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TCORF/IHC
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Passive Microwave Data Exploitation via the NRL Tropical Cyclone Webpage

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Sponsored by: NOAA Joint Hurricane Testbed

Collaborators:
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Joint Typhoon Warning Center: Brian Strahl, Brian DeCicco
Central Pacific Hurricane Center: Tom Birchard

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Outline

- Scope of JHT project
- Interpretation of TC Satellite Imagery
  - Introducing new products and whowing a few historical cases
- Discussion of parallax task sunset
- Status and future of microwave imager data

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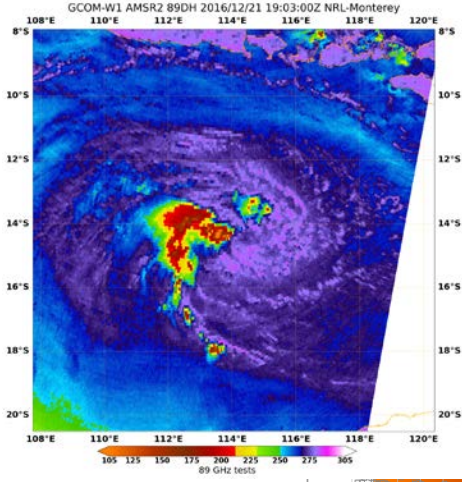
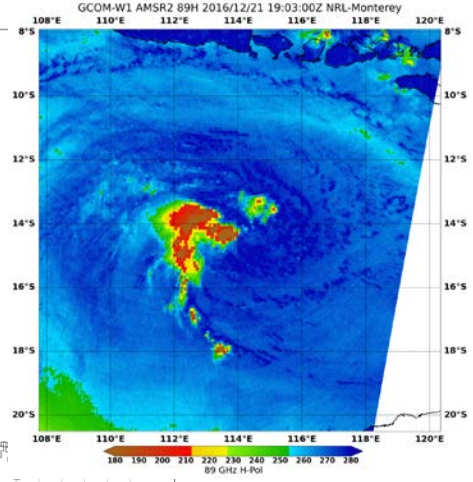
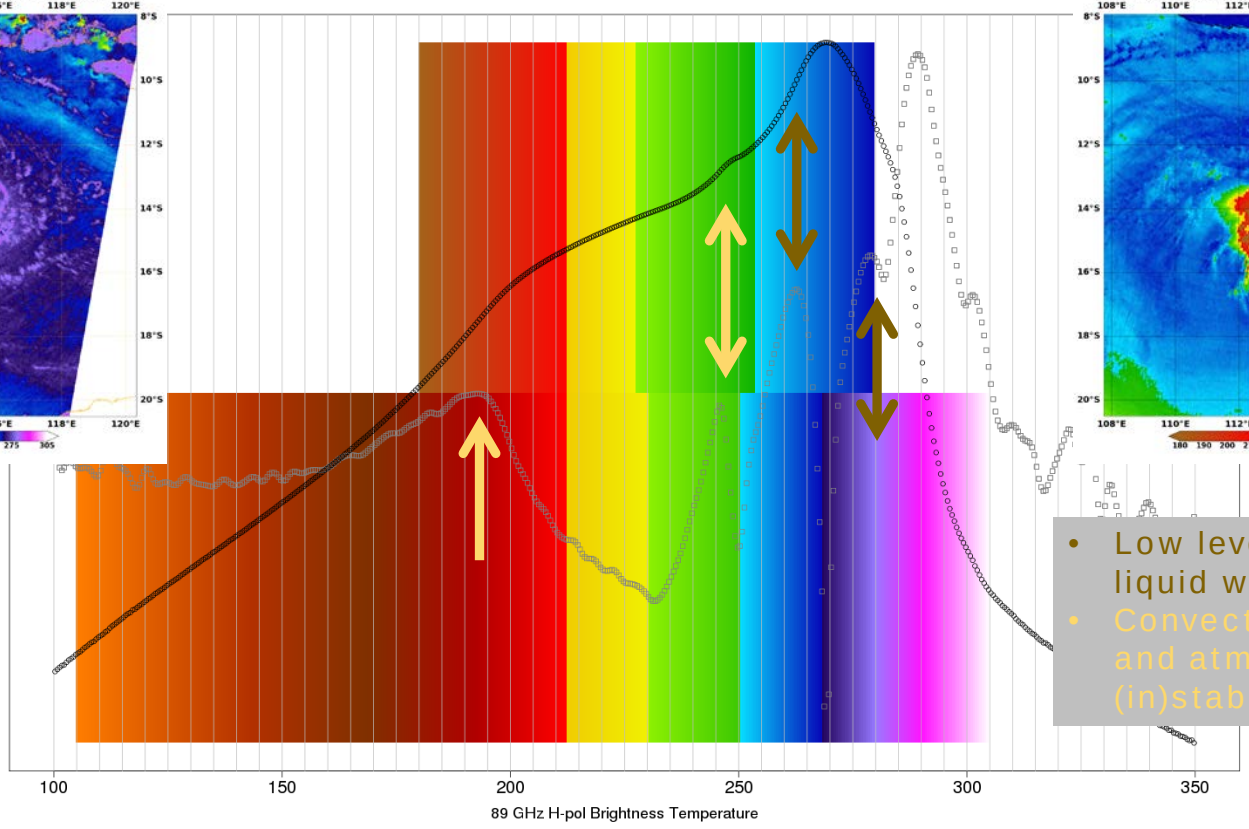
Project Overview

- The NRL TC webpage (http://www.nrlmry.navy.mil/TC.html) provided storm-centric operational and research satellite analyses in a near real-time setting since 1997.
  - Leader in microwave data, showing key hydrometeor structure information
  - Research platform for DoD transition to FNMOC TC
    - https://www.fnmoc.navy.mil/tcweb/cgi-bin/tc_home.cgi
- JHT goals:
  - Provide an updated standardized processing methodology for TC-microwave imager data analysis of near real-time and historical cases.
  - Codify operations into an open source platform that can be shared.
    - Product output as images (current TC web) and eventually data files (direct to AWIPS-2 ingest)
- Results through mid-Year 2:
  - Formalize standardized method of processing microwave imagery into python.
  - Demonstrated and ported a realtime demo mode (ad hoc python/Matlab) to GeoIPS™.
  - Format, stage, and process historical dataset to quantify brightness temperature statistics and populate archive.
  - Deliver real-time tests of new products/visualizations since summer 2016 (see following slides).

Distribution of 89 GHz Brightness Temperatures







Black Line = Log(Counts)
Gray Line = Abs(Derivative)

- Low level cloud and liquid water emission
- Convective Scattering and atmospheric (in)stability

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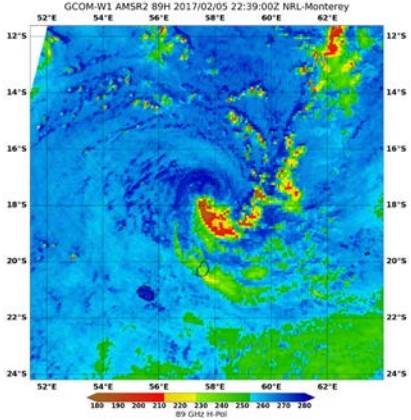
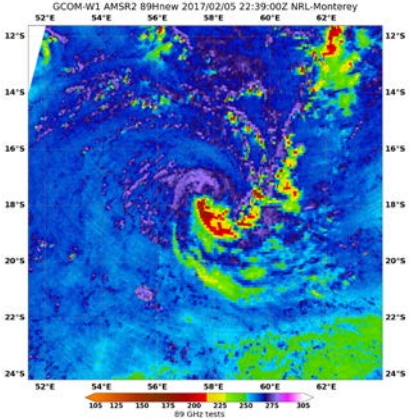
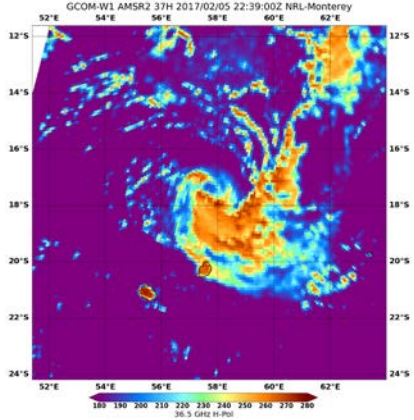
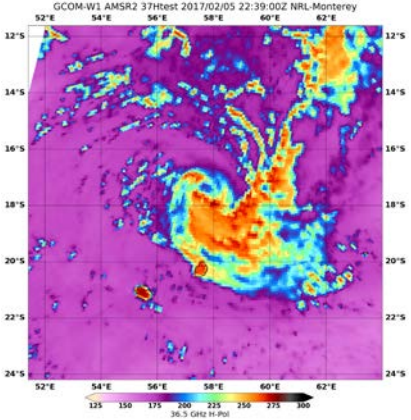
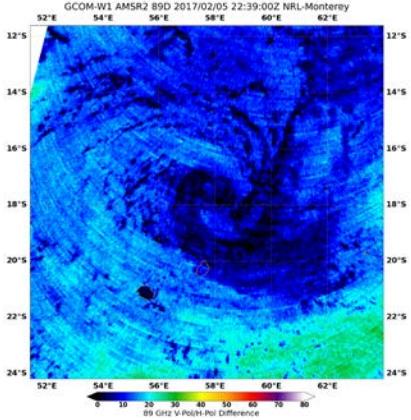
Product Comparison: Carlos (SH042017)

