Written Public Comments on the *Strategic Plan for the U.S. Climate Change Science Program*
Chapter 6: Climate Variability and Change (pp 68-79)
Comments Submitted 11 November 2002 through 18 January 2003
Collation dated 21 January 2003

Page 68, Chapter 6 (Please see submission by James Kinter, Chapter 5 for cross-cutting and linkage comments on Chapters 5, 6, and 7)

Page 68, Chapter 6:
Variability is a central aspect of global change research, i.e. climate variations are often larger than climate change projections. Additionally, the relationship between climate change and variability is not made well enough and should be a highly visible part of this chapter. One cannot explore uncertainties of the climate without considering climate variability and change. Perhaps a sixth question should be added…how does inherent climate variability limit our ability to reduce uncertainty in impacts.

Chapter 6 needs a description of the overall approach, e.g. studies focusing on particularly critical and poorly parameterized processes; synthesis frameworks (including reanalyses, data assimilation, ocean state estimation); modeling (analysis of model runs) and model (including paleoclimate) improvement. Fundamental research needs also include appropriate observing system elements (GCOS, GOOS, GTOS, etc.).

There is a palpable absence of oceanography. While it is trite and over-used to say that the oceans represent the "flywheel" or "memory" in the climate system, it is clear that much of the variability that (may be) predictable is best exploited through an improved representation of the ocean initial state, and an improved representation of the evolution of the ocean.

Further, it is likely that much of the uncertainty about the stability of the climate system (i.e. abrupt climate change or feedbacks) derives from uncertainty about some basic physics in the ocean, notably above-background turbulent mixing.

There is a close relationship between SST, surface heating, and diapycnal fluxes of heat in the ocean. A sensitivity of ENSO amplitude to ocean model diffusivity found in recent coupled climate experiments highlights the importance of correctly representing this relationship and especially the mixing processes that helps govern the relationship.

There is a clear link between SST, surface heating and interior ocean dissipation, and if the problem of climate variability can be thought of in terms of variations in either SST or surface heating, then understanding the long term evolution of the thermocline "sharpness" may bring us closer to accurate models of climate variability and sensitivity. We are at a threshold now in the development of ocean models, where the numerics and hydrodynamics of the flow can be quite robustly solved, and where diapycnal (as well as isopycnal) mixing can be lowered enough to mimic the background values that people estimate for the ocean. The key now is to understand and model the physically important cases of above-background mixing that are known to exist in some parts of the ocean.

The next criticism is that there is an imbalance between what is "doable", what is highly speculative and what is fundamentally problematical. While there can be no doubt that an unpreparedness for abrupt climate change would lead to severe societal disruption should such an event occur, we have very limited tools with which to examine the likeliness of such an event. None of the current observational record is sufficient to tell much about this phenomenon, so we are left with trying to interpret paleoclimate records. From there, we are left with numerical models for any guidance.

But if models were to exhibit such abrupt climate changes, I would strongly doubt that they would be believed. We have already seen that the stability of the thermohaline circulation in the ocean is subject to many interpretations, and which differ dramatically based on modeling assumptions – isopycnal vs. z coordinate, sill overflows vs. coarse topography, sensitivity to boundary conditions, and so on. What we can do here is to devote a substantial modeling effort to trying out mechanisms and comparing with paleo data. In the end, it would seem well beyond a 15-year program, and one which would still leave significant doubt as to its veracity.

Suggestion: The chapter needs to be strengthened, and made more realistic in terms of how the climate variability/change science community should contribute to improved decision- and policy-making (i.e., Question 5). Moreover, there are concrete steps that could be taken in the short-term to dramatically improve the linkages between climate science and the use of climate knowledge. The NOAA-OGP managed "Regional Integrated Sciences and Assessments" (RISA) Program has, via several regional pilot programs in the climatically-sensitive western and southeastern U.S, already demonstrated the effectiveness of the following approach.

Note that the important impacts of both natural and anthropogenic climate variability and change will be manifest as the regional impacts of climate variability. In addition to mastering our ability to observe, understand and simulate global- to continental-scale processes, the ultimate utility of this work hinges on making the connection between regional variability and humans or ecosystems. Rapid progress is already being made in this area via close regional interaction between climate scientists and decision-makers (e.g., farmers, ranchers, water managers, forest managers, public health officials, etc.). Accelerated efforts to build on lessons learned has the opportunity to provide the methodological framework for improved decision-making in the face of climate variability and change. This "no-regrets" strategy will aid decision-makers whether the variability and change is due to humans or not, and it will also be the most effective way possible to develop an adaptive capability in case future climate and variability change turns out to be significant.

First and foremost, the physical science community needs to evolve from a strictly disciplinary "hand-off" or "product-driven" paradigm to one that involves true two-way partnerships with decision-makers. Only by listening and being responsive to these stakeholders can climate science be of maximum utility. Moreover, few stakeholders use climate information in a vacuum – although climate knowledge is perhaps the most widely needed, it is usually only one concern among many others (e.g., institutional, economic, legal, cultural, ecological) that are integrated by a stakeholder in making decisions. For this reason, climate scientists must work with others to ensure that climate knowledge is conveyed in an interdisciplinary or "multi-stress" context that facilitates more effective use. Moreover, this multi-stress approach is most effective when pursued in a multi-agency context. In this manner, stakeholders have the simplest path possible to the knowledge that they require, and in the integrated form that is most helpful.

Another problem with "product-driven" climate service is that it limits the responsiveness of the climate science community to user needs. Research structures that encourage close partnership with social scientists and decision-makers have already proven to be the most effective in making climate knowledge usable. Not only can these interdisciplinary partnerships drive more effective science, they also ensure the most effective assessment of progress and thus the fastest evolution of user-driven climate science.

Given that decisions are mostly carried out at local to regional "place-based" scales, and that policy decisions must be responsive to regional implications, the other key to effective user-driven climate science is that it aggressively work on solving regional-scale climate issues in the absence of national boundaries. For example, the summer monsoon is of critical importance to many decision-makers in the SW US. This means that the Southwest Monsoon of both the U.S. and Mexico must be more of a priority to the climate science community, but also the nature of climate variability and predictability in topographically-complex terrain. It means also that regional scale climate processes and modeling must be more of a priority for the nation's climate observing systems and research.

In terms of implementation, it is unrealistic to develop user-driven climate science and services at a national-scale given current resource limitations. There must be substantial investment in regional efforts where decision-maker need and partnerships are already well established (e.g., western and southwestern U.S.), with expansion into additional regions as stakeholder demand and funding allows. Because climate-society partnerships must be regional, interdisciplinary and multi-agency, as well as research- and training-intensive, it appears inescapable that the partnerships must be university based with strong federal, state and private involvement.

Suggestion: the importance and need for paleoclimatic research needs to be enhanced for several general reasons. First, paleoenvironmental records extending back centuries and millennia provide *the only way* to observe and investigate the full range of climate variability and change, as well as variability in natural (e.g., sun, volcano, trace-gas and insolation) forcing. Moreover, the paleoclimatic record provides the only way to observe and study variability and change prior to significant anthropogenic forcing, and that is thus purely natural. For this reason, the paleoclimatic record provides critical insights in disentangling natural from human-forced climate change, and in narrowing uncertainty about what lies ahead.

The paleoclimatic record also provides the only way to observe how the climate system has responded to large changes in climate forcing in the past. Given the significant debate about how large future change will be, it is critical to base our understanding on observations as well as models. Over recent earth history, there have been numerous climate shifts as large as those likely to occur in the next century. Detailed study of these past changes will provide key insights needed to narrow uncertainty with regard to what might happen in the future.

Study of the paleoclimatic record has uncovered the possibility that the climate system can respond abruptly (non-linearly) and with little warning to changes in climate forcing. For example, we now know from paleoclimatic research that ocean circulation can change dramatically in decades, or even years. Similarly, we now know that hydrologic variability (drought and flood regimes), as well as ENSO and hurricane/typhoon variability, can also shift abruptly for poorly understood reasons. A recent interdisciplinary NAS report makes it clear that abrupt change may be the greatest economic and ecological threat associated with global climate change. Without the paleoclimatic record, observations of abrupt change, as well as a predictive understanding the mechanisms involved will not be possible, nor testable.

Lastly, the paleoclimate record provides the only framework, short of waiting 100 years, to see how realistically state-of-the-art models simulate climate change. The instrumental and satellite records are too short to include any large climate shifts, whereas the paleoclimate record is replete with such changes, both gradual and abrupt, and at scales ranging from global to the regional scales so critical to decision-making. In addition to providing key constraints on climate system sensitivity to altered forcing (i.e., narrowing uncertainty with regard to how much warming will be associated with a doubling of atmospheric carbon dioxide), the paleoclimatic record provides the only observational record against which our ability to simulate key “slow” hydrologic, ocean and cryospheric processes can be tested.

Given the recognized critical nature of the observed climate record, paleoclimate observations provide the only way, short of waiting centuries, to develop a predictive understanding of the complete range of climate system behavior.

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 68, Chapter 6: Chapter six needs to refer to chapter 12 for modeling.

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 68, Chapter 6: Predictions on seasonal to interannual time scales are now done routinely in all parts of the tropics. In particular attention needs to be paid to the tropical Atlantic and Indian Ocean sectors.

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 68, Chapter 6: Since the document as a whole lacks balance when examples from “ecosystems” are mentioned, I recommend that you include in the list of “Impacts on natural resources,,,(line 6), mention of living marine resources and fisheries (lines 10/11).

BILL PETERSON, NOAA/FISHERIES

Page 68, Chapter 6: This contribution focuses on the question, to what extent can predictions of near-term climate fluctuations and projection of long-term climate change be improved?

There is much good discussion of climate fluctuations and climate change in this section. There could be better definition given to the role of better understanding and predicting climate fluctuations (seasonal to interannual timescale) for (i) genuinely improving the representation of these features in global change scenarios, which most recognize is needed for realistic global change scenarios, and is essential for downscaling regional estimates, and (ii) by demonstrating ability at seasonal-to-interannual timescales, to build confidence amongst decision makers and therefore reduce perceived uncertainties in global change projections. There are examples of where this comes out (e.g. p73, lines 26-30, p74 line 31-32), but there is a danger of these points being lost, as they are contained within broader discussions of issues that are specifically oriented at change or variability. A separate section on the intersection and value of variability work to reducing uncertainties in change estimates (and especially regional change estimates) would be useful. The overall question might also be rephrased to reflect this.

Cross reference can be made back to Applied Climate Modeling (sub section 3 in Chapter 4), p48, section entitled “Enhance Model Credibility through a Formal Program of Model testing”. Testing of models for their ability to simulate and predict interannual variability is recognized as a valuable way to achieving enhanced model credibility. The IRI is already contributing to the climate community such an activity, co-coordinating the verification of model predictions from past years, and the generation of real-time 3-6 month ahead predictions, for a suite of state-of-the-science atmospheric GCMs. This comes about through IRI collaborating with NCEP and other U.S. and international institutions. This could be built upon further. Despite the fact that progress has been made in the creation of operational seasonal predictions, injection of enhanced technical infrastructure would further accelerate progress substantially, and IRI and others in the U.S. community are well placed to take advantage of such an increase in technical infrastructure and consolidate this key contribution to the international stage.

IRI, Zebiak and Staff

Page 68, Chapter 6: I am at NASA’s Seasonal to Interannual Prediction Project (NSIPP) and have worked with coupled climate models for over 20 years. I served as a panelist at the second CVC session at the Washington workshop.

I found the chapter to be a thoughtful presentation of the issues confronting USGCRP in this area, and the organization around the five questions appropriate.

Nevertheless I think the chapter lacking in two key aspects: First, although it discusses the correct issues, it does not make a serious attempt at a plan to address them. And second, it fails to make a compelling case for the fundamental importance of variability research in addressing the global change problem. I will limit my comments to these two aspects.

