Written Public Comments on the
Strategic Plan for the U.S. Climate Change Science Program
Chapter 9: Carbon Cycle (pp 100-111)
Comments Submitted 11 November 2002 through 18 January 2003
Collation dated 21 January 2003

Page 100, Chapter 9: Overview comment: The issues of land cover change (Chapter 8), the carbon cycle (Chapter 9), and ecosystems (Chapter 10) overlap extensively. In order to closely link the research strategies for these three areas, the three chapters should explicitly reference each other at key overlapping points, as the IPCC authors did for the Third Assessment Report.

PATRICK GONZALEZ, THE NATURE CONSERVANCY

Page 100, Chapter 9: 1) The role of interannual and interdecadal variability in the regional-climate system should be more acutely considered. These variations will make it very difficult to partition the relative roles of human and natural causes of carbon sequestration or loss from ecosystems. What is the required sampling density to effectively reduce statistical uncertainty in these estimates if an attainment period were to be charted for a decade or less in the future? Ron Neilson USDA Forest Service

2) What are the linkages between Nitrogen, water and carbon sequestration with respect to climate variations? Can the roles of nitrogen deposition be partitioned from natural fixation as they affect carbon sequestration? How are nitrogen uptake and leaching affected by changes in the water cycle and how does that affect carbon sequestration? Can these affects be partitioned from direct human management for enhanced carbon sequestration?

RON NEILSON USDA FOREST SERVICE

Page 100, Chapter 9: The climate change modeling community continues to be draw on process level understanding, stemming from a few leading plant ecophysiology laboratories is the 1970s . However, it is clear throughout the CCSP and from recent discussions with the modeling community that this area of environmental research needs to expand the scale and complexity of experiments (from the leaf to the canopy and ecosystem) if it is to helpfully constrain the role of biospheric processes in predictive climate change models . Key unknowns include: 1) control of respiration; 2) acclimation during CO2-fertilization effect; 3) remote sensing of light utilization efficiency and correlation with C-fluxes .

CHARLES B OSMOND, COLUMBIA UNIVERSITY.

Page 100, Chapter 9: The chapter tends to emphasis processes from the soil surface to the atmosphere. The document would be deficient if it did not recognize belowground processes more. The microbiology is an important component in regulating decomposition of plant material and the loss or gain of carbon in the soil. There is a continuum of scales from the microbe through the landscape to the global level. These scales would be excellent to diagram or describe in this chapter. This concept would also be applicable to oceans. A flow diagram may help integrate these concepts to the reader.

Second Overview Comment: Research should include some effort directed towards full cost accounting. Are there any tradeoffs for carbon sequestration if the flux of other greenhouse gases increase?

Third Overview Comment: Several issues are missing in this chapter that requires research effort. Erosion is one area with questions on the fate of the eroded carbon. A second question is spatial and temporal variability.

CHUCK RICE, KANSAS STATE UNIVERSITY

Page 100, Chapter 9: OVC 1.
Attribution of changes in the carbon cycle related to fossil fuel emissions, land use changes, natural variability is a critical issue

OVC 2. Regional analysis of different land use management schemes will be important in addressing global and regional carbon dynamics

OVC 3: Legacy of land use history is key to understanding current and projected changes in C cycle

OVC 4: Need to better understand the global and regional effects of changes of carbon dioxide and other radiative trace gas species on climate

OVC5: Question 2: Interconnection of marine and coastal ecosystems to land fluxes of nutrients (e.g., iron, P, and N) and other organic compounds are critical controls on marine and coastal ecosystem dynamics and carbon fluxes.

OVC 6: Question 2: The C dynamics can have a major impact marine and coastal ecosystems affecting productivity and marine food chain relationships.

OVC 7: Question 3. Land use histories and changes in disturbance regimes (e.g., fire frequency, fire intensity, pest outbreaks) have a significant impact on ecosystem carbon pools and fluxes. The quantification of these dynamics are critical to understanding current and projected C fluxes.

OVC 8: Question 4: Linkage to social science community is necessary to adequately address decision making processes related to land use management and use of carbon products. Specific engagement of the social science community to assist in defining forest management, cropping system, exports and use of products needs to be developed.

OVC 9: Question 5. Biogenic fluxes of CH_4 needs to researched in collaboration with the research components of Chapter 5 on atmospheric composition.

DR. DENNIS OJIMA, COLORADO STATE UNIVERSITY

OVC 10: Question 6: How will industrial technologies be represented in the mix of potential carbon management practices. The trad-offs or synergisms among different carbon management strategies for the different sectors needs to be evaluated jointly to better assess the social, environmental, and climate benefits or detrimental impacts.

DR. DENNIS OJIMA, COLORADO STATE UNIVERSITY

Page 100, Chapter 9: Proper measurement and modeling of the carbon cycle is dependent on a mechanistic understanding of processes which is often weak at best. There is a need to support basic experimental research and research facilities that addresses problem areas, including: 1) control of respiration; 2) the kinetics of the CO2-fertilization effect; 3) the strength and co-variation of flux and vertical transport in the atmosphere.

JOE BERRY, CARNEGIE INSTITUTION.

Page 100, Chapter 9: The chapter on the Carbon Cycle is curiously placed in the back of the document, yet CO_2 is the single most important greenhouse gas directly influenced by man that is highly suspected of driving the observed climate change during the 20th century. This chapter should be near the front of this document (the leading subject of which is climate change research, not air quality or chemistry – the latter play a role but not a primary one) and probably should be placed before the chapter on "Atmospheric Composition", because, if for no other reason, the sum of the effects of all of the other gases doesn't equate to the effect of atmospheric CO_2 on climate. We don't want to give the impression that complexities of the climate system overshadow the dominating effect of CO_2 in the atmosphere.

[TANS 303-497-6678 – BUTLER, DUTTON, HOFMANN, OGREN, SCHNELL; NOAA/CMDL]

The discussion of the importance of atmospheric carbon observations is missing, in particular, how such observations are key to determining the effectiveness of US carbon management strategies. There is little or no mention of maintaining atmospheric observations of this gas. Such mention should be cross-referenced to Chapter 3, perhaps Chapter 5 as well, but the importance of carbon measurements is not detailed in those chapters either.

[BUTLER 303-497-6898 – DUTTON, HOFMANN, OGREN, SCHNELL, TANS; NOAA/CMDL]

The two "overarching" questions of Chapter 9 (in bold, p.101) are repetitive. The second one is included in the phrase, "and be managed in future years", of the first question.

[TANS 303-497-6678 – BUTLER, DUTTON, HOFMANN, OGREN, SCHNELL; NOAA/CMDL]

NOAA/CMDL

Page 100, Chapter 9: Overview Comments on Chapters 8, 9, and 10

Integrate chapters: These three chapters should be merged into a single chapter that addresses land use/cover, ecosystems, and the terrestrial component of the carbon cycle. The marine component of the carbon cycle and comprehensive carbon cycle modeling could be addressed in a separate chapter or in the chapter on atmospheric composition. Integrating the chapters focused on the terrestrial biosphere would reduce redundancy in the exposition, and more importantly, reduce the risk of analytical inconsistencies. For example, terrestrial carbon cycle models often project a terrestrial CO_2 sink without considering changes in land use that could eliminate the forests assumed to be sequestering carbon in response to higher CO_2 concentrations. Integration of the chapters will also help to focus attention on the key interactions and feedbacks between climate change and terrestrial ecosystems, including albedo as well as carbon cycle changes.

Focus on overriding issues: The draft plan lacks focus and fails to set priorities. Priorities should be based on relevance to refining our understanding of what is required to stabilize heat-trapping greenhouse gases in the atmosphere at a level that prevents dangerous human interference with the climate system. Key issues to highlight are:

- What carbon budget is compatible with different stabilization levels given feedbacks?
  - Ocean CO_2 uptake
  - Climate change and CO_2 fertilization impact on NEP
  - Changes in forest cover impact on albedo
  - Climate change impacts on methane emissions
- How can inventory and inverse estimates of the North American sink be reconciled?
- How can carbon stock changes due to management practices be distinguished from changes due to other factors?
  - CO_2 fertilization, nitrogen deposition
  - Climate variability, climate change
- How will ecosystem services be affected by global change?

DANIEL LASHOF, NRDC

Page 100, Chapter 9: First Overview Comment: This chapter's focus is completely unbalanced, spending 95% of its efforts on the sinks such as oceans and forests, and very little effort on reducing the CO2 load of the atmosphere. For example in the box outlining the chapter question 5 should stop after concentrations and then put the second half of the sentence into another question. The CCRI should allocate more resources, not less, on assessing the impact of changing the carbon balance by reducing fossil fuel in the lithosphere and emitting it into the atmosphere.

