Potential and limitations of the convection-permitting CNRM-AROME climate model in the French Alps

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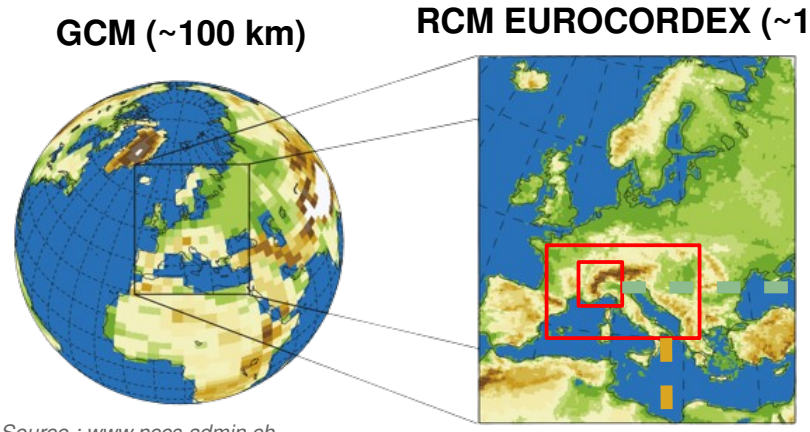
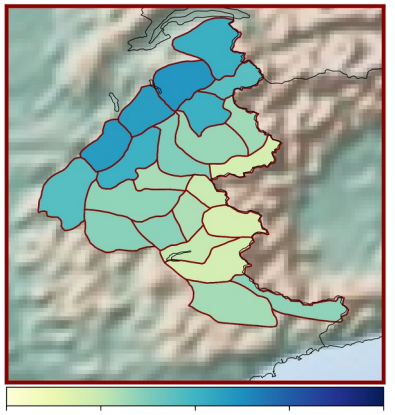
Climate change modelling in mountainous regions
- French Alps / European Alps -



Source : www.nccs.admin.ch

Statistical adjustment
ADAMONT
- S2M reanalysis used as reference dataset -

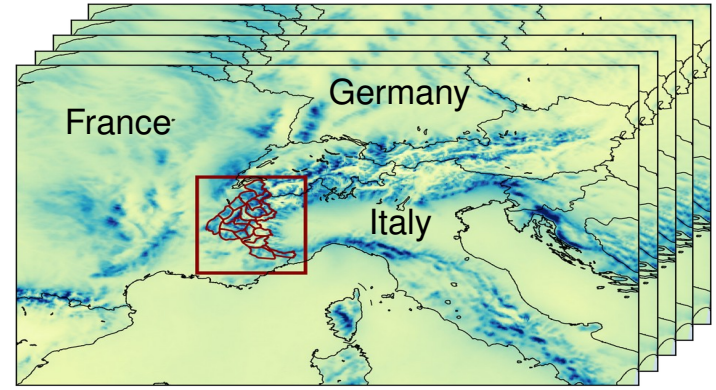
(Verfaillie et al., 2017, Vernay et al., 2022)



S2M – NDJFMA mean precipitation (mm/day) - [1982-2012]

Dynamical downscaling
FPS Convection – CORDEX
- convection-permitting RCM (~3km) -

(Coppola et al., 2020, Pichelli et al., 2021)



AROME – NDJFMA mean precipitation (mm/day) - [1982-2012]

What are the potentials and limitations to the use of CP-RCMs including CNRM-AROME in the French Alps ?

- **In past climate** *(reanalysis driven)* against the RCM CNRM-ALADIN taking the local reanalysis S2M as reference

