SAGE III/ISS Meeting – October 20, 2020

Accounting for the photochemical variation of NO_2 in the SAGE III/ISS retrieval

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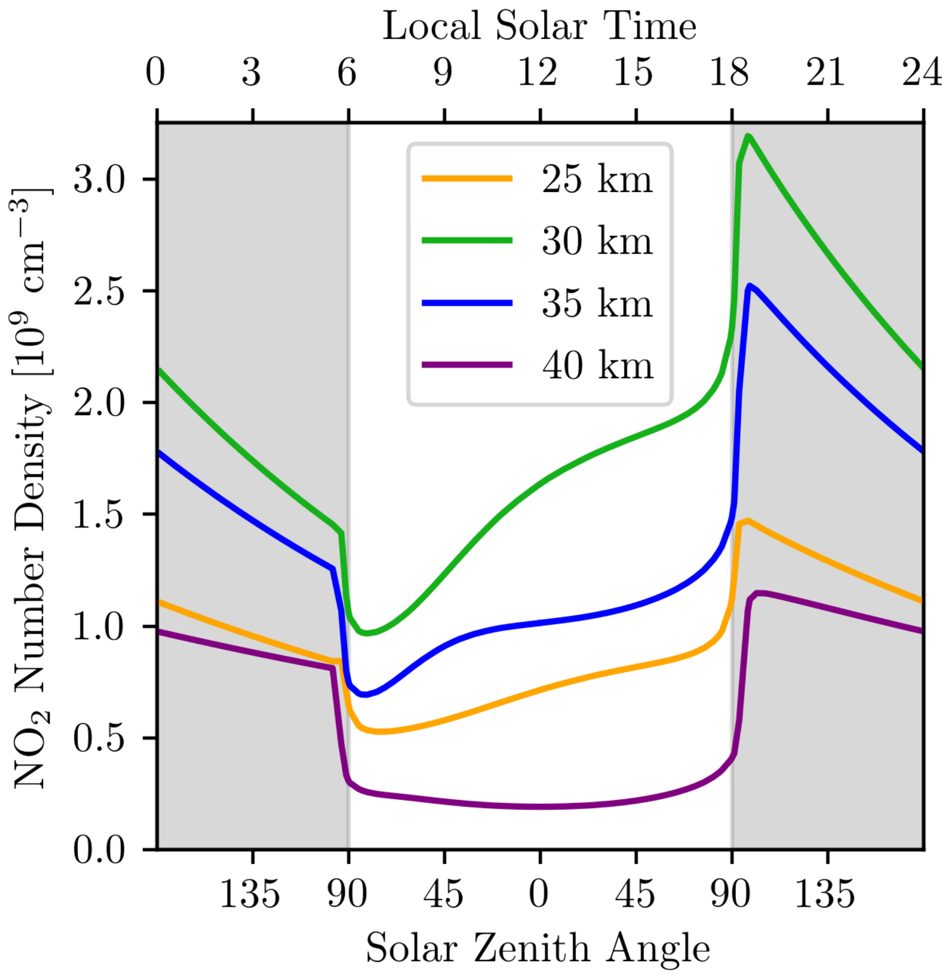
Introduction

- Photochemistry causes the stratospheric NO_2 concentration to vary with solar zenith angle (SZA).
- The SAGE III/ISS retrieval assumes that NO_2 number density has a constant gradient within each layer of the atmosphere.
- This assumption results in a retrieval bias in the SAGE III/ISS NO_2.
- Purpose of this work is to account for diurnal variations in SAGE III/ISS NO_2 retrievals and assess the impact on the resulting number densities.

