Diurnal Cycle Modeling and Scale Factors for NO_2 and O_3

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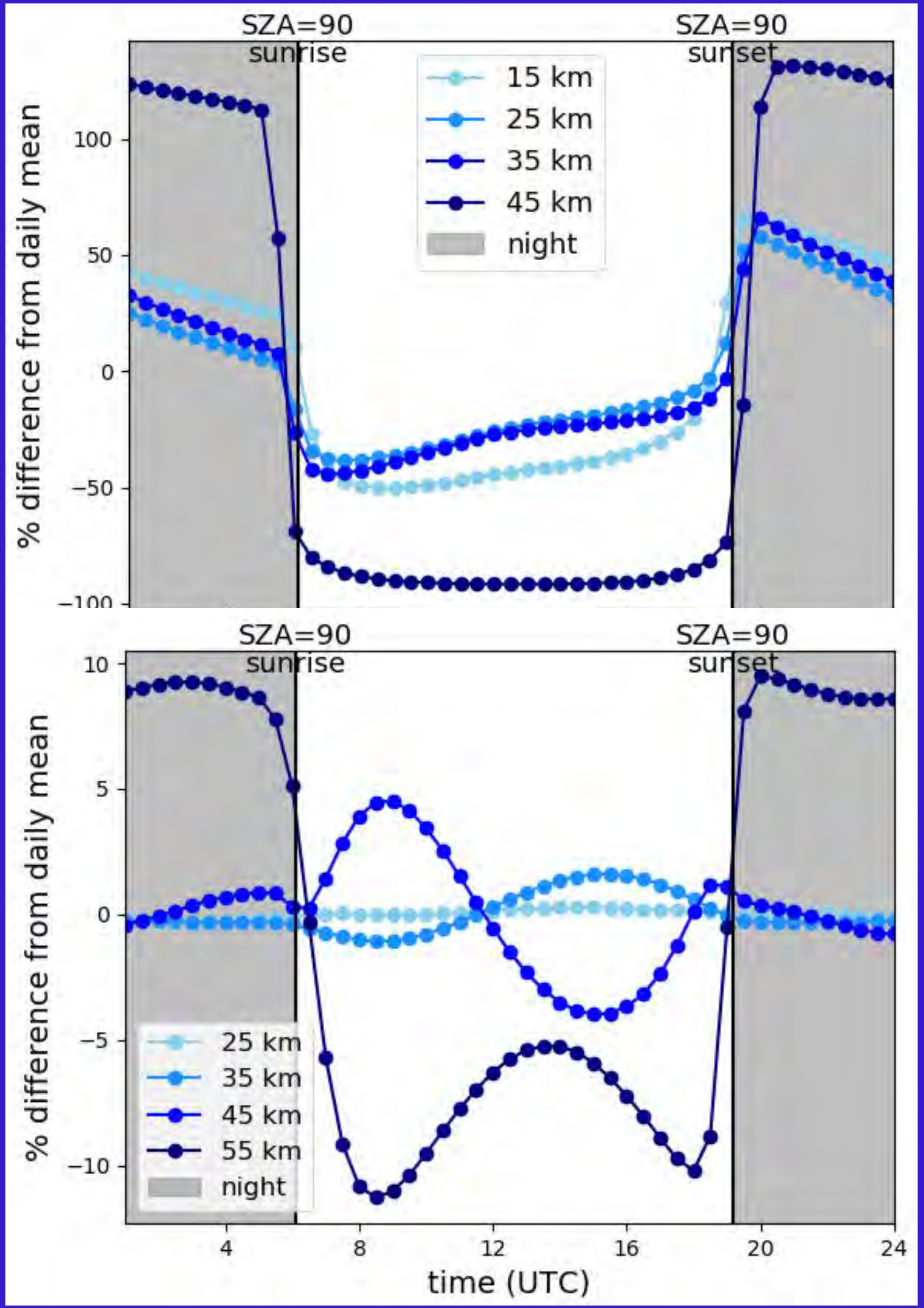
Motivation

- Photochemistry drives large diurnal variability in NO_2
- Diurnal variability matters for O_3 at higher altitudes
- Accounting for diurnal variability improves the comparability of SAGE III/ISS observations other observations: SAGE III/ISS measures at sunrise/sunset while MLS measures mid-day and -night
- Previous studies have used a photochemical box model to account for diurnal variability in NO_2

Diurnal cycles at 0E, 40N for April 2018

NO_2

O_3



Goal: Develop Diurnal Scaling Factors from GEOS-GMI

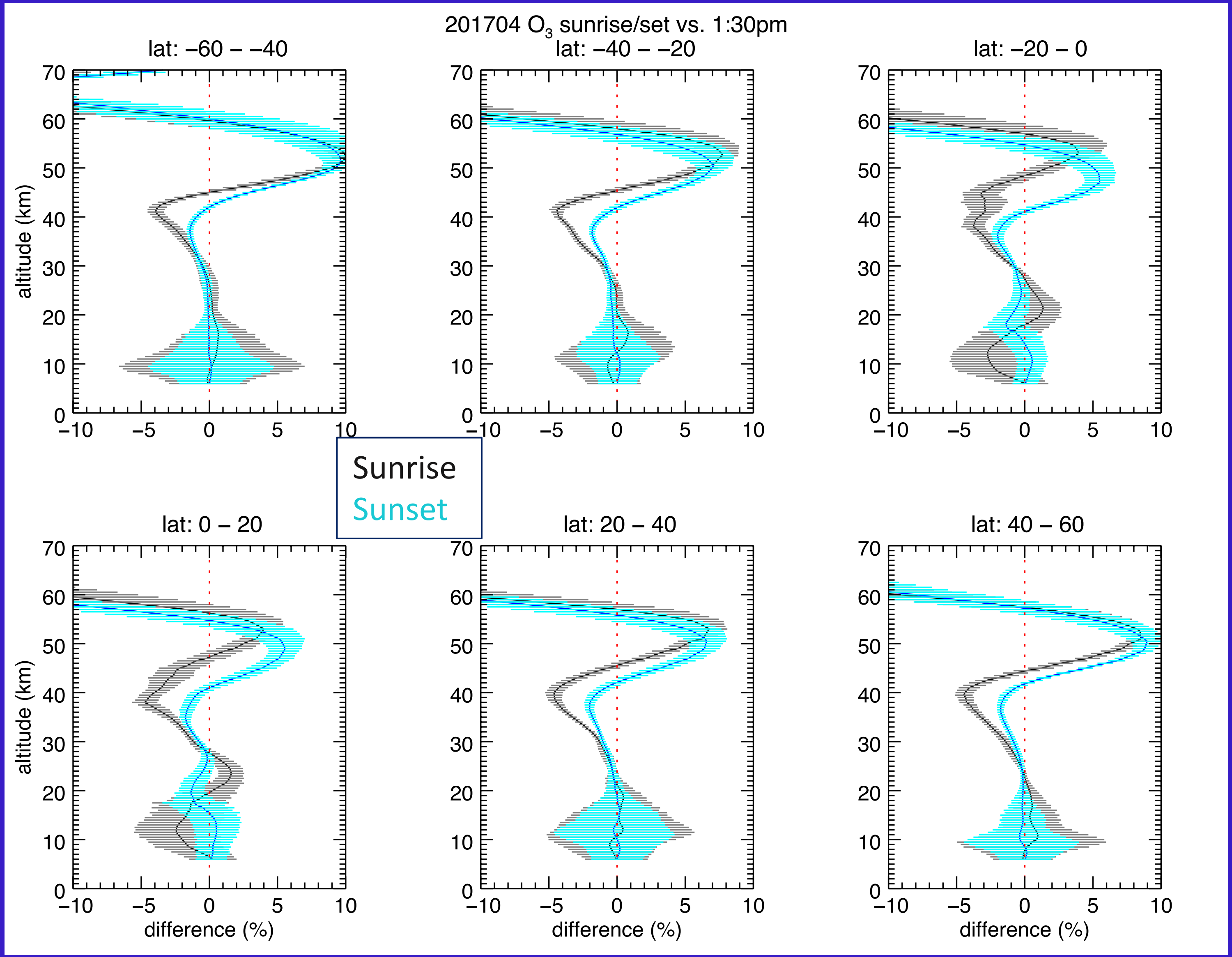
- We develop diurnal scaling factors using output from the GEOS-GMI global 3D atmospheric chemistry model
- Applying scaling factors allows us to account for differences between instruments due to sampling times
- The 3D model accounts for seasonal, latitudinal, and altitude variations in the diurnal cycle

