GACP Progress Report August 2000

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TITLE: Satellite study of the smoke indirect radiative forcing.

Summary

In the 2nd year (see below) we focused our attention on an effort to move beyond detection of the indirect radiative forcing to begin to understand the physical processes controlling the interaction between smoke aerosol and clouds. To do so, we integrated the satellite observations with the theoretical modeling. The exciting results have been recently submitted to the J. Geophys. Res., and the abstract appears below. We find that Twomey's approach continues to hold to first order, but that the strength of the indirect effect can be regulated by the size and hygroscopicity of the aerosol, without varying cloud type or precipitable water vapor. These results can begin to explain discrepancies between previous observational studies.

In the 3rd year we will return the observational component of the study again, focusing on the remote sensing of the indirect effect at different spatial scales and from different instruments. We will also attempt to determine the effectiveness of remote sensing to detect direct and indirect aerosol forcing in the Southern Hemisphere.

2nd Year Progress Report

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OBJECTIVES: To use airborne and satellite imagery over tropical biomass burning regions in order to identify possible smoke indirect radiative forcing. To combine satellite imagery analysis and cloud modeling to identify the physical processes controlling the effect. To estimate the ability of remote sensing to quantify the global indirect radiative forcing produced by tropical biomass burning smoke.

APPROACH: We use AVHRR 1 km data to determine cloud and aerosol properties over South America during the biomass burning season, and combine these data with water vapor data acquired from the Goddard Data Assimilation Office (DAO). This provides our primary multi-year data base in which to look for relationships between cloud properties, smoke optical thickness and precipitable water vapor. The SCAR-B MODIS Airborne Simulator (MAS) data from 1995 allows us to test our AVHRR results with finer resolution data, and to help quantify the role of mixed cloud-clear pixels in both the analysis and in the physical process. In addition we are looking for an understanding of the physical relationships between variables with a numerical cloud model.

TASKS COMPLETED:
(1) Numerical cloud model initiated and tested.
(2) Numerical cloud model performed simulations over a broad range of parameter space.
(3) Development of methodology to link satellite data analysis and numerical modeling.
(4) Expansion of Twomey's approach to include aerosol parameters besides concentration.
(5) Identification of some of the processes controlling indirect effect.
(6) Manuscript submitted to J. Geophys. Res. extending Twomey's approach with combination of satellite observations and modeling results.
(7) DAO precipitable water vapor data validated with AERONET sunphotometer data.
(8) Software developed to ingest and process DAO water vapor data with AVHRR data.
(9) Two years of AVHRR data analyzed.
(10) Four days of MAS data analyzed for aerosol optical thickness and precipitable water vapor.
(11) Scale analysis of remote sensing of indirect effect using MAS data started.

1st YEAR RESULTS which focus on aerosol indirect effect detection and preliminary model studies are detailed in the 1st year progress report, available on the GACP web site.

2nd YEAR RESULTS: are summarized in the following paper

Analysis of smoke impact on clouds in Brazilian biomass burning regions: An extension of Twomey's approach.

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Submitted to J. Geophys. Res., August 3, 2000

Abstract: Satellite remote sensing of smoke aerosol-cloud interaction during the recent Smoke, Clouds and Radiation – Brazil experiment (SCAR-B) is analyzed to explore the factors which determine the magnitude of the response of clouds to smoke aerosol. Analysis of two years worth of data indicates that the response is greatest in the north of Brazil where aerosol optical depth is smallest, and tends to decrease as one moves southward, and as aerosol optical depth increases. Saturation in this response occurs at an aerosol optical depth of 0.8 in 1987, and 0.4 in 1995. To explore the reasons for this, a framework is developed in which the satellite-measured response can be compared to simple analytical models of this response, and to numerical models of smoke aerosol-cloud interaction. It is shown that the droplet-size response to an increase in smoke optical depth decreases with increasing aerosol optical depth, increasing median size of particles, and increasing hygroscopicity. However, for very thick smoke when competition for water vapor is great, there is a saturation in response and under certain conditions, the model even indicates an increase in drop size with increasing optical depth. Thus, two maxima in response may exist; the first (expected) peak exists at small number concentrations and small sizes (i.e, cleaner conditions), and the second at high number concentrations and large sizes. It is suggested that this second peak results from the suppression of supersaturation by abundant large particles and the prevention of activation of smaller particles. Therefore, although to first order smoke optical depth is a good proxy for aerosol indirect forcing, under some conditions the size distribution and hygroscopicity can be important factors. We find no evidence of a dependence of the indirect effect on precipitable water vapor.

