JPSS Data Usage at the

NATIONAL HURRICANE CENTER

MIAMI FLORIDA

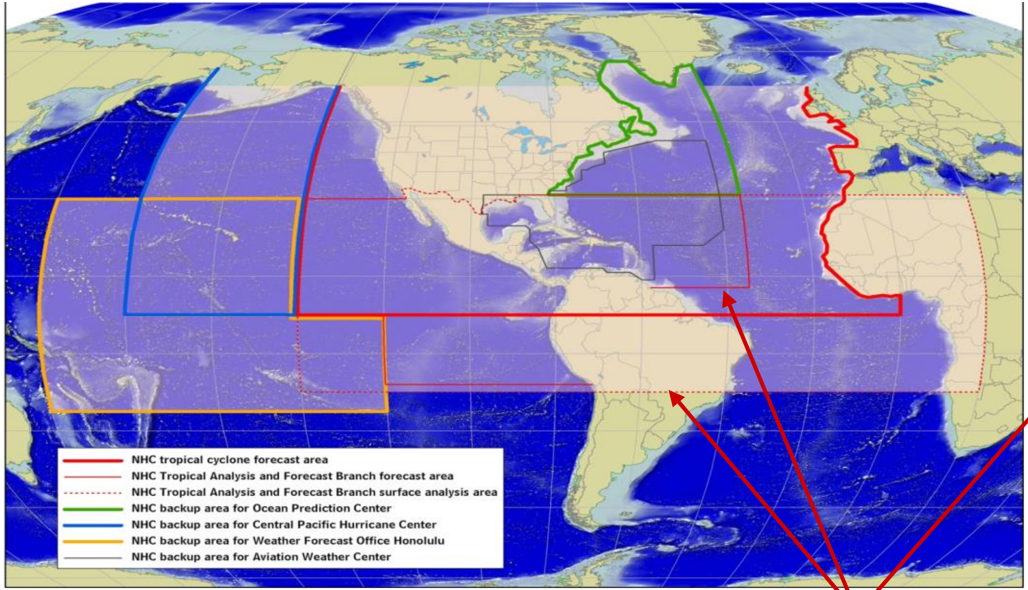
Monica Bozeman

DOC/NOAA/NWS/NCEP/NHC/TSB

NHC Areas of Responsibility

NHC is one of seven Regional Specialized Meteorological Centers (RSMCs) designated by the World Meteorological Organization (WMO) to produce and coordinate tropical cyclone forecasts for various ocean basins

NHC is responsible for both the Atlantic and eastern North Pacific Ocean basins



TAFB Areas

NHC Forecasting Unit Duties

Hurricane Specialist Unit

- Tropical cyclone position and maximum surface wind forecasts to 5 days, wind radii to 3 days, updated every 6 hr
- Wind watches/warnings 36/48 hr before landfall
- 2 and 5 day TC formation probabilities
- Off-season education and outreach
- Applied research

Track (lat, lon): 27-33 variables
Intensity (wind): 9-11 variables
Size (wind radii at 34-, 50, 64-kt): 24-72 variables

Tropical Analysis & Forecast Branch

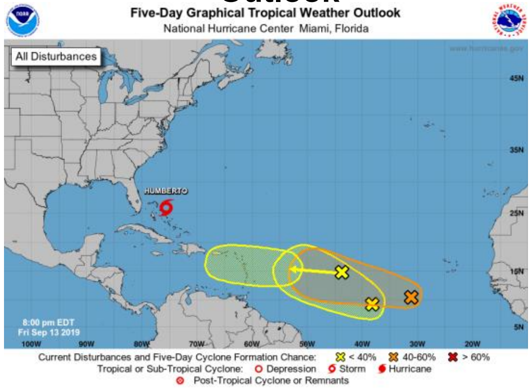
- 24x7 Marine Forecasts
- Marine/ocean and satellite analyses, forecasts and warnings in text and graphical formats (~100 products/day)
- Crisis/decision support spot forecasts for USCG
- Tropical Cyclone Dvorak Analyses for HSU
- OPC, HFO, AWC backups
- Outreach and education to mariners
- Augments HSU staff

Storm Surge Unit

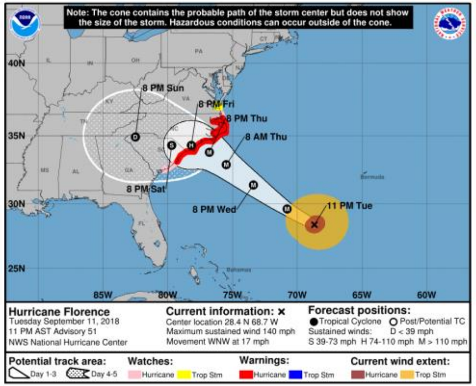
- Generates real-time storm surge forecasts
- Storm Surge Watch/Warnings and the Inundation graphic
- Provides “off-season” Storm Surge planning and preparedness education outreach
- Post-storm analyses and storm surge model verification

NHC Graphical Product Examples

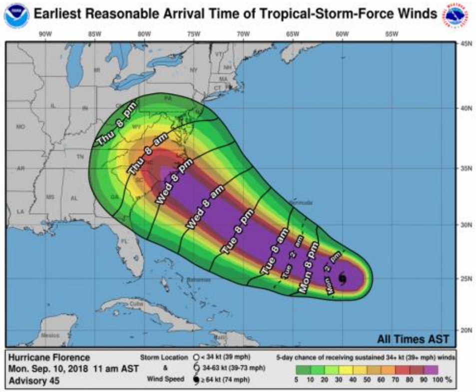
Graphical Tropical Weather Outlook



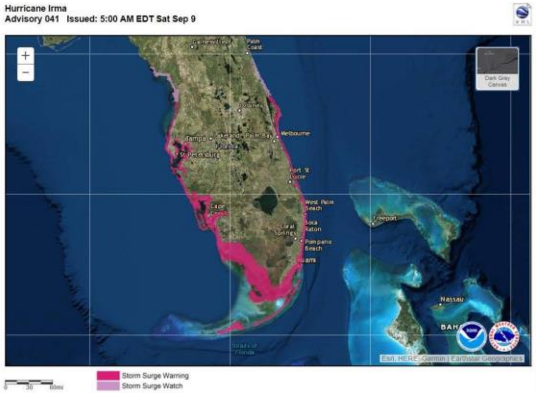
Center Forecast/Cone, Wind Warnings, Size



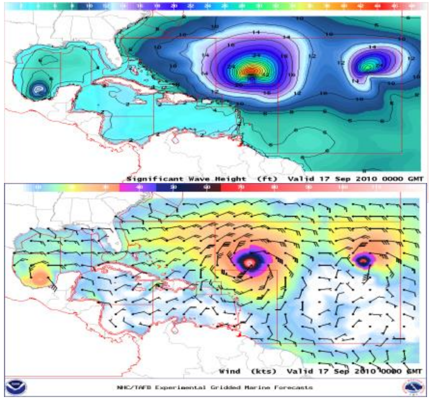
Time of Arrival of Winds



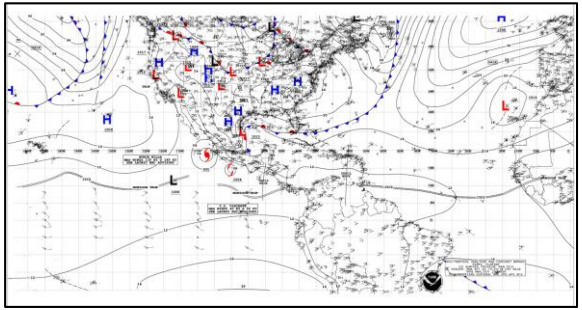
Storm Surge Warning



Marine NDFD Grids

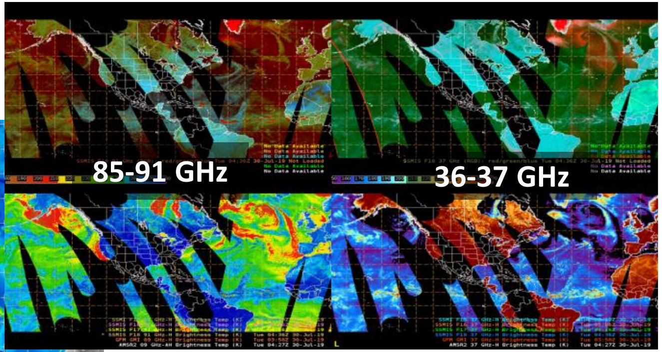


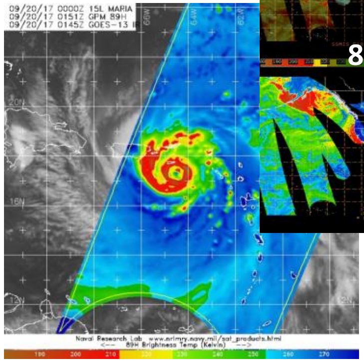
Unified Surface Analysis



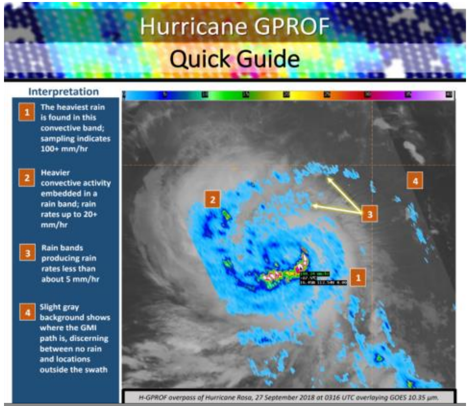
Microwave Imagery

MW Imagery can penetrate through clouds and reveal TC internal structure, yet while 85-91 GHz is able to distinguish deep convection, it cannot always see low-level clouds that depict circulation centers.





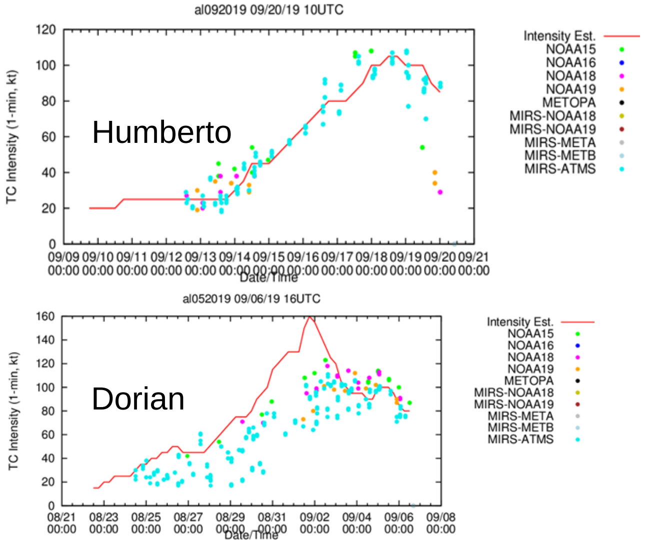
- Analysis and Forecast Applications
    - 89 GHz - ice scattering signal, mid- to upper levels
    - 37 GHz - lower-level water clouds
    - Inner core structure, eye formation
    - Concentric eyewalls, eyewall replacement cycles
        - Large impact on intensity changes
    - Center location, especially before eye formation
    - Vortex tilt through comparison with IR, Vis and by comparison of 89 and 37 GHz channels
    - TC-centered rainfall products from GPROF
- Use all available sources: SSMI, SSMI/S, GMI, AMSR2, AMSU, ATMS



Hurricane Rosa Sept 2018

Microwave Sounder Data

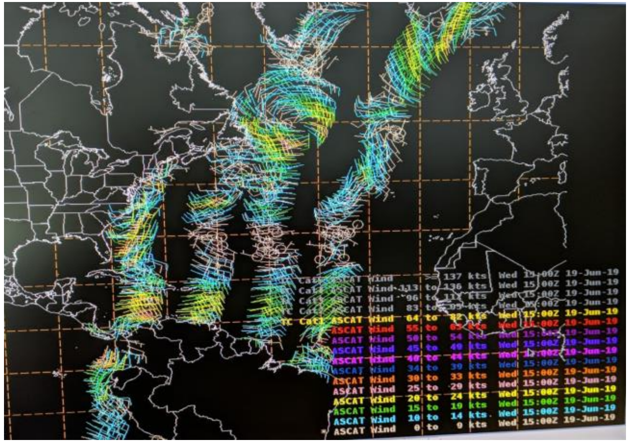
- Intensity and wind radii estimation algorithms from AMSU and ATMS
  - CIMSS version uses channel data
  - CIRA version uses MiRS retrievals
  - Both input to consensus intensity estimation
- Layer and total precipitable water products
  - Dry air intrusions, Saharan Air Layer analysis, Tropical wave analysis
- Warm/cold core structure analysis
  - Extratropical, subtropical, tropical transitions
- NUCAPS displays in AWIPS for TAFB
- Single channels used like imagery
  - Coarser resolution, but still useful

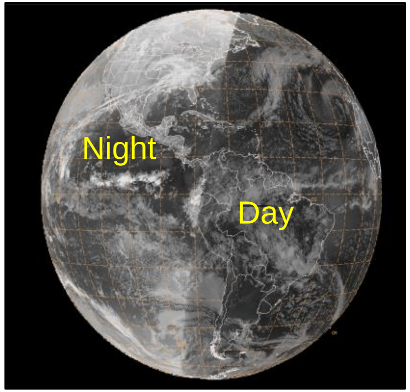


CIRA intensity estimates from ATMS/AMSU showing variability in accuracy

Other LEO Satellite Data

- Ocean surface winds: ASCAT and ScatSat
  - Analysis of closed circulations for TC genesis
  - Wind radii estimates
  - Intensity estimates for weaker TCs
  - TAFB use in gap flow wind events
  - Considering also using winds from SMAP in the future
- Satellite altimetry
  - Wave height estimates for TAFB
  - Input for ocean analysis systems
  - Subsurface temperature structure for Oceanic Heat Content (OHC) for intensity forecasting as input into SHIPS model
- Application of VIIRS Day Night Band (ProxyVis)
  - CIRA trained on DNB and applied to Geostationary imagery
  - Plan to add in the actual VIIRS DBN swaths soon



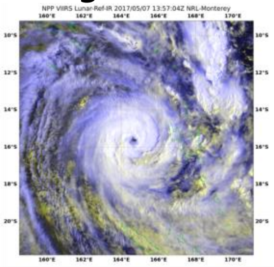


PGRR Tropical Cyclone Projects & PIs

Real-time acquisition, processing, analysis, and operational integration of TC-centric polar orbiting data:

Project Part I: Implementation of a data ingest, standardization, and output system

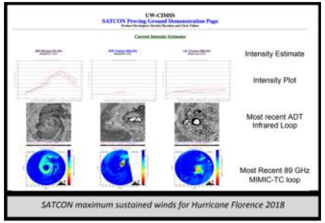
NRL: Josh Cossuth, Mindy Surratt



NRL GeoIPS is used to replace proprietary software that processes multiple data formats within a common infrastructure to normalize satellite data and create TC-centered imagery

Project Part II: Serving forecasters with advanced satellite-based TC center-fixing and intensity information

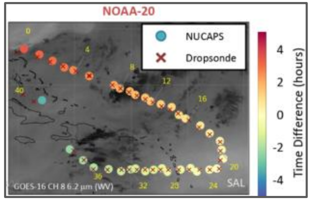
CIMSS: Tony Wimmers, Derrick Herndon



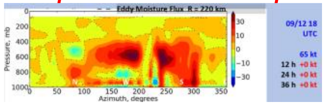
Adapting ARCHER and SATCON algorithms into GeoIPS framework and using JPSS as input. Also assisting forecasters to understand algorithm output with quick guides

Project Part III: Improving Tropical Cyclone Forecast Capabilities Using the JPSS data Suite

CIRA/NESDIS: Galina Chirkova, John Knaff



Development of multiple TC applications using JPSS input data to improve TC intensity forecasting



Collaboration with JPSS Soundings Group:

Understanding the Value of Real-Time NUCAPS Soundings for Hurricane Monitoring and Forecasting when paired with TC Aircraft Reconnaissance missions

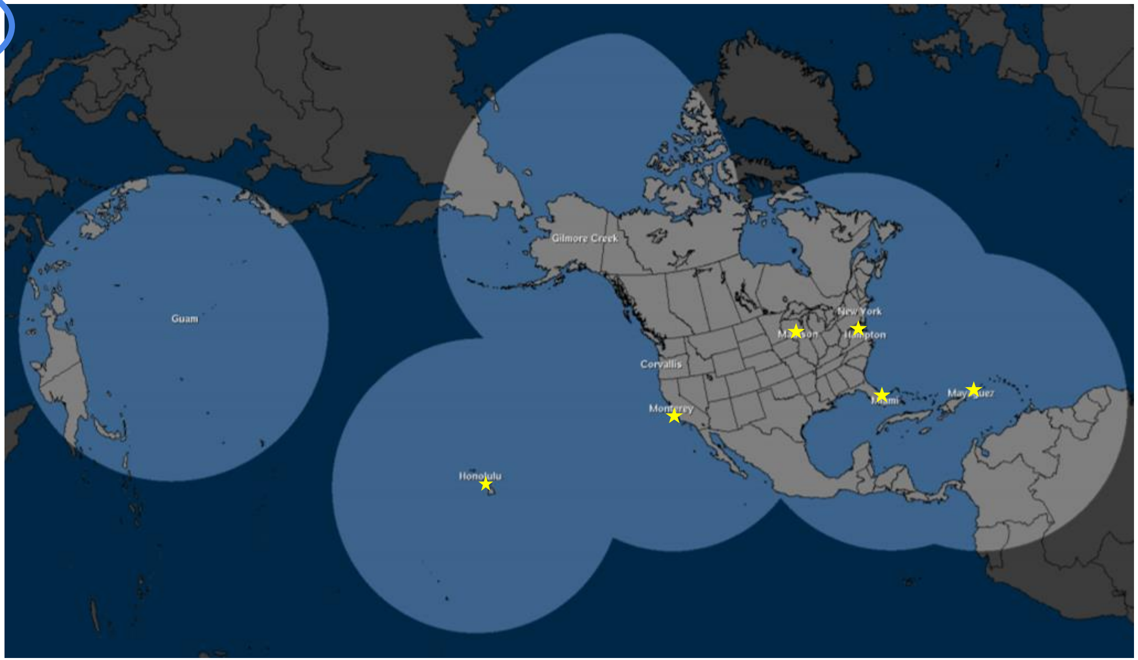
Where can we get the GeoIPS inputs?

Direct Broadcast sites:

- Miami, FL
- Greenbelt, MD (NASA)
- Honolulu, HI
- Monterey, CA
- Mayaguez, PR
- Madison, WI (U Wisc)

Non-Broadcast:

- NESDIS PDA



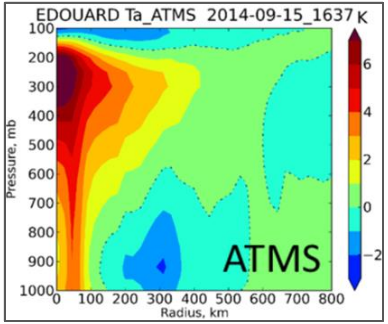
Datasets:

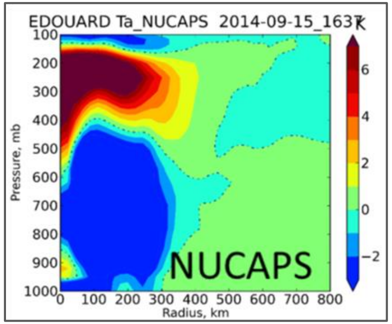
- Passive Microwave Imagers:
    a. GPM GMI
    b. GCOM-W1 AMSR2
    c. F15 SSMI & F16-18 SSMIS
    d. CORIOLIS WINDSAT
- Passive Microwave Sounders:
    a. NOAA 20 ATMS
    b. SNPP ATMS
    c. NOAA 15-19 AMSU
    d. METOP A-C AMSU
    e. MEGHA TROPIQUES SAPHIR

Other N-AWIPS & AWIPS2 products we obtain via non-operational LDM feeds from CIRA & CIMSS

Current Data Limitations

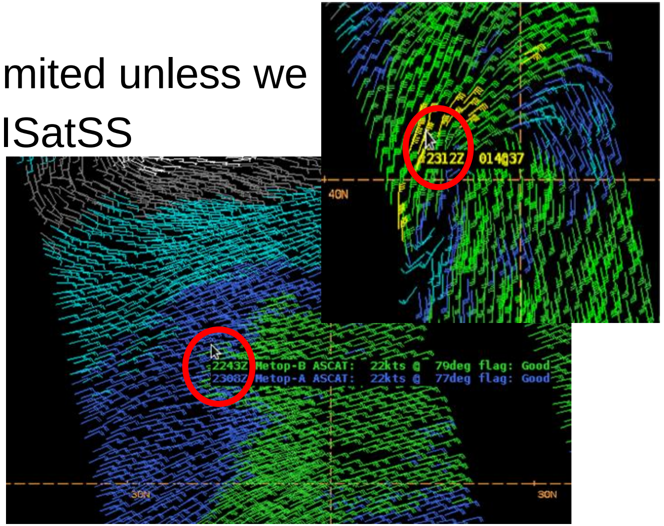
- Data latency limits utility of LEO data
  - Latency of more than 3 hours rapidly decreases the real-time utility of the data as NHC is moving into the next advisory cycle.
  - Main reason why VIIRS is underutilized
    - Ideal latency would be on the order of 30 mins - 1.5 hours
- Large dataset databases needed for algorithm development
  - CLASS site designed for case studies
  - VIIRS especially difficult due to large data volumes
- MiRS and NUCAPS retrievals inaccurate near TC centers
  - MiRS has missing data or unrealistically large warm core in low levels
  - NUCAPS warm core too confined to upper-levels



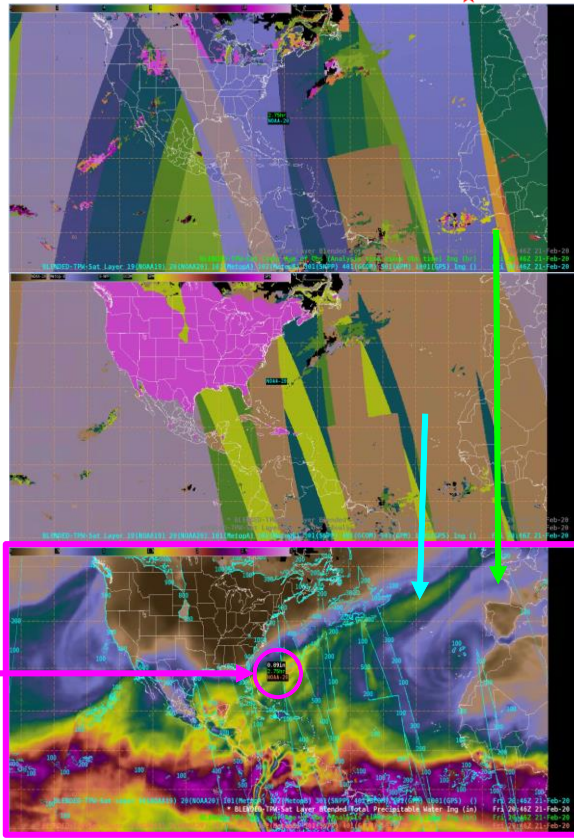


Current AWIPS2 Display Issues

- AWIPS data displays very limited unless we create them ourselves with ISatSS
  - All MW Imagery
  - ASCAT and Ambiguities
  - Altimeters



- D2D sampling of metadata:
  - Feature highly used, but limited datasets leverage this capability to quickly display metadata to save forecasters time
- Operational data availability and awareness
  - PDA support
  - Limited products are plug & play with AWIPS2 → file formats
  - SBN limitations - CONUS coverage or clipped to sectors, not adequate for large NCEP domains



Ideas to Increase JPSS Utilization in NHC Operations

- VIIRS underutilized
  - Use more direct readout to reduce latency
  - Combined VIIRS/ATMS products for TC structure analysis
  - Improved AWIPS displays, combine with GOES
- Improve ATMS/CrIS Sounder TC Intensity/Size Products
  - Characterize retrieval errors as function of distance from TC center
  - Retrieval bias correction schemes for retrievals
  - Coordinate with MIRS/NUCAPS teams to suggest retrieval improvements
  - Continue to re-train HISA, SATCON with additional training datasets
- Leverage data from multiple close orbits (JPSS-1,2)
  - Storm-centered retrieval composites
  - Optimize coverage near TC center

Ideas to Increase JPSS Utilization in NHC Operations

- Moisture products
  - Combined NUCAPS/MiRS retrievals
    - Dry air intrusions
    - Saharan Air Layer (SAL) products for TAFB
  - Shear-relative moisture flux products (MIST)
- New quantitative products
  - Improved RMW and center fixing algorithms
    - Combine ARCHER and other structure analysis algorithms (RMW)
    - RMW important parameter for storm surge, hurricane model initialization
  - Input JPSS into existing statistical intensity forecast algorithms
    - SHIPS model, rapid intensification index
  - Advanced statistical techniques (machine learning)

Ideas to Increase JPSS Utilization in NHC Operations

- TC-centered Data Processing - Continue implementation of GeoIPS
    - Normalization of microwave imagery for quantitative algorithms
    - Storm-centered product generation to improve AWIPS displays
    - Data processing for output to WCOSS for R2O of quantitative algorithms.
    - Processing of direct readout data to reduce latency
- Continue to add JPSS data in AWIPS2
    - Create data in AWIPS2-friendly formats
    - More global coverage
    - PDA user engagement
    - Developer & NESDIS collaboration with the APO and/or TOWR-S to design displays that:
        - Leverage sampling for quick access to metadata
        - Reduces the number of products to load by implementing combo/blended/mosaic products

Follow up questions for NHC?
Email Monica.Bozeman@noaa.gov

Tropical Breakout Session Thursday 9-10am in room 2552/2553

Phone & Google Hangouts: 402-971-0085 PIN: 482 886#

Come and collaborate with other Tropical users & Developers at the IHC!

Relevant Posters:

- 2 Wed: Steven Goodman: NWS Complementary Use of the Geostationary Lightning Mapper (GLM) and Lightning Imaging Sensor (LIS)
- 23 Wed: Jason Apke: Dense Optical Flow Applications for Operational Users
- 25 Wed: James Carr: LEO-GEO Stereo Winds: a Demonstration using MODIS and ABI
- 27 Wed: Houria Madani: GEO-GEO Stereo 3D Winds with a Path into NOAA Operations
- 29 Wed: Patrick Duran: Using GLM Flash Density, Flash Area, and Flash Energy to Diagnose Tropical Cyclone Structure and Intensification
- 31 Wed: Christopher Grassotti: Preliminary Development and Assessment of the NOAA Microwave Integrated Retrieval System for Tropical Cyclones (MiRS-TC)
- 32 Wed: Liqun Ma: Operational Tropical Cyclone Satellite Products
- 33 Wed: Galina Chirokova: How JPSS Data Can Improve Operational TC Analysis and Forecasting
- 11 Thurs: Sheldon Kusselson: The CIRA Advected Layered Precipitable Water (ALPW) Product and Applications to Help Forecast Hazardous Precipitation Events

National Hurricane Center GOES-R User Perspective

Dr. Stephanie N. Stevenson [1,2]

[1] Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO

[2] NOAA/NWS/NCEP National Hurricane Center

HSU forecast cycle

Time (HR : MIN)	Event
00:00	**Issue Tropical Weather Outlook** **Issue Intermediate Public Advisory (if necessary)** **Synoptic time / cycle begins**
00:45	**Receive satellite fix data**
01:00	**Initialize models**
01:10	**Receive model guidance and *prepare forecast***
02:00	**NWS / DOD hotline coordination**
03:00	**Advisory deadline**
03:15	**FEMA conference call**
06:00	**New cycle begins**

Track (lat, lon): 27-33 variables

Intensity (wind): 9-11 variables

Size (wind radii at 34-, 50, 64-kt): 24-72 variables

Public Advisory + Discussion + Watches/Warnings

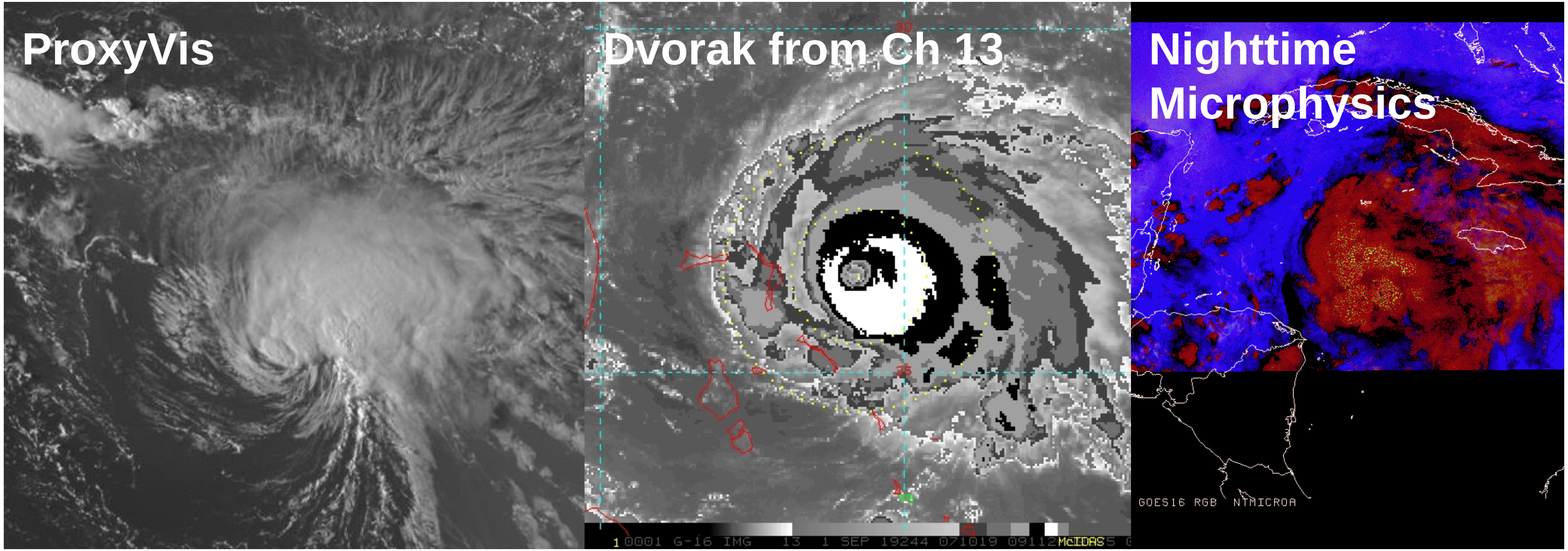
A forecaster can sometimes be responsible for more than one storm!

