OMPS SDR Validation via Forward Simulations

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Outline

- Current issues in UV RT simulations
- Factors affecting the RT simulation
- OMPS simulation vs observations
- Summary and conclusions

Current RT Models for UV Simulations

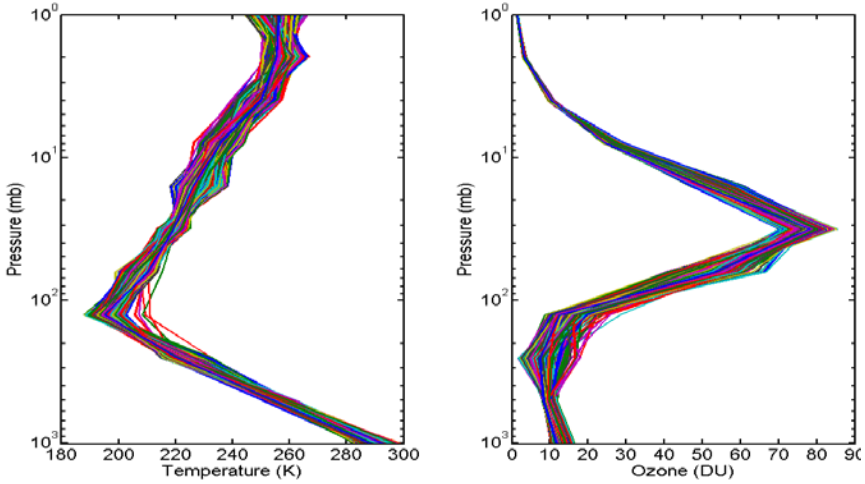
- **TOMRAD**: TOMS RADiative transfer model. The latest version: 2.24
  - Clear-sky, Rayleigh scattering and gases absorption (mainly Ozone) in UV band
- **UNL-VRTM**: UNified Linearized Vector Radiative Transfer Model *(Wang et al, 2014)*.
  - It is an integrated vector radiative transfer model. The core model is VLIDORT *(Spurr, 2008).* The latest version : 2.7
  - Including most of significant RT processes in atmosphere
- **SCIATRAN: (***Rozanov et al., 2014)*
  - An integrated model and the latest version: 3.6.9
  - Both Vector and Scalar model
  - Including all of significant RT processes in atmosphere and ocean
  - The Rotational Raman Scattering (RRS)

Data Used in RT Model

Collocated OMPS/MLS data generated at STAR using NASA algorithm

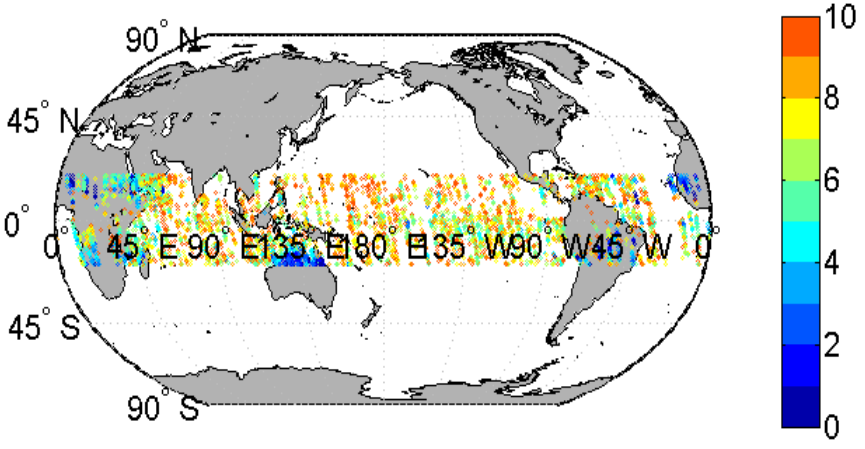
- OMPS wavelengths, solar and satellite viewing geometry, and surface albedo.
- MLS Ozone profiles
- Climatological temperature profiles

The number of profiles: 4478



Co-located OMPS/MLS Ozone Profiles (right) and Temperature (left)

