# Estimating Statistical Extremes, and Exceedance probabilities from 1° x 2° Gridded Monthly Mean Altimeter Data.

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## Introduction

This analysis has employed gridded monthly mean (1° latitude by 2° longitude spatial grid) satellite significant wave height ($H_s$) altimeter data, covering the period October 1992 to September 1998, to derive estimates of significant wave height return values and exceedance probabilities.

## Satellite Altimeter Data

The altimeter data are taken from 3 satellites: ERS-1 (1991-95), TOPEX/Poseidon (1992-98), and ERS-2 (1992-98). Significant wave height data from each altimeter have been extracted, quality controlled and separately calibrated according to linear corrections given in Cotton et al., (1997). These data have then been combined together to generate monthly means and variances on a 1° latitude by 2° longitude global grid. The monthly values (means and variance) have then been combined into seasonal, annual and multi-annual values. The number of samples within the gridded data were checked to ensure that particular months or seasons did not receive preferential sampling. Only values derived from the whole 6 year period are discussed in this report.

## Analysis Procedure

The statistical analysis assumes that the gridded altimeter significant wave height data fit a Fisher-Tippett type 1 distribution. The mean and variance (*VAR*) of the gridded data were then used to generate the FT-1 $\alpha$ and $\beta$ parameters, for each grid square, as follows:

$$\beta = (6^{0.5} / \pi) \,.\, VAR^{0.5} \quad (1)$$

$$\gamma = 0.5772 \text{ (euler's const)} \quad (2)$$

$$\alpha = \text{mean} - (\gamma . \beta) \quad (3)$$

These $\alpha$ and $\beta$ parameters were then used to calculate exceedance probabilities (i.e. the probability that significant wave height measurement would exceed a certain significant wave height threshold, *Xlim* (eqn. 4).

Exceedance probability, P

$$P(x > Xlim) = 1 - \exp( -\exp( -(Xlim - \alpha)/\beta ) ) \quad (4)$$

The $\alpha$ and $\beta$ parameters were also used to generate estimates of return values ($x$) for significant wave heights for a given probability, $P$, eqn (5).

$$x = [ (-\ln (-\ln (1-P) ) ). \beta] + \alpha \quad (5)$$

e.g the probability of a one in a hundred year wave in a three hourly sampled data set (three hours is taken as the time between independent values of significant wave height at any given location), $P_{100}$ is given by

$$P_{100} = 1/ (8 \times 365 \times 100) \quad (6)$$

Thus it is now possible, in principle, to generate maps on the 1° x 2° UK grid of exceedance probabilities for any selected value of significant wave height, by season or year. Similarly one can map return values for any selected probability. The figures on following pages represent a subset of such "maps". When viewing such maps one should always bear in mind the assumptions that have been made in the calculations. Also, although we have generated the maps at the highest spatial resolution that is possible, given the satellite sampling, it is clear that some grid squares cover regions that will contain a widely varying wave climate. One should also remember that these estimates have been derived for the *offshore* wave climate (more than 30 km from the coast).

Figure 1 presents exceedance probabilities for four selected significant wave heights: 1.5 m, 2.5 m, 5.0 m and 10 m. Note that the maximum probabilities occur in the west of the region, and the minimum probabilities on the English east coast. It is evident that the western Irish coastline is the most exposed in the British Isles, with the Western Isles and the south-west tip of Cornwall the most exposed UK coastlines. Figures 2, 3, 4 and 5 present the 1 year, 10 year, 50 year and 100 year return values for significant wave height.

