Dec 7th, 3:15 PM - 4:00 PM

Session 4 Presentation - Improved Coastal and Nearshore Wave Forecasting

Jeffrey Hanson
AcuSea LLC, Kill Devil Hills, NC, hanson@acusea.com

Robert Fratantonio
AcuSea LLC, Kill Devil Hills, NC

IMPROVED COASTAL AND NEARSHORE WAVE FORECASTING

JEFFREY HANSON, PHD
ROBERT FRATANTONIO

2017 OCEAN WAVES WORKSHOP

DECEMBER 7, 2017

OUTLINE

- Objective
- Model Formulation
- Surf Application
- Validation
- Implementation
- Discussion

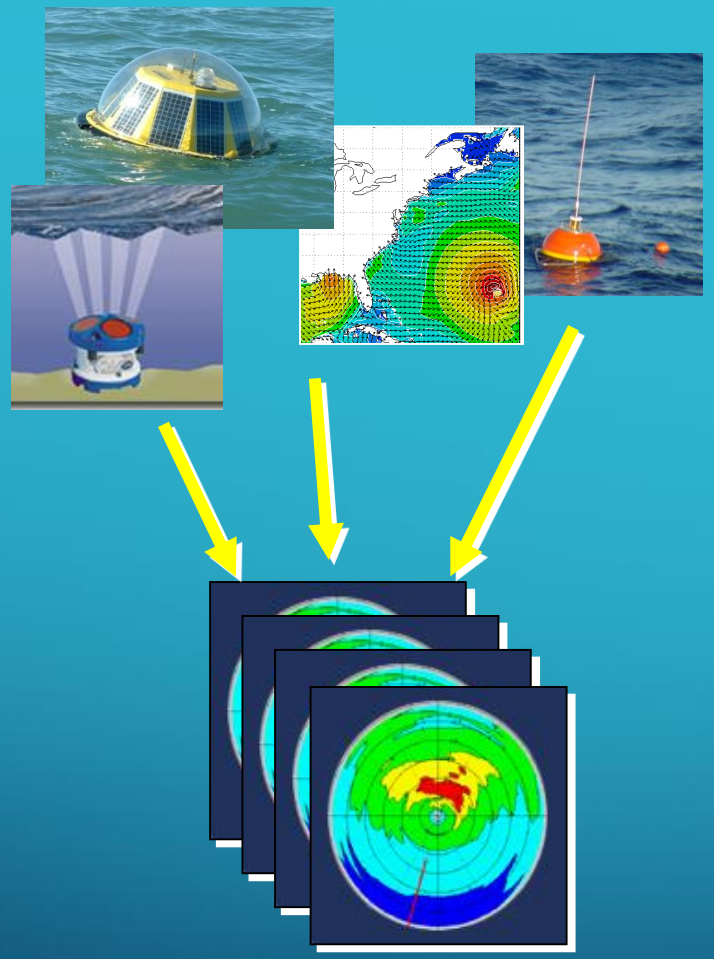
OBJECTIVE

Develop a fast, efficient and accurate nearshore wave forecast based on:

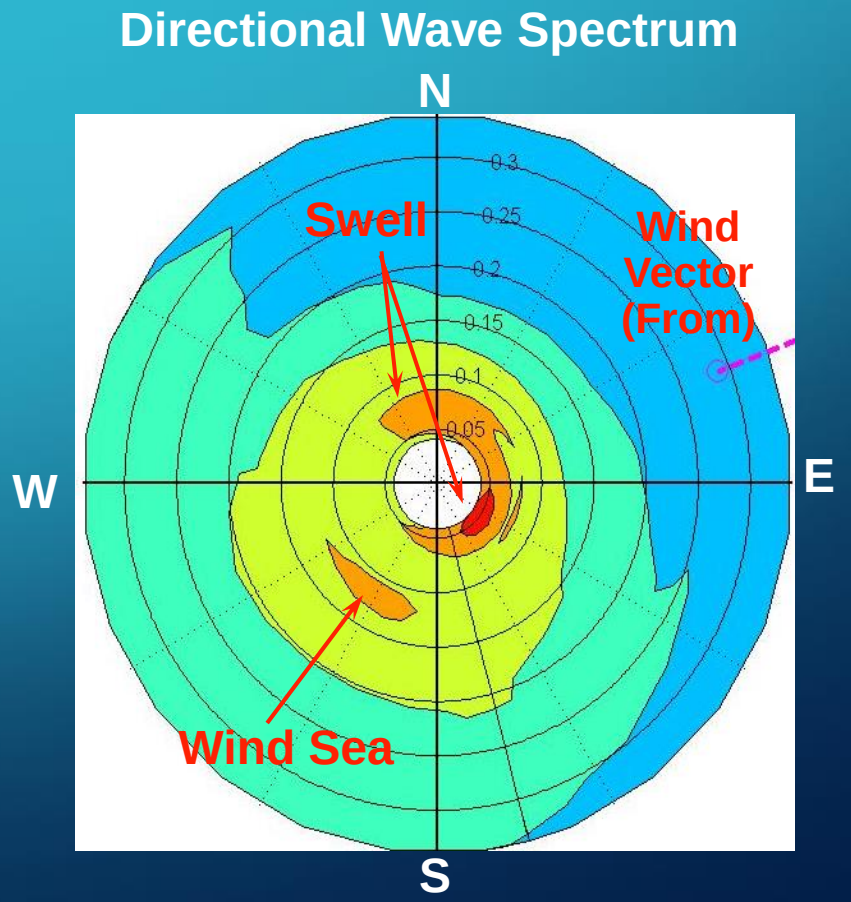
- Operational forecasts
- Real-time buoy observations
- 35 years of solid wave research
- Latest advancements in computing science

The result is a new approach to nearshore wave forecasting, with significant advancements in forecast accuracy and run efficiency.

THE WAVE DATA CHALLENGE

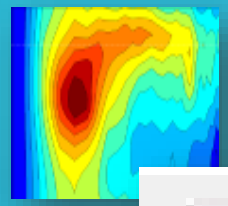


A measurement or modeling study can produce millions of spectral estimates from a data-rich set of directional wave spectra



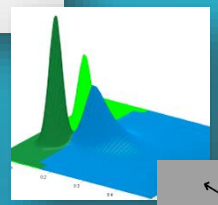
How to get the most out of these data?
Typically only 3 numbers are used to describe wave conditions: Height, period and direction

WAVE DATA ANALYSIS TOOLS

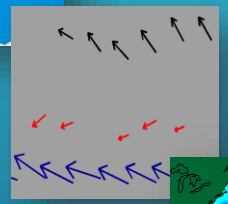


Data Exploration

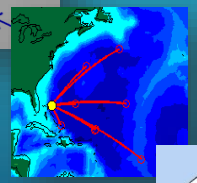
Data Editing



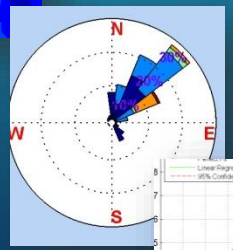
Wave Partitioning



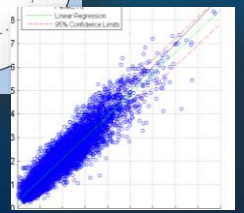
Wave System Tracking



Storm Source Estimation



Climatology Analysis



Measurement / Model Validations

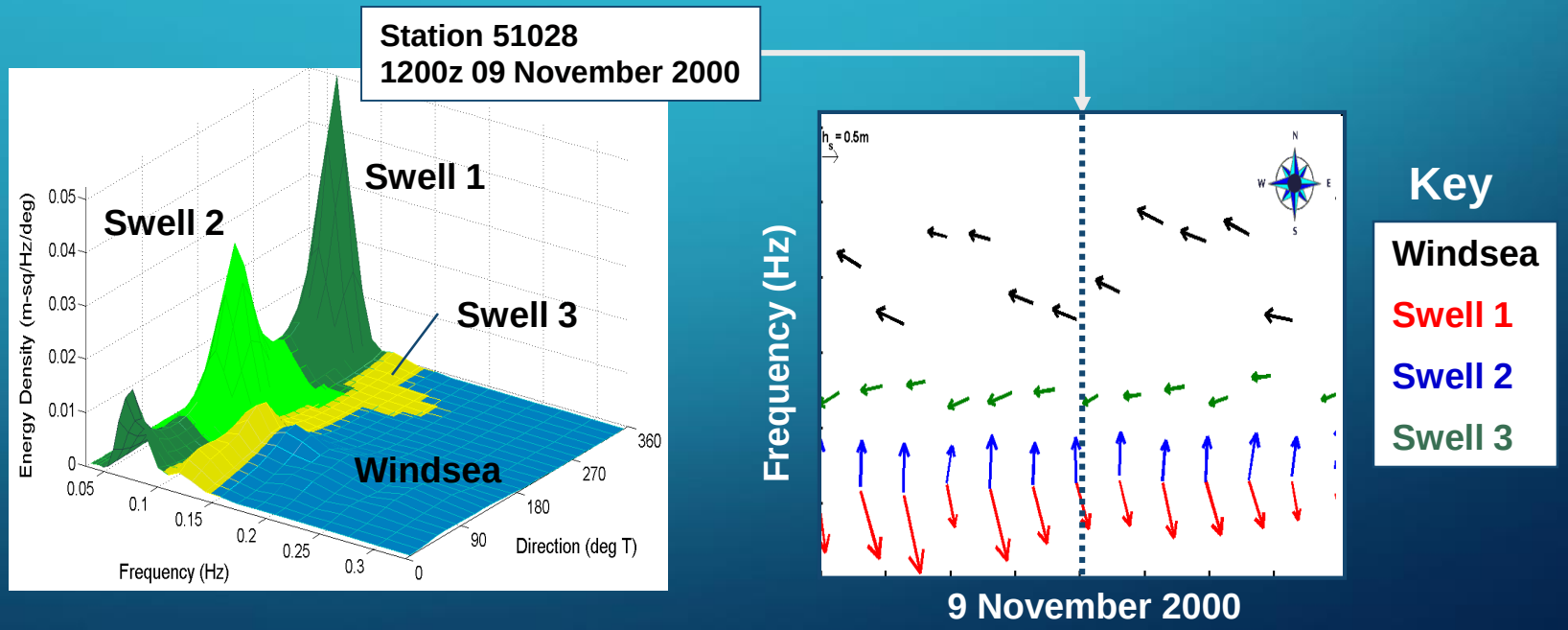
DEFINITIONS

Wave Component

A specific wind sea or swell that is attributed to a region of enhanced energy in a directional (2D) wave spectrum

Wave System

An evolving series of wave components that can be traced to a specific wind generation event on the ocean surface

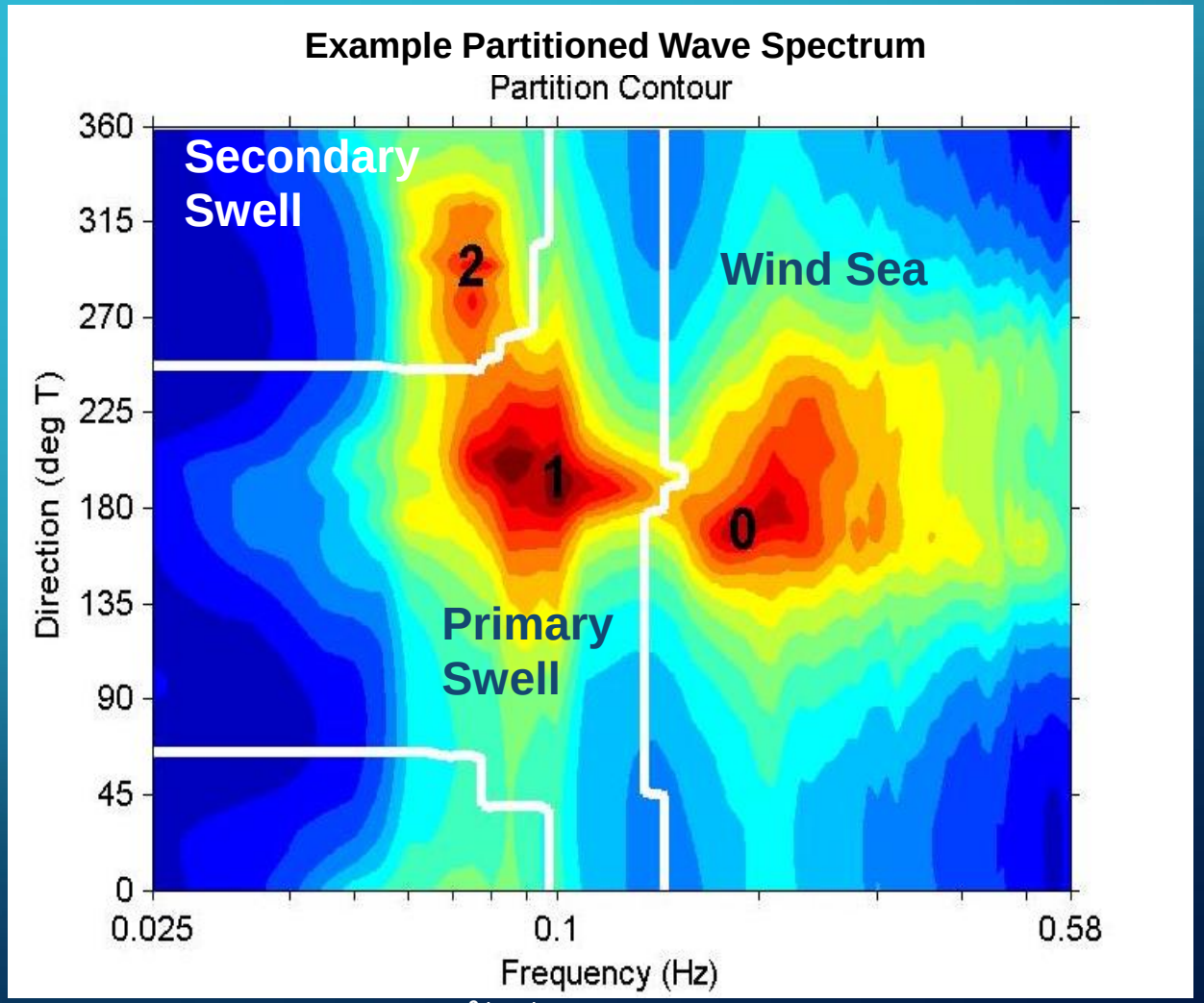


WAVE SPECTRUM PARTITIONING

Watershed tools are used to delineate the spectral boundaries between wave components

Partitioning of wave spectra:

- Gerling (1992)
- Hasselmann et al. (1994, 1996)
- Hanson & Phillips (2001)
- Portilla et al. (2009)



Note: Energy contours in Log_{10} (m^2/Hz/deg)

WINDSEA IDENTIFICATION

- Windseas are defined as waves forced by the local winds
- Windseas can not travel much faster than the component of the wind in the wave direction (wave age factor ~ 1.5)

