

# QOS 2021

October 3 (Sunday) - 9 (Saturday), 2021

▶ Online Meeting

QUADRENNIAL OZONE SYMPOSIUM

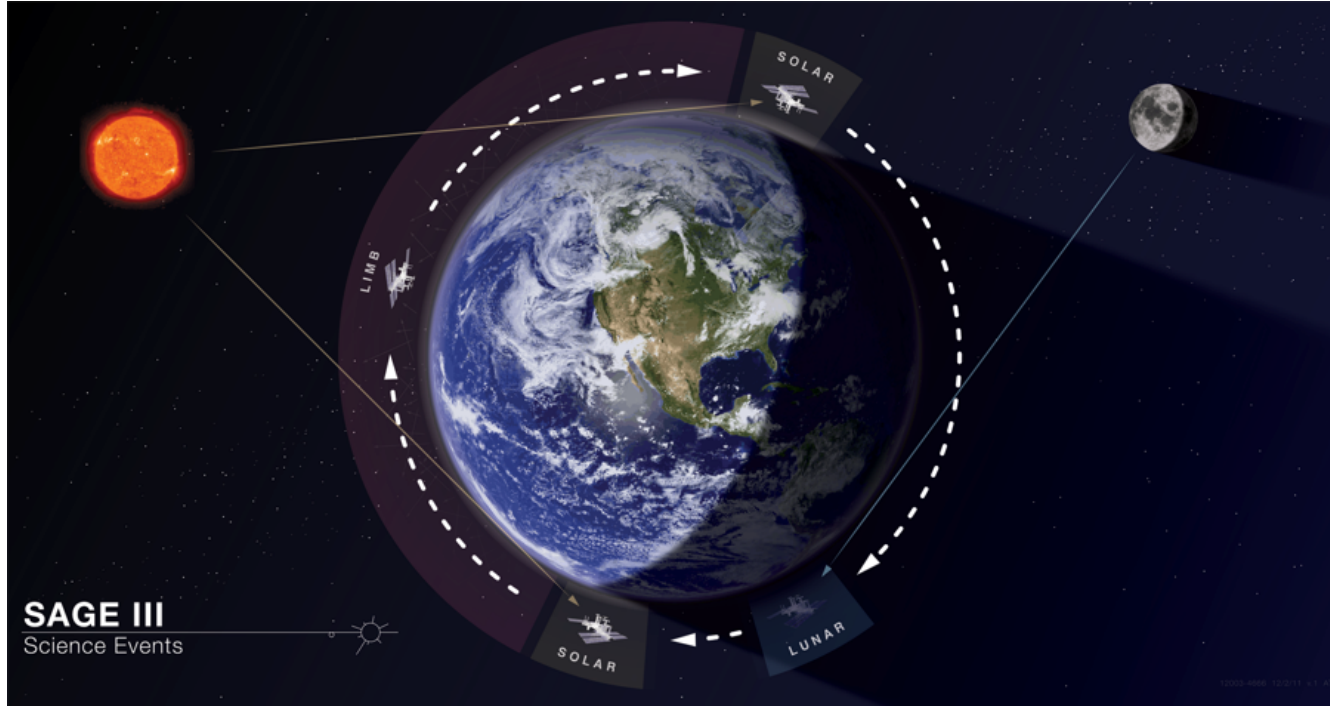
## A\_151: Stratospheric Aerosol and Gas Experiment III on the International Space Station (SAGE III/ISS): Validation of Ozone Using In-situ Measurements

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## Stratospheric Aerosol and Gas Experiment III on the International Space Station (SAGE III/ISS)



Sunrise Moonset (Moonrise\*)

The Stratospheric Aerosol and Gas Experiment III (SAGE III) instrument installed on the International Space Station (ISS) has completed four years of data collection and production of science data products. It continues the legacy of previous SAGE instruments dating back to the 1970s to provide data continuity of stratospheric constituents critical for assessing trends in the ozone layer. Three ozone data products are available for each solar event (one for lunar). When comparing solar events, this presentation focuses on the ozone reported in the ozone\_AO3 data product. This presentation shows the validation results of comparing SAGE III/ISS v5.2 ozone vertical profiles with those of balloon launched ozonesonde measurements, LIDAR, and satellite data from the Microwave Limb Sounder for the duration of the first four years of SAGE III/ISS data, June 2017 – May 2021.

The SAGE III/ISS is a solar and lunar occultation instrument that scans the light from the Sun and Moon through the limb of the Earth's atmosphere to produce vertical profiles of aerosol, ozone, water vapor, and other trace gases. *\*This event depiction includes a lunar moonset. An event with an alternate orbit direction would depict a lunar moonrise.*



## SAGE III/ISS Validation Using Balloon Launched Data, LIDAR and MLS



The ozonesonde data used for this comparison are taken from measurements collected from NDACC, WOUDC, NOAA ESRL, and SHADOZ databases. The LIDAR data has been retrieved from the NDACC database. The Microwave Limb Sounder instrument on NASA's Earth Observing System (EOS) Aura satellite also provides ozone for this comparison. The MLS version 4.23 data is used.

Matching a sonde or LIDAR event with SAGE requires an event within 5 degrees latitude and 24 hours time, with the closest match in distance chosen (only accepted when distance is less than 1000km.) Matching criteria with MLS requires an event within 2 degrees latitude and 24 hours time, with the closest match in distance chosen (only accepted when distance is less than 1000km.) Only MLS nighttime data is used. Meteorological data from JPL Derived Meteorological Products made for MLS v4 data were used for improved ozone profile matching. They provide geopotential height, pressure and temperature for calculations to convert MLS ozone concentrations to number density on an altitude grid.

The Mean Percent Difference is calculated using the interpercentile range.

Profiles considered to be outliers were identified by finding percent difference values greater than +/- 50% in the 20 to 35km range. When matching SAGE with both sonde and LIDAR, there were about 10% of events identified as outliers. These were removed for this study and will be scrutinized for explanation of the large disagreement. One theory is that the sonde data may deviate considerably around the maximum height at the point of the balloon burst.

For this study, we are focusing on the agreement of data between altitudes of 20 – 30km. The SAGE data gains uncertainties about the tropopause and the ozonesonde data availability decreases significantly around the balloon maximum heights.

For additional details in comparing ozone data products with SAGE, please refer to "Validation of SAGE III/ISS Solar Occultation Ozone Products With Correlative Satellite and Ground-Based Measurements" by H.J. Ray Wang et al, JGR Atmospheres, June 2020.

