Use of reconnaissance data in weather forecast models

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NOAA AOML/HRD

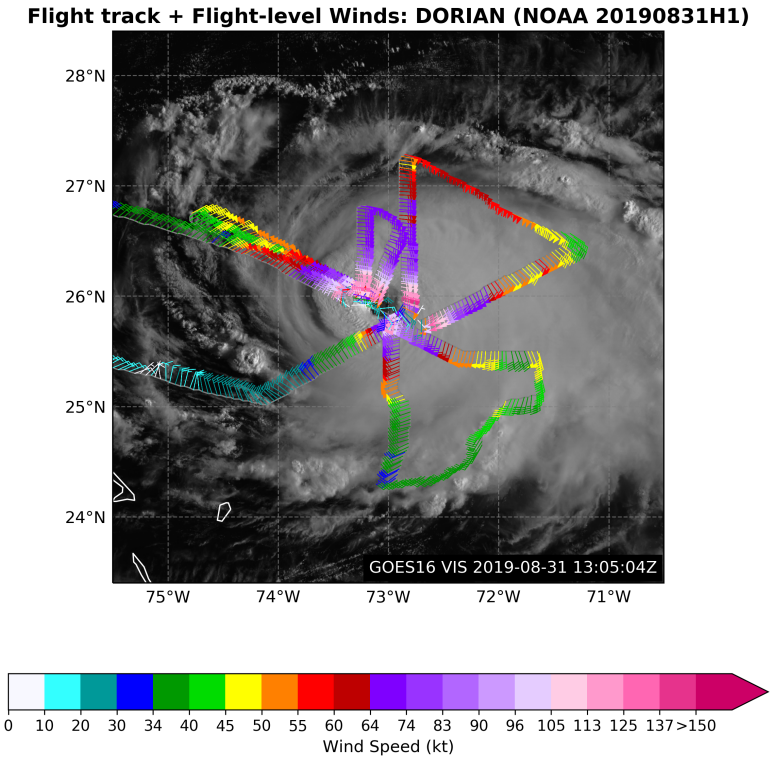
Outline

- Overview of reconnaissance
- History of reconnaissance usage in models
- Recent developments
- Future direction

Overview: Recon Data

INSTRUMENTS USED:

- **Flight-level** – winds, temperature and humidity observed by plane
- **Dropsondes** – dropped from plane to measure winds, temperature, and humidity
- **Doppler radar (TDR)** – estimates 3-D winds
- **SFMR** – estimates surface wind speeds beneath plane

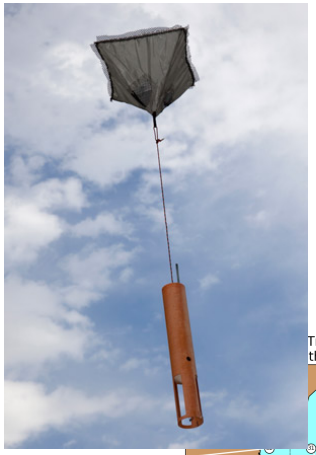


Flight-level winds from a flight into Hurricane Dorian

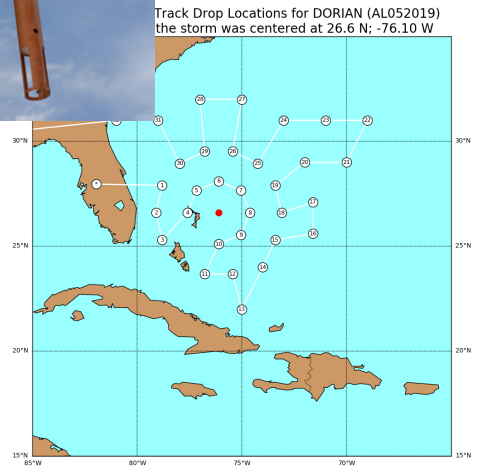
Overview: Recon Data

INSTRUMENTS USED:

- **Flight-level** – winds, temperature and humidity observed by plane
- **Dropsondes** – dropped from plane to measure winds, temperature, pressure and humidity
- **Doppler radar (TDR)** – estimates 3-D winds
- **SFMR** – estimates surface wind speeds beneath plane



Dropsonde



Dropsonde locations from a flight into Hurricane Dorian

Overview: Recon Data

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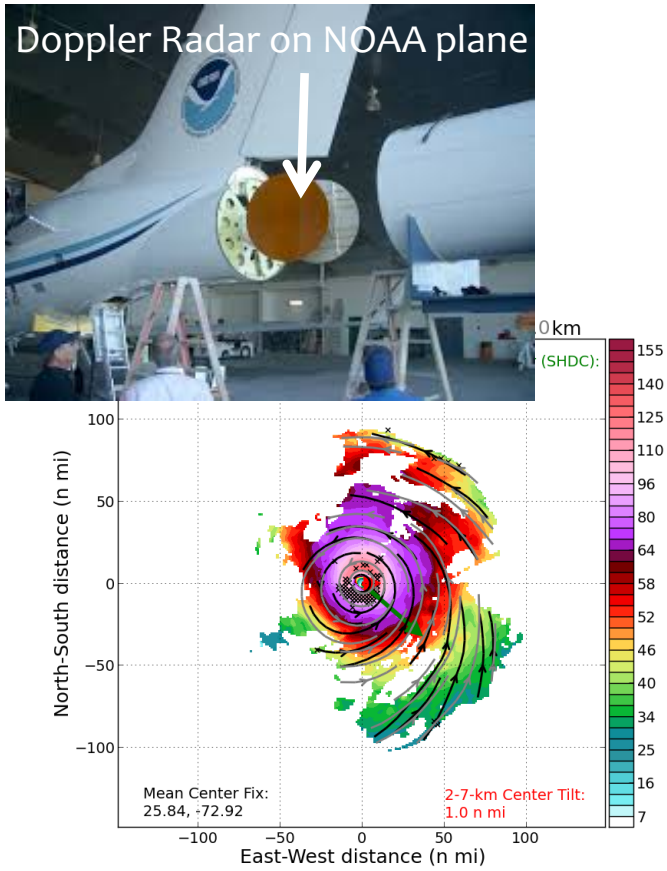


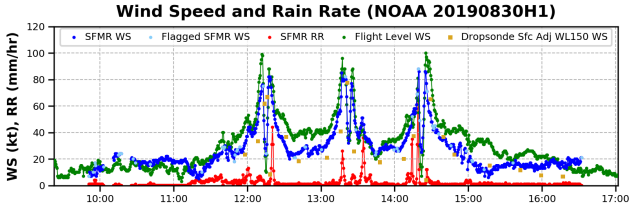
Doppler-estimated winds from a flight into Dorian

Overview: Recon Data

INSTRUMENTS USED:

- **Flight-level** – winds, temperature and humidity observed by plane
- **Dropsondes** – dropped from plane to measure winds, temperature, and humidity
- **Doppler radar (TDR) –** estimates 3-D winds
- **SFMR** – estimates surface wind speeds beneath plane

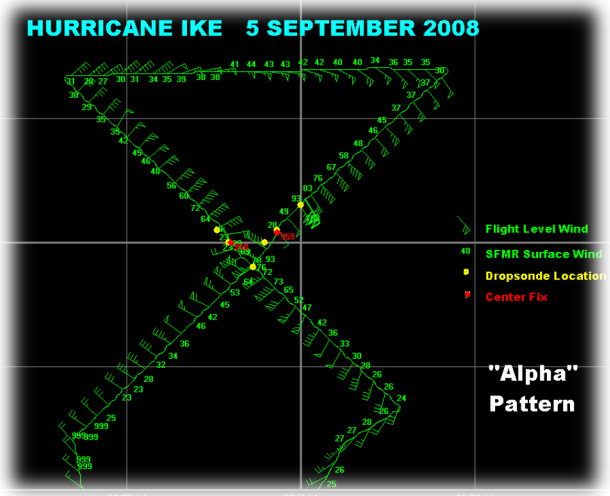
SFMR instrument



SMFR-estimates winds (green) from a flight into Dorian

Overview: Recon Program

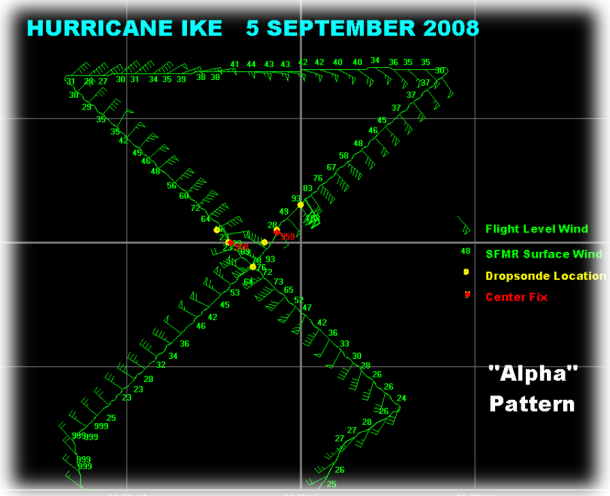
- WC-130J "Hurricane Hunters" from USAF 53rd WRS perform bulk of TC surveillance
- Tasked by NHC mostly to gather TCVitals "center fix"
- Send real-time data, including dropsondes, flight-level obs, and SFMR 10-m wind speed and rain rate



