INVESTIGATION OF POLARIMETRIC ALOS-2 FOR DISCONTINUOUS PERMAFROST MAPPING IN NORTHERN ALBERTA PEATLANDS

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ABSTRACT

Recent climate warming has been pronounced in the arctic and sub-arctic region with the average annual temperature increasing between 2-3°C since the 1950’s [1]. Accelerated temperature increases have driven declines in sea ice extent, snow cover duration, glacier mass, and increase in permafrost temperatures [1]. Increasing evidence from the permafrost zone suggests abrupt permafrost thaw may be the norm for many parts of the Artic and sub-arctic landscape [1, 2]. Climate warming is causing the initiation and expansion of thermokarst, which is the process whereby permafrost thaw causes ground subsidence and the development of characteristic landforms. Even though thermokarst occurs at point locations, it causes surrounding permafrost to thaw more rapidly. Northern Alberta contains a significant component of discontinuous permafrost, which is distributed within wooded palsa bogs and peat plateaus that form part of heterogeneous mosaic of non-permafrost wooded bogs, fens, swamps and other upland forest types. Permafrost distribution and ongoing degradation affects peatland structure, hydrology, and vegetation [3], and has been linked with environmental changes including increased stream runoff [4], greenhouse gas fluxes [1], and forest fire severity [5]. In addition, permafrost distribution is an important consideration for route planning and reclamation design because linear disturbances from seismic lines, pipelines and winter roads result in the rapid and irreversible thawing of the underlying frozen peat [5]. However to date, there has been limited mapping or monitoring of permafrost in Alberta at a scale sufficient for these purposes, with previous airphoto-based interpretations providing only a small-scale delineation of the forest-covered permafrost terrain [7]. Recent work by the Alberta Geological Survey (AGS) has employed a remote sensing and GIS modelling approach to mapping discontinuous permafrost principally from LiDAR [8]. Early results have demonstrated that high classification accuracies (>85%) can be achieved, and that permafrost is more extensive than previously identified even at relatively low latitudes (~56.5°). However, LiDAR is not a suitable methodology for repeated mapping and/or monitoring ongoing permafrost changes at large scale, and cannot assess important indicators of permafrost thermal state such as active layer thickness (ALT).
Recently, we have shown that the long penetrating polarimetric L-band ALOS can provide the required information for cost effective peatland mapping and monitoring in the boreal and subarctic peatlands [1]. The use of the phase of the scattering type provided by the Touzi decomposition [2] permits the demonstration of the unique capability of polarimetric ALOS for the detection of peatland subsurface water flow. Polarimetric L-band ALOS collected from subarctic peatlands in the Wapusk National Park in Canada have been used to demonstrate the excellent capabilities of long penetrating PALSAR for peatland mapping and monitoring [1].

Cost-effective permafrost characterization and monitoring should be possible due to advances in the technology of earth observation satellites. In particular, the long-penetration capabilities of L-band ALOS2 PALSAR should permit large-scale mapping of discontinuous permafrost in peatland areas. Recently, it has been shown that the long penetrating polarimetric L-band ALOS is very promising for monitoring peatland subsurface water flow [8, 9]. The use of the phase of the scattering type provided by the Touzi decomposition [10] permits the demonstration of the unique capability of polarimetric ALOS for detecting subarctic and boreal peatland subsurface water flow, and monitoring bog to fen transformations related to climate warming [8, 9, 11]. Polarimetric L-band ALOS collected over subarctic peatlands (in Wapusk National Park, Canada) and boreal peatlands (in the Athabasca oil sand region) have been used for the demonstration of the excellent capabilities of the long penetrating PALSAR for peatland mapping and monitoring [8, 9].

In this study, the Touzi scattering phase is investigated for mapping discontinuous permafrost in Northern Alberta. Polarimetric ALOS-2 (FP6-4) and field data were collected in August 2014 over discontinuously distributed permafrost within wooded palsa bogs and peat plateaus near the Namur Lake, northeast Alberta. A first analysis of the data quality of the polarimetric ALOS2 image has revealed a residual calibration error of about -33dB. The method developed in [12, 13] is applied to reduce the residual error to -43 dB. This should allow us to fully exploit the excellent ALOS2 performance in terms of low noise floor (NESZ about -38 dB), for accurate measurement of the HV component. The accuracy of low HV backscattering measurement is very important for the extraction of meaningful peatland subsurface water flow information using the Touzi scattering type information [8]. The Touzi decomposition is applied on the polarimetric ALOS2 data collected with the high-sensitive PLR mode of about 4.4mx5.1m resolution at FP6-4 (about 27 degree incidence angle). It is shown that the information provided by the scattering type phase is very promising for detection of relatively deep peatland subsurface permafrost (up to 40 cm). These results are validated jointly with AGS using field data collected during the summer of 2014. A permafrost classification using a combination of Lidar and Landsat data is also used as a reference for the ALOS2 result validation. Further investigation is being conducted at a second site (near Zama airport in northwest Alberta) using polarimetric ALOS2 images collected in 2016 to confirm the potential of polarimetric ALOS2 and the Touzi decomposition for discontinuous permafrost mapping in peatland regions. The potential of polarimetric SAR equipped with longer wavelength (P-band) for detection of deeper permafrost and “eventually” measurement of active layer thickness is also discussed. We also address the possibility of validating this methodology for discontinuous permafrost mapping using the JPL airborne polarimetric P-band AIRMOSS in the context of the AbOVE mission.

References: