Validation of Cloud Properties Derived from GOES-9 Over the ARM TWP Region

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Introduction

Satellite data are essential for monitoring clouds and radiative fluxes where ground-based instruments are unavailable. On April 24, 2003, the ninth geostationary operational environmental satellite (GOES-9) began operational coverage of the Tropical Western Pacific (TWP), replacing the failing fifth geostationary meteorological satellite (GMS-5). The GOES-9 imager provides the opportunity for enhanced monitoring of clouds and radiation over the TWP because it has better spatial resolution and spectral coverage than GMS-5. Real-time processing of hourly GOES-9 images in the Atmospheric Radiation Measurement (ARM) TWP region began operationally in October 2003 and continues. To begin validating this new satellite-derived cloud property dataset, the derived cloud amounts, heights, and broadband shortwave fluxes are compared with similar quantities derived from both ground-based instrumentation and other satellite-derived cloud property retrievals. The GOES-9 results are also compared with Layered Bispectral Threshold Method (LBTM) results from GMS-5 and Earth Radiation Budget Experiment (ERBE) like broadband fluxes. The results will provide guidance for estimating uncertainties in the GOES-9 products and to develop improvements in the retrieval methodologies and input.

Data and Methodology

The GOES-9 data are taken hourly with a nominal pixel resolution of 4 km. To minimize the effects of noise in the GOES-9 visible (0.65 μm) channel, 1-km visible pixel radiances are averaged into 4-km pixels. During daytime, the data are analyzed with the visible infrared solar-infrared split-window technique (VISST), which is an updated version of the methodology described by Minnis et al. (1995b). Initially, each pixel is classified as clear or cloudy using the cloud mask algorithm of Trepte et al. (1999) employing data from the 0.65, 3.9, 10.8, and 12.0 μm channels. For each cloudy pixel, the VISST uses those same radiances to estimate cloud phase, effective temperature, effective height, optical depth, effective particle size, and liquid or ice water path. Cloud-top height and thickness are also derived using empirical methods. At night and near the terminator, the visible channel is unusable, so the cloud height and temperature and a crude estimate of optical depth are estimated using the solar-infrared infrared split-window technique (SIST; Minnis et al. 1995b). This paper focuses on daytime results only. GOES-9 and VISST are used interchangeably to denote any retrievals from GOES-9. The 5-km, hourly GMS-5 data were analyzed using the LBTM (Minnis et al. 1995a; Nordeen et al. 2001a) for the period beginning January 1998 through April 2003.

VISST retrievals were performed on GOES-9 data over TWP domain (10°N - 20°S, 120°E - 180°) from April 25, 2003 to May 31, 2003, and averaged into 1° latitude-longitude regions. Smaller regional retrievals were done over Manus (2.058°S, 147.425°E), Nauru (0.521°S, 166.916°E), and Darwin (12.425°S, 130.891°E) from April-August 2003. TWP domain-wide comparisons are made between GOES-9 and GMS-5 1° averaged retrievals for April 26, 2003 to May 21, 2003, using only the daytime hours of 2300 Universal Time Coordinates (UTC) - 0500 UTC.

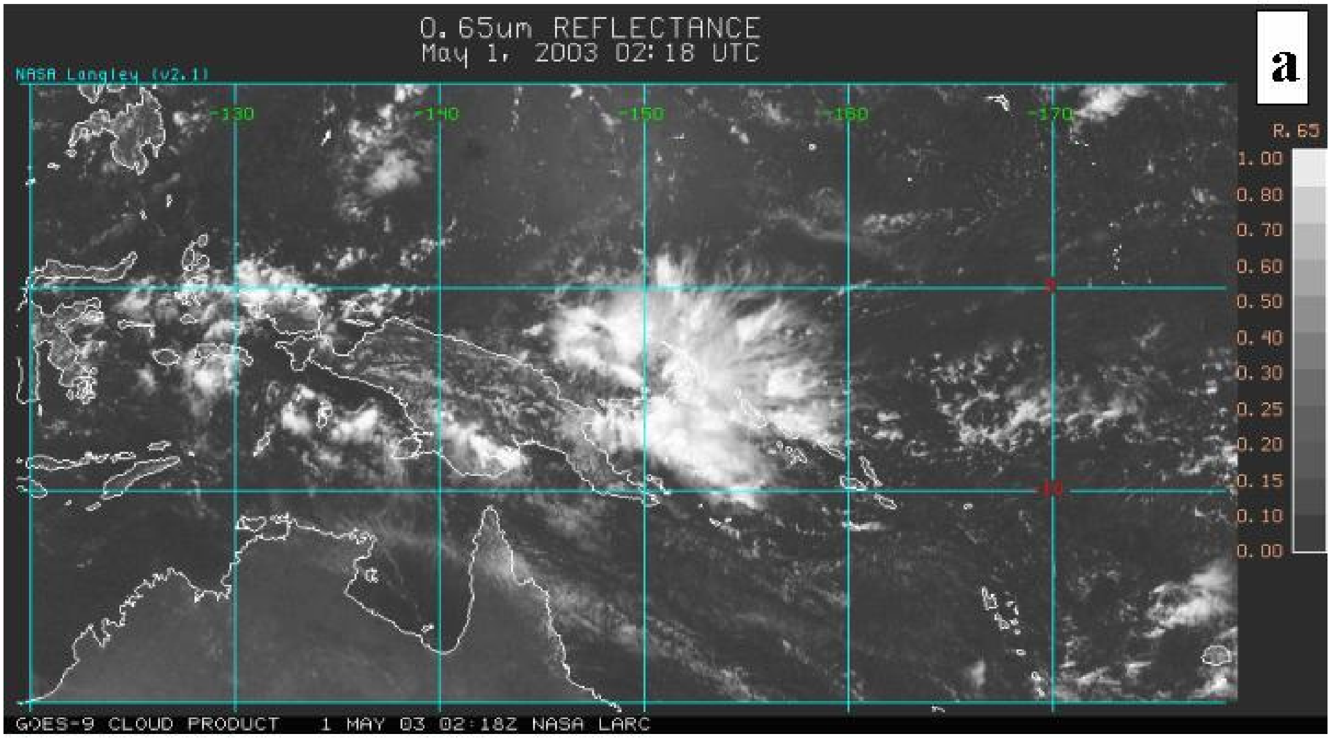
The validation datasets include retrievals and image products from available ARM instruments at Manus, Nauru, and Darwin. These instruments include the millimeter wave cloud radar (MMCR), total sky imagers (TSI), the micropulse lidar (MPL), and ceilometers. The comparisons utilize the active remote sensing of cloud layers (ARSCL)-derived cloud amounts and cloud top heights (Clothiaux et al. 2000). VISST cloud amounts and heights were averaged over all pixels within a 10- and 20-km radius of the site and are compared with 20-min averages of TSI cloud amounts and ARSCL cloud boundary data centered on the GOES-9 retrieval times. The comparisons only include daytime hours. For the TSI data, averages were based on “percent opaque” plus “percent thin” data within the 20 minute window. Cloud fraction from the ARSCL data is defined as the number of cloud occurrences divided by the total number of observations during the 20-min period. An additional validation dataset consists of the broadband shortwave albedos derived from the Clouds and Earth’s Radiant Energy System (CERES; see Wielicki et al. 1998) scanner on the Terra satellite. ERBE-like albedos derived from CERES pixels with centers within the GOES-9 circles around the ARM sites were averaged during a given Terra overpass for comparison with the albedos derived from the GOES-9 narrowband data during May 2003.

