U.S. Climate Change Science Program Planning Workshop for Scientists and Stakeholders, December 3-5, 2002, Washington, D.C.

Breakout Group 1: Climate Change Science Program Elements, December 3, 2002, 2:00-4:00 p.m.

Session 1. Emerging Climate Science Issues (minutes provided by rapporteur Claire Parkinson).

The "Emerging Climate Science Issues" session was opened at 2:00 p.m. by the session moderator Dr. Robert W. Corell, Senior Fellow of the American Meteorological Society's Atmospheric Policy Program and Senior Research Fellow of the Belfer Center for Science and International Affairs at the Kennedy School of Government, Harvard University.

Dr. Corell began with a brief explanation of the purpose of this breakout session, i.e., to: (a) present an overview of Chapter 2 of the November 11, 2002 draft Strategic Plan for the Climate Change Science Program, (b) hear prepared comments on the draft by four invited panelists, and (c) provide an opportunity for those in the audience to ask questions and make comments. He then introduced the two rapporteurs (Margaret McCalla and Claire Parkinson), prior to introducing the main presenter, Dr. Alexander E. (Sandy) MacDonald, Director of the Forecast Systems Laboratory, Office of Oceanic and Atmospheric Research, NOAA, Boulder, Colorado. Dr. MacDonald was tasked with giving an overview presentation of the draft Chapter 2, entitled "Research Focused on Key Climate Change Uncertainties."

Overview: Alexander MacDonald

Dr. MacDonald began with an image from the Sea-viewing Wide-Field-of-view Sensor (SeaWiFS) satellite instrument, highlighting life on land and in the oceans. He then summarized key points in Chapter 2, in particular the chapter's three key questions, selected for inclusion in the Strategic Plan because of offering the prospect of significant improvement in the understanding of climate change phenomena and the prospect of accelerated development of information relevant to policy decisions. These questions are:

1. What aerosols are contributing factors to climate change and what is their relative contribution to climate change?

2. What are the magnitudes and distributions of North American carbon sources and sinks, and what are the processes controlling their dynamics?

3. How much of the expected climate change is the consequence of feedback processes?

In each case, Dr. MacDonald presented an abbreviated version (for slide presentation) of the list of Research Needs identified in Chapter 2 for the specific question and

highlighted one or more of those. For Question 1, he highlighted the need to develop aerosol chemistry/transport models and the need to compare geographic and height dependence of simulated aerosol distributions against satellite and field measurements. He explained these through a set of graphics and animations, beginning with a graphic from the Intergovernmental Panel on Climate Change (IPCC, 2001) identifying the radiative forcings from each of several influencers (several trace gases, different aerosols, land use, the sun, and aviation-induced contrails and cirrus clouds) and the relative level of scientific understanding regarding their impacts (high, medium, low, or very low). He also described a major dust storm over Asia in April 2001, illustrated with SeaWiFS imagery, and explained its importance, both regionally and on a much larger scale.

For Question 2, Dr. MacDonald emphasized the need to strengthen existing carbon measurement networks, mentioning that the current data are too sparse to improve on model estimates for the North American carbon sink based solely on atmospheric data. He advocated a North American Carbon Observing System.

For Question 3, Dr. MacDonald divided the feedback question into the two subquestions presented in Chapter 2. The first subquestion asks "What is the contribution of clouds and water vapor feedbacks?" For this question, the Research Need highlighted by Dr. MacDonald was the need for combined in situ and remotely-sensed measurements of water vapor for process studies, with emphasis on the tropics. He pointed out the importance of the water cycle and vertical energy fluxes and also pointed out the measurements being made in the Atmospheric Radiation Measurement (ARM) Program.

The second subquestion on the feedback topic asks how feedbacks in the polar regions affect climate change. Here the Research Need highlighted by Dr. MacDonald was the determination of basin-wide Arctic sea ice thicknesses. He also presented imagery of sea ice, snow cover, and icebergs, and indicated that a combination of remote sensing and in situ measurements is needed to determine changes in sea ice and snow cover.

Dr. MacDonald concluded by reiterating that a combination of research, observations, and modeling is essential to arrive at the best answers for improved climate prediction and assessment.

Panelist 1: Warren Washington

Following Dr. MacDonald's presentation, Dr. Corell introduced the first of the four panelists, Dr. Warren M. Washington, senior scientist and head of the Climate Change Research Section in the Climate and Global Dynamics Division, National Center for Atmospheric Research (NCAR), Boulder, Colorado.