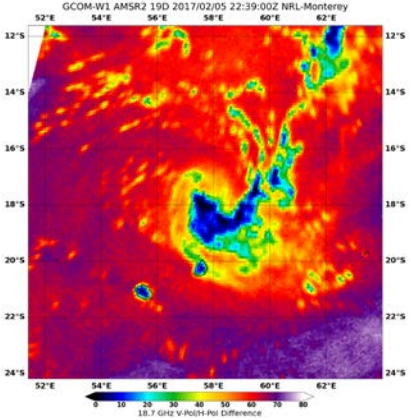


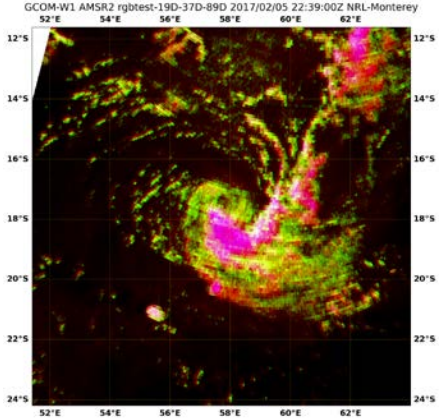


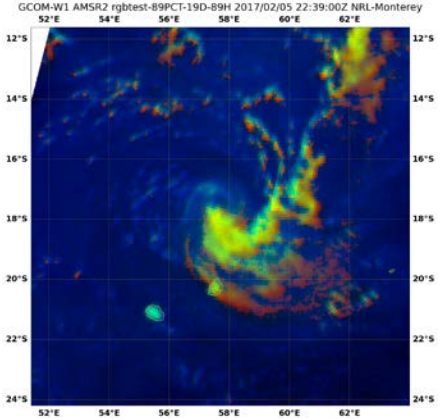












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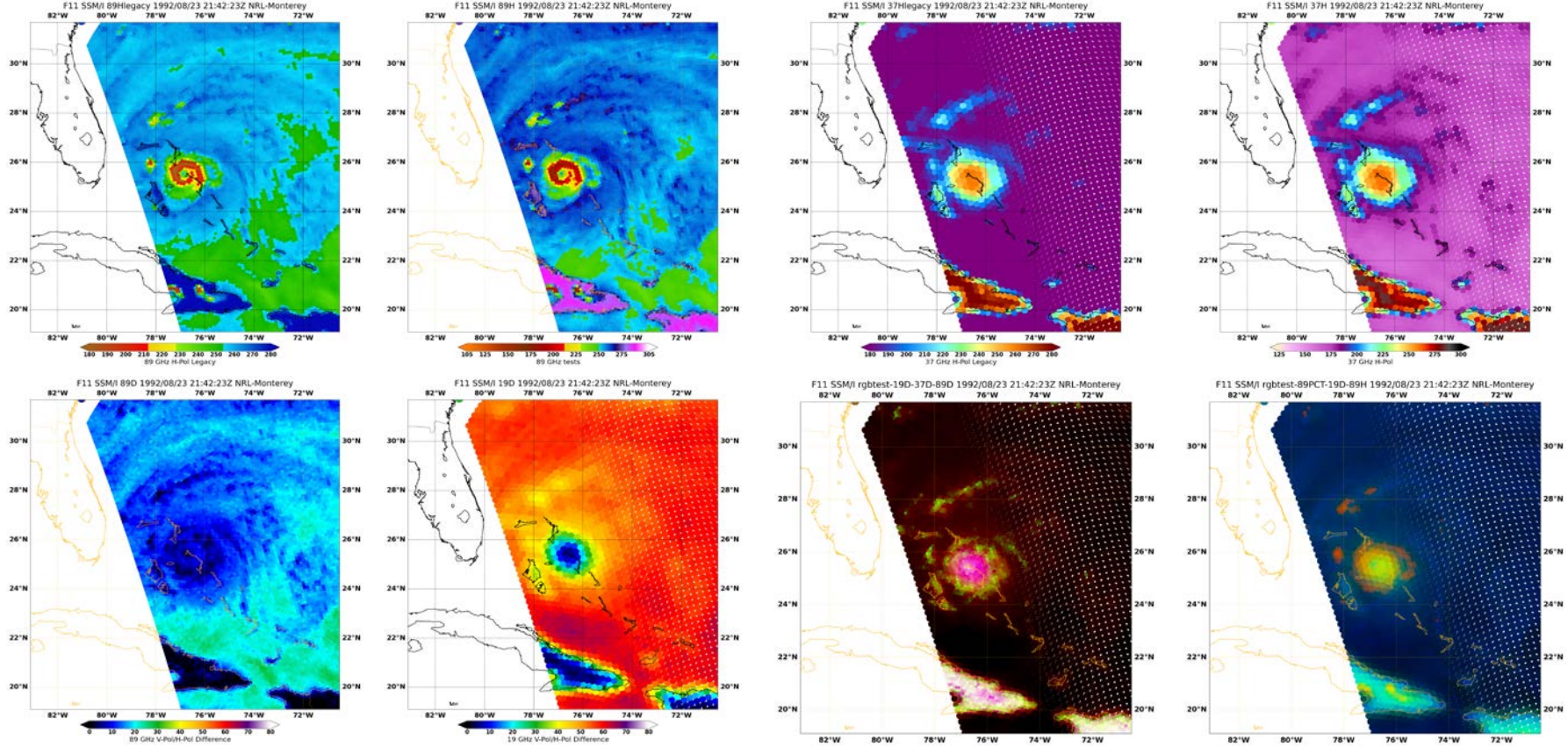
Product Comparison: Hurricane Andrew



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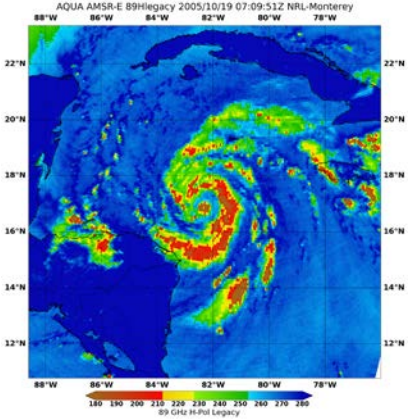
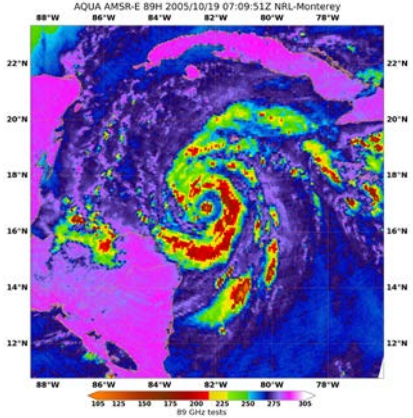
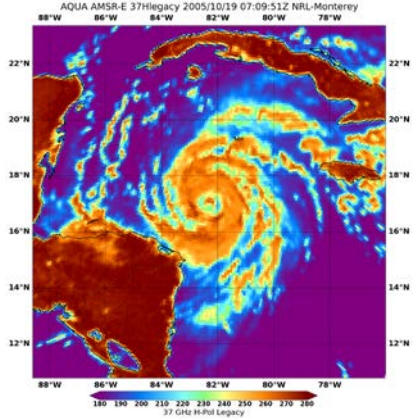
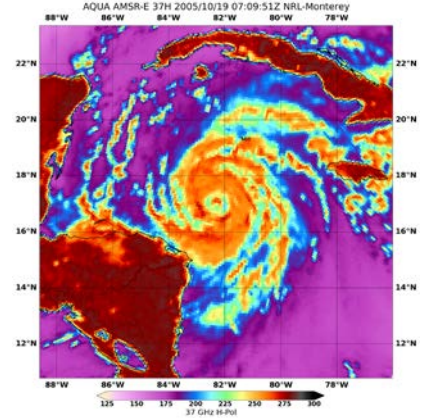
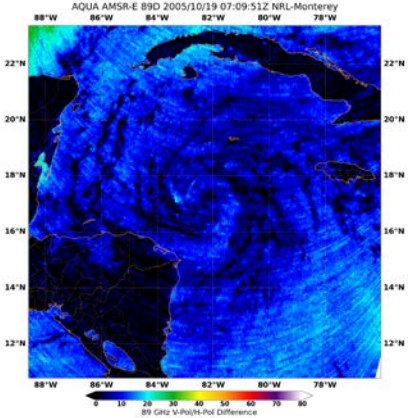
Product Comparison: Hurricane Wilma

