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SIMULATING THE BEHAVIOR OF WIND AND SWELL WAVES GENERATED BY CONSTANT WIND FIELD OVER PACIFIC OCEAN

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Abstract

Wam model is used with resolution 0.25^{O} to simulate wind and swell wave's behavior that is generated with constant wind speeds (0.1 m/sec to 20 m/sec). The area of study is over the Pacific Ocean (24°S - 3°N and135°W - 109°W).

It is found that the model results show for near calm wind case (0.1 m/sec), no significant impact up to 72 hours on wave height, swell and total wave height. It is also shown in the later case that the wave height is mainly swell wave. In this work a threshold wind speed value (about 7 m/sec) is detected. It is found that swell wave height decays (develops) with time as wind speed is below (above) the threshold value.

1- Introduction

Over the last 30 years, wave modeling has been increasingly used in a variety of applications, from ocean forecasting to wave energy production and coastal management. Ocean storms belong to large scales circulation and are mainly related to the processes of wind momentum transfer, nonlinear transfer, current refraction and turbulent dissipation of energy. As waves move toward the shoreline other, physical processes become more important, e.g refraction induced by sudden variations in depth (or by coastal currents) and shoaling.

The operational analysis and forecasting of wind-waves via numerical modeling is a well-established practice, and a substantial volume of literature provides a full description of its present capabilities, more details provided by Komen et al. (1994) and Janssen (2007) and Janssen et al. (1997). Soukissian and Prospathopoulos (2006) proposed that the significant wave height forecasts obtained from WAM-Cycle 4 model are validated by means of TOPEX/Poseidon (T/P) data in specific offshore locations in the central part of the North Aegean Sea. They concluded that the significant wave height from WAM is in underestimation, which has been concluded before in the previous study (Soukissian and Prospathopoulos 2003) from the comparison with buoys at near-shore points.

Gusdal, et al. (2010), studied the significant wave height (Hs) using the operational wave model WAM output at 50 km, 10km and 4km resolution (WAM50, WAM10 and WAM4) and is forced with 10 m/sec surface winds from the numerical weather prediction model HIRLAM to produce a 66 HR forecast. It is validated against EnviSat Radar Altimeter (RA-2) and in-situ observations. They conclusion came up by comparing WAM10 and WAM50 for 2010. The behavior of the two models is quite similar. When comparing WAM10 and WAM4, just small improvements are shown in the higher resolution model. This is due to the fact that the available buoys are located offshore where the advantage of WAM4 can't be seen, also it is found that the introduction of a higher resolution model together with changes implemented in the 10m forcing over the decade 1999 - 2010, has a positive improvement on the forecast of Hs. From the Categorical Statistics we find that the forecasted Hs for the period 2007 – 2010 (WAM10) has a higher hit rate of all exceeding Hs than for the period 1999-2007 (WAM50). It was find a much higher frequency bias in the 2007 - 2010 periods, which indicate that the wave model is forecasting higher wave events than observed.

Mazarakis1 et al. (2012) performed the validation of the accuracy of the WAM wave model over the Ionian and Aegean Seas. The period of validation refers to the first 12 months of operational use of the model at the National Observatory of Athens. The wave model is applied at a resolution of 1/16 degree and is driven by the wind of 10 m/sec, produced by the BOLAM meteorological model operationally run over the same area. Two different sources of data have been used for the verification of the model results. The first data set is provided by a network of buoys deployed over the Greek maritime areas and the second consists of altimeter data, provided by the OSTM/Jason-2 satellite platform. In general they concluded that the WAM model tends to underestimate the wave energy in the region of the Aegean Sea. The comparison with the altimeter data shows that the model has a tendency to overestimate the height for waves lower than 2.5 m and to underestimate the waves higher than 3 m.

The main aim of this experiment is to concentrate on providing an understanding of many processes by using Wam model over an area have no land on the Pacific Ocean. Also how Wam model simulate some phenomena that occur due to variation of westerly wind with different speeds.

