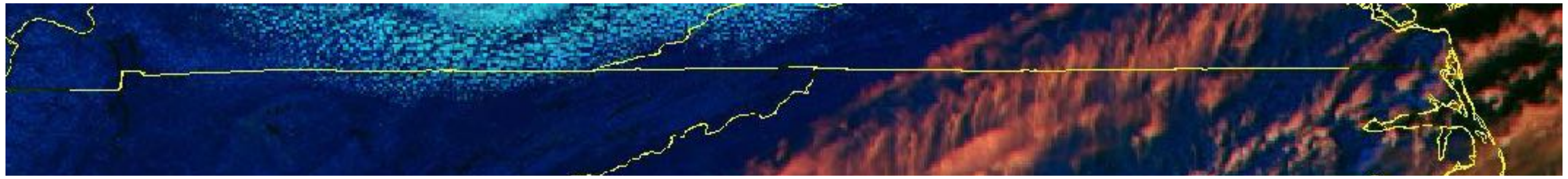
Scripps Institution of Oceanography's LAGRANGIAN DRIFTER LABORATORY

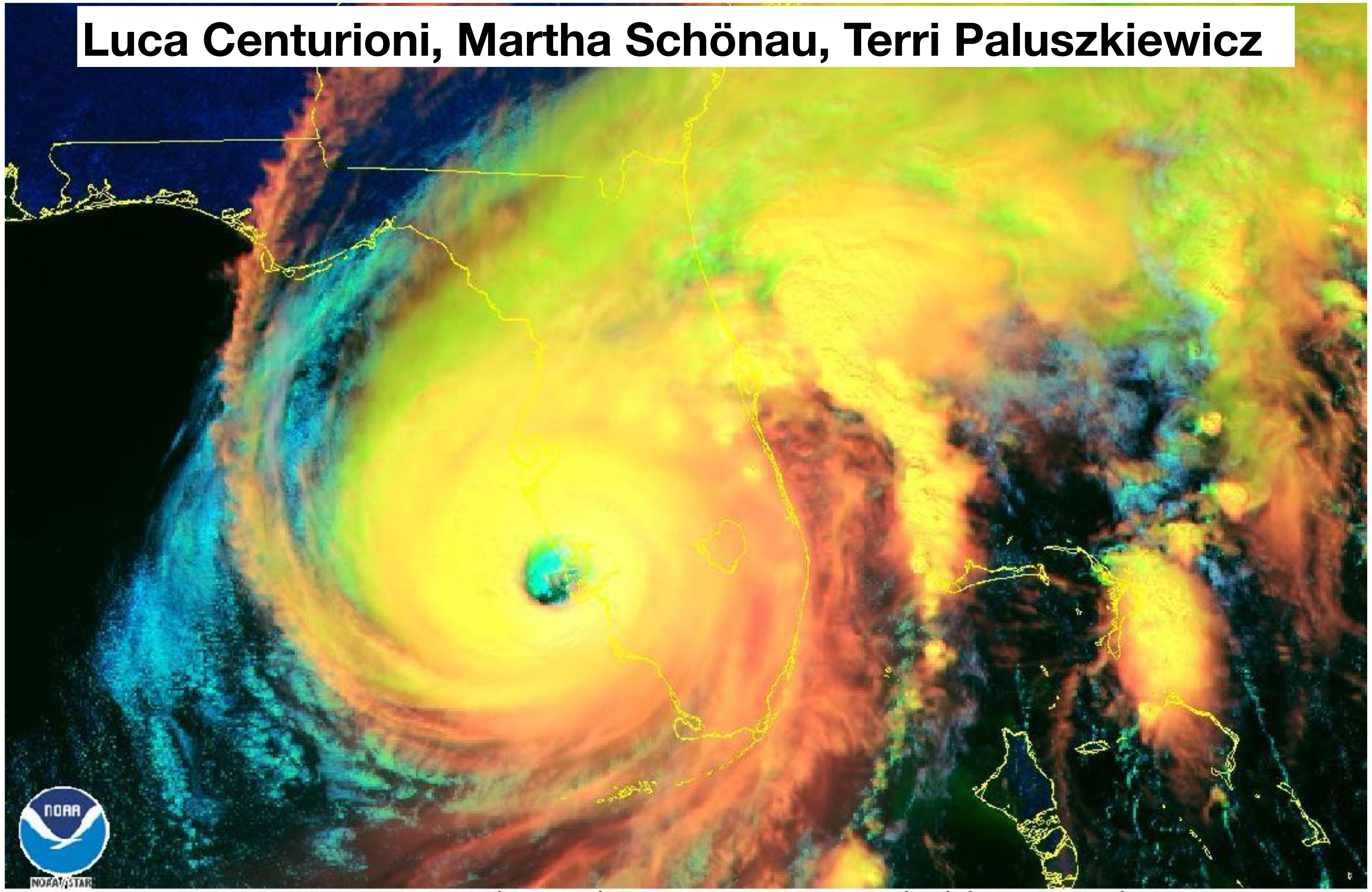
SCRIPPS INSTITUTION OF OCEANOGRAPHY UC San Diego



Wave Observations from Expendable Drifting Buoys

Global Drifter Program Lagrangian Drifter Laboratory (LDL) at Scripps

Luca Centurioni, Martha Schönau, Terri Paluszkiewicz



28 Sep 2022 18:11Z - NOAA/NESDIS/STAR - GOES-East - DayCloudPhase Composite SE

Observations Funded by:

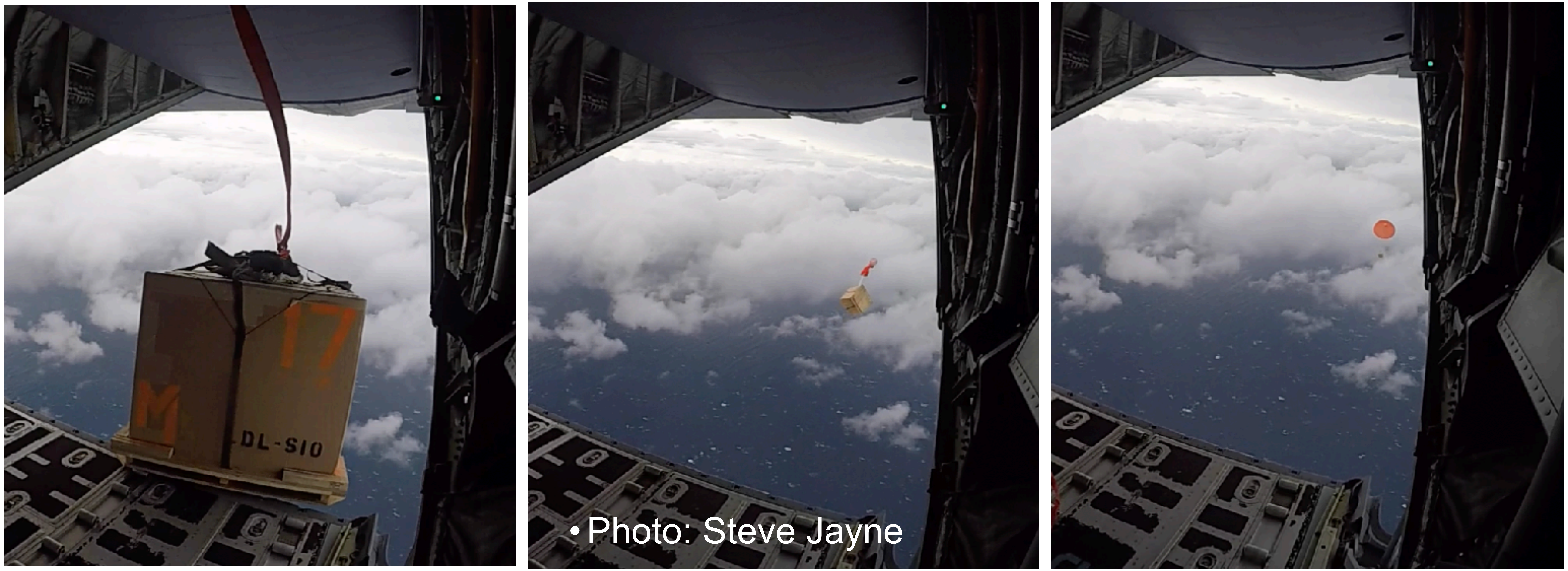
NOPP

Office of Naval Research Science & Technology ONR

NOAA

Outline

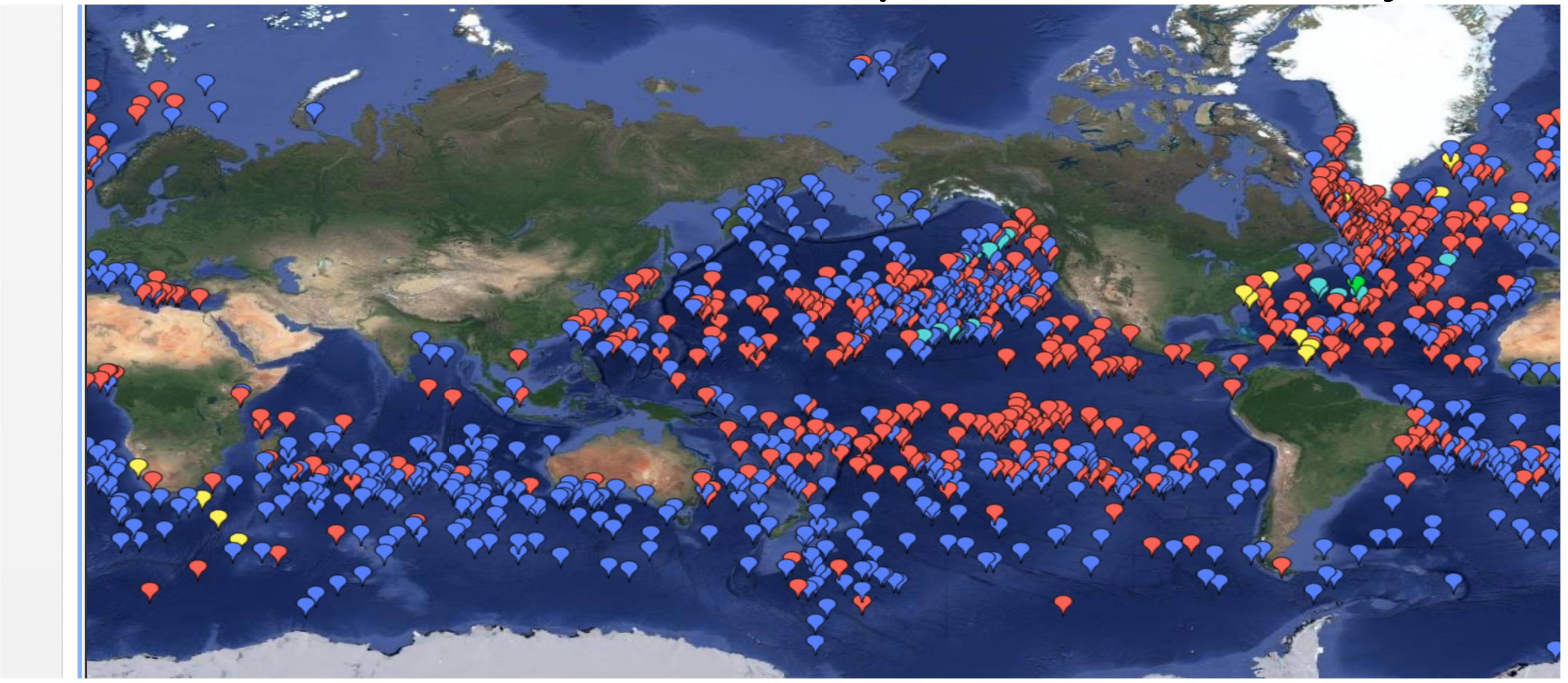
- **LDL Drifters/SVP Family: Reliable, cost-effective, accessible data in near-real time, FAIR-O**
- **Adaptive, targeted wave observations**
- **Sustained deep-water wave observations**



• Photo: Steve Jayne

The Global Drifter Program in a Nutshell

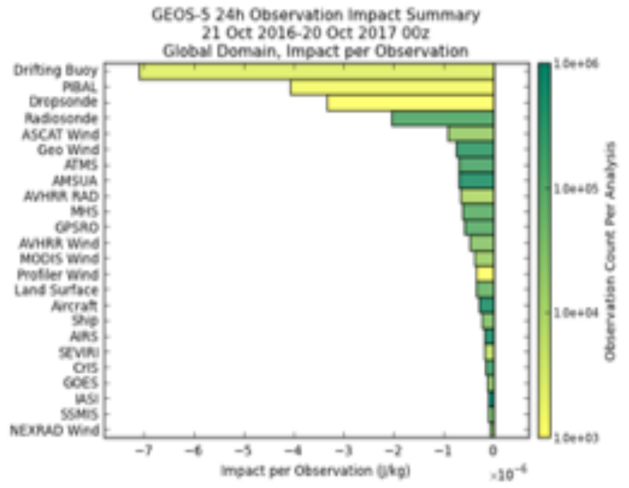
The Only Global Scientific Project for In-Situ Ocean Observing at the Air-Sea Interface



Main Critical Impact Areas

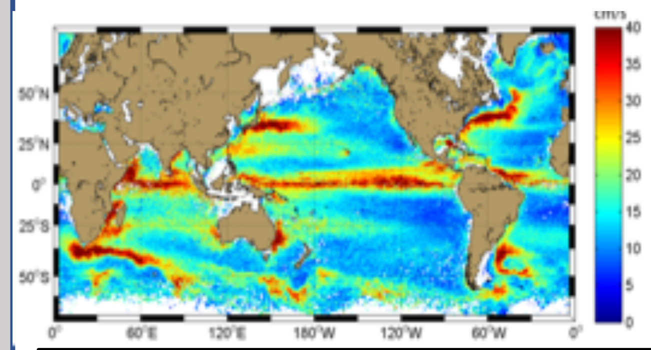
SST From Space Cal/Val

Left: Fractional contribution of SST data by platforms (buoys refers primarily to drifters, that provide more SST data than all the other sources combined). From Kennedy et al, 2011, JGR. Drifters provide X100 daily SST obs than Argo.



SLP for NWP and Climate Indices

Left: Drifters SLP data have the largest positive impact per observations (Centurioni et al. 2016, BAMS). Both forecasting and climate studies benefit from drifter data, especially in the southern ocean where the drifters are essentially the only source of in-situ SLP data.



Science

Over 1,100 paper published to date use drifter data directly

***Overarching Goals*:**

-Further our scientific understanding of the ocean, atmosphere and climate by observing surface physical processes in the global ocean.

-Maintain a global 5ºx5º array of surface drifting buoys to meet the needs for an accurate and globally dense set of in-situ observations: **mixed layer currents, SST**, **atmospheric pressure**, winds, and salinity.

-Build a *collaboration* with the international community to maintain the drifter array.

Metrics:

- Full 5 X 5 array
- Real time data distribution on GTS
- Global data accessibility
- Verified Lagrangian characteristic
- Quality-controlled data, archived

Furthermore, the GDP provides publicly (FAIR-O) available observational baselines in the upper-ocean mixed-layer and fills a unique role in the Global Ocean and Climate Observing System. The positive impacts of the GDP data are large and well documented

See https://gdp.ucsd.edu/ldl/global-drifter-program/ for a complete description of the program

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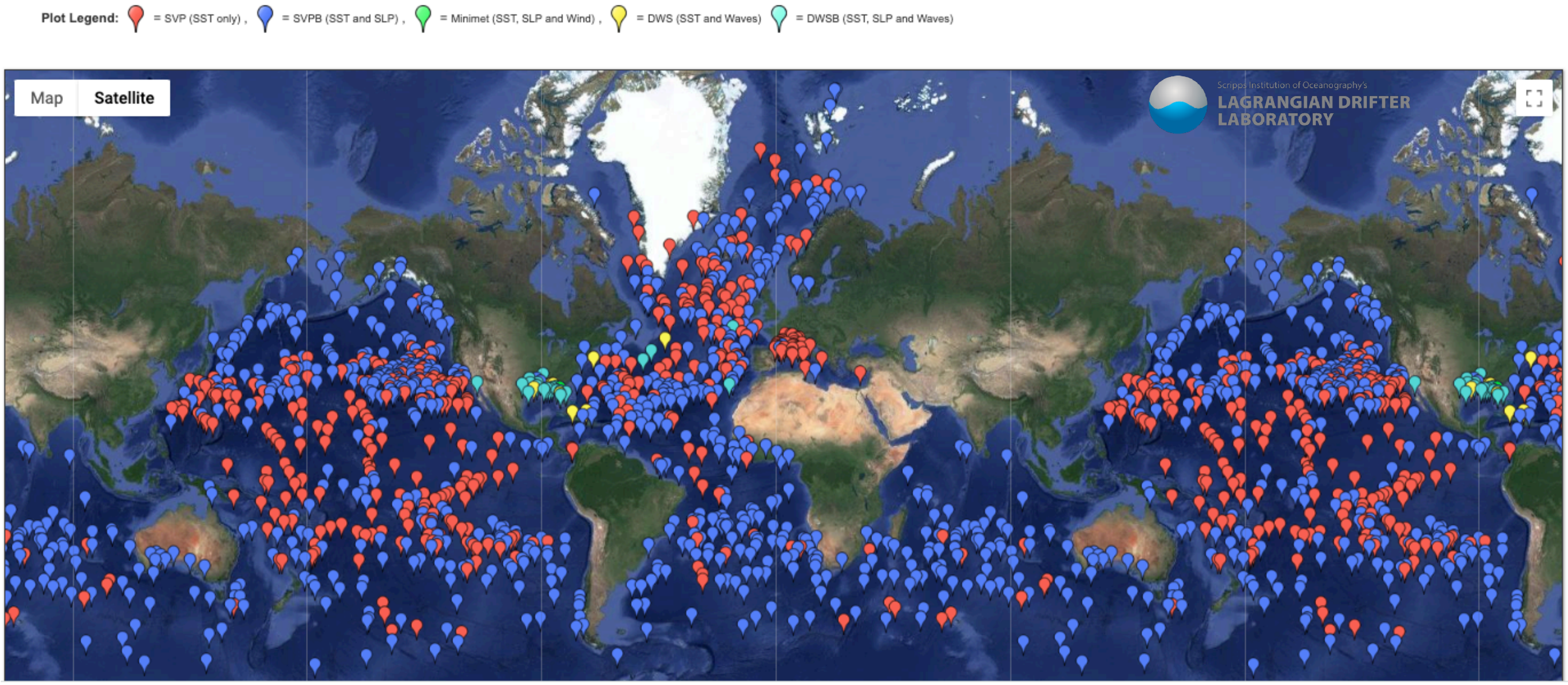
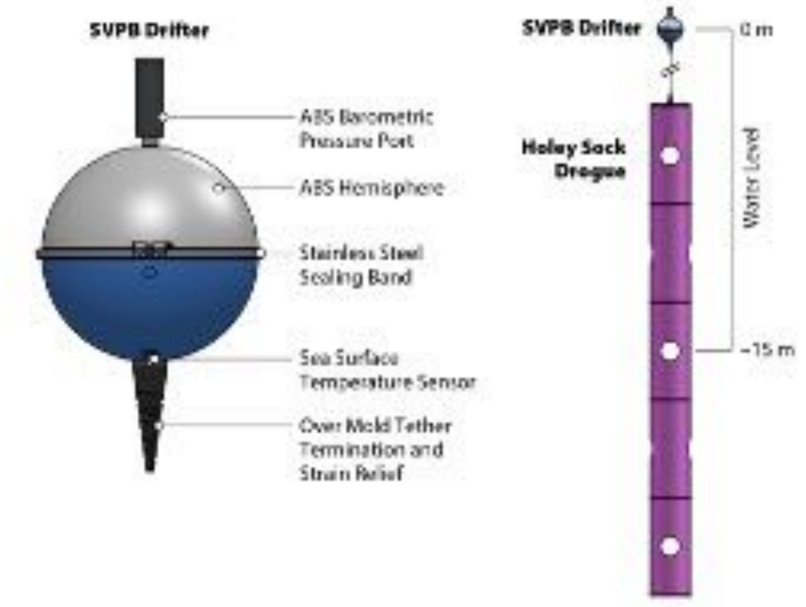
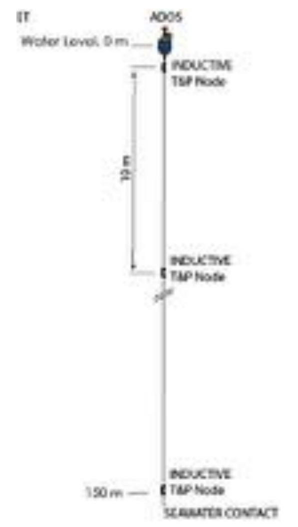
Global drifter array: the SVP drifter family



