SATELLITE ALTIMETER CALIBRATION OF A WAVE MODEL IN ARABIAN GULF

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Abstract: Active sensor devices for the sea surface have been used for many years in order to supply large scale information on the wave and wind fields. Among them, the most important is the satellite altimeter, whose main application so far has mostly been related to the calibration of forecasting or hind-casting models over the oceans. Enclosed or semi-enclosed seas pose a bigger challenge because of the rapidly varying wind and sea state fields, as well as of the relatively scarce time and space density of the coverage. The Arabian Gulf, in particular, is an ideal testing field for the synergy between wave modeling and satellite altimeter wave monitoring, since rainfall, one of the main cases of altimeter disturbances, is rare or virtually absent. Wave climate in the Gulf has already been thoroughly considered in depth and a full WAM based simulating system was setup. There is, however, a comparative scarcity of field data to verify and calibrate such a system, therefore the availability of space data is an important option. This paper presents some comparisons between the WAM based modeling system at Kuwait Institute for Scientific Research (KISR), with ERS-2, Envisat and Jason-1 altimeter data. Some measurements taken by wavemeters located off Dubai were also considered. In addition to that, the importance and the possible causes of small spatial scale oscillation of both wind and wave measurements from altimeter data is considered; such oscillations might

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provide an indication of spatial storm variability on a smaller scale than that of the standard meteo grids.

AVAILABLE DATA

KISR has installed and run a WAM modeling system for the entire Arabian Gulf area for a number of years (Al-Salem et al. 2005, Rakha et al. 2007). The model is normally driven by ECMWF analysis 10m wind field, since at present no real time or forecast capability is required.

The model was modified to operate on a personal computer and was set up for the Arabian Gulf (see Al-Salem et al. 2005), covering the entire Gulf to the 56.8° longitude with a grid spacing of 0.1°. Figure 1 shows the Arabian Gulf grid.

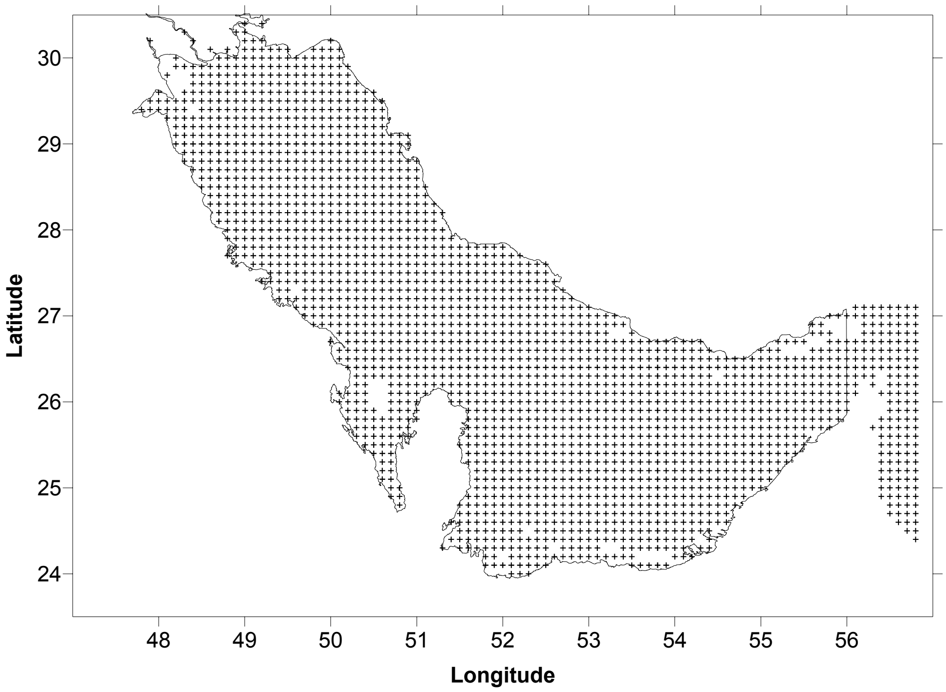

Fig. 1. Grid used for the Arabian Gulf WAM model

24 wave directions (15 degrees resolution) and 25 frequency bands are considered, with a computational time step of 300 seconds. Details on the model convergence and accuracy can be found in Al-Salem et al. (2005).

