A new NASA data product: Tropospheric and stratospheric column ozone in the tropics derived from TOMS measurements

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Short title: TROPOSPHERIC AND STRATOSPHERIC COLUMN OZONE FROM TOMS

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Abstract. Tropospheric column ozone (TCO) and stratospheric column ozone (SCO) gridded data in the tropics for 1979-present are now available from NASA Goddard Space Flight Center via either direct ftp, world-wide-web, or electronic mail. This note provides a brief overview of the method used to derive the data set including validation and adjustments.

1. Introduction

Until recently the primary method to derive TCO and SCO from satellite data was by combining Total Ozone Mapping Spectrometer (TOMS) and Stratospheric Aerosols and Gas Experiment (SAGE) ozone measurements (Fishman and Larsen, 1987). TCO was determined by subtracting SAGE stratospheric column ozone from TOMS total column ozone. By nature of the solar occultation method used for SAGE, measurements of SCO have limited spatial and temporal coverage. On average for any given month there are around only 1 to 2 measurement days within a given 5°-10° tropical latitude band. The limited coverage with SAGE prompts new approaches for deriving column ozone (Ziemke et al., 1998; Hudson and Thompson, 1998).

The objective of this publication is to provide information for the general community on obtaining a recently derived data base of tropical TCO and SCO from NASA Goddard Space Flight Center.

2. Description of the Data

Monthly averaged TCO and SCO data are derived in the tropics for January 1979-present using the convective cloud differential (CCD) method of Ziemke et al. (1998). These data represent version 2. Version 1 was an internal data product used in several trial studies (see references related to CCD data). Version 2 data are the same as version 1 but with an additional adjustment for aerosol contamination of TOMS measurements (discussed below). Horizontal resolution of the version 2 data is 5° × 5° with latitudinal range 15°S to 15°N (centered on 12.5°S, 7.5°S, ..., 12.5°N). This latitude range was chosen based on observed zonal homegeneity of SCO in the tropical lower latitudes. Missing CCD data include some latitude bands for a few months and a large gap of 38 consecutive months (May 1993 through June 1996) of missing data in which there were no suitable TOMS measurements available to apply the CCD technique.

In the CCD method total column ozone is derived from low reflectivity ($R < 0.2$) measurements and SCO follows from nearby column ozone measurements taken above the tops of very high tropopause-level clouds under conditions of high reflectivity ($R > 0.9$). First, above-cloud column amounts are calculated in the Pacific region where tropopause-level clouds are persistent. SCO is then derived for every 5° latitude band and averaged from 120°E eastward to 120°W using only lowest values of above-cloud column amounts (the lowest values coincide with tropopause-level cloud tops). These SCO values are then assumed to be independent of longitude in a given latitude band. This assumption is based on the zonal characteristics of tropical SCO as inferred from Upper Atmosphere Research Satellite (UARS) microwave limb sounder (MLS) and halogen occultation experiment (HALOE) ozone data. We refer the reader to Ziemke et al. (1998) for further details regarding the CCD method.

The CCD data contain useful information regarding tropical TCO and SCO variabilities from monthly to decadal time scales. The study by Chandra et al. (1999) identified a solar-cycle signal (~2-3 Dobson units (DU) peak-to-peak) in TCO using Nimbus 7 (N7) tropical CCD data. Another study by Chandra et al. (1998) identified an El Niño signal (~5-10 DU) in TCO that appeared coupled to dynamical effects involving the shift in convection from the western to the eastern Pacific during El Niño. Figure 1 shows an example of this pattern shift by comparing October TCO version 2 data for the years 1996, 1997, and 1998. Low values of TCO east of the dateline in October 1997 reflect the eastward shift in convection during El Niño. The high values over Indonesia in October 1997 are related to the suppressed convection and change in dynamical transport in the region. The induced dry conditions over Indonesia during El Niño produced a large amount of uncontrolled wildfires. Recovery of the El Niño is seen for October 1998.

