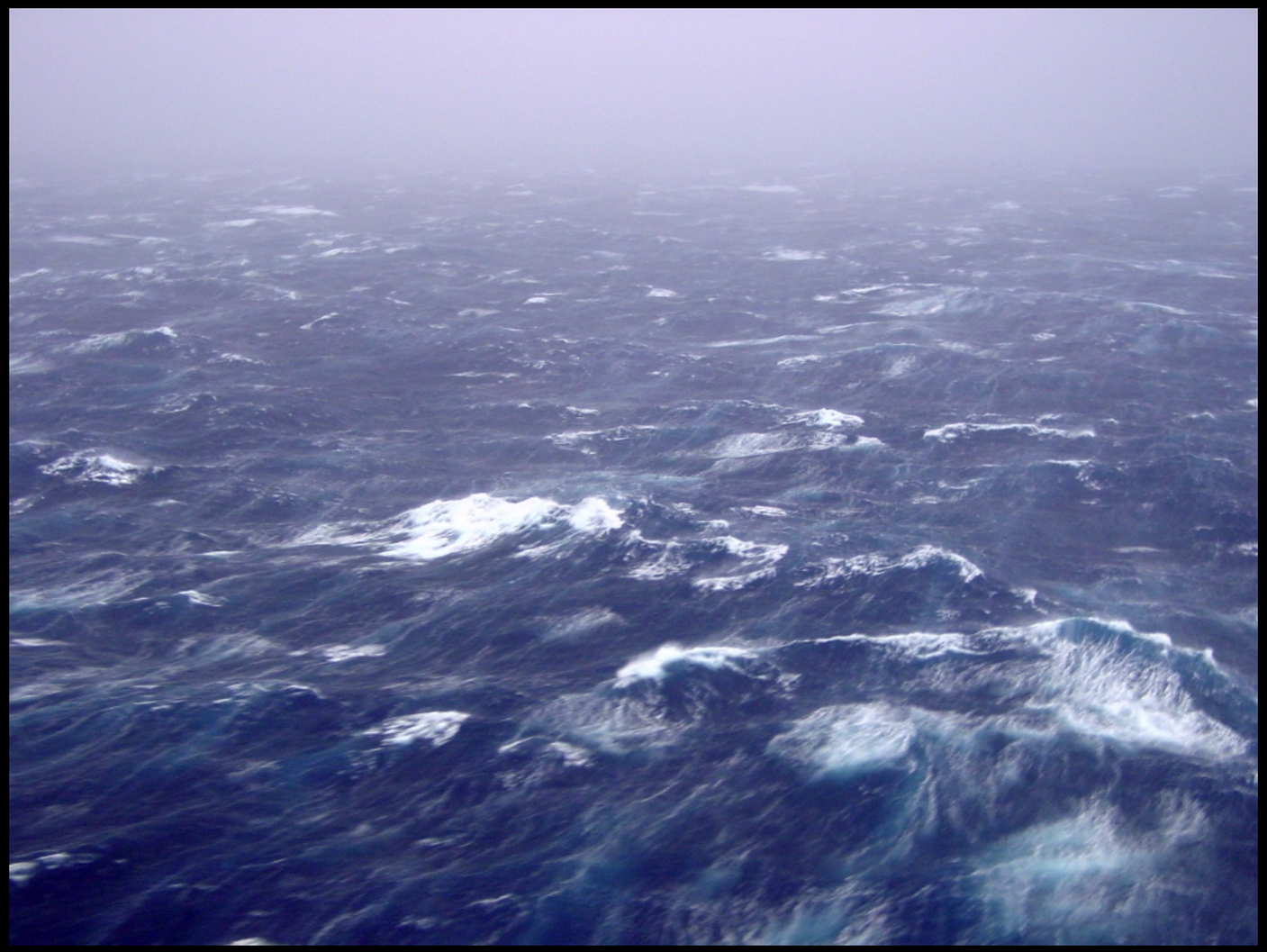
Design Conditions for the Hurricane Met-Ocean Environment: Wind shear

Mark D. Powell*
Florida State University Center for Ocean-Atmospheric Prediction Studies
*Formerly NOAA Hurricane Research Division



Inter-Agency Agreement

NOAA's Atlantic Oceanographic and Meteorological Laboratories

CIMAS Cooperative Institute for Marine and Atmospheric Studies

MIAMI FIU FAU NSU UF THE FLORIDA STATE UNIVERSITY USF

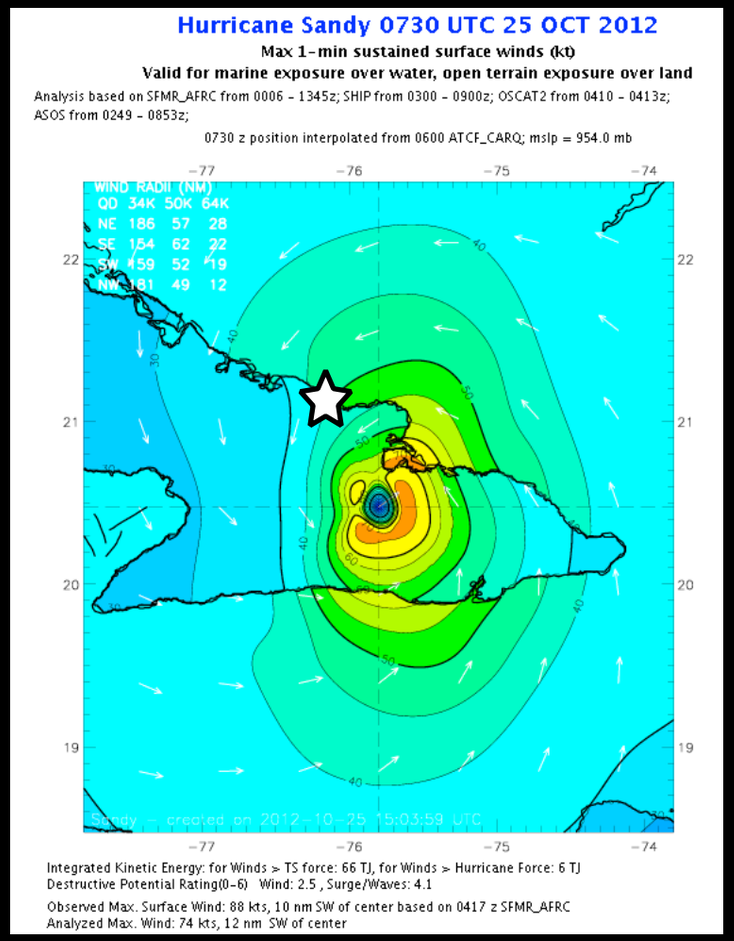
Center for Ocean-Atmospheric Prediction Studies

