# Using Polarized PCRTM-Solar Model to Validate EMIT Surface Reflectance L2A Product


**Xiaozhen Xiong[1*], Xu Liu[1], Ming Zhao[1,2], Qiguang Yang[1,2], Wan Wu[1], Liqiao Lei[1,2]**
**Robert Spurr[3], Philip G. Brodrick[4], David R. Thompson[4], Robert O. Green[4]**

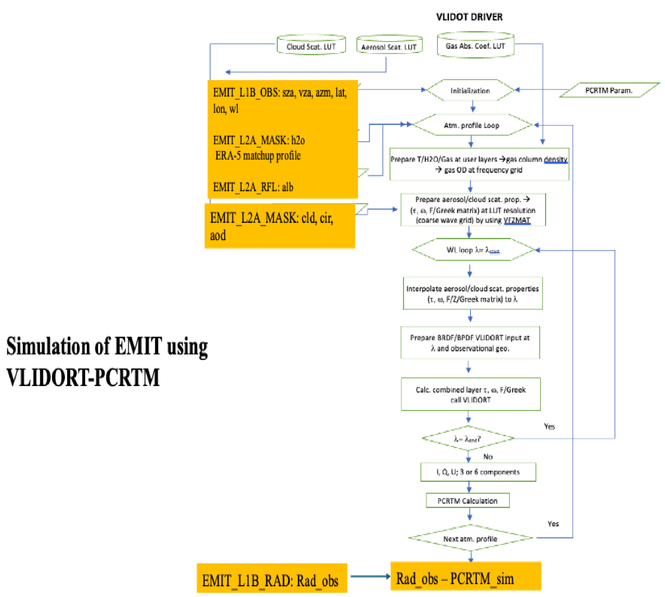
[1] NASA Langley Research Center, Hampton, VA [2] Adnet Systems Inc., Bethesda, MD 20817, USA [3] RT SOLUTIONS Inc., Cambridge, MA, USA [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

E-mail: Xiaozhen.Xiong@nasa.gov


## Abstract


Using the vector linearized discrete ordinate radiative transfer model (VLIDORT), a multiple-scattering multi-layer scattering code, coupled with a fast principal component (PC) radiative transfer model (PCRTM), we can simulate hyperspectral radiation fields from visible to shortwave infrared (VSWIR), i.e., 250 nm to 2500 nm. Since only limited accurate line-by-line calculation using VLIDORT is needed, this coupled PCRTM-VLIDORT approach is very efficient for simulating hyperspectral VSWIR spectra. These simulations incorporate accurately defined optical properties (gas absorptions, molecular and aerosol/cloud particle scattering) and detailed surface reflectance inputs. In this study we used the current L2A products of the Earth Surface Mineral Dust Source Investigation (EMIT) imaging spectrometer as the inputs to PCRTM-VLIDORT to simulate EMIT spectra. Comparing the simulated spectra with EMIT measurements provides an efficient method to validate the current EMIT product.


## VLIDORT-PCRTM Simulation Flow Chart




Simulation of EMIT using VLIDORT-PCRTM

**Fig. 1. Flow Chart of VLIDORT-PCRTM Simulation with inputs from EMIT L2A products**

## Principal Component based Radiative Transfer Model (PCRTM)

- PCRTM is a physics-based RTM which performs limited number of monochromatic RT calculations;
- PCRTM removes spectral redundancy by PC compression and is super fast and accurate: 4 orders of magnitude faster than LBL models,, 0.03 K rms error in IR and 0.05% accuracy relative to reference line-by-line models;
- PCRTM-VLIDORT uses VLIDORT to account for polarized lights due to atmosphere gases/clouds/aerosols scatterings;
- PCRTM has been developed for many satellite remote sensors (AIRS, CrIS, IASI, NAST-I, CLARREO, CPF, SCIAMACHY, OMI, EMIT etc.) with applications in many areas, such as forward model for retrieval algorithms, look-up table generations, AI algorithm training databases, sensor calibrations, high-fidelity simulators …

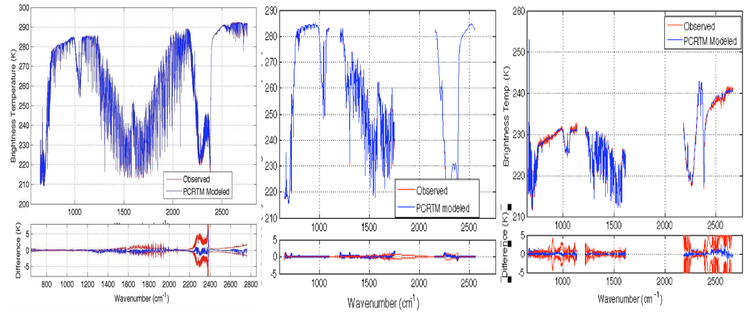



**Fig. 2 PCRTM simulated and IR sounder (AIRS, CrIS, and IASI) observed TOA radiance**

## VLIDORT

- VLIDORT is an open-source RTM, which is idea for NASA SBG projects;
- VLIDORT (current version 2.8.3) is a multiple-scattering multi-layer discrete-ordinate scattering code with a simultaneous linearization facility for the generation of radiation fields and analytic Jacobians (partial derivatives with respect to any atmospheric or surface parameter).
- VLIDORT calculates Stokes 4-vectors [I, Q, U, V] or Stokes 3-vectors [I, Q, U] (linear polarization);
- VLIDORT treats multiple scattering (MS) in plane-parallel geometry, but for the single scattering (SS) field, solar and line-of-sight beams may be computed more accurately for curved spherical media. There is also a "sphericity correction" option for the MS fields;
- In addition to solar scattering, VLIDORT has a complete black-body atmospheric and surface thermal emission treatment, with a full linearization capability for thermal sources;