GOES-16/17 at NHC: Features of interest

- Tropical waves
  - Tracking
  - Environmental favorability for development
- Tropical cyclones
  - Genesis
  - Current location & intensity
  - Speed & direction of movement
  - Environmental analysis
- Convection
- Visibility (fog, smoke, ash)

GOES-16/17 at NHC: Current data and product usage

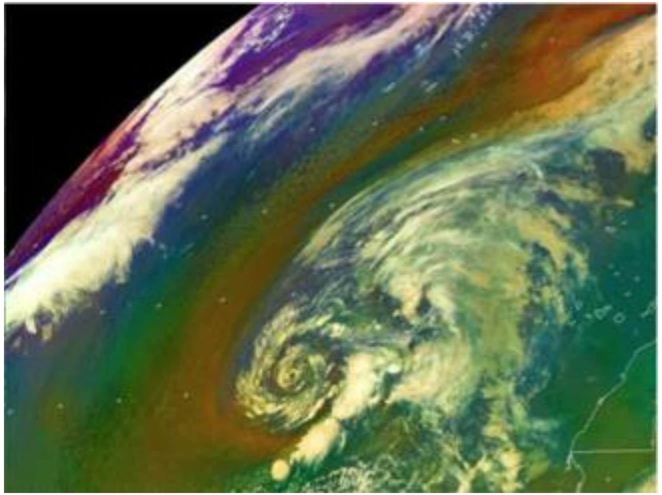
- Tropical cyclone center and intensity fixes
  - Visible, IR window (Dvorak)
  - At night: ProxyVis, SWIR, Nighttime Microphysics RGB



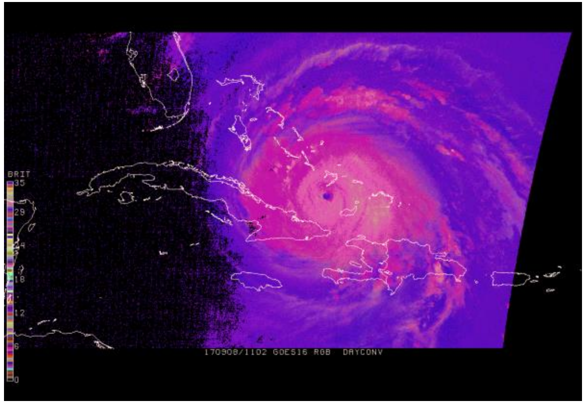
GOES-16/17 at NHC:
Current data and product usage

- Other RGBs commonly used for tropical cyclones

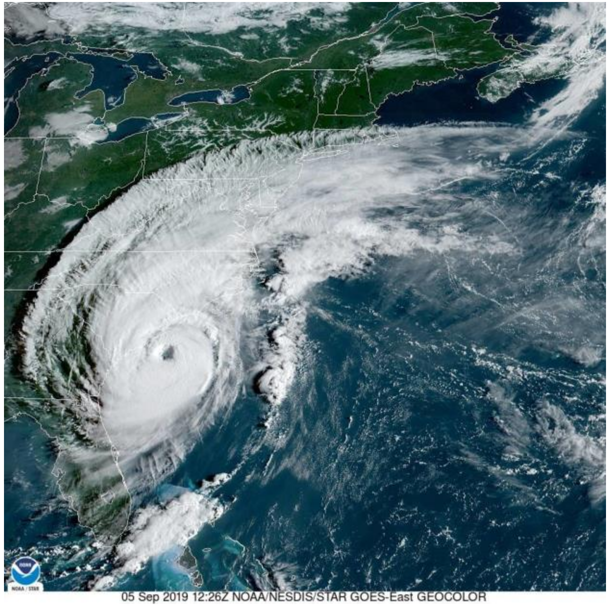
Air Mass: useful to extratropical or tropical transition



Day Cloud Convection: cloud type discrimination, genesis & intensity forecasting

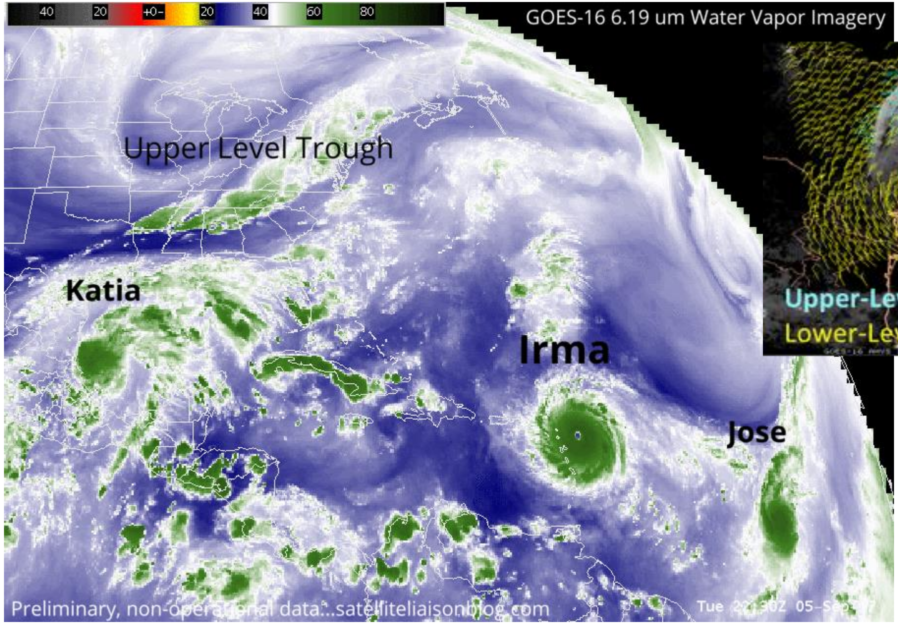


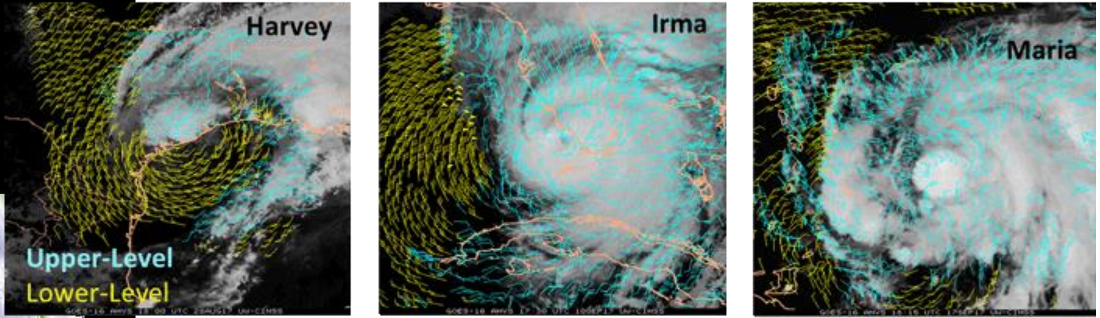
GeoColor: great for public media outreach



GOES-16/17 at NHC: Current data and product usage

- Useful for situational awareness
  - Atmospheric Motion Vectors (AMVs)
  - WV channel(s)





Source: https://www.goes-r.gov/featureStories/monitoringHurricanes.html

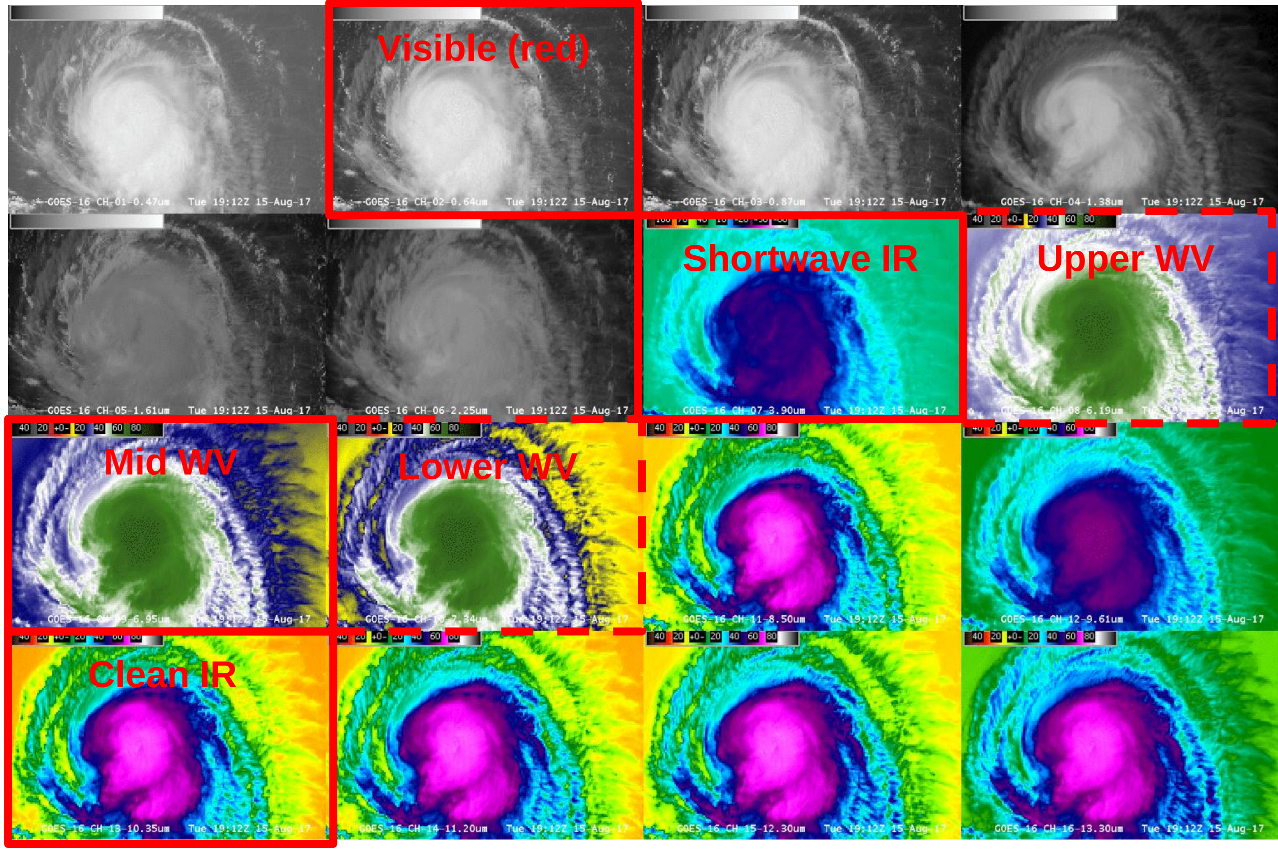
Source: https://satelliteliaisonblog.com/2017/09/01/tracking-irma/

GOES-16/17 at NHC:
Current data and product usage

- Satellite input to statistical models
  - SHIPS intensity model (including RII)
    - Ch 13 (Clean IR Window)
  - TCGI genesis potential
    - Ch 9 (Mid-level WV)
- Experimental for 2020
  - RII version with GLM lightning
- GOES data assimilated into NWP models

GOES-16/17 at NHC: Areas with room for improvement

- New ABI channels
  - Most are still using legacy
  - 3 WV channels
- Multi-channel products
  - RGBs
  - Intensity estimation
- GLM
  - Identifying most useful gridded products



Source: https://cimss.ssec.wisc.edu/satellite-blog

GOES-16/17 at NHC:
Areas with room for improvement

Aletta (2018) - Advisory 1

kt. In addition, GOES-16 1-minute visible satellite imagery showed
that the low had developed a closed surface circulation and a
well-defined center. Advisories are therefore being initiated on

Dorian (2019) - Advisory 4

short-lived thunderstorm areas. GOES-16 1-minute satellite images
have been particularly helpful in locating the center in between
bands of convection to the north and south of the cyclone. The

Dorian (2019) - Advisory 5

A combination of 1-minute GOES-16 visible imagery and microwave
satellite data have helped pinpoint the center, and the initial
motion is 280/12. The subtropical ridge to the north of the

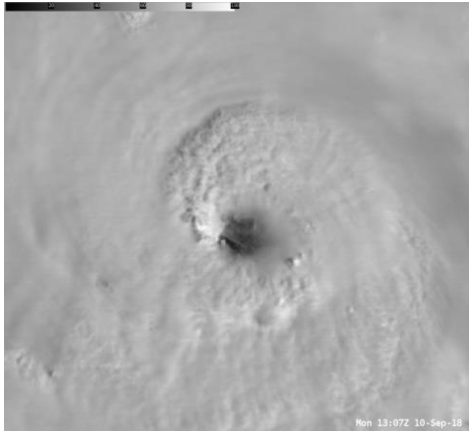
Lorena (2019) - Advisory 1

First-light 1-minute visible imagery from GOES-W revealed that the
disturbance just south of Mexico has developed a well-defined
surface center. The system has also developed an extensive

Carlotta (2018) - Advisory 1

Overnight scatterometer data indicate that the circulation of the
system was open on the northwestern side. High-resolution GOES-16
1-min visible data indicate that the low is now closed, with a
well-enough defined circulation center. Since there is plenty of
banded convection, this system is being designated as a tropical
depression, and the initial wind speed of 30 kt is based off the

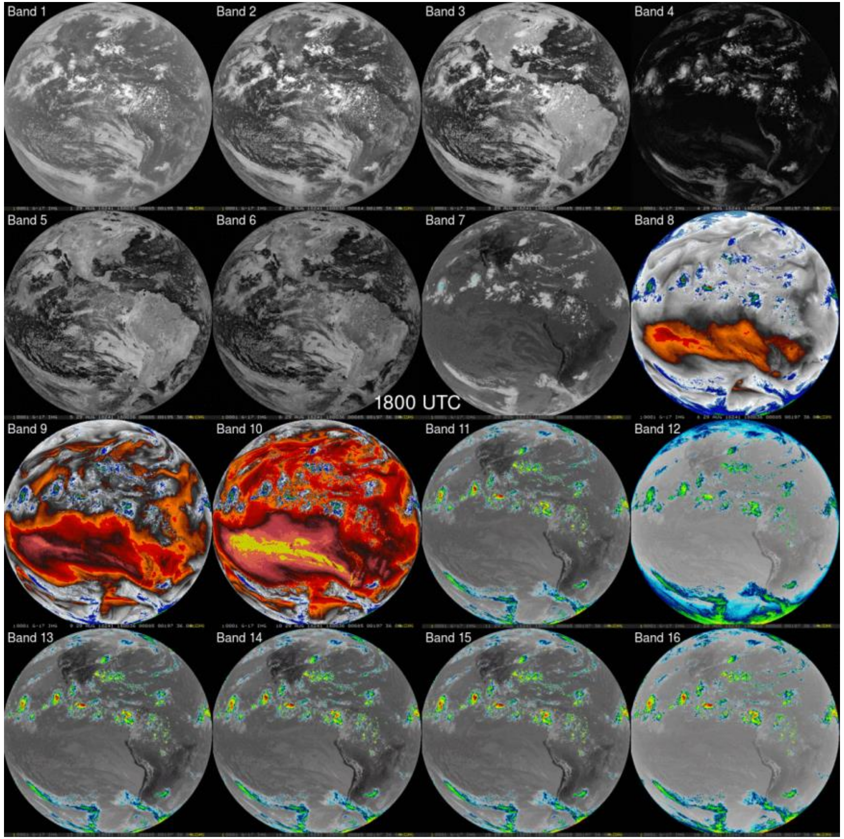
- Mesoscale sectors
  - **Current uses:** identifying circulation centers (esp. in weaker systems), monitoring convective bursts
  - **Unknown:** other benefits of high temporal data (e.g., AMVs)



Source: https://satelliteliaisonblog.com/2018/09/09/

GOES-16/17 at NHC:
Areas with room for improvement

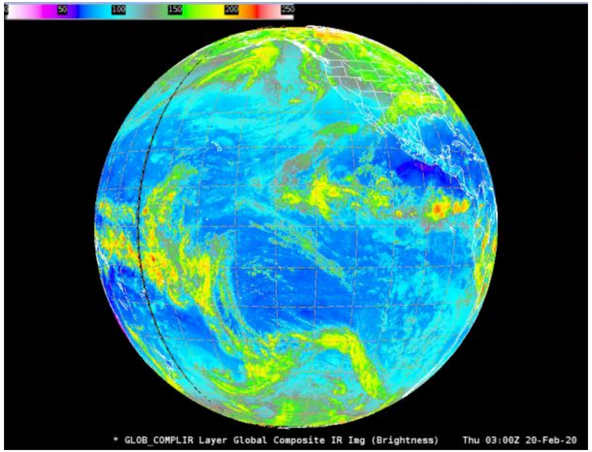
- Guidance during GOES-17 Loop Heat Pipe anomaly imagery degradation
    - NHC did not identify any significant impact to their issued products during OT&E
    - However, it still could cause issues for tropical weather where backup satellites are unavailable
        - Loss of AMVs?
        - Multiple statistical models use IR/WV

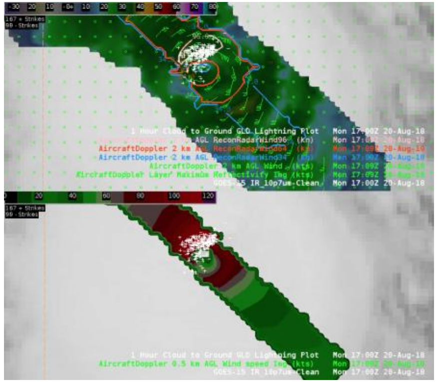


Courtesy of Dan Lindsey

Obstacles for data exploitation: Data formats

- NHC is transitioning to AWIPS-II for displaying data
  - Huge benefit in having one data platform to time match and overlay numerous data resources
  - Incompatible data formats can sometimes delay product delivery or make products unusable by the users





GOES Development Priorities from NHC

- Exploiting GLM data
- Expanding single ABI channel applications
- Multi-channel products with targeted forecast applications
  - Water vapor product using all 3 channels
  - Improved ProxyVis
  - Combined ABI & GLM products
  - Generalized Dvorak intensity estimates
- More quantitative products (automated)
  - Storm structure estimates (RMW, wind radii, etc.)
  - Intensity change prediction (especially rapid intensification)
- Improved observational visualization
  - 3-D, virtual reality, etc.
  - More metadata in source files for sampling and/or overlays in AWIPS-II

Training

- Product applications focused on tropical weather is lacking for some products
  - Without examples of how the product is useful for their analysis or forecast, users can be hesitant to use new products

GOES/JPSS Use for Tropical Marine Weather Forecasting at the TAFB at NHC

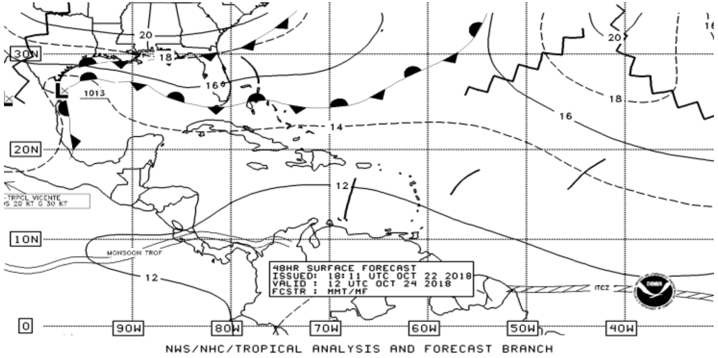
Michael J. Folmer, PhD
Marine Forecaster, NWS/NCEP/OPC
Former Satellite Liaison for TAFB

Nelsie A. Ramos, PhD
Marine Forecaster, NWS/NCEP/NHC/TAFB

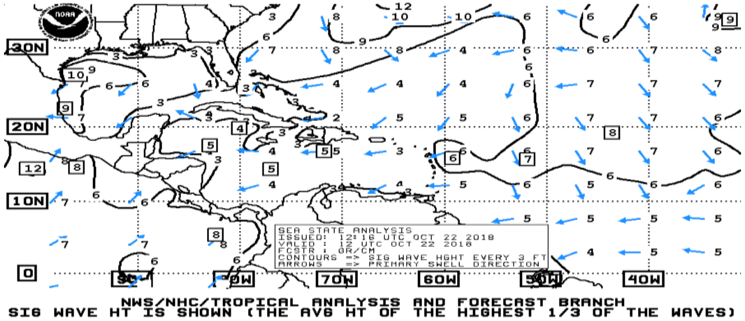
TAFB Products

- ✓ Most text and graphical products generated via a gridded database
- ✓ Products include but are not limited to:
- ✓ **Surface weather analysis and forecasts** - depict major synoptic weather features
- ✓ **Tropical weather discussions** (4/day) - describe major synoptic weather features and significant areas of disturbed weather as well as expected trends to assist in the customer decision making
- ✓ **High seas** (2 day) and **offshore waters** (5 day) marine **forecasts** - forecast and warning information for large transoceanic vessels, and mariners who travel on the oceanic waters adjacent to the U.S. and its territorial coastal waters
- ✓ **Gridded Marine Forecasts**: (surface (10-m) wind speeds and direction, surface (10-m) wind gusts, significant wave heights and marine hazards

