GNSS Reflectometry for Sea Ice Detection

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Global Navigation Satellite System (GNSS) has been widely used to provide positioning, navigation and timing services in civil and military domains since it became fully operational in 1993. In addition to these fundamental services and applications, GNSS could be also used for remote sensing of atmospheric parameters; for instance, by launching LEO satellites and observing refraction signals from GNSS satellites with negative elevation angles. This GNSS-based remote sensing technique termed GNSS radio occultation (GNSS-RO) could be used to estimate the tropospheric water vapor, temperature, pressure, and ionospheric total electron content (TEC) with a high resolution. Meanwhile, GNSS signal reflection over a specific surface, a source of positioning error, which cannot be easily neutralized, could be used to retrieve the surface geophysical parameters. This remote sensing technique is termed GNSS Reflectometry (GNSS-R). The ocean's surface characteristics (ie. ocean surface height, roughness, wind speed and wind direction) could be estimated by GNSS-R. It could be also applied for land applications such as the retrieval of ground vegetation condition and soil moisture. This study focuses on sea ice detection using GNSS-R.

GNSS-R can be used to retrieve main parameters of sea ice (i.e. thickness, concentration, surface roughness and ice permittivity). These parameters can be combined to help characterize different ice types including new ice, young ice, thin first-year ice, first-year ice, and multiyear ice. Sea ice thickness is a key parameter for classification and characterization of sea ice masses, which influence the temperature and circulation pattern of both the ocean and atmosphere and thus can be used for analyses of the Earth's climate.

In the first stage, GNSS-R is used for sea ice coverage detection using UK TechDemoSat-1 data (available online: www.merrbys.co.uk). A new differential Delay-Doppler Map (DDM) is proposed and the ice coverage detection result is validated against data from National Snow & Ice Center, USA (http://nsidc.org).

Then, the study presents a potential sea ice concentration detection method based on GNSS reflection amplitudes considering sea ice permittivity and roughness, which are important parameters for sea ice classification and characterization. The reflection power of cross- and co-polar signals shall be predicted. For this purpose, the Fresnel reflection coefficients for representative examples of sea ice, sea water and snow with circular polarizations at L-band

are presented firstly. The simulated polarimetric ratio for satellites observed at low elevation angle (10°-30°) is then calculated considering sea ice permittivity and roughness. The potential use of reflected GNSS signals for sea ice detection is evaluated through ice concentration measurements. The results show that reflection power loss increases with the increase of sea ice concentration. In addition, the elevation angle has little effect on power gain for low elevation angle 10° - 30°.

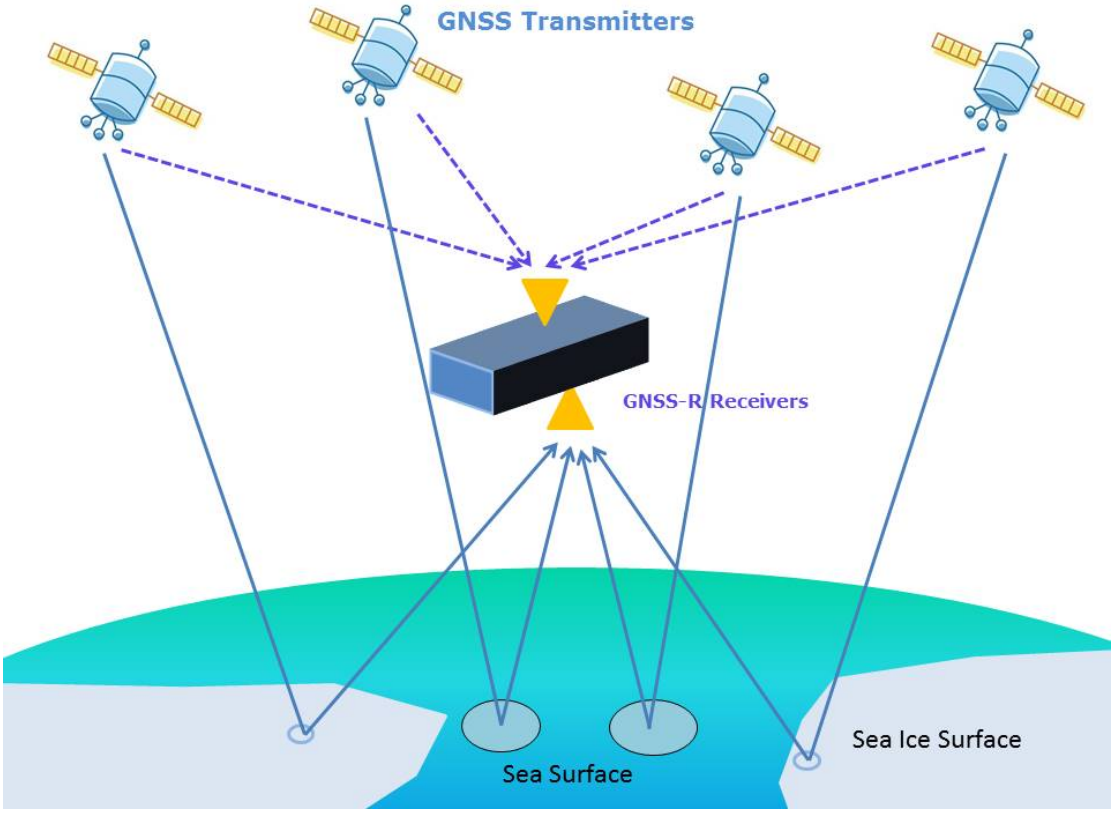

Figure 1. GNSS-R for sea ice detection