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Passive Microwave Data Exploitation via the NRL Tropical Cyclone Webpage

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Project Progress Semiannual Report
End of Year 1

1. ACCOMPLISHMENTS

This project provides multiple thrusts 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), which provides a near-realtime demonstration of research and operational meteorological satellite observations centered on TCs. Project work so far has involved the implementation and near-realtime demonstration of the multi-platform analysis standardization procedure as well as new product delivery, through visualizing new channels, color tables, and product fusions. Statistics on brightness temperature distributions in the climatological data have been calculated to facilitate new product visualizations. Imagery from AMSR2, GMI, Himawari, and GOES has been processed and archived in near-realtime since June 2016. All TC cases globally in that time period have available imagery produced to be evaluated. 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.
    a. Task is 90% complete. Pending: re-coding of ARCHER into python; iterative feedback from POCs on requested improvements.
2. To complement Task 1 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.
    a. Task is 50% complete. Data is staged and ready for processing, pending completion of Task 1 and POC request to move forward on product generation.
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.
    a. Task is 10% complete. Comparative TRMM radar and Cloudsat dataset is downloaded. Identification and colocation of microwave/radar data is being prepared.
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. Availability of improved resolution has suggested revisiting other channels for possible operational utility. Interaction with the JHT POCs has emphasized ability to process other frequencies (such as 18 and 166 GHz) as well as improve RGB false color product fusion between frequencies.
    a. Task is 66% complete. New products have been developed and demonstrated (see Section 2 for examples). Pending: iterative feedback from POCs on request improvements.

Results have been indicated through JHT POC interaction site visits and conference presentations at the Interdepartmental Hurricane Conference, the American Meteorological Society Tropical Conference, and the American Meteorological Society Satellite Conference (see Section 2 for more). Transition demonstration has been provided via near-realtime product development through NRL TC web (see Section 2 for more).

Project Timeline:

Task development remains on schedule. The timeline continues to be flexible and subject to refinement given JHT POCs requests. Steps are continuing along 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-Dec: (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

Jan-Sep: (Tasks 1 and 4) Provide a second round of realtime demos for standardization process, new color products, and new channels.
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.

2. PRODUCTS

- Demonstration of output performed from Tasks 1 and 4 (as well as proposed archival output for Task 2) is shown with the case study product descriptions below. The case

shows an overpass of 12W Lionrock in the West Pacific basin from the Global Precipitation Mission (GPM) Microwave Imager (GMI) from 1821 UTC on August 23rd, 2016. These are examples of realtime deliverables demonstrated in FY16 using the new methodology from this study:

