Joint WMO-IOC Technical Commission
for Oceanography and Marine Meteorology

DBCP-ETWCH Joint Pilot Project on Wave Measurement Evaluation and Testing

….*and other wave measurement issues*

Val Swail and Robert Jensen

Co-Chairs, Pilot Project on Wave measurement Evaluation and Test

DBCP-32 October 17-21, 2016

WMO

IOC/UNESCO

OBSERVATION REQUIREMENTS FOR WIND WAVES

(developed by the JCOMM Expert Team on
Waves and Coastal Hazards Forecasting Systems)

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.
- Wave power resource assessment
- Port and harbour operations

- *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*

ERDC
Engineer Research and Development Center

Are Wave Measurements Actually Ground Truth ?

R. E. Jensen[1], T.J. Hesser[1] and V. Swail[2]

[1]Coastal and Hydraulics Laboratory
[2]Environment Canada

Environment Canada

WISE 2013
NOAA / NCEP
College Park, MD
21 – 25 April 2013

US Army Corps of Engineers®

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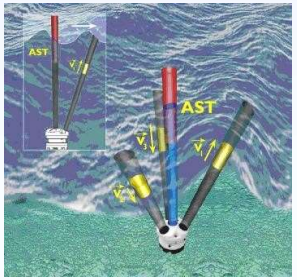
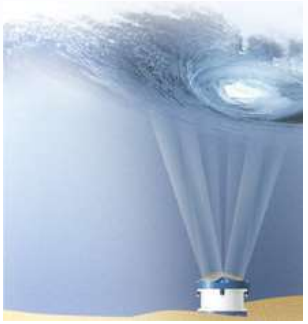
How to “ground truth” the “ground truth” ?





Can Buoy Wave Measurements Actually be used for Climate Trend Analysis?

ERDC
Engineer Research and Development Center

R. E. Jensen[1], Xiaolan Wang[2] and V. Swail[2]

[1]Coastal and Hydraulics Laboratory
[2]Environment Canada

Environment Canada

CLIMAR-4
Asheville, NC
6-9 June 2014

US Army Corps of Engineers®

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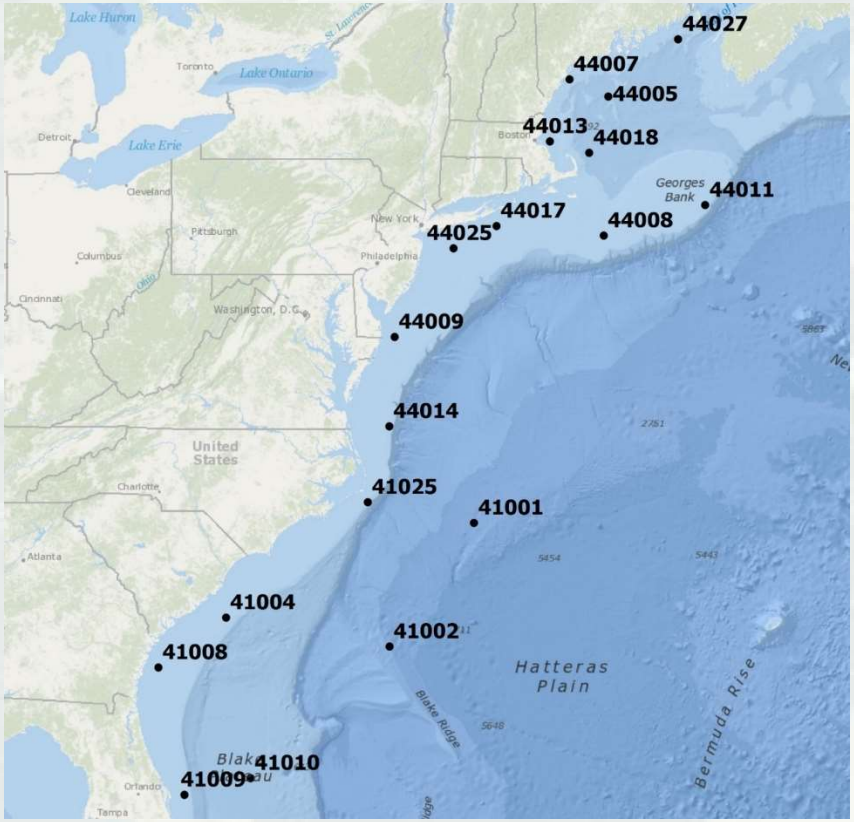
Point Source Measurements

- Livermont et al. (2016)
  - Alternate technique to account for
    - Hull / Payload
  - Criteria
    - US East Coast
    - Operational
    - 10-yr records
  - Analysis of Covariance
    - Tests hypothesis that means of several groups of data are equal
    - Based on hull type / payload
    - Spatial consistency?
  - Linear Models fit to wave records
    - Hardware corrected (5)
    - Payload corrected (8)
    - Corrected for both



Point Source Measurements

Livermont et al., 2015

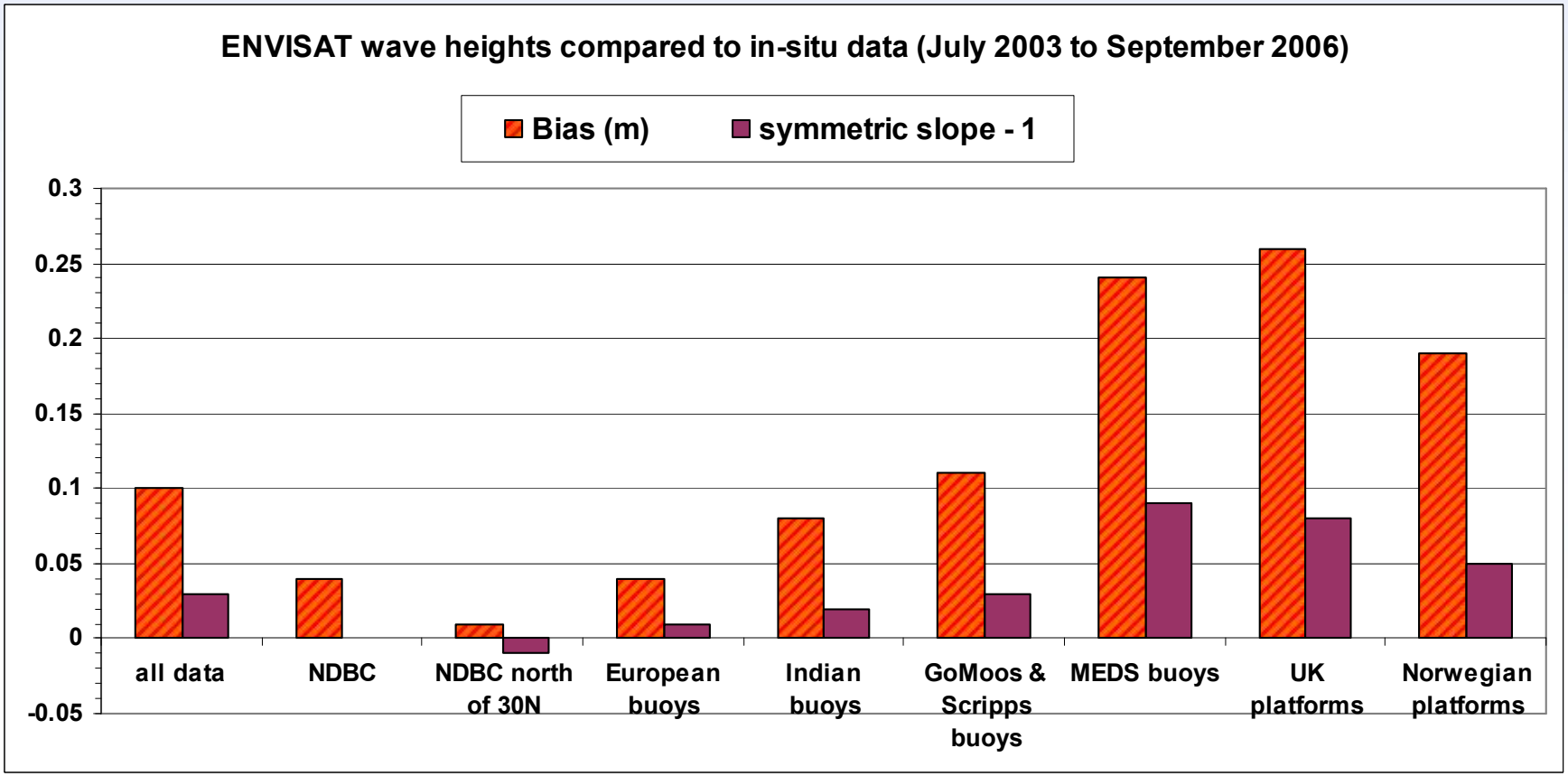
Buoy Number	Original Dataset *Slope (mm/yr)*	Corrected *Slope (mm/yr)*
Buoy 41001	3.027	-0.003
Buoy 41002	0.593	-0.264
Buoy 41004	-4.941	-1.709
Buoy 41008	-3.914	-1.691
Buoy 41009	4.123	-1.909
Buoy 41010	1.590	-1.932
Buoy 41012	3.009	-0.003
Buoy 41013	3.007	-0.003
Buoy 41025	3.009	-0.003
Buoy 44004	-2.625	-1.129

Buoy Number	Original Dataset *Slope (mm/yr)*	Corrected *Slope (mm/yr)*
Buoy 44005	-8.582	-1.311
Buoy 44007	0.282	0.518
Buoy 44008	8.219	1.171
Buoy 44009	8.994	-0.921
Buoy 44011	2.824	1.582
Buoy 44013	14.581	0.115
Buoy 44014	2.640	0.231
Buoy 44017	3.008	-0.003
Buoy 44018	3.011	-0.003
Buoy 44025	7.526	1.052
Buoy 44027	3.008	-0.003

Wave height: White, green or blue water?

