The analysis of Hurricane Michael's intensity at landfall in Florida

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National Hurricane Center

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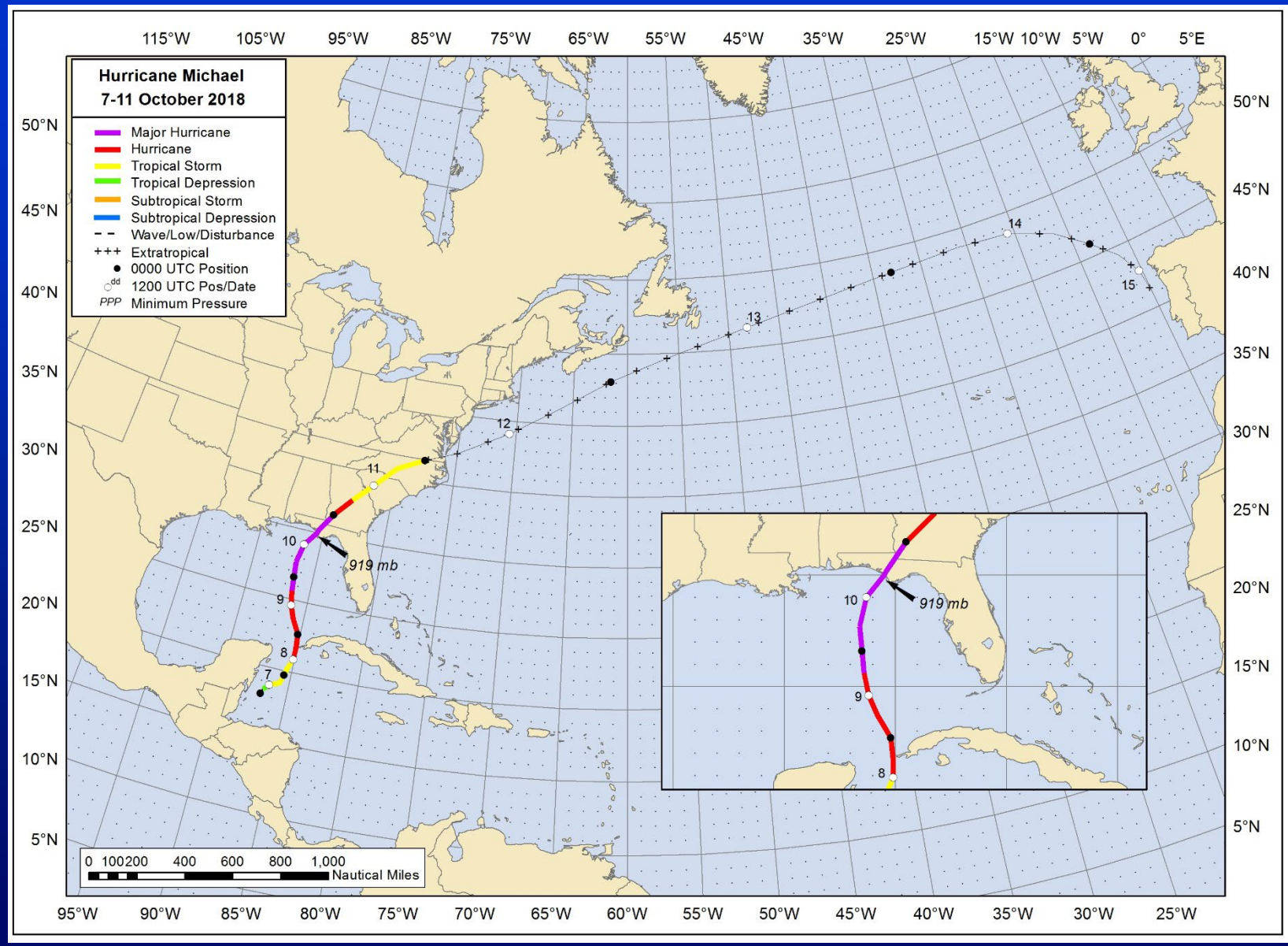
Hurricane Michael Life History

- Formed from a broad low pressure area over the northwestern Caribbean Sea on 7 October.
- Passed near the western end of Cuba on 8 October as a Category 2 hurricane.
- Made landfall near Mexico Beach/Tyndall AFB as a category 5 hurricane on 10 October, causing devastating damage.
- Brought strong winds and heavy rains to other portions of the southeastern United States.



Track of Hurricane Michael

Michael Was Category 4 In Real Time

- Michael was operationally a strong category 4 hurricane with maximum sustained winds of 155 mph.
- NHC routinely conducts post-analysis of tropical cyclone tracks, intensities, and wind radii after the cyclone is over.
- The post-analysis indicates Michael was category 5 at landfall with maximum sustained winds near 160 mph. This small change is typical of post-analysis, but in this case it crossed a major hurricane classification threshold.

Hurricane Michael Intermediate Advisory Number 16A...Corrected
NWS National Hurricane Center Miami FL AL142018
100 PM CDT Wed Oct 10 2018

Corrected pressure in inches in summary block and text

...MICHAEL INTENSIFIES AS IT MAKES LANDFALL NEAR MEXICO BEACH FLORIDA...
...LIFE-THREATENING STORM SURGE...HURRICANE FORCE WINDS...AND HEAVY RAINFALL OCCURING OVER THE FLORIDA PANHANDLE...