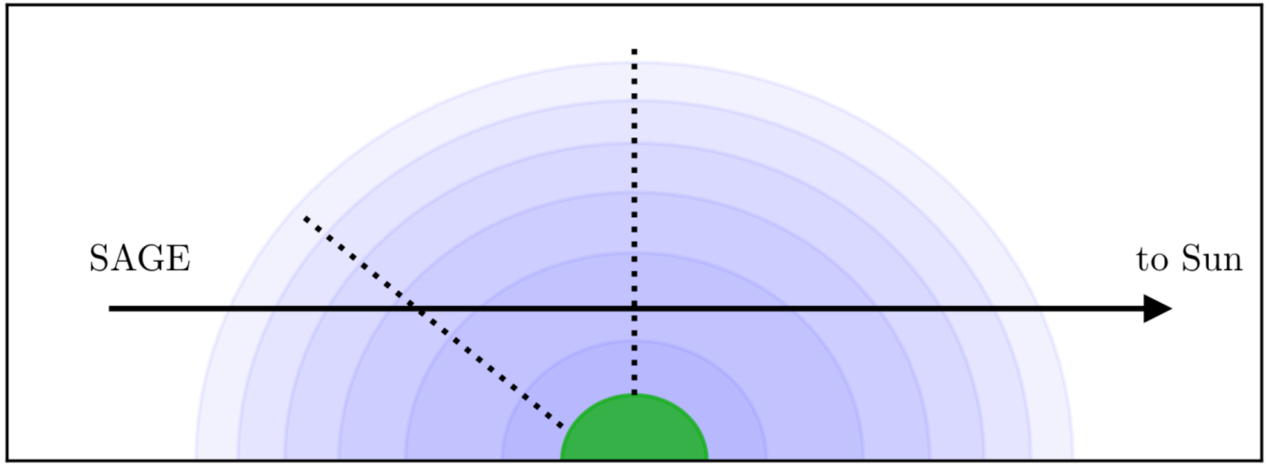
NO_2 Photochemistry

- Decrease in NO_2 at sunrise as it is photolyzed to NO.
- Increase at sunset as NO production ceases.
- Decrease at night from conversion to reservoir species.
- Modelled with PRATMO photochemical box model.



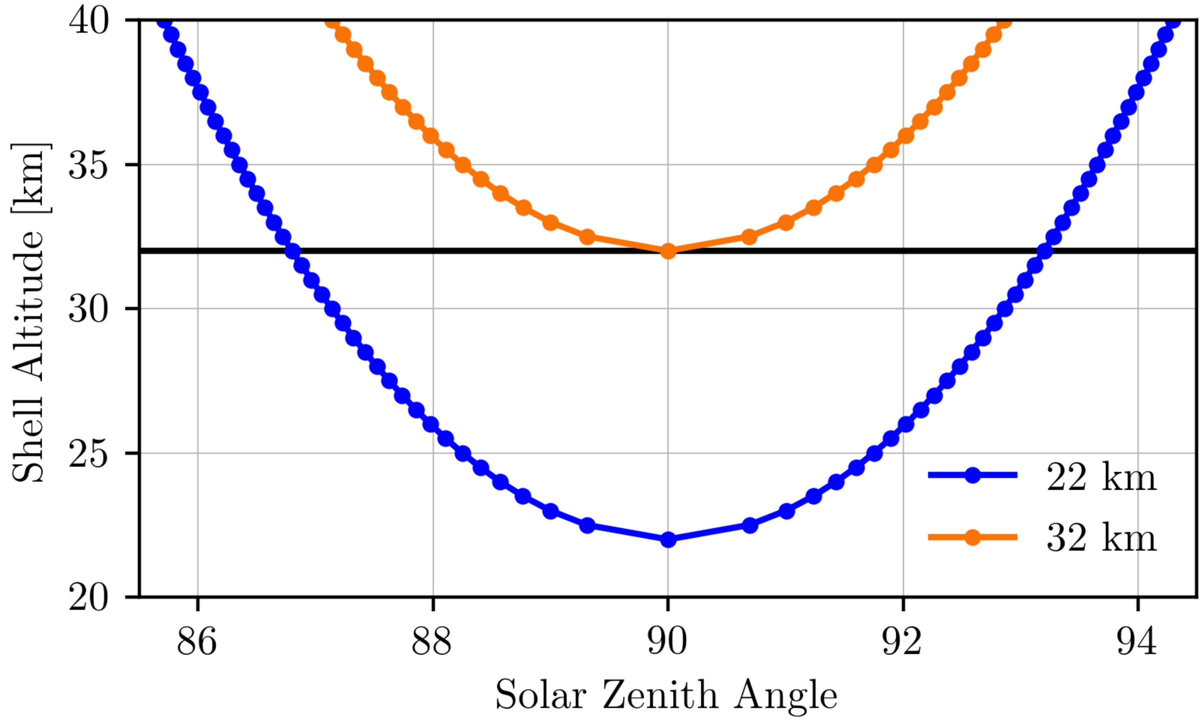
SAGE III/ISS Measurements

- During each occultation SAGE III/ISS looks through multiple layers of the atmosphere.

