Examples of High-Altitude Airborne Dropsondes

Peter G. Black[1]   Vijay Tallapragada[2]

[1] I.M. Systems Group, Inc
[2]NOAA/NWS/NCEP Environmental Modeling Center
College Park, MD USA

Hurricane Florence: 12 Sep, 2018
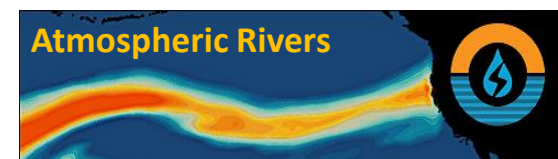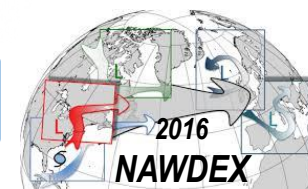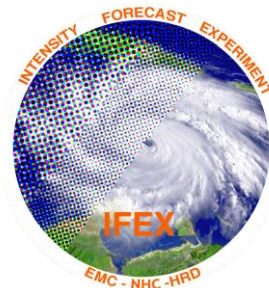**International Space Station**
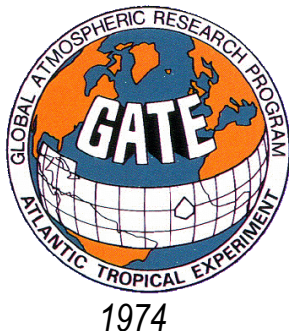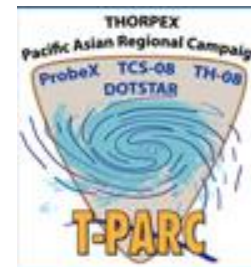**Photos- ESA Astronaut Alexander Gerst**

Workshop: Observational Campaigns for Better Weather Forecasts
10—13 June 2019 ECMWF Reading UK

Emerging Technologies

63 years of >30 Airborne Atmospheric Campaigns
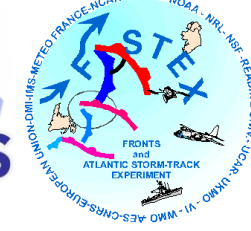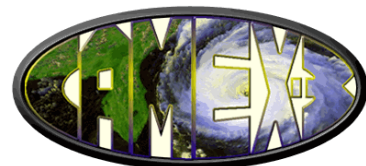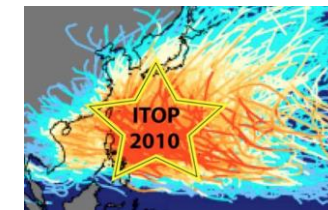
How have our campaigns evolved over the past 5-7 years?
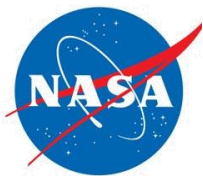
- **High- Altitude**
- **Long- Endurance**
- **UAV**
- **Operational**

HALE

Emerging High-Altitude Airborne Technology

Future Operational Observing Strategy
based upon
Past Research Collaboration

NASA

NOAA/ AF
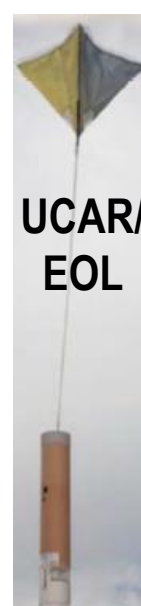

?DAWN OF A NEW ERA?
NASA GLOBAL HAWK AV-6

NOAA G-IV SP   G-550 coming 2022

UCAR/ EOL

AFRC 53rd WRS

NASA WB-57F
TCI 2014-2015

NOW A NEW ERA: Research to Operations (RTO)
Transition to Operational Airborne Technology Takes Flight in the U.S.A.

NOAA G-IV SP Surveillance
N49RF

G-550 coming in 2022

NOAA WP-3D Orion RECO (N42RF)

AFRC WC-130J RECO (10)

NOAA WP-3D Orion RECO (N43RF)

AND AROUND THE WORLD

CWB ASTRA G-100 Surveillance

Taiwan

HK Flying Service Bombardier Challenger-650 RECO

Hong Kong

South Korea

TPARC-II G-II RECO

Nagoya University Japan

KMA King Air 350 Surveillance

Facility for Airborne Atmospheric Measurements, FAAM: BAE-146-301

Deimos

MARSS

UK

Germany

DLR G-550 HALO

DLR Falcon
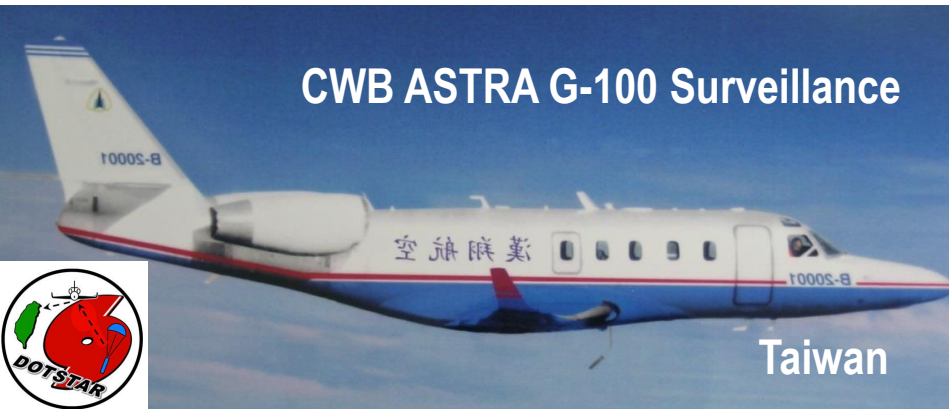
NSF NCAR EOL (Research)

C-130Q Hercules

G-550 HAIPER

OTREC 2019

Glider Sonde- Taiwan

Dropsonde Size

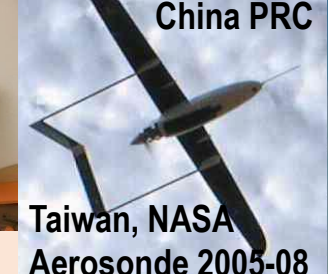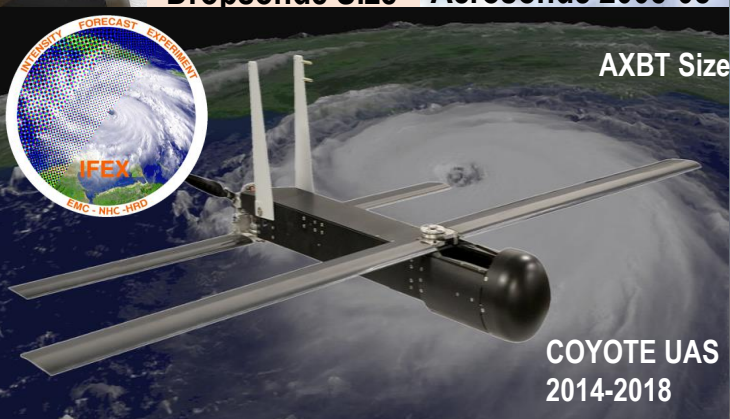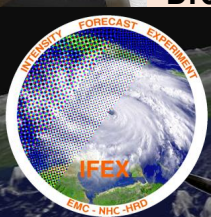CN-1 China PRC

Taiwan, NASA Aerosonde 2005-08

AXBT Size

COYOTE UAS 2014-2018

NASA GLOBAL HAWK UAS
HS3 SHOUT EPOCH 2012-2017

NASA DC-8 2005-2018

NASA WB-57F TCI 2014-2015

NASA ER-2 2005-2018

8

QUESTION ?

Why the increase in aircraft TC observation platforms and
airborne dropsonde instrumentation,
especially in the USA and Asia-Pacific countries, i.e.
locations directly impacted by landfalling TCs?

POSSIBLE ANSWER !

Because satellite platforms are seen as insufficient by themselves
for improving TC warnings and model intensity and structure prediction,
especially <u>Rapid Intensification (RI)</u> and <u>Rapid Weakening (RW).</u>

HERESY ??

Aircraft High-Altitude Long-Range (HALE) Capability Expands Performance Limits/ Model DA Impact
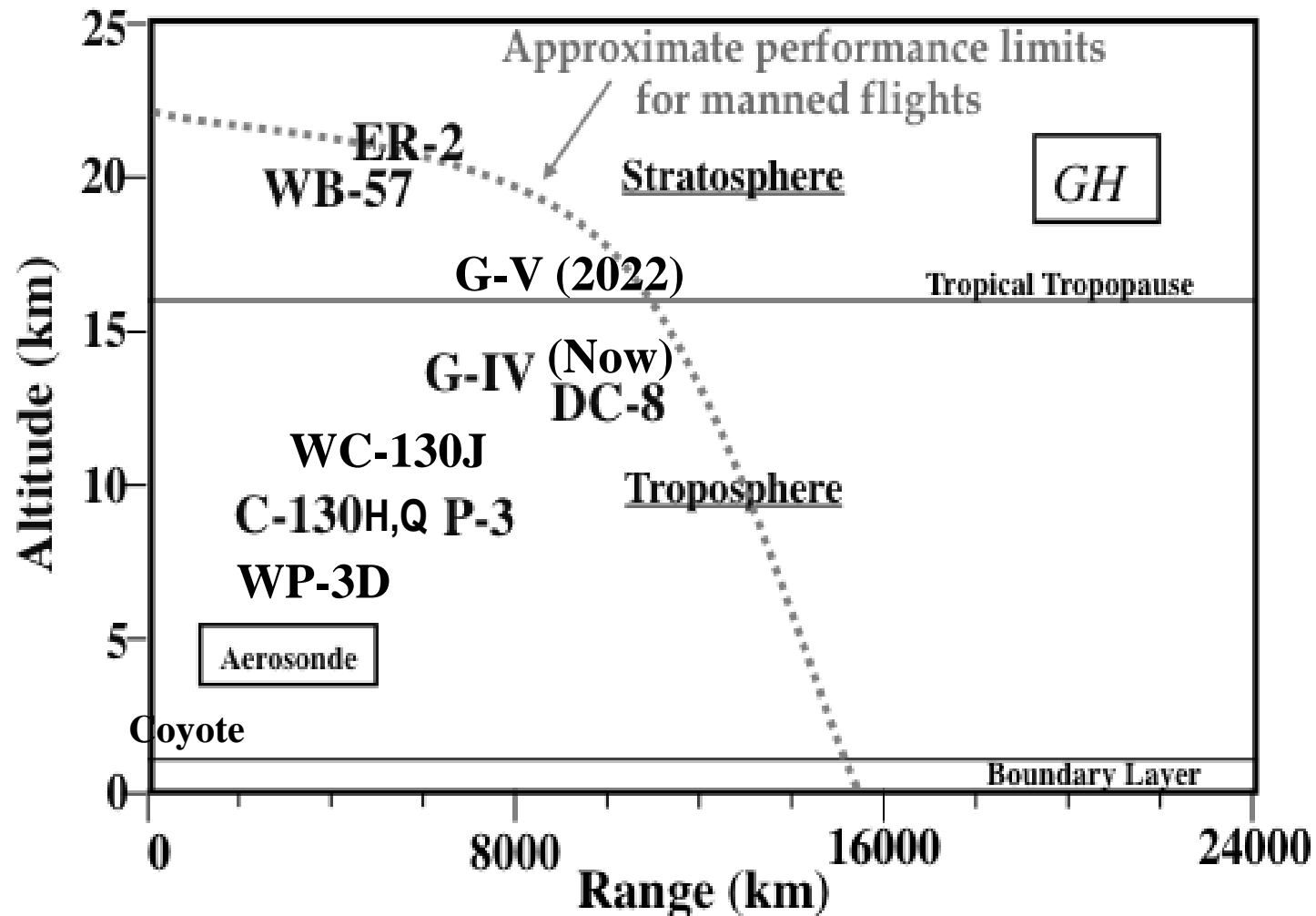
Objective

Provide some insight concerning the scope of airborne observations conducted on a operational basis for use in tropical cyclone model assimilation, especially sondes.

Outline

o **Aircraft platforms used operationally and for numerical model DA in Tropical Cyclones (TC) impacting the U.S., Mexico, Caribbean and the Western Pacific**
- **reconnaissance (inner core flights)**
- **surveillance (environmental flights)**

o **Mixed observational strategy: Global Hawk HALO unmanned and high-altitude manned aircraft innovative observations (SHOUT: 2015-16)**

o **Recent GIV/ P3 TC surveillance/ reco strategy examples: Lane, Florence, Michael- 2018**

o **Florence and Michael forecast impact issues**

o **Recent WPAC dropsonde observations: joint DOTSTAR/ TPARC-II dropsonde flights (STY Trami-2019)**

o **China rocket dropsonde observations (TY Mujigae-2015)**

HA Observational Strategy I: Mix of GH and GIV sondes in near-environment using inner-core large/ small butterfly pattern with far-environment race track

SHOUT2016 Karl 23 Aug 00Z-18Z GH_82 sondes: Mentioned by Jim Doyle in NAWDEX talk
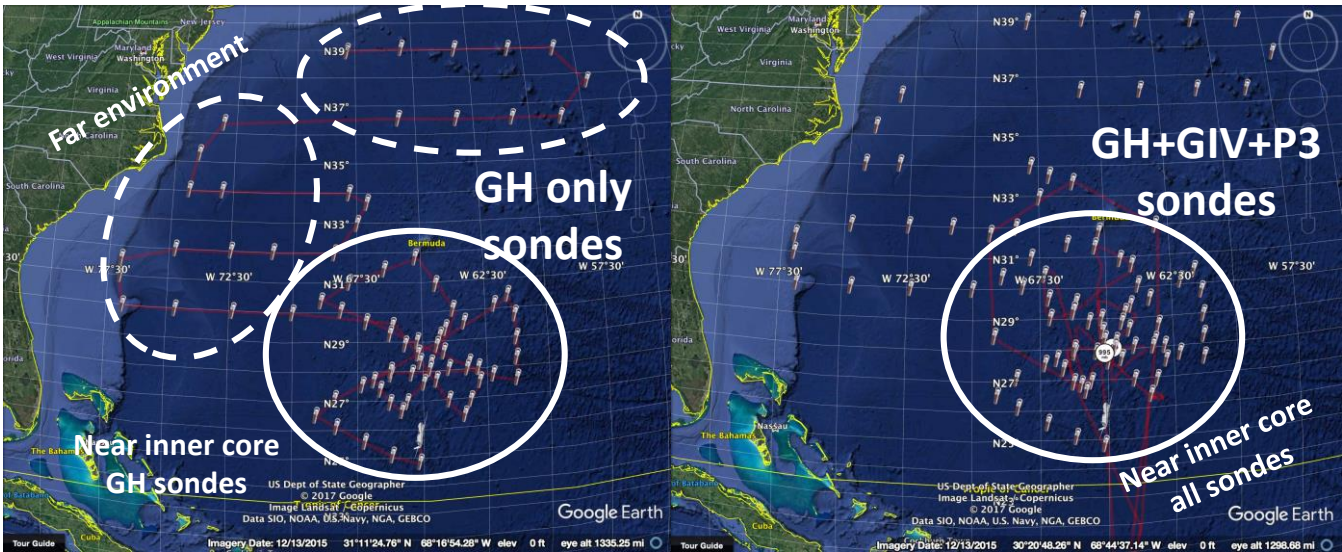
GLOBAL HAWK ERA 2012-2017