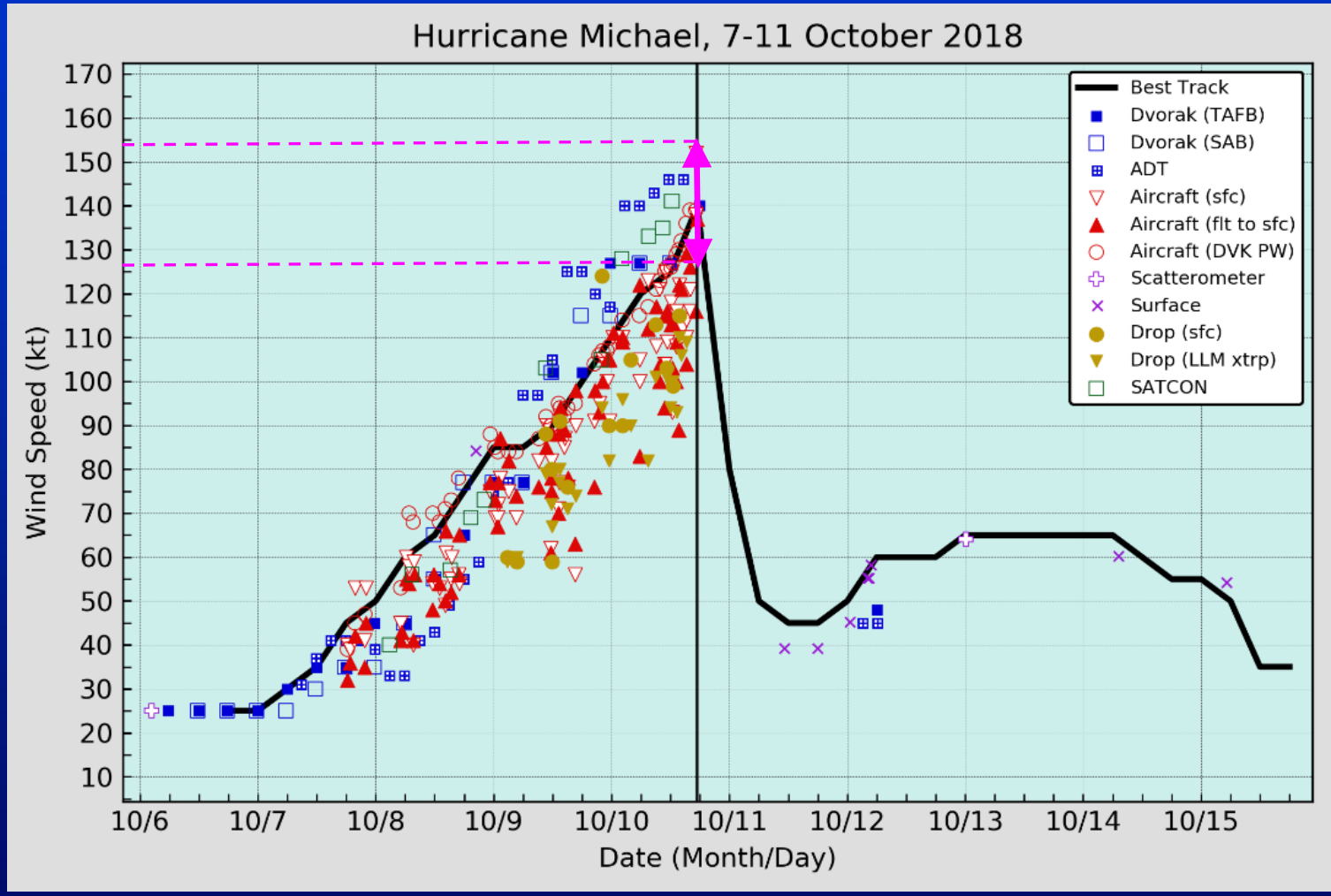
SUMMARY OF 100 PM CDT...1800 UTC...INFORMATION

LOCATION...30.0N 85.5W
ABOUT 5 MI...10 KM NW OF MEXICO BEACH FLORIDA
ABOUT 20 MI...30 KM SE OF PANAMA CITY FLORIDA
MAXIMUM SUSTAINED WINDS...155 MPH...250 KM/H
PRESENT MOVEMENT...NNE OR 20 DEGREES AT 14 MPH...22 KM/H
MINIMUM CENTRAL PRESSURE...919 MB...27.14 INCHES

www.nhc.noaa.gov/data/tcr/AL142018_Michael.pdf

The Best Track Intensity Is More Complicated Than It Sounds

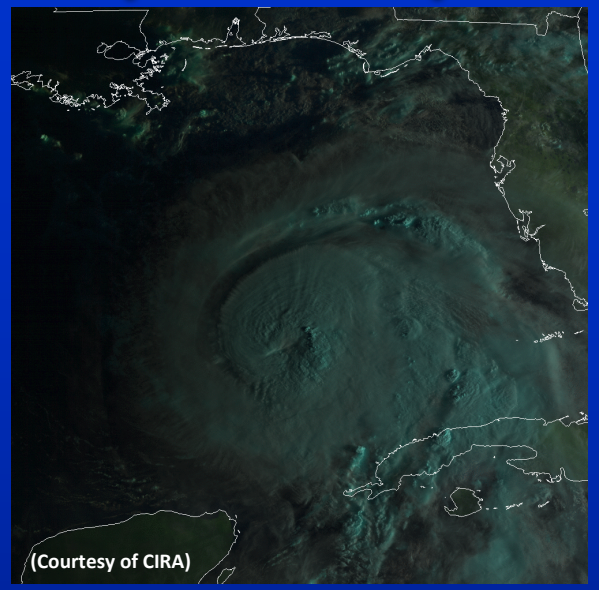
- In an intense hurricane, the maximum sustained winds occur in a very small area near the center at the radius of maximum wind (RMW).
- These winds are usually not directly observed. Thus, they are inferred from other data.
- Forecasters constantly weigh sampling and representativeness issues of many data types using their experience.
- Even when data is plentiful, the NHC best tracks have an uncertainty of ±10%.