2- Data and Methodology

The third generation wave model (WAM), cycle 4, is used to solve the wave transport equation explicitly. The WAM model involves the spectral energy-balance equation which describes the development of the surface gravity wave field in time and space as following:

$$\frac{\partial E}{\partial t} + \nabla \cdot (c_g\ E) = S = S_{in} + S_{nl} + S_{ds}$$

where:

E = E (f, θ, x, t) is the two-dimensional wave spectrum (surface variance spectrum) depending on frequency, f, and direction of propagation θ;

$C_g = C_g$ (f, θ) is the deep-water group velocity;

S is the net source function, consisting of three terms:

S_{in}: energy input by the wind;

S_{ds}: dissipation and

S_{nl}: non-linear energy transfer by wave-wave interactions.

The model was developed by WAMDI, group (1992) at the Max-Planck-Institute für Meteorologie in Hamburg (Germany). It has been installed at about 35 institutions worldwide and is used for research and also operational application. It is also being applied for interpreting and assimilating satellite wave data. This model was operated over the area have no land on the Pacific Ocean bounded by Latitudes from 3°N to 24°S and longitudes from 135° to 109° W with a horizontal resolution 0.25° degree.

The zonal numbers of grid points are 105 points and the meridional numbers are 113 points as shown in Fig. (1).

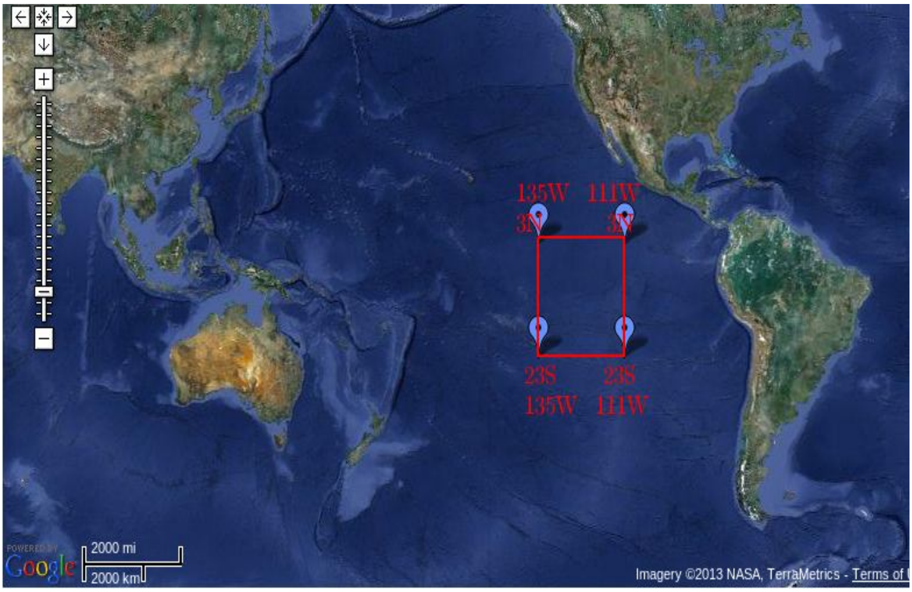

Fig. (1): Area of study on Pacific Ocean.

3- Results

3.1- Results for artificial blowing wind speed 0.1 m/sec

A total significant wave height after one hour from blowing westerly wind with speed of .1 m/sec is shown in Fig. (2), with range from 0 to 1.3 m heights. The initial significant wave height is 1.2 meter when wind blow from west direction over the area of study for one hour as shown in Fig. (2).

As a result of nearly calm wind (speed ≤ 0.1 m/sec) , there is no significant impact of wind into ocean surface. The wave height, significant swell and total significant wave height after 1 HR, 24 HR and 72 HR, are shown in Fig. (2). The figure indicates that the result of wave is mainly swell wave after 1 HR forecast. Also Fig. (3) and Fig. (4) confirm the same result as in Fig. (2), but after 24 HR and 72 HR forecast respectively. The decay of wave heights attains to north, south, and west boundaries with time. This decay is a result of the swell decay with time 24 HR and 72 HR as in Fig. (3) and Fig. (4), where there is no driving wind exist. Fig. (5), shows the decay of significant wave heights at different three Longitudes, 131° W, 123°W, and 111°W with constant latitude 11°S, where all waves heights are mainly swell. The rate of decay of wave height in western part of the domain is faster than that in eastern part, at longitude 131^{o} W where greatest value for the rate of decay was at the second day, while at longitude 123^{o} W the greatest value for the rate of decay wave heights were obtained at the fourth day, and at longitude 111^{o} W the greatest value for the rate of decay wave heights at the sixth day.