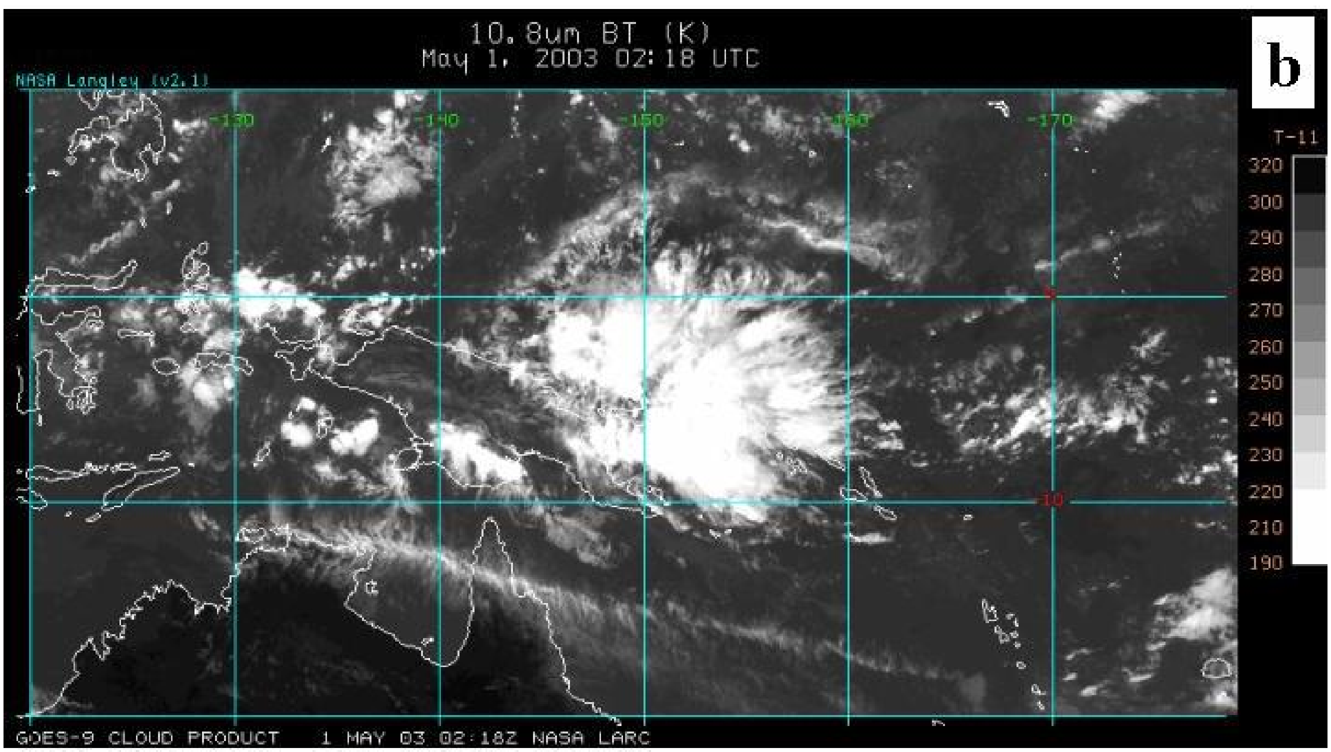
Results

Figure 1 shows GOES-9 visible and infrared imagery as well as cloud phase and cloud-top height retrievals from VISST at 0218 UTC May 1, 2003. The cloud features are fairly well-resolved with possible underestimation of thin cloud amounts in a few areas like those around 8°N, 163°E, and 5°N, 175°W. The results from scenes like those in Figure 1 are averaged to compare with GMS-5 and surface observations.

Figure 2 shows the daytime averaged GOES-9 and GMS-5 cloud amounts, heights, and differences for the TWP domain. On the whole, the GMS-5 retrieval yields considerably more cloudiness than its GOES-9 counterpart. Nearly all of the GMS-5 cloud amounts (Figure 2b) exceed 70% north and east of Australia while the GOES-9 amounts (Figure 2a) in the same area range from 35 to 95%. Mean cloud heights from GOES-9 (Figure 2c) are generally greater than or equal to those from GMS-5 (Figure 2d), which has fewer values above 9 km. As indicated in Figure 2e, the height differences are greater than 1 km in many areas. The differences are around -1 km for a few regions with low clouds west of

Australia. The cloud amount differences (Figure 2f) are as great as -50% around 2°S and 175°E and up to 10% over New Guinea.





