APPENDIX B : Satellite Altimeter Data

B1. Introduction

Marine remote sensing satellites can now measure a range of parameters over the whole of the world s ocean surface. Measurements of ocean winds, waves, currents, temperatures and ocean colour are now possible from radar scatterometers, synthetic aperture radars (SARs), radar altimeters, radiometers, and optical sensors. Of these, the SAR and altimeter are capable of making wave measurements. SAR image data can give high spatial resolution images of sea surface radar backscatter, whilst SAR wave mode data provides estimates of the characteristics of the low frequency ocean wave spectrum. The satellite altimeter gives estimates of wind speed, significant wave height, and now wave period, but only in a narrow band directly beneath the track of the satellite. With almost continuous data since 1985 (apart from a gap in 1990-1991), satellite altimeters offer one of the longest time series of satellite derived global ocean data. SAR wave data have been (at least in principle) available since the launch of ERS-1 in 1991, and a number of authors have developed processing schemes and techniques to generate climatologies (e.g. Bauer and Heimbach, 1999, Mastenbroek and de Valk, 2000). However, whilst much progress has recently been made, it is difficult to interpret SAR data without the input from wave models, and SARs are still not able to measure short waves with periods less than about 7 s.

In JERICHO we were specifically concerned with coastal wave climate, and because of the shortcomings of SAR data it was decided to concentrate on satellite altimeter wind and wave data. Even so, previous studies with altimeter data have concentrated on offshore locations, so JERICHO represents a new application of altimeter data.

B2. Altimeter Data

B2.1. General Introduction

The satellite radar altimeter sends a pulsed signal directly down (at nadir) from the satellite, which is subsequently reflected from the sea (or land) surface and received back at the satellite. The time delay between transmission and reception allows an accurate measurement of the distance between the satellite and the ocean surface and hence, if the orbit height of the satellite with respect to a known surface is known, the height of the sea surface with respect to that same surface can be determined. Over the years since the launch of Geosat in 1985, procedures and models have developed such that the ocean surface height can now be measured to centimetre scale accuracy. When averaged over large regions millimetre scale changes in sea level can be detected.

Whilst the delay between the transmission and reception of the radar signal gives information about the location of the sea surface, the shape and strength of this returned pulse provides information from which accurate estimates of significant wave height and surface wind speed can be made. Most recently, thanks to work at Southampton Oceanography Centre (Davies et al., 1997), an estimate of wave period may also be made.

For more information on altimetry see http://www.satobsys.co.uk/Altimetry/

B2.2. Significant Wave Height

Because of the time difference between the reception of the radar signal reflected from the wave peaks and the wave troughs, the leading edge of the returned altimeter pulse is smeared out in time. The slope of this leading edge thus gives a measure of the height of the waves lying within the footprint of the radar beam (5-15 km in diameter at the ocean surface). In fact, when compared against *in situ* measurements this derived estimate of significant wave height gives a residual root mean square of about 0.3 m, close to the estimated accuracy of the *in situ* measurements themselves (see Figure 1). The altimeter has the added benefit of being largely unaffected by extreme sea conditions (except during very heavy rainfall, which attenuates the radar signal), whereas buoy and ship data can become increasingly unreliable in high seas.

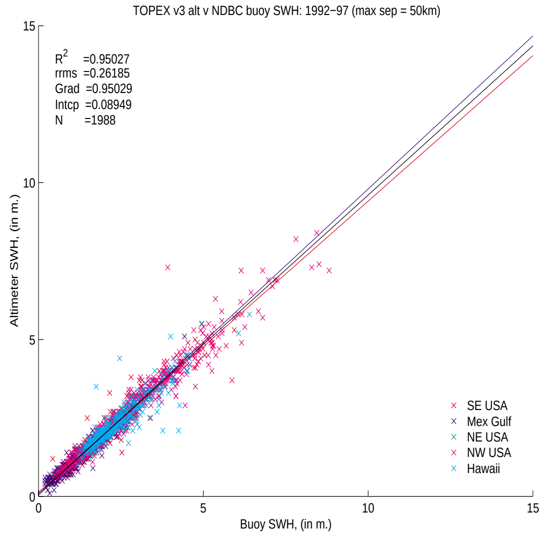

Figure 1. Scatter plot of co-located altimeter and buoy significant wave height data. Three regression lines are shown, alt on buoy, buoy on alt. and the principle component. From Cotton, 1998

B1.3. Wind Speed

An estimate of surface wind speed is generated from the radar altimeter measurement of normal incidence surface backscatter ($\sigma 0$), which is itself derived from the power of the reflected radar pulse received back at the altimeter. The physical principle behind this wind speed measurement is that the wind blowing over the ocean surface generates small centimetre scale ripples (at a similar wave length to the radar, ~2.3 cm for Ku band), which reduce the power of the signal reflected directly back up toward the altimeter and hence reduce the measured backscatter ($\sigma 0$).