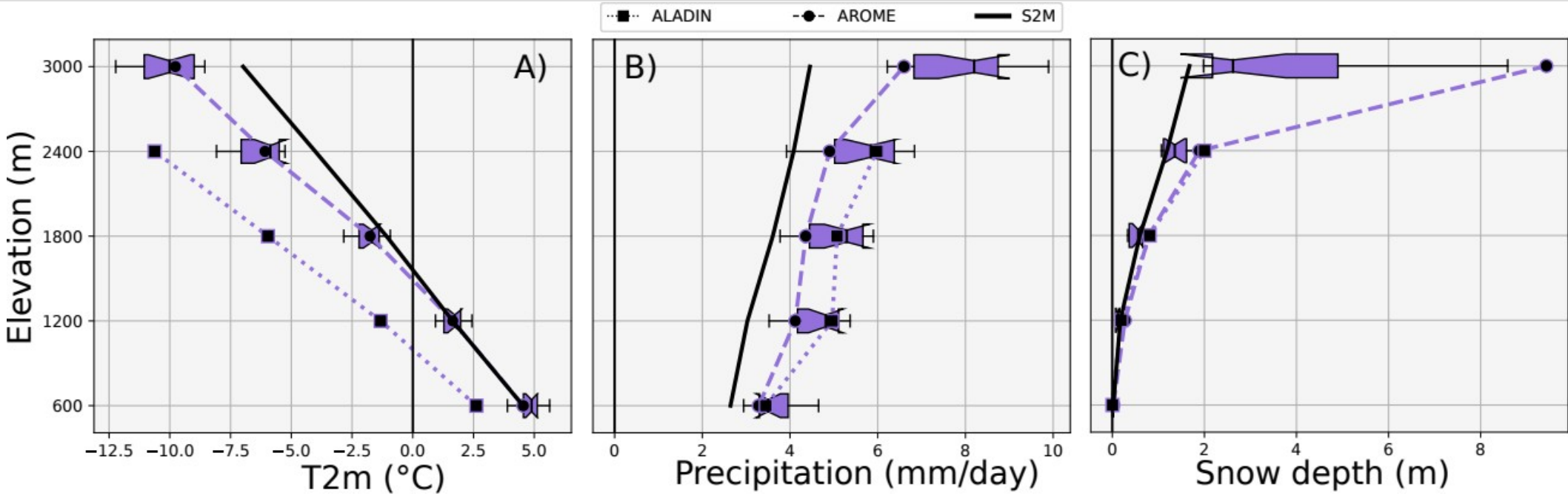
- **In climate projections** *(GCM driven)*, comparing the RCM CNRM-ALADIN and the statistical adjustment ADAMONT

  → ***Monteiro et al. 2022***

FPS Convection CP-RCMs ensemble evaluation

*- ERAi driven – [2000-2009] – **NDJFMA** -*

French Alps



Boxplot = statistics of the ensemble of mean NDJFMA values [2000-2009]

Compared to S2M reanalysis

- **A - Cold bias** for ALADIN and for all CP-RCMs
- **B - Higher amount of precipitation** for all models
- **C - Higher snow depth** simulated by all models
  (even higher for AROME, with spurious snow accumulation)

Ensemble of **14 CP-RCMs simulations**

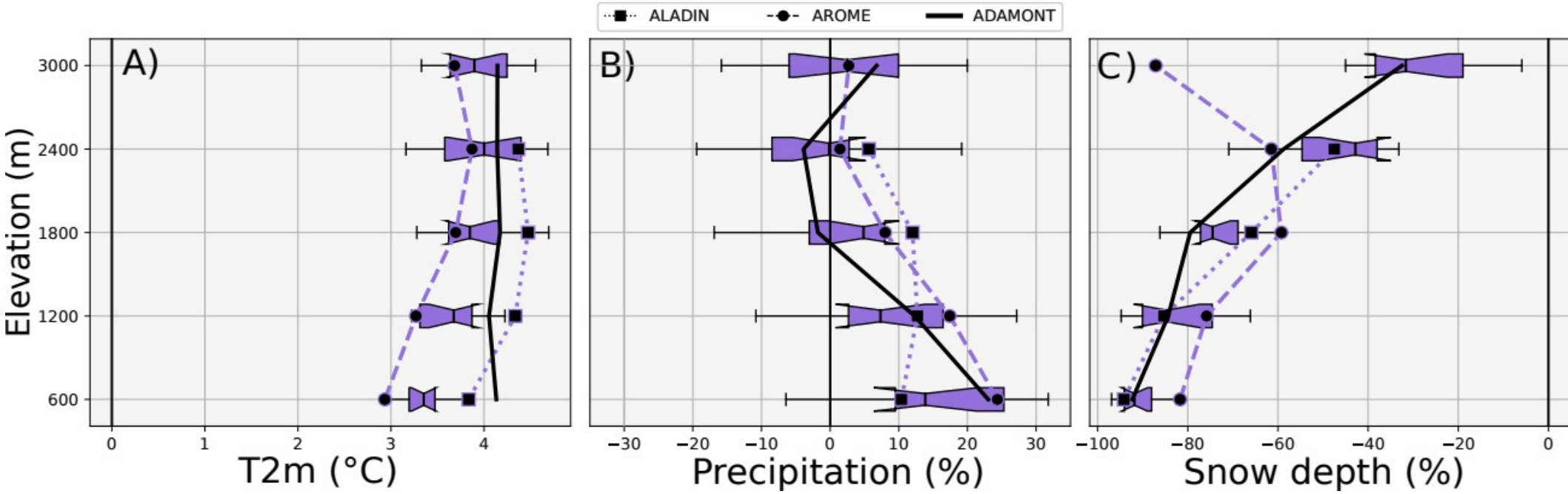
HCLIM38-AROME, KNMI-HCLIM38h1, CNRM-AROME41t1, CLMcom-BTU-CCLM5-0-14, CLMcom-JLU-CCLM5-0-15, CLMcom-CMCC-CCLM5-0-9, CLMcom-KIT-CCLM5-0-14, CICERO-WRF381BJ, IPSL-WRF381BE, UHOH-WRF381BD, IDL-WRF381BH, AUTH-MC-WRF381BG, BCCR-WRF381DA, WEGC-WRF381BL