The slow decay at eastern part can be understood as result of the transport of swell from west to east, while there is no source of swell from western boundary, so this proved that there is a delay time for decay, in spite of there is no wind speed blowing at each point, we still have wave height.

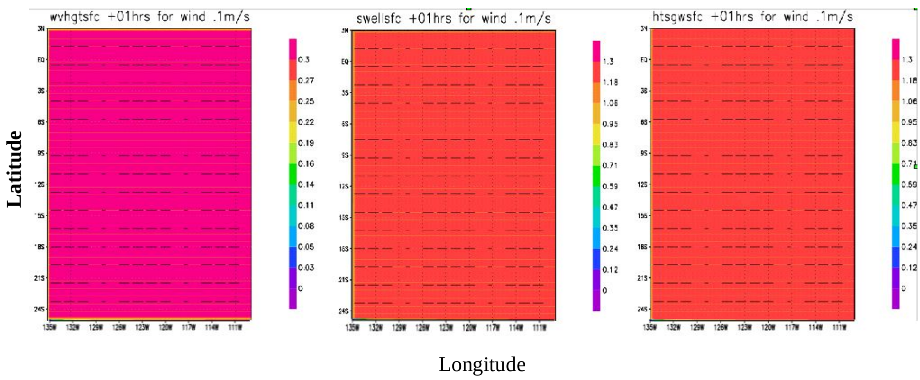

Fig. (2): One hour forecast for significant wave height of wind wave, swell, and the total height (respectively from left to right) in case of nearly calm wind (0.1 m/sec)

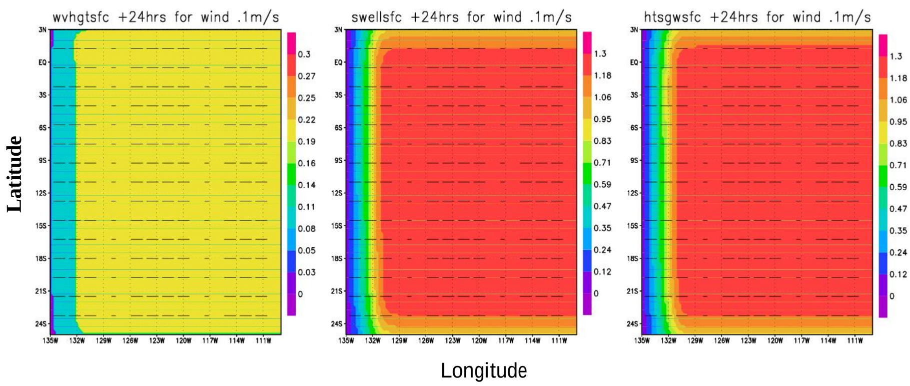

Fig. (3): 24 hours forecast for wave height of wind wave, swell, and the total significant height (respectively from left to right), in case of nearly calm wind (0.1 m/sec).