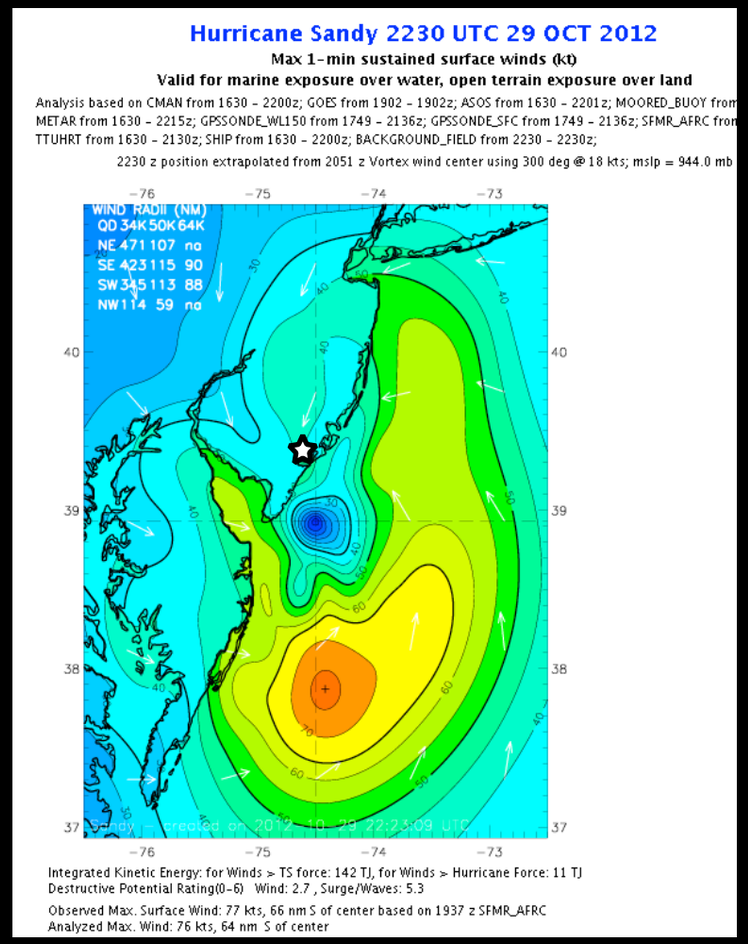
Department of Energy
Office of Energy Efficiency and Renewable Energy

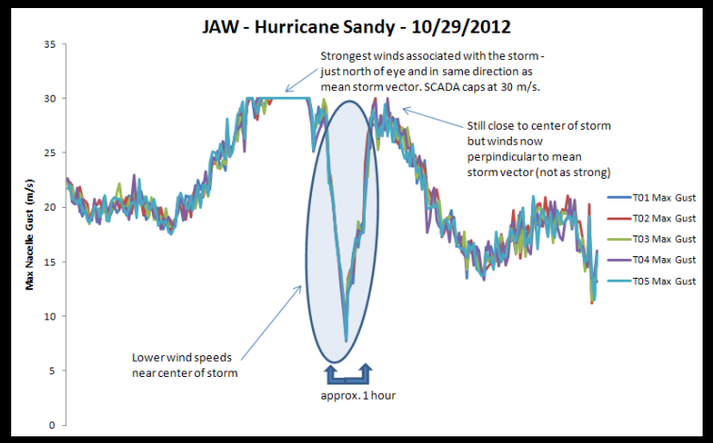
Hurricane Sandy

Gibara wind farm in Holguin Cuba

Jersey Atlantic wind Farm (Five 1.5 MW turbines)