Second 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 100, CHAPTER 9: ALTHOUGH THE *DRAFT STRATEGIC PLAN* ADDRESSES THE NEED FOR INCREASED MONITORING OF NORTH AMERICAN CARBON SOURCES AND SINKS AND THE INFLUENCE OF RESOURCE MANAGEMENT ON CARBON STORAGE, IT APPEARS TO OVERLOOK THE POLICY IMPLICATIONS ASSOCIATED WITH CARBON MANAGEMENT. FOR EXAMPLE, MUCH OF THE INTEREST IN AUGMENTING TERRESTRIAL OR OCEAN CARBON SINKS THROUGH HUMAN MANAGEMENT IS TO OFFSET ANTHROPOGENIC EMISSIONS AND/OR TO OBTAIN CARBON "CREDITS" THAN CAN BE UTILIZED IN A CARBON MARKET. AS SUCH, AN IMPORTANT CONSIDERATION IN CARBON MANAGEMENT IS THE EXTENT TO WHICH ISSUES SUCH AS VERIFICATION OF CARBON SEQUESTRATION AND POTENTIAL FOR LEAKAGE CAN BE ADDRESSED OVER GEOGRAPHIC SCALES RELEVANT TO COMMERCIAL CARBON SEQUESTRATION PROJECTS. THE IMPLICATIONS OF THESE ISSUES FOR ECONOMICS AND POLICY ARE LIKELY TO BE A SIGNIFICANT DRIVER OF FUTURE TRENDS IN ATTEMPTS AT CARBON MANAGEMENT. THE CCSP SHOULD TAKE A LEADERSHIP ROLE IN ESTABLISHING THE BASIC SCIENCE THAT CAN BE USED IN THE DEVELOPMENT OF CARBON MANAGEMENT PROGRAMS.

VICKI ARROYO AND BENJAMIN PRESTON, PEW CENTER ON GLOBAL CLIMATE CHANGE

Page 100, Chapter 9: **First Overview Comment:** This chapter generally overstates the case for terrestrial carbon sequestration by often ignoring limitations on implied carbon sequestration processes. Appropriate temporal and spatial scales needed to assess whether systems are truly carbon sources or sinks relative to the atmosphere are also generally not considered.

Appropriate baseline reference conditions against which to measure carbon gains and loses incurred by multiple rotation forests or land use change must be agree upon to avoid artificial carbon sources or sinks in the carbon accounting.

Second Overview Comment: Given developing interest in awarding carbon credits, there may be temptation to replace various ecosystems shown to have low carbon storage with ecosystem capable of high carbon storage. This could work against biodiversity conservation objectives.

JACK E. JANISCH, OREGON STATE UNIVERSITY (FORMERLY)

Page 100, Chapter 9: Nitrogen Cycle
The CCSP has a chapter on studying the carbon cycle because of its dominant importance in controlling greenhouse warming, and because it is the recipient of major anthropogenic inputs from fossil fuel emissions, land use conversion, and biomass burning. There is also a chapter on ecosystems, a recognition that ecosystem change may itself exert significant influence on global climate through their control of biogeochemical cycles.

For similar reasons, there should be a major emphasis on studying the nitrogen cycle. While nitrous gasses are lesser contributors to global warming directly, excess organic nitrogen is a major threat to aquatic and coastal ecosystems, which in turn can affect climate through their regulatory functions. Furthermore, the degradation of ecosystems from excess nitrogen, including increases in the size or number of "dead zones," eutrophication, algal blooms, alterations is species composition, and other structural and functional changes, will have a cumulative impact with climate change on these systems. The combined effect may pass critical thresholds in some cases, leading to a non-linear response.

While atmospheric carbon has increased by approximately 30% over pre-industrial levels, environmental nitrogen, mostly from agricultural fertilizer production and use, land clearing, an fossil fuel combustion, has increased by over 100%. Excess nitrogen accelerates productivity to the point where other nutrients and resources become limiting, thus depleting those components from the system, increasing vulnerability to other changes, and reducing quality. The problem is relatively unquantified in the coastal zone, with consequent uncertainties in the effect.

The CCSP ecosystems chapter mentions nitrogen and "nutrients" among the list of research questions. This comment is therefore one to suggest a greater emphasis on nitrogen, since it is already included.

NOAA-NESDIS, KINEMAN

Page 100, Chapter 9: The draft Chapter 9 and its supporting 'white paper' provide a logical and comprehensive framework for development of detailed research plans and budgets.

During the Chapter 9 breakout session at the workshop in December, several participants noted that there is some overlap among the research questions in Chapter 9. Some participants found this confusing and suggested various ways of re-organizing or re-stating the questions. In my view, overlap among the questions is inevitable. The draft chapter handles the overlap very well. Rearranging the questions will only create new problems and will not improve the document. Including question 3 to address integration is perhaps confusing to some, but definitely a good idea.

There was considerable discussion of the purpose and scope of Chapter 9 at the December workshop. Some participants felt there should be much more detail in both analyses of existing information and in statements of priorities for future research. In my view, it is obvious that Chapter 9 and the other draft chapters of the CCSP Strategic Plan are intended to forge a broad consensus on general research needs and priorities among diverse agencies and other stakeholders. A more detailed statement of specific priorities is an important next step, but it is critical to get the broad consensus first.

The "state of knowledge" summary in Chapter 9 is well-conceived, accurate, and concise. It is skillfully written for the particular and important purpose of forging broad consensus among scientists and policy makers who have high levels of interest and expertise in carbon cycle issues. People who are not already familiar with these issues will no doubt find the chapter's synthesis of the "state of knowledge" somewhat difficult to comprehend. However, the chapter was not written for them, nor should it be.

SUGGESTED APPROACH TO DEVELOPING IMPLEMENTATION PLANS FOR TERRESTRIAL CARBON CYCLE RESEARCH

As indicated above, the draft Chapter 9 provides a logical and comprehensive framework for future research. The draft Chapter 9 should be approved with minimal changes and delay so that science management efforts can be redirected promptly to development of detailed implementation plans. The detailed implementation plans should: (a) drill down into the nation’s current portfolio of carbon cycle R&D; (b) identify areas of relative strength and weakness; and (c) highlight critical priorities for gap-filling R&D.

Quantification of carbon sources and sinks in forests is a critical and generally strong area in the nation’s carbon cycle research portfolio. Current programs such as FACE, FORCARB, and Ameriflux are addressing key information needs and should be continued. There is, however, an urgent need to strengthen the Forest Inventory and Analysis (FIA) Program in the US Forest Service. FIA is the only source of consistent information on the extent, condition, and health of forests across the nation. FIA plays a critical role in carbon cycle assessments, i.e., it is the primary source of ‘ground truth’ for the FORCARB model and emerging assessment methods that integrate data from ground plots, remote sensing platforms, and atmospheric monitoring networks. Unfortunately, the quality, timeliness and availability of FIA data are not adequate to meet the needs of carbon cycle researchers and other FIA user groups. Ongoing efforts to improve the quality, timeliness and availability of FIA data should be reviewed and accelerated.

The nation’s carbon cycle research portfolio includes many good projects that will help determine how the carbon sequestration potential of existing forests might change in response to changes in atmospheric carbon dioxide concentration and other environmental variables. The FACE Program (Free Air Carbon Dioxide Enrichment) is very valuable and should be continued. Outside the FACE program, there is a general need for (a) greater emphasis on experimentation and hypothesis testing, and (b) less emphasis on modeling exercises that are not tightly coupled to experimentation and hypothesis testing.

The nation's current portfolio of terrestrial carbon cycle research has a glaring weakness. There is no coherent R&D strategy directed to promising solutions for enhancing forest carbon sequestration and biomass energy production. Projects in this area are too few in number and grossly under-funded. The forest products industry is responding to this situation by developing a "Consortium for Research on Carbon Sequestration in Managed Forests." Through the Consortium, the industry is prepared to join with government agencies and universities to develop an effective research strategy and fill critical information gaps. Critical research questions include:

What are the major direct and indirect effects of managed forests and wood processing systems on the global carbon cycle?

How can current and emerging forest technologies be deployed most effectively to enhance sequestration and biomass energy production while sustaining biodiversity?

What the most important economic and technological barriers to enhancing forest carbon sequestration and biomass energy production?

ALAN LUCIER, NATIONAL COUNCIL FOR AIR AND STREAM IMPROVEMENT, INC.

Page 100, Chapter 9: The only gases discussed in this section are CO_2 and CH_4. While these two gases are C gases, their flux and cycles are closely tied to nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) in terrestrial ecosystems. Not including these nutrients in the studies described in questions 1, 4, and 6 will limit the success of the experiments and studies. This is especially true for understanding terrestrial sinks in agricultural ecosystems and evaluating the management practices of these ecosystems and providing the information needed to achieve the objectives of chapter 10 – Ecosystems. Nutrients should be included in the studies.

STEVEN E. HOLLINGER, ILLINOIS STATE WATER SURVEY

Page 100, Chapter 9: Overview
Carbon uptake and release are not static, but dynamic responses to important influences, especially including climate itself. The research should feature prominently the climate sensitivity of uptake and release. Also, the dynamic nature of uptake and release cannot be captured in single campaign-type studies but will require periodic (on the ground) re-evaluation under a range of environmental conditions. Question 1. What are the magnitudes and distribution of North American carbon sources and sinks and what are the processes controlling their dynamics?