Many thanks to all contributors from the FPS Convection - CORDEX

FPS Convection CP-RCMs ensemble projections

***- Changes over the 21st century – NDJFMA** (SSP5 – RCP8.5)*

French Alps



Boxplot = statistics of the ensemble of mean NDJFMA change values calculated as [2090-2099] - [1996-2005]

NB : AROME, ALADIN & ADAMONT mean NDJFMA change values are calculated as [2080-2099] - [1986-2005]

- **A - Smaller warming signal** (~1°C) **of the CP-RCMs ensemble** compared to ALADIN and ADAMONT

- **B - Small and heterogenous changes for winter precipitation** with a slight increase at low elevation

- **C - Strong decrease of snow depth at low elevations**, different among models but consistent with warming

Ensemble of **11 CP-RCMs simulations**

ICHEC-EC-EARTH_HCLIM38-AROME, KNMI-EC-EARTH_HCLIM38h1-AROME, CNRM-CM5_CNRM-AROME-41t1, CNRM-CM5_CLMcom-BTU-CCML5, MPI-M-MPI-ESM-LR_CLMcom-JLU, ICHEC-EC-EARTH_CLMcom-CMCC-CCLM5-0-9, MPI-M-MPI-ESM-LR_CLMcom-KIT, MOHC-HadGEM2-ES_CLMcom-DWD, NorESM1-ME_BCCR-AUTH-MC-WRF381DA, IPSL-CM5A-MR_WRF381DA, SMHI-EC-Earth_FZJ-IDL_WRF381DA

Many thanks to all contributors from the FPS Convection - CORDEX

Conclusions & outlooks

Potentials of CP-RCM simulations in the French Alps

- Lower temperature biases of CP-RCMs than ALADIN simulations
- More realistic precipitation (mean values and spatial patterns) of CP-RCMs than ALADIN simulations

Limitations of CP-RCM simulations in the French Alps

- Cold bias at intermediate and high elevation in winter *(for the whole ensemble)*
→ Related to the representation of the surface atmosphere exchanges and microphysics parameterizations
- Overall overestimation of the snow cover *(too extended, persistent, high)*
→ Combined effect of the precipitation and temperature biases and difficiencies of some snow schemes

→ Monteiro, D., Caillaud, C., Samacoïts, R., Lafaysse, M., & Morin, S. Potential and limitations of convection-permitting CNRM-AROME climate modelling in the French Alps. *International Journal of Climatology*, 1– 24. https://doi.org/10.1002/joc.7637 , 2022

Outlooks

- On-going exploration of FPS Convection CP-RCMs ensemble wrt temperature, precipitation and snow cover indicators, expanding at the scale of the European Alps
- On-going work on assessing a snow related European Alps reference dataset

