

Evaluation of Cloud Detection Biases in Geostationary Satellites using CALIPSO and MODIS Data

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INTRODUCTION

With the launch of a new generation of Geostationary satellites (GEO) such as Himawari and GOES-16 & 17, cloud detection using satellite imager data has been greatly enhanced with increased spectral bands, and higher temporal and spatial resolutions. A concern for all geostationary sensors, however, are changes in instrument sensitivity and algorithm performance at different viewing for daytime and nighttime. CALIPSO lidar observations provide a valuable reference for assessing these impacts as the satellite flies in a sun-synchronous orbit and crosses a wide range of GEO viewing angles each day.

This paper will present the cloud mask results using the imager data from Himawari (AHI) and GOES-16&17 (ABI). The detection algorithms have been adapted from the Cloud and Earth's Radiant Energy System (CERES) MODIS Edition 4 cloud mask, and adjusted and tuned to geo-satellites. They are used operationally for the CERES Time and Space Averaging (TISA) gridded cloud products and for near-real-time retrievals for weather and nowcasting applications.

DATA

Geostationary Satellites Observations:

- **GOES-16 & 17** ABI channels used: 0.64, 0.86, 1.37, 1.6, 3.9, 6.9, 8.4, 11.2, 12.3, 13.3 μm
- **Himawari-8** AHI channels used: 0.64, 0.86, 1.6, 3.9, 6.2, 8.6, 11.2, 12.4, and 13.3 μm
- Pixel resolution 2km, subset to 6km resolution for TISA

Ancillary inputs:

- For CERES TISA processing: NASA Global Modeling and Assimilation Office (GMAO) GEOS-54 surface skin temperature and atmospheric profiles: to predict Top-of-Atmosphere (TOA) 3.9, 11, and 12- μm clear-sky temperatures and correct for atmospheric attenuation
- For real-time processing: Global Forecast System (GFS) atmospheric profiles
- Dynamically generated 0.65- μm clear-sky overhead albedo maps
- Daily snow and ice maps from the National Snow and Ice Data Center (NSIDC)
- 10' surface emissivity, water percentage, IGBP ecosystem, and elevation maps
- MODIS aerosol optical Thickness (AOT) through MATCH hourly data

CALIPSO Version 4.10 VFM and 5-km cloud layer products

CERES-MODIS Edition 4 cloud mask results

METHODOLOGY

- Basic logic of GOES-16 & 17 and Himawari-8 cloud masks are similar to CERES-MODIS Ed4 (CM Ed4) cloud mask (Trepte & Minnis, IEEE, revision submitted)
- GEO cloud masks use subset of MODIS channels. Many tests and thresholds have been adjusted for individual GEOsats.
- Developed GOES-16 & 17 specified thin Cirrus tests using 1.37 μm which has different spectrum response function from MODIS. The thin Cirrus detection have been extended to snow-covered areas.
- Applied VZA dependent standard deviation for IR test to reduce GEO cloud fraction VZA dependency.

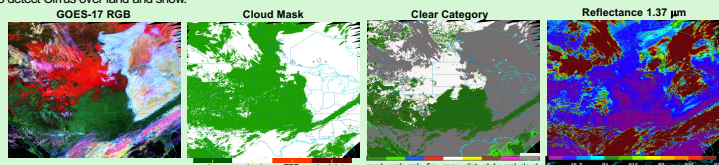
RESULTS

Real-time cloud mask and cloud retrieval results for GOES-W, GOES-E, MeteoSat-11, MeteoSat-8, and Himawari are available on the NASA Langley "Satellite Imagery and Cloud Products" webpage (<https://satcoms.larc.nasa.gov/>).