The algorithm used to convert $\sigma 0$ into surface wind speed was derived empirically from co-located measurements of altimeter $\sigma 0$ and buoy measured wind speed. The algorithm in current, almost universal, usage was derived by Witter and Chelton (1991) for Geosat data, and has since been applied to ERS-1, ERS-2 and TOPEX/Poseidon data. Figure 2 shows the form of this $\sigma 0$ to wind speed relationship. When compared against *in situ* wind measurements, altimeter wind speeds show a residual root mean square of 1.5 ms^{-1} or better (see Figure 3). Recent studies by SOC and others have developed improved wind speed algorithms which include a dependence on both $\sigma 0$ and significant wave height and have shown (r.r.m.s) accuracies of close to 1.2 ms^{-1}.

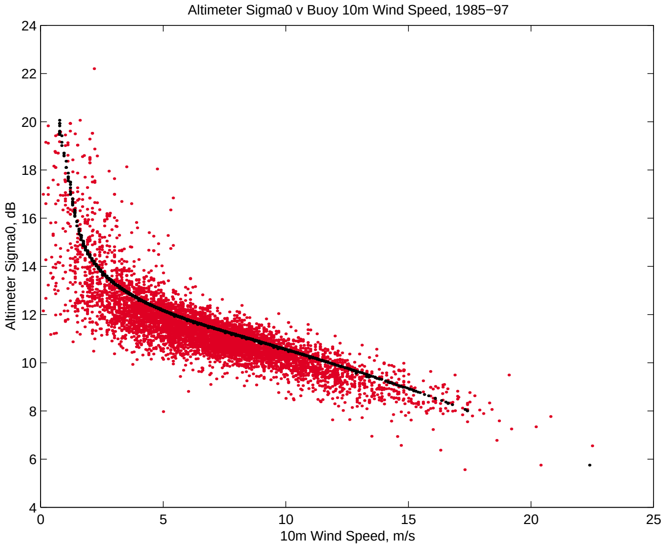

Figure 2. Scatter plot of altimeter σ^0 against buoy measured 10m wind speed. The black line indicates the σ^0/U10 relationship defined by the Witter and Chelton (1991), algorithm. From Cotton, 1998.

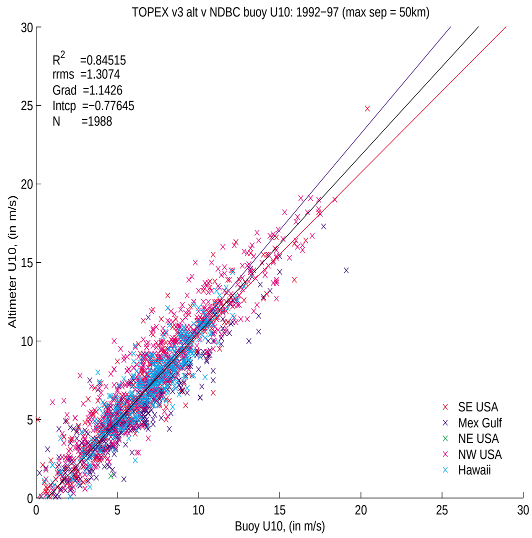

Figure 3. Scatter plot of co-located altimeter and buoy wind speed data. Three regression lines are shown, alt on buoy, buoy on alt. and the principle component. From Cotton, 1998

B1.4. Wave Period

A new algorithm to derive altimeter estimates of zero upcrossing wave period has been recently developed and tested at Southampton Oceanography Centre [Davies et al., 1997]. A theoretical algorithm was developed based upon the theory of wave statistics, and on the relationship of the moments of the wave spectra to the wave parameters that can be measured by a radar altimeter (significant wave height and radar backscatter). Further empirical developments resulted in the inclusion of a wave age (see below for a definition) dependent term in the final proposed algorithm. Wave period estimates derived from this algorithm were then tested by Cotton [1998] against independent buoy data. This confirmed that the altimeter could provide a useful estimate of wave period (to an accuracy of 0.7s), over a range 4-12 s in the open ocean (see Figure 4). However, these comparisons also indicated that linear calibrations should be applied to data from different satellites to ensure consistency.