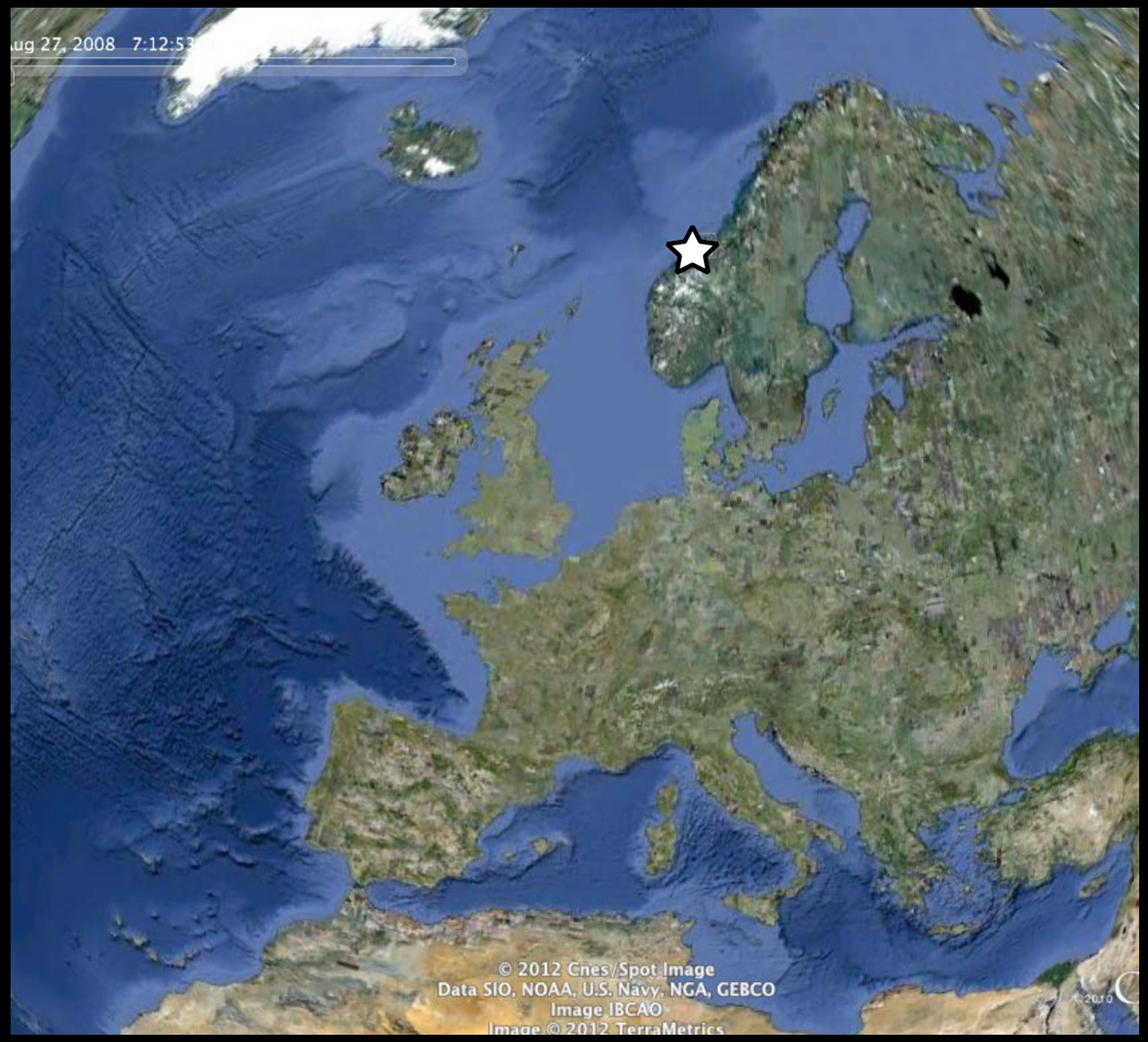




- Design Conditions
  - Current Standards
    - IEC 61400-3
    - DNV-RP-C205
    - API RP 2A-WSD

Hurricane wind and wave conditions can cause widespread damage in the Gulf of Mexico

- Oil/Gas-based standards
  - Reference Norwegian sea data for wind profile and turbulence assessments
  - Froya location (63 N) data applicable to hurricane areas?
  - Winds in Froya study did not reach hurricane conditions

