SAP 2.3 "Aerosol properties and their impacts on climate"
COLLATED PUBLIC COMMENTS
11 July -25 August 2008

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[Notes from Mian: Nathan Taylor is a graduate student in Don Collins' group. Don is one of the expert reviewers]

GENERAL COMMENTS

NOAA/OFCM

There are numerous typographical and grammatical errors in the SAP. Examples include (but are not limited to):

(1) Executive Summary, Page vii, Lines 43 – 44, where the text reads: "This not an indirect effect …" should be changed to read: "This is not an indirect effect …"

Typo. No longer applicable.

(2) Chapter 1, Page 7, Lines 19-20, where the text reads: "Information for past years on the source types and strengths and even the worlds regions that dominate emissions are difficult to obtain …" should be changed to read: "Information for past years on the source types and strengths and even the world regions that dominate emissions is difficult to obtain …"

Also it is not clear if TOA is an acronym defining "Top-of-Atmosphere" or "Top-of-the-Atmosphere." Both terms are used in the SAP. Moreover, many acronyms are used without first being defined (especially in Chapter 1). Even though an acronym list is provided at the end of chapters, we believe it would be preferable to consistently define acronyms when first used as well as include the acronym definitions in a list of acronyms.

For the next iteration of this SAP, please consider having a technical editor proofread the SAP to correct for typographic errors, grammatical errors, inconsistent terminology, and incorrect/inconsistent acronym use.

Samuel P. Williamson, NOAA/OFCM

Chapter 1 has been mostly re-written. Emission part has been moved to Chapter 3 and modified. TOA and all other acronyms have been introduced and carefully defined. Furthermore, we have created an "Acronyms and symbols" list for all acronyms used in the report.

Forrest M. Mims III

The draft report generally provides a fine review of the status of aerosol science today. This review addresses only some obvious issues and errors that need revision or correction. A major concern is the puzzling cover art, which presents a very misleading image of the role of aerosols in climate change. The increase of such misleading art should concern the climate science community.

I did not learn about this report until Saturday night, August 23, 2008. Therefore, there was not time to do a thorough review in time for today's deadline (August 25). Announcing this kind of document in the Federal Register is well and good, but the typical specialist does not regularly read the Register. Therefore, I request that review opportunities for future NASA reports of this nature be announced in the open literature and on various NASA and other web sites.

Forrest M. Mims III

The Federal Register is the official mechanism for pre-dissemination of government publications.

The cover design is highly misleading and fails several of NASA's Guidelines for Ensuring the Quality of Information (1). The image is apparently designed to suggest that a large cloud of aerosols floating over a major city is causing the crumbling of a large foundation surrounding Earth, which is shown through two circular windows. This suggestion is falsified by the fact that the satellite image that illustrates aerosols (on the right), the subject of the report, does not show urban aerosols. Instead, it dramatically illustrates one of the most widespread aerosol sources on

the planet: Saharan dust. The image also shows that sub-Sahara Africa is a major source of biomass burning aerosols. The aerosol image includes many of Africa's largest cities, including Cairo, Capetown, Durban, Johannesburg, Tripoli, etc. These cities have local air pollution problems, but they are not indicated by any obvious red on the report's cover, and the optical depth at their locations is nowhere near that of the enormous regions covered in red. Thus, it can be reasonably concluded that any aerosol emissions from African cities in this image are completely dwarfed by the Saharan dust (upper red streak) and smoke (lower red blotch). Please take note that during summer African dust frequently reaches my observation station in South-Central Texas, from where I have regularly tracked the increased optical depth caused by this massive aerosol source since 1990. For all these reasons, the cover design is at best inaccurate and at worst biased to falsely suggest that anthropogenic aerosols are somehow reflected in the satellite imagery below. In the interest of accuracy and objectivity and to fulfill the requirements of NASA's Data Quality Guidelines (1), the cover illustration should be replaced with art that objectively portrays the world's major aerosol: desert dust. The curious image of crumbling sky scrapers simply doesn't belong and might best be replaced by an image of sand dunes under a cloud of blowing dust.
Forrest M. Mims III
Reference.
1. The relevant data quality guidelines include the following excerpts from http://www.sti.nasa.gov/FINAL_NASA_guidelines.pdf
C.2.a.2. Objectivity. The measure of objectivity refers to the extent that the information is accurate, clear, complete, and unbiased. The following principles relate to these dimensions of information objectivity:
Accuracy
• Information products disseminated by NASA will be based on reliable, accurate data that has been validated.
Lack of Bias
• NASA will utilize systematic analysis and review processes to remove potential biases from its information products.
• To the extent possible, NASA will ensure that information is presented without the appearance of bias.
C.2.b. Quality Level for Influential Information
NASA requires a higher standard of quality for information that is considered influential. Influential scientific, financial, or statistical information is defined as NASA information that, when disseminated, will have or does have clear and substantial impact on important public policies or important private sector decisions.
Forrest M. Mims III
The cover is only for the draft form; the final publication will use the standard CCSP format.

Douglas Hoyt
I suggest the authors of SAP 2.3 read the following paper and the papers it references.
Hoyt, D. V. and C. Frohlich, 1983. Atmospheric transmission at Davos, Switzerland, 1909-1979. Climatic Change, 5, 61-72.
This paper and others show no long-term trends in aerosol loading in the atmosphere. GCMs do not use measured aerosol loading but rather used modeled aerosol loading based upon industrial

activity. The measured aerosol loading shows that these modeled aerosol loadings are erroneous in all the GCMs.
Douglas Hoyt
Many studies since 1983 have show changes of aerosol loadings, especially over mid-latitude land regions presumably because of the changes in emission control policies and economic development. Models have also made very significant progress since 1983 and many of them are able to generate realistic aerosol loading, as shown in many recent literatures.

David L. Hagen
Cosmic ray ion nucleation is potentially a significant cause of ionization, nucleation, aerosols, and clouds which are inversely solar modulated. However, the draft report makes no mention of "Svensmark" or "cosmic", "ionization", "modulation" etc. Recent evidence and models indicate that galactic cosmic rays are a significant cause of ionization, nucleation, aerosols, and clouds which are inversely modulated by solar wind, and geomagnetic field
Following are additions to correct this serious omission.
David L. Hagen
This report focuses on anthropogenic aerosols. Cosmic ray nucleation is outside of the scope.

Alan Carlin
Your draft appears to totally omit the most significant aspect of aerosols and their impact on climate, namely, the research showing that cosmic rays act to influence low level cloud formation and that solar variability in turn determines the intensity of cosmic rays that strike the Earth's atmosphere and therefore low level cloud formation.
This important aspect of aerosols arises because aerosols are nucleation cores for water droplet and thus cloud formation. Water droplets have to exceed a critical diameter. Only then will they grow on their own in water vapor saturated air. If they are too small, they will evaporate again or stay at a finite size, too small for further growth. In general, aerosols are neutral particles. Often they are made up by dipolar molecules like sulfur acid, sometimes they are homopolar such as carbon soot. Since H2O molecules are also dipolar molecules, dipole-dipole attraction will help to form droplets. Even better would be the presence of isolated positive or negative charges. Charge to dipole attraction is considerably stronger, droplets could form more easily, and the critical radius of droplets can also be reached more easily. Charges do not exist freely, however, at least not for longer times.
High energy cosmic rays generate a lot of charged collision products which will attach themselves to aerosols. This helps cloud formation, even if the charges neutralize after a short time. Modulation of cosmic ray intensity by solar activity changes cloud formation and thus the albedo. This is the most probable mechanism for the strong solar imprint on the climate shown by numerous studies.
At least the following papers need to be carefully discussed and their contents evaluated in this regard in your draft:
Kirkby, Jasper, 2007, Cosmic Rays and Climate, Surveys in Geophysics, 28: 333-75, available as CERN-PH-EP/2008-005 at http://arxiv.org/PS_cache/arxiv/pdf/0804/0804.1938v1.pdf
Shaviv, Nir, 2005, Cosmic Rays and Climate, PhysicaPlus, Issue No. 5, May 1; available at http://physicaplus.org.il/zope/home/en/1105389911/1113511992_en
Svensmark, Henrik, 1998, "Influence of Cosmic Rays on Earth's Climate," Physical Review Letters, Oct. 15.

