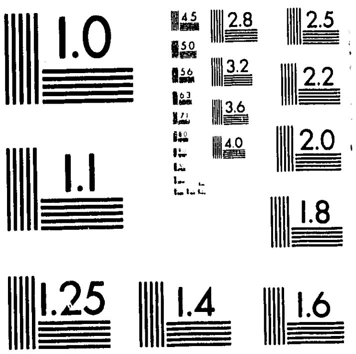
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Time-Dependent Behavior of Mount Pinatubo Aerosol

Joseph Michalsky
Atmospheric Sciences Research Center
University at Albany, State University of New York
100 Fuller Rd
Albany, New York 12205
(518)442-3809

Nels Larson
Pacific Northwest Laboratory
P.O. Box 999
Richland, Washington 99352
(509)376-4333

INTRODUCTION

The 15-16 June 1991 eruption of Mount Pinatubo delivered approximately 20 million metric tons of SO_2 to the stratosphere. This is about three times the estimate for El Chichon (Bluth et al., 1992). While El Chichon's volcanic plume was confined mostly to the northern hemisphere, the SO_2 plume from Mount Pinatubo straddled the equator resulting in a more symmetrical global distribution of the H_2SO_4-H_2O aerosol that results from the photochemical conversion of the SO_2. Dutton and Christy (1992) find that the average Mount Pinatubo aerosol cloud as measured at two southern and two northern hemisphere sites exceeds the El Chichon aerosol optical depth for the first 10 months by about 70%. This is consistent with the extra SO_2 loading and more uniform dispersal of the plume between hemispheres. They found the global and northern hemispheric temperatures of the lower troposphere to be 0.4 and 0.7° C below normal, respectively, by June 1992. This is consistent, thus far, with the predictions of Hansen et al. (1992).

This paper follows the aerosol optical depth change over three northern mid-latitude sites for the first sixteen months following the eruption. The technique to derive volcanic aerosol optical depth from ground-based measurements (which are, by their nature, total column aerosol optical depth measurements) follows the technique developed in an earlier paper to examine El Chichon aerosol (Michalsky et al., 1990). The three sites' time-dependent behavior is discussed and compared. Comparison of El Chichon and Mount Pinatubo aerosol optical depth change with time is also discussed for the one site that operated before, through, and after both eruptions.

DATA

Aerosol optical depth measurements are taken at three mid-latitude US sites: Richland, Washington; Boulder, Colorado; and Albany, New York. In Richland the instrument is a sun-tracking solar radiometer with five filters centered on 428, 486, 535, 785, and 1010 nm. Data have been taken continuously since before 1980 at this site, and an analysis of these data through the El Chichon epoch appear in Michalsky et al. (1990). In Boulder and Albany the data are acquired using the rotating shadowband photometer. This instrument, which measures total and diffuse horizontal illuminances and calculates direct normal illuminance, is not a conventional sunphotometer. Its operation and cross-calibration with a standard sun-tracking radiometer is examined in LeBaron et al. (1989). The photometer measurements are in a single broad band centered on 555 nm.

Direct normal spectral irradiance from the instruments on clear or partially clear days is used with the Langley technique to calculate total column optical depth at each of the wavelengths. The Langley technique assumes exponential extinction with changing air mass, i.e.,

$$I = I_0 * \exp(-\tau * m),$$

where I and I_0 are the spectral irradiances at the bottom and top of the atmosphere, respectively, m is the air mass relative to a value of one in the zenith direction, and τ is the total column optical depth. Plotting the natural logarithm of the measured direct spectral irradiance versus air mass results in a straight line for clear stable conditions. The slope of this line, as determined from a least squares fit, is the total column optical depth. Molecular water and oxygen bands are avoided through judicious filter selection; molecular, or Rayleigh, scattering is a well known function of wavelength and pressure, therefore, it is removed by subtraction; seasonal climatological values for total column ozone are used to subtract ozone optical depth in the Chappuis band of ozone; this yields the aerosol optical depth.

ANALYSIS

The automated measurements permit every clear or partially clear day's data to become a candidate for Langley analysis. On some occasions when there are too few data for a Langley plot, or the Langley plot indicates an unstable condition, previously determined calibrations of extraterrestrial spectral irradiances (the intercept in the least squares fit to the Langley plot) may be used to calculate an average optical depth. These data yield between 135 and 210 data points per year, depending on a site's climatology.

To ascertain the seasonal patterns in the time-averaged optical depth, all data acquired with the stratosphere unperturbed, or minimally perturbed by volcanic aerosols, are superimposed on a single year. The background data from the first half year is appended and data from the second half year is prepended to the data. A lowess smooth of the data (Cleveland, 1979) is applied, in order to obtained approximately monthly averaged data with the influence of outliers deweighted. Fig. 1 contains background data for Boulder, Colorado. As is typical of most sites, there is a maximum during early summer and a minimum in the early winter. The background contains a little more than 16 months' data. As the volcanic perturbation reverts to background levels, we will be able to add more data to our background data set and determine a better averaged behavior.

