A downscaling and adjustment method for climate projections in mountainous regions

applicable to energy balance land surface models

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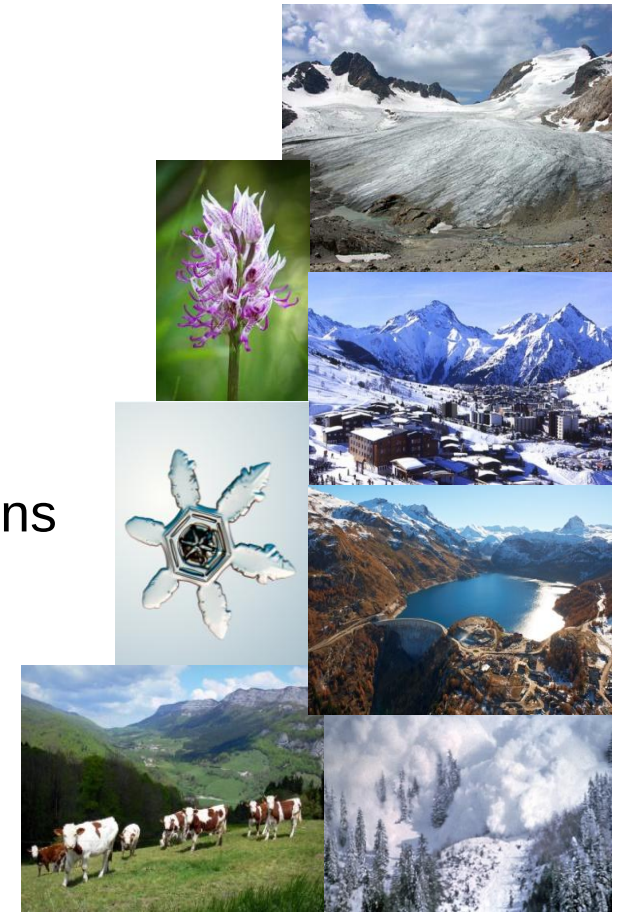
The issue

- Strong societal demand about **climate change** impacts and its **adaptation/mitigation**
- Mountain regions :
  - snow availability
  - impacts on glaciers & water resources
  - ecosystem vulnerability
  - climate-related hazards

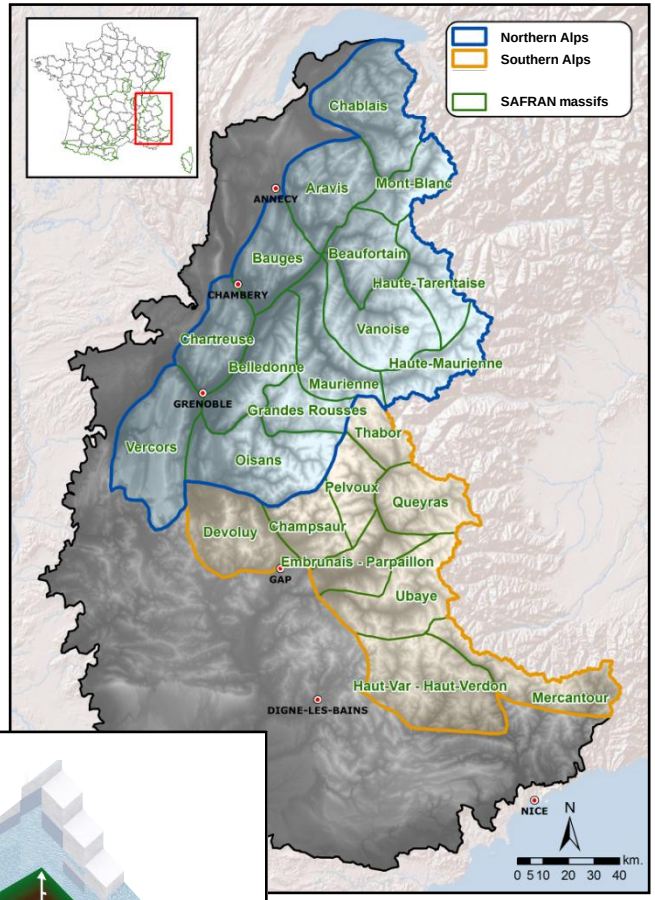
→ I**mpact models** sensitive to sub-diurnal variations

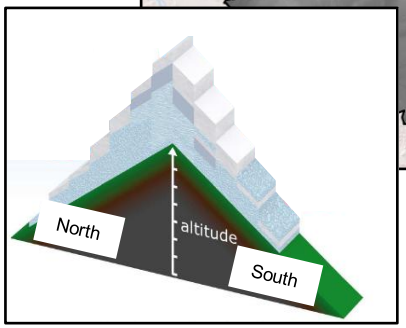


Downscaling and bias-adjustment method :

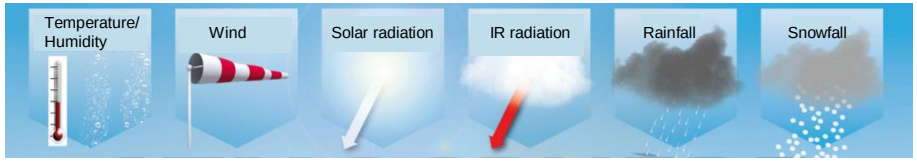
- quantile mapping & weather regimes
- vs. a meteorological reanalysis (SAFRAN)
- multi-variable and hourly

Reanalysis & snow modelling

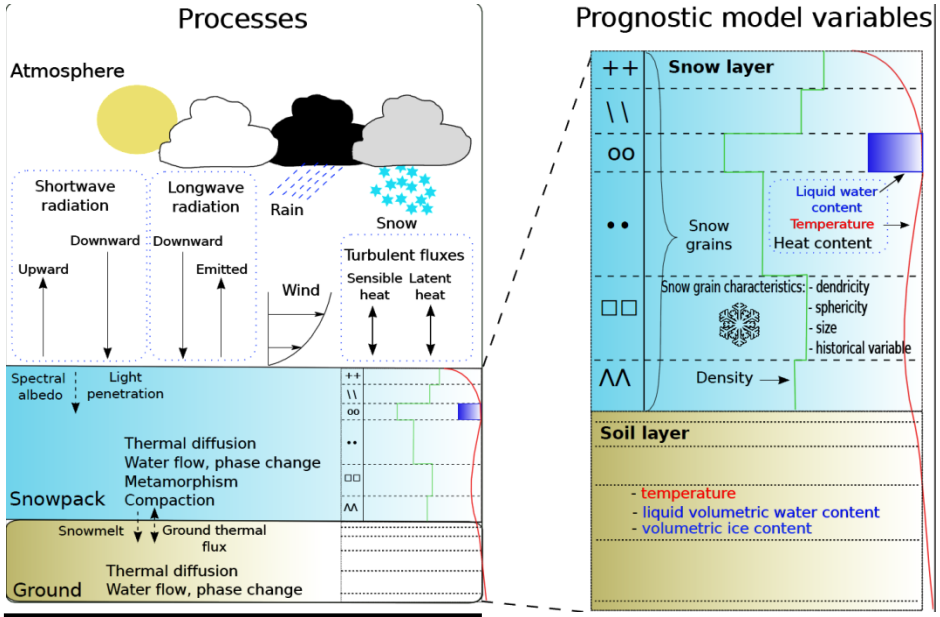




Spatial subdivision by massifs & 300 m elevation bands



SAFRAN reanalysis used as « pseudo-observation »



Snow model ISBA-Crocus

Downscaling & adjustment chain

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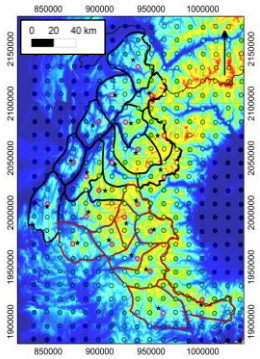

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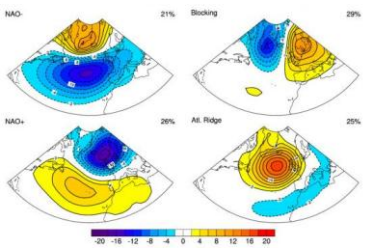

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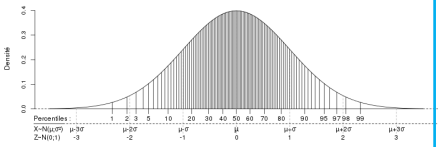

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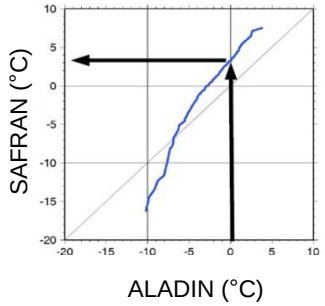

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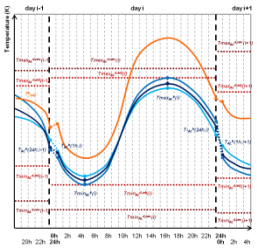

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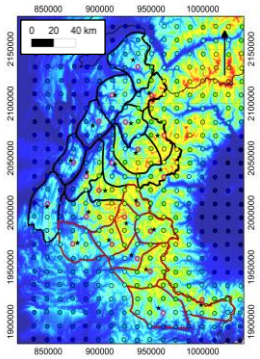

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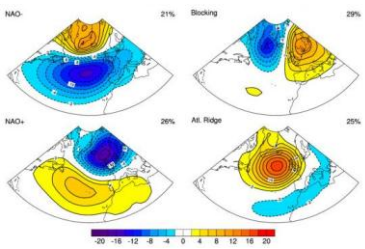

