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Climatic change effects on hydro-metereological variables in the Alps: a case study on the upper Arve catchment at Chamonix (France) over the last 50 years

Alessandra Viani (1), Thomas Condom (2), Baldassare Bacchi (1), Isabella Zin (3), Delphine Six (4), Frederic Gottardi (5), Antoine Rabatel (4), and Samuel Morin (6)

(1) DICATAM, Università degli Studi di Brescia, Brescia, Italy (vianialessandra@gmail.com), (2) IRD, CNRS, Université Grenoble Alpes, Grenoble, France, (3) Université Grenoble Alpes, CNRS, IR, Grenoble, France, (4) LGGE,CNRS,Université Grenoble Alpes, Grenoble, France, (5) EDF/DTG, Grenoble, France, (6) CNRM-GAME, CEN Météo-France, CNRS, Grenoble, France

Hydrological changes in partially glaciated catchments are expected under future climate scenarios, with consequences for water availability and management at catchment and regional scales. In order to correctly predict the magnitude of such changes and envisage adaptation and/or mitigation measures against water related hazards, a good understanding of the water cycle dynamics at different spatial and temporal scales is needed.
The Upper Arve catchment in Chamonix (202 square kilometers), situated in the French Northern Alps, between the two massifs of Mont Blanc and Aiguilles Rouges, is a perfect case study for evaluating the sensitivity of the alpine water cycle to climate change. It is highly glaciated (32% of the total area in 2012) with three important glaciers: Glacier du Tour, Glacier d'Argentiere and Glacier de la Mer de Glace. Its elevation ranges from 1025 up to 4295 m a.s.l. and the exposure of the ice cover is generally north and east oriented. Long term time-series exist of (i) glacier mass balance, (ii) meteorological (in-situ and reanalyses) and (iii) hydrological data.
The objectives of the presented study were:
1 – To characterize the inter-annual regimes of the different climatological and hydrological variables: precipitation, temperature and discharge;
2 – To estimate trends on the previous variables, at different temporal scales (annual and monthly) for different altitudes, and compare them to usually observed values in alpine regions;
3 – To infer from the previous statistical analyses and from a cross-analysis between the different considered variables the catchment's hydrological evolution during the last 50 years.
Results showed precipitation, temperature and discharge regimes typical of high mountainous partially glaciated catchments.
In the long term period, this catchment is characterized by an evident retreat of glacier.
Long term trends over the past five decades show no significant change in the annual amount of precipitation. At the same time, a significantly increase of the number of rainy or snowy days is observed, related to an increase of the number of days with small precipitation intensities. Particularly, we have estimated a significant positive trend in the number of liquid precipitation days with intensities less than 10 mm per day (+ 49 days/year from 1934 to 2014).
On the other hand, temperature increases significantly of about 0.3 K per decade in average over the lower part of the catchment (between 1100 and 2100 m a.s.l.). This increase is slightly greater than the previous estimated trends over the French Alps. At the same time, a weaker trend is estimated at higher altitudes, from 3000 to 3600 m a.s.l., which is a more surprising result with respect to the previous published values. Finally, an hydrological regime shift is observed with a melting season occurring earlier for the last two decades.