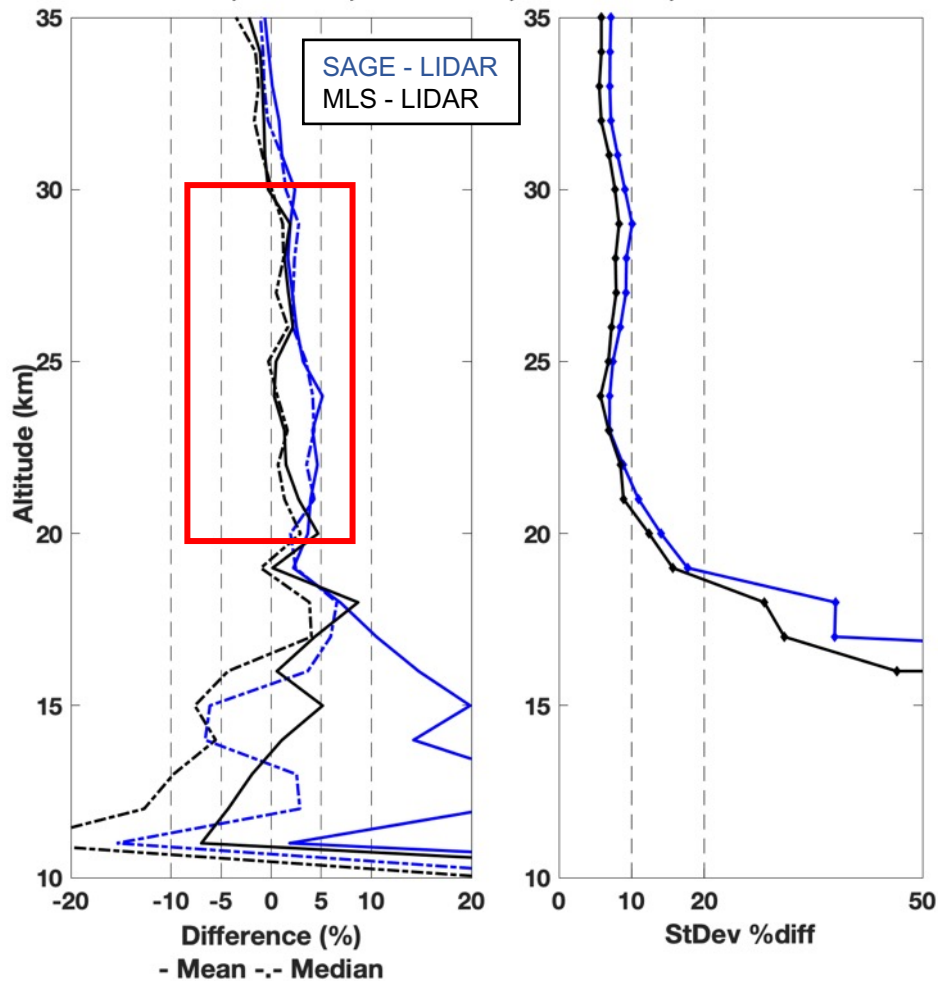
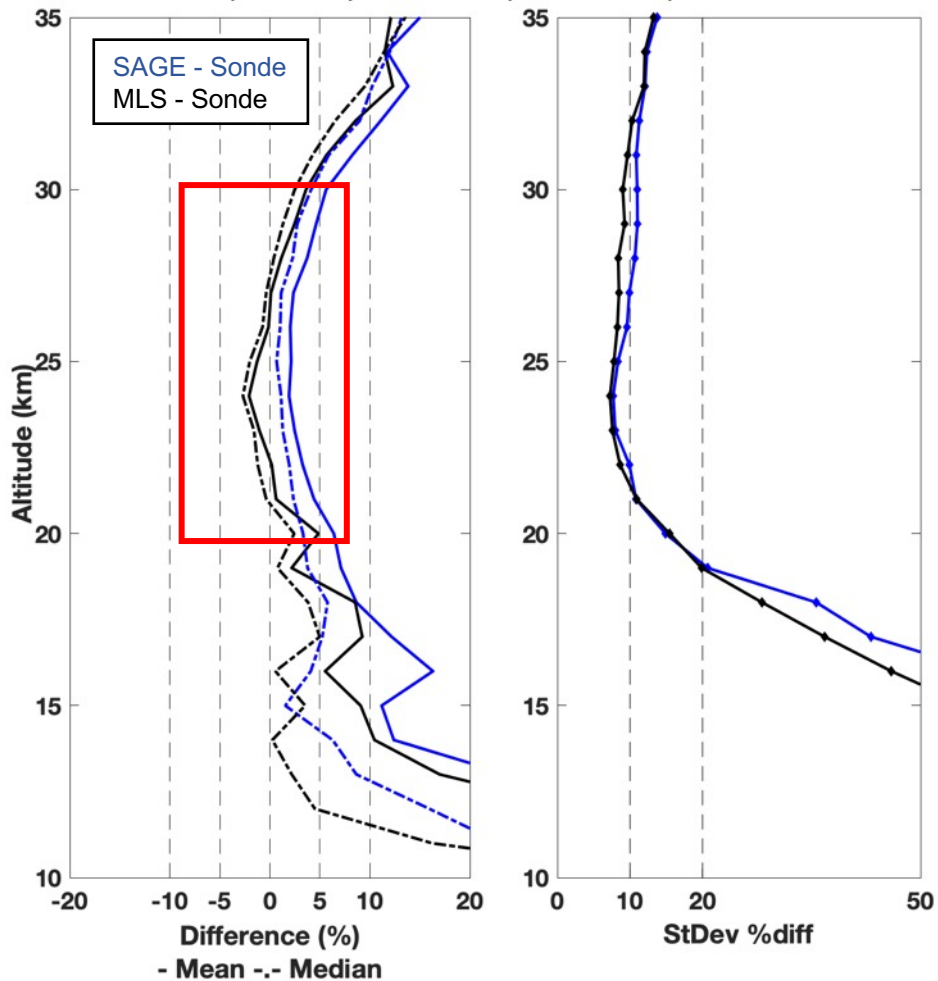


## SAGE III/ISS Ozone Validation: Solar Occultation



**SAGE and Sonde Ozone Comparison (SAGE - Sonde)/Sonde\*100 n = 590**  
Season= All; Lat = All; Evtnt= Solar; Station= All; Product= AerO3

**SAGE and LIDAR Ozone Comparison (SAGE - LIDAR)/LIDAR\*100 n = 176**  
Season= All; Lat = All; Evtnt= Solar; Station= All; Product= AerO3



SAGE and MLS agree with the **ozonesonde** data within 5% difference between 20 and 30km. Both satellites show that the satellite data is increasingly larger than the sonde when moving up or down from the maximum ozone peak. The standard deviation of the 5 differences is consistent around 10.

