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Snow-mantle remote sensing from C-band spaceborne SAR interferometry using a model-based synergetic retrieval approach in Central Apennine

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Snow-mantle extent (SCM, Snow Coverage Map), its local thickness (Snow Pack Depth, SPD) and mass (Snow Water Equivalent, SWE) are the main parameters characterizing snow deposits. Such parameters result of particular importance in meteorology, hydrology and climate monitoring applications. Anyway, in the general case, the considerable geographical extension of snow layers and their typical spatial heterogeneity makes it impractical to monitor the above three parameters regularly (i.e. with a high spatial and temporal resolution) by means of direct or indirect in situ measurements, suggesting the exploitation of satellite technologies to obtain such data.
Snow cover patterns are governed by effects of topography, land cover, wind redistribution, solar irradiance, and air temperature. On the other hand, in the last few decades, a general back-scaling of snow observation networks occurred worldwide. Based on the above considerations, space-borne C-band SAR sensors (such as those operating in Sentinel-1 A and B missions) are particularly suitable for the analysis of snow deposits, providing data with resolutions up to some meters, with global coverage and a few days revisit time. Moreover the specific radar-signal's wavelength and the availability of different polarization channels makes this class of SAR sensors particularly suitable for the analysis of snow deposit characteristics.
SAR data processing can be performed in different ways in order to obtain, at different extents, information on the above mentioned parameters of interest: 1) Backscattered power, studying the effects of backscattering at the air-snow interface, at the snow-ground interface, together with the volumetric effects of the snow layer; 2) Differential Interferometric SAR (DInSAR), analyzing the effects of air-snow refraction and the snow-ground reflection, together with the coherence and phase-shifts between two sequential images; 3) SAR polarimetry (PolSAR), taking advantage of the interaction between the polarized incident wave and the anisotropic surface and volume of the snow layer, which causes depolarization effects which can be analyzed and translated in useful information). In particular, the distinction between wet and dry snow can be obtained with a certain degree of accuracy by combining the above three methods of SAR data analysis, with the possibility of enhancing such information with the aid of satellite data coming from multi-spectral optical sensors.
Most of the satellite remote sensing applications have been focused on major mountain systems, such as the Andes, the Alps, or the Himalayan region. Other important mountain systems, like the Italian Apennines, have not been extensively considered probably due to their complex orography and the high variability of their snow cover. Nevertheless the central Apennine has a central role for the meteorological dynamics in the Mediterranean area, and it hosts the southernmost European glacier –namely the Calderone glacier– whose evolution represents a relevant indicator, at least for the medium latitudes, of the impact of the unfolding climatic changes.

In this work we will present the Sentinel-1 DInSAR processing chain to estimate SCM, SPD and SWE for fresh dry snow, combined with SAR-backscattered data for wet snow discrimination and optical satellite data (e.g., Sentinel-2 and MODIS) for snow extension mapping. The processing chain is tested in central Apennine, using several pilot sites where in situ measurements, including snow pits and ground-probing radar profiling, are available for the considered case studies. The potential of using physically-based Bayesian inversion algorithms, trained by forward electromagnetic and snowpack models, will be also discussed together with the exploitation of C-band weather radar retrieval data of snowfall. The availability, for this area of interest, of a number of measurement sites and the possibility to take advantage of snow-relevant forecasting models, paves the way for a synergetic approach which can allow for an improved estimation of snow-related parameters and, on the other hand, provide a robust and reliable means for the validation of remote-sensed satellite data.