WELLER, ET AL, UNIVERSITY OF ALASKA FAIRBANKS

Page 100: Given the earlier history of energy modeling, I regret that I must conclude that no matter how reasonable this chapter might be, given some understandings of what is included in some of the terms used, it looks too political to serve its purpose. It is just not reasonable to expect a sympathetic reading when the carbon chapter never uses the words "fossil", "fuel", "transportation", "oil", "coal", "renewable", etc etc… The net result is that this chapter just doesn't fit with the rest of the document.

WIENER, INDIVIDUAL COMMENTATOR

Page 100, Chapter 9: Overall, I believe the Strategic Plan for the CCSP to be an excellent first step in defining a national program and I applaud those involved in putting the draft together in such a short time. It's a very daunting endeavor, but one that must get underway. I have focused my comments on Chapter 9 and hope that they will be taken as constructive criticism, not derogatory in any way.

1. Questions 1, 2, and 3 are basically address the same issues with the first focusing on North America. It would make better sense to recast these into three related questions. The implementation can focus on North America as a first priority for any number of political and logistical reasons.

What are the magnitudes and distributions of global sources and sinks and how have they varied in the past?

What are the underlying processes that regulate these sources and sinks?

How will these processes respond to changes in other environmental factors and what feedbacks exist?

The first question simply asks what are the sizes and locations of present day sources and sinks and what can be determined from existing data on their historical variability. The second question goes one step further and asks what regulates these sources and sinks and requires knowledge of processes. The third question asks what are the sensitivities of these processes to other environmental parameters and how strongly are they coupled, i.e., the feedbacks. With process understanding prediction is possible and can be tested using the top-down (inverse) modeling approach applied in answering the first question.

2. Question 5 is really two separate questions. To predict carbon dioxide and methane concentrations, one must first know how terrestial and marine sources and sinks will evolve (which is addressed in Questions 1 and 2), along with fossil fuel combustion. Therefore, Question 5 boils down to "What will be the future atmospheric carbon dioxide and methane concentrations?"

3. There are important links between several of the CCSP components, such as those between the carbon and water cycles. Also, the planetary radiation budget is linked to elements of the carbon cycle, water cycle, atmospheric composition, and ecosystem components. The document should have an introduction that discusses and illustrates the couplings, at least at the level of primary connections. This will also help establish the boundaries of each component and the critical dependencies.

4. The "State of Knowledge" sections should be combined to remove redundancy. Descriptions of the atmospheric and terrestrial knowledge, needs, products, and payoffs are more detailed than for the oceans. However, it is thought that the oceans regulate about half of the CO2 uptake and global primary production (some recent publications

have reduced the terrestrial sequestration numbers). Therefore, the oceans role should be represented in a more balanced manner. Overall, the discussions are fairly general and not particularly informative in terms of establishing what levels of effort are going to be required to achieve the degree of understanding needed.

5. Finally, the schedule for many deliverables is very aggressive. For instance, can we really have a really useful ìState of North American Carbon Reportî completed in two years. While I am sure a report can be written in two years, what would it include? Perhaps a more complete analysis of what information we have in hand already and a establishing a template for future reports would be a meaningful start (but even that may be a challenge). I know there is tremendous pressure to do something in the near term, but organizing this program, building a coherent infrastructure, and executing programs like the NACP will take a lot of effort (and time). On the other hand, have deliverables is necessary and helps keep the program accountable and relevant.

MCCLAIN, NASA

Page 100, Chapter 9: **:** I would like to point out that the carbon cycle includes the emissions of isoprene and monoterpene hydrocarbons as well as a number of other trace gas species, including organic alcohols, acids, and larger compounds (diterpenes, sesquiterpenes, etc.). These emissions are quite large and are now known to play a role in determining the atmospheric composition of the troposphere on regional and global scales. Indeed their presence in areas where there are anthropogenic emissions of air pollutants such as nitrogen oxides and sulfur dioxide, can lead to increased levels of regional ozone and fine aerosols that are important in radiative balance considerations.

These compounds emission rates will be affected by the health of the plants, precipitation, nutrient levels, temperature, light intensity, and the distribution of the species. The emissions will also be impacted by ozone causing reduction in photosynthetic activity by impacting the plants. The most abundant of these natural hydrocarbons is isoprene (a hemiterpene). Isoprene oxidation will enhance the levels of hydrogen peroxide formation and sulfur dioxide oxidation to sulfate aerosols (see . J.S. Gaffney, G.E. Streit, W.D. Spall, and J.H. Hall, "Beyond Acid Rain: Do Soluble Oxidants and Organic Toxins Interact with SO_2 and NO_x to increase ecosystem effects?" Feature Article in *Environ. Sci. Tech.* **21** (6) 519-524 (1987)), and monoterpene reactions with ozone will produce fine secondary organic aerosols. Isoprene has also been clearly connected with enhanced ozone production in areas where anthropogenic nitrogen oxides are high. The Southern Oxidant Study (SOS) clearly demonstrated the importance of natural isoprene emissions on the observed increased ozone levels in urban and regional areas in the Southeastern United States, where deciduous forests are an abundant source of this compound.

Ozone is a potent plant phytotoxin. Increased tropospheric ozone (a greenhouse gas) levels will lead to the stomatal resistance being increased leading to reduced uptake of carbon dioxide, less water emitted through evapotranspiration, and less emission of volatile organic carbon (i.e. isoprene) from the plants. Carbon sequestration under ozone exposures have been shown to reduce carbon uptake in FACE experiments even at moderate levels based in research performed under the DOE PER program (Dave Karnovsky). At 60 ppb levels carbon dioxide uptake even under high carbon dioxide exposure was reduced significantly due to this interaction.

This type of feedback is not really addressed in this document. It would be nice to see this addressed and linked to the Atmospheric Composition section (Chapter 5). I will be sending them a similar comment.

I suggest that there might be additional questions added to the Chapter that addresses this, and offer two possibilities.

Will changes in climate (i.e. changes in temperature and precipitation) lead to significant changes the emission of volatile organic hydrocarbons (isoprene, monoterpenes) that may have feedbacks in the secondary production of regional ozone, aerosols, and other radiatively important species?

What are the feedbacks between carbon dioxide uptake, water vapor and natural hydrocarbon release rates, and exposures to higher levels of ozone and other oxidants due to anthropogenic emissions of nitrogen oxides?

I would suggest that these questions would link to the Water cycle (via evapotranspiration effects) and the atmospheric composition chapters quite nicely under a heading of potential feedbacks of climate change.

I note that this document is attempting to look at methane, which is long over due, and would comment, that there are a lot of other key species that are carbon that must be examined. These compounds are not at the same magnitude of carbon dioxide in terms of mass, but their chemical properties can act to substantially impact the atmosphere in significant ways due to their reactivity and catalytic abilities. I note that OH has a concentration of 3x 10^5 molecules per cc (very small concentration), but plays a significant role in the chemistry of the troposphere due to its reactivity. Similarly, these natural hydrocarbons should not be ignored if we are to adequately explore the global biogeochemical cycles of carbon.

JEFFREY GAFFNEY, ARGONNE NAT'L LABORATORY

Page 100, Chapter 9: I was unable to identify any clear understanding in the draft or white paper of the role of buffering chemicals in the rate of air/ocean transfer of CO2. Failing to understand this mechanism renders all the other aspects of the proposed Chapter 9 inadequate to the task. IPCC's Third Assessment Report (TAR) Chapter 3 discusses this in some superficial measure. The principle was first studied in the 1920's and the scientific community was alerted to hazards of saturating surface waters with C in a famous article by Roger Revelle and Hans E. Seuss in 1957. The draft Chapter 9 appears to regard warming and nutrient saturation as the only mechanisms of harm to coral, but the most significant one is the slight acidification of surface waters as carbon from fossil fuels exceeds the buffering capacity of disolved calcium and borate ion in the ocean.

I have collected extensive references to this, but am not a scientist, and I would hope that someone involved with the preparation of your report will already understand this matter and know how to find the appropriate resources as fast as I could provide them. Please let me know if you want my help.

Since there is no positive evidence that land-base sequestration is not cyclical, the ocean's carbon absorption potential is the only significant natural process that we can be sure will reduce the fraction of emissions of CO2 which remain in the atmosphere. A reasonable estimate of the rate of ocean saturation suggests that by the end of this century under BAU, we will have effectively saturated the ocean. Fuirther air/ocean transfer will occur, but it will require proportionally larger increases in atmospheric levels and much more time.

Before the saturation occurs, there will be an observed diminishment of the rate of air/ocean transfer. This means that in several decades we can see any efforts to reduce emissions offset by a rising proportion of emissions which remain in the atmosphere. It won't make emissions reductions impossible, but will make it harder.

Thus, there is an extremely high premium value on early initiation of reductions, which is borne out by many analyses. Merely stabilizing at current emissions will double the time to eventual near-saturation from one century to two centuries.

