Assessment of the systematic differences in wave observations from moorings.

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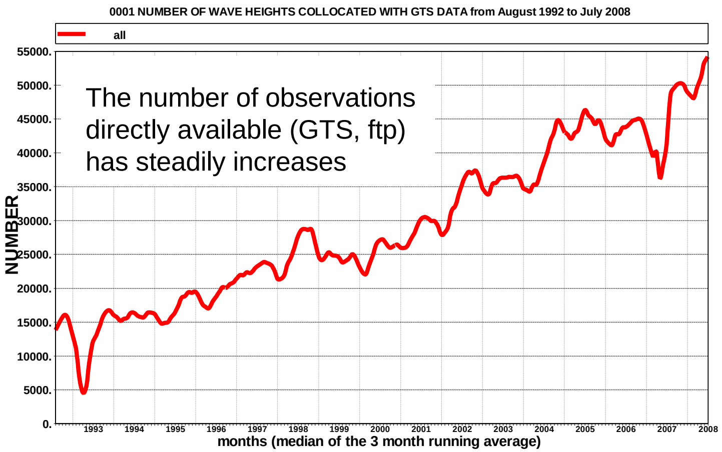
Outline:

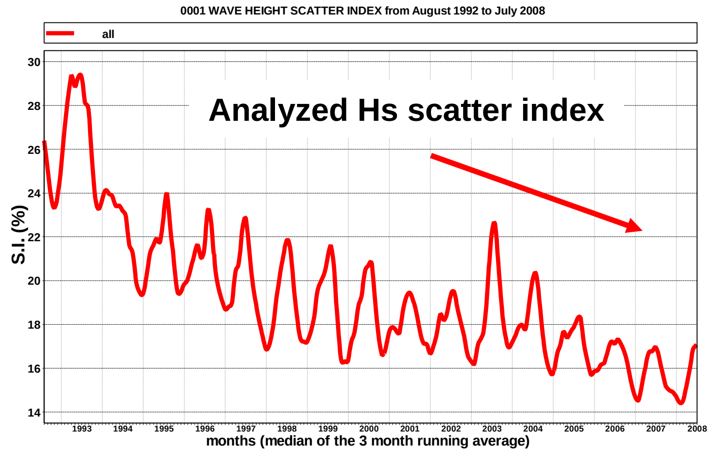
- Introduction
- Motivations
- Discrepancies with respect to altimeter data.
- Similar results from other studies
- Conclusions

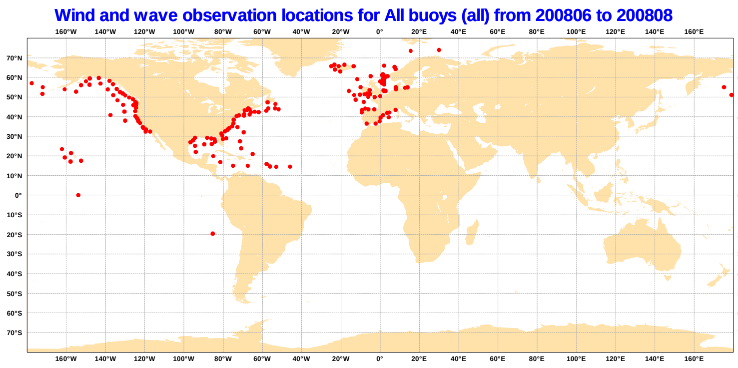
Introduction: wave in-situ data for in-house verification

In situ wave observations have been used to assess the quality of the ECMWF wave model analyses and forecasts since 1992.

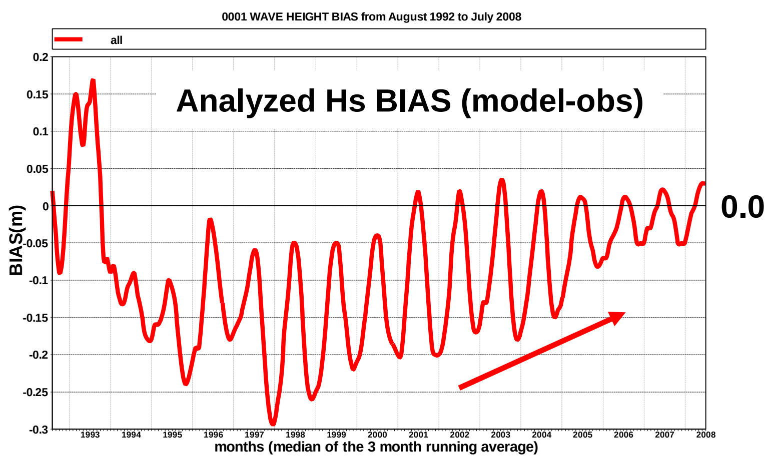
e.g.







Locations of moored buoys, platforms and ships from which wind and wave observations are used in this verification.



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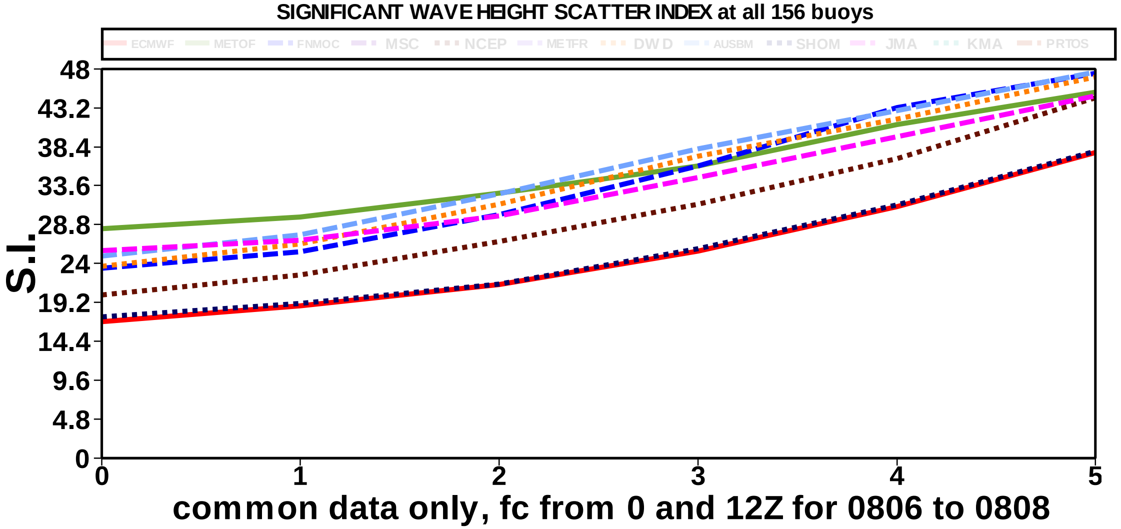
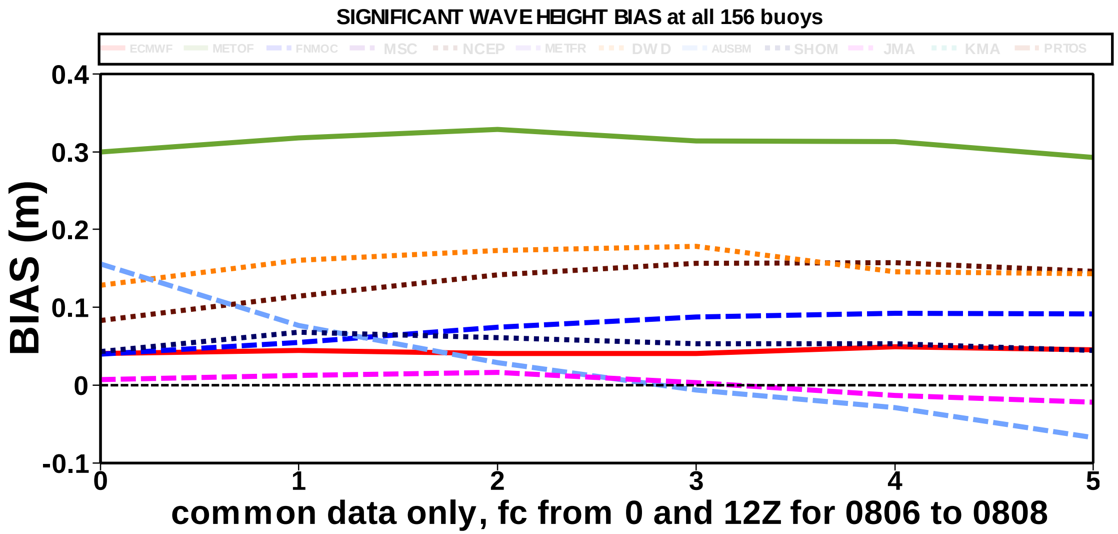
Introduction: in-situ wave data for verification JCOMM model inter-comparison



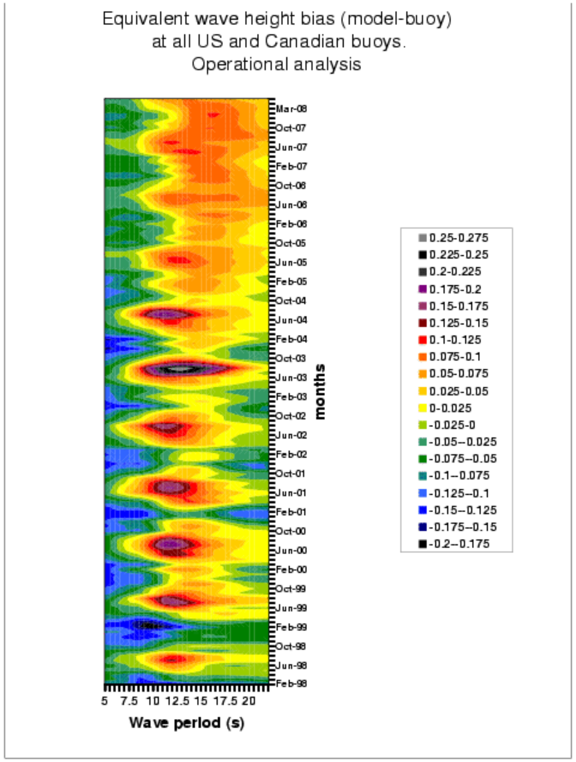
Every month, 12 operational forecasting centers exchange model data at a selected set of locations where wind and waves observations are available. This is a core activity of the JCOMM Expert Team on Waves and Storm surges (ETWS).