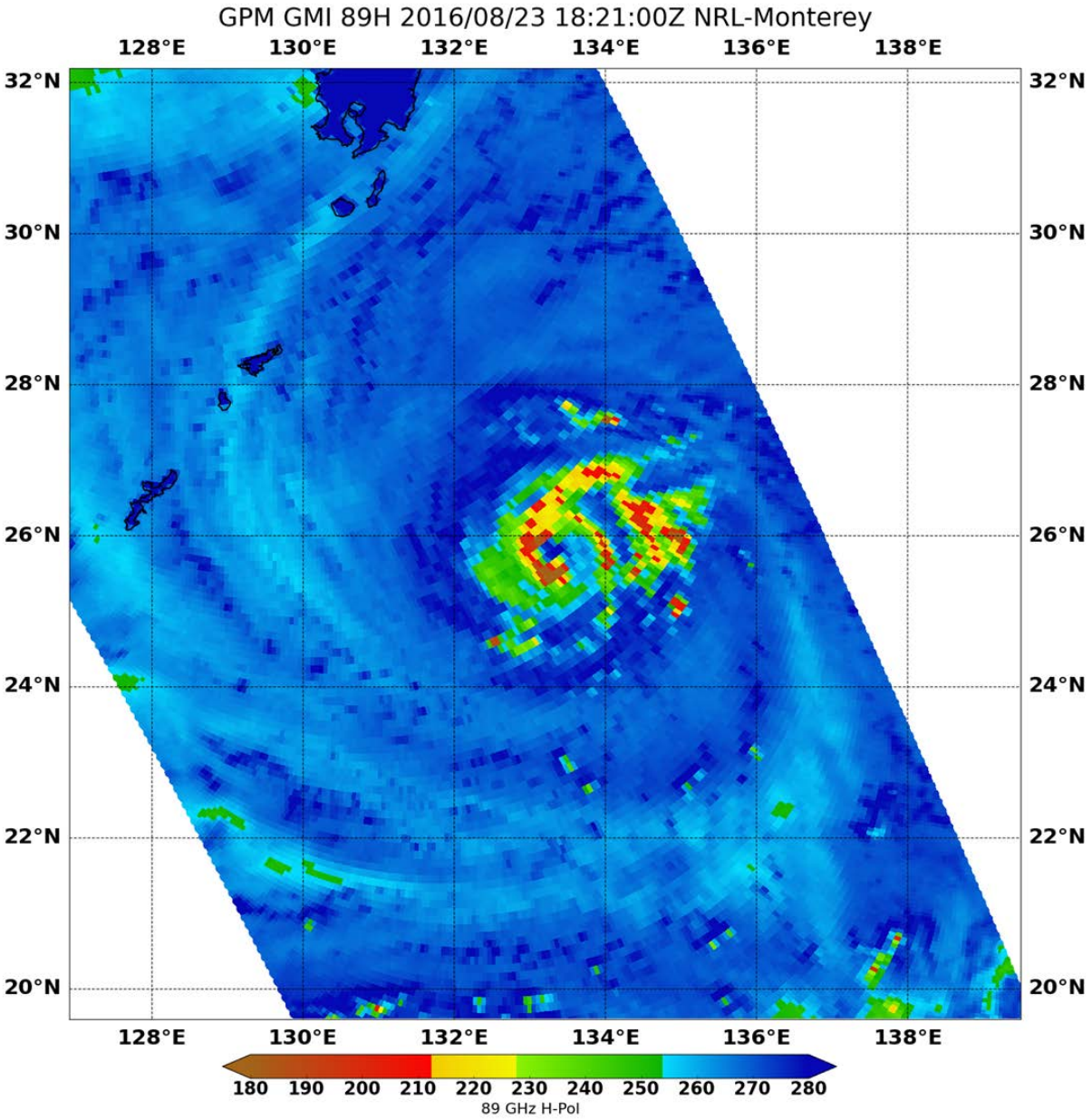

Figure 1: 89 GHz Horizontal Polarization. This is a currently operational product that provides information about convective vigor. Convective ice is shown in a radar-like color scale with heavier convection indicated by lower brightness temperatures. Environmental stability is inferred with the middle-upper end of the scale, with lighter blues to greens indicated a more stable outer environment. The darkest blues indicate liquid water emission from low level clouds as well as land.

