Thin Cirrus Cloud Detection During CRYSTAL-FACE from the Multi-Angle Imaging SpectroRadiometer (MISR)

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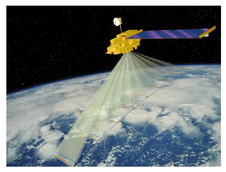
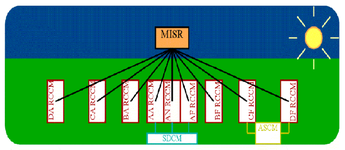
Introduction:

CRYSTAL-FACE provided a rare opportunity to test the Multi-Angle Imaging SpectroRadiometer (MISR) cloud masks. This particular experiment set out to determine how thin of clouds the three automated cloud masks on MISR are able to detect. Through measurements obtained through the various aircraft involved in CRYSTAL-FACE, the future of this experiment is to compare calculated optical depths from aircraft with data collected from the MISR instrument. We have correlated several flights paths with MISR data in preparation for this data as it becomes available.

Description of the MISR Instrument:

MISR has 4 spectral channels, centered at 446 nm, 558 nm, 672 nm, and 866 nm. In addition, MISR has 9 cameras: one that is directed at nadir, four that are directed ahead of the nadir camera (forward cameras) and four that are directed behind the nadir camera (aft cameras). The nadir camera is directed at 0°, while the off-nadir cameras are directed at 26.1°, 45.6°, 60.0° and 70.5°. MISR has a 275 m resolution for all bands for the nadir camera, 275 m resolution for the red bands in the off-nadir cameras, and 1100 m resolution for the other bands in the off-nadir cameras.





MISR Cloud Masks:

MISR has three cloud masks available, which complement each other's strengths and weaknesses.

The Radiometric Camera-by-camera Cloud Mask (RCCM) uses a specific set of spectral and spatial thresholds, categorized by surface type, solar zenith angle, and azimuth angle for each camera. Through the use of three separate thresholds, each MISR pixel is categorized as cloudy or clear, with either high or low confidence. This technique works well over open ocean and some land surfaces, but has some difficulty over bright terrain, such as snow, ice, and desert.

The Stereoscopically Derived Cloud Mask (SDCM) utilizes the parallax effect to determine which regions are clear. The parallax effect allows stereo heights to be calculated. If the stereo height is greater than 562 meters, then the SDCM defines it as a cloud. The SDCM works well for high clouds, even over bright surfaces, but struggles with low clouds and featureless clouds.

The Angular Signature Cloud Mask (ASCM) focuses on the forward-scattering properties of clouds compared to the surface. By taking blue minus near-ir for both the D and C cameras in the forward-scattered direction, and then taking the C-camera result minus the D-camera result, the Band-Differenced Angular Signature (BDAS) is calculated. For cloud cover, the Band-Differenced Angular Signature is more strongly positive than for clear regions. A threshold is applied to the BDAS to create the ASCM. The ASCM does especially well over polar regions, but the forward-scattered signal weakens as one approaches lower solar zenith angles.

Method:

The desired result is to coordinate MISR cloud masks, reflectances, stereo heights and BDAS data to corresponding flight paths. Two possible methods allow for this kind of analysis:

1) Flight path data can be plotted onto a MISR grid. This technique will allow a visual analysis of each scene, to determine which time periods may be the most promising to investigate.

2) Take the latitudes and longitudes for each time step from the flight paths, and provide the corresponding MISR data value for that longitude and latitude. The effect is a graph of MISR data vs. flight time. This method is more useful for numerical analysis.

Complications:

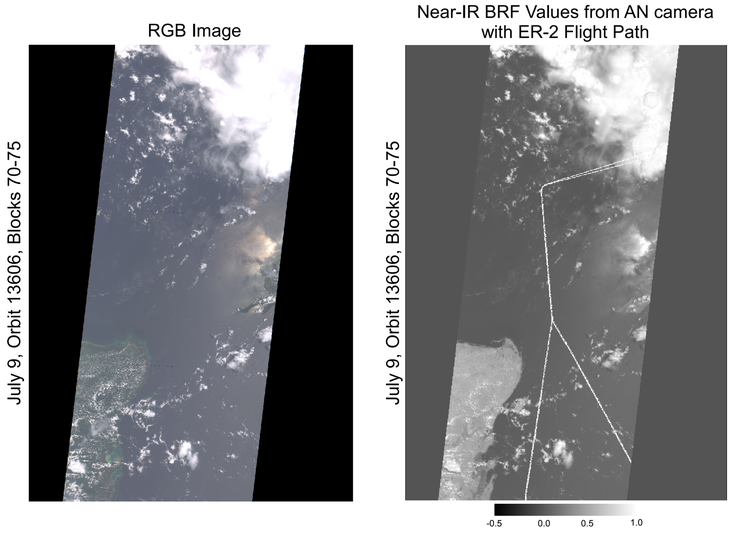
There are a few difficulties in this study, which need to be accounted for.

