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ISAMS OBSERVATIONS OF STRATOSPHERIC AEROSOL

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Abstract

The Improved Stratospheric and Mesospheric Sounder (ISAMS) on board the Upper Atmosphere Research Satellite (UARS) incorporates a 12.1μm window channel for the measurement of aerosol opacity. The retrieval scheme is discussed briefly and preliminary observations of the Mt. Pinatubo aerosol cloud are presented and compared with SAGE II observations at 1.02μm. The effect of aerosol on other ISAMS channels and its spectral dependence is discussed.

Introduction

Within a time span of just 10 years the two major volcanic eruptions of El Chichon in April 1982 and Mt. Pinatubo in June 1991 have injected enormous quantities of sulphate aerosol into the lower stratosphere, thereby perturbing radiative and chemical processes. The launch of the Improved Stratospheric and Mesospheric Sounder (ISAMS) on board the Upper Atmosphere Research Satellite (UARS) took place three months after the Mt. Pinatubo eruption and this paper reports preliminary results indicating that ISAMS is providing useful measurements of the volcanic aerosol cloud. These data will provide important information on a variety of atmospheric problems, such as the use of aerosol as a tracer of stratospheric motions (Boville *et al* 1991, Trepte and Hitchman 1992), understanding the role of aerosol in the radiative energy balance of the stratosphere (Michelangeli *et al* 1989, Labitzke and McCormick 1992) and its participation in heterogenous chemical reactions (Roscoe *et al* 1986, Hofmann and Solomon 1989, Chandra and Stolarski 1991, King *et al* 1991, Pitari *et al* 1991).

Unusually large aerosol opacities also affect the ability of ISAMS and other infra-red remote sensing instruments to retrieve accurate data on temperature and minor atmospheric constituents and this problem will be addressed.

ISAMS Aerosol Measurements

ISAMS is an infra-red limb scanning instrument using the technique of pressure modulator radiometry and wideband radiometry (Taylor *et al* 1992) to measure selected atmospheric parameters with high precision. It is an improved version of an earlier instrument (the Stratospheric and Mesospheric Sounder) flown on the Nimbus 7 satellite. The greater instrumental precision of ISAMS and its increased number of channels provides better coverage both in the vertical and horisontal dimensions for a large number of species (Rodgers *et al*, this conference). Two of the channels contain four-position filter wheels allowing wideband measurements of reactive species unable to be contained in modulator cells. A 'window' channel, positioned at 12.1μm (the best atmospheric window for the lower stratosphere) gives the capability of measuring aerosol opacity.

The ISAMS 12.1μm wideband channel is being used to retrieve an aerosol extinction coefficient with the aim of :

i) creating a 3-dimensional global daily aerosol field for use as input to a correction scheme improving the retrieval of other ISAMS species;
ii) inferring stratospheric motions from the spatial and temporal changes of the volcanic injected aerosol;
iii) providing data for study of effects of aerosol on the radiative balance and chemistry in the lower stratosphere.

Retrieval of the Aerosol Extinction Coefficient

The major gaseous emitters in the 12.1μm channel are O_3, CO_2 and F11. A seasonal climatology has been used for O_3, and a single profile for the other two gases. The *a priori* aerosol climatology consists of a single altitude profile, estimated from SAGE II data (D. Cunnold, private communication), and a very large *a priori* uncertainty ensures that the retrieval is loosely constrained. The extraction of the aerosol extinction coefficient in this paper follows a scheme which corrects for the effects of aerosol on the ISAMS temperature sounding channels in order to obtain more accurate temperatures in the range 15 km to 35 km (see the following sections). The retrieval methods employed are discussed by Marks and Rodgers (1992) and Fig. 1 shows a typical example of a retrieved profile.

Preliminary Observations of the Pinatubo Aerosol Cloud

The 2300 retrieved profiles for 13 November 1991 have been combined to give the sonally averaged aerosol map shown in Fig. 2. The ISAMS data show the extent of the aerosol cloud nearly 5 months after the eruption of Pinatubo. The maximum aerosol opacity occurs within the altitude range 20 – 25 km and within ± 25°of the Equator, but evidently there has been transport of the cloud into northern latitudes with less penetration to southern polar regions. This distribution shows qualitative similarities with the SAGE II measurements at 1.02μm during 1-31 October 1991 (D. Cunnold, private communication) in Fig. 3 and also with results from a general circulation model used to simulate the global transport and dispersal of the Pinatubo aerosol cloud (Boville *et al* 1991).

