Development Status of the Community Radiative Transfer Model (CRTM)

Yong Han, Paul van Delst, Quanhua Liu, Yong Chen, David Groff, Ronald Vogel, Banghua Yan and Fuzhong Weng, Joint Center for Satellite Data Assimilation

Abstract

In the past project year, substantial progress was made in the development and improvement of the Community Radiative Transfer Model (CRTM). A new atmospheric transmittance model was developed and implemented, which combined the strengths from the Compact-OPTRAN model currently in operation and the algorithm used in the UK RTTOV model. Both accuracy and computational efficiency are improved significantly over the current Compact-OPTRAN. To accommodate various sensor-dependent transmittance algorithms and a back compatibility, a multiple transmittance algorithm framework was implemented. To extend CRTM into the Visible region, components for Visible sensors were developed and implemented. A test version of CRTM is now available for Visible as well as IR channels of the GOES-R ABI sensor. Efforts to improve and evaluate surface emissivity models were made for both ocean and land surfaces and for both IR and MW sensors. A new IR emissivity look-up table for the land surface was developed for use in CRTM, and a physical-based multi-layer MW emissivity model over land is being developed. The list of sensors supported by CRTM was extended to include NOAA N' sensors, DMSP SSMIS F17-20, NPP ATMS and CrIS, and FengYun-3 sensors. Progress was also made in collaborations with external research groups working on JCSDA-funded radiative transfer projects to integrate their research results into the CRTM models. In this presentation, we will provide an overview of the activities and results of the CRTM development projects.

Atmospheric Transmittance Module

- **New transmittance model (ODPS)**
  - Algorithm: a combination of Compact-OPTRAN and the algorithm used in RTTOV
  - Variable gases: H_2O, CO_2, O_3, N_2O, CO and CH_4
  - Both accuracy and computational efficiency are improved over the current operational transmittance model (Figure 1)
- **Improved LBLRTM and MonoRTM**
  - LBLRTM is the base model for training CRTM IR transmittance model; MonoRTM will be soon used to train CRTM MW transmittance model
  - Recently both models have been significantly improved by AER Inc. and the CRTM is being retrained to incorporate the results (Figure 2).
- **Improved SSMIS transmittance model that counts the Earth-rotation Doppler shift effect**
  - SSMIS channels 19-22 are affected by Zeeman-splitting and Earth-rotation Doppler shift (Figure 3)
  - A fast transmittance model taking both effects into account has been implemented into CRTM.
- **Multiple transmittance framework**
  - In order to accommodate different transmittance algorithms, a multiple transmittance framework has been implemented.

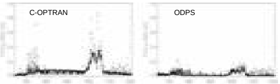


Figure 1. RMS differences between CRTM and LBL base model for IASI band1. Left – current Compact OPTRAN algorithm; right – new algorithm.

Figure 2. Improvement of LBLRTM and MonoRTM models, which are used to train CRTM (from Payne, AER)

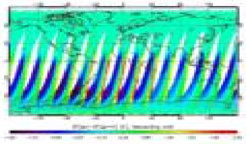
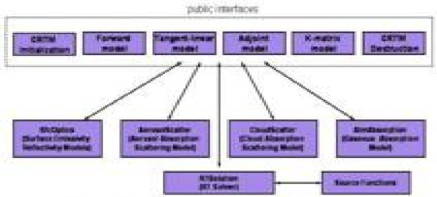


Figure 3. Brightness temperature differences between the RT models with and without inclusion of the Earth-rotation Doppler effect (ERD) for SSMIS channel 20. Both Zeeman and ERD effects have been taken into account in CRTM.



CRTM major modules

Cloud/Aerosol Optical Parameter LUT and RT Solution Modules

- **Visible/UV components**
  - CRTM visible/UV components to support visible and UV sensors have been developed (Figure 4)
  - The cloud/aerosol optical parameter lookup tables have been extended into the visible and UV regions
  - The transmittance model has been extended into the visible and UV regions
  - The radiative transfer RT solution model has been extended to include molecular scattering and azimuth integration.
- **Successive Order of Interaction Radiative Transfer Model (SOI)**
  - The SOI RT solver is being implemented into CRTM by University of Wisconsin, as an alternative to the current Advance Doubling-Adding (ADA) method.
  - The implementation of the forward model is near completion
- **Cloud/aerosol optical parameter LUT and validation of CRTM under cloud/aerosol conditions**
  - The Texas A&M University (TAMU) has developed lookup tables of three bulk-scattering properties, ice crystals, water droplets and non-spherical dust particles for CRTM at wavelengths between 0.225 and20.0 µm (Figure 5).
  - Validation of CRTM by TAMU is under way using a combination of a line-by-line model and the DIScrete Ordinate Radiative Transfer (DISORT) model

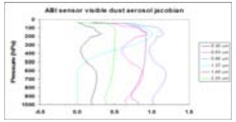


Figure 4. Dust Jacobians at ABI visible channels.

Figure 5. Phase functions of non-spherical particles (from Yang, TAMU)

New supported Sensors

TRMM TMI; GPM GMI; ATSR-1, -2 and AATSR; SSMIS F17-F20; CrIS NPP; FengYun-3 MWTS

Surface Emissivity Module

- **Empirical desert MW emissivity model**

  An empirical desert emissivity model for AMSU channels has been developed and is now under testing. Initial impact tests show substantial increase of the data volume in data usage for NWP (Figure 6)
- **New IR land emissivity LUT**

  A new IR land emissivity LUT has been developed and is now under testing. The LUT was built with proportional blends of the JPL spectral library reflectances to match the 13 GFS vegetation types (Figure 7)
- **Improvement of the FASTEM model**

  The fast MW ocean emissivity model (FASTEM) has been used in CRTM for sea surface MW emissivity calculation. It has been found that at high frequencies (>85GHz), significant errors exit. The error has been significantly reduced by the coefficients re-generated using the NESDIS 2-scale ocean surface emissivity model (Figure 8)

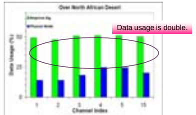


Figure 6. Comparison of the data usage in GSI between the uses of the empirical desert MW emissivity model and the current model.

Figure 7. New IR land emissivity LUT for the 13 GFS surface types.

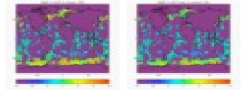


Figure 8. Brightness temperature differences between model and observations at SSMIS channel 18 (150GHz). Left – the use of original FASTEM-3; right – improved FASTEM-3.

Software

- **Setup of CRTM software development environment**
  - CRTM repository - the CRTM code base is now accessible for development via the public EMC subversion server
  - Trac software tool has been established for configuration management
- **Major CRTM software fixes**
  - Bug fix for AddLayers TL/AD functions
  - Bug fix for FASTEM-3 wapper adjoint function
  - Add cloud and aerosol optical property interpolation quality check to prevent non-physical results
  - Turn on solar flag for all IR Channels

Preparation of CRTM Version 2

The beta version of CRTM version 2 will be released in a few months, which will include the following features

- The multiple transmittance framework
- The new transmittance model (ODPS) and fast SSMIS Zeeman RT model, along with the current Compact OPTRAN model
- Visible components for visible/UV sensors
- Improved surface emissivity models
- Improved computational efficiency