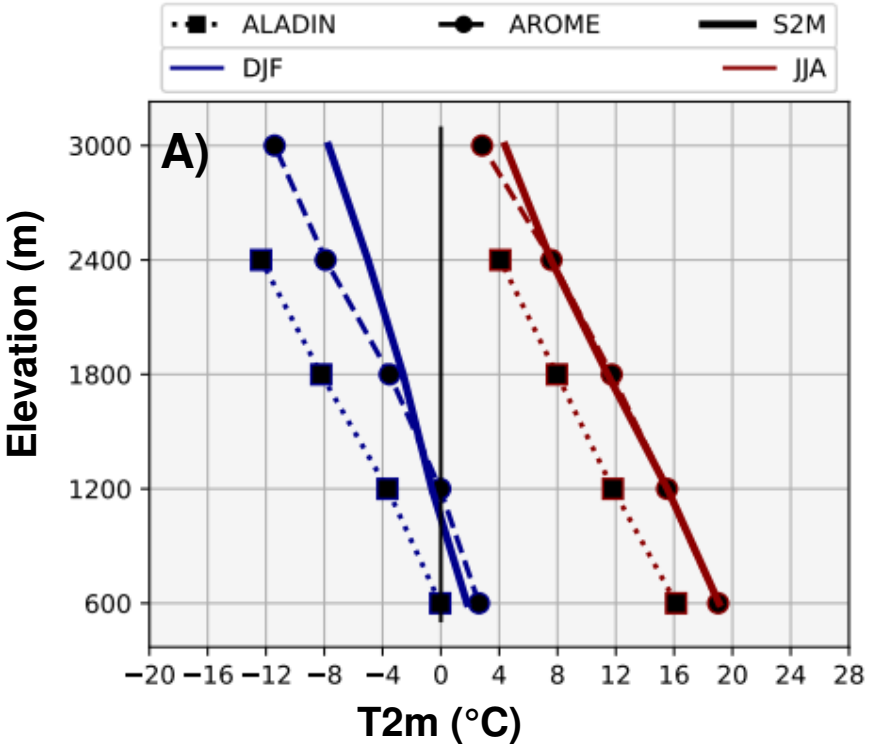
Supplementary materials

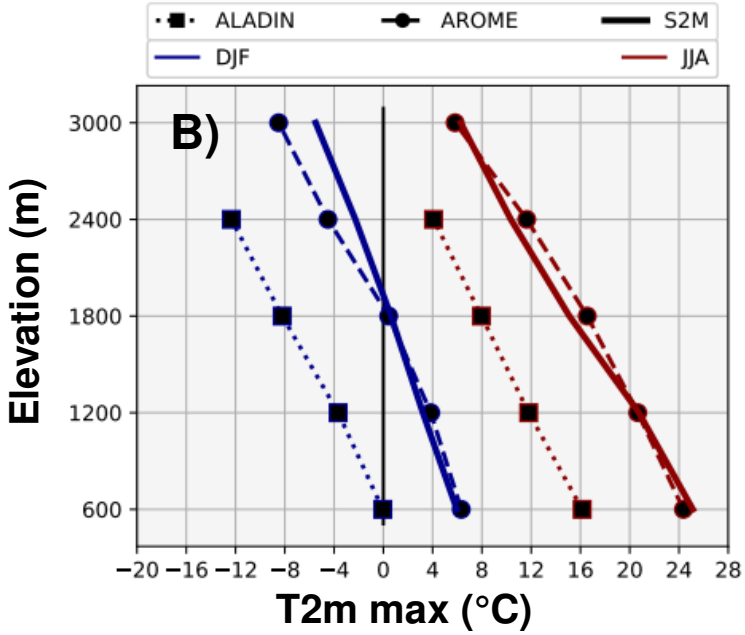
Results – Air temperature at 2m

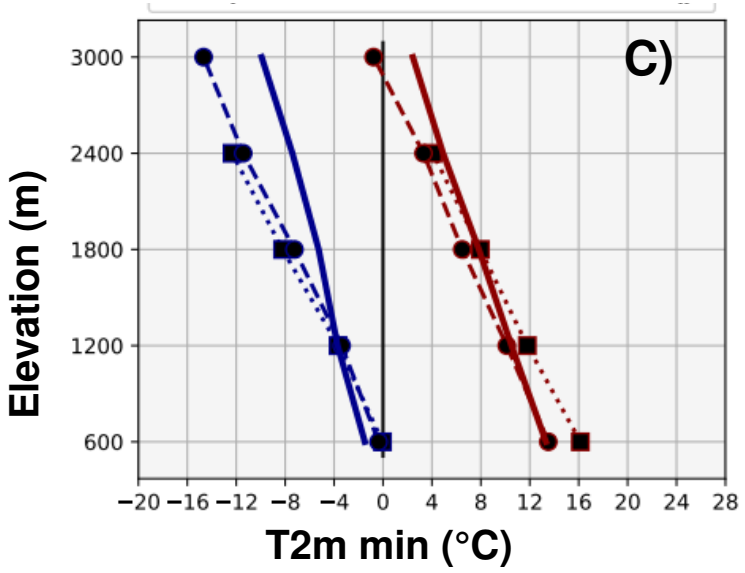
- ERAi driven simulations – [1982-2012] -

French Alps

NB : Each points of the altitudinal profiles are calculated as the mean of all grid points included within a z +/- 150m elevation band







- **A - Cold bias for both models**, stronger in winter at high elevations, from 3°C in AROME up to 7°C in ALADIN in winter at high elevations