SAGE and MLS also agree with the **LIDAR** data within 5% difference between 20 and 30km. The agreements are consistent with SAGE values being comparatively higher and decreasing with rise in altitude. The standard deviation is consistent around 8-10.



## SAGE III/ISS Ozone Validation: Solar Occultation

### Northern Hemisphere (20 – 60N)



#### Ozonesonde

#### LIDAR

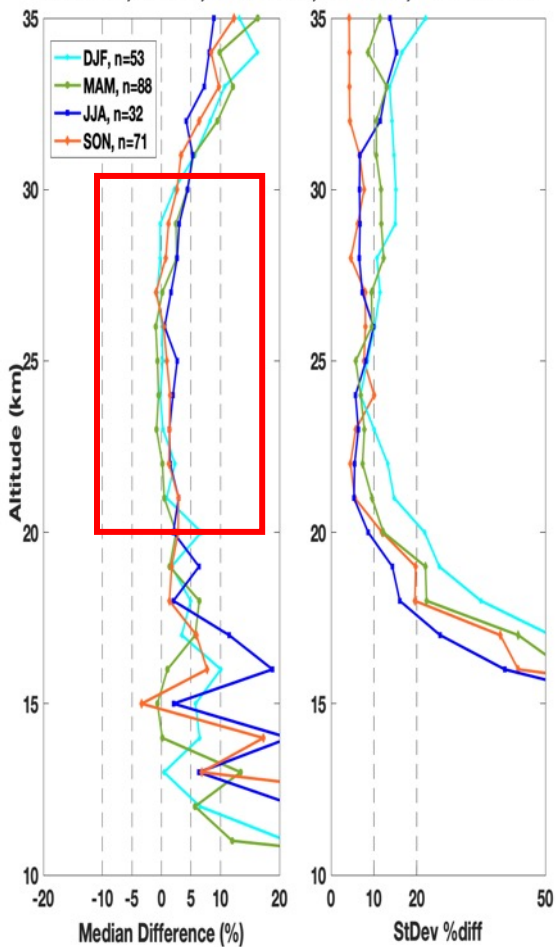
#### Sunrise

#### Sunset

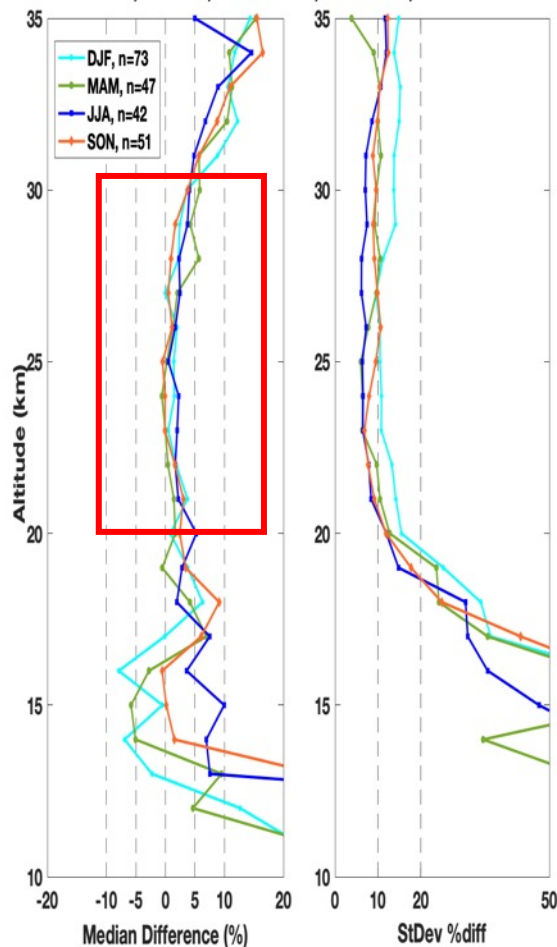
#### Sunrise

#### Sunset

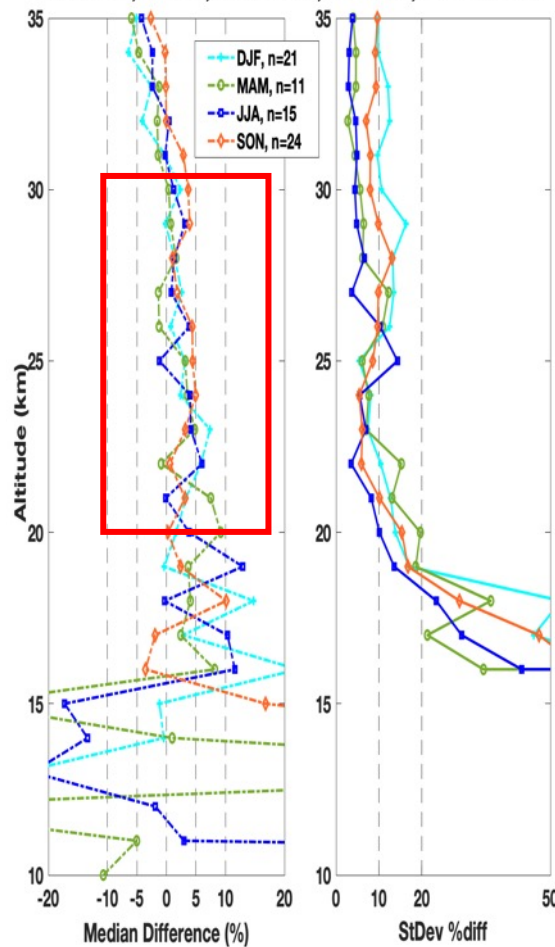
SAGE and sonde Ozone Comparison (SAGE - sonde)/sonde\*100 n = 244  
Season= All; Lat = NH; Evt= Sunrise; Station= All; Product= AerO3