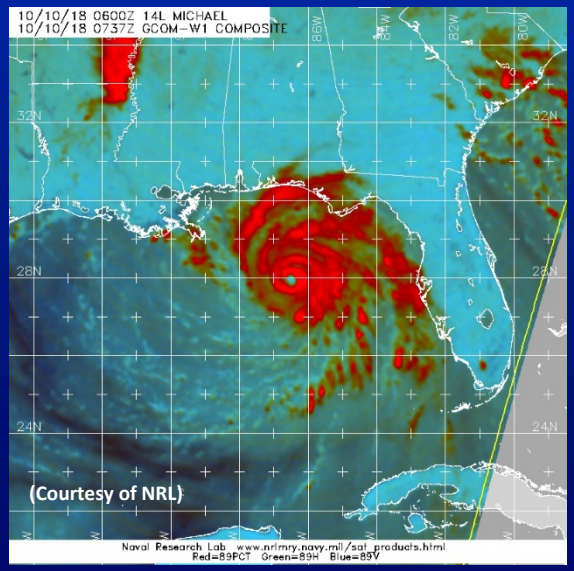
Intensity fix data for Hurricane Michael

Data to Help Analyze Tropical Cyclones

- **Geostationary Satellites**
  - Help determine center location (with varying degrees of confidence)
  - Apply Dvorak Technique (subjective and objective) to estimate a system's intensity
  - Allows forecasters to see features that might influence the future track/intensity



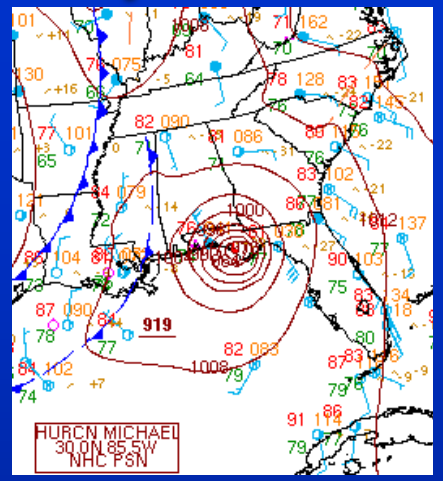
- **Low-Earth Orbiting Satellites**
  - Help determine storm location and structure
  - Some instruments provide intensity estimates



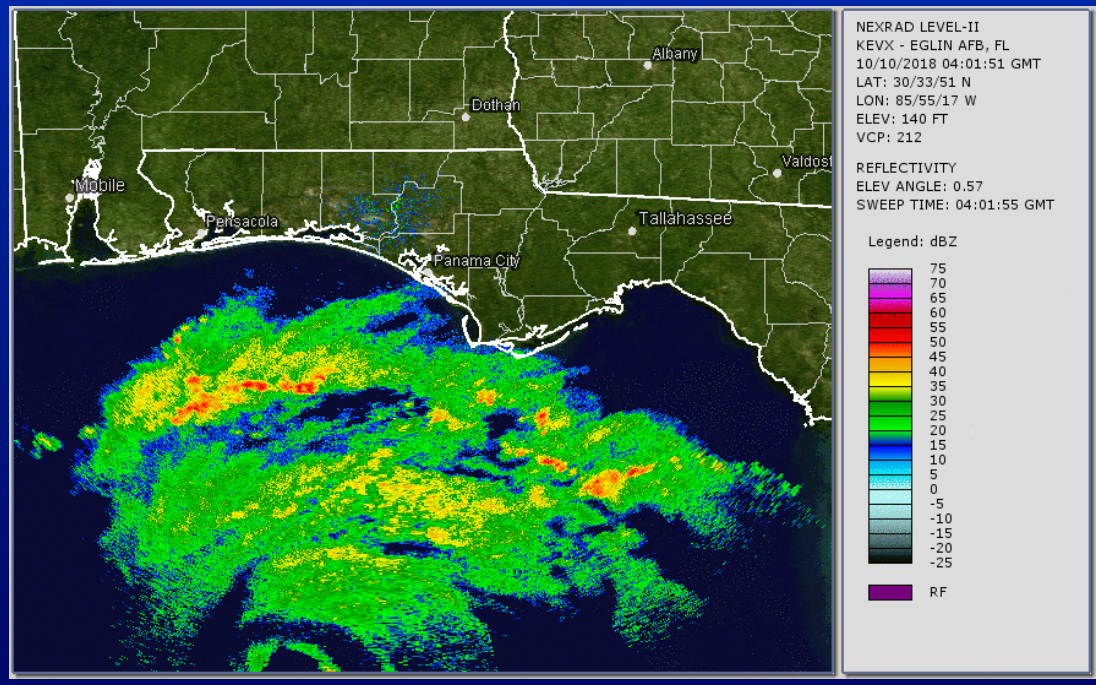
- **Reconnaissance Aircraft**
  - Flight-level winds
  - Dropwindsonde Data
  - Stepped Frequency Microwave Radiometer (SFMR) surface winds