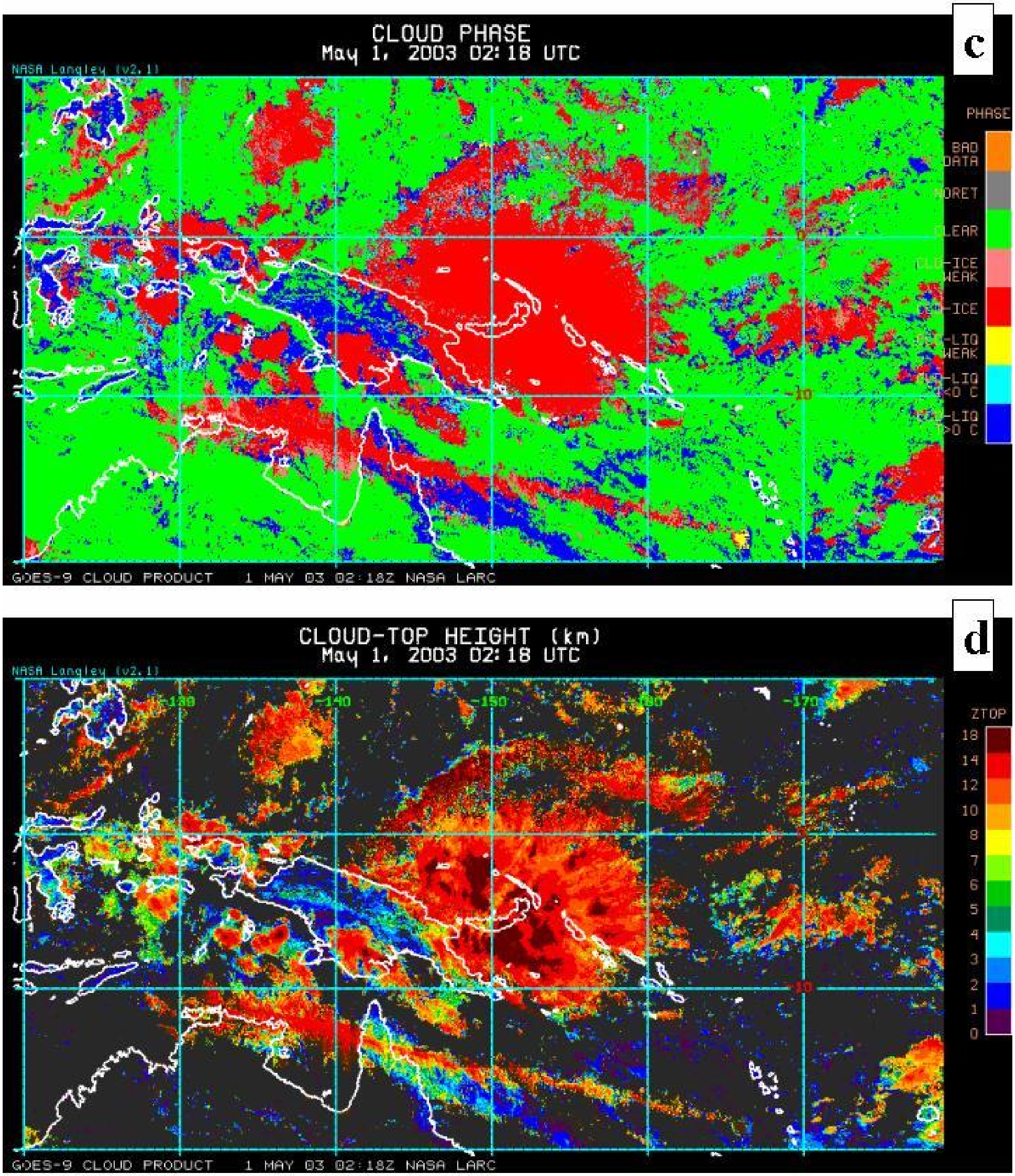


Figure 1. Shows GOES9 visible (0.63 um) (a) and 11 um temperature (b) imagery as well as cloud phase (c) and cloud top height (d) retrievals from VISST, for May 1 2003, 0218 UTC.

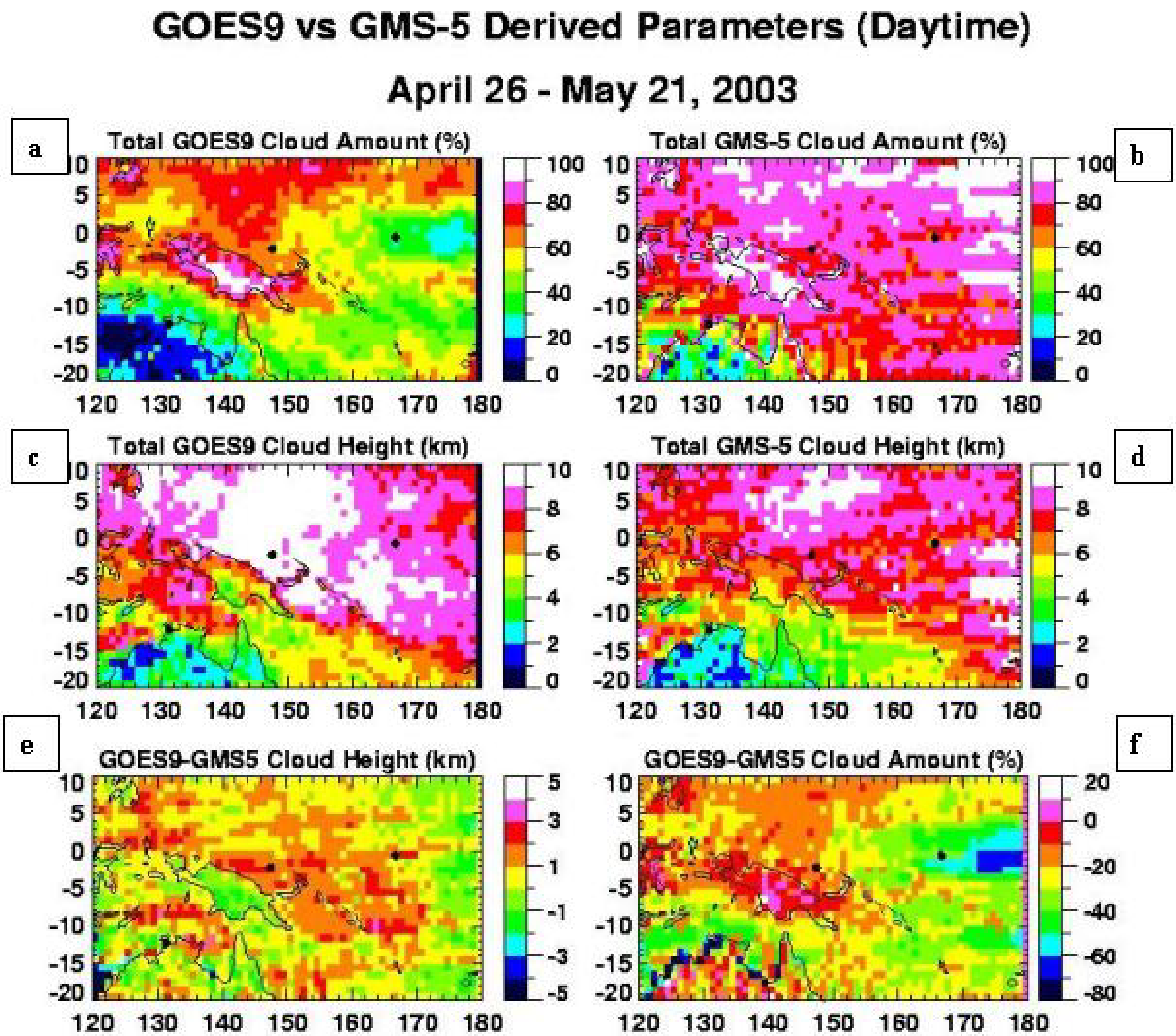


Figure 2. Shows daytime averaged GOES9 VISST-derived cloud amount (a) and GMS-5 LBTM derived cloud amount (b); (c) total cloud height (GMS5) and cloud top height (GOES9). Differences between GOES9 and GMS5 are shown for cloud heights (e), and cloud amounts (f). Data between 2300 UTC - 0500 UTC, from April 26 to May 21 2003, was used in the average.

