



Joint WMO-IOC Technical Commission  
for Oceanography and Marine Meteorology

# Wave Measurement Evaluation and Testing

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Geneva, SWITZERLAND



WMO



IOC/UNESCO

- Overview of Process
- Co-located results
  - Preliminary results
  - Sensitivity testing
    - Hulls
    - Sensors
  - Atlantic / Pacific
- Preliminary Assessments
- Summary
- Recommendations



# Why Do We Need to Test and Evaluate

- Waves are difficult to measure
  - Rapid temporal variation
  - Changes in frequency / directional characteristics
  - Spatial variation requires multiple locations
  - Failures: Loss in continuity
    - Natural
    - Human
- Measurements of surface gravity waves are **estimates**
  - From heave-pitch-roll sensors: HIPPY
  - From accelerations (double integrated)
  - From motion sensors (e.g. angular rate)
  - Particle versus slope following

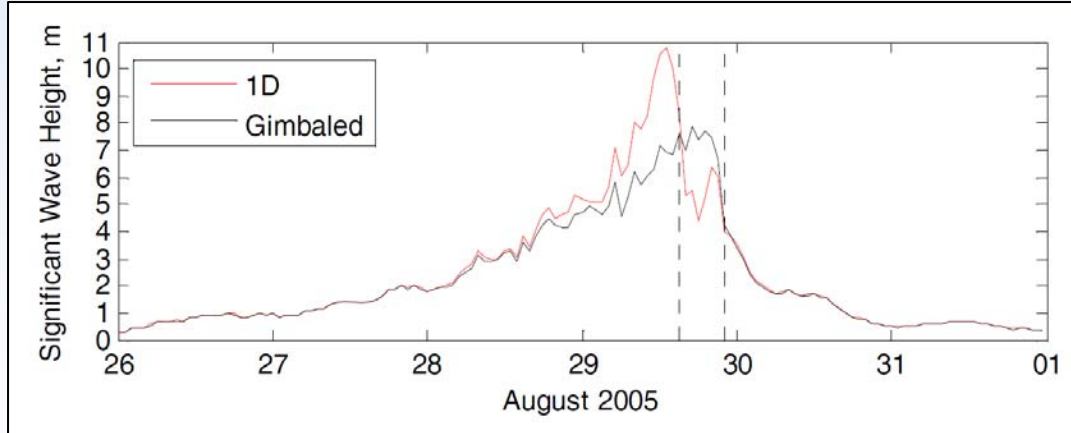


# Why Do We Need to Test and Evaluate

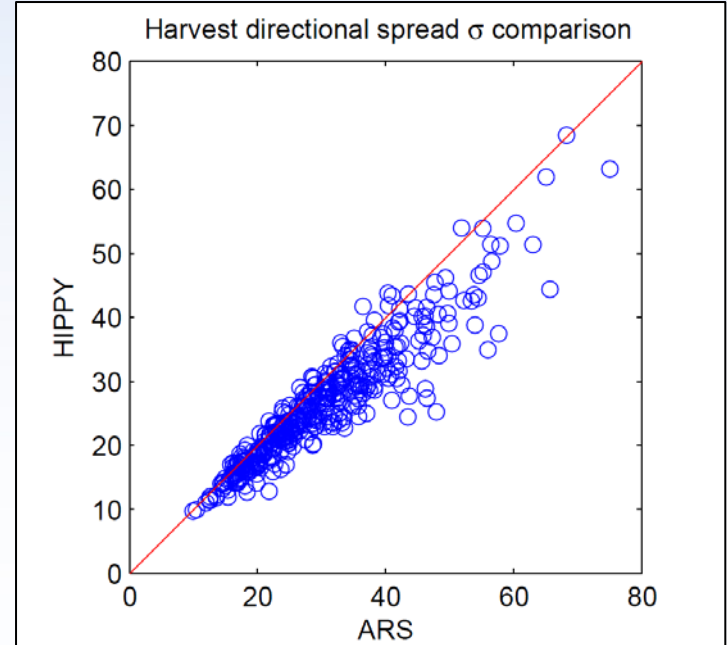
- Wave estimates: Based on buoy response
  - Hulls: shape, size, material
  - Super-structure
  - Mooring (including bridle)
  - Sensors
  - Internal analysis package
- Signal to noise:
  - Contamination of wave records
  - Compliance for universal criteria
    - Reduces uncertainty in wave measurements
      - Provides consistency
      - Device to device
      - Underlying processes correctly evaluated