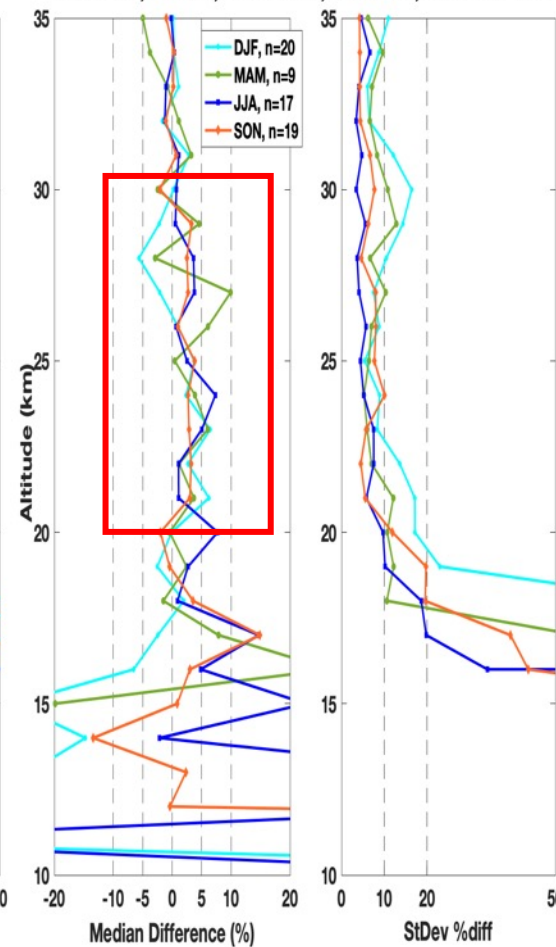
SAGE and sonde Ozone Comparison (SAGE - sonde)/sonde\*100 n = 213  
Season= All; Lat = NH; Evt= Sunset; Station= All; Product= AerO3



SAGE and LIDAR Ozone Comparison (SAGE - LIDAR)/LIDAR\*100 n = 61  
Season= All; Lat = NH; Evt= Sunrise; Station= All; Product= AerO3



SAGE and LIDAR Ozone Comparison (SAGE - LIDAR)/LIDAR\*100 n = 65  
Season= All; Lat = NH; Evt= Sunset; Station= All; Product= AerO3