To determine which dataset provides a more realistic estimate of cloud fraction, the results over the ARM sites are first compared in the scatterplots of Figure 3, which shows GOES-9 and GMS-5 cloud amounts matched to within a half hour window for time period used in Figure 2. As expected, GMS-5 cloud amounts significantly exceed those from GOES-9. At Manus (Figure 3a), the GOES-9 minus GMS-5 difference is -11.8%, while at Nauru (Figure 3b) and Darwin (Figure 3c), the biases are -29.2% and -21.0%, respectively. The root mean square (rms) differences are large: 29.2%, 44.0%, and 30.2% respectively. The two datasets agree better when cloud amounts are large. The GMS-5 retrieval typically yields 40-50% more cloud cover for GOES-9 cloud amounts below 30%.

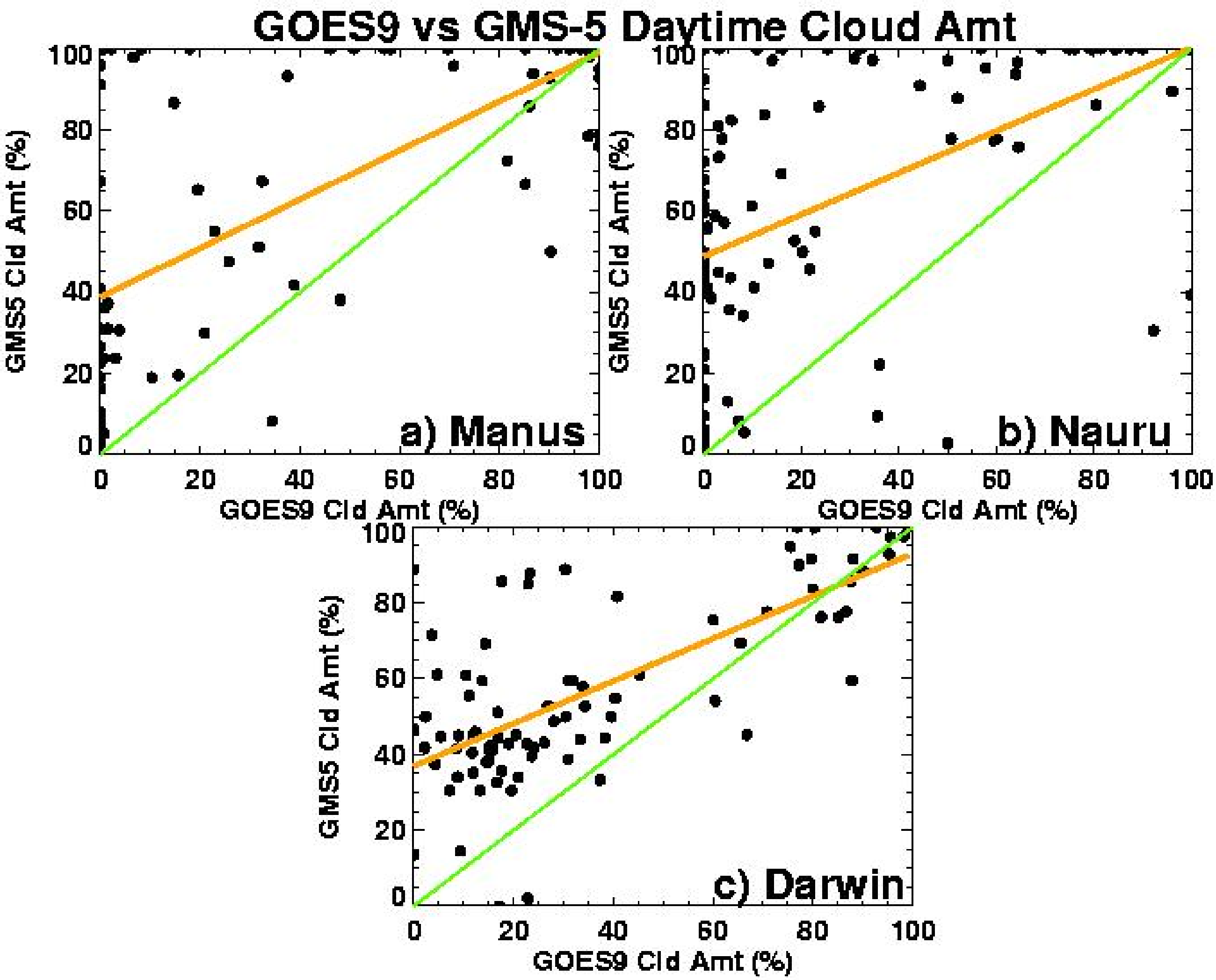


Figure 3. GOES9 vs. GMS5 cloud amounts (within a half hour window) for 2300- 0500 UTC between April 26-May 21, 2003. Tan line denotes line fit, and green line denotes one-to-one correlation line.

The next step to determining which dataset is more appropriate consists of using the ground truth data to compare with the GOES-9 results. Figure 4 shows the GOES-9 daily daytime (2300 UTC - 0500 UTC) cloud amount versus the TSI- and ARSCL-derived cloud amounts averaged over the same time periods. The Darwin TSI (blue) and GOES9 (red) daily averaged cloud amounts (Figure 4a) track each other quite well on a day-to-day basis. The scatterplot in Figure 4b reflects the consistency indicating that the GOES-9 cloud amount never drops to zero yielding a bias of a few percent when the TSI cloud amount is zero. It is clear in this instance that the GMS-5 values are much too large to be realistic. At Nauru (Figure 4c), the ARSCL cloud amounts are generally smaller than the TSI values except when GOES-9 detects very small cloud amounts (Figure 4d). Then, both surface instruments detect cloud amounts of ~25% compared to 3 or 4% from GOES-9. A surprising result in the scatterplot is that the ARSCL yields an average cloud amount of ~65% when both the TSI and GOES-9 amounts are greater than 90%. The mean GOES-9 minus TSI differences in Darwin and Nauru are 4.8 and -11.1%, respectively. The corresponding daily mean rms differences are 12.4 and 21.5%. At Nauru, the GOES-9 cloud amount averages 3.0% less than the ARSCL value with a 26.8% rms difference.