3rd Year Statement of work

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In the 3rd year we intend to :

- Investigate spatial scales on the remote sensing of the indirect effect. The SCAR-B MODIS Airborne Simulator (MAS) data provides 40 m pixel data. This can be compared with 1km AVHRR data.
- Investigate the mixed cloudy and clear pixels to determine smoke effect on the total radiative forcing in the biomass burning regime. In previous studies we ignored ambiguous pixels that could have been either clear or cloudy. Much of the radiative forcing could occur in cloud edges or in

smoke close to cloud edges. Re-analysis of these lost pixels may be important.

- Investigate interannual variability of the indirect effect in South America. The two years studied, 1987 and 1995, are different in terms of smoke and cloud distributions across the region, in terms of point of saturation of the indirect effect and in terms of the strength and spatial extent of the indirect radiative forcing. Two years are not enough to begin to understand the interannual variability of the radiative forcing.
- Continue to use modeling as a tool to help understand the processes behind the observations of the indirect radiative forcing.
- Estimate the overall effectiveness of using remote sensing to estimate radiative forcing for the whole Southern Hemisphere, not just the biomass burning regions themselves where the signal is strong.

GACP BIBLIOGRAPHY

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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.

List of publications (including books, book chapters, and refereed papers), using AMS bibliographic citation form.

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1998

Chu, D.A., Y. J. Kaufman, L. A. Remer and B. N. Holben, 1998: Remote sensing of smoke from MODIS airborne simulator during the SCAR-B experiment., *J. Geophys. Res., 103*.

Feingold, G., S. M. Kreidenweis, and Y. Zhang, 1998: Stratocumulus processing of gases and cloud condensation nuclei: Part I: trajectory ensemble model. J. Geophys. Res., 103, 19,527-19,542.

Hegg, D.A. and Y. J. Kaufman, 1998: Measurements of the relationship between submicron aerosol number and volume concentration, *J. Geophys. Res.*, *103*, 5671-5678.

Kaufman, Y.J., P. V. Hobbs, V. W. J. H. Kirchoff, P. Artaxo, L. A. Remer, B. N. Holben, M. D. King, D. E. Ward, E. M. Prins, K. M. Longo, L. F. Mattos, C. A. Nobre, A. M. Thompson, J. F. Gleason and S. A. Christopher, 1998: The Smoke Cloud and Radiation Experiment in Brazil (SCAR-B)., *J. Geophys. Res.*, *103*, 31,783-31,808.

Remer, L.A. and Y. J. Kaufman, 1998: Dynamical aerosol model: Urban/industrial aerosol., *J. Geophys. Res.*, *103*, 13,859-13,871.

Remer, L.A., Y. J. Kaufman, B. N. Holben, A. M. Thompson and D. McNamara, 1998: A model of tropical biomass burning smoke aerosol size distribution., *J. Geophys. Res.*, *103*, 31,879-31,892.

Yamasoe, M.A., Y. J. Kaufman, O. Dubovik, L. A. Remer, B. N. Holben and P. Artaxo, 1998: Retrieval of the real part of the refractive index of aerosols from sun/sky radiometers during SCAR-B., *J. Geophys. Res.*, *103*, 31,893-31,902.

1999

Feingold, G., W. R. Cotton, S. M. Kreidenweis, and J. T. Davis, 1999: Impact of giant cloud condensation nuclei on drizzle formation in marine stratocumulus: Implications for cloud radiative properties. *J.Atmos. Sci.*

King, M. D., Y. J. Kaufman, D. Tanré, and T. Nakajima, 1998: Remote sensing of tropospheric aerosols from space: past, present and future. *Bull. of Meteor. Soc.*. **80**, 2229-2259, 1999

Longo, K.M., A. M. Thompson, V. W. J. H. Kirchoff, L. A. Remer, S. R. d. Freitas, M. A. F. SilvaDias, P. Artaxo, W. Hart, J. D. Spinhirne and M. A. Yamasoe, 1999: Correlation between smoke and tropospheric ozone concentrations in Cuiaba during Smoke, Clouds and Radiation-Brazil (SCAR-B)., *J. Geophys. Res.*, *104*, 12,113-12,129

Remer, L.A., Y. J. Kaufman and B. N. Holben, 1999: Interannual variation of ambient aerosol characteristics on the east coast of the United States, *J. Geophys. Res.*, *104*, 2223-2232.