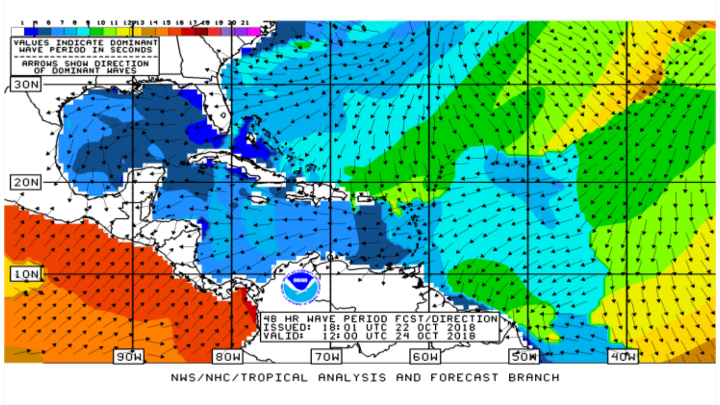
TAFB Products



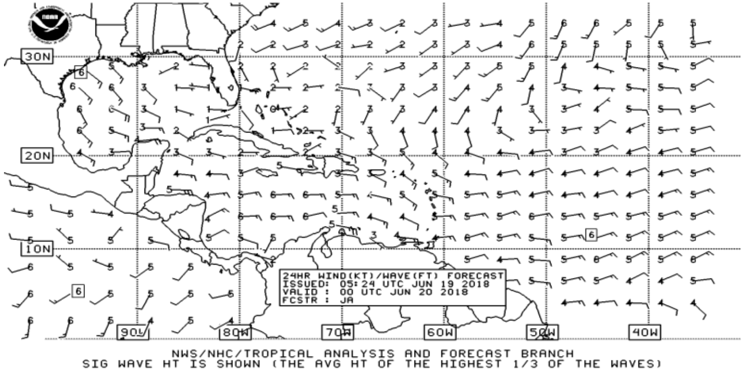
Surface forecast



Sea State Analysis

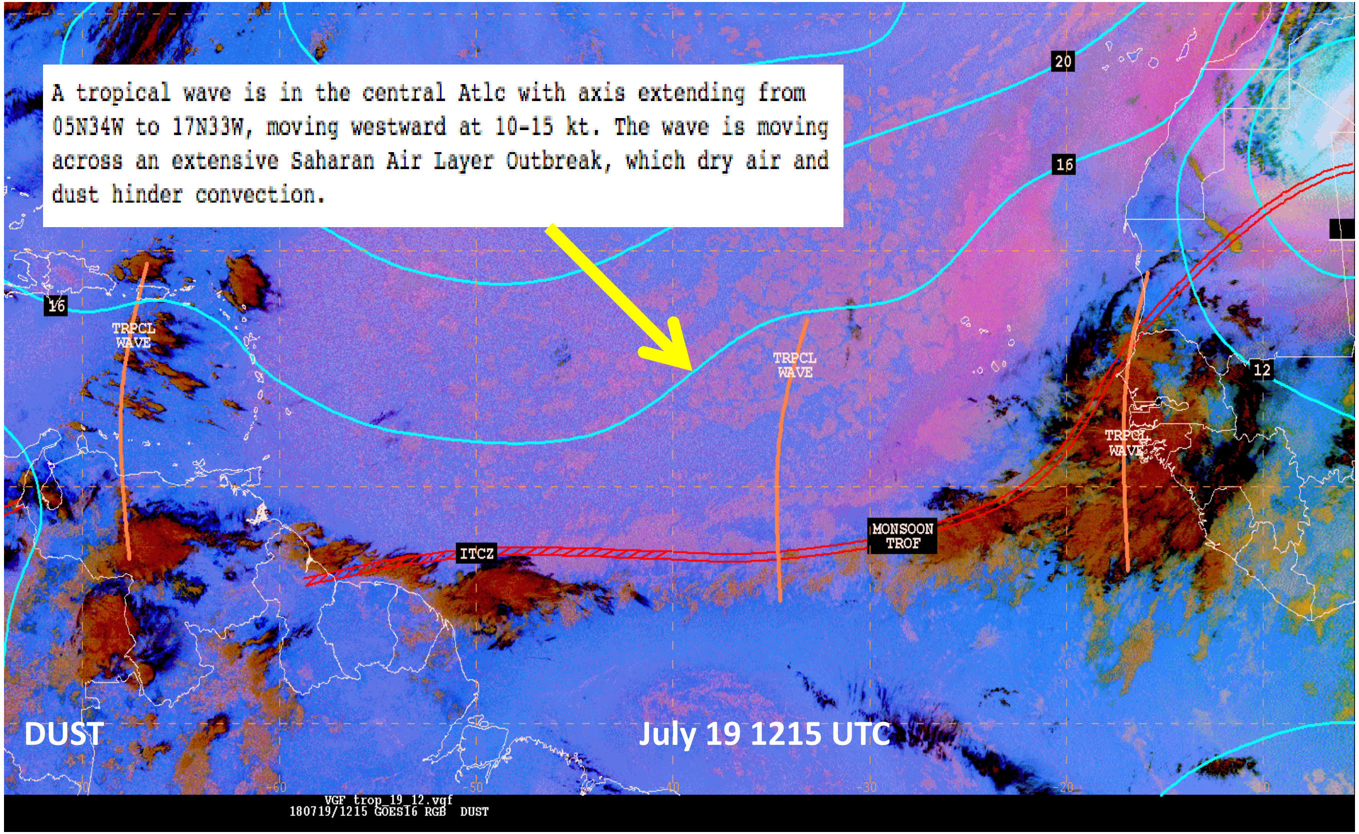


Wave Period/Direction Forecast

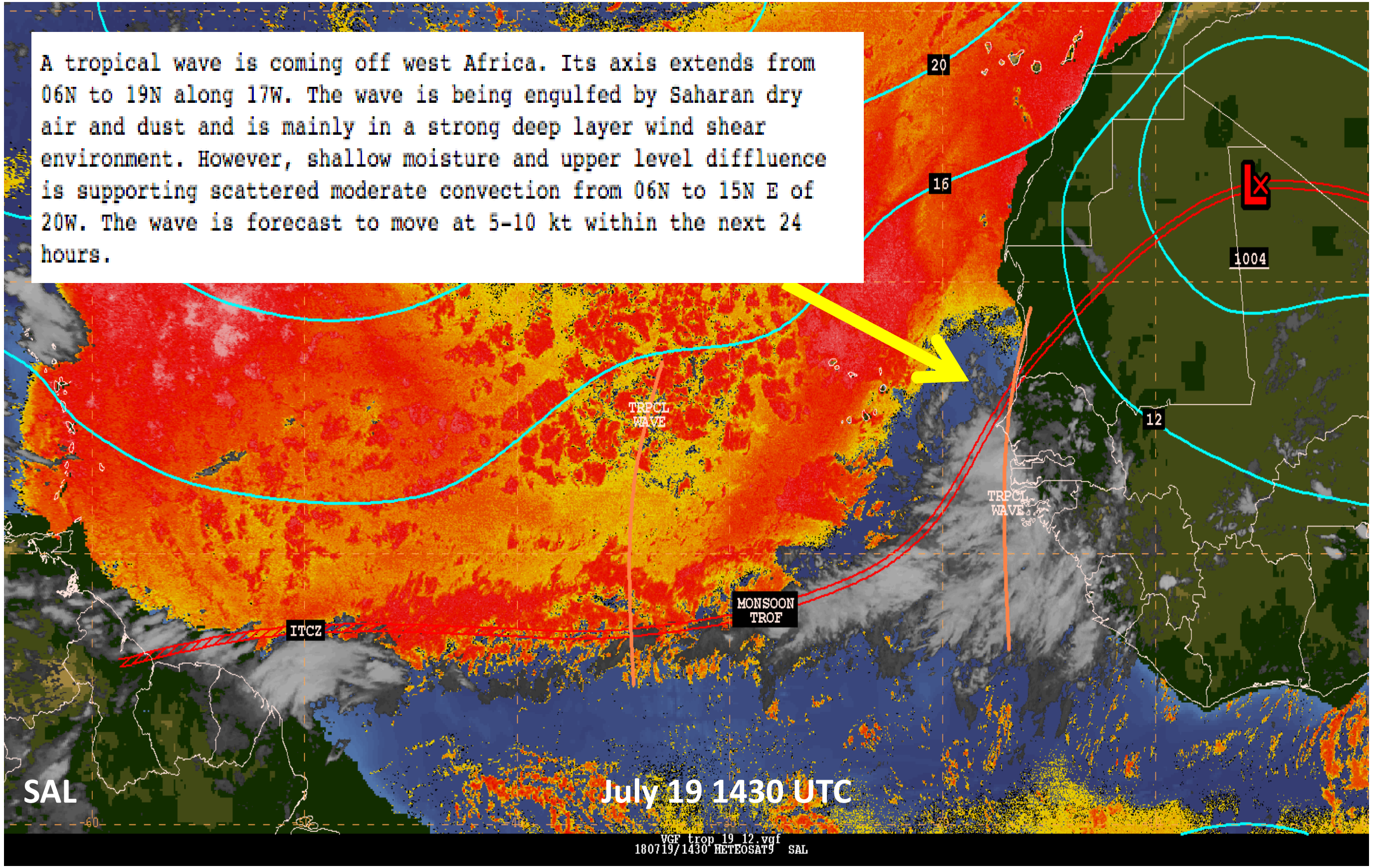


Wind Wave Forecast

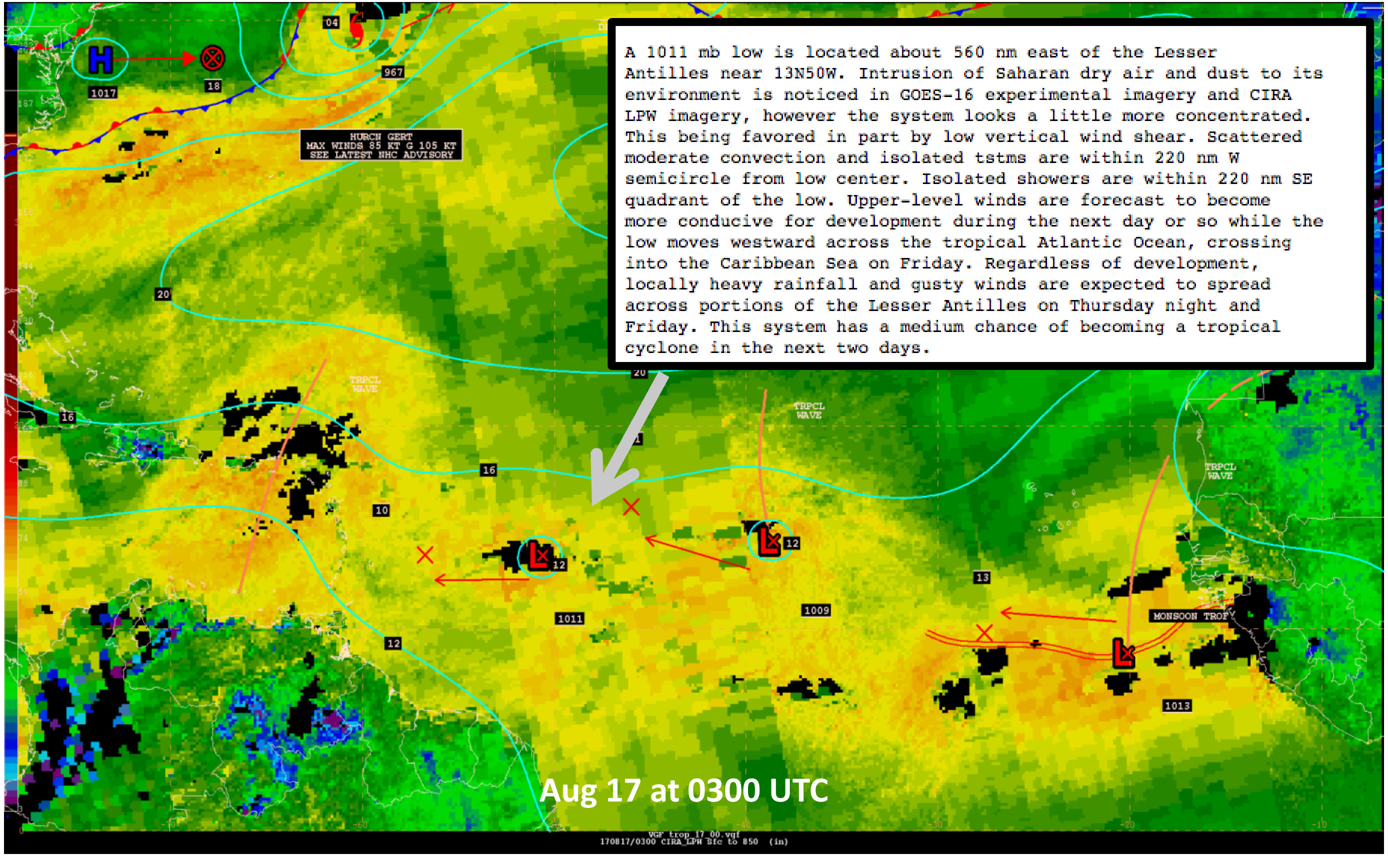
Non-developing Tropical Waves



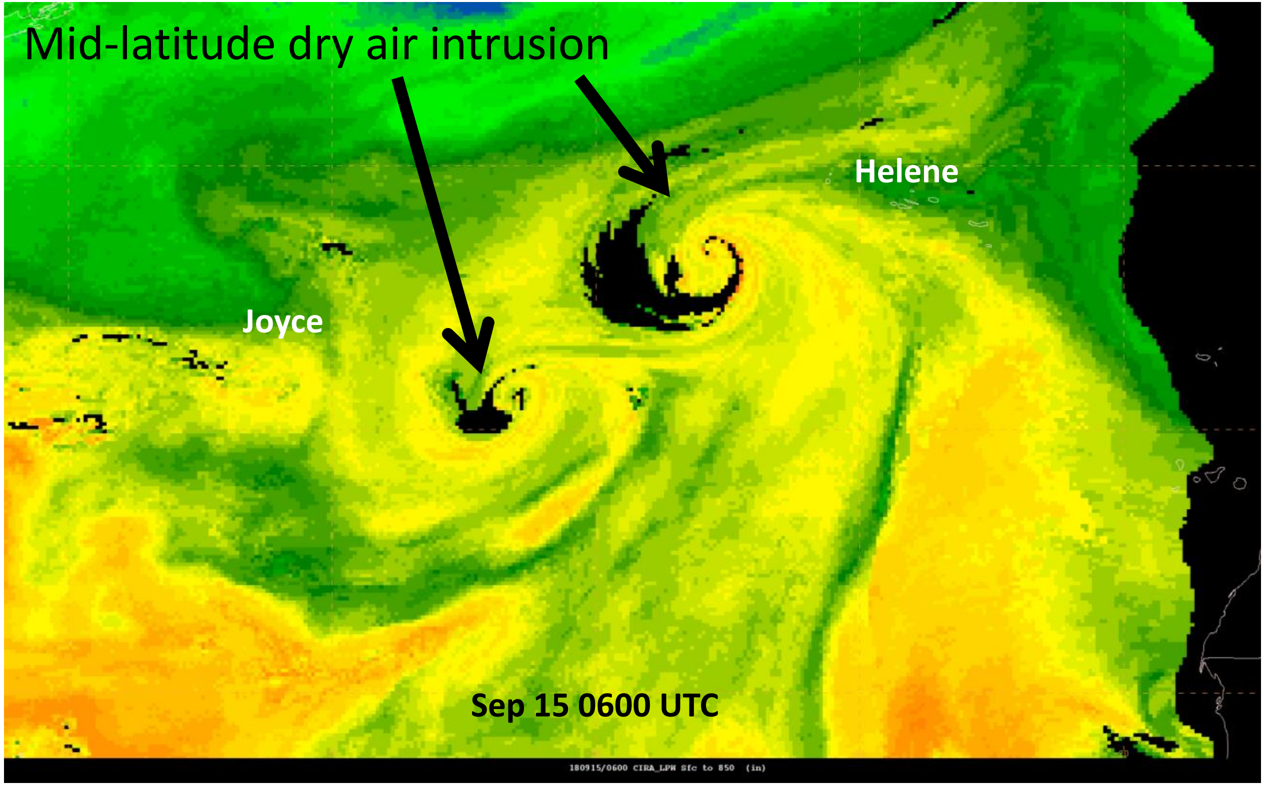
Non-developing Tropical Waves



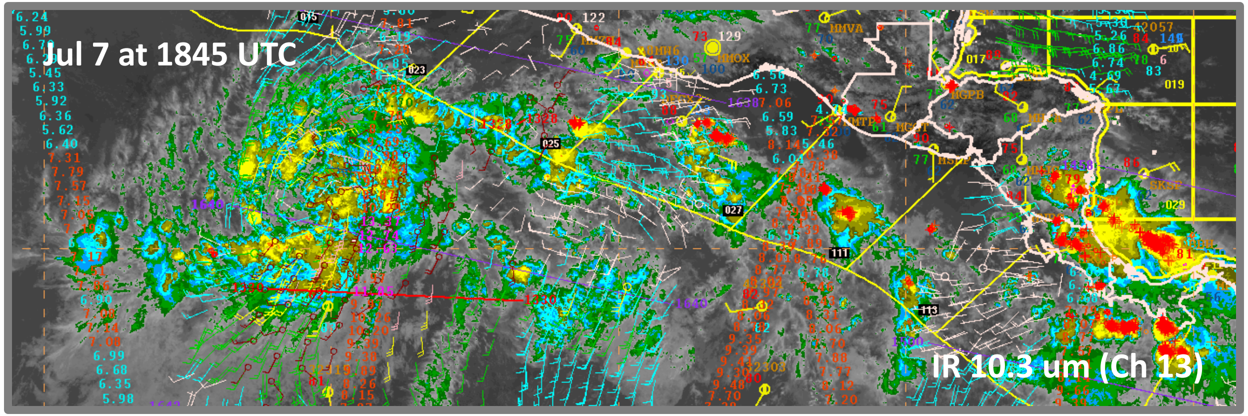
Potential Tropical Cyclone



Helene and Joyce Weakening

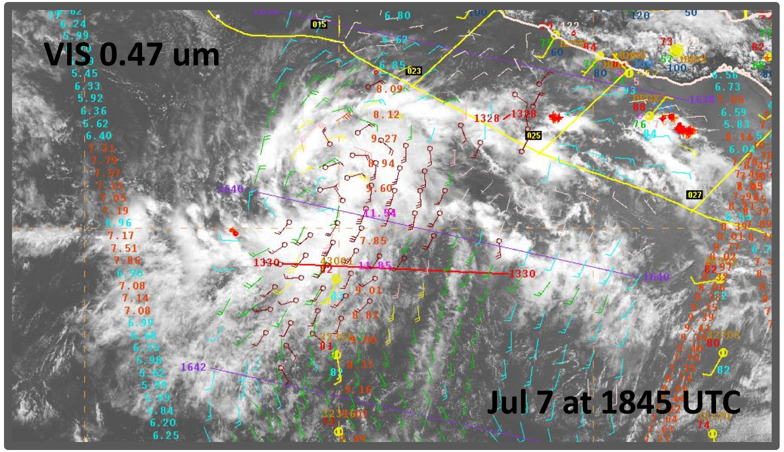


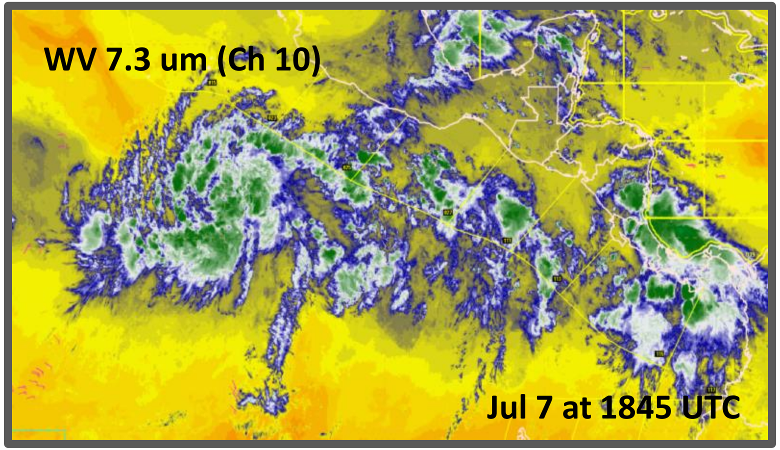
Tropical Storm Eugene Genesis



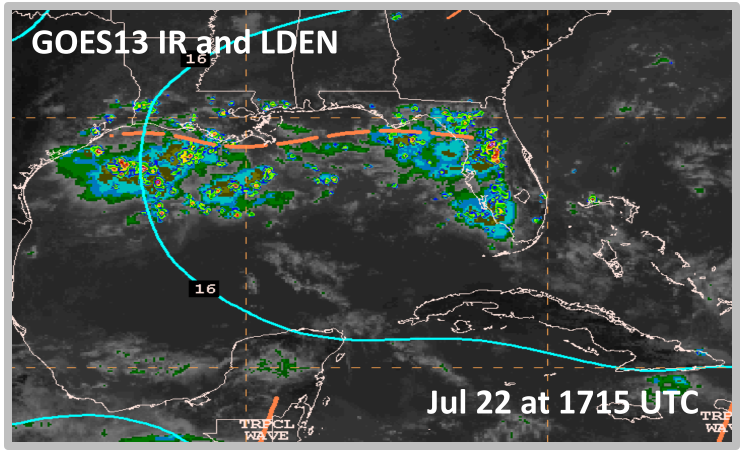
The broad low pressure area embedded within the monsoon trough has developed further and is now Tropical Storm Eugene, the fifth named system of the 2017 East Pacific season. At 07/2100 UTC Eugene was centered near 11.9N 111.2W, or about 665 NM south of the southern tip of the Baja Peninsula. Maximum sustained winds are 35 KT with gusts to 45 KT. Estimated minimum central pressure was 1006 MB. Eugene was moving NW or 310 degrees at 7 KT. Scattered moderate and isolated strong convection is noted within 240 NM of the center of Eugene. Visible and infrared satellite imagery shows increasingly cyclonically curved convective bands around the circulation center in an area of low vertical shear. This environment will remain favorable for Eugene to strengthen, and the system is forecast to become a hurricane within 48 hours. For addition information please refer to the latest NHC forecast/advisory under AWIPS/WMO headers MIATCMEP5/WTPZ25 KNHC.

Tropical Storm Eugene Genesis

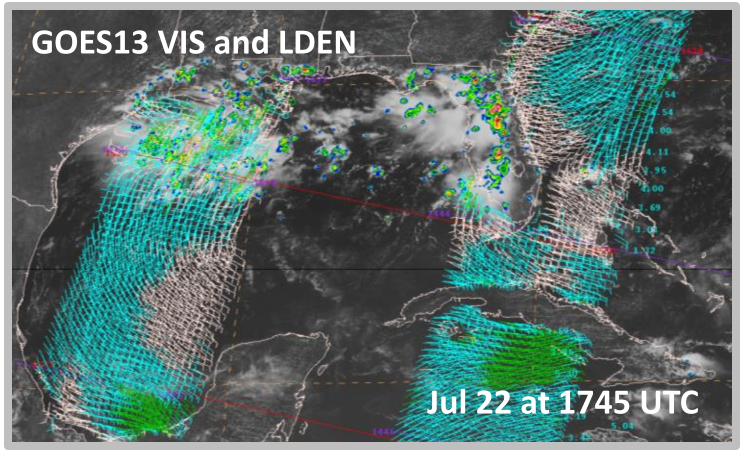




Lightning Density in the Gulf of Mexico

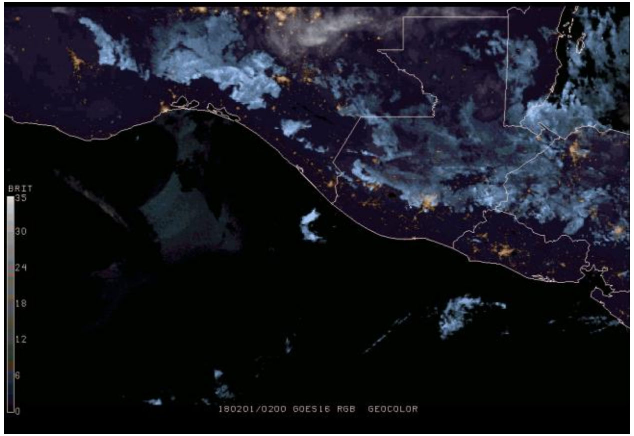


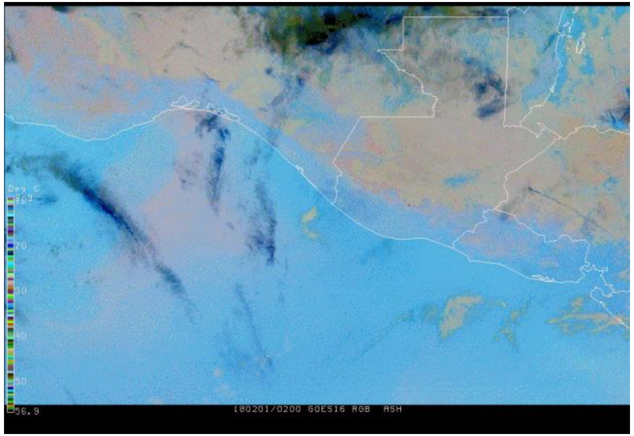
Weak surface ridging continues to dominate across the Gulf with gentle to light southerly winds advecting shallow moisture from the Caribbean. This moisture along with a very unstable environment aloft composed of middle level diffluent flow and an upper level low support an elongated area of low pressure across the northern Gulf analyzed as a surface trough from the Florida big bend near 29N83W west-northwest to SE Texas near 29N94W.

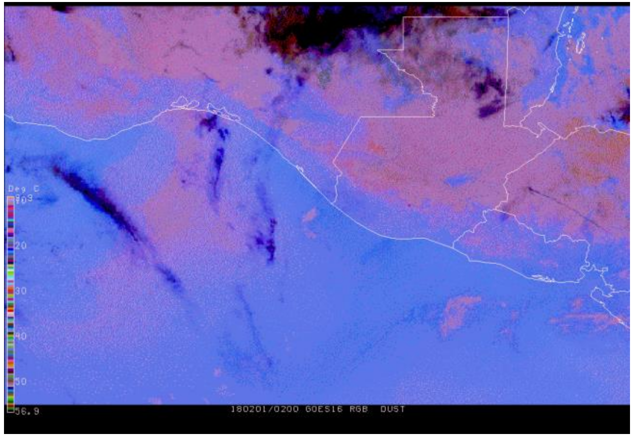


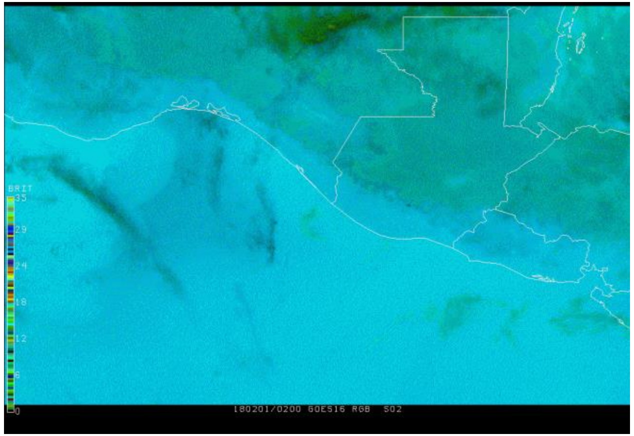
Scattered heavy showers and tstms associated with this area of low pressure are N of 26N E of 96W. Scatterometer data show fresh to near gale winds in the vicinity of the trough associated with this convection. Similar convection is off the SW Florida coast extending about 75 nm into the SE Gulf waters. Not major changes expected during the rest of the weekend.

Volcan de Fuego Eruption on 02/01/18

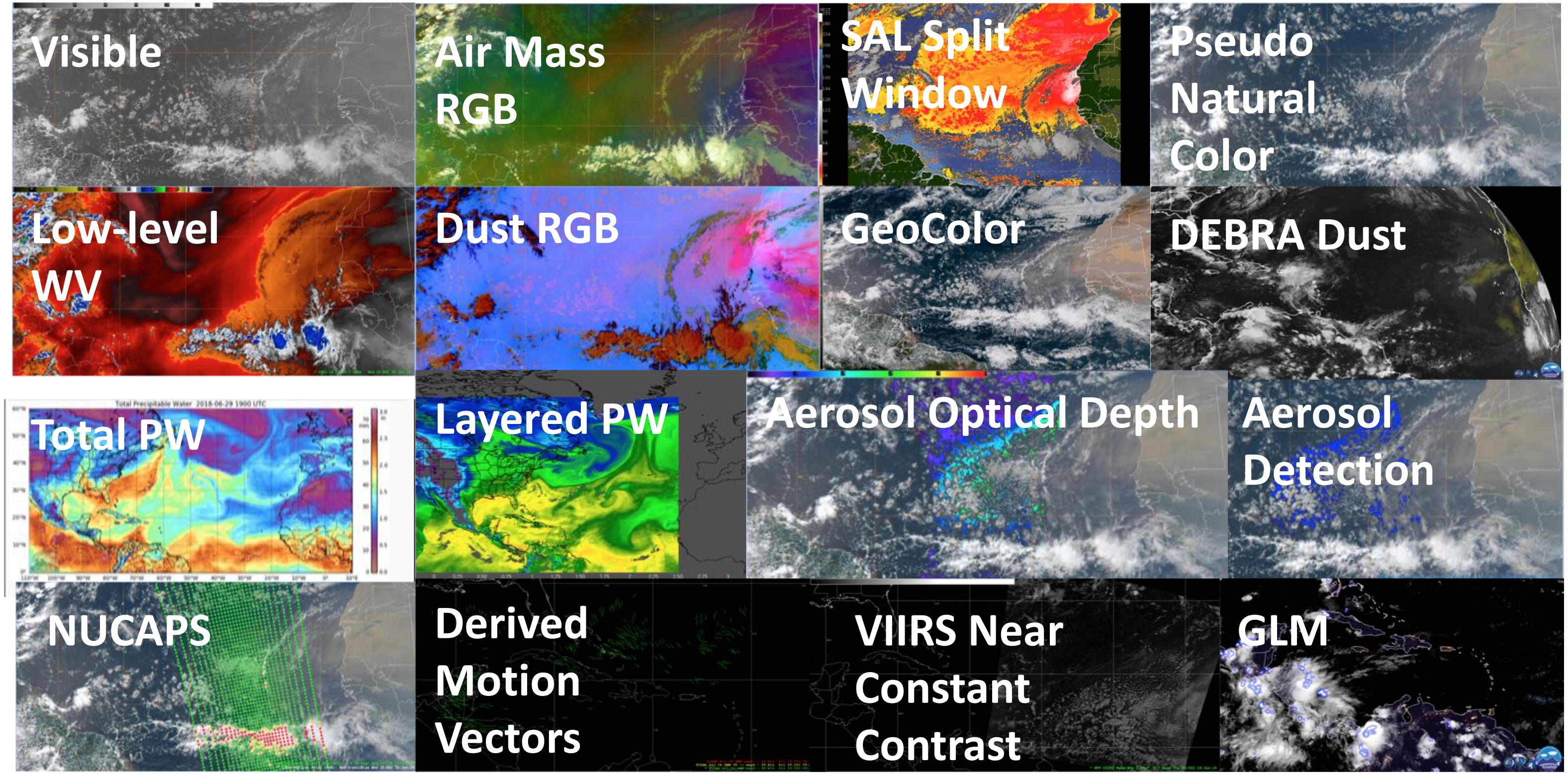




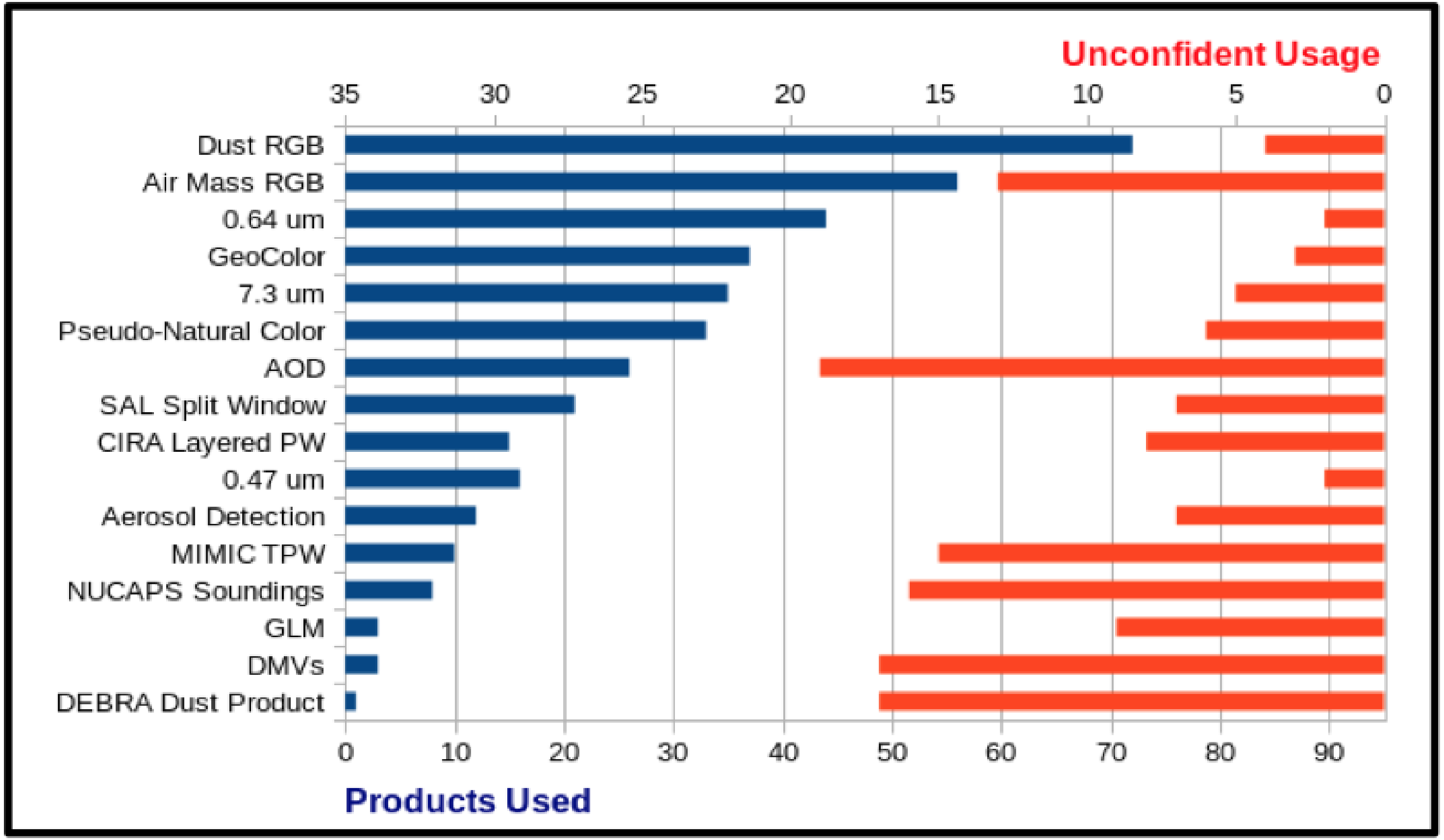




Satellite Products Used for the Saharan Air Layer (SAL) Evaluation (2018)



SAL Product Usage



Satellite data needs

- GLM
  - TAFB is exploring the use of GLM (along with ground-based lightning) to alert mariners to wind hazards associated with strong convection.
    - Gridded lightning can look similar to radar
- Ocean Surface Winds (Scatterometers)
  - Single biggest gap in U.S. satellite constellation for marine forecasting
  - Heavily utilized by NHC for marine & TC forecasting

A Navy perspective on Tropical Weather Applications and Research

26 February 2020

NOAA JPSS/GOES-R PGRR Summit

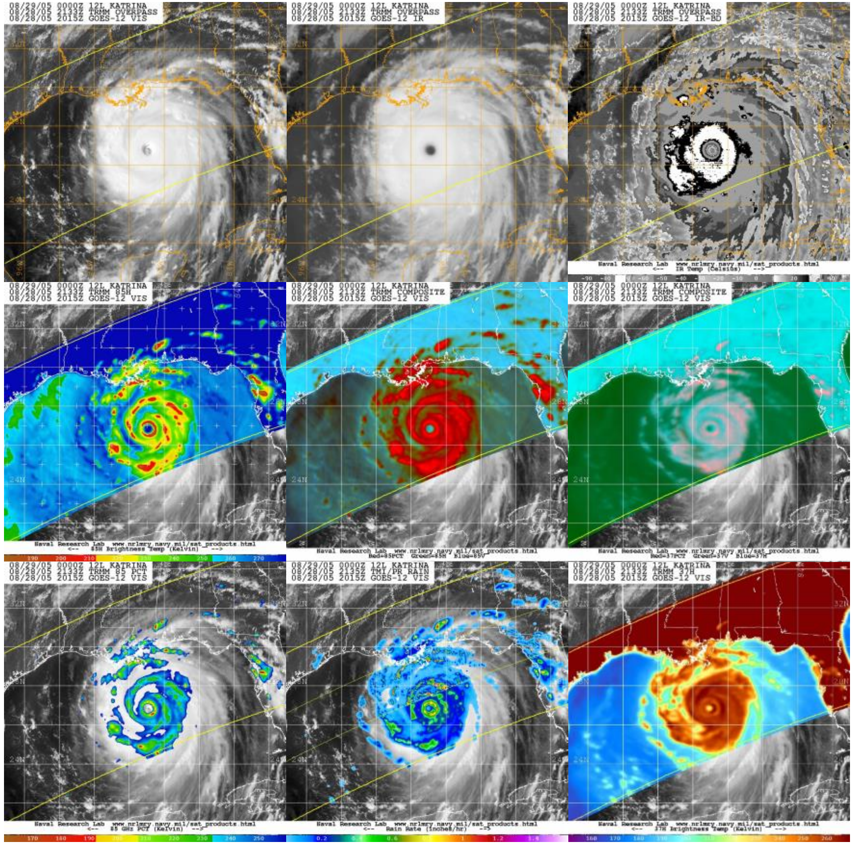
Josh Cossuth

U.S. Naval Research Laboratory

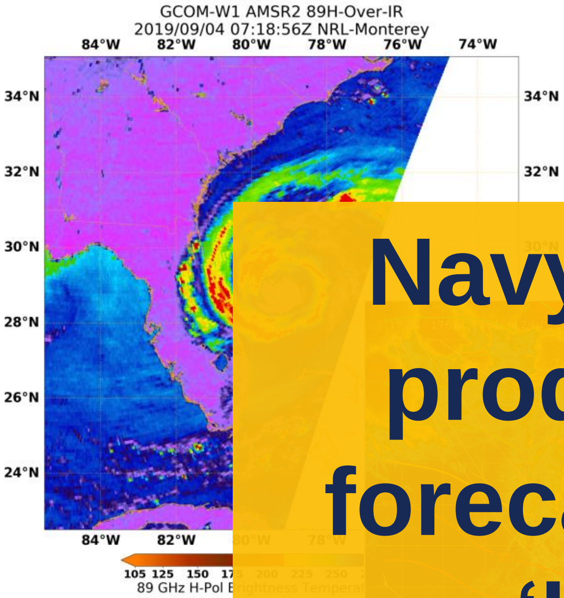
Office of Naval Research

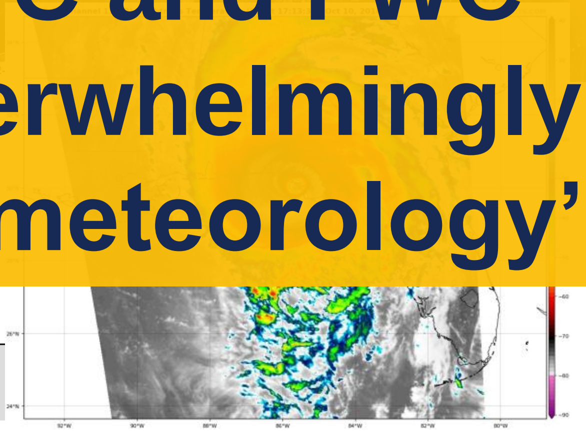
Outline

- Current state of Navy tropical weather forecasting
- Current NRL satellite research projects and efforts
- Related ONR research programs and directions



Cutting-edge Product Access?