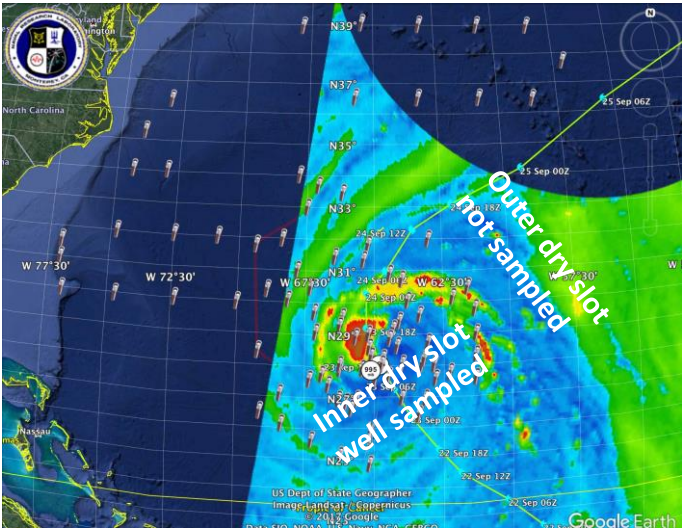### HS3   SHOUT   EPOCH

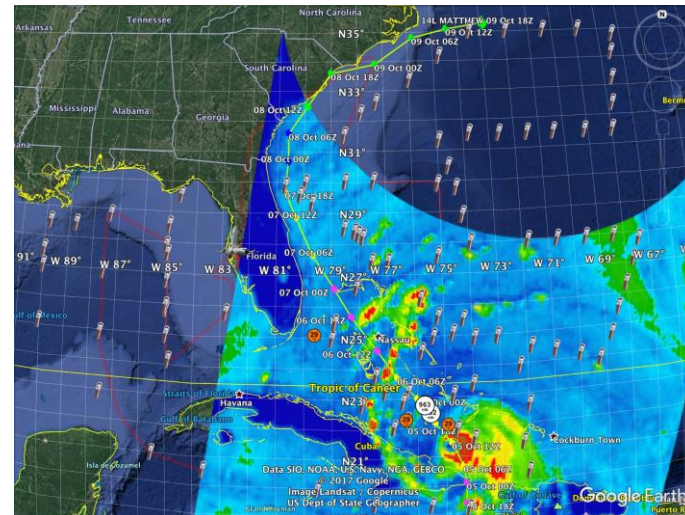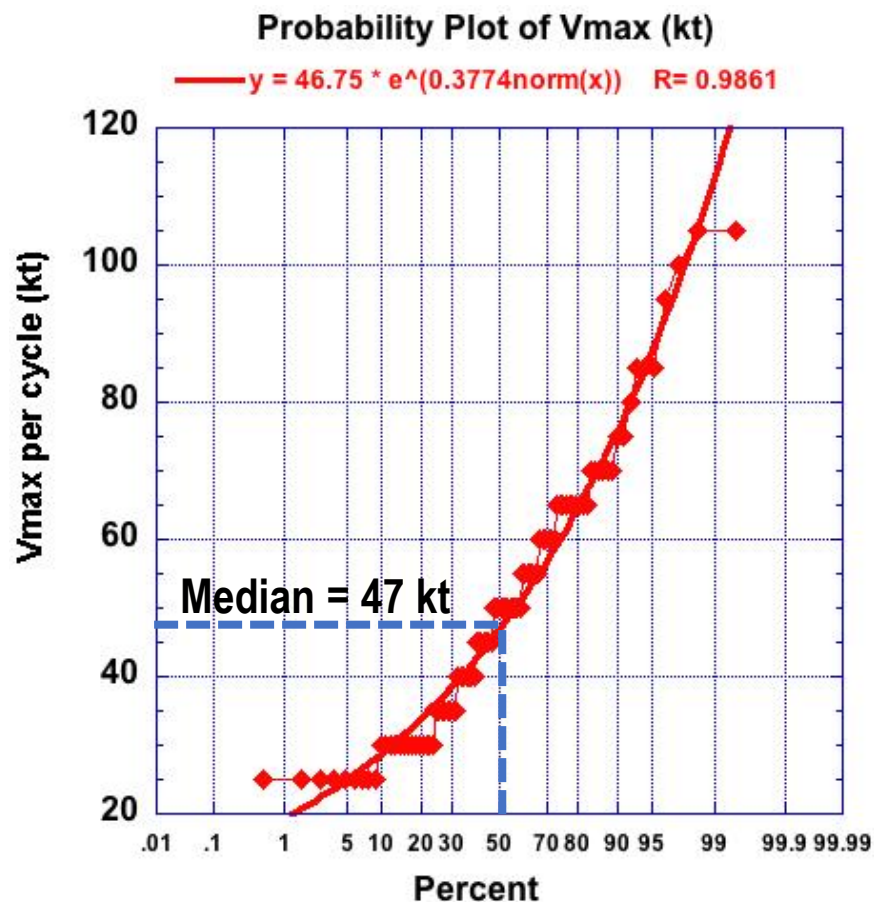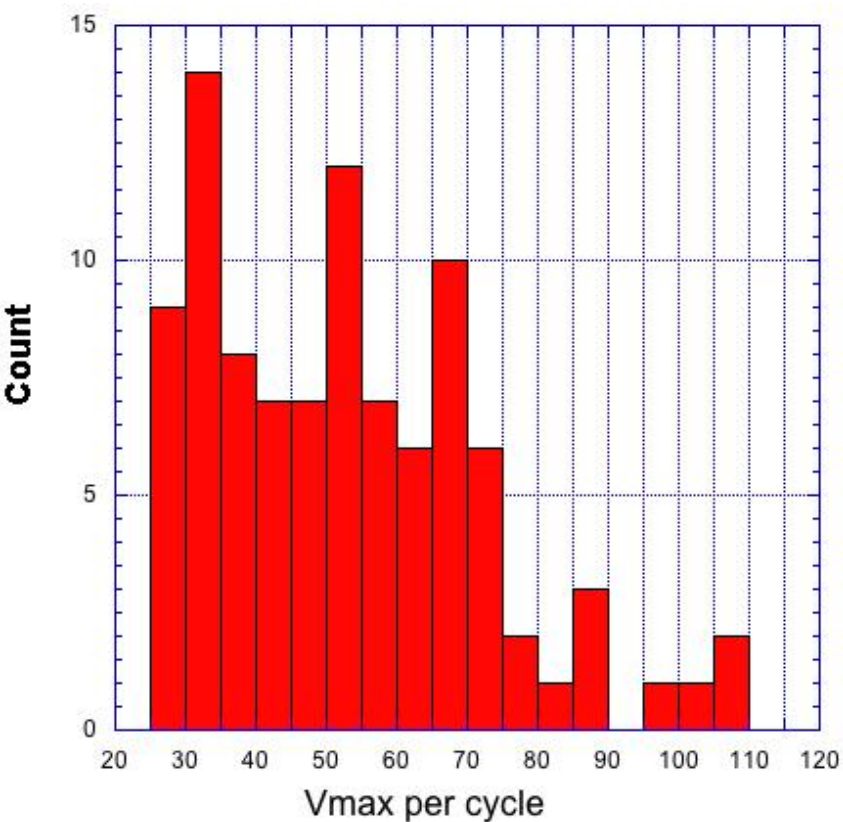2012-14   2015-16   2017

HA Observational Strategy II: Mix of GH, GIV sondes using far-environment race track with P3 inner-core butterfly

SHOUT2016 Matthew 05Oct 08Z-05Oct 20Z GH_61 sondes

Since flight time extends over 17-23 hours, need continuous DA without waiting for 6-, 3- or 1-hour assimilation cycles for max impact.
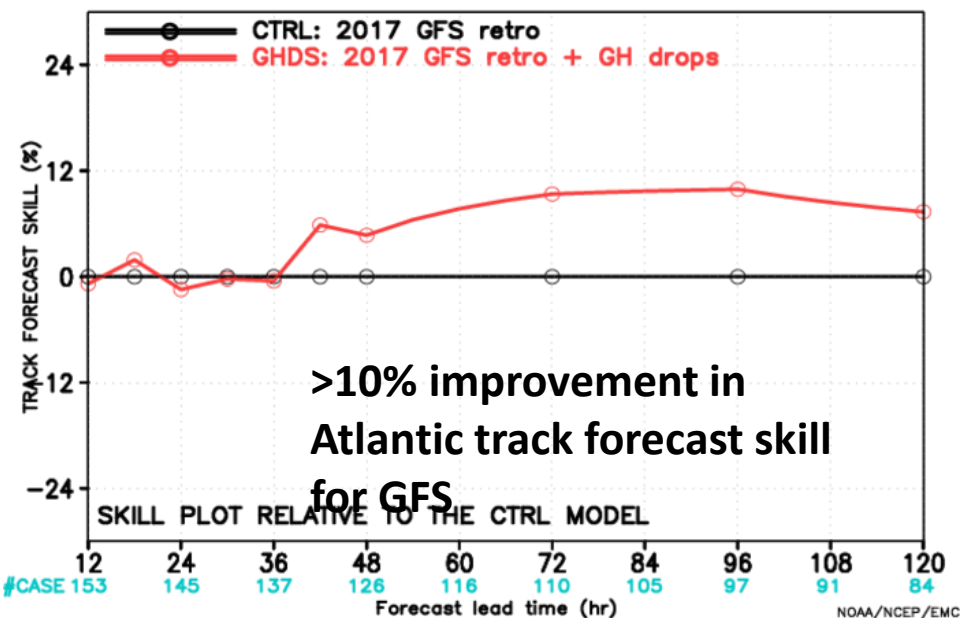
Global Hawk TC Vmax summary statistics- NOT TYPICAL

Early suggestions of Improved track and intensity forecast skill with Global Hawk in Operational GFS & HWRF Models- J Sippel
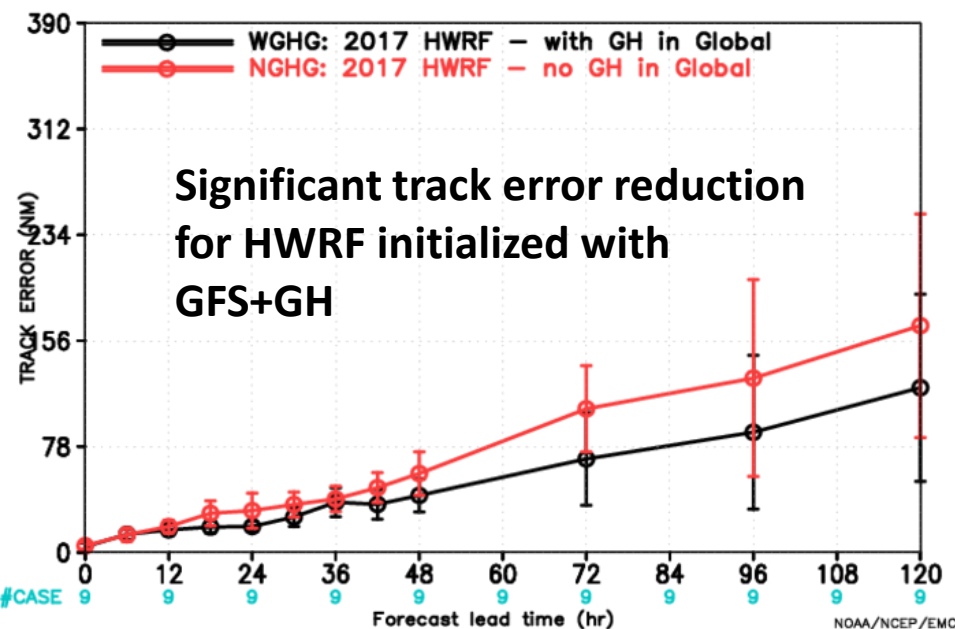## Washing Machine Approach- all sondes

GFS
all 2016 AL storms

HWRF
with GFS w/GH ICs

TRACK FORECAST SKILL (%) STATISTICS
GH drops test

CTRL: 2017 GFS retro
GHDS: 2017 GFS retro + GH drops

SKILL PLOT RELATIVE TO THE CTRL MODEL

>10% improvement in Atlantic track forecast skill for GFS

NOAA/NCEP/EMC

TRACK ERROR (NM) STATISTICS
H217 GH test

WGHG: 2017 HWRF — with GH in Global
NGHG: 2017 HWRF — no GH in Global

Significant track error reduction for HWRF initialized with GFS+GH

NOAA/NCEP/EMC

- *Old single-ring strategy plus enhanced environment with TEMP DROP*

- *A New Strategy Needed: Double Ring using BUFR coms plus ensemble model targeting*

Hurricane Lane

Significance:
First P3 Hawaii deployment
First Hawaii 4-aircraft deployment
First operational wave data- WSRA
Totals:
4 G-IV flts (120 sondes, ~30/flt)
4 WP-3D flts (63 sondes, ~16/flt)
5 WC-130J flts (35 sondes, ~7/flt)
5 NASA DC-8 flts (0 sondes)
14 flights over 4 days
218 sondes over 4 days

