

Quantifying Wave Measurement Differences in Historical and Present Wave Buoy Systems

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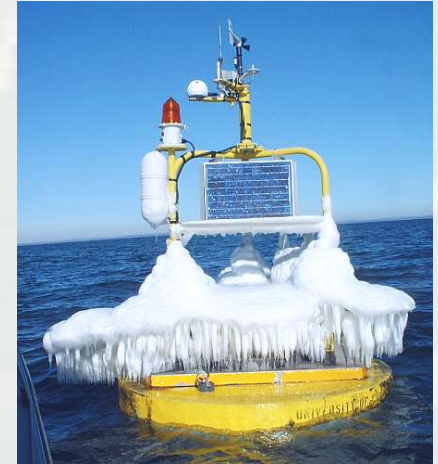
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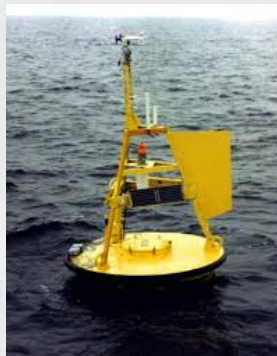
■ Outline:

- ▶ Background
- ▶ Durrant et al. (2009)
 - FLOSSIE
- ▶ Bender et al. (2010)
 - Dual Sensor
- ▶ Foam Buoys: The Future
- ▶ Findings and Conclusions



Background: Motivation

- Problem #1
 - ▶ Wave measurements derived from buoy motion
 - ▶ Variety of buoys spanning 100's of years
 - ▶ Continue to introduce new platforms/sensors/payloads
 - ▶ Limited intra-measurement evaluations
 - ▶ Relied on H_{m0} , T_p , θ_{mean} (metrics based on integral parameters)



Background: Motivation

- Problem #2
 - ▶ $S(f, \theta[a_1, a_2, b_1, b_2])$ or $E(f)$
 - Values span 4 Orders of Magnitude
 - Results in $m^2\text{-s/rad}$ or $m^2\text{-s}$ has little meaning
- Problem #3
 - ▶ Separate measurement differences
 - Based on phase and spatial differences
 - Geophysical variability / noise



The Tests

- **FLOSSIE:**
 - ▶ Investigate accuracy of wave measurements in a 6N (NOMAD) buoy
- Dual Sensor (3DMG / HIPPY)
 - ▶ Investigate the Strapped Down Accelerometer Effect
- Foam Hulls
 - ▶ 3D, 2.4D, 2.3D and 2.1D (SCOOP)

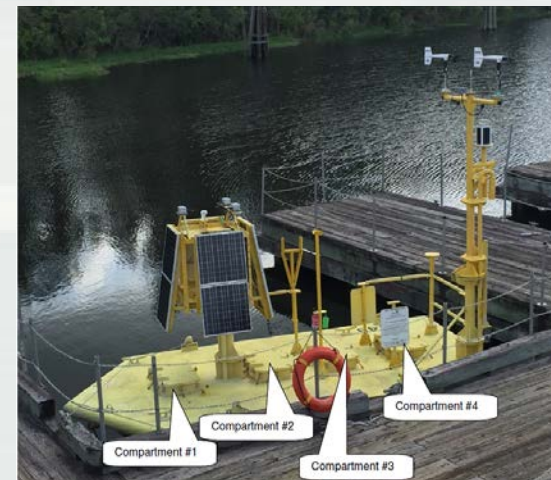


FLOSSIE Study: Monterey Canyon

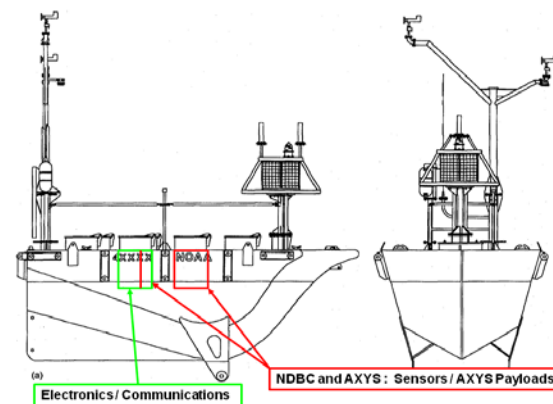


FLOSSIE Study: Monterey Canyon

- Non-Directional Sensor / Payloads
 - ▶ NDBC: Inclinator
 - ▶ NDBC: HIPPY/Magnetometer
 - ▶ ECCC : SDA / AXYS: Watchman
- Directional Sensor / Payloads
 - ▶ NDBC: HIPPY / Magnetometer (DWPM)
 - ▶ NDBC: 3DMG (DDWM)
 - ▶ AXYS: TRIAXYS Next Wave II DWS-WM
- Complete Suite of Met. Sensors
- Data Transfer: IRIDIUM

