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THE WHITE HOUSE

WASHINGTON

December 21, 1990

MEMORANDUM FOR THE PRESIDENT

FROM: D. ALLAN BROMLEY

SUBJECT: Sea Level Rise

The NSC advised us that a sea-level rise issue was raised on your meeting with Pacific Island heads of state last month. Attached is a copy of the NASA report that was discussed in that meeting. Following is a summary of recently published scientific information on sea level rise as well as some facts on U.S. research activity related to this issue.

There are six direct and indirect causes of changes in sea level.

Sea level at any particular place in the ocean varies over time. The direct causes of these variations include vertical land motion and change in the volume of sea water. Indirect causes of changing sea level include: changes in climate, plate tectonics (such as continental drift and similar land mass shifts), ice and snow, and ocean circulation. Climate-related factors that are thought to contribute to sea-level rise include: expansion of the oceans due to temperature increases, and melting of glaciers, small ice caps, and large ice sheets (eg the Antarctic). Sea level rise also varies between different regions of the world. There are areas where sea level rise may be considerably greater than the global average and areas which are less.

Recent scientific evidence predicts some sea-level rise in the next 100 years.

National Academy of Sciences, National Research Council, Sea-Level Change, 1990

> "...On the basis of estimates of global warming of the atmosphere and ocean... One hundred years from now it is likely that sea level will be 0.5 to 1 metre higher than it is at present...."

Intergovernmental Panel on Climate Change WMO/UNEP, Climate Change the IPCC Scientific Assessment, 1990

> "For the IPCC business-as-usual scenario at year 2030, global, mean sea level is 8-29 cm higher than today, with a best estimate of 18 cm. At the year 2070, the rise is 21-71 cm, with a best estimate of 44 cm... Nonetheless, the implied rate of rise for the best-estimate projection corresponding to the IPCC business-as-usual scenario is about 3-6 times faster than over the last 100 years."

Some Pacific Island nations are concerned about sea-level rise.

Some Pacific Island Nations feel particularly vulnerable to the potential for sea-level rise, especially those who live on small islands with less than three metres total elevation. This concern was raised in your meeting with the heads of state and was reiterated in a speech by the Prime Minister of Tuvalu at the Second World Climate Conference two weeks ago. (Tab A)

The U.S. has a solid history of quality research programs on sea level.

Understanding and monitoring sea level is a high priority for the Administration's Global Change Research Program (USGCRP). Some of the activities of the USGCRP include: deployment of stations to measure sea level, global ice sheet observations to monitor changes by remote sensing, regional glacier monitoring, studies of atmospheric and oceanic circulation to estimate temperature change, and studying the geologic record to reconstruct the causes and histories of past changes.

The U.S. has fully participated in the international process which has been examining sea level change. The U.S. has endorsed the United Nations sponsored Intergovernmental Panel on Climate Change (IPCC) as an appropriate mechanism to consider the scientific aspects of climate change. The IPCC has three standing working groups: one on the science of global climate change, another on the impact of such change, and a third on possible responses to changes. The U.S. chairs this third group, called the Response Strategies Working Group. Through these and other programs the U.S. is continuing to work with the international community to provide sound science with which decisions can be made.

The NASA paper on monitoring global change is limited in scope.

Attached is a copy of the article to which you referred during your visit with the Pacific Island heads of state (Tab B). It discusses a recent development by U.S. government scientists, a new technique (passive microwave radiometry from satellites) which provides accurate estimates of global atmospheric temperatures.

Previously, it was believed to be impossible to maintain the calibration of satellite instruments over an extended period of time. Studies have shown otherwise, opening up the entire planet to precise temperature and other measurements, rather than just part of its land area.

The paper did conclude that there was no detectable climate change based on the last ten years of date from this new technique. However, climatologists believe that 30 to 500 years of data is required to predict any trends in climate change. While their ten-year temperature record is too short for use in any analysis of climate change, this new technique will allow relatively precise determinations of the locations and magnitudes of temperature change events in the future.

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Precise Monitoring of Global Temperature Trends from Satellites

ROY W. SPENCER AND JOHN R. CHRISTY

Passive microwave radiometry from satellites provides more precise atmospheric temperature information than that obtained from the relatively sparse distribution of thermometers over the earth's surface. Accurate global atmospheric temperature estimates are needed for detection of possible greenhouse warming, evaluation of computer models of climate change, and for understanding important factors in the climate system. Analysis of the first 10 years (1979 to 1988) of satellite measurements of lower atmospheric temperature changes reveals a monthly precision of 0.01°C, large temperature variability on time scales from weeks to several years, but no obvious trend for the 10-year period. The warmest years, in descending order, were 1987, 1988, 1983, and 1980. The years 1984, 1985, and 1986 were the coolest.

ACCURATE ESTIMATES OF GLOBAL ATMOSPHERIC TEMPERAtures are needed for evaluation of global climate models, detection of climate changes, and a better understanding of the climate system. Global temperatures have generally been estimated from surface temperature records, but there has been much debate regarding, for example, whether these data provide evidence of recent greenhouse warming (1). The primary source of uncertainty is the relatively sparse distribution of thermometers over the surface of the earth. Most of the earth is covered by oceans, and vast oceanic areas go unmeasured. Even over land, the coverage is greatest where the population is greatest; therefore, remote land areas also go unmeasured. An additional problem is that urban sites, which represent only a small part of the globe but where many long-term measurements have been made, have warmed because of heat from man-made structures, and thus these records are difficult to interpret (2, 3). Depending upon how the thermometer data are analyzed, various answers can be expected. In contrast to surface thermometers, sensors on satellite platforms can provide nearly complete earth coverage in as little as one day and can obtain measurements from various levels of the atmosphere. Calibration of satellite sensors is particularly difficult, however. For climate temperature monitoring a precision of 0.1°C is needed, a goal that has been perceived as difficult for any earth viewing radiometer. The difficulty arises from uncertainty about the long-term stability of satellite sensors. In this article, we show that accurate long-term global temperature measurements can be obtained from satellites now operating and discuss data obtained from 1979 to 1988.

