International Beacon Satellite Symposium BSS-2016
Trieste, Italy

Large Area Sea Mapping with Ground-Ionosphere-Ocean-Space (GIOS)

Paul A. Bernhardt*[1], Stanley J. Briczinski[1], Carl L. Siefring[1], Donald E, Barrick[2], Jehu Bryant[3], Andrew Howarth[4], Gordon James[4], Greg Enno[4], Andrew Yau[4]

[1]Plasma Physics Division, Naval Research Laboratory, Washington DC, 20375, USA.
(E-mail: paul.bernhardt@nrl.navy.mil, stanley.briczinski@nrl.navy.mil, carl.siefring@nrl.navy.mil)

[2]CODAR Ocean Systems, 1914 Plymouth Street, Mountain View, California 94043 USA

[3]Raytheon IIS, Chesapeake, VA

[4]University of Calgary, Department of Physics and Astronomy, Institute for Space Research Calgary, AB, T2N 1N4, CANADA
(E-mail: james@phys.ucalgary.ca, yau@phys.ucalgary.ca)

ABSTRACT

Knowledge of the sea is of primary importance for both ship transportation and HF radar clutter prediction. Remote measurements of sea state provide data inputs to operational models for maritime domain awareness. Ocean measurement techniques employing radio waves include (1) passive microwave imagery, (2) ocean microwave emissivity for surface waves, foam detection, temperature and salinity, and (3) microwave and HF radars for wind speed and direction. The HF radars detect ground surface waves over a limited (200 km) range for backscatter measurements of wind speed and ocean currents. Space-based ocean sensors include microwave scatterometers, altimeters for topography, GPS/GNSS satellite receivers for reflectometry, and imaging radars (SAR) [1].

The Naval Research Laboratory has developed a new concept called HF Ground-Ionosphere-Ocean-Space (GIOS) which can view vast regions of the Earth's surface (Figure 1). 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 [2], 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 [3]. 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 eliminate the ocean to satellite distortions of the ionosphere, NRL is developing

a new satellite called CARINA to fly around 200 km below the ionosphere. The HF receiver [4] 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. 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 (Figure 2). The ePOP satellite orbit along close to this illumination path recorded the HF radar transmissions at 17.5 MHz. An FMCW waveform with 8 kHz bandwidth and 6.25 Hz repetition frequency was scattered by the ocean. Range process of the GIOS data shows features of the ocean associated with wind-driven swells, coastal shoaling, shore/ice/floe/sea transitions [5], and dry land (Figure 2). These data are being interpreted using the GIOS model developed at NRL that describes the HF propagation through the ionosphere and the scatter from the ocean. The linear polarization of the transmitted signal is decomposed into right and left hand circular polarizations that propagate with different group velocities as the wave is reflected and refracted by the bottomside ionosphere. After reaching the ocean, the wave is scattered along non-specular paths to the satellite enabling a measurement of the full wavenumber range of the wave height spectrum giving estimates of surface storm regions, land to ice transitions, broken ice, and open ocean regions.

