Passive Microwave Data Exploitation via the NRL Tropical Cyclone Webpage

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Entire Project Period – 9/1/2015 – 8/31/2017

1. General Description of Progress

Overall work towards implementing upgrades of microwave imagery processing in the Naval Research Laboratory's Tropical Cyclone Webpage (NRL TC web; http://www.nrlmry.navy.mil/TC.html) has progressed on schedule. Project work so far has involved the implementation of the multi-platform analysis standardization procedure on the historical dataset and establishing the work-flow for near-realtime operations. Interactions with the JHT POCs at the National Hurricane Center (NHC), Central Pacific Hurricane Center (CPHC), and Joint Typhoon Warning Center (JTWC) occurred in October/November 2015 and February/March 2016. Input provided in these meetings resulted in reassessment of work priorities and reorganization of timeline goals to push forward visualization tasks ahead of historical archiving goals. Preliminary statistics on brightness temperature distributions in the climatological data have been calculated to allow initial progress on color table evaluations and new product visualizations to begin.

2. Transition to Operations

a. Summary of testbed-related activities and outcomes

This current project provides for multiple upgrades to the passive microwave imagery products on NRL TC web. The following tasks represent this effort:

1. Enhancement of the near-realtime 37 and 85/89/91 GHz H/V/PCT/color imagery products for all global TCs is proposed. This includes recalibration of the ice scattering channels to 89 GHz to reduce bias between sensors, bi-cubic spline interpolation, and CIMSS ARCHER recentering. A streamlined and cleaner python based processing and plotting will be used.
2. To complement the above upgrades, this task aims to populate an archive of historical passive microwave data since 1987. Using a similar methodology as in the near-realtime upgrades, a standardized database of both digital data and image products will be generated and made available to the TC community to compliment the near-realtime data.

3. Parallax of the storm based on feature heights and sensor scan angle can misrepresent the TC position. A study and application of a more sophisticated parallax correction scheme is proposed to provide increased confidence in the initialization of the TC center. This work will be achieved by analysis of TC centering and eye structure in co-located satellite radar vertical profiles and passive microwave imagery.
4. The color tables used to visualize the TC were subjectively developed based on a small sample of cases observed by the SSM/I. Resolution and frequency changes since that time necessitate an expanded and quantitative revisiting of this visualization.

Note that interaction with the JHT POCs has emphasized work on tasks 1 and 4, particularly with respect to processing other frequencies (such as 18 and 166 GHz) as well as improved RGB color product fusion between frequencies. Thus, timelines and work are rearranged to give priority to those tasks.

b. <u>What was transitioned?</u>

First tests of new feature transitions at NRL TC web are planned for the upcoming hurricane season. This includes demonstration of work performed in tasks 1 and 4. These tests will be dynamic through the season, with products modified and/or added depending on feedback from JHT POCs.

c. <u>TRL* current vs. start of project</u>

**Technical Readiness Levels (TRLs) are defined below:*

TRL 1: Basic principles observed and reported
TRL 2: Technology concept and/or application formulated
TRL 3: Analytical and experimental critical function and/or characteristic proof-of-concept
TRL 4: Component/subsystem validation in laboratory environment
TRL 5: System/subsystem/component validation in relevant environment
TRL 6: System/subsystem model or prototyping demonstration in a relevant end-to-end environment
TRL 7: System prototyping demonstration in an operational environment
TRL 8: Actual system completed and "mission qualified" through test and demonstration in an operational environment
TRL 9: Actual system "mission proven" through successful mission operations

Start of project TRL:

- Task 1: TRL 3
- Task 2: TRL 2
- Task 3: TRL 2
- Task 4: TRL 2

Current project TRL:

- Task 1: TRL 5
    - Components of microwave data standardization are coded. Python-based graphics are being tested. Near-realtime case studies of products and new channel visualizations have begun.
- Task 2: TRL 4

    - Standardization and analysis procedure processed for historical cases. Work is set-up for generation of historical images, but efforts are currently deferred per POC requests.
- Task 3: TRL 2
    - No change. Work to begin in Year 2.
- Task 4: TRL 3
    - Preliminary analysis of statistical distributions of historical data has begun. Initial tests with alternate visualizations underway.