The first comment really applies to the document as a whole; it reads more like a background document than a plan. This is true of the USGCRP chapters, and somewhat less so for the CCRI chapters; but even in those, there are few specifics other than the "two-center" modeling strategy for IPCC. Chapter 6 assumes that adequate plans for modeling, observation, assimilation, and reanalyses are presented in Chapters 4 and 12. Chapter 4 makes a good case for a "two-center" modeling strategy for IPCC. I strongly support this approach. But I do not think this is an adequate modeling strategy for all of USGCRP research. It is particularly important for Ch 6 to emphasize this and to discuss a larger plan, since it is dealing with SI/Decadal variability and prediction, and their relation to change, areas that involve a bigger community than is represented by these centers. I suggest that the broader, longer-term, USGCRP plans for modeling, observation, assimilation, and reanalyses be laid out in Ch 12 and that Ch 6 refer to those and not to the short-term CCRI plans, such as the two-center strategy. In this regard, it seems strange to me that reanalyses be treated as a short-term issue, since of the main shortcomings of the current situation is that reanalysis are being done as one-shot efforts by weather centers and there is broad agreement in the climate research community that a sustained climate-oriented effort is required.

In the second area—the relation of variability to change—Ch 6 should be strengthened in three respects.

(1) It should make clear that many of the most important effects of global change will be local in space and time: regional changes and changes in the behavior of extreme events. And that, this also being true on for changes on interannual time scale, SI prediction is the ideal testbed for this research.

(2) It should emphasize that seasonal-to-interannual prediction and the simulation of interannual variability are among the strongest validations we have for coupled climate models.

(3) It should bring out in the discussion of the processes controlling the rate and magnitude of climate sensitivity (line 21, pg 71) and their deficient representation in climate models, that these are relatively fast processes, and that they are the same ones that are limiting in models used to study and predict interannual variability. These problems are thus not the exclusive concern of global change research, but of climate modelers working at all time scales. And solutions to them can as easily come from one community or the other, and would best be approached by coordinated efforts from both.

MAX SUAREZ, NASA

Page 68, Chapter 6: This is a very comprehensive and general introduction to all aspects of climate change. However, in reading, or rather, wading through this exhaustive list of every possible aspect of climate change research, it occurs to me that a few important things are lost in the shuffle:

UNCERTAINTY: What level of certainty do we need to determine that human caused alteration of our climate system has occurred and is occurring? A similar question is raised on page 26 line 17 in the box, but is not answered by the subsequent discussion on page 27. We have achieved a certain degree of certainty on this front (66-90%, IPCC, 2001), and need to decide at what confidence level (90-95%?) we will be confident enough to consider the question answered and move on to the next step. CCSP is spending hundreds of millions of dollars toward this endpoint, yet no endpoint has been decided upon (e.g., page 72, line 23). Reviewer's Name, affiliation: Leland Tarnay, Ph.D., National Park Service-Center for Urban Ecology

NATIONAL PARK SERVICE

Page 68, Chapter 6: 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 68, Chapter 6: Overall, I agree with the issues raised in Chapter 6. Major issues are raised and research priorities generally recognize recent scientific developments and are viewed from the perspective of information that will be required for impacts assessments.

Omission: Small-scale ocean feedbacks are called out as an area needing urgent research. An equally or perhaps more important analogous area is terrestrial biospheric feedbacks, particularly those associated with managed landscapes (agricultural and forestry ecosystems). These, like small-scale ocean feedbacks, have strong coupling to the hydrological cycle, but unlike their ocean counterpart, they play a strong role in biogeochemical cycles and will play a central role in follow-on regional and local impacts assessments. For these reasons, we conclude terrestrial biospheric feedbacks associated with agroecosystems should be a research priority. We suggest including the following question under "High priority research":

What are the key terrestrial biospheric feedback mechanisms associated with agroecosystems, how do they link with the hydrological and biogeochemical cycles, and how are they sensitive to management choices?

Comments on Chapter 6

Soil Science of America, Eugene S. Takle, Iowa State University

Page 68, Chapter 6: The AASC has experience in addressing a number of issues related to climate change and variability, as outlined in Chapter 6. Our activities include evaluating and assisting decision-makers in using seasonal weather predictions, monitoring climate extremes including their impact on society and the environment, and providing climate information to a wide range of users. The mix of users and their needs vary from region to region (for example, New England has different requirements for climate information than the southwest US). As a result, the interaction with these users has to be at the state and regional level. It would be more effective to support the existing infrastructure of state and regional climate expertise rather than start from scratch. By using the existing local, state and regional expertise, several of the “products and payoffs” in Chapter 6 with a 5-15 year time horizon, particularly on page 78, could be accomplished much sooner.

AASC, Roger Pielke, Sr.

Page 68, Chapter 6: I applaud the authors of Chapter 6 for more fully recognizing the essential role of paleoclimatic data in answering many of our key questions about the climate system.

C. Mark Eakin, NOAA/National Climatic Data Center

Page 68, Chapter 6: Page 58, Chapter 5: Overview Comments on Chapters 5, 6, and 7 based on my Panel Presentation

Emphasize exploitation of recent and ongoing programs to demonstrate capability to bridge gap between “Research Needs” and “Products and Payoffs” -- especially for 2-4 year horizon -- e.g., ARM Program, including use by GCIP

Acknowledge gulf that exists between (a) obtaining improved understanding of climate system and (b) having society benefit from this new knowledge -- requirements include substantial “impact data sets”, extensive interactions with potential users of mitigation information, and long-term collaboration with social scientists, economists, etc.

Need for greatly enhanced resources if desired progress is to occur -- qualified scientists and institutional funding -- e.g., where are needed people with interdisciplinary expertise?; level of funding of NOAA Laboratories in last 20 years has halved their capability to contribute

PETER LAMB, THE UNIVERSITY OF OKLAHOMA

Page 68, Chapter 6: I would like to see even more emphasis on investigating causes (including possible changes in solar intensity) behind climate change during the “recent” past (*e.g.,* the Medieval Climatic Optimum and the Little Ice Age). Are any factors present during the Medieval Climatic Optimum that could assist in understanding the role of natural climate variability in the present era? What role did the Medieval Climatic Optimum have (if any) in triggering the Medieval Glaciation/Little Ice Age?

JOHN HAYNES, OFFICE OF EARTH SCIENCE/APPLICATIONS DIVISION/NASA HEADQUARTERS

Page 68, Chapter 6: There is too much emphasis on studies of seasonal to decadal climate variability and too little emphasis on the centennial and longer time scales of climate change. The geological record clearly shows large centennial and millennial variability. The recent publication by Dickson et al. showing forty years of continuous freshening in the North Atlantic is the best proof that it is unwise to limit the variability studies to decadal and shorter bands. Projections of climate for next century will be wrong if these longer time scales are ignored.

William B. Curry, Woods Hole Oceanographic Institution

Page 68, Chapter 6: Bathymetry
Ocean bathymetry is a significant boundary influencing ocean circulation patterns. It is that circulation which plays such an important role in shaping the climates of certain regions of the world. The Gulf Stream is a key player in shaping the climate of Northern Europe with all the socio-political implications that has for the rest of the world. Recent modeling experiments at the Naval Research Laboratory have shown these currents can be exquisitely sensitive to small variations in bathymetry. The implications is that detailed, high-resolution bathymetry, especially in critical areas, is a necessary condition to understanding the controlling influences on currents, their contribution to global circulation, and ultimately to global climate and it's variation. The plan should make reference to the value of gridded bathymetry data for use in the ocean current modeling which will be conducted under the CCSP.

NOAA-NESDIS, SHARMAN

Page 68, Chapter 6: Solar Influences on Climate Change
The CCSP strategic plan should include activities to better understand the effects of solar variations on climate and the long term monitoring of solar activity.

The Sun is the engine that drives the Earth's weather. It supplies the radiation that warms the atmosphere and puts into motion numerous processes, ultimately resulting in local weather phenomenon, such as rain. In addition to the Earth's weather, the Sun's short term variations affect the Earth's environment, causing aurora, geomagnetic storms, and high atmosphere disturbances, affecting global telecommunications, navigation, large arrays of electrical power grids, safety of human space flight, and reliability and failure modes of satellites. Microchips used in computers can be affected by cosmic ray impacts, at times creating spurious commands such as spontaneously rebooting a computer system.

While it seems reasonable that the short term variations on the Sun's surface would affect the Earth's climate, the mechanisms for these energy impulses to impact the overall and local weather systems apparently are very complex and not easily discernible. Long-term NOAA weather forecasts currently include extended solar cycle behavior in the algorithm to predict future weather trends.

Recent research by Chambers et al. (1999), Van Geel et al. (1999), Tobias and Weiss (2000) and Solanki et al. (2000) have identified viable "multiplier effects" that can operate in such a way that minor variations in solar activity can result in more significant variations within the earth's atmosphere. Principal among these phenomena is the effect of cosmic rays on cloud cover. Kniveton and Todd (2001) reported "evidence of a statistically strong relationship between cosmic ray flux, precipitation and precipitation efficiency over ocean surfaces at mid to high latitudes." Geomagnetic storms associate with the solar cycle peaks deflect many of the inbound cosmic rays, thus providing an indirect impact of the solar cycle on climate. A review of the models used by the Intergovernmental Panel on Climate Change to predict future greenhouse gas-induced global warming revealed such processes to be inadequately represented and even ignored (Chambers et al., 1999). We recommend that the CCSP strategic plan be modified to include study, monitoring, and prediction of solar influences on climate

Chambers, F.M., Ogle, M.I. and Blackford, J.J. 1999. Palaeoenvironmental evidence for solar forcing of Holocene climate: linkages to solar science. Progress in Physical Geography 23: 181-204.

Kniveton, D.R. and Todd, M.C. 2001. On the relationship of cosmic ray flux and precipitation. Geophysical Research Letters 28: 1527-1530.

Solanki, S.K., Schussler, M. and Fligge, M. 2000. Evolution of the sun's large-scale magnetic field since the Maunder minimum. Nature 408: 445-447.

Tobias, S.M. and Weiss, N.O. 2000. Resonant interactions between solar activity and climate. Journal of Climate 13: 3745-3759.

Van Geel, B., Raspopov, O.M., Renssen, H., van der Plicht, J., Dergachev, V.A. and Meijer, H.A.J. 1999. The role of solar forcing upon climate change. Quaternary Science Reviews 18: 331-338.

NOAA-NEDIS, COFFEY AND ELVIDGE

Page 68, Chapter 6: One of the most important methods of understanding climate involves finding out what happened in the past. The study of paleoclimatology helps the scientific community define the range of natural variability in the climate system at times before humans exerted a measurable influence on the earth's atmosphere, biosphere, cryosphere, and hydrosphere. Data are emerging that suggest different relationships between climate variability and the overall background climate state. One set of studies suggests that climate variability, including El NiÒo, increases when climate gets warmer. Other studies suggest just the opposite. Modeling efforts for forecasting and prediction can not be undertaken without this quandary being addressed. Accordingly, I assert that it is critical for the CCSP to include, more significantly than it currently does, the study of past climate and its variability in its Strategic Plan. The Holocene (the last 11,000 years) is briefly mentioned as one of the intervals of interest, but understanding the Holocene as well as the last interglacial and preceding interglacials (especially MIS 11) is of utmost importance in understanding interglacial climate change and variability. In addition to developing time series of climate variables, a necessary component of this work is understanding the functioning of the proxies used for climate reconstruction. This "proxy development" is a large part of the mission of the paleoclimate community and is central to the constant improvement of climate records and to reducing the uncertainty in ancient as well as modern climate data.

Julie Friddell, USACE-ERDC-Cold Regions Research and Engineering Laboratory

Page 68, Chapter 6: The discussion of research efforts seems to view climate change as if it were a stationary phenomenon; that is, because climate change is a stationary phenomenon, having an answer 5–15 years from now (see “Products & Payoffs” in various parts of the chapter) is just as good as having it today. This view completely ignores the fact that climate change involves a very large “biogeophysicochemical” system containing considerable momentum that increases as GHGs trap more heat in the atmosphere. Holding such a view is a mistake because it eliminates the possibility of realizing the potential benefits of acting sooner, when the climate system is easier to influence, having less momentum.

On this last point, cumulative worldwide anthropogenic CO_2 emissions through 2002 amounted to about 1,800 Gt of CO_2 (see analysis in *Chemical Engineering Progress*, December 2002, page 9). Based on recent trends, they will reach about 1,930 Gt by 2007 (+7.0% in 5 years), 2,070 Gt by 2012 (+14.5% in 10 years), and 2,210 Gt by 2017 (+22.5% in 15 years). From these projections, taking sooner actions seems like a more prudent policy position.

In summary, the discussion completely misses that time matters, and a good answer today may be much better than an exact answer 10 years from now.

