Detection of snow cover, temperature and precipitation trends in the European Alps over the last century using model and reanalyses data

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Outlook

- Methods and Tools (MAR and SAFRAN-CROCUS)
- Model evaluation/comparisons
- Recent trends
- Feedback and processes

Rmq : For precipitation evaluation and trends refer to HESSD paper in review:
`https://doi.org/10.5194/hess-2019-690`

MAR RCM

GCM ⇒ too coarse and irrelevant for high mountainous, alpine terrain

Dynamical downscaling with MAR-RCM

http://mar.cnrs.fr

MAR v3.9

- 7 kms HR, hydrostatic
- 24 vertical levels
- SISVAT surface scheme (detailed snow processes)
- ERA-20C (1902-2010) and ERA5 driven (1981-2018)

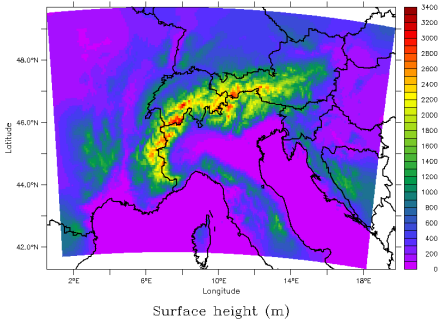


Figure: Surface elevation of MAR-Alps domain (7 kms)

SAFRAN-ADAMONT

SAFRAN-CROCUS reanalyses *(Durand et al., 2009)*

- French Alps divided into 23 massifs, 300 m altitude slices
- Météo-France NWP model + obs. assimilation
- CROCUS snow model driven by atm.fields → snow depth, SWE

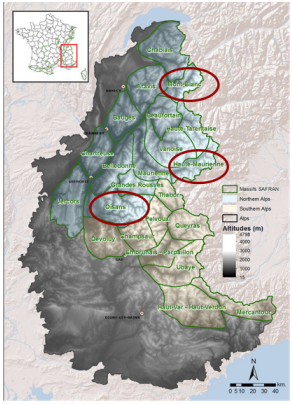
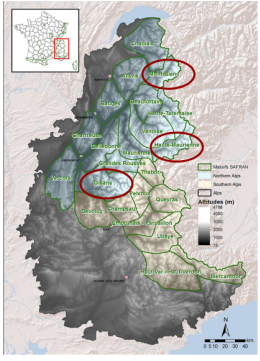


Figure: SAFRAN massifs division of the French Alps Source : modified from H. Francois (IRSTEA)

Period and area of interest

This study :

- 1981-2010 period for evaluation/comparison
- Comparisons with late spring (May) accumulation on Mer de Glace, Argentières (Mont-Blanc) and Gebroulaz (Vanoise) glaciers from GLACIOCLIM (`https://glacioclim.osug.fr/`)
- Longest common period for trends (1959-2010)
- **French Alps with focus on Mont Blanc, Haute Maurienne and Oisans massifs**
- Large altitude range
- Large share of the French Alps glacier
- Focus territories of the Trajectories initiative (Arve, Maurienne and Romanche valleys)



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Snow Water Equivalent (Late Spring)

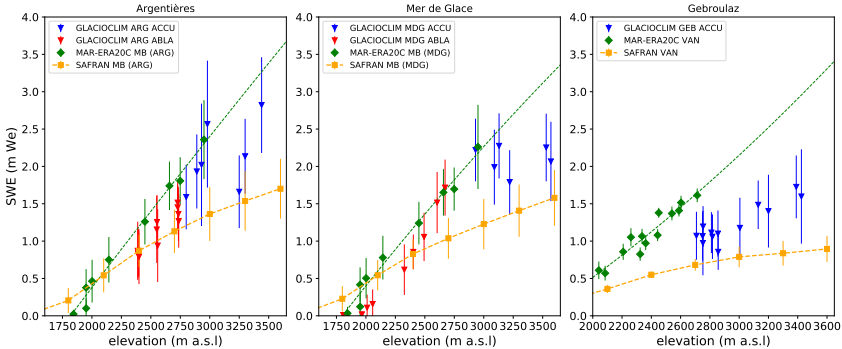


Figure: Late spring mean snow accumulation (in m SWE) over 1993-2010 in GLACIOCLIM measurements for accumulation (blue) and ablation zone (red), MAR-ERA20C (green) and SAFRAN-CROCUS (orange) for Argentières (left), Mer de Glace (centre) and Gebroulaz (right) glaciers. Error bars +- std. dev. of annual mean

- Higher accumulation at high elevations in MAR than in SAFRAN-CROCUS du to higher precipitation (see annex).
- "Ground truth" in between the two data sets.

