Ocean forecasting and altimetry

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Météo-France, the French national weather service, is closely involved with satellite altimetry as a major user of operational data. It generates daily sea-state forecasts using numerical models that assimilate real-time data from satellites such as ERS-2. These forecasts are broadcast to seafarers to ensure the safety of ships and their crews, in the form of marine forecast bulletins, or for special support operations. Meteorological data are also used to calibrate radar signals emitted and received by the satellite, to validate derived geophysical data (wind speed, wave height, and so on), and to evaluate the impact of atmospheric effects on the radar signal.

Introduction

Météo-France, the French national weather service, is a major user of operational data derived from satellite altimetry. It generates daily sea-state forecasts using numerical models that assimilate real-time data from satellites such as ERS-2. These forecasts are broadcast to seafarers to ensure the safety of ships and their crews, in the form of marine forecast bulletins, or for special support operations. Because it allows us to measure sea surface height, satellite altimetry is helping us to better understand the ocean and to analyze it and predict patterns of change. It therefore offers clear opportunities to further our knowledge in all areas related to marine forecasting, and especially for sea-state predictions.

Météo-France is also closely involved during the preparatory phases of satellite altimetry missions, helping to define sensors, for example by running simulations to determine observation sensitivity using a wave model developed in house—simulations have provided a priori proof of the value of such measurements—and through calibration/validation actions in collaboration with the global scientific community. Météo-France is a vital link in the altimetric data processing chain, since meteorological data providing an accurate description of the atmosphere along the radar signal's path will be sent in real time to the SSALTO multimission ground segment at CNES.

Marine meteorology

The origins of meteorology can be traced back to the sea. When the French and British fleets in Crimea were torn apart by a storm that had previously wrought havoc throughout Europe, the Emperor Napoleon III, on the advice of the French astronomer Le Verrier, decided to create the forerunner of Météo-France.

Météo-France keeps a daily watch on the sea surface to monitor and forecast ocean weather conditions. Measurements that can help us to better understand, observe and predict the ocean-atmosphere interface are therefore of great value for forecasting sea surface conditions—this is the purpose of marine meteorology, aided by satellite altimetry.

Meteorological data for altimetry (SSALTO)

The radar altimeter signal is refracted and attenuated by the atmosphere. We need external data to evaluate these atmospheric effects.

For example, the pressure field at the sea surface enables us to estimate the signal path delay due to the vertical structure of the dry atmosphere. Atmospheric water vapor content, which also contributes to signal refraction and attenuation, can be estimated from measurements made by radiometers onboard the satellite. However, radiometers are not stable over time, so an external estimation based on meteorological models is useful to correct instrument drift. Sea level pressure is also used to isolate the signal due to the deformation of the ocean surface caused by atmospheric pressure. Météo-France provides all the data required to process and correct altimetry signals by the SSALTO multimission ground segment at CNES.

Bulletins and assistance

The chief mission of marine meteorology is to issue regular bulletins and special warnings for seafarers. These bulletins provide a brief description of sea state, which is derived by superimposing wind sea and swell. Sea state is a key factor affecting marine safety. It also dictates many operations at sea, for example on offshore platforms. Sea state predictions rely on special numerical models that assimilate real-time altimetry data. Until Jason-1 enters service, ERS-2 is the only satellite supplying such measurements, which are used daily at Météo-France.

Predicting sea state

While the sea may appear very chaotic and therefore virtually impossible to describe and predict in any detail, mean wave height depends on wind speed. A mean, statistically based description of sea state is therefore possible. Numerical wave prediction models allow us to forecast how superimposed wave trains are going to evolve at sea.

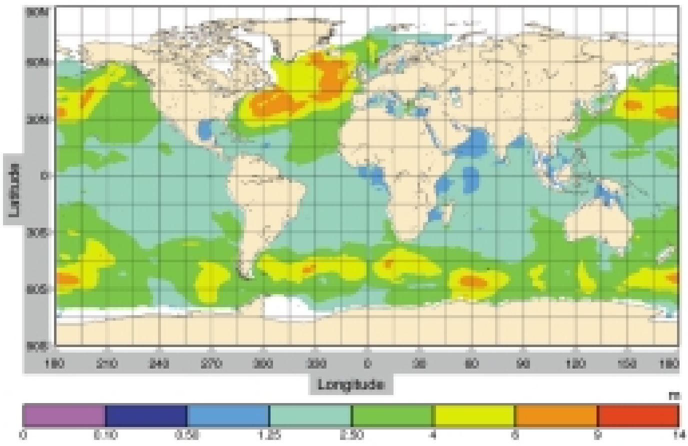

Figure 1: Wave field ($H_{1/3}$) calculated by Météo-France's VAG global model.