Overview: Recon Program

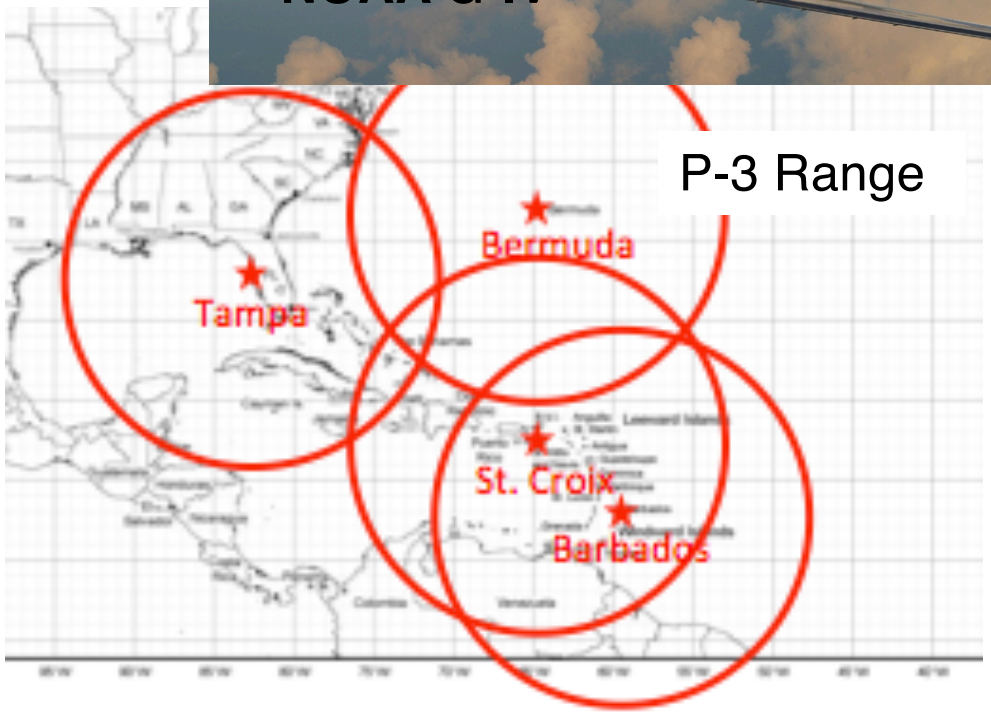
Typical C130 mission stats:

- 1-10 kft (TD-Hur)
- 3200 nm (10-h)
- Fix frequency (3-24 h) depends on threat to US interests



Overview: Recon Program

- NOAA also uses a G-IV and two P-3s
- G-IV used in environment and near storm
- P-3 used mostly in-storm
- Both aircraft transmit dropsondes, flight-level obs, SFMR, and Doppler radar data



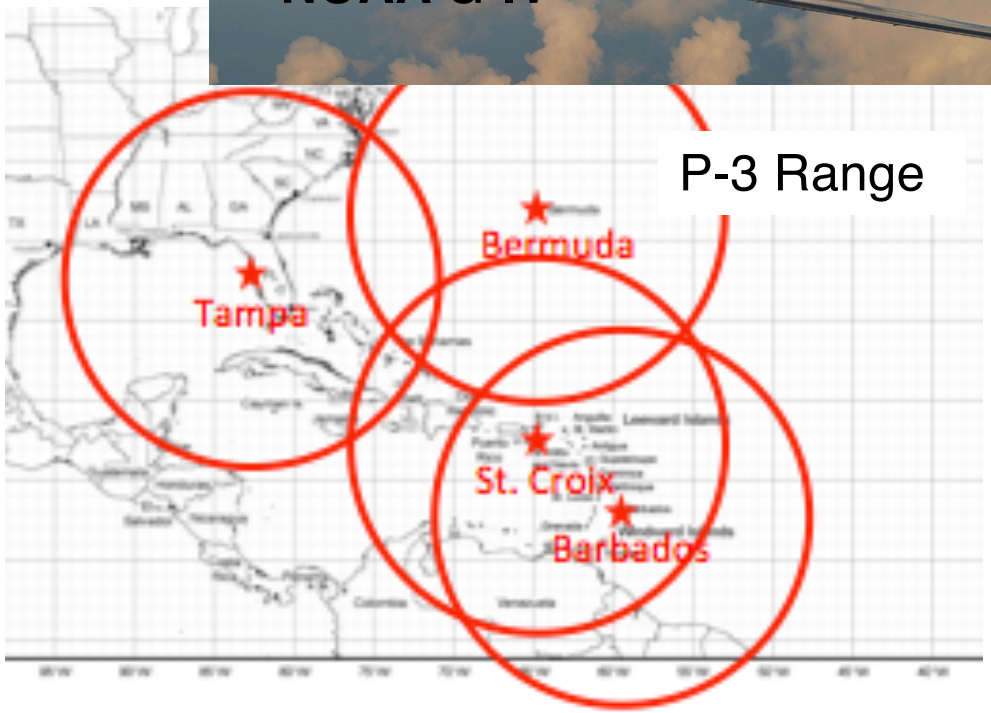
Overview: Recon Program

Typical G-IV mission

- 42 kft cruise altitude
- 3600 nm (8h)

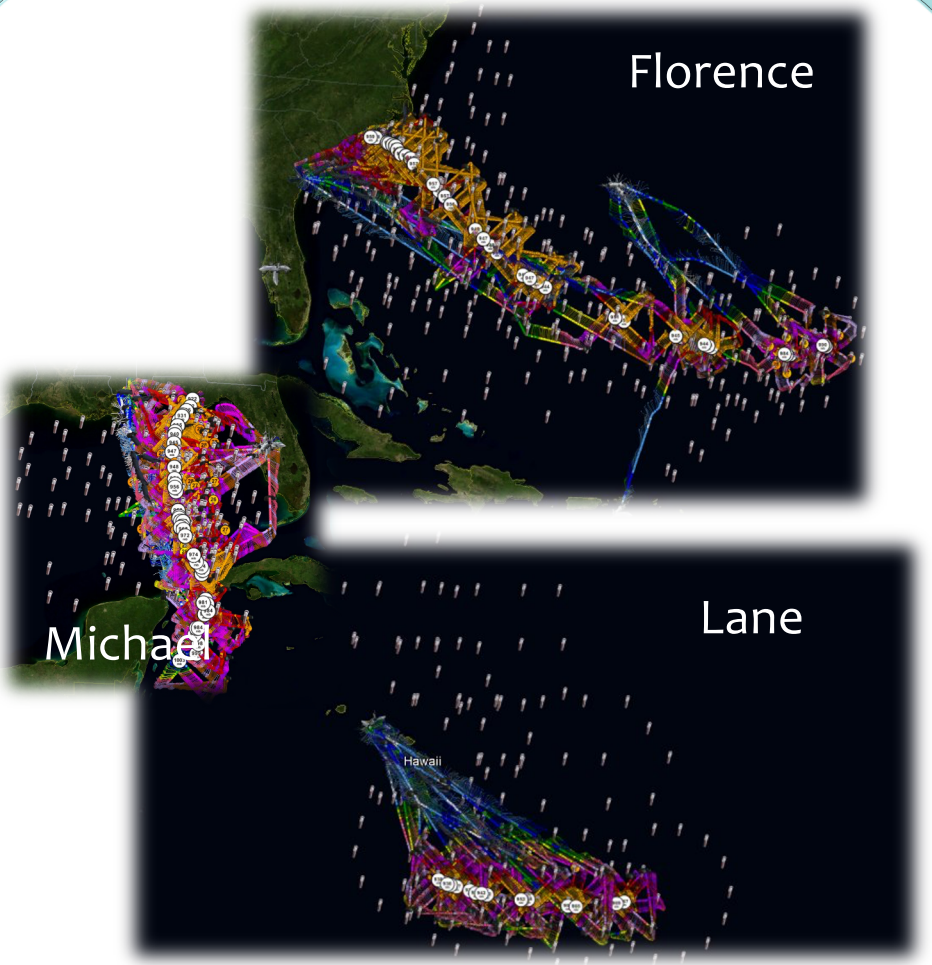
Typical P-3 mission

- 10 kft cruise altitude
- 2100 nm (8h)

