This NASA Research Announcement (NRA), titled “Support for Atmospheric Composition – Modeling and Analysis (ACMA/06)”, offered opportunities in research that contributes to the understanding of the sources, transformation, and transport of trace species in the Earth’s atmosphere. The research strategy in atmospheric composition encompasses an end-to-end approach for instrument design, data collection, analysis, interpretation, and prognostic studies. NASA expects to provide the necessary monitoring and evaluation tools to assess the effects of climate change and air quality forecasts that take into account the feedbacks between local, regional, and global air quality and global climate change. Drawing on global observations from space, augmented by suborbital and ground-based measurements, NASA is uniquely poised to address these issues. This integrated observational strategy is furthered via modeling studies that together with this suite of observations allow us to test our understanding of atmospheric processes.

The research conducted under this NRA will address the following topical areas:

- Map emissions and export of trace gases and aerosols important to air quality and climate,
- Quantify the role of long-range transport of trace gases and aerosols on regional environmental degradation,
- Understand the effects of air pollutants such as ozone and aerosols on climate and the effects of climate change on air quality,
- Measure, understand, and predict trends in the oxidizing power of the atmosphere,
- Improve numerical weather prediction,
- Separate the diverse warming and cooling influences of aerosols on regional and global scales, and
- Unravel the magnitude of the aerosol effect on clouds and precipitation, on regional and global scales, and its sensitivity to aerosol chemistry and cloud dynamics.

Also solicited were a limited number of studies that will elucidate requirements and evaluate remote sensing concepts for future space-based observations of atmospheric composition.

NASA received 63 proposals and selected 13 for funding.

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William Collins/University of California, Berkeley
The Longwave Radiative Effects of Aerosols From Synthesis of A-train Observations

The goal of this project is to derive the effects of soil dust and other aerosols on the longwave radiation emitted to space. The team will synthesize observations from Aura and other satellites in the NASA A-train to obtain this objective. The optically thick
Marvin Geller/Stony Brook University
Gravity Wave Parameterization in GISS Climate Models

Atmospheric gravity waves play a crucial role in the exchange of momentum between vertically separated regions of the atmosphere. This proposal is to fund the Principal Investigator's collaboration with NASA GISS scientists in implementing gravity wave parameterizations in the NASA GISS climate models. Currently, these models either use Rayleigh drag or a parameterization that was developed almost twenty years ago and has not evolved to take account of developments since its time of development. We propose to start by implementing the Alexander and Dunkerton spectrally-based gravity wave parameterization because of its physical transparency, flexibility, and computational efficiency, together with the fact that published results indicate it gives results that compare well with other-state-of-the-art gravity wave parameterization schemes. We plan on interacting with another NASA-funded group studying gravity wave
parameterizations to also start work on physics-based treatments of gravity wave sources. The proposed research is essential to develop NASA climate models that correctly treat troposphere-stratosphere interactions and examine chemistry-climate interactions in the troposphere-stratosphere.

Andrew Gettelman/National Center for Atmospheric Research
Confronting Coupled Climate-chemistry Models with Data

Coupled Chemistry-Climate Models (CCMs) are a critical tool for understanding the complex interactions between climate and chemistry. Evaluating the ability of these models to represent key processes is critical if we are to place any confidence in their predictions of changes in the Earth system. In particular, projections of future stratospheric ozone, climate and effects of global change on regional air quality will depend on realistic inclusion of key processes in the models. This proposal will develop a mechanism, in the form of a diagnostic package, to easily evaluate CCM output through comparisons with satellite observations, and facilitate the interaction of the modeling community with the global chemistry observing community. We will focus on several key areas vital for understanding how well the models represent the stratosphere and its interaction with the troposphere with an emphasis on those aspects that affect ozone, climate and air quality. The package will be designed to compare models using a standard developed by an international model intercomparison project, and build on the work that has been done within this project. Much of the data for model comparisons will come from instruments on the NASA Aura satellite, but also include other satellite-based, ground-based, and in situ measurements. The outcomes of this project will be a better understanding of the future evolution of chemistry and climate, as well as a publicly available open source diagnostic package that can be used to analyze output from CCMs and compare the models to observations and/or to other models. We will focus initially on working with members of five modeling groups. The package will be used to support upcoming WMO/UNEP scientific assessments of ozone depletion and IPCC climate change assessment reports.