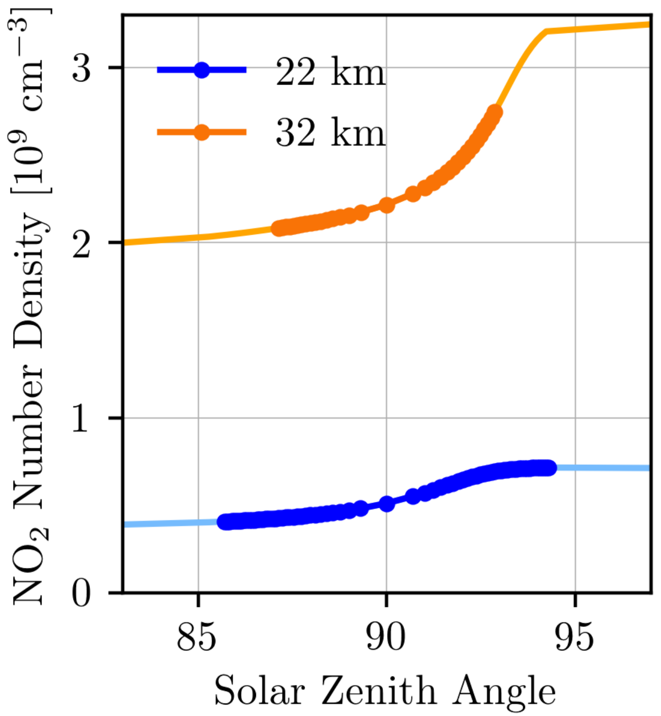


- Retrieval assumes that the number density of each constituent has a constant gradient within each layer (shell).

NO_2 along the SAGE III/ISS Line of Sight (LOS)



Change in SZA with shell altitude along two lines of sight for a simulated sunset occultation.



Change in NO_2 at tangent altitudes of 22 km and 32 km for the same simulated sunset occultation.

Scaling the NO_2 – Part 1

- Account for diurnal variations by scaling NO_2 according to SZA at each point along the LOS.
- First “undo” the SAGE III/ISS retrieval to get the optical depths,

$$\tau = \sigma X_0 n_0$$

- X_0 is the path length matrix: each row represents a LOS for a particular tangent point altitude, and each column represents a different altitude through which the LOS passes.

Scaling the NO_2 – Part 2

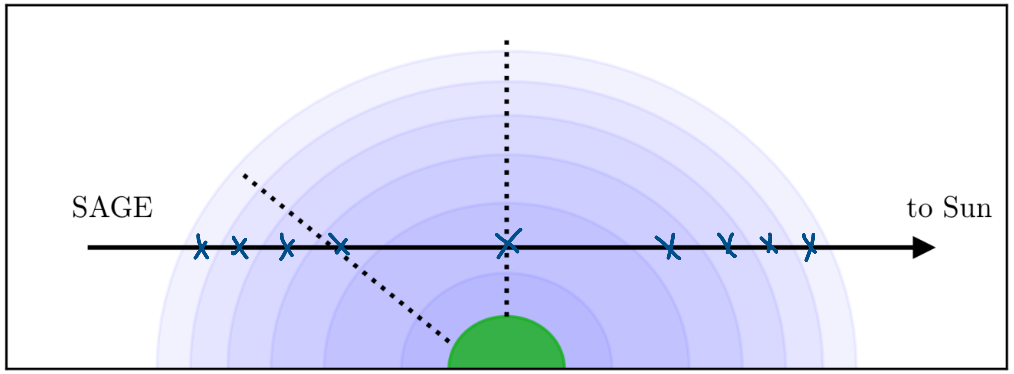
- Use optical depths, along with a new matrix X_{dv} to find the number densities accounting for diurnal variations,

$$n_{dv} = \sigma^{-1} X_{dv}^{-1} \tau$$

- Here each element in the path length matrix is multiplied by a scale factor that depends on solar zenith angle.

