# NIST Rapid Response Windfield Estimates for Hurricanes Florence & Michael

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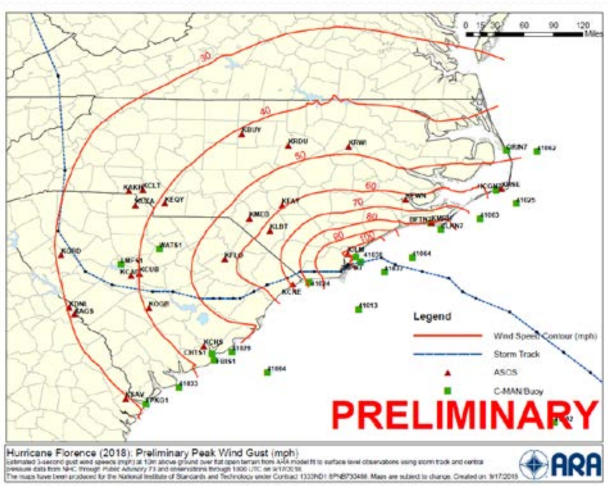
WG/CAS Briefing
Nov. 14, 2018

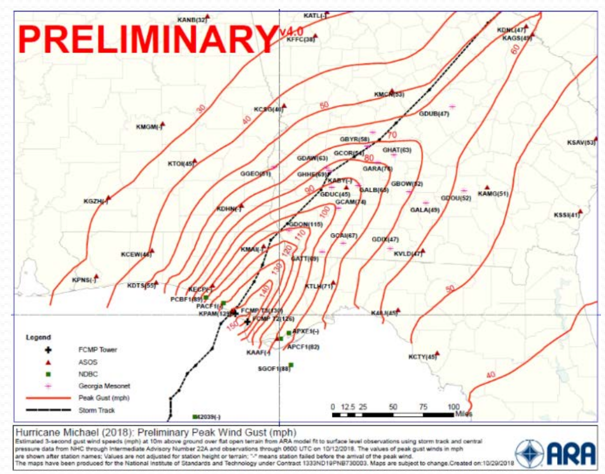
# Hurricane Windfield Mapping

Starting with the 2017 Hurricane Season, FEMA began to Mission Assign NIST to produce rapid post-storm windfield estimates needed to drive their Hazus Hurricane Model

- Produce wind swath maps typically within 1, 3, and 7 days following landfall, working closely with our support contractor, Applied Research Associates (ARA)
- Windfields for (Harvey), Irma, Maria, Nate, Florence, and Michael




Hurricane Florence (2018): Preliminary Peak Wind Gust (mph)




Hurricane Michael (2018): Preliminary Peak Wind Gust (mph)

# Windfield Mapping Methodology (1/4)

Windfields are created by fitting a hurricane windfield model to surface-level observations of wind speed, direction and atmospheric pressure

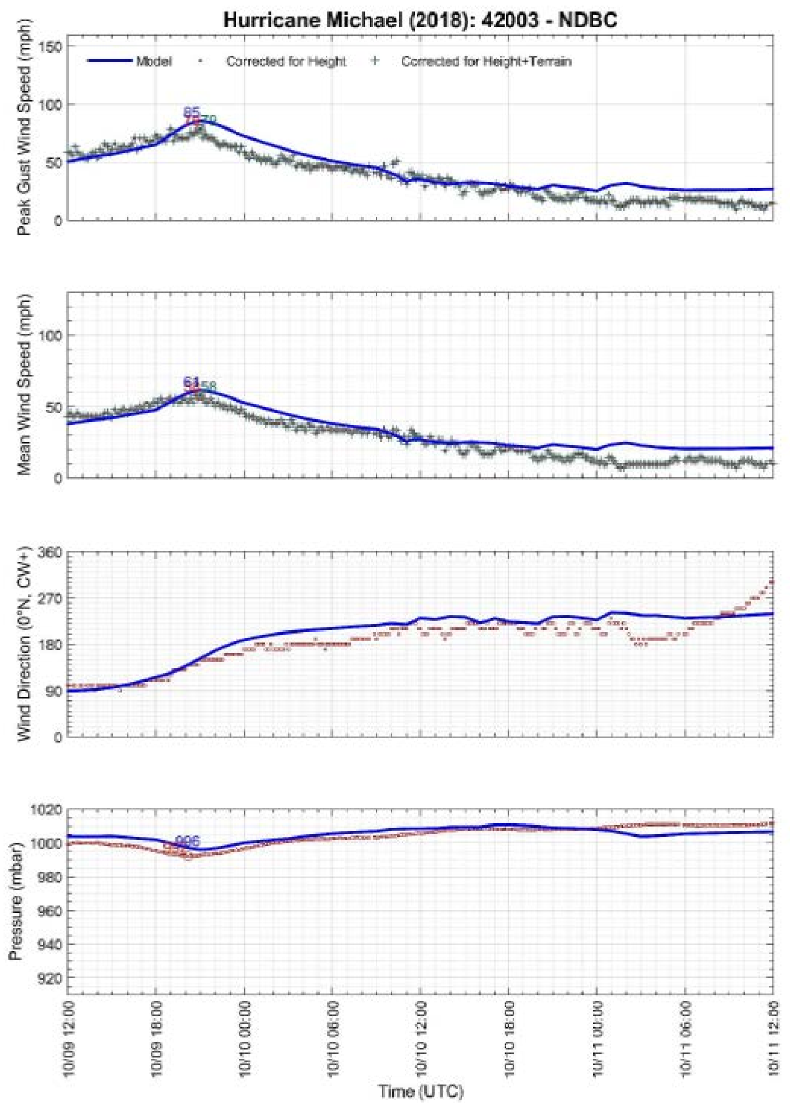
- Use track and minimum central pressure from NHC advisories
- Collect surface-level observations
  - Primary data - ASOS and nearshore data from NDBC
  - Also use data from mobile instruments, state mesonets, and other sites, as available –challenge is often getting needed metadata
    - Anemometer location, height, installation details, type, sampling and signal conditioning

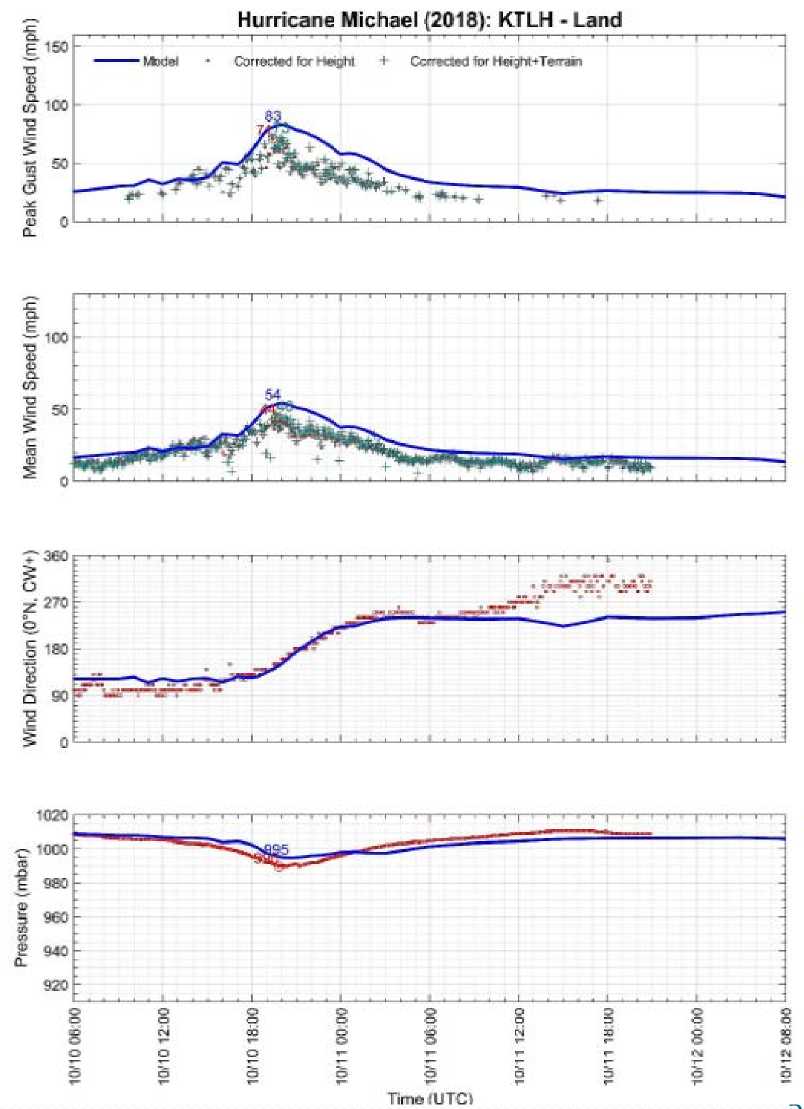
# Windfield Mapping Methodology (2/4)

