A RECONFIGURED

ATMOSPHERIC SCIENCE

PROGRAM

U.S. Department of Energy
Biological and Environmental Research
Advisory Committee

April 2004

PREFACE

Aerosols are defined as a system of colloidal particles dispersed in a gas. In the atmosphere one finds naturally occurring aerosols, such as volcanic particles and sea salt, and man-made or anthroprogenic aerosols from combustion sources. When the US Global Change Research Program (USGCRP) was defined in the late 1980s, seven core elements were selected. The highest priority was Climate and Hydrologic Systems. The Role of Clouds was the sub-topic of highest priority. Study of clouds necessitates a study of aerosols because they are key to shaping droplet size distribution and development of precipitation. The study of aerosols is a very complex subject and it has been difficult to make progress. The importance of aerosols has been recognized now as essential to reduce uncertainties associated with climate model results.

The importance of aerosol research has become a discussion item at high levels within the Climate Change Science Program (CCSP). One of the key areas addressed by the National Research Council (NRC) in their June 2001 report requested by the President was the influence of aerosols in the atmosphere. As a result, one of the CCSP priority areas addresses uncertainties associated with atmospheric distributions and effects of aerosols. Chapter 3 of the *CCSP Strategic Plan* involves aerosol research. CCSP Goal #2 of that Strategic Plan, to improve quantification of the forces bringing about changes in the Earth's climate and related systems, specifically calls for research during the next 2-4 years on aerosol properties and their impacts on climate.

Another key priority of the *CCSP Strategic Plan* is to increase modeling capability focusing on improving model physics, particularly with respect to clouds and aerosols. CCSP Goal #3, to reduce uncertainty in projections of how the Earth's climate and environmental systems may change in the future, focuses on climate models and their uses and limitations including sensitivity, feedbacks, and uncertainty analyses. Recently, DOE's Office of Science released its facility needs outlook for the next 20 years. The second priority item was to enhance UltraScale Scientific Computing Capability. Adequate computing support for modeling will aid and strengthen aerosol research.

In an effort to respond positively to the growing need for aerosol research and reduction of uncertainties, the Department of Energy's Office of Biological and Environmental Research (BER) decided to reconfigure their Atmospheric Science Program (ASP) into a research program that emphasizes radiative forcing from natural and anthropogenic aerosols. That necessitates phasing out the Atmospheric Chemistry and Environmental Meteorology Projects by the end of FY 2004 and reconfiguring the ASP into an aerosol research program that will be able to award grants to academic and other non-governmental research institutions and to make financial commitments for research support to Federal laboratories in FY 2005.

The Director of the DOE's Office of Science charged the Biological and Environmental Research Advisory Committee (BERAC) with the responsibility of providing guidance to enable the most effective and appropriate configuration of the ASP. The Chair of BERAC requested that an Expert Panel be formed to accomplish the task. Such a Panel was formed. See Appendix A for its membership. The Panel met in Washington, DC, November 17-19, 2003. The Agenda for the meeting may be found in Appendix B. This report contains the results of the panel's deliberations. It provides guidance and details to the Office of Science on a reconfigured atmospheric science program (ASP).

ACKNOWLEDGEMENTS

The Panel would like to acknowledge the many scientifically based briefings that were presented to them. The briefings allowed the Panel to attain a solid basis on what aerosol research was being funded by Federal agencies at the present time. Briefings came from Federal agencies whose aerosol research is coordinated through the CCSP, from other Federal agencies, from grant programs supported by BER/ASP, and from various National Laboratories. Those who gave the briefings emphasized the science. To them we owe a debt of gratitude for a job well done. Details may be found in the agenda for the meeting (Appendix B).

Jerry Elwood served as the primary contact with the Office of Biological and Environmental Research. He was always available. His guidance and suggestions were very helpful in preparing for the panel meeting and in reviewing the Panel's report. Without support from Peter Lunn, the task would have been much more difficult. Peter served as an advisor to the chair and used his knowledge of the scientific subject matter and the aerosol community wisely.

The Oak Ridge Institute for Science and Education (ORISE) provided logistical support for the meeting and preparation of the report. Mikki Dawn and Bruce Warford were present in Washington to serve the needs of the meeting. We thank them for their services there and their continued service in the preparation of this report.

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EXECUTIVE SUMMARY

In response to the needs of the Climate Change Science Program (CCSP), the Office of Biological and Environmental Research (BER) of the Department of Energy (DOE) decided to reconfigure its Atmospheric Science Program (ASP). The goal of the reconfigured ASP is to understand the role of atmospheric aerosols in radiative forcing of the Earth's climate. The DOE's Office of Science tasked the Biological and Environmental Science Advisory Committee (BERAC) with the responsibility of carrying out the planning for the proposed program. An *ad hoc* panel of experts was convened. They met on November 17-19, 2003. Representatives of Federal agencies and other stakeholders conducting climate research relevant to aerosols briefed the Panel. Based on their discussions and the expertise of the Panel, a recommended ASP reconfiguration plan was prepared and is presented in this report.

The Panel concluded from its discussions that the role of aerosols in climate forcing was a critical factor in climate change assessment, as well as an essential element in advancing the state of the art in climate modeling. Aerosol forcing appears to be the same order of magnitude as the effect of greenhouse gases, but far more uncertain. The forcing has two major components, direct and indirect. The former is related to direct scattering and absorption of radiation by suspended particles. The latter is related to the effect of particles on cloud hydrometeor size distributions that change cloud reflectivity. There are also indirect effects on precipitation, resulting from hydrometeor nucleation and growth modulation. The direct effects of aerosol forcing are much better understood than the indirect effects, especially with regard to airborne sulfate and soil dust particles. Knowledge of the indirect effects is largely anecdotal from observations, but with support from long standing knowledge about cloud microphysics processes.

Assessment of the limited work to date on aerosol forcing indicated that two large areas of uncertainty were relevant where the reconfigured ASP could help fill the gaps. These are (1) the indirect effects of aerosols on clouds and (2) the role of black carbon and organic aerosols on climate. The Panel identified these two areas as the major foci of the reconfigured ASP. Both of these areas involve complex physical chemistry questions that need to be investigated in-depth to improve the understanding of aerosol climate forcing and reduce uncertainties.

The proposed ASP would contain four major elements. The key elements are: (1) focused laboratory experiments, (2), well-designed field measurements, and (3) fundamental theoretical and process modeling. The first two require a fourth element, development and application of new instrumentation and measurement methods that will provide direct, continuous observations of the single scattering reflectivity and absorptivity of particles as well as continuous measurement of aerosol size and composition from nuclei to large particles.

The following are specific conclusions and recommendations:

- The concept of reconfiguring the ASP within BER from atmospheric chemistry and environmental meteorology projects to a program emphasizing radiative forcing of climate from aerosols has great merit in contributing to the CCSP goals and as such should be implemented as soon as practical.

- The reconfigured ASP should have as its goal the reduction of uncertainties in two specific gap areas. These are (1) the indirect effects of aerosols on clouds and (2) the role of black carbon and organic carbon aerosols on climate forcing.

