryosphere (see Box 1): snow (Chapter 4), ice in the sea (Chapter 5), ice on the land (Chapter 6), frozen ground (Chapter 7) and river and lake ice (Chapter 8). The societal and ecological impacts of changes in the different components of ice and snow are discussed in each chapter. The final chapter (Chapter 9) returns to a holistic view, presenting some regional perspectives and looking at implications of current and projected changes, and at policy responses. The report is based on scientific knowledge and each chapter is written by experts in their field.





Changes in the polar regions are important to the rest of the world

In addition to receiving less sun radiation than temperate and tropical regions, the polar regions are cold because ice and snow reflect most of the solar radiation back to space, while open sea and bare ground absorb most of the solar radiation as heat. When the ice and snow cover begin to shrink because the climate is getting warmer, more solar radiation tends to be absorbed, which in turn accelerates the melting. This process develops slowly, but as more and more bare ground and open sea are exposed, the warming will increase and the snow melting will acceler-

ate. Less ice and snow cover also means that less heat will be used for melting, which will contribute to the warming trend. In these ways, reduced ice and snow cover warms up polar regions and accelerates global warming. This is an example of what scientists call positive feedback, a self-reinforcing effect, in the climate system.

Climate scientists call the changes in the external natural and human-made factors that can explain the global warming over the last 150 years “climate forcings” (see also Chapter 3). Forcing is measured in watts per square metre of the Earth’s surface – in other words, the rate of adding (warming) or subtracting (cooling) energy or heat

from the Earth's heat balance. If all ice and snow were to disappear, and the effect of this were to be evened out across the globe, the Earth would receive 3 to 4 watts more heating per square metre than it does now⁴. For comparison, scientists believe that the climate forcing from all the additions and subtraction resulting from greenhouse gases, particulate matter, aerosols, solar radiation changes, and volcanic eruptions over the last hundred years equal about 1.6 watts per square metre³. This illustrates that the ice and snow covered surfaces in high latitude and high altitude regions contribute an important and essential cooling function for the whole planet.

Some of the feedbacks and interactions that result from warming in the polar regions are complex and very hard to predict. In the Arctic there is another positive climate feedback that may amplify global warming significantly. The uppermost part of the frozen tundra contains between 200 and 400 billion tonnes of carbon stored in organic material produced by the tundra vegetation² (Chapter 7). This organic material breaks down slowly and if the permafrost starts to thaw, decomposition will speed up and release the greenhouse gases methane and carbon dioxide. In addition, there are probably some thousand billion tonnes of methane frozen deep

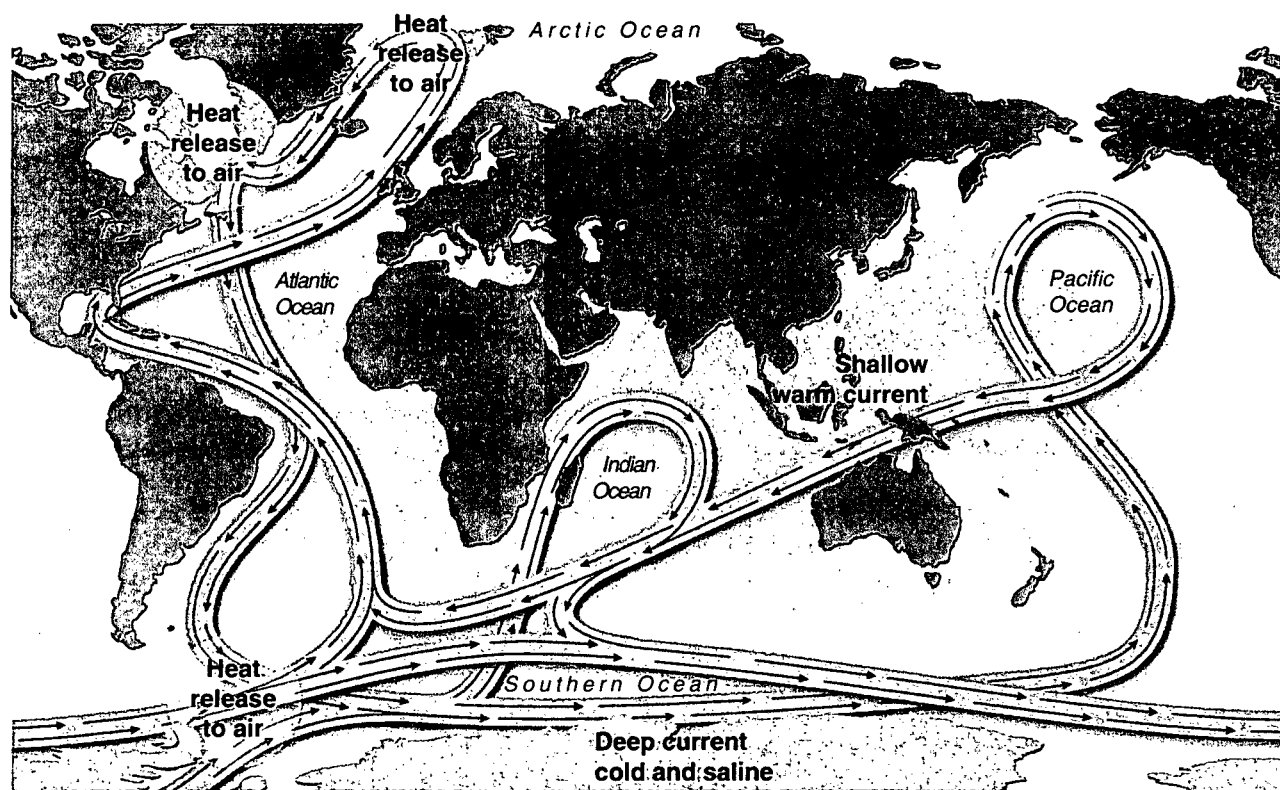


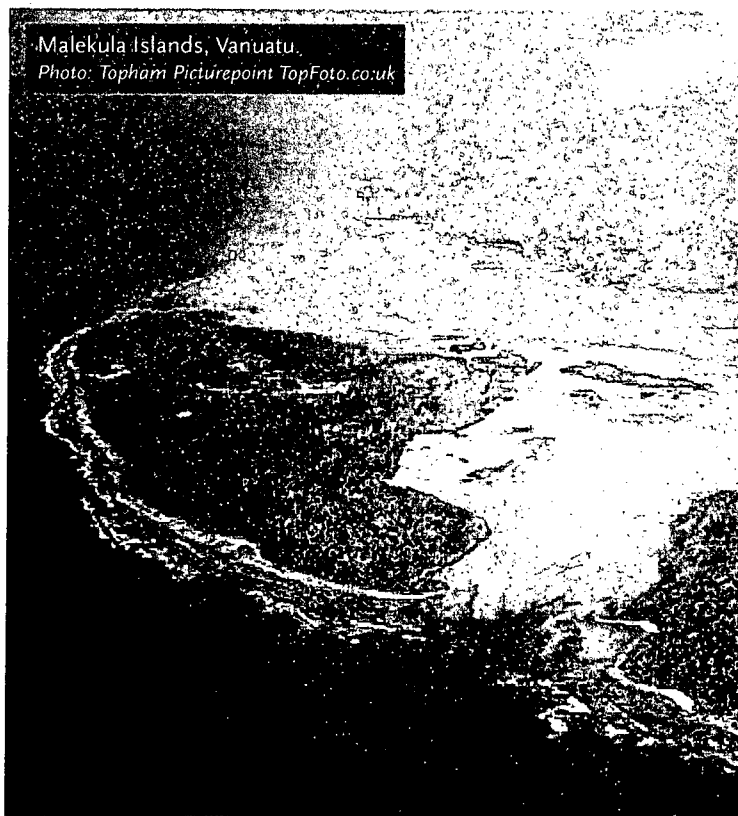
Figure 2.1: Thermohaline circulation, showing areas of major ocean-air heat transfer.

inside or below the permafrost (methane hydrates). We thus risk a situation where global warming melts the permafrost, which in turn adds extra greenhouse gases to the atmosphere, in all likelihood amplifying the warming. On the other hand, a considerable melting of the deep permafrost is necessary before the store of frozen methane could be affected, and that will take many years. During that time, the warming may cause the boreal forest to expand across the tundra, which will remove carbon from the atmosphere. But tree crowns absorb more heat from solar radiation than the flat, white tundra, which can again increase warming². Thus, what the net effect will be on the global climate from these processes is unknown.

Another factor that may affect the global distribution of heat is a change in the major ocean currents caused by melting of ice, excess warming of ocean waters and their freshening. One of the main factors driving the ocean circulation is the formation of deep, dense water in the Greenland Sea, the sea near Baffin Island in eastern Canada, and in the Weddell Sea in Antarctica³. Water becomes heavier as it gets saltier and colder. The cold and saline water in these areas sinks and flows along the bottom of the world's oceans while the warmer water flows closer to the surface of the ocean to these colder areas, where it releases its warmth, and becomes colder and more saline. This thermohaline circulation (Figure 2.1) forms a major system of ocean currents, which is also called the Great Ocean Conveyor Belt. The North Atlantic Current is a part of this system. Thermohaline circulation may be affected by melting and freezing processes, such as reductions in the extent and thickness of sea ice (Chapter 5) and input of lighter fresh water from melting glaciers (Chapter 6). The IPCC³ projects a 25 per cent reduction in this century of the North Atlantic Current because of a weakening of the deep water formation.

Changes from melting ice and snow affect people's homes and livelihoods worldwide

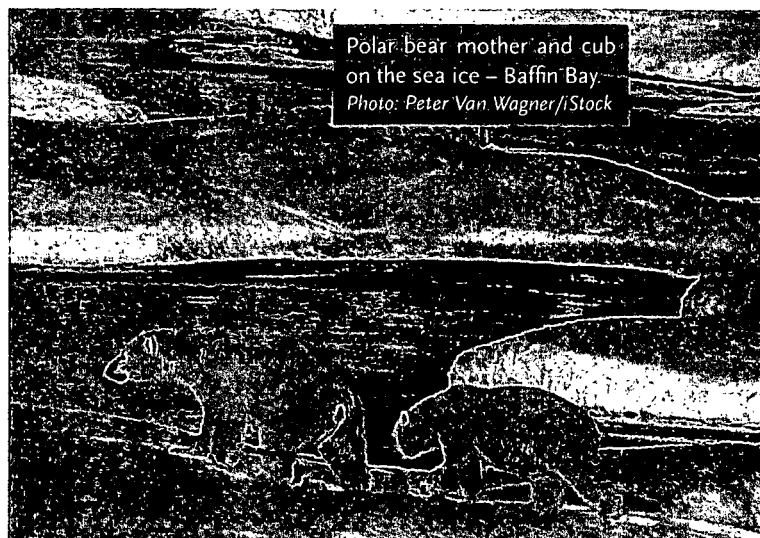
Sea-level rise is one of the most obvious consequences of melting ice on land (Chapter 6). The global sea level is currently rising by about 3 mm per year mostly because seawater expands as it gets warmer and because melting glaciers and ice sheets add fresh water to the oceans³ (Chapter 6). The IPCC³ projects that the sea level may rise by as much as half a metre in this century, mainly caused by the thermal expansion of seawater. There is,





of course, also the potential for the sea level to continue to rise a great deal more. If all the ice masses on land melted the sea level could eventually rise by around 65 metres³. This is virtually unthinkable, since the average temperature on Antarctica, where most of this ice is located, is now about -30°C to -40°C . But even a minor melting of these ice masses would have significant consequences. For example, if the ice melts by 20 per cent in Greenland and 5 per cent in Antarctica at the same time, the sea level will rise by 4 to 5 metres. This will have not only major consequences for the small islands in the Pacific, Caribbean, and the Indian Ocean, but also for countries like the Netherlands and Bangladesh; and cities and coastal infrastructure in many other countries will be affected negatively.

With few exceptions, all the alpine glaciers of the world are losing mass and it is predicted that this trend will continue as global warming progresses⁵. Glaciers in alpine areas act as buffers. During the rainy season, water is stored in the glaciers and the melt water helps maintain river systems during dry periods. An estimated 1.5 to 2 billion



people in Asia (Himalayan region) and in Europe (The Alps) and the Americas (Andes and Rocky Mountains) depend on river systems with glaciers inside their catchment areas. In areas where the glaciers are melting, river runoff will increase for a period before a sharp decline in runoff. Without the water from mountain glaciers, serious problems are inevitable and the UN's Millennium Development Goals for fighting poverty and improving access to clean water will be jeopardized.

The ecosystems and biological diversity in polar and mountain regions will change significantly in a warming world. The zone along the edge of the sea ice is bursting with life despite what at first glance appears to us to be one of the most hostile environments on the Earth. Both the underside and the top surface of pack ice, as well as openings in the ice, are home to myriad marine plants and animals – from long strands of algae under the ice and innumerable small crustaceans, to seals, marine birds, and polar bears (Chapter 5). The ice-edge zone is a biological oasis in the spring and summer when the sun shines around the clock². Many species are specifically

adapted to the ice and they will have major problems surviving if the ice should disappear. The same goes for the tundra, where many species are completely dependent on an environment of snow and permafrost. If large parts of the tundra are replaced by trees and shrubs, an expected result of global warming, many of the species that live on the tundra will lose much of their current ranges². Paradoxically, we can expect a greater biological diversity because different species will migrate north from the south.

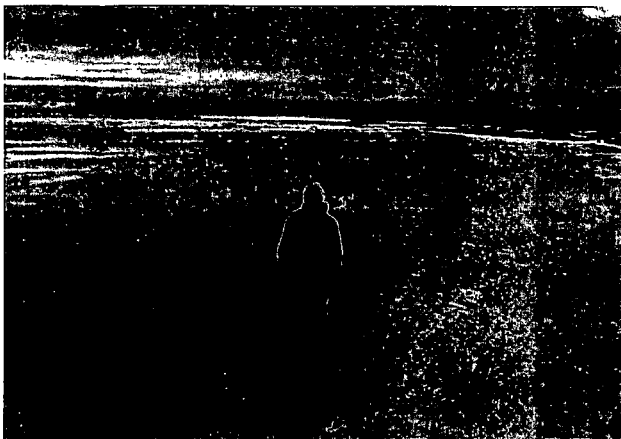
People who depend on the living resources in the northern regions will have to adapt to major changes. Agriculture and the fishing industry may profit from a moderate warming, while those who live in a traditional way

from the land – such as Saami, Arctic Athabaskan, Inuit and other Peoples – will face great challenges. This has already become evident.

Access to energy and mineral resources in the polar regions will increase as ice melts. The sea ice is the main barrier to maritime transport and access to the major continental shelves that surround the Arctic Ocean, where projections place a large part of the world's remaining petroleum resources. The increased interest in petroleum resources in the North is undoubtedly also linked to the decline of the sea ice. For example, it has been calculated that the length of navigation season through the Northern Sea Route along the Siberian coast will increase from 30 days to 120 days in this century, if

Snowfall in China.
Photo: UNEP/Still Pictures





Looking out on sea ice covering Hudson Bay, Canada.
Photo: John Main



Snowshoeing in Massachusetts, USA.
Photo: Nicholas Craig Zwinggi/iStock

the projections of the scientists come true². Ironically, the feasibility of recovering petroleum resources from polar regions has increased because of global warming and the consequent thaw.

Because ice and snow are crucial components of the climate system, extensive research is conducted on them both in the polar and alpine areas of the world. In addition to extensive national research programmes, a global project entitled Climate and Cryosphere (CliC) is developed by the World Climate Research Programme (WCRP) of the World Meteorological Organization (WMO), the International Council for Science (ICSU) and the Intergovern-

mental Oceanographic Commission of United Nations Educational, Scientific and Cultural Organization. The International Geosphere-Biosphere Programme (IGBP) of ICSU is also important. The International Polar Year 2007-2008 (IPY) is jointly conducted by WMO and ICSU and represents one of the most ambitious coordinated science programmes ever attempted. It includes research and observation in both the Arctic and the Antarctic and explores the strong links these regions have with the rest of the globe. IPY is a truly international endeavour with over 60 countries participating in more than 200 projects covering a wide range of research disciplines, from geophysics to ecology to social science and economics.

The Cryosphere

Ice and snow in the seas, on the surface of the earth, and in the ground are collectively known as the cryosphere (see 'The Cryosphere', inside front cover). Snow, ice sheets and sea ice cover about 15 per cent of the Earth's surface during the peak period in March to April, and about 6 per cent in August to September. Permanently-frozen ground, or permafrost, is found in both polar and alpine areas and covers about 20 per cent of Earth's land areas. Ice and snow store more than 80 per cent of the fresh water on Earth, mainly in the big ice sheets in Greenland and Antarctica with a combined volume of about 30 million cubic kilometres.

The various components of the cryosphere play strong but different roles within the climate system.

- Due to their large volumes and areas, the two continental ice sheets of Antarctica and Greenland **actively influence the global climate** over time scales of millennia to millions of years.
- Snow and sea ice cover large areas too, but have relatively small volumes. They vary in size over the seasons. Snow and sea ice are connected to **key interactions and feedbacks** at global scales (albedo, ocean circulation). Permafrost is another important feedback component in the climate system through the methane cycle. Together with seasonal snow, permafrost influences soil water content and vegetation over continental-scale northern areas.
- Glaciers and ice caps, as well as seasonal ice on lakes, with their smaller areas and volumes, react relatively quickly to climate effects, influencing ecosystems and human activities on a local scale. They are good **indicators of change**, reflecting trends in a range of conditions and seasons, from winter lowlands (lake ice) to summer alpine areas (mountain glaciers). Despite the total volume of glaciers being several orders of magnitude smaller than that of the two major ice sheets, they currently contribute more to sea-level rise.

Seasonal variation in the extent of ice and snow cover is greatest in the Northern Hemisphere. Imagine the Earth with white caps on the top and bottom (2.2). The top cap increases by a factor of six from summer to winter, while the bottom cap only doubles from summer to winter. This difference is due to snow cover: in the Northern Hemisphere snow cover on land varies from less than 2 million km² in the summer to 40 to 50 million km² in the winter³. There is little snow cover in the Southern Hemisphere. In Antarctica, land ice covers about 14 million km² year-round, with little change from summer to winter. Sea ice cover in the Arctic varies between approximately 7 and 15 million km² seasonally, while sea ice cover in the Antarctic, though about the same extent at its peak, varies much more – from around 3 million km² during summer to 18 million km² in winter. This means that there is less multi-year sea ice in the Antarctic than in the Arctic, where much of the sea ice is older than one year.

Northern Hemisphere
March



Southern Hemisphere
September

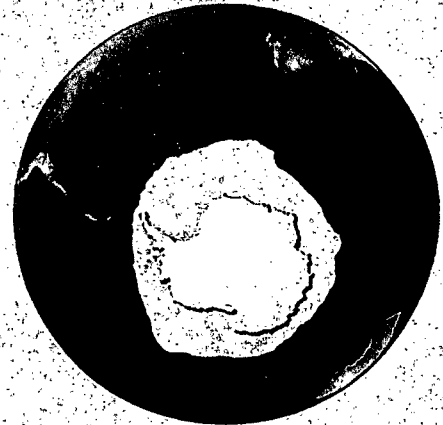


Figure 2.2: Ice and snow cover at peak periods in the annual cycles, Northern and Southern Hemispheres.

Source: Based on NASA Blue Marble NG, with data from the National Snow and Ice Data Centre

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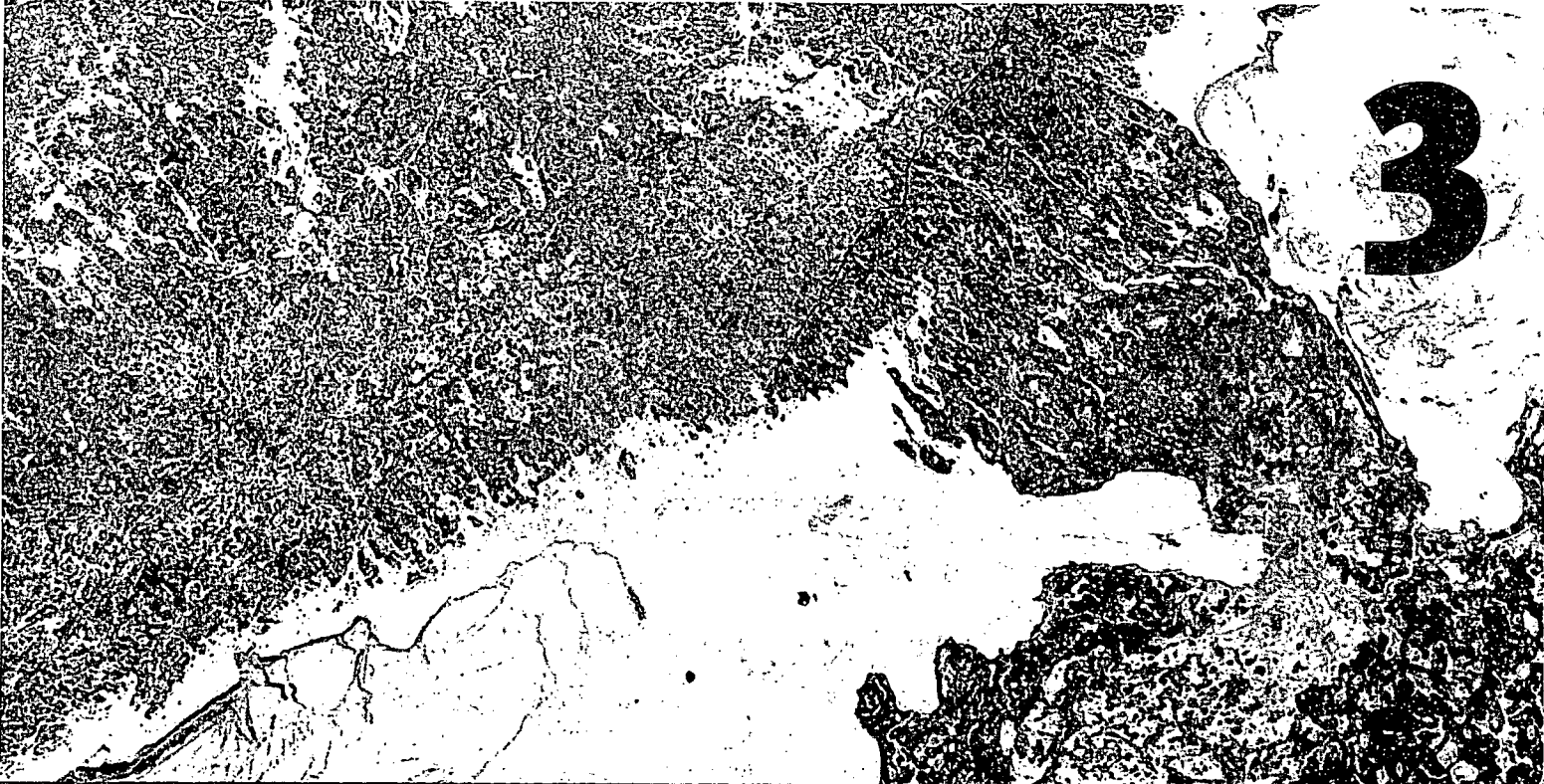
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3

Why are Ice and Snow Changing?

James E. Overland (lead author, Pacific Marine Environmental Laboratory/NOAA, Seattle, WA, USA); **John E. Walsh** (International Arctic Research Center, University of Alaska, Fairbanks, AK, USA) and **Muyin Wang** (Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, USA)

Why are Ice and Snow Changing?

Summary

Changes in ice and snow are influenced by variability within the climate system itself and by external factors such as greenhouse gases, solar variability, and volcanic dust – factors that act on time scales from months to hundreds of thousands of years. During the 21st century, the most important external influence on high latitude climate and on ice and snow conditions will be the increase in greenhouse gases. Natural climate variability will still impose regional, decadal, and year-to-year differences, and feedbacks will become increasingly important in the climate system. Before 2050 the ice albedo feedback will accelerate the loss of Arctic sea ice. Warmer temperatures will reduce the area of snow cover and produce an earlier melt in snow-covered regions. This reduced snow cover will itself speed up warming.

Forces that drive the climate system

Atmospheric climate, represented primarily by temperatures, precipitation, and winds, undergoes externally-forced changes as well as natural, internal variations.

External forcing factors include greenhouse gas fluctuations, dust from volcanic eruptions, and variations in the amount of solar radiation reaching the top of the atmosphere. These changes in atmospheric conditions influence the amount of ice and snow cover in a particular region and the regional climate is affected by them in turn. In the 21st century the most significant change in external forcing for high latitude climate, and therefore the largest influence on ice and snow conditions, will be the increase in greenhouse gases. The IPCC 4th Assess-

ment Report¹ notes that it is highly likely (90 per cent confidence) that humans have already contributed to a rise in global temperatures due to an increase in greenhouse gas forcing. Carbon dioxide (CO₂), a primary greenhouse gas, is now near 380 ppm (parts per million of the atmosphere) and currently has a greater concentration than during any of the previous interglacial warm periods over the last 500,000 years. CO₂ is projected to reach 480 ppm by mid-century.

In addition to external factors, there is a large and natural random aspect to climate change that produces differences from year to year, decade to decade, and place to place. This variability is caused by instabilities in the air flow on the rotating Earth and this effect is greater near the poles than near the equator. Examples of natural variability are the warmer temperatures in the European Arctic in the 1920s and 1930s, and the cooler temperatures in the 1960s.

When the climate trend from future greenhouse gas forcing is added to the natural range of climate variability, the result is a shift during the 21st century to overall warmer temperatures, with many consequences for the cryosphere. The Arctic will experience warmer high and low temperature extremes. The warmer average will lead to a loss of sea ice and to earlier snow melt and river break-up – trends that are observed now. Globally, the freezing level (also called snow line) in mountainous regions will continue to move up mountain slopes and larger proportions of precipitation will fall as rain rather than as snow. In Antarctica, where current warming trends are not widespread, models project that increased warming will affect the central parts of the huge Antarctic ice sheet later in the century.



During the 21st century, the most important external influence on ice and snow conditions will be the increase in greenhouse gases.

Photo: Ian Britton/FreeFoto.com

Learning from the past

The direct influence of variability of the sun's radiation at the Earth's surface is the major influence on the Earth's climate over a scale of hundreds of thousands of years. Long-term variation in temperatures and CO₂ are inferred from Antarctic ice cores (see the timeline on the inside back cover). The last 10 000 years have been a warm period in the Earth's history. Before then were the ice ages, each lasting approximately 100 000 years, with interglacial warm periods. The timing of the ice ages is set by changes in solar radiation, amplified by CO₂ and water vapour changes and by the position of continents and oceans. These solar changes over glacial time periods are caused by changes in the Earth's orbit, and by the tilt and orientation of the Earth's axis.

Evidence from tree rings and other temperature proxies (Figure 3.1) suggests that during the previous 500 years global temperatures were 1.0°C cooler than those of the 20th century during a period roughly from 1300 to 1870 – known as the Little Ice Age. While overall temperatures during the Little Ice Age were cooler than now, there was much year-to-year variability and some warm periods². The coldest part of the Little Ice Age, from 1645 to 1715, was also a time of minimum sun spots, referred to as the Maunder minimum. Although there is a correspondence in time, the causal connection between sun variability and Earth climate is a subject of ongoing debate. It is clear, however, that the 20th century was recovering from the average colder temperatures of the 19th century and earlier.

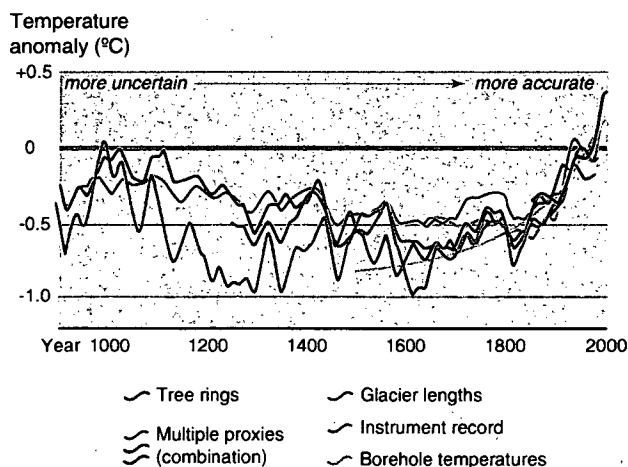


Figure 3.1: Global mean surface temperatures over previous centuries from various proxy records. Temperature estimates before 1500 are considered much less reliable.

Source: based on NRC 2006³

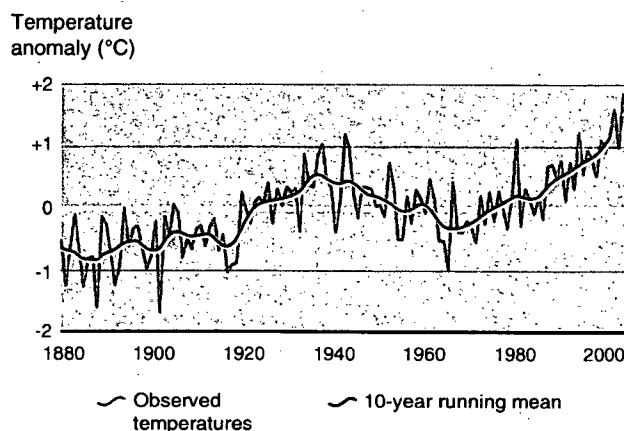


Figure 3.2: Changes in Arctic mean annual land temperatures from 1880 through 2006. The zero line represents the average temperature for 1961–1990.

Source: M. Wang; data from CRU 2007⁴

A history of Arctic land temperature anomalies from 1880 through 2006 is shown in Figure 3.2. In the late 1800s the Arctic was relatively cold, although there is some uncertainty around these early temperature estimates. The Arctic warmed by about 0.7°C over the 20th century. There was a warm period in the 1920s to 1940s and cold periods in the early 1900s and in the 1960s. Over the last decade the temperatures were about 1.0°C above the 20th century average.

Figure 3.3 shows that the largest recent gains in annual temperatures for the planet are over the North American Arctic, north central Siberia, and on the Antarctic Peninsula. These recent increases in temperature are confirmed by changes in other features: loss of sea ice, shift of tundra to shrub vegetation, and migration of marine and terrestrial ecosystems to higher latitudes⁵.

Natural climate variability is organized into spatial patterns of high and low pressure regions, represented by the Arctic Oscillation (also called the Northern Annular Mode) and North Pacific patterns in the Northern Hemisphere, and the Southern Annular Mode in the Southern Hemisphere. The patterns of surface temperature anomalies when the Arctic Oscillation and Northern Pacific patterns are in their positive extreme are shown in Figure 3.4. When either of the patterns is in its positive extreme, the pattern contributes to an overall Arctic warm period. In recent years (2000–2005), however, the pattern of warm temperature anomalies is circumpolar in distribution and different from either of the two major 20th century climate patterns. We are truly in a new and uncertain climate state for the northern polar region^{6,7}.

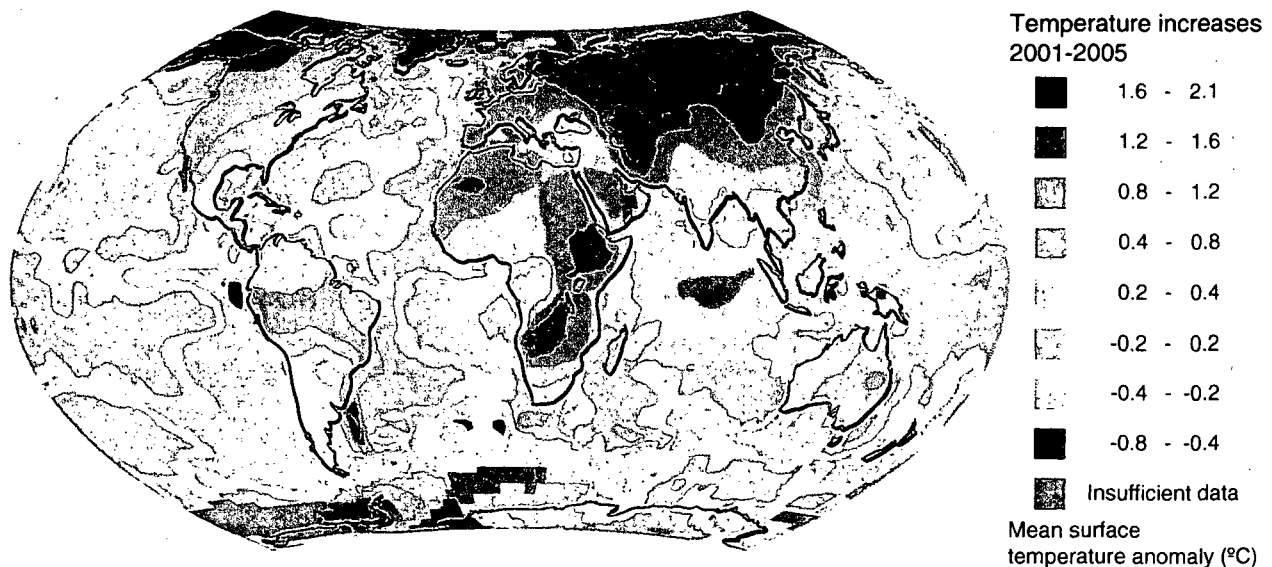


Figure 3.3: Increases in annual temperatures for a recent five-year period relative to 1951–1980. Warming is widespread, generally greater over land than over oceans, and greatest at high latitudes in the Northern Hemisphere.

