Evaluation and diagnostics of ECMWF tropical cyclone forecasts in 2020

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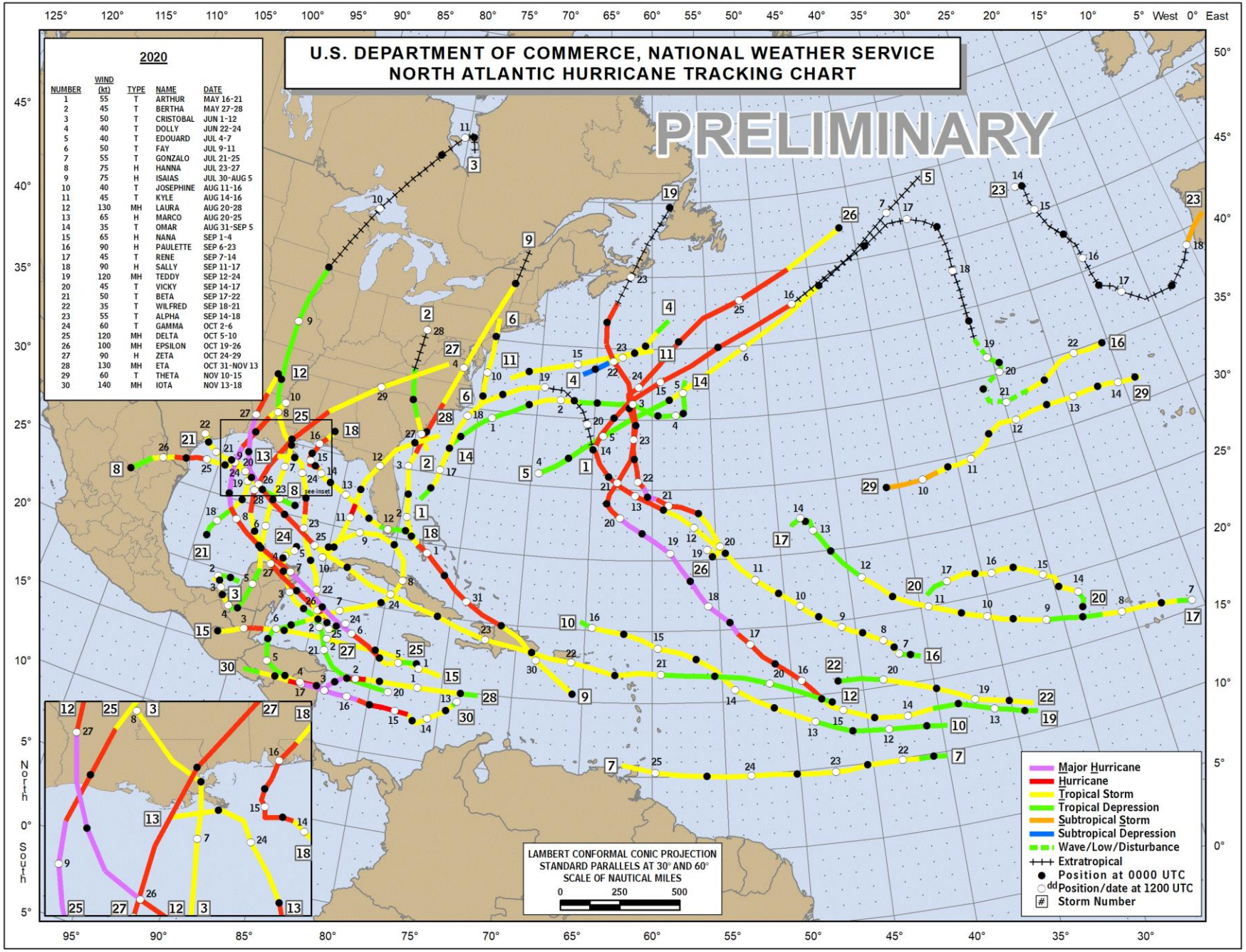
UEF 2021, Online, 1 June 2021

