Written Public Comments on the
Strategic Plan for the U.S. Climate Change Science Program
Chapter 2: Research Focused on Key Climate Change Uncertainties (pp 17-25)
Comments Submitted 11 November 2002 through 18 January 2003
Collation dated 21 January 2003

Page 17, Chapter 2: This chapter reflects the understanding that the first step in improving our understanding of climate change is to address the many uncertainties that remain. That focus is important. But equally important is that the reduction of uncertainties take place in the most critical areas. Aerosols are important, as are sources and sinks and clouds and water vapor, but equally important are uncertainties in: the accuracy of historical reconstructions of climate; uncertainties regarding the global warming potential of individual greenhouse gases or other human activities; uncertainties regarding the influence of solar output on climate; and uncertainties regarding proper accounting for the urban heat island effect in surface temperature records.
KENNETH GREEN, FRASER INSTITUTE

Page 17, Chapter 2: Note my general comments on Chapter 1. A key uncertainty must be the interaction between natural modes of variability, particularly El Nino, and climate change.
JULIA SLINGO, NCAS/CGAM, UK

Page 17, Chapter 2: **First Overview Comment:** The draft Strategic Plan says (p. 17) that the CCRI will address three key areas "where accelerated development of decision support information is possible" and where "focused effort would rapidly lead to critical decision support information." Chapter 1 assures (p. 15) that "the CCRI pro-grams will produce deliverables useful to policymakers in a short time frame (2-4 years)." It is one thing to establish (and to explain) priorities, so that certain questions will receive effort (including funding and assignment of researchers) that is greater than for other questions because the need for answers to the priority questions is regarded as relatively urgent or because there is a belief that the priority questions can be answered with comparative ease. It is quite another to create expectations of policymakers, the media, and the public that may not be possible to achieve without sacrificing objectivity, accuracy, or valuable compre-hensiveness.

Disappointment largely is a function of expectation, and, based on numerous comments at the December workshop, it appears that the draft Strategic Plan is setting the stage for inevitable disappointment on the part of those who might rely on the CCRI timetable described in the Strategic Plan.

We agree with the numerous workshop participants who urged elimination of the two-to-four year time frame. Examples include: Dr. James Hansen (NASA-Goddard) who, according to our notes, said that the proposal in question "seems to think science can be ordered up;" Dr. Linda Mearns (NCAR), who, according to our notes, cautioned against pretending that all uncertainties can be reduced, because that "leads to the worst result – false certainty;" Professor Henry Jacoby (MIT), who, according to our notes, explained that the reasons for tension between the two-to-four year time horizon and "the pace of science" are "funda-mental" and that we "won't get resolution" of the clouds issue within that time frame; and Dr. Bob Corell (Harvard), who, according to our notes, said he had not been in a single breakout group that thought the two-to-four year time frame was "realistic." There were many disagreements among the workshop participants, but there was virtual unanimity on this particular issue.

We appreciate that, in February 2002, the White House issued a *Global Climate Change Policy Book* that, among other things, said: "The CCRI . . . will adopt performance metrics and deliverable products useful to policymakers in a short time frame (2-5 years)." We believe that the workshop was held to enable those responsible for development of the Strategic Plan to benefit from information and insights. In view of the virtual unanimity of workshop participants on the issue of the CCRI's time frame, and, more importantly, on the soundness of the reasons for their stated, collective view, there should be no reluctance to drop the two-to-four year time frame. This is especially true since the President's February 12, 2002 speech concerning climate change set the standard that should govern the time-frame issue: "When we make decisions, we want to make sure we do so on sound science; not what sounds good, but what is real."

We believe that, in addition to eliminating specific time schedules for deliver-ables, the Strategic Plan should avoid qualitative assurances, such as "rapidly lead to critical decision support information" or "deliverables useful to policy-makers in a short time frame." The draft Plan fails to explain its optimism regarding the CCRI, particularly in view of the "Research Needs" identified on pp. 18, 19-20, 21-22, and 23-24 to answer the questions raised in Chapter 2.

DONALD H. PEARLMAN, THE CLIMATE COUNCIL.

Page 17, Chapter 2: In Chapter 2, I propose to add the following question to the questions already discussed:

What are the atmospheric and climate responses to changes in total solar irradiance and solar spectral irradiance?

The sun is the engine that drives the weather and climate machines. Solar energy leaving the sun, or solar irradiance, varies by huge amounts within limited wavelength regions but a very small amount when integrated over the total solar spectrum. The largest changes occur in the extreme ultraviolet (EUV) and x-ray parts of the solar spectrum as well as the flux of energetic particles associated with solar activity. Physical process modeling demonstrates that much of the large solar changes are manifest in the dynamics, chemistry and microphysical properties of upper atmosphere. How energy, mass and momentum are transported from the upper atmosphere to the lower atmosphere is not well understood. In fact model results are not validated for all conditions due to a lack of relevant measurements; routinely made and readily available.

Changes in total solar irradiance affect the lower atmosphere. Small changes in solar irradiance, as observed, should produce small changes in the lower atmosphere. Since these small changes may be too small to be observed in weather records, a long-term authoritative record of solar irradiance is needed. The long-term record can be used to compare with the long-term atmospheric record. TSIS data will provide the required monitoring measurements and, when merged with data from SORCE, Nimbus 7, SMM, ERBS, NOAA 9, NOAA 10 and UARS, can be used as the foundation of the authoritative long-term record.

HERBERT KROEHL, NOAA-NESDIS

Page 17, Chapter 2: The stated research foci on key climate changes: aerosols, North American carbon budget, and feedback mechanisms (water vapor/cloud/polar region), seem to be missing a number of needed research on critical processes including the role of ocean in climate change, and the consequence of anthropogenic effects on sea level rise. Crticial scientific questions relating these two research foci include:

* What is the role of the ocean in increasing heat flux forcing and feed back to long-term climate changes? What is its consequence of global sea level change? What is role of bathymetry (roughness of sea floor) in thermohaline circulation change and resulting climate change?

* Can we accurately measure and characterize the 20th century sea level signals? Can we accurately predict sea level rise due to anthrogenic effects?

Today half a billion people worldwide live on coastlines within 5 meters above sea level, more than 80% of Americans live within one hour drive of a coast, any short-term or long-term sea level change relative to vertical ground motion is of great societal and economic concern. Research foci with the associated policy change is critical to be considered in view of the impact of the inevitable consequence of sea level rise.

C. K. SHUM, OHIO STATE UNIVERSITY

Page 17, Chapter 2: First Overview Comment: Transport of long-lived radiatively active trace gases, photochemically active trace gases, and aerosols remains a key uncertainties in determining the time and space scales by which changes in atmospheric composition, and the carbon cycle impact the climate system. The impact of these interactions will differ significantly depending on the global location. For example, surface emissions of aerosols, NOx, and VOCs have been shown to have a much greater impact on ozone formation when emitted in tropical regions. The vertical distribution together with aerosol composition determines the radiative impact. Nor is upper troposphere/lower stratosphere exchange well characterized. Because it is a sub-grid scale process, vertical transport is poorly represented in one of the key tools we use to assess climate change, climate system models and GCMs. Experimental campaigns are needed to develop, test and refine transport parameterizations˜particularly aircraft studies of compounds that can be used as tracers of surface emissions, and their behavior in deep convective cells. Studies at both temperate and tropical latitudes are needed to improve our analytical framework for estimating the sources and sinks of CO2, N2O, CH4, O3, aerosols, NOx, CO and VOCs. Such a series of studies will require considerable resources and cooperation amongst several communities. By focusing on transport rather than aerosols, a grand challenge could be transformed into an issue that cuts across chapters, and comes closer to evaluating air pollution as a climate forcing. If not included here, then it should be included in Chapter 12 as a cross-cutting issue at a minimum.

BETH HOLLAND, NCAR

Page 17, Chapter 2: While it is important to understand sources and magnitudes of uncertainty, there also needs to be clarity as to what kinds of uncertainties are needed by decision makers. How should information with an inherent degree of uncertainty be best communicated? What uncertainties are anticipated and expected? What can be learned regarding useful supplemental information from existing decision practices? The road from credible science to public use is still being learned and needs to be understood as clearly from the public use capability as from the science capacity. IRI and its partners can help in the realization of research that improves understanding of interaction between the environment and society (e.g., p. 14 of CCSP). There remains much work to be done to accomplish key goals and it will be important to build on lessons learned rather than starting anew.

IRI, ZEBIAK AND STAFF

Page 17: First box. Three bullets are included here. I believe a fourth bullet is required, as below:

4. How will dynamics and productivity of terrestrial, freshwater and marine ecosystems respond to climate change? What modifications must be made to management strategies and management models to permit optimal harvest of plants and animals in the face of uncertainties in climate change?

Page 24. Line 21. Insert text which elaborates on the “fourth bullet” proposed. Should the drafters of this document agree, I will be happy to write a draft of the required page or two of text for their consideration.

BILL PETERSON, NOAA/FISHERIES

Page 17, Chapter 2: **In order to make progress on climate change, research should enable planning 100 years into the future.**

The average research timeframe for the Strategic Plan, 5-15 years, is too short. Research should examine projected impacts at least 100 years out and should use this data to adequately mitigate short as well as long-term impacts. For example, the Strategic Plan proposes to measure permafrost temperatures and thaw patterns for five years in sufficient detail to establish regional thaw patterns. In order to establish regional thaw patterns caused by climate change it is necessary to look at the data for a number of decades, not five years. In addition, the EPA and IPCC already have data that proves that Artic sea ice is not as thick as it used to be and melts earlier in the spring.

Public lands and water management agencies need to conduct a complete and thorough analysis to determine the full scope and breadth of projected impacts from global climate change. As mentioned above, most public land and water management plans project scenarios only five to ten years into the future, however, because of the time parameters of climate change, agencies should study climate change impacts for the next 100 years and use this data to plan at least 20 years into the future. Any failure to conduct such long-term analysis endangers public land and water resources, and violates agency mandates to leave resources unimpaired for the enjoyment of future generations.

CHRISTINE CORWIN, BLUEWATER NETWORK

Page 17, Chapter 2: Another goal of the Bush Administration's climate program is to reduce uncertainty for future sea level rises during the 21st century and quantification of permafrost contributions to the carbon budget and climate warming. (p. 24) The IPCC and EPA have already studied and released predicted ranges for sea level rise. As with most scientific research, it is absolutely impossible to reduce the uncertainty of this data to zero. Instead of spending money to reduce inherent uncertainties, the government should spend taxpayer dollars on research on actual emissions reductions and economic impacts, especially among poor communities.

IMMEDIATE GREENHOUSE GAS EMISSIONS REDUCTIONS

The earlier mandatory emissions reductions are introduced, the greater chance we have of lessening and slowing projected warming and sea level rise. In addition, if we begin reducing emissions now, it will be less expensive than if we begin reducing emissions later, since emissions are increasing each year.

Time is of the essence and it would be irresponsible to substitute unnecessary research for the immediate implementation of commonsense solutions. If we begin reducing our greenhouse gas emissions now, it will take a lot less time to stabilize the climate.

According to the IPCC report, stabilization of atmospheric concentrations of carbon dioxide at 450, 650, or 1,000 ppm would require global anthropogenic carbon dioxide emissions to drop below 1990 levels, within a few decades, approximately a century, or in the next 200 years, respectively. Stabilizing greenhouse gas emissions at lower levels, and therefore sooner, is critical, because it will help avoid the worst predicted impacts of climate change.

Currently, the Bush Administration's voluntary greenhouse gas intensity reduction target is set at an 18 percent reduction in emissions *intensity* between now and 2012. This voluntary reductions target will allow actual greenhouse gas emissions to increase 12 percent over the same period.

The Strategic Plan should include research on mandatory emissions reductions strategies for key sectors, such as transportation and electricity production. In addition research should be conducted on mandatory emissions reporting systems and should focus on absolute emissions and not emissions intensity.

CHRISTINE CORWIN, BLUEWATER NETWORK

Page 17, Chapter 2: Regional Climate Change" is missing from the plan altogether. It is mandatory that regional change and affects be a priority issue. This is a "hand-in-glove" issue (quite literally). Getting the large scale representation correct is obviously necessary, but it is regional manifestations that are experienced by people. If they do not see issues of importance to them being included, credibility will suffer if not lost.

CRESS. PNNL

Page 17, Chapter 2: It is our view that studies of the distribution of CO2 and related tracers in air are an essential component of global carbon cycle research, and that such studies are under-represented in the strategic plan for the Climate Change Science Program, as currently drafted. The importance of atmospheric measurements is well illustrated by the IPCC report, where they are used to support estimates of sources and sinks of CO2, both globally and regionally. Atmospheric measurements over North America and elsewhere remain highly relevant for the North American Carbon Program and other CCSP goals. The changes proposed below will help to elevate atmospheric measurements to their appropriate importance in the overall program.

RALPH KEELING, SCRIPPS INSTITUTION OF OCEANOGRAPHY, MICHAEL BENDER, PRINCETON, U., PIETER TANS, CMDL

Page 17, Chapter 2: The draft Strategic Plan contains well-reasoned and documented presentations of areas in which better scientific understanding would help inform climate policy. It also discusses needs in the areas of climate observation, data management, and climate modeling that support and build on necessary progress in theory. However, particularly in the discussion of the Climate Change Research Initiative (CCRI), the perception is created that a focused effort for 2 – 4 years could significantly reduce uncertainties in climate science. This is misleading because it can lead to unrealistic expectations.

The Marshall Institute agrees with the position taken by many at the CCSP Workshop, that many climate system uncertainties remain unresolved after 20 years or longer of study and are unlikely to be resolved in the next 2 – 4 years. More effort should go into analyzing uncertainties from the standpoint of what is unknown, but likely knowable with a reasonable amount of effort, what may turn out to be unknowable anytime soon because some aspects of climate may be chaotic, and why these uncertainties are important to policy makers.

Acknowledging that some aspects of the climate system will not be resolved in the short-run is important for at least two reasons:

1. it helps focus research on those aspects of the climate system where near-term research can be valuable and illuminating, and

2. it avoids creating unrealistic expectations among the users of climate research.

Comments on Chapter 2

In his February 14, 2002 remarks announcing his climate change initiative, President Bush articulated his vision for U.S. climate research, when he said:

> Our nation will continue to lead the world in basic climate and science research to address gaps in our knowledge that are important to decision makers.
>
> When we make decisions, we want to make sure we do so on sound science; not what sounds good, but what is real. [1]

Thus, the vision for the CCSP should be:

> To provide decision makers with the highest quality science that they need to establish effective climate policy by reducing the uncertainties in our understanding of climate processes and probable future climate change, regardless of cause, to a level that will allow rational choices between the policy options they face.