Data to Help Analyze Tropical Cyclones

- **Surface observations**
  - Ship and buoy reports
  - Fixed land-based observing sites
  - Portable data platforms and storm chasers



- **Radar**
  - Provides rain distribution and wind (Doppler) information
  - Useful for “now-casting” during an event and a few hours prior, and for post-analysis

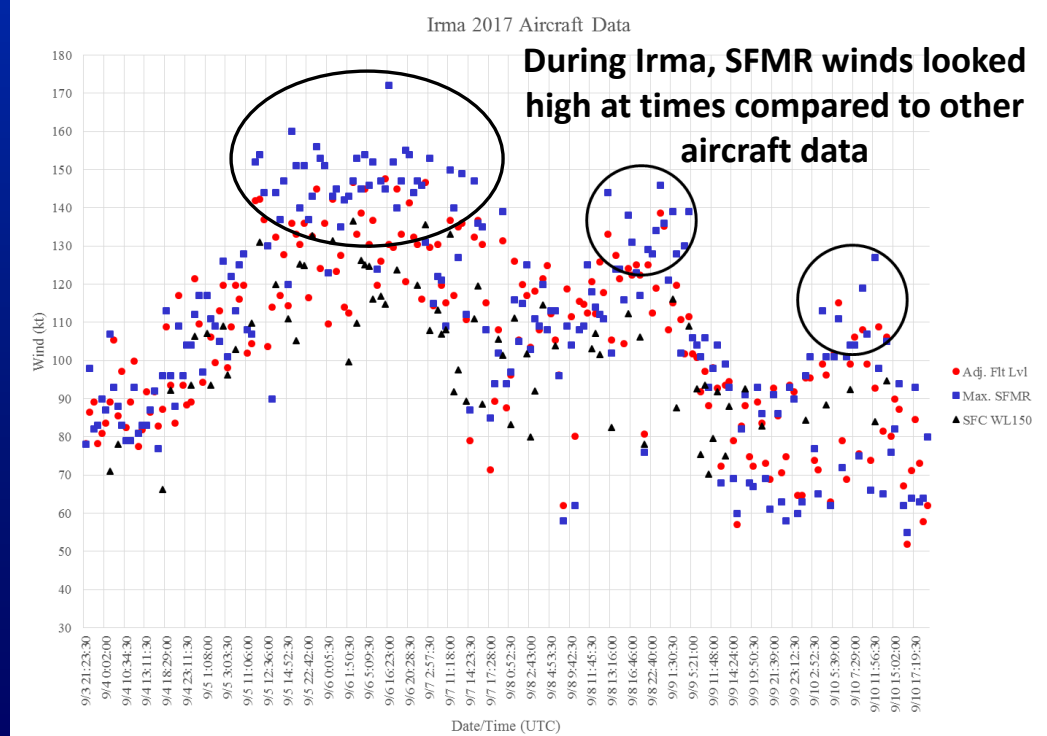


Sounds like a lot of data but…

Only a fraction of the storm circulation is sampled by most of these data types.

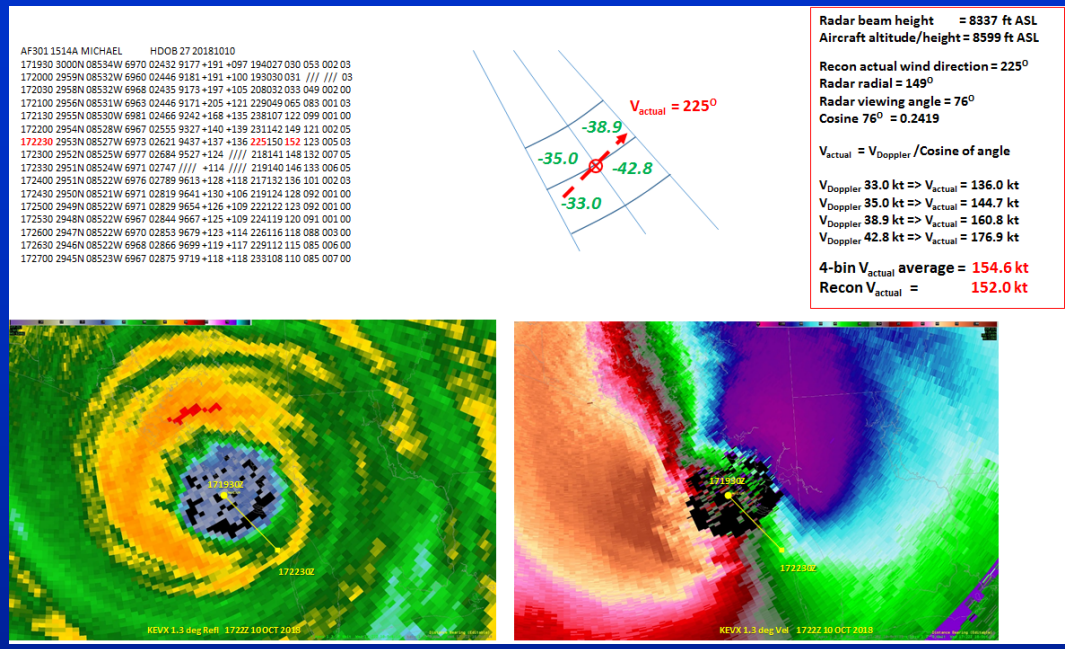
Issues on Evaluating TC Intensity: Aircraft Data

