Modelled weather and snow climatology - Satellite detected and modelled snow cover comparison in the Pyrenees (FLUXPYR project)

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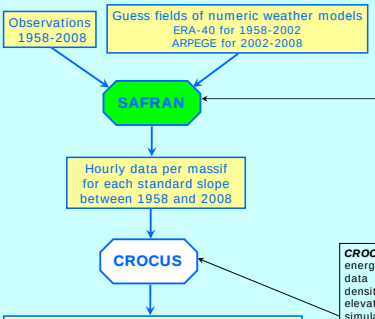
Modelled weather and snow climatology of the Pyrenees

Principle

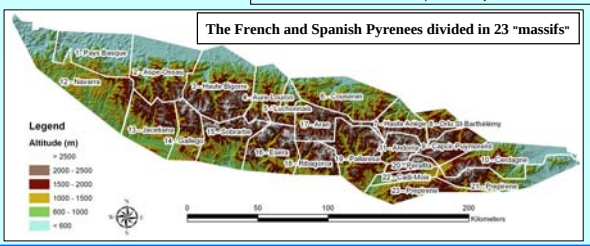
SAFRAN and CROCUS (Durand and al.,1999), two French numerical models for daily weather and snow conditions in mountains, are used to get hourly data between 1958 and 2008.
The spatial resolution of theses data is not grid points, but the "massifs" (a "massif" is a climatologically homogeneous area, its surface is roughly 200 km² - see map of the Pyrenees below).
For each massif, data are available for a set of standard slopes, as a function of elevation (by step 300 m), aspect (6) and slope angle (20°, 40° and flat).



SAFRAN (Durand et al., 1993) is a meteorological application of spatialization (or "analysis") of the observed weather data available over the considered elevations and aspects of the different mountainous massifs.
Automatically, SAFRAN combines the observed information with preliminary estimations. These "guess" fields are here computed from the results of the ERA40 outputs (ECMWF analyses).
As outputs, SAFRAN provides the main relevant atmospheric parameters affecting the evolution of the snow surface parameters at hourly time step : air temperature and humidity, wind speed, cloud cover, snow and rain precipitation, long wave radiation, direct and scattered solar radiation.
This software has been used for more than 17 years in real-time avalanche hazard forecast and it is presently also used for several research and operational applications as hydrology.
The present analysis has been carried out on 23 French and Spanish Pyrenees massifs at different elevations and aspects during the 1958-2008 period .

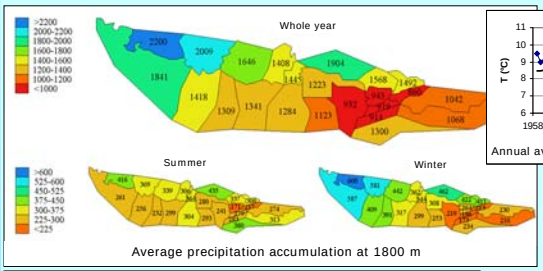
CROCUS (Brun et al., 1992) is a numerical snow model calculating the energy and mass evolution of the snow cover. It uses the meteorological data provided by SAFRAN and simulates the evolution of temperature, density, liquid water content and layering of the snow pack at different elevations, slopes and aspects. The originality of the model is its ability to simulate snow metamorphism and to represent each snow type in a comprehensible form. Each simulated slope is free of snow on 1 August of each year and the simulated snow pack then evolves every hour from the first snowfall until the complete melting without reboot. The computed snow state for a given hour is thus based only on the snow state of the previous hour and on the SAFRAN atmospheric analysis of the current hour.

The French and Spanish Pyrenees divided in 23 "massifs"

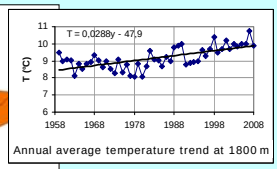


Application: modelled climatology of the Pyrenees

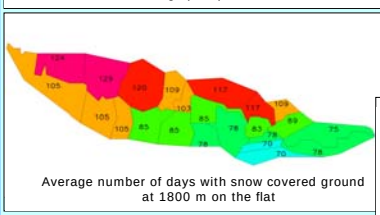
Statistical processing of the data supplied by SAFRAN and CROCUS between 1958 and 2008 gives a modelled climatology of the Pyrenees, both for mountain meteorological and snow parameters.
This climatology has been made for 2 meteorological parameters (air temperature and precipitation accumulation) and for 2 snow parameters (snow depth and number of days with snow covered ground).
The studied periods are winter (December-January-February), summer (June-July-August) and the whole year.
These climatology results are shown in map form or in trend form.
A validation has been made, by comparison of the results of modelled and observed data in 23 French and 6 Spanish weather stations.



