# Comparison of Arctic Cloud Cover Statistics Between MODIS, AVHRR Pathfinder, and GLAS


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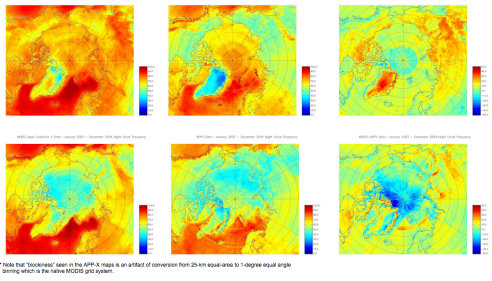
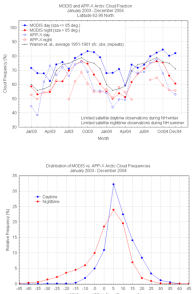
## MODIS Aqua and AVHRR APP-X Arctic Cloud Fractions

The six maps below detail Arctic cloud frequencies from the Aqua MODIS Collection 5 cloud mask (MOD35, left) and APP-X (Polar Pathfinder-Extended, center) data sets for the period January 2003 – December 2004. Top row is daytime, bottom row is nighttime. The right-most maps show differences (MODIS minus APP-X) between the two results. MODIS cloud amounts are generally higher than APP-X during daytime (warm season), especially in N. Canada, Siberia, and Greenland. At night (cold season), differences are generally smaller except for some portions of Greenland's east coast and the Canadian archipelago. The line plot at top, far right shows time series of monthly mean cloud frequencies for the two data sets, day and night separately. Note that from May through September, the daytime values compare very well, then diverge rapidly as polar darkness descends. At night, December through April values are quite similar. The Warren, *et al.* (1986) values for day and night together are shown (black line) for reference.

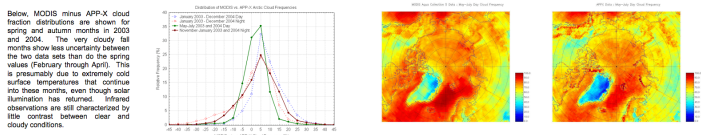


* Note that "blockiness" seen in the APP-X maps is an artifact of conversion from 25-km equal-area to 1-degree equal angle binning which is the native MODIS grid system.

Time series of MODIS and APP-X monthly data from January 2003–December 2004 (top). At bottom are distributions of MODIS minus APP-X cloud fractions for day (blue curve) and night (red curve). Greater uncertainty between the two data sets is expected during nighttime conditions due to less available information delineating clear skies from cloudy. The mode is +5%.



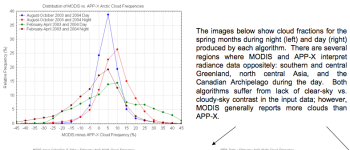
The two histograms below show distributions of MODIS minus APP-X cloud fractions for several seasons and solar illumination conditions. The top figure compares day and night difference distributions from the entire period (dashed) to those of the summer (solid green) and winter (solid brown) months. We may conclude that overall, nighttime results from terminator months (spring and autumn) does not differ significantly from deep polar winter. However, differences between the two data sets during daytime diverge when terminator months are included.



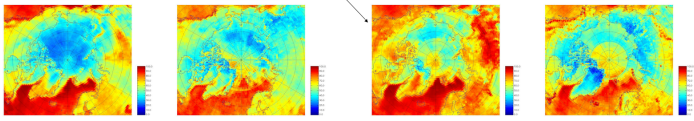
The maps in the four images below show average summer (top) and winter (bottom) cloud frequencies from Aqua MODIS (left) and APP-X (right) during 2003 and 2004. Cloud patterns and amounts agree quite well during the summer months (MJJ). During winter (NDJ), the largest difference is seen in central Asia near 60N. MODIS generally reports more clouds over all of northern Eurasia and NE Quebec during winter.



Below, MODIS minus APP-X cloud fraction distributions are shown for spring and autumn months in 2003 and 2004. The very cloudy fall months show less uncertainty between the two data sets than do the spring values (February through April). This is presumably due to extremely cold surface temperatures that continue into these months, even though solar illumination has returned. Infrared observations are still characterized by little contrast between clear and cloudy conditions.

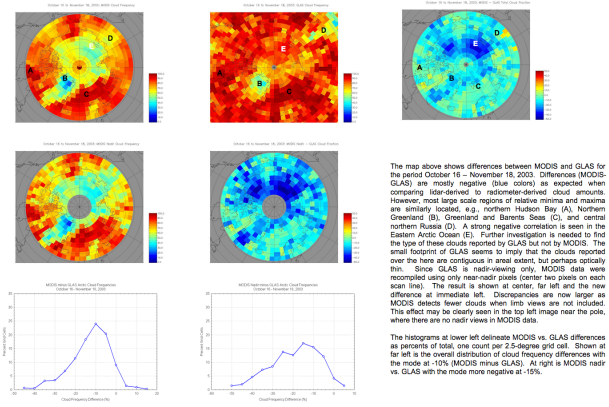


The images below show cloud fractions for the spring months during night (left) and day (right) produced by each algorithm. There are several regions where MODIS and APP-X interpret radiance data oppositely: southern and central Greenland, north central Asia, and the Canadian Archipelago during the day. Both algorithms suffer from lack of clear-sky vs. cloudy-sky contrast in the input data; however, MODIS generally reports more clouds than APP-X.



