The Impact of Ocean Observations on Wind and Wave Models for Application in the Offshore Industry

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Outline

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3. Ocean Observations II: Model Development
4. Ocean Observations III: Validation
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Introduction

Oceanweather Inc. (OWI) is a small company based in Stamford (CT) formed in 1977

Functions as a specialized consulting firm serving the coastal and ocean engineering communities

Primary focus is on the analysis of marine surface wind fields for application in ocean response models – particularly in application of storm events

Hindcasting and Forecasting Applications

- Oil and Gas Exploration/Production
- Coastal Engineering Projects
- Global Shipping
- Offshore Wind

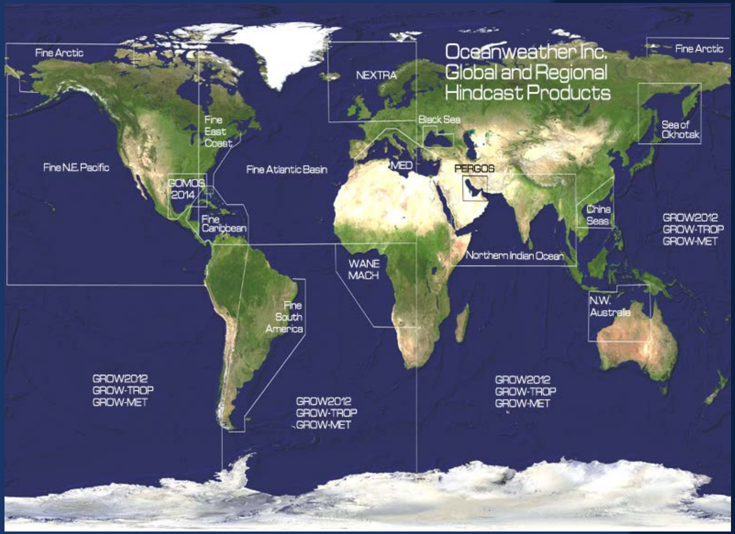
Government/University Projects

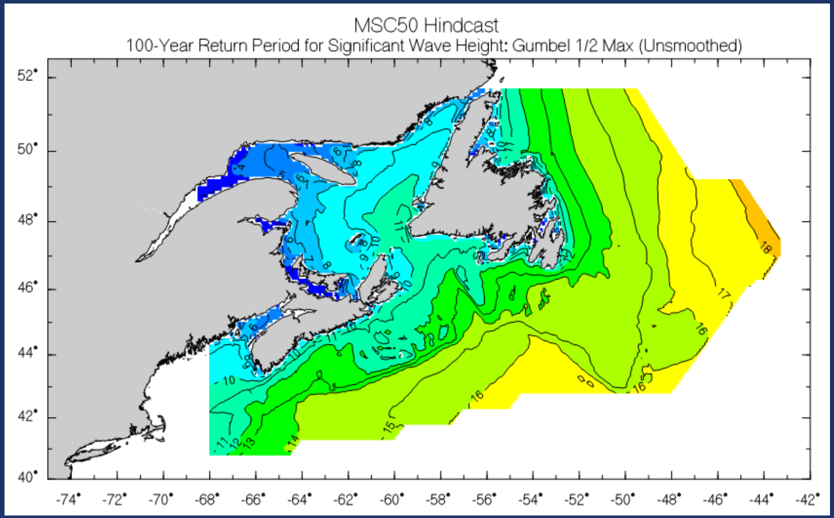
- FEMA Flood Mapping
- Wave Information Study (US Army Corps of Engineers)
- Environment Canada

Introduction

Hindcast production of long-term wind, wave, current databases for use in design and assessment of operability conditions

Wind forcing in storm events still a dominant source of error in driving ocean response models. Storm modeling and analysis a major component of OWI studies.