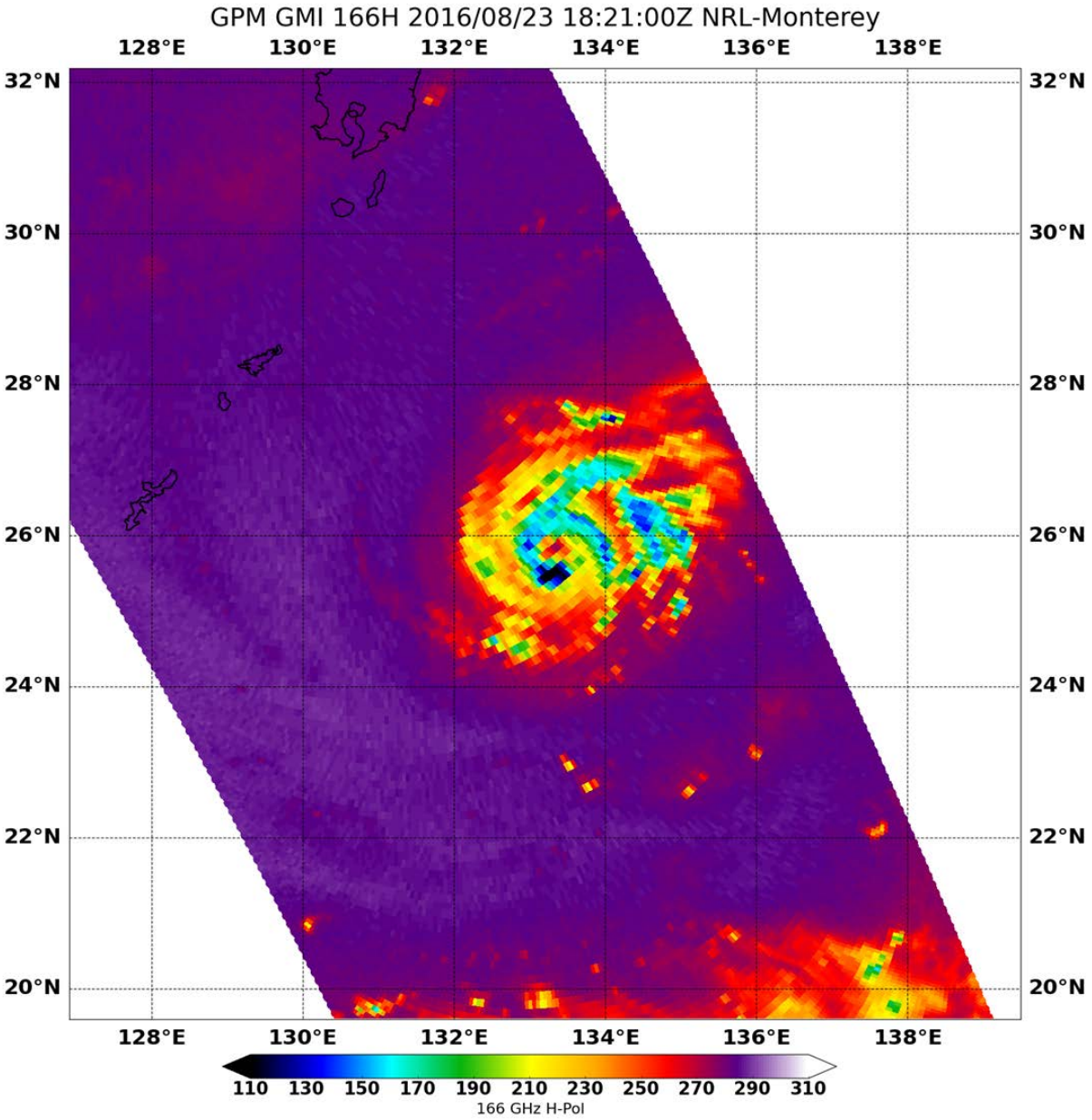

Figure 2: 166 GHz Horizontal Polarization. This is a new proposed product that provides information about cloud ice content. Unlike 89 GHz (Figure 1), there is no ambiguity of signal from surface and low level atmospheric features. However, this channel is currently available only on GMI. There are similar frequencies (150 GHz, 183 GHz) available on other sensors that may be likewise beneficial. Also note that future missions, especially from CubeSats and SmallSats, will include similar frequencies.