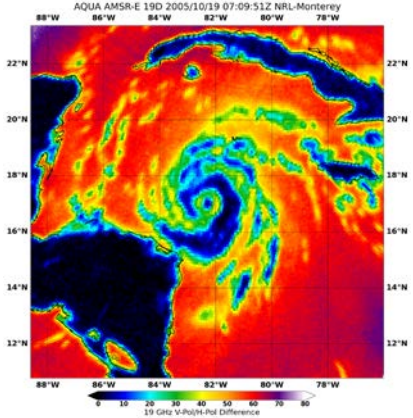


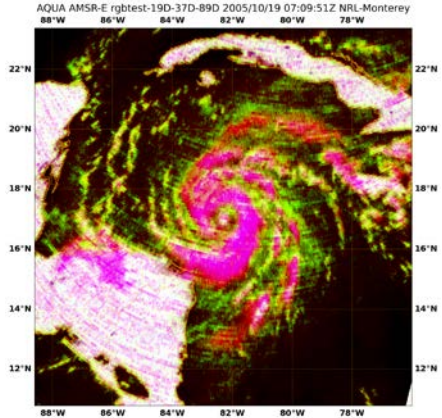


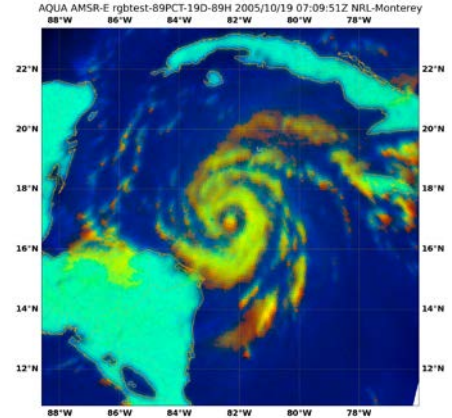






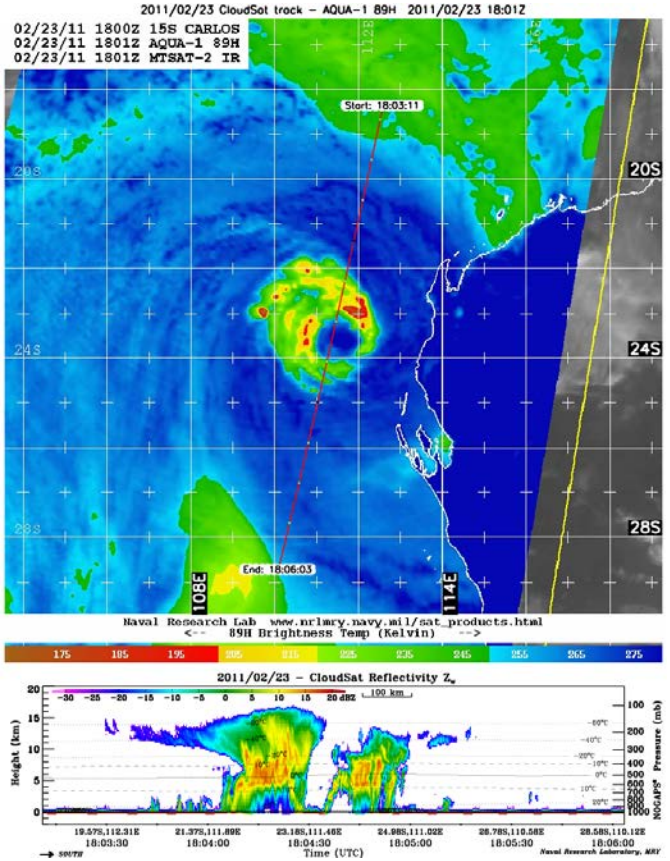






Parallax Estimate via MI/Radar

- Passive microwave imagery is frequently used to estimate low-level center due to IR or Vis ambiguity
- Yet, conically scanning microwave imagers have high earth incidence angles of ~50-55 degrees, leading to positional error of hydrometeor features
  - ARCHER estimates parallax based on assumed average height by frequency (10 km for 89 GHz, 2 km for 37 GHz)
- Original Plan:
  - Develop a statistical relationship between the brightness temperatures and their effective heights/parallax corrections using coincident microwave imagery and space-based vertical radar (i.e., TRMM and GPM).
- However, preliminary investigations and discussion with JHT POCs indicated a potential lack of operational utility, based on the following…

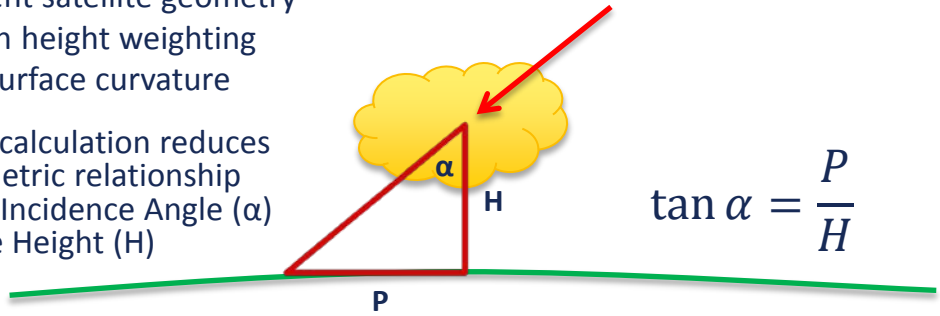


What is gained by Parallax Correction

To simplify, assume:

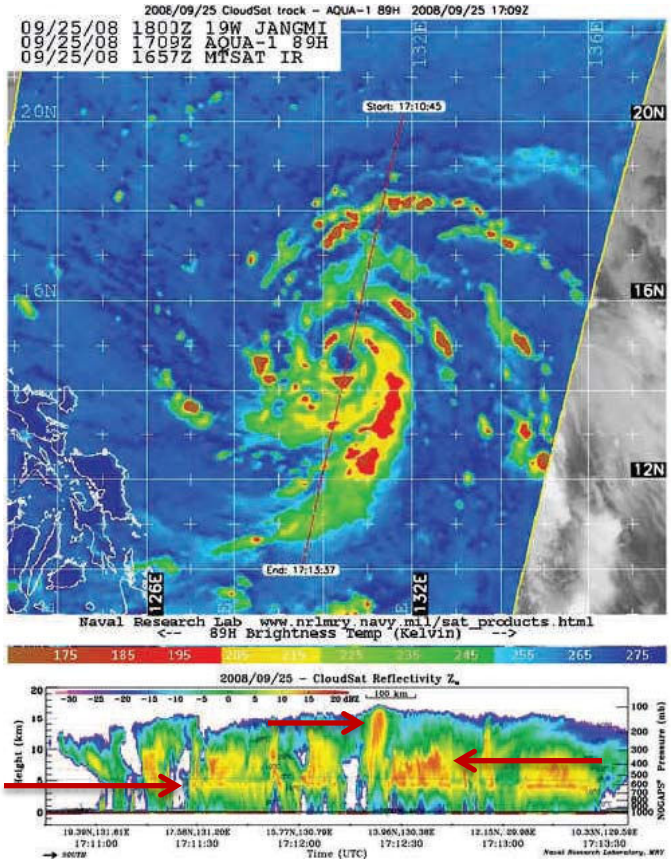
- Consistent satellite geometry
- Gaussian height weighting
- Ignore surface curvature

