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UNITED STATES SENATE

**HEARING ON
GLOBAL CHANGE RESEARCH:
OZONE DEPLETION AND ITS IMPACTS**

Friday, November 15, 1991

Washington, D.C.

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1 HEARING ON GLOBAL CHANGE RESEARCH:
2 OZONE DEPLETION AND ITS IMPACTS
3

4 Friday, November 15, 1991
5

6 U.S. Senate
7 Committee on Commerce, Science,
8 and Transportation
9 Washington, D.C.
10

11 The committee met, pursuant to notice, at 9:33 a.m. in
12 Room SR-253, Russell Senate Office Building, Hon. Al Gore,
13 Jr., presiding.
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1 OPENING STATEMENT OF HON. AL GORE, U.S. SENATOR FROM
2 TENNESSEE

3 Senator Gore: Well, let us get this under way. Let me
4 welcome all of our witnesses and tell you how grateful I am to
5 all of you for arranging your schedules to be here today.

6 This is another in a series of earth science roundtables,
7 and the difference between a roundtable and a hearing is that
8 this proceeding is a little more informal in the flow of
9 discussion. I will have a few brief opening comments and will
10 call upon my colleague Senator Gorton for any that he might
11 have, and then what we will do is we will take very brief
12 opening statements, and I would like to limit everybody to
13 only three minutes in the opening comments.

14 I assure you that you will have plenty of time during the
15 proceeding this morning to come back and make whatever points
16 you wish to emphasize during the discussion. But during the
17 discussion that will follow these opening statements, I want
18 to encourage give and take and disagreement if it is
19 necessary, the elucidation of subtleties that you think are
20 important.

21 I would like, however, to suggest that you follow this
22 rule, the same one that we follow over on the Senate floor,
23 where over the past 200 years they have discovered that it is
24 best to direct all statements through the chair. That has
25 minimized fist fights during the past two centuries on the

1 Senate floor. Not that we expect any here this morning, but
2 if you could direct your comments through the chair that would
3 be helpful.

4 I might also, before I give my opening comments, note
5 that we are honored to have in attendance in the audience the
6 Ozone Secretariat for the United Nations Environment Program,
7 Dr. K.M. Sarma from Nairobi. Dr. Sarma --

8 Voice: I think he may be late.

9 Senator Gore: He may be a little late, okay. Well, we
10 will be honored when he arrives.

11 And Dr. Steve Lee-Babty, we will be honored later by his
12 presence, and the Co-Chair of the UN Ozone Technology -- oh,
13 he was the Co-Chair, all right.

14 We are honored to have with us as part of the panel the
15 Co-Chairs of all three of the UN ozone panels: Doctors Watson
16 and Albritton on the science of ozone depletion and the
17 synthesis of the UN ozone report, Dr. van der Leun from The
18 Netherlands, who was the Co-Chair of the impacts panel along
19 with Dr. Manfred Tevini of Germany; and Dr. Steven Andersen,
20 Co-Chairman of the strategies for reducing emissions panel.

21 One other thing. Senator Gorton has reminded me that we
22 are going to have some votes on the Senate floor this morning
23 in connection with unemployment. So at various times,
24 unfortunately, I will have to recess the proceeding for 7, 8
25 minutes at a time, race over and vote, and then come back. So

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1 I will just warn you about that ahead of time.

2 Now, just by way of my opening comments, we are here
3 today to examine the latest information on the damage that we
4 are doing to the stratospheric ozone layer and what it means
5 to us, our health, our food supply, and the global ecological
6 system.

7 On October 22nd the United Nations Environmental Program
8 released the executive summary of a report entitled "A
9 Scientific Assessment of Stratospheric Ozone, 1991." That was
10 the first of three parts of a UNEP assessment of ozone
11 depletion due to be released in its entirety early next year.
12 Many of the scientists involved in the study felt that the
13 gravity of the findings was such that advanced word of the
14 nature of the findings ought to be available to peoples and
15 governments throughout the world in advance of the normally
16 slower process by which such information gets published.

17 That has been done with the first of the three panels.
18 The other two will be presented in essence here this morning.
19 The information contained in the other two will be heard
20 publicly for the first time in this session this morning. We
21 are very interested in hearing that.

22 Overall, this was the second such assessment done since
23 the Montreal Protocol was signed in 1987, and the protocol
24 itself called for these international assessments so that
25 policymakers would have the information needed to revise and

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1 update the protocol as new scientific data becomes available.

2 Like that first assessment in 1989, this new one includes
3 very disturbing new data, indicating that ozone radiation is
4 even more serious than we thought. Many of our witnesses
5 today were involved in writing the 1989 assessment concluding
6 that ozone depletion was occurring very much faster than most
7 models predicted.

8 As a result of that report, of course, the Montreal
9 Protocol was amended to require more rapid phaseout of CFC's,
10 halons, and other ozone deleting chemicals.

11 According to the report released on October 22nd, ozone
12 depletion is occurring even faster than thought in that 1989
13 update and it is occurring over more of the globe, everywhere
14 except a narrow band along the Equator, apparently, and
15 throughout most of the year. And one of the most troubling
16 findings, of course, was that it is occurring in spring and
17 summer, when the sun angle is such that the rays are not
18 scattered over a larger swath of the earth's surface and are
19 able to do more damage.

20 Depletion is occurring, according to the report, not only
21 in the Antarctica ozone hole, but also in the Arctic and mid-
22 latitudes, over our heads here in the United States for
23 example. And worst of all, it appears from the new findings
24 that the depletion is accelerating. According to the data,
25 the ozone layer above the United States is thinning between 3

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1 and 5 percent per decade.

2 According to Sherwood Rowland, who testified before our
3 committee in April, that means the ozone layer has thinned
4 about 10 percent since the 1960's. We often hear a shorthand
5 description that there has been a 4 to 5 percent depletion,
6 but that is just since the monitoring began in 1978, and when
7 you extrapolate that rate back to the time when the actual
8 depletion started it is about a 10 percent cumulative loss
9 above the mid-latitudes here since the 1960's, according to
10 Dr. Rowland.

11 That is significant, it is widespread, and it will have
12 major impacts on the environment and on people worldwide. We
13 are only now determining what those impacts will be.

14 We will hear some testimony today that will be very
15 surprising to many people, I imagine, because the evidence now
16 coming in is in some cases really startling. Unfortunately,
17 however, there has been too little research on the impacts of
18 ozone depletion and the impact specifically of increased
19 ultraviolet radiation which results from the depletion. Until
20 recently, much of the data was preliminary and incomplete.

21 But fortunately there have been a number of good solid
22 studies completed in the last year or two that give us a much
23 clearer picture. The new UN report effectively summarizes
24 that new research and it provides the most thorough assessment
25 to date of the impacts of ozone depletion.

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1 The news is not good. Researchers here today have
2 discovered that increased UV radiation will reduce the
3 quantity and quality of crops, increase skin cancer and
4 cataracts, suppress the human immune system, and disrupt
5 marine ecosystems, with effects on the entire oceanic food
6 chain.

7 According to the report, a 10 percent decrease in ozone
8 will lead to between 1.6 and 1.75 million additional cases of
9 cataracts per year worldwide and at least 250,000 additional
10 cases of skin cancer per year. There are indications that
11 increased UV radiation suppresses the human immune system that
12 protects us from disease, and it is now clear that ozone
13 depletion will directly affect the health of many, many
14 millions of people worldwide.

15 The impact on ecosystems, trees, plants, phytoplankton,
16 all seem vulnerable to these increased levels of ultraviolet
17 radiation. No doubt there will be other serious consequences,
18 many of which cannot yet be anticipated, due in part to a lack
19 of research.

20 Last year the Federal Government spent almost one billion
21 dollars on global change research, most of it at agencies
22 under the jurisdiction of this committee. I personally feel
23 that we have to do more in researching the impacts of this
24 extra dosing of ultraviolet radiation. I think it is very
25 shortsighted that we have neglected this as much as we have.

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1 Well, with that let me turn to Senator Gorton for any
2 opening remarks he might make, and then we will have our
3 opening statements from the witnesses.

4 [The prepared statement of Senator Gore follows:]
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1 STATEMENT OF HON. SLADE GORTON, U.S. SENATOR FROM
2 WASHINGTON

3 Senator Gorton: Mr. Chairman, at 10:00 o'clock or
4 immediately after our vote I have a markup of the supplemental
5 appropriations bill, so I will only be here until that first
6 break. Therefore, I would much rather try to hear the
7 presentations of each of these people, except to welcome a
8 constituent, Dr. Weiler.

9 Senator Gore: Very good.

10 Let us start off with Robert Watson, Branch Chief of the
11 Upper Atmosphere Research Tropospheric Chemistry Program at
12 NASA. Dr. Watson, if you could lead off we would appreciate
13 it.

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1 STATEMENT OF DR. ROBERT T. WATSON, BRANCH CHIEF, UPPER
2 ATMOSPHERE RESEARCH TROPOSPHERIC CHEMISTRY, EARTH SCIENCE AND
3 SPACE APPLICATIONS DIVISION, NATIONAL AERONAUTICS AND SPACE
4 ADMINISTRATION HEADQUARTERS, WASHINGTON, D.C.

5 Dr. Watson: Thank you, Senator Gore and Senator Gorton.

6 The key findings of the scientific assessment included
7 the following. Based on ground-based and satellite data,
8 ozone losses are now occurring in both hemispheres, not only
9 in the winter but spring and summer. The only area of the
10 globe we have not observed ozone loss is in the tropics.

11 During the period of the 1980's, we saw a 3 percent ozone
12 loss in the summer over populated areas in the USA and Europe,
13 and effectively the trends, as Senator Gore stated, during the
14 1980's are faster than the trends observed in the 1970's by
15 about 2 percent. In other words, ozone depletion is
16 accelerating.

17 In Antarctica ozone losses continue in the springtime,
18 they continue on into the early summer. That is December down
19 in Antarctica. And for the last 5 years we have had very deep
20 and extensive ozone holes, so that the biennial modulation
21 that we used to see in the early 1980's has disappeared at
22 least during the last 3 years.

23 The ozone loss is primarily occurring in the lower
24 stratosphere, below 20 kilometers. This has significant
25 ramifications for the radiative forcing of the earth's

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1 climate. Dr. Albritton will touch upon that particular
2 subject.

3 Clearly, the Antarctica ozone hole is due primarily to
4 manmade chlorine and bromine. We now believe the weight of
5 evidence strongly suggests that the observed mid-latitude
6 ozone losses are largely due to chlorine and bromine.

7 Even if we have the amended Montreal Protocol ratified
8 and complied with by all nations of the world, the amount of
9 chlorine in the earth's atmosphere today, which is about 3.5
10 parts per billion, will increase to about 4 parts per billion
11 or so by the year 2000. We therefore believe there will be
12 additional ozone losses during the 1990's, at least comparable
13 to those of the 1980's.

14 There are, however, approaches to limit future ozone
15 depletion. It means we will need additional controls on
16 CFC's, halons, methyl chloroform, carbon tetrachloride, and
17 controls on the HCFC's that are proposed as potential
18 substitutes in some uses.

19 In addition, our report points out that if methyl bromide
20 is partly anthropogenic in nature then we can have a significant
21 savings on the amount of bromine in the atmosphere, hence
22 saving future ozone depletion by controls on methyl bromide.

23 The last point I would like to make is we now have for
24 the first time direct evidence that we have significant ozone
25 depletion. There is the increase of ultraviolet radiation at

1 the ground. Each time in spring time in Antarctica when there
2 have been massive ozone depletions we have seen increases in
3 ultraviolet radiation at the ground to the level we would have
4 predicted from theoretical calculations.

5 Thank you.

6 Senator Gore: Thank you very much.

7 I might note parenthetically, we will get back to this
8 later but methyl bromide is used for preventing misshapen
9 fruit and for preserving grain, is that correct?

10 Dr. Watson: Correct.

11 Senator Gore: We are going to be hearing a lot more
12 about that, so I wanted to just throw that in.

13 Dr. Dan Albritton is Director of the Aeronomy Lab at NOAA
14 in Boulder, Colorado. Dr. Albritton.

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1 STATEMENT OF DR. DANIEL L. ALBRITTON, DIRECTOR, AERONOMY
2 LAB, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, BOULDER,
3 COLORADO

4 Dr. Albritton: Thank you, Mr. Chairman, Senator Gorton.

5 In addition to the request that our scientific group
6 summarize the new findings on stratospheric ozone depletion,
7 the United Nations has also asked us to summarize the present
8 state of understanding of how ozone depleters and ozone
9 changes may relate to the heat budget of the planet, in
10 particular how this heat budget change may relate in fact to
11 the CFC's and other compounds.

12 There have been two major findings of the UN panel that
13 relate to trace gases and the heat budget. As Dr. Watson
14 indicated, the ozone loss appears to be concentrated in the
15 lower stratosphere, and this for the first time raises the
16 possibility that ozone losses are indeed related to changes in
17 the heat budget in the lower atmosphere, and I will provide
18 some details for that finding.

19 The second emphasis of our report was to examine very
20 carefully the indices that the scientific community placed on
21 the trace gases, in an attempt to show the relative measure
22 that each of the trace gases contributes to the heat budget of
23 the planet. And there have been some very significant
24 findings in terms of how well those indices can be calculated,
25 and I will try to summarize those points.

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1 First of all, the relation between ozone loss and the
2 heat budget of the atmosphere. As Dr. Watson indicated, the
3 loss being in the lower stratosphere raises the possibility
4 that it cools that lower part of the atmosphere, and a cooler
5 lower stratosphere means that less heat is radiated from that
6 slab of the atmosphere down to the lower part of the
7 atmosphere where the climate system actually functions.

8 So ozone loss in this region caused in fact by the
9 chlorine- and bromine-containing compounds may in fact mean
10 that less heat is radiated to the lower part of the
11 atmosphere.

12 Now, the direct effect of the CFC's and the other
13 greenhouse gases has been a tendency toward warming. So now
14 for the first time there appears to be an indirect effect on
15 the heat budget due to these same compounds. In fact, the
16 preliminary calculations of this group indicate that this
17 tendency toward a reduction in radiation may in fact roughly
18 offset in many latitudes the direct effect that these
19 compounds are having.

20 So here for the first time we have to more closely
21 examine the connections between ozone loss and the climate
22 system. There is still considerable research to do in this
23 regard.

24 What our group did was examine the change in the heat
25 budget, and now climate scientists must apply that change in

1 the heat budget to asking the questions of how it actually
2 changes patterns on the surface, like temperature or rainfall.

3 The second point that I mentioned our group examined is
4 how well scientists can compare greenhouse gas A to greenhouse
5 gas B. Many of these gases also have direct and indirect
6 components. What our group found was that perhaps our
7 understanding in calculating the indirect effects are not as
8 solid as in fact had originally been thought a few years ago.

9 Let me give you an example. A gas like methane can
10 directly trap earth's radiation and directly contribute to the
11 heat budget, but it also creates water vapor, which is itself
12 a greenhouse gas. It also influences other lower atmospheric
13 greenhouse gases and those can contribute. Our ability to
14 calculate in the full impact of those molecules, both the
15 direct effects and the indirect effects, will require
16 considerable more research.

17 Senator Gore: Thank you.

18 We will come back to a lot of that, because of course if
19 the cooling partly offsets the warming from CFC's, that places
20 even more emphasis on CO2 as a greenhouse gas, and that has
21 provoked a reaction in many quarters. So I am sure we will
22 have some discussion of that here today.

23 Dr. van der Leun, as I mentioned, is from The
24 Netherlands. He is with the Institute of Dermatology at the
25 University Hospital of Utrecht in Heidelberglaan in The

1 Netherlands. Did I get that close?

2 Dr. van der Leun: Close.

3 Senator Gore: Close.

4 I hope our other witnesses will not think it
5 inappropriate for me to suggest that Dr. van der Leun and
6 after him Dr. Andersen, since they are providing the first
7 information on these other two UN assessment panels, take a
8 couple of extra minutes in addition to the 3 that we are
9 allocating to others.

10 So Dr. van der Leun, please proceed with your findings on
11 the impact of this extra ultraviolet radiation.

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1 STATEMENT OF DR. JAN C. VAN DER LEUN, INSTITUTE OF
2 DERMATOLOGY, UNIVERSITY HOSPITAL UTRECHT, UTRECHT, THE
3 NETHERLANDS

4 Dr. van der Leun: Thank you, Mr. Chairman, for the
5 opportunity to contribute to this hearing.

6 My testimony is based on the work of the panel on
7 environmental effects, and today we released the summary of
8 the update 1991. I will take the opportunity to highlight a
9 few key elements of our report.

10 Our work starts with the relationship between
11 stratospheric ozone and ultraviolet radiation. Stratospheric
12 ozone is the main limiting factor for the penetration of solar
13 ultraviolet radiation to the earth, and it is for that reason
14 that we are worried about release of ozone that would be
15 expected to lead to increased ultraviolet radiation, and that
16 is indeed confirmed now by measurements in our Antarctic
17 region, as Dr. Watson already told.