Wind data are derived from ECMWF 6-hour analyses, so they should be as reliable as possible, considering the relatively coarse grid of the global model. No weather Local Area Model was used and the values are simply interpolated to the finer grid of the WAM model.

Figure 2 shows an example of the 10m wind field interpolated on the WAM grid.

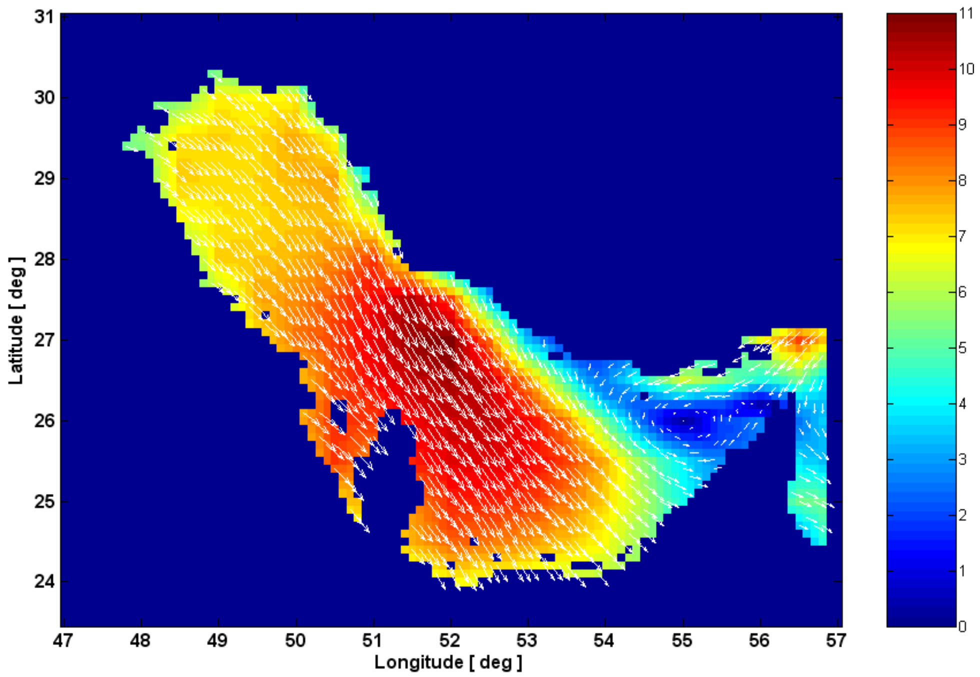

Fig. 2. ECMWF 10m wind field interpolated on KISR WAM grid

Since no recent wavemeter data is presently available for the Northern Part of the Gulf, and the only regularly available field data are collected by an ADCP profiler located on shallow water at about 8m (DMD) water depth and 200m offshore Dubai, by the Coastal Zone & Waterways Management Section of the Dubai Municipality. It should be taken into account that the ADCP is located in an area significantly sheltered by The World islands for the NW-SW sector and by Port Rashid breakwater for the NE sector as shown in figure 3.