We are an engaged user of ocean observations for

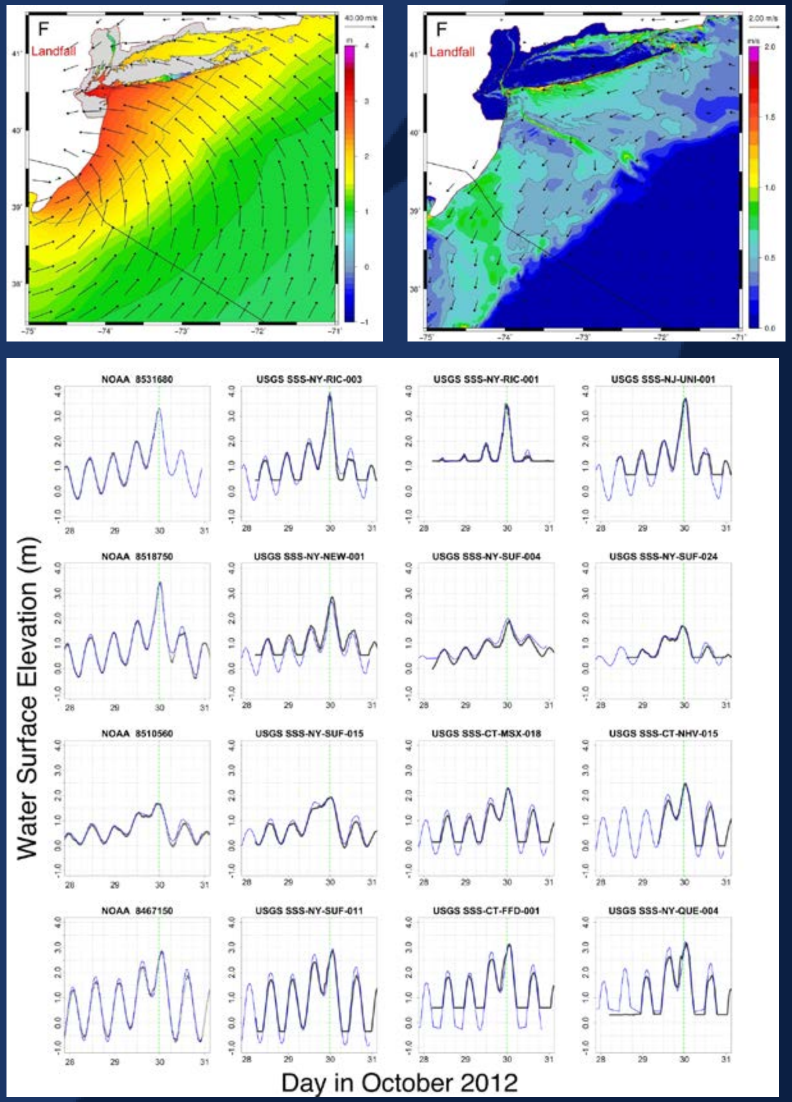
- Analysis of Marine Wind Fields
- Development of Atmospheric and Ocean Models
- Validation of Long-Term Wind and Wave Climatologies

Wind Analysis for use in Advanced Circulation (ADCIRC) Storm Surge Model

OWI provides detailed reanalysis of historical tropical cyclones and extra-tropical events for use in storm surge modeling

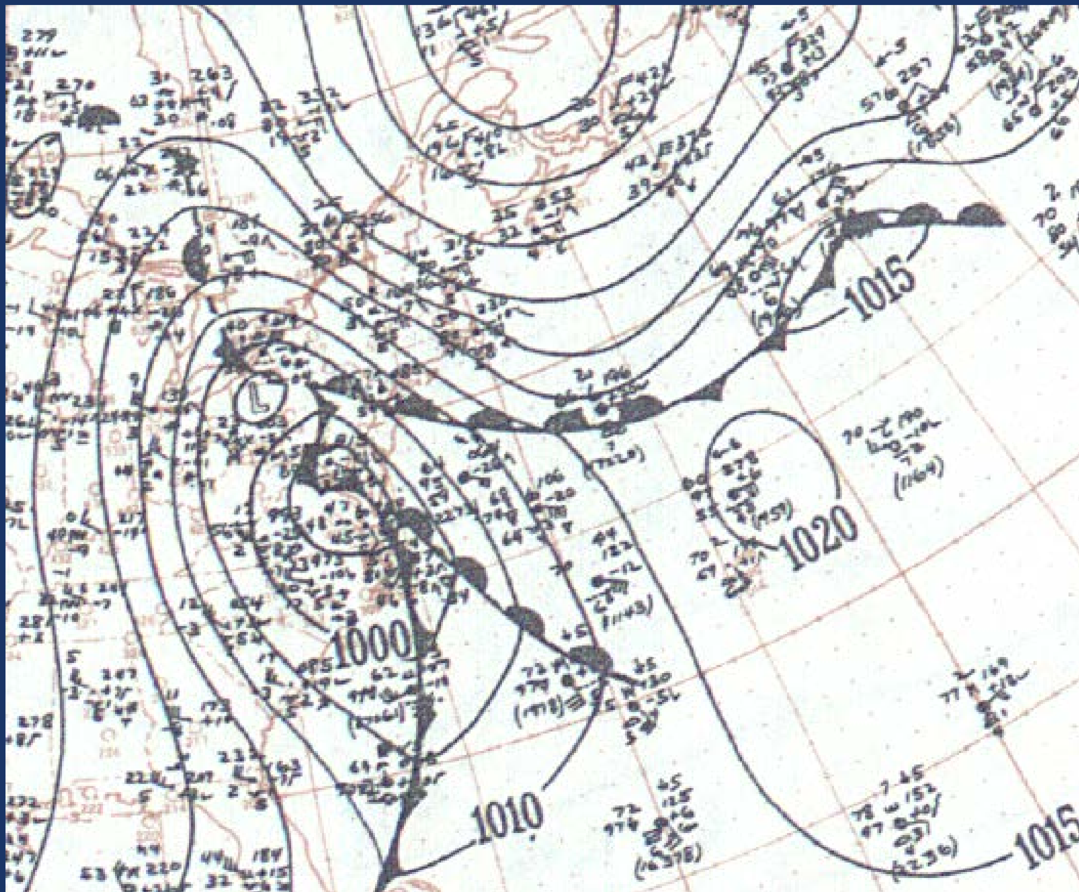
Our wind analyses have formed the basis for much of the FEMA flood mapping studies as well as US Army Corps of Engineers regional flooding studies

