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REPORT ON COMMUNITY RADIATIVE TRANSFER MODEL (CRTM) DEVELOPED AT US JOINT CENTER FOR SATELLITE DATA ASSIMILATION (JCSDA)

NOAA-WP-16 provides a report from the JCSDA for CGMS consideration.

REPORT ON COMMUNITY RADIATIVE TRANSFER MODEL (CRTM) DEVELOPED AT US JOINT CENTER FOR SATELLITE DATA ASSIMILATION (JCSDA)

Fuzhong Weng[1], Mitch Goldberg[1], Yong Han[1] and Paul van Delst[2],
[1]NOAA/NESDIS/Office of Research and Applications
[2] UW/SSEC/CIMSS, Madison, Wisconsin

1. EXECUTIVE SUMMARY

The development of fast and accurate radiative transfer models for clear atmospheric conditions has enabled the direct assimilation of clear sky radiances from satellites in numerical weather prediction models. Currently, many fast models also handle the scattering and emission processes that dominate cloud and precipitation. Some analytic Jacobian schemes, crucial components for satellite data assimilation, have also been developed. For the operational data assimilation system, distinct features from each radiative transfer model may ultimately be combined in the more refined versions of the scattering radiative transfer by taking the advantages of speed and accuracy relative to benchmark solutions, storage efficiency for coefficients, inclusion of Jacobian, and potential developments for future instruments.

After the establishment of the Joint Center for Satellite Data Assimilation (JCSDA) program in the United States of America, the radiative transfer scientists from governments, academia and private sectors are being funded to integrate all radiative transfer components under a community radiative transfer model (CRTM) framework. The CRTM includes all necessary radiative transfer components and is optimized for computational and storage efficiency. More importantly, the CRTM has accommodated the growing requirements in direct assimilation of satellite radiances under clear and cloudy conditions and will soon include some critical components for air quality and trace gas data assimilation. The first version of CRTM has been recently implemented into NOAA and NASA research and operational data assimilation systems.

The CRTM version 1 simulates the microwave and infrared radiances observed by instruments on board spacecraft for a given state of the atmosphere and Earth's surface. It includes components that compute the gaseous absorption of radiation, absorption and scattering of radiation by hydrometeors and aerosols, and emission and reflection of radiation by ocean, land, snow and ice surfaces. All of these component results are then used to perform accurate radiative transfer to yield simulated satellite sensor radiances. In addition to the forward model, the corresponding tangent linear, adjoint and K-Matrix models have also been developed and included in the CRTM package for calculations of the radiance sensitivities with respect to the state variables. The software was designed with a balance between the computational efficiency and flexibility for future extension and improvement.

1. 1 COMMUNITY RADIATIVE TRANSFER MODEL (CRTM)

Simulation of atmospheric radiative transfer involves a number of physical processes. One of the main goals of the CRTM framework is to provide for the development of models for these processes independently of any other. The components of the radiative transfer processes considered by the CRTM are loosely divided into four main categories,

1. Absorption of radiation by the gaseous constituents of the atmosphere,
2. Absorption and scattering of radiation by clouds and aerosols,
3. Surface emission of radiation and surface interaction with downwelling atmospheric radiation, and
4. Solution of the radiative transfer equation.

In some cases the above are further split into subcategories, e.g. cloud and aerosol scattering are treated separately, surface optics is split into both surface types and spectral subcategories, etc. The CRTM framework was designed to allow for a relatively natural division of the software implementation of the above categories into modular entities (see Figure 1) so that as new or updated algorithms are developed, they can be easily integrated.

