GOESR3 Periodic Reporting

Reporting Period: July 2018 – December 2018 (1st half of FY18 funding cycle)

Team Lead: John M. Haynes
Team Members: Yoo-Jeong Noh, Steven D. Miller, Andrew Heidinger
Project Title: Improving the ABI Cloud Layers Product for Multiple Layer Cloud Systems and Aviation Forecast Applications
Project Number: 479

Executive Summary

This project seeks to improve the classification and categorization of multilayer cloud scenes by the GOES ABIs, while simultaneously improving the Cloud Cover Layers (CCL) product that identifies the height category of clouds in any given ABI pixel. The general methodology is threefold: (1) To investigate the usefulness of certain cloud proxies, such as layer relative humidity, by training on actively-sensed cloud layer boundaries; (2) To develop a new multispectral retrieval that uses ABI radiances to determine separation between cloud layers in known multilayer situations; and (3) To fuse this information together with our own statistical cloud base algorithm, which has been trained on radar and lidar-observed cloud boundaries.

In this reporting period we report that the transition of our improved CCL products to the ABI is complete in its initial form. The algorithm, which is part of the NOAA Enterprise Cloud Processing System, now identifies six types of cloud layers instead of the initial three that were present before this project started. An expansion to flight-level based vertical levels is in progress. We have continued development on our multispectral retrieval algorithm, while simultaneously evaluating our newly-delivered algorithm against active-sensor based observations of cloud boundaries. This evaluation shows expected deficiencies in low cloud detection when there are multiple cloud layers present, thus motivating the remainder of the work we proposed for this project. During this period we also explored ways to implement machine learning techniques to the problem of low cloud detection with the ABI, and demonstrated some promising initial results.

Progress toward FY18 Milestones

This section will address overall progress toward FY18 milestones achieved during July to December 2018 reporting period (new progress). Milestones, bulleted and in italics, are referenced.

- Complete implementation of the statistical cloud base algorithm on ABI data.

The implementation of our statistically-based CCL algorithm, as originally developed for Suomi NPP, is now complete and ready for operations with the GOES ABI. The codebase is part of the NOAA Enterprise cloud algorithm suite, providing an easy transition to operations. Continued development is always ongoing, however, in coordination with Dr. Heidinger at NESDIS. For example, we are currently moving from a 3 vertical level system to one that implements 5 vertical levels based on flight levels instead of pressure. We assisted the code implementation for the flight level-based layers in the CLAVR-x system led by Dr. Heidinger and continue tests to provide more effective display tools of the complex 3-D cloud information with increased layers in collaboration with the CIMSS team.
We are also producing and disseminating this product in real-time at CIRA through our SLIDER interface (http://rammb-slider.cira.colostate.edu). An example GeoColor and CCL product including the March 3, 2018 Nor'easter that affected the eastern U.S. is shown in Figure 1. Note that the implementation now includes six cloud categories, which is an improvement over the initial three. Cloudiness in this example transitions smoothly from low cloud in the warm sector to mid+low cloud approaching the warm front, to high+mid+low clouds near the center of the system. This is consistent with our understanding of the synoptic scale structures of such storm systems.

- **Collect validation datasets** *(Active remote sensing products from CloudSat, CALIPSO, and EarthCare (if available); ARM site remote sensing products)*

Collection of CloudSat and CALIPSO products for comparison and algorithm training purposes continues. Notably, CloudSat and CALIPSO are again producing collocated data products (after a period of non-overlap during transition to a different orbit). We have developed code to match ABI data to the track of these active instruments, and regularly update and utilize these matchups. At present we are heavily utilizing these global-scale datasets for evaluation purposes. We will further pursue coincident observations at the ARM ground sites in the next reporting period.