The map of 100 year return values seems to agree well, qualitatively, with the current authority, the HSE guidance notes (though we understand they are to be withdrawn). All these maps confirm a significantly rougher climate on the western exposed coasts, the southern most tip of Cornwall experiencing the most severe conditions of the UK mainland (though not as severe as the west coast of Ireland). The most sheltered region is the eastern sector of the English Channel, between the Isle of Wight and the Dover Straits.

| Return Period | Holderness (1° x 2° grid) | Holderness (DJC TOPEX analysis) | Lyme Bay (1° x 2° grid) | Lyme Bay DJC TOPEX analysis) | St Gowan |
|---|---|---|---|---|---|
| 1 year | 5.63 m | 5.46 m | 7.95 m | 6.65 m | 8.87 m |
| 10 year | 6.97 m | 6.73 m | 9.87 m | 8.23 m | 10.99 m |
| 50 year | 7.91 m | 7.62 m | 11.22 m | 9.40 m | 12.48 m |
| 100 year | 8. 32 m | 8.00 m | 11.80 m | 9.82 m | 13.12 m |

Table 1. Return values of significant wave height for the three JERICHO locations. The offshore values derived from the gridded (1° x 2°) altimeter data, and values from DJC's (see Carter[1] and Carter[2]) analysis of TOPEX data closest to the site.

For Table 1 we have extracted the 1 year, 10 year, 50 year and 100 year return values from the grid squares closest to our three JERICHO locations. We see that St. Gowan shows the largest values, and Holderness the lowest. It is to be expected that the values from David Carter's analyses (Holderness and Lyme Bay) are lower than those derived from the gridded data, as the gridded values represent the wave climate across the entire 1° x 2° grid square, whereas Carter's values are for the point on the TOPEX satellite track closest to the JERICHO coastal site. The difference between the two estimates is larger for Lyme Bay, perhaps an indication of the greater sheltering that is gained as one enters Lyme Bay, compared to the relatively exposed Holderness coastline. The agreement between the two sets of values for Holderness is particularly encouraging, suggesting that the necessarily less rigorous technique used to derive the extreme values from the gridded data is providing reliable estimates.

## Conclusions

Gridded values of means and variance in significant wave height have been used to generate maps of exceedance probabilities and return values of significant wave height around the UK coastal seas. Analysis of these maps reveals expected patterns of relative exposure and sheltering, and qualitative comparisons with estimates from other sources suggests that these values can be regarded as reliable indicators.

## References

Cotton P.D., P.G. Challenor, and D. J. T. Carter, An assessment of the accuracy and reliability of Geosat, ERS-1, ERS-2, and TOPEX altimeter measurements of significant wave height and wind speed, proceedings of CEOS wind and wave validation workshop, June 1998, ESTEC, Noordwijk, The Netherlands. ESA WPP-147.

Carter$_1$, D. J. C., Waves and winds in Lyme Bay, JERICHO Technical Report, 10pp, 18 September 1999.

Carter$_2$, D. J. C., Holderness deep water wave climate data set and extreme wave height, JERICHO Technical Report, 7pp, 2 September 1999.