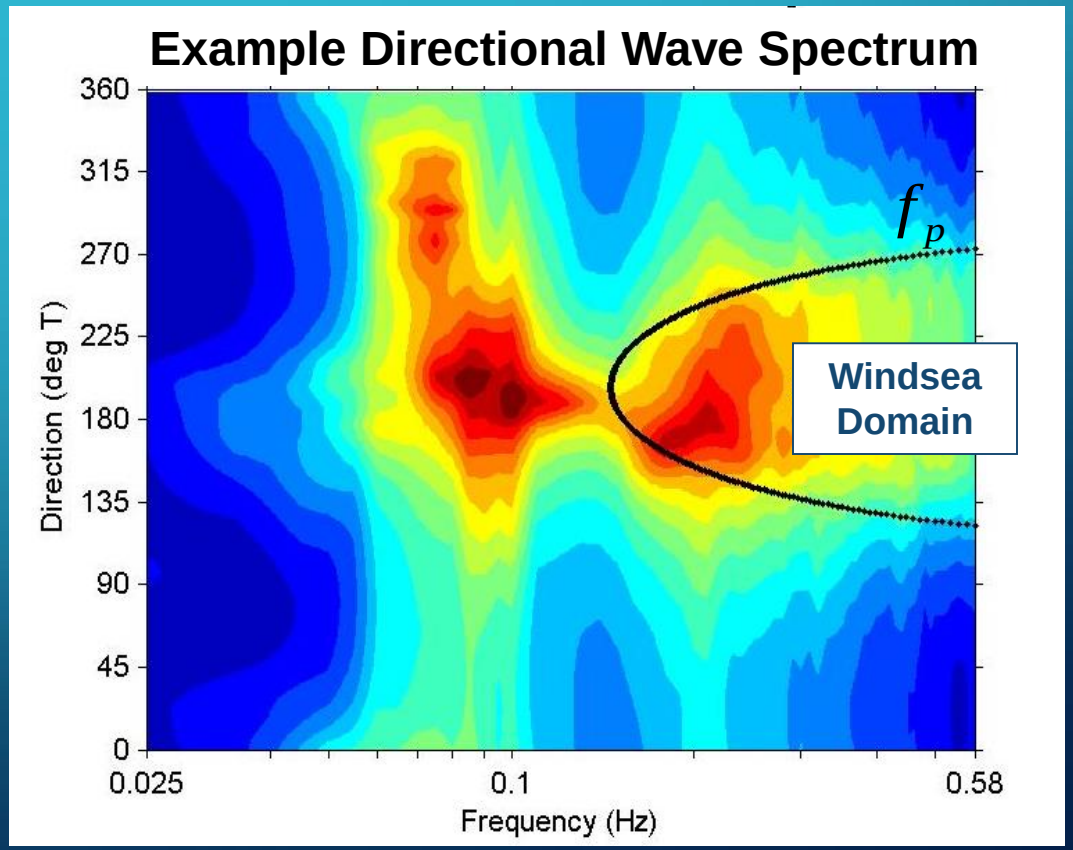
Directional Wave Age

Windsea peaks fall within the parabolic region:

$$c_p \le (1.5) U_{10} \cos\delta, \text{ or}$$

$$f_p \ge \frac{g}{2\pi}\left[1.5 U_{10} \cos\delta\right]^{-1}$$

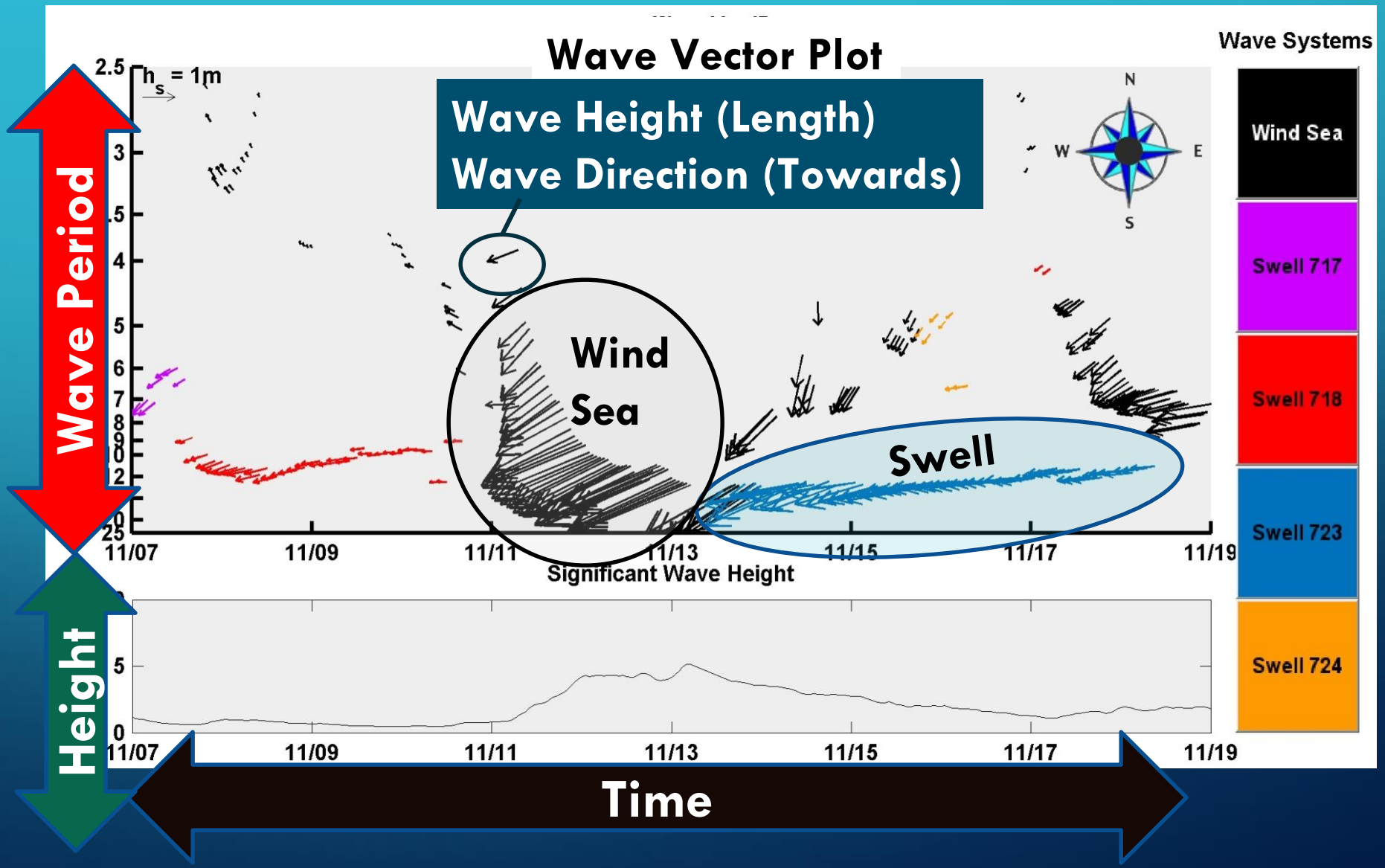
$\delta =$ wind-wave angle



Note: Energy contours in Log_{10} (m^2/Hz/deg)

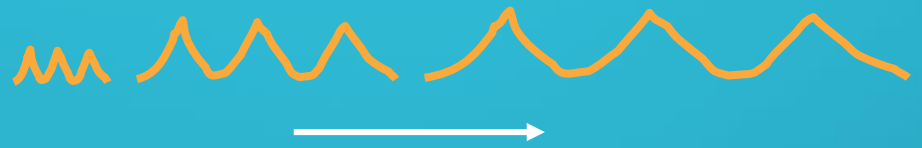
WAVE SYSTEM TRACKING:

NOR'IDA: NOVEMBER 2009, NORTH CAROLINA NDBC 44056



STORM SOURCE ESTIMATION USING WAVE DISPERSION

Distant Storm



Deep water dispersion relationship

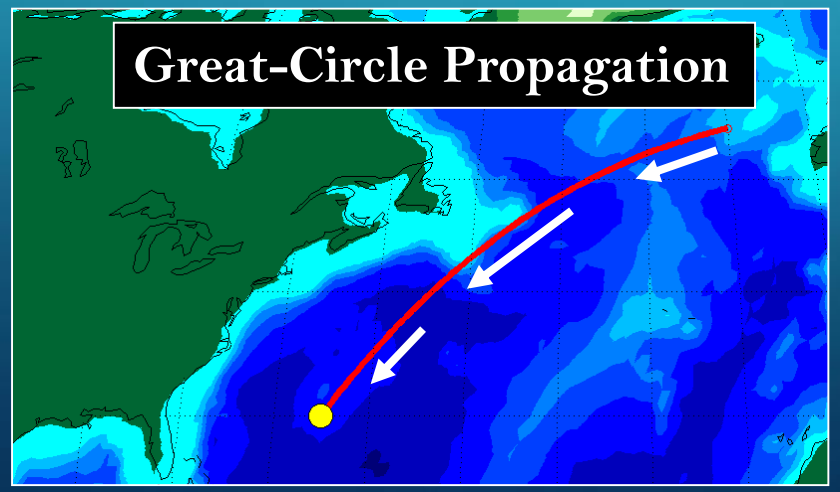
$$\omega^2 = gk$$

ω= Radian frequency
k = Wavenumber

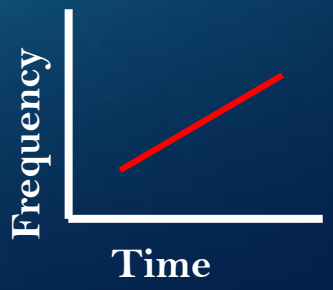
Local Observation

Wave energy travels at the Group Velocity

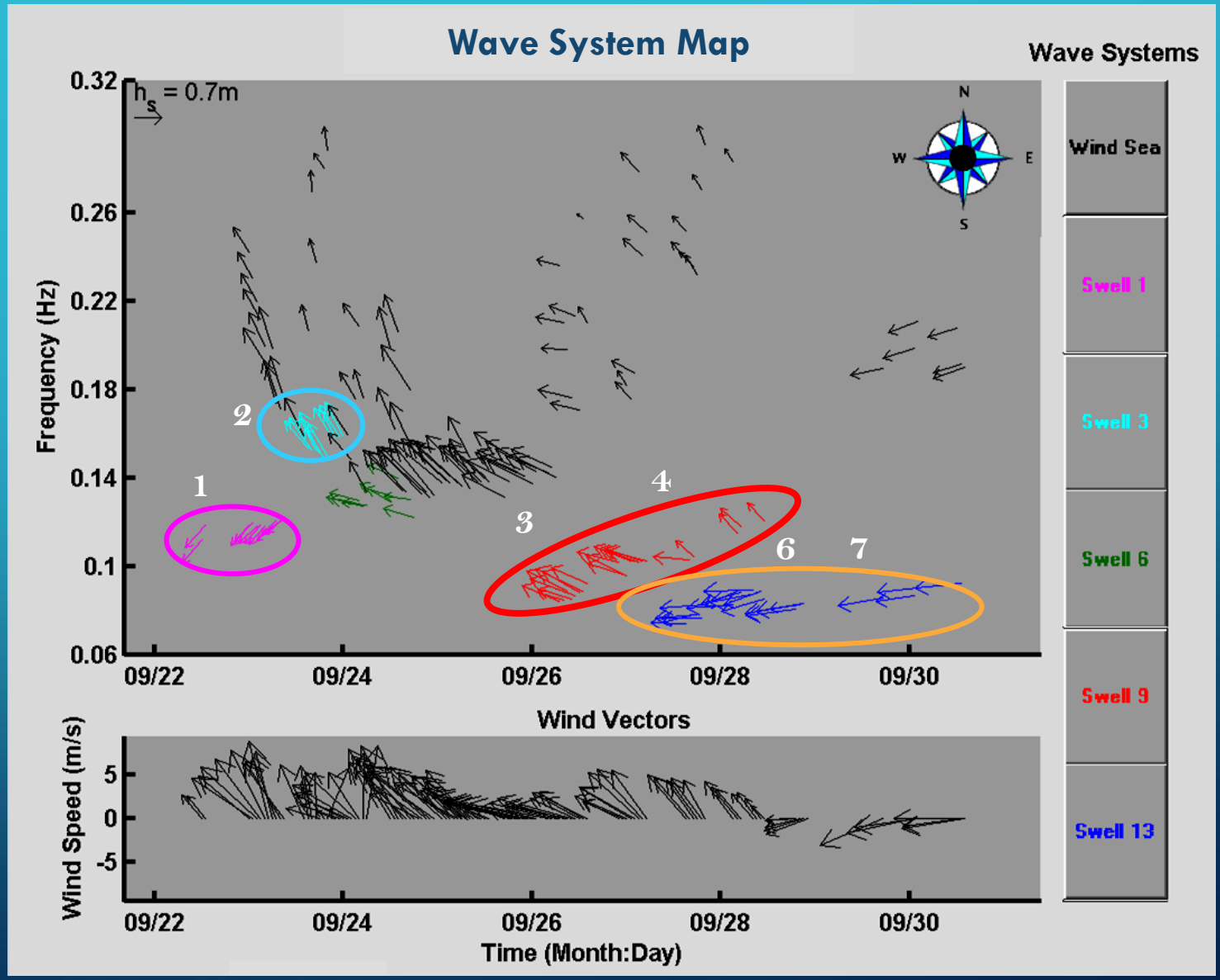
$$c_g = \frac{\partial \omega}{\partial k} = \frac{g}{2\pi\omega} = \frac{\text{distance } (x)}{\text{time } (t - t_\circ)}$$



Distance traveled and origination time are obtained from the *f(t)* slope and intercept.