ECMWF

2020: An extraordinary Atlantic hurricane season in extraordinary circumstances



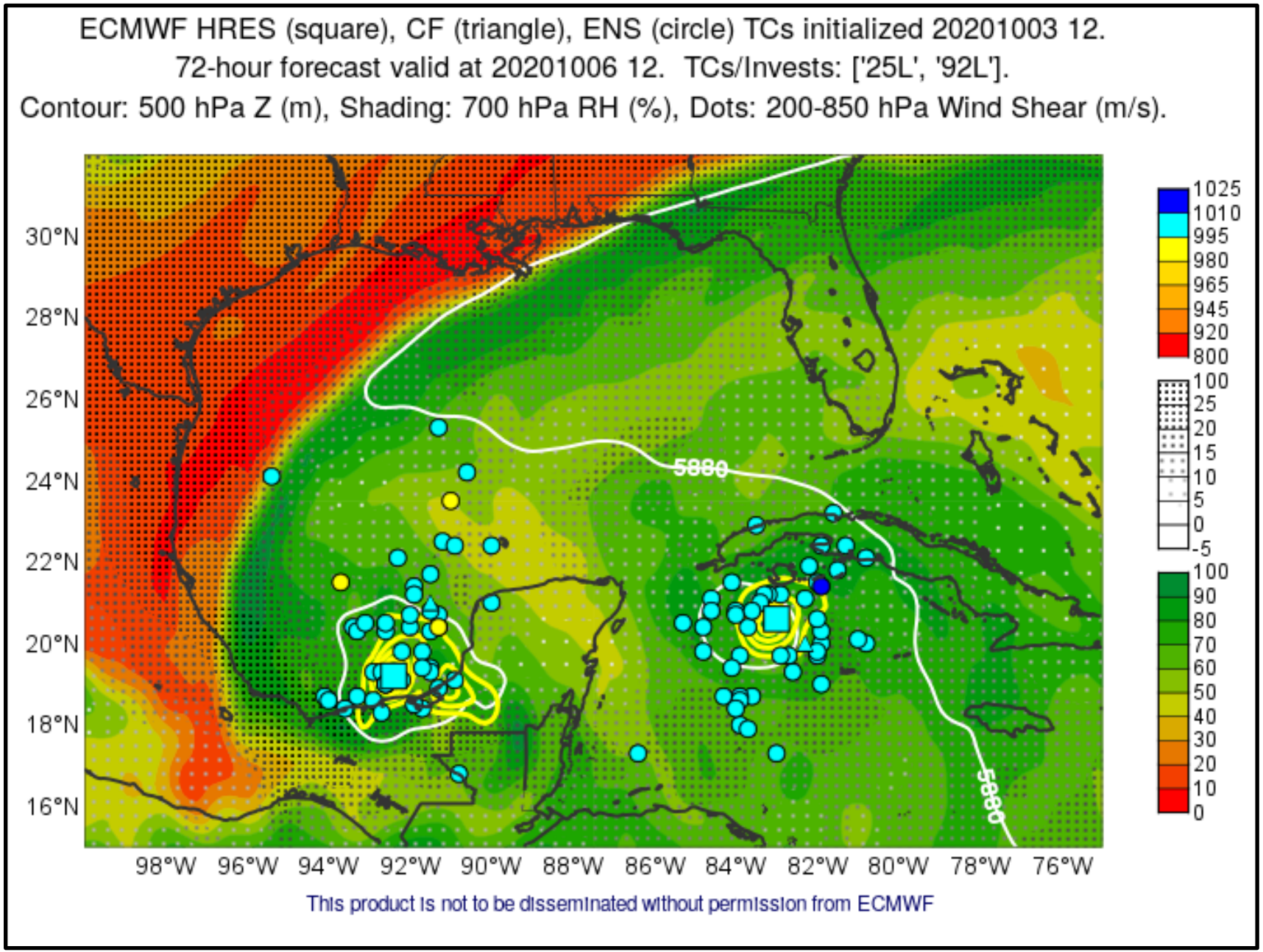
ECMWF

Objectives

1. To provide guidance for research aircraft mission planning

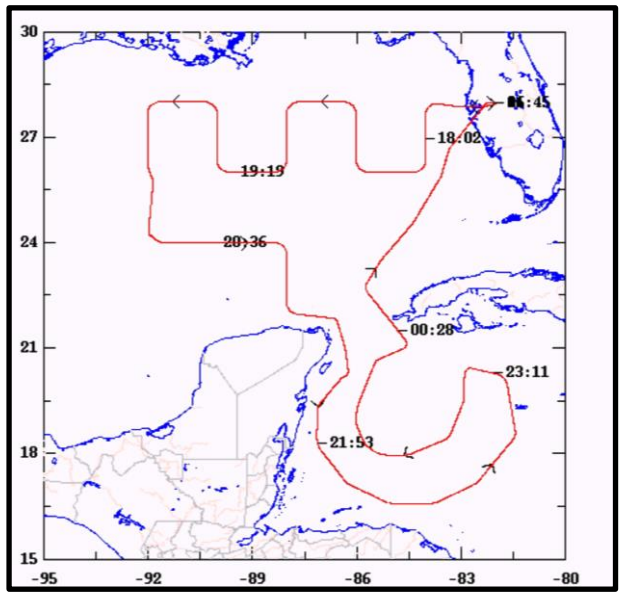
2. To provide insights into forecasts and their errors
   a. Position (“track”)
   b. Formation (“genesis”)
   c. Intensity (central pressure; maximum wind speed)

1. Research mission planning: HRES and Ensemble Products

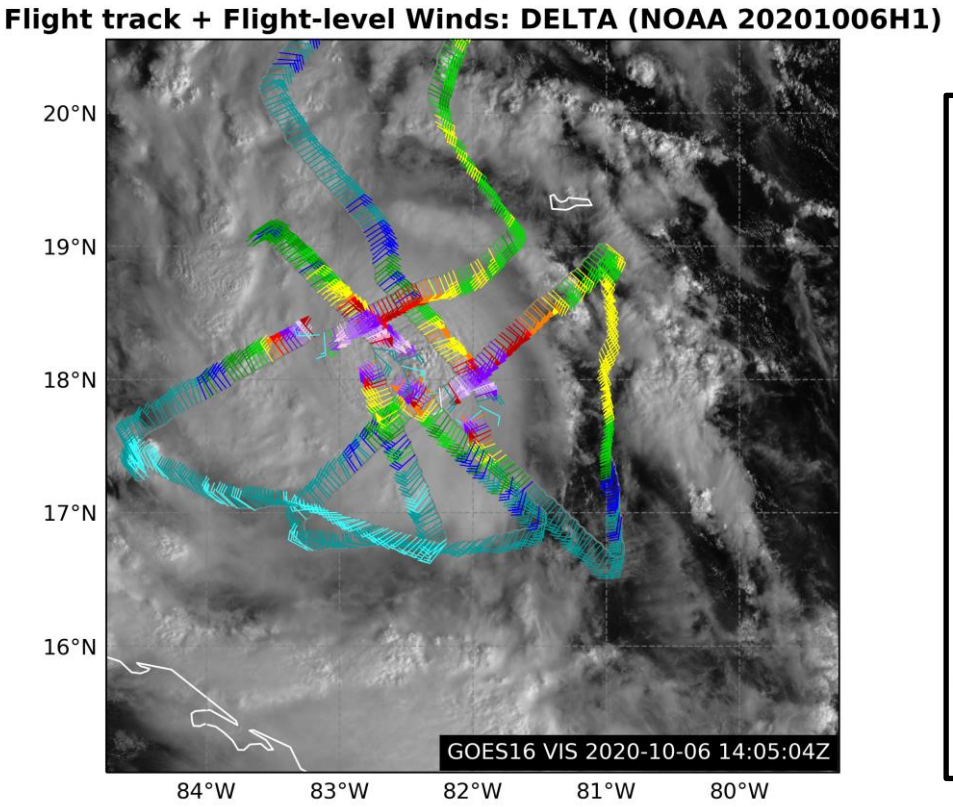


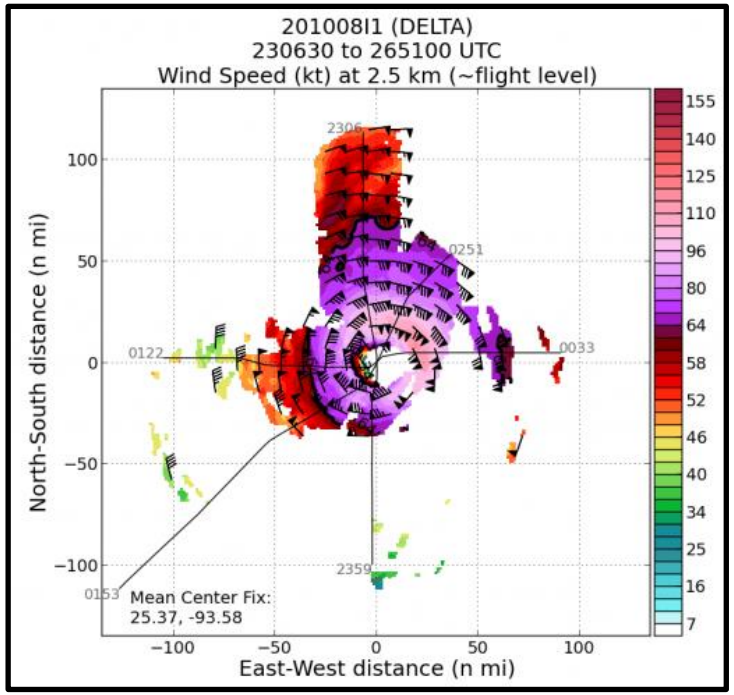
Research and Operational missions: Hurricane Delta

Synoptic Surveillance: Dropwindsondes



Inner-Core Sampling: Airborne Doppler Radar; in-flight data; Dropwindsondes; SFMR





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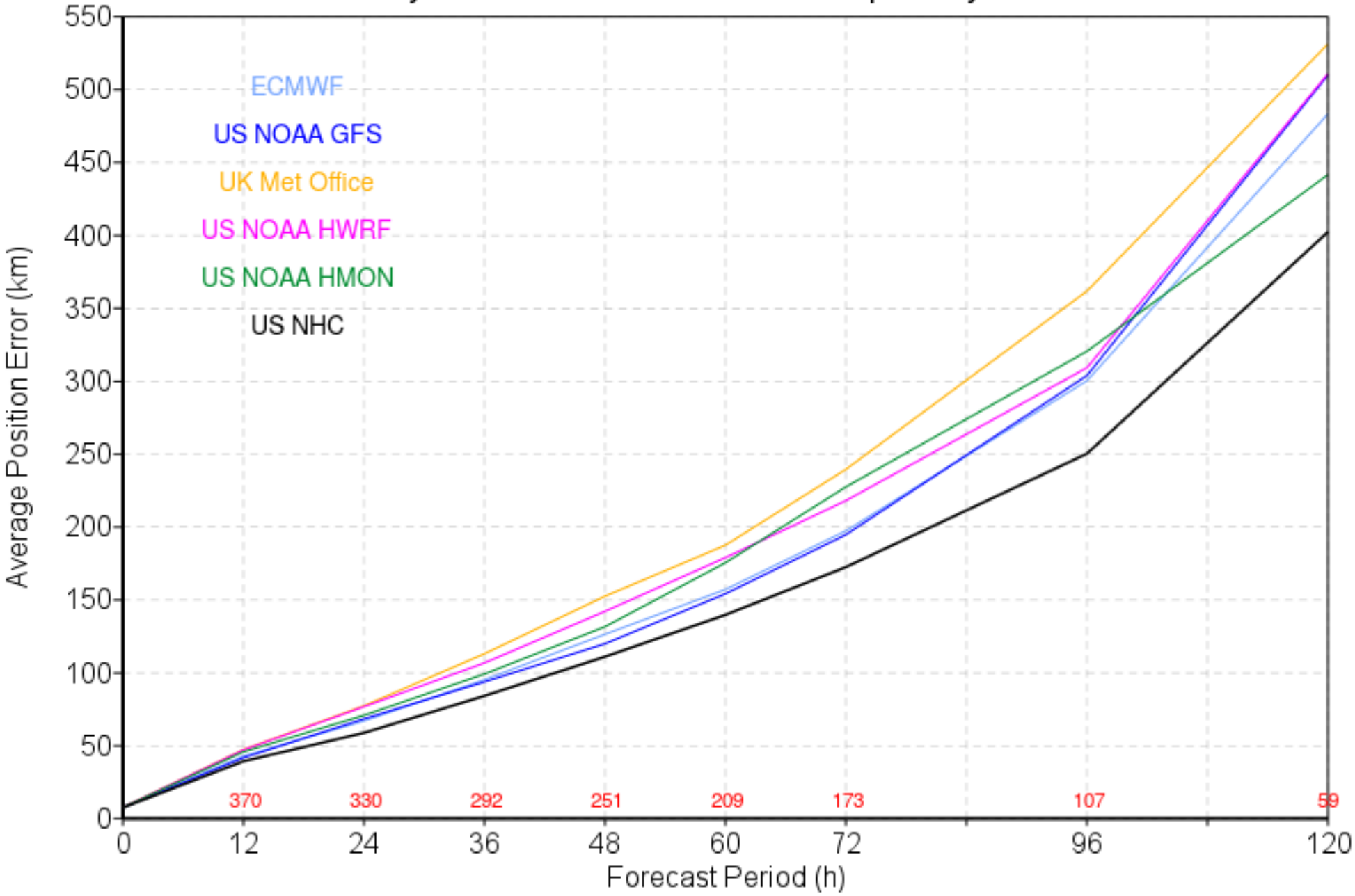
NOAA / U.S. Office of Naval Research