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Methodology. In late 1978, a series of passive microwav radiometers was launched aboard the TIROS-N series of Nationa Oceanic and Atmospheric Administration (NOAA) satellites. Thes radiometers, or microwave sounding units (MSUs), are Dicke-typ radiometers designed to measure the thermal emission of radiatio by atmospheric O_2 at four frequencies near 60 GHz (4). Th atmospheric concentration of O_2 is constant in both space and tim (5), and thus O_2 provides a stable temperature tracer. The stron interaction of radiation from 50 to 70 GHz with O_2 throug rotational energy transitions causes absorption and emission. As th channel frequency of the MSU approaches the 60-GHz peak in th absorption complex, higher levels in the atmosphere will be mea sured (Fig. 1) (6). We have analyzed data from MSU channel 2 which measures the temperature of the middle troposphere at 53.7 GHz. At 57.95 GHz, MSU channel 4 can be used to monito temperatures of the lower stratosphere. MSU channels 1 and 3 ar more difficult to interpret for climate purposes because channel 1 i too sensitive to surface effects on the earth and cloud water, wherea channel 3 detects radiation from a strong temperature-transitio region between the troposphere and stratosphere (the tropopause The four channels have traditionally been used to obtain vertica profiles of temperature in remote regions of the earth where weathe balloon data are not available. However, because the weightin

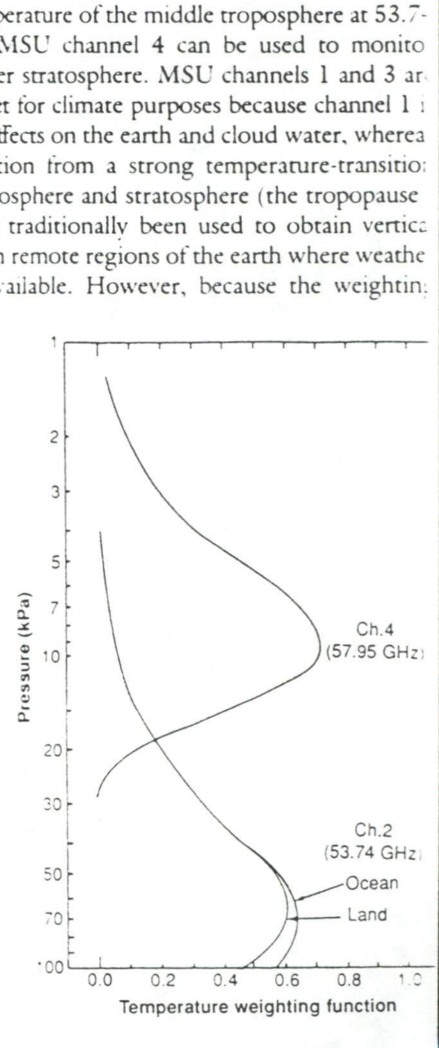


Fig. 1. Temperature weighting functions (unitless) for MSU channels 2 (mid-troposphere) and 4 (lower stratosphere). Also shown are the different channel 2 weighting functions for ocean and land surfaces, which arise because the less emissive ocean reflects more of the downwelling atmospheric radiation back upward. Sensitivity to the surface radiation itself cannot be implied from the magnitudes at the intersection of the curves with the surface. [Adapted from (6)]

functions for each channel are vertically broad (Fig. 1), retrieval of adequate data on the vertical temperature structure of the atmosphere that are needed for computer modeling of the weather has been difficult. The temperature measurement within a constant-pressure depth, however, rather than at traditionally measured specific pressure levels, is completely adequate, even preferable in some respects, for climate monitoring.

The MSUs are externally calibrated, after each earth scan of the instrument, by measurement of the cosmic background radiation (for our purposes, constant at 2.7 K), and a warm target in the instrument that has its temperature monitored with redundant platinum resistance thermometers. This calibration design is considered to be the best available for microwave radiometers because any temperature changes in the instrument components are canceled out. The earth-viewing measurements are then calculated as a "brightness temperature" (T_b) by interpolation between these two reference extremes. The term "brightness temperature" acknowledges that the temperature measurement is actually based upon radiative brightness and is only equal to a thermometric temperature when the emitting body is completely "black" (nonreflective). This condition is nearly true of measurements of the atmosphere from MSU channel 2.

Satellite intercomparison. Because two MSUs have usually been simultaneously operating on separate satellites, a comparison between them shows how different sensors agree in their measurements and gives an estimate of errors. The NOAA-6 and NOAA-7 MSUs were simultaneously operating during a period of nearly 2 years (29 June 1981 to 16 April 1983). These satellites are in sun-synchronous, near-polar orbits, and have constant local crossing times of 7:30 a.m. and p.m. and 2:30 a.m. and p.m., respectively. The precession rates of their orbits are quite different so that in a single day there are many differences (but also many overlaps) in the areas of the globe sampled by the two satellites. The MSUs scan across the satellite subtrack, and thus paint out swaths of coverage about 2000 km wide beneath the satellites.