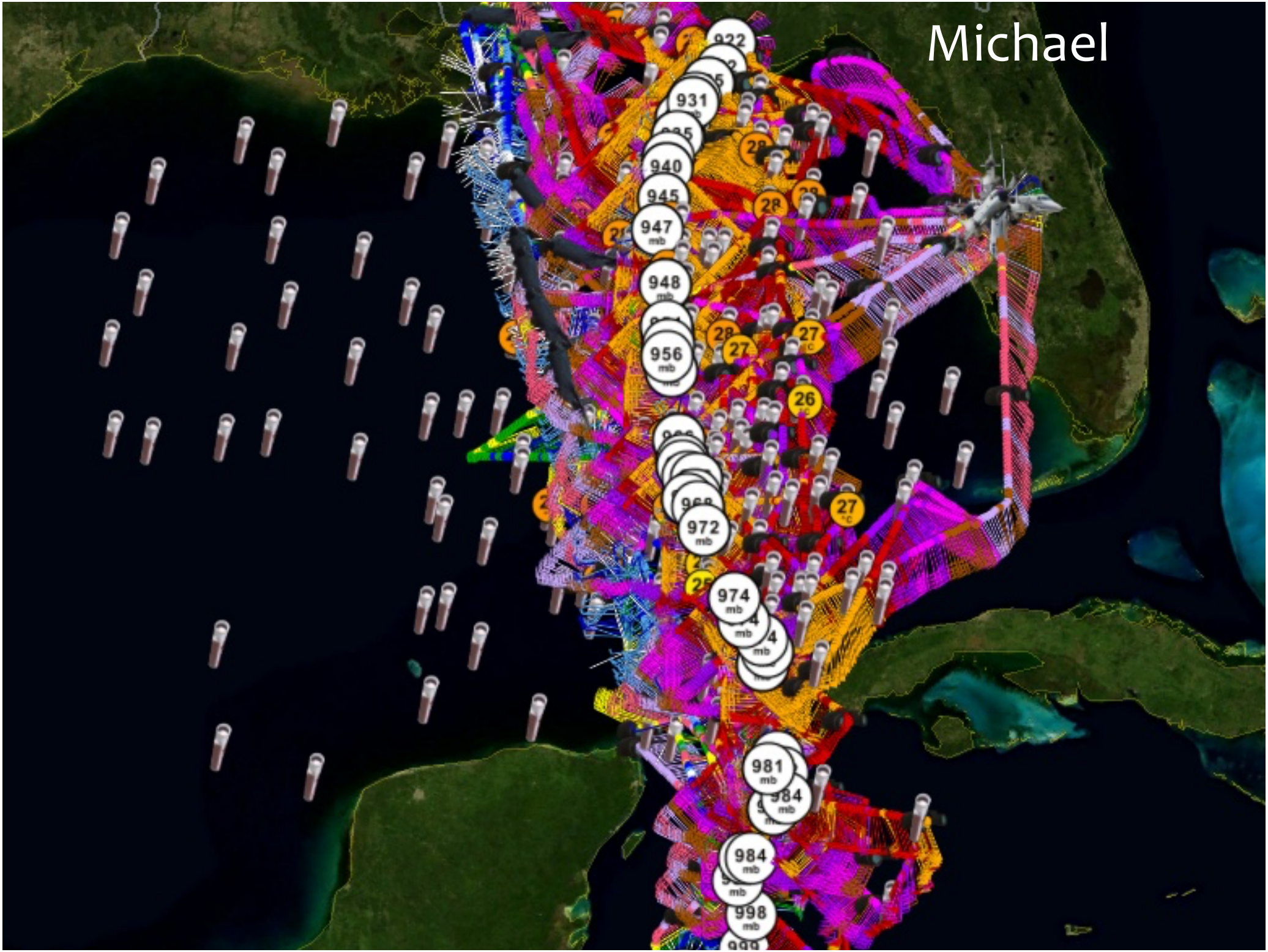


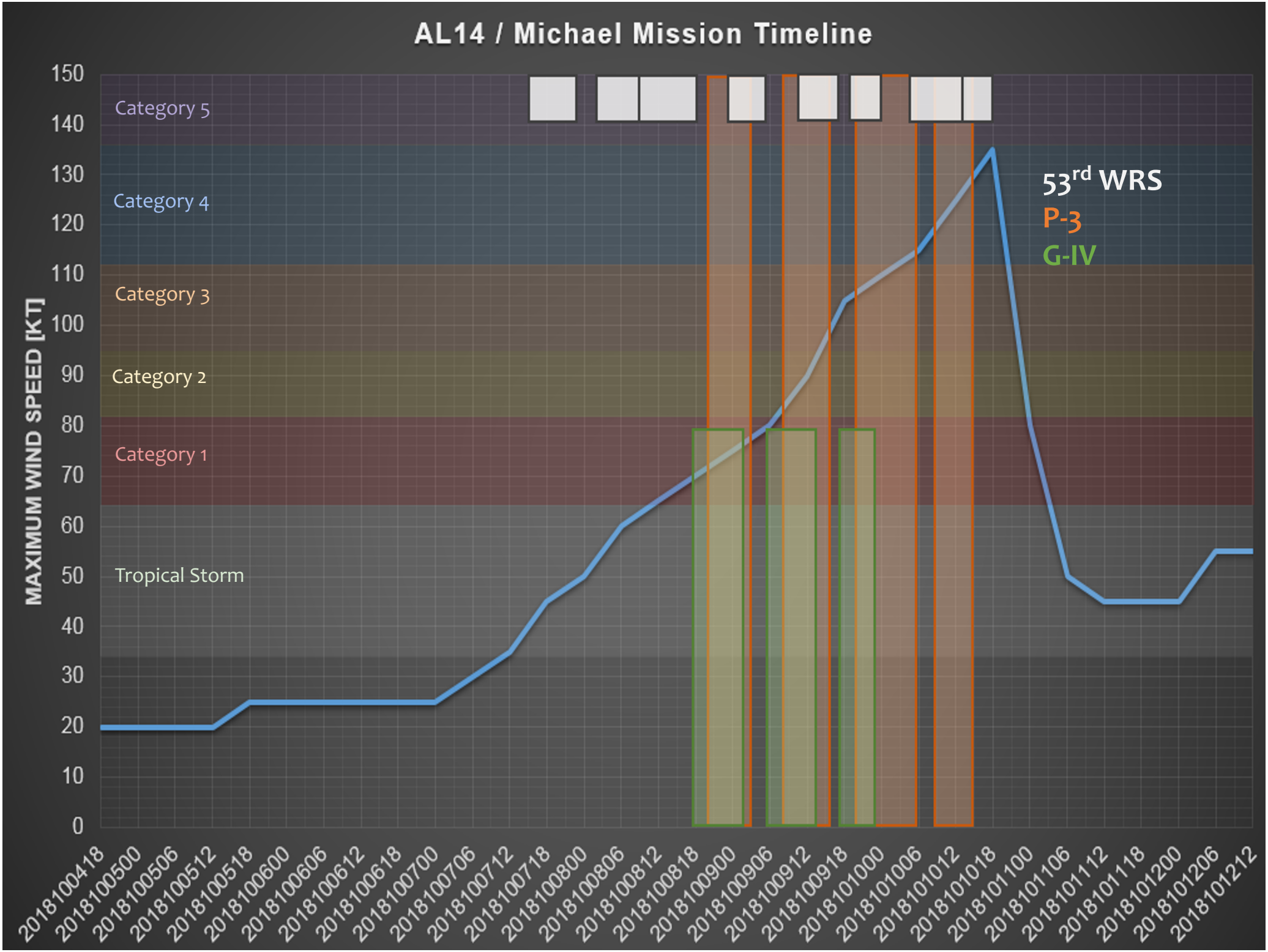
Overview: 2018 Operations

- Nearly 120 missions into 15 tropical systems
- Over 1900 dropsondes deployed
- At one point, simultaneous operations from Hawaii, Caribbean, and US East Coast