Courtesy A.K. Magnusson

Why Do We Need to Test and Evaluate



Bias: altimeter Hs – in-situ Hs

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

How is your wave measurement?

"My waves are 10%
higher than your waves."

"10%? That's a lot!"

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.

WAVE MEASUREMENT

Quality is job 1

Joint WMO-IOC Technical Commission
for Oceanography and Marine Meteorology

Pilot Project-Wave Evaluation and Testing
FLOSSIE and Other Testing

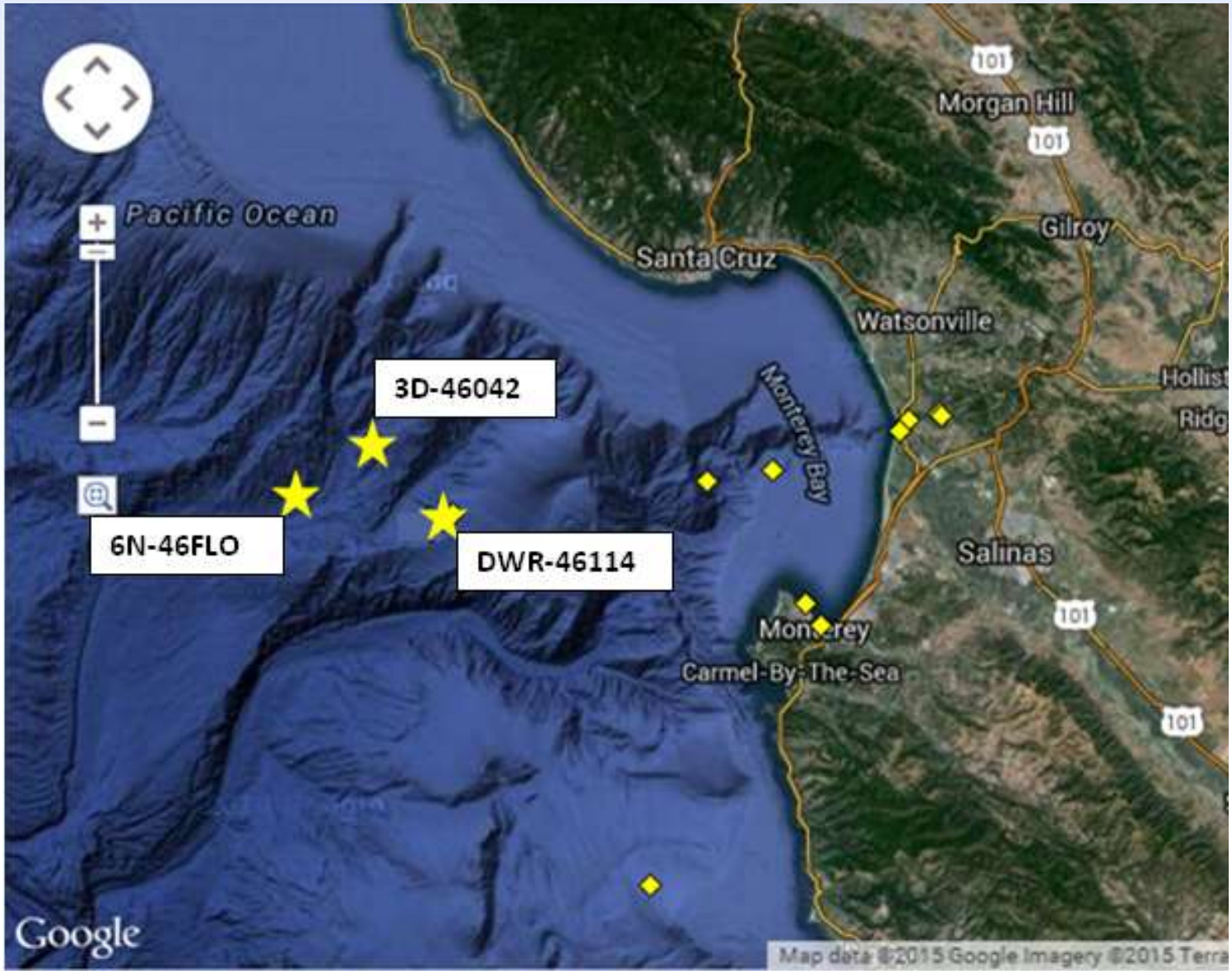
R. E. Jensen

DBCP-32 Science and Technology Workshop
18 October 2016
La Jolla, CA

WMO

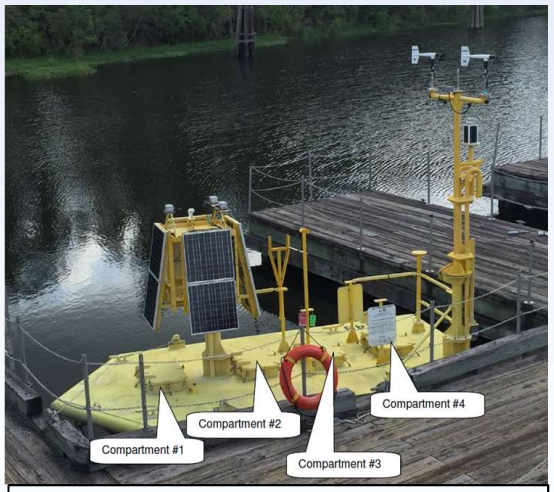
IOC/UNESCO

Buoy Farm: Pacific / Monterey Canyon

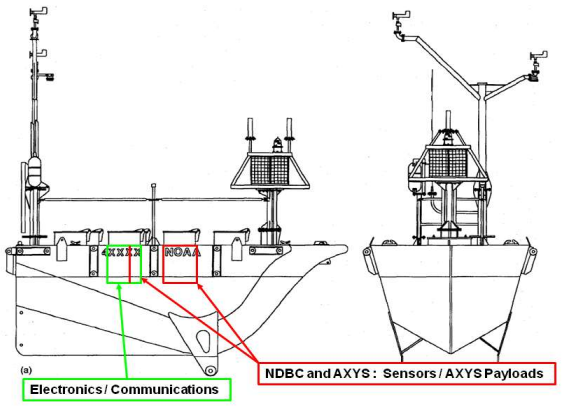


What FLOSSIE Returns

- Non-Directional Sensor / Payloads
  - NDBC: Inclinometer
  - 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 Staff



B.Lee70

Evaluation Preliminary 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?
  - Over the mean differences are small
  - **Spread of +/- 1-2.0-m is a concern**
  - **Deviations grows with increasing H_{mo}**
  - Moments in direction?
- Can we relate those differences to
  - Sensor/payload type
  - Hulls, super-structure, mooring
  - Analysis package

Need ECCC SDA (Watchman) processed

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Slide 16

B.Lee70 Boram Lee, 9/24/2008

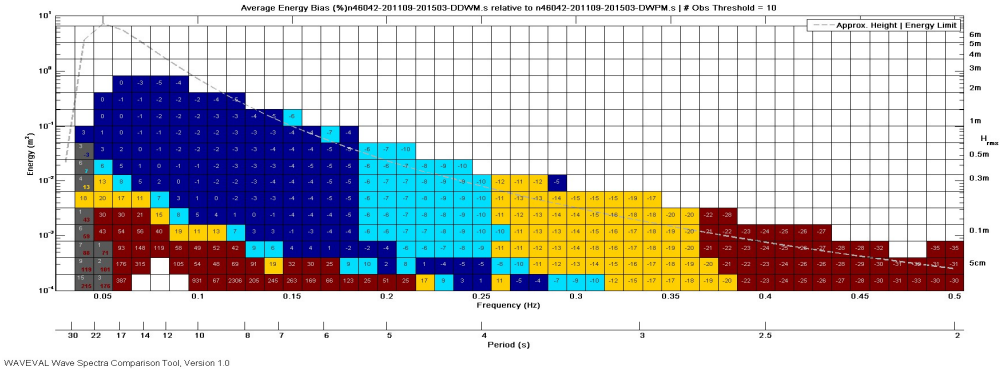
B.Lee66

Recommendations

- Cannot <u>overstress</u> the importance of
  - Continued Test and Evaluation of wave measurement systems
  - **Metadata are as important as the data itself !**

