

Evaluation of VIIRS cloud top property climate data records and their potential improvement with CrIS

FIRST YEAR REPORT

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Specific goals of this proposal are to:

- Evaluate the contractor cloud products developed from VIIRS data,
- Implement cloud-top height/pressure retrieval software at the Atmosphere PEATE based solely on IR hyperspectral data (i.e., AIRS, IASI, and eventually CrIS),
- Analyze the hyperspectral IR data independently from that of the imager, at least initially. The approach is to build a daily map by adopting a common grid, intercompare the gridded cloud heights, and decide on a straightforward way to use the hyperspectral IR data to improve problem areas in the imager products,
- Continue to develop an approach in parallel that merges the imager and sounder data more directly using MODIS+AIRS (Aqua) and also AVHRR+IASI (MetOp-A). This additional complexity provides a mechanism to improve the imager pixel-level cloud top heights. This process will be extended to regional and subsequently global data,
- Implement MODIS+AIRS and VIIRS+CrIS software for use with direct broadcast data,
- Compare VIIRS cloud products to those from VIIRS+CrIS upon launch of NPP, and
- Conduct studies to evaluate the cloud products from morning/afternoon imager-sounder sensor pairs and their uncertainties. Our intent is to mitigate cloud height differences caused by sensors so that we can isolate morning and afternoon cloud signatures.

This report summarizes results for the period June 2011 – April 2012, the first year of funding for this particular effort. The team is pleased to report significant progress towards accomplishment of the above stated goals. We also want to note two new papers that have been submitted this year as part of this effort (Weisz et al. and Smith et al.) that are complementary to a new paper on MODIS Collection 6 activities led by Dr. Baum. Now that the NPP platform has reached orbit successfully and data are beginning to flow, we anticipate that the research will progress rapidly and result in more papers being prepared and submitted this year.

Papers Submitted over past year

Baum, B. A., W. P. Menzel, R. A. Frey, D. Tobin, R. E. Holz, Ackerman, S. A., A. K. Heidinger, and P. Yang: MODIS cloud top property refinements for Collection 6. In press, *J. Appl. Meteor. Clim.*

Weisz, E., W. P. Menzel, R. Frey, E. Borbas, N. Smith, and B. A. Baum: An approach for improving cirrus cloud top pressure/height estimation by merging high spatial resolution VIIRS data with high spectral resolution CrIS data. In press, *J. Appl. Meteor. Clim.*

Smith, N., W. P. Menzel, E. Weisz, A. Heidinger, and B. A. Baum: A uniform space-time grid for comparison of global satellite cloud products: Characterization and sensitivity studies. Submitted to *J. Atmos. Oceanic Technol.* and currently under revision.

First Year Progress

A brief summary of recent progress is listed below.

1. To simplify the procedure of processing multiple imagers within our organization, we recognized that over 50% of our processing software is related to simply setting up all the required ancillary data and associated radiative transfer calculations for a granule of data. Since each imager pixel requires an atmosphere and surface properties, we made the decision to develop a separate software package to perform all these functions. In brief, a package has been developed in Python to set up all the necessary ancillary data required by the MODIS and VIIRS cloud masks, and is based on a given imager granule's geolocation file. Further effort will expand the package to include the additional information necessary to process an imager file to infer cloud top height and cloud phase. The software package results in more consistency and efficiency in processing efforts, and is much more easily maintained and refined than historical software packages. (effort led by Dr. Baum)
2. The team has had numerous discussions pertaining to the process of building global gridded data sets from instantaneous pixel cloud products. MODIS has a set of Level-3 gridded products, but there are issues that we want to address. These issues arose during the GEWEX cloud product evaluation effort over the past six years. Dr. Nadia Smith has improved our ability to compare regional and

global cloud products from multiple sensors (e.g., VIIRS and CrIS) and has submitted a paper on this research.

