SEA SURFACE ALTIMETRY BASED ON AIRBORNE GNSS SIGNAL MEASUREMENTS

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ABSTRACT:

In this study the focus is on ocean surface altimetry using the signals transmitted from GNSS (Global Navigation Satellite System) satellites. A low-altitude airborne experiment was recently conducted off the coast of Sydney. Both a LiDAR experiment and a GNSS reflectometry (GNSS-R) experiment were carried out in the same aircraft, at the same time, in the presence of strong wind and rather high wave height. The sea surface characteristics, including the surface height, were derived from processing the LiDAR data. A two-loop iterative method is proposed to calculate sea surface height using the relative delay between the direct and the reflected GNSS signals. The preliminary results indicate that the results obtained from the GNSS-based surface altimetry deviate from the LiDAR-based results significantly. Identification of the error sources and mitigation of the errors are needed to achieve better surface height estimation performance using GNSS signals.

1. INTRODUCTION

GNSS-R is a promising technique that can be exploited to remotely sense a range of geophysical parameters, as originally proposed by Martin-Neira (1993). One specific application area of GNSS-R is sea surface altimetry. Compared to radar altimetry, GNSS altimetry is able to provide much larger data coverage due to the fact that the airborne or spaceborne receiver can receive signals transmitted from multiple GNSS satellites and reflected over a large sea surface area. The current radar altimeters are not able to measure mesoscale processes that are the dominant error source in global climate modelling, while GNSS altimetry provides a potential and inexpensive way to measure such processes. A quite comprehensive treatment of the theory of GPS-based ocean altimetry is provided by Hajj and Zuffada (2003). Also, a number of experiments under different scenarios were conducted by researchers and reported in the literature. GPS altimetry experiment over a lake was carried out by Treuhaft *et al* (2001). Bridge-based experiments were reported by Rius *et al* (2011). Airborne experiments were carried out and reported by Lowe *et al* (2002) and Rius *et al* (2010). Results of ESA's spaceborne PARIS experiments and altimeter in-orbit demonstrator were reported by Martin-Neira *et al* (2011).

In this paper we investigate sea surface altimetry using GNSS signals. One study is how the altimetry performance is affected by the surface roughness, especially when the surface wave height is rather high, owing to strong local wind and/or swells. A low-altitude airborne experiment was conducted in June 2011 by a UNSW-owned light aircraft flying off the coast of Sydney when the sea surface was rather rough. A LiDAR experiment was conducted in the same aircraft, whose first objective was to monitor the Sydney coastal areas to provide information for future infrastructure development; and the second one was to estimate the sea surface height as a reference to the results generated from the GNSS-based altimetry. A two-loop iterative method is proposed to estimate the surface height using the arrival time difference between the direct and reflected GNSS signals. This method is comparatively simple and can be readily implemented. Through processing the experimental data it is demonstrated that the LiDAR data not only can serve as a reference for mean sea level (MSL), but they also provide the statistics of the sea surface roughness, including the significant wave head (SWH), the root-mean-square (RMS) wave height, and the maximum wave height. Note that there are a significant number of reports in the literature on using LiDAR for sea surface topography (Reineman *et al* 2009 and Vrbancich *et al* 2011). It is observed that there is good agreement between the wave head statistics calculated from the LiDAR data and those obtained from a Waverider buoy. In the case of GNSS-based altimetry, some preliminary results are produced. Compared to the results obtained from the LiDAR data, the estimation error associated with the GNSS-based method is large. Finding the error sources and mitigating the estimation errors is the topic of ongoing work.

The remainder of the paper is organised as follows. The following section presents the basic theory of GNSS-based altimetry and describes a two-loop iterative method for calculating surface height. Section 3 describes the airborne GNSS experiment and the LiDAR experiment. Section 4 presents experimental and estimation results, and Section 5 concludes the paper.

2. GNSS-BASED SEA SURFACE ALTIMETRY

2.1 Fundamentals

The principle of the GNSS altimetry is quite simple, as illustrated in Figure 1. The receiver may be either on an airborne or on a spaceborne platform, and receives the signals transmitted by three GNSS satellites and reflected by the water or ice surface. Depending on the surface roughness each signal may be reflected at many surface points and received by the receiver via the down-looking antenna. However, the surface point of interest is the specular point from which the signal propagation path length is the minimum. The sea surface height is calculated by measuring the delay of the direct signal and that of the reflected signal. The delay or code phase of the direct signal can be readily determined by cross-correlating the received signal with a code (C/A-code or P-code) replica. The