GACP Progress Report, FY 1999

Name: Cora E. Randall (with Dave Rusch, Frank Eparvier, Mike Callan and Todd Clancy)

Institution: University of Colorado, Laboratory for Atmospheric and Space Physics

Title: Solar Mesosphere Explorer Measurements of El Chichón Aerosols

Proposal Abstract:

We propose to "resurrect" data from the Solar Mesosphere Explorer (SME) in order to provide the climate community with information regarding stratospheric aerosol forcing after the eruption of the El Chichón volcano in 1982. The database provided by this proposal will enable climate modelers to subtract stratospheric aerosol effects from column measurements in order to define the tropospheric aerosol contribution after the El Chichón eruption. The goal is to provide the climate community with the optical depth of aerosols in the visible, near infrared and thermal infrared spectral regions. Specifically, SME radiance data from the 0.44, 1.27, 1.87, and 6.8 μm channels will be used. We propose to improve on previously published retrieval techniques in order to extract and publish extinction and size distribution information over more extended spatial and temporal regimes than previously possible.

Goals:

Our primary goal is to provide to the climate community the aerosol extinction profiles and vertical optical depths at 6.8, 1.87, 1.27 and 0.44 μm derived from SME measurements in the aftermath of the El Chichón eruption. The object is to improve and extend the algorithms that were originally used to derive size distribution parameters and the 6.8-μm extinction and optical depth.

Objectives:

To understand and predict global climate change, it is necessary to accurately assess the radiative forcing caused by atmospheric aerosols. Of the natural radiative forcings, injections of aerosols into the stratosphere by volcanic eruptions are the most significant with regard to the global radiation balance. The overall purpose of this program is to extend the satellite measurements of global stratospheric aerosol profiles back in time to the eruption of El Chichón in 1982, using SME data. SME made global measurements of aerosols from several months prior to the eruption of El Chichón through 1986. The SME radiance data are being inverted to calculate aerosol extinction profiles at 0.44, 1.27, 1.87 and 6.8 μm. These profiles and the total vertical optical depths derived from them will be provided to the climate community for input to global models.

Approach:

The approach is to modify existing codes [Eparvier *et al.*, 1994] to develop new algorithms for calculating aerosol extinction at the four SME aerosol wavelengths. Previously, aerosol extinction profiles and vertical optical depths at 6.8 μm were calculated from the SME data, but with limited temporal and spatial resolution and coverage. Proposed improvements to the new inversion codes include reducing the amount of radiance profile binning, to improve the temporal and spatial resolution of the derived extinction profiles. The intent is also to use a water vapor climatology for subtraction of the water vapor component in the 6.8 μm channel, to allow calculations of extinction beyond late 1984 (the limit of previous work). In previous work [Eparvier *et al.*, 1994], aerosol extinction profiles were not calculated at wavelengths of 0.44, 1.27 and 1.87 μm. This is because the goal of that work was to produce size distribution parameters, and this was possible without completing a full inversion of the data. The approach here is to invert the slant path radiance profiles to obtain profiles of the phase-modulated extinction coefficients. Assumptions for size distribution parameters (and thus the scattering phase function) based on the work of Eparvier *et al*. will then be used to calculate the aerosol extinction profiles and vertical optical depths in all channels. Other improvements to the algorithms include using NCEP data to model the Rayleigh contribution to the near-IR radiance profiles, rather than climatological temperatures.

Tasks Completed:

The SME radiance data have been restored from backup tapes and are now online. The 6.8-μm retrieval algorithms have been improved, and all data have been inverted with the new algorithms to generate extinction profiles. The most significant improvement here is that instead of calculating only weekly (and thus zonally) averaged profiles, the profiles have been inverted on an event-by-event basis. Aside from increased temporal and spatial resolution, one benefit of the event-by-event retrievals is the added information regarding random and systematic errors in the retrievals.

To run the retrievals on an event-by-event basis required significant changes in the water vapor subtraction procedure. Previously, the contribution to the radiance profile from water vapor emission was calculated by performing a linear least squares fit to the correlation between the radiance profile to be inverted and a separate radiance profile acquired either before, or at least 30 months after, the eruption of El Chichón. All profiles acquired during these time periods were tested; of these, the profile corresponding to the optimum fit was then subtracted from the profile to be inverted. The correlation included all altitudes below 16 km and between 40 and 70 km. This method potentially leads to large errors in the water vapor subtraction, since any seasonal variations in water vapor are disregarded. To avoid this in the new inversion code, correlations are restricted to those profiles that were acquired during non-El Chichón periods within two weeks of the day of year corresponding to the data to be inverted. Also, to prevent aerosols at 16 km or lower from influencing the least square fits, they include only altitudes between 36 and 54 km.

Algorithms have been developed for calculating extinction profiles at 1.27 and 1.87 μm. This requires inverting the slant path radiance profiles and removing the Rayleigh scattering component to obtain phase modulated aerosol extinction profiles. Then, assumptions for size distribution parameters can be used to determine the scattering phase function, and with this aerosol extinction profiles can be calculated. This is accomplished using size distribution parameters already derived by Eparvier *et al.* [1994]. We are currently evaluating if the signal to noise ratio is high enough for the algorithms to be applied reliably on an event-by-event basis; this looks very promising. Before the end of the first year, these extinction profiles and the vertical optical depths will be available for distribution. Finally, algorithms for inverting the lower wavelength data are now online, but require modifications before 0.44-μm extinction profiles can be calculated.

Future Plans and Results:

These are described in sections B and C.

Reference:

Eparvier, F.G., D.W. Rusch, R.T. Clancy, and G.E. Thomas, “Solar Mesosphere Explorer satellite measurements of El Chichón aerosols. 2: Aerosol mass and size parameters”, *J. Geophys. Res.* 99, 20,533-20,544, 1994.

FORM B: GACP SIGNIFICANT HIGHLIGHTS

Name: Cora E. Randall

Institution: LASP/University of Colorado

The following figure shows the event-by-event 6.8-µm extinctions from 22 to 28 km at a latitude of 15 N, from January, 1982 through 1984. These retrievals compare well with the results reported by Eparvier *et al*. [1994], but indicate some systematic variability which was not apparent in the earlier results. For instance, there appears to be a steep increase in extinction at 22 and 24 km immediately after the eruption of El Chichón in early April of 1982, then a significant decrease at 22km (leveling off at 24 km) before the maximum extinction is observed in September. This morphology will be investigated in future work. These data, as well as the vertical optical depths derived from them, are available on request.

Title:
Graphics produced by IDL
Creator:
IDL Version 5.1.1 (Win32 x86)
Preview:
This EPS picture was not saved
with a preview included in it.
Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

SME 6.8-µm event-by-event extinction at 15° N from 1982 through 1984.

FORM C: FUTURE PLANS

Name: Cora E. Randall

Institution: LASP/University of Colorado

Sensitivity tests will be run on the 6.8-µm retrievals to evaluate systematic errors due to water vapor subtraction. Based on these results, we will explore the possibility of replacing the current subtraction algorithm with an algorithm utilizing climatological water vapor profiles. Sensitivity tests will also be run on the 1.27 and 1.87-µm retrievals to evaluate systematic errors due to the size distribution assumptions employed. NCEP temperature profiles rather than climatological profiles will be used in the near-IR inversions. The algorithms for inverting the 0.44-µm radiance profiles will be refined, and extinction profiles at this wavelength will be generated. All extinction profiles and vertical optical depths will be made available for distribution.