

**Collated Public Comments**  
**Public Comment Period 04/23/08-06/09/08**

SAP 5.2 "Best practice approaches for characterizing, communicating, and incorporating scientific uncertainty in decision making"

**Reviewers:**

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Sent by Marta Cehelsky ([mcehelsk@nsf.gov](mailto:mcehelsk@nsf.gov)) on behalf of Kathie Olsen

## GENERAL COMMENTS

### **NOAA-RC**

The NOAA Research Council requested reviews of the Draft Synthesis and Assessment Product 5.2, "**Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Climate Decision Making**". This report is one of 21 synthesis and assessment products being prepared by the U.S. Climate Change Science Program (CCSP). This is an opportunity for NOAA to provide a thorough review that will help improve the final government report. The Council Executive Secretariat received the following comments during the public comment period, which we will submit to the CCSP office for its consideration as part of the overall public comments.

As the title implies and is stated on line 67, this is a tutorial. It seems to fill that bill. It is a lengthy discussion of what is known and not known about climate change. It does not state what the outlook is for climate change, but only the research that has been done and statements about the findings and implications. The wording is very careful.

The report brings home the tremendous difference in weather prediction and prediction of climate change. There are places one would expect to see a connection made and more references to the meteorological literature, for instance Lorenz's seminal work on non-periodic flow.

Also, in one of the few references to anything being done today in weather forecasting, the PoP forecasts are attributed to the "Weather Bureau" which no longer exists.

**RESPONSE: We have added a paragraph in Part 1 on chaotic systems that includes a reference to Lorenz' 1963 paper "Deterministic nonperiodic flow" in the *Journal of Atmospheric Science*. We have removed all references to "Weather Bureau".**

There are a few references to the IPCC, and the document seems at points to be questioning the IPCC reports. The discussion on line 465 sets the stage for that. Line 1633 questions the IPCC "...strategies for producing IPCC summary statements..."

**RESPONSE: We have added two additional references near line 1633, one of which is a Policy Forum piece in *Science* that makes the same point. We have also added language from "Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainty."**

The concept of "odds" is not defined and is used incorrectly throughout. The "odds" of an event is defined as the ratio of the probability of occurrence of an event to the probability of its non-occurrence. Therefore, odds of 1 to 999 are associated with a probability of .001. Also, note that the preposition "to" rather than "in" is used in connection with odds; while, probabilities are given as, say, "1 chance in 1000" for a probability of .001.

**RESPONSE: We have added footnotes that read "Strictly odds are defined as  $p/(1-p)$  but when  $p$  is small, the difference between odds of 1 in 99 and 1 in 100 is often ignored when presenting results to non-technical audiences."**

## ***NOAA-RC-COMMENTS ON FIGURES***

**Fig. 2.1:** Seems the scale would normally be from 0 (on the left) to 1.0 (on the right) instead of the way it is presented. That use is also in Fig. 2.2. However, Fig. 2.3 runs zero to unity. Why mix the orientations?

**RESPONSE:** This is the way the authors published their findings.

**Fig. 3.3:** There are two lines on A, but neither is identified. I believe the curved line is the "trend line." The diagonal is what would be called perfect reliability in the meteorological world. Also, normally, I would expect the "estimated" to be on the abscissa and the outcome to be on the ordinate. Suggest the scales be the same on the abscissa and ordinate, and the diagram be square with equal scales. Then the role of the diagonal line would be more apparent.

**RESPONSE:** This is the way the authors published their findings. Presumably they did not make the diagram square because there is considerable compression in the respondent's judgments. The reviewer correctly interpreted the lines, suggesting that the problem is not serious. However, we have added an explanatory sentence in the caption.

**Fig. 5.2:** Not sure these figures are documented quite well enough. Today's condition noted would be helpful. I suppose in the left figure, given no increase would be zero? If the abscissa on the right figure is the mean temperature difference between the pole and the equator, what is it today?

**RESPONSE:** We have added clarifying text to the caption.

**Fig. 6.3:** I didn't note the background for "structural uncertainty." I presume this means the model errors were not considered.

**RESPONSE:** The language has been modified to clarify this issue.

**Fig. 6.5:** Not sure I understand it. For instance, RFF made an estimate of the primary energy consumption for 2000 in 1964 of 135, and it turned out to be 80? The ordinate does not go to zero, so at what point is the "actual consumption in 2000" line? The use of a line to express the actual, extending over all years, but not extending to 2000 seems confusing. Why not leave the line off and just state the actual value?

**RESPONSE:** We believe that the diagram is clear. We've had hundreds of folks look at it in various contexts over the past 6 months, and none have had any problem interpreting it correctly. Indeed, that reviewer has also interpreted it correctly. We have made no change.

## ***NOAA/OFCM***

The Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) appreciates the opportunity to review Synthesis and Assessment Product (SAP) 5.2, "Best Practice Approaches for Characterizing, Communicating and Incorporating Scientific Uncertainty in Climate Decision Making." We offer general and specific comments below for your consideration when updating the SAP.

We believe that the SAP is well written and provides useful and instructive information. However, we believe that the next draft of this document should include a discussion on the following two elements:

(1) How the user perceives vulnerability and how that perception influences the user's assessment of uncertainty. For example, if people perceive that they are not vulnerable to a particular event or atmospheric condition, they may become overconfident and not exercise sound judgment in making decisions or assessing risk.

**RESPONSE: CCSP 5.2 addresses the issue of how expert professionals should characterize and deal with uncertainty in the analysis of climate change and its likely impacts. It is not intended to address issues of how laypeople perceive and make judgments in the presence of risk and uncertainty.**

(2) Past experience and how past experience influences risk acceptance. For example, if people's past behavior in response to a particular event or atmospheric condition resulted in no adverse impact, people may become overconfident in assessing risk in the present situation and, as a result, may be willing to accept more risk than is, perhaps, prudent.

