

A Long-Term Merged Global Ozone Data Set

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Abstract - Using data from a series of space-based ozone measurement systems we are producing a consistent, calibrated ozone time series that can be used for trend analyses and other studies. To produce the total column ozone time series we use data from Total Ozone Mapping Spectrometer (TOMS) instruments on Nimbus 7 and Earth Probe, and data from the Ozone Monitoring Instrument (OMI) flying on the Aura spacecraft. Both total column ozone and the ozone vertical profile data are produced from the Solar Backscatter Ultraviolet (SBUV) instruments on Nimbus 7 and SBUV/2 instruments on a series of NOAA spacecraft. A global zonal mean merged ozone data time series covering the period from 1970-1972 and 1978-2010 has been produced for total column ozone. A similar profile data set has been constructed, but is still in preliminary form due to uncertainty in calibration adjustments as a function of latitude and altitude.

Keywords: ozone, climate gas, satellite remote sensing

1. INTRODUCTION

Stratospheric ozone is a fundamental climate component of our atmosphere. Ozone absorbs solar ultraviolet radiation in the stratosphere, leading to heating that modifies the dynamics of the stratosphere. The total column amount of ozone overhead determines the amount of ultraviolet light that is transmitted to the ground. Because of this, stratospheric ozone is a key climate parameter, and the abundance of ozone directly affects the Earth's biosphere. The release of ozone-depleting substances by human industrial activity has led to a decrease in ozone abundance that is well documented. The paradigm of the NASA Earth System "missions to measurements" program shifts the focus from individual instrument data sets to Earth system parameter records constructed from multiple instruments and measurement systems.

2. The Merged Ozone Data

Data from a series of instruments have been used to construct the Merged Ozone Data (MOD). The oldest data are from the Backscatter Ultraviolet (BUV) instrument which flew on NASA's Nimbus 4 mission. Data are available from 1970 through 1972, though with reduced coverage in 1972 because of reduced spacecraft power. Data from the Total Ozone Mapping Spectrometer (TOMS) and Solar Backscatter Ultraviolet (SBUV) instruments on Nimbus 7 provide global mapping of ozone from 1979 to 1993. Ozone mappers were subsequently launched on Earth Probe (TOMS) and on Aura (OMI). Meanwhile NOAA launched a series of SBUV/2 ozone profiling instruments on satellites beginning in 1984 and continuing to the present. The coverage periods of ozone instruments used to create the merged ozone data set are shown in Table 1.

Table 1. Ozone coverage by instrument.

ozone profilers	coverage
Nimbus 4 BUV	4/70 - 11/72
Nimbus 7 SBUV	11/78-6/90
NOAA 9 SBUV/2	02/85-02/98
NOAA 11 SBUV/2	12/88-3/01
NOAA 16 SBUV/2	10/00-6/10
NOAA 17 SBUV/2	7/02-6/10
ozone mappers	
Nimbus 7 TOMS	11/78-4/93
Meteor 3 TOMS	09/91-12/94
Earth Probe TOMS	8/96-12/05
Aura OMI	10/04-12/10

While both the ozone mapping instruments and the ozone profiling instruments can derive total column ozone, only the SBUV and SBUV/2 instruments can derive the ozone vertical distribution. The instruments and ozone retrieval algorithms for TOMS are described by McPeters et al., (1993) while the SBUV retrieval algorithm is described by Bhartia et al. (1996).

In order to create the merged ozone data, each time series was first averaged into a monthly average zonal mean. In order for a zonal mean to be considered valid it must be fully sampled; i.e. most of the measurements for the zone cannot be near the zone boundary. It is also required that data from at least two thirds of possible days are required for a valid monthly average.

Each individual instrument was calibrated as well as possible by the original instrument team, but comparisons with the ground-base network (Miller et al., 1996) show that there remain distinct instrument-to-instrument differences in the retrieved ozone. The philosophy for producing the merged data set is to take the individual data sets and combine them by making simple offsets in ozone based on overlap periods or comparison with other data sets (bootstrapping). The correction offset is determined as the average difference in the 50°S to 50°N zone. No time dependence is applied to an individual data set. (The only exception is the instrument on NOAA-9, which had a distinct shift in calibration after orbit precession through the terminator and is treated as though it were two distinct instruments.) All the monthly zonal means for an instrument are adjusted by that fixed offset. There is no latitude dependence

applied. All the data sets available for each month are then averaged together to produce the final merged ozone time series.

The MOD total column ozone data have been archived under NASA's MEaSUREs program (Making Earth System data records for Use in Research Environments). The original MOD data and detailed descriptions of how the data set was created are available from the link: http://acdb-ext.gsfc.nasa.gov/Data_services/merged/index.html

3. Total Column Ozone

In Figure 1 we show the long term change in global ozone in the merged ozone data. Here global ozone is defined as the area weighted average from 65°S to 65°N. The polar regions are excluded because these instruments are unable to measure ozone during polar night. In order to better show changes in ozone of a few percent, we deseasonalize the data by calculating the percent difference from the two year average of the chosen reference period - 1979-1980. The difference between the January 2005 global average, for example, and the average of January 1979 and January 1980 is plotted as a percent difference.

