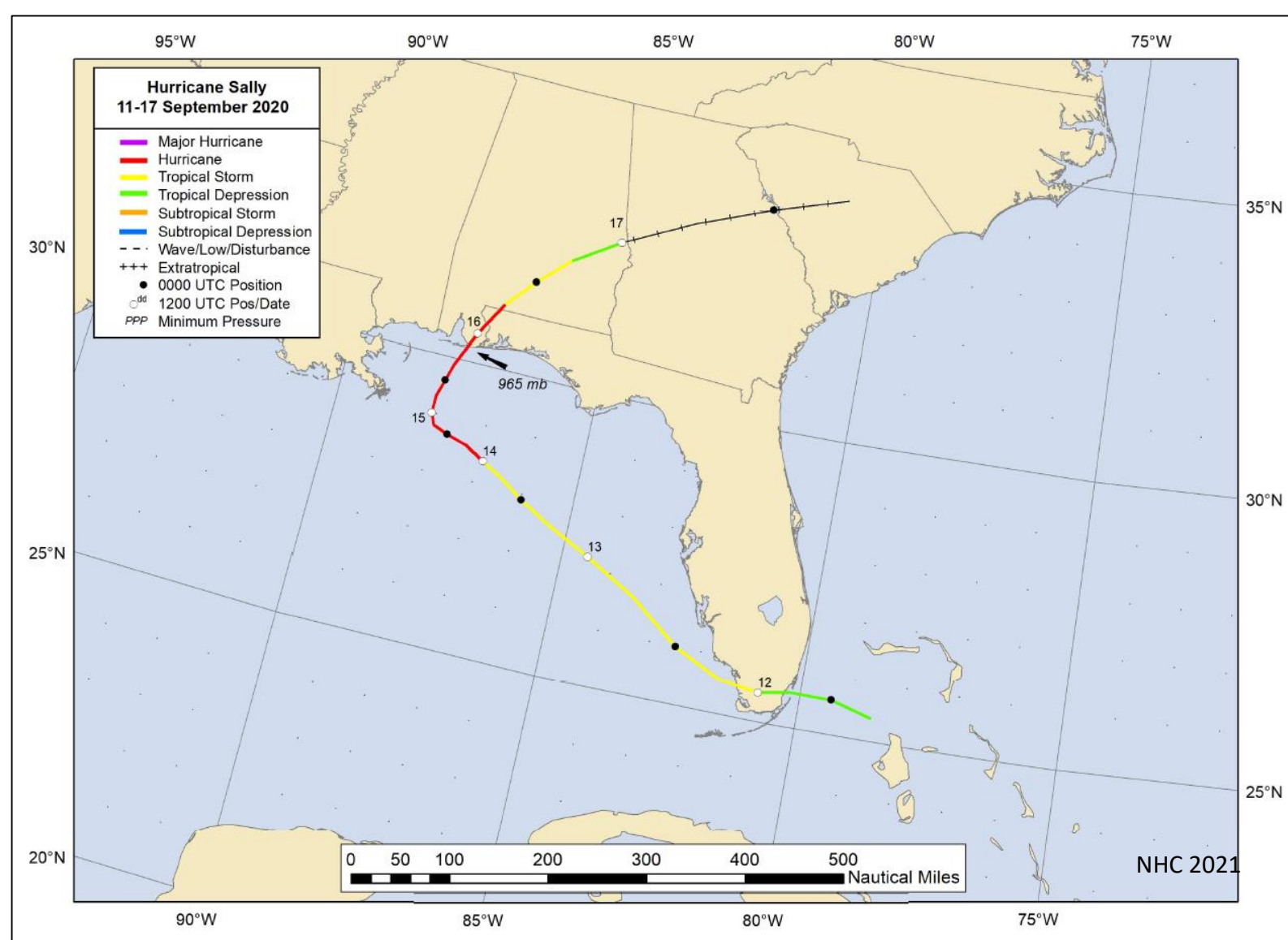
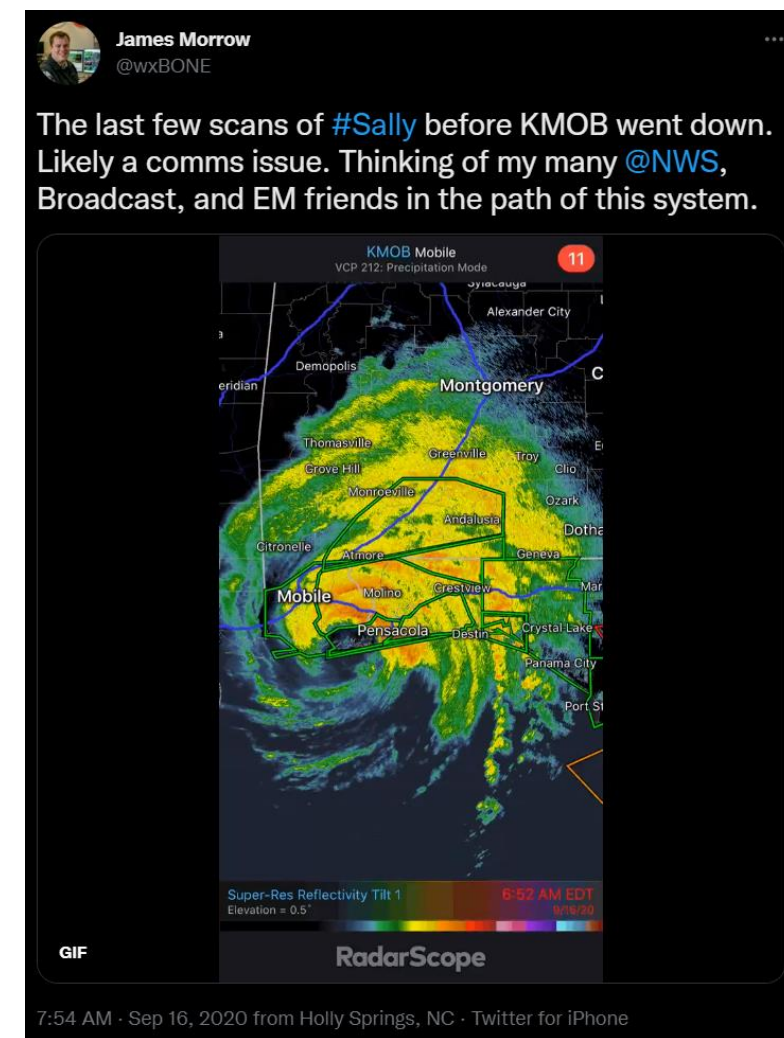


## 1. Project Summary

**Context:** Sally was part of the hyperactive 2020 north Atlantic hurricane season, making landfall at Gulf Shores, Alabama, USA as a high-end category 2 hurricane inflicting long-duration winds of up to 95 knots. Sustained hurricane-force winds impacted both coastal Alabama and the far-western Florida panhandle [1].

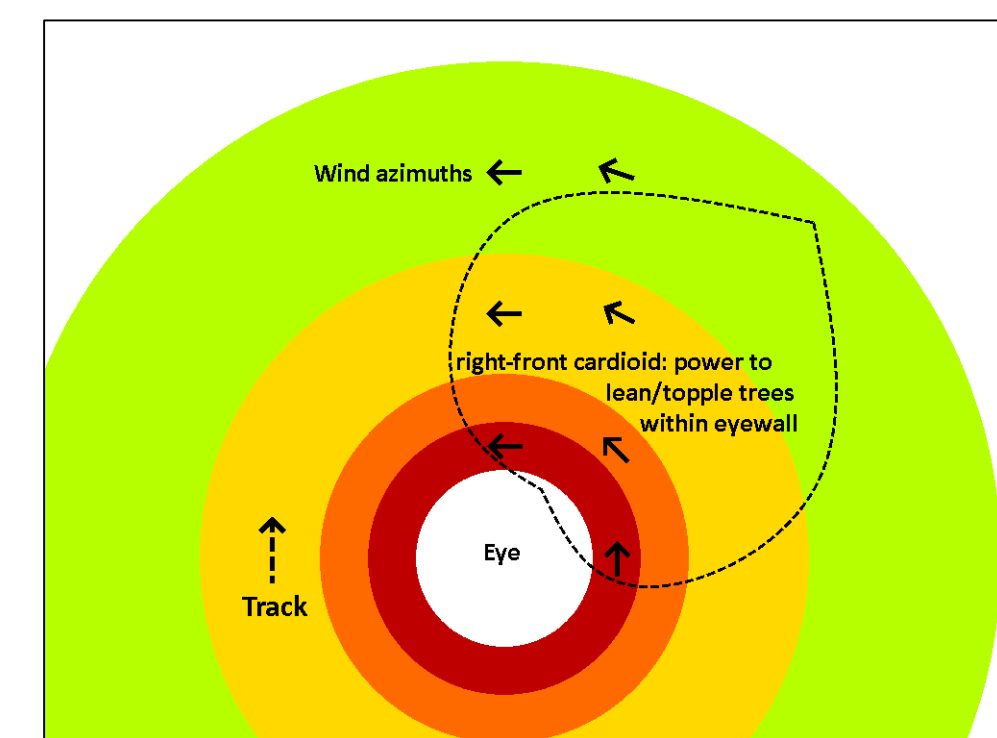


**Purpose:** This study fills important gaps in the instrumental record by statistically analyzing tree-lean azimuths to reconstruct 1. An eye-spanning transect of Hurricane Sally's maximum-wind field at landfall, plus estimate of eye diameter; and 2. Sally's offshore eye diameter and position of wind-center three hours before landfall. These analyses could help validate meteorological hindcasts, be useful in the event of Doppler radar malfunction (as happened immediately after landfall for this event!), and contribute uniquely along the many vulnerable coastlines of the world lacking access to such technologies.



