Validation of a 3-D Cloud Product (UW-CAVP) Derived from NASA Atmospheric InfraRed Sounder (AIRS) Radiances with MODIS, CALIPSO, and NCEP GFS Using McIDAS-V Version 1.0

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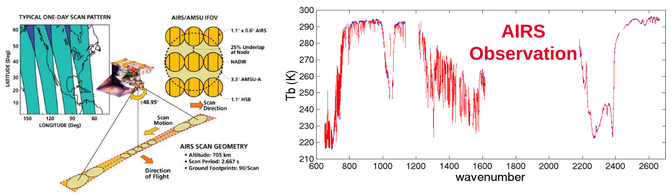
Abstract

The University of Wisconsin-Madison AIRS Cloud Amount Vertical Profile (AIRS CAVP) is a product currently being developed to provide a three-dimensional view of cloud structure in the atmosphere obtained through passive remote sensing. It uses high spectral resolution infrared data from AIRS (Atmospheric Infrared Sounder) on the A-train satellite Aqua and ECMWF model temperature fields to create a cloud amount profile for 25 vertical layers from the surface to the tropopause. As this is a new product, the validity and accuracy of AIRS CAVP must undergo thorough testing. McIDAS-V is an open source interactive imaging tool released by the Space Science and Engineering Center (SSEC) at UW-Madison in September 2010. It can be used to visualize, manipulate, and assess various types of data including satellite images, grid data, soundings, and hydra files (the format of the CAVP product). The purpose of this study is to use McIDAS-V to visualize and validate the CAVP product through comparison with collocated MODIS products, CALIPSO lidar cloud retrievals, and NCEP GFS model data. The CAVP product shows good spatial representation of both high and low-level clouds as compared to MODIS cloud images. CALIPSO vertical cross-section comparisons with CAVP were used to confirm cloud base estimates including low cloud detected through optically thin high clouds.

Data Sources

AIRS



The AIRS instrument is a hyperspectral, scanning IR sounder aboard the A-train satellite Aqua. It measures 2378 IR spectral channels over the range of 3.7 – 15.4 μm with a spatial resolution of 13.5 km at nadir, as well as 4 Vis/NIR spectral channels with a spatial resolution of approximately 2.3 km. AIRS attains complete global coverage daily using cross-track scanning, divided into granules of 6 minutes of calibrated radiance data containing 135 scan lines of 90 cross-track fields of view between ±49.5°.

MODIS

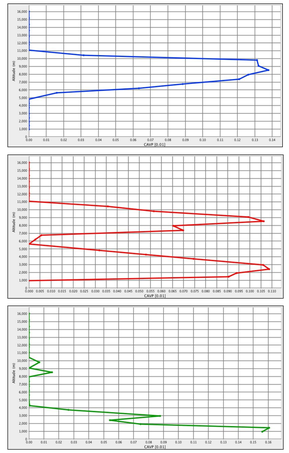
The MODIS (Moderate Resolution Imaging Spectroradiometer) instrument is also found on Aqua as well as the Terra satellite. It measures 36 spectral bands ranging from 0.4 μm to 14.4 μm in wavelength with high radiometric sensitivity. Two bands are imaged at a resolution of 250 m at nadir, five bands at 500 m, and the remaining 29 bands at 1 km. MODIS attains complete global coverage daily using cross-track scanning, divided into granules of 5 minutes of calibrated radiance data containing 406 scan lines of 270 cross-track fields of view between ±55°.

CALIPSO

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite is also part of the A-train constellation of satellites, following a few minutes behind Aqua and allowing for coordinated observations. It combines an active lidar instrument with passive IR and visible imagers to obtain the vertical structure and properties of thin clouds and aerosols. CALIPSO is a joint U.S. and French mission that has been in operation since April, 2006.

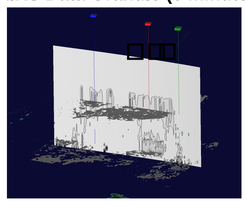
Visualization of AIRS CAVP

CAVP Pixel Vertical Profiles

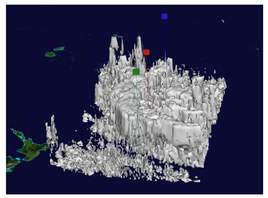


The UW-Madison CAVP algorithm uses both spatial and spectral filtering of AIRS radiances to detect cloud amount from the top of the atmosphere to the surface using 25 discrete layers. The 3-D nature of the AIRS CAVP product allows for numerous methods of visualization using the McIDAS-V software. For example, the 1-D vertical profile of a single pixel can be viewed using a vertical profile probe, both horizontal and vertical 2-D cross-sections can be taken, and the 3-D cloud structure of the granule can be viewed as an iso-surface. Single granules or entire orbits can be displayed and animated to highlight different times or features.

AIRS Data Granule (6 minutes)

