Monitoring of short-lived snow coverage by SAR data around Livingston Island, South Shetland Islands in Antarctica

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Abstract

Snow is the component of the Cryosphere with the largest seasonal variation in spatial extent. Because of the large extent of terrestrial snow cover and the difficulties in obtaining ground measurements over cold regions, remote sensing represents an important tool for studying snow properties at regional to global scales. In fact, accumulation and rapid melt of snow are two of the most dynamical seasonal environmental changes on the Earth's surface. The large scale changes in snow cover are useful as indicators of climate changes. Snow also affects other components of the Earth's climate system as rainfall, air temperature, atmospheric pressure and others. The main aim of this research is to trace the use of different satellite data and approaches to track the dynamics of the development of short-lived snow coverage and its seasonal dynamics around Livingstone Island, South Shetland Islands, in Antarctica. Natural objects like water, snow and wet snow were analyzed and mapped according to the European Space Agency data (ESA) Copernicus program (Copernicus Scientific Data Hub). Results have been obtained for quantitative changes of wet snow cover and its dynamics**.** It has been proven that even for a short time span there has been an expansion of the areas taken up by wet snow, which is an unequivocal evidence of climate changes. The demonstrated results are a representative sample of the last two years, but the study is based on a longer period and the focus is on the data provided by SAR (Synthetic Aperture Radar). The presented monitoring methodology is financially accessible and irrespective of the economic developments of the regions and the place of research. The monitoring results can be used not only to monitor wet snow, snow, water , but also to monitor vegetation and soils.

Keywords: *Snow cover, Radar satellite data, Optical range, Sentinel-1 SAR, Antarctica*

Introduction

Because ice and snow reflects sunlight (whereas oceans absorb it), the Antarctic ice cap is one of the Earth's natural defense mechanisms, helping to regulate the temperature of the oceans and the atmosphere. An increase in temperature in this region could cause a positive feedback

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loop (melting ice and snow causing a further increase in temperature, etc.), and this has the potential to influence climate patterns all over the world. Copernicus ice monitoring services keep an eye on the poles and give us insight into the rate at which the wet snow coverage extent is changing over time (Copernicus. Europe's eyes on Earth, 2018). The subject of the study is monitoring of short-lived snow coverage, or so-called wet snow, and its dynamics for Livingston Island, South Shetland Islands in Antarctica.

Each natural object or entity reflects the sun's radiation that has fallen on it in a specific way, characteristic of itself and its condition. This unambiguous correspondence is the basis for identifying the type and condition of the Earth's natural objects in the reflected solar radiation (Mardirossian G., 2000; Spasova T., R. Nedkov., 2017).

Figure 1 demonstrates test areas on an optical image of Sentinel - 2. Spots were taken to reflect the spectral reflectance of water, wet snow and ice. Before composing points, a composite of the image was made and using 4, 3 and 2 spectral bands using the RGB model. Spectral characteristics are curves that distinguish natural objects. These test points are arbitrarily made to calibrate with SAR images for much better quality monitoring.

The main purpose of this study is to track the use of different types of data, Synthetic Aperture Radar (SAR) data and approaches to study the dynamics of wet snow cover by remote sensing and the importance of this monitoring of climate change.

Methodology

Verification and validation of SAR images is done using the Tasseled Cap Transformation (TCT) model used and based on pre-selected test areas with ice, wet snow and water. The selection was made using terrestrial data from Livingston Island near the Bulgarian Antarctic Base, St. Klement Ohridski (located at 62 ° 38 '29 "S, 60 ° 21' 53" W), East Coast of the South Bay, in Livingston, South Island. Terrestrial data are only used for calibrating aerospace data (Correia, A., et al. 2017; Mardirossian G., 2000). Test areas were selected from locations without field data. When different climatic phase transitions occur, different changes occur in the snow coverage, therefore the evaluation indicators also change.

One of the indexes in the study is Wetness from TCT with components BR - Brightness,GR - Greeness, W - Wetness suitably, composed in RGB model. In that case, the achieved results have a changed structure in comparison to the primary received data. It allows more precise recognition and classification of the different components (vegetation, soil, water) of the land cover (Nedkov R.,2017).

The observation of the spectral changes observed in the melting of snow and wet snow through the use of spectral characteristics requires the use of different spectral channels. The methodology of this study includes selection of satellite data as input data (Sentinel -2 optical data) to obtain TCT images and SAR images from Sentinel -1 SAR, including the selection of appropriate time series with the appropriate resolution for tracking the snow cover (presence of snow , wet snow, water) (Spasova T., R. Nedkov, 2017). Verification of SAR images with hh-polarization is based on representative TCT test areas. The melting snow and short-lived snow coverage can be investigated and recorded by the C-band of Sentinel-1, but as an indicator it is necessary to study the wetness from TCT. The lack of qualitative data from an optical image is compensated sufficiently by SAR images and Merge approach (Sentinel -1 in dB (decibel) and TCT from Sentinel- 2) and the use of SAR in dB can be clearly used as a validation method (Spasova T., Nedkov R., 2017). The resolution and hh - polarization in the area is also absolutely sufficient (Nedkov R., Spasova T., 2016) to map the dynamics of wet snow or short-lived snow coverage during phase transition seasons, the presence of constant snow cover and ice for the rest of the year. The radar data does not depend on the weather conditions in the Antarctic and is of high quality and resolution for climate change monitoring.