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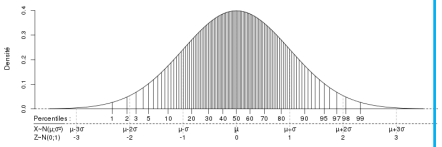

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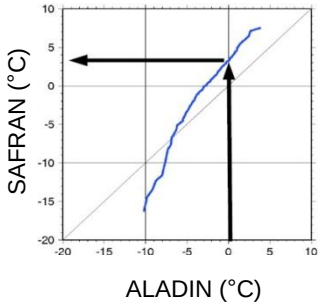

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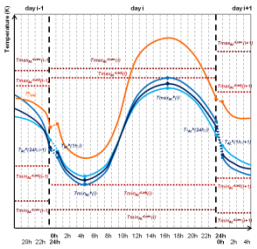

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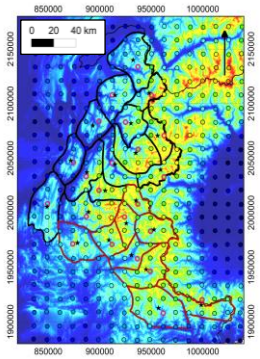

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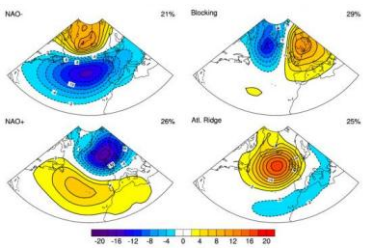

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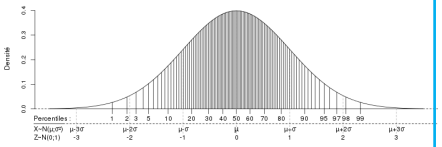

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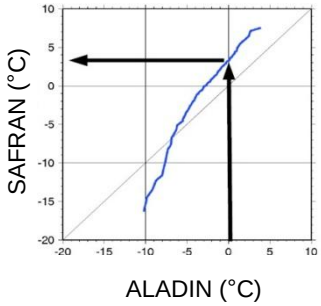

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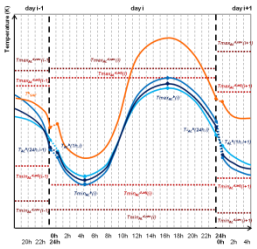

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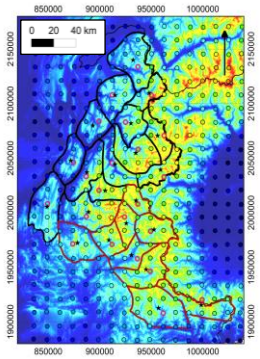

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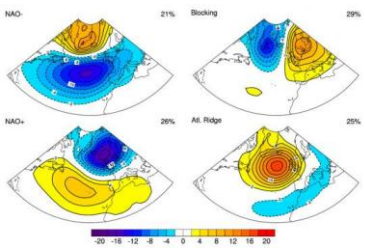

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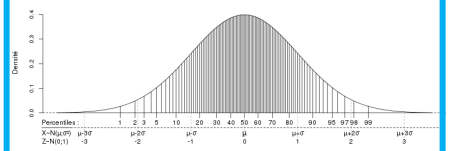

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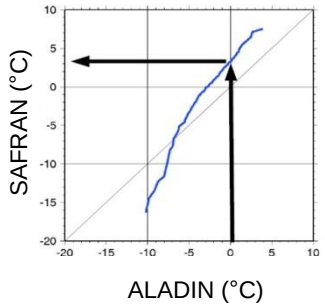

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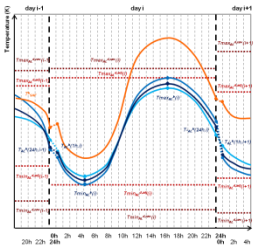

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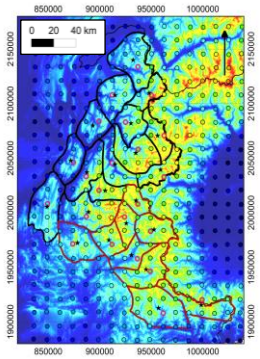

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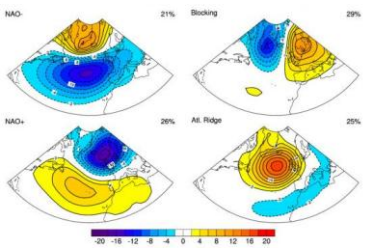

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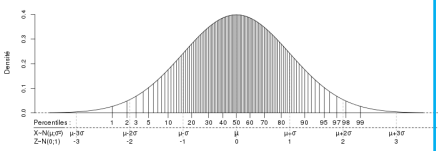

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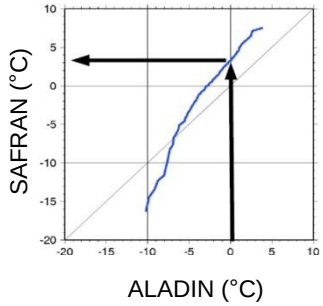

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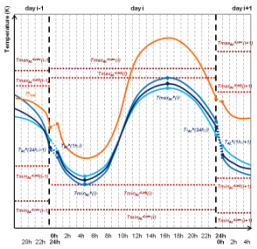

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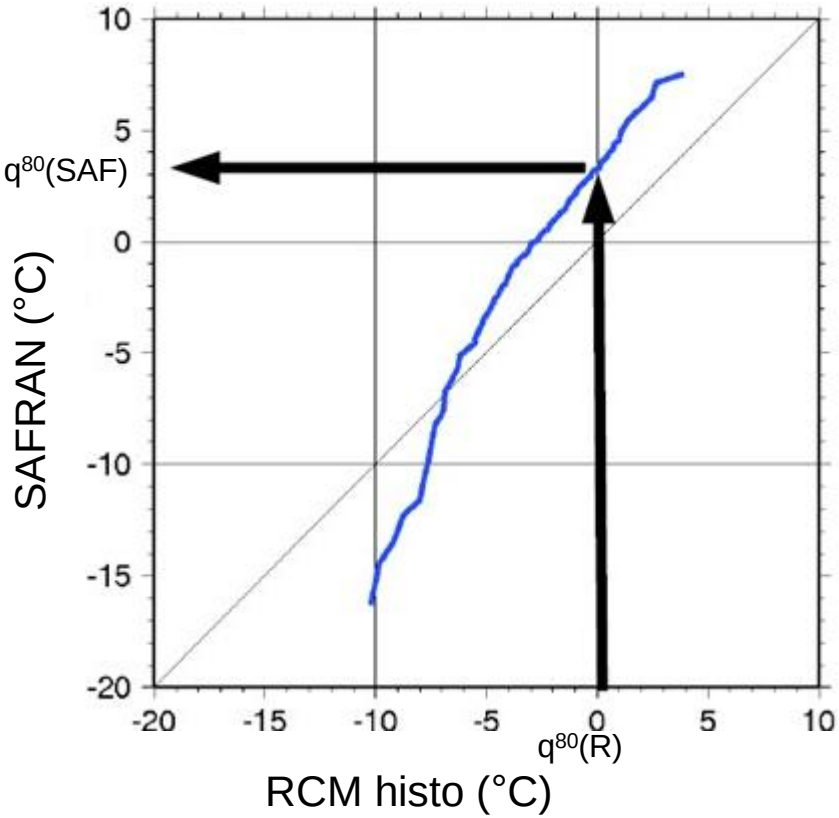
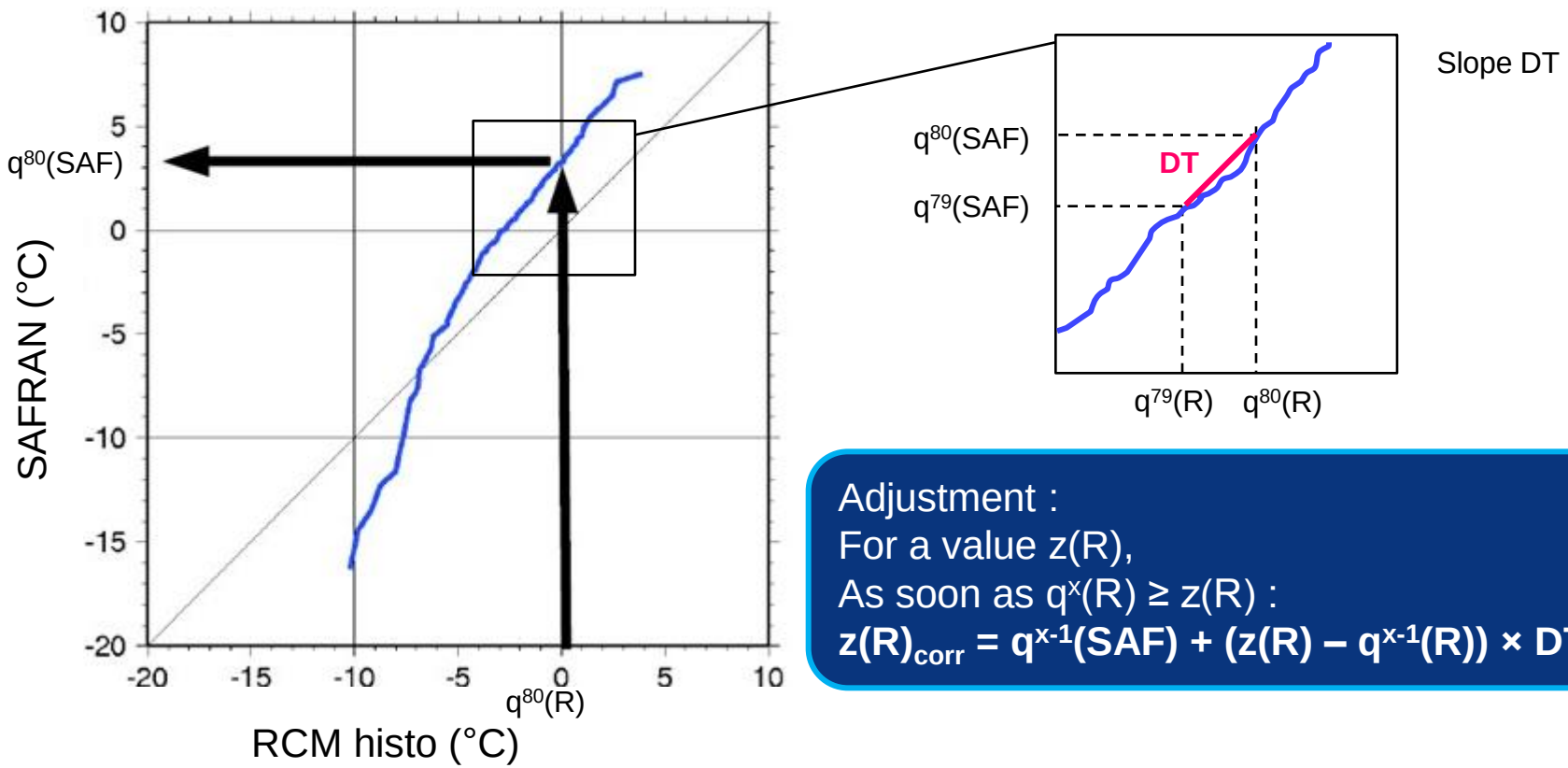
Downscaling & adjustment chain