Parallax (P) calculation reduces to trigonometric relationship using Earth Incidence Angle (α) and Feature Height (H)



$$\tan\alpha = \frac{P}{H}$$

Sensor	Earth Incidence Angle (deg)	4 km Mean Height	8 km Mean Height	14 km Mean Height
AMSR-2	55	5.7	11.4	20.0
SSMIS	53.1	5.3	10.7	18.6
Windsat 10.7 GHz	50.1	4.8	9.6	16.7



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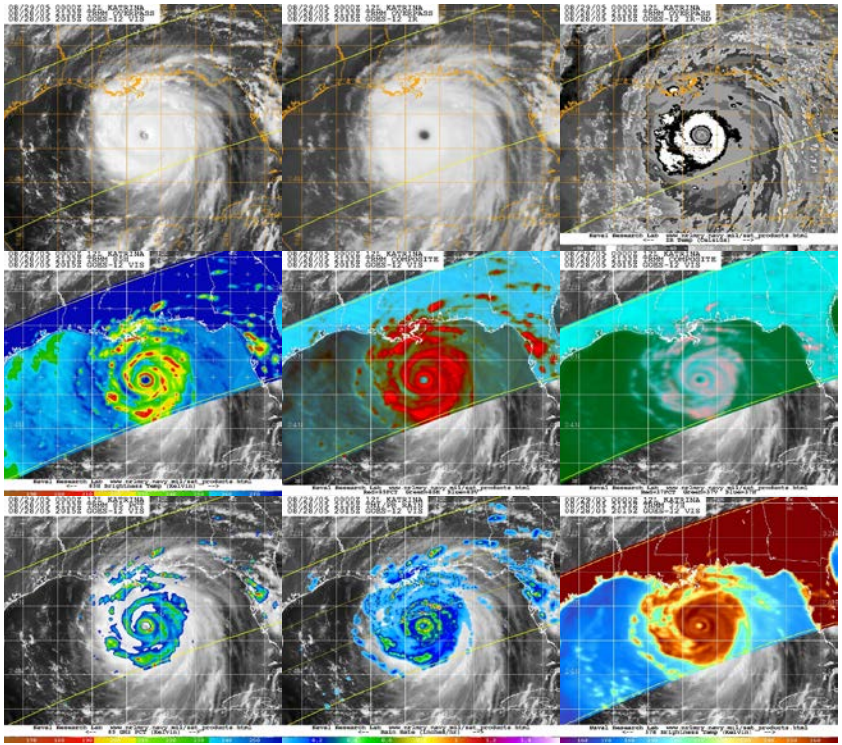
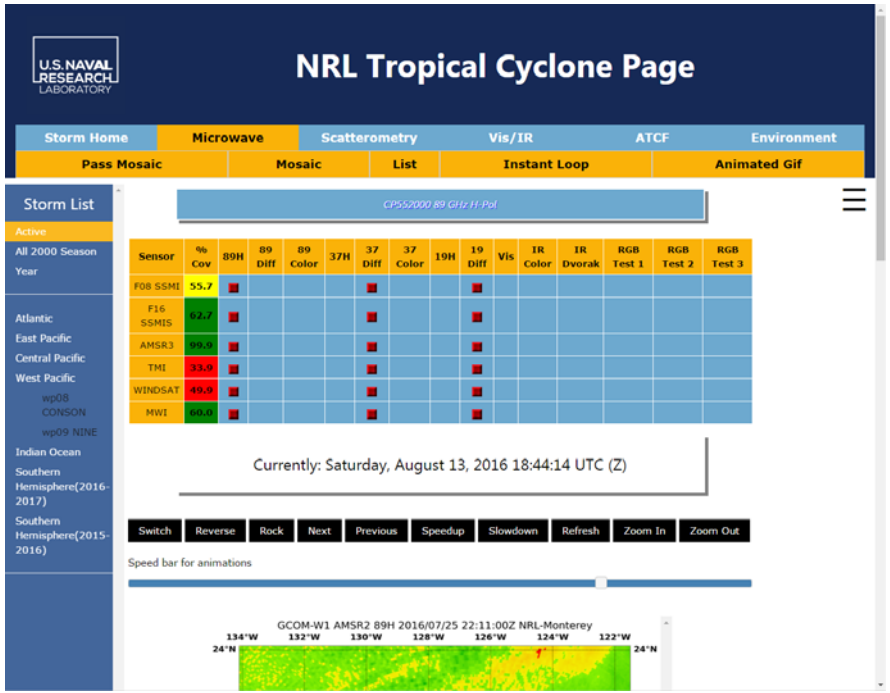
Project Status Summary

- Enhancement of currently available satellite data provides the ability to better focus on features of interest
  - Storm properties and their importance are better highlighted with visualization refinements via quantitative analysis
- Finishing the JHT:
  - Add SSMIS, SSM/I, WINDSAT, and SAPHIR to 2017 season realtime demo
  - Finalize new products and reprocess 1987-2012 cases globally
- Beyond:
  - Work with NCEI to transition products and data to NOAA



Proposed NRL TC Webpage Design



Desktop View

Mobile View

Proposed Product

- Remaining the same:
  - Satellite/Product table
  - Ability to access and download real-time/archived image files
- New:
  - New web layout in HTML5, CSS, Javascript
  - Responsive layout to work on all screen sizes
  - Redesigned visualizations (e.g., looping, thumbnails, comparison slider)
- Status:
  - Contractor working on test version on NRL dev server
  - Currently only microwave imagery, but plans to add Vis/IR, scatterometry, and model overlays

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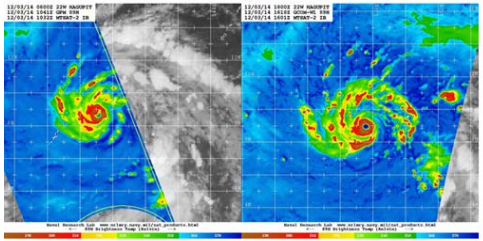
Status of Microwave Constellation

- The loss of several key satellites, especially those with high resolution and rapid refresh inclined orbits (TMI and MADRAS)) has decreased the mean revisit time of areas. Key sensor loss years:
  - MADRAS (2013)
  - TMI (2015)
  - F19 SSMIS (2016)
- Older research and development satellites are well beyond their planned lifetime and may be expected to terminate at anytime. DMSP missions are also reaching design limits and will decline soon after. Launch years for older sensors :
  - F15 SSM/I (1999)
  - WINDSAT (2003)
  - F16 SSMIS (2003)
  - F17 SSMIS (2006)
  - F18 SSMIS (2009)

