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# 44 Years of climate reanalyses in the French Alps (1958-2002): methodology, validation and results for the main meteorological parameters and related snow cover conditions.

**Y. Durand**, G. Giraud, M. Laternser, P. Etchevers, B. Lesaffre, L. Mérindol.
Météo-France/CNRM/CEN, 1441 rue de la Piscine, 38400 St-Martin d'Hères, F.

Since the early 1990s Météo-France has used an automatic system of three numerical models that simulates meteorological parameters, snow cover stratigraphy and avalanche risks at various altitudes, aspects and slopes for several mountainous massifs of the French Alps and the Pyrenees. Due to the lack of sufficient amount of directly observed long-term snow data, this SAFRAN-CROCUS-MEPRA model chain, usually applied for operational avalanche forecasting, is here used for retrospective snow and weather climate analyses during the 1958/2002 period. The used method merges all the available observed information with guess-fields values issued from the newly reanalysed atmospheric data (ERA-40) of the European Centre for Medium-Range Weather Forecasts.

As the lake of observed meteorological data was important until 1980, a specific validation of the SAFRAN meteorological analyses was needed. The result of these comparisons shows that the analysed air temperature error (RMS) is between 1.5 and 2 °C and the precipitation error (only for not equal 0 precipitation) is without any bias. The difference between measured data and SAFRAN analysed data are low even in the case where none validation stations were used by the model. These validations show the capacity of the SAFRAN model to reproduce the mountain meteorological climatology since 1958 and then to give correct information to the CROCUS snow model.

As overall trend during the observation period 1958-2002 the annual air temperature has been rising in the order of magnitude by about 1 °C. However, variations are large

at varying altitudes and for different seasons and regions. At around 2000 m a.s.l. trends are most pronounced. Temperatures are rising in spring, but falling in autumn. This temperature drop in autumn and early winter also produces the most striking regional differences. A main characteristic is also a large year-to-year variability with regard to the smoothed trend lines. Particularly in late winter and early summer temperatures during recent years remain rather homogeneously at high levels.

Precipitation trends are rather diverse making it hard to detect clear tendencies. As a general trend the annual precipitation is slightly rising, mainly due to rises in summer and (weaker) also in autumn, but rather drops in winter and (weaker) also in spring. Year-to-year variability is big and trends remain uniform at varying elevations. In northern massifs, snow precipitations trends follow the temperatures changes, however, in the far south, strongly dropping early winter temperatures do not necessarily result in increasing snowfalls, since total precipitation is strongly decreasing itself.

Snow parameters in the French Alps are characterised by a marked declining gradient from the north-western foothills to the south-eastern interior regions. Enhanced at low elevations, trends in snow depth evolution are mainly negative. However, in early winter, snow depth is increasing at medium and high altitudes, stronger in the south than in the north, but low elevations remain throughout negative. On the other hand, late winter shows clear decreasing trends in all massifs and at all elevations. Whereas the number of days with snow on the ground shows little evolution, the duration of continuous snow cover is clearly declining at all elevations. Although continuous snow cover tends to start earlier, it also melts much earlier

The striking tendency towards a polarisation of poor snow winters at low elevations and severe snow winters at high elevations, particularly in the south, can be well understood interpreting temperature and precipitation trends. In autumn temperatures are cooling while precipitations are slightly rising. In spring temperatures are strongly rising and precipitations decreasing. Temperature trends are most pronounced at around 2000 m a.s.l. making this altitude most critical for snowpack evolution. Only the northern massifs at this altitude are (still) cold enough to produce and maintain a regular winter snow cover while highly variable winters with immense year-to-year fluctuations are a typical feature in the southern massifs.