- Convert windspeed observations to equivalent 3 second peak gust speeds at 10 m over flat open terrain
- Select initial estimates of radius to maximum winds (RMW) and Holland B pressure profile parameter
- Estimate windfield using ARA Hurricane Model (Vickery et al., 2000)
- Compare modeled wind speeds, directions and atmospheric pressures with observations
- Revise model parameters and iterate until differences are minimized


Directional effective surface roughness length for Billy Mitchell Airport at Cape Hatteras, NC computed in Masters et al. (2010)

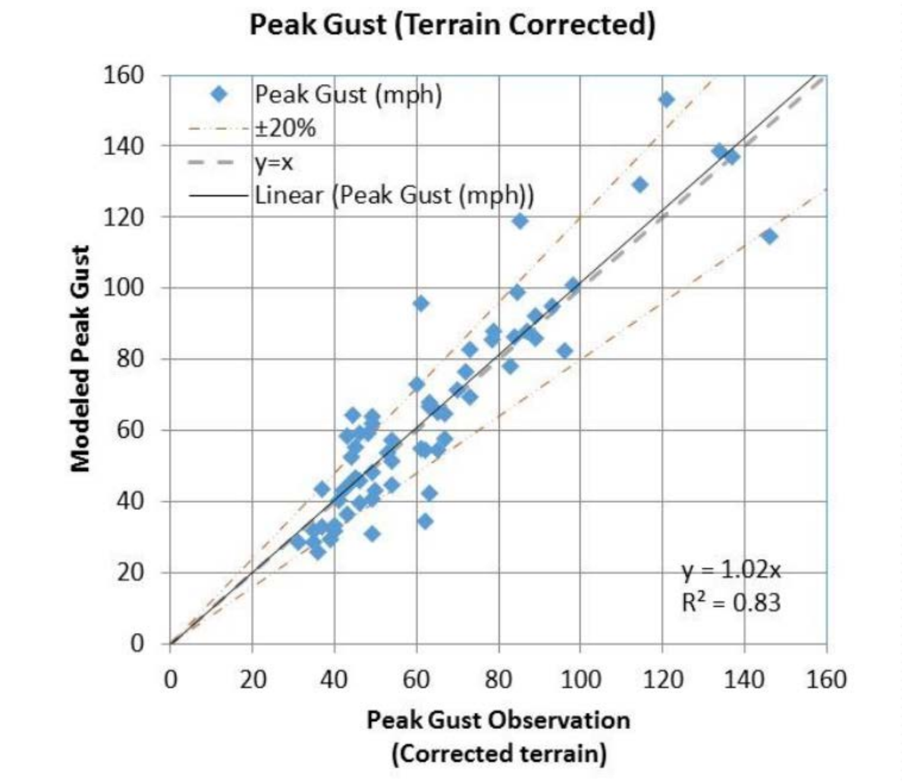
# Windfield Mapping Methodology (3/4)

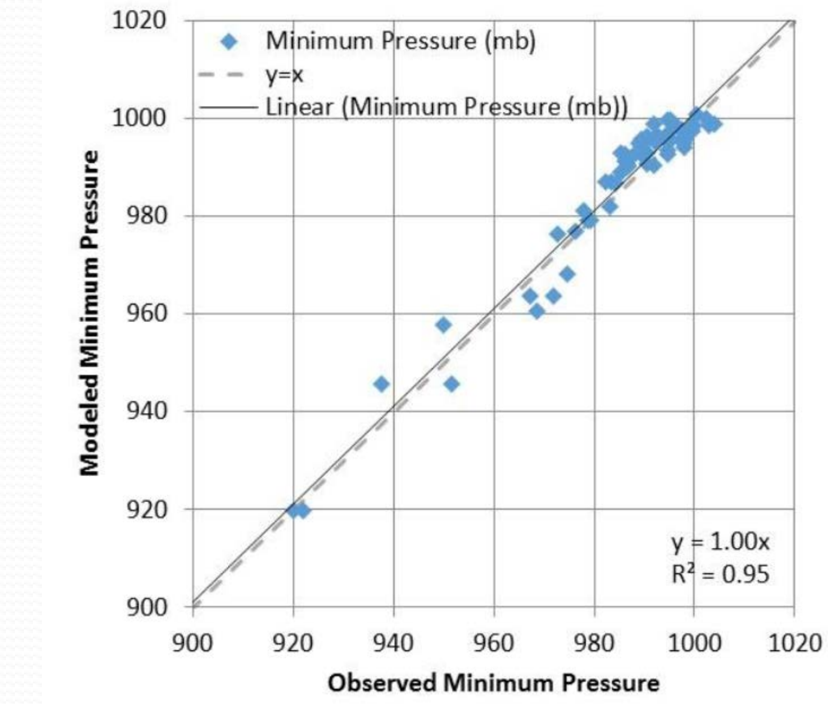


# Windfield Mapping Methodology (4/4)

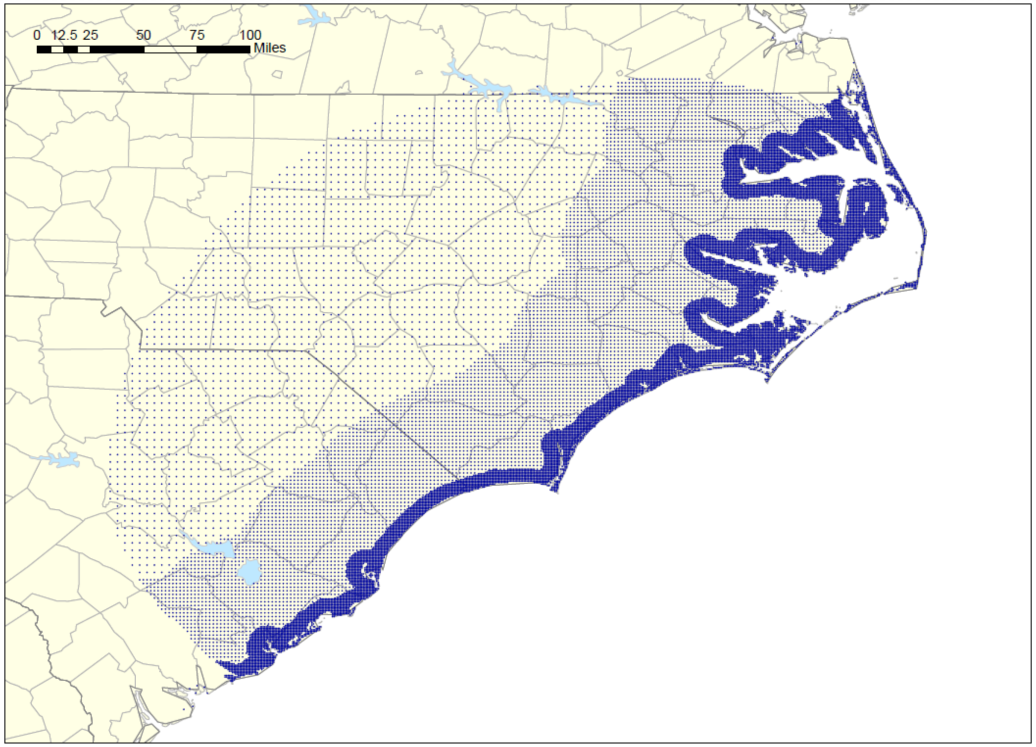
## Hurricane Michael Plots of Model vs Observations



# Windfield Products

- HAZUS windfield input file
- PDF windfield maps
- GIS files of the windfield contours
- Plots of model fits to observed data
- Modeled time series of wind speeds, directions and atmospheric pressures at grid points over high wind areas
  - ≈1 km grid spacing at highest density locations along coast
- Maps showing exceedance level over design wind speeds