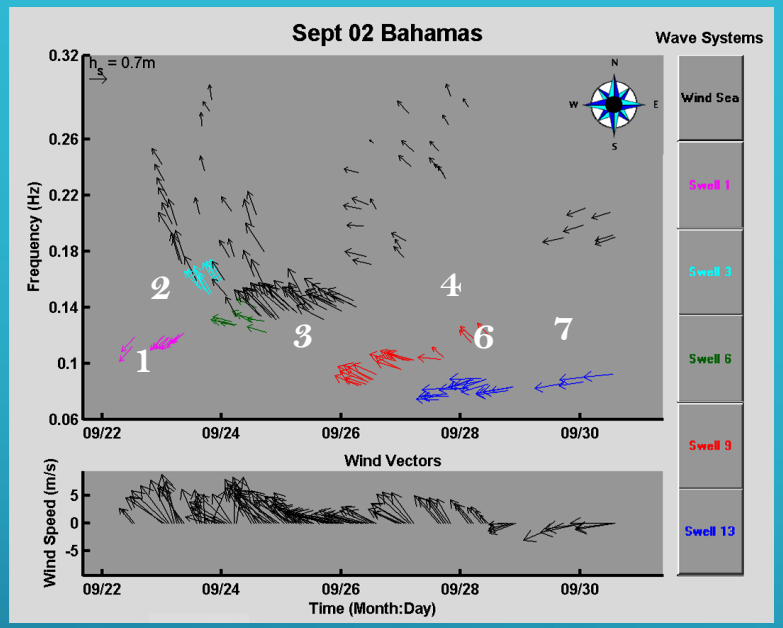
EXAMPLE RESULTS: NORTH ATLANTIC SWELL TRACKING BAHAMAS SEPTEMBER 2002



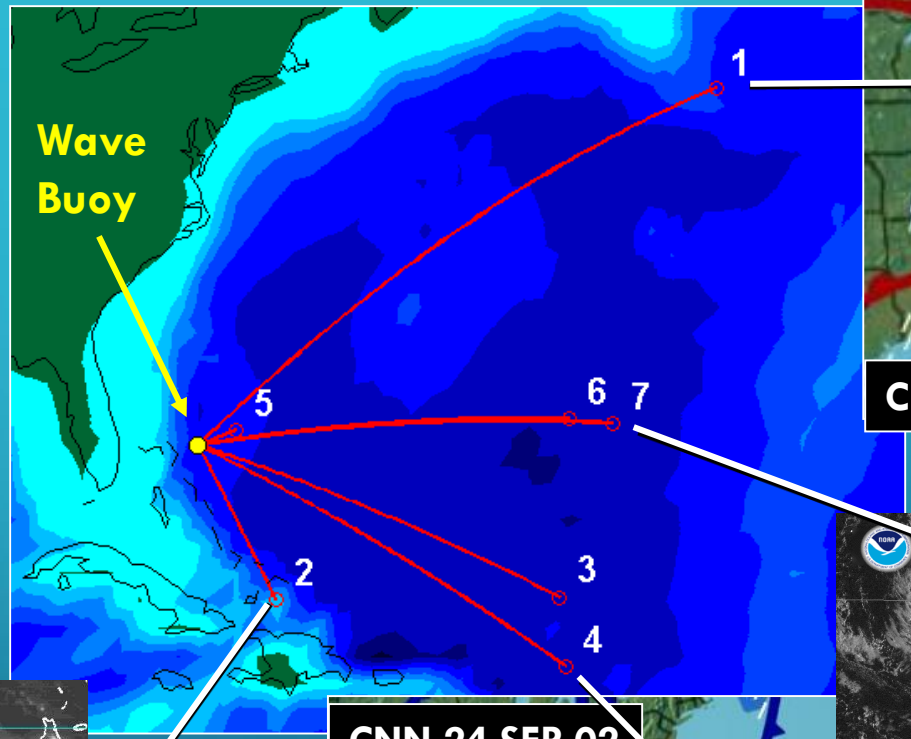
J. Hanson
WaveForce Technologies

EXAMPLE RESULTS: NORTH ATLANTIC SWELL TRACKING
BAHAMAS SEPTEMBER 2002

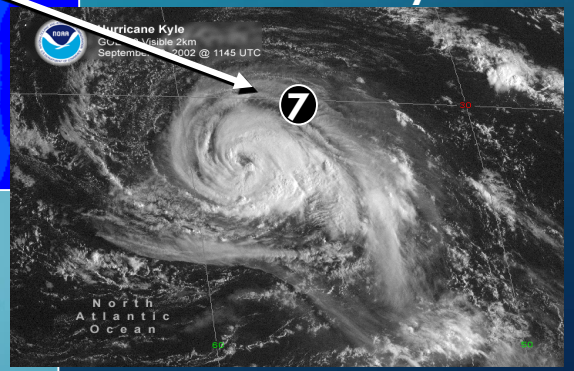
Swell Event Map



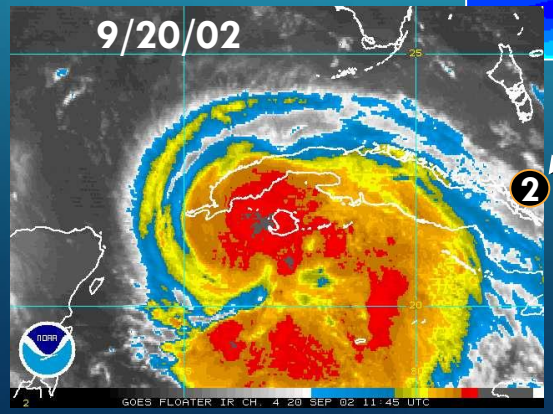
Tropical Storm Josephine



Hurricane Kyle

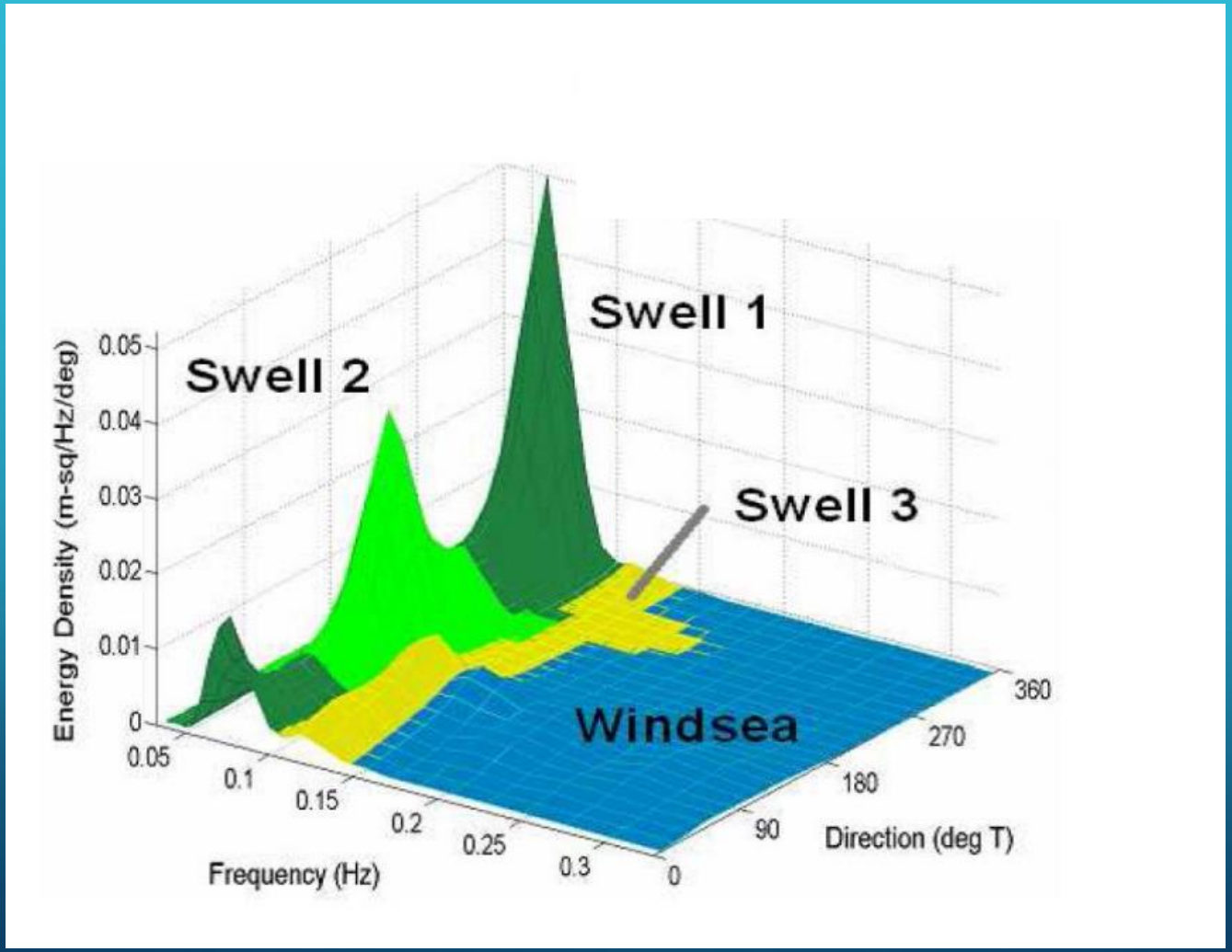


Hurricane Isidore 9/20/02



Hurricane Lili

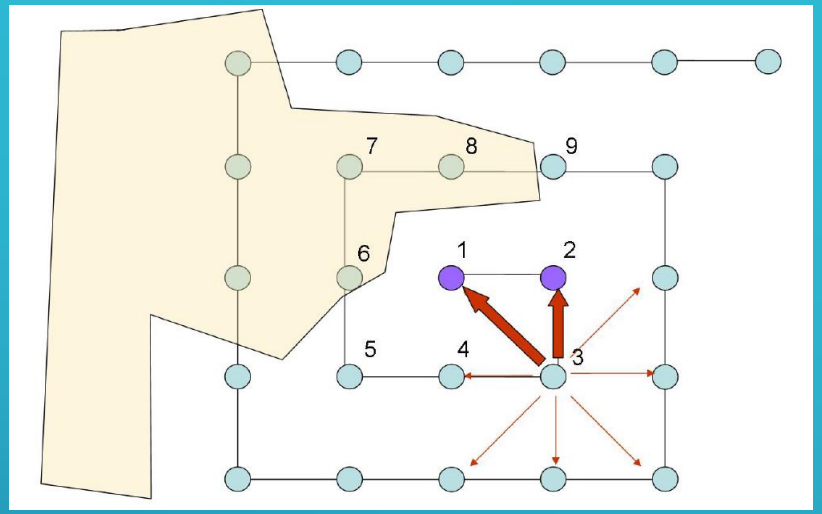
WAVE PARTITIONING FOR WAVEWATCH III

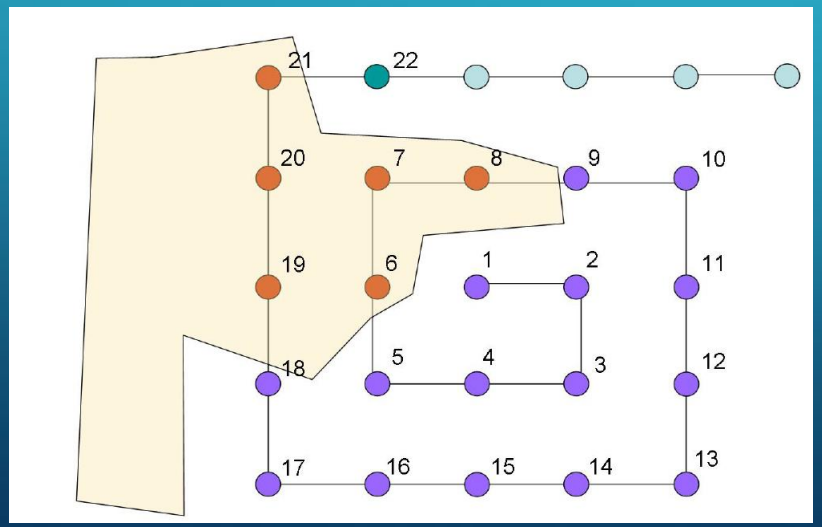


- Operationally run by NCEP
- Wave partition fields available via OpenDAP server (netCDF)

Hanson and Phillips, 2003; Tracey, Tracey and Hanson, 2007

SPATIAL/TEMPORAL WAVE TRACKING FOR SWAN – NWS WFO DEMONSTRATION PROJECTS





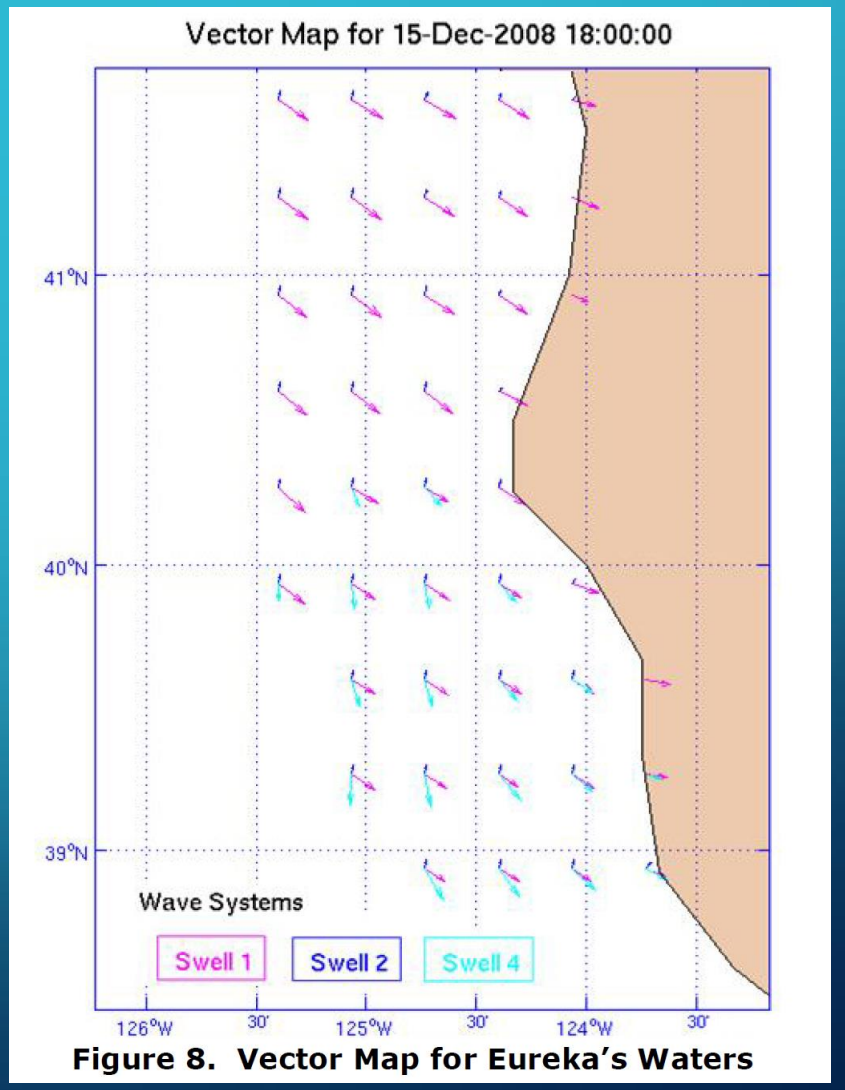
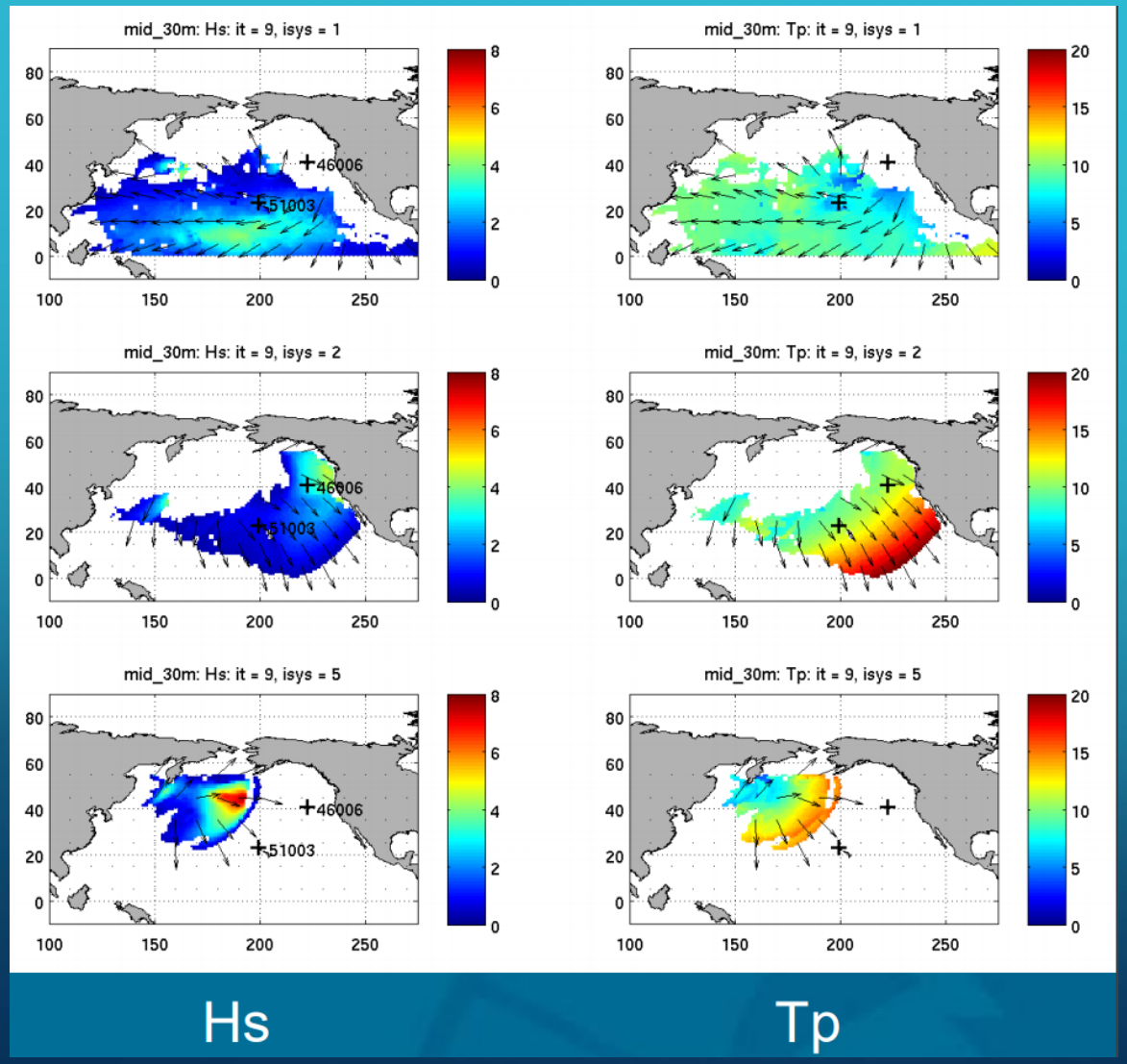