- Quantile-quantile historical SAFRAN/RCM diagrams



Downscaling & adjustment chain

- Adjustment of RCM values (histo + scenarios) vs. SAFRAN



Adjustment :
For a value z(R),
As soon as $q^{x}(R) \geq z(R)$:
$\mathbf{z(R)_{corr} = q^{x-1}(SAF) + (z(R) - q^{x-1}(R)) \times DT^{x}}$

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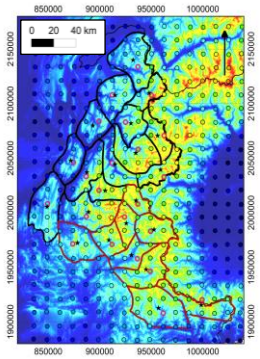

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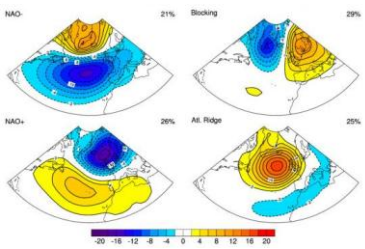

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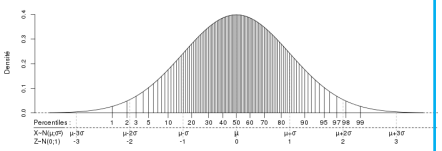

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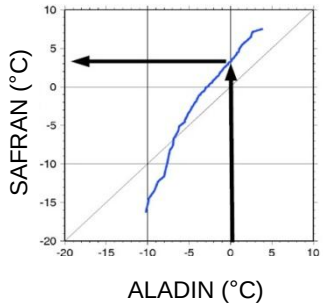

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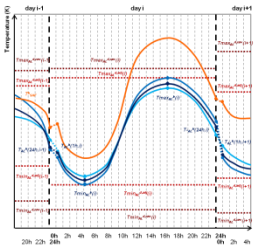

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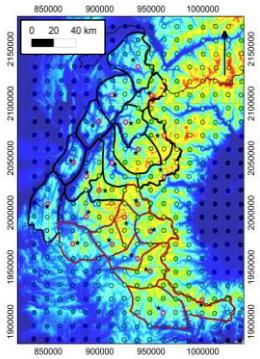

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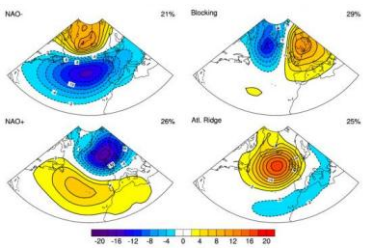

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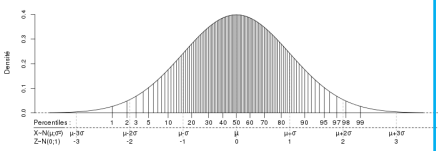

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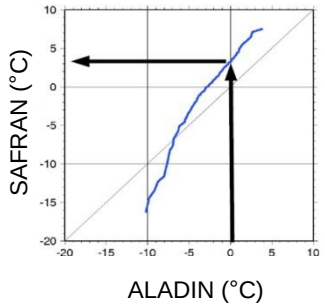

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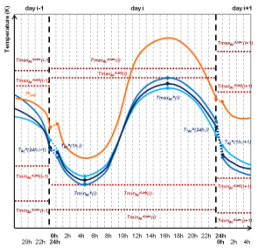

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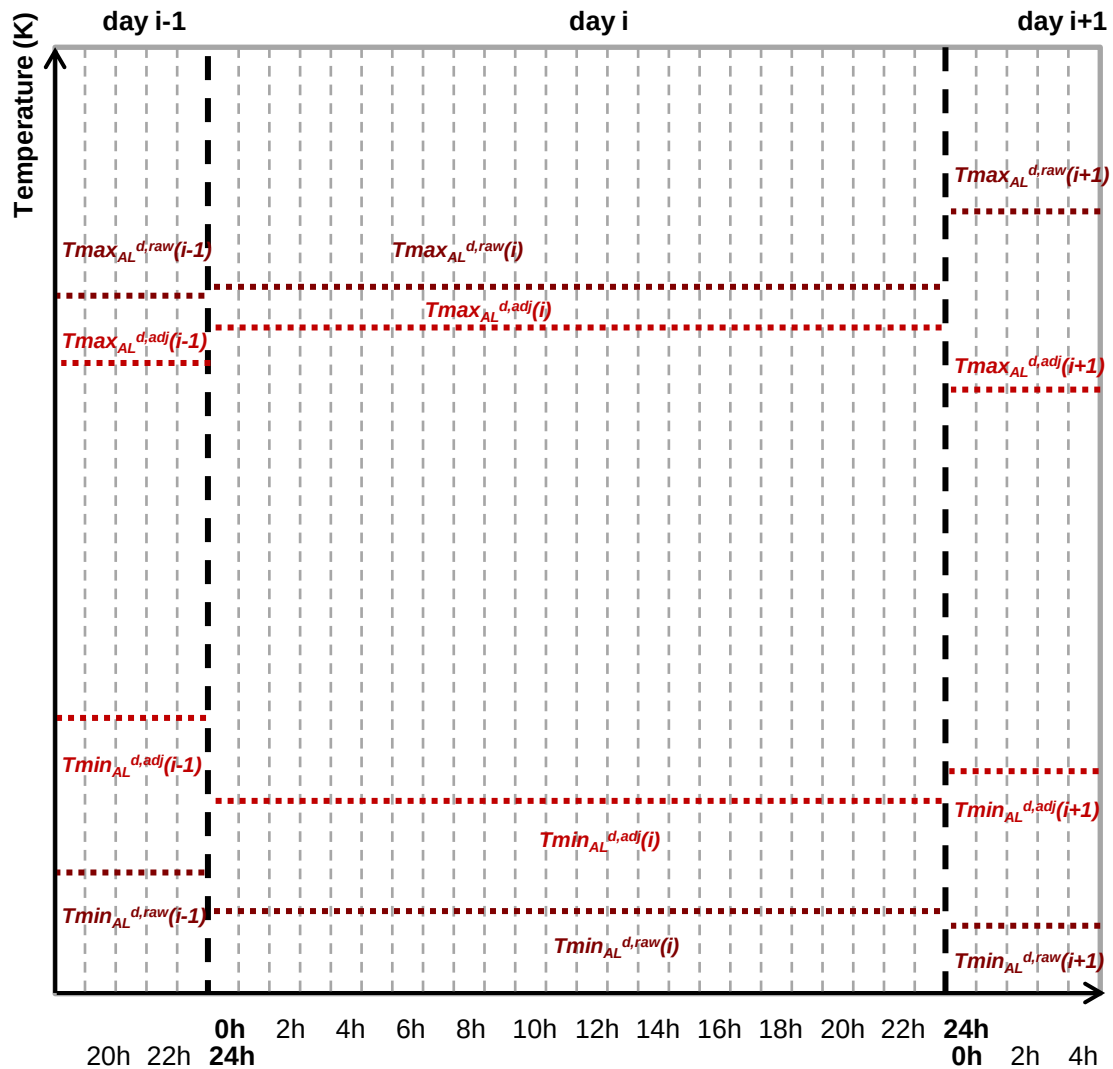

