PhD Defense — 28th February 2023

Modeling climate trends and variability in High Mountain Asia to understand cryosphere changes

Mickaël Lalande

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Institut des Géosciences de l'Environnement (IGE, Grenoble, France)

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Bertrand DECHARME (CR, CNRS)	Rapporteur	Frédérique CHERUY (CR, CNRS)	Examinatrice
Richard ESSERY (Prof., Univ. of Edinburgh)	Rapporteur		
Delphine SIX (Physicienne CNAP, UGA)	Examinatrice	Martin MÉNÉGOZ (CR, CNRS)	Invité

Context: what is snow?

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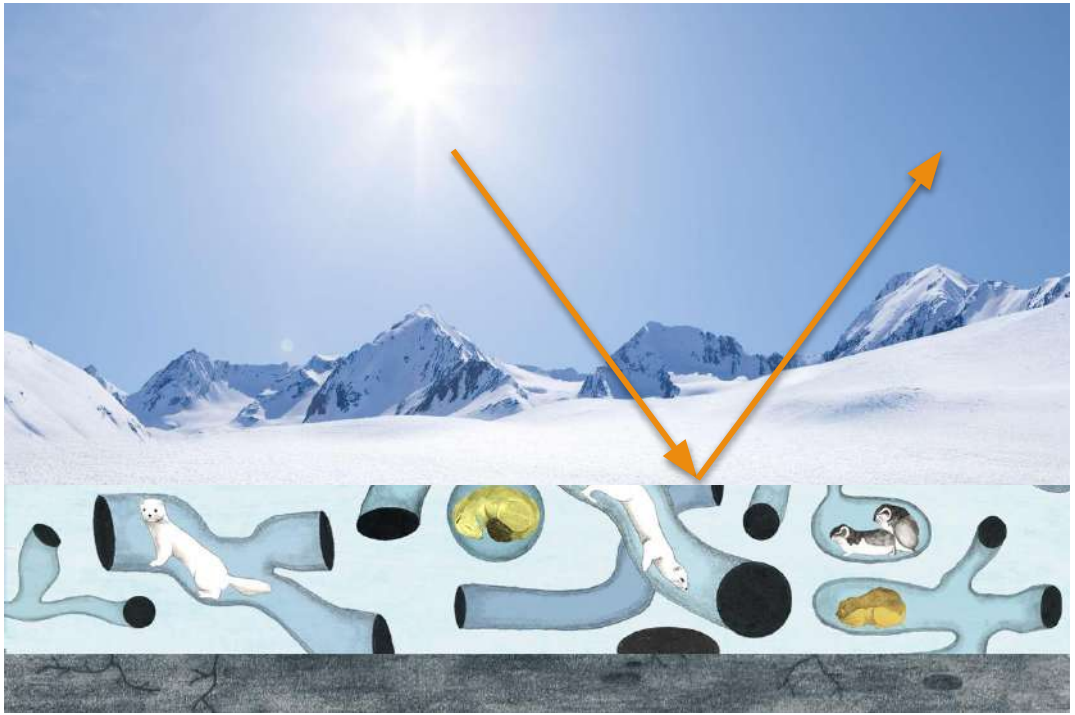

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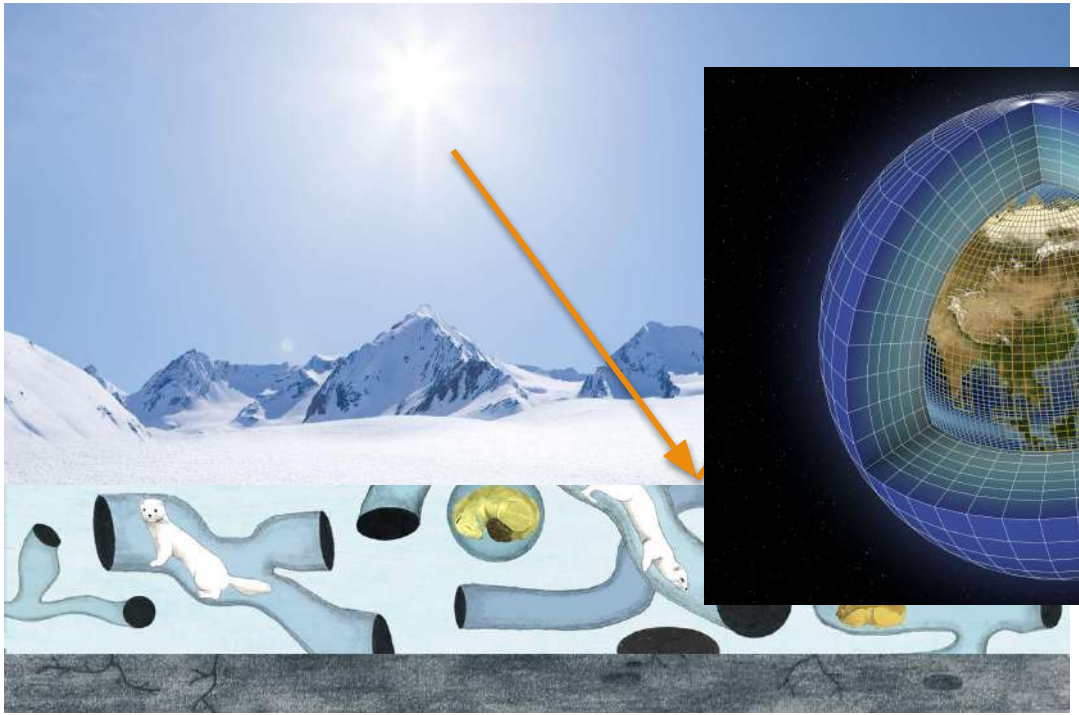
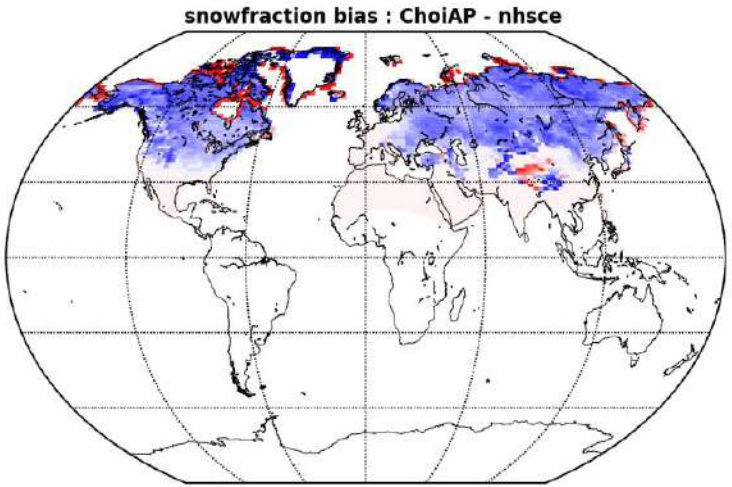


Context: snow bias in IPSL model CMIP5 versus CMIP6

Biais de la fraction de couverture de neige
(i.e., fraction de neige simulée - observée)

Ancienne version



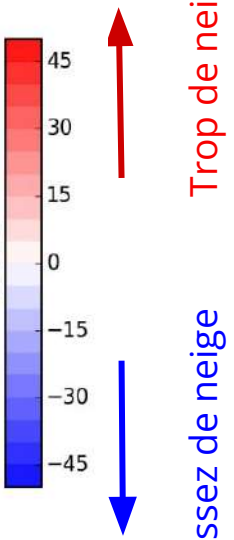


Fig. 7 Cheruy et al. (2020)

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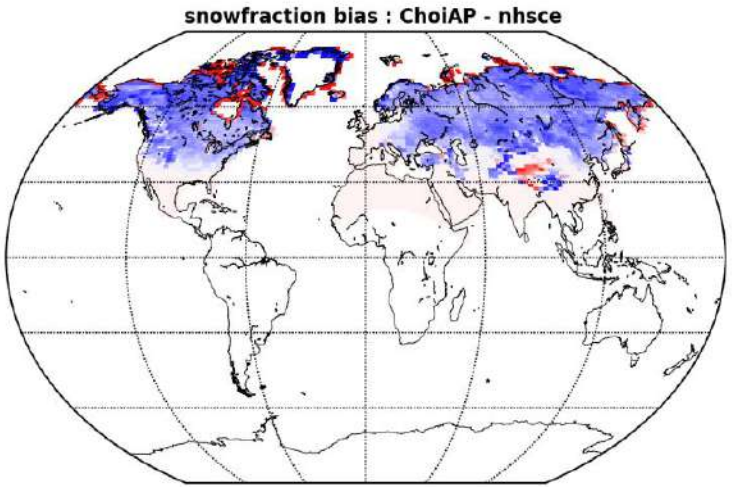

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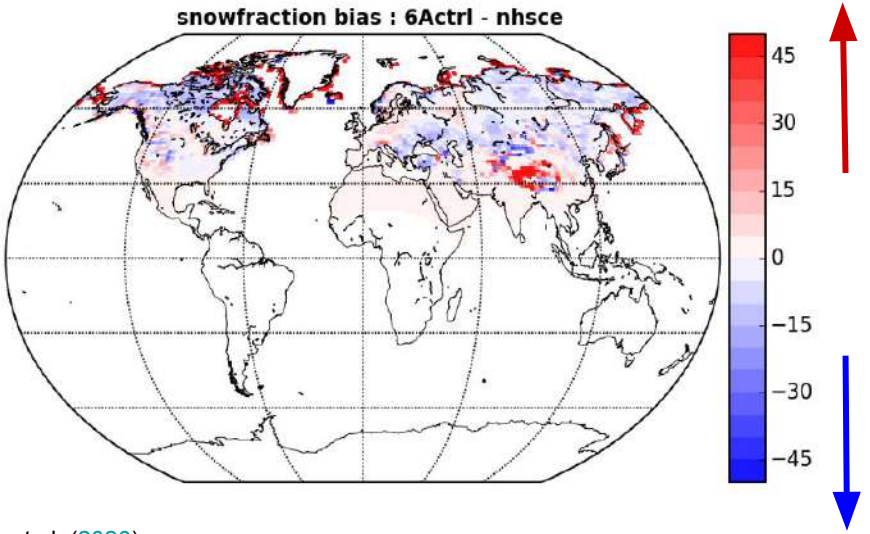

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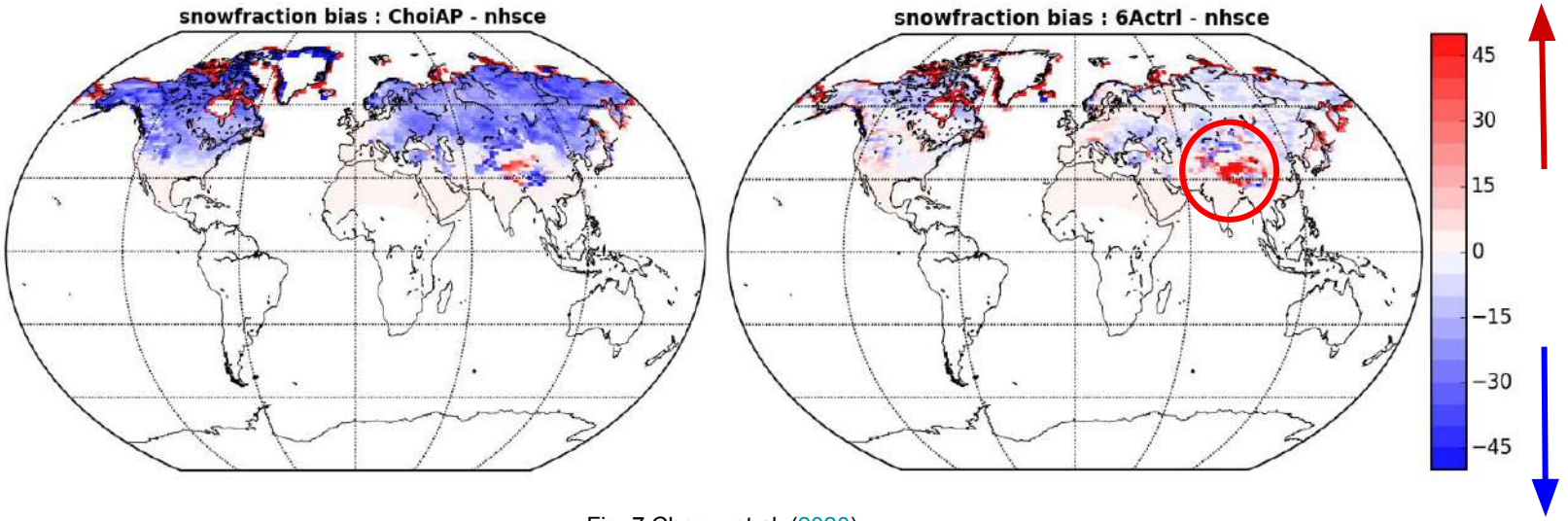

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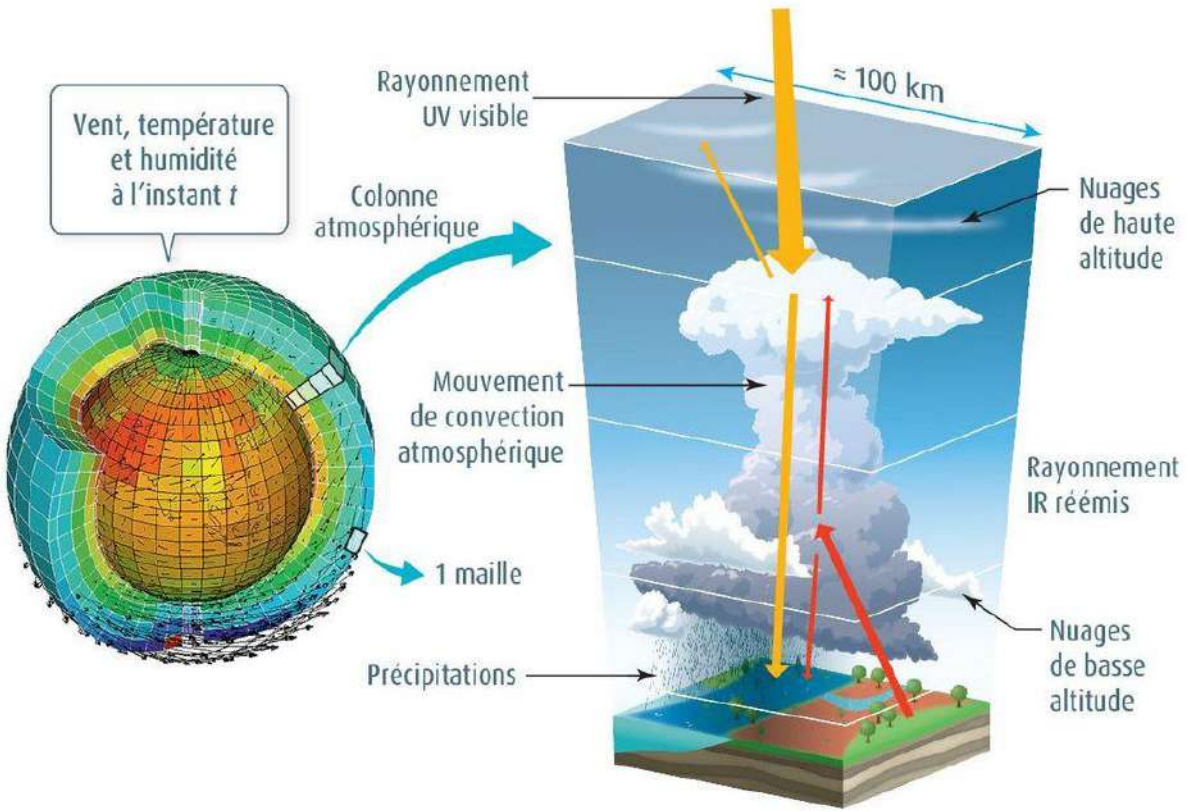
Qu’est-ce qu’un modèle de climat ?



