TITLE: Recent Airborne Experiments in Multistatic GNSS Sensing of Ocean Roughness using GISMOS

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The GNSS Instrument System for Multistatic and Occultation Sensing (GISMOS) was developed as a facility instrument for the National Science Foundation (NSF) HIAPER aircraft. GISMOS is designed to retrieve water vapor profiles from measurements of atmospheric bending effects on occulting radio-navigation (GNSS) signals and to estimate ocean surface roughness from the scattering effects on GNSS signals. This paper will describe two experiments in measuring ocean surface roughness using GISMOS. The first experiment was conducted in February 2008 for the purposes of providing an initial calibration and validation of GISMOS. During those experiments, the HIAPER aircraft was flown over NOAA-NDBC buoys in the Gulf of Mexico and retrievals of surface slope statistics were compared against the in-situ measurements obtained from the buoys. The second experiment is scheduled for February-March, 2009, during which time GISMOS will be flown on a NASA aircraft, along with the Passive-Active L/S Band (PALS) instrument [Wilson, et al. 2001], to further the development of methods of sensing ocean salinity using microwave measurements. That experiment will take place over regions of the Labrador Sea known to exhibit high wind speeds. In our final paper, we expect to present the results of the GISMOS calibration activities from 2008 as well as preliminary results for the PALS experiments in 2009.

GISMOS provides the ability to record radio-navigation signals in 10 MHz bandwidths around the L1 (1575.42 MHz) and L2 (1227.6 MHz) frequencies from up to three antenna sources. When configured for multistatic radar, one source is the direct signal from the navigation antenna on the top of the aircraft and the other two are the corresponding reflected signals from matched right- and left-hand circularly polarized antennas on the bottom of the aircraft. A software-defined radio is used to generate the delay-Doppler waveforms through "open-loop" correlation of the reflected signals. The shape of the delay-Doppler waveforms depends on the scattering cross-section of the ocean surface and, in particular, the distribution of surface slopes determined by wind-generated waves. To increase our processing speed for these data sets, we developed new software for the IBM cell (CEBA) processor that can perform the required large array cross-correlations. This software allows efficient post-processing on low-cost consumer electronics (unmodified Playstation gaming machines). A non-linear least squares approach is then used to fit a geometric optics model to the delay-Doppler waveforms, in which the probability density function (PDF) of ocean surface slopes is parameterized by the up-wind and cross-wind variances.

Two flights of GISMOS on the HIAPER Gulfstream V aircraft were conducted over NOAA buoys 42001, 42002, 42003, and 42035, in the Gulf of Mexico, on February 13 and 20, 2008. We have successfully calculated delay-Doppler waveforms from multiple satellites observed simultaneously and are presently comparing these waveforms and PDF retrievals against the corresponding buoy measurements. Waveforms are generated at three discrete Doppler offsets; -400, 0 and 400 Hz, relative to the Doppler of the direct signal, producing samples of the 2-D (delay and Doppler) waveform. A 1 msec coherent integration period (equal to the Doppler-free C/A code period) and a 100 msec incoherent integration period are used. An example of a delay-Doppler map (DDM) is shown in figure 1.

Following previous work, the noise floor is estimated and removed, and waveforms are normalized to constant total area. A scattering model is then fit to batches of 25 averaged waveforms (2.5 s) to estimate two slope variances and the principal axis direction. The model DDM is shown as the solid surface in figure 1. An initial comparison of two results from this batch estimate showed favorable agreement with the wind vector recorded from the buoys (9.4 m/s, 79 deg. vs. 11 m/s, 110 deg, once converted to wind speed using the [Wilheit, 1979] model). We are continuing to process the remaining data from the 2008 experiment, to evaluate the results using a larger set of observed satellites, with diverse measurement geometries. Additionally, the buoys used in this experiment record a 2-dimensional, long-wave, surface height spectrum. Incorporating these direct measurements of the surface roughness into the comparison would allow a more direct evaluation of the surface scattering model and its dependence on slope PDF.

While the purpose of the 2008 experiment was limited to testing the performance of GISMOS, the objectives for the 2009 flight with PALS are more substantial. This experiment will represent the first collection of an extensive set of L-band microwave radiometry data coincident with reflected GNSS signals, allowing a test of the ability to generate roughness estimates from the reflected signals and use these to correct measurements of sea surface salinity from microwave brightness temperature. Following a similar post-processing as described above, we intend to use the estimated slope PDF's as input to an emission model [such as described in Yueh, et al., 2001], to predict the equivalent brightness temperature change due to roughness. These results would then be compared with the measured L-band brightness temperatures and S-band scattering cross-sections obtained from PALS.

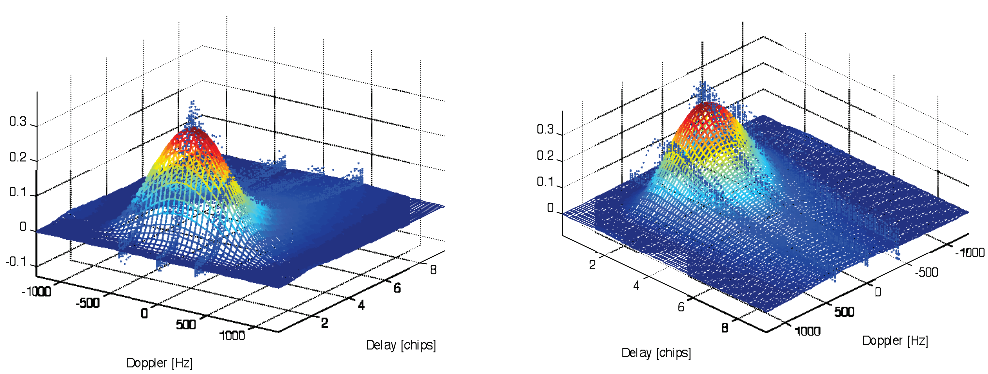

Figure 1, Example Delay-Doppler Map (DDM) Generated from Reflected GNSS Signals Superimposed on the Best (Least Squares) Model DDM.