MONITORING OF THAWING PROCESS USING ENVISAT ASAR GLOBAL MODE DATA

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1. INTRODUCTION

Several studies have reported on applications of active microwave sensors to detect freeze/thaw transitions in terrestrial ecosystems. Terrestrial ecosystems exhibit marked differences in dielectric properties between frozen and thawed states, results in changes in radar backscattering coefficients. Most of previous studies were carried out based on the C-and Ku-band scatterometer measurements due to their global coverage with high temporal resolution.

The C-band scatterometer sensors on board ERS satellites have been actively investigated for detecting the freeze/thaw states [1-3]. It provides complete coverage every three days at latitudes above 40° latitude. Studies on freeze/thaw cycles of interior Alaska and Siberia showed that changes in dielectric properties of frozen scatterer results in a decrease of backscatter for all land cover classes. Algorithms to monitor the freeze/thaw of the upper layer of the soils have been developed using the normalized radar cross section (NRCS) at 40° incidence angle. They are based on the change detection approaches that determine backscatter values exceeding the average of summer (thawed) and winter backscatter values.

On the other hand, the Ku-band NASA Scatterometer (NSCAT) data were used to detect freeze/thaw transitions at sites in the BOREAS study area in Canada [4] and in Alaska [5]. NSCAT had a broader swath width than the ERS-1 scatterometer and higher temporal resolution (twice-daily). In case of Ku-band, a strong decrease in backscatter was observed during spring thaw (4–6 dB). Again, algorithms to monitor the freeze/thaw transitions using NSCAT ware developed based on a temporal change detection of five-day smoothed backscatter measurements.

Although NSCAT operated for only about 9.5 months, a follow-on instrument, the SeaWinds scatterometer on board Quikscat, has similar characteristics to NSCAT. Bartsch et al. (2007) [6] applied Quikscat data to detect thawing state in central Siberia. They developed a rigorous algorithm for detecting thaw events based on significance of diurnal changes during spring thaw. Compared to previous methods which depend on temporal change detection approaches with threshold values, it allows investigation of large regions without calibration by ground data and determination of thresholds.

2. DETECTION OF SEASIONAL THAWING WITH ASAR GM DATA

Researches on freeze/thaw cycles on permafrost region have been focused on the use of scatterometer data mainly due to their high temporal resolution. SAR remote sensing allows Earth observation with high spatial resolution but poor temporal resolution. There have been a few studies on the use of SAR data to freeze/thaw processes in the cold regions, e.g., [7] and [8], but the use of SAR data can still be considered to be in an experimental stage.

The ENVISAT ASAR Global Monitoring (GM) mode can provide several measurements per week with varying incidence angles and 1 km resolution. Due to its high temporal sampling rate, ASAR GM mode has a high application potential for analyzing freeze/thaw process. Fig. 1(a) shows an example of time series of normalized backscattering coefficient at 30° incidence angle [9] for a permafrost test site in Yakutsk study area which is investigated as part of the ESA DUE PERMAFROST project (www.ipf.tuwien.ac.at/permafrost). Although time series of ASAR GM data are quite noisy, one can find seasonal variations in temporal backscattering coefficients. Backscattering coefficients obtained in summer season are higher than those obtained in winter season. However, temporal change detection approaches with threshold values can hardly applicable because of the high noise in backscattering time series and fluctuating seasonal backscatter patterns according to different land cover types and climate conditions.

In order to use ASAR GM time series for analyzing freeze/thaw states, a least square fitting of piecewise step function is introduced in this study. The thawing date can be determined by minimizing the sum of squared residuals between measured backscattering time series and a pre-defined step function. Fig. 1(b) shows examples of determined piecewise function for

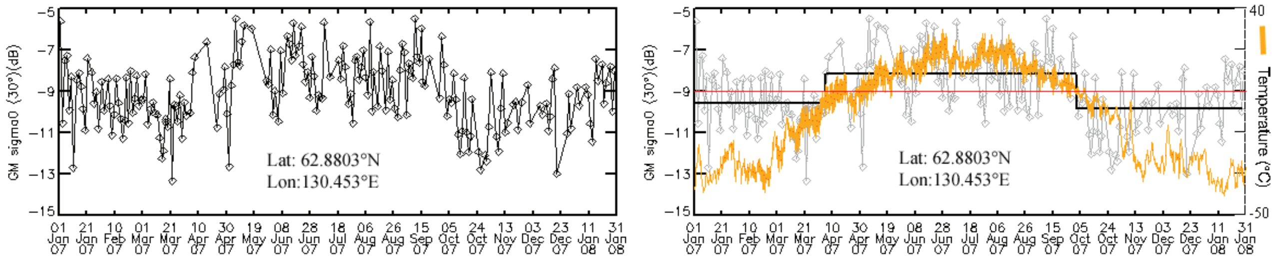

Fig. 1. (a) Normalized ASAR GM time series for a test sites in Yakutsk. (b) Piecewise function fitted to ASAR GM time series and nearest ECMWF air temperature data

timing freeze/thaw states from ASAR GM time series and ECMWF air temperature data.
Dates correspond to a jump discontinuity of the piecewise function indicate freeze/thaw transition inferred in ASAR GM time series. Estimated freeze/thaw dates reveal good agreements with the general freeze/thaw transition of mean daily air temperatures.

3. CONCLUSION

In this paper, a new method for detecting thawing process has been presented base on ENVISAT ASAR Global Mode data sets. An experiment result for Siberian permafrost area illustrates that it can be a promising approach in monitoring permafrost ecosystems. Moreover, the method proposed in this study has a good potential for analyzing temporal changes of any other noisy time-series data sets. Since the estimated thawing event derived from ASAR GM data are exclusively based on temporal changes of backscatter, studies on relating radar derived parameters to fundamental environmental processes in permafrost ecosystem should be further investigated. More detailed verification on the proposed freeze/thaw detection method will be helpful to establish an operational monitoring system for high latitude permafrost.

4. REFERENCES

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