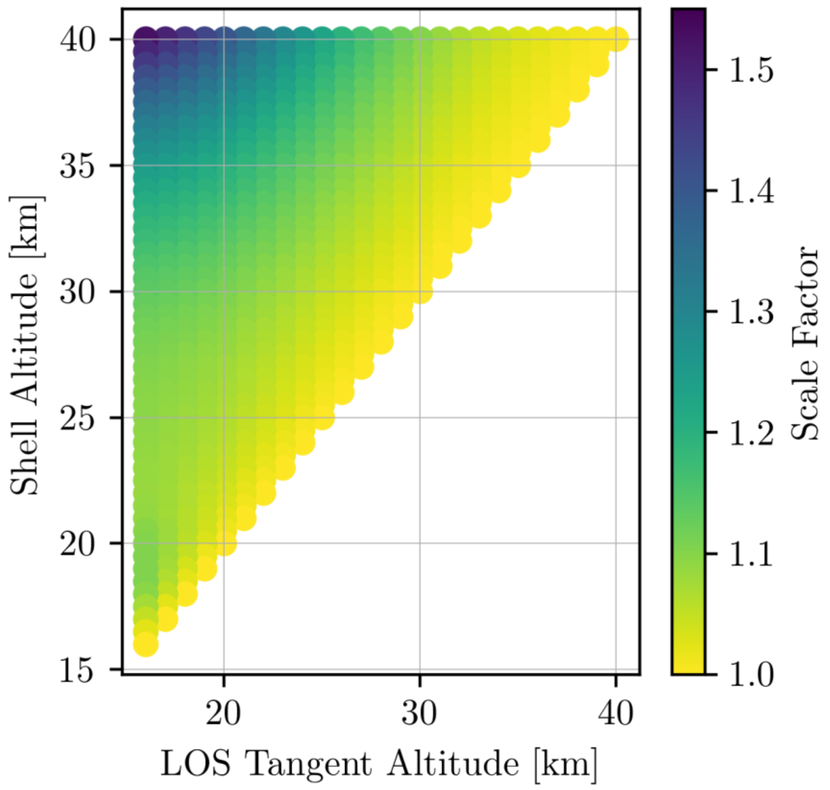
The Scale Factors – Part 1

- LOS for a tangent altitude intersects all the shells above it,

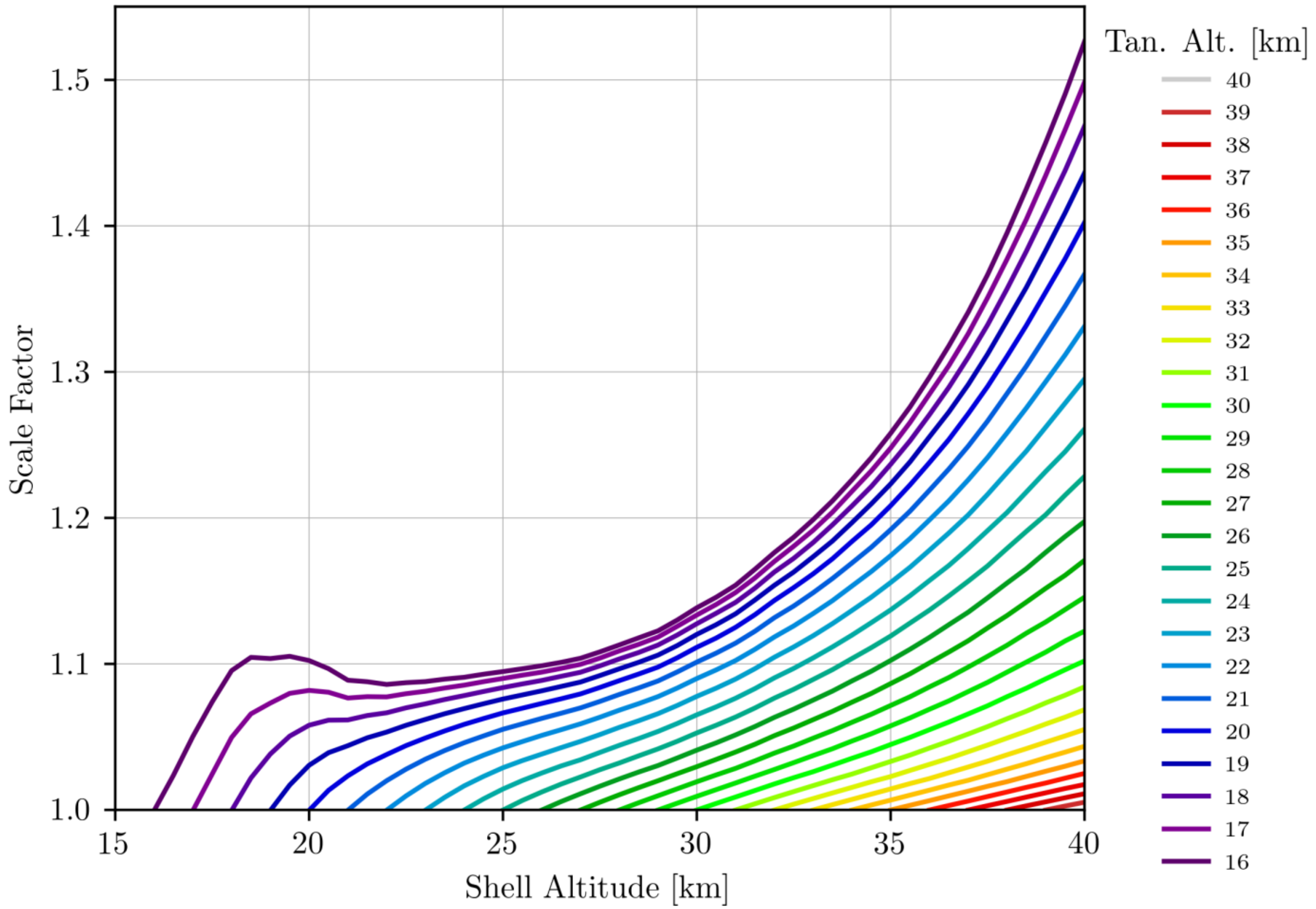


- Use PRATMO to calculate the NO_2 at the solar time corresponding to the midpoint of each intersection.
