1. Introduction

The Community Radiative Transfer Model (CRTM), developed at the US Joint Center for Satellite Data Assimilation (JCSDA), simulates satellite microwave (MW) and infrared (IR) radiances and computes radiance derivatives (Jacobians) with respect to the state variables. It is an essential component of the Gridpoint Statistical Interpolation (GSI) data assimilation system at the NOAA National Center for Environmental Prediction (NCEP) Environmental Modeling Center (EMC). The development of the CRTM was stimulated by recent research activities in the radiative transfer (RT) modeling community to fully utilize the information of satellite measurements under all weather conditions for numerical weather prediction (NWP). CRTM-V1 was implemented with many recent achievements to improve the modeling of both clear and cloudy satellite radiances. Another important purpose of developing the new model was to design a framework for research groups and developers to simplify the implementation of experimental algorithms and allow it to be easily tested and evaluated in the operational environment and thereby accelerate the transition from research implementation of CRTM-V1.

2. What can CRTM-V1 provide?

- Forward model: satellite radiance simulation
- Tangent-linear model: $\delta L = \langle L(x) \rangle \delta x$
- Adjoint model: $\delta L = \langle L(x) \rangle \delta x$
- K-Jacobian ( Jacobian) model: $\partial L / \partial x$
- Covering Microwave and infrared sensors

3. Component descriptions

3.1 CRTM-V1 component diagram

3.2 Gaseous absorption model (Compact OPTRAN)

The channel, or spectral-response-function (SRF) convolved transmittance is modeled as

$$T_{ch} = T_{wv} T_{ozone} T_{dry ~ gas}$$

where $T_{wv}$ is the water vapor transmittance and $T_{ozone}$ and $T_{dry ~ gas}$ are the effective transmittances of ozone and dry gas (McMillin et al., 1995), respectively. The transmittance component on the right side of the above equation is computed as

$$T_{ch}(\lambda_d) = e^{-\int_0^\lambda_a k_{wv} dl}$$

$T_{wv}$ predictions such as temperature and pressure

The CRTM employs a suite of IR and MW surface emissivity and reflectivity models covering land, ocean, ice and snow surfaces.

- **IR sea surface emissivity model**: The IR sea surface emissivity model utilizes a lookup table of sea surface emissivities derived from the emissivity model for a wind-roughened sea surface (Wu and Smith, 1997). The lookup table variables are zenith angle (67 from nadir to 66.5°), frequency (503 from 600-3000cm-1), and wind speed (23 from 0-15ms-1). Currently linear interpolation is performed between the lookup table values.

- **IR land surface emissivity database**: The IR emissivity model used over land, snow and ice is provided by an emissivity database (Carter et al., 2002). The database contains surface reflectance measurements as a function of wavelength in both visible and IR spectral regions for 24 surface types. The emissivity is calculated as one minus the reflectance under the assumption of a Lambertian surface in the IR spectral region.

- **MW ocean emissivity model**: The MW ocean emissivity model is based on FASTEM-1 (English and Hewson, 1998). It takes satellite zenith angle, water temperature, surface wind speed, and frequency as model inputs and computes surface emissivity at vertical (V) and horizontal (H) polarizations.

- **MW land emissivity model**: The MW land emissivity model (LandEM) computes land surface emissivity for various surface types, including snow, deserts and vegetation using the two-stream radiative approximation (Weng et al., 2004). The emissivity database contains sets of emissivity spectral data measured at a zenith view angle of 50 degrees for various surface types. The window channel observations are used to identify the snow or ice type that best describes the surface condition observed by the window channels. After a spectrum is identified, it is adjusted for the requested zenith angle by using LandEM (Weng et al., 2004).
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