GEOS-GMI simulation

- GEOS-GMI includes the GMI stratospheric and tropospheric chemistry in the GEOS earth system model
- 119 species, 385 reactions
- 72 vertical levels (surface to 1Pa), ~100km horizontal resolution
- 30-minute output
- Meteorology is constrained by the MERRA2 reanalysis
- Simulation covers 2017-2019

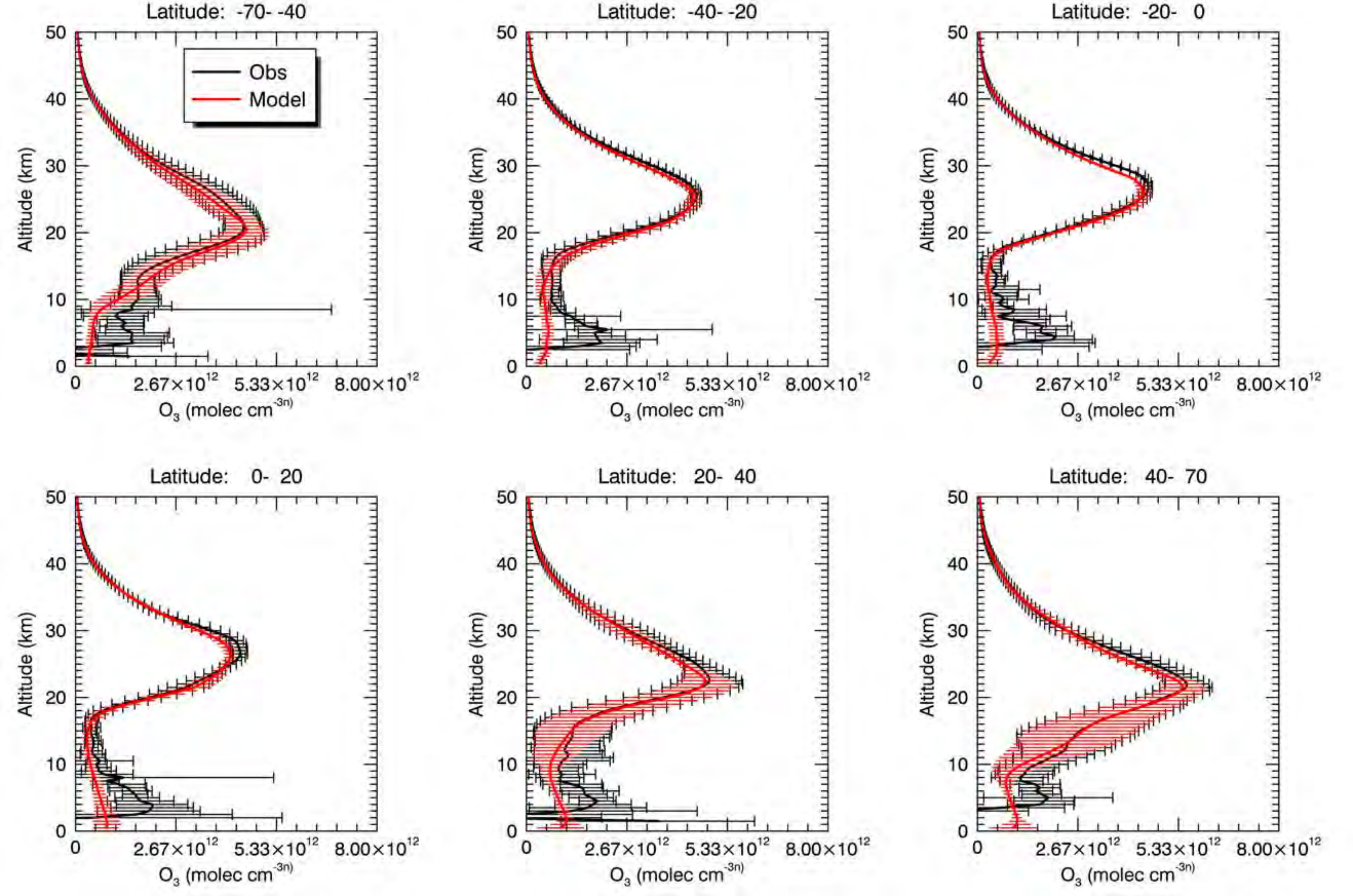
Sunrise/Sunset vs. 1:30pm differences

- Model simulation provides vertical profile of diurnal differences
- Errorbars show the standard deviation