What is really needed is a very much more thorough discussion of cosmic ray nucleation and solar modulation including at least the following additional material:
Svensmark and FriisChristensen (1996) discovered that incident cosmic rays modulate global low level cloud cover. In earth like atmospheres, Svensmark et a. (2006) found that new aerosol particle production is proportional to negative ion density. Cloud cover further varies about 2% over the 11 year solar cycle. Svensmark (2007) formulated a theory of cosmoclimatology where ion nucleation of aerosols form cloud condensation nuclei. This varies with cosmic ray variations which are inversely modulated by the total solar irradiance and solar wind. Rusov et al. (2008a) , (2008b) further develop a bifurcation model of galactic cosmic ray cloud formation and provide experimental support. Following Svensmark's preliminary experimental confirmation, CERN, the European Organization for Nuclear Research, is creating the CLOUD atmospheric research facility to quantify cosmic ray atmospheric aerosol nucleation. Marsh (2003) showed correlations between the El Niño–Southern Oscillation and galactic cosmic rays. Usoskin et al. (2004) show latitudinal influence on cosmic ionization clouds. Harrison and Stehenson (2006) find that with sudden transient reductions in cosmic rays (Forbush events) there corresponding simultaneous decreases in diffuse insolation, and thus with clouds. They note that high cosmic ray fluctuations correlate with 2% higher diffuse insolation and a 19% increase in overcast days.
Some References for Cosmoclimatology:
Svensmark, Henrik, Cosmoclimatology: a new theory emerges. A & G, February 2007, Vol. 48 #1, 18-24.
Svensmark, Henrik, Jens Olaf P. Pedersen, Nigel D. Marsh, Martin B. Enghoff, & Ulrik I Uggerhøj, Experimental evidence for the role of ions in particle nucleation under atmospheric conditions, Proc. Royal Soc. A. 2006, 1773.
Rusov, V; A. Glushkov, V. Vaschenko, O. Mihalys, S. Kosenko, S. Mavrodiev, B. Vachev, Galactic Cosmic Rays - Clouds Effect and Bifurcation Model of the Earth Global Climate. Part 1. Theory, Atmospheric and Oceanic Physics, (2008) In Press
Rusov, V; A. Glushkov, V. Vaschenko, O. Mihalys, S. Kosenko, S. Mavrodiev, B. Vachev, Galactic Cosmic Rays – Clouds Effect and Bifurcation Model of the Earth Global Climate. Part 2. Comparison of Theory with Experiment. Atmospheric and Oceanic Physics, (2008) In Press.
I. G. Usoskin & N. Marsh, G. A. Kovaltsov, K. Mursula, O. G. Gladysheva, Latitudinal dependence of low cloud amount on cosmic ray induced ionization, Geophysical Research Letters Vol. 31, L16109, doi:10.1029/2004GL019507, 2004.
Harrison. R. Giles; & David B. Stephenson, Empirical evidence for a nonlinear effect of galactic cosmic rays on clouds. Prod. Roy. Soc. A. V462, Nr 2068, Apr. 8, 2006, 1221-1233.
Marsh, Nigel, Galactic cosmic ray and El Niño–Southern Oscillation trends in International Satellite Cloud Climatology Project D2 low-cloud properties, J. Geophysical Research, V. 108, No. D6, 4195, doi:10.1029/2001JD001264, 2003.
As best I can determine neither the word Svensmark nor the words cosmic ray are found anywhere in this draft. Cosmic ray collision products as a driver to modify aerosols and thus as a driver to enhance droplet and cloud formation are not mentioned as best I can determine. Continued failure to discuss all these papers and the references contained in them would make the report useless for reaching any valid conclusions as to the effects of aerosols on climate change. It is all too easy to attribute climate change to anthropogenic causes when the most likely major cause, solar variability and its effects on aerosols, are totally ignored. The result is to attribute the effects of solar variability to anthropogenic effects of climate change. This is a

totally invalid approach from a scientific viewpoint. The apparent omission of these effects, in fact, raises critical questions concerning the objectivity and usefulness of your current draft.
Alan Carlin
This report focuses on anthropogenic aerosols. Cosmic ray nucleation is outside of the scope.

Nathan Taylor

Answers to the review questions:

1. Are the goals, objectives and intended audience of the product clearly described in the document? Does the product address all questions outlined in the prospectus?

   The goals are somewhat clearly described. I think that a few more sectional statements of objectives and results at the beginning of each would be helpful. I was often bogged down in the technical parts and lost track of what the intention of the work was.

   The audience is never mentioned in the document. In the concluding section there are some hints that this is for those with the ability to expedite future work, but till then it is dark. I think that greater emphasis on the concluding section in the executive summary, with a few more particulars would be good.

   For the main part the questions of the prospectus are answered. I think a bit more might be said on measurement capabilities and specifically instrumentation, both *in stitu* and remote.

2. Are any findings and/or recommendations adequately supported by evidence and analysis? In cases where recommendations might be based on expert value judgments or the collective opinions of the authors, is this acknowledged and supported by sound reasoning?

   Yes, they do seem to be so.

3. Are the data and analyses handled in a competent manner? Are statistical methods applied appropriately?

   The data analysis is some what haphazard, as is often the case in reviews. I think that it would be nice if less of the results were, as it appears, pulled from papers unsupported and more tabulation done. Clearly lack of comparability is a problem with many of the works reviewed. Yet, I do feel that more organization and belabored structure would help.

4. Are the document's presentation, level of technicality, and organization effective? Are the questions outlined in the prospectus addressed and communicated in a manner that is appropriate and accessible for the intended audience?

   The documents presentation is perhaps slightly flawed. As I noted in my somewhat brief run down of suggested modifications, there is too much novel-esque structure, i.e., gradual build up to a conclusion. It is better in this type of work to state the conclusion, present the defense of these points, and then rehash. Also, it would be good if the structure of the entire paper was a little more heavy handed.

   As there is some difficulty as mentioned above in finding structural points among disparate studies, it is important to emphasize and those that you can. Specifically, with each section, outline the points that you

are going to make and the subsections in the section's introduction. There are some places in the document where the structure seems to be lost and logical flow suffers.

5. Is the document scientifically objective and policy neutral? Is it consistent with the scientific literature?

   It does seem to be.

6. Is there a summary that effectively, concisely and accurately describes the key findings and recommendations? Is it consistent with other sections of the document?

   I didn't find it to be so. First, the executive summary does not parallel the document in structure. The findings section is well done, I thought, but it would be better if more of the specific recommendations were presented in the executive summary.

This document has been very significantly revised. Now the ES is parallel to the documents structure, and the "way forward" is presented in the ES.

7. What other significant improvements, if any, might be made in the document?

   i) The abbreviations DRF and DRE are needlessly opaque.

Clarified. DRE is no longer used, and DRF is explained in Chapter 1, 2, Glossary, and acronym list.

   ii) More attention to instrumentation, both in defining the state-of-the-science and especially in recommendations. This in terms of all manner—in *stitu*, remote, and networks.

Improved.

   iii) More attention given to citing works, especially when used heavily.

Done.

   iv) The figures are at poor resolutions, and at times are not cited.

All figures are now of high quality.

SPECIFIC COMMENNTS:

Executive Summary

NOTE: The Executive Summary was mostly rewritten, and because of that, many of the public comments are no longer applicable. This is especially true in terms of typos and rewording of statements.

Forrest M. Mims III
Executive Summary, Page iii.
The Executive Summary lacks a concise abstract of the principle findings in the report. The non-specialist reader needs a one paragraph, plain language summary that flatly states the following:

- Aerosols are both natural and anthropogenic particles suspended in the atmosphere.
- Aerosols include sea salt, desert dust, black carbon [or soot], sulfate, pollen and so forth.
- Aerosols are monitored with high accuracy from the surface and with good accuracy from space.
- The net impact of aerosols is a slight cooling, but we do not yet fully understand how to incorporate aerosols into climate models.
- While significant advances have been made in monitoring and understanding aerosols and their distribution and seasonality, climate change research requires a commitment to long-term, high quality aerosol monitoring from the surface and from space.

Forrest M. Mims III
The reviewer made a very good statement about what was needed upfront in the Executive Summary. In the total overhaul of this section, we feel we now meet the reviewer's requirements.

Executive Summary, Page iii, Lines 16-17.
Remove comma after "sea salt" In the following line and consider adding "soot": "On a global basis aerosol mass derives predominantly from natural sources (e.g., sea-salt, and dust)."
Suggested revision would read: "On a global basis aerosol mass derives predominantly from natural sources (e.g., sea-salt, dust and soot [or black carbon or smoke] from forest fires)."
Forrest M. Mims III
We decided to keep the sentence, as it was, because while some fires are indeed sources of natural aerosol, most biomass burning aerosol including soot, comes from anthropogenic sources, either intentional burning of fuel or agricultural fires. Also, sea salt and dust dominate the mass loading of natural aerosol.