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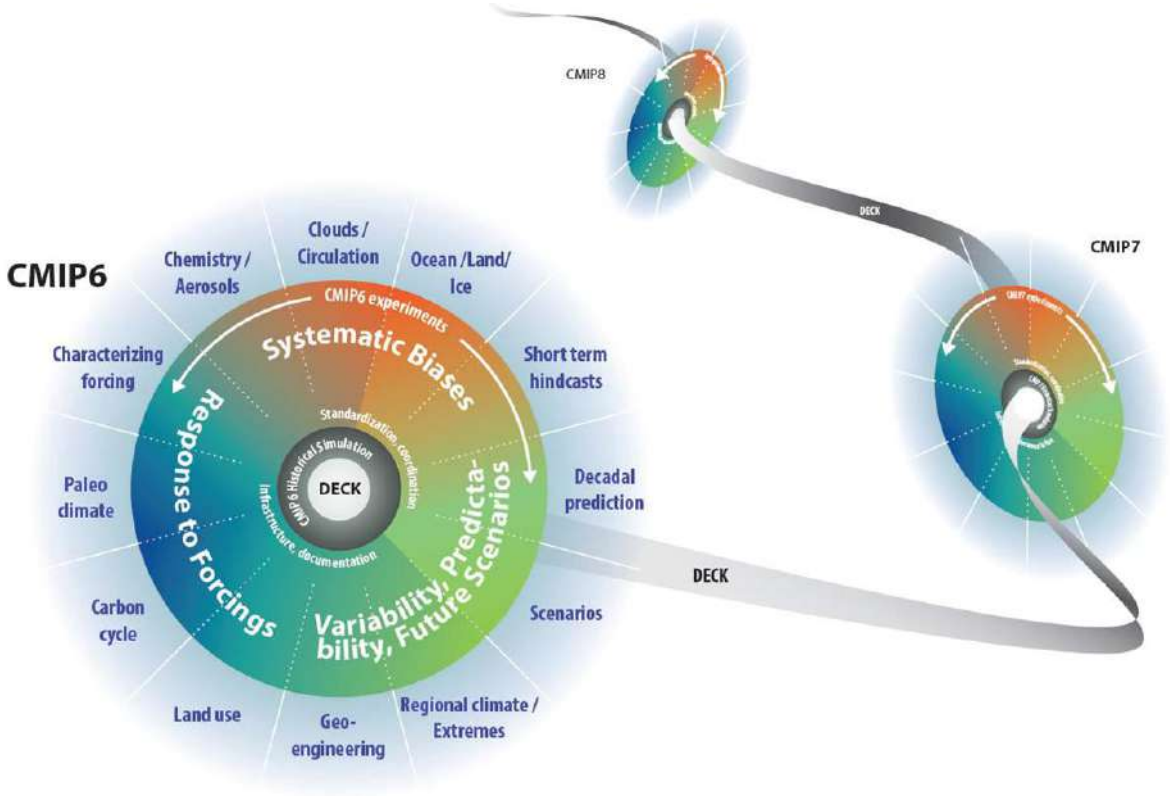
- Modélise les composantes du systèmes climatique : atmosphère, océan, cryosphère et biosphère
- Ils sont basées sur les équations de la mécanique des fluides et de la thermodynamique ainsi que sur les principes de conservation de la masse et de l’énergie
- Pour transcrire ces équations sous forme numérique, le globe est découpé en petits cubes, les mailles
- Plusieurs types de modèles : GCMs, RCMs, etc.

Projet d'intercomparaison des modèles couplés phase 6 — CMIP6



Eyring et al. (2016)

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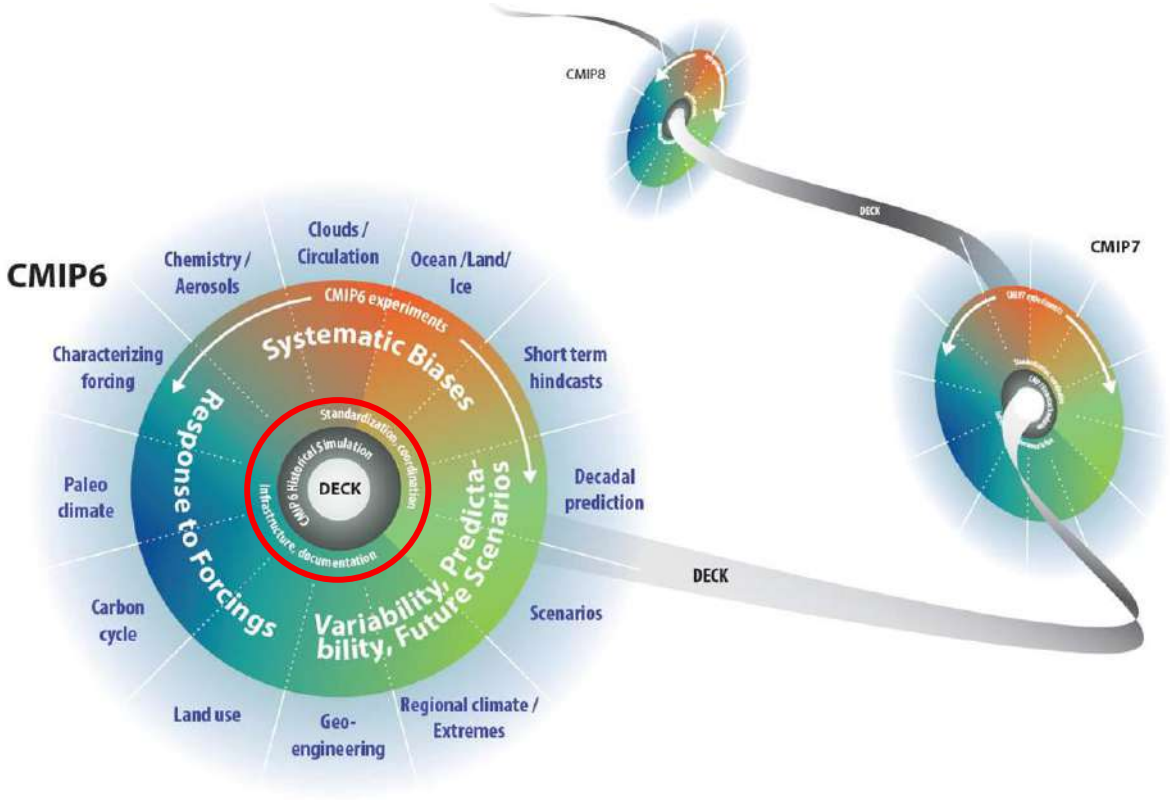

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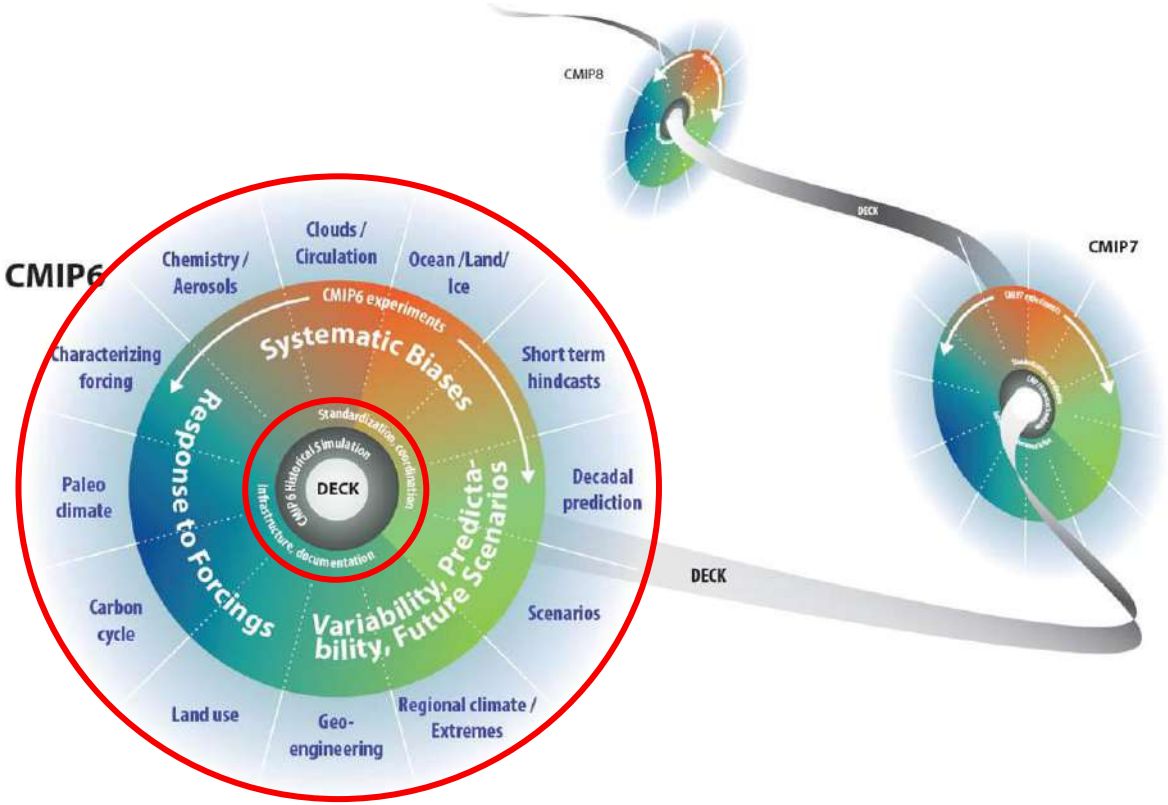

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- 21 MIPs :
  - Response to Forcings
  - Systematic Biases
  - Variability, Predictability, Future Scenarios

Objectifs de cette thèse

L'enjeu de cette thèse est d'étudier la variabilité et les tendances climatiques en HMA. Elle se décline en deux objectifs principaux :

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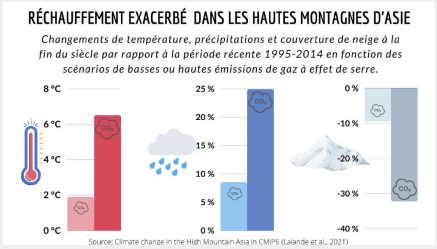

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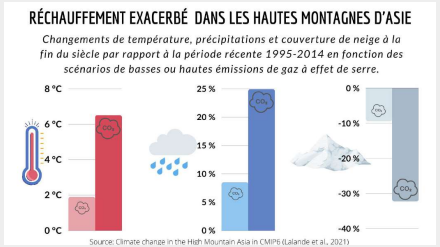
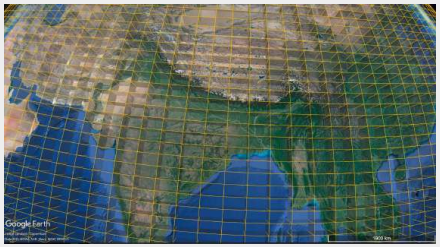


#2 Description et évaluation du modèle de l'IPSL en HMA



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- Améliorer la représentation de la couverture de neige en région de montagne dans les GCMs.

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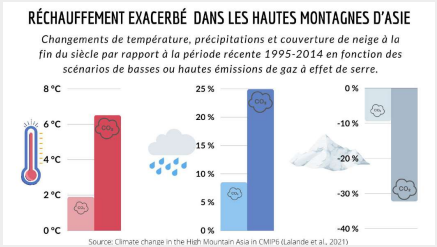

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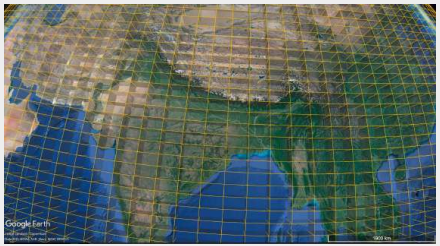

#3 Paramétrisation de la couverture de neige en région de montagne

Partie #1

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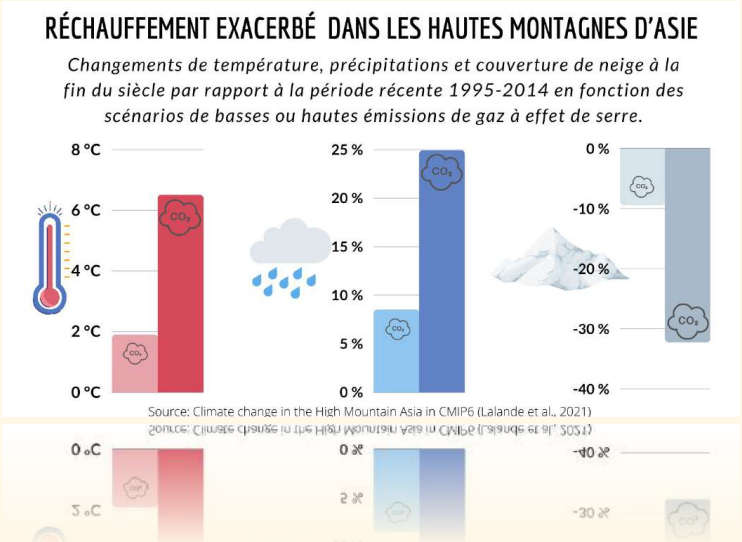

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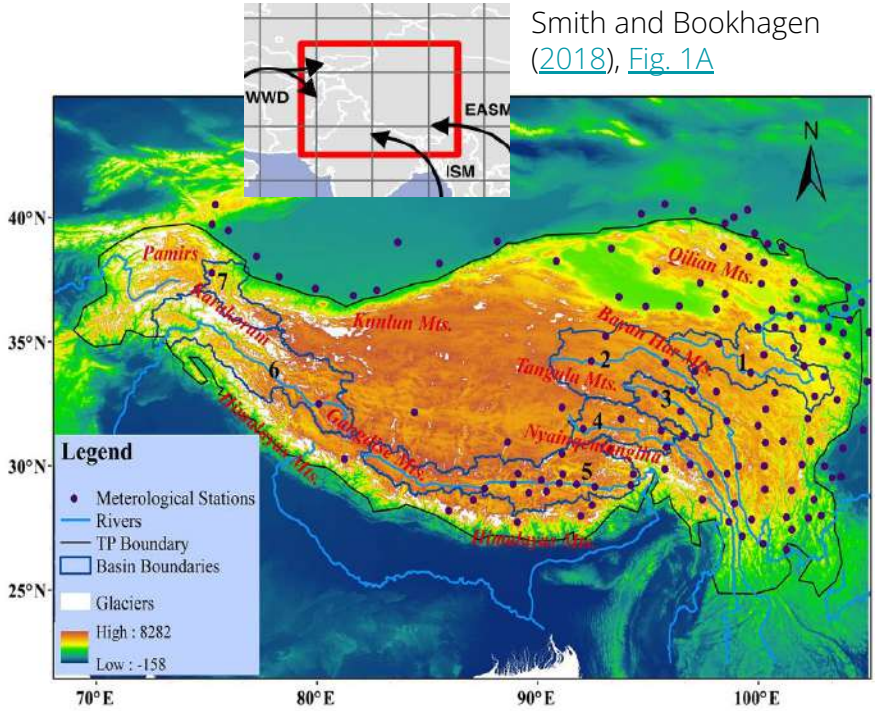

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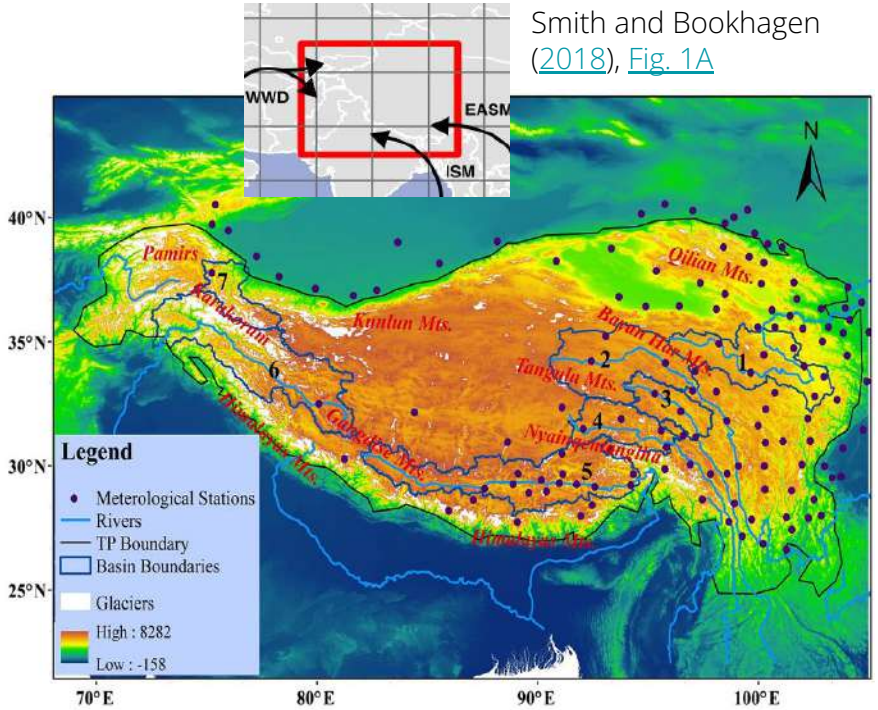