Dr. Washington began his remarks by praising the draft Chapter 2 as an excellent start. He then listed five key forcings of the climate system: greenhouse gases, sulfate and carbon aerosols, stratospheric and tropospheric ozone, volcanic eruptions, and land surface and biomass burning, and showed the IPCC 2001 plot of radiative forcing

magnitude versus level of scientific understanding shown earlier by Dr. MacDonald. Dr. Washington explained that even with the flaws in current state-of-the-art models, they still reproduce the globally averaged temperature record from the late 1800s to the present fairly well. He illustrated this with several time series of global average temperatures since the late 1800s, simulated with the inclusion of different sets of forcings, separating out, for instance, sulfate aerosols, greenhouse gases, and volcanic eruptions.

Dr. Washington concluded his presentation by listing and discussing specific problems and gaps in Chapter 2. In particular:

(1) Regarding p.19, lines 7-10, Dr. Washington indicated that it's not likely that aerosols will favorably offset carbon dioxide forcing on a global basis, although might provide important offsets regionally.

(2) P.19, lines 11-12 should be rephrased to avoid having it appear that polluting the air is beneficial because of having a cooling effect.

(3) Regarding pp. 19-20, it is doubtful that the North American Carbon Program will be able to provide critical information to decision makers on a time scale as short as 5 years, in view of interannual and decadal variations.

(4) Regarding pp.22-24, Dr. Washington feels it is essential to include a large, coordinated field experiment for the polar regions, to provide an integrated picture of the feedback mechanisms critical for improving climate modeling of those regions.

(5) The chapter does not include any discussion of land surface changes and ozone changes and their impact on climate changes.

(6) A recent paper in *Science* by Lohmann and Lesins suggests that the indirect aerosol effect is smaller than previously estimated. This needs to be tested, as that could reduce one of the major error bars on climate forcing.

Panelist 2: V. Ramanathan

Dr. Corell then introduced the second panelist, Dr. V. Ramanathan, Victor C. Alderson Professor of Applied Ocean Sciences and Atmospheric Sciences at the Scripps Institution of Oceanography (SIO), University of California San Diego.

Dr. Ramanathan centered his talk around four major points, the first being that "air pollution and climate change are linked through aerosols and tropospheric ozone," illustrated with a flow chart of interactions between global and regional processes. Dr. Ramanathan's second point was the need to focus on the problem regionally, as he illustrated forcefully with an April 2001 image of aerosol optical depth from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite.

Since the aerosols are concentrated regionally, their impacts vary greatly depending on the location.

Dr. Ramanathan's third major point was the identification of the tropics as a large source for black carbon and the advocacy of a focus on Asia, Africa, and the Amazon as three regions contributing in a major way to the black carbon problem. He indicated that our knowledge is so limited on this issue that we do not even know whether black carbon has a warming or a cooling effect overall.

Dr. Ramanathan's fourth and final major point was the importance of the hydrological cycle. Water availability is likely the major environmental issue for this century, making the water cycle of critical importance.

In closing, Dr. Ramanathan indicated that the aerosol community is well organized and listed the members of the Steering Committee and the Federal Agency Advisory Group for the National Aerosol-Climate Interactions Program.

Panelist 3: Michael Schlesinger

Following Dr. Ramanathan's presentation, Dr. Corell introduced the next panelist, Dr. Michael E. Schlesinger, Professor of Atmospheric Sciences and Director of the Climate Research Group at the University of Illinois at Urbana-Champaign.

Dr. Schlesinger centered his talk on four assertions and two conclusions, beginning with:

Assertion 1. We will not be able to learn the value of the Earth's climate sensitivity (ΔT_{2x}) from global climate models (GCMs).

He illustrated this point by showing a plot of the temperature sensitivity simulated by six different models, showing the large range in results, from 0.3 to 5.2°C. He then asserted, as Assertion 2, that we can learn the value of the climate sensitivity from the observational temperature record and provide it to the GCM modelers as a target to be reproduced, illustrating this with plots of observed temperatures from 1855 to 2000. He also showed results from a simple climate/ocean model and highlighted the importance of anthropogenic contributions.

Assertion 3, that the value of climate sensitivity estimated from the observed temperatures is strongly dependent on the radiative forcing, was illustrated by Dr. Schlesinger with a plot of sensitivities determined from a variety of combinations of radiative forcings. The sensitivities ranged from 1.1 to 5.0°C. This led to Dr. Schlesinger's first conclusion:

Conclusion 1: To reduce the uncertainty in the estimated value of climate sensitivity, we must reduce the uncertainty in the radiative forcing, not only by aerosols (as focused on in the Plan) but also by the Sun and volcanoes.

