SIGNAL: SAR FOR ICE, GLACIER AND OCEAN GLOBAL DYNAMICS

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1. INTRODUCTION

Recent observations indicate a dramatic increase of polar ice mass losses from glaciers, ice caps, and the Greenland and Antarctic ice sheets [1]. As a result, several new studies predict a global mean sea level rise more than twice as large as the projections from the IPCC 2007 report. Models of ice mass loss are, however, in their infancy, so projections of future sea-level rise are still associated with high uncertainty. One key parameter that is missing for a better understanding of the intricate dynamics of the polar ice mass balances is a detailed and accurate knowledge of the 3-D ice surface topography and its changes at fine spatial and temporal resolutions [2].

SIGNAL is an innovative earth exploration mission proposal with the main objective to accurately quantify topographic changes in polar regions. Measurements of glacier velocities and ocean currents provide valuable additional information for a better understanding of the Arctic and Antarctic water cycle. To fulfill the ambitious science objectives, a sensor is required that is capable of monitoring all critical regions with a high spatial resolution and a short revisit time, independent of weather conditions and solar illumination. The best means to fulfill the scientific requirements is to use high-frequency synthetic aperture radar (SAR) that is capable of providing low penetration and sensitive phase measurements. The ideal candidate appears to be Ka-Band (35 GHz), which assures adequate atmospheric transparency and a high spatial resolution when using a bandwidth up to 500 MHz. Additionally, by introducing interferometric capabilities, it will be possible to assess minimal changes in height as well as velocities (currents). The use of highly innovative digital beamforming techniques and the concentration of data acquisitions over polar regions will allow for a compact satellite design [3]. This paper will compare possible instrument and mission concepts and discuss the expected performance of the mission in the selected configuration. In particular, the potential use of a pair of formation flying twin-satellites will be considered, setting it apart from existing Ka-band polar-region focused SAR mission concepts [4].

2. MISSION GOALS

The primary goal of SIGNAL is to study and characterize the dynamics of Arctic and Antarctic ice masses and their relation to the global water cycle. This goal can be reached by quantification of the topographic changes of polar glaciers, ice caps, and the Greenland and Antarctic ice sheets, the systematic observation of the dynamics (velocity) of fast flowing glaciers. In addition, SIGNAL will allow the characterization of ocean currents and their spatiotemporal changes with respect to (or as indicator of) increase of sea level, water temperature and changes in salinity.

Secondary goals of the mission include the generation of high-precision topographic maps on a regional basis for hydrologic purposes, i.e. water levels of rivers, lakes, wetlands and seasonally flooded areas, as well as high-precision mapping of selected coastal.

3. METHODOLOGY

One of the main drivers of the mission is to be able to measure topographical changes of ice-sheets and glaciers. Since these have a short decorrelation time, which renders DInSAR techniques useless, the choice is to observe these variations by evaluating time series of high resolution digital elevation models produced using single pass InSAR. Ka-band has been chosen because the short wavelength minimizes the penetration into snow and ice.

The 2-D motion of fast moving glaciers will be studied using feature tracking-techniques. Here, the up to 500 MHz bandwidth available at Ka-band will allow high resolution estimates of this horizontal motion. Last, the use of along-track interferometric techniques will be considered. At Ka-band, these techniques will perform best with very short along-track baselines, compatible with a compact space-borne SAR mission.

4. MISSION AND INSTRUMENT CONCEPT

The SIGNAL mission concept relies on the combination of interferometric, speckle and feature tracking techniques to measure horizontal and vertical displacements with unprecedented accuracy and resolution. The use of interferometric techniques requires at least two antennas that simultaneously map the scene from slightly different incident angles. For this, several implementation options will be explored and compared to each other with regard to both their performance and cost effectiveness. One option employs a single satellite with multiple antennas. Another option is the use of two small satellites flying in a close formation. The short wavelength enables the employment of rather small antennas onboard a light-weight and low-cost satellite bus. Due to the lower precipitation rates at higher latitudes, only a rather small fraction of the data takes will be affected by a significant attenuation from rain and snowfall. The concentration on high latitudes allows moreover for frequent revisits as desired for the observation of polar dynamics. The convergent satellite tracks near the northern and southern turns provide also a unique opportunity for innovative calibration techniques, e.g. via the combination of data from multiple incident/aspect angles.

REFERENCES

[1] H. D. Pritchard1, R. J. Arthern1, D. G. Vaughan1 and L. A. Edwards, "Extensive dynamic thinning on the margins of the Greenland and Antarctic ice sheets", Nature, doi:10.1038/nature08471

[2] D.J. Quincey and A. Luckman, "Progress in satellite remote sensing of ice sheets", Progress in Physical Geography 2009; 33; pp 547-567

[3] G. Krieger, N. Gebert, and A. Moreira, "Multidimensional Waveform Encoding: A New Digital Beamforming Technique for Synthetic Aperture Radar Remote Sensing"

[4] Moller D., Heavey B., Hodges R., Rengarajan S., Rignot E., Rogez F., Sadowy G., Simard M., Zawadzki M.: "The Glacier and Land Ice Surface Topography Interferometer (GLISTIN): A Novel Ka-band Digitally Beamformed Interferometer", ESCTC 2006, College Park, Maryland.