3. Validation and Adjustments

The CCD TCO version 2 data presented in this note include a new aerosol adjustment (Torres and Bhartia, 1999) applied to the clear-sky low-reflectivity ($R < 0.2$) TOMS total column ozone measurements. Because absorbing aerosols in the troposphere absorb backscattered UV, the amount of column ozone measured by TOMS in the presence of aerosols is underestimated. The aerosol adjustment makes a correction for this error. Globally, the largest adjustments (~8-10 DU) are over north Africa from around April through September and are associated with dessert dust particles.

For the CCD method, measurements are restricted to latitudes 15° S to 15° N. Figure 2 shows a 1979-1999 climatology of the adjustment in the low-latitude tropics for the months of January, April, July, and October. The largest adjustments occur in July (and also August, not shown) in the south Atlantic with values up to 6-8 DU. The adjustments in the Atlantic are caused by smoke from Africa and Brazil. The large values north of 15° N seen over Africa in July are caused primarily from desert dust coming from the Sahel and Sahara regions (spanning latitudes around 10° N to 28° N). The Sahel is a large dry grassland area south of the Sahara and has been especially dry since 1968. The aerosol adjustment also indirectly corrects for sea glint errors (~1-3 DU) as can be seen in Figure 2 over ocean in January south of 10° S and in July north of 10° N. The sea glint effect is a function of solar declination and is caused by bright surface reflection. The version 2 CCD TCO data include full month-by-month aerosol adjustment at all grid points.

In the study by Ziemke and Chandra (1999) it was noted that there appeared to be an instrument offset between N7 and Earth Probe (EP) TOMS CCD TCO measurements. In that study a constant 5 DU was subtracted from EP TOMS CCD TCO data relative to N7. This was partly based on direct comparison with ozonesonde TCO measurements from several tropical stations. Subtraction of the constant 5 DU amount did not affect analysis of the variabilities present in the data. A unique property of the CCD method for deriving tropospheric column ozone is that it is the only current approach not affected by inter-instrument calibration errors (the CCD method differences only individual-instrument TOMS measurements of total column and SCO). The reason for the offset between N7 and EP instruments is not clear. Preliminary analysis indicates that it is related to a wavelength-dependent error in EP TOMS measurements which largely affects low-reflectivity scenes. The current version 2 data have no adjustments (such as the 5 DU constant amount noted). Users of version 2 data must be aware that there may be an offset of several DU between N7 and EP TOMS TCO measurements.

Validation of the CCD method is discussed by Ziemke et al. (1998) and further by Ziemke and Chandra (1999). These studies compared CCD data with ozonesonde and satellite measurements from Upper Atmosphere Research Satellite (UARS) microwave limb sounder (MLS) and halogen occultation experiment (HALOE). Figure 3 shows newer results from a comparison between version 2 CCD TCO and recent ozonesonde measurements from the Southern Hemisphere ADditional OZonesondes (SHADOZ) campaign (A. M. Thompson, personal communication, 1999). For this comparison, 5 DU was subtracted from all EP TCO measurements. For stations further south than 12.5°S (southern-most CCD gridded latitude) the comparisons still show similar seasonal cycles and similar magnitudes. Despite the two data sets being distintly different in both technique and spatial/temporal coverage, they show good qualitative agreement.

4. Obtaining the Data

The CCD TCO and SCO data may be obtained via world wide web (http://hyperion.gsfc.nasa.gov/Personnel/people/Ziemke,_Jerry/) or direct ftp over the internet:

ftp jwocky.gsfc.nasa.gov,

logon: anonymous,

passward: (your e-mail address),

cd pub/ccd.

Because these are small data sets, the data can also be obtained via electronic mail from the e-mail address and contact person listed below:

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Code 916, Chemistry and Dynamics Branch