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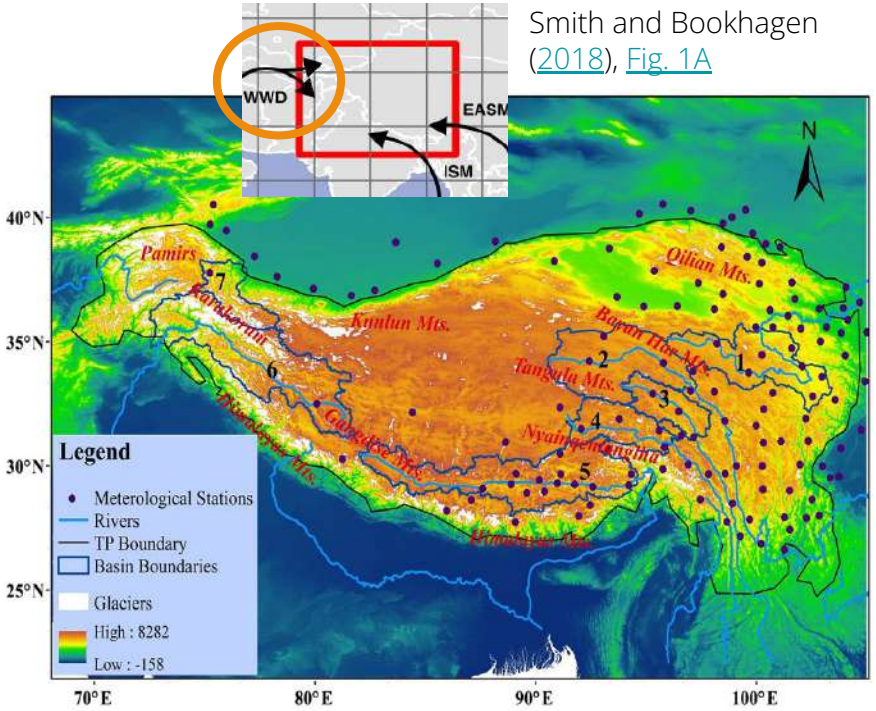

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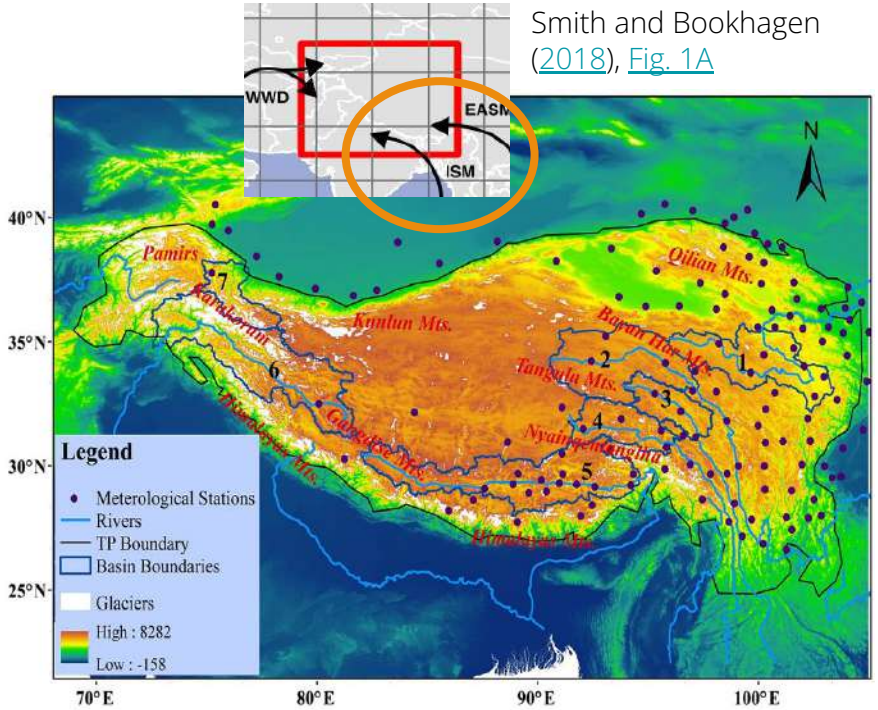

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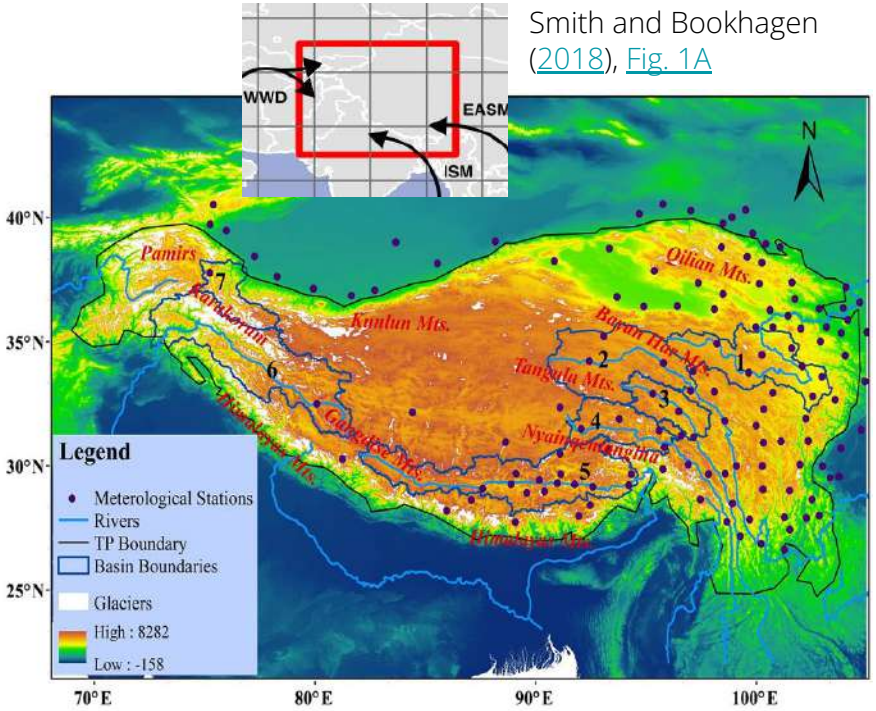

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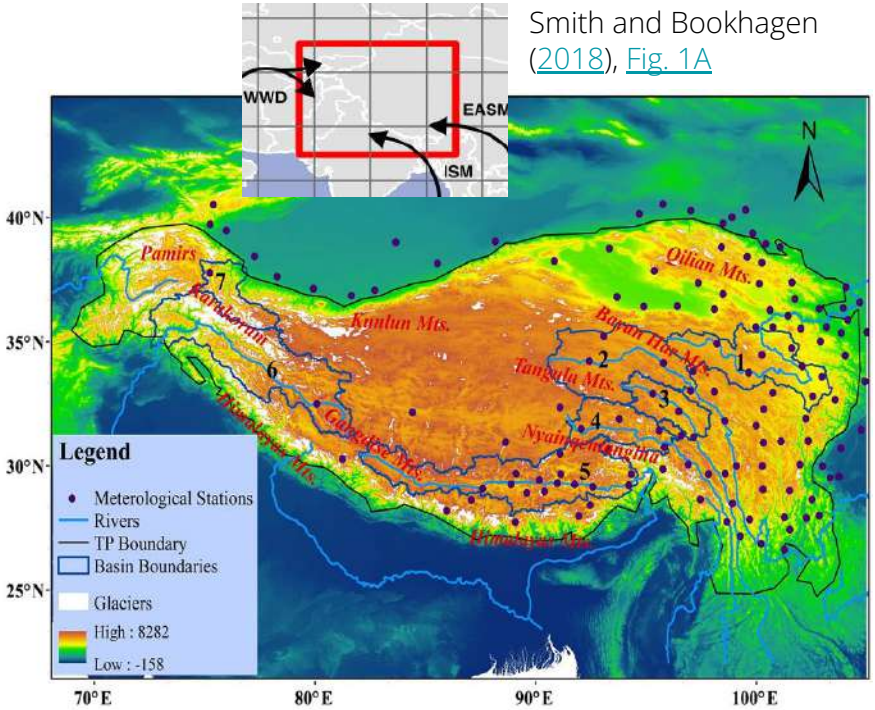

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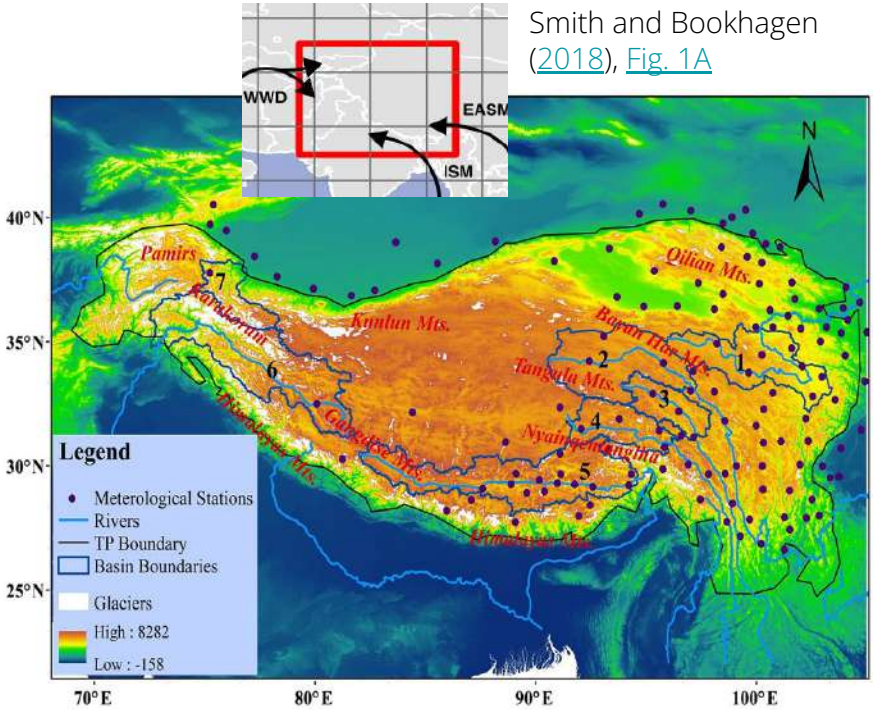

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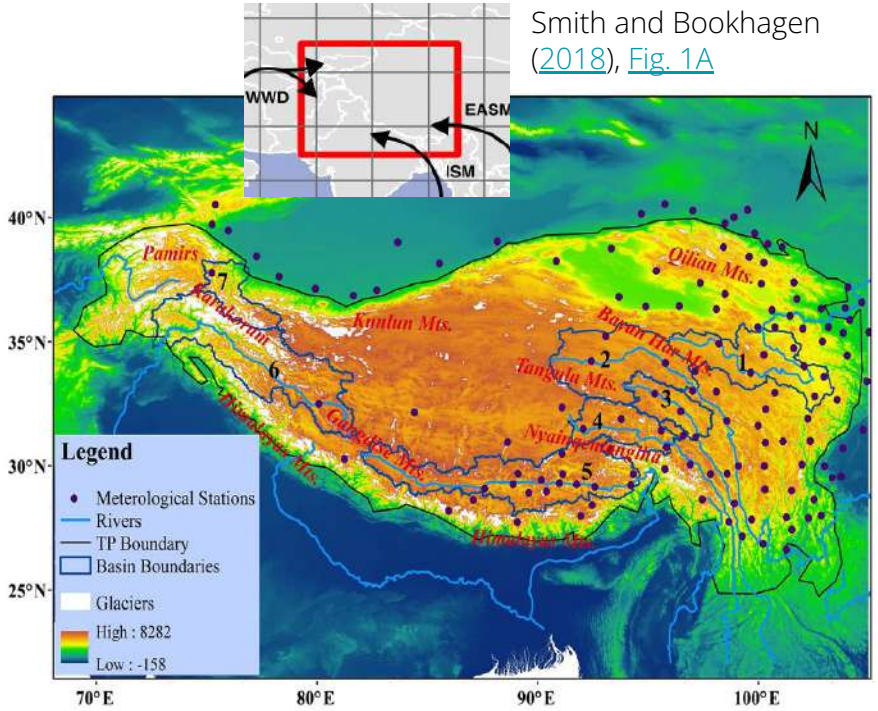

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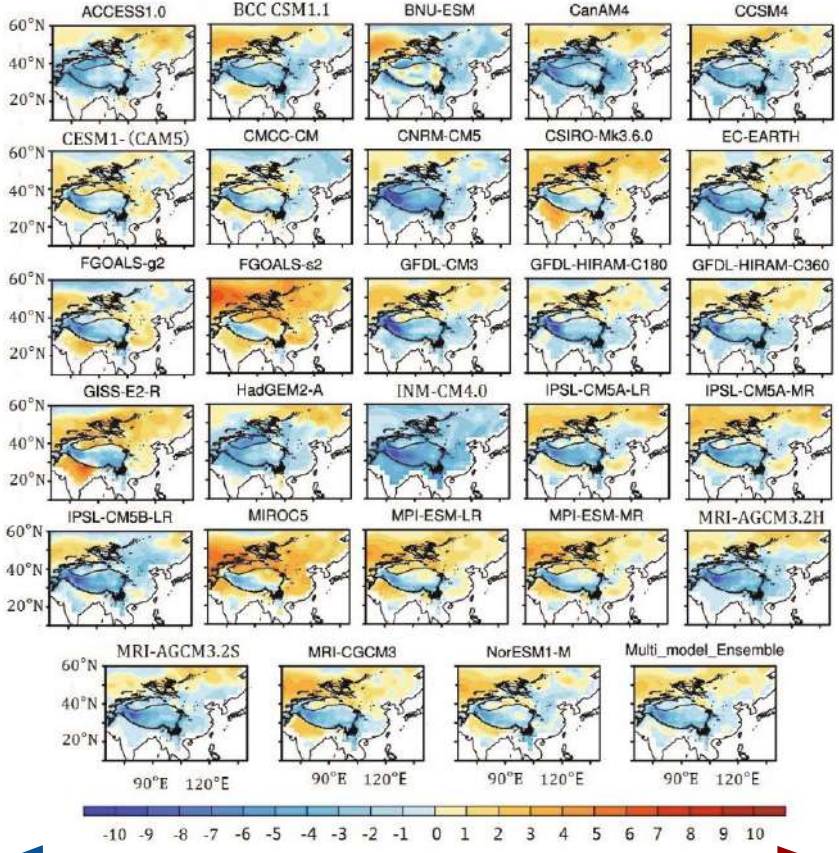
Use of GCMs (even if coarse spatial resolution ~50-300km) provides a coherent picture of the large-scale temporal and spatial patterns of key variables at a regional scale !

“Cold bias” over Tibetan Plateau



Too cold

CMIP5 cold bias
(Chen et al., 2017; Fig 2)

Too hot

- Cold biases in models from first AMIP experiments over HMA and TP (Mao and Robock, 1998)
- Possible explanations: excess precipitation (Lee & Suh, 2000), snow–ice albedo issues (Su et al., 2013), cold biases in T500 due to smoothed topography (Boos and Hurley, 2013), snow cover parameterization and boundary layer (Chen et al., 2017), lack of high-elevation observation stations in the CRU (Gu et al., 2012), etc.