Although most ocean climatologists are aware of the process of buffering, they seem to have widely divergent views of the best way to describe this, and its importance. It has been my experience that a better way to understand the issue is to understand a multiplicity of those views. This is also a more disturbing way to understand it, because there are multiple mechanisms for impacts that aggravate the conventionally held view of a gradually warming planet that can be brought under control whenever it becomes desirable.

NED FORD, SIERRA CLUB

Page 100, Chapter 9: This chapter addresses our options for managing carbon sources and sinks. Somewhere in this chapter it should address the reduction of naturally-occurring methane emissions such as enteric emissions from domestic and wild animals. Preliminary estimates have indicated that *not* producing methane from enteric emissions in the short run (30-50 years), could equal the combined best management practices of carbon sequestration by forest and soil management for sequestration. Furthermore, [1] animal energy utilized in the production of methane is an energy waste and feed and forage energy intake efficiency would increase (a payoff) and [2] methane *not produced* will never have to be dealt with again but sequestered carbon may have to be re-sequestered again at a later date (decomposition or oxidation of sequestered organic matter in soil, litter, vegetation, forest products, and woody debris). There should be at least a few Specific Questions addressing research on manipulation and/or management of enteric emissions.

LOWRY A. HARPER, USDA-ARS, WATKINSVILLE, GA.

Page 100, Chapter 9: This chapter addresses our options for managing carbon sources and sinks. The questions posed as the framework for this chapter are good ones that must be addressed if we are to progress toward a reasonable method of quantifying the effects of climate change.

Somewhere in this chapter it should address the reduction of naturally-occurring methane emissions such as enteric emissions from domestic and wild animals. Preliminary estimates have indicated that *not* producing methane from enteric emissions in the short run (30-50 years), could equal the combined best management practices of carbon sequestration by forest and soil management for sequestration. Furthermore, [1] animal energy utilized in the production of methane is an energy waste and feed and forage energy intake efficiency would increase (a payoff) and [2] methane *not produced* will never have to be dealt with again but sequestered carbon may have to be re-sequestered again at a later date (decomposition or oxidation of sequestered organic matter in soil, litter, vegetation, forest products, and woody debris). There should be at least a few Specific Questions addressing research on manipulation and/or management of enteric emissions.

STEVEN R. SHAFER, USDA-ARS

Page 100, Chapter 9: The questions posed as the framework for this chapter are good ones that must be addressed if we are to progress toward a reasonable method of quantifying the effects of climate change.

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

Page 100, Chapter 9: 1. There should be more emphasis placed on: How will the likely intensification and extensification of agriculture that will accompany increasing population and a more meat-rich diet affect soil carbon storage on agricultural land?

2. There should be more emphasis placed on: How will intensification of forest harvesting that will accompany increased demand for paper and wood products as population increases affect soil carbon storage on forested lands?

3. There should be more emphasis placed on: How will climate changes that result in the melting of permafrost and the subsequent draining and drying of northern peatlands affect soil carbon storage?

4. There should be more emphasis placed on: How will changes in fire frequency that occur in response to climate change and forest management changes affect soil carbon storage on forested lands?

5. There should be more emphasis placed on: How will climate change that results in drying of tropical and subtropical peatlands influence fire frequency and soil carbon storage.

6. There should be more emphasis placed on: How will climate change that includes significant changes in precipitation and soil moisture regimes in uplands and wetlands affect methanogenesis and methanotroph activity?

7. There should be more emphasis placed on: How will climate warming affect soil organic carbon (SOC) storage? There is an unacceptably high level of uncertainty in how warming in conjunction with increasing atmospheric CO2 and changes in soil moisture will influence soil organic carbon storage. Some models project decrease in SOC and some project increases. This plan should place a high priority on reducing this uncertainty because of this important feedback and because of the importance of SOC to soil productivity.

8. There should be more emphasis placed on: How would an intensification of the hydrologic cycle and an intensification of agriculture affect the rate of soil erosion and subsequent loss of soil organic carbon storage?

9. There should be more emphasis placed on: How will an intensification of the hydrologic cycle affect the redistribution of soil organic carbon associated with eroding upland sediments that are deposited in alluvium and reservoir sediments? In general there is an important linkage to the water cycle that is not given enough emphasis.

10. With regard to monitoring and verification of carbon sequestration via land use conversion and improved management practices, there is a need for more emphasis on several aspects of this problem. First there is a need to establish the potential net gain for a given sequestration practice. It must be acknowledged and quantified that the starting point (how much carbon is there to start with) is critical for estimating how much carbon can ultimately be accumulated. A site that has been very well managed previously has higher carbon initially and a lower potential for sequestration. Second, it is necessary to quantify uncertainty about the "permanence of the sequestered carbon. It is generally acknowledged that shorter term carbon gains owing to improved management or land use changes can be lost very quickly one the sequestration-friendly practices are modified or abandoned. Any carbon accounting scheme should include provisions for penalties that could compensate for future losses. Thirdly, carbon sequestration in forest biomass is particularly problematic when it can not be assured that the forest biomass will not ultimately be harvested.

11. There should be more emphasis placed on: How will changing forest species composition (as has been suggested will occur in response to climate change) influence soil and biomass carbon storage potential on forested lands?

12. One of the key uncertainties that constrains our ability to predict the future response of soil carbon storage to climate change is how will mature crop and forest plants experience physiological acclimitization that many studies have shown could limit gains in NPP and water use efficiency. The plan should emphasize the need to reduce uncertainties in this area.

13. There should be more emphasis placed on: will changing forest species composition (as has been suggested will occur in response to climate change) influence net plant isoprene emission that will in turn influence ground-level ozone concentrations.

14. In general throughout the plan there is a need to re-evaluate the allocation of resources that are used to support 1. *In situ* Measurement of Inventory and tracking of carbon stocks for purposed of trend detection, calibration and validation of modeling , monitoring and validating carbon sequestration trading programs 2. Field process studies for quantifying ecosystem response to climate change, land use change and management changes - these studies underpin the carbon trading schemes 3. Field, regional, and global modeling 4. Remote sensing as a tool for measuring carbon stocks and as inputs to climate/vegetation models and for tracking land use change.

15. The plan does not mention methane hydrates that purportedly contain more carbon than all known coal reserves and may be the next major worldwide source of energy and emission of CO2. The plan should emphasize the need to evaluate the risk of exploiting this resource in this way.

16. The plan does not mention the possibility that the wide-scale release of methane hydrates to the atmosphere that could occur if there were significant changes in sea level, and possibly in the thermo haline circulation could result in a major climate disruption as the atmospheric burden of methane increased substantially. The plan should emphasize the need to evaluate this risk in detail. This would obviously link to the chapter on abrupt changes.

17. In the context of carbon sequestration in soils, the plan should emphasize the need to discriminate among various factors influencing change in soil carbon storage: among them changes in atm. CO2, Atmospheric Nitrogen Deposition, Climate Variability/Change, changes in species composition/ changes in crop genetics and most importantly how these processes are dynamic and may increase sink strength during some portion of the future scenario but after some threshold is reached they may then act to decrease sink strength (e.g. Warming).

18. There is a need for more background information that acknowledges the immense body of scientific work summarized by the various IPCC, National Academy of Science, and other related reports. This information should contain citations.

19. There is a need for prioritization of the critical questions and research directions. The prioritization should be based on some combination of A. scientific uncertainty that blocks progress B. cost C. ability to achieve results under the stated program time frame.

THOMAS G. HUNTINGTON, U.S. GEOLOGICAL SURVEY

Page 100, Chapter 9: This chapter is not well written or well organized. In some cases, it is incorrect in its factual content, which could greatly reduce its overall credibility and effectiveness. The questions are redundant and, therefore, should be rephrased in a more concise way. More importantly, it is not consistent with the planning efforts of the CCSP

Interagency Working Group. In particular, the products and payoffs are not consistent with the CCSP planning documents for the oceans. I hope that the review process resolves these issues before it is published in April. Below are my specific comments by page and line number.

FEELY, NOAA

Page 100, Chapter 9: Overview Comments

Q1 and 3. I am glad to see the program address carbon at the national and global scale. The quest to know the spatial patterns, magnitudes of fluxes and their dynamics is relevant and on target, but needs some refinement. . The dynamics question is complex because multiple time scales are underway. For example, we need to understand the sizes of different C pools, the time scales of their fluxes and which pools are being perturbed to answer these complex questions correctly. Forests over disturbed soils may be a source of C in one situation and a sink in another where soils C pools are not being disturbed; examples include cases in Sweden and Indonesia.

Q4. We need to increase our focus on landuse change. It is my feeling and that of growing evidence in the literature that landuse change is more important than the effects of elevated CO2 or N fertilization with regards to studying the carbon balance. As forests and vegetation age, their capacity to take up C will diminish and the current ability of the biosphere to take up anthropogenic emissions of C will decrease.

Q5. Some would argue we need to consider VOC emissions too. While they are a small portion of GPP (< 1%) they may be a considerable fraction of NEP.

