Community Radiative Transfer Model (CRTM) Support to Satellite Cloud Radiance Assimilation

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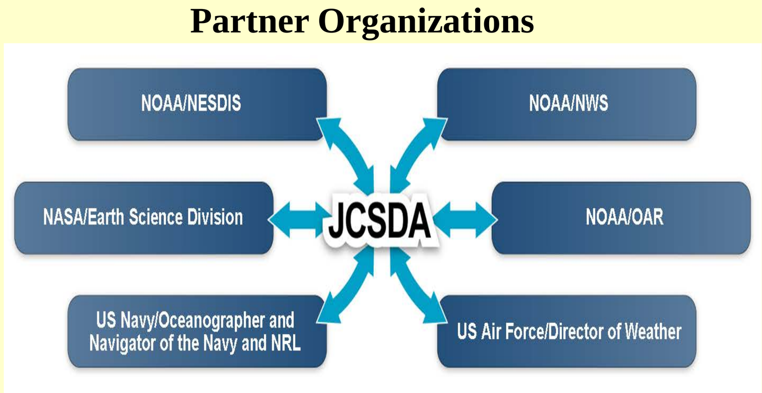
1. Introduction

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 cal/val

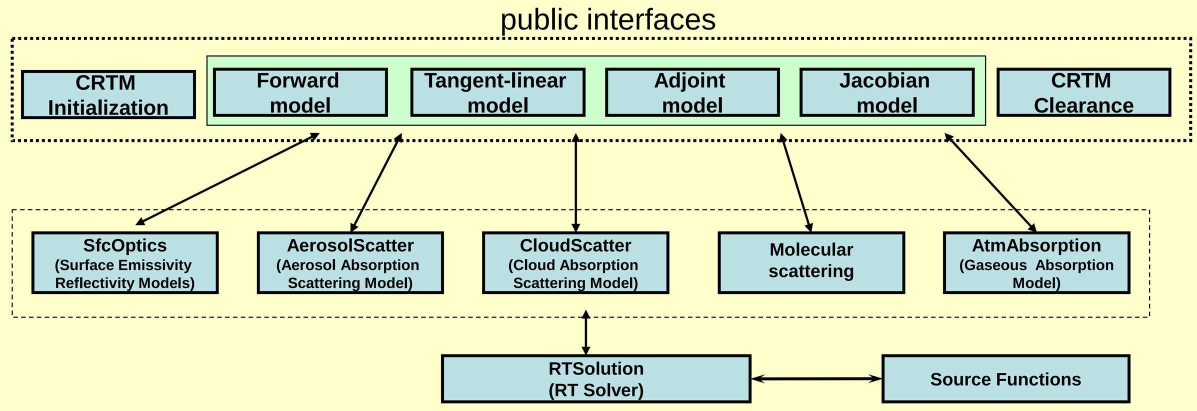
Joint Center for Satellite Data Assimilation (JCSDA) Partner Organizations



Support more than 100 Sensors

GOES-R ABI
TIROS-N to NOAA-19 AVHRR
TIROS-N to NOAA-19 HIRS
GOES-8 to 14 Imager
GOES-8 to 14 sounder
Terra/Aqua MODIS
METEOSAT-SG1 SEVIRI
Aqua AIRS, AMSR-E, AMSU-A, HSB
NOAA-15 to 19 AMSU-A
NOAA-15 to 17 AMSU-B
NOAA-18, 19 MHS
TIROS-N to NOAA-14 MSU,
DMSP F13 to 15 SSM/I
DMSP F13,15 SSM/T1
DMSP F14,15 SSM/T2
DMSP F16-20 SSMIS
Coriolis Windsat
TiROS to NOAA-14 SSU
METOP-A IASI AMSUA, MHS, HIRS, AVHRR
FY-3 IRAS, MWTS, MWHS, MWRI
SNPP CrIS/ATMS/VIIRS
AMSR2, AMSR-E, TMI
AHI_himawari8
others

