Aerosol Forcing from the Indian Ocean Experiment and the ARM-SGP

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Introduction

The tropical Indian Ocean provides an ideal and unique natural laboratory to observe and understand the role of anthropogenic aerosols in climate forcing. This region is probably the only place in the world where an intense source of anthropogenic aerosols, trace gases, and their reaction products (e.g., sulfates, ozone) from the northern hemisphere is directly connected to the pristine air of the southern hemisphere by a cross-equatorial monsoonal flow into the intertropical convergence zone (ITCZ).

The Indian Ocean Experiment (INDOEX) was conducted by an international team of American, European, and Indian scientists who collected aerosol, chemical, and radiation data from ships and surface stations beginning in 1996 and culminating in a multi-platform field experiment conducted during January and March 1999. As part of INDOEX, a new surface observatory was established in the Maldives. The Kaashidhoo Climate Observatory (4.965ºN, 73.466ºE) is designed for making long-term observations of aerosol chemical composition, microphysics, and radiative fluxes.

We report here some of the findings from INDOEX and compare the INDOEX aerosol forcing with that derived for the Atmospheric Radiation Measurement (ARM) Program Southern Great Plains (SGP) site. This comparison provides us with an unique opportunity to discover if the continental aerosols over the United States have as large a surface forcing as that observed over the polluted Indian Ocean. Our objectives are as follows:

1. Incorporate measured aerosol properties into radiation models.

2. Estimate the aerosol radiative forcing using observations from various instruments at the surface and top of the atmosphere (TOA).

3. Examine the effect of various aerosol species to the forcing at the surface and the top of the atmosphere.

4. Compare the anthropogenic aerosol forcing from INDOEX to that for the SGP.

Results

The INDOEX results cited below are taken from papers cited in the reference list.

- A persistent haze layer that spread over most of the northern Indian Ocean during wintertime was discovered. The optical thickness of this layer ranges from as high as 0.5 to 0.6 in the northern Arabian Sea and Bay of Bengal to about 0.1 to 0.2 in the southern equatorial Indian Ocean. The layer, a complex mix of organics, black carbon, sulfates, nitrates, and other species, subjects the lower atmosphere to a strong radiative heating and a larger reduction in the solar heating of the ocean.

- The aerosol reduction is particularly strong in the photo-synthetically active region of 0.4 μm to 0.7 μm. The diurnal mean clear-sky surface forcing is in the range of -10 Wm^{-2} to -40 Wm^{-2}.

- An aerosol model was derived from extensive measurements of aerosol properties and radiative fluxes made in the haze plume off the Indian subcontinent.

- The modeled and measured radiative fluxes (total, direct, and diffuse) show excellent agreement (within the accuracy of the radiometric observations) when the measured aerosol properties are incorporated into the radiation model.

- The surface forcing is larger than the TOA forcing by up to a factor of three. Thus, the TOA forcing may not be a reliable indicator of aerosol climate effects, at least for the Indian Ocean aerosol. Soot is the major contributor of large atmospheric absorption.

- Preliminary results compare the surface forcing at the SGP to that found during INDOEX (Figure 1). However, further work or refinement is needed before a definitive evaluation can be made.

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References and Related Publications

Conant, W. C., 2000: An observational approach for determining aerosol radiative forcing: Results from first field phase of INDOEX. *J. Geophys. Res.*, **105**, 15,347-15,360.

Jayaraman, A., D. Lubin, S. Ramachandran, V. Ramanathan, E. Woodbridge, W. Collins, and K. S. Zalpuri, 1998: Direct observations of aerosol radiative forcing over the tropical Indian Ocean during the Jan-Feb 1996 Pre-INDOEX Cruise. *J. Geophys. Res.*, **103**, 13,827-13,836.

Meywerk, J., and V. Ramanathan, 1999: Observations of the spectral clear-sky aerosol forcing over the Tropical Indian Ocean. *J. Geophys. Res.*, **104**, 24,359-24,370.