Results

The comparative analysis of the results of TCT image and SAR images indicates the presence of more wet snow, which is a clear evidence of climate change. Data from Sentinel -2 MSI (MultiSpectral Instrument) can be used to clearly locate the presence or absence of water, snow and ice. Optical images from this area have a lower temporal resolution, making them less suitable for monitoring, as wet snow melts faster. Spectral bands used to detect snow cover are 4, 3, 2, (**Figure1**).

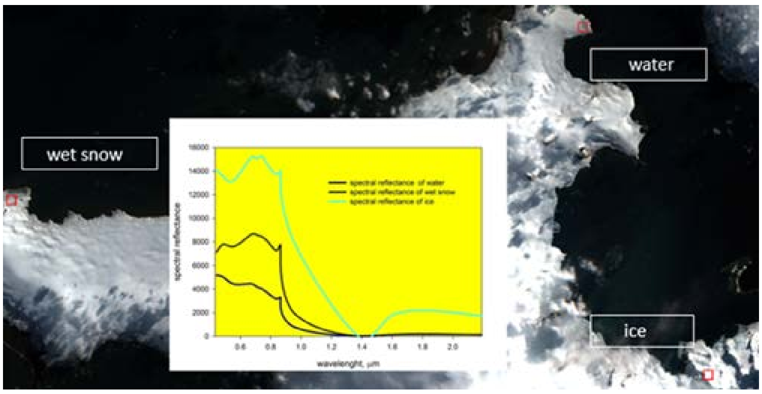

Figure1: Composite image from Sentinel-2 with the test areas – bands 4, 3, 2 date: 30/03/2017 and spectral characteristic of water, wet snow and ice for the test areas (Source: Authors own)

The SAR images with hh - horizontal polarization (**Figure 2**) from two consecutive years (from the same period of the year), the spectral and reflectance distribution of wet snow in dB(decibel) are also reliable ways to validate wet snow data and locations with large change in values 22 - 25 dB, which is a sure sign of climate change. This is a representative sample of a period of more than five years and the values are being studied. Values between 25 and 28 dB indicate wet snow or short-lived snow coverage (Spasova T., Nedkov R. 2017), values above 30 dB are an ice indicator (Gochev D., Nedkov R., Dimitrova M. 2017). Among the presented SAR images from 2017 and 2018, certain segments can be observed where the climate change tendency, even for a period of one year, is considerable. Although the image is 20 days later, it can be assumed that in 2018 the areas of wet snow and water have a much larger area, which is a tendency for unfavorable climate change in these latitudes, and which could affect drinking water worldwide.

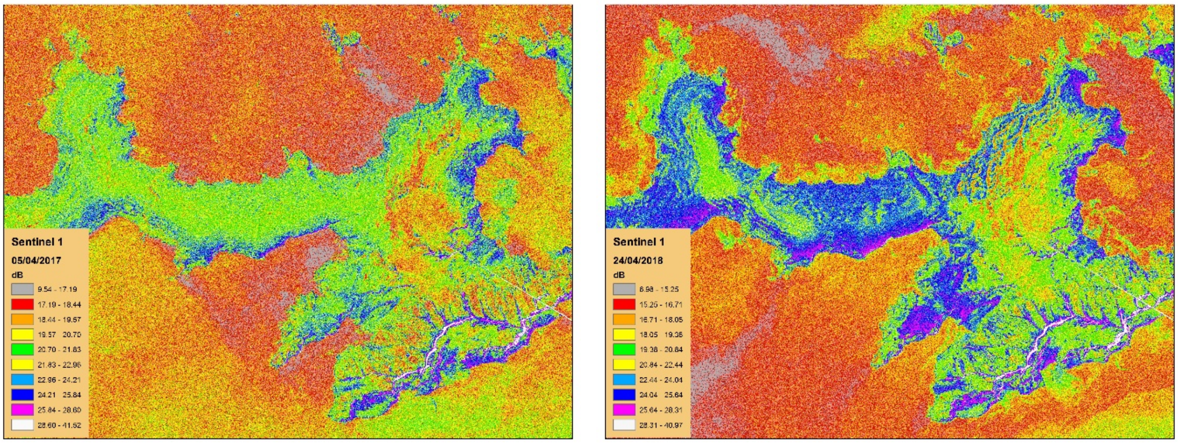

Figure 2: SAR images in dB, Sentinel -1 (2017, 2018) (Source: Temenuzhka Spasova)

In **Figure 2** in bright and dark blue color (or values between 22 - 25 dB) are the places depicting wet snow and covering quite large areas in 2018.

Conclusion

The year-round monitoring, conducted in in hard accessible places like the Antarctic, is difficult and expensive but the impact of this area is not only local but global. Therefore, the SAR-validated database study, which has a good enough resolution, attempts to show the real melting trend of snow as much as possible. This trend can be explored on the basis of the presented methodology as the ESA gives free access to its data. The survey data is representative of samples and can be used not only for wet snow monitoring but also for all other natural objects. With a rise in temperature, the sea- level will rise and this is a threat to a large number of island and lower-lying countries. Wetlands are likely to become wetter and droughts will become more common. One of the main things in "Adaptation to Climate Change" is to prevent or reduce human's negative impact on climate change. There is no way to prove that there are impacts and significant changes in the environment without constant monitoring.

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