MEMORANDUM FOR THE RECORD

Subject: Hearing on the Science of Global Climate Change before the House Subcommittee on Energy and Environment (Chairman Calvert), Committee on Science; October 7, 1997

Members

Present: Chairman Calvert (R-CA), Sensenbrenner (R-WI), Rohrabacher (R-CA), Coburn (R-OK), Ehlers (R-MI), Doyle (DPA), Roemer (D-IN), Hooley (D- OR), Johnson (D-TX)

Witnesses: See Attached

Hearing Summary:

On October 7, the House Energy and Environment Subcommittee (Chairman Calvert (R-CA)) met to examine the current state of understanding relative to the science of global climate change. This was the first of two hearings to address issues related to agreements that may be considered at the meeting of the Third Conference of Parties to the United Nations Framework Convention on Climate Change to be held in Kyoto, Japan, this December. Appearing before the Subcommittee were representatives from NASA, the Department of Energy (DOE), the University of Maryland (UMD), and the Massachusetts Institute of Technology (MIT). Both Science Committee Chairman Sensenbrenner (R-WI) and Space and Aeronautics Subcommittee Chairman Rohrabacher (R-CA) attended the hearing and expressed concern that the United States refrain from signing any agreement in Kyoto that would result in a negative impact on the U.S. economy, particularly as the science of global climate change is still "uncertain." Other Members suggested that the scientific debate was sufficiently mature for policy makers to respond by encouraging energy conservation and increasing the U.S. investment in developing new technologies for alternative energies and efficient energy use.

Member Questions/Issues**:**

Chairman Calvert - emphasized the Subcommittee's support for climate change research. After commenting on the lack of scientific consensus relative to the human impact on global warming, the Chairman questioned if some of the debate could be attributed to whether individual scientists believe the climate system is fragile or resilient. Dr. Spencer agreed, adding that the field of climatology is full of specialists, and very few scientists have a "big picture" view.

Chairman Rohrabacher - stated he was "petrified" the U.S. might "take major actions" to "give power away" at Kyoto based on some "cockamamie" theory of global warming. He then questioned the panel whether the science behind global warming was stronger, weaker, or the same as the science theory from the 1970's indicating that Earth was entering a period of global cooling. All of the panel members stated that the current science behind global warming was stronger; there is a better understanding of how Earth's systems interact, more testing is conducted, and much more science data is available.

Congressman Roemer -- acknowledged that the debate surrounding the science of global warming was not over. However, Mr. Roemer indicated that he felt the science to be "sufficiently mature" for policy makers to make necessary decisions, and questioned the panel on whether the science contributing to the IPCC statements in 1995 was now stronger, weaker, or the same. Dr. Spencer said all three, Dr.'s Robock and Patrinos said it was stronger, and Dr. Prinn said it was about the same. Mr. Roemer questioned the panel on a recommended course of action if one were to assume the Earth was on a "rapid warming pathway." Dr. Prinn responded that if rapid warming were true, the development of modest emission control targets by developed countries would be "missing the point," adding that we would have to address activities of developing countries. Dr. Robock agreed with Dr. Prinn; Dr.'s Spencer and Patrinos had no comment.

Congressman Doyle - stated it was "unrealistic" to wait for absolute scientific consensus before acting on climate change concerns, but added that he was concerned with the prospect of agreements at Kyoto being "even-handed" by not exempting developing countries. He also stated that the U.S. should invest in developing new technologies, including nuclear, to address global climate change.

Congressman Corbin - questioned the panel on whether policy makers should examine an option of limiting population growth, if you assume there is a negative impact on climate change from human use of fossil fuels. Dr. Robock and Dr. Prinn agreed that slowing population growth would be better for the Earth's environment. Dr. Patrinos and Dr. Spencer had no comment. Mr. Corbin asked whether all of the known physical processes are in the current climate change models. Dr. Spencer responded that current models could not accommodate all the variables. Dr. Robock responded that the models include the basic necessary processes.

Congresswoman Hooley - expressed interest in the role of global warming in deforestation. Dr. Patrinos indicated that deforestation was related to global warming as some trees would migrate and others would die, but it is unclear what the final mix would be, so it is uncertain if the result would be "good" or "bad" on forests. Dr. Prinn commented that an increase in CO2 is good for trees, but added that the changing nature of ecosystems is difficult to assess. Ms. Hooley asked the panel what kinds of technology needed to be developed to address global warming. Dr. Robock said we need to develop technology to address two areas: (1) living in a warmer climate; and, (2) reducing greenhouse gasses/ CO2 emissions.

