Analysis of North East Wave Climate Variability from Altimeter Data

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Introduction

This analysis has employed satellite significant wave height (H_s) altimeter data, covering the period 1985-96, to investigate the spatial and temporal characteristics of (inter-annual) variability of wave climate in the North Eastern Atlantic. The intention is to identify the major large scale patterns of variability which may in turn influence the coastal wave climate. The results of this study will then be used to identify patterns which contain links with large scale atmospheric features, and may thus be combined with predictions from large scale climate models to generate predictions of future wave climate close to the UK coast.

Data

The altimeter data are gathered from 4 satellites: Geosat (1985-89), 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 on a 2° latitude by 2° longitude global grid. The altimeter data analysed here cover the period 1985-96.

Annual Cycle

Away from the tropical regions, the largest signal of variability in wave climate is the annual cycle. It is therefore important to accurately characterise this signal, and then remove it from the data, before inter-annual variability can be investigated. A simple sine model was fitted individually to the monthly mean H_s values in each 2° x 2° grid square, and the cycle thus identified is presented in Figure 1. The annual mean H_s, and the annual range in H_s can both be seen to decrease Eastwards into the English Channel and Southwards into the North Sea (from > 3 m at 20° W , to 1 m or less at the south-eastern tip of Kent). The month of maximum wave height is January or February everywhere. When the percentage reduction in variance achieved by fitting the annual cycle is considered, Figure 2, it becomes clear that the annual cycle describes less of the variability in the gridded and averaged altimeter data in these more sheltered regions (~50% at 15°-20°W, ~20% off the South Eastern English coast). This effect may be genuine, but it may also be a consequence of the poorer sampling of these regions by the altimeter.

The satellite altimeter cannot retrieve a valid ocean return when any land lies within its footprint (7-9 km diameter), thus the closest measurement it make to land is ~4km at best. A further problem occurs when the altimeter ground track is leaving the land and coming on to the sea, when the altimeter can take up to 5 seconds to regain "lock" on the ocean surface. In this case altimeter measurements of the ocean surface are not regained up to 30km from the coast. This restriction can thus reduce the sampling of semi-enclosed and coastal seas, and effect the accuracy with which average altimeter data can be used to represent a mean climate.

Another, sampling related problem could be small scale spatial variability along the coastline, caused by local bathymetry, nearby land topography, and perhaps local currents. For instance a single 2° grid square centred at 1° E and 51°N covers both the Eastern end of the English Channel and the mouth of the Thames Estuary. Clearly the wave climate of these two regions, within a single grid square, will be effected in different ways by passing weather systems.

It should therefore be considered whether it is worth carrying out further analyses on data presented on a different grid, if possible with higher resolution.

Modes of Variability from Empirical Orthogonal Functions

Empirical Orthogonal Analyses identify separate, orthogonal, modes of variability in data sets. EOF analysis was carried out on the gridded altimeter data set, after the annual cycle has been removed. The procedure was carried out on 2 regions, the whole of the North Atlantic (80°W - 10°E, 30°N - 65°N) and the North Eastern Atlantic (20°W -10°E, 45°-60°N).

The most significant EOF mode on the larger scale (Figure 3) has a bi-modal structure, with a dividing line running SE of the Southern tip of Greenland towards the West Coast of the Iberian peninsula. This mode explains 42.2% of the inter-annual variance in the altimeter H_s data, and has a time series which bears considerable resemblance to the North Atlantic Oscillation Index. Note how the associated time series, combined with the spatial pattern, indicates a period of steadily rising wave heights in the North Eastern Atlantic from 1987-1994. In more recent years, however, this trend can be seen to have reversed. The first EOF mode for the reduced NE Atlantic region (Figure 4) exhibits almost exactly the same spatial and temporal patterns, but explain a larger proportion of the variance, 58.5%. However, the magnitude of this mode decreases close to the European coastline. Thus whilst it would appear that it still represents a significant amount of variability in the West, including South Wales (St Gowan) and the South West coast of England (possibly as far as Lyme Bay), this pattern has little effect on the East coast of England and the rest of the Southern North Sea.

The second EOF mode accounts for 15.3% of the variance in the North Atlantic, and 22.3% in the reduced area. Thus the first two modes together represent over 80% of the inter-annual variance in the wave height climate for this smaller region. Again the features found for the larger area (Figure 5) map almost exactly onto the smaller region (Figure 6). The most significant feature of this mode in the Eastern Atlantic is the opposite sign of two regions to the Southwest and Northeast of the UK. No atmospheric index has yet been identified which matches the time series associated with this mode. Again we see that this mode has the largest magnitudes offshore, and the least apparent significance to the southern North Sea. This may be a genuine effect, or a consequence of the sampling and grid scale limitations discussed above.