We averaged the channel 2 T_b data from the separate satellites at 2-day intervals over both the Northern and Southern hemispheres in 2.5°-latitude bands with cosine-latitude weighting to account for the decrease in surface area of these bands toward the poles. We reduced contamination of the measurements by large thunderstorm complexes, which cause infrequent depressions in T_b over small areas (6, 7), by excluding any scan lines that had individual footprint measurements that deviated by more than 1.5°C from their average relationship to both neighboring footprint measurements. The resulting variations in the 2-day averages are dominated by the seasonal change of temperature (8), termed the annual cycle. This annual cycle is sinusoidal in shape, and a smoothed cycle was computed for each satellite individually. Then this cycle was subtracted from the original 2-day time series to arrive at the anomalies in temperature, that is, the temperature deviations from the average temperature for a particular time of year. A period of data considerably longer than 2 years is necessary for a more representative annual cycle (and thus, more representative anomalies), but the short-term data are utilized only for satellite intercomparison. Several revealing observations can be made from the data (Fig. 2):

1) The standard deviation (SD) of the sums of the data from the two satellites is much larger than the SD of their differences. This relation means that both satellites were measuring nearly the same temperature variations and implies that hemispheric temperature anomalies can be measured with relatively little error from a single satellite. The 2-day average difference between these satellites was about 0.05°C, and for monthly averages, the difference improved to about 0.011°C. Similar noise was found in monthly comparisons between data acquired from sensors on (i) TIROS-N and NOAA-6 (0.012°C), (ii) NOAA-7 and NOAA-9 (0.012°C), (iii) NOAA-9 and NOAA-10 (0.006°C), and (iv) NOAA-10 and NOAA-11 (0.008°C), although much shorter overlap periods were available. Thus, we estimate that the precision of monthly satellite measure-

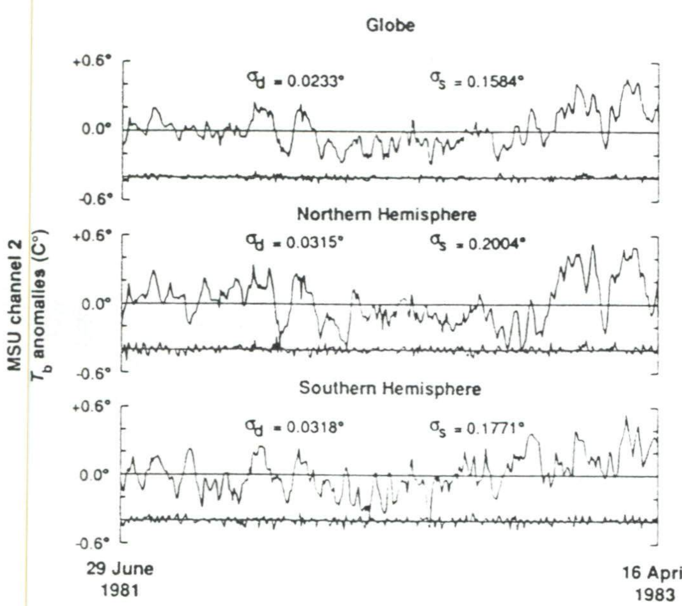


Fig. 2. Comparison between global MSU channel 2 T_b values from NOAA-6 and NOAA-7 during a nearly 2-year period (29 June 1981 to 16 April 1983) when both satellites had MSUs operating. Time series of global and hemispheric satellite averages (sum divided by 2) and differences (difference divided by 2) are shown by the large-variation and small-variation curves, respectively. The difference time series are offset −0.4°C for legibility. The SD of the two-satellite sums (σ_s) and differences (σ_d) are also listed.

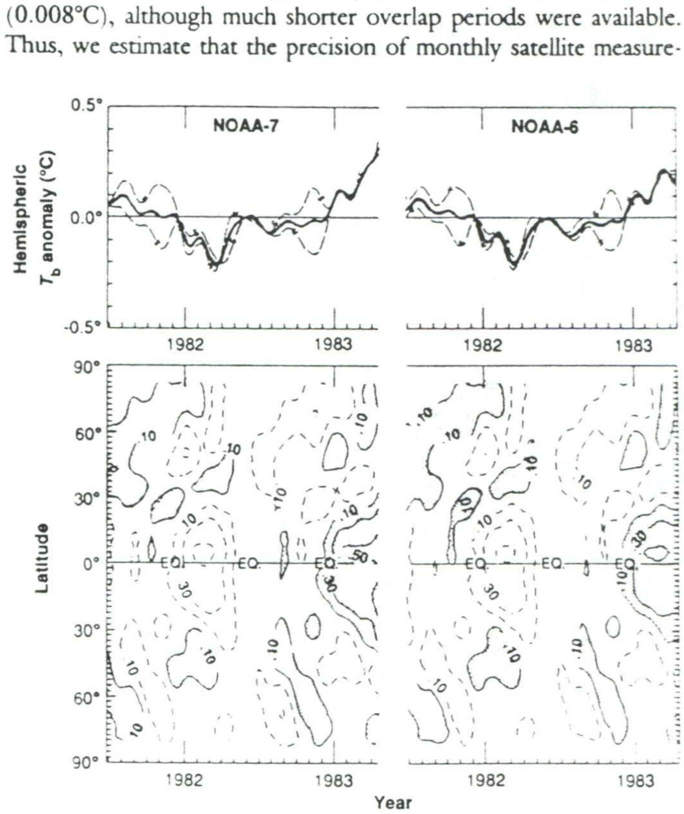
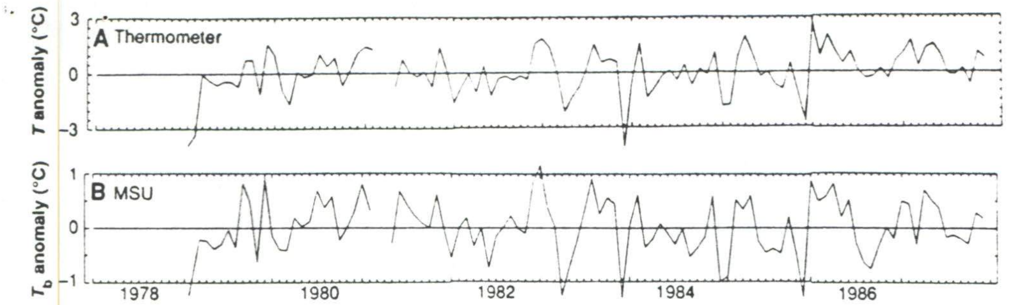


Fig. 3. Low-pass filtered hemispheric (top) and zonally averaged (bottom) MSU channel 2 T_b anomalies during the 2-year overlap period of NOAA-6 (right) and NOAA-7 (left); "N" and "S" labels represent Northern and Southern hemispheres, respectively, and the global time series is the heavy line. The time series do not agree near the beginning and end of the period because of the low-pass filter and the lack of data past the end of the period for NOAA-6 or before the beginning of the period for NOAA-7. Warm zonally averaged anomalies are stippled.



