MONITORING ICE-ONSET ON LAKES AND RIVERS IN NORTHERN SIBERIA WITH TERRASAR-X IMAGERY

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ABSTRACT

The timing and duration of ice-onset on lakes and river channels is a relevant climate signal since it is strongly driven by the air temperature. Space-borne imaging radar is a suitable tool for the detection of freeze processes, as the backscattering of radar waves is highly dependent on the dielectric properties of the surface. For this study, a time series of high-resolution TerraSAR-X images recorded during fall and winter 2012 was analysed. The images cover several lakes and river channels located in the central Lena Delta, North Siberia, Russia. On the basis of radar signature analysis and of classification results from visible inspection of the images, the potential of change detection and intensity-thresholds for the separation of thin ice covers and water surfaces is discussed.

1. INTRODUCTION

Lakes and river channels are a frequent land cover type in Arctic tundra landscapes. In our study area, the Lena River Delta in northernmost Siberia, they cover more than 30% of the surface [1]. The timing of ice-onset is an important climate variable, as it depends on air temperatures, beside other factors such as lake size and depth [2, 3]. Remote sensing provides a means for obtaining regional information in the high Arctic where ground-based data networks are sparse. Spaceborne radar is a suitable tool to detect ice-onset on a regional scale, whereas the use of optical sensors is restricted due to darkness and cloud covers. Radar systems can monitor the earth surface at comparatively high spatial resolutions (on the order of 1 to 20 m), which allows to detect small-scale surface characteristics such as small lakes and narrow river channels, which are often present in permafrost environments [4]. A high temporal as well as spatial resolution is essential for this application, as many lakes are smaller than 1ha and freeze-up can occur during one night. TerraSAR-X is an extremely suitable platform due to its fast revisit time of 11 days, and its high spatial resolution of only a few meters. While several studies exist showing the potential to monitor ice-decay with SAR data [e.g. 5, 6], only few studies exist addressing the detection of ice-onset [7].

2. INVESTIGATION AREA

The lakes and river channels investigated in this study are located in the southern central part of the Lena Delta in northernmost Siberia, Russia at 72°N and 126°E. The area is characterized by arctic tundra ecosystems [1] and underlain by continuous permafrost. The riverbed is in its natural form, the channels investigated here are secondary channels of the Lena river. Freeze-up of the lakes and river channels usually occurs in the beginning of October when the air temperatures stay below 0°C. Air temperatures measured 120 km southeast of the investigation area are shown in Fig. 1 for autumn 2012.

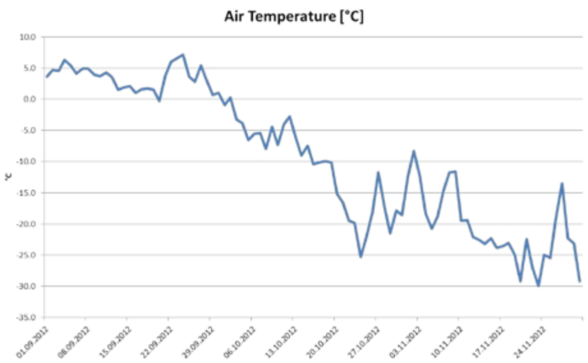

Figure 1 Air temperatures in Tiksi, RU, from September to November 2012 (Data source: NOAA).

3. MATERIAL AND METHODS

A time series of TerraSAR-X images recorded during fall and winter 2012 was available for this study. The images were acquired in identical acquisition geometry in the stripmap mode in HH polarization and delivered in SSC format. Acquisition dates were 25/09, 06/10, 17/10, 28/10, 08/11, 19/11 and 30/11. Image processing, including geocoding and multi-looking, were performed with the SARScape software. The pixel size after geocoding is 13.2m x 13.2m. A 3x3 Lee filter was applied for speckle and noise reduction.

Histograms of the backscattering intensity values of several lakes and river channels were computed for each date. One example is shown in Fig. 2. In addition, visual analyses of the backscattering patterns on the water bodies were conducted to determine whether the water body is (partly) ice covered or not. An image subset displaying the conditions during ice-onset is shown in Fig. 3.