Conclusions

The dominant large scale patterns of wave climate variability in the north-eastern Atlantic have been characterised as an annual cycle and two EOF modes. It appears that the coastal climates of the regions on the south western English and Welsh coasts may be reasonably well characterised by these signals, but that the eastern English coast and southern North Sea may not. If the altimeter data are to be further used to characterise the wave climate in the southern North Sea and Eastern English Channel, it may be necessary to repeat the analysis on an alternative, possibly smaller scale, grid.

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.

Significant Wave Height Annual Cycle 85/97

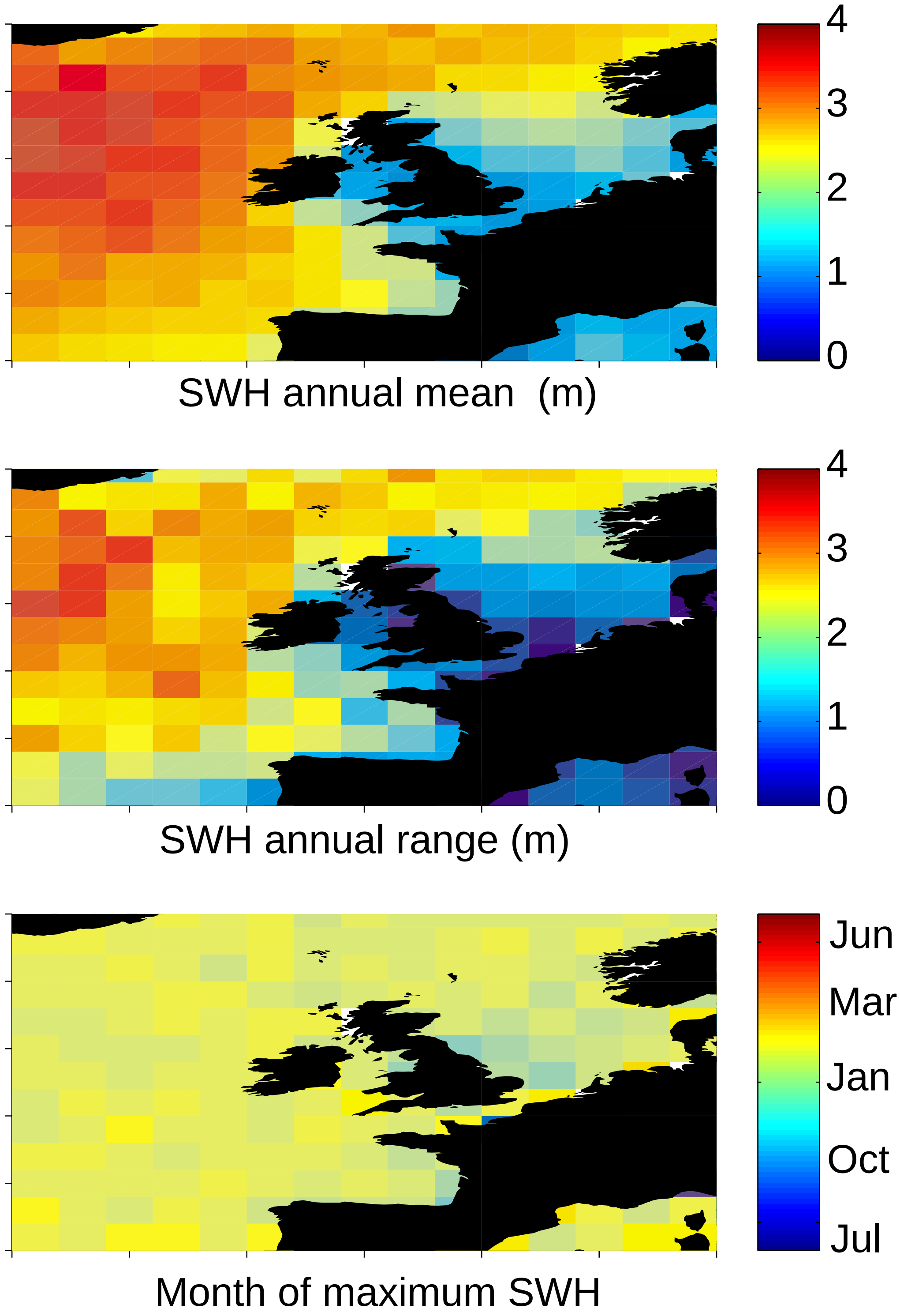

Figure 1. Coefficients of significant wave height annual cycle fitted to monthly mean altimeter data: (top) annual mean H_s, (middle) annual range in H_s, (bottom) month of maximum H_s