Chairman Sensenbrenner - stated that science is accepted only when the public accepts the conclusions, adding that global warming may be "cooling off." The Chairman said he was worried recommendations of Kyoto may dislocate the U.S. economy, adding that he was also concerned with trying to explain to Wisconsin constituents this winter why heating fuel prices are significantly higher due to global warming "even though it's twenty degrees below zero outside." Dr. Robock commented that there would be "winners and losers" when trying to address global warming.

Statement Concerning the Role of Water Vapor Feedback in Global Warming

Roy W. Spencer

Senior Scientist for Climate Studies

NASA Marshall Space Flight Center

Huntsville, Alabama

Presented to the House Science Committee

Subcommittee on Enegrgy and the Environment

7 October 1997

I would like to thank the members of the Subcommittee for the opportunity to review the results of our recent research on global warming.

Introduction

Because the atmosphere is so complex in its behavior, the science of global warming is complex as well. Probably all climate scientists will agree that anthropogenic greenhouse gas increases in the atmosphere should perturb the Earth's radiative energy balance to some extent. But it is much less certain whether we will recognize the effects of this perturbation. I contend that the physics contained in current general circulation models (GCM's) are still insufficient to have much confidence in their predicted magnitude of global warming.

There are several reasons for this uncertainty, some of which include: 1) the radiative perturbation due to an anthropogenic doubling of carbon dioxide is small, about 1% of the Earth's natural cooling rate; 2) naturally occurring water vapor is a far more important greenhouse gas than is carbon dioxide, and it varies considerably in space and time; 3) the feedback effects of clouds and water vapor are still poorly understood; and 4) while the Earth as a whole is in radiative balance (incoming sunlight equaling outgoing infrared radiation, thus maintaining a fairly constant temperature) the surface is far out of radiative balance. This latter fact is due to evaporation and convection processes, which absorb excess heat from the surface and transports it to the upper troposphere. This upper tropospheric heat can be more efficiently radiated out to space since it is above most of the heat-trapping vapor. Thus, convective overturning of the atmosphere, and not radiation balance, largely determines the surface and upper tropospheric temperature distribution.

In this context, much of my team's research is designed to better understand why global tropospheric temperature measurements from satellites (Spencer and Christy, 1992) and weather balloons have cooled slightly (-0.05 deg. C/decade) in the last 19 years (Fig. 1; also see written testimony by John R. Christy, Senate Committee on Environment and Public Works, 10 July 1997), even though surface temperatures reportedly have increased (by about 0.10-0.15 deg. C/decade). This apparent discrepency has been debated recently in the scientific literature (Hurrell and Trenberth, 1997; Christy et al., 1997). There are two main issues raised by all of these measurements: 1) are the satellite and balloon measurements of slight cooling incompatible with global warming predictions?, and 2) is the disagreement between surface and deep layer temperatures incompatible with the physics contained in current GCM's? I will deal mainly with the latter question.

Even the seemingly small level of disagreement between surface and deep layer temperature trends can not be reproduced by current GCM's, which slave globally-averaged deep tropospheric temperatures to any surface temperature fluctuations (e.g. Hurrell and Trenberth, 1997). However, we know that convective air currents and the air-conditioning effects of water cause the atmospheric temperature profile to change by a much larger amount, about 80 deg. C, between the surface and 10 km altitude when compared to a hypothetical Earth without these processes (Manabe and Strickler, 1964). Thus, it is critical to validate whether the parameterizations of moist convective processes in GCM's are realistic enough to capture the ways in which the tropospheric temperature profile fluctuates naturally in response to this transport of heat from the surface to the upper troposphere.

Figure 1 is a bar graph of the Global

I will summarize one of our research efforts in which we are analyzing new satellite measurements of middle and upper tropospheric water vapor from the SSM/T-2 instrument flying on the Defense Meteorological Satellite Program satellites.

The Role of Water Vapor in Global Warming

The water vapor in GCM's increases in response to the warming produced by doubling of carbon dioxide, causing a "positive water vapor feedback" on temperature. All GCM's produce values of water vapor feedback that are so similar to one another that the modelers view this agreement as evidence for its validity. This view has been further bolstered by several observational studies that have proported to validate the positive water vapor feedback paradigm (Rind et al., 1991; Ramanathan and Collins, 1991; Soden and Fu, 1995). Unfortunately, these studies neglected the role that tropospheric circulation systems have in redistributing water vapor spatially. Water vapor feedback can only be meaningfully evaluated over entire circulation systems, such as the entire tropical half of the Earth, or preferably over the whole Earth (Lau et al., 1996; Spencer and Braswell, 1997). Thus, those studies did not validate positive water vapor feedback. They merely observed that the warm, ascending branches of tropospheric circulation systems have more water vapor than the cooler, descending branches. This will always be true, even in the case of negative water vapor feedback.

It is my contention that the physics contained in GCM's are still insufficient to have much confidence in the predicted magnitude of global warming, partially because the cloud microphysical processes which help determine water vapor feedback are still poorly understood. A statement from the body of the 1995 Intergovernmental Panel on Climate Change (IPCC) report also supports this view:

" Feedback from the redistribution of water vapour remains a substantial uncertainty in climate models....Much of the current debate has been addressing feedback from the tropical upper troposphere, where the feedback appears likely to be positive. However, this is not yet convincingly established; much further evaluation of climate models with regard to observed processes is needed."

- ***Climate Change 1995, IPCC Second Assessment***

To appreciate the water vapor feedback problem, it is useful to recognize that we generally associate a warmer surface with higher water vapor contents of the air above that surface. This positive relationship typically occurs in the turbulent boundary layer, which occupies only the bottom 1-2 km of the troposphere. However, it is the humidity structure of the entire depth of the atmosphere that determines water vapor feedback, and thus the magnitude of global warming. Above the boundary layer, in the free troposphere, other less well understood processes control the humidity of the air. The primary moistening process in this layer is evaporation of clouds (Fig. 2).

Diagram of how evaporation

Fig. 2. Schematic of a typical warm season tropospheric circulation system, with its cycling of water through evaporation, cloud formation, rainfall, and cloud re-evaporation. These rainfall systems control the supply of water vapor to the cloud-free air, whose efficiency at cooling the Earth increases nonlinearly as the humidity decreases.

In the tropics, and at higher latitudes during the warm season, these clouds are usually deep convective in nature, with strong updrafts of warm moist air in their cores. These cloud processes are not explicitly represented in GCM's, due to their very small spatial scale compared to the scales resolved in the models. Instead, their effects on the atmosphere are parameterized. The same model limitations hold true for the smaller stratus and cumulus clouds that form near the top of the boundary layer (Fig. 2).

What is the process that controls how much water vapor is supplied to the environment from rainfall systems? The answer is cloud water. Some portion of all of the cloud water contained in a rain system will fall back to the surface as precipitation, while the rest evaporates into the air. This evaporated cloud condensate constitutes the primary humidity source for the free troposphere. The fraction of the total condensed water that falls out as rain is called the "precipitation efficiency (ε)" of the rain system. If all water falls out as rain, ε =1. If none of it falls out as rain, ε=0. A typical rain system has an efficiency near 0.5. However, these cloud formation, rain-out, and dissipation processes are only crudely represented in GCM's at the present time. It has been shown theoretically that high rainfall efficiency leads to a cool and dry climate, while low rainfall efficiency leads to a warm, moist climate (Renno et al., 1994), through its control of humidity.

The important question for water vapor feedback and thus climate change is not so much what the current rainfall efficiency is, but how it changes as greenhouse gas concentrations increase. If the efficiency decreases during warming, then we have a potential negative water vapor feedback, which could mitigate, rather than enhance, the small amount of direct warming due to carbon dioxide increases. There is some evidence that precipitation efficiency increases with temperature. For instance, we know that warm tropical precipitation systems are more efficient than cold, high latitude systems. The observation that heavy rain can fall out of rather shallow tropical clouds is evidence for this. Other processes controlling precipitation efficiency are not well understood, however. We have embarked on an investigation of these issues with a high-resolution cloud-resolving model run in a climate mode in order to address some of the deficiencies in the GCM's.

Satellite Measurements of Upper Tropospheric Humidity

New water vapor measurements of the middle and upper troposphere are now being derived from the SSM/T-2 water vapor sounder on the DMSP satellites. These microwave measurements have the advantage of being able to sense through most cirrus clouds. These new measurements reveal that vast stretches of the tropical upper troposphere (averaged over the 6-12 km altitude range) are very dry, with half of the tropics being covered by relative humidities below 20% on a daily basis (Spencer and Braswell, 1997). Individual layer-average humidities fall as low as 2%. These low humidities are extremely important, for they provide radiative exhaust ports through which the Earth can lose radiant (infrared) energy most efficiently. Furthermore, their ability to lose energy increases nonlinearly as the humidity falls (Lindzen, 1995). Pierrehumbert (1995) argues that these dry zones are the controlling influence on the average climate of the tropics.