The Marshall Institute shares the concern expressed by many presenters and commenters at the December 3 – 5 CCSP Planning Workshop about the lack of prioritization in the long list of research objectives presented in the draft Strategic Plan. We are also concerned about the limited discussion of the basis for prioritization presented in the draft Strategic Plan.

Pg. 165 of the draft Strategic Plan states:

> The CCSP will adopt a problem-driven rather than a disciplinary approach in setting priorities and sequencing investment, identifying for early action and support those projects and activities that meet agreed-upon criteria in the following areas:
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> - Relevance/Contribution;
> - Scientific Merit;
> - Readiness;
> - Deliverables;
> - Linkages; and
> - Costs.
>
> Some projects and activities may be identified for early implementation because they lay the foundation for subsequent work in other areas …

Since no further discussion of these criteria was provided in either the draft or at the Workshop, the meaning of those criteria and their weighting for priority setting are unclear. To provide a clearer understanding of the criteria on which the priorities will be assessed, the Marshall Institute recommends that they be renamed and reordered. Our recommended criteria, in order of importance, are:

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[1] www.whitehouse.gov/news/releases/2002/02/20020214.5.html

1. Potential Value to the Decision-making Process;
2. Scientific Merit;
3. Probability of Success;
4. Cost; and
5. Importance to Other Projects/Programs.

Providing value to decision makers is the stated goal of the Strategic Plan. Therefore, the first basis for prioritization should be the value and contribution a specific effort could provide to decision makers. This is a combination of Relevance/Contribution and Deliverables, and we have replaced both of these with Potential Value to Decision-making Process. Scientific Merit must always be an important criterion and we have placed it second. Similarly, in targeted research, Probability of Success and Cost are important considerations, and we have placed them third and fourth. It is critical that elements of this program support each other, and, as acknowledged in the draft, there is often a rational sequencing of research, where certain objectives must be achieved before other programs can be undertaken. In response to these needs, we have added Importance to Other Projects/Programs as our final criterion.

The original list included Readiness, which assumes an aspect of Probability of Success. Targeted projects and programs should not be undertaken until the appropriate knowledge foundation has been built. The original list also included Linkages, which we assume is part of Importance to Other Project/Programs.

The Marshall Institute believes that these criteria are appropriate for the targeted research that will make up the majority of the CCSP. However, we also believe that a significant portion of the remainder should be devoted to basic research to improve our understanding of the climate system. This research would not have immediate value to decision makers and may have a low probability of success. The key criterion in judging such research should be scientific merit. Budgetary constraints will inevitably limit such research to a smaller part of the total program, but it is the part of the program that offers the greatest opportunities for new insights, for identifying truly emerging issues, and for creating the intellectual capital that is needed for the long term. Basic research is a national asset and also is an important part of a targeted program that is infused with uncertainty.

WILLIAM O’KEEFE, GEORGE C. MARSHALL INSTITUTE

Page 17, Chapter 2: Scientific research in three areas should be a high priority:

1. achieving the theoretical understanding of important climate processes needed to better understand both natural and potential human influences on the climate system;

2. building and maintaining the climate observation network and data management system needed to generate, store, and make accessible to researchers the high quality data required to provide the empirical insights to the climate system and its changes that can lead to improved theoretical understanding and to build and test climate models; and

3. developing from an improved observational system the empirical information and theoretical knowledge needed to assess adaptation options.

Achieving the Theoretical Understanding of Important Climate Processes
<u>Needed to Better Understand Potential Human Influences on the Climate System</u>

The need to improve our theoretical understanding of the climate system is well recognized in the CCSP Strategic Plan. The USGCRP portion of the Plan identifies many areas in which our understanding of the fundamentals of climate processes is inadequate, and the CCRI has as one of its goals to "… reduce the most important uncertainties in climate science …" [2] However, the Plan has insufficient focus on the most critical uncertainties, the ones that would contribute most to improving our understanding of the differences between natural climate variability and anthropogenic climate change.

As the National Academies of Science pointed out in the quote presented above, "… an ability to differentiate anthropogenic change from natural variability is fundamental to help guide policy decisions …" [3] Natural variability is not a random phenomenon; it is the result of changes in the levels of the natural drivers of the climate system and their feedbacks. Until natural climate change and feedbacks we understand accurately predictions of the potential effects of human activities will remain extremely uncertain.

The key topics in which better observational understanding is needed to assess natural vs. anthropogenic change are the effects of water vapor, clouds, aerosols, solar variability, and ocean currents. Chapter 2 of the CCSP Strategic Plan highlights uncertainties about aerosols, water vapor, and clouds in determining feedbacks. NASA's plans, discussed at the CCSP Planning Workshop, include ongoing measurements of solar irradiance. This will provide an important basis for a better understanding of its role in determining climate. However, the draft Strategic Plan does not include a similar focus on the role of ocean currents. This is a critical omission, particularly since on Pg. 48 the draft Strategic Plan states:

> All current climate models fail to adequately simulate several climate processes and their feedbacks. One example of such a process is ocean mixing, *which to a large extent controls the projected rate of global warming*. (emphasis added)

And Pg. 50 continues:

> Of particular note among the key uncertainties in climate change modeling is the role of the ocean. Because of computer resolution, none of the current coupled climate models resolve the small ocean eddies (with horizontal scale of tens of kilometers) that constitute the dominant scale of ocean variability. These eddies are *thought to play a substantial role* (emphasis added) in regulating oceanic heat

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[2] CCSP and Subcommittee on Global Change Research (2002): *Our Changing Planet: The Fiscal Year 2003 U.S. Global Change Research Program and Climate Change Research Initiative.* Pg. 14

[3] NAS (1998): *Decade-to-Century Scale Climate Variability and Change: A Scientific Strategy.* Preface.

> transport (via boundary currents) and heat and carbon storage by regulating transport to deep water.

The draft Strategic Plan outlines a series of computer studies to evaluate the effects of the inadequate characterization of ocean currents on the performance of climate models, but it does not include priority for theoretical and observational studies to improve our basic understanding of the role of ocean currents in the climate system. If ocean currents do, to a large extent, control the rate of global warming, are the small ocean eddies the mechanism of this control? If so, how should they be factored into estimates of natural variability and potential anthropogenic climate change?

The Role and Limitations of Climate Models

Evaluating the effects of the various natural and anthropogenic drivers of the climate system involves the use of climate models. While the Marshall Institute has expressed and continues to express concern about the misuse of climate models, it recognizes their value as scientific tools to help understand the complexities of the climate system. However, model development should proceed only as fast as theoretical understanding of the climate system and validation permit.

Simply adding more parameters to models is unlikely to improve them. As Dr. Syukuro Manabe, who helped create for NOAA the first climate model that coupled the atmosphere and oceans, observed:

> Models that incorporate everything from dust to vegetation may look like the real world, but the error range associated with the addition of each new variable could result in nearly total uncertainty. This would certainly represent a paradox. The more complex the model, the less we know! [4]

Unfortunately, much of the current climate policy debate draws on forecasts of future climate generated by climate model simulations, a role for which they have yet to be validated. The most complex of these models, called General Circulation Models (GCMs), attempt to simulate global climate by mathematically modeling the physical processes in the atmosphere and oceans that are known to affect climate, e.g. the way heat is transferred in the atmosphere, from atmosphere to the oceans, and through the oceans.

GCMs were developed as research tools to allow scientists to study relationships among the various components of the climate system. They were not meant to be used to predict the climate of the next century or to be policy drivers, but this is how they have and are being used. However, as the National Academies of Science concluded:

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[4] Quote from an article by Revkin, A.C., “The devil is in the details,” *The New York Times*, July 3, 2001, Pg. D2.

> … climate models are imperfect. Their simulation skill is limited by uncertainties in their formulation, the limited size of their calculations, and the difficulty in interpreting their answers that exhibit almost as much complexity as in nature. [5]

Because the goal of the CCSP is to inform policymakers with the best possible projections of future climate along with their uncertainties, a high priority of the CCSP must be to better understand our climate system, the major processes that affect it, and to use that understanding to determine whether climate models can be improved to the degree needed to make useful projections of future climate for policy making.

On Pg. 7, the draft CCSP Strategic Plan observes:

> Even if the scientific community were to develop a "perfect" model of global climate, it would not be possible to predict the level and rate of future changes in climate resulting from human activities. This is because these activities are not predetermined, but rather depend on human choices, which will, in turn, affect future climate conditions.

The draft continues with the observation that climate models:

> … are useful for performing "If …, then …" scenario experiments that make it possible to begin to explore the potential implications of different technological and institutional conditions for future emissions, climate, and living standards.

While a "perfect" climate model is an impossibility, criteria can be established for a "successful" model. A successful climate model is one that can be validated by its ability to (1) reproduce well-observed past climate, (2) correctly simulate current regional climate, both temperature and precipitation patterns, and (3) match vertical temperature profiles in both the atmosphere and the oceans. Current climate models do not meet these criteria.

It has been claimed that climate simulations have demonstrated the ability to back-cast the last 140 years of global average temperature. This claim is unsupported because of the high level of uncertainty in both the surface temperature record and the model predictions.

It is readily acknowledged in all assessments of currently available climate models that they cannot simulate regional climate; different models not even agree on the direction of projected change at the regional level.[6] The inability of currently available models to project regional climate change is a serious concern for at least two reasons:

1. an accurate assessment of the risks and benefits of climate change can only be made if reliable information is available about change at the regional level, and

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[5] NAS(2001): *Climate Change Science: An Analysis of Some Key Questions.* p. 15.

[6] IPCC (2001a) : *Climate Change 2001: The Scientific Basis,* Chapter 10.

2. the inability of models to accurately project change at the regional level reinforces doubts about their global projections, since the global projection is the sum of regional projections; the skill shown in simulating current global average climate conditions may be a fortuitous balance of large positive and negative systematic errors or the result of calibrating models to match known conditions.

The inability of currently available models to simulate vertical temperature profiles in the atmosphere is also well documented. In its examination of the difference between surface and mid-troposphere temperature changes over the past 20 years, the National Academy of Sciences concluded:

> … models need to include more realistic representation and coupling of the stratosphere, troposphere, and ocean to fully capture the vertical structure of temperature change. [7]

While the current generation of models have been "calibrated," they have not been "validated." The distinction between the two is critical, but often misunderstood. A model can be calibrated, i.e., tuned, to match a set of measured conditions. This is the process that is used for the currently available models. However, validation requires that the model successfully reproduce measured conditions, physical processes and their interactions. Given the many, well-documented shortcomings in the present day understanding of climate processes, it is not surprising that a validated climate model is not available.

It may prove impossible to develop "successful" climate models. It is well known that weather is chaotic. Since climate is the long-term average of weather, it, too, may be chaotic. If climate is chaotic, then just as it is impossible to forecast the weather more than about a week in advance, it may only be possible, at best, to forecast climate a few decades in advance. Determining whether climate is predictable or not should be a high research priority.

Even if it proves possible to develop sufficient understanding of climate processes to build a "successful" climate model, it may still prove difficult to predict climate more than a few decades into the future because the economic inputs are unknowable. The IPCC *Special Report on Emissions Scenarios* [8] highlights the problem. Using the best available estimates of future population, economic growth, technological development, and attitudes towards control of local and regional environmental quality, economic modelers came up with scenarios for baseline carbon dioxide emissions (projected carbon dioxide emissions in the absence of any effort to control them) in 2100 that varied by a factor of more than eight. Efforts to control carbon dioxide emissions could lead to an even greater potential range of emissions in 2100. As the TAR results implied, using such a large range of carbon dioxide emissions as input to a hypothetically "successful" climate model would result in a potential range temperature changes in 2100 that would provide no useful guidance to policymakers. Furthermore, important variables besides

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[7] NAS (2000): *Reconciling Observations of Global Temperature Change.* p. 70.

[8] IPCC (2000): *Special Report on Emissions Scenarios*, 599 p

carbon emissions – population and economic growth rates, technological developments and changes in the world's energy mix – cannot be predicated in any meaningful way.

A research finding that climate is unpredictable, either because climate is chaotic or because economic inputs are unknowable, would be disappointing to climate modelers. However, it would be highly valuable to policymakers and resource managers who need to know not only what is known, but also what is unknown, but knowable, and what is both unknown and unknowable. And at this time we do not know whether it is possible to build a successful climate model.

One indication of the need for better theoretical bases for models is the growing evidence that GCMs overstate the rate of warming actually being experienced in the climate system. These models compensate for this higher rate of warming by invoking the cooling effects of aerosols. However, while we know qualitatively that some types of aerosols create cooling (while others contribute to warming), we do not have the observational data or theoretical understanding needed to accurately determine the quantitative effects of aerosols in the climate system. Thus, the addition of aerosol effects to GCMs to match historical global average temperature is primarily "curve-fitting". We will not be sure that we have adequately explained historical temperature patterns until we have both provided better quantitative descriptions of aerosol behavior *and* explored alternate hypotheses for these patterns.

If successful climate models can be developed, and that is an open question at this time, it would remove one of the two major uncertainties in the projection of future climate, the impact of greenhouse gases on global climate. (The other major uncertainty is the rate of increase in atmospheric concentrations of greenhouse gases.) One measure of the impact of greenhouse gases on climate is *climate sensitivity*, the equilibrium temperature rise that would occur as the result of a doubling of atmospheric CO_2 concentration. The IPCC [9] still estimates climate sensitivity at 1.5 – 4.5 ^{o}C. This range is based not on statistical analysis, but on the judgment of the IPCC experts who drafted the Third Assessment Report.

The breadth of the range of estimates for climate sensitivity and the resulting range of temperature changes over a 100-year period seriously affects policy discussions. The lower end of the range indicates that while rising CO_2 concentrations in the atmosphere would have an impact on climate, it would be relatively smaller and slow in developing. The upper end of the range indicates a larger, faster impact and the potential need for more immediate action. While there have been many advances in our theoretical understanding of the climate system over the last 20 years, uncertainty in the estimates of climate sensitivity has not been reduced. One measure of success in a research program to build better understanding of the climate system is whether it leads to a reduction in the uncertainty range for climate sensitivity, and allows the estimation of the confidence level associated with that range.

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[9] IPCC (2001a): op. *cit.*, Pg. 561

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The first priority for the CCSP should be improving the theoretical understanding of the climate system, focusing on the roles of clouds, water vapor, aerosols, solar variability, and ocean currents. This information, which will come from an improved observational system, should be used to improve climate models. But, model development should proceed only at the pace dictated by improved understanding. The measures of success for such an effort should be the degree to which:

1. natural climate variability can be explained and quantified;

2. the uncertainty in climate sensitivity can be reduced,

3. regional temperature and precipitation patterns, and the vertical distribution of temperature in the atmosphere and oceans, can be understood; and

4. models can be validated against past climate conditions.

