MULTI.TEMPORAL OBSERVATIONS OF SNOW COVER CHARACTERISTICS IN ALPINE REGIONS WITH MULTIFREQUENCY PASSIVE MICROWAVE SENSORS AND COMPARISON WITH C-BAND SAR DATA.

P.Pampaloni[1], M.Brogioni[1], G.Macelloni[1] S.Paloscia[1], E. Palchetti, , S.Pettinato[1], E.Santi[1],
A. Crepaz[2], A. Cagnati[2]

[1] Institute of Applied Physics - IFAC-CNR
Via Madonna del Piano 10, 50019 Sesto Fiorentino, Firenze, Italy
[2] Centro Valanghe Arabba, CVA, Arabba, Italy

Presenting author: P.Pampaloni e-mail: P.Pampaloni @ifac.cnr.it,
Ph: 0039 055 522 6462 – FAX: 0039 055 522 6434 –

Monitoring of snow cover is crucial to the study of global climate changes, for water resource management, as well flood and avalanche risk prevention. Indeed, snow cover is the major component of the cryosphere and plays a significant role in the global water cycle and the climate system. Optical sensors can monitor snow cover in cloud free conditions and several systems have been developed for operational monitoring of snow parameters from remote sensing data. However, only microwave sensors are able to acquire data independently of daylight and in adverse weather conditions. Much experimental and theoretical research regarding the sensitivity of microwave sensors to snow depth, wetness and water equivalent, has been carried out since the early 80's years. Several algorithms for the retrieval of these quantities from multifrequency radiometric data have been developed and tested with SMM/I and AMSRE data. Moreover, the potential of SAR data in detecting wet snow has been explored using C-band data from satellite. However, satisfactory results for operational use have not yet been obtained due to both scarce accuracy of the algorithms and the course ground resolution of the passive sensors.

This paper is a report of an experiment for the acquisition of multi-frequency, multi-temporal passive and active microwave data carried out on the Italian Alps in the winters 2006-2007, 2007-2008 and 2008-2009. The site selected for the experiment was a relatively flat area located in North-East Italy on the Mount Cherz at an altitude of 2010 m asl. Brightness temperature data were collected with ground based microwave radiometers at C- (6.8 GHz), Ku- (19 GHz), and Ka-band (37 GHz) in vertical and horizontal polarizations installed in a shelter, together with an infrared sensor at 8-12 micron wavelength and operating continuously 24/day in the winter months.

The microwave instruments were self-calibrating, dual polarized, digital radiometers with an internal calibrator based on two loads at different temperatures (250 K ± 0.2 K and 370 K ± 0.2 K). The beamwidth of the corrugated conical horns was 20° at -3 dB and 56° at -20 dB for all frequencies and polarizations. The cross polarization was lower than -30 dB. The relative wide antenna beams guaranteed data collection from a significant average portion of snow. The digital output signals were recorded in a notebook computer together with the temperatures of the calibrating loads. Calibration checks in the 30 K - 300 K range were carried out before and after the measurements by means of an external blackbody and a noise source added to the sky emission measured by means of a reflecting plate. The radiometer accuracy (repeatability) was estimated to be better than ±1K.

C-band backscattering data at VV pol and 23° incidence angle were acquired from ENVISAT ASAR at the revisit time of satellite. Each image was calibrated and filtered with a Gamma MAP filter with kernel size 5x5 to reduce the speckle.

In addition to microwave measurements, the temperature of snow and soil was continuously monitored with Pt 100 probes. Moreover, all the other significant parameters of the soil/snow system were measured with conventional approaches. Soil moisture and surface roughness were measured at the beginning of the experiment, while snow parameters (grain shape and size, liquid water content, density, water equivalent, surface roughness and hardness) were monitored at regular time intervals or every times the snow cover underwent significant changes.

Radiometric data collected on dry snow, showed small fluctuations related to diurnal solar cycle and presented a time delay of microwave brightness temperatures with respect to the snow surface temperature. The measurement of these delays, together with a correlation analysis of the brightness and physical temperature of snow, made it possible estimating the thickness of layers that mostly contributed to microwave emission at the various frequencies.

The backscattering coefficient measured at the nominal incidence angle of 23° as a function of time on the Cherz plateau showed that the highest value was on dry snow in winter, which then decreased in springtime, when snow was wet, and increased again in June on snow free terrain. The dependence of the backscattering coefficient on local incidence angle was studied by exploiting the variation of this angle due to terrain topography on a homogeneous, open area, without the presence of steep slopes. The local incidence angle over this area varied between 8° and 38°. Several snow cover maps were generated from multitemporal ASAR images taken with the same observation geometry. In these maps forested areas as well as areas of radar layover and shadow were excluded from the analysis based on the observation geometry and auxiliary information obtained by DEM and ortophotos. Wet snow was identified by a threshold set to -3 dB with respect to a reference image obtained under dry snow cover or bare ground conditions. The total snow extent was estimated by comparing images taken at different dates.

Both active and passive microwave data were compared with snow measurements in a wide variety of snow conditions and with model simulations. The used model was based on the Advanced Integral Equation Method (AIEM) to represent soil surface, coupled with a layer of snow whose electromagnetic properties were described by the Dense Medium Radiative Transfer Theory under the Quasi Crystalline Approximation (DMRT-QCA) applied to a medium (air) filled with sticky spherical ice particles. The upper interface of the snow layer was considered flat, whereas the snow-ground interface was assumed to be rough. In order to calculate the brightness temperature of the snow, the DMRT radiative transfer equation was solved by imposing the boundary conditions at the top and the bottom interfaces of the snow layer. Simulation performed by using ground data as inputs to the model were found to be in good agreement with experimental data. A sensitivity analysis was performed to estimate the potential of both active and passive sensors in estimating the main snow parameters in alpine environment