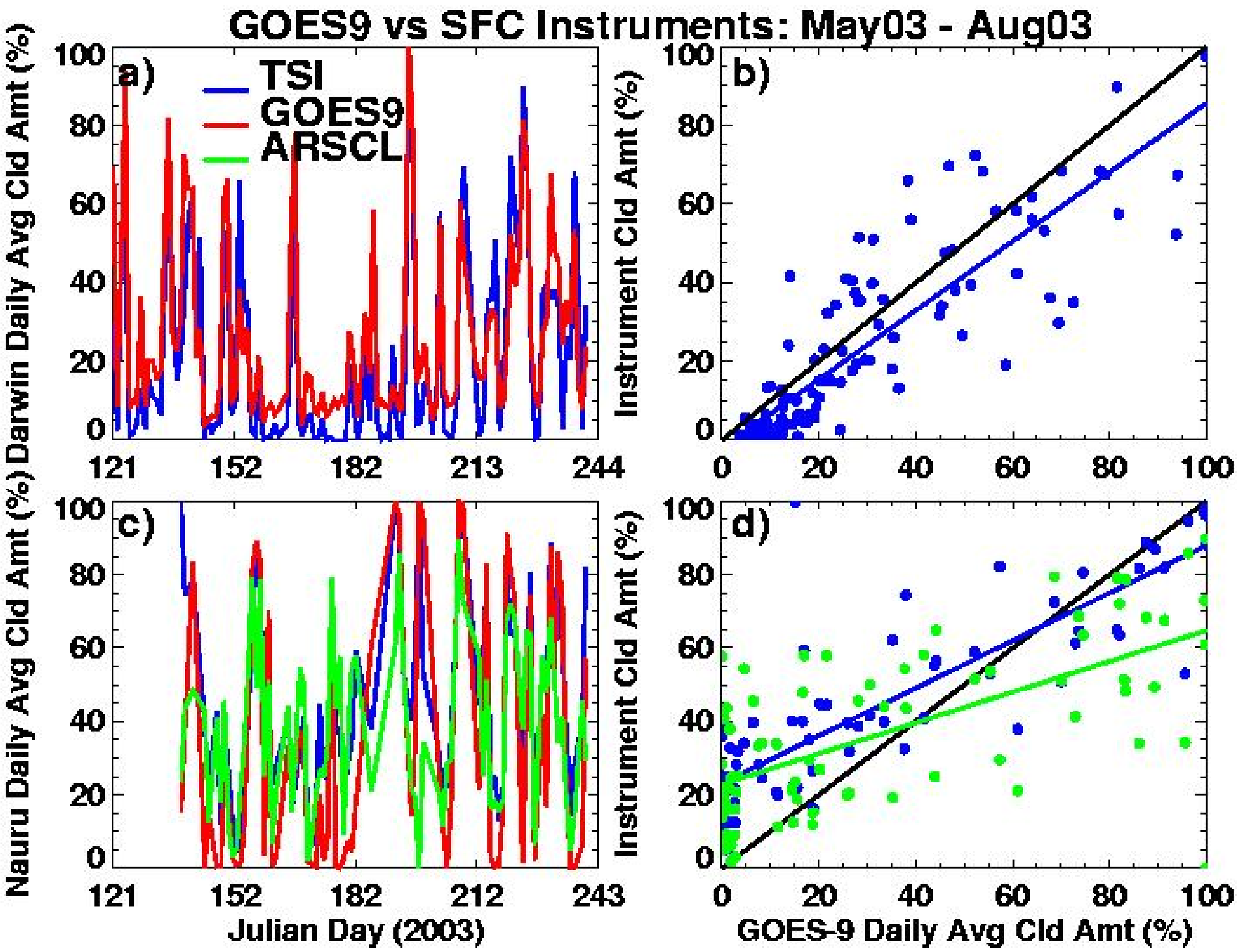


Figure 4. GOES9 daily daytime cloud amount vs. TSI-derived and ARSCL-derived cloud amount. Darwin TSI (blue) and GOES9 (red) daily averaged cloud amounts are shown in (a) and the scatterplot in (b); Nauru TSI (blue), GOES9 (red) and ARSCL (green) are shown in (c). A scatterplot of TSI vs. GOES9 (blue) and ARSCL vs. GOES9 (green) for Nauru are shown in (d). Data from 2300 - 0500 UTC was used in the averages. In the scatterplots, one-to-one correlation line is denoted in black.

Figure 5 shows scatterplots of the CERES ERBE-like broadband shortwave albedo versus their narrowband-based GOES-9 values. In general, the albedos are fairly well-correlated. On average, the GOES-9 minus CERES albedo differences are -0.015 for Manus (Figure 5a), -0.005 for Nauru (Figure 5b), and 0.003 for Darwin (Figure 5c). The corresponding rms differences are 0.113, 0.037, and 0.029, respectively. Both the range and scatter of the data are greater at Manus where cloud amounts are typically much larger than over the other two sites.