**RESPONSE: Again, CCSP 5.2 addresses the issue of how expert professionals should characterize and deal with uncertainty in the analysis of climate change and its likely impacts. While the behavioral responses of lay decision makers is an important topic, it lies outside of the scope of this paper.**

The document has a number of grammatical and typographic errors. Some of these errors are listed in the specific comments below. Before issuing the next version of the SAP, please ensure that these errors have been corrected.

**RESPONSE: The lead author and an expert editor we retained have done a careful proofreading. If there are specific problems we have missed, please point them out.**

## ***SUSAN SOLOMON***

General-Lines 1-3107. Please change all occurrences of the use of the word 'we' to 'I', consistent with the comment on lines 50-54 (and the way it is done sometimes in this document).

**RESPONSE: Morgan is not the sole author. The language on the cover page has been changed to a "lead author" and "contributing authors" format to more clearly reflect this fact.**

### ***CECIL DEWAYNE***

As you know, I have reservations about putting out this SAP without an explicit statement that it may not outline what other SAPs give as guidance for documenting and communicating uncertainty and in fact, may be at odds with some of the guidance given in other CCSP reports. We should further state that more detailed discussion of uncertainty specific to and associated with topics in other SAPs is more appropriately given in those SAPs. Hopefully some explicit statement to this effect has been added to 5.2. Additionally, I know the decision has been made to not expand the scope of 5.2 to address this issue among others. Do you know if the decision been made to expand our discussion of uncertainty in the physical science behind, and social impacts of, climate variability and change in a formal CCSP document?

**RESPONSE: We were asked to produce a review and best advice given the current state of the art. The fact that several SAPs were done in parallel, and adopted somewhat different strategies, should not constrain future analysts to use those strategies. To clarify this point we have added a new and expanded footnote to the start of Part 9.**

**We are unable to answer the question posed at the end of this comment.**

### ***JOHN SENN***

Chapter 8, Page 134, Lines 2752 and 2753: Comment: I think it would be helpful to explain/define what a "non-technical" audience member is as well as why reaching out to those people is important. I don't have specific language to insert or resources to suggest, but I think it's imperative to discuss the importance of communicating complex information to an audience with a basic scientific knowledge.

**RESPONSE: In the preface we write:**

**While the language is largely semi-technical, much of it should also be accessible to non-expert readers who are comfortable with treatment of technical topics at the level of journals such as *Scientific American*. We have also prepared a "Non-Technical Summary." Readers who lack the time or background to read the detailed report, may prefer to start there...**

**We believe that this implicitly says that we define "non-technical audience" as those who are *not* comfortable with treatment of technical topics at the level of journals such as *Scientific American*.**

**We have added a phrase near the end of the preface to explain why we are including this non-technical discussion.**

### ***STEVEN SHERWOOD***

Overall: I enjoyed reading this and felt that the informal tone was very welcome and useful, especially the summaries (where I have no critical comments to offer). Bravo to the authors.

**RESPONSE: Thank you for your kind words.**

## ***NATIONAL SCIENCE FOUNDATION***

NSF has no specific comments on the technical aspects of the report. There are a number of spelling and punctuation errors that, no doubt, a technical editor will correct. We do have some issues regarding the organization, structure, and tone of the report that should be considered by the authors.

The current Executive Summary reads more like an introduction to the report in that it identifies the types of issues discussed in each section rather than providing the key conclusions and recommendations of the overall report. Perhaps this could be revamped and used as an introduction.

The "Non-Technical Summary" has very useful information and examples at the non-technical level. However, the style is somewhat informal compared to other SAPs and the "tone" comes across as patronizing of non-specialists. If shortened and rewritten, it could serve as the Executive Summary, although it would be important to capture the key points of conclusions and recommendations (and not section by section) rather than referring the reader to a section of the report for specifics.

**RESPONSE: We have been round and round on the issues of an "Executive Summary," whether there should be a "Non-Technical Summary," and similar matters.**

**Our original instructions from Jim Mahoney and Richard Moss were to write a summary of the state-of-the-art and guidance for expert practitioners, which we did.**

**When NOAA arranged for the NRC to review the document they broadened the scope to include other audiences, which resulted in the NRC review complaining that the document did not address the needs of those audiences. To accommodate this broadened objective, we wrote the rather extended non-technical summary. If we made it more formal and shortened it, it would no longer meet that need. We tried hard to write it in a straightforward style. Since receiving this comment, we have had several non-technical people read it and they report that they do not find it "patronizing." If NSF has specific counter evidence, we'd value receiving that.**

**Given that much of this paper is a review of the state of the art, we believe that organizing the Executive Summary on a section-by-section basis is the most useful way to help busy readers learn what is covered, or find what they are looking for.**

**Perhaps if the goal posts had not moved several times over the course of this effort, the organization would have been different. As it is, we do not propose to change any of the front matter.**

## SPECIFIC COMMENTS

### Executive Summary

#### *NOAA RC*

Executive Summary, Page 5, Line 77: Change 'introduce' to 'introduces'.

**RESPONSE: Change made.**

#### *NOAA/OFCM*

Executive Summary, Page 5, Lines 77-78: The word "introduce" should be plural as it is used in this context. Later in the same sentence, the word "frequentist" should be defined in a footnote to assist understanding by the more general public reader of this document. Please consider making the suggested modifications in the updated version of the SAP.

**RESPONSE: We have made the word plural and have added an explanatory phrase after frequentist.**

Executive Summary, Page 6, Line 94: The term "cognitive heuristics" should be further described in this sentence or in a footnote to assist understanding by the more general public reader of this document. The term is explained later in the document but the reader will encounter this term for the first time in the Executive Summary. Since some readers may only read the Executive Summary, we believe it is worthwhile to define "cognitive heuristics" in the Executive Summary. Please consider defining this term in the updated SAP's Executive Summary.