18 It is also confirmed by surrounding areas. During the
19 breakup of the ozone hole, branches of it go over inhabited
20 areas of southern Australia and scientists in Melbourne have
21 measured that there are actual increases of ultraviolet-B
22 radiation, in full agreement with the decrease of ozone
23 overhead.

24 Now, there are also measurements suggesting negative
25 trends in ultraviolet-B radiation, especially in this country,

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1. measurements over a long period of time, and that would
2. indicate a decrease of ultraviolet radiation while ozone was
3. also decreasing, and that has been puzzling for some time.

4. Senator Gore: That is because of air pollution.

5. Dr. van der Leun: I think that that is the main cause of
6. this other shield, consisting of tropospheric ozone, aerosols,
7. clouds, and most measurements are done in industrialized
8. areas.

9. Our report emphasizes that there is no guarantee whatever
10. that these factors will continue to work in the same
11. direction. Indeed, we are spending a lot of effort to reduce
12. these factors, and in some cases with success, with initial
13. success.

14. So if these factors reverse, the increase of ultraviolet-
15. B radiation by ozone radiation will be amplified, rather than
16. reduced. So we have many reasons to consider the effects.

17. Our report first starts with human health. Increase of
18. non-melanoma skin cancer is confirmed by new observations and
19. the present estimate is that a 10 percent loss of ozone, if
20. sustained over a long period of time, will lead to an increase
21. of the incidence of this type of skin cancer by 26 percent.
22. That is a smaller number than in the previous report. That is
23. due to new information.

24. This type of cancer is not only caused by UVB radiation,
25. but also to some extent can be caused by UVA radiation, which

1 is not affected by ozone. So that decreases the sensitivity
2 of the incidence for ozone change.

3 Eye problems. We have new experimental data implicating
4 ultraviolet-B even more than before in eye problems. We have
5 no new quantitative estimates, but the new data amplify the
6 estimates given earlier. If we would have 10 percent less
7 ozone over the past decades, there would now be more than a
8 million additional cases of blind people in the world due to
9 cataracts.

10 Ultraviolet radiation has influences on the immune
11 system. Dr. Kripke will certainly tell more about this. The
12 concern for our committee and for all of us is that this might
13 lead to increase of infectious diseases.

14 Plants and animals are also sensitive to ultraviolet
15 radiation. Many of them grow less under increased ultraviolet
16 radiation. One of the concerns is that this will lead to
17 smaller production in agriculture and fisheries, but there is
18 a lot between the individual organisms and the production of
19 agriculture and fisheries and we need a lot more knowledge to
20 come to real predictions there.

21 In the wild ecosystems one species will be more sensitive
22 than another, and this may lead to shifts in the competition
23 ratios and even to loss of species. Again, that is a real
24 loss for the earth.

25 We need a lot more data. In many places our report says

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1 there is good reason for concern, but we have no solutions, no
2 final answers. So that is the reason we need much more data,
3 and I am glad you emphasized that point.

4 Thank you, Mr. Chairman.

5 [The prepared statement of Dr. van der Leun follows:]

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1 Senator Gore: Thank you.

2 I am going to suggest that we change the order slightly,
3 with your indulgence, Dr. Andersen. Since Senator Gorton has
4 another committee that he is going to have to attend, I would
5 like to take his constituent, Dr. Susan Weiler, out of order
6 and introduce her by saying she is the Executive Director of
7 the American Society of Limnology and Oceanography, with the
8 Department of Biology at Whitman College in Walla Walla,
9 Washington, and is also empowered to represent here today some
10 of the work that has been done and is in progress by Dr. Ray
11 Smith's team.

12 Dr. Smith is in the Antarctic right now. He and his
13 colleagues have also worked on this problem of ultraviolet
14 radiation's impact on the oceanic food chain.

15 We are very honored that you could be here, Dr. Weiler.
16 If you can proceed.

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1 STATEMENT OF DR. SUSAN WEILER, EXECUTIVE DIRECTOR,
2 AMERICAN SOCIETY OF LIMNOLOGY AND OCEANOGRAPHY, DEPARTMENT OF
3 BIOLOGY, WHITMAN COLLEGE, WALLA WALLA, WASHINGTON

4 Dr. Weiler: Thank you very much, and I would also like
5 to applaud you for calling for more research. We know so
6 little about biological systems in comparison with the ozone
7 and other things, which we have already heard we do not know
8 much about, either. So it really is something where we do not
9 really know enough to say too much at this stage.

10 What we can say is that it is already very well known
11 that current levels of UVB radiation affect phytoplankton
12 cellular processes, including primary production, DNA
13 integrity, which is likely to affect future generations, and
14 also cell viability.

15 Because species vary greatly in their sensitivity to UVB
16 radiation, it is possible that increased UVB would change
17 phytoplankton species competition and abundance, as well as
18 total primary productions. And again, as we heard before,
19 this is likely to have impacts beyond the primary producers.
20 These effects will ripple through the food chain and have
21 impacts that we really cannot predict right now.

22 Okay, so we know a fair amount about what happens at
23 current levels of UVB. It has been extremely difficult to
24 measure or predict what is going to happen with increased
25 levels of UVB, because the current generation of lamps,

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1 artificial lamps, bear no relation to the solar spectrum that
2 is observed in the UVB regime and we know that biological
3 consequences are extremely dependent on individual wavelengths
4 of radiation.

5 So you cannot just say: Okay, we are going to increase
6 UVB by this much and it is going to have that effect. You
7 have to say: We are going to have so much of this wavelength,
8 a little more of this, a little less of whatever. And you
9 have to integrate over that. And you simply cannot do that by
10 artificially augmenting radiation with lights.

11 The one advantage of the ozone hole, if you could call
12 anything an advantage, is that we are now seeing severely
13 increased levels of UVB radiation in that region resulting
14 from the ozone hole. So for the first time we can actually
15 look over the short scale at the effect of natural levels of
16 UVB radiation.

17 Because of this, there has been a lot of research since
18 around 1987, when the first programs went down there. There
19 has been a lot of research concentrating on impacts in the
20 Antarctic, and I think one thing to point out to people is I
21 think we have a tendency to say: Well, if something happens
22 in the Antarctic, what does that mean to us here in temperate
23 latitudes?

24 This is a natural laboratory and we can learn things
25 about even temperate species that we cannot learn by studying

1 them at this latitude because of the limitation on light.

2 Anyway, the major Antarctic biological research findings
3 today are: Number one, that, like present levels, increased
4 levels of UVB also adversely affect marine phytoplankton
5 through decreases in primary production, DNA damage, and
6 presumably other factors that have not been studied yet.

7 Measurements by state of the art instruments confirm that
8 UVB penetrates to significantly, ecological significant depths
9 in the water column. I think most people tend to think as you
10 get down 5 inches or so you do not have to worry about it
11 because it is absorbed out of the water column, and it is
12 simply not true.

13 Measurements of UVB radiation have now been observed as
14 deep as 70 to 80 meters and ecologically significant levels
15 have been found at depths greater than 30 meters in the water
16 column. So this is something that we really do have to worry
17 about in aquatic systems as well as in terrestrial systems.

18 Antarctic phytoplankton species do have adaptive
19 mechanisms, such as the production of UVB blocking compounds,
20 that are similar to those found in tropical latitudes. There
21 are adaptive mechanisms in these organisms. There was some
22 question as to whether this was the case earlier.

23 And it has also been found that, like at temperate
24 latitudes, species vary significantly in their sensitivity to
25 UVB radiation. Again, this is going to have a dramatic effect

1 potentially on the type as well as the availability, the total
2 availability, of food to higher levels of the ecosystem, such
3 as fish and commercially important species.

4 Because species vary in their response to UV, ozone
5 depletion might cause changes in species composition or
6 nutritional state and changes in the abundance, size,
7 distribution, or nutritional value of primary producers could
8 affect higher trophic levels by reducing feeding efficiency,
9 potentially causing nutritional deficiencies and other things
10 that could reduce food availability to higher trophic levels,
11 even if total primary production did not decrease. And again,
12 everything suggests that it will decrease. It already has
13 based on the short-term experience.

14 Thank you.

15 [The prepared statement of Dr. Weiler follows:]
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1 Senator Gore: Just to draw this out for a minute before
2 Senator Gorton has to leave, the findings indicate, do they
3 not, that the photosynthesis and the growth in production of
4 phytoplankton has decreased by 14 percent in the areas with
5 the higher dosage of UVB in the Antarctic?

6 Dr. Weiler: Around 6 to 12 percent when integrated over
7 the entire water column. The effects at surface are much
8 higher, and of course that is where the primary productivity
9 is, generally higher near the surface. It has been reduced by
10 as much as, I think, around 20 percent.

11 Senator Gore: At the surface?

12 Dr. Weiler: At the surface.

13 Senator Gore: Now, the phytoplankton production zone is
14 about 30 meters deep, 50 meters deep?

15 Dr. Weiler: Again, it varies with season, with water
16 type, a variety of other factors. Depending on the clarity of
17 the water, it could occur down to no more than a couple of
18 meters or it could occur, in the clearest water, down to about
19 150 meters.

20 But in the Antarctic it is probably around 40 meters.

21 Senator Gore: Is it accurate to say that most of the
22 zone where phytoplankton productivity occurs is penetrated by
23 ecologically significant levels of ultraviolet radiation?

24 Dr. Weiler: This is particularly true in the Antarctic.
25 Yes, that would be true generally speaking, because in the

1 Antarctic the phytoplankton concentrate in the upper water due
2 to the melting of ice in the springtime, because this water is
3 less dense, so it forms a lens on top, so it confines mixing
4 to shorter, smaller depths than would be found otherwise.

5 So these organisms are confined to the upper levels, even
6 though at other times of the year they might be going down
7 further.

8 Senator Gore: Now, the blooming, the blooming of
9 phytoplankton, is in the same time of the year when the ozone
10 hole is over it, right?

11 Dr. Weiler: That is increasingly true. The major bloom
12 occurs around October through November, and the ozone hole has
13 been most pronounced around the first week or so in October.
14 But now as the ozone hole is getting larger and also lasting
15 longer, it's penetrating more and more into that time of
16 maximum growth.

17 Senator Gore: Now, my final question before turning to
18 Senator Gorton is -- well, one note. You mentioned DNA. I
19 have heard it said that over the billions of years of
20 evolution DNA has evolved in a way that the radiation which
21 penetrates it harmfully is the radiation blocked by the ozone
22 layer, and I believe Sherwood Rowland said this, and that for
23 this reason the UV that is coming in extra amounts as the
24 ozone layer is depleted does have an effect on DNA.

25 You said that a suppression of phytoplankton productivity

1 would ripple through the food chain. Is that a linear or
2 arithmetic rippling effect, or is there some non-linear effect
3 that we do not know about?

4 Well, that is a hard question to ask. Is there likely to
5 be a non-linear effect, in your best judgment?

6 Dr. Weiler: I would like to clarify. We do not know for
7 certain, but our best guess is that there will be changes
8 because of the differential sensitivity. It is likely that
9 these effects may be non-linear simply because there are so
10 many confounding species.

11 You have got the producers and some consumers are
12 differentially sensitive to those, and then you have got
13 secondary producers that are selective on some of the primary
14 consumers. So we will see impacts, but we cannot predict how
15 much that will happen.

16 Senator Gore: We will turn to Senator Gorton.

17 Senator Gorton: I am not going to ask any questions, so
18 let us go on to the next one.

19 Senator Lott: Mr. Chairman, I do have a statement I
20 would like to submit for the record.

21 Senator Gore: Sure.

22 [The prepared statement of Senator Lott follows:]

23 [COMMITTEE INSERT]

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1 Senator Lott: And depending on what happens with this
2 vote and the subsequent votes, I do have some questions
3 specifically for Dr. Watson to put in the record, if you could
4 respond in writing.

5 Senator Gore: Sure, absolutely. We want to encourage
6 that. I appreciate that.

7 I took Dr. Weiler out of order and I apologize for doing
8 this out of order.

9 Senator Gorton: Thank you. I thank you for that.

10 Senator Gore: Let us move on. Dr. Stephen Andersen is
11 Director for the Technology Transfer and Industry Program at
12 the EPA and is a Co-Chair, as I said earlier, of that third
13 part of the UN assessment panel.

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1 STATEMENT OF DR. STEPHEN ANDERSEN, DIRECTOR, TECHNOLOGY
2 TRANSFER AND INDUSTRY PROGRAM, U.S. ENVIRONMENTAL PROTECTION
3 AGENCY, WASHINGTON, D.C.

4 Dr. Andersen: Thank you, Senator Gore, Senator Gorton,
5 and Senator Lott.

6 The 1991 UNEP technical and economic assessment was
7 undertaken by over 240 experts from 48 countries, and they
8 produced six separate reports that are not only quite large,
9 but also quite detailed, and I think their findings are
10 impressive.

11 The assessment will not be final until December of this
12 year, but I am able to report consensus findings and
13 conclusions. I will report to you on the progress at
14 eliminating these chemicals, about the technical feasibility
15 of a faster phaseout, and some of the special circumstances of
16 developing countries and their phaseout.

17 Since 1986 there has been a 40 percent worldwide decrease
18 in the consumption and production of CFC's. This is faster
19 than predicted by the 1989 assessment and it is faster than
20 the controls of the Montreal Protocol as amended in London.
21 At that rate of progress, we will meet the 1995 Montreal
22 Protocol goal next year.

23 It is also impressive to look at the work that has been
24 part of this progress. Already by the end of this year,
25 several multinational companies will eliminate their use of

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1 ozone-depleting solvents in all of their worldwide operations.
2 By next year, the first automobiles will have ozone-safe air
3 conditioners and the first domestic refrigerators will be
4 commercially available. Many other ozone-safe technologies
5 are fully commercial.

6 We also had progress in the area of fire protection. The
7 international fire protection community has virtually halted
8 the emissions caused by discharge testing, training, and
9 accidental discharges.

10 The second point I would like to make is that, based on
11 this elaborate evaluation, we have concluded that it is
12 technically feasible in developed countries to phase out the
13 production of CFC's and halons by 1997 or earlier, methyl
14 chloroform as early as 1995, and carbon tetrachloride in the
15 vast majority of its applications by 1995.

16 These rapid schedules require the use of transitional
17 HCFC's and HFC's for the important applications of
18 refrigeration, air conditioning, insulating foam, and for some
19 aerosol, sterilization and minor solvent uses. Toxicity
20 studies and risk assessments are not yet complete for some of
21 these important transitional substances.

22 The halon phaseout is contingent on the use of recycled
23 halons as the primary supply, and I think it is a real credit
24 to the fire protection industry that what was first considered
25 in 1987 as essential for all applications we now are finding

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1 that an adequate supply will carry essentially fire protection
2 uses well into the next century.

3 The final important technical conclusions of the
4 technical and economic assessment is that there are efforts
5 that can be made in the developing countries to accelerate
6 their phaseout. It is important to developing countries that
7 the technologies are available, that technical assistance,
8 including information and training, be provided, and that
9 there be an accelerated effort at financing.

10 There has also been some impressive progress in the
11 developing countries and I will just cite one, which is the
12 case of Mexico, that has announced to the world that they will
13 make it a goal to phase out the ozone-depleting substances on
14 the same schedule as the developed countries if adequate
15 financing is available.

16 The final point I would make is that part of this great
17 progress with developing countries is due to some innovative
18 partnerships with multinational corporations and associations,
19 and I think we can look forward to more progress if that
20 cooperation continues.

21 Thank you.

22 [The prepared statement of Dr. Andersen follows:]

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1 Senator Gore: I think it ought to be noted for the
2 record that Mexico was also the first nation to sign the
3 Montreal Protocol.

4 I wanted to make one point before we go to vote. Wearing
5 your EPA hat, section 606 of the Clean Air Act, the
6 anniversary of the signing of which is today, legally requires
7 the President through his agent, the head of the EPA, to
8 accelerate the phaseout schedule to bring the deadline from
9 the year 2000 much nearer to the present time.

10 You have said in your statement that it is
11 technologically feasible to do that. The requirement I refer
12 to is contingent upon the availability of new scientific
13 information which says the health and environmental impacts
14 are more serious than thought when the act was passed.

15 Since the act was signed, we had the April report and we
16 had the report of October 22nd. Is EPA recommending that this
17 provision of the law be triggered and that faster phaseout be
18 implemented?

19 Dr. Andersen: Senator Gore, I am here to only represent
20 the technical and economic assessment, and I cannot represent
21 the position of EPA.

22 Senator Gore: All right. I will come back to that and
23 try to get it out of you another way.

24 [Laughter.]

25 Senator Gore: That is why I wanted to mention it before

1 my colleagues left, to give fair warning on that one.

2 We are going to have a short recess for this vote. I
3 anticipate it will take about 8 minutes to run over and back,
4 so we will crank it back up then.

5 [Recess.]

6 Senator Gore: The session will come back to order.

7 Let me follow up briefly on a question, while Dr. Kripke
8 is returning, with you, Dr. Weiler. I wanted to clarify this
9 business about productivity in the oceans. Just to make sure
10 that I have a clear understanding of this business of the food
11 chain, phytoplankton are these very small critters, plants.