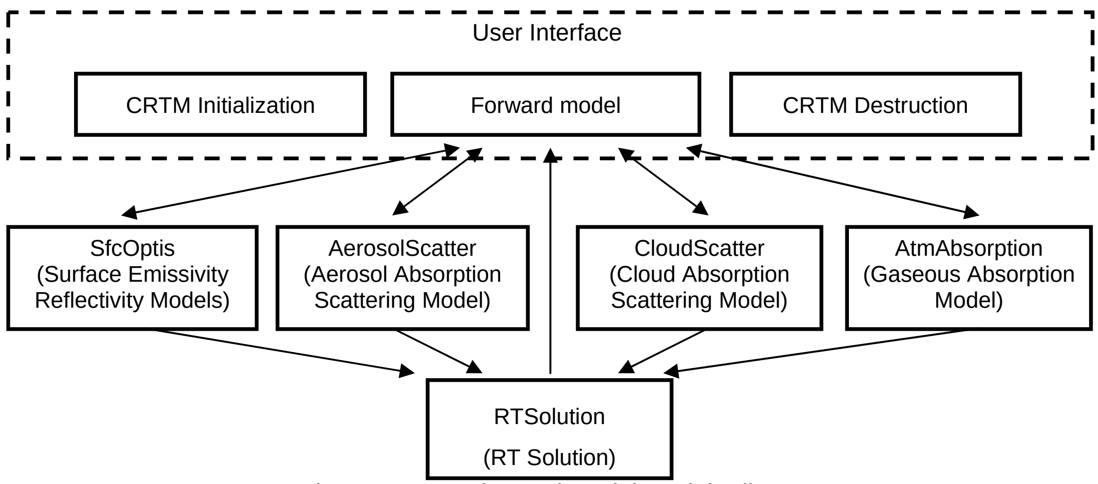

Figure 1 CRTM forward model module diagram

1. 2 FUTURE DEVELOPMENTS (CRTM VERSION 2)

CRTM Version 2 release will include absorbing and scattering aerosols, Stand-alone AIRS radiative transfer approximation (SARTA) developed by University of Maryland at Baltimore County (UBMC) and Optimal Spectral Sampling (OSS) developed by AER. Inc., improved surface emissivity models for polarimetric microwave instruments.

2. RECOMMENDATIONS

At the recent JCSDA workshop, in May 2006, the radiative transfer working groups developed a series of actions and recommendations to JCSDA program management, space agencies, operational centers and international advisory groups. Some of these actions may be also recommendations to the CGMS. They are itemized below.

2.1 JCSDA should set up a CRTM development environment and common data sets for testing the radiative transfer accuracies.

(a) In order for the research groups in different organizations to effectively implement their research results into CRTM, it is necessary to establish a CRTM repository site with version control that opens to the JCSDA funded RT research groups. However, the current NOAA network system prohibits the repository site to be set outside of the network firewall and therefore anyone outside of the network can not effectively use the repository. JCSDA management should solve the issue to bring the CRTM repository site outside of the firewall.

(b) A common test data set will be very useful for CRTM development. JCSDA should generate data set from ITSC and Cloudsat that are matched with NWPs global and regional analysis data.

2.2. Accurate radiative transfer modeling for surface emissivity, cloud and aerosol types

(a) Modeling of the Earth surface emission and reflection requires the Earth surface to be classified according to the surface radiometric characteristics. These classifications are often inconsistent with those from the LDAS, which usually classifies the surface types physically. Similar issues may also exist when dealing with cloud and aerosol in CRTM.

(b) When the satellite FOV covers multiple surface types, a simple and effective method should be applied to take the multiple types into account. A simple weighting, e.g. emissivity = *f**e_vegetation + (1-*f*)*e_snow, where *f* is the fraction of the vegetation coverage and e_vegetation and e_snow are the emissivity of the vegetation and snow surfaces, respectively.

2.3. Consistency between the NWP clouds and RT model.

CRTM should be extended from the current plane-parallel RT scheme to that which takes cloud/precipitation distributions into account. An important requirement for the RT scheme is the consistence with the NWP cloud model. Uses of cloud resolving model to produce high spatial resolution clouds and precipitation; statistical and explicit cloud parameterization on clouds for RT models.

2.4. Extending CRTM to shorter wavelength

Currently the CRTM covers only MW and IR sensors. With the ongoing implementation of the aerosol component, CRTM should be extended to visible and ultra-violet regions for aerosol remote sensing. JCSDA radiative transfer working group should interact with NASA aerosol group for type specifications (e.g. mass, composition and types) and understand the requirements