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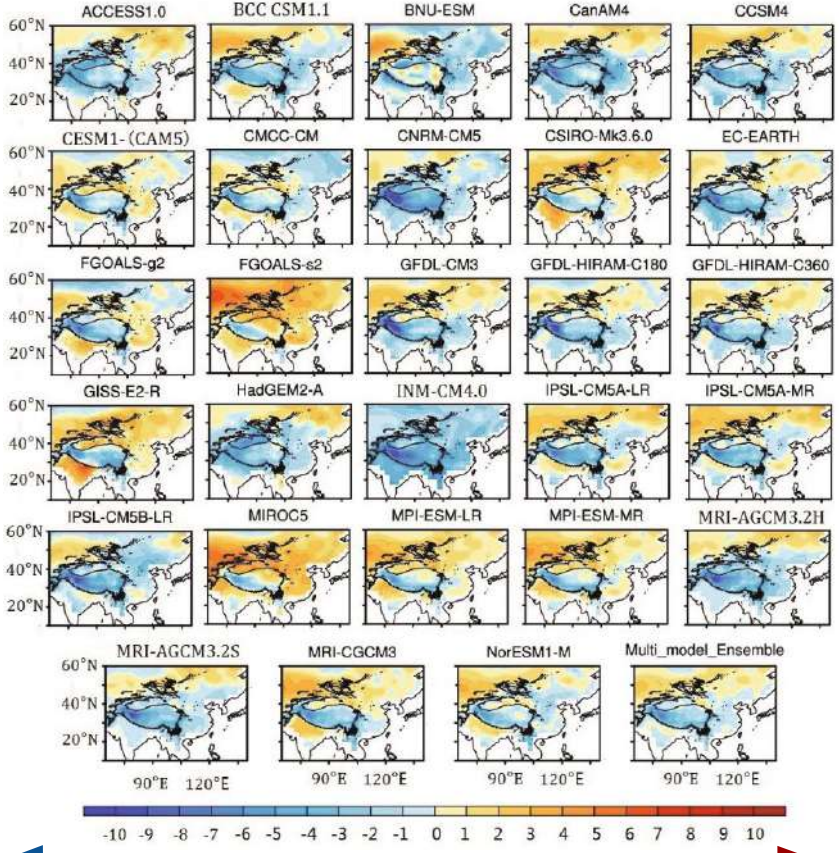

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Our study

1. Biases in CMIP6 for near-surface air temperature, total precipitation and snow cover extent?
2. What are the links between the model biases?
3. Do the model biases impact the trends?
4. Projections over the next century?

Data and methods

- 26 CMIP6 GCMs simulations for historical period 1979-2014
- 10 CMIP6 models for the future projections: SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5 (O'Neill et al., 2016)

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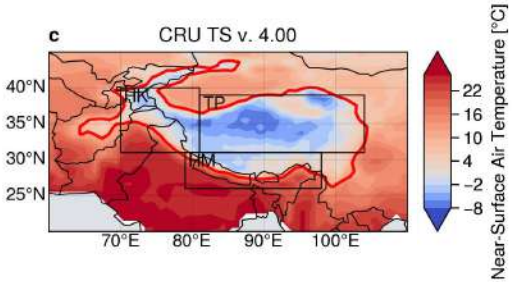

Annual climatologies (1979-2014)

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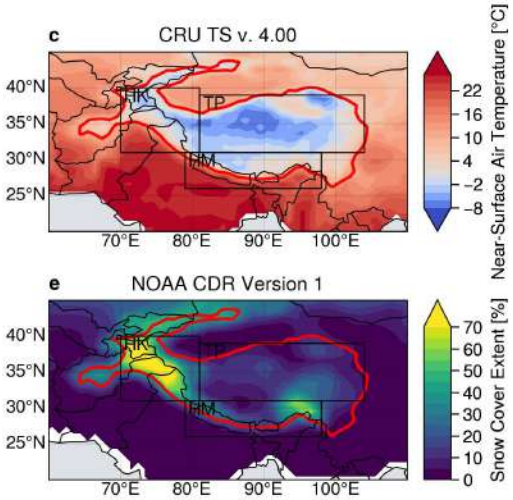

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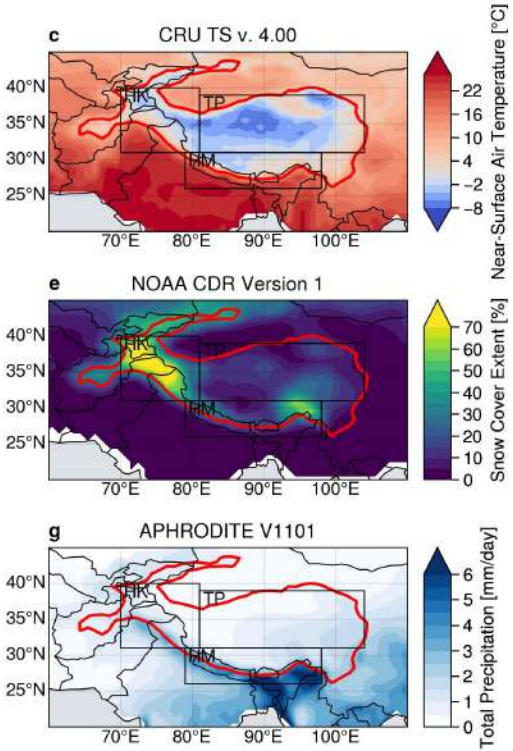

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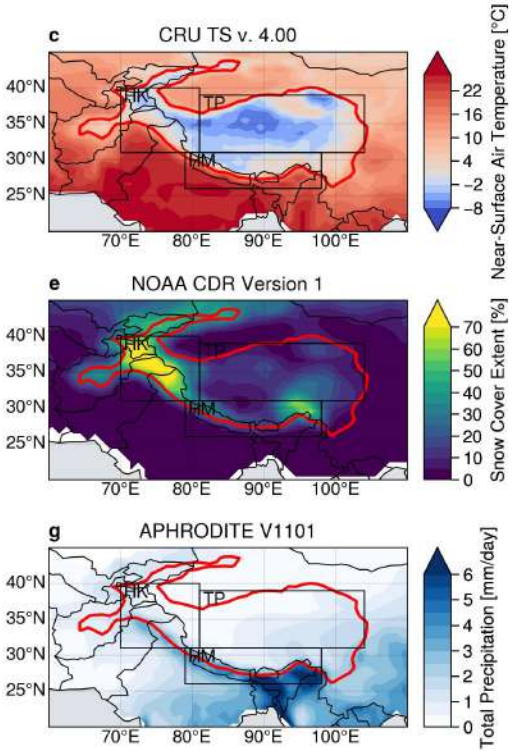

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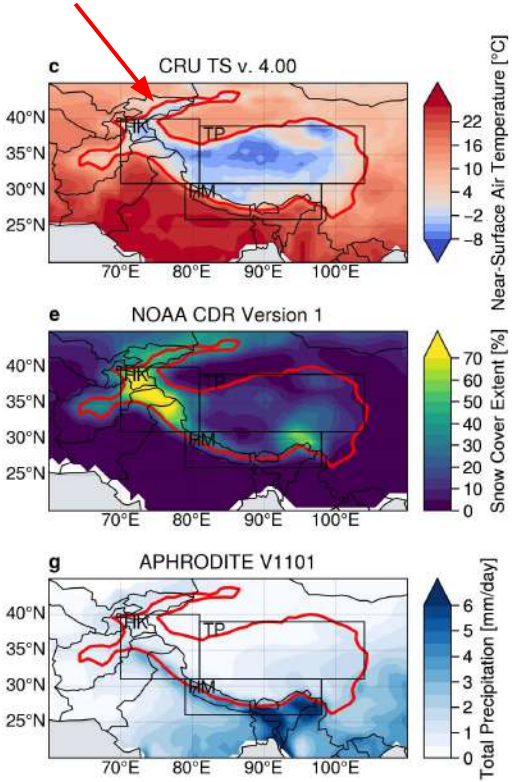
- Domain: High Mountain of Asia (HMA) including the Tibetan Plateau (TP), with elevation higher than 2500 m.asl (red contour)



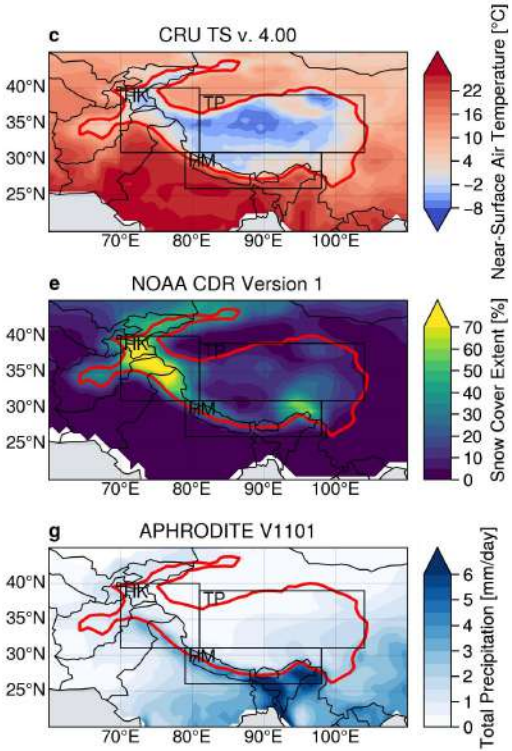
Annual climatologies (1979-2014)

Data and methods

- 26 CMIP6 GCMs simulations for historical period 1979-2014
- 10 CMIP6 models for the future projections: SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5 (O'Neill et al., 2016)

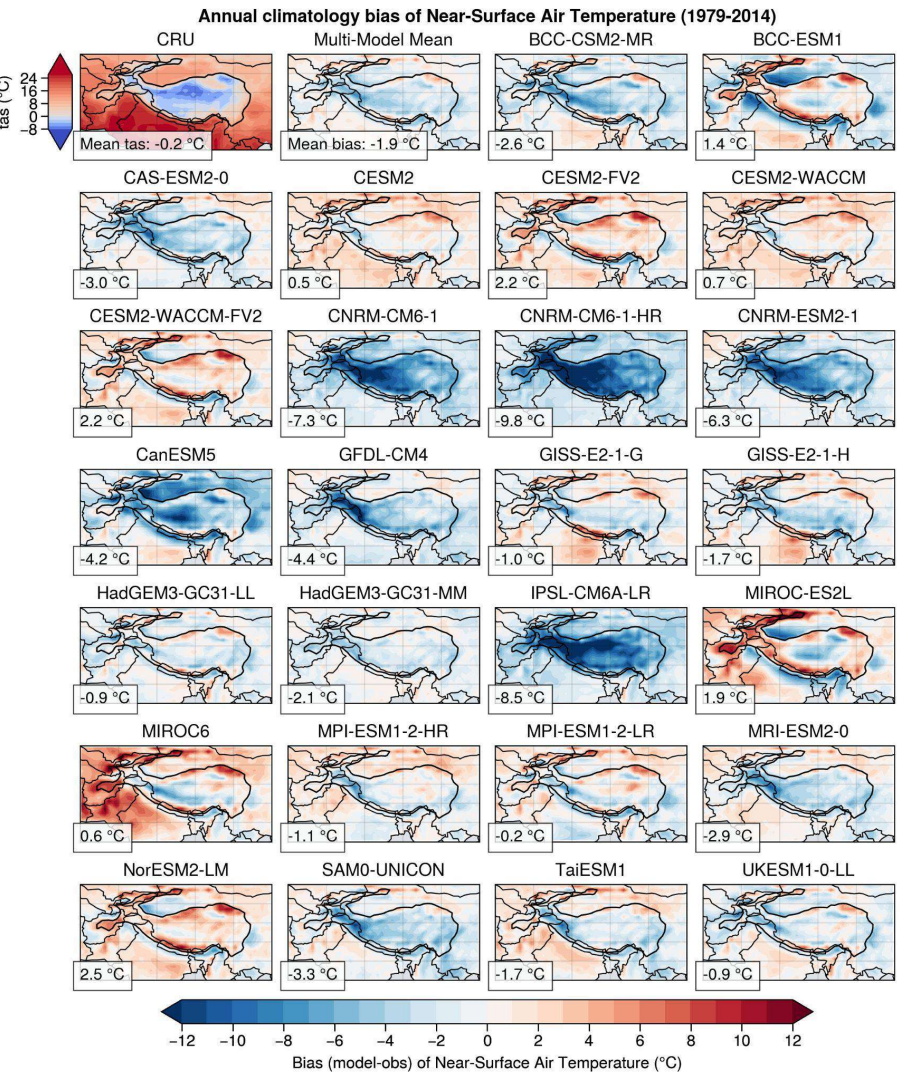
- Observations: CRU (0.5°; Harris et al., 2014), NOAA CDR (> 100 km; Robinson et al., 2012) / Snow CCI (~5 km; Naegeli et al., 2021), APHRODITE (0.5°; Yatagai et al., 2012) and GPCP (2.5°; Adler et al., 2016)
- Reanalyses: ERA-Interim (~80 km; Dee et al., 2011) and ERA5 (~30 km; Hersbach et al., 2020)

- Domain: High Mountain of Asia (HMA) including the Tibetan Plateau (TP), with elevation higher than 2500 m.asl (red contour)
- Seasons: winter DJFMA (WDs) and summer JJAS (Asian summer monsoon)



Annual climatologies (1979-2014)

Spatial biases and metrics



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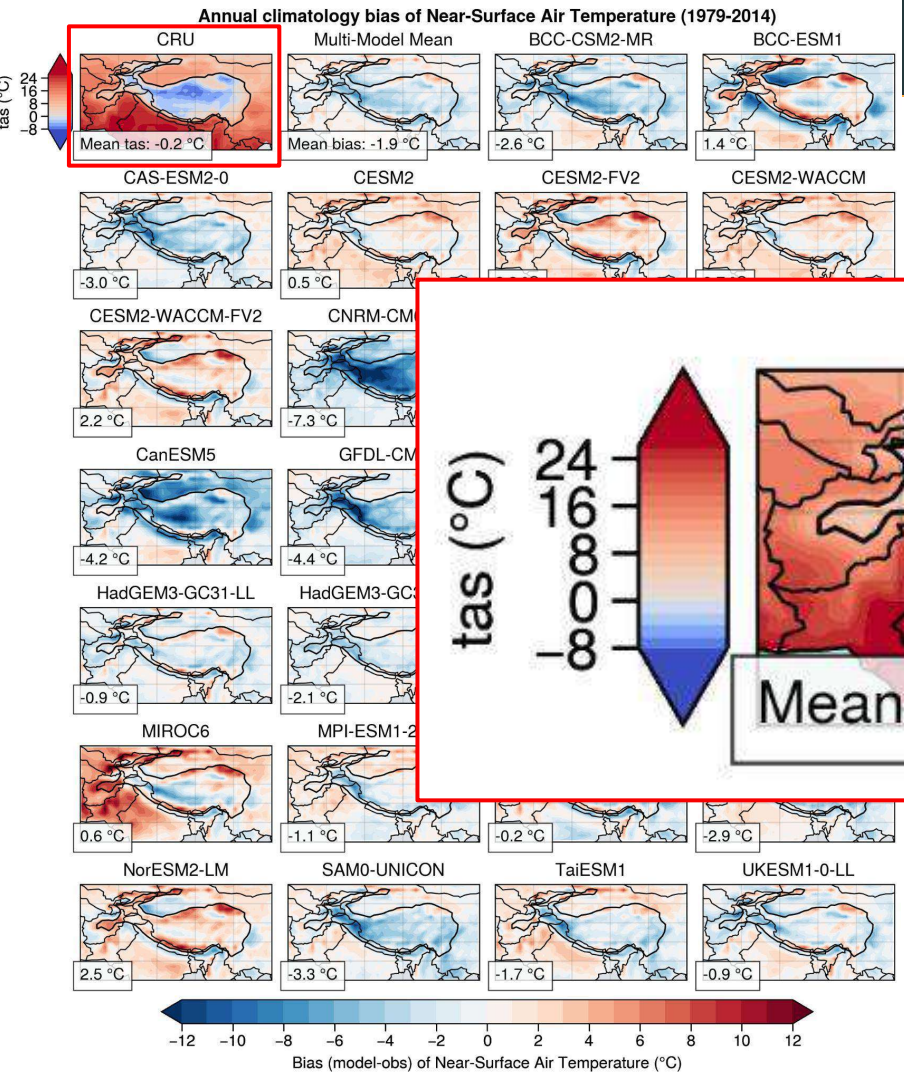