Active with the ADCIRC modeling group and routinely collaborate with model developers



Figures depict maximum water elevation (top left), maximum currents (top right) and water surface elevation comparisons (bottom) at various NOS and USGS stations from University of Notre Dame ADCIRC simulation using OWI wind forcing during Sandy (2012)

Hindcasting of Historical Storms

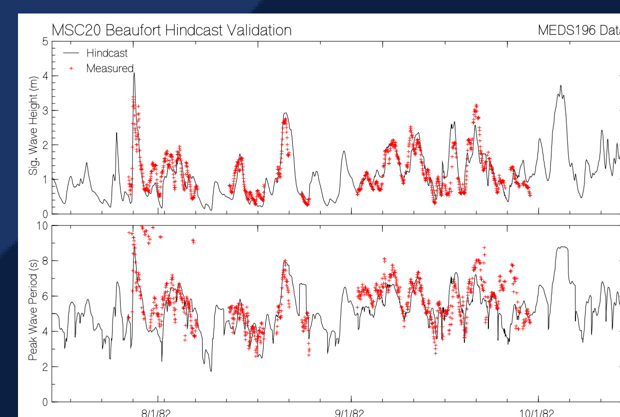


Atmospheric Reanalysis

Ocean Observations Adjusted for Height/Stability

Data Assimilation and Kinematic Analysis

Ocean Response Models



Ocean Observations: Data Assimilation

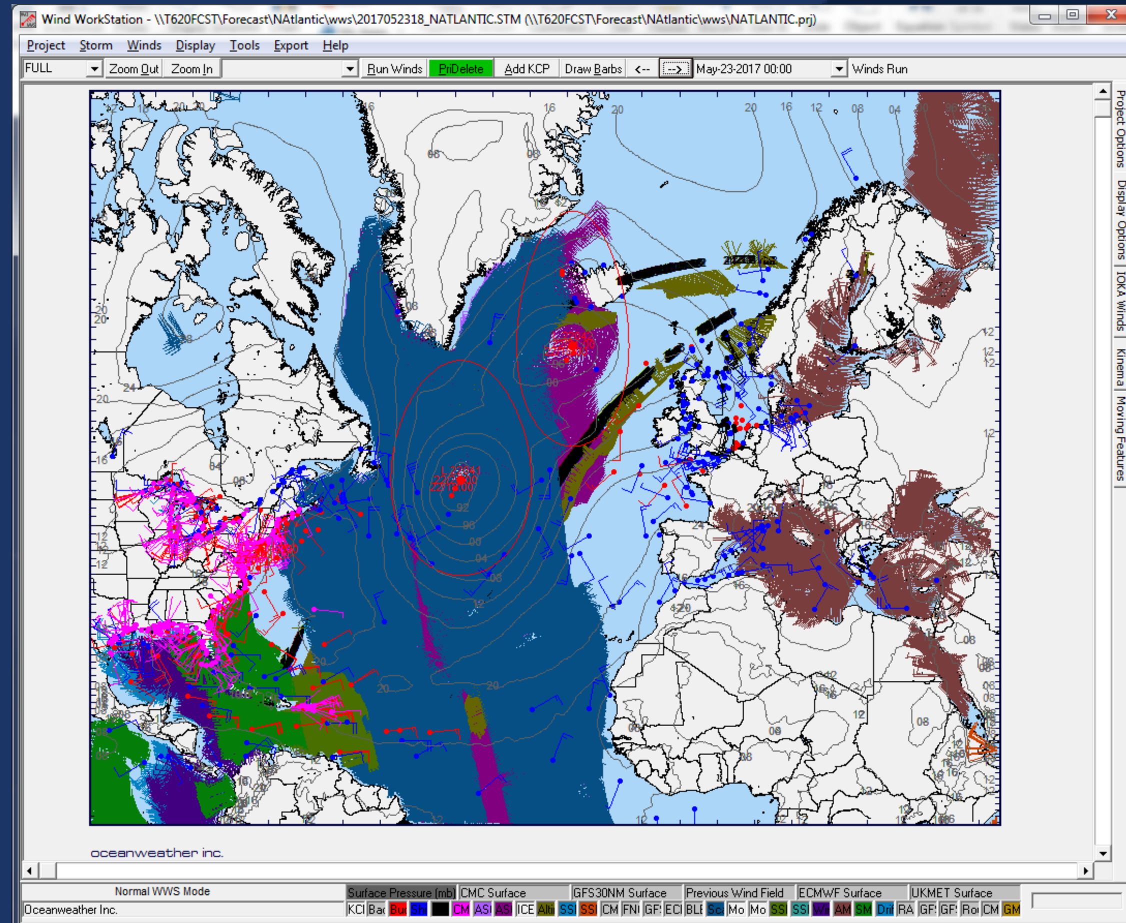
oceanweather inc.