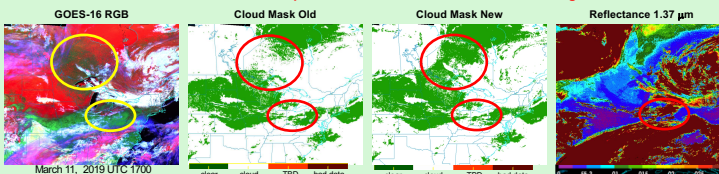
Pixel-Level Cloud Mask Results

GOES-17 Daytime Cloud and Snow Detection

In this GOES-17 example on March 15 2019, 1600Z, local time around 9am near terminator, clouds and surface snow shown in the RGB image are correctly identified by GEO Cloud Mask and Clear Category. Reflectance of 1.37 μm , combined with other channel tests was used to detect Cirrus over land and snow.

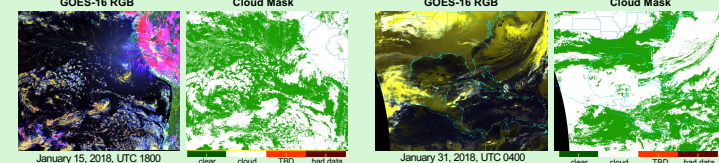


GOES-16 Cloud Mask Improvements in Snow Covered Forest Regions



GOES-16 Low Cloud and Thin Cirrus Detection

In Sun Glint Ocean

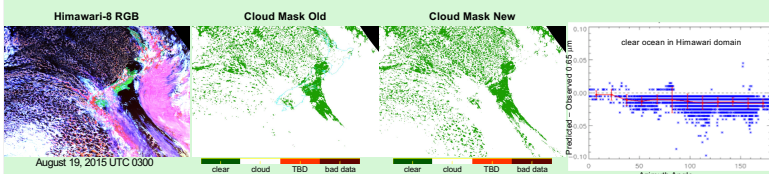


GOES-16 Nighttime Cloud Mask

over Land and Ocean

Himawari Daytime Low Clouds in SH Ocean

Biases in clear sky prediction often causes mis-identification of clouds. In this daytime ocean case east of Australia, original cloud mask over-detected clouds, mainly due to the predicted clear sky (CS) 0.65 μm reflectance were too dark by roughly 0.015 (right plot), causing the VIS test (Obs. 0.65 Ref - CS 0.65 Ref > 0.015) pass to call the "clear holes" clouds. With the help of ratio of 2.1 to 0.65 and IR tests, the false clouds were reduced in the new cloud mask.



CONCLUSION

- Pixel-level examples of GOES-16 & 17 and Himawari-8 cloud mask results for daytime and nighttime, over land and ocean are presented. The monthly GOES-16 and Himawari-8 regional cloud fraction are compared with CM Aqua Ed4 and CALIPSO.
- Spatially and temporally matched GEO cloud mask with CALIPSO VFM shows good agreement in zonal cloud amount except for CALIPSO 80km clouds.
- GEO Cloud fraction biases increase as view angles increase, especially over daytime ocean.

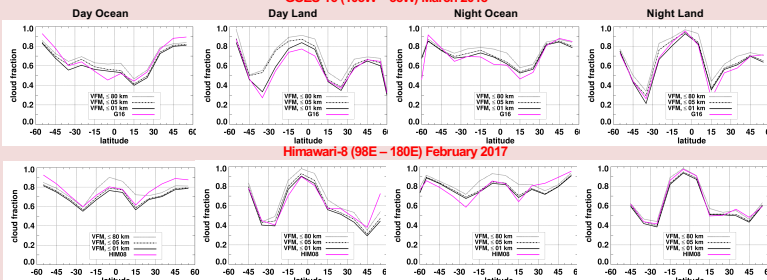
Future work:

- Improve 0.65 μm clear sky prediction to better account for the angle dependency in bi-directional models.
- Increase spatial resolution of predicted TOA clear sky IR (3.9, 11, 12 μm) maps to smooth cloud detection along coasts.

