Simulation of UV Radiance Using UNL-VRTM

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1. Introduction

The Unified Linearized Vector Radiative Transfer Model, UNL-VRTM, is used to simulate the radiances at ultra-violet wavelengths. Using the collocated Microwave Limb Sounder (MLS) ozone profiles with Suomi NPP OMPS SDR data, the simulation uncertainties in terms of bias and accuracy are characterized. In general, the differences are less than 5% across OMPS scan position at all channels.

The bias is in general attributed to several factors such as variable absorption gases, assumption of surface reflectance, Rayleigh scattering on TOA reflected radiance in UV region. The sensitivity studies show that considering only ozone, and/or the assumption of constant surface reflectance within UV region may cause significant errors to the TOA reflectance. The aerosols are also important components for accurate simulation of hyper-spectral UV radiance. It is shown that that the simulated radiances may increase, comparing with those from clear sky condition if non-absorbing aerosol (e.g. sulfate) is considered in RTM. Conversely, the radiances decrease if absorbing aerosols (e.g. soot) is taken into account. With an alternative radiative transfer model, SCIATRAN which includes the effect of rotational Raman scattering, the simulated difference between measurements and simulations can be reduced to some extent, particularly for the wavelength larger than 330 nm.

Implications of this study is several folds: 1) Forward simulations of UV radiances can be a powerful tool for OMPS validations and 2) it is very likely to explore the direct UV radiance assimilation in NWP models .

2. Review of Radiative Transfer Models

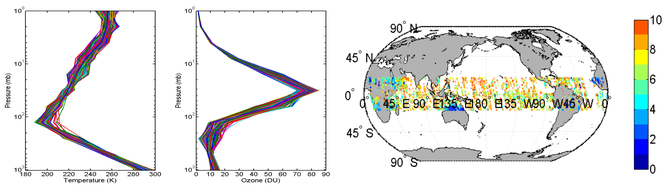
- TOMRAD is a vector radiative transfer model and is specifically used in UV region radiance simulation for pure Rayleigh scattering atmosphere with gases absorption (mainly ozone) (*Dave, 1964*). Only considering ozone absorption and Rayleigh scattering, Using fixed surface reflectance (331 nm) for all wavelengths, Cannot handle multiple scattering and absorption by cloud and aerosol particles, Without considering the effects of Raman scattering
- The Unified Linearized Vector Radiative Transfer Model (UNL-VRTM) is a comprehensive software package for the simulation of atmospheric remote sensing observations and for the inversion of aerosol, gas, cloud, and/or surface properties from these observations (*Wang et al., 2014*). The forward radiative transfer model integrates five modules for the calculation of aerosol single scattering, gas absorption and radiative transfer. These five modules include a linearized vector radiative transfer model VLIDORT, a linearized Mie and T-matrix scattering code, a surface bidirectional reflectance distribution function (BRDF) module, and a module for line-by-line calculation. The outputs include not only the Stokes 4-vector elements, I, Q, U and V, but also contain their sensitivities (Jacobians) with respect to physical and optical parameters of aerosol and/or cloud.
- SCIATRAN is an integrated software package for the modeling of radiative transfer processes in the terrestrial atmosphere and ocean, especially, including the calculation of Raman scattering (*Rozanov et al., 2014*).

3. Technical Approaches for Simulating OMPS

3.1 Radiative Transfer Model:

- Using UNL-VRTM model: It is an integrated vector radiative transfer model, including most of significant RT processes in atmosphere.
- Adjusting the surface albedo
- Using SCIATRAN model to calculate the effect of rotational Raman scattering

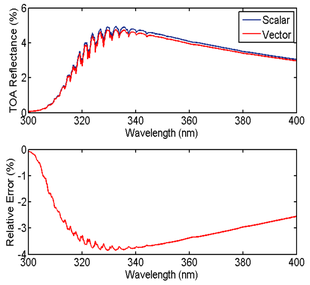
3.2 Collocated Data



- OMPS wavelengths, solar and satellite viewing geometry, and surface albedo
- MLS ozone and temperature profiles
- Latitude: -20 to 20 degrees