Source: based on Hansen and others 2006⁸

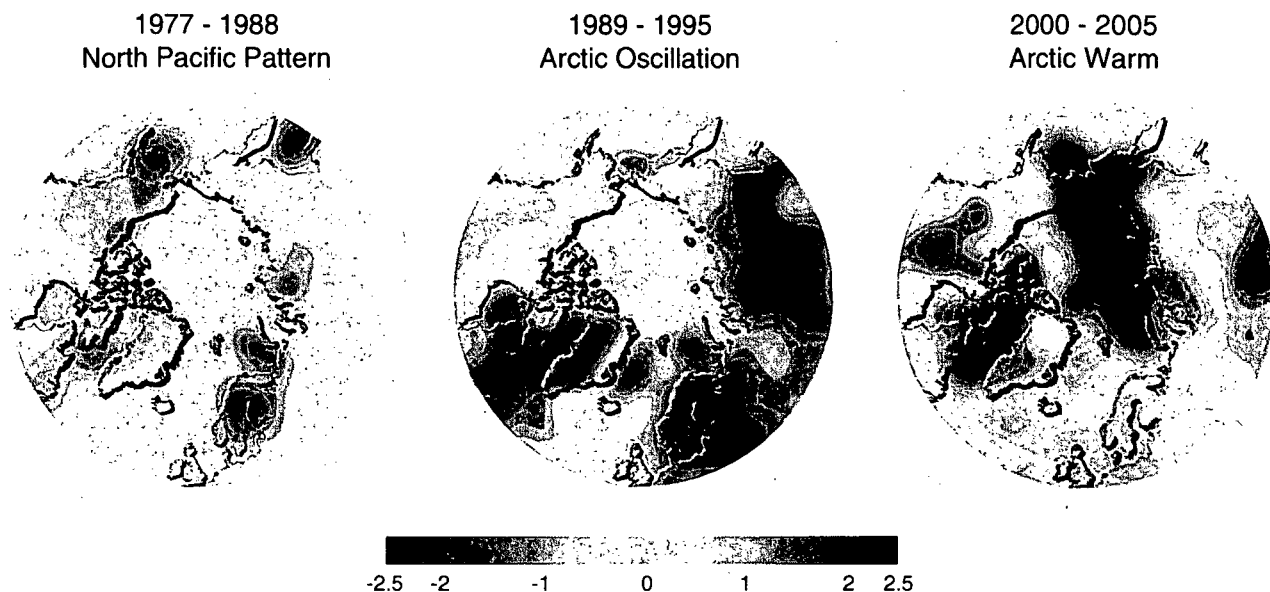


Figure 3.4: Recent Northern Hemisphere surface temperature anomalies averaged over periods with different types of dominating pattern of natural variability. The Northern Pacific pattern was dominant in the Arctic from 1977 to 1988, while the Arctic Oscillation dominated the region from 1989 to 1995. In spring 2000 to 2005 neither of these alternate states is evident – the recent warm period in the Arctic represents a new and uncertain climate pattern.

Source: J.E. Overland; data from NOAA/ESRL 2007⁹

Using climate models to examine the 20th century and to look ahead

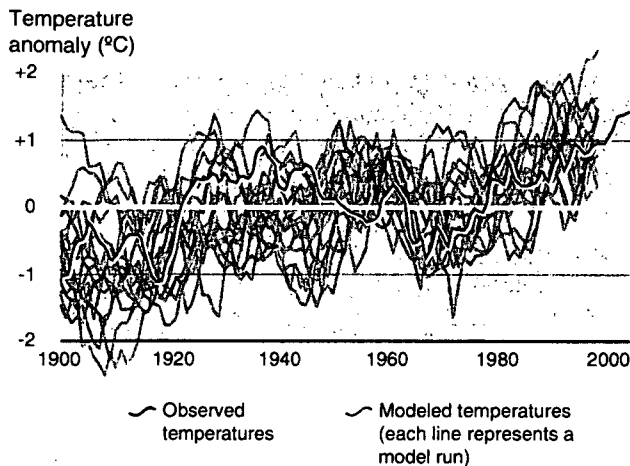
We can understand the relative influence of external forcing from greenhouse gases and internal natural variability of the climate system for the 20th and 21st centuries through the use of atmosphere-ocean coupled climate models. To enable comparisons of the climate model runs for the Intergovernmental Panel on Climate Change Fourth Assessment Report¹, the World Climate Research Programme (WCRP) established an archive containing model results from over 20 national climate

centres around the world, for the recent past and for the future. These models were run several times, starting with slightly different conditions but with the same external forcing, to simulate the effects of natural variability.

Arctic

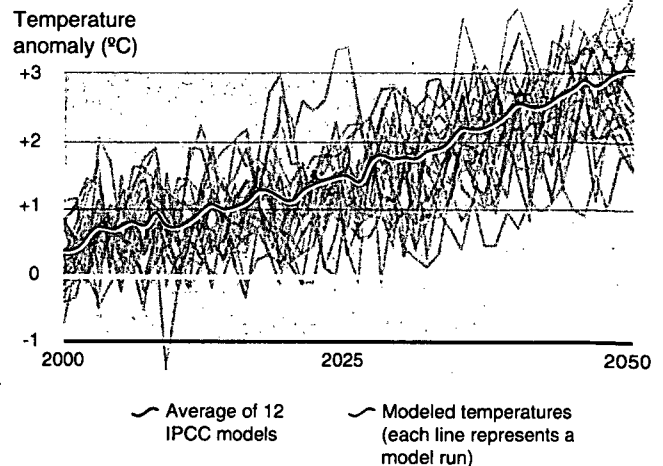
Figure 3.5(a) shows model runs for a subset of models, recreating the Arctic winter land temperatures of the 20th century. By the end of the century virtually all model runs arrive at temperatures that are above the 20th century mean, implying the importance of greenhouse gas forc-

Figure 3.5: 20th century (a) and 21st century (b) Arctic land temperatures: results from IPCC models



(a) Observed Arctic winter land temperatures and model recreations for the 20th century. Note that although these model runs are able to capture the range of Arctic warm and cold periods, the timing of the peaks varies, suggesting that the early 20th century warming was due to random causes, while the increases at the end of the century shown by all the models supports CO₂ as an external forcing of the Arctic climate system.

Source: based on Wang and others 2007¹⁰



(b) Projected Arctic annual land temperature increases for the first half of the 21st century relative to the average temperature for 1980–99. The average of the models (the blue line) shows an increase of 3°C by 2050. The averages of the runs from each of the 12 models show increases from 2–4°C, the range of uncertainty in these model projections.

Source: based on Wang and others 2007¹⁰

ing in raising Arctic temperatures in recent decades. Earlier in the 20th century, observed temperature extremes are similar to those generated by the models, but the timing is different. This difference in timing indicates that the warm period in the early 20th century was a result of natural variability of the Arctic climate system, and that the late warm period of the 20th century had contributions both from an anthropogenic, forced trend due to greenhouse gases and from natural variability. There is no evidence from the internal atmospheric structure of these early and late 20th century warm events that would indicate that they are both part of a simple climate oscillation.

Looking forward, we can project that 21st century climate will have contributions from both greenhouse gas forcing and internal natural variability. Figure 3.5(b) shows projected annual land temperature increases for the Arctic. The average of all the model simulations shows an increase in Arctic annual mean temperatures of 3.0°C by 2050, with the various models showing increases ranging from 2.0–4.0°C. The individual model runs show a trend towards warmer high and low temperature extremes. Differences between models reflect the uncertainty around representations of climate physics. Models appear to be less reliable in projecting cli-

mate variables other than temperature – such as precipitation or wind conditions¹¹.

Antarctica

The temperature trends for Antarctica show that late 20th century warming was primarily along the Antarctic Peninsula without significant warming trends elsewhere on the continent. The proximate cause for the warming on the Peninsula was the increase in the magnitude of the Southern Annular Mode during the period from 1960 to 2001, a change that implies stronger winds, reduced sea ice, and warmer temperatures upwind of the Peninsula, which contributed to the local warming. There are indications of warming higher up in the atmosphere over Antarctica over the last 30 years, but causes cannot be assessed¹².

Model experiments for the end of the 21st century do show broader patterns of warm surface temperatures throughout Antarctica. The delay in the response is thought to be the result of the large thermal inertia of the Southern Ocean¹³ or details of the internal physics of the Southern Annular Mode¹⁴, but uncertainties are large.

Feedbacks and interactions

Feedback refers to the modification of a process by changes resulting from the process itself. Positive feedbacks accelerate the process, while negative feedbacks slow it down. Part of the uncertainty around future climates relates to important feedbacks between different parts of the climate system: air temperatures, ice and snow albedo (reflection of the sun's rays), and clouds.

An important positive feedback is the ice and snow albedo feedback (see also Chapters 2, 4 and 5). Sea ice

and snow have high albedo. This means that they reflect most of the solar radiation. With warmer polar temperatures, the area of sea ice and snow cover decreases, exposing new expanses of ocean and land surfaces that absorb an increased amount of solar radiation. This increase of total absorbed solar radiation contributes to continued and accelerated warming. Many IPCC climate models suggest a major loss in sea ice cover by the mid 21st century caused by albedo feedback from shrinking snow cover and increased open water areas in summer¹⁵.

A second feedback is negative: the cloud-radiative feedback. Its future impact is important but uncertain. Increased cloud cover, an expected result of global warming, increases the reflection of solar radiation away from the Earth's surface, but it also increases the net long-wave radiation emitted downward from the same clouds back to the surface¹⁶. The net effect of increased cloudiness is expected to be a small decrease in radiation received by the Earth's surface.

One of the great challenges of climate change science is to understand the net effect of these rather complex interactions (Figure 3.6). This is not just a question of understanding the physics of climate systems – many of these interactions and feedbacks also involve the living world. For example, the increase in shrub growth in tundra regions due to high-latitude warming leads to a decrease in albedo in summer, but an increase in snow retention in winter over large areas of land. Another feedback comes from melting permafrost that releases methane, a powerful greenhouse gas, into the atmosphere, which then amplifies the greenhouse effect. The need to understand these interactions has led to an increase in interdisciplinary studies in recent years and is a focus of research being conducted through the International Polar Year 2007–2008.

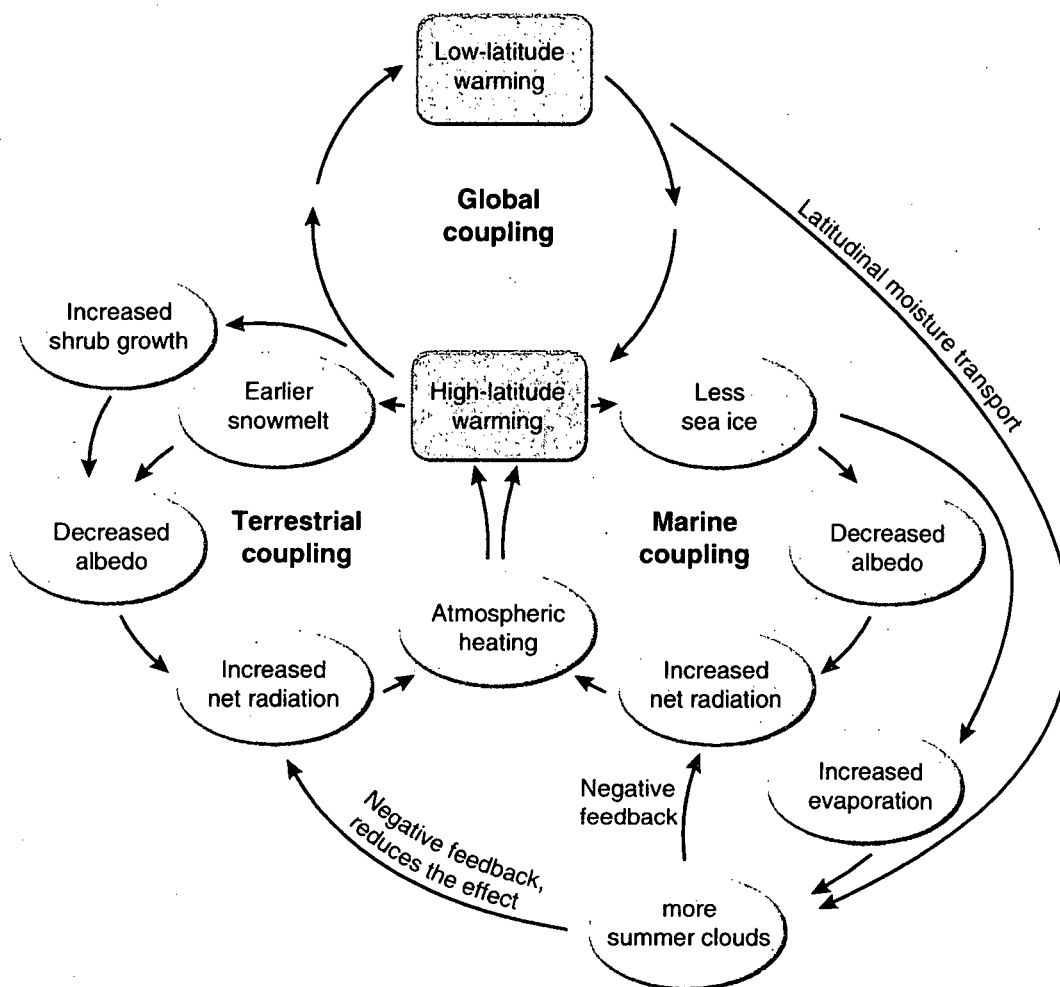


Figure 3.6: Feedbacks. This conceptual diagram illustrates the connectivity of the positive ice/snow albedo feedback, terrestrial snow and vegetation feedbacks and the negative cloud/radiation feedback.

Source: based on Chapin III and others 2005¹⁷

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Snow

Roger C. Barry (lead author, National Snow and Ice Data Center, Boulder, CO, USA); **Richard Armstrong** (National Snow and Ice Data Center, Boulder, CO, USA); **Terry Callaghan** (Abisko Scientific Research Station, Abisko, Sweden); **Jessie Cherry** (International Arctic Research Center, University of Alaska, Fairbanks, AK, USA); **Shari Gearheard** (Cooperative Institute for Research in Environmental Sciences, Boulder, CO, USA); **Anne Nolin** (Oregon State University, Corvallis, OR, USA); **Don Russell** (Environment Canada, Whitehorse, YK, Canada) and **Christoph Zockler** (World Conservation Monitoring Centre, Cambridge, UK)

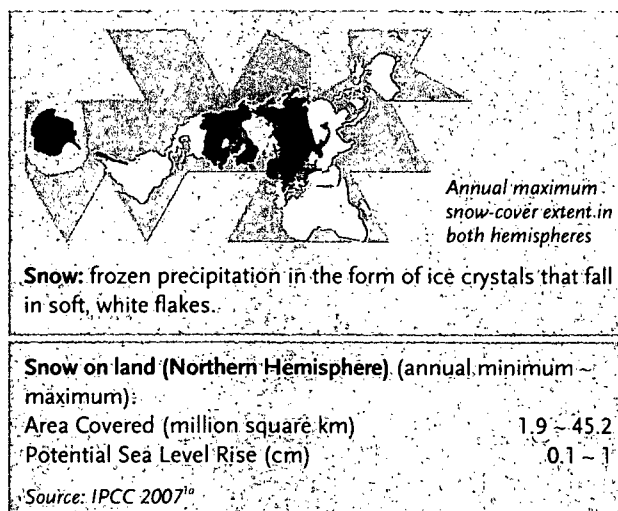
Snow

Summary

Snow exerts a huge influence on climate, through its high reflectivity, insulating properties, and cooling of the atmosphere, and on surface hydrology, through its effects on water resources in many parts of the world. Mean monthly snow-cover extent in the Northern Hemisphere has decreased at a rate of 1.3 per cent per decade during the last 40 years, with greatest losses in the spring and summer months. Climate models project significant decreases in snow cover by the end of this century, with reductions of 60 to 80 per cent in snow water equivalent (depth of water resulting from snow melt) in most mid-latitude regions. Increases are projected for the Canadian Arctic and Siberia. Higher temperatures and rises in snow line are projected for many mountain regions. Changes in snow cover, such as the formation of ice layers in snow due to increased frequency of snow thaw, have widespread impacts as snow is an important ecological factor. Snow-cover changes also have impacts on human well-being and economic activities, including water resources, agriculture, animal husbandry, transportation and winter recreation such as skiing.

Introduction to snow

Snow occurs predominantly on the northern continents, on the sea ice of the Arctic Ocean and on Antarctica. On the Northern Hemisphere continents, snow covers a maximum mean area of 45.2 million km², typically in January. The minimum snow-cover extent usually occurs in August and covers a mean area of 1.9 million km², most of which is snow on the Greenland ice sheet and on mountain glaciers. As a result, snow cover is



the surface characteristic responsible for the largest annual and interannual differences in surface reflectivity (albedo) in the Northern Hemisphere (Figure 4.1). In the Southern Hemisphere, excluding the 14.5 million km² area of Antarctica, terrestrial snow covers a much smaller area, mostly in the Andes and Patagonia, and it plays a smaller role in global climate. Limited summer melt occurs in the Antarctic Peninsula and on the coasts of western Antarctica.

Snow is an important climate variable. Due to its high albedo, snow cover increases the amount of sunlight reflected from Earth's surface. The low thermal conductivity of snow insulates the ground, and its cold, moist surface affects the transfer of heat and moisture to and from the atmosphere. Thus, snow cover exerts a signifi-

February



August



Figure 4.1: Mean snow-cover extent (dark blue) and sea-ice extent (light blue) in the Northern Hemisphere between 1966 and 2006, for February and August. The difference in snow cover between seasons causes significant differences in the surface reflectivity (albedo).

Source: Based on Armstrong and Brodzik 2005¹

cant influence on climate and hydrology. Snow cover affects large-scale atmospheric circulation. Early season snow-cover anomalies in the Northern Hemisphere, for example, are known to lead to changes in atmospheric circulation. Autumn snow cover can also affect climate on a seasonal scale, with impacts extending into the subsequent winter. Snow cover is also a sensitive indicator of regional climate variability and change. Realistic simulation of snow cover in models and forecast schemes is essential for simulating surface energy balance and predicting winter water storage and year-round runoff.

Snow cover influences human activities directly and indirectly. Seasonal snow cover is the main source of runoff in many mountain regions, and over one billion people depend on it for their water supplies. Snow is a

major factor in transportation, winter sports, agriculture and animal husbandry such as reindeer herding. It influences ecosystems and is important for conservation of biodiversity.

Trends and outlook for snow

Snow accumulation and melt are governed primarily by air and soil surface temperature, precipitation, wind and surface relief. Precipitation determines the overall amount of snow but air temperature determines whether the precipitation falls as rain or snow and governs the rate of snow melt. The recent rise in global temperatures, and the warming trends predicted for the future (see Chapter 3) thus affect global snow cover.

Data from satellite monitoring (see box on measuring snow cover extent) from 1966 to 2005 show that mean monthly snow-cover extent in the Northern Hemisphere is decreasing at a rate of 1.3 per cent per decade (Figure 4.2). For the calendar year of 2006 average snow-cover extent was 24.9 million km², which is 0.6 million km² less than the 37-year average². In the Northern Hemisphere, spring and summer show the strongest decreases in snow-cover extent. Satellite observations of snow-cover extent show a decreasing trend in the Northern Hemisphere for every month except November and December, with the most significant decreasing trends during May to August³. The average Northern Hemisphere snow-cover extent for March and April decreased by 7.5 ± 3.5 per cent from 1922–2005⁴ (Figure 4.3).

Snow covered area (million km²)

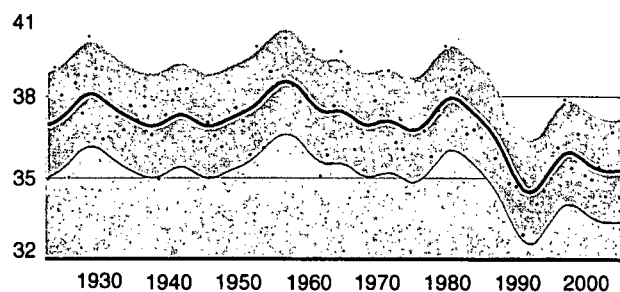


Figure 4.3: Northern Hemisphere snow-covered area (SCA) for the spring (March–April) from 1922–2005. The linear trend shows a decrease in SCA of $2.7 \pm 1.5 \times 10^6$ km² or 7.5 ± 3.5 %. The shaded area represents the 5 to 95% range of the data.

Source: Based on IPCC 2007⁴, updated from Brown 2000⁵

Snow cover anomaly (million km²)

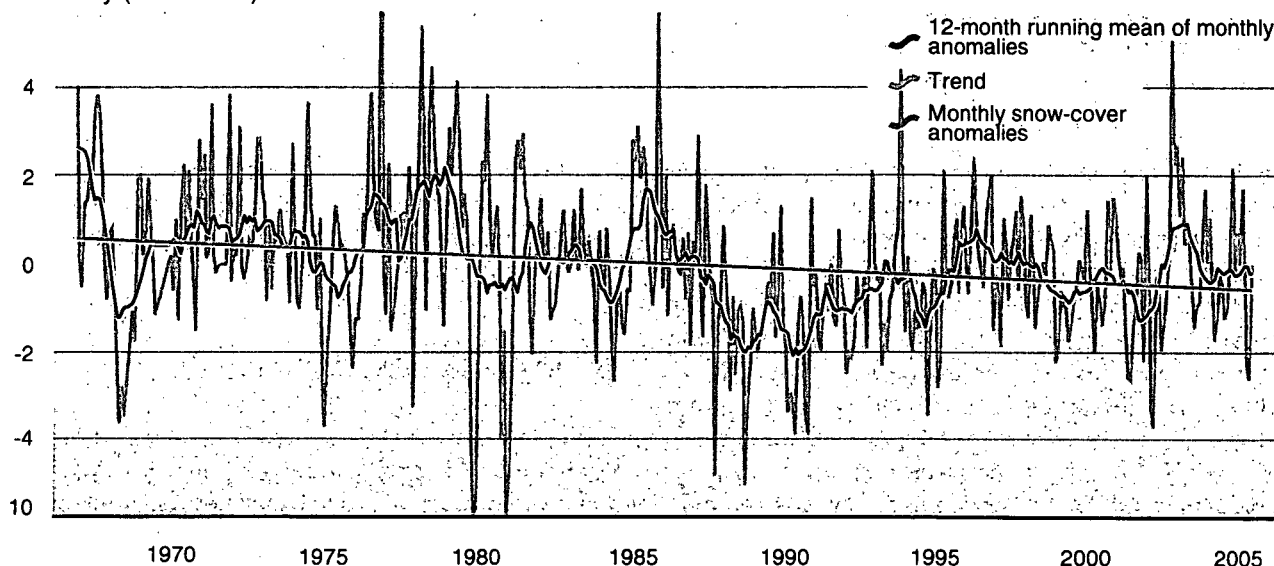


Figure 4.2: Northern Hemisphere snow-cover extent departures from monthly means from 1966 to 2005, with the 12-month running mean also shown. The decreasing trend of -1.3 per cent per decade is significant at the 90% level.

Source: M.J. Brodzik; data from NOAA snow charts revised by D. Robinson, Rutgers University



Snow covered mountains in Alaska
Photo: P. Sioja/USGS National Wildlife Health Center (US)

Measuring snow-cover extent

Snow-cover fluctuations in the hemispheres are monitored by satellite. Since 1966 the National Oceanic and Atmospheric Administration (NOAA) has produced snow-extent charts on at least a weekly basis^{6,7}. Until 1999 the charts were primarily derived from the manual interpretation of satellite images taken within the visible band of the electromagnetic spectrum. Passive microwave data, available since 1978, and other data are now included in the source data for the charts^{8,9}.

Satellite passive microwave sensors can detect the snow surface through clouds and in darkness but may not detect

shallow snow that can be seen in visible band imagery. As a result, time series from microwave and visible data sources can differ. Data sets from both sources show a similar range for maximum Northern Hemisphere snow-cover extent that exceeds 40 million km² consistently^{1,10,11}. NOAA data, derived primarily from visible band sensors, show a significant decreasing trend in mean monthly snow-cover extent (see text). Microwave data indicate a similar decreasing trend that is not significant at a 90% level. While NOAA data show decreasing trends in every month except for November and December (see text); data from passive microwave sensors is less clear. Both data sets indicate significant decreasing trends during May to August (see text).

Regional trends in snow cover

Examination of regional trends in spring snow-cover duration from 1969–2003 using NOAA snow-cover data shows the western United States to be among the regions with the strongest decreases (Figure 4.4). This supports results from studies based on measurements on the ground^{12,13}. Springtime snow cover shows a decline particularly in the Pacific Northwest region of the western United States, where snow water equivalent, a common snow cover measurement equivalent to the depth

of water which would result from snow melt, has decreased by as much as 50–75 per cent¹³. This decrease is attributed to an increase in temperature¹⁴; observations of temperatures in the western United States already show warmer winters¹⁵. There is abundant evidence of earlier spring warm spells in the western United States since 1950 at elevations below 2500 m, with impacts on snow-cover duration as well as amount. There are more frequent rain-on-snow events and snow melt begins earlier, with stream flows increasing in March and April and decreasing in May and June¹⁶.

In contrast, for most of northern Eurasia there has been a long-term increase in snow depth and the duration of snow cover¹⁷. At Abisko in subarctic Sweden, increases in snow depth have been recorded since 1913¹⁸. During 1935–1995, snow-cover duration increased by about four days per decade in northern European Russia and small areas of west central Siberia and decreased by about two days per decade over southern and southeastern Siberia¹⁹.

Outlook for snow cover

Decreases in snow-cover extent and duration will contribute to continued and accelerated temperature in-

creases, due to changes in the albedo of the land surface (see Chapter 3). In Alaska, 95 per cent of recent summer warming trends have been attributed to the decrease in snow-cover duration²⁰.

Shallow snow cover at low elevations in temperate regions is the most sensitive to temperature fluctuations and hence most likely to decline with increasing temperature⁴. In locations where snow accumulates at temperatures close to its melting point, small increases in temperature will have large effects on snow cover. For example, in the Pacific Northwest region of the United States, the temperate snow cover of the Cascade Range of mountains could be reduced by over 20 per cent with an increase in mid-winter temperatures of only 2° C²¹.

Mountain regions are particularly sensitive to climate change²², and increases in mean minimum temperatures are more pronounced at higher elevations than in valleys²³. Temperatures are projected to continue rising in the mountains of the western United States, with accompanying reductions in snow cover²⁴. Similar changes are expected in other mountainous regions of the world. In central Chile, air temperature data from 1975 to 2001 show an increase in elevation of the 0° C isotherm (the line on a map linking points at which the mean temperature is 0° C) by 122 m in winter and 200 m in summer²⁵. It is estimated that the snow line of the European Alps will rise about 150 m for every 1.0° C increase in winter temperatures²⁶. Climate model projections indicate that the Alps and Pyrenees will experience warmer winters with possible increases in precipitation²⁷, which, as in the western United States, will raise snow lines, reduce overall snow cover, and decrease summer runoff.

Snow water equivalent and snow-covered area are modelled in General Circulation Model experiments to predict global changes in snow cover. A comparison of results

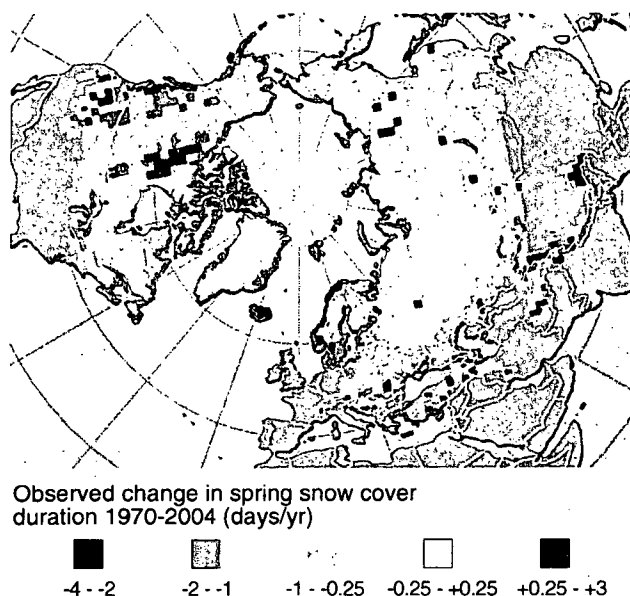


Figure 4.4: Trend (days/year) in spring (February–July) snow-cover duration from 1970–2004 from the NOAA weekly snow-cover dataset. Changes exceeding $\sim \pm 1$ represent significant local changes at the 95% level. Greenland was excluded from the analysis.

Source: R. Brown, Environment Canada; data from D. Robinson, Rutgers University

Local observations of snow-cover changes

In many areas of snow cover, there are local people who rely on the snow for water, recreation, travel, and other activities. Through constant and close interaction with snow, these people develop a great body of knowledge about it. People who possess knowledge of snow include mountain villagers, ski patrollers, mountain climbers, and perhaps more than any other group, Arctic residents, especially Indigenous Peoples. These people have the most interaction with snow, as snow is present for most of the year and they depend on it for their livelihoods.

In the Canadian Arctic, Inuit and their ancestors have depended on snow, and held a keen understanding of it, for millennia. Traditionally, Inuit lived in snow houses called *igluit*. The ability to travel depended partly on the condition of snow cover, for example, hard, soft, deep, or drifted snow. Snow forms on the land or sea ice, running parallel with the dominant wind, helped hunters to navigate; this practice is still used by some today (Figure 4.5). Saami reindeer herders in Fennoscandia have also traditionally depended on snow for their activities and survival. Herders closely observe snow conditions and modify their herding strategies accordingly. For example, in hard snow conditions, herders may keep reindeer close together so that strong animals help to crush icy snow layers, allowing weaker animals to graze³⁰. If the snow is relatively soft, animals may be allowed to graze a wider area. Today, Inuit no longer live in snow houses and some Saami employ modern technologies, such as helicopters or motorbikes, to herd reindeer. But elders, and many hunters and herders, still possess traditional knowledge about snow. They constantly gain new knowledge about snow and other aspects of the environment, and incorporate this knowledge into their everyday lives.

Many traditional knowledge holders have noticed changes in snow in recent years, along with other changes in the environment and climate. In projects such as the Arctic Climate Impact Assessment, scientists have begun working cooperatively with these people in order to understand environmental change in the Arctic. A number of other projects have documented indigenous knowledge of environmental change in the Arctic, primarily in Alaska and the Canadian Arctic^{31–34}. Snow is a common theme in many of these studies. For example, in Nunavik (northern Quebec), residents observe less snow cover in spring time. This restricts travel into the bush by snowmobile to hunt and collect

firewood³⁵. Less snow in the hills also means fewer cold storage places for fish, which are kept cool in snow patches. This problem is shared by some communities in the Canadian territory of Nunavut³³. At Clyde River, Nunavut, Inuit observe that permanent snow patches, *aniuvat*, are disappearing and at a quicker rate than in the past. In the community of Baker Lake, Nunavut, changes in snow have already had serious consequences. Changes in wind patterns are packing snow harder than normal, making it difficult or even impossible to build snow houses, which are still used for emergency shelters. Weather events seem to be less predictable to elders in the area, and hunters are being caught in unexpected storms unable to make shelter; several deaths in recent years have been blamed on this change in snow^{33,36}.

Communities all over the Arctic are living with environmental change and constantly responding to impacts of this change. Snow changes are only one part of this and local observers in the North will acknowledge that snow is bound in a web of environmental processes that are all connected. Knowledge of snow must be accompanied by knowledge of wind, weather, seasons, animals, ice, water, and ocean currents. With their long history in the Arctic and their continued use of the land, ocean, and ice, Arctic Indigenous Peoples play an important role in understanding the Arctic environment and its changes, including snow changes.



Figure 4.5: Arctic Indigenous Peoples have depended on snow for millennia, for example, using snow forms to navigate. This close interaction with snow makes them important observers of snow changes.

Photo: Shari Gearheard

from model simulations to a data set derived from NOAA visible band imagery found the model simulations of annual and interannual variability in snow-covered area to be reasonable at continental to hemispheric scales²⁸. At regional scales, however, significant model biases were identified over Eurasia at the southern boundary of the seasonal snow cover. A simulation from one such model projects decreases of 60–80 per cent in monthly maximum snow water equivalent over most middle latitudes by the end of this century (Figure 4.6). The largest decreases are projected over Europe, while simulated increases are seen in the Canadian Arctic and Siberia.

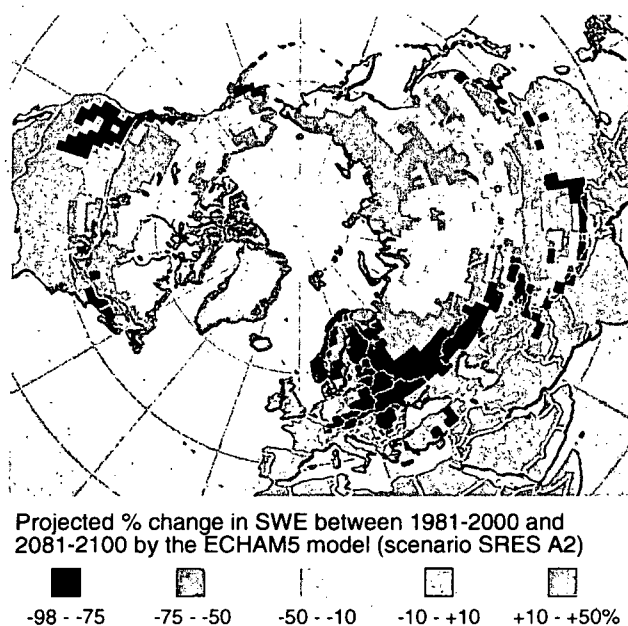


Figure 4.6: Percent change in monthly maximum snow water equivalent (SWE) between 1981–2000 and 2080–2100, simulated by the ECHAM5 climate model under conditions defined by the SRES A2 emission scenario (RUN 2). Results are plotted for grid points with a mean maximum SWE of 10 mm in 1981–2000.