Dropsonde locations and flight-level winds from all missions into Florence, Michael, and Lane


Michael
931
940
945
947
mb
948
mb
956
mb
28
27
26
972
mb
974
mb
981
mb
984
mb
984
mb
998
mb


AL14 / Michael Mission Timeline
MAXIMUM WIND SPEED [KT]
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Category 5
Category 4
Category 3
Category 2
Category 1
Tropical Storm
53rd WRS
P-3
G-IV
2018100418
2018100500
2018100506
2018100512
2018100518
2018100600
2018100606
2018100612
2018100618
2018100700
2018100706
2018100712
2018100718
2018100800
2018100806
2018100812
2018100818
2018100900
2018100906
2018100912
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2018101118
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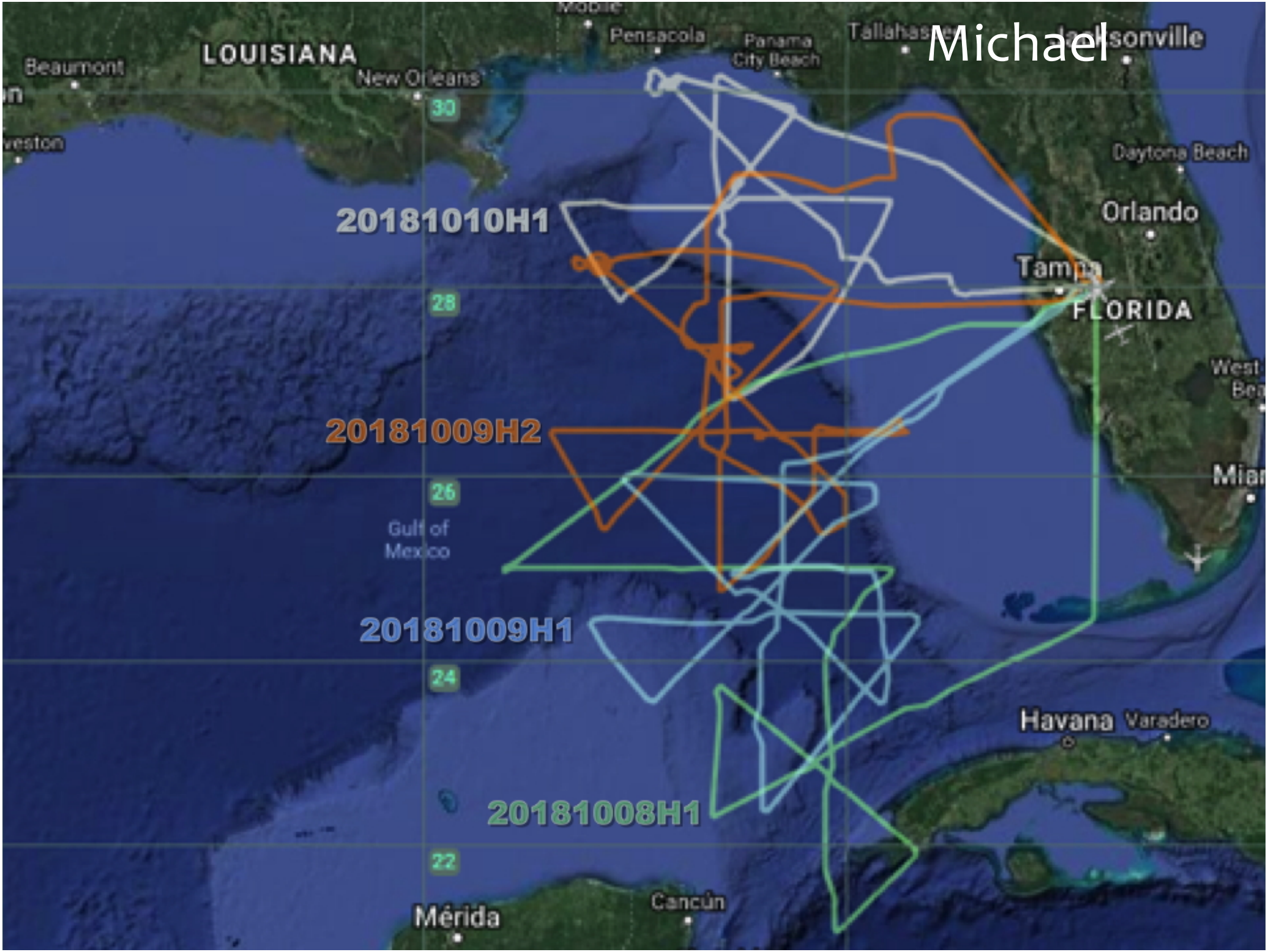
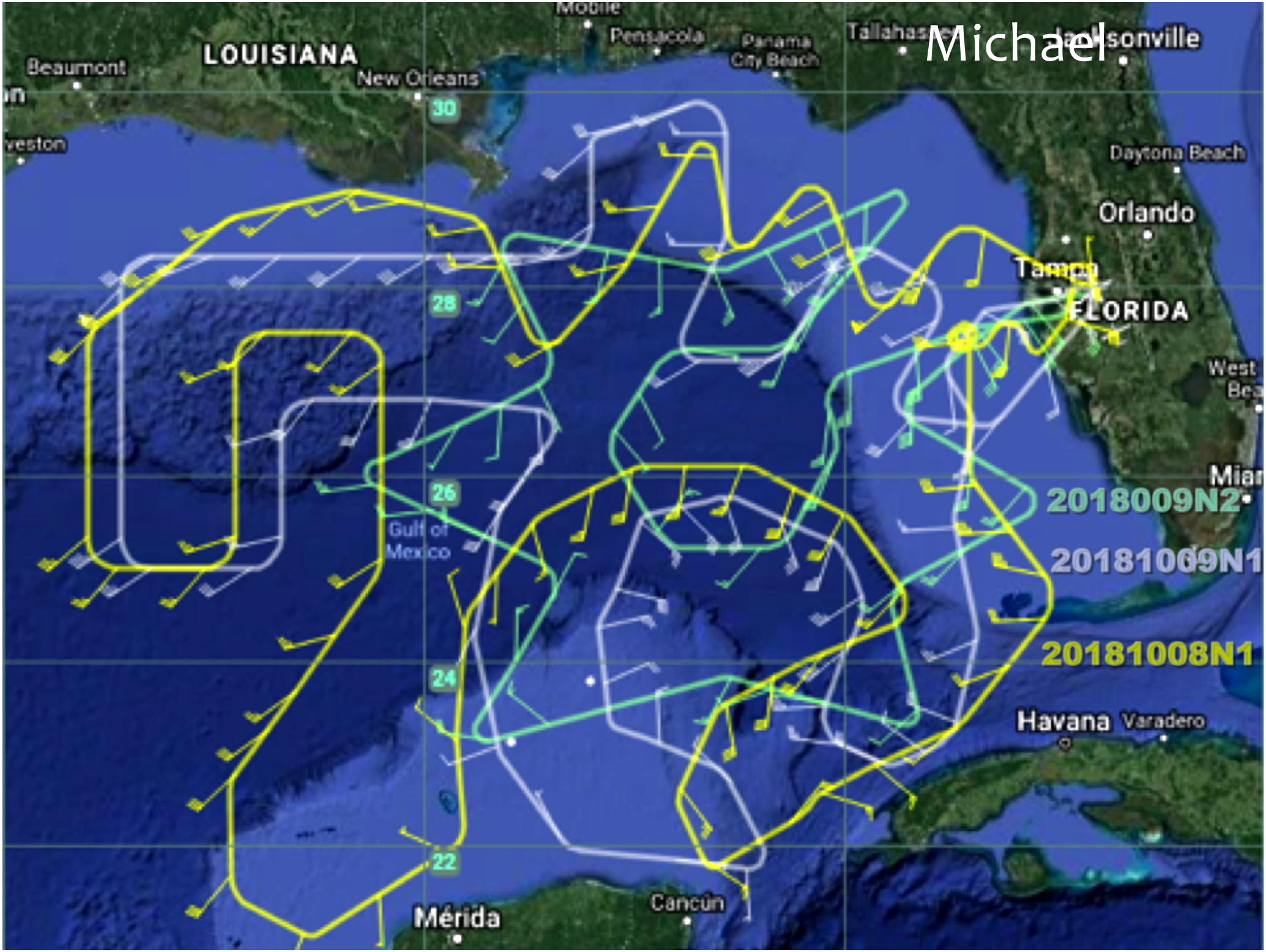
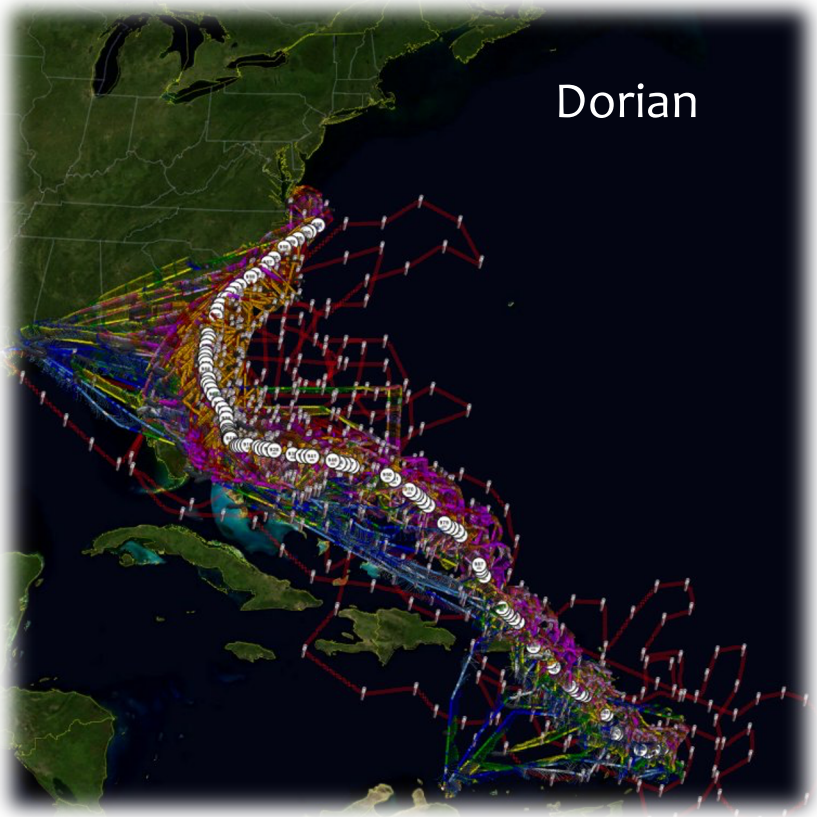
2018101212


