Terra Antartica Reports
2008, **14**, 163-168

Low-Frequency Microwave Emission of the Antarctic Plateau: DOMEX 04, an Experimental Campaign for the Calibration of Space-Borne Radiometers

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INTRODUCTION

The monitoring of glacial environments requires knowledge of the interaction between snow structure and reflectance properties; this can be achieved by analyzing a large set of ground measurements, including spectral, snow and climate data. Due to difficulties related to the extreme environmental conditions, satellite sensors are the most suitable tools for observing temporal and spatial variations in the extensive snow-covered areas of Antarctica.

Microwave data on the Antarctic region at frequencies ranging from 6.8 GHz to about 90 GHz (*i.e.* from 5 cm to 0.3 cm of wavelength) have been and are still being collected by means of satellite sensors, and results have been reported in several papers (*e.g.* Cavalieri et al., 1991; Long et al., 2000; Jezek et al., 1993). Other missions carrying L-band radiometers (1.4 GHz, 21 cm of wavelength), such as the ESA Soil Moisture and Ocean Salinity mission (SMOS) and NASA's AQUARIUS mission are planned for the near future. The quality of these radiometric data is a key issue of these missions that can only be assured through pre-launch calibration of the instruments, followed by comprehensive post-launch calibration and validation experiments.

Different strategies and methodologies are defined for each single mission during the preparation phase. Nevertheless the possibility of introducing into the calibration procedure the observation of an external independent target whose characteristics are not related to the system on board the satellite, represents an attractive opportunity. Methods for calibrating space-borne radiometers by using cold reference targets are indicated in Ruf (2000).

Compared to other natural scenarios Antarctica, and in particular the plateau (Dome-C) which hosts the Italian-French Concordia station, appears to be an ideal site for such calibration thanks to its large size and uniform spatial structure, as well as to detailed knowledge of the vertical profile of ice. The latter was obtained in the framework of the European Project for Ice Coring in Antarctica (EPICA); the

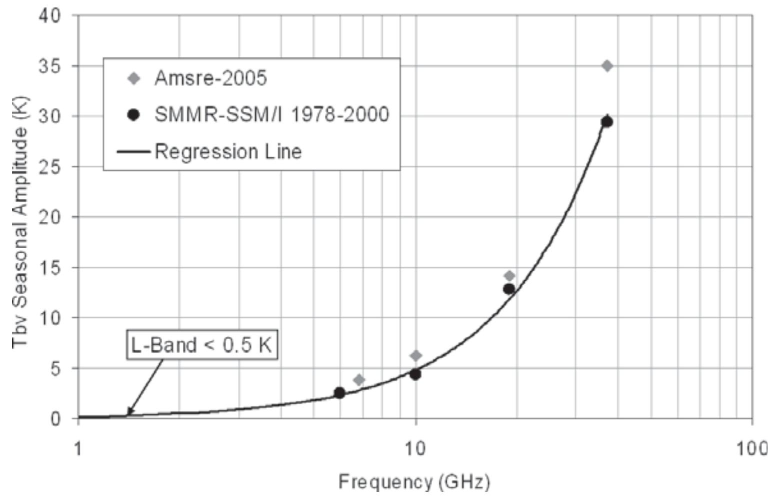


Fig.1 - Mean seasonal variation in brightness temperatures, vertical polarization, as a function of frequency measured at Dome-C (Black point: 1978-2000 SMMR-SMMI data, Grey Diamond: 2005 AMSR-E data).

properties of the entire ice pack, such as mean particle size, density, temperature and impurities, were measured from drilled ice cores. Measurements collected by satellite sensors in the 5 to 37 GHz range show that the mean seasonal peal-to-peak differences of Brightness Temperature (Tb) of the area decreased when the frequency decreased (Fig. 1). The Tb annual variability at C-band was about 5 K, while that at L-band (extrapolated from measurements using a polynomial fit) was estimated to be lower than 0.5 K. At the latter frequency the extinction of ice and snow is low (due to the small imaginary part of the complex permittivity) and influenced negligibly by the upper 10 m; below 10m the firn shows no significant seasonal variations in temperature. Nevertheless the applicability of the Dome-C plateau as a suitable target for calibrating and monitoring the performance of low frequency microwave radiometers and the physical effects governing microwave emission from deep ice sheets must be better understood. For this reason, and in view of the forthcoming launch of L-band space-borne radiometers (*i.e.* SMOS, Aquarius), an experiment for measuring emission at C- and L-bands was planned for the 2004/2005 Austral summer. The experiment was supported by ESA within the framework of the SMOS calibration programme and by the Italian *Programma Nazionale di Ricerche in Antartide* (PNRA).