**Hurricane Florence (2018): Wind Grid**

Wind grid for the evaluation of wind speed from ARA model. Points with 3-second gust wind speeds of 40 mph or greater at 10m above ground over flat open terrain are shown. Grid spacing is approximately 1km within 10km from the coast; 2.5km grid spacing for locations from 10km to 100km from the coast; 5km spacing for locations beyond 100 km. The maps have been produced for the National Institute of Standards and Technology under Contract 1333ND1 8PNB730488. Maps are subject to change. Created on: 9/27/2018

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# Applications/Users

## Hazus Loss Estimation

- FEMA HQ Response Geospatial Office
- Provides more accurate results from Hazus than using the NHC windfield data

## Post-Storm Data Collection and Research

- NWIRP coordination of post-storm investigations
- FEMA Building Science Branch
  - inform Florence and Michael Pre-MAT deployment and data analysis
- NIST Disaster and Failure Studies
- NSF-supported data collection – RAPID, GEER, StEER, CONVERGE
- Numerous academic, professional, and other private sector organizations

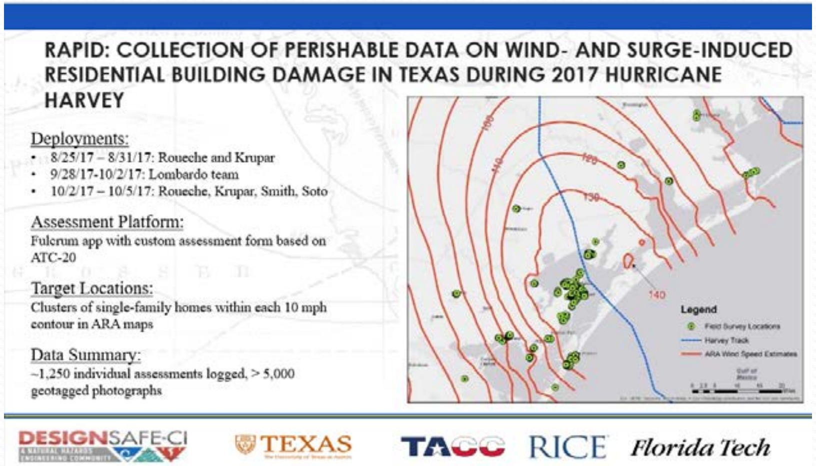
## Dissemination

disasters.geoplatform.gov
https://fema.maps.arcgis.com/apps/MapSeries/index.html?appid=048d65997322496a8bb6eea3efce4df2

NHERI DesignSafe-CI Recon Portal
https://www.designsafe-ci.org/recon-portal/

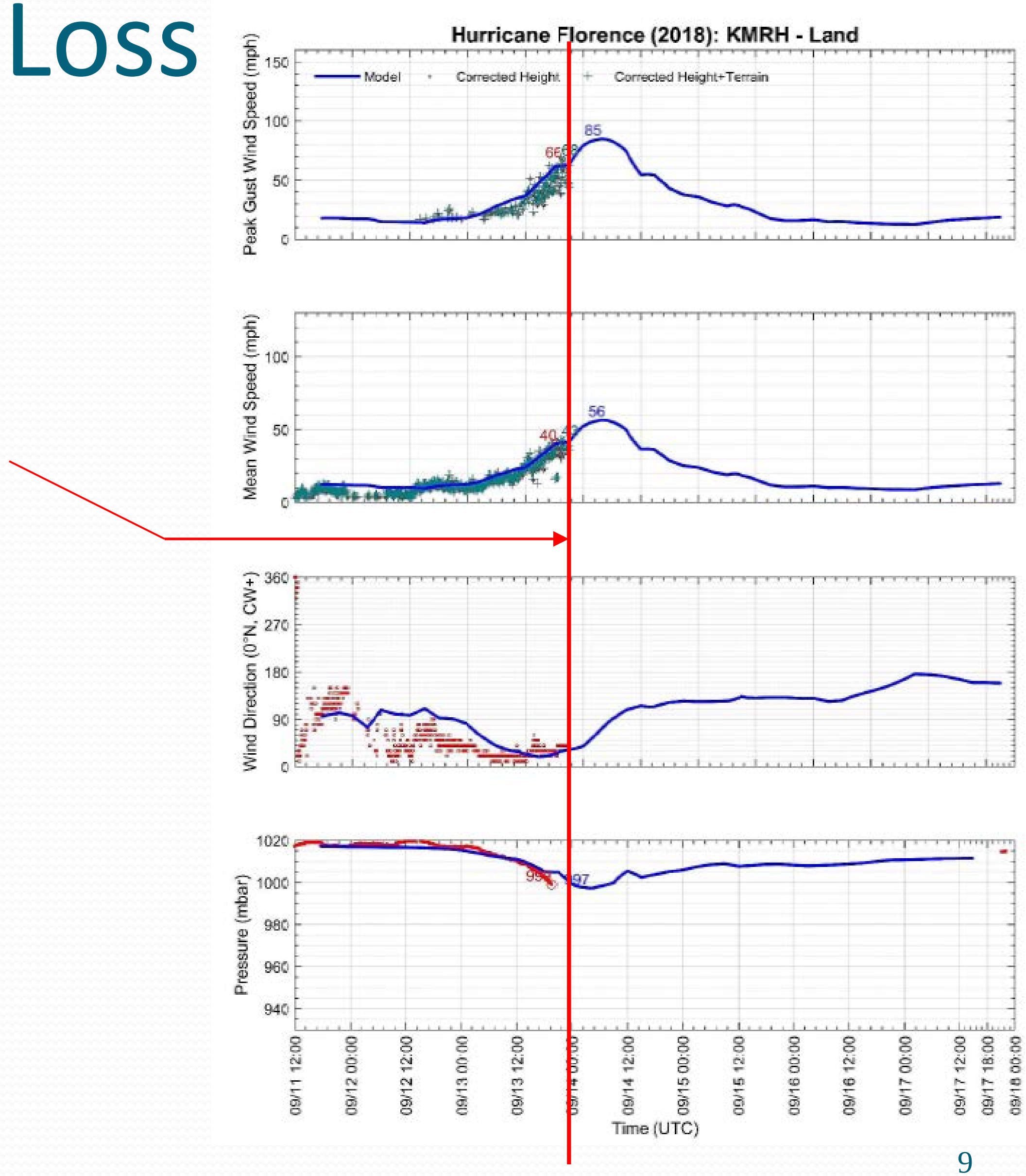
**Development of data collection sampling strategy and analysis of building performance during Hurricane Harvey**

(NSF-funded RAPID Award No. CMMI-1759996, Principal Investigator - Dr. David Roueche, Auburn University)



# Challenge -Data Loss

- Many ASOS stations failed to during Florence and Michael
- Problem has existed for decades

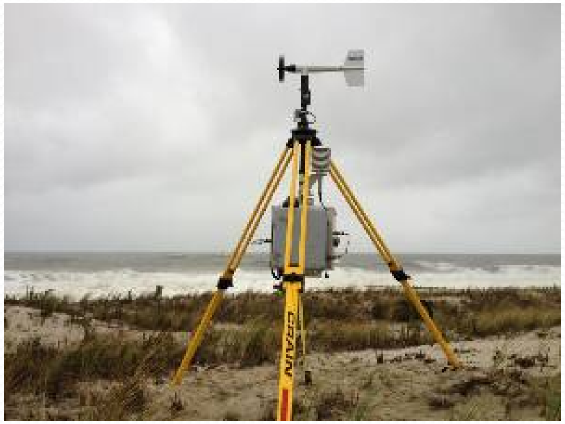


# Data Collection/Access Challenges

## Mobile Sensors

- University assets deployed but data behind paywall
  - Texas Tech University deployed 48 sticknets (2-m towers)
  - 45 reported in real time, but data access controlled by corporate sponsor