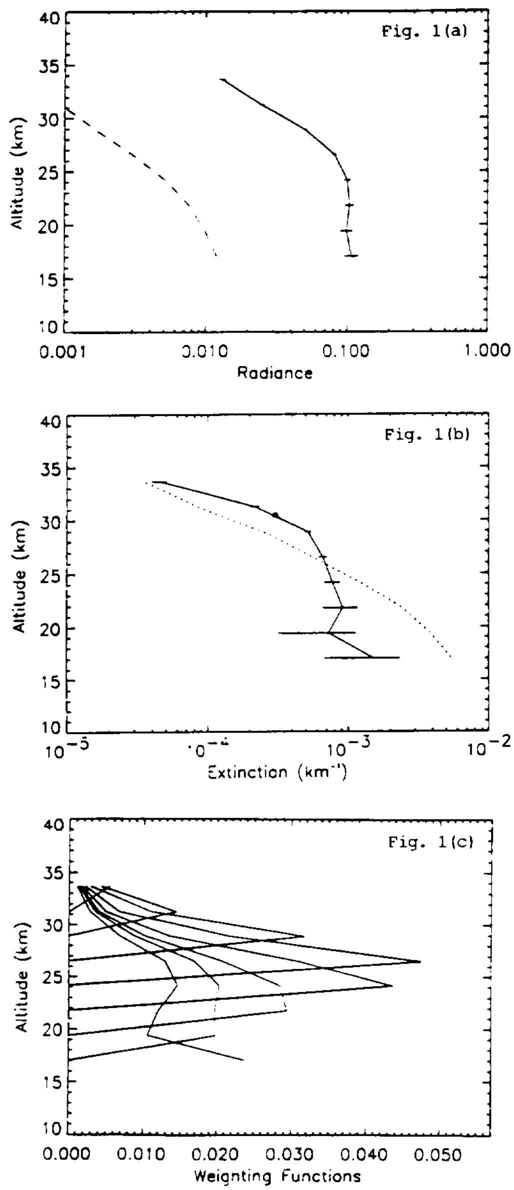

Fig. 1 Results from a typical aerosol retrieval from 13 November 1991 near the Equator.

Fig. 1.(a) The observed radiance profile in the 12.1μm channel (*full line with error bars*). The radiance unit is the fraction of a 290K blackbody. The uncertainties in the measured radiances are plotted as a dashed line.

Fig. 1.(b) The retrieved aerosol extinction profile (full line with error bars). The *a priori* aerosol profile is shown as a dotted line.

Fig. 1.(c) The weighting functions.

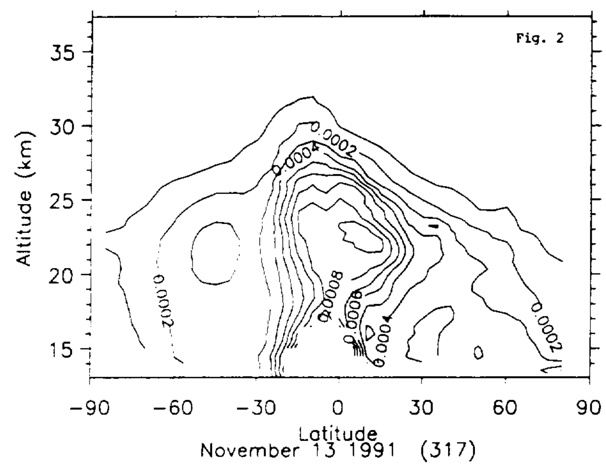

Fig. 2 The ISAMS sonally averaged 12.1μm aerosol extinction for 13 November 1991.

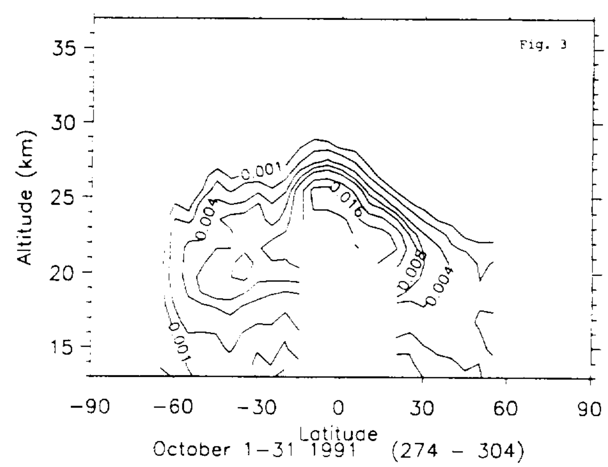

Fig. 3 The SAGE II sonally averaged 1.02μ aerosol extinction from 1-31 October 1991. The latitude range of the data is from 69°S to 58°N.