Hindcasting of Historical Storms

Analysis of modern storms for hindcasting and forecasting applications include a wealth of in-situ and satellite derived wind/wave data

Data shown on this plot include:

- Buoys (moored and drifting)
- Ships
- Offshore Platforms
- Coastal Land-Based Stations
- Altimeters (wind and wave observations)
- Scatterometers (winds)
- SSMI



Wind WorkStation: Graphical Wind Analysis Tool
Data Coverage +/- 3 hours in North Atlantic

Ocean Observations: Data Assimilation
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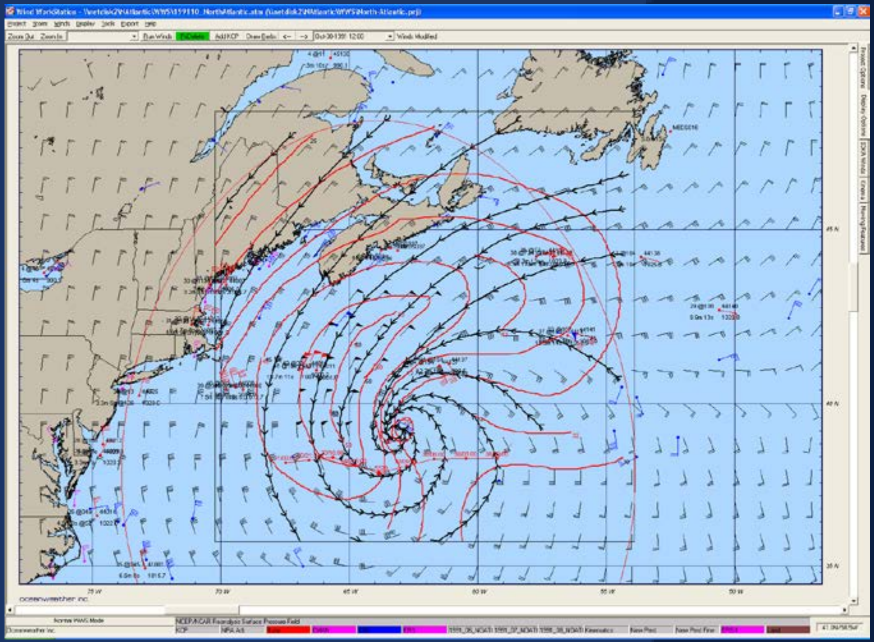
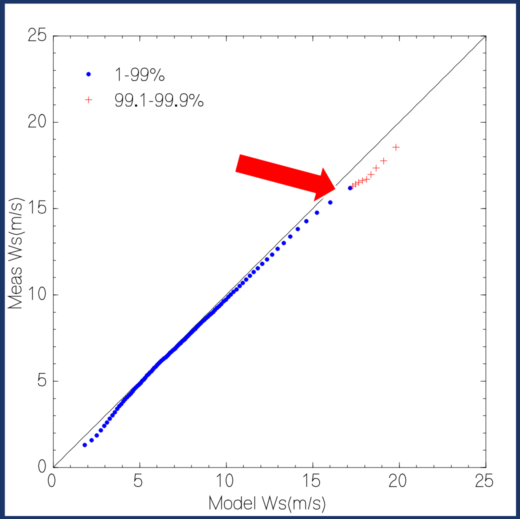
Wind data from various in-situ and satellite sources are applied in direct assimilation or in the manual kinematic analysis of storm events

Data for each source represent differing calibration and error structure

Unless the limitations of the measurement are understood, direct use in assimilation can lead to bias in resulting hindcast