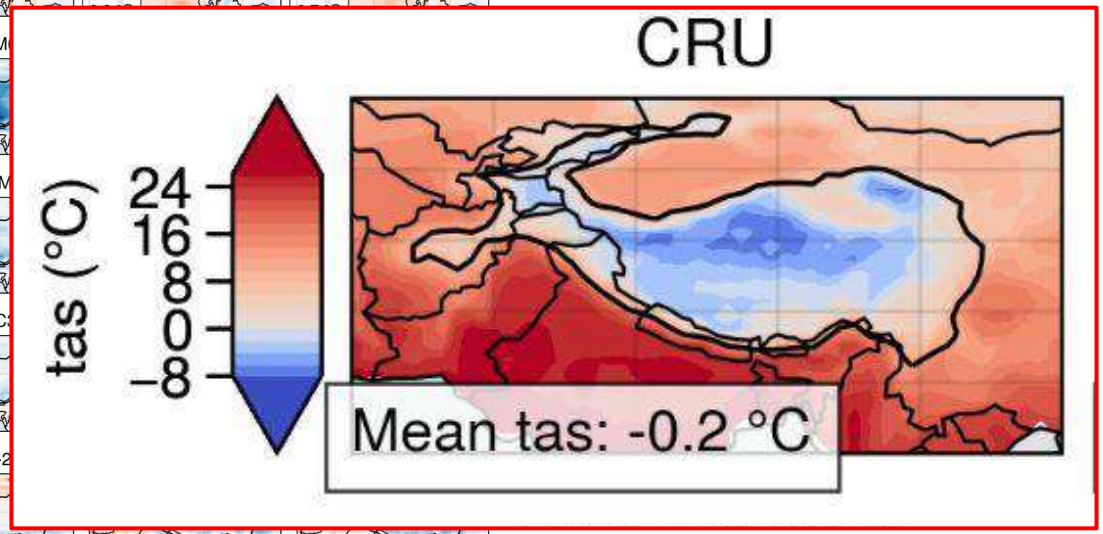

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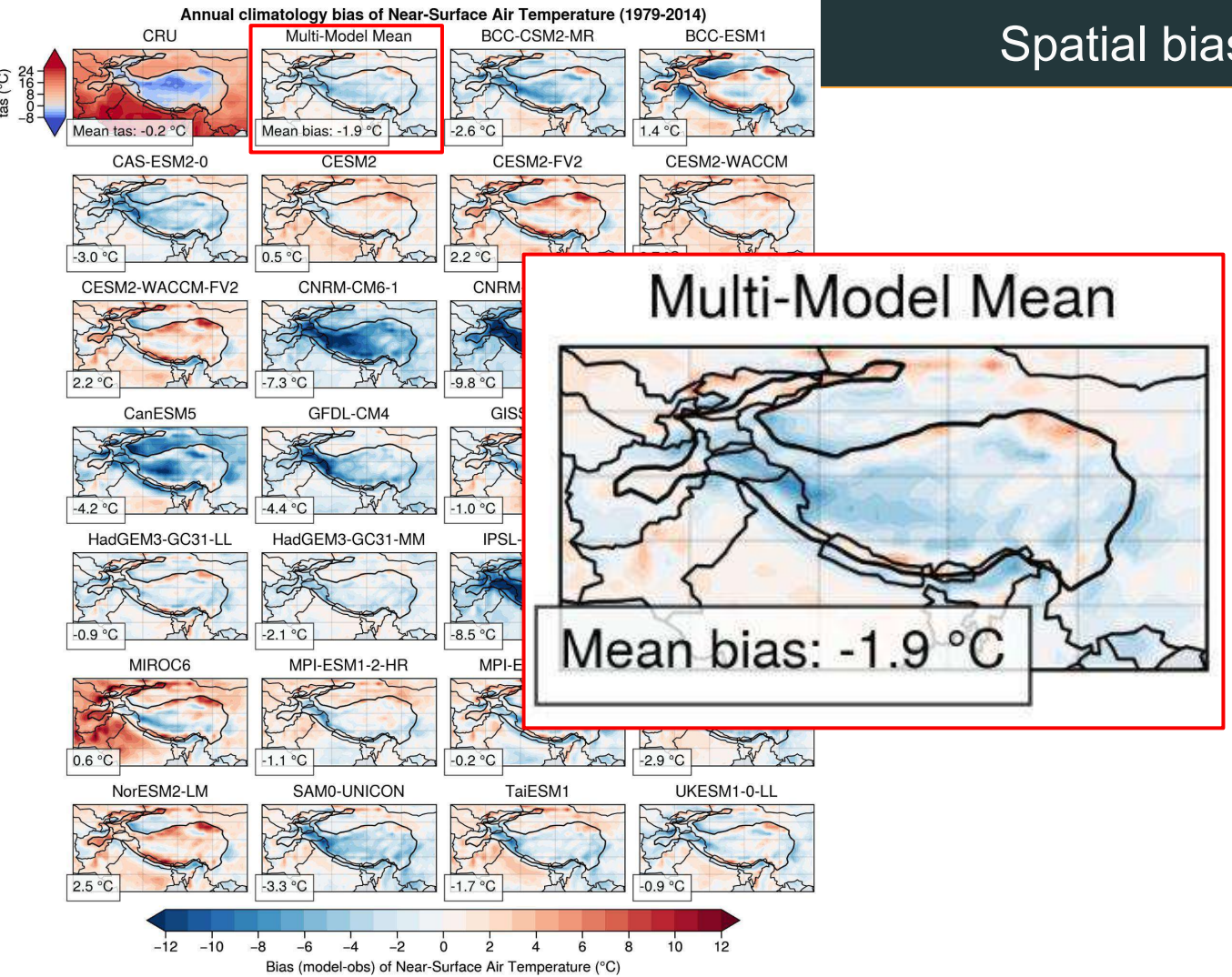

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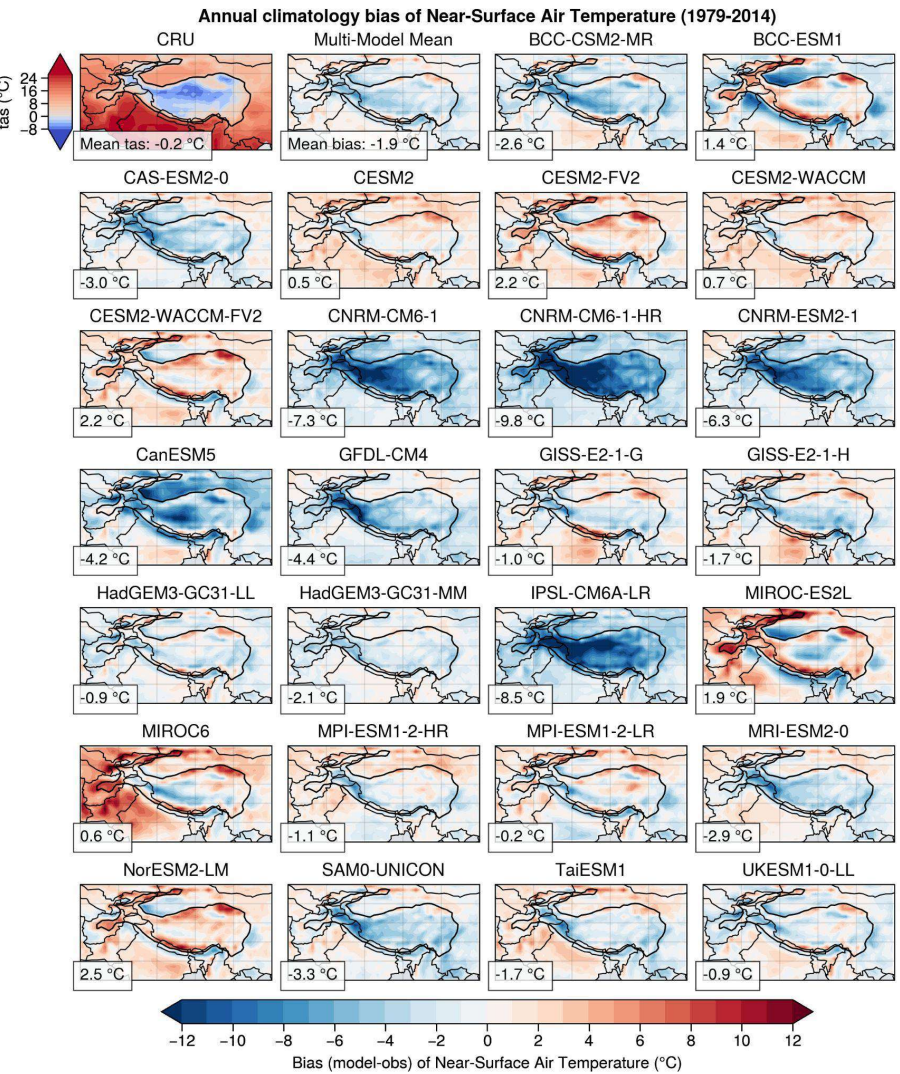

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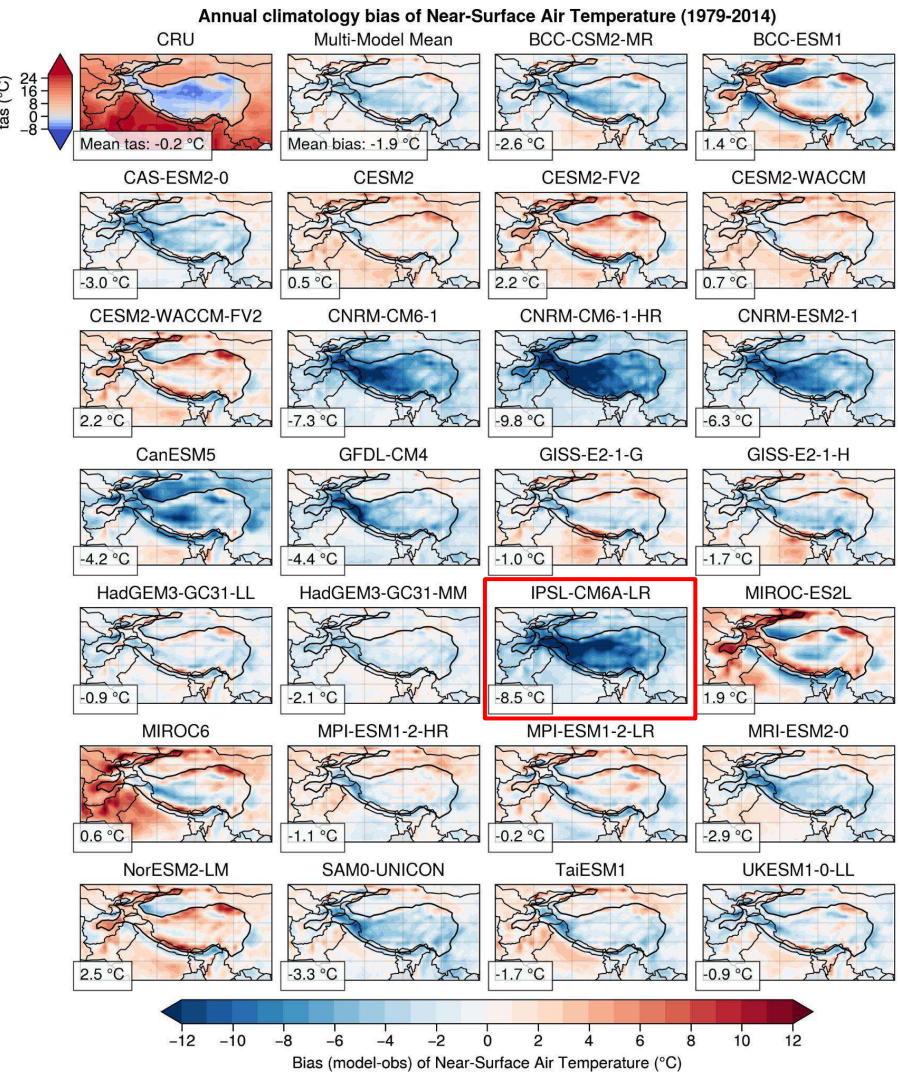

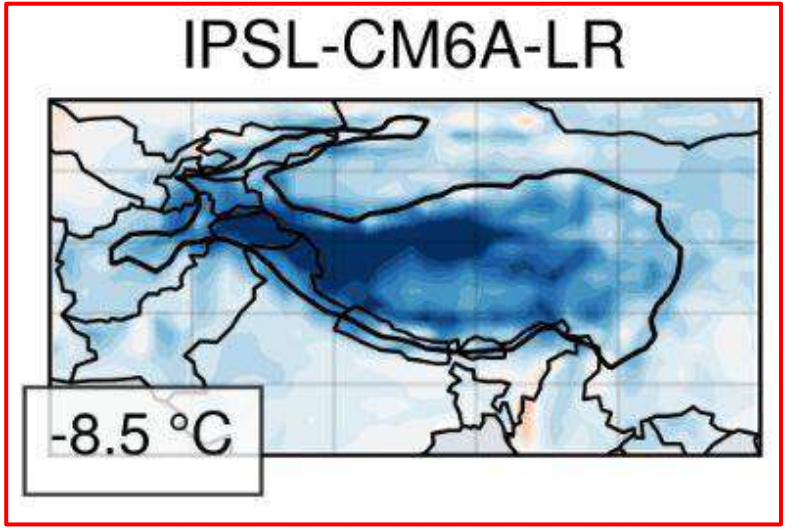

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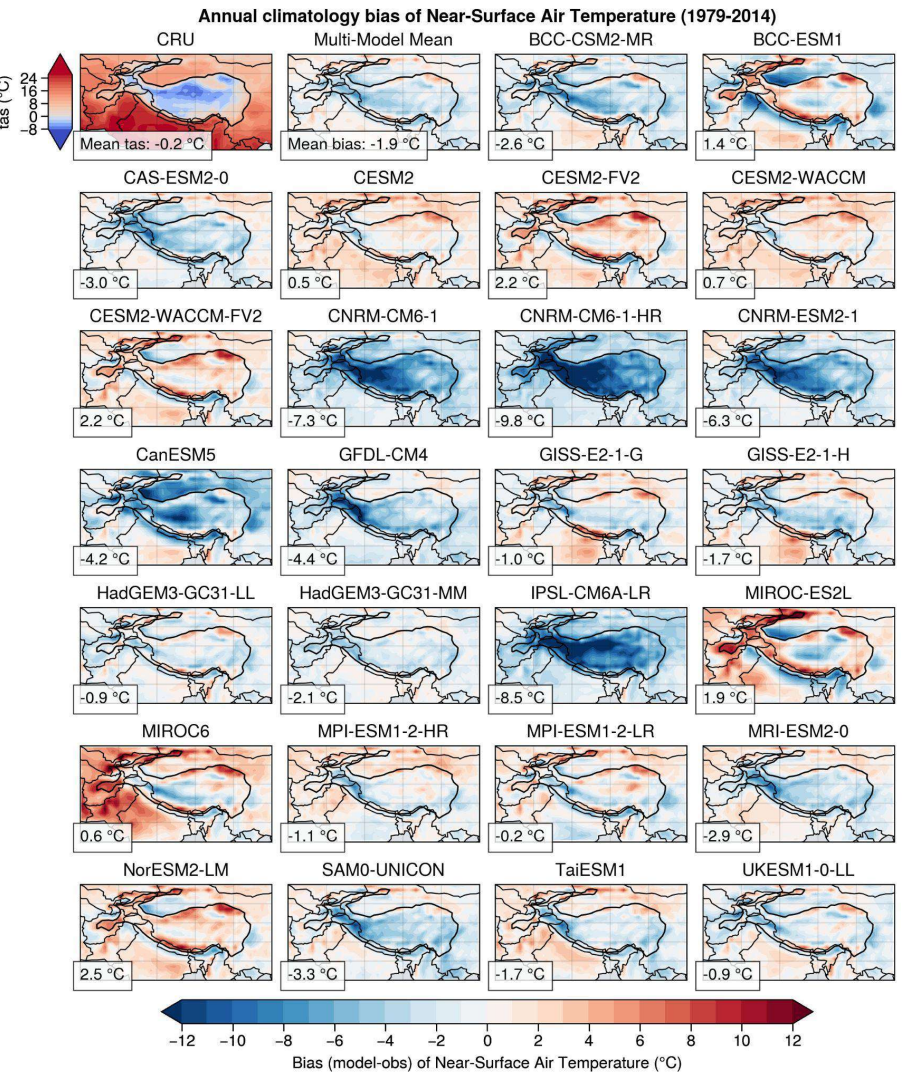