12 Dr. Weiler: Right, single-cell organisms.

13 Senator Gore: Single-cell organisms in the top layer of
14 the ocean, that bigger critters feed on, and then critters
15 that are bigger still feed on them, and so on up the food
16 chain. That is a simplistic way of putting it, but is that
17 pretty accurate?

18 Dr. Weiler: That is correct, they are the base of the
19 food chain, just like grasses are for cows.

20 Senator Gore: Therefore, if you have a 14 percent or at
21 the surface 20 percent, overall a 6 to 14 percent, decrease in
22 the amount of basic food available at the bottom of the food
23 chain, that would mean probably a decrease in the amount of
24 food available all the way up the food chain, including the
25 bigger fish that provide part of the human diet, correct?

1 Dr. Weiler: That is correct. If the effect is linear,
2 you would expect about that same amount at each of the trophic
3 levels reduction.

4 Senator Gore: But it may be worse than that?

5 Dr. Weiler: That is correct.

6 Senator Gore: Because at higher levels in the food chain
7 any interruption in the mix of species might have effects that
8 are difficult to predict, that would have as a consequence
9 more loss of food at that level of the chain, correct?

10 Dr. Weiler: That is correct, and there are a couple of
11 reasons for this. One is that there is such a tremendous
12 range in the size of the phytoplankton cells. Even though
13 they are all single-celled organisms or virtually all, the
14 size variation can be a couple of orders of magnitude.

15 So you have organisms that are better adapted to feeding
16 on a particular size class. And then in addition to that,
17 there are changes in the nutritional value of cells. So they
18 are not all -- a single cell of a diatom is not the same in
19 terms of food as a single cell of a dinoflagellate or a blue-
20 green algae or whatever it might be.

21 It is really hard, again. We know that the species vary
22 in their sensitivity, but we cannot yet predict and say, okay,
23 if you increased UVB radiation by such and such, the long-
24 term effects would be that you would get more of this species
25 and less of that.

1 Then even if you did not change the species composition,
2 UV does not just alter primary production. It also influences
3 things like protein content, dry weight of cells, et cetera,
4 et cetera, and cells tend to develop more protein or less.
5 Those effects on nutritional status, even if everything else
6 stayed the same, would have some sort of an effect.

7 So it presumably is non-linear, but we do not know in
8 what way it will change.

9 Senator Gore: I hope we will have a chance to discuss
10 that further also, and we will hear from another witness about
11 the impact, not on the oceanic food chain, but on the
12 terrestrial food chain.

13 Now, however, I would like to turn to Dr. Margaret
14 Kripke, Chairperson of the Department of Immunology at the
15 M.D. Anderson Cancer Center at the University of Texas in
16 Houston. I have heard of Dr. Kripke's work for many years
17 now, and with the report of this impact assessment panel the
18 world is beginning to pay more attention to the effects of
19 extra UV radiation on the human immune system.

20 I think it is fair to say that Dr. Kripke is one of, if
21 not the world's leading expert, on this subject, and we are
22 very anxious to hear what you have to say, Dr. Kripke.

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1 STATEMENT OF DR. MARGARET L. KRIPKE, CHAIRPERSON,
2 DEPARTMENT OF IMMUNOLOGY, M.D. ANDERSON CANCER CENTER,
3 UNIVERSITY OF TEXAS, HOUSTON, TEXAS

4 Dr. Kripke: Thank you very much, Senator Gore. I very
5 much appreciate the opportunity to be here to make some
6 comments on this topic.

7 My interest in this topic comes from research that we
8 have carried out in the laboratory over about the last 20
9 years. We started out to investigate the immunology of skin
10 cancers and have ended up investigating the immunological
11 effects of ultraviolet radiation.

12 So at this point what can we actually say about the
13 immunological effects of ultraviolet radiation? Well, from
14 animal models we can say unequivocally at this point, based on
15 evidence from many laboratories, that ultraviolet radiation
16 interferes with certain immunological functions. These
17 include a decreased resistance against skin cancers, including
18 melanoma, decreased activity of the skin's immune system,
19 decrease of some systemic immune responses, and a decrease in
20 the ability of some of the white blood cells to take up
21 foreign particles, including bacteria.

22 The second thing that we can conclude from the animal
23 studies is that recent studies have demonstrated that these
24 immunological effects of ultraviolet light can have an
25 influence on the course of some infectious diseases.

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1 Specifically, there is decreased immunity to herpes simplex
2 virus, to Leishmania parasites, to microbacteria, to candida
3 albicans, and increases in the severity of infections with
4 these particular agents.

5 For humans we also know that immune cells in the skin are
6 damaged by exposure to ultraviolet light. We know that the
7 proportions of white blood cells in the circulation are
8 changed after exposures to sunlight or to tanning salon
9 lights.

10 We know that a cell-mediated immune reaction initiated in
11 the skin called contact allergy is decreased after ultraviolet
12 radiation of the skin. There are recent studies by Dr. Wayne
13 Streilein and his colleagues at the University of Miami in
14 humans that I think have provided the most important recent
15 findings in this area.

16 This group has found that the sensitivity of humans to
17 immune suppression by ultraviolet light is genetically
18 controlled, and this means that some people are more sensitive
19 to immune suppression by ultraviolet light than others. They
20 have also shown that people who are very sensitive to the
21 immunological effects of ultraviolet light are more likely to
22 develop skin cancer.

23 So it appears that immune suppression is an additional
24 risk factor in light-skinned populations for the development
25 of cancers of the skin.

1 The third point, and an extremely important one, is that
2 the amount of pigmentation present in the skin is not
3 protective against immunological damage. This is rather
4 surprising because we know that pigmentation protects against
5 sunburn and it protects against skin cancer. But apparently
6 it does not provide any protection against immunological
7 damage from ultraviolet light.

8 So we know that ultraviolet light affects the immune
9 responses in humans. We know that the population at risk of
10 such alterations is very large and is not limited to
11 Caucasians who are at risk for skin cancer.

12 What we do not know is the significance of these findings
13 for infectious diseases in humans. With the possible
14 exception of herpes simplex virus, we have no information on
15 the effects of ultraviolet radiation on infectious disease
16 processes.

17 Another important point is that we do not know if
18 sunscreens which protect against sunburn also protect against
19 immunological damage, and we need to know the answer to that
20 question as well.

21 I would like to conclude by leaving you with three
22 questions to think about. First of all, the immune system is
23 the body's main defense mechanism against infectious diseases.
24 It is what keeps us healthy. And if you want an illustration
25 of what it does for you, all you have to do is look at people

1 who do not have an immune system, people with AIDS, people
2 with combined immunodeficiency diseases. These people are at
3 lethal risk of death from infectious diseases. So anything
4 that perturbs this immune system, our body's defense
5 mechanism, constitutes a serious threat to the maintenance of
6 health.

7 The second point is that there are two major public
8 health problems in the world. These are inadequate nutrition
9 and infectious diseases. These are the real health problems
10 worldwide, and anything that exacerbates these two problems
11 are likely to have a devastating effect on human health.
12 Ultraviolet radiation has the potential to adversely affect
13 both of these things by affecting plants and by affecting the
14 immune system.

15 Finally, a point that you raised earlier, Senator Gore,
16 is that we are not in a position at the present time to
17 evaluate the health effects of ozone depletion. We do not
18 have enough information. In my opinion we do not have enough
19 information because there has been a lack of sustained
20 commitment to funding of research on effects in this area, and
21 I was very happy to hear you make that point earlier.

22 We will never be able to make predictions in this area
23 unless we spend the money to get the answers, and these are
24 long and hard and difficult questions.

25 Thank you very much.

1 [The prepared statement of Dr. Kripke follows:]
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1 Senator Gore: Correct. Just to interject a question
2 here. There is another class of diseases that are affected by
3 a suppression, or potentially affected by a suppression of the
4 immune system. There are all of those diseases which could be
5 more of a threat because the body's ability to fight them off
6 is suppressed.

7 There is also a whole category of diseases which are
8 characterized by the immune system attacking healthy cells, or
9 malfunctioning in some other way.

10 Lupus would be an example of that. Epstein-Barr would be
11 an example of that, and chronic fatigue syndrome. Graves'
12 Disease would be an example of that latter category.

13 I asked the staff to check, and it looks as if all of the
14 diseases in that latter category have been increasing in their
15 occurrence fairly significantly in the last two decades. Is
16 that correct?

17 Dr. Kripke: That is correct.

18 Senator Gore: What category would a disease like
19 arthritis be in. Is that related to the immune system more
20 directly?

21 Dr. Kripke: Rheumatoid arthritis is thought to be an
22 immunological disease. The pathogenesis of the disease is
23 related to the body's immune reaction.

24 Senator Gore: So that would be in that category also?

25 Dr. Kripke: Yes, that is possible.

1 Senator Gore: According to the National Center for
2 Health Statistics, in 1969, 92.9 out of 1,000 Americans
3 suffered from arthritis. 20 years later, the number had
4 jumped to 126.5, a 36 percent increase in only 20 years. And,
5 to show that it is not a reflection of the aging of the
6 American population, for people between the ages of 18 and 34,
7 there was a 78 percent increase in the number of cases.

8 Just to take arthritis as an example, is it reasonable to
9 express the concern that increased dosage of UV-B radiation
10 could be implicated in the increasing frequency of a disease
11 involving the malfunction of the autoimmune system?

12 Dr. Kripke: It is possible, but that would be widely
13 speculative at the present time. I know of no information
14 that links ultraviolet light effects on the immune system with
15 the occurrence of arthritis or other autoimmune diseases. The
16 only known link is the ability of ultraviolet light to trigger
17 lupus erythematosus, and the mechanism of that is not known.

18 Senator Gore: Now, let us take that one then. I asked
19 the earlier question because it is troubling that there would
20 be an across-the-board increase, and a fairly dramatic
21 increase, in the incidence of all of these diseases that come
22 as a result of a malfunctioning immune system.

23 You say that, in the case of lupus, there is a known link
24 between exposure to ultraviolet radiation and the onset of
25 lupus, correct?

1 Dr. Kripke: That is correct.

2 Senator Gore: Do you think that it is reasonable to say
3 -- I do not know quite how to express the question; you know
4 what I am getting at --

5 Dr. Kripke: I know what you are getting at, and let me
6 put it in terms that I am comfortable with.

7 Senator Gore: Yes.

8 Dr. Kripke: Is this something that should be looked at?
9 There is no information. We cannot speculate on whether
10 ultraviolet light is important here or not, because no one has
11 really asked that question in a scientific way.

12 So the information does not exist. I would also point
13 out that one of the great increases in cancer at the present
14 time is also in some of the lymphomas, particularly non-
15 Hodgkins lymphoma; which, again, is immunologic; the cancer of
16 the immune system, which is increasing in the population for
17 no apparent reason.

18 Senator Gore: Now, you mentioned herpes. There, too,
19 you feel there is a definite link to exposure to ultraviolet
20 radiation and the onset of herpes in some patients?

21 Dr. Kripke: It is very well established, from the
22 medical literature, that ultraviolet radiation -- sunburns --
23 will trigger herpes simplex virus infections of the oral
24 cavity.

25 These kinds of experiments have also been done on

1 experimental animals as well; and in the animal models, it has
2 been fairly well documented that at least some of the effects
3 of ultraviolet radiation on the viral disease are mediated by
4 the effect of ultraviolet light on the immune system.

5 So here, we have a link between ultraviolet light,
6 immuno-suppression, and an infectious disease process.

7 Senator Gore: Now, drawing back your focus a little bit
8 to look at the epidemiology of this category of diseases, in
9 assessing the impacts of extra ultraviolet radiation --
10 ultraviolet B radiation -- should we include, in our
11 assessment of the likely impacts, a probable increase in the
12 rate of spread of diseases in this category?

13 Dr. Kripke: In which category?

14 Senator Gore: Those diseases that are intimately related
15 to the efficient functioning of the immune system.

16 Dr. Kripke: I know you would like me to say yes to that
17 question --

18 [Laughter.]

19 Senator Gore: No, seriously. Let me clarify the
20 question. I really do not want you to say yes, if you do not
21 feel the answer is yes, seriously.

22 Dr. Kripke: Senator Gore, if there is no information,
23 you cannot get an answer. It is as simple as that.

24 Senator Gore: Okay. All right. Well, I appreciate your
25 response. We will come back to this as well.

1 I want to now turn it to Dr. Alan Teramura, professor,
2 and chair, of the Department of Botany at the University of
3 Maryland in nearby College Park. Dr. Teramura was also a
4 member of the Impacts assessment panel. We are interested in
5 hearing from you.

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1 STATEMENT OF ALAN H. TERAMURA, PROFESSOR AND CHAIRMAN,
2 DEPARTMENT OF BOTANY, UNIVERSITY OF MARYLAND, COLLEGE PARK,
3 MARYLAND

4 Dr. Teramura: Thank you very much, Senator Gore, for the
5 opportunity to participate in this rectangle table. My
6 training has been in stress physiology. And over the past 15
7 years, I have been examining the effects of increased levels
8 of solar, ultraviolet radiation on crop plants, on forest tree
9 species, as well as on native plants.

10 And so what I want to do in the next 2 or 3 minutes here
11 is try and encapsulate some of the conclusions from these
12 studies, as well as studies from others.

13 We know that a large number of agricultural crop plants
14 and forest tree species and native plants, may be negatively
15 impacted by increases in ultraviolet radiation. Some of these
16 plants are directly affected by increases in ultraviolet
17 radiation. Others will be indirectly affected, because
18 exposure to ultraviolet radiation can alter these plants
19 interactions with other plants, as well as alter their
20 capacity to be able to defend themselves from disease or from
21 insect attack. So both a direct, as well as an indirect
22 affect on plants seems to be the case.

23 Because of extremely small number of studies which have
24 specifically examined UV effects on crop yields, it is
25 presently not possible for us to make any sort of

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1 comprehensive, quantitative assessments of crop losses due to
2 increases in solar, ultraviolet radiation.

3 Furthermore, due to the limited number of on-going
4 studies -- I know of only two or three studies world-wide,
5 using realistic, UV supplements, I do not believe that we will
6 be any closer to a quantitative assessment in the near future.

7 However, we do have experimental data to show that yield
8 in some specific crops, such as Essex soybean, which happens
9 to be the most important -- economically-speaking -- the most
10 important soybean for the mid-Atlantic States, will be
11 decreased with increases in solar, ultraviolet radiation. We
12 also have specific examples for decreases in production for
13 Loblolly pine, which is probably the most important commercial
14 tree species for your State, Tennessee, as well as
15 Mississippi.

16 Due to the presence of genetic adaptations in our modern
17 crop plants, an optimist would say that plant breeders may be
18 able to help us by utilizing these beneficial, genetic
19 adaptations and breed for more UV-resistant crops in the
20 future. So that would be an optimist.

21 Those that are a pessimist, however, would point out that
22 we currently do not know enough about these UV-resistant crops
23 to know whether they might not carry some genetic baggage in
24 the sense of being less disease-resistant, and perhaps require
25 a higher water or fertilization applications. So there are

1 some down sides to breeding, as well.

2 Whereas breeding may help minimize the impacts -- the
3 negative impacts on crop plants, breeding is not an option for
4 natural plant communities, and is probably not a very good
5 option for forest tree species.

6 Long-lived tree species tend to accumulate the damaging
7 effects of ultraviolet radiation over many years. And it is
8 because of this long, life-span, and the length of time
9 required for breeding, that we think that forest tree species
10 and forests, in general, may be particularly vulnerable to
11 increases in ultraviolet radiation.

12 Due to differences in species sensitivity that was
13 mentioned earlier, both in native plants as well as in forest
14 tree species, that means that more resistant species are going
15 to replace more sensitive species to UV radiation, resulting
16 ultimately then in changes in bio-diversity of forests, as
17 well as natural ecosystems.

18 Since other climatic changes, such as CO2 and global
19 warming will occur simultaneously with increases in
20 ultraviolet radiation, it is logical to be concerned how
21 plants will respond to that combination.

22 CO2 generally increases plant growth, and UV radiation
23 generally decreases it in the most simple case.

24 Senator Gore: Just to interject on that point -- when
25 you say CO2 increases plant growth, the limiting factor in

1 plant growth is the availability of nutrients and sunlight,
2 correct?

3 Dr. Teramura: In many cases, it is. But we know that if
4 you increase CO2 for most plants, that their growth will
5 increase, as well, if they have enough nutrients and water.

6 Senator Gore: Okay, but if the nutrient loading, if the
7 availability of nutrients is kept at its present limit, and
8 CO2 is increased, then the studies indicate that what?

9 Dr. Teramura: It always happens that the most limiting
10 factor, then, will limit the growth of the plant. And if it
11 happens to be water or nutrients, then that will limit growth
12 before CO2.

13 Senator Gore: This is an aside, or a
14 parenthetical -- but I am informed that laboratory experiments
15 which purport to show that extra CO2 stimulates plant growth
16 are ones that have accommodated the plants by supplying lots
17 of extra nutrients at the same time.