Introduction: in-situ wave data for verification

Standard wave observations (Hs, Tp, Tz) are useful, even more insights can be gained if Spectral observations are used:

From simple equivalent wave height biases using 1d spectra (below) to more advance spectral partitioning and swell tracking (right):



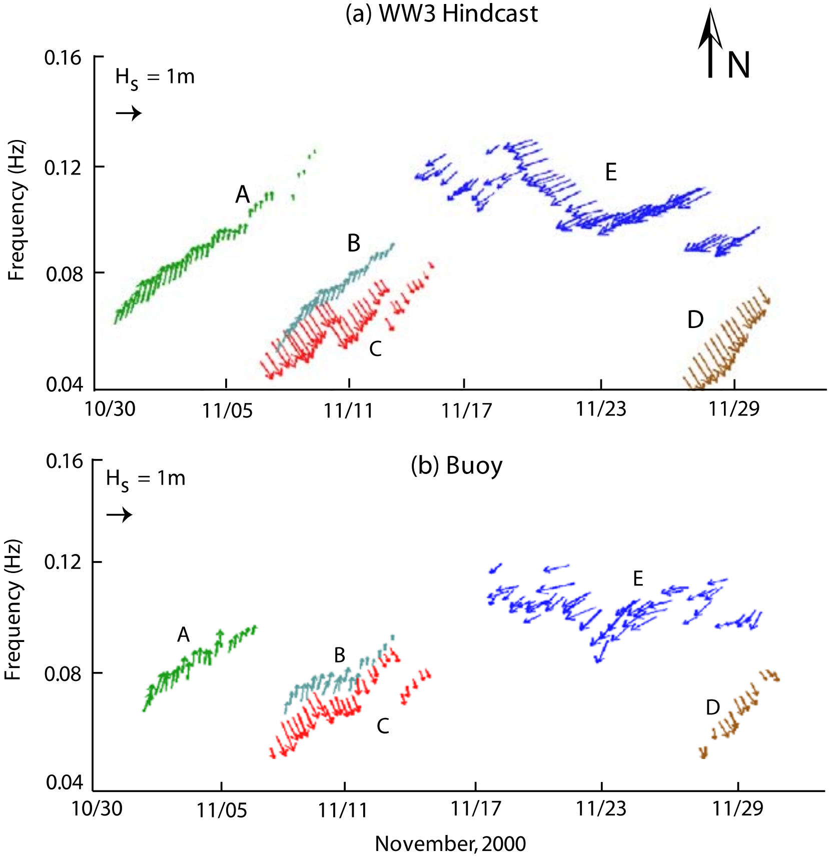
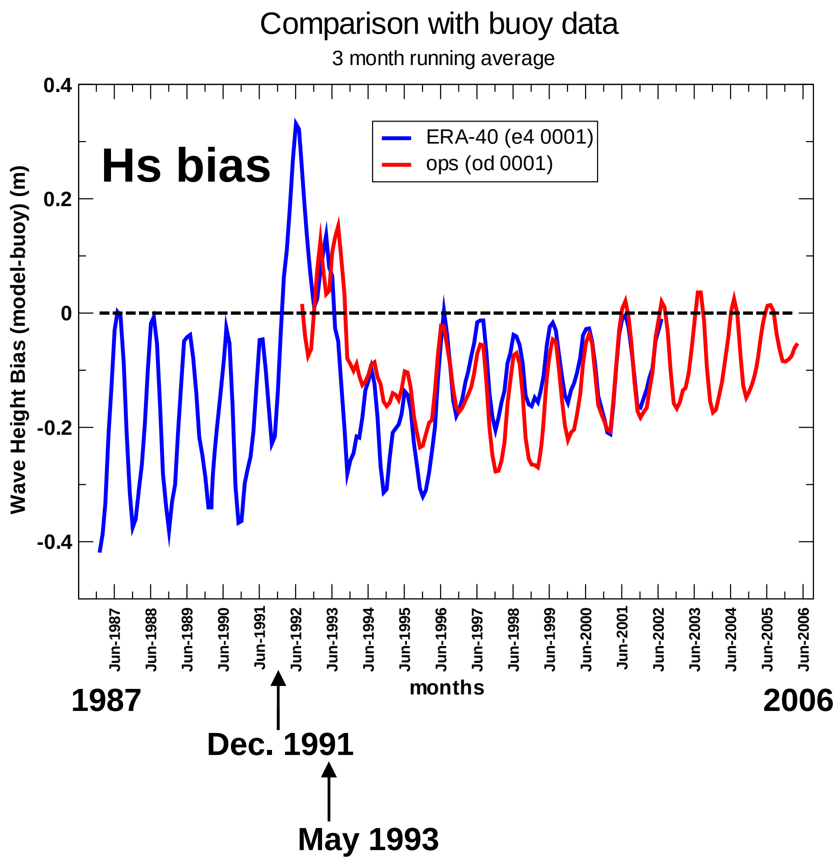
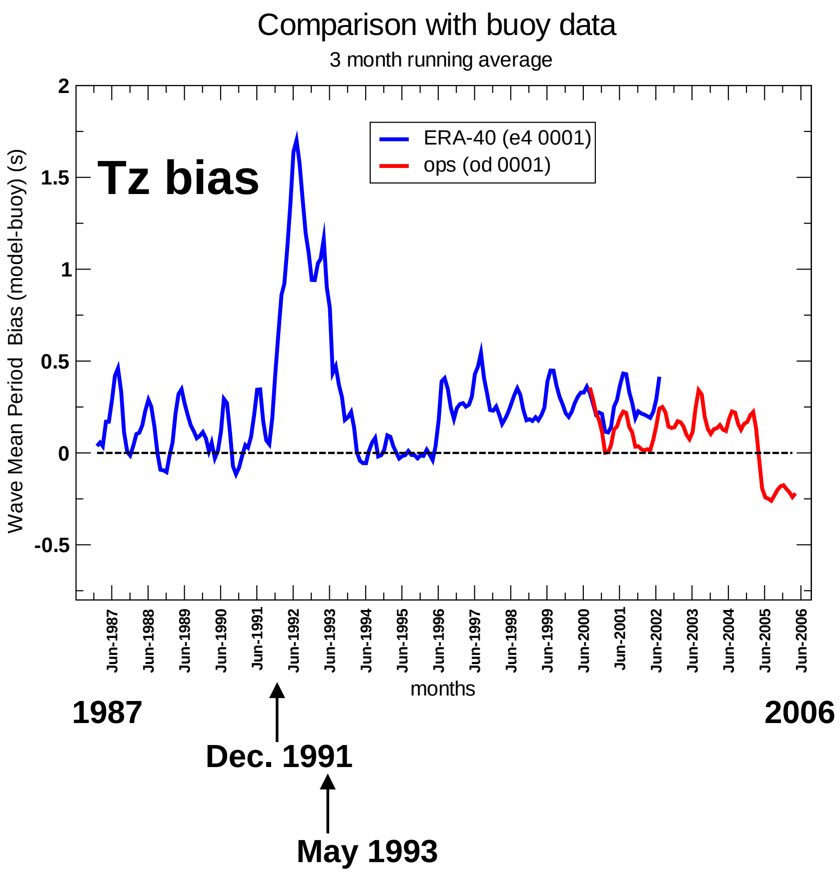


Fig. 9. Vector history of most energetic wave system events during November 2000 at Station 51028: (a) WAVEWATCH III hindcast, (b) NDBC Station 51058 observations.

From Hanson et al. 2008: Pacific Hindcast Performance of Three Numerical Wave Model. Submitted to JOAT.

Motivations: problem with wave data in ERA-40 (ECMWF 45 year reanalysis) due to bad use of altimeter data





Between Dec. 1991 and May 1993 low quality ERS-1 altimeter data were wrongly assimilated.

Between Dec. 1991 and May 1993 low quality ERS-1 altimeter data were wrongly assimilated.

Note: this problem was originally spotted by KNMI. This emphasises the need for 'in-house' monitoring tools.

Motivations: ECMWF interim reanalysis

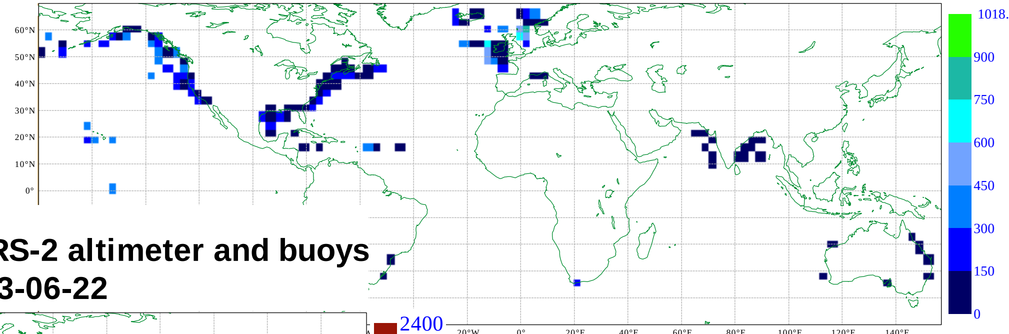
Since the end of ERA-40, much has been learnt on how
to best use different kind of observations. Moreover, the different
aspects of the models underpinning this effort have improved.
In preparation to an extensive reanalysis to be carried out in a few
years, it was decided to 'redo' the period from 1989 to present with
a much improved system than ERA-40 (including the wave model).

This effort is ongoing (it is currently in 2006).

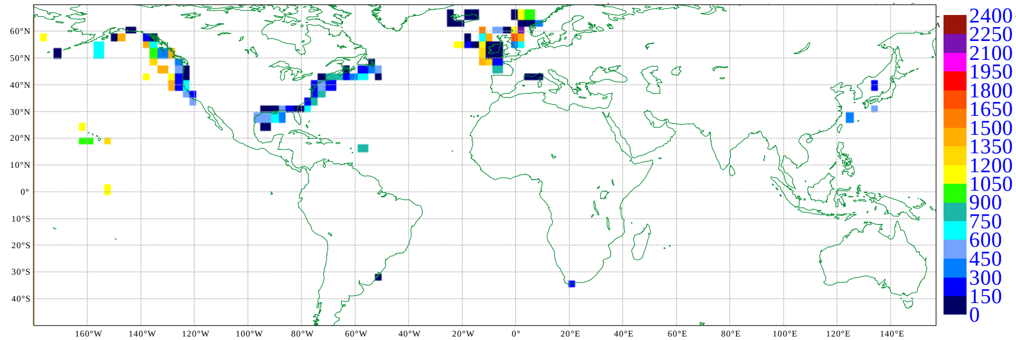
Wave data for reanalyses:

There is a need to properly calibrate altimeter data. This can be done using all available in-situ data.
For wave heights, the coverage is still limited but those satellite missions lasted long enough to yield enough collocations:

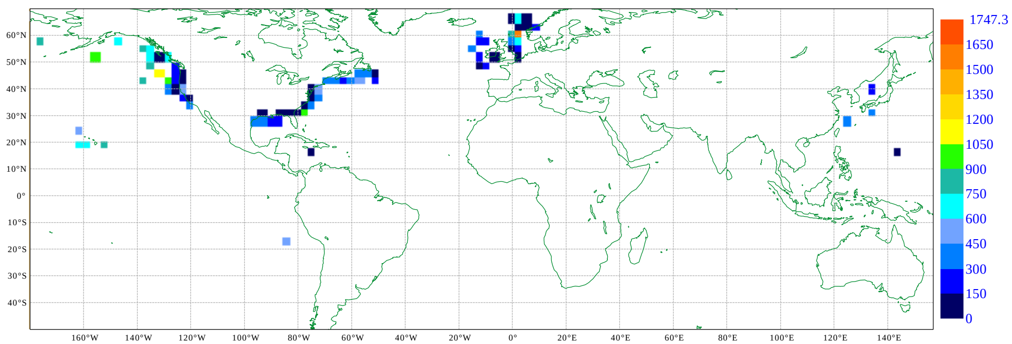
Number of collocations between ENVISAT altimeter and buoys 2003-07-21 to 2006-05-13

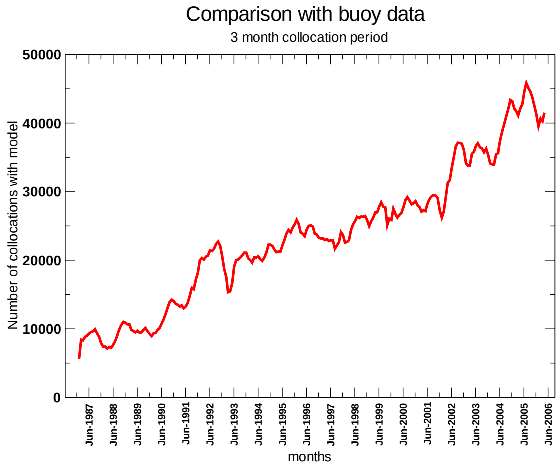


Number of collocations between ERS-2 altimeter and buoys 1996-06-03 to 2003-06-22



Number of collocations between ERS-1 altimeter and buoys 1991-08-01 to 1996-06-03





1987 **2006**

The number of wave buoys available on the GTS has steadily increased over the years.