- **Begin testing of daytime/nighttime lookup tables for determination of lower cloud boundaries (including high/low separation distance) in multilayer situations. Compare this physically based method to a statistically based method based on existing CloudSat/CALIPSO cloud boundaries.**

We will be focusing more heavily on the lookup table method for determining low cloud boundaries in the next reporting period (see next section). We have, however, been rigorously evaluating our CCL retrieval against CloudSat radar and CALIPSO lidar cloud boundaries. Figure 2(a) shows a cross-section through some ABI-identified cirrus as viewed from the active sensors. The radar and lidar cloud boundaries are shown in the rainbow and purple colors, and the vertical bins that the ABI CCL product shows as containing cloud are shown by the blue background color. Note from the figure that although low cloud is quite common when there is cirrus above it, the CCL product rarely identifies it. This is, of course, a known limitation of the CCL methodology, whereby clouds are extended downward from the ABI cloud top as modulated by the column water path. There is no mechanism in place allow separation between two layers. This problem is a chief focus of this project.

In addition to the multispectral approach we proposed, we have been experimenting with using machine learning techniques to improve detection of low clouds under higher cloud layers. An implementation of the random forest algorithm to this problem, as trained by coincident ABI and CloudSat observations, including auxiliary layer humidity information from a forecast model (discussed in last reporting period), is shown in Figure 2(b). The machine learning technique greatly increases low cloud detection, and is relatively inexpensive to run in real-time. Therefore, we will continue pursuing this method in parallel with our other work on this topic.

- **Present results at GOES-R meeting and at AMS or AGU.**

Our work will be presented at the 15th Annual Symposium on New Generation Operational Environmental Satellite Systems at the American Meteorological Society (AMS) 2019 Annual meeting in Phoenix, Arizona.
Plans for Next Reporting Period

• Create lookup tables of nocturnal 3.9 and 11.2 \( \mu m \) BTD using radiative transfer code.

In the next reporting period we will focus most of our efforts on a combination of (a) the spectral retrieval we proposed, including radiative transfer work in the 0.64, 1.38, 3.9 and 11.2 \( \mu m \) channels, and (2) the machine learning method we developed and described earlier in this document. We will test our retrieval on idealized cases obtained from ABI/CloudSat/CALIPSO matchups.

• Visit Aviation Weather Center to meet with potential users of the product. Gather input from users, demonstrate early results.

We have been in contact with Amanda Terborg, Aviation Weather Center (AWC) Development Meteorologist, to arrange a visit to AWC to show our current work and gather input from potential users of our product. We expect this visit to occur in the next reporting period. This interaction will be important in guiding our focus for the remainder of the project.

• Publish results in a journal.

We are in the early stages of writing up our CCL evaluation and machine learning work, which includes aspects of the relation of cloud cover to layer humidify as outlined in our last semi-annual report.

Additional Information

1. Interaction with operational partners

• See above; a visit to the Aviation Weather Center will occur within the next year.

• Leveraging the JPSS PGRR efforts, we continue to obtain aviation users’ need through monthly telecons and accommodate user feedback for improvement of display and training. Major Kerrin Caldwell, Chief of Weather Requirements and Resources located at Air Combat Command Headquarters (Langley Air Force Base, Virginia) visited CIRA on 18 December 2018 and presented a talk at CIRA’s seminar, titled “US Air Force Operational Weather Structure and The Meteorological Forecast Process”. She attended a CIRA group meeting on aviation-related projects and research topics where she was introduced to on-going CIRA satellite algorithm developments. The CBH/CCL products were shown at this meeting.

2. Conference/workshop participation

• The CIRA team participated in 2018 FAA’s Aviation Weather Research Program Review Meeting and introduced CIRA’s aviation research and satellite products at ACCAP Virtual Alaska Weather Symposium.
  

3. Outside project publicity – None.

4. Journal articles – None prepared or anticipated in this reporting period.
Figure 1. (a) CIRA GeoColor image and (b) our improved Cloud Cover Layers for GOES-16 on March 3, 2018 at 18:42:33 UTC. As displayed using CIRA's SLIDER tool.

Figure 2. Vertical/horizontal cross sections through a subsample of ABI-identified cirrus. Rainbow colors are CloudSat radar reflectivity. Purple colors are locations of lidar backscatter indicative of clouds. The blue background shows where the CCL product identifies cloud in the given vertical level bin (low, middle, or high). (a) is for our improved CCL products, and (b) is for our improved algorithm using machine learning techniques.