CRTM extension for UV/Visible Sensors

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Abstract
The CRTM visible radiative transfer (RT) algorithm is developed and implemented. This development allows users to simulate and assimilate radiance/reflectance for ultraviolet and visible sensors. The new solver is also used in the microwave and infrared radiance simulations and assimilation, and it reduces computation time and achieves a very accurate Jacobian calculation under aerosol and cloudy conditions. For microwave and infrared sensors, the difference in the forward calculations between the baseline solver and the new solver is negligible (< 0.001 K). The accuracy in the Jacobian calculation for the baseline solver depends on a selection of a delta optical depth, the smallest sub-layer optical depth in the algorithm.

The UV/Visible simulation capability enables us to study the impact of aerosol vertical distribution on satellite radiance measurements. The vertical distribution of aerosols is important for air quality forecasting. The aerosol mass at a high altitude can statistically be transported for a long distance.

CRTM Updates
A new loop over Fourier expansion series for azimuth angles is added. The phase matrix is extended with the Fourier coefficients. The operational OPTRAN algorithm is applied for generating absorption coefficients for the fast visible transmittance calculation. For the GOES-R ABI sensor, the accuracy for transmittance is about 0.001 for visible channels and better than 0.2 K for IR channels. The aerosol types are updated (see table). Look-up tables for cloud and aerosol properties are also extended to include the visible part.

Result
The new repository braches EXP-Visible is created for the CRTM development to include solar radiation for UV/Visible sensors. The new development is validated with the operational CRTM code in the trunk (operational). The operational code uses a delta optical depth of 0.001, while the new RT solver uses analytical solutions for layer transmittance and reflectance matrices and it may be considered as a reference. For forward IR and MW brightness temperature calculations, the difference between the operational code and this new code is less than 0.001 K and approaches zero for finer delta optical depths. The following figure shows that the difference may be as large as 12%, 1.5%, 0.1% for the delta optical depths of 0.001, 0.0001, and 0.00001, respectively.

Theoretical Basis
UV/Visible sensors measure backscattered solar radiation that depends on atmospheric gaseous absorption, scattering/absorption of molecules, aerosols, and clouds, as well as surface reflectance. The backscattering depends on geometry parameters including relative an azimuth angle between sun and sensor viewing directions.

Conclusion
The CRTM visible module can be useful for both retrieval and assimilation. It shows that aerosol vertical distribution has a significant impact on satellite measurements. For UV/Visible sensors, surface bidirectional reflectance model (BRDF) and molecule/aerosol/cloud polarization are also important. The following developments are under consideration:
1. Surface BRDF models over ocean and land;
2. MODIS-like aerosol LUT and CMAQ LUT;
3. Microwave cloud LUT for non-spherical particles;