Building and Maintaining the Climate Observation Network

Chapter 3 of the draft Strategic Plan is devoted to the important goal of achieving good climate quality observations, monitoring, and data management. This should represent the second priority in the CCSP. High quality, consistent climate data are required to provide empirical insights, which can lead to the theoretical understanding needed to both illuminate policy decisions, improve climate models and provide a means for model validation.

The National Academy of Sciences in its 1999 assessment of the US climate observing system, reached the following finding and recommendation:

> FINDING: There has been a lack of progress by the federal agencies responsible for climate observing systems, individually and collectively, towards developing and maintaining a credible integrated climate observing system, consequently limiting the ability to document adequately climate change.
>
> RECOMMENDATION: These agencies should work through the US Global Change Research Program process and at higher government levels to:
> - reverse the deterioration of the existing global observational capacity;
> - identify critical variables that are not adequately measured;
> - build climate observing requirements into their operational programs as a high priority;
> - revamp existing climate programs and some climate-critical parts of the operational observing programs through implementation of the ten principles of climate monitoring proposed by the National Research Council; and
> - establish a funded activity for the development, implantation, and operation of climate-specific observational programs. [10]

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[10] NAS (1999a): *Adequacy of Climate Observing Systems.* Pg. 5.

The NAS elaborated on the type of system needed to provide adequate climate monitoring and how it should be funded and managed as follows:

> A monitoring system is needed to detect secular changes in the global environment. Even for research purposes alone, the system must be in place long enough to see a few cycles of change … from an operational point of view of tracking the environmental state of our planet, a system is needed essentially for the duration of the perturbations and response. Obviously such a multipurpose system would fulfill important research needs; however, its cost is likely to be significant, particularly when integral costs are considered and not just annual costs. Therefore, it must satisfy operational purposes if it is to be sustained. *An essential shift is needed within the federal government: the federal government must recognize that monitoring the changes in the global environment on significantly longer time scales than demanded by operational meteorology is in the forefront of the national interest.* (emphasis added)[11]

No visible progress has been made since 1999 in implementing these recommendations, but the CCSP Strategic Plan offers an opportunity to reverse the deterioration of the climate observing system, and to create the type of long-term monitoring system that the NAS recommended.

Data must not just be collected, they must also be verified, stored and made accessible to all researchers who can use it. This is a daunting task. As was reported at the December 3 – 5 CCSP Workshop, NASA's Earth Observing System is now generating three trillion bytes (3 terabytes) of data per day, and the system archive currently contain four quadrillion bytes (4 petabytes) of data. Workshop participants also heard cautionary tales of data collected in the 1970s by the first Landsat satellite that were subsequently lost. The data management challenges facing the CCSP are huge, but they must be met.

To be useful the climate observing system must be global. CCSP Workshop participants heard many reports that such a system does not now exist, and that the necessary resources, both dollar and people, are not being allocated to make bring it into existence. The satellite systems NASA has launched recently and the ones they plan to launch in the next few years will address some of this problem, but not all of it. Satellite measurements must be supplemented and verified by Earth-based measurements. One CCSP Workshop presenter argued correctly that to be valid, climate data should be measured by at least two independent means and analyzed by at least two independent groups. Further, such validated information should be archived so that it is widely available

The systems necessary to make the measurements either do not exist or are deteriorating. The problem is particularly acute in developing nations. A recent report from the Global Climate Observing System (GCOS) Secretariat indicated that 43% of African, 33% of Asian, and 43% of the South American stations in the GCOS surface and upper air

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[11] NAS (1999b): *Global Environmental Change: Research Pathways for the Next Decade* pp. 428-429..

networks were “silent” in 2000, making none of the expected reports. [12] While the requirements to build an effective global climate observing system have been discussed in general terms, no detailed plan, with cost and human resource requirements, is evident for accomplishing this vital task. The CCSP, as part of its international cooperation efforts, should seek the development of such a plan.

Several of the other points made at the CCSP Workshop include:

- The climate observation system must be designed, operated, and maintained to deliver climate quality data. This is a higher standard than needed for other applications. For example, one presenter at the CCSP Workshop stated that for weather purpose, knowing temperature within 1°C was sufficient, but for climate purpose, temperature needed to be known within 0.1°C.

- The climate observation system must be run on an operational basis, not a research basis. Much of current climate observation data is collected as part of research programs. These typically have short-term funding and are terminated when the research objective is complete. Climate data need to be collected on a long-term basis, the same way that weather data are.

- Funding support for the climate observation system must be on a long-term basis, even if it is appropriated on a year-by-year basis.

To summarize, a successful climate observing network is one that would provide the data necessary to generate the empirical insights into the climate system needed to develop theoretical understanding and generate near-term policy and planning benefits. These data will also be critical in testing climate models. The climate observing system should have an assured source of long-term funding and a management structure that is oriented toward a service rather than a research role.

Empirical Knowledge and Theoretical Understanding of Adaptation

On Pg. 8, the draft CCSP Strategic Plan lists four issues that scientific research needs to address. The last of these is “How readily can adaptation take place in different natural and socio-economic systems?” The draft continues:

> … development of adaptation options that are useful regardless of the origin of observed changes, will help clarify the importance of variations and potential changes in climate for the environment and society, and potentially broaden opportunities for management of risks and realization on benefits.

Although this is an important conclusion, the Intergovernmental Panel on Climate Change (IPCC), among many others, points out, that the current level of knowledge about adaptation is inadequate:

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[12] UNFCCC Secretariat (2001): Global Climate Observing System: Progress report on developments in the global climate observing system and activities related to decision 5/CP.5. FCCC/SBSTA/2001/MISC.9

> Current knowledge about adaptation and adaptive capacity is insufficient for reliable prediction of adaptations; it is also insufficient for rigorous evaluation of planned adaptation options, measures, and policies of governments. [13]

Research on adaptation options should be the third priority in the CCSP, especially in view of the fact that mitigation options currently are limited, unknown, or not cost-effective.

Little of the research listed in the draft CCSP Strategic Plan appears aimed at developing adaptation options. Chapter 3 discusses the research needed to addresses the question "How do we improve observations of biological and ecological systems to understand their response to climate variability and change?" While this research is necessary to provide input to an adaptation research program, it does not constitute such a program. Similarly, some of the information gathered in the USGCRP programs on water cycle, carbon cycle, ecosystems, and human responses to environmental change could also provide inputs to an adaptation research program, but research in these areas does not appear focused on adaptation issues.

An adaptation research program should start with a reassessment of the vulnerability of the U.S. to climate change. The many criticisms leveled at *Climate Change Impacts on the United States,* the report of the National Assessment Synthesis Team, obviates it as a basis for an adaptation research program. Once key vulnerabilities have been identified, the attractiveness of adaptation should be assessed on a sector-by-sector basis. Previous studies, e.g. *The Impact of Climate Change on the United States Economy*, edited by Robert Mendelsohn and James E. Neumann, indicate that adaptation is particularly attractive for some sectors, with agriculture and forestry offering the greatest opportunities.

Many of the adaptation options identified in the proposed feasibility study will require scientific research and technical development. General scientific research, to better understand adaptation mechanisms, should be carried out as part of the CCSP. However, technical development, and highly focused scientific research aimed at answering specific questions in support of the technical development, should be the responsibility of other government programs, e.g. the Climate Change Technology Initiative (CCTI), or the private sector. The skills needed to execute and mange technology development are different from the skills needed to execute and manage scientific research. Lumping these two different endeavors in a single program is likely to make one or both of them less effective.

A successful adaptation research program is one which develops a set of adaptation options that can be used by policymakers as part of an overall strategy for responding to climate change and variability weighted in terms of natural versus anthropogenic components. As has often been pointed out, implementation of adaptation options will make the U.S. less vulnerable to ever present climate variability and reduce the damage

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[13] IPCC (2001b): *Climate Change 2001: Impacts, Adaptation, and Vulnerability.* p. 880.

caused by extreme weather events, whether or not climate changes. Adaptation options of choice should be those that cost effectively increase resiliency.

WILLIAM O'KEEFE, GEORGE C. MARSHALL INSTITUTE

Page 17, Chapter 2: This chapter addresses the role of aerosols, carbon sources, sinks and the feedback processes. However, it fails to address three problems of key importance to climate research and decision makers. They are: **(A)** whether the current warming trend, apart from any man-made component, also has a significant natural warming component, **(B)** whether the mechanism of climate changes is correctly understood (given the failure to successfully model Pleistocene climates) and **(C)** whether global warming can be controlled (given the uncertainty about its causes). In the following I address these questions in more detail.

First Overview Comment on Chapter 2: What is the proportion of the natural to man-made components of the current global warming?

The ongoing global warming has been shown to be associated with El Nino to varying degrees (1, 2). The average global surface air temperature anomaly of all seasons classified by NOAA's Climate Prediction Center from 1950 to 2000 as El Nino is positive and for La Nina negative (3). It appears that the warming of the past several decades was related to increased intensity and frequency of El Nino and decreased occurrence of La Nina.

The man-made impact on the global mean temperature could be convincingly demonstrated by showing the physical link between the atmospheric greenhouse-gas concentrations and the variation of ENSO. Thus far, modeling efforts with conflicting results were unable to do so (4, 5).

In the Zebiak-Cane model used for seasonal prediction of current ENSO anomalies (6), stronger insolation in boreal spring and weaker insolation in autumn leads to increased frequency and intensity of El Nino (7). It therefore appears that the changing frequency of El Nino is linked, at least in part, to the changes of short wave radiation income in transitional seasons.

In order to clarify the uncertainty, the following research tasks are suggested:

- Refine modeling studies of ENSO response to increased greenhouse gas concentrations and to variations of insolation.

- Model ENSO variability in response to insolation income over the past and future 2000 years.

- Analyze and compare the impact of the greenhouse gases and insolation on the climate of the transitional seasons in models and compare the results with observations.

- Determine the dependence of ENSO anomalies on the indirect variation of shortwave radiation income to the equatorial Pacific in transitional seasons via cloud cover oscillations etc. Both empirical and modeling studies are needed.

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Second Overview Comment on Chapter 2: Is the mechanism of natural climate changes fully understood ?

During the last million years the climate changed many times between interglacial and glacial conditions. Paleoclimatic evidence has revealed multiple cases of abrupt shifts in the global and regional environment, which occurred within decades and centuries, long before man could have had any impact on the climate system. Although the underlying cause of the Pleistocene climate changes has been identified as the variation of the Earth's circumsolar orbit, the mechanism of the shifts remains unexplained. This also holds for the last transition from the interglacial into the glacial mode that occurred approximately 115,000 years ago. At that time, within three thousand years, the sea level dropped by at least 30 meters at an average rate of a meter per century. The last interglacial/glacial transition is an episode of particular relevance, because the principal orbital trends today are qualitatively similar to those of 115,000 years ago (1,2).

The conventional theory of ice ages assumes that the decrease of summer insolation to the high latitudes caused the temperature drop and expansion of snow and ice fields, thereby triggering global cooling. Mathematical models, including those used to predict near future climate, thus far have been unable to reproduce the glacial inception. Credence in the climate models is seriously affected by this failure.

There is another theory of glaciations which was first advanced by Tyndall in 1872 (3) and has been since further developed (4). According to this theory, the oceans warmed when the polar ice grew. Later, when the increased polar ice masses disintegrated and ice invaded the lower latitudes, uniform cooling took place.

The study of past ENSO using the Zebiak-Cane model supports Tyndall's theory. The calculated frequency of El Nino and La Nina rapidly changed at the end of the last interglacial. During the interglacial La Nina was dominant while in the early glacial the frequency of El Nino-type anomalies almost doubled, while that of La Nina decreased (5).

Judging by analogue with current climate, El Nino anomalies are associated with warmer tropical oceans and a higher global mean temperature. Thus paleoclimatic data indicate that at the end of the last interglacial global warming may have co-existed with the growth of polar ice and the drop of sea level. If so, the interpretation of the global warming trend as solely or mostly the result of increased greenhouse gases would be flawed and the IPCC expectation of future sea level rise may need revision.

In order to reduce the uncertainty, the following research tasks are suggested:

- Thorough modeling analysis of Tyndall's theory of glaciations. Comparison with observed current climate changes.

- Reconstruction of the last interglacial/glacial transition from paleoclimatic archives in as much detail as possible.

- Reproduction of the principal aspects of the above transition in global circulation models.

- Modeling studies of the impact of shifting insolation intensity in transitional seasons on key elements of climate system in extratropical latitudes.

- Modeling studies of the difference between the climatic response to increased greenhouse gases and the redistribution of insolation. Comparison with paleoclimatic archives.

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4. G. Kukla, and J. Gavin, *Global and Planetary Change* (submitted).
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Third Overview Comment on Chapter 2: To what degree can the control of greenhouse gases reduce global warming?

The understanding of ongoing climate change is complicated by recent paleoclimatic findings. It appears that the increasing trend of global mean temperature is due not only to the greenhouse gases. It is likely to also have a natural component, driven by the ongoing long term insolation shift (1, 2). In this situation even a complete cut of greenhouse gas emissions and total removal of the man-made CO2 from the atmosphere could not fully eliminate the warming. The reduction will depend on the proportion of natural and artificial components responsible for the trend.

The following research tasks are proposed to address the problem:

- Refine and intensify modeling of differences in the climate impact of the increasing greenhouse gases as opposed to changing insolation in transitional seasons.

- Define the fingerprints of the two processes and identify them in the observational records.

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GEORGE KUKLA, LAMONT-DOHERTY EARTH OBSERVATORY OF COLUMBIA UNIVERSITY.

Page 17, Chapter 2: First Overview Comment: The term uncertainty is utilized without any clear definition of the term. As this is the main theme of much of the report, it portrays an incorrect image of climate science that everything is uncertain and that no one can or should act until the uncertainty levels are diminished. It then goes on to lay out a high risk strategy of waiting until an unknown day for uncertainties to be reduced before any action can be taken. The risks are high as the lifetime of greenhouse gases in the atmosphere is long and mitigation efforts will not take immediate effect, unlike some other pollutants. This also ignores decades of research by US institutions and others that have reduced uncertainty levels on a wide range of climate issues. A guide to the uncertainty levels is clearly included in the IPCC's Third Assessment Report.
We would therefore strongly recommend that the report and the research efforts around it not revolve around reducing uncertainties per se, but rather provide new and useful information for policymakers. Finally, to infer that policymakers must have 100% certainty before taking any decisions is not consistent with the current situation. As the report notes, there are many uncertainties surrounding terrorism, but the government is not waiting for 100% certainty before taking preventative measures such as increasing security in airports.