Figure 8. Vector Map for Eureka's Waters

Devaliere, Hanson and Luettich, 2009

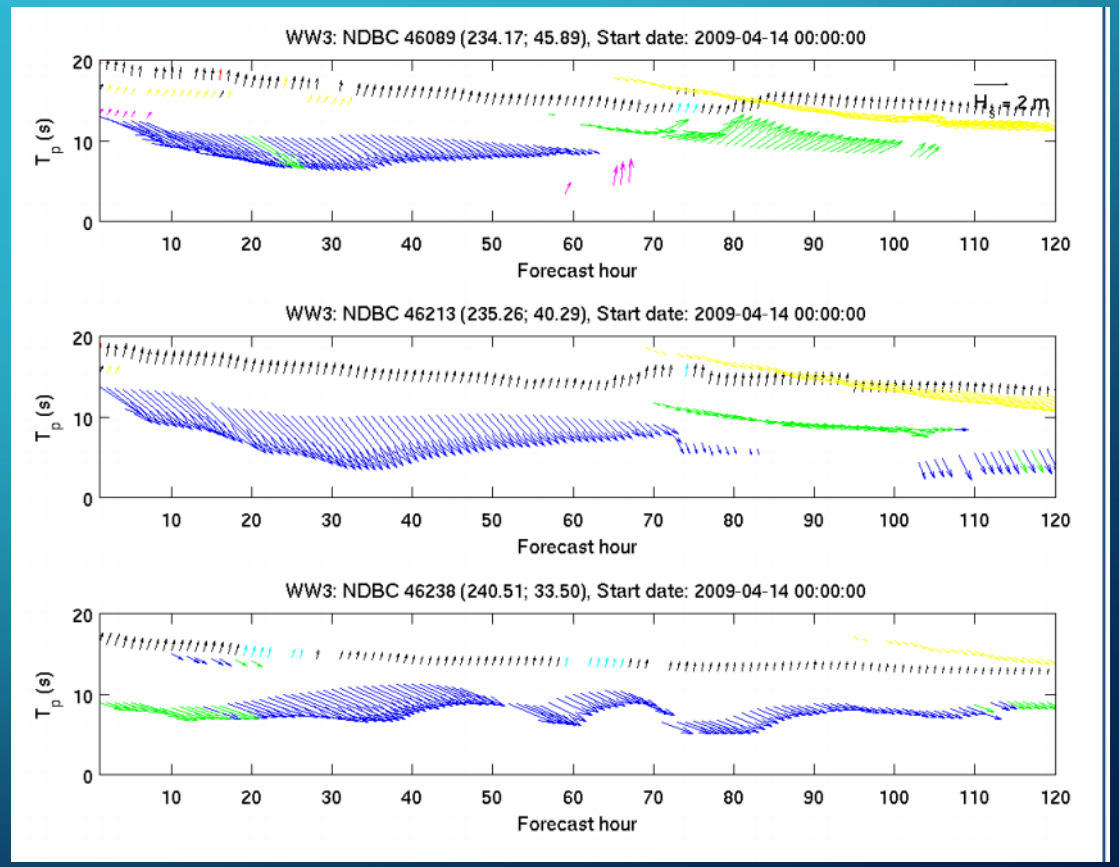
OPERATIONAL WAVE TRACKING FOR SWAN: NWS NEARSHORE WAVE PREDICTION SYSTEM

Spatial



Hs Tp

Temporal



van der Westhuysen, Hanson and Devaliere, 2013

NEARSHORE WAVE FORECASTING RE-INVENTED

WaveForce technologies

Wave System Approach

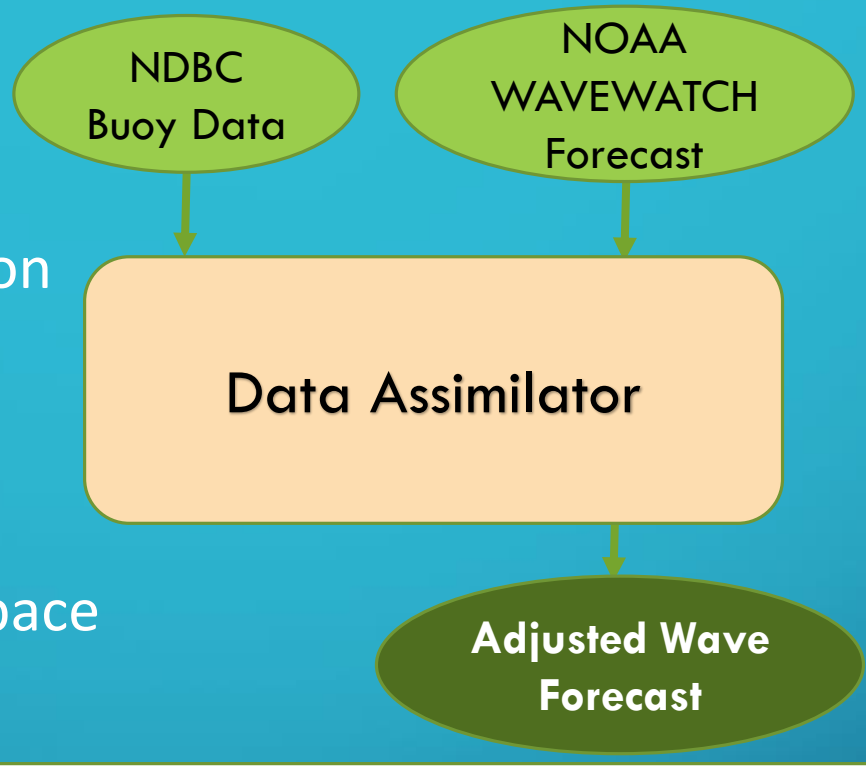
- Buoy data assimilation
- Surf breaking model – Wave systems
- Hi-resolution nearshore bathymetry (FEMA, USGS, USACE)

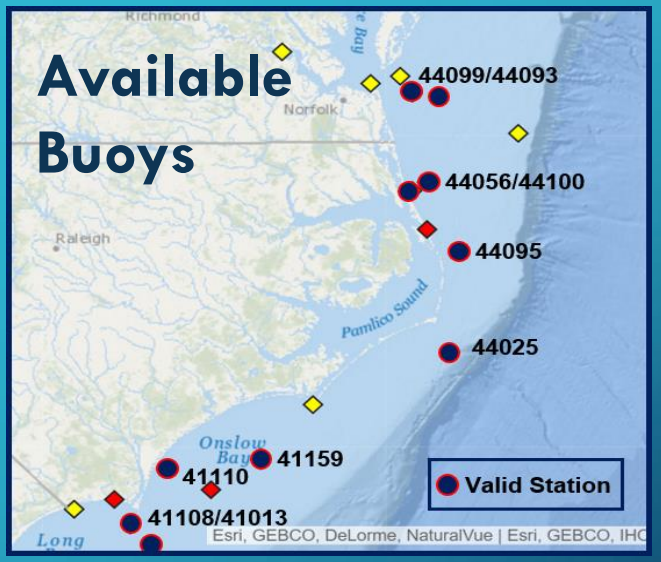
Modern Computing Techniques

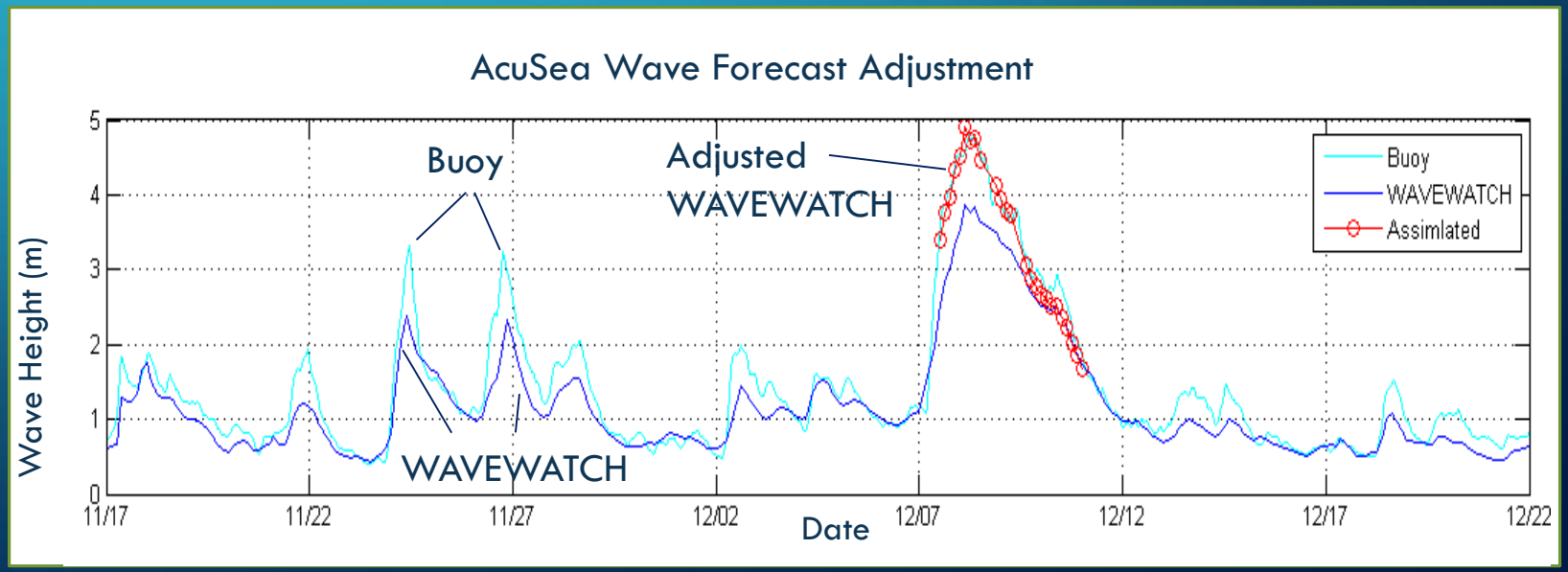
- Data Fusion – Merging data from the WWW
- Artificial Intelligence – Advanced machine learning algorithms
- State-of-the-Art Cloud Computing – Fast and efficient computing

DATA ASSIMILATION

- Custom Wave System assimilation
- Buoy adjustment of operational forecasts
- Propagated through time and space