1) Clouds experience a "parallax effect" when viewed from a non-nadir camera, making their line-of-sight location different than the location indicated by the aircrafts.

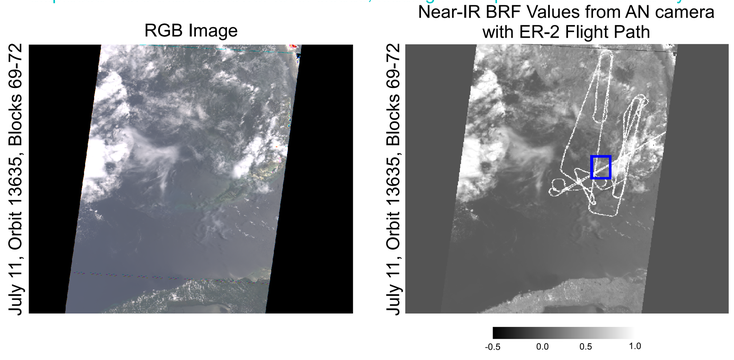
2) MISR data is collected over a very brief period of time compared to aircraft data. Thus, a graph of MISR data versus time, for correlation to the aircraft, is not truly accurate. The larger the displacement is between the aircraft measurement time and the MISR overpass, the more likely a cloud is to have formed, modified, or dissipated. Therefore, a large difference in time introduces a high error.

Cases During CRYSTAL-FACE:

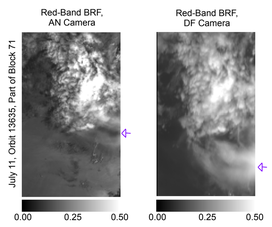
July 9th saw a mixture of dense cloud cover, patchy cumulus, and isolated cirrus clouds just east of the Yucatan Peninsula: Of the three realized opportunities for MISR, this overpass provided the most variety for analysis.



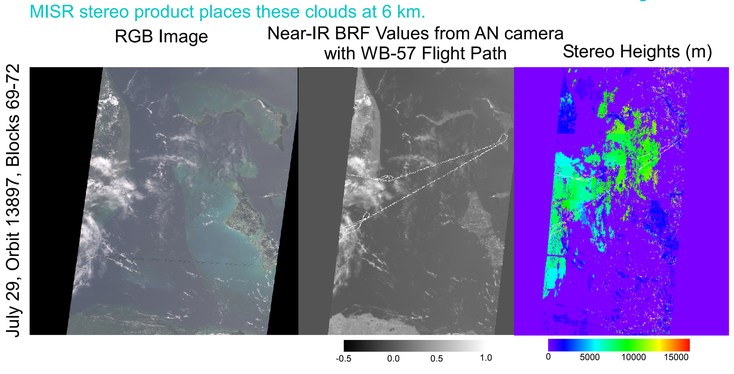
July 11th also saw a mix of cloud cover types. However, in terms of cirrus cloud measurements, most of the prominent cirrus clouds were above low-level clouds. These conditions do not allow for a vaidation of either the RCCM or the SDCM, which may be receiving some information from the lower level clouds. However, the ASCM may be validated, due to the oblique angle. The upper-level cirrus clouds will be displaced more than the lower level clouds, leading to a separation of the cloud layers.



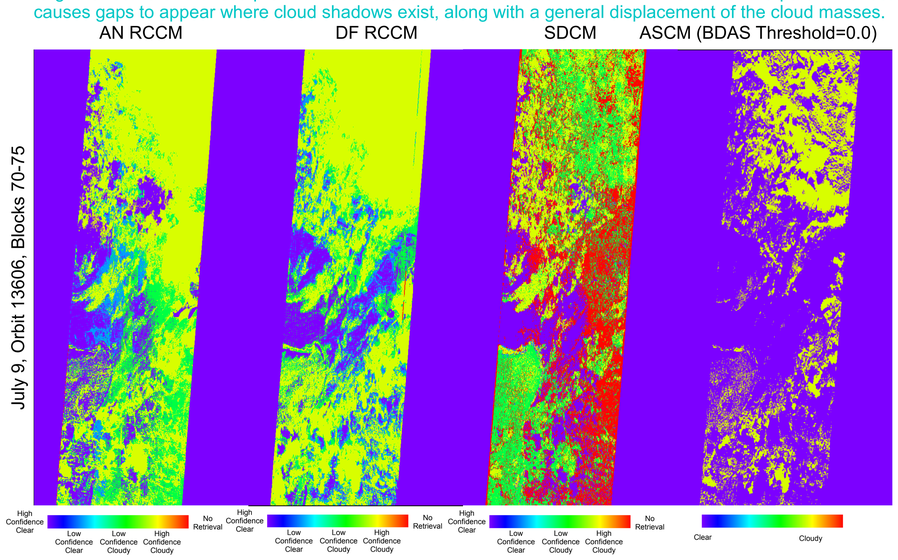
The boxed region has been focused on to the right. The AN camera shows lower clouds in the top half of the image, with high clouds above them (shown by the blue arrow). The DF camera provides more separation to these cloud fields.