Source: Texas Tech University



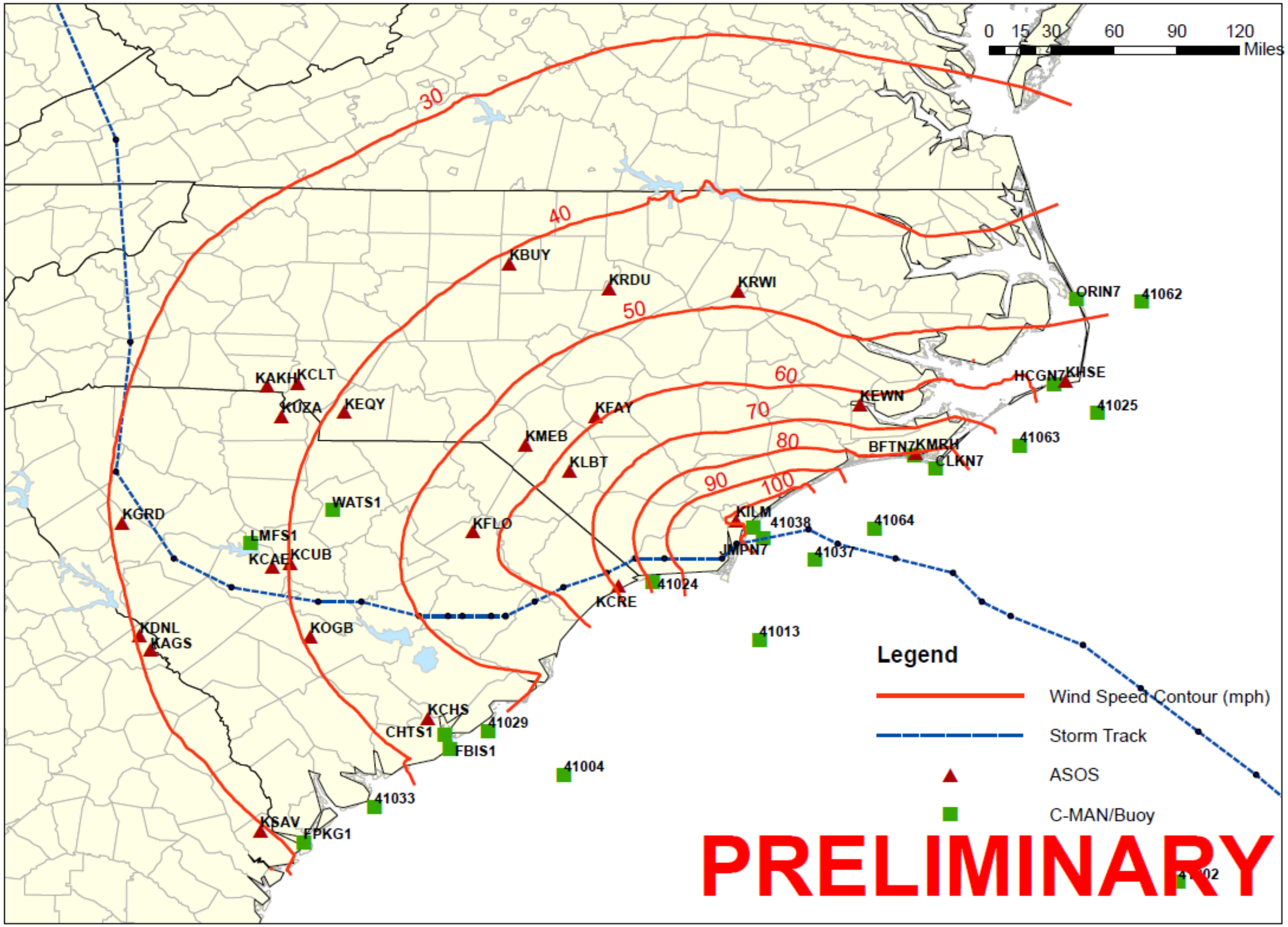
- Lack of funding limited deployment of mobile assets
  - University of Oklahoma only deployed one of its two radar trucks
- Potential New Data Source - USGS Rapid Deployment Gages (RDG)
  - Additional metadata needed to support rapid windfield assessments
  - Will meet with USGS to explore ways to improve

# Innovations for the Coming Year

**Leveraging work to be conducted for the NIST Technical Investigation of Hurricane Maria**

- Improved modeling procedure to better handle strongly asymmetric hurricane wind fields
- Formalized process for optimizing fit of the hurricane model to the observed data
  - based on experimental design techniques and statistical assessment of goodness-of-fit
  - include explicit quantification of uncertainty
  - partially automated process

# Hurricane Florence (1/2)




Hurricane Florence (2018): Preliminary Peak Wind Gust (mph)
Estimated 3-second gust wind speeds (mph) at 10m above ground over flat open terrain from ARA model fit to surface level observations using storm track and central pressure data from NHC through Public Advisory 73 and observations through 1800 UTC on 9/17/2018.
The maps have been produced for the National Institute of Standards and Technology under Contract 1333ND1 8PNB730488. Maps are subject to change. Created on: 9/17/2018

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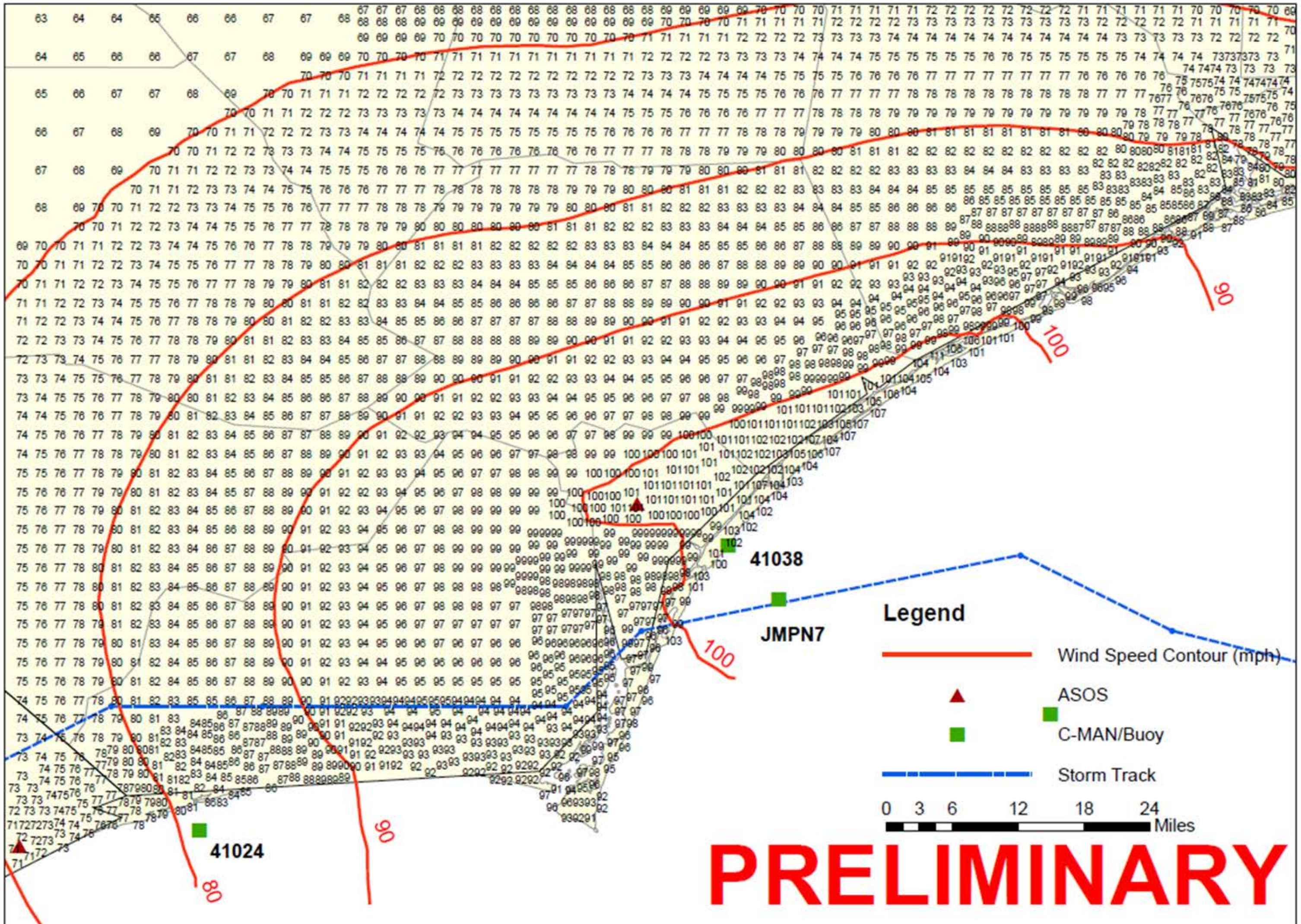
# Hurricane Florence (2/2)