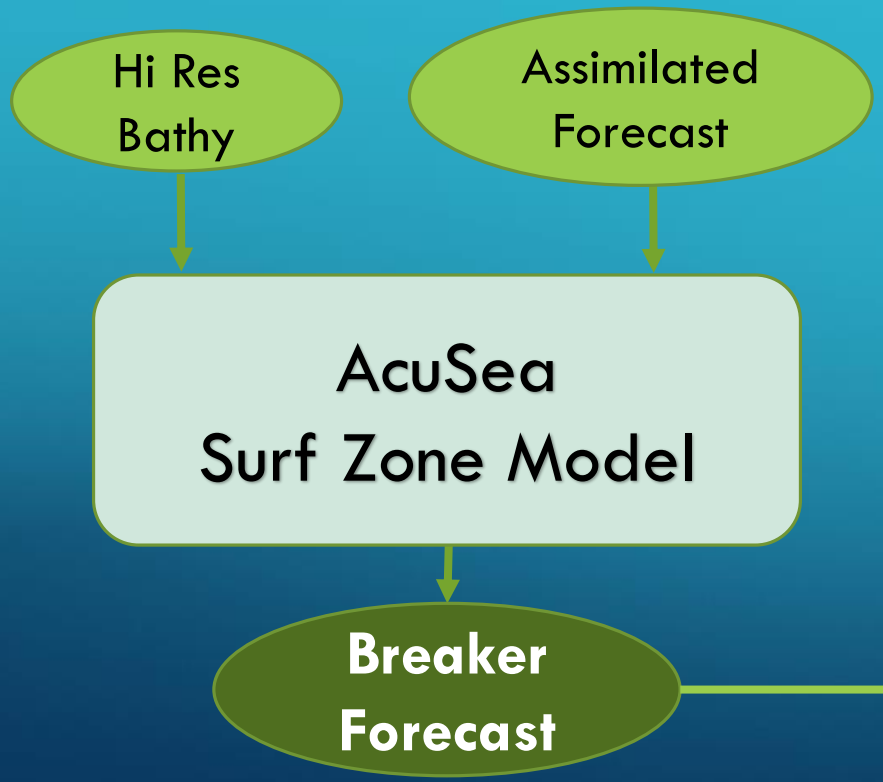






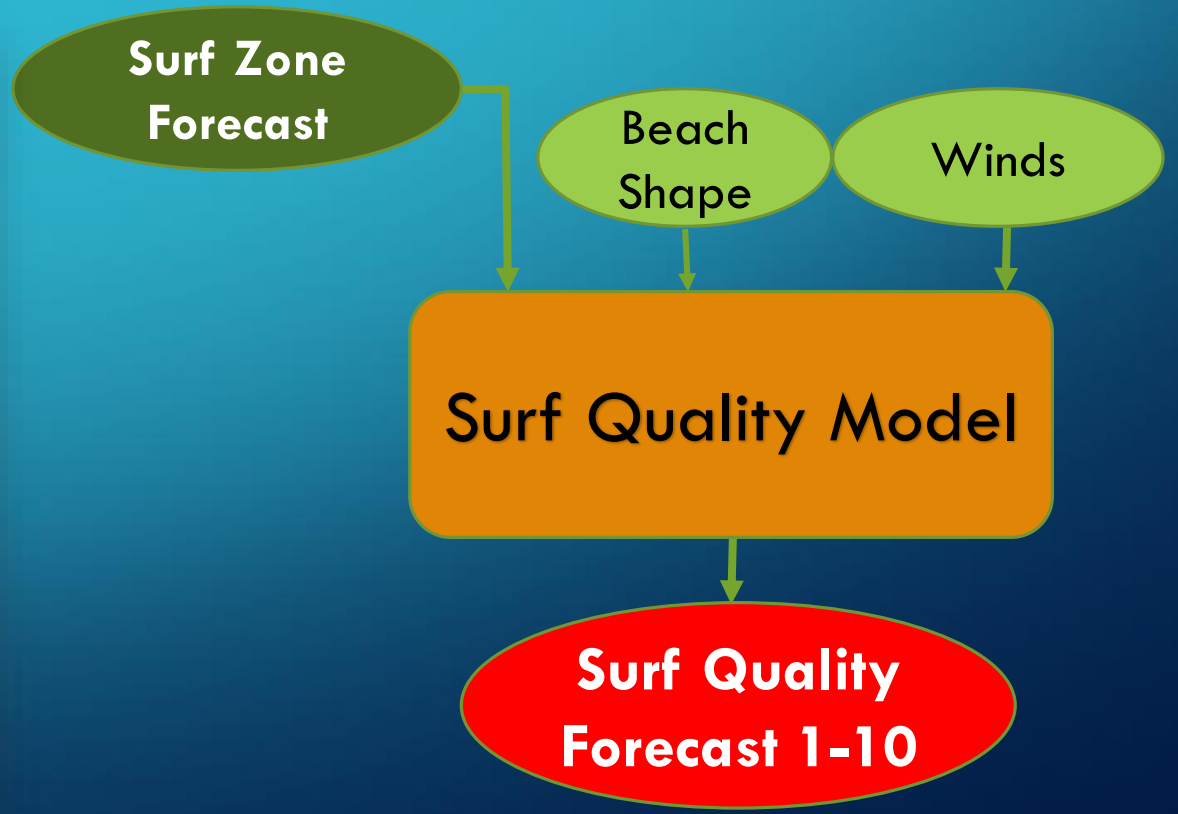
SURF ZONE MODEL

- Synthesizes 35 years of wave research
- Operates on assimilated wave systems (Hs/Tp/Dm)
- High computational efficiency

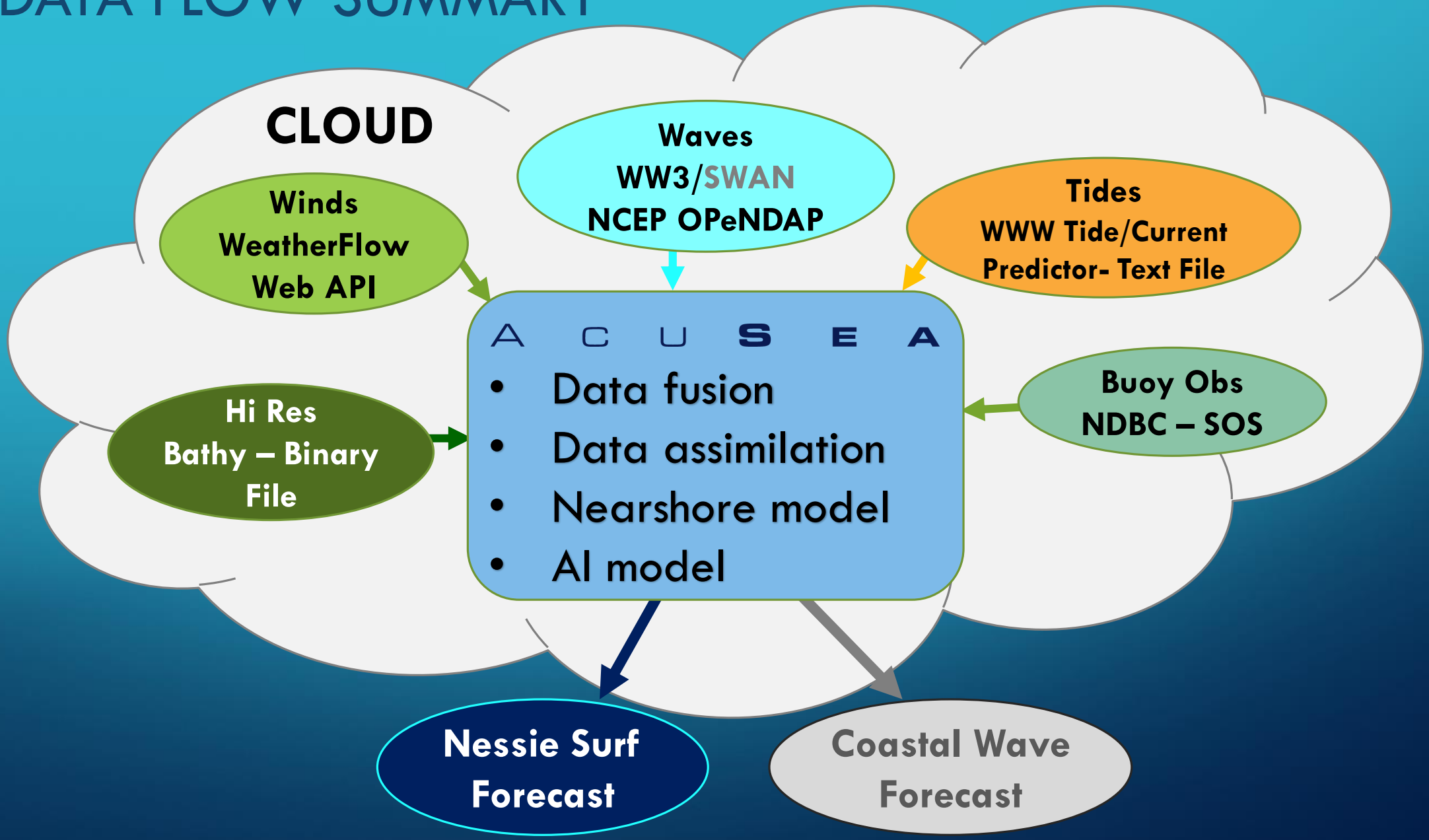


SURF QUALITY MODEL

- Fusing winds, waves, beach slopes and bar profiles
- Neural Network Algorithms



DATA FLOW SUMMARY

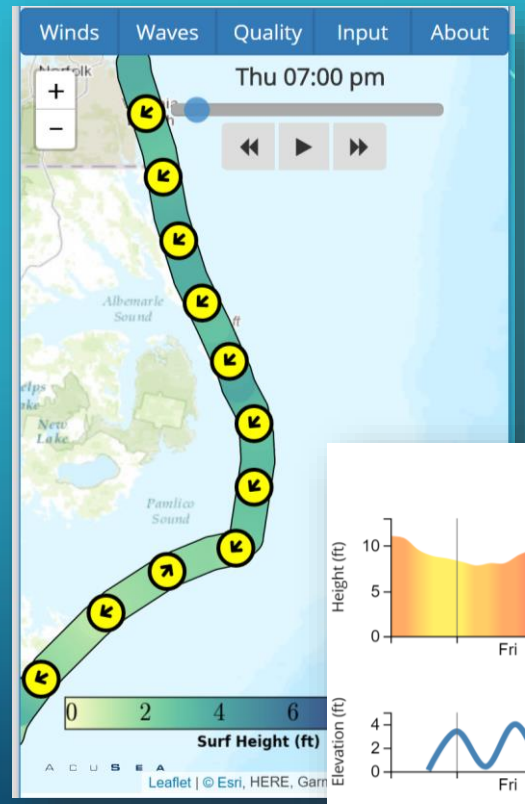


MODEL DEMONSTRATION: NESSIE SURF FORECAST

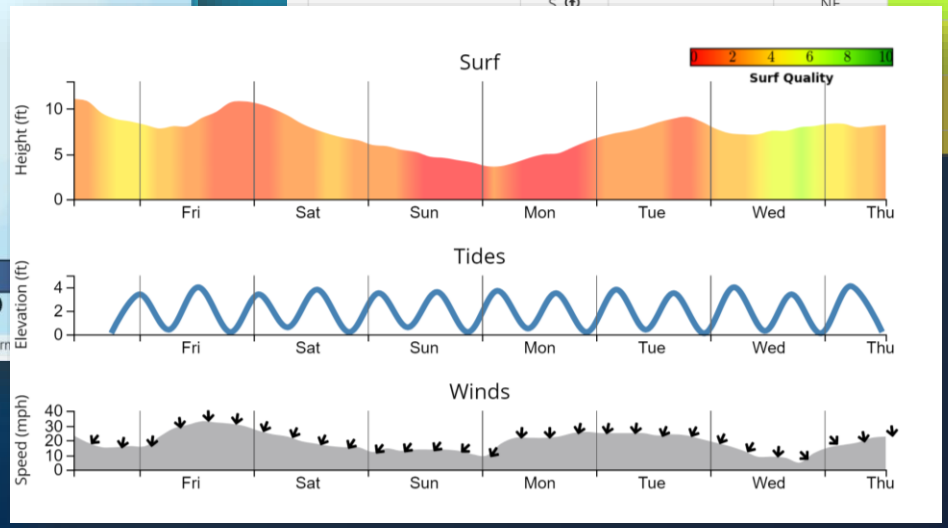
Packaged in a mobile-friendly online site

AcuSea Nessie Model:

- Surf Zone breaker heights
- Online data fusion
- Efficient cloud computing
- Artificial Intelligence learning
- Very high resolution along shore
- Mid-Atlantic and Hawaii



Day	Winds	Tide	Waves	Quality
Thu 06/08 08:00 pm	23 mph N	High (7:48 pm)	6-9 ft, 7 s NE	1-2
Thu 06/08 11:00 pm	17 mph N	Falling	6-9 ft, 7 s NE	2-4
Fri 06/09 02:00 am	15 mph NW	Low (2:23 am)	5-7 ft, 7 s NE	3-5
Fri 06/09 05:00 am	15 mph NW	Rising	5-8 ft, 9 s E	4-6
Fri 06/09 08:00 am	14 mph W	High (8:09 am)	5-7 ft, 8 s NE	4-6
Fri 06/09 11:00 am	11 mph W	Falling	5-7 ft, 8 s NE	5-7
Fri 06/09 02:00 pm	8 mph SW	Low (2:04 pm)	4-6 ft, 8 s NE	7-9
Fri 06/09 05:00 pm	15 mph S	Rising	4-6 ft, 8 s NE	6-8



VALIDATION

The Surf Community helped us build an Outstanding Product…

TEST AND EVALUATION PHASE: July-October 2017

- Product Review Team (30 members)
- Surf height and quality logging
- Site feedback
- Buoy validation


Ian Cross

We Need Your Input!
Submit your Observations and Comments Here:

Name
Please enter your name

Date/Time
Please enter the date and time of your observation (Local Time)

Location
Please select your location

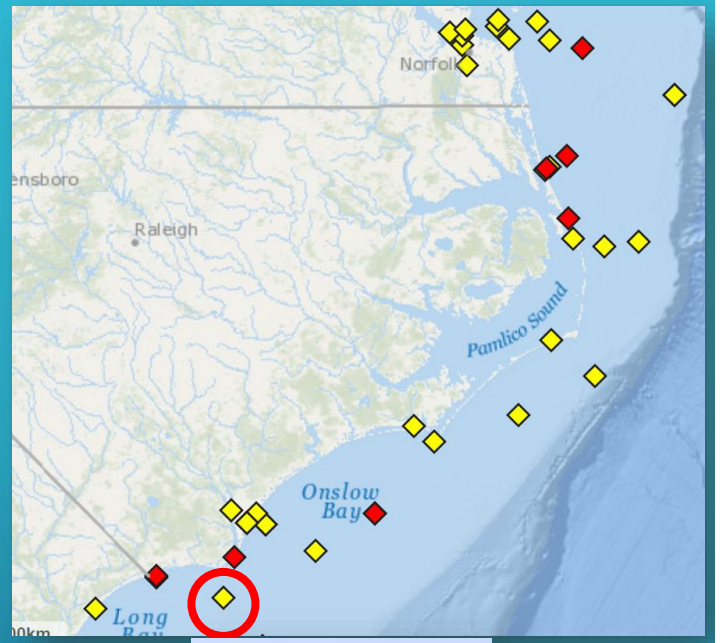
Surf Height (ft)
Report the wave face height