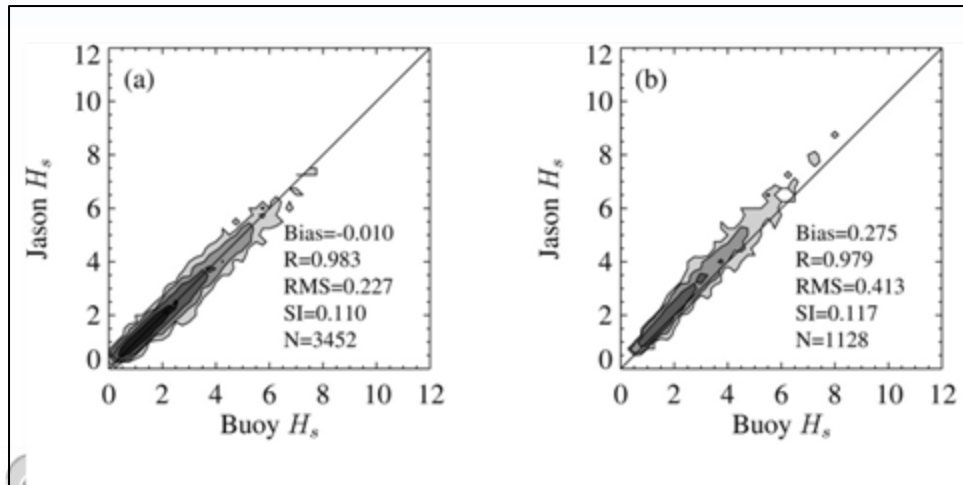
# Why Do We Need to Test and Evaluate



Bender et al. (2009)



Teng and Bouchard. (2005)



Durrant et al. (2008)

- Datawell Mark III ***RELATIVE REFERENCE***
- *CDIPtool* selected as the evaluation tool

The screenshot displays the CDIP website interface. At the top, there are logos for CDIP (The Coastal Data Information Program), Scripps Institution of Oceanography, and USACE. The main navigation bar includes 'Themes', 'Recent', 'Historic', and 'Documents'. A search bar is present with a 'Station ID' dropdown and a 'search' button. Below the navigation, there are links for 'news | contact us | home' and 'index | faq'.

The left sidebar contains a 'Documentation' menu with the following categories and sub-items:

- FAQs & Summaries
- Glossary
- Publications
- Introduction
  - History and Funding
  - Program Goals
- Wave Measurement
  - Wave Generation
  - Wave Dynamics
  - Irregular Waves
  - Spectral Analysis
  - Gauging Waves
  - Hurricane Events
  - Tsunami Events
- Instrumentation
  - Underwater Sensors
  - Surface Buoys
  - Meteorological
- Data Acquisition
  - System Organization
  - Hardware
  - Software
- Data Processing
  - System Organization
  - Software
  - Quality Control
- Data Management
  - Stations and Sets
  - Files and Storage

The main content area is titled 'Wave Sensor Comparisons' and shows a dropdown menu for 'CDIP\_44235\_v\_AXYS\_44255'. Below this, there are tabs for 'Time Series Plots', 'Wave Component Plots', 'Metadata', and 'Documentation'. A table of frequency ranges is displayed:

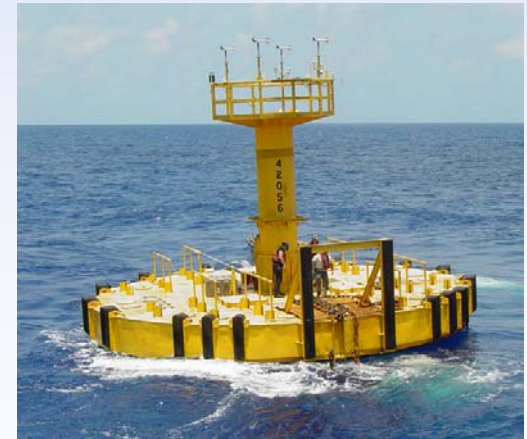
All Waves	Forerunners	Long Swell	Short Swell	Long Seas	Short Seas	Wind Chop
0.03-0.50Hz	0.03-0.05Hz	0.05-0.08Hz	0.08-0.12Hz	0.12-0.25Hz	0.25-0.40Hz	0.40-0.50Hz

The 'Wind Chop' range (0.40-0.50Hz) is highlighted in red. Below the table, there is a map of the site location in British Columbia, Canada, with a red pin indicating the station location. The map is labeled 'Site Location'.