Latitude: -20 to 20 degrees

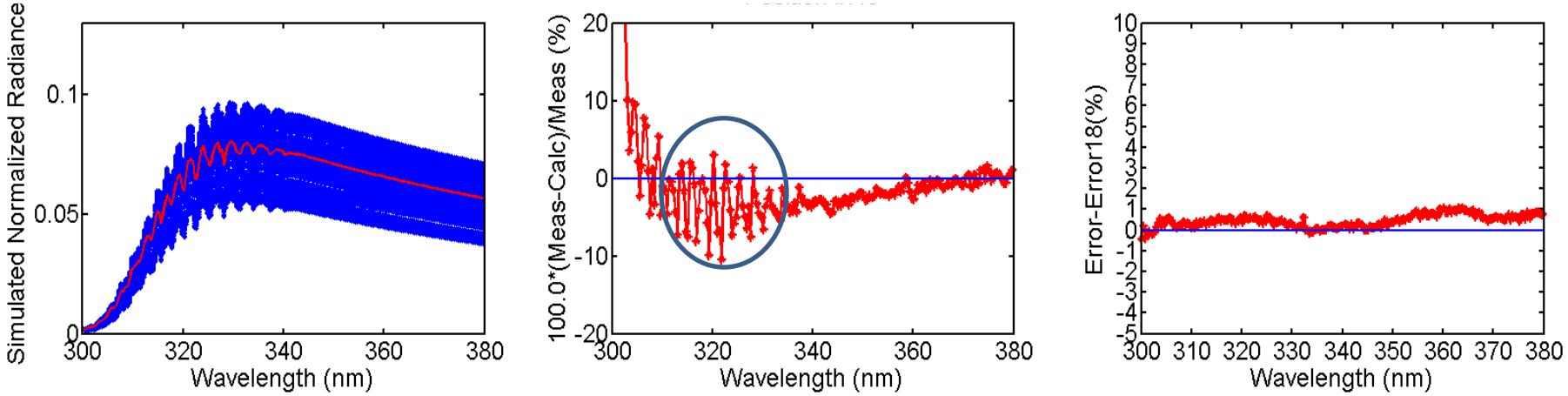


Surface Reflectivity at 331 nm

Current Issues in TOMRAD Simulations

Simulated Normalized Radiance at OMPS cross-track Position 19

Simulated Normalized Radiance Observation - Simulation (Obs-Sim) $(Obs\text{-}Sim)_{19} - (Obs\text{-}Sim)_{18}$

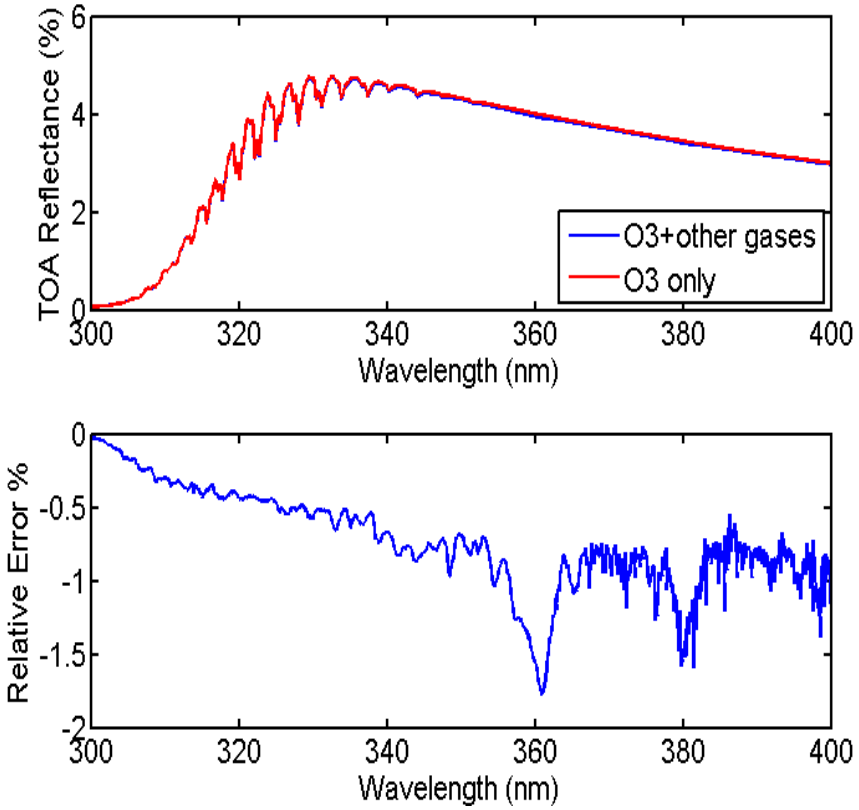


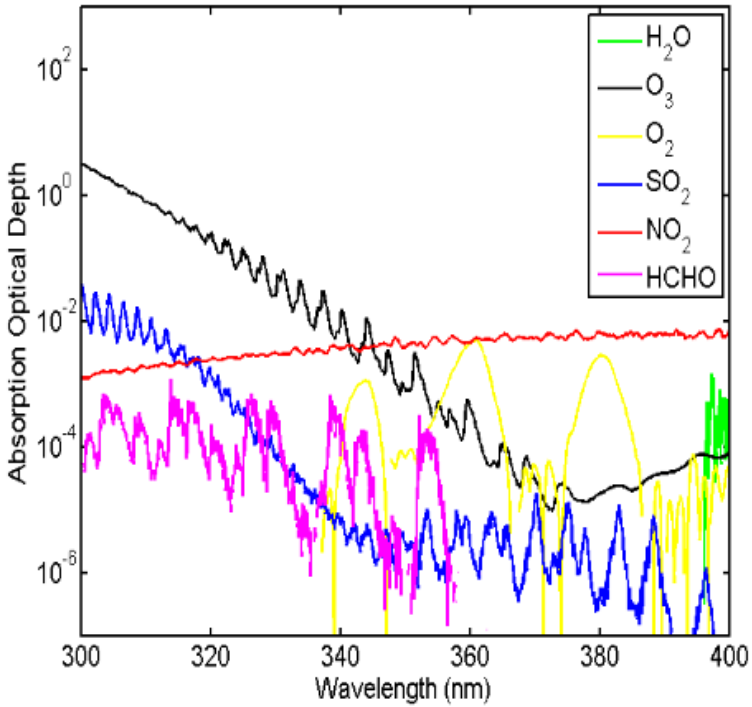
- Normalized Radiance (NR= radiance divided by solar flux)
- The simulated OMPS NR for position 19 (left); the averaged percentage difference (middle); the difference between position 19 and 18 (right).
- Large deviations between simulations and observations for wavelengths less than 340 nm.
- The large oscillation is not noise but physical effect not accounted for very well in the RT simulation.

