Joint WMO-IOC Technical Commission
for Oceanography and Marine Meteorology

Wave Measurement Evaluation and Testing

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WMO

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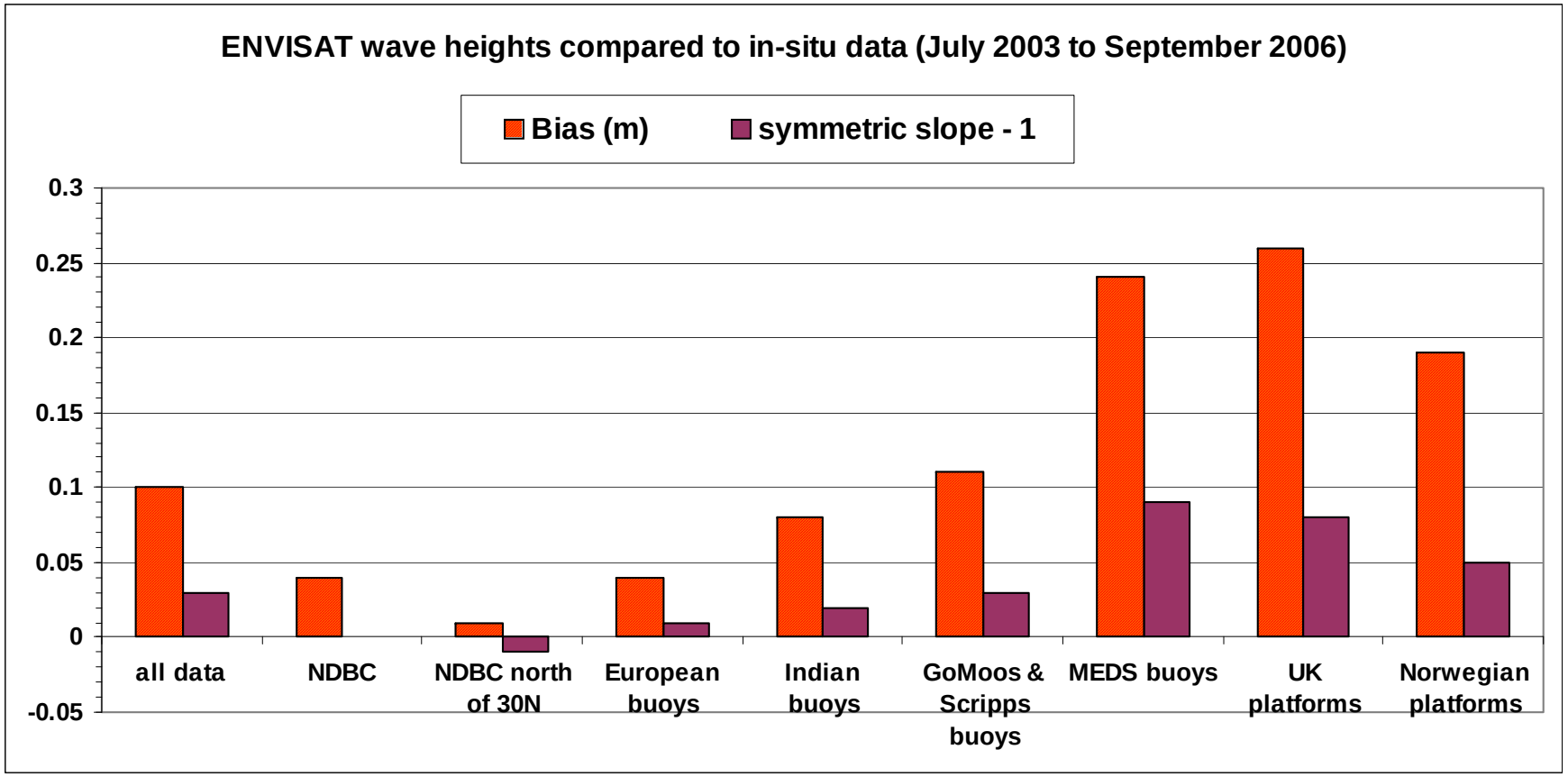
Outline (following the “modified-Resio” approach)

- Motivation
- Approach
- Conclusions and Recommendations
- Preliminary Results
- Summary

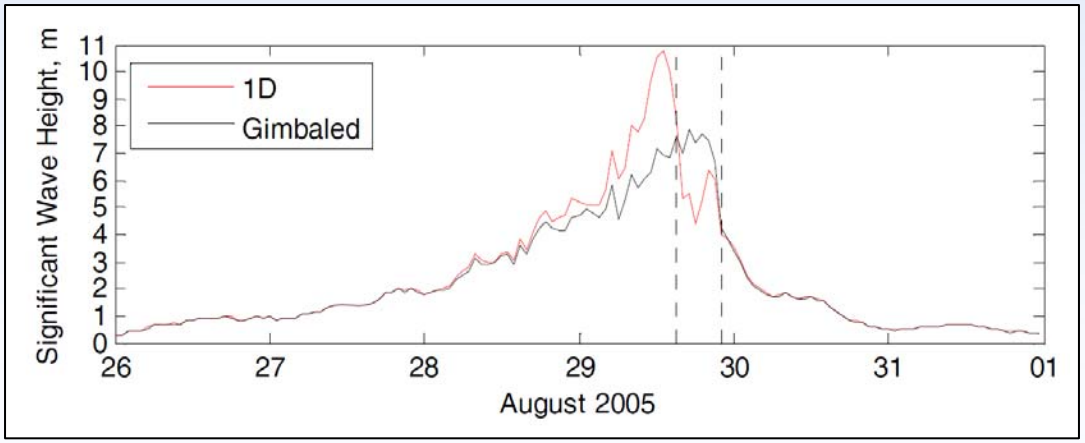
Discrepancies in wave observations:



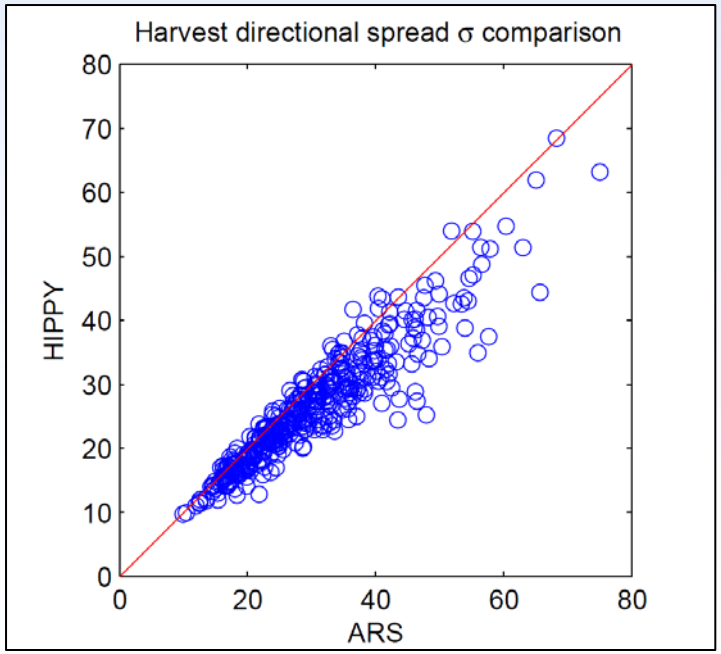
Bias: altimeter Hs – in-situ Hs

Symmetric slope: ratio of variance altimeter to variance in-situ

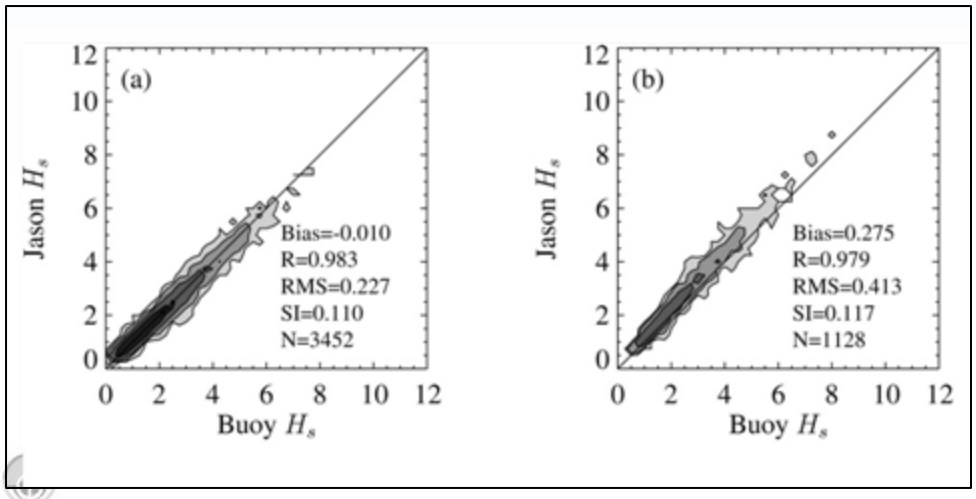
Why Do We Need to Test and Evaluate



Bender et al. (2009)

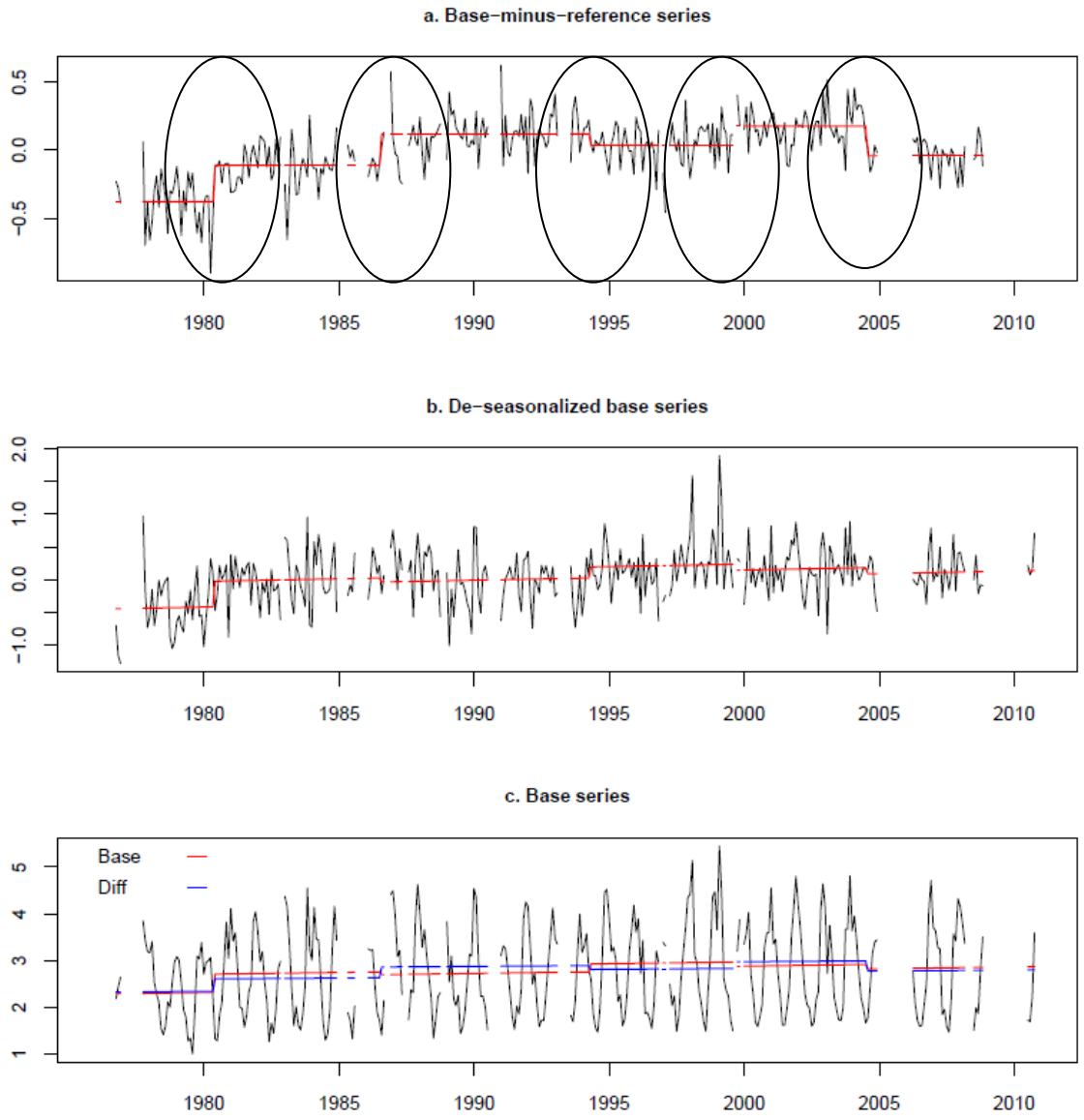


Teng and Bouchard. (2005)



Durrant et al. (2008)

46005 - Washington



OBSERVATION REQUIREMENTS FOR WIND WAVES

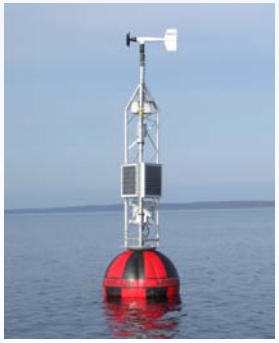
(developed by the JCOMM Expert Team on Wind Waves and Storm Surges)

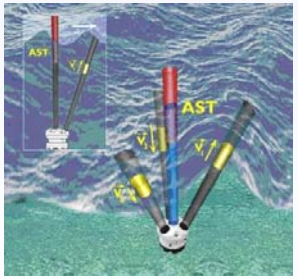
Applications:

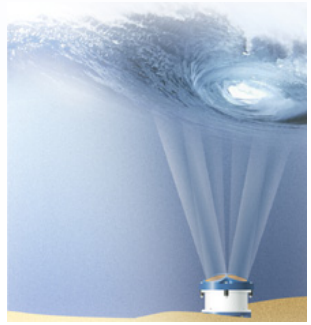
- Assimilation into offshore wave forecast models
- Validation of wave forecast models (and hindcast and reanalysis)
- Calibration / validation of satellite wave sensors
- Ocean wave climate and variability
- Role of waves in coupling
- Coastal zone modelling – erosion, sediment transport, inundation etc.