3. Now that NPP is in orbit and the sensors are providing data, the imagery from VIIRS has proven to be nothing short of spectacular. However, this imager has none of the infrared absorption channels found on MODIS, either in the water vapor or CO₂ absorption bands. This will impact the inference of cloud top height. One of our primary goals is to supplement the VIIRS information with that from CrIS. Previous research (by W. P. Menzel, funded by NASA ROSES) led to an approach for how the convolution of data could occur. Dr. Elisabeth Weisz led a paper on this topic that is currently in press (i.e., accepted for publication) with the Journal of Applied Meteorology and Climatology; publication of this article is imminent.

Highlights of Research Results

1. A goal of our effort is to ensure continuity in the cloud products from MODIS to future sensors. The MODIS cloud top property products are not static however, and a number of improvements have been incorporated for upcoming Collection 6 processing. These improvements are detailed in Baum et al. (in press, publication imminent in JAMC). In brief, the Collection 6 cloud top height and IR phase products will be available at 1-km resolution for the first time, and will be much improved because of extensive comparison to CALIPSO Version 3 cloud products. An illustration is shown in Figure 1 for a MODIS granule recorded at 1630 UTC on 28 August, 2006, over the northern Atlantic Ocean. In the false color image (Figure 1a), ocean is dark, land is green, cirrus is blue, optically thick ice (southern tip of Greenland) and optically thick ice cloud are magenta, and low clouds are yellow/white. Figure 1b shows results obtained from the Collection 5 MYD06 product for IR phase at 5-km resolution, and Figure 1c shows the same set of IR phase tests applied at 1-km spatial resolution. For the Collection 5 results, the “mixed-phase” pixels are merged into the “uncertain” category to emphasize that much of the optically thin cirrus cannot be reliably discriminated as ice phase. The planned Collection 6 discrimination of ice phase clouds is improved in the results shown in Figure 1d.

2. While the new VIIRS imager has many advances over previous sensors, it lacks infrared (IR) spectral bands that are sensitive to absorption by carbon dioxide or water vapor. The use of such bands provides greater sensitivity to cloud top height/pressure (CTH/CTP) estimation than can be obtained from use of window bands alone. The lack of absorbing IR bands will have the most impact on the inference of CTH/CTP for semi-transparent ice clouds. The CrIS (Cross track Infrared Sounder) on NPP/JPSS, with sounding bands in both the CO₂ and H₂O spectral regions, offers complementary measurements to VIIRS but at lower spatial resolution. CrIS is better suited to infer cloud-top pressure for cirrus because of the hyperspectral sounding measurements in the CO₂ and H₂O absorption bands, whereas VIIRS is able to detect clouds of small horizontal extent and describe clouds with large horizontal variations. Under the earlier NASA ROSES work by Menzel et al., an approach to combine the horizontal detail of VIIRS (using Moderate resolution Imaging Spectroradiometer, MODIS, data as a proxy) with the absorbing IR spectral bands of CrIS (using Atmospheric Infrared Sounder,

AIRS, data as a proxy) was developed for cloud detection and CTP estimation. We note that this approach can be applied to any imager/sounder pair. The cloud structures at CrIS horizontal resolution (13.5 km at nadir) are related to those at VIIRS resolution (880 m at nadir) through a regression relationship of CrIS cloud top pressure gradients against CrIS measurements convolved to VIIRS spectral band response functions. The regression relationship is applied to simulated pre-launch VIIRS radiance measurements to determine CTPs at sub-kilometer resolution. That is, the VIIRS+CrIS merging-gradient approach provides cloud pressures/heights at 1–km spatial resolution. The “merging gradient” CTPs are converted to cloud top heights and compared to the CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) Version 3 cloud product.

Figure 2 shows an example comparison for data from a very complex cloud scene containing multiple cloud layers. For optically thin ice clouds and also clouds of small vertical extent, the combined (proxy) VIIRS+CrIS CTHs compare much better with CALIOP than the individual VIIRS CTHs. The retrieval performance is found to be best for high clouds above 6 km. The VIIRS+CrIS biases for this cloud scene with respect to CALIPSO are 0.7 km lower than from the 3.4 km bias for VIIRS alone; VIIRS+CrIS biases are similar to those for CrIS, but they are accomplished at 1 km resolution (improving the standard deviations from 2.5 to 1.9 km). This work was prepared in a journal article by Dr. Elisabeth Weisz and is now in press, with publication imminent. As soon as VIIRS and CrIS data become fully available in spring 2012, this approach will be implemented, tested, and modified if necessary.