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T_{AL}^{h} : hourly adjusted ALADIN T, with
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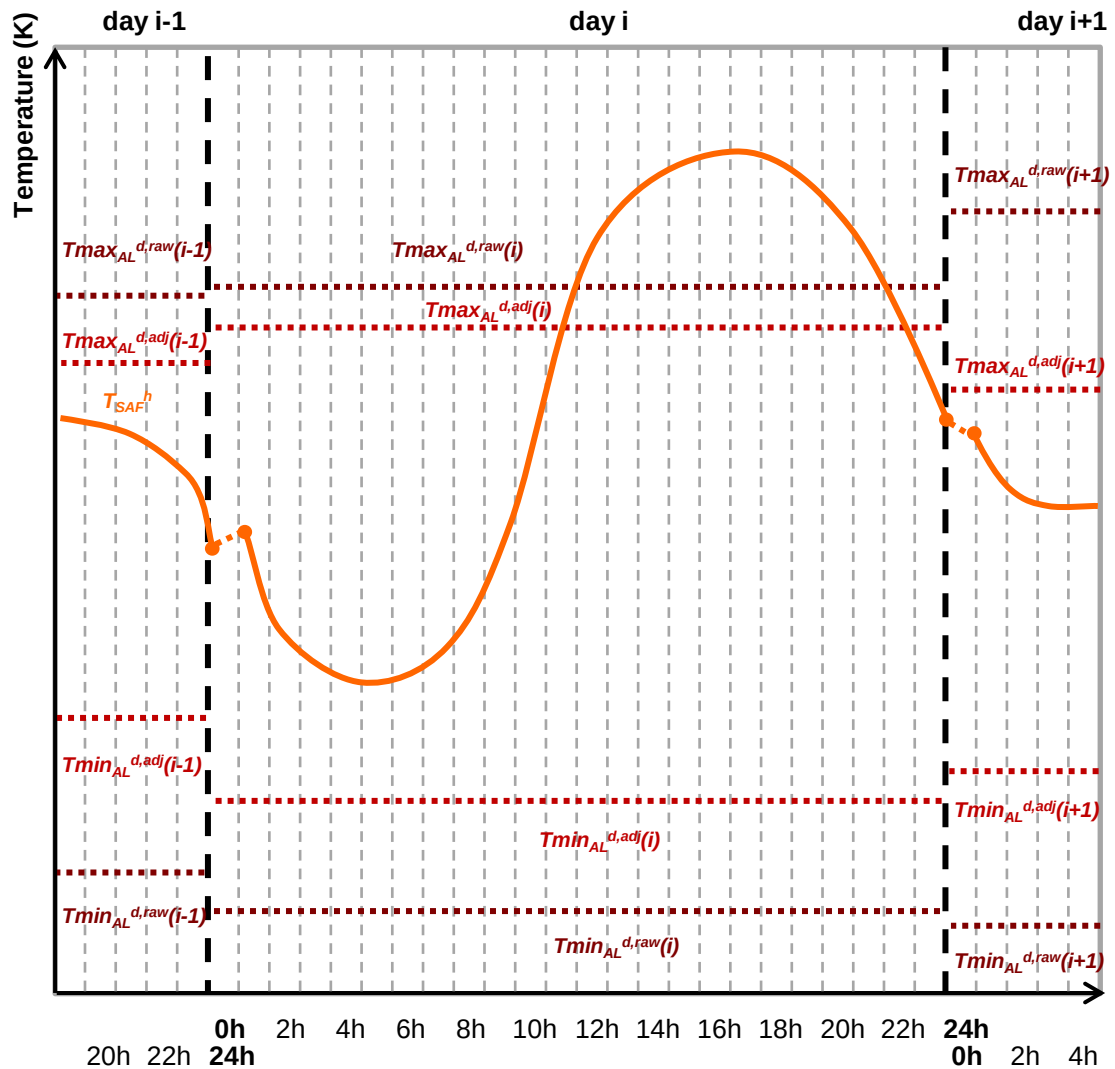

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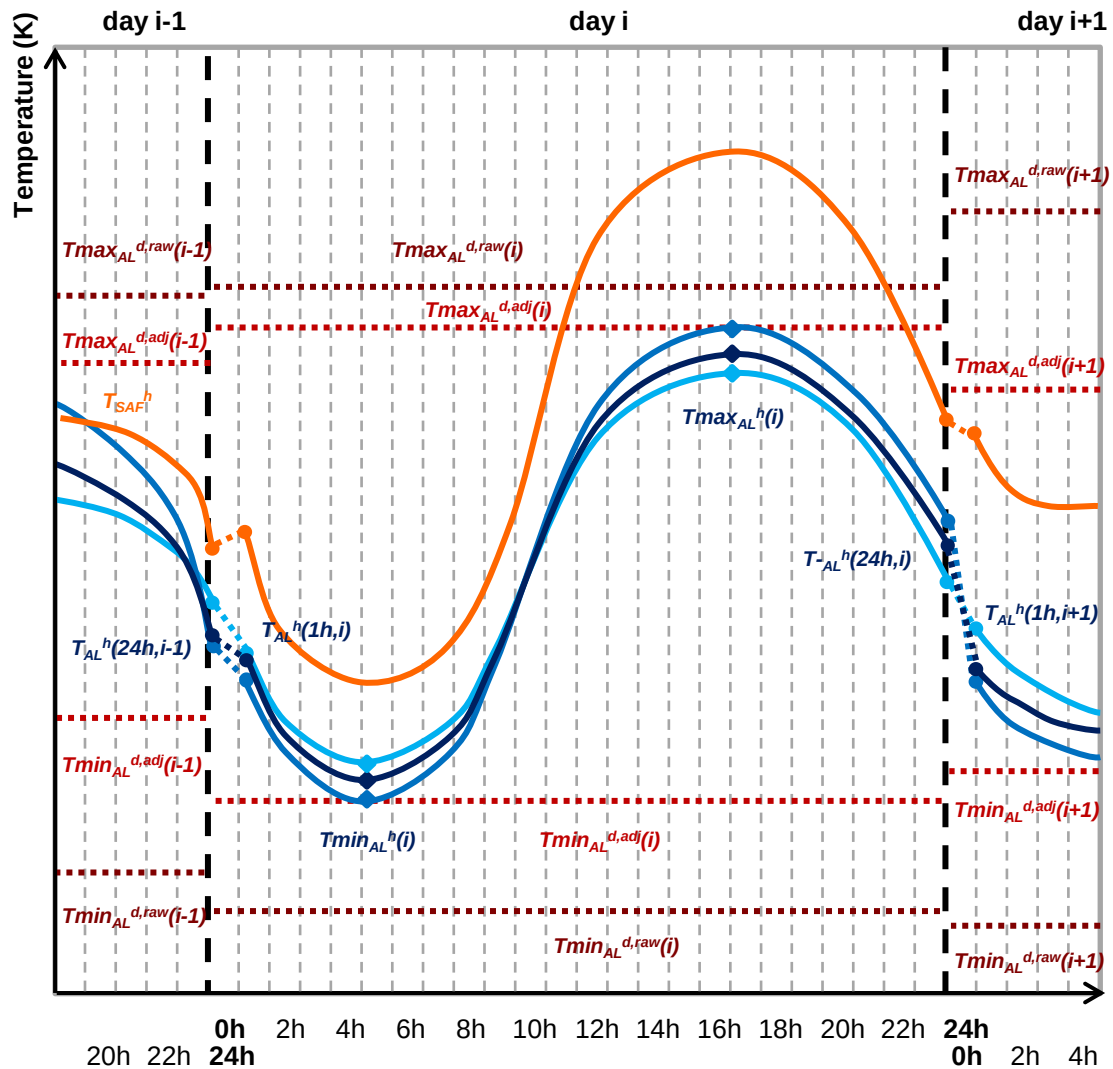
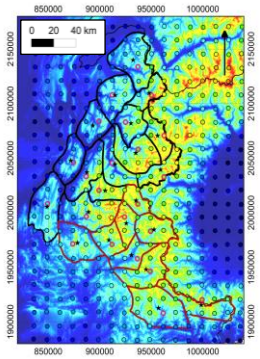


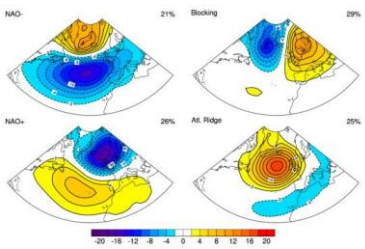
T_{SAF}^{h} : hourly T from SAFRAN analog
T_{AL}^{h} : hourly adjusted ALADIN T, with
α = 0
α = 2 (final value)
α = ∞
$Tmin/max_{AL}^{d,raw}$: daily min/max raw ALADIN T
$Tmin/max_{AL}^{d,adj}$: daily min/max adjusted ALADIN T