I'd also add we need to understand better the interannual variability of the biosphere to take up carbon. The year to year differences in the rate of growth of CO2 in the atmosphere is on the order of +/-3 Gt. What climate, ocean and biosphere drivers cause this variability, eg what is the role of volcanos, El Nino, NAO etc on the capacity of the biosphere to take up carbon?

Understanding switches (phenology, water table, drought, growing season etc) is also critical, such as warming of the artic may blow off carbon as peat gets exposed to air. This is happening in Indonesia, as noted in a recent Nature paper. Drought can decouple the relationship between respiration and temperature, a process poorly incorporated in many biogeochemical models.

Research will need multiple approaches at multiple scales. The vision articulated in an Ecosystems paper by Canadell et al is a good start. We need inversion models, CO2 concentration and flux measurement networks, satellites and remote sensing, ground data, biomass inventories, process modeling and ecophysiological measurements to understand causes and effects. Proper scaling of remote sensing information will need the expansion of flux networks on different land management and stand age classes.

Aerosol loading in the atmosphere needs to be quantified better. Evidence arising from the Aeriflux network is indicating that dust and aerosols increase light use efficiency and GPP. There is also evidence that the atmospheric aerosol thickness is increasing world wide globally. Better information on aerosols is needed to assess global GPP and to correct remote sensing information obtained from satellites and is used to scale C fluxes regionally and globally.

A strong effort to assess land use and land use change will be key using remote sensing and ground based data..

Recent findings from Ameriflux indicate that temporal variations in CO2 can be used to infer large scale fluxes, averaged over longer time scales. With development of cheaper CO2 sensors, one can distribute them widely and improve the density of CO2 information that can be used by the inversion model community, using either global or regional models.

Efforts along the line to create and develop better linked carbon/ climate models that incorporate models that assess biophysics, biogeochemistry, and ecosystem dynamics is needed to produce better scenarios of climate change and to guide policy better.

BALDOCCHI, UNIVERSITY OF CALIFORNIA, BERKELEY

Page 100, Chapter 9: In general the Carbon Cycle chapter captures the key issues enumerated in the US Carbon Cycle Science Plan (Wofsy and Sarmiento). The primary focus on the North American carbon cycle is important give it is potentially a large current sink, in some sampled forests. However, this should be "systematically' extended to test and discriminate the prominent hypothesis (past forest-cutting, changing rain/climate, nitrogen fertilization, CO2 fertilization, air-pollution (O3/acid rain) on a regional basis. In addition the methodologies to quantify the carbon cycle need to be objectively evaluated and validated.

The range of methods and monitoring strategies should be identified and critically analyzed. Eddy flux measurements of CO2 should be validated with biometric studies and demonstrated to be meaningful measure of carbon exchange on a site to site basis. Novel method such as simultaneous data on CO2 and O2 (R. Keeling, M. Bender) should be gathered on a local and regional level to extend its value as robust method to discriminate between the Oceanic and Terrestrial Sinks. The developed method using isotopic information on CO2 (C. Keeling, P. Tans) should be implemented more extensively. Undersampled areas such as the arid and semi-arid system should be sampled. New promising remote sensing methods such as solar infrared absorption of column CO2 need to be nurtured. Potential satellite and remote sensing, technologies should be developed and evaluated for their suitability.

Experimental scaling method from plot scale to regional should be developed and linked (from ins-situ, to towers, to column to satellites). Models should be intimately linked.

It is important to develop and harness platforms such as the Columbia University's Biopshere-2 Research Center and the FACE sites to gain mechanistic insight into into how ecosystems function and influence the carbon cycle under changing conditions. In particular feed-backs such as terpene (e.g.. isoprene) production by plants and its response to climatic stresses can effect the carbon cycle. For example, terpenes have been hypothesized to help Plants manage stress (Sharkey et al.), and it is know to produce ozone in air when NOx is available which will damage plants. Such carbon cycle feedbacks need to be tested and evaluated.

Paleorecords of the carbon cycle need to be gathered and analyzed over a wider geographic coverage. The ocean sink should be constrained by better satellite imagery of productivity, more pCO2 data on surface ocean, and inverse modeling. The role of limiting nutrients such as Fe, N, P, and their variability in effecting the ocean carbon cycle needs both measurement and modeling. Using state of the art ocean models with biogeochemistry is ripe to be harnessed for such applications.

Coarse carbon cycle models such as Century should be coupled with more detailed ecological soil-plant-water-microbes process models to examine trace gas fluxes (CO2, CH4, N2O) in mechanistic detail.

Key but uncertain carbon-cycle feebacks such as soil respiration-temperature-humidity, wildfires-fireSuppression-biomassburning, response of large reservoirs such as the peet, the thermohaline circulation and nutrient upwelling should be identified.

DUBEY, LOS ALAMOS LABORATORY

Page 100, Chapter 9: There are several ecosystem processes may need to be highlighted as feedback to the climate system, for example: 1) Increased vegetation growth in the Arctic, which has been detected in the past two decades using satellite data, due to climatic warming may have significantly altered the carbon budget in the region; 2) Increased frequency of drought in some semi-arid regions likely has feedback to atmosphere by changing albedo and reducing the ecosystem ability to absorb carbon dioxide in the atmosphere.

GENSUO J. JIA, UNIVERSITY OF VIRGINIA

Page 100, lines 7-9: this phrasing rather underplays the amazing acceleration in the rise of CO2 over the past 150 years—a much more specific indication, and even a figure, should be used.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 100; line 8. I believe you should clearly state how much the atmospheric concentrations of CO2 and CH4 have increased since pre-industrial times.

RICHARD A. FEELY, NOAA PMEL

Page 100, Lines 13–15: "*Elevated atmospheric CO_2 concentrations, additions of nutrients, and changes in land management practices can significantly enhance (and sometimes reduce) ecological carbon sinks.*"

Not only is this text biased towards "carbon-sink optimism", it may also not be true (see Page 8, Lines 9–10), which is later recognized on page 101, lines 1–4. Here is how the text should read:

"*Elevated atmospheric* CO_2 *concentrations, additions of nutrients, and changes in land management practices can significantly* ~~*enhance (and sometimes reduce)*~~ [alter] *ecological carbon* ~~*sinks*~~ [storage]."

DAVID L. WAGGER, PH.D., SELF

Page 100, lines 13-15: This sentence overstates the positive effects of elevated atmospheric CO_2, addition of nutrients, and changes in land management on vegetation productivity. It should be acknowledged that accumulating literature suggest:

a) vegetation growth response to elevated CO_2 may be ephemeral or may affect foliage quality for herbivores. Carbon sequestration predictions via CO_2 fertilization may be unrealistic if growth relationships to available soil nutrients are not also considered.

b) addition of nutrients may trigger undesirable relationships between trophic levels that interfere with carbon sequestration objectives or predictions. Does this imply whole regions will be fertilized?

c) changes in land management practices often only result in re-accumulation of carbon stores lost during settlement, not new sinks or increased stores relative to historical levels. An old-growth forest stand converted to agricultural land, for example, then back to forest still may take centuries to recover carbon lost when the old-growth stand was harvested.

JACK E. JANISCH, OREGON STATE UNIVERSITY (FORMERLY)

Page 100; line 13. This sentence doesn't make any sense at all. I would write it like this&. Large-scale temporal changes in land use management, biological productivity, and air-sea exchange of CO2 can have a large impact on whether or not a given region is a net source or sink for carbon on an annual basis.

RICHARD A. FEELY, NOAA PMEL

Page 100, line 14: Putting parenthetically that these types of things can "sometimes reduce" sinks is really hiding the fact that for the past 150 years the biosphere has been a rather large source of carbon to the atmosphere. And it is not just land management that contributes to this, but also land conversion (which is not really being managed).

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 100, lines 15-16: Many engineering solutions to sequester atmospheric CO_2 have been proposed, including Fe fertilization of oceans, injection into bedrock, etc. Fossil fuels burned to implement these solutions, as well as used in the extraction, refinement, or manufacture of used fuels or fertilizers, however, count against carbon sequestered by these methods in the full carbon accounting. That manufacture and fertilization maybe separated in space, for example, does not release fertilizers or wood products from carbon debts incurred in their manufacture.

It may be absurd that fossil fuels, which are storing carbon underground, are being extracted and burned in attempts to sequester atmospheric CO_2.

JACK E. JANISCH, OREGON STATE UNIVERSITY (FORMERLY)

Page 100, line 15: Just as uncertainty is associated with climate change, it is essential to indicate that these supposed sequestration options are quite uncertain.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 100, Line 15: Engineering and agronomic (agriculture and forestry) approaches for carbon sequestration ...

LOWRY A. HARPER, USDA-ARS, WATKINSVILLE, GA.

Page 100, Line 15: Engineering and agronomic (agriculture and forestry) approaches for carbon sequestration ...

STEVEN R. SHAFER, USDA-ARS

Page 100; line 15. Reducing CO2 emissions should be discussed along with options for CO2 sequestration, in my opinion.