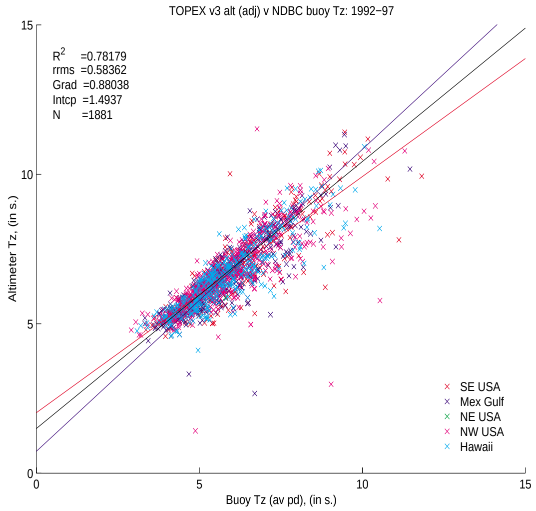

Figure 4. Scatter plot of co-located OPEX wave period data with NDBC buoy data.

Within JERICHO (JTR-9, JTR-19), the performance of the new altimeter Tz parameter in sheltered seas was tested. It was concluded that the calibrated algorithm was capable of providing estimates of wave period to a residual root mean square accuracy of 0.5 s in the North Sea. However, some sea state dependence remained and it was found that the algorithm could not provide reliable estimates in conditions where moderate to large wave heights and low winds occurred together. It was therefore recommended that the use of the algorithm should be restricted to conditions with wind speeds above 2 ms^{-1} and altimeter derived pseudo wave ages of less than 13. [Pseudo wave age, $\xi = 2.56.\ (H_s^2.g^2/U_{10}^4)^{0.3}$]

B3. Altimeter Satellite Missions

To date, measurements from 4 satellites have provided global altimeter wind and wave data, starting with Geosat in 1985 (until September 1989), followed by ERS-1 (August 1991 — June 1996), TOPEX/Poseidon (October 1992to the present day) and ERS-2 (May 1995 to the present day). New and planned missions include: the US Navy s Geosat Follow-On altimeter satellite, which was launched in February 1998 but is not yet fully operational; the US/French JASON altimeter satellite, which will be launched in June 2000 as a follow-on mission to TOPEX/Poseidon; and ENVISAT, the European Space Agency (ESA) follow on to the ERS missions, which has a launch scheduled for June 2001.

B1.1. Geosat

The Geosat altimeter satellite was built and operated for the US Navy. It was launched into polar orbit with an inclination of 108¡ (so reaching a maximum latitude of 72¡). For the first 18 months of its operational life time, April 1985 —September 1986, Geosat carried out the Geodetic mission, with closely spaced ground tracks on a non-repeating orbit cycle. Geosat was subsequently moved to a repeating 17 day orbit, in the Exact Repeat Mission. Geosat started providing data in April 1985 and continued into 1990, though global data effectively ceased in September 1989 when the satellite performance began to deteriorate.

B1.2. ERS-1

The ESA satellite ERS-1 was designed to carry out a wide ranging programme of Earth remote sensing research. To achieve this ERS-1 operated a suite of remote sensing instruments, including a radiometer, scatterometer, synthetic aperture radar and radar altimeter. It was launched in July 1991 into a sun-synchronous 98¡ inclination polar orbit. ERS-1 was operational from August 1991 to May 1996, and was placed in a sequence of 3 day, 35 day and 168 day repeat orbits in order to fulfil the various aspects of its mission. Only very recently (March 2000) did ERS-1 finally fail.

B1.3. ERS-2

ERS-2 was built by ESA as a successor to ERS-1, and carried an almost identical suite of instrumentation. It was launched in April 1995 into a sun-synchronous 98¡ inclination 35 day repeat polar orbit, 20 minutes ahead of ERS-1. After the ERS-2 commissioning phase ERS-1 ceased regular operation in June 1996 and ERS-2 took over.

B1.4. TOPEX/Poseidon

TOPEX/Poseidon is a dedicated marine altimetric satellite, and is a joint US/French programme. The main instrument is the dual frequency TOPEX altimeter, but the satellite also carries the experimental solid state single frequency Poseidon altimeter which operates 10% of the time. TOPEX/Poseidon was launched in July 1992 into a 66¡ inclination orbit with a near 10 day repeat cycle, and became fully operational in October 1992. After some degradation in performance of the main TOPEX altimeter, the back-up B-side altimeter was switched on in February 1999 and took over. It is intended that the JASON mission will continue the TOPEX scientific programme after launch in June 2000.