Rank	Community	State	Rating	Score	FEMA 2022
1	Centur District	AL	Very High	52.28	100
2	Centur District	FL	Relatively High	39.34	100
3	Centur District	FL	Relatively Moderate	36.98	100
4	Centur District	AL	Relatively Moderate	25.38	100
5	Centur District	AL	Relatively Moderate	24.08	100

**Methods:** Five study subsites were selected for locations spanning the coastline impacted by Sally's inner eyewall as it made landfall. These barrier islands and peninsulas host a mosaic of fire-managed longleaf pine (*Pinus palustris*) savanna and also maritime forest. The subsites host a robust population of excellent bio-indicators: open-grown mixed-age pines satisfying strict selection criteria. We sampled a total 557 high-quality pines of mixed maturity. We infer clock-times for the most destructive winds at each subsite by referring to ground-based weather stations mentioned in [1].



**Findings:** We determined Sally's pre-landfall wind center to be in good agreement with advisories from the National Hurricane Center (NHC) during a 3-hour interval just before landfall [2]. Furthermore, our two estimates of Sally's eyewall diameter—calculated from different models as 52-66 km before landfall and 43-60 km at landfall—not only fail to significantly differ from each other, but are also both validated by radar-based estimates.

## References

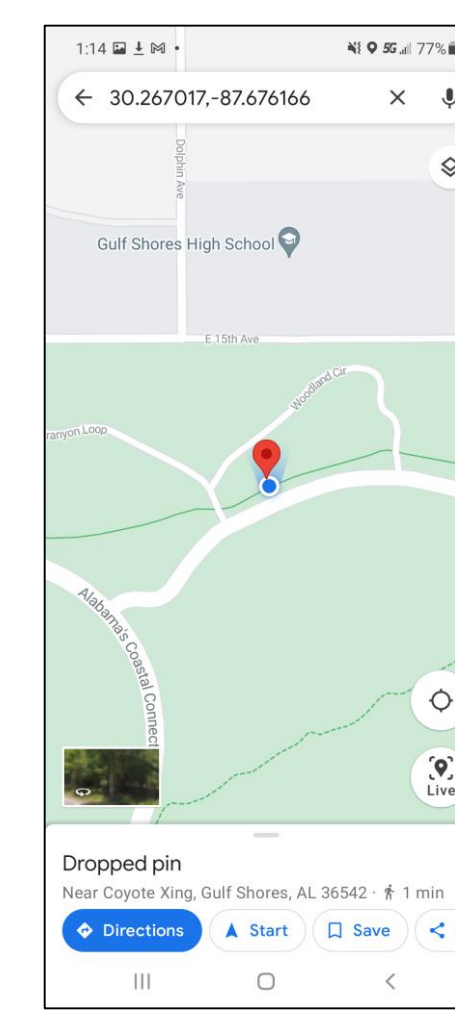
- National Oceanic and Atmospheric Administration, National Hurricane Center. 'Tropical cyclone report: Hurricane Sally AL192020', (2021).
- National Oceanic and Atmospheric Administration, National Hurricane Center. 'Hurricane Sally Advisory Archive', <https://www.nhc.noaa.gov/archive/2020/al19/> (accessed 1 April 2022).
- National Oceanic and Atmospheric Administration, Hurricane Research Division. 'Hurricane Sally 2020', [https://www.aoml.noaa.gov/hrd/storm\\_pages/sally2020/](https://www.aoml.noaa.gov/hrd/storm_pages/sally2020/) (accessed 7 April 2022).