Source: R. Brown, Environment Canada; data from ESG 2007²⁹

Snow as an ecological factor

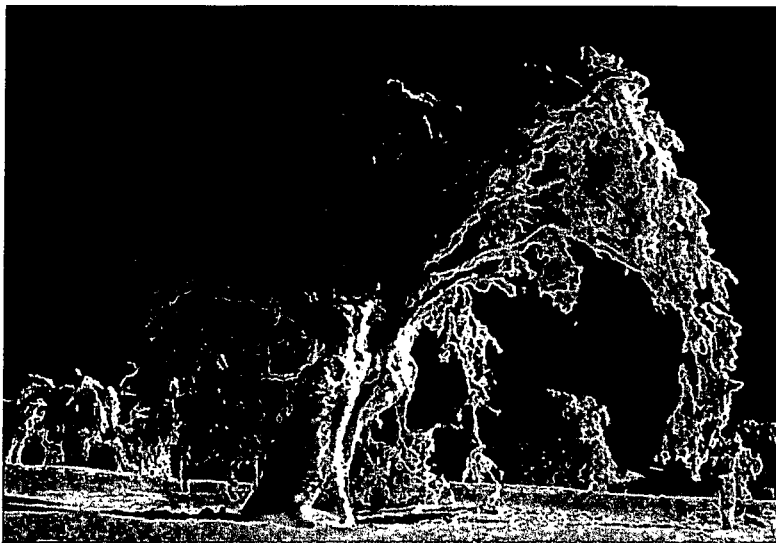
The importance of snow as an ecological factor has been recognized by science since at least the beginning of the 20th century^{37,38}. However, even today many observations remain anecdotal. In the 1950s, Gjaerevoll³⁹ analysed the way in which the alpine plant community structure was shaped by snow. Within the past decade, snow manipulation experiments have explored the effects of snow depth and snow-cover duration on plant communities and ecosystem processes^{40–42}. Recently, models of snow cover have been applied to ecological problems⁴³.

Snow cover plays a dual role in terms of temperature regulation. The high albedo of snow cover reduces net radiation, and snow also acts as a heat sink, removing energy from the atmosphere in the form of heat. This means that the presence of snow cover inhibits soil warming until the snow melts, preventing biological activity that requires temperatures above 0°C. However, snow is an efficient insulator, keeping soil temperatures near 0°C and reducing the extremes of temperature experienced by vegetation and soil in the zone under the snow (subnivean cavity). In autumn, the insulation effect of snow on unfrozen ground can even result in fungal decay of the vegetation, which can kill reindeer calves when they eat the vegetation⁴⁴. The subnivean environment is also very humid. Under thin snow packs in spring, light levels permit limited photosynthesis for lichens and evergreen tundra shrubs⁴⁵. This is an important adaptation given the short growing season. Plants in the “greenhouse of snow” created by the subnivean cavity can start to grow weeks before neighbouring plants covered by deep snow.

Snow exerts forces on the objects that it covers. For example, snow in southern Finland at the end of March, estimated to weigh 100–120 kg per m², compresses the

■ ■ **Figure 4.7:** Snow has many effects on vegetation, including the ability to deform and break trees with its weight (see beech trees, left). Trees with a narrow canopy (see spruce trees, right) collect less snow and are less likely to suffer damage.

Photo: (left) Fillies Wo/UNEP/Still Pictures, (right) Terry Callaghan



shoots of bog moss⁴⁶. The weight of snow can deform and break trees³⁸ (Figure 4.7), branches and the soft tissues of plants such as grasses and forbs. Snow can facilitate the spread of some woody plants by pressing branches to the ground surface – the branches then develop roots and form new individuals. Snow pressing directly onto vegetation protects it, to some extent, from grazing. Plants that are covered by the snow are also protected from drying out in the winter and from erosion of tissues by ice crystals. For this reason, the height of vegetation is often uniform and correlated with snow depth⁴⁷.

Snow also supports weight, including the various ground pressures that passing animals exert. While snow can support small animals such as birds, small mammals, hares and foxes with only minor deformation, larger mammals such as reindeer and moose experience a critical snow depth above which they cannot move. Snow can, therefore, enhance access across the landscape for animals by smoothing the terrain or forming bridges across gullies, or it can inhibit access by being too deep or too soft. The solid matrix of snow can be shaped and made into dens for polar bears. The consistency of snow

also allows the formation of a subnivean cavity in which small mammals nest and feed, protected from predators such as foxes and snowy owls. Along streams in late winter, the subnivean cavity can be as wide as 2 m.

Snow provides a habitat for some “primitive” forms of life. A relatively abundant and diverse array of micro-organisms can be found on both seasonal snow cover⁴⁸ and persistent snow on glaciers⁴⁹. These organisms include algae that can colour the snow red, blue or green, bacteria, fungi, diatoms, viruses, rotifers and tardigrades. On Signy Island, a small subantarctic island, cell numbers range from 5000 cells per cubic millimetre for coloured snow to 1 to 2 cells per cubic millimetre for clean snow⁴⁹. The presence of organic matter in and on snow reduces albedo and results in local melt and accumulation of nutrients.

The fractional snow cover (snow in patches) in the spring months affects the breeding of certain ground nesting species, such as waders, ducks and geese (see box on migratory sandpipers and snow). Fractional snow cover, particularly associated with small-scale topographical differences within the landscape, also affects the distribution of plant communities and species. Plant communities that are characteristic of depressions where snow accumulates have short growing seasons and are waterlogged after thaw³⁹ whereas communities on wind-exposed ridges are more drought tolerant⁵⁰. Traditional Saami knowledge has described the influence of snow cover on the vertical distributions of lichens that live on mountain birch stems in the subarctic; *Parmelia olivacea* grows above the winter snow line, whereas *Parmeliopsis ambigua* grows below the snow line and is covered by snow for six months per year⁴⁷.

Snow accumulates debris and chemicals including plant nutrients and pollutants from the atmosphere. Some of these, such as atmospheric nitrogen⁵⁴ and seeds, accumulate over the winter and are then released or re-





Migratory sandpipers and snow on the Arctic tundra

Snow very much determines the distribution of Arctic birds. In the spring, 24-hour daylight and vast food supplies attract billions of waterbirds to migrate from virtually all corners of the world to breed in the Arctic. These migratory waterbirds need snow-free patches to feed and nest in the tundra.

For sandpipers breeding in Greenland and Arctic Canada, such as the knot, dunlin and sand-erling, both the density and timing of breeding have been shown to be strongly related to snow cover. Successful breeding for these birds depends on finding a nesting area with the right size of snow-free patches and timing breeding so that the chick-rearing period in July coincides with the emergence of insects. Breeding too early can mean losing the clutch due to adverse weather events or due to predation by Arctic foxes, which prey more easily on nests in small snow-free patches. In Siberia, researchers found that, while patch size does not matter for the well-camouflaged ptarmigan, breeding density of passerines and sandpipers increases strongly with the size of the snow-free patches.

The highest density of breeding sandpipers is found in central-eastern Greenland, where continental climate conditions provide an ideal balance between snow-free patches and suitable vegetation. In the northern-most part of Greenland, the vegetation is thinner and fewer sand-pipers breed. Further south the conditions are different again. The Atlantic climate, with more snow, allows only late breeding. Large areas in the Arctic do not harbour any sandpipers at all, due to greater snow depth and later thawing. If the current observed trend of increased snow fall continues, the best breeding areas in Greenland will shift further north and push more and more birds to the edge, with a smaller window for breeding. The most affected species are those that breed in the high Arctic. In northern Europe, most of Siberia, and Alaska, earlier thawing will mean more snow-free patches and more favourable conditions for sandpiper breeding at lower latitudes.

Sources: Møltøfte 1985⁵¹, Rysgaard and others 2003⁵², Summers and Underhill 1996⁵³

distributed over the landscape. Snow melt provides an important source of nitrogen for tundra ecosystems and can result in a flush of moss growth in spring. However, the accumulation of chemicals by snow can have negative effects on vegetation. Although accumulations of nitrate can be potentially assimilated by mosses and related plants under the snow pack, at high concentrations characteristic of areas south of the Arctic, both nitrate and sulphate can cause physiological damage to plants under the snow⁵⁴.

Just as snow has numerous effects on vegetation, vegetation in turn exerts major effects on snow-cover dynamics^{20,55,56}. Wind can remove up to 70 per cent of the snow cover in alpine areas, as well as in polar regions and on the prairies⁵⁷. Trees and tall shrubs reduce wind speeds and thereby affect the distribution of snow on the ground⁵⁸. The forest canopy can trap snow, especially in mountain regions with coniferous vegetation, resulting in increased snow depth underneath the vegetation⁵⁹. Depending on the canopy characteristics of the vegetation, the opposite scenario can also occur. In dense coniferous forests, up to 60 per cent of snow fall can be intercepted⁶⁰ by the canopy and stored on the branches of the trees. This results in a decrease in snow depth underneath the vegetation, as much of the snow changes to gas (sublimates) or blows away before it falls to the ground⁶¹. Snow that reaches the ground has been “filtered” by the canopy and is less dense than that in open areas.

Vegetation also affects the amount of snow precipitation and the rate of snow melt. Trees and shrubs affect surface albedo – for example, black spruce can intercept up to 95 per cent of incoming radiation. Trees and shrubs thus increase local temperatures that affect snow

fall, thereby indirectly moderating the amount of snow precipitation. The presence of a forest canopy generally slows the rate of snow melt (up to three fold) because it reduces net radiation and wind speeds⁶², while a shrub canopy slightly increases the rate of snow melt. Snow within shrub canopies is deeper and less dense, which reduces heat transfer through the snow pack and increases winter soil temperatures by 2 °C relative to adjacent shrub-free tundra⁶³. In spring when the snow starts to melt, the contrasting albedos of the vegetation and the snow enable the vegetation to transfer heat to the ground, resulting in local melt which creates holes in the snow around vegetation.

Impacts of projected snow-cover changes on ecosystems

The effect of future snow regimes on vegetation will involve complex interactions between changes in the duration of snow cover and changes in snow depth. The timing of snow cover has effects on the productivity of ecosystems. For areas of seasonal snow cover, the snow-free period in summer determines the length of the potential growing season for plants and thus ecosystem and net primary productivity⁶⁴ (Figure 4.8). The timing of the spring melt has a great impact on productivity as, in the Arctic, leaf production occurs relatively late in the season following thaw when the amount of solar radiation received is already at its maximum or declining. At an alpine site, productivity was decreased by 3 per cent for each day that snow melt was delayed⁶⁵. In contrast, the timing of onset of winter snow has less influence on productivity as it comes at a time when solar angles are low and potential plant production is also low.

The increased snow cover that is predicted in some northern areas as temperatures rise will affect both ecosystem structure and function. Long-term experimental increases in snow cover affected species abundance, height of the vegetation, and diversity of plant functional types in the Alaskan tundra⁴⁰. The increase in snow cover had a greater impact on vegetation than experimental summer warming, partly because insulation by increased snow in winter caused higher soil warming than increased air temperatures. In the subarctic, an experimental doubling of winter snow cover on a peat moss bog increased air and soil temperatures and strongly increased moss growth⁴¹. This increase in moss growth could increase the carbon sink effectiveness of northern peat lands in areas where snow depth increases.



Figure 4.8: The duration of snow cover is a major determinant of the length of the growing season for plants. Shown here is a persistent snow patch in western Greenland. With increasing distance from the centre of the snow patch, the growing season becomes longer, and thus plant communities become more developed and productivity increases.

Photo: Terry Callaghan

More frequent winter thaws can also affect ecosystems. Thawing changes the mechanical properties of snow dramatically. This can reduce the insulating properties of the snow cover, with increased potential for frost penetration into the soil and root damage to certain plant species. During the brief thaw, soil microbial activity may also release greenhouse gases. This occurs at a time when plant uptake of carbon, which could offset the increase in atmospheric carbon, is not possible, and adds to atmospheric concentrations of greenhouse gases. In addition, re-freezing occurs after thawing, which forms ice layers that can be on the surface, throughout the snow cover or, if snow falls after a thawing event, under the snow in contact with the ground. Ice layers can act as a mechanical barrier, preventing herbivores such as musk oxen⁶⁶ and reindeer from digging through the snow to reach critical lichens and other forage (see box on the snow-loving deer of the Arctic). This greatly affects their health in winter and can determine their survival⁶⁷. Ice layers may also inhibit the diffusion of organic compounds that reindeer possibly use to detect food⁶⁸. Presence of ice layers affects the survival of other animals such as voles as well⁶⁹. Ice layers can act as a barrier to small mammals accessing shelter, food, nests and protection from predators.

Snow cover in mountain regions is a critical source of freshwater; changes in snow cover could have indirect effects on ecosystems due to changes in availability of these water resources. One potential effect is increased intensity and size of wildfires because of moisture stress on mountain forests. There could also be impacts on anadromous fish, which require high stream flow for their migration to the ocean after hatching in fresh water.



The snow-loving deer of the Arctic

Reindeer and caribou (*Rangifer tarandus*) have been called chionophiles, snow loving. In fact, Arctic island subspecies of *Rangifer* are associated with a snow environment for up to ten months out of the year. *Rangifer* are the most dominant large mammal species in Arctic environments. The species has specialized adaptations in order to thrive in a cold environment. Their diet is energy rich winter lichen, which they obtain mostly by digging (cratering) under the snow^{70,71}. Large hooves aid in the cratering and allow *Rangifer* to better travel through snow⁷²⁻⁷⁴. *Rangifer* are the only member of the deer family in which both males and females grow antlers. Pregnant females retain their antlers until after spring-time calving, allowing them to dominate the social hierarchy in late winter. This dominance allows them to displace lower ranked animals from feeding craters, saving valuable energy⁷⁵. The large migratory herds of *Rangifer* migrate north into regions of rapidly melting snow in spring during the calving period. The pregnant and birthing cows feed along the snow-melt line, and the newly emerged forage that they ingest is highly digestible, protein-rich and critical for milk production.

Although under normal conditions *Rangifer* are able to thrive in snow environments, snow can also severely limit the annual productivity of herds. During deep snow years, more energy is expended in digging to the lichens than is derived from eating them, so caribou limit cratering or move in search of more favourable snow conditions⁷⁵. Under deep snow conditions, *Rangifer* severely deplete their fat and protein reserves to meet their daily energy needs. Late snow melt and deep snow stalls

movement during spring migrations. Under severe conditions, calves are born before the herds arrive at the calving grounds. In such years, up to 40 per cent of calves can die before they are a month old⁷⁶. In northwestern North America, recent warming has led to a dramatic increase in the number of days of above freezing temperatures during the *Rangifer* migration period. Thawing and subsequent re-freezing of snow results in ice layers in the snow pack which hinder travel of *Rangifer* and make it harder to crater for food⁷⁶. There have been catastrophic declines in the Peary caribou on the Arctic islands of North America and they are now considered endangered (Figure 4.9). The formation of ice layers that prevent the caribou from accessing food has been identified as the chief cause of the declines^{77,78}.

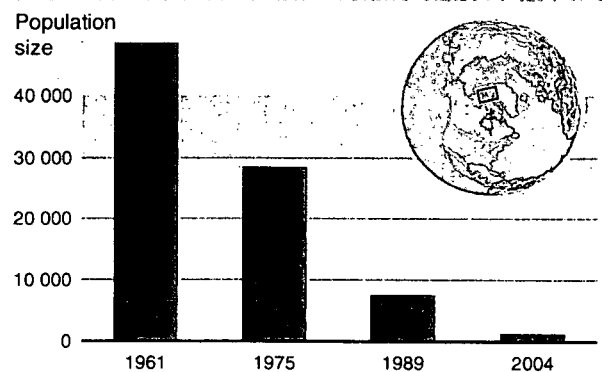


Figure 4.9: Population size of Peary caribou in the Canadian Arctic islands from 1961 to 2004, showing major declines.

Source: Based on data from D. Russell

Impacts of snow-cover changes on human economies and well-being

Impacts on water resources

One of the most dramatic impacts of changing snow cover is on water resources. Snow cover in mountain regions provides critical water supplies, serving nearly one-sixth of the global population with freshwater for domestic, agricultural and industrial uses⁷⁹. Much of the arid American West⁷⁹ and Central Asia⁸⁰ (Figure 4.10) depends heavily (about 75–85 per cent) on snow melt to supply water for municipalities and agriculture. Snow melt driven water resources are crucial for generation of

hydroelectric power, particularly in the American West, Canada, and Europe^{81,82}. The declining springtime snow cover in the Pacific Northwest of the United States and rising snowlines projected for many mountain areas, noted in the 'Trends and outlook' section above, threaten these critical water supplies.

Mountain snow cover typically develops in the autumn and grows to a maximum depth in early spring (Figure 4.11). As day length and sun angles increase, so do air temperatures, causing snow cover to warm and begin to melt. Snow cover balances the availability of water in mountain environments. Where winter precipitation falls as rain, surface runoff occurs almost immediately. In contrast,

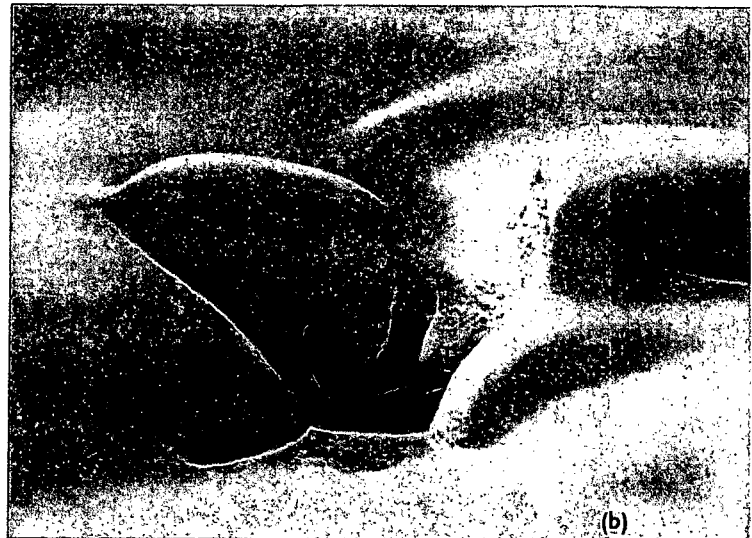
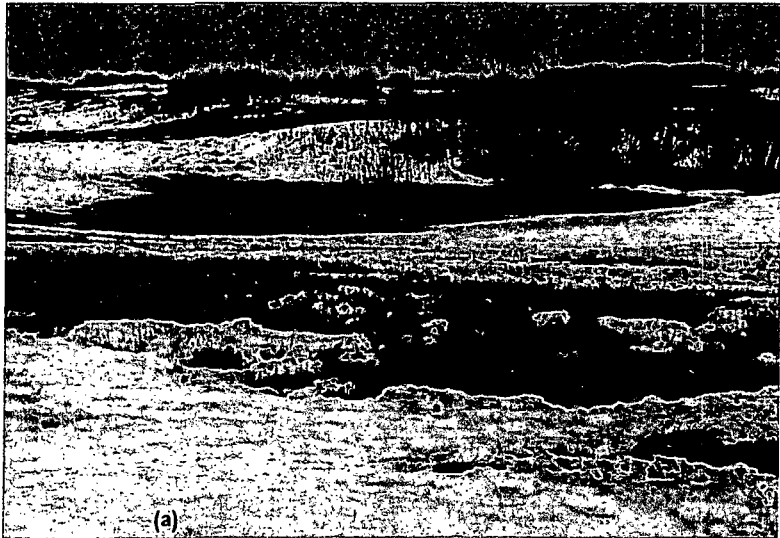


Figure 4.10: Snow cover provides critical water supplies used for many purposes.

(a) Melting of prairie snow cover, seen here in Saskatchewan, Canada, provides spring ponds that are essential for recharge of groundwater and soilwater, for farm water supplies and as spring wetlands for waterfowl migrations through what is otherwise a semi-arid environment.

(b) Melting of alpine snow cover forms a small stream in the Rocky Mountains in British Columbia, Canada. This segment of the Rocky Mountains contains the headwaters of the Columbia River, which supplies water to a large area of western Canada and north-western United States including many important irrigation and hydroelectric generation projects.

Photos: J. Pomeroy

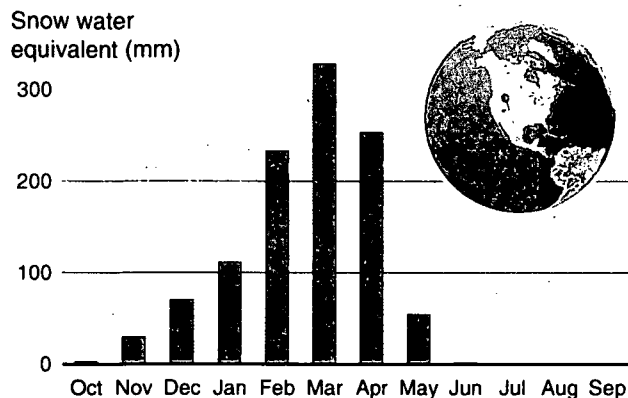


Figure 4.11: Mean monthly snow water equivalent, a common snow pack measurement, for Columbine Pass, Colorado from 1971 to 2000, showing a typical seasonal pattern in a mountain environment.

Source: Based on data from the U.S. National Resources Conservation Service

snow stores water during the winter and then melts in the spring and early summer, creating peak stream flows in the afternoon and an overall seasonal peak flow. In many semi-arid mountain environments, snow melt buffers the transition into the dry summer season. Mountain snow is also a key source of groundwater, since a significant portion of the snow melt enters the soil and drains downhill into valley sediments⁸³. The timing, spatial distribution, and volume of snow melt are critical for determining how much water flows as surface runoff into rivers and lakes and how much becomes groundwater. Earlier snow melt across the western United States, for example, caused a one to four week earlier runoff for mountain rivers and longer periods of summertime low-flow⁸⁴.



Impacts on agriculture – crops and animal husbandry

The dramatic impacts of snow cover on vegetation also apply to agricultural crops. Gradual changes in snow cover, as well as incidences of extreme snow events, can have a strong impact on crops both at the start and end of the growing season. Snow typically disappears in the spring before the start of the growing season. If it occurs during the growing season, snow can insulate crops from cold air or cause damage by freezing crops or breaking off branches and stems. An early autumn snow may prevent a farmer from being able to harvest crops because snow can damage the plants, prevent



■ Children playing in the snow.

Photo: Martha Main

■ **Figure 4.12:** A herd of reindeer belonging to the Nenets, an indigenous people of the Russian Arctic, feed by digging under the snow in western Siberia. Reindeer herding, practiced for centuries by several Arctic peoples, is strongly impacted by snow cover.

Photo: Lars Miguel Utsi/www.ealat.org

them from ripening, or interfere with operation of machinery. In the long-term, changes in snow distributions and their impacts on the local water budget can contribute to changes in vegetation type^{85,86} and change the economic cost-benefit of raising certain crops.

Changes in snow distribution can also influence animal husbandry. During extreme snow events, livestock can get lost, stressed, or fail to give birth successfully⁸⁷. The melting of spring snow creates muddy ground conditions that, if prolonged, can lead to animal weight loss. In subsistence communities such as those across the Arctic, access to traditional hunting or herding of caribou and reindeer is strongly impacted by snow distribution⁸⁸ (Figure 4.12).

Impacts on recreational sector

Changes in snow distributions have had strong impacts on the recreational sector. Skiing is one example that is important to the economies of mountainous regions of North America, Europe, and Asia^{89,90} (see text box on alpine ski resorts). Snowmobiling, used both recreationally and for transport in cold regions, is a growing pursuit and is, of course, dependent on a healthy base layer of snow. In 1985, snowmobiling contributed \$300 million to the state economy of Minnesota alone⁹¹. Other less widespread winter sports such as dog mushing, sledding, and snowshoeing can be important to local economies, and are impacted when snow arrives anomalously late, too little, or not at all.

Making snow on the slopes of a ski resort.
Photo: UNEP/Still Pictures



Alpine ski resorts

Winter tourism is a significant part of the economy of Alpine countries and the most important source of income in many regions. In Austria, winter tourism revenue makes up 4.5 per cent of GNP and half of the total income from tourism. Much of winter tourism is based around the ski industry, which is dependent on reliable snow conditions. Although snow fall is expected to increase at high elevations, it is winter temperatures that largely determine the depth of snow that accumulates on the mountains. The Alps are currently warming at roughly three times the global average. Climate models project an increase in winter temperatures of about 1° to 3° C from 1990 conditions by 2050, with greater warming at higher elevations. An analysis of snow cover in the Alps concluded that each increase of 1° C corresponds to a 150 m move up the mountain of the line marking the lower limit of adequate snow for ski resorts. This means that each degree of warming will result in a further decline of snow conditions to the point that more and more current ski operations will not be viable (Figure 4.13).

Adaptation measures include more artificial snow making and expanding and building ski areas at higher elevations and on north-facing slopes. As the climate warms and the snow cover declines, many low-elevation ski resorts will not be able to adapt and will be forced to switch to other types of tourism or close.

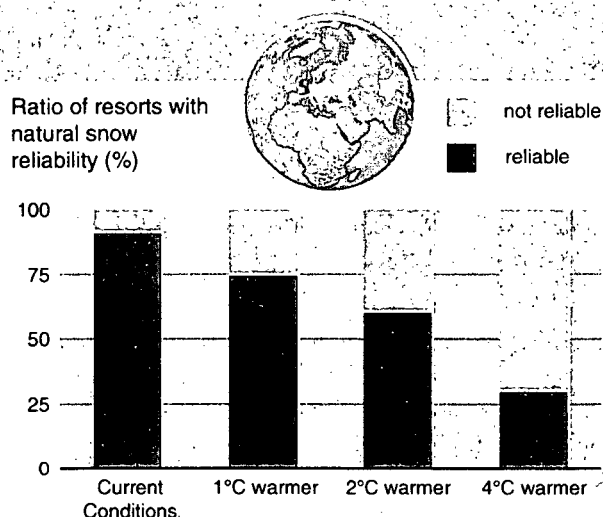
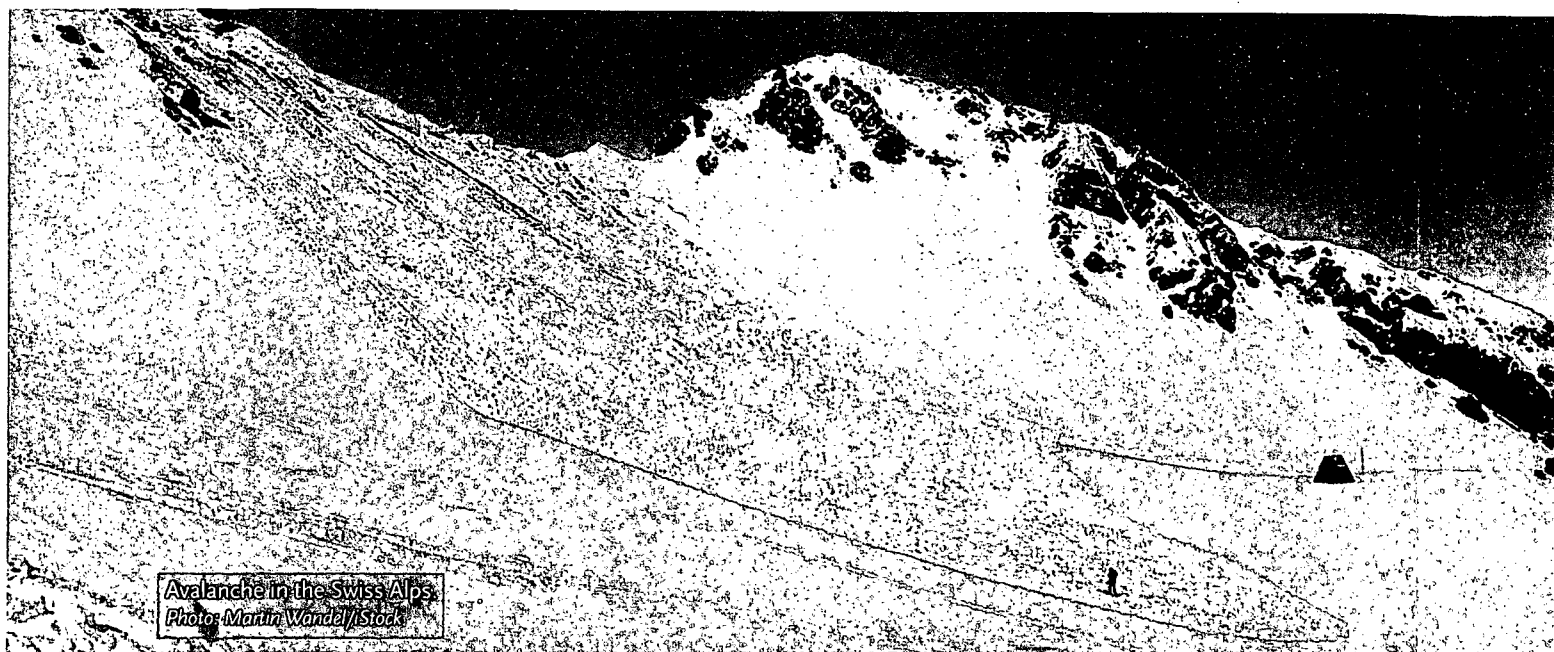


Figure 4.13: Per cent of existing ski areas in the Alps with natural snow-reliability under current conditions and warmer conditions, based on an analysis of 666 medium to large ski areas in France, Austria, Switzerland, Italy and Germany. Natural snow-reliability means on average a season of 100 days with at least 30 cm of snow on upper ski run.

Source: Based on Agrawala 2007⁹⁰



Avalanche in the Swiss Alps
Photo: Martin Wandell/Stock

Impacts on industry and infrastructure

Certain industries depend heavily on reliable snow cover. Oil and gas companies, for example, use ice roads in the Arctic to gain access to resource fields. In order to protect the tundra ecosystem, temperature and snow-depth criteria must be met before a company builds an ice road. Other industries benefit from less snow, as snow-removal costs can be significant for both small and large businesses. Events such as mid-winter melting or rain-on-snow can cause flooding and lead to damage of roads, bridges and homes⁹².

The amount of snow per event, number of events per season, timing within the day and work week⁹³ all affect the economic impact of snow. The economic impact of a snow event on a region's infrastructure also depends on population density. For example, the Northeast Snow Impact Scale (referring to the northeast region of the United States) takes population density as well as snow-cover extent into account in assessing economic impacts of a snow event⁹⁴. Expectations also play an important role in determining the economic impact of climate changes⁹⁵, including changes in snow cover. Weather model forecasts that depict weather

conditions over a broad area have become important management tools for economic sectors impacted by snow. While they are not always accurate, they are the best available source of day-to-day information for most industries.

Impacts on environmental hazards

Snow avalanches, in which large quantities of snow slide down a mountainside, are major hazards in steep terrain, causing economic losses, injury and loss of life. Fatalities due to avalanches in the western United States increased to 25 per year in the 1990s⁹⁶. In the European Alps, there was an average of 114 victims per year between 1975 and 1988, three quarters of them mountain and 'off track' skiers⁹⁷. Factors that create high risk of avalanches are: slopes of 35–45°, new snow accumulations of 50–100 cm, and high wind speeds; the order and thickness of layers within the snow pack are also important⁹⁸. Increasing events of rain-on-snow as in the western United States, noted in the "Trends and outlook" section above, may enhance the triggering of avalanche release. This is an increasing risk at lower elevations and in coastal mountains with rising winter temperatures.

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Ice in the Sea

Sebastian Gerland (lead author, Norwegian Polar Institute, Tromsø, Norway); Jon Aars (Norwegian Polar Institute, Tromsø, Norway); Tom Bracegirdle (British Antarctic Survey, Cambridge, UK); Eddy Carmack (Fisheries and Oceans, Canada, Institute of Ocean Sciences, Sidney, BC, Canada); Haakon Hop (Norwegian Polar Institute, Tromsø, Norway); Grete K. Hovelsrud (CICERO: Centre for International Climate and Environmental Research, Oslo, Norway); Kiri Kovacs (Norwegian Polar Institute, Tromsø, Norway); Christian Lydersen (Norwegian Polar Institute, Tromsø, Norway); Don K. Perovich (U.S. Army ERDC - Cold Regions Research and Engineering Laboratory, Hanover, NH, USA); Jackie Richter-Menge (U.S. Army ERDC - Cold Regions Research and Engineering Laboratory, Hanover, NH, USA); Stine Rybråten (CICERO: Centre for International Climate and Environmental Research, Oslo, Norway); Hallvard Strøm (Norwegian Polar Institute, Tromsø, Norway); and John Turner (British Antarctic Survey, Cambridge, UK)

Ice in the Sea

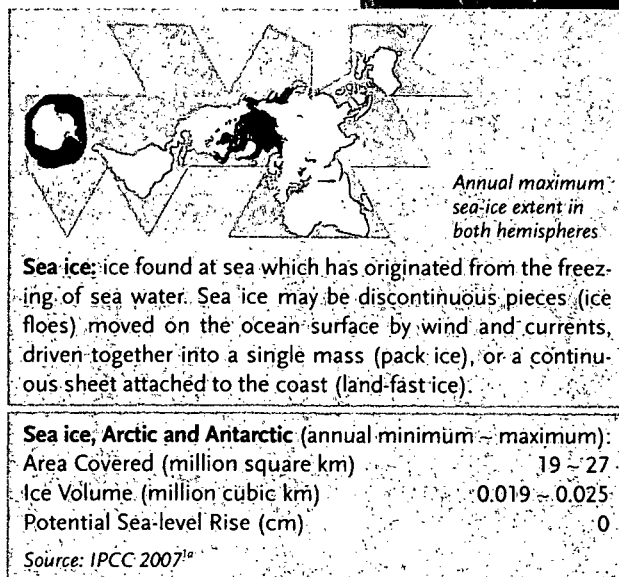
Summary

Sea ice plays a key role for climate and is important as habitat and for human activities and economies. Observations show and models indicate that climate and sea-ice regimes are changing. Sea-ice extent in the Arctic decreased substantially during the last 30 years; Antarctic sea ice is decreasing in some areas, but overall it has shown a slight increase during this period. Climate models project further decreases in sea-ice extent in the Arctic during this century and comparable decreases in Antarctic sea-ice extent. There are uncertainties attached to the rate at which these changes will occur, and there is a risk of tipping points being crossed and abrupt reductions in sea ice occurring. To reduce these uncertainties, more large-scale continuous observations are needed, especially of ice and snow thickness.

Changes to sea ice will have major impacts on both the physical and biological environment at all scales from global to regional. The reduction in albedo (reflection of solar radiation) resulting from less ice cover is a feedback mechanism that accelerates the rate that sea ice declines and also the rate at which Earth warms. Changes in sea ice contribute to altering the ocean thermohaline circulation, especially in the North Atlantic.