Michael
LOUISIANA
Beaumont
New Orleans
Pensacola
Panama City Beach
Tallahassee
Jacksonville
Daytona Beach
Orlando
Tampa
FLORIDA
West Palm Beach
Miami
Gulf of Mexico
Havana
Varadero
Cancún
Mérida
30
28
26
24
22
20181010H1
20181009H2
20181009H1
20181008H1


Michael
LOUISIANA
Beaumont
New Orleans
Pensacola
Panama City Beach
Tallahassee
Jacksonville
Daytona Beach
Orlando
Tampa
FLORIDA
West Palm Beach
Miami
30
28
26
24
22
Gulf of Mexico
20181009N2
20181009N1
20181008N1
Havana
Varadero
Cancún
Mérida

Overview: 2019 Operations

- Over 120 missions into 13 tropical systems
- Almost 2700 dropsondes deployed
- Over 50 flights into Hurricane Dorian!



Dropsonde locations and flight-level winds from all missions into Dorian

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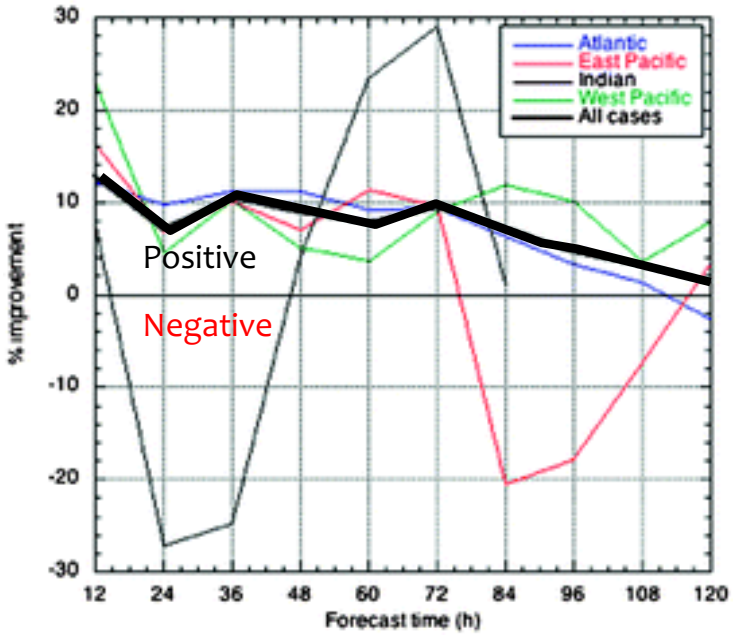
History of recon usage: Observations outside TC

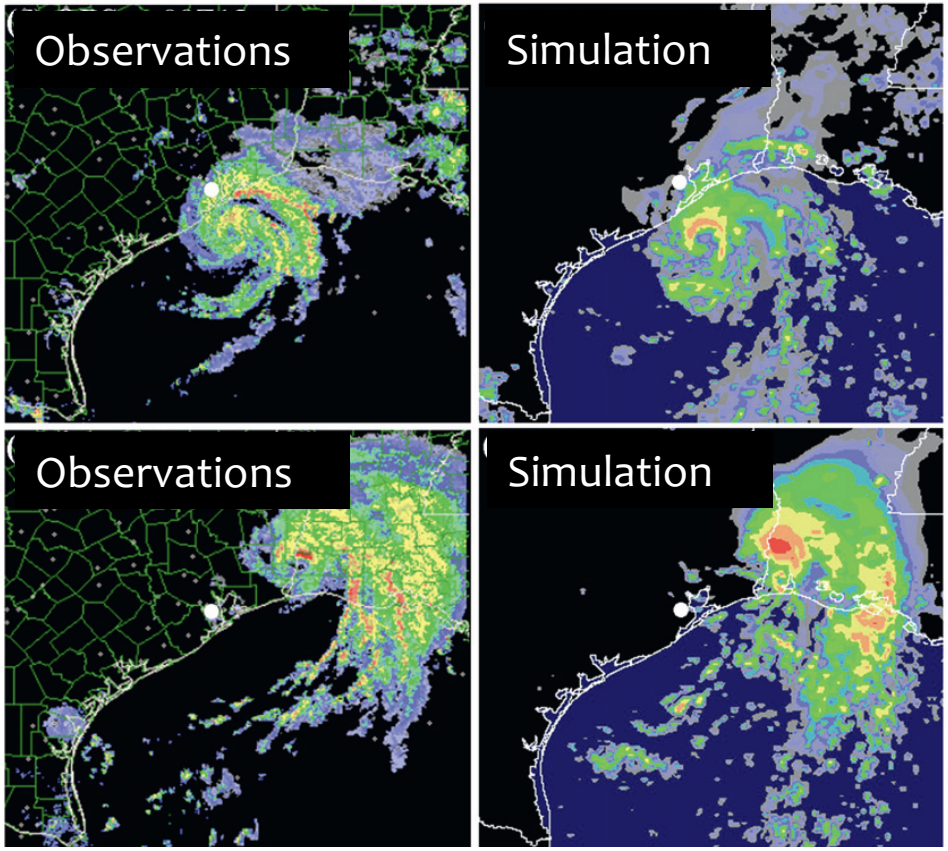
Dropsonde impact on GFS TC track



Percent improvement as a result of assimilating dropsondes in September 2008 (Aberson 2011)