- A well-balanced program consisting of field measurements, laboratory experiments, theoretical analysis with process modeling, and development and application of new instrumentation will be required to address the goals of the reconfigured ASP.

- The reconfigured ASP needs to be closely coordinated with the DOE Atmospheric Radiation Program (ARM) program and vice-versa as well as collaboration with other stakeholder programs in order to make most effective use of limited resources.

- The reconfigured ASP should look to the climate modeling program within DOE and the larger Climate Change Science Program (CCSP) as a test bed for applying knowledge and parameterizations gleaned both from the reconfigured ASP and the ARM programs.

As an adjunct to the development of the reconfigured ASP, the panel believes that a new, well instrumented, mobile aerosol chemistry and physics laboratory would facilitate and enhance the capabilities for the study of aerosols effects, especially if it were used in parallel with the new ARM mobile facility that is being developed.

The Panel also noted that in view of the recognized importance of aerosol research, the area appears to be seriously under-funded relative to other components of the CCSP. Noting the limitations on national funding for research, perhaps the apportionment of resources should be reviewed at all levels including individual agency portfolios as well as OMB allocations to agencies in support of the CCSP.

INTRODUCTION

This report was requested by DOE's Director of the Office of Science to give guidance to the Office of Biological and Environmental Research (BER) in creating a program to reduce uncertainties in climate science due to radiative forcing from natural and anthroprogenic aerosols. This subject has become a priority issue in climate research. It needs to be addressed as soon as practical in order to improve knowledge of the significance of climate forcing by aerosols. This knowledge will add to the sophistication and accuracy of climate model results.

The Director of the Office of Science charged the Biological and Environmental Research Advisory Committee (BERAC) with the task of providing the requested guidance. Forming a program on aerosols necessitates reconfiguring the present Atmospheric Science Program (ASP) that consists of the atmospheric chemistry and environmental meteorology research projects into an aerosol research program focused on radiative forcing of the atmosphere.

An expert panel was convened under BERAC. Briefings were provided to the Panel on what aerosol research was being supported at present. Briefings were given by scientists from Federal agencies who are involved in the Climate Change Science Program (CCSP) and other Federal agencies not involved in the CCSP, from BER program managers who direct related research through grants, and from representatives of the National Laboratories. Much of the ongoing research focuses on global modeling of aerosol effects on climate, remote sensing of aerosols from space, and the production of aerosols from anthropogenic and natural sources.

The Panel discussed the field of aerosol research and noted there were gap areas causing uncertainties that potentially could be filled by the reconfigured ASP. Two areas of great uncertainty were highlighted. They were (1) indirect effects of aerosols on clouds and (2) the role of black carbon and organic aerosols on climate

To accomplish the goal of filling gaps and reducing uncertainties requires a balanced program consisting of laboratory experiments, field measurements, theoretical analyses and process modeling, and the development and application of new instrumentation. Components of the program are discussed in detail in the following pages. Because such a program could consume vast resources, priorities are indicated, where possible, that will enable available resources to be used to the best advantage. Also included is a suggested enhancement that would cause some elements of the research to proceed more rapidly and in greater depth were resources available.

Since the Panel received extensive briefings on the current status of aerosol research supported primarily by Federal resources, it seemed appropriate to comment on several issues that transcend the reconfigured ASP. Hopefully, these comments will strengthen aerosol research programs.

CHARGE TO THE PANEL

The Director of the DOE Office of Science charged the Biological and Environmental Research Advisory Committee (BERAC) with assembling a small group of experts to provide guidance to the DOE's Office of Biological and Environmental Research (BER). The group was requested to provide guidance on what a reasonable and appropriate program would be, considering:

- major scientific uncertainties and knowledge gaps concerning both direct and indirect effects of aerosol radiative forcing,
- a limited budget,
- research currently funded in this topical area by DOE and other Federal agencies, especially those supporting significant amounts of focused research on this topic, and
- facilities and capabilities currently available and that potentially will become available for such research within the DOE laboratory system.

The group was requested to identify and provide its recommendations to the Director of the Office of Science through BERAC. This would enable the Office of Science to target its investments in aerosol radiative forcing research, in terms of scope, priorities, and areas of specific emphasis where results would yield substantial and important scientific payoffs.

A copy of the letter sent to the Chair of BERAC from the Director of the Office of Science may be found in Appendix C.

APPROACH TO THE CHARGE

It is important when responding to the above charge to discuss many aspects of the reconfigured program as well as the environment in which the reconfigured ASP will reside. The Panel made a concerted effort to look at aerosol research from a broad perspective and then agree on where the BER/ASP program could have a significant impact. Discussions also took place on how such a program would relate to and be complimentary with other ongoing environmental programs in BER.

The chemistry of aerosol particles in the atmosphere involves complex processes and interactions with gases and clouds. Important reductions in uncertainties concerning the role of aerosols in climate forcing will require a major research program involving four elements. The elements are: (1) laboratory experiments, (2) field measurements, (3) theoretical analyses based on fundamentals of physics and chemistry, and (4) development of instruments for sampling and characterization of aerosol particles in the field and in the laboratory. The fourth element is ancillary to the first two.

Laboratory studies are needed to investigate under controlled conditions key microscale properties and processes that are hypothesized to be relevant to radiative forcing. Field measurement programs provide the basis for characterizing atmospheric aerosols and their interactions with clouds, directly or indirectly influencing the Earth's radiation balance. The role of aerosols on different spatial and temporal scales needs to be investigated systematically both under terrestrial and marine conditions due to differences in the aerosols and the ways in which they interact with their environment. Integration of results from field and laboratory studies and their application to climate impacts requires the use of conceptual or numerical models. These analyses will lead to parameterizations of aerosol processes that can be transferred to climate models under development in other programs within, as well as outside, DOE.

Recent advances in aerosol measurement technologies offer major opportunities for new instrumentation applicable both to laboratory experimentation and field programs. A number of areas are noted that will foster development of new measurement techniques. These will improve capabilities to determine directly physical and chemical properties relevant to aerosol radiative forcing. An important element of any instrumentation program should be focused on development of robust, cost-effective instrumentation suitable for sustained field measurements. Instrumentation specifically for use on aircraft as sampling and measurement platforms also must be considered.

