Cloud Retrievals From GOES-R

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Abstract: The next generation of USA geostationary satellites will have an enhanced imager, the Advanced Baseline Imager, that will enable improved detection and retrieval of cloud properties. Use of new channel combinations for retrievals is discussed.
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1. Introduction

The need for real-time cloud information from satellites has grown during the past decade with advances in numerical weather prediction (NWP) models and assimilation techniques [1], as well as increased demands for improved air traffic safety and more accurate surface radiation information. Geostationary satellites (GEOSATs) are the only source for deriving the necessary cloud properties over large areas in a timely fashion. Currently, cloud-top heights are being generated operationally by NOAA NESDIS from Geostationary Operational Environmental Satellite (GOES) sounder CO_2-slicing channels and are assimilated into a numerical weather prediction model [2]. Cloud microphysical properties are also being generated in a near-real-time from GOES imager data [3], and used to enhance aircraft icing diagnoses [4], and are being considered for assimilation into NWP models to improve the hydrological balance within the model. These and other uses for cloud properties are being further developed but are limited in many ways by the accuracy of the satellite-retrieved information. Those retrievals are, in turn, constrained by the spectral content and spatial resolution of the satellite imagers and sounders.

For example, multilayered clouds cause considerable error in the retrieved cloud properties because the spectral radiances typically correspond to some combination of the radiances from the lower and higher clouds. While methods have been developed for detecting overlapped clouds [5,6], and retrieving the properties of the upper and lower layers [6], they require certain combinations of spectral channels that are unavailable on most GEOSATs. Detection and estimation of cloud properties, such as cloud phase, at night are also highly restricted because of the few infrared channels (3.9, 10.8, and 12.0 µm) available on most GEOSATs. The capability to discriminate clouds from heavy aerosols is also difficult with current GEOSATs because of their limited spectral content. Spatial resolution also impacts cloud detection and interpretation because some cloud elements, such as cumulus, are smaller than the pixel sizes and are either confused as clear areas or as optically thin clouds.

The next generation of GEOSATs developed in the United States, GOES-R, will help reduce errors resulting from the pixel resolution and spectral channels available on the current series of GOES. The GOES-R Advanced Baseline Imager (ABI) will have 16 spectral channels with resolutions ranging from 0.5 to 2 km [7], as compared to the current GOES imager that has 5 channels and resolutions between 1 and 4 km. This paper examines the prospects for using the ABI data to improve cloud retrievals for future real-time analyses.

2. Data

Table 1 summarizes the ABI resolution and wavelengths λ and compares them with those from the current GOES-12 imager and the Meteosat-8 Spinning Enhanced Visible and Infrared Imager (SEVIRI), the most advanced GEOSAT imager at present. The ABI has 11 more channels than the current generation of GOES imagers with resolution enhanced by a factor of 2. SEVIRI has 4 fewer channels than the ABI, but the high resolution visible channel HRV is a broadband channel similar to the old Meteosat visible channel. It has no counterpart in the ABI array. Because the SEVIRI data are similar to the future ABI, in that many channels are in common and they are available from a GEOSAT perspective, they provide the best basis for testing new ABI-like algorithms. The Moderate Resolution Imaging Spectroradiometer (MODIS) on the polar-orbiting *Terra* and *Aqua* has channels similar to all of the ABI bands, except for those at 6.2 and 10.35 µm. Thus, MODIS data can alos be used for developing and testing many of the ABI techniques. GOES-10 and 12 data can be used in a limited manner. Theoretically simulated data are needed to take advantage of the new 10.35-µm band.

3. Methodologies

There are many different techniques being used to derive cloud properties from the various satellite datasets. To simplify discussion, this paper begins with the algorithms employed by the Clouds and Earth's Radiant Energy System (CERES) Project to derive clouds from MODIS data [8,9] and used to analyze GEOSAT data for various

Table 1. Summary of spectral channels on GOES-R (ABI), GOES-12, and Meteosat-8 (SEVIRI) imagers.

GOES-R		GOES-12		Meteosat-8	
central λ (µm)	resolution (km)	central λ (µm)	resolution (km)	central λ (µm)	resolution (km)
0.47	1	-	-	-	-
0.64	0.5	0.65	1	0.63	3
0.86	1	-	-	0.81	3
1.38	2	-	-	-	-
1.6	1	-	-	1.60	3
2.2	1	-	-	-	-
3.9	2	3.9	4	3.9	3
6.2	2	-	-	6.2	3
6.7	2	6.7	4	-	-
7.3	2	-	-	7.3	3
8.5	2	-	-	8.7	3
9.7	2	-	-	9.7	3
10.35	2	-	-	-	-
11.2	2	10.8	-	10.8	3
12.3	2	-	-	12.0	3
13.3	2	13.3	-	13.4	3
HRV	-	-	-	0.70	1

projects [3]. The current CERES cloud detection algorithm uses the MODIS 0.65, 1.38, 1.6, 3.7, 8.5, 10.8, and 12.0-µm channels during the daytime and the 3.7, 6.7, 8.5, 10.8, and 12.0-µm channels during the night. The 6.7-µm channel is used over the polar regions. Despite this array of channels, some difficulties remain. Discrimination between heavy dust aerosols and clouds is often problematic with the dust being classified as clouds. A number of studies over the past decade indicate that the absorption of blue light by dust aerosols can be used to discriminate the aerosols from clouds even over desert backgrounds [10,11]. Using the 0.47, 0.64, and 2.2-µm channels together with infrared approaches that make use of the 8.5, 10.8, and 12.0-µm channels [12], it will be possible to dramatically reduce the misclassification of aerosols as clouds during both day and night with the ABI.