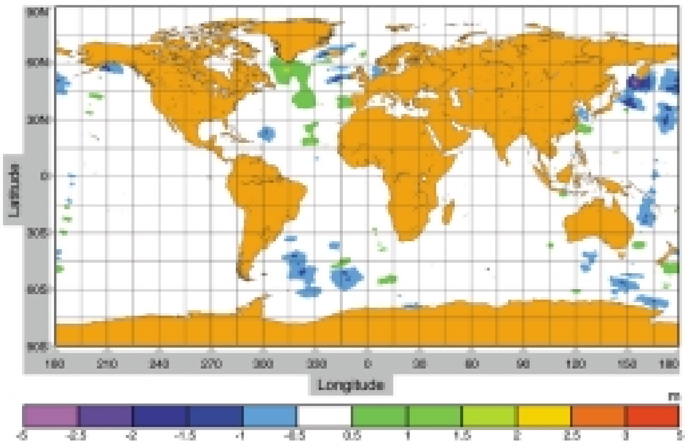

Figure 2: Corrections to initial data (analysis increments) calculated by wave model from ERS-2 altimetry data for March 8, 2001 at 00.00 UTC. Only corrections larger than 0.5 meters are shown.

Many weather services use wave models every day to predict sea state all over the globe. Such models are also capable of generating more refined output in certain areas.
An example wave field ($H_{1/3}$) calculated by Météo-France's global VAG model is shown in figure 1.

Tropical cyclones

Swell generated by tropical cyclones can be estimated and predicted using wave models. Altimeters are capable of tracking cyclonic waves in real time. Cyclones also generate storm-surges, which cause sea level to rise above normal due under the combined effect of lower pressure in the atmospheric column and the accumulation of water blown by winds towards the coast.

Observing waves

There are relatively few buoys around the globe transmitting data in real time (about 100, all but a few in the Northern Hemisphere) and they are all located near coastlines. Ships provide valuable information, but visual observations are not easy and data quality is therefore very uneven.
The radar altimeter is the only instrument offering almost global coverage with sufficient accuracy for most applications. The arrival of real-time altimetric data has encouraged the development of methods to extrapolate ocean surface observations in time and space. For example, many weather centers use wind and wave data from ERS-2 to estimate wave heights at any point. These data are extrapolated using meteorological models and wave models.
Corrections to initial output from wave models derived from ERS-2 altimetry data for March 8, 2001 at 00.00 UTC are shown in figure 2.
Only corrections larger than 0.5 meters are shown.

Measurement campaigns

Measurement campaigns are regularly organized to improve our understanding of the physical processes taking place at the air-sea interface.
Altimeter data complement in-situ measurements from instruments deployed during such campaigns. Some instruments are fitted on buoys, others on ships or airborne platforms.

Calibrating and validating satellite data

Meteorological data are used to calibrate radar signals emitted by the satellite and to validate derived geophysical data such as wind speed and wave height. In particular, data from moored buoys and meteorological models are used to extrapolate observed measurements in space and time on the basis of what we know about the underlying physical processes involved. Figure 3 shows an example comparison between $H_{1/3}$ data derived from a global model (WAM) and from TOPEX/POSEIDON.

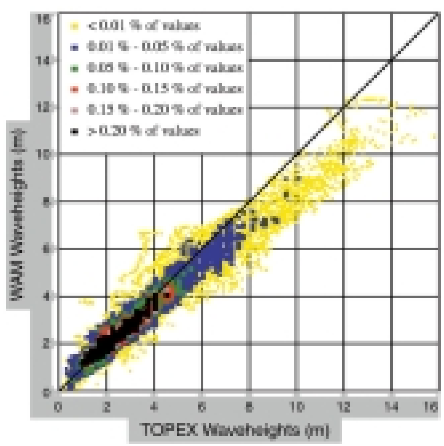

Figure 3: Comparison of $H_{1/3}$ data derived from a global model (WAM) and from TOPEX/POSEIDON.

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