**RESPONSE: We have added a phrase to clarify.**

Executive Summary, Page 7, Lines 128-131; and PART 8. COMMUNICATING UNCERTAINTY, Page 137, Lines 2822-2825: The text on Lines 128-131 and Lines 2822-2825 reads: "One key finding [in this literature] is that there is no such thing as an expert in communication – in the sense of someone who can tell you ahead of time how a message should be framed, or what it should say. Empirical study is absolutely essential to the development of effective communication." To add clarity to the important subject of effective communication, we recommend changing the two sentences to read as follows: "One key finding is that empirical study is absolutely essential to the development of effective communication. With this in mind, there is no such thing as an expert in communication – in the sense of someone who can tell you ahead of time (i.e., without empirical study) how a message should be framed, or what it should say." Please consider incorporating this modification in the updated SAP.

Note: The above change also makes the text more consistent with that in Part 8, page 136, Lines 2806-2809. The text in these lines reads: "One of the clearest findings in the empirical literature on risk communication is that there is no such thing as an expert who can design effective risk communication messages without some empirical evaluation and refinement of those messages with members of the target audience."

**RESPONSE: We have changed the language as requested in all three places where it appeared in the report.**

### ***SUSAN SOLOMON***

Preface, Lines 50-54: This report is different not just in that it is methodological; it is also single-author. That is a very important aspect that makes this document quite different from other CCSP assessment products that have appeared thus far, and the implications of this should be stated clearly here. Please add a few sentences indicating this. Suggested text is: "This report was written by a single author with advice and contributions from 7 other uncertainty experts. Unlike other CCSP products, it does not represent the joint efforts of a team of multiple authors and hence cannot be considered a consensus reflecting multiple views across a range of experts in the field."

Lines 1-3107: Please change all occurrences of the use of the word 'we' to 'I', consistent with the comment on lines 50-54 (and the way it is done sometimes in this document).

**RESPONSE: Morgan is not the sole author. The language on the cover page has been changed to "lead author" and "contributing authors" format to more clearly reflect this fact. All the authors have agreed on the entire text, and several contributing authors wrote extended portions of the paper.**

### **Non-Technical Summary**

#### ***NOAA RC***

Non-Technical Summary, Page 14, Line 254: Another source of measurement error, not identified in this section, is the error associated with using a point measurement to represent an area (e.g., rain gauges used to estimate rainfall over a region).

**RESPONSE: We have added language that introduces this idea.**

Non-Technical Summary, Page 14, Line 264: "...if the sum of rainfall..." seems better.

**RESPONSE: Change made.**

Non-Technical Summary, Page 14, Line 269: Remove 'Finally' (used again at the beginning of the next paragraph)

**RESPONSE: Change made.**

Non-Technical Summary, Page 21, Line 421: Incomplete sentence '... mathematical models fit existing.'

**RESPONSE: Added the missing word "evidence."**



Non-Technical Summary, Page 24, Line 493: "set" takes the singular form of the verb "has" rather than "have."

**RESPONSE: Change made.**

Non-Technical Summary, Page 26, Line 537-538: Remove 'Many weather forecasters and other technical professionals have argued that one should not try to communicate about uncertainty to non-technical audiences'. This is not true; weather forecasters do communicate probabilistic precipitation forecasts and stream flow forecasts. Additionally, there are efforts in the National Weather Service to communicate more uncertainty information regarding forecasts.

**RESPONSE: We believe that the statement was true as written. We also agree that NOAA, the National Weather Service, and many others have worked hard to improve the communication of uncertainty about forecast to non-technical audiences. We have removed the explicit reference to "weather forecasters."**

Non-Technical Summary, Page 26, Line 545: Change 'weather bureau' to 'National Weather Service.'

**RESPONSE: Corrected the language here and elsewhere.**

Non-Technical Summary, Page 28, Lines 573 and 580: "Small wonder" is used twice in close proximity.

**RESPONSE: Replaced both with better language.**

### ***SUSAN SOLOMON***

Lines 184-223: This box contains material that is confusing and in some cases incorrect. Among the difficulties are that it omits deforestation as a major source of carbon dioxide (not just coal, oil, or natural gas); I found this misleading. Further, I don't think there is a well-defined standard of a 'conventional pollutant' that stands in contrast to the global warming issue, so I had difficulty with that phrase. Please note that carbon dioxide and other long-lived greenhouse gases are one example of a type of persistent pollutant but there are many others (persistent organic pollutants for example). The diagram above line 193 is not incorrect in principle but the description of it is too oversimplified, because at least two major greenhouse gases do behave this way, tropospheric ozone and methane (and it is noteworthy that the latter has been observed to stabilize in the past decade so the picture isn't correct for the #2 greenhouse gas; I don't find the use of the word 'most' helpful with regard to this). I had difficulty with so much of this box that my recommendation is to drop it.

**RESPONSE: We are trying to keep things simple for a lay audience. We have found that large numbers of lay people simply do not understand that once emitted, CO<sub>2</sub> remains in the atmosphere for a very long time so that stabilizing emissions is not sufficient.**

**We have added a reference to land clearing and forest burning.**

**We have modified the phrase that said "most other" to read "several other." (Note: while CH<sub>4</sub> has a half-life of decades, H<sub>2</sub>O, which is the most important greenhouse gas of all, has a half-life of days). The relevance of POPs, metals, or other long-lived pollutants in soils and aquatic ecosystems to this simple explanation is unclear to us, and we have not introduced that complication.**

Lines 462-465: Please state the significance of this sentence or drop it. It might mean that the process of discussion with colleagues helps any researcher (no matter how expert) to improve their understanding of possible errors, while working in isolation doesn't. Or it might mean that IPCC doesn't have the right membership (not sufficiently broad). Without information on how to interpret this statement, it is not appropriate in an assessment because it is left dangling as to its import.

