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Global Navigation Satellite System-Reflectometry (GNSS-R) from the UK-DMC satellite for remote sensing of the ocean surface

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Satellite microwave remote sensing techniques can be successfully used to determine properties of the ocean surface that are fundamental not only for climatic research (i.e. identification of trends in temperature, wind and waves, modelling of the energy exchange between ocean and atmosphere, etc.), but also for operational oceanography, to identify dangerous sea states.

In this context, Global Navigation Satellite System-Reflectometry (GNSS-R) represents an innovative and promising approach to ocean remote sensing, and has already experienced numerous advancements in the last few years. The main advantages of using GNSS signals for remote sensing are excellent temporal resolution, global coverage and long-term satellite mission lifetime. GNSS-R exploits signals of opportunity from GNSS constellations, such as GPS or Galileo, scattered by the ocean surface, to remotely sense ocean surface conditions. In particular, the scattered GNSS signals contain information about sea surface roughness, which influences the scattering configuration, and ultimately the scattered GNSS signal properties.

In this paper, we focus on the analysis of satellite-measured GPS-R signals from the Surrey Satellite Technology Ltd UK-DMC mission. We examine the GPS-R signal power to retrieve the information about sea surface roughness, expressed in statistical terms, by means of the sea surface Mean Square Slopes (MSSs). MSSs are the second order moment of the ocean wave spectrum in the upwind and crosswind directions.

The GPS-R signal scattered from the ocean can be processed to produce a 2-D map of the average scattered GPS power, in a delay-Doppler domain. Basically, the received signal is coherently correlated with a locally generated replica, and incoherently summed over several “looks”, to obtain the average power as the output of the GPS receiver [1]. The 2-D representation of the average scattered GPS power, as a function of the delay and the Doppler frequency, is known as delay-Doppler (DD) map.

DD maps can be used to infer the sea surface characteristics, since they change in dependence of the roughness level of the sea surface. An analysis on DD maps has been carried out here by comparing DD maps obtained using GPS-R data downlinked and processed by a software receiver on the ground, with DD maps generated using a theoretical model, to retrieve the MSSs of the ocean scattering surface.

The theoretical maps are obtained using the Zavorotny-Voronovich (Z-V) model of the scattered GPS power, as a function of the delay and the Doppler frequency, in the bistatic case [2]. The Z-V model is based upon the Geometric Optics limit of the Kirchhoff approximation, which considers the scattering from large-scale mirror-like facets on the ocean surface as the fundamental contribution to the scattered power.

The Z-V model relates the scattered power to the Bistatic Radar Cross Section (BRCS), which represents a measure of the surface’s ability to scatter the incident power towards the receiver, and it strongly depends on the surface MSSs. Therefore, the simulated maps vary with respect to the MSSs, even though these variations are quite small. It is then possible to estimate the real MSSs from a data DD map by performing a fitting between the data map and the simulator output maps. The fitting is carried out by choosing those MSSs values for the simulated map which minimise the mean square error between the data and the model map.

Several data DD maps, corresponding to different seconds of a single UK-DMC data collection, have been analysed, and the retrieved MSSs have been compared with MSSs calculated using the Elfouhaily model for the sea surface spectrum [3], as well as collocated buoy directional wave spectra from the US National Data Buoy Centre.

Results obtained from the use of DD maps from spacecraft altitudes complement previous analyses conducted with delay waveforms alone (i.e. a 1D delay map of the scattered GPS power [1]), and DD maps from aircraft [4]).

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