Estimating waves in Lyme Bay for the STORM model

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15 October 1999

1 Introduction

Wave height climate statistics in the English Channel and into Lyme Bay are provided by the conveniently located TOPEX Track 061. However, the altimeter does not give directional information. Nor does it provide data near the location required by Halcrow for 'STORM', its shallow water wave model. A previous JTR (18 Sept. 1999) examined variations in wave height observed along the TOPEX Track 061, and concluded that the mean and extreme wave heights decrease with locations moving into the Bay. This report re-examines data along Track 061 together with data along Track 146, which comes off the coast into Lyme Bay and crosses Track 061 around 50.25°N 2.82°W. in order to provide an input data set for the 'STORM' model.

Figure 1 shows the location of the TOPEX GAPS data along these tracks (at 6 km spacing) and that of the location required for 'STORM'. Note the considerable distance from the coast before the TOPEX altimeter gives measurements along Track 146.

The wave model also needs to input wave directions at the boundary; these are taken as the wind direction at the Met. Office buoy at 50.6°N 2.7°W.

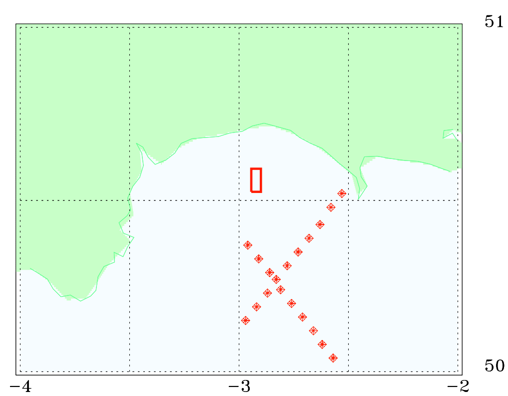

Figure 1: Locations of TOPEX GAPS data along Tracks 061 & 146, and the location where data are required as input to the 'STORM' model (the small box).

2 Variations in Hs with latitude

Figure 2 show the mean values of significant wave height, H_s, against latitude along the TOPEX tracks 061 and 146 across Lyme Bay. These means were calculated from the SOC GAPS data set, using only altimeter passes which gave good H_s values at all locations plotted (138 transects for Track 146, but only 71 for Track 061 mainly because so many observations at the most northerly location near Portland Bill were discarded by the quality checks).

The linear regressions, of mean H_s on latitude, shown on the figure, gave slopes of -1.20 and -1.07 for 061 and 146 respectively, with standard errors of 0.04 and 0.08, suggesting that the difference is not significant.

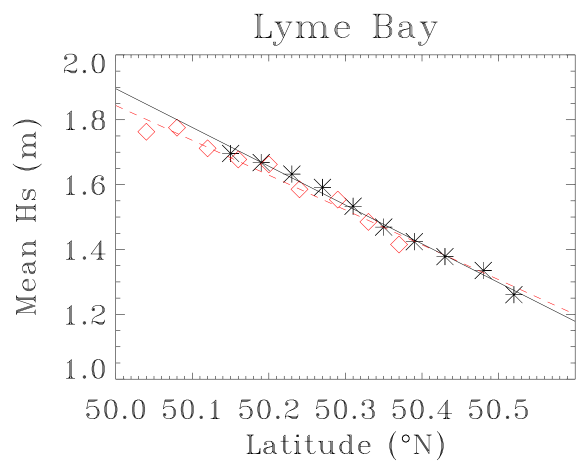

Figure 2: Mean wave height from TOPEX tracks across Lyme Bay; Track 061 (*:into Lyme Bay)& 146 (diamond: out of Lyme Bay).

However, to derive a latitude correction to get estimates of H_s for the 'STORM' model, it would seem more sensible to use changes in individual values, i.e. to study variations in the ratio of H_s with latitude. Figure 3 shows the results, taking the ratios of H_s at each location with that at the cross-over of the two tracks (50.27°N 2.83°W for Track 061, and 50.24°N 2.81°W for Track 146). The changes in ratio with latitude seem to be very close to linear, with slopes of -0.71 and -0.57 (s.e. 0.02 and 0.03) for Tracks 061 and 146 respectively. Omitting the most northerly location on Track 061 from the regression give a slope of -0.68 (s.e. 0.02). These values show a significant difference, suggesting a possible longitude effect. The lack of more northerly data from Track 146 and no justification for expecting the ratios of H_s to be linearly related to latitude means we have little evidence for the ratio between wave height at the TOPEX cross-over and that at the 'STORM' location. But Figure 3 would suggest a ratio at 50.55°N of about 0.8.

