Satellite Observing Systems

Southampton Oceanography Centre

Calibration and Validation of JASON Wind Wave Data Based on in situ Data.

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Calibration / validation of JASON & TOPEX IGDR wind /wave data against buoys.

Procedures used which allow for errors in satellite and in-situ data.

Over 400 triple co-locations of JASON, TOPEX, and buoy data.

Orthogonal Distance Regressions between JASON – Buoy, TOPEX-Buoy, and JASON-TOPEX to derive calibration correction functions

Analysis of triple co-locations (JASON, TOPEX and buoy) to derive estimates of error in each data source.

Data, and Data Processing

Altimeter Data

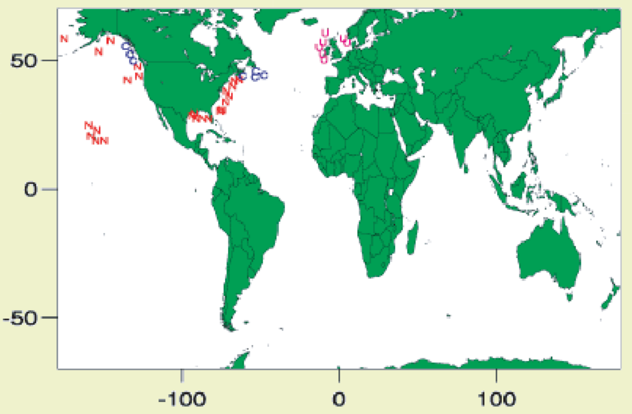
JASON IGDR data, cycles 2-23 (7-10 reprocessed)
TOPEX IGDR, cycles 345-360, 362-366.
1 Hz Data (Hs, σ0 +0.63 dB)

Parameter	JASON IGDR Check	TOPEX IGDR Check
IGDR flags	Qual_1hz_alt_data, Qual_1hz_alt_instr_corr (not c8) Rad_surf_type, Ice_flag	geo_bad_1: 1 altbad_2:4,6
σ0 range	0-20	0-20
H range	-130.0m < H < 100.0m	
H s range	0-25	0-25
U10 range		0-20
sdHs range		
sdH range	<0.2m	
sdAGC range		0.000001 < sdAGC<0.1
Attitude		
Dry trop corr.	-25.0m < mdtc < -19.0m	
Wet trop corr.	-5.0m < rwtc < -0.001m	
iono corr.	-4.0m < ic < 0.4m	
ssb corr.	-5.0m < ssb < 0.0m	
Ocean Tide	-50.0m < ot < 50.0m	
Solid Earth Tide	-10.0m < set < 10.0m	
Pole Tide	-1.5m < pt 1.5m	

Table 1 TOPEX and JASON IGDR Quality Checks

Buoy Data

34 N. Hemisphere Buoys:
- 20 US NDBC buoys
- 9 UK Met Office Offshore Buoys
- 5 Environment Canada Buoys



Buoy U10, Ta, Tp, Hs, Tair, Tsea, Wdir, ...) retrieved from standard met. records within 30 minutes of satellite overpass.

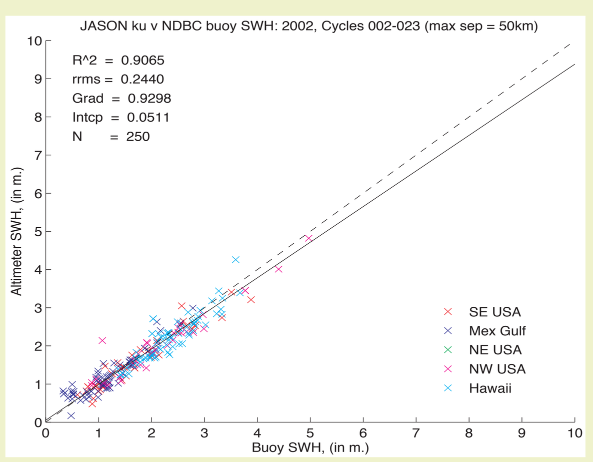
Satellite data taken from valid 1 Hz record closest to buoy (< 50 km)
186 triple co-locations found in 100 days data