SVP and SVP-B

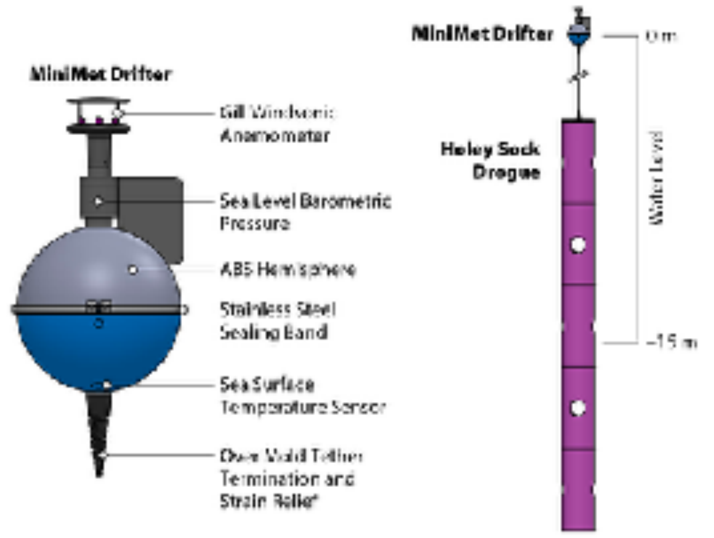


Atmospheric data and currents



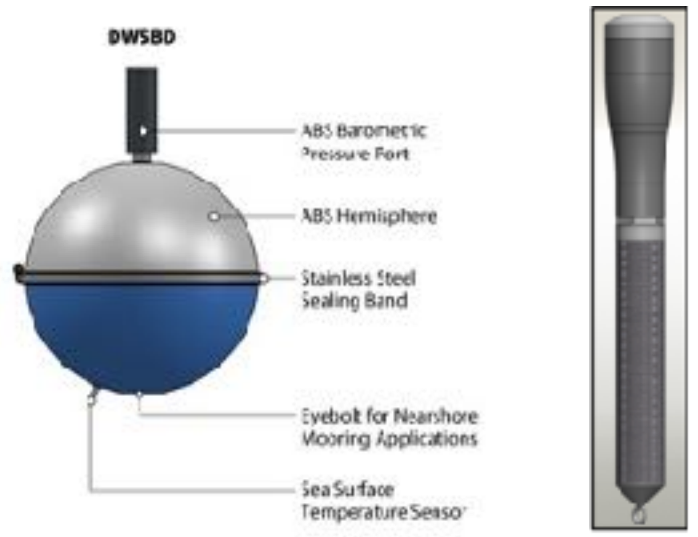
ADOS

Atmospheric and Upper Ocean Heat Content



MiniMet

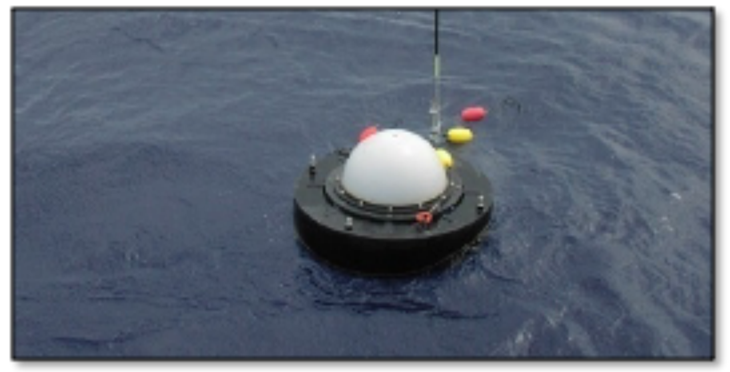
Atmospheric data (SLP and winds)



DWSD-B and A-DWS

Atmospheric data and waves

Directional Wave Spectra Drifters



Prototype/testing

LDL DWS MOORING

A-size DWSD

- Delivered first batch to 53rd/NRL for 2022 Hurricane Season
- Adds flexibility to targeted deployments

Significant Milestones:

- **2005:** First prototype (GPS, bottom pinger and ADCP)
- **2015:** Release of TRL 9 DWSD by the GDP/LDL at Scripps Institution of Oceanography to sustain a global array of wave sensors.
- **2015:** Global pilot array implementation begins
- **2018:** Targeted deployments (air-drop) in front of hurricanes
- **2019:** Atmospheric rivers deployments (air-drop) off the US west coast
- **2021:** A-size version release

Key Features

- Cost-effective, scalable to sustain global operations
- Expandable sensor suite
- Low power system, endurance consistent with other SVP drifters
- Shared hardware with the Surface Velocity Program instrument class
- Available in traditional, recycled of biodegradable or plastic
- Drifting or moored
- GTS ready, readily fits into operational forecasting and advisory enterprise

Sensors in the Basic Configuration

- GPS
- Sea Surface Temperature
- Barometer

Telemetry

- Two-way Iridium telemetry for fast data relay (< 1 min) and over-the-air mission control

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Directional Wave Spectra Drifters

Clockwise: DWSD fabrication, DWS sensor test against DWR by Datawell. DWSD deployment.

Sampling

- GPS based system
- Power Spectral Density and Co-Spectra are Computed with FFT.
- First 5 directional spectrum parameters, a_0, a_1,b_1,a_2, and b_2 are transmitted in real time

Examples of Validation

- Datawell Directional Wave Rider - dual mooring 300 m apart (1 year)
- Inter-comparison in Adriatic Sea with CNR-ISMAR
- Evaluation with Datawell DWR in Queensland
- Comparison in Port of Naples with Bottom mounted Nortek -ADCP (Presented in Centurioni et al. 2016)
- Duck's shallow water buoy farm
- On-going WW3 Comparisons (see viewer)

Real-time data display

- In-house developed SQL system integrated with Iridium server
- Real-time data relay, GTS (AWIPS), and ERDDAP server access
- Dedicated Hurricane Viewer: https://gdp.ucsd.edu/apps/projects/noaa/hurricane.html
- Serving data to other integrated viewers

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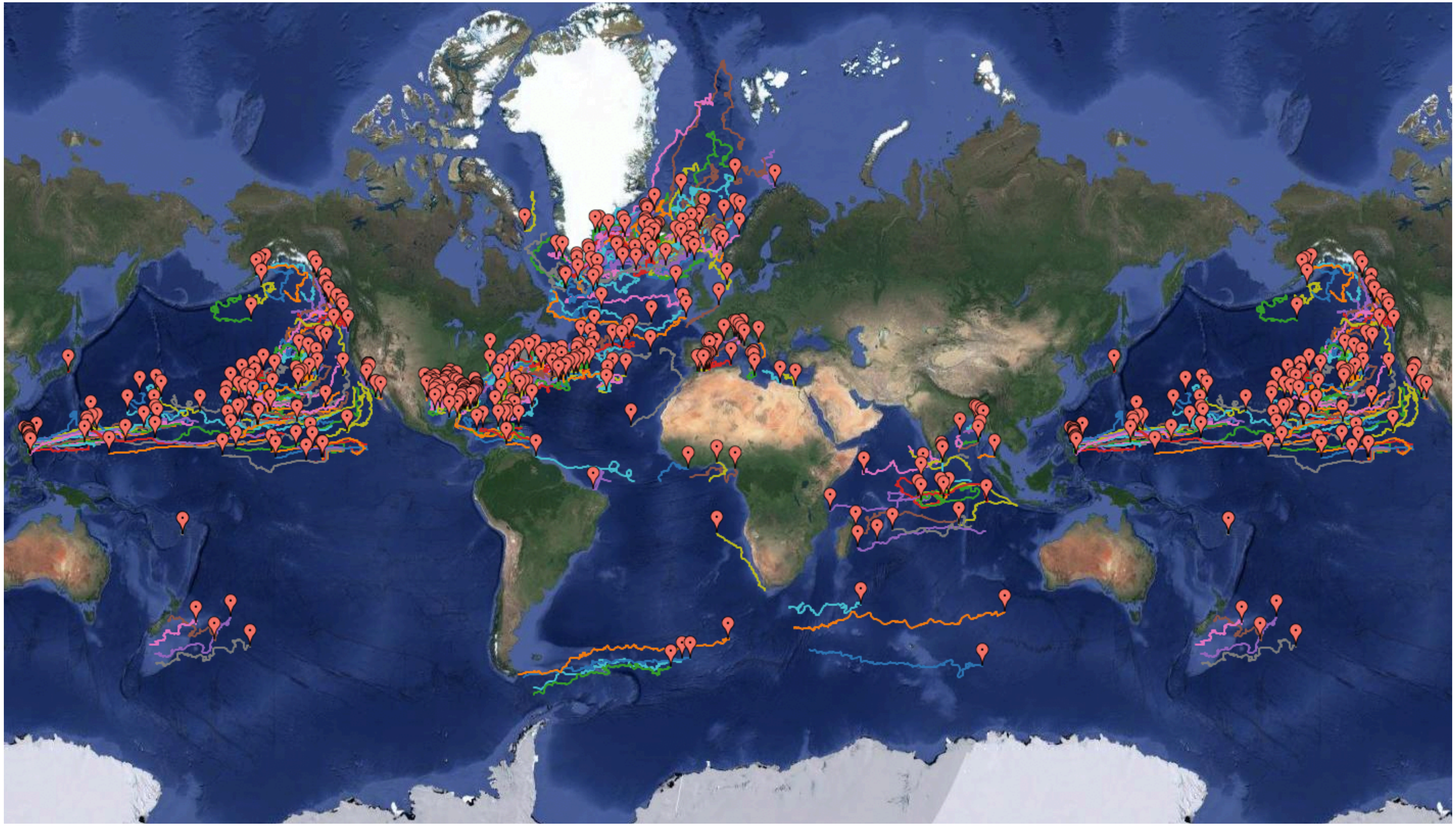
Directional Wave Spectra Drifters Deployed

Trajectories of 430 A/DWS/B Drifters



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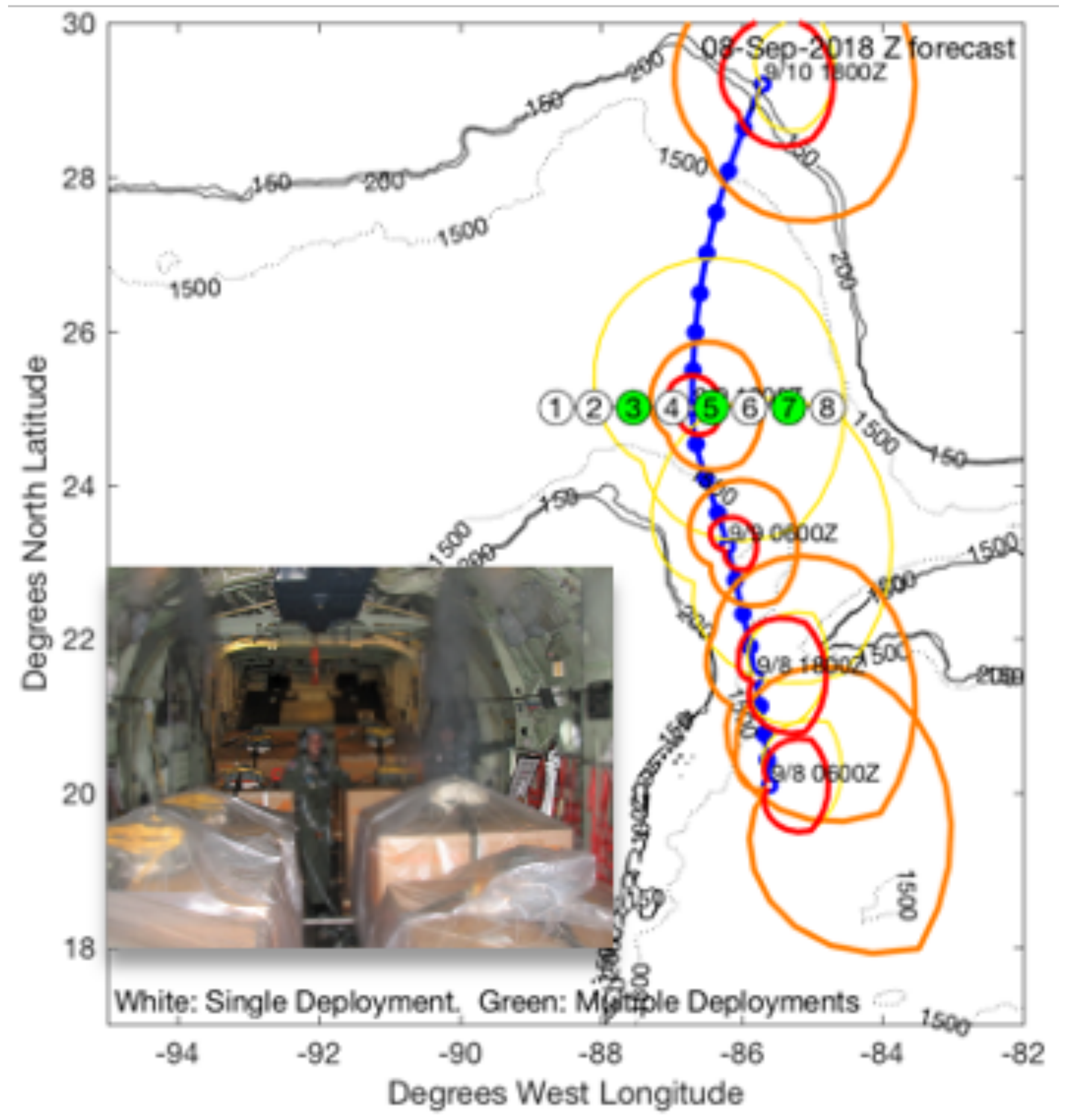
Scientific approach: sustained, adaptive, targeted

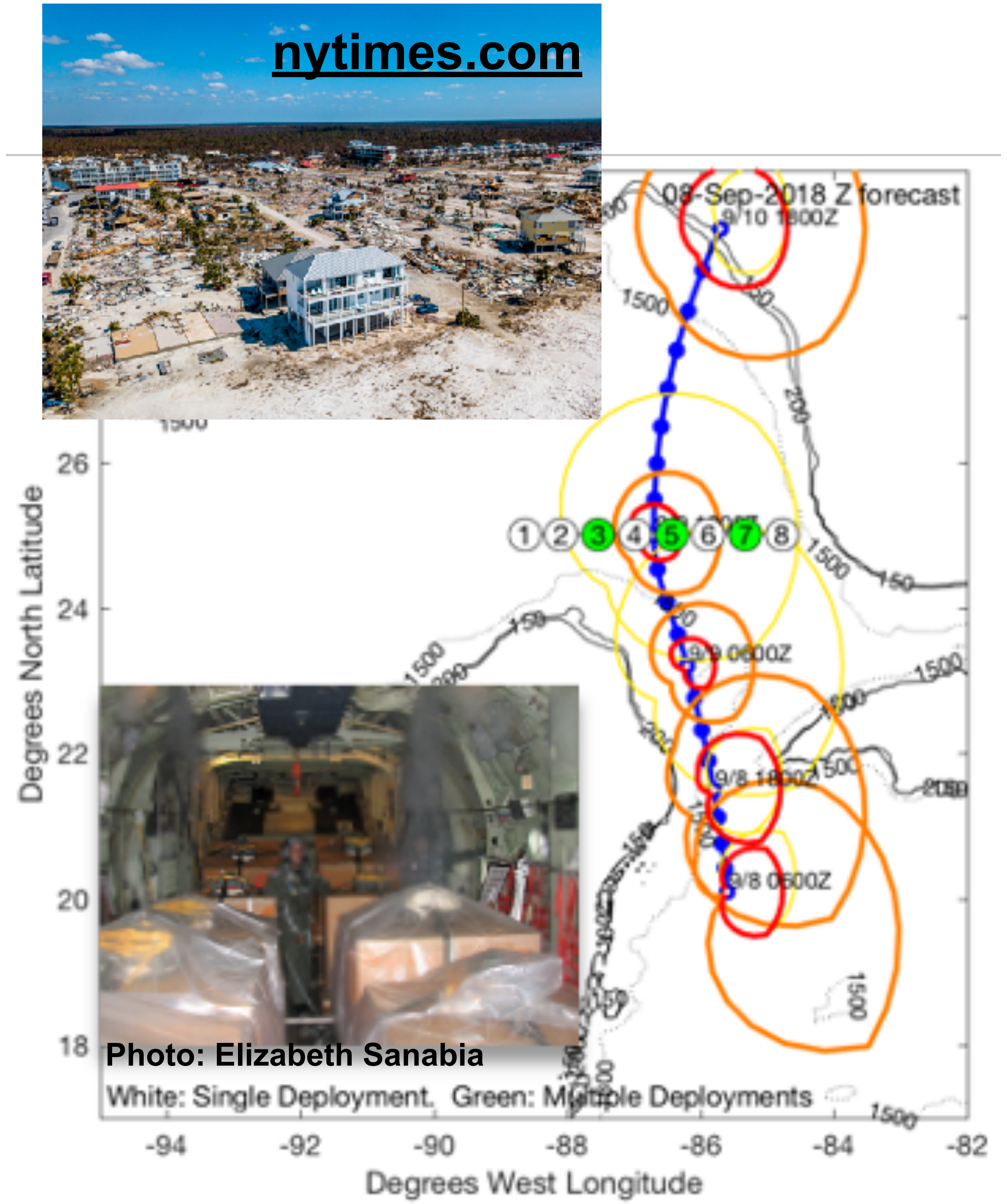


First hurricane air-deployment of GDP wave buoys ever. See NOAA research news: (2018) https://research.noaa.gov/article/ArtMID/587/ArticleID/2388/Drifting-buoys-track-Hurricane-Michael-in-the-Gulf-of-Mexico

- **LDL Drifters/SVP Family: Reliable, cost-effective, accessible data, near-real time, FAIR-O**
- **Adaptive and targeted wave observations**
- **Sustained deep-water wave observations**

Test deployment: A-Size Drifters by AOC NOAA P-3

Hurricane Wave Observations: Hurricane Michael (2018)