Second Overview Comment: The chapter displays an inadequate understanding of sensitivity and uncertainty. As mentioned in previous comments, both significant sensitivity and uncertainty may actually be characteristics of a properly modeled climate system because of its inherent feedbacks, rather than indicative of inadequate modeling (though they can be as well). Given our inability to ascertain exact values of model parameters and initial conditions, the model system for climate behavior may produce results that diverge for arbitrarily small changes in model parameters under certain conditions. This possibility means that extreme events can occur under a wide range of conditions and that hard decisions may have to be made in the face of great inherent uncertainty.

As mentioned before, the mathematical structure of climate models should be investigated to ascertain whether theoretical basins of climate-system behavior (i.e., climate attractors) actually exist and, if they do, what their “boundaries” are. One place in the chapter—“*Improved understanding of thresholds and nonlinearities in the climate system, especially for coupled atmosphere-ocean, oceanic deepwater, hydrology, land surface, and ice processes (5-15 years)*” (page 75, lines 33–35)—somewhat alludes to this, and a few other places in the document do as well (page 84, lines 6–7; page 85, lines 17–19).

David L. Wagger, Ph.D., self

Page 68, Chapter 6: First Overview Comment: Understanding climate variation requires looking at its impacts not only on gross climate features (e.g. temperature or precipitation) but also the synergistic variation in related phenomena, including biological processes (e.g. fire frequency or drought limits on agricultural sustainability), air pollutant emission, atmospheric chemistry, etc. This can only be accomplished with sustained field measurements supported by wide-view data such as global meteorological data, satellite observations, and coordinated data collection for climate-related phenomena such as hydrology, crop production, etc.

The current emphasis on seasonal or intermittent “snapshot” field programs entails an unacceptable risk of unrepresentative sampling and failure to observe infrequent but significant events. Furthermore, the very variability that you seek to understand (e.g. effects of ENSO cycles, the northern annular oscillation, or even random variation) appears as uncertainty in such programs, rather than being a focus of understanding.

Long term understanding comes from long time-series data.

-California Air Resources Board

Page 68, Chapter 6: This planned endeavors in this chapter are generally satisfactory but certain additions are needed to make it complete and realistic.

S.A. CHANGNON, ILLINOIS STATE WATER SURVEY

Page 68, Chapter 6: While climate variability and change are often mentioned together to cover a large part of the spectrum of climate research, the priorities of this Chapter need some clarification. Question no. 1 should not be dicussed here, but in another Chapter on Feedbacks. A new structure for Chapter 6 may include: natural variability of certain phenomena, classified by their timescales: interannual for ENSO and monsoons, decadal for ENSO, monsoons and other phenomena such as PDO. Each deserves a study of their predictability, improved simulation and observational networks. Second, the question of change can be addressed. (I am glad to see land use change mentioned next to emissions.) The lack of adequate study of the effects on interannual or other scales of variability of global change in scenario simulations has been pointed out by IPCC. It is mentioned here in the text, but only briefly, and is the last point in a long list of Products and Payoffs that are too detailed. This is going to be a very interesting field of research for the near future and will significantly contribute to the reduction of uncertainty of climate projections and confidence in their global as well as regional results. The text is heavily biased towards sea level (variable) and Arctic (location) and needs to be more balanced.

Lydia Dümenil Gates, LBL

Page 68, Chapter 6: It is always refreshing for me to see the words Climate and Variability together in the context of Global Change because "climate" is implicitly assumed to be the steady-state of the Earth system after averaging out the erratic fluctuations of "weather" (primarily an atmospheric phenomenon). Following that logic, climate "change" is necessarily slow and secular. Basically, we are looking for a trend or a drift of some kind, to be detected in the presence of strong noise caused by weather, seasons, inter-annual modes, inter-decadal variability, and so on. Little by little we are realizing that the clear separation of time-scales originally anticipated is not there, a not-so-gentle reminder that strongly nonlinear systems with many degrees of freedom tend to be variable at all scales. The paleoclimatic record concurs with examples of abrupt and often long-lasting deviations traceable both to external (solar) forcing and to internally generated variability. So, in the end, the question of what is change and what is variability is now completely open. It is tempting to decide that change is anthropogenic while variability is natural, but the question of attribution is very far from resolved and in fact is at the very core of the CCRI Plan. Wisely, the authors have not attempted to provide a separate definition for each the two terms in connection with climate.

Overall I'm quite impressed with the plan laid out in Chap. 6, largely because the authors have not shied away from asking the truly difficult (scientifically challenging) questions but also the questions that are truly important (by actual and potential economic/human impact). These are the questions about extreme climate events (#4) in regional regimes, and abrupt change (#3). These questions stand out from the more classic issue of feedback mechanics (#1) and the mandatory question about helping to adapt to new conditions (#5) in the presence of uncertainty in our predictions (#2).

Disagreement:
My concern is about the indiscriminate use of the word "model" as an essential tool to address these and many other questions. I get the impression that this word is quasi-synonymous with next-generation coupled GCMs. The future capabilities of these complex models are determined almost entirely by progress in computer hard-ware, which is impressive but still too slow to catch up with the issues at hand. In my opinion GCMs of the foreseeable future will continue to be invaluable for question #1 (feedbacks) and also to provide a baseline for question #2 (uncertainty quantification), but not the final answer. There will be progress in GCM-based approaches to questions 3-4, but it will be slow because climate-driven GCMs manipulate, by design, grid-scale means. They do not seek either to resolve fast change in space or time because they are based on the assumption that partial differentials exist. Moreover the resolved gradients have to be kept quite small to control numerical instabilities due to the nonlinear terms. There is some attention to variances inside some sub-grid parameterization schemes but they are procedurally deprived of using correlations beyond the grid-scale and the time-step which are computational artifacts. Conceivably grid-scale variances could be transported by a GCM, but that is a quantum leap in GCM design. And it is the higher-order moments that contain information about the extreme/localized events anyway.

Suggestions:
1/ line-item for alternatives to GCMs
Because of these inherent limitations of GCMs, complementary approaches are in order to address questions 2-4 in any real depth. The so-called "nonlinear" geophysics community at AGU, EGS and elsewhere has been actively seeking such approaches over the past couple of decades. Statistical physics has been a constant source of inspiration with scaling and critical phenomena theory. So has turbulence theory (a complex system with well-known nonlinear equations) and chaos theory (complex behavior in simple

nonlinear systems). This need for alternative modeling approaches should to be spelled out explicitly for the simple reason that the GCM community will otherwise suck up every last research $ made available, essentially by entitlement. On the other hand, if a non-negligible fraction of the new resources is wisely ear-marked for alternative modeling and data analysis efforts, they should be made contingent on bone-fide interaction with the (mainstream) climate research- and stakeholder-communities. To emphasize this point, I will point out that ENSO forecasting is used on p. 69 to illustrate improved modeling (and, of course, observations). Well, it has been shown that statistical forecasts (an alternative to physics-based GCM forecasts) have the same if not better skill, and cost a small fraction of the price in computer power and in R&D overhead.

2/ innovative GCM validation

3/ hybrid climate modeling
In summary, climate variability and change is one of those grand scientific challenges that calls for more observational and computational resources but also for more creativity. Hybrid modeling approaches (e.g., GCMs+stochastics) will likely take us beyond the current limitations of any current approach alone. Furthermore, this should become obvious after an earnest attempt to validate GCMs against observations, (spatial) scale by scale, (statistical) moment by moment, both in the instrumental era and in the paleoclimatic record.

4/ risk-management using "climate derivatives"
Finally, a quick comment on the critical question #5 on strategizing for adaptation to change in the presence of uncertain forecasts. This issue is dominated by our assessment of extreme event dynamics. I would suggest that the CCRI invest into the feasibility of a sound risk-management technique based on climate "derivatives". They would work just like the emerging weather-derivatives market in the financial/insurance sector, but be brokered between regions and countries by governments and the UN. Note that the dynamics of weather (hence climate) derivatives are only weakly dependent on forecasting skill, hence the weak modeling link highlighted above. Incidentally, being grounded in negotiation and partnership, climate-derivative contracts could be powerful stabilizing forces in the international security landscape.

Anthony Davis, Los Alamos Nat'l Lab

Page 68, Chapter 6: This chapter is very well organized, with research needs and products nicely phrased under five main questions that I believe are of essence in understanding and predicting climate variability and change and linking the knowledge to decision support and policy making. However, the plan can be improved in the following areas:

1) I like the general idea of separating near-term focus under the CCRI plan and longer term and broader research investigations under the USGCRP plan. This distinction is clearly called out in Chapter 1 and the overview of Part I (page 15). However as I go through the USGCRP plan, I am quite surprise to find a time

frame of 2-4 years placed under many "Products and Payoffs." In many cases, such a short time frame is highly unrealistic and seems to contradict what the USGCRP plan is representing (long term goals and broader science questions). Examples are: "refined estimates of the role of climate feedback processes in affecting climate sensitivity and improvements in their representation in climate models, …", and "increased understanding and confidence in attribution of the causes of recent and historical changes in climate." I believe we have to either breakdown these larger tasks/products into smaller ones to justify the time frame, or use a more appropriate time frame for the problems at hand.

2) Throughout Chapter 6, the issues of scaling and regional climate predictability were emphasized, rightfully so, in the context of process representation in climate models (Question 1), regional variability and predictability (Question 2), downscaling methods/information for extreme events (Question 4), and climate change impacts (Question 5). Indeed this issue of improving our understanding and capability to model regional climate variability and change (and the associated uncertainty) has been a major obstacle to the use of climate information such as seasonal forecasts and climate projections in developing management strategies and decision support. I recommend this issue be specifically called out as an overarching question with Research Needs and Products/Payoffs listed accordingly. It was noted on page 73 (line 10-15) that our understanding of regional-scale variability and regional climate models are much less advanced than large-scale variability and global climate modeling. Significant improvements will require a well-structured research program on methods of modeling regional climate, regional climate predictability studies, evaluation and diagnostics of regional simulations, and development of regional climate datasets. Unless focused efforts are dedicated and supported to address these issues, they will remain buried as extra steps in bridging climate research and application. I would even argue that regional climate modeling should be placed under the CCRI plan because in order to deliver the CCRI products within 2-4 years, it is certain that regional climate modeling is needed to provide regional climate change scenarios at the scales suitable for impact assessment. It is not possible that GCMs be run at spatial resolution near 50 km within the 2-4 years timeframe to deliver regional climate information for impact assessment.

3) The term "Climate Process Team" was first introduced on page 48 of Chapter 4 under "Applied Climate Modeling". It seems to be a new approach of organizing climate research, and it is referenced again in Chapter 6 on page 72 as an important mechanism for focusing the research on climate sensitivity. This mechanism needs to be much better defined because it seems to carry implications on how scientists are supposed to collaborate (perhaps be associated with teams of the two modeling centers at NCAR and GFDL) in the future setting.

RUBY LEUNG, PNNL

Page 68, Chapter 6: The tone and information of paragraph 1 on page 69 (lines 1-7) are not representative of the research in climate variability as of the current date. The discussion of this paragraph (and other general ideas of 6) at the CCSP meeting were contentious. Shukla made the plea that we must trust climate models and therefore make the dogmatic claim that the climate is changing because models can't reproduce the present climate without adding in human factors such as CO_2 increases. I disagree with Shukla's view and agree with the view given by Stephen Schwarz later in the session. In particular, Schwarz's comment about model veracity going from rumor to myth to gospel was exactly correct. The fact that today's models cannot explain the present global average temperature fluctuations without adding model-tuned forcings such as CO_2 could well be a failure of models to reproduce natural variability in the first place. Models cannot provide "proof" of anything.

Indeed, the statement (line 4-5) " observed global warming during the 20th century exceeds the natural variability of the past 1000 years" is supported by a single proxy time series (Mann et al.) but contradicted by many others, including Esper et al. 2002. Esper et al. 2002 show that at least six times in the last 1000 years there have been warming episodes as great or greater than that of the 20th century. Thus, lines 4-5 are incorrect and should be deleted or changed (see below).

Again, the idea of modeled sea ice extent success in the Northern Hemisphere was promoted in IPCC 2001 and here in lines 1-2. Yes, the two models of IPCC 2001 indicate similar trends to observations since 1979 of sea ice extent in the Arctic, but those same two models show trends in the Southern Hemisphere sea ice of OPPOSITE sign to observations. This was hidden in IPCC 2001, and should not be overlooked here (however, it was pointed out in GRL, Gregory et al. 2002).