Factors Influencing RT simulation in UV Region

- Absorption gases: Ozone and other absorption gases
- Surface reflectance
- Rayleigh scattering
- Rotational Raman Scattering

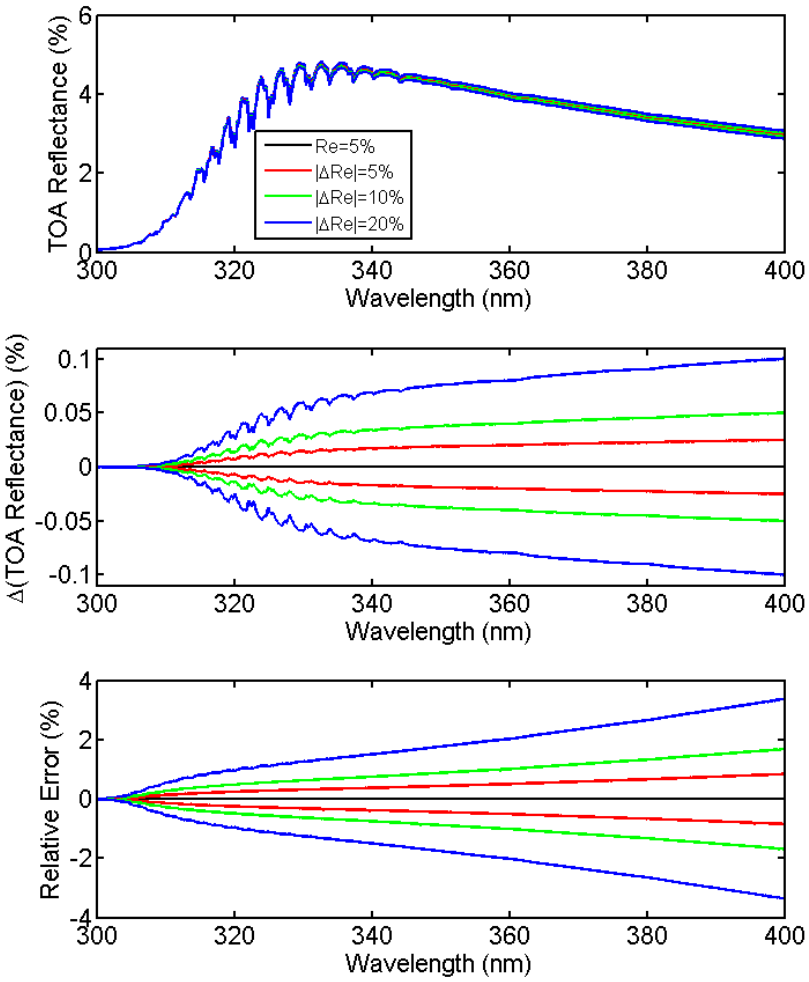
Simulations Including More Gaseous Components



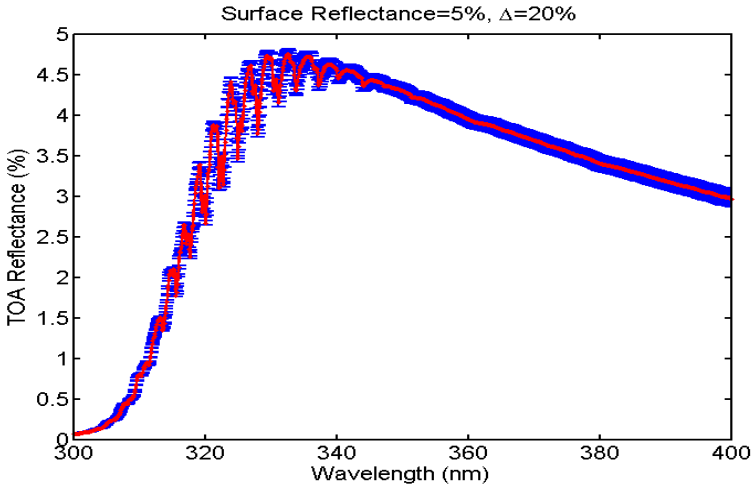


- In TOMRAD simulation, only ozone considered
- Two simulations, one is only ozone and the other more absorption gases are considered.
- **If only ozone is considered, the TOA reflected radiance can be overestimated** by up to 2% for wavelengths larger than 340 nm