RICHARD A. FEELY, NOAA PMEL

Page 100, Lines 15–16: "*Engineering approaches for carbon sequestration provide additional options to reduce atmospheric greenhouse gas concentrations or reduce their rate of increase.*"

The text about engineering approaches "*to reduce atmospheric greenhouse-gas concentrations or reduce their rate of increase*" leaves out an obvious approach that is readily available and highly effective—improving energy efficiency. This provides an equivalent effect.

Admittedly, the contextual difficulty here is that carbon sequestration is "post-emission"—it seeks to remove CO_2 already released to the atmosphere —whereas improving energy efficiency is "pre-emission"—it seeks to reduce CO_2 emissions (pre-emission) per unit of output. Because the first paragraph (page 100, lines 7–9) does mention anthropogenic CO_2 emissions, inclusion of energy efficiency here is warranted.

Notwithstanding any contextual difficulty, the text could read as follows:

"*Engineering approaches ~~for carbon sequestration provide additional options to reduce~~* [for reducing] *atmospheric greenhouse gas concentrations or ~~reduce~~ their rate of increase* [include carbon sequestration for increasing sinks and improving energy efficiency for reducing sources].

DAVID L. WAGGER, PH.D., SELF

Question 1 (p. 101), however, is a good start for an American research program and it has much wider scientific implications than North America alone. *[Tans 303-497-6678 – Butler, Dutton, Hofmann, Ogren, Schnell; NOAA/CMDL]*

NOAA/CMDL

Page 101, line 9: Change "predict" to "project"—and be careful not to overplay the potential policy significance of this. While we might do some sequestration here in North America, the US lifestyle causes a lot of loss elsewhere, and this should be a key question being looked at. In addition, sequestration should likely only count the increases in uptake that we cause, not the background uptake that has been going on.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 101, line 22-28. Focus is on interagency and this is a government report but needs to address the private sector as they will be the driving force for change.

SOIL SCIENCE, GLASENER

Page 101, line 28 or before: **(41-S)** Is it appropriate to add to this introduction a statement to the effect that CCSP is concerned with the natural carbon cycle and human impacts on it but not with evaluating/inventing specific sequestration strategies? There is a hint at this on Page 109, but it might be useful to have it here also.

HP HANSON, LANL

Page 101, lines 32-33: Unless regenerating forests are expected to accumulate a biomass greater than that of the original forest, which was cleared, then the atmospheric-forest carbon pools are cycling only and there is no net gain in carbon storage. This needs to be clear so that carbon released when forests are harvested is weighed against carbon sequestered in regenerating forests. Otherwise, carbon sinks will be counted but carbon sources ignored and/or carbon sources relative to the atmosphere could be mis-identified as carbon sinks. In either case, carbon accounting will not balance and carbon sinks may be substantially overestimated.

Data also appear to indicate forest uptake of atmospheric carbon is eventually balanced by carbon losses late in succession—e.g. net carbon exchange is eventually zero. Thus, carbon sequestrations in forests eventually reaches an upper limit. Research suggests this limit is not easily overcome by use of multiple-forest rotations due to carbon loses incurred when trees are harvested. Fairly specific decomposition and growth rates are needed. Climate-change induced temperature or disturbance regime change may also affect predictions of forest carbon stores.

JACK E. JANISCH, OREGON STATE UNIVERSITY (FORMERLY)

Page 101; line 32. Recent modeling efforts using the TransCom-3 results by Gurney et al (2002) have shown that the net sink for carbon in North America is closer to 1.0 billion metric tons of carbon per year. Several other lines of evidence agree with this estimate, including the land-based estimates of Pacalla et al. (2001). I believe the 1.8 estimate is no longer appropriate.

RICHARD A. FEELY, NOAA PMEL

Page 101, line 32ff: This summary of the State of Knowledge is really based on one paper that many in the scientific community do not agree with. It gives a number to two significant figures with no indication of the uncertainty in it—the only such specificity in the whole report. In addition, this contradicts a statement on page 103 indicating that we don't know the sink. The indication of variability alone (for which no range is given, however) suggests that giving a figure to two significant figures is not justified.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 101, l. 34: Could include conversion of eroded soils to grasses (Conservation Reserve Program) and agricultural practices (conservation tillage).

CHUCK RICE, KANSAS STATE UNIVERSITY

Page 101, Line 34: after including add ìconservation tillage,î 102:37 after north America add: ì(such as conservation tillage, pastures, urbanization)î

BONTA, USDA

Page 101, line 39. "from forest inventory.." where is the data from agriculture land surveys? There is and still is a bias towards forestry in the IPCC and this report. Below ground carbon is often lost and or not considered yet it is the largest non-ocean pool.

SOIL SCIENCE, GLASENER

Page 102: On p.102 an important element is missing under Research Needs – specifically the need for sustained measurements of vertical profiles. The North American Carbon Program (NACP), an implementation plan of the U.S. Carbon Cycle Science Plan (CCSP), explicitly identifies as its first priority an atmospheric observing system consisting of sustained continuous measurements on towers, and sustained frequent vertical profiles from small aircraft in the atmosphere. The measurements include CO_2, CO, CH_4, and other species useful for the interpretation of the data, such as isotopic ratios. The current sentence, "multidisciplinary investigation of atmospheric concentrations", is vague and does not clearly represent the NACP plan. *[Tans 303-497-6678 – Butler, Dutton, Hofmann, Ogren, Schnell; NOAA/CMDL]*

NOAA/CMDL

Page 102, line 3: The "errors" should be indicated—if one knows the uptake to two significant figures, then an error (uncertainty) analysis was likely done.

Michael MacCracken, LLNL (retired)

Page 102, line 9, add Research Question:
What is the climate sensitivity of carbon uptake and release?

WELLER, ET AL, UNIVERSITY OF ALASKA FAIRBANKS

Page 102, lines 10-12: The US is currently a sink because it very likely was previously a source. Both should be quantified, and a net estimate generated.

Comments on Chapter 9

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page102; line 11: insert
What are the physical and chemical data that govern the stability of carbon sources and sinks as temperature changes and potentially catalyzing reactions are introduced.

NIST

Page102 Lines 16-21: Biomass and soil carbon inventories are very important, but measurement methods need to be improved to support credible inventories.

PAUL HANSON, ORNL.

Page 102, line 16-27, There needs to be a discussion of the spatial and temporal scales of these observations. For this information to be useful in the decision making process the scales will have to match the decision making scale.

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

PAGE 102; LINE 20. CHANGE TO READ&..OPEN-OCEAN AND COASTAL OCEAN PROCESS STUDIES. RICHARD A. FEELY, NOAA PMEL

Page 102, line 20. 'range lands" really should use grazing lands not range lands, and there is no such thing as an "unmanaged ecosystem". Sounds good from the ecological point of view but no management is management and because of changes in animal species, and plants species all lands are affected by humans so they are really being managed to some extent, or at least influenced. Wet lands (other than cropped ones) are not considered here yet they are very important in the carbon cycle and they are impacted by management practices.

SOIL SCIENCE, GLASENER

Page102 Lines 21-23: What is the justification for the field program on carbon sources and sinks having an initial focus on the central locations of the US? What does center mean? Such a focus seems to ignore forested regions of the east and west that have arguably the greatest carbon storage potential.

PAUL HANSON, ORNL

Page 102; line 24: … entire continent. Temporal and spatial fluxes of fossil fuel sources of CO2 will be needed to resolve the regional fluxes of C from various ecosystems resulting from different land use.

DR. DENNIS OJIMA, COLORADO STATE UNIVERSITY

Page 102; line 24. change to read&. Research on ecosystem and ocean processes that control&&

RICHARD A. FEELY, NOAA PMEL

Comments on Chapter 9

Page 102, line 27, add this sentence to end of paragraph: "Improved global atmospheric observations of CO_2 and related tracers (O_2/N_2, CO_2 isotopes) will be needed to support atmospheric inversions.

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

Page 102, line 28. Blank line need to add the need for "on farm research" All to often research is done on small plots and this does not reflect what is done in the real world of land management and farming.

SOIL SCIENCE, GLASENER

Page102 Lines 29: A product focused on soils should be added to this Question (i.e. Question #1 on page 101).

PAUL HANSON, ORNL.

Page 102, line 31 Change to: "Quantitative measures of atmospheric CO_2 and CH_4 concentrations and related tracers in undersampled locations. Ralph Keeling, Scripps Institution of Oceanography,Michael Bender, Princeton, U., Pieter Tans, CMDL

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

Page 102, lines 38-40. Same comments as above about rangeland.

SOIL SCIENCE, GLASENER

Page 102, line 38: How will these landscape-scale estimates of carbon stocks differ from the estimates currently used to prepare the U.S. national emissions inventory?

DANIEL LASHOF, NRDC

Page 103: Question 2 (p. 103) is good, but it is also incorporated completely into Question 3. This redundancy should be resolved and it would probably be done best by removing Question 3. The oceans remain the largest long-term repository of excess carbon and a research program neglecting the oceans is doomed to fail. Notably, the text includes studying the effects of ocean carbon sequestration (p. 104, lines 15-16), which comes back in Question 6.

