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Carrier phase altimetry using Zeppelin based GNSS-R observations and water gauge reference data

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The increasing number of transmitters in global navigation satellite systems (GNSS), like GPS, Galileo, Glonass or Compass, provide observations with an increasing coverage for positioning but also for remote sensing. A space based GNSS remote sensing application is radio occultation, a limb sounding method. Globally distributed vertical profiles of temperature, water vapour and electron density are provided operationally for weather forecast and ionospheric monitoring. Another application is GNSS reflectometry (GNSS-R) that is currently developed especially for ocean remote sensing. The high reflection coefficient of water is crucial for GNSS-R.

This study presents a method that uses GNSS phase observations for lake altimetry with the potential for ocean application. Phase observations are deduced from a GORS (GNSS Occultaction Reflectometry Scatterometry) receiver in Master-Slave-Configuration. The Master sampling dedicated for direct signal acquisition is connected to an up-looking antenna with right hand circular polarization (RHCP). Two Slave samplings dedicated for acquisition of the reflected signals are connected to down-looking antennas with right- and left-hand circular polarization (RHCP and LHCP). Based on in-phase and quad-phase (I, Q) sample components, an altimetric phase residual is retrieved. This residual can be related to the height of the reflecting surface. An altimetric challenge arises from the unknown ambiguity of phase residuals that introduces a height bias. The presented study uses ancillary data deduced from water gauges to mitigate the ambiguity bias. Reference tracks are formed by linear surface height interpolation between the water gauge stations. At crossover points of reflection tracks with reference tracks a phase ambiguity estimate is determined for bias mitigation.

For this study airborne GNSS measurements were conducted aboard a Zeppelin NT (New Technology) airship with a geodetic receiver for navigation and a GORS receiver for reflectometry. The corresponding Zeppelin campaign was conducted in Sep 2012. It comprised three days with in total 13 flight hours over lake Constance (9.0°-9.8°E; 47.5°-47.8°N). Compared to a similar Zeppelin campaign in Oct 2010, Slave tracking problems could be solved providing reflection events with continuous tracks of up to 30min. The airship's trajectory is determined from navigation data with a precision better than 10cm in Precise Point Positioning mode supported by additional GNSS ground station data. Water gauge reference data around the lake is provided by stations at Friedrichshafen, Konstanz, Lindau and Romanshorn.

Situated in vicinity of the Upper Rhine Plain the lake surface is affected by gravity anomalies in this region. As a consequence geoid undulations with up to 1m amplitude occur along the lake. Predictions of surface height undulation (including GCG-05 model) agree with phase altimetric retrievals. An example event shows a standard deviation of only 2cm (4cm) for RHCP (LHCP) data. The corresponding mean difference with 53cm (51cm) for RHCP (LHCP), respectively, is related to the residual ambiguity bias persisting after mitigation with reference data.