## Figures

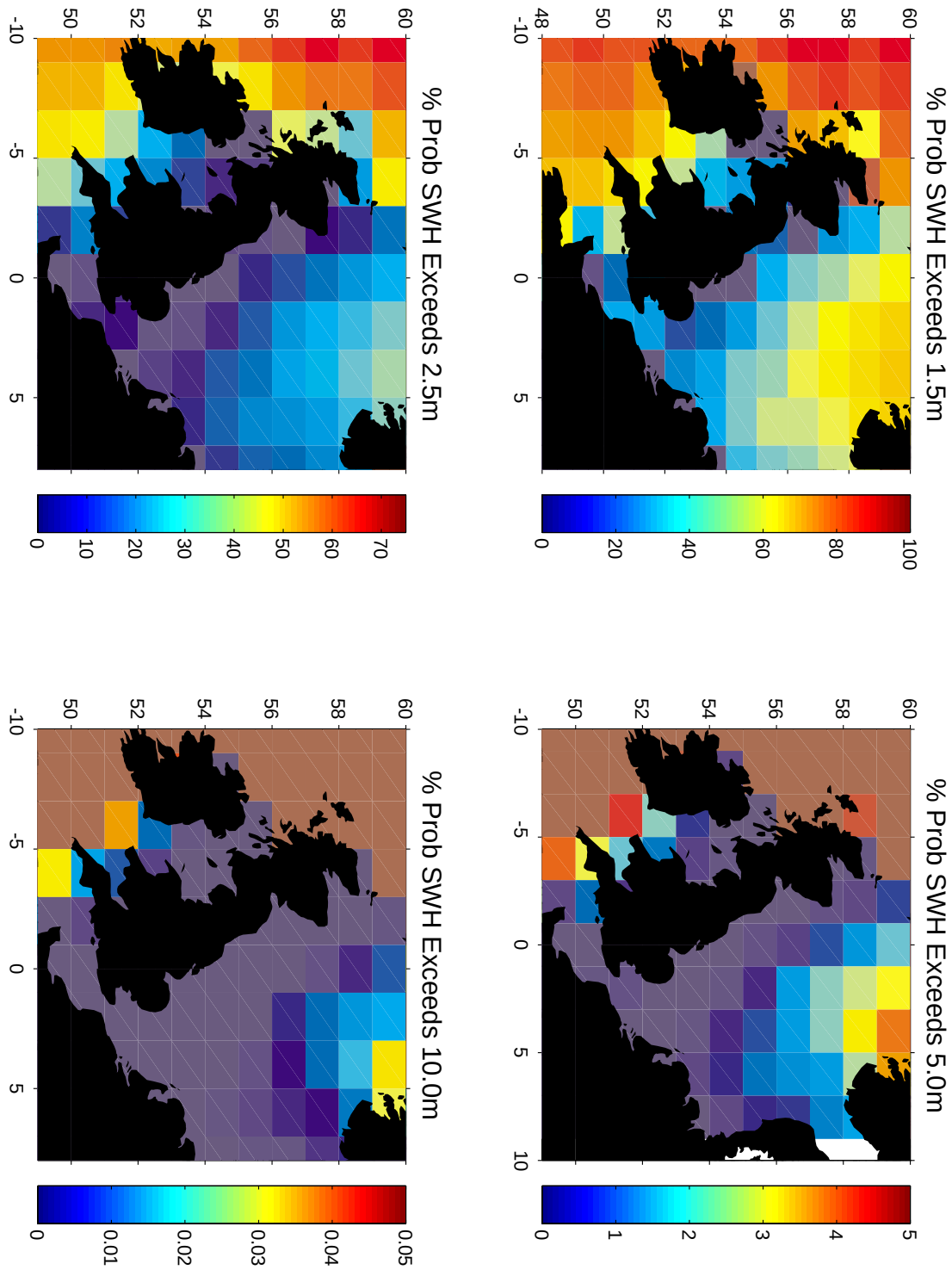


Figure 1 Maps of Percentage Probability of Significant Wave Height exceeding (a) 1.5 m (b) 2.5 m, (c) 5.0 m and (d) 10.0 m.