The main plot area shows two time series plots for the frequency range 0.4 - 0.5 Hz. The top plot is titled 'CDIP 46138 (blue) vs. CA 46185 (red) | Frequency Range: 0.4 - 0.5 Hz' and displays 'Wave Height (m)' on the y-axis (0 to 0.5) against time on the x-axis (09/04 to 08/06). The bottom plot displays 'Peak Period (s)' on the y-axis (2.0 to 2.5) against the same time period. Both plots show data for CDIP 46138 (blue) and CA 46185 (red) sensors, with the CA 46185 data showing a distinct peak period around 2.2 seconds.

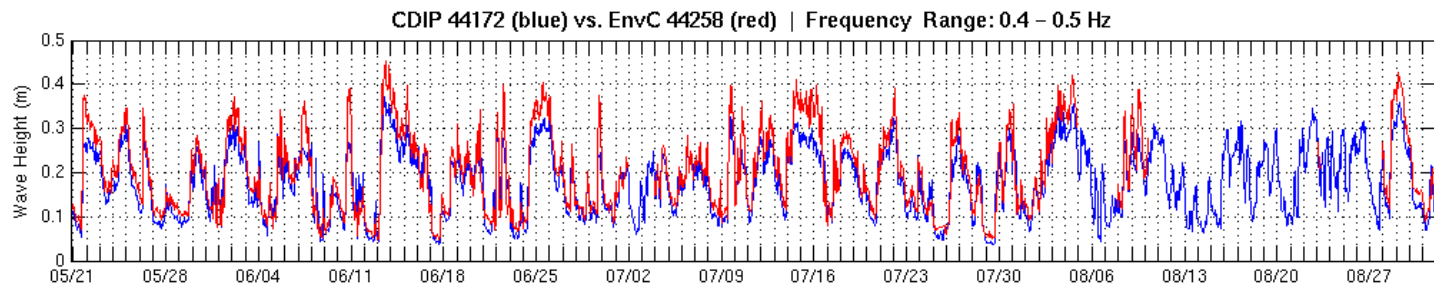
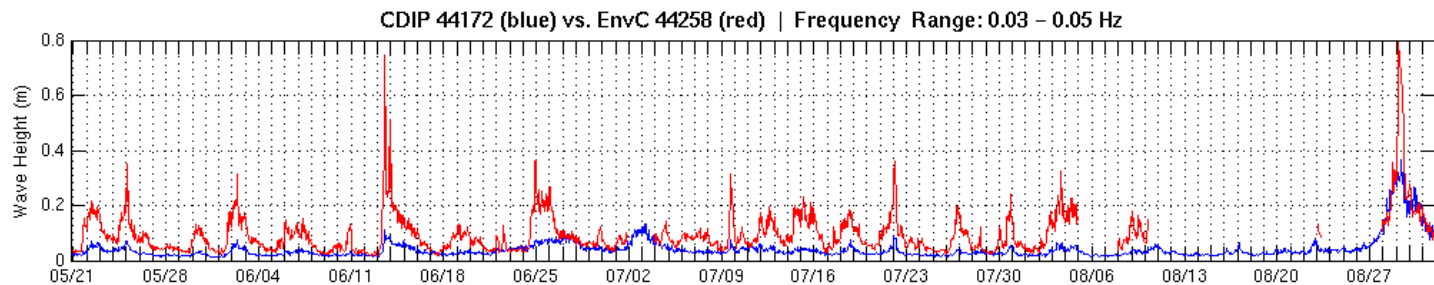
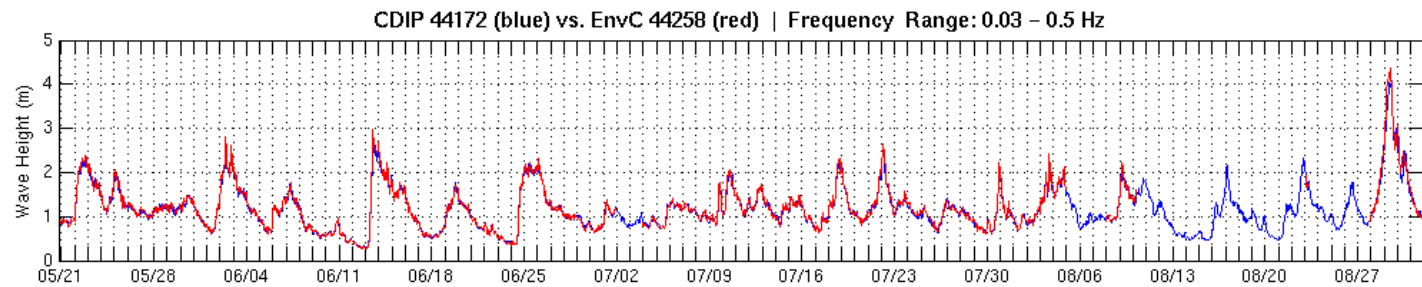
# Evaluation Procedure: Co-located