Tasks will be tested via NRL TC web, which represents a TRL 6/9 near-realtime operational product demonstration page.

d. Lessons learned

Not currently applicable

e. Next steps – future plans

Development is on schedule. Future steps will progress via the following revised timeline (amended using JHT POC feedback):

2015

~~Sep-Dec: (Tasks 1 and 2) Process historical images and T_B statistics~~
~~Nov: Interact with POCs at NOAA/NHC to assess operational needs~~

2016

Jan-Apr: (Task 4) Perform statistical analysis on historical T_B distributions and formulate revised color table and ranges
~~March: Present Mid-Year 1 results and collaborate at IHC~~
April: Present and collaborate at AMS Tropical Conference
May-Aug: (Tasks 1 and 4) Provide demos of standardization process, new color products, and new channels for transition to realtime datasets.
Aug-Oct: (Tasks 1 and 4) Real-time tests of standardized data on NRL TC webpage
Sep-Dec: (Task 3) Find, gather, and process all cases with satellite radar passes through TC center.
Nov: Interact with POCs at NOAA/NHC to evaluate updated goals
Nov-Dec: (Task 4) Revise, finalize color tables, ranges based on POC/IHC feedback

2017

Feb-Apr: (Task 2) Quality control and apply standardization process to historical data archive.
March: Present Mid-Year 2 results and collaborate at IHC
March-May: (Task 3) Develop statistics on radar profiles and microwave T_B, feature height parallax
May: (Task 2) Populate ftp archive with climatological netCDFs, images
July-Sep: (Task 3 and 4) Real-time tests of revised color tables and parallax correction scheme on real-time NRL TC page images.

Timeline is flexible. This project can be subject to further refinement should the JHT POCs request further emphasis in certain tasks.

i. Has it been approved for transition yet? Plans for future transition?

Not currently applicable

3. Milestones

a. Completed

The passive microwave TC analysis standardization methodology as described in Task 1 has been coded and applied toward the goal of processing the brightness temperature statistics of historical imagery (Figure 1). Further, prototype imagery has been tested and generated to demonstrate new visualizations, color ranges, and channels (Figure 2). Finally, preliminary work on statistical analysis of historical cases is allowing refinement of color ranges to conform to observed physical distributions (Figure 3).

b. Not completed

The original goal of reprocessing the historical dataset and generating an archive of reference imagery in Year 1 has been moved to Year 2. This allows prioritization of the analysis of physical break points in brightness temperature statistics to inform new visualizations and channels (for example, as shown in Figures 2 and 3). Otherwise, all work is completed as scheduled in timeline milestones.

i. Reasons

Task 2 work was postponed at the request of JHT POCs in favor of pushing forward work with Tasks 1 and 4. Timeline is otherwise on schedule given reordering of priorities.

ii. Mitigation plan

While current work is expected to continue at nominal pace, the details of this project are flexible so as to allow the JHT POCs breadth in pushing the work direction to prioritize certain operational needs. However, at this time, it is not expected that change in goals are needed.

4. Publications

a. Journal articles published

Not currently applicable

b. Journal articles in process (what stage?)

Not currently applicable

c. Other publications/presentations

Cossuth, J., R. Bankert, K. Richardson, and M. Surratt, 2016: Passive Microwave Data Exploitation via the NRL Tropical Cyclone Webpage: JHT Project Status. *70th Interdepartmental Hurricane Conference/ Tropical Cyclone Operations and Research Forum*, Miami, FL, OFCM/NOAA.

Richardson, K. A., R. L. Bankert, and J. Cossuth, 2016: Naval Research Laboratory Tropical Cyclone Demonstration Web Page: Plans and Upgrades. Proceedings, 32nd Conf. on Hurricanes and Tropical Meteorology, San Juan, PR, Amer. Meteor. Soc., P185. [Available online at https://ams.confex.com/ams/32Hurr/webprogram/Paper292706.html.]