Snow cover duration

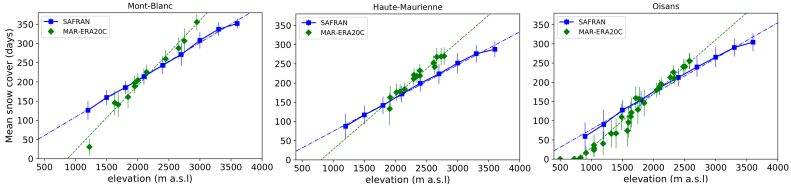


Figure: Snow cover duration (days, threshold = 20mmWe) over 1981-2010 for SAFRAN-CROCUS (blue) and MAR-ERA20C (green) for Mont Blanc (left), Haute-Maurienne (centre) and Oisans (right) massifs.

- Moderate to high underestimation < 1500 m in MAR: warm bias (1-2 C) and higher rainfall ratios (see annex).
- Extrapolated altitude of 365 days of snow cover in MAR consist. with actual glaciers equilibrium line.

Trend in snow cover duration

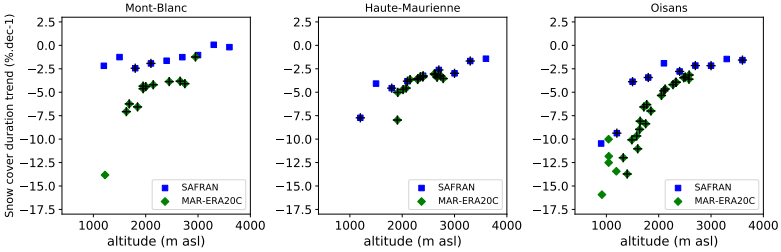


Figure: Relative trend in snow cover duration (%.decade) over 1959-2010 for SAFRAN-CROCUS (blue) and MAR-ERA20C (green) for Mont Blanc (left), Haute-Maurienne (centre) and Oisans (right) massifs. Black cross for significant trends ($p<0.05$)

- Higher decrease at low elevation in MAR (bias?)
- Lower decreases at high elevations

Trend in Nov. to April T2m

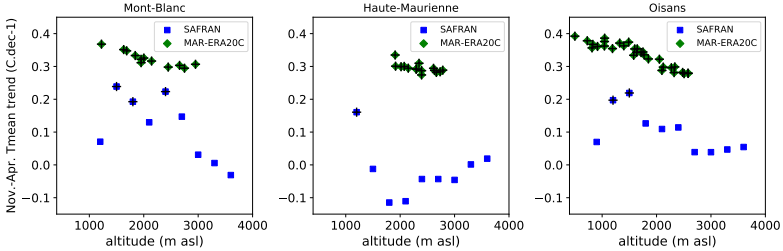
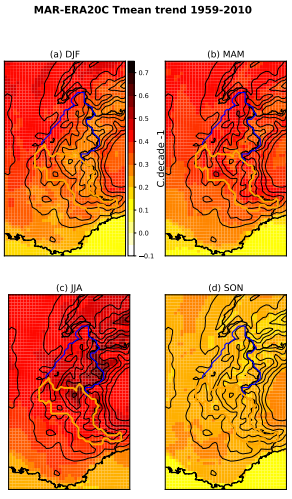


Figure: Nov. to April 2m temperatures trend (C.decade^{-1}) over 1959-2010 for SAFRAN-CROCUS (blue) and MAR-ERA20C (green) for Mont Blanc (left), Haute-Maurienne (centre) and Oisans (right) massifs. Black cross for significant trends ($p<0.05$)

- Spurious trends in SAFRAN : *to be verified* !
- Higher warming ($\sim$ 0.4 C.dec-1) at lower elevations in MAR in agreement with former studies.

Feedback and processes : Temperature trends and altitude

- We focuss on MAR : realistic interaction between atmosphere and snow-pack
- We look at seasonal trends as function of elevation
- French Alps divided between northern part (NWA, blue) and southern (SA, orange) at around 45°N