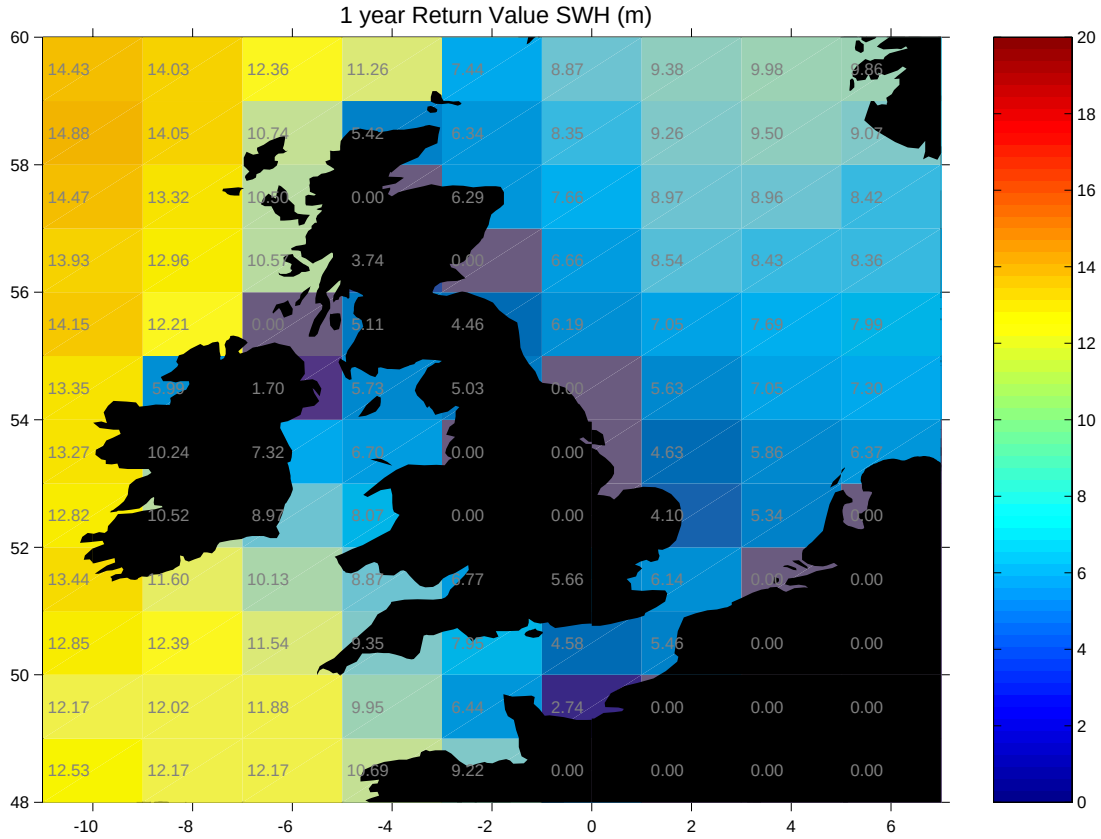


Figure 2 One year return values of significant wave height around the British Isles.