Spectral Dependence of Aerosol and its Effects on Other Channels

Aerosol extinction has a spectral variation dependent on its composition and particulate size distribution, but approximates to a continuum within the ISAMS channels.

Fig. 4 shows the effect of aerosol on the ISAMS 16.3μm CO_2 wideband channel which is used for temperature sounding between 15 km and 35 km. At 25 km near the Equator, the measured radiance is 50% greater than the calculated signal. Fig. 5 shows the presence of aerosol in the wideband channel used to measure O_3. Even larger effects are seen in some of the other the channels.

The most obvious effect of the aerosol is at latitudes between 20°S and 20°N and at heights between 15 km and 30 km, but the aerosol is still a significant contaminant at all latitudes and at heights above 30 km in the tropics.

The spectral dependence of the aerosol must be known in order to correct for aerosol extinction in all channels. The spectrum is a function of the aerosol loading (Hummel *et al* 1988), therefore the aerosol extinction coefficient in any channel, relative to that at 12.1μm, is a function of position and time. Furthermore, for the ISAMS constituent channels, errors in retrieval of a target gas due to aerosol contamination arise not only from the effect of the aerosol on the measured radiances but also from its effect on the measured temperatures which are used in the retrieval.

Work is underway to derive empirically the spectral dependence using all the ISAMS wideband channels to retrieve extinction coefficients at several wavelengths from climatological data for target and contaminant gases.

Temperature Correction Scheme

As described above the ISAMS 16.3μm CO_2 wideband channel is affected by aerosol, and so it is omitted from the initial temperature retrieval resulting in mainly climatological data below 35 km. These temperatures are used to retrieve an initial 12.1μm aerosol extinction coefficient. A second temperature retrieval is then performed including the 16.3μm CO_2 wideband channel and using the initial aerosol extinction multiplied by an estimate of the 16.3μm to 12.1μm extinction ratio as a contaminant absorber.

Summary

It is already clear from the first several months of data that the 12.1μm window channel of the ISAMS instrument can provide useful aerosol measurements. These can be applied to improve ISAMS measurements between 15 km and 35 km in the presence of aerosol in the other channels. The evolution of the aerosol cloud from the Mt. Pinatubo eruption has been mapped by ISAMS from late September 1991 onwards (with exception of the period 18 January 1992 to 28 March 1992). Studies of the behaviour of the cloud and its spectral properties are continuing, as is further data acquisition.

Acknowledgements

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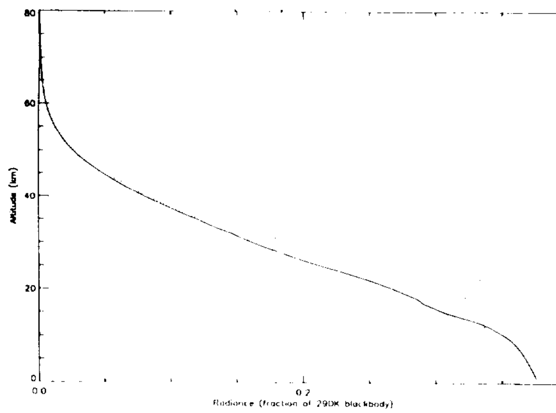

Fig.4 Comparison of the measured zonal mean radiance in the ISAMS 16.3μm temperature sounding channel (dotted line) and the calculated radiance (full line) near the Equator on 13 November 1991.

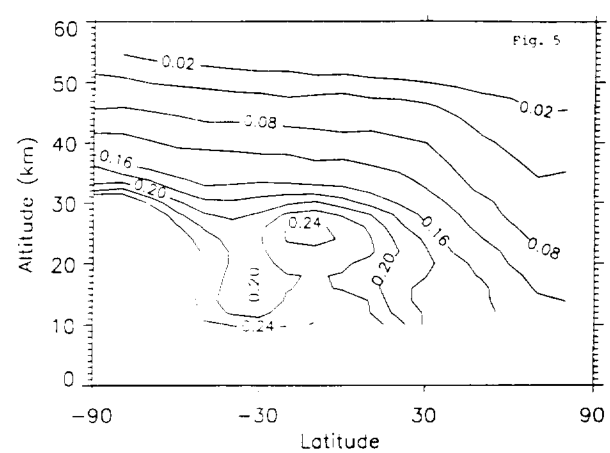

Fig. 5 The zonally averaged radiances in the channel used for ozone measurement on 13 November 1991.

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