2a. Preliminary NHC Verification of Atlantic Tropical Cyclone Position Errors



2a. Remarks on Position Forecast Errors (Atlantic Basin)

- 1-3 day forecasts
  - ECMWF and NCEP GFS performed best

- 4-5 day forecasts
  - All models (including ERA5) produced higher average errors than in most recent years.
  - Errors associated with several Atlantic TCs gaining significant latitude as they moved into the extratropics

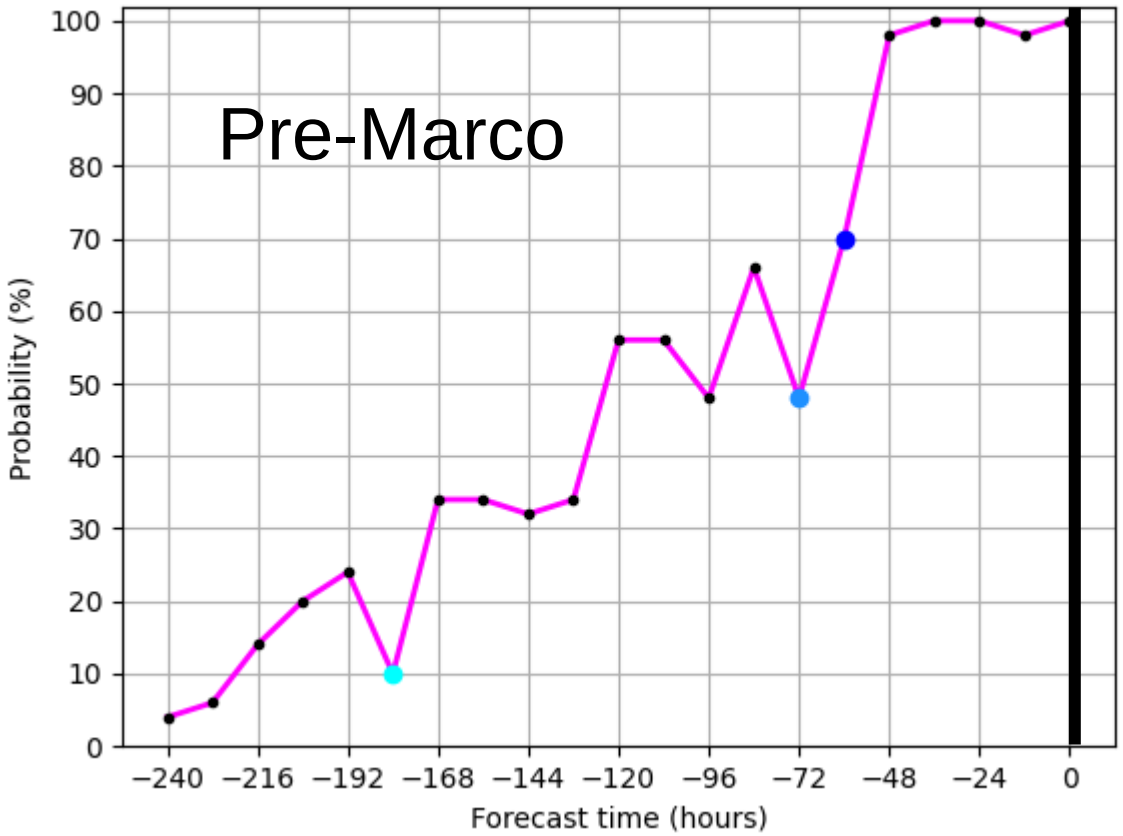
- Position errors of initially weak TCs are overall larger than those of strong TCs

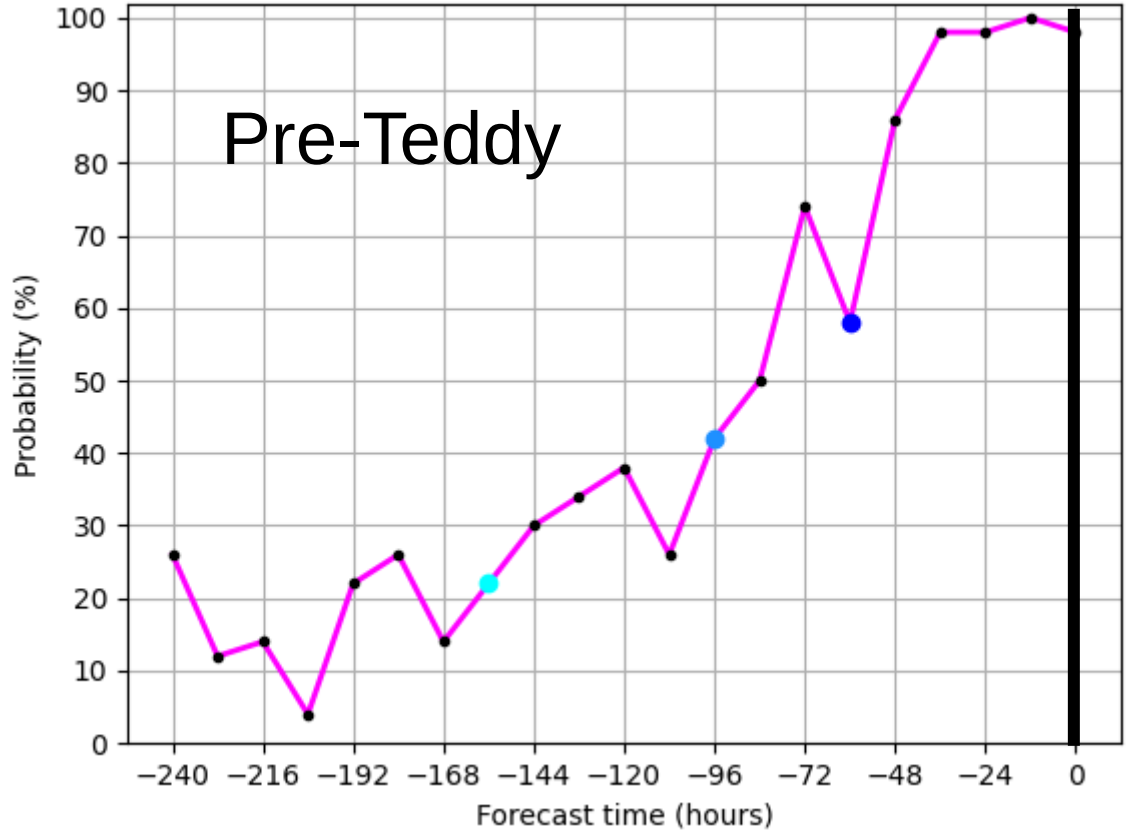
- Overall, other NWP centres are catching up each year