Effects of Surface Reflectance



Error Bar for ΔRe=0.20



- Surface reflectance fixed to be 0.05 for all wavelengths
- A disturbance, 5%, 10%, and 20%, to the surface reflectance.
- The errors increase with increasing of wavelengths.
- In TOMRAD simulation, the OMPS surface reflectance at 331 nm is used for all wavelengths. **This assumption may cause significant errors to the TOA reflectance.**

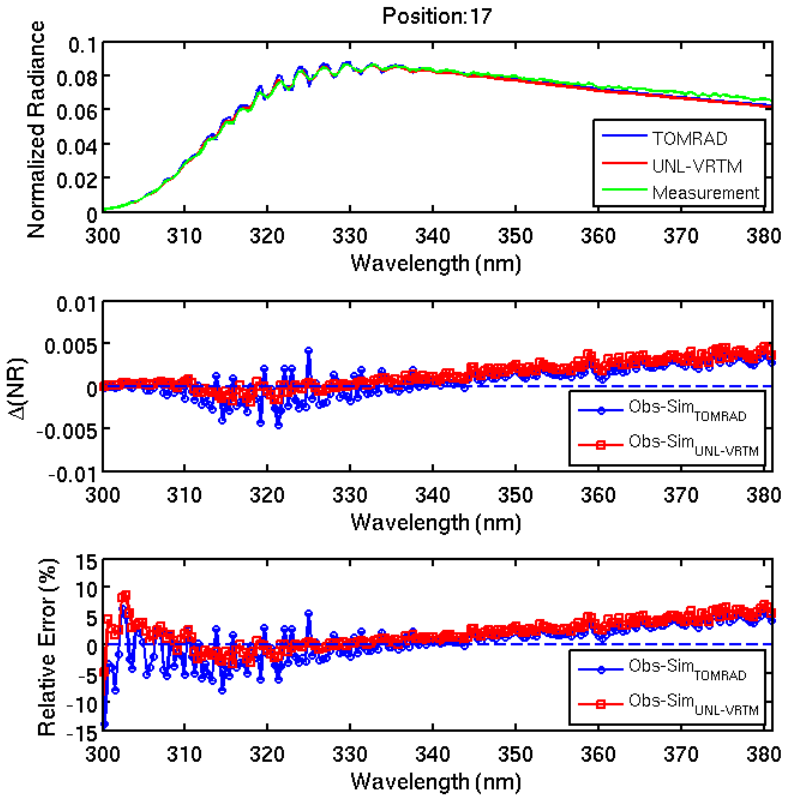
Current Issues in TOMRAD Simulation

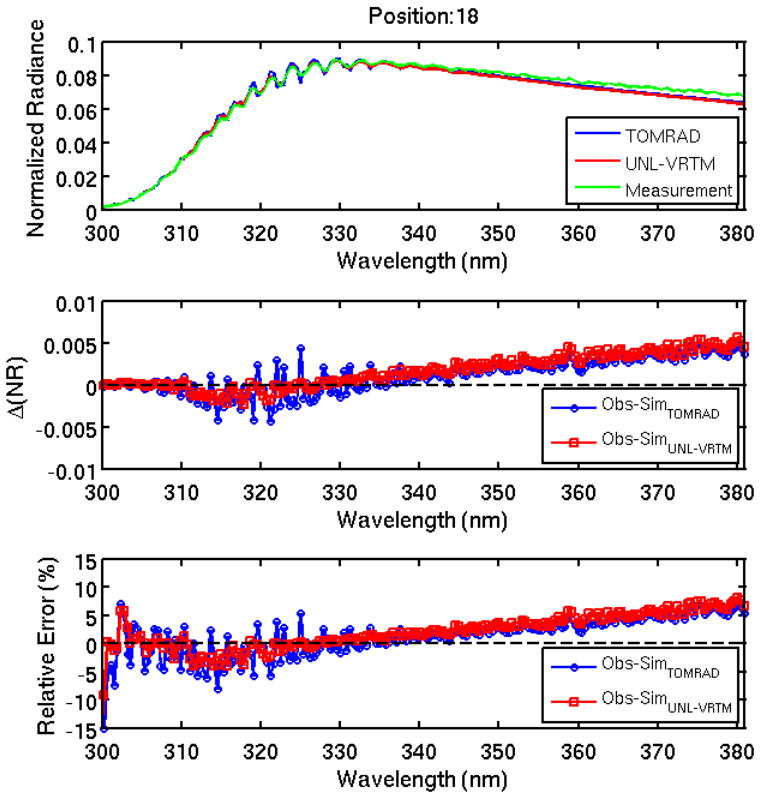
- In TOMRAD model, only Ozone absorption considered, and the Ozone absorption cross section data (from Bass and Paur (1985)) only covers a wavelength range from 241 nm to 342 nm.
- Fixed surface reflectance for all wavelengths
- Pre-calculated LUTs for Rayleigh scattering coefficient suggested by Bates (1984).
- Considering no Raman scattering