Sea ice is a complex environment with a diversity of habitats and seasonal variation to which life in the polar seas is closely adapted. Many species are now being affected by changes in sea ice in the Arctic, and, if the changes continue, there is a strong risk of species extinctions. There is a range of direct consequences of changes in sea ice for economies and human well-being – including threats to indigenous cultures and opening of new sea routes and economic opportunities.

Source: NASA



Introduction to sea ice

Seen from space, the Earth is dominated by the colours blue, white, and grey-brown. Blue from the ice-free ocean surfaces, white from snow, ice and clouds, and grey-brown from snow-free and ice-free land surfaces. The brighter the colour, the more the sun's rays are reflected back into space, and the less the Earth warms up. An important part of the Earth's white surface area is sea ice.

In the Arctic, winter sea ice extends over an area of approximately 15 million km² at its peak in March and up to 7 million km² in September, at the end of the summer melt season. Corresponding numbers for the Southern Ocean

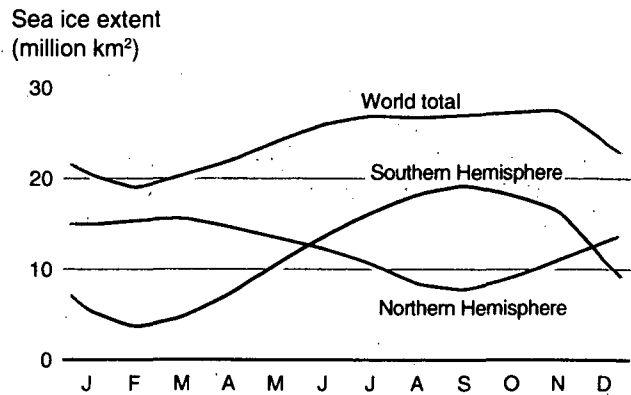
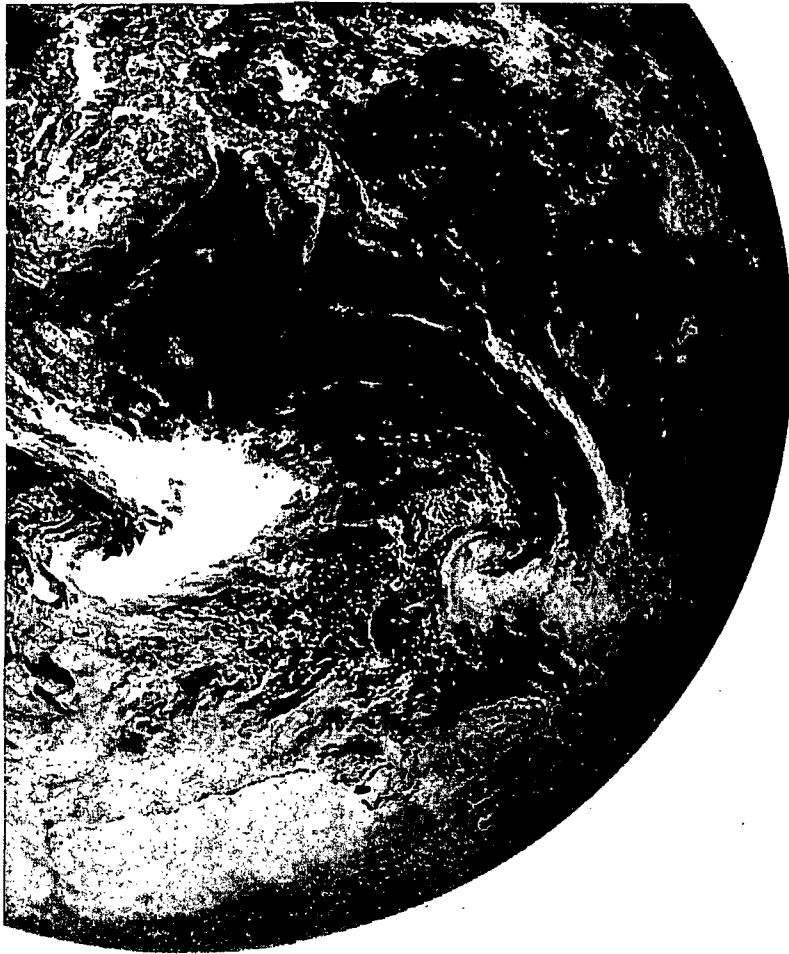


Figure 5.1: Monthly average variations in sea-ice extent in total and in both hemispheres.

Source: Based on Thomas 2004¹ (amended from original by J. Comiso, NASA)

around the Antarctic continent are approximately 3 million km² in February during the Antarctic summer and 18 million km² at the height of winter in September (Figure 5.1). In regions with seasonal sea ice, the ice cover achieves a thickness varying from less than 1 metre to more than 2 metres, depending on air and water temperatures and other conditions. In regions where ice survives the summer, thicker, multi-year ice is formed. But these conditions are changing. Sea ice has decreased in the Arctic and is projected to decline much more in both polar regions, with consequences to climate, ecosystems and human livelihoods.

Sea ice is extremely important to the climates of the polar regions because of the part it plays in insulating the

atmosphere from the huge heat source in the ocean, its role in the formation of bottom water (the densest water found in the ocean, which is extremely important in the circulation of the ocean), and the part it plays in feedback and amplification processes. Snow-covered sea ice is highly reflective and returns a lot of sunlight back to space. In contrast, when sea ice is not present the dark ocean can absorb this heat from the Sun.

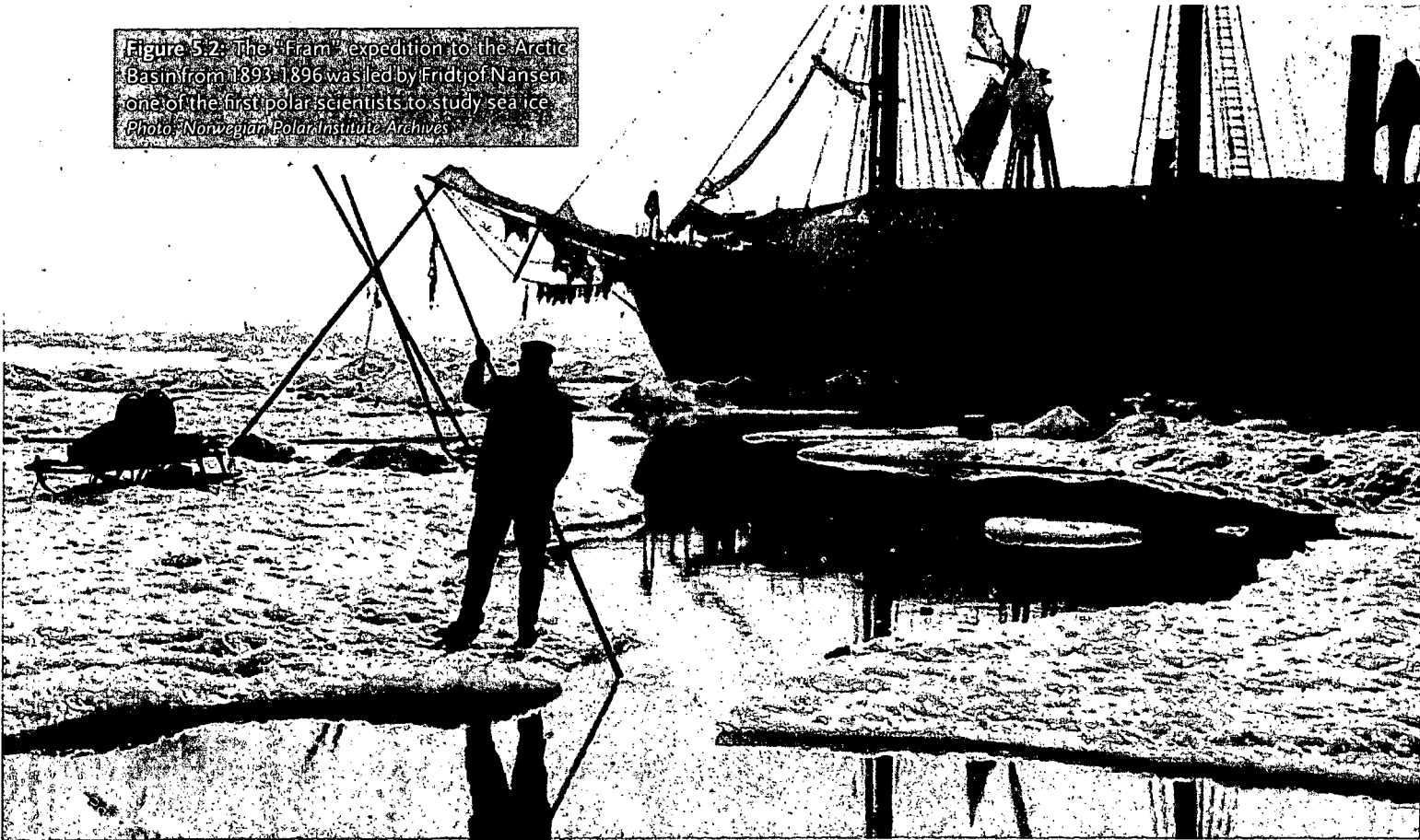
Sea ice is home to many ice-associated organisms, from tiny algae and crustaceans to penguins, polar bears and whales. Many organisms in Arctic and Antarctic marine food webs depend on the ice itself or on processes connected with sea ice. And sea ice is important to humans.

It affects transportation routes, navigation and access to resources such as fish and oil in polar waters and in seas with seasonal and periodic ice cover. It is crucial to the livelihoods and cultures of coastal Arctic indigenous people.

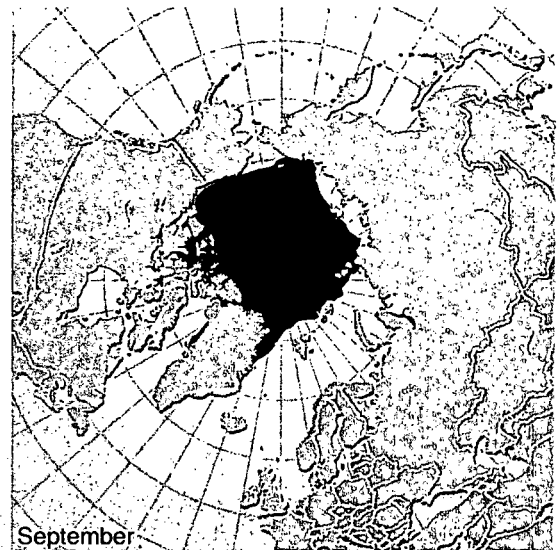
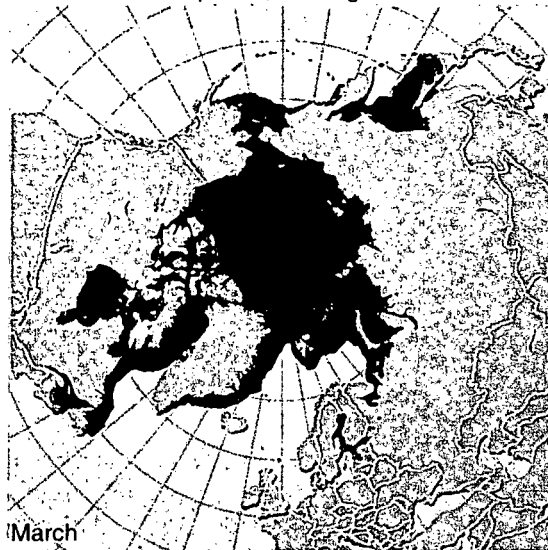
People have been studying sea ice for millennia, from Arctic indigenous people who continue to study and adapt to sea-ice conditions as part of their daily lives, through 16th century commercial whalers, to the early polar scientific researchers of the 19th century (Figure 5.2). During the 20th century scientific research on sea

ice became more sophisticated, with ship expeditions and ice drifting stations (mostly Russian) in the Arctic and various expeditions to Antarctica. Modern polar research is supported by ships or land-based stations with advanced instrumentation, satellite observations and moorings as well as advanced modelling. During the International Polar Year (2007–2008) research activity is aimed at improving understanding of sea ice, its interaction with atmosphere and ocean, its role in marine ecosystems, and the consequences of changes in sea ice brought about by global warming.

Figure 5.2: The "Fram" expedition to the Arctic Basin from 1893–1896 was led by Fridtjof Nansen, one of the first polar scientists to study sea ice. Photo: Norwegian Polar Institute Archives



Northern Hemisphere, average sea ice extent 1979-2003



Southern Hemisphere, average sea ice extent 1979-2002

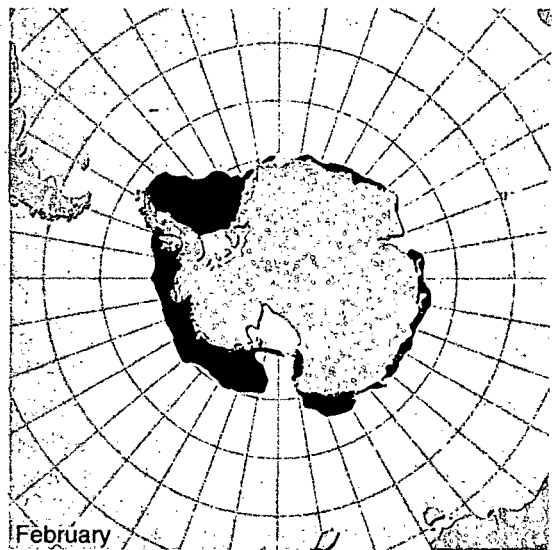
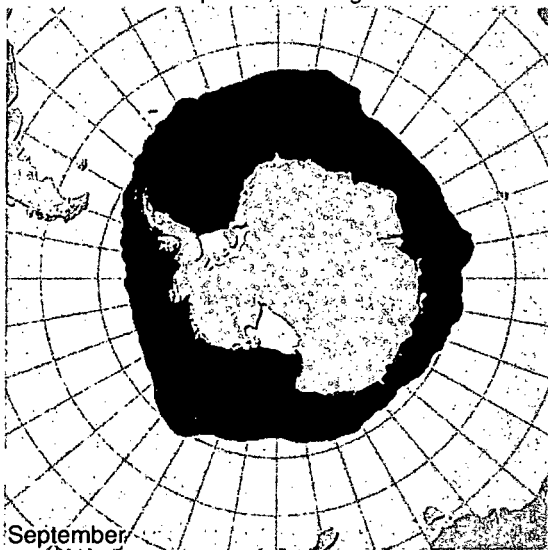


Figure 5.3: Maps of average sea-ice extent in the Arctic summer (September) and winter (March), and in the Antarctic summer (February) and winter (September). They represent average sea-ice extent from 1979 to 2002/2003, based on passive microwave satellite observations. The two polar regions are drawn to the same scale.

Source: Based on Stroeve and Meier 1999 updated 2005³ (Antarctic); Armstrong and Brodzik 2005⁴ (Arctic)

Trends in sea ice

Passive microwave sensors on satellites have monitored the extent of the sea-ice cover since 1978². This technique is widely used to investigate fluctuations in ice extent over the seasons, variability between years, and long-term trends. The seasonal variation of ice extent is much greater in the Antarctic where there is about six times as much ice in winter as in summer. Currently, in the Arctic, ice approximately doubles from summer to winter. Figure 5.3 shows the average minimum and maximum extents of Arctic and Antarctic sea ice in recent decades.

Northern Hemisphere trends

Despite considerable year-to-year variability, significant negative trends are apparent in both maximum and

minimum ice extents, with a rate of decrease of 2.5 per cent per decade for March and 8.9 per cent per decade for September⁵⁻⁷ (Figure 5.4).

There are major regional differences (Figure 5.5), with the strongest decline in ice extent observed for the Greenland Sea (10.6 per cent per decade). The smallest decreases of annual mean sea-ice extent were found in the Arctic Ocean, the Canadian Archipelago and the Gulf of St. Lawrence. In the marginal Arctic seas off Siberia (the Kara, Laptev, East Siberian and Chukchi Seas) a slight negative, but not significant, trend in ice extent was observed between 1900 and 2000⁸.

Figure 5.6 compares the Arctic sea-ice extent in September for the years 1982 (the record maximum since 1979) and 2005 (the record minimum). The ice extent was 7.5

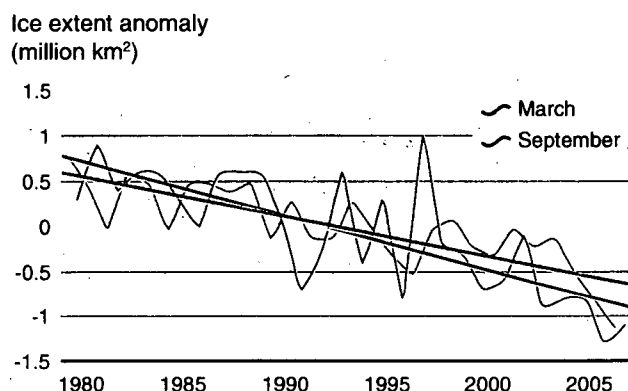


Figure 5.4: Time series of the difference in Arctic sea-ice extent in March (maximum) and September (minimum) from the mean values for the time period 1979–2006. Based on a linear least squares regression, the rate of decrease in March and September was 2.5% per decade and 8.9% per decade, respectively.

Source: Data courtesy of National Snow and Ice Data Center (NSIDC)

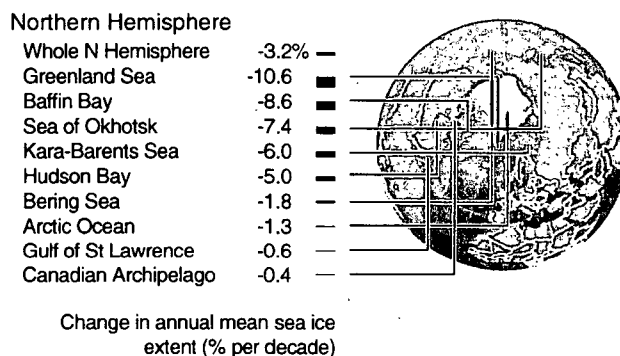


Figure 5.5: Regional changes in Arctic annual mean sea-ice extent (% per decade) for the period 1979–2004.

Source: Data courtesy of NASA 2007a⁹

million km² in 1982 and only 5.6 million km² in 2005, a difference of 25 per cent. As has been observed in other recent years, the retreat of the ice cover was particularly pronounced along the Eurasian coast. Indeed, the retreat was so pronounced that at the end of the summer of 2005 the Northern Sea Route across the top of Eurasia was completely ice-free (see section below on shipping and tourism).

Ice extent is only part of the equation. To assess changes in ice cover it is also important to look at ice thickness – however ice thickness is difficult to monitor and measurements are much more limited. Satellite-based techniques have only recently been introduced and there is no comprehensive record of sea-ice thickness. There are many datasets of ice thickness from measurements taken opportunistically, including holes drilled through

the ice, observations from ships, upward-looking sonars moored at the sea floor¹⁰, and above-ice surveys using laser techniques and electromagnetic sensors¹¹.

The most comprehensive source of ice-thickness observations were the sonar profiles made from submarines cruising under the Arctic ice cover from the 1950s to the 1990s. These observations were made irregularly, but researchers were able to group them for comparison into seven regions and into two time periods. Rothrock and others¹² concluded from these records that a substantial thinning of the ice occurred in several regions between the period 1956–1978 and the 1990s, with an overall 40 per cent decrease in thickness from an average of 3.1 m to 1.8 m. Other later publications dealing with analyses of submarine-based sonar data conclude that the thinning rates may have been less than this^{13,14}.

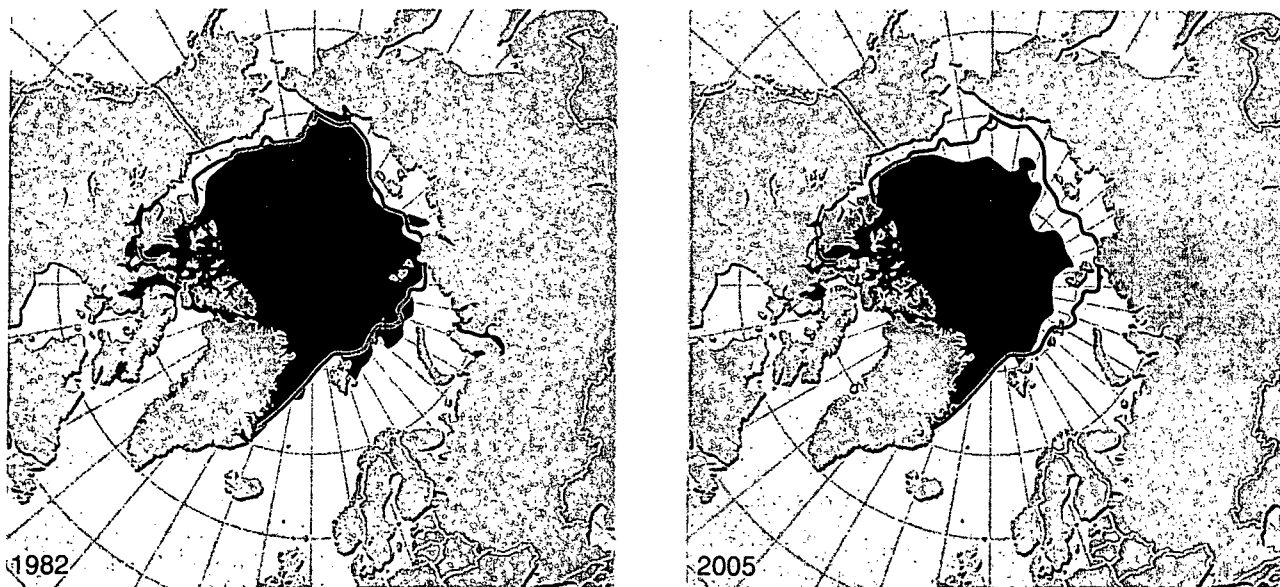
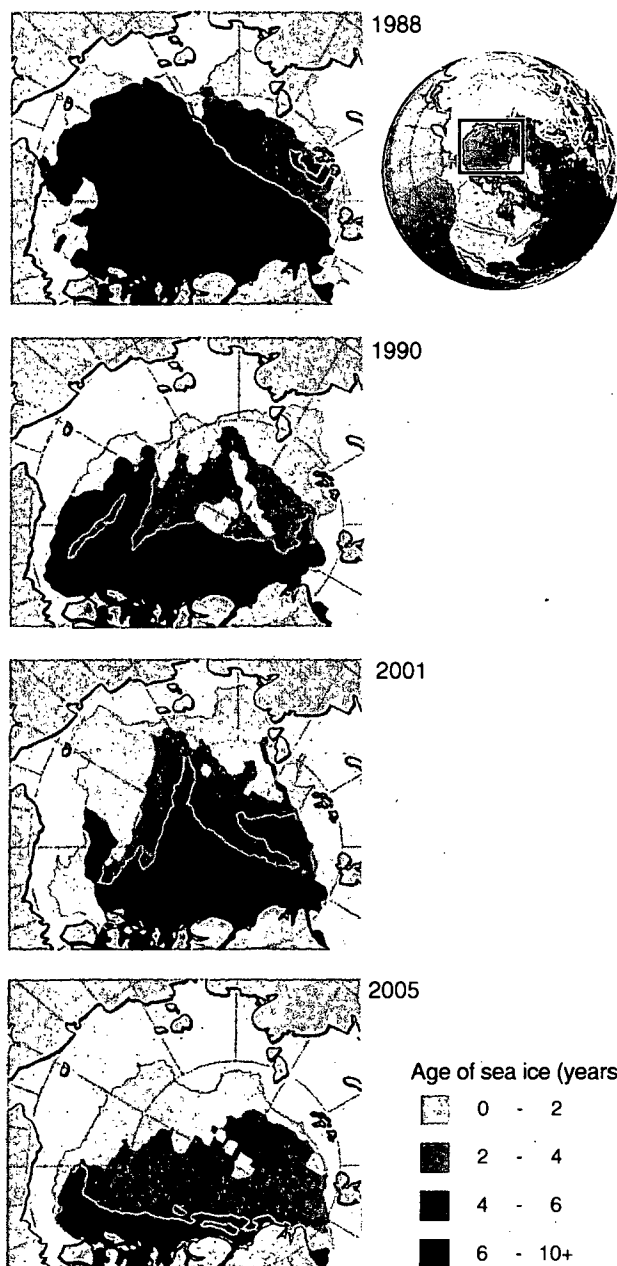


Figure 5.6: Arctic sea ice minimum extent in September 1982 and 2005. The red line indicates the median minimum extent of the ice cover for the period 1979–2000. The September 2005 extent marked a record minimum for the period 1979–2006.

Source: Data courtesy of National Snow and Ice Data Center (NSIDC)



Thickness of land-fast ice is monitored from coastal sites in Arctic Canada, Svalbard and Siberia^{8,15,16}. Most sites show large variations among years and among decades. Data extending back to 1936 from sites off the coast of Siberia show, in general, no significant trends up to 2000⁸. Consistent observations at Svalbard do not go that far back in time, but monitoring during the last decade showed that during the warmer-than-normal winters of 2005/2006 and 2006/2007 the land-fast ice in most Svalbard fjords was less extensive, thinner and lasted for a shorter time than normal.

The age of sea ice in the Arctic is also changing. Studies show that in recent years there is a higher proportion of younger ice to older ice than was observed in the late 1980s⁶ (Figure 5.7).

Southern Hemisphere trends

In contrast to the Arctic, there are signs of a slight increase in the extent of annual mean sea ice over the period 1979–2005 (+1.2 per cent per decade) based on the NASA Team retrieval algorithm¹⁸. The IPCC²⁰ concluded that this overall increase was not significant and that there are no consistent trends during the period of satellite observations. There are, however, indications that sea ice may be increasing more at the period of minimum coverage (March) than at the period of maximum sea-ice extent in September. There is also regional variation (Figure 5.8) with an increase, for example, in the Ross Sea (+4.8 per cent per decade) and a loss in the Bellingshausen Sea (–5.3 per cent per decade).

Figure 5.7: Change in the age of ice on the Arctic Ocean, comparing September ice ages in 1988, 1990, 2001 and 2005. This analysis is based on results from a simulation using drifting buoy data and satellite-derived ice-concentration data¹⁷. The darker the colour, the older the ice.

Source: Based on Richter-Menge et al. 2006⁶



Antarctic sea ice.
Photo: Mlenny/iStockphoto.com

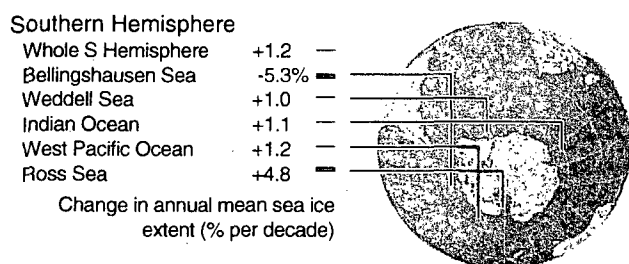


Figure 5.8: Regional changes in Antarctic annual mean sea-ice extent (% per decade) for the period 1979–2004.

Source: Data courtesy of NASA 2007a⁹

There are far fewer observations of sea-ice thickness for the Antarctic than for the Arctic because of the lack of submarine measurements. It is therefore not possible to detect any trends in Antarctic sea-ice thickness over recent decades.

The reasons for the very different trends in Arctic and Antarctic sea-ice extent over recent decades are not known at present and resolving this important question is a high research priority. Researchers are examining changes in the atmospheric circulation of the two polar regions as well as changes in ocean circulation.

Outlook for sea ice

Northern Hemisphere

Climate models project a continuing decrease of ice extent in the Arctic^{19,20} accompanied by thinning of the ice. The most dramatic change, projected by about half the current climate models developed as part of the IPCC assessment report 4 (AR4), is a mainly ice-free Arctic Ocean in late summer by 2100 (Figure 5.9 upper right). The projected change in the winter is smaller: 15 per cent decrease in sea-ice extent (Figure 5.9 upper left). The annual average decrease projected is 25 per cent by 2100. These seasonal differences will result in increased amplitude of the seasonal cycle of sea-ice extent (greater differences between seasons). A model that examines sea-ice volume projects that it will decrease even more than the ice extent, with reductions of annual means of about 60 per cent by 2100²¹.

In the transition zone between high Arctic and subarctic, and in the subarctic, where seasonal ice dominates now (including the Barents, Baltic, Bering and Okhotsk Seas), expected trends are: reduced ice extent, shorter ice seasons and thinner ice. More frequent winter warm spells may also result in snow melting and refreezing as superimposed ice. The two most recent northern winters (2005/2006 and 2006/2007) were warmer than normal in the European Arctic and several of these effects were clearly visible in, for example, the Barents Sea and the Baltic Sea.

Southern Hemisphere

Around Antarctica the projected annual average decrease of sea-ice extent is similar to the Arctic, at around 25 per cent by 2100. Both polar regions show the largest per-

centage changes in late summer (Figure 5.9 upper and lower right) and an increase in the amplitude of the annual cycle. However, in Antarctica the projected change in sea-ice volume of around 30 per cent is about half the value projected for the Arctic, and the increase in amplitude of the seasonal cycle is also less pronounced²¹. The difference in sea-ice volume change can be explained by the finding that the most rapid thinning of sea ice occurs in regions of thicker ice. On average the sea ice over the Arctic is thicker than around Antarctica at present.

Sea-ice retreat: potential for tipping points and enhanced rates of change

There is evidence for the occurrence of tipping points in the future, manifested as periods of abrupt decrease of Arctic sea-ice occurrence²². These abrupt changes may result when the ice thins and the rate of retreat becomes more rapid for a given melt rate. Typically they would

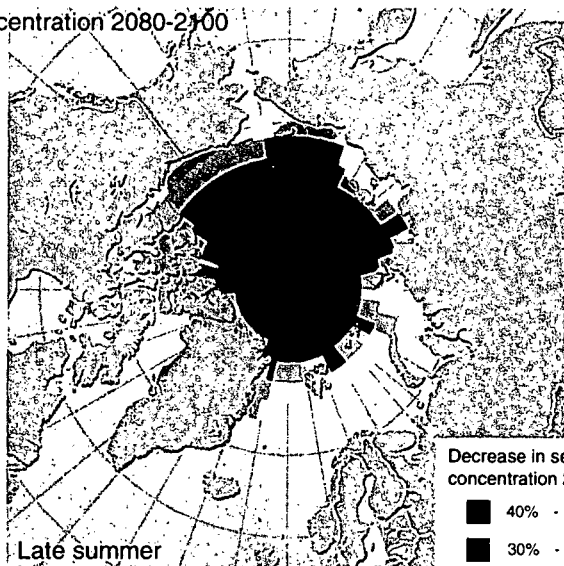
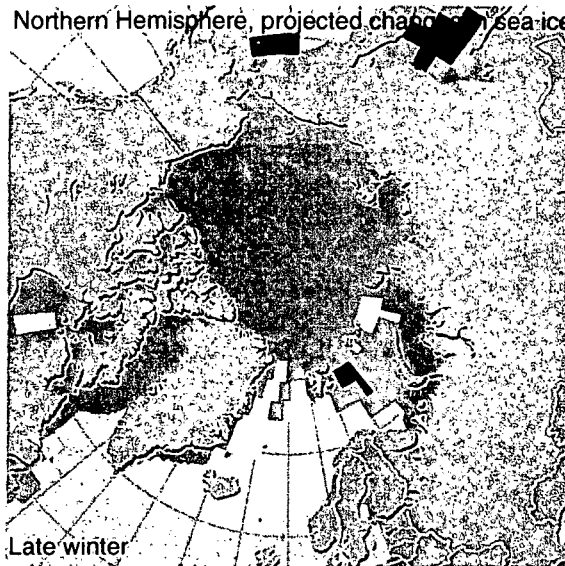
■ **Figure 5.9: Sea-ice concentration change over the 21st century as projected by climate models.** The data are taken from climate model experiments of 12 (out of 24) different models that were conducted for the IPCC Assessment Report 4 using the SRES A1B greenhouse gas emission scenario. Plots on the right show changes in late summer and those on the left show changes in late winter.

Notes:

- 1) Sea-ice extent is the area in which a defined minimum of sea ice can be found. Sea-ice concentration is the proportion of the ocean area actually covered by ice in the area of the total sea-ice extent.
- 2) Small ocean inlets, such as those in the Canadian Archipelago, while not showing a decrease on these plots, are also expected to experience a decrease in sea-ice concentration – this is an issue related to the resolution of the climate models.

Source: Based on data from T. Bracegirdle, British Antarctic Survey

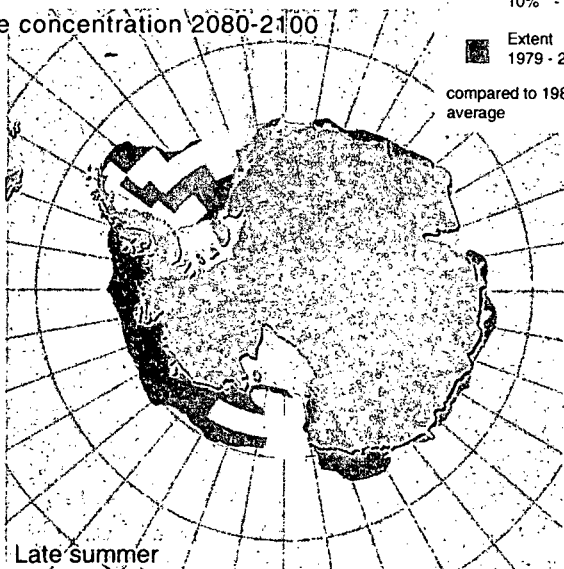
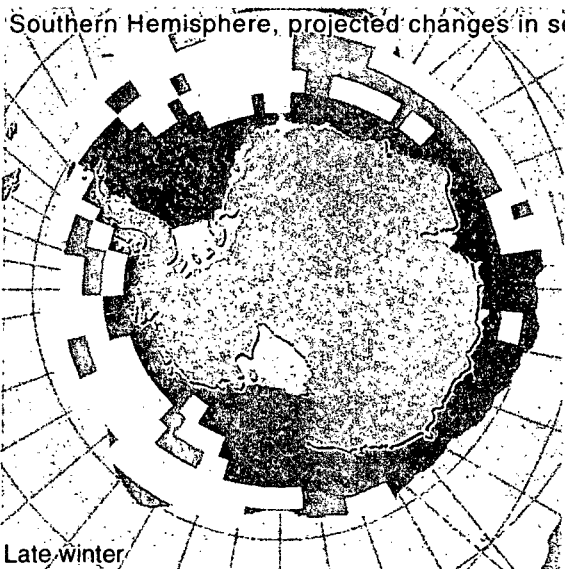
Northern Hemisphere, projected changes in sea ice concentration 2080-2100



Decrease in sea ice
concentration 2080-2100

- 40% - 50%
- 30% - 40%
- 20% - 30%
- 10% - 20%
- Extent
1979 - 2002/2003
compared to 1980-2000
average

Southern Hemisphere, projected changes in sea ice concentration 2080-2100



occur over a period of five to ten years, during which time almost all the summer ice can disappear. There are indications that abrupt reductions early in the 21st century could result in a largely ice-free Arctic in the summer as early as 2040²³. However, most current climate models do not project that the Arctic will be free of ice in summer this early in the century, so there is still significant uncertainty over this issue.