Summary

The first-look imagery from VIIRS data is spectacular – the current effort is to let the calibration stabilize and tune the cloud mask. The new Python system for assembling the necessary ancillary data is almost completely in place and is sufficient for the cloud mask work. At SSEC, we are currently able to process an entire day of VIIRS data using this Python system, which is invaluable for assessing the impact of each cloud mask code modification on a global scale. Further details on this can be provided if there is an interest. In subsequent work, we will begin building cloud top products that rely on the cloud mask. As soon as the Community Radiation Transfer Module (CRTM) is integrated, which will happen in the very near future as we are now already quite close, the necessary components will be available for building the cloud phase and cloud top height products. On a parallel path, software is in place to infer cloud top height from CrIS data, and will be used as soon as CrIS data become available. These cloud products will be evaluated during co-incident orbits between the NPP platform and the Aqua platform. Every three days, the orbits of the two platforms will align for an orbit or two. Over the course of a month, we expect to obtain global coverage of co-aligned Aqua and NPP cloud products, and will have the CALIPSO lidar cloud products for evaluation (cloud phase and cloud boundaries).

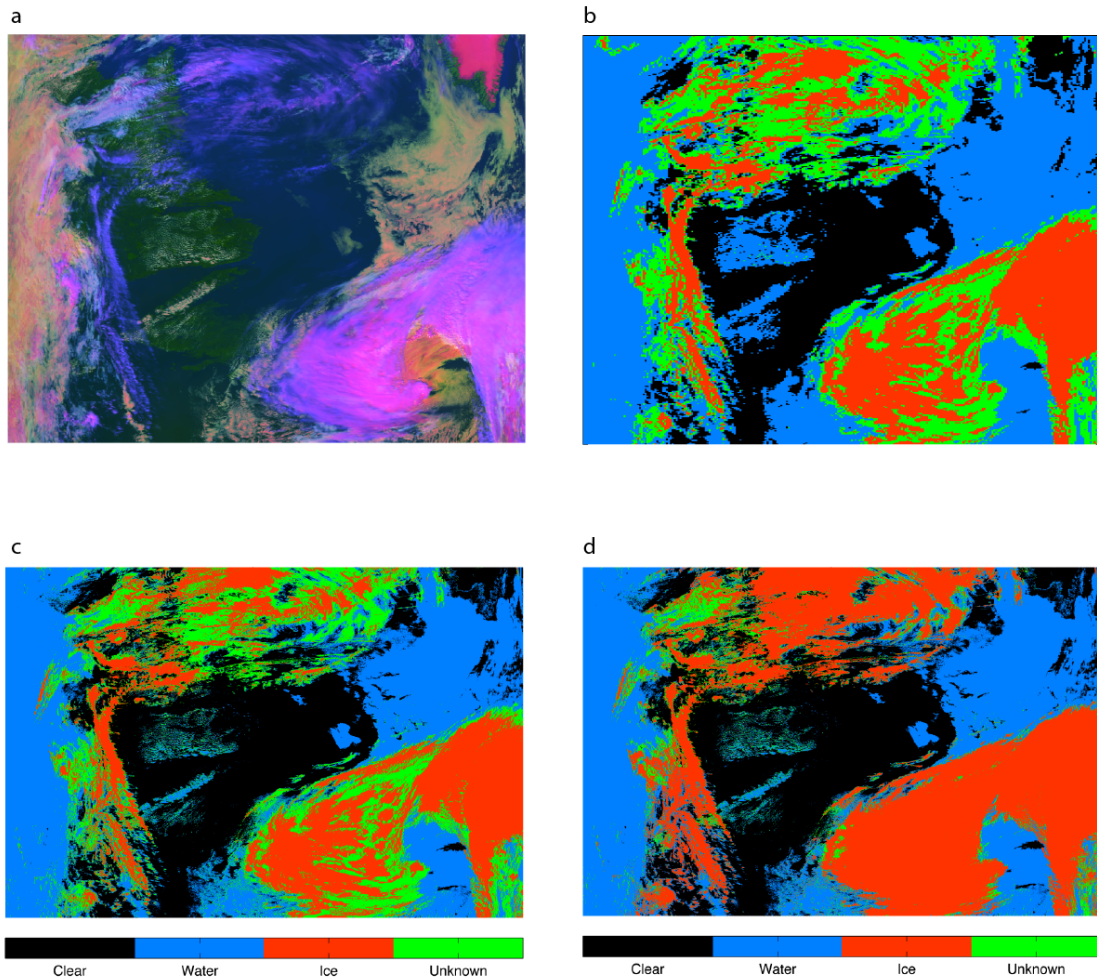


Figure 1: Results of IR cloud phase for a MODIS granule at 1630UTC on 28 August, 2006, over the northern Atlantic Ocean with Nova Scotia and Newfoundland in the center left of the image and Greenland in the upper right hand corner of the image. (a) a false color image (Red: 0.65 μm ; Green: 2.15- μm , Blue: 11- μm reversed) where ocean is dark, land is green, cirrus is blue, optically thick ice cloud is magenta, and low clouds are yellow/white, (b) Collection 5 IR phase results at 5-km resolution, (c) Collection 5 IR phase algorithm applied at 1-km spatial resolution, and (d) improved IR cloud phase. For the Collection 5 results, the “mixed-phase” pixels are merged into the “uncertain” category, as will be done with Collection 6.

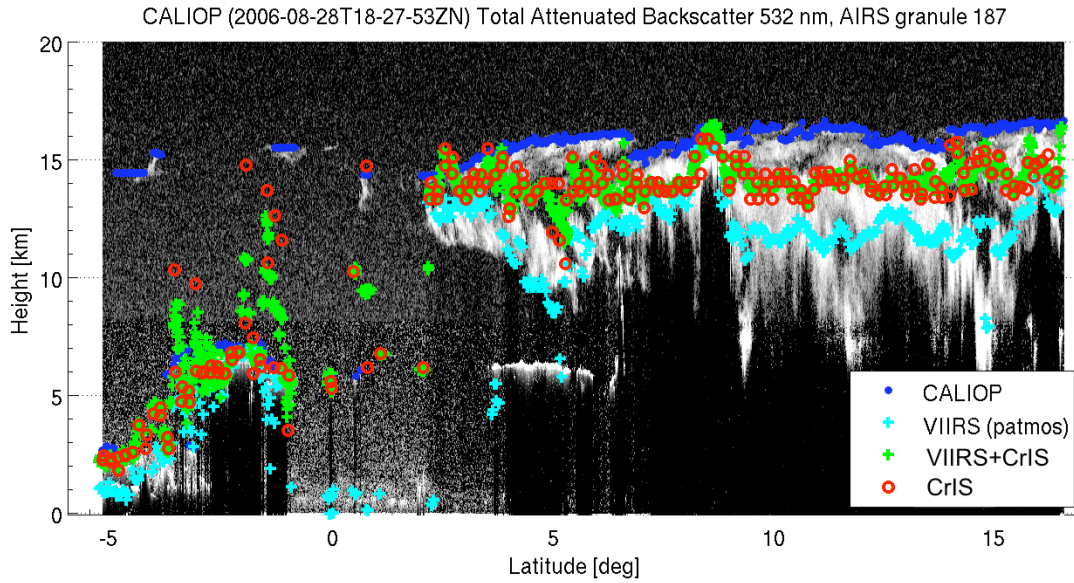


Figure 2: Cross-section along the CloudSat/CALIPSO track for AIRS granule 87 (28 Aug 2006). CALIOP 532 total attenuated backscatter /km/steradian (background). CTHs from CALIOP, VIIRS (proxy), VIIRS+CrIS (both proxy), and CrIS (proxy) are plotted as blue dots, cyan pluses, green pluses, and red circles, respectively.