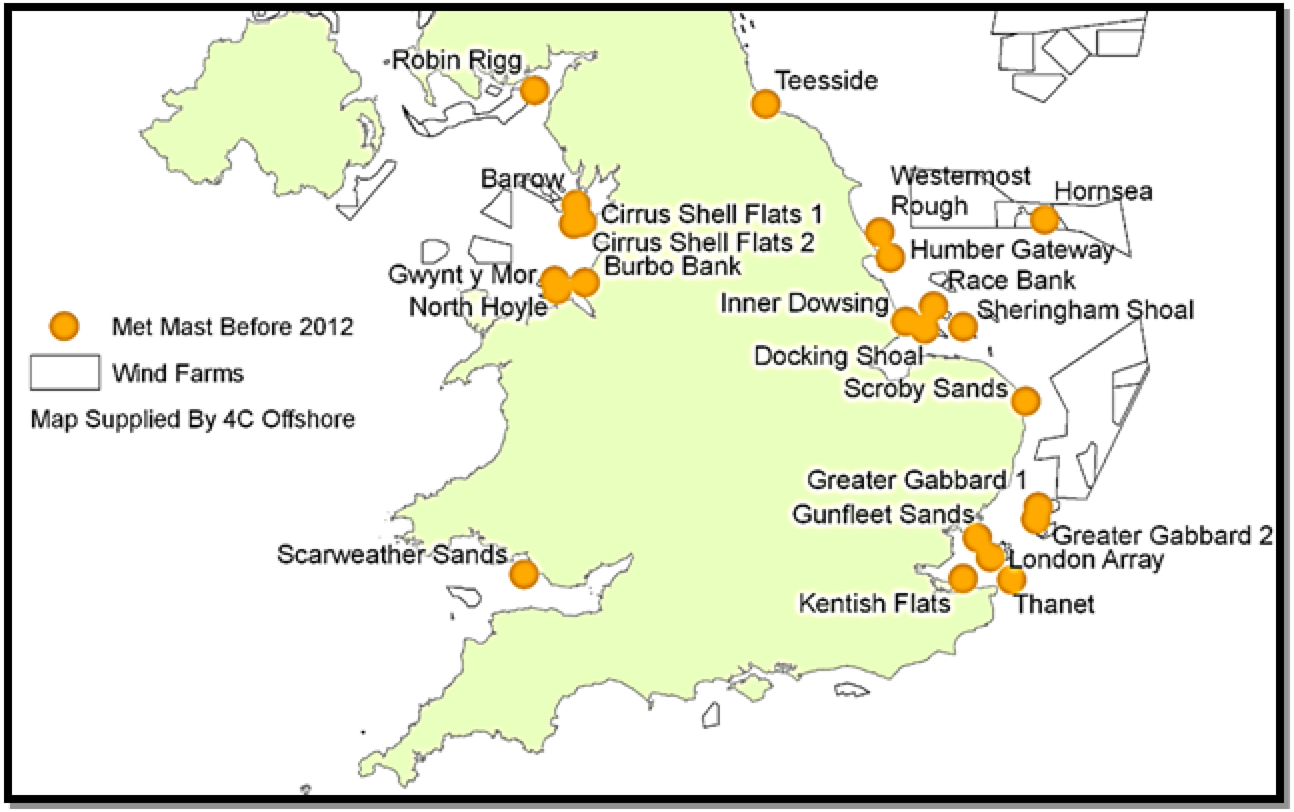
The WindSentinel™

Offshore Wind Resource Assessment Buoy

The WindSentinel™

The Need:

Masts in 30-50m water depth - $15 million



The WindSentinel™

- AXYS NOMAD buoy design supporting a Vindicator® simultaneous pulse LiDAR
- Standard system contains full meteorological and ocean data, including waves
- System capable of supporting a full environmental sensor assessment suite, including microwave temperature sensor, water quality, and bat and bird sensors
- Designed for minimum 10m depths up to 500m and beyond
- Powered by 40 lead acid batteries, charged by 2 x 210w solar panels, 1Kw wind turbine and a back-up diesel generator

The WindSentinel™

- Capable of operating in 15m significant waves with over 60 years of proven survivability
- Can be towed by a tug boat or on the deck of a ship or barge
- 3 - 6 ton mooring

Power Supply

- 40 lead acid batteries
- 2 X 210W solar panels
- Wind Turbine
- Diesel Generator
- 940 gallons of diesel fuel

Why So Much Power?

» Full met ocean sensor suite
» LiDAR – 120 W continuous

What can go wrong?