JENNIFER MORGAN, WORLD WILDLIFE FUND

Page 17, Chapter 2: There appears to be a major omission of uncertainty topics. The three cited topics are, in brief, aerosols, carbon sources and sinks, and feedback processes. The major missing item is "system memory", through which the Earth's climate system rate-of-change is moderated by the storage of and rate of exchange of energy. The major energy storage medium is the global ocean, and the internal mixing and transfer of energy within that body is arguably the least known of all the dominant climate-related parameters and processes. Coupled with coastal and air-sea interactions, the dominant boundary condition is the bottom. Without significantly improved knowledge of the ocean's bathymetry, currents, internal waves, and mixing processes cannot be adequately modeled. Less than 1% of the oceans floor has been mapped at sufficiently fine scales.

High-resolution ocean bathymetry is a prerequisite for investigations into five key climate questions. These are (1) how climate variations induce changes in global ocean circulation, (2) how global sea level is affected by climate change, (3) how the ocean circulation may vary on interannual, decadal, and longer time scales, (4) how the earth's under-sea surface is being transformed, and (5) how this information can be used to better understand the salient processes, and to predict future changes.

Research required: Improved oceanic bathymetric data globally, for which the only economically feasible technique is radar altimetry from space.

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R. KEITH RANEY, JOHNS HOPKINS UNIVERSITY APL

Page 17, Chapter 2: Chapter 2 centers on three key questions, the first dealing with aerosols, the second with carbon sources and sinks, and the third with feedback processes. These are listed at the start of the chapter and then detailed within the chapter. Within the chapter, the third question is divided to "What is the contribution of clouds and water vapor feedbacks?" and "How do feedbacks in the polar regions affect climate change?" I think those two subquestions are sufficiently important that it would be preferable to have four questions listed at the start of the chapter: the current first two questions, plus (replacing the current third question) the cloud/water vapor question and the polar regions question. This would make the four opening questions more comparable to each other and would also ensure that clouds are highlighted up front. This is particularly important because clouds are now often presented as the single most important climate component to focus on for current model and forecast improvements. Furthermore, the change would be very easy to do (see Specific Comments on Chapter 2 below).

CLAIRE L. PARKINSON, NASA GODDARD SPACE FLIGHT CENTER

The fundamental premise is that the CCSP should focus on reducing key uncertainties. In the broad sense, this is a reasonable start. However, the interpretation of reducing uncertainties is narrow; it concentrates solely on improving our scientific knowledge such that our confidence in model projections is reduced. This is fundamentally the IPCC approach. It leads to programs that meet the needs of the science community, but may not meet the needs of policymakers and others who need information to formulate long-range plans. Improved estimates of longwave radiation, for example, may improve climate models, but this assumes that models and other components of the system are well-known. The long time series measurements made at Hawai'i as part of the JGOFS program in a sense *increased* our uncertainty. Prior to the time series, we were confident that the subtropical gyre of the North Pacific was a stable, unchanging ecosystem. Instead, we have learned that it changes significantly on decadal time scales, and that these changes impact carbon cycling. Do we know less? In a sense, yes, because the present generation of ecosystem models cannot reproduce these dynamics. But in a larger sense, we have characterized and begun to quantify our uncertainty. This can be considered a “reduction in uncertainty” but not in the sense used in the report.

Studies that characterize and quantify uncertainty can then be coupled with a focus on the “vulnerabilities” of the system. This requires a much closer linkage with the policy/private sector (the “human dimension”). As we make longer-time scale projections, other processes (especially those on the human dimension side) become increasingly important. For example, projections of the survival of juvenile salmon in Oregon’s coastal ocean depend on the physical/biological environment as well as on California energy policy that affects water releases in the Columbia River hydroelectric system. By studying the vulnerabilities of society on climate processes, we can then begin to focus our science on characterizing/quantification of uncertainty on these critical issues. Roger Pielke has discussed such an approach in a recent *Space News*.

Although this broad definition of uncertainty may not appeal to scientists, it will produce knowledge that can be used by managers, planners, and policymakers. It directs research to those areas of greatest vulnerability (and hence interest) to the planning community. Moreover, the characterization of uncertainty may be stratified by time scale. Projections at 1-2 year time scales may not need to consider some processes that are important for projections at decadal time scales. By bringing the human dimension and climate science needs together now, the CCSP would be an effective program for coping with an uncertain future.

This comment follows from the first. I am surprised that there is nothing mentioned specifically on water availability and the hydrological cycle. As much as I am interested in carbon cycling, it is a decadal-scale (and longer) process. But water availability (which has seasonal to decadal-scale variability) is of more importance to more people. Moreover, it is the bridge between the physical climate and carbon cycling. I think this is a serious oversight in CCSP.

MARK R. ABBOTT, OREGON STATE UNIVERSITY

Page 17, Chapter 2: Guiding Principles—Water Vapor and Cloud Feedbacks are the Main Cause of Uncertainty

The climate change problem is first a problem of physics and chemistry. We are burning fossil fuels. The increased concentration of greenhouse gases and aerosols is altering the Earth's radiation budget. Climate will change in response to changes in the Earth's radiation budget. The key elements which have to be pursued are tracking the concentrations of atmospheric constituents and learning how these constituents affect the Earth's energy budget. The constituent which has the strongest influence on the energy budget is water, either as vapor or condensed and frozen as water and ice in clouds. The document fails to recognize the key role that water vapor and clouds play in the climate system. Aside from the brief highlight in Chapter 2, section 3, little is said. Clouds and water vapor get relegated to Chapter 7 of Part 2, the Water Cycle. While placing it there may make sense to bureaucrats, "Water Cycle," as has been the case for the past several decades and was evident at the Climate Conference, is used to mean land-surface hydrology. Placing water vapor and cloud-feedbacks in Chapter 7 hides the problem and all but ignores the crucial role that these feedbacks play in shaping the climate, and of course, creating what is evidently deemed an unacceptable level of uncertainty.

While it is clearly possible that the oceans, biospheres, and ecospheres will come into play and affect the buildup of the gases, aerosols, etc., their potential for significantly altering the global-scale changes anticipated for this century have yet to be demonstrated. On regional and seasonal scales ocean, biospheric, and ecosystem changes are bound to affect the local climate. Clearly they need to be studied. But, radiative equilibrium at the tropopause has to be maintained globally. Under this global constraint, local changes have a way of being compensated for in other parts of the system. Furthermore, if water vapor and cloud feedbacks are not worked out correctly, there is little hope for working out the local influences on the oceans, biospheres, and ecospheres.

Also, research focused on biospheric and ecosystem input and response seems ill-focused. The bio- and ecosystems are complex and messy. Research on bio and ecosystems seems unlikely to yield clear answers to questions such as: where is the CO_2 that is emitted into the atmosphere going? Where is the CH_4 coming from? One could sink a lot of money into such ill-posed problems, money in the form of observations and modeling, and miss the ultimate drivers: clouds and the radiation budget.

JIM COAKLEY, OREGON STATE UNIVERSITY

Page 17, Chapter 2: The chapter provides some key insights into climate change uncertainty. As a general comment the focus is on the long-term uncertainty which from a climate change perspective is acceptable; however, for a food security evaluation the uncertainty in climate may be more critical for the variation in precipitation and temperature within the growing season. Grain production and rangeland production in the United States are dependent upon these two parameters and changes within a growing season may be more critical than long-term changes.

STEVEN R. SHAFER, USDA-ARS

Page 17, Chapter 2: Chapter 2 "Research focused on key climate change uncertainties" consists of three sections dealing with aerosols, North American carbon sources and sinks, and feedback processes. The basis for the selection of these three topics is not given. The document should present a long list of sources of uncertainty and a process whereby these are prioritized, preferably by some quantitative assessment of the contribution of each to the overall uncertainty in the present predictive capability for climate change, and then come up with a short list of the areas where research needs to be focused. Perhaps that was done in identifying the above three focus areas. If so, the process must be presented to make a convincing argument that the right subjects have been identified. If not then the process should be carried out and presented.

STEPHEN E. SCHWARTZ, BROOKHAVEN NATIONAL LABORATORY

Page 17: What are the magnitudes and distributions of North American carbon sources and sinks, and what are the processes controlling their dynamics?

Why the emphasis on North American carbon sinks? Why is a North American sink better than, say, an Amazon sink? The two are especially interchangable in view of likely future carbon emission/sequestration trading.

RAYMOND PIERREHUMBERT, THE UNIVERSITY OF CHICAGO

Page 17, Chapter 2: First Overview Comment: We suggest that the CCRI, in estimating the magnitude and distribution of North American carbon sources and sinks, establish working partnerships with the states to develop data that serve both state and national goals. Frequently, federal programs gather data (e.g. on resource conditions) that, while statistically valid for inference and hypothesis testing at the national level, have such small sample sizes and such wide confidence intervals at the regional level within states as to be completely useless for monitoring, assessment and evaluation at the state level. The states react by cobbling together their own, often idiosyncratic, data sets, which in turn cannot be aggregated in ways useful to the nation. A coherent state-national partnership strategy would be far more cost-effective.

Second Overview Comment: The logic of eliminating uncertainty as a prelude to decisionmaking is fundamentally flawed. It is impossible to fully characterize any open system, especially one of the scale of Earth's climate. A much better approach is to identify particular uncertainties that pose significant risk of incorrect decisions. This requires reviewing an array of policy options in light of uncertainty and performing triage – grouping policy options as:

1) Those that have little or no risk – so-called "no regrets" options – that can be implemented with no further research.
2) Those which appear likely to have strongly negative consequences and can be rejected with no further research.
3) Those which have potential to strongly perturb the system but for which crucial data indicating their reliability are lacking – these then suggest a policy-relevant prioritization of research.

Using this approach, certain policy options, such as improved residential energy efficiency, can be seen as desirable without further study (although further research may improve the precision of benefit calculation), while other options, such as indiscriminate venting or flaring of natural gas can be seen to be undesirable activities, despite their short-term cost saving in petroleum production.

Policy areas that have the potential to be highly leveraged vis-a-vis climate dynamics include such measures as stringent new controls on sulfur emissions, since there is large uncertainty regarding how, where, and how much aerosol cooling is driven by sulfates.

Among the research areas addressed in this Plan, aerosol research covering natural and anthropogenic emissions, atmospheric processing, long range transport, primary and secondary optical effects, and improved model fidelity to observations, clearly rises to the top of the list of "policy relevant research."

CALIFORNIA AIR RESOURCES BOARD

Page 17, Chapter 2: The National Academy of Sciences is about to endorse an international effort in coordinated polar research. Founded on the heritage of International Polar Years (1882-3, 1927-8, 1957-8[the IGY]), the Fourth International Polar Year is shaping up to be a major resurgence of attention on the role of polar regions in our climate and on exploration of its most remote regions at the base of the ice sheets where exotic forms of life occur and interplanetary methods can be developed and tested. It would be constructive to acknowledge this effort in the CCSP. The third question of the CCRI (expanded on pages 21-24) would be an obvious place to mention the benefits of contributing to an international research effort being planned to begin in the year 2007.

R.BINDSCHADLER/NASA

Page 17, Chapter 2: The chapter fails to make a convincing case that the uncertainties suggested for study are "key" to a general understaing of climate change. No case is made that understanding these areas is a prerequisite to making effective policies.

MECKING, STANFORD UNIVERSITY

Page 17, Chapter 2: The three questions: aerosols, carbon and feedbacks are not "parallel". The first is quite specific and should not be singled out from a host of other factors, such as clouds, water vapor, carbon dioxide and the like. It strikes me that this is the current "fad" factor. While important and less well understood at present, it's improper to highlight it this way. Better to say there are many recognized factors and some, like aerosols, need relatively more study. To focus so sharply on aerosols, runs a serious risk of ignoring or forestalling progress understanding other factors also know to be important. Carbon, the second item, is currently a NASA research focus. It is a multidisciplinary study. But NASA also has identified the water cycle as another equally important research issue. This equivalence is missing in this critical chapter. The third question (feedbacks) encompasses a wide range of processes, again, some better understood than others. Each should be of equal stature to the first two questions, rather than bundled together in an overarching question that obscures their prominence.

R.BINDSCHADLER/NASA

Page 17, Chapter 2: The discussion of aerosols needs significant broadening. Aerosols play a significant role in the energy budget, as is appropriately noted. However, there is evidence that they also play substantial roles in the hydrologic system. This needs substantial highlighting, and should be on a par with the discussion of the cooling effect. It would be particularly important to discuss this on page 18, lines 13-31, where needs are identified, and on page 19, lines 7-10.

The discussion of the carbon sources and sinks needs significant broadening and is unbalanced in its present form. As it stands, it focusses heavily on North America, with only a small attempt to place this in the broader context of carbon cycle science for the globe as a whole. A more process-oriented discussion is needed for scientific balance. In particular, it is very important to describe the fact that in the future the 'sink' is likely to become a source, as CO2 is given back to the atmosphere, particularly via respiration, and particularly in a warmer climate if such occurs in the 21st century. Carbon cycle feedbacks need to be carefully considered and need to be presented in a careful way to balance this discussion. In its present form, the discussion seems more insular than I believe US science wants to be.

The discussion of carbon cycle also seems to promise a great deal without much discussion of uncertainties. In particular, the claim of major returns within five years is hard to support without a discussion of boundary layer uncertainties: transport of CO2 is not likely to be well defined on this time scale.

SUSAN SOLOMON, NOAA

Page 17: Neither I nor anyone I know believes that the only important uncertainties needing faced were about aerosols, and carbon sources and sinks, and feedbacks as inferred from this section.

There should be a more clear statement of the sources of uncertainty in Climate Models. Given that weather forecast models go ‘numb’ after a few days to a week – climate models should offer something more than just another set of fuzzy mean results – with little or no connect to the real world scales of weather phenomena.

Recent revelations about Polar Subsidence Events and Global Weather Phenomena – reviewed by Professor Marcel Leroux, in Dynamic Analysis of Weather and Climate, Wiley-Praxis, 1996,1998 (English translation) demonstrates the lack of capability of the present GCM technology to cope with these all-important dynamic processes, and their interactions. Irradiance is important – on one scale, but these very much higher energy fluid dynamics preclude irradiance models from providing more than highly smoothed and under-representative climate/weather scenarios.

GARY D. SHARP, CENTER FOR CLIMATE/OCEAN RESOURCES STUDY

Page 17, Chapter 2: What was the process by which something became a CCRI priority? This process needs to be more transparent. The polar regions question is weak and not compelling.