Navy users of new tropical products (JTWC and FWC forecasters) overwhelmingly use 'bookmark meteorology'

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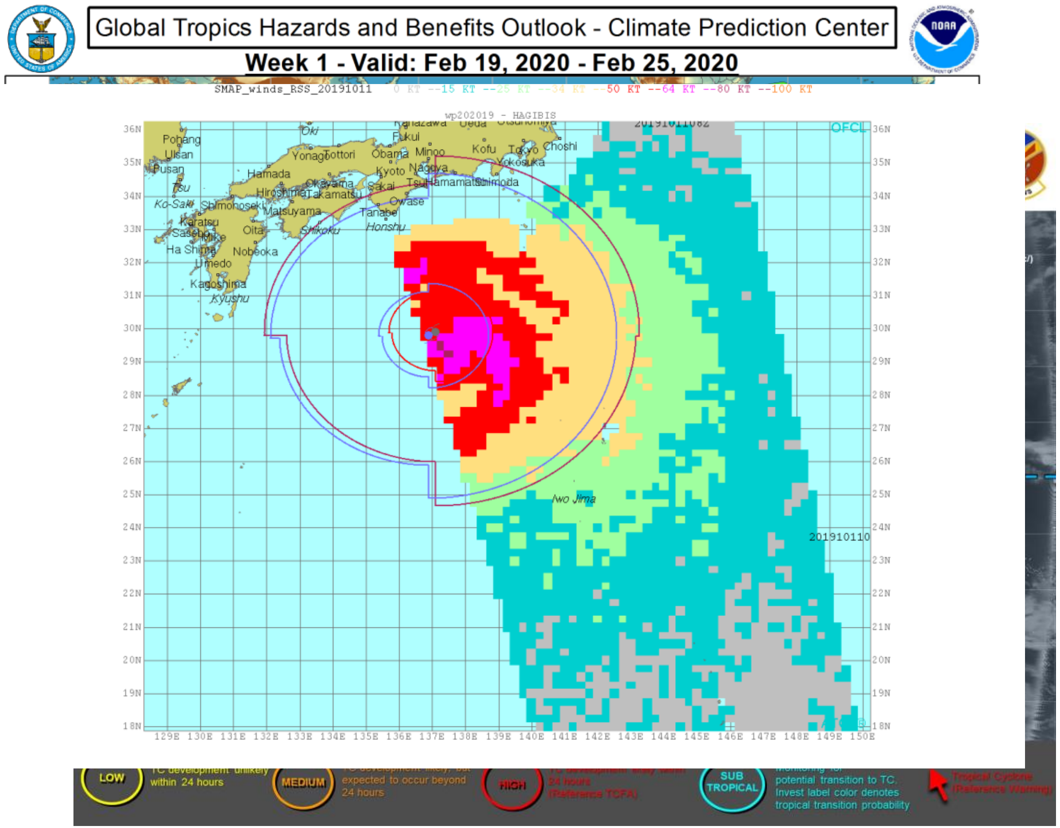
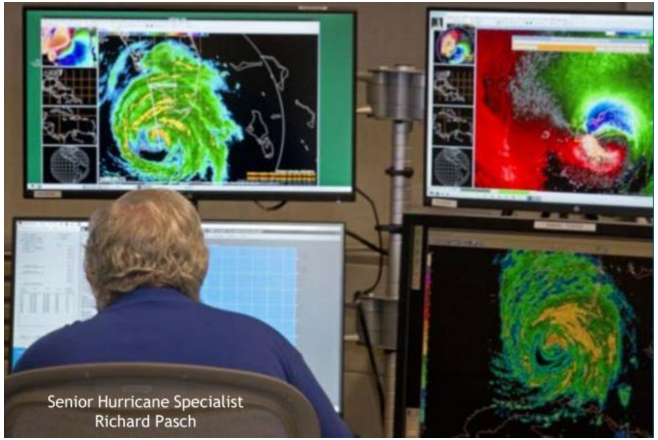
JTWC Forecasting Set-up

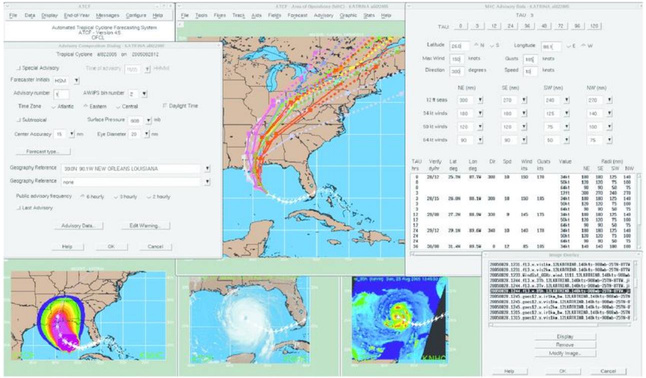
- Formation:
  - Long range: models, MJO, OLR
  - Short range: models, visible and infrared Geo
- Once formed, most tropical cyclone analysis and forecasting occurs within the Automated Tropical Cyclone Forecasting (ATCF) environment
  - Increasing concurrent testing of AWIPS-2
- To maximize utility of satellite products, JTWC forecasters need to access to information within the ATCF
- While using NRL TC webpage (and CIMSS, CIRA, etc.) helpful, it is not integrated into operations



Relevant User Challenges

- NOAA satellite data and products are essential toward fulfilling the Navy's mission
- Need better integration of tools and products into decision making systems
  - For tropical cyclones, that is ATCF
  - Websites are great as proving grounds and prototypes, but useful products should be transitioned into operational software for their potential to be fully realized
- For existing products, difficulties occur with:
  - Reliance on research tools that have not be operationalized
  - High latency (especially for polar orbiters)
  - Improper planning for new satellite feeds
  - Lack of continuity or training for product replacements

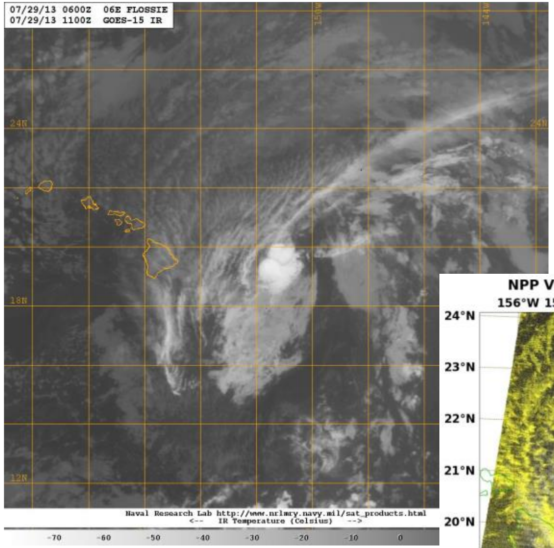


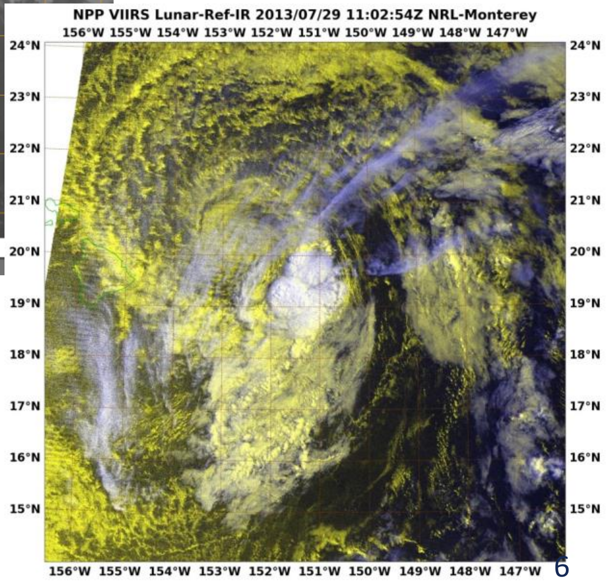


Towards Unified Processing

- NRL has been developing a python-based, open source satellite process package – GeoIPS (the Geolocated Information Processing System) to drive near real-time product generation. Goals:
  - Share NRL product knowledge with meteorology community
  - Leverage new developments back into Navy operations using the same platform for research, development, and operational processing

- Base prototype code now available on GitHub:
  - https://github.com/USNavalResearchLaboratory/GeoIPS





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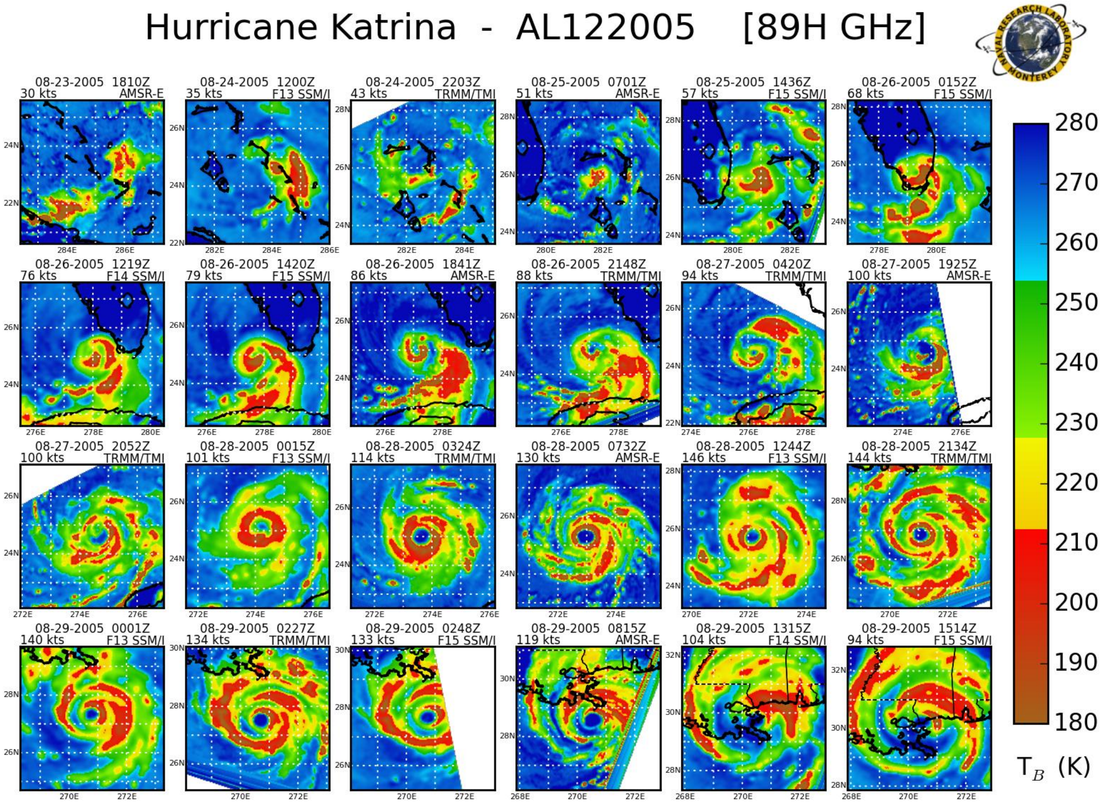
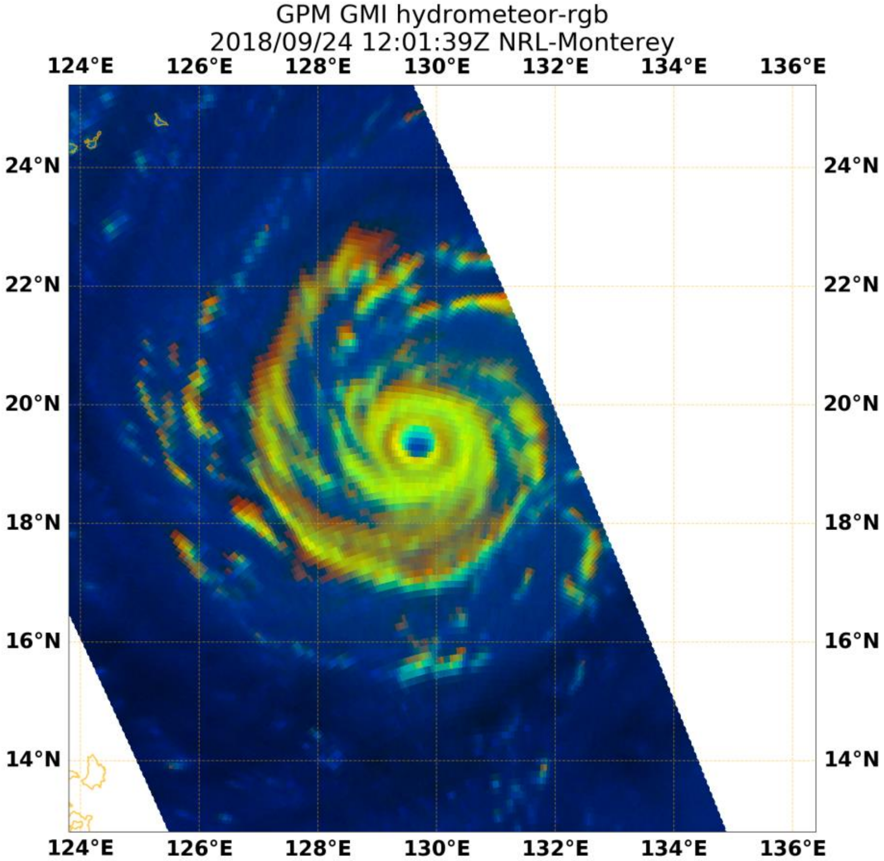
Developer Goal: New products for new needs

- Desirable to leverage a developer platform that is shared with the operational system
  - Current vision is toward sharing python libraries
- Work with users to mitigate largest operational shortfalls and anticipate upcoming needs:
  - Need to be agile with available observing constellation
  - Get ahead of current capabilities – focusing on storm structure as track and intensity metrics become saturated
- Develop and validate new visualizations that describe highly evolving situations

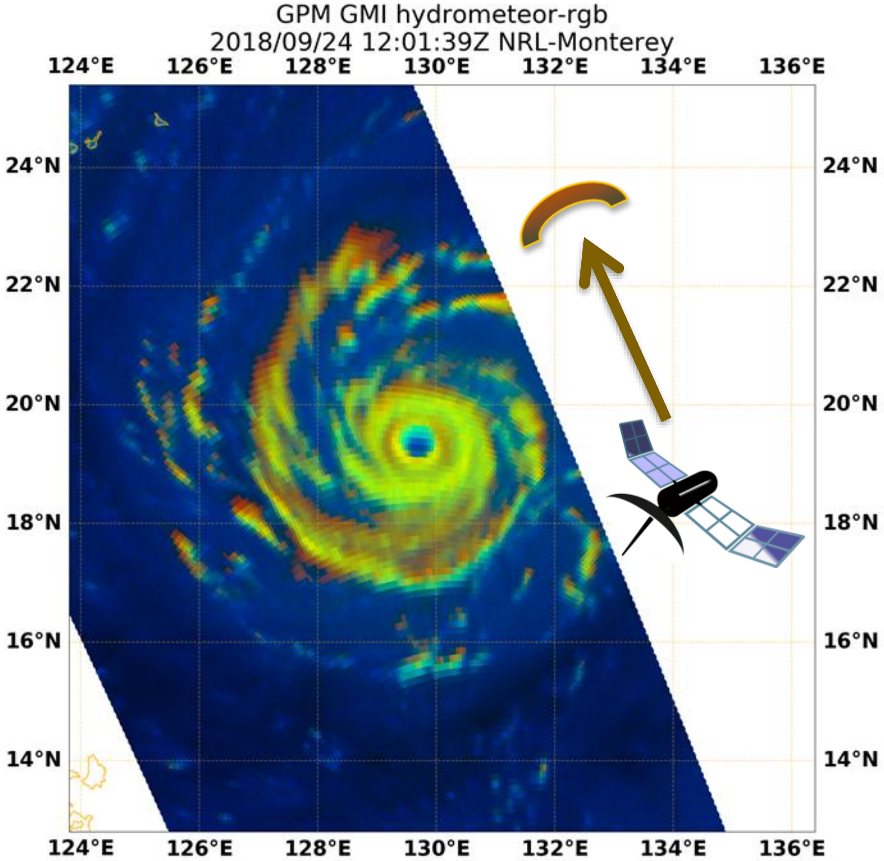


Hydrometeor False Color

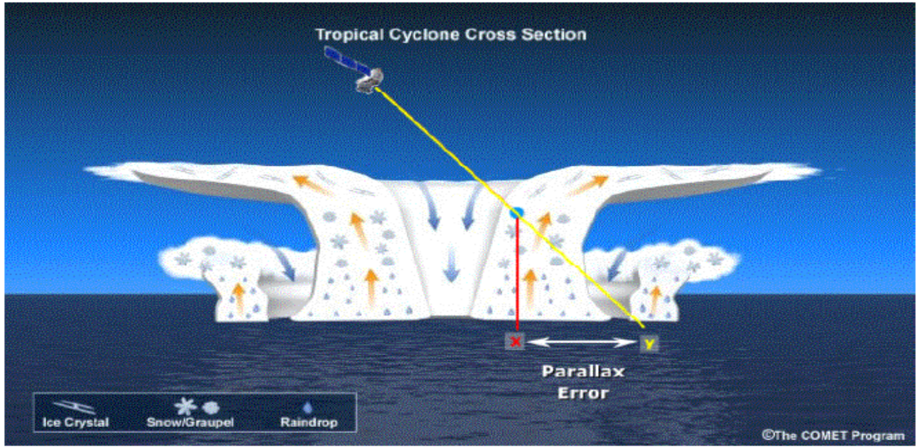


- Ice scattering and liquid emission signals are combined to provide diagnosis of microphysics
  - Used to discriminate vertical convective structure and its symmetry.
- In this case:
  - Relative shading of yellow/orange indicates vertical alignment of concentric eyewalls and banding
- Interpretation:
  - **Red** pixels represent convective ice only
  - **Green** pixels show low level precipitating liquid water and land
  - **Yellowish/orange** pixels show varying 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

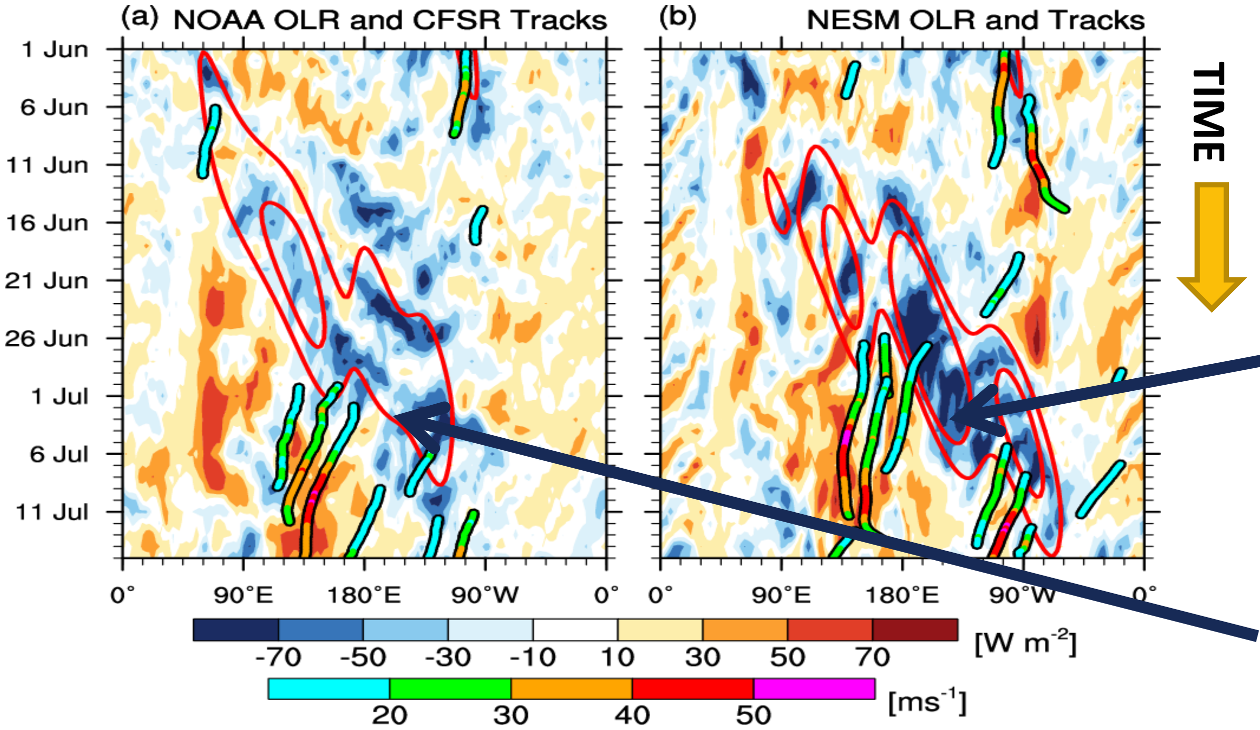
Parallax Analysis



- Combining frequencies also demonstrates magnitude of parallax between ice and liquid convective cores
- Magnitude of parallax error on the order of position error (~10 km). Needs to be accounted for positioning, structure analysis, etc.



TC Prediction using Navy ESPC



0-10°N OLR anomalies shaded from (a) NOAA obs. and (b) 45 d NESM forecast. MJO-filtered OLR anomalies are contoured in red every 15 W m^{-2}.

Navy ESPC 45-day forecast from 2015060112

45-day forecast captures both MJO and elevated TC genesis in this example

TC genesis more common during active MJO phase

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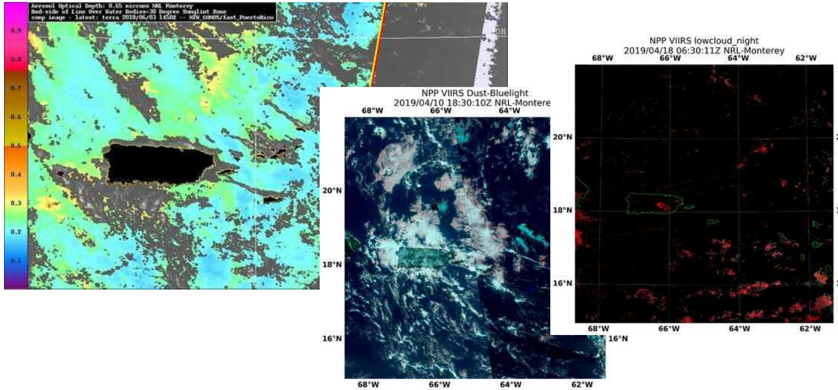
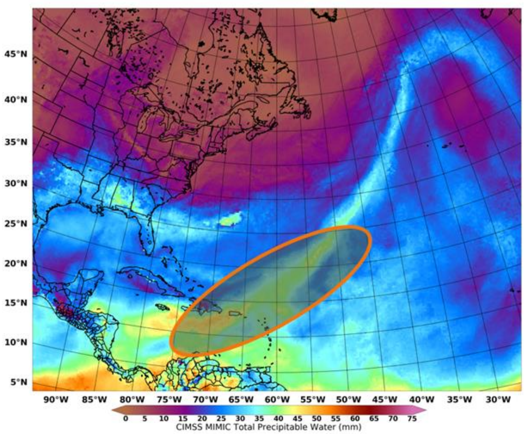
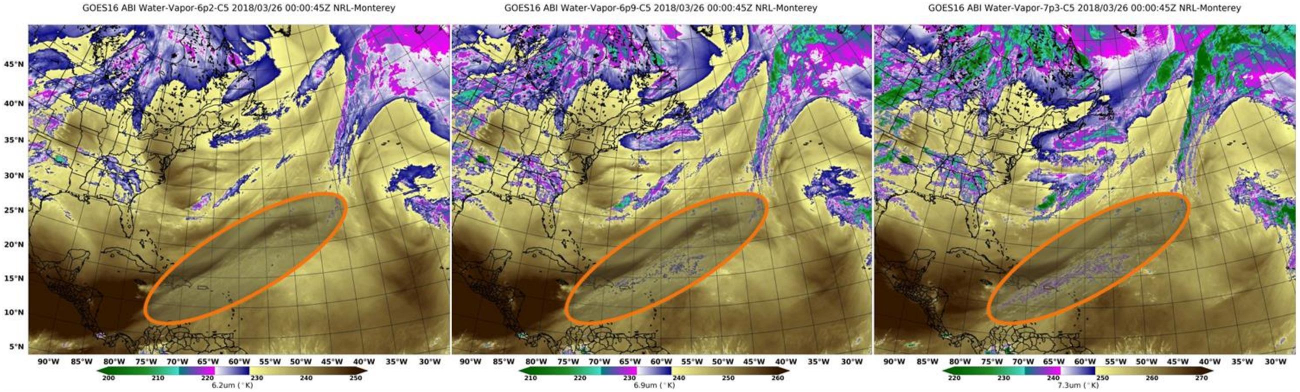
More Tropical Weather Satellite Research at NRL

- (Right) NexSat: demonstration website for real-time new product testing with partners and field campaigns

- (Below) Atmospheric Rivers: comparing structural signature between TPW and GOES water vapor channels







"Upper" Level: ~360 hPa

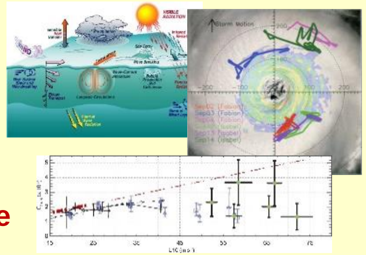
"Middle" Level: ~440 hPa

"Lower" Level: ~620 hPa

ONR's Tropical Cyclone Programs

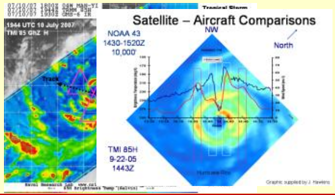
FY00-04: Coupled Boundary Layers/Air-Sea Transfer (CBLAST)

- **Focused on processes that occur in the oceanic and atmospheric wave boundary layers. Re-examined existing observations of hurricane-ocean boundary layer, wave condition, and hurricane energetics.**
- **FY03: A coordinated field campaign of coincident airborne in situ and remote sensing measurements, together with air-deployed, in-situ measurements using a refinement of observing strategies to better understand the air-sea interfacial boundary layer under high winds and strong shear.**
- **Improved understanding of drag at surface led to first realistic pressure/wind relationship in mesoscale models.**



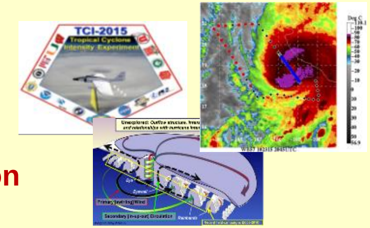
FY07-11: Tropical Cyclone Structure (TCS)

- **Focused on storm scale processes that produced increasingly reliable intensity and surface wind radii predictions (structure). Applied research (ONR 6.2 core) developed and transitioned COAMPS-TC; first skillful operational mesoscale TC model. Two Field Campaign Years with T-PARC and ITOP.**



FY14-18: Understanding and Predicting the Impact of Outflow on Tropical Cyclone Intensification (TCI)

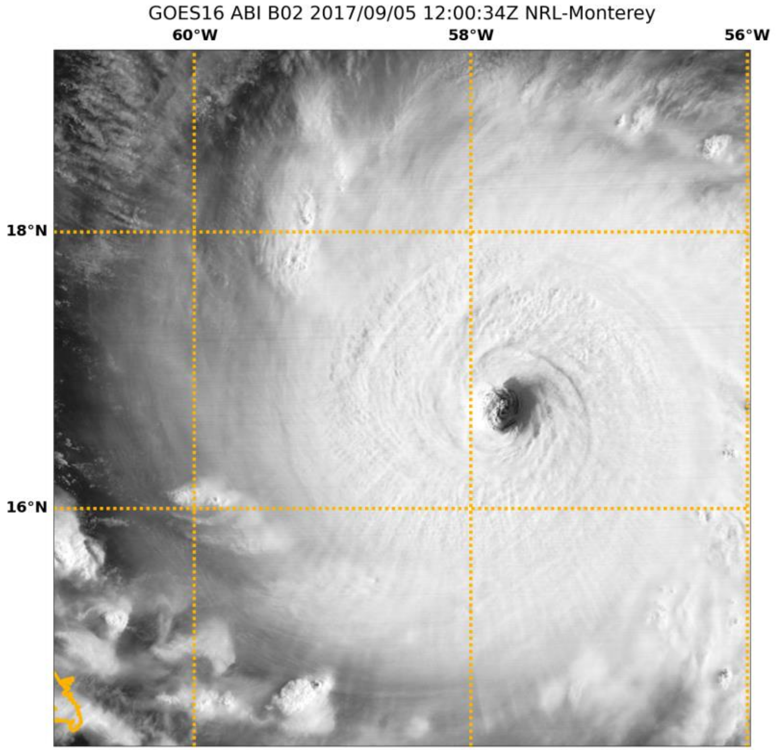
- **Focused on enhancing the understanding of dynamics of the upper-level outflow of tropical cyclones (TCs) and its connection to the larger-scale environment.**
- **Improved upper level physics; demonstrated value of in-situ observations for better model initialization and DA; improved the ensemble through initial condition sensitivity**



Programmatic Formula: Focused research efforts tying state-of-the-science theory with targeting observing methods can successfully improve numerical representation of tropical cyclones towards more accurate prediction.

ONR: Toward the Future

- Programmatic Goals:
  - Tropical Cyclone Rapid Intensification (TCRI) initiative FY20-FY24
    - Leverage high resolution models, field campaign, satellite data, and AI for understanding physical processes that modulate intensity change
  - Geolocated Information Processing System (GeoIPS)
    - Expand initial seed effort by NRL to joint community development with SatPy
    - Interface with other community packages and AWIPS-2 visualization systems
    - Develop standards for sharing satellite products, algorithms, and accelerating transition into operations



Thanks!