**RESPONSE: In response to another reviewer's comment above, we have elaborated and added references on this issue in the main text. We do not believe that any change is needed in the non-technical summary.**

***MARILYN AVERILL***

Non-Technical Summary, Page 9, Line 163: Clarify. Consider changing to "How human activities and choices may result in emissions of gases and in particles, and in changes in land use and vegetation, which together can influence future climate."

**RESPONSE: The suggested change has been made.**

Non-Technical Summary, Page 11, Line 203: 70% to 90% of what baseline?

**RESPONSE: Added "from today's levels."**

Non-Technical Summary, Page 12, Line 221: 70% to 90% of what baseline?

**RESPONSE: Added "from today's levels."**

Non-Technical Summary, Page 12, Line 226: Change to "and otherwise deal with uncertainty in describing and explaining climate change and its impacts."

**RESPONSE: We have not changed. The current text is a more accurate description of the objective of this report.**

Non-Technical Summary, Page 18, Line 343: A word is missing after "fit existing."

**RESPONSE: Added the word "evidence."**

Non-Technical Summary, Page 22, Line 439: Add language: "occurred, and some uncertainties will never be resolved."

**RESPONSE: While we agree that there are uncertainties that will never be resolved, given that the paragraph is phrased in terms of "how climate may change over the coming decades and centuries" the key uncertainties about what will change will be resolved once the changes have occurred. We have not complicated the sentence with the addition.**

## **Chapter 1**

### ***NOAA RC***

Part 1, Page 37, Line 756: Comma after "empirical."

**RESPONSE: Comma added.**

### ***NOAA/OFCM***

Part 1: Sources and types of uncertainty, Page 14, Lines 247-253: The text on these lines summarizes how systematic errors contribute to uncertainty. We believe that it would be helpful to provide more examples of systematic errors. Therefore, we recommend appending the following text to the last sentence on line 253: "Further inaccuracies and uncertainties occur with the recording, reporting and archiving of measurement data." Please consider incorporating this text in the updated SAP.

**RESPONSE: A sentence has been added.**

Part 1. SOURCES AND TYPES OF UNCERTAINTY, Page 33, Line 681: The text on this line reads, in part: "... should be the sum or their probabilities." We believe the word "or" should be "of." Please incorporate this correction in the updated version of the SAP.

**RESPONSE: Correction has been made.**

Part 1. SOURCES AND TYPES OF UNCERTAINTY, Page 37, Line 755: The text on this line reads: "... such as demand elasticity's or prices in economics ..." We believe the word "elasticity's" should be changed to "elasticities" so that the text reads: "... such as demand elasticities or prices in economics ..." Please incorporate this correction in the updated version of the SAP.

**RESPONSE: Thanks...the changes editors make! We have corrected this.**

Part 1. SOURCES AND TYPES OF UNCERTAINTY, Page 41, Lines 842-843: The text on this line reads: "Many of the big issues we have reported on involve scientist quibbling about small degrees of uncertainty." We believe the word "scientist" should be changed to read either "scientists" or "a scientist." Please incorporate this correction in the updated version of the SAP.

**RESPONSE: Typo corrected.**

***PETER GUTTORP***

This is a very limited (and limiting) view of when uncertainty can be well described by a distribution. In the Bayesian framework of de Finetti (and many others) there is no need for a "true value", there is only uncertainty described by distributions. The concept of empirical quantities, in the context of climate models and, more generally, modern measurement devices, is not well defined.

**RESPONSE:** The statement is correct, but given that we are talking about atmospheric and other physical and biological processes that do exist, and for which at least in principle there are "true values", we do not think that a change is warranted.

**Chapter 2**

***PETER GUTTORP***

Chapter 2, Page 49, Line 977: I think it would be appropriate to refer to (and discuss) the definitions set forth in the fourth assessment of IPCC, working group 1.

**RESPONSE:** We have added text and a table that does so.

***NOAA/OFCM***

Part 2: The importance of quantifying uncertainty, Page 17, Line 337: The text on this line reads: "One the other hand ..." We believe the word "one" should be changed to "on." Please consider incorporating this correction in the updated SAP.

**RESPONSE:** Typo corrected.

**Chapter 3**

***NOAA/OFCM***

Part 3. COGNITIVE CHALLENGES IN ESTIMATING UNCERTAINTY, Page 55, Line 1136: Text on this line reads: "The heuristic of 'representativeness' says that people expect to see in single instantiations ..." We believe the term "instantiations" should be defined or explained in a footnote to help the understanding of the general public reader. Please consider adding this clarification in the updated version of the SAP.

**RESPONSE:** Added a clarifying phrase.

## Chapter 4

### ***PETER GUTTORP***

Chapter 4, Page 68, Lines 1383-1419: This is a rather simplistic description of the use of stochastic models in precipitation modeling. For example, the work of Hughes, Charles and Guttorp (1999, Applied Statistics 48: 15-20) indicates that stochastic models may produce correct descriptions even under climatic changes, i.e., nonstationary scenarios. The description here indicates that these models would only be valid under stationarity, or stable climate. Furthermore, the description of frequentist limitation is extremely naive: neither Bayesians nor frequentists can avoid using models. The interplay between science and statistics (of whatever flavor) is the essence of model building. To say that there are no objective methods for model building is simply incorrect.

**RESPONSE: We agree with the reviewer's comment and have modified Box 4.1 accordingly, adding a reference to the paper suggested by the reviewer as well as a related, more-recent paper, Charles *et al.* (2004).**

## Chapter 5

### ***NOAA RC***

Part 5, Page 74, Line 1570: Change 'Figure 4.1' to 'Figure 5.1'

**RESPONSE: Fixed typo...thanks for the very careful proofreading!**

Part 5, Page 84, Lines 1780-1782: Seems to need rewording/clarifying.

