Response of the snow cover over France to climate change

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The climate change over the mountain regions is not an easy question because it is strongly modulated by the surface elevation and the horizontal gradient of this variable is not compatible with the horizontal resolution of the GCMs. The current resolution of the next CMIP5 exercise (100-200 km) does not allow to represent the mountains over France, except a coarse dome in the South-Eastern part corresponding to the Alps. The typical resolution of the next CORDEX exercise (50 km) enables to represent the main three mountains (Alps, Pyrenees and Massif Central) but the horizontal gradient of elevation is not steep enough and this has consequences on the representation of local precipitation and winds. In addition the maximum elevation is not high enough, which has consequences on the snow cover. Given the horizontal scale of ridges and valleys, a 1 km mesh would be necessary for an accurate representation of the mountains, but it is not yet compatible with centennial integrations with the present capacity of computers.

However the mid-latitude mountainous areas are vulnerable to global warming, because the reduction of the snow cover has a strong impact on water resources and tourism, even with a moderate increase in mean temperature. To investigate this question, we have developed, in the framework of the French national project SCAMPEI (http://www.cnrm.meteo.fr/scampei/) a four-step procedure to evaluate the snow cover over France:

Step one. The ARPEGE-climate-V4 AGCM model (Déqué, 2007) derived from the ARPEGE-IFS code has been run over 1950-2100 with monthly bias-corrected sea surface temperatures of the CMIP3 contribution by the AOGCM version of this model (A1B scenario). The AOGCM resolution is 300 km, whereas the AGCM has a variable horizontal resolution ranging from 50 km over Europe to 300 km in the southern Pacific.

Step two. The ALADIN-climate-V4 limited area RCM (Déqué and Somot, 2008) based on the above model, but with a 12 km resolution over a domain centered on France has been driven by the above AGCM. Figure 1 shows the surface elevation over France by the AOGCM, the AGCM, and the RCM.

Step three. The daily surface variables and fluxes have been corrected by the quantile-quantile method described in Déqué (2007). The reference data is the SAFRAN reanalysis (Quintana-Séguí et al., 2008). This reference offers hourly surface data and fluxes in 615 homogeneous areas within France (about 30 km horizontal resolution) at different altitudes (300 m vertical resolution).

Step four. The statistically corrected variables have been used as an input of the ISBA-ES soil-vegetation-snow model (Boone et al., 2001).

The output of this process is, inter alia, a daily data base of high resolution snow cover with different altitudes for each area. Because of the statistical pre-processing, the snow cover climatology is in fairly good agreement with the observations during the 1961-1990 period. The process has been repeated with SRES scenarios A2 and B1 in order to explore the uncertainty. It is planned to include two other French RCMs at similar resolution, and a direct statistical downscaling to SAFRAN data of some CMIP3 AOGCMs to deepen the uncertainty analysis.

Figure 2 shows the mean number of days per year with snow on the ground in France as a function of surface elevation for the 1961-1990 period (solid line), the 2021-2050 period (three dashed lines corresponding to B1, A1B and A2 forcings) and the 2071-2100 period (three dotted lines corresponding to B1, A1B and A2 forcings). One can see that up to 3000 m, the number of days with snow cover (> 1cm) decreases. The 3 mid-century scenarios have a similar response, whereas at the end of the century, the response is ranked by the GHG concentration. In the worse scenario (A2), The number of days with snow cover on the ground is reduced by 25% at 3000 m, 33% at 2400 m, 50% at 1800m and 75% at 1200m. This result confirms the sensitivity study in the Mont Blanc region by Martin et al. (1997).

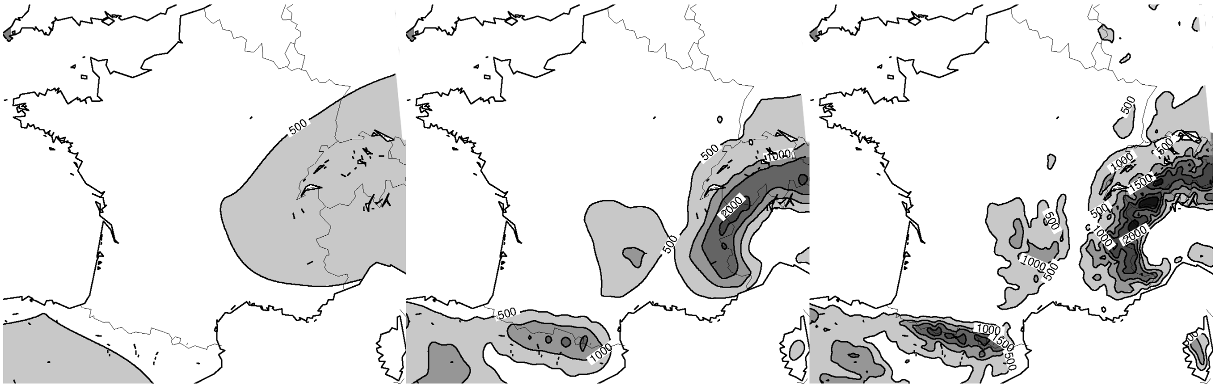

Figure 1: Surface elevation (m) of the 3 atmospheric models involved in the process. AOGCM (left, resol. 300 km), AGCM (middle, resol. 50 km), RCM (right, resol. 12 km). Contour interval 500 m

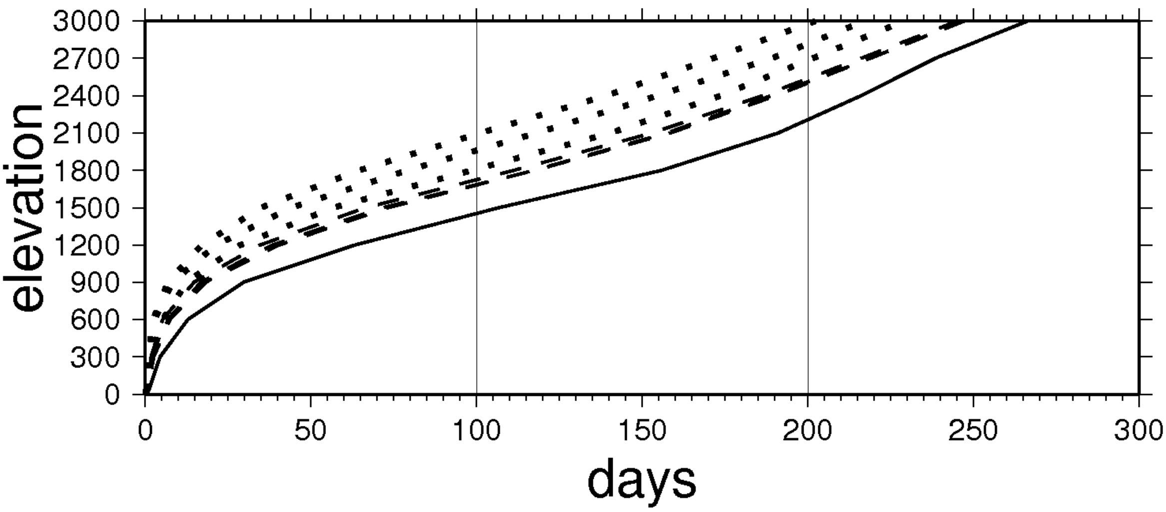

Figure 2: Mean number of days per year with snow on the ground (abscissa) as a function of surface elevation (ordinate, m) for 1961-1990 (solid), 2021-2050 (dash) and 2071-2100 (dot). The 3 scenarios correspond to B1, A1B and A2.

Acknowledgements:

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