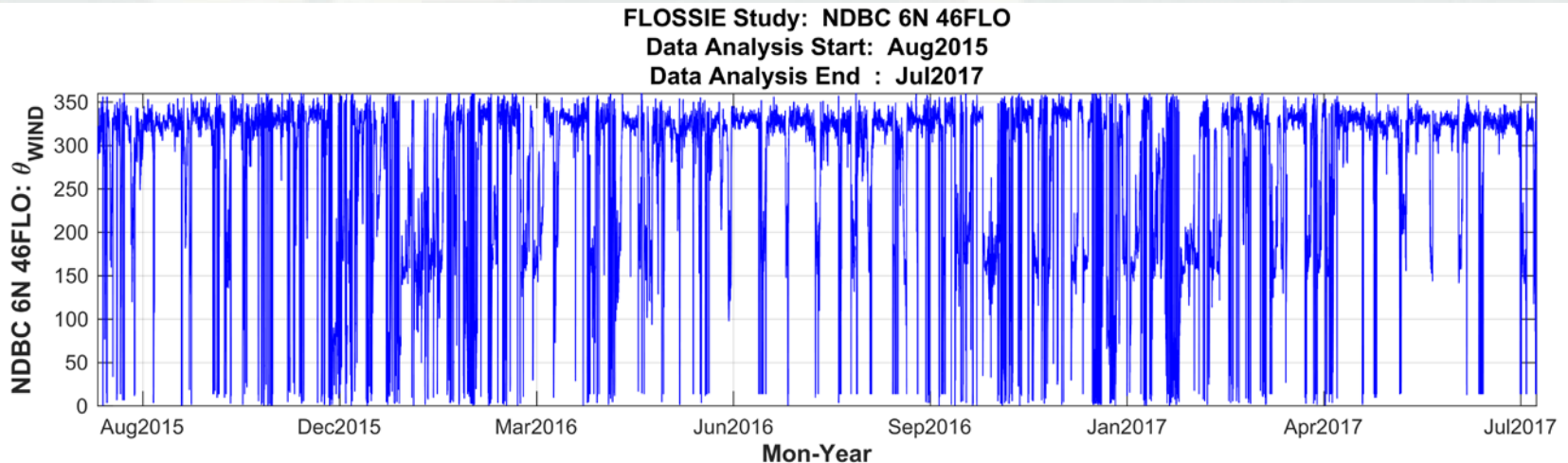
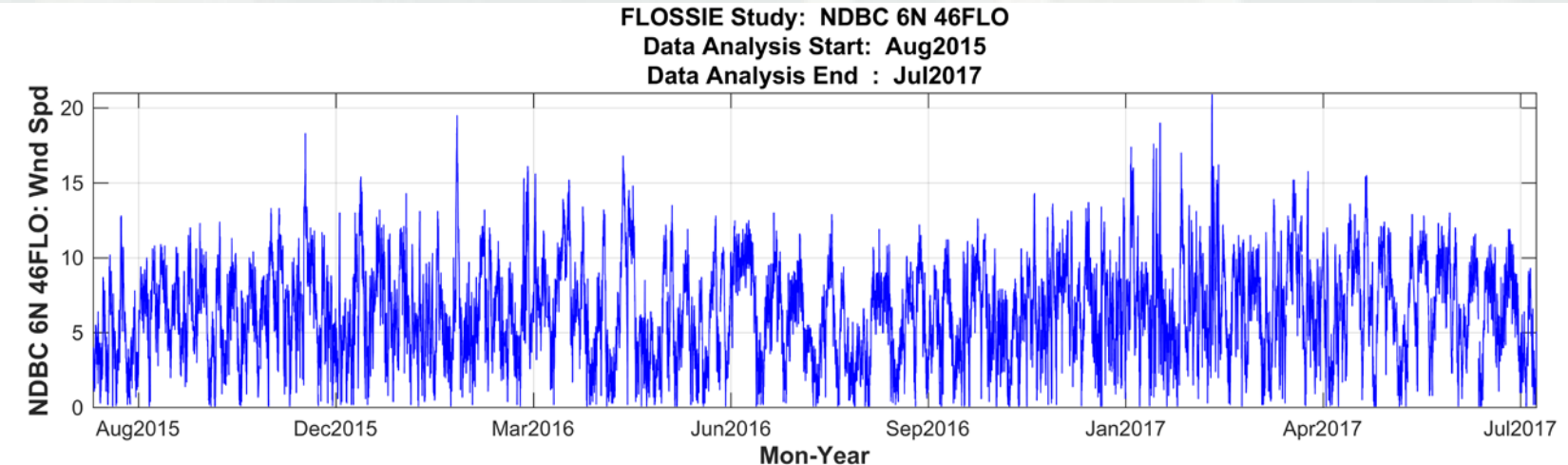