Why are hurricanes so important to Wisconsin anyway? Developing satellite-based TC applications at CIMSS

Anthony Wimmers, Chris Velden, Tim Olander, Derrick Herndon

Cooperative Institute for Meteorological Satellite Studies (CIMSS)
University of Wisconsin - Madison

GOES-R:

- Advanced Dvorak Technique (ADT v9.0)
- Hurricane vortex-scale atmospheric motion vectors

JPSS:

- ARCHER center-fixing, integration to AWIPS
- SATellite CONsensus intensity estimate (SATCON)
- Merged TPW

Other:

- AI-based TC intensity estimation
- Next steps

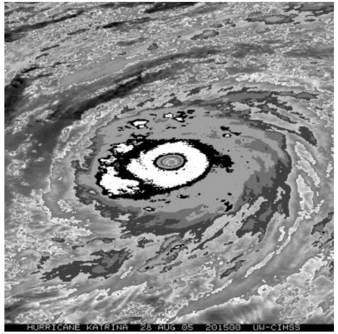
Selected TC Applications-CIMSS: GOES-16/17

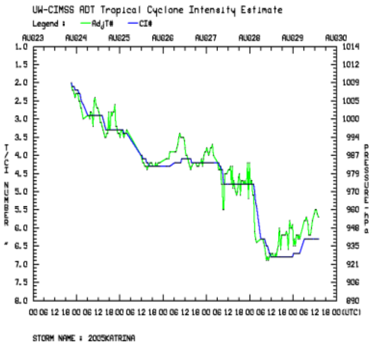
Recent Upgrades to the Advanced Dvorak Technique (ADT v9.0)

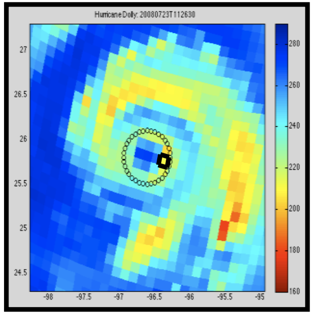
Product Description: ADT is a computer-based algorithm that provides rapid-refresh objective estimates of TC intensity derived from geostationary satellite IR imagery.

Users: -- Operational TC community: NHC, CPHC, JTWC, RSMCs (WMO Regional TC forecast centers), National TC forecast centers

-- TC Research community: ADT is an archive for studies of TC intensity behavior and long-term trends, and a benchmark for new sat-based methods (SATCON, AI-based methods, etc.)







Selected TC Applications-CIMSS: GOES-16/17

Recent Upgrades to the Advanced Dvorak Technique (ADT v9.0)

Current Development Status: Latest version (9.0) is being transitioned into NESDIS Ops. with the goal to have operational ADT estimates available for the 2020 TC season (GOES-16, Atlantic; GOES-17, East/Cent Pacific): https://www.ssd.noaa.gov/PS/TROP/adt.html

Based on prior user feedback, added functionalities in v9.0 include:

1) ARCHER 2.0 for auto TC center fixing--Employs VIS/IR/SWIR from GEO and 37/85GHz from LEO (SSMIS/AMSR2/GMI) to arrive at best estimate

2) Improved operability on Sub-Tropical systems, and storms undergoing Extratropical Transition (ET)

3) Addition of TC surface wind radii estimates based on Knaff et al. methodology

4) Operability with Himawari and GOES-R series (will function through GOES-17 heat pipe anomaly periods with minimal impacts)

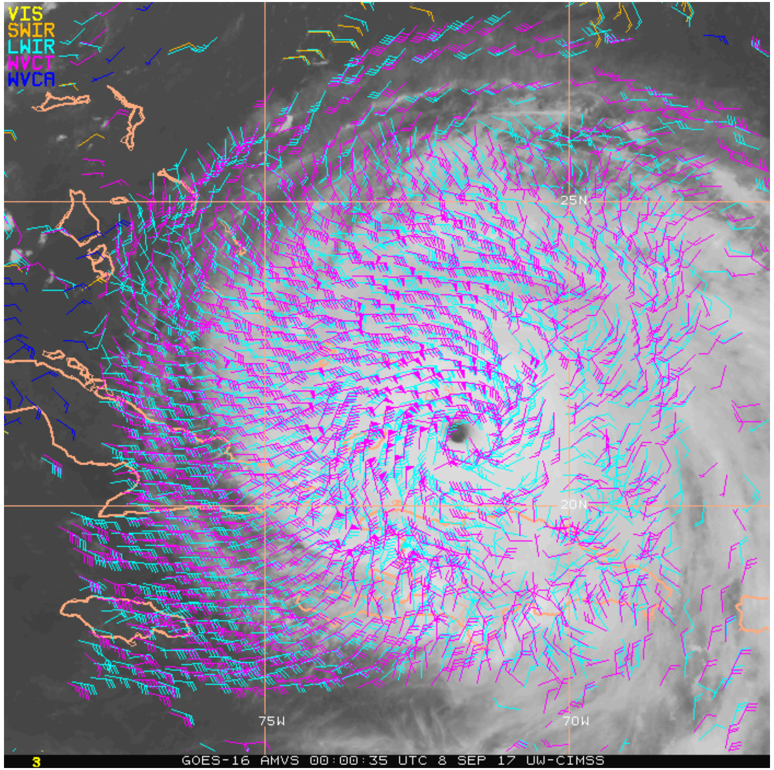
Potential future ADT science upgrades and solutions:

-- Develop a quality indicator for the current intensity estimates

-- Explore AI/Deep Learning approaches to augment the ADT image analysis and retrieval of TC intensity (SSEC2022)

Selected TC Applications-CIMSS: GOES-16/17

Hurricane Vortex-scale Atmospheric Motion Vectors (AMVs)



Enhanced (high spatiotemporal) wind vector estimates around TCs derived from GEO satellite rapid-scan (meso sector) multispectral imagery using the NESDIS operational GOES-R tracking algorithm.

Selected TC Applications-CIMSS: GOES-16/17

Hurricane Vortex-scale Atmospheric Motion Vectors (AMVs)

Users: -- Operational TC community: TC analysis centers (NHC, CPHC, JTWC, RSMCs) and NWP centers (e.g. NCEP/EMC HWRF model, FNMOC/NRL COAMPS-TC model)
-- TC Research community: For studies of TC-env. interactions (e.g. outflow, vertical wind shear), storm-top diagnostics, TC modeling

User Apps: TC analysis--Enhanced wind information to assess TC structure/health
Data assimilation--to better initialize TC NWP models

Current Development Status: Product is in beta testing at UW-CIMSS. Real-time demonstration (GOES-16) planned for the 2020 Atlantic TC season. Proposal is pending to transition the product (in collaboration with NESDIS/STAR) into NESDIS Ops for routine dataset processing and dissemination.

Selected TC Applications-CIMSS: JPSS

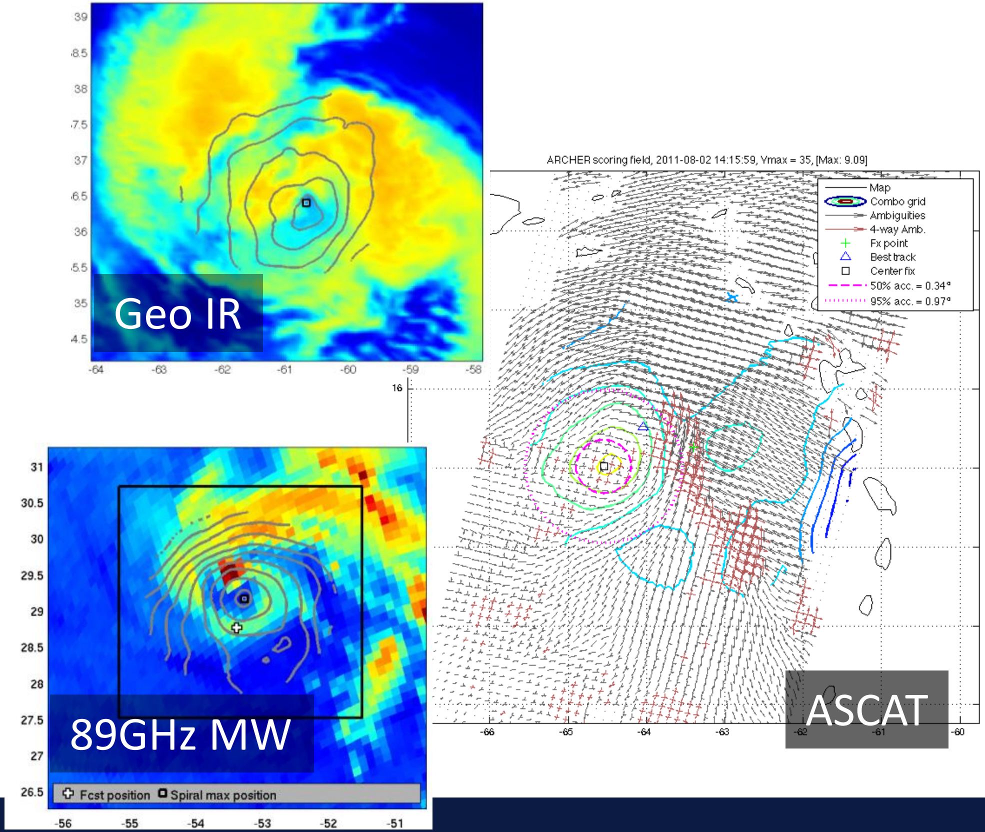
ARCHER (rotational center-fixing)

Purpose:

- Resolves a TC rotational center automatically from multi-platform satellite imagery (Geo, JPSS, scatt.)
- Includes <u>uncertainty</u> estimates
- Used as a starting point for many other algorithms

Development in JPSS

- Integrate ATMS and VIIRS
- Incorporate into the GeoIPS platform, which will bring this product output to AWIPS in an open-source, standardized format.



Selected TC Applications-CIMSS: JPSS

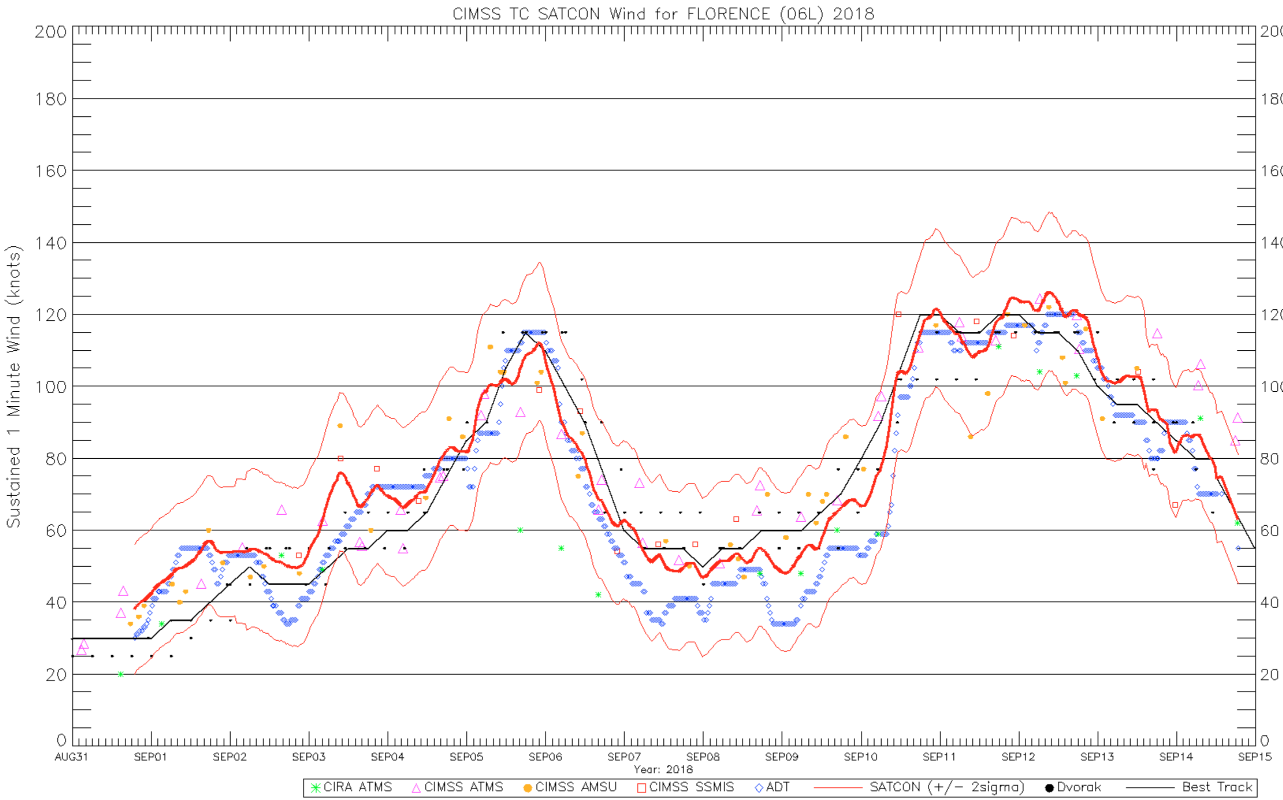
SATCON (Satellite Consensus TC intensity estimation)

Purpose:

- Produces an optimized estimate of TC intensity by incorporating ADT, MW-derived estimates.

Development in JPSS

- Incorporate JPSS-1+
- Reconfigure to work as a backend on GeoIPS



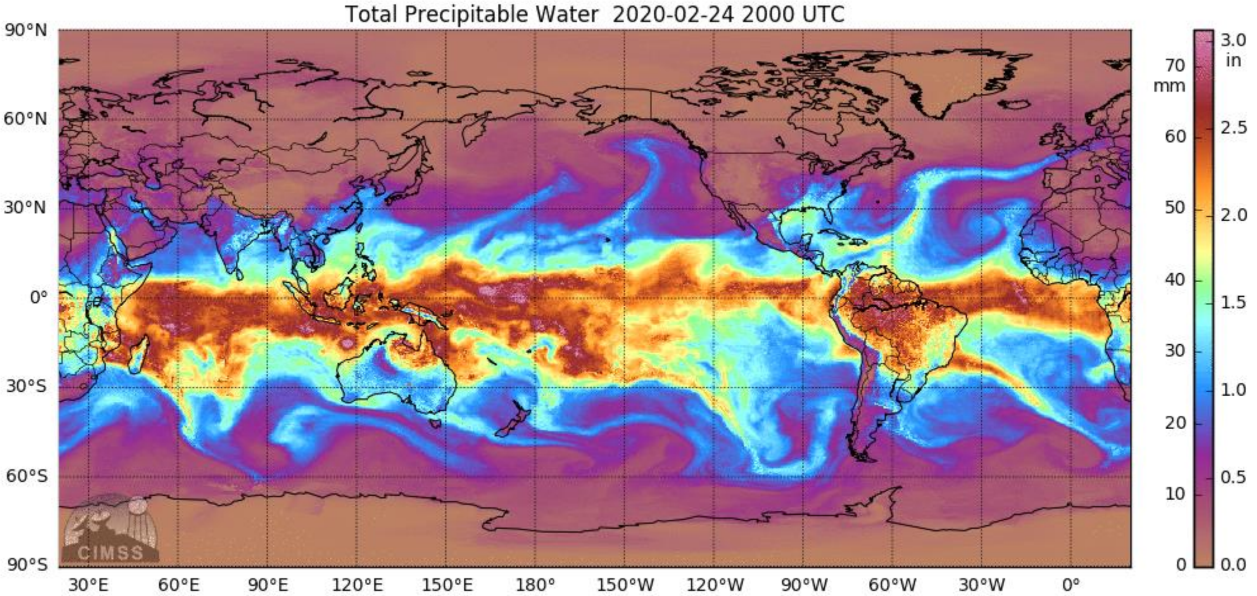
Selected TC Applications-CIMSS/CIRA: Merged TPW

Purpose:

- Present tropical weather environment, show critical moisture thresholds for TC growth/decay, atmospheric rivers, stability (layered)
- (More in the Hydrology session)

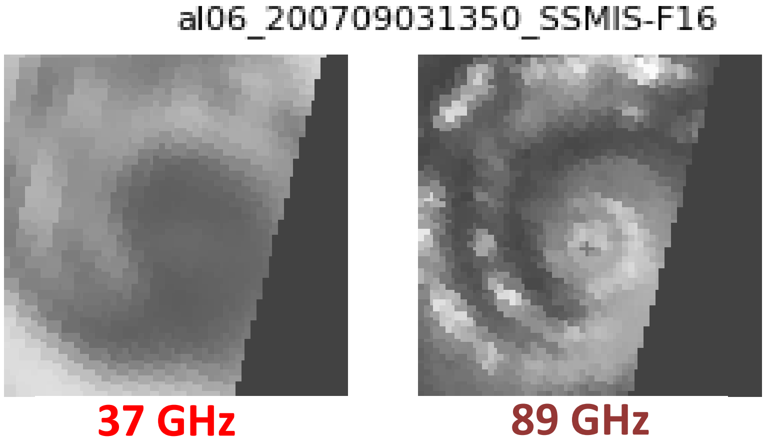
Development in JPSS

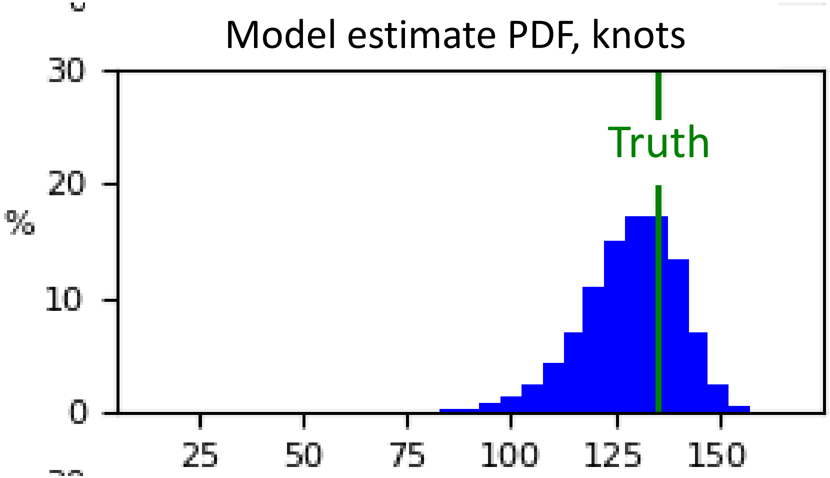
- Incorporate JPSS-1+
- Merge CIMSS's MIMIC-TPW and CIRA's Blended TPW, for the best of both worlds



Selected TC Applications-CIMSS: Other

AI-based TC intensity estimation





Summary:

- Demonstrates the ability of AI to produce a probabilistic, near SoTA estimate of TC intensity from PMW imagery (Wimmers et al. 2019).

Future Work:

- Supported by ONR for further development to use more complicated inputs and structured results.

Selected TC Applications-CIMSS: Other

Next steps: Managing a crowdsourced AI competition

Purpose:

- Use the wisdom of the crowd to determine the best TC intensity ML method
- Partnering with Kaggle and NCEI

Details:

- NCEI provides a training dataset (HURSAT)
- Kaggle members develop ML models to estimate TC intensity
- Models are validated with a *subsequent* TC season
- *The Kaggle site remains active for years afterwards, for future ML model intercomparison*

Extras

Selected TC Applications-CIMSS: GOES-16/17

Hurricane Vortex-scale Atmospheric Motion Vectors (AMVs)

Attributes of the enhanced AMV product for TC apps include:

1) Uses regional ('MESO') scans of VIS/IR/WV with 1-min. sampling that can be pointed at targeted regions like hurricanes within view of GOES-16.

2) Tailors the AMV processing to optimize coverage to capture smaller-scale TC flow fields (e.g., use full spatial res imagery, increase target density, relax QC constraints)

3) Employs novel optical-flow tracking methodology to further enhance the TC cold cloud central dense overcast region (CDO--storm top)

4) Datasets can be produced in real time at 15-min intervals for rapid info refresh

Potential future product upgrades and solutions:

-- Document/validate the enhanced vector quality, refine QA procedures/thresholds

-- Explore novel DA methods (dynamic initialization, Hybrid Ens.) to better exploit the increased information content on hurricane scales to improve model predictions

Tropical Weather

A Developer Perspective

J. KNAFF, CORP, RAMMB

What Needs Current Products Address?

- **TC Intensity estimation**
- **TC wind structure estimation**
- **TC intensification**
- **TC Formation**
- **TC environmental monitoring**
- **Forecaster efficiency**
  - **Reduce number of products**
  - Outputs go directly into operational workstations

Product	Purpose	Development Inputs	Product Inputs
Hurricane Intensity and Structure Algorithm (**HISA**) OSPO NDE	1. 1-min maximum winds 2. 34-, 50-, 64- knot wind radii 3. 2-D winds ATCF FIX	MIRS Retrievals • ATMS • AMSU Best Tracks Aircraft times	MIRS Retrievals • ATMS • AMSU TC Location TC intensity (wind radii)
Multi-Platform TC Surface Wind Analysis (**MTCSWA**) OSPO NDE (ongoing)	3-hourly 2-D surface winds with TCs 1. Radius of Maximum Winds 2. 34-, 50-, 64- knot wind radii ATCF FIX NetCDF GRAPHIC	IR-based proxy for flight-level winds AMSU/ATMS 2-D winds ASCAT AMVs (global) TC Best Tracks Aircraft for validation	TC intensity (estimated) TC location (estimated)Global Constipation of Geostationary satellites AMSU/ATMS 2-D winds ASCAT AMVs (global)
Rapid Intensification Prediction Aid (**RIPA**) Operational at JTWC Web for NHC/CPHC	Global forecasts of probabilities associated with Rapid Intensification (various threshold and lead times) Deterministic forecast for Intensity Consensus ATCF AID	SHIPS/LGEM Large-Scale Diagnostics (Developmental) • IR-based convective vigor • IR-based size	Real-time SHIPS/LGEM Large-Scale Diagnostics (NHC, CPHC, JTWC)
Tropical Cyclone Formation Product (**TCFP**) OSPO NDE (ongoing)	Global forecasts of probability of TC formation (34-kt) for 0-24h, 24-48h, 0-48h Web	Global Water Vapor Imagery GFS analyses TC Best Tracks	Global Water Vapor Imagery GFS forecasts TC Locations
Proxy Visible CIRA via LDM ISATSS (NHC –AWIPS-2)	Nighttime visible imagery proxy, seamless night-to-day capability IMAGE	VIIRS	ABI

Improvements to existing products

- **HISA**
  - **Create a TC version of** MIRS that uses a TC climatology as the first guess
    - This will result in better convergence in the cloudy scenes near the TC center (i.e., the warm core)
  - Re-consider deconvolution to arrive at higher resolution

- MTCSWA
  - Add L-Band winds (SMAP, SMOS) to the Analysis
  - Add C-Band (AMSR2) and Synthetic Aperture Radar (SAR) winds to the analysis

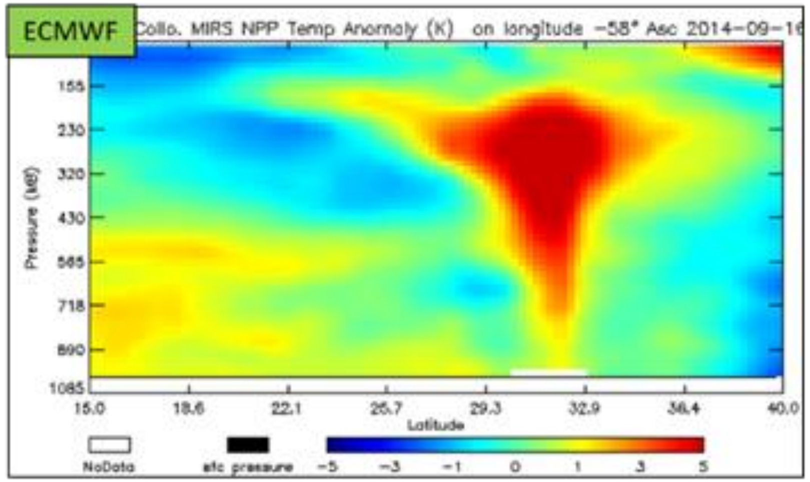
- **RIPA**
  - Add **microwave imagery/products to the mix**
  - Examine additional **satellite-based, and aperture independent metrics for size and intensity**
  - **Add subjective information**, which historically has been/is available in real time.

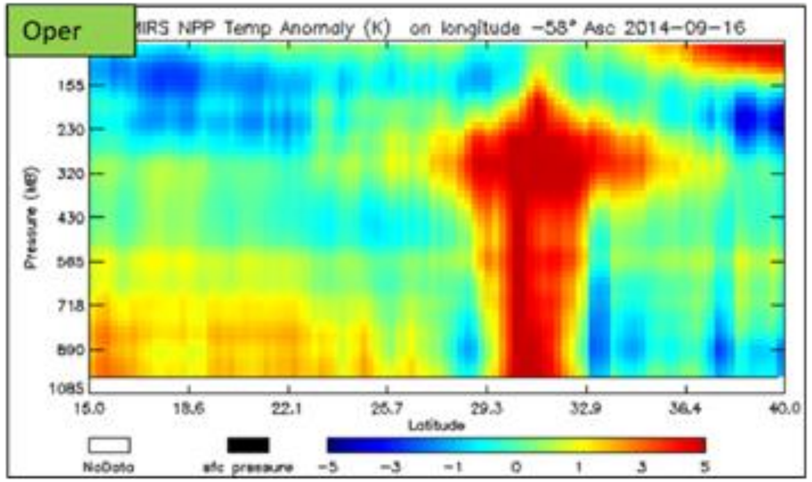
- TCFP
  - Follow and track suspect disturbances
  - **Extend to 5-days**
  - Utilize model Ensembles

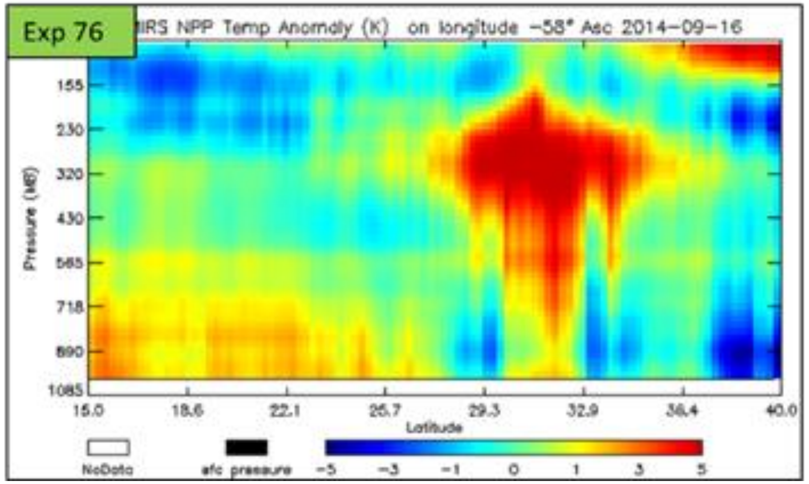
- Proxy Visible
  - Improve the representation of cold/high clouds by using more ABI channels or more advanced statistical methods

Low hanging improvements… big reward

IMPROVE MIRS Retrievals







Operational MIRS

- Fails to converge to a solution near the center
- Warm core poorly estimated
- This is not a systematic error!