Calibration Procedure

"Orthogonal Distance Regressions (ODR)" -
Errors to be found in both satellite and reference data set, neither data set represents the "absolute" truth.
ODR mininises residual variance by fitting a line orthogonal to direction of maximum variance.
Calibration equations are presented which give the correction needed for satellite data (outliers more than 5σ from initial fit are first removed)

Results (1) - JASON (Ku) v Buoy

JASON v NDBC Buoy Wave Height



Ku band Calibration correction:
Hs(cor) = 1.0472Hs(JKu) - 0.0137 resid. rms=0.2440m
95% conf limits 0.9954-1.0991 -0.1116 - +0.0842

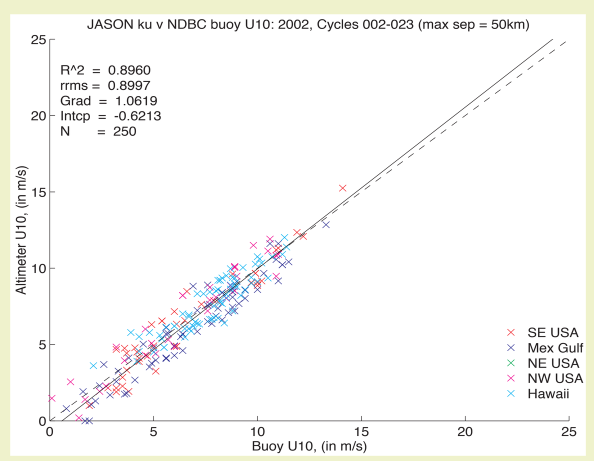
No significant difference between Jason Ku and Buoy Hs (confidence limits ± 5% on gradient, ±10 cm on intercept)

C band regression results:
Hs(cor) = 0.9389Hs(JC) + 0.1547 resid. rms=0.3864m
95% conf limits 0.8688-1.0090 0.0190- 0.2904

UKMO results
Hs(cor) = 0.9052Hs(JKu) + 0.0378 resid. rms=0.4475m
95% conf limits 0.8443-0.9661 0.1413- 0.6139

CMEDS results
Hs(cor) = 0.9551Hs(JKu) + 0.0336 resid. rms=0.2496m
95% conf limits 0.8515-1.0587 -0.1763 - +0.2434

JASON v Buoy Wind Speed



Calibration correction:
U10(cor) = 0.8561 U10(J) + 1.6099 resid. rms=0.8997m/s
95% conf limits 0.7537 - 0.9584 0.8482 - 2.3715

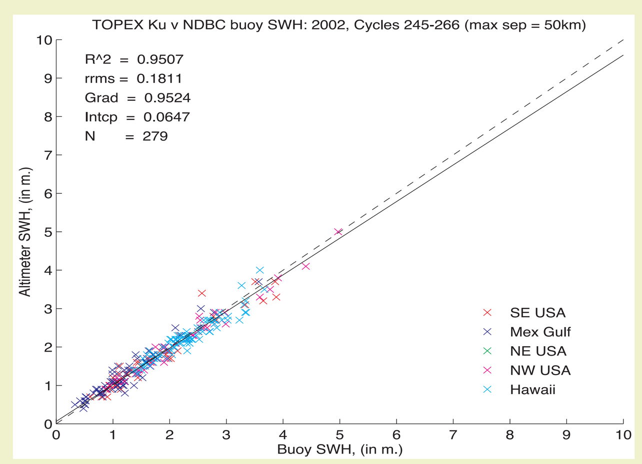
Jason underestimates low winds and overestimates higher wind speeds, consistent with results from other altimeters.

UKMO results
U10(cor) = 0.8513 U10(J) + 1.0868 resid. rms=1.0608m/s
95% conf limits 0.7450 - 0.9576 0.2878 - 1.8857

CMEDS results
U10(cor) = 0.8240 U10(J) + 1.2865 resid. rms=1.2943m/s
95% conf limits 0.6962 - 0.9518 0.3299 - 2.2430

Results (2) - TOPEX IGDR v Buoy

TOPEX v NDBC Buoy Wave Height



Ku Calibration correction:
Hs(cor) = 1.0520 Hs(T) - 0.0674 resid. rms=0.1811m
95% conf limits 1.0233 - 1.0806 -0.1227 - -0.0121