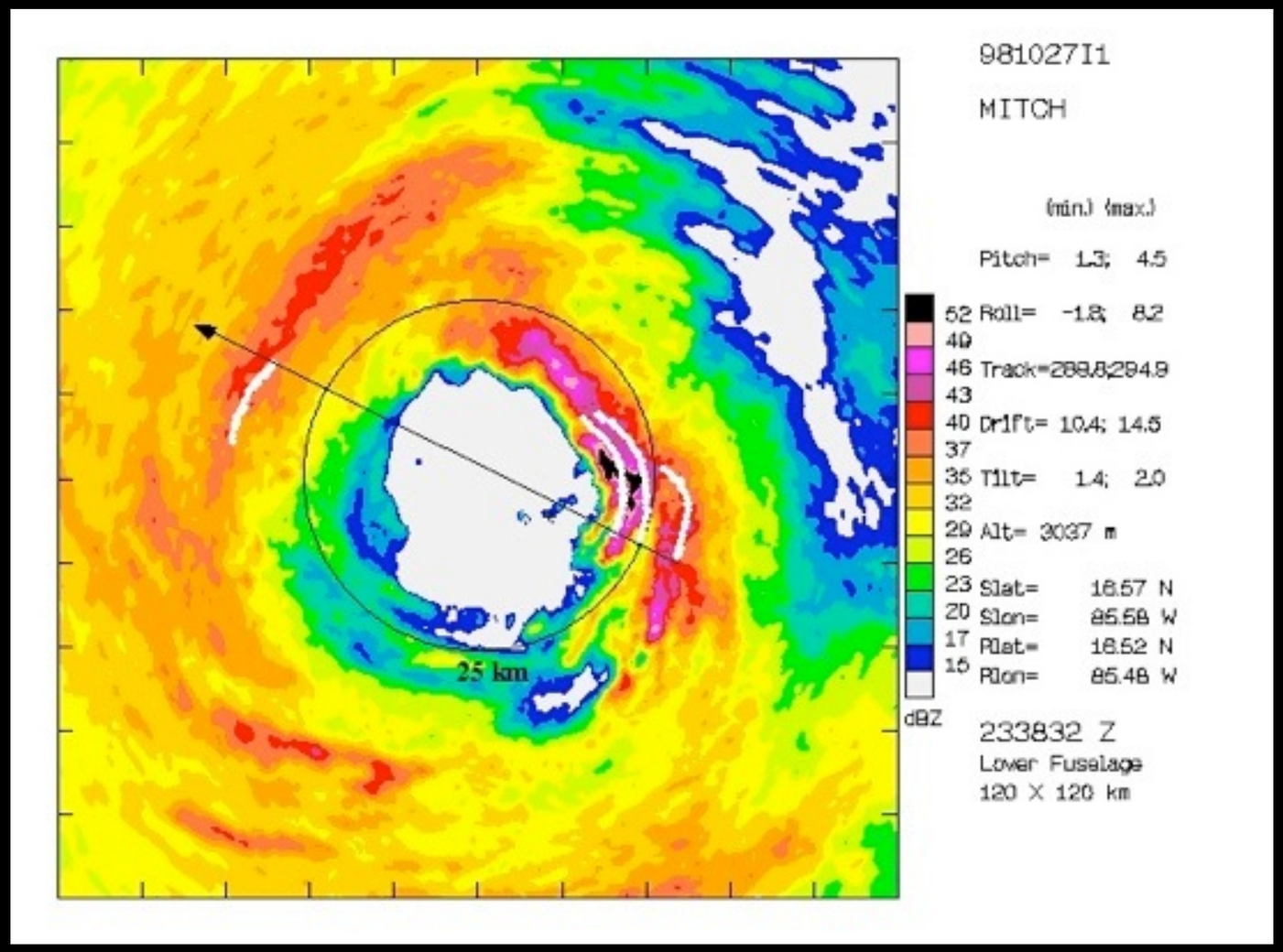


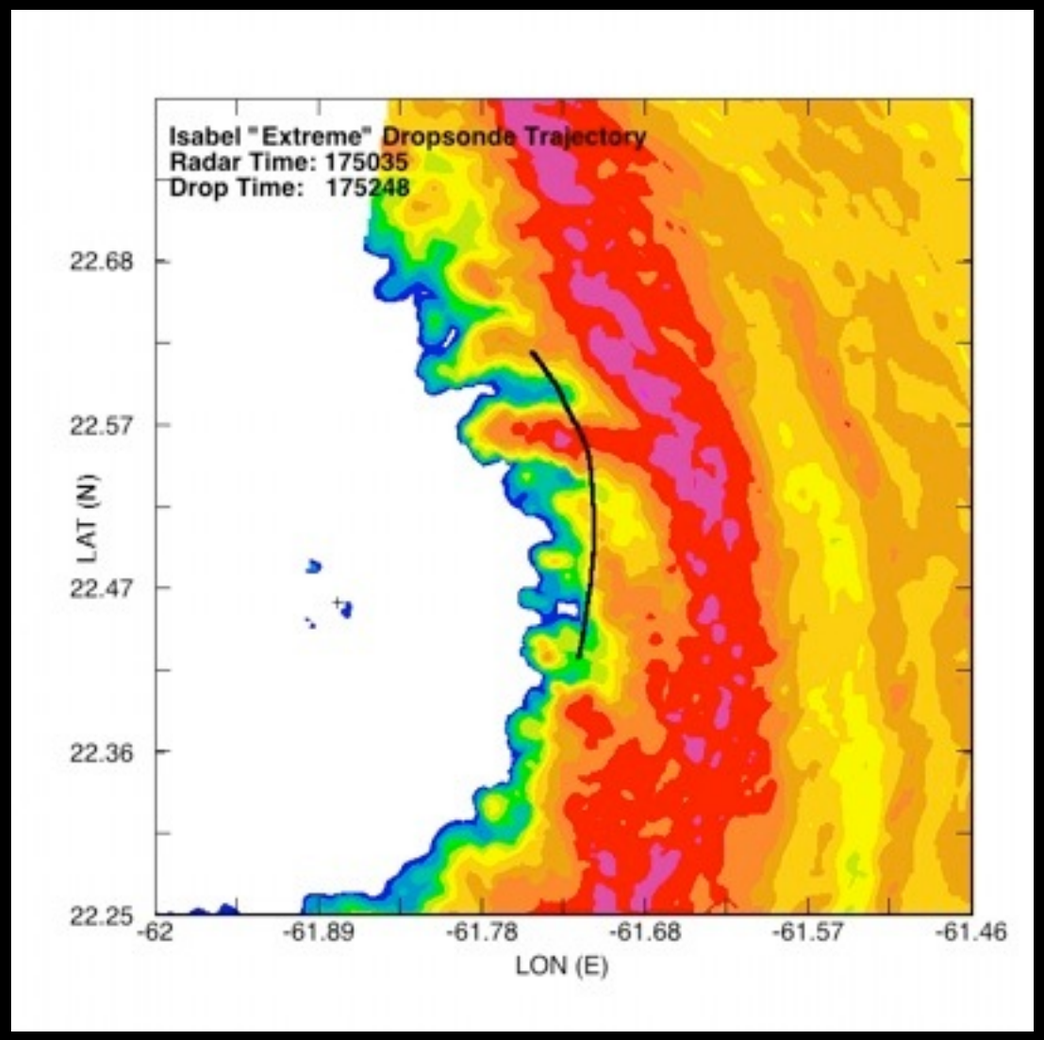
Standards out of date with latest research

- IEC 61400-3 12.3 Assessment of wind conditions, DNV-RP-C205
  - IEC: “The roughness of the sea surface increases with wind speed and thus the turbulence intensity will increase as a function of wind speed.”
- ABS: Offshore Wind Turbine Installations, API RP 2A-WSD
  - Profile Power law (Alpha 0.14) implies constant roughness with wind speed (equivalent to open terrain over land),
  - *“For strong wind conditions, such as a hurricane”* Profile log law (Froya) has no roughness dependence
  - Turbulence intensity increase with wind speed, no roughness dependence

