The Stratospheric Water and Ozone Satellite Homogenized data set (SWOOSH): A long-term database for climate studies

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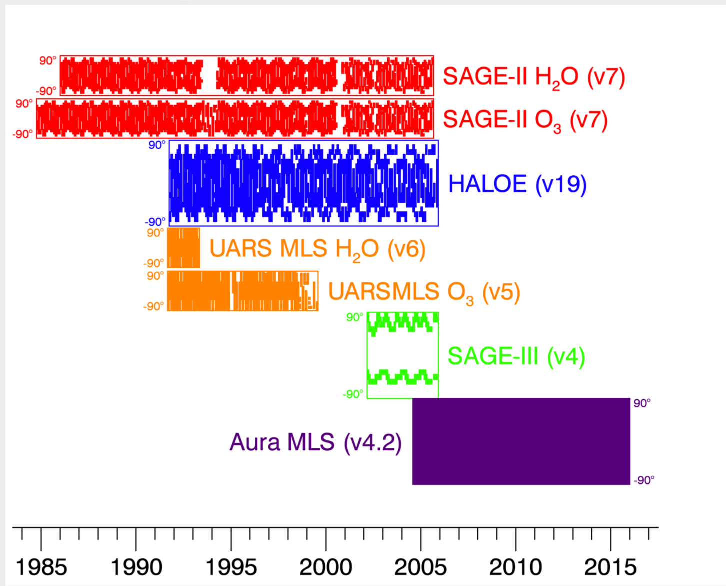
Introduction

Vertical profiles of ozone from the upper troposphere to stratosphere have been retrieved from a number of limb sounding and solar occultation satellite instruments since the 1980's. In particular, measurements from the SAGE instruments, UARS MLS, UARS HALOE, and most recently Aura MLS, have provided overlapping data since 1984. In order to quantify interannual- to decadal-scale variability in ozone, it is necessary to have a uniform and homogenous record over the period of interest. With this in mind, we merged the aforementioned satellite measurements to create the Stratospheric Water and Ozone Satellite Homogenized (SWOOSH) data set, which contains vertically resolved zonal-mean (2.5°) monthly-mean water vapor and ozone concentration at levels covering the stratosphere.

This poster describes the process of merging the satellite data sets, which involves adjusting the data to a reference measurement using offsets calculated from coincident observations taken during instrument overlap periods. Along with the primary SWOOSH product (i.e., merged monthly-mean ozone and water vapor), a large amount of additional information is stored in SWOOSH, including the individual satellite records (both unadjusted and adjusted versions), uncertainty estimates, and other statistics such as the number of measurements and standard deviations. This poster presents examples of the types of information stored in SWOOSH.

Constructing SWOOSH

Input data



For each profile

- Quality screening w/ published recommendations
- Calculate equivalent lat as a fxn of height from MERRA reanalysis
- Put on MLS vertical grid (12 levels decade^{-1}, 316 – 1 hPa)

Adjust data to match reference satellite

- For each satellite, profiles are matched with the reference instrument (see box to right) during instrument overlap time period
  - Match criteria = closest eq. lat for profile within 1 day, 1000 km
- Matched pairs are used to compute the mean difference from the reference as a fxn of (lat, pressure)
- These mean differences are "offsets" that are use to adjust the non-reference data so that it is in agreement with the reference satellite (see box lower left)

Grid data

Time resolution: Monthly-mean (1984 - 2016)
Vertical resolutions: 31 pressure (316-1 hPa), 21 isentropic (300-650 K)
Horizontal resolutions: 2.5°, 5°, and 10° zonal-mean, 30° lon x 10° lat, 20°x5°
- Both Regular and eq. lat grids for zonal-mean product

Information stored (each gridbox):
- Mean value, uncertainty, # data points, standard deviation
- Each satellite (both uncorrected, and corrected)
- Combined = mean of individual satellite means (N-weighted)
- Combined, w/ filling for missing data