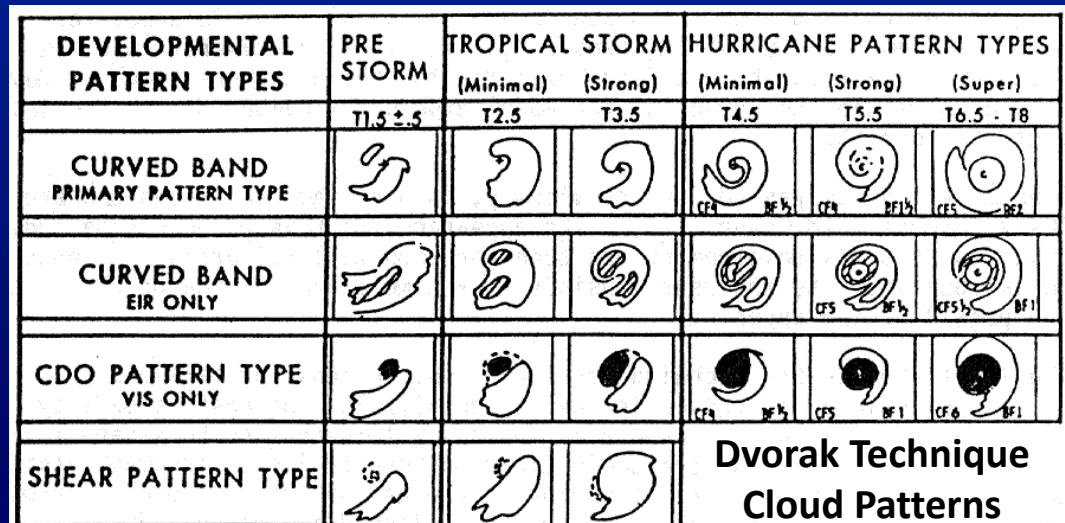
- **Aircraft flight-level winds**
  - Measured above the surface – need adjustment to surface
  - Data only along flight path
  - Measured winds can be unrepresentative
- **SFMR winds**
  - Estimates the wind speed from the foam coverage on the ocean surface
  - Data only below the aircraft
  - Rain/wind separation
  - Wave shoaling effects
  - *Possible instrument bias at high winds – under study*
- **Dropsondes**
  - Measure winds only where the sonde is falling
  - Like flight-level winds, data can be unrepresentative



Issues on Evaluating TC Intensity: Other Data

- **Surface observations**
  - Rarely in the right place to sample the maximum winds
  - *Instruments often don't survive the hurricane*
  - Instrument exposure is an issue
- **Doppler radar winds**
  - Radar only measures winds along the beam
  - High temporal sampling can cause unrepresentative results
  - Require vertical adjustment to the surface
- **Satellite intensity estimates**
  - Infers intensity from cloud patterns or other satellite measured quantities
  - Measurements not precisely correlated to intensity
- **Wind-pressure relationships**
  - Based on empirical statistics for previous cyclones
  - Inherent imprecision

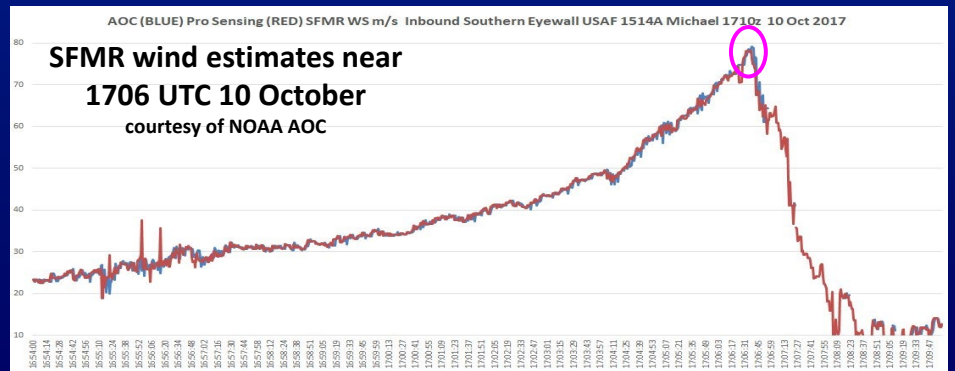




Dvorak Technique Cloud Patterns

Aircraft Winds At Landfall

- Maximum flight-level winds: 152 kt/175 mph at 700 mb (about 8,000 ft) in the southeastern eyewall. Using standard NHC reductions, the surface wind estimate is 137 kt/158 mph.
- Maximum SFMR surface wind estimate: 138 kt/ 159 mph. Note the near-by data dropout ('///').
- Reconstruction of the missing winds by the NOAA AOC indicates a maximum wind estimate of 152 kt during the dropout.
- This occurred where the water was 85-90 ft deep, so shoaling waves effects are possible.
- Dropsondes were not available.

