Geophysical Research Abstracts
Vol. 21, EGU2019-2424, 2019
EGU General Assembly 2019

Impact of recent climate change in the Arctic on snow physical parameters retrieval using SAR data (Svalbard)

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Arctic snow cover dynamics exhibit strong changes in terms of extent and duration due to recent climate change conditions (Mudryk et al., 2018; Lemke & Jacobi, 2011). In this context, innovative observation methods are helpful for a better comprehension of the role of the snow for climate research and hydrology. The spatial variability of snow properties is here addressed for the Ny-Ålesund area, Svalbard (N 78°55' / E 11° 55') using satellite radar images in the X-band. This remote sensing method removes the limitations and ambiguities of optical imaging limited by the polar night and cloud cover.
This study contributes to the "Precip-A2" project (OSUG@2020, Grenoble, France), focusing on snow and its interaction with the atmosphere: chemistry, radiative processes, and precipitation. One sub-task of the project is dedicated to X-band active radar measurements (SAR) to retrieve physical properties of arctic snow (spatial variability, depth estimation), involving consistent ground network including a large international partnership (France, Germany, Norway, Italy).
1. Climatology context: for Ny-Alesund area, a change in the occurrence frequency of source region of air masses has been identified. Consequently, an increase in temperature and water vapour content was detected (Dahlke and Maturilli, 2016). Temperature time series since 1969 were analyzed and an increase in annual temperature of ∼0.07 C per year was found. This increase is mainly driven by a positive seasonal trend in winter (DJF); thus, influencing the fraction of annual precipitation falling as snow / rain.
2. Remote sensing application: a set of ten SAR images was provided by the DLR during winter 2017 from the TerraSAR-X sensor (3.1 cm, 9.6 GHz) in dual co-pol HH, VV (2.5 m resolution). Descending and ascending orbits were combined at 35-38° incidence angles to avoid topographic constraints. The data were processed with the ESA "SNAP" toolbox. Output products: non-polarimetric analysis providing regular snow mapping from March to June 2017 and polarimetric analysis related to the physical properties of the snow pack. The non-polarimetric mode (single polarization HH or VV) processed with adaptive thresholding (Nagler et al., 2000) allows retrieving snow cover areas (SCA) and their temporal evolution, which are afterwards compared to optical Sentinel-2 simultaneous acquisition for dates without clouds. SCA results are well correlated (0.95) assessing the interest of SAR images in regard of optical mode suffering from polar night and cloud coverage. The polarimetric analysis is based on a co-polar phase difference (CPD) set between HH and VV polarization (Leinss, 2015). Results indicate that CPD values are linked to the snow metamorphism: positive values for dry snow, negative values after recrystallization processes. The best R2 correlation performances between estimated and measured snow height are ranging from 0.51 to 0.75. However, the X-band signal is strongly influenced by the snow stratigraphy: internal ice layers reduce or block the penetration of the signal into the snow pack. Due to warming during winter season coupled with increasing soil temperatures, this snow metamorphism evolution more relevant of temperate region seems unfortunately to occur now in this Arctic area (Boike et al., 2018).