Conclusion

As discussed above, rainfall systems have an important influence on the humidity of tropospheric dry zones, with a small change in humidity causing a potentially large change in the trapping of infrared energy. If the average temperature of the tropics is indeed sensitive to small humidity fluctuations, why does the tropical atmosphere remain at so stable a temperature? I continue to believe the basic reason is that feedbacks in the climate system are predominately negative, causing any perturbation from the average state to be damped out, and restoring the system back to a stable temperature. In this context, it is interesting to note that the average value of positive cloud feedback in 19 GCM's fell by 71% between 1990 and 1995 (Cess et al., 1996; IPCC, 1995). As the physical processes in GCM's continue to be improved, and as faster computers allow more detailed physics to be incorporated, I expect that the predicted magnitude of global warming will continue to fall, as it has since the first IPCC assessment in 1990. In the mean time, observations from NASA's Earth Observing System AM and PM satellites will provide new information on upper tropospheric vapor, cloud, and radiation processes that will be critical for advancing our understanding of climate variability and improving the physical processes contained in the GCM's.

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Roy W. Spencer

NASA/Marshall Space Flight Center

Global Hydrology and Climate Center

Huntsville, Alabama 35806

(205) 922-5960 (voice)

(205) 922-5788 (fax)

roy.spencer@msfc.nasa.gov (e-mail)

RESEARCH AREAS:

Satellite information retrieval techniques, passive microwave remote sensing, satellite precipitation retrieval, global temperature monitoring, space sensor definition, satellite meteorology.

EDUCATION:

1981: Ph.D. Meteorology, U. Wisconsin - Madison

1979: M.S. Meteorology, U. Wisconsin - Madison

1978: B.S. Atmospheric and Oceanic Science, U. Michigan - Ann Arbor

PROFESSIONAL EXPERIENCE:

4/87 - present: Space Scientist

NASA/Marshall Space Flight Center

10/84 - 4/87: Visiting Scientist

USRA NASA/Marshall Space Flight Center

7/83 - 10/84: Assistant Scientist

Space Science and Engineering Center, Madison, Wisconsin

12/81 - 7/83: Research Associate

Space Science and Engineering Center, Madison, Wisconsin

SPECIAL ASSIGNMENTS:

U.S. Science Team Leader, Advanced Microwave Scanning Radiometer, 1996-present

Principal Investigator, a Conically-Scanning Two-look Airborne Radiometer for ocean wind vector retrieval, 1995-present.

U.S. Science Team Leader, Multichannel Microwave Imaging Radiometer Team, 1992-1996.

Member, TOVS Pathfinder Working Group, 1991-1994.

Member, NASA HQ Earth Science and Applications Advisory Subcommittee, 1990-1992.

Expert Witness, U.S. Senate Committee on Commerce, Science, and Transportation, 1990.

Principal Investigator, High Resolution Microwave Spectrometer Sounder for the Polar Platform, 1988-1990.

Principal Investigator, an Advanced Microwave Precipitation Radiometer for rainfall monitoring. 1987-present.

Principal Investigator, Global Precipitation Studies with the Nimbus-7 SMMR and DMSP SSM/I, 1984-present.

Principal Investigator, Space Shuttle Microwave Precipitation Radiometer, 1985.

Member, Japanese Marine Observation Satellite (MOS-1) Validation Team, 1978-1990.

Chairman, Hydrology Subgroup, Earth System Science Geostationary Platform Committee, 1978-1990.

Executive Committee Member, WetNet - An Earth Science and Applications and Data System

Prototype, 1987-1992.

Member, Science Steering Group for the Tropical Rain Measuring Mission (TRMM), 1986-1989

Member, TRMM Space Station Accommodations Analysis Study Team, 1987-1991.

Member, Earth System Science Committee (ESSC) Subcommittee on Precipitation and Winds, 1986.

Technical Advisor, World Meteorological Organization Global Precipitation Climatology Project, 1986-1992.

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AWARDS:

1996: AMS Special Award "for developing a global, precise record of earth's temperature from operational polar-orbiting satellites, fundamentally advancing our ability to monitor climate."

1991: NASA Exceptional Scientific Achievement Medal

1990: Alabama House of Representatives Resolution #624

1989: MSFC Center Director's Commendation