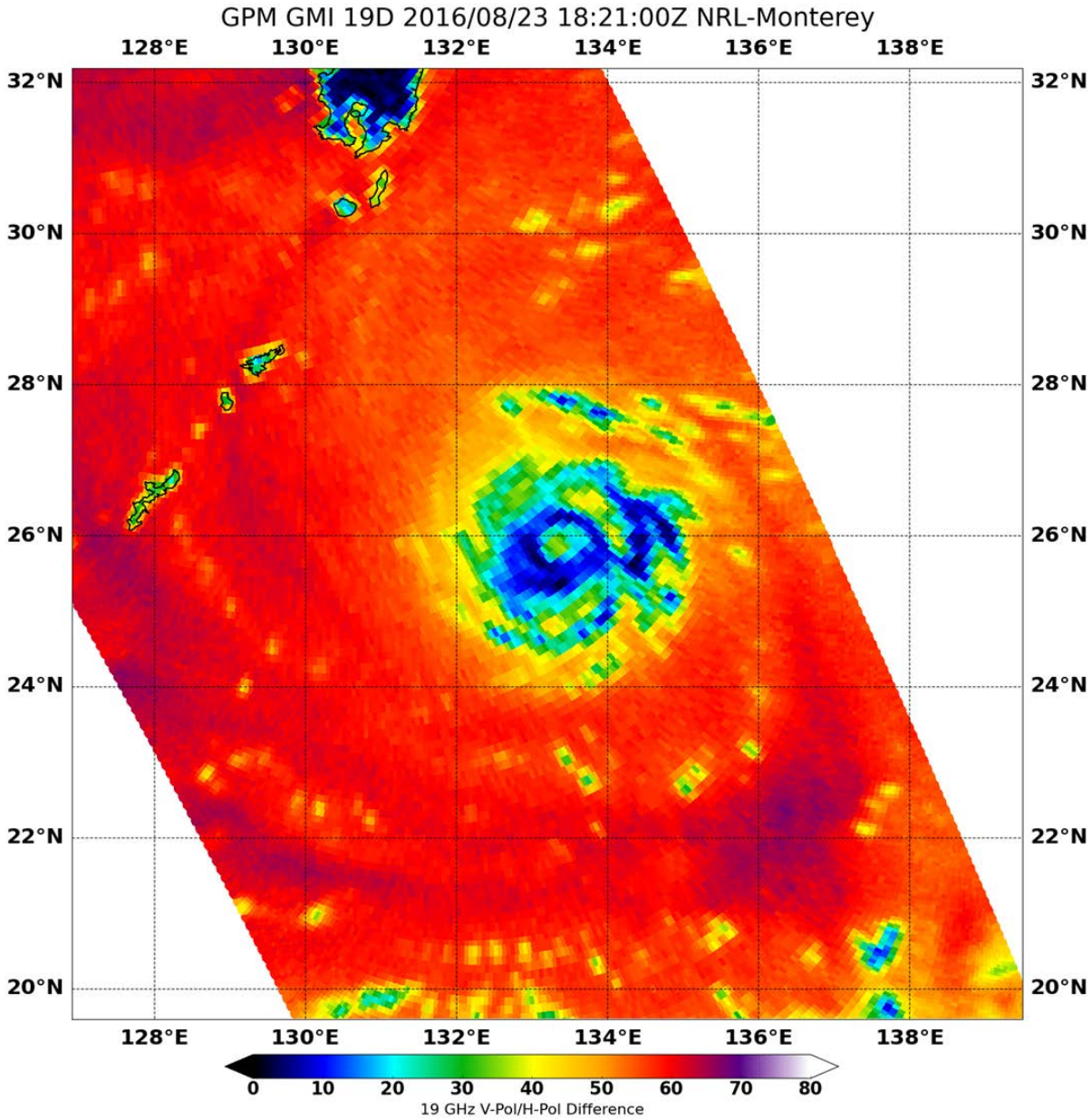

Figure 3: 19 GHz Polarization Difference. This is a new proposed product that takes the difference between the Vertical and Horizontal polarizations at 19 GHz, allowing differential ocean emission to be maximized. This provides an assessment of cloud water content – the closer to zero, the more that surface emission is masked. Unlike 37 GHz, there is much less ambiguity of signal due to scattering by ice. This allows a more robust analysis of low level structure (e.g., the closed eyewall in this example) to infer trends in intensity and structure change. Note that this analysis cannot be provided over land and that SSM/I and SSMIS are too coarse to provide useful structure analysis.