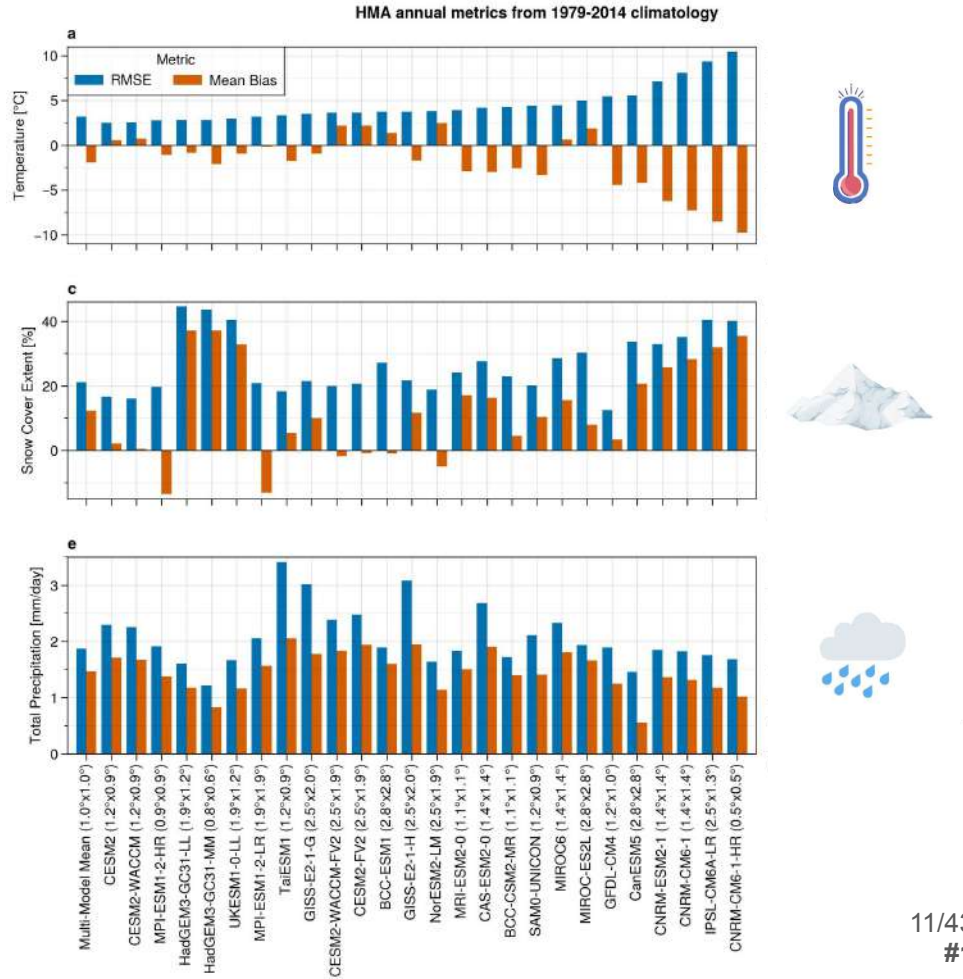

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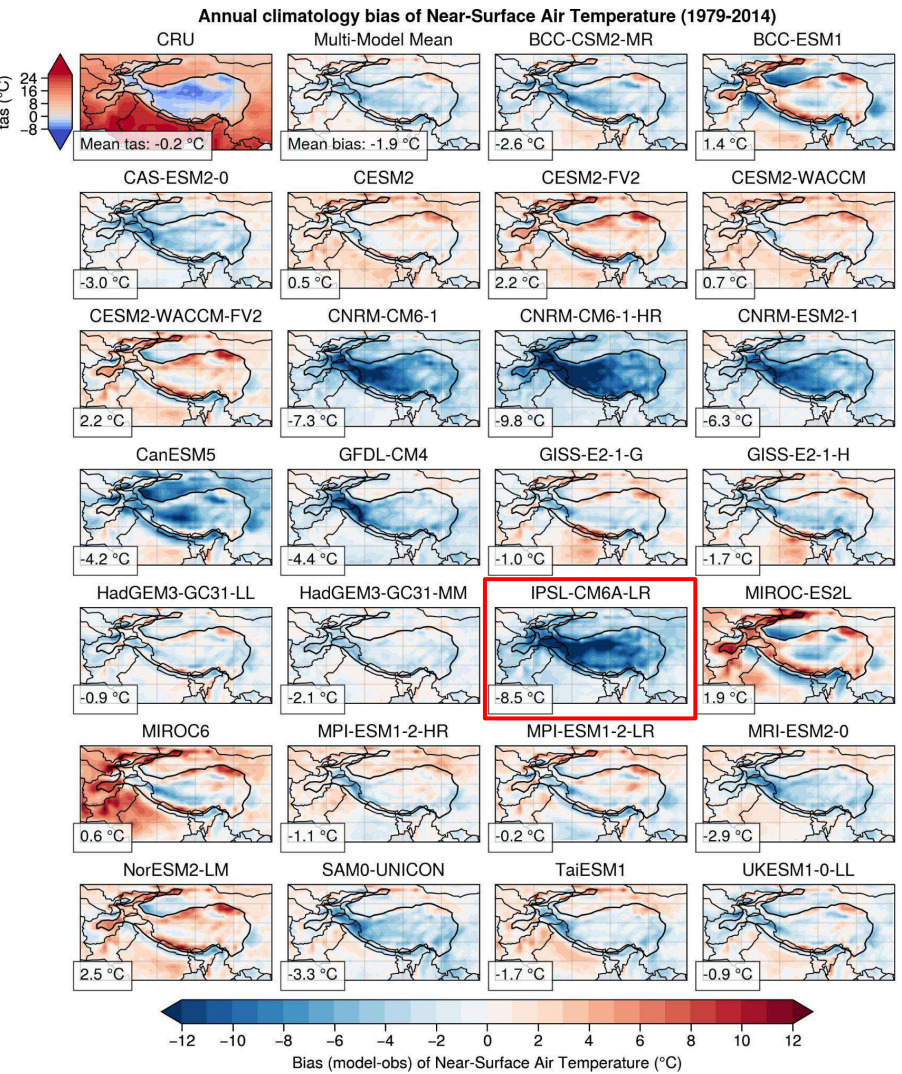

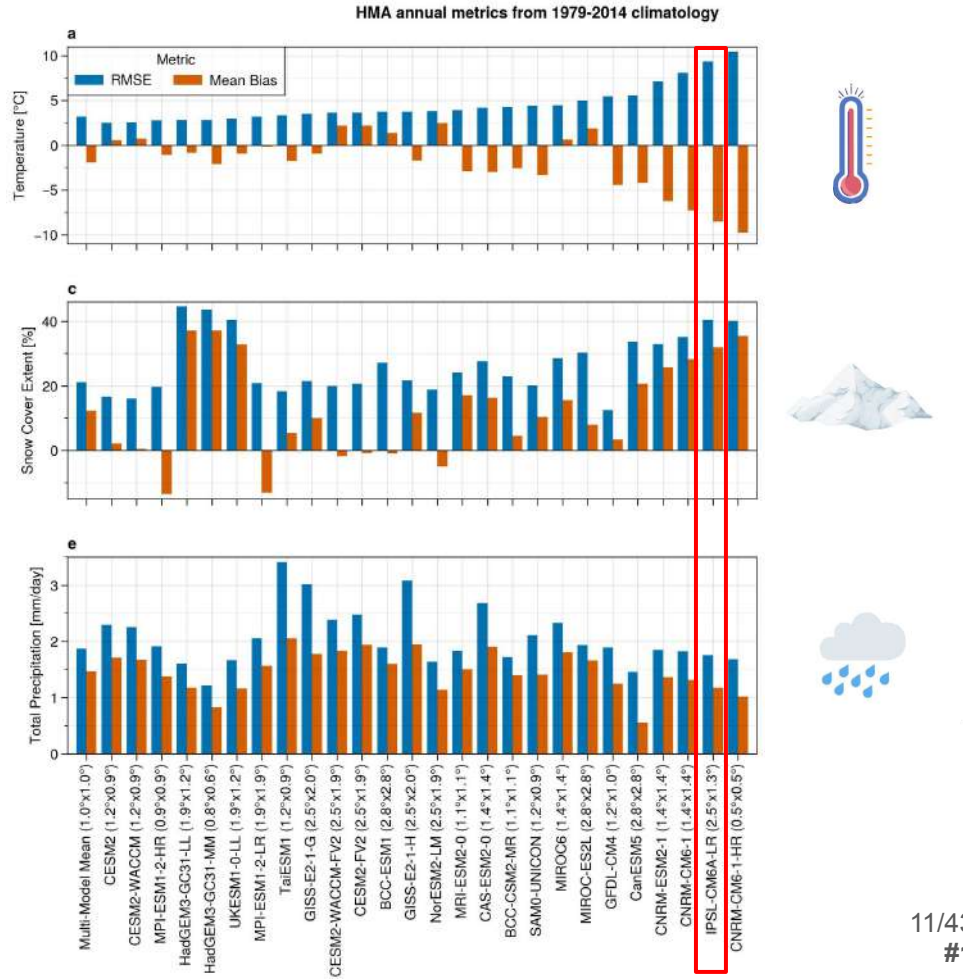

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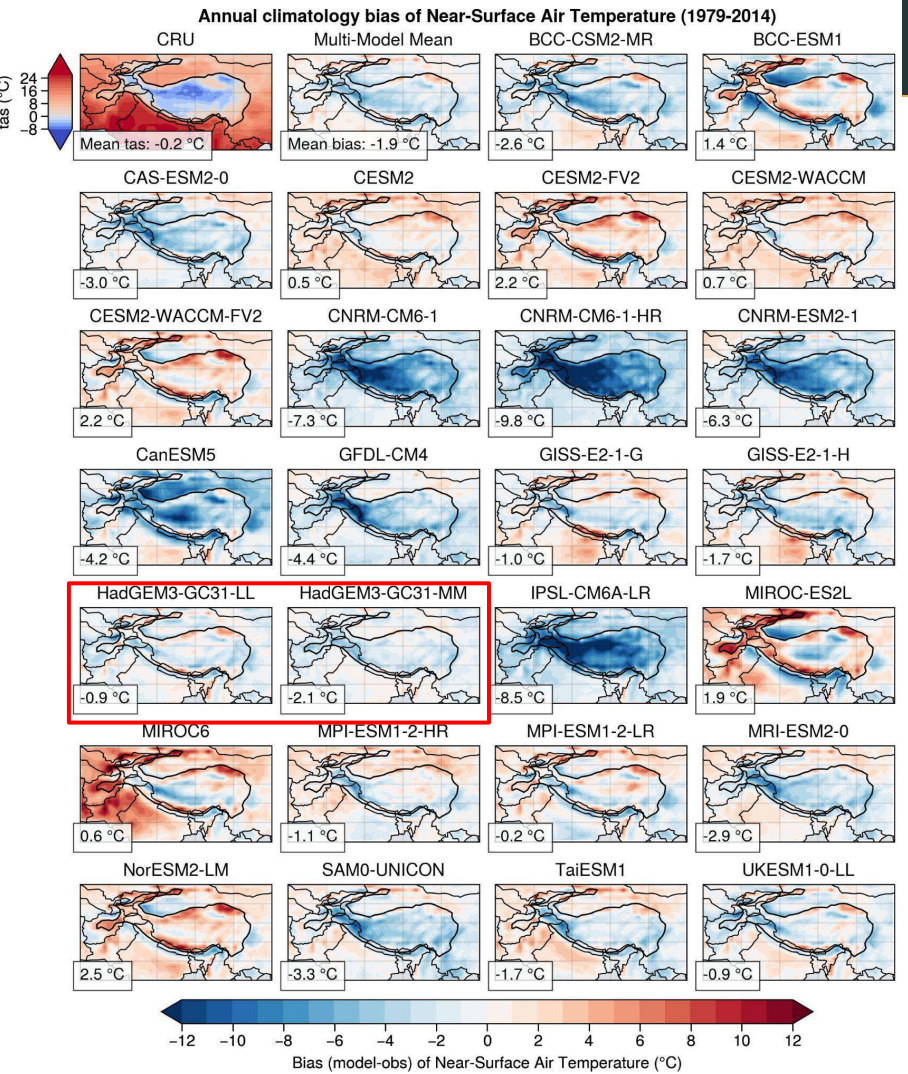

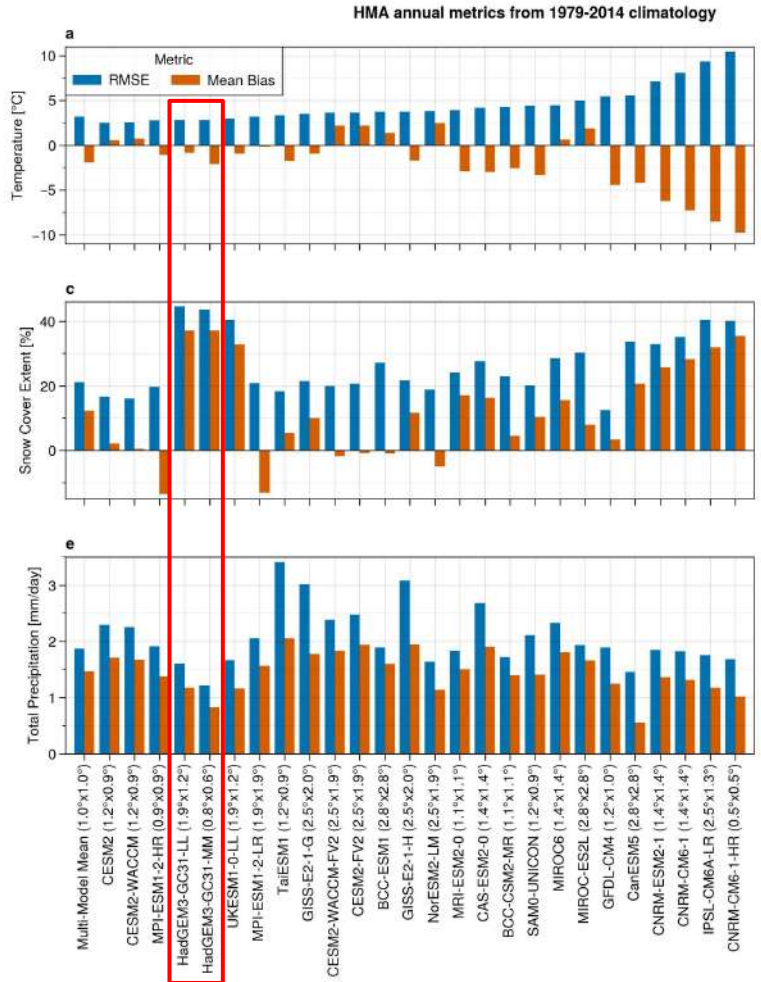

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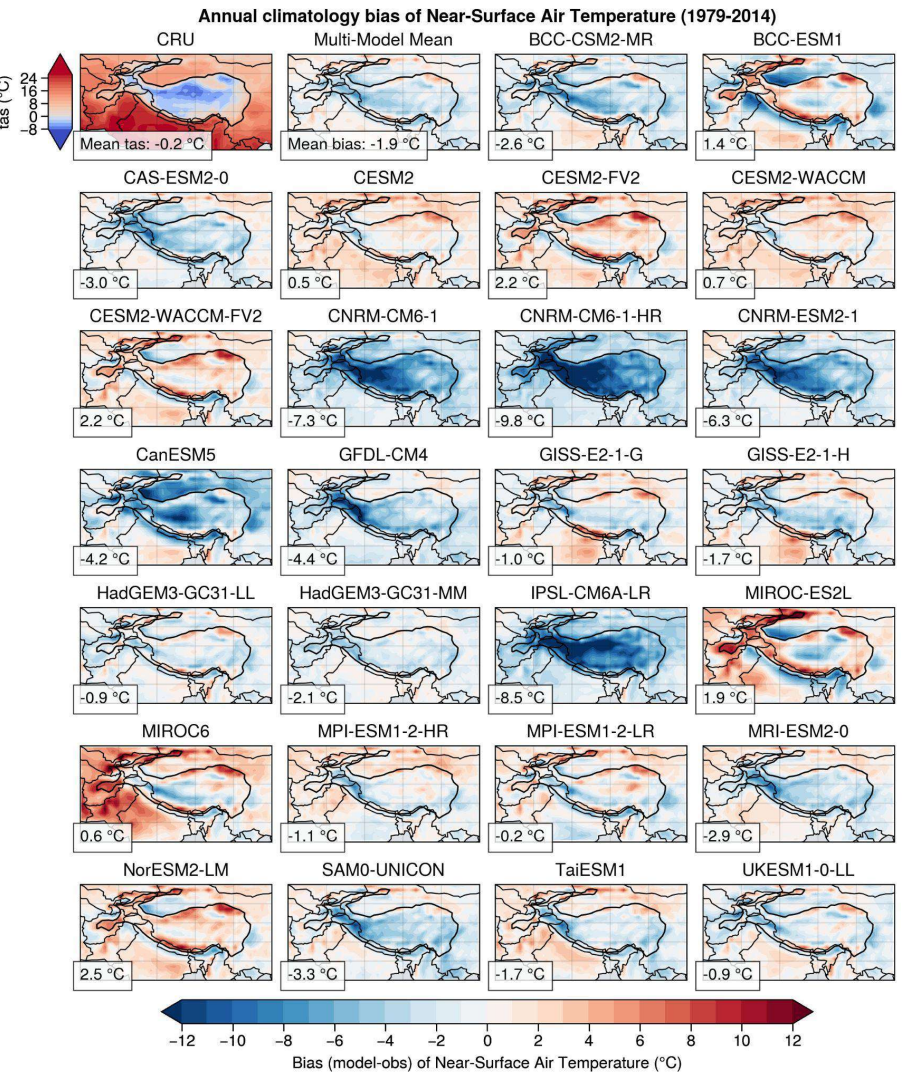