- A blend of different operational model predictions is overall superior to the predictions from any individual model

2b. Probabilistic Prediction of Tropical Storm Formation

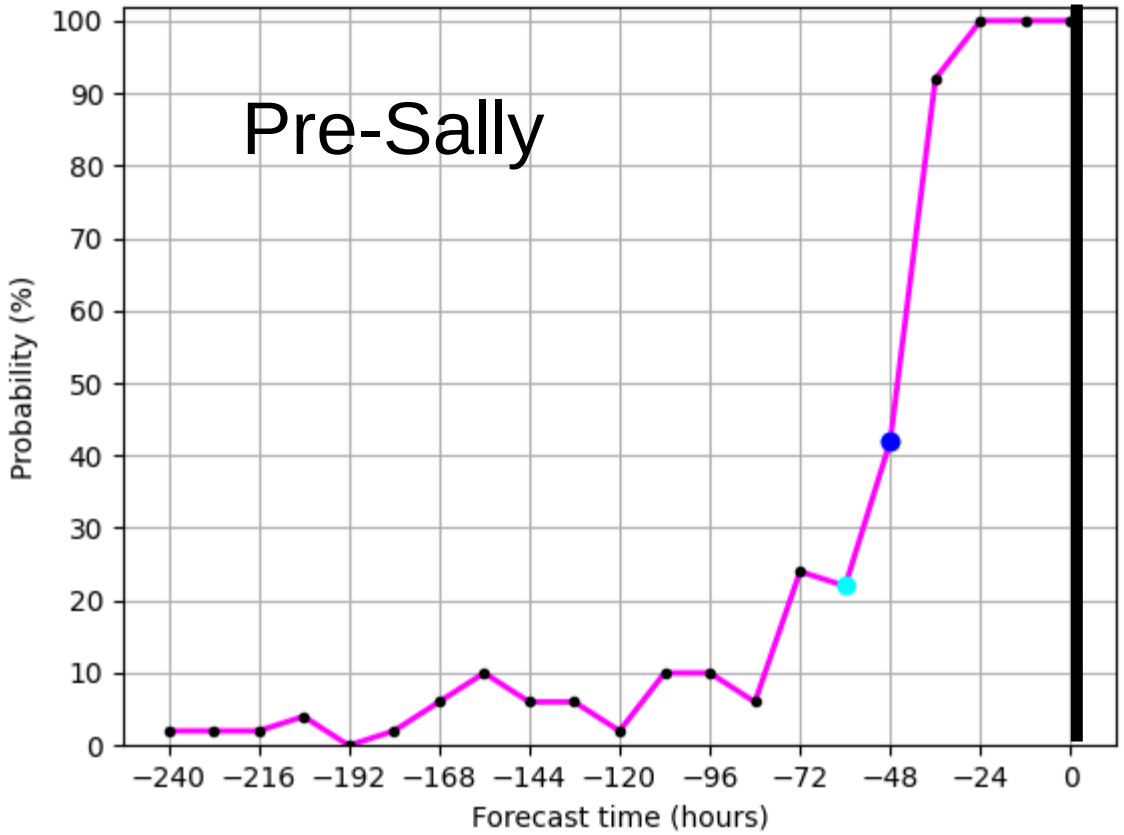
- **Straightforward cases**
- ECMWF >30% chance of TC 5 days prior to being a tropical storm
- Relatively **high** 700 hPa relative vorticity at this lead time
- **Ensemble-based probability that a TC exists within 500 km of the actual location of the TC (or wave) at a given time, as a function of forecast lead time**

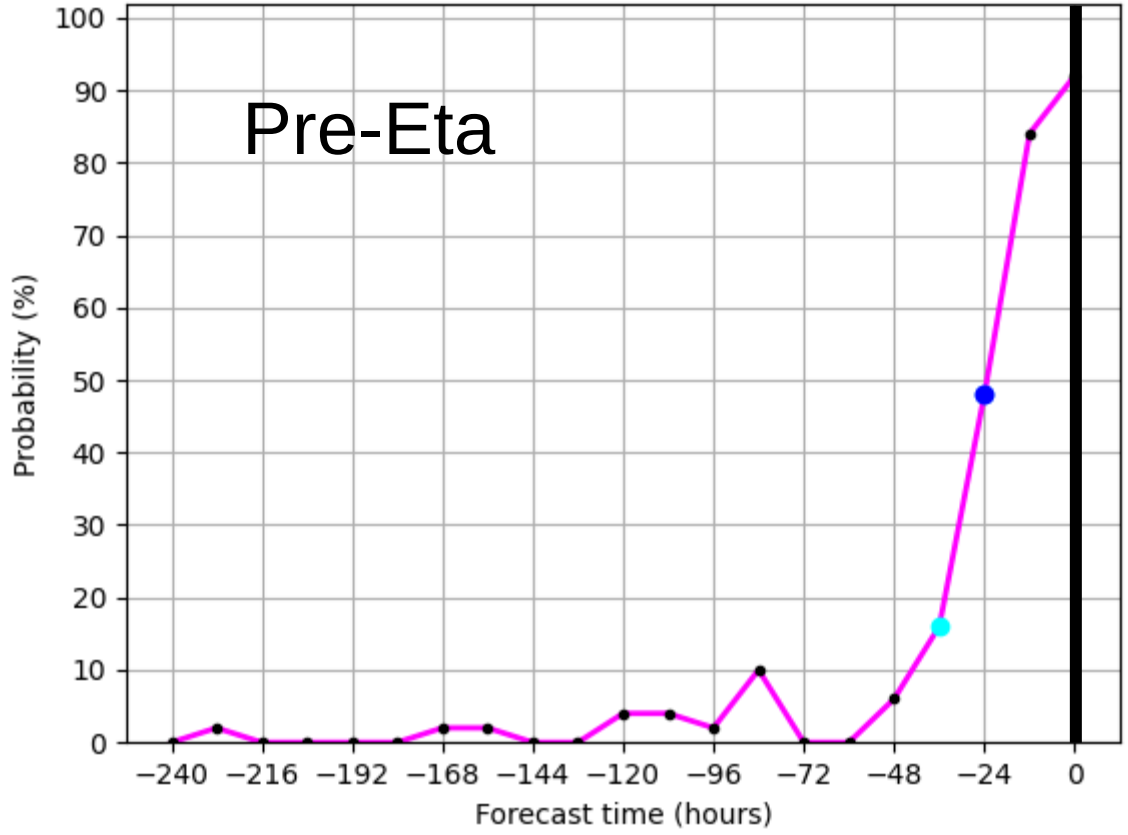




2b. Probabilistic Prediction of Tropical Storm Formation

- **Difficult cases**
- ECMWF 0-10% chance of TC within 5 days
- NHC 0-10% chance of TC within 5 days and 0-30% chance of TC within 2 days
- Relatively **low** 700 hPa relative vorticity 5 days prior to being a tropical storm





2b. Remarks on Forecasts of Tropical Storm Formation (Atlantic Basin)

- Large waves are well-predicted – no obvious “misses”