ANTONIO J. BUSALACCHI, EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER (ESSIC), U. MARYLAND

Page 17, Chapter 2: Chapter 2 proposes research focused on key climate change uncertainties: the kinds of issues that "offer the prospect of significant improvement in understanding of climate change phenomena, and where accelerated development of decision support information is possible." As noted by a panelist in the breakout session on this chapter at the public workshop, December 3-5, 2002, any summary of key climate change uncertainties is painfully incomplete unless it includes key uncertainties about **climate change impacts and responses** as well as climate changes themselves. This is a key to the policy relevance of CCRI. The accelerated development of decision support systems that is at the core of CCRI is at least as important in relation to uncertainties about climate impacts as to uncertainties about climate dynamics. This imbalance in defining key uncertainties needs to be addressed by adding a fourth organizing question to Chapter 2: **"What are the vulnerabilities, adaptive capacities, and prospects for resilience of U.S. regions and sectors with respect to possible climate change impacts?"** The science of regional climate change forecasting in the U.S. has progressed to the point where such assessments are, in Brian Flannery's words (representing U.S. industry), "ready for prime time;" and the first national assessment of possible climate change impacts and adaptation potentials was an important source of learning not only about what we already know but also about what we need to know and can learn in a matter of a few years.

THOMAS J. WILBANKS, OAK RIDGE NATIONAL LABORATORY

Page 17, Chapter 2: Research areas 1-3, Add to end (this material includes references for research areas 1-4):

4. What is the relative contribution of solar activity to climate change?

The statistical evidence for a solar activity link to global climate change is strong. However, discussion of a real physical connection often focuses on the associated changes in solar irradiance, which are quite small. Another possibility is that an unexpected physical mechanism may be involved.

The underlying research findings are as follows: (1) Sunspot cycle lengths, which are inversely proportional to mean solar activity, were found to be strongly correlated (0.95) to the cycles' mean Northern Hemisphere land air temperatures; cycle lengths ranged from 9.7 to 11.8 years, and the period of record was 1851-1987 (Friis-Christensen and

Lassen, 1991). (2) The addition of Southern Hemisphere data did not appreciably change the result. (Friis-Christensen, 1993). (3) The addition of proxy data (1500-1990) confirmed the original findings (Lassen and Friis-Christensen, 1995). (4) The proper cause-effect ordering was determined to be present at the 99% significance level (Reichel et al., 2001). The investigators concluded that "This indicates the existence of a physical mechanism linking solar activity to climate variations."

The general idea for what may be the appropriate alternative mechanism isn't new. The University of Minnesota's Edward Ney pointed the way in the journal Nature in 1959. He noted the large ionizing effects on the stratosphere and troposphere of solar-cycle modulation of galactic cosmic rays. "If one assumes a connexion between ionization and storminess, for example, one might also expect a correlation of Earth temperature and the sunspot cycle... One might therefore account qualitatively for Humphrey's paradox of the 'hot sun and the cool Earth'." Ney's idea about an electrical-convective effect on day-to-day weather appears to have been realized by the finding that cosmic-ray perturbations are linked to same-day thunderstorm-frequency perturbations (Lethbridge, 1990). And his suggestion of an electrical-convective climate connection is consistent with greenhouse-warming theory.

Solar heating, by itself, wouldn't make for a hot earth. It is the positive feedback due to seawater evaporation and water vapor greenhouse warming that poses the threat. We have a user-friendly earth only because of the powerful cooling effects of global convection and the large-scale meridional circulation (Lindzen, 1990), whose vertical component is convection-driven.

Electricity may help to jump-start the convection. Weak electric fields have long been known to promote the coalescence and growth of small water droplets (Lord Rayleigh, 1879). Droplet growth would reduce evaporative cooling. This would increase the net latent heating associated with droplet condensation, and help advance the growth of developing cumulus clouds to the more energizing rainfall and glaciation stages (Markson, 1978; Markson and Muir, 1980).

The electrical-convective effect would regulate global climate by virtue of its flexible power to suppress Earth's water vapor greenhouse effect. This would be a two-step process, beginning with variable convective venting of the planetary boundary layer. Deep convective clouds carry near-surface heat and moisture past the bulk of the water vapor to the relatively dry upper troposphere, where the remaining heat is more effectively radiated to space. The second step would be the variable poleward transport of cold, dry upper air. This air flows from the global convection centers in the intertropical-convergence and midlatitude zones to their respective subsidence centers in the subtropical and polar regions. The supply of dry air to the surface in these regions would help to regulate the water vapor greenhouse effect and surface temperatures there.

The cold-air factories of the polar regions run on dry air, and midlatitude polar-front storms may launch much of this air poleward by way of cumulus convection (Tracton, 1973). Subsequent buildup of cold polar air masses and midlatitude temperature gradients would have positive feedbacks on midlatitude storms. Electrical-convective regulation of ensuing cold-air outbreaks would have further effects on circulation and climate.

The past 100-plus years of generally increasing solar activity and solar wind magnetic screening would have suppressed cosmic ray flux, atmospheric electricity, and convection, thereby increasing water vapor greenhouse surface warming. The notable mid-century solar activity decline would have led to the observed 25-year global cooling, while the steep solar activity increase after 1980 would have driven surface temperatures on up, also as observed.

An analysis comparing past climate patterns to the carbon-14 content of ancient tree rings (Denton and Karlen, 1973) points to a 2500-year periodicity linked to solar activity variations, spanning the past 20,000 years. The Little Ice Age of global mountain glacier expansion which peaked about 1700, in step with the Maunder minimum of solar activity (Eddy, 1976), capped the cold phase of the last 2500-year cycle.The investigators projected that this cooling will be followed by an extended warm period peppered with shorter-term fluctuations, "similar to that of the Roman Empire and Middle Ages."

It has been said that if the striking statistical support for sun-induced climate change is correct, human-induced greenhouse warming would have played little role in the surface warming of the last century. This is supported by the fact that water vapor is a far more important greenhouse gas than carbon dioxide. What's going on between solar activity and our changing climate? It's time we found out.

Research Needs

Apply Granger causality testing (statistical analysis of lead-lag structures) to reported sun-weather relationships such as galactic cosmic ray perturbations and solar flare events vs. same-day thunderstorm frequency perturbations, to further verify the existence of a fast-acting (electrical) mechanism.

Perform laboratory and numerical modeling studies of the effects of weak electric fields on water droplet coalescence and growth.

Perform field studies of (1) the effects of fair-weather electric fields on the growth of cumulus cloud electric fields, cumulus cloud droplets, and the developing clouds themselves; (2) the effects of natural and artificial injection of positive ions into the bases of developing cumulus clouds, and of negative ions into the cloud tops; and (3) the effects of solar x-ray and interplanetary particle disturbances on the earth's electric field, regional/global thunderstorm activity, and near-surface water vapor concentration (e.g., Markson, 1983).

- Develop preliminary numerical models to simulate the full-blown solar-galactic electrical-convective water vapor greenhouse effect on Earth's present global circulation and climate.
- Use the electrical-convective model to simulate the known climate variations of Earth's recent past.

- Use our knowledge of the magnetic evolution of sun-like stars and Earth's own magnetic dynamo (including both orbit-related and mantle-related changes in the flow of Earth's liquid core) to simulate the great climates of Earth's history.
- Use the electrical-convective model to simulate future short-term and long-term climate changes, subject to inputs from the NOAA Space Environment Center.

Products and Payoffs

- Improved understanding of the processes that control Earth's water cycle and its changes.
- Improved understanding of the processes that account for the role of the polar regions in climate change.
- Improved understanding of the role of the global electrical circuit in climate change.
- Improved understanding of the components and operation of Earth's climate system.
- Improved understanding of past and present climates.
- Improved outlook for better climate projections and long-range weather predictions.
- Improved outlook for understanding Earth's various global climate oscillations in terms of internal feedbacks to externally-regulated climate changes.
- Improved outlook for a unified theory of climate change.
- Reduced climate-change uncertainties and fears.

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RICHARD NEWELL, NOAA CORPS (RET.)

Page 17, Chapter 2: The chapter provides some key insights into climate change uncertainty. As a general comment the focus is on the long-term uncertainty which from a climate change perspective is acceptable; however, for a food security evaluation the uncertainty in climate may be more critical for the variation in precipitation and temperature within the growing season. Grain production and rangeland production in the United States are dependent upon these two parameters and changes within a growing season may be more critical than long-term changes.

JERRY L. HATFIELD, USDA-ARS NATIONAL SOIL TILTH LABORATORY

Page 17 Line 4: Understanding the magnitude and distribution of North American carbon sources and sinks and associated processes is an important area of focus.

PAUL HANSON, ORNL

Page 17, line 4: Replace the third question by: "3. What is the contribution of clouds and water vapor feedbacks? 4. How do feedbacks in the polar regions affect climate change?" In line with this change, reduce lines 1-4 on p.21 to "3. What is the contribution of clouds and water vapor feedbacks?" and put lines 20-21 on p.22 in a shaded box, with the question in those lines preceded by a "4."

CLAIRE L. PARKINSON, NASA GODDARD SPACE FLIGHT CENTER

Page 17, Line 4: Chapter contents, Add to end:

4. What is the relative contribution of solar activity to climate change?

RICHARD NEWELL, NOAA CORPS (RET.)

Page 17, Lines 6-9: Page 17: Suggest identifying by science areas and prospect of significant improvement in lines 6-9 to read:
The Climate Change Research Initiative (CCRI) will address key and emerging climate change science areas (e.g. acceleration of hydrological cycle) that offer the prospect of significant regional and global satellite derived observations of climate change phenomena (e.g. precipitation), and whereby improved development of decision support is possible.

TWITCHELL, GEWEX

Page 17, lines 11-13: This phrasing is commended, and should be paid attention to earlier. That is, the scientific community identifies the key uncertainties.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 17, Line 18: First paragraph, Add to end: A fourth key area of uncertainty outlined here is solar activity.

RICHARD NEWELL, NOAA CORPS (RET.)

Page 17, Line 19 – Page 19, Line 14. We support the proposed intensive efforts to better understand the role of aerosols and clouds in climate change. Two key elements of uncertainty are the magnitude of the forcing of black carbon (BC) and the emissions inventory. Current estimates of the total forcing of carbonaceous aerosols range from negative to positive. The relative contributions from on-road and off road diesel-powered vehicles and gasoline-powered vehicles are not known with any precision.

GEORGE WOLFF, PH.D., GENERAL MOTORS

Page 17, Line 19: The Draft plan correctly identifies influences of aerosols among the greatest uncertainties in climate change science (e.g., page 17). The key reason for the importance of aerosol research is the large uncertainty in aerosol forcing. This uncertainty is a consequence of the heterogeneity of aerosol types, properties, and processes, of the short residence time and intermittent removal processes of aerosols, and of the ill characterized geographical distribution of the mass loading and properties of aerosols.

The draft report states (page 18):

> Enhanced aerosol-climate research is needed to deliver focused information ... that would be helpful in quantifying the role of aerosols n regional and global climate change in decision relevant terms.

There follows a list of "research needs."; it is actually a list of seven activities. There is no apparent order to the list nor any specification either of the required product of this research or of how to specify that required product. Then follows a list of "products and payoffs". This list also consists of seven items, three of which start with the word "improved", e.g., "improved global aerosol climatology", "improved assessment and attribution of observed climate changes" again without any statement of how much improvement is either required or expected.

Much more desirable would be a statement along the following lines:

> Radiative forcing of climate by aerosols (direct and indirect) is far and away the greatest source of uncertainty in climate forcing over the industrial period. Research is required to reduce this uncertainty to a degree that it will no longer preclude meaningful inferences of climate sensitivity from examination of forcing and response over the industrial period.

There would follow a list of key contributors to uncertainty in aerosol direct radiative influences and in aerosol influences on cloud properties and the hydrologic cycle. This list would then lead to specification of research objectives (with quantitative statement of required accuracy) and of research activities needed to meet these requirements,.

STEPHEN SCHWARTZ, BROOKHAVEN NAT'L LAB

Page 17, line 22: The term "atmospheric residence time" should be explained. Note that it needs to be differentiated from the term used to refer to the time that the excess CO_2 contribution versus the lifetime of a particular CO_2 molecule will affect atmospheric composition.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 17, lines 23-24: The items in parentheses are not sources, as is implied. The sources are coal-fired power plants and similar facilities.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page17 line 25: There is no evidence of an increase in global background aerosol at locations like Mauna Loa where the CO2 trends have been established. They may however play a very important role in affecting surface temperature trends from land based measurements and key coastal ocean measurements. Most of the information that we have about the global distribution of aerosols comes from sun photometer measurements and there is a critical need for more information on aerosol trends and characteristics at night.

BILL PORCH -LOS ALAMOS NATIONAL LAB

Page 18: There is not enough emphasis on indirect radiative forcing of aerosols. The administration appears to rely too heavily on Black Carbon control i.e. there is no research proposed on mixing state of aerosols and Jacobsen's 12 feedbacks.

CALIFORNIA AIR RESOURCES BOARD

Page 18, lines 8-11: It is not clear from when the period 2-4 years starts. Is the intent to indeed have results by 2006 so that they can feed into the next IPCC assessment? If so, this is commendable and should be mentioned, especially since it will help to explain the time period of interest.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 18, Line 13: he interaction of aerosols and other climate system controls could be as important as the direct and indirect effects of aerosols alone. This interaction has recently been explored for climate of the Last Glacial Maximum by Claquin et al., 2003, Climate Dynamics, DOI 10.1007/s00382-002-0269-1

PATRICK J. BARTLEIN, DEPT. GEOGRAPHY, UNIV. OREGON

Page 18, Line 13: Add under Research Needs the following bullet:

- Extend laboratory-based spectroscopic studies to permit quantitative measurements of the optical and radiative properties of all aerosols that must be included in realistic atmospheric radiative transfer models.

- Improve confidence in measurement results by strengthening the internationally accepted metrology framework enabling quality measurements based upon documented traceability to accepted references, including standard methods, materials, and data.

NIST, HRATCH SEMERJIAN

Page 18, L11 - Why 2006?

RONALD STOUFFER, GFDL/NOAA

PAGE 18, L14-31 - Distributions of natural and anthropogenic aerosol distributions are needed.

RONALD STOUFFER, GFDL/NOAA

Page 18, line 14: It is not enough to know the composition of organic aerosol, because the composition is myriad. The important bulk radiative and thermodynamic properties of the aerosol must also be known. The most important of these are the refractive index (at multiple wavelengths) and the hygroscopicity. I suggest inserting the words "refractive index and hygroscopicity" after the word "composition". Other important properties include a measure of the influence of the compound on surface tension.

STEVEN GHAN, PNNL

Page 18, Lines 14-15: What is the definition of a “stronger intensity” effort? What is the baseline? Need specificity.