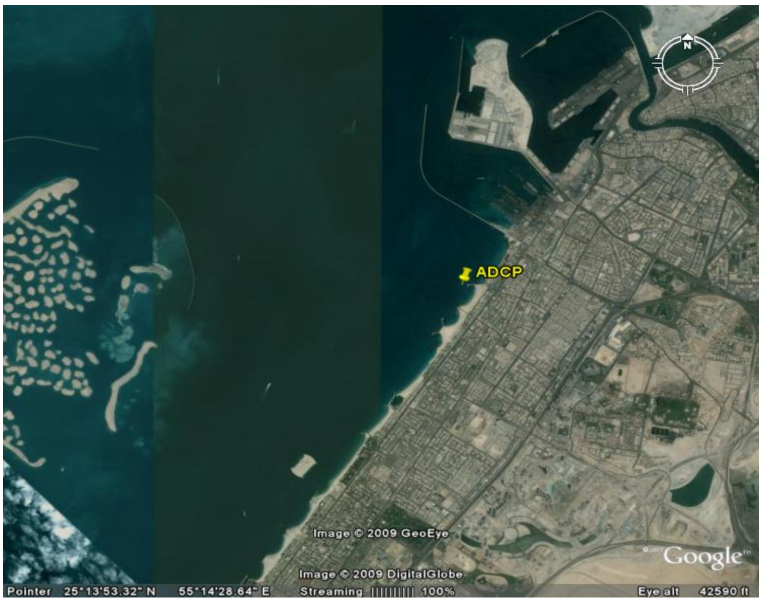

Fig. 3. DM ADCP position

Altimeter data come from various sources: NASA (Jason-1 and TOPEX/Poseidon) and ESA (ERS-1, ERS-2 and Envisat). Data collection has however become much easier due to the Radar Altimeter Database System (RADS, Naeije et al. 2006); it is therefore an easy task to locate all the orbits which interest the Gulf. Figure 4 gives an example for ERS-2 passages.

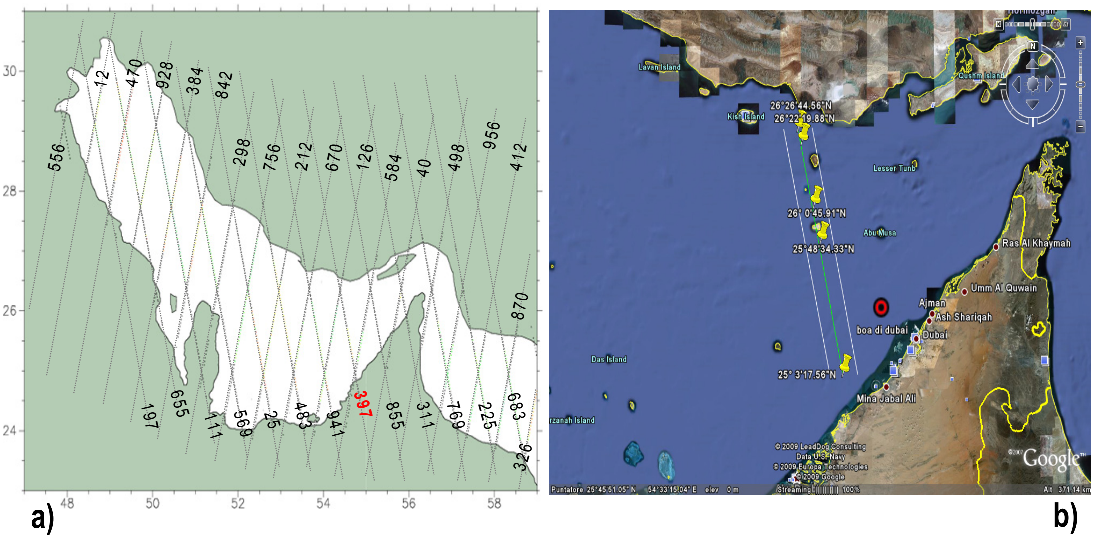

Fig. 4. a) ERS-2 passages on the Arabian Gulf area; b) track 397 and island interference

Of course the coverage varies with time, as satellites go in and out of commission, or their orbits are changed; a certain amount of elaboration is therefore necessary. Figure 4b) for example, shows that one interesting orbit flies over two islands, thus making the data useless unless a careful analysis is carried out of each individual track.

Based on over 15 years of WAM model running, a number of storms were selected for comparison with altimeter data; while most tracks can be of interest, in the following only a few examples will be given, and in particular from the northern and southern parts of the Gulf i.e. around Kuwait (in the following referred to as zone N) and off the UAE (zone S).

RESULTS AND ANALYSIS OF DATA

In order to analyze and correctly apprise the results, it should be remembered in the first place that no data assimilation is carried on, nor has the WAM model ever been calibrated, and in the second place that the ECMWF wind field sampling interval (i.e. 6 hours) is quite large considering the relatively small size of the basin.