Executive Summary, Page iii, Lines 17-19.
The following sentence is awkward:
"Manmade aerosols, arising mainly from a variety of combustion sources (e.g., "smog"), usually overwhelm the natural ones in areas in and downwind of highly populated and industrialized regions, or areas of intense agricultural burning."
Suggested revision might read:
"Anthropogenic ~~Manmade~~ aerosols, arising mainly from a variety of combustion sources (e.g., "smog" and smoke), usually overwhelm ~~the~~ natural aerosols ~~ones in areas~~ in and downwind of highly populated and industrialized regions and ~~, or~~ areas of intense agricultural burning."
Forrest M. Mims III

Sentence was modified to closely what the reviewer suggested.

Executive Summary, Page iii, Lines 25-26.
The following sentence fails to note that ALL aerosols affect forcing and the language is somewhat confusing:"The addition of manmade aerosols to the atmosphere may change the radiative fluxes at the top-of-atmosphere (TOA), at the surface, and within the atmospheric column."
Note there is considerable variability in *natural* aerosols, especially seasonal smoke and dust. Thus, a suggested plain language revision might read:
"The addition of ~~manmade~~ aerosols to the atmosphere alters the intensity of sunlight arriving at the surface and scattered back into space, ~~may change the radiative fluxes at the top-of-atmosphere (TOA), at the surface, and within the atmospheric column.~~"
Forrest M. Mims III
The reviewer's concern about not including natural aerosols in a definition of radiative forcing has been addressed in that sentence. We now define the term 'radiative forcing' in chapter 1 that is used consistently throughout the document.

Executive Summary, Page iii Lines 33-39.
The following needs help:
"On a global average the sum of direct and indirect forcing by anthropogenic aerosols at the TOA is almost certainly negative (cooling) and thus likely offsets the positive forcing (warming) due to anthropogenic greenhouse gases on a global-average basis, and taking into account the sum of longwave and shortwave forcings. However, as the forcings are exerted in different spectral regions and exhibit different magnitudes in different locations the offset cannot be considered to be neutral in terms of effects on Earth's climate."
Here's a plain language revision for your consideration:
"~~On a~~ The globally summed average [or simply "the global average"] ~~the sum~~ of direct and indirect forcing by anthropogenic [only anthropogenic? Not natural aerosols?] aerosols at the TOA is almost certainly negative (cooling) [insert comma here] and [insert comma here] thus [insert comma here] likely offsets the positive forcing (warming) due to anthropogenic greenhouse gases ~~on a global-average basis, and taking into account the sum of longwave and shortwave forcings.~~ However, as the forcings are exerted in different spectral regions and exhibit different magnitudes in different locations [insert comma here] the offset caused by aerosols may have other ~~on cannot be considered to be neutral in terms of~~ effects on Earth's climate."
Those "other effects" especially include the major impact on subcanopy plants. Please let me know if you want to expand on this.
Forrest M. Mims III
The reviewer pointed out a particularly mangled sentence with suggestions on improvement. Several other suggestions were made. The sentence has been rewritten.

Executive Summary, Page ix, Lines 39-40 and Page X, Line 18.
Various mentions of "dimming" and "global dimming" need clarification. For example, consider this sentence from the report (page ix):
"Systematic changes in observed global solar radiation (a sum of direct and diffuse solar radiation) reaching the surface (so-called dimming or brightening) have been reported in the literature."

The total irradiance definition of global dimming given here does not match the geographical definition of global dimming given on pages 52 and 128. (See comment below.) This is highly confusing.
Forrest M. Mims III
Discussion on 'dimming' and 'brightening' has been removed from the Executive Summary because it was considered to be too detailed.

Executive Summary, Page x, Lines 41-43.
The following sentence needs a disclaimer about major concerns expressed by the National Weather Service and others regarding the impact of poor site placement and the urban heat island effect on the historical instrumental record. This is a huge problem (1), and it nicely justifies the urgent need for the aerosol community to continue doing what is a generally first class job of monitoring aerosol trends.
"A key requirement for forcing over the industrial period is as input to GCM calculations, necessary to evaluate the performance of these models in calculating climate change over the industrial period by comparison with observations." (Emphasis added.)
Time has run out for this review, and a suggested revision will be sent on request.
Reference:
1. Robert Leffler and Kelly Redmond, *Factors Affecting the Accuracy and Continuity of Climate Observations,* National Weather Services Headquarters, Climate Services Division (June 2004). (Accessed at http://www.weather.gov/om/csd/pds/PCU6/IC6_2/tutorial1/PCU6-Unit2.pdf)
Forrest M. Mims III
The offending sentence has been removed. The idea now is that there is something very uncertain in the models if they can all produce the same temperature change (right or wrong) using wildly varying aerosol representation. The ES is using this as an example of the uncertainty in the model predictions, not advocating that the temperature patterns of the last century are correct.

Executive Summary, Page xi.
The Executive Summary ends with no mention of the impact of soot on the albedo of ice and snow. This is a major forcing addressed only briefly in Table 3.5 on page 107. Hansen et al., and others have produced excellent papers that address this. There is no time to add those references now, but they will be sent on request.
Forrest M. Mims III
Soot on ice and snow was considered to be too detailed for the Executive Summary.

David L. Hagen
Executive Summary, Section: 4.2 Representations of aerosol … (GCMs), Page ix, line 3
After "cloud fraction and amount of condensate" insert:
"Nor do they include the impacts of solar modulated cosmic ray ionization-nucleation on low level cloud formation, water content, albedo, and temperature."
To read:". . .Most models did not incorporate forcing associated with aerosol effects on cloud fraction and amount of condensate. Nor do they include the impacts of solar modulated cosmic ray ionization-nucleation on low level cloud formation, water content, albedo, and temperature. Comparison of the indirect effect in various models . . ."
David L. Hagen, AcrossTech
Executive Summary, Section: 4.2 Representations of aerosol … (GCMs), Page ix, line 5

Add "Major volcanic eruptions should confirm the negative climate feedback (-1.4 K/W/m2) and 6.8 month intrinsic response time evaluated by Mt. Pinatubo's eruption."
David L. Hagen

Executive summary, Section 4.4. Looking forward, Page ix, Lines 27-28.
Change to:
"All progress in estimating aerosol indirect effects requires a better understanding of the basic processes of nucleation-aerosol-cloud interaction including solar-cosmic ray impacts."
(Comment: Svensmark et al. (2007) showed aerosol nucleation is proportional to negative ion concentrations. Harrison & Stephenson (2006) show cosmic ray induced ionization influences clouds. Marsh (2003) shows cosmic ray correlate with the El Niño–Southern Oscillation. These impacts need to be incorporated.)
David L. Hagen

Executive Summary, Section 6.1 Page x, Line 34
After ". . . uncertainty in aerosol forcing." Insert the following sentence:
"Incorporating solar modulated cosmic ray nucleation will add radiative and non-radiative impacts in global climate models."
David L. Hagen

Executive Summary, Section 6.3 Page xi, Line 18.
Insert:
"Solar modulated cosmic ray nucleation primarily affects the albedo and temperature-long wave radiation of low clouds (< 3 km)."
David L. Hagen
RESPONSE TO ALL OF THE ABOVE COMMENTS: This reviewer's comments centered on an agenda calling for a detailed discussion of solar modulated cosmic ray ionization-nucleation processes on clouds. The team considered these comments and decided that they were not appropriate to this report or the Executive Summary, since this report is focusing on assessing anthropogenic aerosol forcing. Thus, suggested inserts of cosmic ray ionization and a detailed addition concerning the Mt. Pinatubo eruption were not included.

John F. Pittman
Chapter Executive Summary Page iii lines 34-39:
You say "On a global average the sum of direct and indirect forcing by anthropogenic aerosols at the TOA is almost certainly negative (cooling) and thus likely offsets the positive forcing (warming) due to anthropogenic greenhouse gases on a global-average basis, and taking into account the sum of long wave and shortwave forcings. However, as the forcings are exerted in different spectral regions and exhibit different magnitudes in different locations the offset cannot be considered to be neutral in terms of effects on Earth's climate." Yet on page viii line 3-4 you state "The total sky aerosol direct climate forcing at the top of the atmosphere shows a wide disparity among models, varying from slight warming (+0.04 W m-2) to cooling (–0.63 W m-2)." You cannot say that it is almost certainly negative, when your information states you do not know whether it is positive or negative in effect. You also state on page ix line 41-44 "However, the lack of reliable long-term observations of aerosol trends over both land and ocean during this time period makes it difficult to assess the role aerosols have played in the multi-decadal change of surface solar radiation" You need to state that "due to the uncertainties in models and

measurements, and the near order of magnitude differences, the total effect, if any, is, at present, undefined and indefinable."
John F. Pittman
The reviewer identifies a series of estimates of aerosol forcing, some positive and some negative, that appear to contradict the general statement that "On a global average basis, the sum of direct and indirect forcing by anthropogenic aerosols at TOA is almost certainly negative (a cooling influence),…" Scientific consensus, as reported by the IPCC AR4, concludes that aerosol forcing at TOA is negative *on a global basis with the sum of direct and indirect forcing*. Certainly, there are *local situations* where combinations of aerosol type and altitude, cloud type and surface albedo result in a positive aerosol radiative forcing. Just because we can identify these local situations doesn't mean that estimates on a global basis are still too uncertain to assign a general sign (positive/negative) to the aerosol radiative forcing.