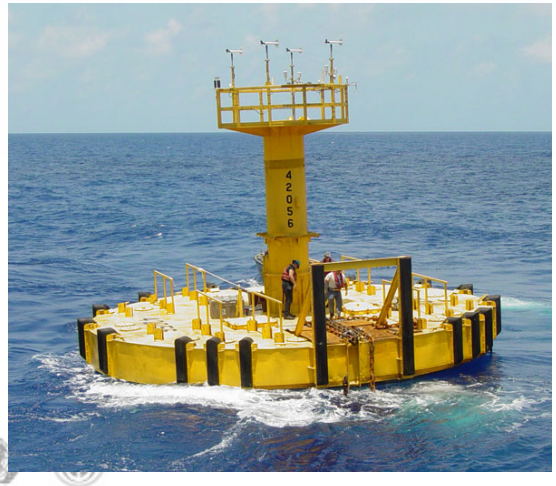
- Reference:
- *OceanObs09 paper Swail et al.*
- *OceanObs99 paper Swail et al.*
- *DBCP-22 Meeting Report October 2006*
- *ETWS-II Meeting Report March 2007*
- *CBS/OPAG-IOS/ET-EGOC-3 Doc. 7.2.6*

How to “ground truth” the “ground truth” ?









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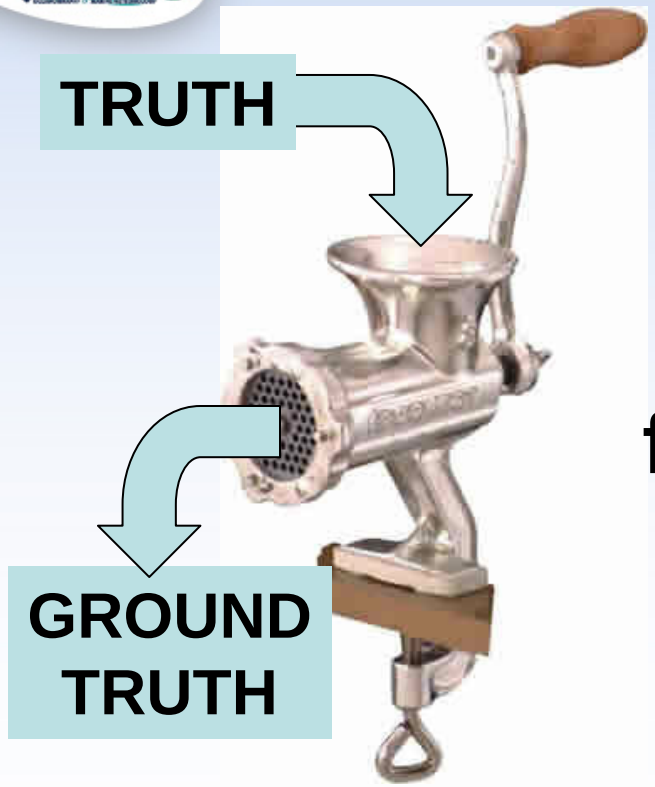


New System for obtaining "ground truth" for wave measurements

Or

What about an independent group of assessors??

Courtesy Don Resio

OceanObs09

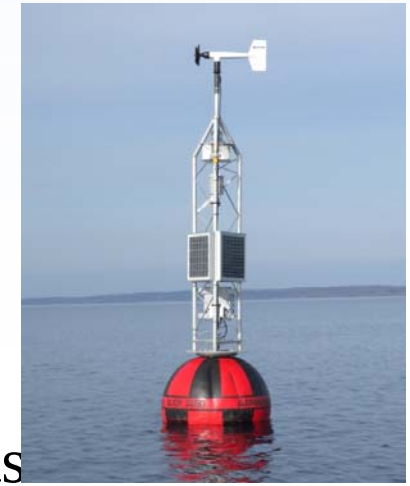
“Continuous testing and evaluation of operational and pre-operational measurement systems is an essential component of a global wave observing system, equal in importance to the deployment of new assets”

Swail et al., *Wave Measurements, Needs And Developments For The Next Decade*. OceanObs09 publication.

Evaluation Procedure

- Co-Located Procedure
  - Period of record consistent
    - Time consistency between device
    - Similar geographic/hydrographic

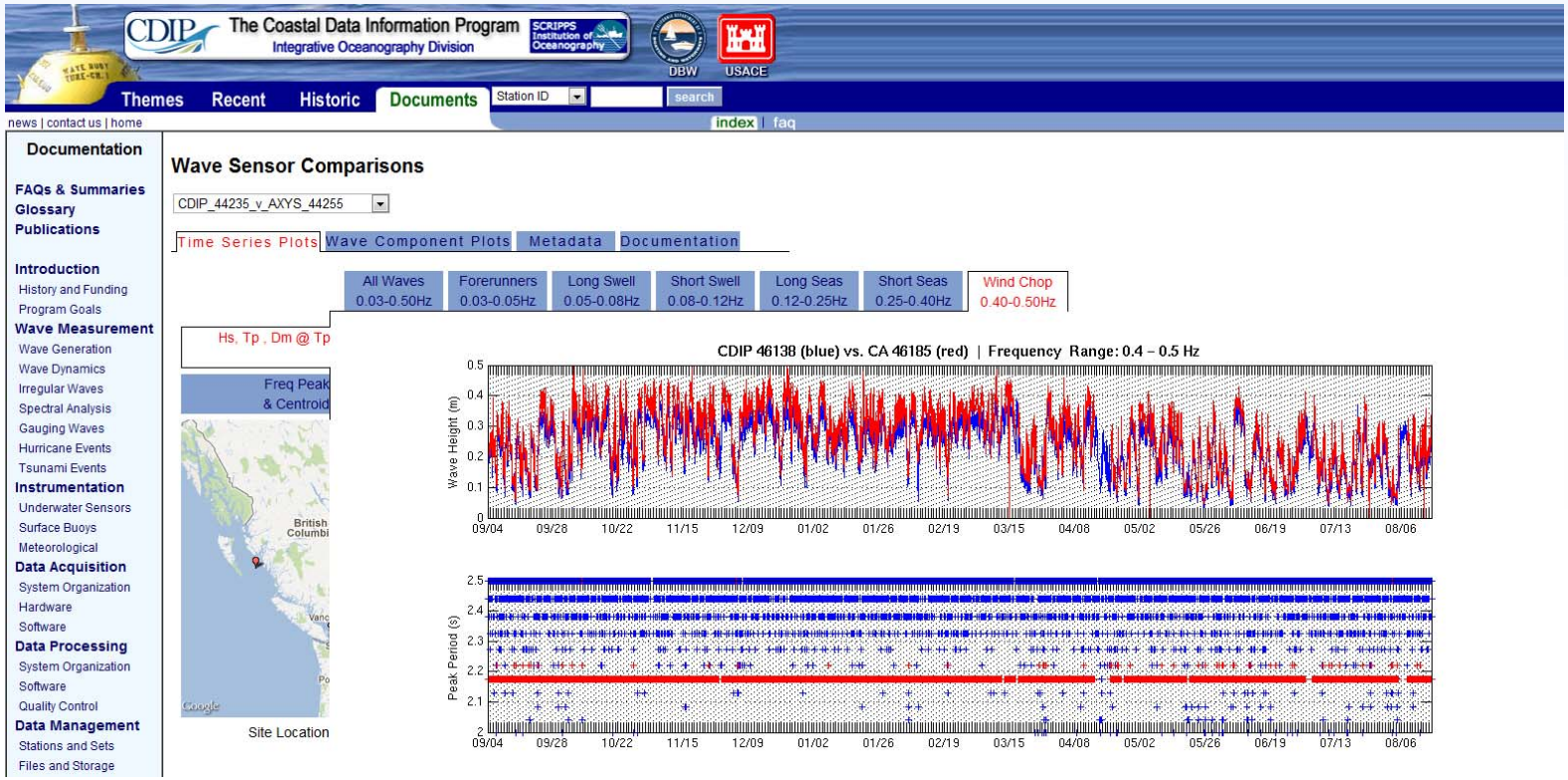
- Alternatives
  - Co-deployments in one location
  - Buoy Farm – multiple deployments
  - Multiple sensors in one buoy