First hurricane air-deployment of GDP wave buoys ever. See NOAA research news: https://research.noaa.gov/article/ArtMID/587/ArticleID/2388/Drifting-buoys-track-Hurricane-Michael-in-the-Gulf-of-Mexico

Schönau et al., in prep

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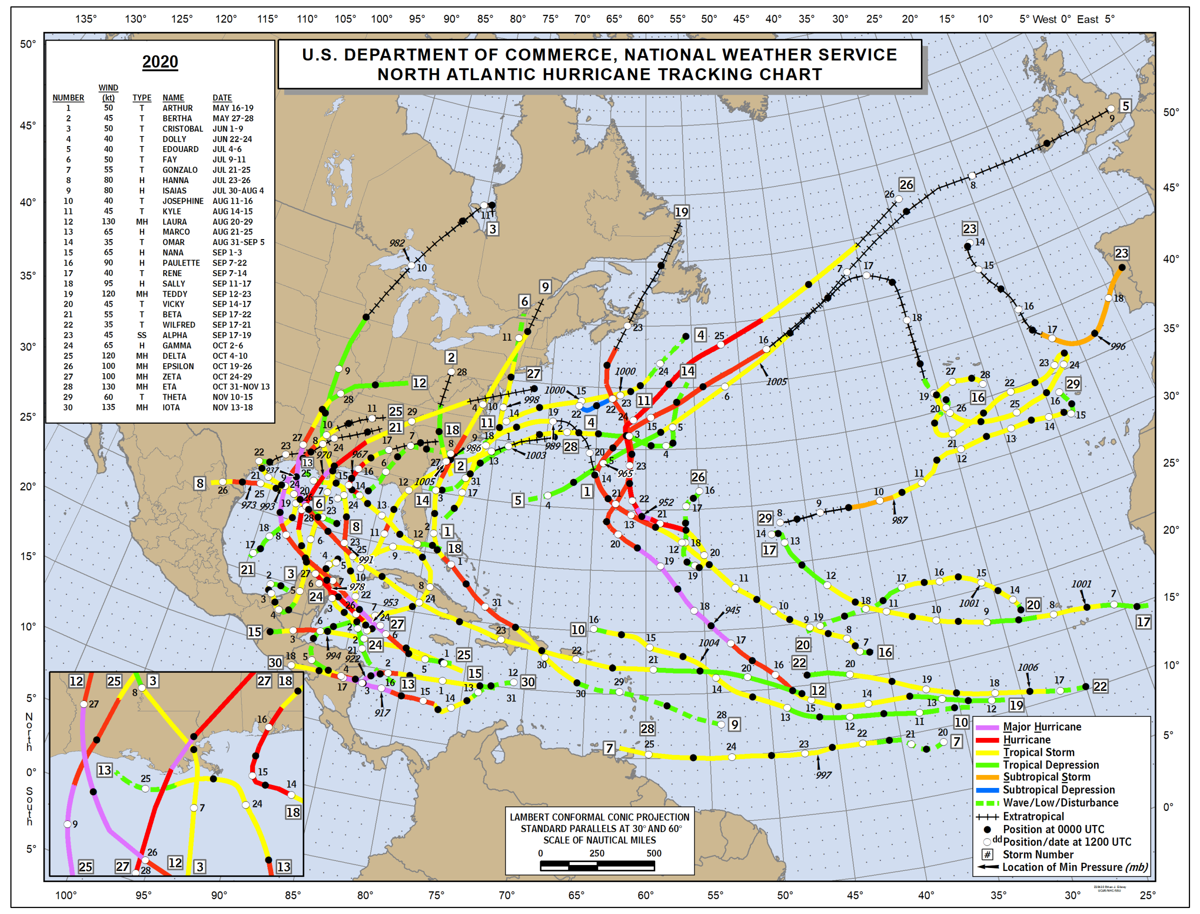
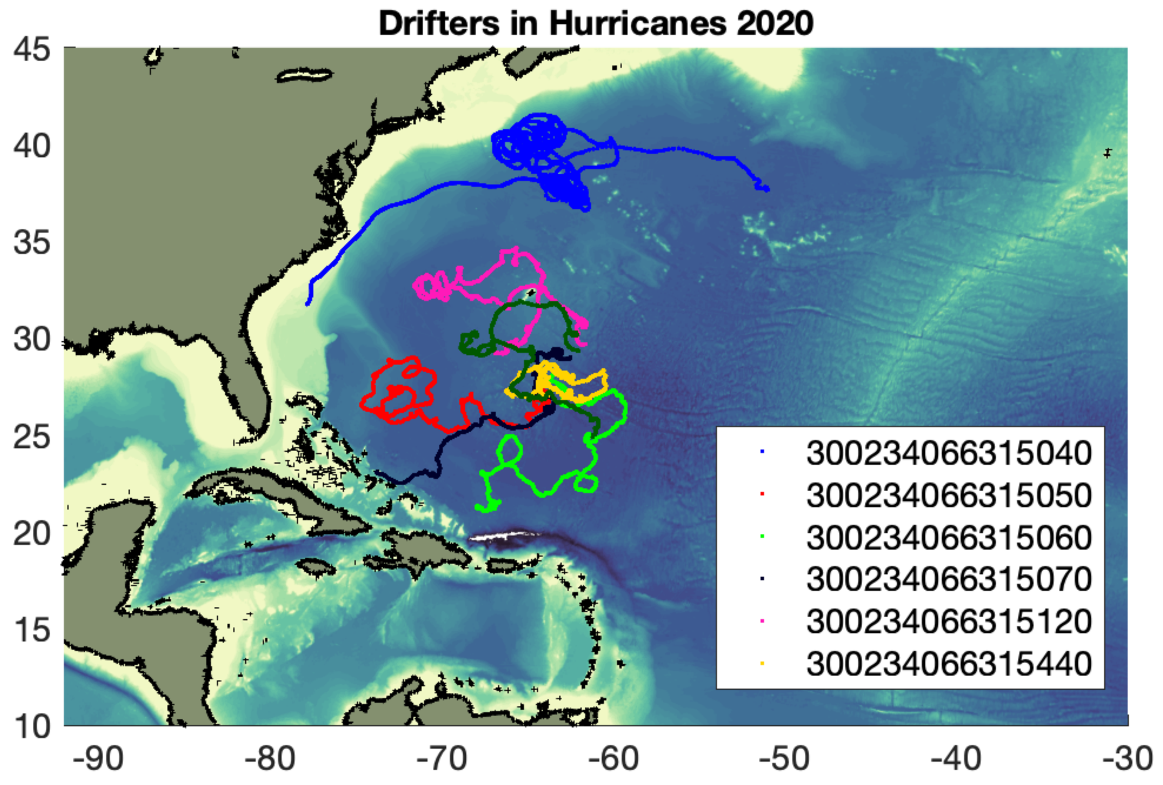
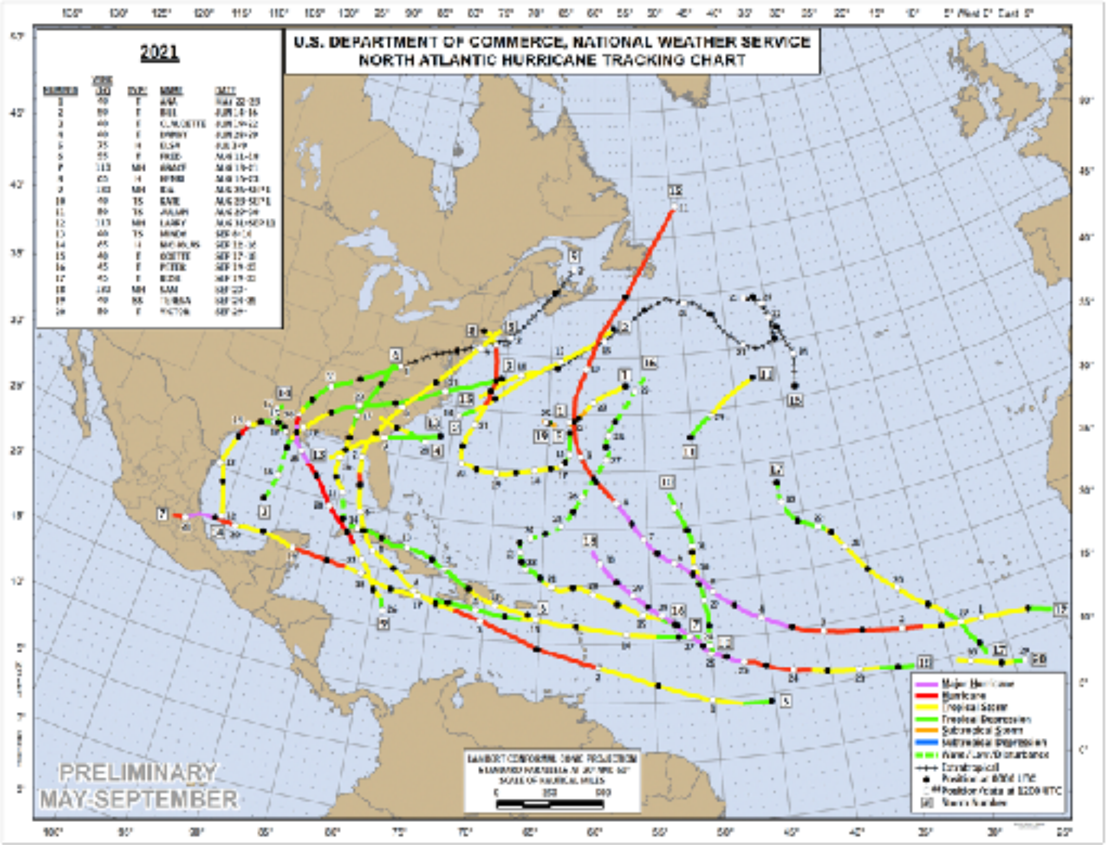
Building out an array of observations