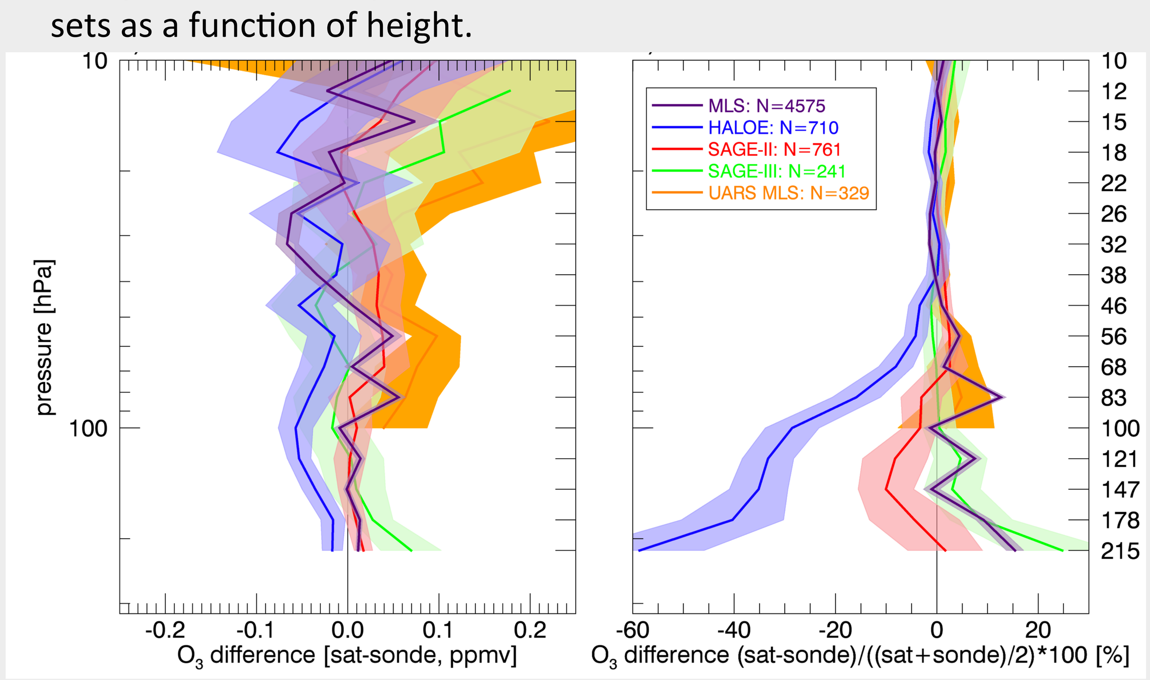
Choosing a reference

- Rather than simply averaging a set of data to create a merged record, in SWOOSH the data from each satellite are adjusted to match the "most accurate" satellite.
- For ozone, the "most accurate" satellite is determined through comparison with ozonesonde matches.

Ozonesonde stations using in comparison

Station	Latitude	Longitude	# Soundings	Period
Alert (CAN)	82.5	-62.3	1028	1987-2011
Resolute (CAN)	74.7	-95.0	885	1978-2011
Uccle (BEL)	50.8	4.4	2299	1996-2013
Boulder (USA)	40.0	-105.3	698	1991-2015
Wallops (USA)	37.9	-75.5	1779	1970-2013
Hilo (USA)	19.4	-155.0	1717	1982-2013
Natal (BRA)	-5.5	-35.3	661	1979-2013
Samoa (USA)	-14.2	-170.6	992	1995-2013
Lauder (NZL)	-45.0	169.7	1275	1986-2008
Davis (ATA)	-68.6	78.0	270	2003-2013
Neumeyer (ATA)	-70.7	-8.3	1553	1992-2015

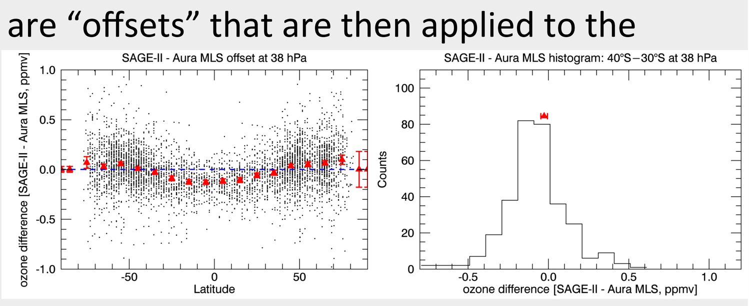
- The plot below compares the matched ozonesonde and satellite data sets as a function of height.



- SAGE-II is used as the reference measurement in SWOOSH, as it provides consistent agreement with ozonesondes and a long record of overlap with other satellites.
- Aura MLS is used as the reference for water vapor.