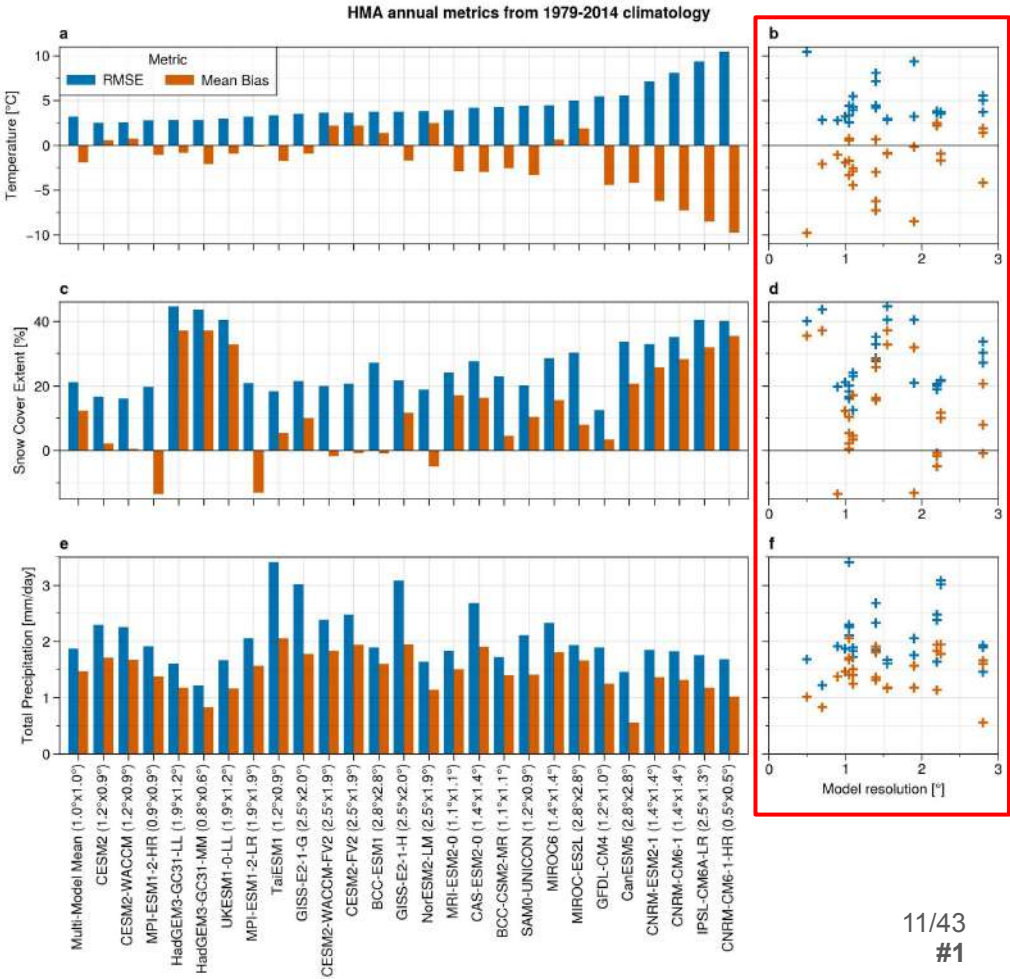

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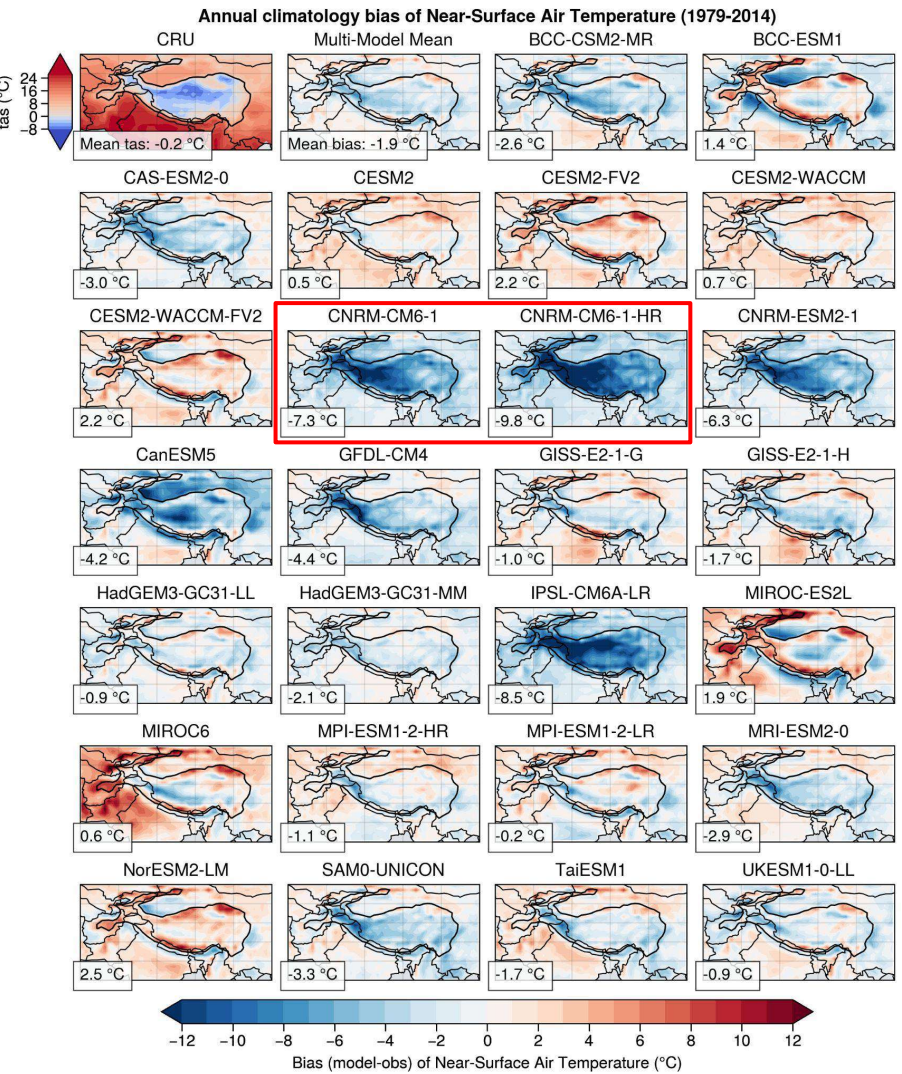

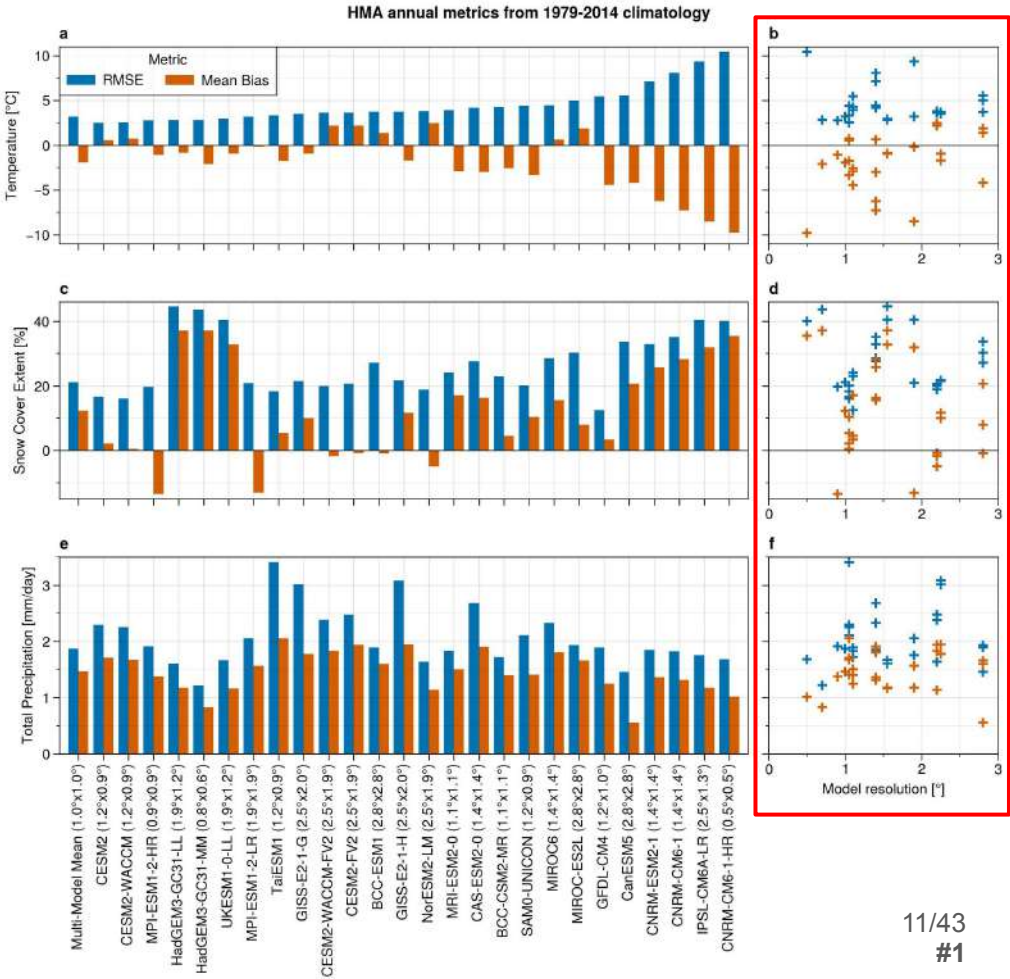

Historical trends analysis

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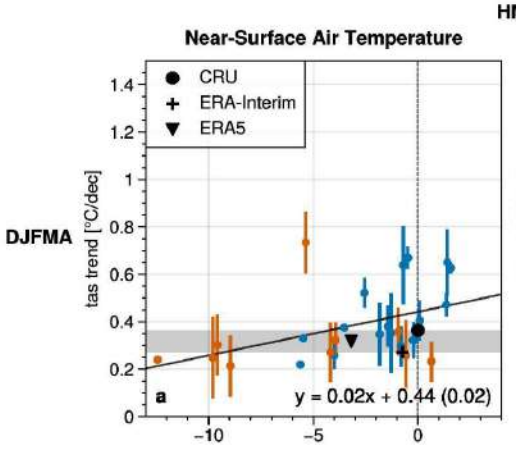

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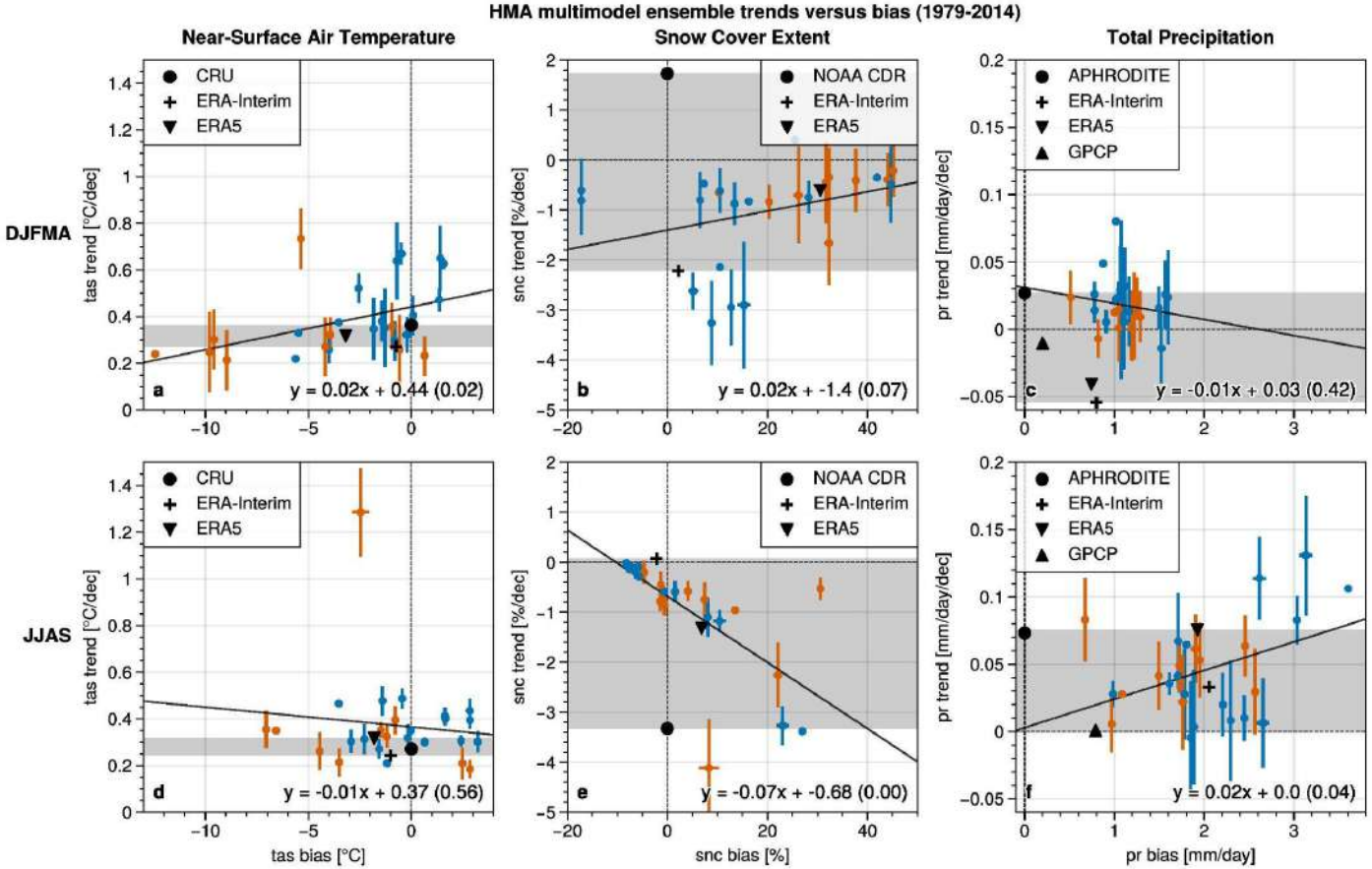