Chapter Executive Summary Page iii lines 41-45 and page iv 1-14
Paragraph should be deleted. On the credibility of climate predictions / De la crédibilité des prévisions climatiques Author(s): D. Koutsoyiannis 1 | A. Efstratiadis 2 | N. Mamassis 3 | A. Christofides 4, it has been shown that the models that produce the projected impacts have been falsified for the regional scale, And are thus unlikely to be correct for larger scale. See also, The use of the multi-model ensemble in probabilistic climate projections Claudia Tebaldi1, Reto Knutti2 2007 Abstract: "…This paper outlines the motivation for using multi-model ensembles, reviews the methodologies published so far and compares their results for regional temperature projections. The challenges in interpreting multi-model results, caused by the lack of verification of climate projections, the problem of model dependence, bias and tuning as well as the difficulty in making sense of an 'ensemble of opportunity', are discussed in detail." This paragraph is speculative as shown by the Tebaldi/Reto 2007 and Koutsoyiannis et al 2008, where not only can these models not be used for regional predictions, but that they also have not been verified nor validated for larger scale. In particular you state "For example, the direct cooling effect of sulfate aerosol varies by a factor of 6 among the models, because of different extensive aerosol properties (e.g. sulfate amount) and different intensive properties (e.g. scattering efficiency) used in the models." "In addition, the aerosol indirect effect on cloud brightness varies by up to a factor of 9 among models. This situation is in part a consequence of the large uncertainty in the mechanisms and magnitude of climate forcing by aerosols, and in part due to the differences in cloud amounts between models." If a difference of a factor from six to 9 fold, almost an order of magnitude difference, does not indicate to the authors that the reproduction of the observed trend is because the models have been tuned to do so, they need to re-read Tebaldi/Reto 2007 and Koutsoyiannis et al 2008
John F. Pittman
We agree with the reviewer that there is "tuning" in the models in order for them to represent the same temperature change over the past century, despite widely differing aerosol representation. This is one of the main points of this assessment and it is highlighted in the Executive Summary, as the reviewer notices. This does not mean that there is no value in using GCMs for climate prediction. The way forward to increase the value of model predictions is to better constrain their aerosol representation and reduce the flexibility that they can employ in "tuning". Eventually, the combination of models and observations will result in more certain predictions.

Chapter Executive Summary Page iv line 44

Add "Models will need to be validated and verified in order to provide the needed accuracy for determining the effects of aerosols." Your statements of 6 to 9 fold disagreements of models indicate that this sentence is needed.
John F. Pittman
The idea is to reduce the factors of 6 to 9 in models' representation of aerosols. This is the idea behind better constraining models with observations. The better the constraints, the more certain the predictions.

Chapter Executive Summary Page v Line 16
Add "With improved field data and studies, it is anticipated that newer, more accurate models will be shortly available." Your statements of 6 to 9 fold disagreements of models indicate that this sentence is needed.
John F. Pittman
See above

Chapter Executive Summary Page v line 37
"Models also provide critical links among different observations, and can simulate the past and project into the future." This should be changed to "Models also provide critical links among different observations. Models cannot at present simulate the past nor project into the future with validity due to the current large variability in the different models."
John Pittman, Private Citizen
Observations cannot predict the future, and the observational record is so short, that it is hard to estimate what aerosols were like in the past, as well. Models are our only source for that information. They are an uncertain source, but still the only tool available. Just because there are uncertainties now does not mean that we should dispense with an important tool. Also, as computer power increases and observations become better, model predictions make very important leaps forward. We compare the state of today's weather forecasting models with those 30 years ago, and there are significant improvements in prediction accuracy. The same will be true with climate models.

Chapter Executive Summary Page vii line 12
"measurements are needed for model evaluation" add "and model verification."
John F. Pittman
To us, model "evaluation" and model "verification" are the same thing.

Chapter Executive Summary Page x line 19 -20
You state: "Simulating long-term aerosol variations with global models can link long-term trends of emissions" You need to add at the front "Upon completion, and validation of models incorporating new data and techniques, simulating long-term aerosol variations aerosol loading, and radiative effects…." At present the models with their wide variance cannot be assumed to do this; nor have they been verified and validated as you indicated on pages viii, ix and xi.
John F. Pittman
We removed discussion of long-term aerosol trends from the Executive Summary, because of too much detail.

Nathan Taylor
Executive Summary: I would like to see more conclusions/recommendations in the summary.

The Executive Summary has been almost completely rewritten. Now that the conclusions are more visible and the entire last section is devoted to the Way Forward, instead of being fragmented through out other sections.

Executive Summary: I would like to see more direct references to sponsored programs so that policy makers could see what is working and then given ideas of what would be good to continue supporting, as in point 2.
We felt that we needed to keep the ES streamlined without too much detail. The current sponsored programs are shown in Chapter 2 and recommended supporting in Chapter 4.

Executive Summary: The terms used to designate anthropogenic and total aerosol influence are indistinguishable except by the artificial definition. It would be better to prefix radiative forcing with "a" for anthopogenic, "t" for total, and if used, "n" for natural (i.e., ARF, TRF, or NRF) or some similar scheme so that one is not forced to constantly reference the definitions.
In this rewrite, we decided to define the term of aerosol radiative forcing with caveats that this forcing was a perturbation between two states, and that these states must be specified. This is specifically described in Chapter 1.

Executive Summary: It might be useful to have sections in the executive summary correspond to those in the body.
In this revision we followed the reviewer's suggestion and followed the outline of the main body of the report.

Chapter 1

EPA
In the main table of contents and the table of contents for Chapter 1, the line for section 1.2.2 has the spelling "climage."
Joel Scheraga, EPA
Corrected

NOAA/OFCM
Chapter 1, Page 2, Lines 39 – 42
The text on these lines uses such terms as "deliquescence", "effloresce", and "interstitial particles." These terms are hardly common terms for public reading and should be defined in a footnote or simplified. Please consider modifying the text so that a reader who is less-versed in the subject matter can easily grasp the author's intent.
Samuel P. Williamson, NOAA/OFCM
Done. These terms were unnecessarily technical for the purposes of this report, and have been eliminated.

David L. Hagen
Chapter 1 Introduction, Section 1.1, Page 2 Fig. 1.1 Line 19

Upper right add incoming “cosmic rays” above “new particle formation”.
Section 1.1, Page 2, Description for Fig. 1.1 Line 35
After “ . . .influence climate.” insert:
“Cosmic rays create ions which enhance nucleation”.
David L. Hagen

Chapter 1 Introduction Section 1.2.1, Direct & Indirect effects, Page 5 Fig. 1.2
Add “Cosmic rays” coming from the upper left as causing “ions – nucleation” as input to “Aerosol Haze”. Page 5, Fig. 1.2 description near line 8 add.
”Cosmic ray nucleation correlates with low cloud temperature and outward radiation.”
David L. Hagen

Chapter 1, Introduction Page 5, Line 37 After Section 1.2.2 and before Section 1.3, Line 37
Add section: “1.2.3 Cosmic ray nucleation with solar modulation
Solar modulation of cosmic ray ionization forming low level clouds is just beginning to be recognized, measured and modeled. Svensmark and Friis Christensen (1997) discovered that incident cosmic rays modulate global low level cloud cover. Marsh and Svensmark (2000) showed high correlations between cosmic rays and low level cloud temperatures. In earth like atmospheres, Svensmark et al. (2006) find new aerosol particle production is proportional to negative ion density. Cloud cover further varies about 2% over the 11 year solar cycle. Svensmark (2007) reviews the theory of cosmoclimatology where ion nucleation of aerosols form cloud condensation nuclei. This varies with cosmic ray variations which are inversely modulated by the total solar irradiance and solar wind. Rusov et al. (2008a), (2008b) further develop a bifurcation model of galactic cosmic ray cloud formation and provide experimental support. Following Svensmark’s experimental confirmation, the European Organization for Nuclear Research (CERN) is creating the CLOUD atmospheric research facility to quantify cosmic ray atmospheric aerosol nucleation. Marsh (2003) showed correlations between the El Niño–Southern Oscillation and galactic cosmic rays. Usoskin et al. (2004) show latitudinal influence on cosmic ionization clouds. Harrison and Stehenson (2006) find that with sudden transient reductions in cosmic rays (Forbush events) there corresponding simultaneous decreases in diffuse insolation, and thus with clouds. They note that high cosmic ray fluctuations correlate with 2% higher diffuse insolation and a 19% increase in overcast days. These effects now need to be quantified, incorporated into Global Climate Models, and validated.”
David L. Hagen