18 Dr. Teramura: That is right.

19 Senator Gore: And therefore, if in the wild, or in the
20 forest the availability of nutrients is not increased, and
21 there is a little more CO2 in the air, you are not going to
22 get extra plant growth there.

23 Dr. Teramura: That is correct.

24 Senator Gore: Go ahead.

25 Dr. Teramura: But just assuming that, all else being

1 equal, that if CO2 does increase growth, in general, UV
2 decreases plant growth. And that leads, then, people to make
3 the assumption that one, CO2 will cancel out the effects of
4 ultraviolet radiation.

5 Senator Gore: So even if you had more nutrients to go
6 with the extra CO2, the additional growth might well be
7 cancelled out by the impact of the extra UV ratings.

8 Dr. Teramura: That is what the common assumption is.
9 The point I would like to make is that this is not always
10 borne out by experimental evidence. The evidence seems to
11 suggest that under dual stresses, plants are even more
12 adversely affected than under a single stress. So the case
13 may actually be worse -- rather than just a cancelling out,
14 plants may actually do much worse.

15 And then the final point I would like to make is related
16 to some recent evidence coming from the Federal Republic of
17 German which seems to suggest that even in the absence of
18 further ozone depletion, some sensitive plants are already
19 sensitive to present-day ambient levels of ultraviolet light,
20 such as the garden bean.

21 [The prepared statement of Dr. Teramura follows:]
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1. Senator Gore: Now thank you very much.

2 Just a brief follow up here -- is it true that soybeans
3 and rice are particularly susceptible to having their growth
4 rate and quality suppressed by extra UV radiation?

5 Dr. Teramura: They probably have the best information
6 for soybean than any other crop plant, or any plant in the
7 world. And in one field study examining soybean for a 6-year
8 period, a 25-percent ozone depletion was simulated during the
9 6-year period. The yield was reduced in soybean by 20 to 25
10 percent each year. That is quite a substantial loss.

11 Senator Gore: It is one for one.

12 Dr. Teramura: It is one for one.

13 What we do not know, however, is whether this can be then
14 extrapolated to all the soybeans grown throughout the United
15 States, as well as throughout the world.

16 Senator Gore: There may be some varieties that are less
17 susceptible.

18 Dr. Teramura: There are some varieties that are less
19 susceptible. We know that. And so what we need to -- what we
20 do not know, however, is how all soybeans can respond, and
21 whether -- what the implications of breeding for this
22 additional UV resistance may be.

23 In rice, we have more limited preliminary information.
24 It seems as though maybe on the order of 200 different
25 cultivars of rice have now been screened for UV sensitivity.

1 And between 1/2 and 1/3 of all of those cultivars are very
2 sensitive to ultraviolet light.

3 The other side of the equation is a small proportion of
4 those rice cultivars, maybe 10-percent, seem to be very
5 resistant. Again, that suggests to us that possibly, we may
6 be able to breed around the problem. But we still really do
7 not know about some of the problems associated with breeding.

8 Senator Gore: Well also, if you are forced by extra UV
9 loading to focus on a narrow part of the spectrum of the
10 genetic diversity of rice, you are severely limited in your
11 ability to select traits from across the spectrum in order to
12 confer resistance characteristics against the rapidly evolving
13 pests and blights that they are constantly having to fight
14 off. Is that correct?

15 Dr. Teramura: That is correct. One way of getting
16 around that, is using some of the techniques of molecular
17 biology and biotechnology. Right now, some individuals have
18 been able, actually, to clone the genes that cause sun-tanning
19 in plants. And if you can take sun-tanning genes, and put
20 them into your modern, crop plants, you may be able to protect
21 them as well. But that is still -- it is not really science
22 fiction, but it is still quite distant.

23 Senator Gore: Well, it would not be wise or prudent to
24 pin our hopes for the future of the world's food supply on
25 that?

1 Dr. Teramura: Absolutely not. That is too much of a
2 risk, I think.

3 Senator Gore: And in any event, genes are found
4 predominantly still, for most food species, in the wild and in
5 the genetic homes, the Vavilovian centers, and the land races.
6 And if those are damaged by the extra UV radiation, then the
7 potential availability of genes of the sort you are looking to
8 clone is going to be sharply diminished.

9 Dr. Teramura: And furthermore, even if you assume that
10 the breeders, the scientists working with crop genetics can
11 improve crops for the future, against harmful UV effects, you
12 still are not going to be able to do anything for native
13 plants, nor will we have much impact for forest tree species.
14 Despite the fact that agricultural plants are certainly of
15 vast economic importance for humans, probably 80 percent of
16 all plant material really lies in forests. And we know very
17 little about effects of UV on forest tree species.

18 Senator Gore: Okay, I keep saying we are going to come
19 back to this stuff. This is all so interesting. But we are
20 going to move on here.

21 Dr. Ari Patrinos is Acting Director of the Environmental
22 Sciences Division with the Department of Energy. We are happy
23 to welcome you, Dr. Patrinos. The Department of Energy asked
24 to participate in this hearing a few days ago. And I think it
25 is not only appropriate, but extremely helpful to have the DOE

1 perspective here.

2 Please proceed.

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1 STATEMENT OF DR. ARI PATRINOS, DIRECTOR OF THE
2 ENVIRONMENTAL SCIENCES DIVISION, OFFICE OF HEALTH AND
3 ENVIRONMENTAL RESEARCH, OFFICE OF ENERGY RESEARCH, U.S.
4 DEPARTMENT OF ENERGY

5 Dr. Patrinos: Thank you, Senator Gore.

6 I welcome the opportunity to respond to your invitation
7 to present the Department's views on stratospheric, ozone, and
8 its climate change implications.

9 As you may know, for over 12 years, we have been in the
10 business of global environmental change. And our current
11 focus is primarily on improving the capability to predict
12 global and regional climate change.

13 Our research, more directly related to stratospheric,
14 ozone depletion, involves primarily modeling stratospheric,
15 atmospheric chemical processes and their impacts on climate
16 change.

17 We also fund research for many years on the nature of
18 ultraviolet radiation, induced damage to DNA, and the repair
19 to that damage as a surrogate to studying damage from ionizing
20 radiation.

21 DOE is certainly concerned about the mounting evidence of
22 stratospheric ozone depletion caused by CFC's. The summary of
23 the unit report that we discussed this morning certainly
24 indicates a worsening situation. We believe that despite some
25 remaining scientific uncertainties, it is clear that action to

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1 curb CFC production and use is both prudent and justified.
2 And, in fact, that action is an integral part of the
3 Administration's policy.

4 However, we would like to focus on statements in the
5 Executive summary of the UNEP report that may be perceived, in
6 our opinion, to have strong climate change implications for
7 stratospheric ozone depletion. We believe the statements to
8 be based on calculations using simplified, radiative, transfer
9 models and are not necessarily supported by existing data.

10 Although the report is careful in describing a possible
11 climate impact in terms of radiating forcing, like my
12 colleague, Dan Albritton pointed out, it is important to
13 emphasize that any impact on climate change would be highly
14 uncertain.

15 In the UNEP Executive summary, particularly in the
16 section on recent, scientific findings, you find the assertion
17 that for the last decade, middle and high latitude ozone
18 depletion in the lower stratosphere should have cancelled the
19 radiative forcing caused by increases in CFC's at these
20 latitudes.

21 We would like to underscore some of the uncertainties
22 that have been voiced in the report, and also articulated by
23 my colleague, Dan Albritton. First, we believe that this
24 conclusion is based, as I said before, on the application of a
25 one-dimensional, radiative, transfer model, over various

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1 latitudes and seasons using the measured changes and CFC's and
2 ozone concentrations.

3 Second, we believe that the calculations assumed that the
4 entire ozone depletion occurred evenly over the bottom 7
5 kilometers of the stratosphere. In actual fact, 20 percent of
6 the stratospheric depletion occurred in the upper
7 stratosphere.

8 Senator Gore: If I could interrupt you at that
9 point -- I did not -- I saw this in your prepared statement.
10 And I do not know where that -- with all due respect -- I do
11 not see that in the report. You say the calculations assume
12 that the entire ozone depletion occurred evenly over the
13 bottom 7 kilometers of the stratosphere. Is that correct?

14 Dr. Watson: Actually, no. There were two, very
15 different calculations. They did, primarily, assume that the
16 ozone depletion was in the lower stratosphere. One assumed a
17 constant ozone depletion -- they said it was -- over the 7
18 kilometers. Another actually had a different function. It
19 was more at 15 kilometers than at 22.

20 One of the biggest problems is a quantitative knowledge
21 of the ozone depletion of 40 kilometers was fairly poor. The
22 database just was not very good. So we did, indeed, assume
23 most, if not all of the ozone depletion, was centered around
24 the tropopause, the lower part. But we did not assume it was
25 evenly distributed.

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1 Senator Gore: All right, you might want to go back and
2 take a look at that.

3 Dr. Patrinos: I did, I certainly will correct it for the
4 record.

5 Third, there is a much stronger seasonal, and latitudinal
6 variation in ozone depletion, as compared to CFC's. And
7 therefore, the net effect on climate cannot be estimated -- in
8 our views -- by only considering global average effects.

9 And fourth, the magnitude, and even the sign of the
10 change in the radiative forcing due to decreased, lower,
11 stratospheric ozone concentrations are very sensitive to the
12 assumed temperature change in the lower stratosphere, where
13 chemical, dynamical, and radiative effects all play important
14 roles.

15 In a sense, all these distinctions that I have described,
16 the uncertainties, may not simply be adequately -- and
17 adequately taken into account with one-dimensional radiative
18 transfer calculation such as those used in the UNEP study.

19 Furthermore, as my colleagues described, any resulting
20 climate change impacts would require the application of more
21 comprehensive climate-change models, the general circulation
22 models, the GCM's.

23 I would like to conclude by saying a few words about the
24 global warming potential that my colleague Dan Albritton
25 mentioned. We agree with the statements in the Executive

1 summary regarding the many uncertainties in the global warming
2 potentials for short-lived, atmospheric constituents.

3 However, we remain very concerned about the representation
4 of the carbon cycle used in computing the many -- the GWP's
5 for all the various assessments in the intergovernmental panel
6 climate change calculations. We are particularly concerned
7 about the assumed representation of atmospheric carbons that
8 have been used, and the serious under-representation of the
9 sinks of carbon in the atmosphere.

10 Thank you.

11 [The prepared statement of Dr. Patrinos follows:]

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1 Senator Gore: Just to interject a couple of points
2 here -- on the -- I did not want to interrupt you again in
3 your lists of criticisms of the study. You said you would go
4 back and look at the one about assuming --

5 Dr. Patrinos: Not criticisms, I am just pointing out --

6 Senator Gore: Your view -- what in your view are short-
7 comings of the work. And we had an exchange on the first one,
8 which you say you will go back and take a look at.

9 You say, third, there is a much stronger seasonal and
10 latitudinal variation in ozone, as compared to CFC's and
11 therefore the net effect on climate cannot be estimated by
12 only considering global, average effects.

13 It is my understanding that the model that the panel used
14 looked at each latitude, and each season, and did not just do
15 a global averages. And this is the subsequent analysis. Am I
16 correct on that, Dr. Watson, Dr. Albritton?

17 Dr. Watson: Yes, that is correct.

18 Dr. Patrinos is right because there is a very different
19 radiative forcing of the CFC's, which are uniformly
20 distributed over the globe, relative to the ozone potential,
21 cooling or decrease of radiative forcing, you do need to
22 believe -- I believe a full, climate model that couples
23 together both radiation and dynamics before you can be really
24 sure of what the impacts on the surface are.

25 Senator Gore: Maybe these fellows cannot say this, but I

1. would like to say, on my own authority, that I am given to
2 believe that during the work of the panel, there was a
3 significant amount of communication between the panel and the
4 operators of at least one three-dimensional model at the
5 Geophysical Fluid Dynamics shop at Princeton.

6 And I feel that the record should reflect this fact.
7 Because the panel decided to try to get the important
8 information in their work available to the peoples and
9 governments of the world as soon as they were confident that
10 it was accurate.

11 In doing so, they knowingly opened themselves to the
12 criticism that not every "I" was dotted and "T" was crossed.
13 And they attempted to cover that problem by having
14 communication with those that could simultaneously check some
15 of this on the three-dimensional model.

16 Their wording was very careful, and phrased in terms of
17 the radiative balance. In some of the popular summaries and
18 reporting of their work, understandably, there was emphasis on
19 the finding that a cooling effect of ozone being destroyed
20 would, at least, partially offset the consequence of the CFC
21 molecules, themselves.

22 Further analysis will have to examine whether that is
23 true or not. Now, the Department of Energy, I have a
24 tremendous respect for your expertise, Dr. Patrinos, and I
25 mean no implication here that you are not saying exactly what

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1 you think the scientific reality is.

2 As an institution, is it unreasonable for me to feel that
3 the Department of Energy is especially interested in any
4 finding that might tend to put more pressure on the United
5 States Government to implement policies that might reduce
6 carbon dioxide? Is there that extra sensitivity in DOE?

7 Dr. Patrinos: No, there is not, Senator. The research
8 program in the policy, in the Office of Policy, I clearly
9 separated. I would like to submit for the record the most
10 recent volume of the research and environmental change of our
11 Program published by the Oakridge National Laboratory in
12 Oakridge, Tennessee.

13 [The information referred to follows:]

14 [COMMITTEE INSERT]

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1 Senator Gore: Well, I certainly respect their expertise.

2 [Laughter.]

3 Senator Gore: I thought you phrased that very well.

4 Dr. Patrinos: Thank you, Senator.

5 Senator Gore: Now the UNEP report does make clear that
6 these uncertainties in the models -- that there are
7 uncertainties in the models -- used to determine the linkage
8 between CFC's and global climate. Do you question the fact
9 that these latest findings indicate that there is at least
10 some offset in the way of cooling from destroyed ozone
11 offsetting the warming effect of the CFC's themselves?

12 Dr. Patrinos: There may be an offsetting in the
13 radiative balance. That does not necessarily translate into
14 an offsetting into the cooling effect at the surface.

15 Senator Gore: What is your best guess.

16 Dr. Patrinos: I will give you an example of the role of
17 ice caps and clouds. For several years we have been assuming
18 that the feedbacks in a warming climate were in fact positive.
19 Today, after many years of research, we are certainly not sure
20 and in fact, in at least one case, for the case of clouds, we
21 are almost certain that the feedback is negative.

22 Senator Gore: Well --

23 Dr. Patrinos: So I argue against a very simple
24 explanation of a very complex climate phenomenon.

25 Senator Gore: I do not want to introduce another whole

1 subject in here. The last round table we had was on that
2 subject and the conclusion, I do not want to duel with you on
3 it but most of the water vapor in the atmosphere is not in
4 clouds and overall the water vapor impact is, I think it is
5 fair to say, almost certainly positive, but coming back to
6 this question.

7 My understanding of the debate that has been raging about
8 what exactly these findings mean for the role of CO₂, is that
9 most people have come to the tentative conclusion that there
10 is almost certainly some offset, something in the order of 80
11 percent might, according to many who have looked at this, be
12 the eventual answer, but they just do not know yet. However,
13 most of those who have looked at it carefully feel that there
14 definitely is some offset.

15 Dr. Albritton, I am a nonscientist trying to summarize
16 the discussions in the scientific community. Have I done so
17 with some semblance of accuracy?

18 Dr. Albritton: I think the UNEP report used the words,
19 tendency towards cooling, to represent the point I think that
20 you made and that is that if you reduce radiative forcing
21 towards the lower part of the atmosphere, certainly that is
22 less heat input and while certainly you have to calculate what
23 the role of transport and dynamics may introduce in terms of
24 distributing that heat, but the heat used the "tendency
25 towards cooling" of a way of generally expressing that that

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1 is, at least, the initial direction.

2 Senator Gore: Now let me ask you a hypothetical
3 question, Dr. Patrinos. If, and you do not have to accept the
4 validity of the hypothetical but if you would suspend a
5 judgment for the moment. If the cooling effect, if there was
6 a cooling effect, from the destruction of ozone, and it did
7 tend to cancel out a significant amount of the warming effect
8 from the CFC molecules themselves, that would tend to place
9 even more emphasis on strategies for reducing CO2 as a way of
10 mitigating global warming, correct?

11 Dr. Patrinos: I would think so. Yes.

12 Senator Gore: I appreciate your response. Bearing in
13 mind that you do not buy into, you still suspend a judgment
14 on, one key element in that hypothetical.

15 Dr. Patrinos: I do indeed.

16 Senator Gore: Dr. Shelby Tilford, Director of Earth
17 Science and Applications at NASA, attended the last one of
18 these sessions and has today been very patient and I
19 appreciate it very much. Please proceed.
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1 STATEMENT OF SHELBY TILFORD, DIRECTOR OF EARTH SCIENCE
2 AND APPLICATION DIVISION, NATIONAL AERONAUTICS AND SPACE
3 ADMINISTRATION, WASHINGTON, D.C.