- **A -** Almost **no bias in AROME in summer,** cold bias of 3.5°C in ALADIN

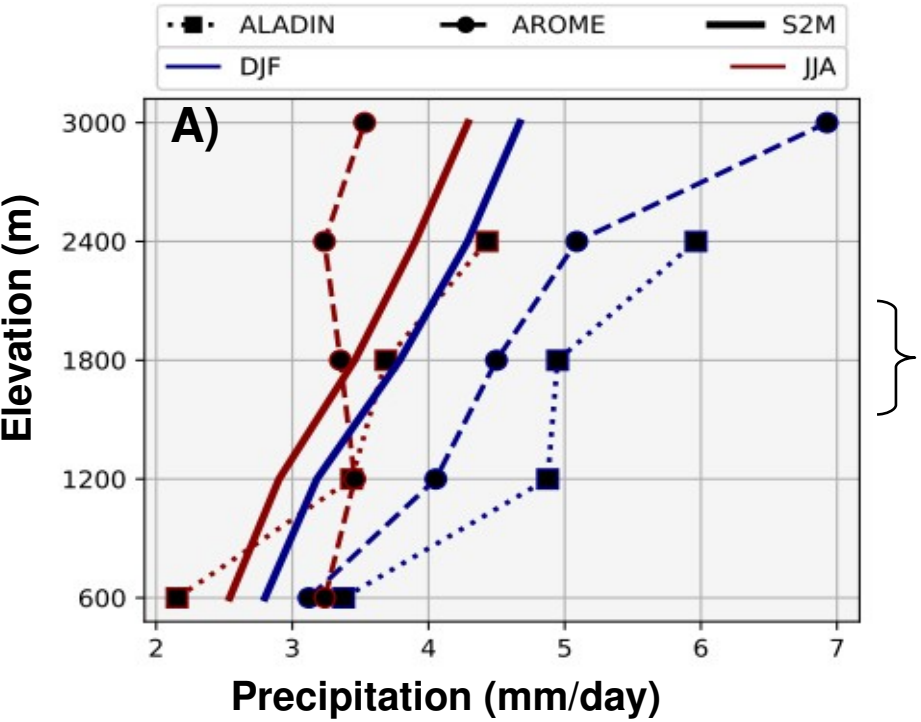
- **B -** Strong underestimation of **T2m max** for both seasons in ALADIN

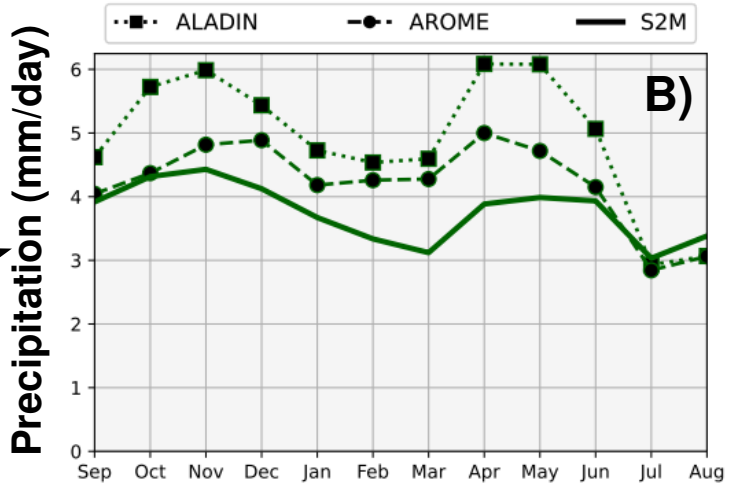
- **C -** Strong underestimation of **T2m min** in winter at high elevation for both models

Results – Cumulated precipitations

- ERAi driven simulations – [1982-2012] -

French Alps



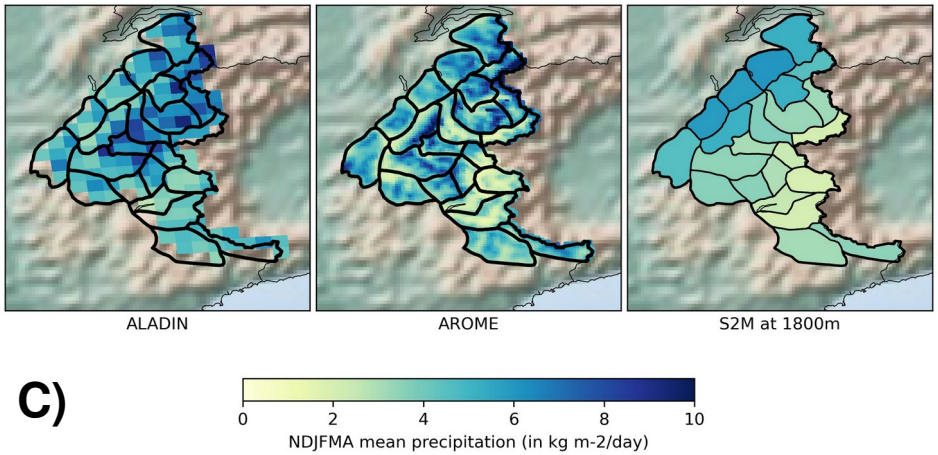


1800m

• **B -** Overall more pronounced accumulation over the winter period for both models (may be closer to the "reality" due to undercatchment of rain gauges)

• **A -** Higher amount of precipitation for ALADIN and AROME in winter (the more in ALADIN)