Taking this into account, it is comforting to see that while the quality of fitting between model and altimeter may vary, most features of the measured data are reproduced by the model. The following figure 5 shows some of the results for the southern area (zone S).

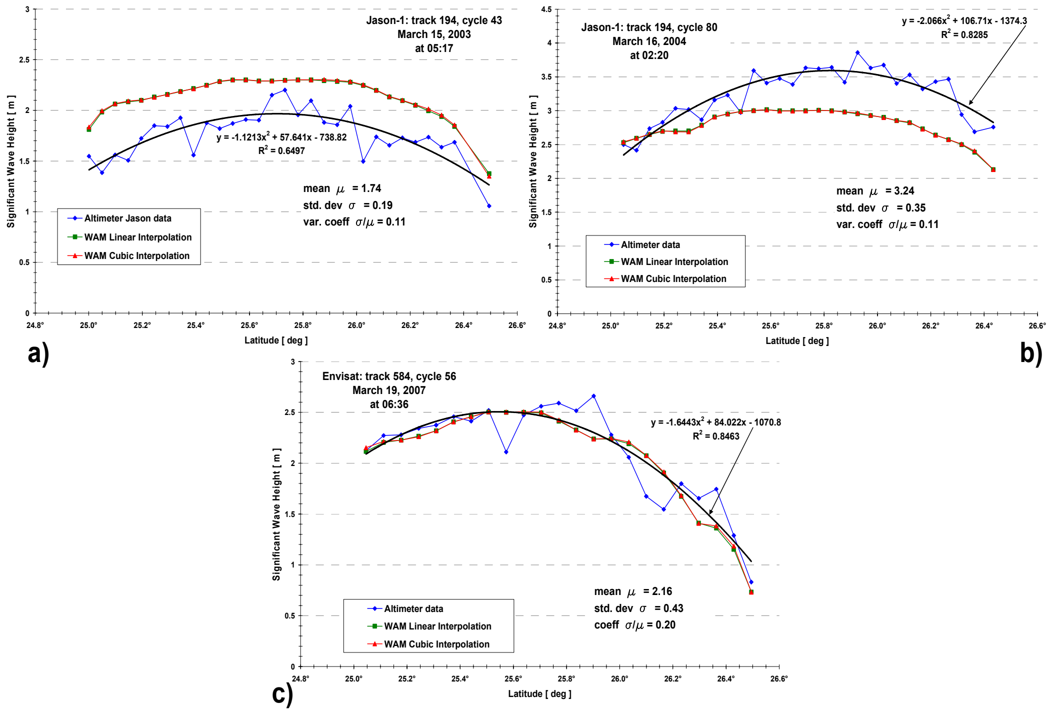

Fig. 5. Matching between WAM and altimeter data for zone S

While there is definitively a strong bias in some of them, the general behaviour of the spatial wave height is always respected, and in some cases the matching is impressive. A similar remark can be made for results in the northern zone N (see figures 6 and 7).