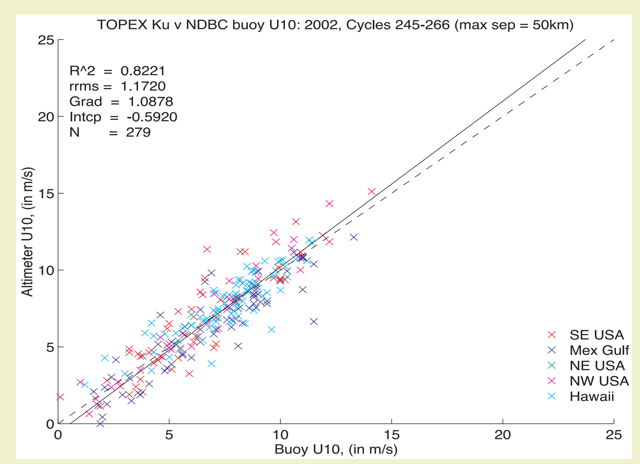
Topex IGDR underestimates Buoy Hs by about 5%, and shows a lower rms than JASON (0.1811m compared to 0.2440m)

C Calibration correction:
Hs(cor) = 1.0363 Hs(T) - 0.0974 resid. rms=0.2120 m
95% conf limits 0.9937 - 1.0790 -0.1821 - -0.0127

UKMO results
Hs(cor) = 0.9189 Hs(TKu) + 0.3013 resid. rms=0.3320m
95% conf limits 0.8730-0.9649 0.1219- 0.4807

CMEDS results
Hs(cor) = 0.9174 Hs(TKu) + 0.0476 resid. rms=0.4044m
95% conf limits 0.7540-1.0807 -0.2896 - +0.3848

TOPEX v Buoy Wind Speed



Calibration correction:
U10(cor) = 0.8375 U10(T) + 1.1720 resid. rms=1.1720m/s
95% conf limits 0.7370 - 0.9380 0.8692 - 2.4035

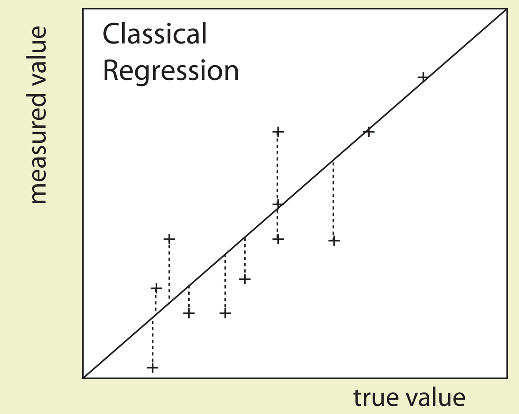
TOPEX underestimates low winds and overestimates higher wind speeds, following expected pattern - seen in other altimeters.

UKMO results
U10(cor) = 0.8156 U10(J) + 0.6144 resid. rms=1.2840m/s
95% conf limits 07426 - 0.8886 -0.1166 - +1.3453

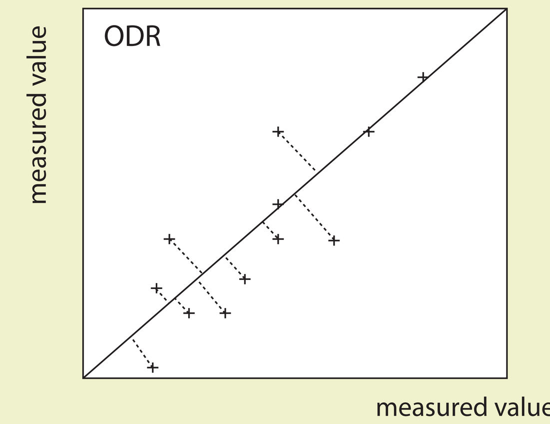
CMEDS results
U10(cor) = 0.8240 U10(J) + 1.2865 resid. rms=1.2943m/s
95% conf limits 0.6962 - 0.9518 0.3299 - 2.2430

