Long term stratospheric ozone record obtained by merging ozone profiles from different satellites

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1. Motivation and goals

It's important to have a homogeneous long term ozone record to monitor and further improve our understanding and attribution of long term changes in vertical distribution of ozone. Randel and Wu (2007) derived a stratospheric ozone profile data between 1979 and 2005 by using Stratospheric Aerosol and Gas Experiment (SAGE-I and II) measurements supplemented by ozonesonde data from Syowa (69^{0}S) and Resolute (75^{0}N) for polar regions. Hassler et al. (2008) generated a global database for O3 and other trace gases by using measurements from satellite instruments (e.g. SAGE-I/II, HALOE, POAM-II/III) and ozonesondes at over 100 stations spanning from 82ON to 90OS. By combining data from multiple sources, the database from Hassler et al. (2008) has much better temporal and spatial coverage than Randel and Wu (2007). Inhomogeneities (e.g. systematic offsets and/or drifts) between the different data sources, however, were not removed from their version 1 database.

As part of the NASA MEaSUREs GOZCARDS project, the main objective of this study is to establish a global stratospheric ozone record (or Earth System Data Record) from 1979 to present by merging multiple satellite measurements. This would extend the study of Randel and Wu (2007) with better temporal and spatial coverage. Unlike Hassler et al. (2008), offsets between different measurements will also be adjusted before merging those data to create a homogeneous long term ozone record.

2. Data and approach

Ozone measurements from SAGE-I/II/III, HALOE, UARS MLS, Aura MLS and ACE-FTS (see figure 1) are used to establish monthly zonal mean records from late 1978 to present. The ozone monthly means from each instrument were first analyzed individually. The best estimates of long term ozone record were then generated by combining results of all satellite measurements after adjusting their values to a common reference level. Procedures for processing and combing the ozone data are described following.

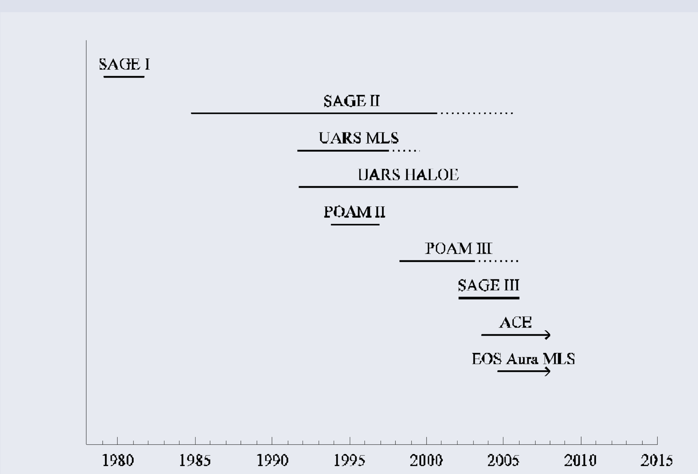

Figure 1 Timeline of satellite missions and instruments being considered for the GOZCARDS project and the creation of ozone and other stratospheric composition Earth Science Data Record (ESDR).

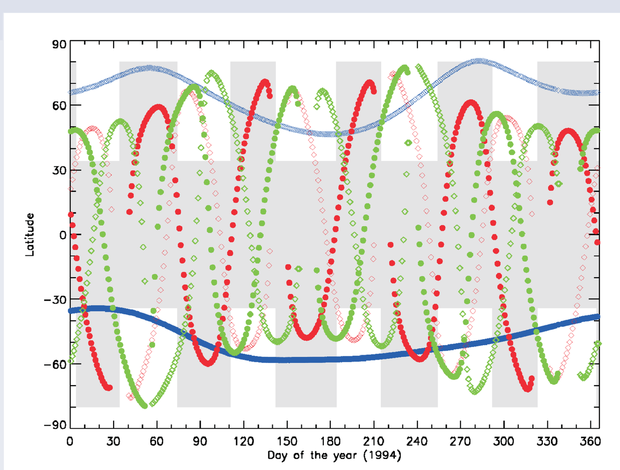

Figure 2 Yearly latitudinal coverage for some of satellites used in this study. Shading shows the UARS MLS coverage for 1994, red and green dots represent the (1994) SAGE II and HALOE occultation locations, respectively, while blue symbols in polar regions represent the SAGE III occultation locations for 2003. There is clearly a large variation in the available coverages.