Schwarz's point is that models have been so tuned to reproduce the current climate, that it is no scientific feat to show that a model in fact reproduces what it was tuned against (global average surface temperature). And, that this tuning in fact does not guarantee that other aspects of the models are yet useful for analysis and prediction. Since we do not know what is the "full suite of natural and anthropogenic forcings " (line 5-6) one cannot make the statement that we know what their inclusion produces in the climate system. "Curve fitting" is a weak form of science from which to conclude that one has discovered what made the climate do what it did.

What should the first paragraph pg 69 say? The following is a scientifically defensible statement:

Over the past decade, global change research has indicated that: decreases in Northern Hemisphere sea ice extent may have exceeded what would be expected from natural variability alone in model simulations though the same models are deficient in reproducing Southern Hemisphere sea ice changes, large climate changes can occur within decades or less, yet last for centuries or longer, and that different realizations of the NH temperature history from proxies make it unclear whether the warming of the 20th century is unique in the past 1,000 years though some suggest unusual warming rates. In addition, some of the various forcing factors known at present which influence climate are difficult to quantify (e.g. aerosols, land use changes) while natural modes of variation (e.g. ENSO, NAO) are difficult to express through model equations, thus there remains fundamental uncertainty as to what actually caused the climate of the 20th century to behave as it did.

Christy, University of Alabama in Huntsville

Page 68, Chapter 6: This chapter addresses impacts on natural resources and industry and suggest the consequences are Œfar-reaching,. Perhaps the greatest and most significant effect by climate variability on human well-being will be the effect on the production of food and fiber by agriculture worldwide. There should be at least a few Specific Questions addressing climate variability and the ability of agricultural production to adapt.

Lowry A. Harper, USDA-ARS, Watkinsville, GA.

First Overview comment: This chapter addresses impacts on natural resources and industry and suggest the consequences are ‘far-reaching’. Perhaps the greatest and most significant effect by climate variability on human well-being will be the effect on the production of food and fiber by agriculture worldwide. There should be at least a few Specific Questions addressing climate variability and the ability of agricultural production to adapt.

Steven R. Shafer, USDA-ARS

Page 68, Chapter 6: In order to understand and respond to the five questions, please consider utilizing NOAA's Cooperative Weather Observer Network (COOP), the nation's largest and oldest weather network. The modernization of COOP is closely related to the President's Climate Change Research Initiative, providing a richer source of data to improve weather and climate forecasting and to contribute to climate change research. The COOP network is the primary source for monitoring U.S. climate variability over weekly to interannual time frames. These data are also the basis for assessments of century-scale climate change. The modernized COOP network will add to NOAA's vision of an-end-to-end monitoring program that "takes the temperature" of the earth's systems. NOAA is also developing and implementing a Climate Reference Network (USCRN), which will compliment COOP. Please see July, 2002 NOAA Magazine article on the COOP Program at:
<http://noaanews.noaa.gov/magizine/stories/mag45.htm>http://www.noaanews.noaa.gov/magazine/stories/mag45.htm or
<http://noaanews.noaa.gov/>http://www.noaanews.noaa.gov/ then click to July 2002 edition.

Andy Horvitz, NOAA/National Weather Service

Page 68, Chapter 6: Climate Variability AND Change, reads like either/or, more the latter and less the former. What are the links between the two? As stated in the document, “Perhaps most fundamentally, we do not yet have a clear understanding of how these natural climate variations may be modified in the future by human-induced changes in climate”. This line of reasoning and research is not followed through.

Comments on Chapter 6

Experience with ENSO should be held up as an example and should be used as a road map by which to gain confidence in longer time scales and the forced climate problem

Data integration, assimilation, or synthesis(in contrast to Chapters 3,7,8) are not emphasized for atmosphere, ocean, land, and/or coupled data assimilation, reanalyses, incorporation of remotely-sensed observations. One of the key advances in climate science of the past 5 years has been the NCEP reanalysis. One aspect of the future strategy should be a program on reanalysis for climate of the atmosphere, ocean, land, and coupled system.

Predictability limits, likelihood of induced changes, are mentioned, yet there is little emphasis on research into probabilistic forecasts, and ensemble approaches.

It is awkward that the observational requirements are unclear until Chapter 12. For that matter, the emphasis on observations and role of process studies are relatively weak in this chapter.

What is the role of NCEP? No strategy for research in support of operational climate prediction.

How and where do process studies come in?
Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. Maryland

Page 68, Chapter 6: ENSO is the most important climate signal on earth, after the annual cycle, but its treatment in Chapter 6 does not reflect its importance nor adequately describe the challenges, tasks and products/payoffs to be gained. There is a need for greater specificity and we need to say how we can expect to get from the high-priority research questions to the desired products & payoffs. I will now comment specifically on the treatment in several subsections of Chapter 6 and make suggestions on each. Items in single quotes refer to existing text, while items in double quotes (and blue) are specific suggested additions or changes to text. Unquoted material is for the benefit of the scientific editors to help them in their task. Occasional references are included parenthetically for the editors' benefit but are not expected to appear in the final text.

Enfield, NOAA

Page 68, Chapter 6: Missing section on HOW (between priority questions and products/payoffs): As pointed out by Tony Busalacchi, and as a general conclusion of the workshop, the CCSP document is not yet a strategic plan because to does not address how we will get from the priority questions to the desired products and payoffs. I am assuming that a subsection will be inserted into every chapter to address this deficiency and I present here my suggestions for the HOW items corresponding to the two ENSO bullets under products/payoffs. I am also assuming that these must be very terse – one paragraph each -- and that more details would properly appear in a subsequent implementation plan.

Comments on Chapter 6

(a) We must have a HOW item that addresses our strategy for improving our deficient model prediction capability. I am specifically referring to the tropical Pacific ocean-atmosphere models that attempt predict the NINO 3.4 SSTA index. I have no specific text to suggest because I am not a modeler. I think that improvement of the forecast amplitude is a very difficult problem and I have no clue as to the appropriate strategy for doing this. However, the timing aspect can almost certainly be improved by dealing with the spring barrier problem since that addresses two of the aspects most poorly dealt with at present by the models when they do successfully predict an El Niño warming: the onset and the end of the event, which are both masked by the spring barrier. Therefore I suggest that the HOW item be written by a modeler and that it incorporate some mention of the spring barrier role in the strategy.

(b) The HOW item for the second bullet of products/payoffs should address the (at least) two principal ways in which recent and ongoing research on interdecadal variability and other-ocean extensions of ENSO can be leveraged to improve our climate impact forecasts:

1) "Recent research has revealed that ENSO teleconnection patterns in the United States are nonstationary and are modulated by certain interdecadal climate modes, which means that in many regions the probability models currently being used for probabilistic impact forecasts should not be static but rather conditioned on the current (and if possible also the expected) state of the relevant interdecadal modes. Additional modulation effects have not yet been identified in other regions; these are presumed to exist and must be identified. Moreover, in all cases our understanding of how the interaction between time scales occurs is inadequate and must be improved from analysis of intstrumental and paleoclimate observations and through diagnostic modeling."

2) "It is now recognized that the ENSO-altered troposphere frequently (but not invariably) causes a sequestration of heat in the form of SST anomalies, which appear in the warm tropical Atlantic and Indian Oceans with a 1-3 season delay with respect to the equatorial Pacific; that these 'other-ocean' anomalies are required for realistic model simulation of ENSO impacts (cf, Lau and Nath, 1994 and others); and that the altered warm pools can produce secondary effects on surrounding continental climates during the boreal summer periods following winter ENSO peaks. Similarly, moisture anomalies are sequestered as snow and ice (or lack thereof) in ENSO winters and are subsequently released in the spring to affect continental climates in the late spring and early summer. Further research is needed to determine how the relevant tropospheric bridges work so that models can be made to successfully predict when heat and moisture sequestration will occur, while the effects of the modified other-ocean warm pools and delayed moisture release on post-ENSO summer climates must also be better understood and predicted." Note that the sequestration of oceanic heat and continental moisture in the Americas sector are particularly relevant to the North American (summer) Monsoon development and that existing US CLIVAR and GEWEX programs will need to shoulder the burden of doing this research.

ENFIELD, NOAA

Pages 68-70: The question of how to structure interactions between the producers and users of scientific information is misleading if one expects an answer. The range of users and decision-makers, in terms of their characteristics, starting levels of interest and background, and capacities to respond, is so great that each sector or place or other functionally self-defined group of users makes sense.

It is also critical to understand that users faced with new information cannot know, in most cases, how they will eventually use it. Climate information applications are just beginning, and the users will need time to adjust their processes to incorporate it, and then there will be further adjustment to reflect other users' behavior, and so on. The dynamics of each situation are likely to differ, and the specifics are what matters to the user, not some global view of what they ought to be like or ought to do. This will take time and patience and will only be impeded by rationalistic prescription from unknown agencies or persons.

Wiener, Individual commentator

Page 68, line 3: It is really unfortunate that the issue of seasonal-interannual prediction is not treated in its own section as the whole approach to the research has a different emphasis. There should be a separate goal and research effort.

Michael MacCracken, LLNL (retired)

PAGE 68, LINES 3-4: CHANGE QUESTION 3 TO READ **"…SUCH AS THE COLLAPSE OF THE OCEAN THERMOHALINE CIRCULATION, INCEPTION OF A DECADES-LONG MEGADROUGHT OR RAPID…"**

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 68, line 5ff: It is really unfortunate that this section does not explain what the GHG issue is about and how it works. This is also totally missing from the entire report.

Michael MacCracken, LLNL (retired)

Page 69, lines 1-7: Well said, although the last two lines really underplay the IPCC's key findings. In that the State of Knowledge sections are really so limited, the IPCC reports should be indicated 9along with some NRC reports, perhaps) as the baseline understanding of the science.

Michael MacCracken, LLNL (retired)

Page 69: Over the past decade, global change research has indicated that: decreases in Northern 1

This paragraph is an excellent statement of the scientific consensus. Not a word of it should be changed.

Raymond Pierrehumbert, The University of Chicago

Page 69, Lines 1-5: lines 33, 34: 1,000 to 10,000 years does not extend far enough back into earth's history. The research should go back to 2 million years, since the earth has experienced 20 glacial advances and retreats in that time period. See also comment 3 above.

OREST LEWINTER, CITIZEN

Page 69, lines 1-7: "Over the past decade, global change research has indicated that . . ." This is inconsistent with the careful language and qualifications in other summaries of the state of current understanding of climate change in the Strategic Plan. For example, the statement that "the observed global warming during the 20th century exceeds the natural variability of the past 1,000 years" is disputed by many reputable scientists and its appearance here, without mention of the assumptions it relies on, implies a definite answer to what was earlier presented as a research question. I suggest deleting lines 1-7.

Joseph L. Bast, The Heartland Institute

Page 69, l. 1-7 needs to be cross-referenced and checked with Chapter 3. Lydia Dümenil Gates, LBL Cross-reference to climate variability and its interaction with the carbon cycle.

Lydia Dümenil Gates, LBL

PAGE 69, LINE 5: INSERT NEW SENTENCE **"PLACING INSTRUMENTAL RECORDS IN THE CONTEXT OF LONGER TERM VARIABILITY THROUGH PALEOCLIMATIC ANALYSIS HAS BEEN KEY TO THESE FINDINGS."**

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 69, Line 6-7: This statement contradicts earlier statements. There needs to be consistent views on this fact.

Ronald Stouffer, GFDL/NOAA

Page 69, line 9 – may be better to state that global change research has significantly *contributed* to our knowledge of the …. (along with other programs geared more directly toward the seasonal to interannual problem).

IRI, Zebiak and Staff

Page 69, lines 9-16): As far as it goes, I like very much what has already been written. In particular, I like that the paragraph (line 14) says '…has led to skillful forecasts…' and does NOT say '…skillful model-based forecasts…'. The fact is that ENSO outlooks currently being issued are based mostly on our diagnosis of the ENSO cycle as we see it developing in the ENSO observing system and NOT on the predictions being made by statistical and numerical ENSO models. Two important recent papers have shown that model performance for the 1997-98 event was notably deficient in predicting both the magnitude and timing of the event. Moreover, only 7 of 12 models are presently showing a warming at the end of 2002, whereas the observing system has made it obvious since July that we are in a developing El Niño. Additionally, many models were giving a falsepositive prediction for an El Niño one year earlier (for 2001-2002). Hence, the paragraph correctly suggests that the success achieved thus far lies in the established ENSO observing system and that our research has led us to an ability to issue successful outlooks based on our interpretation of the observations. What the paragraph does not do is describe the unrealized predictive potential in the ENSO system, nor the challenge for the future and an allusion to how that challenge can be met.