G-IV: green, brown, blue, orange

DC-8: purple

WP-3D: red, black

16

Google

Image may be subject to copyright   100 km   Terms of Use

Hurricane Florence
8-15 Sep 2018

New DOUBLE RING GIV plan

GIV Tracks: 9 total (4 double rings)
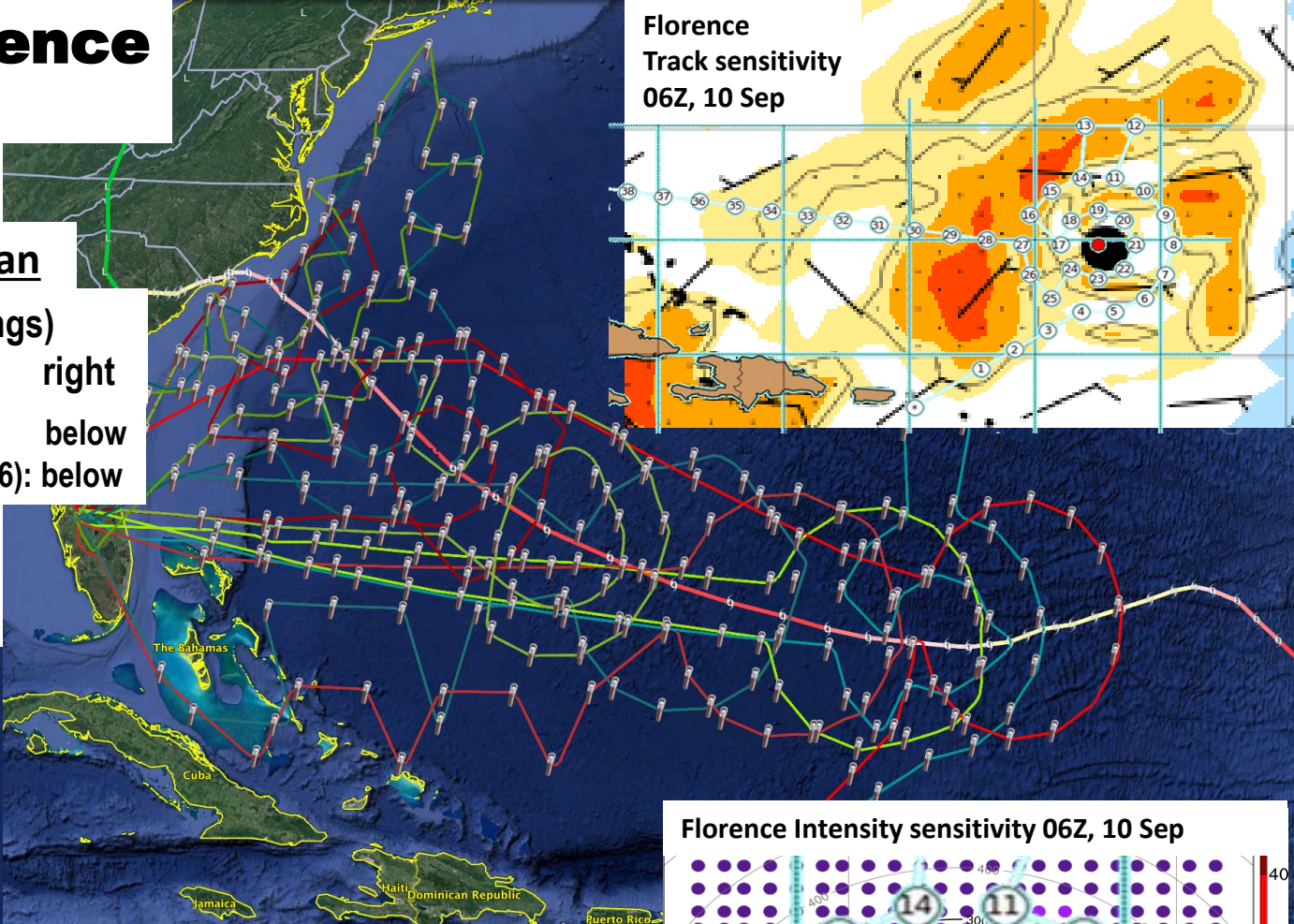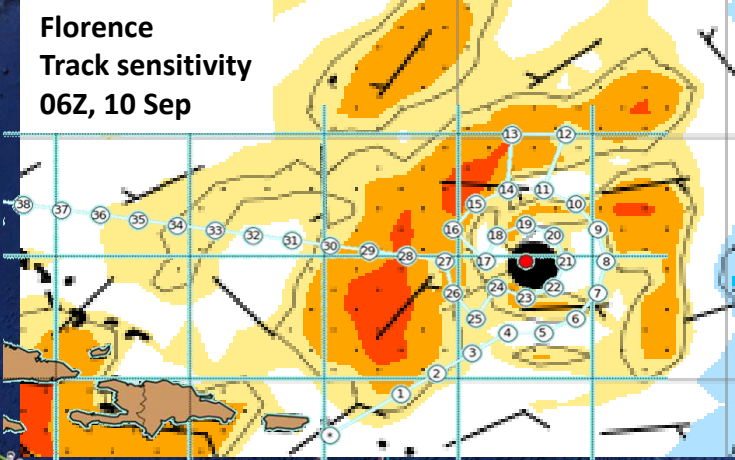Sondes: 281   right

WP-3D Tracks (3) and Sondes (82):   below
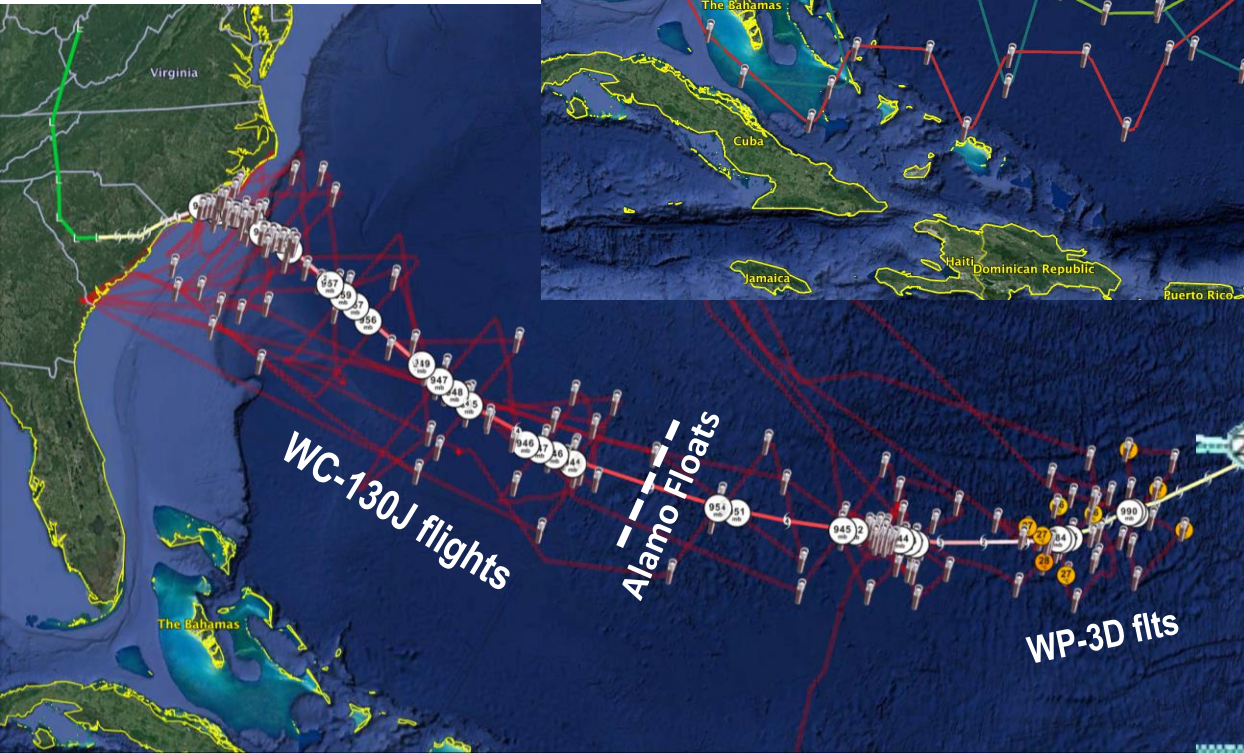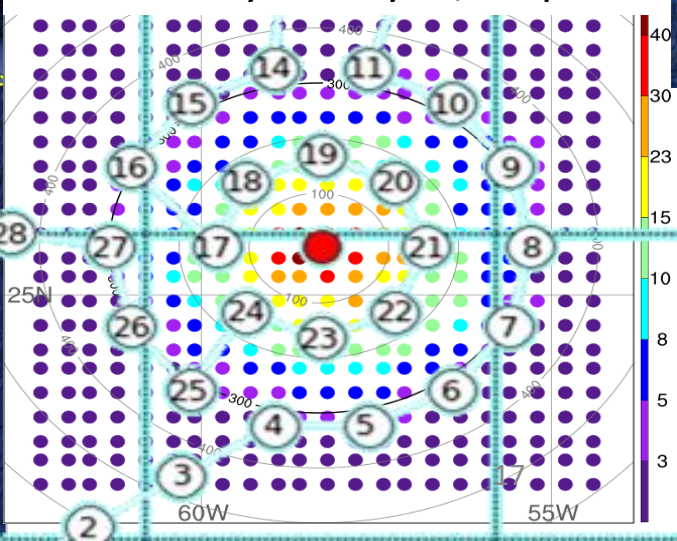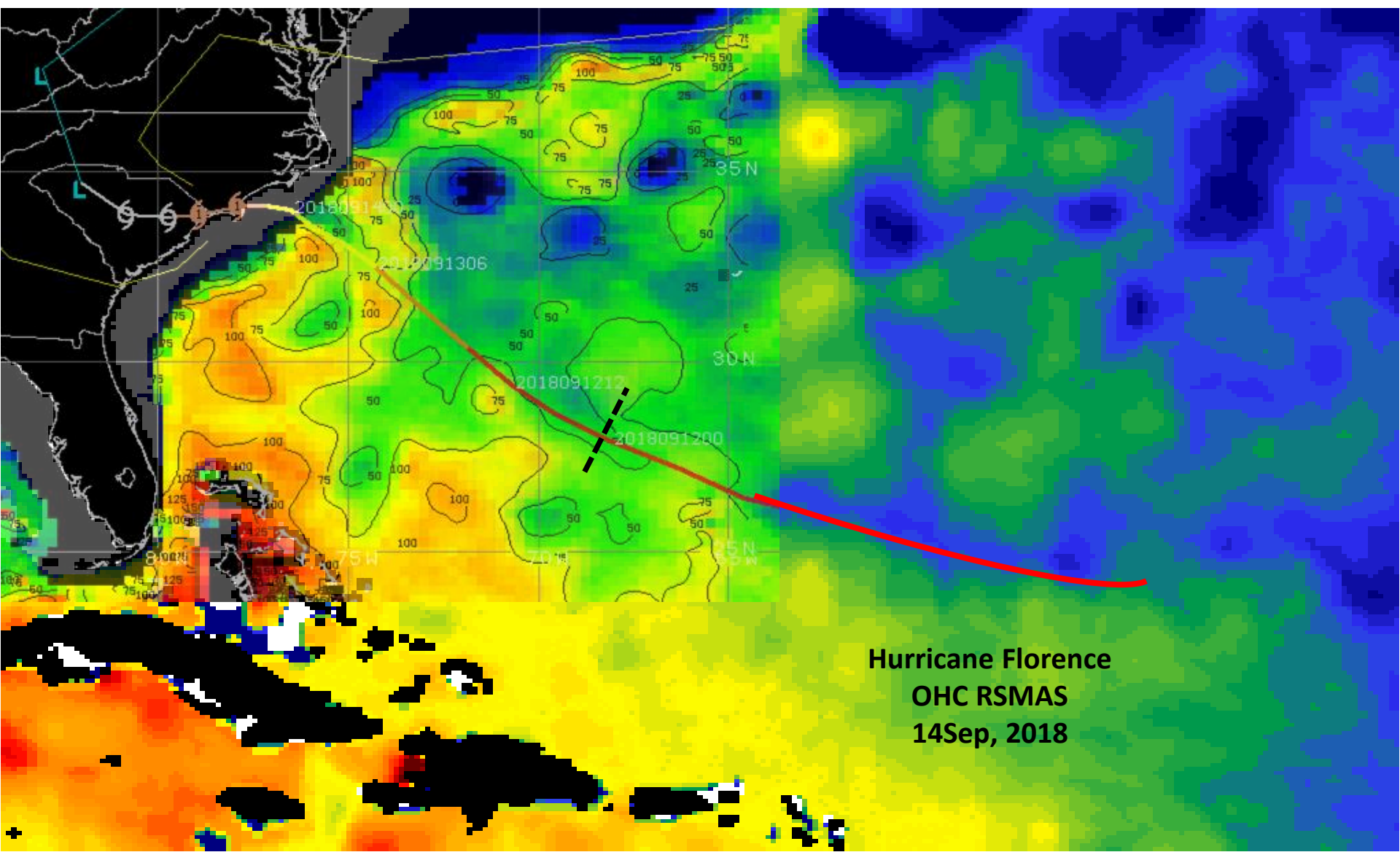WC-130J Tracks (8) and Sondes (196): below

Total flights: 20
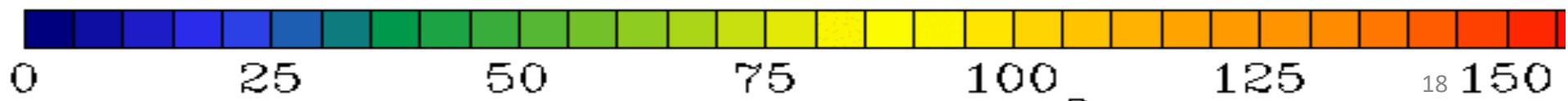**Total Sondes: 559**

Florence
Track sensitivity
06Z, 10 Sep

Florence Intensity sensitivity 06Z, 10 Sep

WC-130J flights
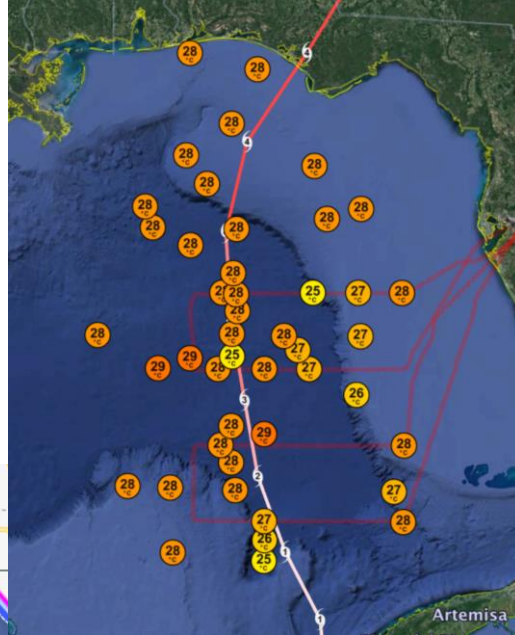
Alamo Floats

WP-3D flts

Hurricane Florence
OHC RSMAS
14Sep, 2018
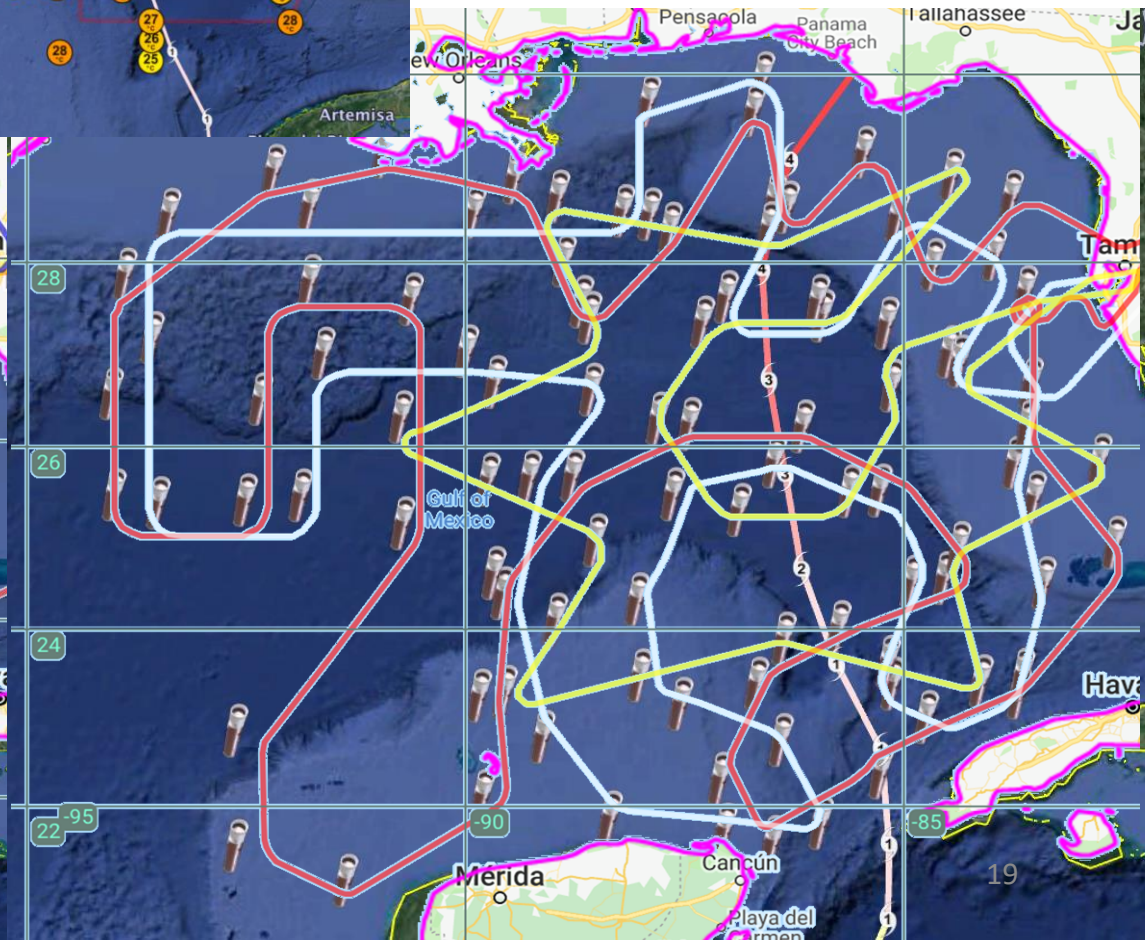
Hurricane Michael
8-10 Oct 2018