[TANS 303-497-6678 – BUTLER, DUTTON, HOFMANN, OGREN, SCHNELL; NOAA/CMDL]

NOAA/CMDL

Page 103, Lines 3-4. Need to get data at field level, that is where land use and land use change will take place. Regional and continental scales are of little use for making on farm decisions nor are regional and continental scale models.

SOIL SCIENCE, GLASENER

Comments on Chapter 9

Page 103, lines 6-8: Will the report be accurate or precise? It is essential that the uncertainties or ranges be given.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 103; line 14. change to read&..large uncertainties remain in this estimate due to regional and seasonal variations in the air-sea exchange of CO2, seasonal and interannual variations in new production, and inadequate representation of the coastal margins in observing systems and modeling efforts.

RICHARD A. FEELY, NOAA PMEL

Page 103, line 16: This is a rather definitive statement, but only about a limited question of local uptake. Is there any definitive indication that this is having any noticeable effect on the global uptake? Are any unused nutrients going back to the deep ocean?

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 103, line 17-18: Iron fertilization of the ocean should not be considered a carbon management option due to the extensive environmental impacts likely to attend any widespread application.

DANIEL LASHOF, NRDC

Page 103, line 21: So now we only have "estimates—there are uncertainties.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 103, lines 36-39: Well, now it seems that we have to get much more information. This all really needs to be redone indicating that we have estimates now and the objective is to get the research to reduce the estimated ranges and improve confidence in the estimates.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 104: Question 3 (p. 104) is redundant and unnecessary. The "State of Knowledge" paragraph suggests that the intent is perhaps to promote in some vague way satellite observations. We already have land use and management in Question 4, which seems to leave unaddressed "natural" changes (at least "not deliberate" manipulations) in terrestrial ecosystems responding to global change. But one could argue that those are already included in Question 1 because undoubtedly we are going to learn about those things in the NACP. Therefore, we strongly recommend removing Question 3. (Reinforcing our recommendation to remove Question 3 is the formulation of "Illustrative Research Questions", which is inexplicably broad and vague.) The satellite observations can easily be woven into the other Questions.

[TANS 303-497-6678 – BUTLER, DUTTON, HOFMANN, OGREN, SCHNELL; NOAA/CMDL]
NOAA/CMDL

Page 104; line 2. The timing for the southern ocean work should not be highlighted by itself. The most appropriate course of action is to create a timeline for all of the program activities. This is an activity of the CCSP scientific steering committee that is still under discussion.

RICHARD A. FEELY, NOAA PMEL

Page 104; line 6: Products and Payoffs: Change to the following: Quantification of the variability of the air-sea exchange of CO2 in the North Atlantic and North Pacific on seasonal to interannual time scales using in-situ and remote measurements (> 4 yrs)

Inventories and changes in the rates of uptake of both natural and anthropogenic CO2 in the ocean interior. There is evidence that oceanic ventilation and rates of biogeochemical processes vary during events such as the Pacific Decadal Oscillation, the North Atlantic Oscillation, and the El NiÒo-Southern Oscillation. Understanding these variations will allow us to document the influence of interannual and decadal variability on ocean uptake of fossil CO2, and the governing processes (> 4 yrs).

Improved models of ocean biogeochemical processes based on linkages with ocean observations from repeat transects and time-series measurements (2-4 yrs).

RICHARD A. FEELY, NOAA PMEL

Page 104, Line 7-9: There is a need for observations of nutrients in the below the surface to help evaluate model performance.

RONALD STOUFFER, GFDL/NOAA

Page 104, line 14: autonomous, stable, and easily calibrated CO2 sensors (> 4 years).

NIST, HRATCH SEMERJIAN

Page 104, line 27, Reinsert sentence from white paper: "These tools and techniques include use of chemical tracers, isotopes, ratios of O2 to N2 and improved analysis and modeling capabilities." Ralph Keeling, Scripps Institution of Oceanography,Michael Bender, Princeton, U., Pieter Tans, CMDL

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

Page 104, line 28: The phrase "with significant uncertainties" needs to be defined to make any sense. This needs to be done in the context of the type of question being posed. If global emissions continue their rapid increase, the uncertainties in the carbon budget don't matter much at all, whether in terms of carbon concentration or, more importantly, in terms of temperature response. On the other hand, if there is a commitment to achieving stabilization of the atmospheric CO_2 concentration, then the uncertainties are important. Using a word like "significant" in a blanket way is simply inappropriate.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Comments on Chapter 9

Page 104, lines 36-37: These are strangely phrased questions—what we need to have are quantitative results with indications of the likely ranges or uncertainties.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 105, Line 8. Insert "improved process models" after "development of".

JOE BERRY, CARNEGIE INSTITUTION.

Page 105, lines 15-17: The dialogue with stakeholders should already be ongoing. It is nice to see a recognition that there will need to be international cooperation—mention of the relevant programs would be useful.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 105, lines 20-37: Without an indication of funding needs and amounts, these indications of a time period are meaningless. What should be stated is how much would be needed over what period to reduce the uncertainties by how much—so what estimated improvement in accuracy can be gotten for what level of investment?

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 105, line 41 to Page 106, line 2: This is all quite vague—really need to be more specific about what types of information will be transferred, etc.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 106, Line 3: Specific comment [page 106, line 3]. Potential of hyper-spectral imaging for the detection of "effects of land use changes"

OSMOND, COLUMBIA UNIVERSITY

Page 106: Question 4 (p. 106) is good and appropriate. Land management has likely been the major driver of changes in terrestrial carbon storage until now. This is an appropriate place to address human dimensions. *[Tans 303-497-6678 – Butler, Dutton, Hofmann, Ogren, Schnell; NOAA/CMDL]*

NOAA/CMDL

Page 106, lines 9-10: While wood products can count towards carbon storage, their generation does not automatically guarantee carbon is being sequestered. Under prevailing harvest practices, roughly 50% of above-ground mass of a harvested live tree is often converted to CO_2 within a couple years of harvest. This is because much of the tree's tissues exist as or are converted to fine/waste material during the machining processes that then rapidly decompose, are burned, etc. Thus wood products can store carbon, but much carbon has historically been released in their manufacture. For the wood products industry to claim storing carbon in lumber, etc using short rotations is equal or superior to using long forest rotations to store carbon it must show carbon in lumber is accumulating over short rotations relative to carbon stores in forests being logged. This implies that evaluating whether forests are c sources or sinks relative to the atmosphere is a question of c mass pools as well as growth rates and decomposition rates over forest succession.

Given this, it would be inappropriate to point to a newly built house and say it was storing carbon without weighing the carbon mass 'stored' in the house against carbon loses incurred throughout the harvest and manufacturing cycle (e.g. dead roots, foliage, bark, etc). We also know that unless locked up in some form of permanent storage, such as a land fill, wood products ultimately decompose, even if they hang around in buildings for a century or two. Most structures, however, do not last this long, and not many people want new landfills in their backyards.

JACK E. JANISCH, OREGON STATE UNIVERSITY (FORMERLY)

Page 106, lines 10-12: As with forests, increased crop growth does not guarantee increased carbon storage. Increased NPP of annual crops, for example, may mean shorter growth cycles but each is still followed by a decomposition cycle.

JACK E. JANISCH, OREGON STATE UNIVERSITY (FORMERLY)

Page 106; line 15: …Change research and Human Contribution research elements to…

DR. DENNIS OJIMA, COLORADO STATE UNIVERSITY

Page 106, line 31-39:
The statement of research needs supporting maintenance and enhancement of long-term experimental sites is most welcome and necessary. However, with the possible exception of the Long-Term Ecological Research (LTER) network these are actually a set of sites with individual research histories and not a "national network" in a meaningful sense for global change science purposes. Even the USDA Forest Service Forest Inventory and Analysis (FIA) program operates on different standards across the country. For example, southeastern states with commercially valuable timber resources are inventoried thoroughly, frequently, and to greater standards of precision than elsewhere. In Alaska, the "national" FIA program still has incomplete ground coverage, and major uncertainties because standards are set for large estimation error. The existing data sources are really only capable of a pilot study of carbon sources and sinks. A commitment to build a sustained program with common standards and network direction, studies, and reporting is required, and it is certain to be more than a 2 to 4 year effort.

WELLER, ET AL, UNIVERSITY OF ALASKA FAIRBANKS

Page 107: Question 5 (p. 107) is somewhat repetitive because if we understand the dynamics of the carbon cycle on land (Q.1 & 4) and in the oceans (Q.2) we can make a reasonable prediction of its future. What's missing is that climate change itself could significantly affect our predictions for the carbon cycle even if we understand carbon dynamics pretty well. CH_4 is specifically mentioned here and Human Dimensions pops up. With respect to Human Dimensions, obviously the future anthropogenic emissions of greenhouse gases are an important factor in determining future atmospheric concentrations, but it is not a good idea to ingest a prediction of human policies into a physical/chemical/biological coupled model. We should work with emissions scenarios as outside boundary conditions. Then the coupled models can tell us how the physical world is expected to respond to our actions. How society can achieve certain emissions targets is better treated as a separate problem. *[Tans 303-497-6678 – Butler, Dutton, Hofmann, Ogren, Schnell; NOAA/CMDL]*

NOAA/CMDL

Page 107, line 1-2, Techniques exist for the estimation of above ground biomass from remote sensing platforms. These provide estimates within the same degree of error as ground-based estimates.

