Working Group 5

What is needed to evaluate and improve GCM calculations of aerosol forcing?

Charge: Prioritize key research questions and approaches (modeling, field, laboratory and satellite observations) to address them.

Discussion

J. Hansen (NASA/GISS) began the session by suggesting that it would be useful to focus on two topics: aerosol/hydrologic cycle interactions and aerosol/chemistry interactions.

Aerosol-hydrologic cycle interactions:

A. Del Genio (NASA/GISS) began the discussion by pointing out four important problems in modeling physical processes with regard to the indirect effect of aerosols. 1) Varying the assumptions (i.e. frequency of occurrence and location of clouds) of cloud processing of aerosols in models can get the indirect effect to vary by a factor of three. GCMs tend to form clouds in the lowest layer and this must be artificially suppressed in the model simulations. In addition, aerosol-cloud interactions depend on the efficiency of rain-out, and small changes in this parameter can make a huge difference in model results. This underlies the importance of making an accurate determination of precipitable cloud fraction. 2) Also important is how clouds interact with dynamics on synoptic timescales. A big question is how to separate aerosol and meteorological effects on clouds. S. Kreuger (Utah) said that even cloud resolving models still can't deal with turbulence eddies. Although monthly mean precipitation is usually good in models, V. Ramaswamy (NOAA/GFDL) pointed out the problems with spatial variability of clouds. B. Collins (NCAR) suggested that to constrain the physical processes in GCMs, it would be useful to develop a CTM (driven by observed meteorology) with the same parameterizations of a GCM. One could then focus experiments to highlight transport problems in models. 3) When making use of field observations (for input or validation), we don't know small-scale meteorology. It is possible to do this in conjunction with aerosol measurements but is not typically done. 4) Higher level clouds, such as cirrus and convective, are also suggestive of aerosol influence making it important not to leave these out.

Aerosol-chemistry-climate interactions:

On the topic of chemistry-climate interactions, D. Jacob (Harvard) pointed out that the SO_2 oxidation pathways are not well-constrained and that this is critical to calculate aerosol number concentrations. The understanding of how aerosols affect chemistry and vice versa is critical for modeling the indirect effect. The CACTUS model at Harvard has addressed the effect of chemistry on direct forcing; however, the indirect effect has not been adequately addressed. The SO_2 oxidation pathway will affect nucleation and subsequent growth of an aerosol particle and we must be able to model this for an accurate representation of the indirect effect.

Black carbon:

Additional problems in models that were discussed include difficulty modeling black carbon (BC). V. Ramaswamy stated that the vertical profile of BC is not well-known. The potential lofting of BC into the upper troposphere can significantly affect its lifetime, however there are very few observations of BC in the free troposphere with which to confirm model results. We need BC data for verification of models. J. Hansen pointed out that BC is much more difficult to grid in models than sulfate because it depends on complete/incomplete combustion. Satellites do fairly well with this (i.e. can get a rough estimate of SSA) but this data must be combined with field studies. J. Penner (Michigan) pointed out that carbon aerosols are relatively constant with altitude and that this can be determined from lidar measurements. J. Hansen agreed but added that this data is not known as a function of time, prompting V. Ramaswamy to point out the need for long-term measurements of these species.

Scavenging and vertical distribution of aerosols:

J. Penner noted that vertical distribution of aerosols between models varies by a factor of ten in the free troposphere and that this is an important problem to overcome. D. Jacob said that scavenging within model simulations is a large source of uncertainty. J. Hansen brought up the importance of understanding high-level clouds in order to get at the indirect effect. Laboratory experiments could be helpful with this. J. Penner said that we also need exploratory studies of ice clouds and that GCM studies could motivate people to put more resources into studying this issue.