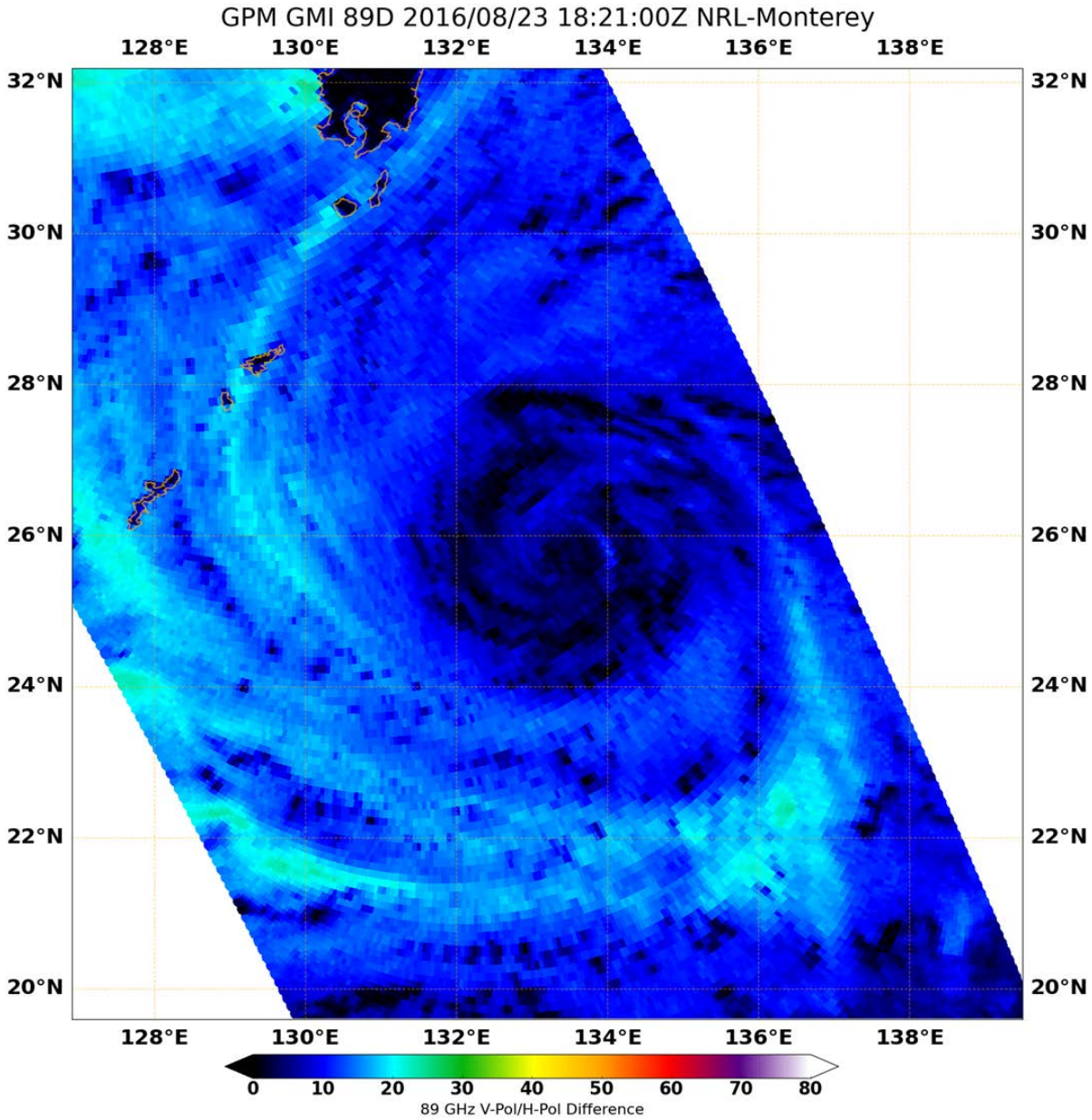

Figure 4: 89 GHz Polarization Difference. This is a new proposed product that takes the difference between the Vertical and Horizontal polarizations at 89 GHz, allowing differential ocean emission to be maximized – the closer to zero, the more that surface emission is masked. While 89 GHz is not strongly sensitive to liquid emission, the higher resolution allows a finer detail of structure compared to 19 and 37 GHz products. Note that ice scattering is still strongly present and not mitigated, thus is this more useful for center diagnosis and spatial extent rather than structural diagnosis.