R. Riley & NDBC Techs



FLOSSIE: Wind / Wave Summary

- Buoy Farm General Characteristics: Winds / Waves
- Winds at 5m elevation

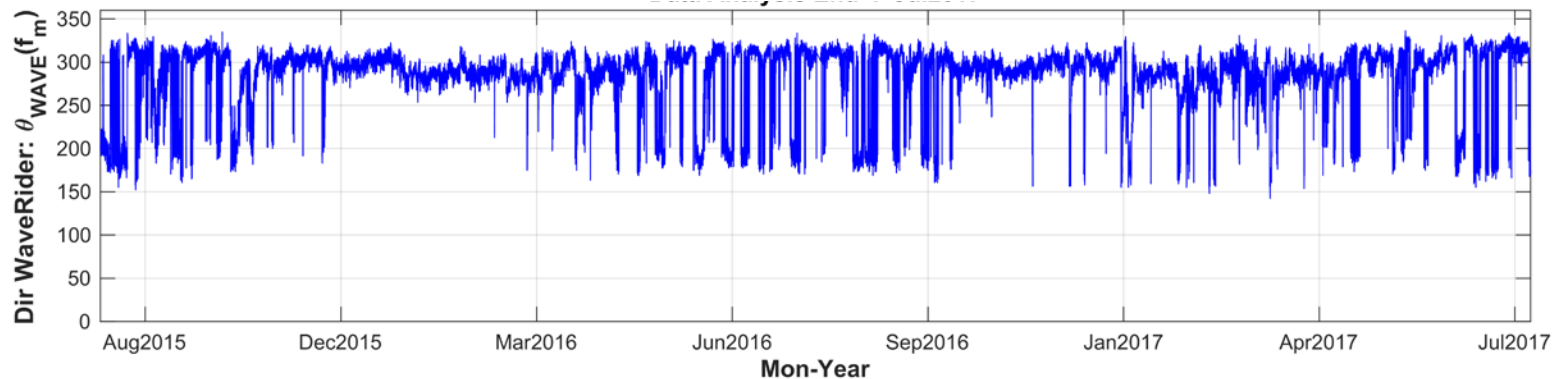
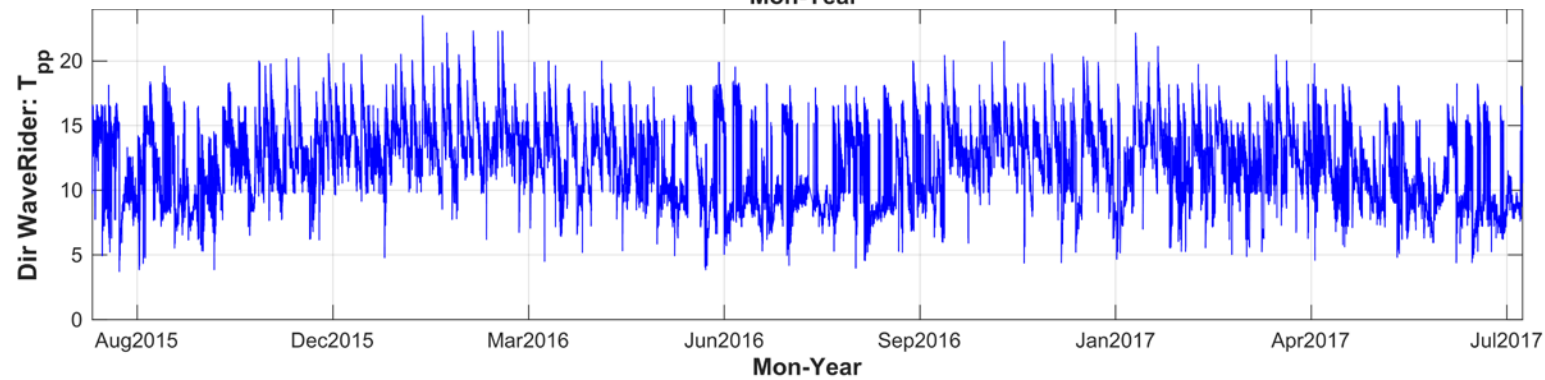
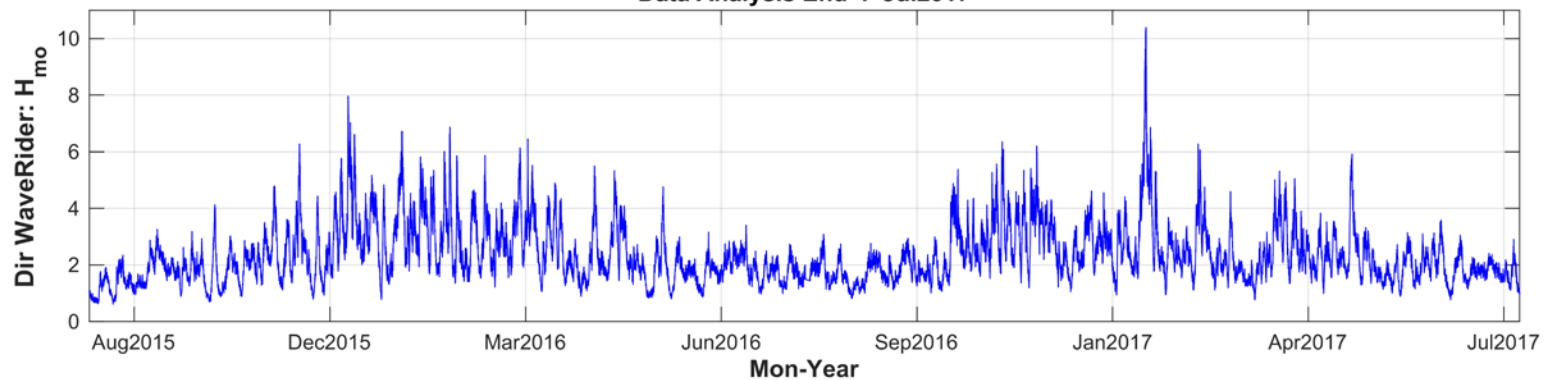


FLOSSIE: Wind / Wave Summary

FLOSSIE Study: Directional WaveRider 46114

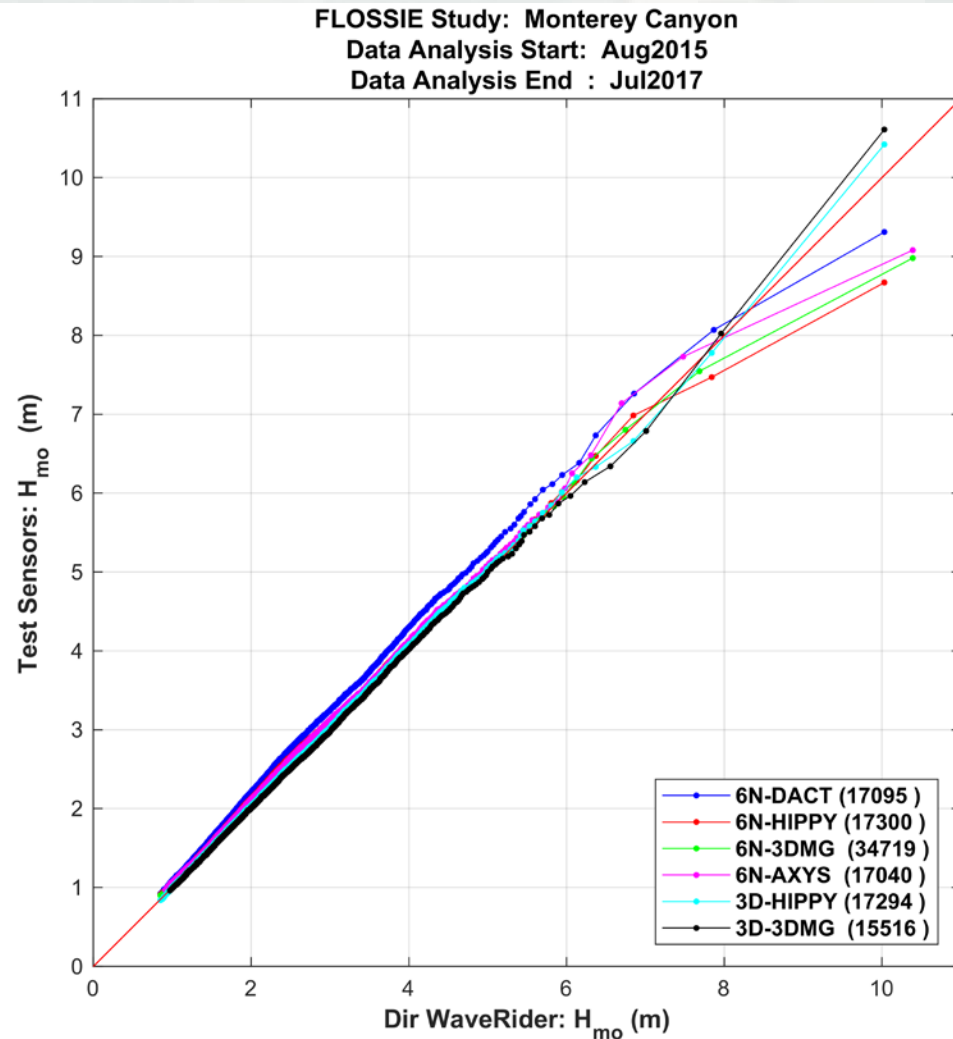
Data Analysis Start: Aug2015

Data Analysis End : Jul2017



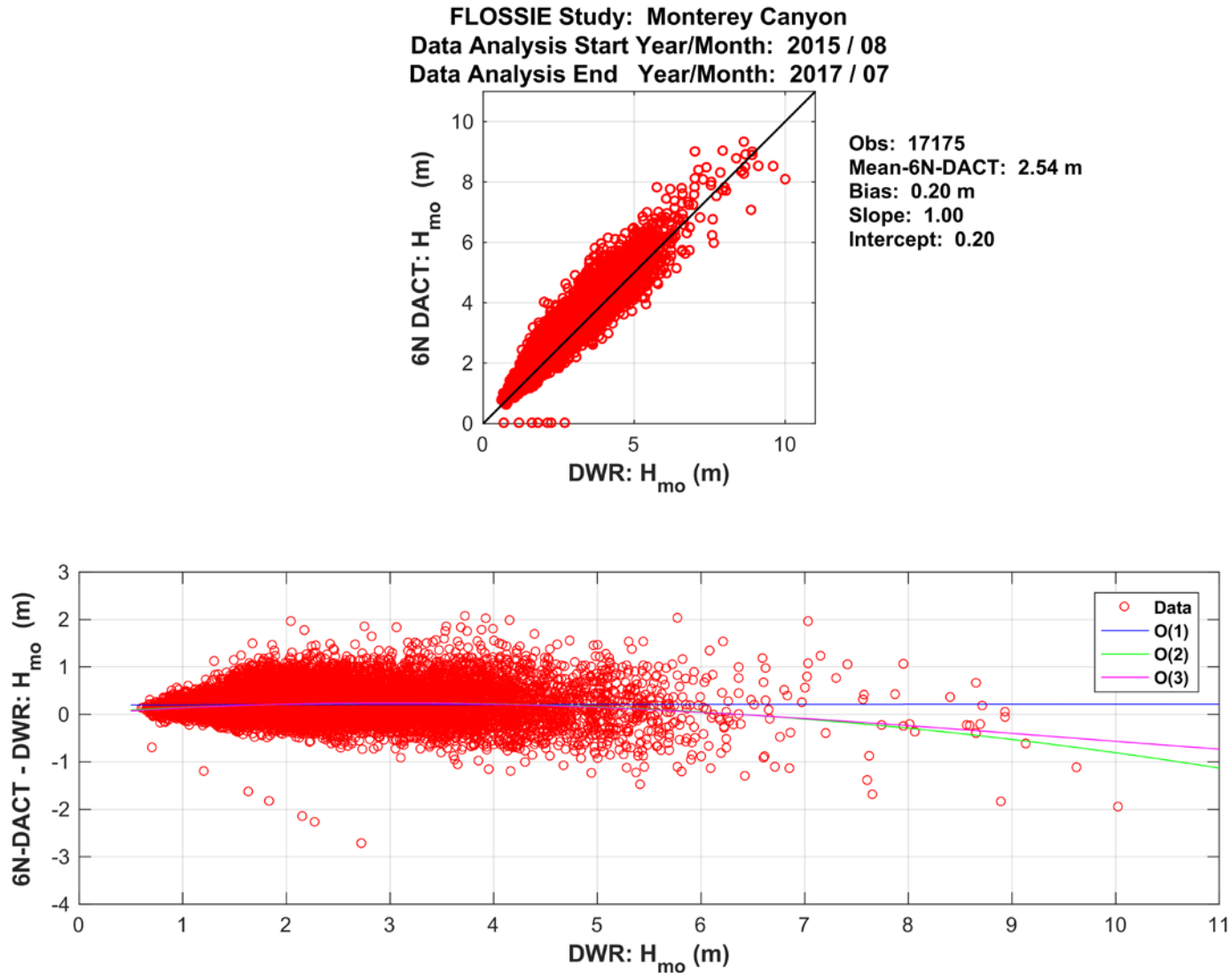
FLOSSIE: Intra-Measurement Evaluation

- Relative Reference Examination (WaveRider)



