Optimizing an Observable for Ocean Wind Speed Retrieval from Calibrated GNSS-R Delay-Doppler Maps

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The fundamental measurement produced by Global Navigation Satellite System Reflectometry (GNSS-R) is the cross-correlation between the scattered signal and a local copy of the GNSS code and carrier, producing a bivariate function defined as the delay-Doppler map (DDM). The shape of the DDM is sensitive to the roughness of the scattering surface and, through various empirical models, the ocean surface winds. Ocean winds can be retrieved by fitting a scattering model to DDM observations, or identifying an observable, such as trailing edge slope or DDM area exceeding a threshold. A variety of such methods have been demonstrated with airborne experiments. With the selection of the CYGNSS mission by NASA, there is now a need to extend these methods to spaceborne measurements.

The surface area incorporated into the DDM observation is substantially larger for a satellite receiver than for an airborne receiver. For example, the iso-range ellipse corresponding to a power reduction of 1/e from the peak, has a semi-major axis of 5.6 km when observed from an aircraft at 15 km. This grows to 28 km for a satellite receiver at 500 km. Satellite observations will require an observable based upon a smaller section of the DDM, limited by the resolution requirement (the CYGNSS requirement is 25 km). This presents an observable having a much higher sensitivity to scattered power than to the functional shape of the DDM. In the examples above, the change in peak power for a 1m/s change in wind speed (at 25 m/s) is approximately the same order (-0.14 dB for aircraft, -0.16 dB for satellite). Sensitivity of DDM trailing edge slope (normalized to peak power), however, reduces to 7% of that for the airborne case. The extent of the diffuse scattering observed in DDMs observed from airborne receivers enabled retrievals to be made from the functional shape alone, without any requirement on power calibration. CYGNSS, however, will employ extensive calibration of the reflected signal, allowing that information to be incorporated into the wind retrieval with a higher weight than in previous airborne experiments. This paper will present a first look at optimization of wind retrievals from calibrated DDM observations. We will start with an assumed observable formed by a linear combination of the resolution-limited DDM samples as $P = \sum_{k=1}^{N} a_k \, Y_I(\tau_k, f_k)$ where $Y_I(\tau_k, f_k)$is the DDM power computed from an incoherent average of M waveforms at discrete steps in delay,τ_i, and Doppler,f_i. The coefficients, a_k, will be selected to maximize the SNR, and thus the sensitivity of P, in the presence of noise, using a statistical model for the DDM observations. This model could also be used to identify DDM samples showing low sensitivity in the observable (low a_k) which could be eliminated to reduce the data storage and transmission requirements.