P1.70 NIGHTTIME RETRIEVAL OF CLOUD MICROPHYSICAL PROPERTIES FOR GOES-R

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1. INTRODUCTION

Currently, multi-spectral algorithms are being used at NASA Langley Research Center to retrieve microphysical cloud properties from satellite imagery in near-real time over a variety of domains. For nighttime imagery, the Solar infrared-Infrared-Split window Technique (SIST) is applied to data from the Geostationary Operational Environmental Satellite (GOES) over the Continental US, the Spinning Enhanced Visible InfraRed Imager (SEVIRI) over Europe, the Multi-functional Transport Satellite (MTSAT) over the tropical western Pacific and to Moderate Resolution Imaging Spectroradiometer (MODIS) imagery over the globe. As part of GOES-R Cloud Algorithm Working Group (AWG) efforts at CIMSS, NASA Langley's SIST is being integrated into the GOES-R application framework by removing it from its native environment and revising it to function in the Geostationary Cloud Algorithm Testbed (GEOCAT).

This paper presents first results from new SIST retrievals conducted on SEVIRI imagery that is being used as a proxy for GOES-R Advanced Baseline Imager (ABI) data. SIST-derived cloud properties calculated within the GOES-R cloud application team's developmental framework are presented. Alterations to SIST, primarily related to using a new option that allows cloud temperature, T_{cld}, and cloud thermodynamic phase to be determined prior to the invocation of SIST, are discussed.

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2. DATA

Prior to the launch of GOES-R and ABI, the Cloud Algorithm Working Group is utilizing SEVIRI imagery for algorithm development purposes. This study uses results from SEVIRI imagery from August 2006, the Working Group's chosen benchmarking month. The 3.9-, 10.8- and 12-micron channels are used in this preliminary version of the nighttime algorithm. Because the algorithm development is being done within the GEOCAT framework, various ancillary data sets already integrated into that framework are utilized by SIST, as well as results from the various algorithms. Surface characteristics such geotype and wavelength-dependent emissivities from the SeeBor database (Borbas et al., 2007) are obtained via GEOCAT and, notably, the cloud temperature and phase are obtained from baseline algorithms used by the working group.

Numerical Weather Predication (NWP) forecast data sets obtained from National Center for Environmental Prediction (NCEP) Global Forecast System (GFS) model data are used to convert cloud temperatures to cloud heights and vice versa, as well as for input to the Radiative Transfer Model (RTM) used within GEOCAT and for simulating cloud radiances within SIST. The fast RTM currently utilized by the GOES-R Cloud Algorithm Working Group is the PLOD/PFAAST (Hannon et al., 1996).

3. ALGORITHM

Because both SIST and its daytime counterpart, the Visible-Infrared-Solar infrared-Split window Technique (VISST) from Minnis et al., 1995, are routinely applied to SEVIRI imagery (see http://www-pm.larc.nasa.gov), transitioning the existing SIST to work in GEOCAT involved extensive alterations to SIST. Several modifications were made in order to exploit SIST's skill in determining cloud optical depth, effective particle size and water path.

3.1. Current Version

The current SIST determines the cloud physical parameters that produce the minimum difference between observed and modeled brightness temperature differences for each satellite pixel. Cloud optical depth, effective particle size, water content and temperature of both water and ice clouds are obtained, as well as phase discrimination (Minnis et al., 1995). Observed Brightness Temperature Differences (BTDs) between 3.9 and 10.8, as well as 10.8 and 12 microns, are compared to modeled BTDs and cloud physical parameters are inverted. Those parameters that produce the minimum difference between observed and modeled BTDs for each pixel are assumed to describe the cloud. SIST discriminates between optically thin and thick clouds, but optical depth is reliably derived only for optically thin clouds.