- Series of evaluations
  - Hull, sensor, payload package (3D / 6M)
  - 3D: sensor, payload package (3DM / ARS)
  - 6M: sensor
    - Standard MEDS operational buoy
    - Added the TriAXYS sensor
  - TriAXYS:
    - Standard MEDS 3D operational buoy
    - MEDS 3D Foam
    - MEDS 6M with TriAXYS
- Data yet to be evaluated
  - 51001: HIPPY, 3DM (3-m) Hawaii - NW
  - 46042: HIPPY, 3DM (3-m) PAC
  - 46029: HIPPY, 3DM (3-m) PAC
  - 44014: HIPPY, 3DM (3-m) ATL



# Evaluation Procedure: Co-located

## Time Series Analysis for specific differences

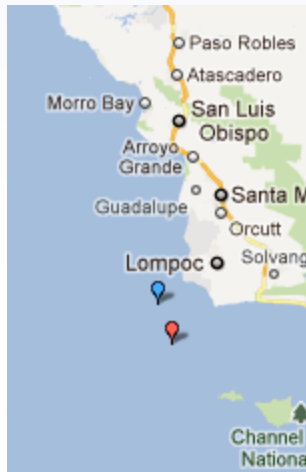




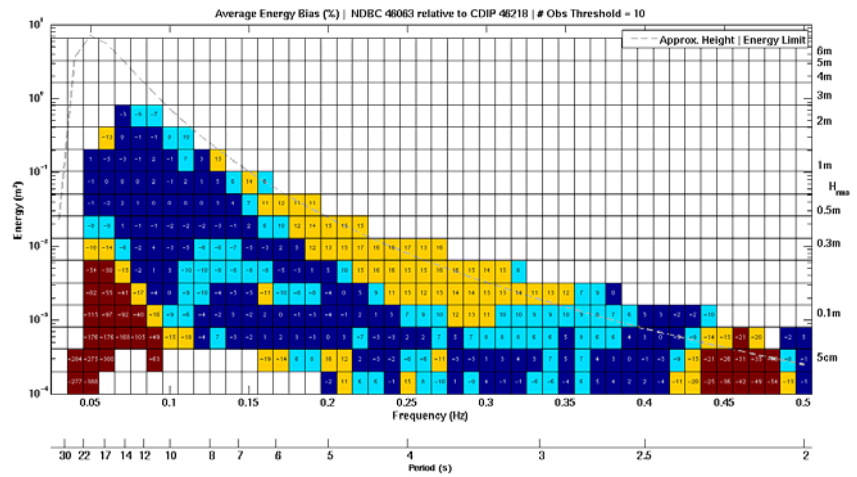
# Evaluation Procedure: Co-located

## Analysis of Hull / Sensor / Payload Package

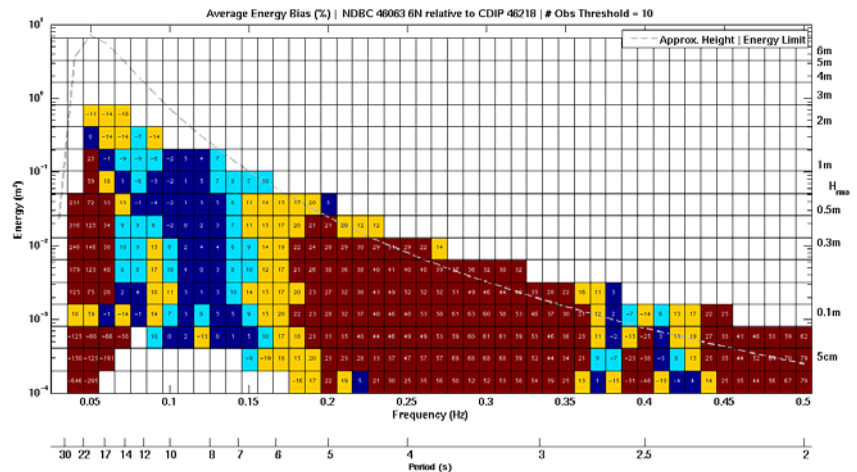