3. CRTM Modules and Supported Sensors

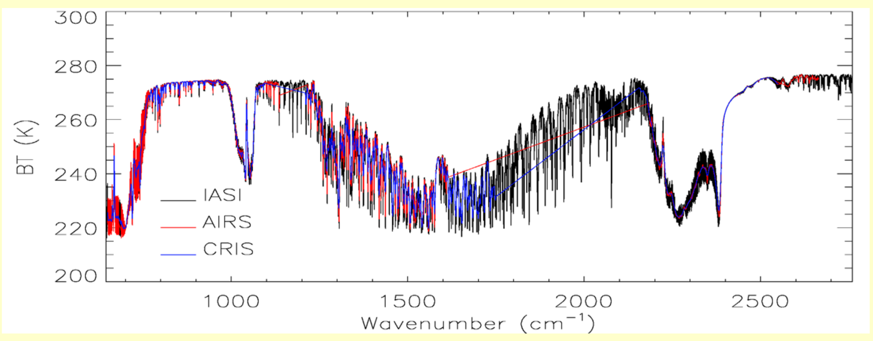


CRTM main modules

4. CRTM Transmittance Model

4.1 Transmittance Model

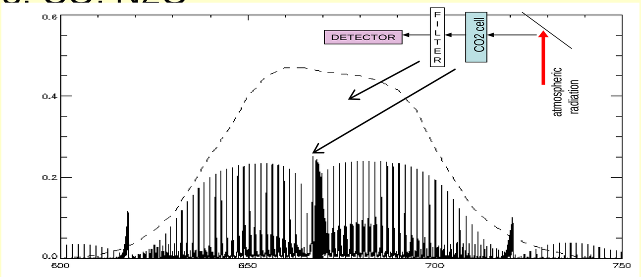
- The transmittance model is to compute atmospheric transmittance from absorbing gases
- In addition to the ODAS model, a new transmittance model ODPS (Optical Depth in Pressure Space) has been implemented in version 2.
- Currently supported input trace gases: H_2O, CO_2, O_3, CO, N_2O and CH_4



CRTM simulated IASI, AIRS and CrIS spectrum

4.2 Specific Transmittance Model

- Zeeman-splitting for affected microwave channels
- Stratospheric sounder unit transmittance to account for onboard CO_2 cell pressure leaking.
- NLTE Model



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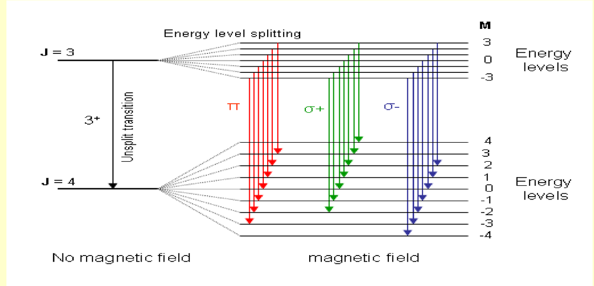


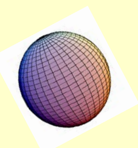
Zeeman effect:
The O_2 transition line is split into many sublines, which can change transmittance.

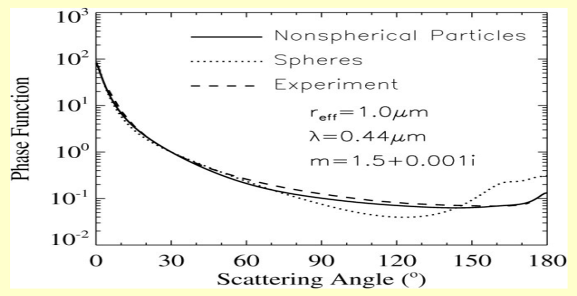
5. Aerosol and Cloud Models

Aerosols:
Global Model, GOCART
Dust, Sea Salt, Organic carbon,
Black carbon, Sulfate
Regional Model
CMAQ is under implementation.
Aerosol 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.