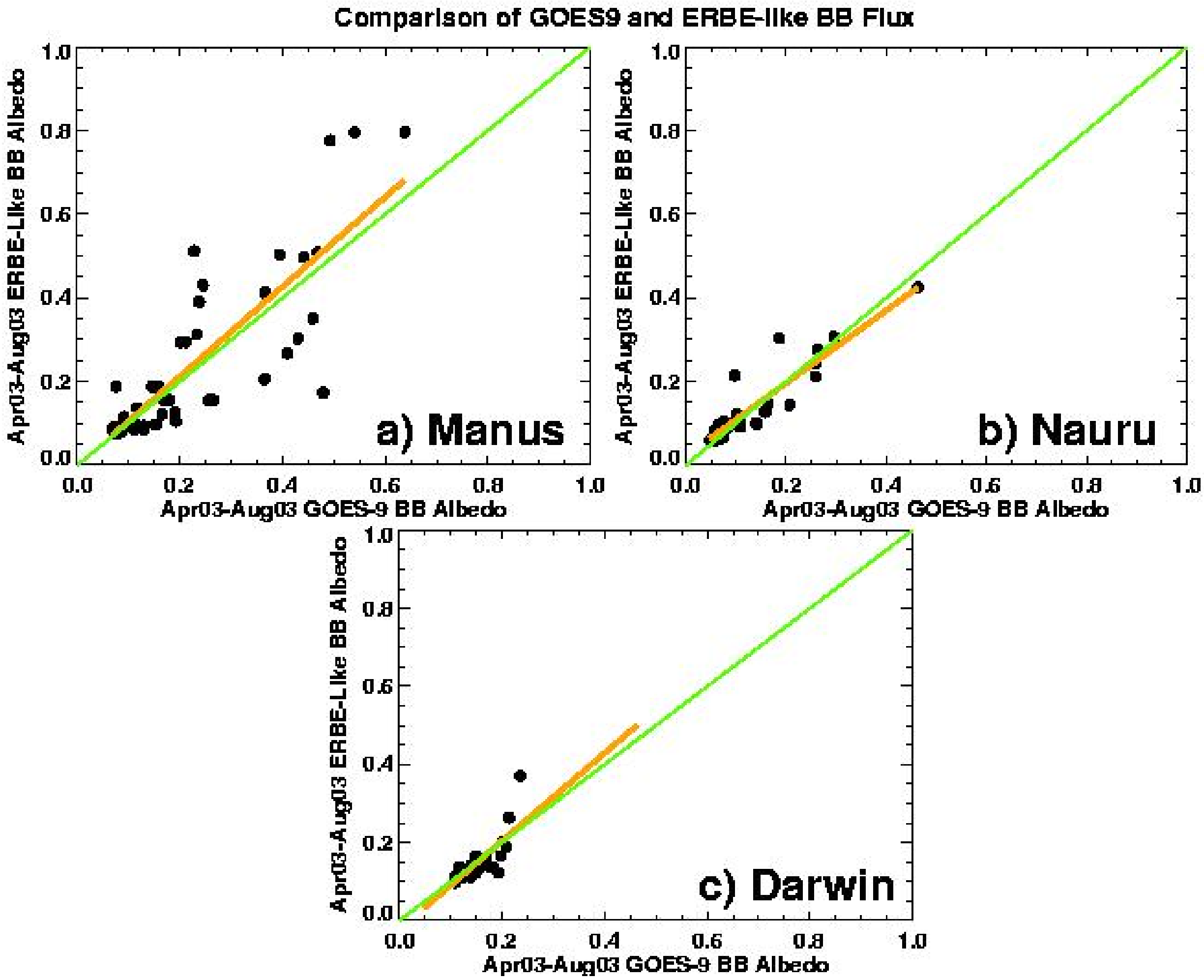


Figure 5. Comparison of ERBE-like broadband shortwave albedo to GOES9 for a) Manus, b) Nauru, c) Darwin. Tan line denotes line fit, and the green line denotes one-to-one correlation line.

Cloud Fraction Comparison

Comparisons were also performed using the individual VISST 20-km radius cloud fraction and the 20-minute averaged cloud fractions derived from TSI and ARSCL. The cloud amounts derived by the various methods are placed into four bins: 0-20%, 20-50%, 50-80%, and 80-100%. Values along the diagonal indicate that both methods agree on the binned cloud amount. Table 1 shows a comparison of daytime TSI and GOES-9 VISST cloud amounts for Nauru and Darwin during May through August 2003.

For Nauru (Table 1a), TSI and VISST agree in 56% of all cases. The most obvious error class is GOES-9 underestimating the TSI in 28% of cases by classifying clouds as 0-20% bins, as seen in the daily average comparisons (Figure 4d). The TSI average cloud amount is 47.7% compared to 38.8% from the VISST yielding a bias of -8.9% and an rms difference of 24.9%. At Darwin (Table 1b), TSI and GOES-9 VISST agree in 68% of cases, with GOES-9 somewhat overestimating TSI's 0-20% binned cases (14% of cases). The average cloud amount for TSI is 21.0% versus 26.6% for VISST, leading to a bias of 5.6% and an rms error of 20.0%.

Table 1a. Comparisons of Daytime Cloud Amount Bins from TSI and VISST at Nauru

		0 - 20	20 - 50	50 - 80	80 - 100
T	80 - 100	1	1	1	22
S	50 - 80	6	3	3	6
I	20 - 50	21	6	3	1
	0 - 20	25	1	0	0

VISST

Table 1b. Comparisons of Daytime Cloud Amount Bins from TSI and VISST at Darwin

		0 - 20	20 - 50	50 - 80	80 - 100
T	80 - 100	0	1	2	5
S	50 - 80	0	5	3	2
I	20 - 50	3	7	3	2
	0 - 20	53	13	1	0

VISST

A comparison of daytime ARSCL and GOES-9 cloud properties was also performed for Nauru and Manus (Table 2). At Nauru (Table 2a), VISST and ARSCL agreed 50% of the time, with the most obvious error classes being where ARSCL predicted 20-50% cloud for the VISST 0-20% bin (13% of cases) and also where VISST predicted 80-100% cloud for the ARSCL 0-20% bin (5% of cases). Both ARSCL and VISST yielded an average cloud fraction 37.0% with an rms difference of 37.6%. At Manus (Table 2b), ARSCL and VISST cloud amounts agreed 63% of the time to within the limits of the bin range. Almost 53% of those cases were in the 80-100% cloud fraction bin reflecting the greater cloud fraction at Manus. The average ARSCL cloud fraction was 73.3%; 8.2% less than that from the VISST. The rms difference is 35.1%.

Table 2a. Comparisons of Daytime Cloud Amount Bins from ARSCL and VISST at Nauru

		0 - 20	20 - 50	50 - 80	80 - 100
A	80 - 100	3	2	3	12
R	50 - 80	5	1	2	6
S	20 - 50	13	3	3	3
C	0 - 20	33	5	1	5

VISST

Table 2b. Comparisons of Daytime Cloud Amount Bins from ARSCL and VISST at Manus

		0 - 20	20 - 50	50 - 80	80 - 100
A	80 - 100	1	3	3	53
R	50 – 80	1	3	3	7
S	20 - 50	2	3	2	5
C	0 - 20	4	2	2	8

VISST

Cloud Height Comparison

A comparison of daytime ARSCL and GOES9 20-km diameter averaged VISST cloud heights was made for Manus, and also for Nauru. The comparisons were binned up into cloud height classes based on ARSCL-detected cloud top height (zt): low clouds (ARSCL <4 km), mid-level clouds (4 km <ARSCL <7.5 km), and high-level clouds (ARSCL >7.5 km). Further distinctions were made within these classes for cloud thicknesses (dz): thin cloud cases (ARSCL-detected dz <1.5 km), medium dz (1.5 km - 3.5 km for mid- and high-level clouds, or 1.5 - 4.0 km for low clouds), and thick cases (dz >3.5 km). Only cases having VISST-derived cloud amount greater than 90% are examined here. Cloud cases are termed liquid if VISST classified at least 90% of the clouds as water. Likewise, they are defined as ice, if VISST defined at least 90% ice cloud.