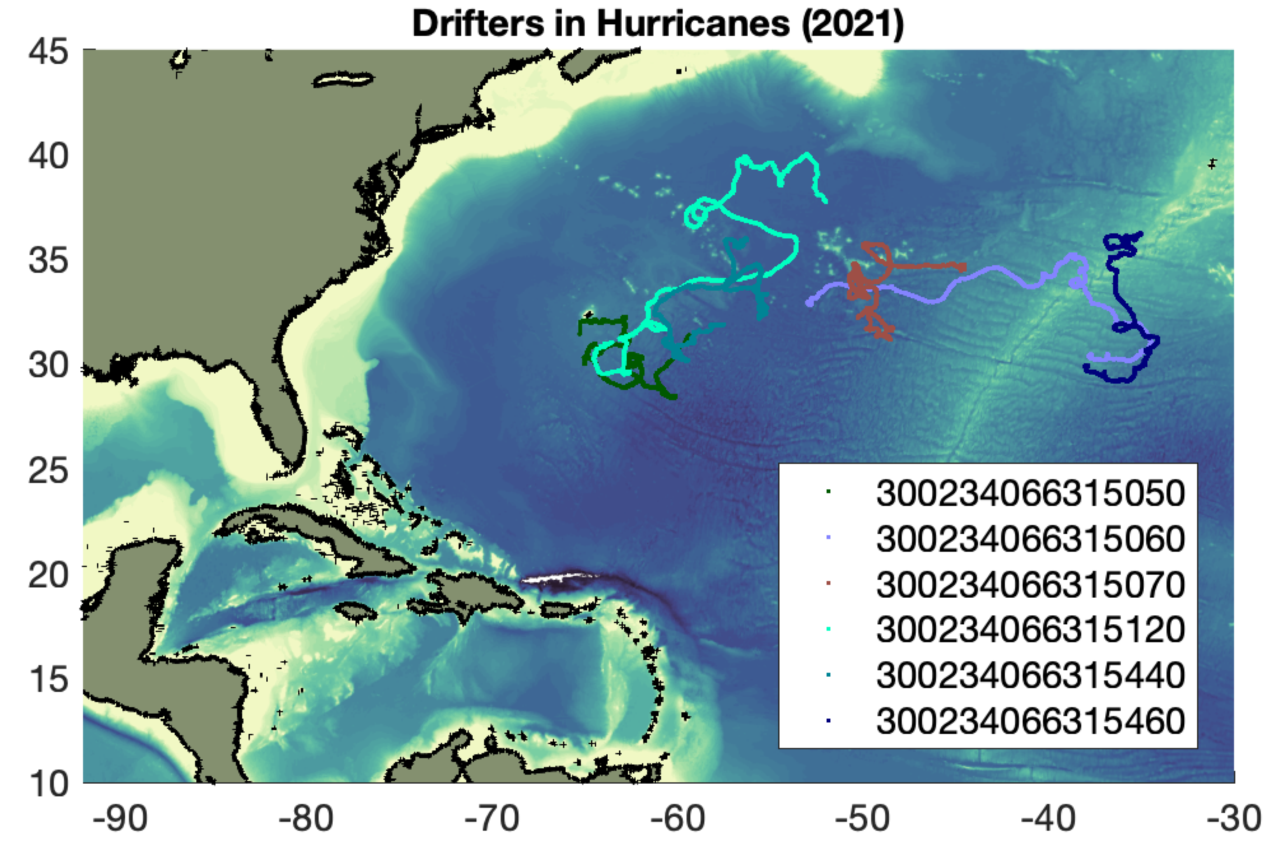
2020 Hurricane Season

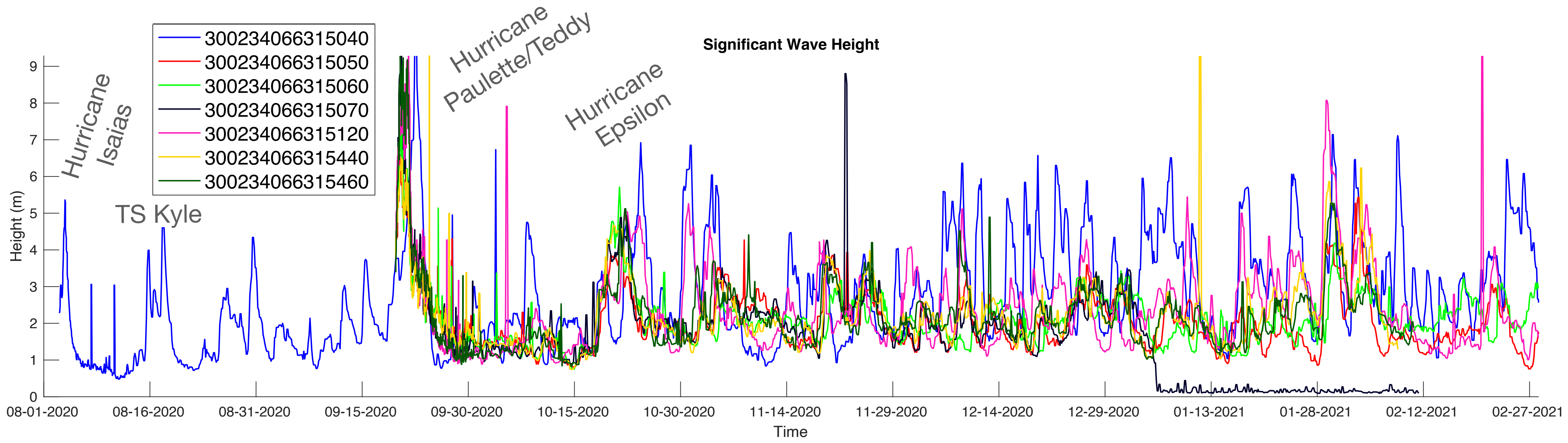


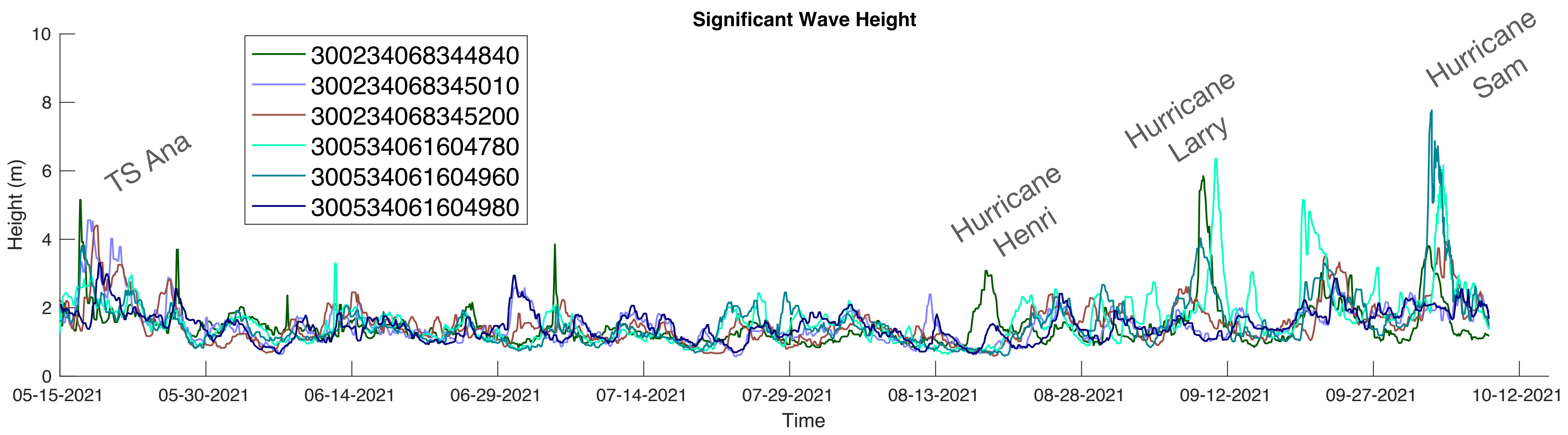


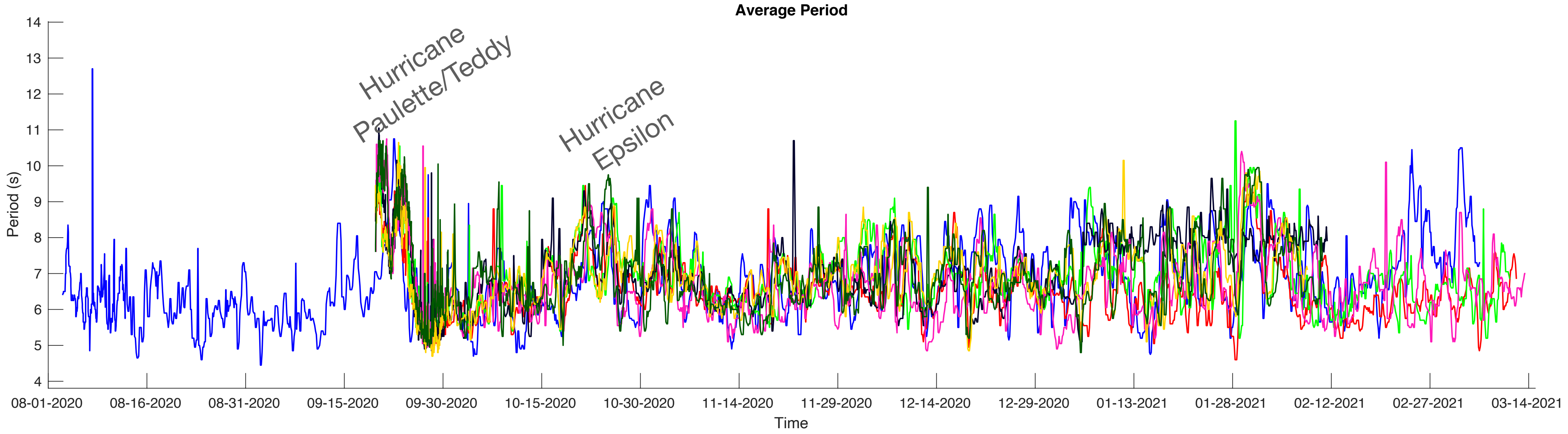
2021 Hurricane Season

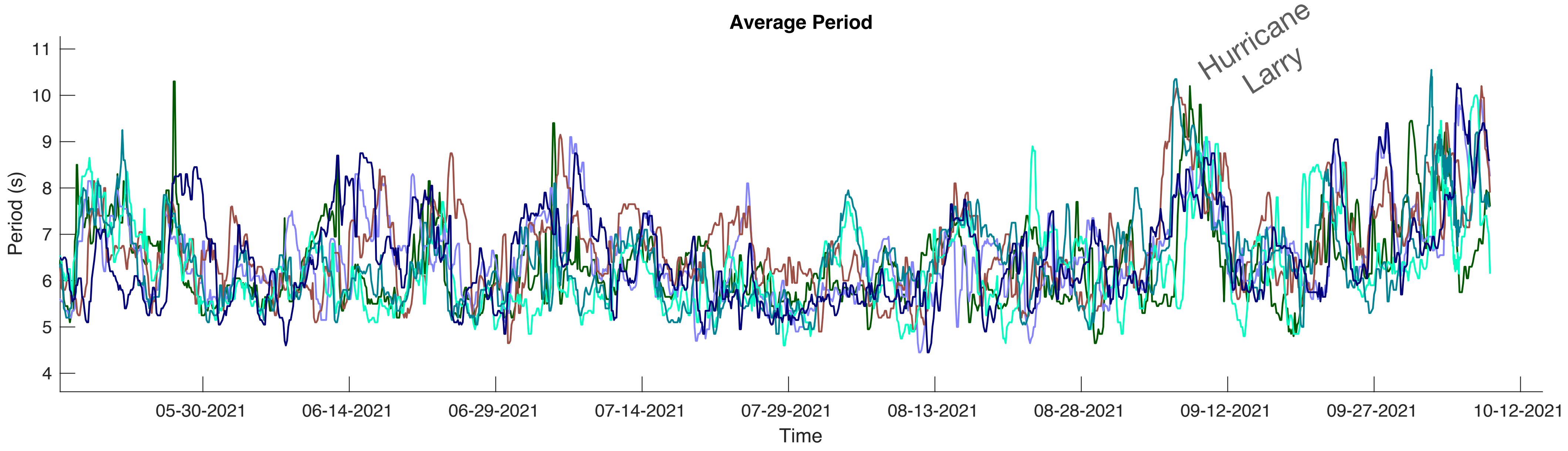












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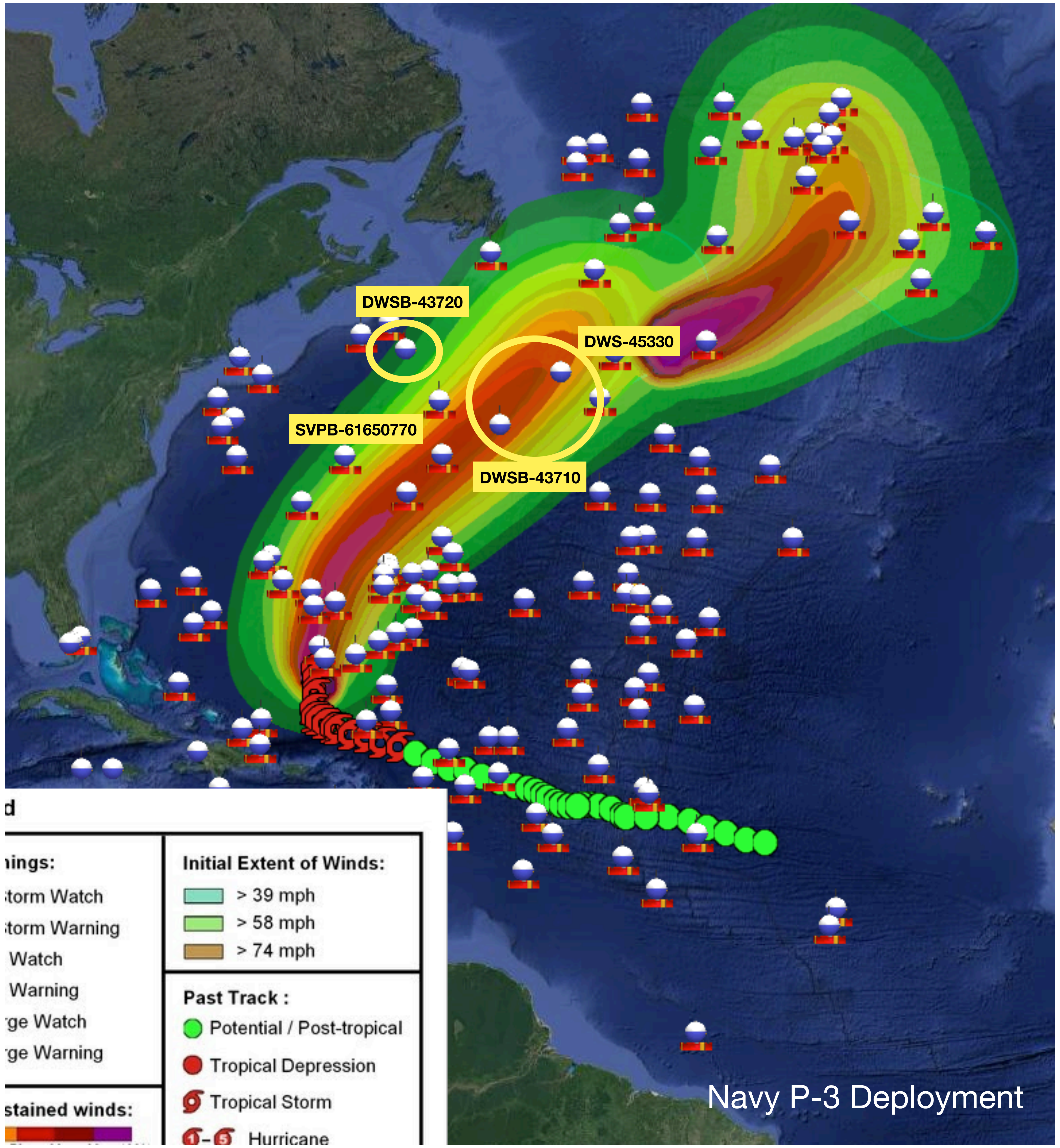
September 4-12, 2022

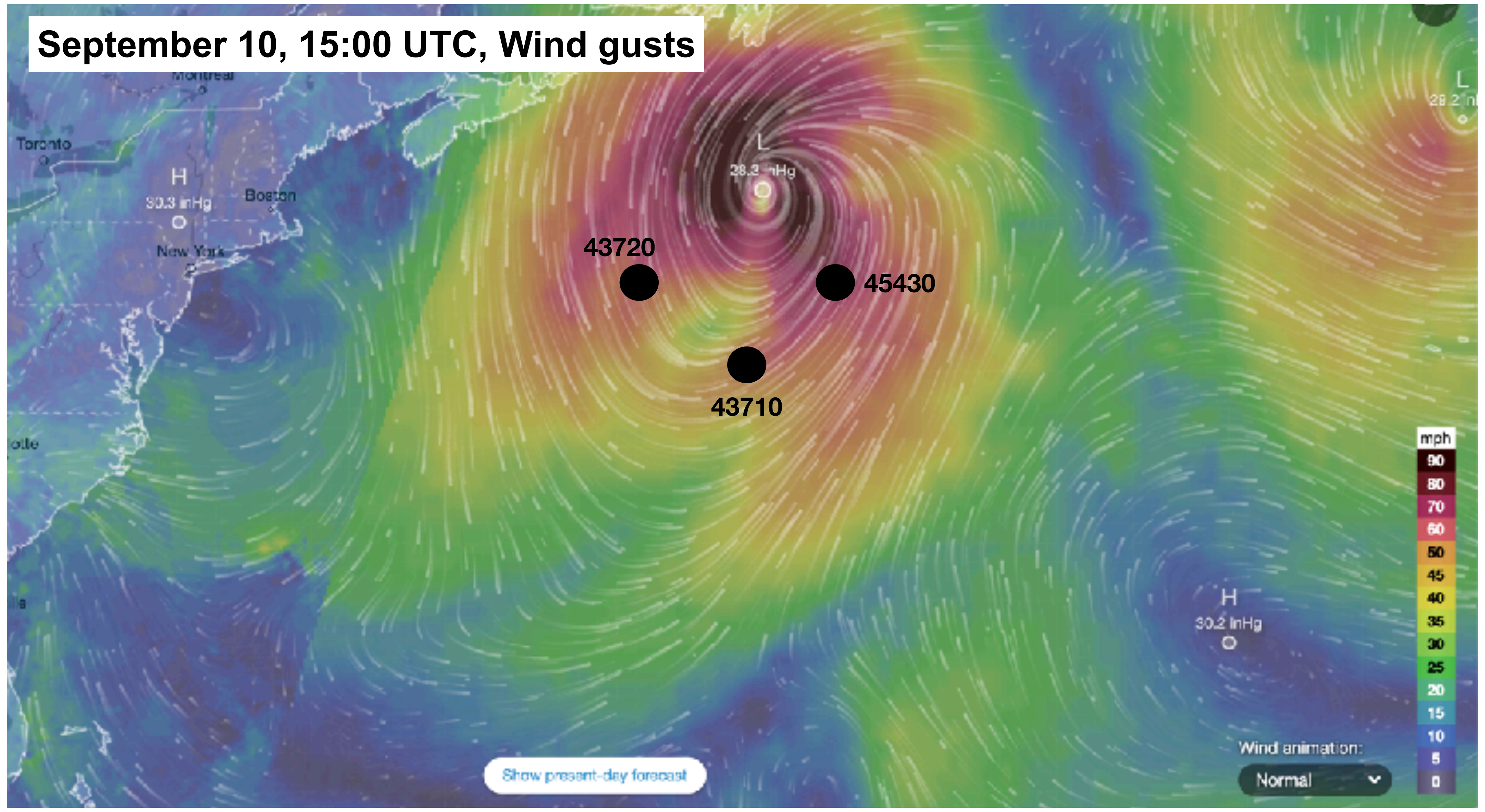
Hurricane Earl: SLP, wave magnitude and direction

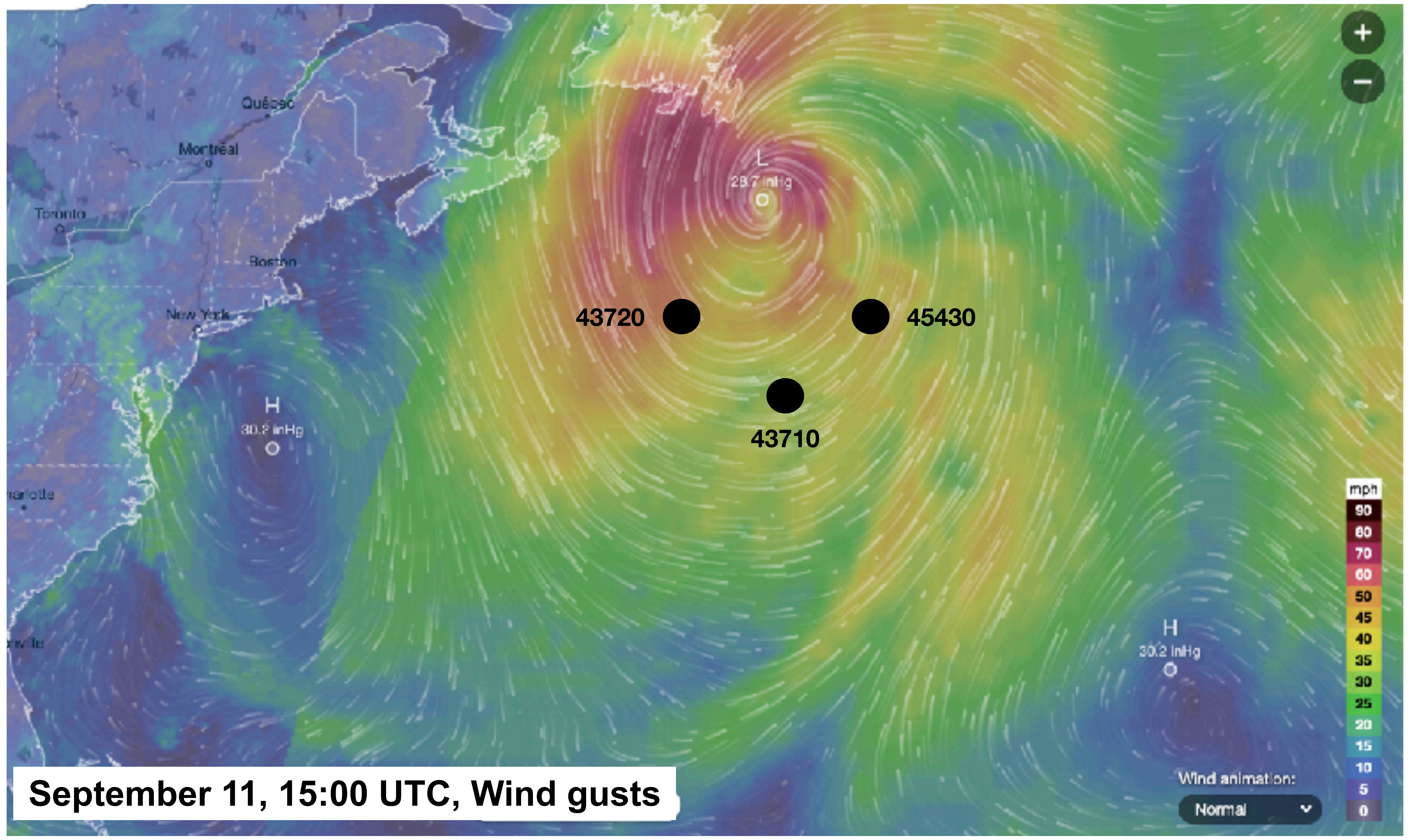


Sea level pressure: DWSBD 300234068943720

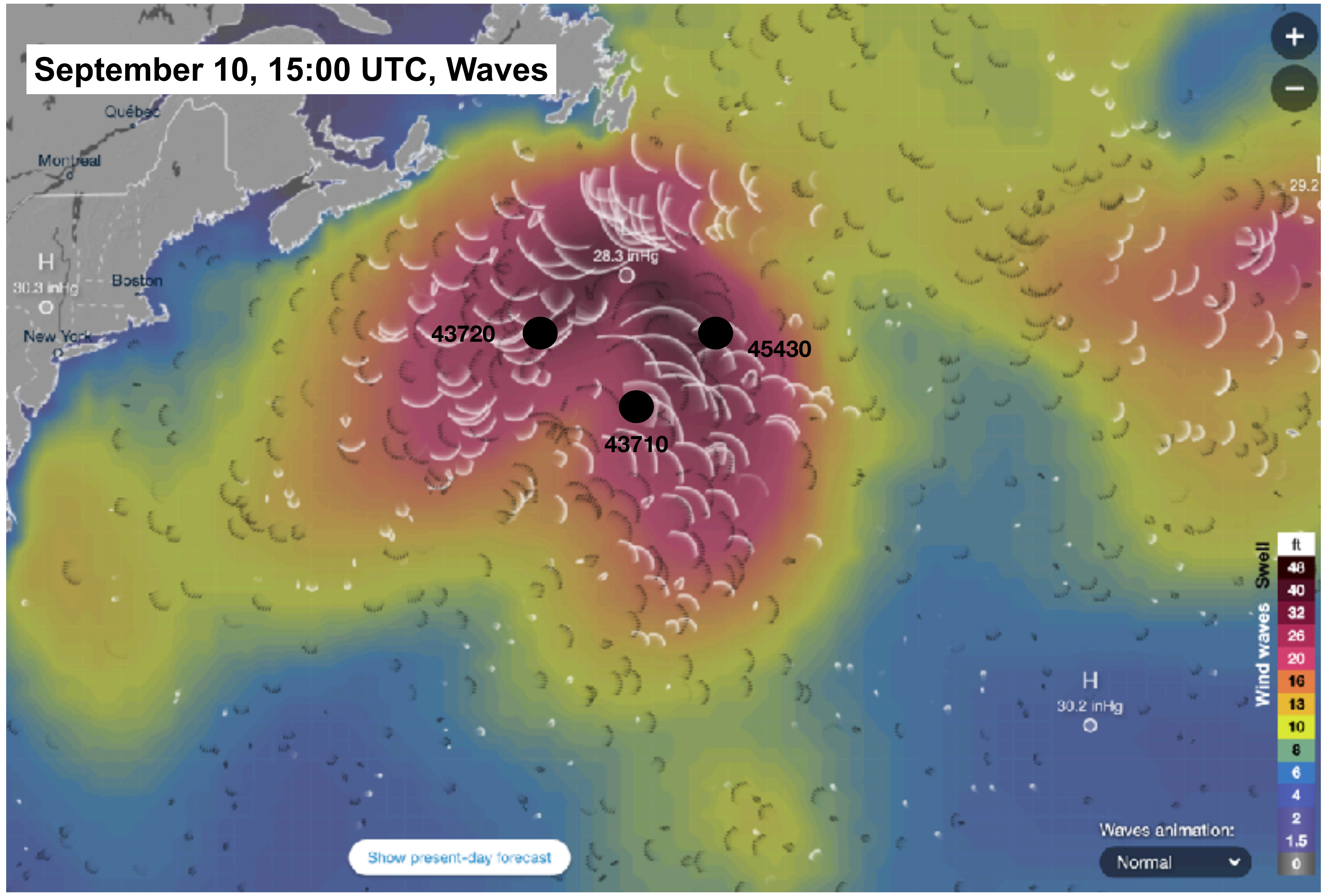
Sea level pressure: DWSBD 300234068943710