Key words: HF Radar, Ocean Surface, Wave Height Spectrum, Oceanographic Studies

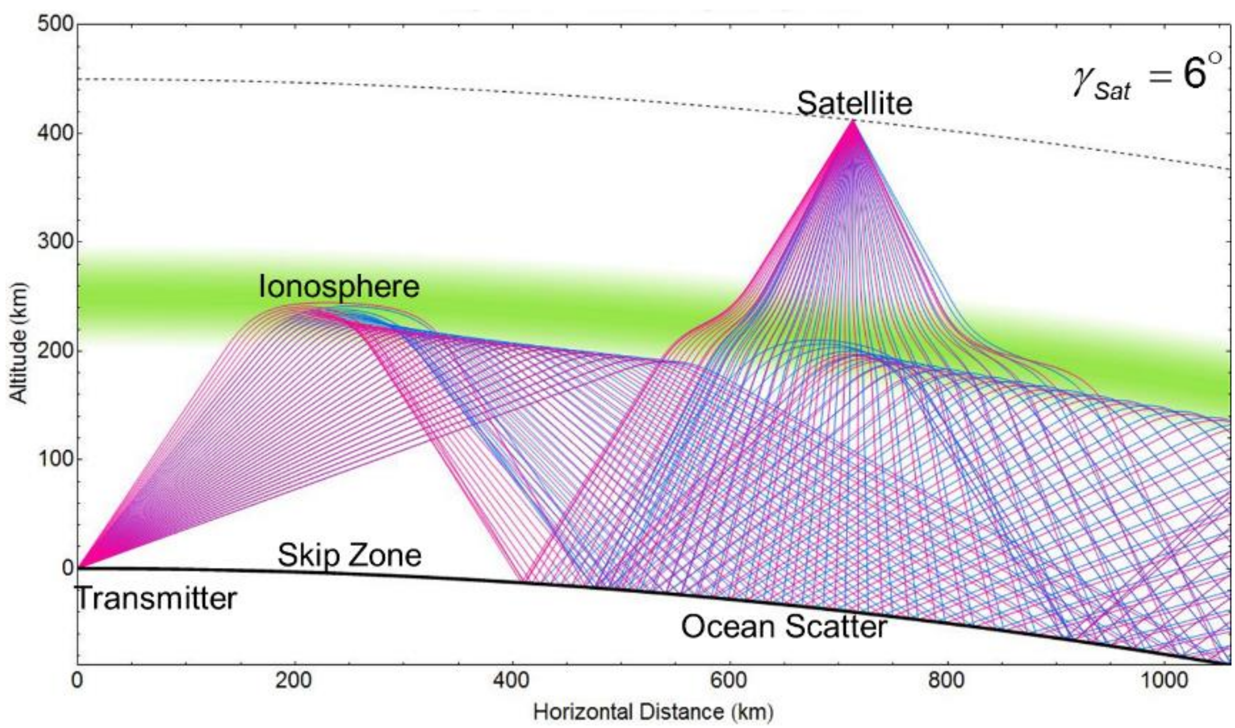

Figure 1 Ground-Ionosphere-Ocean-Space (GIOS) concept with sky wave illumination of the ocean for large area mapping of surface roughness. The satellite receiver determines the position of the ocean scatter by time delay (group range) and frequency (satellite motion Doppler shift). The O-Mode (Blue) and X-Mode (Purple) rays propagate along different paths to the ocean and satellite. Crossed dipoles on the satellite are used to separate the polarization modes.

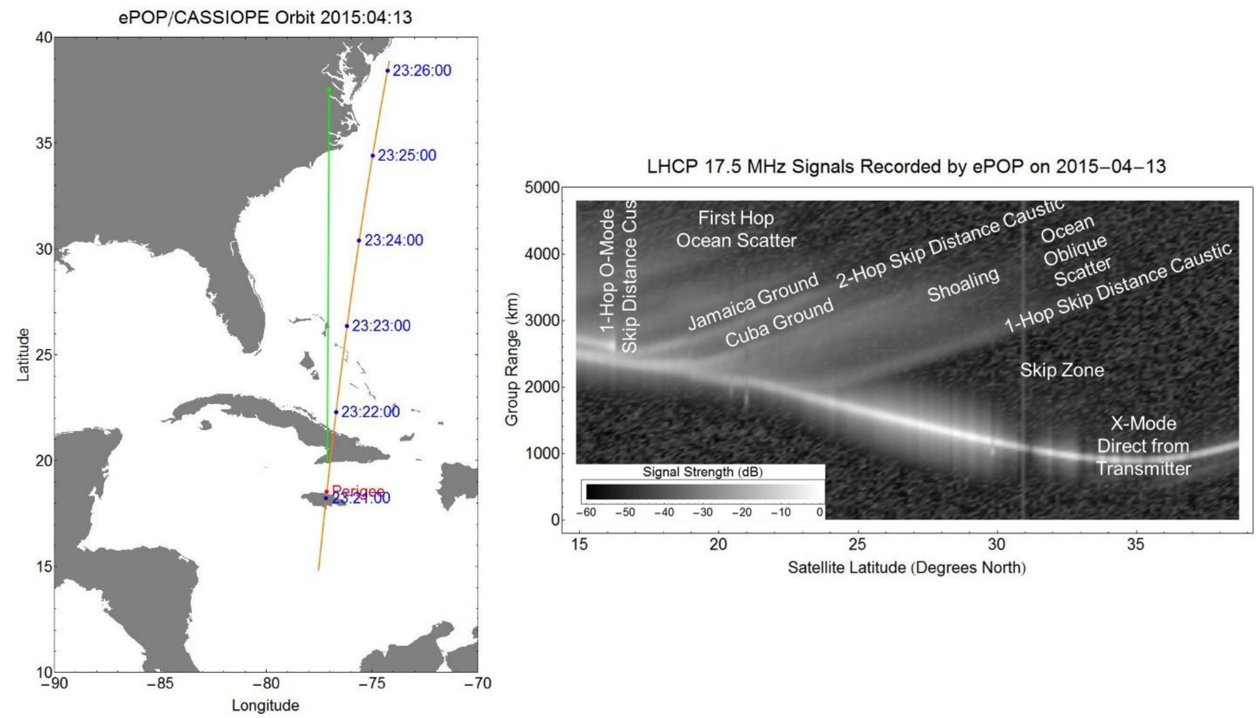

Figure 2 Ocean and island illumination by an 8 degree HF radar beam (green) at 17.5 MHz (Left). The HF receiver on the ePOP satellite is observing the ocean along a nearly parallel orbit (orange). The HF radar beam illuminates the Caribbean Sea as well as Cuba and Jamaica. Shallow regions to the north of Cuba introduce wave height growth (shoaling) that is detected by increased radio wave scatter from this region. Surface scatter of HF waves to the ePOP radio receiver instrument (RRI) showing multiple features of the ionosphere, ocean and shore (Right). Range and Doppler processing of the transmitted HF waveforms can yield maps of the wave-height spatial spectrum along the earth illuminated by the HF beam.

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Acknowledgements: We would like to thank co-investigators and the CASIOPE support team at University of Calgary. This work was supported by the 6.1 Base Program at the Naval Research Laboratory and by DARPA.