For the Manus high-cloud category (Table 3a), which contained most of the cases (161), relatively good agreement was found in ice cases. In thin ice cloud cases, GOES-9 average zt was 11.6 km versus 12.5 km for ARSCL. For medium thickness cases, the VISST cloud top was 11.1 km, 1.5 km less than that from ARSCL. For the thickest cases, agreement was best with the VISST zt averaging 11.7 km and ARSCL averaging 12.3 km. However, for the two water cases, the zt agreement was not very good. The medium thickness ARSCL cloud top was 14.0 km versus 8.6 km for VISST. This difference is

Table 3a. Comparisons of daytime cloud-top height (km) and thickness (km) from ARSCL and GOES-9 over Manus for low cloud amounts greater than 90%, April - August 2003

ARSCL dz (km)	liquid 1.5 - 3.5	ice <1.5	ice 1.5 - 3.5	ice >3.5
N	2	12	30	119
ARSCL zt	14.0	12.5	12.6	12.3
VISST zt	8.6	11.6	11.1	11.7
zt rms	5.5	2.2	2.1	1.4
ARSCL dz	1.8	1.3	2.5	10.0
VISST dz	1.5	2.4	2.4	4.6
dz rms	0.8	1.6	0.8	6.0

most likely due to the presence of a thin cirrus cloud over a thick water cloud resulting in VISST classifying the cloud as water. Most of the radiance signal observed by the GOES-9 would be due to the lower cloud. The cloud thicknesses derived from the VISST are too large for the thin clouds and too small for the thick clouds.

The agreement was not as good for the 11 medium-height cloud cases (Table 3b) over Manus. All of the VISST cases except one were classified as ice clouds. For the lone thin ice cloud case, the ARSCL-defined zt was 4.4 km and VISST at 9.8 km. For the medium dz category, ARSCL determined the cloud tops at 6.0 km versus 11.3 km for VISST. Agreement for the thickest category was slightly better at 6.3 km for ARSCL and 9.5 km for VISST. For the lone thick liquid cloud case, agreement was still not very good. ARSCL defined cloud top height as 5.5 km, and VISST defined it as 2.3 km. In the ice cloud cases, it is likely that differences are due to the lack of MMCR data at Manus because the GOES-9 infrared temperatures are not likely to be significantly colder than the temperature at cloud top for these cases, which are all optically thick. The liquid water case needs to be examined further.

Table 3b. Comparisons of daytime cloud-top height (km) and thickness (km) from ARSCL and GOES-9 over Manus for mid-level cloud amounts greater than 90%, April - August 2003

ARSCL dz (km)	**liquid >3.5**	**ice <1.5**	**ice 1.5 - 3.5**	**ice >3.5**
N	1	1	3	6
ARSCL zt	5.5	4.4	6.0	6.3
VISST zt	2.3	9.8	11.3	9.5
zt rms	n/a	n/a	5.4	3.7
ARSCL dz	5.4	1.0	2.0	5.9
VISST dz	0.9	4.8	3.5	2.4
dz rms	n/a	n/a	1.5	3.7

For the lowest water clouds (Table 3c), the thin cloud comparison yielded close agreement between the ARSCL zt (3.1 km) and the VISST zt (3.4 km). The rms error and bias were both 0.3 km for this case. The medium thickness clouds agreed almost exactly at 2.9 km, with an rms difference of 0.4 km. However, for ice clouds, the cloud heights were in gross disagreement. For thin cases, the VISST zt was 13.0 km versus 1.5 km for ARSCL, and for medium thickness cases, the VISST cloud top height was placed at 11.2 km versus 3.1 km for ARSCL. Again, the lack of MMCR data to detect the upper level cloud probably causes the problems in the ice cases since the VISST cannot retrieve ice at the temperatures corresponding to cloud heights below 4 km in the Tropics.

The comparison of ARSCL and VISST-derived cloud heights for Nauru (Table 4) did not yield as many cases (N = 44) as for Manus (N = 184). For the highest cloud levels (Table 4), the thin ice cloud cases show excellent agreement. On average, the ARSCL zt was 11.8 km, only 0.2 km higher than the VISST retrieval. The rms difference is 1.6 km. The lone medium thickness high-cloud ice case was in good

Table 3c. Comparisons of Daytime Cloud-Top Height (km) and Thickness (km) from ARSCL and GOES-9 Over Manus for Low Cloud Amounts Greater than 90%, April - August 2003

ARSCL dz (km)	liquid <1.5	liquid 1.5 - 4	ice <1.5	ice 1.5 - 4
N	2	3	2	3
ARSCL zt	3.1	2.9	1.5	3.1
VISST zt	3.4	2.9	13.0	11.2
zt rms	0.3	0.4	11.6	8.3
ARSCL dz	1.1	2.4	1.2	2.5
VISST dz	0.8	1.0	4.6	4.1
dz rms	0.3	1.6	3.7	2.1

Table 4. Comparisons of Daytime Cloud-Top Height (km) and Thickness (km) from ARSCL and GOES-9 Over Nauru for Cloud Amounts Greater than 90%, April - August 2003

ARSCL dz (km)	high, ice <1.5	high, ice 1.5 - 3.5	low, water <1.5	low, ice <1.5
N	27	1	1	3
ARSCL zt	11.8	9.2	2.2	1.6
VISST zt	11.6	9.1	3.3	10.9
zt rms	1.6	n/a	n/a	9.3
ARSCL dz	0.8	1.6	0.1	0.2
VISST dz	2.3	1.3	0.7	2.8
dz rms	1.8	n/a	n/a	2.7

agreement: 9.2 km for ARSCL and 9.1 km for VISST. Like the Manus results, the mid-level cloud cases do not show good agreement (not shown), probably for the same reason noted earlier for the Manus site. For the low-level clouds, there was only one case of liquid thin cloud for which the ARSCL cloud top was at 2.2 km versus 3.3 km for VISST. For the ice cases (thin cloud), agreement was very poor presumably due to the lack of MMCR data.