Turbine damage in hurricane conditions

The Vindicator® III

» The world's only commercially available simultaneous pulsed LiDAR - manufactured by Optical Air Data Systems (OADS)

- No moving parts
- Designed for deployment in a hostile environment

» Three beams pulsed simultaneously 1,000 times a second averaged to one second data

» Attitude Heading and Reference System tracks angular motion and direction to correct wind speed and direction for each pulse back to orthogonal axis

The Vindicator® III

» No mechanical compensation

» Buoy heave can be post processed out of wind speed

» Enables deployment on a free-floating platform

» Initially proven by AXYS at Race Rocks off the coast of British Columbia, October, 2009

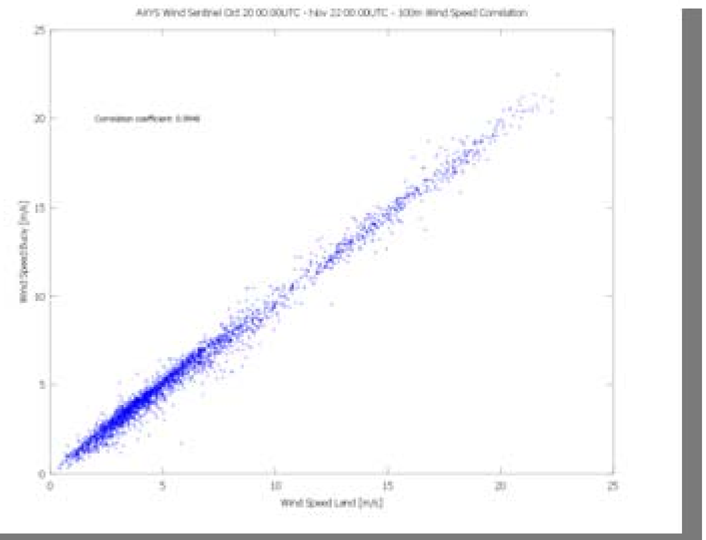
Validation

<u>Results of Race Rocks Trial</u>

- » Wind Speed Correlation at 150m:
  - Slope – 0.967
  - Offset – 0.161
  - R^2 – 0.99
- » GL-Garrad Hassan Review & Conclusion:

Floating LiDAR mean wind speed agreed to within 2% of the reference LiDAR

- » Specifically designed so that sea state has minimal impact on correlation quality
- » Full paper and raw data available for review
- » Other data available from Grand Valley State University



Validation

<u>Testing to take place in 2013</u>

- » DTU – Vindicator® III test to DTU and NORSEWiND standards: *March - July*
- » Fishermen’s Energy – GL-Garrad Hassan study off Atlantic City: *Mid March*
- » US Navy – DNVKEMA study off California: *September*

Track Record

<u>4 Deployments to date</u>

1. Race Rocks AXYS Trial: October – November 2009
2. GVSU – US Department of Energy funded research
   - » Deployed and redeployed three times between October 2011 and December 2012, including 36 miles offshore on Lake Michigan

Track Record

<u>4 Deployments to date</u>

3. Fishermen's Energy of New Jersey - Private developer wind resource assessment
   » Initial deployment February 2012
4. National Cheng Kung University (NCKU)
   » Deployment May 2013

Track Record

» No significant issues encountered despite the system having been deployed during Hurricane Sandy and the loss of wind turbine. Full reports available.