Downscaling & adjustment chain

1. Neighbouring RCM grid points

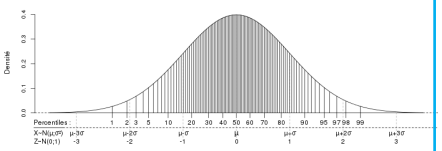


2. RCM & ERA-Interim regimes

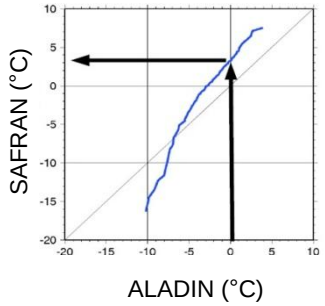


3. SAFRAN : 1h → daily

4. Percentiles of historical RCM & SAFRAN (variable, season, regime)

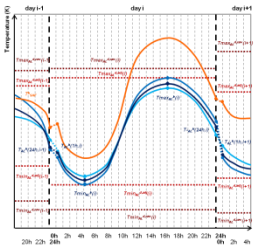


5. Quantile mapping (variable, season, regime)



6. SAFRAN analogous days, criteria:
- same month
- same regime
- coherent Pr.
- consecutive days (when possible)

7. Adjusted RCM : daily → 1h (shape from SAFRAN analogues)



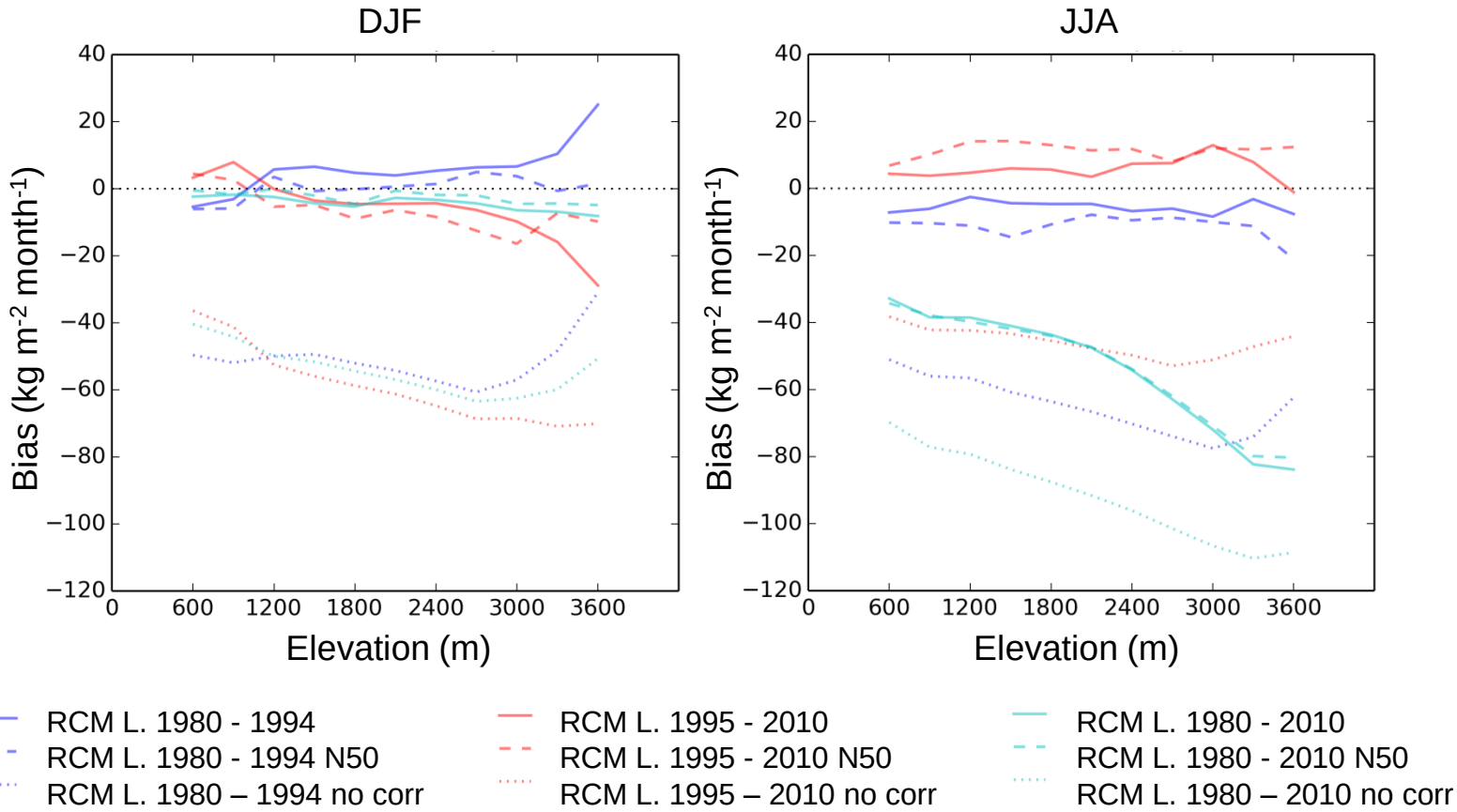
8. Total precipitation separation into rain and snow (1°C threshold) + additional quantile mapping of rain and snow separately

Method evaluation

- Downscaling and adjustment of **ALADIN-Climate** RCM driven by **ERA-Interim** reanalysis (domain centred on France)
- **Temperature, precipitation, snow depth**
- 300 m elevation bands for **each massif** and integrated for **Northern & Southern Alps**
- **2 neighbour selection methods** : simple 2-D & more complex N50 (3-D with more weight on altitude)
- **3 « learning » periods** (percentiles) : 1980-1994, 1995-2010 & 1980-2010
- Correlation, ratio of standard deviations, altitudinal gradient, interannual evolution, annual cycle, PDF, RMSE, bias, …

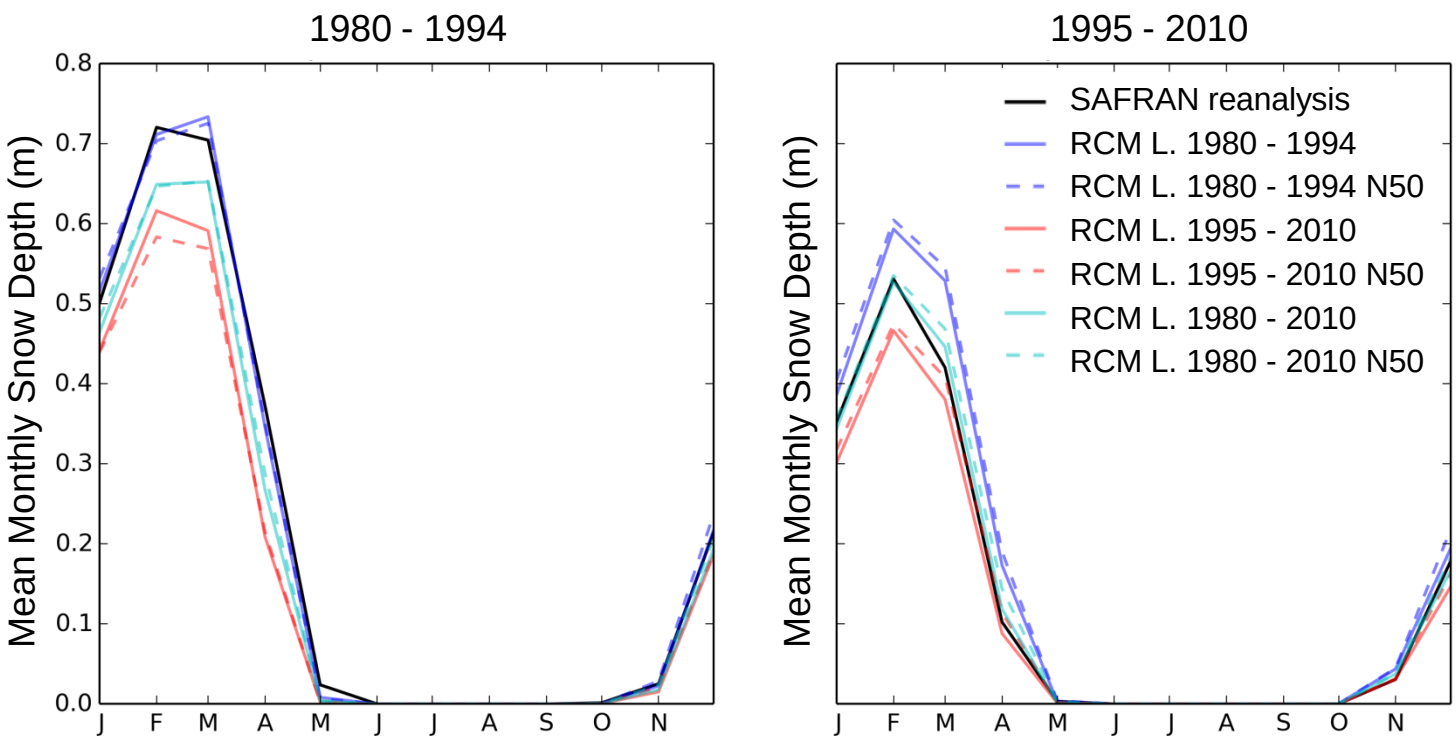
Method evaluation

Ex1 : Biases for precipitation in the Southern Alps (1980-2010)



Method evaluation

Ex2 : Annual cycle of snow height in the Northern Alps at 1200 m (1980-1994 & 1995-2010)