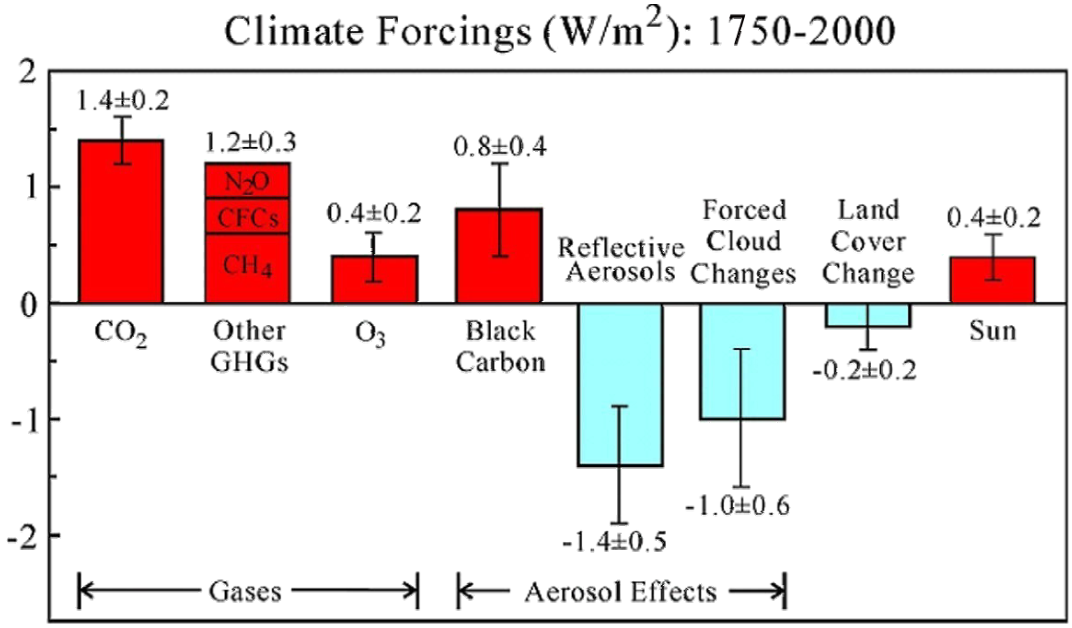


Figure 1. Global annual-mean radiative forcings for the period of 1750-2000. Error bars are partly subjective 1 F (standard deviation) uncertainties.

Figure 1 shows factors responsible for the forcing of climate change since the industrial revolution. Two areas of great uncertainty in aerosol forcing are (1) the indirect effects of aerosols on clouds and (2) the role of black carbon and organic aerosols on climate**.** Focused studies supported by the reconfigured ASP of processes by which aerosols affect clouds and by which organic and black carbon aerosols affect the scattering and absorption of light will generate data and insights that can be used by the global climate modeling community to narrow uncertainty in aerosol radiative forcing.

The indirect effect of aerosols on clouds occurs when aerosol particles or gas phase precursors of aerosols modify properties of clouds, thereby changing hydrometeor size distributions, cloud cover, cloud lifetime, cloud albedo, and precipitation. This effect dominates the current uncertainty in climate forcing. The effect is uncertain because processes by which aerosols modify clouds and responses of cloud systems to these changes currently are not well understood.

It has only recently been discovered that organic aerosols are a significant component of the global aerosol burden. Sources of these particles, the history of their abundance in the atmosphere, the evolution of their chemical and physical properties in the atmosphere, their interactions with gas phase reservoirs, their impact on cloud processes, and their optical properties are not well known. Organics may be either hydrophobic or hydrophilic. They may enhance or retard water uptake or change reactivity. Some organics may also absorb visible light. Black carbon particles that absorb visible light may lead to significant global warming. It is critical to determine the geographical abundance and properties of black carbon since their influence on climate is generally opposed to that of other aerosol types such as sulfate that does not absorb sunlight. The effects of aerosols create both positive and negative forcing that is an addition to the influence of greenhouse gases such as carbon dioxide. Reduction of emissions of such carbon particles that result in a positive forcing may offset in the short term some of the positive forcing due to the increasing concentration of greenhouse gases in the atmosphere.

DOE also sponsors the Atmospheric Radiation Measurement Program (ARM). It is essential that the reconfigured ASP interacts closely and collaborates with ARM. Not only should some field programs be conducted near ARM instrument sites, but also ARM radiative property studies will benefit from and complement those of the reconfigured ASP. In addition, the new mobile ARM laboratory will be a useful first step toward the study of aerosol sources, transformations, and fates.

Likewise, the reconfigured ASP must be closely interactive with the DOE climate modeling effort since the modeling program has been designed with a goal of developing, testing and applying coupled atmosphere-ocean climate models to simulate and predict climate change at the sub continental spatial scale and on a time scale of decades to centuries. The models are to account for, among other things, effects of changes of atmospheric composition. This includes both greenhouse gases and aerosols that alter the radiation balance of the Earth.

It is envisioned that the program outlined below also will interact with field programs, satellite observations, and modeling studies conducted by other agencies, thereby filling gaps in aerosol research led by other agencies.

There are several characteristics that have been real strengths of the earlier ASP that should be maintained and encouraged in the reconfigured program. The first is the strong collaboration between researchers in universities, national laboratories, and the private sector that ASP has facilitated. Such opportunities are not as readily available in many other agencies. The ASP program encouraged open-ended collaborations. This significantly facilitates development of "new science" and must be a continuing characteristic of the reconfigured ASP.

One of the more important leveraging activities was derived from collaborative programs fostered by the NARSTO (initially named the North American Research Strategy for Tropospheric Ozone) partnership. NARSTO has promoted sustained intramural communication and cooperative projects (including policy relevant science assessments) not only between Federal and state government agencies, but also between university and industry in Canada, Mexico and the U.S. Since 1994, NARSTO has evolved from a focus on tropospheric ozone chemistry to broad overview of all aspects of aerosols in air pollution. The organization is now considering further extension of its scope of activities to climate related aerosol projects. As such it will continue to be an important partner for the reconfigured ASP.

The second characteristic is the combination of meteorology, laboratory, field, and modeling studies in the ASP. While the latter three often occur to various degrees in other programs, strong meteorological interactions on different spatial and temporal scales have been extremely beneficial to the previous focus on air quality. These interactions will continue to be important for understanding aerosols and their processing in the atmosphere. The atmosphere is an environment where non-linearities in the chemical and physical processes that are associated with mixing and dispersion both horizontally and vertically may contribute significantly to the time-dependence of the chemical and optical properties of aerosols. Thus interactions with meteorology remain an important factor.

COMPONENTS OF THE PROGRAM

The Panel decided there were two areas of great uncertainty in aerosol forcing that, if supported by BER, could make a significant impact on aerosol research. Those areas are (1) the indirect effects of aerosols on clouds and (2) the role of black carbon and organic aerosols on climate. A balanced program should be composed of laboratory experiments, field programs, theoretical analyses based on fundamentals of physics and chemistry using process modeling and historical archives as well as instrument development for sampling and characterization of aerosol particles. Details of the components follow.

LABORATORY STUDIES

A key component of a program designed to elucidate both the indirect effects of aerosols on climate as well as the contribution of carbonaceous species to radiative forcing is a set of directed and focused laboratory experiments. The role of aerosols in modifying cloud properties depends on their chemical composition as well as their size. The chemical composition includes the distribution of species within the aerosol itself. For example, the presence of hydrophilic materials on the surface can promote water uptake while the presence of hydrophobic materials may decrease it. In addition the molecular structure of organics at the interface can have a significant impact on water uptake. Irregular, corrugated surfaces of even hydrophobic organics adsorb water to a much larger extent than a smooth surface of the same material. Such interfacial effects may not only alter water uptake, but also the kinetics and mechanisms of their oxidation that leads to the conversion of a hydrophobic to a hydrophilic surface. Optical properties of particles depend on these factors as well.