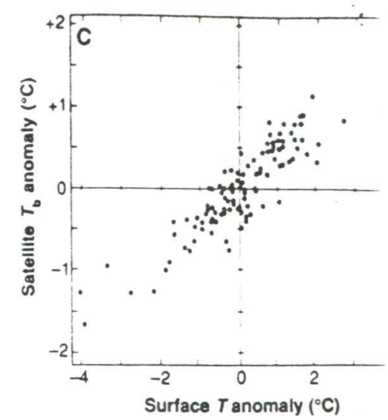


Fig. 4. Time series of monthly U.S. surface air temperature anomalies (**A**) and MSU channel 2 T_b anomalies (**B**) for the period 1979 to 1987. Their scatterplot (**C**) has a correlation coefficient (r) of 0.89, and an explained variance (r^2) of 79 percent. March and April 1981 satellite anomalies are not included because of a high percentage of missing data.

ments is about ±0.01°C for the globe.

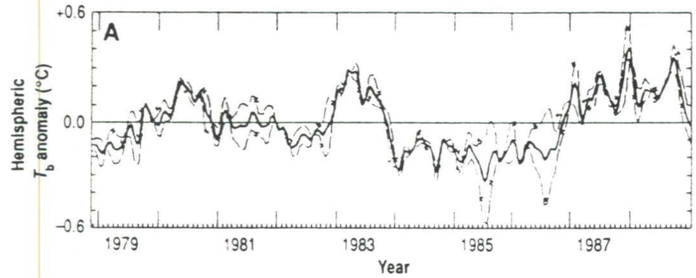
2) The sums of the two sets of data reveal that dramatic globally averaged warming and cooling events of greater than 0.5°C can occur in less than 2 weeks. The warmings, representing huge energy exchanges, are possibly associated with stormy periods when large amounts of latent heat were released in precipitation of moisture previously evaporated from the sun-warmed ocean. The coolings might be from formation of widespread low-level cloudiness, which reflects significant amounts of incoming solar radiation.

3) The long-term drift of one instrument relative to the other, seen in the difference time series in Fig. 2, is so small that it is virtually unmeasurable. Any trend is less than ±0.01°C for the 2-year period. This high degree of stability was unexpected. The four other satellite overlaps mentioned above also gave no indication of drift.

Further evidence that the measurements were repeatable is shown by low-pass filtered (*9*) times series of hemispheric (and global) temperature anomalies from NOAA-7 and NOAA-6 data and the zonally averaged distribution of those anomalies (Fig. 3). The zonal averages allow examination of which latitude bands of the earth were responsible for the warm or cool events seen in the hemispheric and global time series. The zonal average patterns are nearly identical between satellites. Such agreement improves our confidence that even regional areas can be studied to find the origins of the hemispheric anomalies.

Comparisons with United States and global thermometer measurements. Although the above results indicate that the sampling provided by a single satellite is geographically extensive and that the measurements are radiometrically stable enough to be useful for monitoring climate, it still must be demonstrated that MSU measurements are closely related to temperature. Earlier investigators have made point comparisons between weather balloon dat. and satellite measurements (*10–12*). The differences between indi vidual radiosonde and satellite measurements are generally less thar 1.0°C. These differences are usually attributed to (i) the isolatec balloon sampling compared to the large area represented by a singl satellite measurement (a circular footprint 110 km in diameter); (ii errors in calibration of the balloon thermometer before its release (iii) the random noise of a single MSU measurement, about 0.3°C and (iv) time mismatches between the satellite and balloon observa tions. We compared the 1980 through 1988 MSU observations tc T_b data obtained from radiosondes launched twice daily by 6 National Weather Service offices around the United States. The T data were calculated with the radiative transfer equation for MSU channel 2, and thus the radiosondes had to reach a fairly high pressure altitude, 2 kPa or less. Only MSU data within 200 km o the radiosonde location and within 3 hours of its release time were included. The comparisons revealed that there were biases of up tc ±1°C between the two data sets; the biases are most easily related tc the difference in time between the release time of the radiosonde (all simultaneous at 00 and 12 GMT) and the MSU observatior times, which are sun synchronous. After correction for these biase on a station-by-station basis, we found no long-term trend in the 9 years of differences between MSU and radiosonde-calculated T values and a monthly SD of 0.068°C.

The MSU data also can be compared to records of temperature variability from near-surface thermometers. Even though they arc different variables, their common variability helps to assess how wel coupled the near-surface temperature variations are to the deep laye variations. Although the global distribution of thermometers is suspected by many researchers as being inadequate for accurate monitoring, the distribution over the United States is widel



