21st century snowfall changes over the French Alps : the role of temperature

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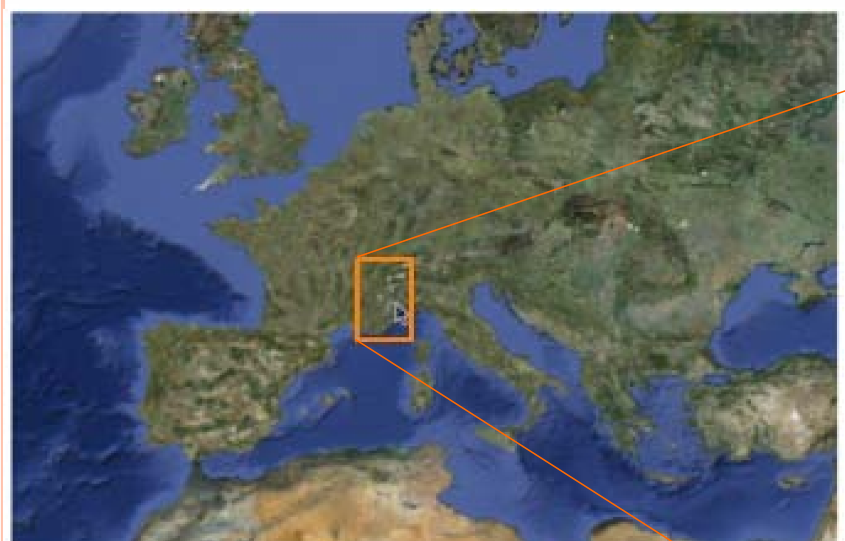
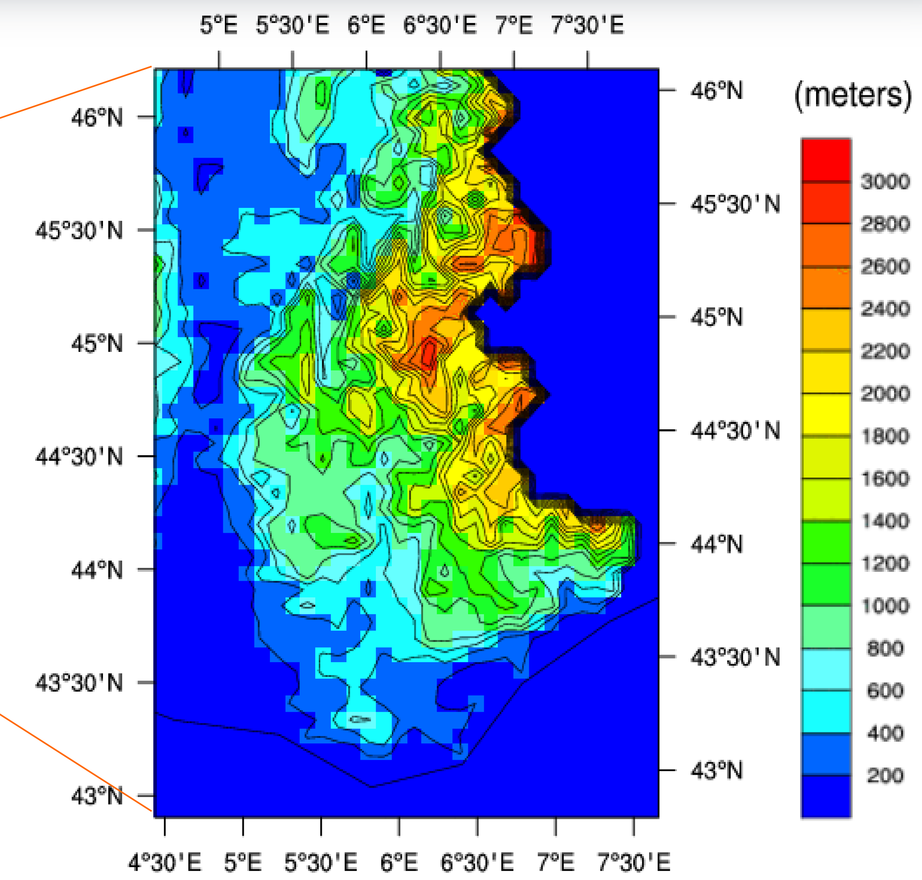
The robustness of snowfall changes over the French Alps simulated during the 21st century is studied through the analysis of a very large ensemble of high-resolution regional climate projections obtained either through dynamical or statistical downscaling. Associated uncertainties are evaluated and related to temperature changes.

