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JOINT CENTER FOR SATELLITE DATA ASSIMILATION (JCSDA) PROGRESS REPORT ON THE USE OF CLOUD CONTAMINATED RADIANCES IN NWP

In response to CGMS Recommendation 34.09

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

Development of fast and accurate radiative transfer models including atmospheric scattering is essential for assimilation of cloudy radiances from satellites in numerical weather prediction models. Currently, JCSDA community radiative transfer model (CRTM) includes fast computations of optical parameters of clouds and precipitation. Preliminary tests from assimilating SSMIS cloudy radiances at sounding channels in mesoscale models are encouraging and show great potentials for improving storm structure analysis. JCSDA is investing new resources for testing cloudy radiances with NCEP global forecast system.

JOINT CENTER FOR SATELLITE DATA ASSIMILATION (JCSDA) PROGRESS REPORT ON THE USE OF CLOUD CONTAMINATED RADIANCES IN NWP

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3. Perot System

1. EXECUTIVE SUMMARY

Development of fast and accurate radiative transfer models including atmospheric scattering is essential for assimilation of cloudy radiances from satellites in numerical weather prediction models. Currently, JCSDA community radiative transfer model (CRTM) includes fast computations of optical parameters of clouds and precipitation. Preliminary tests from assimilating SSMIS cloudy radiances at sounding channels in mesoscale models are encouraging and show great potentials for improving storm structure analysis. JCSDA is investing new resources for testing cloudy radiances with NCEP global forecast system.

The CRTM version 1 simulates the microwave and infrared radiances observed by satellite instruments for a given state of the atmosphere and Earth's surface. It includes components that compute 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 (Liu and Weng, 2006).

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.

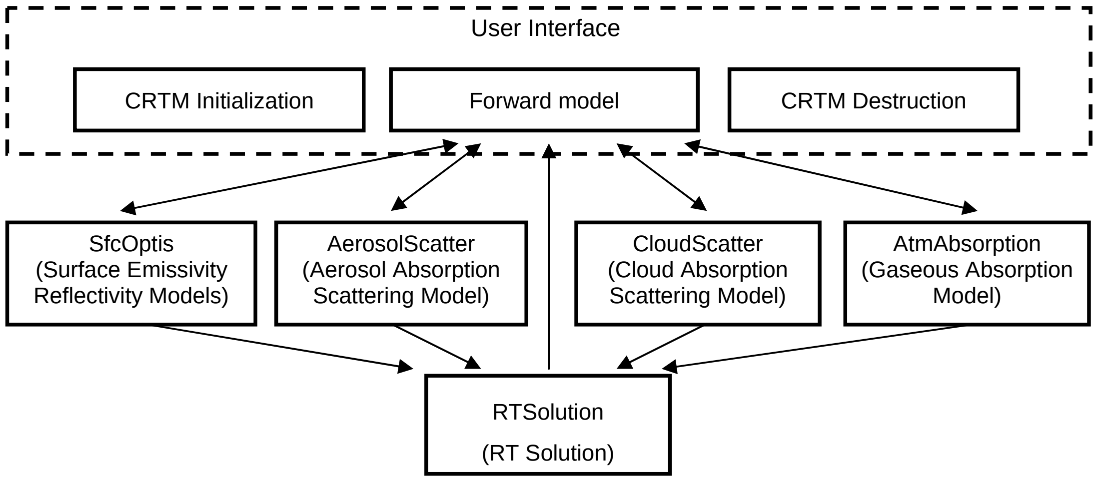

Figure 1 CRTM forward model module diagram

CRTM recent enhancements also include absorbing and scattering aerosols, Stand-alone AIRS radiative transfer approximation (SARTA) developed by University of Maryland at Baltimore County (UBMC), Zeeman splitting for SSMIS (Han et al., 2007), gas absorption coefficients for past instruments for reanalysis, and improved infrared surface emissivity models.