**SAGE comparison to in-situ data stratified by SAGE occultation type (Sunrise or Sunset) and by season.**



## SAGE III/ISS Ozone Validation: Solar Occultation

### Southern Hemisphere (20 – 60S)



Ozonesonde

LIDAR

Sunrise

Sunset

Sunrise

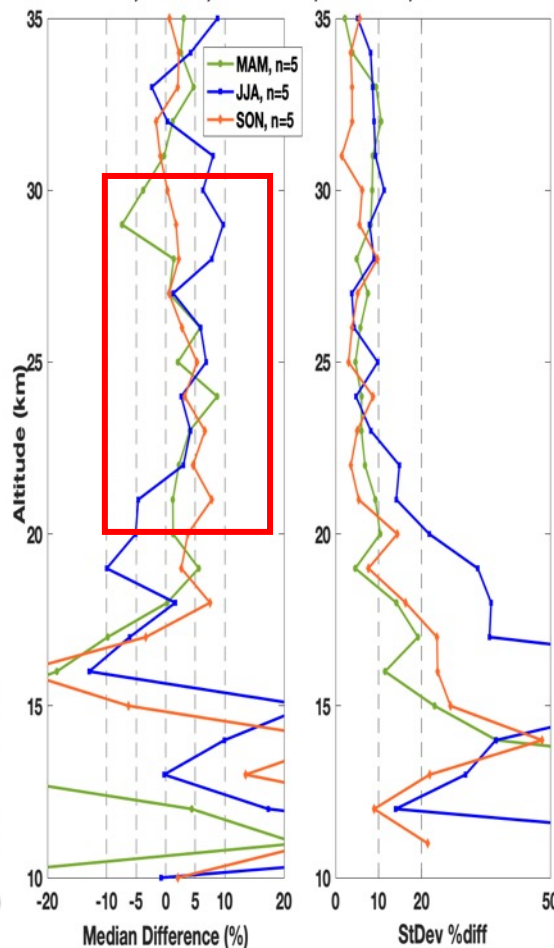
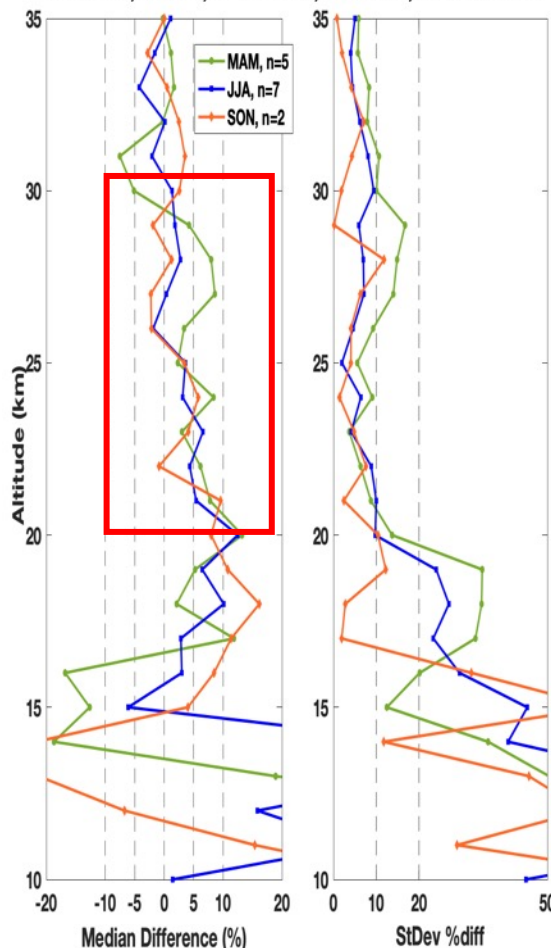
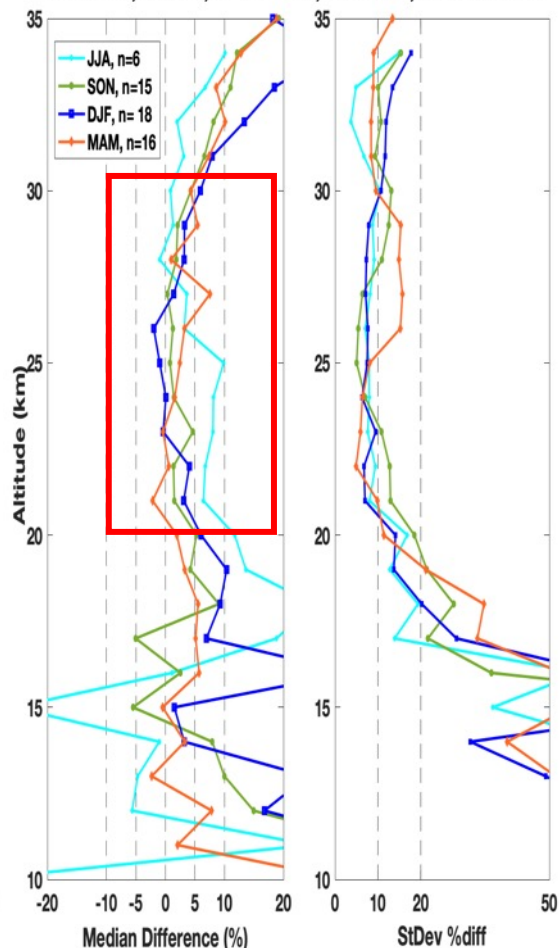
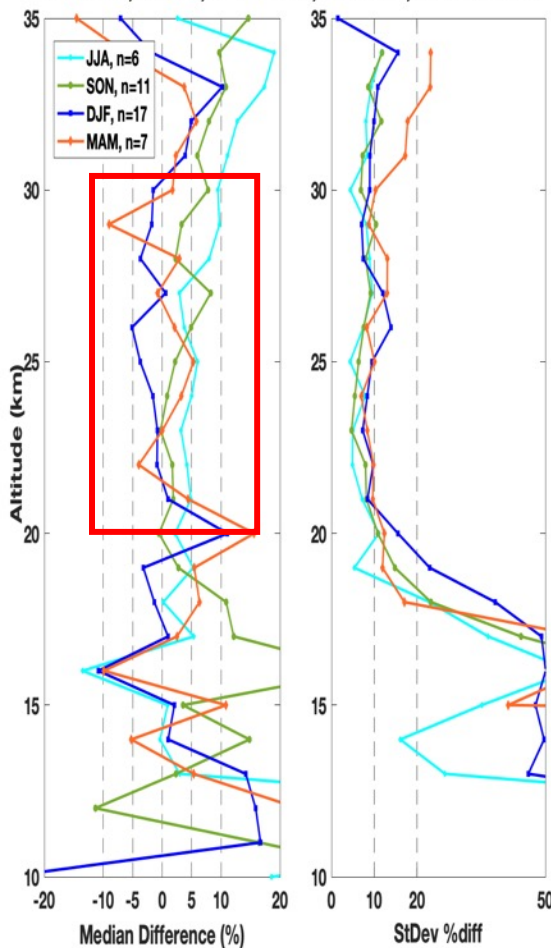
Sunset