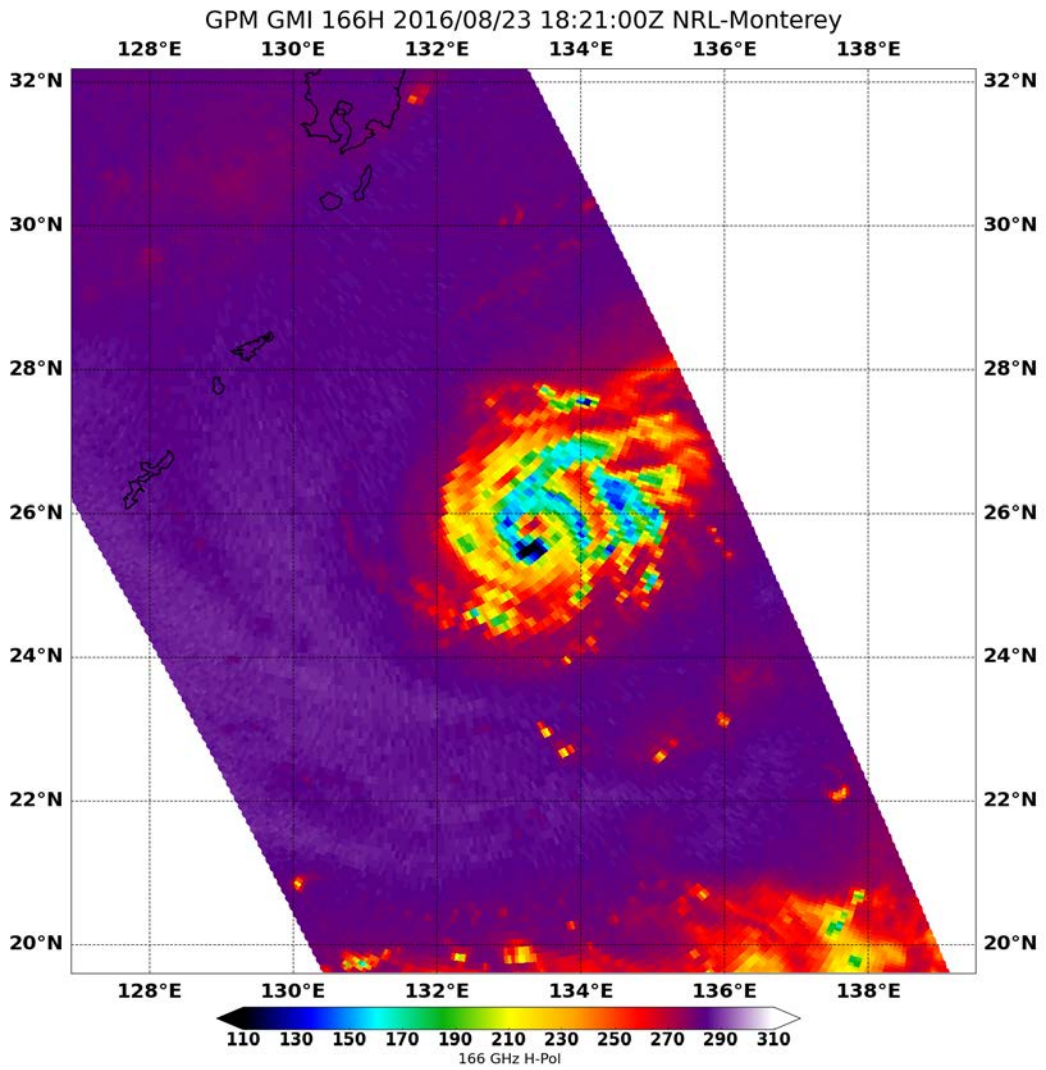
Passive Microwave Imager Coverage of Typhoon Hagupit

1030-2300 UTC on December 3, 2014

2020+ – Projected Satellite Coverage



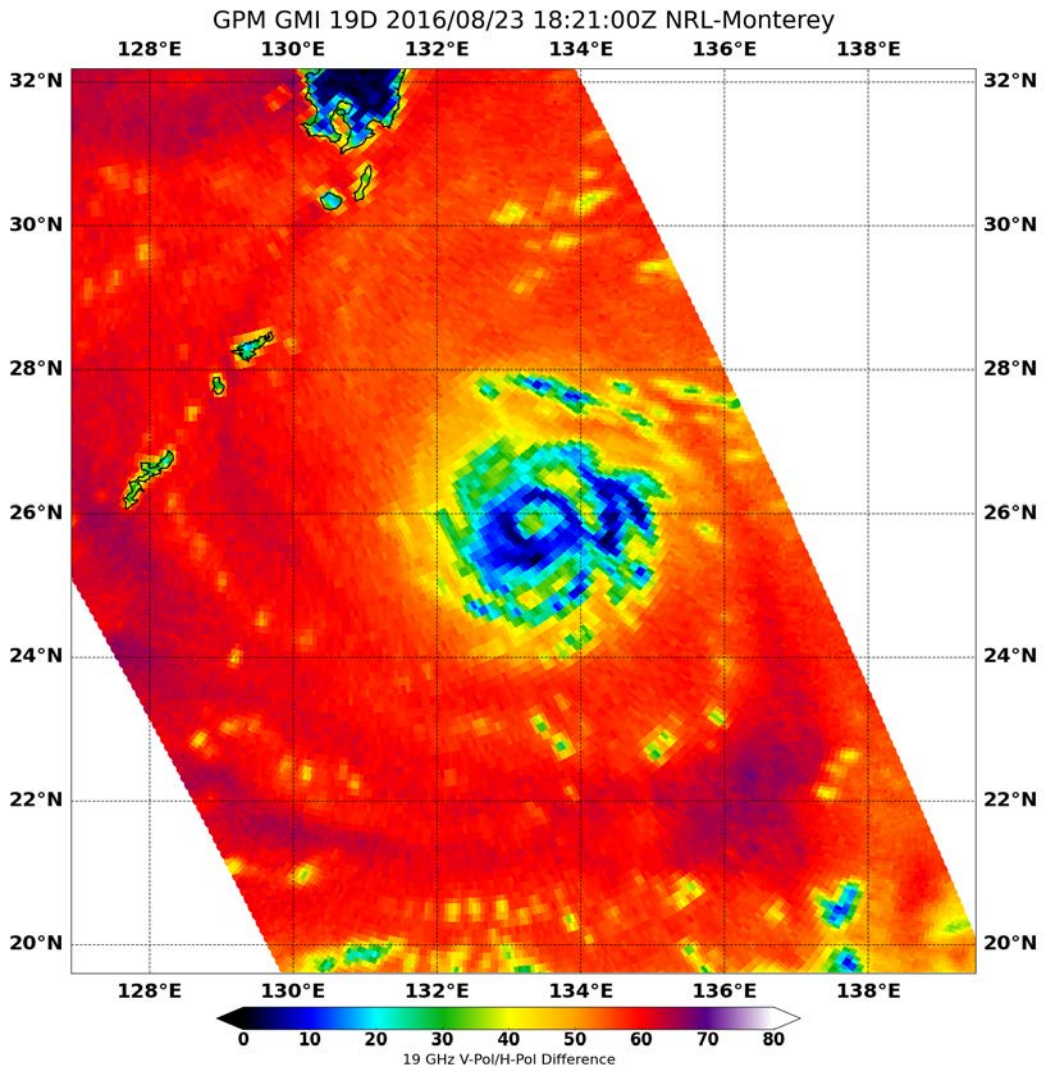
Extra Slides



166 GHz Horizontal Polarization

Proposed Product

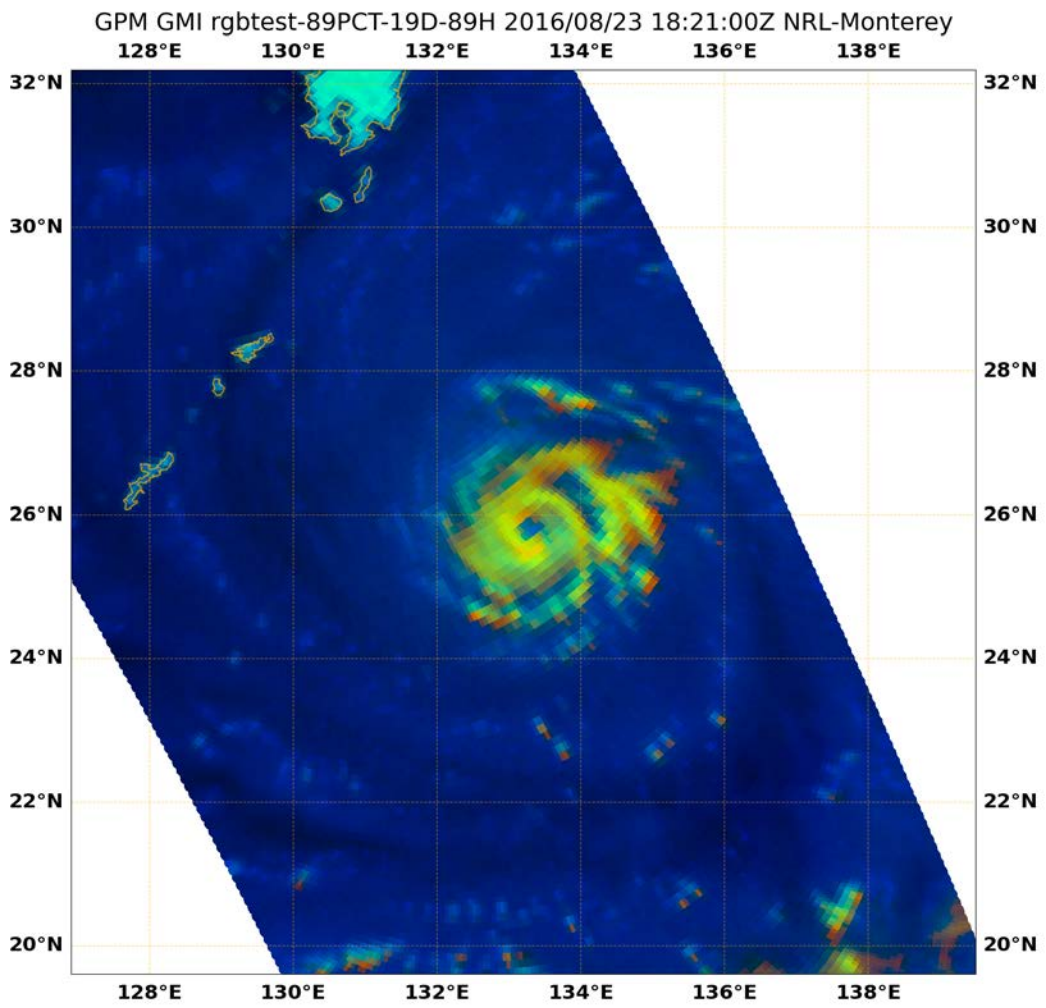
- Focuses on Cloud Ice content
  - No ambiguity of signal from surface/low levels like 89 GHz
  - Much larger brightness temperature/color range better gauge convective intensity
- Only available on GMI
  - 150 GHz and 183 GHz are on other microwave imagers/sounders and could be similarly beneficial
  - Future missions (especially cubesats) will include similar higher frequencies