4 Dr. Tilford: Thank you Senator Gore.

5 I am pleased to be here today to discuss the U.S.
6 Government's role in future global stratospheric measuring and
7 the role of NASA's Earth Science Program. Since the Congress
8 established the NASA's Upper Atmosphere Research Program in
9 1976 I think we have made great strides.

10 The program tends to not only look at the global
11 measurements but also to process studies, laboratory studies
12 and the utilization with the other agencies of aircraft to
13 understand processes. Recently, with the better understanding
14 of the role in the lower atmosphere, I think the laboratory
15 program has put more emphasis on the understanding of
16 heterogeneous chemistry in trying to understand especially the
17 roles of aerosols and SO₂, with the recent understanding that
18 this is where much of the ozone action is taking place. There
19 is current campaign going on in the Arctic, the second major
20 effort to understand the depletion of ozone in the Arctic,
21 what the mechanisms are, how that coupled with the satellite
22 measurements might help us predict the role of various
23 chemicals in the next few years.

24 There is a number of ongoing efforts to measure global
25 ozone. It includes the no operational meteorological

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1 satellites which include the Solar Backscatter Ultraviolet; we
2 are very fortunate in still maintaining the total ozone
3 mapping spectrometer on the Nimbus-7, as well as a SBUV
4 instrument. We have an aflotation experiment on the earth
5 radiation budget satellite which has been very useful in
6 determining very precise trends in ozone.

7 This year we have been extremely fortunate. We launched
8 a second TOMS instrument on a Soviet satellite in August and
9 that instrument is performing well and we are getting data
10 down. And I would like to provide you with the first complete
11 image that came out of the U.S./USSR program.

12 Senator Gore: Thank you.

13 Dr. Tilford: We also were very fortunate in September to
14 launch the Upper Atmosphere Research Satellite which is the
15 first comprehensive approach to try to understand the
16 chemistry, the dynamics and the radiation input to the upper
17 atmosphere. The satellite contains ten instruments, nine of
18 which are dedicated to understanding the Stratosphere; the
19 tenth to understanding the total output of the sun, two of
20 those instruments are dedicated to looking at the solar UV
21 output from the sun, such as we have a better idea on the
22 production and destruction of ozone from solar UV but also to
23 address the amount of solar UV variability that ultimately
24 reaches the ground.

25 In the future we have a number of shuttle payloads

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1 experiments which we hope will characterize the stratosphere
2 much more precisely. It has been done in the past and at the
3 same time provide inter-calibration for a number of
4 instruments that are flying on different satellites. This
5 includes a number of experiments from the U.S. but also a
6 number of international investigators. I might add that on
7 UARS, we also have a number of international participants, in
8 order to be able to look at this from a global perspective.

9 In the future we plan to fly an additional TOMS on an
10 earth probes mission in 1993. We plan to fly a follow-on
11 earth probes on the Japanese ADEOS platform in 1995 and then,
12 as the earth's observing system comes on line, we expect to
13 fly a number of instruments including high-resolution infrared
14 dynamical limb sounder or HRIDLS; we plan to measure
15 Tropospheric carbon monoxide. We plan to fly an additional
16 stratospheric aerosol and gas experiment for precise ozone
17 profiles and either a microwave limb sounder or a far infrared
18 instrument to measure precisely things like OH and enhanced
19 levels of species important in the ozone chemistry.

20 We also look to fly a very important Tropospheric
21 Emission Spectrometer which will give us much information in
22 terms of what the interaction especially in the lower
23 stratosphere upper troposphere chemistry might be. There is a
24 huge international effort, as I have covered here. I think it
25 is extremely important. This is a global problem.

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1 I think in terms of the ozone program over the last 15
2 years a number of lessons have been learned. I have
3 emphasized some of these in the past and previous hearings but
4 I think, fundamentally, it requires a long-term commitment,
5 stable commitment to carrying out the research involving the
6 scientific community in making sure the assessments are
7 carried out on an international basis.

8 I think there is a number of other lessons learned as we
9 move into the global changery now. Those that I just
10 indicated but I think it is extremely important to involve the
11 scientific community at the earliest possible time, maintain
12 stable funding and because of some of the questions you ask I
13 think it is extremely important to make sure that much of the
14 research is done outside of the regulatory agencies. Thank
15 you very much.

16 [The prepared statement of Dr. Tilford follows:]
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1 Senator Gore: Thank you very much. We will hold
2 questions on that. I will have some questions later on the
3 amount of work being done to really assess how much ultra
4 violet radiation is fitting the surface. But we will come
5 back to that.

6 Our last participant is Dr. Robert Worrest, Program
7 Manager for the Stratospheric Ozone Research Program, with the
8 U.S. Environmental Protection Agency, and unlike Dr. Anderson
9 who is also at the EPA, but was representing the international
10 panel, Dr. Worrest you are here representing EPA. We are
11 looking forward to hearing from you.

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1 STATEMENT OF ROBERT WORREST, PROGRAM MANAGER,
2 STRATOSPHERIC OZONE RESEARCH PROGRAM, U.S. ENVIRONMENTAL
3 PROTECTION AGENCY, WASHINGTON, D.C.

4 Dr. Worrest: Thank you, Mr. Chairman.

5 I welcome the opportunity to participate in this
6 discussion. You have requested that I provide you with some
7 of my background as well as some of the information regarding
8 the Agency's ongoing stratospheric ozone research program.

9 Senator Gore: That is correct. And I should add that,
10 in addition to speaking for EPA, you are also speaking in your
11 own right as a researcher and scientist in this area and we
12 look forward to hearing about that too.

13 Dr. Worrest: As you mentioned I am the program manager
14 for EPA's Stratospheric Ozone Research Program, as well as its
15 Global Change Research Program. Prior to coming to
16 Washington, DC to EPA headquarters I was a professor of
17 radiation biology at Oregon State University and carried out
18 research there addressing the effects of solar ultraviolet
19 radiation on components of the marine echo systems.

20 Since coming to Washington, DC I have taken on the
21 management of the two research programs that I mentioned. In
22 addition, I participated as co-author in the 1989 UNEP Effects
23 Environmental Effects Panel Report as well as for the 1991
24 update, as mentioned by Dr. Watson, even with an immediate
25 phase out of all CFC's and related compounds, current levels

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1 of clearing loading in the atmosphere commit the world to an
2 unavoidable decrease in stratospheric ozone well into the next
3 century.

4 As mentioned in your opening statement, Mr. Chairman, the
5 ecological and human health research must be pursued in order
6 to develop adaptive strategies to the inevitable ozone
7 decrease before any potential serious problems arise. The
8 goal of EPA's stratospheric ozone research program is to
9 provide policy relevant information and to yield early
10 warnings of potentially dangerous impacts of ozone depletion.

11 To develop such information the Agency's research program
12 focuses on the impacts of ozone depletion in areas that have
13 global implications such food production and human health.
14 EPA's research program is part of an overall inter-agency
15 coordinated program with the federal coordinating council on
16 science, engineering, and technology committee on earth and
17 environmental sciences. It involves such agencies as NASA,
18 USDA, DOE, and SF, the National Marine Fisheries Service, the
19 National Institute of Environmental Health Sciences and many
20 others. The scope of EPA's Stratospheric Ozone Research
21 Program ranges from, as I mentioned, human health effects to
22 the biological implications of ultraviolet radiation changes
23 at the earth's surface.

24 Particular attention is given to the impact on food
25 production in developing world and to the development of crop

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1 varieties resistant to higher levels of ultraviolet radiation.
2 Specific research topics are Human Health, Wetland Rice
3 Ecosystems, Marine Ecosystems and the Atmospheric Transport
4 and Fate of the CFC Substitutes and their degradation
5 products. I have submitted, for the record, a more detailed
6 description of EPA's research and I look forward to
7 participating in the discussion that follows. Thank you.

8 [The prepared statement of Dr. Worrest follows:]
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1 Senator Gore: Thank you very much. Speaking for EPA, I
2 would like to know what you have to say about the question
3 that I put earlier to Dr. Anderson, Section 6 of the Clean Air
4 Act which calls for the phase out of chlorofluorocarbons
5 imposes on the administration a legal requirement to
6 accelerate the phase out, if and when significant new data
7 showing that the health and environmental effects are worse
8 than known when the Act was passed become available.

9 The Administrator of the EPA, Bill Reilly, said publicly
10 that he felt we should accelerate the phaseout back in April
11 when the first report was submitted. I do not know if his
12 words were in the context of specifically addressing the
13 section 606, I doubt they were but he made that general
14 statement.

15 And then after the April report we have had the October
16 22 report, just as one Member of the Senate, it seems to me
17 that these two new reports, the first saying that depletion
18 was taking place 200 percent faster than thought and the
19 second one including these dramatic new findings about the
20 health and environmental impact of the extra ultraviolet
21 radiation seem to me to trigger the provisions of the law
22 which require the administration to accelerate the phase out
23 of the chemicals that are causing all this damage.

24 Has the EPA recommended to the President that the phase
25 out schedule be accelerated?

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1 Dr. Worrest: I took note of the question when you asked
2 it to Dr. Anderson and I must apologize but I am in the Office
3 of Research & Development. I did take note of it and I
4 promise that we will get back to you to address that issue.
5 But I cannot address it as being the scientific arm or the
6 research arm of the Agency, rather than the policy.

7 Senator Gore: Just to turn up the heat a little bit, we
8 anticipate another vote shortly and we have a telephone here
9 at your disposal. If you could call during the break and get
10 a yes or no answer on whether that recommendation has been
11 made, or else, if you want to claim some other, and this is
12 not directed to you personally, Dr. Worrest, I hope you,
13 understand that.

14 Dr. Worrest: I do sir.

15 Senator Gore: I have deep respect for you. You might
16 even agree with what I am getting at, I do not know. If you
17 could formally ask them for a yes or no answer and get them to
18 give some other excuse or else answer it, I would appreciate
19 that. You know is the 1-year anniversary of the signing of
20 the Clean Air Act and the President is celebrating that
21 success, even as he stands in my view, in violation of the
22 law. My colleague, Senator Exon.

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1 STATEMENT OF HON. J. JAMES EXON, U.S. SENATOR FROM
2 NEBRASKA

3 Senator Exon: Mr. Chairman, thank you very much. First
4 I just wanted to compliment you as a Member of this committee
5 and as one of your colleagues on the Senate for calling for
6 this type of a discussion.

7 I guess I must say that I suspect that the very young
8 people of America, grade school kids, seem to be more upbeat
9 and more concerned about what is facing us in the future than
10 many of the adults. Thanks to you, Mr. Chairman, in your
11 leadership in this area.

12 I just wanted to ask a question or two and first say that
13 as one who has been very much concerned about this for many,
14 many years evidently we are beginning to come to a head and I
15 think it is proper indeed, Dr. Worrest, that we have some
16 definitive decisions from the administration on this because
17 unless there is some leadership on this, over on the
18 administration side we are probably not going to get into the
19 remedies as expeditiously as we otherwise should.

20 While saying that I have been concerned about this for a
21 long time, I must tell you that as a Senator from Nebraska, a
22 leading agricultural state, it really got my attention when I
23 read some time ago that unless this warming change was stopped
24 the Corn Belt could move north up into Canada and I do not
25 want the Corn Belt to move north up into Canada, for totally

1 selfish reasons. Nevertheless, that indicates I guess far
2 better than some of the other materials that I have read and
3 looked at as to the potential, dramatic effect on the warming
4 trend.

5 My first question, though is that I suspect that most of
6 you around this table this morning, feel as many of us do that
7 this is a very serious problem. We better get on with it. Is
8 there anyone here at the table this morning that represents a
9 point of view that I have heard expressed in your field that
10 this may be over exaggerated. Is there any body of thought in
11 the scientific academia world at all that maybe we are paying
12 too much attention to this? I suppose there is no one around
13 this table that wishes to take that point of view, is there?

14 Dr. Tilford: Sir, I do not think there is anyone around
15 the table who would make any disagreement with respect to the
16 ozone issue. I think there is an element in the scientific
17 community that yet have uncertainty and have expressed such on
18 the magnitude and rate of global warming. But I do not
19 believe there is any part of a community that does not believe
20 that, based on fundamental physics, as we increase the
21 concentration of carbon dioxide in the atmosphere that it will
22 cause an enhanced greenhouse effect.

23 Senator Exon: How about Dr. James Zumberg that I suspect
24 some of you know of or have heard of. Does he agree, at this
25 point in time, with your viewpoint?

1. [No response.]

2 Senator Exon: Does anyone know Dr. James Zumberg?

3 [No response.]

4 Senator Exon: Well, I am surprised. A former key
5 official of the University of Nebraska at Omaha, most recently
6 head of one of the major universities in California, but if
7 you have never heard of him, maybe I could get some
8 information to you. I took it that his point of view was not
9 exactly the point of view that had been expressed around the
10 table this morning. But in any event, let me ask this
11 question. I noticed that you said, Dr. Tilford, that we
12 needed to have a long range steady support for research. I
13 believe you also said that for the most part you hoped this
14 would be outside the government per se in private industry, or
15 did I misunderstand you?

16 Dr. Tilford: No. My implication was and it was based on
17 a question that was initiated by Senator Gore, that through
18 perception at least, when an agency that has both regulatory
19 responsibility and research responsibility for both doing the
20 research and passing regulations with respect to the outcome
21 of that research, there is frequently either perceived and in
22 some cases unfortunately, real, the charge that some of the
23 research results might have been torqued because of particular
24 opinions of some individuals or some administrations. I think
25 an independent, scientific assessment with the maximum

1 utilization of the scientific community is extremely important
2 and provides the maximum amount of credibility.

3 On the other hand, I do not believe that such research
4 programs can be carried out without the resources of the
5 integrated agencies of the federal government, with the
6 federal government laboratories playing an important part.

7 Senator Exon: As a follow-up to that, then, and this is
8 my last question. Given the fact that we potentially have a
9 very serious long-range problem on our hands that we must
10 address, given also the situation that we have serious budget
11 constraints that all of us who make these decisions have to be
12 alert to, could you, very shortly -- Can you give me an idea
13 of what the cost might be on moving ahead, short range and
14 long range on this proposition from the standpoint of research
15 and development and particularly with costs to the federal
16 government, is it in the millions of dollars a year for 10 or
17 20 years. Is it in the billions of dollars for 10 or 20
18 years? And if so, is it one million, or five billion, or ten
19 billion or more?

20 Dr. Tilford: Well first, Senator, this is not a United
21 States problem by itself. This is an international problem.
22 In addressing it we must address it from an international
23 level. The committee on earth and environmental science as
24 part of a fix-it process, have been putting together a plan
25 over the last few years. My personal assessment of what it

1 takes on an international basis to address the problem at the
2 same rate that we have addressed the ozone problem in the last
3 15 years, is greater than \$1 billion and it is less than \$10
4 billion --

5 Senator Exon: Less than what?

6 Dr. Tilford: Ten per year. It is a big program you have
7 heard around this table.

8 Senator Exon: You are talking billions now.

9 Dr. Tilford: I am talking billions. Right now the
10 United States spends approximately \$1 billion per year on
11 global change research. I had better check that, billion?
12 There is many, many things that still are not being
13 accomplished, as you have heard around this table this morning
14 with respect to simply understanding the impact and effects of
15 ultraviolet radiation on biological systems, we do not have
16 enough research going on to quantify in many cases or model,
17 with any degree of precision, what may happen in the next
18 decade.

19 Senator Exon: Well, that is fine. I guess that is what
20 I wanted to know. My experience has been that when the world
21 takes on any kind of an enterprise the United States of
22 America pays the substantial part, if not most, of the bill.
23 So I guess then, can we get any range. The experts here, if
24 we are spending a billion now, it has got to be more than
25 that. Would you say that \$5 billion a year for the next 10-

1 20 years would be a ball-park figure that we should recognize?

2 Dr. Tilford: I think that is a very reasonable estimate.

3 Senator Exon: Any objection to that around the table.

4 Dr. Watson: No. I think that is probably very close.

5 We have to look at the inter-relationships of issues such as
6 global warming, ozone depletion, loss of bio diversity and an
7 even more critical one and that is water scarcity throughout
8 the world. Each of these issues are highly inter-related.
9 They all change naturally. They all change in response to
10 human activity. It does take an international effort and the
11 number of around \$5 billion a year is probably what it will
12 take if you want answers for wise policy formulation.

13 Senator Exon: Thank you very much. Thank you Mr.
14 Chairman.

15 Senator Gore: Thank you Senator Exon. The Ranking
16 Republican on our subcommittee is of course Senator Pressler.
17 Senator Pressler.

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1 STATEMENT OF HON. LARRY PRESSLER, U.S. SENATOR FROM
2 SOUTH DAKOTA

3 Senator Pressler: Thank you very much Mr. Chairman.

4 Let me first ask a general question, sort of a layman's
5 question. And that is, is the not the United States doing
6 more than any other country in the world -- and I suppose we
7 are, but it seems that I always get newsclips from these
8 international conferences and so forth that the United States
9 is sort of condemned for not doing more.