- **P3 Tracks (5)** and **Sondes (102)** from 800 mb
- **WC-130J** reco **Tracks (8)** and **Sondes (81)** from 700 mb
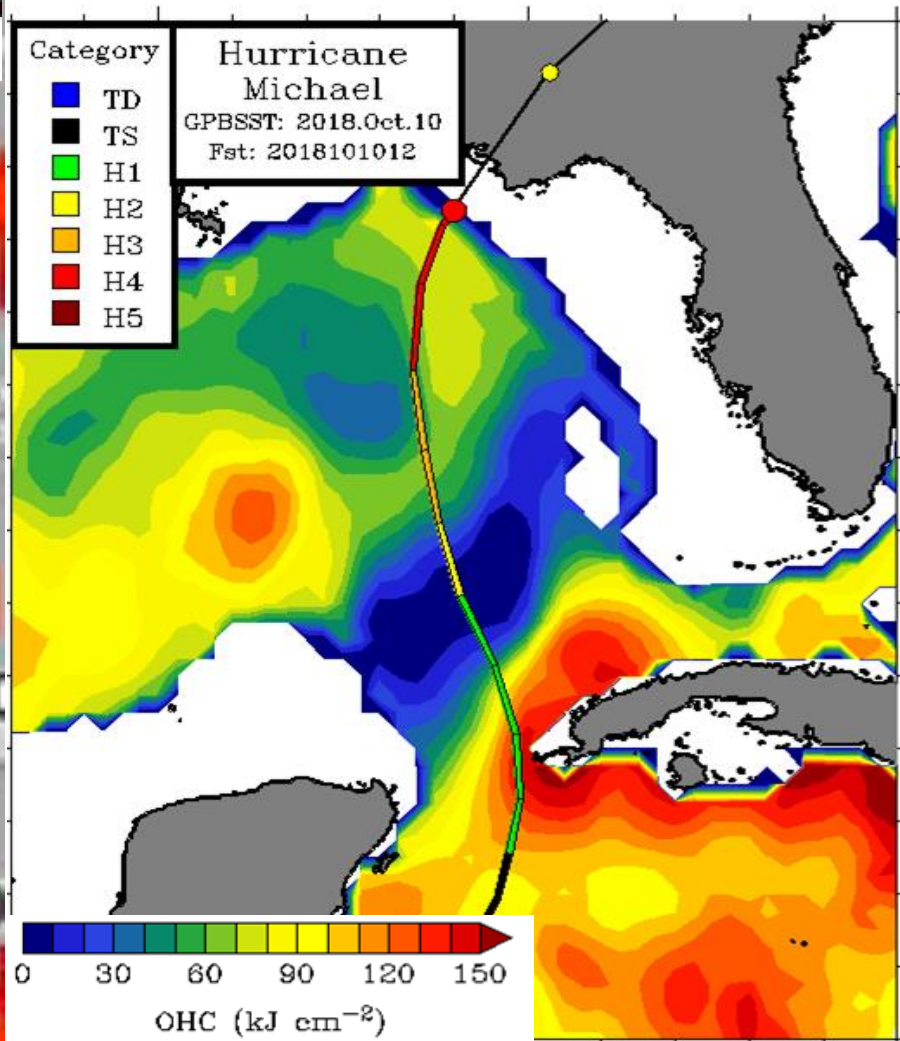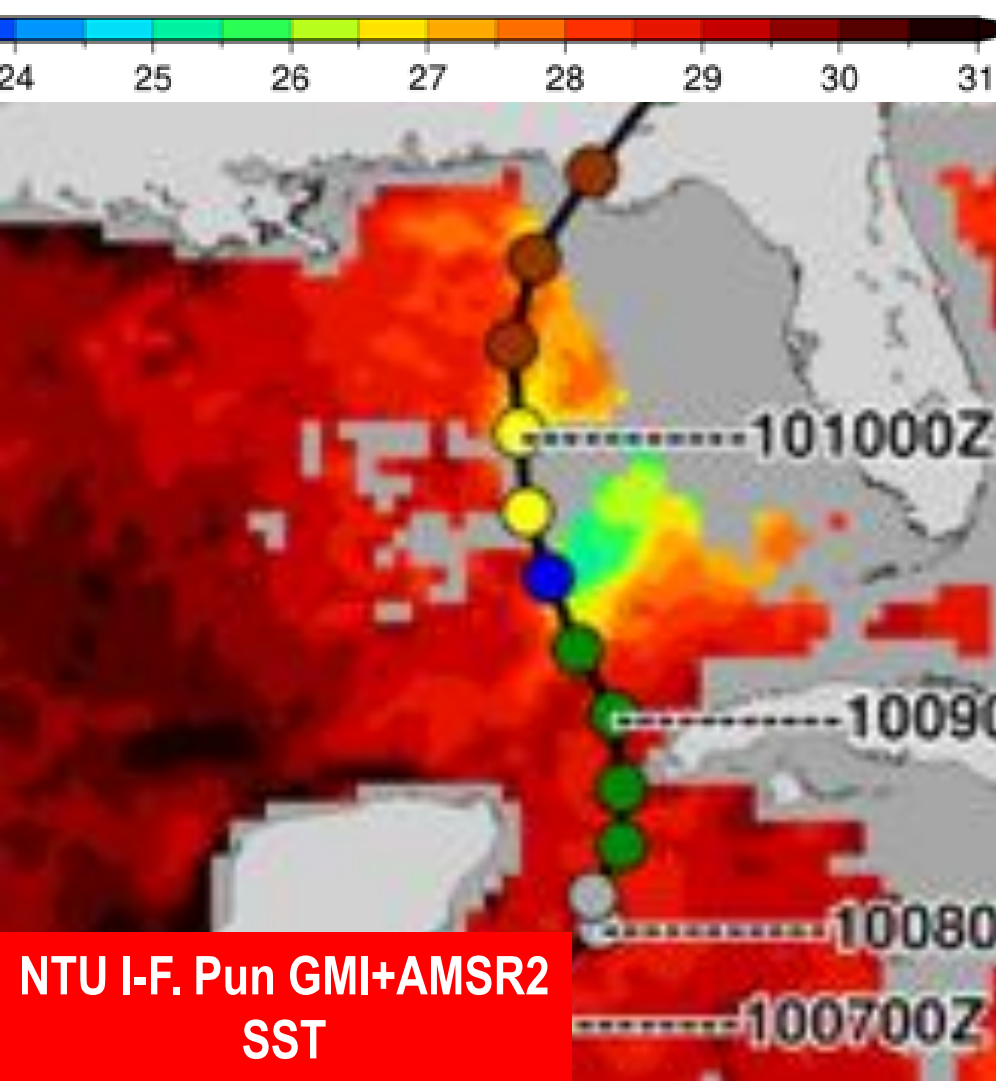- Total Sondes: **270**

Michael Ocean Obs:

- **WP-3D** 6 AXBT flights (2 post-storm: red tracks left)
- **45 good AXBTs (86 deployed; 48% fail)**
- **18** AXCPs/ **11** AXCTDs
- Eight (**8**) Scripps drifters, **3** EM-APEX floats deployed from dedicated WC-130J ahead of Michael on 9 Oct
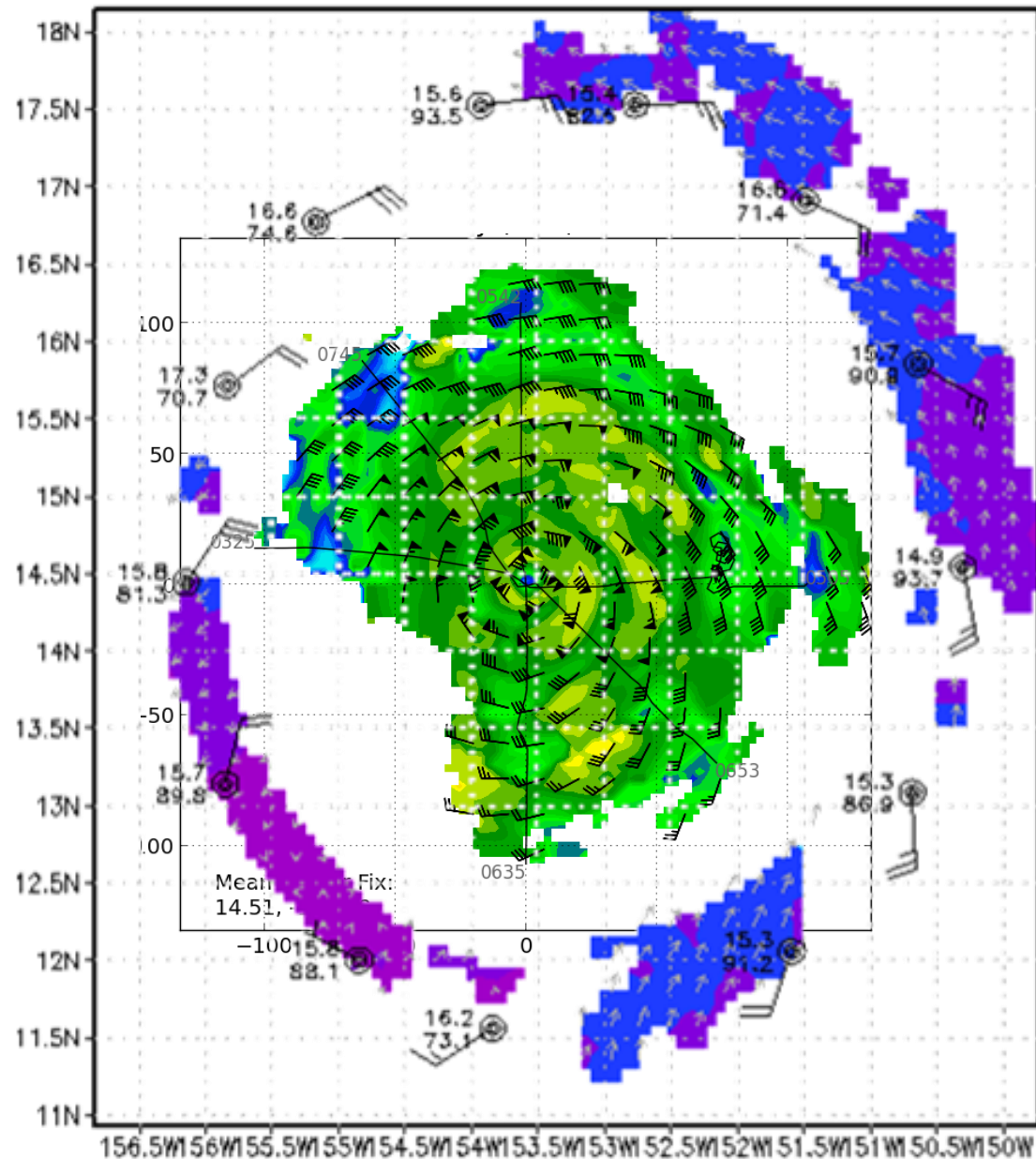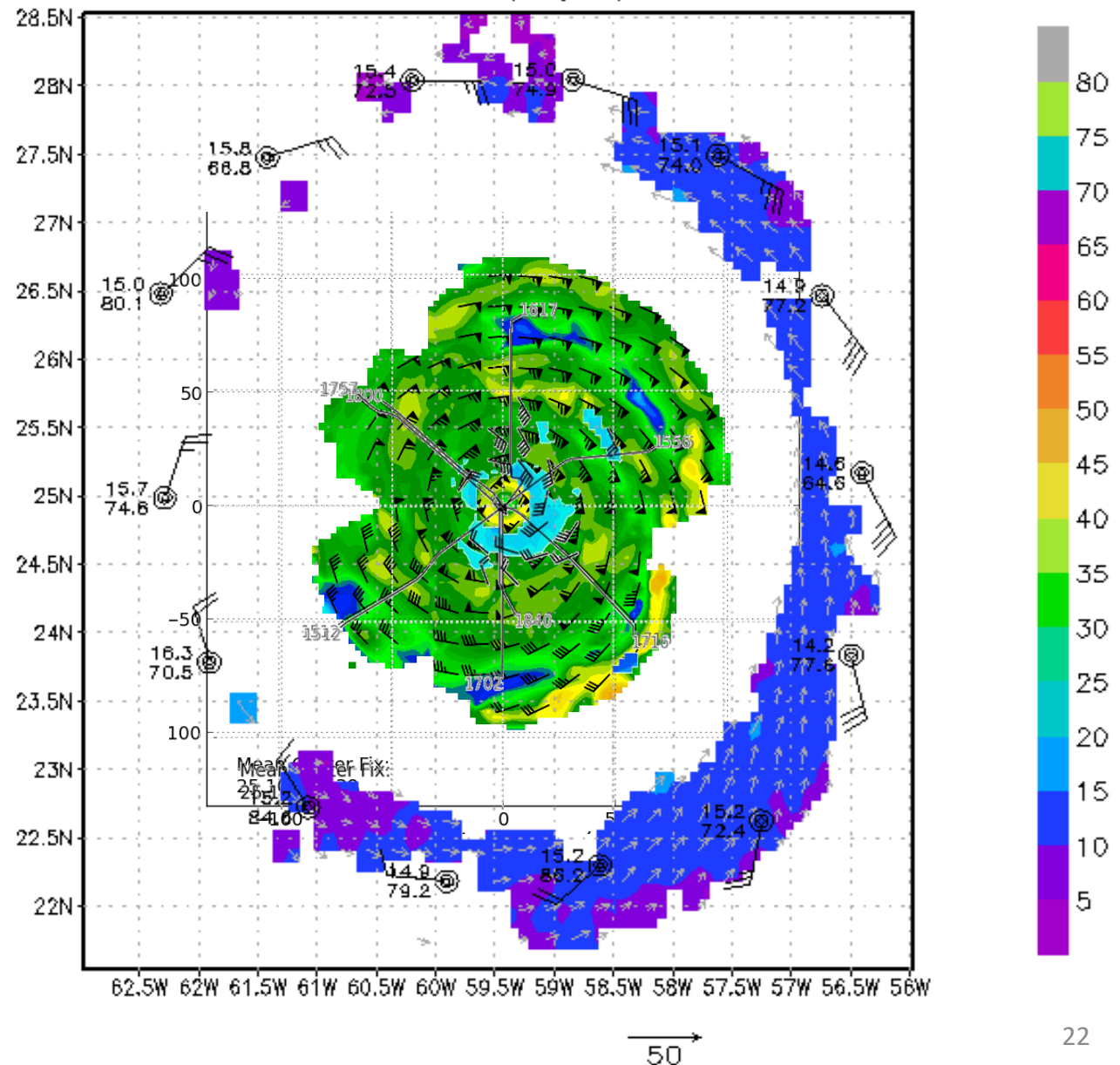
Total GIV Tracks: 3 and Sondes: 87