Date used in this study
SAGE-I (V5.9) with empirical altitude correction (Wang et al., 1996)
SAGE-II (V6.2), HALOE (V19)
UARS MLS (V5), POAM-III (V4)
SAGE-III (V3.0), AURA MLS (V2.2)
ACE-FTS (V2.2 Update)

2.1 Creation of zonal averages

Individual datasets from various instruments have been used to create monthly zonal averages in volume mixing ratio (VMR) and in 10° latitude bins and UARS pressure level (e.g. figure 5). Zonal averages of O3 number density at latitude and geometric altitude will be available later.

2.2 Comparison of zonal means

To quantify offsets we choose SAGE-I/II ozone data as reference standard, since it has the longest time period of measurements and the self-calibrating of solar occultation technique making it not affected by long term instrument drift.

2. Continued

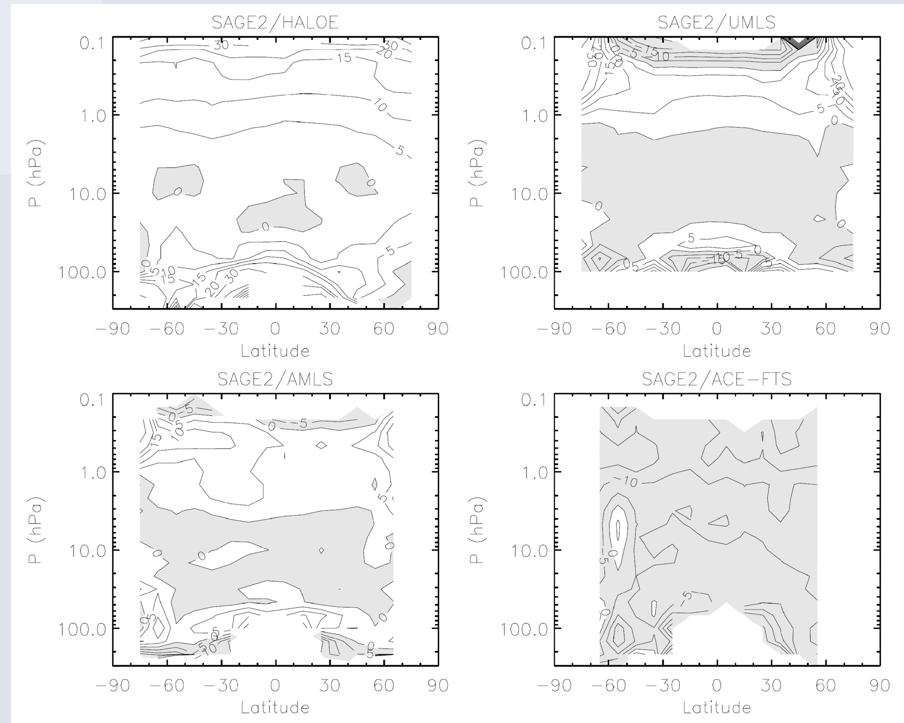

Figure 3 . Average offsets (percent) between various monthly zonal averages for O3, during relevant time periods of overlap: top left panel is for SAGE II versus HALOE, top right panel for SAGE II versus UARS MLS, bottom left panel for SAGE II versus Aura MLS, and bottom right panel for SAGE II versus ACE-FTS. Offsets here represent average percent differences between ozone from SAGE II and other sensors, calculated as 100x((SAGE II value - other sensor value)/SAGE II value). Negative values are in grey.

