SIMULATION STUDY ON OPTIMAL CONDITIONS FOR SHALLOW WATER BATHYMETRY OBSERVATION BY SAR

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ABSTRACT

Shallow water bathymetry is fundamental requirement for environmental information in coastal areas. Traditional bathymetry surveys are not only expensive and time-consuming but also difficult in many shallow water areas, however, indirect technique for remote sensing of shallow water bathymetry such as the optical technique is affected by the weather condition and the water limpidity [1]. High resolution Synthetic Aperture Radar (SAR) images have been demonstrated the potential to map shallow water bathymetry features and this is a new technique to extract bathymetry information for coastal areas quickly and economically [2,3].

Theory of shallow water bathymetry by SAR images has been insensitively investigated and has been made great progress [2,3,4,5,6]. In order to give the optimal conditions for shallow water bathymetry observation by SAR and extract information of shallow water bathymetry form SAR images, it is necessary to derive an analysis expression for SAR mapping shallow water bathymetry.

As far as we known, SAR can't image shallow water bathymetry features directly. It images the bathymetry via surface effects induced by tidal currents flow variation over bottom topography under favorable currents and sea surface winds [4], thus the ability of SAR mapping shallow water bathymetry has close relationship between sea surface currents, sea surface winds and radar parameters, such as radar working wave length, radar incidence angle and radar polarizations.

In this paper, a theory of shallow water bathymetry by SAR images has been improved by applying the continuity equation and the first order Bragg backscattering theory, and replacing the surface wave action balance equation with the high frequency ocean wave spectrum balance equation [7]. An analytical expression for shallow water bathymetry SAR images will be obtained, assuming that the sea surface wind field is homogenous within one scene of SAR image and the relative value of normalized radar backscattering cross section (NRCS) stands for the visibility of SAR images for shallow water bathymetry features. Then the relative NRCS analytical expression for one dimensional shallow water bathymetry SAR images is firstly put forward. This gives the quantitative relation between relative NRCS and hydrodynamic modulation of shallow water bathymetry, which is very important to extract information of shallow water bathymetry from SAR images.

Remember that SAR imaging mechanism of shallow water bathymetry required three conditions, the shallow water, sea surface currents and sea surface winds and the radar parameters [4,6].

Based on above quantitative relationship and under a given shallow water bathymetry parameters, we gives the simulation on SAR shallow water bathymetry under different currents, sea surface winds, radar working wave lengths, incidence angles and the radar polarizations.

All simulated results show the trend of the relative NRCS' change with the shallow water bathymetry. The relative NRCS is first rapidly decreased and then increased with the increase of the height of bottom topography wave, reaches zero at about the crest. And from this position, the relative NRCS increase and then decrease with the decrease of the height of bottom topography wave. While the absolute of negative NRCS, which also means negative modulation, is larger than the positive NRCS, meaning positive modulation.

It was well known that the shallow water bathymetry features is visible on SAR images due to the relative NRCS, the larger relative NRCS, the clearer the shallow water bathymetry is on SAR images. Therefore, according to simulated results, the shallow water bathymetry can be mapped by SAR more easily at higher current speed and lower sea surface wind speed. When both directions

of currents and sea surface winds are perpendicular to the bathymetry features, SAR images is the top-quality, vice verse. While for the radar parameters, lower frequency radar working wave, smaller incidence angle and the VV radar polarization are better for SAR imaging shallow water bathymetry. These simulated results agreed well with some observations and simulated results [6,8].

Wind friction constitutes a major external forcing for generating ocean waves, which serves as homogenous background field on SAR images. Therefore radar signatures of shallow water bathymetry are usually accompanied by wind field signatures. In some cases, the wind field signatures mixed with those of ocean features because the wind field is not spatially uniform or the wind field itself is modulated by other processes with a variation scale close to that of the ocean phenomena of interest. We will also use the analytical expression for shallow water bathymetry SAR images, as well as scale analysis, to obtain the quantitative estimates for the relative weight of wind field signatures in the case of a uniform wind field compared with the hydrodynamic modulation of shallow water bathymetry. The scale analysis result also showed that the shallow water bathymetry signatures are detectable on SAR image only for low wind speed. This is also consistent with some other observations and statistical results [9,10].

In our work, we firstly introduced the SAR imaging mechanism of shallow water bathymetry. And the analysis expression for the shallow water bathymetry SAR image was firstly put forward. The analysis expression gained from the high-frequency wave number spectral density is more convenient for the simulation study on optimal conditions for shallow water bathymetry observation by SAR, and the simulated results have good agreements with some observations and simulated results. The weight of wind field signatures in the case of a uniform wind field compared with the hydrodynamic modulation of shallow water bathymetry was also given used the scale analysis, which shows that the wind has crucial effect on shallow water bathymetry SAR images. For more general results, more measurements, in situ or in the laboratory, are needed.

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