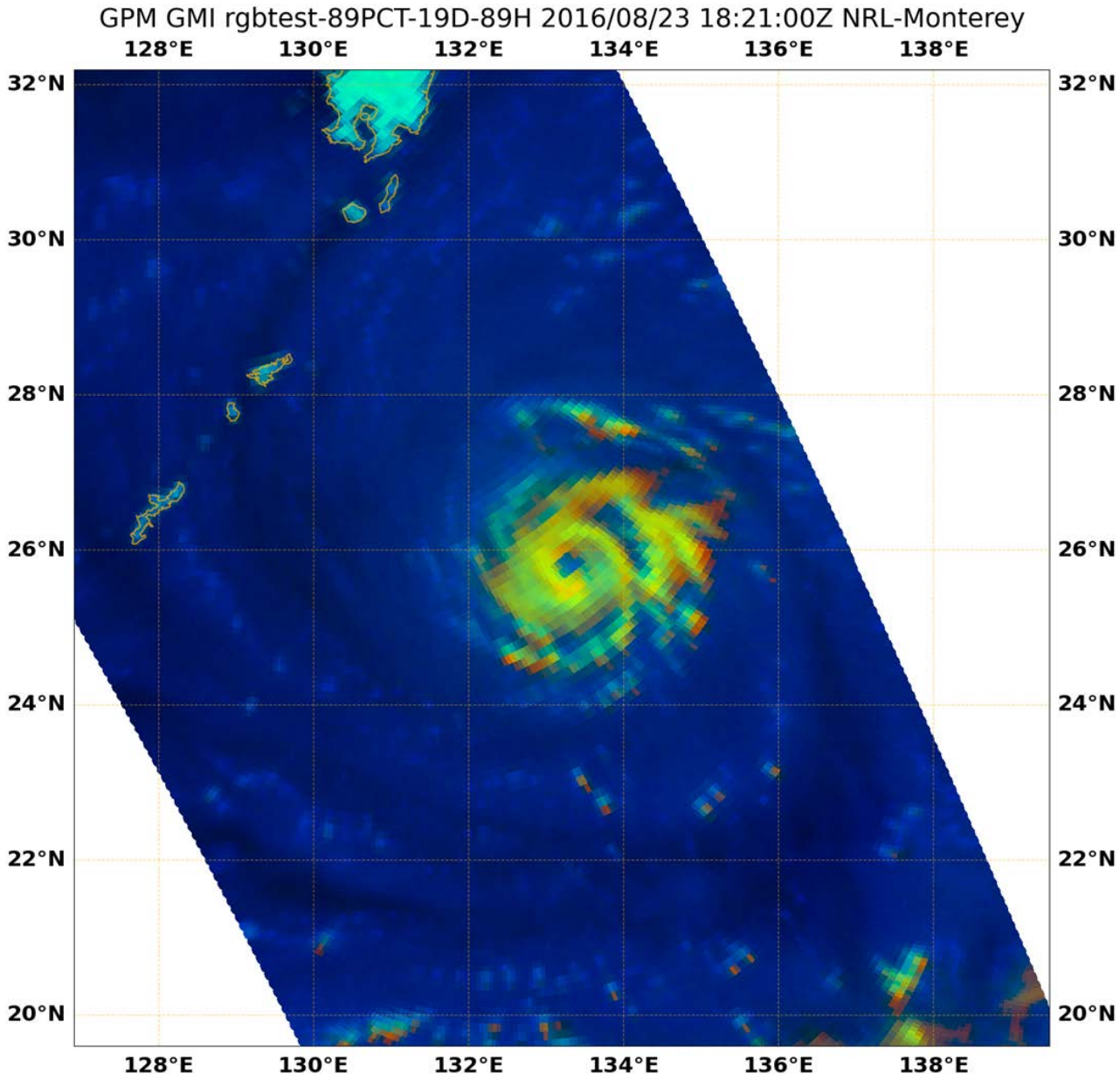

Figure 5: Hydrometeor Type False Color. This is a new proposed false color product that composites information from the 89GHz Polarization Correction Temperature (red gun), 19 GHz Polarization Difference (green gun), and 89 GHz Horizontal Polarization (blue gun). **Red** pixels are convective ice only. **Green** pixels are low level precipitating liquid water (note: land is also bluish-green). **Yellowish**/**orange** pixels show combinations of both convective liquid and ice. **Lighter blue** to **dark blue** colors show shallow non-precipitating liquid water/moist air to drier cloud free areas. This product is intended to discriminate vertical convective structure and its symmetry. In this case, the western eye/eyewall is vertically stacked (yellow/orange) while the eastern eyewall is open at upper levels (lack of red) and elliptical at lower levels (spatial extent of green).

Publications, Conference Papers, and Presentations

Cossuth, J., 2016: New satellite data and applications for tropical cyclone operations by 2025: Agency and Interagency plans. NRL Perspective. 70th Interdepartmental Hurricane Conference/ Tropical Cyclone Operations and Research Forum, Miami, FL, OFCM/NOAA. [Available online at http://www.ofcm.gov/ihc16/Presentations/Panel%202/03-NRL_satellite.pdf.]

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. [Available online at http://www.ofcm.gov/ihc16/Presentations/Session%204/03-NRL_JHT.pdf.]

Cossuth, J., R. L. Bankert, and K. Richardson, 2016: Using Passive Microwave Imagery to Develop Objective Tropical Cyclone Structure and Intensity Analysis and Improved Near-Realtime Products. Proceedings, 21st Satellite Meteorology, Oceanography, and Climatology Conference, Madison, WI, Amer. Meteor. Soc., 3.4. [Available online at https://ams.confex.com/ams/21SATMET20ASI/webprogram/Paper296757.html.]

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.]

Surratt, M., K. Richardson, J. Cossuth, A. P. Kuciauskas, and R. Bankert, 2016: GeoIPS: Next Generation Satellite Data Processing Capability at NRL. Proceedings, 21st Satellite Meteorology, Oceanography, and Climatology Conference, Madison, WI, Amer. Meteor. Soc., P35. [Available online at https://ams.confex.com/ams/21SATMET20ASI/webprogram/Paper296764.html.]