In order to derive nighttime cloud properties for each cloudy pixel, the SIST calculates T_{cld}, cloud phase, optical depth and effective cloud particle size with a minimum error, iterative regression method that matches the observations to parameterized emittance calculations (Minnis et al. 1998, Minnis et al. 1995). A 75-term polynomial defines each emittance parameterization which is a function of optical depth, τ, effective ice-crystal diameter D_e or water-droplet radius r_e, and the temperature difference between the cloud and the surface. BTDs are calculated from the observed satellite radiances such that

$$BTD_{34} = T_{3.9\,\mu m} - T_{10.8\,\mu m}$$

and $$BTD_{45} = T_{10.8\,\mu m} - T_{12\,\mu m}.$$

Atmospheric absorption is accounted for using the correlated k-distribution technique of Kratz (1995).

These quantities are computed assuming that all cloudy pixels are overcast and have a temperature given by an initial estimate of $T_{cld} = T_{10.8\,\mu m}$ over a background with the a priori clear-sky temperature for each channel. The phase and a nominal particle size are also assumed for the initial computation. The calculations of BTD_{34}' and BTD_{45}' are repeated for both liquid and ice clouds by varying D_e or r_e, τ and T_{cld} until the difference between the calculated and observed BTDs is minimized. Specifically, we minimize

$$\sum[(BTD_{34} - BTD_{34}')^2 + (BTD_{45} - BTD_{45}')^2].$$

The selected phase is based on which of the two minimum phase errors is smaller and physically consistent. Cloud height is calculated from the resultant T_{cld} using the appropriate atmospheric profiles. Note that because the radiances observed in a cloudy pixel are assumed to be from a single cloud layer, multi-level scenes or partially cloud-filled pixels can result in less reliable retrievals.

3.2 GOES-R Version

For this version of SIST, rather than employing the usual iterative scheme where T_{cld} is allowed to vary along with τ and particle size, T_{cld} is assumed to be previously determined within the GOES-R algorithm. Additionally, the need to simulate BTD_{34}' and BTD_{45}' for both ice and water models is eliminated due to the fact that phase cam be determined prior to the invocation of SIST. The elimination of iterating with respect to T_{cld} and calculating solutions for both phases results in a streamlined and faster version of SIST.

Within the GOES-R framework, the RTM calculations for each satellite observation have already been made with PLOD/PFAAST and retained, so SIST utilizes those results rather than invoking the correlated k-distribution technique providing consistency with other GOES-R retrievals and additional computational efficiency.

4. CASE STUDIES

The first application of the GOES-R SIST was to SEVIRI imagery covering an area off the westcentral coast of Africa. The 10.8-micron imagery (SEVIRI channel 14) is shown in Figure 1. The areas over the ocean are covered by a mixture of

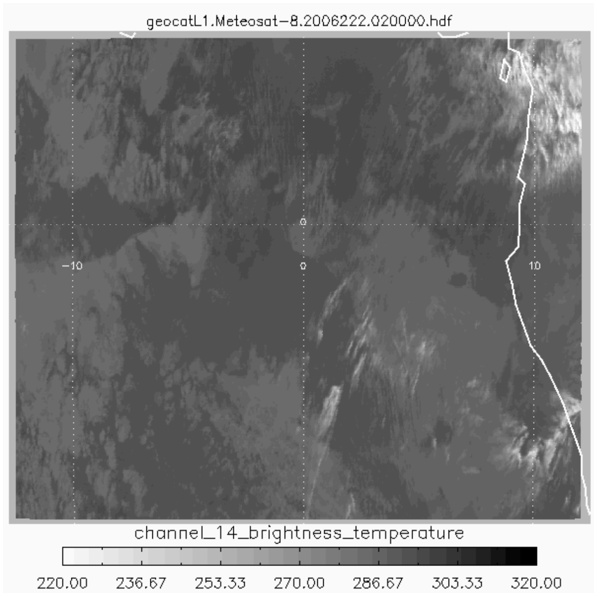

Fig. 1. SEVIRI infrared imagery (10.8 micron) off the coast of Gabon for 2 August 2006, 0200 UTC.

warm clear areas, stratus clouds, both solid and broken, with temperatures around 280° (K) and smaller areas of much colder cirrus clouds over land and sea. In Figures 2 and 3, the input products provided by the GOES-R Cloud AWG and needed for SIST, the derived T_{cld} and phase, are presented.