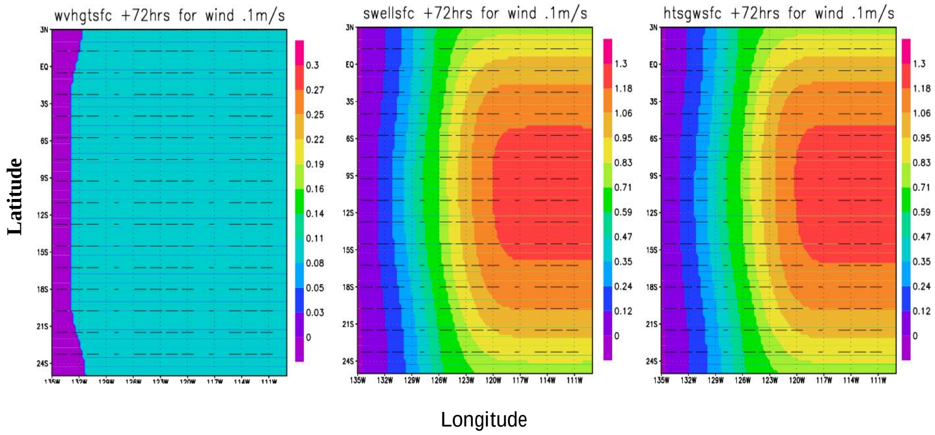

Fig. (4): 72 hour forecast for wave height of wind wave, swell, and the total significant height (respectively from left to right), in case of nearly calm wind (0.1 m/sec).

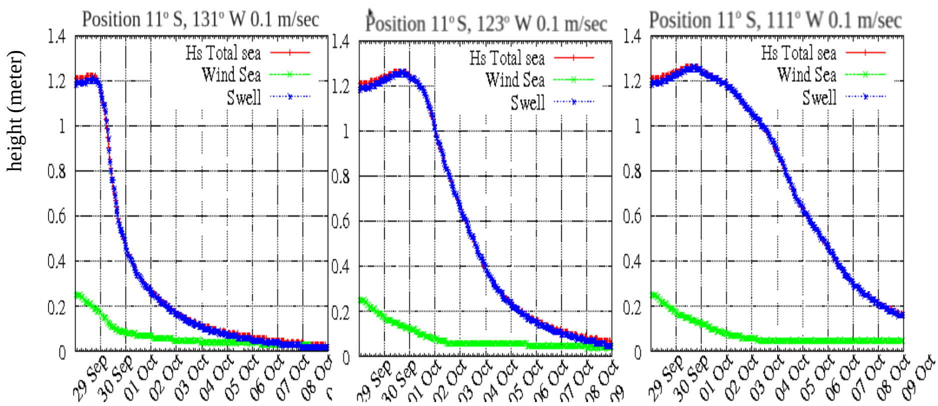

Fig. (5): Time series for decay of total wave, wind sea, swell at constant latitude 11^{O} S and different longitudes (131^{O} W, 123^{O} W and111^{O} W).

3.2- Reversed wind direction

In spite of the smallest value of wind speed (0.1 m/sec), the case of reversed wind from west direction to east direction, is completely shown in Fig. (6), illustrates the swell wave height after 1, 24 and 72 HR forecast. It is noticed that the rate of decay is reversed from right to left.

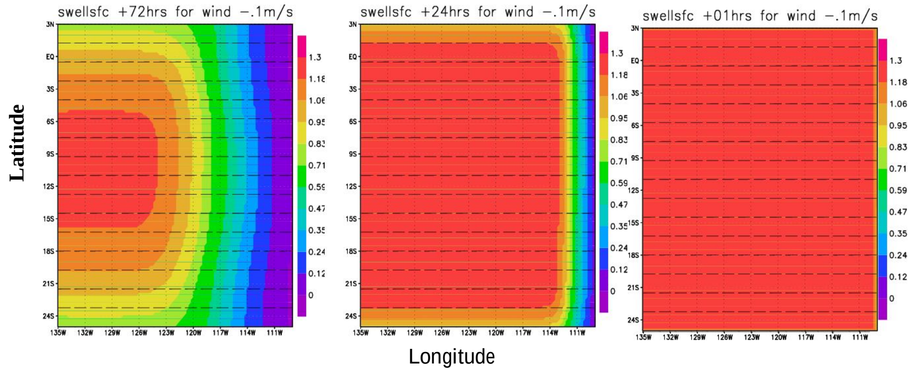

Fig. (6): Swell wave height (meter) after 1, 24, and 72 HRS forecast in case of nearly calm wind (0.1 m/sec) with easterly wind

speed (approximately 7 m/sec), below this threshold value, the swell wave heights were decayed with increasing of forecast time. On the other hand above this threshold value the swell wave heights were developed with increasing forecast time. Swell wave height continued to decay although the wind speed increased until 20 m/sec after one HR forecast only. This confirm that there was a limit for wind duration to increase wave height over sea surface and time delay between impact of increasing wind speed on sea surface height, that looks to be obvious from the Fig. (7), between the time after one hr. and 24 hrs. The model began with initial value of significant wave height 1.25m.

