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GNSS Reflectometry Wind Speeds Errors: Signal Strength Corrections and Rain Effects

Milad Asgarimehr (1,2), Jens Wickert (1,2), and Sebastian Reich (3)

(1) German Research Centre for Geosciences GFZ, Potsdam, Germany , (2) Technical University of Berlin (TU Berlin), Berlin, Germany, (3) Universtity of Potsdam, Potsdam, Germany

GNSS Reflectometry (GNSS-R) as a multistatic radar technique is recently and innovatively utilized to extract wind speed information over ocean surfaces. The recent data from TechDemoSat-1 (TDS-1) and CYclone Global Navigation Satellite System (CYGNSS) launched in July 2014 and December 2016, respectively, are recognized promising to improve hurricane forecasts. This potential is due to providing less precipitation affected data from the inner core of hurricanes compared to other conventional scatterometers whose signals are attenuated during intense precipitations. To this aim, a joint research project of GFZ and university partners aims to develop GNSS-R retrieval algorithms, characterize the errors and prepare the data for assimilation into global weather models as well as evaluating the effects in storm-scale predictions.

Here, we present the initial results of this project which are as follows. First, the technical principles and the wind speed algorithm are described. For developing the wind speed geophysical model function, the collocated ECMWF winds are used. The model is validated by tropical buoys observations. The evaluations report RMSE and bias of 1.9 and 0.1 m/s in comparison to ECMWF winds and 2.4 and 0.3 m/s taking the buoys observations as the reference, respectively. However, current GNSS-R winds neglect the fact that the effective isotropic radiated power of the GPS satellite can play a role as an error source. The GPS satellites have been built in a number of blocks, from different manufacturers and there are some well-documented differences in the angular distribution of the gain. In addition, the most recent satellites are expected to have a higher output power than their end-of-life specification. Hence, these errors are modeled using artificial neural networks and the results demonstrate reductions in the bias compared to buoys measurements which can be significant as they exceed 30% of the magnitude for some satellites.

In addition, the rain effects on GNSS-R winds are investigated by addressing the contribution of atmospheric attenuation during rain, simulating the Doppler delay maps and the attenuated power due to precipitation. It is demonstrated that the atmospheric attenuation does not affect rain retrievals significantly. In extreme conditions, at an elevation angle and a rain rate of 20 degrees and 12 mm/h, respectively, the contribution of rain attenuation to wind speed bias is not larger than 0.5 m/s. However, analysis of TDS-1/TRMM/buoys data demonstrates some effects caused by raindrops hitting the ocean surface. It is shown that these effects increase the surface roughness at wind speeds up to 9 m/s. At higher wind speeds, the damping effect calms the ocean in turn. Consequently, these rain effects result in over/underestimation of the surface winds with respect to the buoys and ECMWF measurements, which is not considered in conventional GNSS scatterometry. These effects of rain on real GNSS L-band scatterometry data are demonstrated for the first time in our contribution.