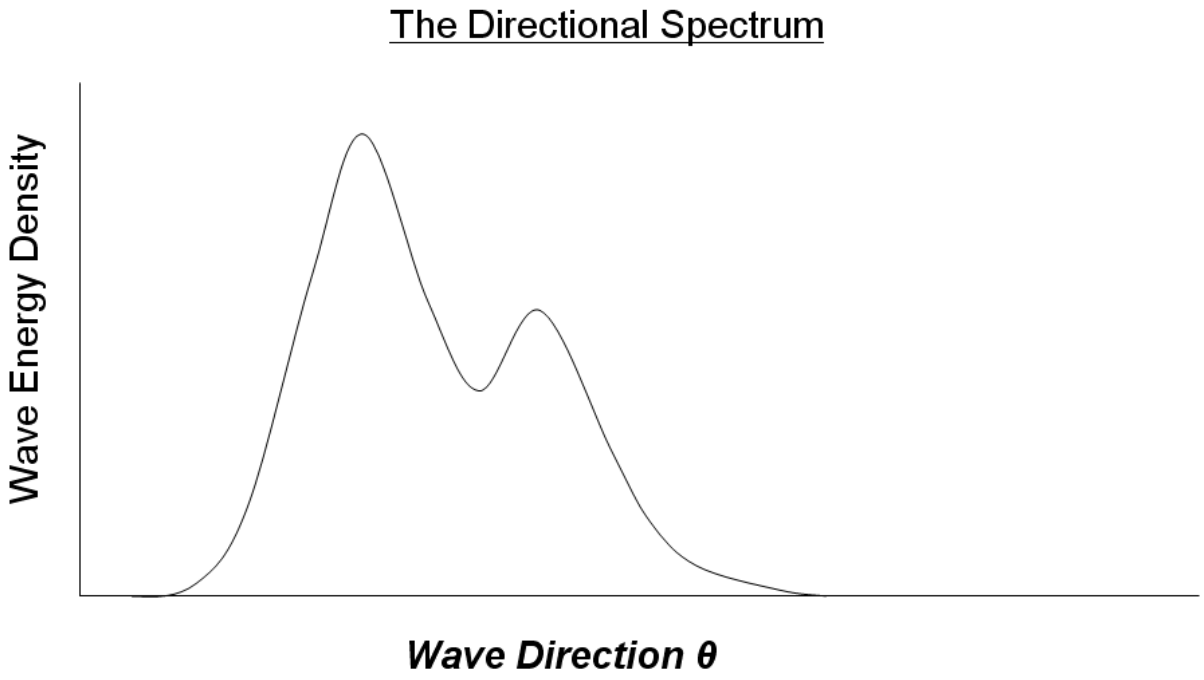
- Analysis based on First-5 principles
  - Does not preclude non-directional measurements

Evaluation Procedure

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



The Outcome and Minimum Requirements for Directional Observations



$$S(f,\theta)=S(f)[a1\cdot\cos(\theta)+b1\cdot\sin(\theta)+a2\cdot\cos(2\theta)+b2\cdot\sin(2\theta)+a3\cdot\cos(3\theta)+b3\cdot\sin(3\theta)+a4\cdot\cos(4\theta)+b4\cdot\sin(4\theta)+\ldots\ldots\ldots\ldots\ldots\text{infinity and beyond}]$$

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

Recommendations

- Continue to test and evaluate
- New PC version now available *WAVEVALtool*
- NDBC 6M NOMAD 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

Intercomparison Activities Underway

Canada

- Contract continued with to CDIP/SIO to
  - Maintain intercomparison web site
  - Provide intercomparison software to partners – new PC version
  - Advise on use of intercomparison methodology and web site - Appendix
  - Advise on intercomparison technical issues
  - Conduct individual intercomparison analyses for participants

- Intercomparison activities – 3 co-deployments
  - Hecate Strait: 3D vs DWR – 3D vs TriAxys when data retrieved
  - Burgeo: 6N vs DWR; TriAxys vs DWR
  - Halifax: 3D vs DWR; 3D vs TriAxys when data retrieved
  - Hecate Strait DWR to be relocated to La Perouse 3D November' 11

Intercomparison Activities Underway

United States

1. Analysis of historical NDBC multiple sensor packages on
   - 44014 (Virginia Beach-Atlantic Ocean offshore of the FRF)
   - 46029 (Columbia River, Oregon Pacific Ocean)
   - 46042 (Monterey, California)**
   - 51001 (Hawaii NorthWest, was operating but not any more)

2. **NDBC Buoy Farm to be located near 46042 Monterey Canyon
   - 3D multiple sensor (46042)
   - 2.4D new buoy with 3DM sensor
   - Datawell Directional Waverider (deployed September 2011).
   -

3. Alliance for Coastal Technologies Report under review. Consensus of all manufacturers is to use a Datawell Mark III or IV as reference to evaluate buoys. The FRF Duck to be the shallow water site to evaluate to the FRF linear array as relative reference.

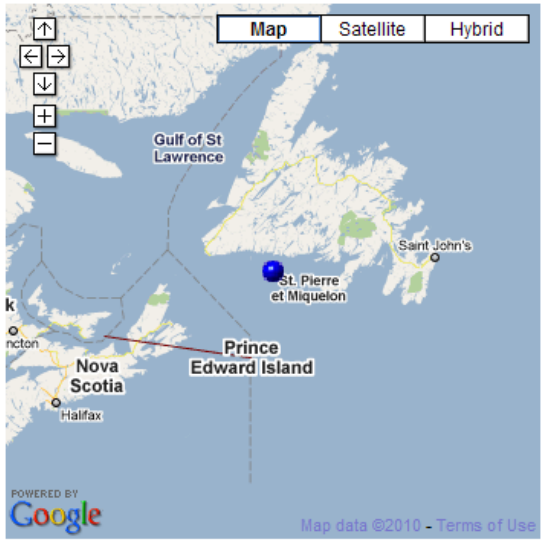
Intercomparison Activities Underway

- **Korea** –multiple co-locations at Ieodo platform. Data to be retrieved at end September for analysis
- **India** –co-location offshore India in 20m water depth with DWR. Data to be retrieved at end September for submission to CDIP for analysis
- **Norway** – Ekofsik platform wave historical data being assembled for submission to CDIP for analysis – LASAR, waverider. Coordination with Conoco regarding deployment of DWR
- **UK** – purchased DWR for research; plan to evaluate K-series buoys
- **ECMWF** – compared co-located Canadian buoys to operational wave model output
- **OGP** – sensitivity analysis of buoy hull size to wave measurement bias (Woodside); interest in providing co-located measurements to CDIP for analysis; Ekofisk logistics
- Interest but no definite plans at the moment: ESURFMAR, Australia, China, Japan

- **Other participants are encouraged to join the WET activity by contacting the co-chairs or Secretariat. (www.jcomm.info/WET)**