GPS sonde probes sample wind profiles

GPS Sonde Trajectories



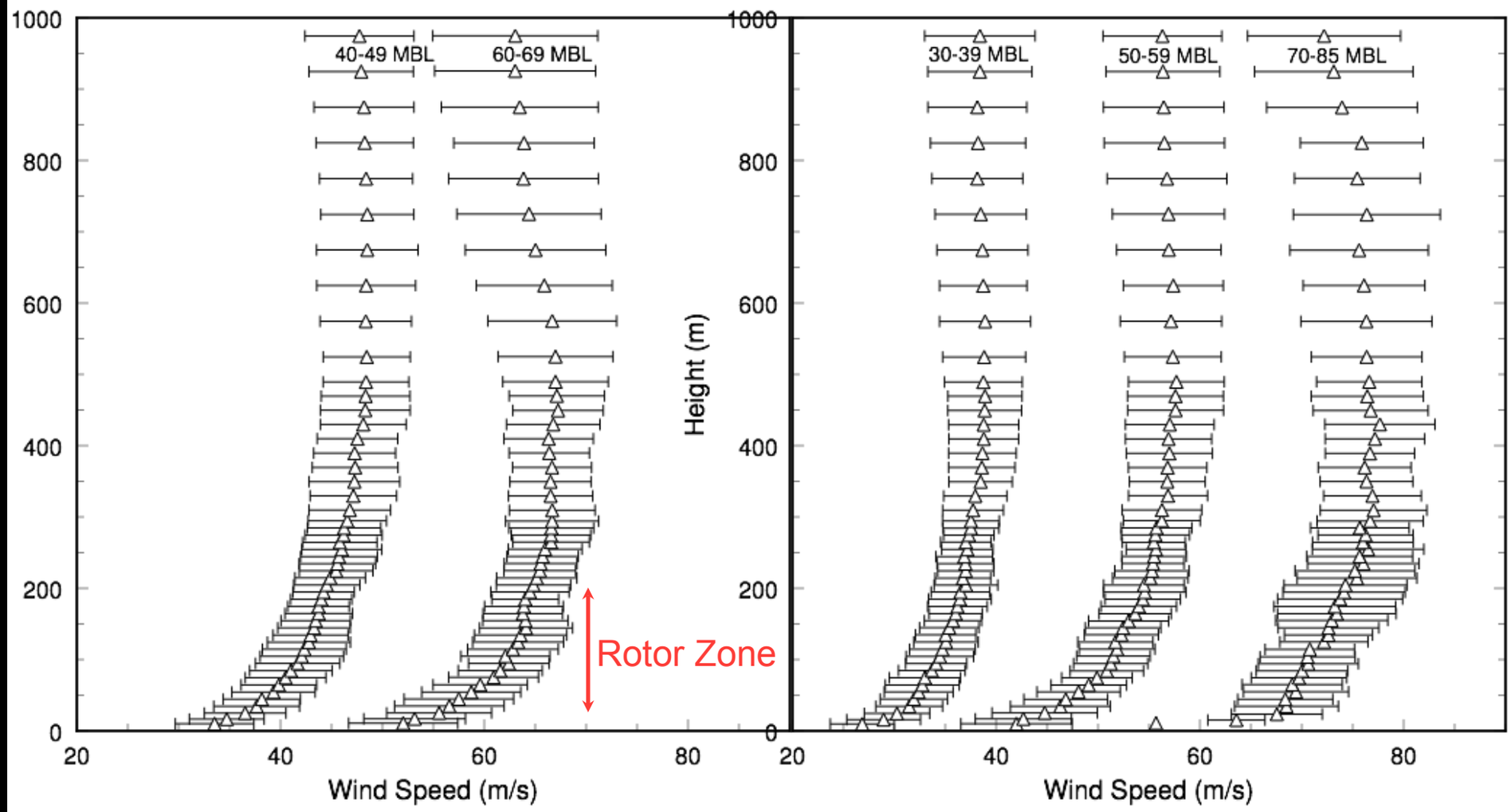


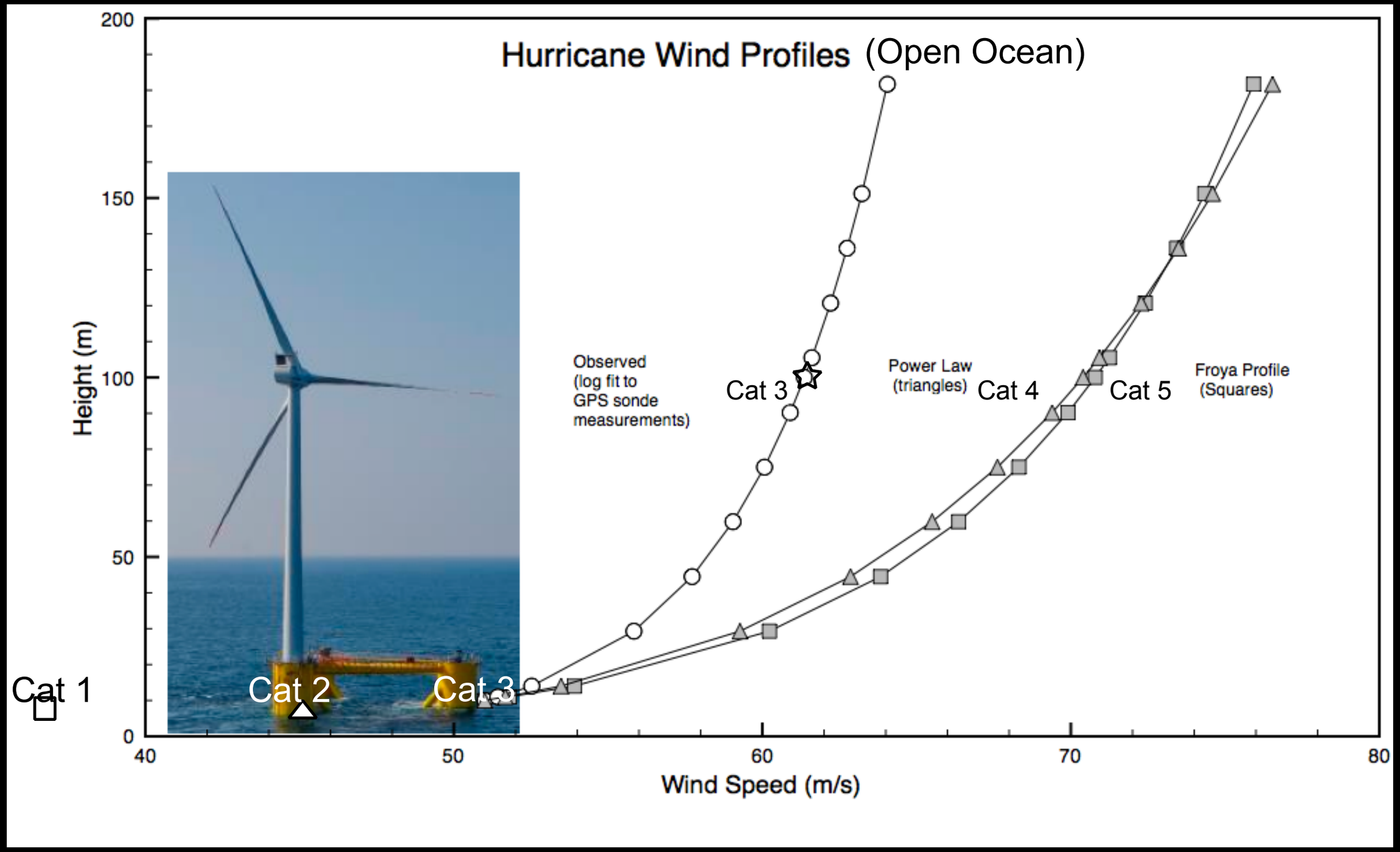
Radar images courtesy of Michael Black, AOML