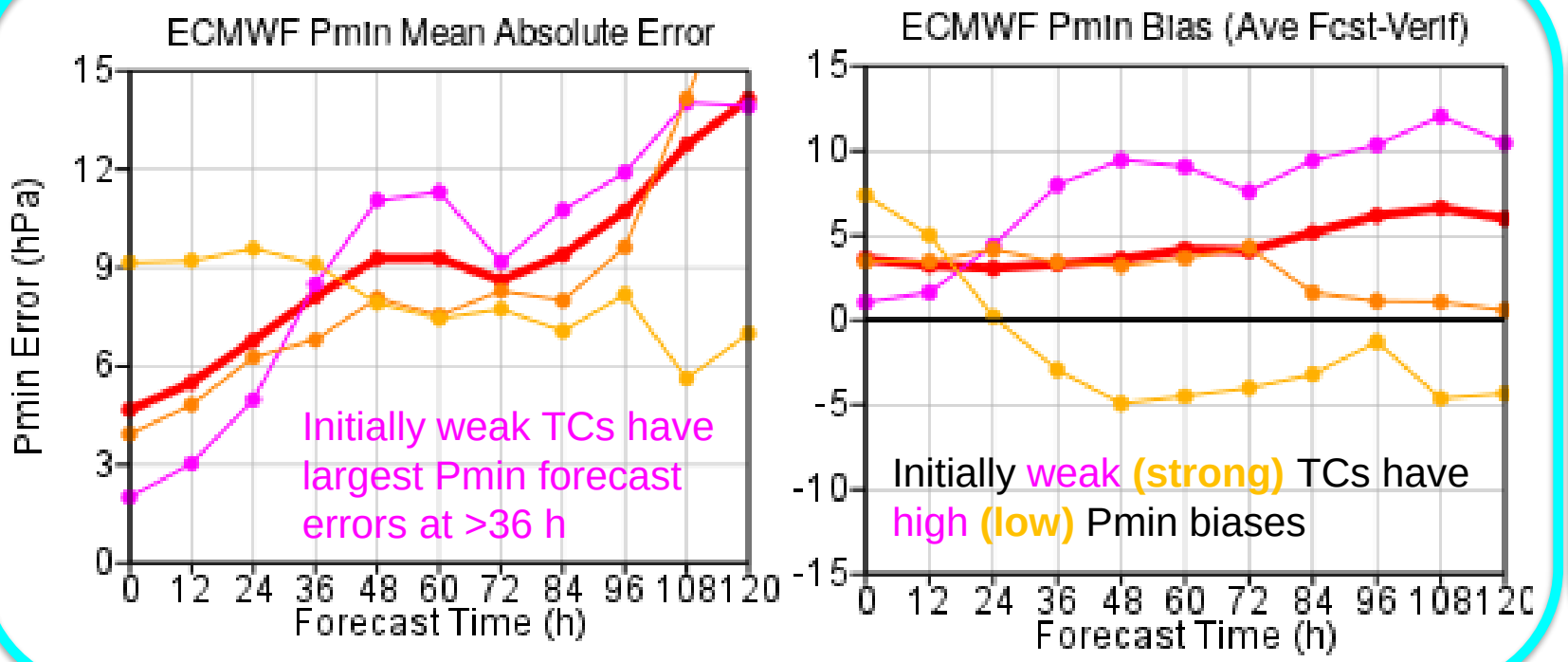
- For weak and/or interacting waves, it is challenging to discriminate between developers and non-developers 2+ days prior to formation

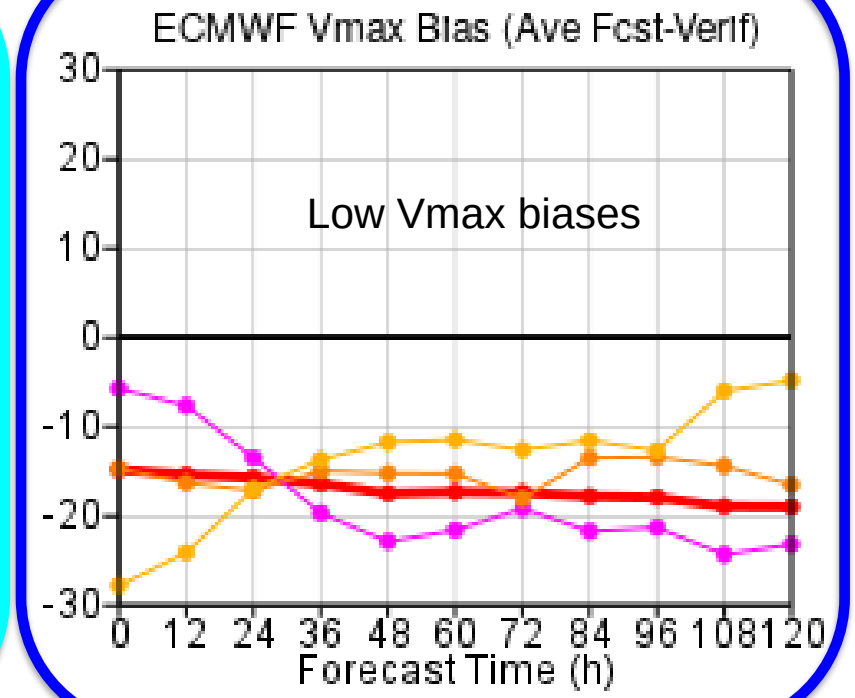
- For non-developing waves, there do not seem to be falsely high probabilities of formation

- Some concerns with ensemble ”jumpiness” (David Richardson)

- Initialization, modelling, and predictability challenges for a variety of multi-scale mechanisms:
  - Distinct, solitary waves with high vorticity
  - Distinct, solitary waves with low vorticity
  - Role of convection in organizing the vortex
  - Wave- Wave / Low Pressure / ITCZ interactions
  - Large-scale interactions

2c. HRES: Tropical Cyclone Intensity Forecasts (Pmin and Vmax)