Discussion

A qualitative look at these preliminary GOES-9 daytime satellite retrievals (Figures 1a-d) shows that VISST overall appears to be correctly identifying the cloud fields in the region. The GMS-5 LBTM-derived cloud coverage (Figure 2) is consistently greater than that from GOES-9. Visual inspection of some cases where the GOES-9 and GMS-5 differ greatly shows that VISST is more likely correct. Since VISST employs four channels for its retrievals, and the LBTM only visible and infrared channels, better detection from GOES-9 is expected. However, other factors might have affected the GMS-5 retrievals. The GMS-5 visible channel is much broader than that used by GOES-9. The LBTM thresholding and predicted clear-sky values applied to GMS-5 were the same as those used for the GOES analyses and do not account for the large spectral differences between the GOES and GMS visible channels. Such differences could lead to a systematic bias in the GMS cloud amounts relative to GOES. Additionally, the GMS-5 visible channel has not been calibrated since 2001 (Minnis et al. 2002), a factor that could bias the derived cloud amounts. On average, the surface-based and GOES-9 cloud amounts over the three TWP sites agree to within about ±5%, a difference that is much smaller than the differences between the GMS-5 and GOES-9 retrievals. Given the qualitative and quantitative data, it is concluded that the GOES-9 results are more representative of the cloud amounts over the TWP domain than those derived from GMS-5 for the period of interest.

The differences between the satellite and surface-derived cloud amounts surface sites vary with location and instrument. Such variations may be a result of the local environments which can be very different. Each site is very close to the coast yet the air-sea interactions can be very different. At Nauru, a tiny island in a drier part of the domain, a low-level cloud plume is frequently created during the daytime, presumably by solar heating of the surface (Nordeen et al. 2001b). The plume is frequently the only cloud in the vicinity and could inordinately affect the both the TSI and ARSCL cloud amount at low cloud fractions because it often passes over the ARM site. Such plume behavior could explain the differences between GOES-9 and the surface cloudiness for cloud amounts below 30%. Also, GOES-9 may be calling partially-filled cloud pixels as all clear or all cloud, missing or overestimating some of the cloud cover that TSI is seeing. At the high end, it is not clear why ARSCL produces much less cloud cover than either GOES-9 or TSI. Perhaps, it is related to precipitation cases when the instruments are turned off. Such effects need further examination. Visual inspection of the satellite imagery, for some of the cases where discrepancies occurred, shows that broken clouds (common over the Nauru region), and possible sub-pixel scale clouds, could be the difference. It is likely that since TSI views a different geometrical area than VISST, and ARSCL cloud amount is derived from its narrow up-looking beam, some discrepancies could be explained by the differences in fields of view sampled by each sensor.

At Manus, the ARSCL cloud amounts are less than those from VISST, on average. Manus is larger than Nauru and the ARM site is more on windward side of the island than at Nauru where it is on the leeward side. Additionally, Manus is in the area where deep convection predominates so that local effects may not be as important as over Nauru. The greatest differences are seen for small amounts of surface cloud cover with large amounts from GOES-9. At this point it is not possible to determine whether this is due to local effects, errors in the GOES-9 retrieval, or the effects of instrument downtime on the ARSCL analysis. For instance, some thin cirrus clouds detected by the MPL cannot be detected by the MMCR. If the MPL is not operating then such clouds could be missed by the MMCR.

At Darwin, the TSI cloud amounts are well correlated with the VISST results but are 5.6% lower with some differences at the low end. High clouds are not as predominant at Darwin as at Manus, so that the discrepancy could be due to differences in low cloud detection. Given the 20-km radius of the GOES-9 cloud fraction, it is possible that GOES-9 detects some low clouds that are essentially out of the Darwin TSI field of view. Since Darwin is located on the coast, it is possible that there is some sea-land breeze systematically producing low-level clouds in the vicinity that are often below the TSI horizon. This possibility should be examined using different averaging radii for the GOES-9 retrievals. Other sources of the discrepancies could be errors in the GOES-9 retrieval related to background reflectance and subpixel cloud cover.

GOES-9-derived cloud heights were compared with single-layer ARSCL clouds at both Manus (Table 3) and Nauru (Table 4). Cases were selected where both ARSCL and VISST-derived cloud amount exceeded 90%. Comparisons were made for thin, medium, and thick cases. In general, the daytime cloud heights between ARSCL and VISST compared well except for the cases that apparently lacked MMCR data to define the upper-layer cloud tops. The best agreement appeared to be for the low water and high ice cloud cases. In general, at Manus, the agreement was best for the thickest clouds, which are likely the most opaque thermally. For Manus, biases were -0.6 km for thick high ice cloud cases, (rms error 1.4 km), and -0.03 km for thickest low level water cloud (0.4 km rms error). Nauru had fewer cases overall (44) than Manus (184), and almost all were thin cloud cases. The best agreement was shown in high thin ice clouds (27 cases) with a bias of -0.2 km and an rms error of 1.6 km.

Summary and Future Work

The VISST retrievals using GOES-9 data over the ARM TWP region are preliminary. However, the comparison of daytime cloud amounts with TSI- and ARSCL- derived cloud amount appears to be fairly good, with daily averages revealing some differences that vary from site to site. Some of the differences may be due to the various methods used to derive the cloud amounts. Differences may also be the result of field of view issues, such as clouds over the adjacent waters that are not measured by the surface instruments. Additional analyses of the differences should be undertaken to examine the sensitivity of the differences to averaging radius size and to the differences in clouds over the land and water parts of the averaging area. However, accurate determination of skin temperature for VISST's clear sky thresholding will be necessary to make sure that any errors of cloud misdetection by VISST are improved. More comparisons with ARSCL-derived data, including nighttime cloud amounts, are needed. Cloud heights, in general, seem to compare well with ARSCL-derived height. Most of the differences appear to be related to lack of MMCR data. However, further study of the datasets is required to ensure that this is source of the discrepancies. The cloud thicknesses derived from GOES-9 were based on empirical functions determined over the ARM SGP. It appears that new tropical thickness relationships should be developed from the ARM sites in the TWP. Broadband SW albedos derived for the April - August 2003 time period appear to be equivalent to those from CERES. Longwave fluxes will be validated in the future. The results of these preliminary comparisons are encouraging and suggest that, at least for daytime, the GOES-9 data can be confidently used for model and process studies.

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