THE EXPERIMENT

The experiment, called DOMEX, took place at Dome-C (Antarctica) from 10 December 2004 to 2 January 2005. It included radiometric measurements from a tower, at different incidence and azimuth angles, and snow measurements using conventional methods. The equipment consisted of an infrared radiometer (8-14 m) and two microwave radiometers (L and C bands, which correspond to

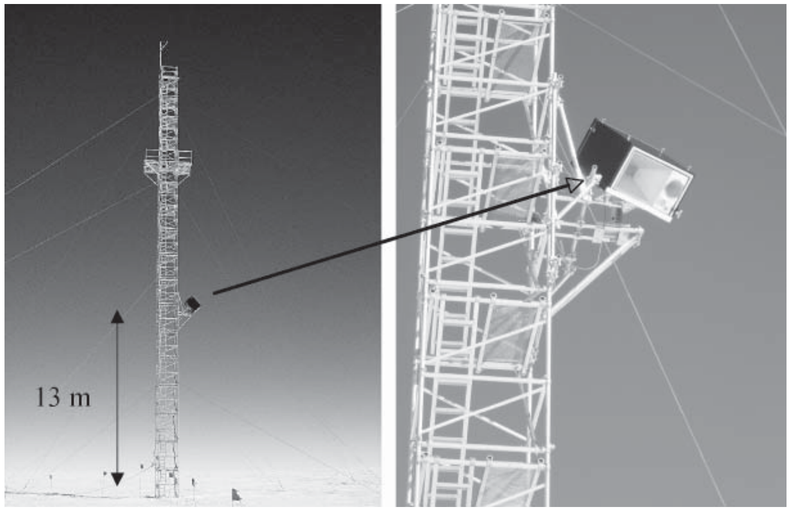
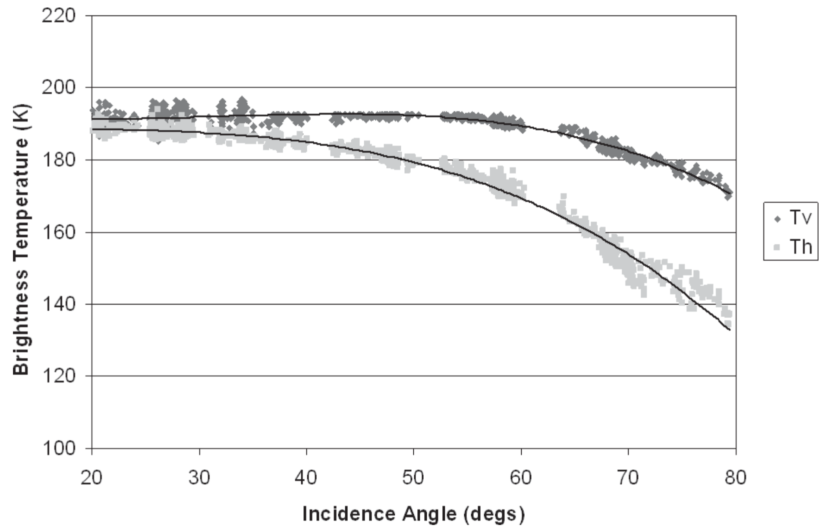


Fig. 2 - Tower installation.