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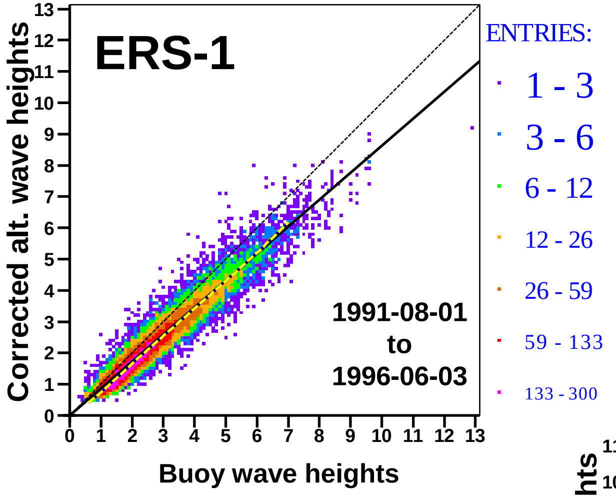
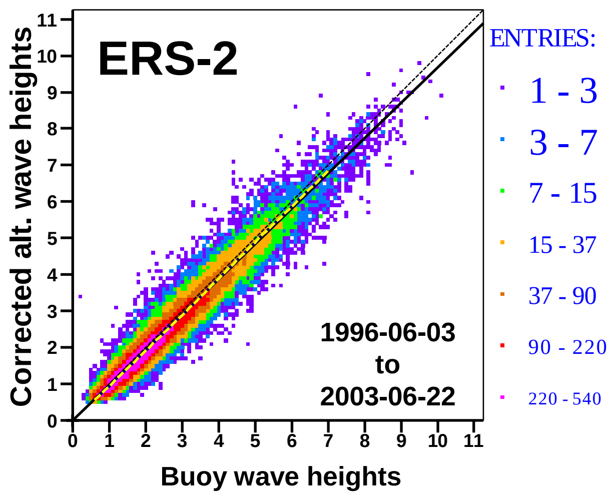
Using all in-situ wave data for the interim reanalysis :

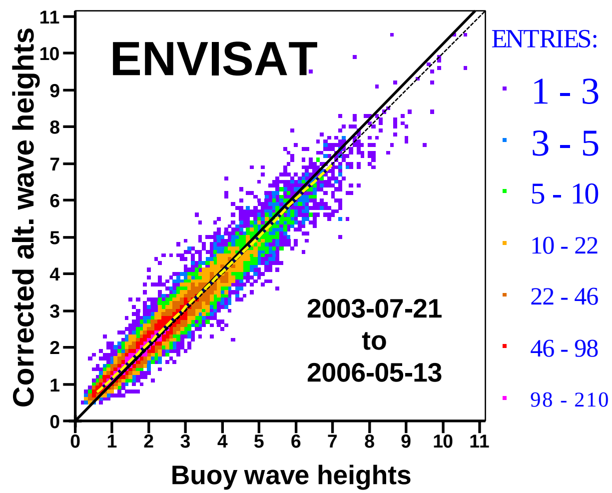


ERS-1 OPR wave heights are biased low when compared to buoys

ERS-2 OPR wave heights are slightly biased low when compared to buoys



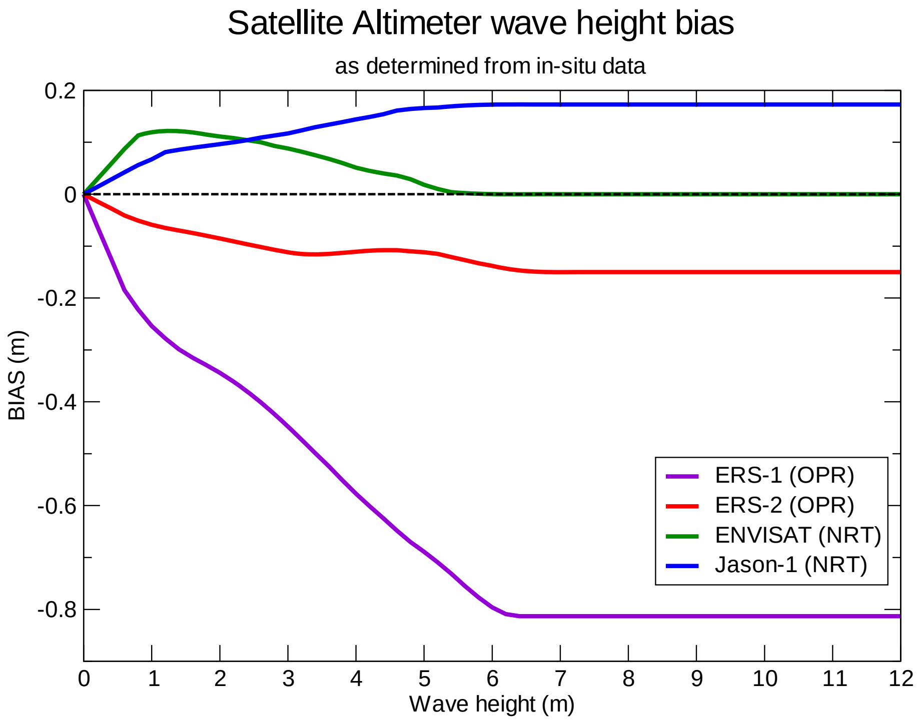
ENVISAT wave heights are slightly biased high when compared to buoys



Note: Jason-1 is similar to results for ENVISAT

Wave data for the interim reanalysis :

Using a non-parametric bias estimation technique,
we have determined the relative bias with respect to all selected buoys



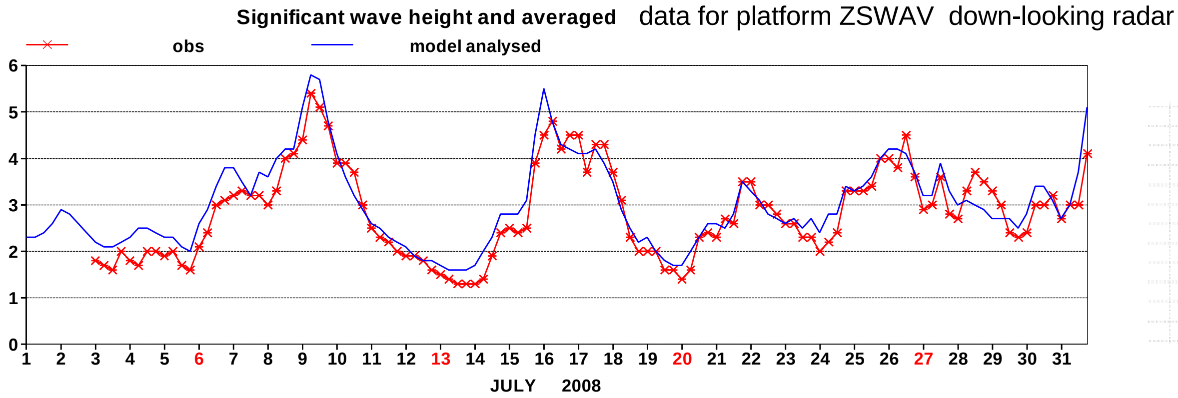
Note: these estimate for the different biases have been used in the current interim reanalysis, but not in the operational analysis !

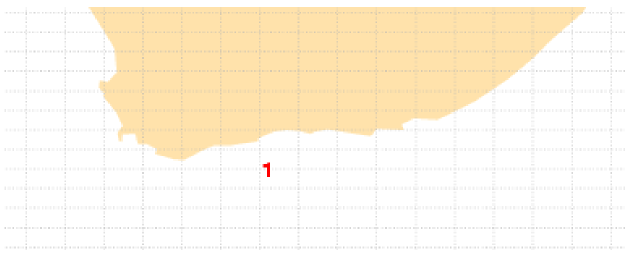
Quality of in-situ data:

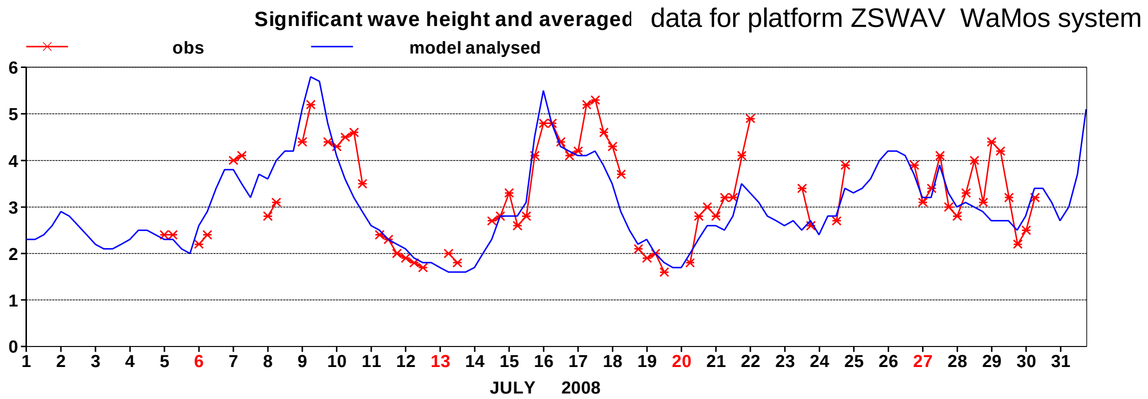
All these activities (validations, calibrations, comparisons,…) rely on well calibrated, consistent in-situ observations.

But, …

Discrepancies in wave observations: an obvious case







The equipment has been supplemented with a WaMos system. Discrepancies between the two systems are apparent