1. 2 SSMIS CLOUDY RADIANCE ASSIMILATION

To demonstrate the impacts of SSMIS on hurricane prediction, we use a Gridpoint Statistical Interpolation (GSI) scheme from National Center for Environmental Prediction (NCEP) and Weather Research and Forecasting (WRF) model for hurricane studies. In June 2006, GSI was released with newly-developed Community Radiative Transfer Model (CRTM). This marriage allows for assimilation of both clear and cloudy radiance from satellites into global forecast systems. Liu and Weng (2006) tested assimilation of the Special Sensor Microwave Imager Sounder (SSMIS) radiance using GSI. The core of GSI is to minimize the cost function which utilizes observations and priori or forecast information through a three-dimensional data variation (3Dvar) method. The data assimilation system finds optimal analysis fields from forecast fields, conventional observations, some retrieval products as observations, and satellite radiances under dynamic constraints following a set of physical laws. It is shown that the initial temperature fields at 200 hPa for the “control-run” shows a typical warm core (see Figure 2a) at the central area of hurricanes. But the warm core is very smooth and weak due to the coarse spatial resolution of the global analysis and the absence of cloud radiance assimilation. The new initial temperature field at 200 hPa for the “test-run” improves in both structure and strength of the warm core (see Figure 2b). The new initial field displays the vortex structure and has the warmest temperature at hurricane center. The initial temperature field at 850 hPa for “control-run” is very smooth (see Figure 2c). The new initial temperature field at 850 hPa for “test-run” shows the warm core at central area and shows the cold temperature associated with the spiral rain band (see Figure 2d). Overall, the temperature field directly from global analysis is weak and lacks of detailed feature with cumulus clouds. The new data assimilation for “test-run” preserves the fine structure associated with clouds in hurricane system.

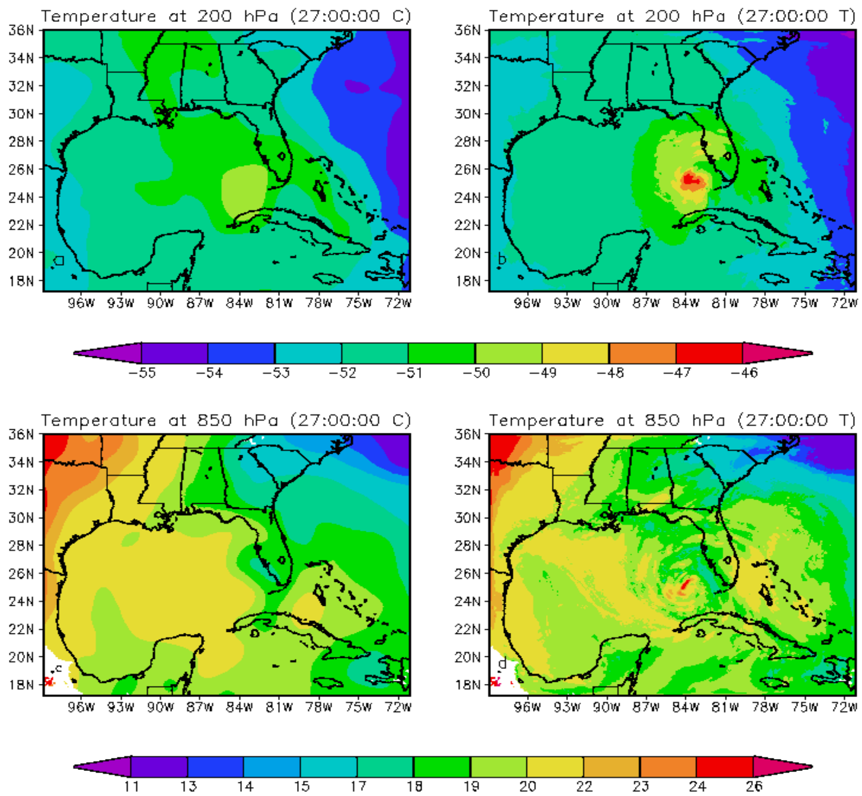

Figure 2. The initial temperature field at 200 hPa for the “control-run” (a), “test-run” (b), and at 850 hPa for the “control-run” (c), “test-run” (d).

2. RECOMMENDATIONS

At the recent JCSDA Science Steering Committee meeting in May 2007, the CRTM capability was appraised as a major accomplishment due to its advanced capability for clear and cloudy radiance assimilation. The SSC members, Dr. Stephen English, UK Metoffice and Dr. Tony McNally, ECWMF, and others are fully aware of this advance. The recommendations from JCSDA SSC and JCSDA CRTM team will be reported to next ITWG.

2.1 JCSDA should acquire more resources for testing cloudy radiance assimilation. NOAA has requested through its FY09 budget appropriation for an increase of funding which has been approved at the DOC level.

2.2. Accurate radiative transfer modeling for surface emissivity

Infrared surface emissivity model in CRTM is being updated with a new data base.

2.3. CRTM should be prepared for both reanalysis and future satellite observation system simulation experiments (OSSE).

2.4. CRTM should be prepared to include all trace gas components in gaseous absorption calculations.

Han, Y, F. Weng, Q. Liu, and P. van Delst, 2007: A fast radiative transfer model for SSMIS upper atmosphere sounding channels, *J. Geophys. Res* 112, D11121, doi:10.1029/2006JD008208.

Liu, Q. and F. Weng , 2006: Radiance assimilation in studying Hurricane Katrina, *Geophys. Res. Lett.,* **33**, L22811, doi:10.1029/2006GL027543.

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