Another mechanism for enhanced Arctic sea-ice retreat, although not for abrupt changes, is linked to the transition from perennial to seasonal sea ice, which introduces new regions to seasonal sea-ice cover. Increased seasonal production and loss of sea ice along the Siberian Continental Shelf appears to be one explanation for an enhanced ocean heat transport into the Arctic Ocean from the Atlantic Ocean²⁴. This enhanced heat transport

is a positive feedback since it contributes to the further loss of sea ice. As most of the sea ice around Antarctica is already seasonal, this mechanism is only relevant to the Arctic.

Global significance of sea-ice changes

Changes in patterns of sea-ice formation and melting have widespread influences, including on global climate and ocean circulation patterns. Ocean circulation is driven partly by gradients in the density of water (known as thermohaline circulation, described in Chapter 2). Sea water density is determined by heat ("thermo-") and salinity ("-haline"). Most of the salt from the water that freezes is added to the water mass below the sea ice. This process leads to an increase of salinity in the surface water in locations where sea ice forms and to freshwater

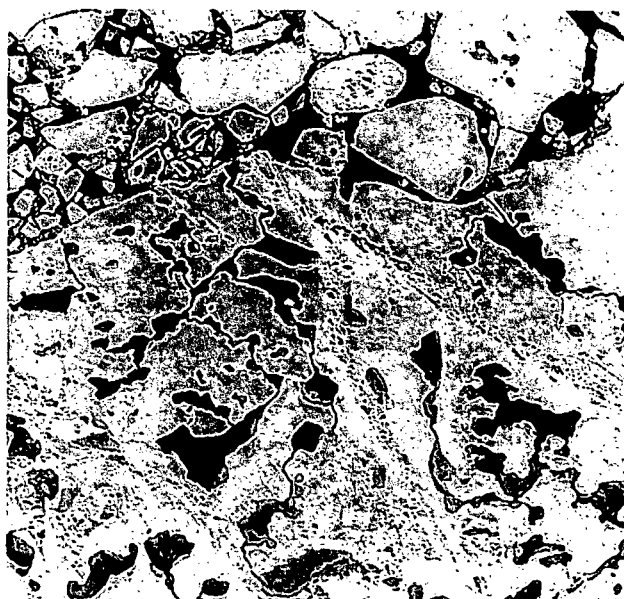


Figure 5.10: Aerial photographs of the Arctic sea-ice cover prior to melt (left) and during the summer melt season (right).
Photos: Don Perovich

input to surface waters in locations where sea ice melts. This means that a significant volume of fresh water is exported as sea ice through Fram Strait and the Canadian Archipelago – this is a major component of the North Atlantic Ocean's salt balance. Changes in sea-ice export will impact both the thermohaline circulation and the location where the warm but relatively salty northward flowing North Atlantic Current sinks beneath the cold but relatively fresh surface water and flows into the Arctic basin (see Figure 2.1 in Chapter 2).

Changes in sea-ice cover are also significant on a global scale because of the potential to amplify climate change through positive feedback mechanisms^{25,26}. A key mechanism is the ice–albedo feedback²⁷. Albedo is a simple but powerful geophysical parameter. It is simple because it is just the fraction of the incident sunlight that is reflected by a surface. If all the sunlight is reflected the albedo is 1 (or 100 per cent reflection), if none is reflected the albedo equals zero. It is powerful because sunlight is the primary planetary heat source and how much of that sunlight is reflected is a key factor determining climate.

Aerial photographs of Arctic sea-ice cover in spring and in summer are shown in Figure 5.10. The spring photo is representative of much of the year when the surface is a combination of highly reflecting snow-covered ice and highly absorbing dark areas of open water. Conditions become more complex in the summer with a mixture of melting snow, bare ice, ponds, and an overall increase in the amount of open water.

The albedos for these different surface conditions are plotted in Figure 5.11a. They range widely, from roughly 85 per cent of radiation reflected for snow-covered ice to 7 per cent for open water^{28,29}. These two surfaces cover the range from the largest to the smallest albedo on earth. Melting snow, bare ice and ponded ice lie within this range. There is a general decrease in the albedo of

the ice cover during the melt season as the snow-covered ice is replaced by a mix of melting snow, bare ice, and ponded ice³⁰. As the melt season progresses, the bare-ice albedo remains fairly stable, but the pond albedo decreases. During summer the ice cover retreats, exposing more of the ocean, and the albedo of the remaining ice decreases as the snow cover melts and melt ponds form and evolve. These processes combine to form the ice–albedo feedback mechanism (Figure 5.11b).

Impacts of changes in sea ice

Overview

Changes in ice within the Arctic Ocean will also have impacts on Arctic marine ecosystems and three 'tipping points' can be hypothesized³¹: the first would occur if and when the seasonal ice routinely retreats past the edge of the continental shelf, thus allowing wind-driven upwelling which would result in increases in primary productivity; the second would occur if and when the Arctic becomes ice-free in summer, thus eliminating multi-year ice and associated ecosystems; the third would occur if and when significant regions within the Arctic basin remain ice-free in winter, thus impacting the distribution of seasonally migrating marine mammals.

Reductions in ice-cover thickness, extent and duration, and changes in current patterns and fronts will likely have both gradual (predictable) and catastrophic (surprise) consequences³²:

- bottom-up controls (such as stratification, mixing and upwelling of seawater) will certainly change;
- keystone predators within a given region may move into the region, move away from the region, or become extinct; and
- linkages between the open ocean ecosystems and the ocean bottom ecosystems may weaken.

Arctic shelf ecosystems are likely to be more sensitive to climatic perturbations than those of temperate shelf areas because a greater degree of warming is expected and because these ecosystems are characterized by comparatively simple food webs and low biodiversity (meaning that loss of one part of the food web has greater consequences).

In the remainder of this chapter we discuss sea ice in relation to ocean and climate processes, summarize the impacts of observed and projected changes on polar marine biodiversity and ecosystems, and look at how both the

physical ice changes and the changes in ice-related ecosystems are affecting human economies and well-being.

Sea ice as a dynamic, complex environment

When observers aboard a ship watch ice floes drifting through Fram Strait (the area between Greenland and Svalbard) they can assume that each piece of ice has a long history. Sea ice that ends up in Fram Strait (and most multi-year ice that exits the Arctic Ocean flows through Fram Strait) often originates from the Siberian

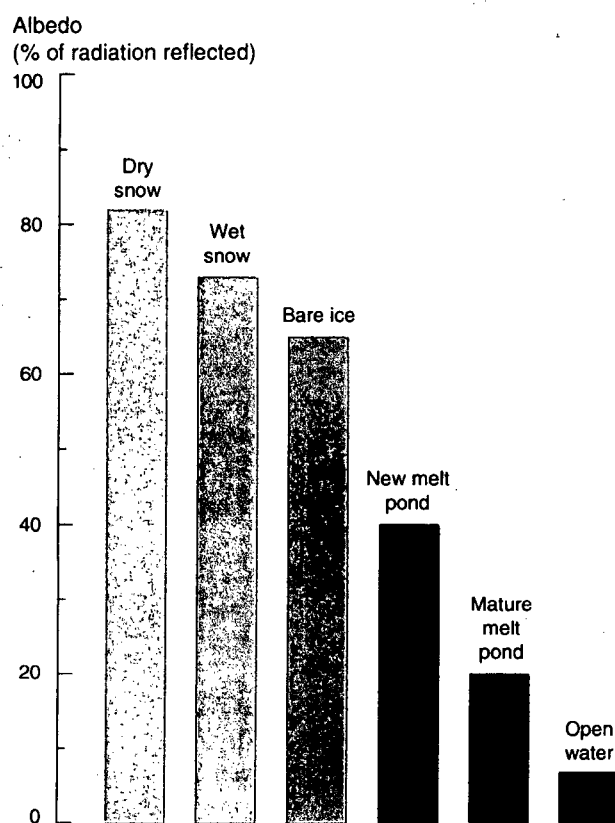


Figure 5.11a: Albedos of basic thick sea-ice surface types.

Source: Based on Pegau and Paulson 2001²⁸, Perovich and others 2002²⁹

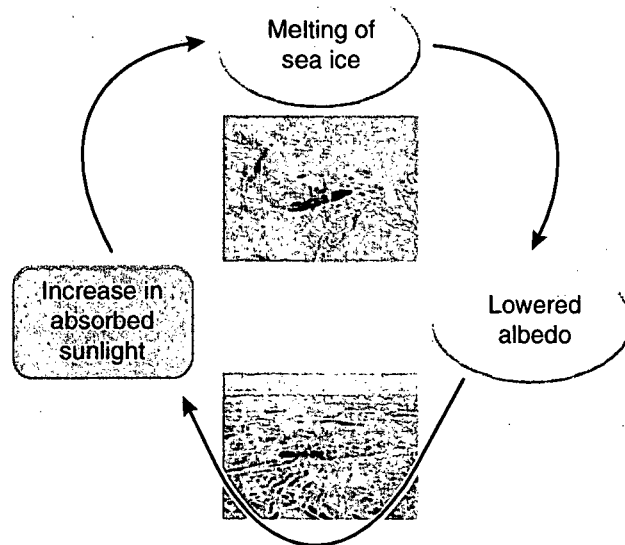


Figure 5.11b: Schematic illustrating the ice-albedo feedback. In spring, the ice is snow-covered and there is very little open water. Most sunlight is reflected, but some is absorbed. This absorbed sunlight leads to melting, which in turn reduces the ice albedo and increases the amount of open water. This causes the albedo to further decrease, increasing the rate of heating and further accelerating melting.

Source: Based on material from D.K. Perovich

Sea-ice research: making sense of sea-ice observations

Cold air, cold water and calm conditions are needed for sea ice to form. Observed changes in ice abundance and thickness can point towards changes in any of these environmental conditions. Ice thickness can also increase due solely to ice dynamics when ice is extensively rafted and ridged.

The fact that pack ice drifts and is constantly changing location makes the interpretation of changes in sea ice in relation to climate change even more difficult, as the following example illustrates. If sea-ice floes start to drift from the East Siberian Sea to Fram Strait at a faster rate, the thickness of the ice for a given temperature history will change because the ice has less time to grow. If the drift speed stays as it was, but the environmental temperature rises, the thickness of the ice will be also less. And, as a third scenario, if snowfall increases and freezing and melting conditions are changed the thickness will be affected. This illustrates how important the physical parameters of the atmosphere and ocean are for the sea ice and for the analysis of sea-ice observations.



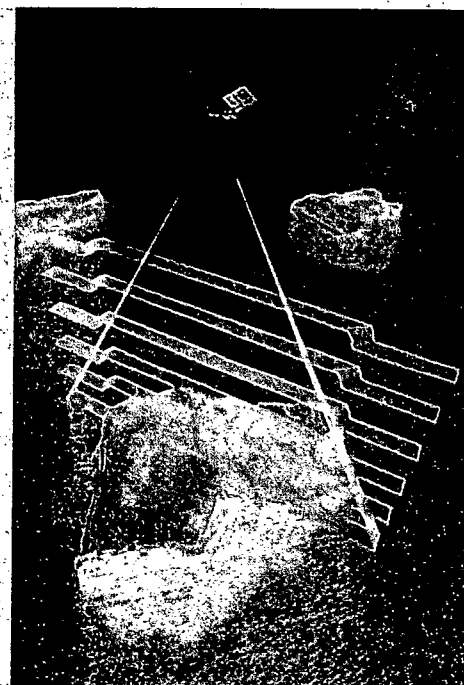
Sea-ice research: International Polar Year and looking to the future

Research on sea ice is a strong focus in the programme of the International Polar Year (2007-2008), with many nations combining resources and expertise to collaborate on large-scale studies aimed at furthering understanding of sea ice, oceans and the atmosphere. These research campaigns involve integration of in situ observations and use of modern technology (automatic sensors, autonomous drifters and floats, and satellites), along with improved climate modelling.

Further development of satellite sensor technology is underway, and this should soon result in higher accuracy and better spatial and temporal resolution of measurements^{33,34}. The new ice-specialist satellite CryoSat-2 (Figure 5.12), to be launched in 2009, and new developments beyond that, will hopefully lead to a much better capacity to observe and understand the status of Arctic and Antarctic sea ice and the processes and factors controlling it.

Figure 5.12: CryoSat-2, artist's impression. CryoSat-2, to be launched in 2009, will improve monitoring of ice thickness. Its altimeter measures distances to sea ice and open water and the difference between the two is used to derive ice thickness

Illustration: ESA – AOES/Medialab



shelf seas, the East Siberian Sea and the Laptev Sea. There, sea ice forms during the Arctic autumn and winter, grows thicker and joins the transpolar drift towards and over the North Pole. Finally, after some two to seven years, the ice floe enters Fram Strait. This transport of ice influences, among other things, the processes governing ocean circulation and the flow of nutrients in Arctic marine ecosystems.

Many factors influence the formation, evolution and degradation of sea ice. Monitoring and research is underway to improve understanding of these factors, how they are linked, and the influence of climate change (see boxes on sea ice research).

Large parts of the Arctic are characterized by complex, multi-year ice³⁵. During Arctic summers, ponds form as snow melts on the ice surface. In autumn the melt

ponds freeze over, snow falls on the surface and new ice forms at the underside of the ice floe. Individual floes freeze together to form larger floes. Rafting and ridging occurs (Figure 5.13) and leads (narrow channels of open water) are formed. Ridges, which can be several metres high, and ice keels, which can extend more than 20 m below sea level, affect wind drag and water drag. Dust and sediments are incorporated into snow and ice through atmospheric and oceanic processes, and ice algae and other organisms colonize the brine channels and the under-sides of ice floes.

In the Southern Hemisphere sea-ice conditions are very different. The Southern Ocean surrounds the Antarctic continent, in contrast to the Arctic Ocean, which is surrounded by land. Since the highest latitude areas in the south are land covered, Antarctic sea ice is on average further away from the South Pole than is Arctic sea ice from

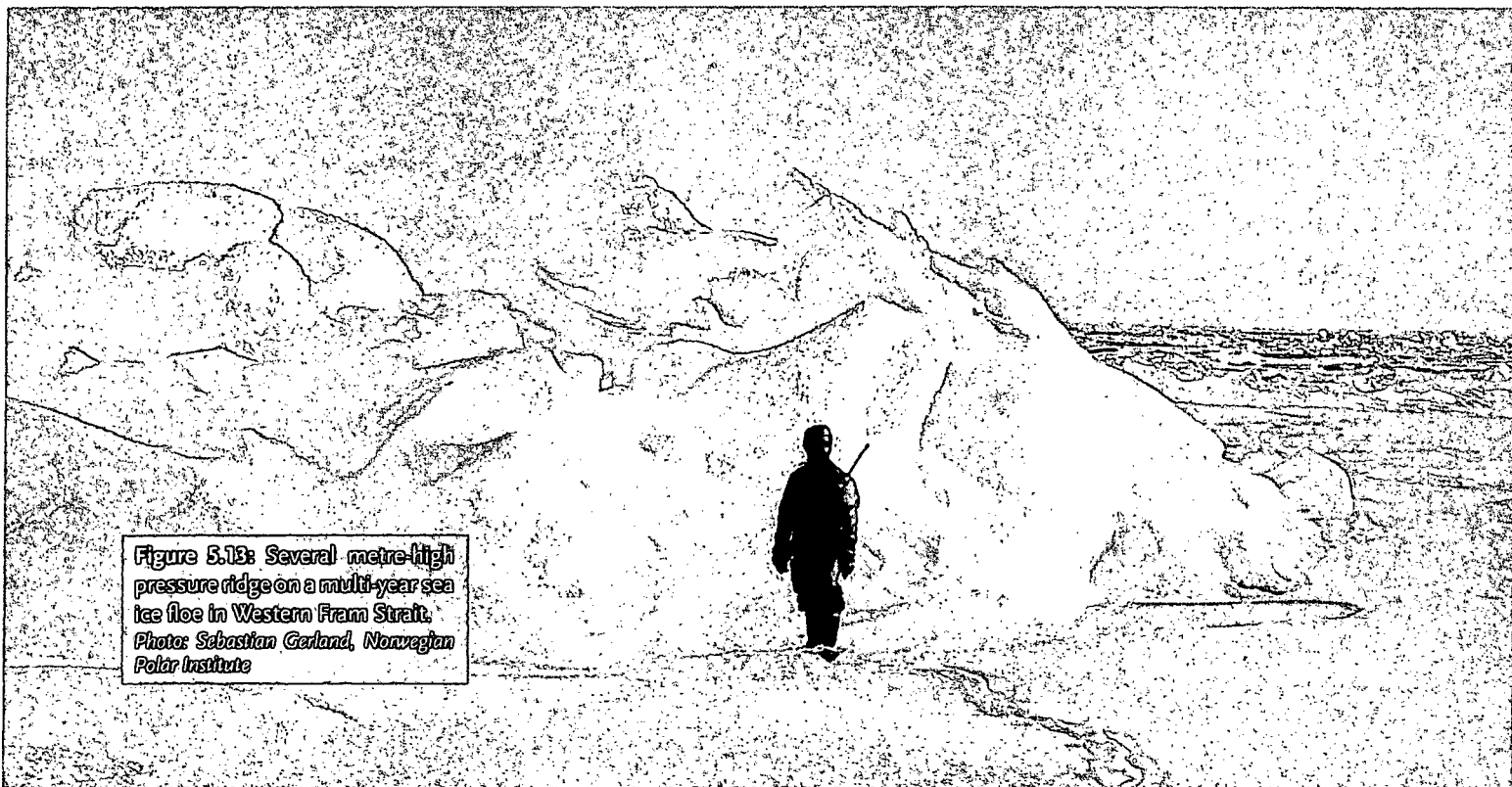


Figure 5.13: Several metre-high pressure ridge on a multi-year sea ice floe in Western Fram Strait. Photo: Sebastian Gerland, Norwegian Polar Institute

the North Pole. During the Antarctic summers, most sea ice breaks up, drifts northward and eventually melts. Consequently, most Antarctic sea ice is first-year ice.

Snow plays an important role in the formation and nature of sea ice in both polar regions, and changes in patterns of precipitation, both as snow and as rain, will have impacts on sea ice. Young ice without a snow cover thickens faster than young ice with an insulating snow cover. Snow properties such as grain shapes and sizes influence the snow's albedo, and the extent and properties of snow are the dominating factors controlling how much energy in the form of solar radiation reaches the ice. Snow can also contribute to the ice mass through transformation into ice. Superimposed ice forms when mild weather melts snow at the surface, or when rain falls. Water percolates downwards through the snow cover and reaches the snow-ice transition zone where it is cold enough that the snow-water mixture freezes. Snow can also be added to ice when seawater seeps into the snow-ice transition through cracks in the ice or from the side of an ice floe, resulting in "snow ice".

Changes in wind strength and wind patterns would also affect many characteristics of sea ice. More wind or more extreme wind events would lead to more ice rafting and ridging and increased ice thickness in some areas. Changes in winds would especially affect coastal areas. Land-fast ice formation and evolution is highly dependent on winds. Ice conditions in bays, fjords and sounds especially will be substantially different in a climate with different wind patterns than at present.

Marine biodiversity associated with sea ice and implications for food webs

Arctic and Antarctic sea ice provides habitats for a wide range of ice-associated organisms³⁶. The diversity of life associated with sea ice is largely dependent on the type and age of the ice. Habitats range in complexity from flat

and uniform under-surfaces of newly-formed fast-ice, through relatively flat areas with brine channels in first-year ice, to three-dimensional and often very complex habitats in older, multi-year ice. In the Antarctic, most sea ice is first-year ice, but additional habitat diversity is provided by the small amounts of multi-year ice, extensive ice shelves, and anchor ice in coastal areas.

Changes in these habitats will have many impacts on ice-associated organisms. Impacts on one type of organism in turn have impacts on other organisms through the polar food webs (see box on sea ice and food webs). Some of the consequences of changing sea ice habitat:

- If multi-year ice disappears, long-lived amphipods and the larger ice algae will decline drastically. If summer pack ice disappears in the Arctic Ocean, the ice-associated macrofauna as well as some of their predators will likely vanish from Arctic drift ice.
- The Arctic system will change from ice-dominated to open-water, with enhanced production in the open water but weaker connections between the pelagic and the benthic systems, meaning less food for bottom-dwelling organisms and their predators³⁷.
- Reduction in ice thickness and extent in the Arctic Ocean is expected to decrease the southward transport of ice-associated organisms on drifting ice, reducing prey availability and carbon input to subarctic seas.
- Changes in the timing of spring may also be important: earlier ice break-up and an earlier onset of the annual bloom in plankton may lead to a temporary mismatch between primary production (algae) and secondary production (the animal life that feeds on the algae) in some areas.
- In the Antarctic, reductions in sea ice may be linked to declines in krill populations, with cascading effects on survival and reproduction of krill predators, such as penguins. However, the relationship between variations in krill stocks and sea-ice extent may be influenced by long-term cyclical patterns as well as climate-induced trends³⁸⁻⁴⁰.



Adélie penguins on sea ice.
Photo: Armin Rose/iStockphoto.com

Sea ice and food webs: complex linkages among ice, oceans and many forms of life

Ice amphipods and polar cod are preyed upon by seabirds and marine mammals^{41,42}. The younger polar cod, which can be found in drifting pack ice, are a particularly important and available food source for seabirds and marine mammals feeding in the marginal ice zones⁴³.

The annual biomass of ice fauna transported with the transpolar ice drift to Fram Strait and the Barents Sea is in the range of a million metric tons^{37,44}. This biomass is released to the open ocean and ocean bottom systems as the ice melts⁴⁵ and is an important source of nutrients.

In the Antarctic, krill represent the primary food source for squid, penguins, some seals and baleen whales; while copepods dwelling in the sea ice are an important food source for adult krill. When krill populations are low, in years following reduced ice extent, salps (gelatinous, barrel-shaped organisms that look rather like jellyfish) are able to exploit the spring bloom of phytoplankton (free-floating algae) and undergo explosive population growth in Antarctic waters³⁹.

Figure 5.14: The ice alga *Melosira arctica* on the underside of Arctic multi-year sea ice.
 Photo: Haakon Hop, Norwegian Polar Institute



Ice algae – the primary producers

Ice algae are the primary producers in ice-associated food webs, and consist primarily of diatoms, but also include other types of algae originating from the pelagic (open-water) system^{46,47}. Large strands of the ice diatom *Melosira arctica* (Figure 5.14) are found in Arctic multi-year ice⁴⁸. The algae attach to ice-crystal structures on the underside of Arctic ice⁴⁹, whereas in Antarctica, an important feature of the sea ice is the infiltration communities of algae, associated with the nutrient-rich snow–ice interface⁵⁰.

Ice algal production may constitute up to 20 to 25 per cent of the total primary production in Arctic waters^{46,51} and 10 to 28 per cent of primary production in Antarctic ice-covered waters¹. In the Arctic, the production of ice algae starts in February and March, about two months earlier than the phytoplankton (free-floating algae) bloom. During the seasonal ice melt, ice algae contribute substantially to the vertical movement of organic matter in the water column and provide food for the invertebrates and fishes living in the depths of the ocean⁵². Areas with extensive ice and algal biomass thus represent “hot spots” with high biomass. These areas can have rich shrimp grounds and abundant clam populations, providing food for marine mammals – for example the walrus, who feed extensively on clams.

Ice fauna – the secondary producers

The smallest animals (less than 1 millimetre) associated with Arctic sea ice include nematode and turbellarian worms, crustaceans and other tiny invertebrates such as rotifers⁴⁷. These organisms feed on algae and microbes⁵³. The macrofauna (animals large enough to be seen with the naked eye) in drifting sea ice consist mainly of several species of ice amphipods (Figure 5.15b), but also include polychaete worms and a species of copepod crustacean^{54,55}. The abundance and biomass of the macrofauna varies with the type of ice as well as the under-ice topography⁵⁴. Land-fast ice may also house amphipods as well as mysids (another small crustacean)⁵⁶ that feed on a mix of ice algae, ice-associated fauna, zooplankton and detritus. Polar cod are often associated with sea ice, where they feed on ice-amphipods as well as the floating zooplankton^{57,58}.

In the Antarctic copepods are the dominant crustaceans found in the small spaces within the sea ice, but amphipods and krill (the shrimp-like crustaceans that are so important to Antarctic food webs) are also associated with ice⁵⁹. Adult krill are mainly herbivorous, feeding on diatoms, although they have a flexible feeding behaviour and are capable of capturing other types of food from different habitats. Adult krill are generally in open water, but can also be found underneath the ice cover. How-

ever, the sea-ice habitat is of most important for larvae and juvenile stages of the krill species *Euphausia superba*. Concentrations up to 3000 individuals per square metre have been observed in under-ice crevices during spring⁶⁰. Sea-ice algae and bacterial assemblages on the underside of ice floes enable the krill larvae to survive the winter months when food in the water column is absent. Sea ice also provides them with an important refuge from predators.

Mammals and birds dependent on sea ice

Marine mammals endemic to polar regions have evolved into specialists that deal extraordinarily well with conditions that would be considered very harsh for most other mammals^{61–63}. Their morphology, life history and behaviour patterns are all finely tuned to deal with cold temperatures and the high degree of variation in temperatures and conditions between seasons and from year to year.

The presence of extensive areas of sea ice is of overriding importance to many polar marine mammals. Most of the marine mammals that are year-round residents of the Arctic or the Antarctic spend much of the year in close association with sea ice. Predictions for changes in sea-ice conditions in polar regions due to global warming are a cause for great concern with respect to polar marine mammal populations. Worst case scenarios certainly include the extinction of some species in the coming decades in the Arctic^{31,64}.

Climate change also poses risks to these polar marine mammals beyond the direct impacts on habitat brought about by alterations to the physical environment. These include^{31,65–67}:

- changes to their forage base (such as shifts in the species, density and distribution of prey species);
- increased competition from temperate species expanding northward;



Figure 5.15a: Underside of multi-year sea ice.
Photo: Haakon Hop, Norwegian Polar Institute



Figure 5.15b: *Gammarus wilkitzkii*, one of the most abundant ice amphipods associated with under-ice habitats.
Photo: Haakon Hop, Norwegian Polar Institute

Weddell seals.

Photo: Michael Hambrey, Swiss-Educ (www.swisseduc.ch) and Glaciers online (www.glaciers-online.net)



- increased predation rates from killer whales (Orcas);
- increased risks from disease and parasites;
- greater potential for exposure to increased pollution loads due to long range transport of pollutants such as PCBs and mercury; and,
- impacts via increased human traffic and development in previously inaccessible, ice-covered areas.

Predicted changes in sea ice in combination with other climate change impacts on Arctic ecosystems, and resultant changes in human activity patterns, will undoubtedly affect the abundance and distribution patterns of species within polar marine mammal communities. The full-time, ice-associated residents of the Arctic and Antarctic are likely going to be negatively impacted, while the seasonal and summer migrants will likely increase in abundance and extend their ranges in a warmer Arctic that is ice-free in summer.

Seals

Many polar seal species depend on sea ice as a birthing, moulting and resting platform, and some seals also do much of their foraging on ice-associated prey^{64,68-72}. Ross seals, crabeater seals and leopard seals in the Antarctic and harp seals, hooded seals, ribbon seals, and spotted seals in the Arctic all breed in drifting pack-ice. Arctic bearded seals breed in areas of shallow water along coast-lines on small pieces of ice that break away from the annually-formed land-fast ice in the late spring. Ringed seals in the Arctic and Weddell seals in the Antarctic breed on land-fast ice. These two species occupy extensive areas of ice that form along coastlines because they are able to maintain breathing holes, even in sea ice that can reach 1 to 2 metres in thickness (see box on ringed seals). All of the ice-associated seals require temporally predictable, extensive areas of sea ice. Current projections suggested for the

The “classic” Arctic ice seal in a changing climate

Ringed seals are the “classic” Arctic seal in many regards, being found as far north as the Pole because of their ability to keep breathing holes open in ice that can reach 2 metres in depth. This species is certainly one of the most vulnerable of the high-Arctic seals to the declines in the extent or quality of sea ice because so many aspects of their life-history and distribution are tied to ice.

Ringed seals also require sufficient snow cover on top of the ice to construct lairs for resting, giving birth and caring for their young (Figure 5.16). The pups are born weighing only 4 kg and both ice and snow must be stable enough in the spring season to successfully complete the six week lactation period⁷³. Premature break-up of the land-fast ice can result in the pups being separated from their mothers, leading to high rates of pup mortality^{74,75}. Spring rains, or high temperatures in spring, can cause the roofs of lairs to collapse, leaving ringed seals subject to increased predation and risks from exposure⁷⁶. Years in which insufficient snowfall takes place prior to breeding results in a similar phenomenon⁷⁷.

Ringed seals are the principle prey for the top predator in the Arctic food chain – the polar bear. Declining sea-ice quality,

extent and season have potentially dire consequences for both of these Arctic animals.

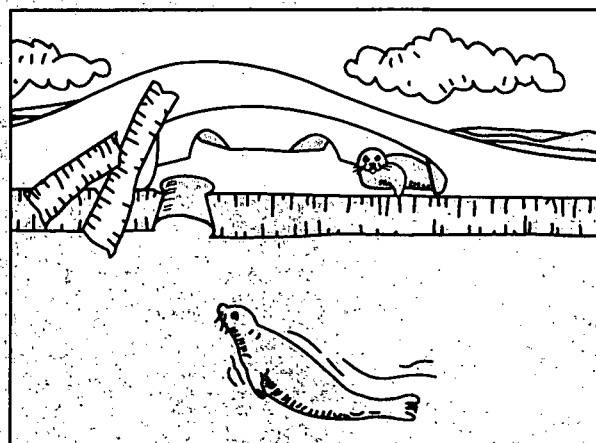


Figure 5.16: Ringed seal pupping lair, with the pup in the lair and the female approaching the haul-out hole from the water. Pups excavate the side tunnels.

Source: R. Barnes, based on Gjertz and Lydersen 1983⁷⁸

rate and extent of decreases in the reach of Arctic sea ice in the coming decades represents major challenges to Arctic seals.

Polar Bears

This largest member of the bear family is a sea-ice specialist. Ice-dwelling seals make up the majority of the polar bear's diet. Like their seal prey their continued existence probably depends on the availability of their primary habitat – the Arctic sea ice. In some parts of the Arctic, polar bears build their maternity dens in snow drifts on multi-year sea ice. In other areas where dens are usually located on islands, the bears are still dependent on the availability of sea ice in the autumn to reach

their denning areas and again in the spring when they leave the dens with their cubs and travel to the prime hunting grounds along the northern ice edge.

Concerns regarding the impacts of climate change on polar bears have been voiced since the time of the first suggestions that Arctic sea ice was thinning and becoming reduced in extent and season⁷⁹. Prolongation of the ice-free period was seen immediately as a threat to polar bears. During the past decade it has become increasingly clear that polar bears are already showing declines in body condition and reproductive output that are attributable to physical changes in the southern parts of their range, particular the decline in the duration of the sea-ice season^{80–83}.

Photo: Jon Aars, Norwegian Polar Institute



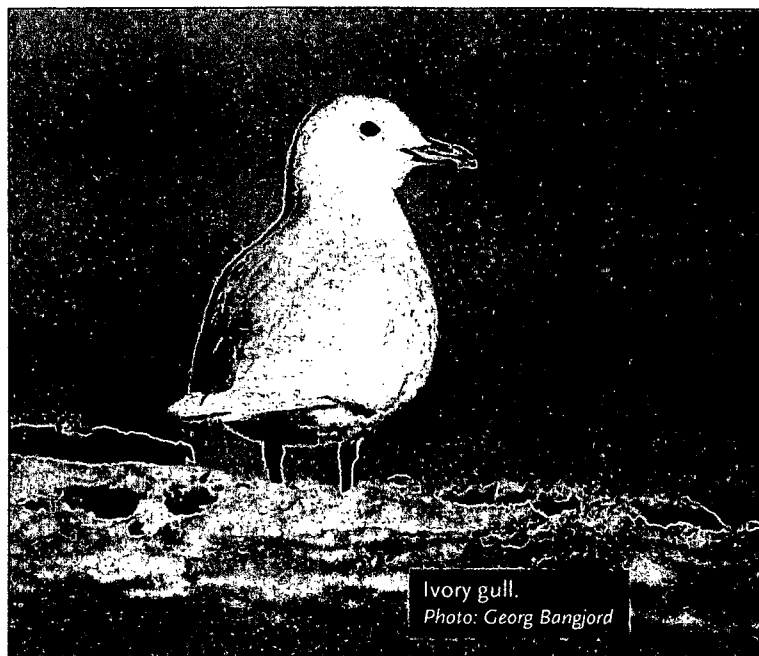
Survival rates of both young and older animals are negatively affected during years with little sea ice in western Hudson Bay in Canada⁸⁴. Additional analyses of climate variability in the past across broader parts of the polar bears' range strengthen the case for pessimism regarding the future of polar bears^{70,85}.