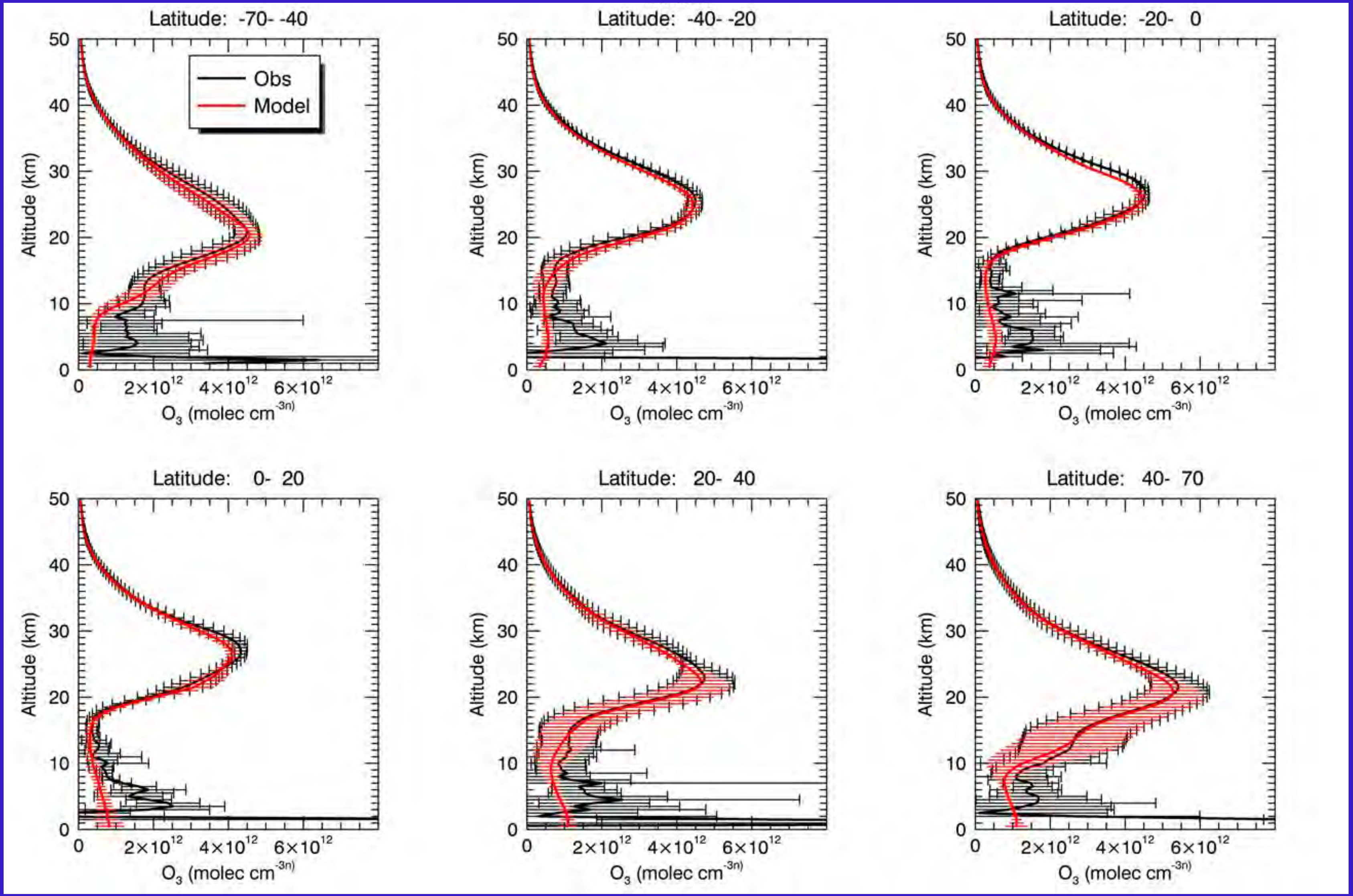
Model Validation: Sunrise DJF Comparison to SAGE III/ISS O_3

- Simulation compares well to SAGE III/ISS observations of the O_3 vertical profiles above 15km
- Error bars show standard deviation



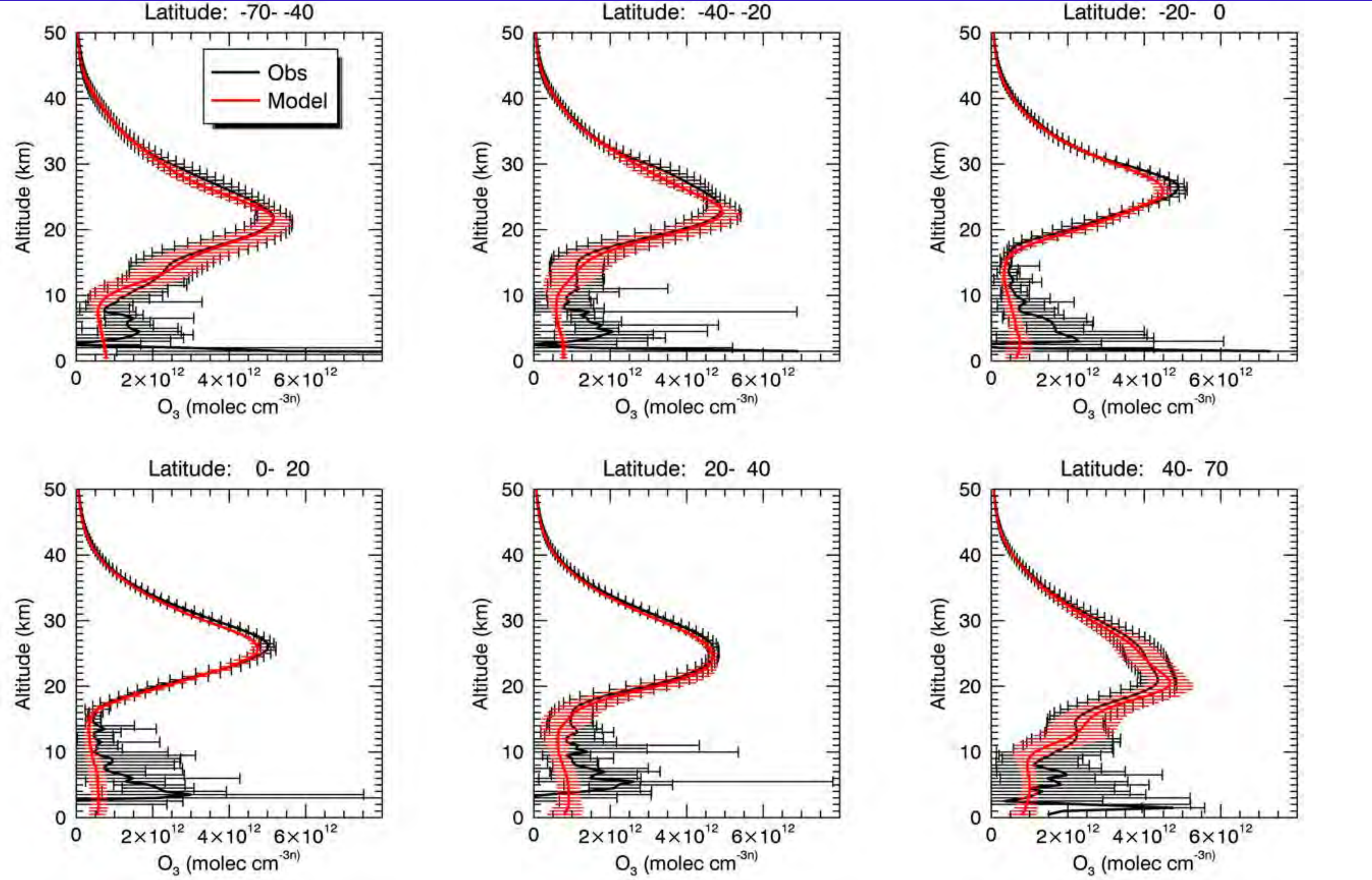
Model vs. SAGE III/ISS Comparison: Sunset DJF O_3

- Simulation compares well to SAGE III/ISS observations of the O_3 vertical profiles above 15km



