STUDY ON CONCEPTS FOR RADAR INTERFEROMETRY FROM SATELLITES FOR OCEAN (AND LAND) APPLICATIONS

Studie zu Konzepten für Radar-Interferometrie über Ozeanen (und Land) im Rahmen zukünftiger Satellitenmissionen

(KoRIOLiS)

SECTION 1: INTRODUCTION

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Synthetic aperture radar (SAR) is a well-established technology for obtaining high-resolution images of the Earth's surface from airborne and spaceborne platforms. Since the *SEASAT* mission in 1978 [*Born et al.*, 1979], SAR images of the backscattered radar power from land, water, and ice surfaces have been used for a variety of applications, such as studies on soil moisture, hydrology, land use, forestry, geology, ice properties, ice dynamics, coastal zones, global change, and ocean winds and waves (for an overview see, for example, the publication by *Guyenne & Danesy* [1997]).

The SAR data interpretation has been further refined by exploiting phase differences between SAR images of the same scene which were taken from slightly different incidence angles and / or at different times. This interferometric processing allows measurements of terrain elevations [*Graham*, 1974; *Zebker & Goldstein*, 1986] and / or of velocities [*Goldstein & Zebker*, 1987]. There are three fundamental approaches to SAR interferometry:

- Repeat-pass interferometry uses conventional SAR images from different overflights of an area on slightly different paths, such as SAR images from different orbits of a satellite. This method can be used for topographic mapping of land surfaces and has been applied extensively, for example, to *ERS* SAR images (see, for example, the paper by *Rocca et al.* [1997]).
- Alternatively, two SAR images can be acquired during a single pass by two antennas which are separated by some distance perpendicular to the flight track. A number of airborne interferometric SAR (InSAR) systems for single-pass cross-track interferometry (single-pass XTI) exist, which are being used for a variety of scientific and commercial applications (see, for example, the paper by *Holecz et al.* [1997]). Since both SAR images are acquired at the same time, also non-stationary topographic features such as ocean waves can be studied by single-pass XTI [*Schulz-Stellenfleth et al.*, 2001]. Single-pass XTI from space was demonstrated with the SRTM mission for topographic mapping of the entire Earth's surface from a Space Shuttle in early 2000 [*Keydel et al.*, 1999].
- Finally, along-track SAR interferometry (ATI) uses two antennas which are separated along the flight track. Both antennas image a scene from the same antenna location with a short time lag. In this case, the phase differences between the two SAR images depend on the targets' displacement during the InSAR time lag and thus on the target velocities. ATI can be used for measuring surface current fields in the ocean [*Goldstein & Zebker*, 1987]. A few airborne ATI systems exist in North America and Europe, which have been used successfully in a number of experiments [*Thompson & Jensen*, 1993; *Graber et al.*, 1996; *Romeiser et al.*, 2000]. Spaceborne ATI was tested within the framework of the Space Shuttle missions SIR-C / X-SAR in 1994 [*Jordan et al.*, 1995] and SRTM in 2000 [*Keydel et al.*, 1999]. Due to unfavorably short time lags, the sensitivity of these ATI measurements of opportunity was very limited, but the general feasibility of current measurements from satellites by SAR interferometry could be demonstrated.

The great success of spaceborne and airborne SAR and InSAR missions and experiments in the 1990s, as well as calls for proposals for future satellite missions by the European Space Agency (ESA) and the National Aeronautics and Space Administration (NASA), have triggered a lively discussion on concepts for new InSAR systems in space for a variety of applications, such as high-resolution topographic mapping, monitoring of topographic changes, biomass assessment, ice monitoring, and ocean current and wave measurements. Most of the proposed spaceborne InSAR concepts and missions, such as the "Interferometric Cartwheel" [*Massonnet*, 1999; *Massonnet et al.*, 2000; *Ramongassié et al.*, 2000] are technology-driven and focus on XTI for land applications. The latter results from the fact that a lot of experience with land applications exists from repeat-pass interferometry with conventional spaceborne SARs and from the SRTM mission and that a number of applications of XTI data have emerged in the course of this development. However, also oceanic applications of InSAR, in particular along-track InSAR, are quite attractive: The feasibility of current and wave measurements by InSAR has been demonstrated in several experiments, the imaging theory is well understood, and quasi-operational methods for the processing of InSAR images of oceanic scenes and for the retrieval of surface current fields and surface wave spectra from InSAR data exist. Potential users at governmental agencies and research institutes express a considerable demand for current and wave measurements with high spatial resolution and wide coverage. Furthermore, some of the proposed spaceborne InSAR systems (e.g. the "Interferometric Cartwheel") have antenna separations in cross-track and along-track directions by design, and others offer various choices for the antenna arrangement, thus they might be suited for oceanic measurements without major modifications. Unfortunately, oceanic measuring capabilities have had low priority in most discussions and publications on spaceborne InSAR concepts, and many people involved in their development are not even aware of the potential of InSAR measurements over the ocean and / or of the theoretical background and the resulting technical requirements for such measurements.

In view of these shortcomings, the German research project KoRIOLiS (an acronym for "Studie zu Konzepten für Radar-Interferometrie über Ozeanen (und Land) im Rahmen zukünftiger Satellitenmissionen" – study on concepts for radar interferometry from satellites for ocean (and land) applications) was initiated in early 2001. Leading German specialists for the remote sensing of the ocean by InSAR, supported by Donald R. Thompson from the Johns Hopkins University / Applied Physics Laboratory, USA, received funding from the German Federal Ministry of Research for a comprehensive review of the state of the art in current and wave measurements by InSAR and an analysis of the potential of different spaceborne InSAR concepts for such measurements. The main deliverable of KoRIOLiS is this report, in which all findings are summarized.

The KoRIOLiS report is freely available to interested readers. It is supposed to provide valuable reference to everybody who intends to use InSAR systems or InSAR data for oceanic measurements, to propose or to develop future InSAR systems, or to evaluate proposed InSAR concepts with respect to their capabilities to measure currents and waves. The uniqueness of the report results from its comprehensiveness: Most of the conclusions are not new, and some new findings may appear trivial to experts, but no other publication offers a comparable overview of all aspects of oceanic applications of InSAR.

The KoRIOLiS report consists of the following sections:

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