- US has used dropsondes for TC model forecast improvement since 1997
- Aberson (2010, 2011) examined impact of dropsondes in GFS
- Significant track improvement globally

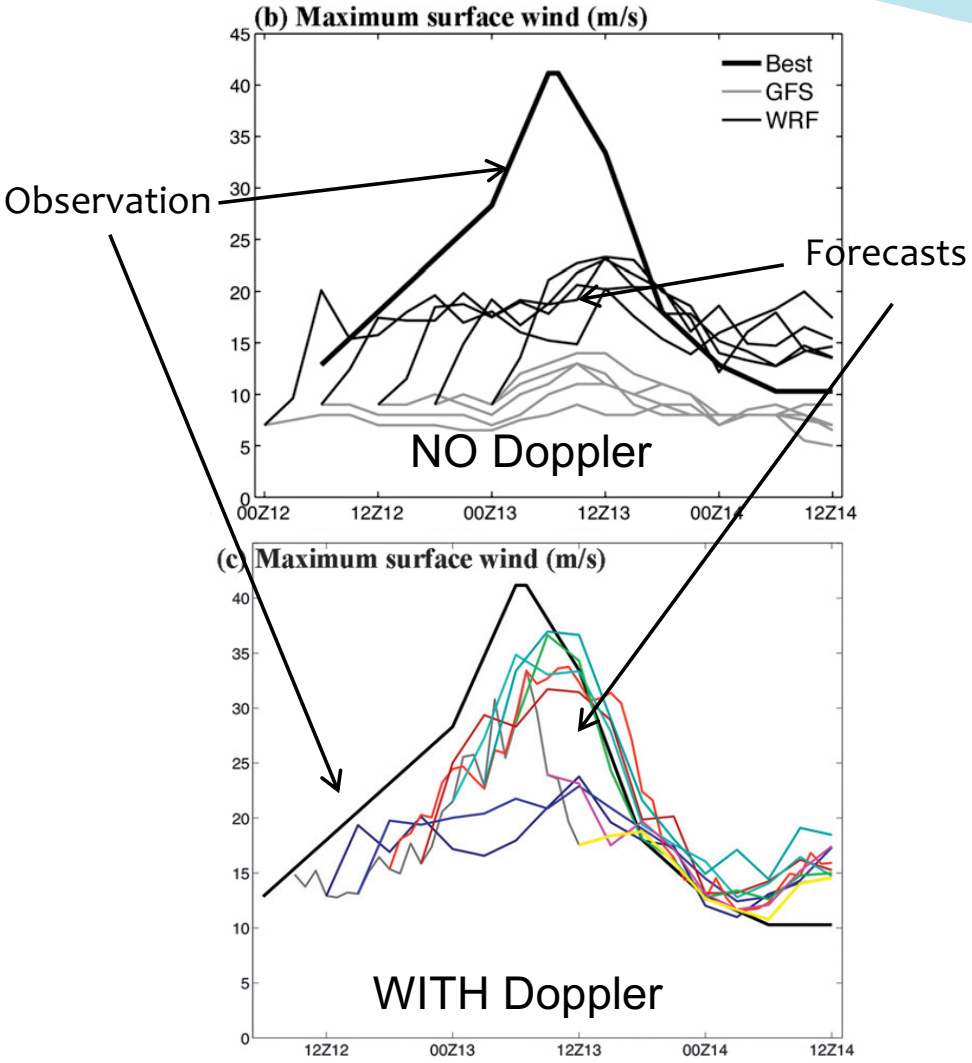
History of recon usage: Observations inside TC



Observations (left) and analyses (right) of reflectivity from Hurricane Humberto with an experimental system

- Starting in 2008, it became apparent that assimilating Doppler velocity data had potential for forecast improvement
- Assimilating radar data significantly improved analyses and forecasts of Hurricane Humberto

History of recon usage: Observations inside TC



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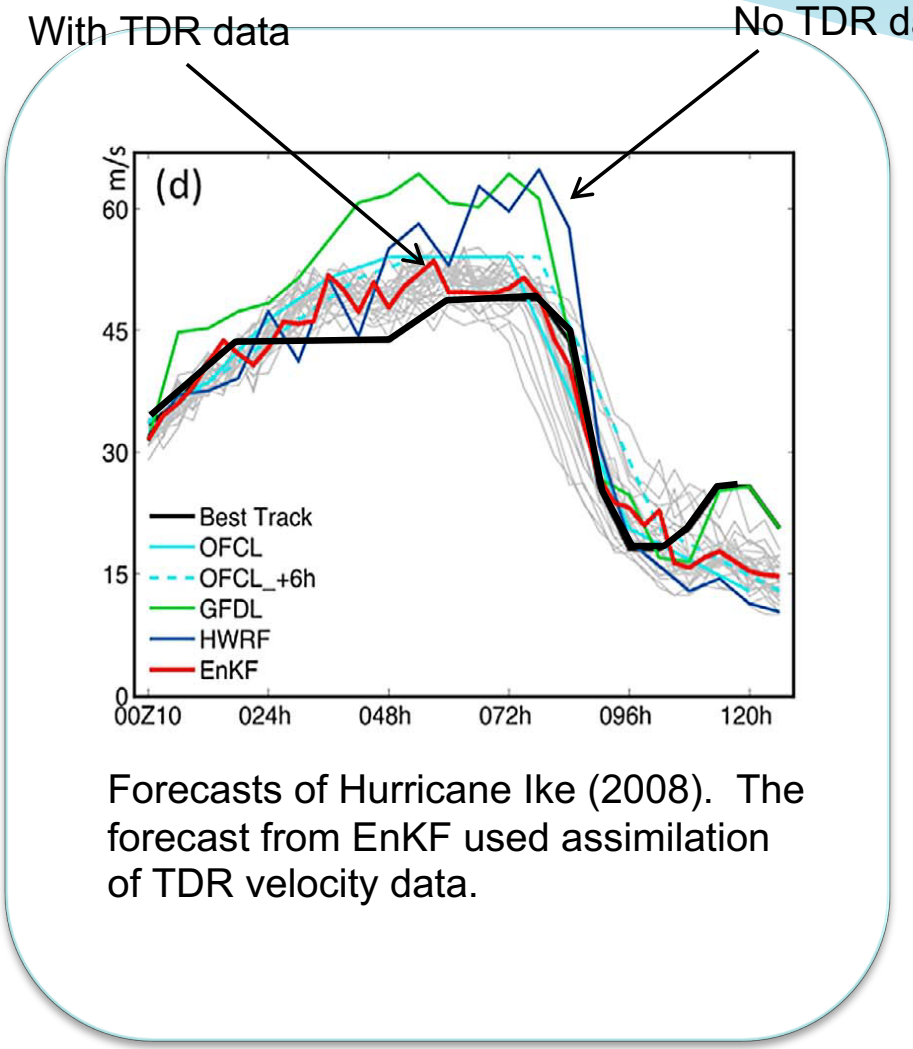
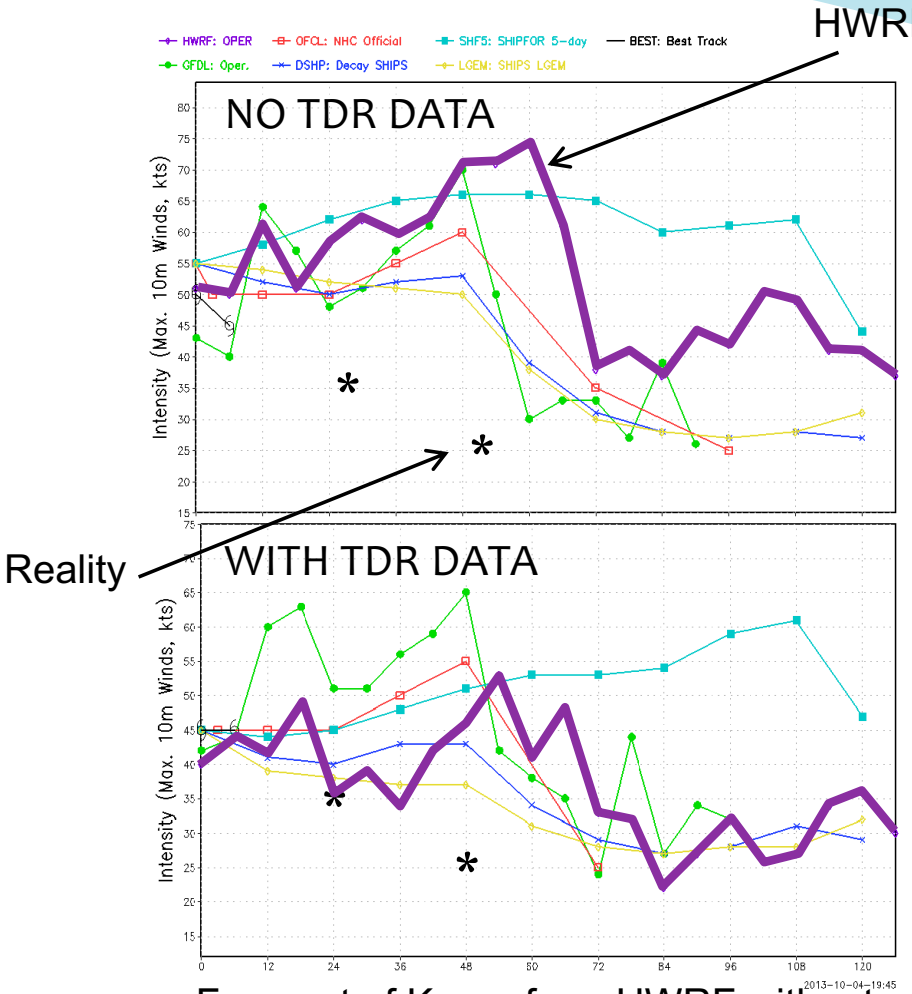
History of recon usage: Observations inside TC