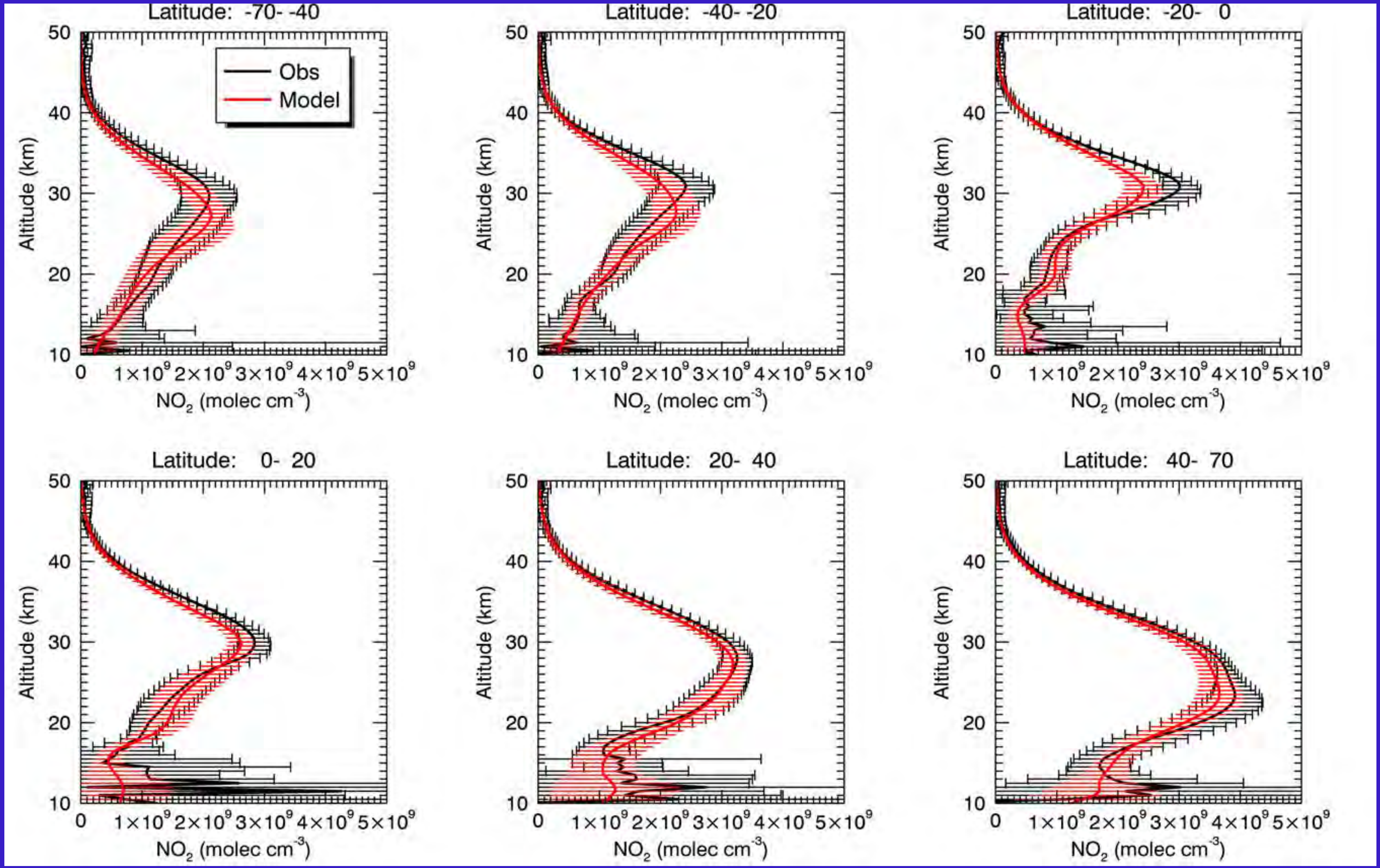
Model vs. SAGE III/ISS Comparison: Sunset JJA O_3

- Simulation compares well to SAGE III/ISS observations of the O_3 vertical profiles above 15km



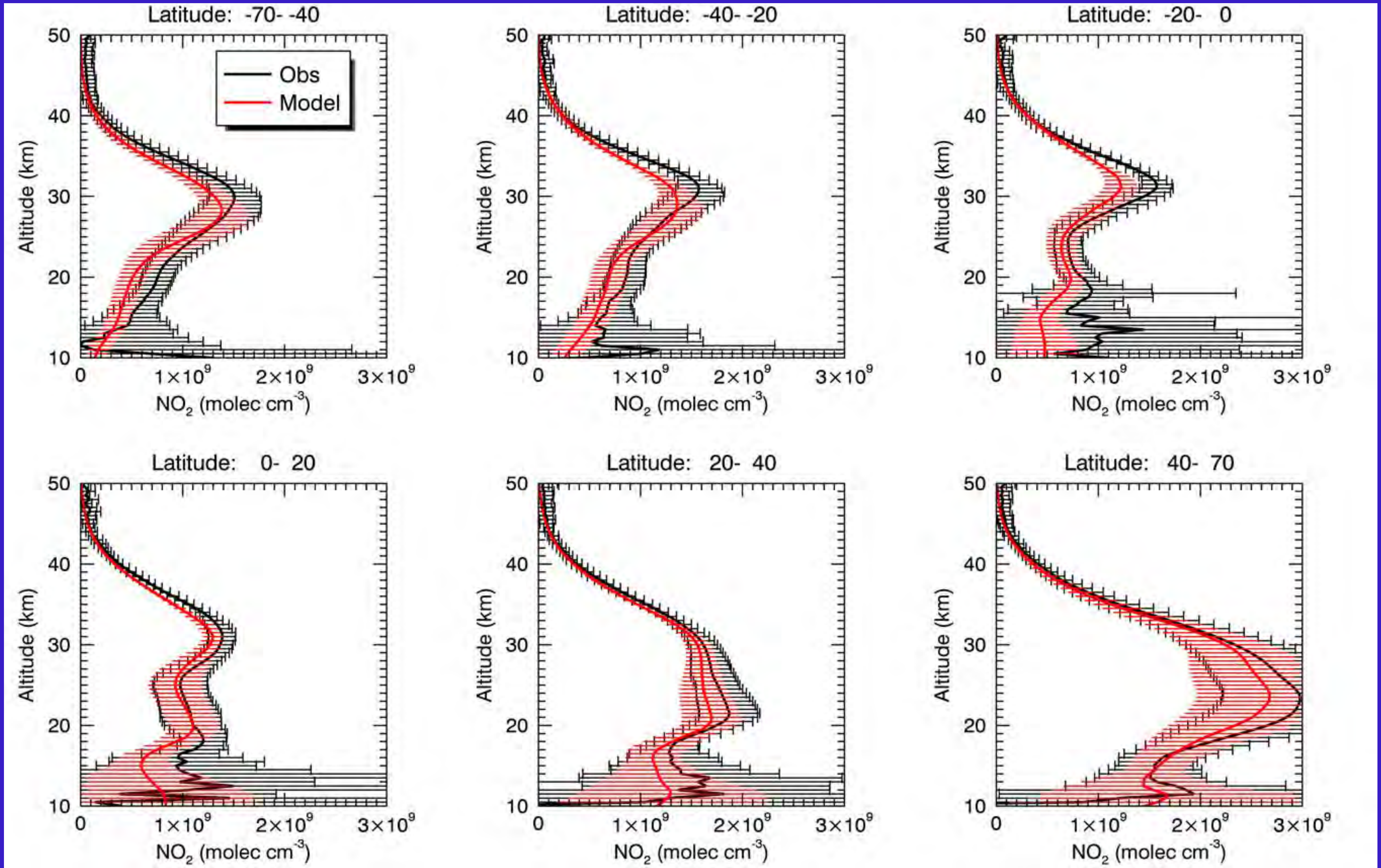
Model vs. SAGE III/ISS Comparison: Sunset JJA NO_2

- Model captures general shape of SAGE III/ISS NO_2 vertical profiles
- Model underestimates the peak around 30-35km