2.1 Variations with wind direction

The previous JTR found that H_s tended to decrease with latitude into Lyme Bay whether the waves were travelling into or out of it (where direction was estimated from wind direction). But there might be differences in the rate of change with direction. This is supported by Figure 4 which shows the distribution from individual values of H_s at 50.84N 2.58W / H_s at 50.27N 2.83W with direction of the wind at the Met. Office buoy. Averaged over 90° segments, the mean ratio varies from 0.73 for winds from 315°–045° to 0.88 for winds from 180°–270°. However, conditions

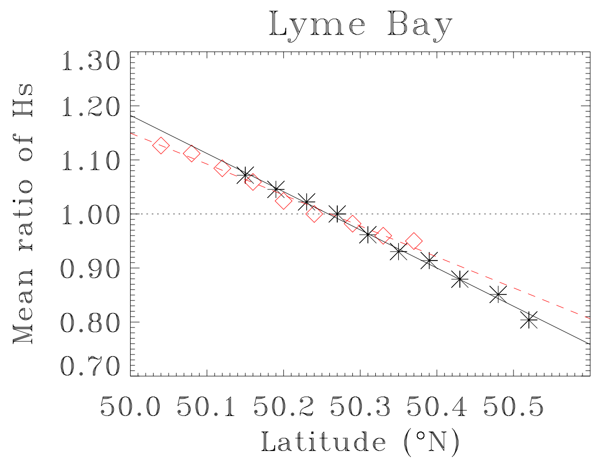

Figure 3: Ratio of wave heights along TOPEX tracks 061 & 146 across Lyme Bay.

could be quite different in the more open location of the 'STORM' model boundary. Track 146 is of little help. Figure 5 shows the ratio from the most northerly point of that track to the cross-over location (50.37°N 2.96°W / 50.24°N 2.81°W) - clearly 'noisier' perhaps because of poor values along this offshore track or because the two locations are so close. Discarding all data where H_s at the cross-over was < 1 m, gives average ratios over 90° sector varying from 0.85 (from 270°–360° - but only 7 values) to 0.91 (from 045°–135°, with 9 values, and a mean from all directions of 0.88 over this latitude difference of 0.13°. These results indicate we do not have sufficient evidence to determine a directionally dependent ratio between H_s at the cross-over and at the 'STORM' location.

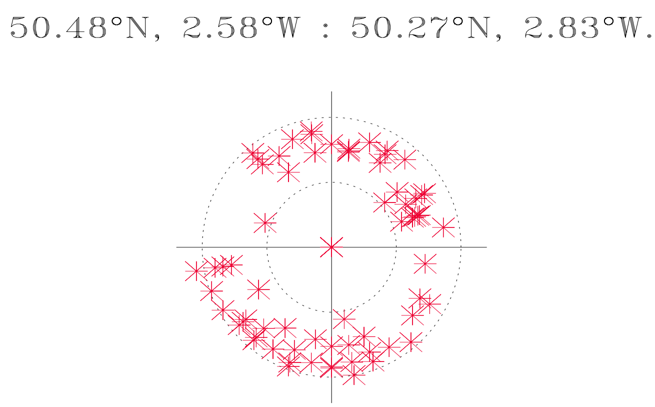

Figure 4: Distribution of Hs ratios (circles at 0.5 & 1) and wind direction (+ve y-axis: North).

3 Data set at the 'STORM' boundary

Following the analysis described in Section 2, it seemed that the best that could be done was to extract TOPEX H_s and zero-upcross period T_z from the the two tracks at their cross-over points - or the nearest GAPS positions to this - for all occasions when the nearby Met, Office buoy

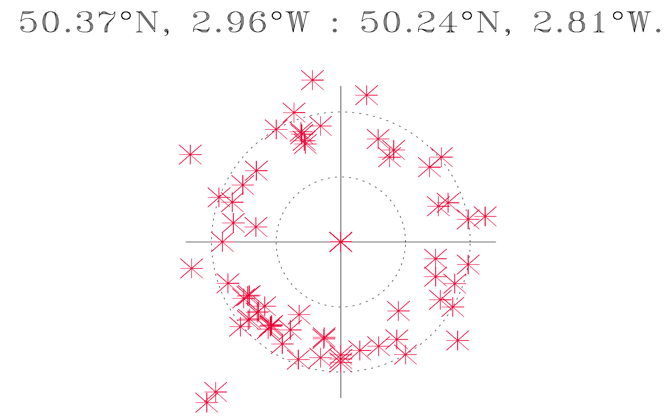

Figure 5: Distribution of Hs ratios (circles at 0.5 & 1) and wind direction (+ve y-axis: North).

measured a wind direction (within 3 hours of the altimeter pass), and take that direction as being the wave direction. These data were accordingly extracted into a data set containing 128 records, 74 from each of the two tracks. To get wave height at the 'STORM' boundary, it is suggested that the extracted values be reduced by 0.8. This leaves the problem of possible modification of T_z, but because of the lack of understanding for the reduction in H_s, it may not be a soluble problem.

4 Extreme wave heights

The cumulative distribution of wave height in the data set described in the above Section is shown in Figure 6. The previous JTC noted that the FT-1 was not a good fit to the very low waves, so here a censored FT-1 has been fitted, with cut-off at 0.8 m. The 100-year return value (based on 3-hourly intervals) is 10.0 m (s.e. 0.6 m). Note this is about 1.1 m higher than the 100-year return value from an uncensored fit. These values are for the cross-over location; the factor of 0.8, to get to the 'STORM' boundary, has not been applied.