Our solutions

- Using UNL-VRTM model
- Considering more absorption gases in UV band such as Ozone, NO2, SO2 etc. The Ozone absorption cross section data is from SAO (Smithsonian Astrophysical Observatory) and other gases absorption cross section is from the latest HITRAN2012 database.
- Rayleigh scattering optical depth and depolarization ratio are calculated accurately from a set of equations recommended by Bodhaine et al. (1999).
- Adjusting the surface albedo
- Using SCIATRAN model to calculate the effect of rotational raman scattering (RRS)

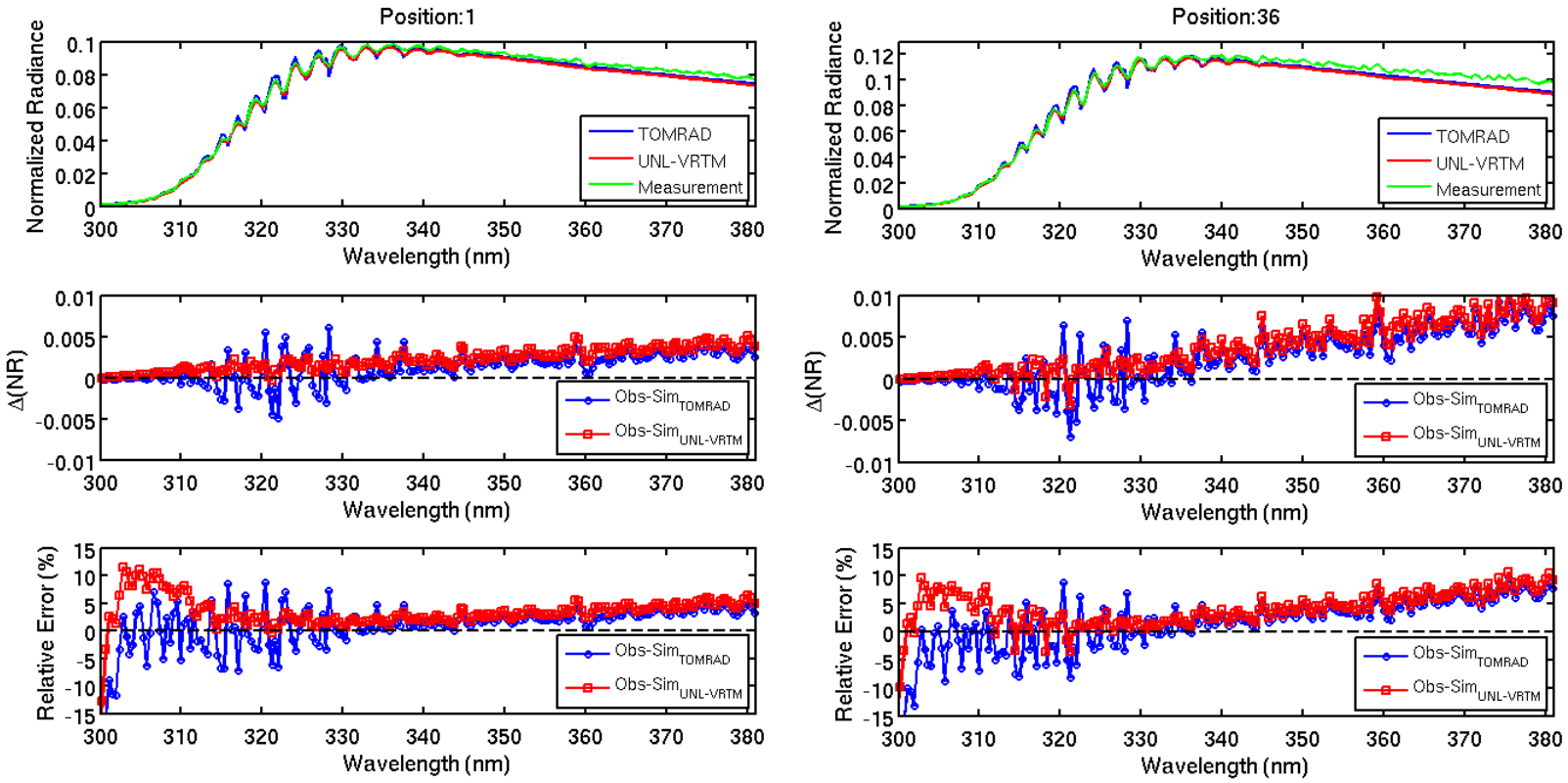
Simulations vs. Measurements
Averaged for all Profiles at near Center Positions