Chapter 1, Page 13, References: Insert the following
Harrison. R. Giles; & David B. Stephenson, Empirical evidence for a nonlinear effect of galactic cosmic rays on clouds. Prod. Roy. Soc. A. V462, Nr 2068, Apr. 8, 2006, 1221-1233.
Marsh, Nigel, Galactic cosmic ray and El Niño–Southern Oscillation trends in International Satellite Cloud Climatology Project D2 low-cloud properties, J. Geophysical Research, V. 108, No. D6, 4195, doi:10.1029/2001JD001264, 2003
Marsh, Nigel D. & Henrik Svensmark, Low Cloud Properties Influenced by Cosmic Rays, Phys. Rev. Letters, 4, Dec. 2000, Vol. 85, No. 23, 5004-5007.
Rusov, V; A. Glushkov, V. Vaschenko, O. Mihalys, S. Kosenko, S. Mavrodiev, B. Vachev, Galactic Cosmic Rays - Clouds Effect and Bifurcation Model of the Earth Global Climate. Part 1. Theory, Atmospheric and Oceanic Physics, (2008) In Press

Rusov, V; A. Glushkov, V. Vaschenko, O. Mihalys, S. Kosenko, S. Mavrodiev, B. Vachev, Galactic Cosmic Rays – Clouds Effect and Bifurcation Model of the Earth Global Climate. Part 2. Comparison of Theory with Experiment. Atmospheric and Oceanic Physics, (2008) In Press
Svensmark, Henrik, & Eigil Friis-Christensen, Variation of cosmic ray flux and global cloud coverage – a missing link in solar-climate relationships, J. Atmospheric & Solar-Terrestrial Physics, V. 59, N. 11, pp. 1225-1232, 1997
Svensmark, Henrik, Jens Olaf P. Pedersen, Nigel D. Marsh, Martin B. Enghoff, & Ulrik I Uggerhøj, Experimental evidence for the role of ions in particle nucleation under atmospheric conditions, Proc. Royal Soc. A. 2006, 1773.
Svensmark, Henrik, Cosmoclimatology: a new theory emerges. A & G, February 2007, Vol. 48 #1, 18-24
Usoskin, I.G. & N. Marsh, G. A. Kovaltsov, K. Mursula, O. G. Gladysheva, Latitudinal dependence of low cloud amount on cosmic ray induced ionization, Geophysical Research Letters Vol. 31, L16109, doi:10.1029/2004GL019507, 2004
David L. Hagen
Addressing the reviewer's comments above collectively: The main focus of this report is anthropogenic aerosols. The cosmic ray source might make a significant contribution to aerosol loading in the upper troposphere, but it is not anthropogenic and is thought to be a small fraction of the total natural aerosol load.

Chapter 1 Introduction Page 5 line 28.
Though you have stated that the "residence time for tropospheric aerosols is typically about a week" page 3 line 5. You do not on page 5 line 28 state the residence time for soot particles and their direct radiative forcing at the surface. Without such information your conclusion, that the total is negative, is unsupported, and is more likely to be positive. You should remove all claims of knowing the sign of the effect, if you do not provide how much and how long the positive radiative forcing, by what you say are mainly soot particles.
John F. Pittman
Positive aerosol direct radiative forcing within the atmosphere is produced by soot, carbonaceous, and some dust particles. However, the conclusion of IPCC AR4 (2007), based on the aggregate of evidence to date, is that on global average and within reasonable uncertainty estimates for black carbon and other component concentrations, the net aerosol radiative forcing is negative (cooling). The Summary provided by this report cites the IPCC community consensus, which in turn represents a synthesis of existing measurement and modeling results.

Chapter 1 Introduction Page 6 line 2-4.
Again you make the unsupported and undocumented claim that models can project future climate change and ignore recent findings that they cannot be expected to do this. On the credibility of climate predictions / De la crédibilité des prévisions climatiques Author(s): D. Koutsoyiannis 1 | A. Efstratiadis 2 | N. Mamassis 3 | A. Christofides 4, it has been shown that the models that produce the projected impacts have been falsified for the regional scale, And are thus unlikely to be correct for larger scale. See also, The use of the multi-model ensemble in probabilistic climate projections Claudia Tebaldi1, Reto Knutti2 2007 Abstract: "…This paper outlines the motivation for using multi-model ensembles, reviews the methodologies published so far and compares their results for regional temperature projections. The challenges in interpreting multi-model results, caused by the lack of verification of climate projections, the problem of model dependence, bias and tuning as well as the difficulty in making sense of an 'ensemble of opportunity', are

discussed in detail." This paragraph is speculative as shown by the Tebaldi/Reto 2007 and Koutsoyiannis et al 2008, where not only can these models not be used for regional predictions, but that they also have not been verified nor validated for larger scale. Especially when you state on page 6 line 20-26. "The accuracies of current measurements to describing relations between aerosol composition and optical and cloud nucleating properties are not well established; consequently, aerosol forcing has been estimated mainly using modeled mass concentrations and assumed aerosol properties. Model simulations, in turn, rely on the representation of processes of aerosol formation and evolution in the atmosphere, and in particular the estimates of emissions of primary aerosol particles and of precursor gases, which are subject to large uncertainties." You admit here the large uncertainties, the lack of established relationships, which model simulations do not get the clouds, i.e. "cloud nucleating properties" and therefore the direct and indirect forcings correct, yet you claim the models can project future climate change? You also state page 6 line 20-22 "The accuracies of current measurements to describing relations between aerosol composition and optical and cloud nucleating properties are not well established; consequently, aerosol forcing has been estimated mainly using modeled mass concentrations and assumed aerosol properties." Your own work indicates that you cannot support such a claim. Another example is page 7 lines 18-21 "The difficulties encountered in quantifying present-day aerosol emissions, are magnified when attempting to develop past or future trends. Information for past years on the source types and strengths and even the world regions that dominate emissions are difficult to obtain, and the historical inventories from pre-industrial time to present had to be based on limited knowledge and database." This claim Page 6 line 2-4 should be removed in its entirety.
John Pittman

This report is a Summary and Assessment, based on the current status of the field. Our responsibility is to present both the strengths and limitations of current measurement and modeling, and to assess likely next steps. As such, we rely primarily on the combination of IPCC and AeroCom community consensus modeling studies for estimates of model uncertainties, which are reflected in the current document. Published measurement-based estimates of aerosol radiative forcing are also given, and their relationship to model-based estimates is discussed. The uncertainties are significant, especially as they relate to indirect effects of aerosols, however, the slate is not completely blank.

Forrest M. Mims III

Chapter I, Page 10, Line 5:
The order of the three gases is reversed from their usual fraction in the atmosphere. The correct order is water vapor, argon and carbon dioxide. Argon may exceed water vapor on mountains and in especially dry regions. (Note that nitrogen and oxygen on line 4 are in the proper order.)
Forrest M. Mims III

Inset #1 has been removed.

Nathan Taylor

Page 1 Line 36: Aerosol *do* influence health.

Yes. This is now mentioned right at the beginning of Section 1.2.

Section 1.3.2: This section could be better organized. In a paper of this length, organization in critical. It seems that there is a good framework, but this type of micro structure sometimes seems neglected.

I think that the sections would benefit greatly from introductions that relate the findings. The current scheme does have the logical flow of gradually building to a point, but I think that a "result-defense-conclusions" flow is more productive in issues this complex.
The chapter, and indeed, the entire document, has been mostly reorganized and rewritten, with the aim of substantial improvement in the respects indicated by the reviewer.

Section 1 page 8 Lines 17-27: When discussing the IPCC reports, name them (FAR, SAR, etc.) or otherwise reference them, but don't leave specification to a date in parentheses.
A uniform referencing scheme is now used for all IPCC reports, consistent with the CCSP standard.

Section 1.4: This should be earlier in section 1. Even if some of the concepts haven't been introduced, just reference later sections.
A statement of purpose for the report is now given at the very beginning of this chapter. As is traditional, a brief summary of the contents of subsequent chapters remains at the end of the Introduction.

Chapter 2

NOAA/OFCM
Chapter 2, Page 32, Lines 45 - 46
The text on these lines reads: "Uncertainties in the column amounts of sea salt and dust are significant as both components …" What is meant by "significant"? Is there a way to quantify how large the uncertainty is? Please consider providing the reader with a more concrete meaning/example of the term "significant."
Samuel P. Williamson, NOAA/OFCM
This statement has been removed.