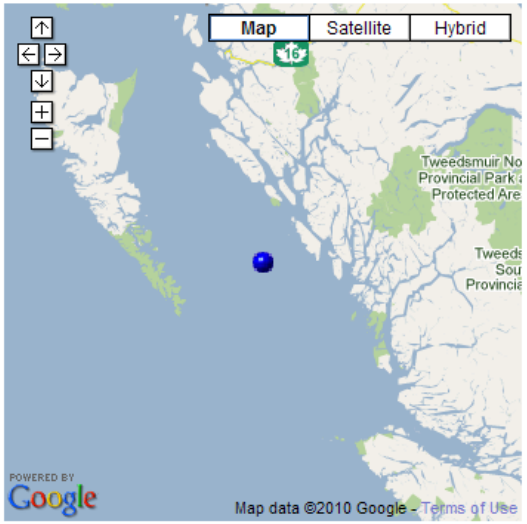
Canadian Co-deployment locations

- Current status: **operational**
- Most recent location: **47 15.91 N 57 20.49 W (47.2652 -57.3415)**
- Instrument description: **Datawell directional buoy**
- Most recent water depth (MLLW): **177 m (581 ft, 97 fm)**
- Measured parameters: **wave energy,wave direction,sea temperature**
- NDBC/WMO identifier: **44235**



170 - Station Map

- Current status: **operational**
- Most recent location: **52 26.20 N 129 47.70 W (52.4367 -129.7950)**
- Instrument description: **Datawell directional buoy**
- Most recent water depth (MLLW): **230 m (755 ft, 126 fm)**
- Measured parameters: **wave energy,wave direction,sea temperature**
- NDBC/WMO identifier: **46138**

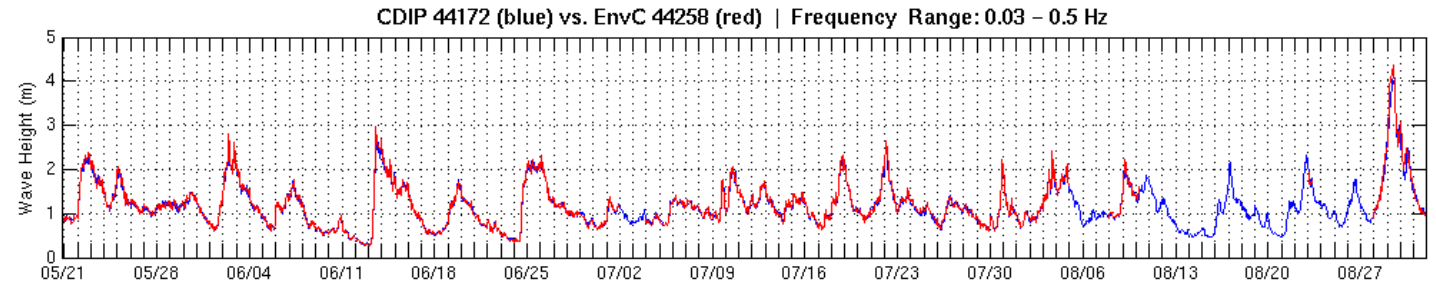


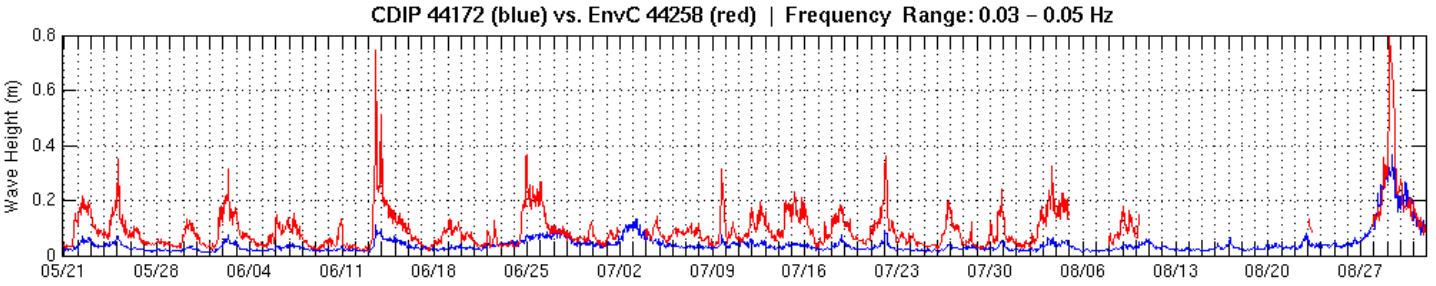
174 - Station Map

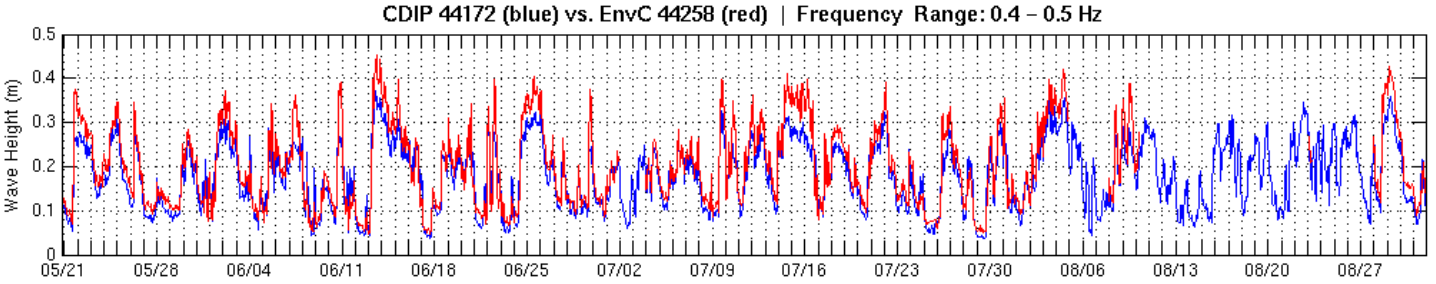
170 co-located with operational 6m NOMAD 44255 plus TriAxys sensor
174 co-located with operational 3m discus 46185 plus TriAxys sensor
170 now co-located with 3m plus TriAxys sensor at Halifax Harbour
174 to be moved with 3m plus TriAxys sensor to La Perouse