B4. Altimeter Sampling

The altimeter measures only in a narrow swath directly underneath the satellite. Unlike wide swath instruments such as the satellite scatterometer or the scanning radiometer, the altimeter is not capable of providing complete global surface coverage in a short period of time. Indeed, for most altimeter orbital configurations, the major part of the ocean surface will never be sampled. The selection of orbital repeat period depends on the scientific objectives of the satellite mission, and a trade-off between spatial and temporal sampling is required. If closely spaced ground tracks are needed, to give maximum surface coverage of time independent fields (e.g. for defining the small scale gravity field), then a non-repeating (the Geosat geodetic mission) or seldom repeating (the ERS-1 168 day) orbit is the best selection. If frequent revisits are required, for instance for calibration purposes against specific ground targets, then a frequently repeating orbit may be chosen (e.g. 3 day), but then the ground tracks are very widely spaced (> 900 km). Table 1 gives the repeat visit and track spacing that have been given by a number of altimeter orbits in the past. Figure 5 illustrates the altimeter ground tracks over the UK for the TOPEX 10-day repeat orbit and the ERS-1 / ERS-2 35 day repeat orbit.

Satellite	Repeat Period	Approximate ground track spacing at equator
ERS-1	3 days	925 km
TOPEX	10 days	280 km
Geosat	17 days	160 km
ERS-1/ERS-2	35 days	80 km
ERS-1	168 days	16 km

Table 1 track spacing and repeat periods of altimeter orbits

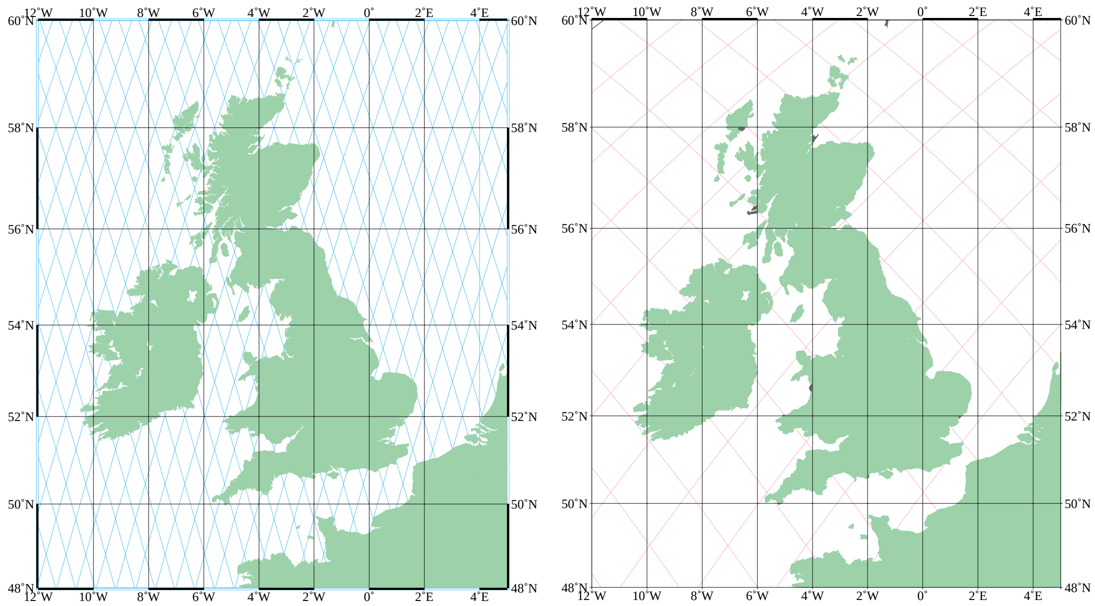

Figure 5. Altimeter sampling patterns over the seas around the UK, for the ERS 35 day cycle (left), and TOPEX 10 day repeat cycle (right).

B5. Altimeter Data Sets used in JERICHO

B5.1. Introduction

Altimeter data were required in three forms for JERICHO, to suit different purposes. Along track individual geophysical data records were required, to extract individual 1 second measurements co-located with *in situ* data for inter-calibration of the satellite and buoy data, and for some local climate studies. Along track data interpolated onto a fixed grid (the GAPS data) were required for studies of inshore wave variability at the three JERICHO locations, and to provide the boundary conditions for the shallow water wave models. Finally, gridded monthly mean data were required for larger scale investigations of wave climate. Whatever the final format of the data, all data sets were subject to the same quality control and calibration procedures, outlined below.