Dr. Schlesinger's Assertion 4 is that the value of climate sensitivity estimated from the observed temperature record has a probability distribution due to the noise in the climate system, illustrated by empirical probability distribution plots incorporating and not incorporating solar variability. These plots illustrate a very large effect from the Sun.

Dr. Schlesinger concluded with Conclusion 2, a statement that to reduce the uncertainty in the estimated value of climate sensitivity, "we must continue to observe and analyze in clever ways the Earth's surface temperature."

Panelist 4: Brian Flannery

Dr. Corell then introduced the final panelist, Dr. Brian P. Flannery, Science, Strategy and Programs Manager in the Safety, Health and Environment Department at Exxon Mobil Corporation.

Dr. Flannery emphasized the importance of management structure in carrying out the research called for in Chapter 2, entitling his presentation "A Proposal for a More Structured U.S. Program in Climate Science." He outlined some of the work Exxon Mobil has done, including taking action to reduce emissions and to promote technological innovation, then listed known gaps limiting climate understanding, including uncertainties in critical climate processes, the incomplete observational record, and limitations of current climate models. The difficulties are compounded by the fact that the Earth's climate is a chaotic system and has significant natural variability, illustrated by Dr. Flannery with tree ring measurements.

Dr. Flannery then outlined three elements of a new, recommended structured approach to the climate studies called for in the Strategic Plan:

1. Focused research programs that address specific, significant scientific understandings, with quantitative deliverables. For each key research area, such as clouds, aerosols, water vapor, sea ice, surface hydrology, and the carbon cycle, the program should assign a responsible agency to quantify the level and nature of the uncertainty, explain its policy relevance, define and conduct research to address the uncertainty, report to Congress, and subject the program to scientific review.

2. Enhanced technical and management capacity for an improved national infrastructure to observe, analyze, understand, and predict climate change and its impact. Dr. Flannery mentioned that "the U.S. has lost its lead in climate modeling relevant to policy assessments … but not in climate science." He praised the Hadley Centre's work to ensure that its results are incorporated in international assessments and indicated that the U.S. program needs a similar effort.

3. Improved U.S. and international assessments of climate change. Dr. Flannery explained that the IPCC process is inadequate for the U.S. and that we need both to

improve the IPCC process and to conduct periodic U.S. oriented assessments tailored to U.S. needs and issues.

Dr. Flannery concluded his presentation by saying that he recommends a package of reinforcing process improvements as outlined in the three elements listed above. This, along with continued funding of curiosity-driven research that may lead to unanticipated insights and results, should produce an enhanced U.S. climate science program.

Questions and Comments from the Audience

Dr. Flannery's comments concluded the Panelist presentations, at which point Dr. Corell reminded everyone that anyone wanting his or her comments to be considered during the revision of the Strategic Plan should submit those comments in writing at the appropriate location on the www.climatescience.gov web site. He then opened the session to questions and comments from the audience. The open discussion period proceeded as follows:

Fred Singer, University of Virginia, commented on the need to examine to what extent natural variability is endogenous versus exogenous. This needs to be understood and illuminated. For instance, only in the last 10 years has the importance of the Sun in climate variability become compelling.

Pat Michaels, University of Virginia, began by indicating agreement with Dr. Ramanathan that it's important to understand whether climate changes smoothly or abruptly. He then commented that most GCMs indicate smooth changes and asked: What processes would induce the nonlinearities, and why aren't they in the models yet, despite the large amount of funding that has gone into the modeling efforts? Dr. Ramanathan replied, indicating that clues in the natural system show some abrupt changes that we'd like the models to be able to reproduce. Dr. Washington followed, indicating that the models have a long ways to go before they can reproduce all of what we'd like and that it's important that we continue to lessen the uncertainties. Dr. Schlesinger indicated that some coupled atmosphere/ocean models do simulate abrupt climate change for some paleoclimatic instances, while agreeing that it's an area needing continued research.

Charlie Kennel, Scripps Institution of Oceanography, stated that basic research is the primary insurance against surprises and asked each member of the Panel to state what he considers to be the single most important thing that we can do in the next five years in our field. Dr. Ramanathan began, indicating that he is reasonably satisfied with the issues being addressed by the CCRI. Dr. Washington indicated that the polar regions should be a high priority in view of the tremendous changes we've seen in them in recent years. Dr. Washington also indicated that we need a balance between basic and applied research, specifically saying that we need to invest heavily in basic research. Dr. Flannery highlighted cloud physics and aerosols, while also agreeing with the need for fundamental basic research. Dr. Schlesinger is not sure how realistic the 2-4 year time

scale is for obtaining some of the desired answers, given the magnitude of complications in the Earth system.