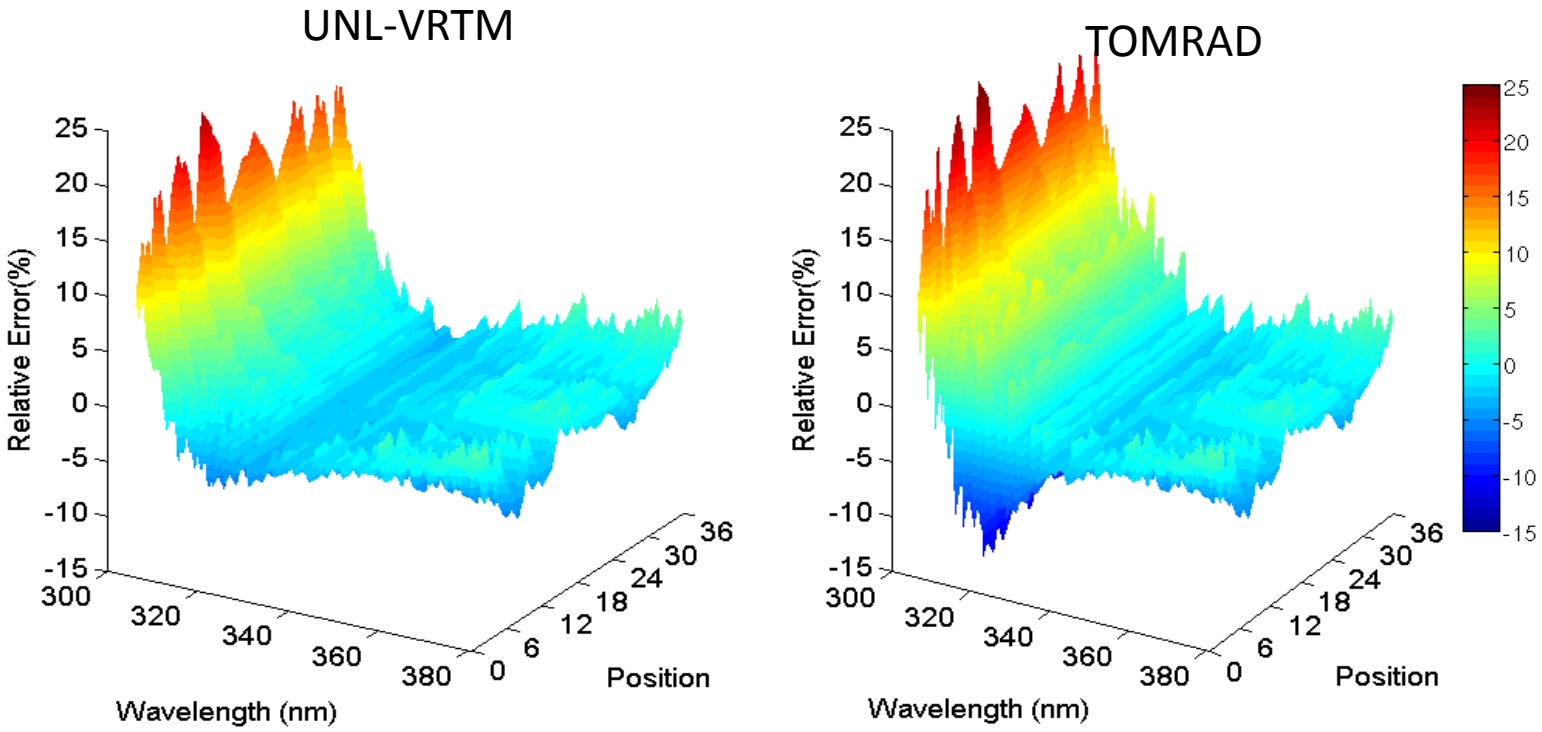
- Averaged simulation and measurement at two near center cross-track positions, 17 and 18
- Using the UNL-VRTM model, the large deviations at near center cross-track positions can be reduced

Simulations vs. Measurements
Averaged for all Profiles at Wing Positions



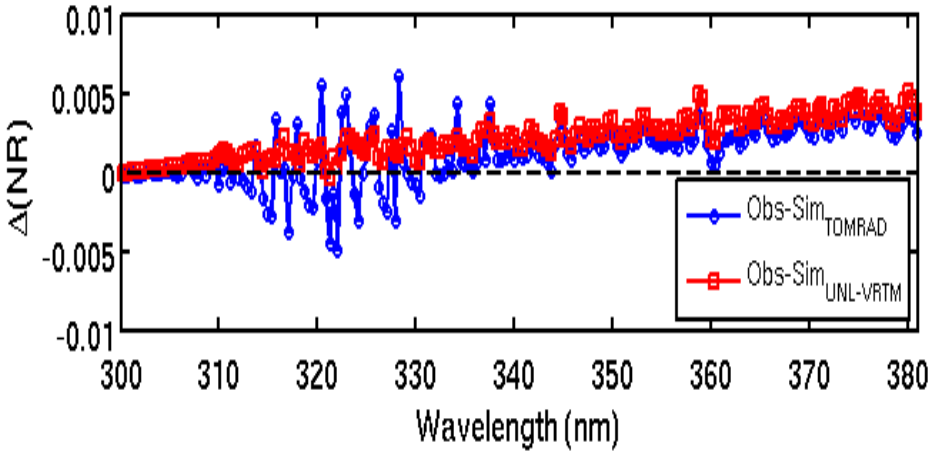
- Similar to the last slide, but for two wing positions of OMPS, 1 and 36
- Using the UNL-VRTM model, the large deviations at two wing positions can be reduced