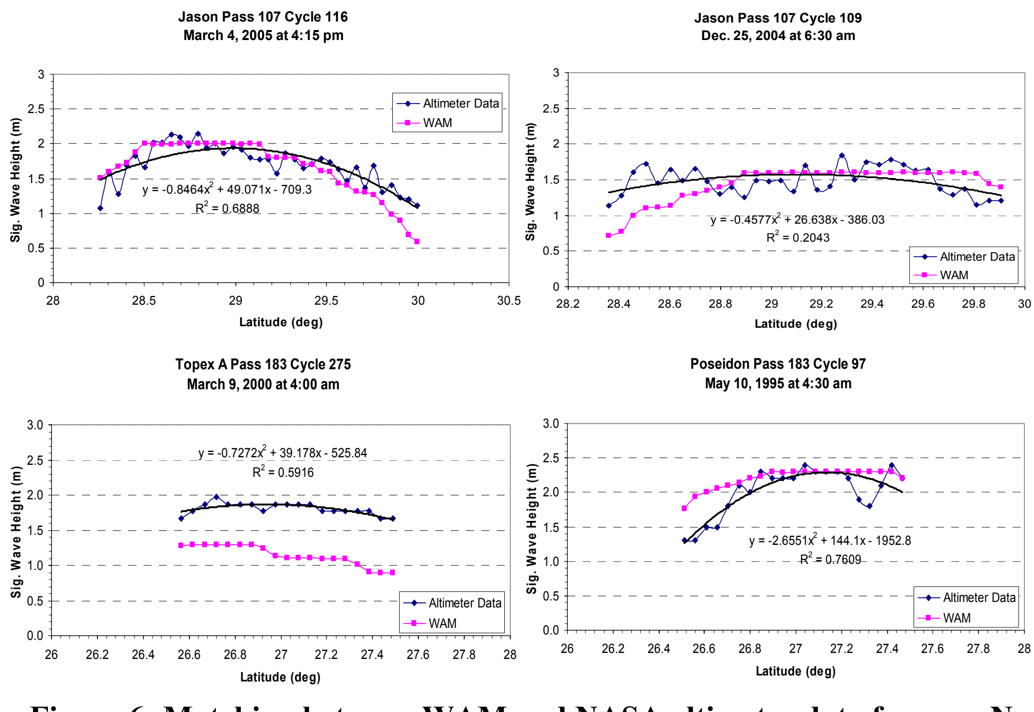

Figure 6: Matching between WAM and NASA altimeter data for zone N

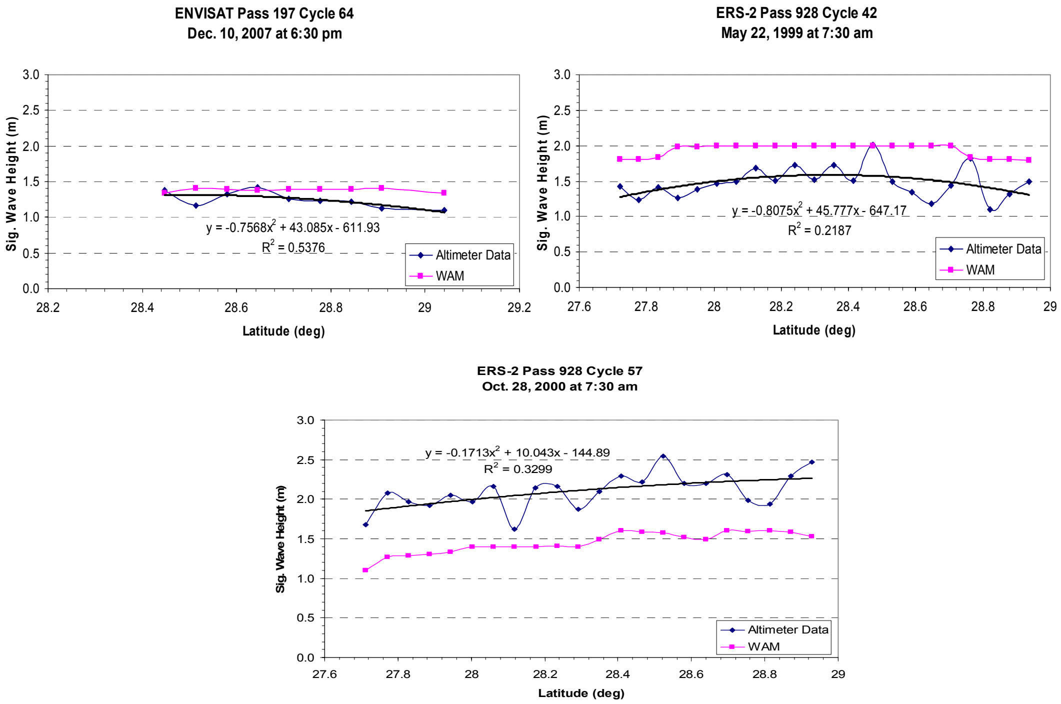

Fig. 7. Matching between WAM and ESA altimeter data for zone N

In particular, for zone S, some data are also available from the ADCP shown in figure 3 and located in very shallow water. The ADCP data comparison with Jason-1 altimeter data is shown in figure 8.