NTU I-F. Pun GMI+AMSR2 SST

Hurricane Michael
GPBSST: 2018.Oct.10
Fst: 2018101012

Category
TD
TS
H1
H2
H3
H4
H5
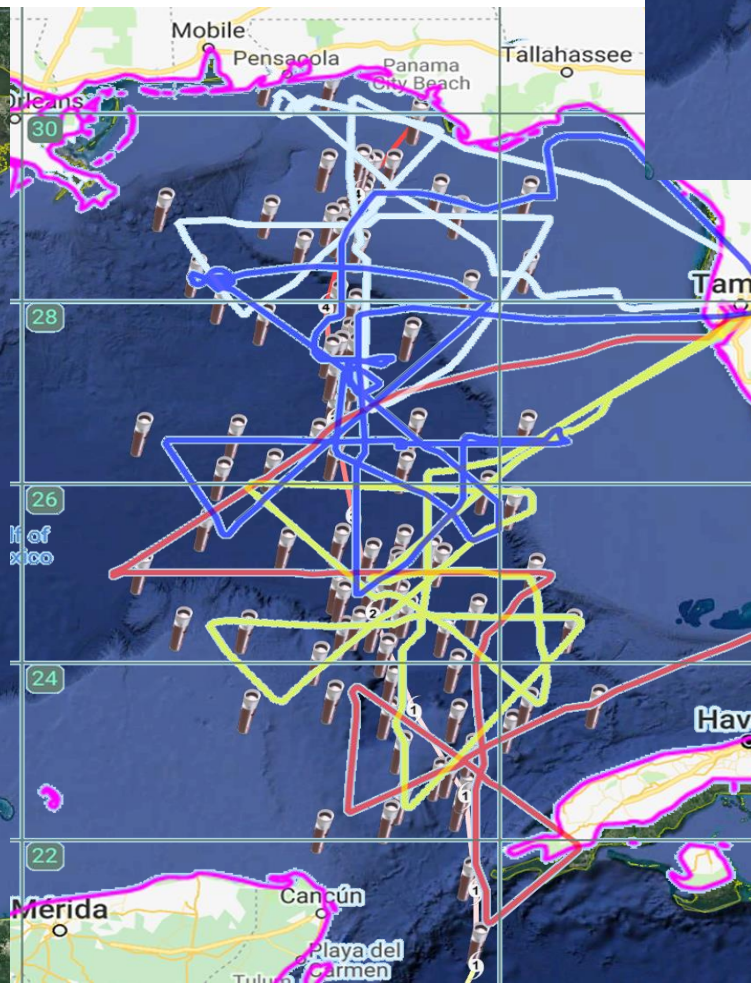
OHC (kJ cm^{-2})

TDR Composite:

Single GIV Loop + P-3 Butterfly

180910N1 Florence at 2 km (m/s) Valid 20180910 1200Z
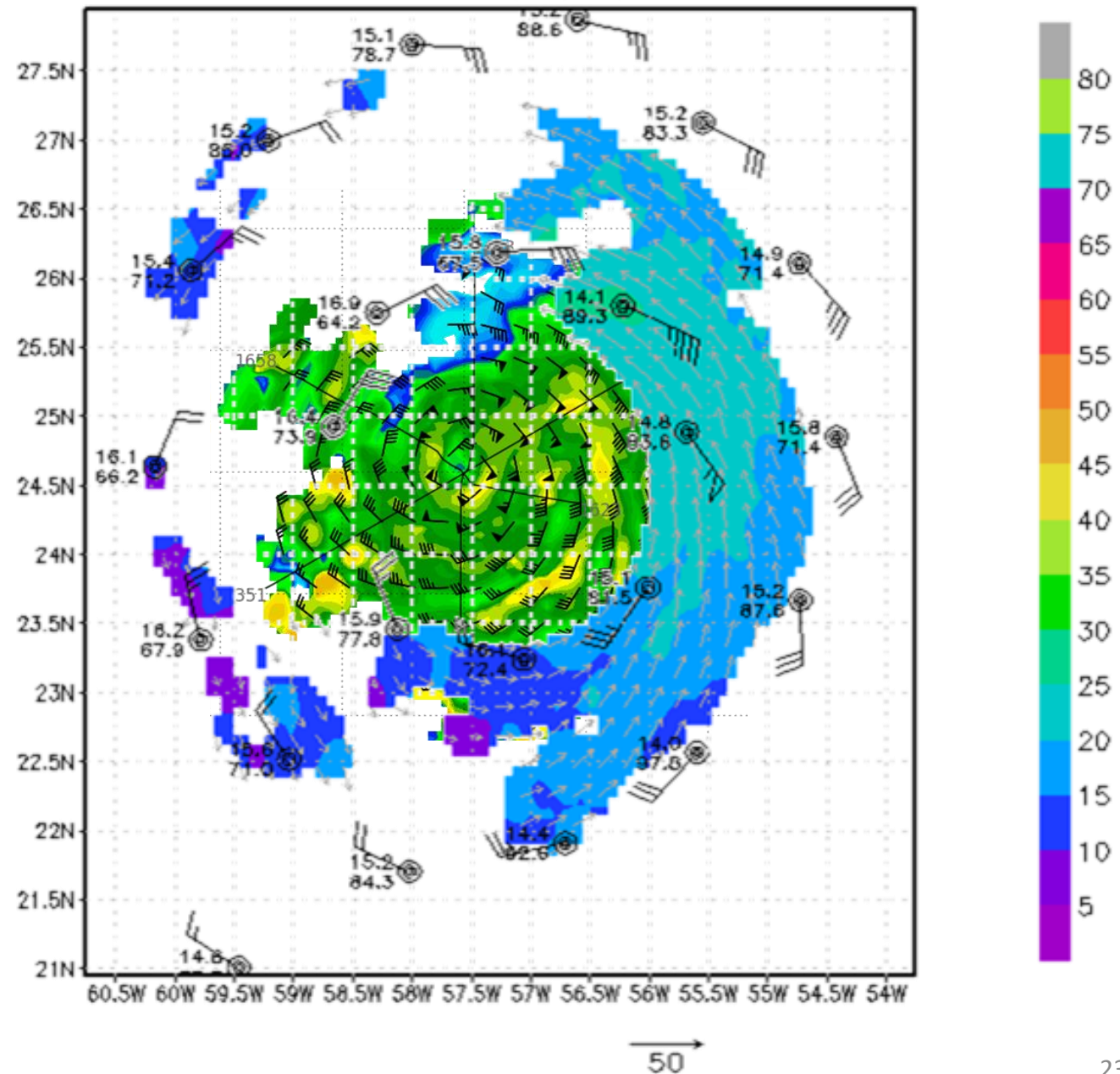
TDR Composite:

Single GIV Loop + P-3 Butterfly

180909N1 Florence at 2 km (m/s) Valid 20180909 1800Z
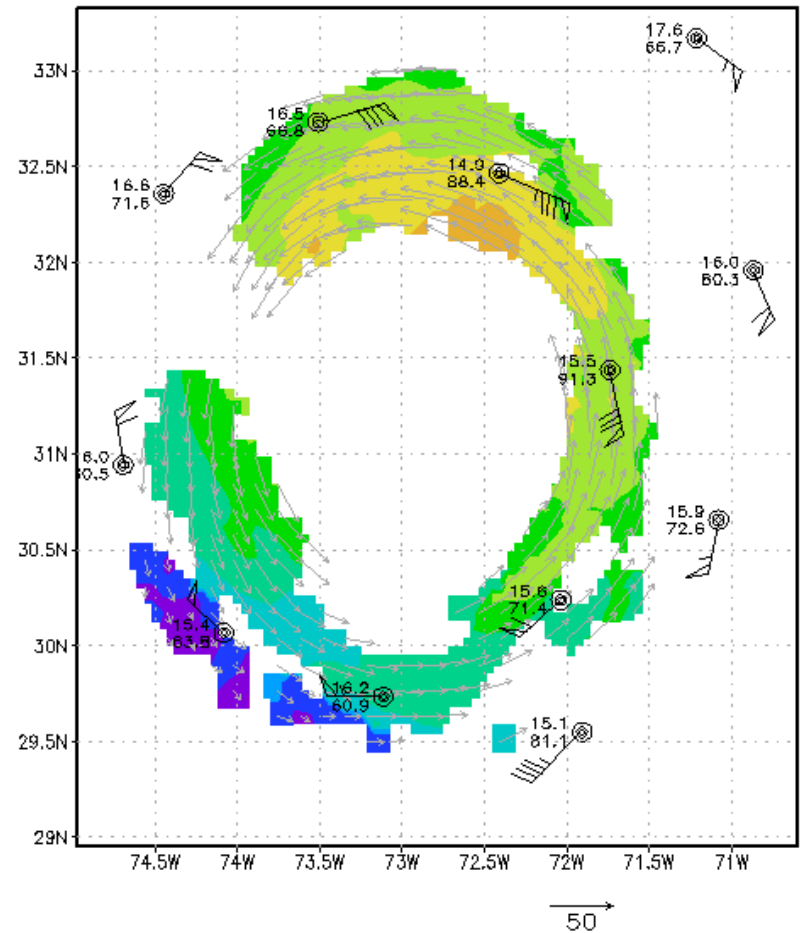
TDR Composite:

Double GIV Loop + P-3 Butterfly

Double GIV Loop Patterns
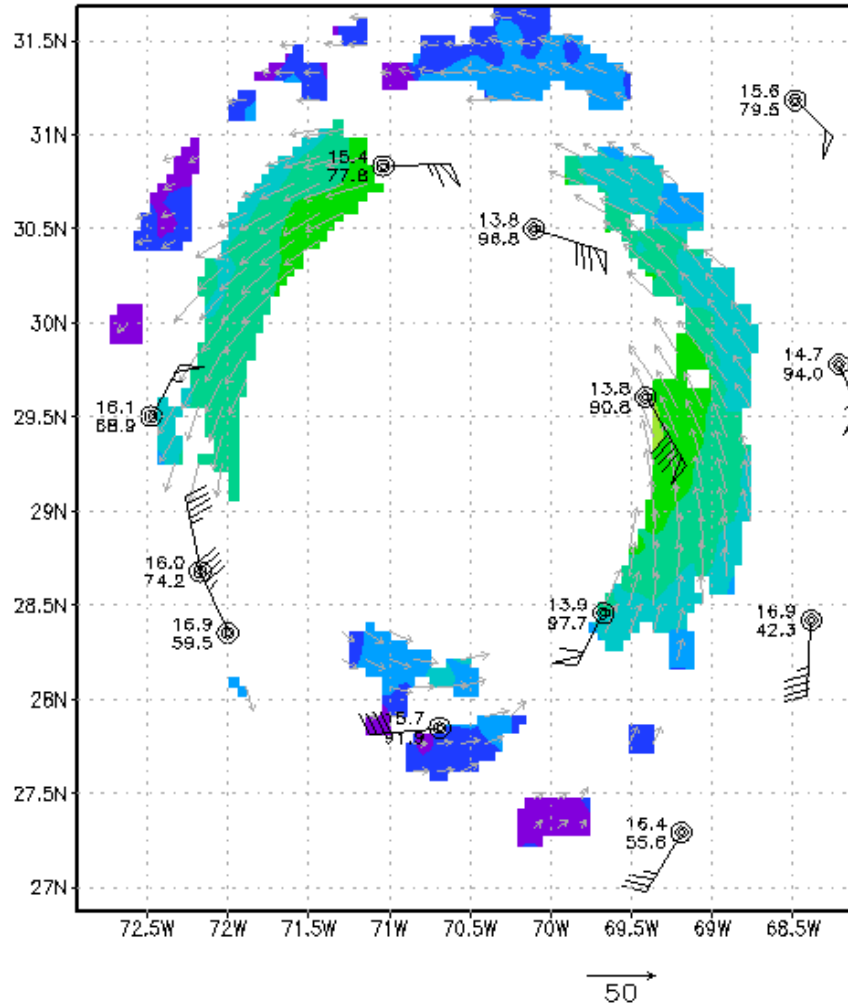


12 Sept 2019 12Z   **13 Sept 2019 00Z**

Global Hawk validation strategy

1. Global Hawk all sondes stratified by storm-relative region
   a. All regions (deny entire GH data set)
   b. Allow only inner core R ≤ 1.83 deg (110 nm, 200 km)
   c. Allow only near-environment R > 1.83, R ≤ 5 deg
   d. Allow only far-environment R > 5 deg
2. Stratify by intensity Tendency, GH all sondes
   a. Non-steady state: Intensification or weakening
   b. Steady-state
3. Stratify with other manned aircraft observations (± 3 hr GH start/end time)
   a. add G-IV sondes only
   b. add WP-3D sondes + TDR + WC-130J sondes
   c. add GIV sondes + WP-3D sondes + WC-130J sondes
4. Targeted GH sondes only (Torn, 2014, Wu, 2019)
   a. Allow sondes within ± 2 sigma of Torn uncertainty maxima,
   b. Deny sondes outside this region
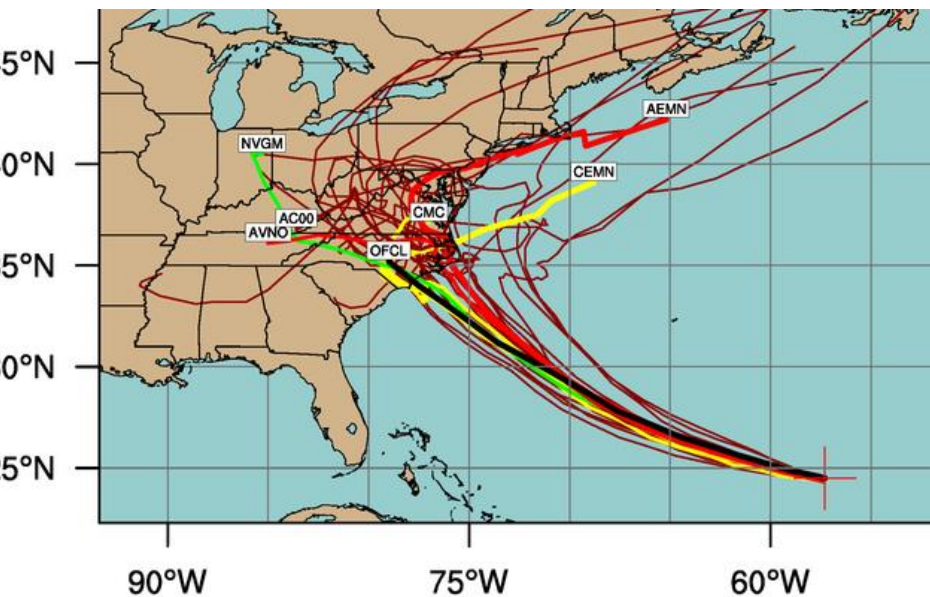   c. Add GIV manned aircraft targeted sondes