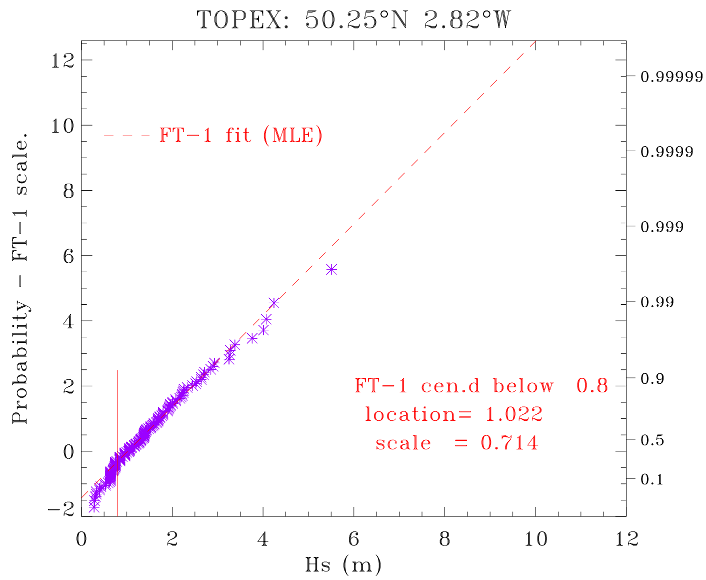

Figure 6: Cumulative distribution of data (with directions) for Halcrow

This was a rather small data set - chosen so that a wind directions were available. Figure 7 shows the distribution of all TOPEX data at this cross-over - 342 values, with 248 above the analysed cut-off of 0.8 m. The 100-year return value from this larger data set is 11.2 m (s.e. 0.4 m).

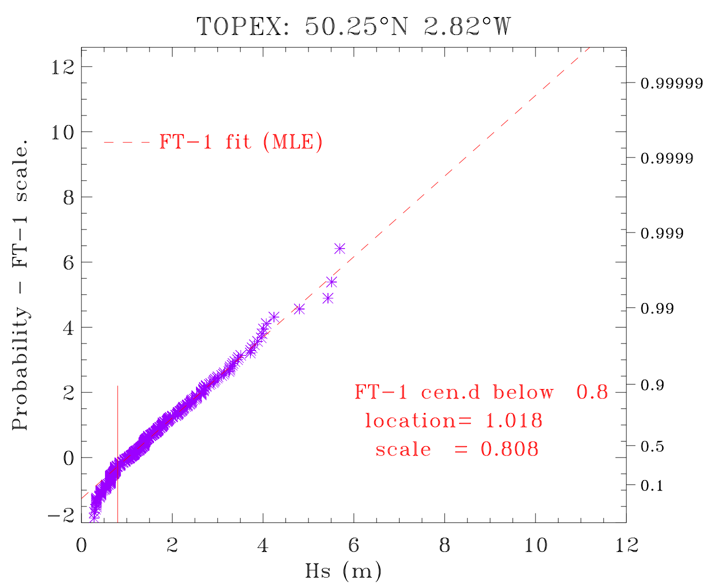

Figure 7: Cumulative distribution of TOPEX data at cross-over south of Lyme Bay.

5 Conclusions

The STORM model for Lyme Bay requires input at the boundary of wave height (H_s), wave period, and wave direction at a site without wave measurements from either buoy or altimeter. Nearby altimeter data - about 20 km away - reveal significant changes in H_s over this distance.

Extrapolation of the trend in altimeter H_s with latitude indicates that H_s at the STORM boundary site is about 0.8 that at the location 0.3° to the south – but the data also suggest a variation in longitude and with wave direction which cannot be adequately resolved.

The reason for this reduction in H_s towards the coast, into Lyme Bay, has not been established; probably refraction, bottom loss, sheltering from the west, and reduction in fetch with offshore winds all play a part. So it does not seem possible to determine any associated changes in wave period.

Clearly, in retrospect, the boundary site of the STORM model should have been placed elsewhere; preferably located further from the coast where smaller spatial variation in H_s might be expected - although off Lyme Bay the variation with latitude seems to be linear out to at least 50.1°N - and located closer to a TOPEX track.

The estimates of extremes have revealed some interesting features. Firstly, the 100-year return value of H_s deduced from the data set prepared for Halcrow (with directional information) is 1.2 m lower than that of 11.2 m from all the altimeter data (i.e. 11% lower). With standard errors of $0.4 - 0.6$ m, this difference might be explained as sampling variability, but it would seem preferable to use the higher value, deduced from the larger data set.

Second, the 100-year values deduced in this JTR from a censored FT-1 are higher, by about 10%, than the values derived in previous JTR's using uncensored fits. From comparisons with buoy data, TOPEX does not appear to have any difficulty in resolving low wave heights, at least down to 0.25 m. The apparently poor fit below about 0.8 m seen in Figure 6 & 7 might be because an FT-1 is not the true distribution - although the bulk of the data appear to fit quite well - or because offshore waves (with most of the low values) and onshore waves are drawn from different statistical distributions. See the discussion on a similar problem off Holderness (JTR dated September 1999). Again, it would be expedient to use the higher values.