• **A -** AROME produces less precipitation than S2M at high elevation in summer

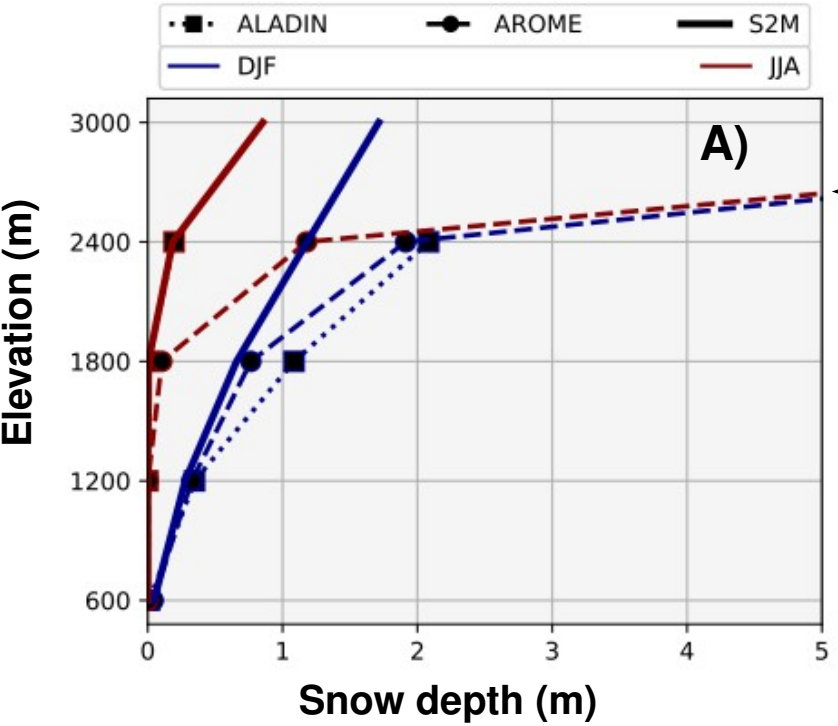


• **C -** AROME reproduces better than ALADIN the North-South & West-East gradient