10 It is kind of like I was in Europe this weekend at the
11 Food and Agricultural Meeting and I wanted to talk about the
12 level of subsidies that the Europeans have on their
13 agricultural products compared to ours and they turned the
14 tables on me and starting talking about hormones, and so
15 forth, which I could talk about to. I was not prepared to
16 very well, and I would like EPA to -- we are doing a lot of
17 things I am just talking here as a kind of a layman but it is
18 kind of confusing because in these conversations I say, well
19 we are not doing enough.

20 And you point out that the United States is doing these
21 things and they say, well, the United States should pay for
22 the Third World countries to do them and it becomes -- all the
23 burden is on us and indeed a lot of the burden should be on us
24 -- but I just wanted somebody to respond to that. I think a
25 lot of people are a little confused.

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1 Can anybody respond to that?

2 Dr. Tilford: My estimate is, in the ozone research of
3 the U.S. probably supports something around 80 to 85 percent
4 of the research -- ozone research -- in the world. I think,
5 with respect to global change research, the number is somewhat
6 less than that. I would still say it is significantly greater
7 than 50 percent.

8 Senator Pressler: Does anyone else want to comment on
9 that general subject?

10 Dr. Worrest: As far the effects or impacts compounded of
11 the stratospheric ozone program, the U.S. probably spends as
12 much as some of the other foreign countries, but it is nowhere
13 near half -- anywhere near 50 percent of a total global,
14 worldwide budget for stratospheric ozone impact studies. We
15 have a program that is around \$5 million to \$6 million a year
16 for the effects component, which is somewhat of a drop in the
17 bucket compared to some of the other countries, especially
18 when you total all the other budgets together.

19 Senator Gore: Can I interject a question there?

20 Senator Pressler: Sure.

21 Senator Gore: It strikes me that there is such a
22 difference between sharing the burden for research and sharing
23 the burden for actually responding to the problem. If our
24 national strategy is to -- and certainly no Member of this
25 committee feels this way -- but if our national strategy as a

1 whole is to emphasize the uncertainties and pretend that it is
2 not yet time to really do anything to solve the problem --
3 then we would naturally put more emphasis on research, and
4 other countries would put more emphasis -- as they are doing
5 -- in responding to the problem.

6 And I was just wondering -- Dr. Watson for example -- if
7 you could estimate the percentage that we contribute to the
8 problem and the percentage of the world's response that we are
9 contributing.

10 Dr. Watson: In the CFC ozone issue, until a few years
11 ago we probably emitted probably about 30, 35 percent of the
12 global CFC emissions. We are, with the Europeans, phasing out
13 probably about an equal rate. We took the leadership role, of
14 course, in 1978 with the aerosol ban, and that was not
15 followed in Europe. However, since that time I would say I
16 have seen now leadership -- both in Europe and in the U.S.A --
17 to phase out to the point we are.

18 However, where we are today is -- additional phaseout of
19 CFC's, halons and methyl bromides as desperately needed if we
20 are to minimize future ozone depletion. This is an
21 opportunity for the U.S. to take a leadership position, if
22 indeed, it wants to minimize future ozone loss.

23 With respect to global warming, we clearly emit somewhere
24 between 20 and 25 percent of the world's emissions of carbon
25 dioxide. Clearly one of the -- obviously it is an individual

1 guess -- is the most single important greenhouse gas. As you
2 yourself know, the U.S. at this moment in time is committed to
3 a series of actions, but is not committed to any particular
4 goals and time tables for emissions controls on CO2.

5 Senator Gore: Sorry to interrupt Senator Pressler.

6 Senator Pressler: That is all right. Under the Montreal
7 Protocol, 70 industrial countries -- including the U.S. --
8 have committed to phase out CFC's by the year 2000. Now do
9 these latest findings regarding ozone depletion during the
10 summer months force us to consider an earlier phaseout
11 deadline?

12 Dr. Watson: I personally believe the answer is yes. The
13 summer period clearly is the time when you have maximum UV
14 exposure at the earth's surface. We have heard from the
15 impacts panel that indeed if you have more UV at the earth's
16 surface we will expect the incidence of skin cancer to
17 increase. I believe these latest findings do show there is
18 indeed a need to increase the rate of phaseout -- I said
19 earlier, not only of the CFC's, but all chlorine and bromine
20 containing compounds. And in addition, we need to have some
21 restrictions also on the use of the substitute compounds --
22 the hydro-CFC's -- as we move in the future.

23 I should note one of the largest producers in the world,
24 Dupont, is already on record saying that they, as an industry,
25 believe we need a faster phaseout of the CFC's. They also

1. believe we need international regulations on fluorocarbon-22,
2. which is one of the substitutes that is currently being used.
3. So I do not believe it is just the scientific community that
4. recognizes the importance of this issue. But it is also
5. shared, at least in part, by some major parts of U.S.
6. industry.

7. Senator Pressler: Now following that up, the EPA
8. analysts estimate that some 12 million Americans will develop
9. skin cancer over the next 50 years due to the ozone depletion.
10. How will the latest ozone depletion findings affect those
11. estimates?

12. Dr. van der Leun: Perhaps I may answer this question.
13. The latest estimate is that for every 1 percent of ozone loss
14. we will have 2.3 percent more incidence of skin cancer. And
15. that adds up like compound interest. 10 percent loss will
16. lead to a 26 percent increase, and it goes steeper up as you
17. go to larger depletions.

18. Senator Pressler: The University of Maryland has
19. conducted research showing that ozone depletion may adversely
20. affect crops such as soy beans and rice. What is the latest
21. information about the crop damage that may be caused by ozone
22. depletion, and could ozone depletion place the world's food
23. security at serious risk?

24. Dr. Teramura: Well basically that study was completed in
25. 1986 on soy beans, and that work was stopped. There was not

1 further funding to continue with that work. Some work was
2 begun on rice and that work is only in the preliminary stages
3 but seems to suggest that increases in ultraviolet radiation
4 can reduce the vegetative growth of rice as well as the yield
5 of some rice varieties. Maybe a third to one half of the rice
6 varieties that have been examined thus far.

7 But more importantly, rice is also a crop that seems to
8 be grown under flooded conditions. And under flooded
9 conditions, you have a tremendous amount of methane produced.
10 It seems that with increased levels of ultraviolet radiation,
11 you change the structure of the rice plant to a structure
12 which may result in increased fluxes of methane through the
13 rice plant itself. But that has not been substantiated. That
14 is only a very preliminary laboratory study that seems to
15 suggest that.

16 Senator Pressler: Let me ask -- this is a question from
17 Senator Lott and there are several questions here but I have
18 been trying to get this tied together into one or two
19 questions, so I will just read his little memo here. This is
20 a question for Dr. Watson and it says the IPCC's scientific
21 assessment published in July of 1990 lists you as one of the
22 lead authors of the report. You are first person named among
23 the authors of chapter 1 of that report entitled, greenhouse
24 gases and arsenals. Am I correct about that. We will just
25 assume that you were here -- I am just speeding this up a

1 little bit.

2 You are also described in a New York Times article of
3 October 23rd as being co-chairman of scientists who prepared
4 the WMO/UNEP scientific assessment of stratospheric ozone 1991.
5 Was that a reasonable and accurate characterization of your
6 role regarding the new ozone report. We will assume it was.
7 To get to the real question -- this is like a trial lawyer
8 here --

9 [Laughter.]

10 Senator Pressler: I will answer the questions as I go
11 here. Now a very significant element of the new study
12 concerning ozone appears to be that of depletion of
13 stratospheric ozone caused by CFCC's will offset in whole or
14 to a large degree the warming that otherwise would be caused
15 by CFCS's and might even offset some of the warming potential
16 caused by the other greenhouse gases. Is that a fair
17 characterization on the part of the new report? And we will
18 say that it is.

19 Dr. Watson: Not quite.

20 Senator Pressler: Not quite, okay.

21 [Laughter.]

22 Senator Pressler: But let me just keep going here so I
23 get this done, and then you can make notes here because this
24 is another page -- because this leads to a very good,
25 interesting point. It is my understanding that estimates of

1 present and future concentrations of CFC's in the atmosphere
2 were incorporated in the climate models that were the basis of
3 IPCC's prediction last year that global temperatures were
4 going to increase over the next century. Is that correct. We
5 will assume it is, but you can expand upon it.

6 Number 5, now you are quoted in the October 23, 1991 --
7 we are finally getting to it here -- now you are quoted in the
8 October 23, 1991 issue of the Wall Street Journal as saying it
9 is not clear whether CFC's have warmed the atmosphere or not.
10 Indeed, a Reuters dispatch from Geneva quotes remarks by -- it
11 must be Rumen Bojkov -- who is described as head of the
12 environment division of WMO as follows: "At the moment on
13 balance it" referring to the ozone depletion of the lower
14 stratosphere "is having a cooling effect which our model says
15 is offsetting 20 to 25 percent of global warming."
16 Furthermore, the November 2, 1991 issue of Science News quotes
17 your colleague at NASA, Dr. Jim Hansen, as saying it is fair
18 to say that it is indeed confirmed that the ozone changes
19 cause a cooling. If that is true, then most of the
20 simulations somewhat overestimate the expected greenhouse
21 warming.

22 We are almost through. The article goes on, including
23 the new information on ozone loss, made lower predictions of
24 global temperature increase by about 20 percent. Hansen
25 speculates it is not a tremendous change but it is

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1 significant, he says. Now do you agree with these statements
2 by Dr. Bojkov and Dr. Hansen? And if you agree with them, are
3 we not faced with the situation where the IPCC has overstated
4 the prediction of future temperature increases?

5 And it goes on, incidentally in the Reuters dispatch that
6 quoted Dr. Bojkov he said that our models were showing a 20,
7 25 percent offset to global warming in the stratospheric ozone
8 depletion. The executive summary report released by WMO and
9 UNEP makes no mention of a model that produced quantitative
10 results, much less than figures cited by Dr. Bojkov. Can you
11 tell us why the executive summary failed to do so, and -- just
12 one moment because I think all this boils down.

13 The same article in Science News that I mentioned
14 earlier, Dr. Hansen is quoted as saying none of the
15 sophisticated climate models used to predict global warming
16 has taken into account the lower stratospheric ozone loss. If
17 that is the case, should not the general circulation models to
18 be relied on by the IPCC in the future be reconfigured so that
19 they can accurately characterize atmospheric dynamics by
20 incorporating the cooling effect of stratospheric ozone
21 pollution, whatever it may be.

22 Now I assume simpler models as distinguished from
23 sophisticated models, could not adequately incorporate the
24 interaction between stratospheric ozone depletion and the
25 other aspects of atmospheric dynamics pertinent to the

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1 potential climate change. Please tell us whether this is a
2 generally valid assumption, and in any event could you give us
3 your best estimate on how much additional research and
4 analysis, and how much time would be required, to reconfigure
5 the more sophisticated general circulation models so they can
6 accurately characterize atmospheric dynamics by incorporating
7 the cooling effect of stratospheric ozone depletion?

8 Dr. Watson: Fine, there is only actually about one
9 question in there in reality.

10 [Laughter.]

11 Dr. Watson: What the report stated was that a decrease
12 of ozone near the tropopause would indeed change the radiated
13 balance of the atmosphere. To put it simply, CFC's -- when
14 you put them into the atmosphere -- lead to a warming of the
15 earth's surface insofar as they increase the greenhouse
16 effect. What we are saying is that ozone has decreased near
17 20 kilometers due to chlorine and bromine containing
18 compounds, of which about half of that chlorine and bromine
19 comes directly from the long lived CFC's. We are saying that
20 decrease of ozone around 20 kilometers could cool the
21 atmosphere around 20 kilometers. And that would change the
22 radiative effects of the atmosphere.

23 So there could be some offsetting effects of the ozone
24 decrease with respect to CFC's. In fact we looked at
25 different latitudes and different seasons, and we find that

1 some latitudes and seasons -- there is a decrease of the
2 radiative forcing -- that is the downward heat into the
3 troposphere -- more than compensates the CFC's.

4 So indeed there could be an offsetting effect of the
5 radiative balance. In fact we believe those models are not
6 good enough to say there is an offsetting effect of radiation
7 at the tropopause. The key question now is, what happens at
8 the earth's surface? We need to do exactly what Jim Hansen
9 suggests, and that is we need the full climate models -- they
10 are three-dimensional models -- that look both at the
11 radiative effects of CFC's, the radiative effects of ozone --
12 to see what the final impact is on surface temperature.

13 It could well be that the ozone decrease near the
14 tropopause has indeed completely offset the direct radiative
15 effects of CFC's. It could well be, and if so it means that
16 the radiative forcing during the 1980's was indeed 25 percent
17 less than we thought. The reason was, CFC's themselves were
18 thought to be 25 percent of the direct radiative forcing
19 during the 1980's. That is one extreme case.

20 If indeed, however, there are some dynamical feedbacks
21 between the change of radiation at the tropopause and the
22 earth's surface, it could be that that is too much of a
23 compensation. We cannot state that with any accuracy at the
24 moment. So one way to say it is -- the CFC's could well be
25 climate neutral -- they could well be climate neutral. It is

1 also possible they are still CFC's -- they are still
2 greenhouse gases but with less of a direct effect than we
3 previously thought.

4 So if one says, should the IPCC take a full model
5 calculation into account the answer is yes, it will be done,
6 if at all possible, for the next IPCC assessment in January.
7 I am also co-chair in that part of the assessment. And in
8 fact, Jim Hansen has promised to do that sort of calculation
9 -- it is actually being funded by EPA. Jerry Marmon (***?) at
10 GFDL with Ramos Rami are also going to try to do the same sort
11 of calculation. And so is the British met office.

12 So there are three major climate modelling groups in the
13 world at the moment who are also quickly trying to find out
14 whether or not a simple assessment is going to turn into a
15 real change in surface climate due to ozone loss. And did the
16 IPCC take into account a growth of CFC's into the future? The
17 answer was yes. It was unfortunately a rather simple
18 scenario, that in my opinion always overestimated the impact
19 of CFC's insofar as it did take into account the London
20 revisions to the Montreal Protocol, which meant that the
21 growth figures that they had in the IPCC assessment was
22 somewhat too large. They only had the control measures of the
23 original London convention.

24 However, let us put it this way. Even in the old IPCC
25 report, we did assume at some stage CFC's were going to sort

1 of start to -- not phaseout -- but phase down. And so the
2 point is, as you move further and further into the future, CO2
3 was always predicted to be a larger and larger share of the
4 greenhouse forcing.

5 Now there is some good news here. Let us not look at
6 this as all bad news. If indeed we have overstated the role
7 of CFC's, then indeed there is some good news. It does indeed
8 mean global warming will be somewhat less than we predicted.
9 But let us say we totally took out the contribution of CFC's
10 -- the extreme case for one second -- it is still 75 percent
11 of what we predicted for the 1980's and it would still be
12 something like 80 to 85 percent of what we predicted by the
13 year 2050.

14 So if we were predicting a temperature change between 1.5
15 and 4.5 degrees by, say, 2050 -- we are now down to 1.25 to
16 say 4 degrees by 2050. So indeed there may be a slight
17 overestimate, but it does make the global warming issue go
18 away. The administration, industry, and the rest of the world
19 have to come to grips with the fact that the models predict
20 there will a surface warming in response to greenhouse gases
21 -- of which CO2 is the single most important gas.

22 Having said that, we all recognize that there are number
23 of uncertainties associated with the carbon cycle, as Dr.
24 Patrinos said. The role of clouds and the role of oceans.
25 The problem is -- how do you have international and national

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1 policy formulation in the face of significant scientific
2 uncertainties?

3 But we must remember -- just like the CFC issue -- CFC's
4 have indeed destroyed ozone. Certainly in Antarctica and
5 almost certainly at mid-latitude. That ozone loss cannot be
6 recovered for many, many decades. The ozone hole will not
7 disappear until after the year 2050. If CO2 and the other
8 long-lived gases like nitrous oxide are changing the earth's
9 surface temperature, and we do not like that, if we wait for
10 cause and effect to be established, it will take many decades
11 -- if not centuries -- to reverse damage to the global climate
12 system.

13 Senator Pressler: So the models could be 20 to 25
14 percent offset.

15 Dr. Watson: Correct.

16 Senator Pressler: Good. Thank you very much Mr.
17 Chairman.

18 Senator Gore: Thank you. Just to follow-up on that just
19 for a moment -- if the role of CFC's in warming the earth must
20 now be called into question -- first of all, Dr. Patrinos, you
21 say in your statement at the conclusion, for the reasons
22 stated DOE believes that caution should be exercised before
23 policy conclusions are drawn.

24 The administration has drawn policy conclusions in
25 stating that it will meet its responsibility to submit a plan

1 for reducing global warming gases by relying on the already
2 undertaken obligation to remove CFC's. If it now uncertain
3 that the removal of CFC's will reduce global warming, then the
4 administration has no plan for reducing global warming gases
5 except one that emphasizes this uncertain physical principle.
6 Do you understand my point?