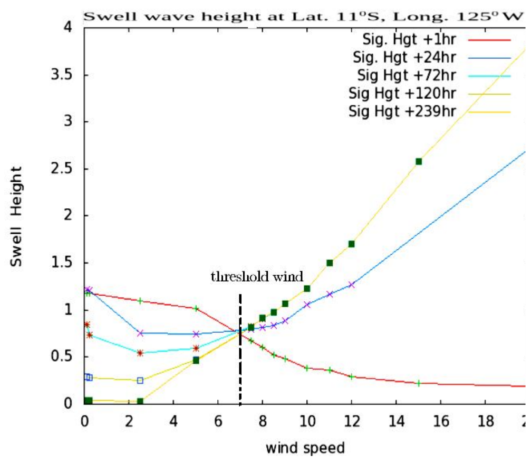

Fig. (7): Swell wave height (meter) at different wind speed (m/sec) after 1, 24, 72, 120, 239 HRS forecast.

Fig. (8), shows total, swell and wind wave respectively for latitude 11^{o} S and longitude 125^{o} W after one hour forecast at different wind speeds 0.1, 2.5, 5, 7.75, 8, 8.5, 9, 10, 11 and 12 m/sec. The figure shows that at initial time, for wind speeds of values less than the threshold value, the significant wave height mainly is produced by swell. This figure also shows that above the threshold value the significant wave height is mainly produced by wind wave. This Figure confirms the previous results as swell height decay with increasing wind speed for one hour forecast. While the wind wave starts with height (0.3 m) less than the initial value of the model (1.3 m) with wind speed from (0.1-2.5m) and then increased until reach the initial value after the threshold.

Below the threshold value, the energy given by the wind to ocean surface as wave height due to energy loss is less than the energy of dissipation as a result of dispersion and breaking, so the swell and the total significant wave height will decrease with time, as shown in the figure. For wind speed greater than the threshold, the energy given by the wind to wave is larger than the energy dissipated, so the wind wave height increases with increases wind speed as stated above.

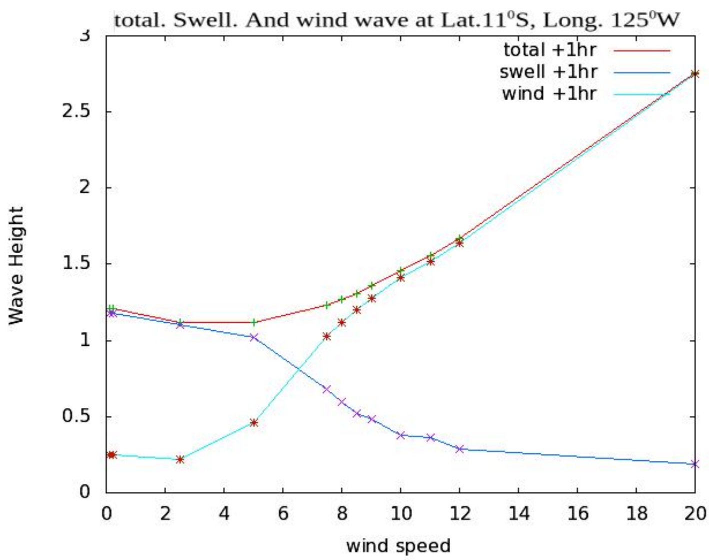

Fig. (8): Wind Sea, swells, and total significant wave height for different wind speeds.

3.4- Pattern of different wind speed before and after threshold

Figs. (9 and 10) show the behavior of total significant wave, wind wave and swell wave height with time from 29 Sep. to 9 Oct. below and above threshold value at 11^{o} S and 125^{o} W.

Below threshold value the wave was decayed and the model deals with height of wave as approximately swell wave and this seems to be acceptable, because the value of wind speed not enough to transfer energy from the wind to sea surface to reach the same height of initiation wave that are already exist as in Fig. (9).

Above threshold value the wave was developed and the model deals with height of wave as approximately wind wave, because the value of wind speed is more enough to transfer energy from the wind to sea surface to overcome the same height of initiation wave that are already exist as in Fig. (10). The characteristics of waves is constant at 1 Oct.

