P4.16 WHAT ARE THE BENEFITS OF COMBINING VISIBLE, INFRARED AND MICROWAVE SATELLITE DATA IN RETRIEVING CLOUD PHYSICAL PROPERTIES?

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1. INTRODUCTION

Observing the physical properties of clouds from satellites remains an important component of integrated climate studies (Asrar et al. 2001). While data from both visible/infrared and microwave sensors contain cloud information, little attention has been paid to the value of combining these data to form a unified, synergistic retrieval approach. Lin et al. (1998), for example, combined visible/infrared and microwave data to examine cloud properties but performed retrievals separately in the respective wavelength regions.

With respect to retrievals of liquid water cloud properties, data from these different sensors are highly complimentary. Visible/infrared retrievals require assumptions about the droplet size distribution, whereas microwave retrievals are free of such assumptions because cloud absorption is independent of size distribution. Furthermore, microwave sensors can provide information on the atmospheric moisture content within clouds. The usually coarse resolution of satellite microwave data has prevented a synergistic approach to be put into practice. However, the improved spatial resolution of upcoming microwave sensors now makes this approach feasible.

The basic question we wish to address is whether microwave measurements can provide additional, beneficial information to retrievals of cloud optical depth and particle effective radius that have used exclusively visible/infrared measurements. This work is part of an effort to combine Global Imager (GLI) and Advanced Microwave Scanning Radiometer (AMSR) measurements from the soon to be launched Advanced Observing Satellite (ADEOS)-II to simultaneously estimate cloud, atmospheric and surface properties. Retrievals are limited here to clouds composed only of water droplets. As an early test of the retrievals, coincident MODerate-resolution Imaging Spectroradiometer (MODIS) and TRMM Microwave Imager (TMI) data are used as replacements for the GLI and AMSR.

2. DATA

MODIS is a multi-channel visible/IR imager that currently flies on NASA's Terra satellite (King et al. 1992). Both MODIS and GLI have 36 channels. Table 1 shows the MODIS channels of interest to this study in comparison to equivalent channels on the GLI. We used the MODIS 1 km product for all channels.

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TMI is 9-channel conical scanning microwave imager on the TRMM platform (Kummerow et al. 1998). The channels of interest here include the 10.65 GHz at vertical polarization (63 km resolution), 21.8 GHz at vertical polarization (23 km resolution), and 85.5 GHz at vertical polarization (5 x 7 km resolution). The 85.5 GHz channel was selected over the 37 GHz channels, which are also sensitive to liquid water, because they have higher spatial resolution and, in this case, greater sensitivity to liquid water. Table 2 shows selected TMI channels in comparison to equivalent channels on the AMSR.

TABLE 1. Comparison of spectral characteristics (in microns) between MODIS and GLI for selected channels.

MODIS		GLI	
Channel	Bandwidth	Channel	Bandwidth
1	0.62-0.67	22	0.60-0.72
20	3.66-3.84	30	3.55-3.88
31	10.78-11.28	35	10.3-11.3

TABLE 2. Comparison of spectral characteristics (in GHz) between TMI and AMSR for selected channels at vertical polarization.

TMI		AMSR	
Channel	Center Freq.	Channel	Center Freq.
1	10.65	3	10.65
5	21.8	7	23.8
8	85.5	11	89

3. METHODS

The retrieval approach is based on the concept of a cost function (Rodgers 1976) defined as

$$\Phi = (x - x_a)^T S_a^{-1} (x - x_a) + (y - f(x))^T S_y^{-1} (y - f(x))$$

where x is a vector of atmospheric, cloud, or surface parameters to be retrieved, x_a is a vector of a priori information for x, the matrix S_a corresponds to the errors associated with x_a, y is the vector of MODIS and TMI measurements, $f(x)$ is the vector of modeled measurements (i.e., forward radiative transfer calculations), and S_y is a matrix containing the combined error estimates of the measurements and forward model. The goal is to minimize Φ.