- Additional Sensor/Payload Deployments
  - TRIAXYS Buoy and Sensor on 3D NDBC Buoy
  - Other Sensor Packages (Drifter Program)
    - L. Centurioni and L. Braasch (SIO)
    - E. Terrill (SIO)
    - DBCP-32: S&T Workshop: Thomson, Crandle

- Other Tests



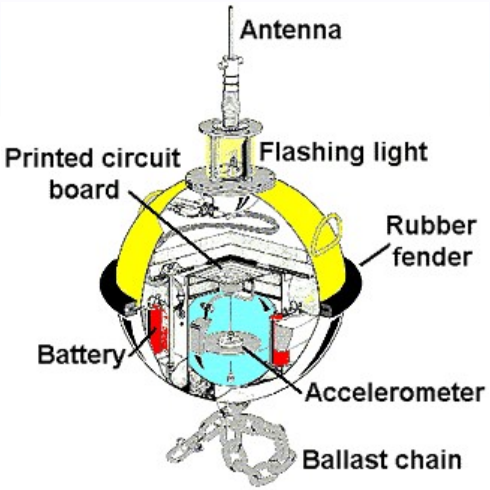
Slide 17

B.Lee66 Boram Lee, 9/24/2008

B.Lee72

New Evaluations: Drifters

- Drifter Program
  - Other Sensor Packages
    - L. Centurioni and L. Braasch (SIO)
    - E. Terrill (SIO)
    - DBCP-32: S&T Workshop: Thomson, Crandle
  - Potential Tests
    - Contained in Datawell Waverider
      - Fall: Pt Loma (ECCC DWR)
    - Fully operational system (Drifter or Tethered ?)



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Slide 18

B.Lee72 Boram Lee, 9/24/2008

Dual Sensor / Single Hull

- Similar concept as FLOSSIE
  - Uses NDBC 3D Aluminum buoy
  - Investigation of motion sensor vs HIPPY
  - HIPPY in this case is relative reference

- Directional Sensor / Payloads
  - NDBC: HIPPY / Magnetometer (DWPM)
  - NDBC: 3DMG (DDWM)
  - 46029 (~1-yr / Datawell DWR)

B.Lee74

Dual Sensor and Foam Hull Evaluations

- Dual Sensor Systems
  - Pacific: 46029 (Pacific NW) / 46042 (Monterey Canyon)
  - Atlantic: 44014 (Mid Atlantic-Virginia Beach)
- Foam vs Aluminum
  - 51000 / 51100 (Hawaiian Islands)
    - Assess and expand to other 30 sites
- Foam 2.3 vs Aluminum (~SCOOP System)
  - 51101 / 51001 (Hawaiian Islands)
  - 42058 / 42T58 (Hurricane Matthew)
    - Assess and expand to other sites 8 (2.3D); 3 (2.4D)

Slide 20

B.Lee74 Boram Lee, 9/24/2008

B.Lee75

SCOOP System Evaluation and Testing

- Mini-FLOSSIE-2
  - What to deploy
    - 3D Aluminum (dual sensor) + Triaxys New Next Wave II DWS-WM
    - SCOOP System
    - Datawell Directional Waverider
    - TRIAXYS buoy?
  - Where NEW
    - Pacific: 46029 (Pacific NW)
    - Atlantic: 44014 (Mid Atlantic-Virginia Beach)
    - Great Lakes: 45002 / 45001 (Lake Michigan / Superior)

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Slide 21

B.Lee75 Boram Lee, 9/24/2008

GDP Wave Buoy Developments

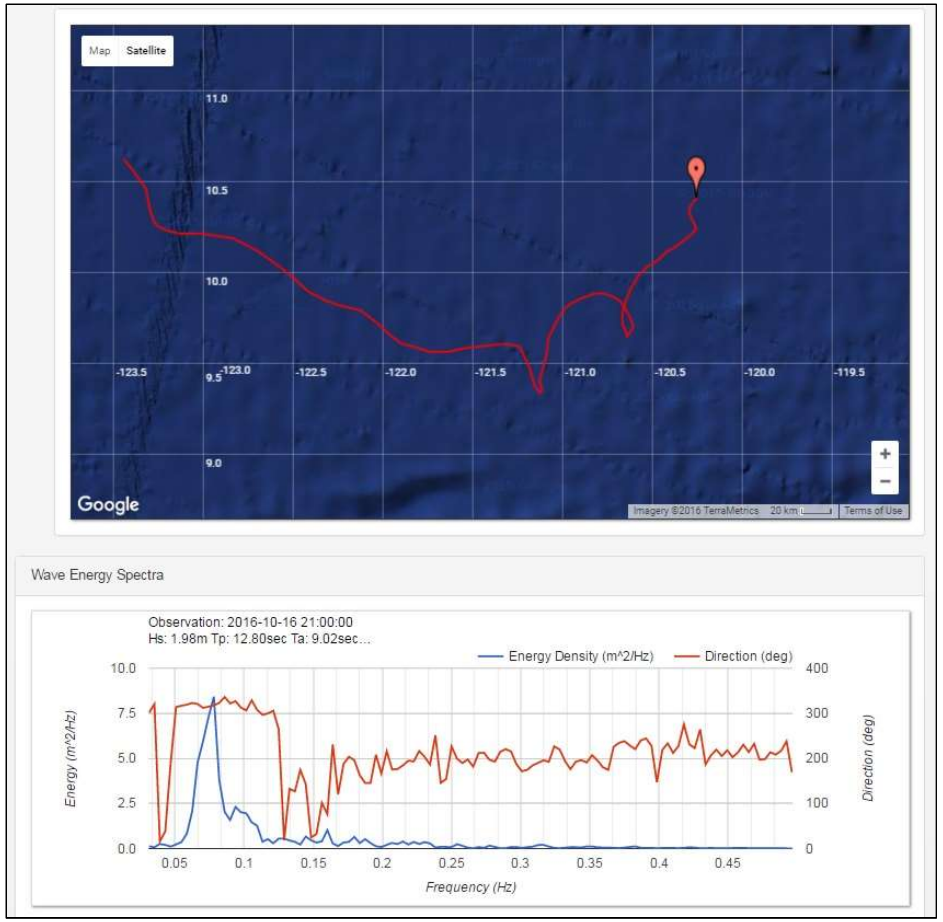
By Lance Braasch and Luca Centurioni

Timeline

2016

- Developments
  - Develop server-side routines for First-5 SBD processing, QC tools, and visualizations
  - Evaluate IMU sensors for next generation viability