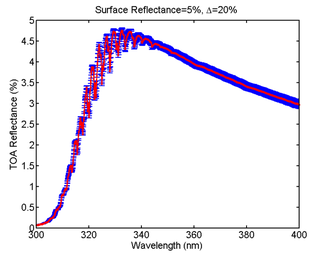
3. Sensitivity Tests

a) Scalar *vs.* Vector



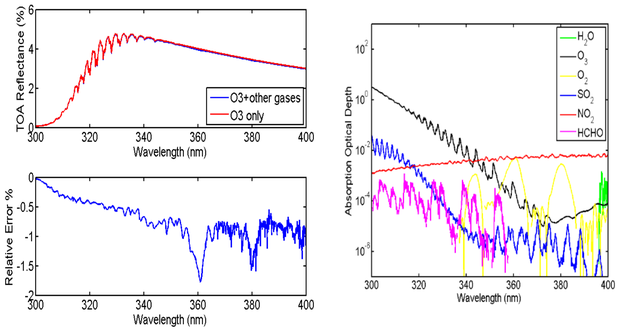
Scalar approximation may overestimate the TOA reflected radiance in UV region (Clear-sky), but the errors are under 4%.

b) Influence of Surface Albedo



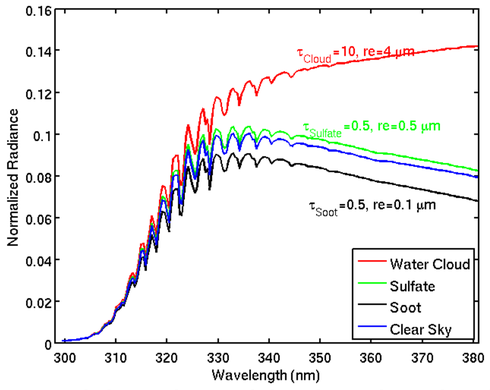
The errors increase with increasing of wavelengths. In TOMRAD simulation, the OMPS surface reflectance at 331 nm is used for all wavelengths. This assumption may cause significant errors to the TOA reflectance.

c) Influence of Gas Absorption



•Two simulations, one is only ozone and the other more absorption gases are considered.
•In TOMRAD simulation, only ozone considered.
•If only ozone is considered, the TOA reflected radiance can be overestimated.

d) Clouds and Aerosols



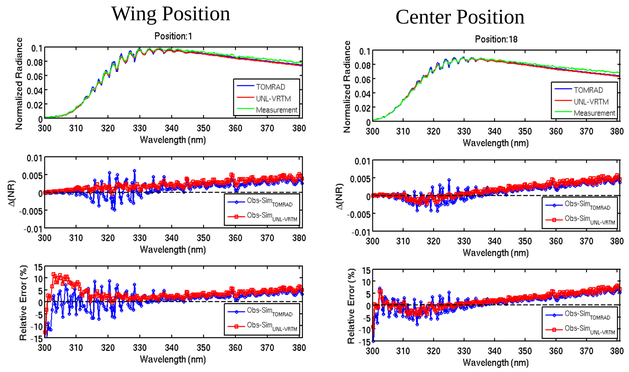
Comparing with the simulations of clear sky condition, the radiances may increase if non-absorbing aerosols（e.g. sulfate）is considered in the RTM. Conversely, the radiances will decrease if absorbing aerosols, like soot, considered.

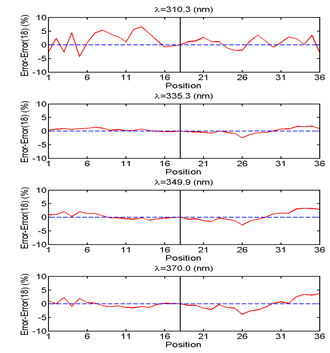
References

[1] Dave, J. V. (1964), Meaning of successive iteration of the auxiliary equation of radiative transfer, *Astrophys. J.*, 140, 1292 – 1303.
[2] Wang, J., Xu, X., Ding, S., Zeng, J., Spurr, R., Liu, X., Chance, K. and Mishchenko, M., 2014. A numerical testbed for remote sensing of aerosols, and its demonstration for evaluating retrieval synergy from a geostationary satellite constellation of GEO-CAPE and GOES-R. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 146. 510-528.
[3] Rozanov, V. V., Rozanov, A.V., A. Kokhanovsky, A., Burrows, John. (2014). Radiative transfer through terrestrial atmosphere and ocean: Software package SCIATRAN. *Journal of Quantitative Spectroscopy and Radiative Transfer*. 133. 13 -71.