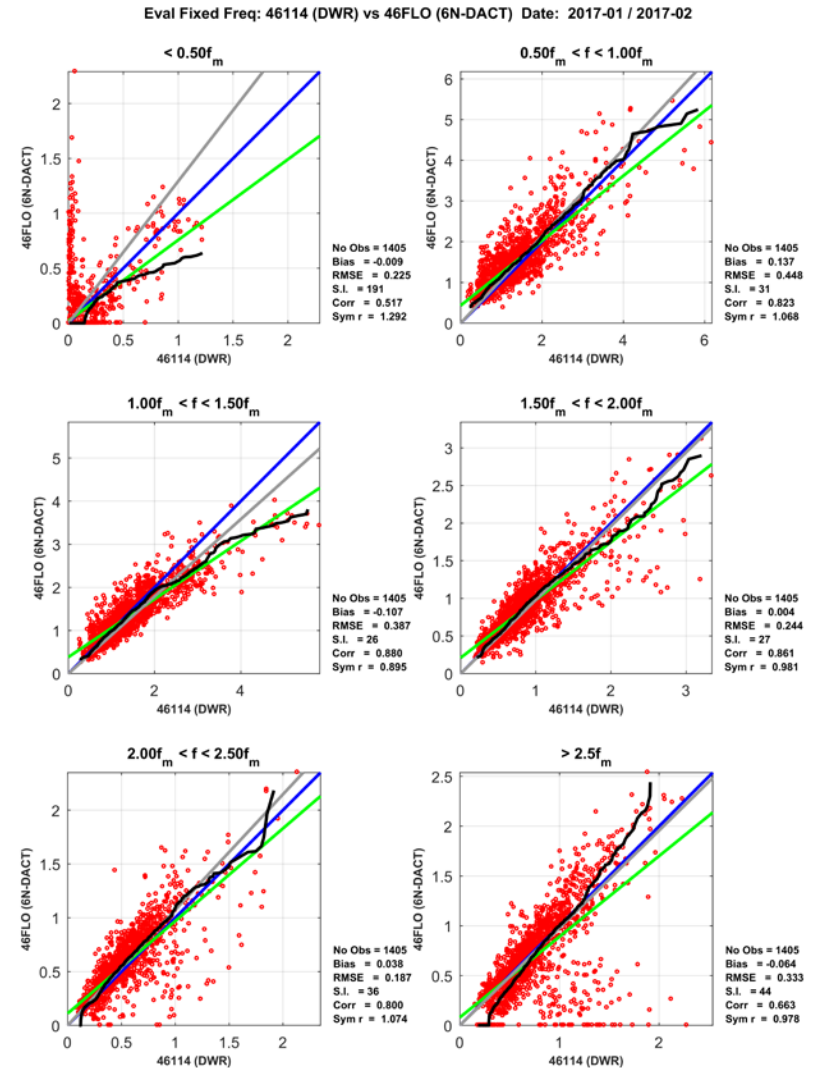
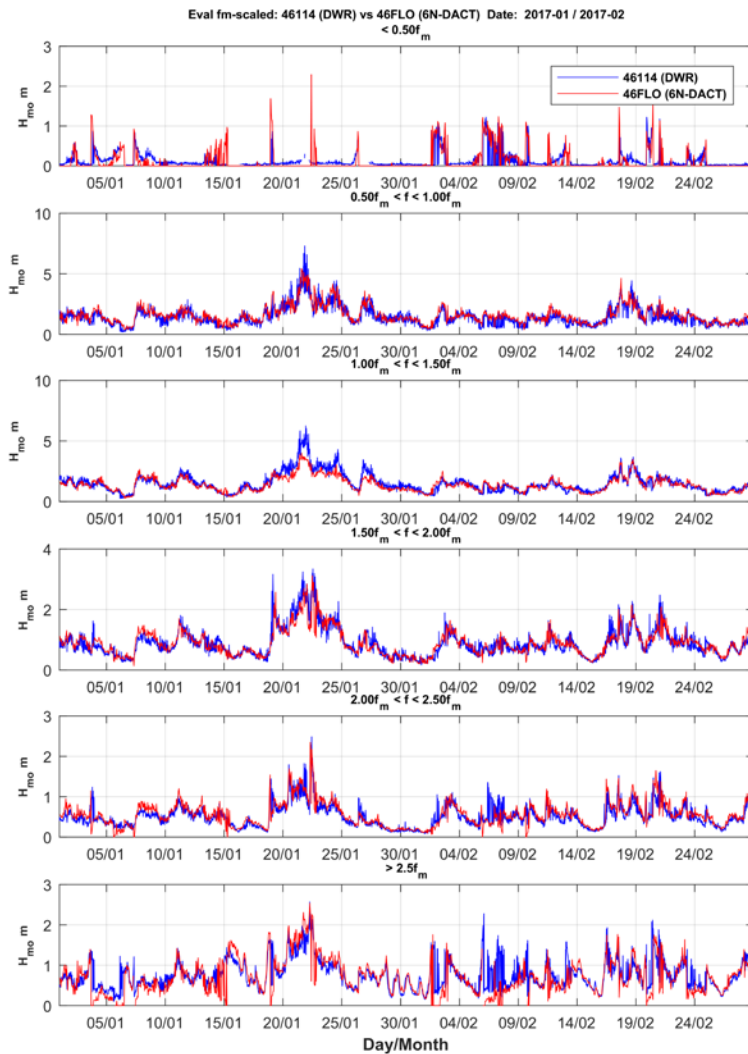
FLOSSIE: Intra-Measurement Evaluation

- Relative Reference Examination (WaveRider)



FLOSSIE: Intra-Measurement Evaluation

Relative Reference Examination RMSE-Bias (WaveRider)



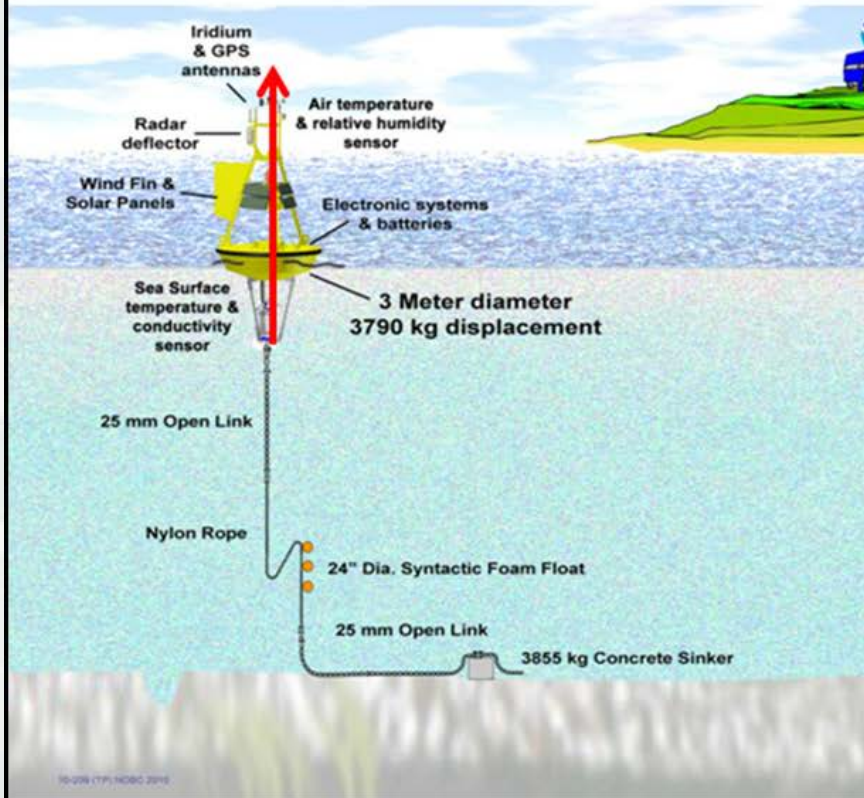
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 - ▶ 3D, 2.4D, 2.3D and 2.1D (SCOOP)