Suggestion: I would make clear what has not yet been achieved with ENSO by adding the following text or something equivalent thereto:

"Unfortunately, dynamical and statistical models of ENSO have not yet realized the predictive potential first visualized for them 10-15 years ago, and they exhibit specific deficiencies in their ability to correctly forecast the amplitude and timing of El Niño events. Secondly, while much has been learned in the last ten years about the extension of ENSO to other ocean basins and of the way in which interdecadal climate modes modulate ENSO teleconnections, these processes are imperfectly understood and the related improvements in ENSO climate impact outlooks have not yet materialized."

I would then end the overview paragraph by describing the challenge for future research:

"The challenge for the future is to recover a significant portion of the still unrealized predictive potential in the ENSO system by improving the model predictions and by incorporating the interdecadal and other-ocean aspects of ENSO variability."

ENFIELD, NOAA

Page 69 between line 10 and 11- definition of climate effects – currently gives examples that are mainly environmental (floods, droughts, wildfires, sea level changes) – include some more specifically socio-economic, like economic recession, mass migration, increased poverty, slowed economic development.

IRI, Zebiak and Staff

Page 69, Line 16: **Add new sentence** "However, paleoclimatic data and modeling studies indicate that changes in ENSO and its extratropical impacts (teleconnections) are likely under a different mean climate. Continued success in ENSO impact prediction will demand a better understanding of how and why ENSO and its impacts have varied during past periods of different mean climate."

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 69, Line 26: **Insert before "We.."** "In many parts of the world (including the U.S.), such events are tied to the ENSO system, which has undergone significant changes in the past, in response to relatively subtle changes in forcing; a better understanding of ENSO behavior under altered climate mean states is needed."

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Comments on Chapter 6

Page 69, Line 30: What is the time scale for "abrupt"? Define.
Ronald Stouffer, GFDL/NOAA

Page 69, L31 - What is the reference for the statement that abrupt climate changes have been simulated in model when forced by projections till 2100?
Ronald Stouffer, GFDL/NOAA

Page 70, this program is **not simply about "*basic* research" –** forecasts of climate variability represent some of the earliest applications of the USGCRP and now the USCCSP in support of decision-making. As is the case with all of the elements of the USCCSP (and USGCRP), a program addressing climate variability and change will continue to incorporate an integrated program of observations, research, modeling/forecasting, assessment and information services.

- More explicitly address the importance **of understanding interactions between and among key modes of variability –** e.g., ENSO/monsoon and PDO/ENSO.

- Incorporate more **explicit attention to documenting and understanding lessons learned from past and current responses** to natural variability – these investigations will provide valuable insights into vulnerability as well as providing opportunities to strengthen the dialogue/partnership with decision-makers highlighted as an objective of the USCCSP.

- **Be cautious about selecting "most vulnerable" regions or sectors** and/or identifying generic "indicators" -- one size does not fit all and each region or sector is vulnerable and/or resilient in very specific ways in specific places. It seems to me that the key is developing a richer understanding of how and why climate variability and change matters to real people *in real places* rather than generic indicators that cannot capture the texture of the interdependence between climate and society.

- Consider the concept of **extreme events and climate risk management** as a possible integrating theme for this chapter – helps to clarify the links between responding to climate variability today and developing climate change adaptation programs for the future. In addition, it provides a natural way to build important linkages between the USCCSP scientific community and the communities of government officials (at all levels) responsible for comprehensive emergency management, community planning and economic development (a linkage that is increasingly being highlighted by national and international development, AID and humanitarian relief agencies).

Eileen L. Shea, East-West Center

Page 69, line 20: "mitigate" is really the wrong word here. For seasonal to interannual predictions, preparation is possible—but the types of changes in climate are not mitigated. And for long-term climate change, virtually no effective mitigation has taken place.
Michael MacCracken, LLNL (retired)

Comments on Chapter 6

Page 70, line 4: If human-induced climate change is the capstone issue of our time (as J. Mahoney puts it), then it is really unfortunate to have "human-activities" sort of tacked on to the end of the sentence. The major questions here need to be redone—one focusing on the human-induced changes to climate in the context of natural influences, and the other dealing with seasonal-interannual climate prediction.
Michael MacCracken, LLNL (retired)

Page 70, Lines 5–10: "*How can emerging scientific findings on climate variability and change be further developed and communicated to most effectively meet the needs of policymakers and public and private sector decisionmakers, in order to enhance human well-being,* ***strengthen the economy****, and reduce risks and vulnerability of climate-sensitive activities and resources?*"

In this (second) overarching question, the infinitive phrase, "[to] *strengthen the economy*", does not fit within the larger context of the prepositional phrase, "*in order …*". It should be either stricken or changed to "protect the economy", which better matches the context of climate variability and change. Similarly, "*to enhance human well-being*" might be changed "to maintain human well-being".
David L. Wagger, Ph.D., self

Page 70, Line 11–A dichotomy exists in the boxed statement about climate elements and climate effects. Listed climate effects are climate extremes and thus are also climate elements.
S.A. CHANGNON, ILLINOIS STATE WATER SURVEY

Page 70, line 11: This is new terminology and should not be used this way, "Climate elements" is fine, but "climate effects" by common usage refers to the changes in the elements. The social, economic and environmental consequences are called "climate impacts".
Michael MacCracken, LLNL (retired)

Page 70, Line1 17-18: **Insert new bullet that reads**: "Strengthened efforts to develop a global database of high-resolution paleoclimatic records designed for climate variability and change study, with emphasis on recovering new centuries- to millennia long records from sources (e.g., glaciers, corals and trees) that may destroyed in coming years."
U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 70, Line 18: **Change to read**: "A standing, research-based infrastructure that brings climate scientists together in partnership with natural scientists (e.g. biologists), social scientists and public/private-sector decision-makers to improve the production and use of climate knowledge."
U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 70, line 21: Chapter 4 does not really cover assessments—this referral to that chapter is not adequate, as that chapter refers to tool development, but does not explicitly cover national and international climate assessments.

Michael MacCracken, LLNL (retired)

Page 70, lines 35-36: This is a rather selective citation, because the Arctic then cooled a bit, indicating perhaps that those early changes were likely (not for sure, by any means) part of natural variations.

Michael MacCracken, LLNL (retired)

Page 71, line 1-2: Warming in the Arctic region has higher magnitude during the past 20-50 years, compared to the average in northern hemisphere. Some "critical zones" such as Arctic region may have been experiencing more significant changes than other regions.

Gensuo J. Jia, University of Virginia

Page 71, line 2: The reference to "400 years" is likely a gross underestimate—maybe 1000, and perhaps 100,000 years or more.

Michael MacCracken, LLNL (retired)

Page 71, Line 2: **Insert new sentence**: "Moreover, paleoclimatic records also reveal the regular occurrence of decades-long "megadrought" at lower latitudes, including the coterminous United States."

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 71, Line 7: Question 1
I think question 1 has to do with climate sensitivity and feedbacks, but the focus ended up being on the feedbacks. The real question should be what is the sensitivity of the climate system. This involves feedbacks as well as response to radiative forcing. Therefore, I would suggest re-wording the question to focus on what is the sensitivity of the climate system, and then under that list the various factors that contribute to sensitivity, such as forcing/response and feedbacks, as well as the issue of model sensitivity versus sensitivity of the real system, and things that could be done to address that issue (e.g. calibration of sensitivity from volcanic eruptions, solar, etc.).

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 71, Line 8: Question 1. Climate sensitivity and feedbacks (also Chapter 2.3)
Clouds, water vapor, ice-albedo have been high priority going back to beginning of GCRP and before. What is different now? Why should we be more successful now than in the past? Valid reasons exist for making progress now, but they are not articulated. Just as importantly, the need for research on the interactions between aerosols and cloud microphysics is not apparent.

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

Page 71, line 9: **(31-E)** Beginning with this subsection, there is a significant amount of material that is virtually identical to that in the subsection beginning on Page 47, line 35. Focus is slightly different, but so many of the words are the same that it's clearly repetition. Serious editing is needed here (or, perhaps, there).

HP HANSON, LANL

Page 71, Line 10: Define "climate sensitivity". The usual definition of global mean surface air temperature change for a doubling of CO2 giving the climate system an infinite time to respond is not used here. Oceanic heat uptake is NOT part of climate sensitivity in the normal definition. Oceanic heat uptake is as important to the uncertainty of the projection for the next century. In addition there is a lot of uncertainty associated with the projection of the emission scenarios and in the conversion of those scenarios to concentrations.

Ronald Stouffer, GFDL/NOAA

Page 71, line 14: “atmospheric convection” is not really identified as a feedback—though its effects may be.

Michael MacCracken, LLNL (retired)

Page 71, line 14: I agree strongly with this statement, but in consideration of the scope of potential future changes in climate and its controls, this list of potential feedback processes should be expanded to include changes in terrestrial vegetation distribution and structure, and in continental hydrology, as they jointly influence both the short-term coupling between the atmosphere and land surface and the longer-term variations of land-cover characteristics and the source components of dust and mineral aerosols.

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

Page 71, lines 20-21: Anytime such a definitive sounding conclusion is drawn, it needs to be explained and an indication given of how accu8rate things need to be, etc. What do all models fail to do?

Michael MacCracken, LLNL (retired)

Page 71, Line 20-21: Too sweeping a statement. What processes are in view here?

Ronald Stouffer, GFDL/NOAA

Page 71, Line 23-31: Sea Ice albedo feedback needs to be included here.

Ronald Stouffer, GFDL/NOAA

Page 71, lines 28, 31: It is not at all clear that there are significant limitations—what is meant here, provide some justification instead of vague words. What is meant by saying “in consideration of response strategies”? There are all sorts of questions—some can be usefully addressed with what we have (like snowline issues in the western US), some not; things are much more involved than indicated here.

Michael MacCracken, LLNL (retired)

Page 71, lines 34-39: These have been high priority in the past.

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

Page 72: For problems that are generic to all climate models, the teams of climate process researchers, observing 13 system specialists, and modelers will work in partnership with designated modeling centers 14

This seems like an unnecessarily restrictive requirement. I can easily imagine a climate process team incorporating a number of universities, which would work effectively without being tied specificallly to the modelling efforts of either NCAR or GFDL. If there is a common software framework for climate modelling, as there should be, the strict partnering requirement is superfluous.
Raymond Pierrehumbert, The University of Chicago

Page 72, Line 1: **Change to read**: "How can satellite, instrumental, and paleoclimatic observations of…"
U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 72, line 8: Climate Process Teams offer a real strength to CCSP. This new approach or strategy could be better described. It is curious they are not attributed to the US Program on Climate Variability and Predictability (CLIVAR) that initiated them, nor any mention at all of the CLIVAR Science Plan.
Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. Maryland

Page 72, line 14: "will work" sounds like an order is being given to all.
Michael MacCracken, LLNL (retired)

page 72, line15 Climate Process Teams are introduced here with little discussion (and they do not appear again.) This seems to be someone's specific comment/idea with little supporting material. It is not clear how CPTs are a research need.
Mark R. Abbott, Oregon State University

Page 72, Line 17: Products and Payoffs: This section is fairly weak, more of same, i.e., refined estimates, more certain estimates, more useful information, etc etc etc
Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. Maryland

Page 72, lines 18-20: This will take much longer than 2-4 years; issue has been being worked on for a quarter century.
Michael MacCracken, LLNL (retired)

Page 72, Line 18-20: Why not include progress on estimates of oceanic heart uptake? Given the recent work of Levitus, it is very important that climate models be tested against this new data. With the increase in computer power, it is likely that ocean eddies will begin to become resolved in the next generation climate models. This seems to be an area that needs brought out more in the document.
Ronald Stouffer, GFDL/NOAA

Comments on Chapter 6

Page 72, Line 20: ... leading to a narrowing of the range of climate model projections for worldwide planning of a stable food and fiber production (2-4 ...
Lowry A. Harper, USDA-ARS, Watkinsville, GA.