Thousands of sondes in hurricanes over the past decade

Open ocean mean wind profiles

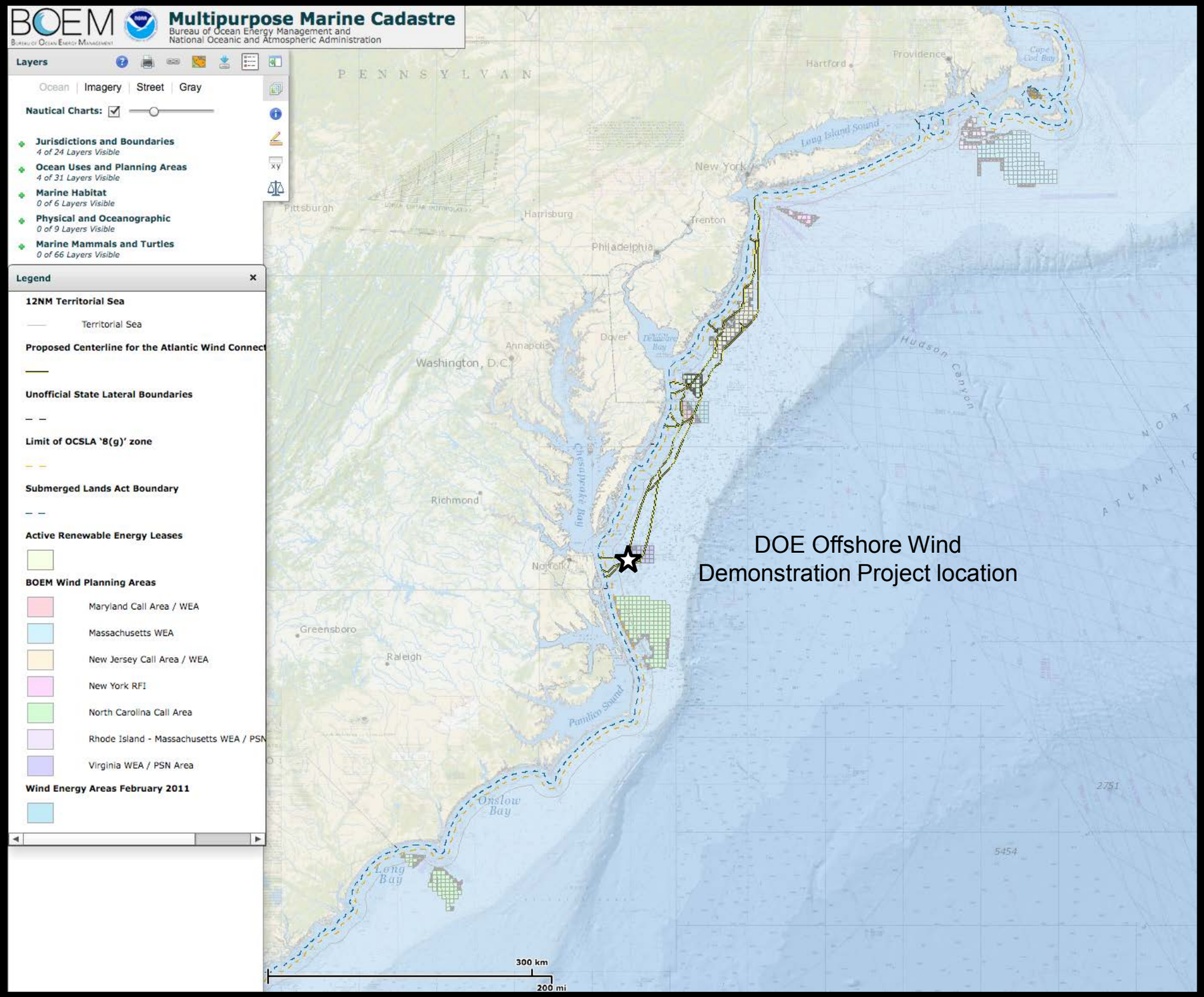
Wind profiles exhibit less shear in extreme winds
Roughness levels off and then decreases with wind speed





