AN EMPIRICAL MODEL TO RETRIEVE OCEAN WAVE PERIOD FROM NADIR ALTIMETER DATA

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3-meter discus buoy
National Data Buoy Center

Abstract. A simple empirical model is proposed to retrieve wave period from Ku-band radar altimeter backscatter and significant wave height. The model formulation is heuristic, and fitted using a large dataset of collocated Topex altimeter and buoys measurements. Empirical models are proposed for the zero up-crossing, the mean and the peak wave period, and compared with models by [Davies et al., 1997] and [Hwang et al., 1998]. Their performance is assessed using an independent validation dataset, and gives a retrieval error of 0.8s. Regional analysis indicates that the wave period models perform better in wind seas than in swell-dominated conditions.

Topex/Poseidon

1. Collocated buoy/Topex dataset

The buoy data originates from the US National Data Buoy Center (NDBC) who provide one-directional buoy spectra for a large number of moored buoys around the coast of the U.S. The buoys used in this study were selected for their location in open water and proximity to Topex tracks. A network of 24 NDBC buoys was used, providing a reasonable representation of the global wave field, although information is lacking in the southern hemisphere (**Figure 1**).

The buoy to altimeter separation criterion was 100 km, thus less stringent than the 50 km separation typical of wind studies, to account for the larger scales of variability of the wave field. The maximum time separation between Topex and buoy data is 1 hour. With these criteria and standard ice and rain flags (Aviso Topex GDR products), the collocation yielded 6344 data points for the period September 1992-December 1998.

The data consist of Topex Ku-band backscatter coefficient and SWH (1 Hz). No attempt was made to compensate for the gradual drift in Topex's estimates towards the end of 1998, which were shown to have no perceptible impact in our dataset ([Gommenginger et al.,2002]). The buoy data include wind speed and direction, SWH, air and sea temperatures, and peak (Tp) wave period from the NDBC metocean parameter records, and onedimensional frequency wave spectra from the NDBC spectralrecords.

Mean (Tm) and zero-crossing period (Tz) were computed from the moments of the one-dimensional ocean wave spectra (see e.g. [Tucker, 1991]) with:

Tm = m0/m1 and **Tz = sqrt(m0/m2)**

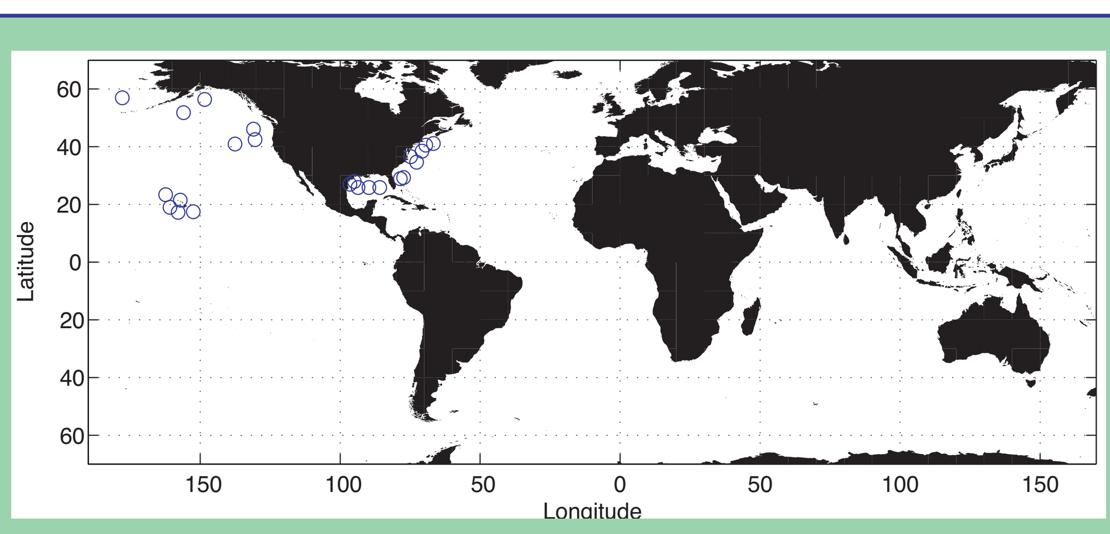


Figure 1: NDBC buoy locations

If you have access - or know of - any buoy wave period data in the Southern Ocean,

we would like to HEAR FROM YOU !

	a (± 95%)	b (±95%)
$T_z = a + b X$	- 0.895 (± 0.126)	2.545 (± 0.045)
$\log_{10}(T_z) = a + b * \log_{10}(X)$	0.361 (± 0.007)	0.967 (± 0.016)
$\log_{10}(T_m) = a + b * \log_{10}(X)$	0.352 (± 0.008)	1.063 (± 0.019)
$\log_{10}(T_p) = a + b * \log_{10}(X)$	0.154 (± 0.021)	1.797 (±0.047)

Table 1: Empirical altimeter wave period models

2. Empirical altimeter wave period model

Our empirical model is based on heuristic reasoning and, unlike previous altimeter wave period models, makes no assumptions on, for example, the shape of the ocean wave spectrum. At nadir, σ0 is related under the Geometrical Optics approximation to the inverse of the mean square slope of the long ocean waves ([Barrick, 1974]):

$$\sigma 0 \sim 1/mss$$

In turn, wave slope is dimensionally equivalent to the ratio of some measure of the wave height and the wave length, L:

$$slope \sim SWH / L$$

The ocean wavelength is related to wave period, T, through the dispersion relationship for deep water gravity waves, so that

$$L \sim T^2 \quad \text{and} \quad mss \sim SWH^2/T^4$$

and thus:

$$T \sim (\sigma^0 SWH^2)^{0.25}$$

Simple empirical models were constructed for Tz, Tm, and Tp, all based on the above equation (**Table 1**).

