“Wave processes in Arctic Seas, observed from *TerraSAR-X*”

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LONG-TERM GOALS

The reduction of the sea ice coverage during the boreal summer will lead to an increased importance of wind waves for the dynamic processes of the Arctic Seas. The large ice free areas lead to longer fetch and thus longer and higher sea state. Wind waves will enhance upper ocean mixing, may affect the breakup of ice sheets, and will likely lead to increased coastal erosion.

The primary long-term goal is a better understanding of the two-way interaction of waves and sea-ice, in order to improve wave models as well as ice models applicable to a changing Arctic wave/ and ice climate.

OBJECTIVES

Over the ocean, synthetic aperture radar is capable of providing wind and wave information by measuring the roughness of the sea surface.

In particular, TerraSAR-X data have been used to investigate the highly variable wave climate in coastal areas (e.g. Lehner et al., 2013). However, the use of these data at the sea ice boundary is still to be utilized in full detail. In addition, TerraSAR-X data provide accurate estimates of the wind field over the ocean as well as the position (and change) of the ice edge and ice drift estimates.

The main objectives of the proposed work are to adapt existing TerraSAR-X wave parameter and ice motion retrieval algorithms for the marginal ice zone in order to:

- analyze the spatial and temporal variability of the wave field in the emerging ice-free regions;
- investigate wave damping in sea ice and the related ice breakup;
- test/develop formulae of wave development (such as fetch laws) for the marginal ice zone;
- provide wave field characteristics and wind data to other research groups within this DRI;

APPROACH

This work is in collaboration with S. Lehner from the German Aerospace Center (DLR). We will use data from the X-band high resolution SAR satellite TerraSAR-X (TS-X), which was launched in June 2007, and its twin, TanDEM-X (TD-X), launched in June 2010. TS-X and TD-X operate from 514km height at sun-synchronous orbits, the ground speed is $7 km \cdot s^{-1}$ (15 orbits per day). Both satellites are orbiting in a close formation with typical distances between satellites of 250m to 500m. They operate with a wavelength of 31mm. The repeat-cycle is 11 days, but the same region can be imaged with different incidence angles after three days dependent on scene latitude. Typical incidence angles range between 20° and 55°. The coverage and resolution depends on satellite mode: *ScanSAR* mode covers 100km strip, *StripMap* mode covers 30km by 50km with a resolution of about 3m, *Spotlight* covers 10km by 10km with resolution of about 1m. A new option, particularly useful for ice coverage investigation is the *Wide ScanSAR* mode which covers 450km by 250km with resolution of about 40m.

Retrieval of wind parameters from TS-X data is based on the *XMOD-2* algorithm, which takes the full nonlinear physical model function into account. At the same time the corresponding sea state can be estimated from the same image. The empirical model for obtaining integrated wave parameters is based on the analysis of image spectra, and uses parameters fitted with collocated buoy data and information on spectral peak direction and incidence angle. The newly developed *XWAVE-2* algorithm derives significant wave height, wave direction and wave length directly from TS-X SAR image spectra without using a-priori information.

WORK COMPLETED

Infrastructure to access and process TS-X data at the University of Vctoria has been put in place. TS-X StripMap and wide-ScanSAR images over the proposed experimental site were recorded during September 2013. These images will be analyzed in terms of wind, wave and ice conditions to guide the preparation of the 2015 field campaign. The entire science team of this DRI prepararED and published a science plan outlying the scientific approaches and goals of this project [Thomson, et al. 2013). I participated in the DRI planning meeting in February.

RESULTS

The capability of retrieving wind and wave and ice information from TS-X data has been demonstarted in several examples in marginal ice zones at diverse locations in the Arctic. An example is given in Figure 1.

The DLR group developed algorithms for the retrieval of sea ice parameters from TS-X data, which were tested during a recent cruise of F/S Polarstern. TS-X Q*uicklook* data were successfully sent to the bridge of the research vessel in near real time.

