PROSPECTS OF RADAR ALTIMETRY AND GNSS REFLECTOMETRY FOR GEODYNAMIC STUDIES

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ABSTRACT

Innovative processing of satellite radar altimetry over solid Earth has been demonstrated and applied to observe geodynamic processes of glacial isostatic adjustment over the former Laurentide Ice Sheet region. In this contribution, we elaborate its scientific contribution, and the prospects of the applications of space-/airborne and land-based Global Navigation Satellite System (GNSS) reflectometry synoptically observed global-scale geodynamic processes.

***Index Terms*—** GNSS Reflectometry, Radar Altimetry, Glacial Isostatic Adjustment, Geodynamics

1. INTRODUCTION

For the past two decades, the Global Positioning System (GPS), or a modern terminology, the Global Navigation Satellite System (GNSS) have demonstrated remarkable capability in precise 3-dimensional positioning of static points as well as kinematic objects. The accuracy of the positioning has been improved to *mm* and *cm* level for static and kinematic cases, respectively, so that its applications prevail in all scientific and engineering fields including Earth and environmental sciences, surveying and navigation. With the U.S. GPS and the Russian GLONASS satellite systems fully operational, modern systems being planned (European Galileo and Chinese Compass, or *Beidou*) and the basic civilian, industrial, military and scientific ground-based network and infrastructure growing exponentially, there have been increasingly new innovative GNSS applications. They include active atmosphere limb sounding using GNSS occultation signals, water level measurements, and reflectometry or altimetry. GNSS reflectometry is poised to potentially make significant new contributions to Earth sciences through the development of new and robust measurement systems for studies such as structures and dynamics of the atmosphere and ionosphere, ocean altimetry, scatterometry, land change, and mass fluxes.

This new application, called GNSS remote sensing, is based on the reflected signal of the GNSS on the Earth's surface. The advantages of this new bistatic radar system to the conventional radar system include denser spatial and temporal sampling by the current 24-satellite GPS constellation, its low cost, and with interdisciplinary applications including atmospheric, space, oceanographic, geophysical and cryospheric sciences. The crucial requirement in GNSS reflectometry is the strength of signal to noise ratio because the reflected signal is significantly weaker than the direct signal. At present, 20–30 dB of antenna gain is required for geodetic mapping for temporal resolution of weeks to months (LaBrecque *et al*., 1999).

Potential of use of the GNSS reflected signal as an ocean remote-sensing and altimetry device was first proposed by Martin-Neira (1993). The so-called Passive Reflectometry and Interferometry System (PARIS) was proposed for a potential altimeter system which would use low-Earth orbiters carrying high-gain antenna to receive GNSS reflected signals.

In this paper, we will study the prospects of potential application of space-/airborne and land-based GNSS reflectometry to the synoptic observations of global-scale geodynamic processes, including the glacial isostatic adjustment GIA. The feasibility of using TOPEX radar altimetry to observe crustal deformation manifested by the GIA processes with a ~2 mm/yr accuracy was demonstrated over the Hudson Bay land region (Lee *et al*., 2008b).

2. ALTIMETRY FOR GEODYNAMICS STUDIES

Satellite radar altimetry has demonstrated its potential to measure non-ocean surface changes, for example, to observe ice sheet elevation changes for ice mass balance studies (e.g., Wingham *et al*., 1998) and inland water level variations for hydrologic studies (Birkett *et al*., 2002). Over land surfaces, satellite radar altimetry has also been used to correct/validate Digital Elevation Models (DEM) (Berry *et* *al*., 2007). Whereas these land altimetry studies focus on static height determination, the potential use of satellite radar altimetry for detecting solid Earth crustal motion over moderately flat land surfaces around Hudson Bay has been first demonstrated by Lee *et al*. (2008a). The TOPEX decadal vertical motion time series is obtained over a 1500 km by 1000 km region covering northern Ontario, northeastern Manitoba, and the Great Lakes region, which is at the margin of the former Laurentide Ice Sheet. The average of the estimated uncertainties for the vertical motion is 2.9 mm/yr, which is comparable to 2.1 mm/yr of recent GPS solutions. The estimated vertical motion is compared with other geodetic observations from GPS, tide gauge/altimetry (Kuo *et al*., 2008), data from Gravity Recovery and Climate Recovery Experiment, GRACE (Tapley *et al*., 2004), and with GIA models, including the ICE-5G (Peltier, 2004) and the 3D-GIA (RF3S20) models (Wang *et al*., 2008). It is anticipated that this innovative technique could potentially be used to provide additional constraints for GIA model improvement, and be applied to other geodynamics studies.

3. GEODYNAMIC STUDIES USING GNSS REFLECTOMETRY

Up to now, only SRL-2 has demonstrated the actual feasibility of measuring valid reflection signals from space (LaBrecque *et al.* 1999), and the GNSS reflectometry and scatterometry experiment onboard of UK's Disaster Management Constellation (DMC) satellite was successful in producing full Delay-Doppler maps from reflected GNSS signals using a 11.8 DB antenna (Gleason *et al.*, 2005). The German CHAMP mission, launched July 15, 2000, carried a GPS reflection experiment with a 10 dB helical antenna. The Argentina SAC-C mission which carried the GPS Occultation and Passive Reflection Experiment (GOLPE) and with a 6 dB helical antenna, to measure the direct, refracted, and reflected ray paths for GPS signals using the JPL TurboStar III/Blackjack GPS receiver. Unfortunately, these antennae do not have enough SNRs to successfully the reflected GPS signals: prior studies indicated that antenna gains ~20–34 dB are required for GNSS altimetry studies.

The algorithm to map solid Earth (or ocean) surface at the specular points using a geometric approach and an iterative-two-step procedures for specular points mapping has been developed by Wu *et al*. (1997). The accuracy of the specular points derived from the reflected GPS signals will depend on the signal to noise ratio, sea surface states, and some error factors like atmospheric conditions. The main concerns in signal to noise ratio is related to the antenna gain, radar cross-section and sea states (over ocean) or radio echo (over land surface).

In this paper, we will provide an analysis of contemporary radar altimetry observations of solid Earth deformation, including the GIA process. We will extend the experience of land-altimetry concept to study the prospects of potential application of space-, aircraft- and land-based GNSS reflectometry to the synoptic observations of solid Earth geodynamic processes, including the GIA. Error analysis using information from current advances of GPS/GNSS receiver hardware and antenna design will be conducted.

4. REFERENCES

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