Forecasts of Hurricane Ike (2008). The forecast from EnKF used assimilation of TDR velocity data.

- Subsequent work showed forecast improvements from assimilating Doppler velocity from recon (TDR)
- These results led to a dedicated effort to assimilate TDR operationally

History of recon usage: Observations inside TC



Forecast of Karen from HWRF without (top) and with (bottom) TDR DA

- TDR data began being assimilated in HWRF in 2013
- For weak storms like Karen, there was substantial improvement of a positive intensity bias in HWRF (purple)

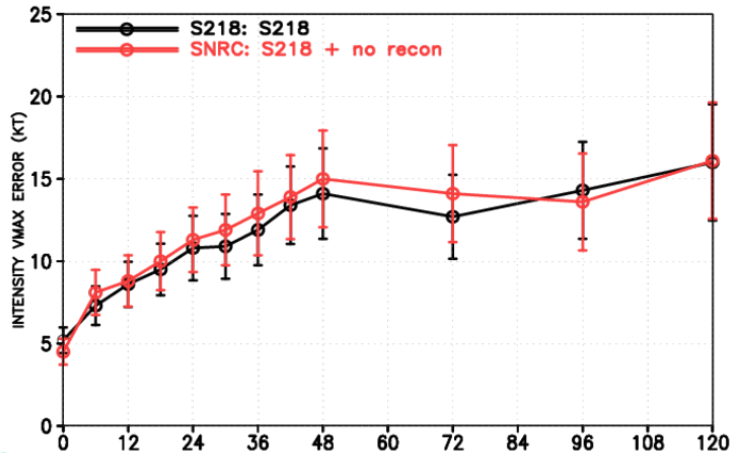
History of recon usage: Observations inside TC

Added recon data shown in red

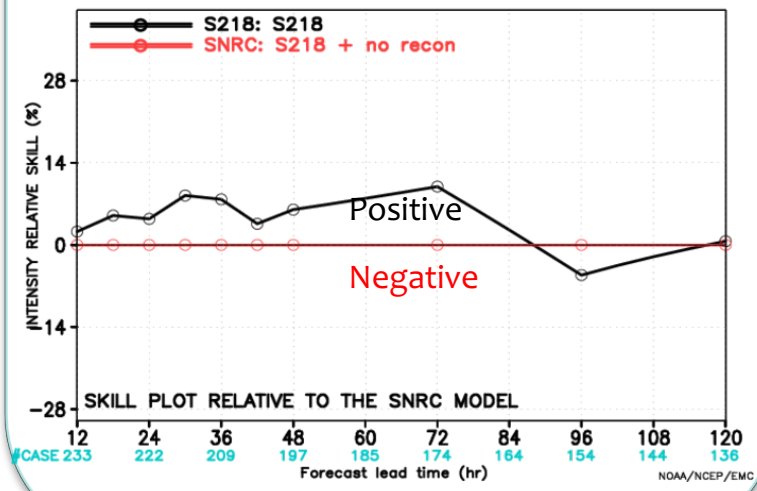
Recon Impact: 2019 HWRF

- Impact of recon in 2016-2018 high impact storms was examined for HWRF
- Many major hurricanes in this sample, which are the hardest to improve
- Recon has a clear positive impact on intensity, about 10% improvement through 72h
- This does not include impacts on FV3

Recon test Vmax error in HWRF



Recon test Vmax skill in HWRF



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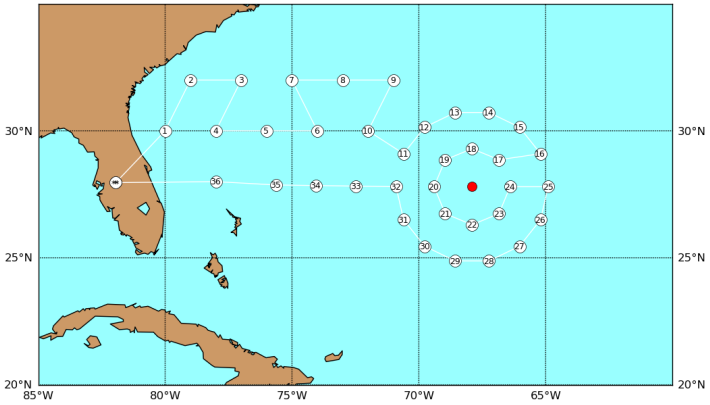
Recent Changes: G-IV missions

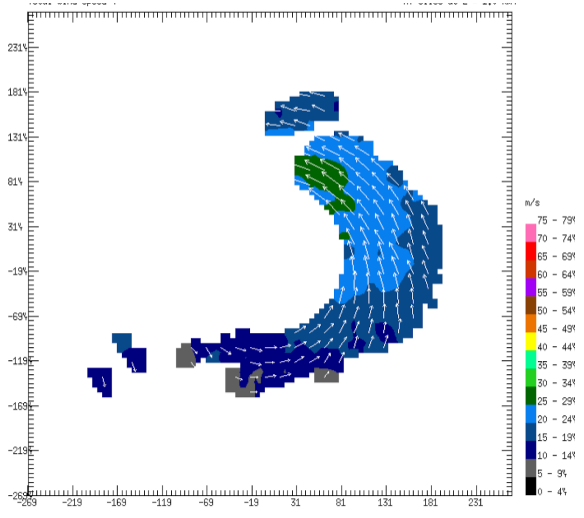
G-IV began two complete circumnavigations at ~90 and 180 nm

- Likely stronger impact on track than that from distant dropsondes
- Recent research also shows that near-vortex data helps constrain vortex structure with impacts on intensity
- G-IV Doppler velocity data more extensive closer to the vortex