Page 72, Line 20: ... leading to a narrowing of the range of climate model projections for worldwide planning of a stable food and fiber production (2-4 ...
Steven R. Shafer, USDA-ARS

Page 72, Line 28: **Change to read**: "…of existing systems, as well as the collection of targeted paleoclimatic time series."
U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 72, Line 30: **Insert new bullet that reads**: "The creation of a paleoclimatic database designed to evaluate the ability of state-of-the-art climate models to simulate observed decadal to century-scale climate change, responses to large changes in climate forcing, and abrupt change (2-4 years)."
U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 72, line 30: This question really has two (or more) quite different questions embedded in it. There really needs to be a separation out of the seasonal-interannual prediction effort.
Michael MacCracken, LLNL (retired)

Page 72, Line 30: Question 2, l. 10. "important details of regional and seasonal scale variability are poorly simulated". This is an absolutely key point, and it doesn't get sufficient attention in the document. To borrow a phrase from Tip O'Neill's assessment of politics, "All weather and climate issues are local". The scientific community has focused so heavily on changes in global mean temperature, that we sometimes forget that the really meaty issues are such local and regional items as:
Will there be significant changes in seasonal snowpack accumulation in the Sierras?
What changes may occur in rainfall and temperature patterns in the corn belt during the 2-3 week period in July when reproduction occurs and grain filling begins?
How do we expect weather and climate patterns to change in those areas where major ecoregions intersect (e.g.- the prairie/forest border in Minnesota)
How might rainfall patterns change in aquifer recharge areas, such as the Texas Hill Country?
Soil Science Society of America, Glasener

I don't mean to imply that such issues should be specifically addressed in a broad document like this, but the point should be made forcefully that finer spatial and temporal resolution in climate models is urgently needed, and that this should be a key focus of science efforts.

Page 72, Line 31: For Question 2, active research in near-term climate prediction has potential benefits for long-term climate prediction. These benefits include an increased understanding of processes that drive our climate (ENSO, NAO, PDO, etc.) and helping

to build a set of tools and skills for communicating both the relevant processes and degree of uncertainty to decision makers. In addition, successes in short-term climate prediction will help build trust and understanding by the public for long-term climate prediction. Therefore, the relationship between short- and long-term climate predictions is much closer on a variety of levels. That close relationship needs to be emphasized more in the section under Question #2.
Jim Angel, Illinois State Water Survey

Page 72 Line 32, Question 2. Predictions of near-term climate
The relative role of ocean vs. land surface are not taken into account. Rather the role of SST forcing is considered here and the role of soil moisture in chapter 7. Yet, in studies of climate variability the two must be considered together. Often times interannual climate anomalies are initiated by the role of the ocean, but the amplitude and duration of the resulting continental impact is influenced by the role of land surface processes such as soil moisture. For that matter, the influence of land surface and land use/land cover changes are not evident.
Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. Maryland

Page 72, line 38 … replace NAO by (NAO/NAM) North Atlantic Oscillation / Northern Annular Mode
Martin Visbeck, Columbia University

Page 73, line 1 … add Southern Annular Mode (SAM)
Martin Visbeck, Columbia University

Page 73, line 1: include in this list the Antarctic equivalent of the Arctic Oscillation (called variously the Antarctic Oscillation (AAO) or the Southern Annualar Mode (SAM)). This is an organizing climate phenomenon with as much importance as the AO.
Severinghaus, Scripps

Page 73, Line 1: Include thermohaline circulation in this list?
Ronald Stouffer, GFDL/NOAA

Page 73, Lines 2 and 18, and page 76 line 23: These sections should recognize not only the data from new observing networks, but also the enhancement and expansion of paleoclimatic observations, such as inserting ìmodern and paleoclimaticî before ìobservationsî in these lines.
C. Mark Eakin, NOAA/National Climatic Data Center

Page 73, lines 5-7: It is not at all clear that the second part follows from the first. Again, things have to do with the questions being asked, etc.
Michael MacCracken, LLNL (retired)

Comments on Chapter 6

Page 73 line 6-7 –"Provision of probabilistic estimates of regional fluctuations in the climate resulting from ENSO extremes (5-15 years)".
It is assumed that this refers to seasonal predictions with a lead-time of several months – this should be clarified as some may read it to be extremes associated with global changes in ENSO (our ability to provide information on which is considerably further off, though the aim referred to in this bullet is an essential step toward such a capability).

- Institutes like IRI are already developing methodologies for the goals in this bullet – arguably we are in a position to provide estimates already, and further improvements expected.
- It should be noted that there is great value in working in regions where the ENSO signal is higher, to develop such methodologies, rather than solely focusing on mid-latitude regions like the U.S., where signals are lower and it is more difficult to robustly identify the best methodologies for downscaling.
- In this bullet, it should be driven home that achieving this goal is critical to capturing these effects in global change scenarios. Global models should be able to capture this tropics-driven interannual variability, and we should be able to confidently downscale it to regional scales (and testing on the interannual timescale is a route to building such confidence in downscaling). Only then will it be possible to attach scientific credibility to regional downscaled estimates of extremes based on global change scenarios.

IRI, Zebiak and Staff

Page 73, lines 8-13: As discussed above, better capacity for modeling and projecting climate variability at the regional level is a key priority for regional, state and local decision makers, many of whom are responsible for policy decisions that may be centrally influenced by or contribute to climate change.
Kenneth A. Colburn, Northeast States for Coordinated Air Use Management (NESCAUM).

Page 73, line 9. What is the 'global average characteristics of climate variability'? Global coupled models still have difficulty with ENSO – this statement gives an over-optimistic impression that current models used for global change scenarios can accurately represent climate variability. Suggest it should be removed or reworded.

IRI, Zebiak and Staff

Page 73, Line 10: This section is very weak. Given the recent work of Levitus, it is very important that climate models be tested against this new data. With the increase in computer power, it is likely that ocean eddies will become resolved in the next generation climate models. This seems to be an area that needs brought out more in the document.
Ronald Stouffer, GFDL/NOAA

Page 73, Lines 10-15—There is a declared need to have regional scale information for decision makers, but the Research Needs (page 73, line 36 to Page 74, line 2) fail to

address regional issues. Furthermore, the Products/Payoffs section (Page 74) does not address regional information on climate variability.
S.A. Changnon, Illinois State Water Survey

Page 73, line 10: Do the "details" really matter for long-term change? Examples are needed when assertions like this are made.
Michael MacCracken, LLNL (retired)

Page 73, Line 11: This statement is not true generally. See Manabe and Stouffer 1996 and IPCC WGI Report 2001. It is the case for the ENSO region.
Ronald Stouffer, GFDL/NOAA

Page 73, line 12. For this bullet, it is really not clear whether these are seasonal to interannual predictions or regional predictions in global change scenarios. If it is referring to seasonal-to-interannual predictions, reference can again be made to the methodological progress already made by IRI and others who are addressing this problem. Again, the 5-15 year timeframe seems long – these seasonal-to-interannual regional prediction questions are more likely the ones where significant further progress can be delivered in the next 2-4 year timeframe.

IRI, Zebiak and Staff

Page 73, lines 18-20 and 28-30): The first bullet is good because it follows up on what is said in the (revised) overview paragraph and sets up a discussion of how to achieve improved forecasts. I'm a bit uneasy, however, about the part that refers to '…modeling of tropical ocean variability…' because it belies the mostly deficient situation I have described in the overview. I think that modeling progress has been made, but much more in the area of ENSO climate impacts than in the area of the tropical Pacific ENSO itself, and I am thinking specifically about the ensemble probability forecasts of temperature and precip now being produced regularly by the IRI and CPC. I will leave it to a modeling savvy editor to decide how that part of the bullet could be improved.

The fifth bullet is also good but ignores a very important point: We only SUSPECT that climate change may be affecting ENSO variability or its climate impacts, it has not yet been conclusively demonstrated (Trenberth notwithstanding). The fact that ENSO return intervals are shorter in the last 20 years is consistent with similar fluctuations we have seen over the last five centuries and which may be due to external forcing unrelated to global warming (e.g., solar; cf Enfield and Cid, JC, 1991). On the other hand, we now know from a number of studies that decadal-to-multidecadal climate modes DO modulate the ENSO teleconnections, which, by the way, is not specifically mentioned in this section, although it is alluded to in the first bullet. One way to remedy this is to add the following to the fifth bullet:

At the end of the present sentence, modify it to say "…and hence climate variability and predictability, especially as related to ENSO impacts." Then we need to add this follow-on sentence, or else add a modified version of it as a separate bullet: "How can these changes be distinguished from those arising from natural interdecadal variability?" Note that this addresses a very important aspect of the need to study natural variability in order to reduce uncertainties about the effects of global warming on climate. As such, it provides Chapter 6 with a clear tie-in to Part One (CCRI).

ENFIELD, NOAA

Page 73, Line 19: why only ENSO? Mention tropical Atlantic and Indian Ocean.

Martin Visbeck, Columbia University

Page 73 line 19 why only ENSO? Mention tropical Atlantic and Indian Ocean.

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 73, Lines 21-23: The global and regional climates are in a constant state of flux due to continually changing input from a variety of different climatic elements. Because of this, it is unlikely that one can ever consider the climate to be at an equilibrium state. As a result, it is difficult to imagine a situation in which we will be able to determine a baseline climatic equilibrium that could be used to compare with climate during weather-related perturbations. The assumption that the climate could eventually 'settle' after disturbances from single climatic elements is thus problematic because other, non-targeted climatic elements are always further perturbing the system. It would be much more appropriate to instead couch this question in terms of "determining the extent to which climatic variance can be attributed to different climate elements" (e.g. 'What percentage of the variability in climate is attributable to deep ocean changes? Sea ice changes? Land surface changes? etc.') This could be accomplished through statistical techniques like multiple regression.

-California Energy Commission

Page 73, lines 21-23: Given continuing changes, equilibrium is never reached.

Michael MacCracken, LLNL (retired)

Page 73, line 27 replace AO by NAO/NAM

Martin Visbeck, Columbia University

Page 73, Line 27: AO - The success of some models in simulating the AO is missing here

Ronald Stouffer, GFDL/NOAA

Page 73, Lines 33-34: 1,000 to 10,000 years does not extend far enough back into earth's history. The research should go back to 2 million years, since the earth has experienced 20 glacial advances and retreats in that time period. See also comment 3 above.

Orest Lewinter, Citizen

Page 73, lines 37-43: Where does remote sensing come in?

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

Page 73, Line 37: Research Needs (p73 line 37-43, p74 line 1-2) is very general. Needs to be sharpened to deliver the products and payoffs, especially those related to variability.

Comments on Chapter 6

IRI, Zebiak and Staff

Page 73, Line 37: need to include diverse synthesis systems (reanalysis etc.)
Martin Visbeck, Columbia University

Page 73, Line 41: **Insert new sentence after "…models.":** "In particular, paleoclimatic proxy sources at risk (e.g., glaciers, corals and trees) need to be sampled before they are destroyed by climate change and/or land-use."

U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 74: 74 should make reference to a climate data center
Martin Visbeck, Columbia University

Page 74 should have one ocean-state estimation bullet
Martin Visbeck, Columbia University

Page 74 should have a climate reanalysis (coupled) statement
Martin Visbeck, Columbia University

Page 74, Line 4: Products and Payoffs: This is a nice list, but how is all this to be done?
Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. Maryland

Page 74, lines 5-7): The first bullet is correct but I am not sure it can be realistically achieved in 2-4 years. I defer to the modelers on this. The second bullet is wrong as written and should be modified. It implies that probabilistic forecasts are not already being made and should say instead they will be improved. Probabilistic, ENSO-related climate impact forecasts are now being made by the IRI (globally) and NOAA/CPC (United States). However, they do not incorporate the other-ocean aspects of ENSO nor the interdecadal modulation of teleconnective impacts, and it must be presumed that the engineering in the ensemble model approach can also be improved.

Solution: "Improved probabilistic estimates … will be provided." Or something equivalent.

ENFIELD, NOAA

Page 74, line 8 replace AO by NAO/NAM
Martin Visbeck, Columbia University

Page 74, line 12 and lines 15-16: These seem to be quite similar
Michael MacCracken, LLNL (retired)

Page 74, Line 15: ...climate variability giving planners and policy developers the ability to anticipate worldwide food and fiber production (see Question ...(**note: no further wording on submission)**
Lowry A. Harper, USDA-ARS, Watkinsville, GA.