Method evaluation

→ Good reproduction of the **statistical characteristics** of SAFRAN variables

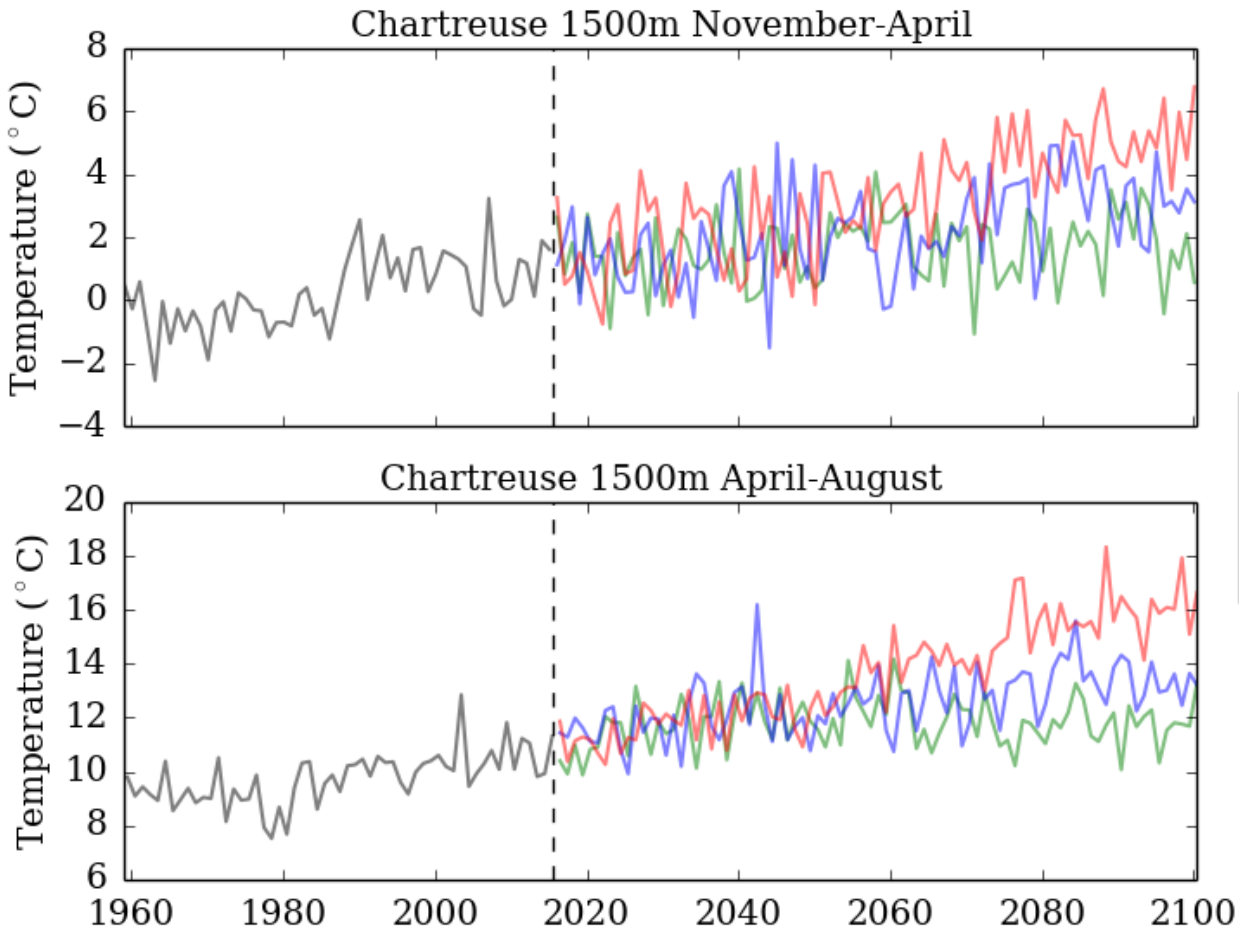
→ Need for the **ultimate quantile mapping** on rain and snow separately (coherency between T and Pr phase)

→ Good **inter-variable consistency** (snow)

→ Limit in the **temporal transferability**?

First results – Meteorological variables

Temperature

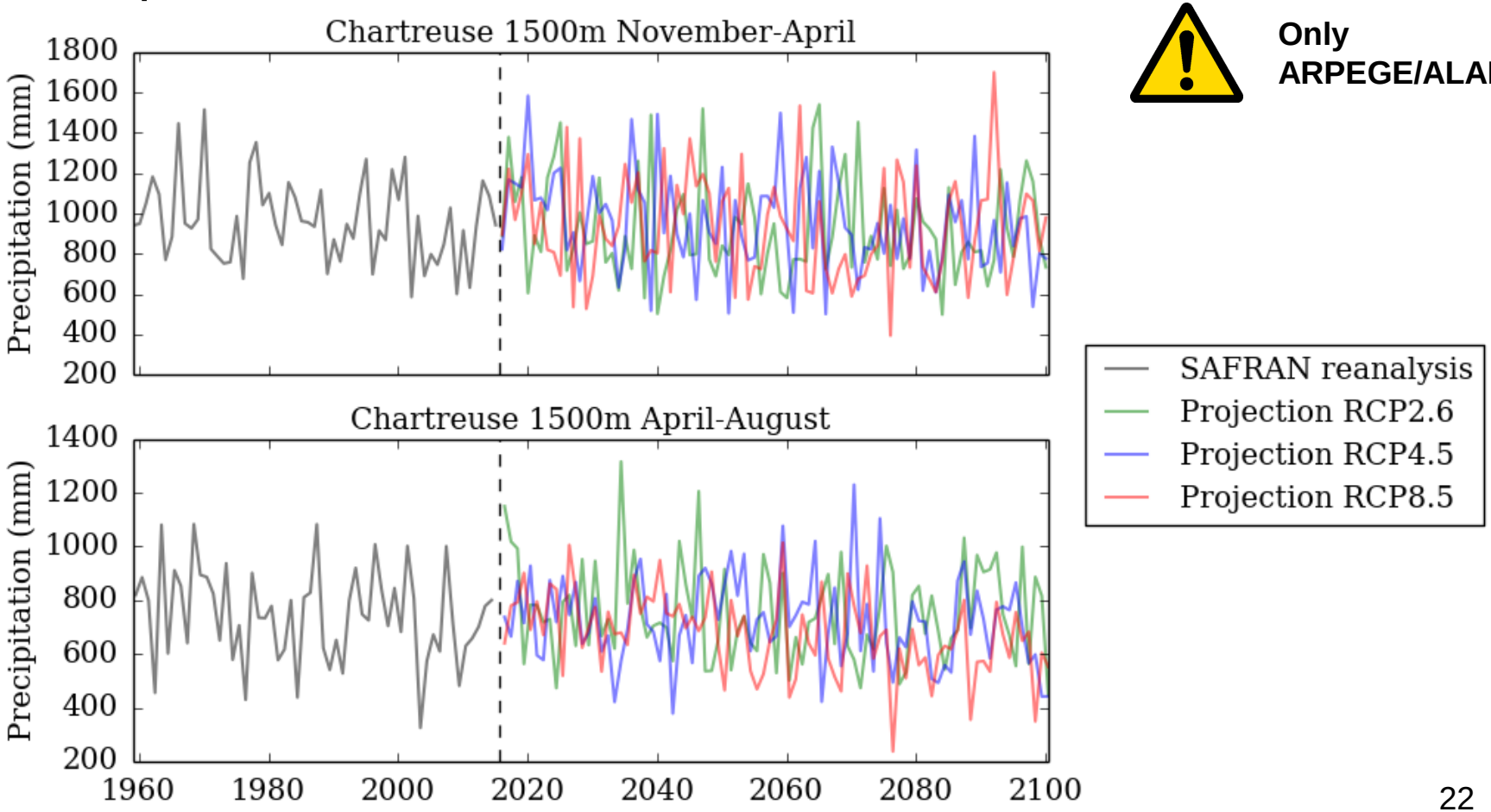


Only ARPEGE/ALADIN

SAFRAN reanalysis
Projection RCP2.6
Projection RCP4.5
Projection RCP8.5

First results – Meteorological variables

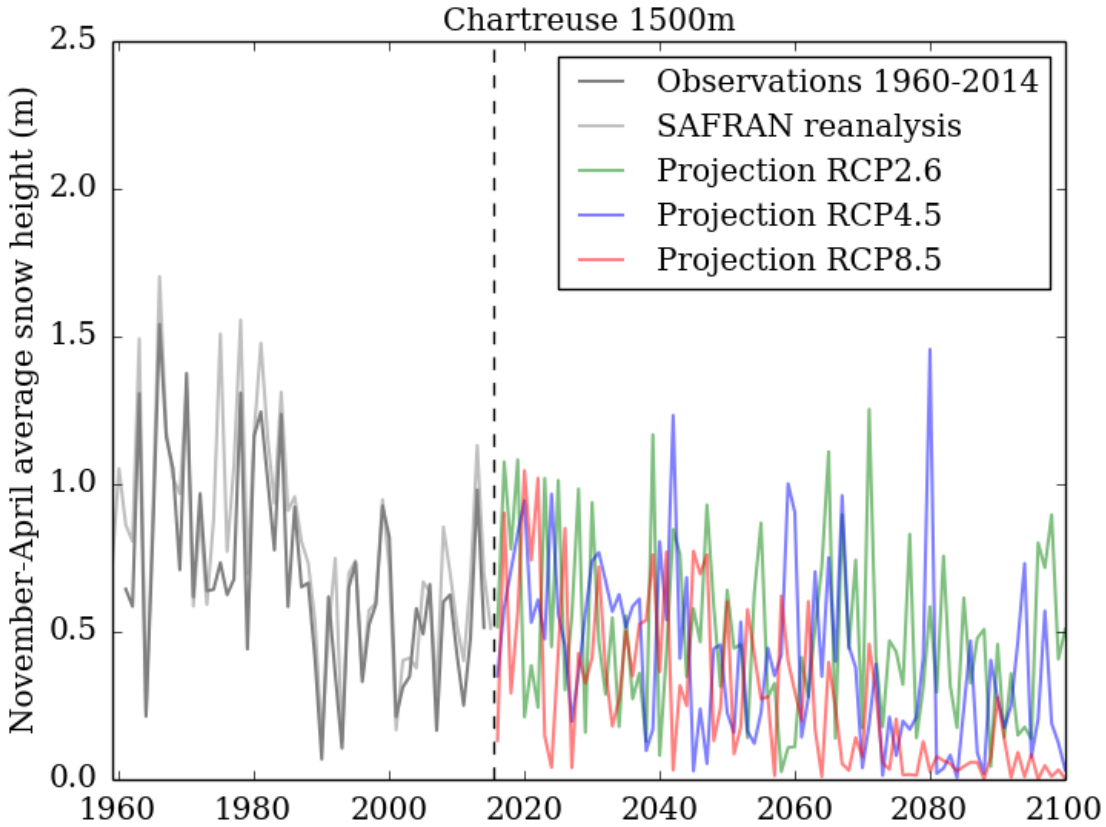
Precipitation



Only ARPEGE/ALADIN

First results – Snow

Snow height from ALADIN – Crocus at Col de Porte



Only ARPEGE/ALADIN

Conclusions & Perspectives

- Generic downscaling & adjustment method for climate projections
- Respects the RCM **chronology**
- Yields **continuous hourly** time series of adjusted meteorological variables (not only Pr & T)→ energy balance land surface models
- Numerous possible applications: natural & artificial snow production, agricultural & forest management, mountain ecosystems, glaciology, glacial hydrology, ...
- **Work in progress :**
  - article in prep. on the evaluation of the method
  - application to all EUROCORDEX EUR-11 simulations (97)
- **Future work :**
  - production of new climate and snow scenarios
  - analysis of the uncertainties

