On the retrieval of the snow temperature profile on the Antarctic Plateau at Dome-C from microwave data

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In the last decades there has been a growing interest in the study of natural phenomena due to the climate changes and the intensification of natural disasters. The Intergovernmental Panel on Climate Changes has established that there is evidence that the greenhouse gasses produced by human activities significantly affected the environment and the global warming. Among all the topics investigated by the researchers, a special attention has been paid to the cryosphere because it represents one of the most important indicators of the climate changes. Many glaciers, the Greenland ice sheet, permafrost and frozen ground, snow cover and Arctic sea ice are exhibiting dramatic changes which alter the ecosystems and consequently the human life. The Earth climate is affected by the polar ice caps which are sensitive to the climate changes and directly influence the energy surface exchanges, clouds, precipitation, hydrological conditions, atmospheric and ocean dynamics. In this scenario, Antarctica plays a fundamental role on the global climate due to its surface (more than the double of Europe), low temperatures (which range from -90° up to -25°) and quantity of ice (the mean ice thickness is 1500 meters). Despite its high importance for the environment, Antarctica is the most unexplored and under-sampled area of the Earth due to the extreme environmental conditions which makes very hard the human presence. Part of these difficulties can be overcome by using remote sensing techniques which rely mainly on satellite measured data. In fact, these techniques almost prescind from the human presence and can be used to obtain estimation of the surface and subsurface characteristics. Up to now, only some attempts of estimating the surface temperature of the Antarctic Plateau have been made (mainly by using optical satellite sensors) and even less is known on subsurface temperature profiles. The measurement of the temperature of the deep snow layers is carried out in few sites only by means of instruments installed on boreholes. The use of microwave passive satellite sensors can make it possible the realization of sub-surface snow temperatures maps which can be useful to determine the spatial and temporal trends of the energy contained in the Antarctic snowpack and hence the evolution of the global warming. In fact, microwaves can penetrate the snowpack for tenths of meters. This latter feature is very important because, depending on the frequency, each wavelength carries information from different layers of the snowpack making possible to estimate some of the snow characteristics at various depths.

Recent research concerning daily measurements both on ground and from satellite have been carried on the area surrounding Concordia Station, the Italian-French base on the Antarctic Plateau at Dome-C (75°06’06’’S, 123°23’42’’E) [1,2]. The analysis of collected data has pointed out a significant correlation between the observed multifrequency brightness temperature and the vertical profile of the snow temperature. In particular, the study performed by means of simple regressions and artificial neural network demonstrated the possibility of estimating the surface and subsurface temperatures of the snow (down to several meters) with an error lesser than 2%.

In this work, the evolution of the Antarctica surface and sub-surface temperatures is investigated on a decennial time scale by means of satellite microwave radiometric data collected by the Advanced Microwave Scanning Radiometer (AMSR-E) and by the Special Sensor Microwave Imager(SSM/I).

In the first phase of the study, a more in depth analysis of the experimental relationships found at IFAC between multi-frequency radiometric and thermometric data has been performed in order to extend the past studies up to the present date. To do that, AMSR-E data have been collected from December 2004 to December 2008 over an area of about 60 km x 90 km around Dome–C (corresponding to a 3x3 pixel grid at C-band centered at the Concordia base). The analysis has been conducted on a great number of images (more than 10000 images, usually 8 images per day); the mean value of the 3x3 pixel area was extracted from each image and then averaged daily in order to reduce noise. This task has been done by using more accurately regressions techniques for improving the accuracy of the estimations. Moreover, a multilayer electromagnetic model which uses as inputs the physical parameters of the snowpack to simulate microwave emission from snow has been refined for better accounting for the Antarctic snow layering characteristics, checking the physical insight of the experimental results and determining the depth of the snow layers which mostly contribute to total emission at each frequency.

Given that microwave satellite data are available since the 80's, in the second part of the work the study has been focused on the estimation of the snow temperature vertical profile for the past decades. To do that multifrequency experimental data from satellite has been used together with the electromagnetic model, which has been inverted with an iterative approach such as the Nelder-Mead algorithm to retrieve temperature vertical profiles. Moreover, inversion algorithms based on statistical approaches (Bayes and Neural Networks) have been considered. Such study will be useful to assess the decennial trend of the Dome-C area especially with regards to the variation on a long-term basis and to forecast the trend for the future.

A further step of the analysis has been the extension of the investigation on a larger area of the Antarctic plateau (several thousands of square kilometers) with the aim to study spatial effects (horizontal and vertical) of the snow temperature variations.

[1] G.Macelloni, M.Brogioni, P.Pampaloni, A.Cagnati, ″Multi-frequency Microwave Emission from the East Antarctic Plateau:Temporal and Spatial Variability ″, IEEE Trans. On Geoscience and Remote Sensing, Vol.45, no.7-1, pp. 2029 – 2039, Jul. 2007

[2] Macelloni G., M. Brogioni, E. Santi, "Retrieval from AMSR-E data of the snow temperature profile at Dome-C Antarctica", Proceedings of Geoscience and Remote Sensing Symposium, 2007. IGARSS 2007, IEEE International, pp. 4233 - 4236 23-28 July 2007