The current situation of polar bears in Hudson Bay, along with the uncertainty regarding their future across the Arctic, led the IUCN (International Union for the Conservation of Nature) Polar Bear Expert Group to suggest upgrading the status of polar bears on the IUCN Red List from "Least Concern" to "Vulnerable"⁸⁶. This has increased pressure to place the polar bear on the United States list of threatened species under the Endangered Species Act. Statements suggesting that the polar bear likely faces global extinction in the wild by the end of this century as a result of global warming are becoming commonplace⁸⁷. While the timing or certainty of extinction is difficult to predict – it is clear that polar bears are "on thin ice".

Whales

In the Arctic a small number of whale species have also become sea-ice specialists. Bowhead whales, white (beluga) whales and narwhals have all "lost" their dorsal fins as an adaptation to ice-living, and live in tight association with sea ice through much of the year.

The actual linkages that bind these species to sea ice are not completely understood, because all three species do spend time in ice-free waters. One commonly-cited suggestion for the attractiveness of ice to these whales is the avoidance of killer whale (Orca) predation⁸⁸, but the extent of their movements into sea-ice areas appears to be excessive for what would be needed to avoid killer whales⁸⁹ and actually can expose them to predation by polar bears⁹⁰ as well as increase the risk of entrapment in the ice. Thus, it seems likely that food availability and lack of competition from other whale species in ice-filled waters is also a major attractant, although few data are available to test



Ivory gull.
Photo: Georg Bangjord

this hypothesis. Whether these species could live in an Arctic with no summer sea ice is uncertain. At very least they would face increased competition from temperate whale species that would expand their ranges northward, as well as increased predation risk^{31,64}.

Seabirds

The abundance and distribution of many seabirds species in polar regions are related to sea ice distribution, particularly to the location of ice edges. Some of the largest seabird colonies in the world occur in the Arctic and Antarctic^{91,92} and changes in sea-ice cover are likely to impact seabirds indirectly through changes in prey availability⁹³. Seabirds, because they respond to anything that affects food availability, are good indicators of a system's productivity⁹⁴. Although seabirds are quite mobile compared to other organisms, changes in the spatial and temporal availability of food can have dramatic effects on their reproduction and survival⁹⁵.



Seabirds tend to aggregate at ice edges or in marginal ice zones where suitable prey is abundant and easily available. Wind-driven upwelling along ice-edges often concentrates important invertebrate and fish prey and thus improves foraging conditions. Diving seabirds also exploit the fauna associated with the subsurface of sea-ice as well as other sorts of prey found in leads deep inside the ice.

In the Arctic, species such as ivory gulls and little auks are very likely to be negatively impacted by reductions in sea ice and the subsequent changes to the communities in which they live⁹⁶. Ivory gulls in the Canadian Arctic have shown significant declines in recent years and these declines have been attributed to changes in sea-ice cover⁹⁷.

In the Antarctic, species such as the emperor penguin, the snow petrel and the Antarctic petrel are likely to be negatively impacted if sea-ice extent changes markedly in the Southern Oceans⁹⁸. However, as with polar ma-

rine mammals, reductions in sea-ice cover will also benefit many seabird species as new feeding areas become available and primary production increases⁹⁹.

Impacts of sea-ice changes on culture and livelihoods of Arctic Indigenous Peoples

Environmental and seasonal cycles are an integral part of the human-environment system in Arctic regions, and the peoples of the north have a long tradition of adapting to shifting environmental conditions. However, the rapidity and pervasiveness of current and projected climate change pose new and unprecedented challenges to the adaptive capacity of local communities and Arctic societies³¹.

Nearly four million people live in the Arctic today, including indigenous and non-indigenous people. Some are hunters and herders living on the land, and others are city dwellers. Many indigenous groups are exclusive

to the Arctic, such as the Chukchi in the Russian Federation, the Iñupiat and Yup'it in Alaska, USA, the Inuvialuit and Inuit in Arctic Canada, and the Greenlanders. Each of these indigenous groups continues to practice traditional, natural resource-based activities while simultaneously participating in and adapting to the contemporary world⁹¹.

Throughout history, a majority of the indigenous peoples of the Arctic have subsisted on the resources of the sea, and they continue this form of livelihood today¹⁰⁰⁻¹⁰². Ringed and bearded seals, beluga, narwhal and bowhead whales, walrus and polar bears are animals used by Arctic indigenous groups for food, clothing and other secondary products. These animals figure predominantly in the mixed cash-subsistence economy of local households and communities. Notably, all of these species depend on sea ice for their survival. Any changes in climatic and sea-ice conditions will therefore have consequences for marine mammals and their habitats, with inevitable impacts for the communities that depend on them.

Climate variability has been shown to affect the abundance and availability of marine mammals in the past and will continue to shape the ability of Arctic peoples to harvest and process these animals in the future. Significant changes with respect to the geography of species distribution and composition, animal health, and disease vectors are expected under future climate change. These changes will in turn affect the hunting activities of the local communities.

Participation in marine mammal harvesting among Arctic indigenous groups is not only important for economic purposes but is a crucial factor in the maintenance of cultural identity and social relationships. A significant amount of the time spent hunting is presently devoted to educating younger generations about weather, ice conditions and the biology of marine species. These

skills and attitudes, which are required for the successful harvesting of marine mammals, are transferable to modern community life and are critical to the preservation of the local indigenous culture and the mixed cash and subsistence economy¹⁰³.

Arctic communities continue to rely on traditional, local knowledge about their environments for travelling and hunting activities as well as for survival. Unfortunately, such knowledge may prove less valuable as ice conditions, weather, and prey distribution become less predictable and more variable, and as available species and hunting ranges change.



Figure 5.17: A hunter's grandchild in her grandfather's skiff in Qeqertarsuaq, Western Greenland. These skiffs are about to replace dog teams as means of transport to the winter hunting grounds. Due to lack of solid ice in the winter time, skiffs are now used all year round by the hunters in Qeqertarsuaq.

Photo: Stine Rybråten

The availability of sea ice as routes for transportation and migration is already reduced in many areas of the Arctic region (Figure 5.17), and evidence of increasingly unpredictable sea ice and weather conditions highlights that hunters are already confronted with increased risks and hazard. In addition to requiring more fuel to reach geographically dispersed prey, adaptation among hunters to climate change may require improved access to advanced technology, larger boats and new navigational aids such as Global Positioning Systems (GPS). These adaptations will require substantial resources and investments on the part of individual hunters and communities, something that may not be possible given the lack of economic investment and opportunities for the inhabitants of these areas at present.

Although Arctic societies have proven to be dynamic and capable of confronting past changes, climate change and its associated effects on sea ice and human activities present new challenges to the adaptive capacity of Arctic communities. The net effects of sea ice changes on communities in the Arctic are difficult to assess. While some changes might be for the better, others might have profound negative effects. To get a more thorough understanding of the actual impacts of changing sea ice conditions and their consequences for influenced communities, further studies where scientists and local stakeholders interact to produce knowledge that is both scientifically substantial and locally valuable are required.

Sea ice changes and economic activities

Reductions in sea-ice thickness and coverage in the Arctic will have large potential impacts on the economic activities in the region. Development of the offshore continental shelves and greater use of coastal shipping routes are likely to have significant social, political and economic consequences for all residents of Arctic coastal areas³¹.

These consequences will have extended effects outside the Arctic region, as will the possible impacts of sea-ice reduction on exploration and production of oil and gas. Simultaneously, increased activity will contribute to an increased risk of environmental damage, e.g. through oil spills and other industrial accidents⁹¹. If the projected changes in climate and Arctic economic activities occur, they will present new challenges for trans-national cooperation and jurisdiction, for example with regard to the management of fisheries, pollution, and the establishment of a common policy for emergency response.

Arctic and Antarctic fisheries

A retreat in sea ice accompanied by changes in ocean temperatures is likely to affect the distribution of fish stocks in both the Arctic and the Antarctic regions. In areas of sea-ice retreat, light penetration in the upper ocean will increase, enhance phytoplankton blooms, and bring about changes in marine food webs³¹. Some species are expected to become more productive with warmer seawater temperatures, while others might suffer a loss in production through, for example, improved conditions for competing species or changes in ocean currents resulting in poorer nutrient conditions. Since migratory patterns as well as competition between species might change, it is likely that positive effects on fishing and fish recruitment in some areas will occur along with negative impacts in the same or additional areas¹⁰⁴.

For Arctic nations, as well as for many nations outside the Arctic region, Arctic marine fishing is an important food and income source. In terms of scale and income, the catch is also an important export commodity and constitutes a large share of the economy of some parts of the Arctic. In 2002 the total catch of wild fish in the Arctic amounted to 7.26 million tonnes, which corresponds to around 10% of the world catch of fish¹⁰⁴. Although access to fish grounds might generally increase, the complexity of changes in



ocean currents, temperature and nutrient availability makes predictions about how fisheries might be affected by sea-ice reductions in the Arctic uncertain¹⁰⁴.

Fisheries in the Antarctic region involve about 18 nations from around the world, including Russia, Ukraine, France, Chile, Argentina and Japan. The total reported catch of toothfish and icefish in 2005/2006 in the regulated Antarctic fishery was 19 890 tonnes, and the krill catch was 106 591 tonnes¹⁰⁵. The krill fishery, which provides feed for aquaculture as well as human food and dietary supplements, is expanding – the krill catch for the 2006/2007 season is projected to be as high as 368 000 tonnes, tripled from the previous year¹⁰⁶.

Projected reductions in the amount of Antarctic sea ice might limit the development of the sea-ice marginal zone, with consequences for the biota¹⁰⁷. On the other hand, greater freshening of the mixed ocean layer from increased precipitation and melting ice might have a compensating effect. The krill fishery, which is restricted to ice-free periods, could become more attractive to nations not already involved if there is a retreat of sea ice in Antarctica¹⁰⁷. Simultaneously, extensive seasonal ice cover is known to promote early krill spawning and

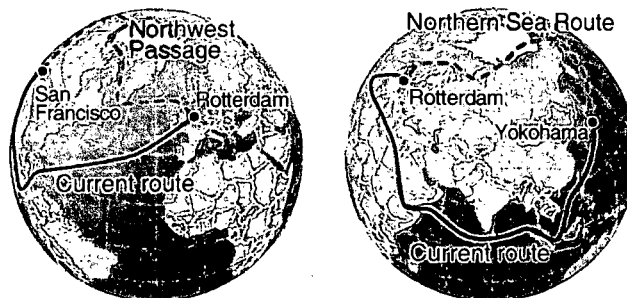


Figure 5.18: The Northern Sea Route and the Northwest Passage compared with currently used shipping routes.

Source: Based on material from Aftenposten, Norway

favour the survival of krill larvae through their first winter. A possible decrease in the frequency of winters with extensive sea-ice development might lead to increased krill recruitment failures and population decline¹⁰⁷. With krill being a key species in the Antarctic ecosystem, a decline in the population will in turn influence higher trophic levels. The combined pressures of exploitation and climate change are thus likely to result in considerable changes to Antarctic fisheries.

Arctic oil and gas

The Arctic holds a great share of the world's reserves. At present the Arctic shares of global oil and gas production are 10.5 per cent and 25.5 per cent, respectively. Additionally, Arctic basins are estimated to hold around 24 per cent of the world's undiscovered petroleum resources¹⁰⁴. These reserves represent enormous wealth as well as significant potential for economic growth and development in Arctic regions, and offshore oil exploration and production is likely to benefit from less extensive and thinner sea ice. However, diminishing sea-ice cover will lead to more icebergs and increased wave activity¹⁰⁷. This, in turn, will create new challenges for the offshore industry, such as the need for costlier equipment.



A cruise ship lands in Antarctica.
Photo: Steve Estvanik/Stockphoto.com

Shipping and tourism

Climate models project that summer sea ice in the Arctic Basin will retreat further and further away from most Arctic landmasses, opening new shipping routes and extending the navigation season in the Northern Sea Route (see box) by between two and four months⁹¹. Previously frozen areas in the Arctic may therefore become seasonally or permanently navigable, increasing the prospects for marine transport through the Arctic and providing greater access to Arctic resources such as fish, oil and gas (Figure 5.18).

In addition to increased cargo shipping, opening of sea routes such as the Northern Sea Route and Northwest Passage will probably increase the number of tourist cruises and passenger vessels in Arctic waters. In the Antarctic, reduced sea ice might provide safer approaches for tourist ships and new opportunities for sightseeing around Antarctica, but may also increase the risk of environmental impacts (see Chapter 9). Increased calving of icebergs from the Antarctic Peninsula may, however, affect navigation and shipping lanes⁹³. Although tourism is expected to experience a longer season in both the Arctic and Antarctic, the industry is highly dependent upon weather conditions. A more unpredictable and rainier climate might reduce the attractiveness of some areas.

The Northern Sea Route

The Northern Sea Route (NSR) is a seasonally ice-covered marine shipping lane along the Russian coasts, from Novaya Zemlya in the west to the Bering Strait in the east. The NSR is administered by the Russian Ministry of Transport and has been open to marine traffic of all nations since 1991. For trans-Arctic voyages, the NSR represents a saving in distance of up to 40 per cent from Northern Europe to northeastern Asia and northwestern North America, compared to southerly routes via the Suez or Panama Canals.

Projected reductions in sea-ice extent are likely to improve access along the NSR. The navigation season is often defined as the number of days per year with navigable conditions, generally meaning days with less than 50 per cent sea-ice cover. For the NSR, the navigation season is projected to increase from the current 20 to 30 days per year to 90 to 100 days per year by 2080 (Figure 5.19). An extended navigation season could have major implications for transportation and access to natural resources^{31,91}.

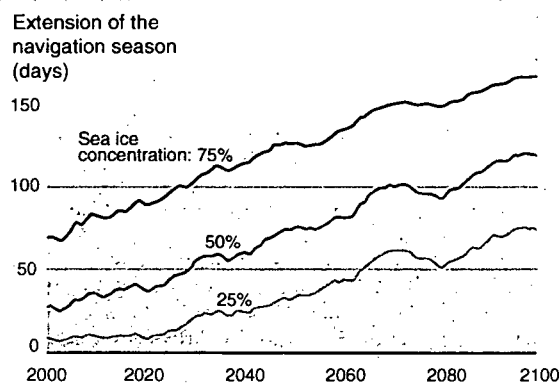


Figure 5.19: Projected increase (days) of the navigation season through the Northern Sea Route as an average of 5 ACIA model projections⁹¹

Source: Based on ACIA 2004⁹¹

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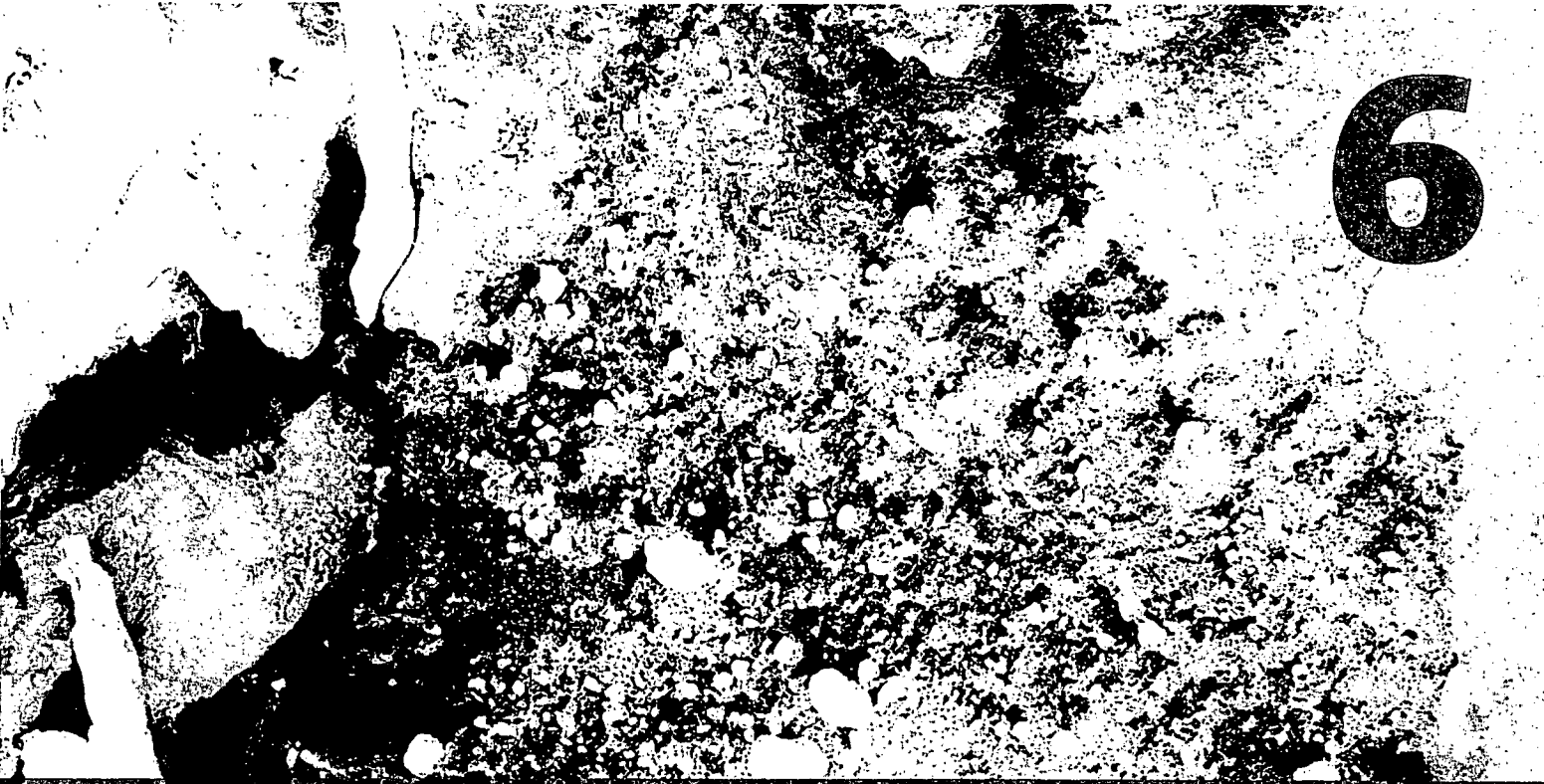
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6

Ice on the Land

6A Ice Sheets

6B Glaciers and Ice Caps

6C Ice and Sea-Level Change

Ice on the Land

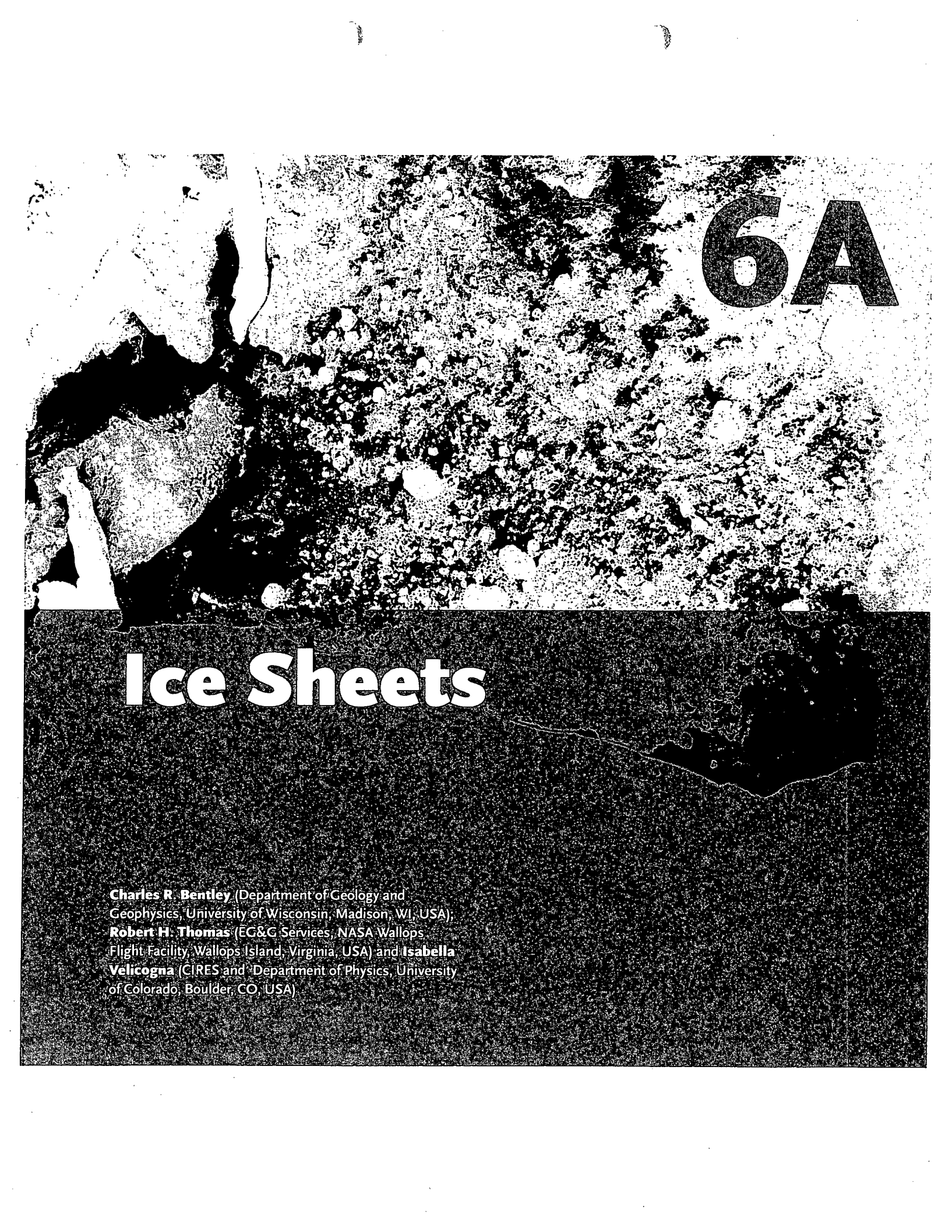
This chapter covers ice masses on land: ice sheets; glaciers and ice caps; and the impact on global sea level of the melting of land ice.

6A The two continental ice sheets, Antarctica and Greenland, make up more than half of the total amount of fresh water and around 99 per cent of the freshwater ice on Earth. The sheer size of these gigantic ice masses results in challenges for systematic research and observation. The growth and vanishing of ice sheets relates to global processes and time scales spanning ice ages. As a consequence, the ice sheets contain snowfall from hundreds of thousands of years ago, a unique record of atmospheric and climatic evolution through several ice ages (see inside back cover). Section 6A deals with the characteristics of the two continental-scale ice sheets, observations on recent changes, and the outlook for the future of Earth's ice storehouses.

6B There are glaciers and ice caps in addition to those associated with the Antarctic and Greenland ice sheets, spread all

over our planet, from the poles to the tropics. Section 6B presents a global overview of these glaciers, looking at their evolution over time, recent changes, the consequences of these changes, and the outlook for the future of the world's glaciers. The final part of 6B is a world glacier tour, highlighting selected regions, mountain ranges and issues.

6C Continental ice sheets as well as glaciers and ice caps exert a strong influence on sea level, as ice that melts from land directly contributes to the rising sea level. Past changes in global sea level, the current situation of accelerating sea level rise, and the outlook for sea level are covered in 6C. The impacts of sea-level rise are, of course, global in nature. In this section we present information on the types and magnitude of these impacts on vulnerable regions, ecosystems and sectors of society.



6A

Ice Sheets

Charles R. Bentley (Department of Geology and Geophysics, University of Wisconsin, Madison, WI, USA), **Robert H. Thomas** (EG&G Services, NASA Wallops Flight Facility, Wallops Island, Virginia, USA) and **Isabella Velicogna** (CIRES and Department of Physics, University of Colorado, Boulder, CO, USA)

Ice Sheets

Ice sheet: a mass of land ice, continental or sub-continental in extent, and thick enough to cover most of the underlying bedrock topography. Its shape is mainly determined by the dynamics of its outward flow. There are only two ice sheets in the modern world, on Greenland and Antarctica; during glacial periods there were others.



Ice shelf: a thick floating slab of freshwater ice extending from the coast (originating as land ice). Nearly all ice shelves are in Antarctica.

	Area Covered (million square km)	Ice Volume (million cubic km)	Potential Sea Level Rise (cm)
Ice sheets (total)	14.0	27.6	6390
Greenland	1.7	2.9	730
Antarctica	12.3	24.7	5660
Ice shelves	1.5	0.7	0

Source: IPCC 2007³

Summary

The vast polar ice sheets are shrinking as our climate becomes warmer. Floating ice shelves and glacier tongues are thinning and even breaking up in both Greenland and Antarctica, probably because of the combined effects of warming ocean waters and increasing summer air temperatures. Much of this floating ice fills coastal embayments, and is pushed seawards by tributary glaciers, which are observed to accelerate, as much as eight-fold, following ice-shelf break-up. At the same time, warmer summers are extending the zone and intensity of summer melting to higher elevations, particularly in Greenland. This increases both meltwater runoff into the ocean and meltwater drainage to the bed, where it lubricates glacier sliding and potentially increases ice discharge into the ocean.

Together these changes have resulted in net losses from both ice sheets at rates that are increasing with time.

Corresponding sea-level rise increased from about 0.2 mm per year in the early 1990s to perhaps 0.8 mm per year since 2003, contributing to the total observed rise during the 1990s of approximately 3 mm per year. Some of the thinning glaciers extend many tens to hundreds of kilometres inland, and whether or not ice losses continue to accelerate will depend partly on whether ice shelves continue to thin, and partly on how far inland the zones of glacier acceleration can extend. These questions represent a major challenge to scientists, and their answers could have a profound impact on all of us. Research planned for the International Polar Year in 2007-2008 aims to answer them.

Introduction to the ice sheets

Greenland and Antarctica contain 98–99 per cent of the freshwater ice on Earth's surface. Buried layers of ice, formed from annual snowfall, preserve records of past

Greenland
Melting on the lower parts of the surface, icebergs calve off from ice sheet edges into ice fjords and the sea

Antarctica
Ice shelves, with subglacial melting. Icebergs calve off from ice shelves

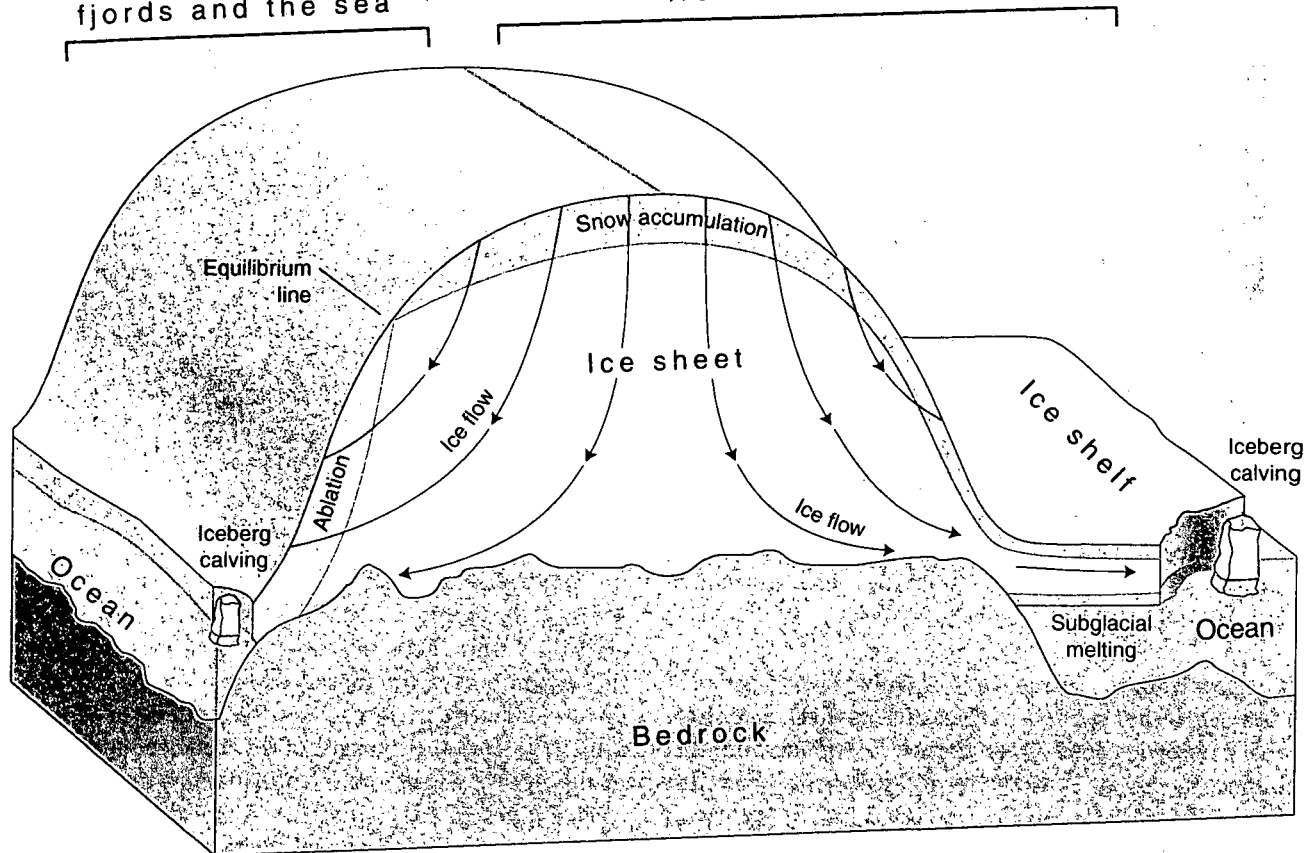


Figure 6A.1: Ice sheets.

Source: based on material provided by K. Steffen, CIRES/Univ. of Colorado

climate and air composition dating back hundreds of millennia. During glacial periods, ice sheets contained more than twice as much ice as that in Greenland and Antarctica today. Sea level would rise by about 64 m if the current mass of ice in Greenland and Antarctica were to melt

completely. Although this would take many thousands of years, recent observations show a marked increase in ice-sheet contributions to sea-level rise. In addition, ice-sheet melting strongly influences ocean salinity and temperature, and also global thermohaline circulation as a con-

sequence (see Chapter 2). Since variations in sea surface temperature also influence fluxes of heat and fresh water to the atmosphere, this forms a feedback mechanism – changes to the ocean caused by meltwater from ice sheets directly influence how much snow builds up on the ice sheets themselves. Ice sheets are thus an active and important part of an interconnected climate system.

The ice cover in Greenland and Antarctica has two components (Figure 6A.1) – thick, grounded, inland ice that rests on a more or less solid bed, and thinner floating ice shelves and glacier tongues. An ice sheet is actually a giant glacier, and like most glaciers it is nourished by the continual accumulation of snow on its surface. As successive layers of snow build up, the layers beneath are gradually compressed into solid ice. Snow input is balanced by glacial outflow, so the height of the ice sheet stays approximately constant through time. The ice is driven by gravity to slide and to flow downhill from the highest points of the interior to the coast. There it either melts or is carried away as icebergs which also eventually melt, thus returning the water to the ocean whence it came.

Outflow from the inland ice is organized into a series of drainage basins separated by ice divides that concentrate the flow of ice into either narrow mountain-bounded outlet glaciers or fast-moving ice streams surrounded by slow-moving ice rather than rock walls. In Antarctica much of this flowing ice has reached the coast and has spread over the surface of the ocean to form ice shelves that are floating on the sea but are attached to ice on land. There are ice shelves along more than half of Antarctica's coast, but very few in Greenland.

Antarctica

Antarctic inland ice ranges in thickness up to 5000 m, with an average thickness of about 2400 m, making Ant-

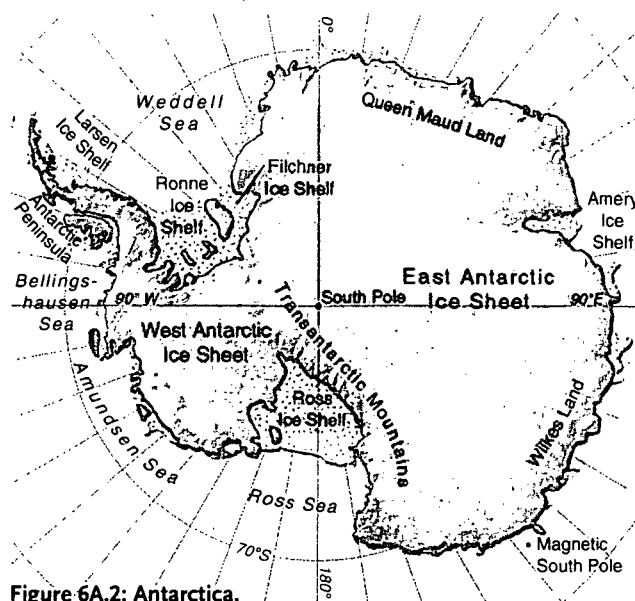


Figure 6A.2: Antarctica.

arctica by far the highest of the continents. Straddling the South Pole, Antarctica is cold even during summer. Much of the continent is a cold desert with very low precipitation rates. Thus, in contrast to Greenland, only a tiny proportion of the mass loss from the Antarctic Ice Sheet occurs by melting from the surface – summer-time melt from the margins of the ice sheet only occurs in the northern Antarctic Peninsula and the northernmost fringes of East Antarctica. Instead, most ice loss from Antarctica is from basal melting and iceberg calving from the vast floating ice shelves.

The West Antarctica Ice Sheet (WAIS) drains mostly into the Ross Ice Shelf, at the head of the Ross Sea; but also into the Filchner/Ronne Ice Shelf (two connected ice shelves), at the head of the Weddell Sea; and into small ice shelves along the Amundsen Sea coast. The Ross and Filchner/Ronne ice shelves are each about the area of Spain (see Figure 6A.2).

