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Ocean wave effects on the retrieved wind field from the scatterometer

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Abstract. The scatterometer is a kind of non-nadir real aperture radar (RAR), which can estimate the wind field of sea surface based on geophysical model function (GMF). GMF describes the empirical relation between the wind field and the sea surface roughness characterized by sigma0. The wind wave is generated from the local wind and the swell wave is independent of the one. Based on the multi-scale scattering model, both wind wave and swell wave will modulate the sea surface roughness. This paper tries to find out the wave effects on wind field retrieval from scatterometer in swell and wind wave by the synchronous scatterometer and buoy data. The wind field data used in this paper are collected from Metop’s Advanced Scatterometer (ASCAT) and buoy of NDBC. The NDBC buoy also provides the synchronous significant wave height (swh) and peak wavelength. From these data, the sea states are divided into swell and wind wave. Then the wave effects on retrieval are analyzed along with the swh and peak wavelength in each sea states. Results show that swell wave has a serious effect on the wind field retrieval. When the swh is higher than 1.5 m or the peak wavelength is lower than 230 m, the retrievals have significant errors.

1. Introduction
The scatterometer is a kind of non-nadir real aperture radar (RAR), which can estimate the wind field from geophysical model function (GMF). The GMF can give the empirical relation between the wind field and the roughness degree of sea surface characterized by sigma0. Some GMF for scatterometer have been developed like CMOD 4 and 5 [1-2]. Wind wave is generated by the local wind field but swell wave is independent of the one. Based on the multi-scale scattering model, both wind wave and swell wave modulate the gravity-capillary wave and bring the variations of sea surface roughness [3]. Common empirical GMF mainly consider the wind wave effects on roughness but lacks of the swell wave. Will the wave parameters in different sea states have different effects on wind retrieval from scatterometer? Some scientists have found that swell can affect the radar backscatter by modulating the small scale roughness of sea surface [4]. Moreover, the presence of swell tends to increase the mean radar backscatter [5]. This paper tries to find out the wave effects on wind field retrieval from scatterometer in different sea states.
2. Method

Figure 1 is the analysis flow. Firstly, we collect the synchronous wind field and other wave parameters. ASCAT can retrieve the wind field and buoy can provide the observed wind field, swh and peak wavelength. Then we distinguish the sea states and divide it into wind and swell dominated wave. For the distinction way of sea states, it is decided simply by comparing the wind speed and the swh for the same location:

1) Wind wave distinction. The wave for which the local wind speed be higher than 6 m/s is considered as wind dominated wave.

2) Swell wave distinction. Based on the wen’s wind directional wave spectrum model [6], the wind speed of 6 m/s corresponds to the swh of 1 m approximately. So the wave for which the local wind speed be lower than 4 m/s and the swh be higher than 1 m is considered as swell dominated wave.

Finally, we analyze the difference of wind field between ASCAT and buoy in each sea states. If there is visible difference, it means wave probably plays a great role in wind field retrieval. Results on wave effects are illustrated along with the wave parameters like swh and peak wavelength.

![Figure 1. The analysis flow of wave effects on the retrieved wind field from scatterometer.](image)

3. Data

Data collected in this work are composed of wind speed, wind direction, swh and peak wavelength. The corresponding date is from May 1, 2011 to August 31, 2011. The retrieved wind field is from Metop’s Advanced Scatterometer (ASCAT). The observed wind and wave parameters are from buoy of NDBC. Data of 8 buoy stations are collected in this work, which are plotted in figure 2. The spatial resolution of the ASCAT is 25 km×25 km. The collected retrieved and observed data are filtered by the 13 km space and 1 hour time synchronization window.

Because the retrieved wind field from ASCAT is about the 10 m blowing height above the sea surface, the observed one must be converted into same height by the equation (1) [7].

\[
U_{10} = \left[ \ln\left( \frac{10}{z} \right) / \ln\left( \frac{H_{\text{buoy}}}{z} \right) \right] \times U(H_{\text{buoy}}) 
\] (1)

Where \(U_{10}\) is the wind speed for 10 m, \(z\) is roughness length and set to be 1.52×10⁻⁴, \(H_{\text{buoy}}\) is the measurement height of buoy.
4. Results
In this section, we analyze the wave effects in case of swell and wind wave in terms of swh and peak wavelength respectively.