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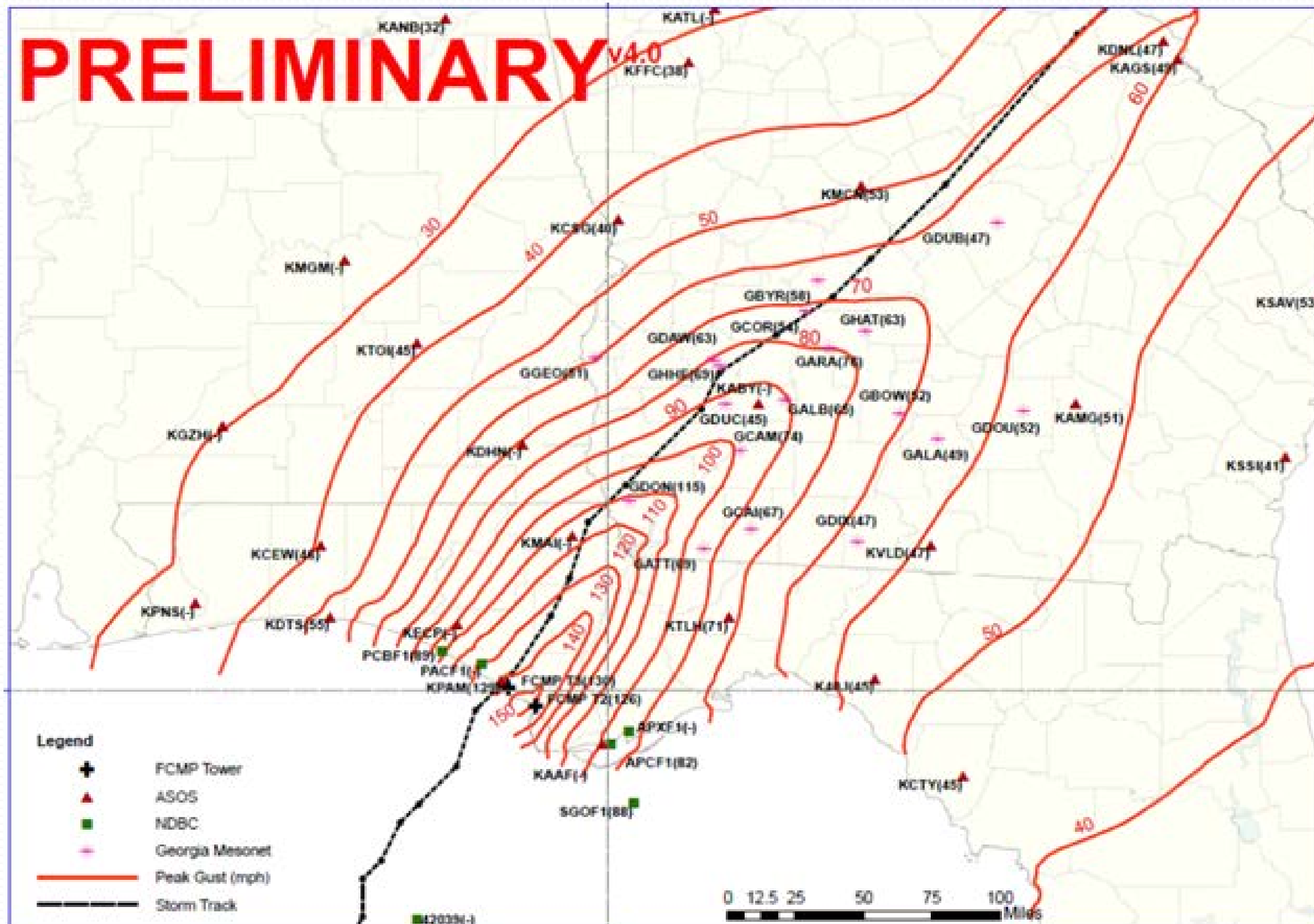
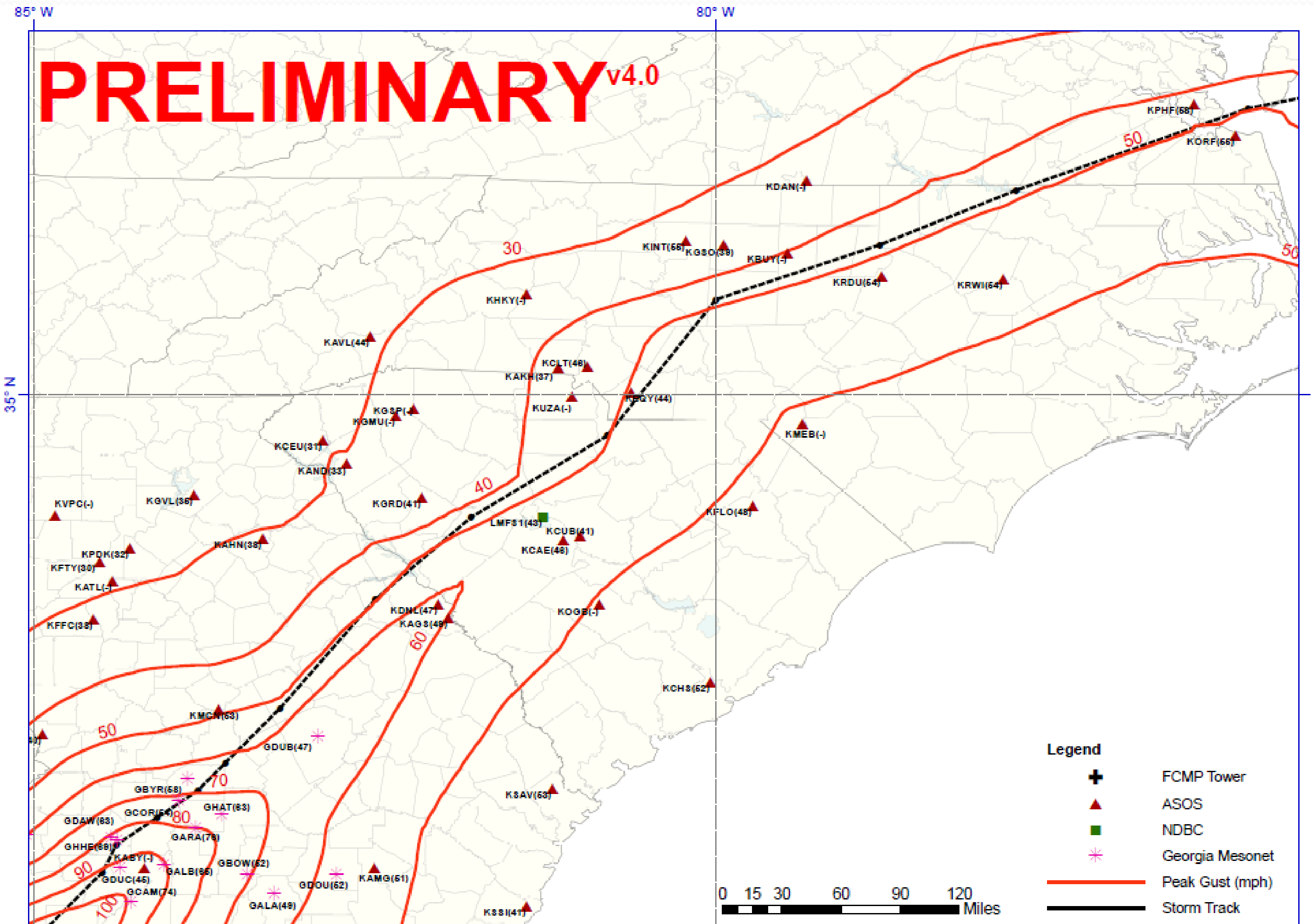
# Hurricane Michael (1/4)




Hurricane Michael (2018): Preliminary Peak Wind Gust (mph)

Estimated 3-second gust wind speeds (mph) at 10m above ground over flat open terrain from ARA model fit to surface level observations using storm track and central pressure data from NHC through Intermediate Advisory Number 22A and observations through 0600 UTC on 10/12/2018. The values of peak gust winds in mph are shown after station names; Values are not adjusted for station height or terrain; "-" means station failed before the arrival of the peak wind. The maps have been produced for the National Institute of Standards and Technology under Contract 1333ND19PNB730003. Maps are subject to change. Created on 10/29/2018