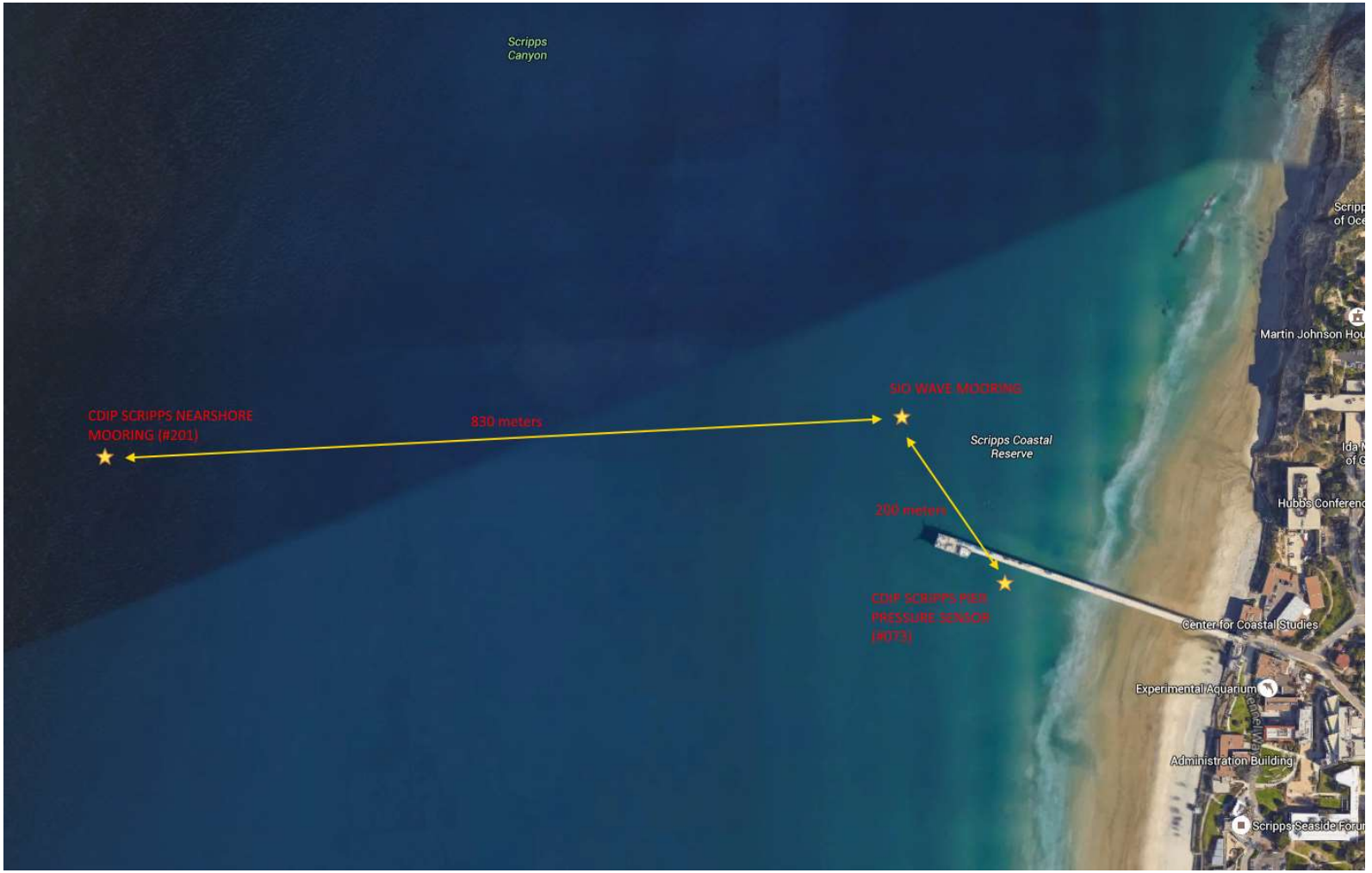
- Deployments
  - Mooring at Bay of Naples co-located with bottom mounted ADCP
  - 4 wave spheres currently deployed in the Pacific
    - 22 wave spheres currently loaded aboard R/V Revelle and queued for deployment in the Pacific
    - 18 wave spheres deployment TBD



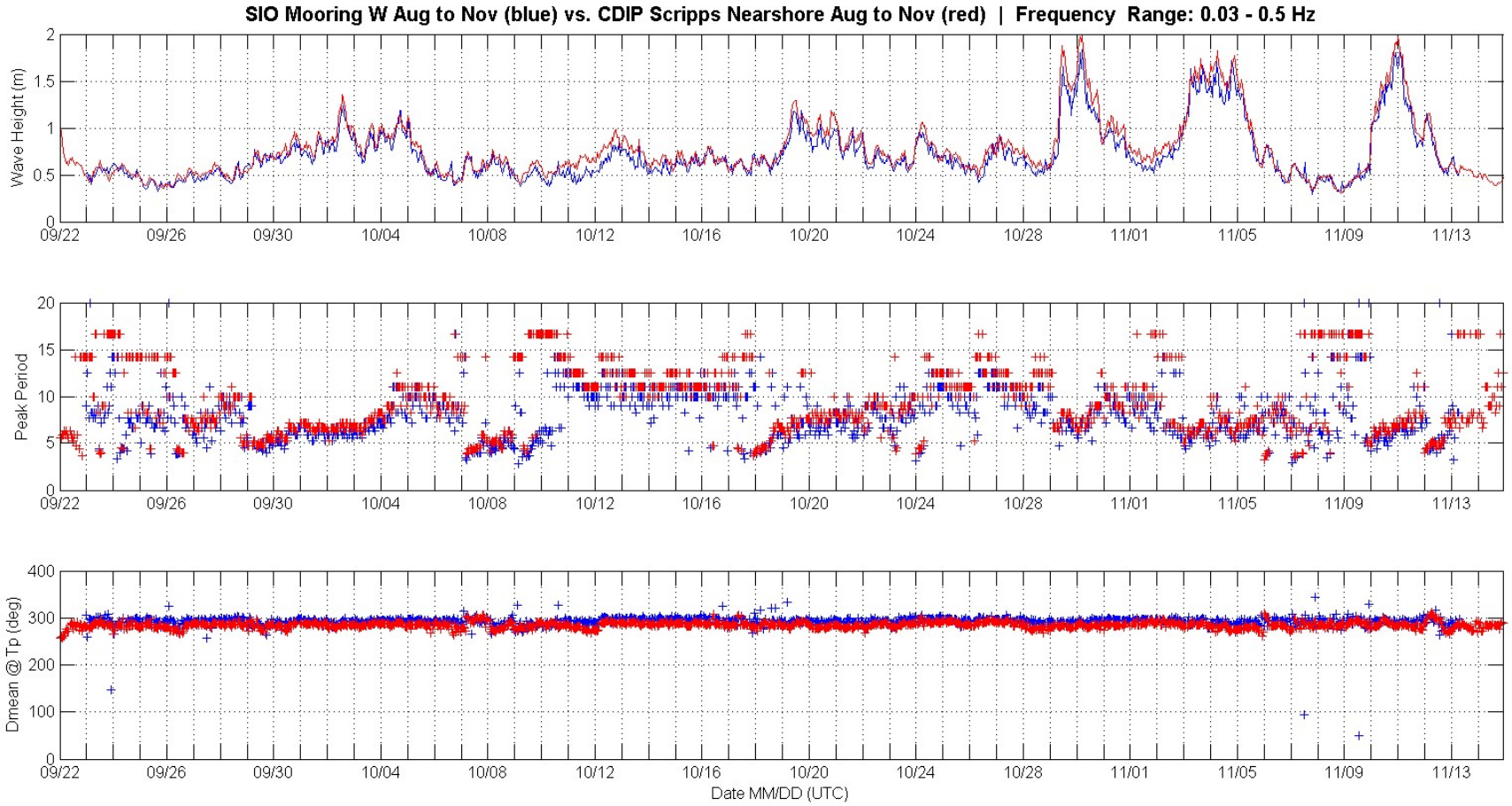
H_{mo} = 1.98m T_p = 12.80sec T_a = 9.02sec

D_d = 317.5degrees

Location of the SIO mooring and of the Other Reference Sensors

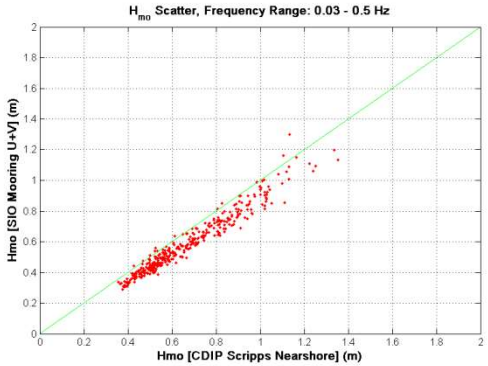


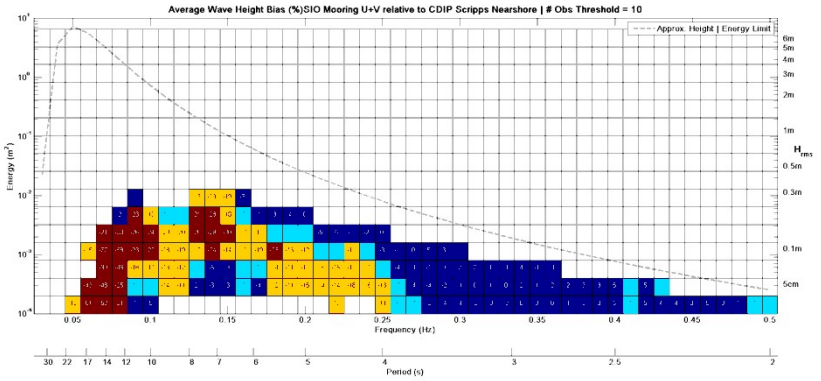
Validation: SIO drifter vs CDIP Directional Wave Rider ~1month long