Page 74, Line 15: ...climate variability giving planners and policy developers the ability to anticipate worldwide food and fiber production (see Question ...
Steven R. Shafer, USDA-ARS

Page 74, lines 19-22: Can these be combined?
Michael MacCracken, LLNL (retired)

Page 74, Line 19-24: The text needs a discussion of the chapter 10 results from the IPCC 2001 WG1 report.
RONALD STOUFFER, GFDL/NOAA

Page 74, lines 23-24: This should likely be moved up in the list. And one may well get better estimates in 2-4 years.
Michael MacCracken, LLNL (retired)

Page 74 line 25 to specific on Arctic issues and exist to some degree already at Paleo data center.
Martin Visbeck, Columbia University

Page 74, Line 26: **Change to read**: "…annual to decadal resolution) regional (e.g., Arctic, tropical Indo-Pacific) climate variability over the past 200-2,000 years…"
U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 74, Line 27: **Insert new bullet that reads**: "A new on-line database of drought and megadrought in North America and North Africa (2-4 years)."
U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 74, line 33: Another product/payoff should be: Improved representation and understanding of the role of land surface processes. I note that the document pays little attention to variability/change in snow cover/amount or permafrost.
Julia Slingo, NCAS/CGAM, UK

Page 74, lines 34-37: Again, there needs to be an indication about how such information might be more useful—would a more accurate projection (if one can figure out its accuracy) really lead to a change in decision?
Michael MacCracken, LLNL (retired)

Page 75: The issue of abrupt climate change is a critical area where policy-makers need information, specifically regarding how to incorporate these risks into decision-making. For example, to what extent does the risk of these abrupt changes influence decision-making under uncertainty? It is unclear the extent to which provisions are made within Chapter 6 for communicating such issues to policy-makers.
Vicki Arroyo and Benjamin Preston, Pew Center on Global Climate Change

Comments on Chapter 6

Pages 75-76: Although this is not a good place to engage in a full argument against the fantasy of down-scaling as a universal answer, I must comment that this is badly overused as an idea of what answers look like and a way to get benefit from knowledge already in hand. Large potential benefits are being missed by using limited resources to advance theory but not to advance local applications and local understandings. Up-scaling from ground-truth to the regional is needed, even if it is not theoretically challenging. Neither is most medicine, but we would hardly tell the medical profession to forget cases they can treat and just work on the interesting ones. Plenty of organizations will do this for themselves when and if they see the power and benefits, or feel the need for competitive reasons, but not until then. We need to connect the dots a few times to learn how its done, and establish some models and procedures. The diversion of effort to only super-computer intensive modeling is quite counter-productive.
Wiener, Individual commentator

Page 75, Line 1: Question - Please define "abrupt" and "collapse". What is the time scale? The text then needs modified to reflect definition.
Ronald Stouffer, GFDL/NOAA

Page 75, Line 1 – Line 36 – The need for improvements in paleoclimatic databases are noted here but no specifics are given. I think it would be valuable to compile all existing proxy temperature databases and compare and contrast them. Is the IPCC hockey stick curve the correct representation or is it more like Espers? Was the Medieval Climate Optimum warmer than it is at present? These are questions that need to be addressed.
George Wolff, Ph.D., General Motors

Page 75, Line 1, Question 3: This should include the importance of obtaining accurate and precise annually-resolved chronologies for paleoclimate records. Current practice in the paleoclimate community produces many records, but few are valuable because dating uncertainties are typically several hundred years for the most recent abrupt changes 11,000 years ago. This prevents knowing whether abrupt climate change was synchronous over much of the globe, or if there were important leads and lags.
Severinghaus, Scripps

Page 75, Line 1, Question 3. Abrupt climate change
The observational requirements are unclear especially for the thermohaline circulation and at ocean depths below that from Argo.
Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. Maryland

Page 75, line 4 ff: This state of knowledge is really inadequate. If the NRC report is the baseline, then reference it. In addition, should not the most important question be “Could human activities trigger abrupt climatic change?”
Michael MacCracken, LLNL (retired)

Comments on Chapter 6

Page 75, line 19ff: This is very vague. There is a need to get at the causes and mechanisms, etc.
Michael MacCracken, LLNL (retired)

Page 75, Line 19: **Change to read**: “New and improved…”
U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 75 line 22 should contain reference to palo climate modeling
MOC abrupt change should be featured not just here.
Martin Visbeck, Columbia University

Page 75, Line 25: "quantitative" and "surprises" seem mutually exclusive. What is really needed?
Ronald Stouffer, GFDL/NOAA

Page 75, line 27 Research Needs: add a paragraph.
The use of a hierarchy of models from simple energy balance to GCMs is critical for understanding abrupt climate change. This is particularly true in light of the second bullet under products and payoff section (Improved understanding of thresholds and nonlinearities in the climate system, especially for coupled atmosphere-ocean, oceanic deepwater, hydrology, land surface, and ice processes (5-15 years)). Simple models of the non-linear dynamics of the climate system would be appropriate to better understand these processes. This fits in with the CPT structure mentioned in the document.

Weller, et al, University of Alaska Fairbanks

Page 75, lines 29-36 Where are the non-paleo observational products?
Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. Maryland

Page 75, line 29ff: These all have a long time horizon, although a very urgent question. Having some rough answer to these questions would be much more valuable to decisionmakers than more details on the general types of changes.
Michael MacCracken, LLNL (retired)

Page 75, line 33: This needs to be more general to recognise that there may be thresholds and non-linearities in the land surface too, such as the sudden loss of Amazonian rainforest and the rapid release of carbon. It’s also possible that there may be as yet unknown non-linearities in the chemistry of the system.
Julia Slingo, NCAS/CGAM, UK

Page 75, Line 36: The proposed time period that will be studied should be stated. Again, this should be at least 2 million years (see comments 3 and 6 above).
OREST LEWINTER, CITIZEN

Comments on Chapter 6

Page 75, line 38: should cite the National Academy report, "Abrupt Climate Change: Inevitable Surprises" here, with ref as given above.
Severinghaus, Scripps

Page 76, Line 1, Question 4. Extreme events
This was probably the weakest part of the chapter. What is the strategy for the research needs?
Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. Maryland

Page 76: Question 4. p. 76. This issue of “frequency, intensity, and location” of extreme weather events is always cited as a key aspect of climate change, and it resonates with the general public, but it is not yet clear whether there is any evidence of increasing occurrence of extreme weather events. The discussion in this document focuses on prediction of such events, but it is also important to fund climatological studies of climate record during the past 200 years to see if there actually are notable trends linked to anthropomorphic changes, or if there is simply a perception of increased extreme events fueled by more extensive news coverage.
Soil Science Society of America, Glasener

Page 76, Question 4. Whether and how are the frequencies, intensities and locations of extreme events, such as major droughts, floods …. Altered by natural climate variations and human-induced climate changes. Lines 10-27 – do not reflect variability – again, a key point can be how successful downscaling of seasonal predictions builds confidence in models and methodologies. Furthermore, since global change projections contain variability – any downscaling should be able to downscale successfully the variability (e.g. ENSO variability) within that global change projection. These issues are better described in the Question 5 piece, e.g. p77 line37 – p78 line 4.

IRI, Zebiak and Staff

Page 76, Question 4: For Question 4 on extremes, much more research is needed to fully explore how climate extremes have behaved in the past and how they might change in the future. Our society has shown a high degree of sensitivity to extreme events. In addition, our data collection effort for extreme events is not adequate and lacks continuity over time (e.g., hail and ice storms). Drought is a good example of the challenges faced in understanding extreme events. Drought occurs on a variety of time and space scales with a wide range of impacts on society and the environment. We have a difficult time measuring and monitoring it now, let alone trying to predict future changes in it. Finally, the characteristics of extreme events (frequency, intensity, location) needs to be explored in both near- and long-term climate predictions.
Jim Angel, Illinois State Water Survey

Page 76, Question 4: The following should be added at the end of this question: "...and how (in turn) are those human - induced climate changes affected (limited or increased) by those human or natural processes?"

OREST LEWINTER, CITIZEN

Page 76, Item 4: This text treats extreme events as if they are separate from the rest of the climate. This text is very muddled. Extreme events are simply the extreme part of a distribution of events, so the focus of research has to be on understanding the **causes of climate (weather) variability**. The question is what factors and processes control the distribution shape?
William B. Rossow, NASA Goddard Institute for Space Studies

Page 76, line 3ff: This is very limited—need to refer to a reference for the real statements of state of knowledge—maybe in a CLIVAR report, etc.
Michael MacCracken, LLNL (retired)

Page 76, line 5 replace AO/NAO by NAO/NAM
Martin Visbeck, Columbia University

Page 76, Line 10: **Insert new first bullet that reads**: "What is the full range of natural drought, flood, and tropical storm variability for each region of interest."
U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 76, lines 10-11: This is a very general question that can be answered now—the question needs to be rephrased to deal with the potential for changes due to human activities.
Michael MacCracken, LLNL (retired)

Page 76, Lines 10-11—Extremes must be closely aligned with to societal factors, and thus to the research identified in Chapter 11. For example, the first question addresses the causes of floods and their hydrology, and these conditions are intimately tied to society, land use, and their changes.
S.A. Changnon, Illinois State Water Survey

Page 76, lines 14-17: This really relates more to surprises than to abrupt changes.
Michael MacCracken, LLNL (retired)

Page 76, Line 19: The term "evaluation of societal and environmental vulnerability and opportunities" is appropriate, and should be used throughout the report.
OREST LEWINTER, CITIZEN

Page 76, line 20: It's unlikely that extreme events will ever be that predictable but their statistics may be.
Julia Slingo, NCAS/CGAM, UK

Page 76, lines 23-27:this is a very limited discussion—so vague as to be essentially useless.
Michael MacCracken, LLNL (retired)

Comments on Chapter 6

Page 76, line 26: Adaptive mesh refinement is another option. Extreme events, such as hurricanes, involve mesoscale, organised convection which climate models find difficult to simulate. Again links with the NWP sector would be beneficial.
Julia Slingo, NCAS/CGAM, UK

Page 76, Line 27: **Insert new sentence after "…Chapter 7).":** "The collection of new high-resolution paleoclimatic data will be required to describe and understand the full range of drought, megadeought, flood, and tropical storm variability."
U.S. CLIVAR SCIENTIFIC STEERING COMMITTEE

Page 76, Line 27–Research Needs should include the "assessment of the societal aspects of impacts from extremes".
S.A. CHANGNON, ILLINOIS STATE WATER SURVEY

Page 76, lines 30-31: This notion seems to me quite poor in concept. The climate system is like a pot of slowly boiling water. Now imagine that what GHGs are doing is slowly turning up the heat and causing more bubbling. This proposal seems to be saying it will try to attribute the factors leading to an individual bubble rising—it cannot be done in terms of the role of long-term climate change.
Michael MacCracken, LLNL (retired)

Page 76, line 33: Change "next" to "21st"—the changes will be occurring this century.
Michael MacCracken, LLNL (retired)

Page 76, lines 36-37: The reasons for needing this need to be explained.
Michael MacCracken, LLNL (retired)

Page 76, after Lines 36-37: We already have a variety of records that do this. The advance will be that we will provide: ìAnnually resolved gridded reconstructions of North American drought over the last 800 years, blending paleoclimatic and instrumental observations (2-4 years).î Reviewerís name, affiliation: C. Mark Eakin, NOAA/National Climatic Data Center

Page 76, add after Line 37: ìAnnually resolved gridded reconstructions of tropical ocean temperatures and related climate phenomena such as El NiÒo and the Pacific Decadal Oscillation (5-10 years).î
C. Mark Eakin, NOAA/National Climatic Data Center

Pgae 76: end of page ñ another product:
Assessment of how climate extremes affect agriculture, water supply, erosion, and water quality, and assessment tools for this purpose.
Bonta

Page 77-78: There appears to be an assumption here that simply providing climate information will be sufficient to ensure successful adaptive management strategies. However, over the past century, societal vulnerability to extreme events has increased despite substantial gains in climate information, simply due to population and economic growth. This trend is expected to continue well into the future. Wouldn't it be prudent to perform an assessment of the capacity of the United States to adapt to climate variability and extremes (in conjunction with vulnerability assessment as outlined in Chapter 11), the necessary changes in infrastructure and institutions to facilitate adaptation, and the costs of making such changes? This could then be incorporated into scenario development to examine a broader range of policy options and explore the relative costs and benefits of different degrees of adaptation and mitigation policies. Also, the *Draft Strategic Plan* seems to assume that adaptive resource management is the responsibility of regional to local policy-makers. Is there not a role for national policy-makers in enhancing adaptive capacity? Given that adaptation is a necessary, but not sufficient, approach to addressing climate change, the CCSP should play an active role in assessing the adaptive capacity of the United States to a broad range of climate change impacts and identifying opportunities for national policy-makers to facilitate adaptation and long-term resource planning.