**RESPONSE: Fixed sentence fragment.**

Part 5, Page 89, Line 1859: Change 'Figure 4.2' to Figure '5.2.'

**RESPONSE: Fixed typo.**

Part 5, Page 91, Line 1878: The statement "While modern computer methods allow investigators to represent all model inputs as uncertain, and propagate them through the model using stochastic simulation..." seems problematic. These must be very simple models, or the simulation is rudimentary. Epstein laid out the principles of Stochastic Dynamic Prediction in 1969, but it has never been used in real world sophisticated weather prediction models because of its complexity and computer running time.

**RESPONSE: We qualified the statement and added a footnote.**

### ***SUSAN SOLOMON***

Part 5, Lines 1560-1578: This paragraph and Figure 5.1 should be heavily edited or dropped for several reasons. First, the paper by Andronova and Schlesinger (2001) was too late to be the basis for the IPCC (2001) assessment; even if it had been a cornerstone work that all other papers later

repeated in full detail, a single paper is not the basis for such a statement in IPCC. This is not the way IPCC assessment works since it takes time for material to be confirmed. Second, that paper is indeed now very far from being the only such analysis now available, and other analyses find different results. That paper, along with many other similar analyses, was assessed in great detail in the WG1 report in 2007. To present only this on the key issue of how to frame uncertainty in climate sensitivity, and to present only such out of date information in this document is extremely misleading. If you wish to discuss this paper's view, and compare it to IPCC's view which is based on this paper along with the full range of others as appropriate, you could provide the necessary material from the 2007 report, but that would be quite lengthy if done properly. Otherwise, please drop this paragraph and the figure since setting the Andronova and Schlesinger paper in context with the rest of the information in the 2007 report is appropriate but comparing to the 2001 report is not.

**RESPONSE: We have eliminated the one sentence that referenced the IPCC. The paper is the first illustration of which we are aware of the type of analysis that we are discussing and thus there is no reason to eliminate the balance of the paragraph.**

Part 5, Lines 1627-1634: These are important issues and they should be treated very carefully. First, it isn't appropriate for a CCSP assessment document to cite unpublished work; please restrict your discussion in an assessment to published papers. Second, if you are going to make statements to the effect that IPCC underestimates uncertainty, it's important for you to state the reasons why and your degree of confidence in such an important assertion. Regarding such topics as aerosols or sea level, it may be that uncertainty limits improved in one direction or another between the time of a published expert solicitation and an assessment based on new data. So citing such cases as proof raises questions as to their comparability in time. Further, it may also be, as noted above, that the process of discussion with colleagues in the work of an assessment helps any researcher (no matter how expert) to improve their understanding of possible errors, while working in isolation doesn't. If it's possible that IPCC underestimates error bars, but it's also possible that the IPCC error bars benefit from joint work and could be better than the views of individuals, then say so; otherwise you are not providing a balanced assessment of the implications of what you are presenting and that is not appropriate in an assessment.

**RESPONSE: As noted above, we have added two additional references to this section, one of which is to a Policy Forum piece in *Science* that makes the same point. We have also added language from "Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainty."**

**This is not the place to enter a debate with the co-chair of WG1 of the fourth assessment. We note, however, that the work reported in the paper:**

**M. Granger Morgan, Peter Adams, and David W. Keith, "Elicitation of Expert Judgments of Aerosol Forcing," *Climatic Change*, 75, pp. 195-214, 2006.**

**was requested by Ron Prinn after early discussions as part of the writing team for Chapter 2 of the fourth assessment. The study was completed and had been reviewed and accepted for publication by *Climatic Change* before the IPCC literature cut-off and was communicated to folks in WG1, but was not cited or used.**

## ***STEVEN SHERWOOD***

Chapter 5, Page 74, Line 1575: Andronova and Schlesinger's distribution is based on only a small subset of the total information available (observations from the 20th century), and is broader than a posterior estimate based on all available information (which would include the laws of nature, ocean mixed layer temperatures, paleoclimate information, etc.; see Annan and Hargreaves 2006 or more recent papers by Forest et al, cited later). Experts and IPCC authors are well aware of the Andronova and Schlesinger result. Although it is possible that experts are overconfident, citing a single study that did not reproduce the current consensus does not prove this. This comment also applies to the caption of Fig. 5.1 that may be very misleading if it implies that the IPCC is too confident. This figure should show the distributions arrived at by other researchers based on different information. If anything, a consensus of all available information would, interpreted in a straightforward Bayesian way, lead to a narrower distribution of sensitivity than that conservatively claimed by the IPCC.

**RESPONSE: As noted above, we have eliminated the one sentence that referenced the IPCC.**

It is very important to make the point that probability distributions, including those of expert elicitations as well as those published in individual studies, have a breadth bias due to the fact that they are typically based on less than the total information available on a very broad and interdisciplinary topic (this issue is touched on later, lines 1703-11, but in another context). This opposes (and may exceed) any narrowness bias due to overconfidence. Also, while confidence bias is well demonstrated among individuals and certainly affects the uncertainty estimates of individual published studies such as those of the speed of light, is there any evidence that this bias affects consensus or summary findings that require many scientists to agree? One might expect the bias to be reduced or even switch sign in this case, given that scientists are predisposed to challenge one another's findings and even grow to professional prominence through doing so.

Annan, J. D., and Hargreaves, J. C., Using multiple observationally-based constraints to estimate climate sensitivity, *GEOPHYSICAL RESEARCH LETTERS* Volume: 33 Issue: 6 Article Number: L06704 Published: MAR 18 2006.