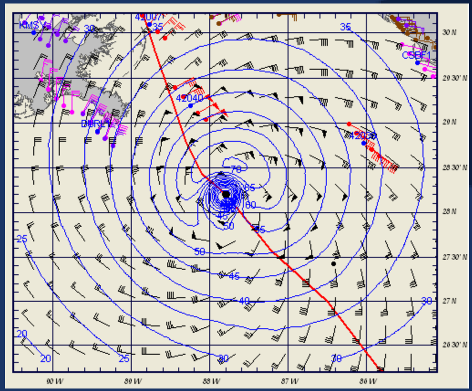


Manual kinematic analysis of "Halloween Storm" of October 1991

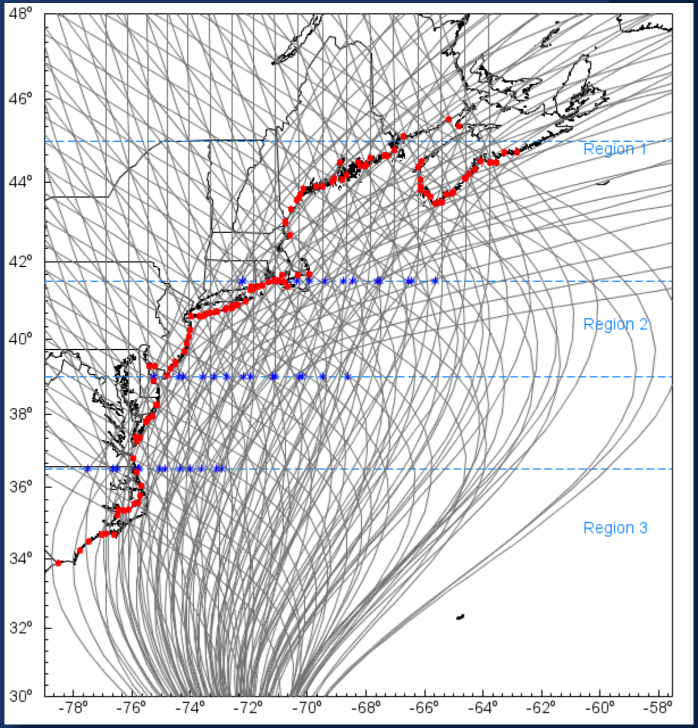


Quantile-Quantile comparison of altimeter wind speeds and MSC50 North Atlantic hindcast. Deviation at high wind speeds not a modeling error, but rather saturation of the instrument in high winds

Impact of Ocean Observations on Model Development: Oceanweather Tropical Planetary Boundary Layer (PBL) Model



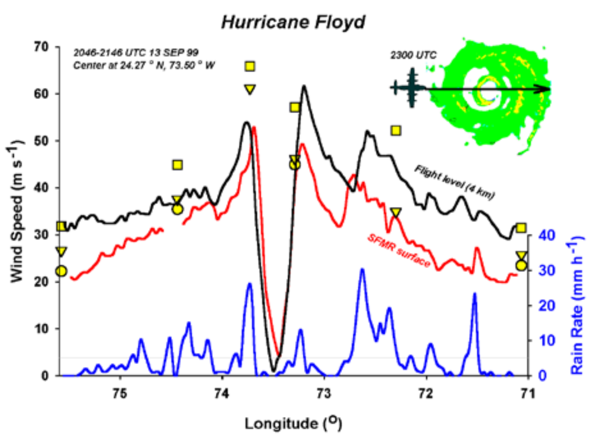
- Model applies a double exponential form of the Holland pressure profile to drive a numerical primitive equation model of the cyclone boundary layer
- Applied in hindcasting studies world-wide
- Useful for synthetic tropical studies – applied in FEMA flood mapping studies and US Army Corps of Engineers regional studies
- Original model tuning (1996) mainly validated against point measurements obtained through chance encounters of tropical cyclones with buoys and platforms offshore

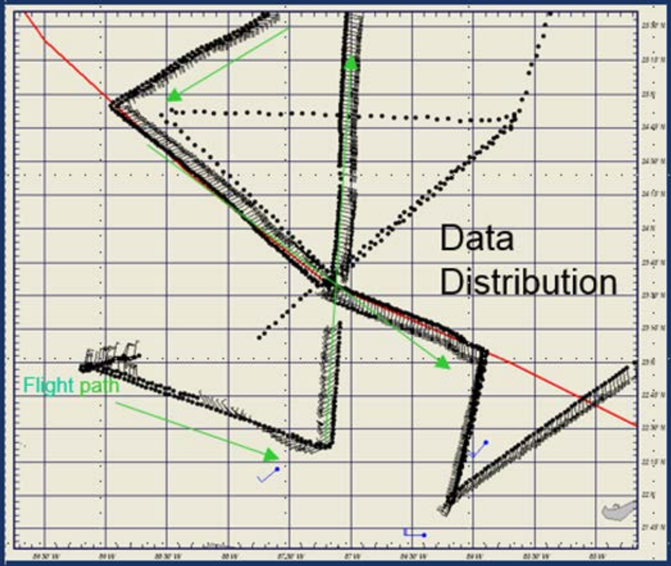


Synthetic tropical tracks applied in the North Atlantic Coast Comprehensive Study (U.S. Army Corps of Engineers)

SFMR: Stepped Frequency Microwave Radiometer

- Surface wind speed estimates taken from aircraft
- Provides data in all quadrants of the storm
- Instrument on NOAA aircraft since 1998
- Data represent a 1-minute peak wind at 10 meter reference level





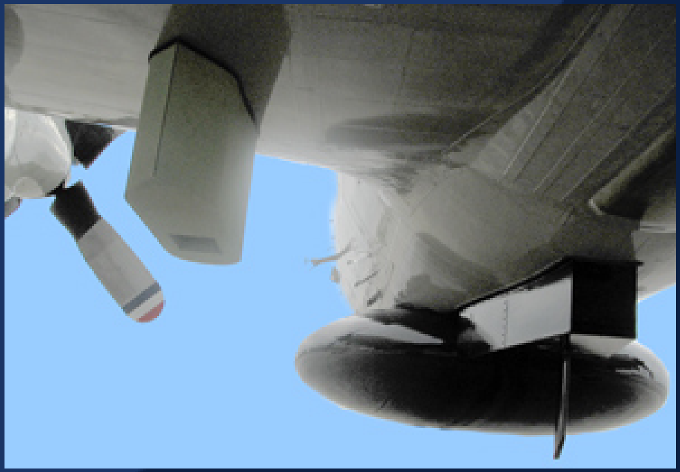


Image courtesy of the Hurricane Research Division

Use of SFMR Data in Tropical Model Tuning:

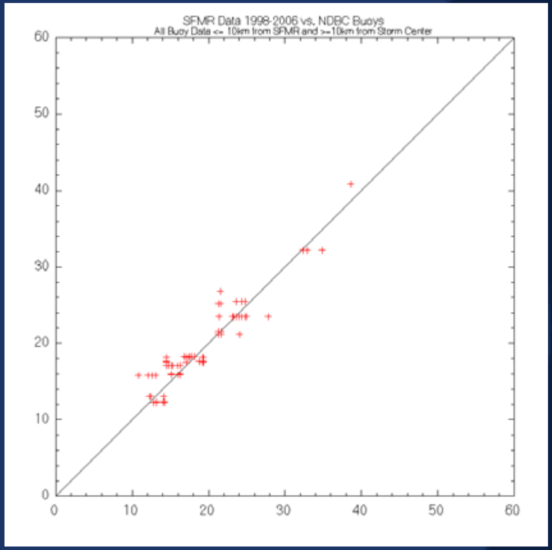
1. SFMR data checked against buoys for consistency

2. Model run for 33 historical hurricanes and compared at snapshot time with good coverage of SFMR in all quadrants of the storm

3. Comparison set allowed inclusion of saturation drag formulation in the PBL model consistent with Powell (2007) which was determined using GPS dropwindsondes

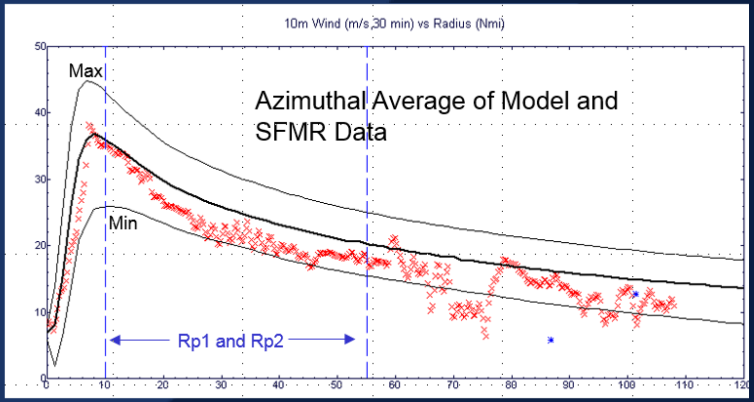
4. New model then validated against independent buoy and platform data to confirm improved performance

SFMR dataset expected to be reprocessed using new wind retrieval algorithm – what effect will this have on the model tuning?

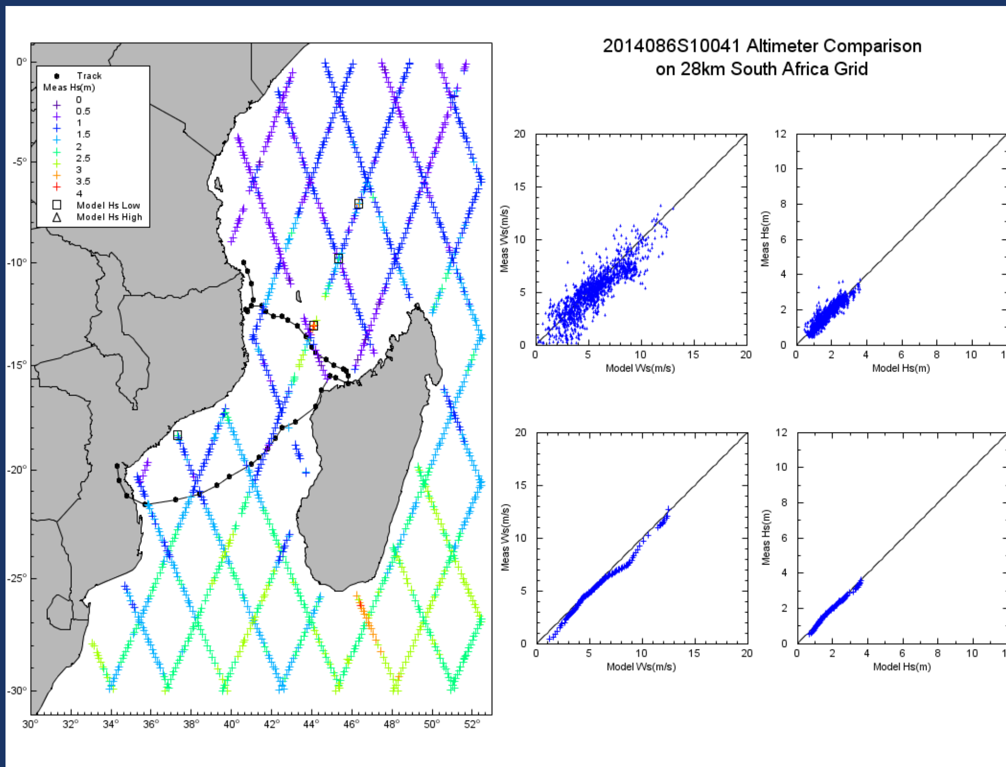


Comparison of 30-minute SFMR wind derived estimates (EDSU Gust Factor Adjustment) with 30-minute average NDBC buoy observations during hurricane conditions