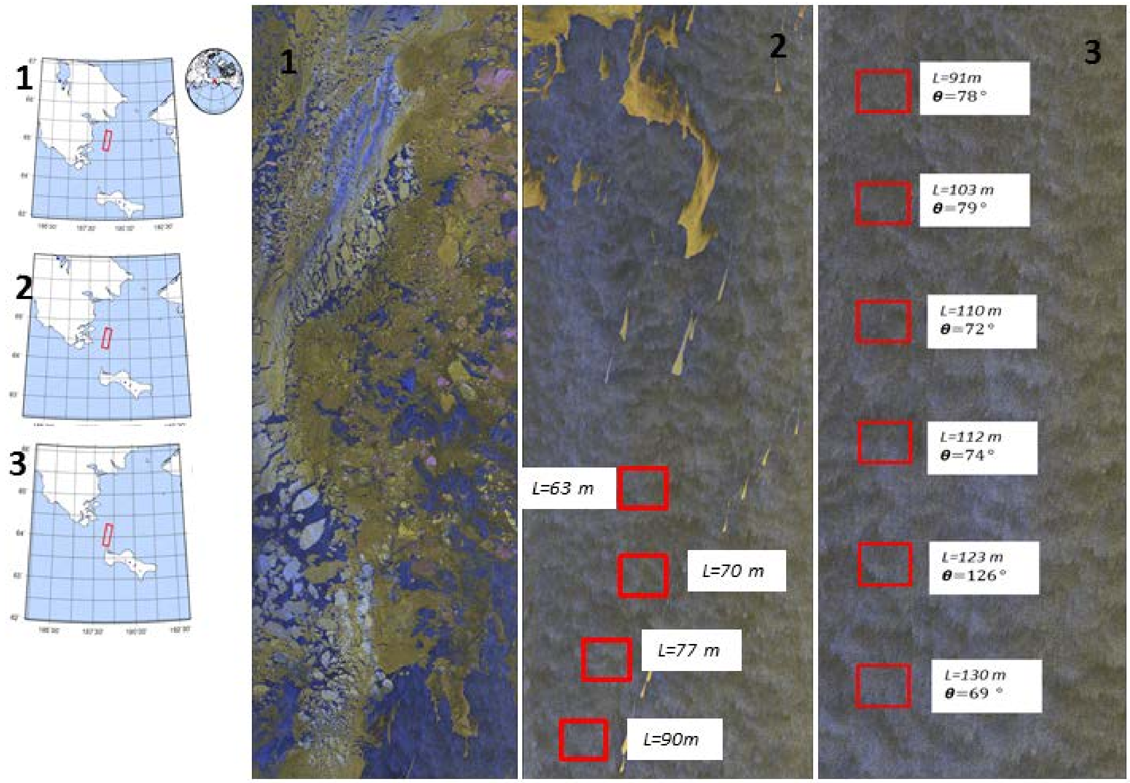

Figure 1: An example of the wave field in off-ice wind conditions in the Bering Sea (Dec 7, 2012), showing the increase in wave length L with increasing fetch

IMPACT/APPLICATIONS

This effort will provide detailed information on wave-ice interaction on a scale that is difficult to achieve with in-situ observation but at a high-resolution commonly not achieved by other satellite-based remote sensing methods. These information, which can be obtained independently of local weather conditions, can guide the development of wave and ice prediction models required for safe marine efforts in the emerging Arctic Ocean.

RELATED PROJECTS

This project is related to several other projects within this DRI. In particular:

1. "Wave Climate and Wave Mixing in the Marginal Ice Zones of Arctic Seas, Observations and Modelling", by Babanin, Young and Zieger. This project proposes to investigate wave climate in the Beaufort and Chukchi Sea and its trends by means of satellite altimetry
2. "Storm Flux: Heat and Momentum Transfer in the Arctic Air–Sea–Ice System" by Thomson. This project will provide in-situ wave observations which will serve for ground-truthing the TS-X wave products.

3. “Radar Remote Sensing of Ice and Sea State and Boundary Layer Physics in the Marginal Ice Zone”, by Graber. This project will provide high resolution spatial wave and ice information during the field campaign. These results will be compared to the larger field of view data form TS-X.

REFERENCES

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PUBLICATIONS

Thomson, and 19 co-authors: Sea state and boundary layer physics of the emerging Arctic ocean. APL-Technical report APL-UW 1306, September 2013 [published]