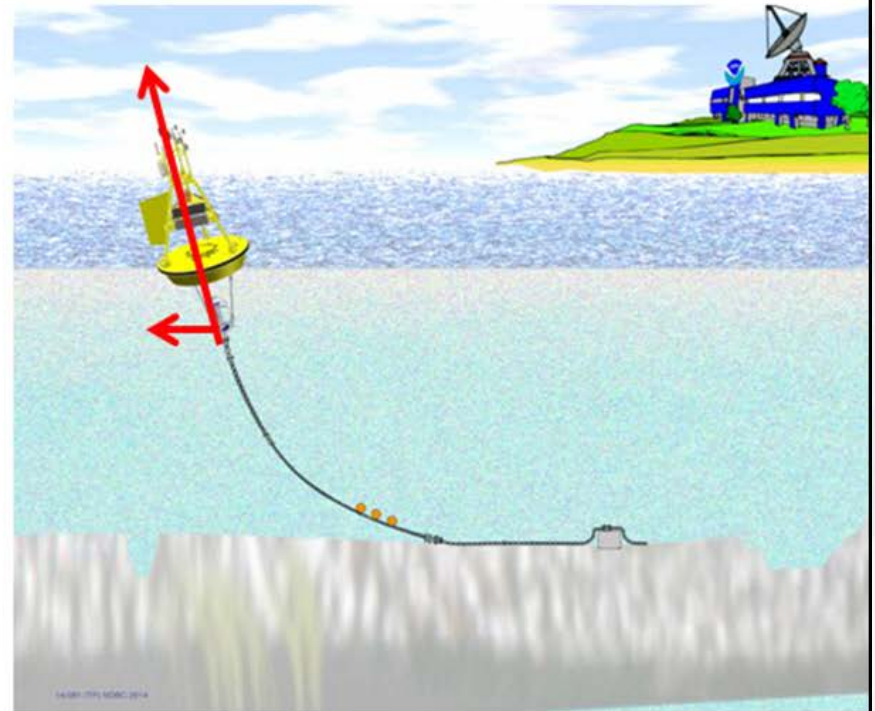


The Bender Effect

Slack mooring to respond to waves

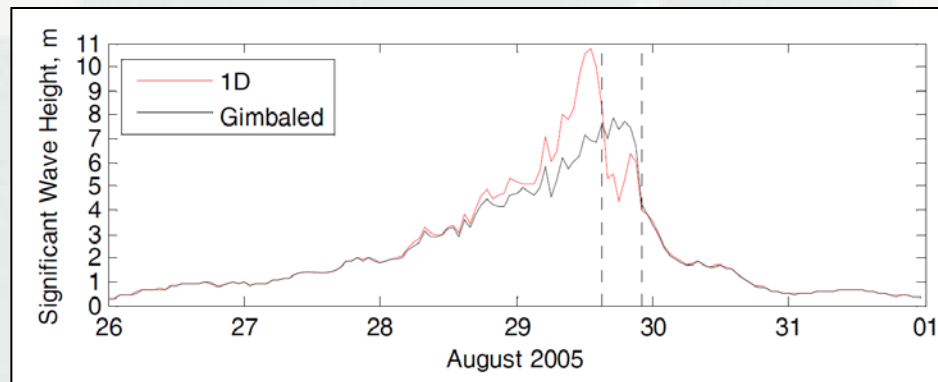


Horizontal forces mapped into "vertical" accelerometer
Results in overestimation



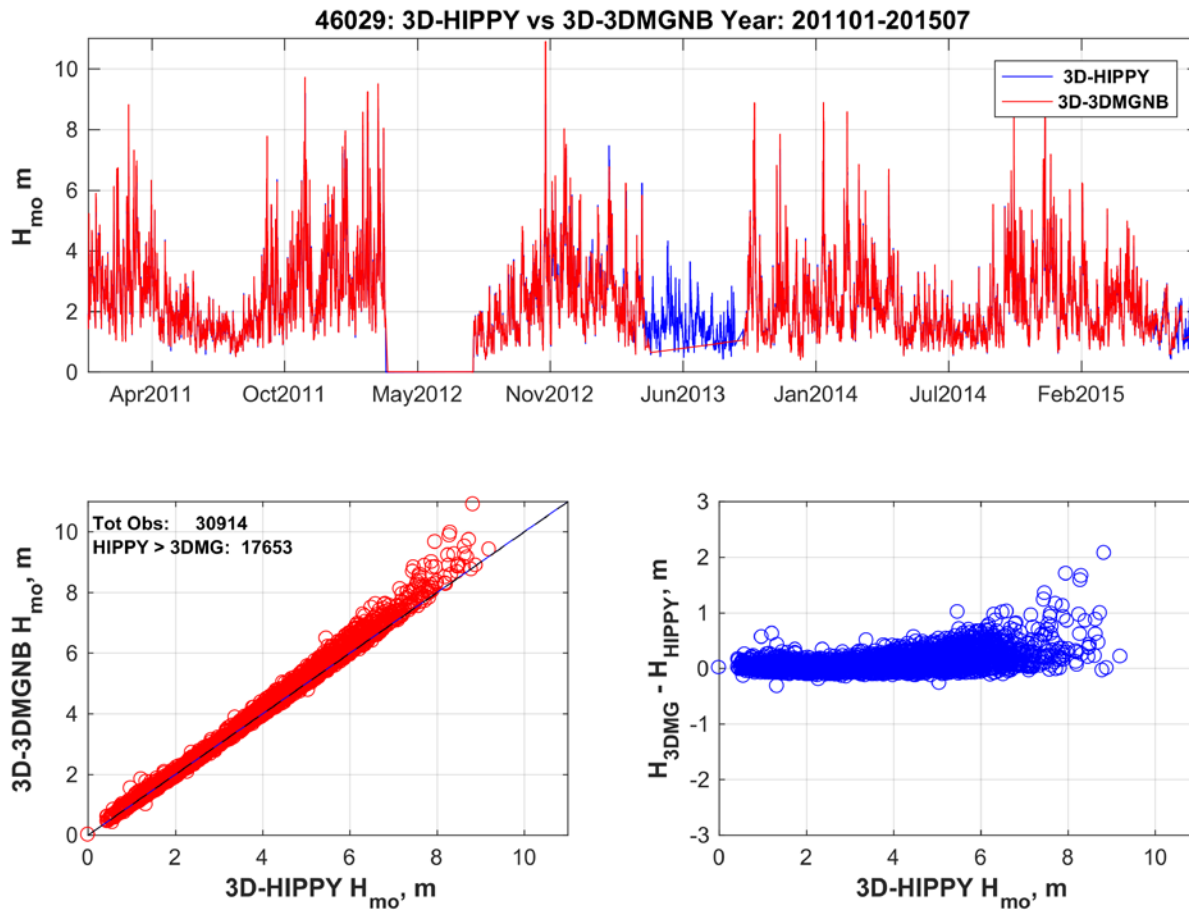
Dual Sensor Tests: SDA

- NDBC 3D Aluminum (46029)
- Pacific Northwest
- Dual Sensor System
 - ▶ HIPPY Sensor
 - ▶ 3DMG WITHOUT Bender Correction (201101-201507)
 - ▶ 3DMG WITH Bender Corrected (201509-Present)
- Datowell Directional Waverider
 - ▶ 201101-Present (with some gaps)