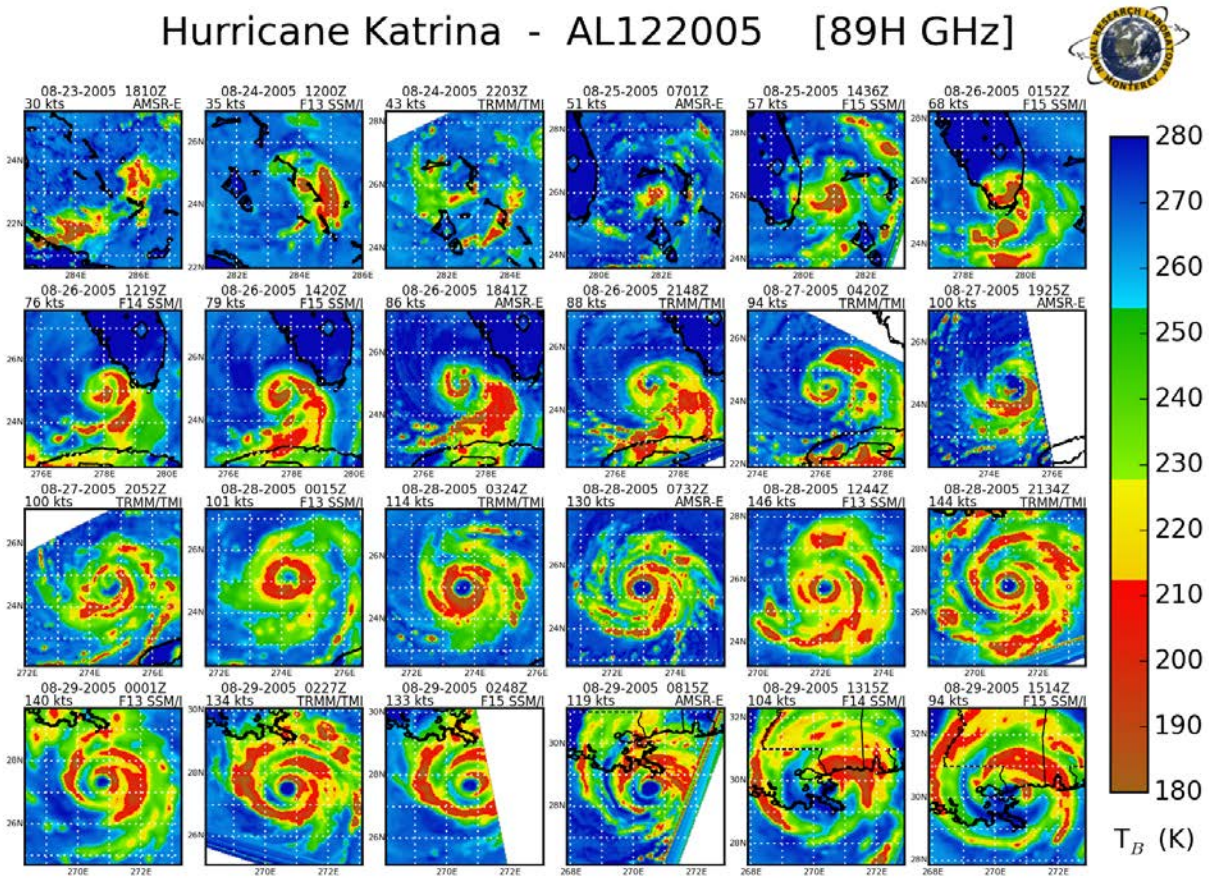

Figure 1: Selected historical passive microwave images of Atlantic Hurricane Katrina (2005) after being processed through our standardization analysis (recalibrated to 89 GHz, bi-cubic spline interpolation, and recentered using CIMSS ARCHER) and plotted in a prototype graphic in python.