Greenbelt, MD 20771

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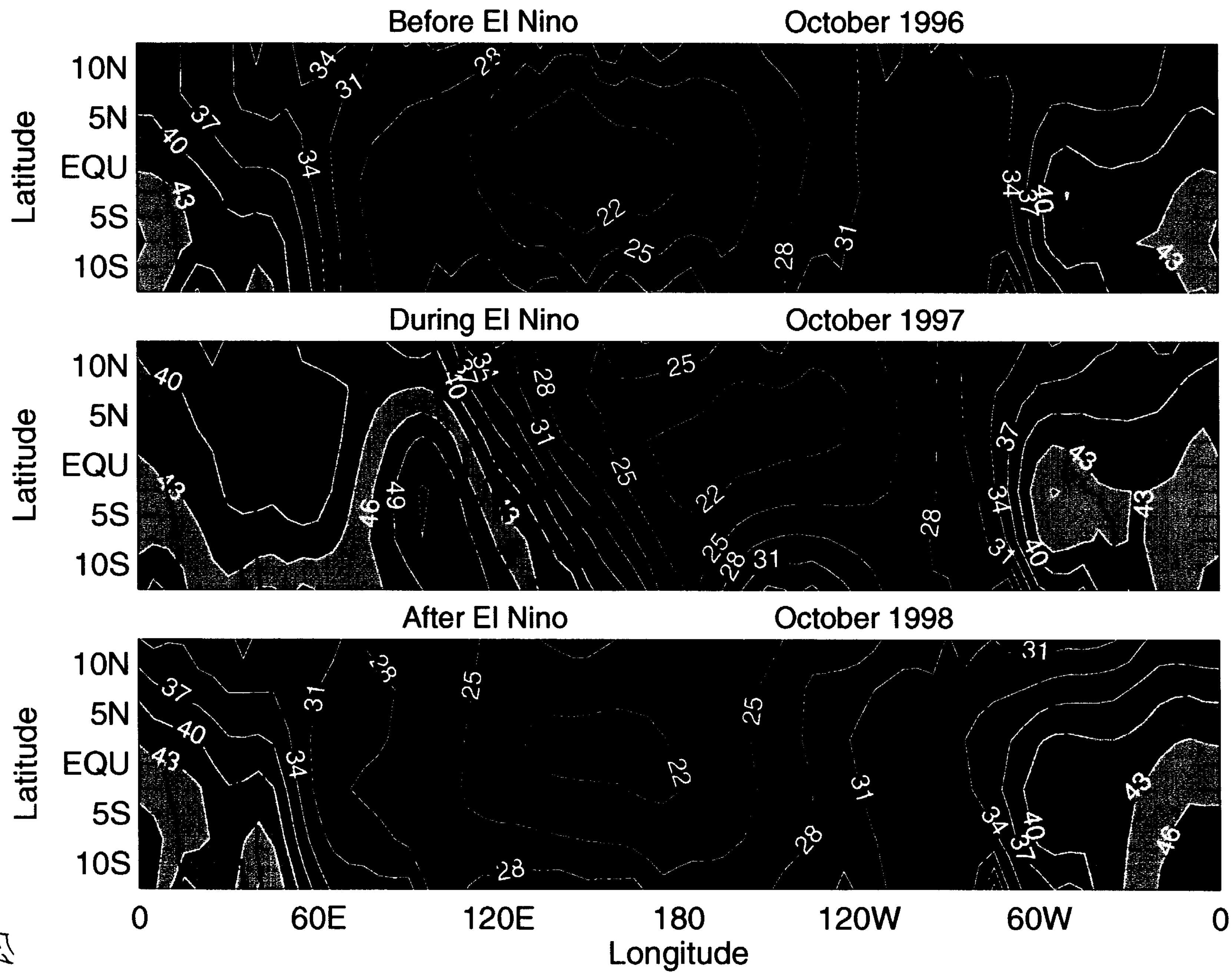
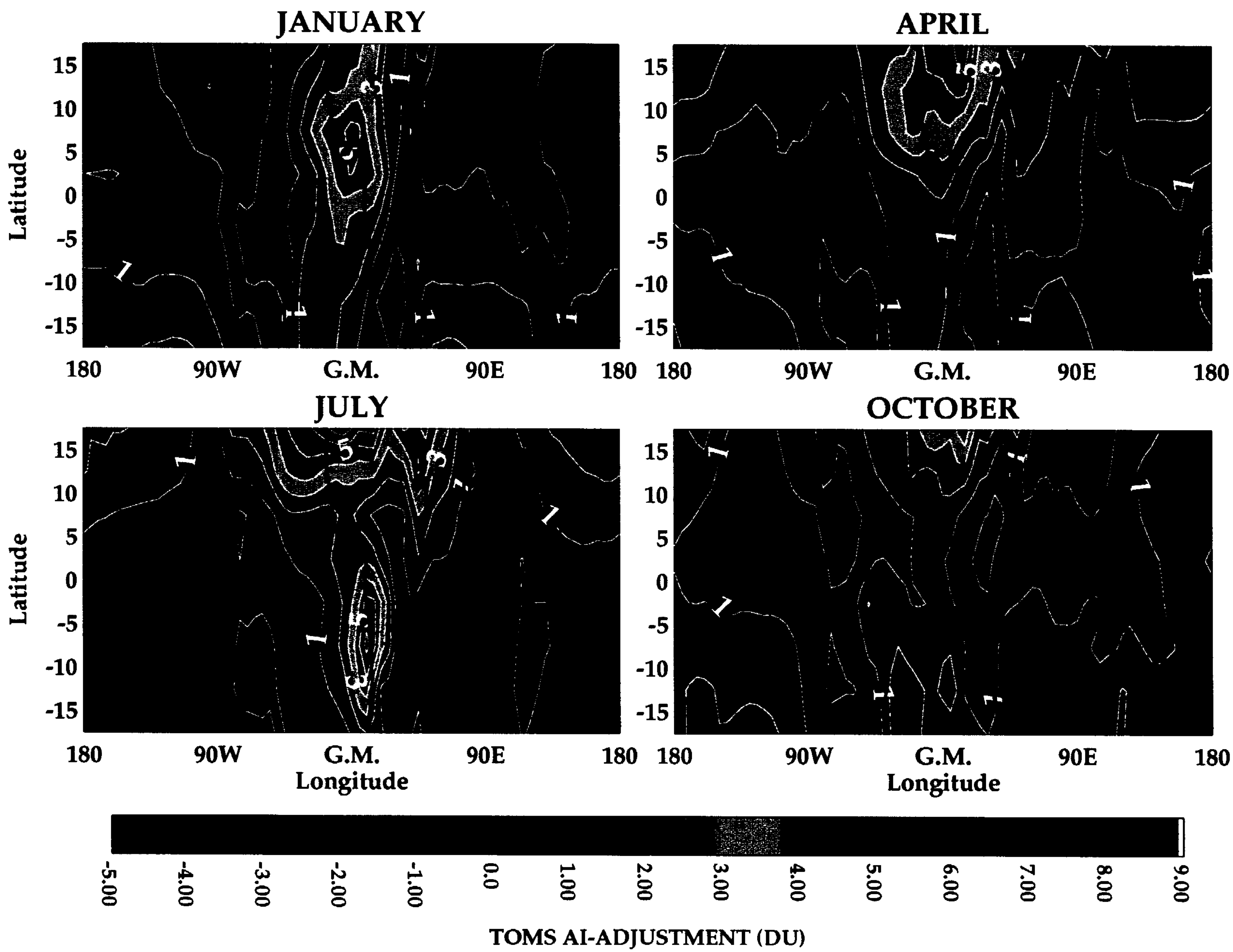
Figure 1. Tropospheric column ozone (in Dobson units) in the tropics derived from the CCD version 2 data which include month-by-month aerosol adjustment. (top) October 1996. (middle) October 1997. (bottom) October 1998. A constant 5 DU amount was subtracted from all EP TOMS TCO measurements to partially correct for potential instrument offset (see text).