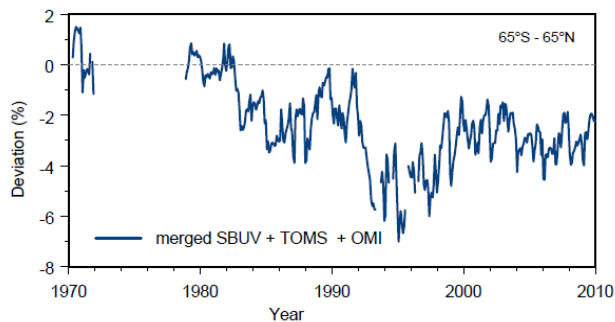


Figure 1. Globally averaged total column ozone shown as a percent difference from the 1979-1980 period.

There are only about two years of data beginning in 1970, but the level of ozone then is similar to that in 1979-1980. There was a decrease in ozone of about two percent in the 1980s. The maximum decrease of four to five percent was observed in the early 1990s following the eruption of Mt. Pinatubo. The level of ozone from 2000 to 2010 is about three percent lower than in 1980.

4. The Ozone Altitude Distribution

A procedure similar to that described to create the merged ozone data record for total column ozone was used to create a similar product for the ozone vertical distribution, but applying the procedure layer by layer. As quality control to check for possible drift errors, comparisons were made with SAGE and MLS profile data where available.

In Figure 2 we show the merged ozone record for the equatorial zone for the upper, middle, and lower stratosphere (blue curves). The upper red curve in each case then gives the percent difference from the 1979-1980 average.

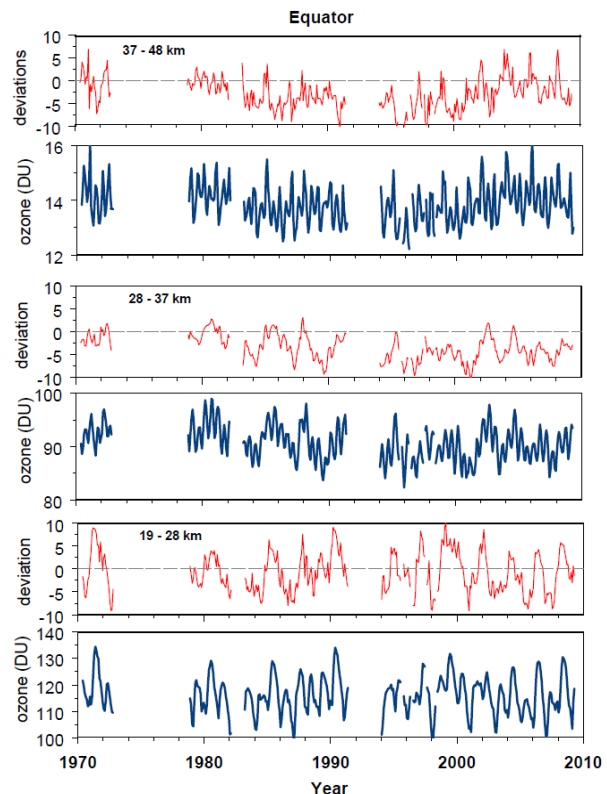


Figure 2. Equatorial ozone in the upper stratosphere, the middle stratosphere, and the lower stratosphere are shown in blue. The red curves give the percent difference from the 1979-1980 reference period.

In the upper stratosphere there are hints of a solar cycle variation superimposed onto the long term changes. The clearest decrease in ozone since 1980 is seen in the middle stratosphere, about 5%. This is the altitude region for which chemical models predict the strongest depletion due to CFCs. There is no clear decrease in the lower stratosphere. This is consistent with the observation that there has been no clearly observed decrease in total column ozone at the equator. While as shown in Figure 1 global ozone decreased by about 3%, this decrease was all at middle and high latitudes.

5. Conclusions: Beyond Merged Ozone

While the MOD data sets just described are probably the best that can be done with the existing data sets, the more advanced approach is to go back to the original data sets and correct the measured radiances in order to make the different instruments consistent. Under the MEaSUREs program, this is being done for the complete series of SBUV(2), TOMS and OMI instruments.

In what will be designated the version 8.6 processing, the principle change will be that new, more accurate ozone cross sections will be used, the Brion, Daumont, and Malicet cross sections (Daumont et al., 1992) rather than the Bass and Paur (1984) cross sections. Also a cloud height climatology based on results from the Aura OMI mission will be used. But the important change for long term trend analysis is that the corrections will be made at the radiance level to make the different instruments consistent. This is important because the

effect of a small calibration error can vary considerably depending on latitude, solar zenith angle, ozone amount, and reflectivity. Only a full re-processing can account for these effects. The reprocessing required in the switch to new ozone cross sections offers the opportunity to also create a consistent set of ozone data records.

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