Data courtesy of Ian Hunter from the South African Weather Services

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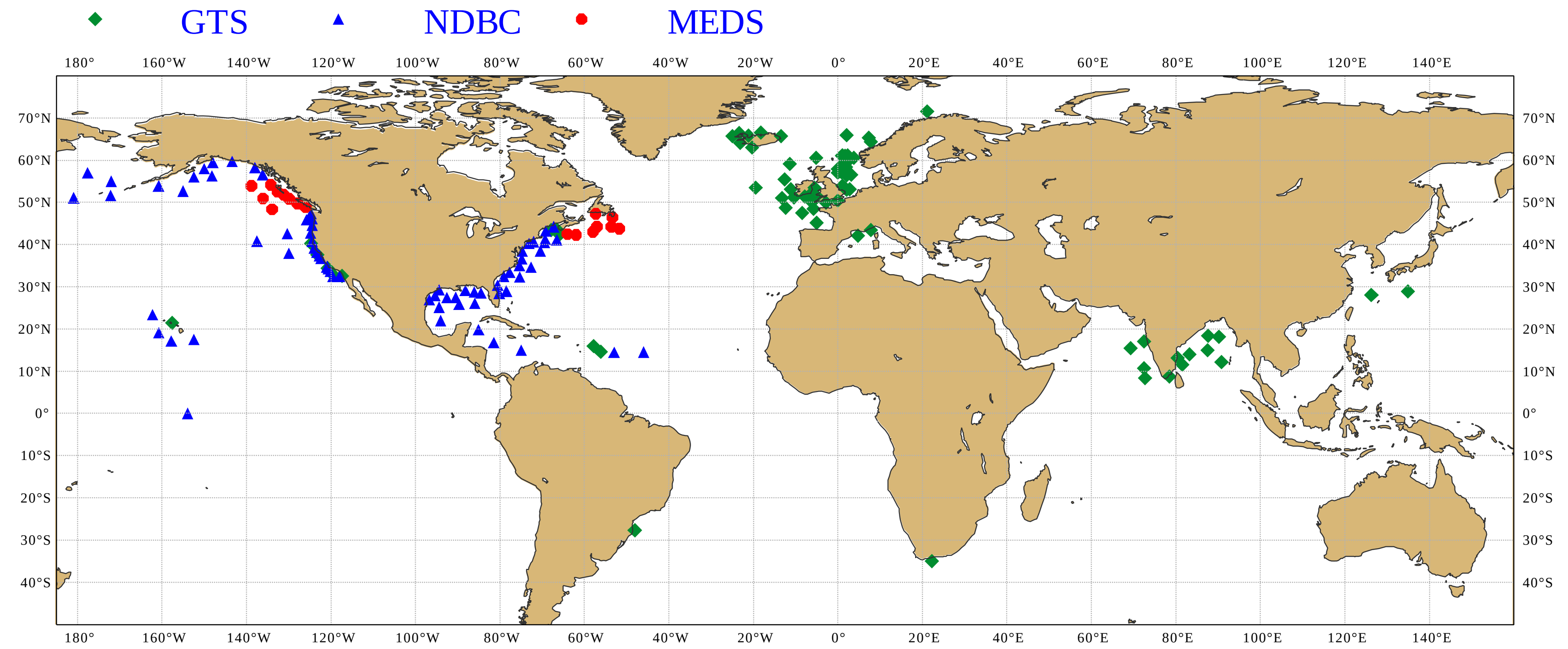
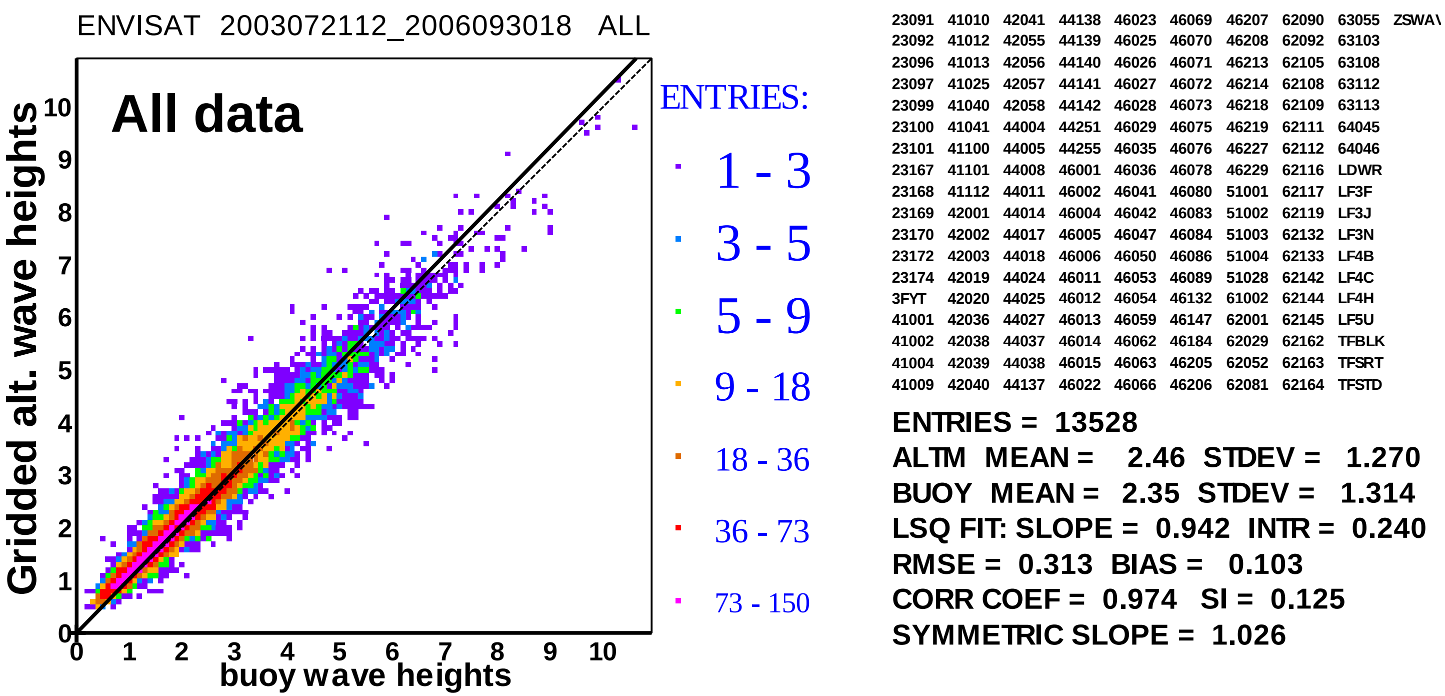
Discrepancies in wave observations: data used for the altimeter calibration



Data are from different sources:
NDBC (from NODC archive (ftp)), MEDS archive online.
GTS: data that were distributed by the Global Telecommunication System and archived at ECMWF. These are mainly from European buoys (UK, France, Ireland, Iceland), Japanese buoys, Indian buoys, Other American centres (Scripps, GoMoos,…), UK and Norwegian platforms and one South African platform (NDBC and MEDS are also on the GTS but slightly better data were obtained from the web).

Discrepancies in wave observations:

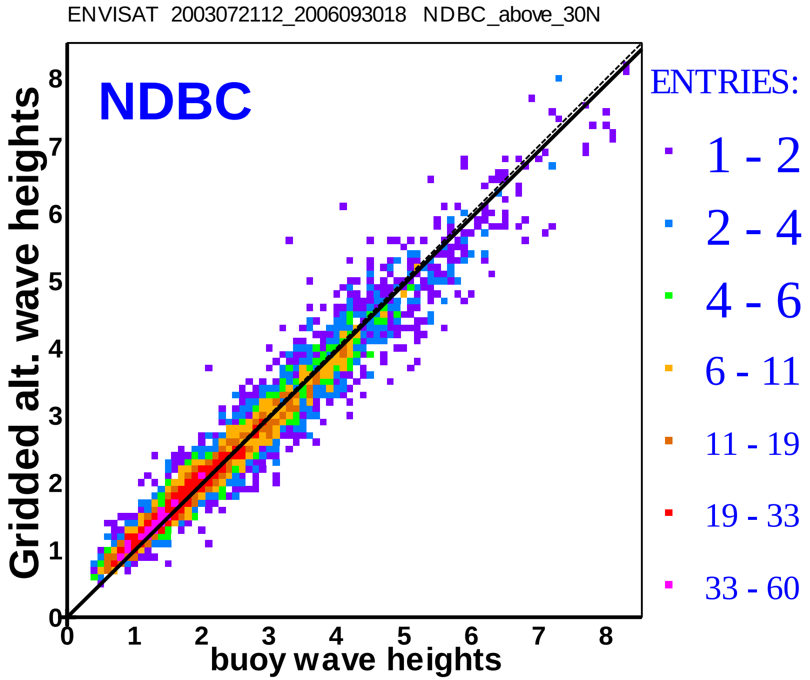
Collocation with ENVISAT



Comparison of gridded altimeter with buoy wave heights for
100. km, 5 % max RCE and 45. degrees max in mean wave dir

Triple collocations are used, in which a model hindcast is also used to determine whether or not altimeter and buoy should be collocated.
RCE: Relative Collocation Error (abs(alt-buoy)/mean(alt,buoy)).
Model mean wave directions at both altimeter location and buoy should not be larger than 45°.

Discrepancies in wave observations:



41001	46011	46054
41002	46012	46059
41004	46013	46062
41013	46014	46063
41025	46015	46066
44004	46022	46069
44005	46023	46070
44008	46025	46071
44011	46026	46072
44014	46027	46073
44017	46028	46075
44018	46029	46076
44025	46035	46078
44027	46041	46080
46001	46042	46083
46002	46047	46084
46005	46050	46086
46006	46053	46089

ENTRIES = 4011
ALTM MEAN = 2.42 STDEV = 1.210
BUOY MEAN = 2.40 STDEV = 1.298
LSQ FIT: SLOPE = 0.910 INTR = 0.227
RMSE = 0.283 BIAS = 0.012
CORR COEF = 0.977 SI = 0.118
SYMMETRIC SLOPE = 0.989

Comparison of gridded altimeter with buoy wave heights for
100. km, 5 % max RCE and 45. degrees max in mean wave dir

Note: NDBC for locations north of 30N

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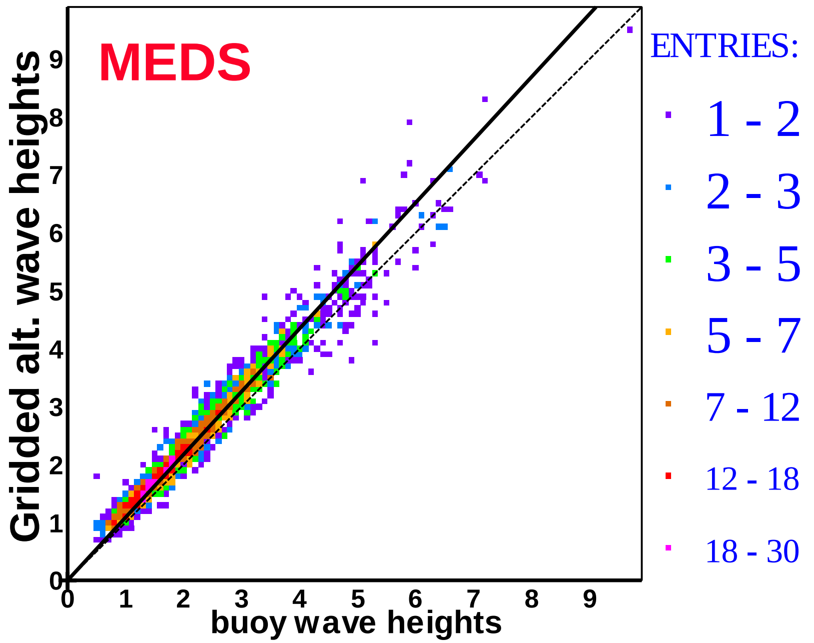
Discrepancies in wave observations:

ENVISAT 2003072112_2006093018 MEDS



44137
44138
44139
44140
44141
44142
44251
44255
46004
46036
46132
46147
46184
46205
46206
46207
46208

ENTRIES = 1707
ALTM MEAN = 2.63 STDEV = 1.219
BUOY MEAN = 2.39 STDEV = 1.191
LSQ FIT: SLOPE = 1.003 INTR = 0.236
RMSE = 0.343 BIAS = 0.243
CORR COEF = 0.980 SI = 0.101
SYMMETRIC SLOPE = 1.087

Comparison of gridded altimeter with buoy wave heights for
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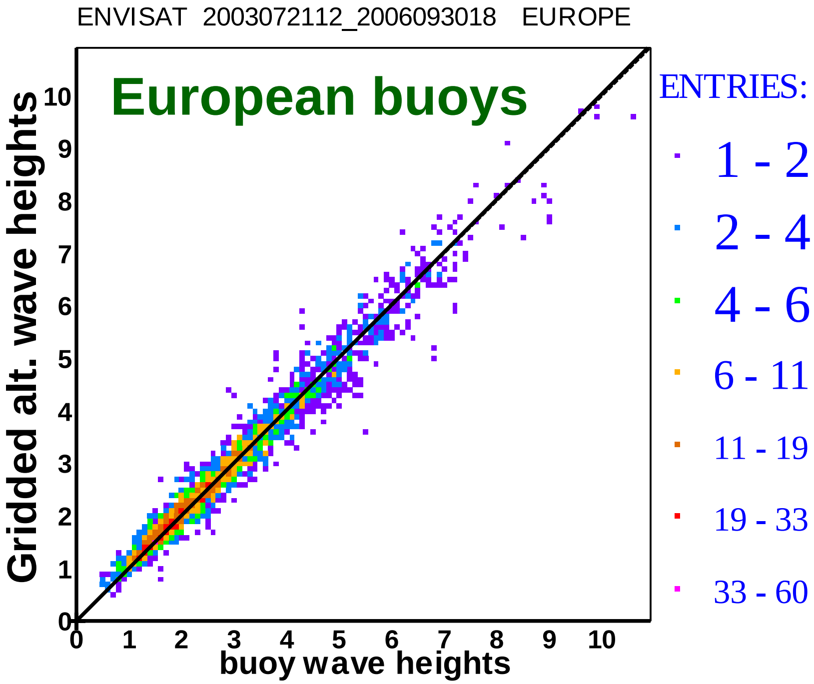
Discrepancies in wave observations:

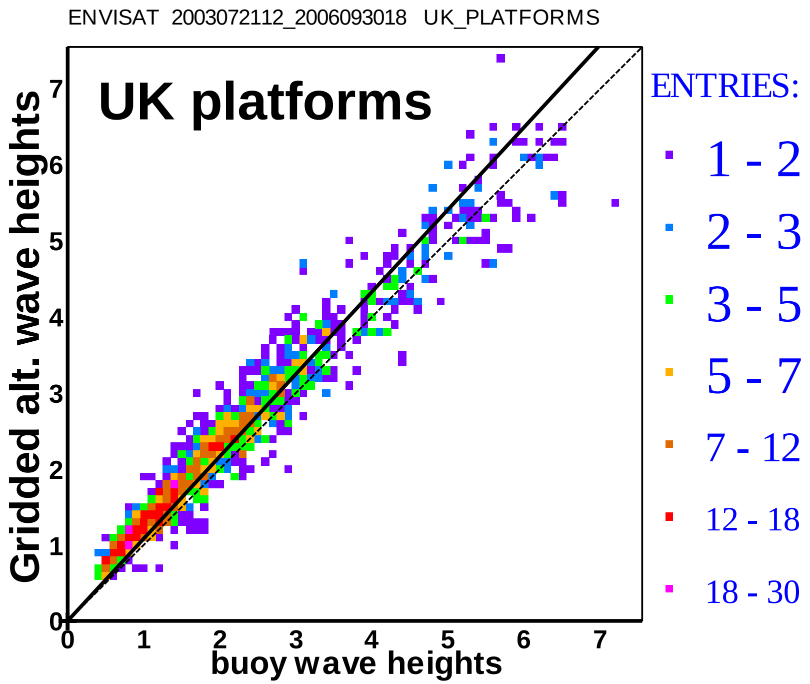


41100
41101
61002
62001
62029
62052
62081
62090
62092
62105
62108
62163
64045
64046

ENTRIES = 2437
ALTM MEAN = 2.93 STDEV = 1.478
BUOY MEAN = 2.89 STDEV = 1.515
LSQ FIT: SLOPE = 0.959 INTR = 0.157
RMSE = 0.280 BIAS = 0.038
CORR COEF = 0.983 SI = 0.096
SYMMETRIC SLOPE = 1.005

Comparison of gridded altimeter with buoy wave heights for
100. km, 5 % max RCE and 45. degrees max in mean wave dir

Discrepancies in wave observations:

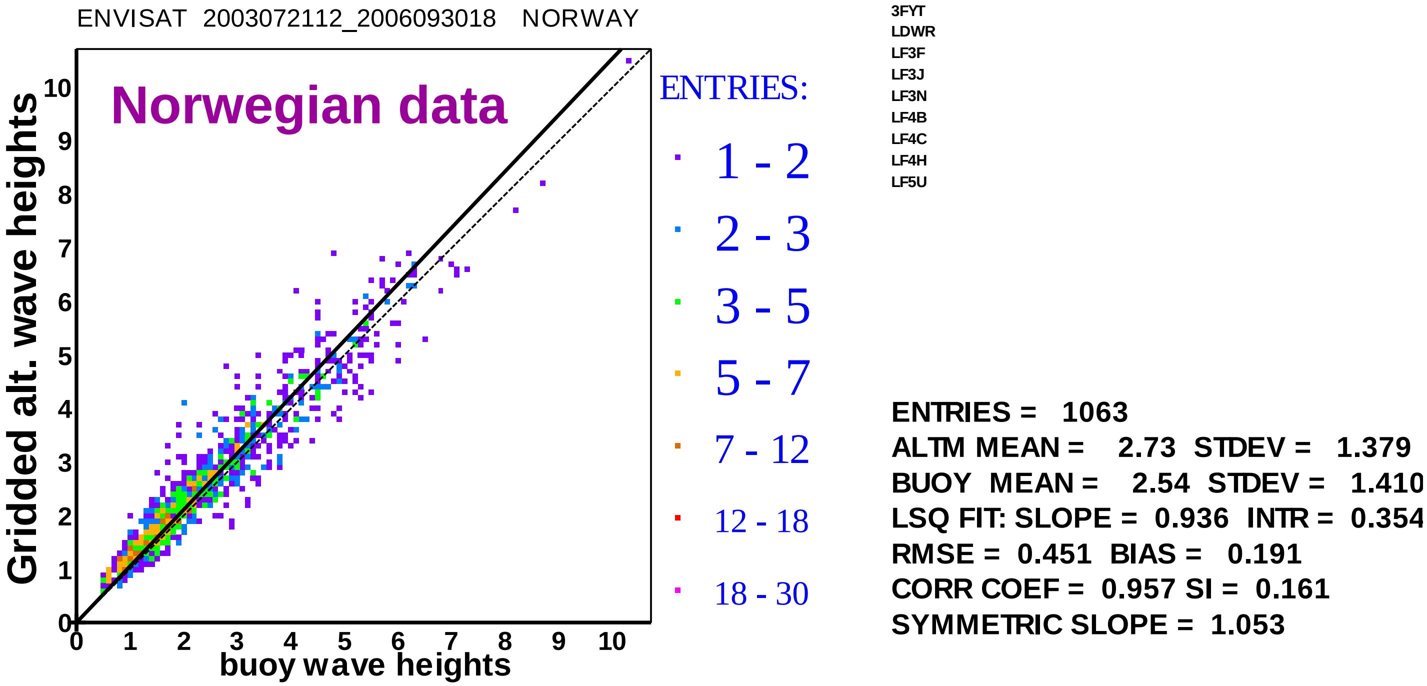


62109
62111
62112
62116
62117
62119
62132
62133
62142
62144
62145
62162
62164
63055
63103
63108
63112
63113

ENTRIES = 1502
ALTM MEAN = 2.41 STDEV = 1.259
BUOY MEAN = 2.16 STDEV = 1.292
LSQ FIT: SLOPE = 0.949 INTR = 0.367
RMSE = 0.390 BIAS = 0.257
CORR COEF = 0.974 SI = 0.136
SYMMETRIC SLOPE = 1.083

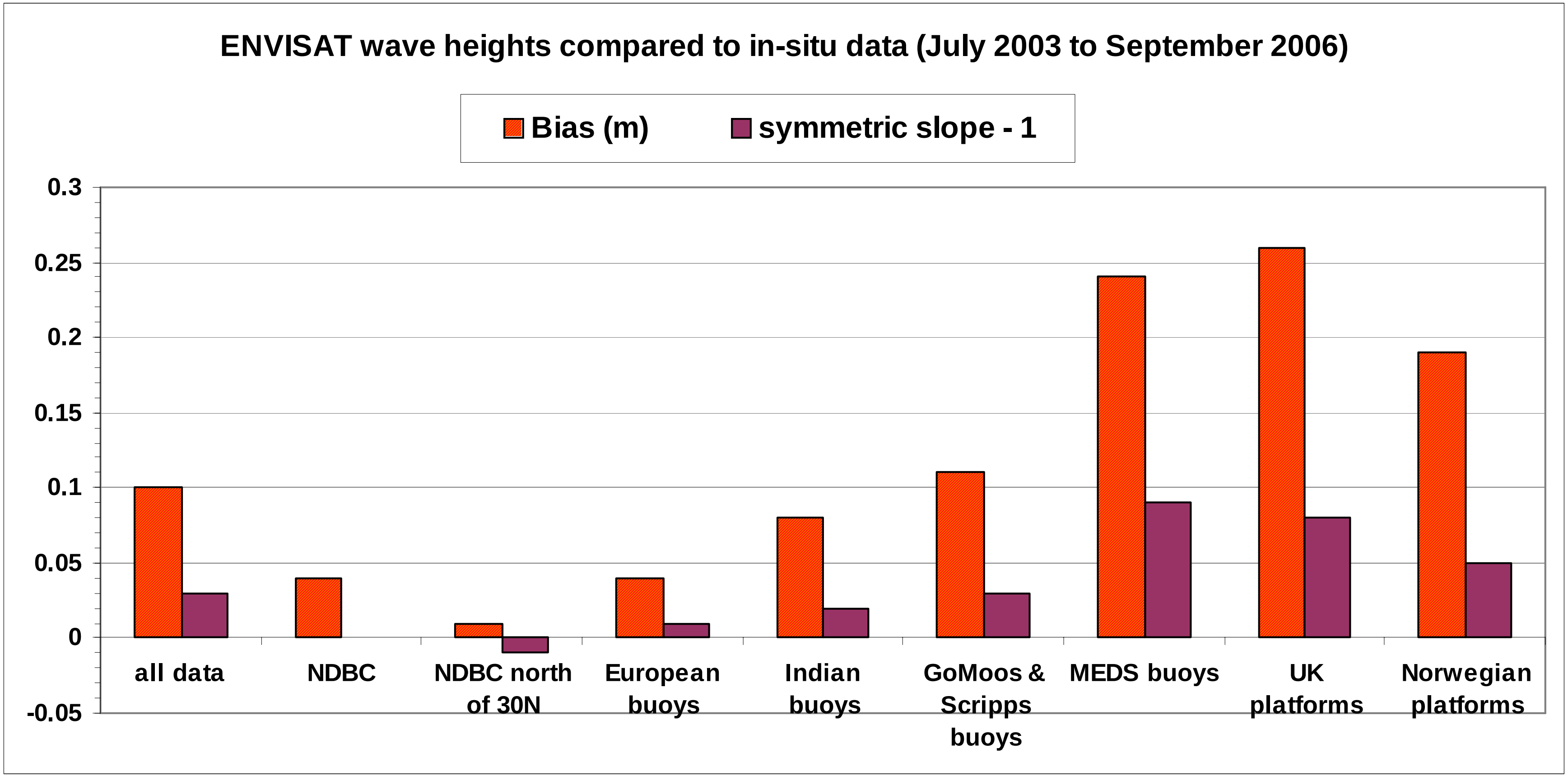
Comparison of gridded altimeter with buoy wave heights for
100. km, 5 % max RCE and 45. degrees max in mean wave dir

Discrepancies in wave observations:



Comparison of gridded altimeter with buoy wave heights for
100. km, 5 % max RCE and 45. degrees max in mean wave dir

Discrepancies in wave observations:



Bias: altimeter Hs – in-situ Hs

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

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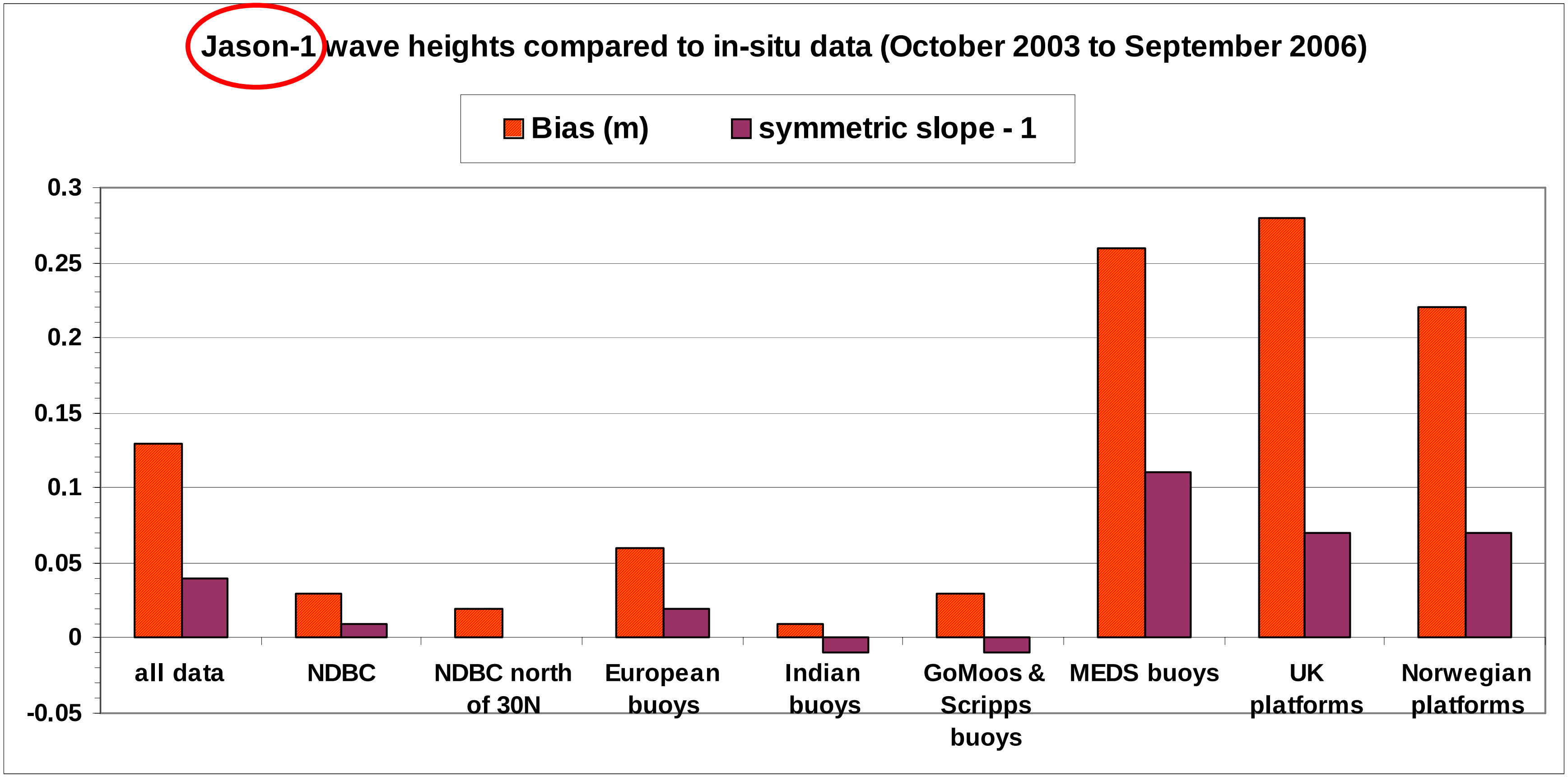
Discrepancies in wave observations:



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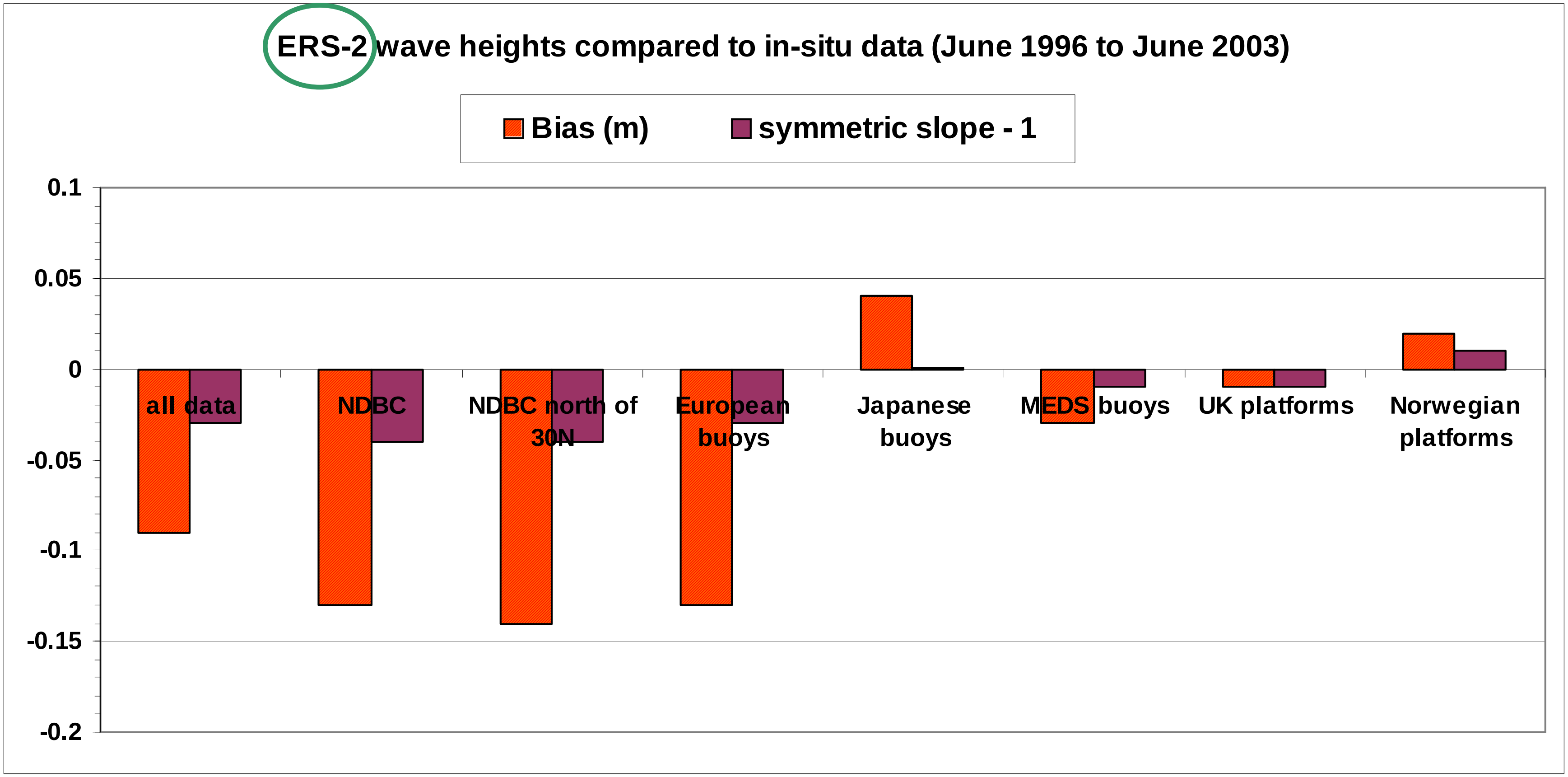
Discrepancies in wave observations:



Bias: altimeter Hs – in-situ Hs

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

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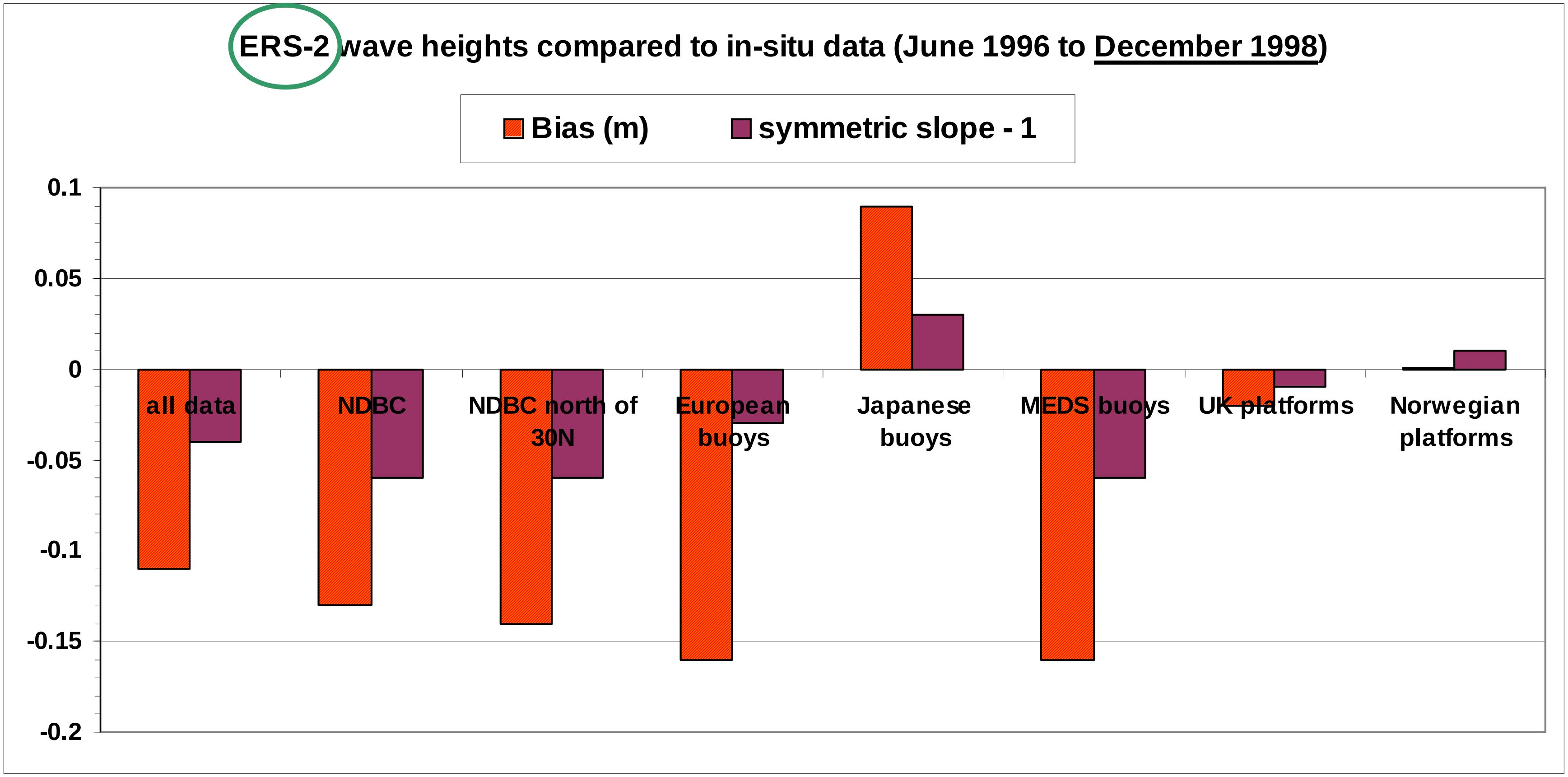
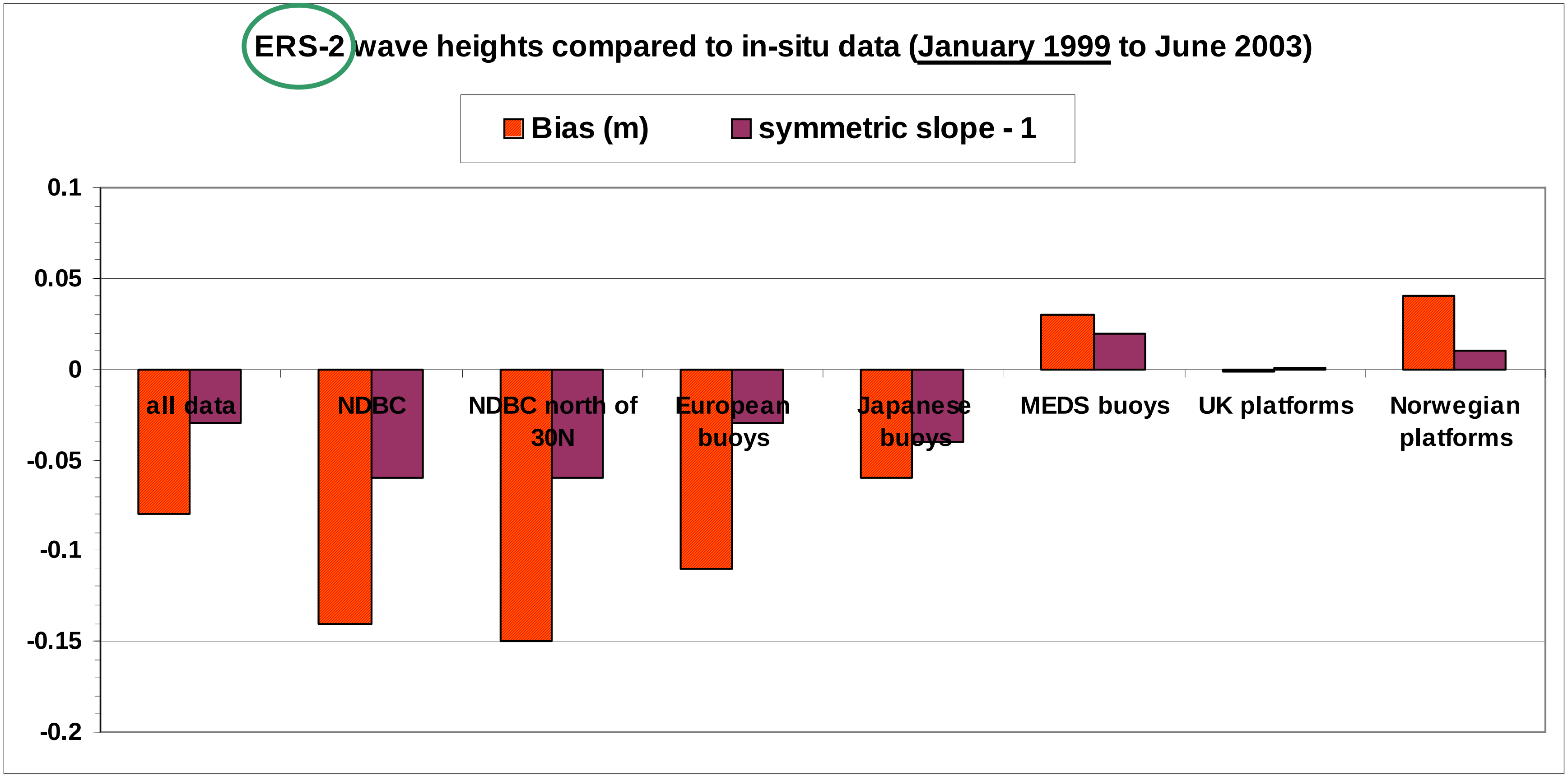
Discrepancies in wave observations:



Bias: altimeter Hs – in-situ Hs

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

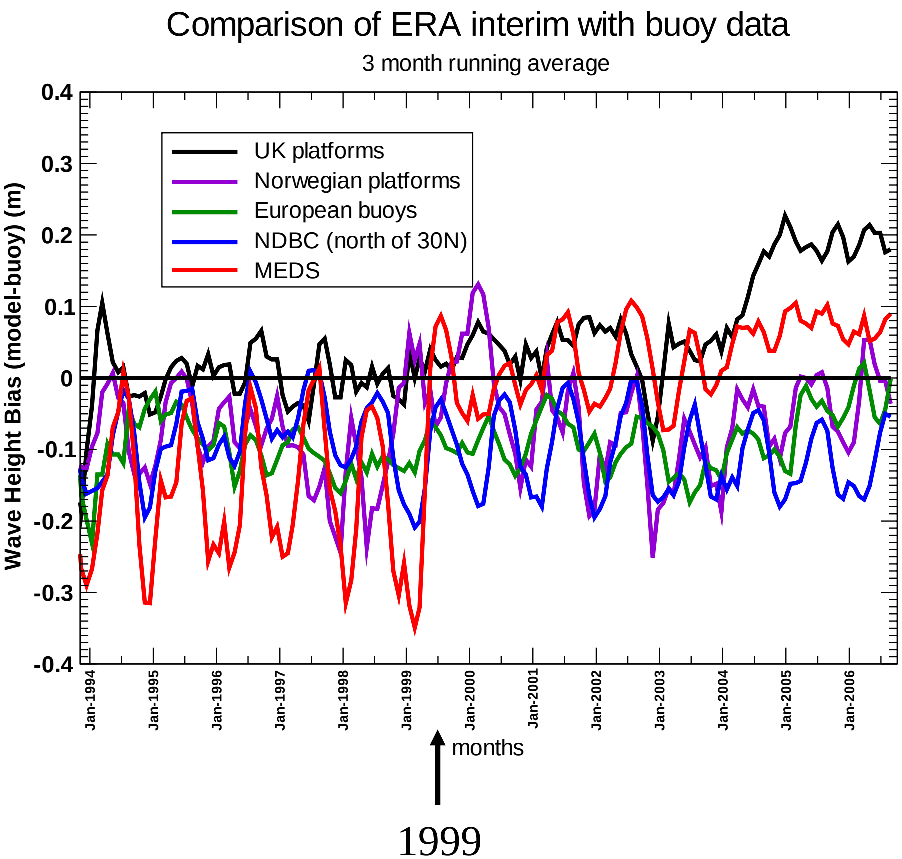
Discrepancies in wave observations:

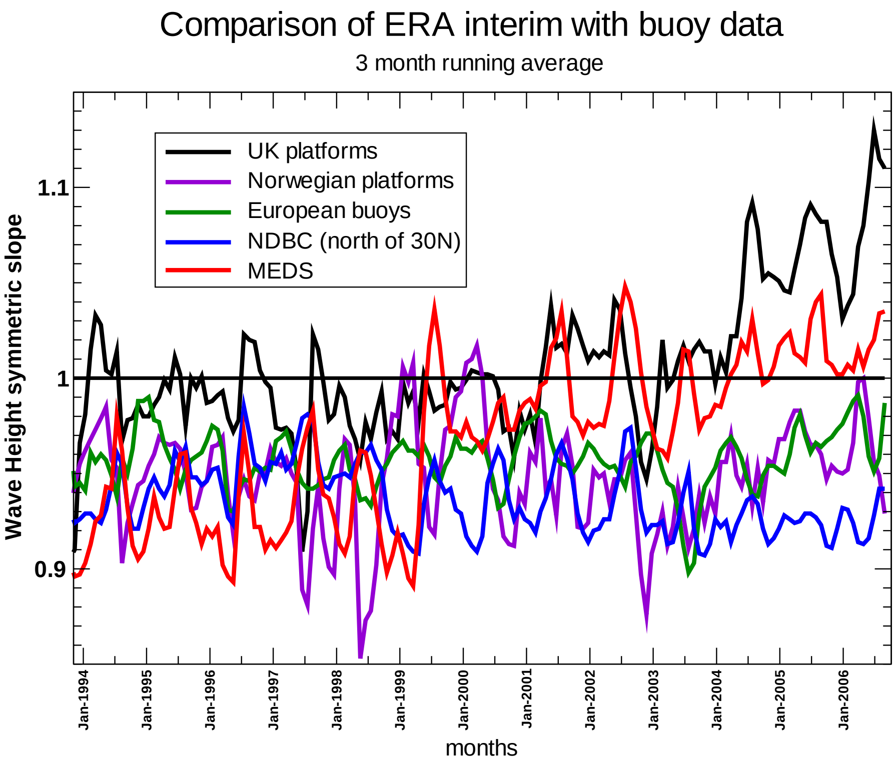


Bias: altimeter Hs – in-situ Hs

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

Discrepancies in wave observations: against consistent re-analysis (ERA interim)





What happened ?

Which one is closer to the 'truth'?

Discrepancies in wave observations: others

Durrant et al., 2008 using ENVISAT and Jason-1

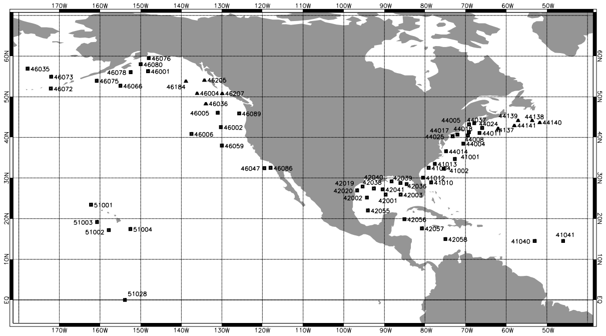
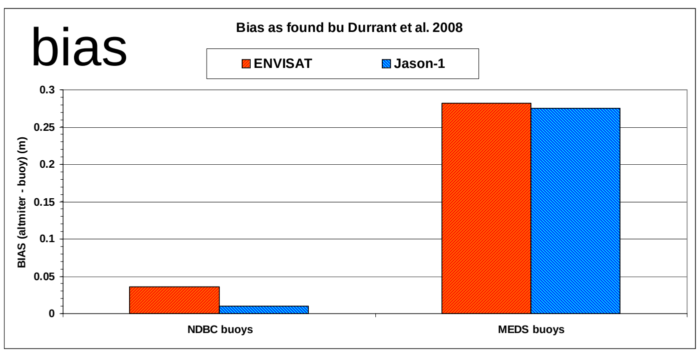


FIG. 2. Buoys used in this study. Buoys from the NDBC are marked with squares and those from the MEDS network are marked with triangles



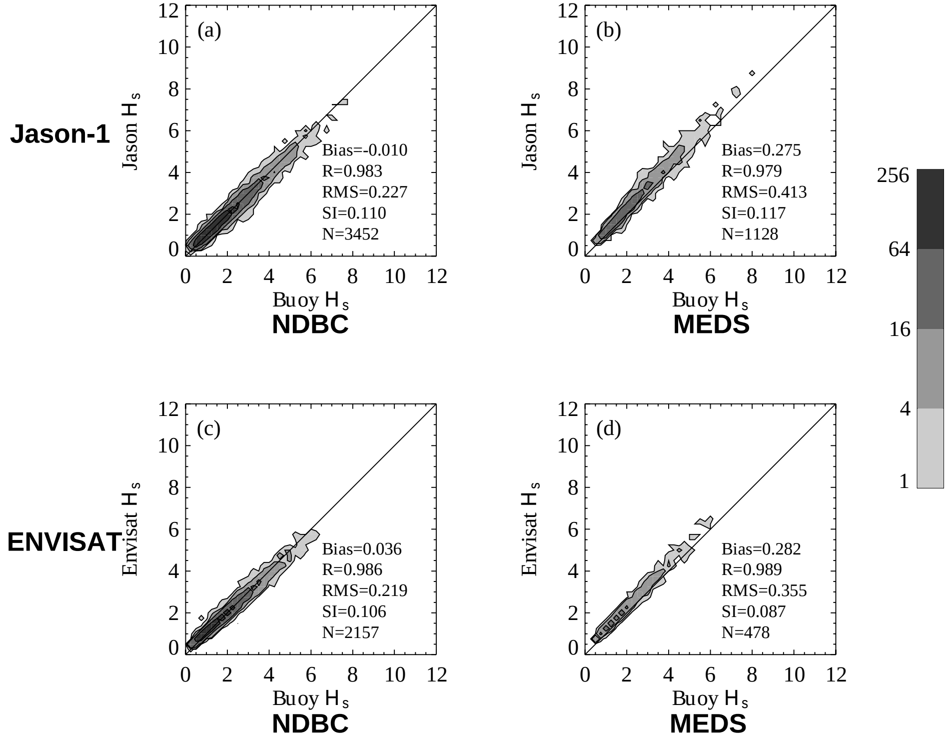


FIG. 3. Scatterplots of co-located H_s observations for Jason-1 and Envisat for both the NDBC and MEDS buoy networks separately. Panels on the top (a and b) show Jason-1 data while those on the bottom (c and d) show Envisat data. Panels on the left (a and c) show co-locations with NDBC buoys only, those on the right (b and d) show co-locations with MEDS buoys only. The number of co-locations in each 0.5 m bin have have been contoured

From
Durrant et al., 2008:
Validation of Jason-1 and Envisat Remotely-Sensed Wave Heights.Accepted for publication in JAOT.