Figure 2 shows the buoy Tz, Tm and Tp against $X = (\sigma^0 SWH^2)^{0.25}$ calculated from the Topex data. The contour lines indicate the density of data points, and show a strong correlation with X for Tz and Tm.

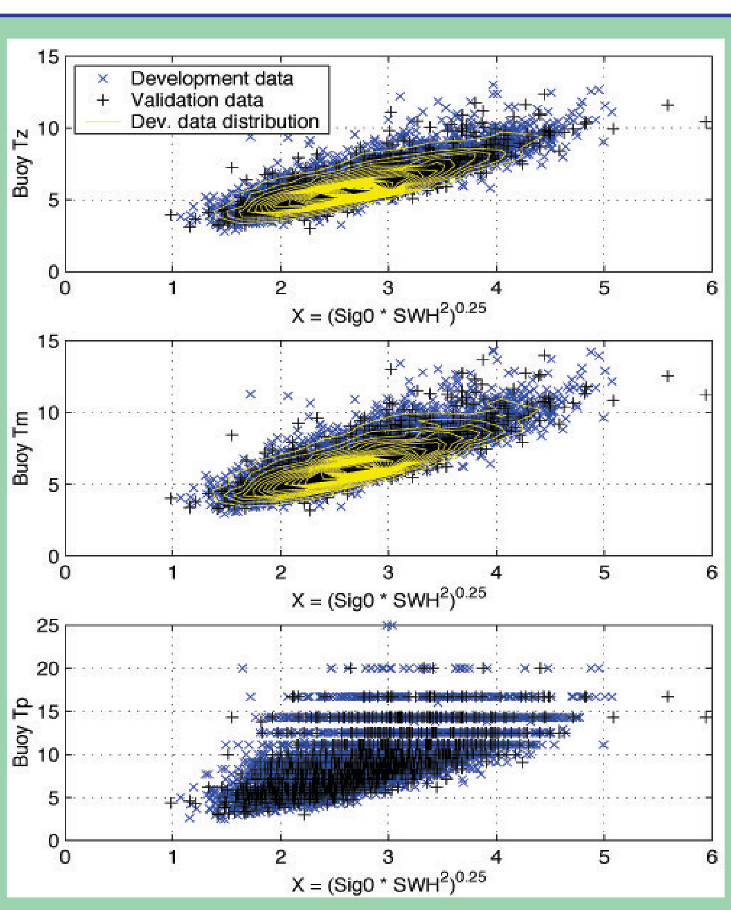


Figure 2: Buoy wave period against $(\sigma^0 SWH^2)^{0.25}$

3. Validation

The performance of all models is evaluated usingthe statistics of the residual wave period error defined as dT =TBuoy - TAlt (**Table 2**).

Based on anindependent validation dataset, the (linear) empirical and the D97 models for Tz return an r.m.s. error around 0.9s, while the empirical log-log model for Tz returns an r.m.s. error under 0.8s. While the empirical models display no bias, D97 is characterised by a large, unexplained, -0.52s bias. H98 performs yet worse both in terms of bias and r.m.s.error.

The empirical log-log model for Tm shows a retrieval error of about 1s.

Models for Tp return errors in excess of 2.8s and large biases, explained partly by the noisy nature of the Tp buoy data (**Figure 2**).

		Development dataset				Validation dataset			
		N	Bias	rmse	Sdev	N	Bias	rmse	Sdev
T_z	$T_z = a + b X$	5075	-0.000	0.871	0.871	1269	-0.009	0.900	0.900
	$\log_{10}T_z = a + b * \log_{10}X$	5075	0.005	0.785	0.785	1269	-0.008	0.797	0.797
T_m	$\log_{10}T_m = a + b * \log_{10}X$	5075	0.000	0.965	0.965	1269	-0.010	0.988	0.988
T_p	$\log_{10}T_p = a + b * \log_{10}X$	5075	-0.216	3.046	3.038	1269	-0.223	3.060	3.052
Davies et al. (1997)	T_z	4742	-0.519	0.856	0.680	1194	-0.525	0.876	0.701
Hwang et al. (1998)	T_z	5075	-0.922	1.362	1.002	1269	-0.926	1.442	1.105
	T_p	5075	0.518	2.674	2.623	1269	0.497	2.859	2.816
		Gulf of Mexico (Validation)				Hawaii (Validation)			
		N	Bias	rmse	Sdev	N	Bias	rmse	Sdev
T_z	$\log_{10}T_z = a + b * \log_{10}X$	266	-0.014	0.608	0.608	268	-0.121	0.853	0.844
T_m	$\log_{10}T_m = a + b * \log_{10}X$	266	-0.058	0.709	0.707	268	-0.009	1.093	1.092
T_p	$\log_{10}T_p = a + b * \log_{10}X$	266	0.345	1.730	1.695	268	0.038	3.177	3.177
Davies et al. (1997)	T_z	249	-0.804	0.937	0.482	260	-0.464	0.904	0.776
Hwang et al. (1998)	T_z	266	-0.466	0.955	0.833	268	-1.198	1.649	1.134
	T_p	266	-0.099	1.763	1.760	268	1.215	3.838	3.640