Model vs. SAGE III/ISS Comparison: Sunrise JJA NO_2

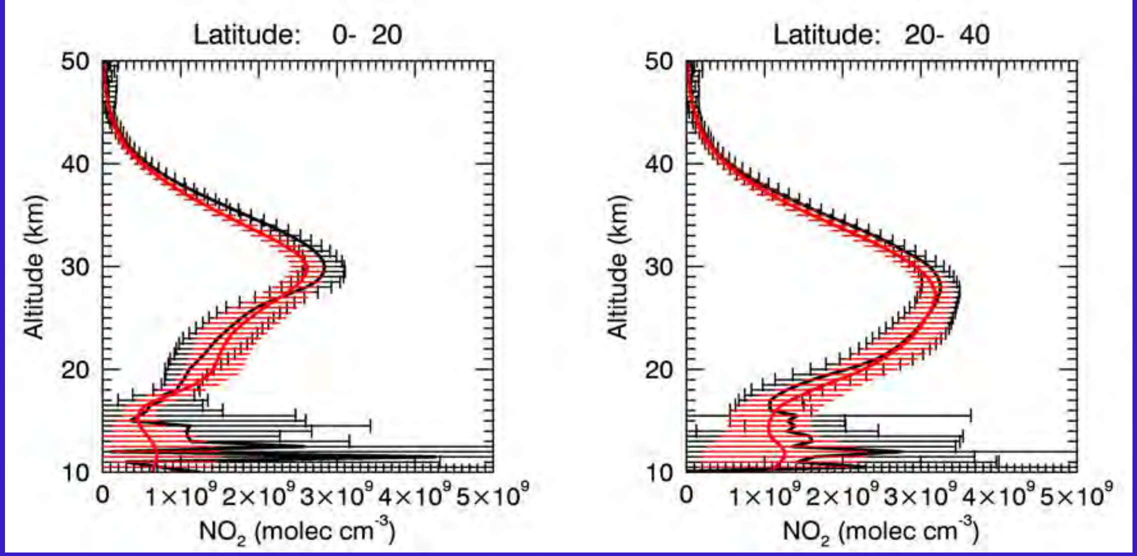
- Model captures NO_2 profile shape above approximately 15km
- Model shows underestimate above 30km in southern hemisphere



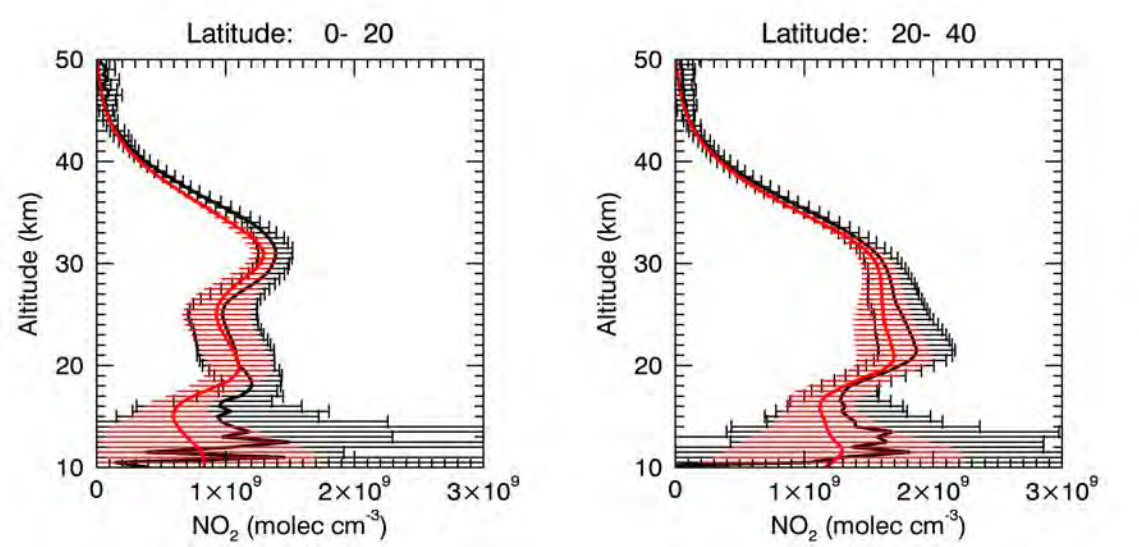
Model vs. SAGE III/ISS Comparison: Sunrise vs. Sunset JJA NO_2

- Simulation captures change in shape between sunset and sunrise

Sunset

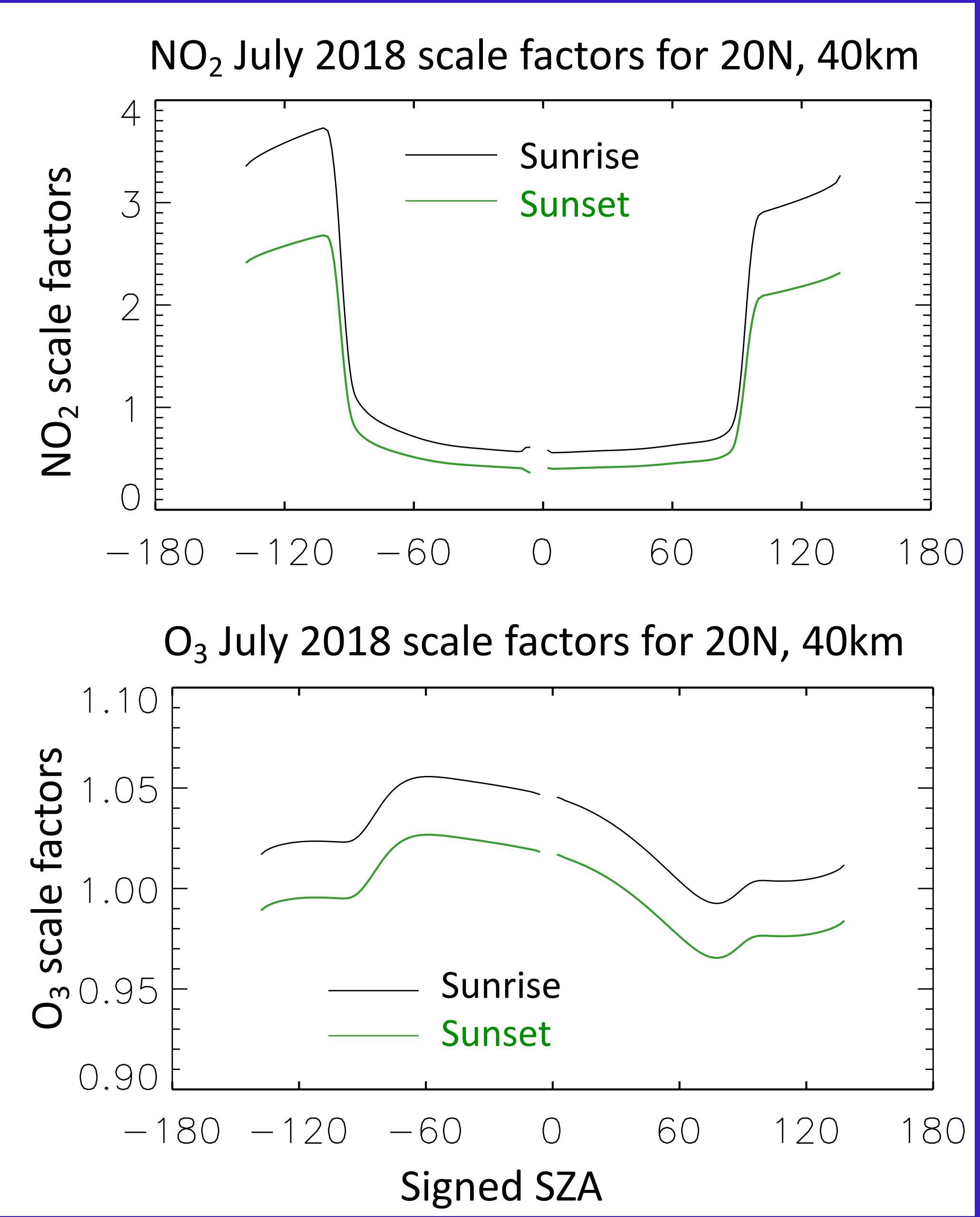


Sunrise



Monthly Scaling Factors

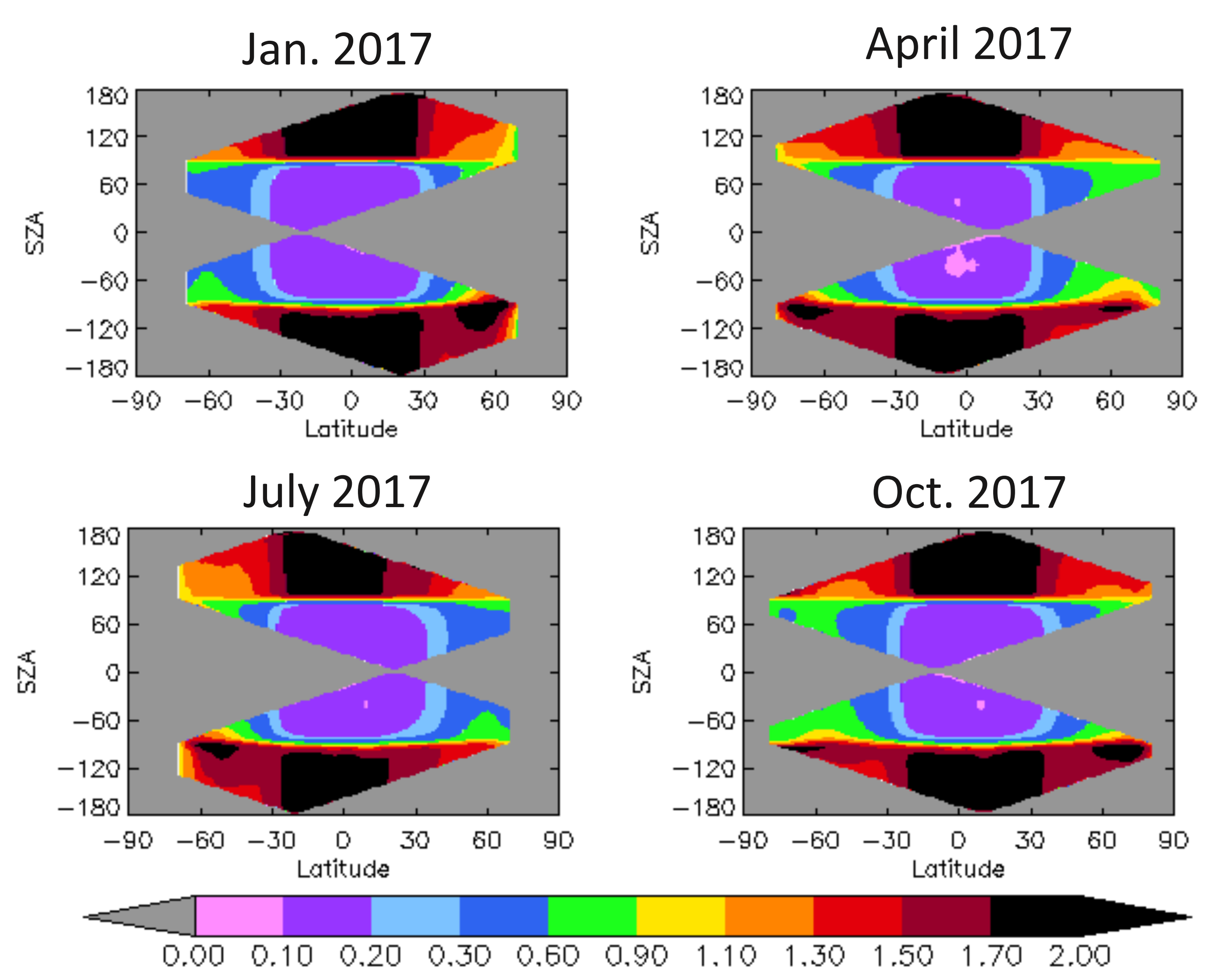
- Using the model we can develop scaling factors that allow us to correct for the observing time differences.
- Scaling factors ratio NO_2 (or O_3) at a given SZA to its value at sunrise or sunset (SZA=90)
- Scaling factors are provided as a zonal mean for each month on a latitude x altitude x SZA grid
- Ozone variability depends on dynamics as well as chemistry, as seen in the GEOS-GMI tendencies
- Taking monthly and zonal means helps remove random variability due to dynamics



Spatial and Temporal variability of Scale Factors: NO_2 at 15km

- Sunrise scale factors are the ratio of the value at each SZA to value at SZA=90 (sunrise)
- Lower values in day (SZA near 0), higher at night
- Not all SZA occur in all months/latitudes