Included in the classification of organics that may be important in modifying cloud properties are biologically derived particles. There is increasing evidence that they contribute to the atmospheric burden of particles over a broad size range and should be considered with respect to their direct and indirect effects on climate.

In the real atmosphere both the structure and the chemical composition of particles will change with time due to interactions with trace gases and other particles. These changes can alter dramatically the properties of aerosols and their impacts on both direct and indirect effects on radiative forcing. It is essential that laboratory experiments be closely coupled to field measurements to investigate the physical and chemical evolution of particles. This will allow interpretation of the field data and appropriate translation into models that will accurately reflect the processing of particles in the atmosphere and how these changes affect their chemical and radiative properties.

The following are examples of the types of laboratory studies that will be useful in coupling the results of field studies to models. The order provides a rough guide to the relative priorities. This is based on relating laboratory studies to field campaigns and models as closely as possible. The highest priority is understanding atmospheric processing of aerosols in the middle and lower troposphere where it is anticipated field campaigns will focus on process studies. The relevant data would provide rigorous tests of models. Nevertheless, this is intended only as a guide and not a rigid program that would exclude outstanding research in associated areas.

With these caveats in mind, the following areas of research would seem most likely to provide the kinds of information needed for interpreting results of field campaigns and translating them into the development of more accurate models:

- Identification through mechanistic and kinetics studies of "intermediate diagnostics" that can be used to provide rigorous tests of models.
- Measurement of kinetics, mechanisms, and products of the oxidation of organic aerosol components (including soot) and precursors by tropospheric oxidants (e.g., OH, O_3, NO_3) for different forms of organics. An example would be as layers on liquid and solid substrates or dissolved in aqueous media containing other typical tropospheric aerosol components such as NO_3^- and SO_4^{2-} .
- Investigation of interactions of organic aerosols and organic-coated aerosols with water vapor and liquid water as well as associated effects on cloud properties and uptake and reactions of trace gases that can modify particle optical properties.
- Investigation of cloud condensation nuclei (CCN) and ice forming nuclei (IN) properties of organics and mixed particles and of time-dependent changes in chemical processing or "aging".
- Determination of optical properties of particles of mixed composition and phase including both inorganics as well as organics (e.g., non-spherical particles of sulfate and water layers on soot, liquid layers surrounding solid cores, surfactant layers on aqueous and solid substrates). Studies with polarization-sensitive nephelometers should be accompanied by theoretical calculations involving non-spherical heterogeneous particles.
- Identification of interactions between natural and anthropogenic aerosols and precursors (e.g., acid-catalyzed reactions of organics in particles).
- Identification of "markers" for natural vs. anthropogenic aerosols.
- Elucidation of the role of trace gases such as NO_x in the formation and further oxidation of organic aerosols.
- Development of methods for determining the biological contribution to particulate matter (PM) as a function of size and their contribution to the direct and indirect effects of PM.
- Elucidation of the distribution of aerosol components within the particle (i.e. surface vs. bulk) and the impacts on the chemistry and photochemistry of the particle.
- Elucidation of the nature of species measured as "black carbon" by current methods (e.g., any high molecular weight polymeric material).
- Studies of the effects of absorbing aerosols including realistic levels of black carbon on the reflectivity (albedo) of snow and ice.
- Elucidation of mechanisms of new particle formation in the atmosphere including nucleation involving ions or trace gases such as ammonia (NH_3) and volatile organic compounds.
- Quantification of coagulation rates of small particles and determination of whether coagulation can be treated with simple Brownian coagulation coefficients or whether particle charging or induced charges need to be determined.

- Reconstruction of the history of aerosols, especially black and organic carbon, during the industrial era using archived aerosol sampling filters, ice and lake cores, and other available repositories. Analyses of pollution records including archives of "black smoke" and "coefficient of haze" in the U.S. and elsewhere over long time periods should be included if they can be interpreted with contemporary sampling and analytical methods.

FIELD STUDIES

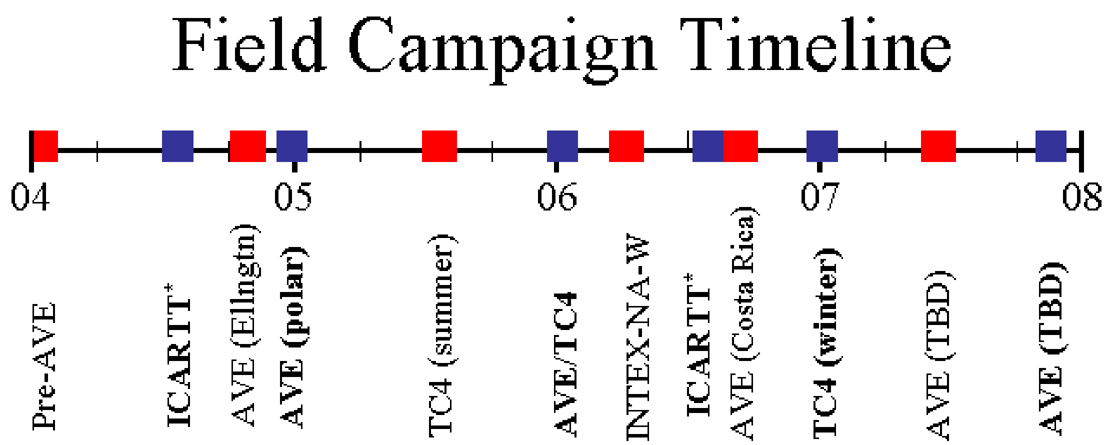
Field studies are an important component of any comprehensive aerosol research program. Real world measurements provide an opportunity to develop understanding of new processes, evaluation of model performance, and verification of satellite data retrievals. Several types of field programs are needed to study aerosols and cloud aerosol interactions. The reconfigured ASP needs to evaluate which field programs will prove most valuable and which can be carried out within available resources.

The design of field measurements addressing aerosol issues may require different approaches ranging from basic sustained monitoring through highly intensive, sophisticated short-term campaigns. Three classes of field programs are envisaged: (1) long-term systematic measurements linked with ARM sites or their equivalent, supplemented by satellite data as well as periodic, regularly scheduled aircraft overflights; (2) systematic ground based measurements supplemented by periodic intensive studies aimed at characterizing long range transport, mega-city plumes, or aerosol life cycles and; (3) highly intensive atmospheric, process-oriented campaigns to test specific hypotheses about aerosol-radiative interactions, especially indirect effects involving cloud processing.

