Large Area Observations of the Ocean Surface with HF Radar Scatter to Satellite and Airborne Receivers

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Remote Sensing of the sea is of primary importance for both ship transportation and HF radar clutter prediction. A new concept has been developed called HF Ground-Ionosphere-Ocean-Space (GIOS) which can view vast regions of the Earth's surface. Ground HF transmissions are reflected by the ionosphere to illuminate the ocean over a few thousand kilometers. HF receivers on low-earth-orbit satellites detect the radio waves scattered by the sea and land surface. Using the theory of radio wave scatter from ocean surfaces, the GIOS data is then processed to yield the directional wave-height spectrum of the ocean. The GIOS technique has several advantages over existing remote sensing methods. First, a large area of the ocean can be sampled to yield the wave-height characteristics with high, km-scale resolution. This measurement scale matches the grid size used in physics-based oceanographic models. The wave height spectrum can be directly compared with temporal frequency spectrum obtained with buoys at specific points in the ocean volume. Furthermore, the GIOS technique uses HF waves which penetrate the dense rain found in hurricanes. Microwave attenuation inside strong sea storms blocks mapping of the sea surface.

The GIOS program at NRL is being developed using both experimental and theoretical methods. To test the GIOS concept, ground HF transmissions from over-the-horizon radars were employed to scatter sky wave signals from the ocean to radio receivers in low-earth-orbit. The HF receiver (RRI) on the Canadian ePOP/CASSIOPE satellite has collected radio signals scattered from the ocean illuminated by ground transmitters in the US, Australia and Northern Europe. This satellite has two dipole antennas in a crossed configuration to measure HF waves below 18 MHz. Right and left hand circular polarization is synthesized from the data from the in phase (I) and quadrature (Q) data provided by the RRI digital instrument. For the ground HF transmission source, the Relocatable Over the Horizon Radar (ROTHR) system in Chesapeake Virginia was used to illuminate the ocean extending from coast of Florida to south of Jamaica. Range and Doppler processing of the radar waveforms yields an ocean scatter map at each time in the ePOP orbit.

Tests of the GIOS concept were conducted with HF receivers on the Canadian ePOP satellite and on aircraft flying over the Arctic Ocean north of Barrow

Alaska. The HF illumination source for the ePOP data collections was the HAARP transmitter in Alaska operating at 4.5 MHz with a 10 degree x 10 degree beam launched with an elevation angle of 30 degrees and a 200 Hz repeating chirp with a band width of 20 kHz. The de-chirp analysis for RRI data acquired in February 2017 is designed to measure the boundary between ice, ocean and broken ice as well as the ice thickness. Subsequent HF tests in March used the SuperDARN radars in Adak and Kodiak at 11.467 and 11.567 MHz, respectively. During the period of 13 to 18 March 2017, a Twin Otter airplane with NRL HF receiver system was flown from Barrow Alaska to observe the sky wave signals propagating via the ionosphere to the Arctic Ocean. Ice and ocean observations during these tests will be compared with buoy and airplane measurements at the same locations and times. All of these experiments will be summarized using both ocean scatter data and wave scatter simulations.