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

Page 107, lines 8-22: This use of greater than 4 years is really vague—is it 10 or 100 years, and for what level of improved quantification?

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 107 Lines 15-16: I support the emphasis on understanding land use change implications on biomass and soil carbon storage.

PAUL HANSON, ORNL.

Page 107, line 29: The question needs to be rephrased to indicate that what we want are improved estimates—we already have some estimates--and what level of certainty is likely or can be achieved.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 107, Line 32: Lack of observations is also a big problem.

RONALD STOUFFER, GFDL/NOAA

Page 108: Analysis of global CH4 dynamics, with the potential for reduced uncertainties, based on 34 a new synthesis of observational data and improved modeling (2-4 years). 35

Here, too, paleoclimate studies can play an important role in testing models. There have been very important changes in CH4 during the holocene, and in the course of glacial-interglacial cycles. These provide an excellent test of methane source and sink models. Much the same could be said with regard to CO2. In fact, resolving the reason for low CO2 during glacial times would be the crowning achievement indicating that we really understand carbon uptake by the oceans (we currently don't)

RAYMOND PIERREHUMBERT, THE UNIVERSITY OF CHICAGO

Page 108, Line 1-42: There is no discussion of future emissions. Are these estimates to come from the IPCC?

RONALD STOUFFER, GFDL/NOAA

Page 108, lines 1-5: Why is there no mention of methane clathrates and their potential to affect the carbon cycle—or at least radiative forcing. This could also be done on page 109 in the set of questions.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 108; line 10. Add the following: How will the ocean carbonate system respond to future increases in CO2, changes in circulation, and inherent climate variability.

RICHARD A. FEELY, NOAA PMEL

Page 108; line 22: … interacting factors influencing ecosystem emission from soil, livestock, and vegetation of CH4 and human …

DR. DENNIS OJIMA, COLORADO STATE UNIVERSITY

Page 108 Lines 28-43: The time frames for products and payoffs for Question 5 are generally reasonable and should be solidified. Deadlines produce results! The deadline for a synthesis of whole-ecosystem warming will likely exceed 4 years. A true whole-ecosystem warming study has yet to be attempted in my opinion. A number of soil-only warming studies that have been going for many years should be summarized in the next two years.

PAUL HANSON, ORNL

Page 108; line 30. Advanced ocean carbon ecosystem models that are able to simulate carbon uptake via biogeochemical processes (> 4yrs).

RICHARD A. FEELY, NOAA PMEL

Page 108, line 30: Though we know little about such modeling, the goal of simulating interannual variability of carbon at landscape scales in 2-4 years seems a tad ambitious. Do sufficiently detailed observations exist (especially of soil carbon) to validate such models?

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

Page 109-110: Chapter 4 poses the following as an important research question:

> "HOW WILL THE EARTH SYSTEM, AND ITS DIFFERENT COMPONENTS, RESPOND TO VARIOUS OPTIONS BEING CONSIDERED BY SOCIETY FOR MANAGING CARBON IN THE ENVIRONMENT, AND WHAT SCIENTIFIC INFORMATION IS NEEDED FOR EVALUATING THESE OPTIONS?"

IN ADDRESSING THIS QUESTION, THE *DRAFT STRATEGIC PLAN* FOCUSES ON NATURAL CARBON SOURCES AND SINKS AS WELL AS THE POTENTIAL TO AUGMENT TERRESTRIAL AND OCEAN SINKS THROUGH RESOURCE MANAGEMENT (E.G., AGRICULTURE AND OTHER LAND MANAGEMENT PRACTICES). HOWEVER, THE ISSUE OF GEOLOGIC SEQUESTRATION AND ITS IMPLICATIONS FOR CARBON MANAGEMENT AND THE CARBON CYCLE IN GENERAL ARE NOT MENTIONED, DESPITE THE FACT THAT THIS COULD BE A PROMISING TECHNOLOGY WHICH HAS THE POTENTIAL TO HAVE A LARGER IMPACT ON THE FUTURE CARBON CYCLE THAN RESOURCE MANAGEMENT. ALTHOUGH GEOLOGIC SEQUESTRATION MAY BE

VIEWED AS A TECHNOLOGICAL CHALLENGE, AND THUS MORE APPROPRIATE FOR THE CLIMATE CHANGE TECHNOLOGY INITIATIVE, THE IMPLICATIONS OF GEOLOGIC SEQUESTRATION FOR THE CARBON CYCLE AS WELL AS POLICY WOULD APPEAR TO FALL UNDER THE REALM OF THE CCSP.

VICKI ARROYO AND BENJAMIN PRESTON, PEW CENTER ON GLOBAL CLIMATE CHANGE

Page 109-110: The text following Question 6 (p. 109-110) has significant overlap with that in Question 5. Perhaps the text (and questions?) can be reformulated to emphasize the difference between "natural" changes (Q.5) and deliberate management (Q.6). *[Tans 303-497-6678 – Butler, Dutton, Hofmann, Ogren, Schnell; NOAA/CMDL]*

NOAA/CMDL

Page 109, line 9ff: Here and in the other sections, the State of Knowledge statements are very vague and not really of sufficient content for a scientific report.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 109, Lines 9-12: "*Questions about the effectiveness of carbon sequestration, the longevity of storage, **the practicality of reducing emissions**, technological options, resultant impacts on natural and human systems, and the overall economic viability of carbon management approaches create an imperative for better scientific information to inform decisionmaking to manage carbon.*"

While this sentence argues for better "scientific information", "practicality" has little to with "scientific information". It is one thing to state that the *effectiveness* of reducing emissions (to prevent or mitigate climate change) is scientifically unsubstantiated; it is a completely different (and also incorrect) thing to state that the "*practicality* of reducing emissions" is scientifically unsubstantiated. "Practicality" is largely a sociopolitical or an economic consideration, and as such, it does not belong here in the text.

DAVID L. WAGGER, PH.D., SELF

Page 109, Line 13: Once again the report states that "there is limited scientific information to support carbon management strategies." This statement is not accurate. As noted in other comments, there is a wide literature and practical experience on carbon management strategies. Perhaps it would assist the study to speak with companies such as British Petroleum, Alcoa, Shell, Lafarge, Dupont and many others who have carbon management strategies in place and are saving money. The above quote in line 13 should be deleted from the report here and in the other chapters where it appears. It is however true that much must be learned in the field of carbon sequestration and storage. If that is the intent of this section it should be clarified.

JENNIFER MORGAN, WORLD WILDLIFE FUND

Page 109, Lines 13-15: "*Presently, there is limited scientific information to support carbon management strategies, and little is known about the long-term efficacy of new* *management practices for enhancing carbon sequestration or reducing emissions or how they will affect components of the Earth system.*"

This sentence is vague because "carbon management strategies" is not clearly defined. On the face of it, this sentence may well be false. For instance, improving energy efficiency is effective and provides continuous benefits relative to the status quo.

DAVID L. WAGGER, PH.D., SELF

Page 110; line 7 after end of sentence: insert
In many cases, physical and chemical data will need to be obtained in order to develop such models.

NIST

Page 110, line13: The key issue is not measuring the change in carbon stock over time, but rather the change in carbon stock that can be attributed to a given management activity. This requires careful attention to the "no project" baseline, as well as confounding factors, including climate variability and change and changes in atmospheric composition.

DANIEL LASHOF, NRDC

Page 110, line15: Many biophysical potential studies have been conducted. These have limited value due to the disconnect between the physical potential and what could be achieved in practice.

DANIEL LASHOF, NRDC

Page 110, lines 15-18: The real question is what the long-term potential is for sequestration—not so much short-term management. The emphasis on this seems a bit overstated unless sequestration is viewed mainly as a transition mechanism until other energy technologies are available.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 110, Line 26: We would suggest adding another product - assessing the mitigation options to keep CO2 and other GHGs from being emitted in the first place.

JENNIFER MORGAN, WORLD WILDLIFE FUND

Page 110, line 39: **(42-E)** Land use is Chapter 8. (I happened to catch this. Other such cross-referencing should be cross-checked.)

HP HANSON, LANL

Page 111, lines 11-15: Such coordinated efforts really take time, and allowance should be made for this.

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 111, line 15-16: What sorts of bilateral activities that would make a difference are envisioned? What would be their intent?

MICHAEL MACCRACKEN, LLNL (RETIRED)

Page 111, line 17: Not listing any references is not acceptable given the very limited summaries of the state of knowledge. The IPCC report, among other scientific reviews, provides one baseline for the science.

MICHAEL MACCRACKEN, LLNL (RETIRED)