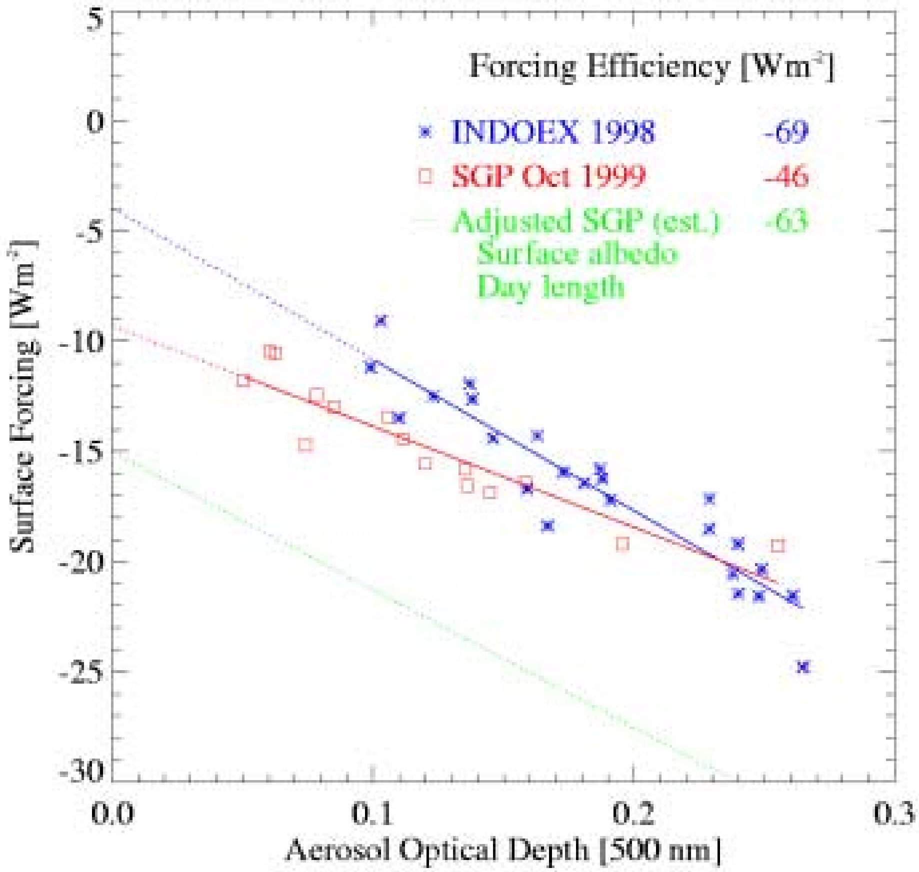

Figure 1. Surface aerosol forcing comparison. The surface aerosol forcing are estimated directly from clear-sky pyranometer measurements at the SGP and during INDOEX. The forcing is a function of the surface albedo and day length and, because they are different for the two locations, they must be normalized by a common standard. The preliminary results for a first-order normalization procedure (green line) are presented. A more definitive comparison will be possible when we have completed developing a more robust procedure, which will not cause such a large alteration in the intercept.

Podgorny, I. A., W. Conant, V. Ramanathan, and S. K. Satheesh, 2000: Aerosol modulation of atmospheric and surface solar heating over the tropical Indian Ocean. *Tellus*, **52B**, 947-958.

Rajeev, K., V. Ramanathan, and J. Meywerk, 2000: Regional aerosol distribution and its long range transport over the Indian Ocean. *J. Geophys. Res*., **105**, 2029-2043.

Satheesh, S. K., V. Ramanathan, X. Li-Jones, J. M. Lobert, I. A. Podgorny, J. M. Prospero, B. N. Holben, and N. G. Loeb, 1999: A model for the natural and anthropogenic aerosols over the Tropical Indian Ocean derived from INDOEX data. *J. Geophys. Res*., **104**, 27,421-27,440.

Satheesh, S. K., and V. Ramanathan, 2000: Observations of large tropical aerosol forcing at the earth's surface and top of the atmosphere. *Nature*, 405, 60-63.