University of Wisconsin-Madison Space Science and Engineering Center
Cooperative Institute for Meteorological Satellite Studies

Evaluation of GOES-R Cloud Algorithms Using SEVIRI and CALIPSO Data

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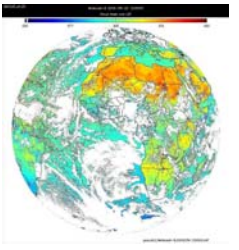
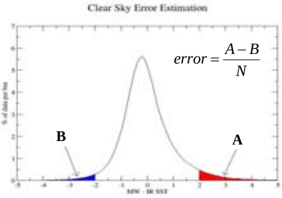
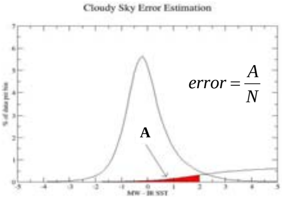
ABSTRACT

Previously, scientists have relied on passive instruments aboard polar-orbiting and geostationary satellites to estimate cloud coverage for both short-term and climatological applications. The recent addition of active cloud profiling missions (e.g., CALIPSO) into the NASA EOS A-Train allows access to a high quality LIDAR data set. These data can be used to characterize the performance of IR cloud algorithms developed for the Advanced Baseline Imager (ABI) that will fly on GOES-R. Although no current geostationary imager has the spectral resolution available from the ABI, the Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) provides enough information to test several of the ABI approaches. Presented are some techniques for evaluating prototype ABI cloud algorithms using SEVIRI and CALIPSO data utilizing an analysis software package called GEOCAT.



Cloud Mask Evaluation Using SEVIRI IR SST and TMI/AMSR-E MW SST





•One method to evaluate the performance and accuracy of the cloud mask utilizes measured differences between a combined AMSR-E/TMI MW SST product (www.ssmi.com) and an IR SST product produced by regressing clear SEVIRI observations (11/12 micron brightness temperatures) with collocated MW SST data.

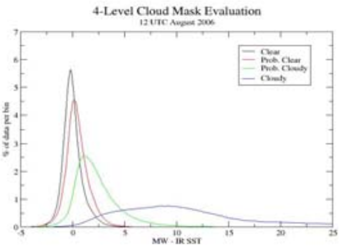
•Regressing the SEVIRI observations with the MW SST data ensures that differences will exhibit little bias in clear conditions.

•The differences are sorted into bins (0.1 K) and errors are estimated by the equations in the figures on the left, where A is the number of points in the red region, B is the number of points in the blue shaded region and N is the total number of points.

•Assuming the IR retrieval is colder in the presence of clouds the left tail (B) of the histogram is assumed to be the result of spatial or temporal errors due to the nature of the MW product (i.e., daily, 25km horizontal resolution). The same amount of error is likely present in the right tail (A) of the histogram so they are removed by subtracting the number of points in B from A. The remaining points in A are believed to be errors in the cloud mask.

•Ideally, clear areas would be depicted by a tight, normal distribution around 0 K while cloudy distributions would peak at large differences. The probably clear/cloudy curves should fall in between, as seen on the right where the performance of the ABI cloud mask for August 2006 is shown.

•Estimated errors calculated for the cloud mask as described above are shown in the table to the right.



Cloud Mask Errors Estimated Over Water

	0 UTC	*6 UTC*	*12 UTC*	*18 UTC*
clear	1.27%	1.45%	1.49%	1.37%
probably clear	4.25%	5.43%	5.45%	5.54%
probably cloudy	55.40%	53.77%	52.65%	52.45%
cloudy	4.84%	4.49%	4.69%	4.69%

Cloud Mask Evaluation Using CALIPSO Cloud Fraction

•Cloud fraction was obtained using an analysis tool called GEOCAT which ingested all CALIPSO data for August 2006 and calculated the fraction of laser shots that detected cloud within each collocated SEVIRI pixel.

•It is important to note that each CALIPSO point only retrieves a fraction of the SEVIRI pixel and is much more sensitive to clouds that cannot be detected using IR alone.

•The table below shows the distribution of the ABI cloud mask over the given ranges of CALIPSO cloud fraction for the month of August 2006.

•The ABI cloud mask detected clear or probably clear pixels about 83% of the time the CALIPSO cloud fraction was 0% and detected cloudy or probably cloudy pixels about 96% of the time the cloud fraction was 100%.

•These statistics were produced using the 1km CALIPSO cloud layers product so thin cirrus might be missed. The lower resolution CALIPSO products will contain more thin cirrus.

•The 1.38 micron channel available on the ABI should also improve results.