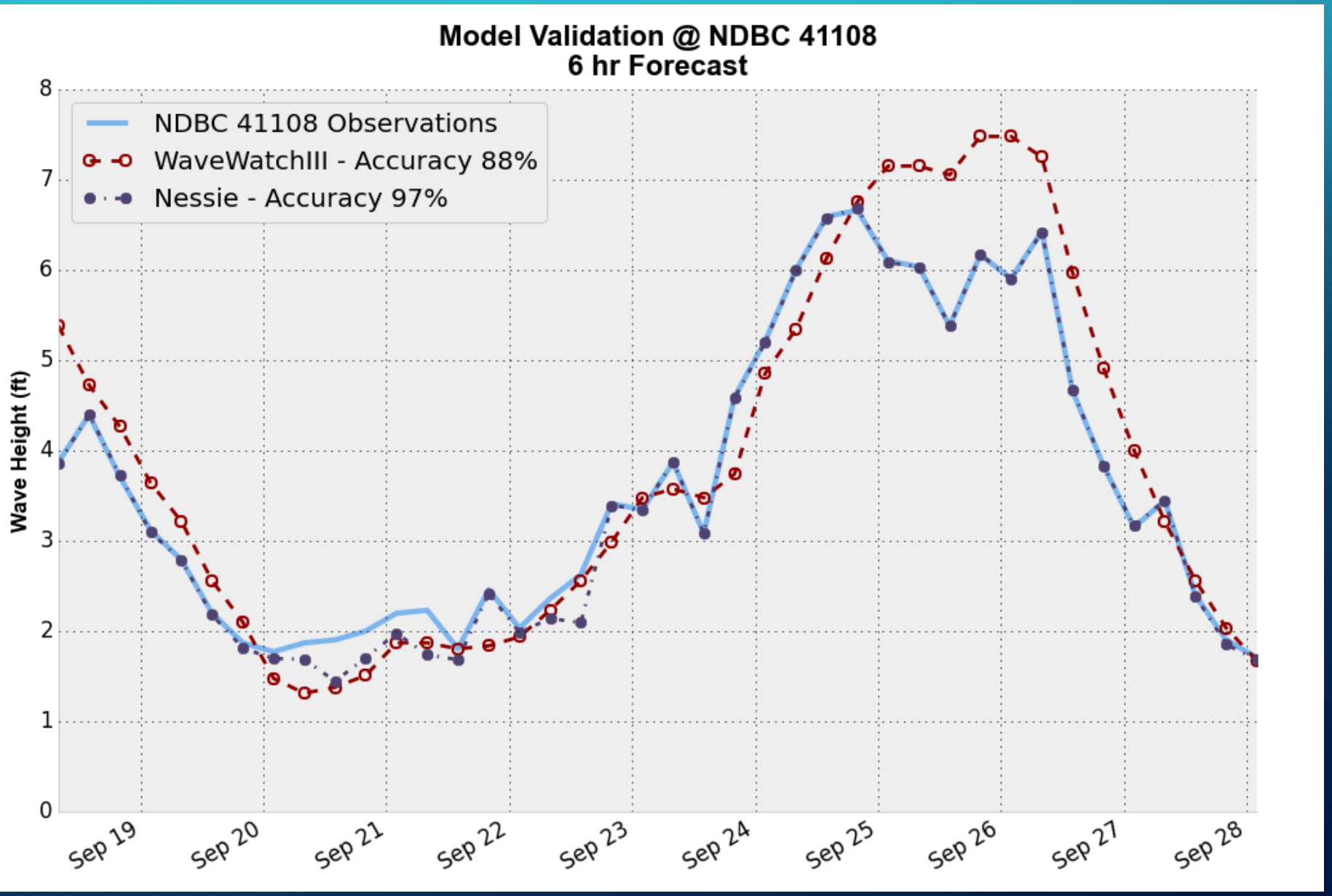
Quality (1-10)
Please select the wave quality

Comments
Comments for AcuSea

STATION 41108 WILLMINGTON

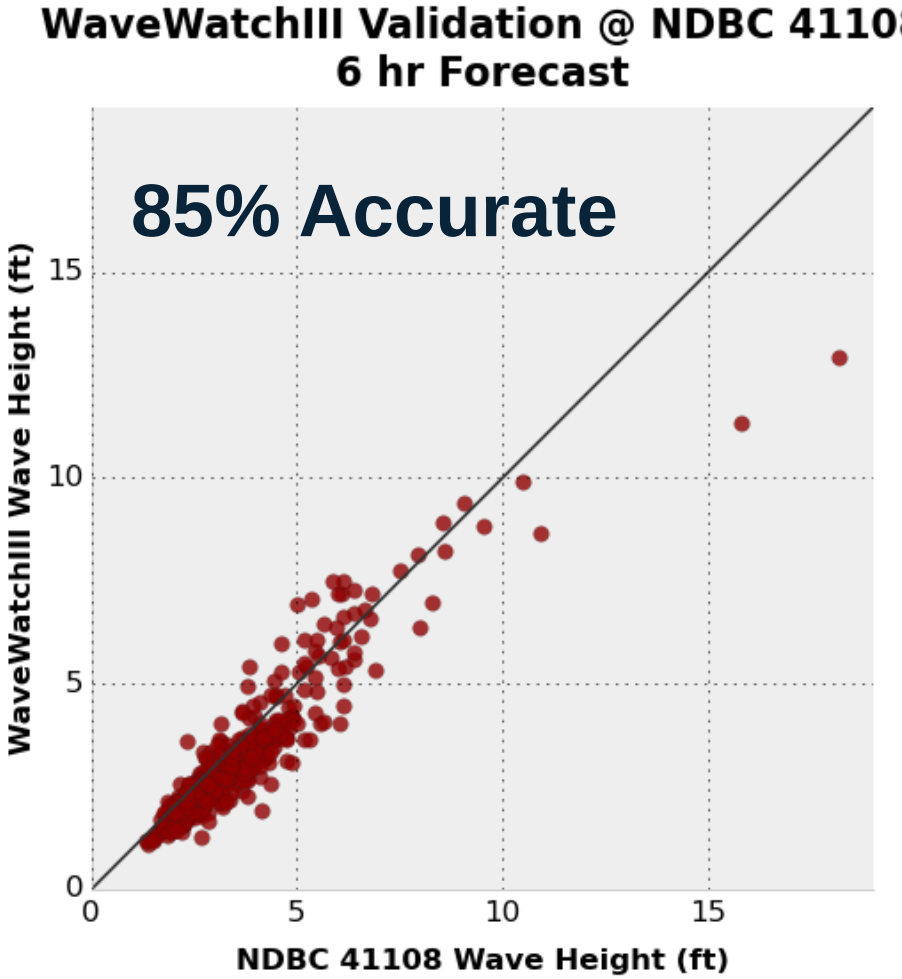
A C U S E A



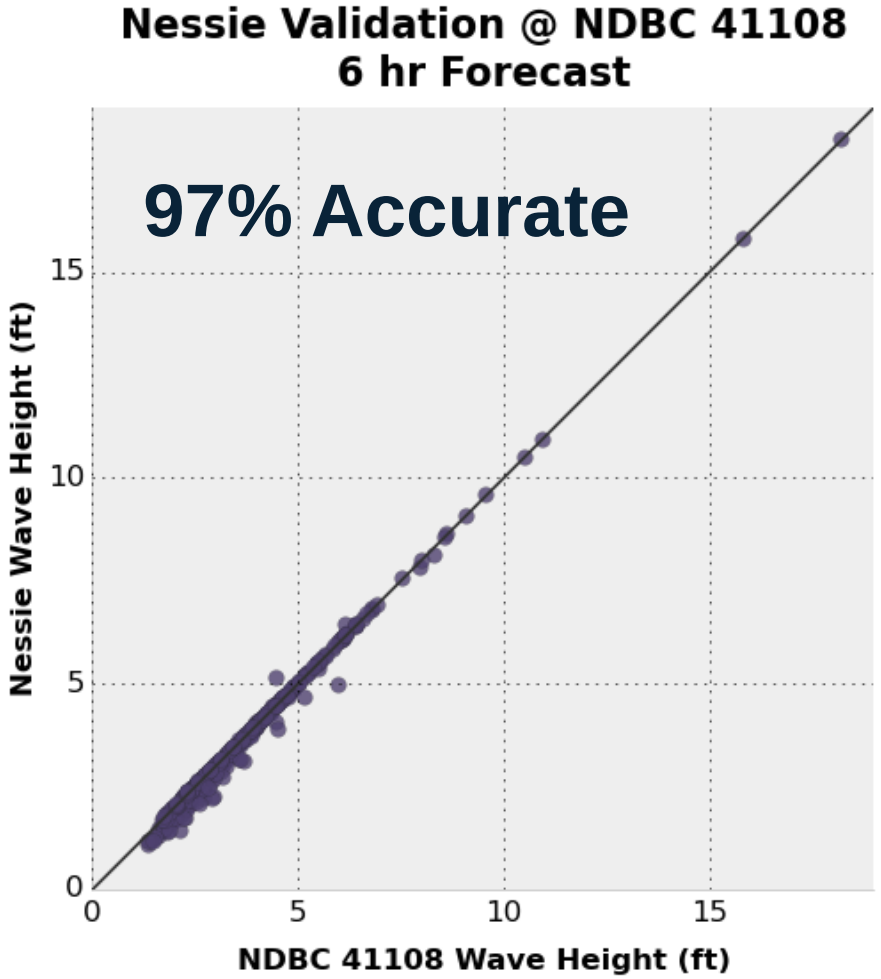


STATION 41108 ALL DATA

A C U S E A



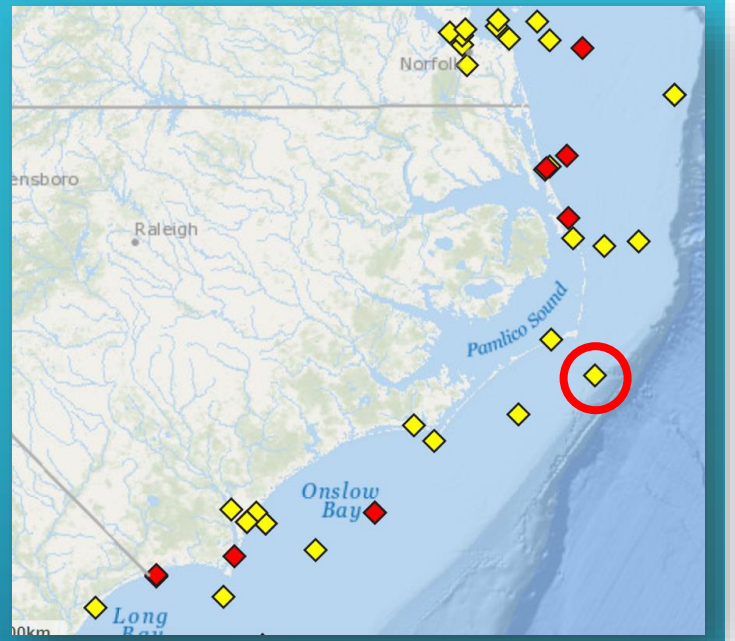
Accuracy (%)	85
RMS	0.76
Bias (m)	-0.41
R2	0.87