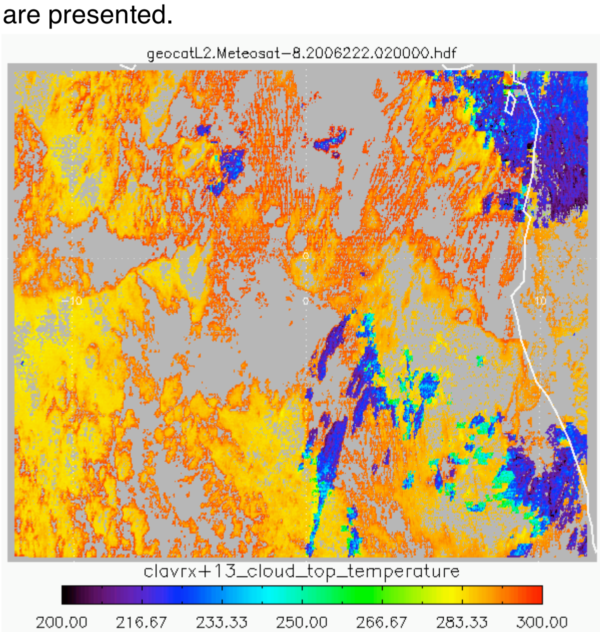

Fig. 2. GOES-R AWG derived cloud temperature for imagery in Figure 1 that is input to SIST.

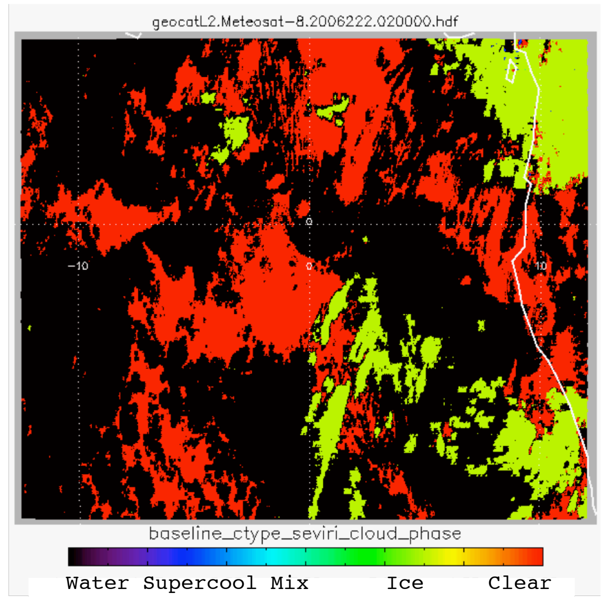

Fig. 3. GOES-R AWG derived cloud phase for imagery in Figure 1 that is input to SIST.

As expected, the stratus cloud temperatures in Fig. 2 are close to the emitted temperatures of Fig. 1, i.e., near 280°(K), but with the impact of partially-filled pixels on the cloud edges apparent. The cirrus cloud temperatures range from about 218°(K) in single layer areas to 250°(K) in multi-layer clouds where larger radiances from the warmer stratus below are affecting the retrieved T_{cld}. The accompanying phases in Fig. 3 appear to describe the scene appropriately with water clouds (black) and ice clouds (green) well-chosen.

The results from SIST, using the inputs from Figs. 2 and 3, are shown in Figure 4. Figure 4a shows the optical depth, ranging from less than 1 to up to 10 or 12 over the ocean. The cirrus cloud optical depths are very small, generally less than 1, but are difficult to visualize with this color scheme. the effective particle size is shown in Figure 4b. Most noticeable are the low r_e of the stratus and the large r_e of the cirrus. The water cloud re appear to be always less than 10 microns, hence more work will be done to investigate this feature. The ice clouds have re greater than 30 microns, therefore are not well-depicted in this figure. In Figures 4c and 4d, the accompanying SIST-derived liquid and ice water paths, respectively, are shown.