## 2. Methods

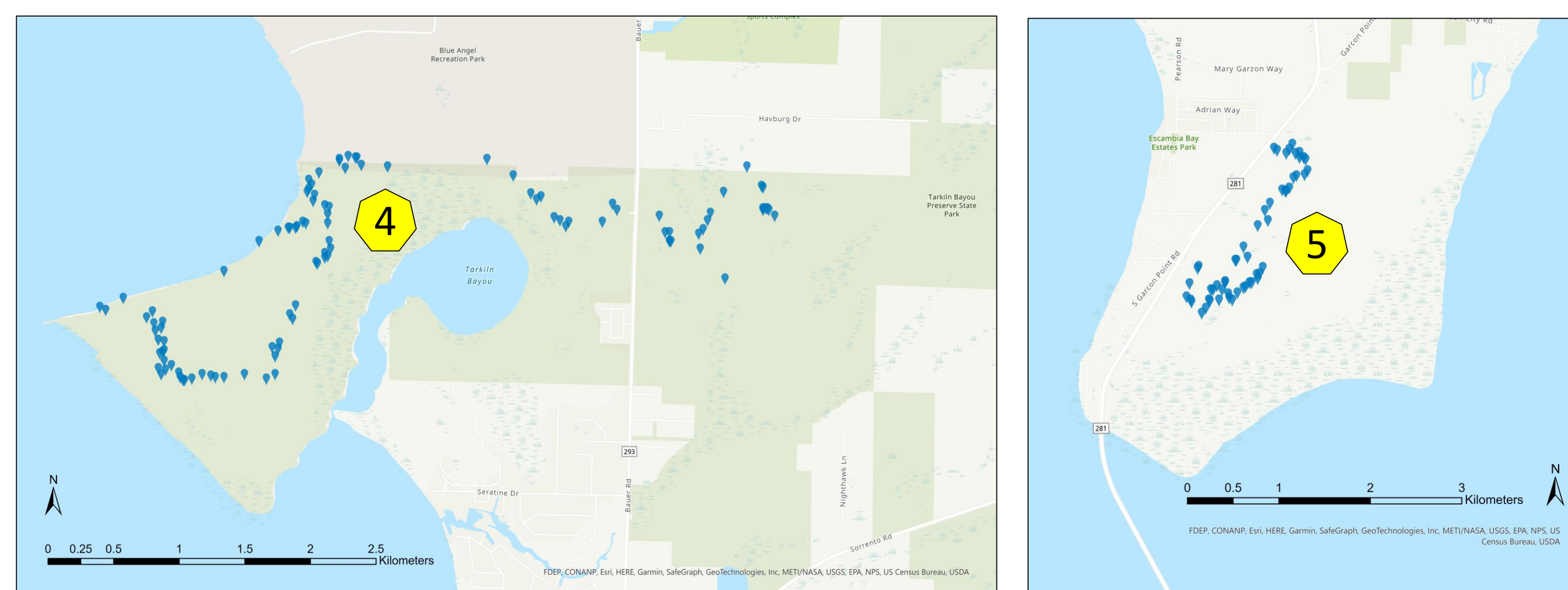
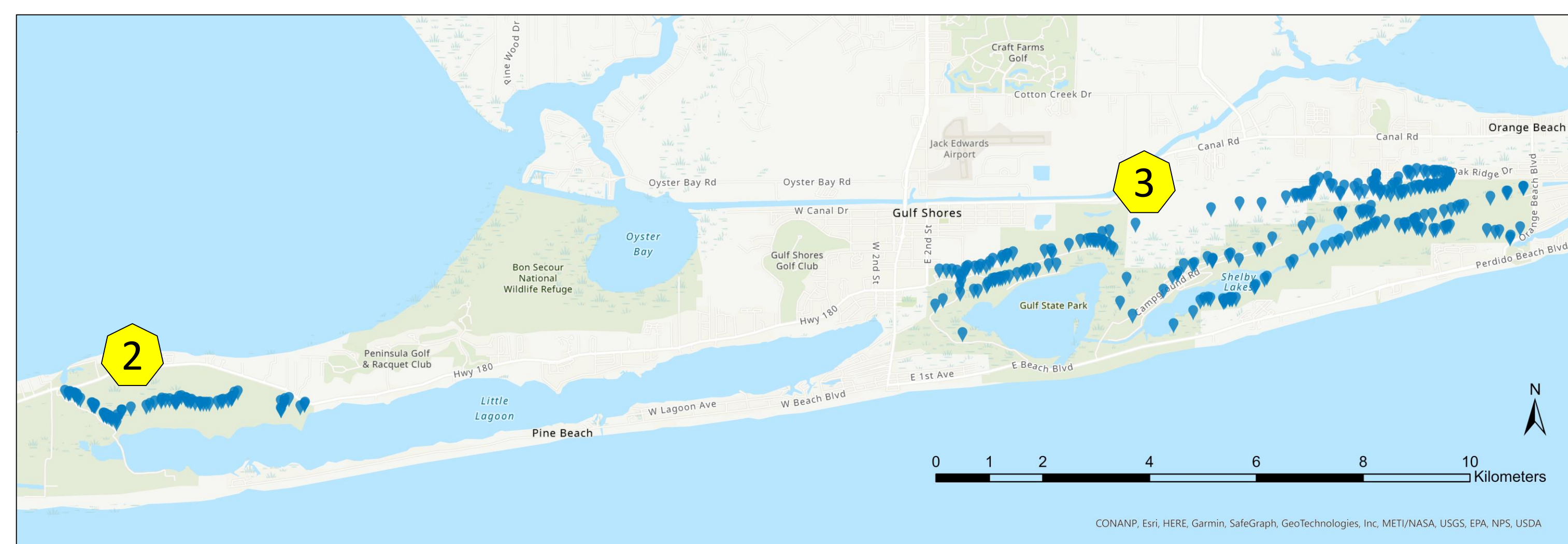


(Above) Study site along the FloriBama coast. Five subsites were selected and sampled in January–February 2022 with high prioritization given to data quality. Weather stations represent a well-distributed source of time-stamped maximum winds.

(Right and right-below) Raw field data for each sample-tree includes information about geographic position, magnetometer bearing relative to tree-lean, and a high-resolution visible-color photograph to support quality control during data entry/classification.