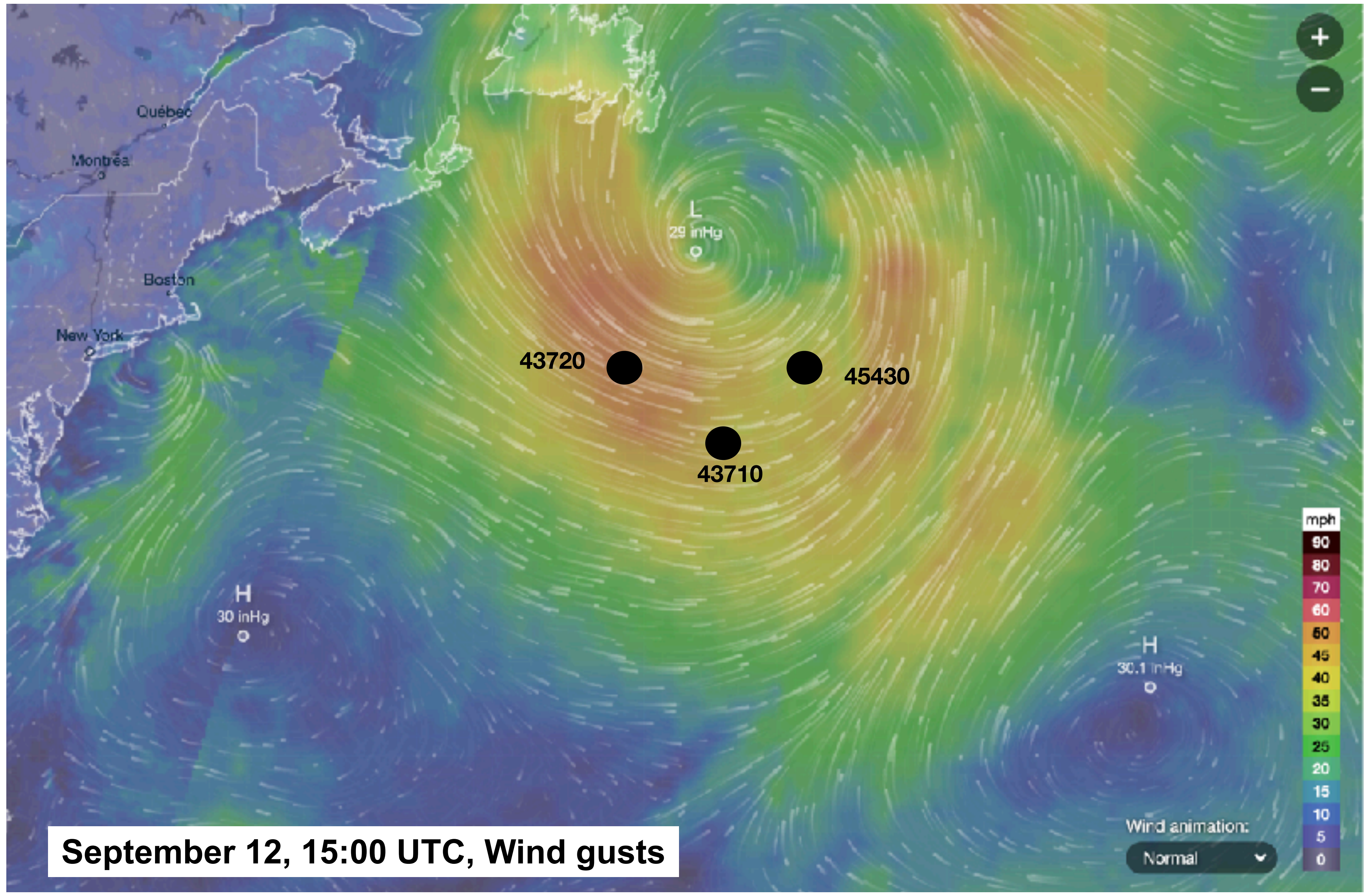
Sea level pressure: SVP-B 300534061650770 ***Note different timestamps**





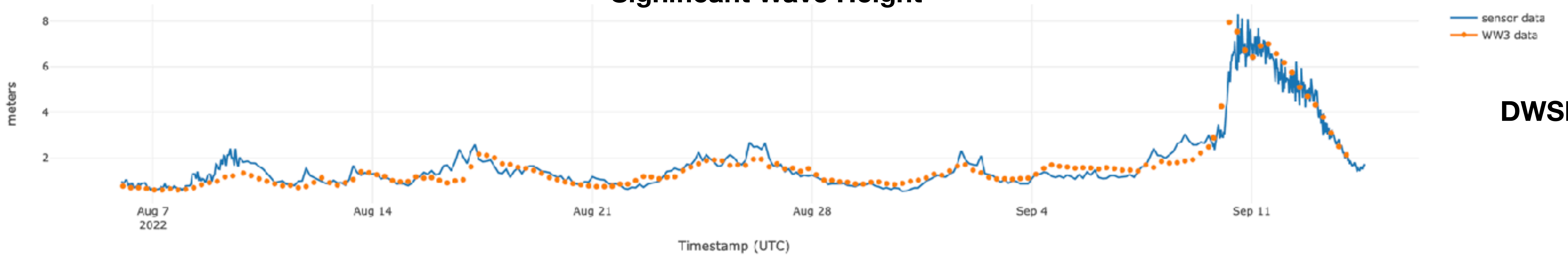
Black dots are rough locations of drifters





Maps from https://www.ventusky.com/

Significant Wave Height



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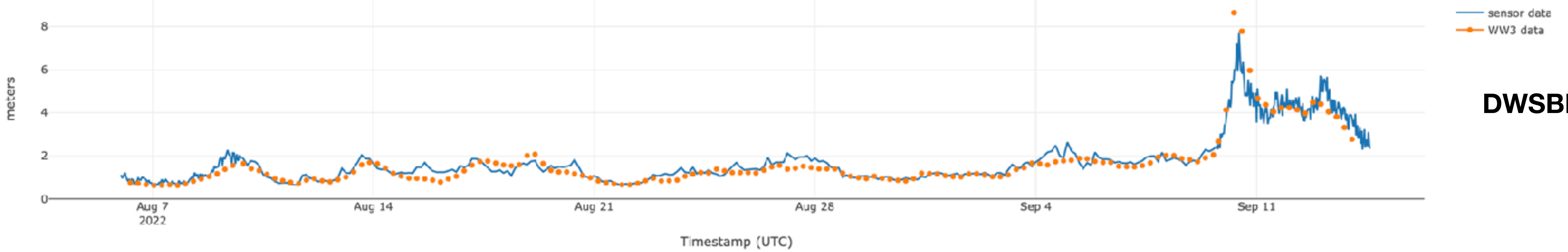
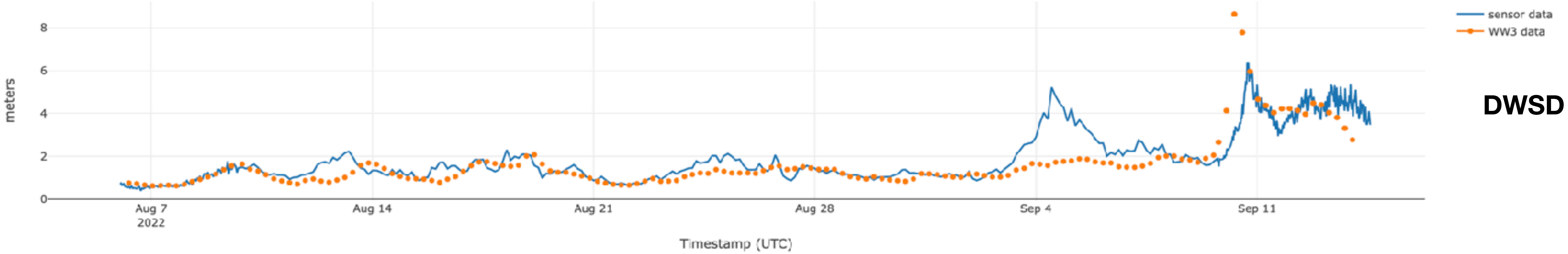
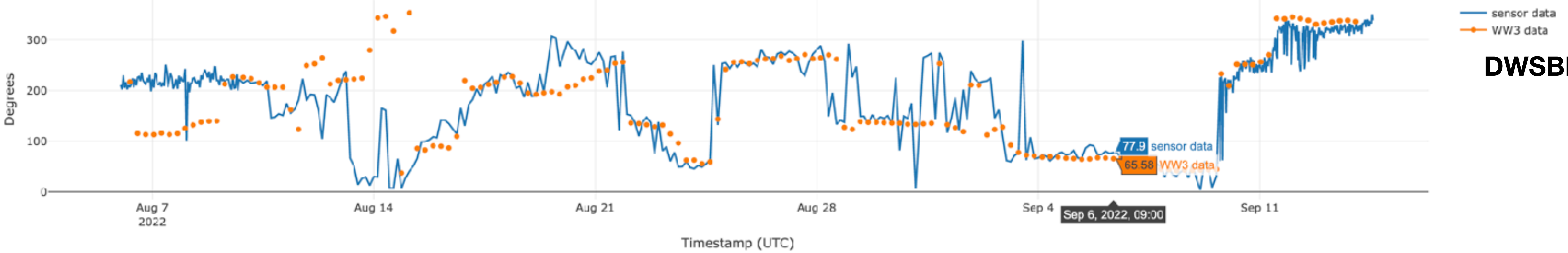


DWSBD 300234068943710



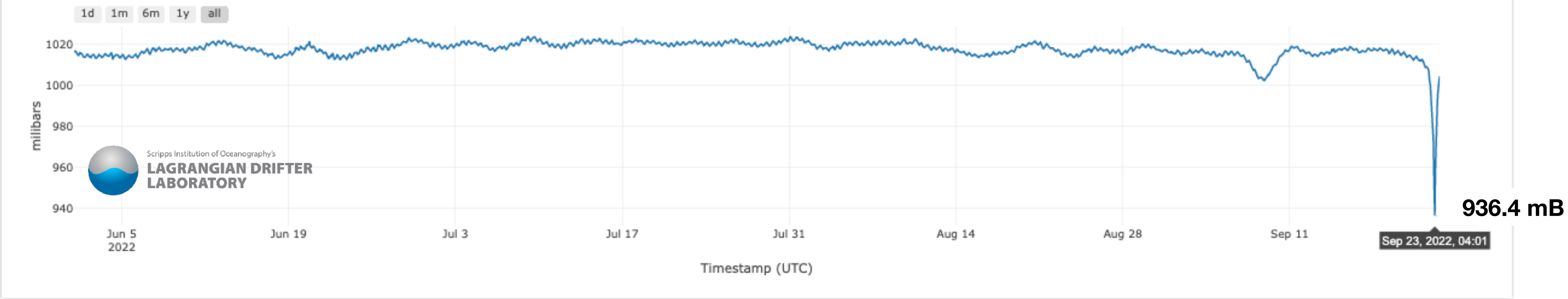
DWSD 30023406845430

Dominant Wave Direction

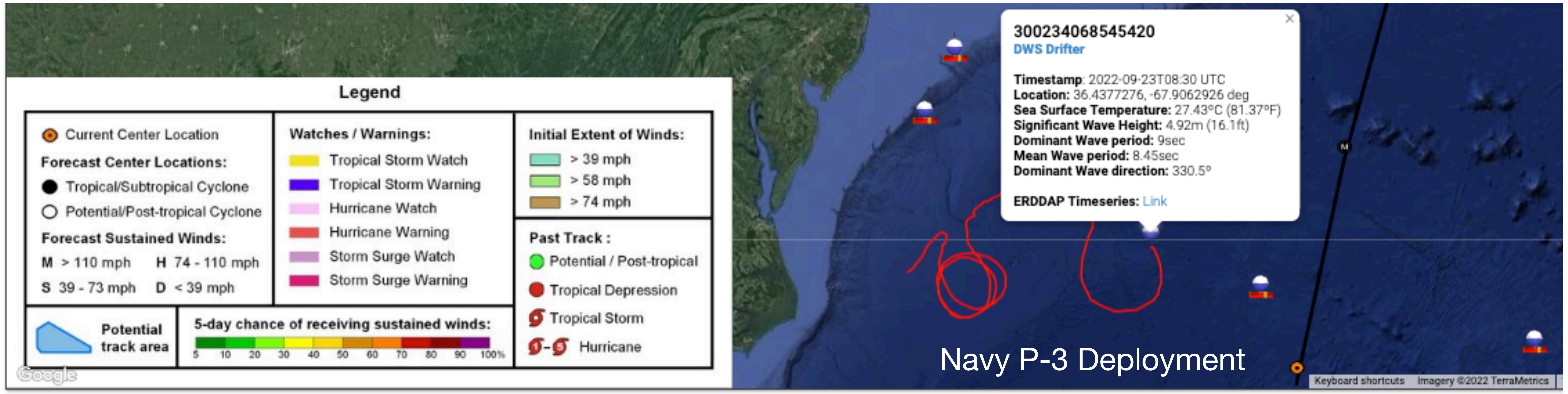


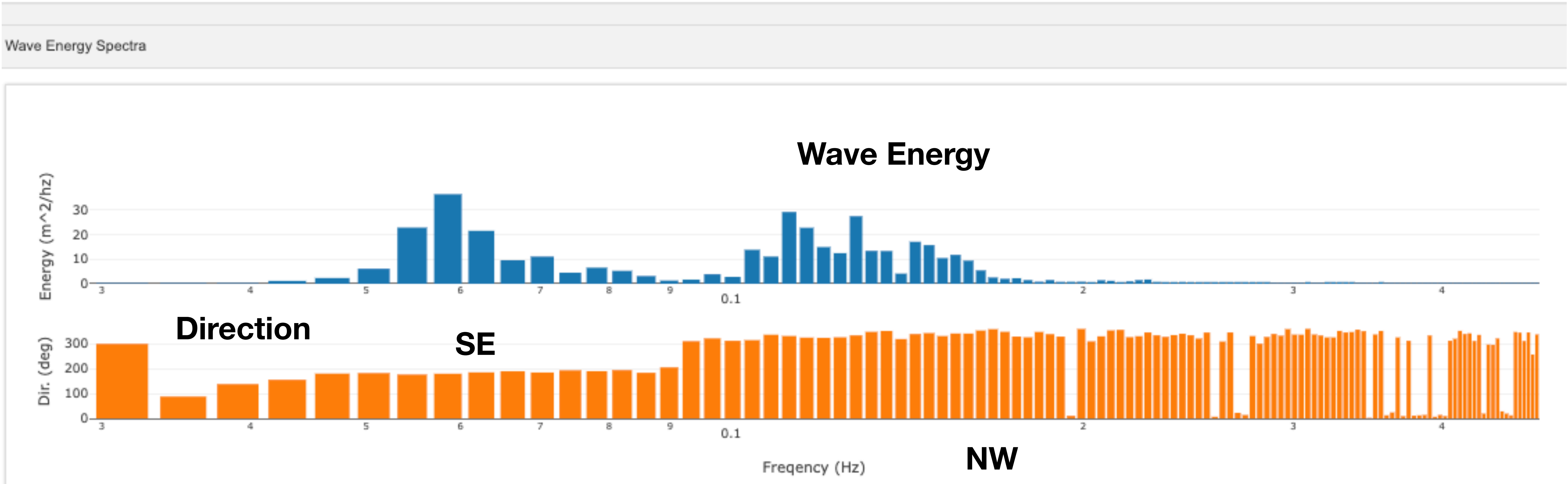
DWSBD 300234068943710

Hurricane Fiona: September 23-30



- SVPB measures Minimum pressure of 936.4 mB under Fiona





- Directional wave spectra inshore of Hurricane Fiona
- Spectra shows wind-sea/swell split

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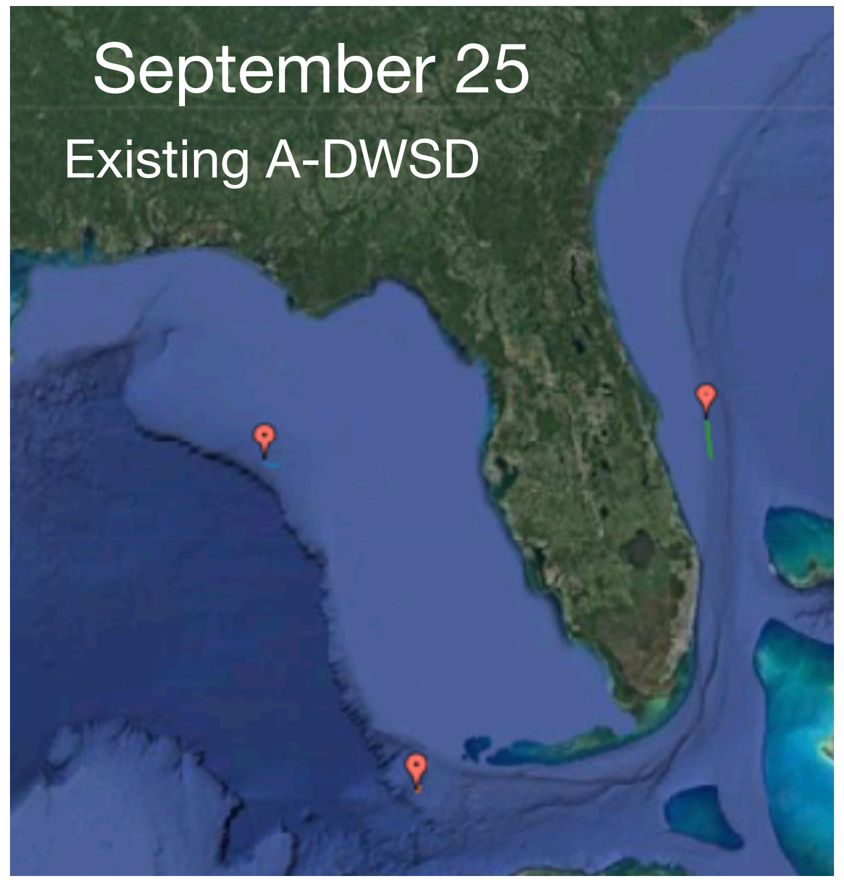
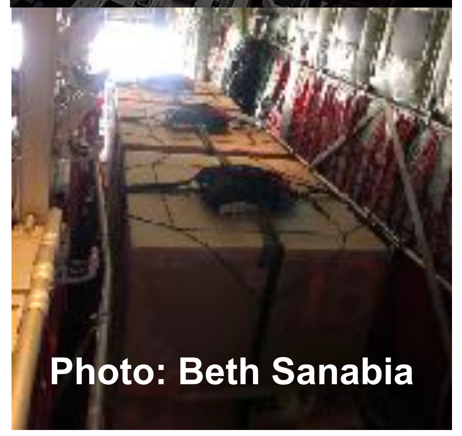
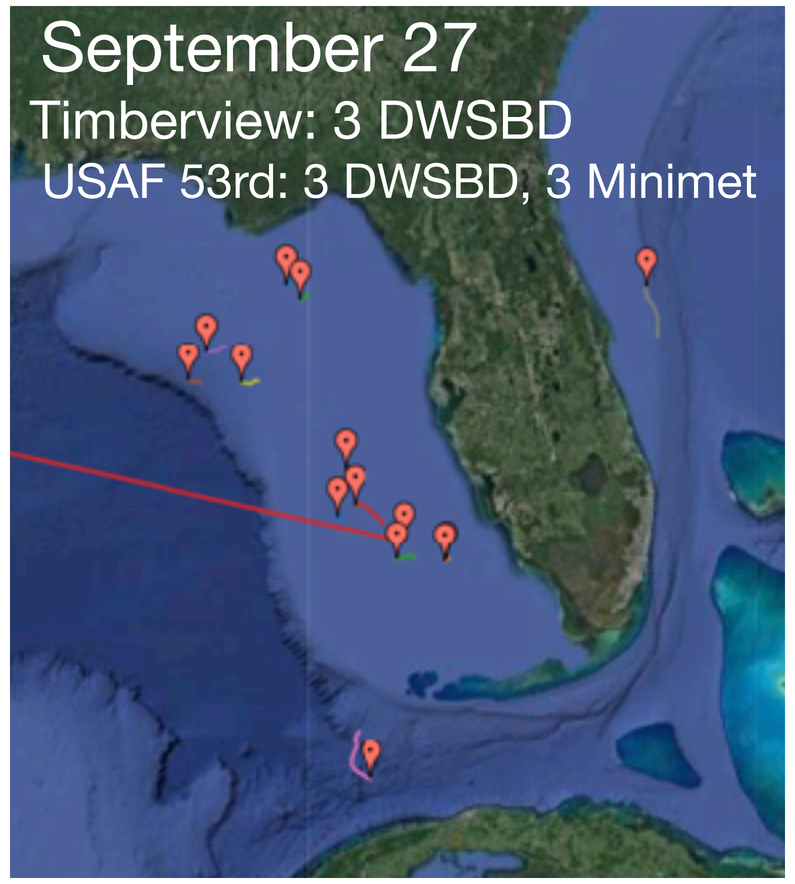
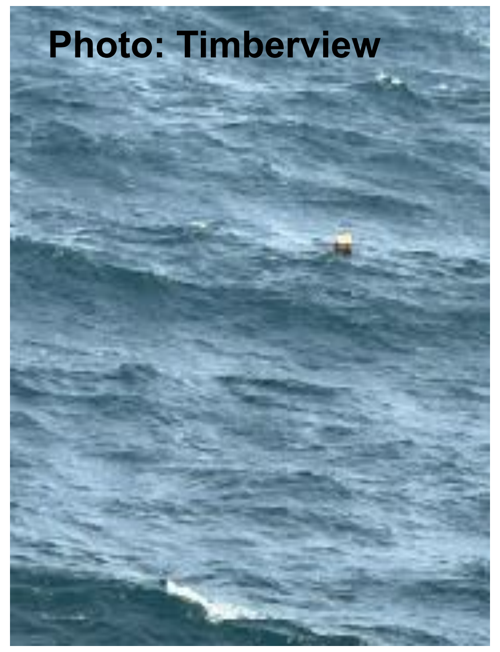
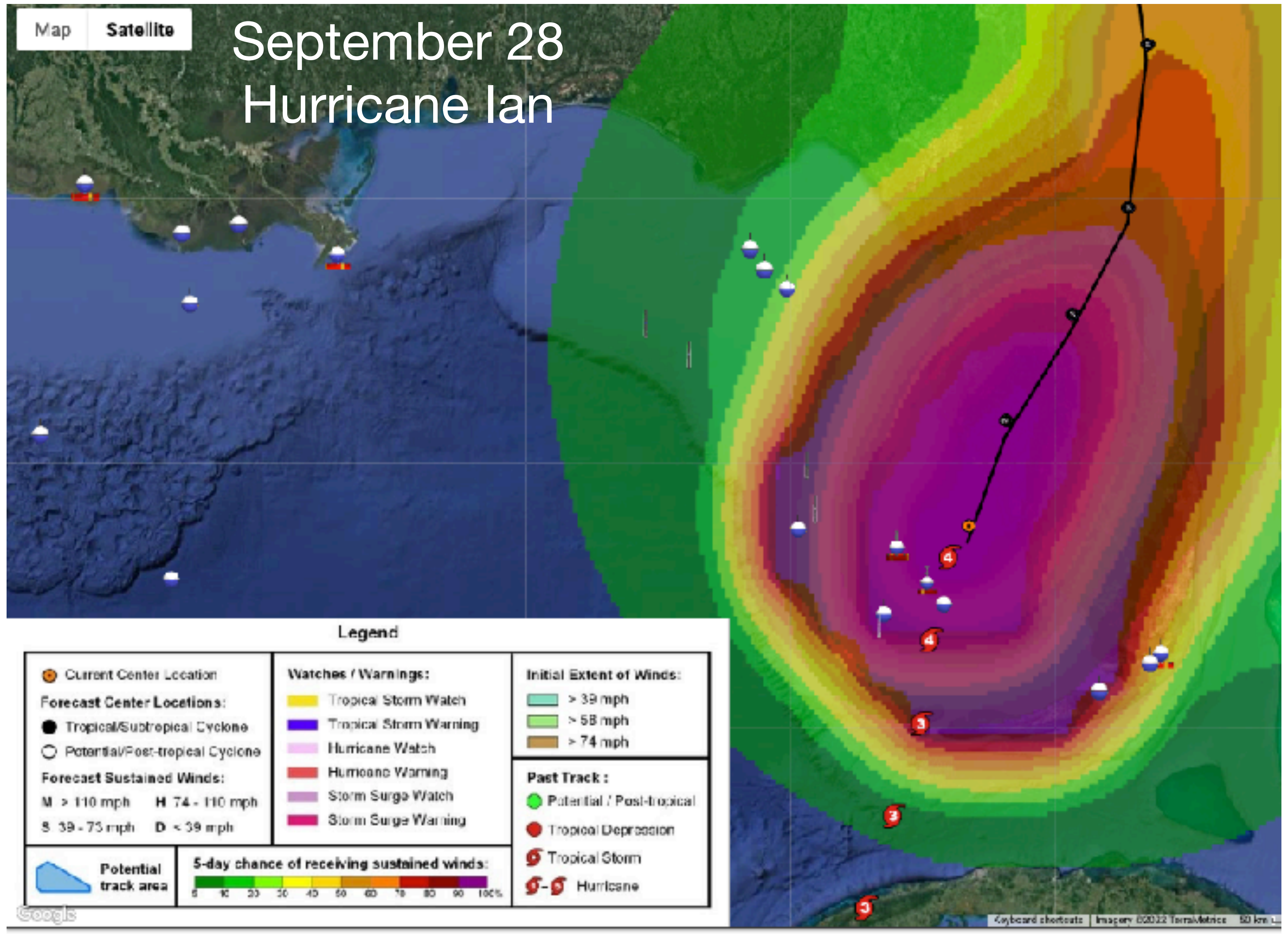
Hurricane Ian: A targeted array (September 25-30)