The DOE has extensive experience with field observations related to atmospheric chemistry and the Earth's radiation budget. This experience should be utilized in the reconfigured ASP. The existing network of ARM sites and the planned transportable laboratory facility afford an opportunity for sustained measurements (one year or more in different locations) if the mobile facilities can be augmented to include a comprehensive suite of aerosol measurements (See section on "Important Program Enhancement" below). With a limited budget, it certainly is highly probable that the reconfigured ASP will not have sufficient funds to support any long-term systematic measurement program. DOE has access to a small aircraft suitable for working in the lower and middle troposphere and it has access to the Proteus aircraft. DOE management must insist on cooperation and collaboration between ARM as well as other DOE programs and the reconfigured ASP.

The DOE field program component related to aerosols should take place in the context of the larger national effort in order to avoid duplication. NASA already is working to obtain global data sets on aerosols from space. Its aircraft field programs have investigated stratospheric aerosols and polar stratospheric clouds. EPA has a network for observing aerosol mass, making chemistry measurements, and monitoring. NOAA has investigated urban aerosols. NSF has sponsored large-scale projects in Asia.

The work carried out by these agencies suggests that DOE should participate in these activities and focus on process studies involving direct and indirect effects of tropospheric aerosols on climate. In particular process studies should be conducted in collaboration with the ARM program in order to use limited resources to maximum advantage. *Table I* provides a timeline of some of the NASA/NOAA/DOE field programs already being planned for the next few years. Several of these programs may be appropriate for participation by the reconfigured ASP. Nevertheless, some smaller, focused field studies by the reconfigured ASP also may be appropriate. Such focused programs might be done first in regions with relatively simple sources so the evolution of aerosols could be better characterized and understood. For example, the East coast of the U.S. would not be a good place to begin such activities because there are so many sources located there creating substantial ambiguity in process interpretation. Also, it is important that instrument packages be state-of-the-art, carefully constructed, and deployed to answer science questions, not just to obtain data for another archive.



Jan. 04	– Pre-AVE- (Costa Rica)
Jul. 04	- **ICARTT***
Oct. 04	- AVE (Ellington)
Jan. 05	– **AVE - polar (Bangor)**
Jul. 05	– TC4 summer (Costa Rica) + CAMEX5 + TEX/MEX
Jan. 06	– **AVE/TC4 (Darwin) + DOE-IOP**
Apr. 06	– INTEX-NA-W, AVE (Ellington)
Aug. 06	- **ICARTT***
Sep. 06	– AVE (Costa Rica)
Jan. 07	– **TC4 winter (Guam)**
Jun. 07	- AVE (TBD)
Nov. 07	- **AVE (TBD)**

* **ICARTT = (ITCT/INTEX-NA/GoMACCS)**

Table I. Timeline of field programs planned by NASA, NOAA, and/or DOE for the 2004-2007 period. Several of these planned field programs may be appropriate for participation by the reconfigured ASP.

Potential goals for field studies include:

- Investigation of the indirect effect of aerosols on clouds in plumes downwind of isolated sources or cities where satellite data suggest that rainfall is suppressed by aerosol pollution. The goal would be to verify rainfall suppression and understand the mechanisms. Several such sites, one in Southeastern Canada and others in California for instance, have been identified where the regional pollution is low so urban aerosol effects appear to be clear. The objective is to carry out a field study in a location where effects are identified to be occurring in continental clouds. Investigation of continental clouds in heavily polluted regions is apt to lead to inconclusive results. DOE could do such a study as a small, focused field program. No other agency is currently investigating this example of indirect effect of aerosols.

- Tracking the evolution of aerosols away from large sources such as forests, forest fires, deserts, and cities. Goals would be to understand the evolution of aerosols over several days, how aerosol optical properties and chemical characteristics change, how they are removed by precipitation, as well as to help to verify satellite retrievals of these properties.

- Determination of the radiative forcing of absorbing carbonaceous particles, dust, and minerals in the atmosphere requires their vertical profiles. These cannot be inferred at this time from satellite measurements alone. *In situ* and aircraft measurements are the only means to gather representative data for understanding the vertical absorption and heating profiles involving these aerosol types. Lidar backscattering profiling also can provide useful information in this area both from surface and aircraft perspectives. An example of this sort of study would be for DOE to become involved in the planned investigations of the Mexico City plume. Mexico City is a significant source of carbonaceous aerosols, so it represents a relatively well-defined source region to investigate. In addition large NSF and Mexican government investigations are planned in Mexico City that DOE could complement. Other agencies will be concentrating their efforts in understanding urban pollution. In the context of radiative forcing, the reconfigured ASP could look at the downwind evolution of the aerosols and their removal by precipitation.

- Investigation of aerosol effects on various cloud systems, mainly over land, to quantify better the indirect effect. It is important to understand how clouds and precipitation remove aerosols or alter their properties. Vertical profiles of aerosols including composition changes need to be measured at multiple locations, perhaps with field data at ARM sites. There already are efforts to understand indirect effects of aerosols at the ARM site in Oklahoma. Collaboration with ARM is a necessity.

- Collaboration with other agencies to understand how remote pollution from Asia, Europe and Africa may be impacting aerosol levels over the United States. Part of the goal in such studies is to understand the natural aerosol background in the United States and thus the extent to which aerosol loading potentially can be controlled. Such a field program is planned by NASA in the next few years. The reconfigured ASP should participate and contribute.

- Explore aerosol nucleation in the atmosphere and its impact on particle and hydrometer size distributions. Determine the role of minor gases such as ammonia. Investigate if ion nucleation is occurring and, if so, whether there is any potential for a sun/weather connection. No agency is focusing on the formation of new particles although a number of research groups are working in this area. This is an opportunity for DOE to lead small, focused efforts.

- Field studies of the effect of aerosols, especially carbonaceous aerosols, on the albedo of snow and ice. The ARM site in Alaska provides an opportunity for ready acquisition of data for temporal variations, including study of possible Spring amplification of melting effects. Cooperation with Russia for Asian measurements is desirable because Asia is the site of the largest snow/ice albedo effects. The possible effect of absorbing aerosols on a glacier retreat could be studied in the United States at Glacier National Park or in Alaska. Greater aerosol loading might be found in Asian regions affected by regional pollution where snow and ice cores suitable for such investigation may have been obtained already for other climate investigations.

MODELING/THEORY

While DOE and other agencies have sophisticated global models for aerosols, there are several types of models or input to models that have not been developed or widely used previously. Models that can resolve cloud fields and do sophisticated microphysical and chemical simulations are needed to investigate indirect effects of aerosols so parameterizations for global models can be designed. Models are needed that can simulate the evolution of aerosols and their optical properties on a regional scale so they can be tested rigorously in field programs. These models need to incorporate the chemistry that leads to the dispersion of black carbon and organic particles, including the formation and atmospheric transport of organic aerosols. It is especially important that mechanisms controlling the lifetime and removal rates of aerosols are quantitatively identified and that the understanding of these mechanisms is captured in climate models. Finally, a database for organic and black carbon aerosols needs to be developed that not only specifies current sources, but also reconstructs the historical record of abundances of these materials.