Lyatt Jaegle/University of Washington
Intercontinental Transport of Pollution: Constraints From Satellite Observations

Atmospheric transport between continents takes 1-2 weeks on average and, as a result, continental emissions of even short-lived species can affect the atmosphere above other continents. Quantifying the effects of intercontinental transport of air pollution on air quality of receptor regions is one of the biggest challenges in atmospheric chemistry today. Space-based observations of atmospheric composition provide a unique opportunity to address this challenge. We propose a comprehensive analysis of intercontinental transport of pollution from Asia, North America, and Europe using the multi-year multi-sensor observations from the Aura, Terra, Aqua, ERS-2, and ENVISAT satellites. Long-term observations of CO, NO2, O3, HNO3 and aerosol optical depths from these satellite platforms provide unique datasets to address our three objectives:
1) What factors control pollution export from North America, Asia, and Europe?

2) Can we quantify the chemical evolution and transport of pollution during transit?

3) How does intercontinental transport affect air quality over receptor continents?

The different sources, chemistry, and loss mechanisms of these species, coupled with the different vertical sensitivity of the satellite instruments offer the ability to examine in intercontinental pollution transport from complementary perspectives. We will use the GEOS-Chem global model of atmospheric chemistry and aerosols to interpret the ensemble of satellite measurements in a unified way. The GEOS-Chem model will also be used to link information provided by satellite observations with ground-based surface measurements of O₃ and aerosols to better constrain the effects of intercontinental transport on the air quality over receptor continents.

Prasad Kasibhatla/Duke University

A Modeling and Analysis Study to Quantify the Impact of Biomass Burning on Tropospheric Chemistry Using Remote Sensing Measurements

The focus of this proposal is on improving our understanding of human impacts on atmospheric chemistry. We plan to develop quantitative estimates of emissions of chemically and climatically important constituents to the atmosphere due to vegetation fires. Our plan is to use remote sensing measurements of atmospheric chemical composition from the MOPITT instrument on the Terra satellite, along with sophisticated modeling and analysis approaches, to better understand the factors that govern fire-driven emissions on a global scale. The specific research objectives of our proposal are to: (i) develop and test ensemble-based inverse modeling approaches for constraining carbon monoxide fluxes from fires using idealized MOPITT measurements; (ii) use the methodology to further refine multi-year estimates of carbon fluxes from fires using real CO retrievals from the MOPITT instrument; and (iii) use the MOPITT-constrained fire product to address scientific questions related to the large-scale chemical and climatic impacts of fire-driven trace gas and aerosol emissions. We stress that this proposal is not a model development proposal, nor is it a proposal focused on the theoretical development of statistical inverse modeling approaches. Rather, our focus is on adapting and applying state-of-the-science data assimilation techniques to develop a scientifically useful fire product for tropospheric chemistry studies, and to use this product in our own scientific investigations.

The proposed project directly relates to NASA’s strategic goal to “study planet Earth from space to advance scientific understanding and meet societal needs”. In terms of the Earth Science Research Program, our proposed work on refining biomass burning trace constituent flux estimates is highly relevant to the specific science objectives of developing an understanding of changes in atmospheric composition and improving the understanding of the carbon cycle and global land cover change. Our proposal is thus directly relevant to the Atmospheric Composition Focus Area, and also contributes to the Carbon Cycle and Ecosystems Focus Area. Our proposed effort builds on our previous
and on-going efforts to use space-based measurements to improve process-level understanding of human impacts on the atmospheric chemical and climate system. The proposed research will help to improve the widely-used Global Emission Fire Database fire product that we have been helping to develop, and also contribute to its use in the cooperative GEOS-CHEM global atmospheric chemical transport model.

**Athanasios Nenes/Georgia Institute of Technology**

The Next Generation of Aerosol-Cloud-Chemistry Interactions in the NASA Global Modeling Initiative

The aerosol indirect forcing is one of the largest sources of uncertainty in assessments of anthropogenic climate change [IPCC, 2001]. Much of this uncertainty arises from the approach used for linking cloud droplet number concentration (CDNC) to precursor aerosol. The principal goal of this proposal will be the continued development of aerosol-cloud interaction modules within the NASA Global Modeling Initiative (GMI). The GMI allows easy interchange of meteorological fields, chemical mechanisms, aerosol microphysical packages and aerosol-cloud interaction parameterizations, and is an ideal tool for evaluating the uncertainty and sensitivity of aerosol indirect effects to a wide variety of modeling approaches towards aerosol-cloud interactions. The proposed improvements include prognostic treatments of cloud droplet formation and explicit computation of droplet size distribution and autoconversion of cloud water to rain. This new framework will explicitly treat vertical variability of cloud liquid water content (LWC) and the evolution of the droplet size distribution as a function of height in the cloud, within an entraining dynamic framework. The improved framework will be used to: i) assess the impact of the improved aerosol-cloud interactions on estimates of the “first” aerosol indirect effect and precipitation, and, ii) investigate the impact of the improved cloud optical depths and explicit droplet size distribution on tropospheric chemistry. A critical component in this effort will be the use of remote sensing products for both the aerosol and cloud parameters. The satellite products that can be directly related to model-resolved properties (e.g., aerosol optical depth and cloud liquid water path) will be used to evaluate the aerosol and cloud fields resolved by GMI.