» 100% data availability during all deployments

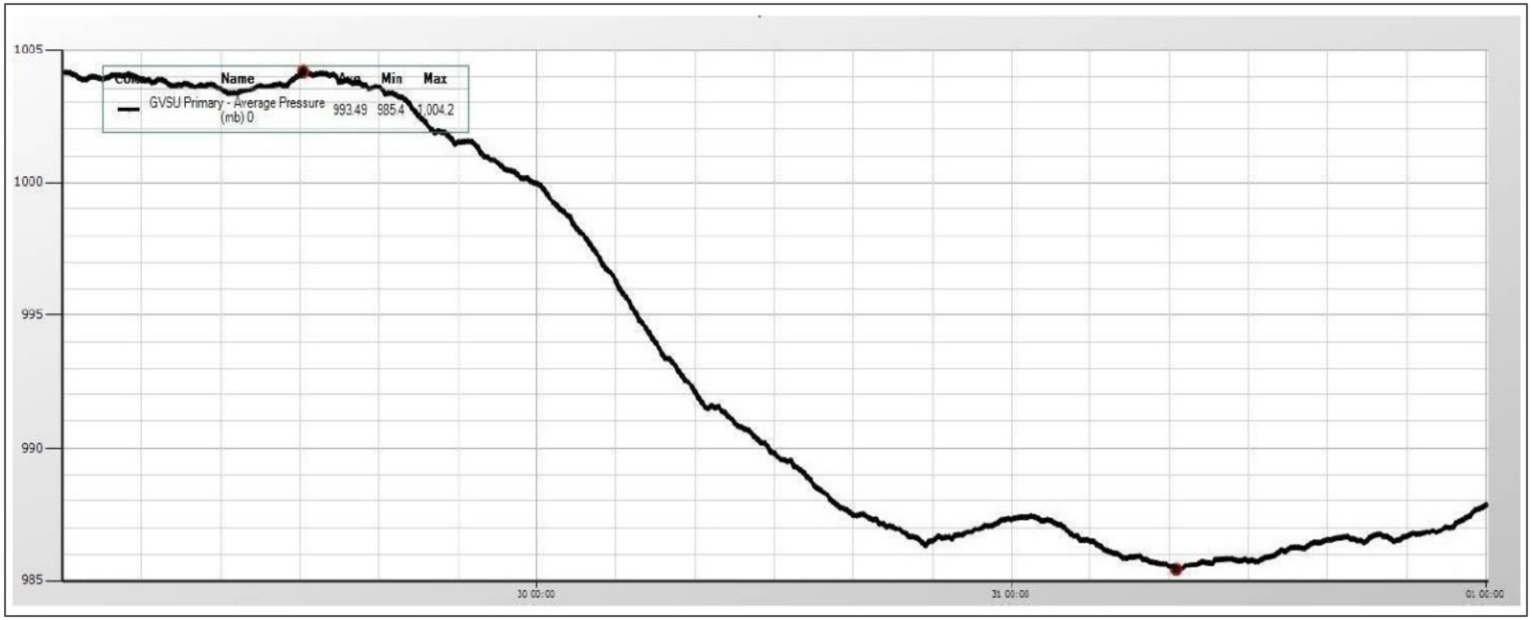
- Both at 1 second and 10 minute average levels

» Data quality

- Ranging from 85% to 97% acceptable data as per sensor criteria


Hurricane Sandy

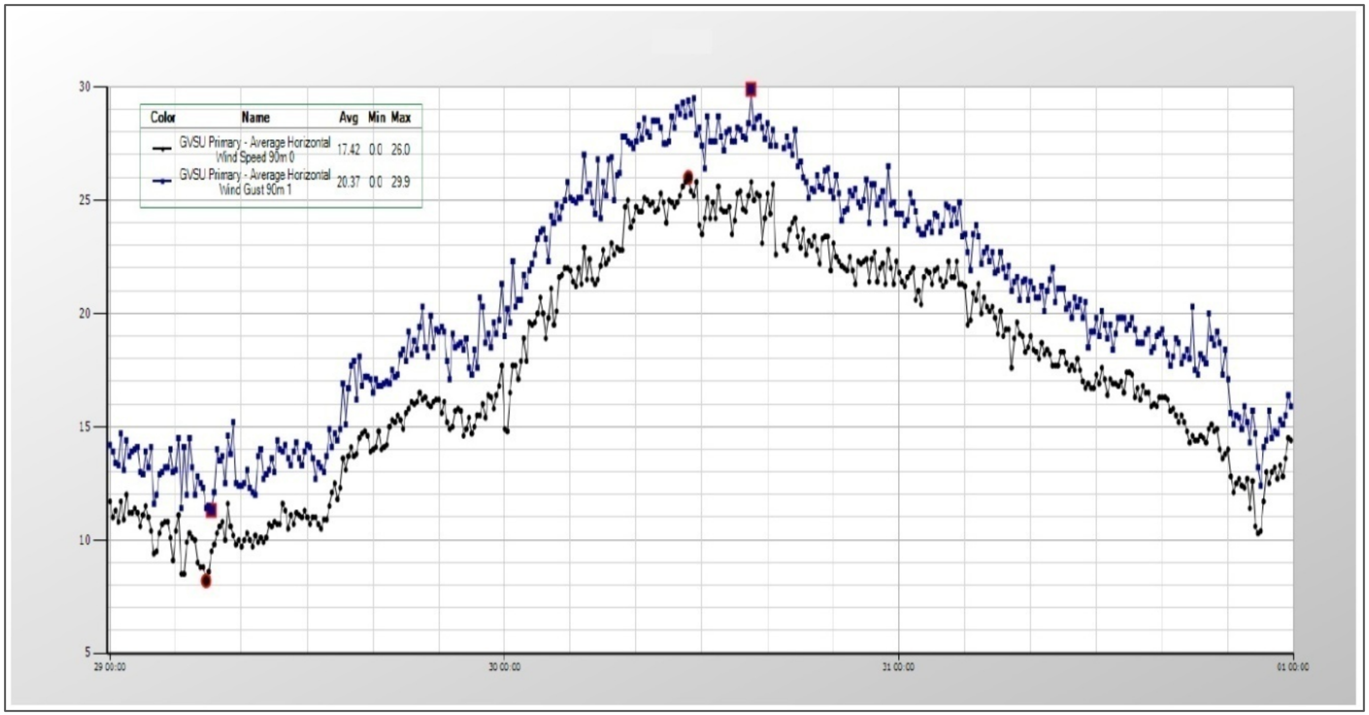
On October 30th, 2012, Hurricane Sandy reached the GVSU WindSentinel™ deployed at the center of Lake Michigan, 36 miles offshore. The WindSentinel™ recorded wind and Metocean data for the entire event.



