Validation of the MERRA-2 Ozone Product

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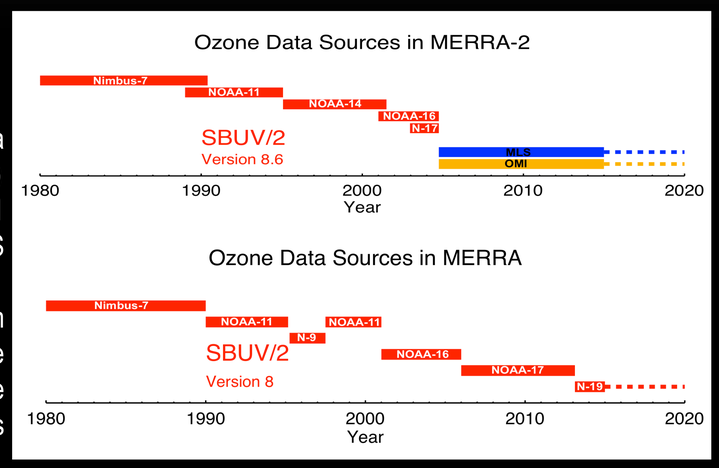
Introduction

The treatment of ozone in NASA's Modern Era Retrospective Analysis for Research and Applications version 2 (MERRA-2) constitutes a significant advance over the original MERRA reanalysis. The most recent version of Solar Backscatter Ultraviolet Radiometers (SBUV) partial column data is used between 1980 and 2004 and then replaced by stratospheric profiles from the Microwave Limb Sounder (MLS) and total ozone observations from the Ozone Monitoring Instrument (OMI). The latter data are assimilated along with the averaging kernels in order to account for the non-uniform sensitivity of OMI measurements to different layers of the atmosphere. The assumed background errors are state-dependent, leading to more realistic analysis increments across the boundaries separating different air masses, in particular in the upper troposphere – lower stratosphere (UTLS).

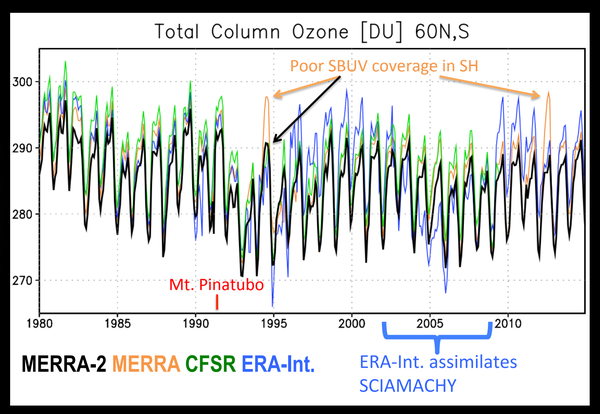
The ozone observing system

- MERRA: SBUV Version 8 at a degraded vertical resolution (12 layers)
- MERRA-2: SBUV Version 8.6 at 21 layers until September 2004 and MLS +OMI afterwards

While the change in the observing system leads to a (single) discontinuity, the decision to switch to Aura data reflects the policy of using the best observations available.



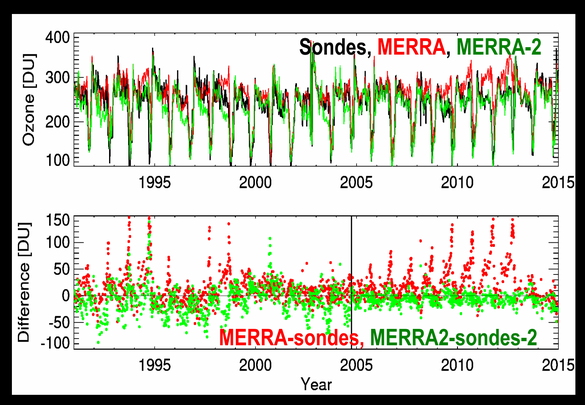
Total ozone column



Time series of the 60°S-60°N total ozone from MERRA, MERRA-2, ERA-Interim and CFSR. All assimilate SBUV ozone. In addition, ERA-Int. concurrently uses multiple other data sources and MERRA-2 assimilates MLS/OMI in place of SBUV in the latter period. These features are discernible in all 4 reanalyses:

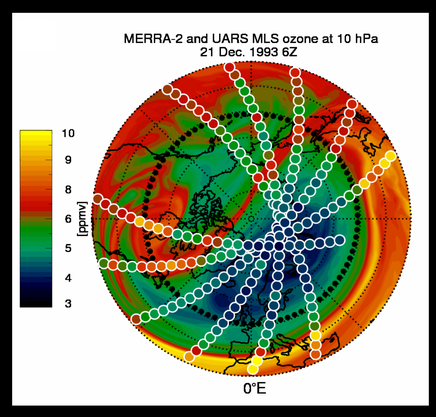
- Annual cycle
- Downward trend in the 1980s and 1990s
- Minimum following the eruption of Mt. Pinatubo
- Modulation consistent with the solar cycle signature

	1991-2004	2005-2014
Sondes-Analysis difference	14.03 DU -6.72 DU	26.56 DU -6.77
Correlation	0.87 0.88	0.80 0.98
Standard deviation of the sonde-analysis differences	30.19 DU 28.23 DU	36.00 11.10



Total ozone derived from South Pole ozonesonde measurements, MERRA, and MERRA-2. The SBUV and MLS/OMI periods are separated. The large excursions arise from limited SBUV coverage.

Comparisons with UARS MLS



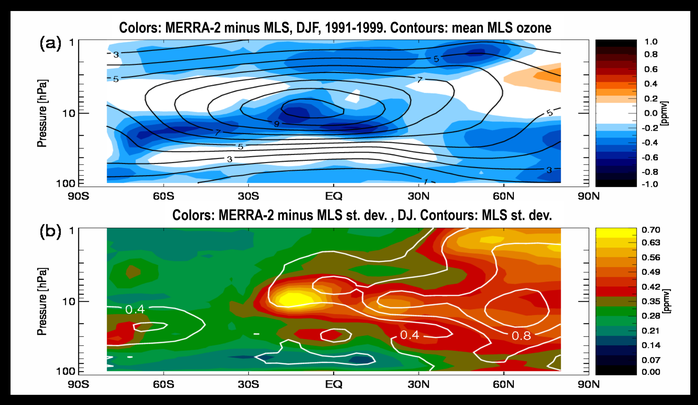
The Microwave Limb Sounder was flown on the UARS satellite. Ozone profile data are available throughout most of the 1990s but the spatial and temporal coverage is spotty.

The plot shows a cross-pole ozone transport event in MERRA-2 at 10 hPa on 21 December 1993 and UARS MLS retrieved ozone mixing ratios. MLS samples the large-scale morphology of the ozone field as well as thin high-ozone filaments in excellent agreement with MERRA-2.

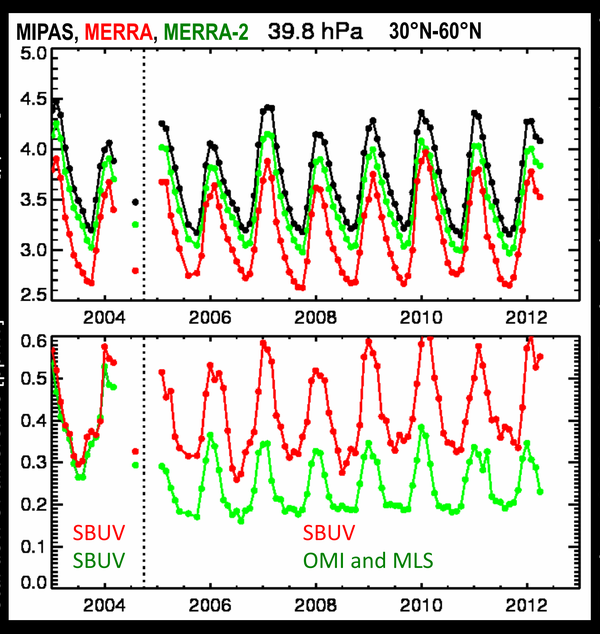
Note that this is in the 'SBUV period' in the reanalysis.