**Paul Newman/NASA Goddard Space Flight Center**

Continued Funding for the Analysis of Spatial and Temporal Variability of Stratospheric Dynamics and Trace Constituents

We propose to analyze how SSTs impact atmospheric dynamical processes, and how those tropospheric dynamical forcings then impact both stratospheric ozone levels and ozone depleting substances (ODSs). The proposal is a renewal of a previous ACMAP proposal that focused on stratospheric ozone recovery. This proposal has two major tasks: exploration of the role of sea surface temperature forcings on atmospheric variability and completion of our work from the previous proposal on effective equivalent stratospheric chlorine (EESC) and ozone recovery.

In the first task, we will explore the role of SSTs in stratospheric variability and ozone recovery. In particular, we are interested in how (or whether) SST forcing is
communicated to the stratosphere. This is motivated by evidence that waves originating in the tropical troposphere may have been responsible for the first southern hemisphere stratospheric warming in the 2002 Austral spring (a weak El Niño year). This task will be performed by analyzing three runs from the GSFC GMAO GEOS-4 model that was forced with specified SSTs. GEOS-4 model runs have been made with: 1) annually recurring seasonal cycle SSTs from the AMIP-II SSTs (aSST) and 2) annually recurring seasonal cycle Hadley SSTs (fSST). These two SST data sets have small differences that are evident in the tropospheric circulation. The third run has been made with the observed monthly varying 1949-1998 Hadley SSTs (vSST). The first two model runs provide a control experiment to compare to our third experiment. In addition, a fourth run has been completed that utilizes the 2002 annually recurring SSTs to investigate whether the odd stratospheric circulation of 2002 resulted from SST forcings.

In the second task we will finish our work on the role of EESC and ozone recovery. EESC is derived from observed ODSs and an age-of-air spectrum. EESC is used to predict stratospheric ozone recovery. This task will occur in 3 phases over then next two years. First, we are completing a more complete description of our EESC calculation. This description and analysis shows quantitative EESC uncertainties and provides new estimates of EESC recovery in the stratosphere. Second, we are validating our estimates of Cly and Bry that are used in the EESC estimates. Third, we will explore uncertainties related to fractional release estimates using both models and observations. This new EESC formulation has led to a major revision of the recovery of the Antarctic ozone hole and has led to revisions of when ODS levels will recover in the mid-latitudes (WMO, 2007). This work will provide a solid foundation for the future scientific assessments of ozone depletion.

Under the Atmospheric Composition focus area NASA provides the necessary monitoring and evaluation tools to assess the effects of climate change on ozone recovery and future atmospheric composition and improved climate forecasts based on our understanding of the forcings of global environmental change. This proposal is specifically targeted to understand climate change forcings on the ozone layer and to improve future predictions of ozone recovery.

Lorraine Remer/NASA Goddard Space Flight Center
Detailed Aerosol Composition From Combined MODIS-OMI Data

Aerosols are a fundamental component of the atmosphere, and yet the term “aerosol” is generic for a great many types of compounds, each affecting the Earth’s energy balance, hydrological cycle and human health differently. There has been little progress in determining aerosol composition from space. Broad classification schemes can be applied to the results from current individual sensors such as MODIS, OMI, MISR and POLDER, but the real strength of these instruments is in combining their capabilities. We propose to combine data from MODIS and OMI to provide a comprehensive characterization of aerosol properties that may lead to chemical speciation of the aerosol particles. With its broad spectral range, MODIS is sensitive to aerosol size, while OMI’s ultraviolet channels are sensitive to aerosol light absorption. Recent laboratory measurements show how spectral absorption in the ultraviolet by aerosols can be related to several different types of combustion sources and organic species. We intend to use
these laboratory results in order to guide the development of a joint inversion where MODIS will differentiate aerosol size and OMI will distinguish absorption characteristics from dust, black carbon and organic compounds. We will first collocate MODIS retrievals within the OMI footprint and intercalibrate the two sensors using common channels. Then we will develop a joint inversion of the data from the two sensors based on the well-understood MODIS aerosol retrieval over ocean. The resulting algorithm will be applied to specific regions of interest, over ocean only, and evaluated against operational products from both individual sensors, and all available ground information. The project is expected to take three years.