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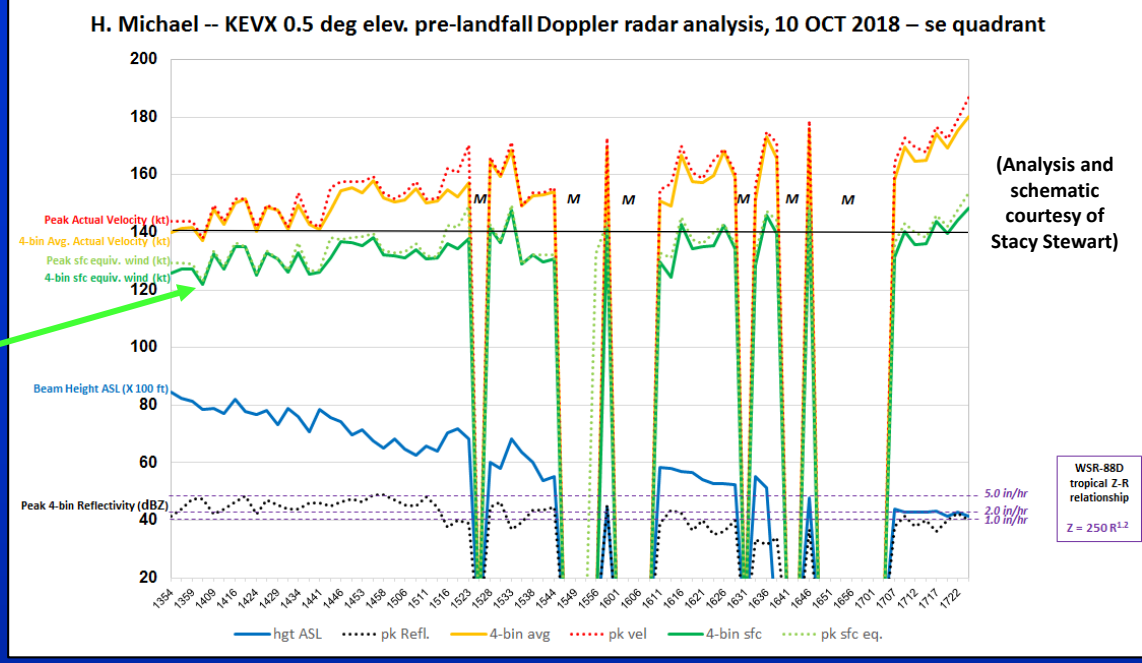
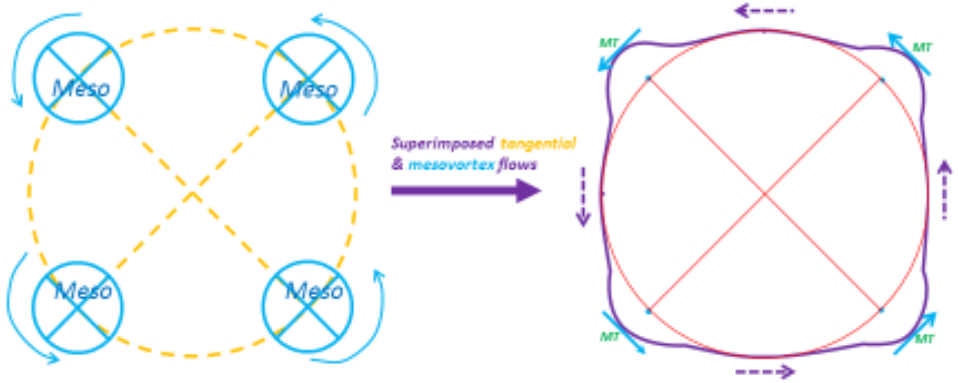
Radar Wind Data Analysis

- Analysis of Eglin AFB radar Doppler winds suggest that the maximum surface winds averaged near 160 mph near landfall, and they may have been higher at landfall.
- Analyzed winds aloft agree well with the 175 mph aircraft wind.
- The analysis is supported by objective analysis of Eglin AFB data and partial analysis of Tallahassee radar data.
- Filtered out were periods ("M") where eyewall mesocyclones caused unrepresentative winds.