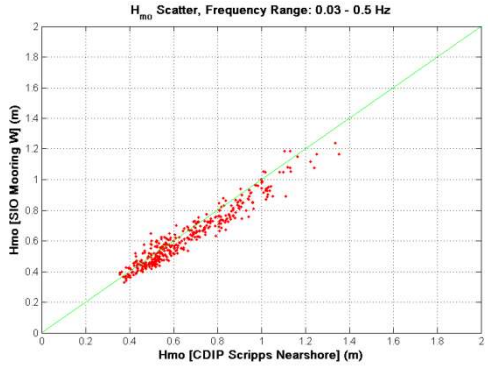
EVAL Wave Spectra Comparison Tool, Version 1.0

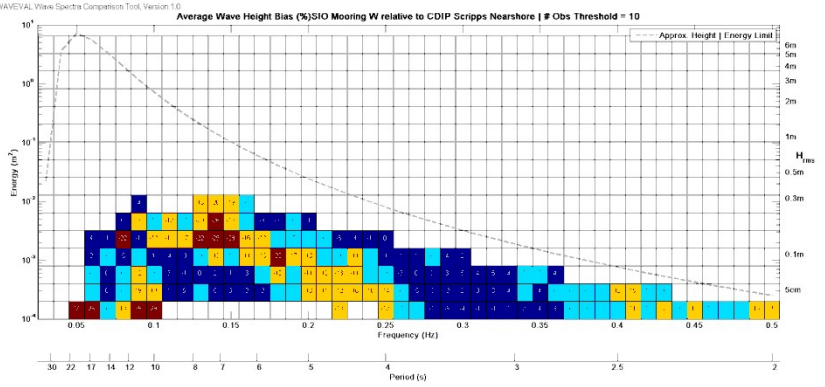
Validation: SIO drifter vs CDIP Datawell Directional Wave Rider with Waveval Tools.
~1month long



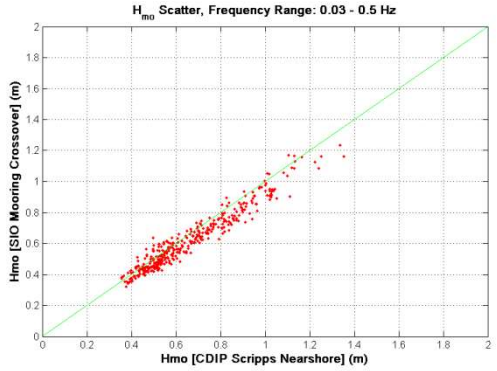


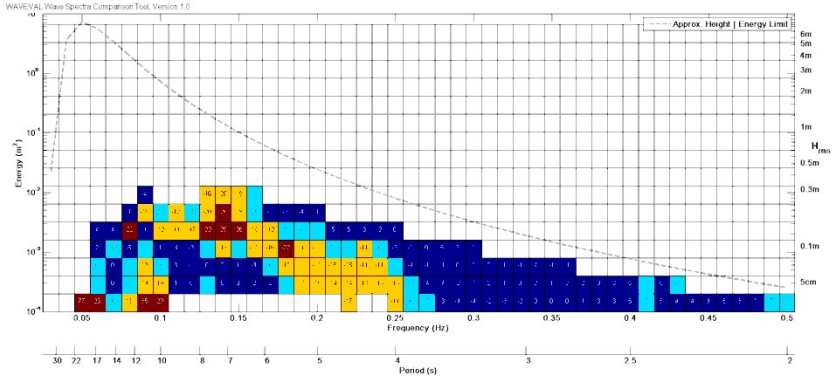
u,v, 2s-30s





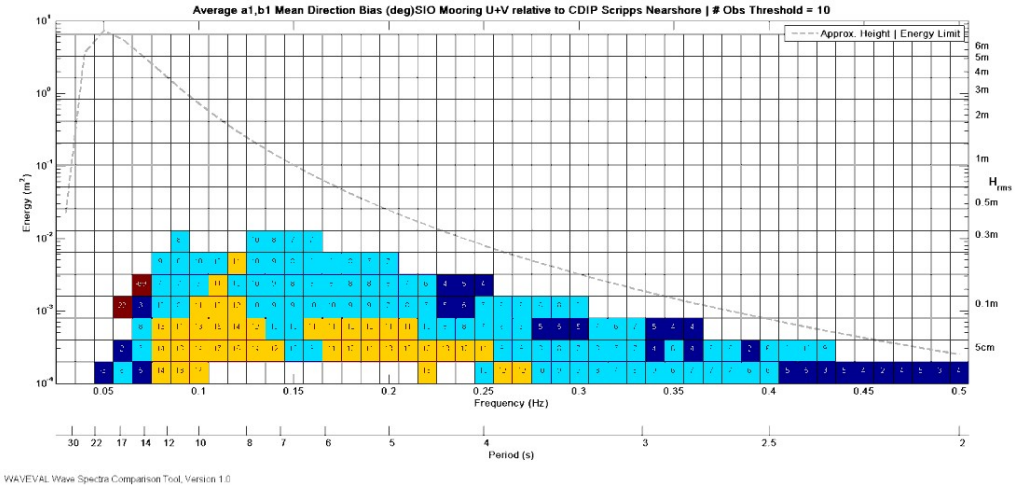
w, 2s-30s



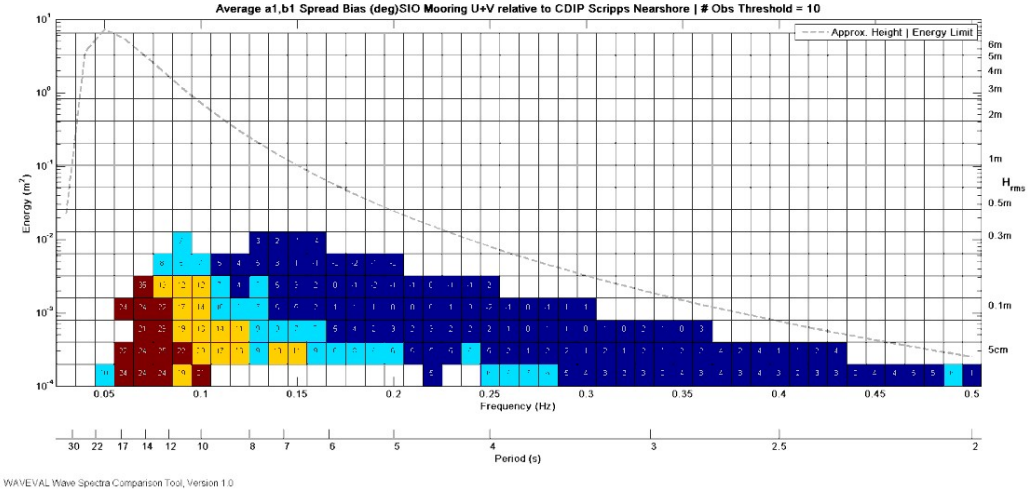


u,v, 2s-6s
w,6s-30s

Validation: SIO drifter vs CDIP Datawell Directional Wave Rider with Waveval Tools.
~1month long