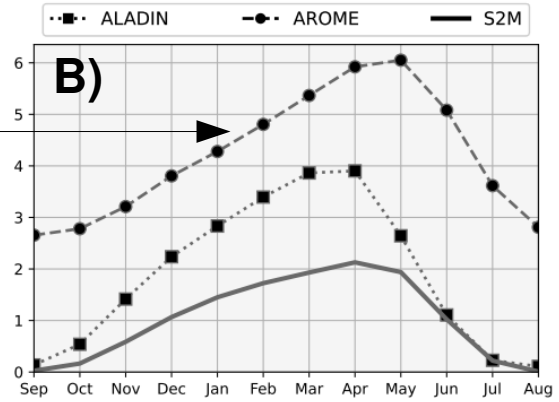
Results – Snow depth

- ERAi driven simulations – [1982-2012] -

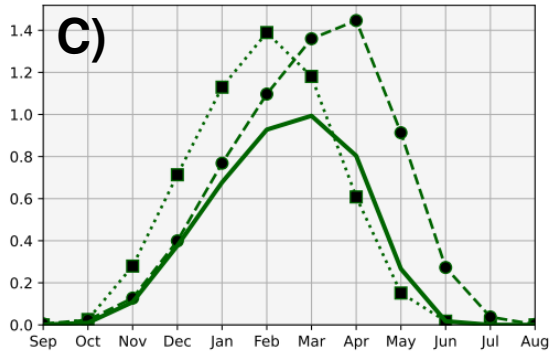
French Alps



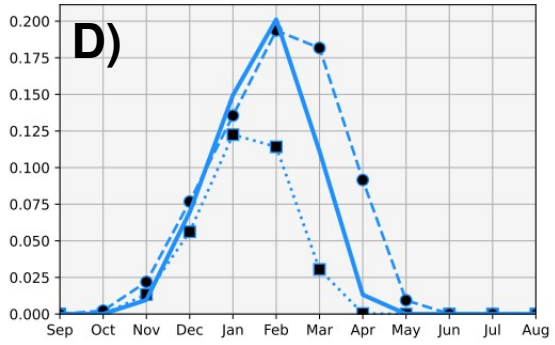
Snow accumulation issues in AROME



2700m



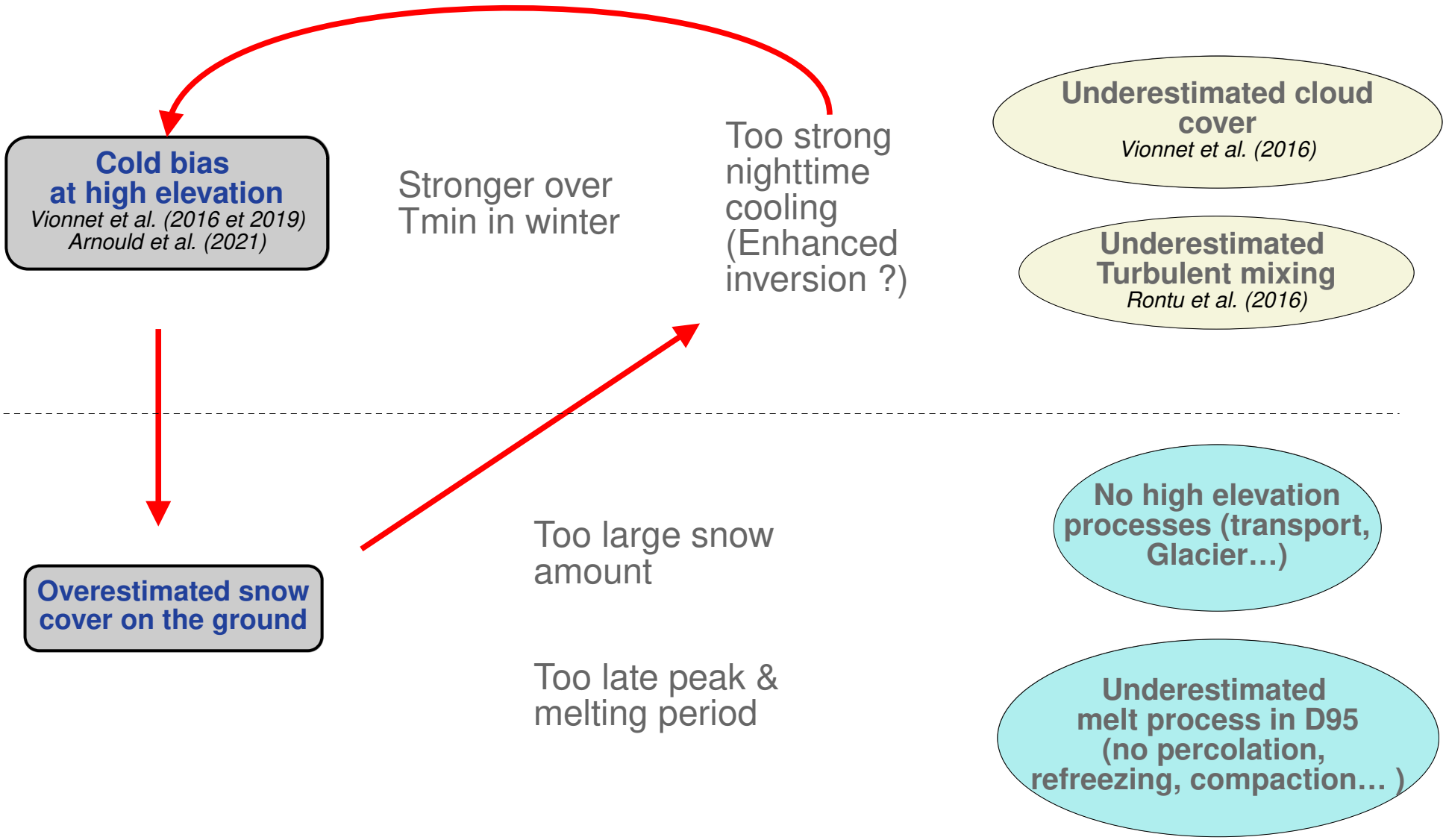
1800m



900m

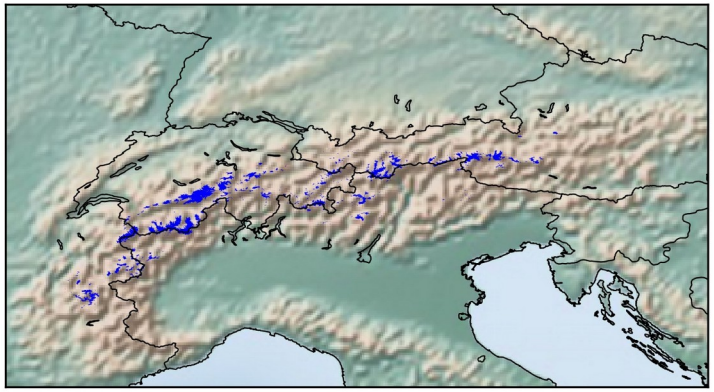
- **A -** Higher snow depth simulated by both models (the more in AROME), differences increasing with elevations
- **C/D -** Too early melt in ALADIN and too late melt in AROME
- **C/D** - Too early snow accumulation in ALADIN