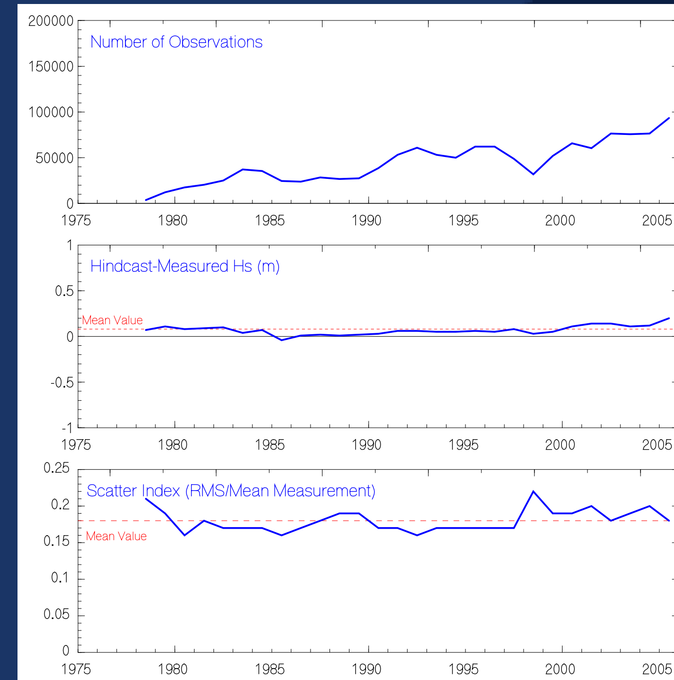
SFMR measurements within 10 km from buoy and within 15 minutes of buoy observation



Wave measurements from buoys and altimetry are used to evaluate the modeled waves



Composite altimeter comparisons during Hellen (2014)



Buoy comparisons 1976-2006 in MSC50

- How consistent are the buoys in time?
- Are all buoys equal?
- How does this change the calibration of the altimetry which depend on buoy measurements?

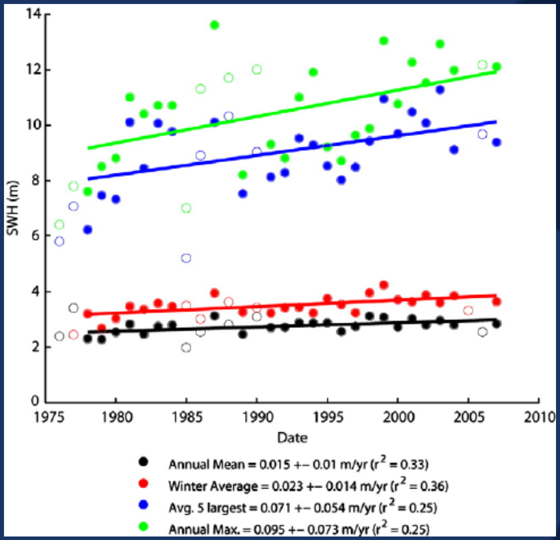
Data Issues: Buoys

Buoy observations from the National Data Buoy Center (US) are routinely applied in model validation, calibration of satellite data and in trend analysis

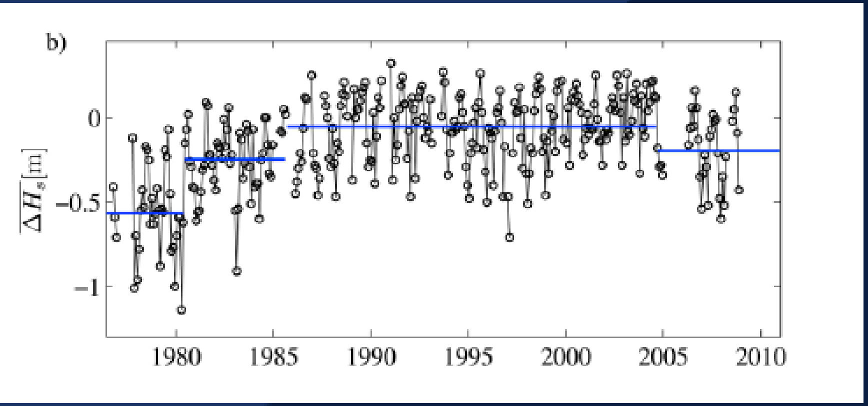
A number of studies have documented the trend of increasing significant wave height based on waves measured by NDBC buoys in the Eastern Pacific

