Improve Clouds and Precipitation Products for NWP

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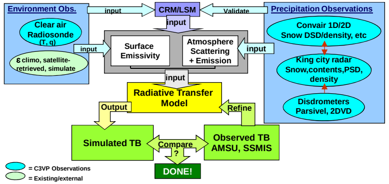
1. Motivation

The goal of this project is to extend satellite microwave direct radiance assimilations from clear sky to cloudy and precipitating conditions. This requires an accurate radiative transfer (RT) model and knowledge on the cloud and precipitation variables that can be explicitly simulated by the NWP models. Our approach is to employ radiative transfer models to directly account for the absorption, emission, and scattering effects by the atmosphere, clouds and precipitation. As a step forward in assimilating microwave radiances for evaluating NWP models. We will combine radiative transfer models with field campaigns data and WRF model outputs, along with NOAA AMSU/MHS and DMSP SSMIS observations to evaluate the impacts of clouds and precipitation microphysics in radiance assimilations. We will focus this study on simulating microwave radiances over cold-season mid-latitude North America continental region.

2. January 22, 2007 Synoptic Snow Over Land

During the winter of 2006-2007 a cold season field campaign conducted by the Canadian CloudSat/Calipso validation project (C3VP) took place. On January 22, 2007 a snowfall event developed as a result of a synoptic scale frontal system passing across southern Ontario. This frontal system produced a widespread of light to moderate snowfall between 0200 and 0800 UTC. Figure 1 shows the NOAA18 Microwave Humidity Sounder (MHS) overpass over the CARE site at 06:45 UTC. Noticed the brightness temperatures (TB) from the five MHS frequency channels 89, 157, 183.3±1, 183.3±3, 190.3 GHz at this time at the CARE site (44.23, -79.78) were relatively cold. They are 229.94, 229.57, 239.96, 247.11, 249.46 degrees Kelvin, respectively. Figure 2 shows the vertical distribution of temperature, relative humidity, and cloud liquid water content (LWC) and ice water content (IWC) from a coordinated aircraft flight spiral descend from just the upstream to the CARE site from 5.9999 to 6.397 UTC. The cloud liquid water content measured by a King probe during this descend was very small (less than 0.03 g/m3). The ice water content distribution was in the range of 0-0.38 g/m3.

3. Radiative Transfer Simulation



Flowchart of the Radiative Transfer Model Simulation

The surface emissivity shown in figure 3 for the CARE site is derived for each MHS channel from the observed brightness temperatures, temperature and humidity profiles from radiosonde, and surface temperature from a ground station near CARE, all from clear air conditions in January 24, 2007. For Mie theory calculation, cloud drop size distributions are assumed gamma function (Liou, 2002). Rain size distributions follow the Marshall-Palmer distribution. The precipitation snow particles are assumed to be spherical and the size distributions to be exponential distributions, even though It is well known that ice particles shapes are complex and can vary from clouds to clouds, The density of snow is determined from the aircraft 2D probe measurements. Maxwell-Garnet mixing theory is used to determine the dielectric constant of the snow. Figure 4 shows the optical profiles of extinction coefficient, single scattering albedo, and asymmetry factor from the Mie calculation using the aircraft data from 05:99 to 06:04 UTC on January 22, 2007.

Figure 1
NOAA MHS Snow Observations January 22, 2007 06Z

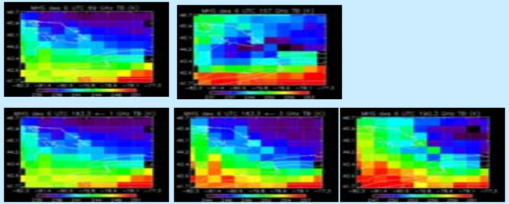


Figure 2
Vertical Distribution of T, q, and water contents

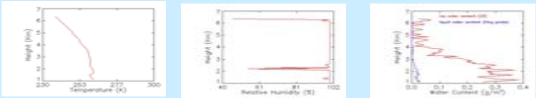


Figure 3
Surface Emissivity from AMSU

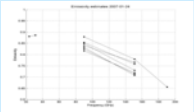


Figure 4
Vertical Profiles of Optical Properties

Extinction coefficient

Asymmetry Factor

Single Scattering Albedo

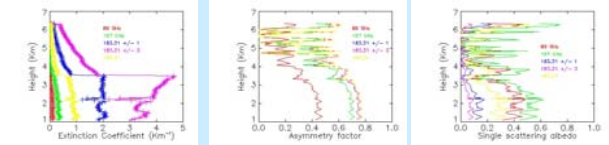


Figure 5
Preliminary Simulation Results

Frequency (GHz)	Observed TB (K)	Modeled TB (K)
89	229.94	231.24
157	229.57	241.59
183.3±1	239.96	260.53
183.3±3	247.11	261.81
190	249.46	262.64

4. Simulation results and Summary

The radiative transfer model used to calculate the brightness temperature using the atmospheric optical profiles and surface emissivity is the successive order of interaction (SOI). The SOI model is basically a combination of the "Successive Order of Scattering" technique (Greenwald et al., 2004), the adding-doubling method (Wiscombe, 1975), and a multiple-streams (discrete ordinates) approach to characterize the angular dependence of the radiation field (Bennartz et al., 2004). Brightness temperature calculations for 89, 157, 183.3±1, 183.3±3, 190.3 GHz using the SOI model and the atmospheric profile from January 22, 2007 at 06 UTC and the observed MHS TBs at 06:45 UTC are summarized in table 1. The radiative transfer model results for 89 and 157 GHz agree fairly well with the observed TBs (2K difference for 89GHz and 12 K for 157 GHz). However, for the three water vapor channels 183.3±1, 183.3±3, 190.3 the difference between model predicted and observed TBs are fairly large (~20K). One of the causes for this problem might be the aircraft temperature and humidity measurements. We're currently investigating other sources of the temperature and humidity data.