Retrieval of GNSS Ocean Reflected Signals

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Ocean reflected signals from the GNSS satellites (received at low-Earth orbiting satellites, airplanes and fixed mountain locations) describe the ocean surface mean height, waves and roughness. The estimated accuracy of the average surface height is of the order of 10 cm for smooth conditions. Thus global observations could be an important new contribution to long-term variations of the ocean mean height as well as the monitoring of ocean mesoscale eddies (with spatial features of 100 km and temporal variability of the order of several days), which result in sea-height changes much larger than the accuracy of the GNSS technique for reflected signals.The ocean reflected signals can be divided into two set of measurements, 1) high elevation measurements (equal to low incidence angles) and 2) low elevation grazing angle measurements. For the first type the ocean reflection cross-section has a limited extent. The reflected signal is coherent with smaller errors due to ocean waves, sampling rate and the internal processing method of the receiver. For low elevations, the signal reveals the incoherent scatter process at the reflection zone. By using open-loop high-precision GNSS receivers, it is possible to provide the in-phase and quadrature components of the signal at high sample rates, which enables investigation of spectral signatures. The GNSS reflected signal is weak, but still able to establish experimental knowledge on the influence of signal multi-path interference and signal disturbances caused by the atmosphere and the ocean reflection. To quantify the potential of the GNSS signals we will present high altitude ocean reflection measurements from the Haleakala Summit on Maui, Hawaii, revealing the spectral characteristics of the direct satellite signal and the ocean reflected signal for low elevation angles. The characteristics of the reflected signal depend on the scattering properties of the sea surface and the footprint of the reflection zone. While the footprint size and shape in turn depends on the signal incidence angle and the relative velocities of transmitter and receiver to the reflection point. Thus the scattering properties of the sea surface are related to the roughness. We will present the spectral properties of the signals as received by a high precision GPS instrument, simultaneously in both phase-locked mode and open-loop raw mode in separate receiver channels. The instrument setup consists of separate L1 and L2 antennas both oriented with the main gain lobe toward the horizon. The use of directive antennas pointed towards the horizon enables signal recordings down to the lowest layers of the atmosphere. The experimental instrumentation consists of prototype high precision receiver electronics, equivalent to the GPS receiver flying on the ESA MetOp satellites. The measurements of the low elevation grazing signals reveal the incoherent scatter process in the reflection zone. Thus a radio occultation retrieval technique for the phase differences between the direct and reflected signal has been applied combined with a statistical retrieval method. The results are derived through a sequential Bayesian estimation method, where the retrieval algorithms are based on a particle filtering technique. The horizontal size of the probability density function, which uniquely describes the ocean reflection zone using the recursive particle filter method, totals from 200 to 500 meters for all data sets. The suggested retrieval method could be an alternative method for estimating the mean ocean height and tilt.