A coordinated programme for global calibration/ validation of altimeter sea state data

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The main aim of this work is to calibrate Jason-1 wind and wave data against a large-scale buoy database. By applying a single calibration procedure, which includes a proper consideration of errors, we aim to bring all historical and current altimeter wind and wave data into agreement. A second aim is to assess the reliability of Jason-1 wind/wave measurements, including an investigation for dependencies on local environmental conditions. Finally, algorithm developments will increase the range and quality of wind/wave information that can be extracted from Jason.

Overview

Applications of altimeter wind and wave data range from the operational use of data in near-real time, through assimilation into forecast models, to the use of carefully calibrated offline products for climatological studies and predictions of extremes.

Accurate calibration is important for all applications, but particularly so for climate studies, where any bias in the altimeter wave heights, even of one or two percent, would affect the statistics. This would then render the database useless for studies of climate change in which trends of one or two percent per annum in annual mean wave heights have been found to be of significance [Bacon and Carter, 1991].

Many authors have carried out calibration and validation studies on wind and wave measurements from spaceborne altimeters, using a variety of data sets and techniques [Cotton et al, 1997]. However, because these authors have used different procedures and different validation data sets, it is difficult to combine their results to form a single combined assessment of the relative accuracies and reliabilities of the measurements from the different altimeters. This confusing situation exists across altimeter and buoy data sets, and creates a major obstacle to the full exploitation of these data.

The calibration carried out within this programme will be consistent with those performed by the same authors on data from all past and present radar altimeters (Geosat, ERS-1, ERS-2, TOPEX/POSEIDON, ENVISAT, Geosat Follow-On).
The principal objective is to apply a consistent calibration procedure across all altimeter and buoy measurements of winds and waves, generate a series of calibration corrections, and so provide users of wave data with the means to achieve consistent measurements of sea state across all altimeter and buoy data sets.

In addition the team will assess the reliability and accuracy of Jason-1 wind and wave parameters under different environmental conditions, and will aim to develop new algorithms to provide new or improved measurements of sea state.

The results will provide a thorough assessment of the reliability and accuracy of wind and wave measurements from Jason, generate new and improved algorithms to increase the range and quality of sea state information retrieved from the altimeter, and, most importantly, provide the means for users to generate a reliable, globally consistent data set across all altimeter and buoy measurements.

Calibration Procedures

Many previous calibration studies have applied quite crude methods of regression to derive relationships between calibration and reference data sets. Very rarely do these studies consider the nature of the errors in the individual data sets, before considering which techniques are most appropriate.

In the general case, errors are found within both the reference and altimeter data sets. Indeed, recent studies suggest the accuracy of altimeter significant wave height data is now close to that of buoy data. If we believe that the errors in the two data sets are equal, then we can generate the factors defining the linear relationship by completing two separate one-way regressions (e.g. altimeter on buoy, buoy on altimeter) and taking the line whose gradient is the geometric mean of the two slopes and which passes through the centre of gravity of the co-located data. More correctly, we should take full account of variance in both data sets by carrying out a full weighted orthogonal distance regression. In practice this procedure has rarely been followed, partly because of the complexity involved in generating associated estimates of error.

Other approaches can also include the effect of other environmental parameters, for example the effect of wave age on the measurement of wave period, by including extra terms in the relationship [Davies et al, 1997]. Stoffelen [1997] suggests that, where errors are not well known, analysis of triple co-locations can achieve simultaneous error modeling and calibration.

Altimeter Wind/Wave Algorithms

In recent years, significant effort has been applied to the problem of improving the accuracy of sea-state data from satellite altimeters.

An accuracy of retrieval for wind speed of the order of two meters per second was quickly achieved with the first algorithms [e.g. Brown et al., 1981], but still has not been significantly improved on.
The algorithm currently used to calculate wind speeds for altimeter geophysical data records (i.e. for ERS-2 and TOPEX) is one generated for use on Geosat [Witter and Chelton, 1991]. This algorithm was developed empirically, through comparisons with buoy data, and depends upon an assumed, unique relationship between the wind speed and the small-scale sea surface roughness caused by wind-generated gravity waves [e.g. Glazman and Pilorz, 1990]. However, a number of studies have demonstrated that the radar backscatter is not uniquely dependent on local wind-driven gravity waves, but also upon larger-scale waves. Authors such as Lefèvre et al. [1995] have therefore tried to include a degree of dependence on larger scales by including significant wave height in their wind speed retrieval algorithms. These new forms of algorithms have brought some limited improvement in accuracy, but they are still largely empirically based. In a recent development, Elfouhaily et al. [1997] have taken advantage of the two frequencies used by the TOPEX altimeter (Ku and C band). In their study they demonstrated that some of the effects due to non-local sea can be removed by considering the difference between the Ku and C Band radar backscatter. A further consideration, adversely affecting the accuracy of all wind speed retrievals from satellite radar measurements, is the need to estimate wind speed for a reference height above the sea surface (usually 10 meters). The radar necessarily makes a measurement exactly at the air/sea interface, and so any measurement must be corrected to the reference height. This is usually achieved by assuming a neutral boundary layer stability, but errors may occur when this assumption does not hold. Indeed, some researchers have found that the accuracy of satellite scatterometer winds depends on local air and sea temperature [Ebuchi et al, 1996]. Thus greater accuracy may be achievable by including some local information (instrumental, climatological or model) in a retrieval algorithm. In fact, it could be argued that satellite radar data are better used to make a direct estimate of wind stress, though there would be significant problems in validating such measurements.

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