MIRS using a COSMIC TC climatology

- Convergence in the core
- More realistic warm core structure
- Better climatologies could be developed

Low hanging improvements… big reward

MTCSWA with SMAP, SMOS, AMSR, SAR winds

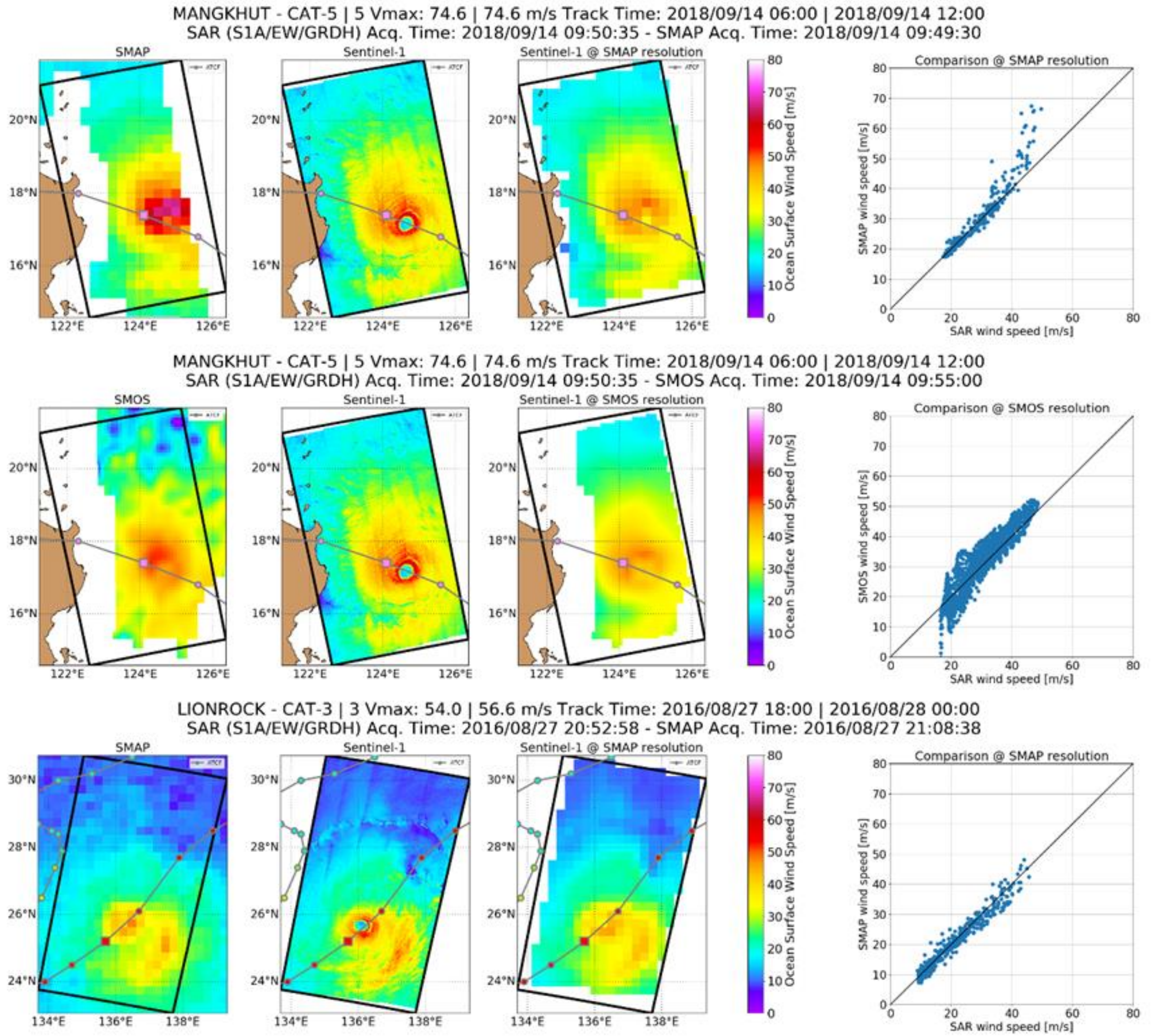


Image credit: N. Reul, A. Mouche (IFERMER)

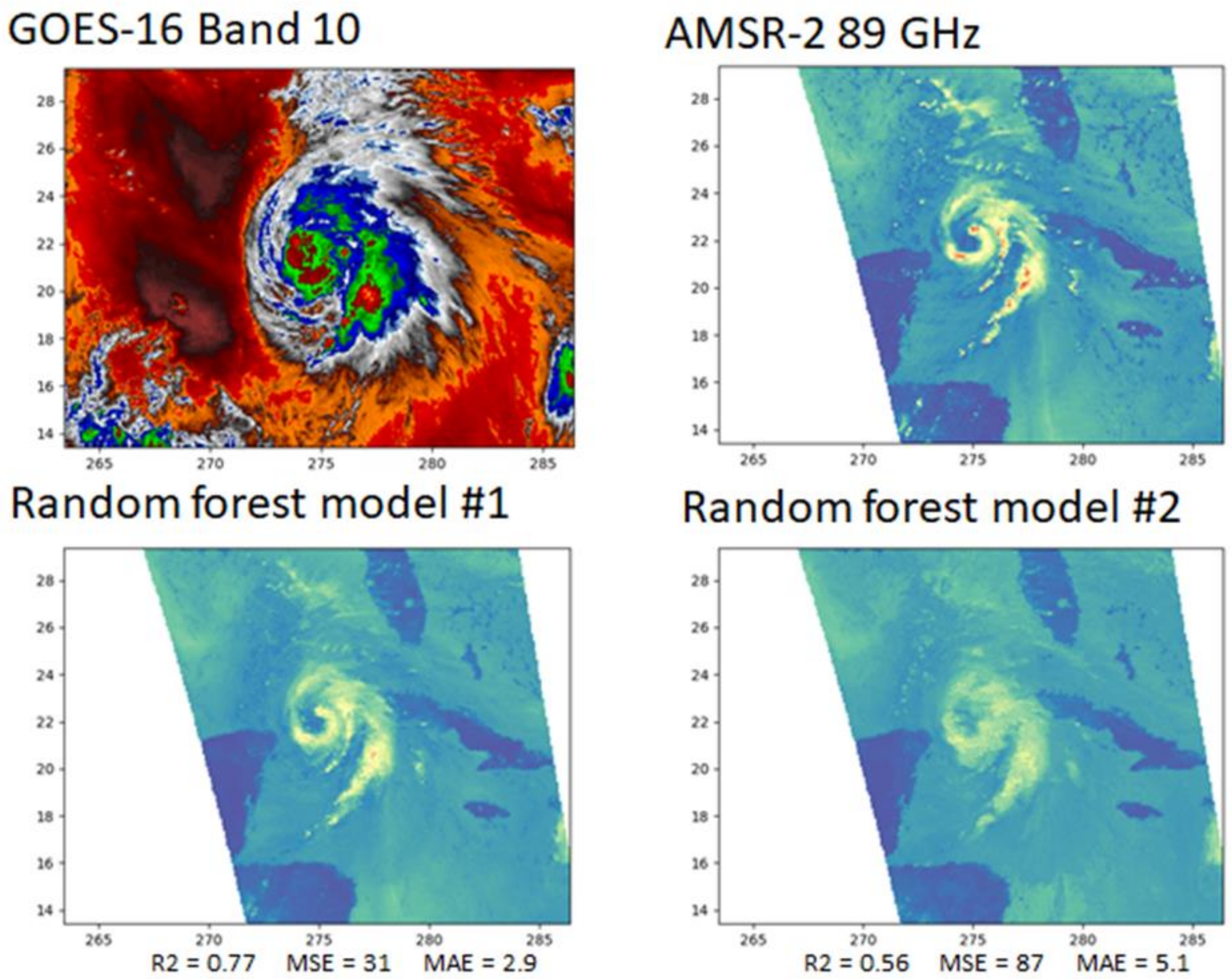
Problems I think should be addressed

1. **Understanding GLM Lightning**… what is seen, when, and what it means?
2. **Improving the use of GOES Atmospheric Motion Vectors** to monitor the TC environment in the 0 to 8h period when models are still running
   - Calibrated with model based measures
3. Using AI/ML to develop **ABI-based estimates of LEO imagery/products**
4. Use satellite-data to provide accurate (+/- 100%) estimates of the **radius of maximum wind**
5. ABI-based estimates of **mid-level moisture and deep layer vertical wind shear**
6. **Automatically track weather disturbances** (pre-depression, cold lows, squalls etc…)
7. Start estimating **winds associated with all surface cyclones** (extra-tropical cyclones, transitioning tropical cyclones, and overland cyclones)
8. **Operational access to relevant LEO data** (e.g., 89 GHz & 37 GHz imagery, and SMAP, SMOS, & SAR winds)
9. AI/ML, DA or data fitting techniques to estimate of **3-D TC winds**

For many of these items there is a implicit need for labeled data sets

This is where researchers and forecasters can interact

New Products: Synthetic 89GHz imagery



- Provides continuity for forecasters
- Provides rapid updates for forecasters
- Can be used as input to other products (e.g., precipitation algorithms)
- Improves the utilization of ABI

Could be applied to other LEO channels or products

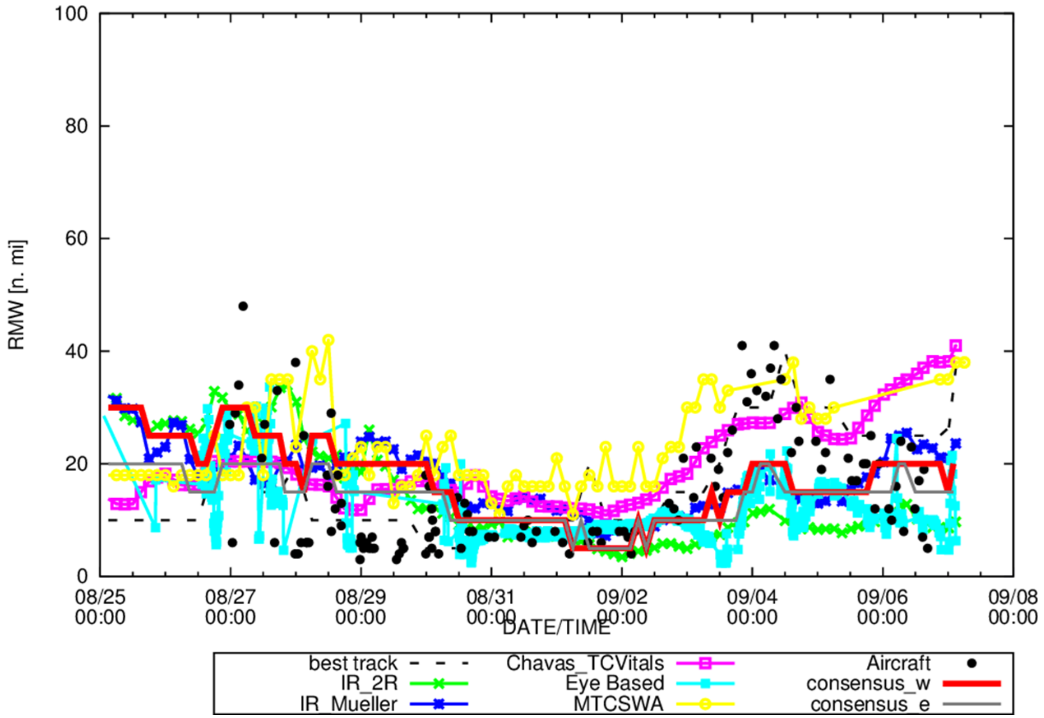
More information during sunlit hours

Image Credit: Chris Slocum

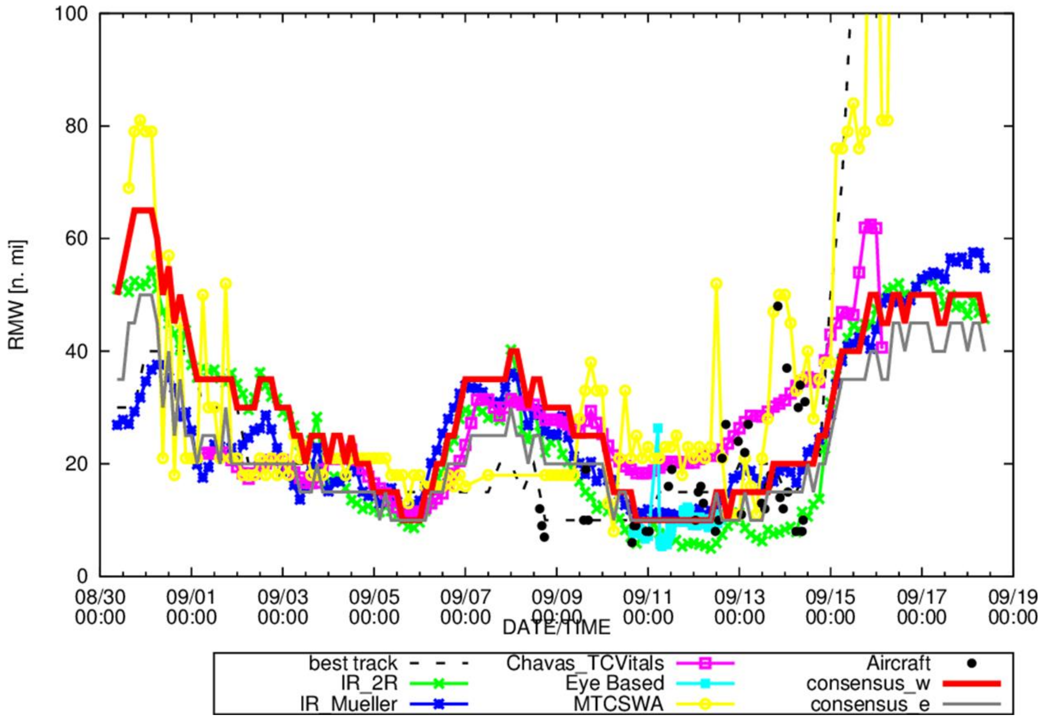
New Products: Radius of Maximum winds

- For improved initiation of NWP
- For Storm Surge
- For wind hazards

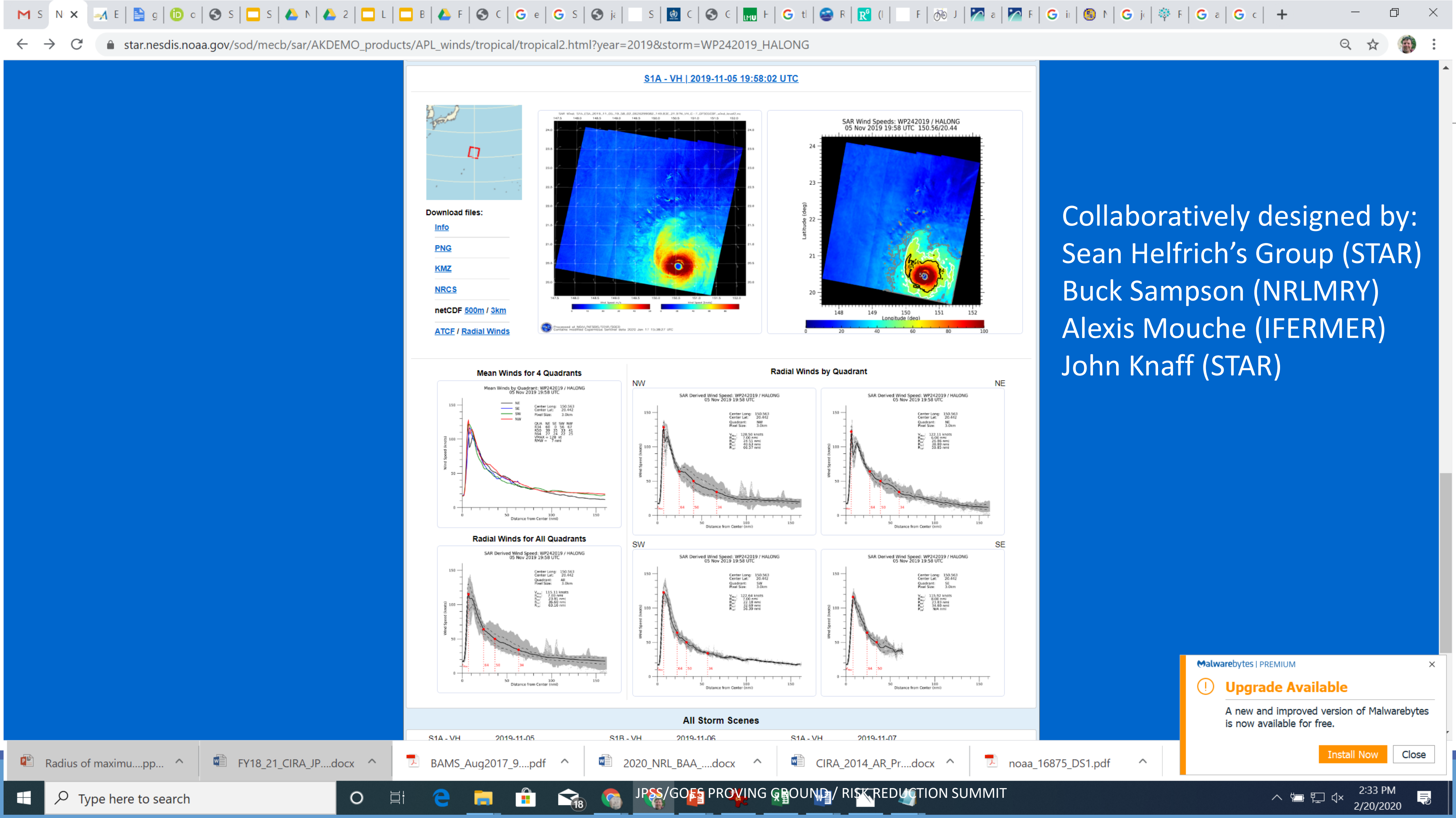
DORIAN (2019)



FLORENCE (2018)



SAR Winds for TCs is in the works



Collaboratively designed by:
Sean Helfrich's Group (STAR)
Buck Sampson (NRLMRY)
Alexis Mouche (IFERMER)
John Knaff (STAR)

JPSS/GOES PROVING GROUND/ RISK REDUCTION SUMMIT

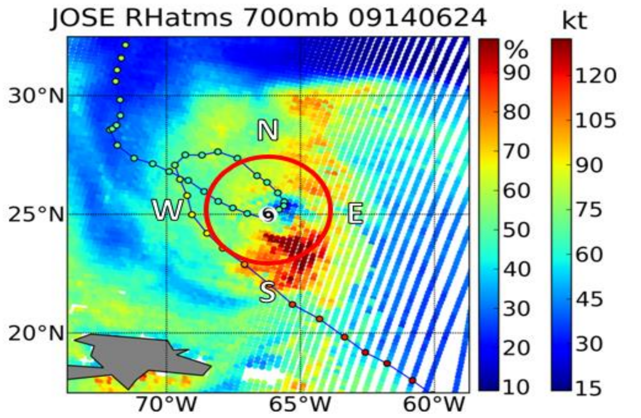
Extra slides

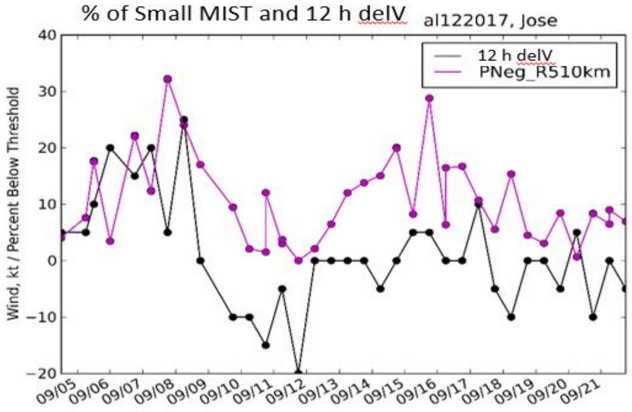
Moisture In-Flux Storm Tool (MIST) (Fall 2019, TC-REALTIME)

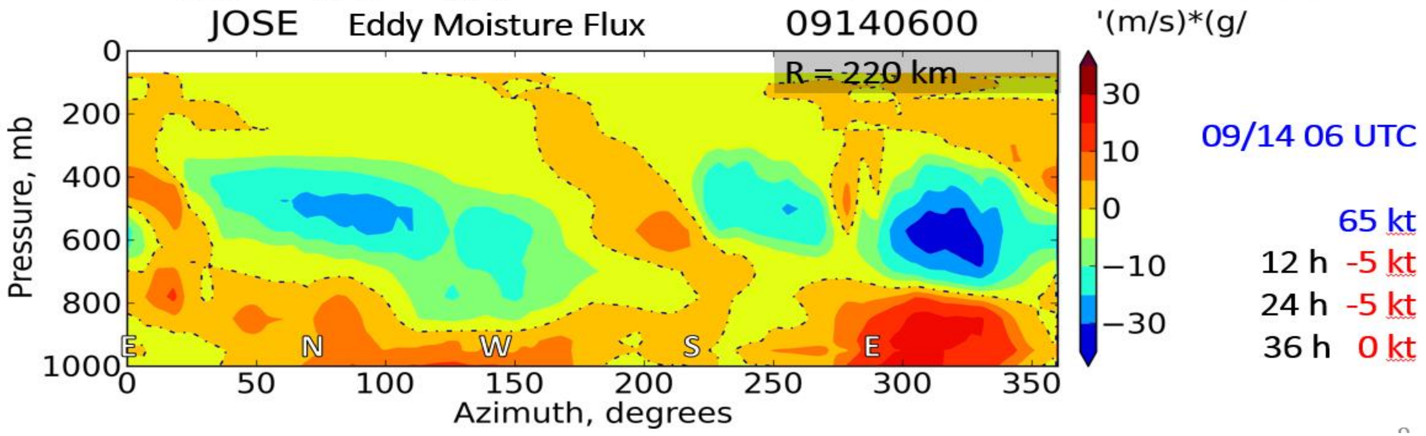
Purpose: use ATMS-MiRS SNPP and NOAA-20 data to

1) develop standalone applications for tracking dry-air intrusions
2) develop dry-air intrusions quantitative parameters for statistical TC intensity forecast models

Status: work in progress on setting up real-time demo for all TC basins







POC: Galina Chirokova

Develop estimates of the 3-D winds in hurricanes using AI, IR imagery and TC vitals

JUSTIFICATION AND PLAN

Justification:

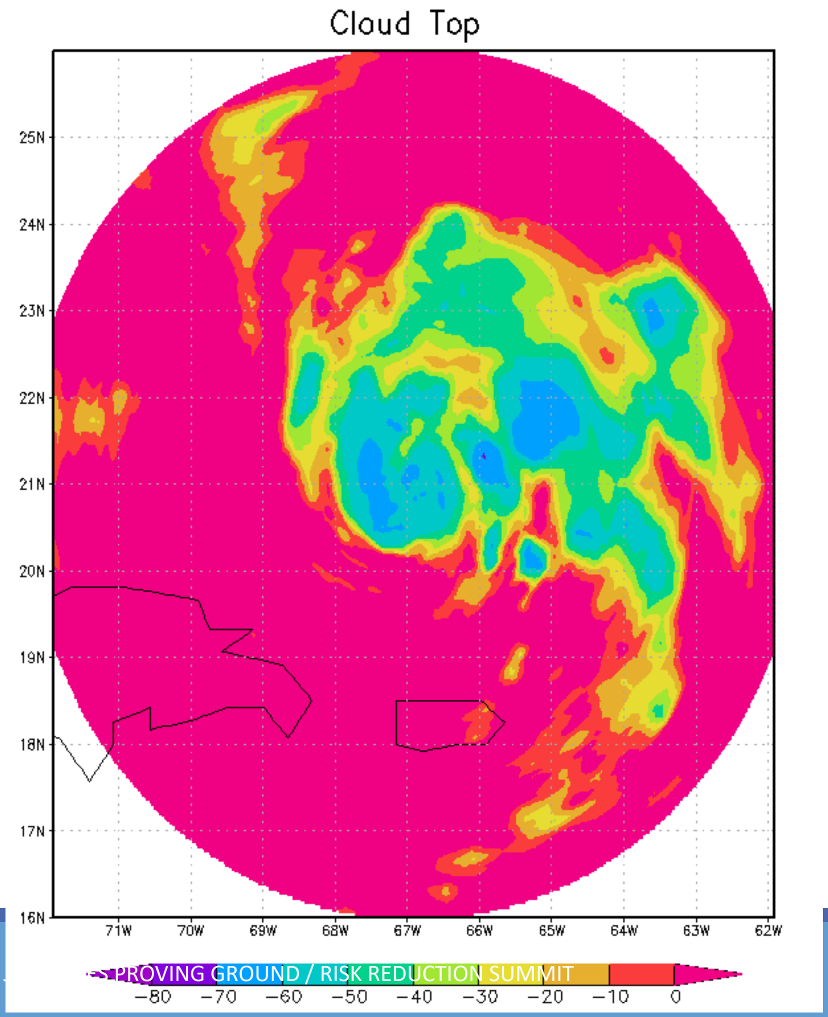
Improved model initialization

Plan:

Use methods developed with GOES-R risk reduction to estimate the 3-D winds using the method of single field principle component analysis (SFPCA)

Development inputs would be HWRF/HAFS simulated ABI imagery and 3-D winds, storm intensity and motion

In application, observed imagery, storm motion and storm intensity would be used to estimate the winds.



EXAMPLE FROM HURRICANE DORIAN (HWRF V2014) 12 UTC 29 AUG, 75 KNOT INTENSITY

INPUT:
Brightness Temp (first panel)
335 @ 11 knots
75 knot intensity

Winds (barbs)
Rel. Vorticity (contour)

Hurricane Intensity and Structure Algorithm (HISA)

HISA provides MW-based TC Intensity estimates:

- Global
- Objective
- Independent of Dvorak

Input:

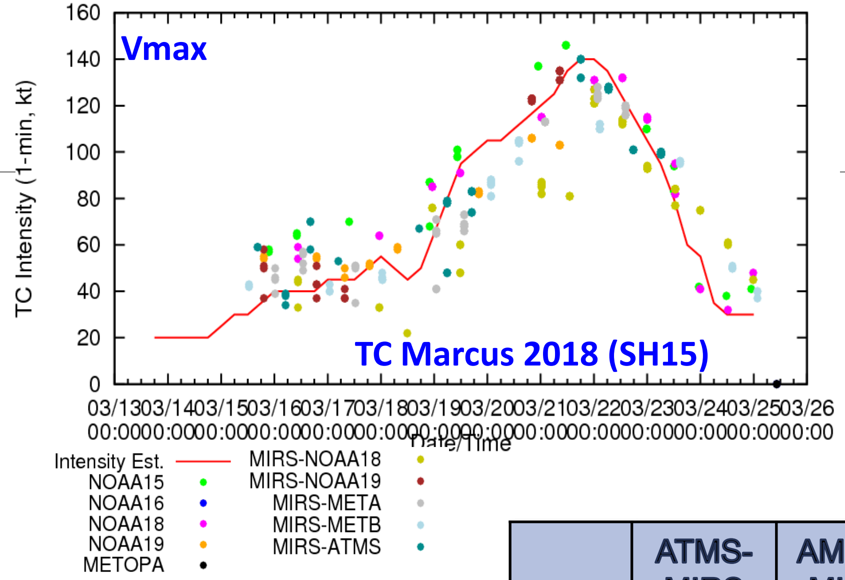
- Temperature profile, CLW from **TROPICS-MIRS** or statistical retrievals
- GFS boundary conditions
- ATCF TC track data

Output:

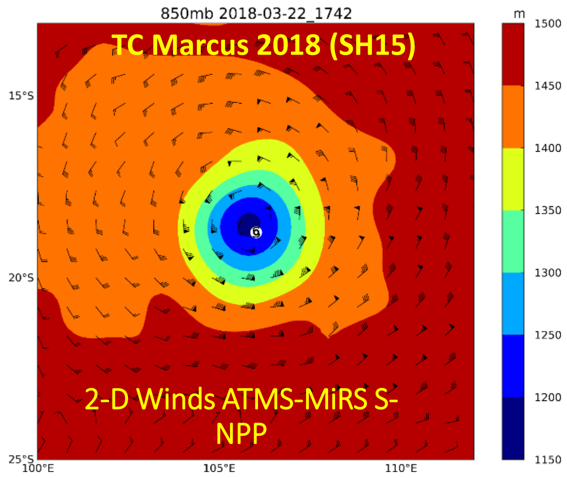
1) Intensity estimates, provided via f-deck
   - Maximum sustained wind (Vmax, kt)
   - Minimum Sea Level Pressure (MSLP, hPa)
2) Surface Wind Radii Estimates (nmi), provided via f-deck
   - R34, R50, R64 for NE, NW, SE, and SW TC quadrants
3) Azimuthally-averaged gradient winds as a function of geopotential height and distance from TC center.
4) Horizontal 2-D balanced winds (kt) for the local TC environment

Operational on ATMS and AMSU on 7 satellites, is upgraded to work with NOAA20 ATMS

Users: NHC, CPHC, JTWC



Results from AMSU and ATMS retrievals



	ATMS-MIRS MAE	AMSU-MIRS MAE
Vmax (kts)	11.1 (1565)	13.2 (4346)
Pmin (hPa)	7.0 (1565)	8.4 (4347)
R34 (nmi)	20.0 (344)	24.9 (1044)
R50 (nmi)	12.0 (215)	10.6 (601)
R64 (nmi)	12.0 (134)	8.9 (336)

Galina Chirokova (CIRA), John Knaff (NOAA/NESDIS), Scott Longmore (CIRA), Mark DeMaria (NOAA/NWS/NHC), Jack Dostalek (CIRA)

AI/ML to track cold lows in imagery

JUSTIFICATION AND PLAN

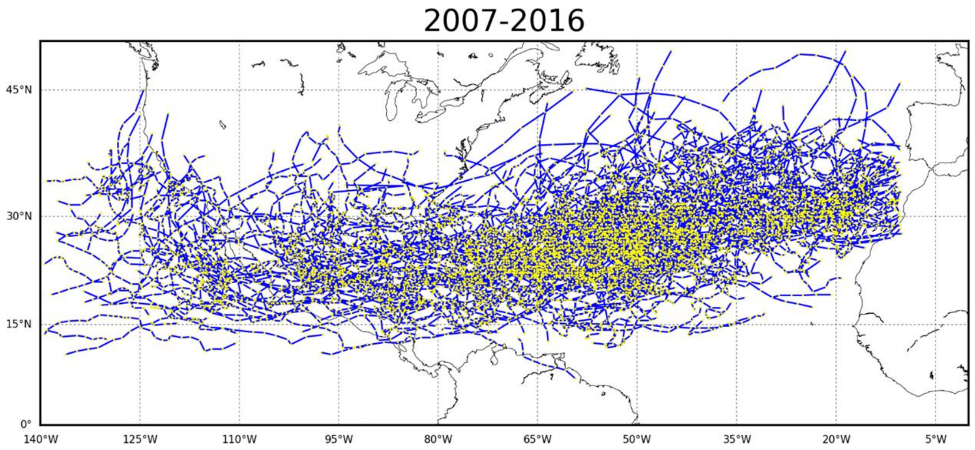
Justification:

These features are still poorly forecasted in global NWP and often impact TC track and intensity forecasts.