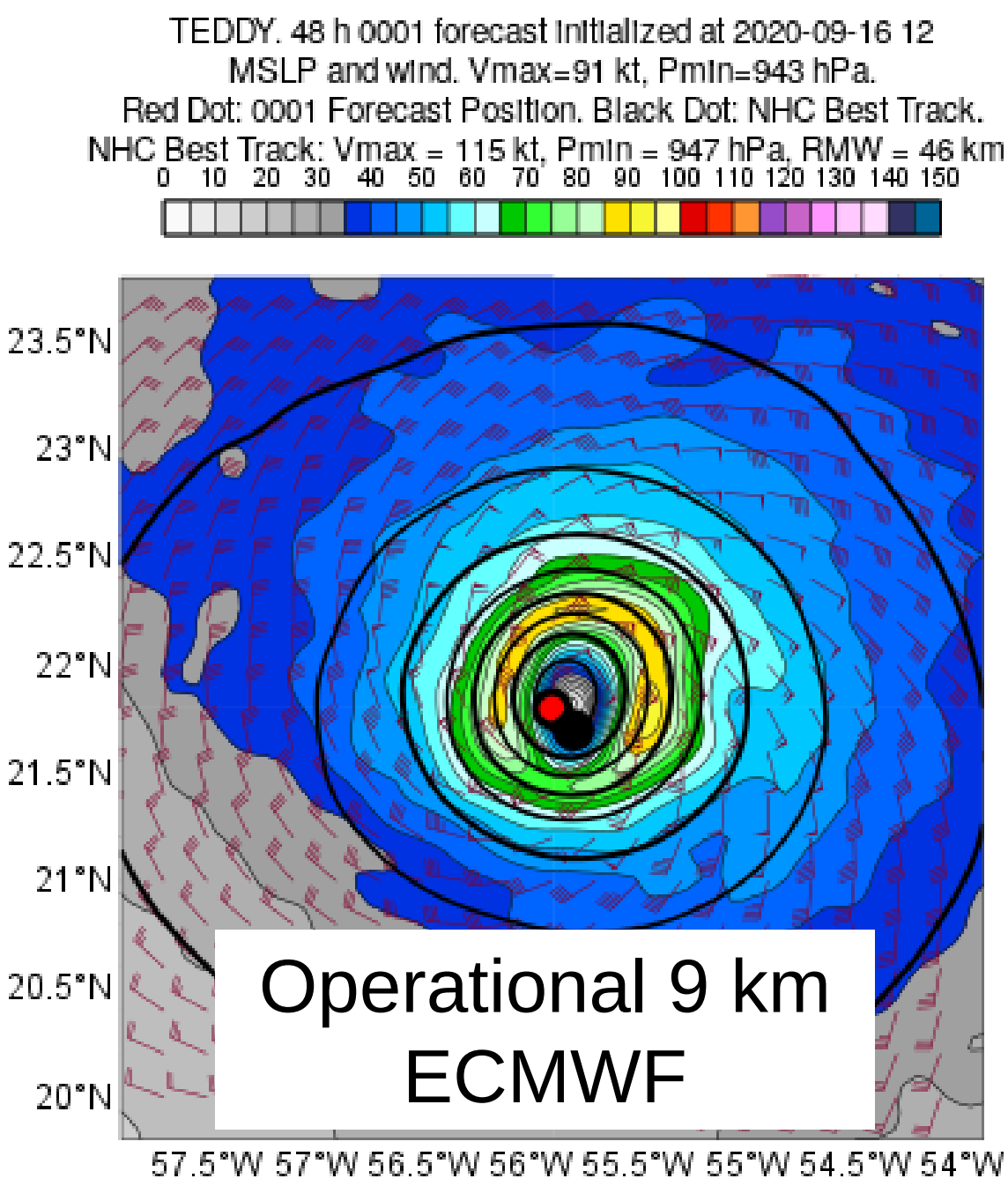


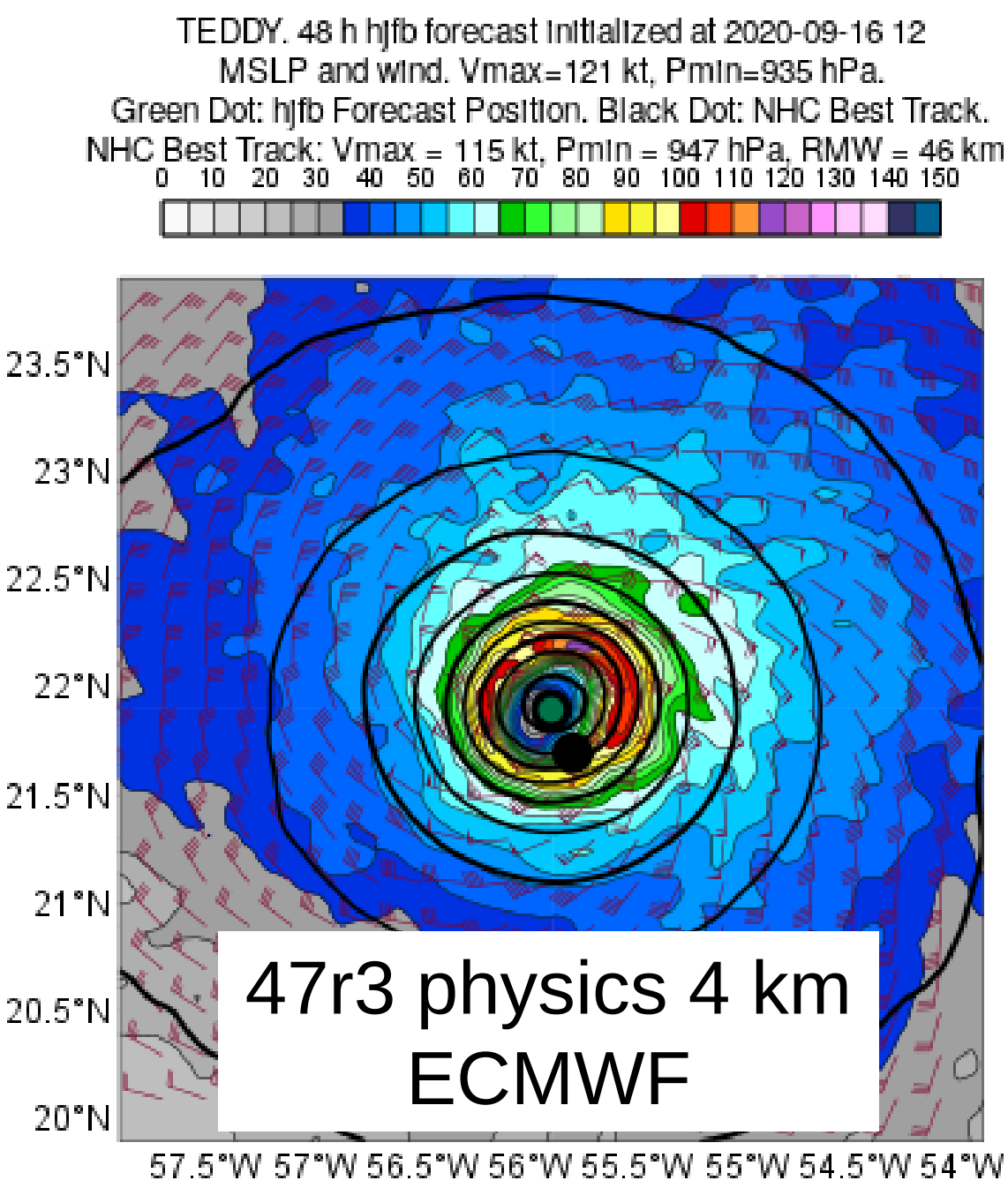
ECMWF Special Topics Paper (in preparation)

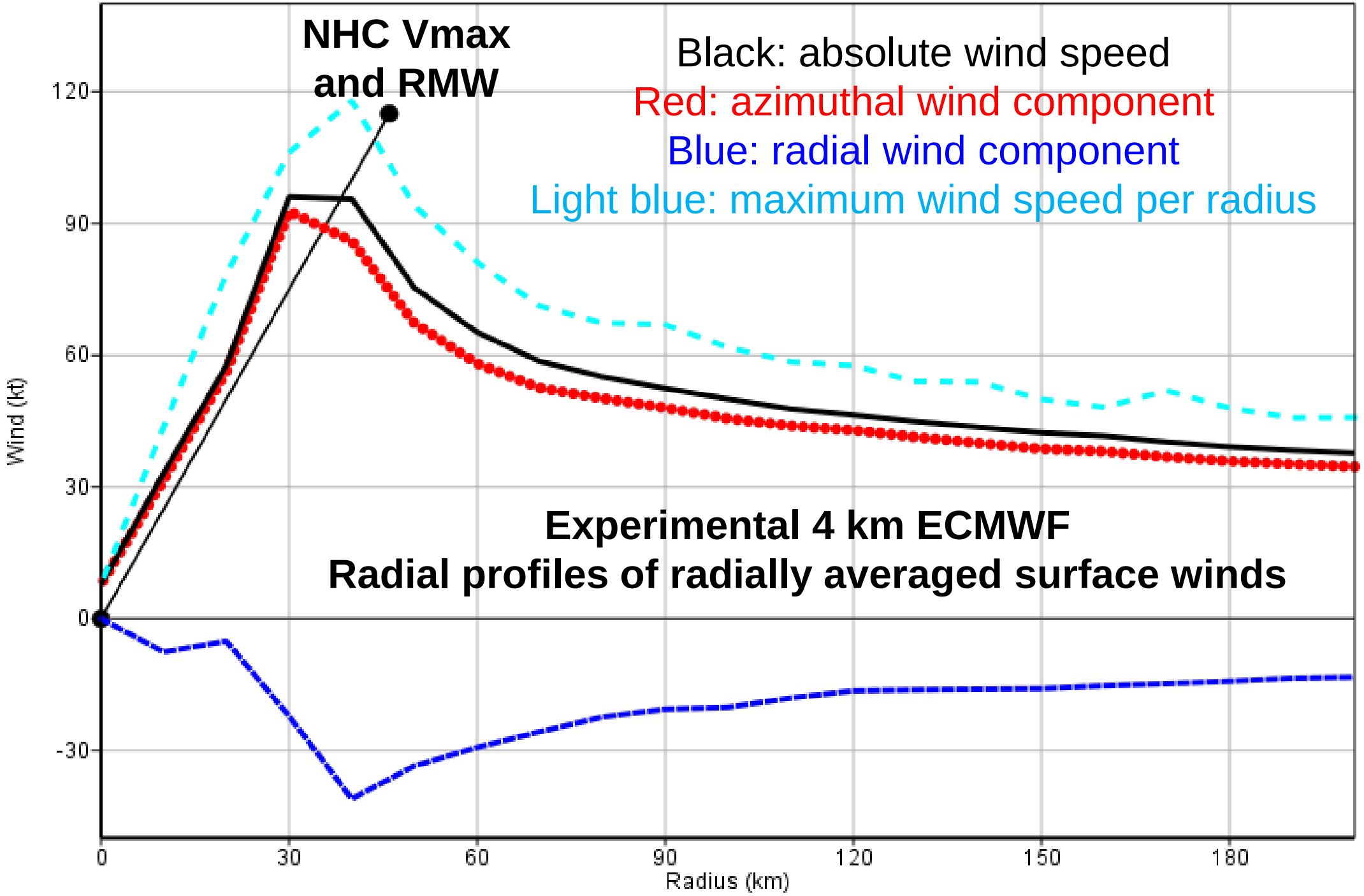
- August 15– September 20, 2020

- 30+ numerical research experiments
  - Modelling (e.g., resolution; coupling; physics; numerics; non-hydrostatic…)
  - Data Assimilation (e.g., microwave; all-sky; AMV; pressure; scatterometer; aircraft; GPS RO; Aeolus …)