Chapter 2, Page 34, Line 33
The last symbol in the equation on this line ("s") is portrayed as a factor in the superscript (e.g., "s" multiplies gamma). We believe that the "s" should be reflected as a subscript (e.g., "gamma sub "s"). Please make the appropriate change to the equation.
Samuel P. Williamson, NOAA/OFCM
The formula has been removed.

Chapter 2, Page 44, Lines 8 - 9
The text on this line reads: "Significant endeavor is demanded in the future to …" We believe this sentence would better express the author's intent if the sentence reads: "Significant effort will be needed in the future to conduct comprehensive assessments." Please consider rewriting this sentence to better express the author's intent.
Samuel P. Williamson, NOAA/OFCM
Done.

Forrest M. Mims III
Chapter II, Page 52, Lines 22-36 and Page 128, Line 22.

The geographic definition of global dimming suggested in the following sentence from Page 52 does not match the total irradiance usage on pages ix and x. (See above.) This, again, is highly confusing.

"While a significant and widespread decline in surface solar radiation occurred up to 1990 (so-called *dimming*), a sustained increase has been observed in the most recent decade. Speculation suggests that such trends result from decadal changes of aerosols and an interplay of aerosol direct and indirect effects (Stanhill and Cohen, 2001;
Wild et al., 2005; Streets et al., 2006b; Norris and Wild, 2007). Other studies suggest that the measured changes in surface solar radiation are local, not global in nature (Alpert et al., 2005)." (Emphasis added.)

This confusion is found in the literature, and this report provides an opportunity to use a consistent definition that does not confuse the reader by inaccurate use of the term "global."

Here is a published example (1) in which "dimming of the planet" is used:

"Manmade particles in ABCs lead to about 1.6 million deaths annually, decrease photosynthetically active solar radiation, have direct agricultural impacts, lead to a large dimming of the planet, …" (Emphasis added.)

Here is a landmark paper (2) on "global dimming" that added the same kind of confusion to this issue that is also found in the present report:

"Solar radiation at Earth's surface (also known as global radiation or insolation) is the primary energy source for life on our planet. . . . The main source for data prior to 1990 in (1–5) was the Global Energy Balance Archive . . . . This global network measures surface radiative fluxes at the highest possible accuracy. . . . " (Emphasis added.)

In the final analysis, aerosols cause a reduction in the direct solar beam and an increase in diffuse solar irradiance. The former is always more than the latter, and together a reduction in full sky ("global") irradiance occurs. The closest this phenomenon can be said to be geographically global is following a major stratospheric volcano eruption, such as the 15 June 1991 eruption of Mt. Pinatubo. While anthropogenic aerosols, desert dust, biomass smoke, sea salt, sulfate and other aerosols are regionally significant, the reduced optical transmission (or increased AOD) they cause is spatially highly variable. This should be explained in the text to avoid furthering the confusion over "global dimming."

An important omission is any reference to the world's longest continuous measurement of atmospheric transmission, the Ellis curve from Hawaii's Mauna Loa Observatory (1957 to present). All papers about this record report no significant change in T other than that caused by major volcanic eruptions. (A slight drop in T in recent years may be a result of increased Asian dust and/or air pollution.) References to the MLO transmission series will be sent on request.

References.

1. Veerabhadran Ramanathan, Atmospheric Brown Clouds: Health, Climate and Agriculture Impacts (Accessed at http://www-ramanathan.ucsd.edu/PASScriptaVaria106.pdf)
2. Martin Wild, *et. al.,* From Dimming to Brightening: Decadal Changes in Solar Radiation at Earth's Surface, *Science* 308, 847-850 (06 May 2005).

Forrest M. Mims III

We have removed "global" to avoid possible confusion.

Chapter II, Page 25, Figure 2.3:

There are several major issues with Fig. 2.3:

1. Misleading Nature of Logarithmic Data Visualizations. It is traditional in the satellite era to visualize aerosols in terms of their aerosol optical depth (AOD), and this is done yet again in Fig. 2.3. These visualizations are highly misleading and even deceptive, for the visualized AOD of desert dust and biomass smoke is often depicted as being only slightly higher than sulfate aerosols evolved from SO_2. In fact, the loss of sunlight through major dust and smoke events can dwarf that which occurs during sulfate events. (I have measured transmission through major volcanic sulfate events in Hawaii and very major smoke events in Brazil during SCAR-B and during 1997.) AOD is actually a measure of atmospheric transmission (T), the fraction of irradiance in a direct beam of sunlight that penetrates the atmosphere and reaches the surface. T is expressed as a percentage (*e.g.,* 90 percent) or a decimal fraction (*e.g.*, 0.92). The aerosol community and, presumably, the modelers, understand that AOD is a logarithmic function, for T = Exp(-AOD). Thus, when the AOD is 0.10, T is 0.90 or 90.48 percent. When the AOD is 0.4, T is only 67 percent. Because the AOD can exceed 5 (T = 0.674 percent) under thick biomass smoke in Brazil (I've measured AOD > 7 there), it is quite obvious that T is a far more intuitive method for expressing the loss of direct sunlight through aerosol clouds.

Please use T in the imagery. The general public and most non-aerosol scientists have no idea that the data in these images is visually misleading, for virtually all satellite visualizations are linear, not logarithmic. For example, satellite visualizations of column ozone, column water vapor, albedo, cloud reflectance, sea level and many other parameters are presented in a linear fashion. *Only optical depth is presented as a logarithmic function and this is rarely, if ever, explained.* This methodology is a recent and highly misleading tradition of the satellite era and does not meet NASA's *Guidelines for Ensuring the Quality of Information* (1). Contemporary aerosol scientists may not know that the use of optical depth is relatively new in the history of measurements of atmospheric transmission. From the late nineteenth century to 1962, the Smithsonian Astrophysical Observatory (APO) expressed the reduction of the intensity of a direct beam of sunlight as the fractional transmission (T). This tradition was continued with the Ellis curve, a 51-year record of atmospheric transmission (T) from the Mauna Loa Observatory (MLO) begun in 1957 (2). The APO and MLO records of T are the longest ever made, and the latter is ongoing. Because AOD is confusing to students, Mims and Brooks used both AOD and T in sun photometer observations conducted by students in the GLOBE program. Mims used both AOD and T in the instruction manual for Radio Shack's Sun and Sky Monitoring Station, a 4-channel sun photometer and solar radiometer acquired by some 12,000 people.

2. The seasons in Fig. 2.3 are improperly labeled. Southern Hemisphere readers will wonder why the image for March is designated "Spring" and the image for September is designated "Fall."

3. It is essential to show visualizations for all four seasons. Fig. 2.3 shows global images for March and September. But June and December are equally important, for major Saharan events occur all year. Please do not use "spring" and "fall" for specific months due to hemispherical differences.

4. The caption of Fig. 2.3 needs amplification. Please consider noting that the 550 nm at which AOD (hopefully to be changed to T) is expressed is green light near the peak of human vision. Otherwise many readers will have no idea of the significance of 550 nm to visibility.

Reference.

The relevant data quality guidelines include the following excerpts from http://www.sti.nasa.gov/FINAL_NASA_guidelines.pdf See Comment 1 above for full text of relevant sections.

Forrest M. Mims III

These AOD plots have been removed from the report.

Chapter 2, Page 35, Figure 2.10. 39.
This figure is incorrectly placed at the top of the page. It belongs in section 2.3.2 or just above it. There is not time to look for other misplaced figures, and this should be checked during the revision phase.
Forrest M. Mims III
Fixed.

Chapter 2, Page 38, Lines 11 and 29.
"AOT" (Aerosol Optical Thickness) is used when elsewhere in the report (including page 38) only "AOD" (Aerosol Optical Depth) is used.
Forrest M. Mims III
AOT has been changed to AOD.