ENVISAT data from April 2003 to April 2006.
Jason-1 data from January 2002 to March 2006.

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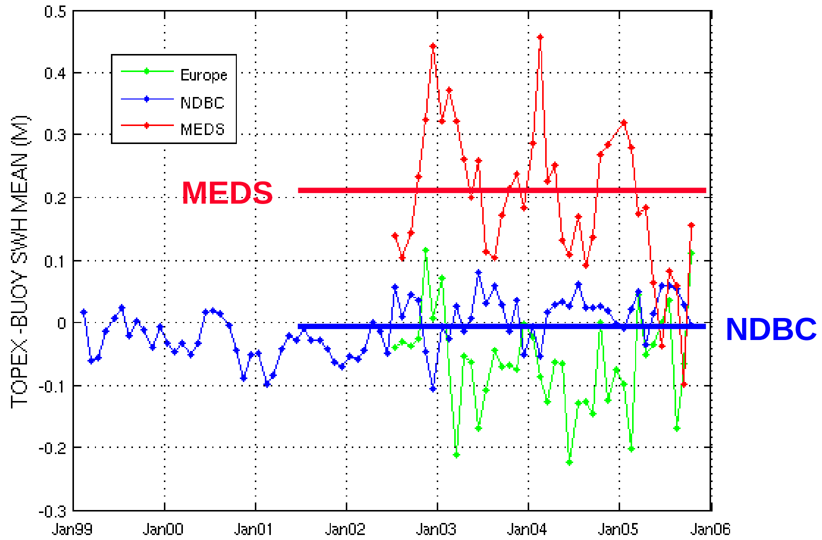
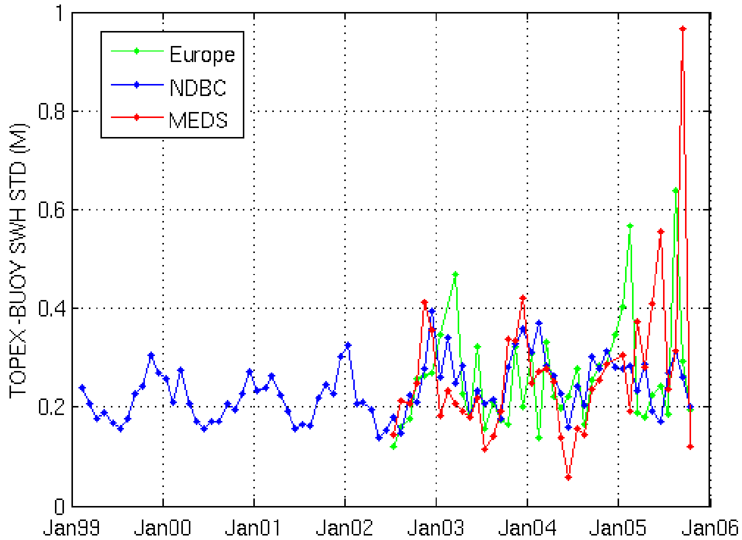
Discrepancies in wave observations: others

Queffeulou P., 2006 using TOPEX, ENVISAT and Jason-1

TOPEX





Similar results reported for other satellites.

From:
Queffeulou P., 2006: Altimeter wave height validation - an update, OSTST meeting, Venice, Italy, March 16-18, 2006.
(http://www.jason.oceanobs.com/html/swt/posters2006_uk.html)

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Discrepancies in wave observations: others

Cotton et al., 2004
using ENVISAT and ERS-2 (FD)

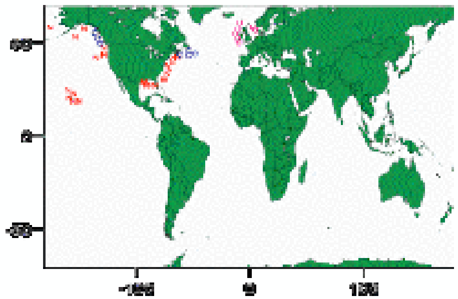


Fig. 1. Map of location of the buoys used for calibration. 'N' marks the locations of NDBC buoys, 'C' identifies the CMEDS buoys, and 'U' the UKMO buoys.

Using multiple regressions, they found systematic differences between the different buoy networks.

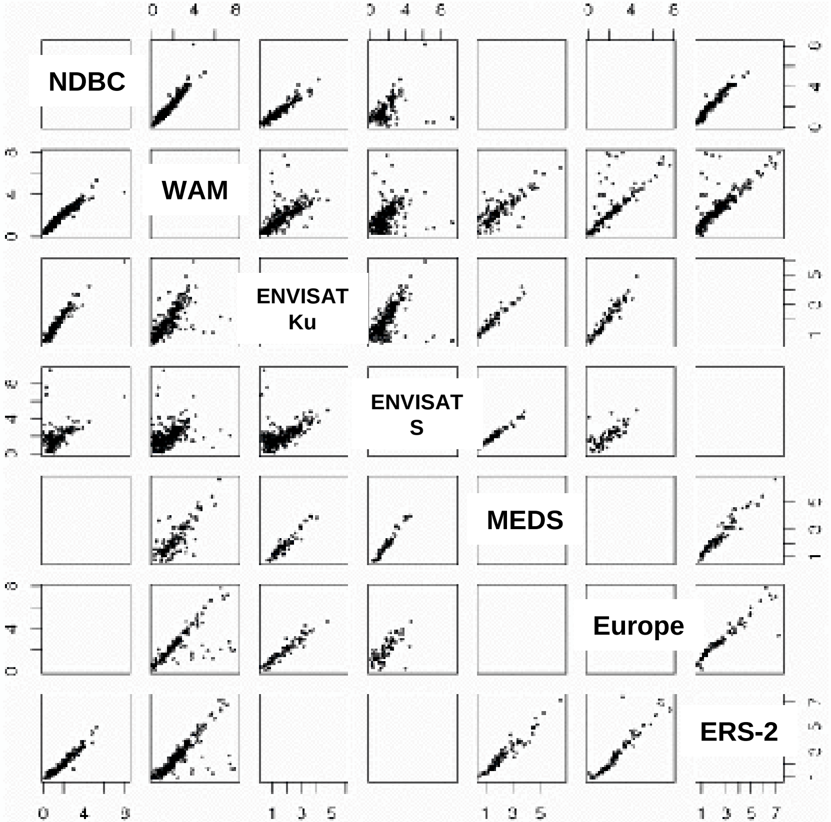


Figure 6. The ENVISAT RA-2, and ERS-2 rgdr Hs, buoy data and model output plotted in pairs of variables. "MF.swh" refers to ECMWF wave height WAM output retrieved by Météo France.

Table 3 – Tabulated Multiple Regression Results for for ENVISAT RA-2, and ERS-2 rgdr Hs, buoy data and model output Errors, (standard deviations) are given in brackets.

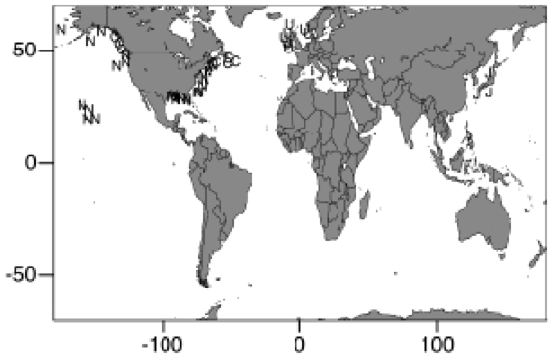
Data Set	α - intercept (sd)	β - slope (sd)	σ - sd (sdsd)
NDBC	0.0	1.0	0.111 (0.003)
UKMO	0.278 (0.007)	0.795 (0.002)	0.399 (0.005)
CMEDS	0.191 (0.041)	0.773 (0.015)	0.152 (0.029)
ECMWF WAM	0.365 (0.030)	0.799 (0.011)	0.696 (0.021)
ENVISAT Ku	0.382 (0.009)	0.779 (0.003)	0.205 (0.006)
ENVISAT S	0.826 (0.041)	0.637 (0.015)	0.942 (0.029)
ERS-2 FD	0.333 (0.017)	0.769 (0.006)	0.234 (0.012)

From:
Cotton, P. D., P. G. Challenor and J.M. Lefèvre, 2004, Calibration of ENVISAT and ERS-2 wind and wave data through comparison with in-situ data and wave model analysis fields.
ENVISAT ERS Symposium, ESA SP572, Salzburg, Austria

Discrepancies in wave observations: others

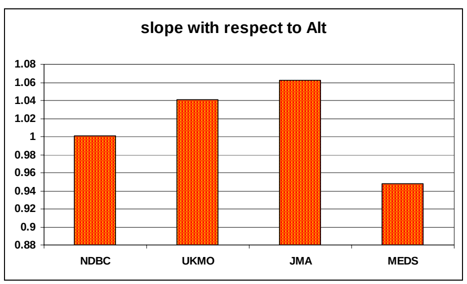
Challenor et al., 2001 using Geosat, TOPEX and ERS-1&2 (FD)

Figure 1 — The positions of the NDBC (N), UK Met Office (U), Japan Meteorological Agency (J) and the Meteorological Service of Canada (C) buoys.



Using the combined, <u>calibrated</u> (against NDBC) altimeter data set,

collocate with other networks:



From: P. G. Challenor and P. D. Cotton, 2001, The joint calibration of altimeter and in situ wave heights in "Advances in the Applications of Marine Climatology - The Dynamic Part of the WMO Guide to the Applications of Marine Climatology WMO/TD-No. 1081, WMO Geneva.

Figure 9 — NDBC buoys plotted against the combined, calibrated altimeter data set.

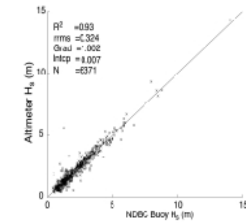


Figure 10 — MSC Buoy H_s plotted against the combined, calibrated altimeter data set.

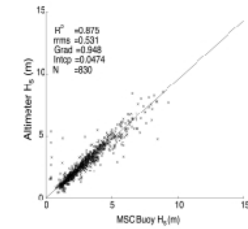


Figure 11 — JMA Buoy H_s plotted against the combined, calibrated altimeter data set.

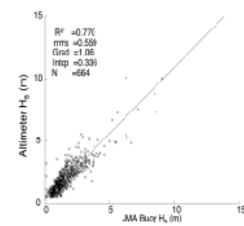


*Table 2—Principal component regression parameters from comparisons of co-located altimeter and buoy significant wave height data. *Co-located data within nearest hour, rather than 30 minutes.*

Data Source	No	Slope	Std. err.	Int. (m)	Std. err.	rms (m)
NDBC	6371	1.002	0.007	-0.007	0.016	0.325
UKMO	1228	1.041	0.021	-0.124	0.072	0.604
JMA*	664	1.062	0.041	0.337	0.080	0.559
MSC	830	0.948	0.024	0.047	0.079	0.531

Conclusions:

- **In-situ data are very useful for validation purposes and calibrations studies.**
- **There is therefore a need for a standardization of observing practice to insure that the limited resources available is used.**
- **What can we do in the mean time?**