Several types of modeling work are represented well in various agencies. There is no need to expand either the number of global climate models that contain aerosols or the number of transport models seeking to locate aerosols. DOE should continue to support its current modeling efforts. Nevertheless, there are two areas in which, additional modeling is needed.

Realistic process models of aerosols for climate simulations are required. Such models, probably regional in spatial scale, need to simulate the evolution of particle size distribution and composition and be related to the meteorological processes so the results of field programs can be simulated and used for climate diagnostics. The models need to incorporate cloud and precipitation processes as well as dry air conditions. The goal of these models is comprehensive testing of the understanding of aerosol evolution in the atmosphere and quantitative comparisons with field or laboratory data.

Cloud resolving models with detailed microphysics (not simply models with so-called explicit microphysics or models with arbitrary auto-conversion parameterizations), that includes aerosols as well as clouds. These models should be used to investigate indirect effects of aerosols on clouds. Since a number of models of marine stratus already exist, emphasis on other types of clouds systems is appropriate, but arguably difficult to characterize.

Models for the formation of secondary organic aerosols need to be considered. This would include contributions of natural and anthropogenic sources, transformation processes affecting these aerosols, and their effects on clouds.

The evolution of carbonaceous aerosols that separates biomass aerosols from fossil fuel combustion carbon needs to be investigated and developed. A special need is to distinguish between the two. This can be accomplished, in principle, using measurements and interpretation of carbon isotope concentrations. Support also should be provided for the development of time-dependent emission (source) inventories, especially inventories for carbonaceous aerosols.

Studies of aerosol archives are critical for the purpose of defining the time-dependent climate forcing due to aerosols, especially carbonaceous aerosols, during the industrial era. DOE has the potential to play a leading role in producing such archival data sets without which climate models cannot reliably simulate and interpret climate change of the past century.

INSTRUMENT DEVELOPMENT

Better assessments of the indirect effect of aerosols on clouds and of the direct effects of aerosols on the climate require that several instrument developments or refinements be carried forward. There are a number of areas in which lack of appropriate instruments is preventing further progress. DOE has significant resources and experience, much of it in residence within the National Laboratories, that should be focused on developing these instruments. Instruments needed to further the understanding of radiative properties of aerosols are discussed first**.** Then instruments needed to improve understanding properties of organic and black carbon aerosols and their impact on clouds are discussed. While all of these instruments need to be developed, some of them are more critical for the radiation balance problem or are more timely based upon recent advances. Priority 1 instruments should be given attention as soon as possible. If funding is limited, priority 2 instruments might be funded at a lower level initially or developed as the reconfigured ASP matures.

Understanding direct radiative forcing of aerosols in general and carbonaceous aerosols in particular requires fundamental knowledge and reliable data on their scattering and absorption properties. The Lorenz-Mie theory has been used for calculating the scattering and absorption of spherical particles, including some simple inclusions, and for calibrating backscattering and extinction measurements such as those from lidars and satellites. Information on the scattering phase function and polarization properties of non-spherical and/or inhomogeneous aerosols at solar and IR wavelengths is extremely limited, yet crucial to proper radiative transfer calculations.

Development of reliable instruments for the *in situ* measurement of the single-scattering albedo covering the solar wavelengths (UV, visible, and near infrared) is urgently needed for particles containing black and organic carbon, dust, and minerals. Such measurements must be made *in situ* without altering aerosol properties. Filter collections are not suitable. This is a priority 1 instrument need since even the sign of the aerosol forcing depends on it. The single scattering albedo is critical to determine heating rates and climate forcing by aerosols. A direct measurement of the single-scattering albedo, the ratio of the scattering and extinction coefficients, is not possible. It must be determined separately from measurements of these two coefficients. The effects of the non-sphericity and inhomogeneity of carbonaceous particles, dust and, minerals must be accounted for in the development of scattering and extinction measurements. Uncertainties must be defined in the determination of the single-scattering albedo of these types of aerosols. Theoretical and numerical methods for the calculation of their scattering and absorption properties should be developed in association with the instrument development. Measurements to characterize optical properties of snow and ice containing black carbon and organic carbon also are needed. This may require instrument acquisition. DOE already has taken the first steps to improve instruments for the single scattering albedo measurement with the recent ARM IOP to investigate aerosol absorption. For the single scattering albedo close to 1, an accuracy of 0.01-0.02 is desired, on the average, although single measurement (unit volume) accuracy that great is not critical.

Angular scattering, including polarization, by aerosols that is represented by the scattering phase matrix or Stokes parameters is important for climate calculations and for reducing remote sensing data. Although a total integrated backscattering instrument has been developed for aerosol study, the angular scattering measurement for various types of aerosols in the atmosphere has not been available and presents an important gap in the understanding of aerosols. The development and laboratory testing of aerosol polar nephelometers for satellite remote sensing wavelengths with application to aircraft platforms will represent a new opportunity in radiative forcing studies. The development of a polar nephelometer also should include the feasibility of measuring complete Stokes parameters. Stokes parameters could characterize aerosol intensive properties (shape, size distribution, and refractive index) far better than current instruments. Such data are needed for satellite and remote sensing measurements in order to reduce the data properly and thus fully utilize their measurements. A more limited instrument measuring the asymmetry parameter would be useful. This is a priority 1 instrument need since Stokes parameters are now poorly known.

Aerosol and cloud optical and chemical properties often are related to particle size. Improved techniques for determining the size distribution and the total mass or volume are needed. Current techniques are often ambiguous because of the assumption that particles are spherical. In addition optical techniques that are very prevalent have inherent problems. Sizing techniques, especially in the 0.5-10 μm size range, that are not based on optical properties need to be developed. These techniques need to be tied to simultaneous measurements of properties such as mass, area (extinction) and number, so distributions can be reliably integrated. This size range is important for aerosols and critical to understanding of clouds. This is a priority 2 instrumentation need since instruments exist in this area, although they are not sufficiently reliable.

There is a need to develop improved measurement methods to characterize the bulk and the size-resolved chemical composition of ambient aerosols in real time, particularly for carbonaceous aerosols. Improved measurements would facilitate the identification of the origin of aerosols, *i.e.* primary versus secondary and fossil fuel versus biogenic. Such measurements would help to elucidate how aerosol particles are processed in the atmosphere by chemical reactions and by clouds and how their hygroscopic properties change as they age. This is a priority 1 instrument need since relatively little is known about organic and absorbing particles, but they are abundant. Although traditional filter samplers are useful, they should be replaced with instruments suitable for real-time measurements of the composition of particles at the molecular level. Important recent advances in the development of such instruments include particle mass spectrometers and single particle analyzers. These new instruments also have important limitations. Some of those limitations are in the quantification of black carbon vs. organic carbon, in the speciation of refractory and volatile organic compounds, and in the calibration of both organic and inorganic components. Important remaining needs are: (1) quantifiable results over a wide range of compounds, a problem for laser ablation aerosol mass spectrometer methods; (2) measurements over a range of volatility so that dust, carbon, and salt are detectable, a problem for thermal decomposition aerosol mass spectrometers; (3) speciation of individual organics, including those containing oxygen, nitrogen, and sulfur; (4) identification of elemental carbon and other carbonaceous material so the makeup of the absorbing fraction is really known; (5) measurements with high time resolution, an inherent problem with filter techniques; (6) identification of source markers such as isotopic abundances in aerosols and; (7) the ability to probe the chemical composition of aerosol surfaces.