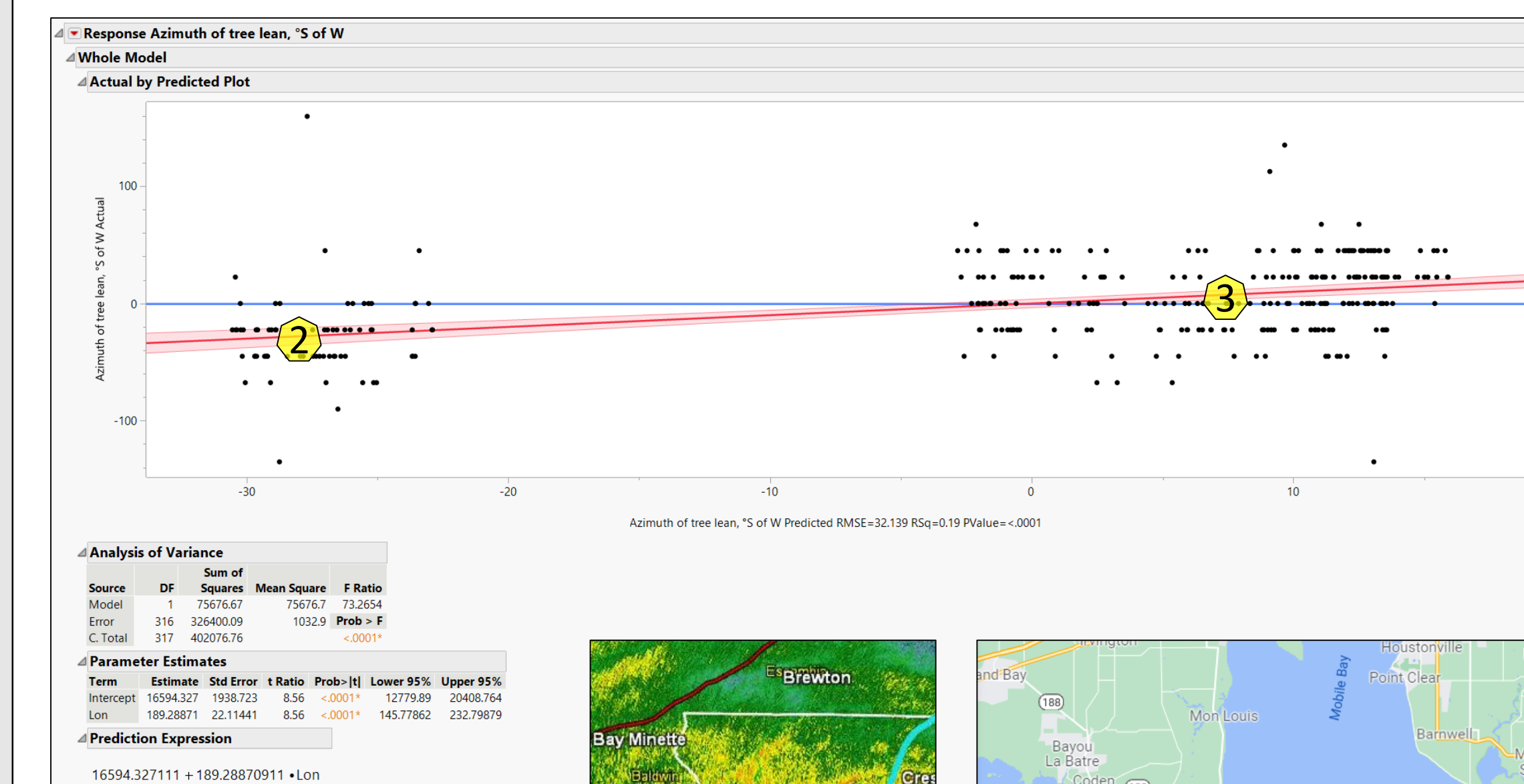


(Below) Subsites with their respective distributions of sampled trees, which themselves represent only a small fraction of high-quality candidate trees. Most points lay within 10 m of an established hiking trail—and all of them did after the incident with the snake. The mid/late-winter timing of field work was important for quality with respect to deciduous hardwood dormancy, favorably droughty conditions, and hazardous reptile/insect sluggishness.