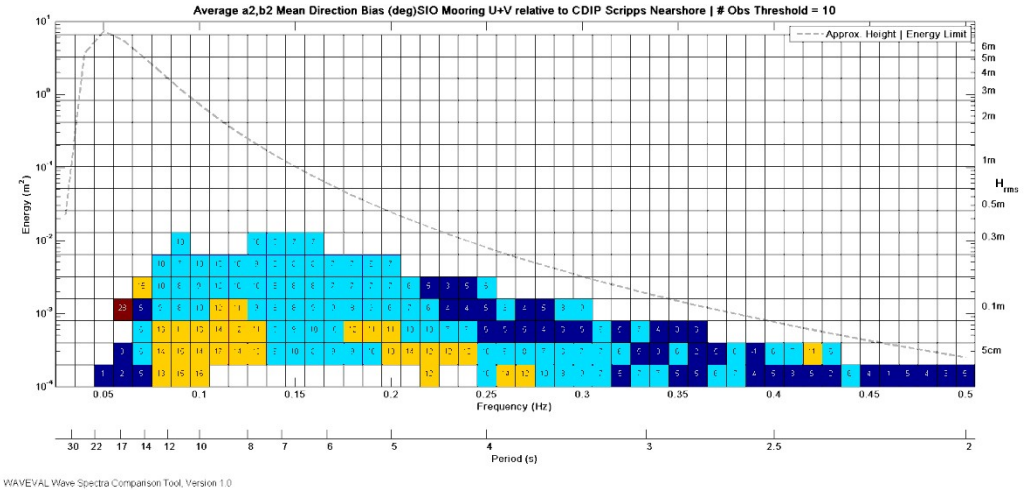


Mean Wave Direction Bias, a_1 and b_1

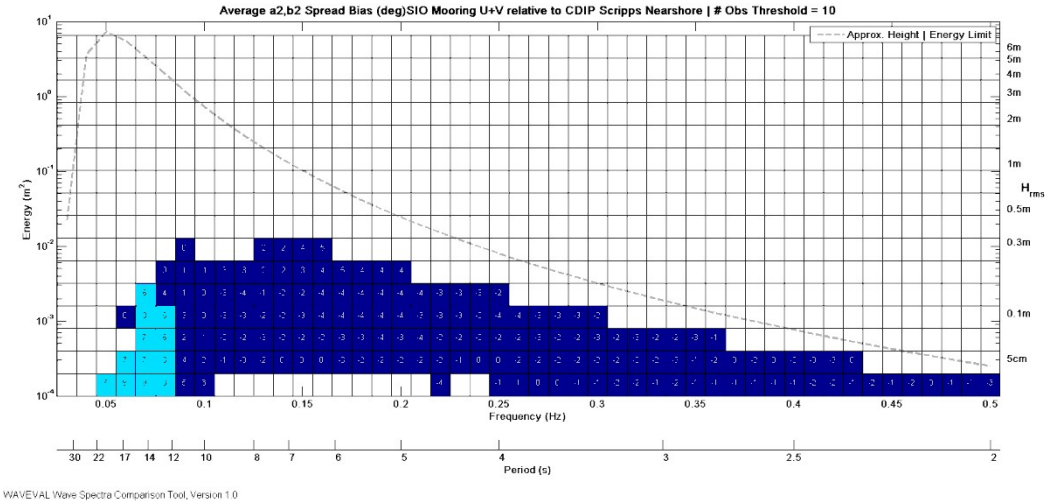


Directional Spread Bias, a_1 and b_1

Validation: SIO drifter vs CDIP Datawell Directional Wave Rider with Waveval Tools.
~1month long