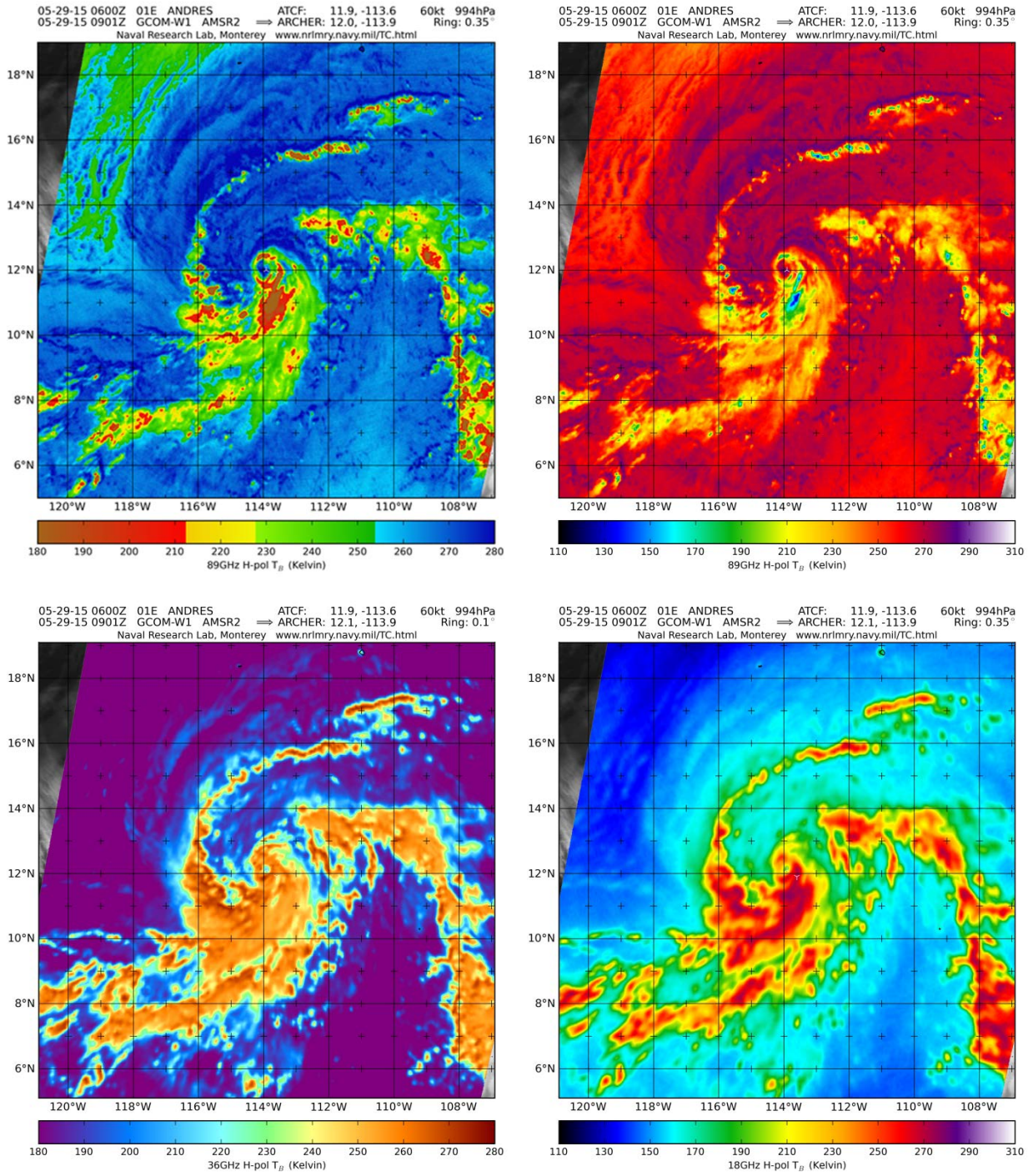

Figure 2: Example test case of new processing and visualization using an AMSR-2 overpass of East Pacific Tropical Storm Andres (2015). Upper panels show the 89 GHz ice scattering channel using the current color table (left) and new color table and range test (right). Bottom panels show the 37 GHz (left) and 18 GHz (right) depictions which emphasize liquid water scattering in the storm structure.