Evaluation Procedure: Co-located

Time Series Analysis for specific differences



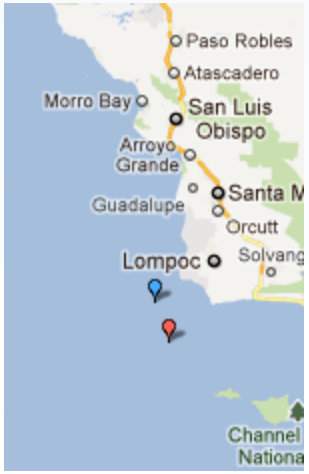


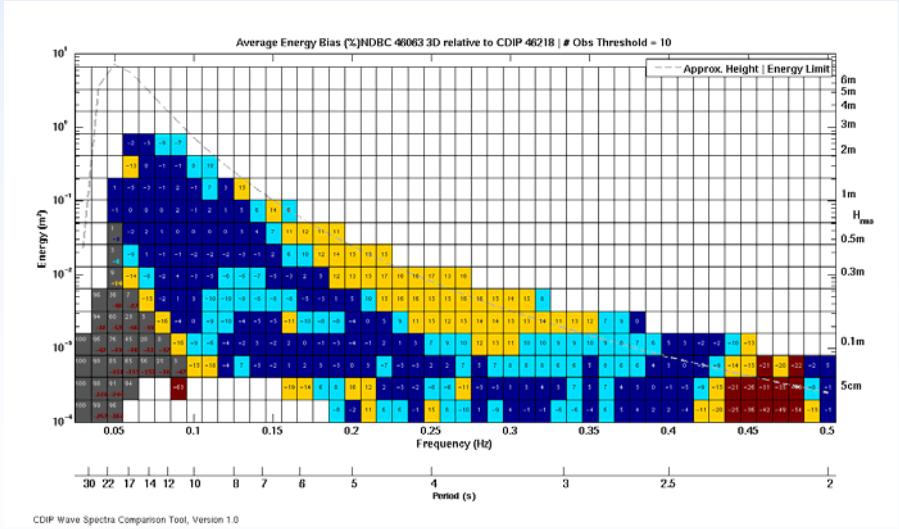


Evaluation Procedure: Co-located

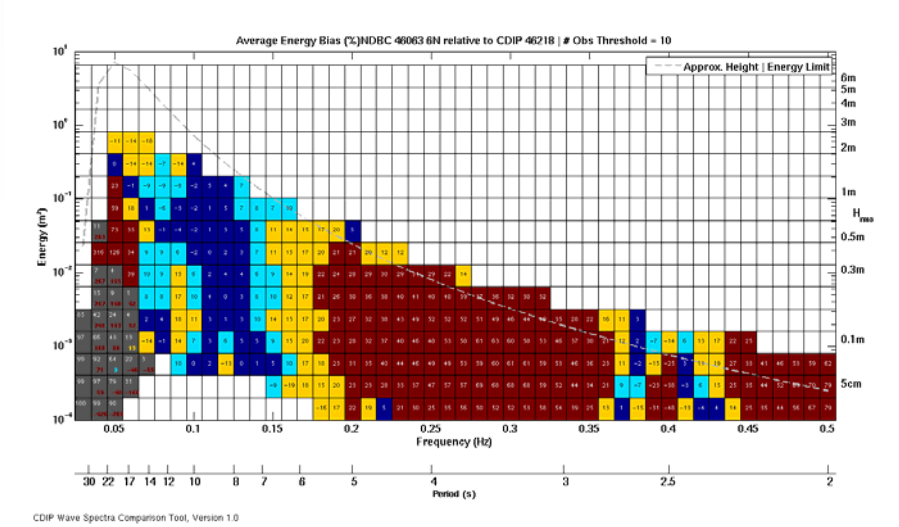
Analysis of Hull / Sensor / Payload Package

3D / ARS / ARES





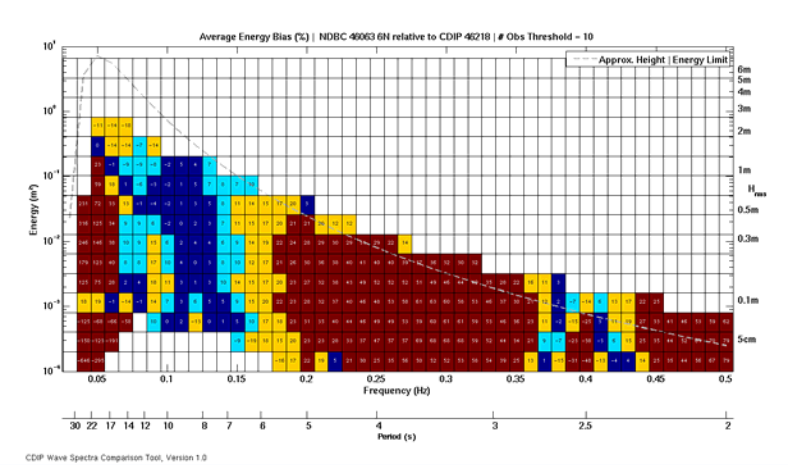
6M / Inclinometer / DACT



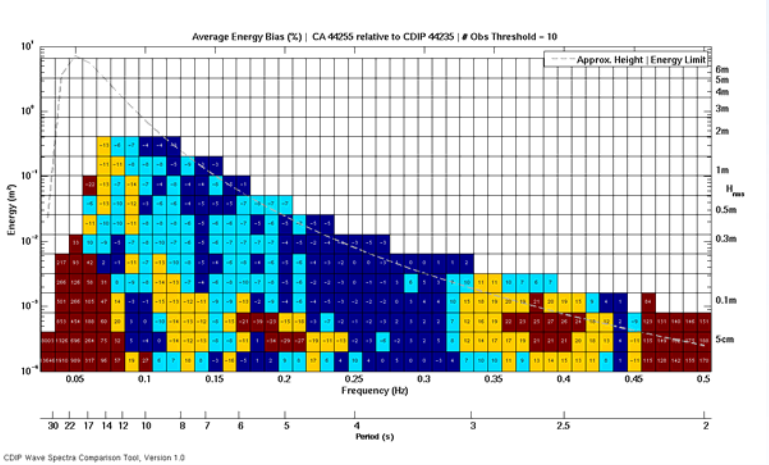
Evaluation Procedure: Co-located

Analysis of: Operational NOMADS

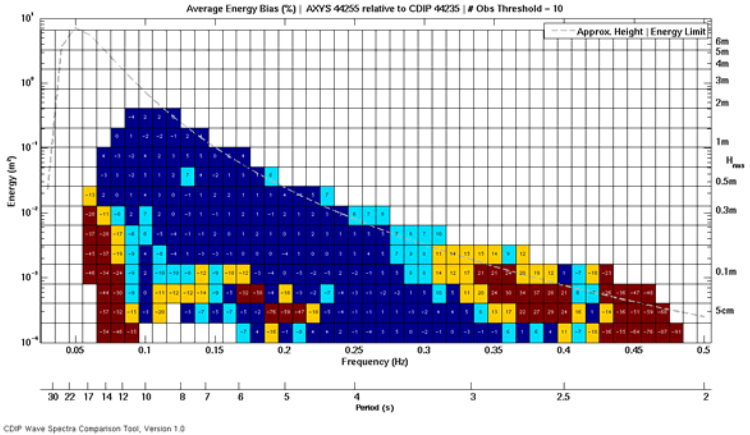
46063 : Inclinometer / DACT



44255: Accelometer / AXYS



44255: TriAXYS* / AXYS



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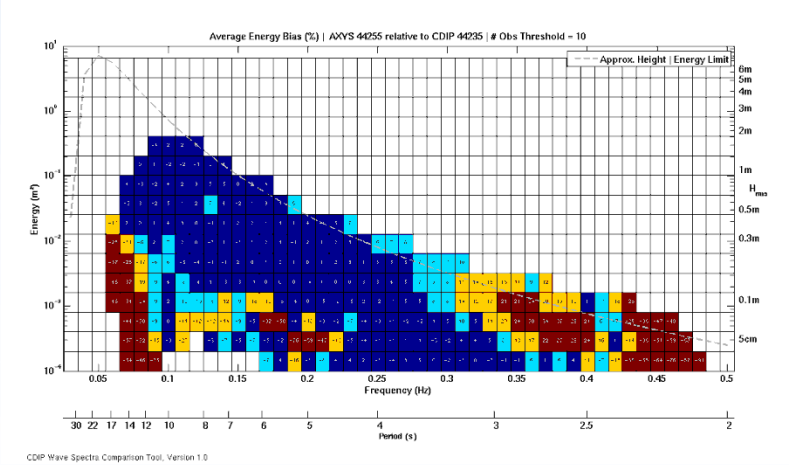
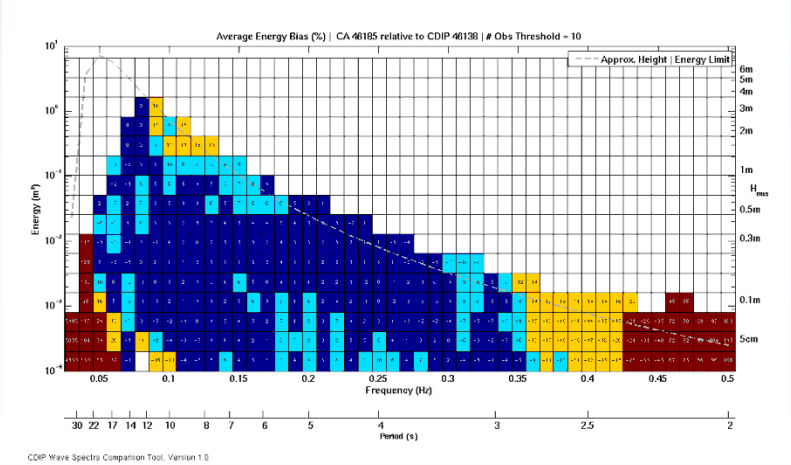
Evaluation Procedure: Co-located