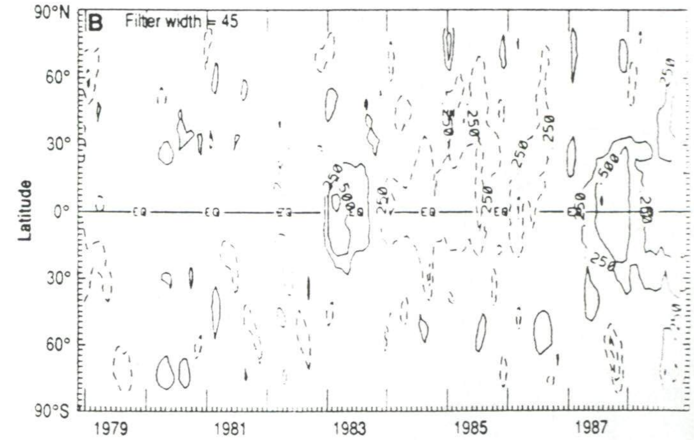


Fig. 5. Hemispheric anomalies (**A**) and zonally averaged anomalies (**B**) about the average annual cycle of MSU channel 2 T_b values for the 10-year period 1979 through 1988; "S" and "N" refer to Southern and Northern hemispheres, respectively; the global time series is in a heavy line. Zonal anomalies are contoured every 0.25°; positive anomalies (warm) are solid and negative ones (cool) are dashed.

accepted as good enough for climate work. We compared monthly temperature anomalies from thermometers over the contiguous United States for the period 1979 through 1987 (*13*) to our monthly mid-tropospheric temperature anomalies from the satellites. The resulting anomaly time series (Fig. 4, A and B) are similar, as verified by a scatterplot (Fig. 4B) and a correlation coefficient of 0.89. This correlation agrees with those between radiosonde near-surface and upper air measurements, for which monthly temperature anomalies range from 0.8 for the eastern United States to greater than 0.9 for the western United States. The surface anomalies are typically two to three times as great as the MSU anomalies. This relation is probably a result of daytime solar heating and nighttime cooling of the surface, which largely control the deeper air mass temperatures over the United States on monthly and seasonal time scales.

Two major research groups have been responsible for hemispheric calculations of temperature anomalies from thermometer measurements, and we refer to them by their leading authors names: Jones (*14, 15, 16*) and Hansen (*17*). Their results have been sufficiently different to spark debate in the climate community and have led to conflicting reports in the popular press regarding global temperature trends. We have compared our satellite-measured hemispheric anomalies to the thermometer-based anomalies from these two groups (Table 1). Again, when the separate systems are viewed as a bivariant distribution in which we wish to determine the level of common variability, these comparisons reveal that the level of agreement between the calculations by Jones and the satellite data is about 40% better than that between the calculations by Hansen and the satellite data. As might be expected for two land-dominated data sets, the Jones and Hansen data are much better correlated with each other, with an explained variance of 94%, than either is with the MSU data. The much lower explained variances for the hemispheres and globe (Table 1) compared to the United States are the result of both poor thermometer coverage over much of the earth and weak thermal coupling between the middle and lower troposphere over much of the oceans. This latter effect was deduced from radiosonde near-surface and deep layer temperature comparisons: When monthly surface temperature anomalies from radiosonde are compared to the corresponding radiosonde-calculated channel 2 anomalies for United States–controlled ocean stations, the explained variances drops to about 35% for the Caribbean, 0 to 20% for the tropical Pacific, and 25% for the tropical south Atlantic. Although there are few high-latitude ocean radiosonde stations, the data suggest that the thermal coupling increases poleward (for example, 52% in Iceland), probably because of the wider range of air mass temperatures encountered there. Thus we would not expect as good agreement between MSU anomalies and tropical ocean surface air temperature anomalies as are obtained over land, even if the oceanic thermometer coverage were adequate. This conclusion is substantiated by the somewhat poorer agreement between the satellite data and combined thermometer and sea surface temperature data from