19 GHz Polarization Difference

Proposed Product

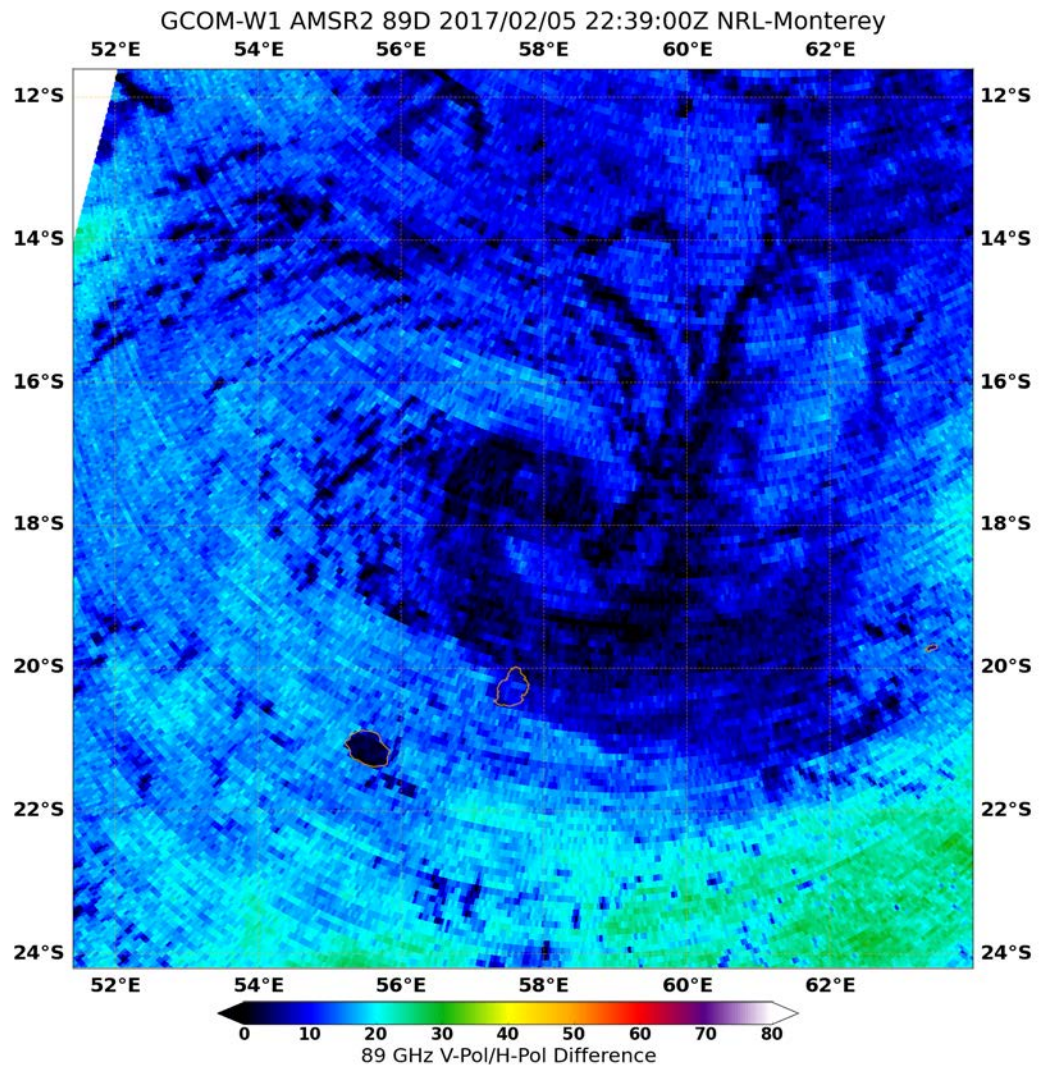
- Focuses on precipitating liquid
  - The closer to 0, the more cloud liquid water that masks surface emission
  - No ambiguity of signal from ice as in current 37 GHz products
  - Able to more easily see low level structure (e.g., closed eyewall) to infer intensity change trend
- Cons:
  - Too coarse on SSM/I and SSMIS for structure analyses
  - Difficult to use over land



Hydrometeor Type False Color RGB

Proposed Product

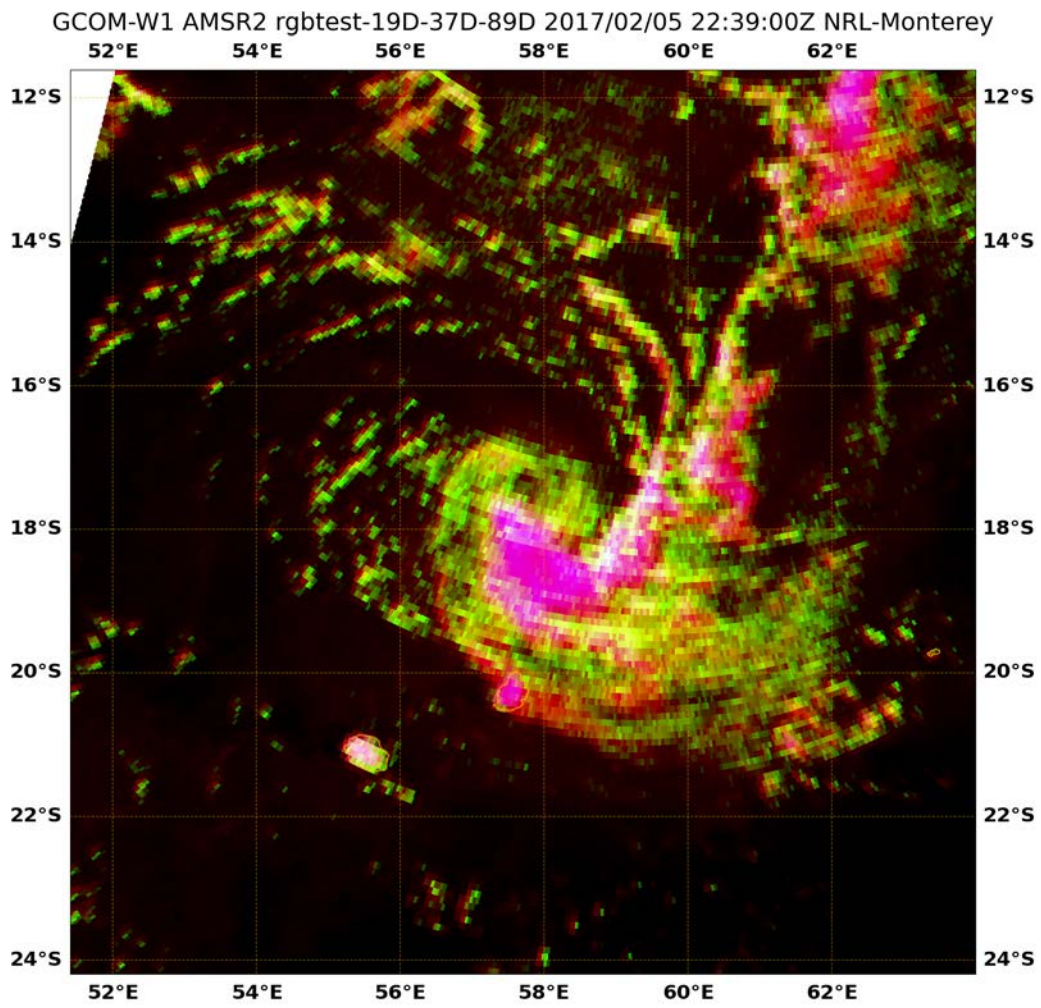
- Interpretation:
  - **Red** pixels are convective ice only
  - **Green** pixels are low level precipitating liquid water
    - Note: land is also bluish-green
  - **Yellowish**/**orange** pixels show combinations of both convective liquid and ice
  - **Lighter blue** to **dark blue** colors show shallow non-precipitating liquid water/moist air to drier cloud free areas
- Purpose:
  - Used to discriminate vertical convective structure and its symmetry.
  - In this case:
    - Western eye/eyewall is vertically stacked
    - The eastern eyewall is open at upper levels, but closed and elliptical at lower levels