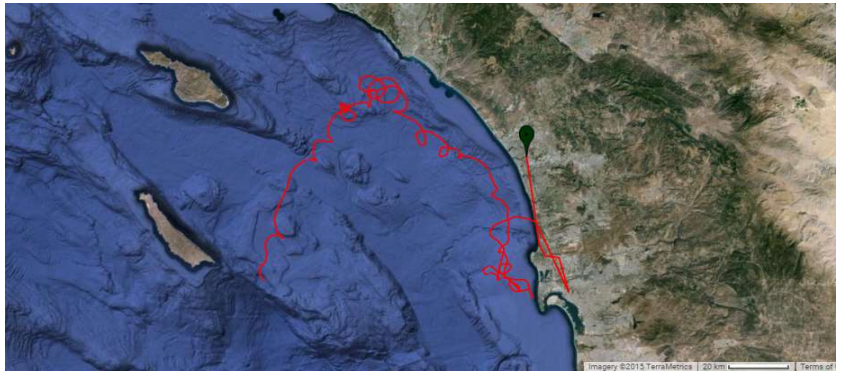


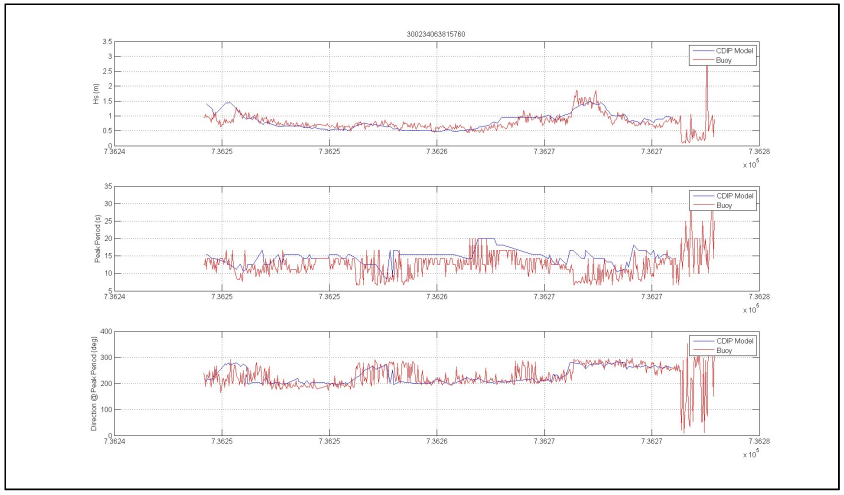
Mean Wave Direction Bias, a_2 and b_2

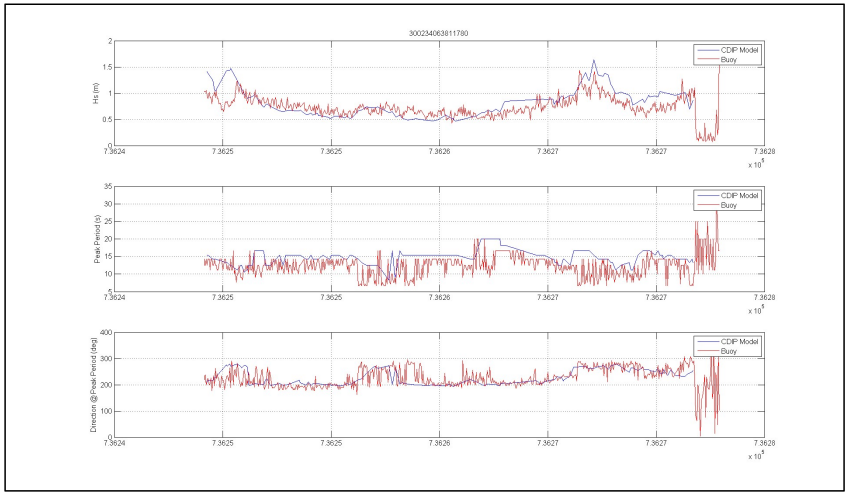


Directional Spread Bias, a_2 and b_2

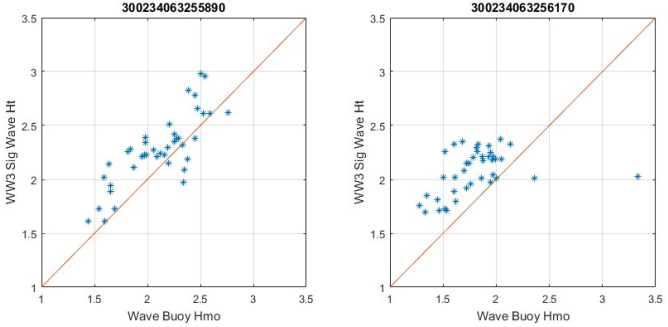
Validation – Wave Sphere

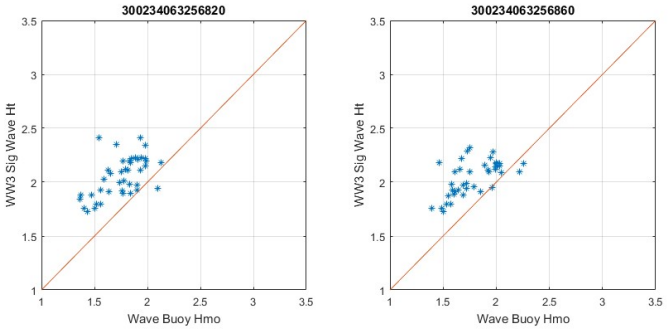


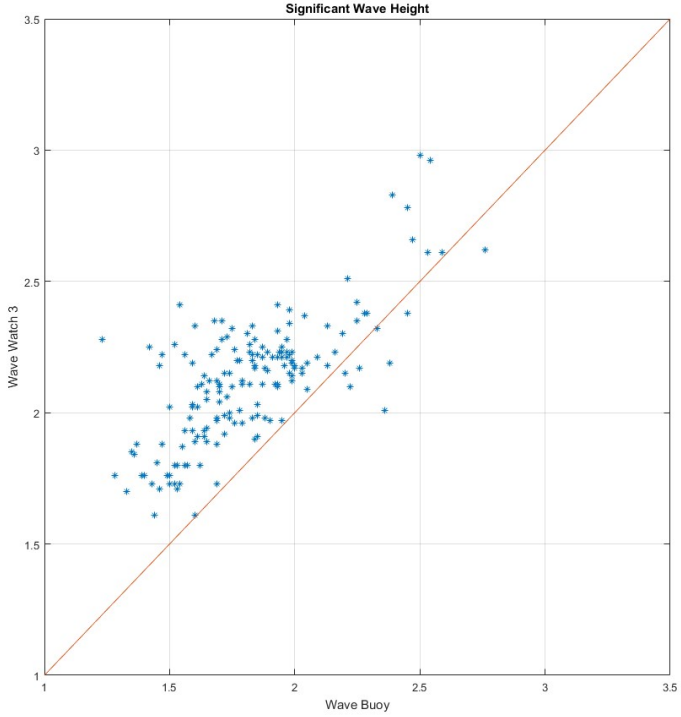




5 Wave Spheres deployed 10/2015. Comparison with CDIP Nowcast HR SWELL model

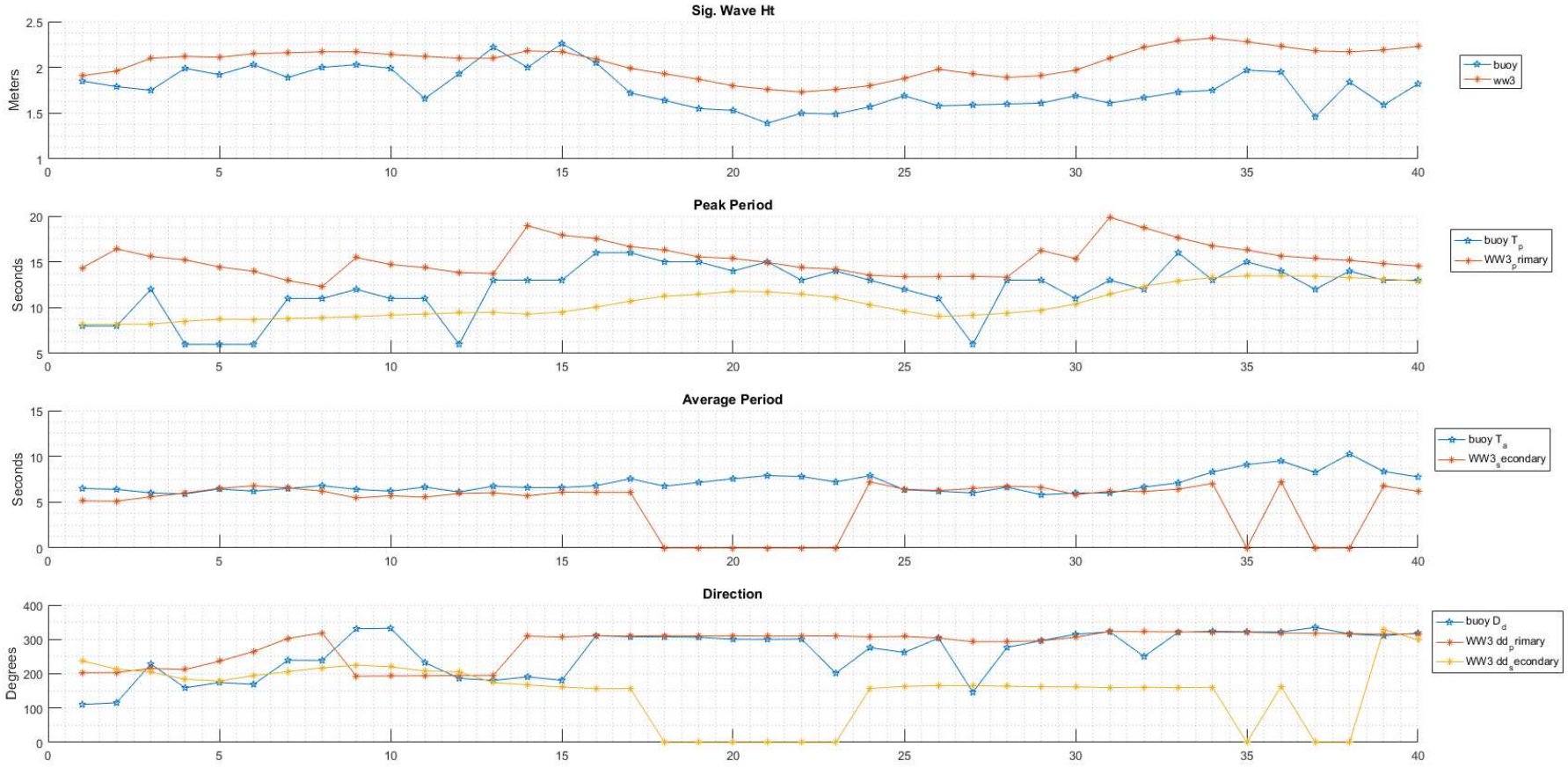






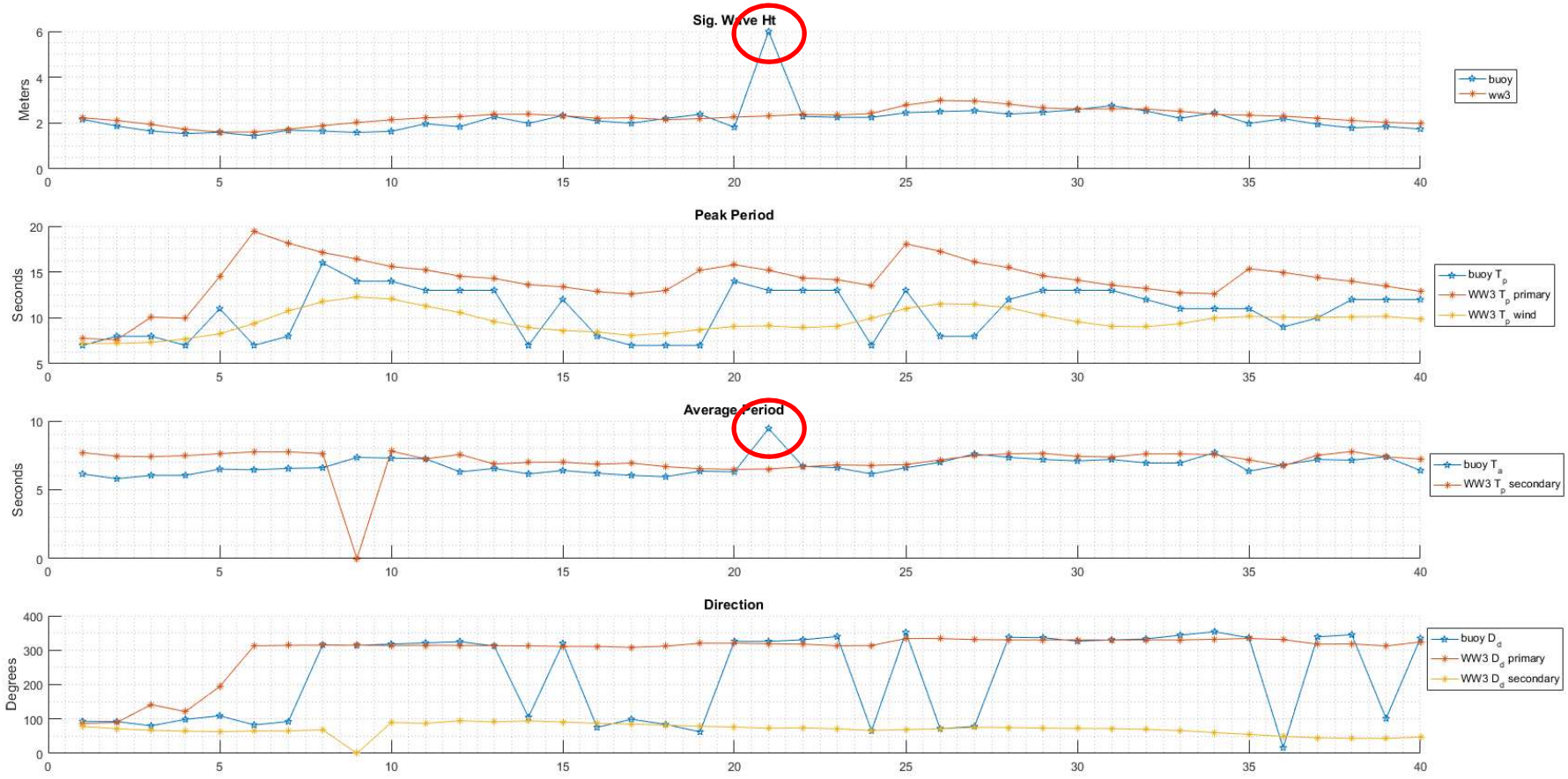
Wave Spheres deployed 9/2016. Comparison with Wave Watch III wave model

Validation – Wave Sphere



Wave Spheres deployed 9/2016. Comparison with Wave Watch III wave model

Validation – Wave Sphere



Gross Errors requiring QC

Roadmap

- Mission Planning
  - Co-location with Directional Wave Rider
  - Deploy Wave Spheres for comparison with Wave Models
- Hardware / Electronics
  - Continue evaluation of MEMS based 9-axis solution
- Data Routing
  - What next?