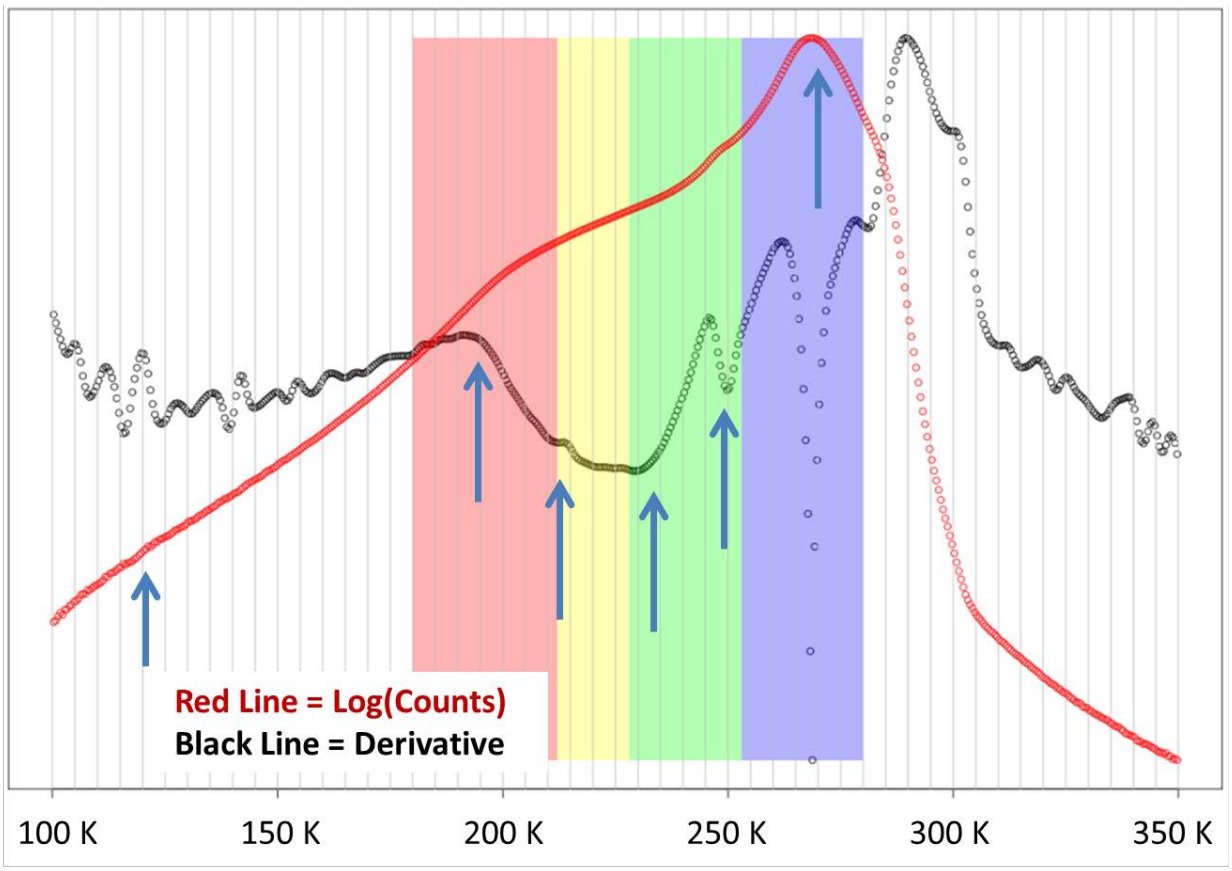

Figure 3: Research graphic depicting the relative distribution of 89 GHz brightness temperatures within 500 km of the TC center using our global, standardized historical dataset from 1987-2012. Background shaded colors represent approximate regions of shading in current 89 GHz colors (see Figure 2 top left). The red line shows the log of counts, while the black line shows the derivative of the red line. Note that the omitted values are relative and lines are scaled. Arrows indicate possible regions of physical changes in observed brightness temperatures. Such areas may be useful color transition/break points.