4.1. Wave effects in terms of swh
Main results are shown in figure 3. Firstly, the swell wave brings significant error for part of the retrieved wind speed from ASCAT data from figure 3(a). The synchronous wave data for the deviated part basically has the higher swh from figure 3(c). So the swh of swell wave plays an important role in the retrieval. When the swh be lower than 1.5 m, there is almost no significant error. When the swh be higher than 1.5 m, there is 10 m error approximately. Secondly, it is encouraging for the wind wave that their wind speed has a good correlation between the buoy and ASCAT and a root mean square error (rmse) of 1.5 m/s from figure 3(b) and (d). Thirdly, the accuracy of retrieved wind direction is worse than the wind speed in wind and swell wave from figure 3(e) and (f). In case of swell wave, wind direction retrieval has unacceptable error from figure 3(e). In case of wind wave, most of the wind direction error remains lower than 15° from figure 3(f). We can also find that the swh of wind wave have some impacts on the wind direction retrieval. When the swh is higher than the 1.5 m it brings a better retrieval performance for wind direction. It is opposite for the effect of swh on the wind speed retrieval in swell wave.
Figure 3. Analysis results of synchronous ASCAT and buoy data in terms of swh, (a) wind speed scatter between scatterometer and buoy in case of swell wave, (b) same as (a) but in case of wind wave, (c) the wind speed error between scatterometer and buoy along with the swh in case of swell wave, (d) same as (c) but in case of wind wave, (e) the wind direction absolute error between scatterometer and buoy along with the swh in case of swell wave, (f) same as (e) but in case of wind wave.

4.2. Wave effects in terms of peak wavelength
Main results are shown in figure 4. This figure is similar to the description in figure 3(c) - (f) but it analyzes the wave effects in terms of peak wavelength. Firstly, figure 4(a) shows the variation of error on retrieved wind speed along with the peak wavelength in case of swell wave. When the peak wavelength is higher than 230 m, there is basically no error. When it is lower than 230 m, the error is unstable and has the rmse of 6.8 m/s. Secondly, from the figure 4(b), the variation tendency on the error on retrieved wind speed along the peak wavelength is not apparent in case of wind wave. Thirdly,
from the figure 4(c) and (d), the wind direction has the serious error but no apparent variation tendency in case of wind wave and swell wave.

Figure 4. Analysis results of synchronous ASCAT and buoy data in terms of peak wavelength, (a) the wind speed error between scatterometer and buoy along with the peak wavelength in case of swell wave, (b) same as (a) but in case of wind wave, (c) the wind direction absolute error between scatterometer and buoy along with the peak wavelength in case of swell wave, (d) same as (c) but in case of wind wave.

5. Conclusions
This paper aims to preliminarily analyze the wave effects on wind field retrieval from scatterometer in different sea states. Firstly, we collect the synchronous wind field and wave parameters from ASCAT and NDBC buoy. From the data, the sea states are divided into swell and wind wave according to the wind speed and swh of buoy for the same location. The main results include three points. Firstly, when the swh be lower than 1.5 m, the retrieved wind speed is almost no significant error in case of swell wave. When the swh be higher than 1.5 m, there is the rmse of 10 m/s approximately. Secondly, when the peak wavelength is higher than 230 m, there is basically no error. When it is lower than 230 m, the error is unstable and has the rmse of 6.8 m/s. Thirdly, the swh of wind wave has some impacts on the wind direction retrieval. The swh of 1.5 m is a boundary. The swh be higher than the boundary brings a better retrieval performance. It is opposite for the effect of swh on the wind speed retrieval in swell wave.

This paper only considers the wave effects along with swh and peak wavelength. Further analysis of other wave parameters will be continued.

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