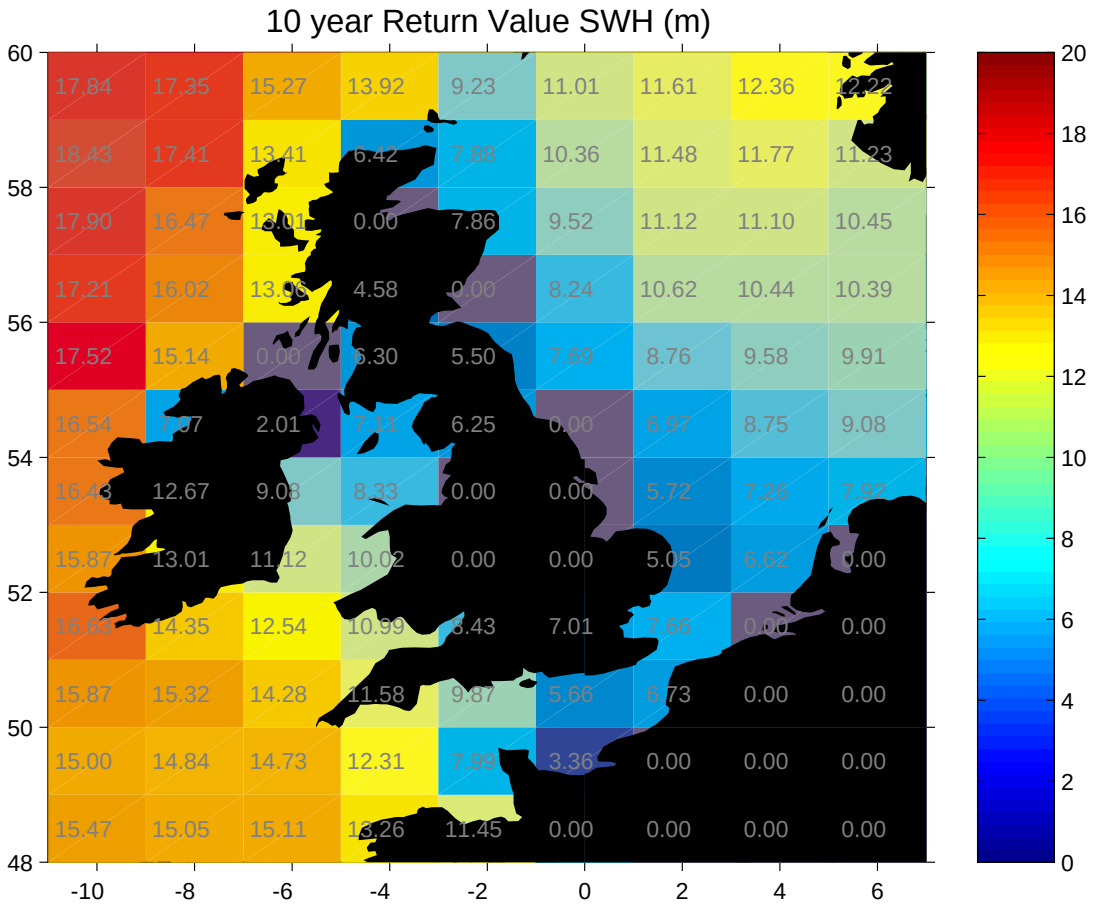

Figure 3 Ten year return values of significant wave height around the British Isles.