TROPICAL STORM FLORENCE (AL06)

EPS track guidance initialized at 1200 UTC, 08 September 2018

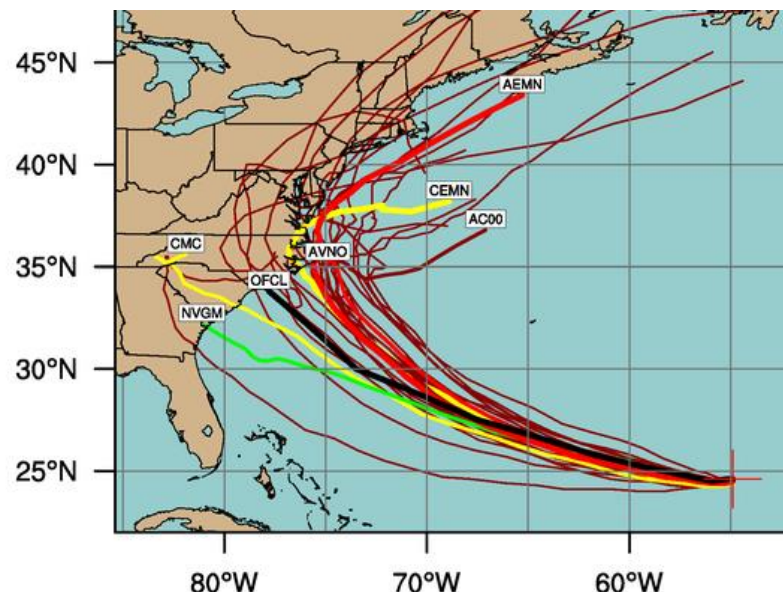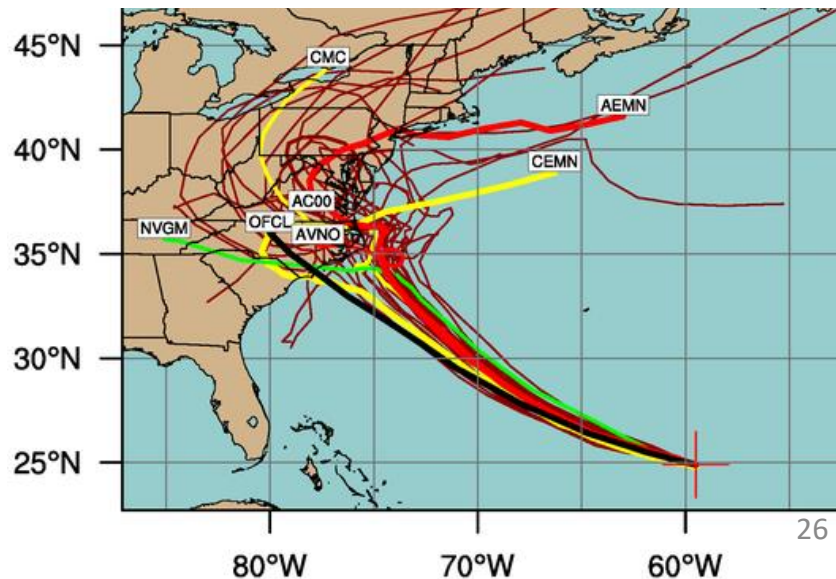Current Intensity: 55 kt   Current Basin: North Atlantic
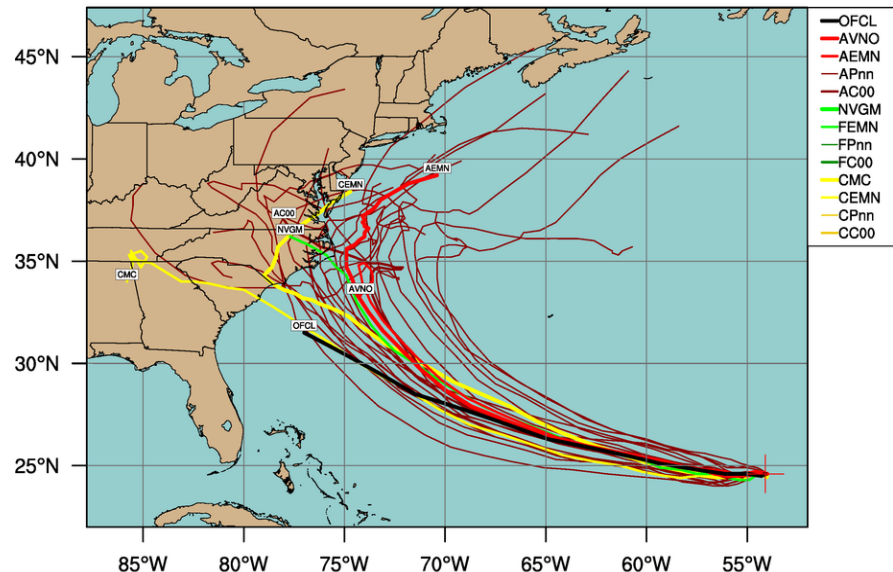
TROPICAL STORM FLORENCE (AL06)

EPS track guidance initialized at 0000 UTC, 09 September 2018

HURRICANE FLORENCE (AL06)

EPS track guidance initialized at 0000 UTC, 10 September 2018
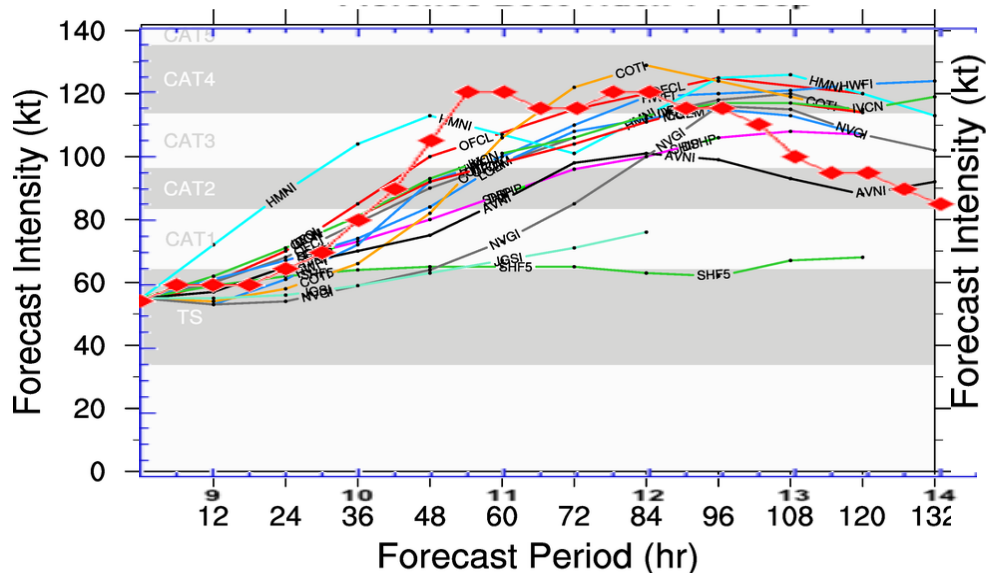
MAJOR HURRICANE FLORENCE (AL06)

EPS track guidance initialized at 1200 UTC, 10 September 2018

TROPICAL STORM FLORENCE (AL06)
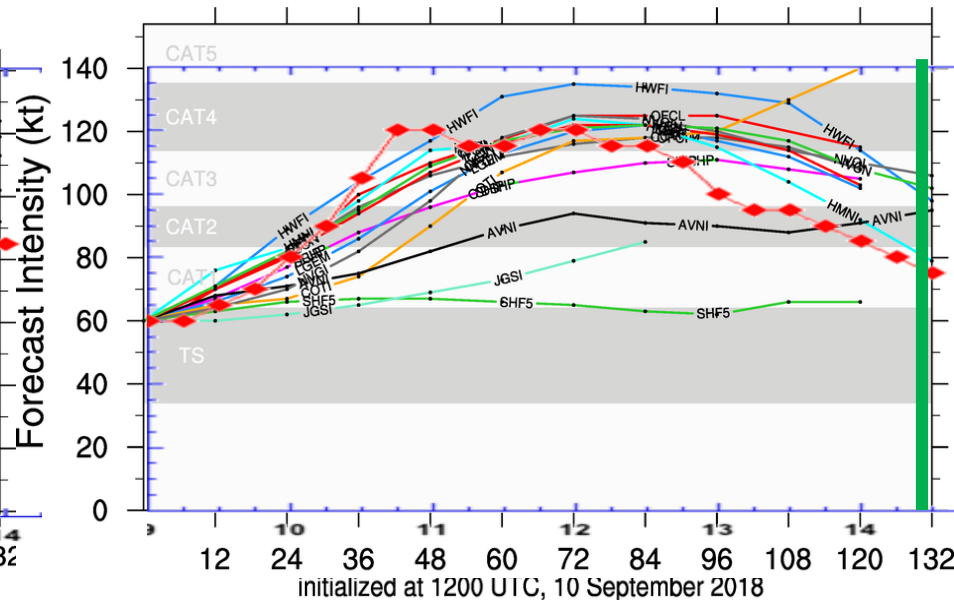Early-cycle intensity guidance
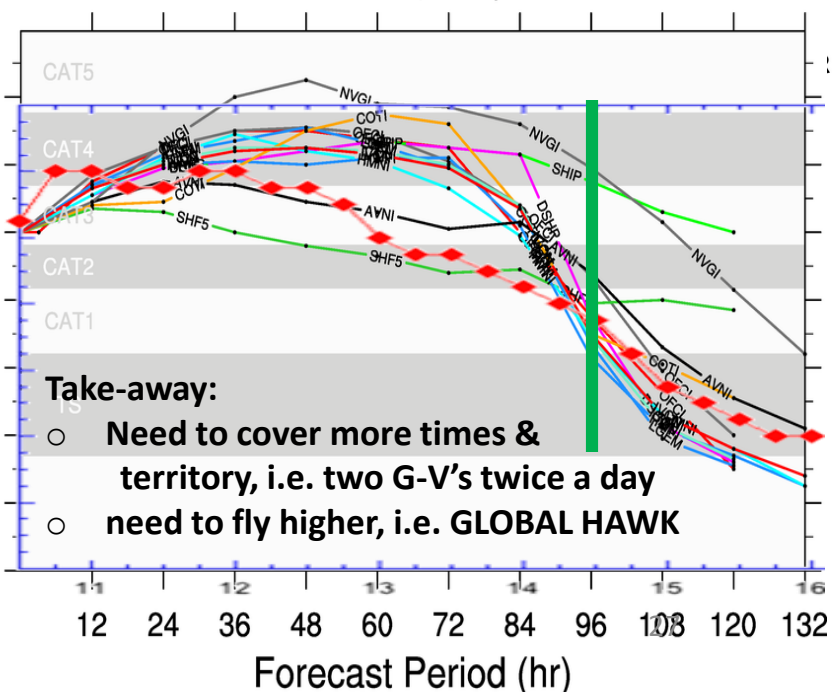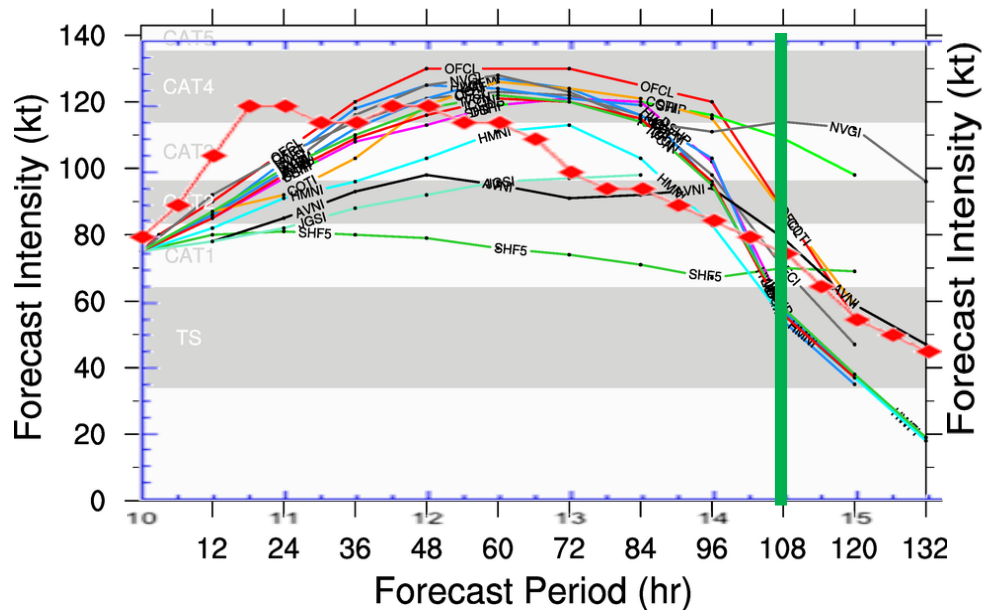initialized at 1200 UTC, 08 September 2018