7 Dr. Patrinos: I understand. That is certainly a very
8 big if, Senator. I would like to --

9 Senator Gore: But the burden of the if is now on the
10 administration because the administration is saying our policy
11 for responding to global warming is to remove the CFC's. And
12 as you say, there is a big if about whether that is effective
13 in responding to global warming. So the burden is shifted,
14 and the administration is now putting all of its eggs in that
15 basket -- or virtually all of them -- when it is now uncertain
16 as to whether that has any effect on global warming.

17 Dr. Patrinos: Senator, the if I was referring to was
18 related to the scientists that in the next few months will
19 apply those more sophisticated climate models, and will
20 translate the potential change in the radiative forcing into a
21 potential climate change. I certainly am not convinced that
22 we will see that particular result -- certainly not on the
23 basis of the evidence I have seen so far. It may be true that
24 the offset has indeed taken place and will take place. But on
25 the basis of what I have seen so far, I cannot conclude that.

1 Senator Gore: I think that is certain fair. But I think
2 my point is also accurate -- that the U.S. Government cannot,
3 with confidence, claim quantitative credit for CFC reductions
4 as a strategy for coping with global warming. The same may
5 also be true for reductions in NOX, carbon monoxide, and non-
6 methane hydrocarbons.

7 But the administration -- and I do not say this about you
8 as an individual at all -- but it is my assessment of the
9 administration that there has been a tendency to always wait
10 for the next study and always wait for more evidence before
11 actually doing anything. And the one thing that it has said
12 it is doing, is reducing CFC's by the year 2000. Now we find
13 that is not with confidence going to do anything about global
14 warming. It may turn out to -- you may be right about that.

15 Dr. Patrinos: Can I respond?

16 Senator Gore: Sure.

17 Dr. Patrinos: I guess I would like to make a very sharp
18 distinction between the stratospheric ozone depletion and CFC
19 connections, and that of Carbon Dioxide and other greenhouse
20 gases and climate change. I think the smoking gun in the case
21 of stratospheric ozone depletion has been found -- and
22 certainly the administration has taken a very proactive role
23 to do away with CFC's as I have said in my remarks.

24 We have found no smoking gun in the climate change.
25 There is still considerable uncertainty whether climate change

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1 has taken place, and there is very much uncertainty about the
2 rate and the magnitude of the change. Certainly I agree that
3 -- given a closed system -- if we continue to pump in
4 greenhouse gases there will be a change in the radiative
5 balance. But the rate and magnitude of that change is very
6 important. And one should take account of a potential
7 adaption of living systems in a very slowly changing climate.

8 Senator Gore: Of course their ability to adapt may also
9 be affected as Dr. Teramura and others -- Dr. Weiler and Dr.
10 van der Leun have said -- by the simultaneous expose to very
11 high levels of ultraviolet radiation.

12 Dr. Patrinos: Absolutely.

13 Senator Gore: The discussion today is primarily about
14 the ozone report, but I would not want to leave the record
15 there with any implication that Dr. Tilford is wrong, for
16 example, in saying that extra CO2 will produce warming. I
17 think he is accurately stating the world scientific consensus
18 on that point. You do not disagree with that, do you?

19 Dr. Patrinos: I do not disagree. I would disagree with
20 the rate and the magnitude.

21 Senator Gore: Yes, well as we continue to double the
22 amount of pre-industrial CO2 levels in the space of the next
23 several decades, it seems to me to be extremely foolish to
24 assume that there will not be major climatic consequences and
25 that is the conclusion the world scientific community is also

1 arrived at. But let me shift back to this -- to our main
2 topic of discussion here.

3 On ozone depletion and extra ultraviolet radiation -- I
4 am a little unclear about how much extra ultraviolet radiation
5 we can expect to get over the next several decades. Am I
6 correct -- Dr. Watson, Dr. Albritton and others who wish to
7 jump in -- that ultraviolet radiation levels increased by
8 about 3 percent in the last decade, 3 to 4 percent, and will
9 increase by about 5 percent during the decade of the 1990's.
10 Is that correct?

11 Dr. Watson: I am not sure we can say --

12 Senator Gore: Excuse me, ozone -- that is the depletion
13 levels -- the depletion level at mid-latitudes was 3 percent
14 in the 1980's, expected to be 5 percent in the 1990's,
15 correct?

16 Dr. Watson: Of that order, yes.

17 Senator Gore: All right now, during the period prior to
18 1978, when the measuring began, is it fair to say that there
19 was an additional depletion of stratospheric ozone at mid-
20 latitudes beginning 50, 60 years at very low levels, when these
21 chemicals were first introduced into commerce?

22 Dr. Watson: The amount of ozone depletion, say before
23 1960, would have had to be extremely small because as you have
24 really pointed out, the levels of chlorine and bromine were
25 extremely small. There was certainly some ozone depletion

1 during the 1970's -- at least in winter.

2 And so the point would be -- in fact we have it in our
3 table here -- that between 1970 and 1991 the number was close
4 to 6 percent total depletion in winter. In the summer it is
5 not obvious whether there was any significant ozone depletion
6 in the summer period. So we have looked at our temperature
7 record -- both summer and winter -- and it is very hard to see
8 any direct observations of an ozone depletion in summer
9 earlier than 1980. That is to some extent why we are a little
10 concerned, of course -- and that is if there was very little
11 in the 1970's, when of course we still have chlorine -- we
12 have got a significant amount in the 1980's. The question is,
13 is it very non linear and therefore in the 1990's might it be
14 much worse than in the 1980's?

15 Senator Gore: What about in the decade after the 1990's,
16 the decade from the year 2000 to the year 2010, what do you
17 expect to occur then?

18 Dr. Watson: Well even with the amended London version of
19 the Montreal Protocol, the amount of chlorine and bromine in
20 the atmosphere should start to decrease. So that means the
21 chlorine levels will be the same, or less, in say between 2000
22 and 2010 as are between 1990 and the 2000. So I would expect
23 as a first approximation, the decade after the year 2000 would
24 be somewhat similar to the decade 1990 to 2000.

25 Senator Gore: So, 5 percent in the 1990's and another 5

1 percent in the decade to follow, correct?

2 Dr. Watson: To a first approximation, yes.

3 Senator Gore: All right. Now if there has been a
4 cumulative increase -- a cumulative decrease at mid-latitudes
5 thus far -- 6 percent you say, is that your figure? Sherwood
6 Rowland says 10 percent.

7 Dr. Watson: I think Sherry's numbers may be a little on
8 the high side. I would use a number -- at least 6 percent in
9 winter and say, at least 3 percent in summer. So at least 6
10 in winter, 3 in summer.

11 Senator Gore: All right, let us go with 6 percent in
12 winter up to 1990. Then you have an extra 10 percent during
13 the following 20 years. We are then looking at further
14 decreases in the years following 2010, correct?

15 Dr. Watson: Yes, it is smaller but still -- indeed,
16 decrease is correct.

17 Senator Gore: All right, so the biological effects that
18 we have heard about here today from Dr. van der Leun and Dr.
19 Kripke, Dr. Teramura, Dr. Weiler -- are effects that are being
20 observed at the current levels. And yet the world ecosystem
21 is going to face levels of ozone depletion that are three
22 times the depletion levels that we are facing now. If we have
23 -- Dr. van der Leun -- let us work with a number of 15 to 20
24 percent. Let us stay with 15 percent ozone depletion at mid-
25 latitudes. What percentage increase in ultraviolet radiation

1 is associated with a 15 percent decrease in stratospheric
2 ozone?

3 Dr. van der Leun: This depends very much on the
4 wavelength of the radiation. Some effects are caused by short
5 wavelengths, and then the effective radiation will go up
6 steeply.

7 Senator Gore: What about UVB?

8 Dr. van der Leun: UVB -- the same applies to UVB, but if
9 we specify the effect we are talking about -- for instance
10 skin cancer -- every 1 percent decrease of ozone will give 1.5
11 percent increase of the effective ultraviolet B. But that is
12 different for the different effects. So -- but it is amplified
13 in some of the important effects. The damage to DNA goes up
14 even steeper.

15 Senator Gore: Now, Dr. Teramura, is there any way to say
16 whether the same thing is true with respect to the effect of
17 extra UV-B on plants?

18 Dr. Teramura: As I mentioned in my earlier statements,
19 it's very difficult to make any sort of comprehensive
20 quantitative assessment. We only have less than a half a
21 dozen field studies that specifically examine the effects of
22 UV on crop plants.

23 But if we do go to those specific studies in soybean or
24 in Loblolly pine, for instance, we would guess that a 15
25 percent ozone depletion could result in about a 15 percent

1 reduction in yield in soybean and about a 15 percent reduction
2 in wood production for Loblolly pine trees.

3 Senator Gore: Now Exon had to go to another committee
4 hearing. He might have asked have there been any studies on
5 corn? Have there been?

6 Dr. Teramura: There have been some earlier studies on
7 corn in the early 1980's, before we really had good
8 instrumentation and good technology. Those early studies show
9 very large reductions in corn yield from ultraviolet light.

10 But I think that those were still equivocal.

11 Senator Gore: Dr. Kripke, is there any way to make this
12 same general statement about the effects on the immune system,
13 that is, the more the stratospheric ozone level is decreased,
14 the more damage done in suppressing the immune system?

15 Dr. Kripke: Yes. I think we can say that even for
16 humans. We can certainly say it for experimental animals.
17 We know that with decreasing ozone, we have increasing
18 ultraviolet light. And all of the immunological effects that
19 have been studied are dose-dependent on the amount of
20 ultraviolet radiation.

21 So, as you increase the amount of ultraviolet light, you
22 also increase the amount of immune suppression.

23 Senator Gore: You said earlier that this appears to be
24 unrelated. The effect of this ultraviolet-B radiation on the
25 immune system appears to be unrelated to the presence of skin

1 pigmentation, as skin pigmentation would, for example, affect
2 proclivity to sunburn the skin.

3 This means then that the entire population, regardless of
4 skin pigmentation, is vulnerable to the suppression of the
5 immune system.

6 Dr. Kripke: Yes. I think that's the correct
7 interpretation of that new finding. I should point out that
8 one of the other new findings is that an individual's
9 susceptibility to immunological effects of ultraviolet
10 radiation seems to be genetically controlled and some people
11 are more susceptible than others.

12 So we are not talking about every individual in the whole
13 world being equally susceptible to ultraviolet light. But,
14 what we are talking about is that the individual differences
15 in susceptibility cannot be predicted by looking at the color
16 of someone's skin.

17 Senator Gore: Now, in the case of soybeans and rice,
18 these are annual crops and the damage done is based upon the
19 exposure during a single growing season.

20 But you found, Dr. Teramura, that in the case of pine
21 trees, Loblolly pines specifically, the longer the dosage
22 continued, the more the effects accumulated and the growth of
23 the trees began to be affected even more the older they got,
24 correct.

25 Dr. Teramura: That is correct. As a matter of fact, in

1 the first few years in some regions, we have seen no effect or
2 the effect was so small that it was not statistically
3 significant. But then, over the course of 2, 3, 4, and more
4 years, these cumulative effects began to be significant.

5 Senator Gore: And since the ultraviolet loading is also
6 going to increase steadily year by year, at least to the year
7 2010, that will compound the effect.

8 Now, Dr. Kripke, where human beings are concerned, and in
9 trying to understand this phenomenon, we are more like pine
10 trees than soybeans in the sense that we accumulate it year
11 after year after year.

12 Do the effects also accumulate in human beings?

13 Dr. Kripke: Well, some do and some do not. We certainly
14 know that the damage in the formation of skin cancer
15 accumulates over long periods of time. So the more damage you
16 get from ultraviolet light, the more likely you are to develop
17 skin cancer. The immunological effects are somewhat more
18 complicated because the immune system has ways of
19 compensating. It is a very dynamic system.

20 So there are some immune reactions that may recover in t
21 he face of continued ultraviolet radiation. There are others
22 that can be lost permanently following ultraviolet radiation.
23 So we have a hard time predicting long-term effects of
24 ultraviolet radiation.

25 I should point out that most of the studies in

1 experimental animals are done with relatively short courses of
2 ultraviolet exposure. So again, we are really lacking
3 information here as well.

4 Senator Gore: Now, based on what you know, what do you
5 tell friends who have children who want to go to the beach or
6 want to play outside all the time? Does this effect your way
7 of thinking about things like that?

8 Dr. Kripke: As my children will tell you, the answer to
9 that question is definitely yes. I think it is very important
10 to protect children against damage from ultraviolet radiation.
11 I have seen a statistic recently that about 80 percent of our
12 life time exposure to ultraviolet light occurs during
13 childhood. And there is now some new evidence that some light
14 exposure during childhood may contribute to the formation of
15 melanoma, the dangerous form of skin cancer, as well.

16 So I think it is extremely important to try to protect
17 children as well as adults from exposure to ultraviolet light.

18 Senator Gore: All of us with children are used to
19 thinking about protection against sunburn and this awareness
20 of the cumulative dose relating to skin cancer has begun to
21 sort of sink in a little bit. Do you think about it also in
22 terms of the immune system?

23 Dr. Kripke: Yes, of course, because it takes much less
24 ultraviolet light to disturb the immune system than it does to
25 cause skin cancer. So yes, I think that is very important.

1 One of the recent controversies in this field has to do
2 with the use of sun screen and whether chemical sun screens
3 are actually protective or not against immunological damage.
4 This is very controversial. It appears that some commercial
5 sun screen preparations are effective, others are not. And it
6 is not clear what the reasons for that is.

7 So this is a controversial area. If we are going to tell
8 people it is okay to go out in the sun because you are going
9 to wear sun screen, we really need to be quite certain that
10 that is true for immunological damage as well as for sunburn
11 and skin cancer.

12 Senator Gore: Could you supply, for the record, the list
13 of those that are effective in protecting against
14 immunological damage and those that are not.

15 Dr. Kripke: I could supply that to you out of a
16 literature. I cannot do that now off the top of my head.

17 Senator Gore: No, I mean for the record, not now. I
18 mean as a follow-up.

19 Dr. Kripke: Yes, that is fine.

20 [The information referred to follows:]

21 [COMMITTEE INSERT]

22

23

24

25

1 Senator Gore: Now, there have been some reports from
2 areas in the edge of the ozone hole, such as Patagonia. Are
3 any of you familiar with those? Dr. van der Leun?

4 Dr. van der Leun: I know about ultraviolet measurements
5 in such areas.

6 Senator Gore: I am thinking about biological effects.
7 There have been some anecdotal reports of people who visited
8 the area and talked with hunters and farmers, et cetera.
9 Anybody familiar with those?

10 Dr. van der Leun: Only from newspapers and not from the
11 scientific literature.

12 Senator Gore: All right. All right. Now, Dr. Watson,
13 has your report been extensively peer reviewed internationally
14 or not?

15 Dr. Watson: The answer is yes. The way we did the peer
16 review, there are 11 chapters. Each chapter was prepared
17 typically between two to five scientists. Each chapter then
18 had a peer review of roughly seven individuals.

19 We then went to Switzerland where there were
20 approximately 80 scientists from around the world from about
21 25 countries, developed and developing. Each chapter had an
22 extensive interview for about 4 hours with at least 25
23 scientists. And in most cases, especially in the most
24 controversial chapters like the one on the radiative impact of
25 ozone loss, we had an additional three or four for our session

1 with about 25 scientists.

2 Each chapter was then discussed in detail for at least 2,
3 if not 3 hours each, in the full plenary with 80 scientists.
4 So I would argue it underwent a very thorough peer review.
5 That is more than any single scientist paper that would ever
6 find its way into the literature where typically, a scientific
7 journal would only have one or two reviewers.

8 Now, having said that, I would like to put something on
9 the record, as I made a mistake a little earlier when I was
10 talking to you. What happens is chlorine will increase
11 between now and the year 2000. It will then very slowly
12 decrease with the London amendments to the Montreal protocol.

13 So by say, 2010, someway between 1990 and 1995 and then
14 it will carry on decreasing. The mistake I made -- that was
15 correct -- the mistake was made was ozone depletion will
16 probably maximize about the time of the maximum chlorine in
17 the atmosphere and that was around the year 2000. And then it
18 will tend to maintain.

19 So there should be no significant ozone depletion between
20 the year 2000 and the year 2010. That was a mistake on my
21 part.

22 Senator Gore: Now, no significant depletion or no
23 significant --

24 Dr. Watson: Additional, additional depletion.

25 Senator Gore: So, in other words, the depletion would

1 continue at the same rate.

2 Dr. Watson: Correct.

3 Senator Gore: So there will be additional depletion?

4 Dr. Watson: What I would envision is, by about the year
5 2000, we may have a little more than 10 percent ozone
6 depletion at mid latitudes in winter and somewhere between,
7 let us say, 5 and 10 percent depletion in summer. It would
8 tend to maintain itself at those particular levels and very
9 slowly decrease.

10 Now this is very important, even though the fact it may
11 not get worse, but the fact it maintains, because, as we have
12 just heard, many of the adverse impacts are cumulative
13 exposure to UV, which of course is related to cumulative
14 decrease in the ozone layer.