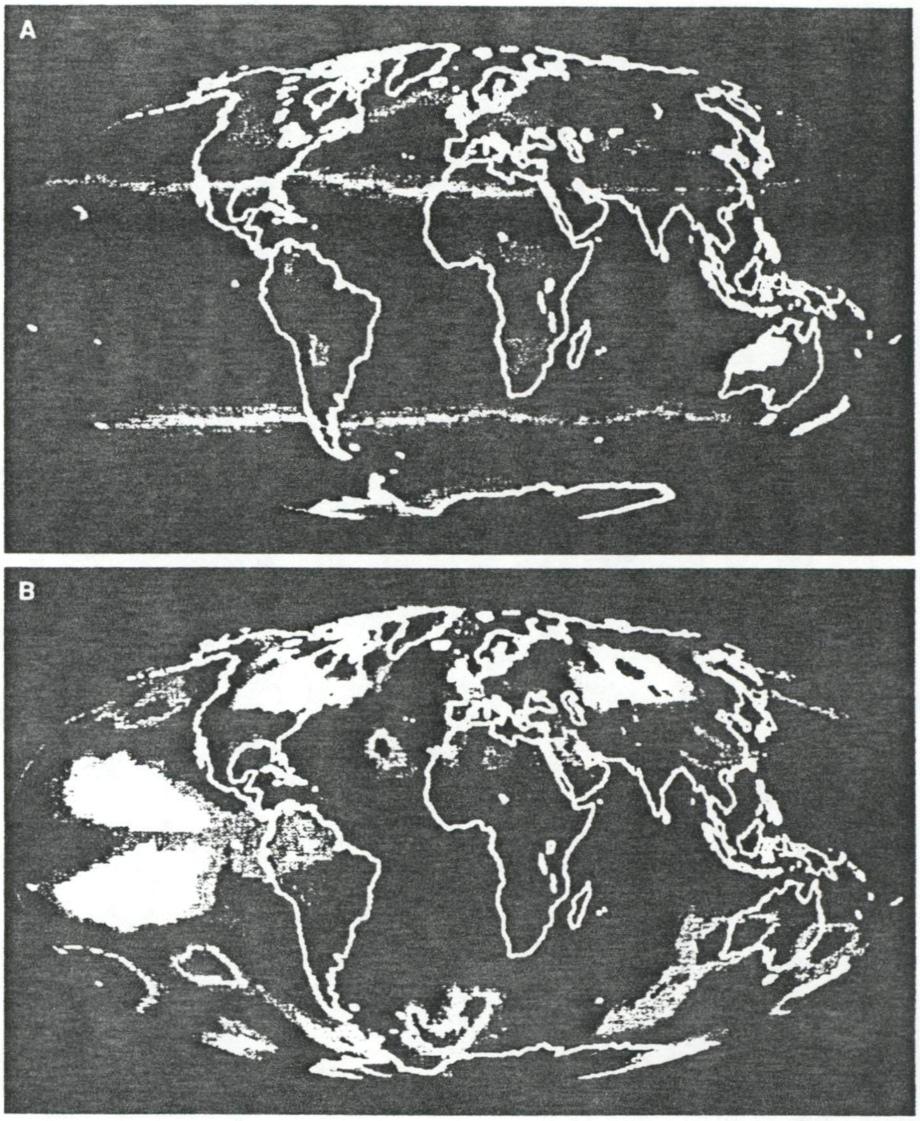


Fig. 6. Average MSU channel 2 T_b (**A**) during the 10-day period 26 January to 5 February and temperature anomalies (**B**) for the same 10-day period during the 1983 ENSO climate anomaly. Temperatures range in top image is gray, representing 235 K, to red, representing 260 K, in 1 K increments; temperature anomalies in bottom image change color every 0.25 K, the blue side of dark gray is colder, red side is warmer.

Table 1. Monthly and annual explained variances (in percent) between MSU and thermometer-measured temperature anomalies for United States (U.S.), Northern (NH) and Southern (SH) hemispheres, and the globe from 1979 to 1988. Thermometer-based calculations for the United States are from Karl (*13*); monthly and annual hemispheric and global thermometer anomalies are from Jones (*14–16*); annual anomalies are from Hansen and Lebedeff (*17*), and hemispheric and global anomalies, which also include sea surface temperatures, are from Farmer *et al.* (*18*).

Source	U.S.	NH	SH	Globe
		Monthly		
Karl	77			
Jones		33	10	35
Farmer		26	11	28
		Annual		
Karl	77			
Hansen		67	27	53
Jones		72	66	74
Farmer		77	24	69

Farmer *et al.* (*18*) (Table 1). The poor agreement raises the important issue of whether near-surface temperatures or deep layer temperatures should be monitored for detection of climate change. Because they are often different from one another over the tropical oceans, it would be best to monitor both in order to gain an understanding of how the entire troposphere behaves. Indeed, it might well be that the oceanic surface air layer is so strongly coupled to sea surface temperature variations that a deep layer mean would provide an earlier signal of possible greenhouse warming.

Global temperature anomalies 1979 to 1988. The first 10 years of satellite data reveal large fluctuations in the hemispheric and global temperatures (Fig. 5A). The Northern and Southern hemispheres trends follow each other for the slower, interannual trends, but often oppose each other on monthly to seasonal time scales. The warmest years, in decreasing order, were 1987, 1988, 1983, and 1980. There is no obvious long-term trend, and anomalies during the first 5 years nearly balance those during the last 5 years. The 1988 warm event was traced to the mid-latitudes, as was the 1980 warm anomaly. Both years included summer heat waves in the United States. The largest warm anomaly in the Northern Hemisphere for the 10-year record occurred in 1987 and 1988 (Fig. 5B). The 1987 and 1983 warm events were associated with El Niño/Southern Oscillation events [ENSOs (*19*)]. During the 1983 ENSO, transfer of heat from record-setting sea surface temperatures in the eastern Pacific to the atmosphere caused major changes in atmospheric flow that impacted weather conditions worldwide. Warming locally exceeded 2°C in two Pacific anticyclones (Fig. 6) that straddled an equatorial zone of intense convective activity caused by the warm water. This event caused globally averaged temperatures to rise more in several months than what is expected within several decades if enhanced greenhouse warming is occurring. Although the 1987 ENSO has been considered weaker than the 1983 ENSO, it was associated with higher temperatures that were more uniformly spread throughout the tropics. The mid-latitudes in both the Southern and Northern hemispheres in 1988 experienced warm conditions that appear to be coupled to the 1987 tropical warmth. The period 1984 to 1986 was dominated by cooler than normal tropical air. The 10-year time series exhibits bifurcation in that there are nine cool or warm years, and only one year (1981) that could be considered "average." This pattern makes the definition of what is "normal" for global temperatures uncertain, for a shown above normal can mean either warm or cool conditions.

The future. Our data suggest that high-precision atmospheric temperature monitoring is possible from satellite microwave radiometers. Because of their demonstrated stability and the global coverage they provide, these radiometers should be made the standard for the monitoring of global atmospheric temperature anomalies since 1979. Their use will allow relatively precise monthly determinations of the locations and magnitudes of temperature change events. The resulting data should provide a greater focus on scientific debate on why temperature anomalies occur rather than whether they occur. The advanced microwave sounding unit (AMSU) will replace the MSU on NOAA satellites in the mid 1990s, and these units will allow extension of the time series into the next century. Various computerized climate models, which predict future changes through time-dependent equations representing physical processes, can now be evaluated with accurate global temperature measurements. These data should result in improved specification of processes in these models, which still require independent verification. These improvements should facilitate more informed policy decisions concerning the effects of anthropogenic greenhouse gas production.

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8. Other, smaller signals are also present in the measurements. These include a small surface temperature contribution (8 percent of the total over land, 4 percent over the ocean), wind-induced roughening of the ocean surface, cloud liquid water effects, water vapor variations, sea surface temperature changes, and soil moisture changes. The effects of variations in each of these parameters on the measured T_b values have been theoretically evaluated, and have been determined to be small for MSU channel 2 (0.01°C or less) on a hemispheric and global basis. Larger effects could conceivably occur over small regions. In contrast, MSU channel 4 is essentially unaffected by any of these changes. The radiative transfer theory involved in the analysis of these effects is covered in (*6*).
9. Low-pass filtering of the time series allows isolation of the more slowly varying temperature variations that are of interest to climatologists. Here, the filter retains 50 percent of the power of cycles having 90-day periods, progressively less power of periods shorter than 90 days, and more power of longer periods.
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20. R. Jenne and D. Joseph provided the MSU data used in this study; R. Hood provided data processing and programming support; N. Grody collaborated on portions of this research and provided general advice; F. Wentz provided updated sea surface emissivity estimates; P. Olsen, F. Soltis, and P. Swanson assisted us in obtaining technical data on the MSU; G. Wilson helped obtain the satellite data sets; discussions with J. Dodge and R. McNider led to the present research.