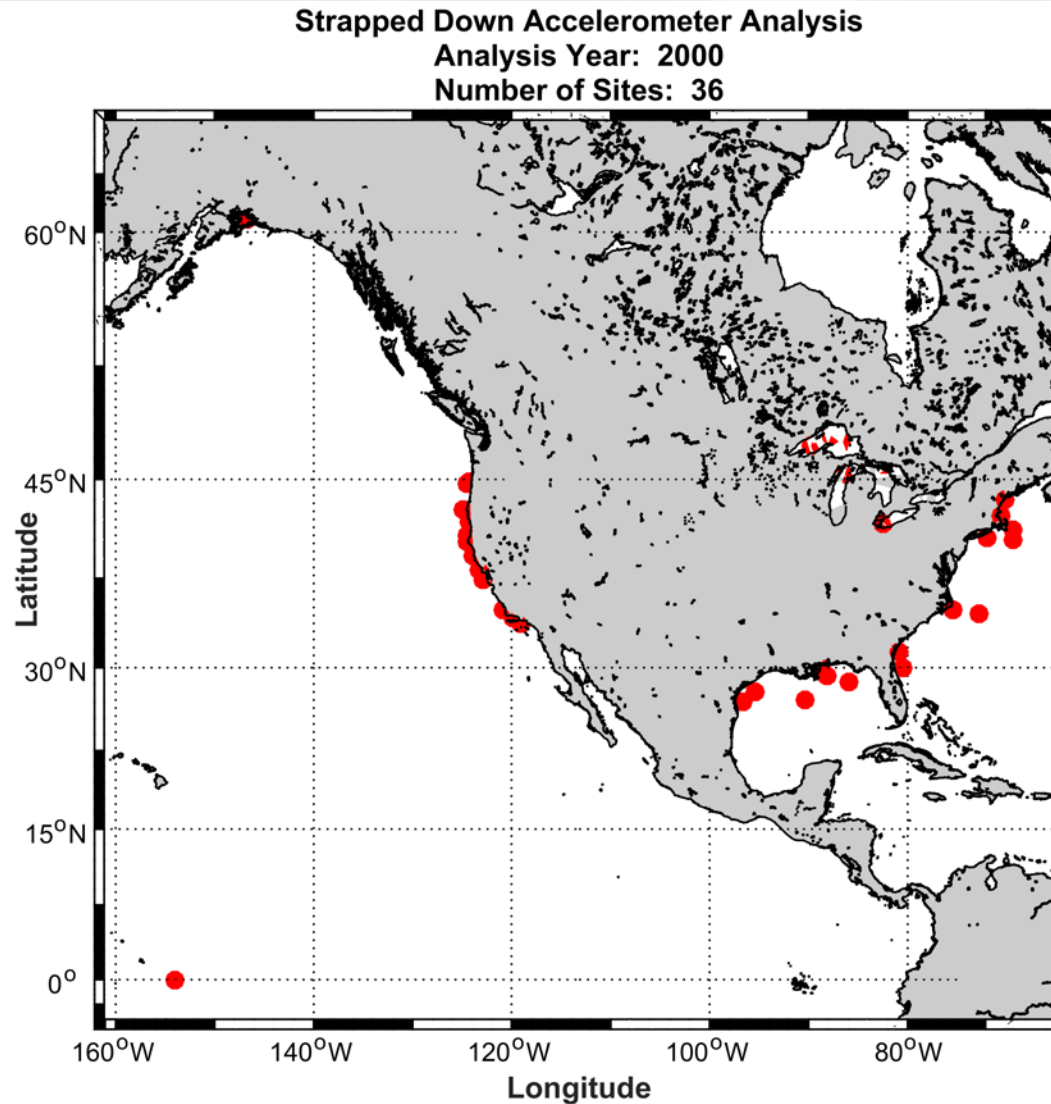


Bender Effect: Work In Progress

- No Bender Correction: 3D-HIPPY vs 3D-3DMG



Importance of Bender Correction



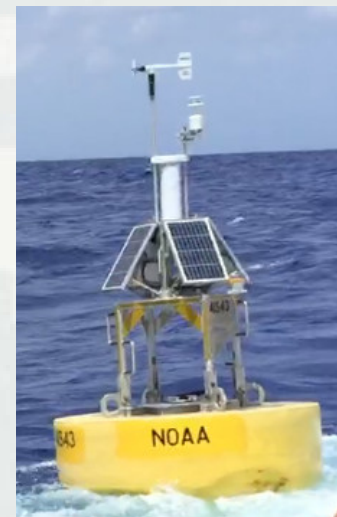
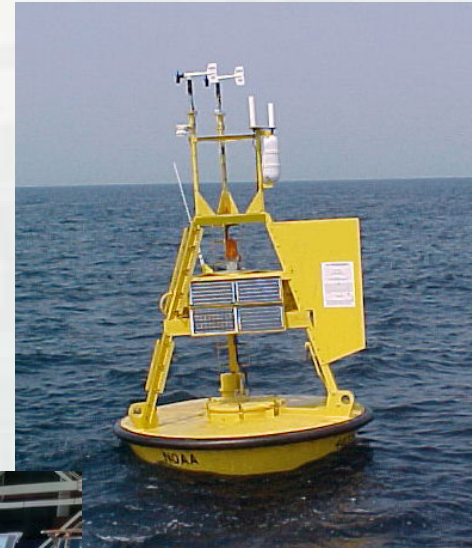
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Foam Buoys: The Future