DEPARTMENT OF TRANSPORTATION, LAWSON

Page 18, lines 14-15: “intensify” instead of “intensity”. Presumably this effort is to determine the spatial and temporal distribution (as everywhere it will be different) of the composition of the aerosols—why say organic (does that include soot aerosols)?

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 18, Lines 14-15: What is the definition of “improved”? How do you quantify what you want to do, and know when you are done (that is, when more effort results in little payoff)?

DEPARTMENT OF TRANSPORTATION, LAWSON

Page 18, Change line 14-15 to read as follows:
Strongly intensify efforts to determine the composition, size, and optical and radiative properties of organic aerosols and develop…

NIST, HRATCH SEMERJIAN

Page 18, lines 14-31: The focus on atmospheric forcing from aerosols is on the climate change aspects, a research need to determine the potential effect of radiative changes on plant productivity and the link to the energy balance of large areas should be considered.

Steven R. Shafer, USDA-ARS

Page 18, lines 14-31: The focus on atmospheric forcing from aerosols is on the climate change aspects, a research need to determine the potential effect of radiative changes on plant productivity and the link to the energy balance of large areas should be considered.

JERRY L. HATFIELD, USDA-ARS NATIONAL SOIL TILTH LABORATORY

Page 18, lines 14-31: This listing of research needs will take massive resources if it is to be done in the time indicated. It is also unfortunate that there is no indication of the relative importance of these points or of how uncertain they are at present and what difference this makes to the overall scientific conclusions, much less to matters considered by policymakers.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 18, lines 16-17: At best, an effort could make these estimates—not “establish” them. Also, it is not at all clear how this will be done.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 18, Line 19: Reduce uncertainties in data interpretations by establishing well-characterized, laboratory-scale test beds for the evaluation and/or calibration of current and developing aerosol measurement techniques, and elucidate metrological interferences which lead to uncertainties in data interpretation.

NIST

Page 18, Line 20: insert
Establish property database on aerosol species to support modeling efforts.

NIST

Page 18, line 20: such models already exist—this effort may work to improve them, but would be waste of much existing effort to really develop them from scratchy. Note on line 37 it mentions “current models” so the text needs to be consistent.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 18L22 - How far into the "past" is past?

RONALD STOUFFER, GFDL/NOAA

Page 18, Line 27: We agree with the assertion that aerosol distribution and its radiative characteristics should be tested in regions with adequate data. However, we disagree with the implicit assumption that the emission database for North America is currently of high enough quality to allow for the testing of existing simulation models. More emission inventory work is needed to better characterize emissions and this work should be coordinated with related efforts such as the on-going work performed by air quality agencies and NARSTO and its members. More emission characterization work needs to be executed using modern methods such as the dilution tunnel developed by the late Professor Glenn Cass. Traditional source test methods for stationary sources have proven to incorrectly estimate emission rates as shown by a recent test result undertaken under partial support from the California Energy Commission.

CALIFORNIA ENERGY COMMISSION

Page 18, line 28: Another important research need is the development of a way to use aerosol observations and models to quantify no only the radiative forcing by anthropogenic aerosol but also the uncertainty in estimates. Comparison of simulated aerosol and other variables with measurements is certainly necessary for this, but a framework for using the comparison to quantify uncertainty is badly needed. We don't want to have to rely solely on climate change simulations to place bounds on indirect forcing estimates, because climate change simulations depend on cloud feedbacks, which are highly uncertain.

STEVEN GHAN, PNNL

Page 18, lines 28: It is strange that there is not a point indicating that desired information would include intercontinental transport of aerosols.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 18, Line 32: Improve the understanding of uncertainties in measurement results used to assess variations in optical extinction at both short and long wavelengths as a function of particle mass, size, morphology, aggregation, and composition by using robust experimental design strategies. .

NIST

Page 18, Line 34: A sound metrological framework will provide confidence in the reliability, impartiality, and stated uncertainty of measurement data, which benefits the quality and utility of databases and models supporting informed policy decisions.

NIST

Page 18, line 34-35 (also Chapter 4, p.51, lines 34-38 and Chapter 2, p.72, lines 25-26): Currently, data are lacking to produce a "global aerosol climatology that includes regional distribution by major aerosol type (e.g., black carbon) and radiative properties." Measurement programs to provide the needed data have been proposed (e.g., NRC, 1996), but only partially implemented. This is an excellent example of the point made

earlier, that some research elements will require more than 2-4 years to produce results. *[Ogren 303-497-6210 – Dutton, Hofmann, Butler, Schnell, Tans; NOAA/CMDL]*
NOAA/CMDL

Page 18, lines 34-43: Link to models, role of CCN is weak.
Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. MARYLAND

Page 18, line 37: Change "current" to "current and improved" models, as you want to validate both, perhaps comparatively.
MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 18, lines 41-43: It is unlikely that the chemistry models, which require significant source information, will really help to significantly improve the climate models.
MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 18, line 43: There needs to be more data on tropospheric ozone, and of the many precursors that lead to it.
MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 19: Information on potential options for obtaining changes in climate forcing via changes in 7 the aerosol forcing, which, similar to those for tropospheric ozone, might be achieved 8 more rapidly than by changing carbon dioxide (CO2) forcing because aerosols have a 9 shorter residence time in the atmosphere. 10

This is actually an argument for giving a higher priority to preventing CO2 emissions rather than carbon aerosol emissions. If we don't prevent additional CO2 emissions today, then they will affect climate for hundreds of years, because CO2 has a long residence time in the atmosphere.
In contrast, warming due to soot would disappear within weeks of when the source was eliminated. It's a good thing to eliminate black carbon, but the above paragraph in the report in no way justifies favoring soot aerosol controls over CO2 controls.
RAYMOND PIERREHUMBERT, THE UNIVERSITY OF CHICAGO

Page 19, Lines 5-6: We agree that it is extremely important to try to consider the uncertainties associated with the different scenarios. These lines and the sentence on page 44 line 10 suggest that US CCSP may try to attach probabilities to the different scenarios. If this is the case, it may be useful to more clearly state this goal and, in general, suggest how this goal may be achieved.
CALIFORNIA ENERGY COMMISSION

Page 19, lines 5-6: This is a laudable objective. It is not at all clear, however, how to derive such estimates. It would help to be giving what present uncertainties are as a metric for comparison.
MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 19, lines 7-10: The working here seems particularly awkward.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 19, Line 15 – Page 20, Line 35. Determining the magnitude of North American and U.S. CO_2 sources and sinks is a high priority. Since the paper by Fan et al. (*Science* vol.282, p. 442, 1998), which indicated that North America is a net sink, there has been much controversy surrounding this issue. Fan's results were based on 1988-1992 CO_2 data. It will certainly be useful to get additional measurements from an expanded monitoring network, but existing data from 1993 to 2002 could be used to check Fan's results now.

GEORGE WOLFF, PH.D., GENERAL MOTORS

Page 19, line 16: Change "intensive" to "intensifying"

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 19, line 18: Using the words "will address" seems to indicate certainty in getting budget resources to undertake these tasks, even though these might be quite large.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 19, line 20 Why are only the coastal oceans mentioned? I think the North Pacific and North Atlantic must also be considered as part of any North American carbon study. Productivity may be lower per unit area but they are much larger in area.

MARK R. ABBOTT, OREGON STATE UNIVERSITY

Page 19, line 23: The phrase "carbon cycle" has not been explained. There also needs to be an explanation of why this is important—surely not just because it has not previously been attempted on these scales. This is a really good example of where the uncertainties ought to be carefully explained and their importance evaluated—how much difference do the uncertainties over North America make in what types of decisions. If there are no controls on emissions, these uncertainties make a miniscule difference. If sequestration is going to be a near-term strategy, they make some difference. This all should be indicated—would be good example where could try to indicate why this is a Presidential priority—as that is not yet clear.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 19, Line 25: Specific Comments on Chapter 3: [page 19, line 25f; page 20, line 10f] Thus far, actual photosynthetic efficiency and biomass yield of complex canopies can't be quantified non-destructively by passive, remote sensing techniques. However, airborne or satellite based methods, which remotely quantify physiological parameters of photosynthesis rather than just the above-ground biomass, will play an increasingly important role to monitor (i) human impact on natural ecosystems and (ii) carbon uptake of ecosystems [page 33 f]. Hyper-spectral reflectance measurements have the potential to evaluate the physiological status of photosynthesis and therefore may be used for large scale ecosystem monitoring in time and space. However, new methods have to be validated for different ecosystems and must be scaled for the various types of canopy structure.

The photosynthetic reflectance index (PRI) and other methods, which are derived from hyper-spectral reflectance measurements, closely correlate with photosynthetic electron transport and therefore are closely linked to carbon gain. They sensitively reflect changes in ecosystem functioning [page 33, line 19] and can be used to monitor spatial shifts/changes in ecotypes on a global scale [page 29, line 8f]. The method is passive and thus can be used from satellites.

Implementation of these methods requires much ground truthing in systems in which the remotely sensed signals can be calibrated against flux measurements.
CHARLES B OSMOND, COLUMBIA UNIVERSITY.

Page 19 Line 30: As a part of the attempt to target near-term investments, current programs to understand and evaluate carbon sources and sinks in North America should peer review the location and numbers of monitoring sites. How many ecosystems or land use categories should be evaluated? Where should they be located? Are current locations of monitoring sites appropriate? Such questions need to be addressed soon for the efficient use of resources.
PAUL HANSON, ORNL

Page 20: Top of p.20. The NACP priorities are not reproduced clearly enough: what are “existing carbon measurement networks”? In this context it should be explicitly stated, “Strengthening existing carbon concentration measurement networks in the atmosphere and oceans”. For example, the flux network and other measurements are already mentioned explicitly. (See also NOAA/CMDL comments regarding Chapter 9.) *[Tans 303-497-6678 – Butler, Dutton, Hofmann, Schnell, Ogren; NOAA/CMDL]*
NOAA/CMDL

Page 20, lines 1-11: This will require a lot of dollars, and these are to be a supplement to the USGCRP. Is there any indication of how much is needed to get useful results in 2-4 years?
MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 20, line 1: "Strengthening existing carbon measurement networks; including atmospheric measurements of CO2 and related tracers (O2/N2, CO2 isotopes), augmenting flux and ...."
RALPH KEELING, SCRIPPS INSTITUTION OF OCEANOGRAPHY,MICHAEL BENDER, PRINCETON, U., PIETER TANS, CMDL

Page 20 line 1-12: to much development listed here that can not expected to yield results within the 2-4 year time frame outlined above.
MARTIN VISBECK, COLUMBIA UNIVERSITY

Page 20, Add the following bullet under research needs (after line 11):

- Ensure that atmospheric monitoring networks and sensors for green-house gases, such as CO_2, CH_4, and N_2O, are referenced to national and international chemical and physical standards maintained by National Metrology Institutes (NMI's).

NIST, Hratch Semerjian

Page 20 Line 1: Strengthening of carbon measurement networks with augmented biometric measurements is essential. Flux-network estimates of carbon exchange have often been subject to change and revision in the recent past. Independent assessments of the net carbon storage or loss from ecosystems will be essential for the long-term credibility of outputs from observation networks like Ameriflux.

PAUL HANSON, ORNL

Page 20, lines 1-3; Agriculture is mentioned as a potential focus on measurements. Need to recognize the diversity in agricultural systems and the seasonal aspects of carbon responses.

JERRY L. HATFIELD, USDA-ARS NATIONAL SOIL TILTH LABORATORY

Page 20, lines 1-3; Agriculture is mentioned as a potential focus on measurements. Need to recognize the diversity in agricultural systems and the seasonal aspects of carbon responses.

STEVEN R. SHAFER, USDA-ARS

Page 20, Lines 1-11: These actions, particularly the improvement of databases on fossil fuel use, land use, land cover and land management, would be far more effective if done in partnership with state and academic institutions.

CALIFORNIA RESOURCES AGENCY

Page 20, line 4. The need for improved in-situ instrumentation is not well justified -- is it improved instrumentation that is needed to address the goals, or rather more measurements? The document doesn't make the case for major drivers for higher accuracy or precision.

SUSAN SOLOMON, NOAA

Page 20 Line 10: Land- or space-based remote sensing methods for assessing changes in above ground biomass are needed. Protocols for reproducible methods of evaluating soil carbon change must be developed.

PAUL HANSON, ORNL

Page 20, line 11 Why are there no research needs associated with the ocean other than coastal surveys? We need better models of primary productivity based on satellite data to cover the short time scales associated with the ocean (especially the coastal ocean). We cannot quantitatively estimate dissolved organic carbon in the ocean. We know little about remineralization of organic carbon. The list goes on.

MARK R. ABBOTT, OREGON STATE UNIVERSITY

Page 20, Lines 13-15: It is also the position of the California Energy Commission that there is a need for studies on the distribution and abundance of North American carbon sources and sinks. We are extremely interested in collaborating with the intensive regional-scale field program described here and suggest that California should be part of this study. We are willing to contribute by providing all the information that is being generated as part of two on-going research projects jointly funded by the California Energy Commission, the California Department of Forestry and Fire Protection, and the California Department of Food and Agriculture.

CALIFORNIA ENERGY COMMISSION

Page 20 Lines 13-18: Models for integrating landscape carbon flux across North America need to be rigorously tested against available data prior to their application.

PAUL HANSON, ORNL

Page 20, line 18 Why is quantitative assessment of ocean models not included? Existing physical models are not suitable for ocean biogeochemistry. Moreover, there are serious deficiencies with the forcing fields and model initialization fields. This should be a specific focus of research in the next 5 years.

MARK R. ABBOTT, OREGON STATE UNIVERSITY

Page 20, line 23: The phrase “will be reduced” raises two points. (1) By how much with what level of additional investment—and how much difference will this make in any useful information for a decisionmaker. (2) The whole first part of the plan seems to be based on the notion that if any uncertainty exists, then no useful information is available and no decision can be made, yet here the presidential initiative is going to have useful results if it just reduces the uncertainty. I agree with the latter perspective, and I would very much urge that it become the basis for the plan.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 20, line 28: **(12-E)**This last bullet needs to be turned into a full sentence to be parallel with the other two.

HP HANSON, LANL

Page 20, Modify line 28.

- Demonstrate and evaluation of measurement approaches to carbon accounting including traceability to national and international standards and the SI units.

NIST, HRATCH SEMERJIAN

Page 20, lines 30-31: What types of near-term information will be provided that will be useful. What sorts of decisions are awaiting such information and how likely is it that some level of effort will reduce uncertainties enough to make a difference in 2-4 years? This is all very vague—which should not really be the case for a 2-4 year defined program. Have the equivalent of Observing System Simulation Experiments been conducted that can provide some indication that the information derived will really be useful?