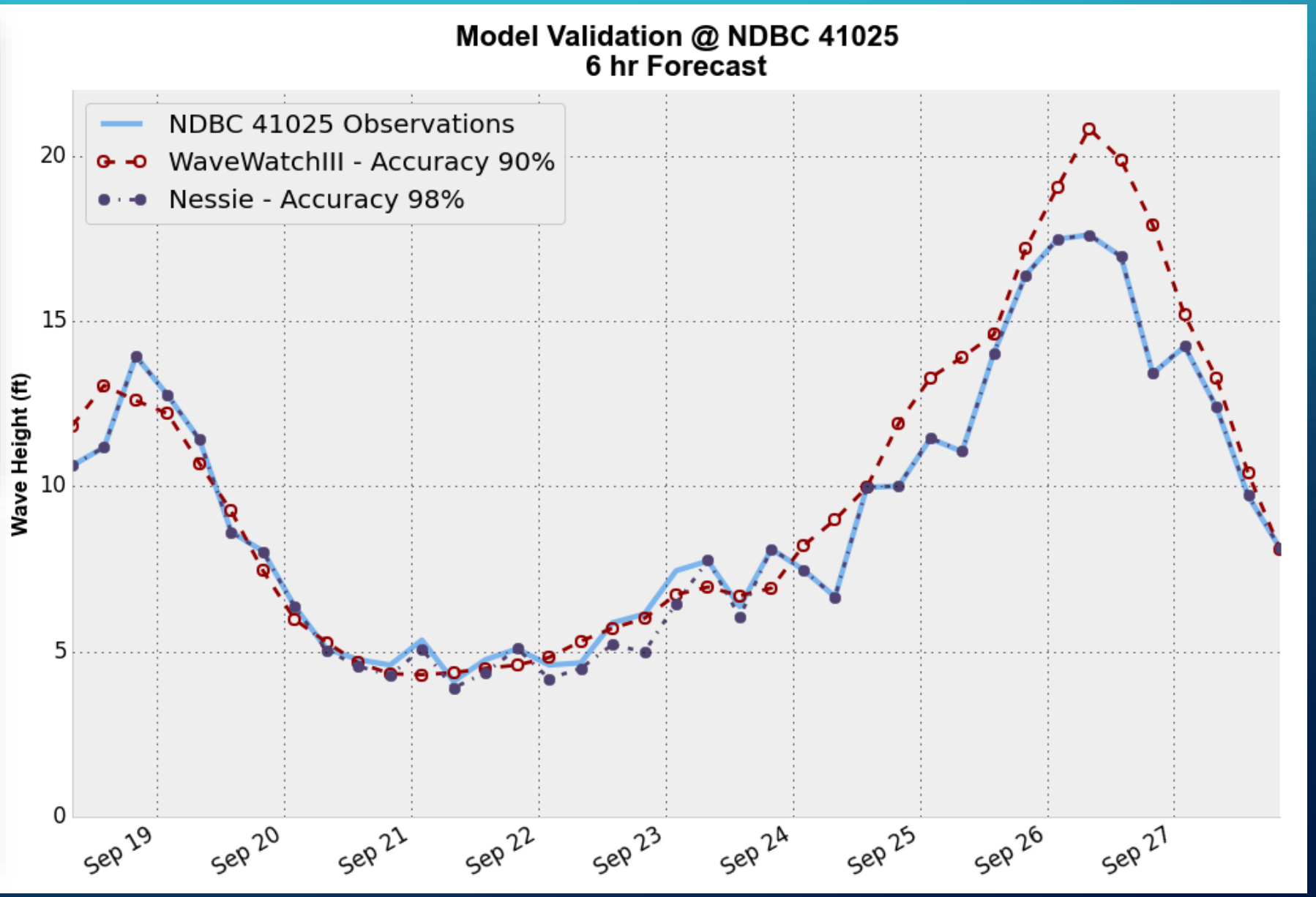


Accuracy (%)	97
RMS	0.17
Bias (m)	-0.08
R2	0.99

STATION 41025 DIAMOND SHOALS

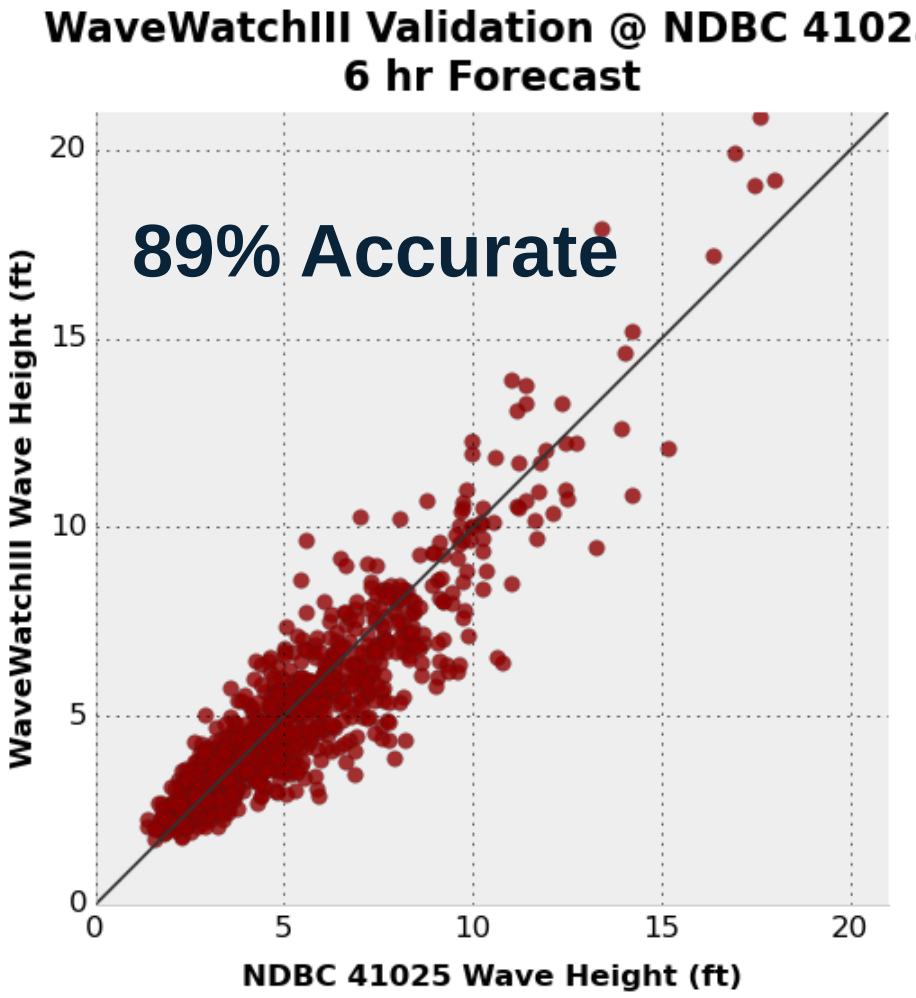
A C U S E A



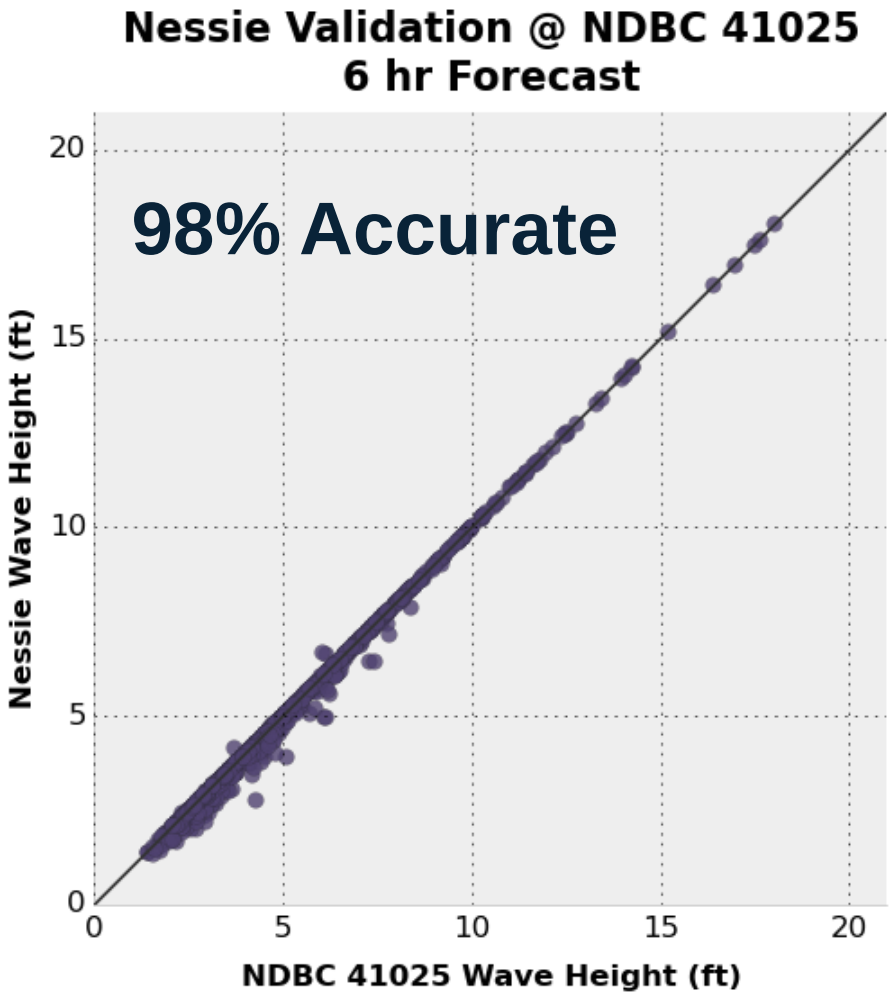


STATION 41025 ALL DATA

A C U S E A



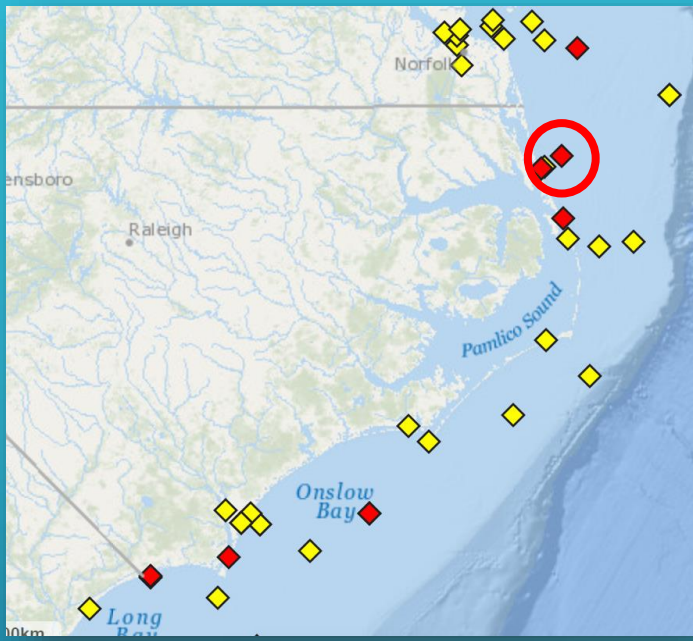
Accuracy (%)	89
RMS	1.06
Bias (m)	-0.16
R2	0.83