SAGE and sonde Ozone Comparison (SAGE - sonde)/sonde\*100 n = 41  
Season= All; Lat = SH; Evt= Sunrise; Station= All; Product= AerO3

SAGE and sonde Ozone Comparison (SAGE - sonde)/sonde\*100 n = 55  
Season= All; Lat = SH; Evt= Sunrise; Station= All; Product= AerO3

SAGE and LIDAR Ozone Comparison (SAGE - LIDAR)/LIDAR\*100 n = 14  
Season= All; Lat = SH; Evt= Sunrise; Station= All; Product= AerO3

SAGE and LIDAR Ozone Comparison (SAGE - LIDAR)/LIDAR\*100 n = 15  
Season= All; Lat = SH; Evt= Sunset; Station= All; Product= AerO3



SAGE comparison to in-situ data stratified by SAGE occultation type (Sunrise or Sunset) and by season.



## SAGE III/ISS Ozone Validation: Solar Occultation

### Tropics (20S – 20N)



#### Ozonesonde

#### LIDAR

#### Sunrise

#### Sunset

#### Sunrise

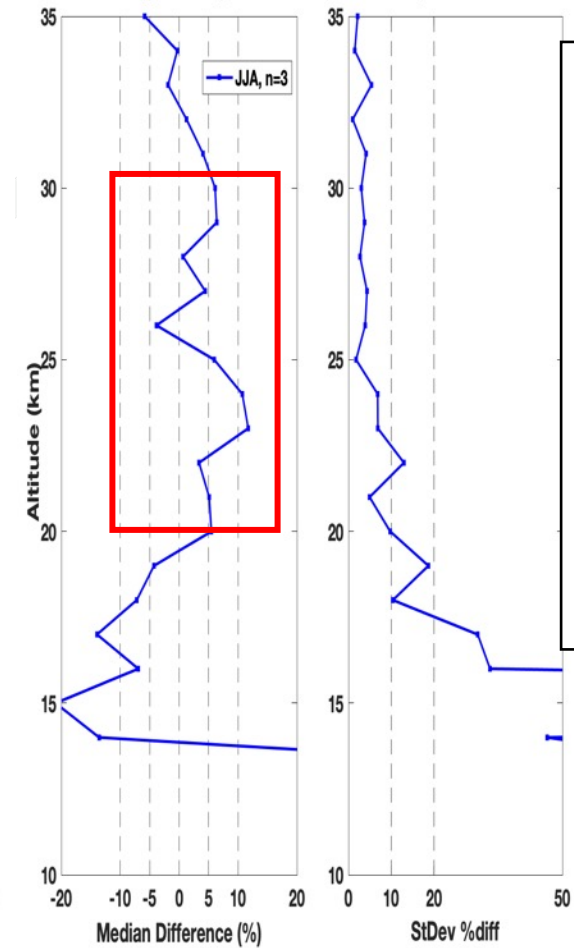
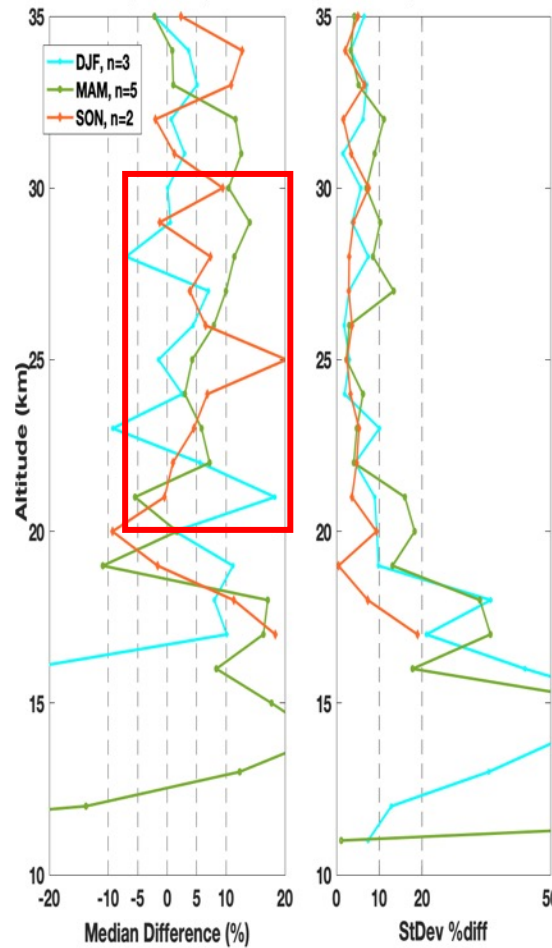
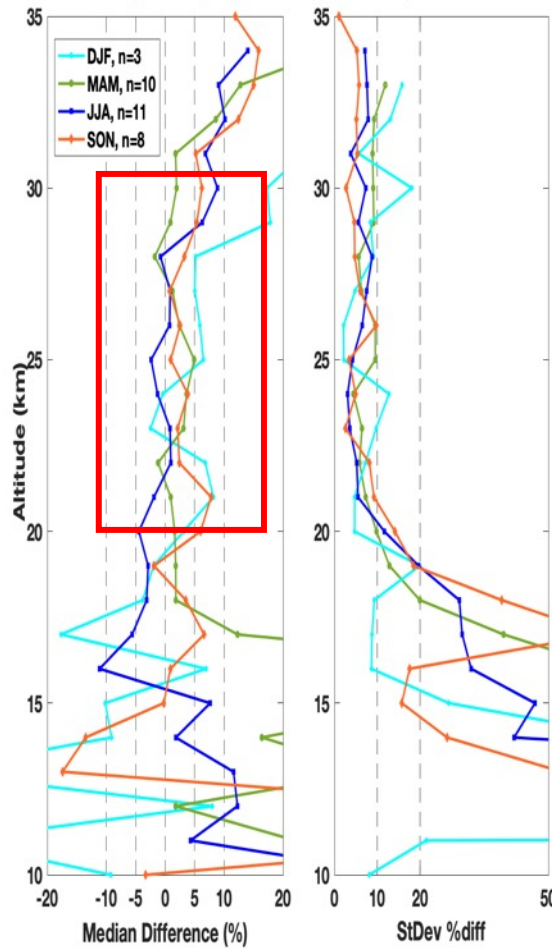
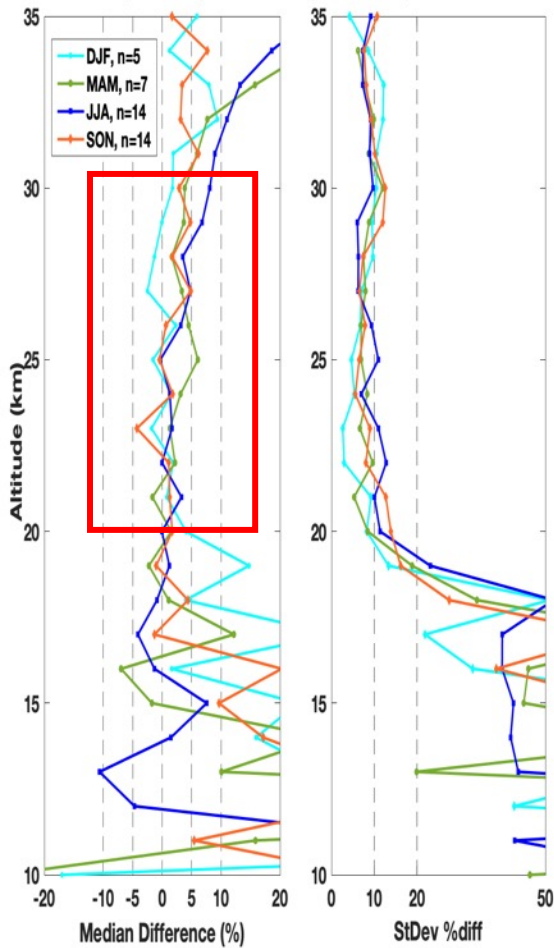
#### Sunset

SAGE and sonde Ozone Comparison (SAGE - sonde)/sonde\*100 n = 40  
Season= All; Lat = TR; Evnt= Sunrise; Station= All; Product= AerO3

SAGE and sonde Ozone Comparison (SAGE - sonde)/sonde\*100 n = 32  
Season= All; Lat = TR; Evnt= Sunset; Station= All; Product= AerO3

SAGE and LIDAR Ozone Comparison (SAGE - LIDAR)/LIDAR\*100 n = 10  
Season= All; Lat = TR; Evnt= Sunrise; Station= All; Product= AerO3

SAGE and LIDAR Ozone Comparison (SAGE - LIDAR)/LIDAR\*100 n = 3  
Season= All; Lat = TR; Evnt= Sunset; Station= All; Product= AerO3



SAGE comparison to in-situ data stratified by SAGE occultation type (Sunrise or Sunset) and by season.