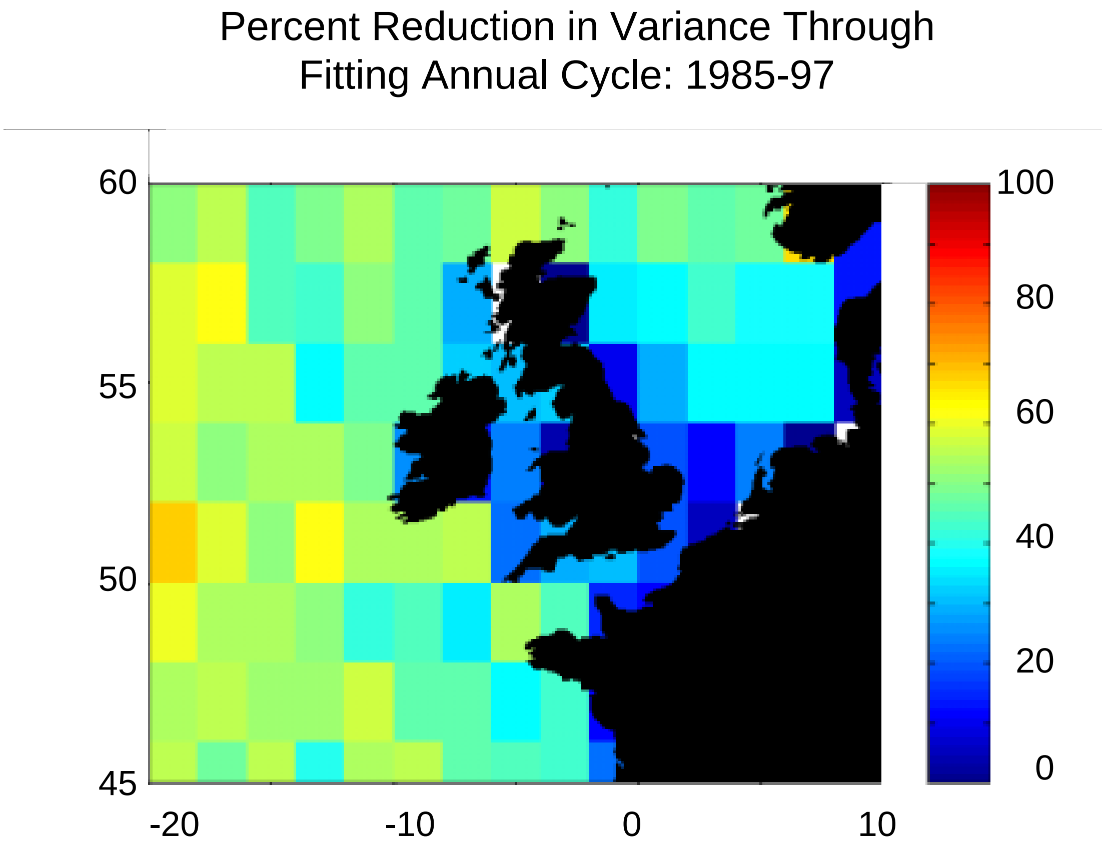

Figure 2. Percentage reduction in variance achieved by fitting annual cycle

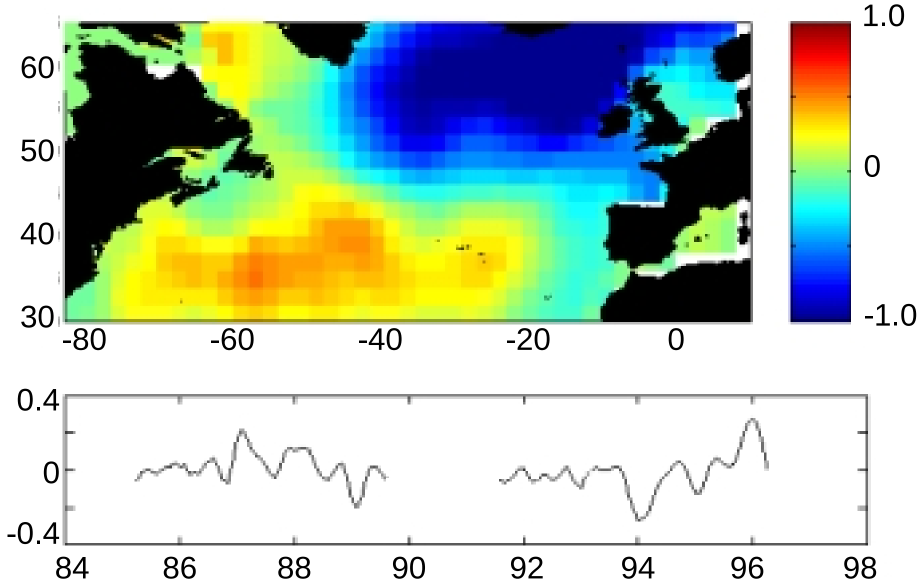

Figure 3. Spatial pattern and time series of 1st EOF mode of interannual variability in altimeter measured