3D / ARS / ARES



6M / Inclinometer / DACT



CDIP Wave Spectra Comparison Tool, Version 1.0



CDIP Wave Spectra Comparison Tool, Version 1.0

# Evaluation Procedure: Co-located

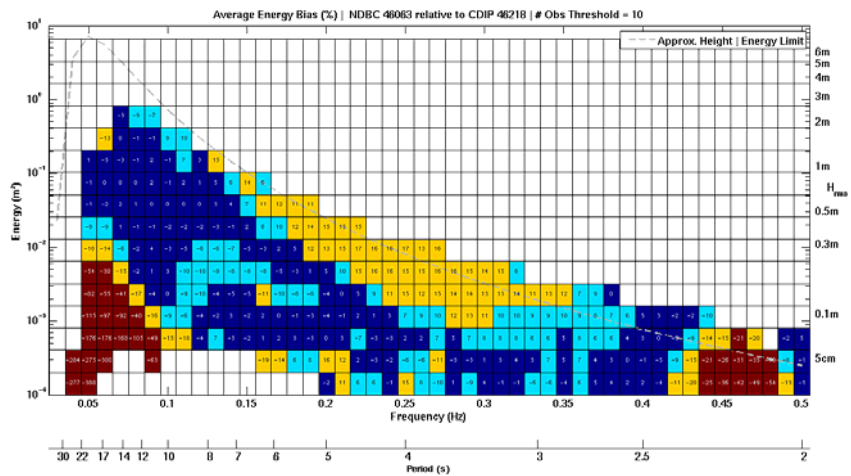
## Analysis of Sensor / Payload Package

3D / ARS / ARES

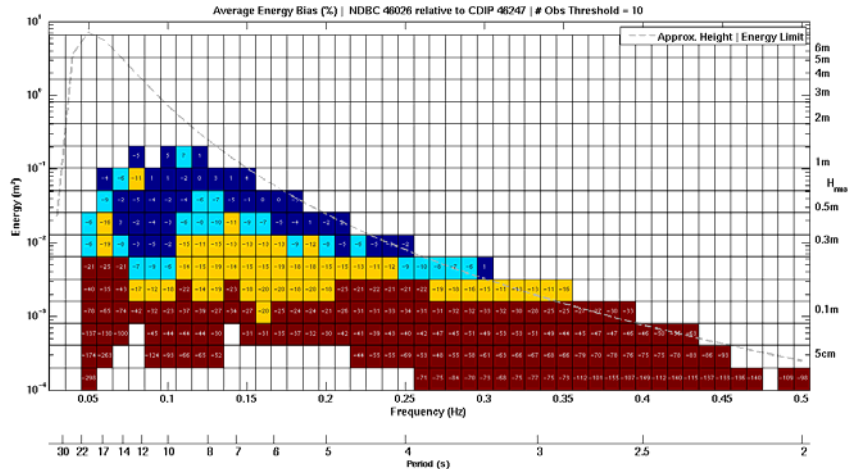
46063: Pt. Conception

3D / 3DM / AMPS

46026: San Francisco



CDIP Wave Spectra Comparison Tool, Version 1.0



CDIP Wave Spectra Comparison Tool, Version 1.0

# Evaluation Procedure: Co-located

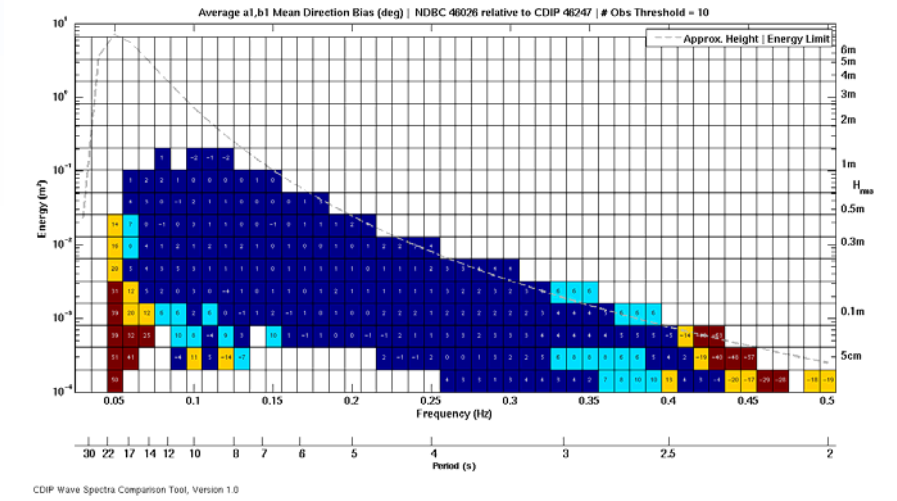
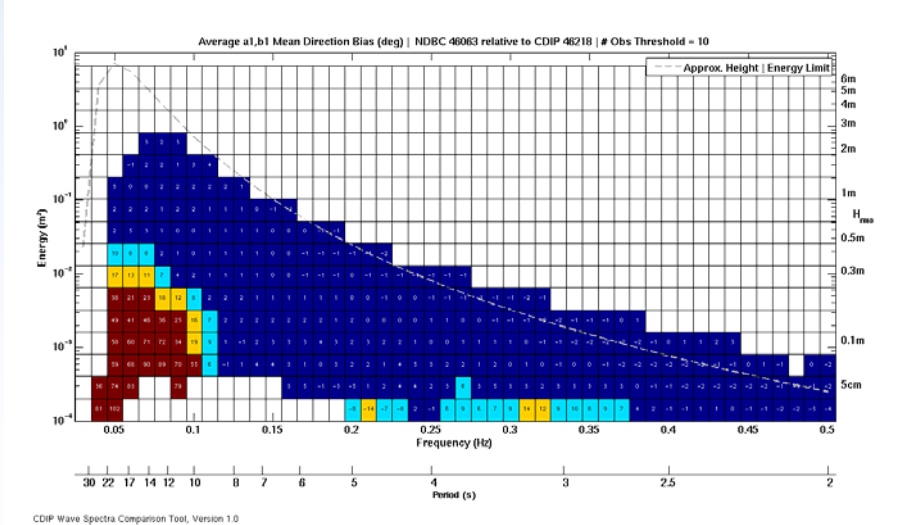
## DIRECTIONAL Analysis of Sensor / Payload Package