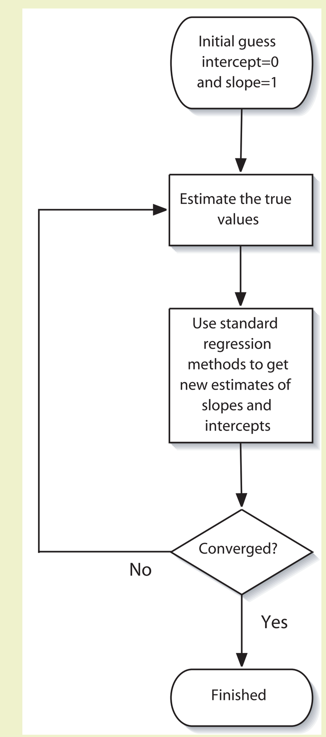
A new method for calibrating satellites

Normally calibrations are performed using a 'standard' which can be assumed to be error free. In this case we can use traditional regression. Our *in situ* data is anything but error free



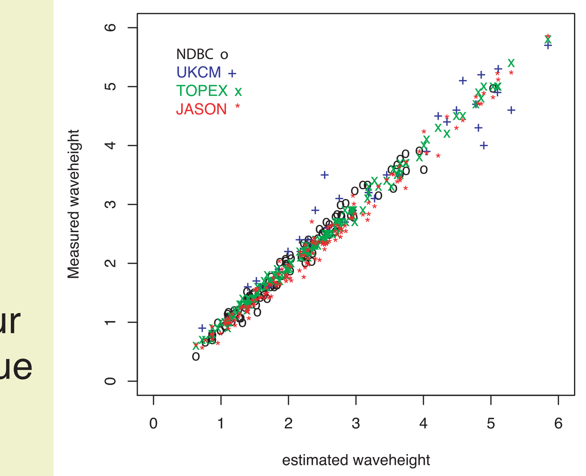
An alternative is to use orthogonal distance regression (ODR). Here rather than minimising the distance in the y direction we minimise the orthogonal distance to the line. However we have to assume that the error variances of both datasets are the same





As an alternative we propose to estimate the 'true value of waveheight at the same time as the intercepts and slopes. The procedure is shown on the left. If our regression equation is $y_i=\alpha_i+\beta_i x$ we estimate the α_i, β_i and x's (i denotes the instrument). Because of a linear indeterminacy we need to set $\alpha_1=0$ and $\beta_1=1$, i.e. the calibration is relative to the NBDC buoys.

The measured wave heights plotted against our estimate of the true values



Results of New Method

Hs	NDBC	UKMO	CMEDS	Jason Ku	Jason C	Topex Ku	Topex C
Intercept	0.0000	0.3290	0.1126	-0.0743	-0.0694	-0.0540	0.0073
sd Intercept	NA	0.0199	0.0193	0.0139	0.0196	0.0065	0.0086
Slope	1.0000	0.9103	0.8763	1.0031	1.0012	1.0122	1.0081
sd slope	NA	0.0076	0.0073	0.0053	0.0074	0.0025	0.0032
Residual sd	0.0057	0.0141	0.0137	0.0098	0.0138	0.0047	0.0061

Discussion

The "residual sd" provides an estimate of error in the different measures of single parameter. According to this measure, TOPEX Ku and JASON Ku show lower random error than NDBC buoy data in their estimate of Hs.
Also, this analysis suggests there is a significant difference, in terms of estimates of Hs, between the buoys deployed by NOAA, the UK Met. Office, and Environment Canada

Final Conclusions

Jason Ku Hs: Not significantly different from buoy Hs, Unadjusted, rms is 0.33m, bias + 7cm.
Seem to be noisier at low Hs. Quality control criteria require confirmation.
Jason U10: Underestimates low winds, overestimates higher wind speeds. Unadjusted, rms is 2.20 m/s, bias + 60cm/s.
TOPEX Ku Hs: Approximately 5% lower than buoy Hs, Unadjusted, rms is 0.18m, bias + 2cm.
TOPEX U10: Underestimates low winds, overestimates higher wind speeds. Unadjusted, rms is 2.13 m/s, bias + 7cm/s.
JASON/TOPEX C Band Hs: HIgher random error than Ku band. Unadjusted, JASON rms=0.5m, TOPEX rms=0.27m.