The strength of this method lies in providing the most probable estimate for x and is thus in a class of so-called "optimal" methods. It has the advantage of describing the retrieval errors in terms of the a priori data and the measurement and forward model errors, and it allows one to quantify the impact of different measurements on the retrievals, which is our goal here. In addition, this approach makes it much easier to include additional measurements at different wavelengths by simply lengthening the necessary vectors.

Ultimately, the retrieval vector x will include 9 parameters: cloud optical depth, cloud top temperature/height, droplet effective radius, cloud liquid water path, total precipitable water, sea surface skin temperature, and surface emissivity at all three microwave channels. We plan to incorporate 6 measurements (see Tables 1 and 2) into the observational vector y. However, early experiments will most likely start with fewer measurements and retrieved parameters and then work up to the full number of retrieved parameters.

The radiative transfer solver used in forward calculations of visible/IR radiances is the Spherical Harmonics Discrete Ordinate Method (SHDOM; Evans 1998). Cloud extinction and single-scatter albedo were estimated using the Modified Anomalous Diffraction Theory of Mitchell (2000). Simple assumptions were made regarding the scattering phase function. Initial plans are to assume a Henyey-Greenstein phase function, which is solely dependent on the asymmetry factor. The asymmetry factor is estimated from the parameterizations developed by Greenwald et al. (2001). Gas extinction is accounted for by the Optical Path TRANsmittance (OPTRAN) approach of McMillin et al. (1995).

For computing forward microwave radiances we used a model applied in our previous work (e.g., Greenwald et al. 1997) that solves the transmittance form of the radiative transfer equation for an absorbing/emitting atmosphere. Gas and cloud absorption are computing from the Millimeter-wave Propagation Model of Liebe et al. (1993).

4. CASE STUDY

Finding a suitable test case was limited to availability of coincident overpasses between Terra and TRMM. A good case of a marine stratocumulus system was found at 1016 UTC on 22 March 2000 off the east coast of southern Africa. Figures 1 and 2 show selected MODIS and TMI images, respectively.

Collocation was performed by collecting all MODIS data that fell within the footprint of the 85.5 GHz channel of the TMI. Only overcast 85.5 GHz footprints with warm clouds were considered for analysis. These situations were determined from MODIS visible and IR data.

5. RESULTS

Results will be presented at the conference.

6. ACKNOWLEGMENTS

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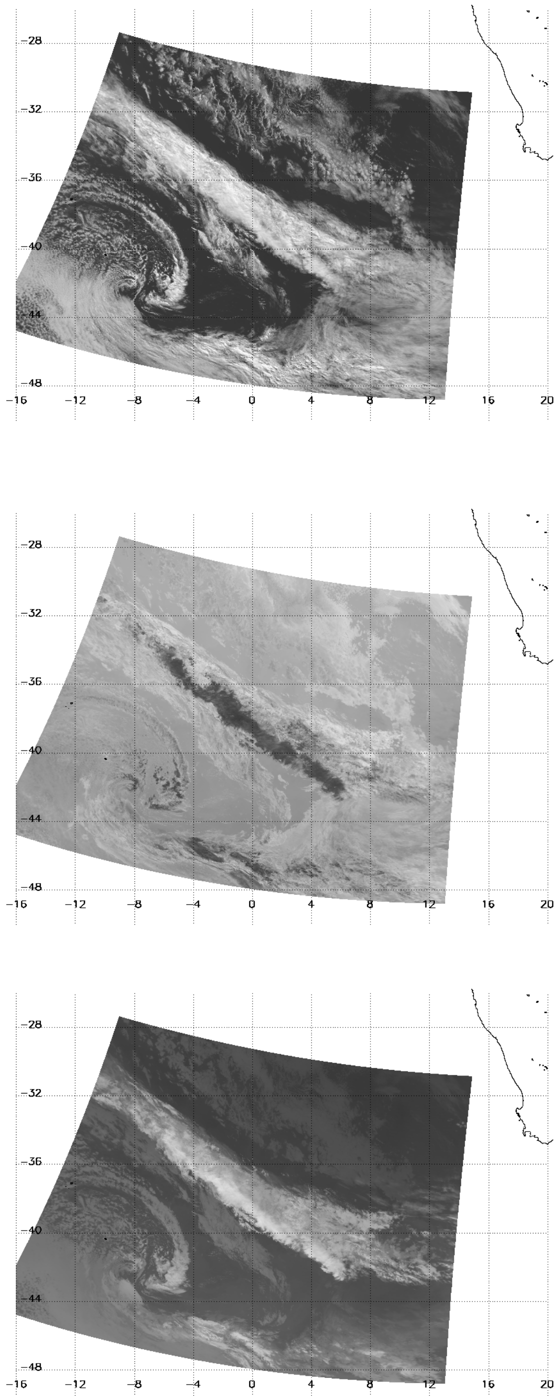