Table 2: Residual wave period statistics (dT = TBuoy - TAlt)

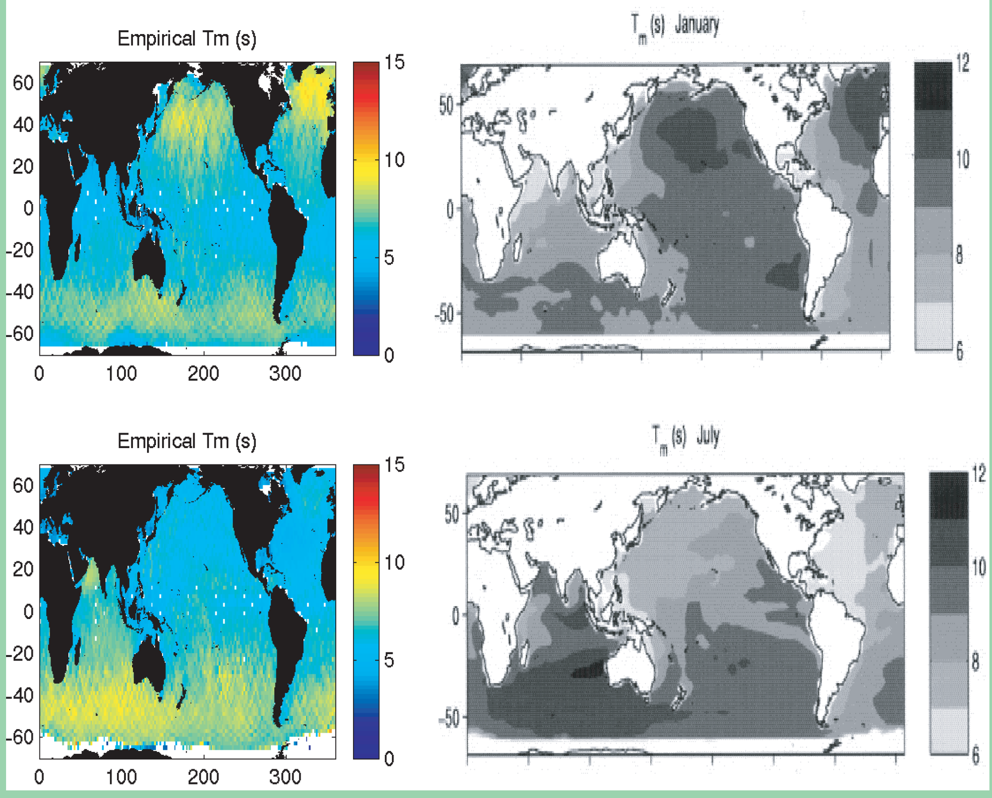
Want more on "Validation" ...?

...then look out for **Gommenginger et al. (2003)**, "Measuring ocean wave period with satellite altimeters: A simple empirical model", **GRL** (accepted for publication)

4. Geographical variability

To better understand the performance of the different models in different sea conditions, we identified, within the validation dataset, the data for the **Gulf of Mexico** (266 points; wind-sea) and for the **Hawaii** (268 points; swell dominated) regions.

In **Table 2** the empirical models show improved performance when tested on the Gulf of Mexico data alone, and poorer performance using the Hawaii dataset alone. This suggests that the empirical models are better suited to wind-sea than to swell conditions.



Monthly-averaged Tm for January and July for:

(left) empirical log-log model over a 2 x 2 deg grid (T/P data for1994)

(right) ECMWF WAM over a 3 x 3 deg grid for January and July between June 1992-May1996 (after Young; 1999)

Figure 3: Altimeter wave period v. ECMWF monthly climatology

5. Conclusions & Future work

This work suggests that wave period can be retrieved globally from altimeter data with an r.m.s. error of the orderof 0.8 s for Tz. Analysis of the altimeter models' performance in different sea conditions shows that they are better suited to wind-dominated seas than to regions with strong swell.

Unlike previous wave period models, these simple empirical models are better able to reproduce a wide range of wave period conditions. However, much validation remains to be done, especially with regards to testing the empirical models with data from the Southern Ocean and the coastal zone.

Together with further validation, future work hopes to include comparative studies with numerical wave models, and the compilation of global wave period climatologies (e.g. **Figure 3**), in order to study the geographical and seasonal/annual variability of the global ocean wave field.

References

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