Plan:

Use an 11 year track (manual) to train AI/ML to automate the tracking using GOES imagery and AMVs

TRACKS WE WOULD USE



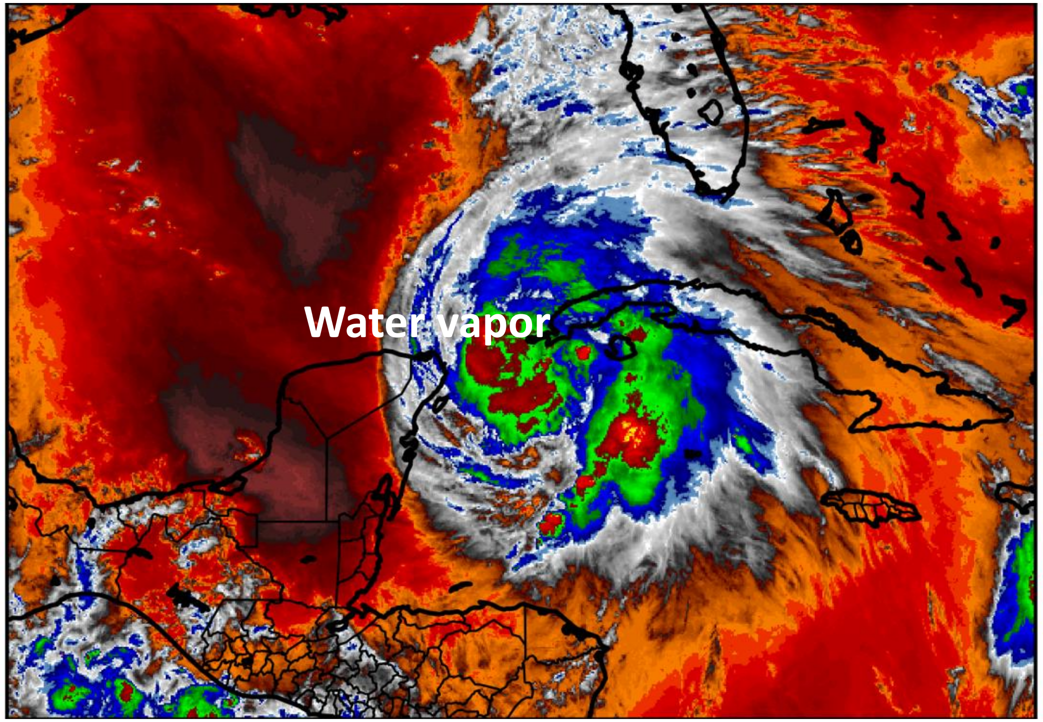
ABI/AHI Synthetic 89-GHz

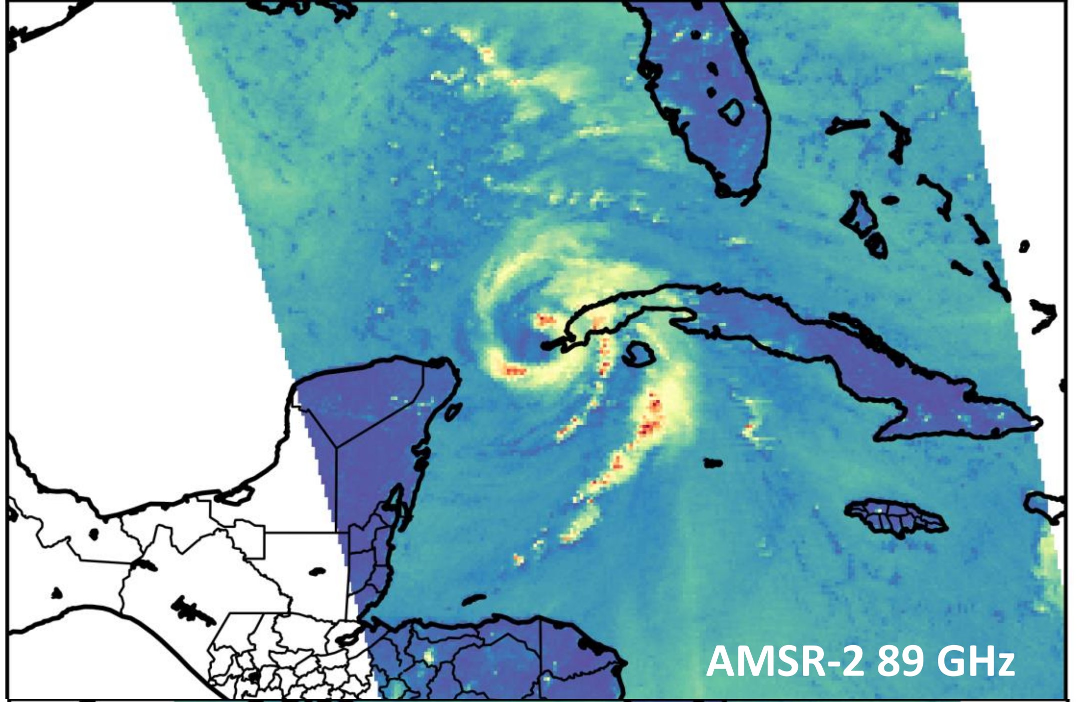
Purpose:

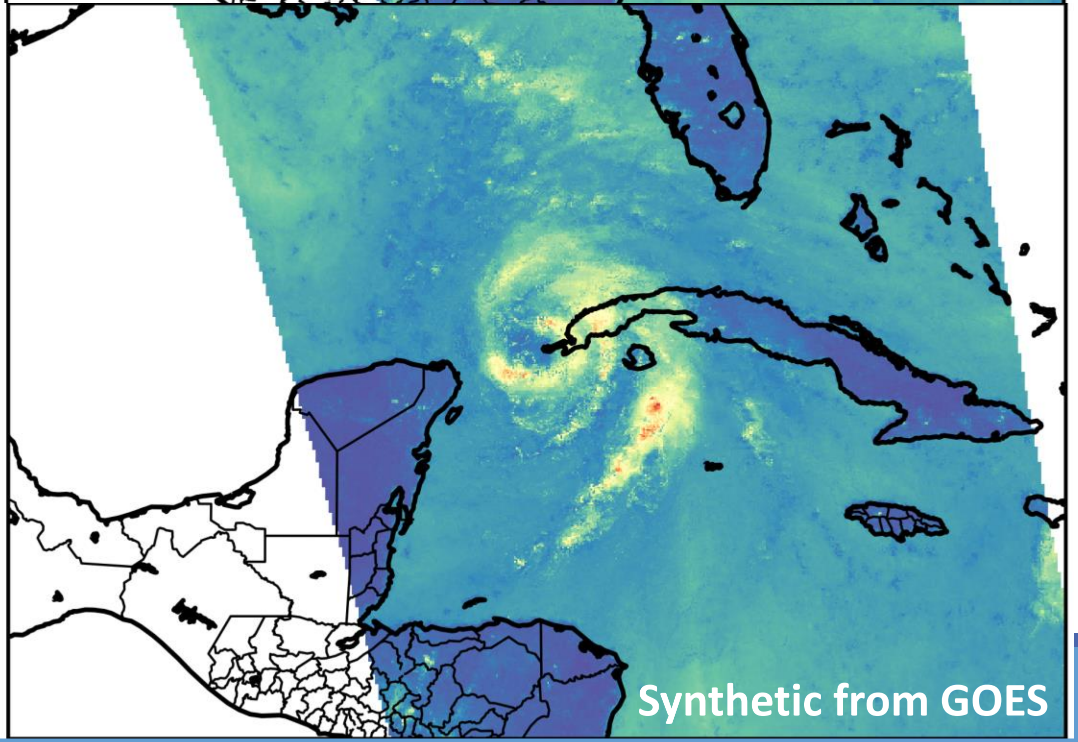
Provide microwave-like data when polar-orbiting data is missing

How:

Supervised machine learning that is trained on features from GOES-16/17 & Himawari-8/9 L1b & L2 products







Tropical Cyclone Formation Product

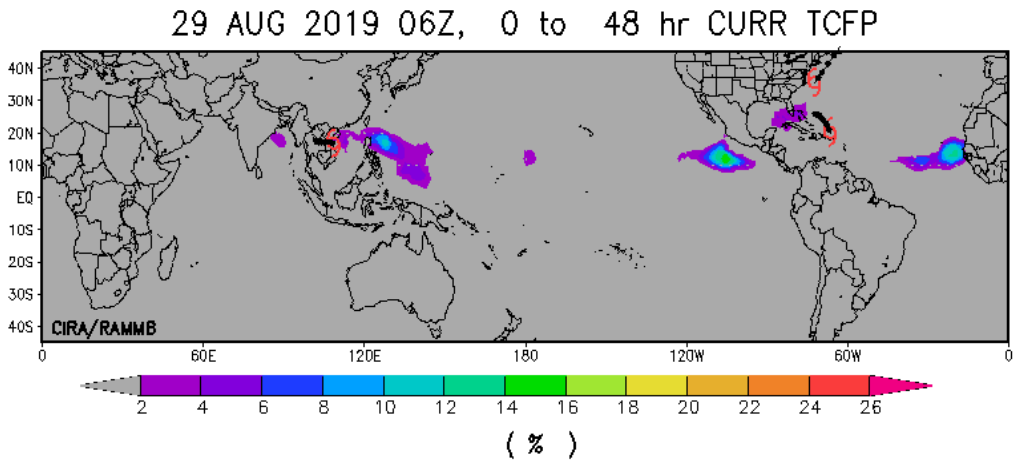
FY20

This product provides global probabilistic forecasts of 24 and 48 tropical cyclone formation

Update to use all geostationary inputs

- Currently degraded
- Enable logic/code to access GOES-17/16 data

EXAMPLE



Improving short-term TC intensity forecasting (Rapid/Unexpected change)

JUSTIFICATION AND PLAN

Improving forecasts of rapid changes in TC intensity are a high NOAA priority

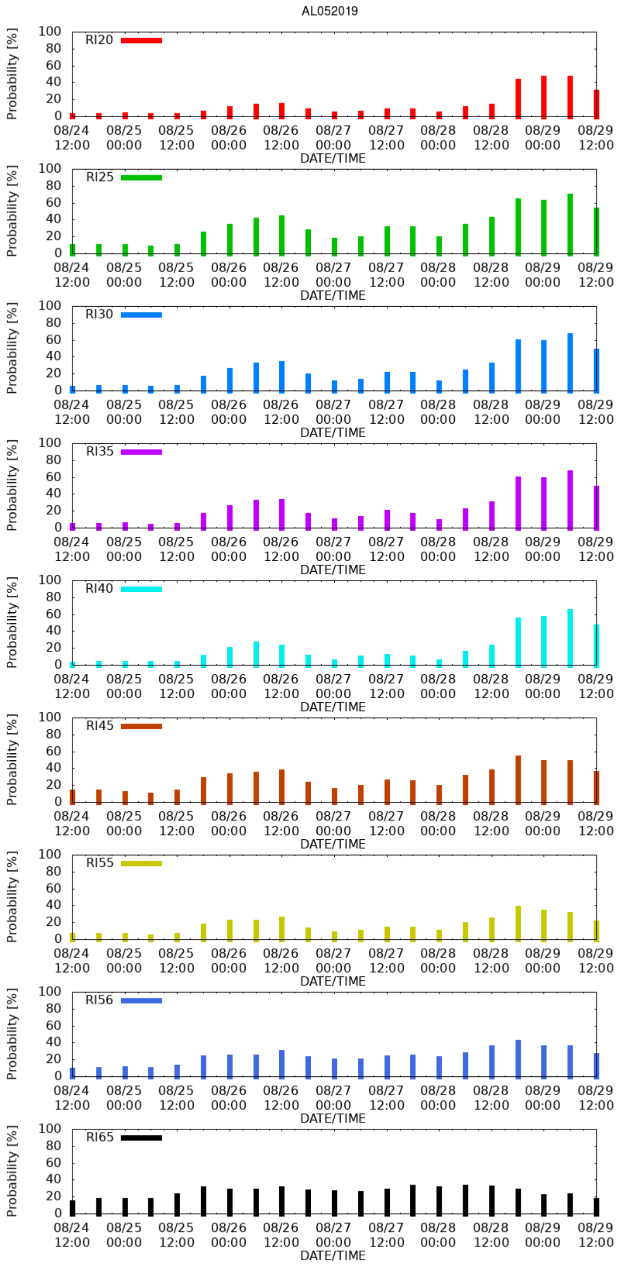
Currently models have been developed for rapid intensification (RI)

PLAN:

Improve current RI guidance

Develop models for Rapid Weakening, Convective decoupling, and extratropical transition

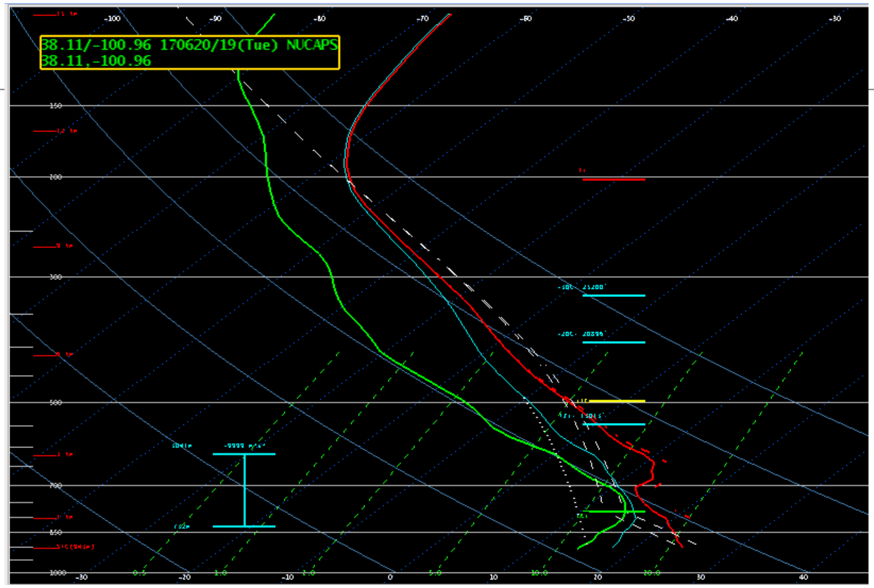
PROBABILITIES FOR HURRICANE DORIAN (8/29 12 UTC)

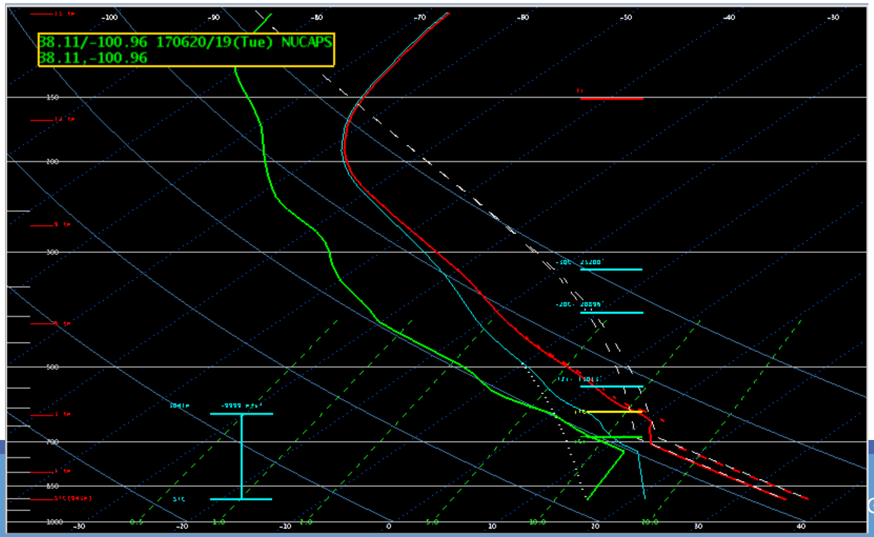


Cooperative Institute for Research in the Atmosphere

JPSS-PGRR-NUCAPS-DATAFUSION

Jack Dostalek, John Haynes





- To use NUCAPS retrievals, forecasters often need to modify the surface layer(s) to match observed T and Td
- Automated modification using GOES-16 and RTMA data to create surface and boundary layer T and Td
- Overall positive feedback from Hazardous Weather Testbed. From blog post: *"The modified NUCAPS soundings have shown significant improvement when compared to the operational NUCAPS soundings …"*
- Example at left from Southwestern Kansas 20 June 2017

3-D hurricane winds via AI/ML

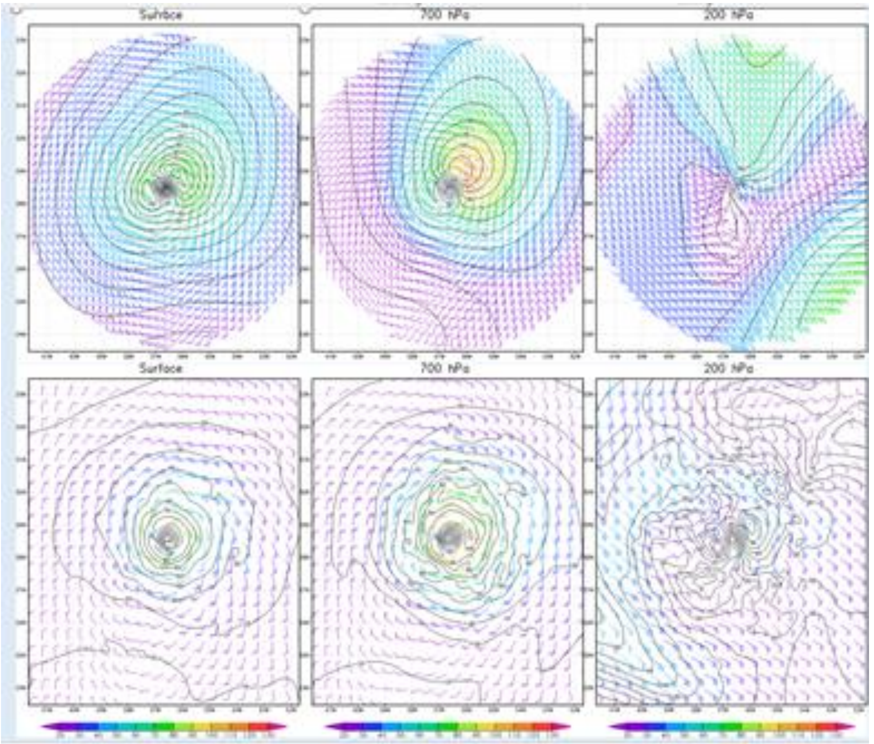
POTENTIAL HURRICANE SUPPLEMENTAL

Motivation:
- Use routinely available information to
- Improving numerical model initialization
- Estimates of tropical cyclone (TC) wind fields.

Proposition:
- Given a single Infrared (IR) image, and routinely produced TC advisory information, that a synthetic 3-D vortex could be estimated.

Method:
- Use HWRF forecast fields and synthetic imagery (+48h) as training
- Use single field principle component analysis (SFPCA) to estimate the winds
- In application use the observed TC vitals & observe IR imagery.

EXAMPLE FOR HURRICANE EDOUARD (2014)



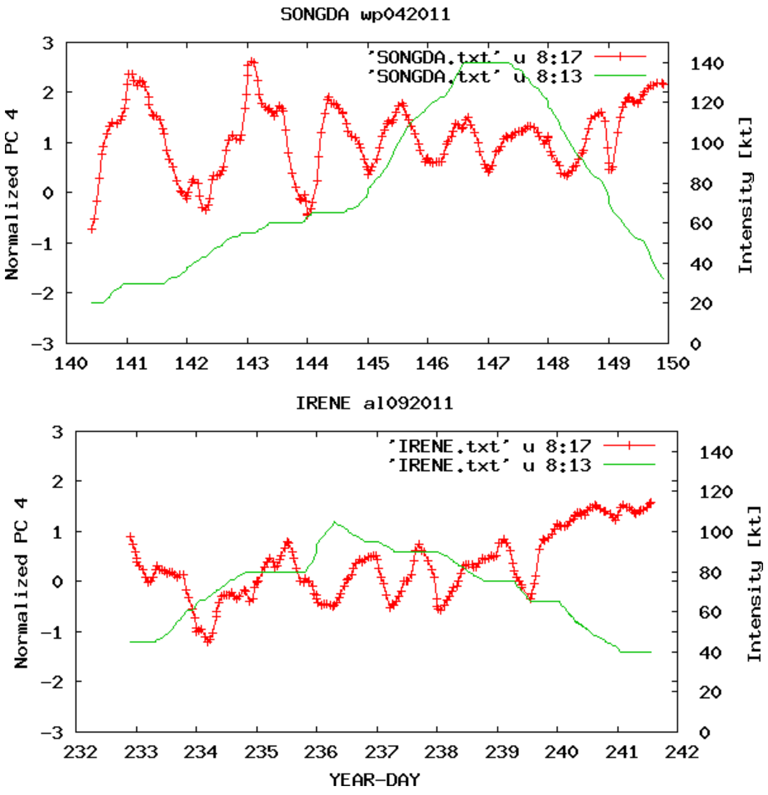
Statistical Estimate

HWRF Truth

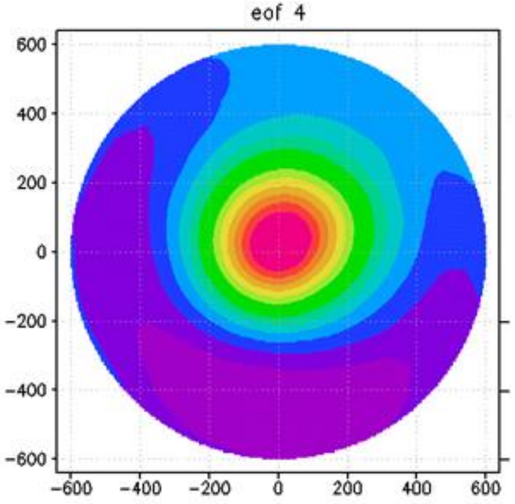
Understand diurnal oscillations of deep convection in TCs

QUANTIFICATION: IR IMAGERY

Time series of PC4



EOF -4
Pulsing symmetric Variability
8.9% of the variance



GFS used for environmental diagnosis

JUSTIFICATION AND PLAN

Diurnal Oscillations of deep convection in TCs often determine timing of intensification/weakening, effect satellite intensity estimates, and are yet fully understood

Plan:

Use the unique satellite dataset, model analyses, and field campaign data to determine causes and effects of diurnal oscillations

- ABI to determine strength of oscillations
- COSMIC to examine variation of boundary layer
- MIRS, NUCAPS to determine environmental oscillations
- Simple models to test hypotheses

Knaff, J.A., C.J. Slocum, and K.D. Musgrave, 2019: Quantification and Exploration of Diurnal Oscillations in Tropical Cyclones. Mon. Wea. Rev., in press, https://doi.org/10.1175/MWR-D-18-0379.1

Develop synthetic Microwave imagery using AI and ML

JUSTIFICATION AND PLAN

Justification:

Microwave imagery is often used to estimate TC intensity, location and convective structure

Microwave imagery is a key input to precipitation algorithms

Microwave data are latent and often miss TCs

Geostationary data is not latent and could act as risk reduction as microwave imager/sounders phase out of operations

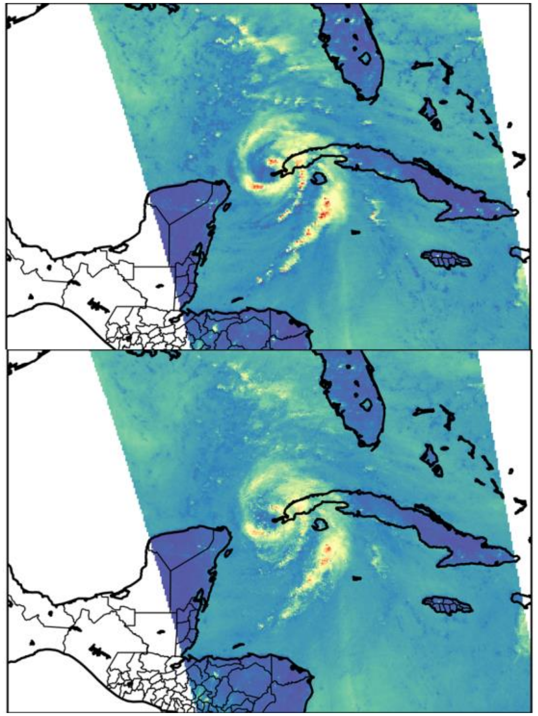
PLAN:

AI/ML has shown ability to estimate 89GHz during the day

We will expand on this ability to night

We will expand this ability to other microwave frequencies, those most useful for TCs and precipitation estimation

EXAMPLE HURRICANE MICHAEL



OBSERVED GMI

Synthetic GMI

Develop a Monti Carlo TC precipitation exceedance probability product

JUSTIFICATION AND PLAN

Justification:

TC rainfall, especially inland rainfall, remains a under forecasted hazard where track and intensity errors in deterministic forecasts fail to provide the full range of possibilities

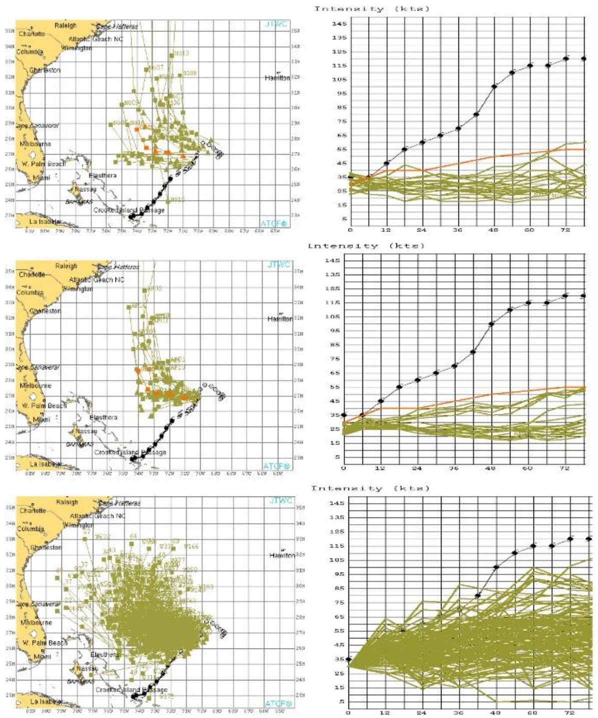
Global model ensembles are under disperse and do not capture the intensities variations of TC

This would improve on Ensemble TRAP

Plan:

Use the track and intensity realizations from the existing Monte Carlo wind probability product (NHC) along with a climatology of rainfall (TC size, TC intensity) to provide probabilities forecasts for rainfall exceedance

EXAMPLE OF MC-GENERATED TRACK AND INTENSITIES FOR JOAQUIN (2015)



Improved utilization of GOES/H8 data for TC environmental monitoring, targeting the 0-6h period between global model runs

JUSTIFICATION AND PLAN

Justification:

TC NWP is considered late guidance (i.e. the currently available model run is 6h old)

Much can change in the TC environment in this 6h period; effecting intensity forecasts

Plan:

Use GOES AMV’s and ABI water vapor images to develop products specifically targeted to monitor vertical wind shear, upper-level divergence, and mid-level moisture to fill in the 6 to 9h gap in information.

DETAILS

Shear can be calculated from upper-level winds and storm motion; calibration would be needed

Divergence would be calculated using AMVs

Moisture in the 700 to 500 mb layer would be calculated (a quantitative value)using radiative transfer.

Moisture In-Flux Storm Tool (MIST) (Fall 2019, TC-REALTIME)

Purpose: use ATMS-MiRS SNPP and NOAA-20 data to

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2) develop dry-air intrusions quantitative parameters for statistical TC intensity forecast models

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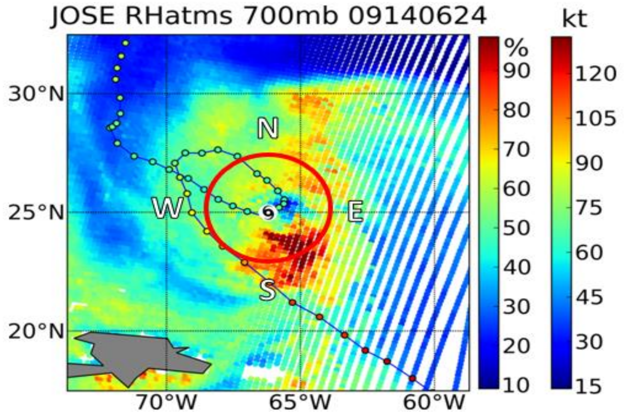

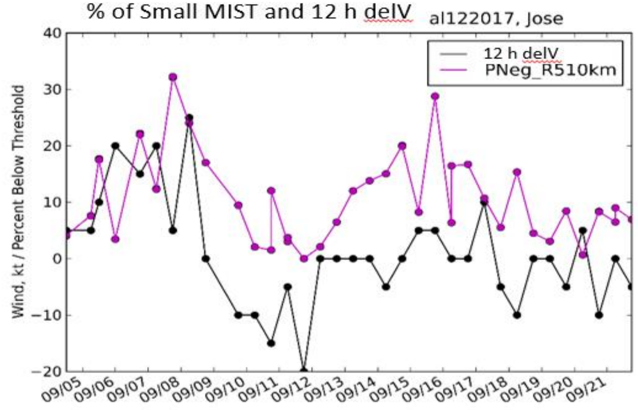

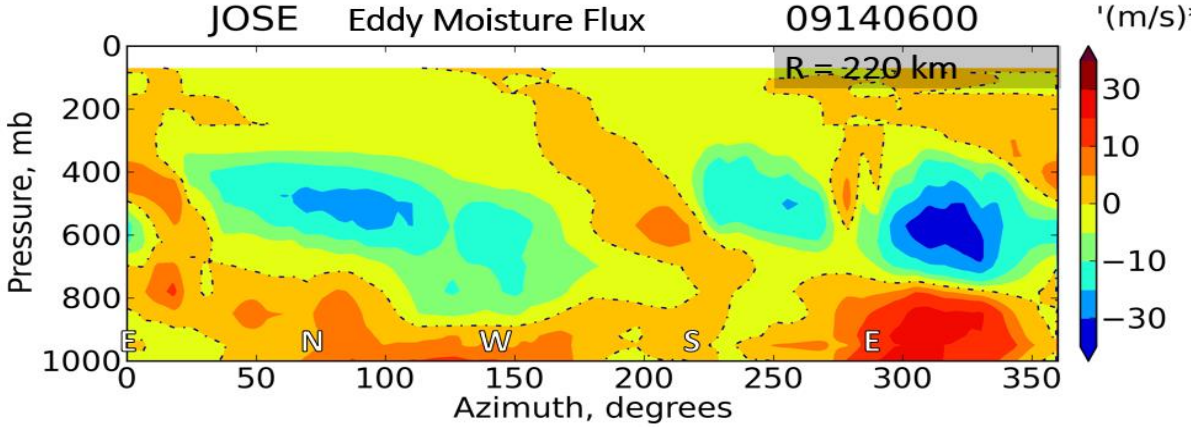

09/14 06 UTC

65 kt
12 h -5 kt
24 h -5 kt
36 h 0 kt

POC: Galina Chirokova

3-D hurricane winds via AI/ML

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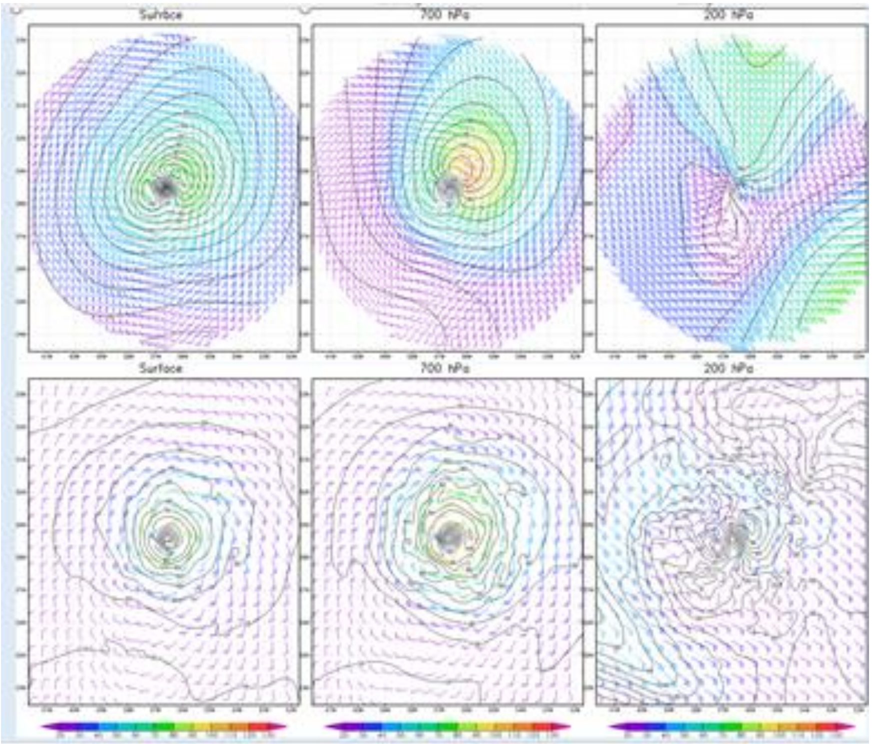
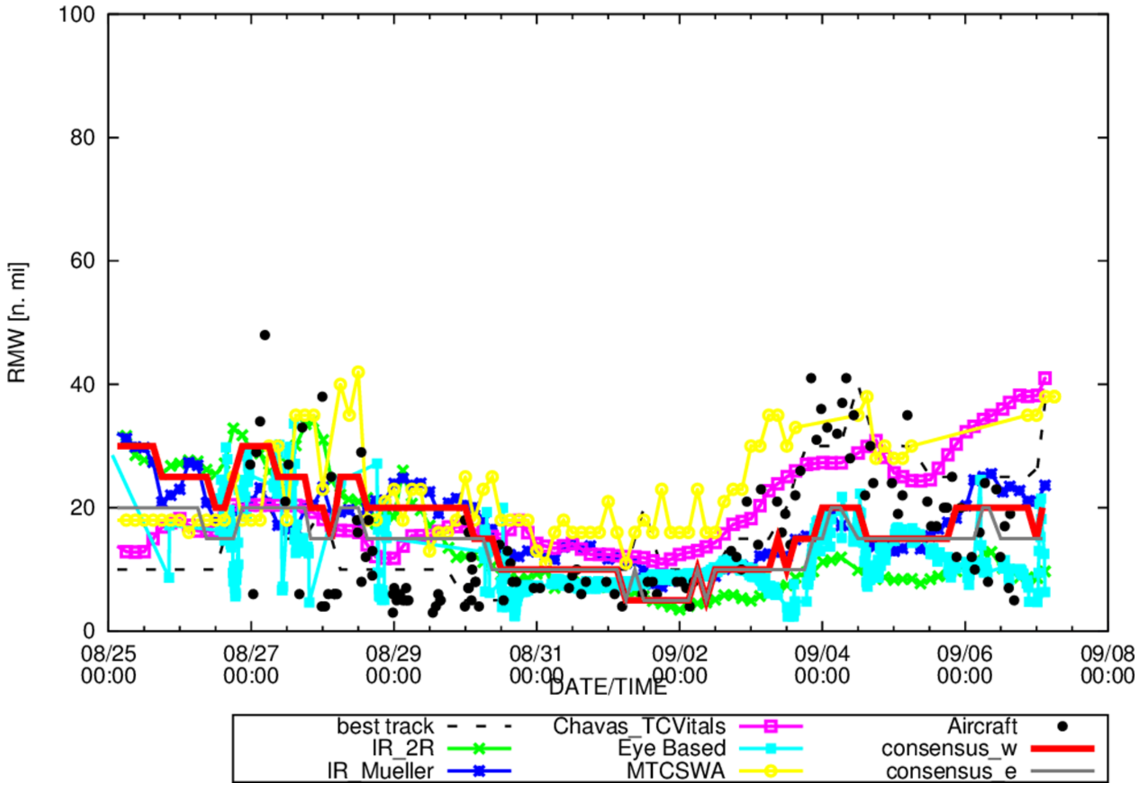


Statistical Estimate

HWRF Truth

Radius of Maximum Winds

EXPERIMENTS (EXAMPLE DORIAN)



NEXT STEPS

Microwave imagery

L-Band

SAR

AMSR2

Statistical Methods

LINEAR DISCRIMINANT ANALYSIS

Linear Discriminant Analysis (LDA) is a classification method originally developed in Fisher (1936).