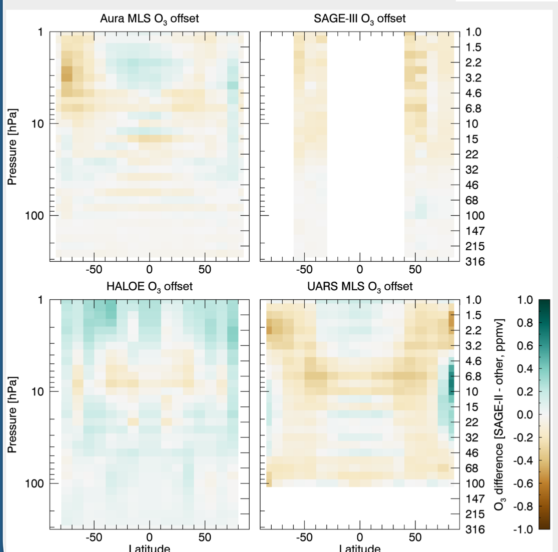
The H in SWOOSH

- Satellite-satellite profile matches between the reference and non-reference are used to compute mean differences in 10° lat bins at each level.
- These mean differences are "offsets" that are then applied to the non-reference data



(Above) Example of O_3 offset adjustment for Aura MLS at 38 hPa. (Above, left) Matched Aura MLS/SAGE-II pairs (dots), the 10° latitude binned means (red filled triangles) with error bars showing the offset uncertainties (95% confidence interval). The mean (over all latitudes) is shown as a horizontal blue dashed line. (Above, right) The histogram of SAGE-II – Aura MLS differences at 38 hPa for the 40°S - 30°S latitude bin. The offset uncertainty for this bin is shown as a horizontal red bar.

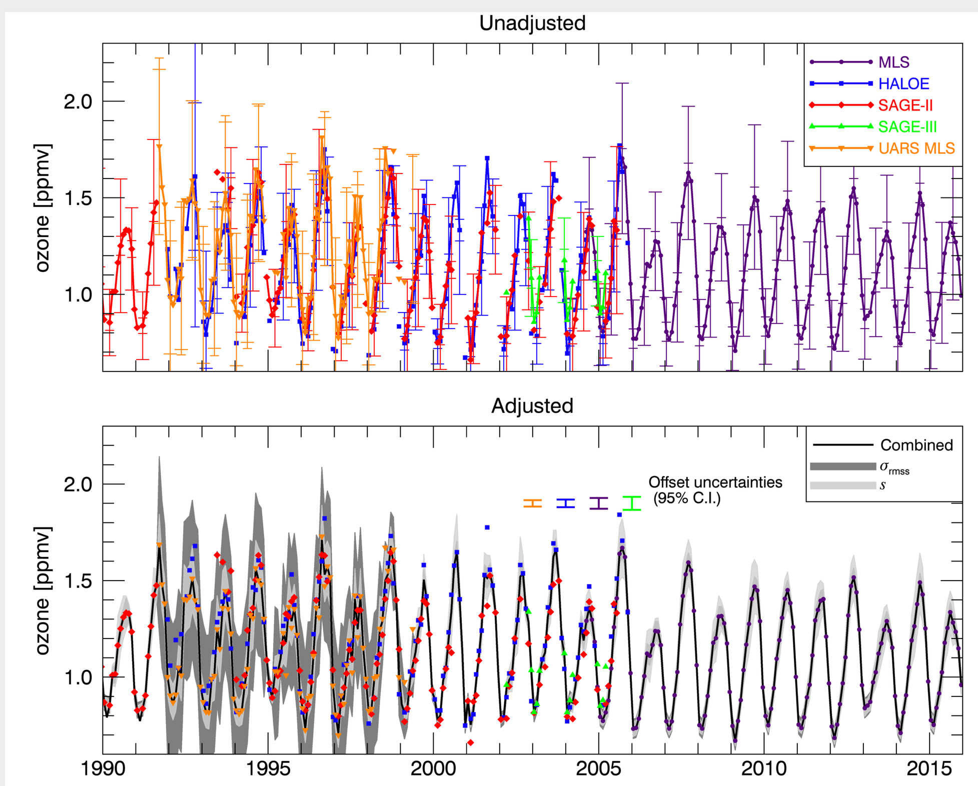
- The plot to the left shows the ozone offsets as a function of height/lat



(Above) O_3 offsets relative to SAGE-II for satellite data sets used in SWOOSH. O_3 offsets are defined as the mean of SAGE-II minus the given dataset. Offsets are computed on the SWOOSH vertical grid in 10° latitude bands.