## MODIS Terra and GLAS Cloud Fractions

The series of maps shown below compares Terra MODIS Collection 5 cloud frequencies with those of the GLAS (Geoscience Laser Altimeter System). The data period covers October 16 through November 18, 2003. The MODIS data were aggregated from Level 2 (5-minute granule) files while the GLAS were averaged from medium-resolution daily values. The time period coincides with that of the fully functional 532 nm channel on the GLAS. MODIS spatial resolution is 1-km and GLAS is about 70-m across-track x 7000-m along-track (one result per second). Both data sets were sorted into 2.5-degree equal-area grids, then converted to equal-angle for display purposes. The top row shows mean cloud frequencies for MODIS (left), GLAS (center) and MODIS minus GLAS (right).

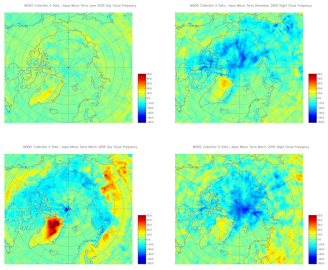


The map above shows differences between MODIS and GLAS for the period October 16 – November 18, 2003. Differences (MODIS-GLAS) are mostly negative (blue colors) as expected when comparing lidar-derived to radiometer-derived cloud amounts. However, most large scale regions of relative minima and maxima are similarly located, e.g., northern Hudson Bay (A), Northern Greenland (B), Greenland and Barents Seas (C), and central northern Russia (D). A strong negative correlation is seen in the Eastern Arctic Ocean (E). Further investigation is needed to find the type of these clouds reported by GLAS but not by MODIS. The small footprint of GLAS seems to imply that the clouds reported over the here are contiguous in areal extent, but perhaps optically thin. Since GLAS is nadir-viewing only, MODIS data were recompiled using only near-nadir pixels (center two pixels on each scan line). The result is shown at center, far left and the new difference at immediate left. Discrepancies are now larger as MODIS detects fewer clouds when limb views are not included. This effect may be clearly seen in the top left image near the pole, where there are no nadir views in MODIS data.

The histograms at lower left delineate MODIS vs. GLAS differences as percents of total, one count per 2.5-degree grid cell. Shown at far left is the overall distribution of cloud frequency differences with the mode at -10% (MODIS minus GLAS). At right is MODIS nadir vs. GLAS with the mode more negative at -15%.

## MODIS Aqua vs. Terra Cloud Fractions

Both Aqua and Terra Collection 5 Level 3 cloud fraction data is currently available for 2005. This allows direct comparisons between the two MODIS algorithms. Shown below (clockwise from top left) are Aqua minus Terra cloud fraction differences for June day, December night, March day, and March night. As seen in comparisons to AVHRR APP-X, daytime March data shows the most variability. Further investigation is needed to find the origins of the nighttime differences over Arctic ice. Daytime differences are caused at least in part by use of band 7 (2.1 μm) rather than band 6 (1.6 μm) for Aqua NDSI (Normalized Difference Snow Index) calculations. Band 7 is somewhat less sensitive than band 6 in terms of clear vs. cloudy sky discrimination. Excepting central Greenland, the very cloudy autumn months (cloud fractions > 80% for many Arctic areas) show few significant differences between the two.



## Conclusions:

Overall, MODIS vs. APP-X (AVHRR) results compare well.

Mode of MODIS minus APP-X cloud amounts is 5% during both night and day conditions with higher variability at night. Distribution of differences is skewed positive during day (MODIS > APP-X), negative during night (MODIS < APP-X).

However, large differences in cloud frequency are found in some regions and seasons, *e.g.*, Greenland, northern NWT, and NE Asia during daytime in spring, western Arctic Ocean north of Canadian Archipelago during spring at night.

Aqua minus Terra cloudiness also shows positive differences over Greenland and NE Asia in spring during daytime. Is 2.1 μm vs. 1.6 μm sensitivity to cloud/snow discrimination an issue?

MODIS vs. GLAS agree reasonably well considering added sensitivity to clouds with active vs. passive sensors.

Major cloud patterns are similar except over far-eastern Arctic Ocean and Beaufort Sea.

Mode of MODIS minus GLAS cloud amounts is -10% to -15%.

Further Work:

Which cloud type(s) are "missing" from MODIS relative to GLAS?
Which cloud test(s) lead to divergent MODIS vs. APP-X results in terminator regions/transition seasons?
How to interpret differences in cloud climatologies between active and passive sensors?