3D / ARS / ARES

46063: Pt. Conception

3D / 3DM / AMPS

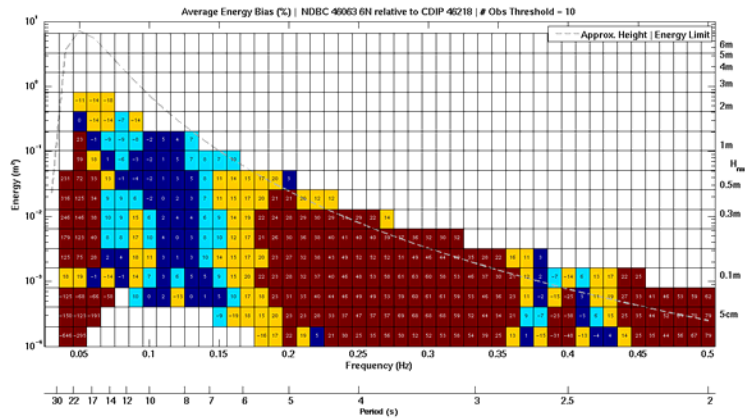
46026: San Francisco



# Evaluation Procedure: Co-located

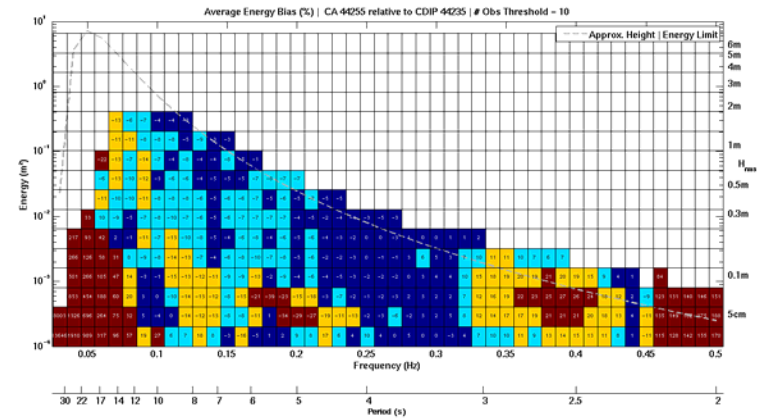
## Analysis of: Operational NOMADS

46063 : Inclinometer / DACT



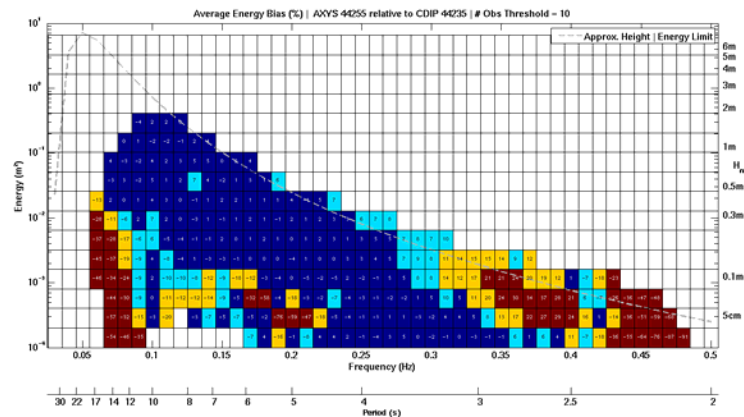
CDIP Wave Spectra Comparison Tool, Version 1.0

44255: Accelometer / AXYS



CDIP Wave Spectra Comparison Tool, Version 1.0

44255: TriAXYS\* / AXYS



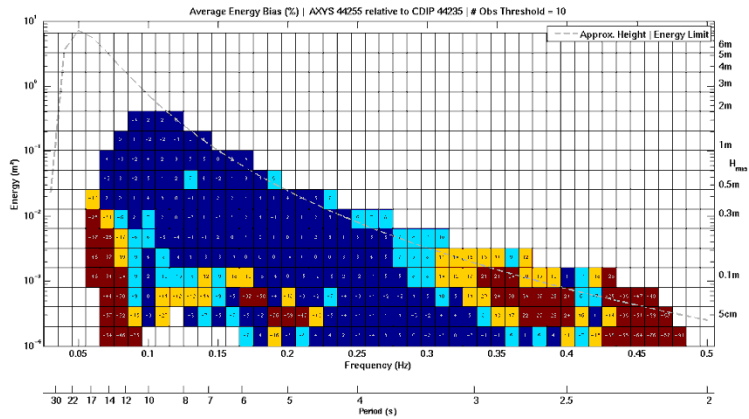
CDIP Wave Spectra Comparison Tool, Version 1.0

