Remote sensing using GNSS bistatic radar of opportunity

Valery Zavorotny

Abstract

In the past decade there has been considerable interest in using signals of opportunity such as those from Global Navigation Satellite Systems for remote sensing of ocean, land, snow and ice. GNSS-reflected signals, after being received and processed by the airborne or space-borne receiver, are available as delay correlation waveforms or as delay-Doppler maps. These bistatic signals collected from the ocean surface can be used for altimetric or wind-scatterometric purposes complimenting traditional monostatic radar techniques. Similarly, information about soil moisture, snow depth and vegetation can be inferred from GNSS reflected signals. The existing research has shown that GNSS reflectometry has the potential to be a low-cost, wide-coverage technique for studying Earth's environmental processes.

In the first part of the talk an overview will be given to above applications of GNSS bistatic reflectometry, whereas in the second part of the talk will focus on the measurements of ocean surface roughness, wind speed and direction using both aircraft and orbital bistatic radars. A theoretical forward model which relates the delay-Doppler map to the bistatic radar cross section, and then to statistical characteristics of the wind-driven waves will be discussed. Algorithms to retrieve wind speed and wind direction using delay-Doppler maps processed from the data collected by the GPS software receiver onboard the NOAA Gulfstream-IV jet aircraft will be demonstrated. Finally, experiments in current and future space-borne GNSS bistatic radar missions such as planned Cyclone Global Navigation Satellite System (CYGNSS) mission will be discussed.

Measurements of soil moisture, snow and vegetation with GPS Interferometric Reflectometry

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Abstract

Not only the GNSS signals themselves present an opportunity, but also GNSS-R receivers of opportunity exist and can be used for remote sensing. For example, signals routinely recorded by GPS receivers installed to measure crustal deformation for geophysical studies can be used for remote sensing of soil moisture, snow and vegetation in the vicinity of their antennas. This technique exploits interference of direct and reflected signals causing the composite signal, observed using signal-to-noise ratio (SNR) data, to undulate with time while the GPS satellite ascends or descends at relatively low elevation angles. The dielectric permittivity of the medium, (or snow pack height) changes the phase of the scattered signal, and thus the phase of the interferometric oscillation. Currently, thanks to the initiative of the EarthScope Plate Boundary Observatory (PBO) soil moisture, snow and vegetation products obtained with these techniques are available from the PBO H_2O network of more than 100 (soil moisture), 150 (snow) and 360

(vegetation) GNSS geodetic stations across Western USA. The retrieval error of the bare soil moisture due to surface roughness in these interferometric techniques has been reported at 3-4% level. The talk will present the overview of this technique and discuss recent results obtained with it.

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Valery Zavorotny (M’01–SM’03-F’10) received the M. S. degree in radio physics from Gorky State University, Gorky, Russia, in 1971, and the Ph.D. degree in physics and mathematics from the Institute of Atmospheric Physics, USSR Academy of Sciences, Moscow, in 1979. Currently he is a Physicist at the Earth System Research Laboratory of the National Oceanic and Atmospheric Administration (NOAA), Boulder, CO. Previously, he was with the Institute of Atmospheric Physics and Lebedev Physical Institute of the USSR Academy of Sciences, Moscow, where he worked on theory of wave propagation through random media and wave scattering from rough surfaces. Dr. Zavorotny’s current research interests are in the areas of modeling of EM wave scattering from rough sea surface, ocean and land remote sensing applications using radar and GNSS reflection techniques. He has more than 150 publications in scientific journals, conference proceedings and book chapters. He was a Co-Editor (together with V. I. Tatarskii and A. Ishimaru) of the book *Wave Propagation in Random Media (Scintillation)*, SPIE Press/IOP, 1993. He was a Co-PI, member of Science Team for Student Reflected GPS Experiment (SuRGE) proposed to NASA as a UnESS mission in 2000-2001. He is currently a Co-PI, member of Science Team for Cyclone Global Navigation Satellite System (CYGNSS) mission (the project awarded by NASA in 2012). He leads a NOAA Airborne GPS Ocean Surface Sensor project in collaboration with Dept. Aerospace Eng. Sci., Colorado University and the NOAA/HRD/AOC.

Dr. Zavorotny has served on the Organizing and Technical Program Committees of several international conferences and workshops. He was a member of the NASA GPS Oceanography Group Organizing Committee in 2002 (Woods Hole, MA); a member of Program Committee and Conclusions Panel Co-Chair of the Workshop on GNSS Reflections in 2010 (Barcelona, Spain). Currently, a member of the Technical Program Committee of the Workshop on GNSS-Reflections in 2015 (Potsdam, Germany). He is a member of the JPL A-team created to discuss the role of reflected signals from Global Navigation and other Satellite Systems (GNSS-R +) in future efforts to inform the next Decadal Survey for NASA Earth Science Mission Directorate. Dr. Zavorotny is a member of AGU and a member of Commission F of the U.S. National Committee of URSI. He was recognized as IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING (TGRS) Best Reviewer in 2010. He is a recipient of the Prince Sultan Bin Abdulaziz International Creativity Prize for Water for development of a new cost-effective technique, GPS Interferometric Reflectometry (GPS-IR), to measure soil moisture, snow depth, and vegetation water content (together with K. Larson, E. Small, and J. Braun).