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GNSS Phase Altimetry of the Sea Level: Numerical Simulation of the Echoes from Waving Sea

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Introduction. Dramatic changes in the natural environment, observed in the present epoch, are threatening and can be dangerous for the future of the whole world human population. Systematic monitoring of these global changes is now critical for detection of log periodic variations and long term trends such as global warming, polar ice melting, raising of the ocean level etc. Extensively developing technologies of observation of the Earth from space provide excellent possibilities for remote measurements of key physical parameters of the atmosphere, ocean and land surface. GPS reflectometry [1] is a relatively cheap technique for in situ measurements of the sea level surface, which can be implemented both at coastal stations of geodetic GPS-networks and specially organized observatories of global environmental monitoring. This technique, however, suffers from errors caused by rapid sea level perturbations, e.g. wind generated waves which can introduce not only random but also systematic biases in the measured data.

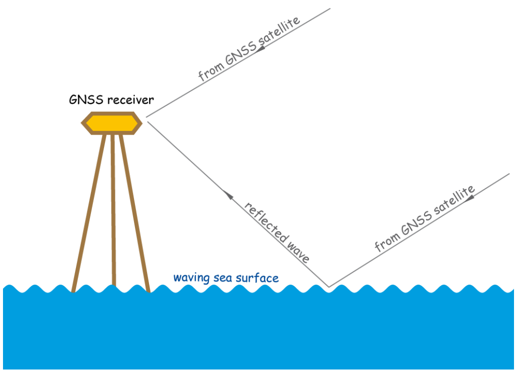

FIGURE 1. General schematic view of the GNSS reflectometric experiment.

In this study, numerical simulation of reflections of navigational space-borne radio beacons from undulating sea surface is performed at the main frequency of the Global Positioning System (GPS) L1 (1575.42 MHz). Electromagnetic field has been simulated with the Finite Difference in Time Domain (FDTD) technique [2] for different model spectra of the sea waves (2D simulation code for s-polarized waves previously used in [3]). Impact of the surface waves on the mean sea level estimate at the monitoring station location is investigated.

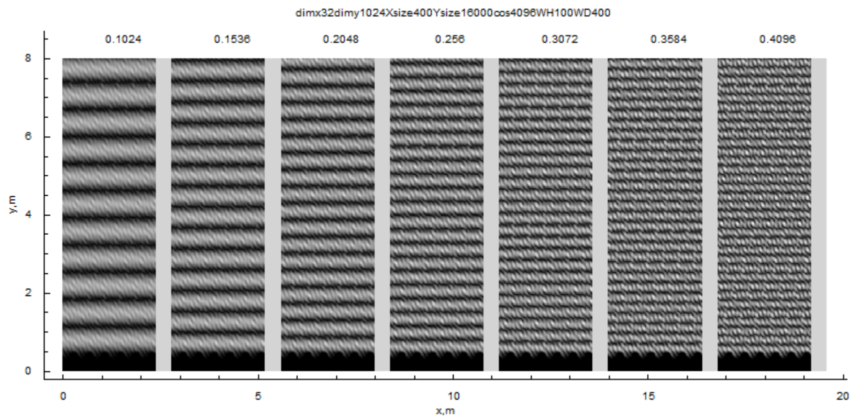

FIGURE 2. Simulated GNSS wave interference patterns over the waving sea surface. Sinusoidal wave profile, wave period 0.4 m, wave height 0.1 m. Sines of the wave grazing angle are shown with the numeric labels.

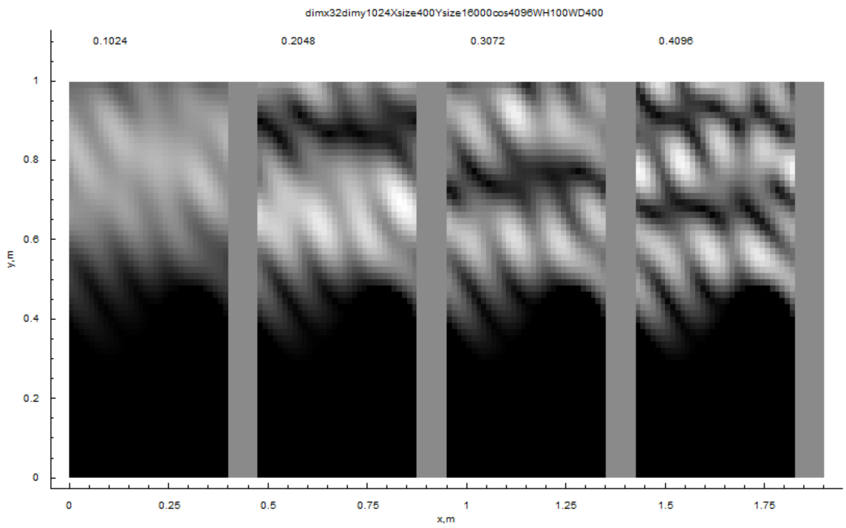

FIGURE 3. Simulated fine structure of the interference patterns. Sinusoidal wave profile, wave period 0.4 m, wave height 0.1 m. Sines of the wave grazing angle are shown with the numeric labels. Shadowing zones in the troughs of the surface profile are clearly seen.

Random and systematic errors, in particular related to partial shadowing of the undulating surface at low grazing angles of the sounding wave coming from a GPS beacon, are evaluated and estimated. Approaches to mitigation of the observational errors using auxiliary support data, including local sea waves spectra recorded in situ, context images/footage video of the surrounding aquatory, local weather conditions (wind speed and so on) are discussed.

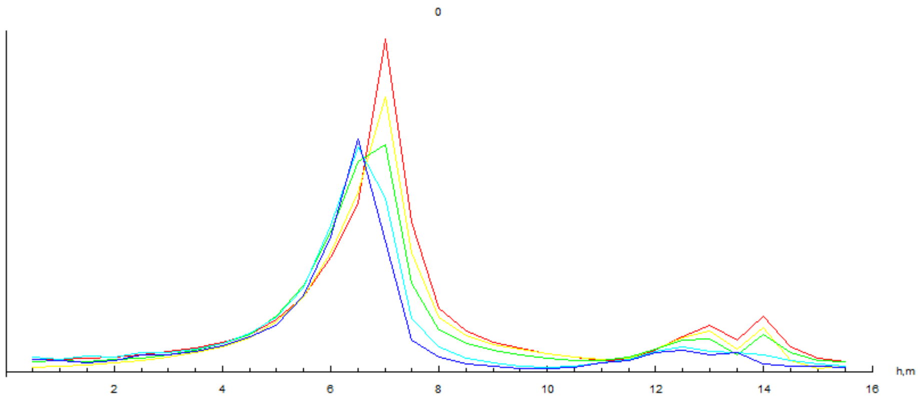

FIGURE 4. Estimates of the sea level (the receiver height over the surface) from the wave interference simulations. Systematic bias of the estimated height is due to sea waves. Red, yellow, green, cyan and blue curves correspond to wave heights 0, 0.05, 0.1, 0.15 and 0.2 m, respectively.

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