Glaciological interest is concentrated particularly on the WAIS because it rests on a bed far below sea level, which may make it particularly vulnerable to accelerated discharge into the ocean. If the entire WAIS were to disappear, sea level would rise by 5 or 6 meters, with major consequences (see Section 6C).

The WAIS was significantly larger during the last glacial maximum, 20 000 years ago, and retreated to near its present extent within the last several thousand years and it is probably still retreating today¹. Several postglacial mechanisms, notably isostatic uplift (a slow rise in the level of the land) and the penetration of ice-softening warmth into the deeper layers, have long response times. The ice sheet is still reacting dynamically to the glacial-interglacial transition and to the postglacial increase in the rate of snowfall². Consequently, the present Antarctic contribution to sea-level change probably reflects a long-term dynamic response of the ice sheet as well as changes in the atmospheric and oceanic climate over the last century.

Greenland

The Greenland Ice Sheet extends from 60° to 80° N, and covers an area of 1.7 million square km. With an average thickness of 1600 m, it has a total volume of about 3 million cubic km (about one ninth of the volume of the Antarctic Ice Sheet) – roughly equivalent to a sea-level rise of 7 m. It comprises a northern dome and a southern dome, with maximum surface elevations of approximately 3200 m and 2850 m respectively, linked by a long saddle with elevations around 2500 m. Bedrock beneath the central part of the ice sheet is remarkably flat and close to sea level, but the ice sheet is fringed almost completely by coastal mountains through which it is drained by many glaciers.

Greenland's climate is strongly affected by its proximity to other land masses and to the North Atlantic, leading

to a proportionately higher rate of exchange of water between ice sheet and ocean than in Antarctica. Summer melting occurs over about half of the ice-sheet surface, with much of the meltwater flowing into the sea, either along channels cut into the ice surface or by draining to the bed via crevasses. The average snow accumulation rate is more than double that of Antarctica. There are only a few ice shelves and, where they do exist, basal melting rates are much higher than in Antarctica – they can exceed 10 m per year. This gives an indication of the potential effect warmer Southern Ocean temperatures would have on Antarctic ice shelves.

The Greenland Ice Sheet is particularly important to the study of sea-level change in a warming climate for two reasons. First, it is likely to respond rapidly to warmer temperatures because surface melting already occurs widely. This means that small increases in air temperatures result in large inland migrations of summer melt zones up the gentle slopes of interior parts of the ice sheet. Increasing summer melt reduces ice-sheet volume directly, by drainage into the ocean, and indirectly, by lubricating the base of outlet glaciers and increasing their total ice discharge into the ocean. Second, Greenland provides a picture of Antarctic conditions if climate warms enough to weaken or remove key ice shelves. Recent observations in Antarctica confirm the early predictions of substantial glacier acceleration following ice-shelf removal.

Recent mass balance analyses

Until recently, it was not possible to determine whether the polar ice sheets were growing or shrinking. Over the last decade, improved remote-sensing techniques combined with accurate GPS positioning have made it possible to estimate ice-sheet mass balance (see box on how to tell if an ice sheet is growing or shrinking).



How to tell if an ice sheet is growing or shrinking

The mass balance of an ice sheet, meaning the rate of change of its mass, is vitally important because changes in mass balance are transformed directly into global sea-level change. Measurement is difficult and a range of techniques has to be used to get an overall picture of change in the ice sheets. There are two basic approaches – the integrated approach and the component approach.

The integrated approach involves measuring changes in the surface height (hence volume) or gravitational attraction (hence mass) of the ice sheet using instruments mounted in satellites. These instruments include radar and laser altimeters and high-precision gravity-measuring systems. Laser altimeters can detect small surface elevation changes, but are hampered by persistent cloud cover. Satellite surveys began only in 2003. Aircraft laser measurements over Greenland began ten years earlier and, although they provide only limited coverage, flight lines can be along specified routes such as glacier flow lines. Radar altimeters have less precision, suffer errors associated with radar penetration into the ice sheet surface, and give poor results in rough or steep terrain, but their longer history is still a boon for measurements of change. The gravity-based techniques can measure changes in overall mass to an astonishing level of precision, but the accuracy of ice-sheet mass balance estimates is hampered by limited knowledge of how much mass change is caused by uplift of the rock beneath by geologic forces.

The component approach involves comparing the mass added by snowfall on the ice sheet to that lost into the surrounding ocean. Mass input is based on estimates of snow-accumulation rates from counting annual layers in snow pits and ice cores, measuring depths to well-dated radioactive fallout horizons, or weather-model simulations. Newer remote sensing methods are promising but not yet fully developed. Mass output by meltwater runoff is generally estimated from models; to that must be added the solid-ice flux, given by the product of ice flow velocity and thickness at coastal margins. Ice thickness is generally measured by radar sounding from airplanes, and ice velocity is measured by repeated GPS surveys of ice markers, tracking of crevasses and other ice features in high-resolution satellite imagery, and analysis of repeated satellite radar images. This last technique, in particular, has made it possible to measure the speed of ice movement over vast regions at high spatial resolution.

All these techniques for measuring mass balance have significant errors but because they offer independent estimates, they provide an increased level of confidence in their collective conclusions. However, interpretation of mass-balance estimates is further complicated by high natural variability that occurs on a range of time scales. Separation of long-term trends in ice mass from the effects of this variability requires observations over long time periods.

Antarctica (see Figure 6A.3)

Measurements by satellite techniques based on gravity indicate mass loss at a rate of 138 ± 73 billion tonnes per year during 2002–2005, mostly from the WAIS⁶. That is equivalent to a rise in global sea level of 0.4 ± 0.2 mm per year, or 10–30% of the global rate measured since the 1950s (see Chapter 6C), and is in good agreement with recent mass-budget estimates¹⁰. However, two interpretations of satellite radar altimetry pointed to a much smaller loss of about

31 billion tonnes of ice per year⁸ or a net gain of about 27 billion tonnes per year⁹. The difference between these estimates from totally independent techniques reflects the uncertainties in these difficult measurements; nevertheless, on balance, they indicate a recent shift to a net loss of Antarctic ice and suggest that losses may be accelerating. Similar conclusions result from studies of Antarctic Peninsula glaciers, indicating that they are melting much faster than previously predicted and are probably already contributing significantly to sea-level rise¹¹.

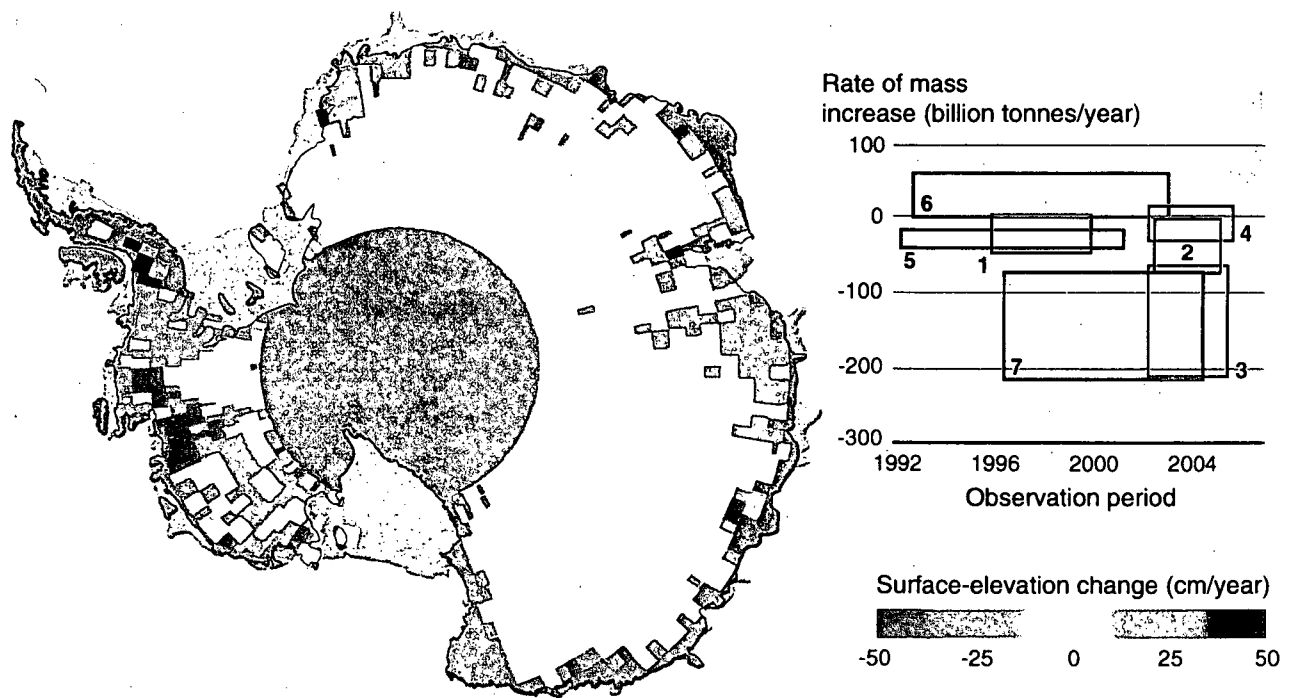


Figure 6A.3: Antarctica, showing rates of surface-elevation change derived from satellite radar-altimeter measurements³. The graph shows rates at which the ice-sheet mass was estimated to be changing based on radar-altimeter data (black), mass-budget calculations (red), and satellite gravity measurements (blue). Rectangles depict the time periods of observations (horizontal) and the upper and lower estimates of mass balance (vertical).

Sources (corresponding to numbers on rectangles): 1 Rignot and Thomas 2002⁴; 2 Ramillien and others 2006⁵; 3 Velicogna and Wahr 2006a⁶; 4 Chen and others 2006a⁷; 5 Zwally and others 2005⁸; 6 Wingham and others 2006a⁹; 7 Rignot and others 2007¹⁰

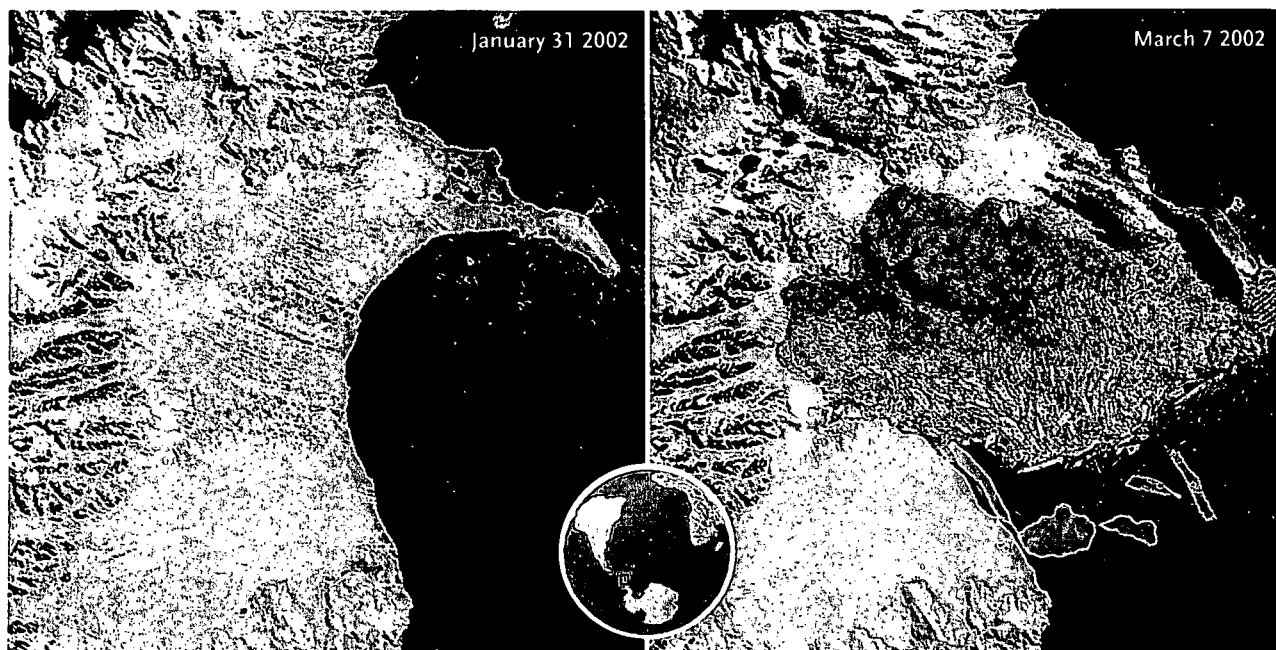


Figure 6A.4: Break-up of the Larsen B ice shelf. These are images from NASA's MODIS satellite sensor. Part of the Antarctic Peninsula is on the left. The image on the left shows the shelf in late summer, with dark bluish melt ponds on the surface. The image on the right, collected only five weeks later, shows a large part of the ice shelf collapsed, with thousands of sliver icebergs at the margins and a large blue area of ice fragments.

Images: National Snow and Ice Data Center

The questionable stability of Antarctic ice shelves in a warming climate was highlighted by the collapse of the Larsen B Ice Shelf in 2002 off the northern Antarctic Peninsula (Figure 6A.4). The significance of this event was highlighted by records from six marine sediment cores in the vicinity showing that this scale of collapse is unprecedented since the end of the last ice age. Research implies that the long-term thinning of the ice shelf has combined with the modern half-century-long warming in the Antarctic Peninsula region to cause its disintegration¹². Moreover, nine other small ice shelves around the Antarctic Peninsula have broken up over the last 100 years.

The Larsen B collapse prompted researchers to look at the implications of ice-shelf decay for the stability of Antarctica's inland ice. Glaciers that fed the former ice shelf have speeded up by factors of two to eight following the collapse¹³. In contrast, glaciers further south did not accelerate as they are still blocked by an ice shelf. The large magnitude of the glacier changes illustrates the important influence of ice shelves on ice sheet mass balance.

Much further south, in the Amundsen Sea sector of West Antarctica, satellite radar measurements show that ice shelves have thinned by up to 5.5 meters per year

over the past decade¹⁴. The thinning of the ice shelves, apparently from ocean currents that are on average 0.5°C warmer than freezing, is mirrored by the thinning and acceleration of their tributary glaciers^{15,16}. These accelerating glaciers drain a region widely believed to be the most vulnerable portion of the WAIS because its bed is so deep below sea level. Collapse of the entire region into the sea would raise sea level by about 1 m.

Elsewhere, recent detailed high-resolution satellite imagery charted the simultaneous rise and compensating fall of a score of patches on the Antarctic Ice Sheet, reflecting extensive water movement under the ice and pointing to the potentially destabilizing effect of subglacial water^{17–19}. Although the volumes of water are tiny in terms of sea-level change, the observations reveal a widespread, dynamic subglacial water system, which may exert an important control on ice flow, and hence on the mass balance of the entire ice sheet.

Greenland (see Figure 6A.5)

Mass-balance estimates for Greenland show thickening at high elevations since the early 1990s at rates that increased to about 4 cm per year after 2000, consistent with expectations of increasing snowfall in a warming climate. However, this mass gain is far exceeded by losses associated with large increases in thinning of the ice sheet near the coast.

Total loss from the ice sheet more than doubled, from a few tens of billions of tonnes per year in the early 1990s²⁰, to about 100 billion tonnes per year after 2000²⁷, with perhaps a further doubling by 2005²⁴. These rapidly increasing losses result partly from more melting during warmer summers, and partly from increased dis-

charge of ice from outlet glaciers into the ocean²². In particular, the speeds of three of Greenland's fastest glaciers approximately doubled since 2000^{28,29}, although two of them have partially slowed since³⁰. The third glacier, Jakobshavn Isbrae (Figure 6A.6), increased its speed to about 14 km per year²⁸ after rapid thinning and break up of its floating ice tongue³¹, without any signs of slowing down. The bed is very deep for several tens of kilometres inland, allowing seaward parts of the glacier to float and break up as the ice thins. By contrast, nearby glaciers with shallow beds have only small thinning rates, indicating a strong linkage between bed topography and glacier vulnerability to change.

In addition, marked increases in ice velocity occurring soon after periods of heavy surface melting suggest that meltwater draining to the base of the ice lubricates glacier sliding³² (Figure 6A.7). This indicates that increased melting in a warmer climate could cause an almost simultaneous increase in ice-discharge rates.

Outlook for the ice sheets

For many reasons, it is not possible now to predict the future of the ice sheets, in either the short or long term, with any confidence³³. Modeling ice sheet dynamic behaviour is seriously hampered by a paucity of observational data about the crucial, controlling conditions at the ice-sheet bed^{2,34}. It is because of these uncertainties that the projections of the IPCC 4th Assessment Report, while including contributions from Greenland and Antarctica at the increased rates observed for 1993–2003, state that “larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise”³⁵.

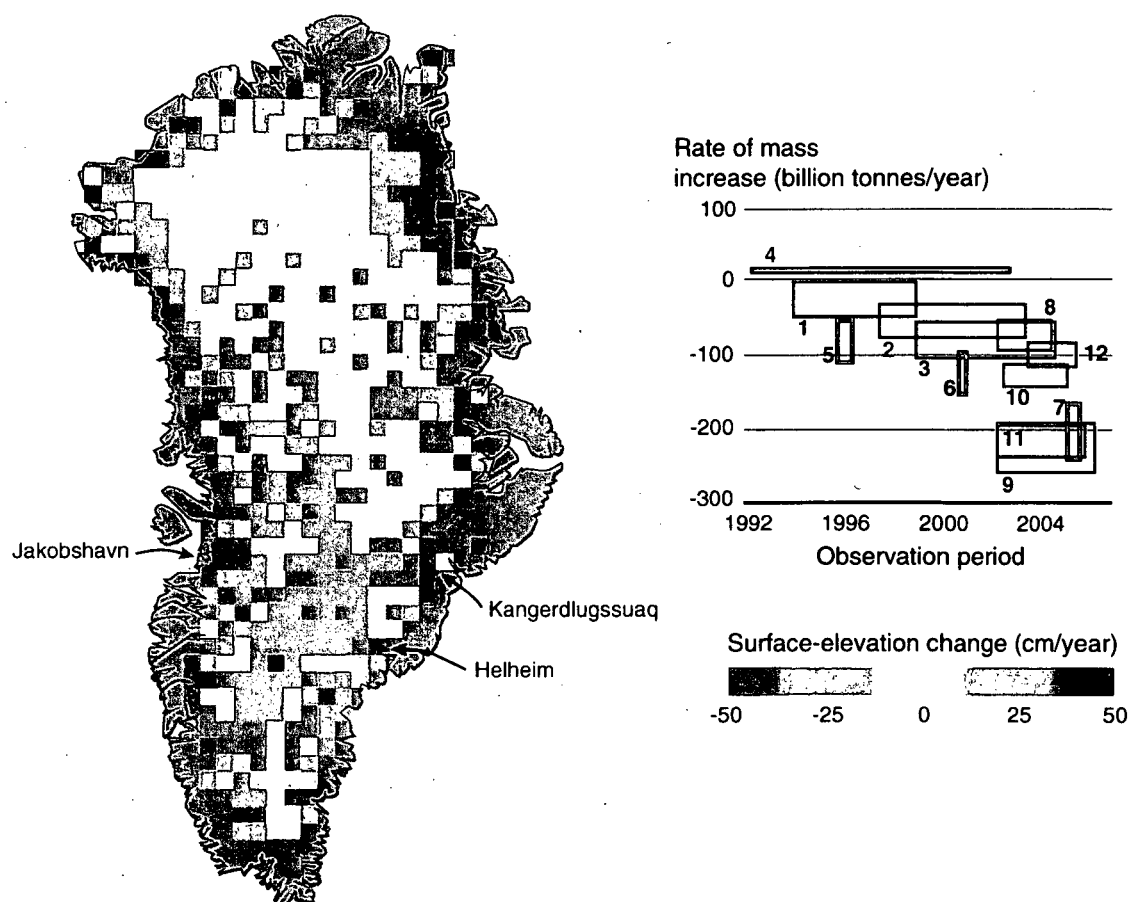


Figure 6A.5: Greenland, showing rates of surface-elevation change between the late 1990s and 2003, derived by comparing satellite and aircraft laser-altimeter surveys. The graph shows rates at which the ice-sheet mass was estimated to be changing based on satellite radar-altimeter surveys (black), airborne laser-altimeter surveys (green), airborne/satellite laser-altimeter surveys (purple), mass-budget calculations (red), temporal changes in gravity (blue). Rectangles depict the time periods of observations (horizontal) and the upper and lower estimates of mass balance (vertical). Jakobshavn, Helheim, and Kangerdlugssuaq are fast glaciers that doubled in speed recently.

Sources (corresponding to numbers on rectangles): 1 and 2 Krabill and others 2000²⁰ and 2004²¹; 3 Thomas and others 2006²²; 4 Zwally and others 2005⁸; 5 to 7 Rignot and Kanagaratnam 2006²³; 8 and 9 Velicogna and Wahr 2005²³ and 2006A²⁴; 11 Chen and others 2006A²⁵; 10 Ramillien and others 2006⁶; 12 Luthke and others 2006²⁶

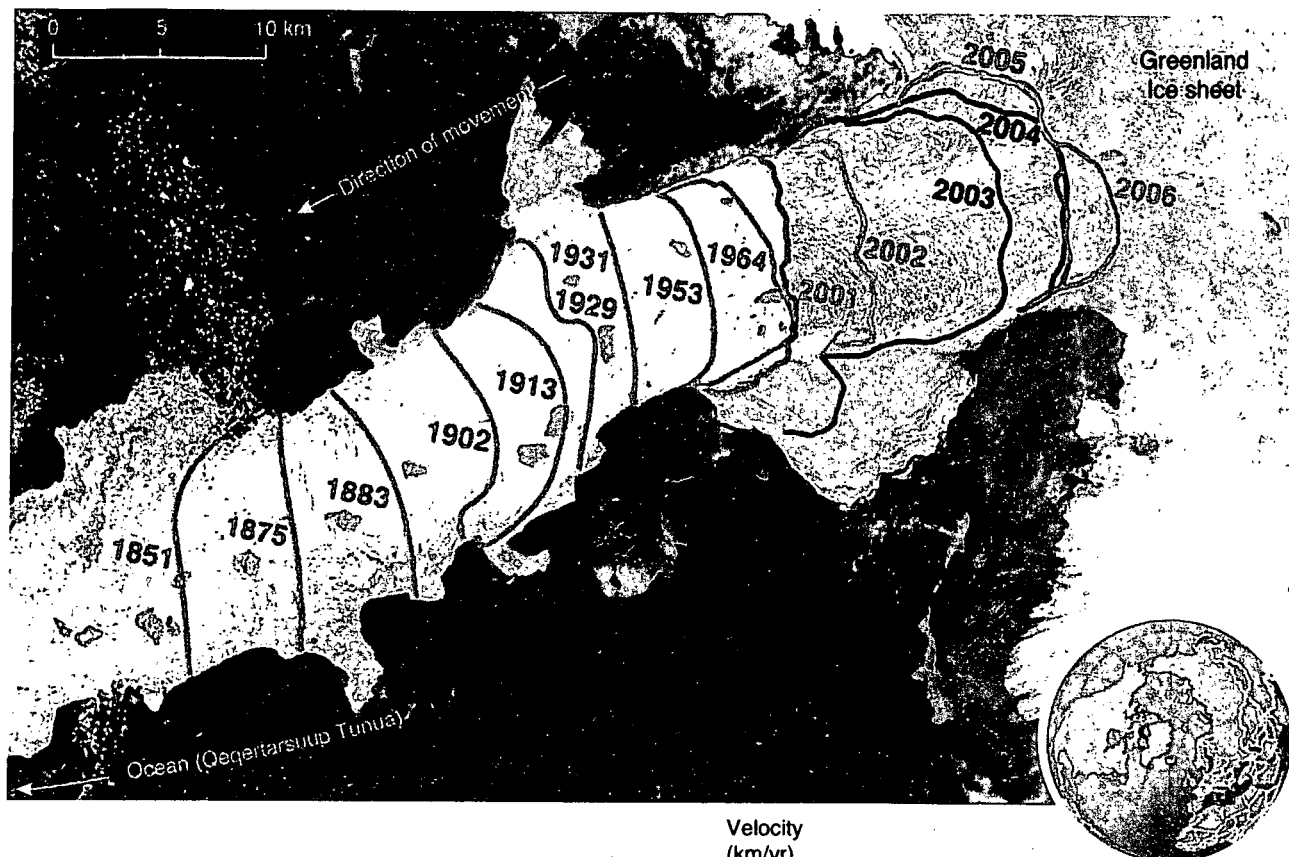
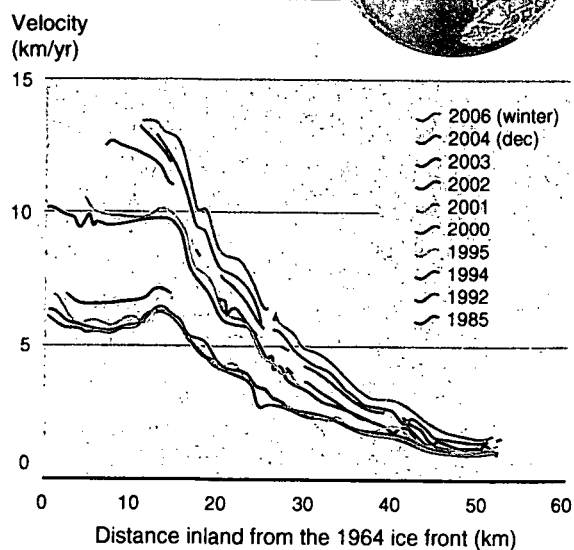


Figure 6A.6: Landsat satellite image of Jakobshavn Isbrae and its fjord, showing locations of the calving ice front in years from 1851 to 2006. The glacier extends through the Illulisat Icefjord, surrounded by mountains. Icebergs calve off from the main glacier, pile up and block the fjord before being released into Qeqertarsuup Tunua (Disko) Bay and Davis Strait. The whiter areas in the fjord are piled-up icebergs and the "real" glacier ends where the greyish striped section ends – showing that this image is from 2001.

The graph shows glacier-velocity profiles for 1985 to 2006. During this period Jakobshavn Isbrae, already the world's fastest glacier, doubled its speed to almost 14 km per year^{28,29} after rapid thinning and break up of its floating ice tongue³¹.

Sources: NASA/Goddard Space Flight Center Scientific Visualization Studio.
Historic calving front locations courtesy of Anker Weidick and Ole Bennike
Source: based on Howatt and others 2007³⁰



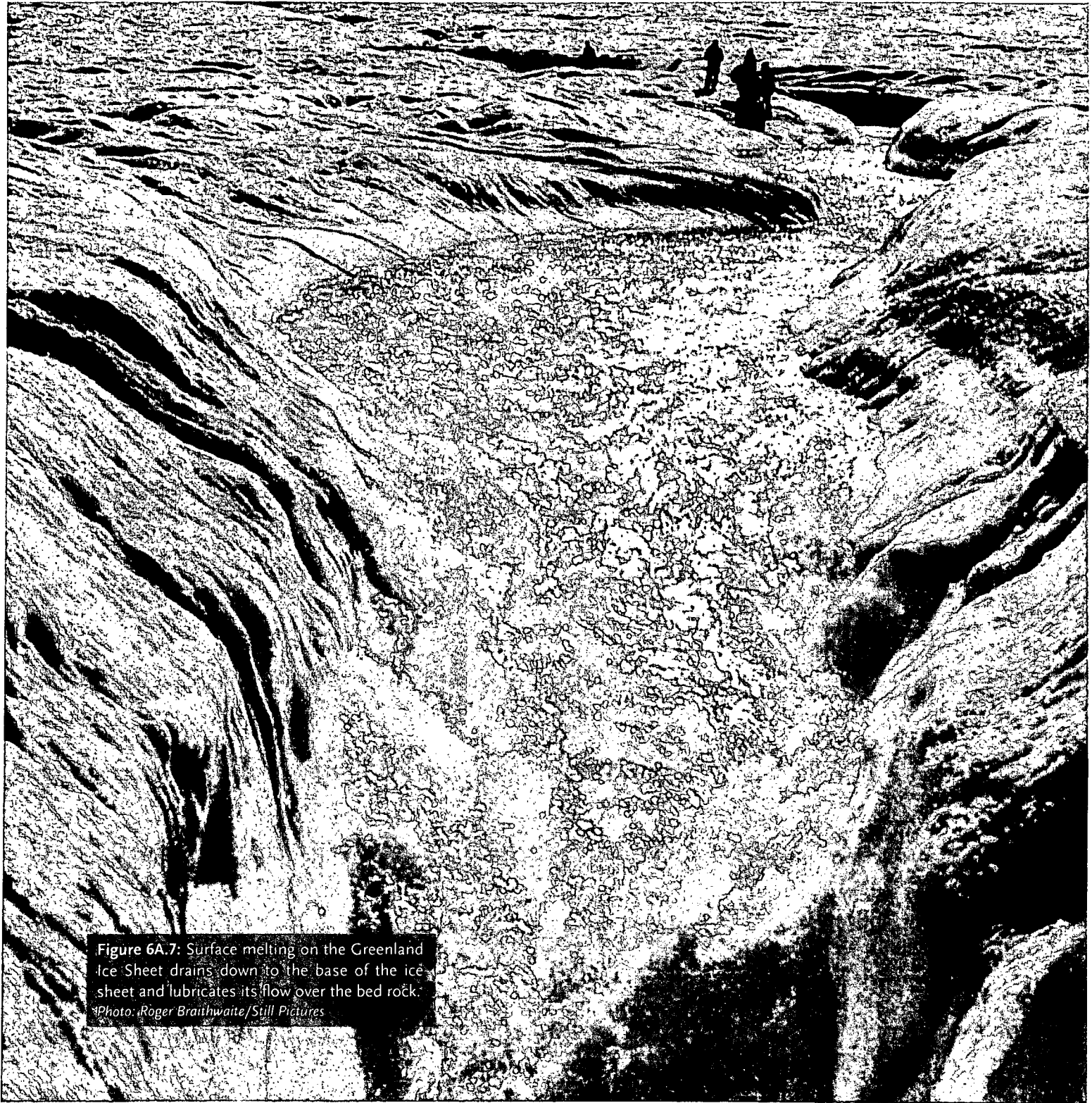


Figure 6A.7: Surface melting on the Greenland Ice Sheet drains down to the base of the ice sheet and lubricates its flow over the bed rock.
Photo: Roger Braithwaite/Still Pictures

Recent signs point to accelerating loss of ice in both Greenland and Antarctica. It is becoming increasingly apparent that some changes, such as the break up of ice shelves in Antarctica, are exceptional when one looks over periods of centuries to millennia. For the ice sheets of both polar regions, some of these very fast changes are caused not by melting (included in the IPCC predictions), but by changes in glacier dynamics (not fully included in the IPCC predictions).

The slow, measured behaviour long associated with the Greenland Ice Sheet is being transformed to the rapidly changing characteristics more typical of big glaciers in Alaska and Patagonia. A zone of glacier acceleration is progressively moving northward, leaving Greenland's southern ice dome under threat from both increased summer melting near the coasts, and increased ice discharge down glaciers that extend their influence far inland. If this continues, it is quite possible that the ice dome in southern Greenland will reach a tipping point, with accelerating positive feedback causing its ever more rapid decline and an associated sea-level rise of about 85 cm. Moreover, continued northward migration of the zone of glacier acceleration would make the far larger northern dome also vulnerable.

In Antarctica, disintegration of the WAIS continues to be the primary threat. The key issue is whether the

main body of the WAIS would accelerate rapidly if its ice shelves were thinned or removed by a warming climate^{36,37}. There are clues. Ice-shelf break up along the Antarctic Peninsula has resulted in massive acceleration of tributary glaciers and ice-shelf thinning further south, along the Amundsen Sea, also appears to have caused glacier acceleration. Here, the acceleration is more modest, but the glaciers are far bigger, so total losses are large. No one knows how far inland the zone of glacier acceleration will spread, and no one knows why the ice shelves are breaking up. However, their thinning is almost certainly caused by increased basal melting, implicating the ocean. And final break up seems to be accelerated if there is sufficient surface meltwater to fill, and over-deepen, crevasses in the ice shelves, effectively wedging the ice shelf apart into fragments.

Observations made over the past five years have made it clear that existing ice-sheet models cannot simulate the widespread rapid glacier thinning that is occurring, and ocean models cannot simulate the changes in the ocean that are probably causing some of the dynamic ice thinning. Consequently, in its Fourth Assessment, the IPCC has taken a conservative approach by not attempting to predict the unpredictable. As a result, these projections³⁵ of future ice-sheet related rises in sea level should be regarded as lower bounds.

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6B

Glaciers and Ice Caps

Michael Zemp (lead author, Department of Geography, University of Zurich, Switzerland); **Wilfried Haeberli** (lead author, Department of Geography, University of Zurich, Switzerland)

Contributing Authors for Regional Perspectives and Glacier Hazards:

Samjwal Bajracharya *Himalayas* (International Centre for Integrated Mountain Development, Nepal); **Trevor J. Chinn** *New Zealand* (Alpine and Polar Processes, New Zealand); **Andrew G. Fountain** *USA and Canada* (Department of Geology, Portland State University, USA); **Jon Ove Hagen** *Norway* (Department of Geosciences, University of Oslo, Norway); **Christian Huggel** *Glaciers and hazards* (Department of Geography, University of Zurich, Switzerland); **Andreas Kaab** *Glaciers and hazards* (Department of Geosciences, University of Oslo, Norway); **Bjorn P. Kaltenborn** *Himalayas* (Norwegian Institute for Nature Research, Lillehammer, Norway); **Madhav Karki** *Himalayas* (International Centre for Integrated Mountain Development, Nepal); **Georg Kaser** *Tropics* (Institute of Geography, University of Innsbruck, Austria); **Vladimir M. Kotlyakov** *Russian Territory* (Institute of Geography, Moscow State University, Russia); **Christian Lambrechts** *Africa* (Division of Early Warning and Assessment, United Nations Environment Programme, Kenya); **Zhongqin Li** *China* (Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, China); **Bruce F. Molnia** *Alaska* (U.S. Geological Survey, USA); **Pradeep Moool** *Himalayas* (International Centre for Integrated Mountain Development, Nepal); **Christian Nellesmann** *Himalayas* (UNEP/GRID-Arendal, Arendal, Norway); **Viktor Novikov** *Central Asia* (UNEP/GRID-Arendal, Arendal, Norway); **Galina B. Osipova** *Russian Territory* (Institute of Geography, Moscow State University, Russia); **Andrés Rivera** *South America* (Centro de Estudios Científicos, Chile); **Basanta Shrestha** *Himalayas* (International Centre for Integrated Mountain Development, Nepal); **Felix Svoboda** *Baffin Island* (Department of Geography, University of Zurich, Switzerland); **Dmitri G. Tsvetkov** *Russian Territory* (Institute of Geography, Moscow State University, Russia); and **Tandong Yao** *China* (Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, China)

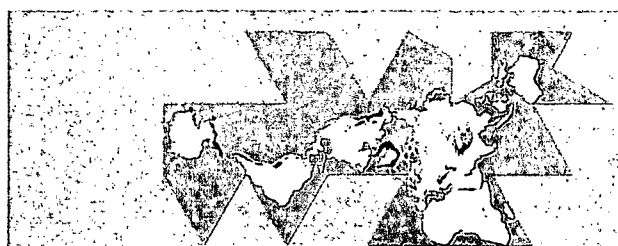
Glaciers and Ice Caps

Summary

Glaciers and ice caps are among the most fascinating elements of nature, an important freshwater resource but also a potential cause of serious natural hazards. Because they are close to the melting point and react strongly to climate change, glaciers are important indicators of global climate.

