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WAVE MODELLING ACTIVITIES OF THE WAM GROUP RELEVANT TO ERS-1

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ABSTRACT

An improved third generation wave model has been developed and successfully tested in various hindcast studies by the WAM (WAve Modelling) Group in both global and regional, deep and shallow water versions. The model will be applied to assimilate wind and wave data from ERS-1. For this purpose the model will be embedded in a comprehensive data assimilation system based on a global atmospheric circulation model together with the WAM wave model. The availability of such an operational system already at the time of the ERS-1 commissioning phase would greatly assist the calibration and validation of the ERS-1 wind and wave sensors.

Keywords: Satellite Wave Data, Ocean Waves, Wave Models, Data Assimilation

1. INTRODUCTION

The availability of global wind and wave data through the launch of ERS-1 and other oceanographic satellites in the nineties opens entirely new perspectives to wave modellers. It also poses major new challenges. One of the principal motivations for the formation of the WAM (WAve Modelling) group in 1982 was to respond to these challenges (Ref. 1). The major goals of the WAM programme with respect to ERS-1 may be defined as:

(1) The development of an improved operational 3rd generation wave model that can make effective use of the satellite data for both global and regional applications.

(2) The incorporation of wave data assimilation methods in operational wave forecasting.

(3) The embedding of wave models and wave data assimilation schemes in a more comprehensive wind and wave data assimilation system which will be able to process all available wind and wave data from both conventional observing systems and oceanographic satellites in a joint operation.

(4) The testing and application of these techniques to assist in the validation of ERS-1 wind and wave instruments during the commissioning phase of the satellite.

Although only the fourth point of this list is directly related to the main subject of the present workshop, it will be shown below that the goals (1) - (3) will already need to have been achieved in order to be able to effectively carry out the last task.

The need for sophisticated models and data assimilation techniques for an optimal instrument calibration and verification exercise follows on the one hand from the incomplete nature of both conventional and satellite wave data (quantitative measurements of the complete two-dimensional wave spectrum cannot yet be obtained by any standard measurement technique) and on the other hand from the coupling of wind and wave signatures in the satellite microwave sensor signals.

2. THE DEVELOPMENT OF A THIRD GENERATION WAVE MODEL

A detailed investigation of nine operational first and second generation wave models in the Sea Wave Modelling Project (Ref. 2) revealed that current wave models of both types suffer from basic deficiencies. First generation models, developed during the sixties and early seventies, are based on physics of wind-wave growth which we know today to be incorrect. It is in principle impossible to tune models of this type to yield correct predictions for all forms of generating wind fields. Second generation models, although based on our present, revised physical picture of wave growth (characterized by an order of magnitude reduction of the wind input and a corresponding enhancement of the nonlinear transfer) suffer from basic limitations in the parameterization of the nonlinear transfer and the representation of the spectrum. This prohibits reliable computations, for example, of the evolution of complex windseas in rapidly changing wind fields or of the transition of a windsea into swell as the waves propagate out of a generation region.

Methods of overcoming these shortcomings were indicated already in the SWAMP study and have since been realized in the third generation wave model developed by the WAM group (Ref. 3). The WAM model

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is available in both global and regional versions and has been extensively tested in hindcast studies of six Eastern Atlantic storms and three Gulf of Mexico hurricane cases. Third generation wave models may be defined as models which compute the full two-dimensional wave spectrum by integrating the basic spectral transport equation for a prescribed form of the source functions without any prior side conditions on the form of the resultant spectrum. Thus the models can be integrated for arbitrary wind fields, yielding arbitrarily complex wave spectra. The transition between windseas and swell is modelled as a continuous process without changes in the formulation of the basic physical processes controlling the transition.

