A fast radiance simulator for the Visible Infrared Imaging Radiometer Suite (VIIRS)

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Introduction

A fast radiance simulator has been developed to simulate the observations made by the Visible Infrared Imaging Radiometer Suite (VIIRS) in both clear and cloudy atmospheres.

- The correlated k-distribution (CKD) model is used to account for the absorption of atmospheric gases;
- The fast radiative transfer models (FRTM) are used for the VIIRS solar and infrared channels, respectively;
- The scattering properties of ice clouds are derived from the MODIS Collection 6 ice model.

The simulator, based on the CKD+FRTM, is assessed by:

- Comparing with simulations using combined line-by-line (LBL) and discrete ordinate radiative transfer (DISORT) models.
- Comparing with the VIIRS observations.

The Correlated k-distribution method

➢ **The CKD for single gas**

Instead of integration over the wavenumber, the transmissivity can be obtained by:

$$T_{\bar{\nu}}(u) = \int_{\Delta\nu} e^{-k(\nu)u} \frac{d\nu}{\Delta\nu} = \int_{k_{\min}}^{k_{\max}} e^{-ku} f(k)dk = \int_0^1 e^{-k(g)u} dg \cong \sum_{j=1}^{N} e^{-k(g_j)u} \Delta g_i$$

where *f(k)* is the normalized probability distribution function for *k(ν)* in the interval Δν, and

$$g(k) = \int_0^k f(k')dk'$$

is cumulative probability function.

➢ **The CKD for multiple gases**

$$T_{\bar{\nu}}(u) = \int_{\Delta\nu} e^{-(k_0(\nu)u_0 + k_1(\nu)u_1 + k_2(\nu)u_2)} \frac{d\nu}{\Delta\nu} = \int_{\Delta\nu} e^{-k_{mix}(\nu)u_0} \frac{d\nu}{\Delta\nu} = \int_0^1 e^{-k_{mix}(g)u} dg \cong \sum_{j=1}^{N} e^{-k_{mix}(g_j)u} \Delta g_i$$

where k_{mix} is the absorption coefficient for the mixed gas:

$$k_{mix}(\nu) = k_0(\nu) + k_1(\nu)\frac{u_1}{u_0} + k_2(\nu)\frac{u_2}{u_0}$$

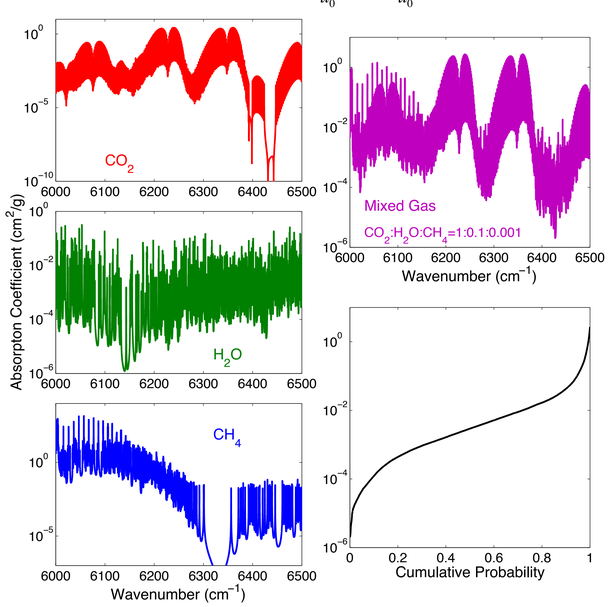

Figure 1. The treatment of multiple gases on the k-distribution model for the VIIRS 1.61 μm channel.