**RESPONSE: The recommended values (and associated uncertainties) for the value of various physical constants discussed in the paper:**

**Max Henrion and Baruch Fischhoff, "Assessing uncertainty in physical constants," *American Journal of Physics*, 54, 791-798, 1986.**

**were developed by the particle data group in a consensus process not unlike that of the IPCC. See: [http://pdg.lbl.gov/2008/html/what\\_is\\_pdg.html](http://pdg.lbl.gov/2008/html/what_is_pdg.html)**

**We have added a reference to and short discussion of Annan and Hargreaves. We have also added a short discussion and reference to:**

**Gerard H. Roe and Marcia B. Baker, "Why Is Climate Sensitivity So Unpredictable?" *Science*, 318, 629-632, 2007.**

Chapter 5, Page 78, Line 1649: outlier misspelled.

**RESPONSE: Typo fixed.**

Chapter 5, Page 78, Line 1656: This sentence is a dangling clause.

**RESPONSE: Sentence fixed.**

Chapter 5, Page 78, Lines 1656-63: A caveat is probably needed at the end of this paragraph. The validity of the objectivity claim made here may be questioned on the basis of the well-known correlation between political leanings and views on nominally positive claims such as climate sensitivity, even among experts. Also, experts who have succeeded in securing support for their research through channels that do not employ peer review may feel unburdened from having to convincingly defend their responses to their peers. This is probably a small fraction of experts but may include some of those who are most influential. This means that the central estimate from an expert elicitation may be reliable, especially if outliers are discarded, but the spread of the probability distribution about this is very hard to estimate from an expert elicitation.

**RESPONSE: We have added a qualifying footnote.**

Chapter 5, Page 90, Lines 1863-69: The Fourth Assessment is typically denoted AR4, not FAR, which is used for the First assessment (1990). Also, the error bars of the expert elicitation should be compared with the total, and error summed in quadrature, of the "direct" and "indirect" bars in the AR4 plot. This would seem (judging by eye) to be roughly the interval [-2.5,-.75] for AR4 and about [-3,0] for TAR, which don't look all that different from the typical elicitation (though is clearly narrower than the broadest elicitation responses). Knowledge of aerosol forcing has been increasing so rapidly that it may not be valid to compare an elicitation published in 2005 with a IPCC report published in 2007, either.

**RESPONSE: We have redrawn the plot to allow direct visual comparison. We display a sum of the 90% upper bound on the distributions from AR4. If we summed them as two independent distributions, the horizontal blue line would move up. We have rewritten the summary statement to read "This comparison suggests that the uncertainty estimates of aerosol forcing reported in AR4 are tighter than those of many individual experts who were working in the field at about the same time as the AR4 summary was produced."**

***PETER GUTTORP***

Chapter 5, Page 82, Line 1729: Although the report generally gives an academic survey of relevant work, its coverage of work and issues on combining expert opinion is weak. The Delphi method is mentioned but more emphasis is needed on its practical implementation in group decisionmaking. When that process does lead to multi-agent convergence, the result may be more a product of "group thinking" than the exchanging of information. When that convergence does not take place, beliefs will need to be combined (normative methods have been published for doing this) or a joint decision made (theories for doing this also exist).

A particular problem arises from the deliberately mixed disciplines of panel members. That can mean that components of a big decision problem are being assessed by individuals with varying levels of expertise, leading to the need to weight their views accordingly (which can be done with the methods mentioned above).



In general, the multi-agent problem has three levels. In the first, the group attempts to reach a consensus. If not controlled, as it is in the Delphi method, issues such as group-think and psychodynamics can denigrate the contribution of individual experts and bias the outcome in favor of the dominant experts. At the next level, in the so-called team approach, the group is assumed to have a common objective (utility function). Then the goal becomes to combine the beliefs of the agents into a single prior distribution (Genest and Zidek, 1986, *Statistical Science* 1: 114-148). More generally, the multi-agent problem becomes a group decision problem where the group must come to a joint decision, such as an industrial standard (see Weerahandi and Zidek, 1983, *Annals of Statistics*, 11: 1032-1046).

**RESPONSE:** For reasons already noted in the paper, we do not think that Delphi methods are appropriate for most applications in the area of climate analysis and assessment. However, in response to the reviewer's comment we have added a paragraph that provides a substantially greater detail about the Delphi method and discusses a number of the contributions on combining experts that have been made by Roger Cooke. The reviewer's discussion about multi agent decision analysis lies outside of the domain of CCSP 5.2. It is an important issue but falls in the area of decision analysis not the characterization, communication and incorporation of scientific uncertainty.

## **Chapter 6**

### ***NOAA/OFCM***

Part 6: Propagation and analysis of uncertainty, Page 24, Line 482: We believe that the term "pretty good" on this line is quite vague. Perhaps a better term in this context might be "effective." Please consider incorporating this modification in the updated SAP.

**RESPONSE:** The wording has been changed.

### ***NOAA RC***

Part 6, Page 98, Line 2036: How does the 53 model versions relate to the 29 parameters (line 2034)?

**RESPONSE:** We have replaced our summary with the authors' language describing what they did.

## **Chapter 7**

### ***NOAA RC***

Part 7, Page 117, Line 2437: Should the word "reliance" actually be "resilience"?

**RESPONSE:** Yes, the word has been changed.

Part 7, Page 118, Line 2456: I don't find a Fig. 5.6. Should this be "Figure 7.3" instead?

**RESPONSE: Corrected.**

### ***STEVEN SHERWOOD***

Chapter 7, Page 117, Lines 2424-2435: an analogy with earthquakes may be useful here. Earthquakes are a well-known and unsurprising phenomenon, but a specific large quake at a specific time is still a big surprise for those hit by it since these cannot be forecast. One can build for earthquakes, but may choose not to do so in places not thought to be seismically active, although earthquakes even in such places are not unknown--genuine surprises. It is very unlikely that we will ever be able to forecast in advance the moment when a particular ice sheet will collapse, until the unmistakable and irreversible signs of this are observed like the p-wave that arrives before the earthquake.