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 21 **– Finally there are some relevant questions** about the more 'dynamic' energetics of the Global Climate System – including Polar Dynamics – although the focus on the Arctic is artificially exclusive, and unrealistic, given the relative energetic transfers that take place in the Southern Ocean around and including Antarctica – the one place from which the recent 50 years temperature records hardly support the GCM projections – or presumptions. Even the discussion of the Arctic sea ice cover understates the known dynamics and previous empirical knowledge of these dynamics – from US Air Force observations during WWII, the Korean war, and Cold War reconnaissance of the region, including floating ice-stations for environmental observations that started in the early 1950s. This is a 'generational' science issue that needs re-connection, via Rand Corporation records, and of other empirical sources.
E.g., Dr. Joseph Fletcher, Russian Arctic Institute, and other particpants in the international Arctic Research Programs initiated by NSF and other US Agencies.

GARY D. SHARP, CENTER FOR CLIMATE/OCEAN RESOURCES STUDY

Page 21: Adequate representation of vertical transport is needed to address the contribution of clouds and water vapor feedbacks to the climate system.

BETH HOLLAND, NCAR

Page 21-23: The identified feedbacks and the research needs ignore any ocean involvement. Clouds and water vapor are important feedbacks, as is the polar region; but so are the ocean and its circulation. Studies should focus more attention on changes in ocean circulation and specifically the observed freshening in the subpolar basins of the circum North Atlantic and its likely impact on circulation and climate.

WILLIAM B. CURRY, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Page 21: various feedback processes are represented in the models. The greatest differences are those 12 associated with water vapor and cloud processes. 13

This statement is incorrect with regard to water vapor. Models substantially agree with regard to the magnitude of water vapor feedback, as stated clearly in the IPCC Third Assessment report and references therein.
The subsequent statement that "scientists do not know..." also gives a distorted picture of the science. It implies that nothing is known about the problem, whereas the processes are in fact modelled in all modern climate models. While there is disagreement in the details of cloud effects, despite cloud effects ALL models still yield substantial warming of the climate.

RAYMOND PIERREHUMBERT, THE UNIVERSITY OF CHICAGO

Page 21: radiative balance and cloud structure from increased upper tropospheric water vapor is 17
potentially quite large and could be positive or negative. 18

This statement is incorrect. The feedback from increased upper tropospheric water vapor is invariably positive.

RAYMOND PIERREHUMBERT, THE UNIVERSITY OF CHICAGO

Page 21, Line 1 – Page 22, Line 18 – The role of water vapor, clouds and the magnitude of the water vapor feedback should be a top research priority. This area must be given sufficient resources.

GEORGE WOLFF, PH.D., GENERAL MOTORS

Page 21, Line 1: All dewpoint and relative humidity data from historical records should be made available in digital format for modeling and analysis. Preliminary data indicates that dewpoints have increased 2 to 4 degrees F from 1997 to 2002 in 15 Midwest states.

PATRICK J. NEUMAN, NWS_NCRFC ,COMMENTS MY OWN..NOT AGENCY.

Page 21, Lines 6: If water vapor is “the most important” greenhouse gas – what is the point of a “hydrogen economy”? What about the effects of residence time (which are much greater for CO_2)? Do we have consensus on water being “the most important” greenhouse gas – or is that one of the uncertainties to address?

DEPARTMENT OF TRANSPORTATION, LAWSON

Page 21, Lines 6–7: “*Water plays a key role in the radiative balance of the atmosphere: water vapor is the most important of the greenhouse gases, ...*”

This is a misleading statement at best, especially if the intent is to divert attention from CO_2 as the main driver of anthropogenic climate change. Unlike CO_2, water has a short atmospheric lifetime, can coexist in three phases, and has a highly variable atmospheric distribution. While water vapor provides baseline greenhouse heating, CO_2 and other GHGs supply the perturbation driving climate change.

DAVID L. WAGGER, PH.D., SELF

Page 21, lines 6-29. Same could have been said, and was, 15 years ago.

ANTONIO J. BUSALACCHI, EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER (ESSIC), U. MARYLAND

Page 21, line 7: Still no explanation of the greenhouse effect or of what greenhouse gases are.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 21, line 7-9: There has been no mention of CO_2 having a radiative effect, much less one that causes worming. There has to be a box that overviews the essential science.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 21, line 8: "results from climate models": add "and observations" - many studies have documented an increase in atmospheric water vapor already.

PHILIP MOTE ON BEHALF OF THE CLIMATE IMPACTS GROUP, UNIVERSITY OF WASHINGTON

Page 21, lines 8-9. Lead paragraph is much too weak. Observations show that there has been an overall increase in water vapor as the climate warms.

SUSAN SOLOMON, NOAA

Page 21 line 9: Most of the warming predicted by the climate models comes from this increase in water vapor. The accuracy and variability of water vapor measurements makes it difficult to establish the increasing trend in global water vapor that these models predict. Improving the calibration of water vapor measurements and increased application and improvement and of microwave and GPS vertically integrated water vapor measurements are needed to test the model predictions.

BILL PORCH -LOS ALAMOS NATIONAL LAB

Page 21, line 11: **(13-S)** Here is a place where "prediction" is fine, but it's also a chance to re-emphasize the distinction. Perhaps the first sentence of this paragraph could be extended to read:

> Predictions of climate change based on known forcings vary in large part because of differences in the way that the various feedback processes are represented in the models, and this adds additional uncertainties to climate projections involving unknown forcings.

HP HANSON, LANL

Page 21, line 11: Change "predictions" to "projections"—and the plan needs to have explained the difference.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 21, Lines 11–29: Discussions of clouds and water vapor should also mention aerosols and particulates because these often provide nucleation sites for water vapor to enter a condensed phase. For instance, this is particularly important in the formation of polar stratospheric clouds.

DAVID L. WAGGER, PH.D., SELF

Page 21L12 - Feedback processes are related to parameterizations of sub-grid scale processes in models. Mention this fact?

RONALD STOUFFER, GFDL/NOAA

Page 21, lines 13-16. Wording that 'scientists do not know' should be rephrased. Not much is ever truly 'known' in the world of science, and this language gives an impression of great uncertainty which is not quite accurate. More accurate would be words like 'uncertainties exist in....' or 'further study is needed of....'

SUSAN SOLOMON, NOAA

Page 21: Line 13 to read:

associated and water vapor, cloud, and precipitation processes. For example…

TWITCHELL, GEWEX

Page 21, line 13: It really is not scientific to suggest that "scientists do not know …" without giving some level of uncertainty or a range. We will never know exactly (even after it happens). The clouds won't go away and won't cover the whole sky—what matters is much more subtle than indicated here.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 21, line 16: These variables are the climate—so if they are the climate, how can they affect the climate?

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 21, line 18: There is really very little basis for thinking that the upper tropospheric water vapor feedback process could be negative, despite what Lindzen suggests. Were it negative, it would be very hard to have had an ice age (as it would have induced a warming influence to prevent it), we never could have had an ice ball Earth (as there would be to much water aloft), we could never have had Cretaceous warmth as the cooling effect would have countered that, plus the amount of water vapor in the upper troposphere increase from pole to equator (so from cold to warm conditions). The IPCC has reviewed studies of this and there is just very little reason to indicate it is possible, and it may well create important inconsistencies with past climates. Phrasing this as if there is an equal chance of positive versus negative is irresponsible.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 21 line19: A 4% change in the amount or reflectivity of boundary layer clouds is as important as a doubling in CO2 in warming or cooling on a global scale. Much more effort is needed to improve cloud amount trends and their vertical distribution and the ability of global scale models to simulate cloud characteristics.

BILL PORCH -LOS ALAMOS NATIONAL LAB

Page 21, Modify line 21 and 22 to read:
…. Better representation of the distribution and radiative properties of water vapor is critical given its…

NIST, HRATCH SEMERJIAN

Page 21, line 25: The parenthetical phrase is not really the definition of parameterization (or more accurately parameterized representation), and has a negative pejorative tone. All models of anything useful have parameterizations that represent the effects of finer-scale processes in terms of the processes that they represent. Medicines are not tested on everyone, but on a sample set; etc., etc.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 21, lines 26-27: Clouds and cloud properties have been included in climate models since the first radiative-convective model by Manabe 35 years ago (and in the first GCM by Leith some 40 years ago for that matter). Intensive efforts to improve these representations (i.e., to reduce uncertainties) have been going on since that time and it has been very hard going. To assert that the CCRI "will" somehow make progress in another 2-4 years is rather presumptuous. It will try to do so. It would be much better to be indicating that the efforts here will be seeking to test and improve parameterizations in ways that improve confidence in the results and representations rather than to promise some sort of reduction in uncertainty for which there is no metric mentioned.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 21, Line 26: (to include time and example):
integrated, four-dimensional data sets (e.g. Coordinated Enhanced Observing Period, 2002-2004, initiated by Global Energy and Water Cycle Experiment) of cloud properties and water vapor will produce to…

TWITCHELL, GEWEX

Page 21, Line 31: add 3 bullets.

o Improve climate modeling by better modeling of feedbacks associated with the hydrologic cycle including evaporation, transpiration, and irrigation.

o Improve climate modeling by accounting for latent heat energy released from condensation of water vapor on snow and ice, which increases melt rates of snow and ice.

o Improve climate understanding by developing models to simulate the conditions that occurred during the Cenozoic geologic era, focusing on the Late Paleocene Thermal Maximum (LPTM) of 55 million years ago. Evidence exists that the LPTM was a period of rapid global warming that resulted in the widespread extinctions.

Account for the following statements and reference material in climate modeling:

" A period of global warming, called the Late Paleocene Thermal Maximum (LPTM) occurred around 55 million years ago and lasted about 100,000 years. Current theory has linked this to a vast release of frozen methane from beneath the sea floor, which led to the earth warming as a result of increased greenhouse gases in the atmosphere." The vast release of frozen methane was preceded by climate warming from the emissions of greenhouse gases by heavy volcanic and flood basalt episodes.
http://www.gsfc.nasa.gov/topstory/20011212methane.html

"ten million years later (55 million years ago), a warm spell led to significant global warming, with Palm trees in Alaska and crocodiles in the Arctic."
http://www.ngdc.noaa.gov/paleo/ctl/beyond.html

"In the late Paleocene temperatures started to rise, which caused change in the vegetation."

"Increasingly warm conditions at the start of the Eocene caused the extinction of some prominent species of the prior epoch."

" The forests that had housed numerous primate relatives were replaced with denser, often tropical, forests. Species either adapted to the new

climate and environments or died out. The pleisiadapiform species that thrived during most of the epoch dwindled and left only a handful of species in the Eocene" (The Smithsonian's Human Origins Program). http://www.mnh.si.edu/anthro/humanorigins/faq/gt/cenozoic/paleocene.htm

"The Late Paleocene Thermal Maximum is relevant because it is the most abrupt warming event ever documented." http://www.washingtonpost.com/wp-srv/national/horizon/sept98/sea.htm

"The striking correspondence between the quantities of carbon introduced without man's influence 55Ma (million years) ago and those now being put into the atmosphere by us, would alone justify this Geological Society meeting." "A 25-27 March 2003 three day international meeting on the geological aspects of coping with climate change, will be held at the Burlington House, London." http://www.geolsoc.org.uk/template.cfm?name=LovellOpEd

Further study of the "Paleontology of the Theodore Roosevelt National Park" may unlock important information on the LPTM. http://www.state.nd.us/ndfossils/education/brochure/brostart.html

PATRICK J. NEUMAN, NWS_NCRFC, COMMENTS MY OWN..NOT AGENCY.

Page 21, Line 31: o Temperature data by itself is inadequate in monitoring changes in climate. Changes in enthalpy (temperature, humidity, phase change - latent heat exchanges) are very important. It can be misleading to look only at temperature measurements without considering changes in humidity (dewpoints). Near surface humidity is very important in determining the rate of snowmelt, and ice thaw due to the latent heat exchange from the condensation of water vapor on cold surfaces.

PATRICK J. NEUMAN, NWS_NCRFC, 2 BULLETS ALL COMMENTS ARE MY OWN..NOT REPRESENTATIVE OF THE AGENCY THAT I WORK FOR.

Page 21, lines 32 to Page 22, line 4: A research need for agriculture on feedbacks is the water from evaporation and potential shifts in water use patterns. The linkage between water use and carbon storage and loss is a critical feedback that should be addressed.

JERRY L. HATFIELD, USDA-ARS NATIONAL SOIL TILTH LABORATORY

Page 21, lines 32 to Page 22, line 4: A research need for agriculture on feedbacks is the water from evaporation and potential shifts in water use patterns. The linkage between water use and carbon storage and loss is a critical feedback that should be addressed.

STEVEN R. SHAFER, USDA-ARS

Page 21, Line 32:

- Combined laboratory, in situ, and remote sensed measurements of water vapor…

NIST, HRATCH SEMERJIAN

Page 21, line 32 to page 22, line 4: These tasks will take a lot of intensive (and expensive) efforts, all with no guarantee of actually making progress.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 21, Line 38-39:

- Extend tests of cloud parameterization using process resolving models for weather prediction to General Circulation Models (GCM) applied to climate change studies

TWITCHELL, GEWEX

Page 22: Improved estimates of global radiative energy losses arising from water vapor variability
in the upper troposphere. 15

One needs to be much more specific with regards to priorities of various possible aspects of water vapor research. As noted in the IPCC report, the specific area regarding upper tropospheric water vapor that needs the most additional research is the role of microphysics in convective systems in determining atmospheric water vapor.

RAYMOND PIERREHUMBERT, THE UNIVERSITY OF CHICAGO

Page 22, lines 5-11. The discussion of the Hornberger document seems misplaced here. Specifics from that document could be quoted where they are in line with this plan, but wholesale importation of that document into this one, as implied by the way it is discussed, is not consistent with the notion of careful review of this document--- the participants in the review of this plan were not given that document, nor were they given any details of its conclusions. This paragraph should be dropped or greatly altered in content.

SUSAN SOLOMON, NOAA

Page 22, L5-18 - Snow-Ice albedo feedback is as important. It seems missing. Reducing uncertainty in this feedback may be more solvable on a 2 to 4 year time scale than clouds.

RONALD STOUFFER, GFDL/NOAA

Page 22, lines 5-11: Is the research described a critical part of the strategy to reduce uncertainty in the contribution of clouds and water vapor feedback on climate change?

DEPARTMENT OF TRANSPORTATION, LAWSON

Page 22, lines 5-11: This discussion is poorly connected to the water vapor and cloud feedback issues. If it is to be retained, it must more clearly establish the connection between surface hydrology and water vapor and cloud feedbacks. For example, would a warmer climate dry the continental surface and the overlying atmosphere?