Validation of the CKD

- The relative error of the transmissivity calculated by the CKD is less than 0.2% compared with those from the LBL simulations
- The CKD is two orders of magnitude faster than the LBL model

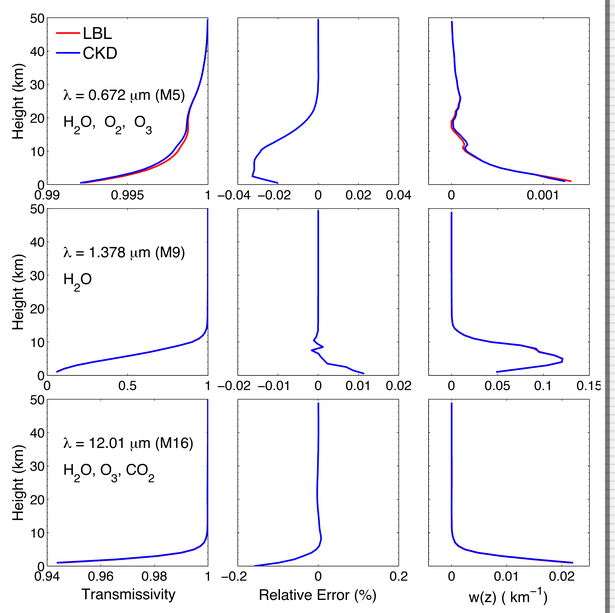

Figure 2. Comparison between the LBL and CKD models for the VIIRS 0.67, 1.38, and 12 μm channels: the band-averaged transmissivity (left), relative error in transmissivity (middle), and weighting function (right) profiles. The U.S. standard atmosphere profile is used in the calculations.

The VIIRS Simulator

- **VIIRS band-averaged radiances can be rigorously calculated by a combination of the LBL and DISORT models; however, this is too time-consuming for practical applications.**
- **The CKD method replaces the LBL to account for gaseous absorption.**
- **The fast radiative transfer models replace the DISORT for solar and infrared channels, respectively;**
- **The lookup tables (LUT) of cloud reflectance, transmittance, emissivity and effective temperature are per-calculated using DISORT.**

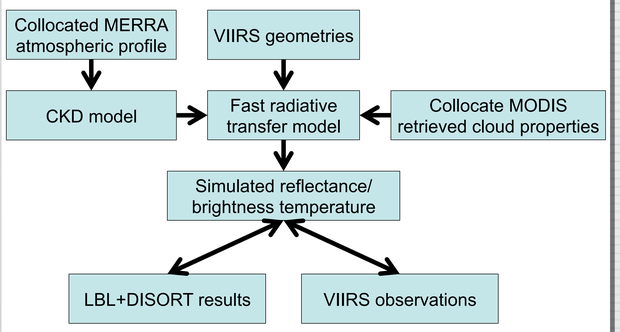

Figure 3. Flowchart outlining the fast VIIRS radiance simulator using the collocated MERRA atmospheric profile and MODIS retrieved ice cloud optical thickness and effective particle size.

Comparison with LBL+DISORT

Visible and near-infrared channels

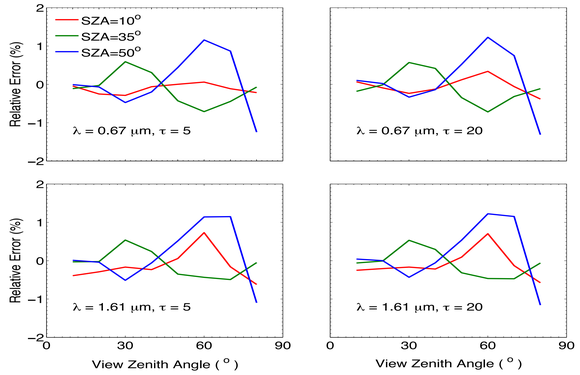

Figure 4. Relative errors of TOA reflectance at 0.67 and 1.61 μm channels simulated by the VIIRS simulator in comparison with the benchmark model (i.e. DISORT with 128-stream).

Infrared channels

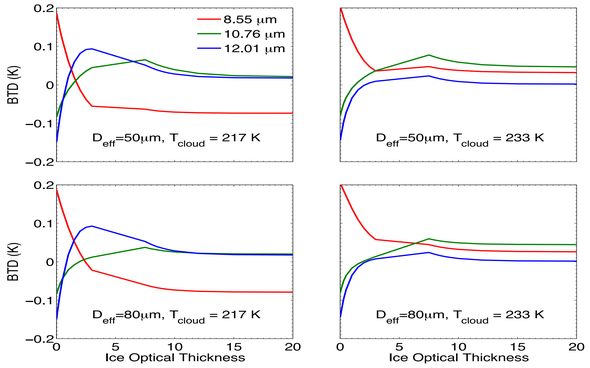

Figure 5. Brightness temperature difference (CKD+FRTM – LBL+DISORT) as a function of ice optical thickness, for view zenith angle of 20° at three VIIRS infrared channels.