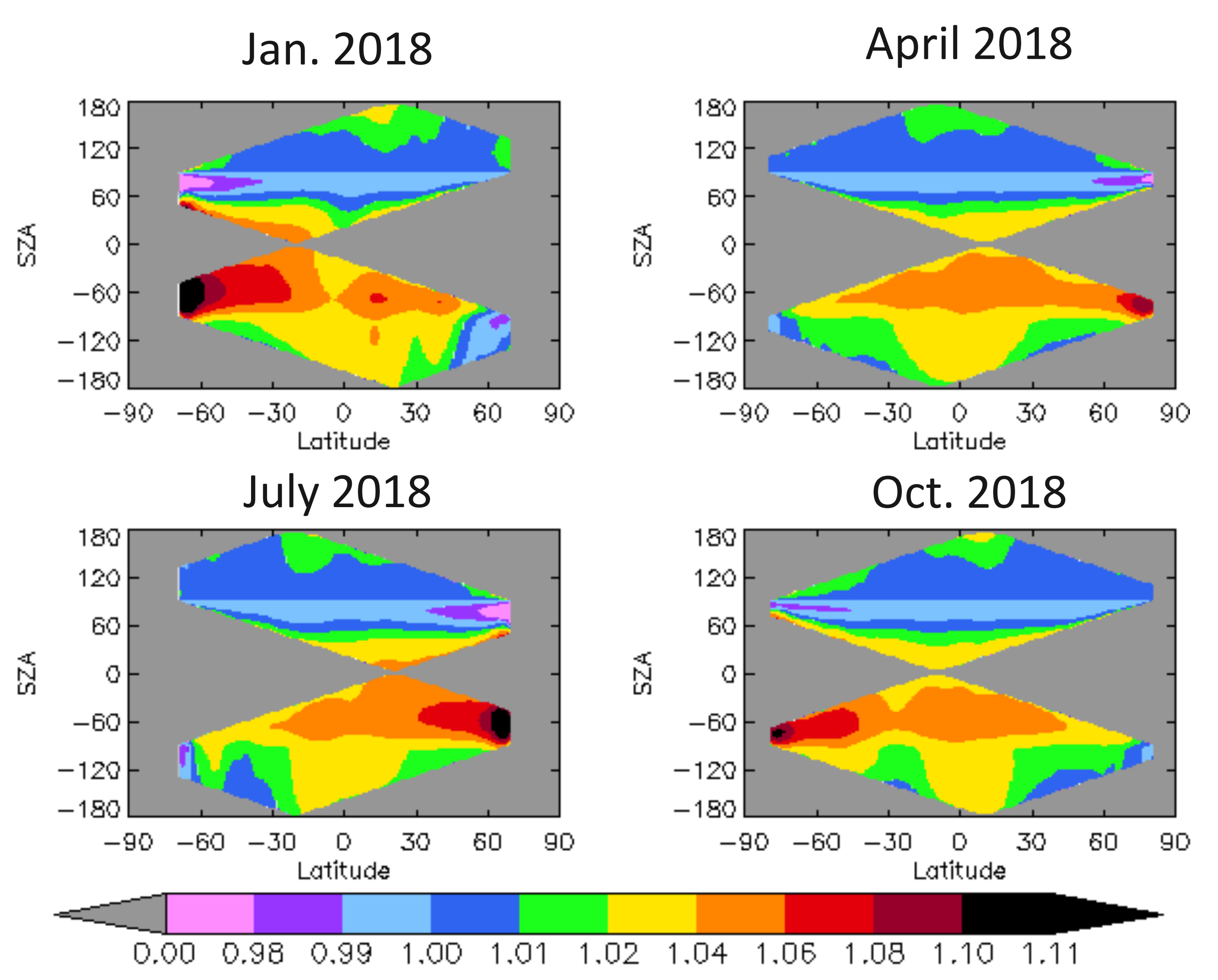
Sunrise Scale Factors



Spatial and Temporal variability of Scale Factors: O_3 at 40km

- Sunrise scale factors are the ratio of the value at each SZA to value at SZA=90 (sunrise)
- Sunrise-sunset asymmetry visible: sunrise scale factor > 1 at sunset

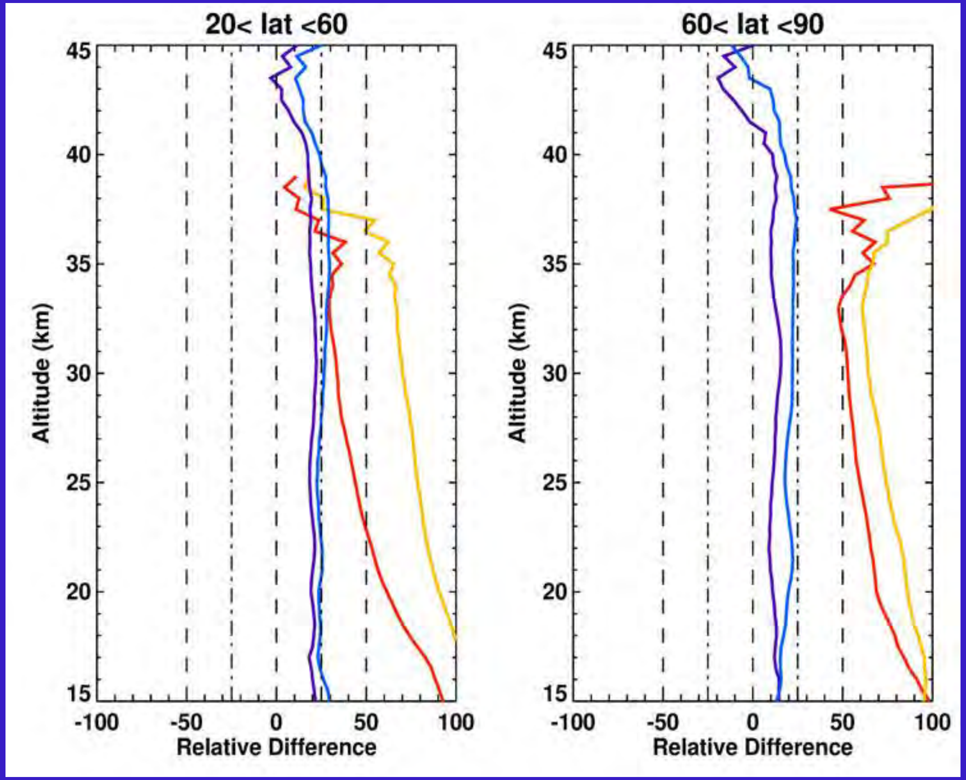
Sunrise Scale Factors



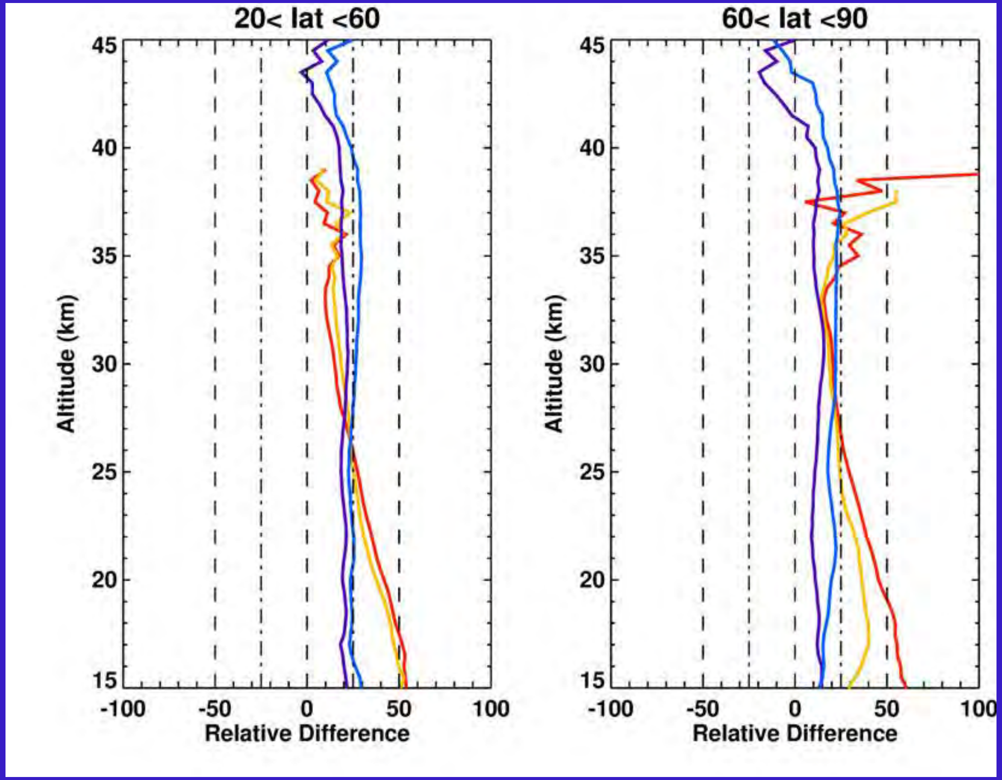
Impact of Applying the Diurnal Corrections