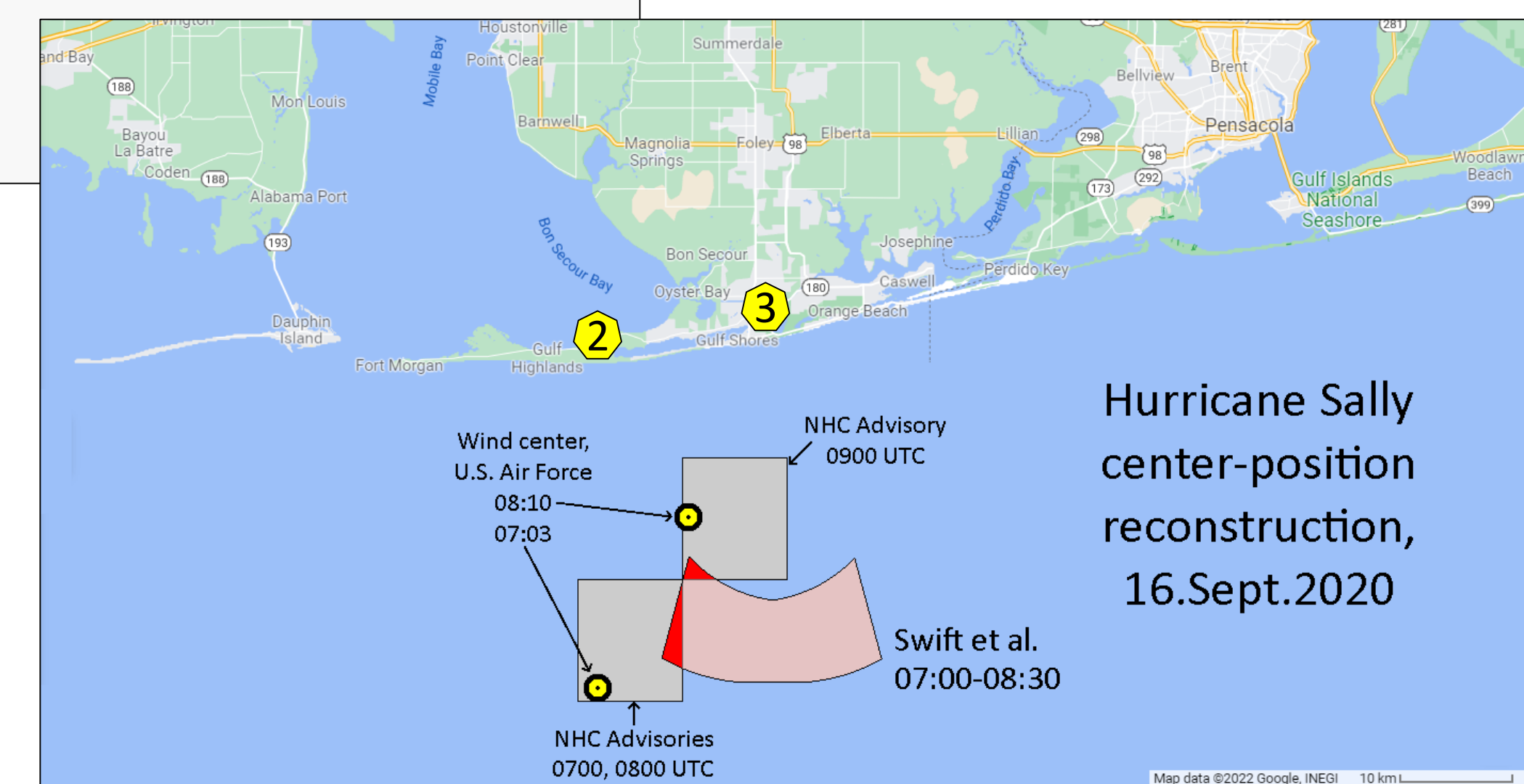


## 3. Landfalling Eyewall Reconstruction

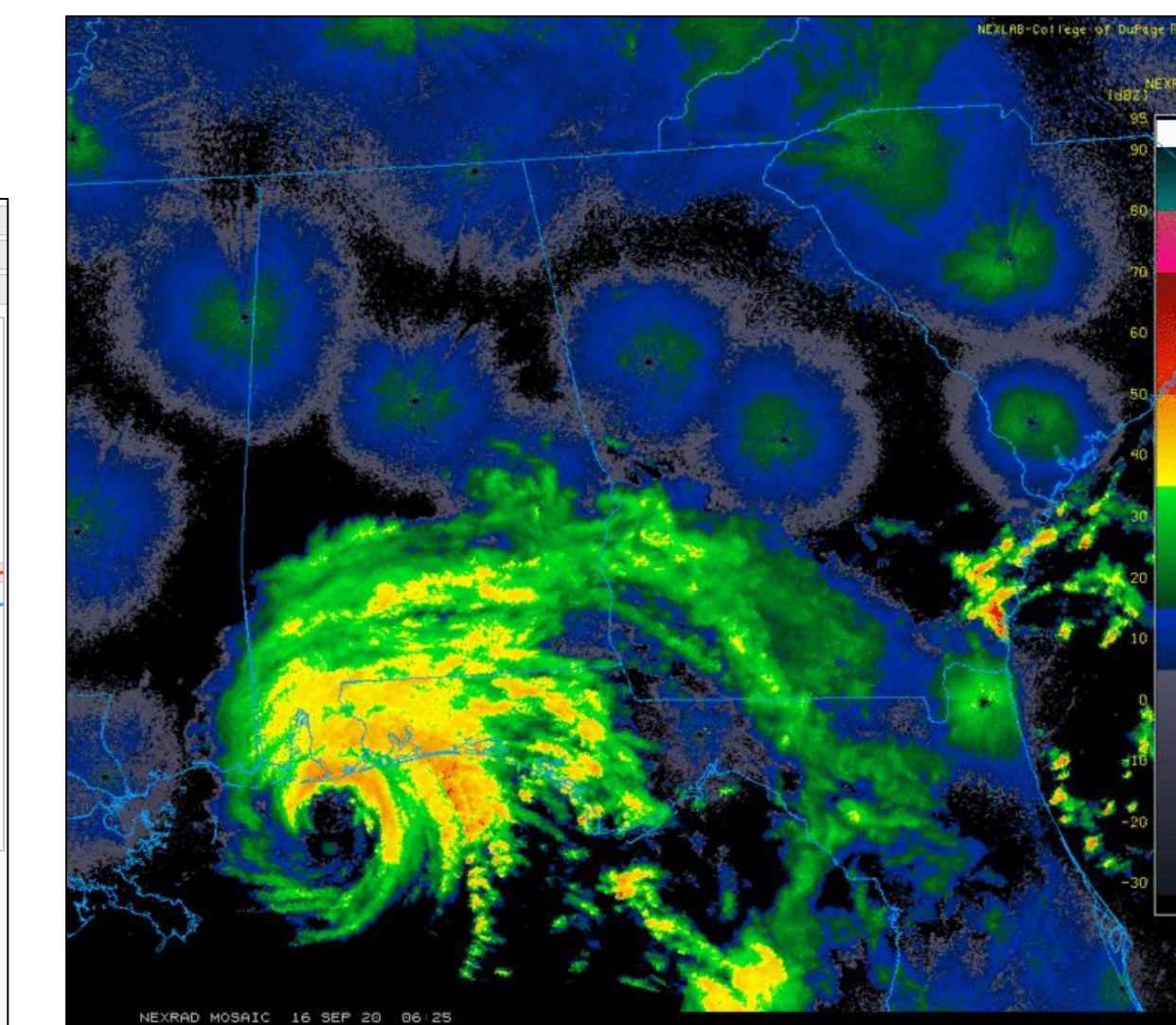
(Below) A least-squares linear regression was fit to tree-lean-azimuth vs. geographic longitude for the combined 'central' Subsites 2 and 3. This simple model enables decent estimation of two important quantities during Sally's prelude to landfall: eyewall diameter (52-66 km) and position of the offshore wind-center (lower-right) showing agreement with independent center estimates [2], [3].