Analysis of: Hull

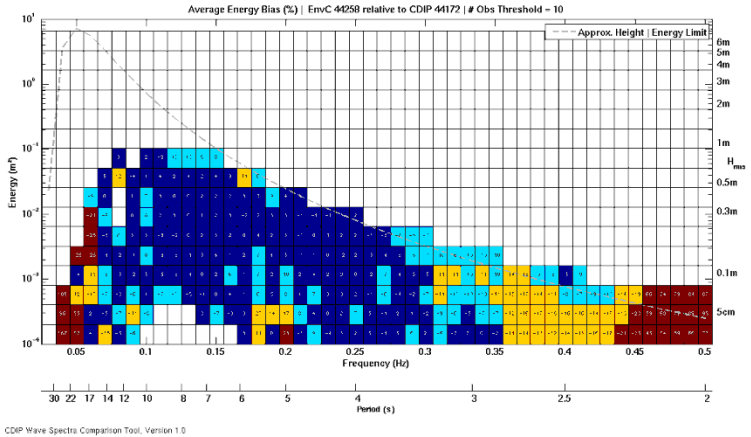
44255: 6M / TriAXYS



46185: 3D / TriAXYS



44258: 3D FOAM / TriAXYS



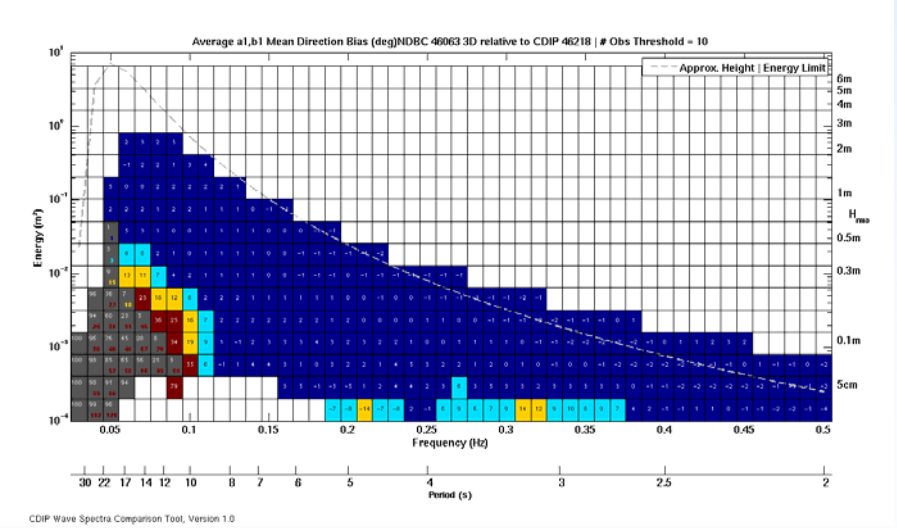
WMO IOC/UNESCO

Evaluation Procedure: Co-located

DIRECTIONAL Analysis of Sensor / Payload Package

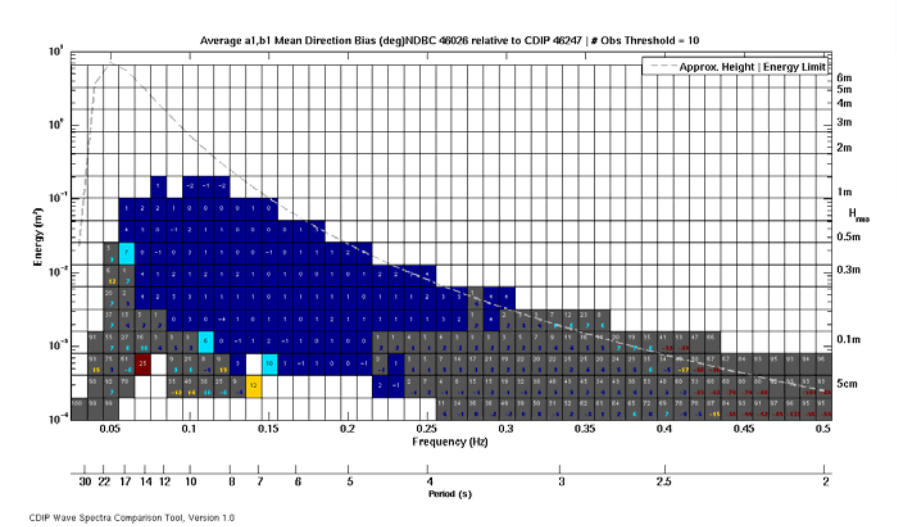
3D / ARS / ARES

46063: Pt. Conception



3D / 3DM / AMPS

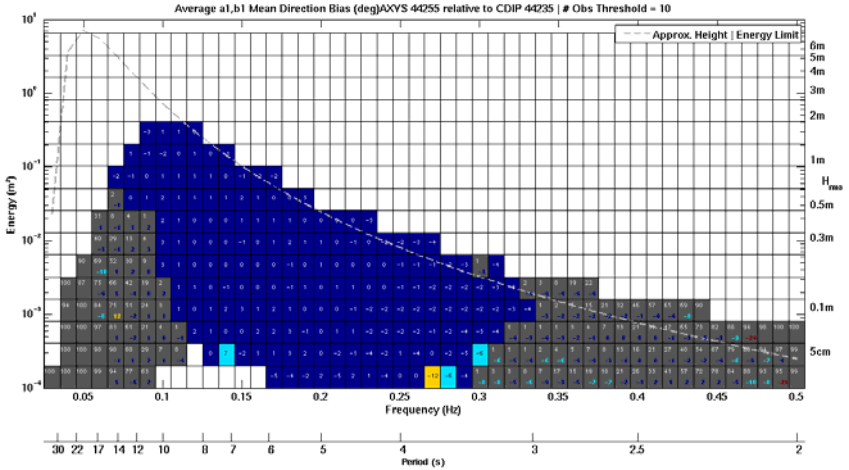
46026: San Francisco

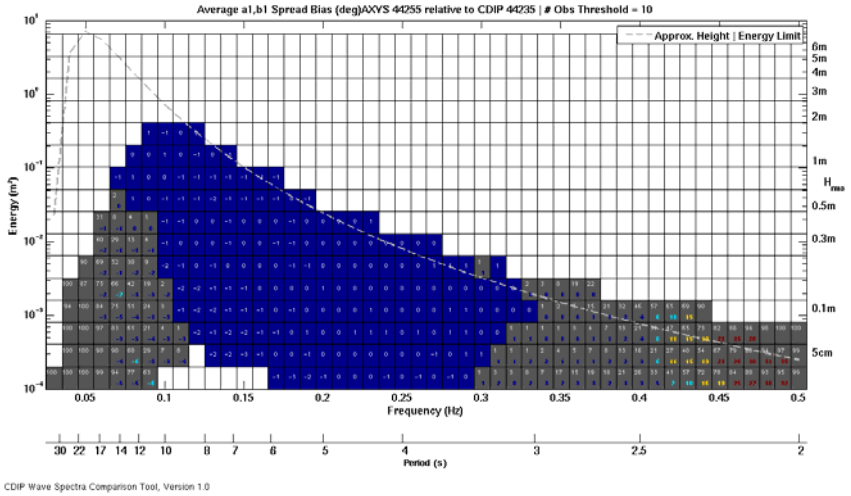


Evaluation Procedure: Co-located

Analysis of: Directional Estimates from NOMAD

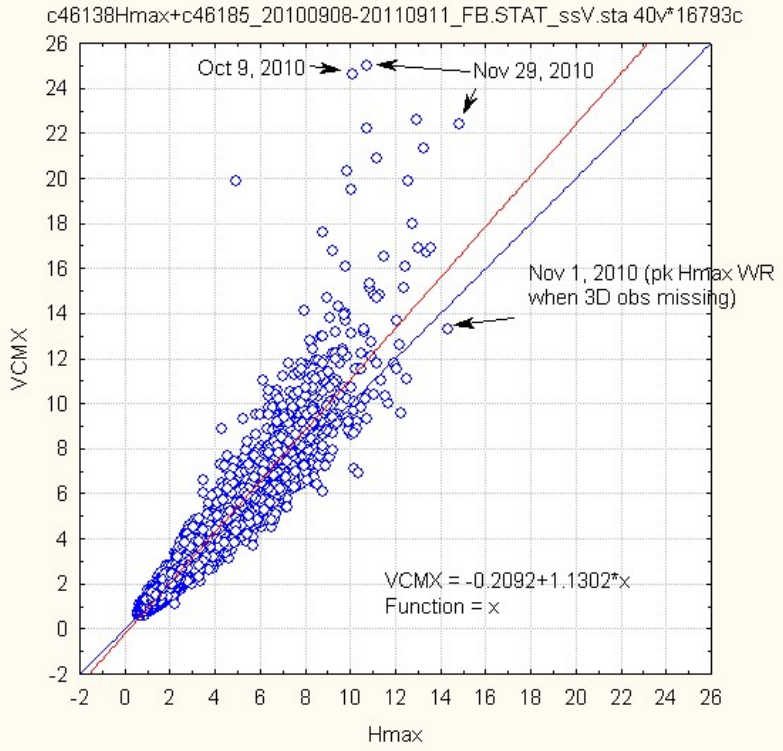
6M / Tri-AXYS/ AXYS

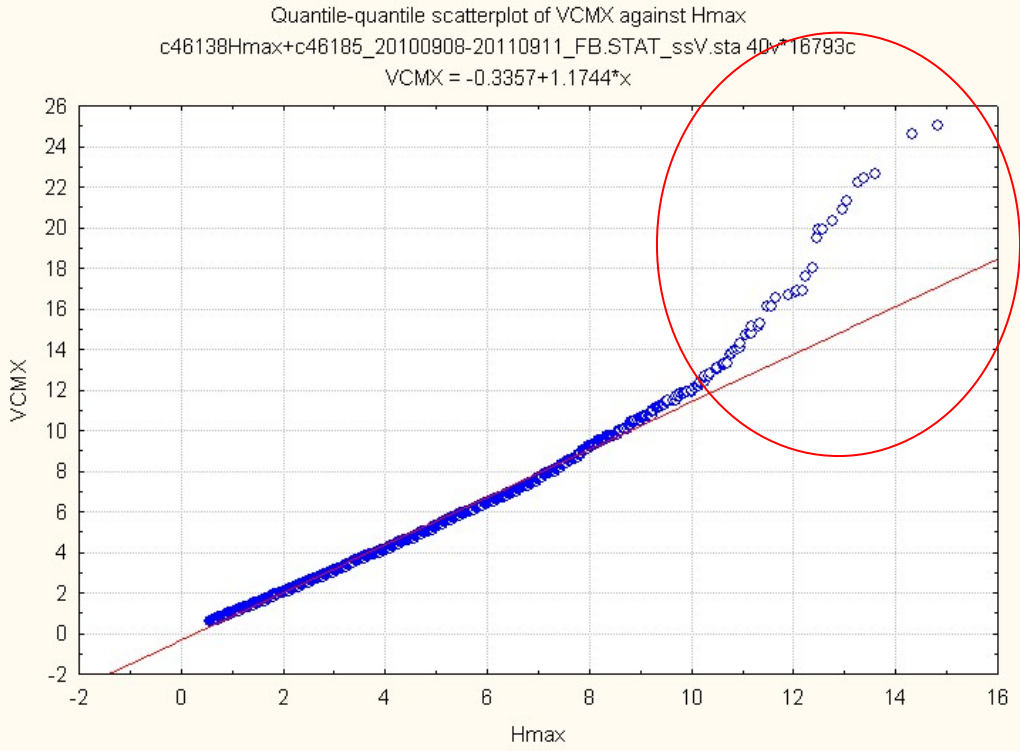




Comparison of H_{max}: 3D to DWR

- 3D (VCMX) shows spuriously high values of Hmax compared to WR Hmax, above Hmax 9 m
- 3D Hmax is also > WR Hmax below 9 m





Recommendations for PP-WET

- Encourage additional agencies/countries to carry out intercomparisons

- In particular as a matter of priority undertake the following:
  - NDBC 6N versus DWR
  - UK K-series buoy versus DWR
  - DWR versus LASAR array at Ekofisk
  - First-5 evaluation of GPS drifter versus DWR

- More directional spectral intercomparisons

Thank you.

PP-WET: Objectives