Tom Grahame, Department of Energy, mentioned that the borehole temperature record over the past millennia shows more variability than some other temperature records and asked the Panel about that record. Dr. Schlesinger responded that the borehole record is indeed of interest.

Blair Henry, University of North Dakota, mentioned that aerosols, which are heavily emphasized in Chapter 2 and by the Panel, were only number 7 on the list of priorities from the National Academy of Sciences. In contrast, priorities 1, 2, and 3 on the Academy list were hardly mentioned. He asked the Panel whether they felt the Academy's top three priorities had been adequately addressed. Dr. Flannery indicated that the Panel had just been asked to comment on the draft Chapter 2, not necessarily to put it in the context of the Academy priorities, although Mr. Henry had clearly brought up an important point.

Keith Dixon, National Oceanic and Atmospheric Administration (NOAA), asked Drs. Washington and Schlesinger where they would start in setting the priorities for a 2-4 year time frame considering the many possible modeling studies, including ensembles and multiple runs with varied sets of forcings. Dr. Washington replied that in the U. S. we've transitioned into a more organized effort than previously, including more individuals and groups trying to do experiments covering all the reasonable forcings. There remains, however, the need also for improvements in the models. Dr. Schlesinger replied that models are indeed being used both for application runs and for research runs, with some of the research runs, for instance, investigating the effects of using higher resolutions.

Lois Dean, urban policy analyst, Department of Housing and Urban Development, pointed out the need to look at local and regional responses. Dr. Ramanathan agreed but stated that the current models are inadequate. He mentioned the need for improved spatial resolution, to 100 km or better.

Dee Ann Divis, United Press International, commented that we've heard today that the models aren't perfect, but we've also been hearing for quite some time that there could be a substantial risk in such occurrences as the thinning of the polar caps. Her question to the Panel: How long will it take to have good enough data to make policy decisions? Dr. Schlesinger explained that 30 years ago the Rand Corporation developed adaptive strategies to make decisions under deep uncertainties. He confirmed that we need to make decisions and act on them, while recognizing that we also might need mid-course revisions, as further work reduces the uncertainties. Dr. Washington added that there is no set threshold under which the uncertainty is considered low enough; hence we need to address the issues and make some decisions before the answers are all available. Dr. Flannery pointed out that indeed actions are being taken and that the more relevant issue isn't when to start taking action but how much action to take.

Paul Epstein, Harvard Medical School, asked whether there are systemic level parameters to indicate whether particular rates of change and variance increase the possibility of abrupt climate change. Dr. Ramanathan agreed that this is an important issue and mentioned several illustrative examples, including one involving black carbon. Dr. Schlesinger mentioned the thermohaline circulation of the ocean as one element with a potential to bring about abrupt climate change.

Bill Orr, National Alternative Fuels Foundation, encouraged the Panel to recommend basic research to improve the accuracy of the climate models.

Cary Presser, National Institute of Standards and Technology (NIST), asked what the standards should be regarding aerosol measurement and validation of models. Dr. Ramanathan replied that there remain many uncertainties regarding aerosols and that the field could benefit from increased standardization.

Jim Patten, Battelle, mentioned that there is evidence that combustion systems are putting out substantial carbon-based and sulphate-based emissions that are quite small and asked whether the modeling community has come to terms with that. Dr. Ramanathan agreed with the first statement and indicated that it's a significant source of uncertainty. Dr. Flannery agreed with the importance of determining the changes in aerosol types.

Gad Levy, NorthWest Research Associates, suggested hybrid models combining probabilistic models with regular GCMs. Dr. Schlesinger responded that this seems to be a worthwhile idea to explore.

Steve Goldberg, Argonne National Laboratory, objected to the repeated mention of "significant" improvements and asked how much of an improvement is needed for it to be labeled "significant".

David Warrilow, U. K. Department of Environment and Rural Affairs, addressed the uncertainty question and risk assessments, and Dr. Schlesinger confirmed that the two go together.

Glenn Juday, University of Alaska Fairbanks, nominated the changes in the boreal forest region as an important emerging issue for the Strategic Plan. He justified this recommendation on the basis of the importance of the boreal forest as a major storehouse of carbon and the extent of the changes currently occurring in it, likely induced by warming.

Chuck Hakkarinen, Belmont, California, asked the Panel members if they had recommendations to the CCRI management regarding how to select tasks in face of limited funds. Dr. Schlesinger responded that he sees that as the objective of the Strategic Plan.