- Illustration: One research experiment
  - 4 km, hydrostatic, New Physics for Cy47r3 (expid: hjfb, thanks to Peter Bechtold)
  - (Near) operational initial conditions
  - Hurricane Teddy, initialized 2020-09-16, 12 UTC

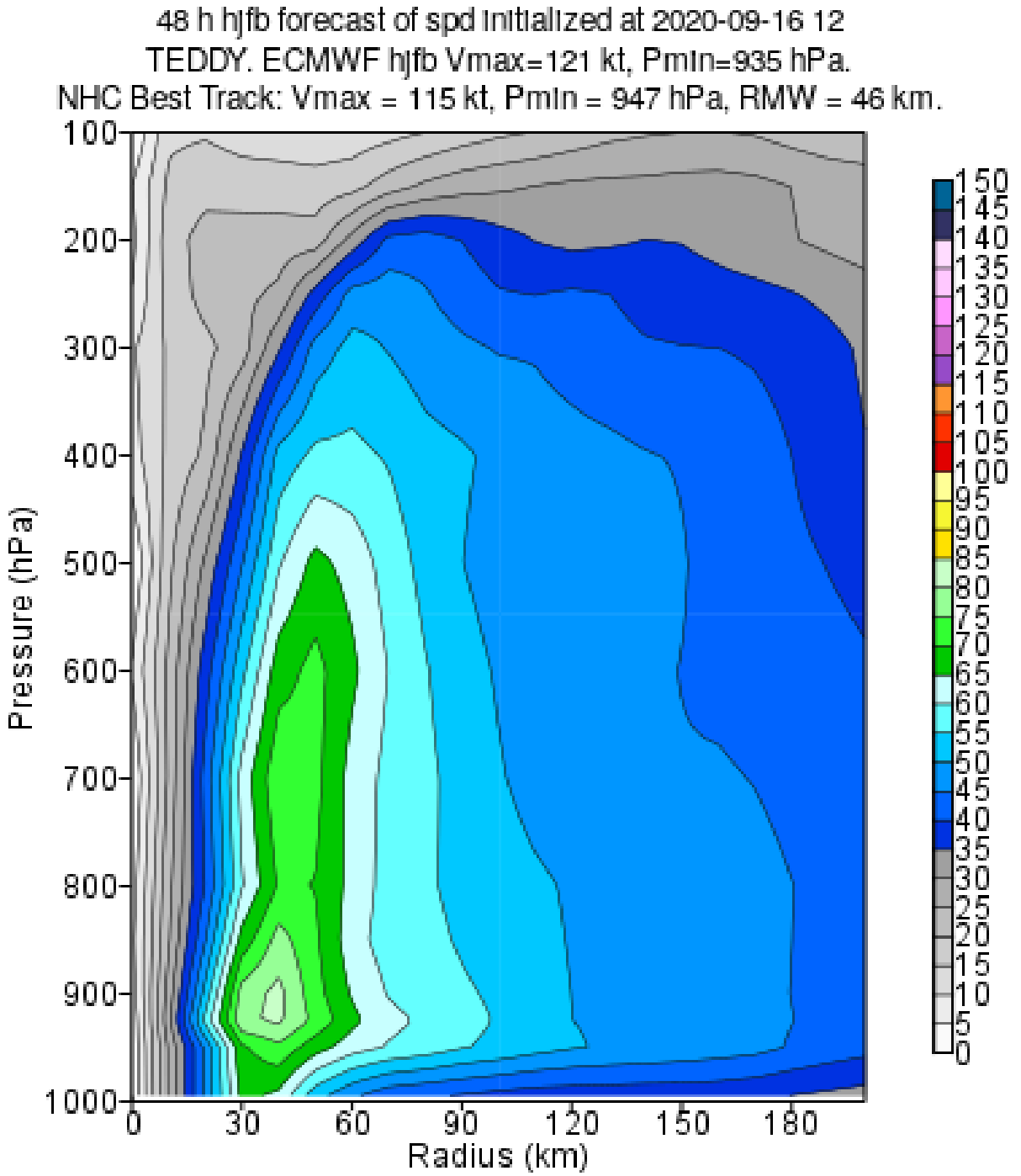

TEDDY. 48 h 0001 forecast Initialized at 2020-09-16 12
MSLP and wind. Vmax=91 kt, Pmin=943 hPa.
Red Dot: 0001 Forecast Position. Black Dot: NHC Best Track.
NHC Best Track: Vmax = 115 kt, Pmin = 947 hPa, RMW = 46 km.
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
23.5°N
23°N
22.5°N
22°N
21.5°N
21°N
20.5°N
20°N
57.5°W 57°W 56.5°W 56°W 55.5°W 55°W 54.5°W 54°W
Operational 9 km
ECMWF