# Hurricane Michael (2/4)

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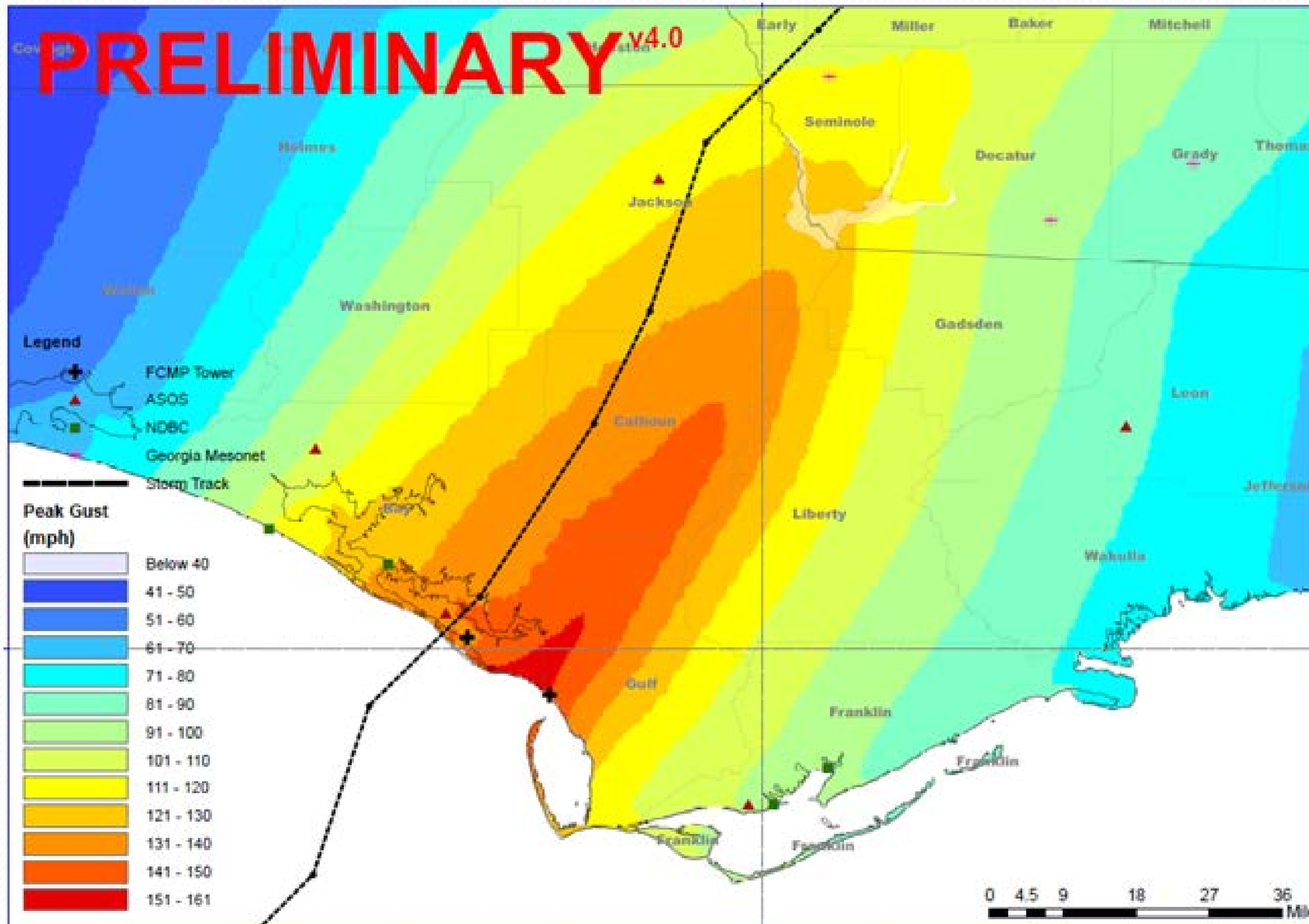
# Hurricane Michael (3/4)




Hurricane Michael (2018): Preliminary Peak Wind Gust (mph)

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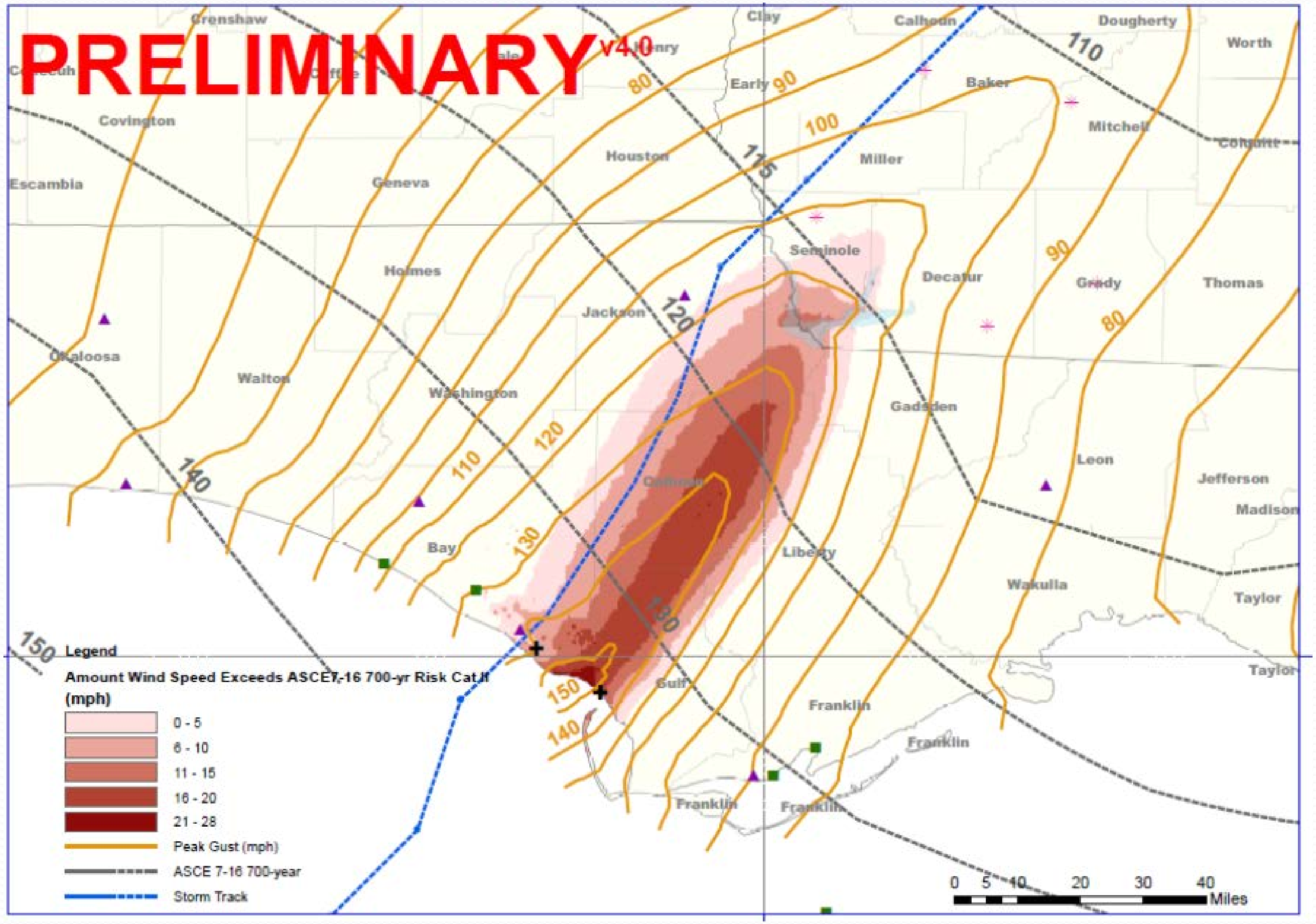
# Hurricane Michael (4/4)




Design Windspeed Exceedance for 700 Year MRI

# The Data Problem

The bigger and more intense the storm, the less hazard data available – the data hole

Hurricane Harvey – the 3 ASOS stations in the Rockport TX area near landfall all failed

Hurricane Irma – 34 of 66 ASOS and C-MAN Stations failed

# Hurricane Irma Station Locations


Wind Speed Sensors during Hurricane Irma (2017)

Station names beginning with the letter “K” are ASOS stations; data buoys and C-MAN stations are all located offshore or at the coast.

Map created on: 9/18/2017.