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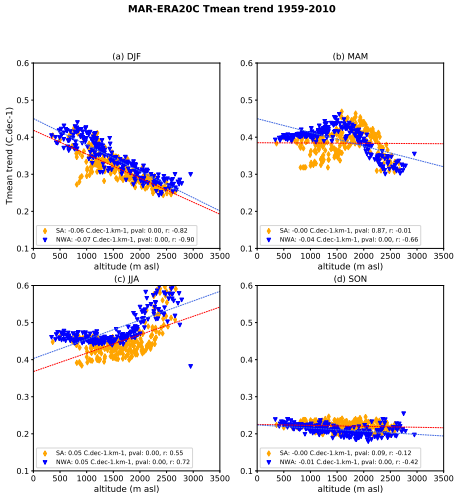
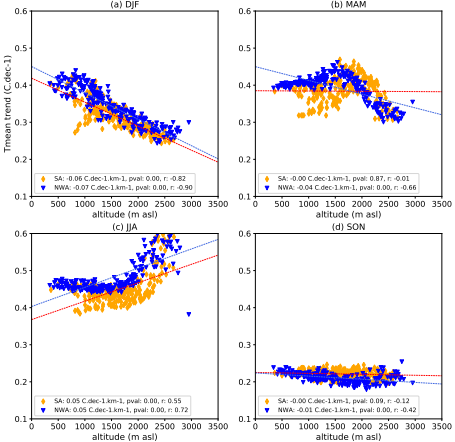
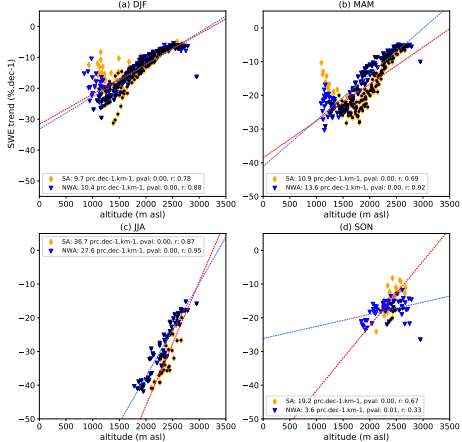


Feedback and processes : Temperature and SWE trends

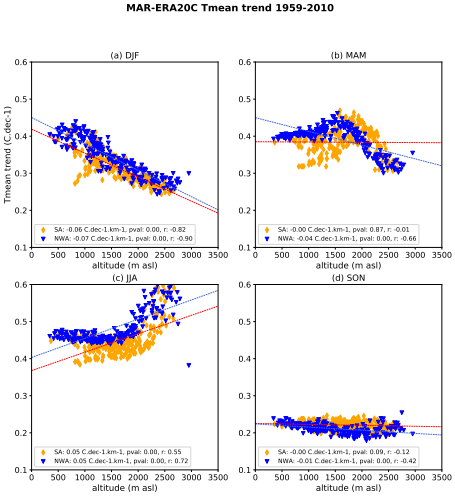
MAR-ERA20C Tmean trend 1959-2010

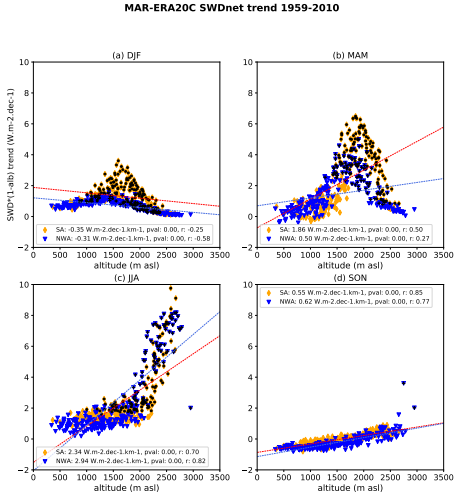


MAR-ERA20C SWE trend 1959-2010

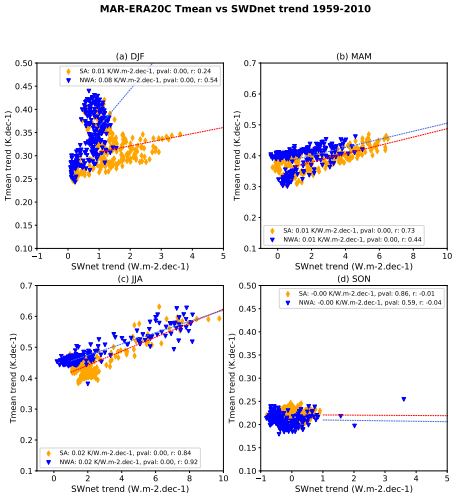


Feedback and processes : Temperature and SWDnet trends





Feedback and processes : Temperature and SWDnet trends



- Snow albedo feedback largely explains relation between temperature trends and elevation in summer and spring
- Relation less convincing in winter
- No relation in autumn (No link between temperature trends and altitude)
- **Perspectives :** Look at other processes and terms of the surface energy balance (LWnet, LWU, LWD, latent and sensible heat fluxes)

Merci ! Questions ?