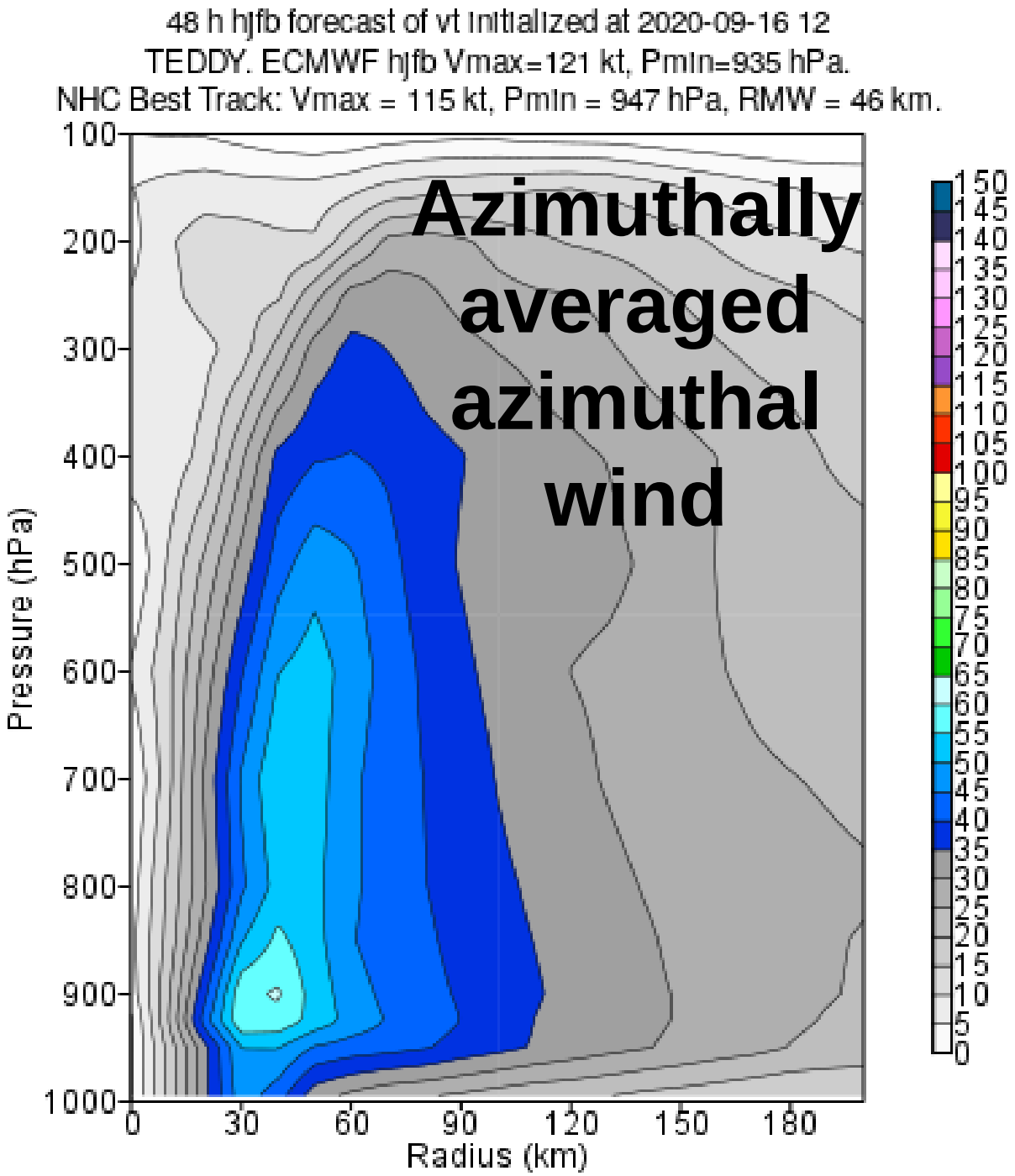

TEDDY. 48 h hjfb forecast Initialized at 2020-09-16 12
MSLP and wind. Vmax=121 kt, Pmin=935 hPa.
Green Dot: hjfb Forecast Position. Black Dot: NHC Best Track.
NHC Best Track: Vmax = 115 kt, Pmin = 947 hPa, RMW = 46 km.
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
23.5°N
23°N
22.5°N
22°N
21.5°N
21°N
20.5°N
20°N
57.5°W 57°W 56.5°W 56°W 55.5°W 55°W 54.5°W 54°W
47r3 physics 4 km
ECMWF

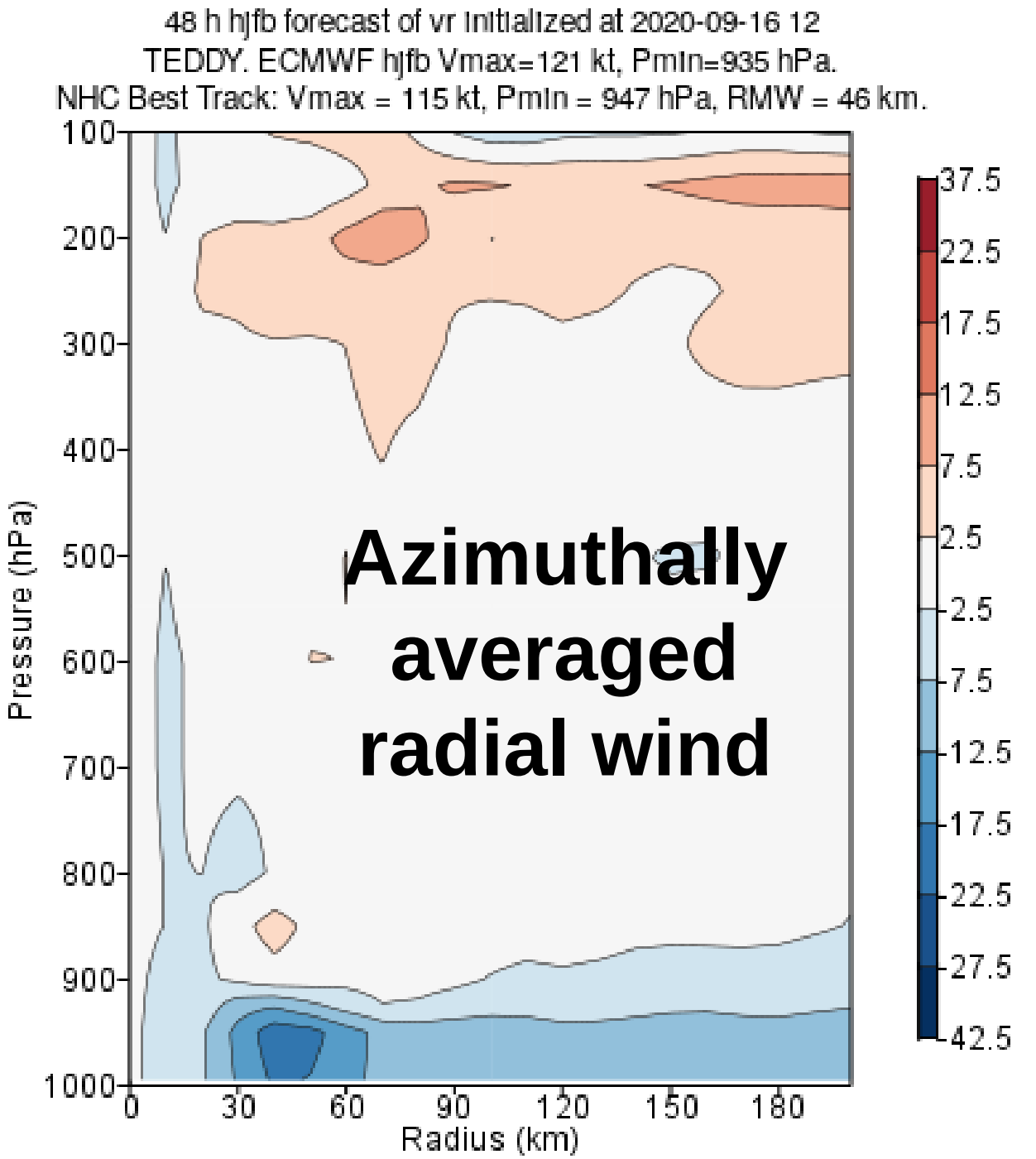

NHC Vmax
and RMW
Black: absolute wind speed
Red: azimuthal wind component
Blue: radial wind component
Light blue: maximum wind speed per radius
Experimental 4 km ECMWF
Radial profiles of radially averaged surface winds
Wind (kt)
120
90
60
30
0
-30
0
30
60
90
120
150
180
Radius (km)

Experimental 4 km ECMWF

r-p profile of azimuthally averaged wind speed




48 h hjfb forecast of vt initialized at 2020-09-16 12
TEDDY. ECMWF hjfb Vmax=121 kt, Pmin=935 hPa.
NHC Best Track: Vmax = 115 kt, Pmin = 947 hPa, RMW = 46 km.
Azimuthally averaged azimuthal wind
Pressure (hPa)
Radius (km)


48 h hjfb forecast of vr initialized at 2020-09-16 12
TEDDY. ECMWF hjfb Vmax=121 kt, Pmin=935 hPa.
NHC Best Track: Vmax = 115 kt, Pmin = 947 hPa, RMW = 46 km.
Azimuthally averaged radial wind
Pressure (hPa)
Radius (km)

2c. Remarks on Forecasts of Tropical Cyclone Intensity Change

- Large tropical cyclones (Teddy; several NW Pacific typhoons) can intensify well in predictions

- However, most predicted tropical cyclones do not intensify as much as in reality

- Accurate representation of convective-scale and mesoscale processes in the initial conditions is necessary

- Intensification is better caught at 4 km with assimilation and/or initialization on these scales
  - Including Rapid Intensification
  - Vmax predictions are less biased

- Large intensity errors exist for initially strong TCs – is the weakening process too slow?

Future Goals

- Complete Special Topics paper

- Deliverable evaluation and diagnostics code framework (Python)

- Additional publications: some ideas
  - Refined analysis of evaluations
  - Process-driven diagnostics of interesting research experiments
  - Future verification methods (e.g. structure; precipitation)