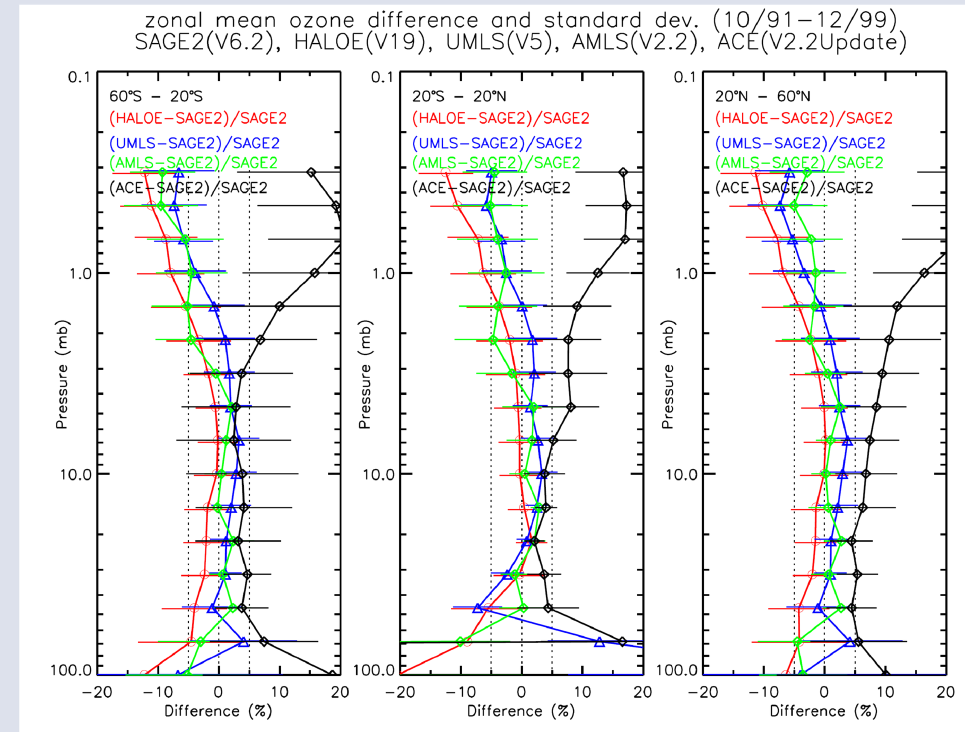

Figure 4 Zonal mean ozone differences and standard deviation between SAGE-II and HALOE (red), **UARS MLS** (blue), **Aura MLS** (green) and **ACE-FTS** (black) expressed as percentage in the form of (other -sage2)/sage2*100. Data were grouped in three latitude bands from 60^{0}S to 20^{0}S, 20^{0}S to 20^{0}N, and 20^{0}N to 60^{0}N.

Since there is no strong latitudinal structure in those offsets, zonal mean differences can also be shown on 3 wider latitude bins as a function of altitude (fig. 4). The agreement between SAGE-II and HALOE, UARS MLS, Aura MLS are within 5% between 1.46 and down to 46.4 and 68 hPa in the tropics and mid-latitude, respectively.

The systematic offsets become larger (~10%) in upper stratosphere/lower mesosphere and close to tropopause. It's also obvious that Aura MLS has better accuracy than UARS MLS in the tropical lower stratosphere below 68 hPa. .

3. Preliminary results and sampling issue

After we derive systematic offsets for every 10° bin and pressure level (e.g. Figures 3, 4), the individual zonal mean O3 series are adjusted to the SAGE-II dataset, used here as a reference because of its high longevity and pedigree, and abundant use in the community. The final estimation of a long term ozone record can then be derived by averaging (equally-weighted) all available satellite data. An example of original and combined O3 time series are shown in figures 5 and 6, respectively.

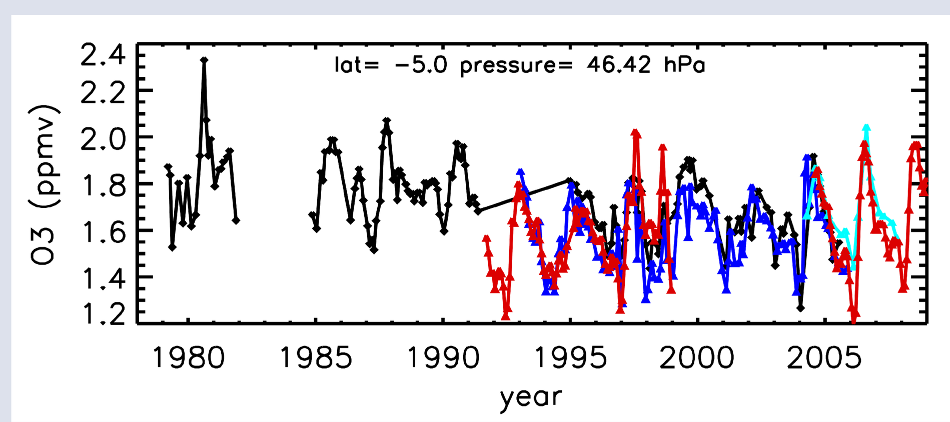

Figure 5 . Monthly zonal mean ozone from SAGE-I/II (black), HALOE (blue), UMLS/AMLS (red), and ACE-FTS (cyan) between 0 and 10°S and at 46.2 hPa.