B5.1.1. Quality Control

A range of quality checks were applied to the individual altimeter data record values to ensure that only valid ocean data were extracted. Data quality can be affected if land, ice or heavy rain lies within the altimeter beam, and it is important to identify and remove such data. Thus appropriate data record flags were checked, and the values for significant wave height, wind speed and radar backscatter were required to lie within an acceptable range. Checks were also made on the within 1 second standard deviations of the backscatter, significant wave height and absolute range measurements. Finally the satellite mispointing angle was required to be less than 1.0¡. Full details of these tests are given in Cotton, 1998.

B5.1.2. Calibration

Comparisons against *in situ* data have shown that measurements made from different satellite altimeters require calibration to ensure that they are consistent with each other and with the surface measurements. Such calibrations have been applied to all data used within JERICHO, and those used are listed below in equations 1-15. All were derived in Cotton, 1998, where more details are available.

Significant Wave Height - Hs.

$$\text{Hs } Geosat_{cal} = 1.1393 \times \text{Hs } Geosat_{uncal} + 0.0118 \tag{1}$$

$$\text{Hs } ERS1_{cal} = 1.1091 \times \text{Hs } ERS1_{uncal} + 0.3355 \tag{2}$$

$$\text{Hs } ERS2_{cal} = 1.0610 \times \text{Hs } ERS2_{uncal} + 0.0350 \tag{3}$$

$$\text{Hs } TOPEX_{cal} = 1.0523 \times \text{Hs } TOPEX_{uncal} - 0.0942 - 0.0004 \times D_{drift} \tag{4}$$

$$\text{Hs } Pos._{cal} = 0.9790 \times \text{Hs } Pos._{uncal} + 0.0333 \tag{5}$$

D_{drift} is the number of days since 25 April 1997.

Note that the TOPEX calibration has a time dependent term, to correct for a drift in wave height measurements which occurred since 25 April 1997 (estimated at 0.4 mm day^{-1}). No TOPEX B-side altimeter data (data since February 1999) were used in JERICHO. These would require a different calibration correction, which has not yet been determined.

(10 m) Wind Speed — U10.

$$\text{U10 } Geosat_{cal} = 0.8961 \times \text{U10 } Geosat_{uncal} + 0.2775 \tag{6}$$

$$\text{U10 } ERS1_{cal} = 0.8964 \times \text{U10 } ERS1_{uncal} + 0.8453 \tag{7}$$

$$\text{U10 } ERS2_{cal} = 0.8767 \times \text{U10 } ERS2_{uncal} + 0.8411 \tag{8}$$

$$\text{U10 } TOPEX_{cal} = 0.8752 \times \text{U10 } TOPEX_{uncal} + 0.6796 \tag{9}$$

$$\text{U10 } Pos._{cal} = 0.8608 \times \text{U10 } Pos._{uncal} + 0.6325 \tag{10}$$

Again, data from the TOPEX B-side altimeter, if used, would require a different calibration. There is no time dependent term for the TOPEX wind speed calibration, as the TOPEX σ0 measurement was not significantly affected by the problems with the A-side altimeter. Note that a —0.63 dB correction was applied to all TOPEX σ0 data.

Wave Period — Tz.

Cotton, 1998, found that, even after the significant wave height had been corrected for each altimeter, the wave period measurements required further calibration, as follows.

$$\text{Tz } Geosat_{cal} = 1.0483 \times \text{Tz } Geosat_{uncal} - 0.7236 \tag{11}$$

$$\text{Tz } ERS1_{cal} = 1.1797 \times \text{Tz } ERS1_{uncal} - 1.6561 \tag{12}$$

$$\text{Tz } ERS2_{cal} = 1.2229 \times \text{Tz } ERS2_{uncal} - 1.9277 \tag{13}$$

$$\text{Tz } TOPEX_{cal} = 1.1358 \times \text{Tz } TOPEX_{uncal} - 1.6966 \tag{14}$$

$$\text{Tz } Pos._{cal} = 1.1463 \times \text{Tz } Pos._{uncal} - 1.8301 \tag{15}$$

B1.2. Geophysical Data Records (GDR)

Where raw GDR data were required they were either extracted directly from the CDs provided by NODC, ESRIN, or AVISO (for Geosat, ERS-1/2, or TOPEX data respectively), or were extracted from the Satellite Observing Systems WAVSAT archive. Contact details are given at the end of this report.