89 GHz Polarization Difference

Proposed Product

- A higher resolution low level liquid water analysis.
  - The closer to 0, the more cloud liquid water that masks surface emission
  - Finer detail of structure compared to 19/37 GHz products.
  - Relative environmental stability seen at higher values
- Cons:
  - Signal saturates quickly and ice scattering not mitigated
  - Difficult to use over land

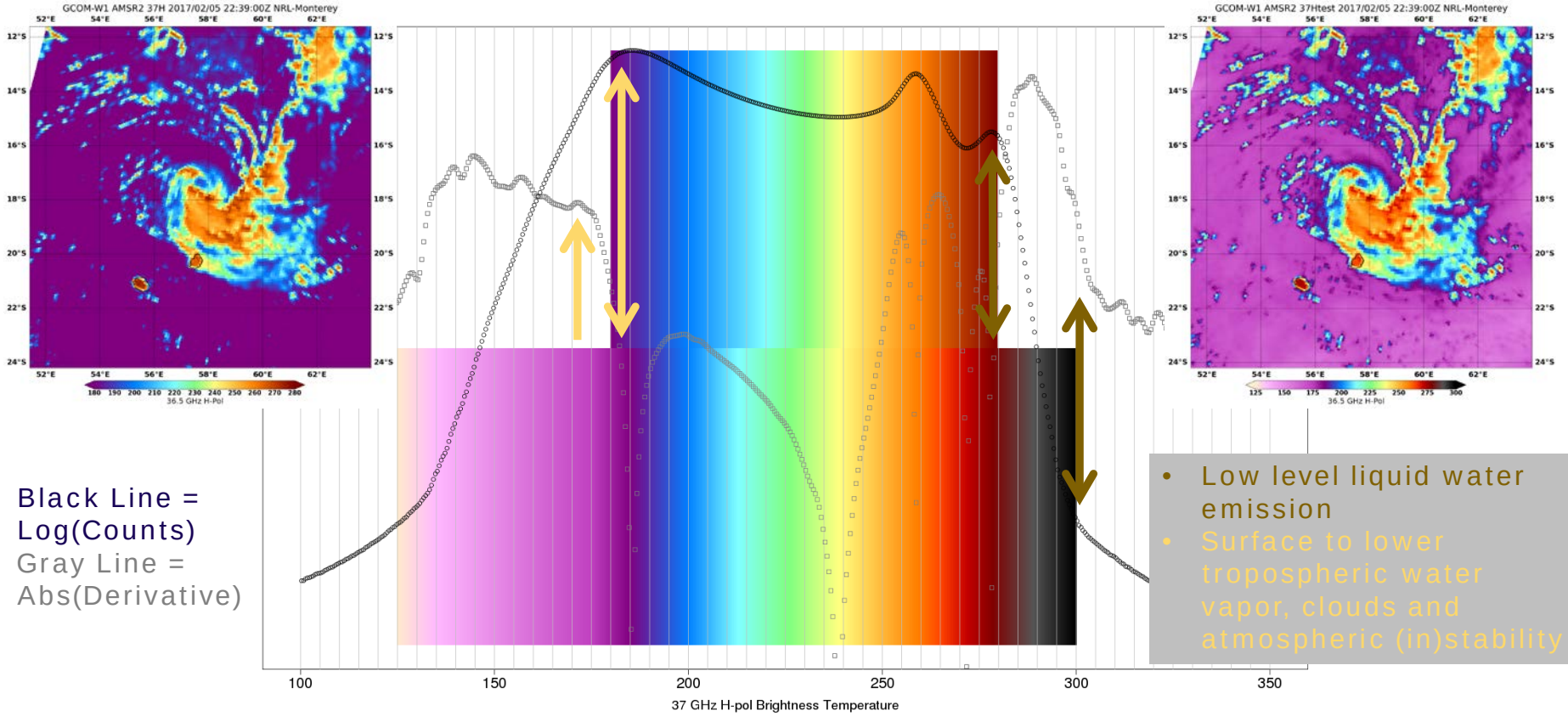


Low Level Enhancement False Color RGB

Proposed Product

- Interpretation:
  - **Magenta/White** represents precipitating convective clouds
  - **Yellow/Green** pixels show lower tropospheric water emission
  - **Black** pixels represent hydrometeor-free oceanic background
- Purpose:
  - Used for weak and asymmetric storms to highlight low level center of circulation and banding/inflow
- Cons:
  - Signal to noise ratio is low since 89 GHz emission signal is leveraged to maximize resolution

Distribution of 37 GHz Brightness Temperatures



Black Line = Log(Counts)
Gray Line = Abs(Derivative)

- Low level liquid water emission
- Surface to lower tropospheric water vapor, clouds and atmospheric (in)stability

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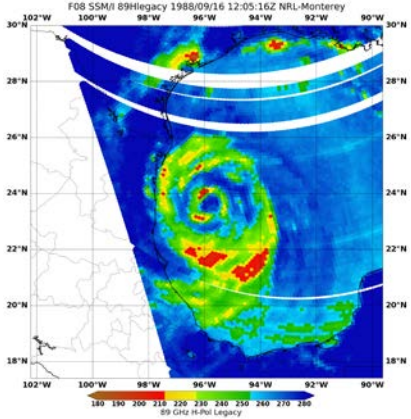
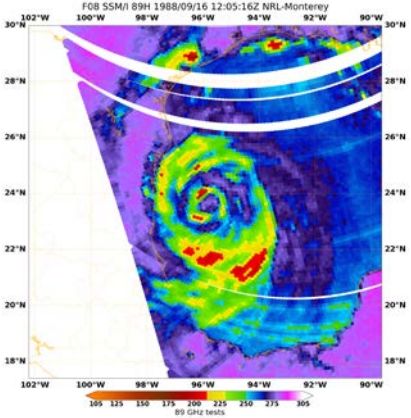
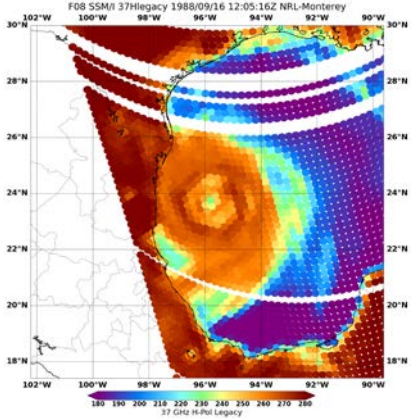
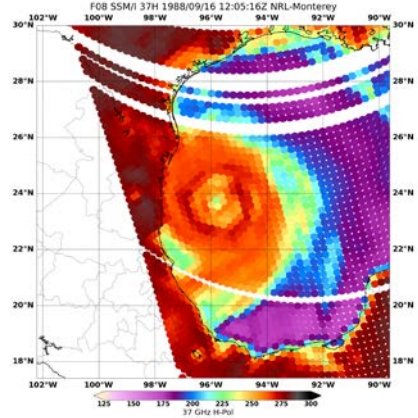
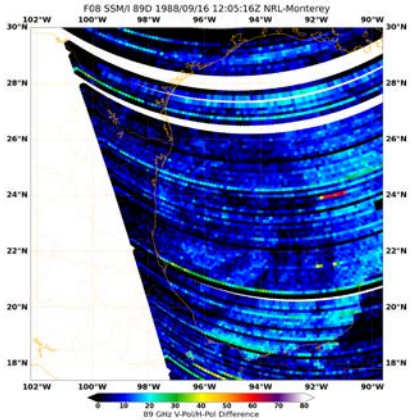
Product Comparison: Hurricane Gilbert