Air Pressure; October 29th – November 1st, 2012

Hurricane Sandy

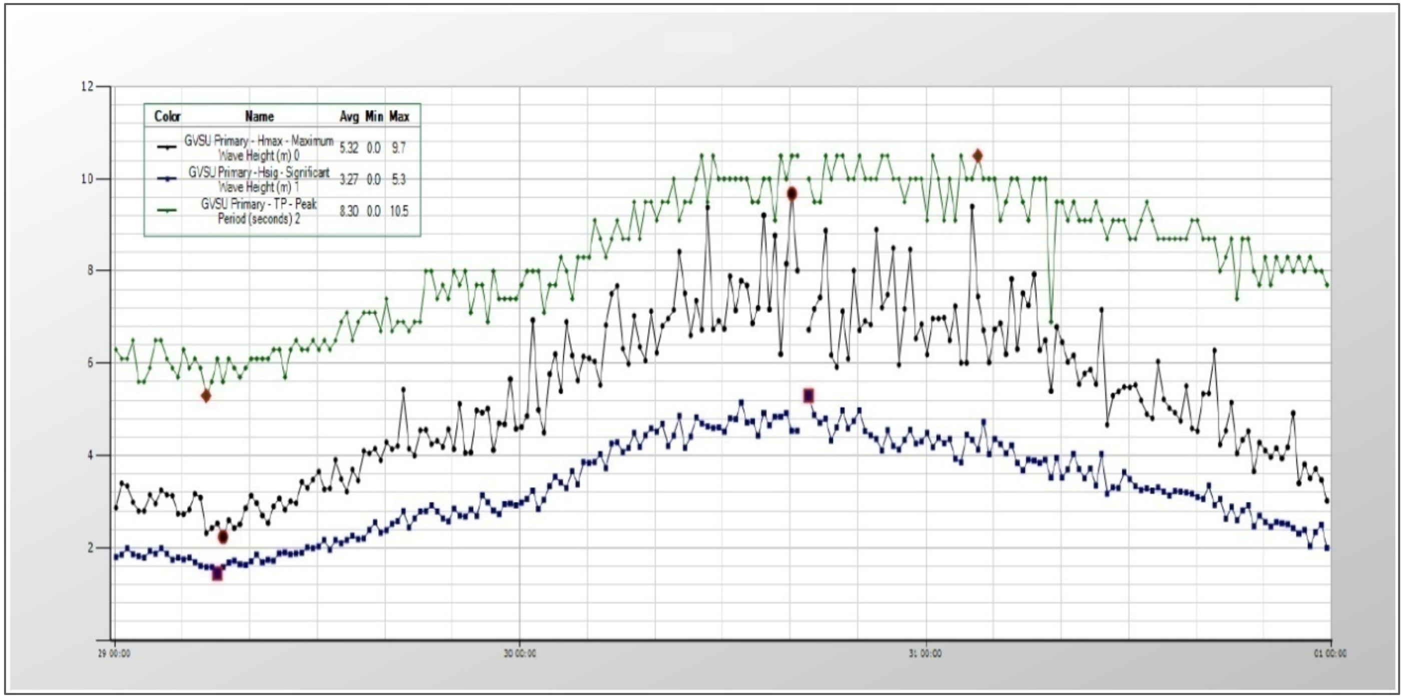
By the time it reached 36 miles offshore on Lake Michigan, Sandy was producing 26 m/s (58 mph) winds; a gale force storm on the Beaufort Scale. The system recorded a gust of 29.9 m/s, nearly 67 mph.



Wind Speeds at 90m; October 29th – November 1st, 2012

Hurricane Sandy

The graph below shows the clear correlation between wind speed and wave height, with peak waves of around 10m (33 feet) coinciding with the highest wind speeds. The system also saw an average period wave of 8.3 seconds. The water depth at this point is 46m, which confirms that these were significant waves.