Wave Measurement Outreach

i. Three sessions on wave measurement, two on in situ measurement and one on remotely sensed measurements, were convened as part of WW-14 (November 8-13, 2015, Key West, USA) to present evaluation results to the end-to-end scientific community (http://www.waveworkshop.org).

ii. Presentations to the ocean climate community at the JCOMM MARCDAT-4, July 18-22, 2016, Southampton, UK),

iii. Presentations to the international wave modeling symposium WISE (22-26 May 2016, Venice, Italy),

iv. Presentations to the Regional Marine Instrumentation Center (RMIC) RA-IV wave workshop (February 29 to March 2, 2016, Gulfport, MS).

v. A chapter on wave measurement is being written for the WMO Guide to Wave Analysis and Forecasting (WMO No. 702).

vi. Provided reviews of wave requirements in the GCOS Implementation Plan, the OOPC Essential Ocean Variables and the Tropical Pacific Observing System 2020 plan

vii. Discussions of wave measurement issues between the PP-WET Co-chairs, JCOMM Co-President (N. Pinardi), JCOMM OPA and SPA Chairs (D. Legler, N. Ashton), Neville Smith, and the Secretariat on the broader issues involving wave measurement noting need to broaden coordination and communication across the 3 JCOMM PAs.

Is this having any effect?!

PP-WET Accomplishments

i. Developed the basis for an international framework for the continuous testing and evaluation of existing and planned wave buoy measurements, including wave measurements from GDP drifters

ii. Established wave measurement evaluation protocol (First-5)

iii. Provided computer code for WavEvalTools online, used by scientific community

iv. Established long-term wave measurement evaluation site (Monterey buoy farm) and analysis system, with online results (CDIP, funded by USACE)

v. Coordinated buoy inter-comparison activities

vi. Disseminated results to scientific community, including end users and data providers, promoting the objectives of the PP.

vii. Provided guidance on best practices, for both data providers and end users (including WMO #702, in progress); ….

viii. Technical Summary of WET results (JTech, in progress)

What next?

Task Team on Wave Measurement (TT-WM) Terms of Reference

The DBCP Task Team on Wave Measurement shall:

1.Continue to coordinate, on an ongoing basis, intercomparisons of wave measurements from different platforms, on an opportunistic basis, in particular from the Monterey buoy farm and FLOSSIE, and the GDP wave drifters

2.Continue to support the development of high quality spectral wave measurements from drifting buoys, including the SVP-Wa buoys;

3.Publish ongoing intercomparison results on the Wave Measurement and Evaluation web site;

4.Monitor technological developments for wave measurements from moored and drifting buoys;

5.Liaise with the different communities making in situ wave measurements, including OceanSITES, the Global Drifter Programme, as well as national moored buoy programmes (coastal and global);

6. Liaise with international programmes including the three Programme Areas of JCOMM (OPA, SPA, DMPA), GCOS/GOOS, OOPC, and other relevant bodies on in situ wave measurement, including user requirements, evaluation, best practices, and emerging technologies;

7.Liaise with the JCOMM Expert Team on Waves and Coastal Hazard Forecasting Systems (ETWCH) regarding the need for in situ wave observations;

Task Team on Wave Measurement (TT-WM) Terms of Reference (2)

The DBCP Task Team on Wave Measurement shall:

8.Review all relevant WMO and IOC Publications on Instrument Best Practices (e.g., JCOMM, CIMO) to make sure they are kept up to date, address WIGOS issues, and comply with Quality Management terminology;

9.Contribute to training material to educate users about appropriate wave measurement procedures and uses of the data, including the need for high quality information for all users;

10.Outreach the wave measurement developments and analyses to DBCP and other scientific fora, including the International Wave Workshop, and organize special workshops on wave measurement as appropriate and necessary.

11.Provide the DBCP Executive Board or the DBCP with technical advice needed for developing in situ wave measurement programmes, including the issues above; and

12.Report to the DBCP Executive Board and the DBCP at its biennial Sessions, with periodically updated Workplans supporting implementation.

Membership: The membership is decided at Panel Sessions and is open to all Panel members.

Potential Workshop on Wave Measurement

- **Objectives:**
  - Follow up to NY 2008 workshop (http://www.jcomm.info/WaveBuoys)
  - review and document user requirements (global, coastal)
  - Review WET Pilot Project results and recommendations
  - Identify and document best practices
  - Enable dialogue among JCOMM PAs, other bodies (GCOS, OOPC), national monitoring agencies, wave experts (ETWCH, etc.)
- **Prospective Participants:**
  - End users (oil industry, wave energy, NWP centres, climate science, NRL)
  - Data providers (NDBC, USACE, CDIP, MetOffice)
  - Manufacturers (Datawell, Axys, Fugro, NDBC)
  - JCOMM PA (Observations, Services, Data Management) and related bodies (OOPC, GCOS, GRA)
  - Wave experts
- **When:**
  - Not before August 2017 for organization requirements
  - 2017 is a very busy year for JCOMM: JCOMM-V October 2017
  - 2017 JCOMM budget largely accounted for already

Potential Workshop on Wave Measurement (2)

- **Where:**
  - accessible, with facilities, reasonable cost, local host, (desirable!)
  - Some logical wave-related (SIO, NCEP), industry-related (IOGP) or JCOMM-related (IOC, WMO) site, or parallel event (DBCP-33, WW15, WISE)

- **Obstacles:**
  - Travel restrictions/policies/priorities
  - Funding support
  - Meeting schedules

- **Potential Sponsors:**
  - JCOMM? – not likely in 2017, maybe not at all
  - Industry – not likely with $50 oil!
  - Manufacturers – not likely
  - Wave energy industry?
  - DBCP?

PP-WET Recommendations

i. Urge the wave measurement agencies to ensure that high-quality wave data is measured for the benefit of a wide range of users, and not to sacrifice quality for quantity;

ii. Encourage member countries, and RMICs with marine responsibilities, to participate in the ongoing intercomparison activities;

iii. Continue the development of wave measurements from drifting buoys, in cooperation with the GDP, to further the evaluation of the technology;

iv. Establish a Task Team on Wave Measurement (TT-WM), to encompass not only the ongoing efforts in wave measurement evaluation and the continuing pilot on wave drifters, but to enable a broader dialogue;

v. Encourage TT-WM members to actively outreach these relevant activities, in relevant scientific and technical fora, and to JCOMM and WIGOS in developing standards and best practices;

vi. Encourage responsible national agencies to address the ongoing deficiencies in wave metadata, and in particular historical metadata.

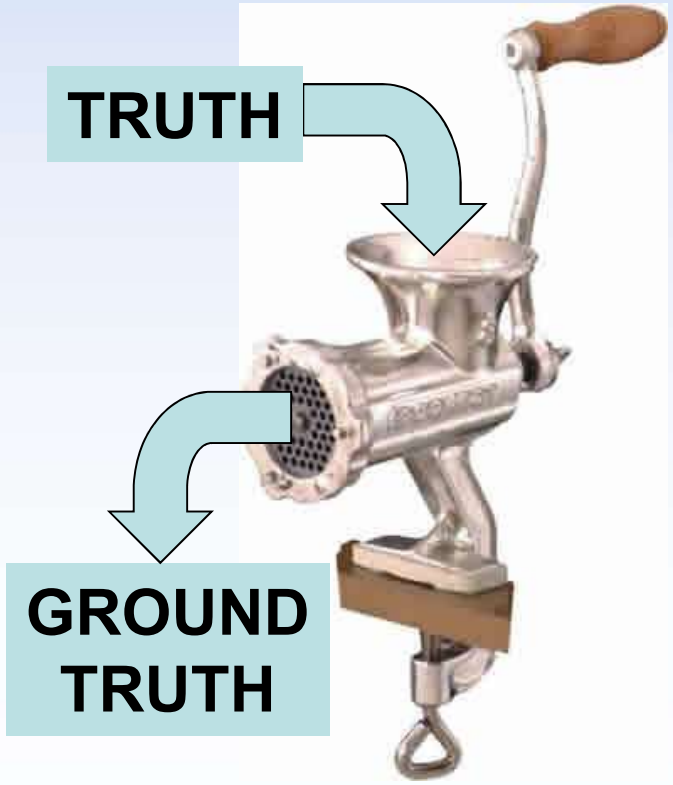
PP-WET Actions

i. Establish a Task Team on Wave Measurement (TT-WM) as a focal point within DBCP for in situ wave measurement discussion, with a Terms of Reference to be developed (***action: DBCP Panel; PP-WET co-chairs, Secretariat; November, 2016***);

ii. Assess interest and feasibility of convening a DBCP workshop on in situ wave measurement issues, including review of user requirements, measurement evaluation, best practices and emerging technologies, and develop a workshop proposal for consideration (***action: Chair, TT-WM; Chair OPA; Secretariat; December 2016***)


SOME QUIT DUE TO
SLOW PROGRESS.
NEVER GRASPING
THE FACT THAT...
...SLOW PROGRESS
IS PROGRESS


SURVIVING
PROGRESS



Thank you!