Website(s) or other Internet site(s)

- The Naval Research Laboratory's Tropical Cyclone webpage (NRL TC web; http://www.nrlmry.navy.mil/TC.html) continues to serve as the primary vehicle for near-realtime product demonstration and evaluation.
    - A beta product testing internet link through this web portal has been provided to project POCs for near-realtime development and evaluation. Public release of this link will be provided after evaluation by POCs.

3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Performers:
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- Note that Co-PI Cossuth has assumed the role of lead PI since the beginning of the progress reporting period.

- Project development has evolved in conjunction with collaborative discussions with Joint Hurricane Testbed (JHT) Points of Contact (POCs) at NHC (Avila, Blake, Roberts, and Landsea) and JTWC (Strahl), as well as other interested partners at NHC, JTWC, and CPHC.

4. IMPACT

- Evaluation of impact on meteorological analysis (both in realtime and research frameworks) is being investigated as the project continues.
    - The combined improvements in scientific understanding of satellite radiative properties as well as increased satellite observation capabilities have allowed new channels and products to be considered.
    - Production of processing code in an open source framework able to be transitioned and more quickly updated will help speed and efficiency of product analysis.
    - Updated and efficient analysis will result more accurate tropical cyclone analysis, thus benefiting society through improved information from operational centers.

5. CHANGES/PROBLEMS

- Interactions with the JHT POCs at NHC, JTWC, and CPHC occurred on October and November 2015 as well as February and 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.
    - Tasks 1 and 4 have been given increased attention in FY16 and FY17 due to forecaster requests for more work in those areas.
    - In particular, Task 4 will also be worked on more heavily through FY17 due to positive feedback from project POCs. Work from other tasks may be reduced in deference to dynamically meeting JHT POC requests.
- Timeline modifications:

    - CIMSS ARCHER tropical cyclone re-centering goal in Task 1 has been pushed back to FY17Q1. Instead of adapting a Matlab executable file within our python analysis, we are working Tony Wimmers (CIMSS) to test a native python ARCHER analysis and bi-cubic interpolation scheme. The delay and extra time will allow a faster and more cohesive code and analysis vehicle.
    - Addition of WINDSAT, SSM/I, and SSMIS data realtime production in Task 1 has been pushed back to FY17Q1 due to delay in a contractor hire.
- Visualization of JHT demonstration products is currently provided via the internet on a beta project directory. A new and enhanced NRL TC webpage has been developed and is currently on our development server. This will be our primary product evaluation portal, targeted for FY17Q2.
- 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.

6. SPECIAL REPORTING REQUIREMENTS

- Project components are currently being demonstrated in a real-time NRL environment, along with an archive of produced products for post-season evaluation. More information about testbed research and transition activities can be found in Section 1. An assessment of the project's Readiness Level is provided below.
    - Task 1: Generation of standardized processing has been produced in the near-realtime demonstration environment since June 2016 and is underway.
    - Task 2: Development of reprocessed archive is deferred, pending comments on 'perfecting' realtime products to provide continuity between archived and realtime product generation.
    - Task 3: No change. Work to begin in Year 2.
    - Task 4: First round of new products and alternate visualizations have been proposed and demonstrated. Evaluation underway.

Task	**Start of Project RL**	**Current Project RL**
1) Standardized realtime python processing	3	6
2) Standardized archive creation	2	5
3) Storm parallax evaluation/correction	2	2
4) New product/color visualization	2	6

Readiness Levels (RLs) are defined below:

TRL 1: Basic research
TRL 2: Applied research
TRL 3: Development of proof-of-concept
TRL 4: Successful validation in experimental environment
TRL 5: Successful validation in relevant environment
TRL 6: Prototyping demonstration in a relevant end-to-end environment

TRL 7: Prototyping demonstration in an operational environment
TRL 8: Actual system completed through test and demonstration in an operational environment
TRL 9: Actual system deployment

7. BUDGETARY INFORMATION

- The project is currently on budget and progressing according to amended tasking priorities set by meetings with project POCs (see Section 5). No major budget anomalies or deviations from the original planned budget expenditure plan are noted or anticipated.

8. PROJECT OUTCOMES

- Current outcome is the production and near real-time demonstration of new tropical cyclone satellite microwave analysis process and product development, which are being demonstrated to project POCs. Determinations of added value, and possible areas of continued development, are assessed as products are generated and POCs acquire time to evaluate them.

- Performance of project goals and insight into possible improvement is achieved via communication with project POCs. Since this project is still active and being developed, assessment of performance measure achievement are ongoing.