In order to demonstrate the ability of this new application of SIST to larger areas in the GOES-R framework, a first full disk analysis was performed. In Figure 5 and Figure 6, a retrieval is shown for SEVIRI imagery from 1 August 2006 at 2300 UTC. The cloud optical depth and the the liqud water paths shown in the figures are promising when

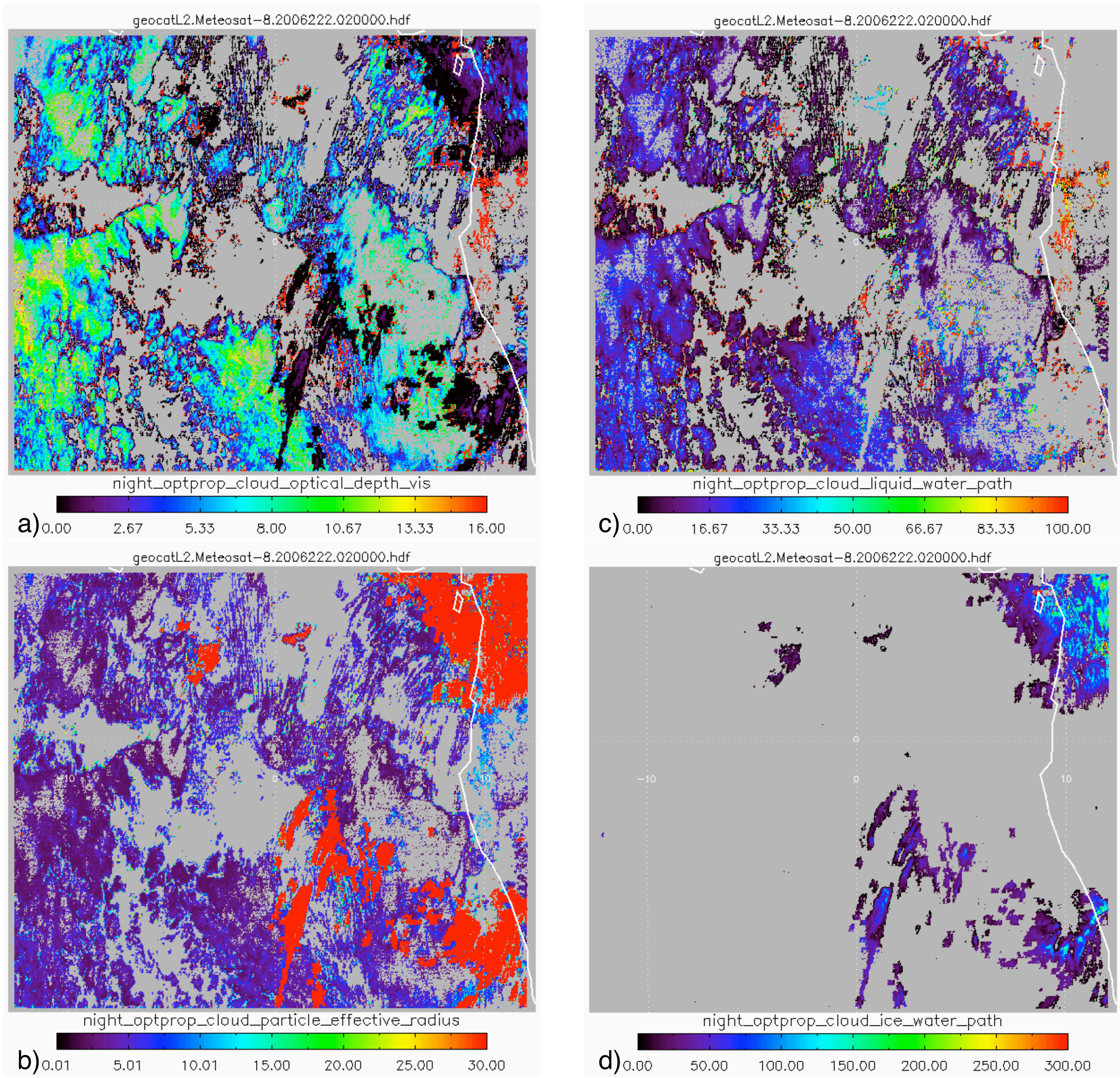

Figure 4. Results from 2 August 2006 0200 UTC. SIST utilized the input from Figs. 3 and 4 to obtain a) optical depth, b) r_e (microns), c) liquid water path (g/m^2), and d) ice water path (g/m^2).

compared to similar retrievals of these quantities.