- For each shell along the LOS, the scale factor is the PRATMO NO_2 at that altitude divided by the PRATMO NO_2 at the tangent point altitude for that LOS.

The Scale Factors – Part 2



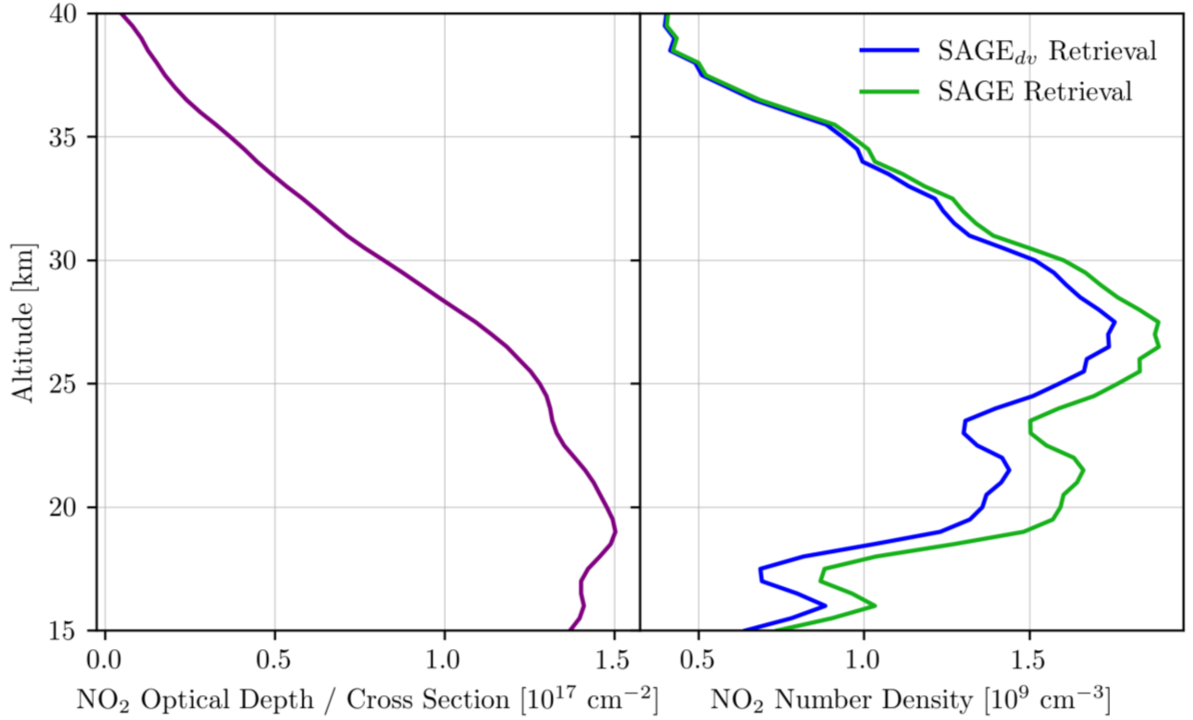
Scale factor matrix for a simulated sunset occultation.