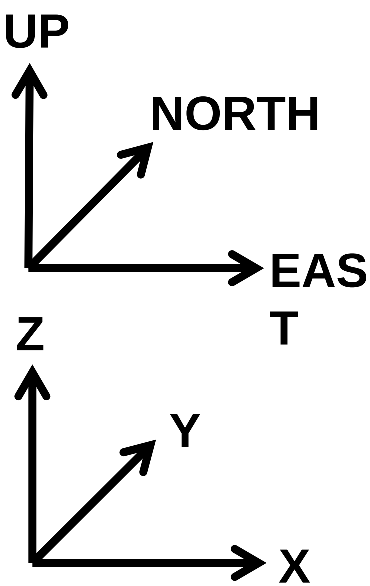


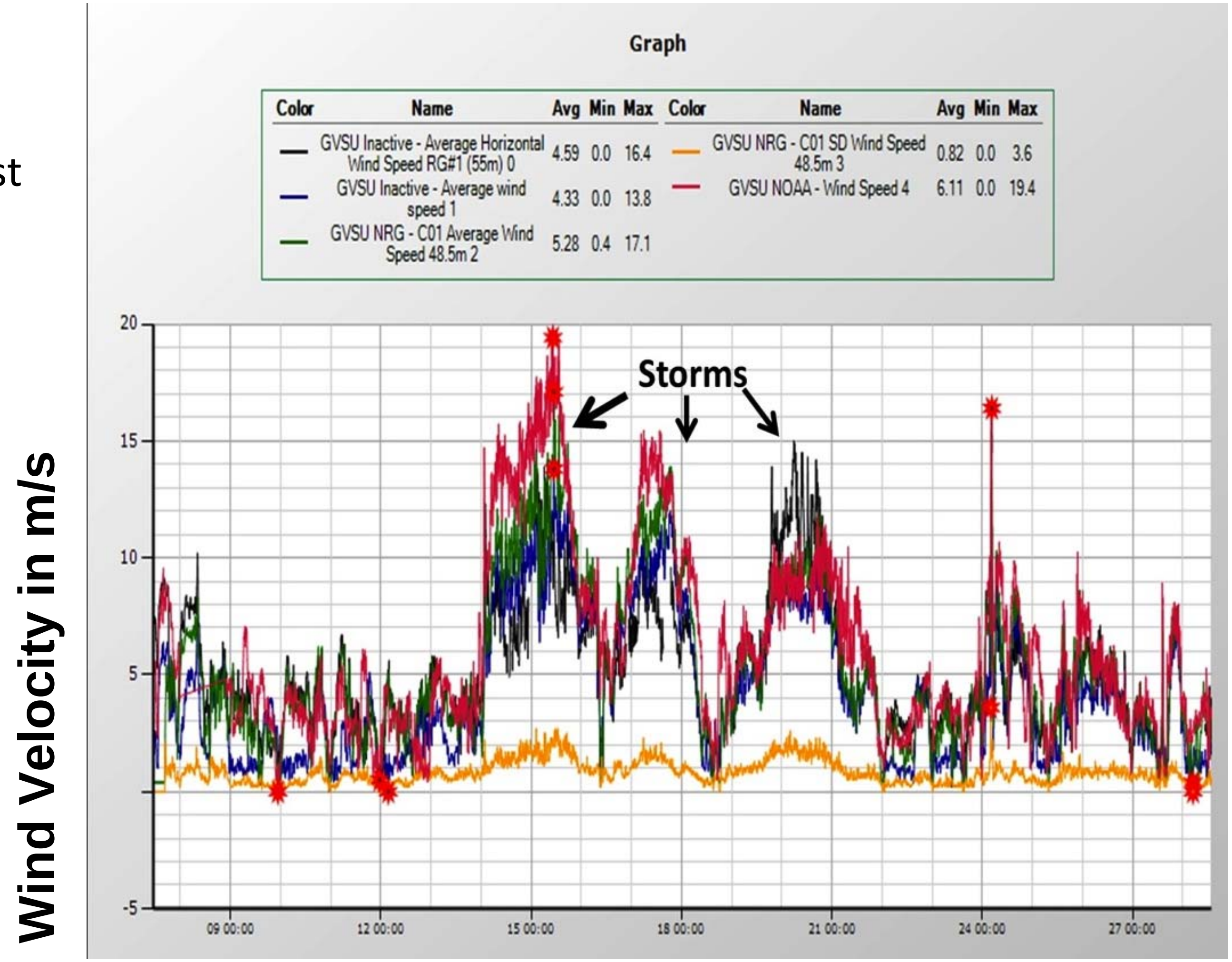
Wave Heights; October 30th & 31st, 2012

On-Shore Analysis and Comparison

- Storm 1 – Winds from NW
- Storm 2 – Winds from West
- Storm 3 – Winds from NE

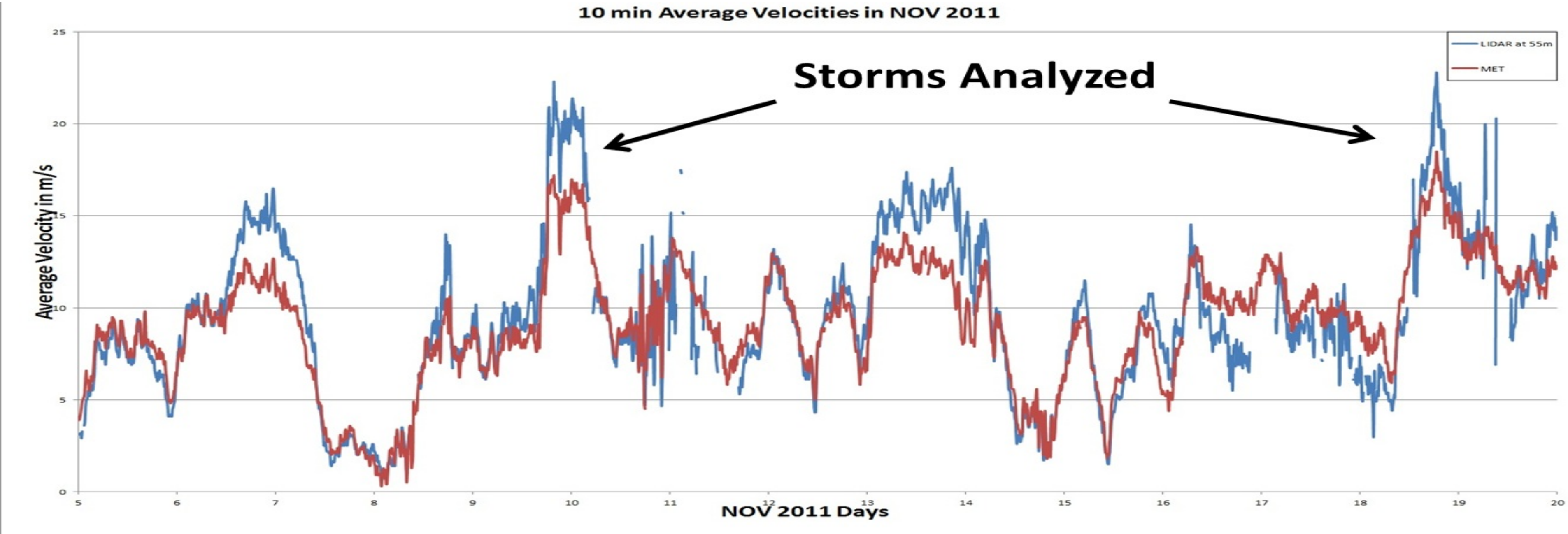
<u>Convention used</u>

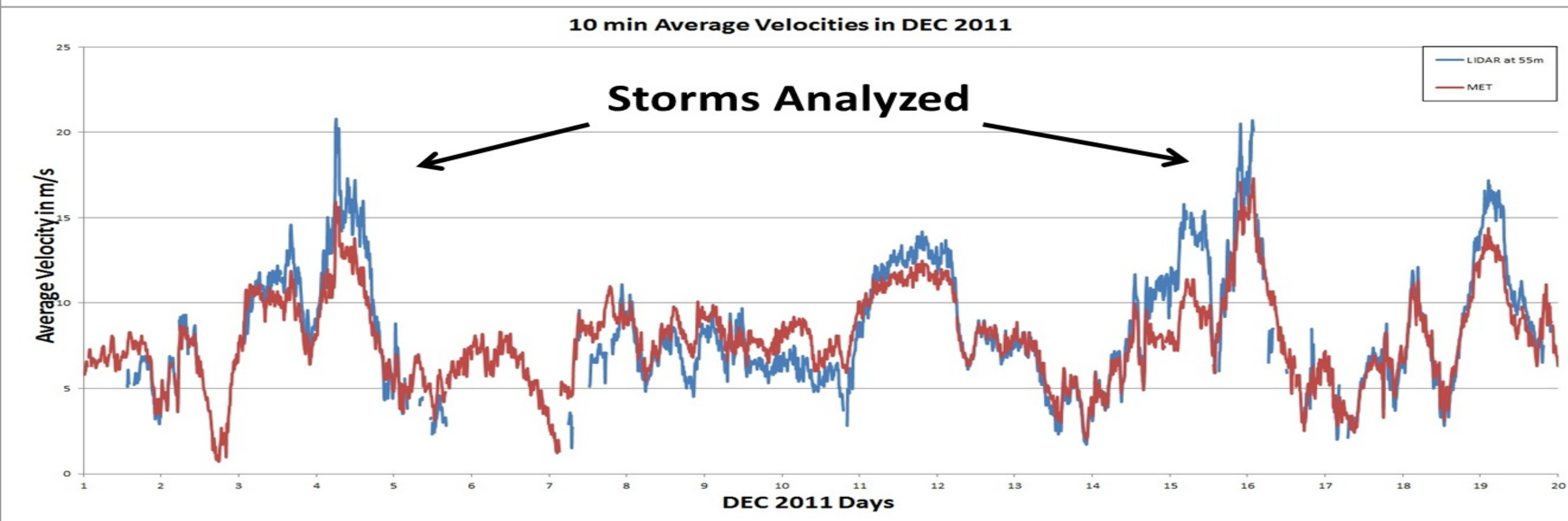




Dates from OCT 2011

Off-Shore Analysis - Lake Michigan