John Pittman
Chapter 2 Measurements Page 28 lines 20-21
You state "Model simulation is also an indispensable tool for estimating past aerosol forcing and projecting future climate due to changes in atmospheric aerosols" Again you make the unsupported and undocumented claim that models can project future climate change and ignore recent findings that they cannot be expected to do this. On the credibility of climate predictions / De la crédibilité des prévisions climatiques Author(s): D. Koutsoyiannis 1 | A. Efstratiadis 2 | N. Mamassis 3 | A. Christofides 4, it has been shown that the models that produce the projected impacts have been falsified for the regional scale, And are thus unlikely to be correct for larger scale. See also, The use of the multi-model ensemble in probabilistic climate projections Claudia Tebaldi1, Reto Knutti2 2007 Abstract: "…This paper outlines the motivation for using multi-model ensembles, reviews the methodologies published so far and compares their results for regional temperature projections. The challenges in interpreting multi-model results, caused by the lack of verification of climate projections, the problem of model dependence, bias and tuning as well as the difficulty in making sense of an 'ensemble of opportunity', are discussed in detail." This paragraph is speculative as shown by the Tebaldi/Reto 2007 and Koutsoyiannis et al 2008, where not only can these models not be used for regional predictions, but that they also have not been verified nor validated for larger scale. Especially when you state on page 6 line 20-26. "The accuracies of current measurements to describing relations between aerosol composition and optical and cloud nucleating properties are not well established; consequently, aerosol forcing has been estimated mainly using modeled mass concentrations and assumed aerosol properties. Model simulations, in turn, rely on the representation of processes of aerosol formation and evolution in the atmosphere, and in particular the estimates of emissions of primary aerosol particles and of precursor gases, which are subject to large uncertainties." You admit here the large uncertainties, the lack of established relationships, which model simulations do not get the clouds, i.e. "cloud nucleating properties" and therefore the direct and indirect forcings correct, yet you claim the models can project future climate change? You also state page 6 line 20-22 "The accuracies of current measurements to describing relations between aerosol composition and optical and cloud nucleating properties are not well established; consequently, aerosol forcing has been estimated mainly using modeled mass concentrations and assumed aerosol

properties." Your own work indicates that you cannot support such a claim. Another example is page 7 lines 18-21 "The difficulties encountered in quantifying present-day aerosol emissions, are magnified when attempting to develop past or future trends. Information for past years on the source types and strengths and even the world regions that dominate emissions are difficult to obtain, and the historical inventories from pre-industrial time to present had to be based on limited knowledge and database."
John Pittman
The statement has been deleted.

Nathan Taylor
Section 2.3: It would be worthy to point out initially and very explicitly that this section relies heavily on work done by Bates. This emerges, but a sentence that says "this entire section is a paraphrase of the 19xx Bates paper <name> published in <journal> ", would be decent.
This section has been changed substantially. The description of the study in Bates et al. paper has been revised with results summarized. Major results of aerosol characterization from NEAQS, MILAGRO, and ICARTT have been added. References to other work (e.g., Koch et al., 2007; Shindell et al., 2008) have also been added. The section now reports on three ways in situ measurements can be used to improve models: validation of CTMs with measured in situ aerosol properties, use of measured optical properties in RTMs, and development of simplifying parameterizations for use by RTMs based on field observations.

Section 2.3 page 34 Lines 32-42: The use of formula in this report is haphazard. Why report this single formulation except (as it appears to me) that it is sufficiently simple, regardless of flow.
Formula removed.

Section 2.3.2 page 35 line 37: The first sentence should say scale with, not proportional.
Done.

Some of the figures in section two are clearly taken from elsewhere but not cited.
Now cited.

Figure 2.14 is somewhat hard to read and probably should be made into a table.
The figure has been redone and we will also ask the EOS editing office to present figure (a) and figure (b) in separated pages with landscape orientation.

Section 2 would benefit from a strong introduction as requested above.
We have enhanced the introduction part. Also this chapter has been tied to Chapter 1 in terms of measurement accuracy requirements.

Section 2.3.5 Page 46 Line 15: The first sentence is strange—do you mean that aerosol can't be seen in the visible spectrum? or aren't dominant? Or that clouds are easier to see? Or that clouds are more ubiquitous? I would reword this informal sentence to say something less vague.
It changes to: "Satellite views of the Earth show a planet whose albedo is dominated by dark oceans and vegetated surfaces, white clouds, and bright deserts."

Section 2.3.5 Page 46 Line 24-32: I feel that the second paragraph needlessly glosses over some subtleties. I think it would be worthwhile to go ahead and introduce the key links in the question—i.e., some aerosol will activate as CCN depending on aerosol and cloud properties, increasing CCN concentrations will increase cloud droplet concentrations.
The paragraph is written as: "Cloud droplets form on a subset of aerosol particles called cloud condensation nuclei (CCN). In general, an increase in aerosol leads to an increase in CCN and an increase in drop concentration. Thus, for the same amount of liquid water in a cloud, more available CCN will result in a greater number but smaller size of droplets (Twomey, 1977). A cloud with smaller but more numerous droplets will be brighter and reflect more sunlight to space, thus exerting a cooling effect. This is the first aerosol indirect radiative effect, or "albedo effect". The effectiveness of a particle as a CCN depends on its size and composition so that the degree to which clouds become brighter for a given aerosol perturbation, and therefore the extent of cooling, depends on the aerosol size distribution and its size-dependent composition. In addition, aerosol perturbations to cloud microphysics may involve feedbacks; for example, smaller drops are less likely to collide and coalesce; this will inhibit growth, suppress precipitation, and possibly increase cloud lifetime (Albrecht et al. 1989). In this case clouds may exert an even stronger cooling effect."

Page 47 Line 20: The paragraph that begins "Feingold et al. . ."—There are multiple ARM sites.
It is SGP site. Specified in text.

Section 2: I believe that the executive summary and first section mentioned AMS quite prominently but it does not seem to be frequently mentioned in this section.
In this revision, discussion of in-situ measurements has been substantially enhanced (e.g., sections 2.2.2, 2.2.3, 2.3.1).

Chapter 3

EPA
Chapter 3, Pages 75-76:
"A primary conclusion of the recent IPCC (2007) report is the elevation of man's influence on the warming climate to the category of "very likely". This conclusion is based on among other things the ability of models to simulate the global and to some extent regional variations of temperature over the past 100 years. When anthropogenic effects are included, the simulations can reproduce the observed warming; when they are not, the models do not get very much warming at all. Practically all of the models run for this assessment (approximately 20) produce this distinctive result. Behind this relative unanimity, however, is an inconvenient truth: in order to produce the observed temperature increase trend, models must use very uncertain aerosol forcing. The greenhouse gas change by itself produces warming in models that exceeds that observed on average by some 40% (IPCC, 2007). Cooling associated with aerosols reduces this warming to the correct level. However, to achieve this response, different climate models use differing aerosol forcings, both direct (aerosol scattering and absorption of short and longwave radiation) and indirect (aerosol effect on cloud coverreflectivity and lifetime), whose magnitudes differ markedly. Kiehl (2007) using nine of the IPCC (2007) AR4 climate models found that they had a factor of three forcing difference in the aerosol contribution for the 20th century. The differing aerosol forcing is the prime reason why models whose climate sensitivity varies by almost a factor of three can produce the 'right' answer. Hence the uncertainty in IPCC (2007)

anthropogenic climate simulations for the past 100 years should really be much greater than stated (Schwartz et al., 2007; Kerr, 2007)."
Comment: The conclusion in Chapter 3 that the uncertainty in IPCC (2007) is incorrect appears to be misplaced
Joel Scheraga, EPA
TAKEN INTO ACCOUNT; IT DOESN'T HAVE TO BE LIMITED TO CHAPTER 3, BUT SINCE IT DERIVES FROM A MODEL DISCUSSION, IT SHOULD AT LEAST BE IN THERE.

NOAA/OFCM
Chapter 3, Page 93, Lines 39 - 40
The text on these lines reads: "e.g., from the University of Miam …" We believe the author is most likely referring to the University of Miami. Please consider revising the text to refer to the appropriate institution.
Samuel P. Williamson, NOAA/OFCM
Not applicable anymore. Text has re-written.

Chapter 3, Page 101, Lines 11-12
The text on these lines reads: "Geographically, it appears that the 'cloud cover' effect produced slightly more cooling in the Southern Hemisphere than did the 'cloud albedo' response." What is meant by "slightly more cooling"? Is there a way to quantify how small the cooling difference is? Please consider providing the reader with a more quantitative measure of the term "slightly more cooling."
Samuel P. Williamson, NOAA/OFCM
ACCEPTED AND DONE.

Chapter 3, Page 115, Lines 24 – 25
The text on these lines reads: "where [blank space] is the size distribution of the …" The blank space results in an incomplete characterization of the preceding equation's variables. We believe that a symbol (perhaps "m") should replace the blank space. Please consider revising the text on this line to more fully characterize equation variables.
Samuel P. Williamson, NOAA/OFCM
Appendix has been removed.