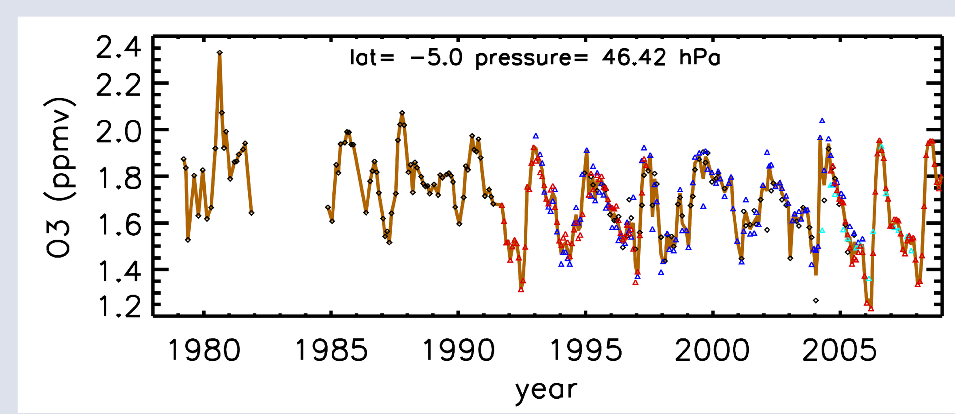

Figure 6 Example of merged O3 data (brown color) between 0 and 10°S and at 46.2 hPa. Individual data after adjusting offsets are indicated by different colors as those in figure 5.

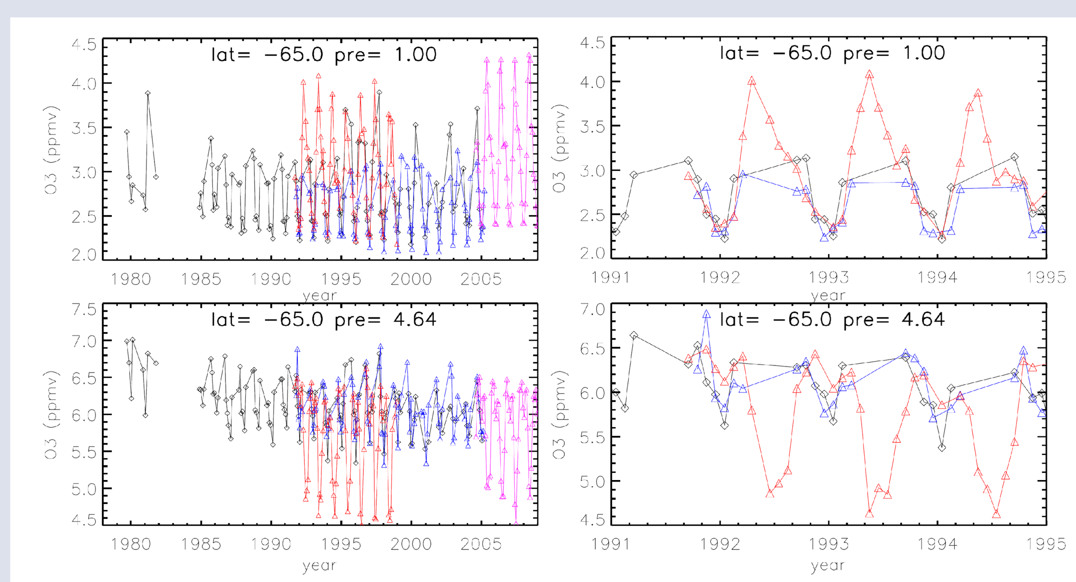

Figure 7 Monthly zonal mean ozone from SAGE-I/II (black), HALOE (blue), UARS MLS (red) and Aura MLS (pink) between 70^{0}S and 60^{0}S and at 1 hPa (top panel) and 46.2 hPa (bottom panel).

Slightly different approach will be used to merge data at high latitudes due to sampling differences and/or less collocated measurements.

In figure 7 there seems to be significant differences in observed seasonal cycle between SAGE/HALOE and two MLS instruments (e.g. left hand side figures). Those differences (i.e. different amplitude) mainly result from different samplings. Due to limitation of orbit geometry, both SAGE-II and HALOE (solar occultation) only observe high latitudes during specific months (e.g. see right hand side plots in figure 7).

Because of potential sampling differences between SAGE-II and other satellites in high latitudes, we will use slightly different approach to merge different satellite data sets.