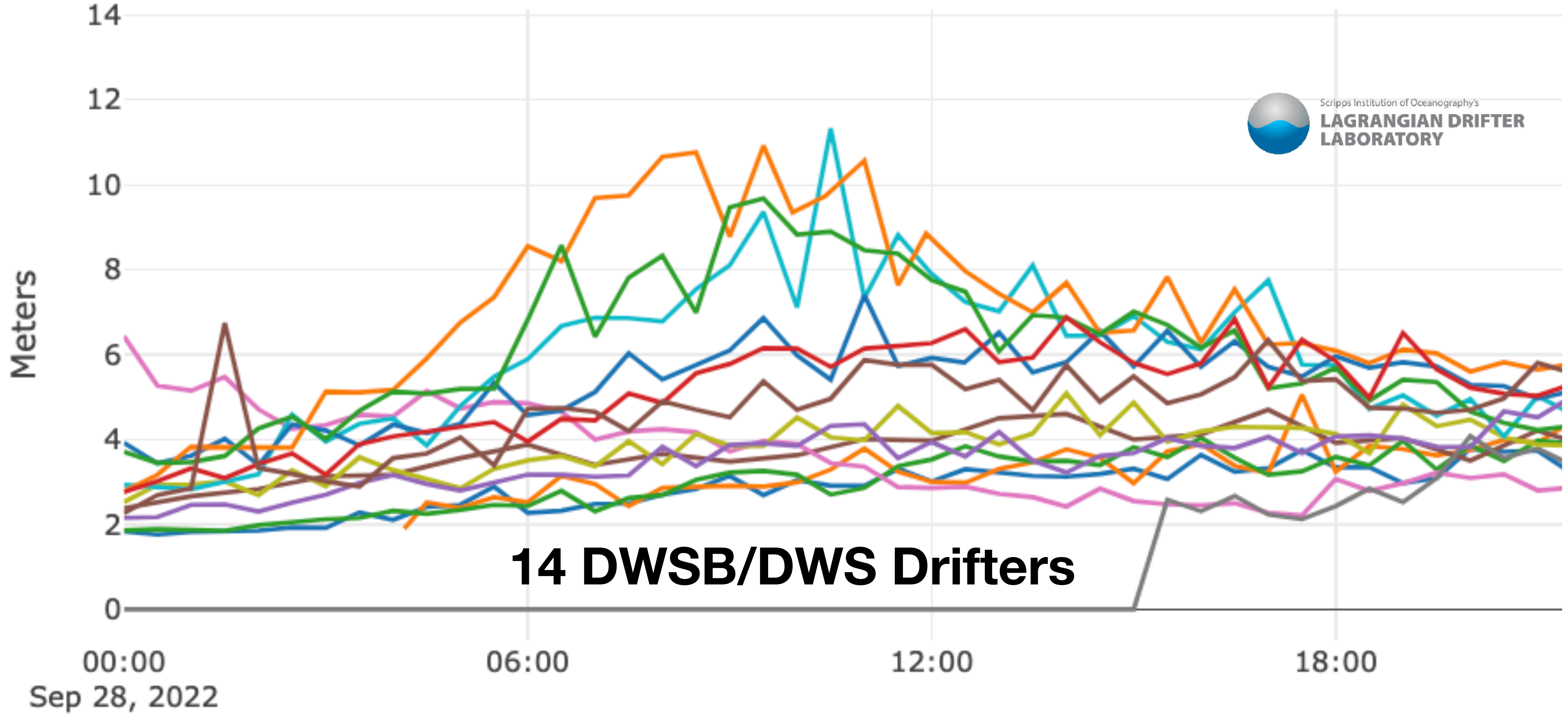








Significant Wave Height across the array on September 28



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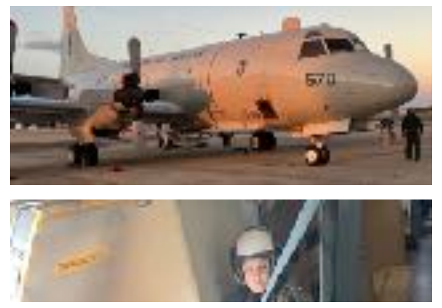
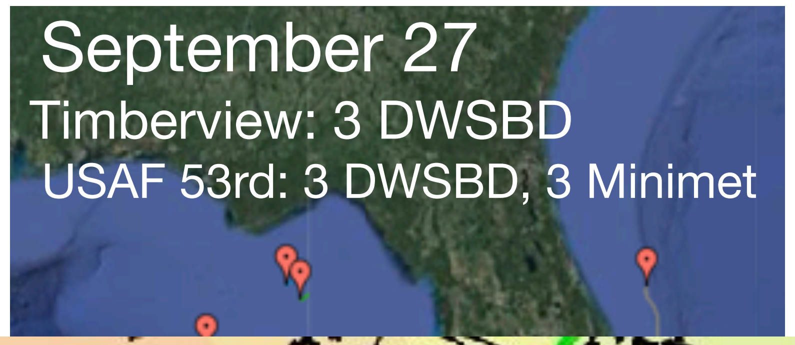
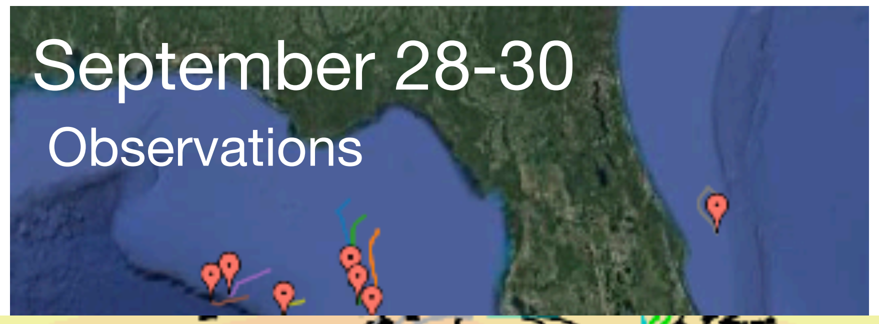
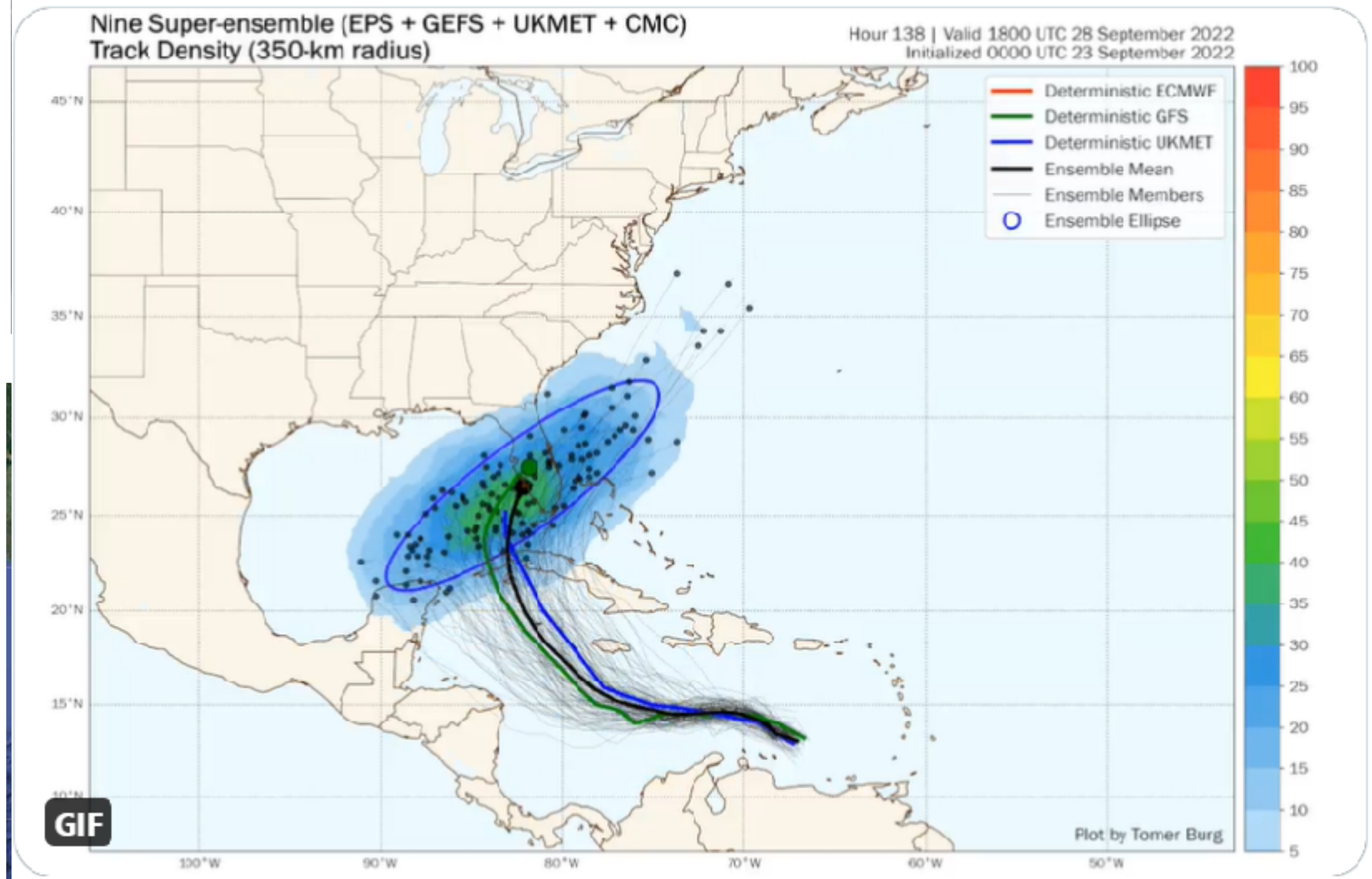
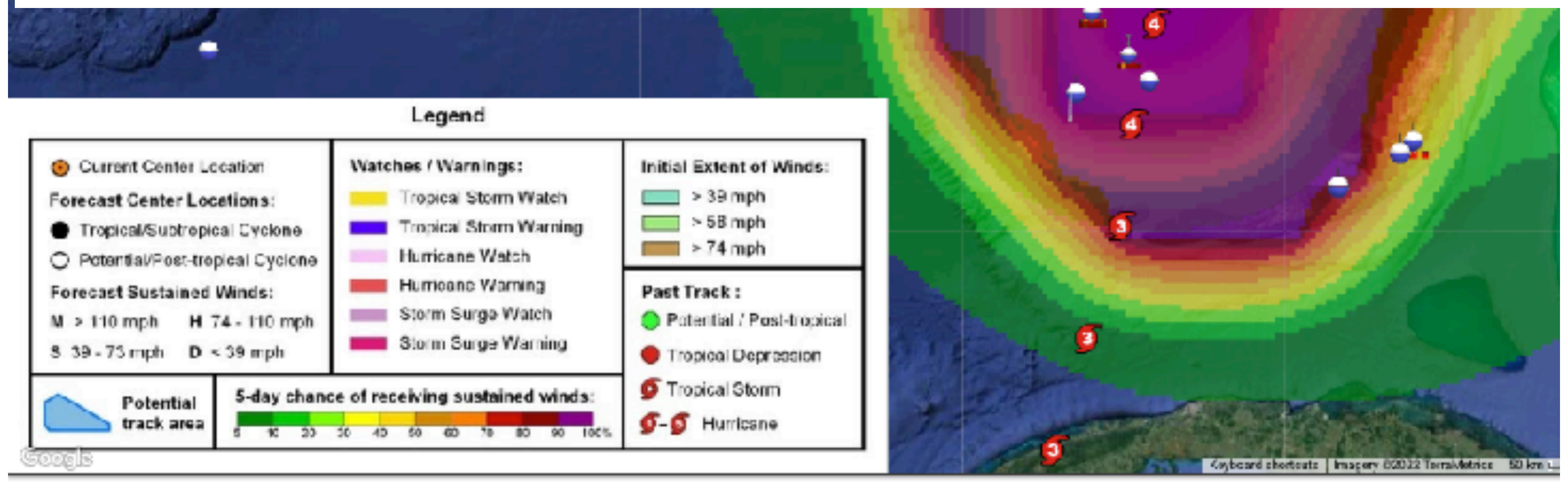
Hurricane Ian: A targeted array (September 25-30)