Main limitations of CNRM-AROME in mountainous regions

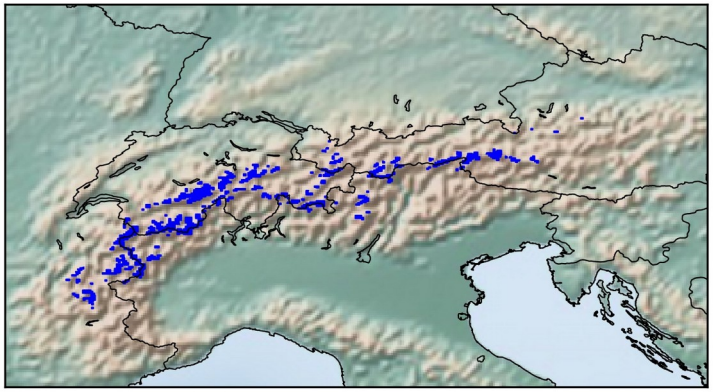


→ Need for sensitivity studies to apportion the contribution of each factor to these biases

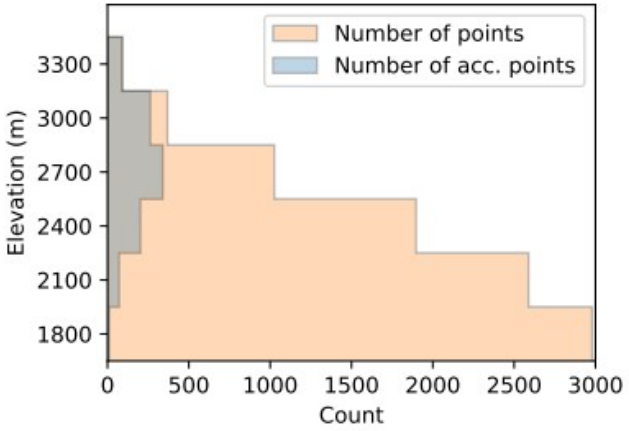
AROME snow accumulation areas



Glaciers locations (from WGI)

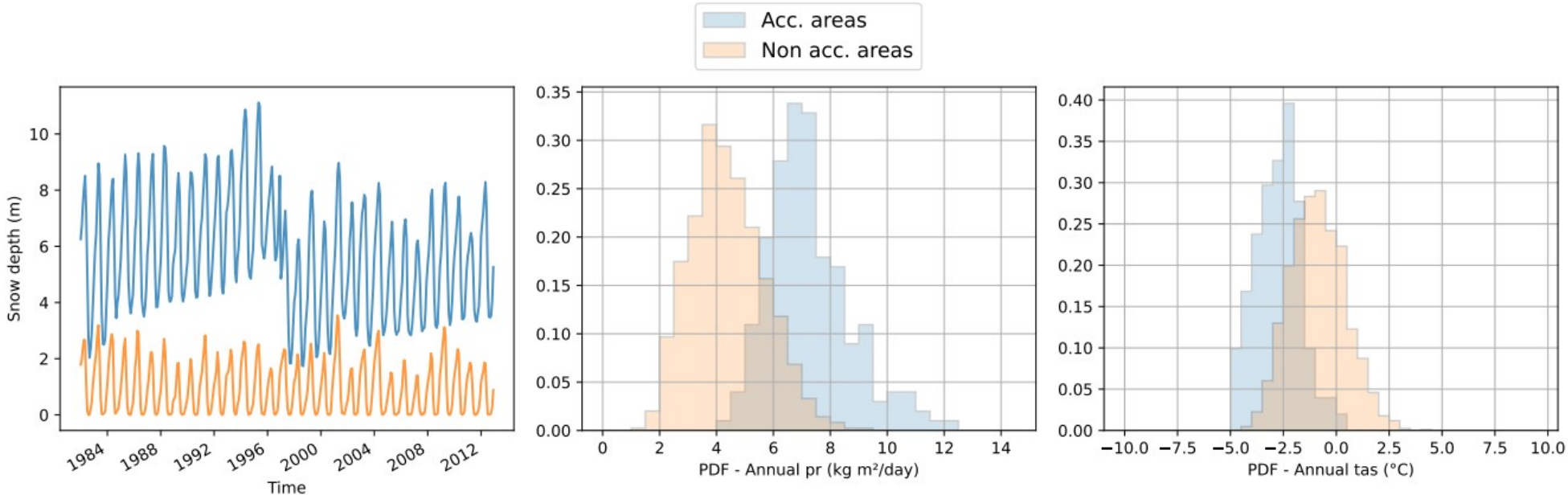


AROME accumulation areas



Note : *WGI = World glacier inventory*

Example at 2400m



- Snow accumulation areas located in and around actual glacier-covered areas (wider)
- Partially explained by different climatology of accumulation and ablation variables