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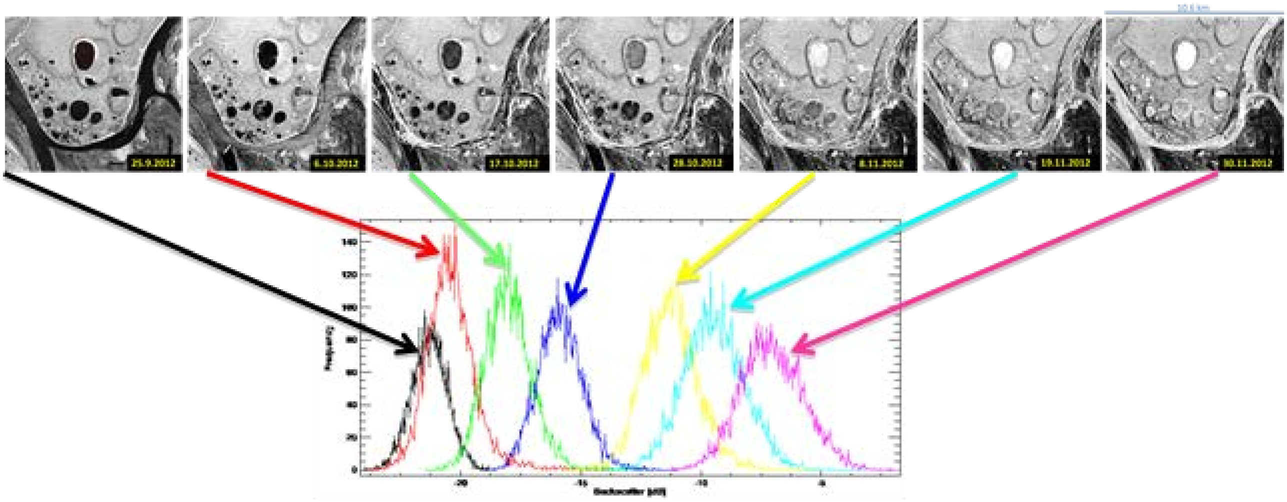

Figure 2 Top: TerraSAR-X time series. Bottom: Histograms displaying the backscattering intensity distribution on the large lake in the upper part of the images in the top.

4. RESULTS AND DISCUSSION

The example histograms in Fig. 2 show a clear backscatter rise from open water to ice covered conditions. This is in agreement with the results from visual inspection of the images and expected freeze-up timing according to the air temperatures. The water surface of the test lake was – according to the results of visual inspection by an experienced user - calm during acquisition of the first image and a thin, smooth ice-cover had developed at the acquisition time of the second image. The histograms of the first two images are mainly overlapping, which makes it impossible to detect the ice-onset using intensity thresholds or change detection. The first clear difference between the backscattering intensities of calm open water and ice appeared on October 17. In this case, the ice-onset would be detected 11 days later compared to the first ice detection via visible inspection, which is too long in case the data have to be used for climate studies or to support weather forecast models. Considering that wind-affected water surfaces show similar backscattering intensities, the use of thresholds for detection of freeze-up might not be considered as a suitable approach at all. The backscattering intensity rises continuously throughout our time series. This is possibly caused by the inclusion of more and more air bubbles trapped in the ice and a typical signal evolution on lake ice surfaces during winter.

5. CONCLUSION AND OUTLOOK

SAR images in high spatial and temporal resolutions are well suited for the detection of ice-onset on lakes and river channels. Visible interpretation of the backscatter intensity patterns allows a robust classification in most cases. Automatic detection is more difficult, as the common and easy to apply thresholding technique is not able to distinguish water from thin ice. Patterns like cracks in thin ice and ice/water interfaces, however, are relatively easy to detect by visible inspection in high-resolution TerraSAR-X imagery. Therefore, edge detection techniques might be suitable to indicate the occurrence of ice on water bodies. Another possibility is to investigate the change in the scattering behaviour of the radar waves at the surface during freeze-up by polarimetric analyses. Future research will investigate the potential of both techniques for automatic detection of ice-onset.

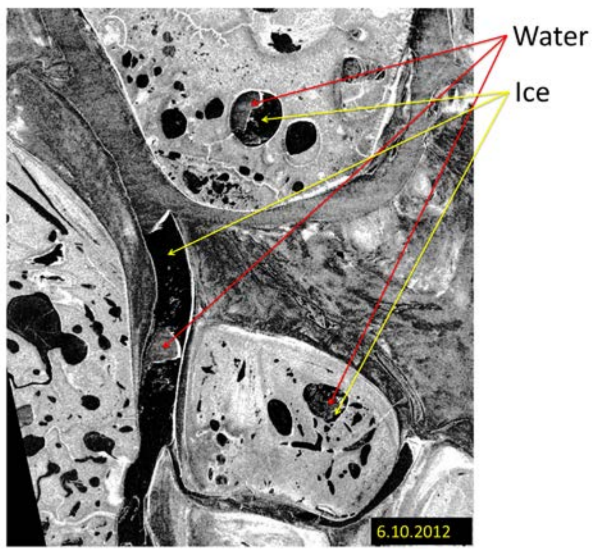

Figure 3 TerraSAR-X image subset. Clear backscatter differences are visible on the water bodies. Dark areas represent areas covered by thin ice, lighter areas display wind effected water surfaces.

6. ACKNOWLEDGEMENTS

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