FORM A: GACP PROGRESS REPORT

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TITLE: Defining a Climatology and the Effects of Absorbing Aerosols: Models and Measurements

ABSTRACT: It is crucial to quantify the amount of absorbing aerosol present in the atmosphere because it may lower the single scatter albedo of otherwise mainly scattering aerosol. These absorbing aerosols consist primarily of dust, smoke from biomass burning, and carbonaceous aerosol associated with fossil fuel burning. These aerosols also may act as cloud condensation nuclei, thereby increasing reflection of solar radiation by clouds. In order to estimate the indirect effect, the quantification of the fraction of absorbing, carbonaceous aerosol relative to natural organic aerosol is needed. In this proposal we plan to use our global aerosol model in combination with analyzed meteorological fields that have been nudged towards observed or fields to enable us to compare predicted absorbing aerosols with observed aerosols as derived from the TOMS instrument (Herman et al., 1997). The TOMS instrument is only able to record absorbing aerosol above about 2 km. We intend to use the model/data comparison to improve estimates for the source strengths of aerosol, fill in the gap in data below 2 km, and to improve the aerosol model itself. Other sources of data (i.e. ground-based and aircraft) will also be used to evaluate the model. The technique developed for determining this absorbing aerosol climatology will be applied to develop sources for the record of the TOMS data. Furthermore, we will carry out studies with a coupled aerosol/climate model in order to understand whether and to what extent absorbing aerosols warm the atmosphere.

As science team leader, we are also conducting a model/data intercomparison. The goal of this part of the project is to identify uncertainties through comparison of the models with each other and to quantify the differences between models and satellite-derived optical depths.

Furthermore, we will begin the planning of a model/data intercomparison of biomass burning aerosols and gases which will further help with the determination of these sources.

GOALS: The goal of this research project is to quantify the direct and indirect forcing by anthropogenic aerosols, particularly those from biomass burning, and to understand their climate impact. We will also summarize recent literature to understand work related to the radiative effects of aerosols and evaluate model capability to assess the climate forcing by anthropogenic aerosols.

OBJECTIVES: One of the largest sources of uncertainty in estimates of the climate impact of biomass aerosols is the magnitude of the total source strength of aerosols from biomass burning. Our present ability to test the model's representation of biomass aerosols and their source strength is unsatisfactory. In Liousse et al. (1996) we found reasonable agreement between our predicted aerosol concentrations and measurement of absorbing aerosols at Amsterdam Island, but our concentrations at the South Pole were underestimated for the time period October - February. Tegen et al. (1997) showed that the optical depths from our smoke aerosols were considerably smaller than those measured locally at several sites in South America (possibly due to an overestimate of the grid-averaged optical depth by a localized measurement); but the model-predicted optical depths were higher than measured off the Western South Atlantic. Another example of the uncertainty in biomass-burning source strengths derives from the comparison of model-predicted CO concentrations and measurements. Saylor and Easter (1996) compared model-predicted CO (which is primarily from biomass burning in Africa and South America) with data from the MAPS instrument and found that their inventory for burning may be substantially under predicted.

Quantifying the radiative forcing by anthropogenic aerosols is one of the most important tasks in the assessment of climate change since this radiative forcing is one of the most uncertain factors affecting climate. The NASA Aerosol Climatology Project has the potential to significantly increase our understanding of the effects of aerosols on climate over the historical past by defining a climatology of aerosols through model/satellite intercomparison and through comparison of a variety of historical data sets. One purpose of our project is to help coordinate the activities of the NASA Aerosol Program science team members and to act as Coordinating Lead Author for Chapter 5 of the IPCC Third Assessment Report. We are also extending our work towards planning a model/data intercomparison related to biomass aerosols and uncertainties related to their source strength.

THIRD YEAR PROGRESS REPORT

We have extended our model simulations of the temperature change expected from including biomass and fossil fuel black carbon in a climate model to 10 years for each perturbation. This was necessary because the calculated standard deviation associated with the 5 years previously calculated was too large. We are proceeding to analyze these results to understand whether the inclusion of black carbon in the model can significantly alter cloud cover and/or the vertical temperature structure in the atmosphere. In particular, we have compared the model-predicted temperature difference anomalies for the surface and mid-troposphere and the column black carbon concentration. Absorption by black carbon alters the vertical structure of temperature as well as the forcing (calculated as a quasi-forcing) associated with black carbon. The change in vertical structure depends on the vertical structure of the distribution of aerosol. Thus, biomass aerosols, injected into the model near 500 mb tend to cool the surface while warming the mid troposphere, and fossil fuel black carbon, injected into the model boundary layer, tends to warm the surface relative to the mid troposphere. We have generated climate model results for the temperature structure in the absence of any

absorbing aerosols. These are being used to gauge the statistical significance of the change associated with absorbing aerosols. We are also proceeding with a calculation of temperature change associated with sulfate aerosols. The suite of temperature change results can then be used in comparison with estimates of regional changes in temperature from observations. We hope to use these results to examine further the appropriate vertical distribution of absorbing aerosol. This should aid us in interpreting the TOMs data which are sensitive to the vertical structure of absorbing aerosols.