Thanks for your attention

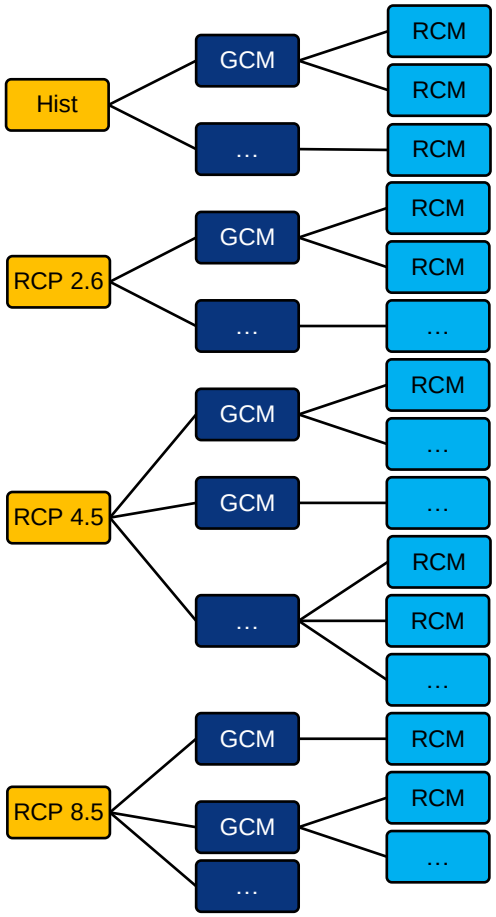
Any question?

Downscaling & adjustment chain

Forcing/ Scenarios

EUROCORDEX simulation

= 4 forcing/scenarios
13 GCMs
10 RCMs

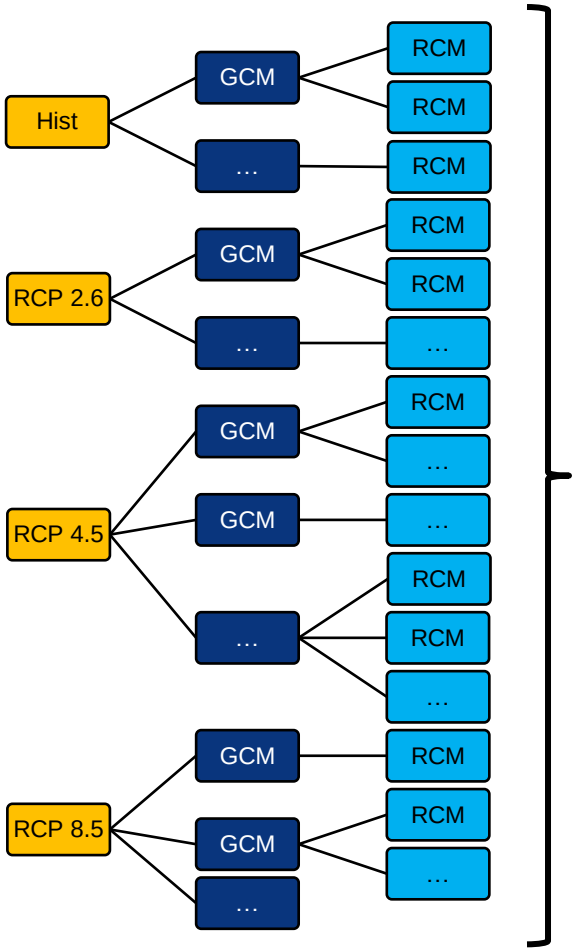


Histo	RCP2.6	RCP4.5	RCP8.5	Total
35	8	20	34	**97**

Downscaling & adjustment chain

Forcing/ Scenarios

EUROCORDEX simulations

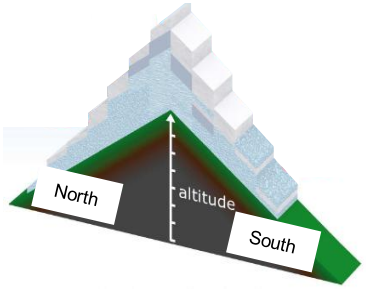


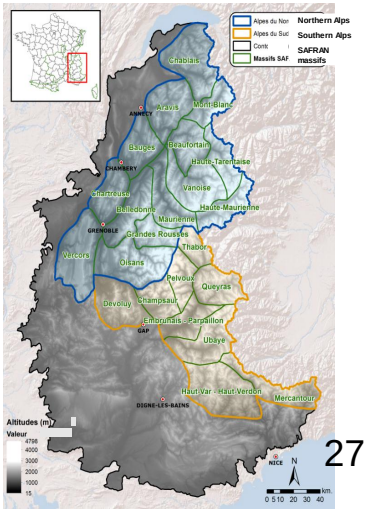
Development of a downscaling and adjustment chain as generic as possible

Quantile mapping vs. SAFRAN

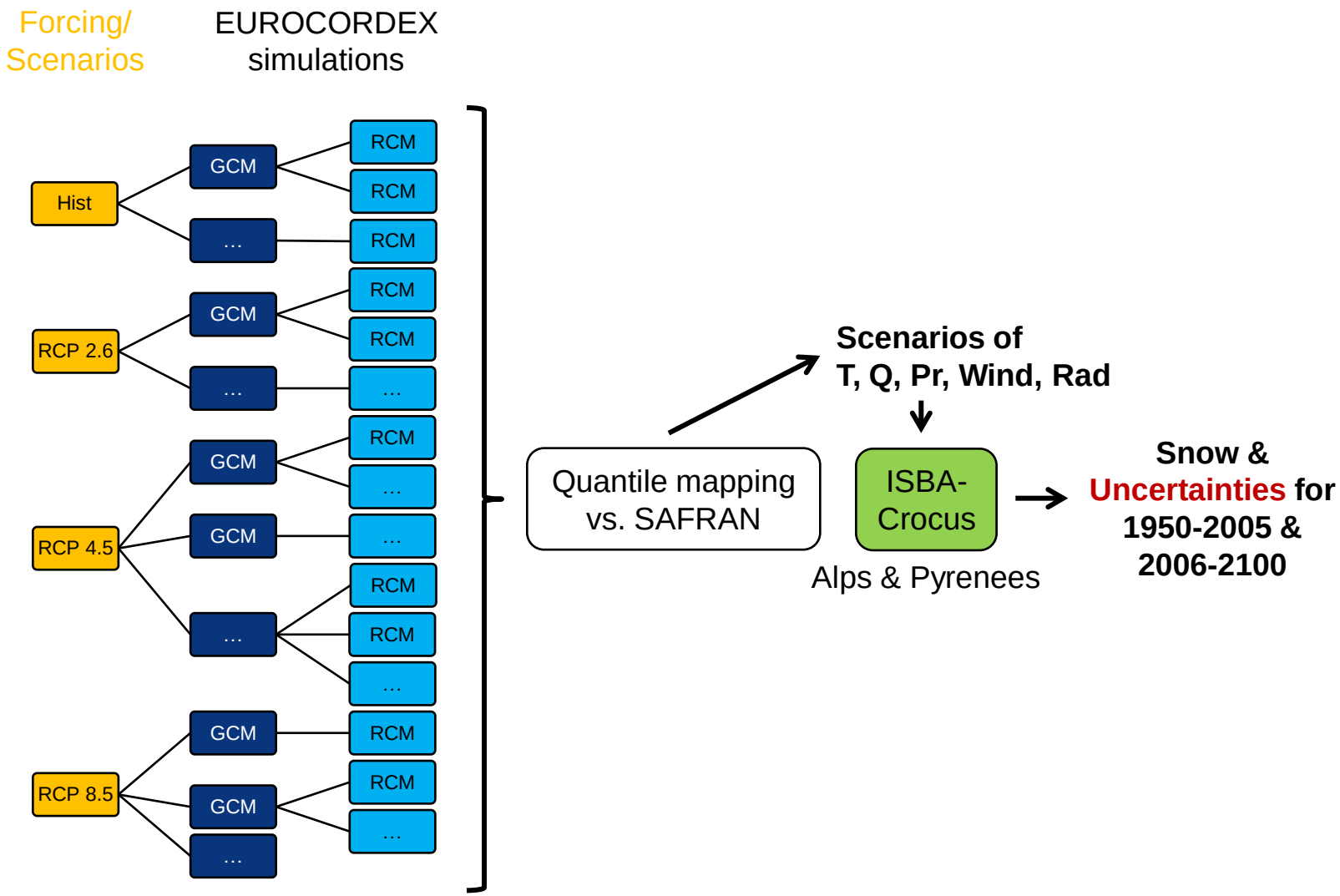
Scenarios of T, Q, Pr, Wind, Rad

Spatial subdivision by massifs, 300 m elevation bands





Downscaling & adjustment chain



The ADAMONT project (2015-2017)

Impacts of climate change and adaptation in mountain regions (IRSTEA Grenoble, CNRM/CEN)

My objectives:

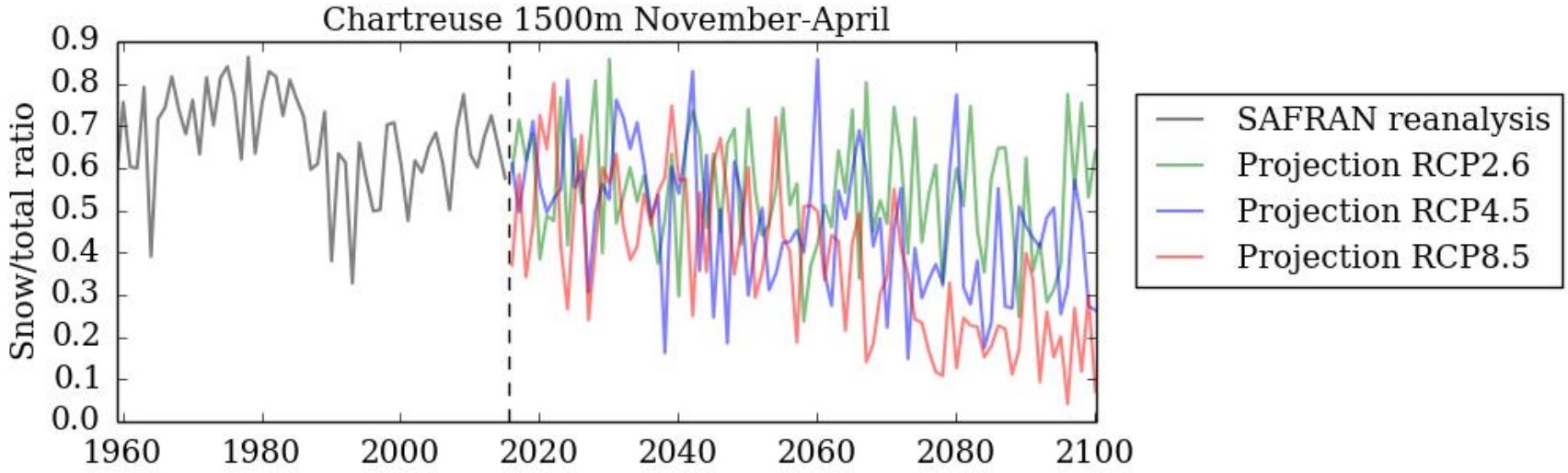
Climate scenarios with downscaling on the mountain regions (Alps & Pyrenees). Simulations of the snowpack driven by these scenarios.

Based on :

- Historical forcing + RCPs scenarios (IPCC AR5, 2013)
- **EUROCORDEX** GCMs/RCMs EUR-11 simulations (12 km)
- **Quantile mapping** vs. SAFRAN

First results – Meteorological variables

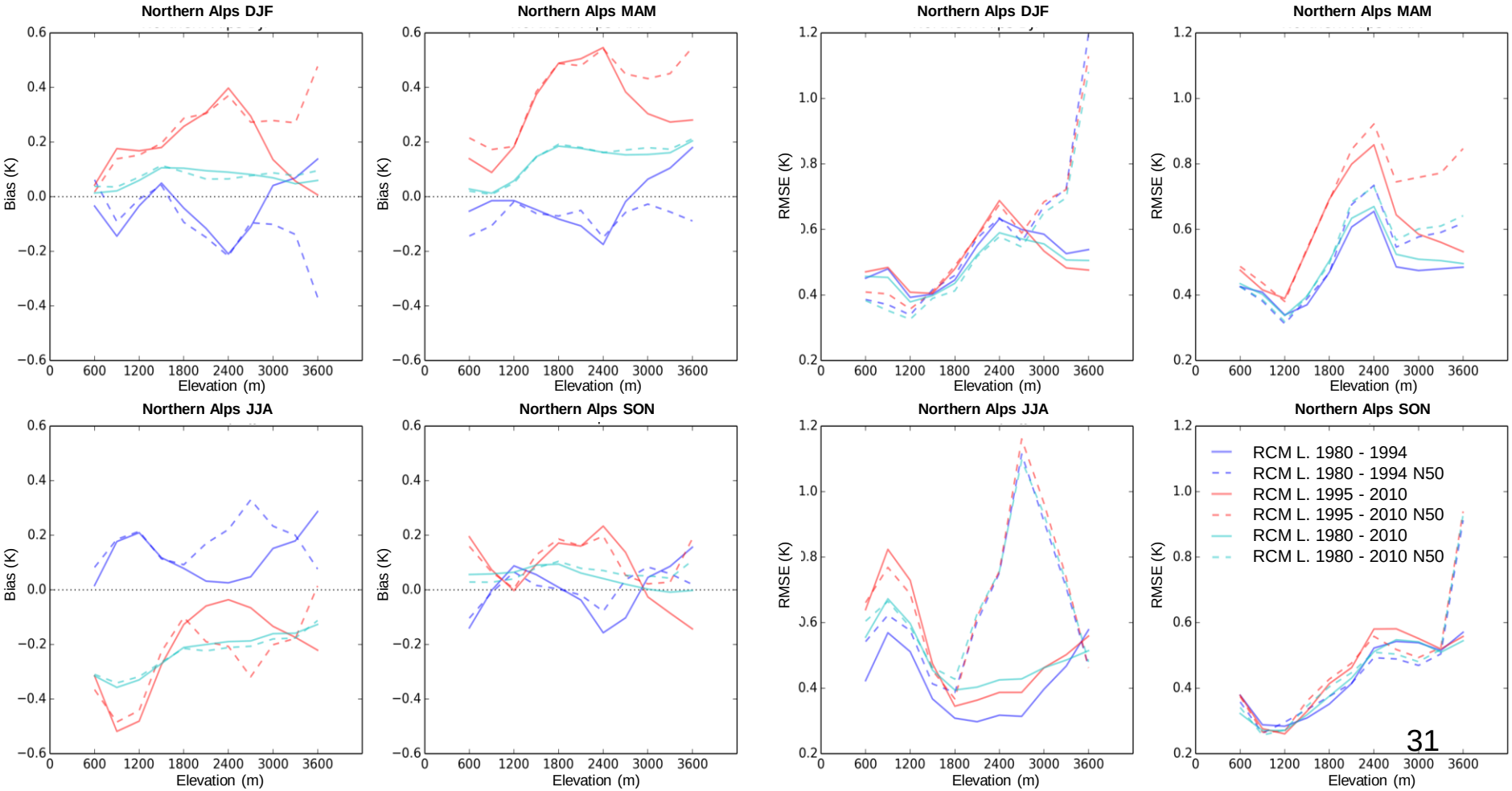
Precipitation phase



Only ARPEGE/ALADIN

Method evaluation

Ex1 : Bias and RMSE for temperature in the Northern Alps



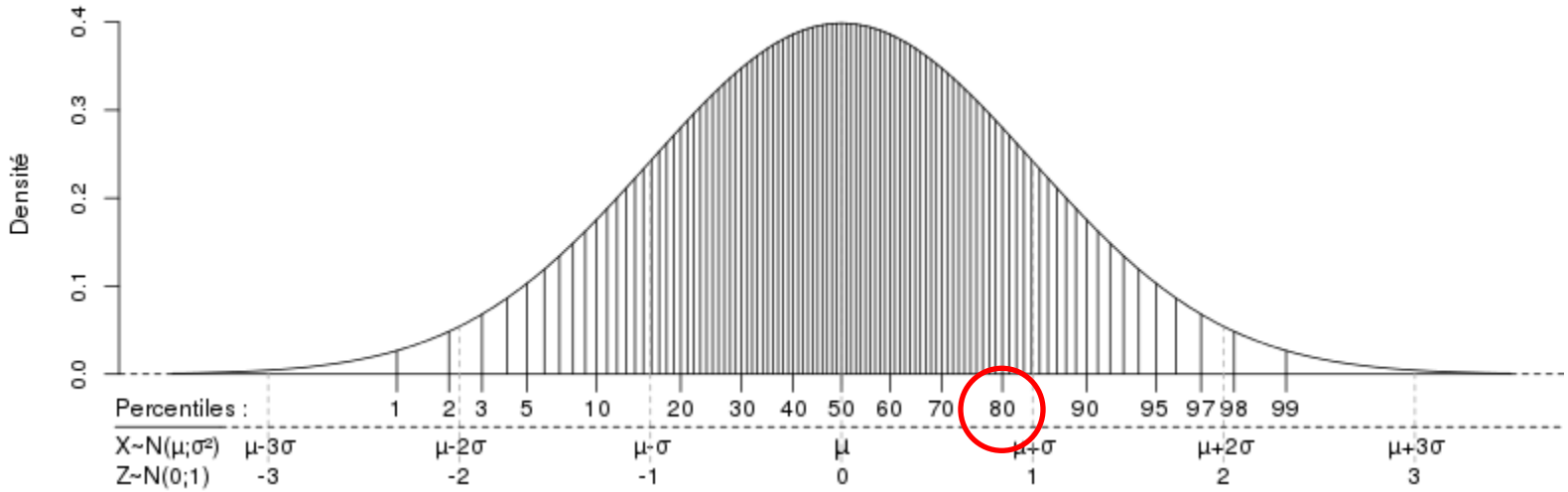
Method evaluation

→ **Good reproduction of the statistical characteristics of SAFRAN variables**

→ **Impact of the spatial selection technique**

Downscaling & adjustment chain

- Percentiles of the historical RCM (1974-2005) & SAFRAN (1980-2011) distributions – for each variable, each season & each regime



Example : q^{80} = value for which 80% of the distribution has a lower value (q^{50} = median)