David Hagen
Chapter 3, Section 3.5 Page 110 Line 11
Insert:"From the Mt. Pinatubo eruption, Douglass & Knox (2005) found a volcano climate sensitivity λ of 0.15 ±0.06K/(W/m2), implying a negative climate feedback of -1.4 (+0.7, -1.6). The intrinsic climate response time was only 6.8 ± 1.5 months. These are opposite the conventional paradigm of positive feedback with long response times. These should be verified with future eruptions correlated with satellite observations."
David L. Hagen

Chapter 3, Section 3.5 Page 111 Line 4
Insert reference:
"Douglass D.H. and R.S. Knox. Climate Forcing by the Eruption of Mount Pinatubo. Geophys Res Lett 32 doi:10.1029/2004GL022119, 2005"

David L. Hagen

Chapter 3 Modeling, Page 106 Secton b Other indirect effects, Line 31
Insert: "Christiansen et al. (2007) thoroughly review the Influence of Solar Activity Cycles (ISAC) on climate, including the experimental and modeling of galactic cosmic rays on aerosols and clouds, with associated inverse solar modulation. "Henrik Svensmark (2007) reviews how galactic climate rays cause ionization with subsequent aerosol formation and cloud nucleation, and how these are modulated by solar irradiance and solar wind. Marsh and Torsten (2006) examine in detail the role of ionization and the related influence of solar activity cycles on climate. These include cosmic ray ion induced nucleation, charge assisted growth, electroscavenging, and global atmospheric electric currents. They further examine the impact on low clouds which show the strongest correlation with galactic cosmic rays. This includes cloud microphysics including precipitation, and cloudy to super-clean states driven by cloud condensation nuclei (CCN). These mechanisms and correlations show significant natural solar forcing of climate distinct from Total Solar Irradiance (TSI) and anthropogenic impacts. It will be important to incorporate them into global climate models (GCM), validate the results and evaluate the uncertainties."
David L. Hagen

Chapter 3 Modeling, Page 110 Line 40
Insert reference: "Christiansen, Freddy, Joanna Haigh, & Henrik Lundstedt, Influence of Solar Activity Cycles on Earth's Climate, Task 700-Summary Report Conclusions and Recommendations, Danish National Space Center, April 11, 2007."
David L. Hagen

Chapter 3 Modeling, Page 113 Line 24
Insert reference "Marsh, Nigel & Torsten Bondo, Task 5-Hypothetical Physical Mechanisms, WP503-Role of Ionisation, Influence of Solar Activity Cycles on Earth's Climate, Danish National Space Center, Sept. 14, 2006"
David L. Hagen

Chapter 3 Modeling, Page 114 Line 35
Insert reference: "Svensmark, Henrik, Cosmoclimatology: a new theory emerges. A & G, February 2007, Vol. 48 #1, 18-24"
David L. Hagen

REPLY TO ALL COMMENTS FROM THIS REVIEWER: Solar and volcanic forcings are outside the purview of this report, which is focused on anthropogenic aerosol forcing, so the various comments concerning them are not relevant here.

Nathan Taylor

Section 3: The acronym MOZART is used before it is introduced in section 3.2.2.
MOZART is no longer mentioned in this revision.

Section 3: In this section do be sure to retrieve graphics from the sources so that they are not of such poor resolution. And make sure that you are citing each source.
Done.

Section 3.3.2 Page 104 Line 7: The 'semi-direct' effect does not require local cloud presence to be considered active. Hansen (1997) describes it as a reduction in "large scale cloud cover in the atmosphere with absorbing aerosols." So this introduction is misleading. A region where cloud formation is inhibited by a stabilizing forcing is not "within or in the vicinity of clouds."
Sentence revised.

Section 3.3 vs 3.3.2: It seems that section 3.3 is addressing GCMs, but 3.3.2 is exclusively higher resolution models. I recommend renaming 3.3.
The chapter has been significantly revised and re-structured. The high resolution model part is now in the "calculating aerosol indirect forcing" section.

Chapter 4

NOAA/OFCM
The text on these lines is part of the "Requirements for Future Research – Modeling" subsection of the "Way Forward" chapter and reads:
"More likely, the off-line aerosol/chemistry models could be used to calculate the difference these processes make in simulations, both for aerosols and radiative forcing, which might provide a zeroth-order estimate of the effect they would have in GCMs. The approach, however, would fail to provide much of the necessary information, for aerosol-climate interactions are highly interactive, and the interaction likely produces unique results. Furthermore, some of these interactions will likely change as climate does."
This text indicates the inadequacy of off-line aerosol/chemistry models. This inadequacy raises the question about what can be done to overcome this inadequacy; yet the author makes no recommendation. Accordingly, we believe the author should make some statement on how the inadequacy of off-line aerosol/chemistry models could be overcome. Please consider adding a statement or recommendation to address the inadequacy of off-line aerosol/chemistry models.
Samuel P. Williamson,
SEVERAL SENTENCES HAVE BEEN ADDED CONCERNING THE MODEL DEVELOPMENT OF ON-LINE ASPECTS THAT WILL LEAD TO MORE SOPHISTICATED CLIMATE CHANGE SIMULATIONS.

David L. Hagen
Chapter IV, Page 130 Line 16
Add: "Particular attention is needed to quantify galactic cosmic ray ionization induced aerosol formation and cloud nucleation, and consequent cloud albedo, water and temperature variations with altitude. The related cosmic ray modulation by solar irradiance and solar wind modulation need to be better understood and incorporated into climate models."
David L. Hagen
NA. Solar forcing is not within the scope of this report.

APPENDIX

One very important property of aerosols is water droplet formation in water vapor saturated air (at 100 % relative humidity). To my knowledge, all climate models assume droplet formation when 100% humidity is reached.
However, according to the laws of thermodynamics a gas to liquid transition is a first order phase transition. Thus, oversaturation is possible – like overheating or undercooling in other first order phase transitions.
The way out is to postulate that always sufficiently many condensation nuclei are present for droplet formation. In general, the condensation nuclei are assumed to be aerosols. For the following I call this postulate the saturation theorem.
In the addendum below, I have given arguments mainly from electrostatics, why i) homopolar aerosols like alkanes from oil soot, ii) homopolar molecules with dipolar radicals like ethanol, iii) dipolar aerosols like sulfur acid have very different attractive forces to the dipolar H2O molecules.
I propose a systematic study of the most common aerosols concerning the humidity limit where water droplets form. This study should be performed under laboratory conditions in ultra-clean air and water vapor with well defined additions of aerosol pollutants, and in a realistic range of temperatures. In addition, 'washing-out' studies should be carried out, e.g. by reducing air pressure, in order to learn when the input aerosol amount is exhausted.
Only if all such studies confirm the saturation theorem of droplet formation, it can be accepted and used without restrictions in climate model calculations..

All members of the team of authors know, of course, that in the hierarchy of attractive forces the case iv), an isolated charge (or an extra charge embedded in an aerosol) has the strongest attraction to H2O dipoles .
However, the only realistic way to generate sufficiently many free charges in the atmosphere is through the collision products of high energy cosmic rays. Most of these collision products decay again. Some of them live up to a microsecond. Such particles like myons or positrons can be embedded in condensed matter and can be used as sensor for specific condensed matter properties. Examples include myon spin rotation and positron emittance tomography. These elementary particles may also live long enough for water droplets to reach the critical radius.

However all members of the team of authors assume (or believe) that cosmic rays of no importance for water droplet and thus cloud formation – otherwise the work of Svensmark had been quoted.
Certainly, such a point of view is respectable, but it requires to carry out experiments of the type suggested above - to prove it.

I do not suggest studies on charged aerosols here. Such studies are under way in Europe (Denmark CERN) and will complement the US activities on aerosols.

Addendum

A theoretical physicist's view on water droplet formation

A water droplet needs a condensation nucleus, which could be an aerosol. Around it, the dipolar H2O molecules assemble and grow. However, the droplet has to exceed a certain critical radius to grow on its own. When the attractive forces of the aerosol are not sufficiently strong, growth will stop before the critcal radius is reached.

Let us ignore for the moment the possibility that aerosols are charged. Then the attractive forces between aerosol particles and H2O molecules are dipole-dipole attraction and the hydrogen bridge bond.

The hydrogen bridge bond is a purely quantum mechanical phenomenon (tunneling of protons), not understood in detail, although realized to exist since the beginning of quantum mechanics. In classical molecular dynamics models the hydrogen bridge bond is simulated by a short range attractive force.

But let us look at the dipole dipole forces. They decay with 4th power in distance, much longer range and much stronger than attraction in a Lennard-Lones potential, as used, e.g., for noble gases.

Dipolar aerosols are. e.g. sulfur acid H2SO4, or hydrochloric acid HCl.

There also exist homopolar aerosols such as carbon soot or oil soot. Hydrated alkanes such as ethanol or methanol have both a dipolar and a homopolar end.

Homopolar aerosols attract water much less, with Lennard-Jones type forces of 7th power in distance.

If however the aerosoles are charged, there is a charge-dipole force which is much stronger than the dipole-dipole forces and which decays only with 3rd power in distance.

Aerosols could be charged with positve protons (H+) or OH- groups arising from dissociated water molecules.

Another source of charges comes from collision products of high energy cosmic rays, which are mostly protons with energies ranging from 1010 to about 1020 eV. The proton rest mass is 109 eV Primary, secondary and much higher order collisions cause an enormous amount of collision particles to be distributed over hundreds of square miles at the high energy end. The 'low energy' particles appear much more often.

ALL APPENDICS ARE REMOVED