July 29th was the final MISR overpass to coordinate with the CRYSTAL-FACE mission. Since this flight had very little cirrus cloud cover, this case has the least to offer in terms of thin cloud detection. There are some clouds on the left side of the image, but the MISR stereo product places these clouds at 6 km.



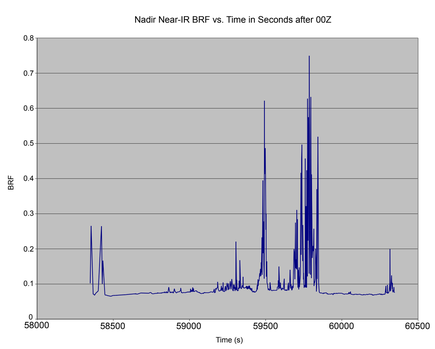
The three MISR cloud masks are shown below. The AN RCCM does a better job on the left side of the image, where sun glint is not a factor. The SDCM works well over the sunglint, but has some trouble over the land mass. The manually thresholded BDAS (ASCM) does not have confidence levels yet, but it seems to gather some of the less prominent cloud cover. The drawback with the BDAS is that the parallax effect causes gaps to appear where cloud shadows exist, along with a general displacement of the cloud masses.

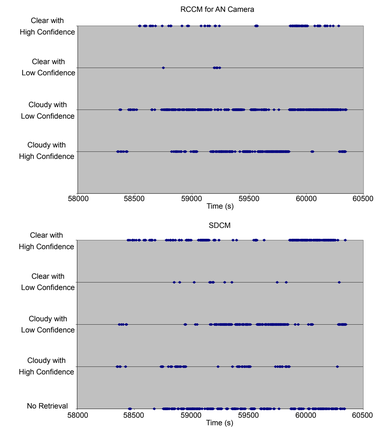


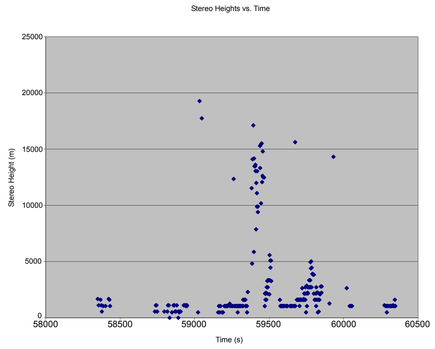
Plotting MISR data as a function of flight time:

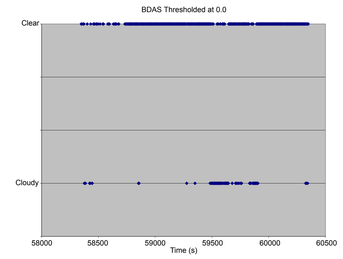
Showing the flight path on a MISR grid provides some visual information on what each aircraft encountered during the overpasses. However, in order to overlay the MISR data with instrument data, the MISR data must be plotted as a function of flight time.

Shown below are graphs of the nadir near-IR BRF, stereo heights, and the three cloud masks. Note that since the flight was moving to the south, the ASCM values for high clouds will be displaced towards later times. Shifting the ASCM towards earlier times lines up the ASCM cloud retrievals with the highest stereo height retrievals, showing that the ASCM is more sensitive to the higher clouds. The RCCM for the AN camera is based on a set of thresholds applied to the nadir camera measured reflectances, while the SDCM labels a feature as a cloud if the measured stereo height is greater than 562 meters.









Future Work:

The task of determining the minimum optical depths from MISR has yet to be achieved. As data from various CRYSTAL-FACE instruments becomes available, the first validations from MISR will begin. As shown above, MISR data has been prepared for the task of comparison to CRYSTAL-FACE instrument data.

For images of the scenes presented here, go to: http://www.atmos.uiuc.edu/~wilson/crystal/home.html
For more information on MISR, go to: http://www-misr.jpl.nasa.gov