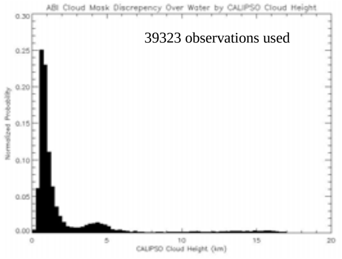
CALIPSO\ABI	Clear	Prob. Clear	Prob. Cloudy	Cloudy
0%	65.59%	17.45%	13.08%	3.88%
0%-50%	26.44%	26.50%	33.83%	13.22%
50%-100%	11.97%	15.08%	38.59%	34.37%
100%	2.08%	2.04%	9.05%	86.83%

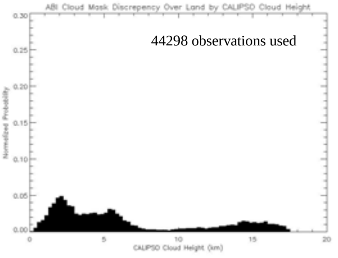
Cloud Mask Evaluation with Respect to Cloud Height From CALIPSO

•The histograms below show the distribution where the ABI cloud mask failed to detect clouds over water or land with respect to cloud and cloud heights determined by CALIPSO for August 2006.

•Over Water the cloud mask has the most trouble with sub-pixel boundary layer clouds.

•Over land thin cirrus clouds can be troublesome due to the clear sky radiance being less certain.





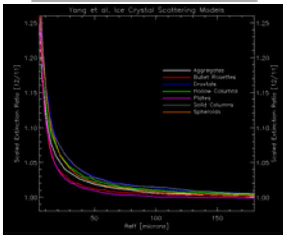
Beta Parameter

Drawing inspiration from Parol et al. (1991) and Inoue (1987), we present a technique to derive a cloud microphysical parameter for non-opaque clouds (e.g. visible optical depth < 6) from split-window measurements, given a retrieved cloud height. The microphysical parameter, β, is defined as given below. We use CALIPSO cloud heights to determine β. Our evaluation of β, which, in and of itself, does not include any assumptions about the cloud particle size and shape distribution, shows that for non-opaque high clouds there is a wide range of values, and therefore setting β=1 may not always be an accurate assumption.

$$\beta = \frac{\ln(1.0-\varepsilon_{12})}{\ln(1.0-\varepsilon_{11})} \approx \frac{(1.0-\omega_{12}g_{12})\sigma_{e12}}{(1.0-\omega_{11}g_{11})\sigma_{e11}}$$

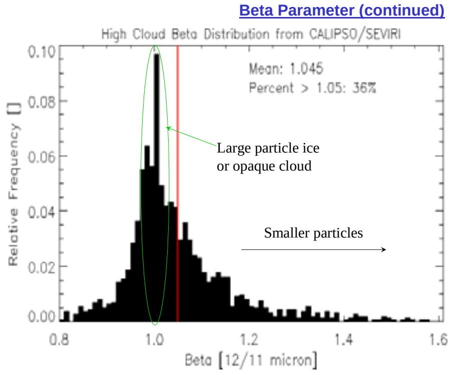
$$\varepsilon_{\lambda} = \frac{I_{\lambda} - I_{\lambda}(clr)}{I_{\lambda}(ac) + t_{\lambda}(ac)B_{\lambda}(T_{eff}) - I_{\lambda}(clr)}$$

Where,
ε_{λ} = effective emissivity
ω = single scatter albedo
g = asymmetry parameter
σ = extinction coefficient
I_{λ} = spectral radiance
t_{λ} = spectral transmittance
$B_{\lambda}(T_{eff})$ = Planck radiance of cloud
clr = clear
ac = above cloud



β can be estimated from the optical properties of the cloud particles (see equation above). The figure to the left shows β as a function of the effective particle radius for several ice crystal habit types (Yang et al., 2005). For particles > 10 μm, a particle habit needs to be assumed in order to retrieve an ice cloud particle size using β.

Beta Parameter (continued)



•For the figure on the left the β parameter was calculated for high clouds (CALIPSO cloud tops < 440 mb) with valid 11/12 micron emissivity values.

•The red line indicates where particle sizes are approximately 30 microns.

•This histogram shows that, for non-opaque clouds, setting β equal to 1.0 may not be an accurate assumption and that there is a broad range of values that are observed.

•Notice about 36% of β values are greater than 1.05.

•Taking into account the microphysical cloud properties, cloud height algorithms may be improved by allowing β to vary.

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References

Heidinger, A. K., M. J. Pavolonis, 2007: Nearly 30 Years Gazing at Clouds Through a Split-Window. Part 1: Methodology. *Submitted to the Journal of Applied Meteorology and Climatology*.

Parol, F., J.C. Buriez, G. Brogniez, and Y. Fouquart, 1991: Information content of AVHRR Channels 4 and 5 with respect to the effective radius of cirrus cloud particles. *J. Appl. Meteor.*, 973-984.

Yang, P., H. Wei, H. L Huang, **B. A. Baum**, Y. X. Hu, M. I. Mishchenko, and Q. Fu, 2005: Scattering and absorption property database of various nonspherical ice particles in the infrared and far-infrared spectral region. *Appl. Opt.*, **44**, *5512-5523*.