**RESPONSE: The analogy is a good one and we have adopted the proposed text (with a footnote that thanks Steven Sherwood).**

### ***MARILYN AVERILL***

Chapter 7, Page 109, Line 2253: Address the issue of how more research can affect uncertainties. Add "Policy makers can make better decisions if they are aware of the nature and extent of climate uncertainties, and if they are informed about the degree to which additional research is likely to reduce those uncertainties."

**RESPONSE: Adding the sentence in the main text would break the flow of argument. We have added a footnote to much the same effect.**

## **Chapter 8**

### ***NOAA RC***

Part 8, Page 134, Line 2759: Change 'weather bureau' to 'National Weather Service.'

**RESPONSE: Corrected the language here and elsewhere.**

Part 8, Page 136, Lines 2807 and 2822: The phrase "there is no such thing" used in close proximity.

**RESPONSE: Reworded.**

Part 8, Page 136, Line 2859: "outliners" should be "outliers."

**RESPONSE: Corrected typo.**

Part 8, Page 139, Lines 2891 and 2892: "a scientist" and "they" don't agree in number, but this is a quote, so I suppose that was what was said/written.

Part 8, Page 140, Line 2897: "scientist" should probably be "scientists."

**RESPONSE: Agree.**

Part 8, Page 140, Line 2900: "day" should probably be "days."

**RESPONSE: Changed.**

### ***NOAA/OFCM***

Part 8. COMMUNICATING UNCERTAINTY, Page 134, Lines 2756-2757: The text on these lines reads: "We do not agree, non-technical people deal with uncertainty, and statements of probability all the time." This text is presented as a new paragraph. This text is a continuation of the text found on lines 2751-2754. Accordingly, we suggest that the text beginning on line 2756 follows immediately the text that ends on line 2754. That is, the text on line 2756 should not constitute a new paragraph. Also, we suggest this sentence be rewritten for added clarity and correct grammar as follows: "We do not agree with the preceding statement. Non-technical people deal with uncertainty and statements of probability all the time." Please incorporate this correction and modification in the updated version of the SAP.

**RESPONSE: New paragraph removed.**

Part 8. COMMUNICATING UNCERTAINTY, Page 134, Line 2759: The text on this line refers to the "weather bureau." The correct term is the "National Weather Service." Please incorporate this correction in the updated version of the SAP.

**RESPONSE: Corrected.**

Part 8. COMMUNICATING UNCERTAINTY, Page 134, Lines 2756-2761: The text in these lines talks about uncertainty and how people deal with uncertainty and the importance of framing uncertainty in familiar, understandable terms. Several of the statements made in these lines are supported by the OFCM document, *Proceedings of the Forum on Risk Management and Assessments of Natural Hazards*. Specifically, page 6-11 in the OFCM document discusses the importance of knowing the audience for which the communication is intended and the diversity that may be embedded in that audience. Please consider adding the OFCM report as a reference in the updated SAP. The complete reference for the OFCM report is:

OFCM, 2001, *Proceedings of the Forum on Risk Management and Assessments of Natural Hazards*, Washington, D.C., 252 pp.

Note: The link for *Proceedings of the Forum on Risk Management and Assessments of Natural Hazards* is: [www.ofcm.gov/risk/proceedings/riskproceedings2001.htm](http://www.ofcm.gov/risk/proceedings/riskproceedings2001.htm).

**RESPONSE: We have added a footnote and citation to the OFCM report.**

Part 8. COMMUNICATING UNCERTAINTY, Page 140, Line 2902: The text on this line reads: "The magazine even went to far as to run an article ..." The phrase, "went to far as to" should be corrected to read: "went so far as to." Please incorporate this correction in the updated version of the SAP.

**RESPONSE: Change made.**

***JOHN SENN***

Chapter 8, Page 134, Lines 2752-2753: Comment: I think it would be helpful to explain/define what a "non-technical" audience member is as well as why reaching out to those people is important. I don't have specific language to insert or resources to suggest, but I think it's imperative to discuss the importance of communicating complex information to an audience with a basic scientific knowledge.

**RESPONSE: We are a bit puzzled by this request, since we think the phrase is self-explanatory. Nevertheless, we have added a footnote.**

***STEVEN SHERWOOD***

Chapter 8, Page 139, Line 2873: should be "...Nobel laureate Sherwood Roland."

**RESPONSE: Correction made.**

Chapter 8, Page 139, Lines 2878-87: I am not a social scientist but these statements do not jibe with my experience at all. Witness for one thing the steady stream of talks now organized for policymakers by the AMS. I suspect that things have changed, at least in climate science, since 1999, or that reluctance to speak to the media is not as universal as claimed.

**RESPONSE: We are pleased to learn that Dr. Sherwood has not had such experiences, but can attest that, while attitudes may have improved, the issue remains a problem. However, to avoid the argument we have removed the phrase "is correct when she" and simply report her observation.**

***MARILYN AVERILL***

Chapter 8, Page 136, Line 2801: Provide some indication of why people should want to understand. Add "People need to understand how they contribute to and are likely to be affected by climate change. Understanding these concepts requires an understanding of the related uncertainties."

**RESPONSE: We believe that this is self-evident and have made no change.**

## Chapter 9

### ***NOAA/OFCM***

Part 9: Some simple guidance for researchers, Page 29, Lines 594- 601: The text on these lines lists four bulleted questions which the SAP authors believe "researchers and policy analysts must ... continually ask themselves ..." We believe that it is equally important that researchers and policy analysts ask themselves whether or not uncertainties related to research results and potential policies are being communicated clearly and consistently. Accordingly, we recommend that the following bulleted question be added on line 601: "Is information about the uncertainties related to research results and potential policies being communicated clearly and consistently?" Please consider incorporating this suggested modification in subsequent iterations of this SAP.