a wavelength of 21 cm and 5.6 cm, respectively) designed and developed at the IFAC laboratories (Macelloni et al., 2002; Cagnati et al., 2004; Macelloni et al., 2005) and adapted to the extreme environmental conditions in Antarctica. The equipment was placed on the observation tower, which was originally installed for the calibration of optical space-borne sensors (Hudson & Brandt, 2005; Six et al., 2003). Figure 2 shows an overview of the installation on the tower and a detailed view of the box containing the instruments. Data were collected 24 hours/day, at different incidence angles, within the SMOS range (30 - 70 degrees) and over 120 degrees in azimuth. In order to characterize the spatial variability and temporal stability of surface layers at the test site on a monthly scale, conventional snow measurements were carried out from the very beginning of the experiment. Some snow pits were dug manually near to the base camp to test the homogeneity of the area on a scale of 1 square km. The following parameters were measured in each layer of snow to obtain an accurate description of layering: temperature, height, density, hardness, grain shape and size (measured using conventional “standard” methods according to Colbeck et al., 1990) and the dielectric constant (measured using the Toikka snow fork). The snow temperature was also monitored by means of a thermal infrared sensor, and by a string of thermistors embedded at different depths in the snowpack down to 10m.

RESULTS

Snow data was reported in Cagnati et. al (2008) and revealed the good spatial homogeneity of the structural characteristics of snow. The angular trend of the brightness temperature, measured during the entire observation period, is represented in figure 3. Due to the different penetration depth of the two frequencies, surface scattering was more significant at C-band (where the Brewster angle effect was evident) than at L-band. Small differences were observed in data



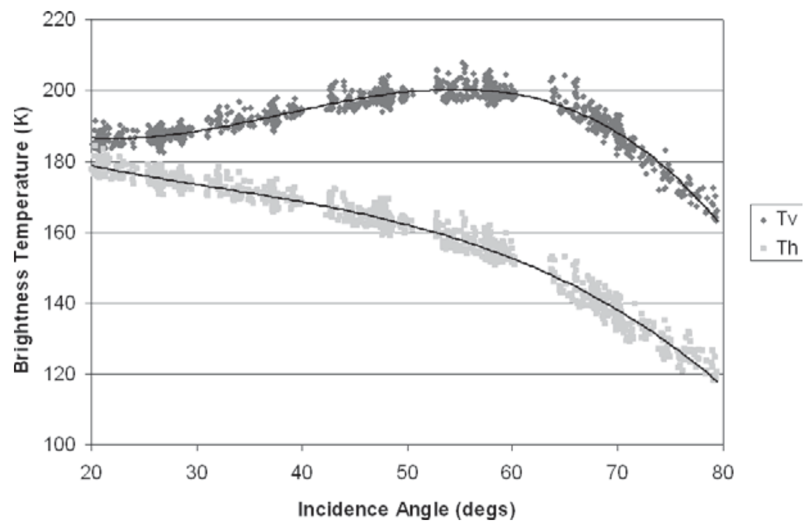


Fig. 3 - L-band (top) and C-band (bottom) Brightness Temperatures at horizontal (grey diamond) and vertical (light grey square) polarization as a function of Incidence Angle.

collected at different azimuth angles; these could be attributed to alteration of snow in some areas during construction of the tower.

The L-band brightness temperature for the entire observation period, measured for a single incidence angle, remained almost constant, whereas the C-band brightness temperature showed a daily fluctuation but an almost constant average value. For example, at an incidence angle of 46 degrees the mean L-band brightness temperature measured at V polarization for the entire campaign was 192.32 K, with a standard deviation of 0.18 K. Comparison of C-band measurements taken at an incidence angle of 55 degrees with satellite data from the AMSR-E revealed a very close agreement between the two measured brightness temperatures at H polarization, while there was a significant difference of around 3 K between the two measurements at V polarization. We believe that this was due to an error in the calibration procedure for the AMSR-E data, thereby demonstrating the importance of introducing an external, independent stable target for controlling the quality of satellite data.

CONCLUSIONS

This first experimental field campaign in Antarctica using low-frequency microwave radiometers was successfully conducted for a continuous period of 20 days, and the first L-band emission measurements are now available for Antarctica. Snow measurement results confirm the spatial uniformity of the physical characteristics of the area near Concordia station. Snow temperature measurements performed over the years down to a depth of 10 m confirm that temperatures vary in the first 5/6 meters only. Microwave measurement data confirm the high stability of the mean L-band brightness temperature measured on a monthly scale at an incidence angle of 20 – 60 degrees.