Laurence Rothman/Smithsonian Astrophysical Observatory
Development of the Hitran Compilation in Support of the NASA EOS Program

The goal of this project is to advance the development of the HITRAN (High-resolution Transmission) molecular spectroscopic database compilation and associated software to support the observational programs of EOS. These programs include the suite of EOS experiments, AIRS, HIRDLS, MOPITT, TES, SAGE III, and future missions including GLORY, NPOESS, and OCO. The priority is for improving the spectroscopic parameters of molecular line absorption transitions that affect the modeling and simulation of atmospheric radiance and transmission retrievals. Satellite remote-sensing retrievals, which now have exceptional signal-to-noise, wide spectral coverage, and reliable retrieval algorithms, are requiring numerous improvements in HITRAN in order not to be limited by the atmospheric absorption database part of the input. Among the needs are improved accuracy and a global consistency of line intensities, improved line shape parameters, addition of missing molecular bands, and representation of phenomena including collision-induced absorption bands and line coupling, that are impacting the retrievals. Data validation is a crucial part of the proposed research. The HITRAN compilation should facilitate a synergism among the many diverse experiments in NASA programs, linking results which have common goals.

Drew Shindell/NASA Goddard Institute for Space Studies
Using and Improving An Interactive Climate Model Incorporating Atmospheric Composition: GISS-PUCCINI

We propose to continue building towards a fully interactive climate model incorporating atmospheric composition within the GISS GCM, and to continue using our model both to enhance the value of satellite datasets and to improve understanding of linkages between composition and climate. Artificial separations by discipline (e.g. chemistry, aerosols, ecosystems) and by region (e.g. troposphere and stratosphere) are being removed as much as possible through intrinsically linking these systems within the GISS GCM ModelE. This model has been exhaustively studied and characterized by groups within and outside of GISS as part of the IPCC AR4 and associated studies. In this proposal, we address continued development of the atmospheric chemistry model and coupling between that component and the aerosol and ecosystems models. The past three years have been a period of great scientific productivity following many years of modelE development, and
we expect the next three years to continue this productivity. We will focus our groups’ efforts on several key areas involving climate and composition, including (not in order of importance): (1) climate forcing by short-lived species, (2) improvement of stratospheric circulation via higher vertical resolution and improved gravity-wave drag (GWD) parameterization, to be evaluated against satellite observations, (3) changes in stratosphere-troposphere exchange with time, (4) the global methane cycle and climate change, (5) interaction between climate-sensitive ecosystem emissions and chemistry/aerosols, (6) long-range transport of air pollution, (7) solar-climate linkages, (8) enhancing satellite datasets via model simulations and evaluation of tropospheric simulations using new satellite observations, (9) air quality-climate interactions, and (10) the regional climate response to the time-dependent inhomogeneous climate forcings from ozone and aerosols compared with dynamic circulation responses. These questions directly address several NASA strategic science outcomes and several aspects of NASA’s Earth Science Research Strategy. While ambitious, we believe the past accomplishments of our small, focused team justify our expectation of progress in numerous areas during a three year funding cycle. National and international collaborations will be continued to better characterize the robustness of the simulations.

Debra Weisenstein/AER, Inc.

Aerosol Modeling for the 3-D Global Modeling Initiative and Chemical Studies in 2-D