Tanré, D., L. A. Remer, Y. J. Kaufman, S. Mattoo, P. V. Hobbs, J. M. Livingston, P. B. Russell and A. Smirnov, 1999: Retrieval of aerosol optical thickness and size distribution over ocean from the MODIS Airborne Simulator during TARFOX, *J. Geophys. Res.*, *104*, 2261-2278.

Wulfmeyer, V., and G. Feingold, 1999: On the relationship between relative humidity and particle backscattering coefficient in the marine boundary layer determined with differential absorption lidar. *J. Geophys.Res.*

Zhang, Y., S. M. Kreidenweis, and G. Feingold, 1999: Stratocumulus processing of gases and cloud condensation nuclei: Part II: chemistry sensitivity analysis. *J. Geophys. Res.*

2000

Alpert, P., J. Herman, Y. J. Kaufman, I. Carmona, 2000: Dust forcing of climate inferred from correlation between TOMS aerosol index and atmospheric model errors. *Atmospheric Res*. accepted.

Feingold, G. and S.M. Kreidenweis, 2000: Does heterogeneous processing of aerosol increase the number of cloud droplets? *In press, J. Geophys. Res.*

Feingold, G., L. A. Remer, J. Ramaprasad and Y. J. Kaufman, 2000: Analysis of smoke impact on clouds in Brazilian biomass burning regions: An extension of Twomey's approach., *J. Geophys. Res., submitted*..

Karnieli, A., Y. J. Kaufman, L. Remer and A. Wald, 2000: AFRI - Aerosol Free Vegetation Index, *Rem. Sens. Environ., submitted*,.

Kaufman, Y. J., A. Karnieli and D. Tanré, 2000: Detection of dust over the desert by EOS-MODIS. *IEEE TGARS, 38, 525-531*.

Kaufman, Y.J., D. Tanré, O. Dubovik, A. Karnieli and L. A. Remer, 2000: Satellite and ground based radiometers reveal much lower dust absorption of sunlight than used in climate models, *Nature*, *submitted*,.

Kaufman, Y.J. , D. Tanré and L. A. Remer, 2000: New Frontiers in Remote Sensing of Aerosols and Their Radiative Forcing of Climate, in *Frontiers in Research of Climate Change*, Kiehl and Ramanathan Editors.

Kreidenweis, S.M., L. A. Remer, R. Bruintjes, R. Kleidman and O. Dubovik, 2000: Smoke aerosol from biomass burning in Mexico: Hygroscopic smoke optical model., *J. Geophys. Res.*, *submitted*,.

Remer, L.A., A. E. Wald and Y. J. Kaufman, 2000: Angular and seasonal variation of spectral surface reflectance ratios: Implications for the remote sensing of aerosol over land., *IEEE Trans. Geoscience Rem. Sens., accepted*,.

Smirnov, A., B. N. Holben, O. Dubovik, N. T. O'Neill, L. A. Remer, T. F. Eck, I. Slutsker and D. Savoie, 2000: Measurement of atmospheric optical parameters on U.S. Atlantic coast sites, ships and Bermuda during TARFOX., *J. Geophys. Res.*, *105*, 9887-9902.

Sabbah I., Charles Ichoku, Yoram Kaufman, and Lorraine Remer, 2000: Climatology of desert dust spectral optical thickness and precipitable water vapor over Egypt in 1998, *J. Geophys. Res., in press*.

Tanré, D., Y. J. Kaufman, B. N. Holben, B. Chatenet, A. Karnieli, F. Lavenu, L. Blarel, O. Dubovik, L. A. Remer and A. Smirnov, 2000: Climatology of dust aerosol size distribution and optical properties derived from remotely sensed data in the solar spectrum., *J. Geophys. Res., submitted*,.