Vicki Arroyo and Benjamin Preston, Pew Center on Global Climate Change

Page 77: In question 5 (weak), it is not clear what infrastructure (IPCC, regional assessments, climate services?) would/could increase communication between users/producers? Two-way communications between stakeholders and producers is critical. Also, the responsiveness of scientific community is lacking.

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Page 77, Question 5: I would rephrase Question 5 to something like "How do we get the right climate information into the hands of those who need it?" This is an area where both the existing State Climatologists and Regional Climate Centers have considerable expertise. It would be much more cost-effective to support the existing infrastructure rather than start from scratch. The mix of users and their needs change from region to region (e.g. Northeast versus Southwest US). As a result, the interaction with them has to be at the state and regional level.

Fourth Overview Comment: There are two categories of time horizons used in this chapter; either 2-4 years or 5-15 years. It is not clear how these were determined. For example, many of the products and payoffs listed under Question #5 (page 78) have 5-15 year time horizons when the existing network of state climatologists and regional climate centers are actively involved today in many of products listed. For example, this group of climatologists already monitors climate extremes and their impacts, and they are actively improving access to climate information and products. Therefore, many of the time horizons in this section are overly pessimistic and could be shortened.

Fifth Overview Comment: One weakness of past climate change research efforts is that the resulting effort has not fit the decision maker's needs. Typically decision makers are only involved at the end of the process. The decision makers have to be involved earlier in the process and the interaction has to be two-way with the climate researchers. In addition, this whole area requires a lot more support than it has received in the past to be effective.

Sixth Overview Comment: While the current state of regional climate models is briefly discussed on page 73, most of the issues raised in Chapter 6 are regional in nature and can not be addressed by the current generation of GCMs. This is particularly true for Question #4 on extreme events and Question #5 on climate products. Therefore, the need for regional climate modeling and statistical methods for downscaling from GCMs should be reiterated in this chapter.

JIM ANGEL, ILLINOIS STATE WATER SURVEY

Page 77, Line 6-7: **Change to read**: "… climate variability and change knowledge be optimally produced and integrated with non-climatic knowledge to ensure…".

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Page 77, Line 7, Question 5. Interaction and information exchange with decision makers It is very surprising that there is absolutely no mention in this chapter of the NOAA-sponsored and internationally supported International Research Institute for Climate Prediction (IRI).

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

Page 77, Line 8 to Page 78, Line 33—This section fails to address the fact that much is already known about how and what climate conditions (indicators) are related to agriculture, water, and energy use. What has failed in the past was not taking this impact information into account in the basic climate change research and modeling. Yet, more impact research is needed , but key linkages should emphasize Chapter 11 research as integral to the Chapter 6 research. Also, the existing regional climate centers would be ideal institutions for this impacts-users focused research.

S.A. Changnon, Illinois State Water Survey

Page 77, Lines 8-27: This section treats as research questions aspects of the climate debate that have been well covered in recent years. National as well as state level assessments have already identified the regions, sectors and relevant decision-makers. The appropriate response at this point is not further study but rather a programmatic response such as an organized outreach to the regions, sectors and decisions. The products outlined on p.78 are useful but only to the extent that they build on existing efforts (e.g. the California Energy Commission's Research and Development roadmaps) and are embedded in a larger program of cooperation with the states.

California Resources Agency

Page 77, line 9: "risk"

Michael MacCracken, LLNL (retired)

Comments on Chapter 6

Page 77, line 9ff: This summary of the State of Knowledge, like the other ones in this chapter, is really an excuse for listing questions. The overview of what we know is basically missing.
Michael MacCracken, LLNL (retired)

Page 77, Lines 9-14: **Change section to read**:
"Research in this area focuses on making climate research more responsive and useful to decision- and policy-makers. Climate knowledge can reduce costs and risks for decision-makers, as well as increase opportunities. For example, the agricultural sector is already using climate information to enhance operations in the SE and SW United States. After several years of close scientist-stakeholder interaction, water and forest (wildfire) managers in western and SE regions are also beginning to use climate knowledge in an increasingly effective manner. With continued population growth and climate change, the need for improved user-driven climate science will become more and more important to decision makers, just as policy-makers will increasingly be under greater and greater pressure to make wise choices. Even in the absence of significant anthropogenic climate change, decision-makers will benefit, making research in this area a "no-regrets" strategy for the climate science community and their partners. Outstanding questions include:".
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Page 77, lines 21-27: There needs to be 2-way interactions with stakeholders in these efforts.
Michael MacCracken, LLNL (retired)

Page 77, lines 28-31: "... how can access to and understanding of climate information and predictions be accelerated and simplified to realize their greatest value to the scientific community, public, and decisionmakers?" This discussion is incomplete. I agree that a better job should be done communicating scientific research on climate change to various audiences, but the Strategic Plan should make note of how the "global warming" debate is driven by headlines in newspapers claiming "new evidence" in support of the most alarmist forecasts of catastrophic climate change. Many environmental advocacy groups, individual scientists, and even professional organizations profit from this sort of attention and therefore cannot be relied on to give a balanced or honest report on the matter. I suggest this problem of hype and exaggeration appearing in the popular press and the publications of environmental advocacy groups be reported in this section of the Strategic Plan, and that the USCCRP publicly disavow these claims when they appear and work with NGOs to stop misrepresenting the climate change story. –
Joseph L. Bast, The Heartland Institute

page 77, line 34 The need to link science and policymakers is identified, but I do not see how the proposed research needs will address this question.
Mark R. Abbott, Oregon State University

Page 77, Lines 34-37, and Page 78, Lines 1-4: **Change paragraph to read**:
"The physical science underpinnings for this research are the observational, diagnostic, and modeling expertise required to develop and assess an ever-improving climate

information service for decision- and policy-makers. Because decisions are mostly carried out at local to regional "place-based" scales, and that policy decisions must be responsive to regional implications, effective user-driven climate science must focus on the needs of regional decision- makers. This requires that substantial investment be made in developing partnerships with stakeholders and social scientists so that the climate science community can be responsive to user needs, and also have objective mechanisms for assessing success. Flow of information must go both ways, from scientists to users, as well as user to scientist. The fact that stakeholders seldom use climate information in the absence of other scientific, economic, institutional, legal and cultural knowledge requires that integrated interdisciplinary approaches be facilitated. Regional decision-making also requires much improved understanding of regional-scale climate variability and how to model this variability."

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Page 77, line 35, through page 78, line 34: NESCAUM welcomes the emphasis in this section on developing new climate information products that will be useful for decision makers at the state and regional level; improving understanding of regional climate variability; and downscaling existing models and simulations to develop regional climate change policy options. We agree that this focus area poses a major research challenge but urge that it receive high priority.

With respect to the proposal on page 78, lines 9-11, for using regional "test beds" to develop and evaluate the effectiveness and potential use of climate information at regional scales, we recommend that the New England states – which, as noted above, have pledged with the Eastern Canadian provinces to pursue a coordinated regional climate action plan – as the first such testing ground. The New England states are already working together to reduce regional emissions, and would serve as an ideal testing ground for products designed to further that process.

Because this type of information is so important for state-level decision making, the five- to fifteen-year time frames for achieving many of the products and payoffs on page 78 appear unnecessarily and harmfully long (e.g., lines 20-21, enhanced extreme event monitoring; lines 30-31, improved documentation of the regional impacts of climate extremes; and lines 32-33, improved access to climate information and products for addressing regional concerns and issues). States are already experiencing many predicted impacts of climate change, such as species migration and increased flooding. To respond effectively, they need better decision tools on a considerably shorter time horizon. Additionally, many states will make long-term decisions in the next fifteen years, such as licensing new power plants, which will lock in capacity with significant GHG impacts for decades. The time frames for products in this section should be shortened to an average of 5-10 years, and the list should be prioritized to produce the tools most needed by states on a faster schedule.

Kenneth A. Colburn, Northeast States for Coordinated Air Use Management (NESCAUM).

Page 78: For just the reasons stated above, the RISAs supported by NOAA are very important and should be expanded and replicated and hived into more places and sectors, and in smaller and different cases. They are very good investments in how to get to what is useful in practice. The Office of Global Programs deserves great credit for these, as does the IRI.
Wiener, Individual commentator

Page 78, Line 4: the task above necessitates looking at finer than regional scales, such as field and watershed scales to look at environmental impacts, as this is where decisions are made.
Bonta

Page 78, Lines 9-11: California may be an excellent “test bed” to evaluate the effectiveness and potential use of climate information at local/regional scales. The California Department of Water Resources is considering, for the first time, the potential effects of climate change in their water resources planning work. Future versions of the California State Water Plan will include technical and policy options to cope with a changing climate. The Commission is actively collaborating on this effort through our research efforts.
-California Energy Commission

Page 78, line 11. Insert after "…at regional scales". These regional test beds should span the full range of the United States' climatic environments, including the Arctic and the tropics.

Weller, et al, University of Alaska Fairbanks

Page 78, Line 16-34: Where is the communication between the scientists and decision makers to resolve the question on P77L15-31?
Ronald Stouffer, GFDL/NOAA

Page 78, Lines 16-33: These products and payoffs should be produced to help predict and mitigate impacts of extreme climate or weather induced events, even if the other research concludes that the most significant climate variations are natural.
Orest Lewinter, Citizen.

Page 78, lines 16-17: This is very vague. What is meant?
Michael MacCracken, LLNL (retired)

Page 78, Lines 16: **Insert new bullets to include things that could be done quickly to serve stakeholders better:**
• Expanded partnerships with social scientists and stakeholders in climatically-sensitive regions to create user-driven climate science and services programs (2-4 years).
• Expanded partnerships with existing stakeholder support institutions, such as state agricultural extension services and land management agencies, to speed use of climate knowledge (2-4 years).

• First-generation "test-bed" integrated climate science and assessment decision support systems for select user groups (e.g., farmers, ranchers, water managers, forest managers and public-health officials) in regions where user demand is already demonstrated (2-4 years).
• Enhanced high-resolution (1 km grid) down-scaled observed climate products for climatically-sensitive regions (e.g., western U.S.) based both on monthly instrumental and annual paleoclimatic data (2-4 years).
• Framework for assessing the effectiveness of regional scale climate science and service (2-4 years).

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Page 78, lines 18-19: What will this mean? How similar or different will it be to the IPCC? It needs to be made clear that this does apparently not mean looking at impacts—just how the climate may change.
Michael MacCracken, LLNL (retired)

Page 78, Lines 22-24: **replace bullet with more aggressive one (many stakeholders can't afford to wait for better observing systems and what they will bring to regional climate science and service)**:
• Assessment and development of enhanced regional climate observing systems to facilitate greater understanding and predictive capability in topographically-complex and climatically-sensitive regions such as the western U.S. (2-4 years).

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Page 78, lines 36-41: A long list of links is not sufficient to enact a major change in interagency and cross program coordination. There is nothing to prevent each agency and each line organization within each agency to continue what it has been doing.
Antonio J. Busalacchi, Earth System Science Interdisciplinary Center (ESSIC), U. Maryland

Page 78, line 41: there are potentially links with Chapter 8 also since changes on land use (e.g. deforestation) can influence the incidence of extreme events and potentially change the natural modes of climate variability.
Julia Slingo, NCAS/CGAM, UK

Page 79 need to list ICOS / G3S (GCOS, GOOS, GTOS)
Martin Visbeck, Columbia University

Page 79, line 17: It is unacceptable that there are no references here. The IPCC reports provide the best overview of the science; after referring to IPCC, then add some NRC, CLIVAR, and other reports.
Michael MacCracken, LLNL (retired)