(Right) Radar shows an initial eyewall strike on Subsites 2 and 3 as Sally continued strengthening over unusually warm shelf waters. Maximum winds at central Subsites preceded those at outer Subsites by up to five hours thanks to Sally's very slow forward speed of <1 m/s.



(Below) Mosaicked Nexrad radar imagery displays Sally's tree-damaging eyewall mid-rampage through Subsites 2 and 3.

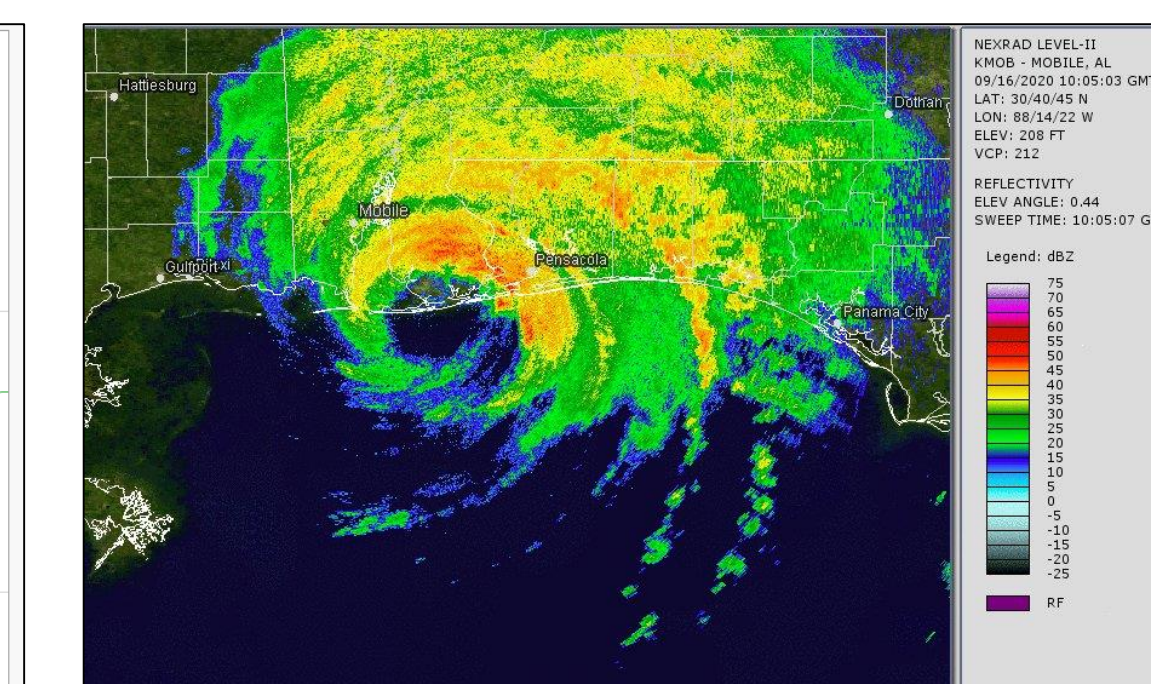
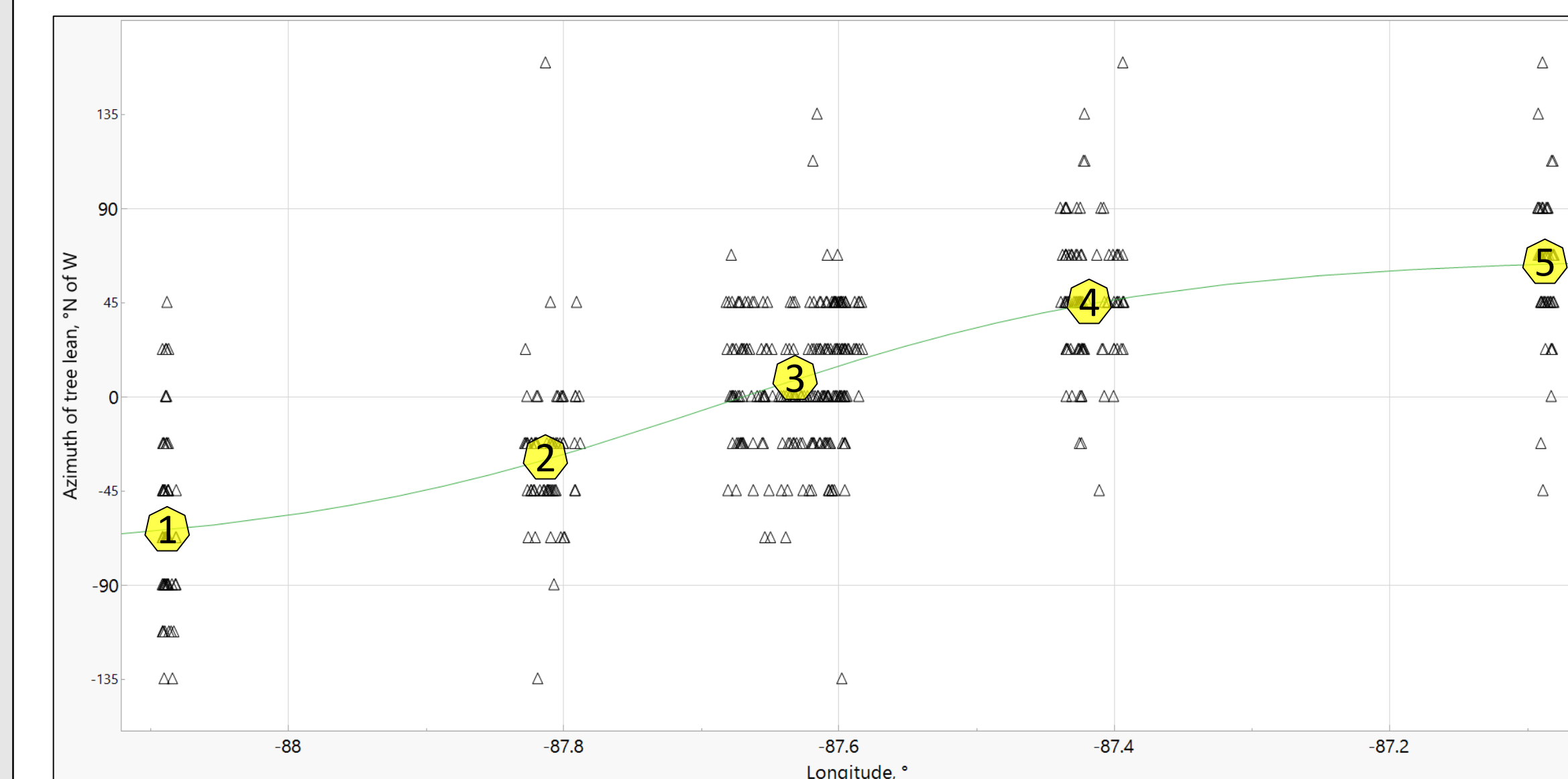


## 4. Landfalling Wind-Center Reconstruction

We fit a Logistic 4-Parameter regression to the complete dataset (right, below) to more completely explore the study site's relationship between tree-lean-azimuth and geographic longitude.

This model explains 57% of variance by optimizing four important spatial parameters of Hurricane Sally. Eyewall curvature is derived from 'Growth Rate', wind center east-west position is derived from 'Inflection Point', and a tremendous amount of information about the eyewall's far-western/eastern limbs may be gleaned from 'Lower/Upper Asymptote', respectively.

This model returns an eyewall diameter of 43-60 km, which is once again in good agreement with our radar-based (below right) validation estimate.



(Left) Data from Subsite 1, on Dauphin Island, shows hints of contamination from Hurricane Nate (2017). Nate made landfall to the west, in Mississippi, and is likely responsible for tipping significant fraction of Dauphin Island's north-leaning pines.

## 5. Conclusions

- We have successfully demonstrated both the viability and utility of this novel fusion of tree surveys and statistical analysis.
- Most all the details of Hurricane Sally's landfall were remarkably well-suited to our methodology.
- The field work was remarkably thrifty with respect to financial cost, equipment, and labor-hours. The main author collected all raw data in ~60 hours on-site with only a smartphone. No expenses were incurred except for those travel-related.
- Perhaps some variant of this method could be applied to other wind-related damage such as that from tornadoes, supercell downbursts, or derechos.