significant wave height climate in the North Atlantic.

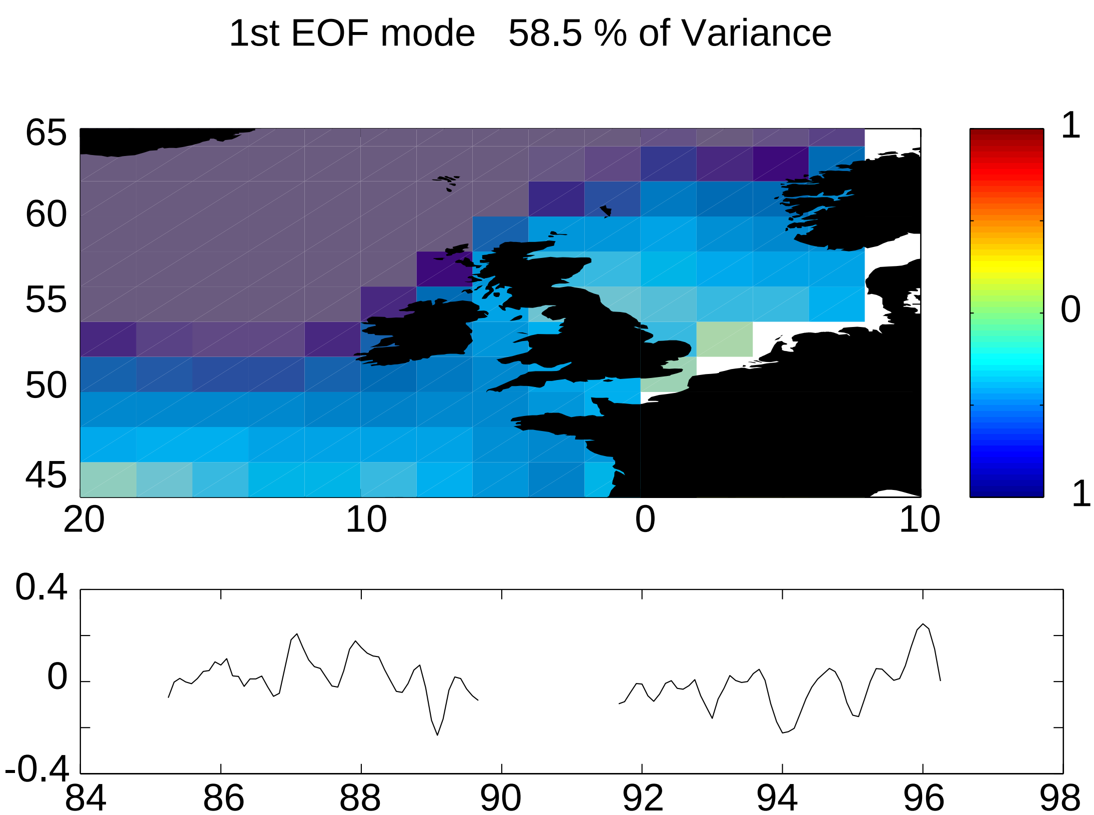

Figure 4. Spatial pattern and time series of 1st EOF mode of interannual variability in altimeter measured significant wave height climate in the North East Atlantic.