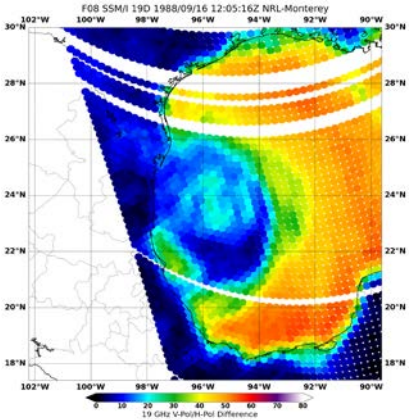


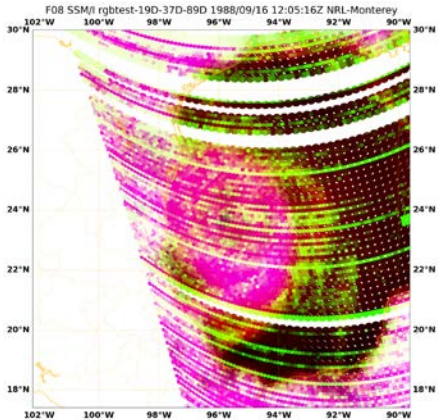


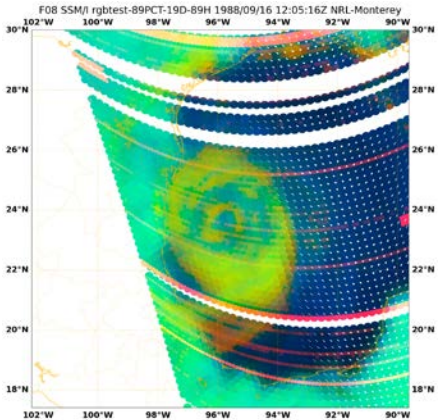












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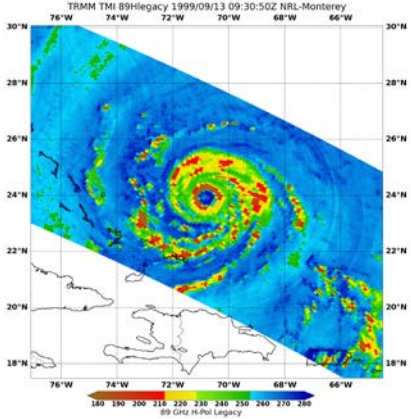
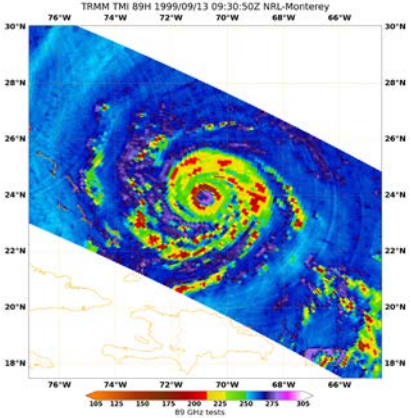
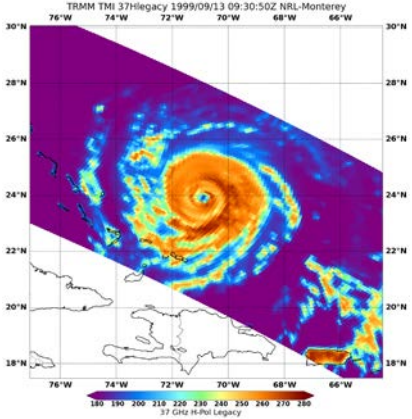
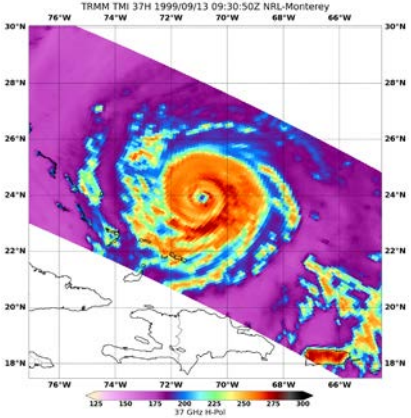
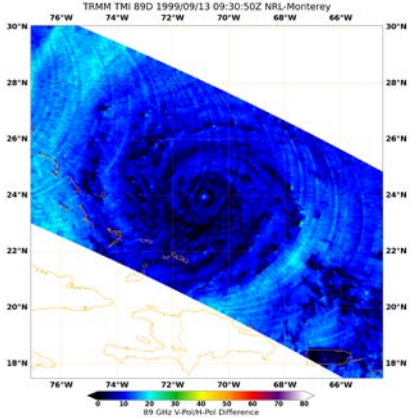
Product Comparison: Hurricane Floyd

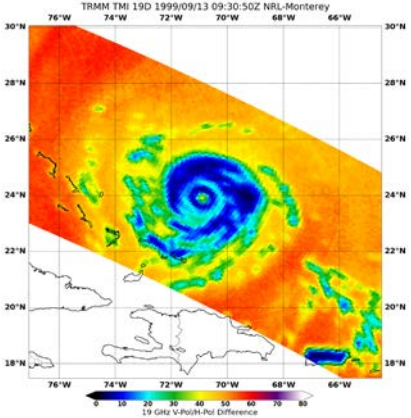


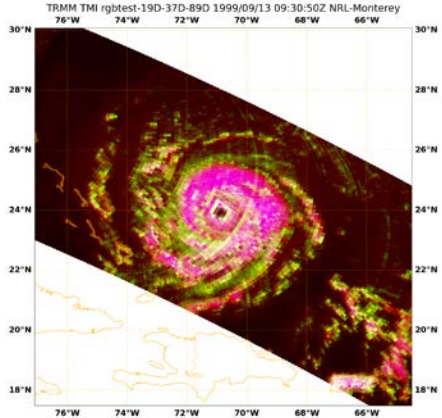


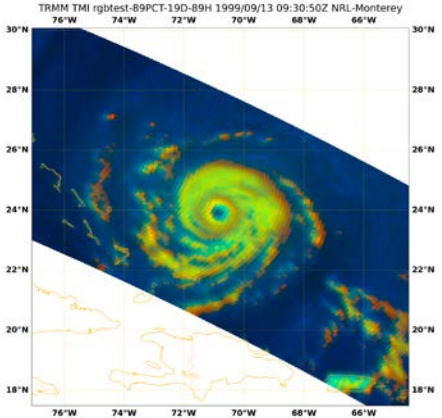












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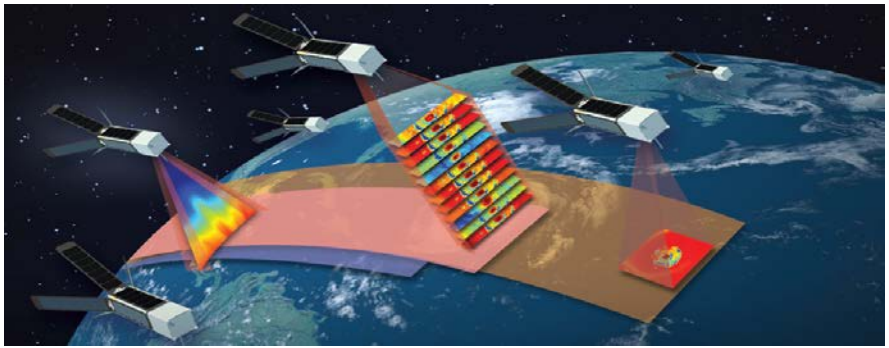
Future Microwave Additions and Alternatives

DoD/JPL Compact Ocean Wind Vector Radiometer (Nov 2017)

- Gap-filler with 3-year life design; Polarimetric wind from 18.7, 23.8, 33.9 GHz; Dual look angle to provide better wind direction than WindSat



Others scheduled for 2022+

- DoD Weather Satellite Follow-on (WSF; 2022):
- JAXA AMSR2 Follow-on (2022+):
- EUMETSAT METOP-SG A and B (2022+):

Potential for Cubesats

- TEMPEST, TROPICS, and other sounders may be operationally useful if near real-time data acquisition can be arranged
- C-Ka bands are not currently in development, though NASA has identified these microwave imagers frequencies as viable (given a large antenna)