- Applying the diurnal scaling factors improves the agreement between SAGE III and OSIRIS NO_2 measurements

No Diurnal Correction



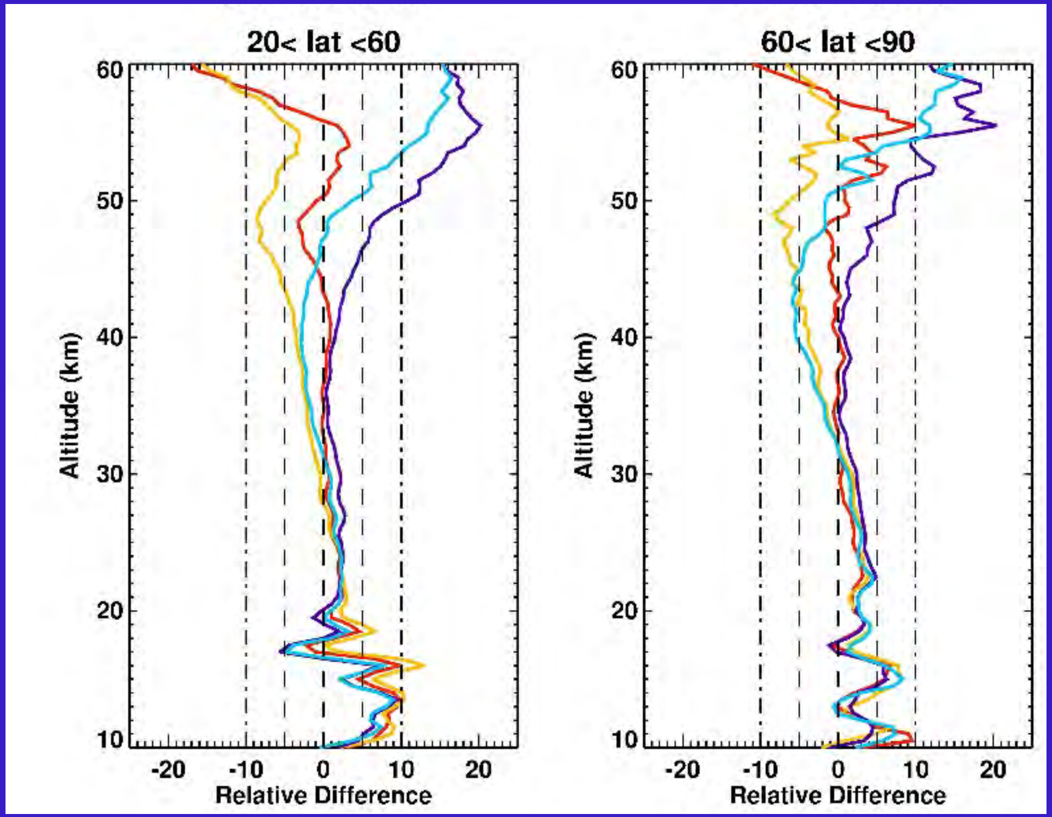
With Diurnal Correction



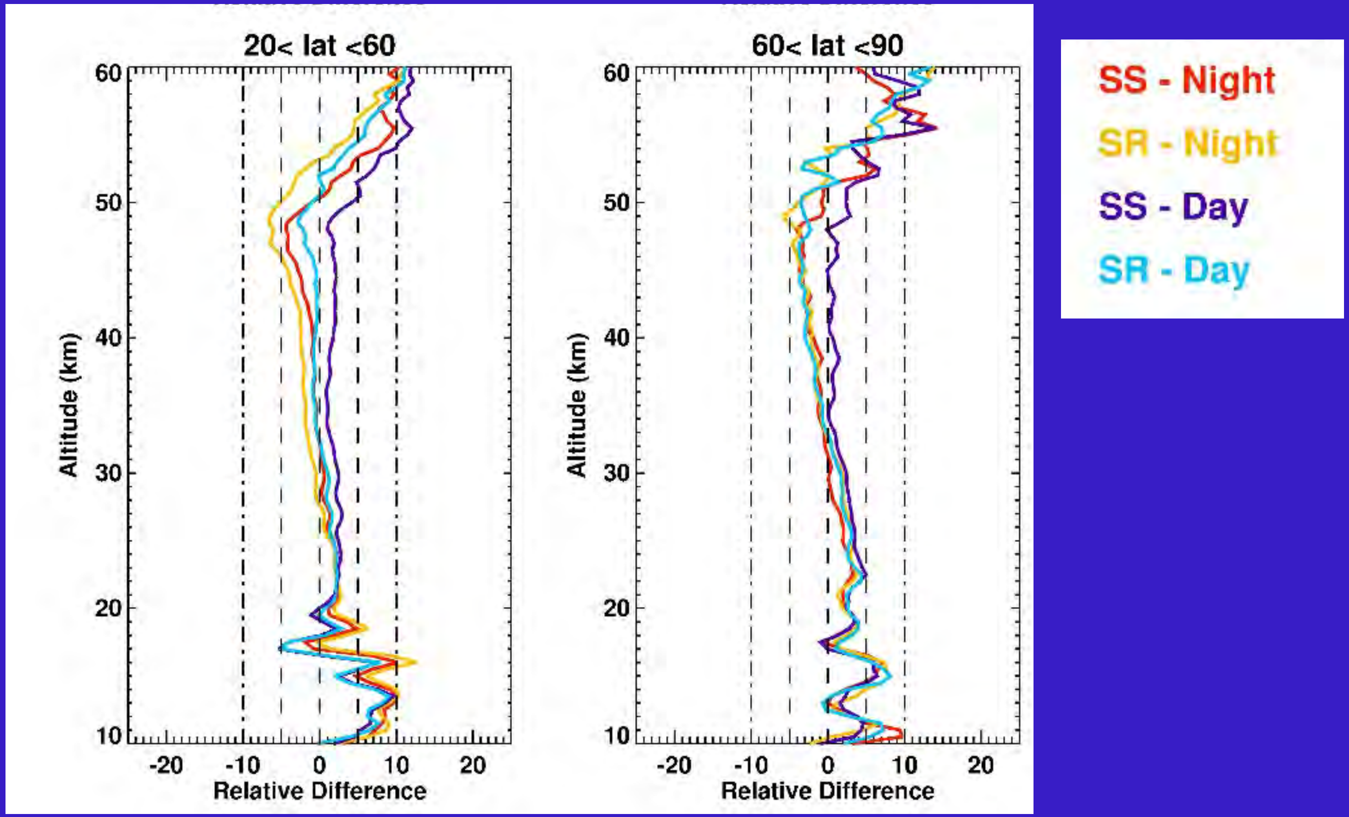
Impact of Applying the Diurnal Corrections

- Applying the diurnal scaling factors improves the consistency of the SAGE III and MLS O_3 comparison

No Diurnal Correction



With Diurnal Correction



Conclusions

- Using the GEOS-GMI chemical model we have developed scaling factors that allow us to adjust observations taken at different solar zenith angles for species with diurnal cycles.
- Diurnal scaling factors from GEOS-GMI are available for O_3 and NO_2.
- We show that these scaling factors improve the comparisons between measurements made at different local times.
- We have produced monthly mean files of the scaling factors - these factors are a function of latitude, altitude and SZA
- Diurnal scaling factors from 2017-2019 are available.