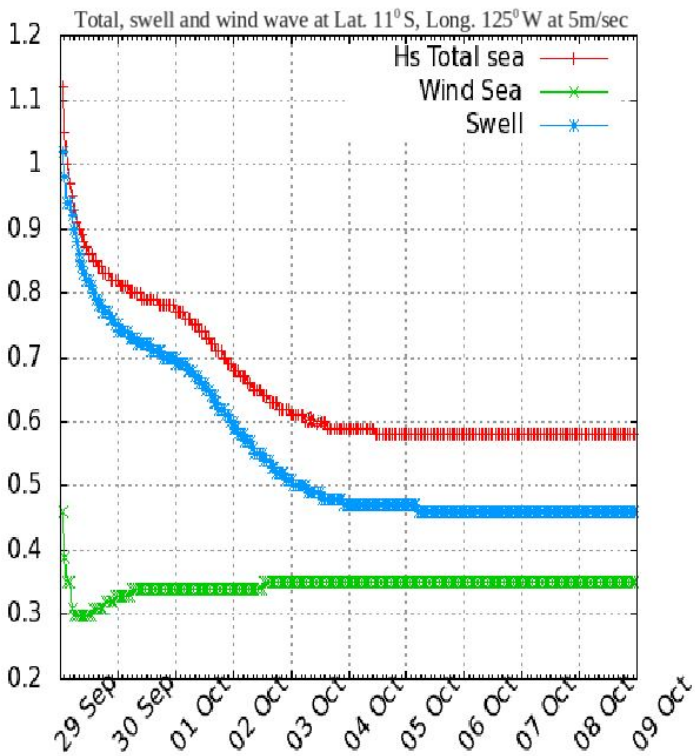

Fig. (9): Behavior of total significant wave, wind wave and swell wave height in meter with time at wind speed 5 m/sec.

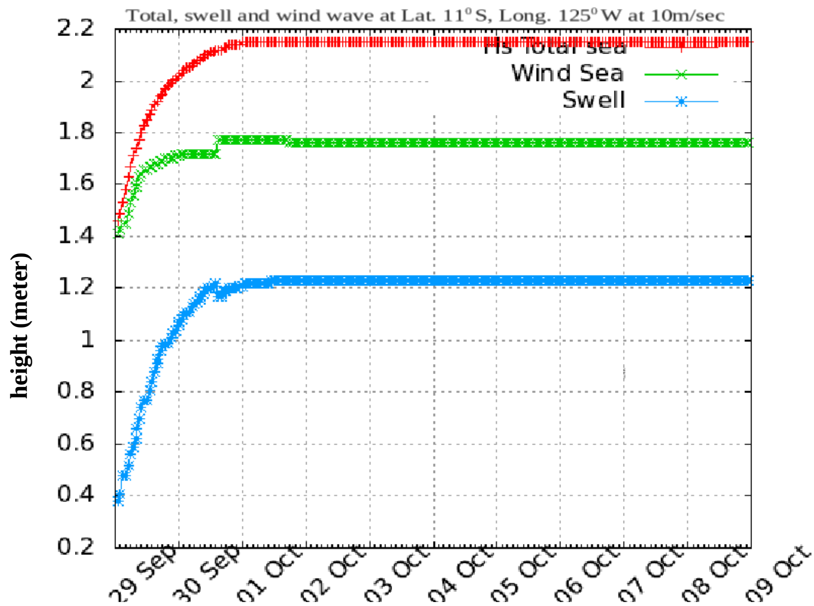

Fig. (10): Behavior of total significant wave, wind wave and swell wave height in meter with time at wind speed 10 m/sec.

4. Conclusion

It is concluded that the threshold wind speed value is approximately at 7 m/sec. Swell wave heights decays with increasing forecast time below threshold, while it develops with increase above threshold value. This provides that, there is a delay time for decay and a limitation of wind duration for increase against wave height.

Swell and the total significant wave height will decrease with time below threshold wind speed, while the wind and total significant wave height increase with the increase of wind speed above threshold.

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