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EFFECT OF STRATOSPHERIC AEROSOL LAYERS ON THE TOMS/SBUV OZONE RETRIEVAL

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Abstract

An evaluation of the optical effects of stratospheric aerosol layers on total ozone retrieval from space by the TOMS/SBUV type instruments is presented here. Using the Dave radiative transfer model we estimate the magnitude of the errors in the retrieved ozone when polar stratospheric clouds (PSCs) or volcanic aerosol layers interfere with the measurements. The largest errors are produced by optically thick water ice PSCs. Results of simulation experiments on the effect of the Pinatubo aerosol cloud on the Nimbus7 and Meteor3 TOMS products are presented.

Introduction

Optically thick stratospheric aerosol layers have important effects on the measurements of the properties of the earth's atmosphere. In particular, they affect satellite borne sensors that derive atmospheric ozone content based on the measurement of the backscattered ultraviolet (buv) radiation. This kind of instrumentation includes total ozone content mappers (Nimbus-7 TOMS, Meteor-3 TOMS) as well as instruments retrieving both total ozone and its vertical distribution (Nimbus-7 SBUV, NOAA9 and NOAA11 SBUV/2).

A non-absorbing stratospheric aerosol layer backscatters much of the incoming UV radiation before it reaches the ozone underneath the aerosol cloud, and, therefore, an error is introduced in the retrieved ozone. The size and direction of the error depend on the aerosol layer altitude, its optical and microphysical properties and on the geometry of the viewing conditions. In this paper we summarize the results of simulation experiments using the Dave aerosol radiative transfer model to quantify the artifact introduced in the TOMS retrieval in the presence of stratospheric aerosol layers.

TOMS Total Ozone Algorithm

To compute total ozone, radiance measurements at a pair of wavelengths, an ozone-sensitive wavelength λ, and a longer wavelength, relatively insensitive to ozone, λ', are paired together. A quantity called N_{pair}, defined as

$$N_{pair} = -100 \log_{10}\left[\frac{(I_\lambda/F_\lambda)}{(I_{\lambda'}/F_{\lambda'})}\right]$$

is computed. In the above expression I and F are respectively the measured radiance and irradiance at the top of the atmosphere.

Three wavelength pairs are used: .3125μ and .3312μ (A-pair); .3175μ and .3398μ (B-pair); .3312μ and .3398μ (C-pair).

The N_A, N_B, and N_C quantities are used to compute the total ozone amounts Ω_A, Ω_B and Ω_C, by an interpolation procedure from a set of lookup tables. These three ozone amounts are weighted and linearly combined to produce the final total ozone amount Ω.

Aerosol Effects

There are mainly two kinds of stratospheric aerosols that may affect the TOMS/SBUV ozone retrieval: nitric acid trihydrate (NAT) and water ice polar stratospheric clouds (PSCs), and sulfuric acid aerosol layers formed in the aftermath of strong volcanic eruptions.

To estimate the magnitude of the errors introduced by stratospheric aerosol layers, simulation experiments were performed using the Dave radiative transfer model (multiple scattering with aerosols). Ozone and aerosol content profiles are prescribed, and the emerging UV radiation at the top of the atmosphere is computed. The obtained radiances are used to retrieve the ozone content as in the SBUV\TOMS algorithm. The difference between the retrieved and the input ozone is the error introduced by the intervening aerosol layer.

Errors introduced by PSCs

A detailed analysis of the PSC effects on the TOMS retrieval is presented in Torres et. al. (1992). PSCs effects were modeled for a high latitude ozone profile (275 D.U.) with peak concentration at 17 km for nadir view condition. Figure 1 illustrates the error introduced as a function of solar zenith angle for PSCs of different optical

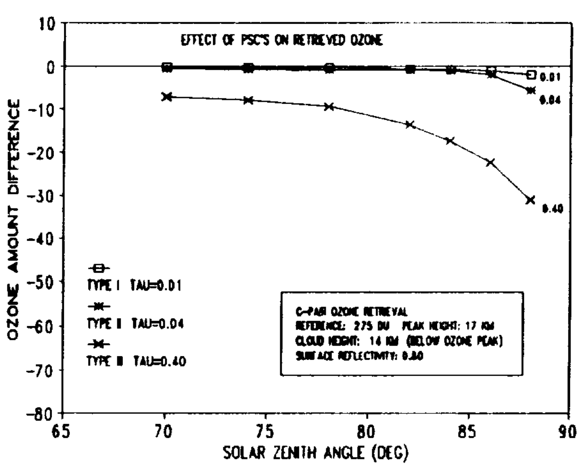

Figure 1. Error introduced in the TOMS ozone retrieval by PSCs below the ozone peak.

thicknesses (tau), when the cloud is situated at 14 km, below the level of maximum ozone. The largest error (30 DU) is produced by the thickest cloud at the highest solar zenith angle.