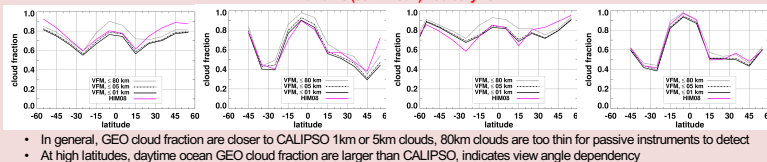
Spatially and Temporally Matched Comparison with CALIPSO

- GOES-16 and Himawari-8 pixel-level cloud mask results were matched with CALIPSO Version 4 VFM and 5-km cloud layer products
- Spatially matched to nearest one pixel within ~5.7km to CALIPSO track. Temporal within 15 mins

Zonal Monthly Cloud Fraction Comparison GOES-16 (105W – 38W) March 2018

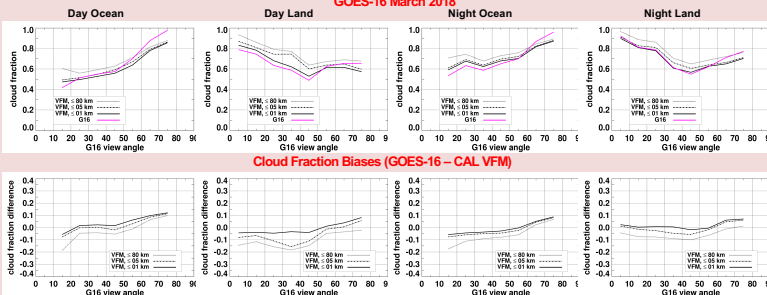


Himawari-8 (98E – 180E) February 2017

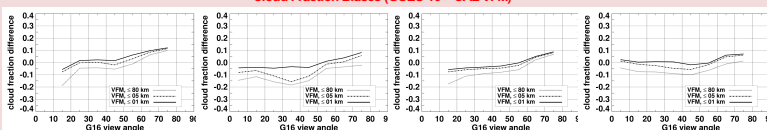


- In general, GEO cloud fraction are closer to CALIPSO 1km or 5km clouds, 80km clouds are too thin for passive instruments to detect
- At high latitudes, daytime ocean GEO cloud fraction are larger than CALIPSO, indicates view angle dependency

View Angles Dependency of GEO Cloud Fraction GOES-16 March 2018

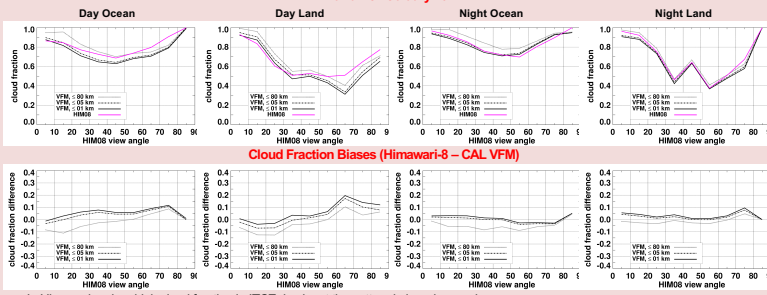


Cloud Fraction Biases (GOES-16 – CAL VFM)

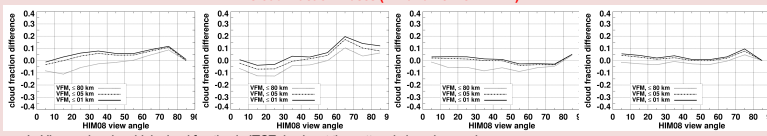


- In GOES-16 region, ocean clouds (both day and night) experience greater view angle dependency than land
- cloud patterns and surface types associated with their geolocations contribute to the variation of view angle dependency curves

Himawari-8 February 2017



Cloud Fraction Biases (Himawari-8 – CAL VFM)



- In Himawari region, high cloud fraction in ITCZ dominant the pattern in low view angles.

Regional Monthly Cloud Fraction Comparison