Research Results

- Variation in wind velocity with height:
  – more pronounced when the buoy is nearshore, approximately 20% increase in mean velocity from 55m to 120m,
  – off-shore, approximately 5% increase (~ uniform with height)
  – for on-shore data, vertical variation is caused by greater roughness over land.

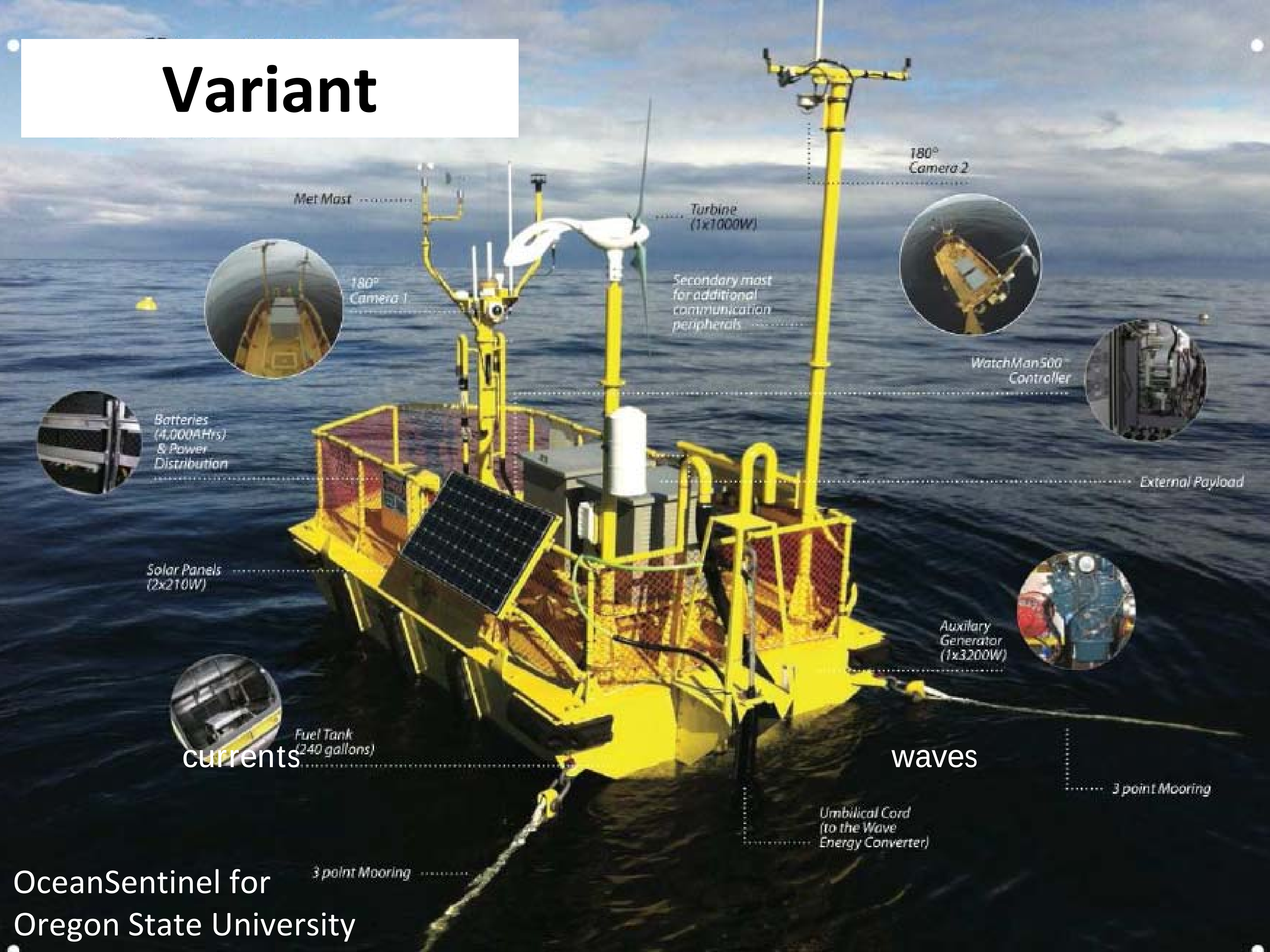
- Turbulent Kinetic Energy (TKE)
  – fluctuations are higher for on-shore location (due to land roughness)
  – fluctuations are much lower for off-shore location.
  – During the peak of the storms the mean TKE increases with height above the water surface.
  – TKE is low before storms (as expected).
  – When comparing storms of equal strength, peak TKE fluctuations are higher for storms coming from over land by ~3X.