27 October 1989; accepted 23 February 1990

CHECK AGAINST DELIVERY

Address

by the

Minister of Tuvalu

n. Bikenibeu Paeniu

to the

rld Climate Conference

Geneva

6, November 1990

to be amongst the main key

rological Organisation (WMO)
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t interesting perspective on

Why Tuvalu is particularly susceptible to Climatic Changes

As some of you may not know, my country has a total land area of only 24.4 square kilometres - only a speck on the maps of the world. This 24.4 square kilometres is further divided among nine islands, ranging in size from Vaitupu which is 4.9 sq.km to Niulakita of only 0.4 sq.km. All our nine islands are low lying coral atolls dispersed over an area of 1.2 million square kilometres of the South Pacific Ocean, none rising more than 2 metres above sea level.

In sharing a number of thoughts with you today, I want to tell you the reality of life in Tuvalu in terms of the impact on our lives of the global climatic changes so far. My country is amongst the most vulnerable to climate and sea level rise in the world. The survival of Tuvalu and the survival of other neighbouring countries in the South Pacific - Kiribati, Tokelau, Tonga, Marshall Islands and so forth - hang in the balance. This eminent gathering therefore could make the difference between Tuvalu's imminent demise and its continued existence.

The scientists have confirmed that global warming is now a certainty. The findings of the international scientific community finalised in Sweden this year, have now been confirmed by the experts gathered here last week. We have learned of the best Scientific and Technical estimates assuming "business as usual" for greenhouse gas emissions which are:

> An average rate of increase of global mean temperature during the next century of about 0.3 de C per decade (uncertainty range of 0.2 to 0.5 deg C).
>
> An average rate of global mean sea level rise of about 6 cm per decade (uncertainty range of 3-10 cm per decade).

Now it is up to the decision makers of the world, particularly those of the leading industrialised nations, to respond with decisiveness and conviction. We know from all the scientific evidence collected to date that the fragile and delicate atmospheric balance on which life and our existence depends has been upset. The threat to the atmosphere comes predominantly from the breath of industrialised civilisation.

We in the island nations cannot afford to wait for more studies and research. We would like to have firm and pragmatic solutions to curb the negative impact of climatic changes on our lives.

We live on these small fragile islands and we know that the problems are now and not tomorrow. The time to act is now or never.

Tuvalu needs help to face up to this challenge. In

As we in the Pacific Island region enter the 1990's, we increasingly face a range of environmental problems far more extensive and more serious than ever before. Problems of ozone depletion, climate change, sea level rise, hazardous waste dumping, driftnet fishing - to name some which fall into this category. These impinge severely on the development process itself of our countries in the Pacific and the overall impact has been, and will continue to be, unfavourable.

Already we in Tuvalu have been experiencing the adverse effects of global warming and the greenhouse effects. I am happy to share with you some of the most salient features.

a. Frequency of Tropical Cyclones

In 1940 there were 2 cyclones, but over the last fifty years the number has risen dramatically - a ten-fold rise to 8 in 1960, 18 in 1980 and 21 so far in 1990. These storms have seriously caused erosion to the already extremely limited amount of land we possess. This in turn bears an impact on population growth and pressure on other resources.

Cyclones have also devastated many of our crops and trees. The loss of trees can cause the interruption of the nutrient cycle above and below the soil. The soil loses fertility, plants and animals lose their habitats, and our food and water supplies and our healthy air is also seriously affected.

b. The Water Table

We have not yet installed measuring instruments to test the rise in sea level but we have noted increased salinity in ground water supplies, attesting to intrusion of sea water into the water table. This increased salinity impacts unfavourably on both the supply of drinking water as well as efforts to grow things, - agriculture being already difficult due to harsh soils.

c. Temperature Changes and Rainfall levels

Despite the rise in the number of cyclones, Tuvalu has been experiencing an increasing number of dry spells, with average annual rainfall declining fro 420 millimetres per annum at December 1980 to 300 millimetres at December 1988 - a drop of 28.6% in the eight year period. Simultaneously, average daily temperatures have risen by 0.5 degree celsius over the last thirty years.

In light of all the above we entreat this Conference to propose measures which promote urgent and pragmatic actions, rather than having this gathering end up as

Action Being Taken by Tuvalu to Prevent/Mitigate Adverse Climatic Changes

a. Energy

Less than 50% of our total population of 8,309 people have access to electricity but 1.8% of household energy consumption is solar generated. We intend to increase this proportion to 3% by 1993. All electricity in the outer-islands is solar generated.

b. Agriculture

We have embarked on a modest re-afforestation programme whereby, between 1970 and 1987 some 115.3 hectares of land was replanted with coconut trees. Early in 1991 we intend to begin a new tree planting exercise, including coconuts, mangoes and citrus. As a further measure, farmers are actively encouraged to inter-crop coconuts with root crops. Again we consciously utilize natural manure instead of chemical fertilizers and promote biological pest control rather than dangerous pesticides in our agricultural practices.

Assistance Tuvalu Needs to Promote a Healthy Environment

We recognise that much more can and needs to be done. For instance we currently use borrow pits dug out by the U.S. Army during the Second World War to help in the construction of an airfield - to dump our garbage, because of limited land space.