**Inputs** VLIDORT is a pure scattering RT model; it ingests total optical properties needed for vector RT and does not distinguish individual atmospheric absorbers/scatterers, and type of surface. Lookup tables for absorption by 22 gases, scattering by various aerosol and clouds, and diverse surface reflectance properties have been built.

**Outputs** outputs include upwelling/downwelling output at any level, as well as atmospheric profile Jacobians (e.g. $O_3$ profiles, see Fig 3) or atmospheric bulk-property Jacobians (e.g. total AOD) and surface properties. For Lambertian problem, we have generated **output 3 components and 6 components**, from which we can re-construct radiance for any given the surface reflectance.

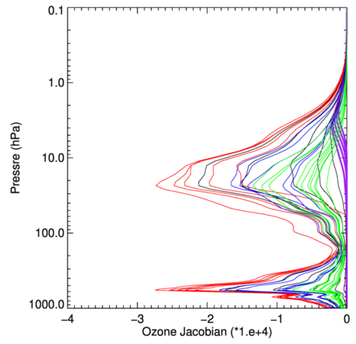



**Fig.3 PCRTM-VLIDORT Simulated Jacobian**

## Simulated EMIT Spectra vs Observations

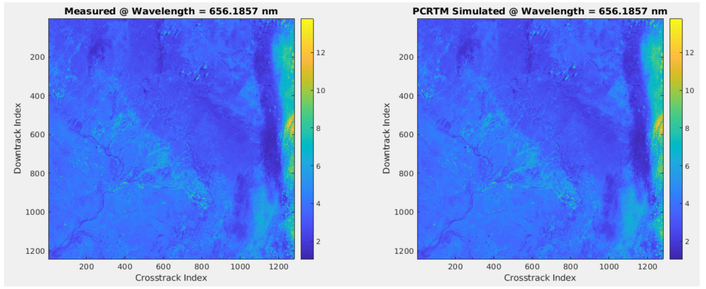



**Fig. 4 EMIT observed radiance at 656.2 nm (left) and the PCRTM simulated radiance (right) using EMIT L2 products as inputs. For 285 EMIT channels, only 173 mono VLIDORT calculation is needed.**

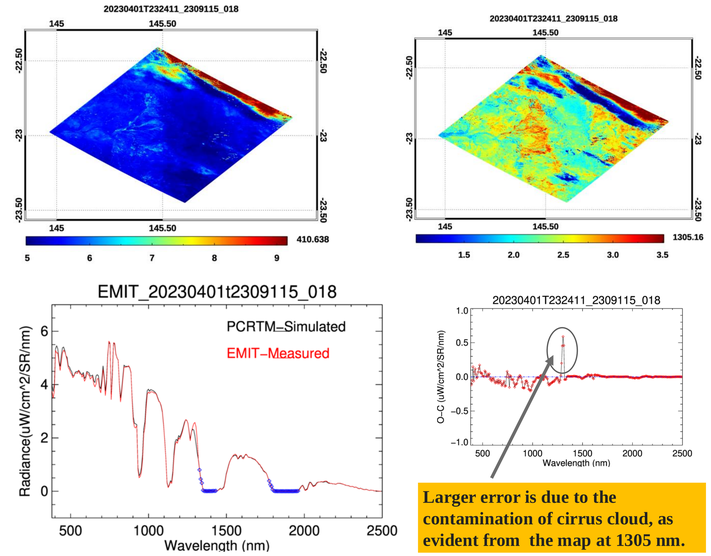



**Figure 5 Comparison of PCRTM-simulated TOA radiance with the EMIT measurement for a granule observed on April 1, 2023. The lower right panel shows the mean error for clear pixels, selected using the cloud flag; however, contamination from cirrus clouds is present from the map in the upper right.**

## Summary

Under the support of SBG project, a VLIDORT-PCRTM simulation system has been developed to simulate hyperspectral radiation fields efficiently. This system uses VLIDORT to accurately calculate monochromatic radiance in limited points as required by PCRTM, then uses PCRTM to convert these limited monochromatic radiance to radiance across the entire spectrum in the UV, NIR, and SWIR ranges. The PCRTM model was trained using a large database of VLIDORT-LBL simulations and is available at various spectral resolution. This coupled PCRTM-VLIDORT system is very fast and highly efficient for simulating hyperspectral VSWIR spectra. As an application, we used the current L2A products from the Earth Surface Mineral Dust Source Investigation (EMIT) imaging spectrometer as inputs to PCRTM-VLIDORT to simulate EMIT spectra. A comparison between the simulated spectra and EMIT measurements demonstrated that the current EMIT L2 products are in good consistent with L1B radiance while using the VLIDORT-PCRTM as a transfer.