Area of interest : the French Alps





(Top) The area of study at the European scale. (Right) The French Alps topography as represented on the 8 km grid used in this study.

In mountainous areas, **fine topography** largely impacts local climate and especially precipitation formation and phase.

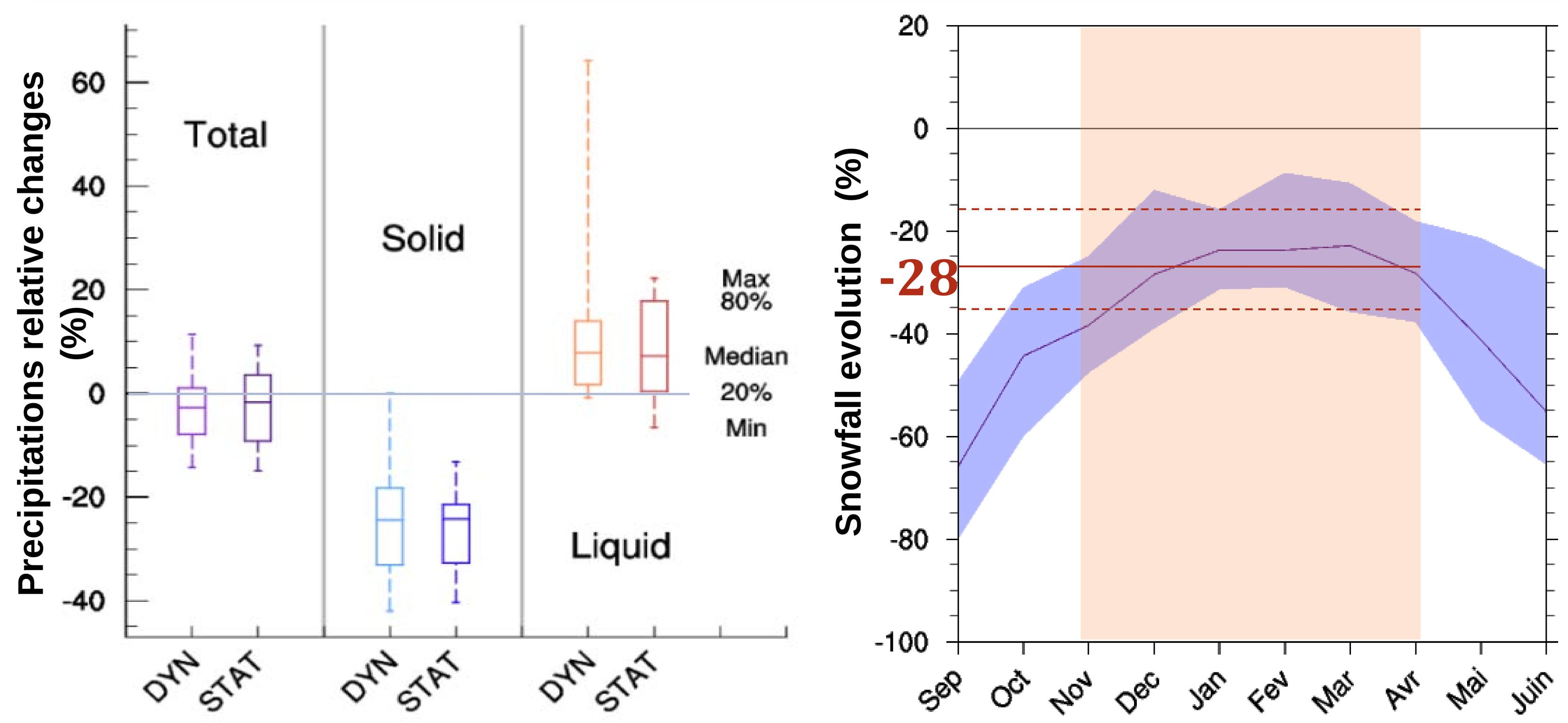
Several **downscaling methodologies** have been developed to better take into account the effect of sharp physiographic features of mountainous areas on climate.