## SAGE III/ISS Ozone Validation: Lunar Occultation



Ozonesonde

LIDAR

Moonrise

Moonset

Moonrise

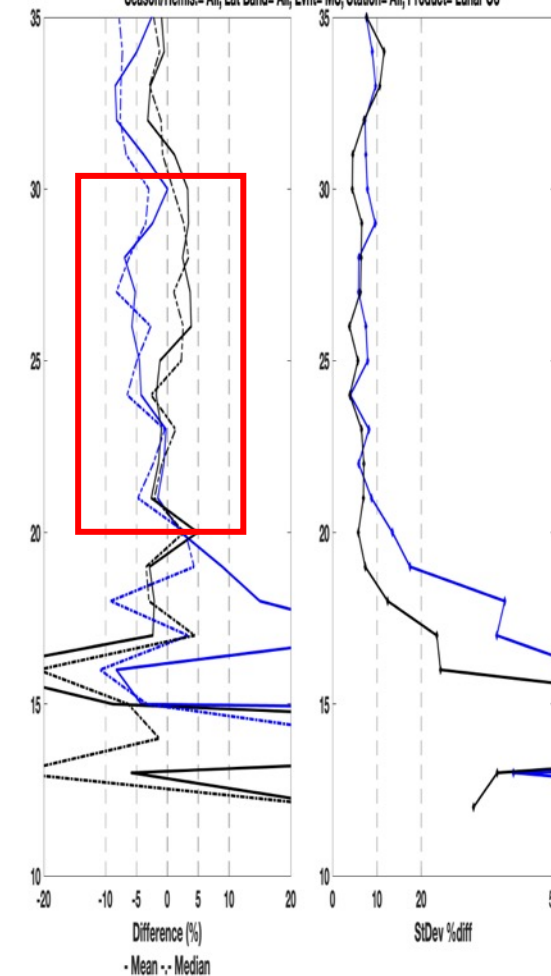
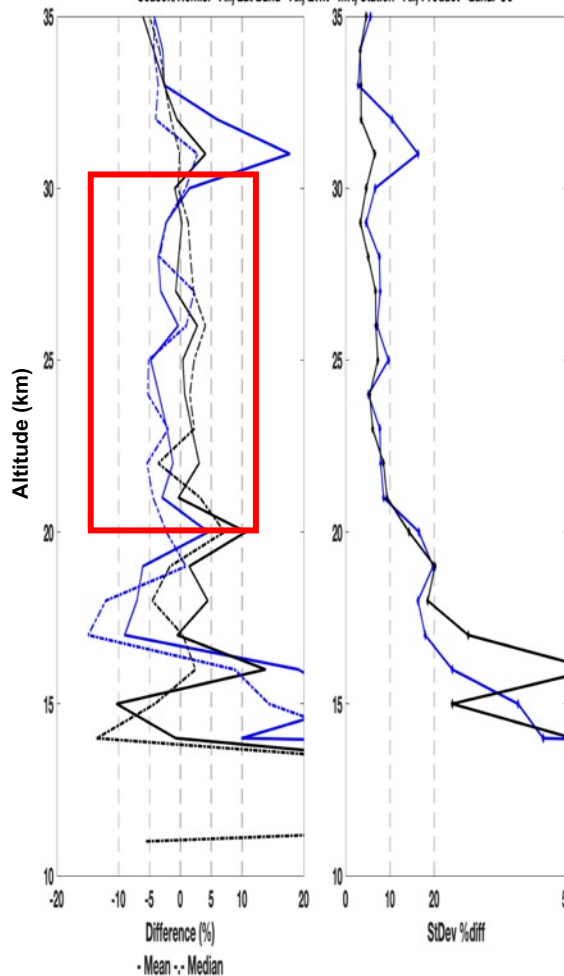
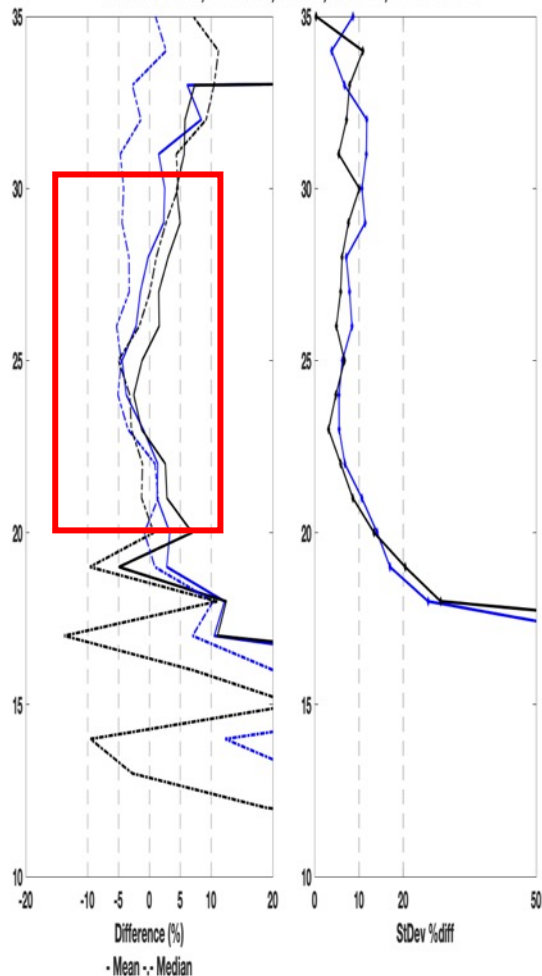
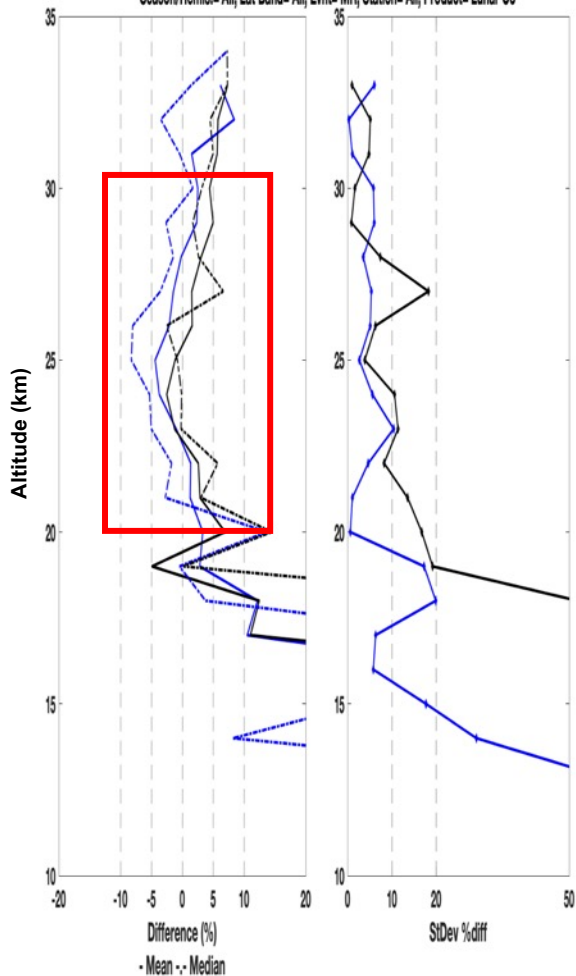
Moonset

SAGE v5.2 and Sonde Ozone Comparison (SAGE - sonde)/sonde\*100 n = 4  
Season/Hemis.= All; Lat Band= All; Evnt= MR; Station= All; Product= Lunar O3

SAGE v5.2 and Sonde Ozone Comparison (SAGE - sonde)/sonde\*100 n = 15  
Season/Hemis.= All; Lat Band= All; Evnt= MS; Station= All; Product= Lunar O3

SAGE v5.2 and LIDAR Ozone Comparison (SAGE - LIDAR)/LIDAR\*100 n = 12  
Season/Hemis.= All; Lat Band= All; Evnt= MR; Station= All; Product= Lunar O3