Figure 2. Climatology (1979-1999) of the aerosol adjustment (in Dobson Units) applied to low-latitude TOMS clear-sky ($R < 0.2$) total column ozone measurements for January, April, July, and October months.

Figure 3. Time series comparisons between version 2 CCD TCO and ozonesonde measurements from six stations (indicated) from the recent SHADOZ campaign. A 5 DU amount was subtracted from EP TOMS TCO measurements as in Figure 1 (see text). Ozonesonde TCO data are not plotted for months having fewer than two profile measurements.

EFFECTS OF 1997-1998 EL NINO ON TROPOSPHERIC COLUMN OZONE (IN DOBSON UNITS)

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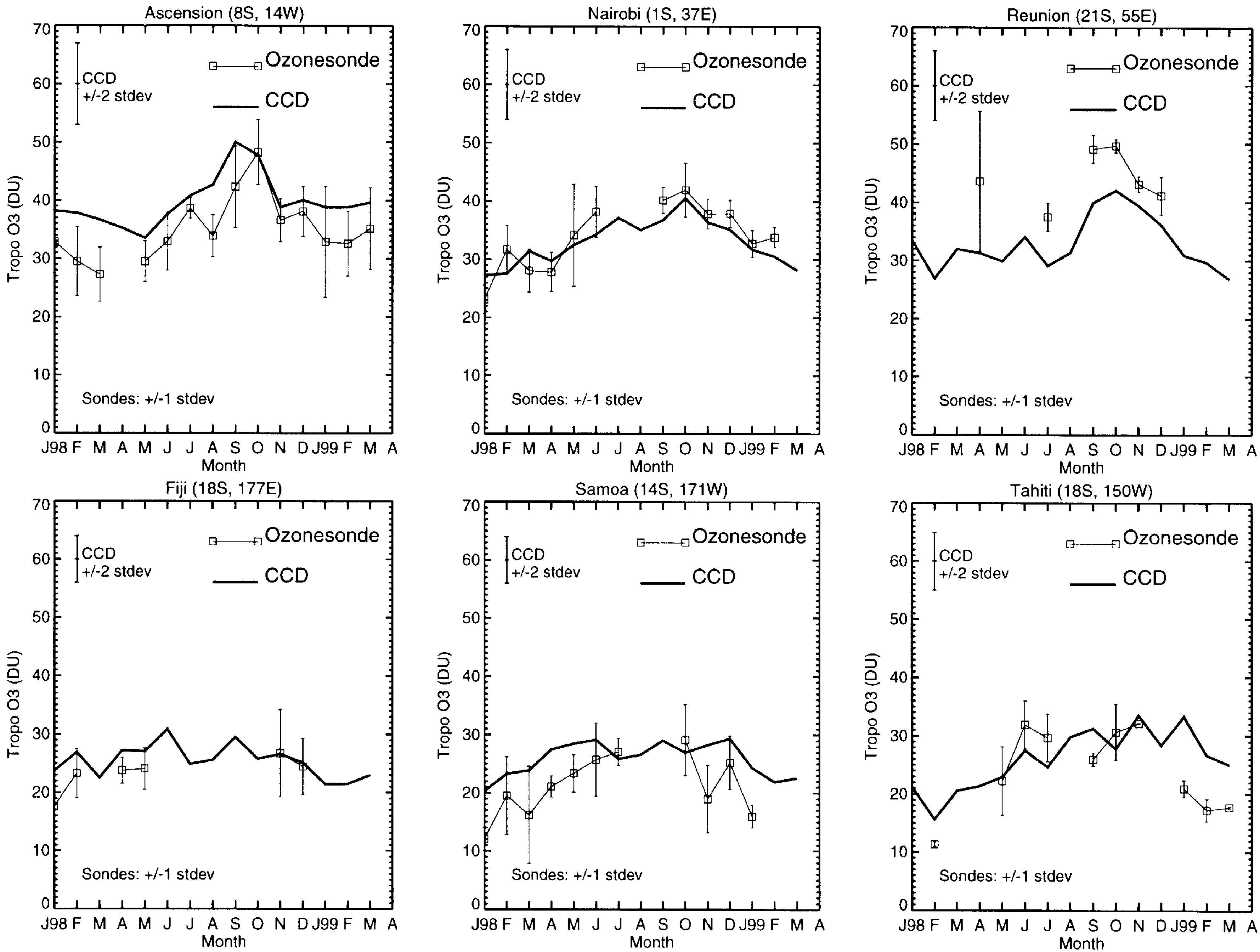
TOMS AI-ADJUSTMENT (DU)

F2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Fiji (18S, 177E)
Samoa (14S, 171W)
Tahiti (18S, 150W)
Ozonesonde
CCD
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Justification for J. R. Ziemke to be the first author

The study of the tropospheric ozone is a continuing project which has resulted in several publications. We work very closely and generally take turns in being the first author. I was the first author of the previous 2 papers. Dr. Ziemke has taken the lead in writing this paper and therefore should be the first author.

Sushil Chandra