**RESPONSE:** The suggested addition has been made here and in the relevant earlier portions of the report.

### ***PETER GUTTORP***

Chapter 9, Page 144, Line 2999: The grey scale "confidence interval" plots are very weird. They are difficult to read, and non-standard.

**RESPONSE:** Figure 9.1 is very similar to the display used by the U.S. National Assessment (see Figure 2.3). When the U.S. National Assessment reported similar ranges with solid bars that had sharp non-overlapping ends, they received complaints and questions about exactly how to interpret a probability that lay at the break point. The shading in Figure 9.1 conveys the fact that mapping words to probabilities is at best approximate, given cognitive and other limitations. As explained in the body of the report, with a few exceptions we do not support extensive use of second order probability (because we think, in most settings, its use confuses more than it adds). However, Figure 9.2 illustrates a strategy that can be used by people who find they simply are unwilling to state a single probability because they cannot get past the implied precision.

Chapter 9, Page 145, Line 3000: Standard practice in statistics and most other fields (except physics for historical reasons) is to go up and down two standard errors (often corresponding at least approximately to a 95% interval) rather than one (67%).

**RESPONSE:** Language clarified.

Chapter 9, Page 145, Line 3010: The idea of plotting the cdf and the pdf on the same scale is not helpful. Overall, in this entire section, there is a lack of acknowledgement of any of Tufte's recommendations, or Cleveland's perception experiments, or Dan Carr's work on government statistics displays. The graphical recommendations are not anywhere near what modern statistical graphics methodology would suggest.

**RESPONSE:** Plotting a PDF over a CDF remains the most effective strategy we know for accurately communicating to both technical and semi-technical audiences at the same time (see discussion in Chapter 9 of Morgan and Henrion, *Uncertainty*, Cambridge, 1990). We are

unaware of any empirical evaluations of other displays since the work reported there. Tufte provides many very fine displays, although most are not related to reporting uncertainties. To our knowledge his design choices are based on his own (generally excellent) esthetic judgments, and have not received systematic empirical evaluations.

Consistent with our proposal (Figure 9.3) Cleveland and McGill argue that box plots are superior to "graphing means and sample standard deviations" (See: William S. Cleveland and Robert McGill, "Graphical Perception and Graphical Methods for Analyzing Scientific Data," *Science* 229: 828-833, 1985).

Cleveland's book, *The Elements of Graphing Data: Revised edition* (Hobart Press, 1994), devotes only a single section (3.3, pp. 132 to 143) to "distributions." No mention at all is made of PDFs or CDFs. The discussion of box plots adds nothing over the earlier discussion we cited by Tukey (1977).

Similarly, Carr's chapter "Graphics in the Physical Sciences" in Robert A. Meyers (ed.), *Encyclopedia of Physical Science and Technology* (Academic Press, 2002) contains only modest discussion of box plots (the only obvious difference being that he makes the entire box solid black. Unlike Cleveland's book, this chapter does contain a straightforward discussion of cumulative distributions (but no discussion of PDFs). Note, however, that Carr's Figure 9, while illustrating a somewhat different point, uses the same strategy that we have proposed which the reviewer claims "is not helpful."

Chapter 9, Page 145, Line 145: Boxplots are only appropriate when there are many groups in the data, and we want to compare distributions between groups. They constitute a massive reduction of the data (from  $n$  to 8 in the suggested display here), and do not give detailed representations of the data distribution. For inspecting single or several distributions, histograms (with careful selection of bin width) carry much more information.

**RESPONSE:** Note that the discussion begins with the phrase "When many uncertain results must be reported." Probability distributions and histograms are clearly superior, but if one wants to report many results as in Figure 5.2, 5.3 or the center figure in 5.4, box plots are clearly superior. We have added a conditioning phrase.

## SUSAN SOLOMON

Part 9, Lines 2984-2988 and figure 9.2: Please drop this recommendation and the associated figure. There is very little value in CCSP now starting a new uncertainty framework for all of its work. Among other matters, it is not well established that one single framework for all fields and discussions is appropriate. I don't think we are there yet. There hasn't been any significant discussion across fields in formulating this new proposal. We tried very hard in AR4 and although there was some progress, full standardization across all fields of climate science wasn't deemed appropriate by the authors and I don't think it should be attempted here without much broader input. Further, if widely adopted, a new framework in which climate scientists now begin to use the words 'very likely' to describe 80% probabilities when for many years we have generally used them for 90% would cause a huge amount of confusion since it will suddenly be the case that

things deemed only 'likely' before are 'very likely' now – not because of better information but because of a new language. Lastly, the figure is nice but figures are less important than language in this case, and the associated words contain many features that would be confusing in discussions that require use of specific language. I think it would be quite difficult to refer to things with a 56% probability as 'likely' while those that are 44% are 'unlikely.' Surely this is much too narrow a distinction between these two very important words, and 'about as likely as not' is probably better for both of them. I am not suggesting that the author try to somehow fix these things. It will be far better for CCSP to accept that uncertainty language standardization along these lines is not an appropriate goal for this document.

**RESPONSE: The footnote on the header for Part 9 has been changed to read "The advice in this section is intended for use by analysts addressing a range of climate problems in the future. For a variety of reasons, many of the CCSP products have already been produced and obviously will not be able to follow advice provided in this section. Most others are well along in production and thus will also not be able to adopt advice provided here. However, the current round of CCSP products is certainly not the last word in the analysis or assessment of climate change, its impacts, or in the development of strategies and policies for abatement and adaptation."**