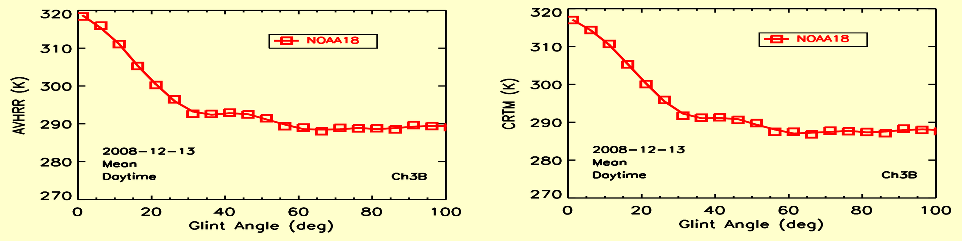


Effect of non-spherical particles. Ding, et al. TAMU

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.

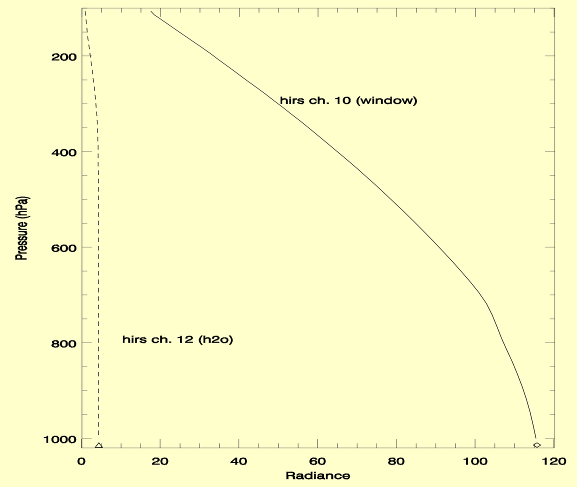


Using the CRTM IR BRDF model, simulations over oceans agree with measurements.

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 clouds. CRTM can simulates 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 calculation. For a pixel with a cloud fraction F, radiance can be expressed as the weighted sum of clear and cloud radiance:

$$R = (1-F)R_{clear} + F \times R_{cloud} \qquad (1)$$

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

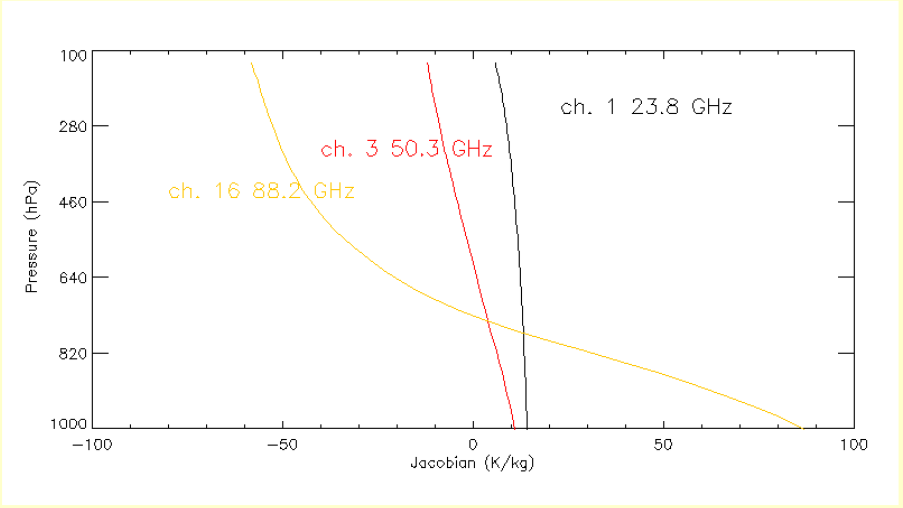
$$\frac{\partial R}{\partial x} = -R_{clear}\frac{\partial F}{\partial x} + (1-F)\frac{\partial R_{clear}}{\partial x} + \frac{\partial F}{\partial x} \times R_{cloud} + F \times \frac{\partial R_{cloud}}{\partial x} \qquad (2)$$

Eqs.(1) and (2) are handled inside the CRTM so that users can directly compute radiance and radiance jacobian 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 that is input to the CRTM. It is important to utilize cloudy 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 radaiance jacobian computation in the absence of clouds will be trigged when users specify a cloud type and effective particle size.



ATMS BT jacobian where clouds are absent for an ocean surface.

a) The effect on clear-sky radiance calculation is negligible (<0.0001K)
b) The extra computation time for the cloud radiance jacobian is negligible.

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