TROPICAL STORM FLORENCE (AL06)
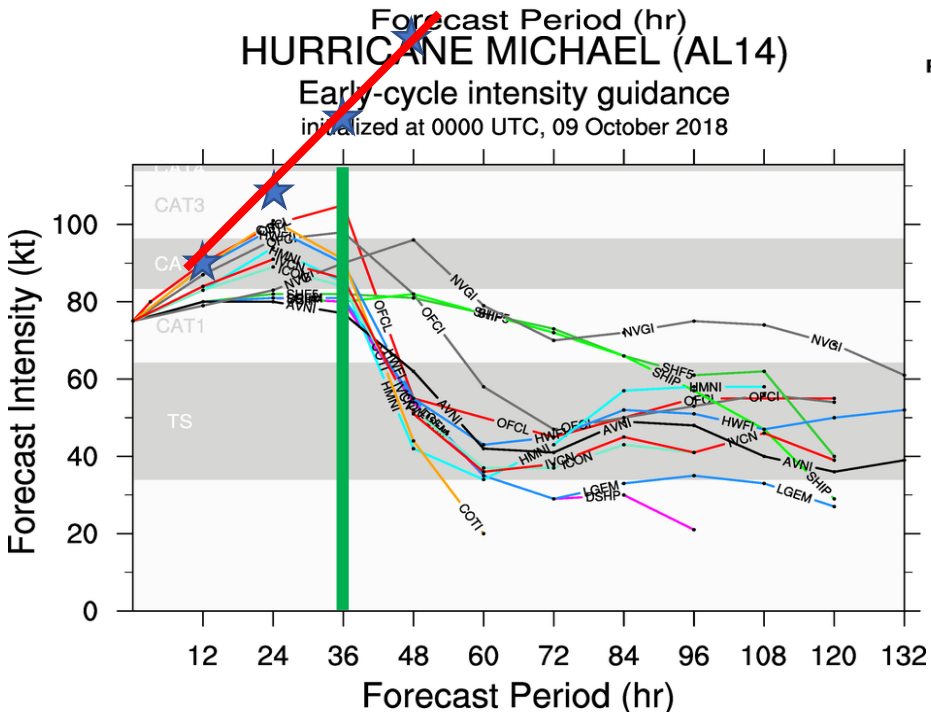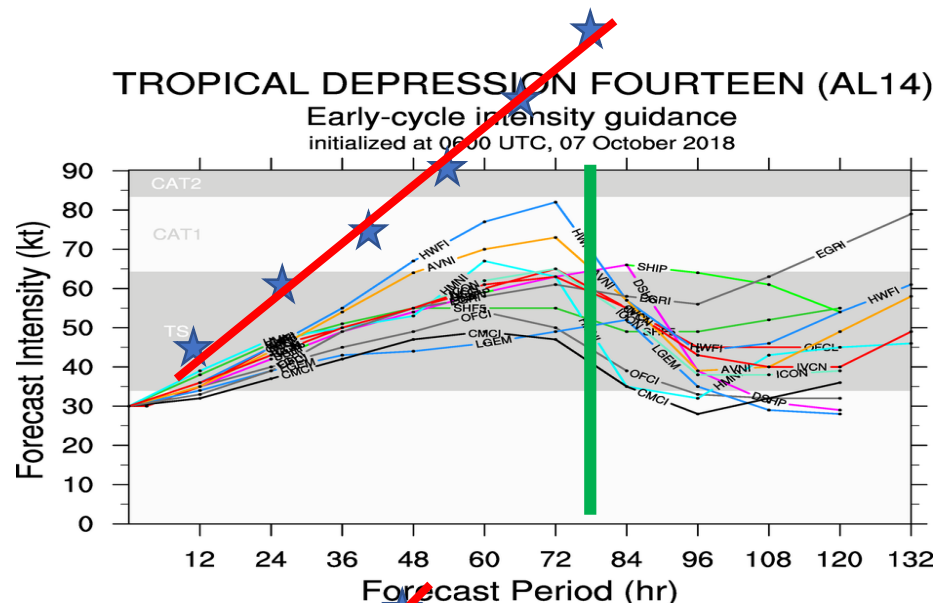Early-cycle intensity guidance
initialized at 0000 UTC, 09 September 2018

initialized at 0000 UTC, 10 September 2018

initialized at 1200 UTC, 10 September 2018

Take-away:
○ **Need to cover more times &**
   territory, i.e. two G-V's twice a day
○ **need to fly higher, i.e. GLOBAL HAWK**

TROPICAL DEPRESSION FOURTEEN (AL14)
Early-cycle intensity guidance
initialized at 0600 UTC, 07 October 2018

TROPICAL STORM MICHAEL (AL14)
Early-cycle intensity guidance
initialized at 0000 UTC, 08 October 2018
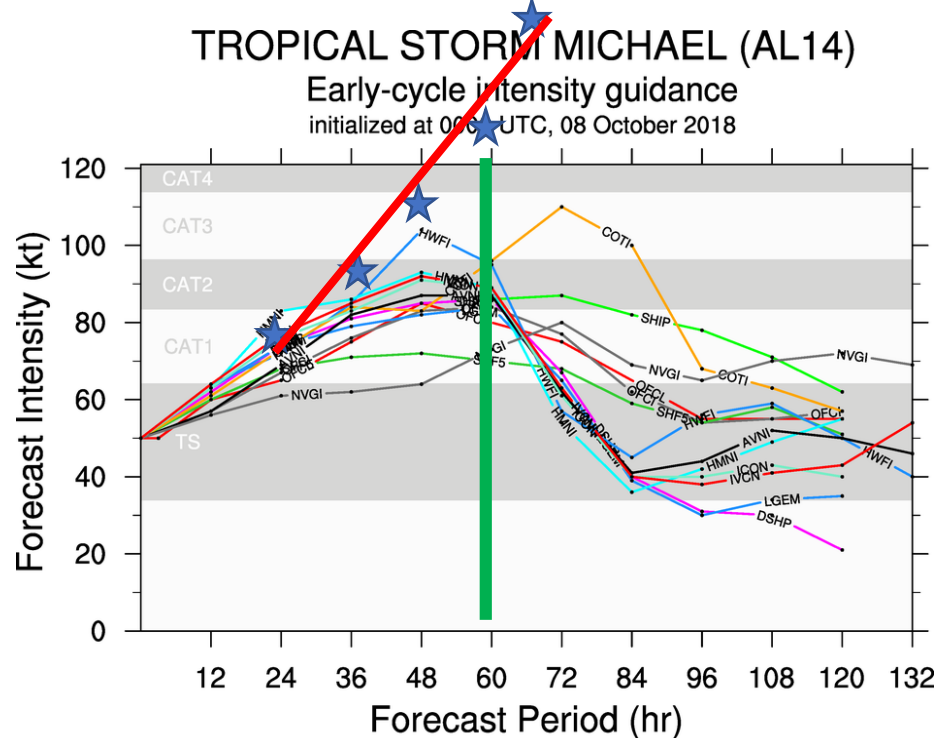
HURRICANE MICHAEL (AL14)
Early-cycle intensity guidance
initialized at 0000 UTC, 09 October 2018

Rapid changes are taking place!

- In **Aircraft Performance Technology:** <u>higher, longer duration flights</u>

- In **Instrument Observation Technology:** <u>dropsonde redesign</u>:
  RD-41, NRD-41 (new RH and Ta sensors), improved GPS 4 Hz winds vs RD-94

- In **Data Transmission**: use of <u>BUFR data transmission</u> with <u>data thinning</u>
  and <u>precision location encoding</u> rather than 40-yr old WMO TEMP DROP
  mandatory and significant level encoding with single location at launch

- In **Model Core Technology:** finite volum vs spline fit approximation

- In **Model Physics:** improved PBL and radiation physics

- In **Data Assimilation (DA)**

- In **Data Targeting Strategy**: use of ensemble model technology to define
  model uncertainty and Adjoint-based sensitivity vs overly-simplified
  Deep Layer Mean (DLM) variance

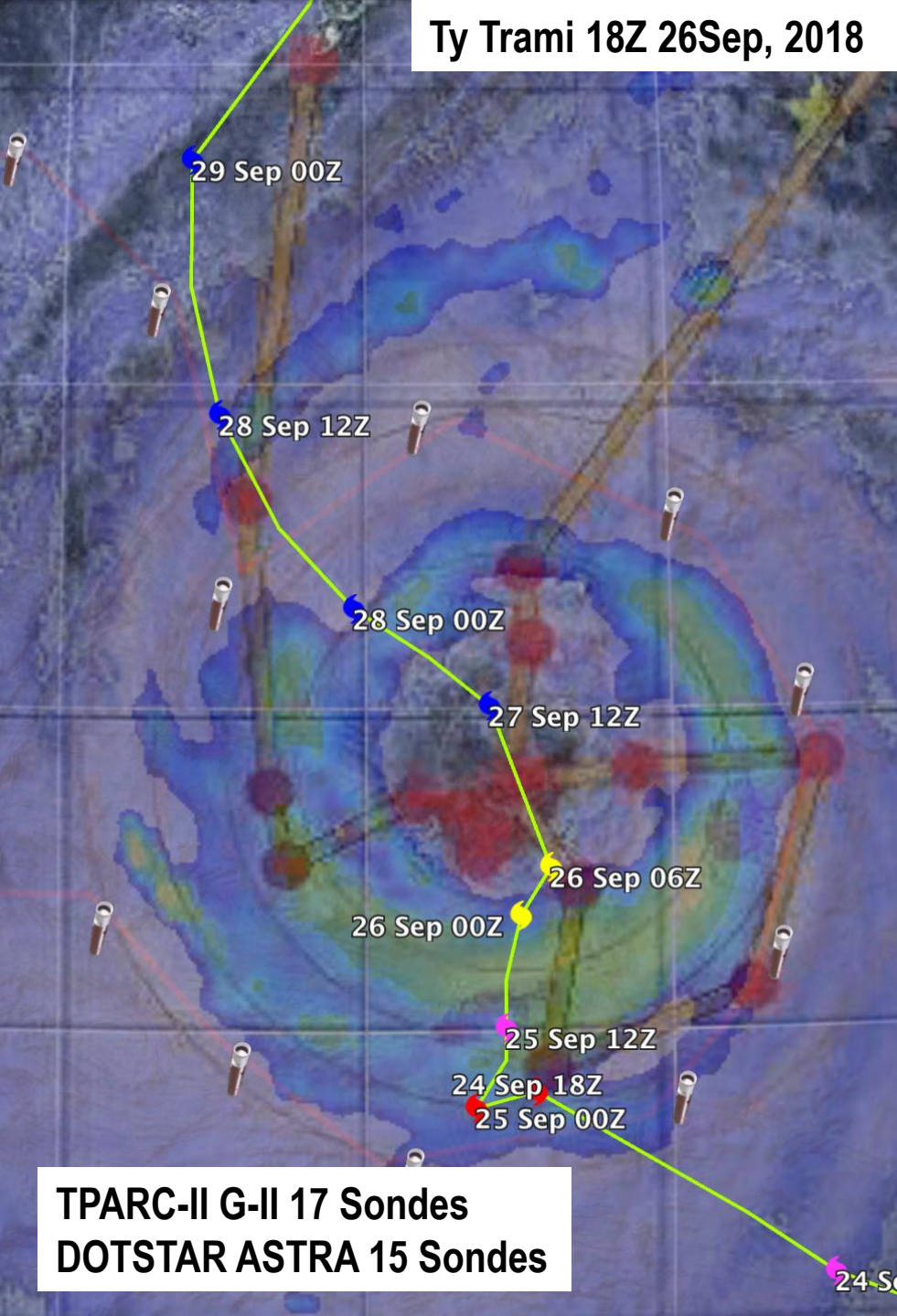- In **CLIMATE CHANGE**: more intense TCs? Need for accurate obs/prediction
  is more critical.   **The time for RTO is NOW!**

Key Questions:

o   **Have new high-altitude dropsonde and Tail Doppler Radar operational taskings improved prediction accuracy and reduced error?**

o   **How can this be diagnosed with all the changes to the observational, Data Assimilation and numerical model forecast system?**

o   **Operational ensemble-based sonde targeting and grouping strategy with TDR data only just beginning**

o   **One promising strategy: International Cooperation comparing different model forecast systems and DA approaches from different countries using same sonde and TDR data groups.**
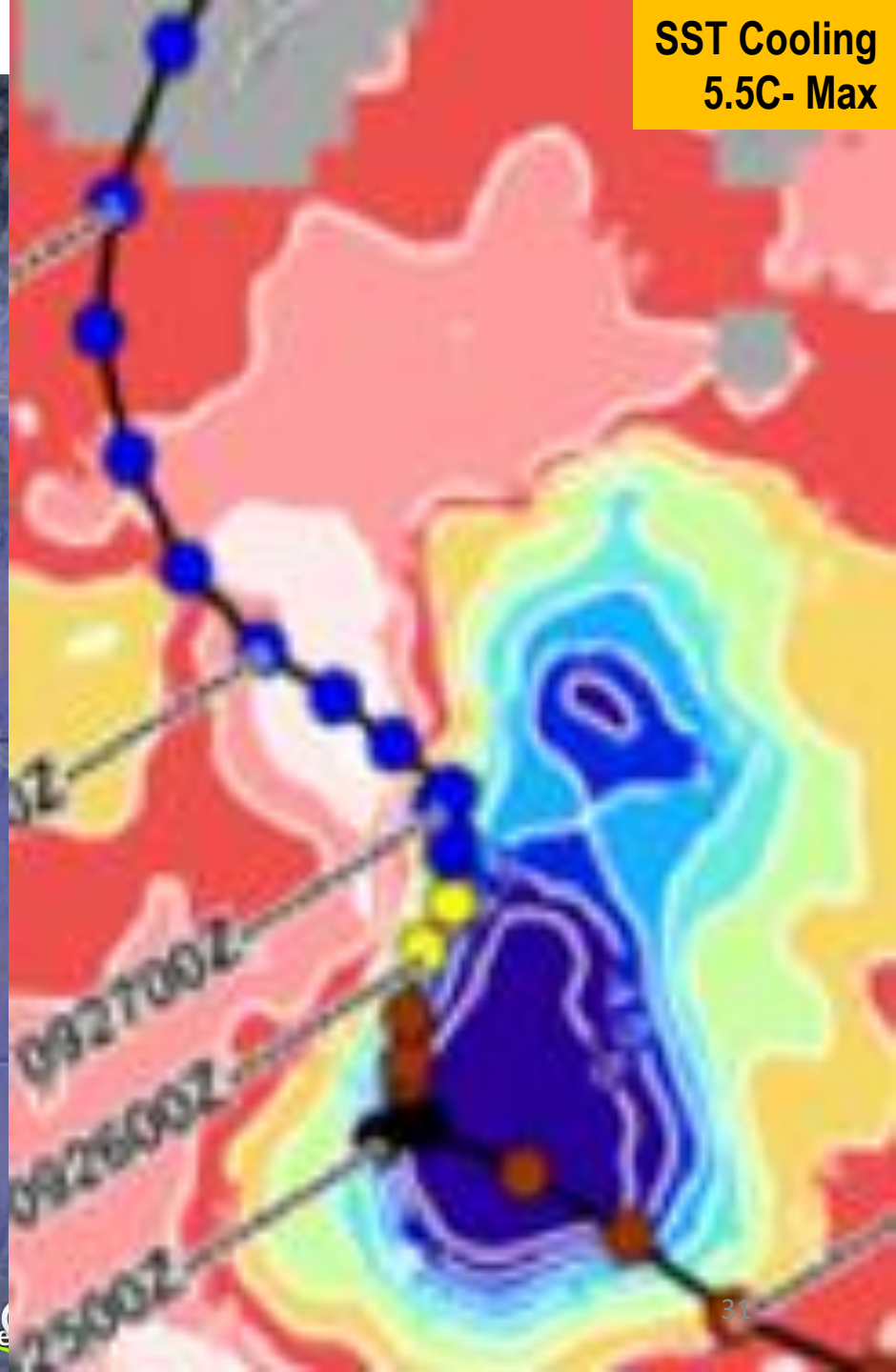
THE JURY IS STILL OUT: But need answers within the next 5 years.
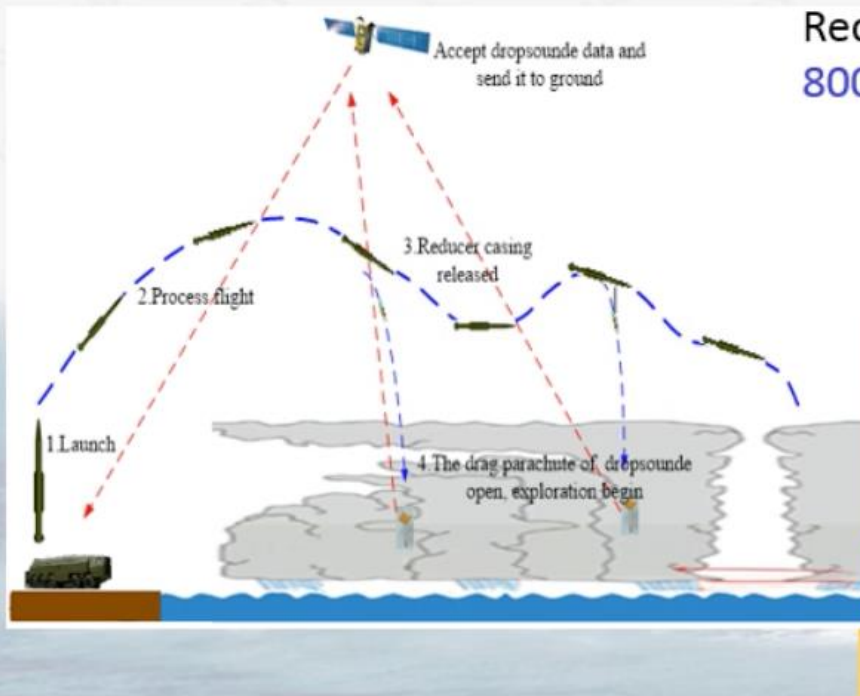
Ty Trami 18Z 26Sep, 2018