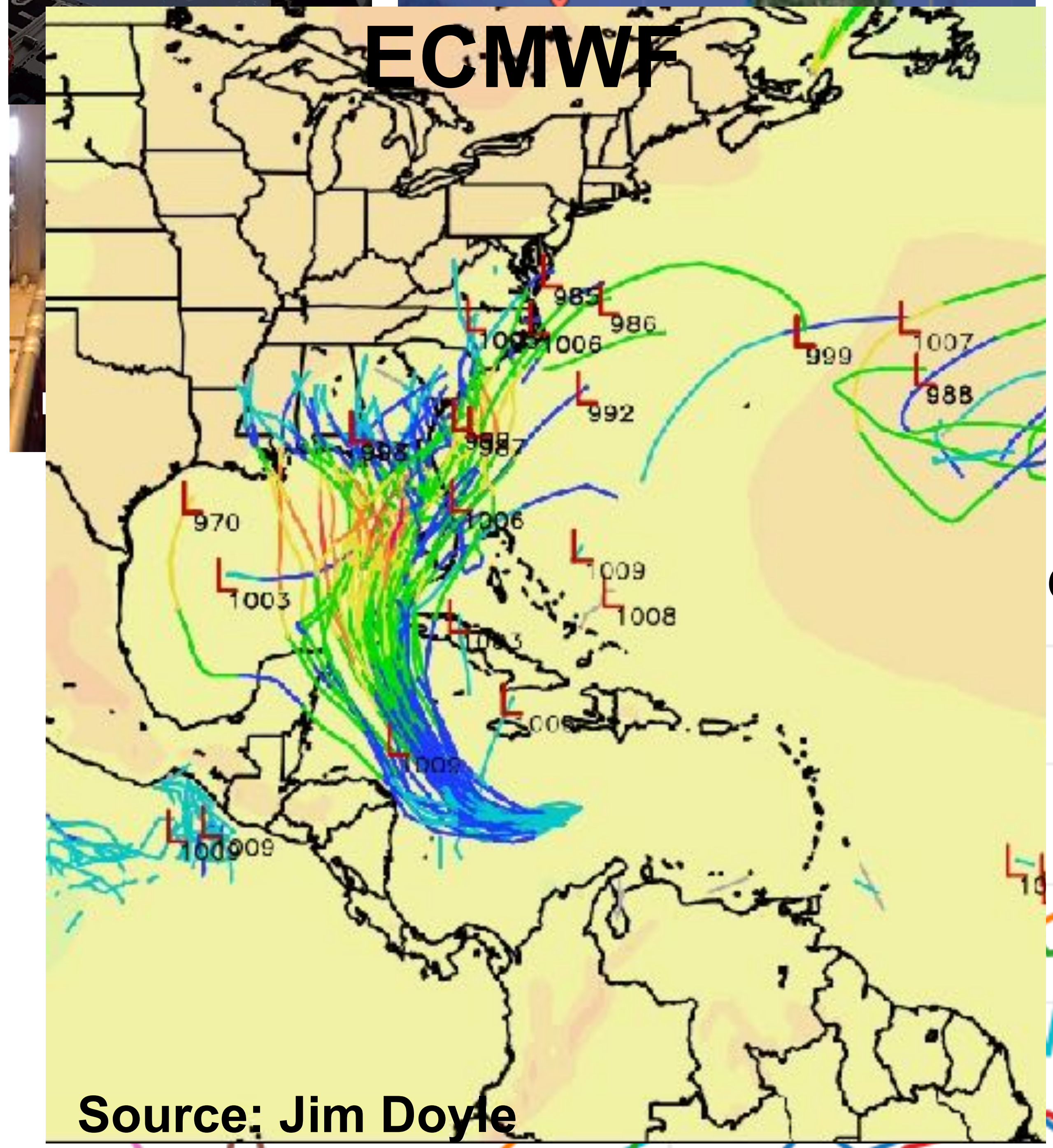


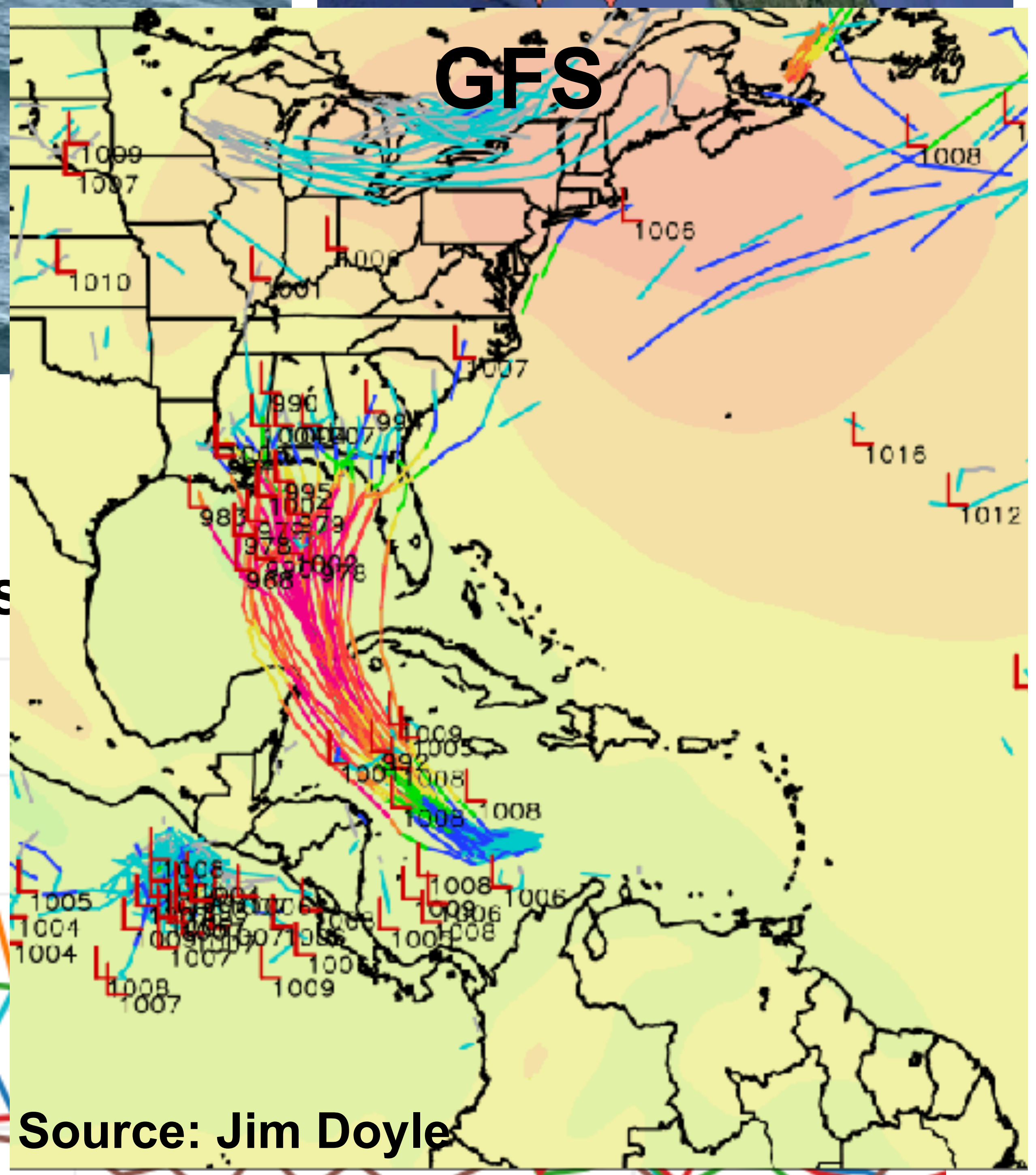


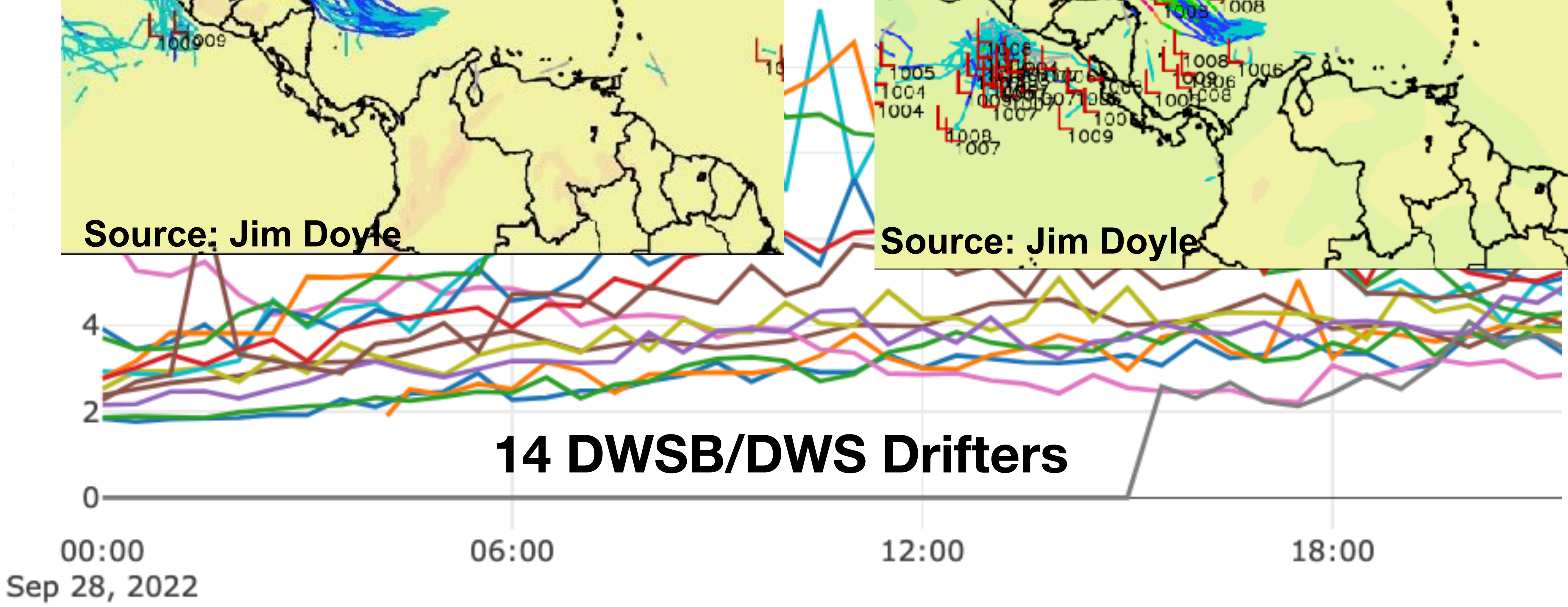




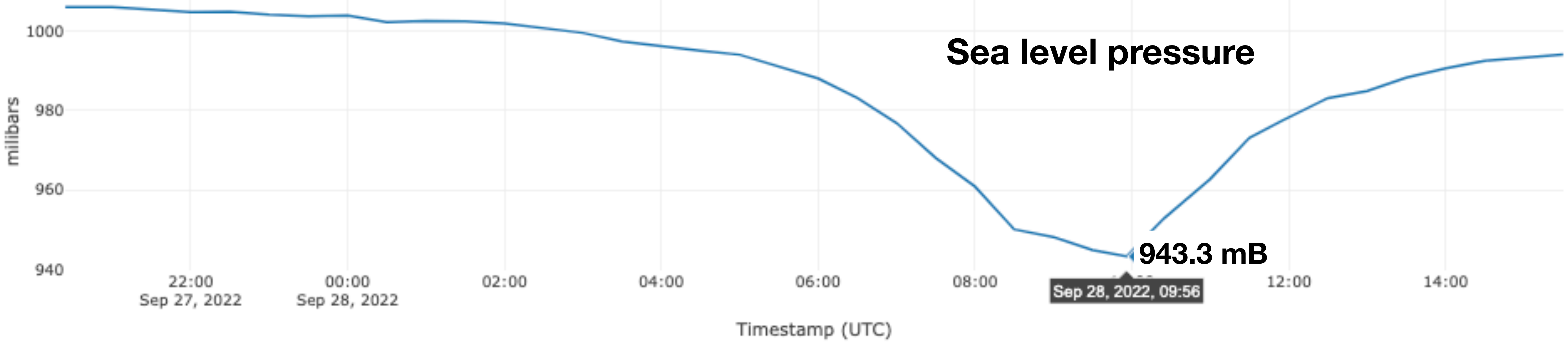


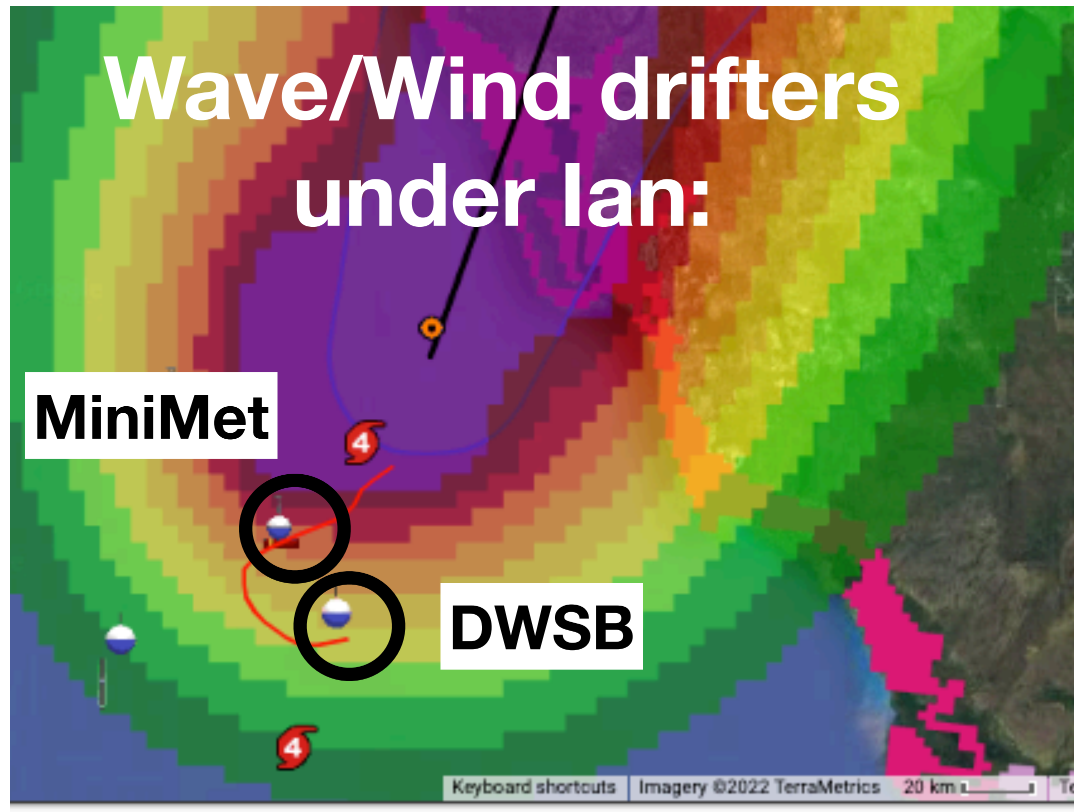


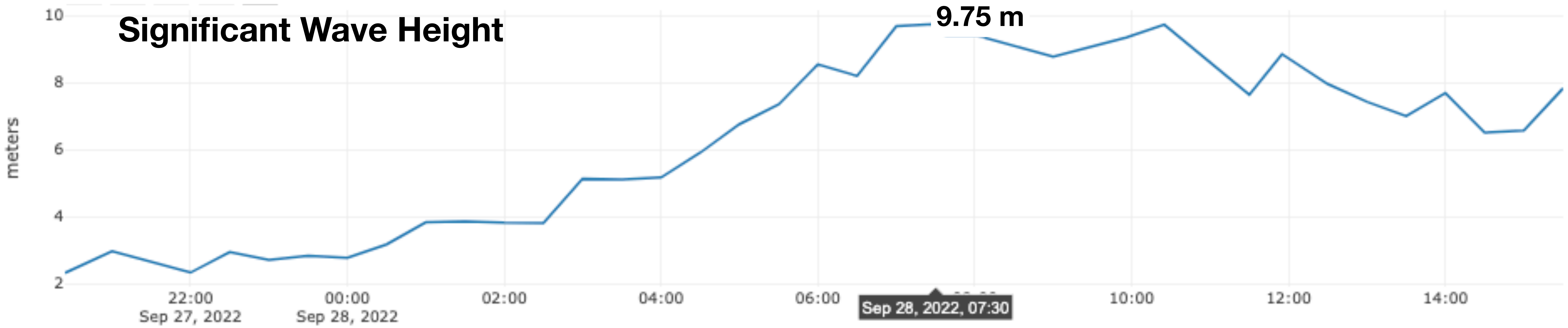


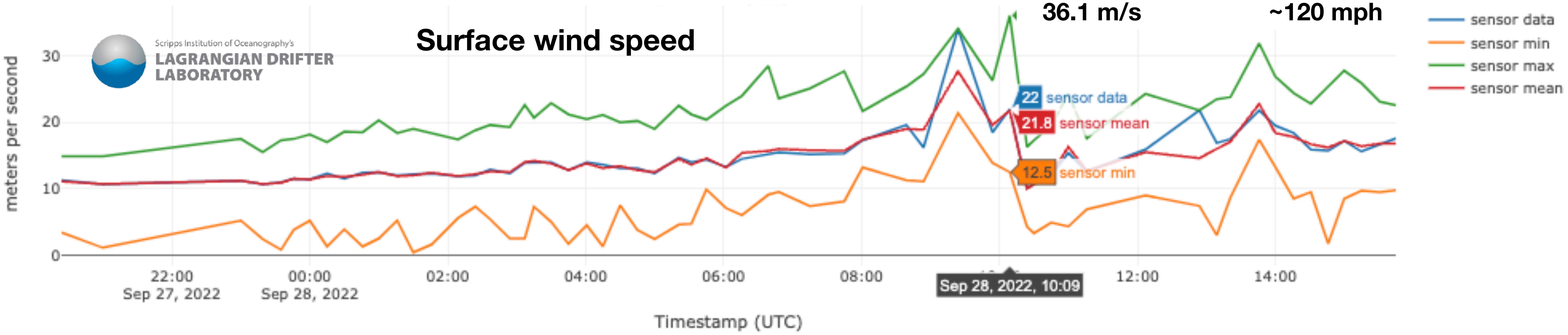


Hurricane Ian: A targeted array (September 25-30)