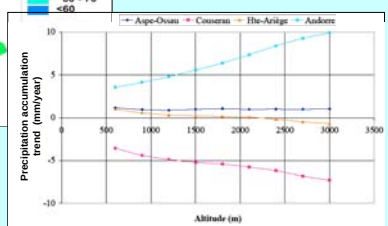
Average precipitation accumulation at 1800 m



Annual average temperature trend at 1800 m



Average number of days with snow covered ground at 1800 m on the flat



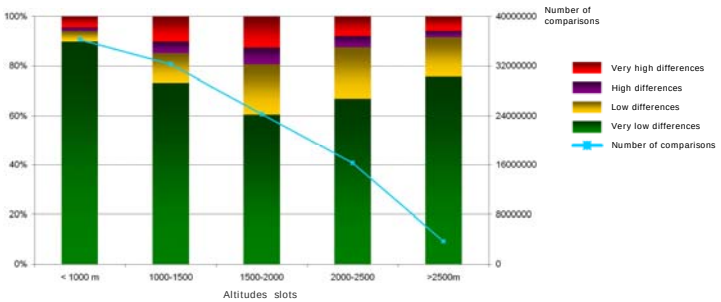
Annual precipitation accumulation trend 1958-2008 as a function of elevation and massif

Satellite detected (MODIS-Terra) and modelled (SAFRAN-Crocus) snow cover comparison in the Pyrenees

Global results about the whole Pyrenees

(February 2000 - July 2010 period)

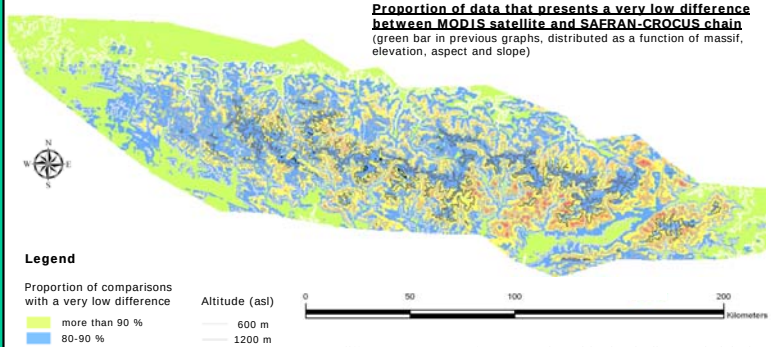
Number of comparisons between modelled and observed snow occurrence divided into four quality classes



The results show low differences between the two data sets on the entire Pyrenees, except for elevations between 1500 and 2000 m where there are more significant differences. Around these altitudes the snow cover is often discontinuous, and there are consequently more differences between the two data set.

Localization of low and high difference sources

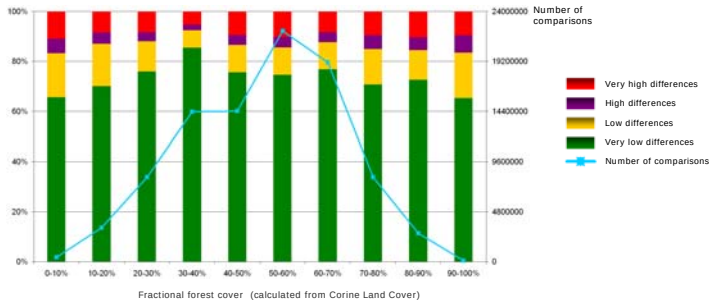
Proportion of data that presents a very low difference between MODIS satellite and SAFRAN-CROCUS chain
(green bar in previous graphs, distributed as a function of massif, elevation, aspect and slope)



Low differences are more frequent at low altitudes (valleys and plains). Unlike the differences are the least frequent at middle altitudes and in the East part of the Pyrenees.

Forest effects

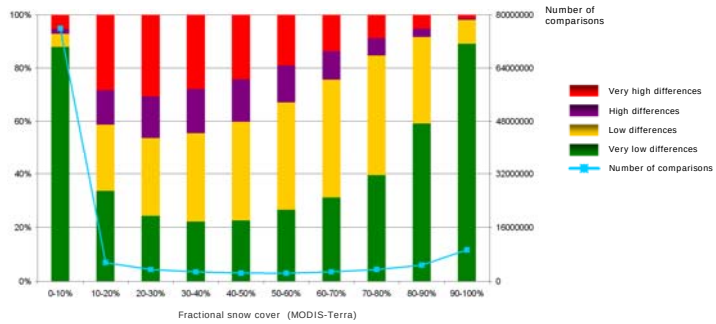
Representation of the four differences classes as a function of the fractional forest cover



Forest areas are not taken into account by SAFRAN-CROCUS and are expected to influence MODIS satellite measurements. However, forest effects do not seem to be a source of difference.

Results depending on fractional snow cover

Representation of the four differences classes as a function of the fractional snow cover



The fraction of snow on ground has an influence on the differences between MODIS-Terra and SAFRAN-Crocus data: very low differences are more frequent when the fraction of snow is null (no snow) or very high (continuous and thick snow cover). On the opposite, high differences are frequent when the snow cover is discontinuous (snow line neighbourhood).

References:

Durand Y., Giraud G., Brun E., Mérindol L., Martin E., 1999. "A computer based system simulating snowpack structures as a tool for regional Avalanche forecast". Journal of Glaciology, Vol. 45, No. 151, pp469-484.

Durand Y., Brun E., Mérindol L., Guyomarc'h G., Lesaffre B., Martin E., 1993. "A meteorological estimation of relevant parameters for snow models". Annals of Glaciology 18 1993, pp65-71.

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FLUXPYR meeting
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