This smoothed background aerosol optical depth is removed from every point in the data set according to the time of year. Once this differenced data set is formed it is smoothed with the lowess function to reveal perturbations to what we assume is background. Fig. 2 is a plot of the points after removing the background, and the smooth line is the lowess estimate of the perturbation to background aerosol. The extent to which we are successful in removing the background is indicated by the deviations about the zero optical depth line before the onset of Mount Pinatubo's aerosol perturbation. The dashed horizontal lines represent ±0.01 optical depth about the zero optical depth line. Therefore, we have a reproducible monthly averaged optical depth to about the 0.01 level.

The effect of Pinatubo began to exceed this background level in the last four months of 1991. The peak optical depth of about 0.15 was reached during the February/March 1992 period. During the summer of 1992 the optical depth fell to about 0.06, but since has begun to increase somewhat. This behavior is virtually identical to that of the El Chichon perturbation (Michalsky et al., 1990) with the exception that the Mount Pinatubo optical depths are larger by about 40 to 50%.

Although there is insufficient space to show the results from the other sites, they confirm this behavior in general, but not quite in detail. For example, Richland data show a somewhat higher peak at the same wavelength. Albany has a lower peak. The differences are within the error of the estimate, however. The most recent data from all three sites will be presented at the meeting.

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Fig. 1. Boulder Background Aerosol vs Time of Year

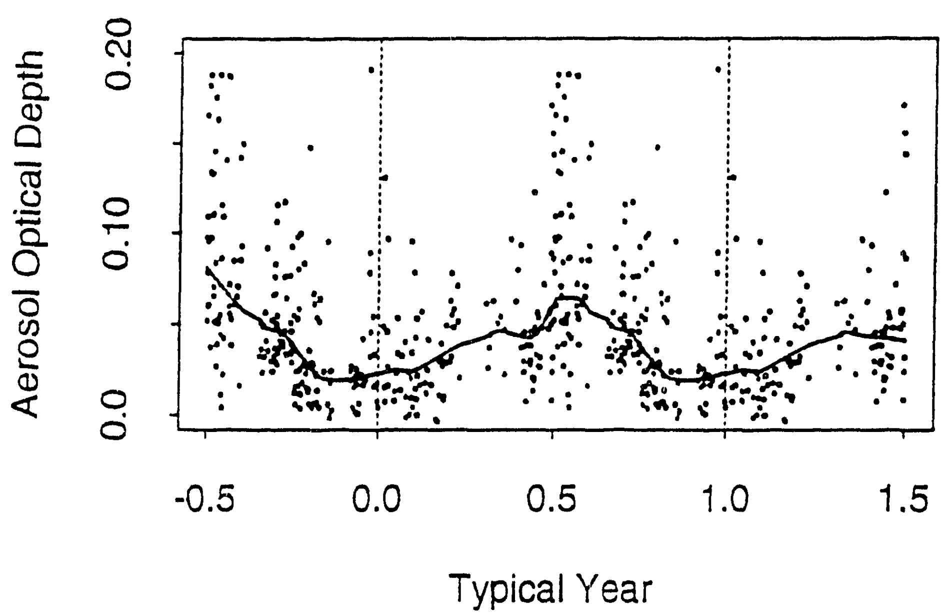
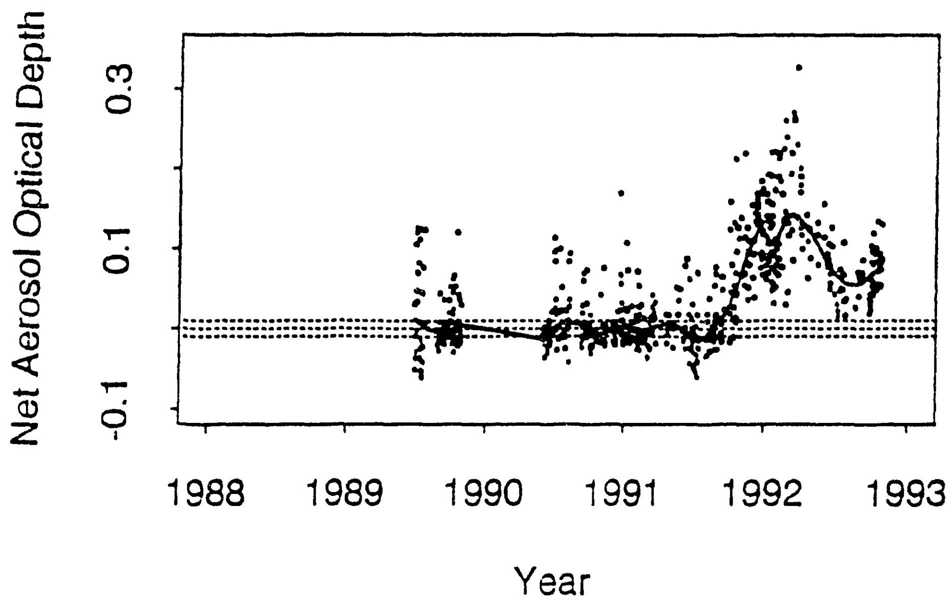


Fig. 2. Pinatubo Aerosol @ Boulder vs Time



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