# Hurricane Irma Data Collection (1/3)

| Name | Lat | Long | Type | Data_Gust Wind | Data_Sustained Wind | Data_pressure |
|---|---|---|---|---|---|---|
| FWYF1 | 25.591 | -80.097 | C-MAN | C | C | C |
| KYWF1 | 24.556 | -81.808 | C-MAN | C | C | Failed |
| MLRF1 | 25.012 | -80.376 | C-MAN | Failed | Failed | Failed |
| NPSF1 | 26.132 | -81.807 | C-MAN | C | C | C |
| PLSF1 | 24.693 | -82.773 | C-MAN | C | C | C |
| SANF1 | 24.456 | -81.877 | C-MAN | Failed | Failed | Failed |
| VCAF1 | 24.711 | -81.107 | C-MAN | Failed | Failed | Failed |
| VENF1 | 27.072 | -82.453 | C-MAN | Failed | Failed | Failed |
| K40J | 30.072 | -83.574 | C-MAN | Failed | Failed | Failed |
| KAAF | 29.733 | -85.033 | ASOS | C | C | C |
| KABY | 31.536 | -84.194 | ASOS | Failed | C | C |
| KAGS | 33.37 | -81.965 | ASOS | Failed | C | C |
| KAHN | 33.948 | -83.327 | ASOS | C | C | C |
| KAMG | 31.536 | -82.507 | ASOS | C | C | C |
| KAPF | 26.153 | -81.775 | ASOS | Failed | Failed | Failed |
| KATL | 33.64 | -84.427 | ASOS | C | C | C |
| KBKV | 28.474 | -82.454 | ASOS | Failed | Failed | Failed |
| KCEW | 30.78 | -86.522 | ASOS | C | C | C |
| KCHS | 32.899 | -80.041 | ASOS | C | C | C |
| KCRG | 30.336 | -81.515 | ASOS | C | C | C |
| KCSG | 32.516 | -84.942 | ASOS | C | C | C |
| KCTY | 29.55 | -83.105 | ASOS | Failed | Failed | Failed |

C = Continuous data within +/- 24 hours of station peak

# Hurricane Irma Data Collection (2/3)

| Name | Lat | Long | Type | Data_Gust Wind | Data_Sustained Wind | Data_pressure |
|---|---|---|---|---|---|---|
| KDAB | 29.177 | -81.06 | ASOS | C | C | C |
| KDHN | 31.321 | -85.45 | ASOS | C | C | C |
| KDNL | 33.467 | -82.039 | ASOS | Failed | C | C |
| KDTS | 30.4 | -86.472 | ASOS | C | C | C |
| KEYW | 24.553 | -81.754 | ASOS | Failed | Failed | Failed |
| KFFC | 33.355 | -84.567 | ASOS | N | C | C |
| KFLL | 26.072 | -80.154 | ASOS | Failed | Failed | Failed |
| KFMY | 26.586 | -81.864 | ASOS | Failed | Failed | Y |
| KFPR | 27.498 | -80.377 | ASOS | C | C | C |
| KFTY | 33.779 | -84.521 | ASOS | Failed | C | C |
| KFXE | 26.197 | -80.171 | ASOS | Failed | Failed | C |
| KGIF | 28.062 | -81.754 | ASOS | C | C | C |
| KGNV | 29.69 | -82.272 | ASOS | C | C | C |
| KGZH | 31.416 | -87.044 | ASOS | Failed | C | C |
| KHWO | 25.999 | -80.241 | ASOS | Failed | Failed | Failed |
| KJAX | 30.494 | -81.693 | ASOS | C | C | C |
| KLEE | 28.821 | -81.81 | ASOS | C | C | C |
| KMAI | 30.836 | -85.184 | ASOS | Failed | C | C |
| KMCN | 32.688 | -83.654 | ASOS | C | C | C |
| KMCO | 28.434 | -81.325 | ASOS | C | C | C |
| KMGM | 32.301 | -86.394 | ASOS | Failed | Failed | Failed |
| KMIA | 25.824 | -80.3 | ASOS | Failed | Failed | C |

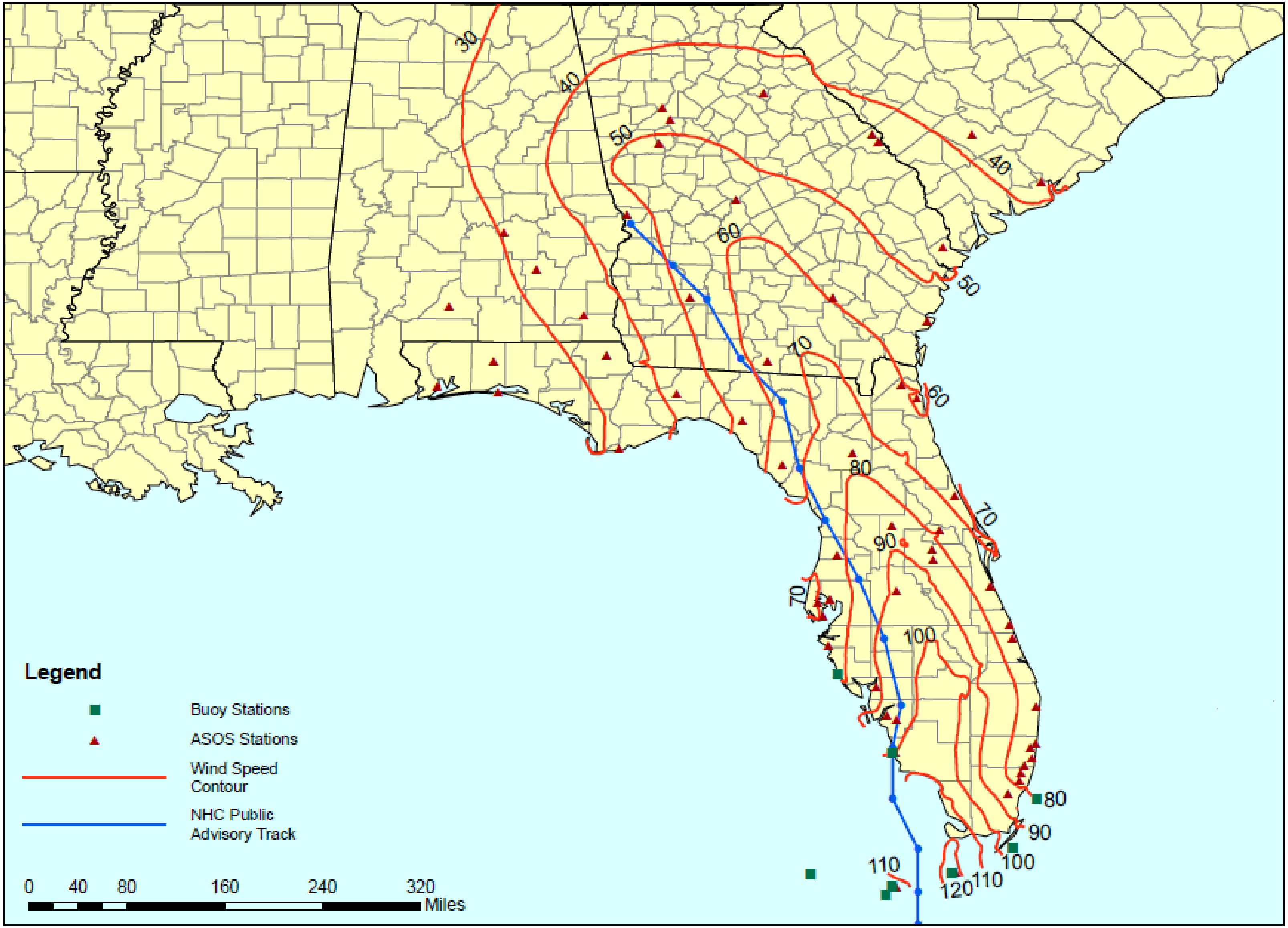
C = Continuous data within +/- 24 hours of station peak