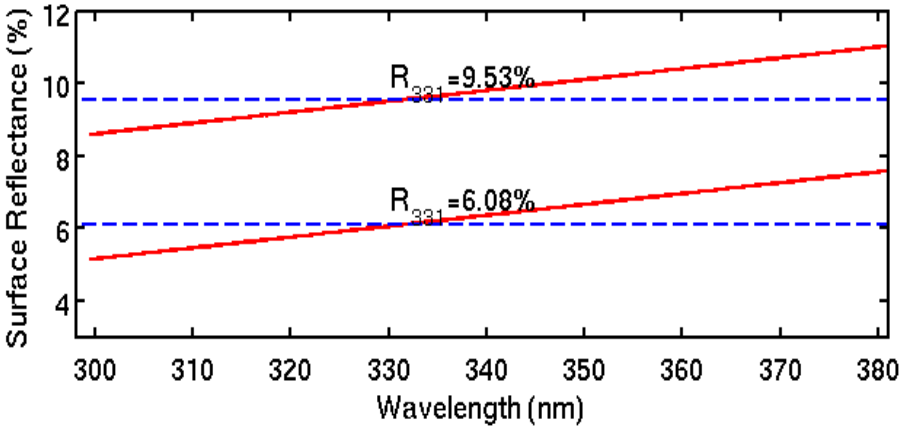
Simulation vs. Measurement



- The surface plot of percentage difference between simulation and measurement for all 36 cross-track positions at different wavelengths.
- Using the UNL-VRTM, with consider of more absorption gases, together with an accurate method to calculate Rayleigh scattering, The large deviations can be significantly reduced for all 36 cross-track positions at wavelengths of 310-340 nm