B1.3. GAPS Interpolated Data

The GAPS (Gridded Altimeter Processing Scheme) data set has been generated by Southampton Oceanography Centre (SOC) to meet a need for altimeter data at exact repeat locations. These data are available for the ERS-1/2 35 day repeat orbits and all the TOPEX (10-day repeat) mission. Geosat data, non 35 day repeat ERS data, and Poseidon data are currently not available within this scheme. The data that are included have been reformatted and interpolated onto a fixed grid, such that data on repeat passes are co-located. It should be noted that some problems were found with TOPEX data for the first data point on a track coming off the land. The significant wave height measurement for this first point was sometimes found to be higher than subsequent points lying further offshore, and more detailed investigation indicated that such values were likely to be in error. It seems that these higher values are a consequence of the along track averaging which is incorporated in the TOPEX GDR data. Hence it is advised that TOPEX coastal data from GAPS are used with care. For access to the GAPS data contact SOC.

B1.4. Gridded Data

Gridded data were used within JERICHO to study larger scale climate, based on monthly means of wind and wave parameters. In all cases the gridded data were constructed in the same basic way. Significant wave data were extracted from the GDR data sets and quality checked. The median value of all the valid data for each separate satellite transect of each grid square within the required period (for JERICHO one month) was then taken and calibrated according to the equations given above. These median values were taken to be independent samples of significant wave height, transect medians were chosen to minimise the effect of outliers.

The average, number, and sum of squares of these median values over the required time period (here 1 month) were all recorded. Thus the monthly mean and variance may be calculated. Where data from more than one satellite were available, they were combined with weights according to the number of transects across each grid square by each satellite. The final product was a gridded monthly data set.

B1.4.1. 2¡ x 2¡ Monthly Mean Gridded Data

Where data from only one satellite are available, a monthly mean 2¡ latitude x 2¡ longitude data set seems to provide the best presentation of wave climate. This ensures that each square gets adequate sampling (at least 5 transects within each month are required) to ensure a representative measurement of the monthly climate. Checks against monthly mean *in situ* data have confirmed this (Cotton and Carter, 1994). This spatial resolution has been found to work well for large scale open ocean studies. Analysis of these data have identified new patterns of wave climate variability (Cotton et al., 1999).

B1.4.2. 1¡ x 2¡ Monthly Mean Gridded Data

For coastal studies, or regional studies where there is high small scale spatial variability in the wave field, a 2¡ x 2¡ grid is too coarse. Grid squares can span peninsulas on either side of which the wave climate may be subject to completely different influences, and so display entirely different characteristics. Thus, where data from more than one satellite are available, it is worth investigating whether it is possible to generate a higher resolution wave climate. With this in mind JERICHO investigated the possible use of 1¡ x 1¡ wave climate (JTR-10), for the period when data from two satellite altimeters (ERS-1/2 and TOPEX: 10/92 —12/98)were available. Unfortunately it became clear that this grid did not receive enough sampling, with a large number of 1¡ grid squares receiving less than 5 transects in a month (Figure 6).

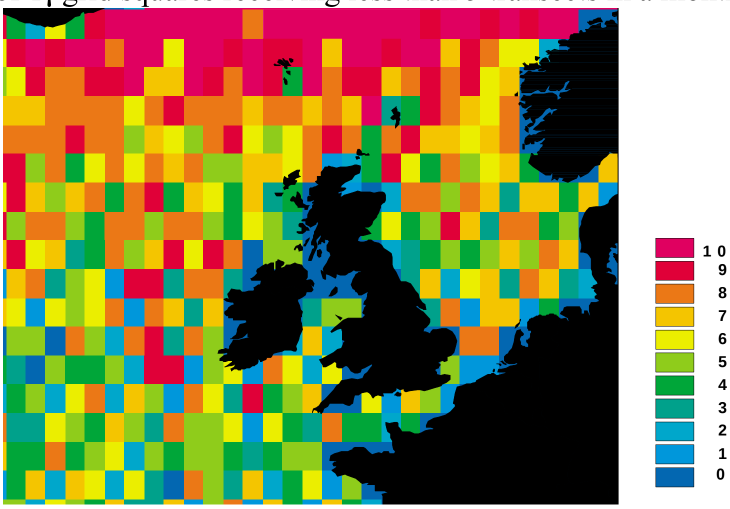

Figure 6. The number of transects per 1¡ x 1¡ grid square (from TOPEX and ERS-1) in December 1992.