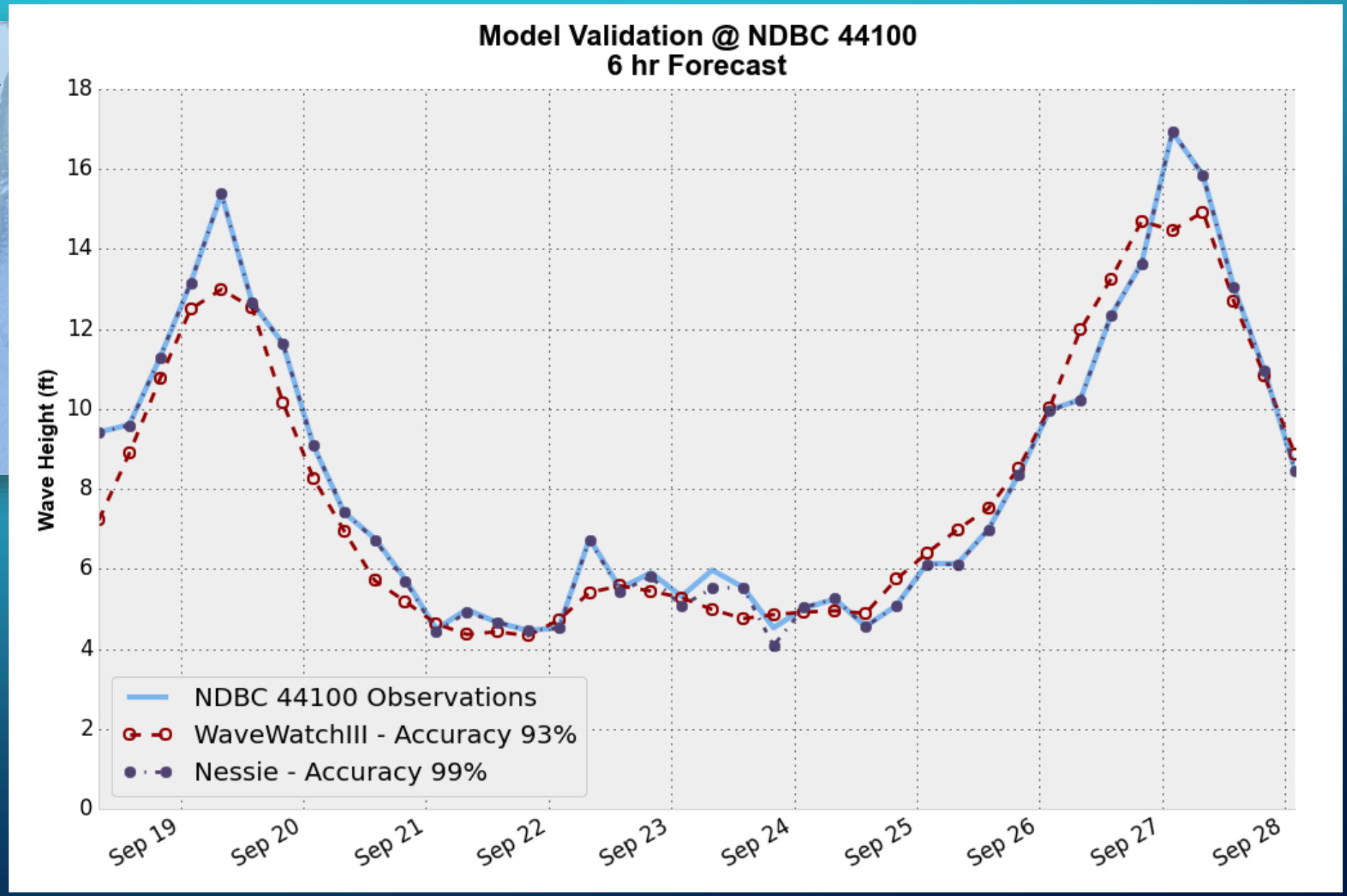


Accuracy (%)	98
RMS	0.17
Bias (m)	-0.07
R2	1.0

STATION 44100 DUCK 26M

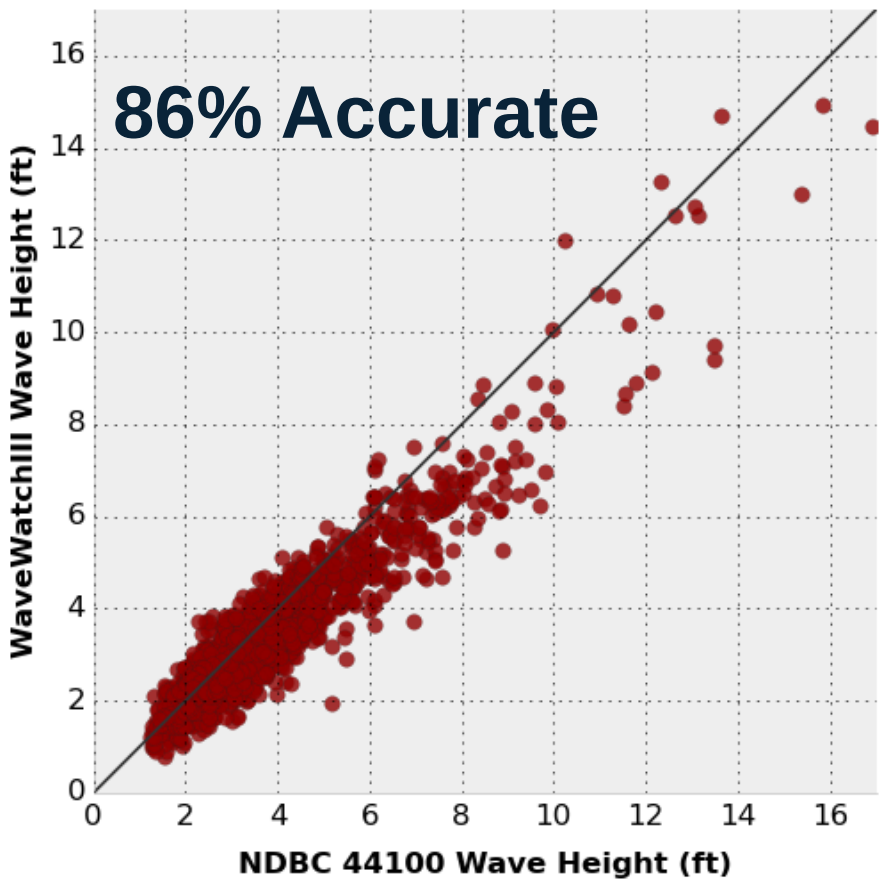
A C U S E A



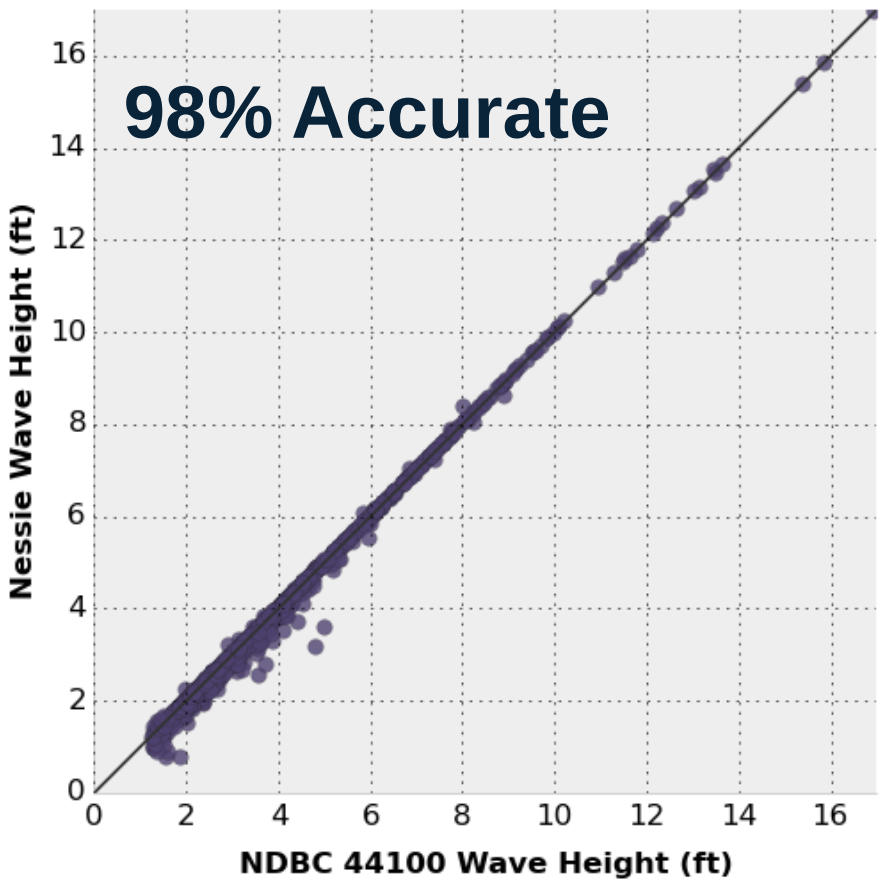


STATION 44100 ALL DATA

A C U S E A

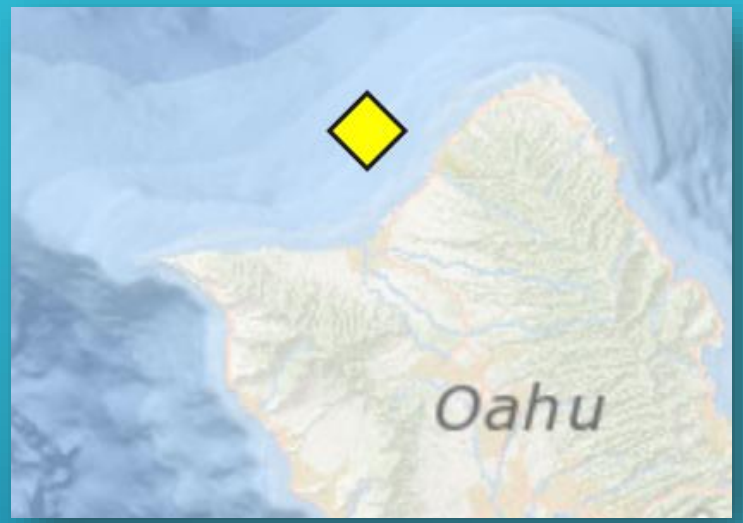


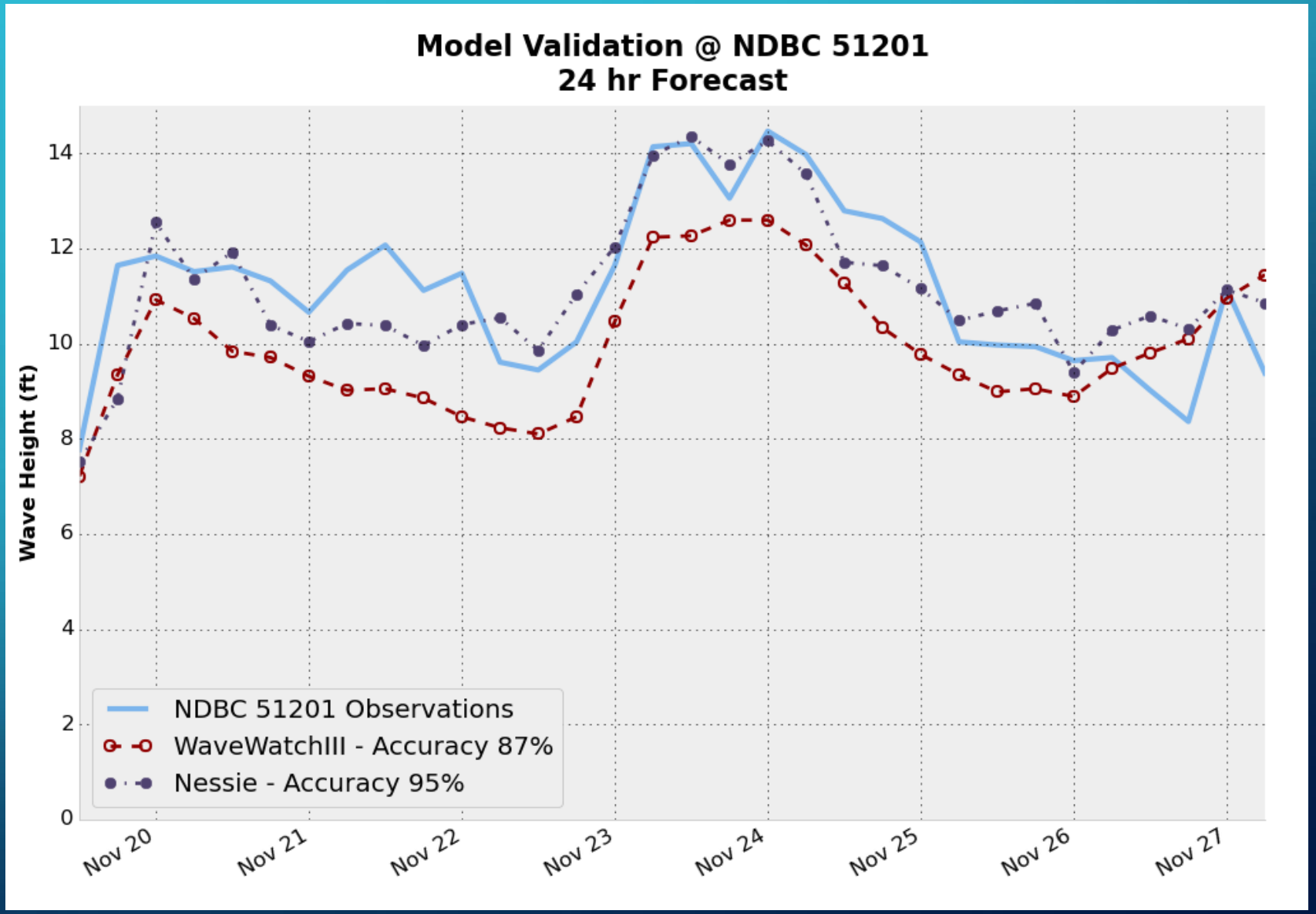
Accuracy (%)	86
RMS	0.82
Bias (m)	-0.41
R2	0.89



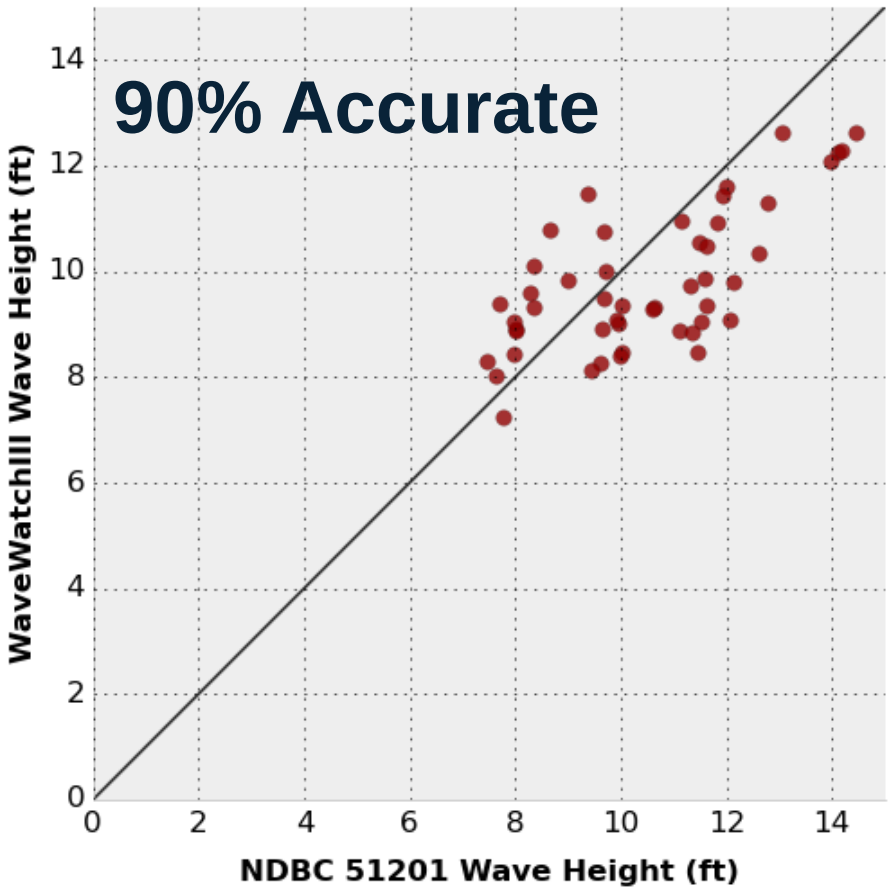
Accuracy (%)	98
RMS	0.13
Bias (m)	-0.05
R2	1.0

STATION 51201 WAIMEA BAY 24-H FORECAST

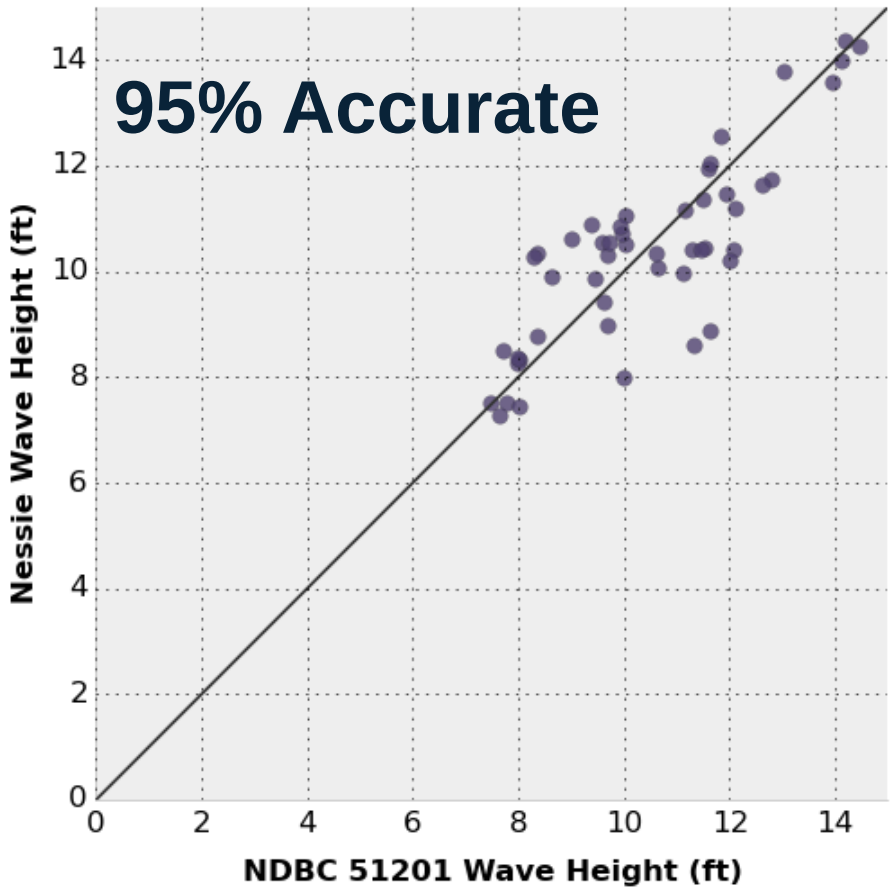




STATION 51201 WAIMEA BAY 24-H FORECAST



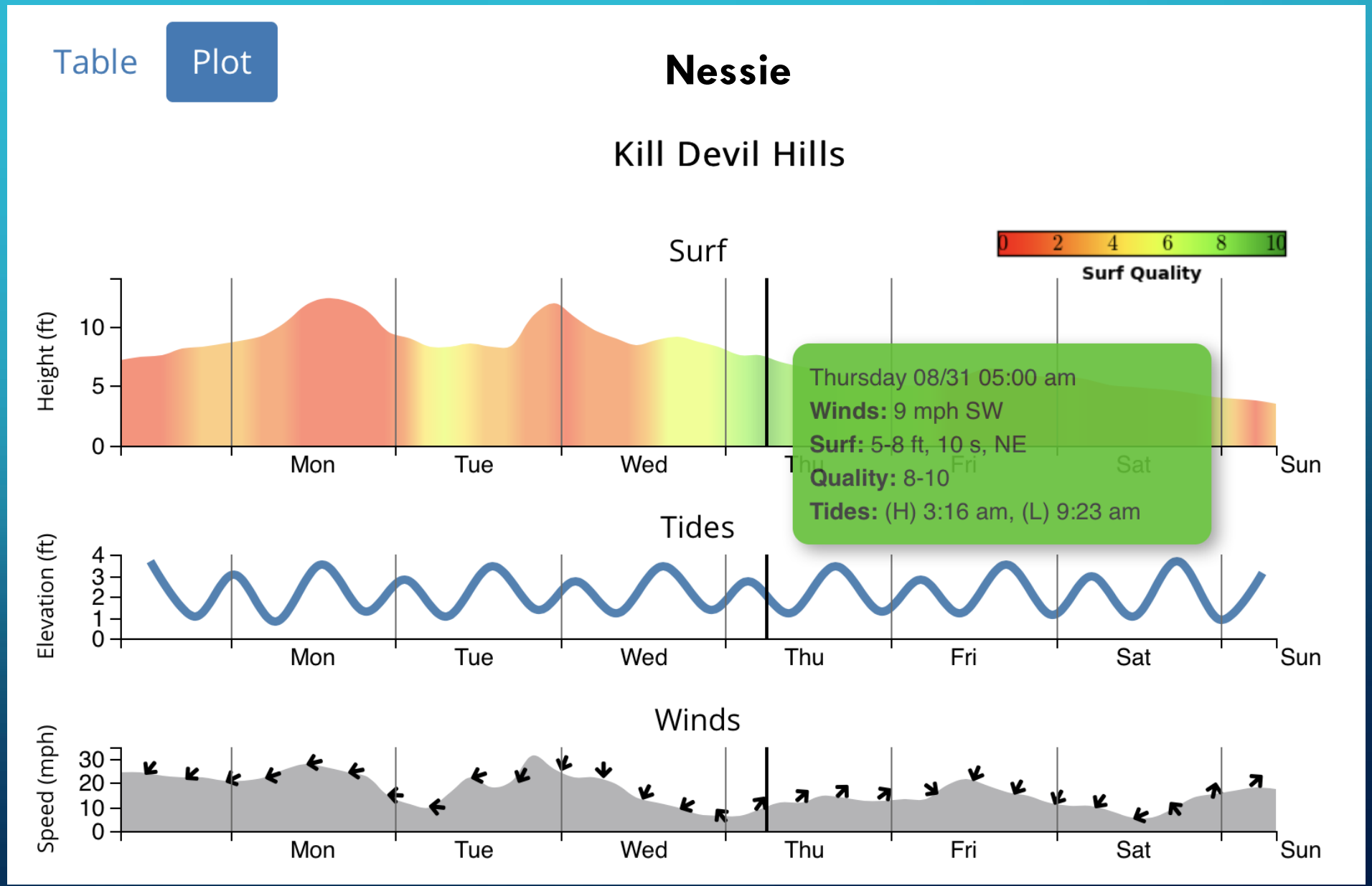
Accuracy (%)	90
RMS	1.54
Bias (m)	-0.7
R2	0.47



Accuracy (%)	95
RMS	1.07
Bias (m)	-0.1
R2	0.69

HOW DO WE MEASURE UP?

Late August 2017 Swell Event
4 Days Out



CASE STUDY

August 31, 2017 Swell Event

Product	4-Day Forecast	Day of Event
A	3-5 ft	5-6 ft; Fair to Good
B	3-5 ft	3-5 ft
Nessie	5-8 ft; Q = 8-10	5-7 ft; Q = 7-9

AcuSea User Reports

User	Location	Height	Quality	Comments
Spike	Duck	5-6	9	…you guys had this forecast 4 days out…
Ben	KDH	6-8	9	…best day of the summer so far
Spike	KDH	6-8	8	…was fun down by Avalon pier.
Mike	Duck	8-10	7	…still large sets coming in…
Ian	Duck	6-8	9	

WHAT'S NEXT?

ACUSEA

We are ready to expand to the coastal/nearshore environment

- Successful operational demo
- Instantly improves operational forecasts
- Improved accuracy lowers risk and saves money
- Endorsed by surfing community
- Works with existing offshore/coastal models (WAVEWATCH, SWAN, etc..)

ACUSEA

DISCUSSION…