- NDBC Migration to:
 - ▶ Foam hulls from Aluminum
 - ▶ Smaller buoys Target: 2.1DV
 - ▶ Self-Contained Ocean Observation Payloads (SCOOP)



Foam Buoys: The Future

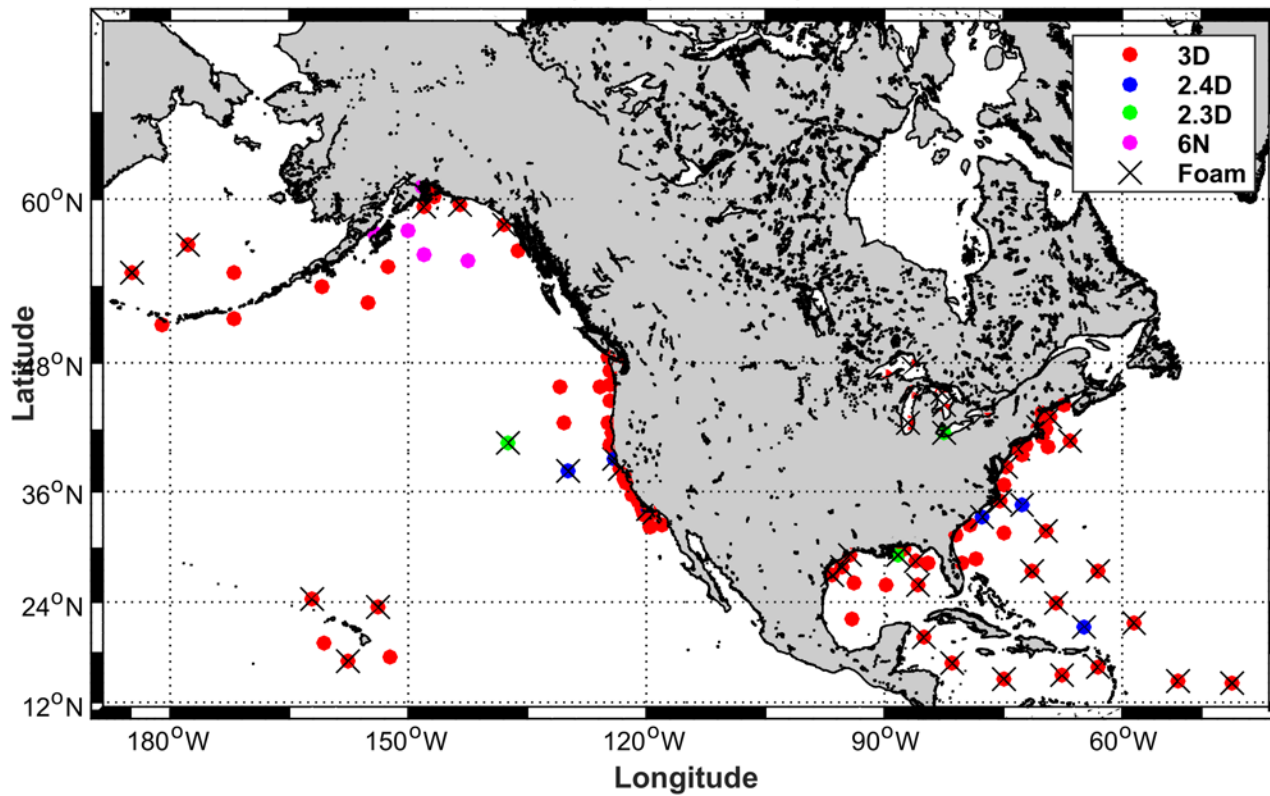
NDBC Configured Buoy Deployments: 2017

3D Alum/Foam : 91 Total Foam : 48

2.4D Foam : 3

2.3D Foam : 6

6N Alum : 5



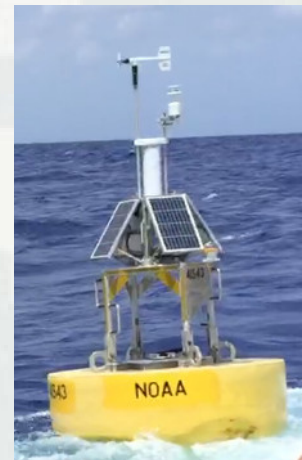
Foam Buoys: The Future

- The 2.1D Foam SCOOP System:
 - ▶ Test and Evaluation: 3 Sites
 - Mid Atlantic (mixed wind-seas / swells N'Easters-TC's)
 - Pacific Northwest (swell dominant-high energy)
 - Lake Superior (wind-sea dominant)
 - ▶ Three Distinct Wave Climates
 - ▶ Covers full frequency range
 - ▶ 3D Aluminum / DWR
 - Mid Atlantic (dual sensor)
 - Lake Superior (0.7 DWR)
 - ▶ Deployed Now (1- to 2-yrs)



Findings and Conclusions

- Over 250 moored wave measurement buoys
- Uses include
 - ▶ NWP forecast assessment
 - ▶ Hindcast assessment
 - ▶ Model development / modifications
 - ▶ Altimeter algorithms
- Quality of wave measurements will vary
- Evaluations using total H_{m0} will mask differences



Findings and Conclusions

- Buoy Farm created to investigate differences
 - ▶ Contains majority of N America wave platforms
 - ▶ FLOSSIE: multiple sensor/payloads in one hull
 - ▶ Dual Sensor on NDBC Flagship 3D aluminum hull
- Can we quantify those differences?
 - ▶ Clear indication 6N estimates biased
 - ▶ Over the mean differences are small
 - ▶ Spread of +/- 1-2.0-m is a concern
 - ▶ Spread grows with increasing H_{mo}
 - ▶ Moments in direction?
- Can we relate those differences to
 - ▶ Sensor/payload type
 - ▶ Hulls, super-structure, mooring
 - ▶ Analysis package



Findings and Conclusions

- Larger systematic differences are a result from
 - ▶ Sensor type
 - ▶ Analysis package
 - ▶ Hulls, super-structure, mooring
- Some biases found could be corrected?
 - ▶ Appears to be analysis:
 - Transformation from acceleration to displacement
- NDBC's 3DMG non-corrected contain biases
- Foam Analysis: R. Bouchard (next)
- Knowing differences in wave platforms could be used to adjust historical data sets in Climate Trend Analyses

NEED TO CONTINUE Test and Evaluations