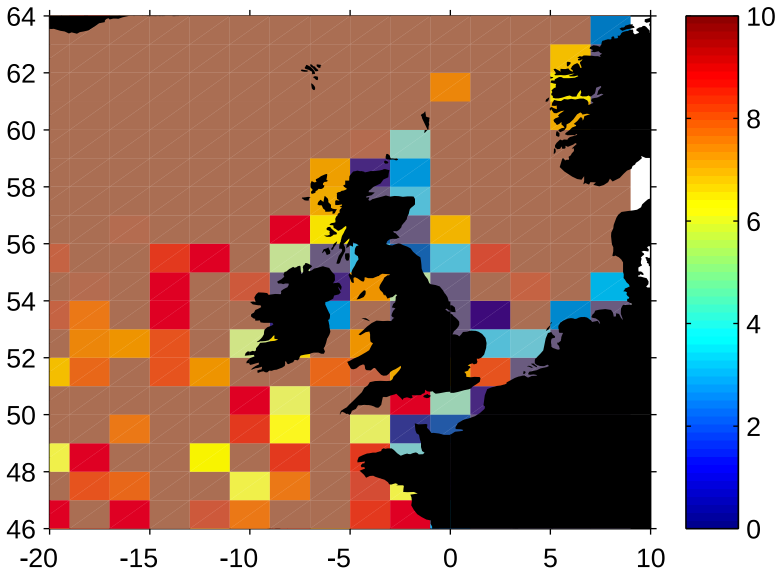

Figure 7. The mean number of transects per 1¡ x 2¡ grid square per month (from TOPEX and ERS-1) in January-March 1992-1998.

A compromise was therefore reached, with a 1¡ latitude x 2¡ longitude monthly mean grid. This grid was found to provide adequate sampling (in terms of the number of satellite transects per month), except for some locations immediately adjacent to the UK east coast, and the NW French, Belgian, and Dutch coastline (see Figure 7). These data were then used for climate studies and to generate indicative maps of statistically derived wave climate parameters(JTR s 18, 26, 31)

B6. Use of Altimeter Data Sets for Coastal Studies

B6.1. Localised Coastal Studies

Satellite altimeter coverage of the coastal waters of the UK now spans a period of approximately 10 years. The recovery of wave heights from satellite observations is very useful for areas greater than approximately 10 km from the coastline. Thus, to be of direct use to coastal engineers these relatively deep water wave conditions have to be transformed to the sites of specific interest with help of a numerical wave model.

Wave direction is the one parameter the altimeter is quite unable to tackle. Even when constrained to be onshore, the direction of approach of extreme waves can be wide.

Future altimeters are expected to lock on to the sea surface in a much shorter distance, which would be helpful. Smaller distances between tracks and a more rapid repeat, say every day or 2 instead of the present 10 from TOPEX, would be very useful - but this combination of smaller distance between tracks and more rapid repeats would require a greater number of altimeters.

The detailed descriptions in the main report of the various data and analyses applied at Holderness, Lyme Bay and Carmarthen Bay show that a site specific approach was required in each case. In all cases a more confident estimate of wave climate including extreme values have been obtained by utilising both *in situ* measurements and satellite data, but the approach varied significantly between the sites. This variation was needed partly because of the differences in data available at each, and partly from the different nature of the sites - especially their varying exposure to the open ocean.

Off Holderness, the wave buoy measurements, including wave directions, were very useful, even though they were only for one winter. TOPEX data in Lyme Bay gave a valuable measure of the large spatial variability of H_s in coastal waters, even in quite deep water; this was also shown by the TOPEX data off the Devon coast.

B6.2. Integration with Wave Models

In general, the integration of satellite altimeter data into wave models was successful, although some desired parameters (direction, peak period) could not be provided.

Halcrow Maritime concluded that the availability of satellite wave data will provide further options of data sources for engineers, as at some places data from conventional sources are unavailable. For these critical positions satellite data could play an important role. However, satellite data are available only at widely spaced time intervals (10 days) as opposed to Met Office analyses which are available at 6 hourly intervals, or *in situ* data which can be hourly (or more frequent). A useful improvement to the satellite data would be the provision of wave directions, important for coastal management and port design. In JERICHO wind directions have been used to replace wave directions, a method which seemed to work well. However, swell wave directions could only be inferred in a general sense.

Whilst the quality of satellite data is now well established, the key question determining future acceptance for applications is: Can the satellite data can be made available at a competitive price, with a sampling density comparable to gridded model hindcast output?