At the present time, great advances have been made in single particle aerosol chemistry, although many further improvements are needed. As yet, such advances have not been applied widely to clouds. Such single cloud drop chemistry measurements would likely revolutionize understanding of cloud chemistry and the chemical impact of aerosols on clouds. It also would be very useful to develop improved CCN spectrometers. This is a priority 2 need since recent advances have been made in CCN spectrometers. It has been demonstrated recently that size resolved cloud droplet chemistry for relatively involatile species can be done with counter flow virtual impactors in front of aerosol spectrometers.

There also are several improvements in gas phase chemistry that are needed to further understanding of aerosols and clouds. Gas phase measurements for H_2SO_4, a major aerosol precursor, have revealed a wealth of new information in the last decade. To make further progress, fast measurements are needed of NH_3, ion clusters, and gas phase organics that might either condense or dissolve into preexisting aerosols or cloud droplets. These are priority 1 measurements since they are critical in advancing understanding of aerosol evolution. There is a dearth of data on SO_2 and dimethyl sulfide (DMS) concentrations from remote locations in the middle troposphere. Instruments exist to measure these species, but they need to be applied to the problem.

DOE should evaluate further the need for aerosol, cloud, and gas phase chemistry measurements based upon payloads now available for DOE aircraft at the ARM sites and in the ARM mobile facility. There is a need for DOE to participate in field missions. The current aircraft, mobile, and ground based payloads should be examined critically for accuracy and reliability. Many new aerosol instruments have been developed in the past few years, some at national laboratories, that should be incorporated into the DOE suite of measurements. Payloads should be coordinated to address critical questions.

Providing proper instruments for the DOE aircraft is a priority 1 need for the reconfigured ASP. If small instrument packages for aerosol particle characterization could be developed and flown inexpensively and regularly through the lower to middle troposphere, a considerable amount of knowledge could be gained about particle distributions, at least over North America. Attention should be given also to "small", inexpensive, fast response aircraft instrumentation to measure a group of particle sizes (e.g. <0.005 - 0.5 μm, 0.5 - 5 μm, 5 – 10 μm). Continuous measurement either in total or by size range of sulfate, nitrate, black carbon and organic carbon, and perhaps a dust measure like Si and a K measure for fires also should be investigated as a part of the aircraft instrumentation.

DOE should evaluate whether improved instruments should be facility instruments or whether they may be selected via proposals for various field programs. The choices mentioned are mutually exclusive. Facility instruments could be developed and improved through competitive proposals. The ARM program also should evaluate its current sites and its mobile facility to determine what the needs are for new instruments for aerosol research.

IMPORTANT PROGRAM ENHANCEMENT

Although it is recognized that resources are scarce and probably will remain so for a number of years, it also is recognized that a high priority issue such as aerosol research must receive support if it is to reduce major uncertainties in climate modeling. With those realities in mind, the Panel decided that it was important to call attention to one area where an enhancement could make a powerful addition to aerosol research. Furthermore, this enhancement coupled with the new ARM mobile facility would add dramatically to the basic knowledge about aerosols.

DEVELOPMENT OF A TRANSPORTABLE LABORATORY

While a great deal can be learned regarding the coupling of aerosols and radiation using focused aircraft campaigns, some key science questions will require longer-term measurement campaigns in order to capture a broader range of variability in aerosols, trace gases, and clouds. Elucidating indirect effects of aerosols on clouds and precipitation would benefit greatly from the availability of a longer-term, fully instrumented fixed site(s). At such a site, it would be possible to do vertical profiling of chemical composition of aerosols and gases as well as clouds on a regular basis over an extended time period. With an astute choice of sampling locations, a wide variety of aerosol-cloud conditions could be measured that would provide an extensive data base from which complex relationships could be ferreted out. Sites that experience transport of aerosols from relatively clean to urban areas under different conditions would provide a variety of aerosol size distributions, optical properties, and chemical composition that could be related to cloud properties.

One possible means of inferring spatial characteristics, at least at ground level, would be a semi-mobile monitoring laboratory that could accommodate the monitoring equipment one would normally use in an intensive field campaign. This facility would be distinct, yet complimentary to the planned ARM mobile laboratory. The reconfigured ASP laboratory could be co-located for extended time periods (months to a year or more) along with the new ARM mobile facility that is currently under construction or, when appropriate, adjacent to other sites such as one of the permanent ARM sites. This transportable laboratory should have sufficient space, power, water, and air-conditioning to support a wide range of aerosol, gas, and cloud instrumentation, including measurements of aerosol particle size distributions, optical properties, and chemical composition.

The ability to collect aerosols, gas, and cloud data on a regular basis vertically would be an important aspect of this activity. It might involve use of the G-1 aircraft at appropriate times, along with other means of vertical sampling using smaller aircraft, lidar, or the use of platforms such as blimps or tethered balloons.

Such a semi-mobile laboratory would have the advantage of being able to sample at a number of locations for different periods of time, depending on specific science questions being addressed and the cooperation of "mother nature" in providing appropriate conditions for examining these problems at a particular site. It would also provide a very convenient mechanism for testing and applying new instrumentation that is developed for the reconfigured ASP. Different types of apparatus could be moved in and out as the science dictates so the laboratory would evolve with the science, minimizing the risk of becoming rapidly obsolete.

Development of a transportable laboratory will require dedication of significant initial funds as well as funds for its continued operation and maintenance. The cost of equipping such a laboratory would depend on many factors. Some existing equipment or new equipment developed for other field campaigns may be very useful in this laboratory and be available for periods of time if not used in other field campaigns. Fully equipping such a laboratory on a permanent basis may not be necessary or desirable.

The Panel sees this as a high priority item only if additional funds become available to the reconfigured ASP. It is neither feasible nor recommended to develop such a laboratory from the anticipated funding level for the reconfigured program.

GENERAL COMMENTS AND OTHER FINDINGS

The Panel received excellent briefings on what aerosol research was being carried out at the present time. As noted earlier, these briefings came from Federal agencies that are coordinated through the Climate Change Science Program (CCSP), from other Federal agencies, from grant programs supported by BER/ASP, and from DOE's national laboratories. The importance of aerosol research and its high priority within the CCSP have been noted. Although not a part of the specific charge from the Director of the Office of Science, the Panel felt that a few words about aerosol research might be useful.

Table II is a summary of expenditures for aerosol research taken from the briefings that were given to the panel. Data are for FY 2003. The total direct support for aerosol research is $23.6 M. There is contributing research that amounts to $29.3 M. With aerosol research becoming a high priority item, it may be time to reappraise its level of funding.