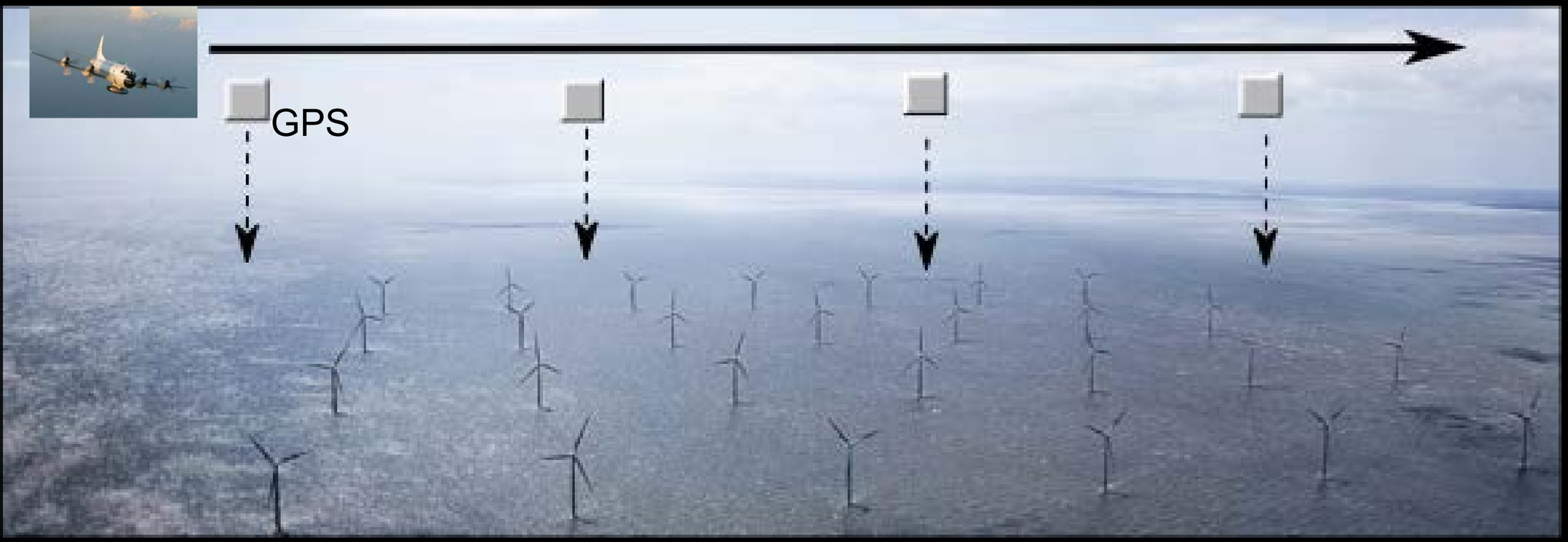
Extrapolate from Surface: winds 14% too high
Extrapolate from 100 m downward, Power law 13%, Froya 30% too low

Wind farms will be in coastal waters
Do open ocean conditions still apply?



M. Powell, Webinar Hurricane MetOcean Design

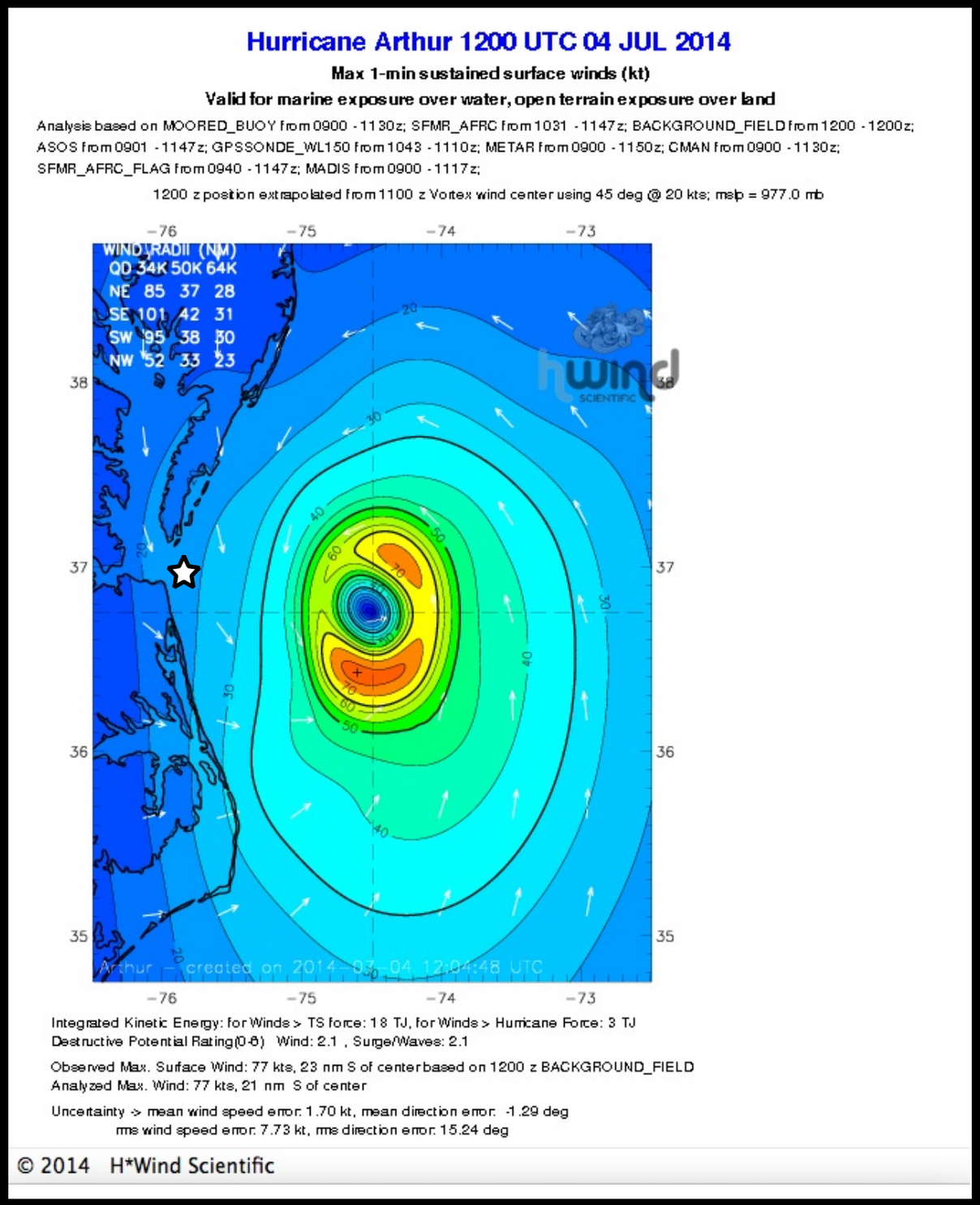
Collect data on coastal hurricane design conditions