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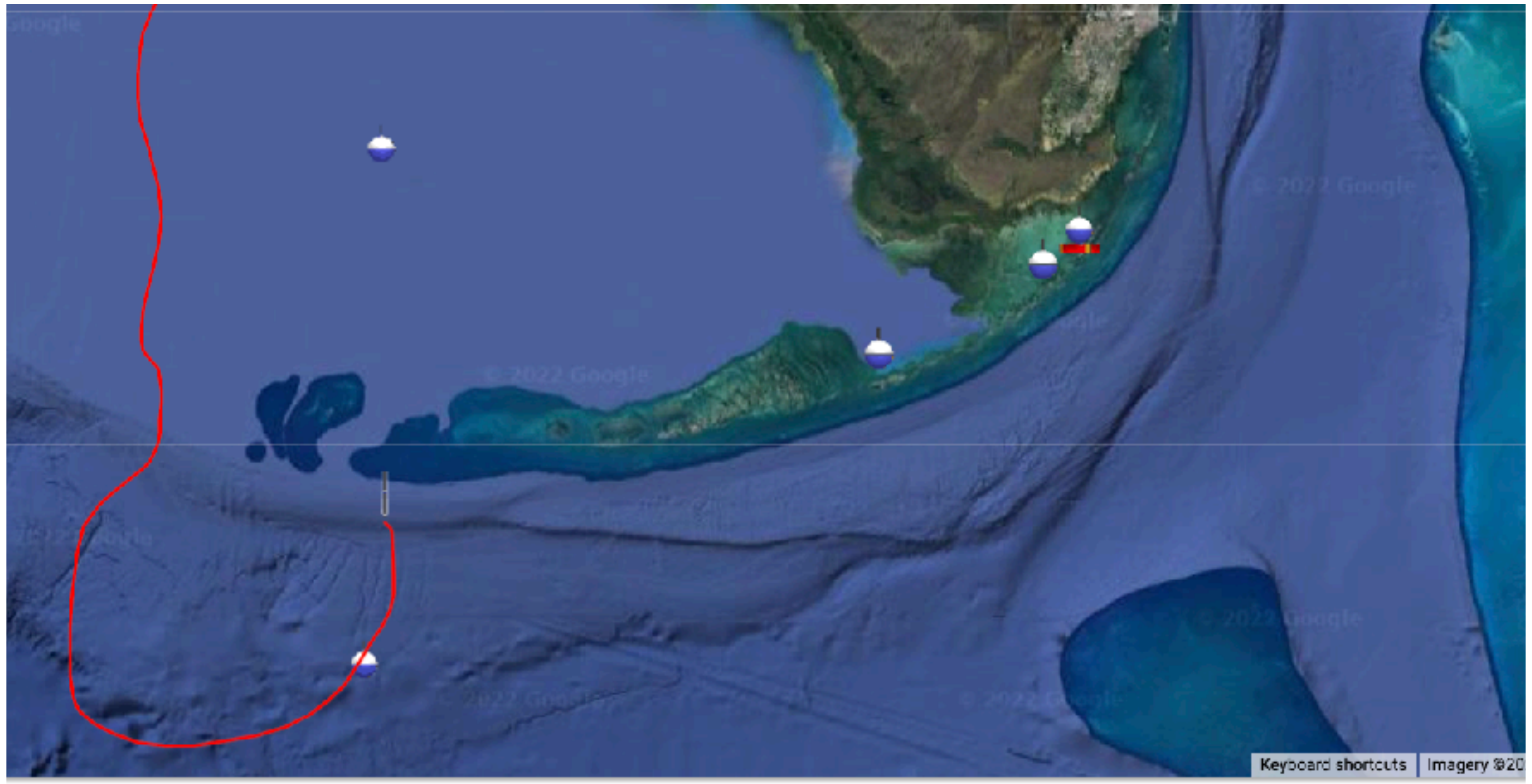
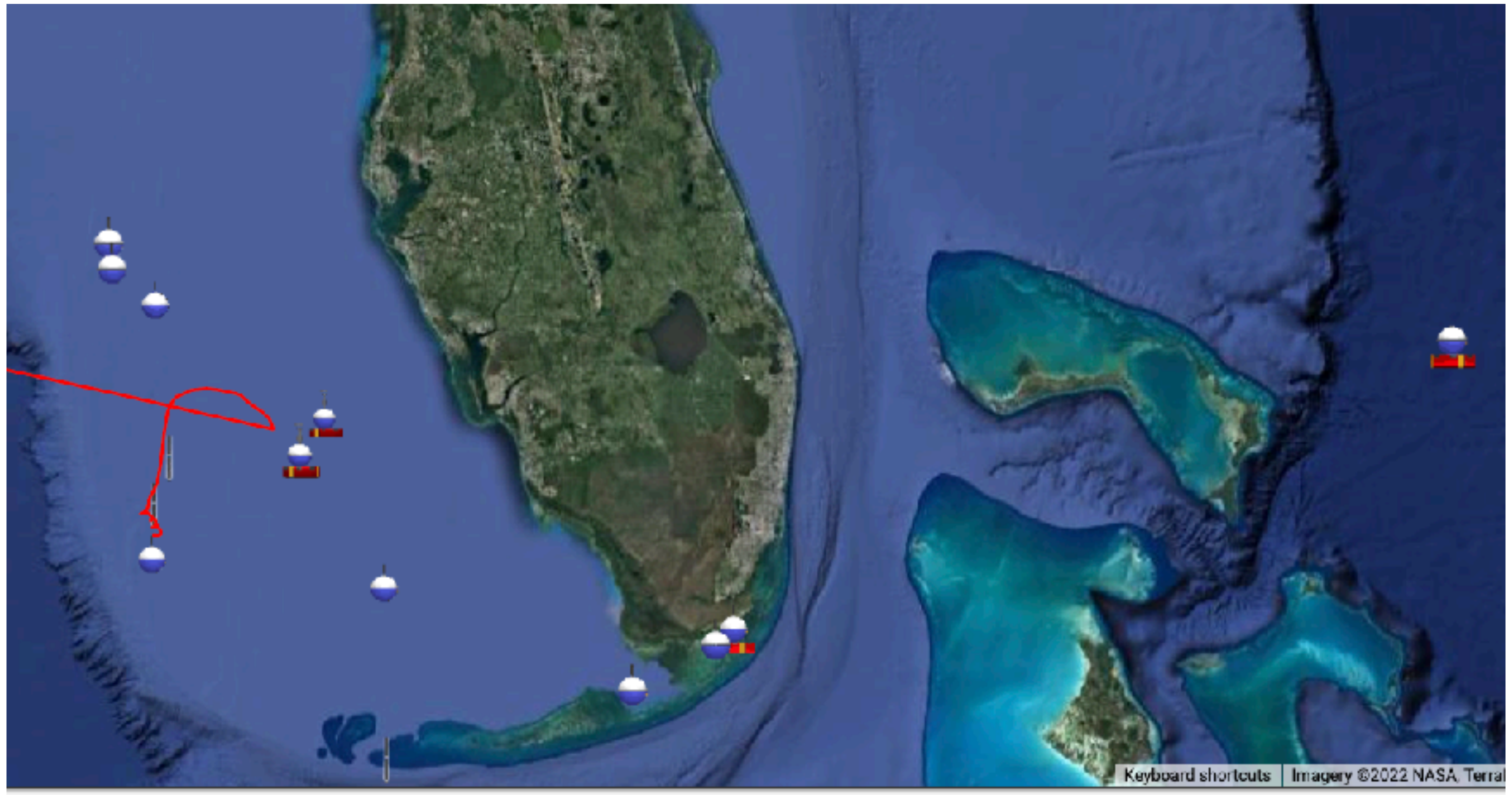
Hurricane Ian: A targeted array (September 25-30)





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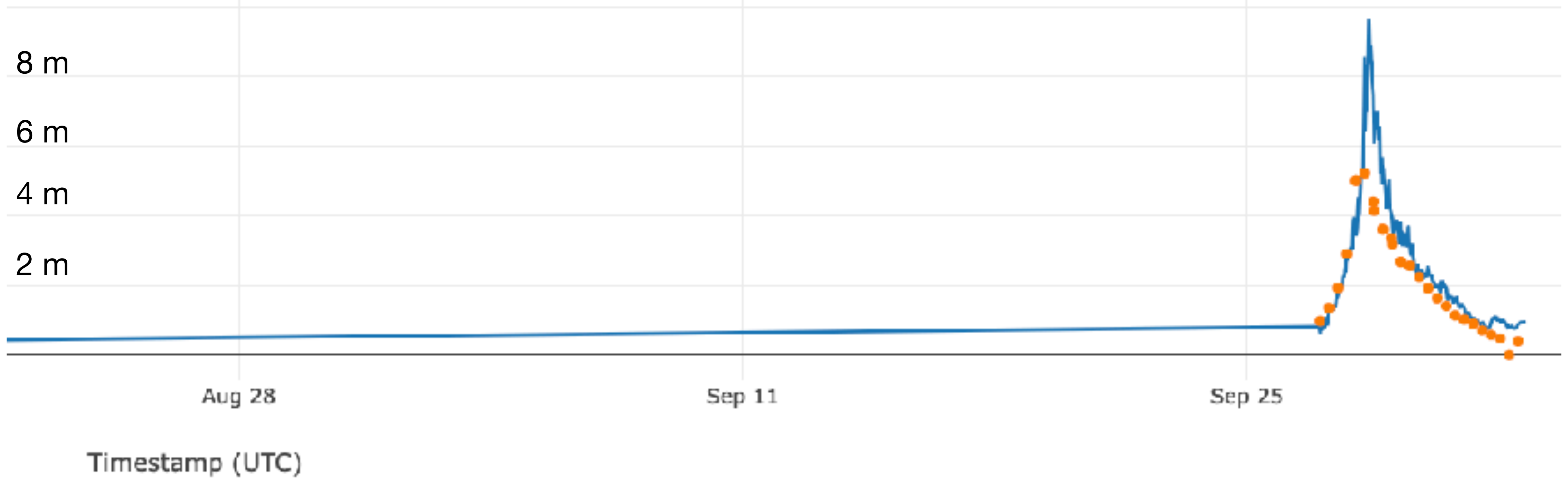
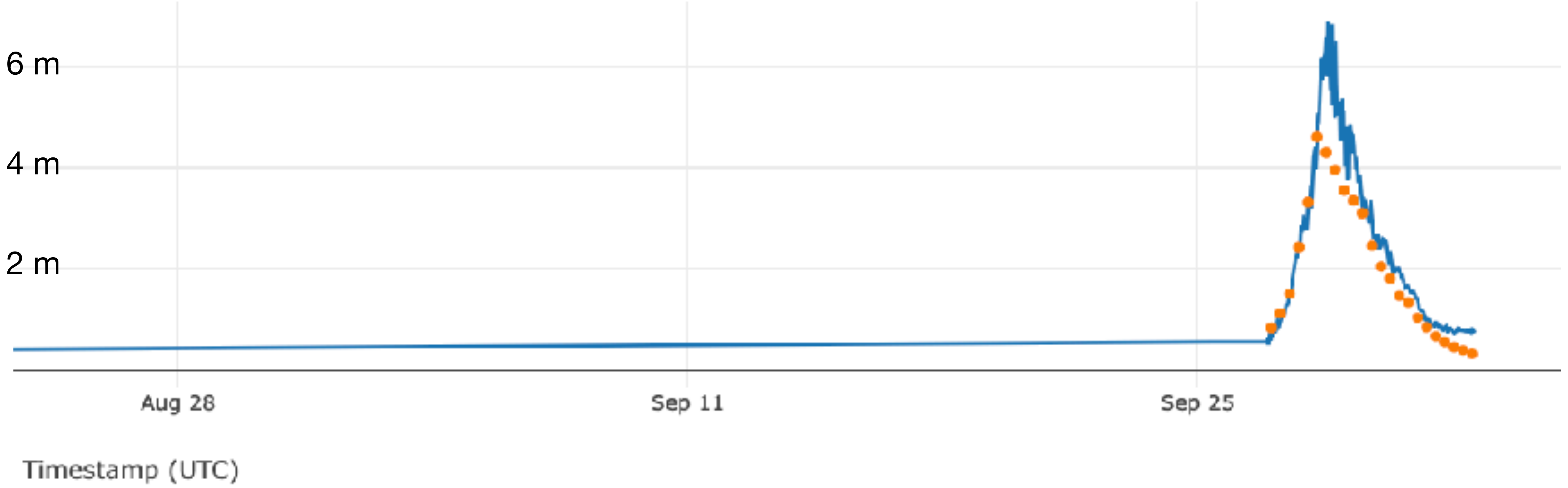
A-DWS Significant Wave Height

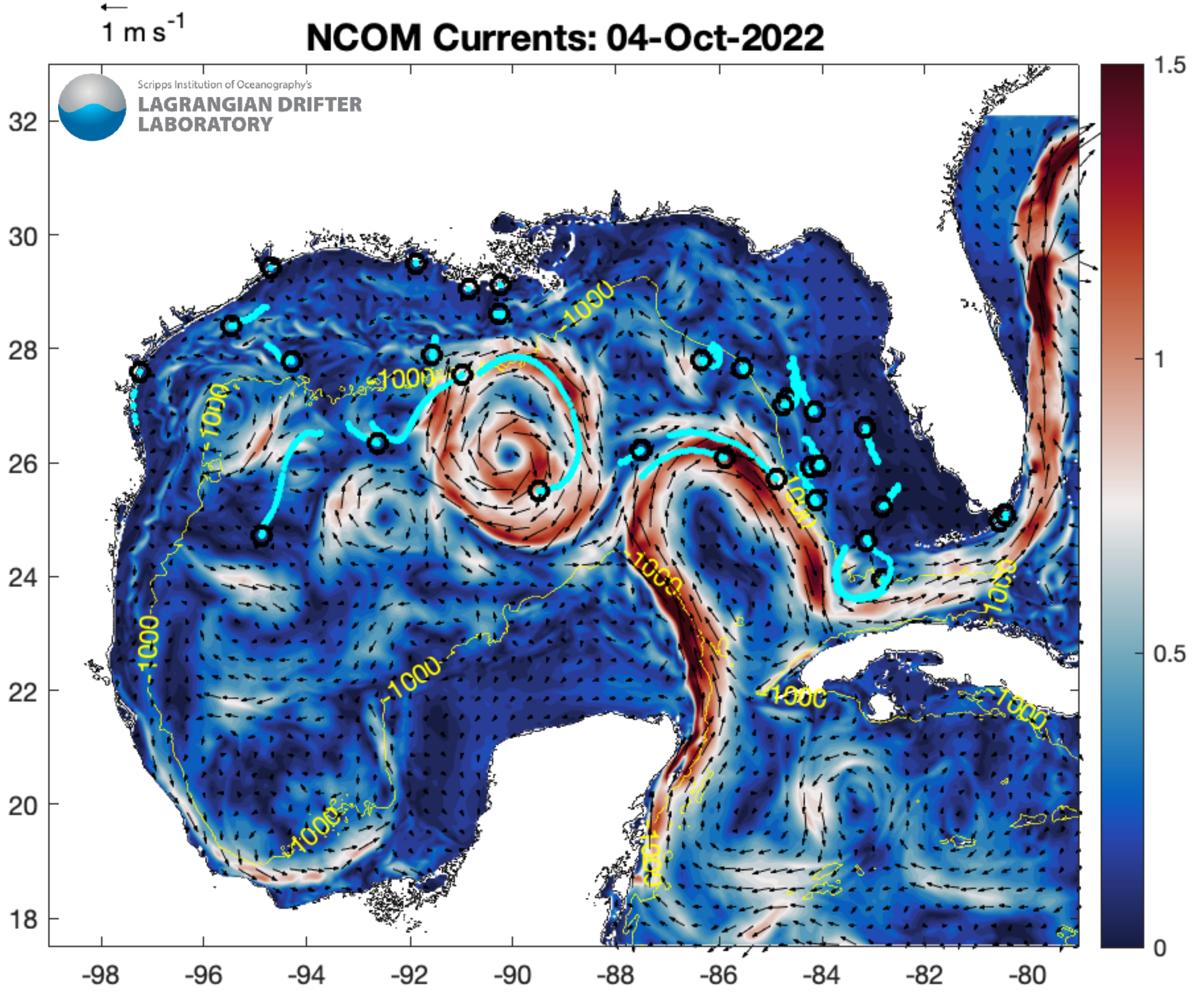


DWSB Significant Wave Height



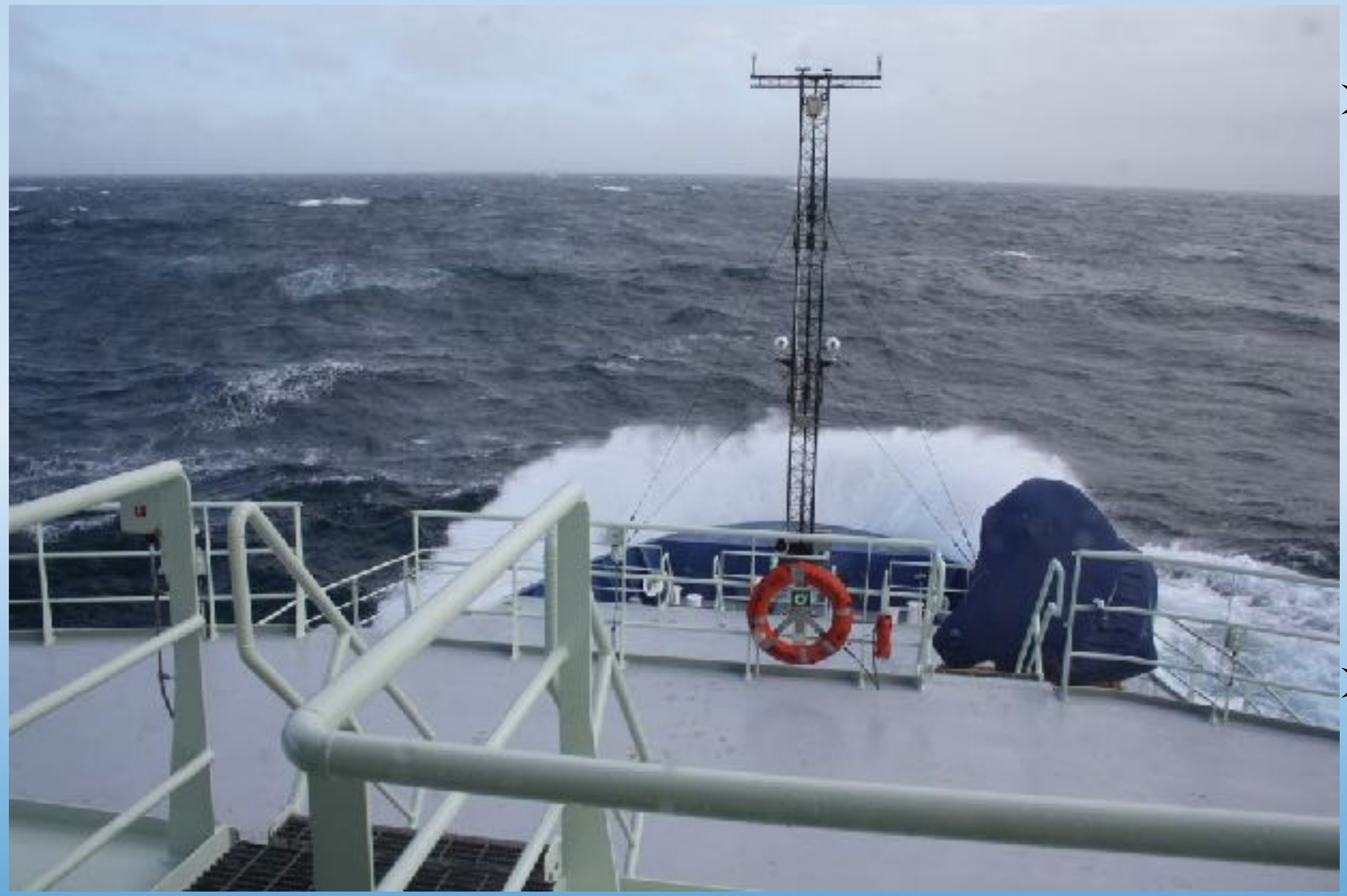
Moving Forward

Gulf of Mexico 2022 Array



- Maintain both a sustained array, adaptable observations and rapid response
  - Scientific and future operational needs
- Provide data following FAIR-O standards

Rationale for *in-situ*, *FAIR*-O, GDP Global Open Ocean Wave Observations



- **Basic Science**: Wave propagation (trans-basin/local), air-sea interaction (e.g. momentum and gas fluxes), wave/current interaction (e.g. wave modulation by strong currents), wave/wave interaction, wave/internal wave interaction (implications for diapycnal mixing), engineering of offshore structures, climate assessment, risk assessment and planning

- **Societal**: Navigation efficiency and safety (wave/Gulf Stream interactions), SOLAS, marine insurers, Lloyd's ship hull strength metric, wave inundation warnings (e.g. India, Sri Lanka, West Africa)

- **Satellite/Airborne missions**: Calibration and validation of remotely sensed significant wave height and spectral characteristics retrievals of the surface wave field

- **Validation and forecasting:** Validation and scientific assessment of wave forecasting products, assimilation of wave data into wave forecasting models, open ocean in-situ Boundary conditions to improve coastal wave forecasts where people live and work

Photo credit: Icelandic Coast Guard

In-situ wave observations in the open ocean are very sparse.

The FAIR-O GDP data policy is CRUCIAL for rapid advancement of science, as demonstrated by nearly 40 years of GDP operations, in contrast with for-profit ocean observing activities

Wave/current interaction can cause serious ship accidents. In-situ data are needed to constrain, validate and assess models

A research based, open data, global array of wave sensors is needed

Centurioni et al, 2019, Frontiers in Marine Science, **6**-419.

Conclusions

- The SVP/DWSD technology developed by the LDL is a sustainable, cost-effective global array of directional wave drifters built using existing drifter technology
  - L/GDP **<u>FAIR-O</u>** data policy supports basic science and forecasting around the globe and encourages participation of both private and public sectors. Note that over 1,200 peer-reviewed publications using traditional drifter data exist
  - Importance of standards (low frequency noise)
- Global wave data are needed for ocean and atmosphere science, forecasting, warnings, risk evaluations for extreme events and regional coastal changes
  - Scientific approach of both a sustained array, adaptive sampling and rapid deployment

Questions?