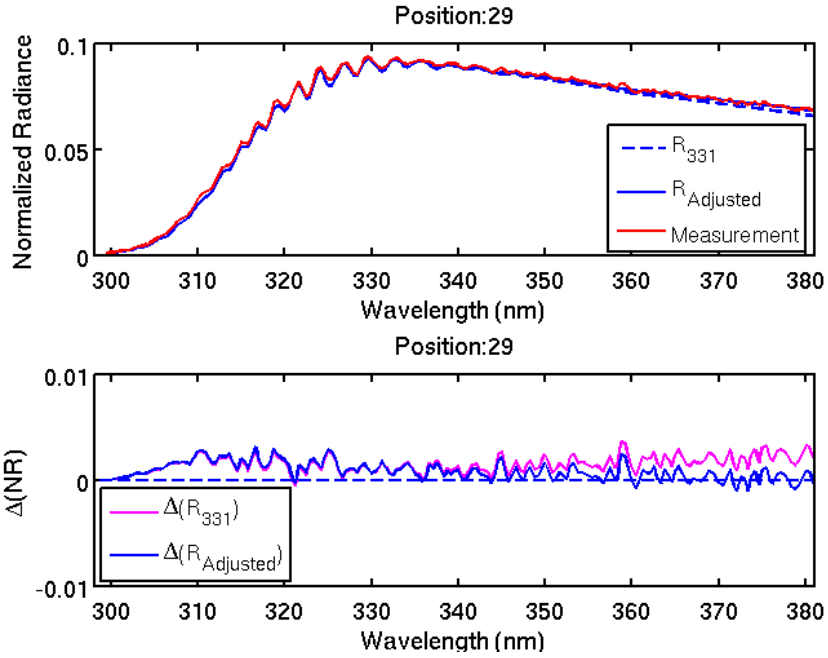
Adjusting the Surface Reflectance

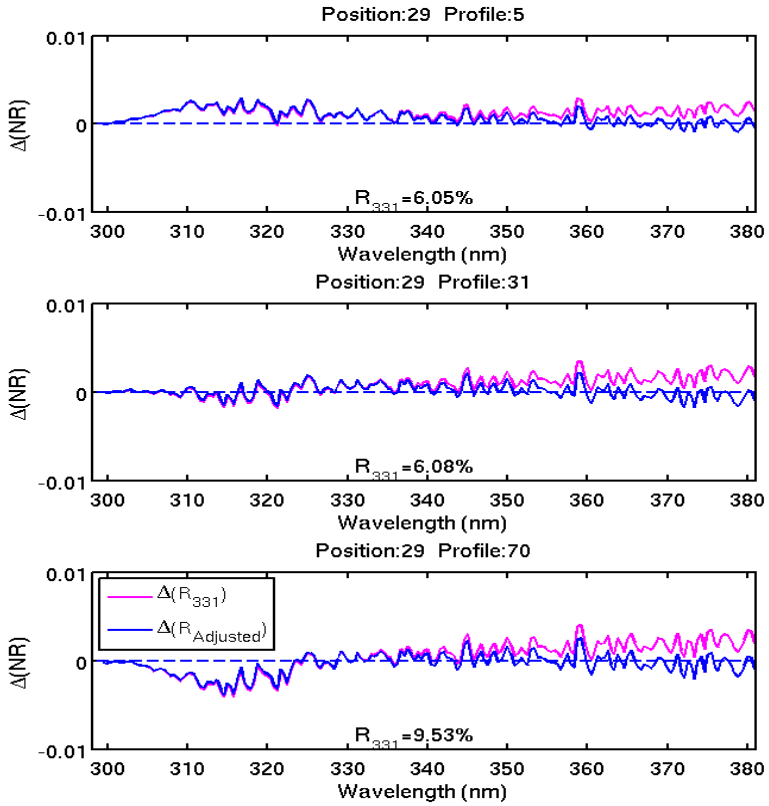




- There is always a positive slope for the curve of NR difference between simulation and measurement.
- Based on the limited surface reflectance dataset, ASTER from NASA JPL, the reflectance increases with the increase of wavelength in UV band.
- In the simulation, the surface reflectance at 331 nm was used for all wavelengths.
- This may underestimate the reflectance for wavelength larger than 331 nm and overestimate it for wavelengths smaller than 331 nm.
- We adjusted the surface reflectance slightly based on the reflectance at 331 nm and suppose there is a positive slope of 0.0003.

Measurement vs. Simulations (Adjusted Surface Reflectance)

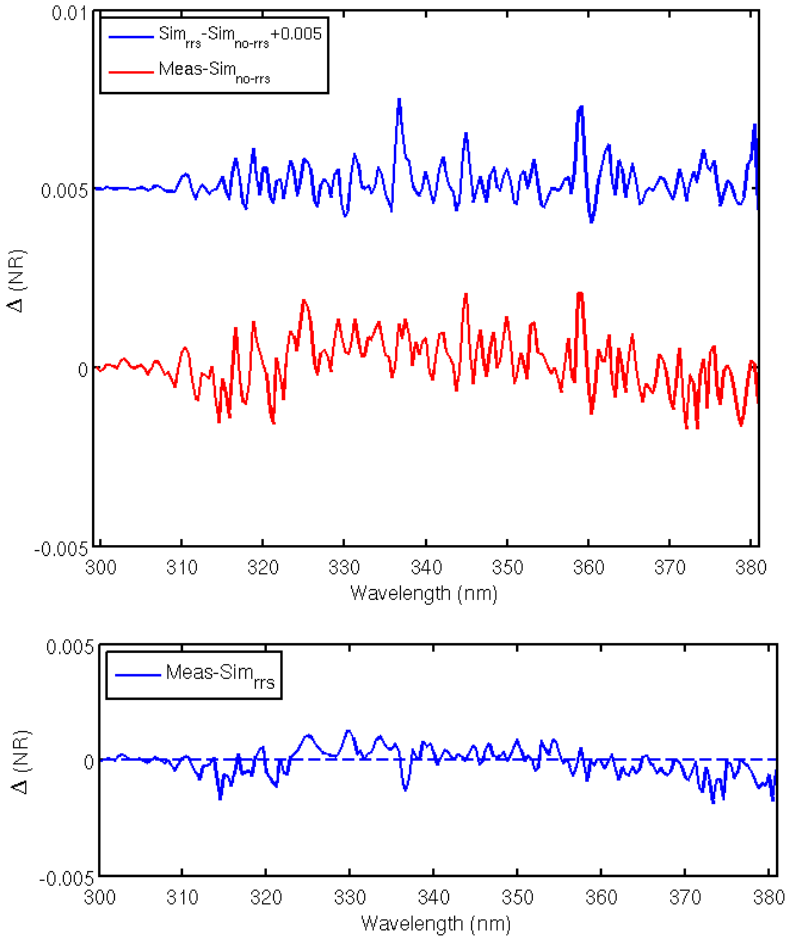




- The comparisons between OMPS measurements and simulation by using adjusted surface reflectance.
- The curve of difference between simulation and measurement becomes more horizontal (blue curve) for both individual profile (right) and average for all profiles (left).
- **There still have some small fluctuations. Carsed by raman scattering?**

The Effect of Raman Scatting

Position: 29 Profile: 31



- By using the SCIATRAN model, we simulated the effects of RRS. Blue curve is the difference between simulations with and without RRS considered. Red curve is the difference between measurements and simulations from UNL-VRTM.
- The peaks and valleys of two curves matched pretty well at most of the wavelengths.
- If the effect of RRS (blue) is removed from the difference between measurement and simulation (red), the difference will reduce and the curve of difference between measurement and simulation with RRS included becomes smoother.

Summary and Conclusions

- By using RTMs, we investigated the effects of different factors on TOA reflected radiance.
- The assumption that surface reflectance within UV region is a constant may cause significant errors to the TOA reflectance.
- By using UNL-VRTM, a vector RTM with consider more absorption gases and an accurate calculation of Rayleigh scattering optical depth, the large variations between measurements and simulations from TOMRAD were significantly reduced at the wavelengths 310-340 nm.
- By using SCIATRAN, a RTM with consider of RRS, the difference between measurements and simulations can be reduced greatly. If the effect of RRS removed, the curve of measurement-simulation difference can be smoothed to some extent, not completely but promising for most of the wavelengths larger than 310 nm.

Thank you!