No satisfying matching could be attained between such local measurements and either altimeter or modelling results, except for the very general coincidence of stormy weather offshore and the high local wave heights; the reason for this, however, becomes evident if the position of the meter is taken into account, figures 3 and 9 located as it is close to the coast on the border of the model grid. If such data are to be made useful towards the calibration of a general wave model of the Gulf, a shallow water model higher resolution should be nested into the general WAM grid so as to take into account the transformation in the coastal zone.

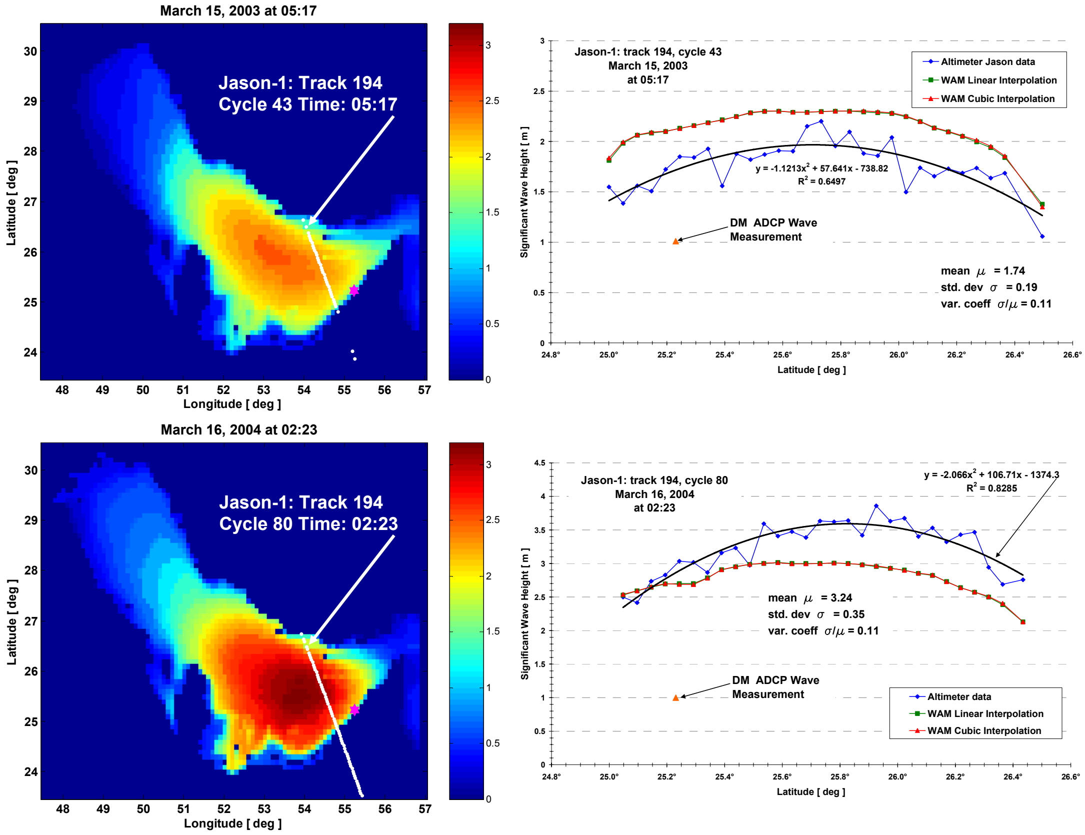

Fig. 8. Comparison with shallow water wave meter (Zone S)