We have also extended our analysis of the sources of aerosols from biomass burning to include the years 1981-1983 and 1985-1991 for Africa based on estimates of burned area and frequency of detection of burning from AVHRR after Barbosa et al (1999). Also, we have developed an initial inventory for aerosols from fossil fuel burning for the time period from 1950 – 1995. The inventory was presented at talk last June.

We also completed a model intercomparison exercise where, for the first time, models for dust, sea salt, organic carbon and black carbon as well as for sulfate, were compared. We have compared the data from the models to both ground based data and to satellite-derived optical depths. A paper is now in press in the Journal of Atmospheric Science.

We have developed new aerosol optical properties for dust and for sea salt. These may also help in alleviating some of the differences in our comparison of model results with the optical depth inferred from satellite.

FOURTH YEAR STATEMENT OF WORK:

We are in the process of writing up our analysis of forcing associated with black carbon aerosols and will extend our analysis of temperature effects once we have completed a simulation that includes sulfate aerosols.

We will also write-up our work to refine the estimates of the total biomass burning source which is based on satellite estimates of burned area. We have developed an initial assessment of biomass burning in Africa for the years 1981-1983 and 1985-1991 based on the satellite analysis of burned area presented by Barbosa et al. (1999). We have extended this analysis to South America using the ratio of fire counts observed in South America relative to those observed in Africa. Moreover, we have used the recent IGBP vegetation map (Belward, et al., 1999) together with biomass density in forested regions given in Gaston et al. (1998) and emissions factors for Andreae (2001) to compute total gas and particulate emissions. Our next step is to use these emissions within a version of the LLNL IMPACT model that we are using at the University of Michigan. This model is similar to the NASA supported GMI model and uses the DAO Assimilation Office meteorological fields to drive the development of aerosol and gas-phase fields. Our model study will be used first to test the ability of the model to reproduce the TOMs satellite analysis of absorbing aerosol index. This part of the project will be carried out by graduate student Y. Zhang. This past summer she worked with Omar Torres of the Goddard Space Flight Center to develop a method for converting the model-calculated smoke and dust concentrations to absorbing index. In her study, the model-derived absorbing index will then be entirely consistent with the observations of absorbing index from TOMs. The comparison of the model-derived absorbing index with that from the satellite will give us a method for testing the specified emissions.

We will also use the gas phase emissions from biomass burning in our version of the IMPACT model that calculates both gas phase chemistry and aerosol concentrations. These model simulations should allow us to carry out an analysis of the total aerosol optical depth in comparison to AVHRR analysized optical depths. We can also analyze whether estimated concentrations of OH in each hemisphere, which depend strongly on the emissions from fossil fuels (mainly in the northern hemisphere) as well as biomass burning (mainly in the tropics) are consistent with the prevailing analyses based on observed concentrations of methylchloroform (Montzka et al., 2000). This part of the project is being carried out by post-doc Akinori Itoh.fields for predicting trace species. We intend to use this model to carry out simulations of biomass burning aerosols to compare with the measured aerosols from TOMs. We will examine these results to improve our specified sources of aerosols from biomass burning and to help build a climatology of aerosols from biomass burning.

We will write up the results of our study of fossil fuel emissions for carbonaceous aerosols over the time period from 1950 – 1995.

We also plan to help develop and participate in a workshop being planned by Eric Kasiske (University of Maryland). Eric and I will develop the plans for the workshop to be held next summer at the University of Maryland guided by the advice of a steering committee. (Eric's effort is funded through the NASA ecology program). Our goal for the workshop is to derive a plan for a model intercomparison and to develop an understanding of the data sources available to make improved estimates for area burned, biomass density, combustion completeness factors, and emissions factors.

FORM D: GACP BIBLIOGRAPHY

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Institution:

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Papers, reports, and presentations refer to those published during GACP by the principal investigator, co-investigators, and other researchers supported by your agency for aerosol research. Include those in progress or planned.

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