Planned G-IV flight track and dropsondes for Hurricane Florence



Analysis of horizontal winds from GIV TDR

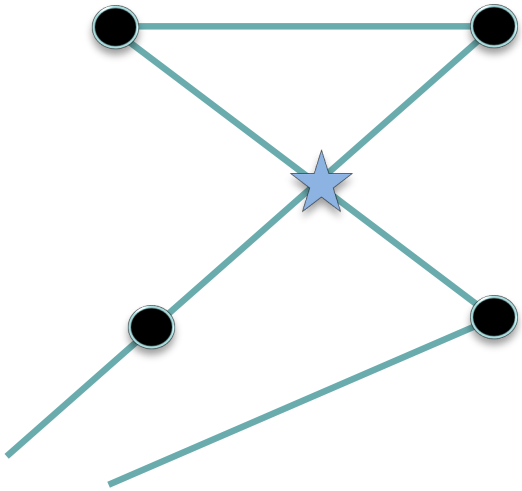


Recent Changes: C-130 missions

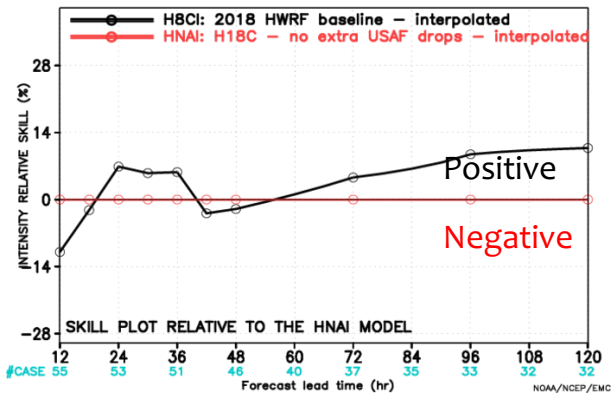
"End-point" dropsondes from USAF C-130 missions

- Dropsondes at end-points of "alpha" pattern from C-130 missions began experimentally in 2017
- Data denial tests suggested a 10% impact on intensity skill
- Based on these results, this practice was implemented operationally in 2018

Example of end-point drop positions



End-point dropsonde test intensity skill



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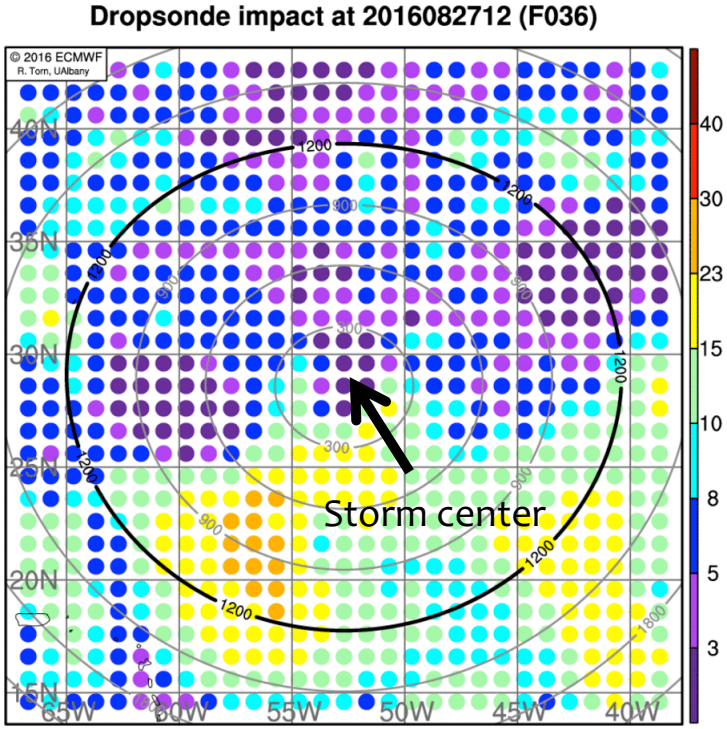
Future direction

- NOAA in process of acquiring another high-altitude jet to replace or supplement G-IV
- "Smarter" environmental targeting in the works (EMC/NHC working with Ryan Torn)
- Major cost-benefit assessment of recon practices underway (focused on dropsondes)



Reduction in track uncertainty due to assimilating dropsondes (Warmer = more reduction), courtesy Ryan Torn

Future direction

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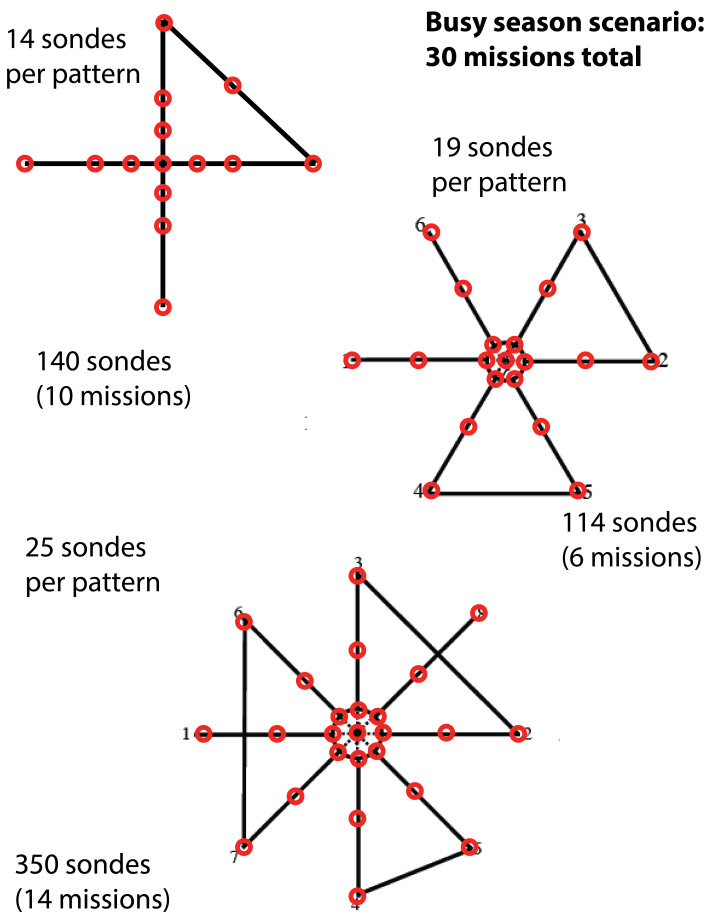
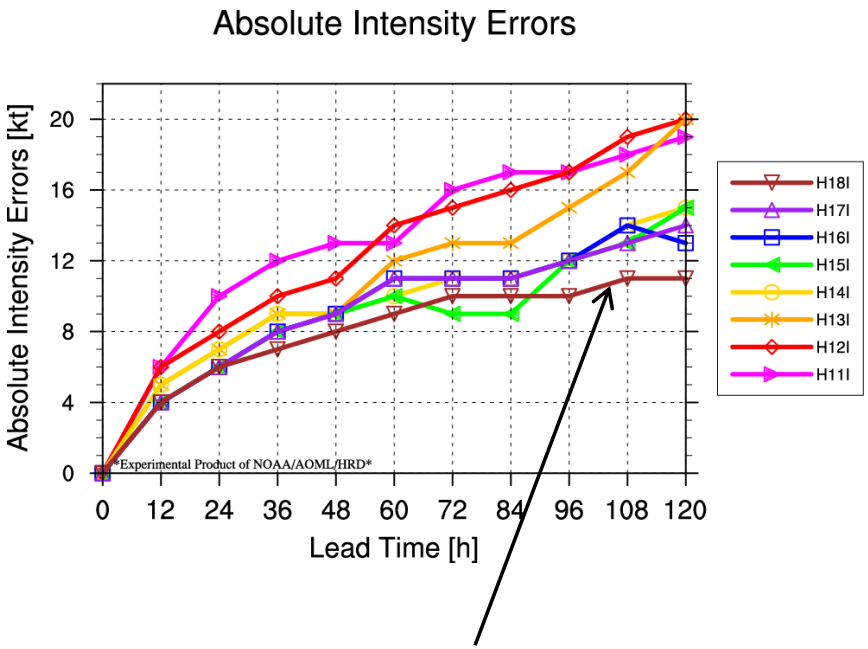


Idealized distribution of sondes to be tested in data denial experiments

Conclusions

- NOAA has an extensive TC reconnaissance program focused on forecast improvement for US threats
- Missions are increasingly focused on gathering data from in and near the TC vortex
- A systematic evaluation of reconnaissance best practices is underway with results forthcoming in next several years

Bonus slide: History of model forecast improvements!



HWRF median intensity error at long lead times have decreased by almost 50% in last decade!

- Significant focus of HFIP has been the development of the HWRF model
- As a result, HWRF intensity errors have decreased significantly over the past decade