A set of 43 very high resolution projections

	Spatial res.	Downscaling method		Data treatment		Period		Emission scenario		
		Dyn.	Stat.	Raw	Debiased	Middle	End	A1B	A2	B1
CMIP3 (x14)	8 km		X	---	---	2046-2065	2081-2100	X		
ARPEGE INT (x3)	8 km		X	---	---	2036-2055	2081-2100	X	X	X
ARPEGE SCN (x4)	8 km		X	---	---	2036-2055	2081-2100	X		
ENSEMBLES (x16)	25 km	X		---	---	2036-2055	---	X		
ALADIN (x3)	12 km	X		X	X	2031-2050	2071-2100	X	X	X
LMDZ (x2)	12 km	X		X	X	2031-2050	2071-2100	X		
MAR (x1)	12 km	X		X	X	2031-2050	2071-2100	X		

Ref.: CMIP3 dataset available on http://esg.llnl.gov:8080/index.jsp; ENSEMBLES dataset available on www.ensembles-eu.org; Others regional projections were realized in the frame of the ANR-SCAMPEI project www.cnrm.meteo.fr/scampei.

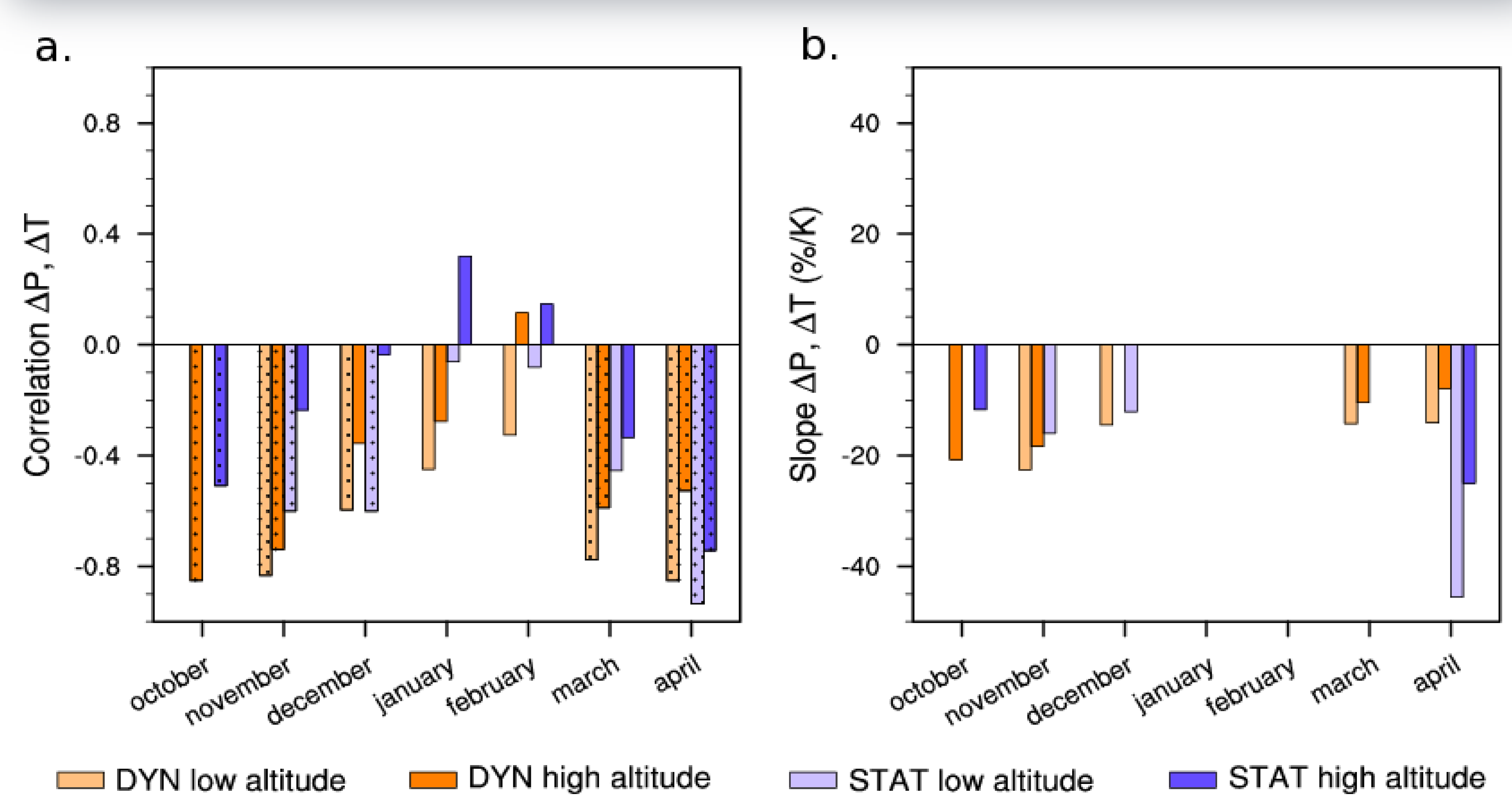
Results : Multi-model changes



(Right) **Relative changes in total/solid/liquid precipitation** at the middle of the century, from November to April, with the A1B emission scenario. (Left) **Seasonal cycle of the changes in solid precipitation.** The dark line is the ensemble median the area shaded in blue depicts the 20%-80% quantile range.