15 So the mistake I made was there would be a further
16 additional ozone loss between the year 2000 and 2010.

17 Senator Gore: Now, what about the effects of -- I am
18 going to throw a curve ball into this discussion here, the
19 effects of Mount Pinatubo in accelerating this depletion.

20 By way of preface, it is my understanding and you correct
21 me, Dr. Albritton if I am wrong about this, but the reason why
22 the ozone hole occurs in Antarctica and at least not so far
23 anywhere else, although the precursors are in the Arctic, that
24 the reason it is in Antarctica is that there are these ice
25 crystals that are made of a water and nitrogen, I guess.

1 And in the vicinity of these ice crystals, the chemistry
2 of depletion takes place much faster. I am given to believe
3 that when sulfate particles are put way up into the atmosphere
4 as they have been apparently by Mount Pinatubo, that that puts
5 particles into the atmosphere in the mid-latitudes that have
6 the same kind of effect that those ice crystals above
7 Antarctica have, in speeding up the depletion.

8 Unlike those ice crystals, these will stay in the upper
9 atmosphere for only 2 or 3 years probably and then fall out,
10 but because they are there, can we expect an extra ozone
11 depletion because of Mount Pinatubo?

12 Dr. Albritton: You are exactly right. In terms of the
13 fundamental role of ice particles in Antarctica, they serve as
14 a surface in the stratosphere for shifting the chlorine from a
15 less reactive into a more reactive form. And one of the more
16 important points made in the UNEP report is that the same sort
17 of surface reactions may well be the reason that the ozone
18 loss at mid-latitudes is occurring in the lower stratosphere.

19 First, that is the level at which the stratosphere
20 sulfate aerosol layer occurs. Secondly, laboratory studies
21 have demonstrated that ozone depleting reactions can be
22 assisted by sulfate aerosols. And third, our simple two-
23 dimensional ozone loss models, when these laboratory data are
24 included, do explain a good fracture of the additional ozone
25 loss we see in the lower stratosphere.

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1 So yes, the weight of evidence suggest that accelerated
2 ozone losses can occur because of the chemistry introduced by
3 volcanic aerosols.

4 You are also correct in that, unlike the long-lived CFC's
5 which have life times of 50 to 100 years, sulfate aerosols
6 from volcanic activity have a short duration, so with Pinatubo
7 having just occurred and a very large amount of sulfate put
8 into the stratosphere, many, many ozone scientists will be
9 watching during this winter period into the coming of next
10 year, to see if there is a noticeably enhanced ozone depletion
11 due to those particles.

12 Not only does this demonstrate, not only would this
13 demonstrate that the ozone loss in the lower stratosphere is
14 particle-assisted, but it would also help us learn a great
15 deal in terms of what one might expect from this sulfate
16 aerosol layer.

17 Senator Gore: Are we going to have monitors in place to
18 measure any increase in UV radiation due to the eruption?

19 Dr. Albritton: Certainly there are monitors well in
20 place in Antarctica. There are some surface sites and
21 continental sites that are looking at UV radiation, but there
22 is not a network of surface monitors for UV radiation.

23 Senator Gore: I have a lot of soybean farmers in
24 Tennessee. Here we have heard that there may be a 1 percent
25 loss of soybean yields for every 1 percent loss of

1 stratospheric ozone. Here we have an event to which the
2 natural system might have been relatively indifferent before
3 we loaded the atmosphere with all these CFC's and now Pinatubo
4 occurs and there is a chance, you say, a significant, a very
5 significant decrease for the next 2 or 3 years in
6 stratospheric ozone because of this.

7 Do I have to tell my soybean farmers that we do not have
8 adequate monitoring to track this and to tell them what is
9 going to happen to yields, et cetera, worldwide as a result of
10 it?

11 Dr. Albritton: Certainly, there are monitors that can
12 tell how much stratospheric --

13 Senator Gore: They do not grow it in Antarctica though.

14 Dr. Albritton: Right. There are monitors that will
15 follow the aerosol cloud where it is there, certainly, both
16 satellite and ground base observations that will show whether
17 there is an ozone change.

18 Senator Gore: No, I am talking about the UV radiation
19 hitting the surface in areas are comparable to Tennessee and
20 South Dakota.

21 Dr. Albritton: There is no widespread surface network
22 to look at the ultraviolet radiation.

23 Dr. Tilford: But Senator Gore.

24 Senator Gore: How did you know I was coming to you next?

25 Dr. Tilford: Well, I just had a feeling. I think what

1 we have discussed this morning is that a linear relationship
2 between the amount of UV-B that penetrates through the ozone
3 layer. If we have a good measure of the change in the ozone
4 layer, then we have a good measure of the amount of additional
5 UV-B that will hit the top of the troposphere.

6 Senator Gore: Well, but because air pollution interferes
7 with it in ways that are different depending upon the kind of
8 air pollution, we have created so much pollution, we have even
9 polluted our ability to monitor the effects of the pollution
10 itself.

11 Dr. Tilford: In fact, tropospheric pollution offsets the
12 amount of UV-B that reaches the ground. You are perfectly
13 correct in that. But I think, for the most part, a few
14 monitors located throughout the world, will give you a
15 reasonable assessment of that particular aspect.

16 The real crucial issue here, I believe, is will there be
17 a significant ozone change due to Mount Pinatubo, and the
18 resulting aerosol layer that is created from that?

19 Senator Gore: Yes, Dr. Worrest?

20 Dr. Worrest: This has been an issue that has troubled
21 both EPA and the USDA for several years. And the actual
22 monitoring of surface UV radiation to try to ground-truth many
23 of the projections that are coming out for models. The USDA
24 actually is now in the process of implementing their
25 deployment or going through the statistical deployment of

1 their ground-based UV-B monitoring network.

2 So this is an area that although it is not timely for
3 Mount Pinatubo, that if all progresses according to plans that
4 USDA has, there will be at least a rudimentary monitoring
5 network for UV-B radiation in the near future.

6 Senator Gore: Could this spike a UV-B radiation that one
7 would expect if Pinatubo did accelerate ozone depletion for a
8 2 or 3 year period? Could a spike like that, shooting the
9 ultraviolet radiation levels up for a couple of years, have
10 significant biological effects on the systems that all of you
11 have studied? Dr. Weiler, any speculation on that or anything
12 to say on that?

13 Dr. Weiler: On the increase?

14 Senator Gore: Yes.

15 Dr. Weiler: Again, it is extremely difficult to extract
16 information on long-term effects when all we really have at
17 present are the effects of short-term model incubations held
18 at a fixed depth. So we do not really know anything about the
19 long-term effects are, positive or negative, in terms of the
20 organism's ability to protect itself over time or the long-
21 term accumulation of damages.

22 But I think we can, at this stage, predict that
23 increasing UV radiation will be worse. We already know that
24 present levels are bad. And from everything we know about
25 action spectra and biological doses, we can predict that it is

1 bad now and it is likely to get worse. Harder to quantify
2 exactly what that will be.

3 Senator Gore: Now, I mentioned in introducing you that
4 you are familiar with the work of Dr. Ray Smith and his group.
5 He is in the Antarctic now, otherwise he would be joining you
6 here.

7 Could you very briefly summarize what they have to tell
8 us? I know that their study has not been published yet and it
9 is expected to be published in Nature, is it, in the next few
10 months?

11 Dr. Weiler: Science.

12 Senator Gore: Science. Can you give us a preview of
13 what the major findings there are?

14 Dr. Weiler: Basically, one of the things they did is
15 they build a state-of-the-art machine for measuring UV-B
16 radiation in the water column. And with that, they were able
17 to go down and say what the dose was, so when they saw an
18 effect, they could relate it back to the dose. And that is
19 something that is very new.

20 They found that integrated over the water column there
21 was something like a 6 to 12 percent decrease in primary
22 production in the short-term bottle incubations. For an ozone
23 depletion that was equivalent to about 43 percent of what, the
24 depletion was about 43 percent of what would have been there
25 otherwise.

1 So it was a fairly significant amount of depletion. But
2 again, in terms of long-term impact, that is harder to see.
3 Now, it is, the depletion we saw was nowhere near the summer
4 solstice. And again, this ozone hole forms to maximize early
5 October and then gets better as the sunlight in the area
6 increases and as day length increases.

7 So we still do not know what the real impact of that same
8 amount of depletion might be, had it occurred later in the
9 year, more into summer, when the days are longer and the sun
10 higher.

11 Senator Gore: But presumably, its impact is maximized if
12 it occurs during the infancy of the plankton communities, when
13 they are just getting their start for the year.

14 Dr. Weiler: When they are just getting started, correct.

15 Senator Gore: Would that be a reasonable assumption?

16 Dr. Weiler: I am glad you brought that up because the
17 organisms that form the spring phytoplankton are locked up
18 over the winter in the bottom of the ice and so they are
19 extremely shade adapted (1) because there is not much light
20 there at all and (2) because even if they were out and the sun
21 was up, they are buried under ice. So they are very shade
22 adapted, a very shade-adapted community. And as the ice melts,
23 they come out into the sun, just as the time that this ozone
24 is depleting.

25 But the real question is what are the optimal limits of

1 adaptation, as well as what is the time course of adaptation?
2 We just do not know with these shade-adapted cells in the
3 early spring are going to be as more or less vulnerable than
4 those same cells later in the year, presumably more adapted,
5 but then also experiencing a higher radiation level.

6 Senator Gore: But, to summarize, at a minimum, we have
7 evidence that confirms that extra ultraviolet B radiation
8 suppresses photosynthesis by plankton and significantly
9 reduces the productivity of those organisms at the base of the
10 oceanic food chain. That is no longer speculation.

11 Dr. Weiler: At least under these certain conditions --

12 Senator Gore: Very good.

13 Dr. Weiler: We also know that these species vary in
14 their sensitivity and we know that with these same doses, we
15 are seeing DNA damage.

16 Senator Gore: All right.

17 Dr. Weiler: And I would like to mention, in terms of you
18 were asking about monitoring UV radiation at ground level.
19 And I would like to say at this point the U.S. National
20 Science Foundation probably has the best system in the world
21 for measuring ground levels of UV ground-level radiation.

22 And they are located at the Antarctic bases in South
23 American and there is now one in the Arctic. But they have
24 not been able to put them at mid-latitudes because there is no
25 money there for it.

1 Senator Gore: Now, the ones in the Antarctic. Those are
2 not the ones that Mr. Darman is trying to cut out right now,
3 are they?

4 Dr. Weiler: Not that I know of.

5 Senator Gore: Is that the NSF? Are those monitors in
6 jeopardy? Is that part of the fight coming on between OMB and
7 NSF and the Navy? Anybody know that?

8 Dr. Tilford: This could be affected indirectly. That is
9 not the source of the fight.

10 Dr. Weiler: But I would also like to say that it would
11 be extremely valuable to have similar instruments.

12 Senator Gore: At mid-latitudes?

13 Dr. Weiler: At mid-latitudes, and hopefully, hooked up
14 with agricultural stations or with National Science
15 Foundation's research.

16 Senator Gore: But Dr. Tilford said one or two might be
17 enough.

18 Dr. Tilford: I said a number. I did not say one or two.

19 Senator Gore: I misunderstood. How many do you think we
20 would need, Dr. Weiler?

21 Dr. Weiler: Well, it depends on what you wanted to know.
22 But I would think you would at least want to know what the
23 impact is on the crops. I do not know how many agricultural
24 stations there are where there is a significant amount of
25 research.

1 I think at present there are something on the order of 8
2 to 10 long-term ecological research centers with the National
3 Science Foundation.

4 Senator Gore: Dr. Patrinos?

5 Dr. Patrinos: I also would like to report that our major
6 program in global environmental change is the atmospheric
7 radiation change measurement program, which will become
8 operational in April of next year at the Oklahoma/Kansas
9 border. And at that site, along with a variety of other
10 atmospheric radiation instruments, we will be monitoring UV.

11 Senator Gore: Good. Very good. Excellent.

12 Dr. Tilford: There are going to be a series of these
13 stations, too, Senator Gore, over the next 5 years.

14 Senator Gore: We are going to have to wind this down.
15 And Dr. Kripke, I excused early, because she has a farm in
16 Texas that she has to get to, but I will ask her for the
17 record about health affects of research funding she referred
18 to earlier. But we want to include that in the record.

19 [The information referred to follows:]

20 [COMMITTEE INSERT]

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1 Senator Gore: I have a number of additional questions
2 for the record for all of our witnesses here. I would like to
3 ask one more before I close. The findings on ozone depletion
4 that are investigated in these UN panel reports, a chronicle
5 of rapid acceleration that surprised many and seem to describe
6 a nonlinear response which, as I understand, the term means
7 that instead of just sort of slowly and gradually responding
8 the same way each year with an increment next year the same as
9 this year, all of a sudden, there are larger effects that were
10 hard to predict if it was just a slow steady progression.

11 That is troubling. My question is, can it be taken
12 broadly as evidence that there is a tendency of natural
13 systems to behave in a nonlinear fashion in response to
14 insults of the kind represented by injecting CFC's under the
15 stratosphere?

16 And if that is the case, is there some warning there for
17 the way we project the course of global warming which is now
18 commonly described in linear terms as a slow gradual process
19 with next year's increment roughly corresponding to this
20 year's increment. Anybody want to tackle that? Dr.
21 Albritton?

22 Dr. Albritton: Certainly several of the surprising
23 discoveries in ozone have been faster than linear process in
24 the global atmosphere. And certain these are no doubt common
25 in other parts of the global system with reference to global

1 warming.

2 Since the ocean plays such a large role in this, the
3 possibility of change, a rather abrupt change in ocean
4 circulation is certainly one of these possible nonlinearities.

5 Senator Gore: Such as a North Atlantic pump?

6 Dr. Albritton: Yes. I think one thing that we have
7 learned from the ozone saga is that there are scientific
8 surprises that cut in all directions.

9 Senator Gore: Well, I would like to express my deep
10 thanks to all of you witnesses. I have learned a great deal
11 this morning.

12 And in closing, let me say that these earth science
13 roundtables, or rectangular tables, as Dr. Teramura described
14 it, are intended to be a little different from regular
15 hearings.

16 And the level of detail we invite from the scientific
17 witnesses is a little more than is customary at regular
18 hearings. It is my feeling that the dialogue between the
19 scientific community and the policy making community has to
20 change, because the process of change in the ecological system
21 now appears to be so rapid that the current slow pace of
22 change of the policy making system really has to change.

23 We need a nonlinear response in the policy making system.
24 But, unfortunately, where science thrives on uncertainty,
25 politics is paralyzed by it. And as a result, I have put a

1 number of questions designed to go beyond the uncertainty, to
2 try to sketch in some of the general areas of agreement in the
3 scientific community so as to minimize the paralyzing effect
4 of the uncertainty as to details on policy making.

5 To use an example, I come from a state that grows a lot
6 of tobacco. And tobacco is important to our economy. And if
7 you ask a scientist today, I am not a scientist, and again, I
8 am on thin ice here, but it is my understanding that if you
9 ask a scientist today what is the exact causal mechanism by
10 which smoking cigarettes causes lung cancer, they will say we
11 are really not sure exactly what happens, but we know that we
12 can go beyond the uncertainty about those details to a general
13 shared understanding that smoking cigarettes causes lung
14 cancer. And we ought to reduce the consumption of tobacco.

15 There are some people, some of them self-interested
16 because their livelihood is based on the tobacco industry, who
17 still insist loudly and longly that there is no connection at
18 all. I think we are at a comparable stage where the threat of
19 civilization is posing to the global ecological system is
20 concerned. We can have long and heated arguments about the
21 exact details of how our insults to the global environment are
22 causing this damage or that damage, but we are far beyond the
23 stage where it is ethical, in my view, where our obligation to
24 future generations is concerned, beyond the stage where it is
25 ethical to say that there is significant uncertainty about the

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1 fact that we are causing significant damage and that we are
2 injecting the risk of catastrophic damage to the global
3 ecological system.

4 Nowhere is the link between cause and effect more firmly
5 established than in the connection between CFC's, ozone
6 depletion and ultraviolet radiation. But even there, as we
7 have seen, there is some remaining uncertainties.

8 We are steadily eliminating the areas of uncertainty. As
9 we do so, the policy responses must begin. On this day, the
10 anniversary of the signing of the Clean Air Act, the President
11 of the United States stands under a legal obligation to
12 accelerate the phase out of the chemicals that are primarily
13 responsible for all of the damage we have been hearing about
14 today.

15 Whether we speed up the phase out or not, damage will
16 continue to occur. But if we do speed up the phase out, we
17 can avoid some of that damage. Why the President refuses to
18 act is beyond me. I think it has to do with the fact I cited
19 earlier, that politics is often paralyzed by any degree of
20 uncertainty. And of course, it is also paralyzed by any
21 inconvenience that might be cause to powerful players who do
22 not want to see change.

23 And on this anniversary of the Clean Air Act, therefore,
24 I would like to formally call on the President to meet his
25 legal obligations under that law and accelerate the phase out

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1 of these chemicals.

2 Thanks again to our witnesses. We stand adjourned.

3 [Whereupon, at 12:39 p.m., the hearing was adjourned.]

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