



1 Type of the Paper: Article

2 **Snow Cover Evolution in the Gran Paradiso National**

³ Park, Italian Alps, Using Earth Observation Data

- 4 Cube
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- 30 Annex 1: February and April maximum snow cover extent in the Gran Paradiso National Park
- 31 (1984-2018). Blue colour corresponds to the snow-covered area, red to the no-snow covered area,
- 32 grey to cloud-covered area and white to the presence of water.





7.2 7.3 7.4







Data 2019, 4, x FOR PEER REVIEW

39 Annex 2: Relative percentage of snow-covered (blue), snow-free (red) and cloud-covered (dark

grey) area in December, January, February and April derived from the monthly maximum snow
 cover area products from 1984 to 2018 in the Gran Paradiso National Park. Light grey bars

42 indicate months where the cloud cover exceeds a relative percentage area of 30%.



- 45 Annex 3: Seasonal aggregations (of monthly time series) reporting (left) the number of cloud-free
- 46 observations ranging from 0 to 3 (the abundance of the classes is shown in the pie chart),
- 47 (middle) the number of snow observations and (right) the snow cover summary for each winter
- 48 season (December, January and February) from 1984 to 2018.









45.3 45.4 45.5

45.6

45.7

45.3

70 71 72

winter season (DJF) 1999-2000

> 7.3 longitude

winter season (DJF) 2000-2001

7.4 7.5

208

89.0%

7.6

of cloud free

number o

















Annex 4: Surface air temperature (top panels), total precipitation (middle panels) and solid precipitation (bottom panels) time series (1950-2014) for the Gran Paradiso National Park obtained from the HISTALP observation-based gridded dataset. The black line represents the time series averaged over the whole extension of the PGNP, while coloured lines indicate spatial averages over different 500 meters-thick altitudinal bins, as indicated in the legend. Grey vertical lines define the time period over which the snow cover analysis is performed (see main text).



Annex 5: Temporal evolution of (top) total precipitation, solid precipitation and (middle) surface air temperature for February (S4) and April (S5) obtained from the HISTALP observation-based dataset from 1984 to 2014 in the Gran Paradiso National Park; (bottom) same as Annex S2 reported here for comparison: relative percentage of snow-covered (blue), snow-free (red) and cloud-covered (dark gray) area in February (April) derived from the monthly maximum snow cover area products from 1984 to 2018 in the Gran Paradiso National Park. Light grey bars indicate months where the cloud cover exceeds a relative percentage area of 30%.

74 The monthly snow cover products for February and April highlighted considerable cloud 75 cover (affecting more than 30% of the park surface) in 11 and 15 out of 34 years, respectively. The 76 analysis of the temporal evolution of snow cover in these two months is therefore affected by large 77 uncertainties. Similarly, February and April snow cover do not show significant trend and 78 correlation with temperature and precipitation in the same month. However, the snow cover time 79 series in April displays significant, positive correlation with the previous winter (DJF) SCA (R =80 0.55, p_value = 0.01). As expected at high elevations, April snow cover is thus not only dependent 81 on precipitation and temperature in the same month but also on snow cover conditions during the 82 previous winter. Indeed, a deep snowpack can postpone spring ablation by several weeks despite 83 precipitation and temperature conditions favourable to snowmelt. Representing the variability of 84 winter snow cover, as well as the snow conditions and the beginning of the melting period, SCA 85 evolution in April can provide valuable information for water resource and alpine ecosystem 86 management.

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90 Annex 6: Details on the implementation

91 The analytical framework is directly implemented on the SDC in Python 3.6 92 (<u>http://docs.python.org/3/</u>) programming language. This language had an extensive standard

- 93 library and multiple add-on packages specific to remote sensing studies (e.g. the Python library
- 94 Numpy to manipulate arrays). In the SDC, all the workflows are performed in Jupyter Notebook
- 95 (<u>http://jupyter.org/</u>), an interactive platform allowing developers to work in a unique environment
- 96 containing at the same time the analysis description, the results (paragraph, equations, figures,
- 97 links, etc.) and the executables documents. Specific Geographic Information System (GIS) software
- 98 such as QGIS (<u>http://qgis.org/</u>) and ArcMap (<u>http://arcgis.com/</u>) are also used to process and
- 99 visualize the information contained in spatial layers.