Merging/Uncertainty example

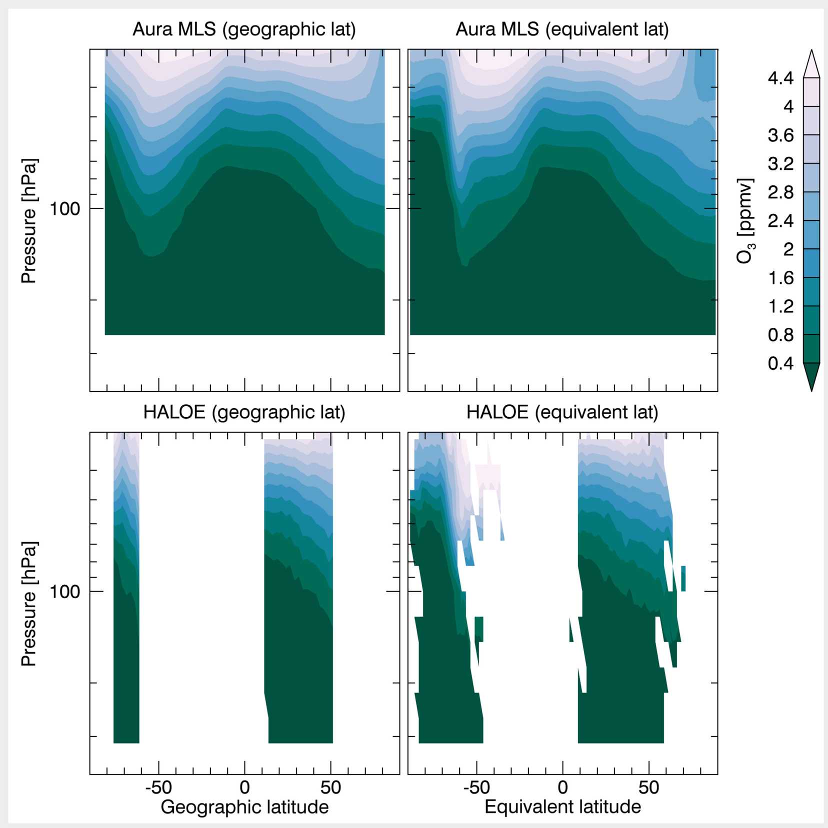
- SWOOSH has individual satellite data and a merged product
- Uncertainties and standard deviations are stored for both



(Top) The uncorrected ozone timeseries in the 30° - 40°S latitude band at 68 hPa, along with the source standard deviation (s_k, wide error bars) and root-mean-sum-of-squares (RMSS) uncertainty values (narrow error bars). (Bottom) The offset-corrected source measurements along with the combined ("anomaly filled") product. The lighter and darker gray shaded regions show the combined RMSS uncertainty (, narrow error bars) and the combined standard deviation (*s*), respectively. The vertical errorbars in the lower panel show the 95% confidence interval of the offset uncertainties for the 30° - 40°S latitude band at 68 hPa.

Example (equivalent lat grid)