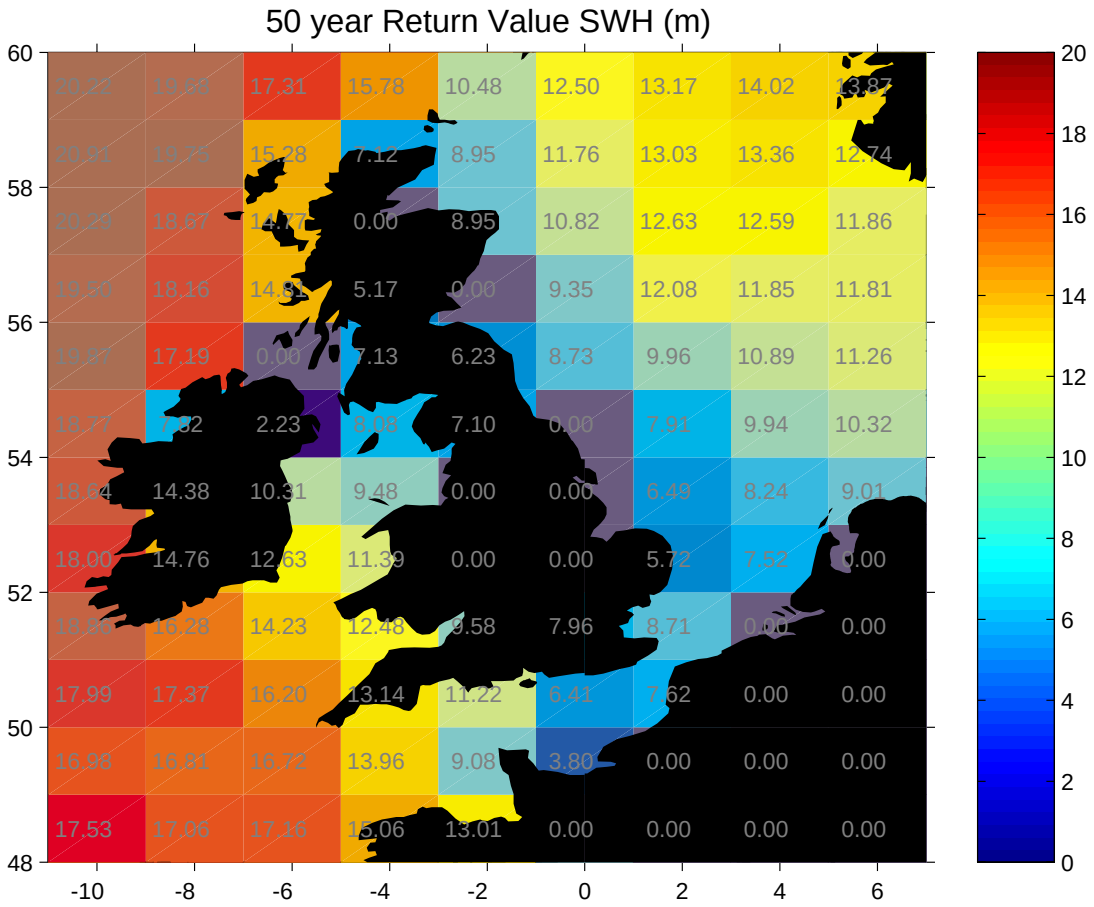

Figure 4 Fifty year return values of significant wave height around the British Isles.

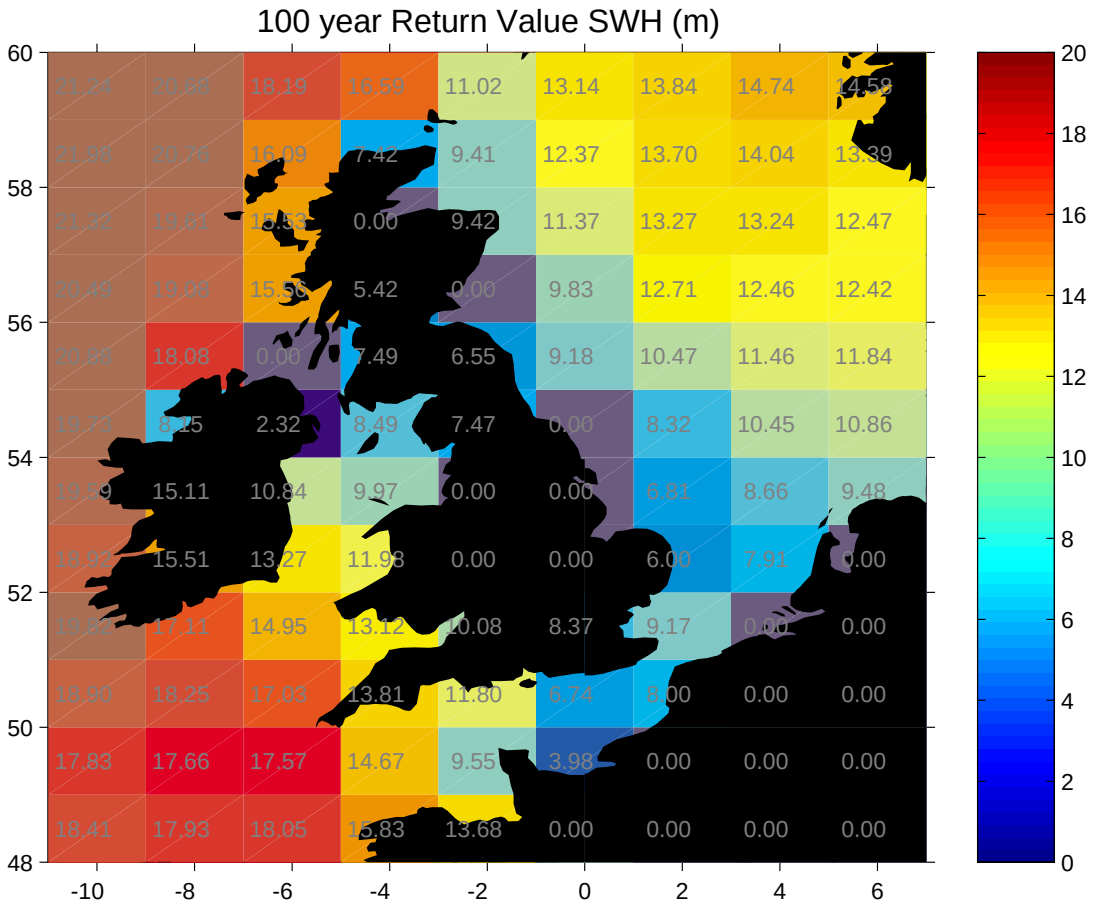


Figure 5 One hundred year return values of significant wave height around the British Isles.