- Develop the basis for an international framework for the continuous testing and evaluation of existing and planned wave buoy measurements
- Coordinate buoy inter-comparison activities.
- Develop technical documentation of differences due to hull, payload, mooring, sampling frequency and period, processing (e.g. frequency bands & cutoff), precision, transmission
- Develop training material to educate users about how to deploy and operate wave sensors appropriately.
- Contribute appropriate material to the JCOMM Standards and Best Practice Guide
- Establish confidence in the user community of the validity of wave measurements from the various moored buoy systems

PP-WET Steering Team membership

- Val Swail, Co-Chair (ETWS, EC)
- Bob Jensen, Co-Chair (USACE)
- David Meldrum (DBCP, SAMS)
- Jean Bidlot (ECMWF)
- Kwang-Chang Lim (KHOA)
- Bill Burnett (NOAA/NDBC)
- Julie Thomas (UCSD)
- Hans Graber (U. Miami)
- Diana Greenslade (Australian Bureau of Meteorology
- Venkatesan (India)
- Bill O'Reilly (UCSD)
- Jon Turton (Met Office)
- Christian Meinig (NOAA/PMEL)
- Anne Karin Magnusson (met.no)
- Kevin Ewans (Shell)
- George Forristall (ForOcean)
- Colin Grant (OGP Metocean)
- DBCP Technical Coordinator

- Secretariat support will be provided by WMO and IOC.

- Boram Lee (WMO)
- Etienne Charpentier (WMO)