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Snow cover dynamics in the Catalan Pyrenees range using remote sensing data from 2002 to 2008 period

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Water resources and its management are essential in many alpine mountainous areas. Snow cover monitoring in the Mediterranean zone requires obtaining accurate snow cartography to estimate the volume of water derived from snow melting and species distribution modelling.
Snow data is usually obtained by field campaigns, but to obtain a spatial and temporal cover of enough detail and quality it is necessary collect an important number of data. However, when a continuous surface is needed, Remote Sensing could provide better snow cover estimation due to its spatial and temporal resolution.
The aim of this study is to map snow cover and analyse its spatial and temporal dynamics using medium and coarse remote sensing data at a regional scale over an heterogeneous area, the Catalan Pyrenees (NE of the Iberian Peninsula). The seasonal snow cover period is from October to June. In this period, regular snowfalls usually take place from December to April, although during the rest of the period, punctual but important episodes of snowfalls are frequent.
To perform this analysis, a set of 96 Landsat images (36 Landsat-5 TM and 60 Landsat-7 ETM+) of path 197 and 198 and rows 31 and 32 from January 2002 to April 2007, and 90 Terra-MODIS images from October 2007 to July 2008, with a different percentage of cloudiness, have been chosen.
The computation of the Landsat-5 TM and Landsat-7 ETM+ data used in snow cover mapping has been carried out by means of the following methodologies. Images have been geometrically corrected by means of techniques based on first order polynomials taking into account the effect of the relief of the land surface using a Digital Elevation Model. Radiometric correction (non-thermal bands) has been done following the methodology which allows us to reduce the number of undesired artefacts that are due to the effects of the atmosphere or to the differential illumination. Finally, cloud removal has been carried out by means of a semi-automatic methodology.
In the case of MODIS images, these have been imported by reading all the necessary metadata to document and interpret them. These products have already been radiometrically and geometrically corrected by USGS in a sinusoidal projection.
Snow cover mapping has been carried out by means of the Normalized Snow Cover Index (NDSI), one of the most widely methodologies used. This methodology proposes a normalized index using green band 2 and Medium Infrared band because of snow reflectance is higher in the visible bands than in the medium infrared bands. NDSI pixels greater than 0.4 are select as snow cover. Although this threshold also selects water bodies, we have obtained optimal results using a mask of water bodies and generating a pre-boundary snow mask around the snow cover. In shadow cast areas, we have used a hybrid classification to obtain the snow cover.
Preliminary results show the snow surface evolution of the Pyrenean basis during the hydrological period, as well as the differences between the different years of study.
The obtained data shows how the basins with Mediterranean influence, placed in the east, receive less nival contribution than those with Atlantic influence, situated in the west. In addition, this data allow establishing the

beginning and the ending of the snowfall cycle. Eastern basins usually have a shorter period than west basins, where the snow line is lower.

The snow cover area average of the studied period is about 1200 km2 and stands out that for the particular period 2006-2007, this area was only about 55% of the average, due to the lack of snow precipitation. It affected the winter sports, an important sector in this area, the vegetation and the extensive livestock, just as the volume of water that flows towards river basins and reservoir when snow melts.

Technical characteristics are different between both sensors. On the one hand, Landsat spatial resolution is better to obtain accuracy cartography, however it is not suitable to determine the frequency of snow falls. On the one other hand, MODIS with its daily temporal resolution allows better temporal monitoring, but with coarse spatial resolution.