STEVEN GHAN, PNNL

Page 22, line 7: Change “predicting” to “calculating”—we will not be making such a prediction.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 22, line 10: Interestingly, there has been no definition given of “weather” or “climate” and this really needs to be done given the audience.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 22, lines 14-18, nothing new here.

Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. MARYLAND

Page 22, line 17: Change “predictions” to “projections”—apparently not even the authors are paying attention to the differences, so they really must need to be explained in this plan.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 22, lines 23-41: What are the short-term deliverables? This section is no different than the subsequent GCRP chapters? Why has this been designated a CCRI initiative? This section is parochial.

ANTONIO J. BUSALACCHI, EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER (ESSIC), U. Maryland

Page 22, line 23: "models consistently predict future warming" - again, it's important to include the fact that observations of the last 50 years *also* show more warming in the Arctic. Many important aspects of "future" climate change have already been observed, and that fact should be mentioned wherever appropriate.

PHILIP MOTE ON BEHALF OF THE CLIMATE IMPACTS GROUP, UNIVERSITY OF WASHINGTON

Page 22, lines 23-33. Temperature changes are expected to be larger in the polar regions, but that doesn't necessarily make them more 'significant', since precipitation is a key factor in the significance of impacts, as well as vulnerability. It could equally well be argued that the tropics are the most vulnerable region. The wording should be carefully changed to reflect that you are talking only about enhanced high-latitude warming here.

SUSAN SOLOMON, NOAA

Page 22, line 24: Change “predict” to “project”. Also, change “much more significant” to “greater” as significance involves a lot more consideration than just how much the change will be. In fact, one can have very significant effects with smaller changes than occur in the polar regions—imagine what a 2 C warming would do in the tropics compared to a 4 C warming in the poles. Judging significance requires much more consideration than just the magnitude of the change.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 22L27 - "Triple absorbed radiation" occurs only locally.

RONALD STOUFFER, GFDL/NOAA

Page 22, line 32: The contribution will be to much more than to the carbon cycle—it is also likely there will be an effect on the global climate.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 22, line 36: The effect is really on the global thermohaline circulation—it is just that it occurs in the Atlantic, which in turn drives the global circulation.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 22, lines 38-39. There is currently a great deal of debate about the real role of the thermohaline circulation in global climate, with some studies arguing for a much larger and dominant role for the tropical oceans (e.g., the work of Mark Kane and colleagues). It is OK to mention the thermohaline circulation, but the strong statements about its key role need softening.

SUSAN SOLOMON, NOAA

Page 22, line 38: there is some controversy over the role of the thermohaline circulation in "determining" global climate fluctuations, with some (e.g., David Battisti, UW) claiming that it plays a negligible role outside the North Atlantic/European sector.

PHILIP MOTE ON BEHALF OF THE CLIMATE IMPACTS GROUP, UNIVERSITY OF WASHINGTON

Page 22, line 40 Why isn't a link made between the physical climate change at high latitudes and carbon cycling? The Southern Ocean is an enormous reservoir of underutilized nutrients, and changes in ocean and atmosphere circulation may greatly affects its role in the carbon cycle. This is a consistent problem with the CCSP; there seems to be only ad hoc links between the "stovepipe" science issues.

MARK R. ABBOTT, OREGON STATE UNIVERSITY

Page 22, bottom: add an additional paragraph, noting the importance of the Arctic Oscillation in Arctic climate change): The Arctic Oscillation is likely a key contributor to Arctic change. However, the controls of the Arctic Oscillation are not understood, nor are the changes that could occur in the Arctic Oscillation in association with greenhouse warming.

WELLER, ET AL, UNIVERSITY OF ALASKA FAIRBANKS

Page 23, lines 4-13. This paragraph should be reworded to reflect what is, and is not, likely based on current understanding. It is a little unbalanced to state such extremes without context. A complete collapse of the ice caps is not a probable scenario.

SUSAN SOLOMON, NOAA

Page 23, Line 7: It is stated that there is evidence that the global sea level has risen in the past by as much as two inches per year in some locations. The approximate time frames should be stated.

OREST LEWINTER, CITIZEN

Page 23, line 7: Congratulations for recognizing that the smaller glaciers are "disappearing rapidly."

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 23, line 9: This reference to past sea level rise occurring at as much as 5o mm per year is really disingenuous, for it refers to a time and situation very different than at present. The reconstructions indicate that since the major retreat from the last glacial maximum ended about 10,000 years ago, there has been relatively little sea level change. The comparison here is like comparing our present medical conditions to that of cavemen (or cave people)—it is not really relevant to what will happen in the future now that society is established on the coastlines at sea levels that have prevailed for a few thousand years.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 23, lines 15-20. This is overstated. Many argue that the tropics are the region with poorest description in models.

SUSAN SOLOMON, NOAA

Page 23, line 15: **(14-E)** Interpreted literally, this first sentence says that representation of polar climate at lower latitudes in climate models needs work. The sentence, clearly, needs work.

HP HANSON, LANL

Page 23, lines 19-20: It is not at all the case that we have to have much more accurate global observations to more "accurately predict (sic—you mean project) future climate change and assess the potential for these changes to be abrupt." The connection is not direct as it would be for a weather forecast. It is true that improved observations and paleoclimatic reconstructions could help improve our understanding of the climate system and how to represent it, but the connection is less direct than indicated.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 23 line 21: The meteorology of the Arctic allows for a concentration of soot aerosols mainly from Eastern Europe and Russia during the winter months. The role that these aerosols play in the spring and early summer months in affecting regional temperatures and sea ice needs further investigation.

BILL PORCH -LOS ALAMOS NATIONAL LAB

Page 23: Line 31:
Warming could also lead to changes (e.g.) acceleration of the hydrological cycle) in polar regions.

Part 2: Comments on the session titled “Emerging Climate Science Issues,” a session under the Conference Breakout Group 1: Climate Change Science Program Elements, held 3 December at the US Climate Change Workshop, Washington, DC.

The moderator for the Emerging Climate Science Issues was Dr. Robert Corell, who opened the session with a brief discussion on the goal of this breakout session. Dr. Alexander McDonald presented the overview on Chapter 2, highlighting the positive points he found in the document and identified several specific research needs. For aerosols contribution to climate change he introduced research needs on the role of aerosols in cloud feedback process using an Arctic example and for both aerosols and carbon the need to place more effort on air mass transport. Also for both aerosols and carbon there is a need for improving the observation systems. He identified the need for research on cloud, water vapor, and Arctic ice feedback. Dr. McDonald’s thoughtful analysis was enforced by the short presentations of the panelists.

Each panelist raised issues in their brief talks that stimulated the follow-on open discussion period. Examples are:

- Dr. Warren Washington noted that short (2-4 years) carbon cycle study is not sufficient to get a trend. He mentioned that to quantify polar feedback a large scale experiment, with both satellite and in situ measurements are needed, and ozone needs to be included.
- Professor V. Ramanathan presentation added excellent issues for the discussions to follow. He added to the 4 year time period for emerging issues several realistic topics, such as natural aerosol transport from Asia, Africa, and elsewhere needs more focus. In regard to emissions of CO2, he pointed out that the United States has decreased while China, the former Soviet Union, and the rest of the world increased CO2 emissions. He identified the hydrological cycle as an issue. He also noted model results differ greatly, especially if cloud feedback and troposphere temperature (not surface) are introduced.
- Professor Michael Schlessinger stated in his presentation that global temperature change cannot be determined by present models. To reduce uncertainties in prediction of climate change it will be necessary to include radiative forcing by the sun and volcanic clouds.
- Dr. Brian Flannery brought to the group practical implications of climate change on industry and the economy of other industrial nations.

All four panelists identified new research topics or topics that require additional focused research. The thoughtful presentations stimulated intelligent inquiries or statements from the audience indicated by → and clear replies from the panelists indicated by ¨ by the following:

→ Natural variability on decadel scale or longer impact on Earth’s climate.
  ♦ Sun's influence must be addressed.
  ♦ CCRI focus is on next 2-4 years.
→ Why are models not catching sudden changes and what processes are missing?

- There is a need to study teleconnections, such as the Indian Ocean and the Pacific Ocean in recent years.
- The large error basis in models damp out rapid changes.
- Changes in polar regions are a high priority to reduce surprises.
- Bore hole records show climate variability, including abrupt changes.

→ What basic research is needed?

- Thermohaline studies may show reasons for sudden climate change.
- Basic cloud physics research is needed to reduce uncertainties.
- Cost-benefit analysis of urban plume transport.
- Gas to particulate research.
- Boreal forest migration and size role in carbon uptake.
- Probalistic climate prediction.

TWITCHELL, GEWEX

Page 23, line 25: What are "perched lakes"—lakes with perch in them? And the ice below is not really "permanent"—can be affected by human activities and likely only appeared during the glacials.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 23, line 33: Change "evaluating" to "improved evaluation of"

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 23, line 37: insert a paragraph

The climate station network in the Arctic and Subarctic is sparse and prone to measurement error. The terrestrial precipitation network has also been degraded by the closure of many monitoring stations in the former Soviet Union and a trend toward automation in Canada. The National Weather Service operates only five official recording stations in Arctic Alaska (an area of 210,000 km2), and four of those are within a few km of the coast. Streamflow monitoring stations are also being closed as agencies try to balance stagnant budgets with increasing political pressures from more populated temperate regions. The U.S. Geological Survey currently only gauges five rivers in Arctic Alaska. We must increase and maintain our basis of monitoring climate or we will never be able to quantify the subtle climate change signal from a very noisy record.

WELLER, ET AL, UNIVERSITY OF ALASKA FAIRBANKS

Page 23, Line 38: Research Needs (Feedbecks from Polar Regions)

Specific research foci on West Antarctica Thwaites/Pine Island glacier mass balance mentioned is critically important, however, there are numerous regions in Antarctica are presently not understood. Mass balance research should extend to all regions of Antarctica, Greenland, and world mountain glaciers.

C.K. SHUM, OHIO STATE UNIVERSITY

Page 23, Line 38-Page 24, Line 7: One of the reason we don't understand cloud properties in polar regions is a lack of reliable observation data. Estimating cloud properties, even cloud fraction, over snow covered surface is challenging. However, clouds affect the surface radiation balance in polar region very much. This in turn affects the ice coverage in the region. Understanding cloud properties in polar regions needs to be mentioned in the research need section.

SEIJI KATO, HAMPTON UNIVERSITY

Page 23, line 38: add new bullet:
Determine the controls of the Arctic Oscillation, the full range of its impacts on the Arctic, and possible interactions between the Arctic Oscillation and greenhouse forcing.

WELLER, ET AL, UNIVERSITY OF ALASKA FAIRBANKS

Page 23, lines 39-41: What is a "sufficient" period? Is this not an uncertainty in itself? Does this project really contribute to reducing uncertainty and enhancing decision tools within the next 2-4 years?

DEPARTMENT OF TRANSPORTATION, LAWSON

Page 23, lines 39 - 41**:** revise the bullet.
Determination of basin-wide Arctic sea ice thickness*,* ice type, sea ice extent, and concentration, particularly in the marginal seas, at a sufficient temporal scale to determine if observed historic changes are present across the basin and to enhance the existing record.

WELLER, ET AL, UNIVERSITY OF ALASKA FAIRBANKS

Page 23, line 40: A better explanation is needed of how this information will be gathered in 2-4 years.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Pages 24-25, references: Recommend references also be correlated to text (via numbers).

DEPARTMENT OF TRANSPORTATION, LAWSON

Page 24, lines 1-3: An explanation is needed of why this information would be critical.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 24, lines 1-3. Rather specific goal - needs more justification if it stays.
As elsewhere, goals on page 24 need to be clarified as to what is long-term and what is realistically short-term.

SUSAN SOLOMON, NOAA

Page 24, line 4: revise the bullet
Assessment of the mass balance changes of the Greenland and Antarctic ice sheet, their variability and potential contributions to sea level change, using modern techniques including satellite laser altimetry.

WELLER, ET AL, UNIVERSITY OF ALASKA FAIRBANKS

Page 24, lines 6-7: The five-year timeline is inconsistent with the goal of producing results in 2-4 years.

Page 24, Line 6: insert
Measurement of chemical properties governing CO2 and CH4 adsorption and stabilization in key Arctic soils.

NIST

Page 24, line 8 Research Needs: add a bullet**.**
Assessment of the relationships among changing permafrost extent, surface energy budget, soil drying, vegetation changes and their feedbacks on climate.

WELLER, ET AL, UNIVERSITY OF ALASKA FAIRBANKS

Page 24, lines 10-11: "its impacts on global climate, and its potential navigability …"

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 24, lines 12-14: Not clear this can be done at the cold temperatures of high latitude, certainly not in 2-4 years.

ANTONIO J. BUSALACCHI, EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER (ESSIC),
U. Maryland

Page 24, line 14 I am extremely skeptical of our ability to measure surface salinity with sufficient precision, accuracy, and spatial resolution to detect changes in equatorward transport from space. Moreover, changes at depth will not be accessible from space platforms.

MARK R. ABBOTT, OREGON STATE UNIVERSITY

Page 24, line 15: There has been no discussion of assessments to this point. An explanation is needed of how these will be done. If what is meant is a survey of the scientific literature, then this should be said and the word assessment saved for the process involving stakeholder interactions with the scientific community and scientific information.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 24, Line 17-19, more reliable assessment of future sea level changes
This research area is critically important. However, sea level signals are results or origins of interdisciplinary disciplines including solid-Earth, ocean, atmosphere, cryosphere, hydrosphere, and requires significant more details of research needs, measurement systems to have been addressed in this strategic plan.

C.K. SHUM, OHIO STATE UNIVERSITY

Page 24, lines 17-19: How will the assessment be done, and what will make it "more reliable"? Why is rapid sea level change set at 10 mm/yr and is this relative change locally or global average change? On line 18, the word "estimates" should be "projections> Also, there really needs to be a difference indicated between the concept of uncertainty and the concept of a range of results based on possible scenarios for the future.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 24L17-19 - Sea level changes - Most freshwater on the planet is contained in the Antarctic ice sheet. There is little discussion of this fact. Accurate projections of future sea ice changes will need to make estimates of changes in Antarctic ice sheets. Also, the heating of ocean is as important to future sea level changes over the next 100 years (WG1 report TAR) as ice melt. This needs mentioned here.

RONALD STOUFFER, GFDL/NOAA

Page 24. Line 21. Insert text which elaborates on the “fourth bullet” proposed. Should the drafters of this document agree, I will be happy to write a draft of the required page or two of text for their consideration.

BILL PETERSON, NOAA/FISHERIES