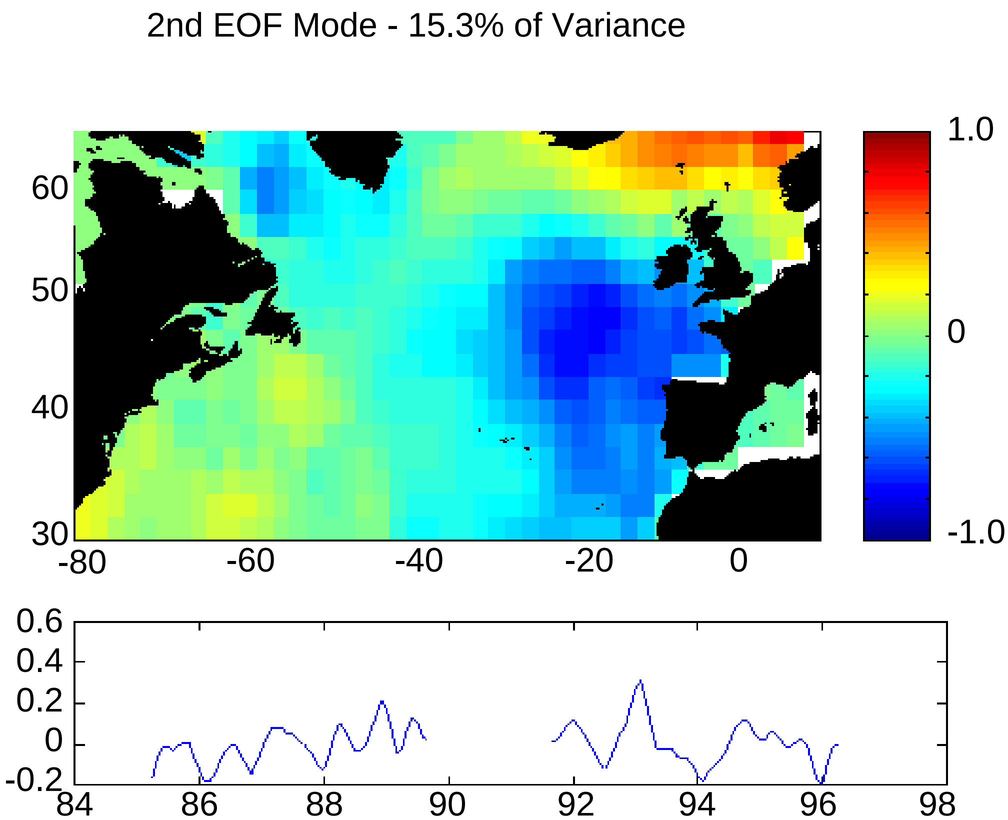

Figure 5. Spatial pattern and time series of 2nd EOF mode of interannual variability in altimeter measured significant wave height climate in the North Atlantic.

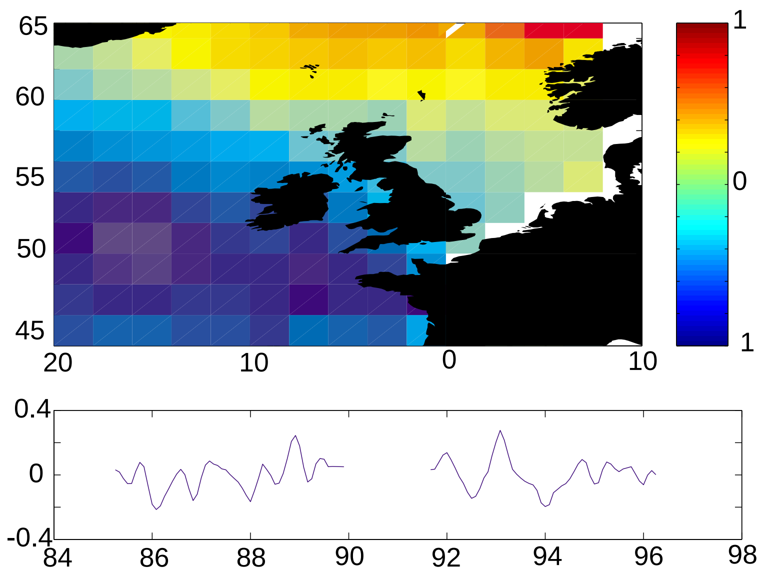

Figure 6. Spatial pattern and time series of 2nd EOF mode of interannual variability in altimeter measured significant wave height climate in the North East Atlantic.