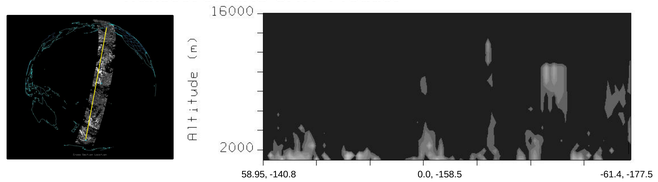


CAVP 0.05 Iso-surface



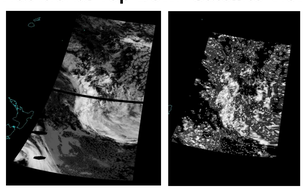
AQUA Polar Orbit

Transect of AIRS CAVP Product



Validation with MODIS

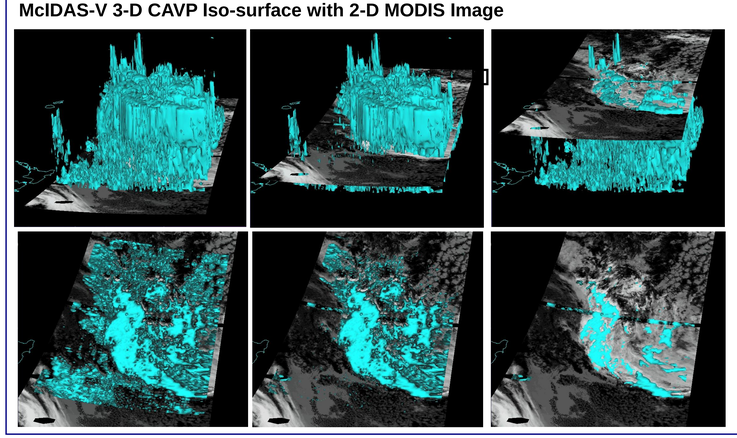
Traditional Top-Down Satellite View



• Traditional MODIS image displays show cloud top pressure or height in high spatial resolution , but cannot indicate areas of low cloud underneath high cloud.

• Good agreement between AIRS CAVP and MODIS for low, mid-level, and high cloud cover are shown by moving the 2-D MODIS L2 Cloud Top Pressure – Infrared product image display up through the AIRS CAVP 0.05 iso-surface (below).

McIDAS-V 3-D CAVP Iso-surface with 2-D MODIS Image

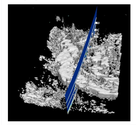


• AIRS CAVP cannot resolve small-scale variations in cloud top height as well as MODIS due to the coarser resolution of AIRS IR data.

• AIRS CAVP cloud tops and bases can appear flatter than in reality because the product is calculated for vertical layers; features falling inside the layers are smoothed out.

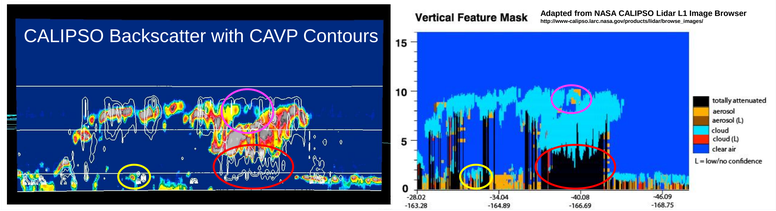
Validation with CALIPSO Lidar

• When viewed as contours of AIRS CAVP along the CALIPSO path, 1) CAVP cloud tops are slightly higher than CALIPSO lidar cloud tops, 2) CAVP misses some smaller features, possibly due to features falling entirely within a CAVP layer, and 3) misses upper cloud base for thin clouds above thick mid-level clouds (pink).



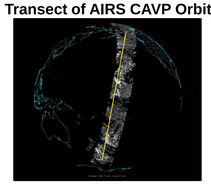
• CALIPSO measurements confirm that CAVP can detect low clouds below optically *thin* high clouds (yellow).

• AIRS CAVP can produce false detection of low clouds in areas where total attenuation has occurred in CALIPSO measurements (red).

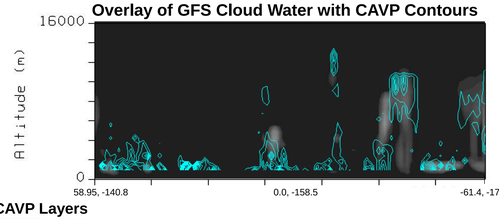


Validation with NCEP GFS Model Data

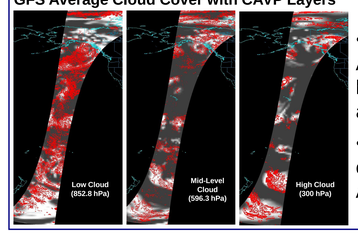
Transect of AIRS CAVP Orbit



Overlay of GFS Cloud Water with CAVP Contours



GFS Average Cloud Cover with CAVP Layers



• Reasonable agreement was found between AIRS CAVP and NCEP GFS for presence of high cloud and mid-level cloud, particularly in areas of most dense cloud cover.

• The GFS model is missing known low stratus clouds in the north Pacific that are detected by AIRS CAVP and CALIPSO.

Conclusions

• A flexible tool (McIDAS-V) was used to validate a 3-D cloud product against 2-D lat/lon MODIS data, 2-D height/orbital track CALIPSO data, and 3-D GFS model data.

• Good agreement was found between AIRS CAVP and MODIS for low, mid-level, and high cloud tops, but MODIS cannot provide cloud base validation.

• CALIPSO was used to validate AIRS CAVP cloud base and low cloud below optically thin high cloud, but only in a nadir cross-section below the satellite.

• The CAVP product indicates that low stratus clouds in the north Pacific are not well represented in the GFS model. Reasonable agreement was obtained for mid and high-level cloud, however additional validation of the CAVP product is required before it can be fully utilized to validate the complete 3-D model cloud fields.

References

•Plokhenko, Y., W. P. Menzel, H. E. Revercomb, E. E. Borbas, P. Antonelli, E. Weisz, (2008), Analysis of multi spectral fields of satellite IR measurements: Using statistics of second spatial differential of spectral fields for measurement characterization. *International Journal of Remote Sensing*, *29*, 2105-2125, doi:10.1080/01431160701268988.

•Achtor, T., (2011). McIDAS-V—Accessing, visualizing and analyzing multi and hyperspectral environmental satellite data. Presented at *AMS National Conference 2011*, Seattle, WA.

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