5. SUMMARY AND FUTURE WORK

Results from this first application of a revised SIST are encouraging and show potential for application to full disk imagery from SEVIRI and ABI. While these results reveal some shortcomings, it is expected that these will be corrected as the algorithm matures.

Potential enhancements to SIST, including the use of 8.7 and 13.3-μm data will be examined. Additionally, retrievals from day/night transition areas will be conducted to access the possibility of using SIST for twilight.

Validation for both case studies and longer time scales remains a top priority, as well as comparisons to full-blown SIST algorithm retrievals from NASA Langley and from results provided by other GOES-R AWG team members. The full-blown SIST is used to process MODIS imagery data for the Clouds and the Earth Radiant Energy System (CERES) project, so MODIS-derived results that can also mimic ABI will be used. The integration of SIST into GEOCAT should facilitate

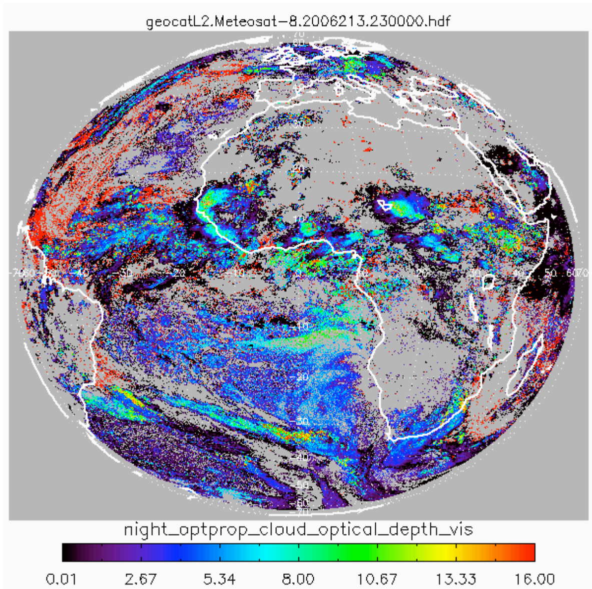

Fig. 5. SIST-derived cloud optical depth for 1 August 2006 2300 UTC.

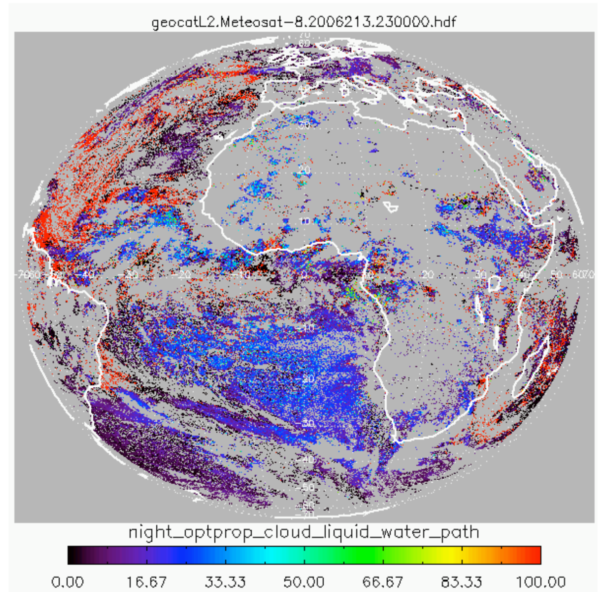

Fig. 6. SIST-derived cloud liquid water path (g/m^2) for 1 August 2006 2300 UTC.

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