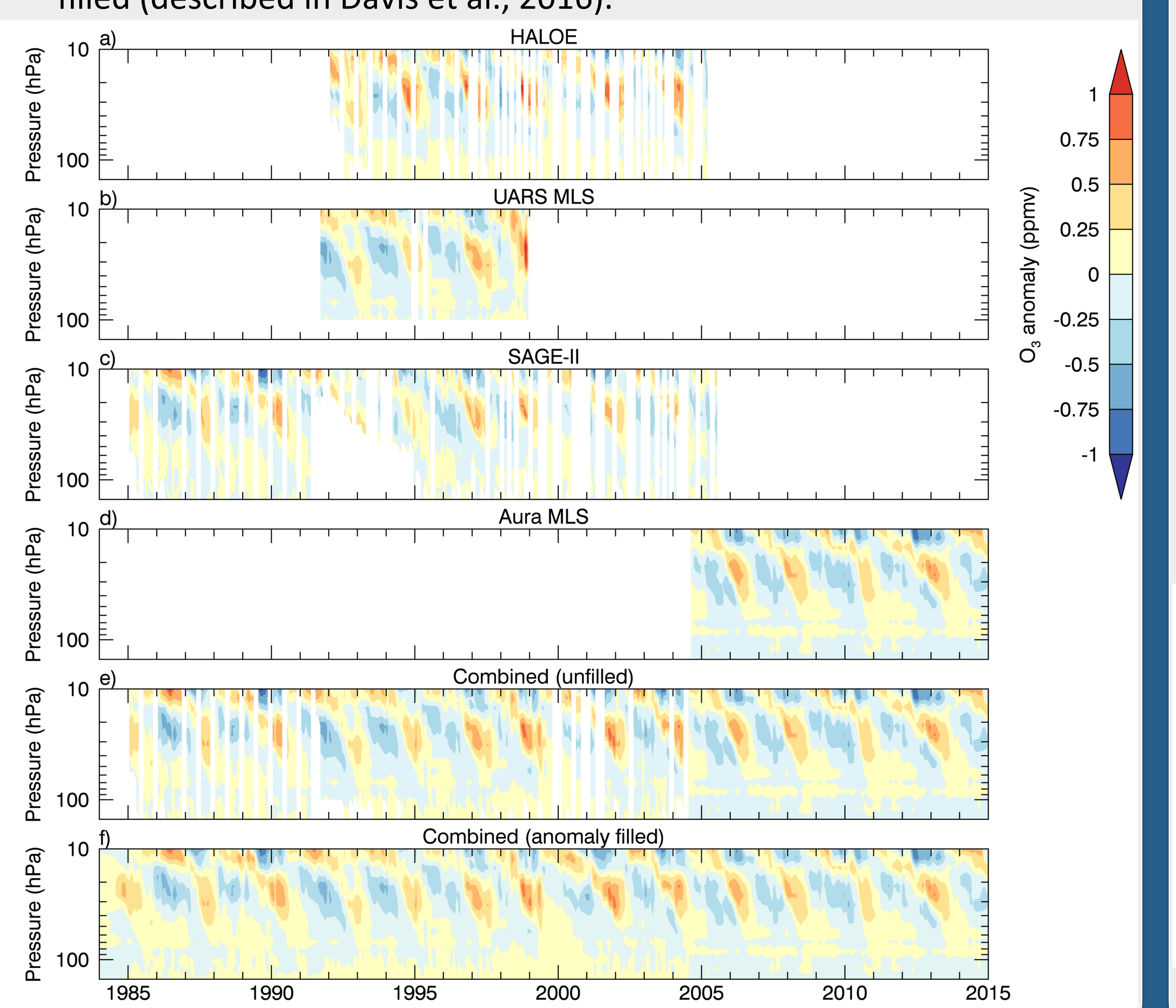
- In addition to the normal geographical latitude grid, SWOOSH data are also gridded on an equivalent latitude grid, computed separately at each level using MERRA PV.



Ozone height vs. latitude plots on geographic latitude (left column) and equivalent latitude grids (right column), for October 2004. Increased data coverage and increased depth of Antarctic ozone depletion is apparent in the equivalent latitude gridded data.

Example (QBO & gap filling)

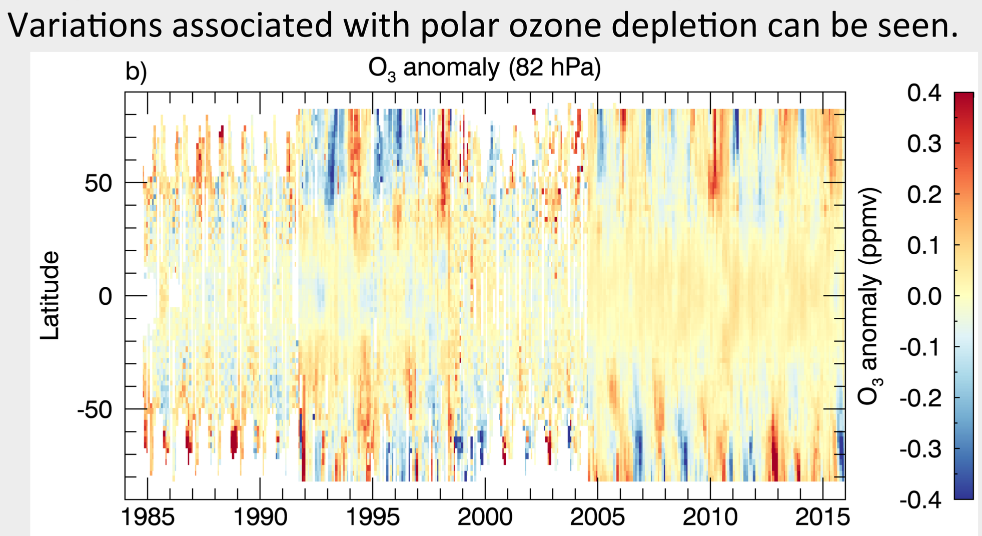
- This example illustrates the utility of having a combined record for studying phenomena like the quasi-biennial oscillation (QBO).
- Also shown is the "anomaly-filled" product where data gaps have been filled (described in Davis et al., 2016).