A analysis of the data by Gemmrich et al. (2011) linked most of the apparent trend to changes in the buoy payload and hull type over time

Buoys were designed for input into operational weather models for improving forecasts – a complete understanding of changes in data acquisition and processing is needed before the data can be applied for other purposes



Significant wave height trend analysis at NDBC buoy 46005 West Washington (Pacific Coast) from Ruggiero et al (2010)



Analysis of step changes detected in NDBC buoy 46005 data as analyzed by Gemmrich et al. (2011)

Data Issues: Buoys

Durrant (2009) found 10% systematic difference in significant wave height between the NDBC (US) and MEDS (Canadian) buoy network using altimetry as a common reference

10% is a large difference: buoy data from these networks and others are not only used to calibrate the altimeter but as validation to operational ocean wave models

The Joint Technical Commission of Marine Meteorology (JCOMM) in coordination with Environment Canada and the US Army Corps of Engineers have been co-locating different buoy types and measurement platforms to assess the relative differences due to hull type, instrumentation, processing, etc.

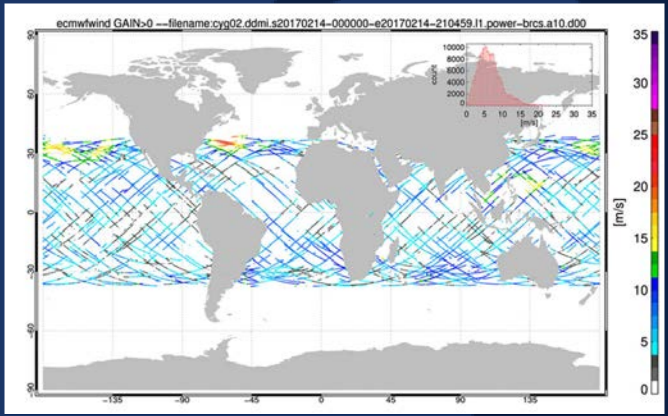
Improvements in our understanding of the impact of sensors changes and good documentation of metadata for historical data will yield improvements in wave climate analyses

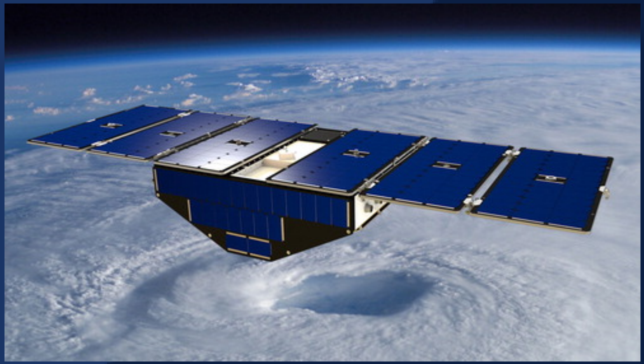
Buoy farm offshore Monterey, California used in FLOSSIE experiment to test differing hull types, sensor/payloads and processing of commonly use ocean buoys

New datasets and updates to existing data platforms are in constant development

Older datasets are being reviewed and cross-calibrated for reprocessing

The challenge for OWI and users of the data is to understand its application/limitations





Cyclone Global Navigation Satellite System (CYGNSS)
A new NASA earth science mission

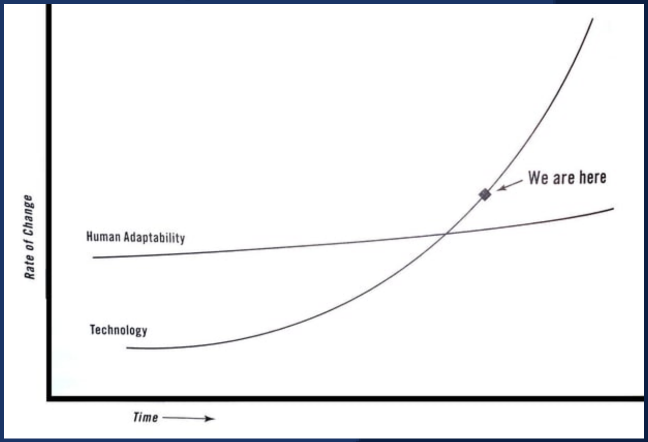
Data release to PODACC just started (May 2017)

Designed to observe high winds in tropical cyclones with high temporal and spatial coverage

Images from CYGNSS Project

Summary

- Ocean observations can and do impact the quality and use of forecasts and hindcasts performed for the offshore industry
- Effective use of observational data critically depends on our understanding of what is being measured and limitations on its use
- Meta data on observational and processing changes are key to identification of step changes in historical data before trends are derived
- The increasing number of ocean observations and cross calibration of different platforms make it essential that our understanding of the data keeps up with rate of change
- New ocean datasets will provide more detail in storm conditions which lead to the development of improved models



From Thank You for Being Late – Thomas Friedman