In LDA, a linear combination of variables that best separates two or more groups is developed.

This is formalized as the discriminant function (δ), which is the scalar projection of the data vector (x) in the direction of maximum separation (i.e., Mahalanobis distance), which is called the discriminant vector,(a).

$$\delta = \vec{a}^T \vec{x}$$

Probabilities are based on prior performance

LOGISTIC REGRESSION

Logistic regression (LR) is a model where the dependent variable is a defined category (1 or 0).

LRE is a special generalized linear model, where the natural log of the odds ratio based on categorical data is fit to a linear combination of independent predictors (x_1, ..., x_n) with intercept b_o and weights ($b_1 \dots b_n$), and p_e (event), $\boldsymbol{p_n}$ (non-event)

$$\ln\left(\frac{p_e}{1-p_n}\right) = b_o + b_1 x_1 + \cdots + b_n x_n$$

The conditional distribution is a Bernoulli distribution

The LR model predicts probabilities in the form

$$p_{RI} = \frac{1}{\left(1+e^{-\left(b_o+b_1x_1 \ldots + b_nx_n\right)}\right)}$$

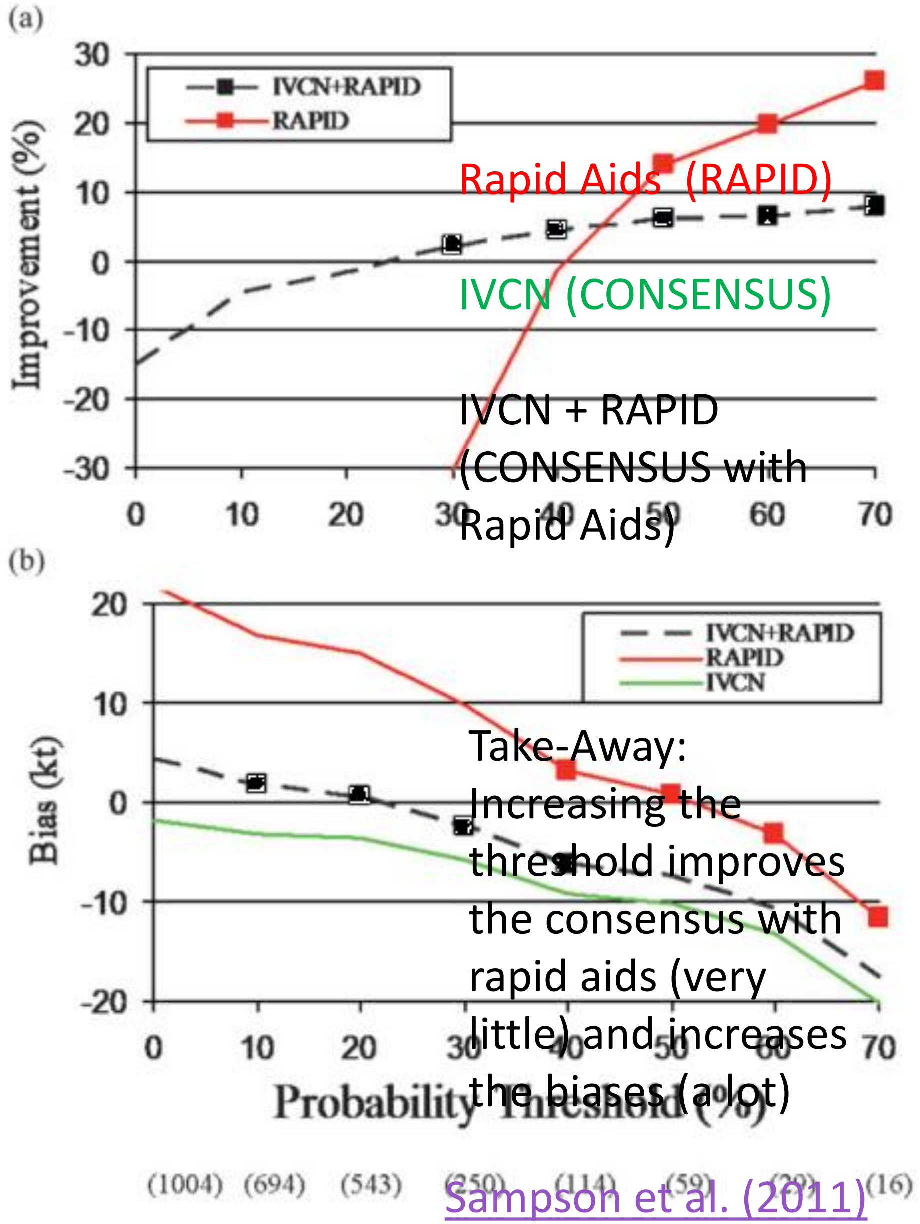
Deterministic RI Forecasts

Triggered if the consensus probability exceeds 40%

Largest intensity change threshold for each lead time is created

Deterministic forecasts for 24, 36, and 48 h, if triggered are added to the intensity consensus.

Trigger Sensitivity



Rapid Aids (RAPID)

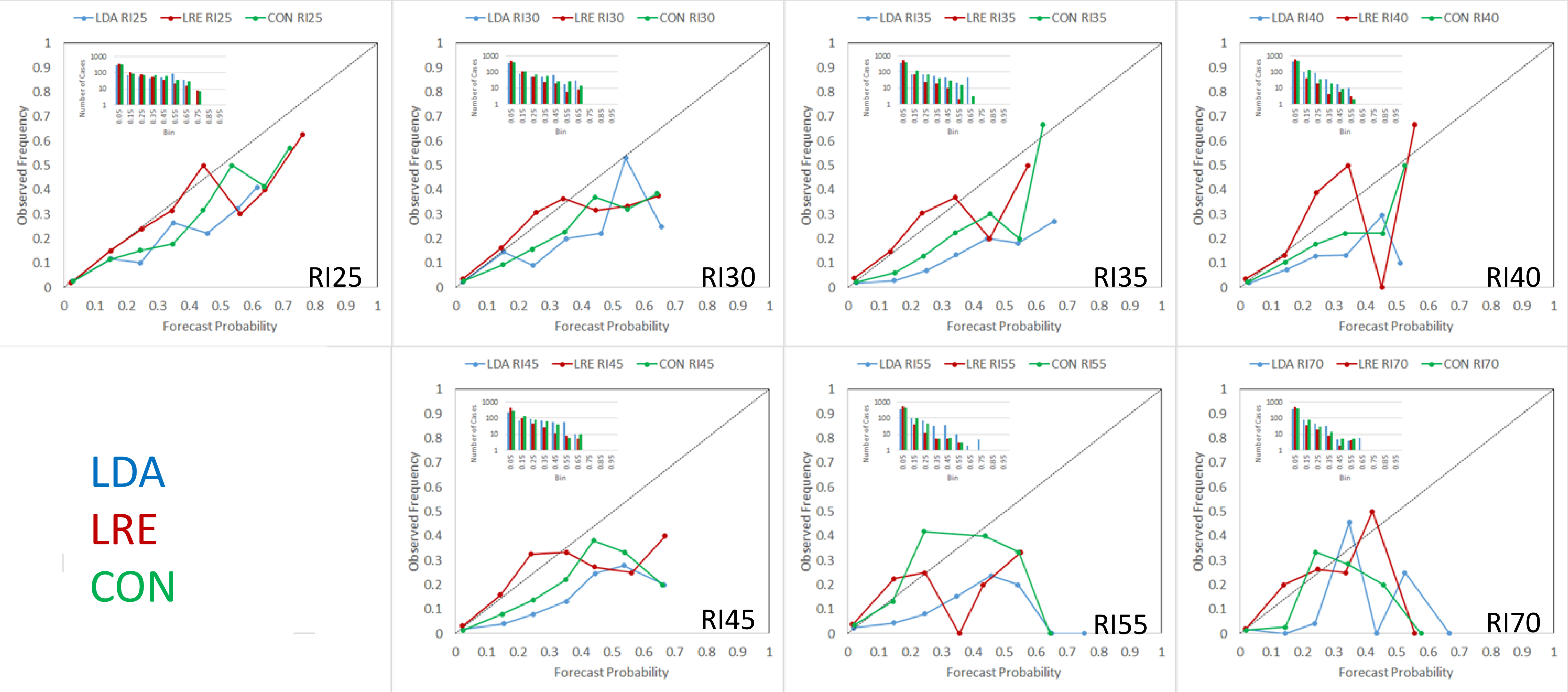
IVCN (CONSENSUS)

IVCN + RAPID (CONSENSUS with Rapid Aids)

Take-Away: Increasing the threshold improves the consensus with rapid aids (very little) and increases the biases (alot)

Sampson et al. (2011)

Independent Reliability



Full details are described in Knaff et al. (2018)

Knaff, J. A., C. R. Sampson, and K. D. Musgrave, 2018: An Operational Rapid Intensification Prediction Aid for the Western North Pacific. Wea. Forecasting, 33(3), 799–811, doi: /10.1175/WAF-D-18-0012.1.

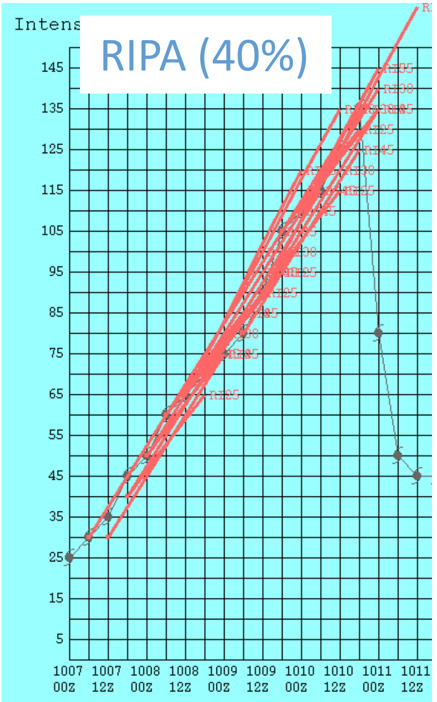
Rapid Intensity Guidance (RIPA) –BASED ON 2017 MODEL VERSIONS

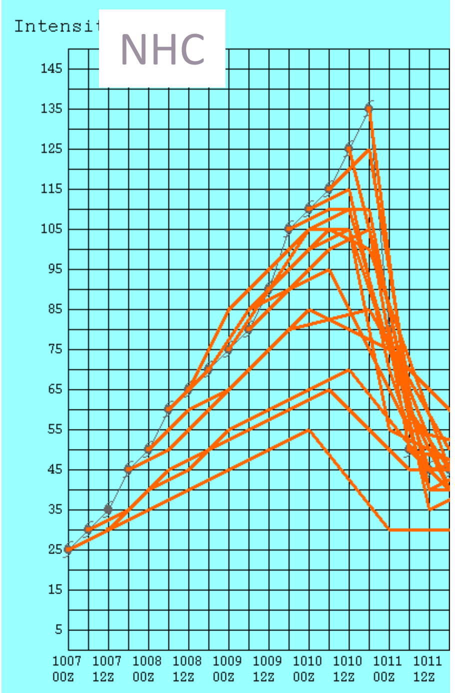
Based on synoptic conditions and Infrared imagery

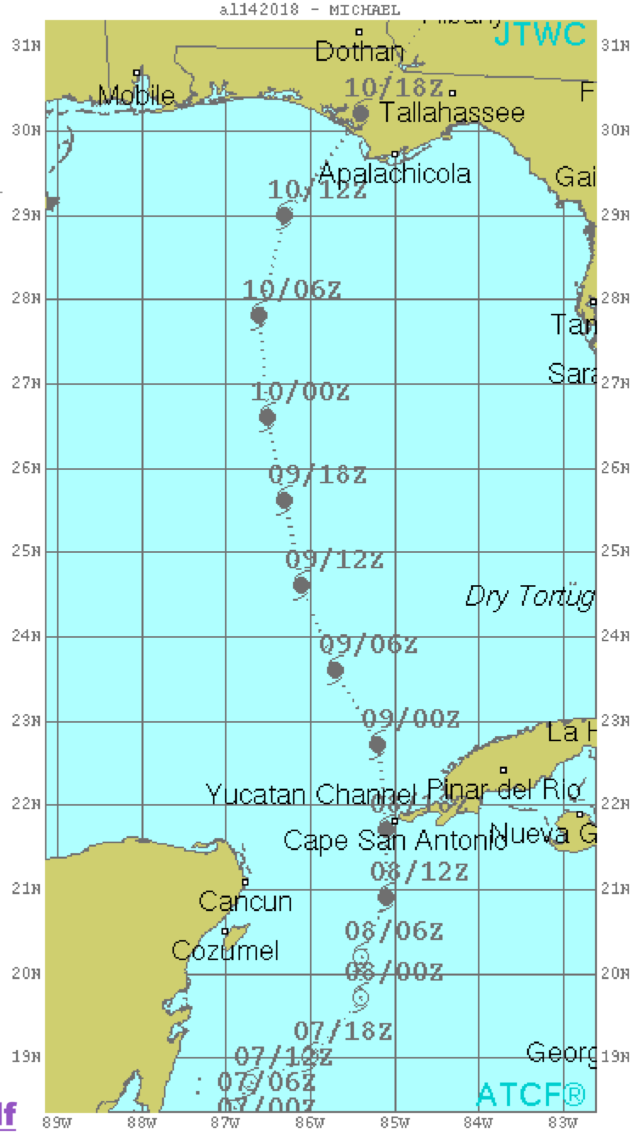
Produces RI guidance when conditions are favorable

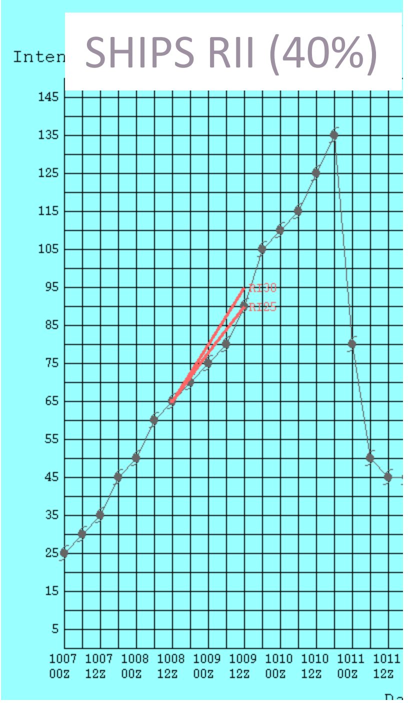
Gave solid intensity guidance for RI event, especially early

Not available to NHC forecasters … yet.









Operational at JTWC, more information at:

https://www.nrlmry.navy.mil/atcf_web/docs/pdf/WAF-D-18-0012.pdf

Updates and improvements (2019)

A SECOND TRY… GOING TOWARDS THE CHARM…

Engineering fixes

Initial intensity has to be at least 35 kt to trigger deterministic forecasts

Deterministic forecasts truncated at landfall

Probabilities from the various models are forced to be consistent (e.g., RI30 cannot exceed RI25)

Targeted changes

DATA AND DATA TREATMENT

Use developmental data from all JTWC's basins (2000-2017)

Rectify the predictor co-linearity (Potential intensity vs. current intensity)

Fix issues that showed up in the independent verifications (IR-based predictors)

Use independent verifications from all basins to guide our development

Adding NHC's thresholds…. 20kt/12h, 55kt/48h, 65kt/72h

SUMMARY OF CHANGES

-Bigger and more comprehensive dataset

-Cap current intensity at 75 knots… this answers the question of how close to eye formation is the storm?

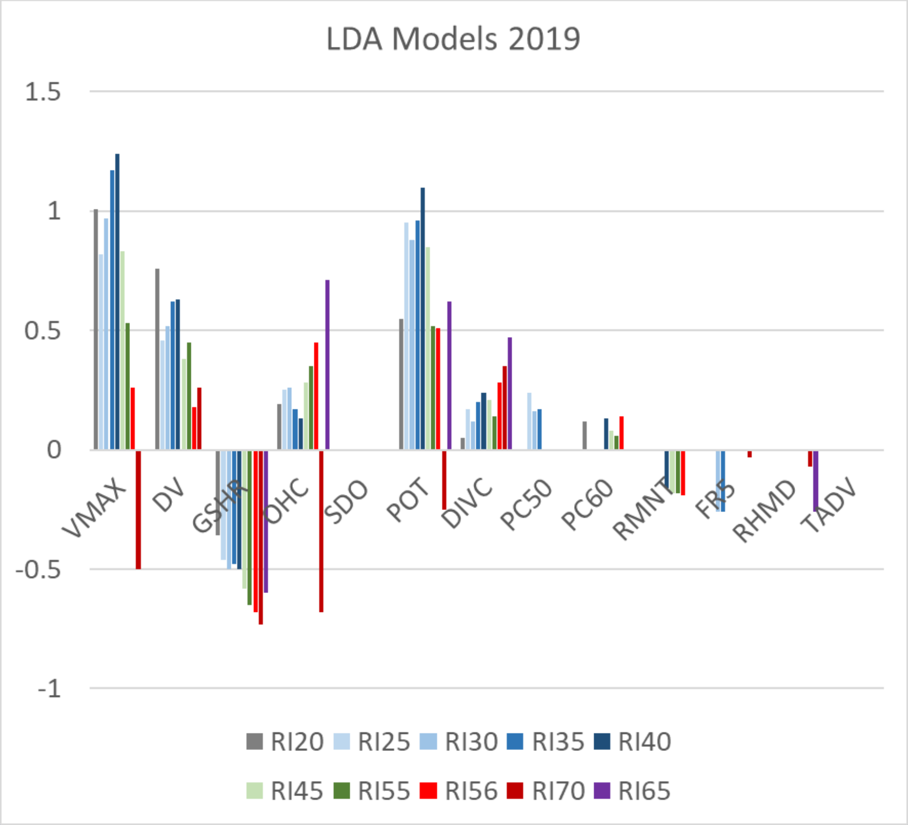
-Removal of the infrared standard deviations at longer leads

-This concept worked, especially with the examination of infrared predictors and treatment of potential intensity (east Pacific)

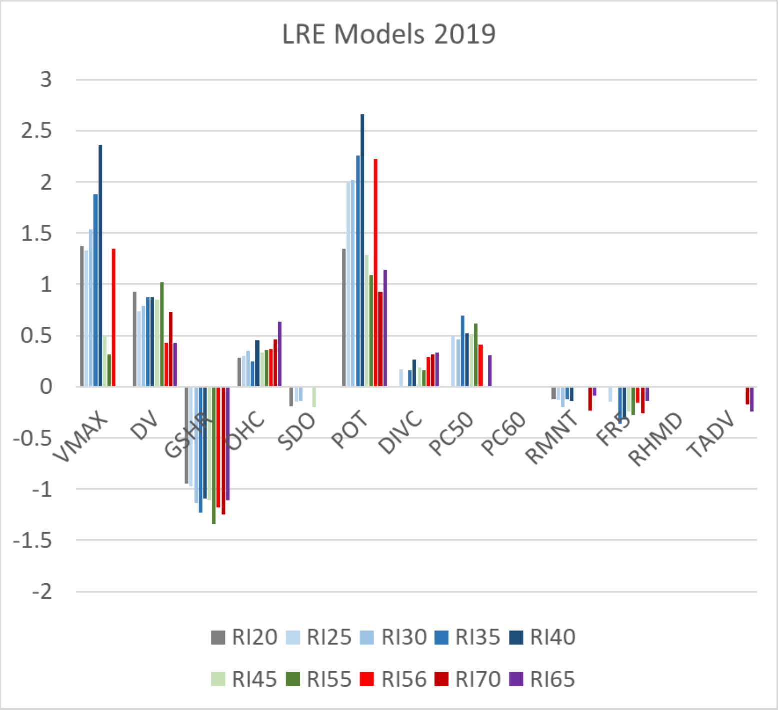
-methods still work very well!

New models (weights)

LDA



LOGISTIC REGRESSION



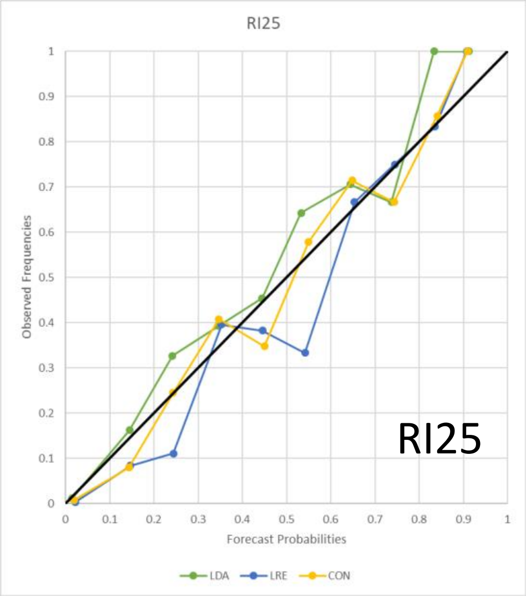
Constructing independent forecast

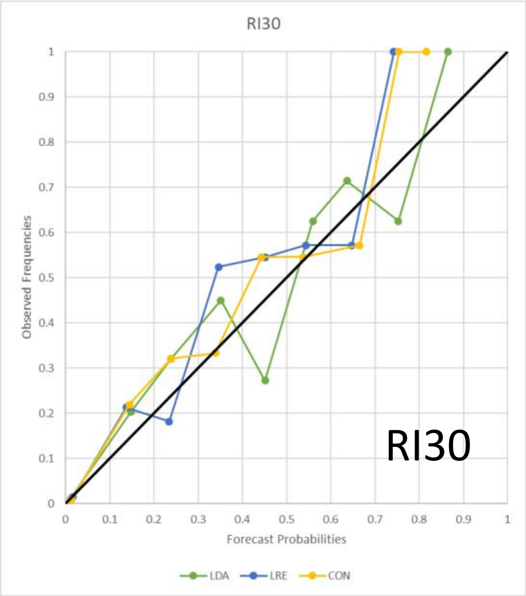
Use the operationally generated SHIPS large-scale diagnostics files

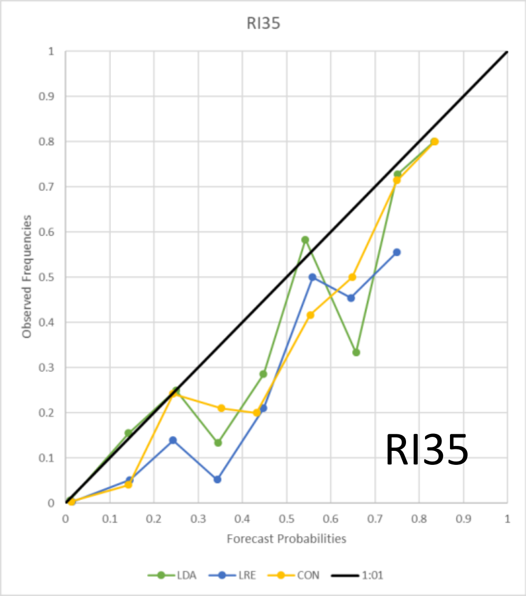
- These files will produce what the forecasters would receive in operations
- 6-hour old GFS forecasts
- Real-time track errors
- Real-time position and intensity errors (CARQ)
- Any other issues with operational data

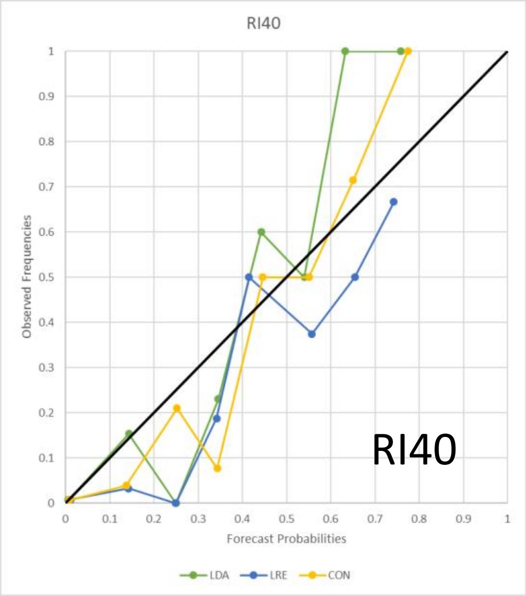
Verification was conducted using these files during 2018 and 2019 through April.

Independent Reliability (this year's model)

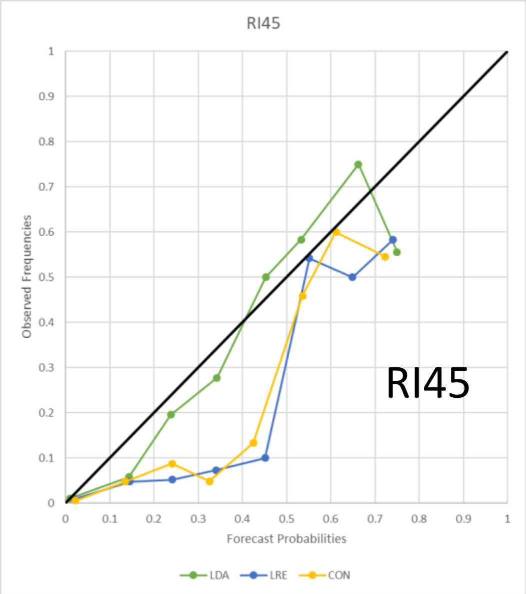


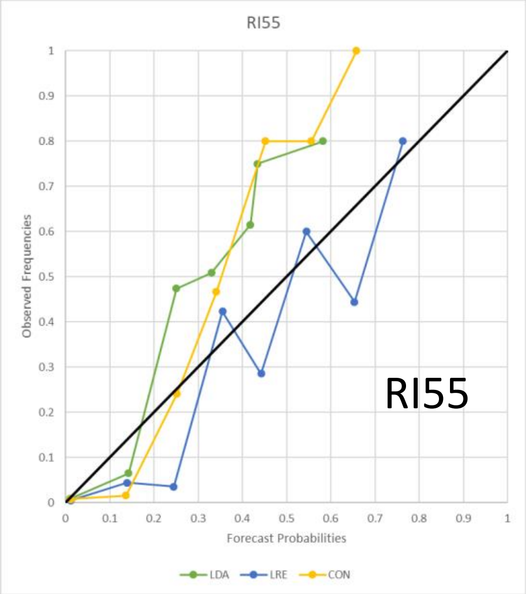


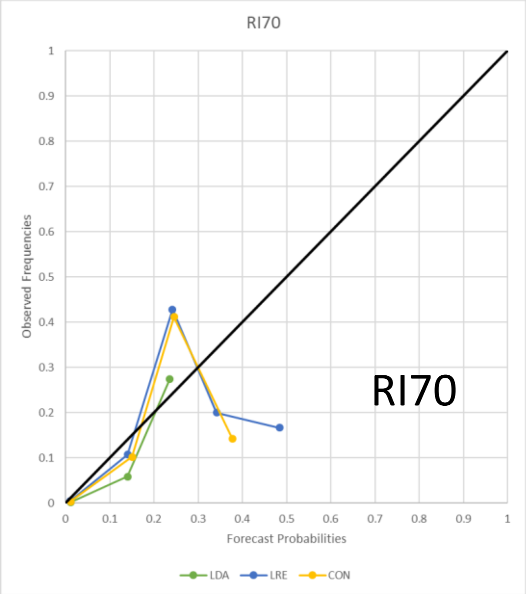




LDA
LRE
CON







Independent Verification (Atlantic) with NHC's thresholds