We know there are more environmentally friendly methods of solid waste management, but due to financial and other constraints we cannot access them.

Already the EEC is providing funding in the areas of coastal reclamation and solar energy, while the Australian Government has promised to supply us with equipment to test the rise in sea level. But there has been a rather slow response from donors to our request for rehabilitation assistance for damage caused by the most recent Cyclone Ofa - which occurred in February of this year.

Therefore we urge the developed countries to come to our assistance in designing and implementing a comprehensive environmental strategy. We need assistance in the training of a number of national experts in environment and climatic changes as well as the strengthening of our national capabilities to monitor onsite climatic changes and sea level rise.

Regional and Global Perspective

On a regional perspective, the Pacific Island governments have demonstrated unity on environmental issues where we have perceived outside activiites likely to cause damage to the environment and threaten our small islands and fragile ecosystems.

Our opposition to these abuses by others of our environment has led to our undertaking collaborative efforts in a number of areas.

In particular, I refer to the South Pacific Nuclear Free Zone Treaty, the Convention for the Protection of the Environment and Natural Resources of the South Pacific Region which recently came into force, our actions on Driftnet Fishing and our collaboration through the South Pacific Regional Environmental Programme.

We welcome and encourage the participation of other governments in these important areas where our small island countries have already joined together with some of our larger neighbours to protect our common heritage.

Some of our developed partners present here today may be asking themselves what they can do to help countries like Tuvalu withstand this problem. At a Summit between leaders of the South Pacific sovereign nations with President Bush, held at Hawaii on 27 October, the environment and climatic changes were amongst the contentious issues discussed. At one point, President Bush asked - "What can we, the United States do in order to help countries in the South Pacific?" I replied immediately - "Mr President, can I answer that question?" He looked at me and said - "Go ahead". Then I said - "Well, the United States could help countries like Tuvalu in building coastal protection schemes such as those the FEC are already providing us with though we would need more assistance in this area; we would need to built more water catchments. I went on saying: "I am pretty sure I shall be the only Head of a South Pacific Government that will be present at the forthcoming Second World Climatic Conference in Geneva early next month. At that Conference, Ministers will deliberate on Ministerial Declaration which will, inter alia, include provisions for developed countries to cut down their emmission rates of greenhouse gases; for developed countries to provide the necessary resources to developing countries to help them establish the required measures and infrastructures which will lessen the impact of the Greenhouse effect." Then I said, "Mr President, I look forward to the support of the United States on this Ministerial Declaration".

On the same token, and in anticipation of a similar question from our developed partners present here today, I will add the following:

- Provide assistance at the regional level to help us strengthen the South Pacific Regional Fnvironmental Programme

- Help us train our nationals in the areas of environment and climatic changes

- Help us to strengthen both at the national and regional levels our capabilities of monitoring and detecting cyclones and other natural disasters in order to allow us prepare in advance

- Help countries in the South Pacific establish a pragmatic and reliable Disaster Preparedness and Rehabilitation Programme.

Ministerial Declaration

I support the Draft Ministerial Declaration presented to us by our experts merely because I consider it a start of an imperative process towards a Framework Convention on Climate. I must admit however that I am not happy with the commitments made by a number of the industrialised countries which has resulted in a weak Declaration. It appears that science has been ignored by a number of decision makers. I would be content if such stance is done on goodwill. But if science is being deliberately ignored, then I will regard such an attitude as one of total selfishness, and inhuman.

The problem we are addressing right now is of a global nature. We need the cooperation and support of all nations in this world. We in Tuvalu, and this goes as well for our sister countries in the Pacific, the Indian Ocean and the Carribean, contribute little or nothing to the problem and yet we will be the first to suffer. Our survival is at stake.

I may come from a poor and small nation but the fact of life is that my country and its people in particular are a distinct race of our earth planet. Like yourselves, we are citizens of the world - our world. We have our own language and culture. We have a God given right to live on earth. We may be small but we have a spot there to maintain in our biosphere. We contribute to the diversity and balance of the earth's ecosystem. It will therefore be an injustice should we in Tuvalu and the island nations, be denied our right to live in our homeland.

The nations of the developed world carry an enormous burden of responsibility. The problem is clear and the options for action are clear. This Conference therefore presents a clear opportunity for effective and speedy action. These countries which have been contributing to the accumulation of greenhouse gases for so long continue to pollute our atmosphere. I say this with no sense of criticism for past actions - indeed the world has only in the past few years of telling us, human beings, to be more responsible in the maintenance of the earth's balanced ecosystem. Afterall the earth was not created by a human being. And if we do not respond positively to the challenge, then I feel the catastrophy will take place as predicted by science. Such is not at all fair to Tuvalu.

My bigger neighbours in the Pacific - Australia and New Zealand - have been quick to act with decisive national policies. However, the effects of their efforts will not be enough on the global scene. It is up to the large industrialised economies of the world to respond to the clear challenge. Let us all bind ourselves together and pragmatically solve the problem as responsible citizens - brothers and sisters - of the world. We will surely bring about peace and prosperity to all if we join together in addressing the problem.

TABLE 2

EMISSIONS REDUCTIONS EXPECTED IN THE YEAR 2000
DUE TO CURRENT ENVIRONMENTAL COMMITMENTS
AND OTHER INITIATIVES ASSUMED IN THE ANALYSIS

CURRENT COMMITMENTS	MILLIONS OF TONNES REDUCED (Carbon Equivalents) 2000[4]
o TREE INITIATIVE	~9
o DOE ENERGY EFFICIENCY INITIATIVES	28
o DOE APPLIANCE STANDARDS	4
o DOE RENEWABLE INITIATIVES	4
o CLEAN AIR ACT	17
o LANDFILL REGULATION	44
o CFC PHASEOUT & MONTREAL PROTOCOL	551

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[4] Assumes a 100 year time horizon in GWP calculations.