The zonal mean MERRA-2 December-February (DJF) ozone is lower than MLS in most of the stratosphere.

The standard deviation of the differences in DJF is ~10 % on average with larger values in the regions of high ozone variability and up to ~15 % in the upper stratosphere. The estimated MLS precision is between 3 % and 8 % in the stratosphere with 10 % - 20% accuracy.



Comparisons with MIPAS



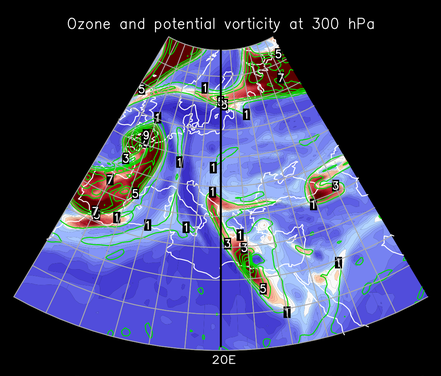
The Michelson Interferometer for Passive Atmospheric Sounding was flown on Envisat, 2002-2012. The top plot shows the 30°N-60°N zonal mean ozone from MIPAS, MERRA and MERRA-2 interpolated to the 39.8 hPa pressure level. Both reanalysis are biased low with respect to MIPAS but the bias is smaller in MERRA-2 at that level.

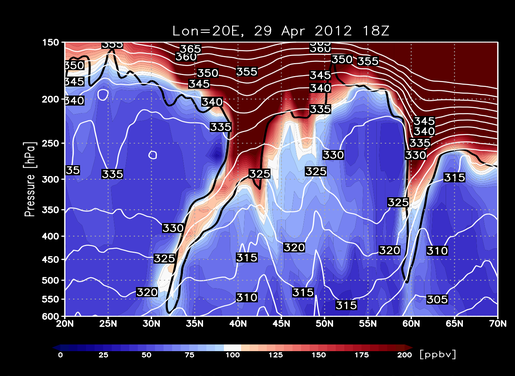
Time series of the standard deviation of the reanalyses minus MIPAS differences (bottom plot):

- ~10 %-13 % st. dev. (w.r.t. MIPAS average) for MERRA
- The same for MERRA-2 before MLS was assimilated
- In the MLS era MERRA-2 minus MIPAS st. dev. drop significantly

The use of MLS modifies stratospheric profiles in MERRA-2

UTLS ozone: a stratospheric intrusion





This transect of ozone, potential vorticity and potential temperature fields, from MERRA-2 shows a stratospheric intrusion event over Europe (20°E) on 29 April 2012. In this event, air from the stratosphere with high ozone mixing ratios (represented in red) is transported into the lower troposphere, where the ambient mixing ratios are lower (represented in blue). The transport from the stratosphere is also highlighted by the dynamical tropopause (the 2-potential-vorticity-unit contour, shown in black) being distorted, with the white isopleths showing the potential temperature. High quality of the UTLS ozone structures in MERRA-2 is confirmed by ozonesonde comparisons (not shown).

Features of MERRA-2 ozone relevant to science

- Realistic total ozone (small low bias exists)
- Temporal continuity; a single jump when Aura data are introduced
- Good representation of transport – consistency with dynamical fields
- Improved variability in the lower stratosphere in the Aura period compared to MERRA
- Improved representation of the southern polar ozone

Comprehensive validation results will be published

SPARC Reanalysis Intercomparison Project

2015 S-RIP/SPARC Data Assimilation Workshop, Paris