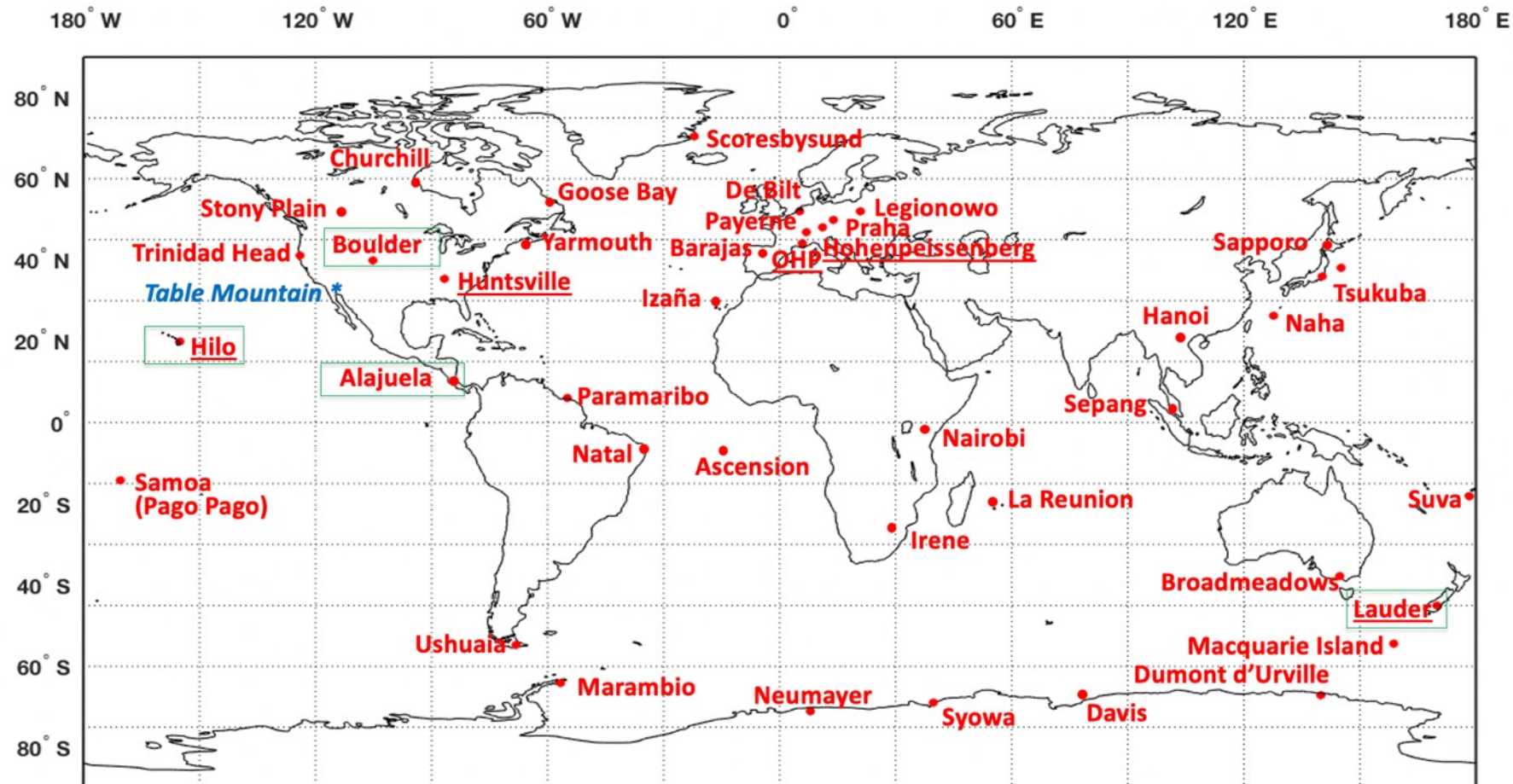
SAGE v5.2 and LIDAR Ozone Comparison (SAGE - LIDAR)/LIDAR\*100 n = 9  
Season/Hemis.= All; Lat Band= All; Evnt= MS; Station= All; Product= Lunar O3



SAGE comparison to in-situ data stratified by SAGE occultation type, Moonrise or Moonset.



## In Situ Site Locations



Map of ozonesonde sites matched to SAGE III data within June 2017 to May 2021 are shown in red. Sites that also have NDACC LIDAR data that have been matched to SAGE are underlined. One site has NDACC LIDAR data only and is shown in blue. NDACC frost point hygrometer sites matched to SAGE III water vapor are outlined in green.



## Summary



- The SAGE III/ISS Level 2 ozone\_AO3 concentrations show good agreement with coincident measurements from the in-situ database sampling of ozonesonde and LIDAR stations. SAGE solar data agrees within percent differences of 5% in the altitude range of 20–30km with mid-latitude sondes and LIDAR. In general, the results are similar between the sunrise and sunset solar occultation SAGE event data types. SAGE lunar percent differences are also impressive with 5-7% differences in this altitude range. Using MLS to compare with in-situ data as well shows comparable statistics. MLS and SAGE have very similar standard deviation of percent differences which may mean that it is dominated by natural variability and uncertainties of the in-situ data.
- Stratification of event types into latitude ranges show that the Northern Hemispheric comparison of SAGE with ozonesondes show the greatest amount of consistency in their agreements. Note that the number of events available are the highest in this hemisphere and when comparing with the ozonesonde database.
- Stations such as the NOAA Earth System Research Laboratory (ESRL) in Boulder, CO and the National Institute of Water and Atmospheric Research (NIWA) in Lauder, NZ have planned ozonesonde launches to coincide with SAGE III/ISS overpasses. The number of stations within the NDACC community that use the SAGE III Validation tool to plan balloon launches with a SAGE flyover is growing. Please take advantage of the SAGE III/ISS Validation Prediction Tool when planning LIDAR, ozonesonde, frost point hygrometer, etc. measurements. <https://sage.nasa.gov/validation/>
- We would like to acknowledge the upper atmosphere observational community for their active participation in the ongoing SAGE III/ISS validation program. Particularly NDACC ([www.ndacc.org](http://www.ndacc.org)), WOUDC ([www.woudc.org](http://www.woudc.org)), NOAA ESRL (<https://www.esrl.noaa.gov/gmd/>), and SHADOZ (<https://tropo.gsfc.nasa.gov/shadoz/index.html>). Please visit these sites for individual station and contact information. Meteorological data provided by the JPL Derived Meteorological Products <https://mls.jpl.nasa.gov/dmp/> were used with MLS data for improved event matching.