Comparison with VIIRS Observation

The fast simulator (i.e. CKD+FRTM model) is used to calculate TOA reflectance at the visible/near infrared channels, and the brightness temperatures at the infrared channels.

Datasets:

- Collocated MERRA atmospheric profile (temperature, pressure, and gas density)
- Collocated MODIS retrieved cloud optical thickness and effective particle size (only ice clouds considered in this poster)

The simulated reflectance or BT in the red region of Figure 6 is compared with VIIRS observations at four VIIRS channels.

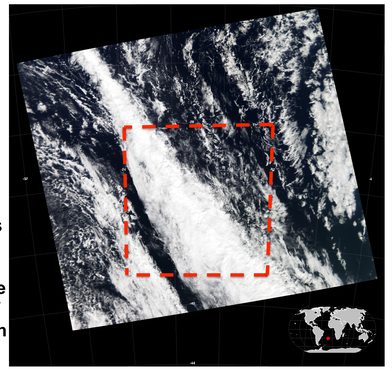

Figure 6. RGB image of a MODIS data granule on August 6, 2012 at 15:05 UTC. The red dashed line rectangle shows the region of the simulation.

Visible and near-infrared channels

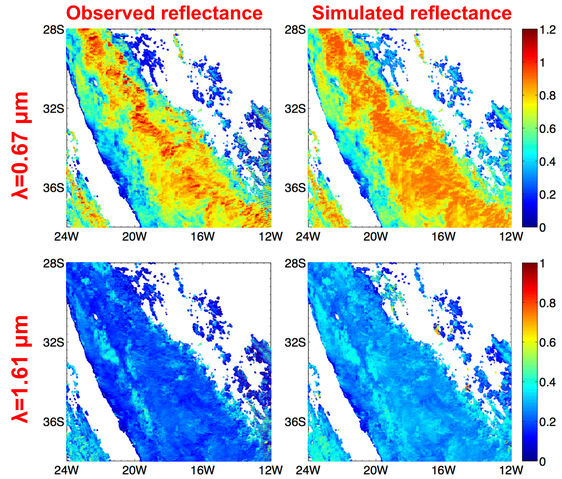

Figure 7. Comparison of the simulated reflectances with the corresponding VIIRS observations at 0.67 and 1.61 μm channels.

Infrared channels

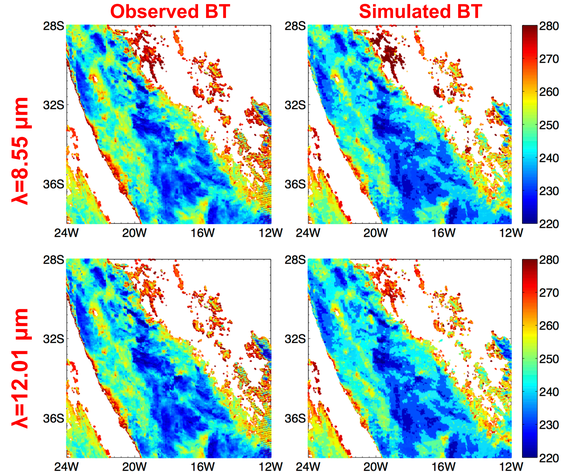

Figure 8. Comparison of the simulated brightness temperature with the corresponding VIRRS observations at 8.55 and 12.01 μm channels.

Conclusion

- **A fast radiance simulator for the VIIRS has been built based on a combination of the CKD and fast radiative transfer models;**
- **The simulator is validated by the rigorous solution given by the LBL+DISORT. The relative errors for the TOA reflectance at visible and near-infrared channels are less than 1.5%, and the brightness temperature differences at infrared channels is less than 0.2 K.**
- **The simulator is approximately two to three orders of magnitude faster than the standard LBL+DISORT model.**
- **Because the scattering properties of ice clouds are derived from the MODIS C6 model, the simulated TOA reflectance is larger than the VIIRS observations, but reflectance patterns are largely reproduced. The simulated and the observed brightness temperature at the infrared channels agree quite well.**

Acknowledgments

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