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Snow mapping from MODIS products: the application of an improved cloud removal methodology to the Po river basin

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Digital snow maps are a powerful tool for reproducing large-scale snow distribution and extension. The use of such information for hydrological purposes is now considered an outlet of great practical interest: when combined with local assessments or measurements of the snow water equivalent (SWE), it allows to estimate the regional snow resource. In this context, MODIS (MODerate resolution Imaging Spectroradiometer on board Terra and Aqua satellites) daily Snow Covered Area product has been widely tested and proved to be appropriate for hydrologic applications. However, within a daily map the presence of cloudiness can hide the ground, thus preventing any snow detection.

On the basis of previous studies, we recently developed a new methodology for cloud removal able to deal with the problem in wide areas, characterized by an high topographical and geomorphological heterogeneity such as northern Italy. Given the Aqua/Terra daily snow map of the basin, the standard condition shows a cloud-free part and a cloud-covered part. The latter is the assessment area, where a stepped procedure for cloud reduction combines temporal and spatial information obtained from neighboring areas to estimate whether there is snow. While conceiving the new method, our first target was to preserve the daily temporal resolution of the product as far as possible. In cases when there were not enough information on the same day within the cloud-free part, or in the nearest days, we adopted an improved method which ensures an acceptable reproduction of the micro-cycles which characterize the transition altitudes (where snow does not stand continually over the entire winter).

Daily binary (snow/not snow) maps of ten years (2003-2012) have been analyzed and processed with the support of a Digital Elevation Model (DEM) of the basin with 500 m spatial resolution. We deeply investigated the issue of cloudiness over the study period, highlighting its dependence on altitude and season. Snow maps seem to suffer the influence of overcast conditions in mountain zones and during the melting season, exactly where and when snow detection is more useful for hydrologic purposes. For such reason, an highly optimized cloud removal procedure is necessary to benefit of complete and reliable daily maps. The new methodology has been compared against previous solutions, showing a clear improvement in the performance for such case study. The validation has been carried out introducing virtual clouds to some clear-sky days and running the algorithm on the fictitiously masked areas. The accuracy has been tested by comparing the removed cloud output with the original cloud-free map.

The overall framework under development is directed to an assessment of the snow water equivalent at the scale of the Po basin in the last decade, combining remote sensing with ground measurement of snow depth and density. Understanding the variability of snow duration, distribution and snow water equivalent at the basin scale is a first important step in modeling climate change impacts on the regime of the major Italian river.