Needed measurements: long-term systematic monitoring:

On the topic of what measurements are needed to improve model simulations, S. Krueger pointed out the importance of integrated, high quality data sets to get meaningful information and that it's probably better to push for fewer sites with many types of instrumentation rather then extending the instrumentation over a greater number of sites. He suggested extending ARM to more sites in conjunction with aerosol studies. J. Penner suggested that taking ARM capabilities to the ACE-2 measurement site in Tenerife could provide useful data. D. Anderson (NASA/HQ) stated that one must decide what surface and aerosol types need to be measured and over what time period. B. Wielicki (NASA/LARC) said it would be useful to pick surface sites by aerosol type to gain insight into this problem and suggested getting at the 2nd indirect effect by taking satellite data and sorting it by meteorological state and amount of aerosol (and particle size distribution). This would give us ensemble distributions sorted by different parameters. J. Hansen brought up the importance of involving the meteorological community in measurement campaigns. B. Wielicki said that the lack of an integrated effort in the US is an obstacle. D. Anderson said that the NSF doesn't support systematic observations. In fact there is no agency that can now advocate for long-term systematic monitoring. R. Somerville (SIO) pointed out the need to define "continuous" when discussing this type of strategy. He also asked whether it's the lack of observations that is the limiting factor, or if it's the lack of people using available data for model input and validation.

Modeling resources:

On this topic, B. Wielicki pointed out the problem that there is currently no program to fund cloud modeling. He stated that there seems to be a "black hole" between cloud resolving models and GCMs. We need to devote more time to cloud resolving models as most resources go towards GCMs. A. Del Genio pointed out that we need increased analysis of existing data, and that a greater complexity is not necessarily the way to go.

Conclusions and Recommendations

Key research questions:

As a result of the above discussion, the research questions were decided upon and organized into the following categories in order of priority:

1) What is the global distribution of aerosols and their characteristics?
2) How are aerosol effects coupled to the hydrologic cycle?
3) What are the key chemistry-climate interactions?

The first two correspond to the direct and indirect aerosol climate forcings, while the coupling to chemistry is directly related to the first two, but is separated due to its different modeling requirements. Key issues in chemistry-climate interactions include the need to better understand SO_2 oxidation pathways (homogenous versus heterogeneous) and hygroscopicity, as both have an effect on aerosol number concentration and the magnitude of the indirect effect. The order of prioritization reflects the need to obtain a better knowledge of aerosol distribution before the indirect effect can be realistically simulated.

Different approaches to investigate these questions include satellites, fixed long-term sites, field studies, specific laboratory studies, and model studies. One type of approach, by itself, is not sufficient to answer the above questions. The most complete and accurate information must use a combination of all of the above, and one cannot be given more importance than another. WG#5 therefore does not prioritize among the methods.

Modeling priorities:

In regards to modeling the indirect effect, priorities are:

1) Funding for modeling research and data analysis
2) Long-term, systematic observations
3) High resolution modeling on a variety of scales

The brainpower needed to analyzing existing and ongoing data sets is seriously limited, and funding for this data analysis must be available to make the best use of the observations. Observations must include both a top-down and bottom-up approach to be most effective. In order to effectively evaluate parameterizations of subgrid processes, high resolution modeling on a variety of scales is needed to improve the accuracy of the model results. In this, there is a need to explore the connections between cloud-resolving and global models.

WG#5 also pointed out that the indirect aerosol effect on high-level clouds has so far received almost no attention and should be given a priority equal to that of low-level clouds. The possibility exists that high-level clouds provide a significant positive forcing, which may offer an explanation of how a large negative forcing by low clouds could be consistent with observed global warming. As the greatest uncertainty with respect to aerosol-climate interactions is the indirect effect on clouds, the modeling will serve best to be carried out in concert with both a top-down and bottom-up approach to the analysis. Both have a high priority, but the top-down approach will be essential for reducing the uncertainty in the indirect effect.

NACIP will serve best by making the enhanced coordination of existing programs such as GEWEX, GCSS, BSRN, and ARM (to name a few) with the aerosol program a priority. The utilization of existing programs and capabilities will allow for the best results with a minimum of expenditure. Priority must therefore be given to coordinated programs with long-term measurement capability.