Moreover, comparison of C-band measurements at an incidence angle of 55 degrees with satellite data from the AMSR-E showed very close agreement between the two measured brightness temperatures. On the basis of this preliminary experiment, we can confirm the spatial uniformity and temporal stability of the Dome-C area, at least on a monthly scale. The possibility of using this area as an extended calibration target for future space-borne radiometer missions is also confirmed. Nonetheless, it would be interesting to extend the time interval of measurements to at least the entire summer period and to evaluate spatial uniformity on a larger area. In order to investigate these aspects, and also to provide a contribution to the International Polar Year, a new experimental campaign is planned for 2007/2009.

Acknowledgements - Research was carried out in the framework of a project on Glaciology funded by the Italian Programma Nazionale di Ricerche in Antartide (PNRA). This work is a French-Italian contribution to the CONCORDIA Station. This work was also funded by ESA (ESA contract N. 18060/04/NL/CB). The authors are grateful to the Italian-French logistic team at Concordia Station for their kind assistance during the experimental campaign and to Roberto Ruisi (IFAC-CNR) for his contribution to the construction of the instruments.

REFERENCES

Cagnati A., Crepaz A., Macelloni G., Pampaloni P., Ranzi R., Tedesco M., Tomirotti M.,& Valt M., 2004. Study of the Snow Melting – Refreezing Cycle Using Multi – Sensor Data and Snow Modelling. *J. of Glaciology*, **50**, 170, 419-426.

Cagnati A., Macelloni G., Salvietti E. & Valt M., 2008. Snow surface characteristics at Dome C, Antarctica. *Terra Antarctica Reports,* this volume.

Cavalieri D J., Crawford J.P., Drinkwater M.R., Eppler D.T., Farmer L.D., Jentz R.R., & Wackerman C.C., 1991. Aircraft active and passive microwave validation of sea ice concentration from the Defense Meteorological Satellite Program Special Sensor Microwave Imager. *J. Geophys. Res.*, **96**, C12, 21989-22008.

Colbeck S. C., Akitaya E., Armstrong R., Gubler H., Lafeuille J., Lied K., McClung D.& Morris E., 1990. International Classification for Seasonal Snow on the Ground. *Intern. Commission for Snow and Ice -IAHS*.

Drinkwater M., Floury N. & Tedesco M., 2003. L-band ice sheet brightness temperatures at Dome C, Antarctica: spectral emission modelling, temporal stability and impact of the ionosphere. *Annals of Glaciology*, **39**, 391-396.

Hudson S.R., & Brandt R.E. , 2005. A Look at the Surface-Based Temperature Inversion on the Antarctic Plateau. *J. Climate*, **18**, 1673-96.

Jezek K.C., Merry C.J., & Cavalieri D.J., 1993. Comparison of SMMR and SSM/I Passive Microwave Data Collected over Antarctica. *Annals of Glaciology*, **17**, 131-136.

Long D.G., & Drinkwater M.R., 2000. Azimuth Variation in Microwave Scatterometer and Radiometer Data over Antarctica, *IEEE Trans. Geosci. and Remote Sens.*, 38, **4**, 1857-1870.

Macelloni G., Paloscia S., Pampaloni P., Ruisi R., Dechambre M., Valentin R., Chanzy A. & Wigneron J.P., 2002. Active and passive microwave measurements for the characterization of soils and crops. *Agronomie,* **22**, 581-586.

Macelloni G., Paloscia S., Pampaloni P., Brogioni M., Ranzi R., & Crepaz A., 2005. Monitoring of melting refreezing cycles of snow with microwave radiometers: the Microwave Alpine Snow Melting Experiment (MASMEx 2002-2003), *IEEE Trans. Geosci. Remote Sensing*, **43**, 11, 2431- 2442.

Six D., Fily M., Alvain S., Henry P. & Benoist J.P., 2003. Surface characterization of the Dome Concordia area (Antarctica) as a potential satellite calibration site, using SPOT4/Vegetation instrument. *Remote Sensing of Environment*, **89,** 83-94.