RadAlp: Potential of radar remote sensing for the estimation of liquid and solid precipitation in the French Alps

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Improving the estimation of precipitation in high-mountainous areas is a major challenge for the assessment and management of water and snow resources (production of drinking water and hydroelectric energy, needs related to agriculture and tourism) as well as for the prediction of natural risks (floods, flash-floods, land-slides, debris flows etc.). To characterize and anticipate the risks associated with intense precipitation and snowpack melting, it is necessary to obtain highly resolved observations spatially (1 km^2 or better) and temporally (hourly or better) of liquid and solid precipitation, that can hardly be obtained using conventional hydrometeorological *in-situ* networks in a high mountain range like the Alps.

The coverage of high mountain regions poses also a set of complex problems for radar remote sensing that begin to be addressed in the French Alps. Such problems, related to the topography and the vertical structure of precipitation, can be summarized by the following dilemma. Installing a radar at the top of a mountain allows 360° visibility and therefore the ability to detect precipitating systems on a regional scale. This is particularly relevant for summer convective events exhibiting large vertical extension. But precipitation is likely to undergo significant changes between the altitude of its detection and its arrival on the ground, including phase changes when the 0°C isotherm is located between the radar altitude and the ground, as this is frequently the case in cold periods. On the other hand, installing a radar at the bottom of a valley makes it possible to guarantee better estimates in all weather conditions at the scale of a vulnerable site (an alpine town for example), but at the cost of reduced visibility at the latter. In addition, while the interactions between electromagnetic waves and liquid precipitation are fairly well understood and quantified, the backscattering and absorption of ice and melting hydrometeors is much more complex due to the diversity of shape and density of these hydrometeors. This is a particularly crucial challenge in the context considered.

As part of the ARAMIS network, Météo-France deployed an X-band Doppler polarization diversity radar in 2014 on the summit of Mont Moucherotte (1920 m ASL) in the immediate vicinity of the city of Grenoble. Despite the contribution of polarimetry, attenuation of electromagnetic waves in the melting layer at this wavelength, combined with the heterogeneity of filling of the radar beam (NUBF), remains a limitation for X-band radar measurements made for such an elevated radar site for estimating liquid and solid precipitation on the ground. The IGE owns a research radar called XPORT, with characteristics similar to those of the Météo-France radar. This radar was installed on the IGE site down in the valley (220 m ASL). Various in-situ sensors (meteorological station, disdrometers) and remote sensing sensors (MRR) installed nearby complete this observation system. Since 2016, a quality dataset has been acquired using XPORT and the Moucherotte radars, MRR and in-situ sensors.

Two studies recently conducted will be presented:

1) The melting layer that develops below the altitude of the 0°C isotherm determines the occurrence of rain and snow at ground level and creates several artefacts for radar measurement (bright band, attenuation), which affect rain and snow estimates. We have developed an algorithm for automatically detecting the characteristics of the fusion layer (high and low altitudes, altitudes and peak values of the various polarimetric and Doppler parameters). A climatology was established for the radar observations from the data of about forty episodes covering the annual cycle.

2) We started addressing the issue of X-band attenuation by comparing path-integration attenuation estimates (PIA) obtained from the decrease in the backscattered signal from mountains during precipitation (Mountain Reference Technique) with total differential phase estimates on the radar-mountains round trip. In addition to the results obtained with the XPORT radar for rain during summer convective episodes, we were able to document a very interesting winter case with the characterization of the attenuation in the different parts of the melting layer, during its rise and passage at the level of the Moucherotte radar. The temporal evolution of the melting layer was characterized in detail in a concomitant way using XPORT data.

Keywords: radar remote sensing , rain and snow, melting layer, X-band attenuation