Belledonne range, North-East of Grenoble, Feb. 2018

Nov. to April T2m

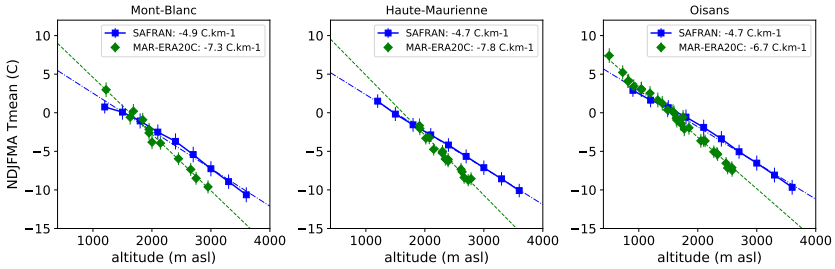


Figure: Nov. to April 2m temperatures (C) over 1981-2010 for SAFRAN-CROCUS (blue) and MAR-ERA20C (green) for Mont Blanc (left), Haute-Maurienne (centre) and Oisans (right) massifs.

Nov. to April Precipitation

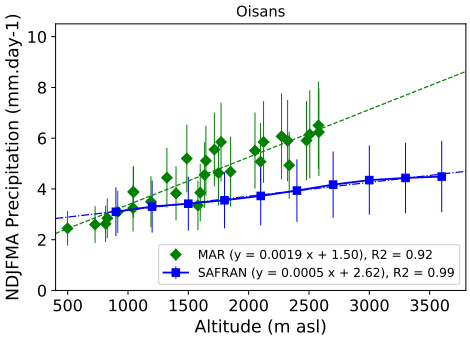


Figure: Nov. to April total precipitation (mm.We.day-1) over 1981-2010 for SAFRAN-CROCUS (blue) and MAR-ERA20C (green) for Oisans massif.

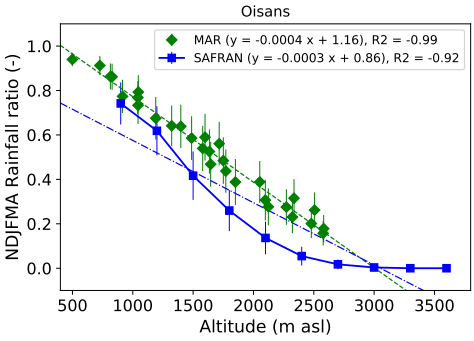
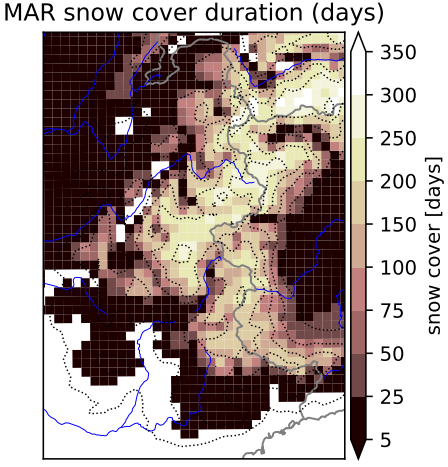
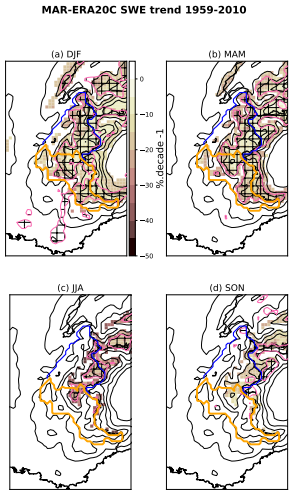


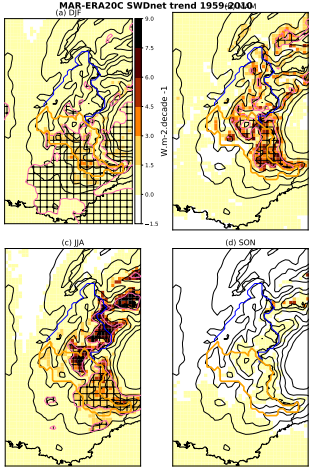
Figure: Nov. to April rainfall ratio to total precipitation (-) over 1981-2010 for SAFRAN-CROCUS (blue) and MAR-ERA20C (green) for Oisans massif.

Snow cover duration



SWE and SWDnet trend





Precipitation and snowfall trend