29 Sep 00Z

28 Sep 12Z

28 Sep 00Z

27 Sep 12Z

26 Sep 06Z

26 Sep 00Z

25 Sep 12Z

24 Sep 18Z
25 Sep 00Z

24 Se

TPARC-II G-II 17 Sondes
DOTSTAR ASTRA 15 Sondes

SST Cooling
5.5C- Max

0927 00Z

0926 00Z

0925 00Z

31
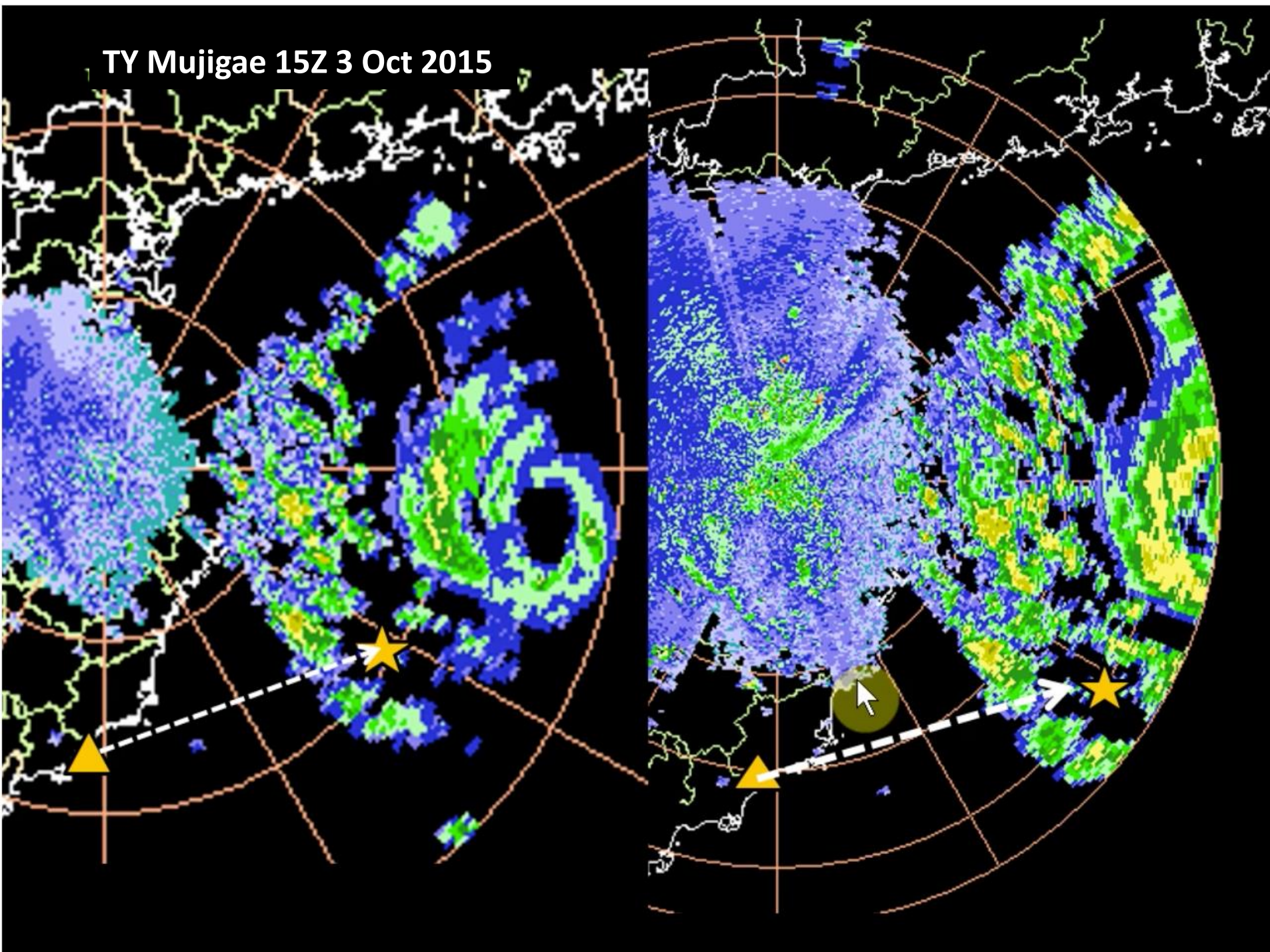
Scheme of the rocket dropsondes by COSIC and CMA since 2012

Revolver
3000 to 800 m/s

Reduction bin
800 to 100 m/s

Dropsonde
100 m/s to 15m/s

Accept dropsounde data and send it to ground

2.Process flight

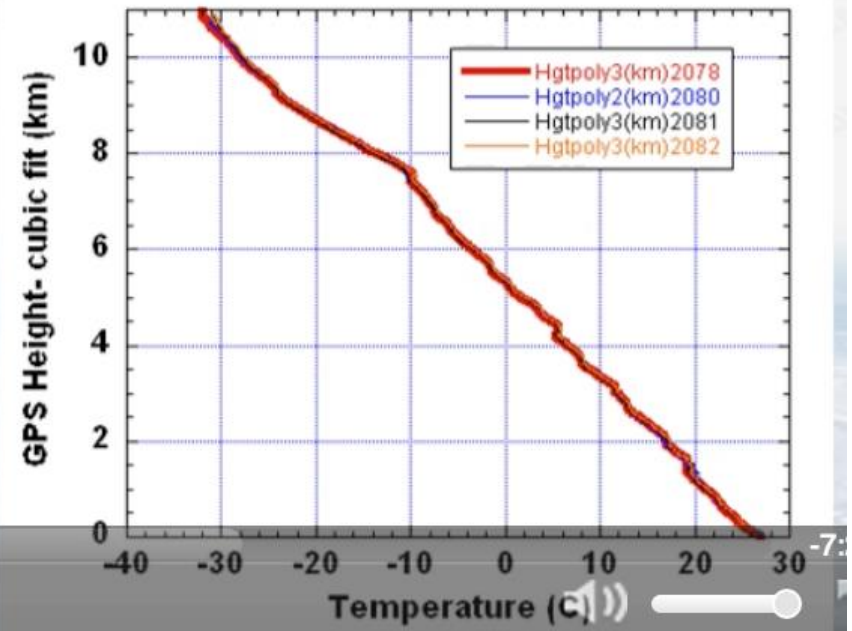3.Reducer casing released
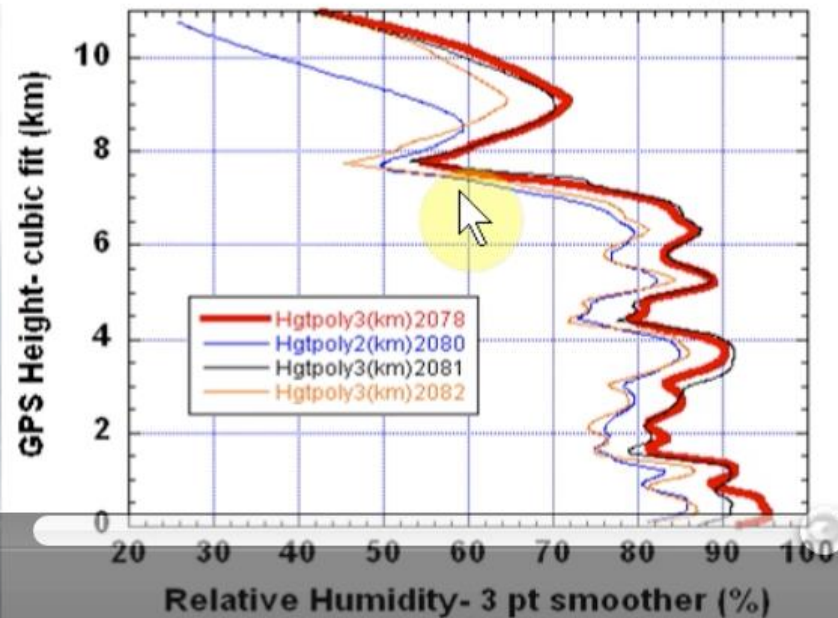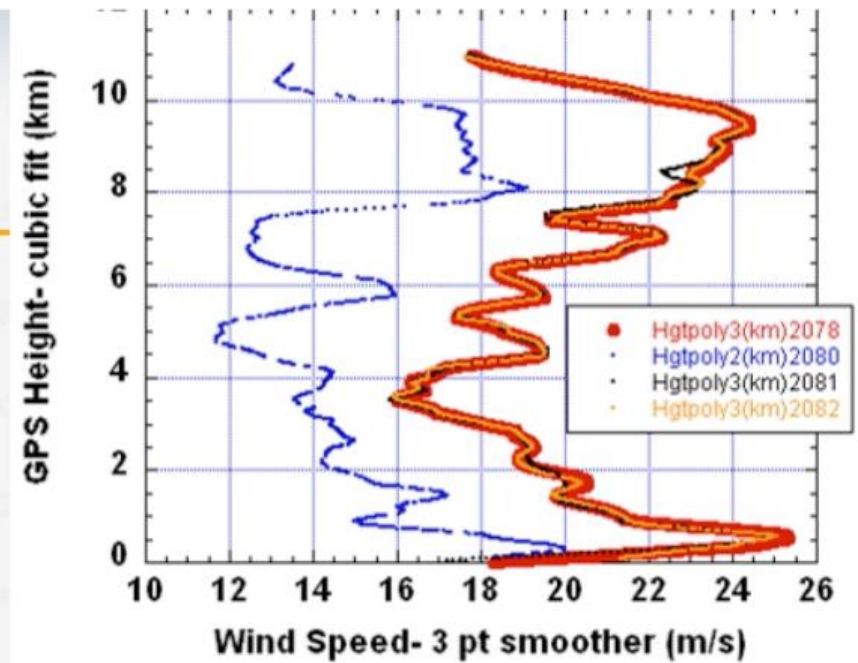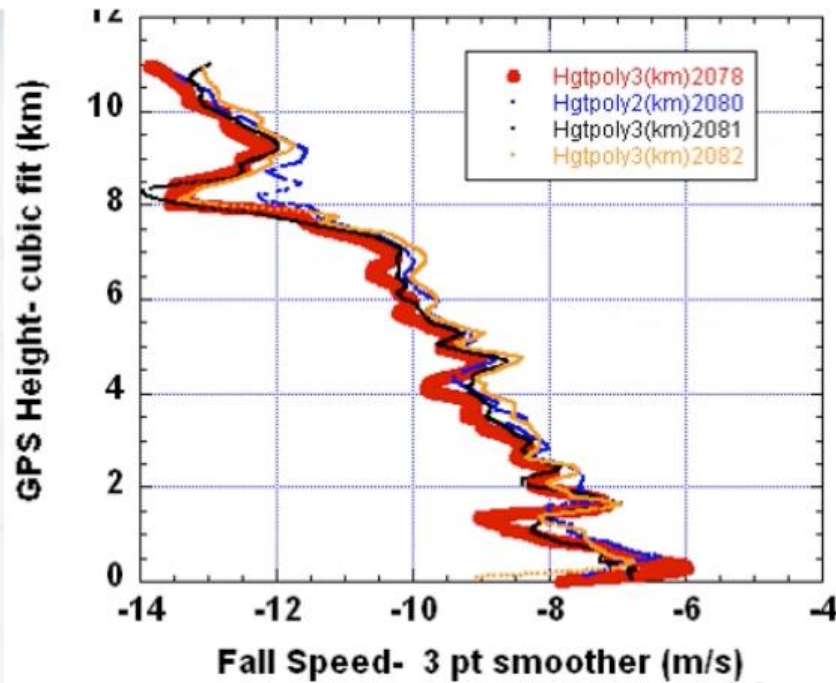
1.Launch

4.The drag parachute of dropsounde open, exploration begin
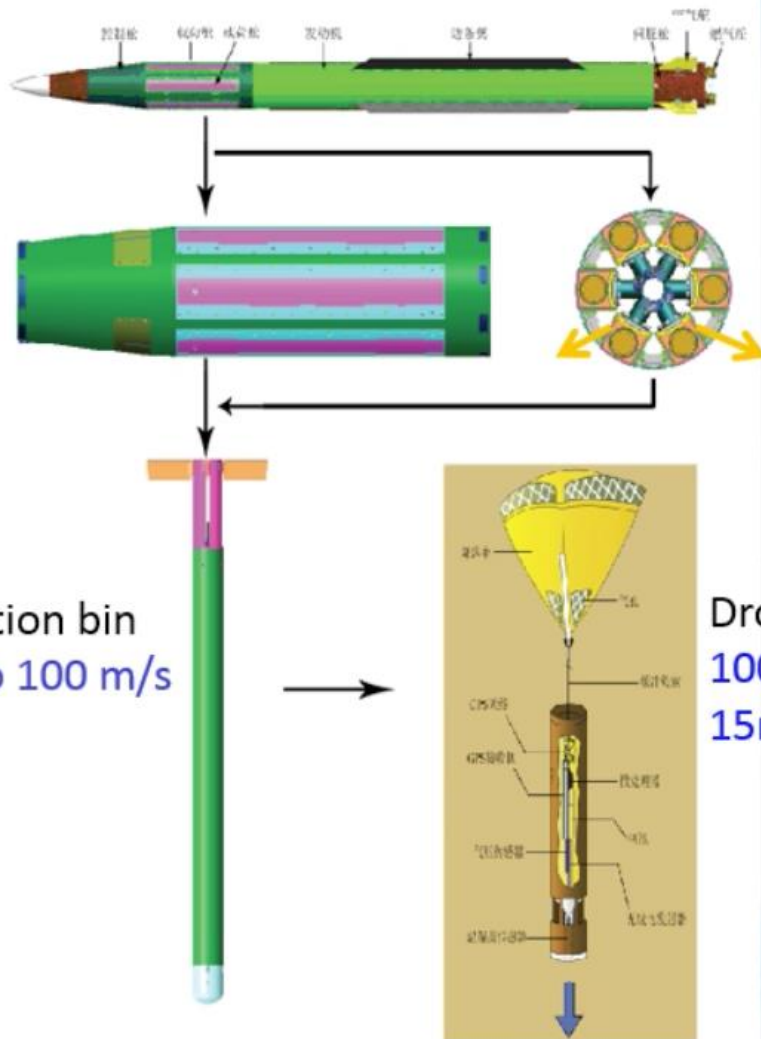
TY Mujigae 15Z 3 Oct 2015

Overview of the dropsondedata

Felix 2007

Irma 2017

Katrina 2005

Irma 2017

QUESTIONS?

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