# Evaluation Procedure: Co-located

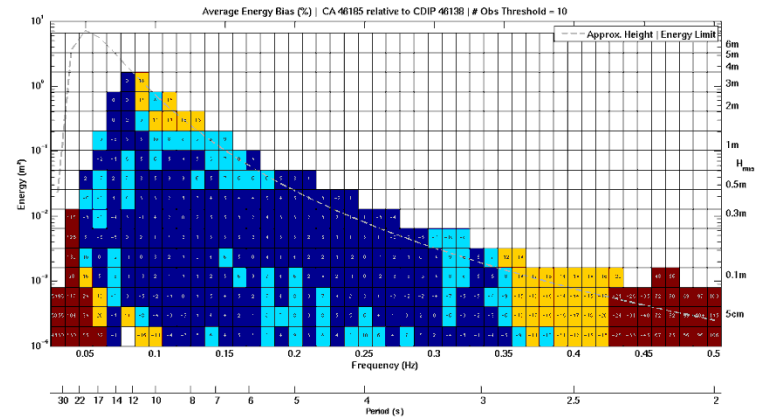
## Analysis of: Hull

44255: 6M / TriAXYS

46185: 3D / TriAXYS

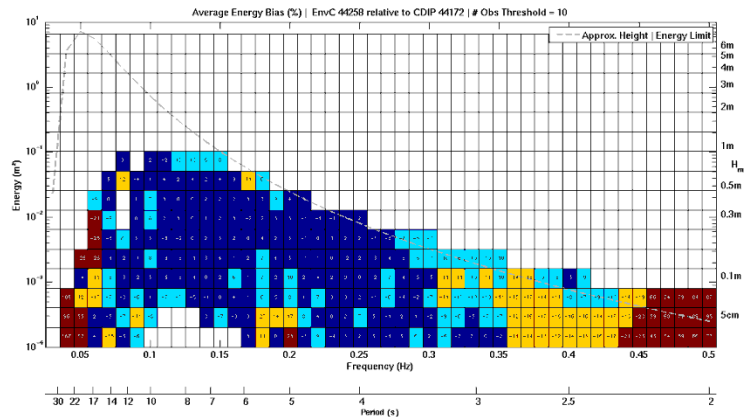


CDIP Wave Spectra Comparison Tool, Version 1.0



CDIP Wave Spectra Comparison Tool, Version 1.0

44258: 3D FOAM / TriAXYS

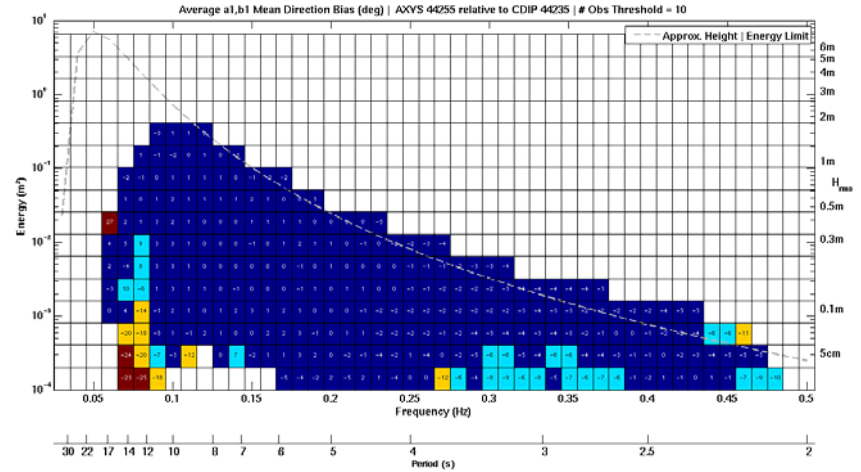


CDIP Wave Spectra Comparison Tool, Version 1.0

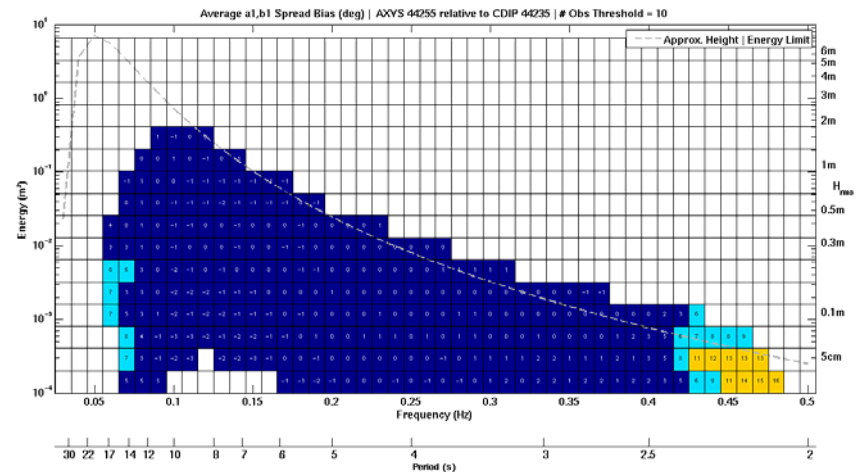
# Evaluation Procedure: Co-located

## Analysis of: Directional Estimates from NOMAD

6M / Tri-AXYS/ AXYS



CDIP Wave Spectra Comparison Tool, Version 1.0



CDIP Wave Spectra Comparison Tool, Version 1.0

# Evaluation Preliminary 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 NOMAD requires further evaluation
  - Co-location definition violated
- NDBC's 3DM motion sensor appears to contain biases
  - Multi-sensor evaluation underway
- NOMAD's capability to estimate directions

- Continue to test and evaluate
- New PC version now available *CDIPtool*
- NDBC 6M NOMAD evaluated to Directional Waverider (co-location)
- Evaluation of Buoy Farm Data Sets Monterey, CA
- Evaluation of multi-sensor packages (NDBC)
- Meta data for historical wave measurement platforms
  - **Sensor**, payload, analysis packages
- Bench Test analysis packages (IEEE, time series, etc)
- Real-time data transmission of time series