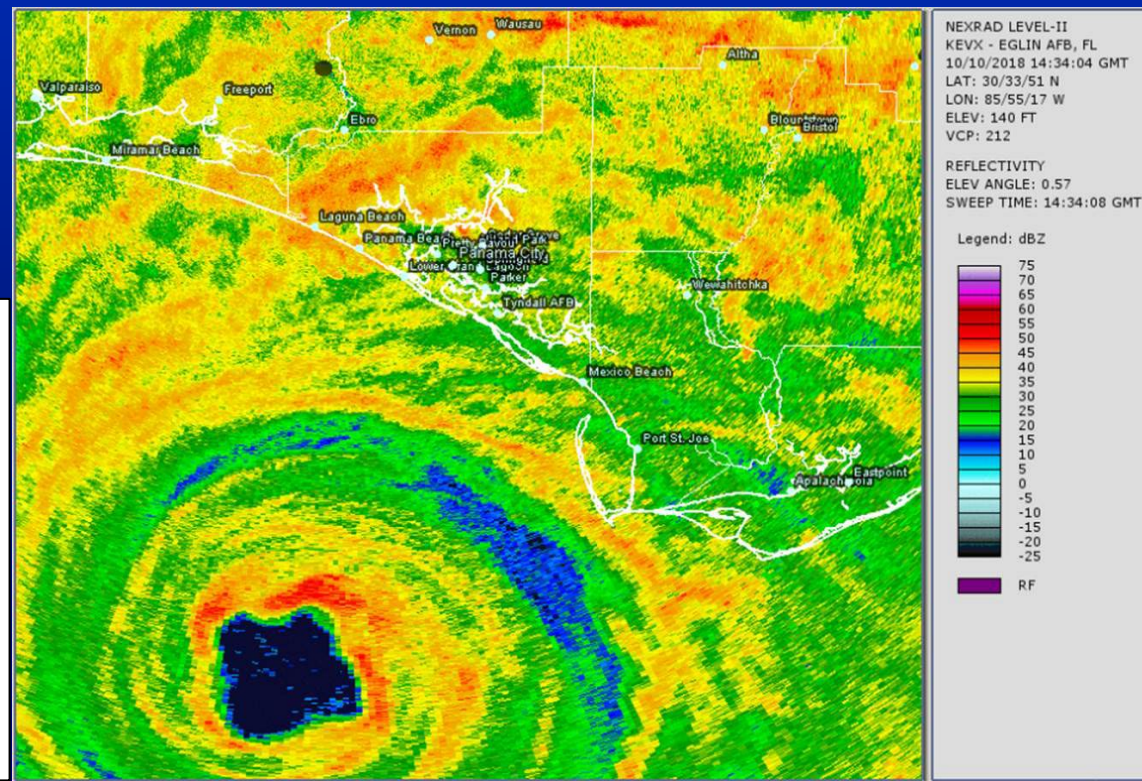


(Analysis and schematic courtesy of Stacy Stewart)

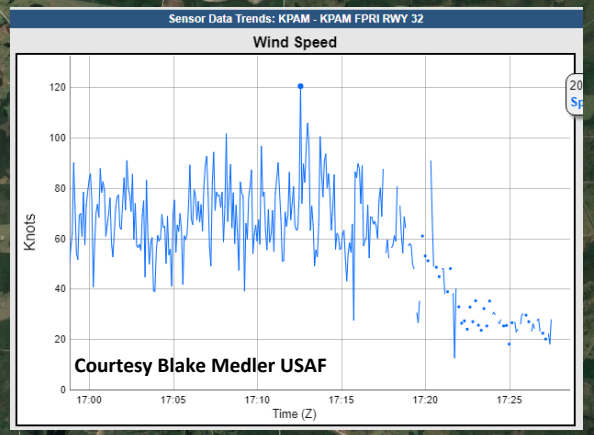


The tangential & mesovortex combined flows can only be accurately assessed at locations ***MT*** where both flows directions *exactly* coincide, thus allowing for symmetrical/circular flow to be assumed at those points.

This allows for an accurate assessment of the Cosine of the Radar Viewing Angle (RVA) and, therefore, V_{actual} to be calculated.



Surface Wind Data In The Core



Tyndall AFB ASOS – 86 mph 2-min winds and a gust to 139 mph

FCMP Tower T3 – 106 mph 1-min winds and a gust to 129 mph – blew over during the strongest winds

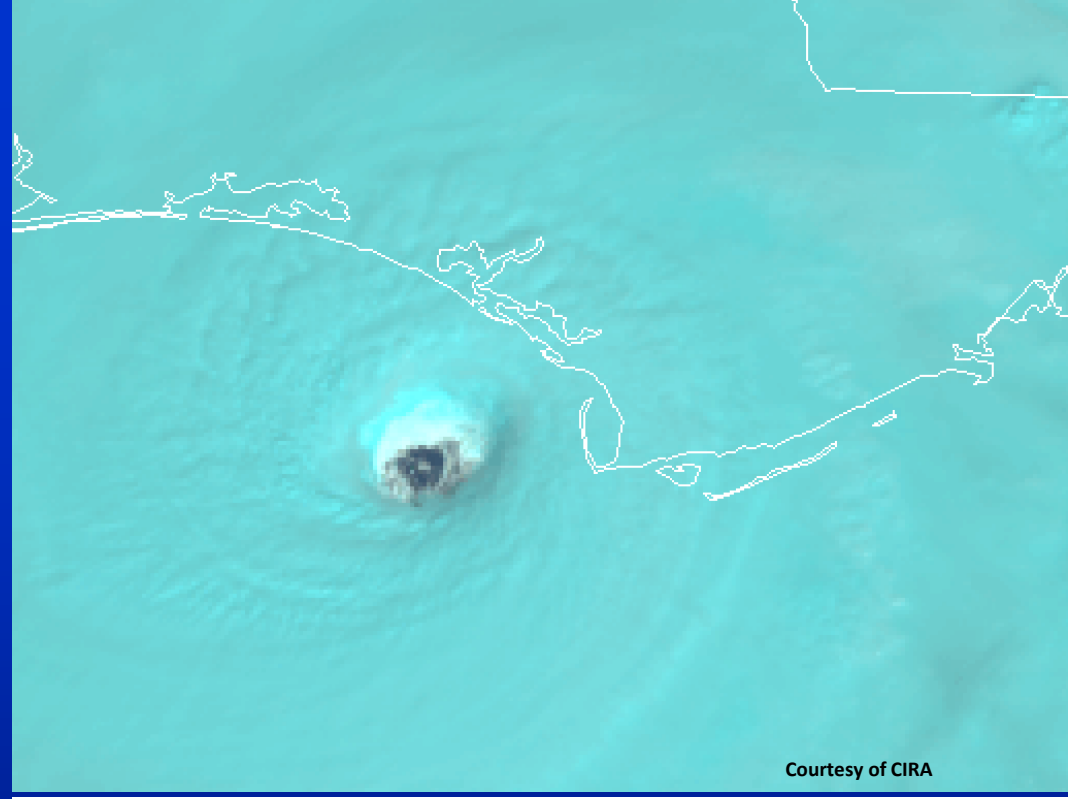
The reported winds are well below both the operational and final best track intensities, which is typical during landfalling hurricanes. However, the sites were likely not optimally located to sample the maximum winds.