# Hurricane Irma Data Collection (3/3)

| Name | Lat | Long | Type | Data_Gust Wind | Data_Sustained Wind | Data_pressure |
|---|---|---|---|---|---|---|
| KMLB | 28.103 | -80.646 | ASOS | Failed | Failed | Failed |
| KMTH | 24.726 | -81.052 | ASOS | Failed | Failed | Failed |
| KOGB | 33.462 | -80.858 | ASOS | C | C | Failed |
| KOPF | 25.907 | -80.28 | ASOS | Failed | Failed | Failed |
| KORL | 28.545 | -81.333 | ASOS | C | C | C |
| KPBI | 26.685 | -80.099 | ASOS | C | C | C |
| KPGD | 26.917 | -81.991 | ASOS | C | C | C |
| KPIE | 27.911 | -82.688 | ASOS | C | C | C |
| KPMP | 26.25 | -80.108 | ASOS | Failed | Failed | C |
| KPNS | 30.473 | -87.188 | ASOS | C | C | C |
| KRSW | 26.536 | -81.755 | ASOS | C | C | Failed |
| KSAV | 32.119 | -81.202 | ASOS | C | C | C |
| KSFB | 28.78 | -81.244 | ASOS | Failed | Failed | C |
| KSPG | 27.765 | -82.627 | ASOS | C | C | C |
| KSRQ | 27.401 | -82.559 | ASOS | C | C | C |
| KSSI | 31.252 | -81.391 | ASOS | Failed | Failed | Failed |
| KTLH | 30.393 | -84.353 | ASOS | C | C | C |
| KTMB | 25.648 | -80.433 | ASOS | Failed | Failed | C |
| KTOI | 31.861 | -86.012 | ASOS | Failed | Failed | N |
| KTPA | 27.961 | -82.54 | ASOS | C | C | C |
| KVLD | 30.782 | -83.277 | ASOS | Failed | Failed | Failed |
| KVRB | 27.656 | -80.418 | ASOS | Failed | Failed | Failed |

C = Continuous data within +/- 24 hours of station peak

# Hurricane Irma Windfield




Hurricane Irma (2017): Preliminary Peak Wind Gust(mph)

Estimated 3-second gust wind speeds (mph) at 10 m above ground over open terrain from ARA model fit to surface level observations using NHC storm track and central pressure data through Forecast/Advisory 52 at 0300UTC on 9/12/2017.

Map is subject to change. Created on: 9/18/2017.

# A Persistent Problem!

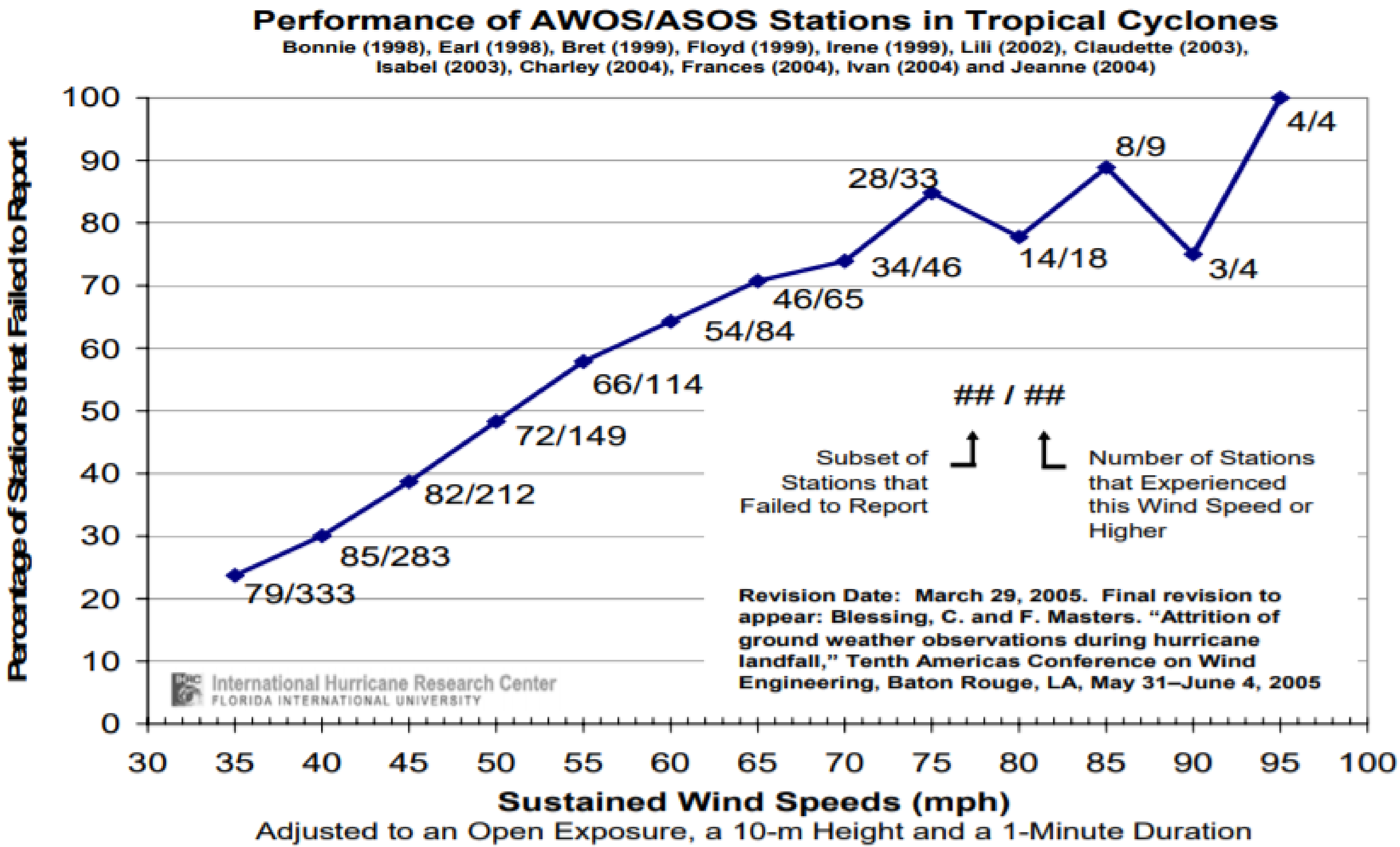



*Figure 3. Percentage of stations that failed to report during twelve tropical cyclone landfalls during 1998-2004*

(Masters and Blessing, 2005)

# Solutions

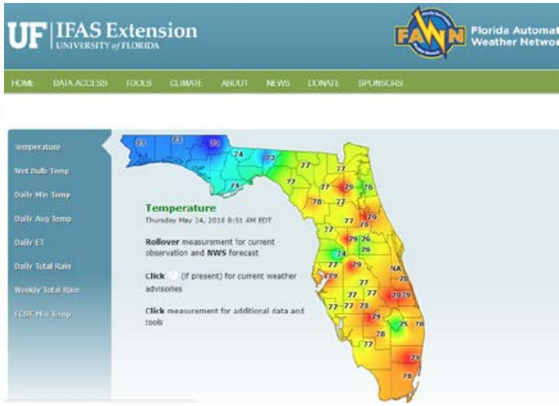
1. Harden existing observation systems
   - See NWIRP Strategic Plan Objective 2 subsection on Hardening Observing Systems
2. Increase the number of observation assets
   - Fixed
   - Mobile
3. Develop next generation of sensors
   - In situ
   - Remote

# 1. Harden Existing Observation Systems

- Identify the problem(s) with ASOS and other systems
  - Power?
  - Communication?
  - Other?
  - Has this problem been studied by NOAA?
- Identify potential solutions
  - Technical issues
  - Funding issues

# 2. Increase Number of Observation Assets

- Fixed
  - Leverage existing observing systems
    - local mesonets
    - observing systems with other primary purposes
  - Challenges
    - data collection protocols, data formats, metadata




- Mobile
  - Leverage existing federal observing capabilities
    - NSSL, Other NOAA, USGS, Other Federal?
  - Digital Hurricane Consortium and other
    - OFCM leads coordination efforts in real time
    - Need for off-season planning, training, coordination, development/adoption of common data formats/management

# 3. Develop Next Generation of Sensors

- Rapid advances in sensor, communication, power harvesting, technologies would seem to provide opportunity to develop low cost sensors that could be deployed en masse
- NIST 2018 Disaster Resilience FFO included the following focus area:
  - development of new sensors and methods to collect spatiotemporal data on windstorm phenomena, including surface-level winds and near ground velocity profiles, atmospheric pressure, and storm surge flooding and velocity over what is normally dry land (water level, current, and waves).
  - Proposals currently under review
- Any NSF or NOAA programs in sensor development?

# NIST Rapid Response Windfield Estimates for Hurricanes Florence & Michael

## Questions?

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