Detection of multilayered clouds and unscrambling of the cloud layers will also be possible to an unprecedented level with the ABI complement of infrared channels. On the current operating GOES, the imager has either 12.0 or 13.3 µm as the fifth channel. Only the latter is available on all imagers after GOES-11. Both channels are valuable for detecting multilayered clouds when used in conjunction with the 0.64-µm band. Figure 1 shows an example of overlapped cloud detection applied to GOES-10 and 12 imagery taken at 1915 UTC, 5 May 2005 over the southern Great Plains. The pseudocolor RGB image (Fig.1a) shows the presence of a cirrus deck overlying low stratus and stratocumulus clouds. A brightness temperature difference method (BTD, [5]) was applied to the results of the CERES algorithm used on GOES-10 data (Fig. 1b) to classify the ice and liquid water clouds as single or multi-layered. Similarly, a CO_2-slicing technique [6], was applied to the GOES-12 data to classify the clouds according to height, optical thickness, and layering (Fig. 1c). In this instance, the BTD method appears to perform slightly better than the latter in discriminating single from multi-layered clouds. With the ABI, both methods could be used together to make an optimal assessment of the layering and the CO_2-slicing method retrieval could be used to retrieve the cloud properties of each layer [6]. Additionally, the techniques could also be used together with the 3.9 and 8.5-µm channels to detect multilayered clouds at night.

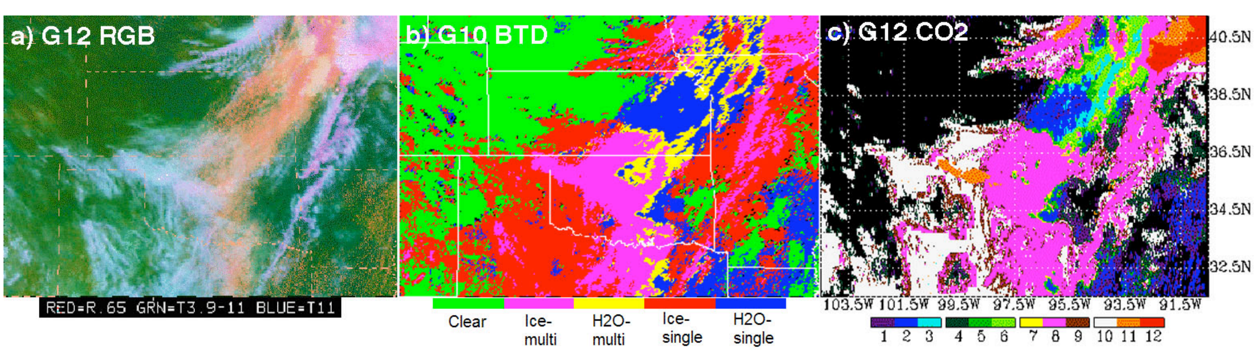

Fig. 1. Cloud layering from GOES imagery, 1915 UTC, 5 May 2005. (b) Phase is given for single-layer retrieval. (c) 1-3: low single-layer, 4-5: mid single-layer, 7-9: multi-layer, 10-12: high single-layer

Enhanced retrievals of cloud microphysical properties should also be possible with the new channels on the ABI. Separate retrievals of cloud particle sizes at 1.6, 2.2, and 3.9 µm can be used to interpret the vertical structure of the clouds, which will improve the estimation of cloud ice and liquid water paths and provide information about precipitation from those clouds [13]. Better estimation of thin cirrus cloud properties will be possible with the aid of the 1.38-µm channel [14]. The 10.35-µm channel has not been used on any satellite imagers to date but aircraft-based measurements have shown potential for detecting thin cirrus clouds and for improved retrievals of ice crystal sizes when used in conjunction with the 10.8 and 12.0 µm channels [15]. It will be especially useful for nocturnal retrievals of cirrus clouds. Similarly, the infrared complement will significantly enhance phase discrimination at night, a change that will improve the diurnal consistency of retrieved cloud properties.

Overall, the greater resolution of all channels will result in better cloud discrimination and retrieval. In particular, the 0.5-km resolution of the ABI visible channel will enhance the quality of the retrieved properties in partially cloud-filled infrared pixels that would otherwise be interpreted as overcast [16].

4. Concluding Remarks

Many challenges, including calibration, validation, simulation, and modeling, must be addressed in order to develop the optimal algorithms and data processing systems that will exploit the ABI capabilities. Fortunately, they can be met by careful analyses that employ the latest radiative transfer techniques as well as data from GOES, MODIS, SEVIRI, and airborne sensors, active remote sensing from airborne, surface, and satellite-based radar and lidar, and from other passive radiometers on the ground. These new algorithms, when applied to the GOES-R ABI, will dramatically improve near-real-time cloud monitoring and interpretation and produce results that will be invaluable for many applications including weather forecasting and air safety.

5. References

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