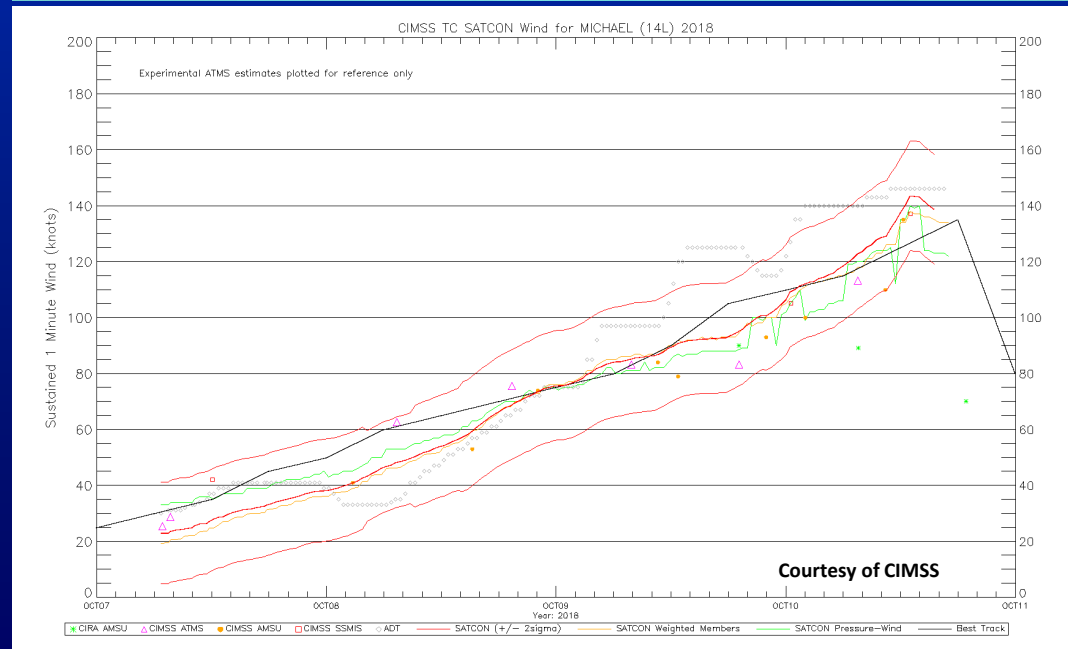
FCMP Tower T2 – 108 mph 5-min winds and a gust to 127 mph – likely outside the strongest winds

Springfield
Parker
Shell Island
Tyndall AFB
East Bay
Crooked Island
Overstreet
Mexico Beach

Satellite Intensity Estimates

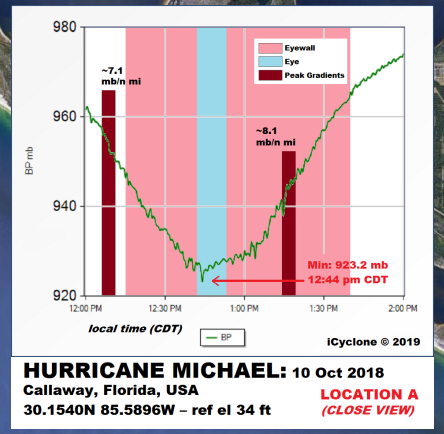
- Subjective Dvorak Technique estimates: 160 mph.
- Objective Advanced Dvorak Technique estimates: 160-165 mph.
- Satellite microwave data estimates: 125-155 mph.
- The Satellite Consensus technique from the Cooperative Institute for Meteorological Satellite Studies (CIMSS) estimates: 160-165 mph.





Surface Pressure Data In The Core

Storm Chaser Josh Morgerman – 923.2 mb in NW corner of eye



Tyndall AFB ASOS – 922.4 mb – hurricane-force winds at time of minimum pressure – incomplete record

FCMP Tower T3 – 920.2 mb in eye

USGS Portable – 929.7 mb near RMW

Surface and aircraft pressure data support a landfall central pressure of 919 mb. Using several wind-pressure relationships, this suggests a landfall intensity near 160 mph. In the Re-analysis Project, a storm with Michael's pressure and other parameters would be called category 5.

Putting It All Together

- While there remains uncertainty, the available data favors increasing the landfall intensity of Michael from 155 to 160 mph.
- This is a small change that is normal for post-analysis. However, it increases Michael's landfall intensity from category 4 to category 5 on the Saffir-Simpson Hurricane Wind Scale.
- Other known category 5 landfalls in the United States (including Puerto Rico):
  - San Felipe Hurricane, Puerto Rico (1928)
  - Labor Day Hurricane, Florida Keys (1935)
  - Camille, Mississippi and Louisiana coasts (1969)
  - Andrew, south Florida (1992).
- Additional re-assessment of the landfall intensity may occur when current research on the SFMR data is complete.