4. Ozone zonal averages: Validation

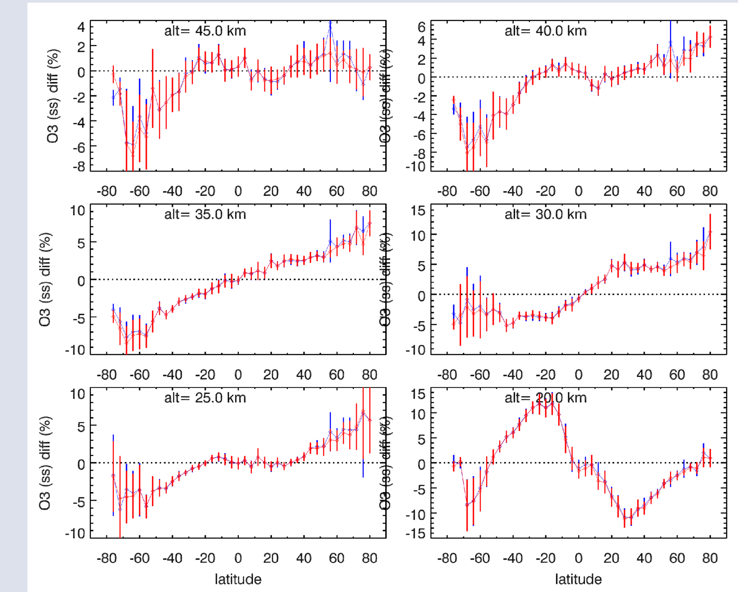

Figure 8. Mean differences and 2 standard deviations in SAGE-II O3 zonal means compared to Randel and Wu (2007) from 15 to 40 km at every 5 km interval. Zonal mean values are calculated for every 4° latitude bin. Positive differences indicate values from Randel and Wu (2007) that are higher than those from this study. Red and blue colors indicate results from two independent calculations.

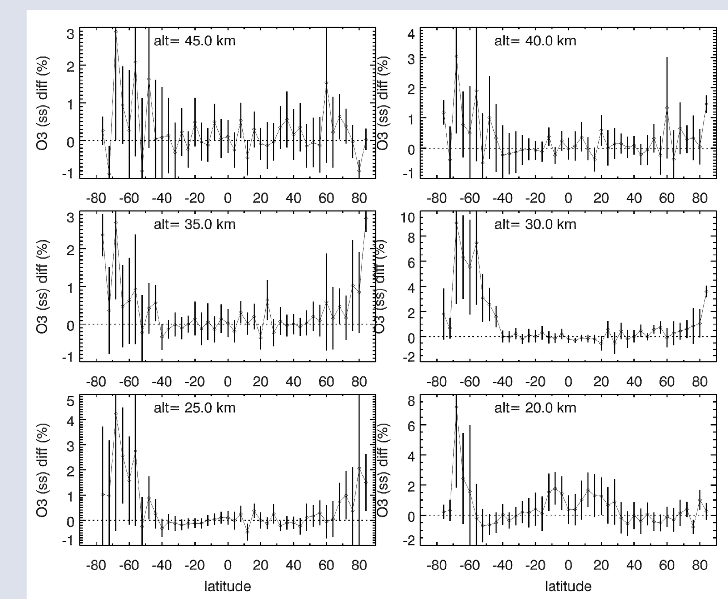

Figure 9. Similar to Figure 7, but adjusting the latitude of all O3 profiles used to calculate zonal means in this study by 4° (to the North).

To validate SAGE-II monthly zonal mean O3 created here, we compared those with similar results from Randel and Wu (2007).

The SAGE-II monthly zonal mean O3 in number density and geometric altitude were calculated in every 4° latitude bin. All data between 1991 and 1994 were excluded from comparison to prevent possible outliers affected by Pinatubo aerosols.

Comparisons show unexpected latitude-dependent differences between these two results, as shown in Figure 8. Monthly zonal mean O3 from Randel and Wu (2007) shows negative biases of ~5-8% in the S.H. high latitudes between 40 and 25 km. Those biases decrease toward the equator and become positive in the N.H., with maximum positive biases of ~5-8% at N.H. high latitudes.

The same latitudinal structure also occurred in comparisons of sunrise data (figure not shown).

The reason for this difference is not clear, but preliminary studies indicate that this could result from a latitude mismatch of ~4° between these two results; see Figure 9, which corrects for such a potential offset.

5. Summary and future plans

- Monthly zonal mean O3 files from SAGE-I, SAGE-II, SAGE-III, HALOE, UARS MLS, Aura MLS and ACE-FTS have been created. A preliminary merged O3 time series by using SAGE-II as reference standard has been produced
- Slightly different approach will be used in high latitudes to merge data (very few or no collocated points between SAGE-II and other satellites).
- We need to further check the latitudinally dependent structure in the differences verses the zonal mean raw data from Randel and Wu (2007); and would like to compare with other long term O3 profiles.
- We will work on a zonal average product that uses density (or DU) and height rather than volume mixing ratio and pressure as coordinates. This is fairly straightforward for the occultation datasets from the SAGE set, HALOE, and ACE-FTS, but MLS data need to be converted to this new coordinate system
- The first version of merged stratospheric ozone data will be available to public in the next few months

6. References

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