Fig 1. MODIS visible (top), near-infrared (middle), and infrared (bottom) images.

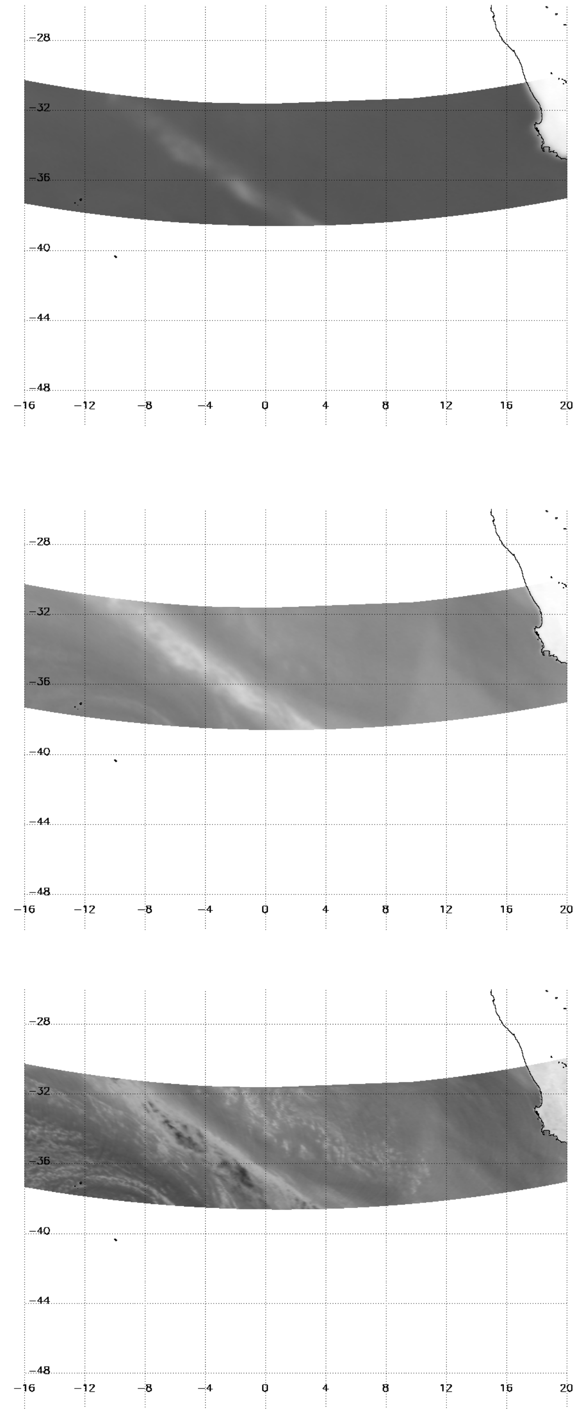

Fig 2. TMI 10.65 GHz (top), 21.8 GHz (middle), and 85.5 GHz (bottom) images.