The objectives of this study are better understanding of the formation and evolution of atmospheric aerosols, including both chemical and physical processes, and their influence on chemistry and climate in the global atmosphere, and the use of observational data for model validation. This proposal seeks funding for participation in the Aerosol Working Group of the Global Modeling Initiative Science Team, along with a small amount of funding to enable continued use of the AER 2-D chemistry-transport-aerosol model for collaborative investigations of new observations or proposed chemical processes. This proposal continues work previously funded under NNH04CC39C. It maintains continuity in the Global Modeling Initiative (GMI) Aerosol Working Group, in which we have been a participant since 1998. Several years of preliminary work in comparing and synchronizing the AER 40-bin sectional aerosol model and the University of Michigan 2-mode aerosol model have prepared us to implement the AER sectional aerosol module into the GMI 3-D stratosphere-troposphere model, where aerosols will interact with mid-latitude and polar chemistry. Debra Weisenstein is the only member of the Aerosol Working Group with specific expertise in stratospheric aerosol modeling and observational data, an important consideration as the GMI model is expanded to include both tropospheric and stratospheric chemistry and aerosols in a combined model. Our work in implementing an aerosol prognostic ability, including calculation of detailed size distributions, in the Global Modeling Initiative model will ultimately aid in understanding the role of aerosols in clouds, precipitation, and climate. It will also help to solidify understanding of the atmospheric sulfur budget by linking the sources of sulfur in the troposphere with the concentration and size distribution of observed aerosols in the stratosphere. Modeling provides a key link in testing our understand of atmospheric processes and attributing causes to observed variability.
Aerosols are major atmospheric constituents that influence air quality and affect climate. We propose to study the fundamental processes that control the abundance of climate relevant particles in the Earth’s troposphere, focusing on new particle formation and subsequent microphysical aging as well as possible feedback mechanisms. The proposed work involves 3-D modeling using a global chemistry model (Harvard GEOS-Chem) coupled with an aerosol microphysics model. The modeling results will be analyzed and compared with relevant field measurements and satellite data. The primary thrusts of the proposed research will address three key questions: 1. What are the key parameters controlling the formation of secondary aerosols in the troposphere, and what are the spatial distributions and temporal variations of new particle formation? 2. What is the microphysical fate of newly formed particles and their probability of maturing into cloud condensation nuclei? 3. How do atmospheric aerosol concentrations respond to changes in Earth’s climate, solar activity, and global emissions?

The first question is aimed at resolving a persistent uncertainty concerning the major sources of global aerosols. We will apply a recently developed nucleation sub-module (containing options to use various hypothesized nucleation mechanisms) to study particle formation in the troposphere. Existing land, ship, and aircraft based measurements related to nucleation will be analyzed and compared with 3-D model calculations. To address the second question, we will couple a size and composition resolved aerosol microphysics model with GEOS-Chem. The spatial and seasonal variations of particle number and size properties and the role of long-range transport will be investigated. Various aerosol properties derived from the simulated particle size distributions will be compared with Satellite measurements. The third question deals with long-term changes in aerosol abundance and potential important feedback mechanisms involving nucleation. Our preliminary studies indicate the existence of a positive feedback involving nucleation (global warming → reduced nucleation and aerosol abundance → less aerosol cooling → more warming). We also find that the effect of solar activity on climate can be amplified through the influence of cosmic ray ionization on particle formation and a positive nucleation feedback. These important processes will be comprehensively investigated during this project.

This study will seek to develop, in addition to a better understanding of basic aerosol physics and atmospheric chemistry feedbacks, useful and practical numerical algorithms for incorporating such processes in predictive models.
reduced uncertainty; and (3) separate the diverse warming and cooling influences of aerosols on regional and global scales.

Due to the recent launches of the Geoscience Laser Altimeter System (GLAS) and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) satellite instruments, a continuous multi-year global aerosol profiling can be achieved. This unique capability adds great value to aerosol and cloud research by complementing the increasingly sophisticated passive remote sensing that measures the columnar aerosol and the TOA fluxes with high accuracy, including the MODe rate resolution Imaging Spectroradiometer (MODIS), Multi-angle Imaging SpectroRadiometer (MISR), and Ozone Monitoring Instrument (OMI), Clouds and the Earth’s Radiant Energy System (CERES), among others. Such emerging capability of satellite remote sensing provides an unprecedented opportunity to better characterize the 3-D distribution of aerosols and to explore the aerosol direct radiative effect in cloudy conditions. Specifically, we propose to integrate satellite retrievals from MODIS, MISR, CALIOP, GLAS and model simulations from the Goddard Chemistry Aerosol Radiation Transport (GOCART) to enhance our capacity to

(1) generate an observationally constrained global data set of three-dimensional distributions of aerosol extinction through optimally integrating active and passive satellite remote sensing data and model simulations of global aerosols; and

(2) assess the aerosol direct radiative effect (DRE) on solar radiation at the TOA and surface and the vertical distribution of aerosol heating in both clear and cloudy conditions using the observationally constrained aerosol 3-D distributions.

The proposed work, built upon our previous efforts to derive measurement-based DRE in clear conditions, focuses on observationally constrained estimates of DRE in cloudy conditions and vertically resolved aerosol absorption. This effort will reduce uncertainties in the current estimate of the aerosol direct effect and forcing. The outcomes from this proposed research will also have much broader impacts in addressing a number of climate and environmental change issues that depend critically on the vertical distribution of aerosols. The overall objective of this proposal is in concert with a top priority identified by the Climate Change Research Initiative "to develop reliable representations of the climate forcing resulting from atmospheric aerosols". The project addresses NASA's Earth Science Research Program's priority scientific questions related to "How does the Earth system respond to natural and human-induced changes?"