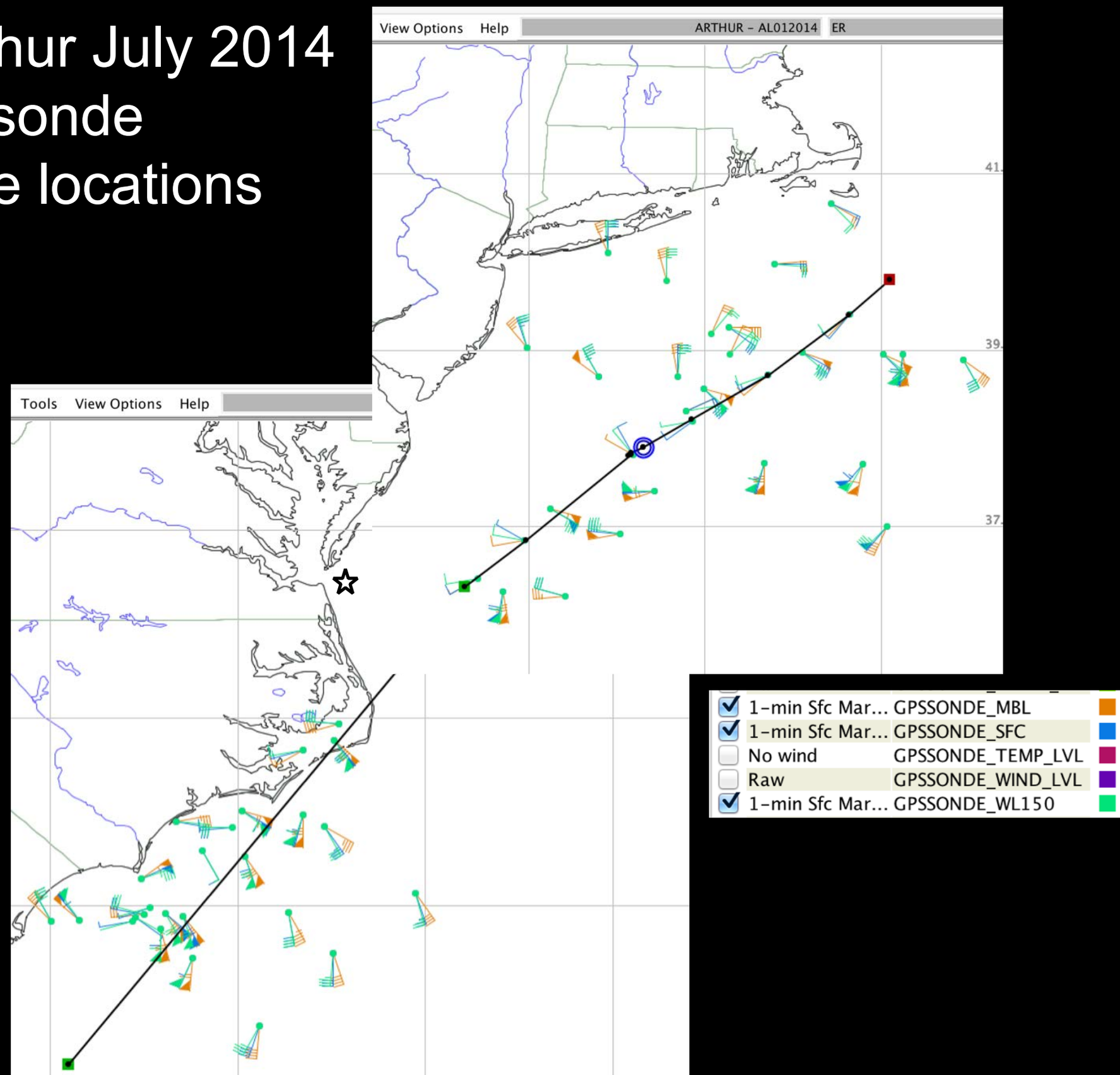
Schematic of NOAA P3 “piggyback” flight pattern showing hypothetical wind farm fly-by with expendable launches at a 2 km interval for 20 km.

Photo: Dong Energy “Gunfleet Sands 1” farm off SE England.

Hurricane Arthur July 2014



Hurricane Arthur July 2014
GPS sonde
wind profile locations



Postprocessed Sondes within 500 km of storm center

Hurricanes

Dennis 1999
Floyd 1999
Isabel 2003

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Thanks!

Photo: Eranti Engineering Oy http://www.erantiengineering.fi/pilot-wind-turbine.htm