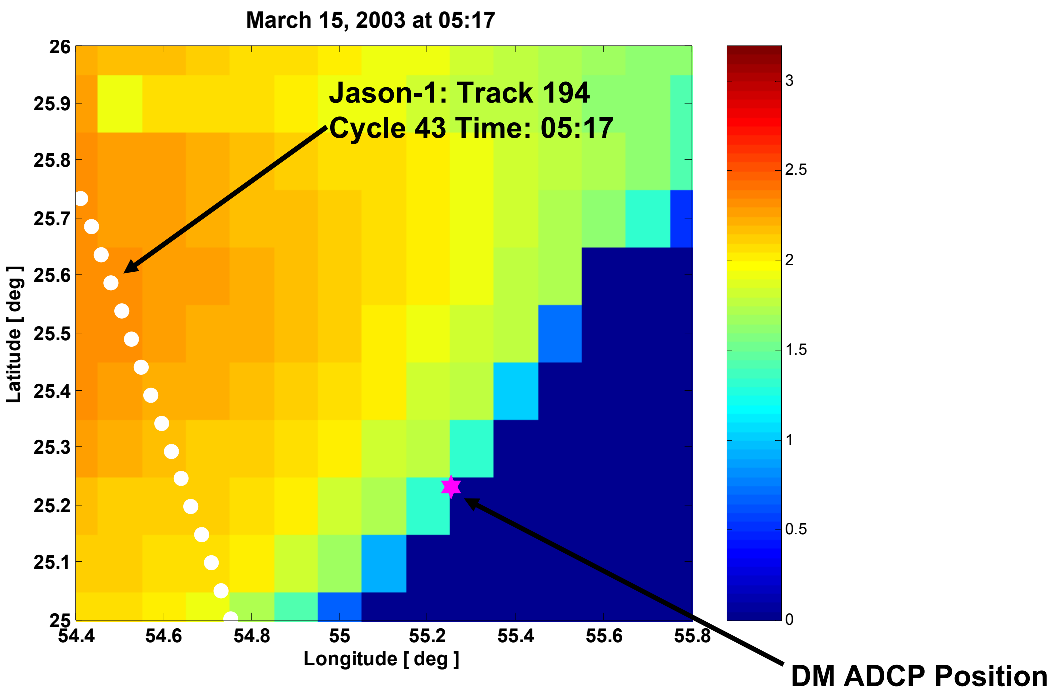

Fig. 9. Location of coastal wave meter (Zone S)

An important feature in all the results is the presence of random variation of both wind and wave data around a generally regular trend; even though such variability has been noticed and studied before, there are two aspects that are here worth considering: on the one hand, the time scale is smaller than what was considered in previous studies; on the other hand, the irregularity of wave data seems to be of the same magnitude, or even larger, than the irregularity of wind data, against all intuitive expectation. The scatter index (standard deviation of the difference normalised by the mean of the data) varies between 0.10 and 0.20, very similar to the values presented for the Tyrrhenian sea by Pugliese Carratelli et al. (2008).

An important possibility, first considered by Abdalla and Cavaleri (2002) on a larger spatial scale, is that such variations could provide an indication of small scale spatial storm variability: the stream of altimeter (ERS, Envisat and TOPEX) wind and significant wave data, acquired at intervals a few kilometres could be used to provide an indication of such variability ("gustyness") on a scale that is far lower than the resolution of meteorological models present, and probably also future. It is possible that gustyness is an important element in understanding extreme wave distribution, even though there are still open questions before satellite estimates become reliable enough to provide a quantitative estimate of the phenomenon. All this data could provide an interesting benchmark for sea surface signal simulation techniques (Della Rocca and Pugliese Carratelli 2000, Pugliese Carratelli et al. 2006 and 2007), but in order to do so single altimeter wave shapes would have to be examined (each significant wave height value is computed as the average of many values obtained by analysing radar pulses).

CONCLUSIONS AND FURTHER DEVELOPMENTS

The wave fields in the Arabian Gulf have been simulated for many years with a WAM model run by KISR and driven by ECMWF winds. Significant wave heights for a number of important storms as measured by various satellite altimeter have been compared with such simulations, and the results often show a good agreement, despite the lack of sea level data assimilation and the coarse wind grid. While the introduction of a Local Area Model for the forcing wind and the nesting of local models in the coastal area appear to be a necessity, the altimeter data have shown to be an excellent tool to calibrate a Wave Model even on a restricted sea. Significant wave height and wind speed values show a consistent scatter around their average values, as it was found in the past in both the Oceans and in the Mediterranean Sea. How much of this scatter is due to instrumental errors and how much to wind gustyness is not as yet clear, but further work on the Gulf should help clarify this point.

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