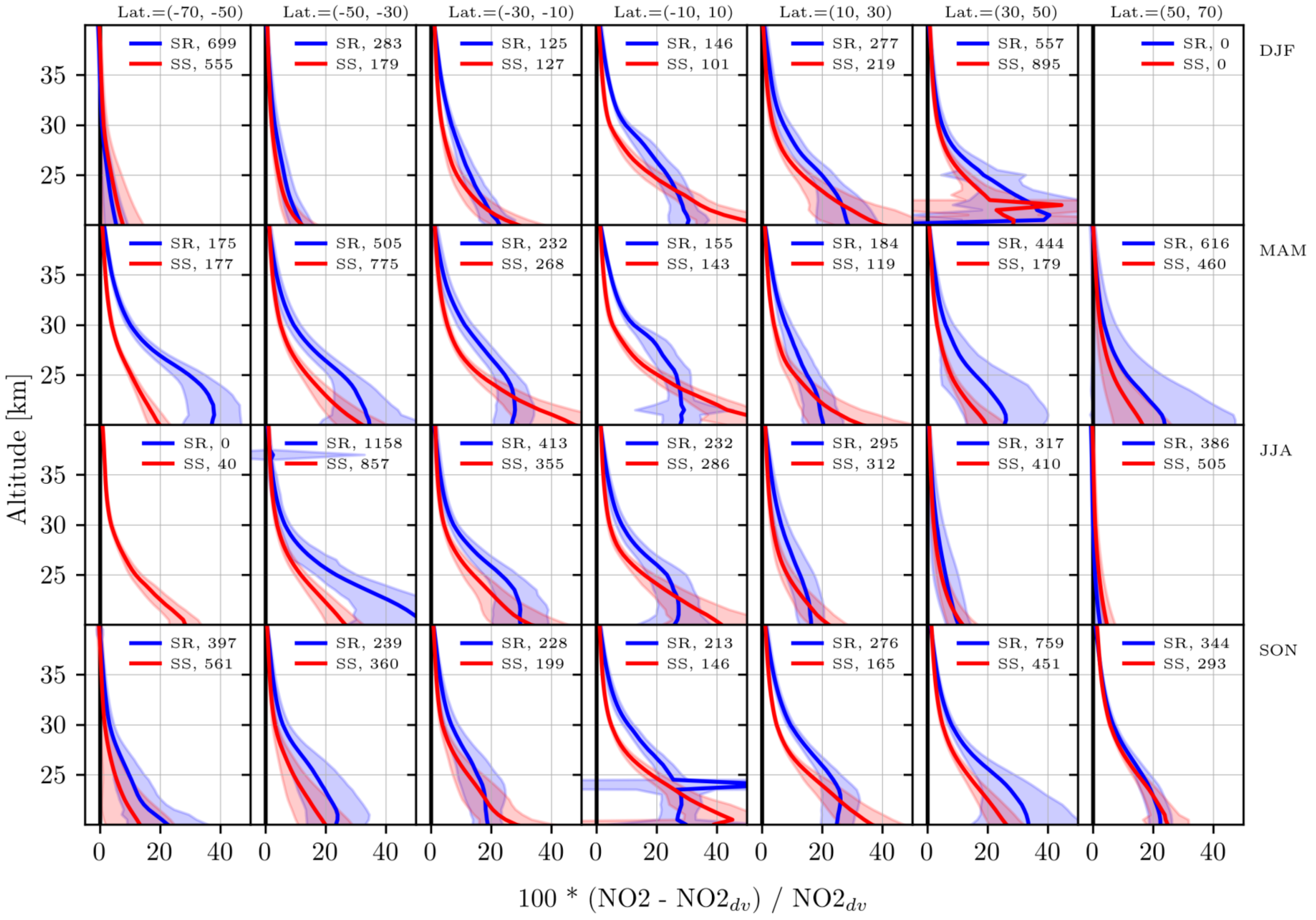
Scale factor along each LOS for a simulated sunset occultation.

Scaling the NO_2 – Part 3

- Use the scale factors along with the optical depths to find the NO_2 number density that accounts for diurnal variations.
- Number density from diurnally varying retrieval is always lower.