The STORM and SWAN model results gave an indication of the evolution of waves into very shallow water, but the provision of input data - wave height, period and direction - at outer boundaries fixed relatively close to the coast did cause problems. It would have helped to have had models covering larger areas so that boundaries were further offshore, where scales of spatial variability are larger and where altimeters coming off the land can be expected to make measurements. Models with local wind energy input (e.g. PRO-WAM or SWAN on a coarser grid) would be needed for this. Optimum boundary conditions might be obtained by use of an offshore wave model e.g. UKMO model with assimilated satellite altimeter data.

References

Bauer, E. and P. Heimbach, 1999, Annual validation of significant wave heights of ERS-1 synthetic aperture radar wave mode spectra using TOPEX/Poseidon and ERS-1 altimeter data, *J. Geophys. Res*., 104, pp13345-13357.

Cotton, P. D. 1998, A feasibility study for a global satellite buoy inter comparison experiment. Southampton Oceanography Centre Research and Consultancy Report, No. 26, 73pp.

Cotton , P. D. and D. J. T. Carter, 1994, Cross calibration of TOPEX, ERS-1 and Geosat wave heights, *J. Geophys. Res.,* 97, 11383-11392.

Cotton, P. D. and P.. G. Challenor, 1999, North Atlantic wave climate variability and the North Atlantic oscillation index, , Proc. 9th ISOPE conference, Vol III, pp12-18, Brest, France, June 1999, ISOPE, Cupertino, CA.

Davies, C. G., P. G. Challenor, P. D. Cotton, and D. J. T. Carter, 1997, Measurements of wave period from radar altimeters, Ocean Wave Measurement and Analysis , proceedings of the third international symposium WAVES 97, Nov 3-7 1997, Virgina Beach VA., pp 819-826, ASCE, Virginia,

Mastenbroek, C and C. F. de Valk, 2000, A semiparametric algorithm to retrieve ocean wave spectra from synthetic aperture radar, *J. Geophys. Res.,* in press.

Witter D. L. and D. B. Chelton, A Geosat altimeter wind speed algorithm and a method for wind speed algorithm development, *J. Geophys. Res*., 96, 8853-8860.

JTR-1 Analysis of Co-located UKMO Open Ocean Buoy and Satellite Data, D. Cotton, Jul-98.

JTR-9 Assessment of altimeter Tz (preliminary), D. Cotton, Mar-99

JTR-10 Altimeter data on a 1¡ x 1¡ grid, D. Cotton, Mar-99

JTR-18 Analysis of wave height climate variability from 1¡ x 2¡ monthly means, D. Cotton, Jun-99

JTR-19 Analysis of altimeter wave period estimates in the North Sea, D. Cotton, Jun-99

JTR-26 Estimating statistical extremes and exceedance probabilities from 1¡ x 2¡ monthly data set D. Cotton, Oct-99

JTR-31 Report on CCA of NAO and Wave Climate, D. Woolf, Nov-99

Contacts for Satellite Altimeter Data

- AVISO - For TOPEX data:
  AVISO / Altimetrie
  18, Avenue Edouard-Belin
  31401 Toulouse Cedex 4
  FRANCE
  Tel: +33 561 751 014
  Email: aviso@cls.cnes.fr

- ESA/ESRIN - ‘For ERS1 and ERS2 data
  EOHELP
  ESA-ESRIN
  Via Galileo Galilei
  00044 Frascati,
  ITALY
  Tel: +39 6 941 80777
  Fax: +39 6 941 80272
  Email eohelp@esrin.esa.it
  http://earth.esa.int/catalogues

- NODC — For Geosat data
  National Oceanographic Data Center
  User Services
  NOAA/NESDIS E/OC1
  SSMC3, 4th Floor
  1315 East-West Highway
  Silver Spring, Maryland 20910-3282
  Tel: +1 301-713-3277
  Fax: +1 301-713-3302
  Email services@nodc.noaa.gov
  http://www.nodc.noaa.gov/

- SOC — for GAPS data
  Peter Challenor
  James Rennell Division
  Southampton Oceanography Centre
  European Way
  Southampton S014 3ZH
  UK
  Tel: +44 (0)23 8059 6413
  Fax: +44 (0)23 8059 6400
  Email pc@soc.soton.ac.uk
  http://www.soc.soton.ac.uk/JRD/SAT/socsatweb/

- SOS — for WAVSAT data
  Satellite Observing Systems
  15, Church Street
  Godalming
  Surrey GU7 1EL
  UK
  Tel: +44 (0)1483 421213
  Fax: +44 (0)1483 428691
  Email info@satobsys.co.uk
  http://www.satobsys.co.uk/