Although the present WAM third generation model overcomes the basic shortcomings of first and second generation models and has been shown to be able to successfully simulate complex windsea and swell spectra for highly variable wind fields, more extensive applications of the model will presumably reveal deficiencies also in this model. However, the principal advance of the third generation model, namely the formulation of the model alone in terms of the transport equation, without any prior restrictions on the spectral shape, will make it possible to introduce future improvements of the model at the proper level. This is at the source functions, which describe the physical processes controlling the spectral energy balance, rather than in the form of the spectrum obtained by integrating the transport equation.

3. ASSIMILATION OF WAVE DATA INTO WAVE MODELS

Very little experience exists yet in the assimilation of wave data into wave models. Current wave models are routinely run using only the driving wind fields as input, without subsequent correction of the model wave prediction or hindcast with the aid of independent wave observations. The problem of wave data assimilation differs in several important aspects from standard atmospheric data assimilation methods for atmospheric models (Ref. 4).

(1) Wave data assimilation may be expected to significantly improve wave model prediction, but is not essential for the operation of wave models. Wave prediction is not primarily an initial value problem. As the wave field is continuously being generated by the prescribed wind field, the wave prediction skill is maintained after the initial wave field information has lost its impact on the evolving wave field.

(2) The region of influence of a wave measurement is strongly dependent on the wave field itself. Swell from a distant storm, for example, will generally have a significantly larger spatial correlation scale than a locally generated windsea.

(3) The correction of a predicted model wave field on the basis of wave measurements will in many cases require a simultaneous modification of the generating wind field which produced the erroneous wave field. Otherwise the uncorrected wind field will regenerate an erroneous wave field.

(4) Wave measurements by both conventional techniques (wave buoys, wave staffs, wave pressure measurements, visual estimates, etc.) and remote sensing techniques (altimeter wave heights, SAR image spectra) are invariably incomplete. One therefore requires additional information from a wave model prediction to reconstruct the best guess two-dimensional wave spectrum required as model input. In the case of SAR image spectra, information on the local wind is also needed in order to determine the modulation transfer function which enters in the relation between the SAR image spectrum and the wave spectrum.

The impact of these features on wave data assimilation is discussed more fully in Ref. 4. Here we note only that the coupling between wind and wave data mentioned in (3) and (4) above imply that wind and wave data assimilation need to be carried out jointly within the framework of a comprehensive data assimilation system including both types of data.

4. COMPREHENSIVE WIND AND WAVE DATA ASSIMILATION SYSTEMS

The requirement for a joint data assimilation system for wind and wave data follows not only from the interdependence of the information from both types of data in the assimilation cycle, but also from the cross coupling of these data in the satellite sensor signals. One of the motivations for designing the principal microwave instrument AMI of ERS-1 with a common C-band for both the scatterometer and the SAR was to obtain simultaneous mean backscatter and backscatter modulation data at the same microwave wavelength. It was anticipated that this would aid in the separation of the wind and wave influences in the signals of these two instruments. To develop improved sensor algorithms which take these effects into account, first guess wind and wave fields from models are required. It follows that the assimilation schemes will need to include the satellite data already at the level (Ib) of calibrated physical sensor data, rather than at the higher level (II) of retrieved geophysical data. The structure of such a general data assimilation system, and its relation to other processing centres planned for ERS-1, is discussed in Ref. 5.

5. APPLICATION TO ERS-1 WIND AND WAVE DATA CALIBRATION AND SENSOR VALIDATION

During the commissioning phase of ERS-1, wind and wave data derived from ERS-1 sensors will be compared with in situ data obtained by conventional measurement techniques during specific experimental campaigns or from continuously operating measurement stations. As discussed above, a simple one-to-one comparison between satellite sensor data and conventional measurements is not possible, as the remote sensing and in situ instruments measure different quantities. A relation between the two types of measurement can be established only with the aid of algorithms which, for optimal application, require first guess fields derived from models. Thus a reliable assessment of the optimal satellite instrument performance can be carried out only in the context of a fully operational wind and wave data assimilation system in which all available data are brought together and tested with respect to their mutual consistency with the aid of dynamical wind and wave models.

6. REFERENCES

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