4. Comparisons between Simulations and OMPS Measurements

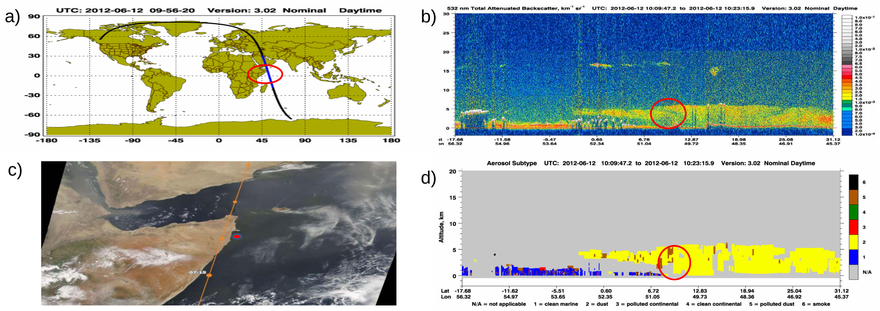
Averaged for all profiles at different cross-tracking positions





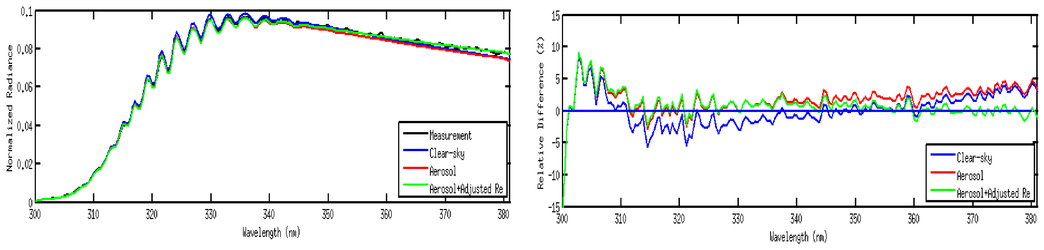
Difference between simulation from UNL-VRTM and OMPS measurement at various wavelengths for all 36 positions

5. Dust Case

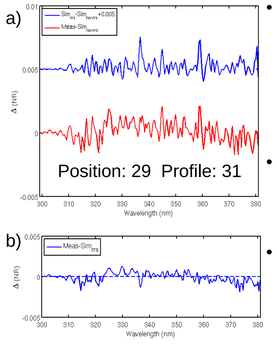


a) CALIPSO orbital track. Date: 2012-06-12, Time: 09:56; b) 532 nm total attenuated backscatter, red circle marked the location of OMPS; c) MODIS Terra corrected reflectance (True Color) and orbital track. Date: 2012-06-12. Time: 07:15; Red point shows the location of OMPS; d) CALIPSO aerosol subtype shows that the aerosol is dust.

UNL-VRTM Simulation vs OMPS Measurement



6. The Influence of Raman Scattering



- Since UNL-VRTM does not include Raman scattering, we use the SCIATRAN to demonstrate the effects of RRS. Blue curve in Figure a on the left is the differences between simulations with and without RRS. Note an offset of 0.005 is added.
- Red curve is the differences between OMPS measurement and simulation from UNL-VRTM (without considering RRS).
- If the effects of RRS are subtracted from the differences between OMPS measurement and UNL-VRTM simulation in red curve, the difference become smaller as shown in Panel b.

7. Summary and Conclusions

- In this study, OMPS calibrated SDRs are co-located with MLS derived ozone profiles. Simulated OMPS radiances from UNL-VRTM are compared with OMPS measurements. In general, the differences are less than 5% at all wavelengths, except for at wavelength less than 310 nm.
- The influences of surface reflectance on UV radiance are simulated. It is shown that the surface reflectance at 331 nm used for all wavelengths may cause significant errors to the TOA reflectance.
- Combining the co-located MODIS and CALIPSO data, effects of dust aerosols on UV simulation are included in the simulations.
- The effects of RRS on UV simulation are accounted through using SCIATRAN model.