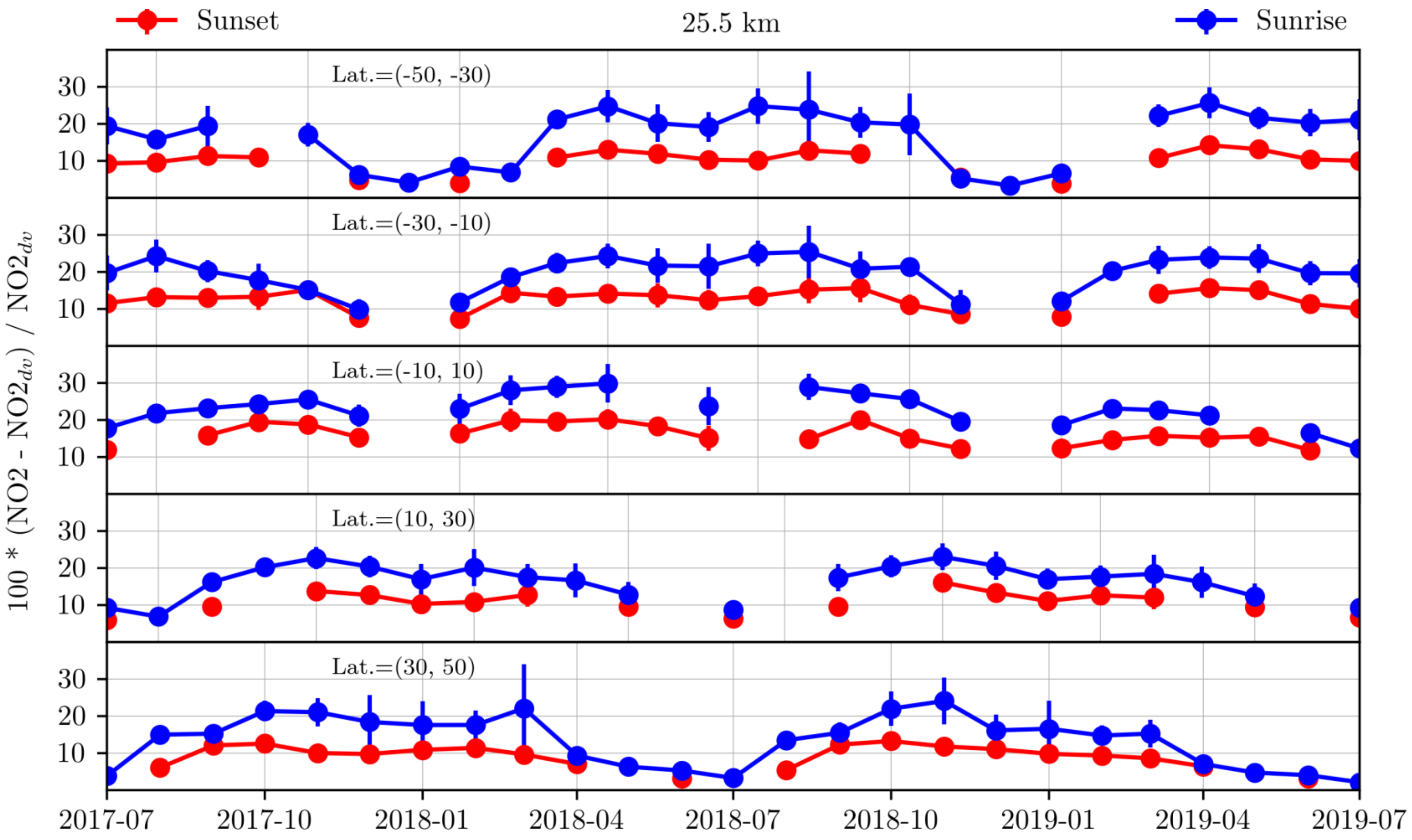


Results – Part 1



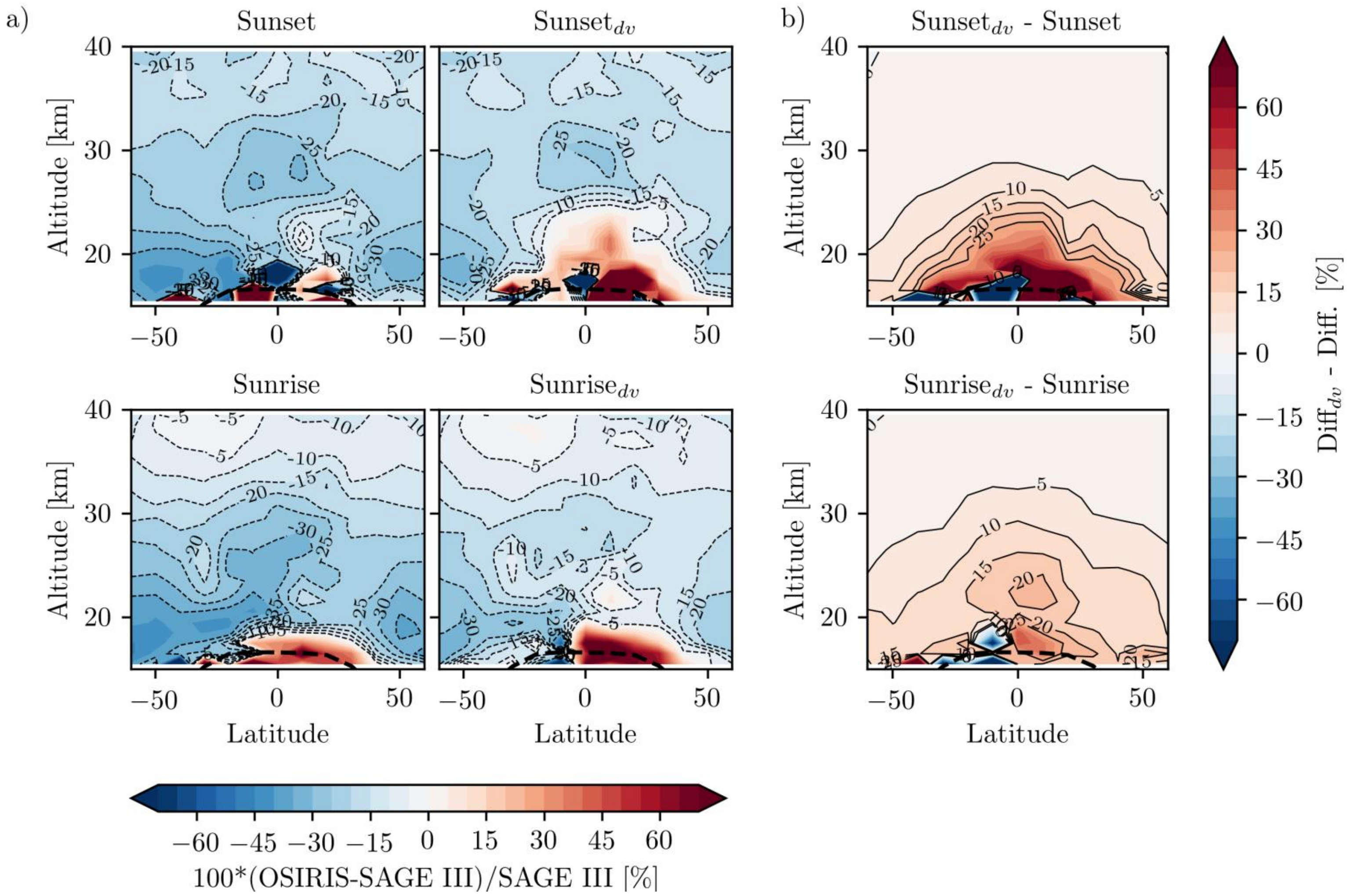
- Difference between SAGE v5.1 retrieval and diurnally varying retrieval.
- Difference becomes greater than 10% below 30 km.
- Greatest difference at high latitudes in winter.

Results – Part 2



- Difference between SAGE v5.1 retrieval and diurnally varying retrieval in the time series at 25.5 km.
- Sunset decrease ranges from 5-20%, sunrise decrease ranges from 5-30%.

Comparison with OSIRIS



- Difference between coincident OSIRIS and SAGE III NO_2 measurements for both SAGE retrievals.
- SAGE NO_2 biased high, better agreement after including diurnal variations.

Conclusions

- We developed a new retrieval that uses publicly available SAGE III/ISS NO_2 data that accounts for photochemical variations along the LOS.
- Neglecting diurnal variations always biases the resulting NO_2 number density high.
- The diurnal effect is most important below 30 km where it becomes greater than 10%.
- The effect is more important at sunrise than sunset and at high winter latitudes.
- Accounting for diurnal variations improves agreement between SAGE III/ISS and OSIRIS NO_2 by up to 20% at lower altitudes.
- Preprint available: https://amt.copernicus.org/preprints/amt-2020-331/