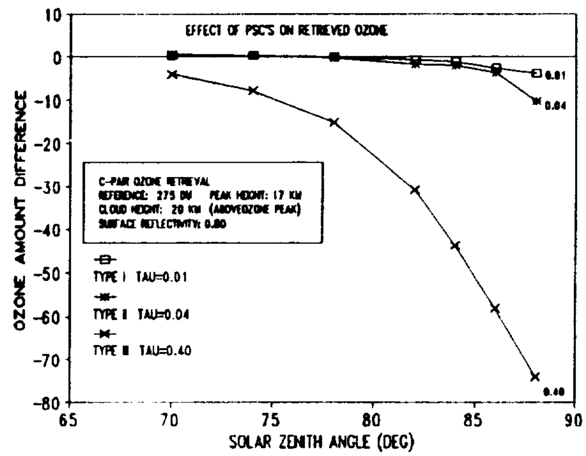

Figure 2. As in fig. 1 for PSCs above the level of maximum ozone concentration.

As shown in figure 2, much larger errors are produced by PSCs located above the ozone maximum (20 km). For the modeled conditions, a water ice PSC of optical depth 0.4 produces an ozone underestimation of 75 D.U. when the solar zenith angle is 88 degrees. Some of these ozone under-estimations appear in the TOMS maps as areas of reduced ozone, commonly referred to as ozone mini-holes. Not all of the TOMS retrieved ozone mini-holes, however, are artifacts created by PSCs. On occasions, mini-holes are largely real ozone depressions resulting from dynamical processes in the lower stratosphere (Rood et. al., 1992).

Volcanic Aerosol Effects

An across-scan bias characterized by peak ozone values near the ends of the scan and minimum values around the nadir, is commonly observed in the nimbus 7 TOMS ozone retrieval in the aftermath of strong volcanic eruptions as in the cases of El Chichon (1982) and Pinatubo (1991). The effect of the Pinatubo volcanic cloud was simulated using as input a 275 D.U. low latitude ozone profile (peak at 26 km). The aerosol cloud was set at 26 km consistent with lidar profiles over Mauna Loa (Defoor et, al 1992) and over Sao Jose Dos Campos, Brazil (Clemesha and Simonich, 1992). A lognormal particle size distribution was assumed. Figure 3 shows a comparison of the observed and the modeled across-scan bias for an aerosol cloud of optical thickness 0.2 (at 360 nm).

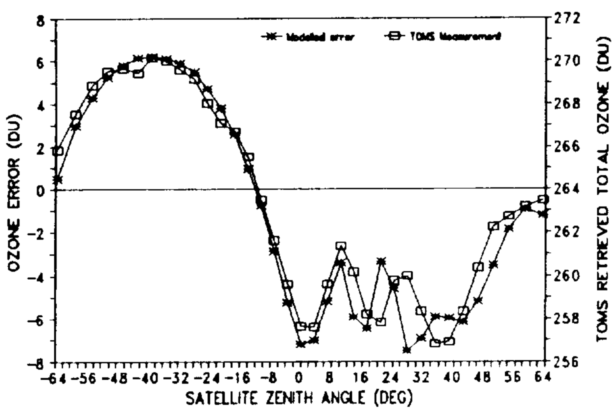

Figure 3. Observed and simulated Nimbus7 TOMS across-scan bias for an aerosol layer of optical thickness 0.2 at 26 km.

Best results are obtained for a mean radius of 0.4 microns and standard deviation of 1.5. The TOMS measurement is the average scan for a ten degree wide latitude belt centered at the equator during the 9/10-9/16 1991 time period. Absolute errors of 1% to 2% in the retrieved ozone are introduced by the aerosol cloud. The structure observed around the nadir position is related to the aerosol scattering phase function.

The Meteor3/TOMS instrument measured an anomalous effective reflectivity during the first few *months after its launch in* August 15 (Pan et. al., 1992) Simulation experiments indicate that a combination of high solar and satellite zenith angles and relative azimuth angle in the vicinity of 0 and 180 degrees when an optically thick volcanic

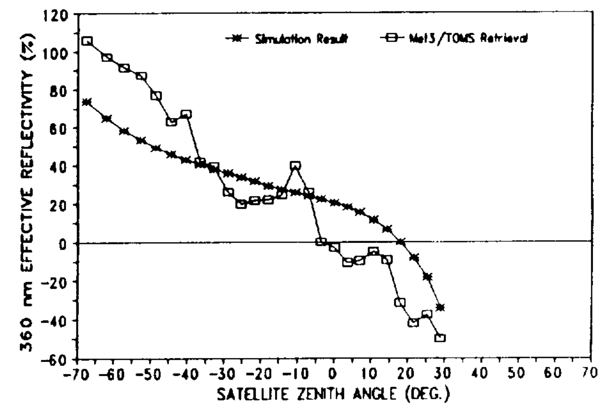

Figure 4. Observed and modeled Meteor3 TOMS across-scan reflectivity bias for a volcanic cloud of optical thickness 0.2 at 26 km.

cloud is present, produces an effective reflectivity field similar to the observed by the Meteor3/TOMS sensor, characterized by extremely high values at one end of the scan and extremely low, even negative, values at the other end. Figure 4 displays a comparison of the Meteor3 TOMS retrieved reflectivity for a scan near the equator on September 26 1991, to the results of the simulatedreflectivity when an optically thick aerosol layer interferes with the measurements. The magnitude of the error of the Meteor3/TOMS total ozone retrieval is being investigated.

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