Table II–CCSP FY 2003 Funding for Aerosol Research
Relevant to Climate Change by Agency
(Dollars are in millions)

Agency	**Core Programs**[1]	**Contributing Programs**[2]
DOE	3.0[3]	7.0[3]
EPA		15.3
NASA	12.0	
NOAA	5.8[4]	
NSF	2.8[4]	7.0
TOTALS	**23.6**	**29.3**

[1] Focused on aerosol-climate research

[2] Not directly focused on aerosol-climate research but relevant to aerosol-climate

[3] Prior to reconfiguration of the Atmospheric Science Program

[4] Relevant aerosol-climate research, contained within a number of related programs having a broader scope than aerosol-climate interactions

There is no question but what the CCSP is a well organized activity within the Federal agencies. In fact it is a model of interagency cooperation, especially at the highest levels where it has the attention of Cabinet Officers. Nevertheless, managers at the program level carry out the actual management and operation of the elements of the CCSP. They are the people who know the researchers, read proposals, have them reviewed, and make recommendations for support. Informal get-togethers and consultation can be an important way to trade information, discuss and support experiments and field studies of mutual interest, and focus on areas that need development or additional support. Meetings of agency program managers to discuss issues of mutual interest will enhance and help develop what is at present a small, but viable aerosol research program.

The DOE’s national laboratories are an important component of the national science establishment. Their accomplishments and capabilities are well known. It appears that a great deal of on-going research in the labs could have application to the reconfigured ASP and be compatible with grants and contracts being made by BER program managers. Regular meetings of Headquarters and National Laboratory program managers involved in aerosol and aerosol related research and development would allow on-going work to be made known and discussed more widely. Instrumentation could be brought to completion more quickly then tested and used within the reconfigured ASP.

RECOMMENDATIONS

The Panel in response to the charge from the Director of the Office of Science makes the following recommendations:

1. The concept of reconfiguring the Atmospheric Science Program (ASP) within the Office of Biological and Environmental Research (BER) from programs of atmospheric chemistry and environmental meteorology to a research program emphasizing radiative forcing of the climate from natural and anthropogenic aerosols has great merit for contributing to advancing climate science and should be implemented as soon as practical.

2. The reconfigured ASP should have as its goal the reduction of scientific uncertainties in two specific gap areas that were identified by the Panel. These are (1) the indirect effects of aerosols on clouds and (2) the role of black carbon and organic aerosols on climate.

3. To carry out the goals for the reconfigured ASP, it will be necessary to have a well-balanced program consisting of laboratory experiments, field measurements, theoretical analyses and process modeling, and the development of instruments for sampling and characterization of aerosol particles in the laboratory and the field.

4. The reconfigured ASP has to be closely coordinated with and collaborate with the Atmospheric Radiation Measurement (ARM) program as well as other programs to make the most effective use of limited scientific resources.

5. To optimize the reconfigured ASP resources, continued fostering of collaborative programs with federal, state, and non-governmental organizations, as well as international entities is essential.

6. The reconfigured ASP should look to climate modeling program within the DOE and the larger Climate Change Science Program (CCSP) as a test bed for applying knowledge and parameterizations gleaned from the aerosol and ARM programs.

7. Although budgets are extremely tight, the Office of Science and BER should argue vociferously for increased support for the reconfigured ASP since aerosol research is now a very high priority within the Climate Change Science Program (CCSP).

APPENDICES

<u>**APPENDIX A**</u>

BERAC PANEL MEMBERS
ATMOSPHERIC AEROSOL PROGRAM RECONFIGURATION

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APPENDIX B

BERAC PANEL AGENDA
ATMOSPHERIC AEROSOL PROGRAM RECONFIGURATION

November 17 - 19, 2003
AGU Conference Center
2000 Florida Ave., N.W.
Washington, DC

November 17, 2003 (Day 1)

8:30 - Continental Breakfast - Conference Center, Rooms B/C

9:00 - Panel Meeting begins - Conference Room A
Introductions - Panel members and DOE Staff

9:20 - Comments on agenda - Gene Bierly

9:30 - Charge to the Panel - Jerry Elwood
Background and rationale for reconfiguration
Constraints on the program

10:00 - Panel report to BERAC - Panel/Gene Bierly
Approach to reaching the report
General discussion as to contents of the report
Outline of report
Drafting responsibilities of Panel Members
Timing of report
Guidelines for a new science team

11:00 - Scientific elements/components of an aerosol research program - Panel

12N - LUNCH - Conference Center, Rooms B/C

12:50 - Meeting reconvenes, Room A

12:55 - Briefings to set the stage on what already is being supported by the Federal Government under the Climate Change Science Program (CCSP) and other mechanisms. Please look for gaps that could be filled by the reconfigured DOE program.

1:00 - CCSP Draft Program/Implementation Plan - Dan Albritton
NOAA Aerosol Program - Dan Albritton

1:45 - NSF Aerosol Program -Jay Fein

2:15 - NASA Aerosol Program - Don Anderson

2:45 - EPA Aerosol Program - Terry Keating

3:15 - Coffee Break

3:30 - Simon Chang, NRL-Monterrey and DHS (tentative)

4:00 - NARSTO - Jim Meagher - NOAA

4:30 - NAS/NRC/BASC activities - Amanda Staudt

6:00 - Dinner on your own. There are many restaurants in the local area. Brochures are available.

November 18, 2003 (Day 2)

8:00 - Continental Breakfast - Conference Center, Rooms B/C

8:25 - Panel Meeting begins - Conference Room A

DOE Briefings

- what is being supported now in aerosol research
- briefings to include facilities and capabilities useful for the reconfigured program

8:30 - DOE Headquarters - Jerry Elwood, BER

8:35 - Atmospheric Science Program and background on the Tropospheric Aerosol Program (TAP) - Peter Lunn, BER

9:00 - Atmospheric Radiation Program (ARM) - Wanda Ferrell, BER

9:15 - DOE Climate Modeling Program - Jeff Amthor, BER

9:30 -Steven Schwartz, BNL
10:00 - Coffee Break

10:15- Urban Aerosol and Megacity Studies - Jeff Gaffney, ANL

10:45 - Capabilities for Field Studies - Pete Daum, BNL

11:15 - Modeling Capabilities - Doug Rotman, LLNL

11:45 - Specialized Facilities - Steve Colson, EMSL

12:15 - National Energy Technology - Bill Aljoe, NETL

12:45 - LUNCH - Conference Center, Rooms B/C

1:15 - Questions/discussion with speakers

2:15 - Closed meeting
- General comments
- Identification of gaps
- Needs of modelers
- Other essential or very important elements needed in program
- Drafting of report

6:00 - DINNER (TBD)

November 19, 2003 (Day 3)

8:00 - Continental Breakfast - Conference Center, Rooms B/C

8:30 - Drafting of report continues

12 N - LUNCH - Conference Rooms B/C

1:00 - Drafting continues/completed

2:00 - Discussion of draft report with DOE management

3:00 - Panel meeting ends