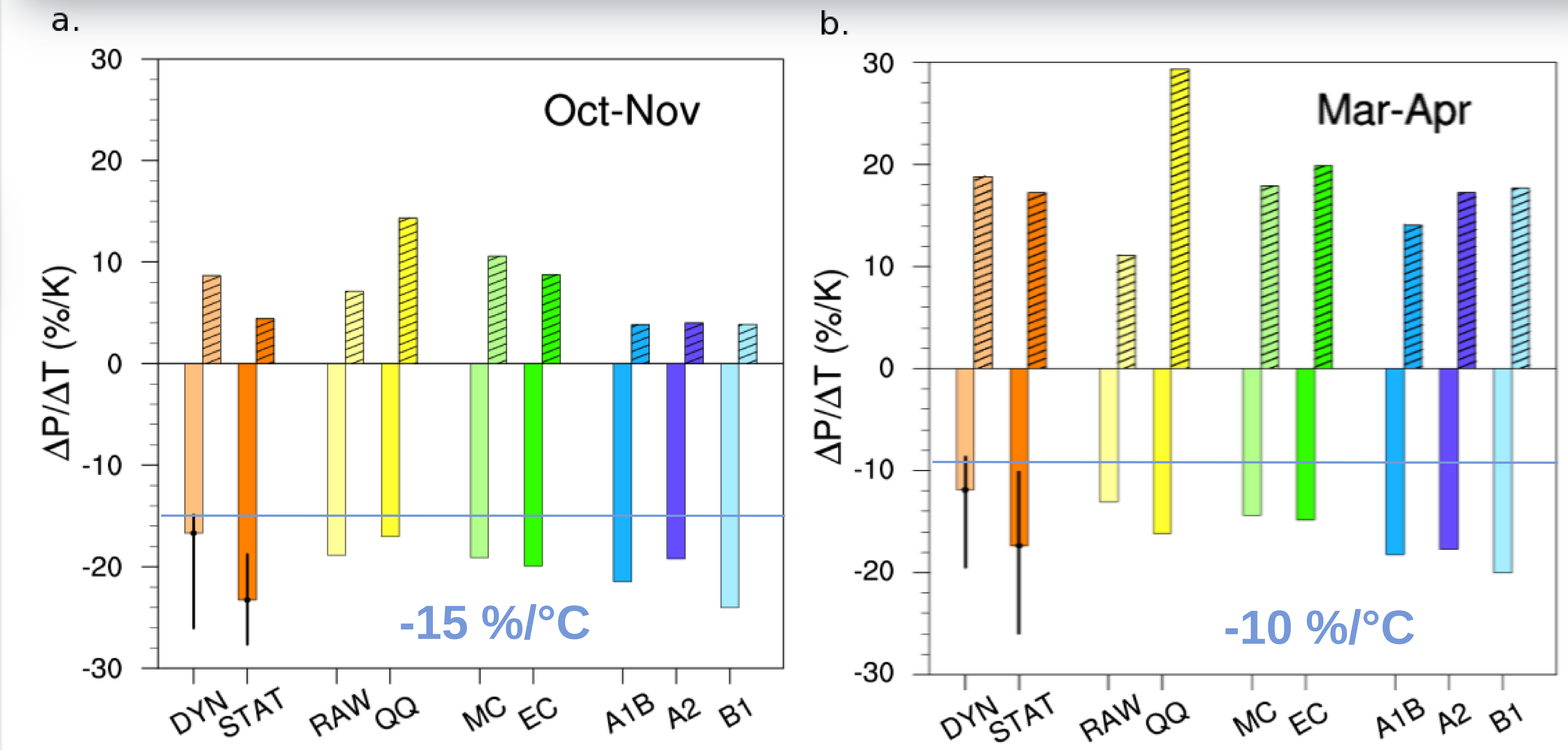
- All models project a decrease in solid precipitation.
- Strong seasonality of solid precipitation relative changes.

Correlation between warming and snowfall changes



(a) **Monthly inter-model linear correlation** and (b) **regression coefficients between relative changes in solid precipitation and temperature changes**, from October to April, for the middle of the 21st century and with the A1B scenario. Dots in (a) indicate when the correlation is significant at the 0.05 level. Regression coefficients in (b) are plotted only when the correlation is significant.

ΔP/ΔT : a robust quantity



Ratio between relative precipitation change and temperature change for multiple sets of projections (hatching for liquid precipitation, solid precipitation elsewhere). (a) Average for October-November and (b) March-April. Different comparisons are shown: (1) between statistical and dynamical downscaling, (2) between raw and bias corrected results of dynamical downscaling, (3) between the middle and the end of the century and (4) between different emission scenarios.

Conclusions

❖ Large decrease in solid precipitation

-30% on average in winter in the middle of the century (A1B)

❖ Robustness on the sign of solid precipitation change, contrary to liquid or total precipitation changes

❖ Good confidence in ensemble projected snowfall changes because :

- Small sensitivity of snow projections to the downscaling method and a higher sensitivity to the models.
- At the beginning and at the end of the cold season, temperature increase explains a large part of snowfall uncertainties.
- At the beginning and at the end of the cold season, the ΔP/ΔT ratio is robust to downscaling method, use of bias correction, period of the century and emission scenario.

❖ No significant link found between temperature and snowfall changes during winter's coldest months.

Cf. Piazza et al. (2012), *21st century snowfall changes over the French Alps: the role of temperature*, submitted in Climatic Change.

Acknowledgments :
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