Glaciers reached their Holocene (the past 10 000 years) maximum extent towards the end of the Little Ice Age (the Little Ice Age extended from the early 14th to mid-19th century.) Since then, glaciers around the globe have been shrinking dramatically, with increasing rates of ice loss since the mid-1980s. On a time-scale of decades, glaciers in various mountain ranges have shown intermittent readvances. However, under the present climate scenarios, the ongoing trend of worldwide and fast, if not accelerating, glacier shrinkage on the century time-scale is not a periodic change and may lead to the deglaciation of many mountain regions by the end of the 21st century.

Glacial retreat and melting of permafrost will shift cryospheric hazard zones. This, in combination with the increasing socio-economic development in mountain regions, will most probably lead to hazard conditions beyond historical precedence. Changes in glaciers may strongly affect the seasonal availability of freshwater, especially when the reduction of glacier runoff occurs in combination with reduced snow cover in winter and earlier snowmelt, less summer precipitation, and enhanced



Glacier: a mass of surface-ice on land which flows downhill under gravity and is constrained by internal stress and friction at the base and sides. In general, a glacier is formed and maintained by accumulation of snow at high altitudes, balanced by melting at low altitudes or discharge into the sea.
Ice cap: dome-shaped glacier with radial flow, usually covering a highland area. Much smaller than an ice sheet.

Glaciers and ice caps (lowest and [highest] estimates):

Area Covered (million square km)	0.51 [0.54]
Ice Volume (million cubic km)	0.05 [0.13]
Potential Sea Level Rise (cm)	15 [37]

Source: IPCC 2007¹

evaporation due to warmer temperatures. The most critical regions will be those where large populations depend mainly on water resources from glaciers during the dry season and glaciated mountain ranges that are densely populated and highly developed.

This chapter on glaciers and ice caps is divided into two parts: 1) Global Overview and Outlook, and 2) Glacier Changes around the World.

Part One: Global Overview and Outlook

Introduction to glaciers and ice caps

Glaciers and ice caps form around the world where snow deposited during the cold/humid season does not entirely melt during warm/dry times. This seasonal snow gradually becomes denser and transforms into perennial firn (rounded, well-bonded snow that is older than one year) and finally, after the air passages connecting the grains are closed off, into ice². The ice from such accumulation areas then flows under the influence of its own weight and the local slopes down to lower altitudes, where it melts again (ablation areas). Accumulation and ablation areas are separated by an equilibrium line, where the balance between gain and loss in the ice mass is exactly zero. Where glaciers form thus depends not only on air temperature and precipitation (see Figure 6B.1), but also on the terrain, which determines how much solar radiation the glacier will receive and where ice and snow will accumulate.

In humid-maritime climates the equilibrium line is at a relatively low altitude because, for ablation to take place, warm temperatures and long melting seasons are needed to melt the thick layers of snow that accumulate each year^{3,4}. These landscapes are thus dominated by 'temperate' glaciers with firn and ice at melting temperatures. Temperate glaciers have a relatively rapid flow, exhibit a high mass turnover and react strongly to atmospheric warming by enhanced melt and runoff. The ice caps and valley glaciers of Patagonia and Iceland, the western Cordillera of North America, and the mountains of

New Zealand and Norway are examples of this type of glacier (Figure 6B.2). The lower parts of such temperate glaciers may extend into forested valleys, where summer warmth and winter snow accumulation prevent development of permafrost.

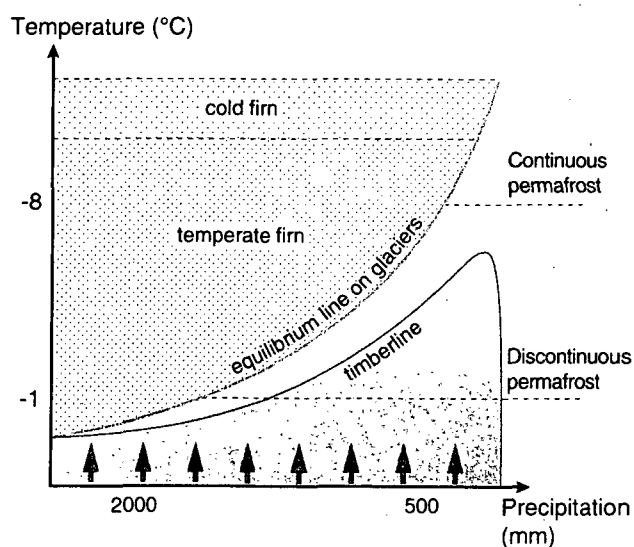


Figure 6B.1: Schematic diagram of glacier, permafrost and forest limits as a function of mean annual air temperature and average annual precipitation. Forests verge on glaciers in humid-maritime climates and grow above permafrost in dry-continental areas.

Source: Based on Shumsky 1964³ and Haeberli and Burn 2002⁴

In dry continental areas, on the other hand, such as northern Alaska, Arctic Canada, subarctic Russia, parts of the Andes near the Atacama Desert, and many central-Asian mountain chains (Figure 6B.3), the equilibrium line is at a relatively high elevation with cold temperatures and short melting seasons. In such regions, glaciers far above the tree line can contain – or even consist entirely of – cold firn and ice well below melting temperature. These glaciers have a low mass turnover and are often surrounded by permafrost³.

Glacier responses to climatic changes

The response of a glacier to climatic change involves a complex chain of processes^{5,6}. Changes in atmospheric conditions (such as solar radiation, air temperature, pre-

cipitation, wind and cloudiness) influence the mass and energy balance at the glacier surface^{7,8}. Air temperature plays a predominant role, as it is related to the radiation balance and turbulent heat exchange, and it determines whether precipitation falls as snow or rain. Over time periods of years and decades, changes in energy and mass balance cause changes in volume and thickness, which in turn affect the flow of ice through internal deformation and basal sliding.

This dynamic reaction eventually leads to changes in the length of the glacier – the advance or retreat of glacier tongues. In short, the glacier mass balance (the change in vertical thickness) is the direct signal of annual atmospheric conditions – with no delay – whereas the advance or retreat of glacier tongues (the change in horizontal length) is an indirect, delayed and filtered signal of climat-



Figure 6B.2: Franz Josef Glacier, New Zealand. This temperate glacier receives several metres of precipitation a year and its tongue extends from almost 3 000 m above sea level down to 400 m above sea level, ending in the rainforest.

Photo: Michael Hambrey, SwissEduc (www.swisseduc.ch) and Glaciers online (www.glaciers-online.net); data from the World Glacier Monitoring Service, Zurich, Switzerland

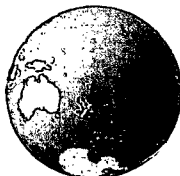


Figure 6B.3: Tsentralniy Tuyuksuyskiy Glacier, Kazhak Tien Shan in August 2006. This cold to partly temperate glacier extends from 4200 m above sea level to about 3400 m above sea level and is surrounded by continuous permafrost.

Photo: V.N. Vinokhodov; data from the World Glacier Monitoring Service, Zurich, Switzerland



ic change⁹. The advance or retreat of a glacier is, though, an easily-observed and strong signal of climatic change, as long as it is observed over a long enough period. If the time interval of the analysis is longer than the time it takes a glacier to adjust to a change in climate, the complications involved with the dynamic response disappear^{10,11}.

Over time periods of decades, cumulative length and mass change can be directly compared. Special problems are encountered with heavily debris-covered glaciers with reduced melting and strongly limited 'retreat', glaciers that end in deep-water bodies causing enhanced melting and calving, and glaciers undergoing periodic mechanical instability and rapid advance ('surges') after extended periods of stagnation and recovery. But glaciers that are not influenced by these special problems are recognized to be among the best indicators of global climate change^{12,20}.

They essentially convert a small change in climate, such as a temperature change of 0.1°C per decade over a longer time period, into a pronounced length change of several hundred metres or even kilometres (Figure 6B.4) – a signal that is visible and easily understood.

Past glacier fluctuations and current trends

The Late Glacial and Holocene (the period since about 21 000 years ago)

At the time of the peak of the last ice age about 21 000 years ago, glaciers covered up to 30 per cent of the land². Glacier fluctuations can be reconstructed back to that time using a variety of scientific methods. Understand-

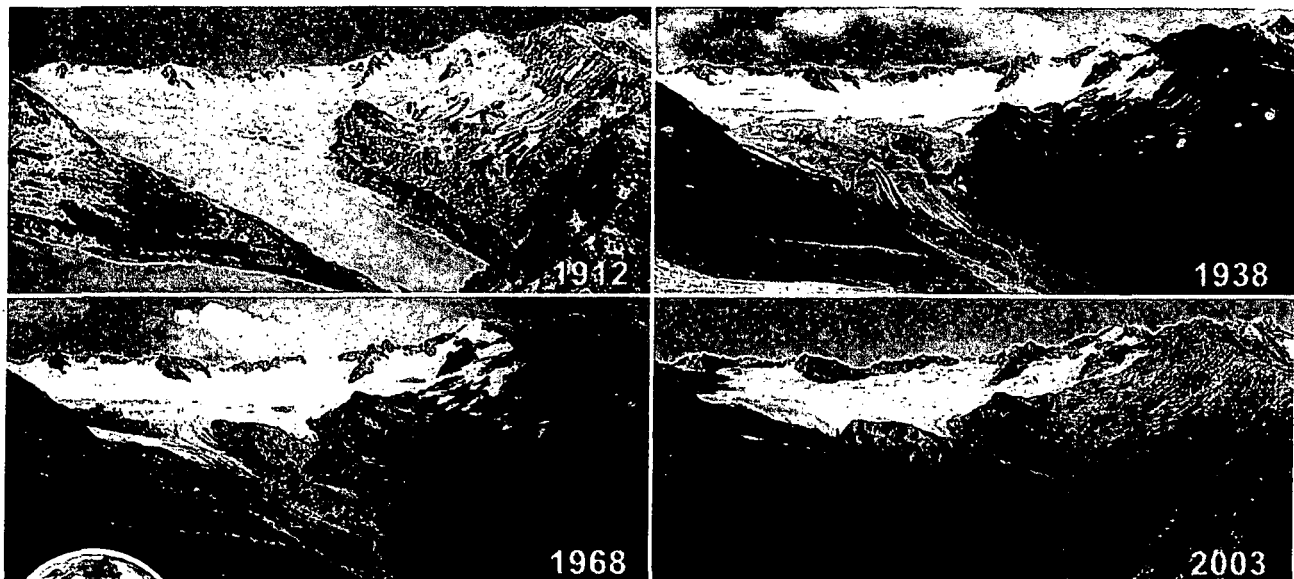


Figure 6B.4: Shrinking of Vernagtferner, Austria. This glacier in the European Alps lost almost 30% in area and more than 50% in mass between 1912 and 2003.

Source: Data and photos, taken by O. Gruber (1912), H. Schatz (1938), H. Rentsch (1968) and M. Siebers (2003), provided by the Commission for Glaciology of the Bavarian Academy of Sciences and Humanities (www.glaziologie.de)

ing how glaciers have varied in the past has become central to understanding the causes and possible future of contemporary glacier change. Historical reconstruction of glaciers in the Alps, Scandinavia, Alaska, the Canadian Rockies, Patagonia, the Tropics of South America, Tibet, the Arctic and Antarctica shows that the fluctuations in the state of the glaciers are largely consistent with the reconstruction of climatic and environmental changes provided by other indicators, such as ice-cores, tree-line shifts, pollen records and lake sediments¹⁴.

General warming during the transition from the Late Glacial period (between the Last Glacial Maximum and about 10 000 years ago) to the early Holocene (about 10 000 to 6000 years ago) led to a drastic general glacier retreat with intermittent periods of re-advances. About 11 000 to 10 000 years ago, this pronounced warming reduced the glaciers in most mountain areas to sizes comparable with conditions at the end of the 20th century¹⁵. In northern Europe and western North America, which were still influenced by the remnants of the great ice sheets, this process was delayed until about 6000 to 4000 years ago. Several early-Holocene re-advances, especially those in the North Atlantic and North Pacific as well as possibly in the Alps, cluster around an event about 8000 years ago, and were likely triggered by changes in the ocean thermohaline circulation and subsequent cooling resulting from the outbursts of Lake Agassiz¹⁴.

On a timescale of hundreds of years there were periods of synchronous glacier advance around the world – peaking in the late Holocene in the Northern Hemisphere, and in the early Holocene in the Southern Hemisphere¹⁶. The difference in the amount of sunlight that reaches the Earth's surface in the two hemispheres¹⁷, accounts for these differences in long-term glacier evolution¹⁶.

Glaciers in the tropics were rather small or even absent in the early- to mid-Holocene, gradually re-advancing from about 4 000 years ago, probably as a result of increasing humidity¹⁸. The moraines (accumulations of unsorted, unstratified mixtures of clay, silt, sand, gravel, and boulders deposited by the glaciers) that were formed during the so-called Little Ice Age (from the early 14th to the mid 19th centuries) mark a Holocene maximum extent of glaciers in many regions of the world, although the time period for this maximum varies among the different regions.

There is evidence that mountain glaciers had retreated during various periods of the Holocene in many regions of both hemispheres at least as much as they had in the 1980s–1990s¹⁴. However, caution must be exercised when using glacier extent as an indicator of climate; the glacier surfaces of the European Alps today, for example, are still far larger than expected given the climatic conditions of the past decade, and are thus not in equilibrium¹⁹.

Since the end of the Little Ice Age

There has been a general retreat of glaciers worldwide since their Holocene maximum extent towards the end of the Little Ice Age, between the 17th and the second half of the 19th century, with intermittent periods of glacier re-advance in certain regions. Direct measurements of glacier fluctuations started in the late 19th century (see box on worldwide glacier monitoring) with annual observations of glacier front variations²⁰. These observations and the positions of the Little Ice Age moraines are used to measure the extent of glacier retreat. Total retreat over this time period of glacier termini (the ends of the glaciers) is commonly measured in kilometres for larger glaciers and in hundreds of metres for smaller ones²¹.

Worldwide glacier monitoring

Worldwide collection of information about ongoing glacier changes was initiated in 1894 with the foundation of the International Glacier Commission at the 6th International Geological Congress in Zurich, Switzerland. Today, the World Glacier Monitoring Service continues to collect and publish standardized information on ongoing glacier changes. WGMS is a service of the Commission for the Cryospheric Sciences of the International Union of Geodesy and Geophysics (CCS/IUGG) and maintains a network of local investigators and national correspondents in all the countries involved in glacier monitoring. In addition, the WGMS is in charge of the Global Terrestrial Network for Glaciers (GTN-G) within the Global Climate/Terrestrial Observing System. GTN-G aims at combining (a) in-situ observations with remotely sensed data, (b) process understanding with global coverage, and (c) traditional measurements with new technologies by using an integrated and multi-level strategy²⁰. Recently, a scientific working group has been established to coordinate the monitoring and assessment of glacier and permafrost hazards in mountains²².

To keep track of the fast changes in nature and to assess corresponding impacts on landscape evolution, fresh water supply and natural hazards, monitoring strategies will have to make use of the rapidly developing new technologies (remote sensing and geo-informatics) and relate them to the more traditional methods.

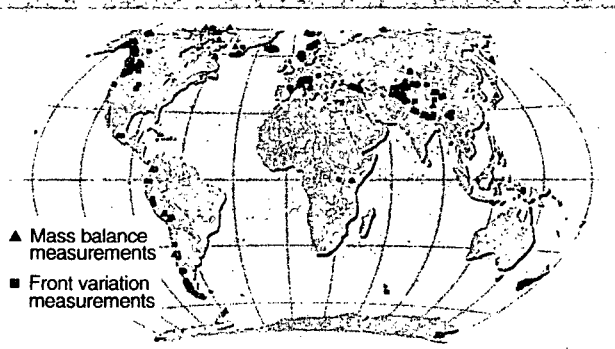


Figure 6B.5: Worldwide glacier monitoring. The locations of glaciers with available front variation and mass balance measurements are shown.

Source: Locations of glacier observations provided by the World Glacier Monitoring Service, Zurich, Switzerland; background glacier cover based on the glacier layer of the Digital Chart of the World, provided by the National Snow and Ice Data Center, Boulder, USA.

Characteristic average rates of glacier thinning (mass loss), calculated from data on changes in length over long time periods, are a few decimetres water equivalent per year for temperate glaciers in humid-maritime climates, and between a few centimetres and one decimetre water equivalent per year for glaciers in dry-continental regions with firm areas below melting temperature^{21,23}. These calculated values of glacier mass loss can be compared to glacier mass balance values from direct glaciological measurements, which are available for the second half of the 20th century.

Thirty reference glaciers with almost continuous mass balance measurements since 1975 (Figure 6B.6) show an average annual mass loss of 0.58 m water equivalent for the past decade (1996–2005), which is more than twice the loss rate of the period 1986–1995 (0.25 m), and more than four times the rate of the period 1976–1985 (0.14 m). The results from these 30 continuous mass balance series correspond well to estimates based on a larger sample of more than 300 glaciers, including short and discontinuous series²⁴.

The mass loss of glaciers and ice caps (excluding peripheral ice bodies around the two ice sheets in Greenland and Antarctica) between 1961 and 1990 contributed 0.33 mm per year to the rising sea level, with about a doubling of this rate in the period from 1991 to 2004²⁴. A step-change in climatic conditions would cause an initial mass balance change followed by a return towards zero values, due to the glacier's adaptation of its size (surface area) to the new climate. The observed trend of increasingly negative mass balances over reducing glacier surface areas thus leaves no doubt about the ongoing change in climatic conditions.

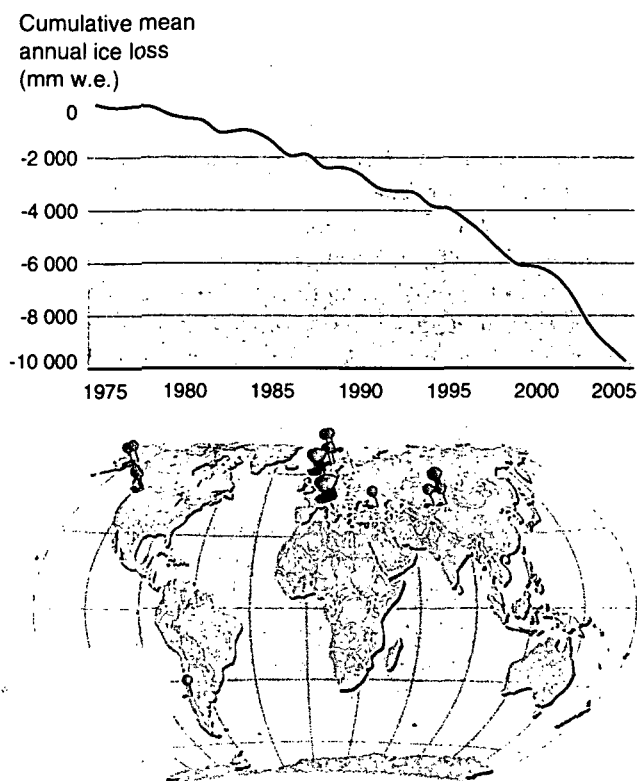


Figure 6B.6: Mass balance reference glaciers in nine mountain ranges. The 30 glaciers lost on average more than 9.5 m water equivalent in thickness over the period 1976–2005.

Source: Data from the World Glacier Monitoring Service, Zurich, Switzerland

Outlook for glaciers

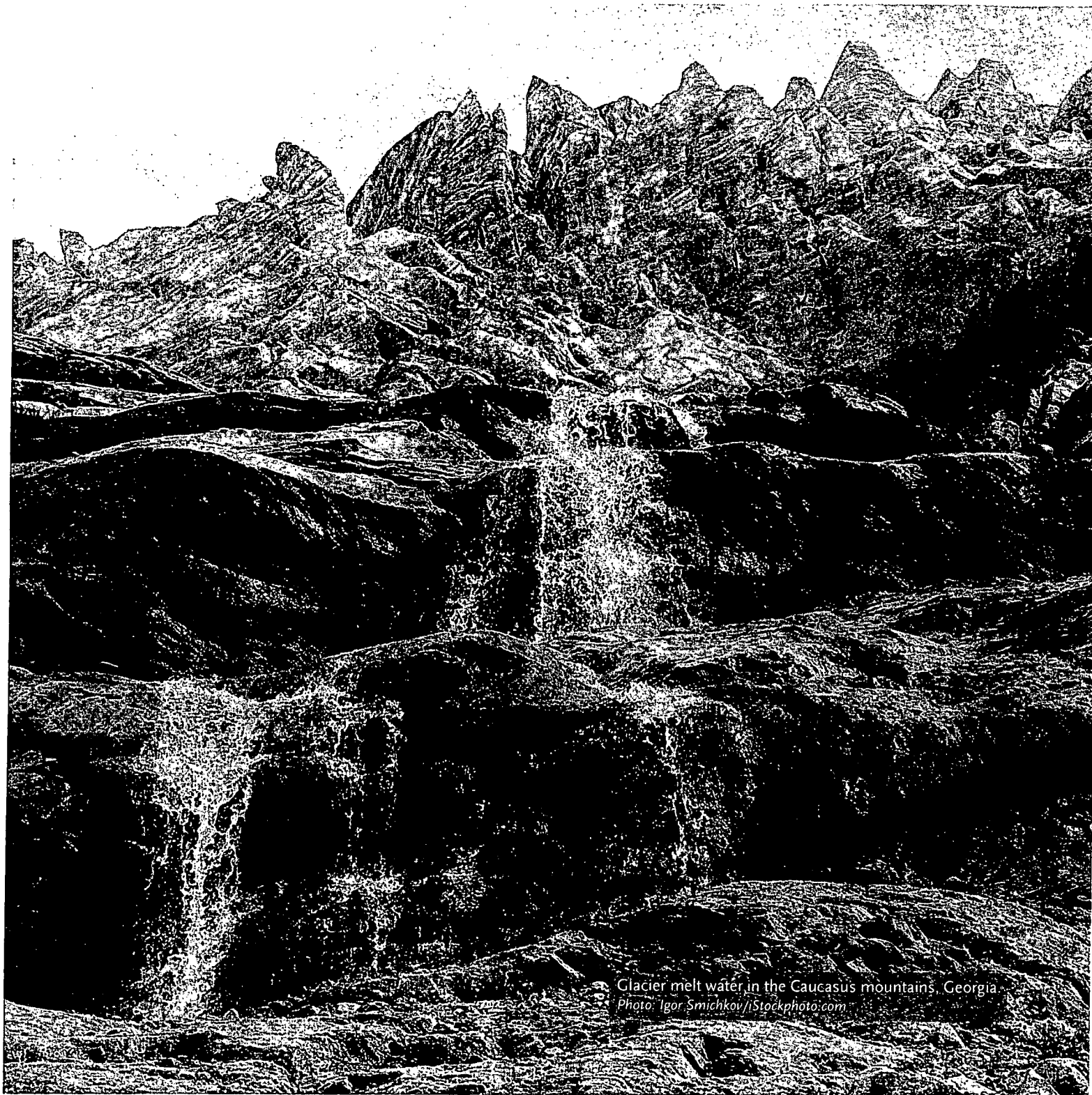
The total increase of global mean air temperature of about 0.75 °C since 1850 is clearly manifested in the shrinking of glaciers and ice caps worldwide¹. The sensitivity of glaciers in humid-maritime areas to this warming trend has been found to be much higher than that of glaciers in dry-continental areas^{7,21}.

According to climate scenarios for the end of the 21st century, changes in global temperature and precipitation range between +1.1 to +6.4 °C and –30 to +30 per cent, respectively¹. Such an increase in mean air temperature will continue the already dramatic glacier changes. Cold continental-type glaciers will react in the first instance with a warming of the ice and firn temperatures, whereas glaciers with ice temperatures at the melting point will have to convert the additional energy directly into melting^{7,8}.

Low-latitude mountain chains like the European Alps or the Southern Alps of New Zealand, where glaciers are typically medium-sized and found in quite steep mountains, will experience rapid glacier changes in adaptation to the modified climate. A modelling study shows that the European Alps would lose about 80 per cent of their glacier cover should summer air temperatures rise by 3°C, and that a precipitation increase of 25 per cent for each 1°C would be needed to offset the glacial loss¹⁹.

In heavily glacier-covered regions like Patagonia (Argentina, Chile) or the St. Elias Mountains (Alaska), the landscape is dominated by relatively few large and rather flat valley glaciers. Because long, flat valley glaciers have dynamic response times beyond the century scale^{10,11}, rapid climate change primarily causes (vertical) thinning of ice rather than (horizontal) retreat and area reduction. For such cases, conditions far beyond equilibrium stages, perhaps even run-away effects from positive feedbacks (mass balance/altitude), must be envisaged^{20,25}. Downwasting or even collapse of large ice bodies could become the most likely future scenarios related to accelerating atmospheric temperature rise in these areas, and have already been documented^{26,27}.

Under the present climate scenarios¹, the ongoing trend of worldwide and fast, if not accelerating, glacier shrinkage on the century time scale is of a non-periodical nature and may lead to the deglaciation of large parts of many mountain regions in the coming decades.



Glacier melt water in the Caucasus mountains, Georgia
Photo: Igor Smichkov/iStockphoto.com

Glaciers and natural hazards

Changes in glaciers may well lead to hazardous conditions, particularly in the form of avalanches and floods, and thus have dramatic impacts on human populations and activities located in glacierized mountain regions. The majority of glacier hazards affect only a limited area – often only a few square kilometres – and mostly pose a danger to densely populated mountain regions such as the European Alps. In some cases, however, glacier hazards have far-reaching effects over tens or even hundreds of kilometres and thus also affect less densely populated and developed mountain regions. The long-term average annual economic loss from glacier disasters or related mitigations costs are estimated to be in the order of several hundred million US dollars²⁸. The largest disasters have killed more than 20 000 people, for instance the Huascarán rock-ice avalanches in Peru in 1970 (see box on deadly ice avalanches of Glaciar 511 in the Cordillera Blanca in Part 2 of this chapter), or the Nevado del Ruiz lahars (rapidly flowing volcanic debris flows) in Colombia in 1985.

A systematic assessment of hazards can only be achieved by identifying the physical processes involved. Generally speaking, the most important types of hazards are as follows: glacier floods, hazardous processes associated with glacier advance or retreat, ice and rock avalanches, periglacial debris flows, and ice–volcano interactions^{29,30}. Particularly severe disasters have often resulted from a combination of these processes or chain reactions^{13,31}.

Glacier lake outburst floods represent the largest and most extensive glacial hazard, that is, the hazard with the highest potential for disaster and damage (up to 100 million m³ break-out volume and up to 10 000 m³ per second runoff). The Himalayas, Tien Shan and the Pamirs (see box on glacier lake outburst floods and glacier surges in Central Asia), the Andes, but also the European Alps are among those regions most severely affected by this type

of hazard. Glacier floods are of particular concern in view of the rapidly retreating glaciers and the corresponding formation and growth of numerous glacier lakes^{30,32–34}.

In terms of hazard, ice and rock avalanches may be roughly grouped by volume. Avalanches with volumes smaller than 1 million m³ are mostly of concern to densely populated and developed mountain regions such as the European Alps^{41–43}. Avalanches with a volume of 1 to 100 million m³ or even more have usually more far reaching effects and the potential to completely devastate mountain valleys. The most recent such disaster occurred in 2002 in the Caucasus with a 100 million m³ ice-rock avalanche that extended more than 30 km downstream and killed more than 100 people (see box on the 2002 Caucasus ice-rock avalanche and its implications). These types of mass movements and the relationship between their magnitude and their frequency have recently become more and more important in research because of concerns that they may become more frequent with continuing atmospheric warming, permafrost degradation and related destabilization of steep glaciers and rock walls⁴⁴.

Debris flows from periglacial areas have frequently caused damage to life and property in mountain areas⁴⁸. Unconsolidated sediments, uncovered by glacier retreat during the recent decades, and degradation of stabilizing permafrost in debris slopes are the main sources of the largest debris flows observed in the European Alps^{31,49,50}.

Ice-capped volcanoes pose particularly severe hazards because large mass movements (avalanches, lahars) may result from the interactions between material that erupts from the volcanoes with ice and snow^{51,52}. Alaska, the Cascades and the Andes are among the regions most affected by hazards posed by the interaction between volcanoes and glaciers^{53,54}.

Chain reactions and interactions between the aforementioned processes play a crucial role in determining the

Glacier lake outburst floods and glacier surges in Central Asia

Almaty (population 1.2 million) is subject to the risk of floods from torrential rainfalls and glacial lake outbursts. A glacier-induced debris flow in July 1973 in the mountains south of Almaty deposited over 4 million m³ of debris into the safety dam, which had been specially constructed to prevent the catastrophic impacts of such floods. Before this dam was built in 1967, debris flows caused many casualties and severe destruction in 1921 and 1956.^{35,36}

In July 1998, a glacier lake outburst flood in the Shahimardan Valley of Kyrgyzstan and Uzbekistan killed over 100 people.³⁷ In August 2002, another such event in the Shakhdara Valley of the Tajik Pamir Mountains claimed 23 lives.³⁸ In both cases the local communities did not receive early warnings and were not prepared. These tragic lessons have prompted better coopera-

tion between meteorological services in glacier flood hazard detection.

The increasing number of glacial and moraine lakes in Central Asian mountains is a matter of great concern.^{35,39} One of the surging glaciers that poses a potential threat is the 15 km long Medvezhi (Bear) Glacier in the Pamirs mountains of Tajikistan (Figure 6B.7). Its surges have repeatedly caused lake formation, outburst and subsequent floodings. In 1963 and 1973, the surge of the glacier was so significant (1 to 2 km increase in length) that the ice dam exceeded 100 m in height and dammed a lake of over 20 million m³ of water and debris.⁴⁰ The outburst of that lake generated a series of large flood waves. Due to early warning and monitoring, there were no victims, although infrastructural damage was significant.

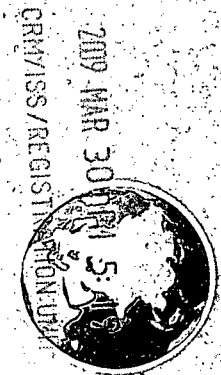
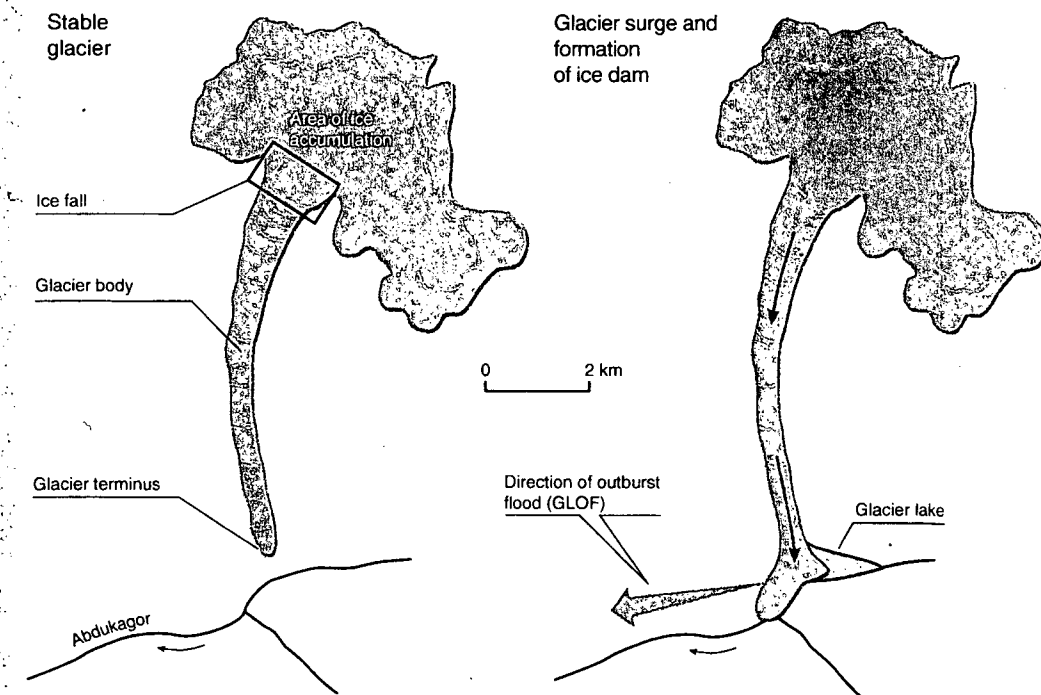


Figure 6B.7: Formation of lakes and glacier lake outburst floods (GLOFs) by Medvezhi Glacier, Pamirs.

Source: Tajik Agency on Hydrometeorology

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