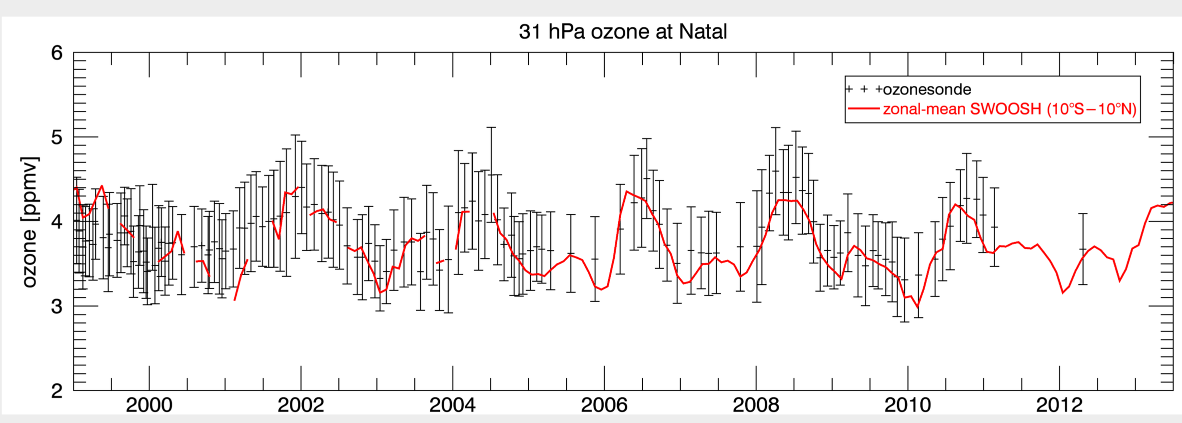
The tropical average (10°S – 10°N) ozone concentration anomaly as a function of height and time for each satellite data set in SWOOSH (a-d), as well as the two combined products (e-f).

Example (variability)

- The plot below shows interannual variability at 82 hPa.
- Variations associated with polar ozone depletion can be seen.



- Below is a comparison with the Natal, Brazil (5°S) ozonesonde record
- QBO-related variability is well captured by SWOOSH



Plotted above are the Natal, Brazil (5°S) ozonesonde record points from individual flights (black + with error bars). Error bars are the 95% confidence interval for the mean within a 2 km layer average centered on 31 hPa. The SWOOSH zonal mean record averaged from 10°S – 10*N is also shown (red line).

References

SWOOSH overview paper:

Davis, S. M., Rosenlof, K. H., Hassler, B., Hurst, D. F., Read, W. G., Vömel, H., Selkirk, H., Fujiwara, M., and Damadeo, R.: The Stratospheric Water and Ozone Satellite Homogenized (SWOOSH) database: A long-term database for climate studies, Earth Syst. Sci. Data Discuss., doi:10.5194/essd-2016-16, in review, 2016.

SWOOSH ozone evaluations:

Tummon, F., et al. (2015), Intercomparison of vertically resolved merged satellite ozone data sets: interannual variability and long-term trends, *Atmospheric Chemistry and Physics*, *15*(6), 3021-3043.

Hubert, D., et al. (2015), Ground-based assessment of the bias and long-term stability of fourteen limb and occultation ozone profile data records, *Atmos. Meas. Tech. Discuss.*, *2015*, 6661-6757.

Harris, N. R. P., et al. (2015), Past changes in the vertical distribution of ozone - Part 3: Analysis and interpretation of trends, *Atmospheric Chemistry and Physics*, *15*(17), 9965-9982.

Get SWOOSH

Data available at http://www.esrl.noaa.gov/csd/swoosh/

Conclusions

- SWOOSH provides a vertically-resolved homogenized and merged record of satellite stratospheric ozone and water vapor extending from the 1980's to present.
- SWOOSH should be useful for assessing interannual and longer-term variability and trends in ozone.
- SWOOSH will continue to be updated with Aura MLS data.
- Future work will investigate addition of OMPS-Limb data to SWOOSH as an eventual MLS replacement.