Forthcoming Installations

US NAVY

September, 2013

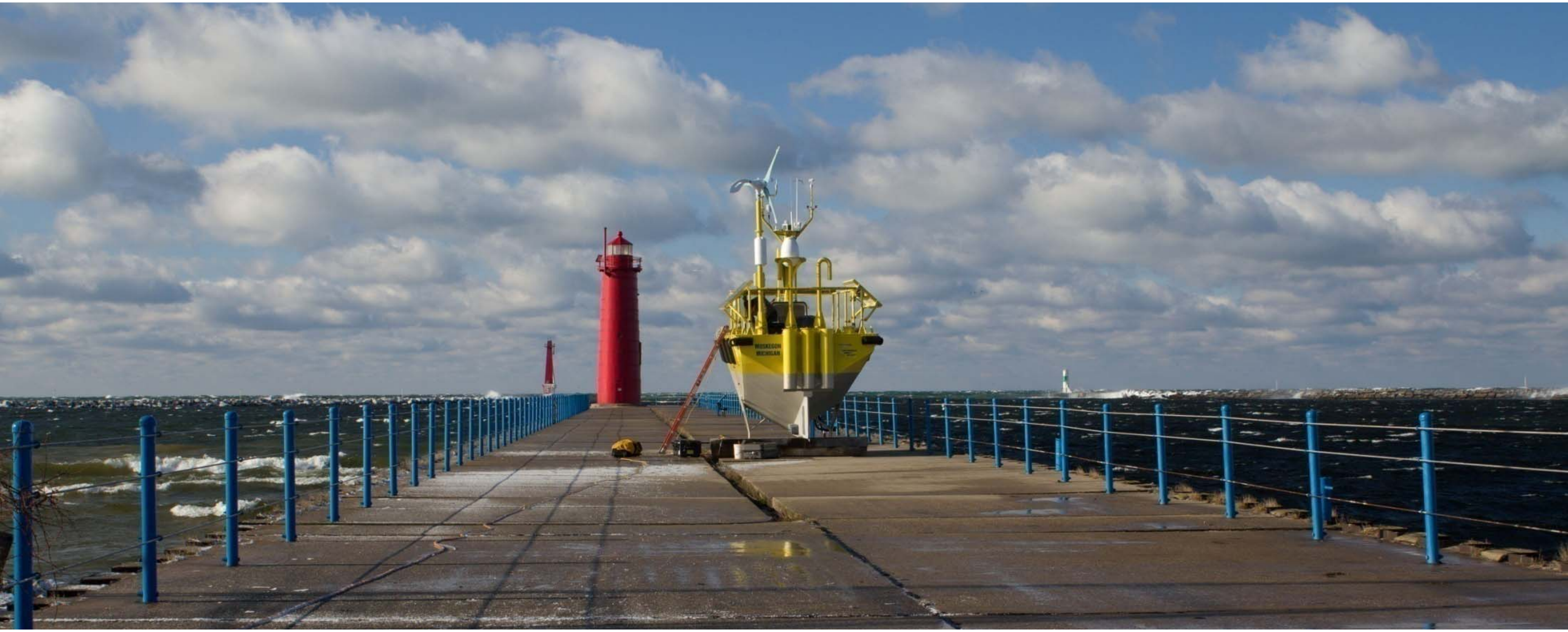
Variant



OceanSentinel for
Oregon State University

The WindSentinel™

The Future of Offshore Wind Resource Assessment



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