1. Introduction

The Community Radiative Transfer Model (CRTM), developed at the Joint Center for Satellite Data Assimilation, is a fast radiative transfer model that has been designed to perform simulations for passive microwave, infrared and visible satellite-based instruments. Current CRTM instrument capabilities include all NOAA satellite instruments, NASA MODIS and many foreign meteorological satellites. The CRTM has been utilized to support the assimilation of satellite radiances in the NCEP GSI system, the retrieval of operational satellite products in the Microwave Integrated Retrieval System (MIRS), the calibration of instrument sensors within the international remote sensing community, air quality applications and various projects at CICS/ESSIC.

2. CRTM

- CRTM was initially proposed to support primarily the JCSDA partners to assimilate satellite radiance data into global/regional forecast systems.
- It is now also supporting US satellite program developments through generating a high quality proxy data for algorithm tests, developments and integrations.
- It has been used in the NOAA/NESDIS microwave sounding product system.
- It can be used to generate the synthetic satellite radiances from NWP nature runs for observation system simulation experiments (OSSE).
- It is linked to other key projects such as climate reanalysis and satellite calibration.

3. CRTM Modules and Supported Sensors

4. CRTM Transmittance Model

4.1 Transmittance Model

- The transmittance model is to compute atmospheric transmittance from absorbing gases.
  - In addition to the ODAS model, a new transmittance model ODPS (Optical Depth in Pressure Space) has been implemented in version 2.
- Currently supported input trace gases: H2O, CO2, O3, CO, N2O and CH4.

4.2 Specific Transmittance Model

- Zeeman-splitting for affected microwave channels.
- Stratospheric sounder unit transmittance to account for onboard CO2 cell pressure leaking.
- NLTE Model

5. Aerosol and Cloud Models

Aerosols:
- Global Model, GOCART
- Dust, Sea Salt, Organic carbon, Black carbon, Sulphate

Regional Model:
- CMQ is under implementation.
- Aerosols are assumed to be spherical particles. Spheroid shape for dust is under consideration.

Clouds:
- Liquid, Rain, Snow, Ice, Graupel, and Hail
- Non-spherical particles for ice cloud are used for Visible and IR bands.

6. Surface Emissivity and Reflectance

The CRTM surface capabilities are divided into Water, Land, Ice, and Snow.
- CRTM computes emissivity and reflectance internally.
- CRTM accepts user defined emissivity data.
- CRTM uses Ocean BRDF IR model.
- Other BRDF is under development.

7. Satellite Cloud Radiance (v2.2.0)

7.1 Overcast radiance

NCEP data assimilation system utilizes clear-sky radiances and radiances not affected by clouds. Cloud height is a critical parameter for determining those radiances not affected by clouds. CRTM can simulate black cloudy radiances (cloud emissivity=1) for multiple single cloud layer simultaneously without significant increase of computational time. Figure at the right shows the simulations for HIRS. For the window channel 10 (solid line) and the TOA radiance decreases as the cloud height increases. For the water vapor channel 12 (dashed line), the TOA radiance remains unchanged for the cloud below 400 hPa because the weighting function is close to zero below 400 hPa. Diamond and triangle symbols represents clear-sky radiance.

7.2 Cloud fraction

Infrared and microwave sounders have a pixel size of 10 ~ 50 km at nadir. Most pixels are partially cloudy. However, the CRTM is one-dimensional radiative transfer that computes radiance under either clear-sky or cloudy condition in each channel. For a pixel with a cloud fraction F, radiance can be expressed as the weighted sum of clear and cloud radiance:

\[ R = (1 - F)R_{\text{clear}} + F \times R_{\text{cloud}} \]  

(1)

The derivative (or jacobian) of radiance to any geophysical parameter can be written as:

\[ \frac{\partial R}{\partial x} = \frac{\partial R_{\text{clear}}}{\partial x} \times (1 - F) + F \times \frac{\partial R_{\text{cloud}}}{\partial x} \]  

\[ \frac{\partial F}{\partial x} \times \frac{\partial R}{\partial x} = \frac{\partial R_{\text{cloud}}}{\partial x} \times (1 - F) + F \times \frac{\partial R_{\text{cloud}}}{\partial x} \]  

(2)

Eqs (1) and (2) are handled inside the CRTM so that users can directly compute radiances and cloud jacobians for partially cloudy cases.

7.3 Cloud radiance jacobian at non cloud condition

The CRTM does not compute cloudy radiance jacobians where clouds are absent in the input fields. However, cloud radiance assimilation and satellite product retrievals need the jacobian to infer cloud information even when clouds are absent in the model background information. It is important to utilize cloudly radiance information to improve analyses when observed clouds are not realized in the model background.

Using a revised threshold for cloud water content, the CRTM can provide jacobians for cloud water content and effective radius. The cloudy radiance jacobian computation in the absence of clouds will be triggered when users specify a cloud type and effective particle size.

CRTM 2.1.3 Release

CRTM 2.1.3 release is available from ftp.emc.ncep.noaa.gov at jcsda/CRTM/REL-2.1.3