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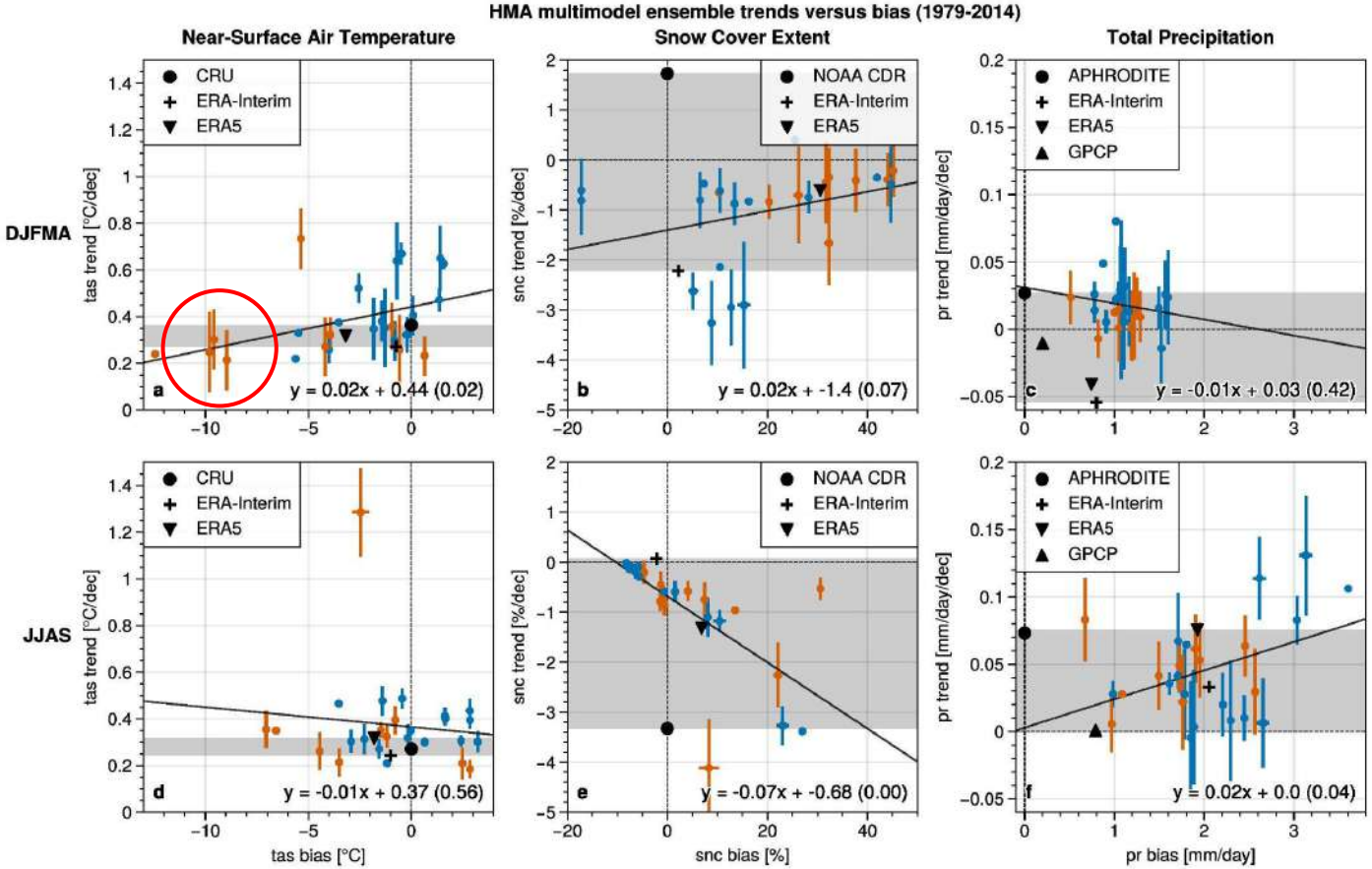

- No obvious link between model biases and trends
- Some strongly biased models have trends close to observations

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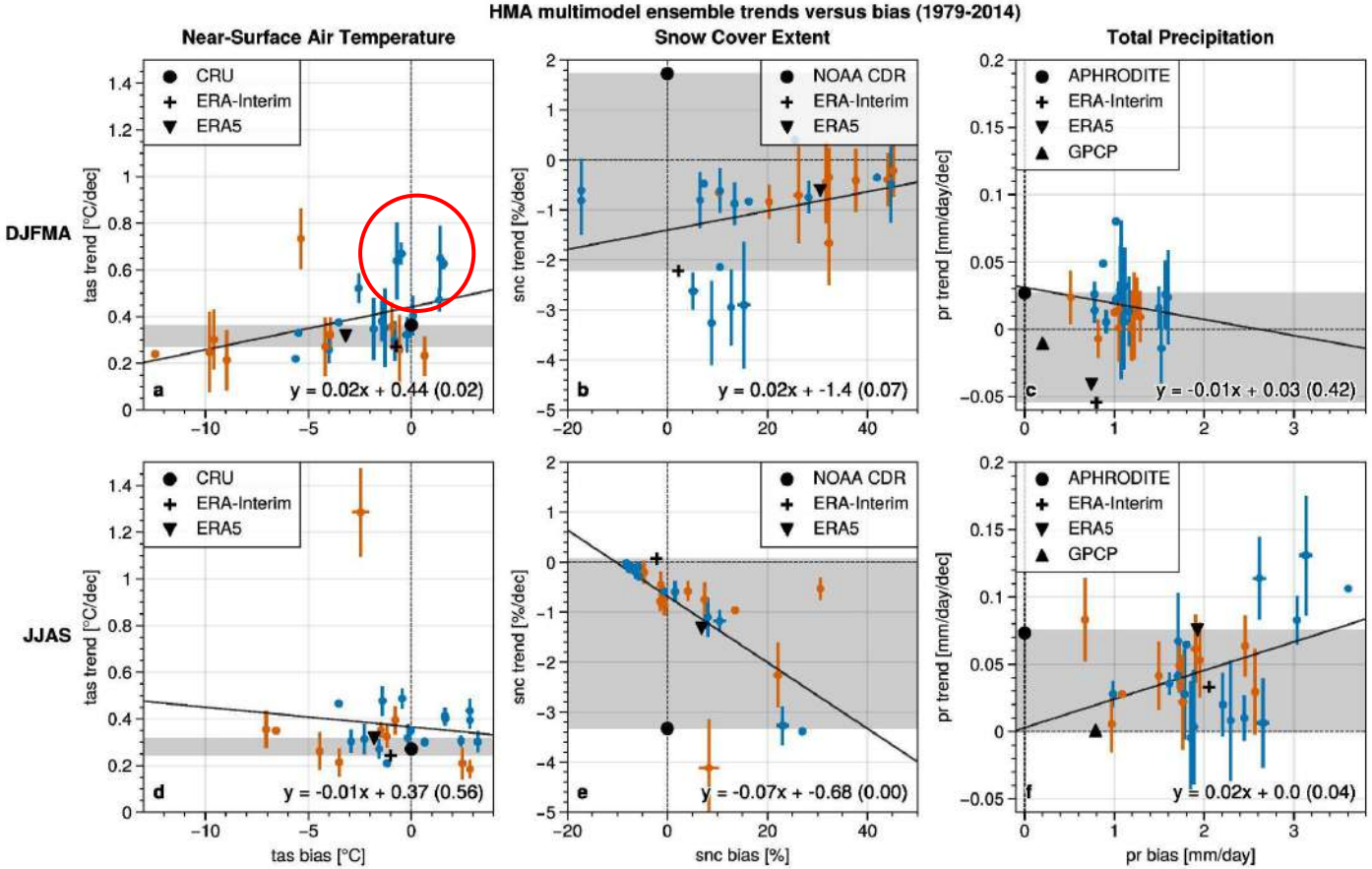

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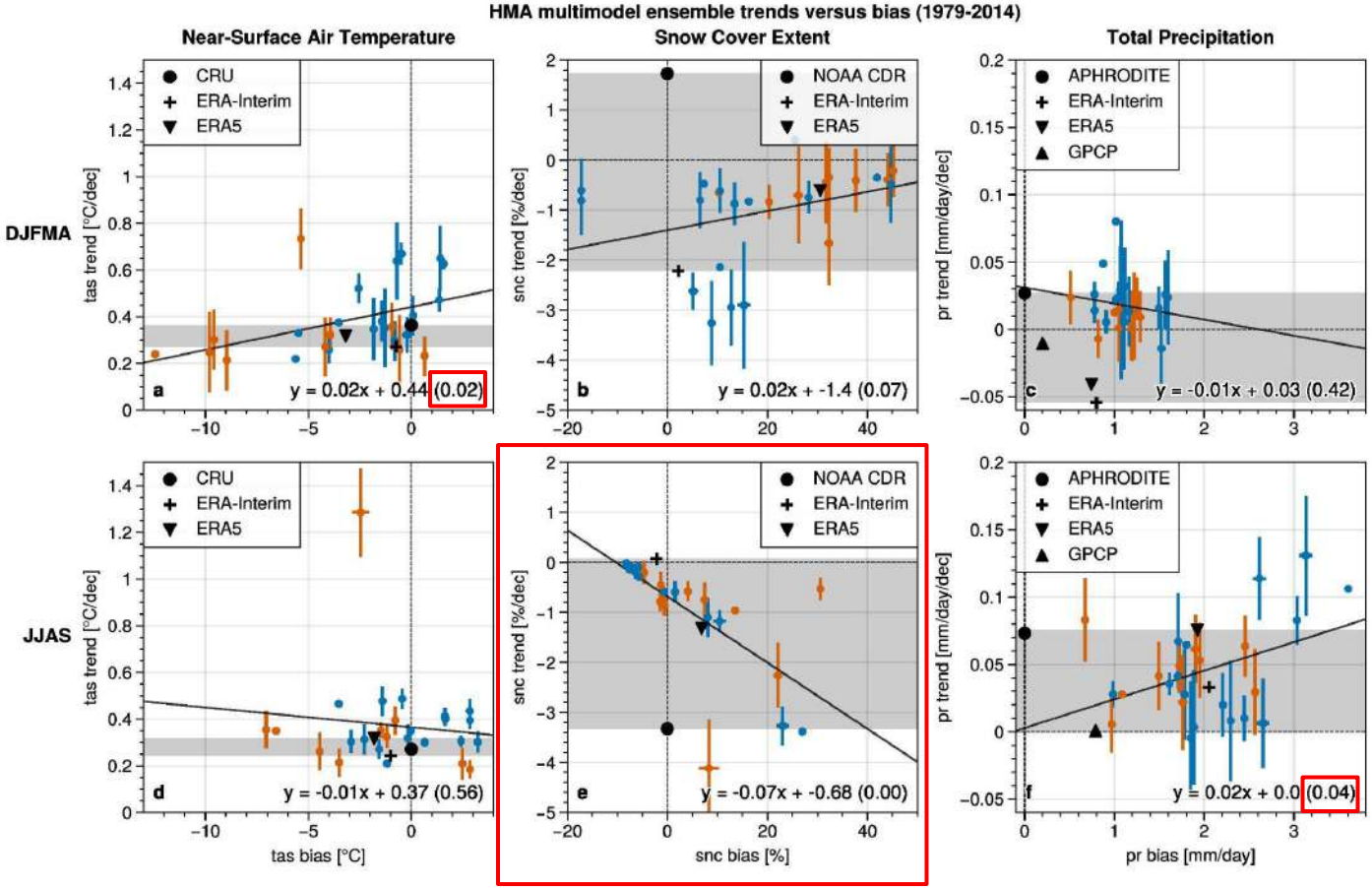

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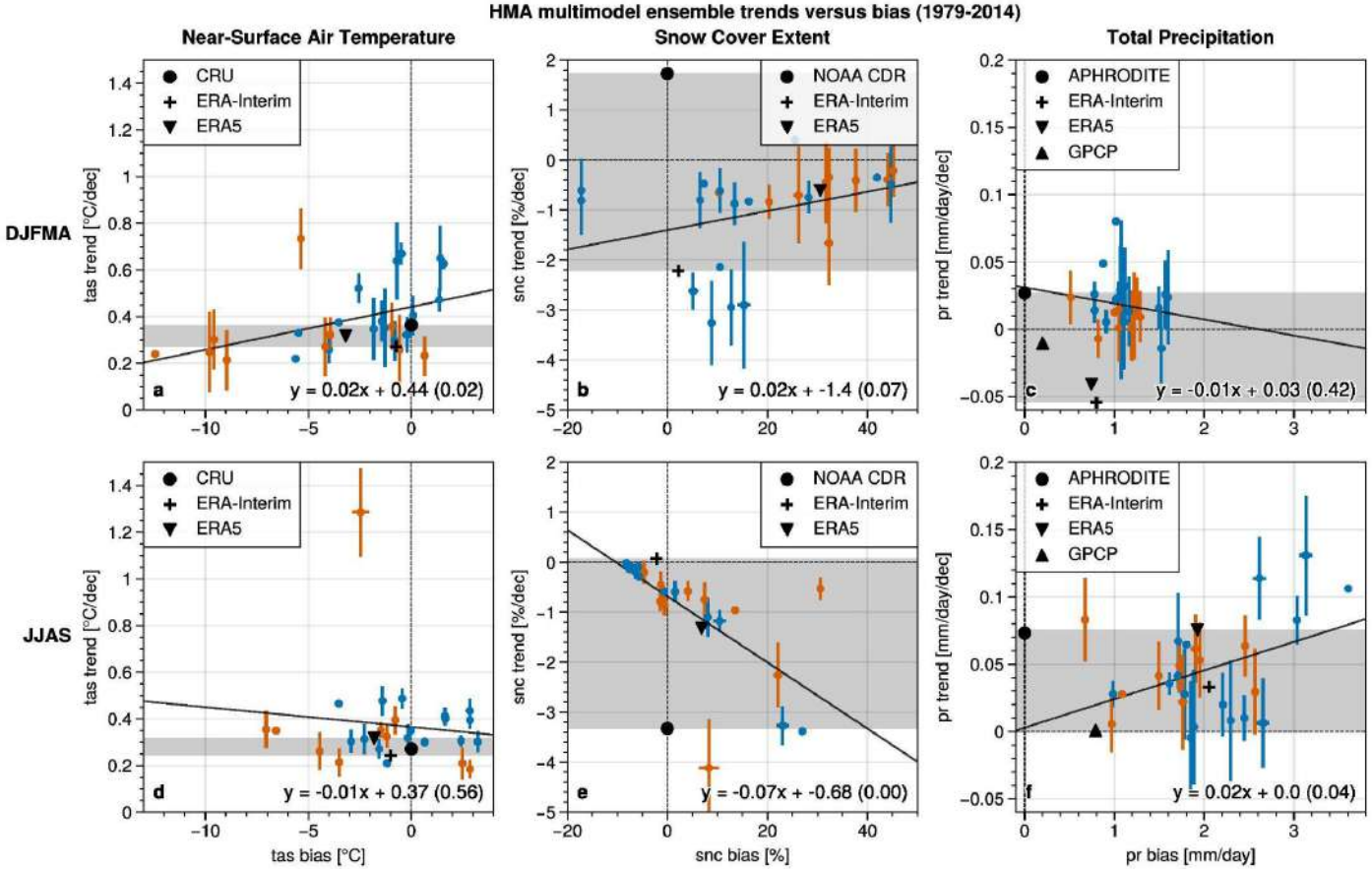

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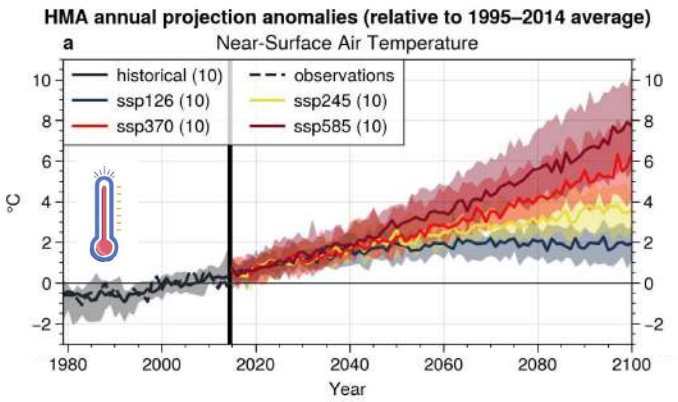
-> All available models are kept for projections (orange points)

Projections



- annual median 2081-2100 with respect to 1995-2014 average:
  - tas: 1.9 [1.2 to 2.7] °C (SSP1-2.6) to 6.5 [4.9 to 9.0] °C (SSP5-8.5)

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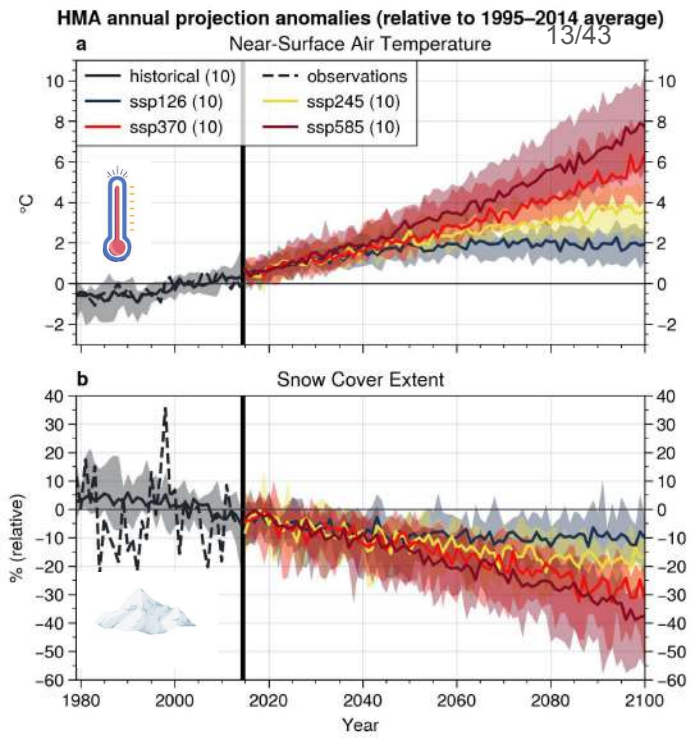

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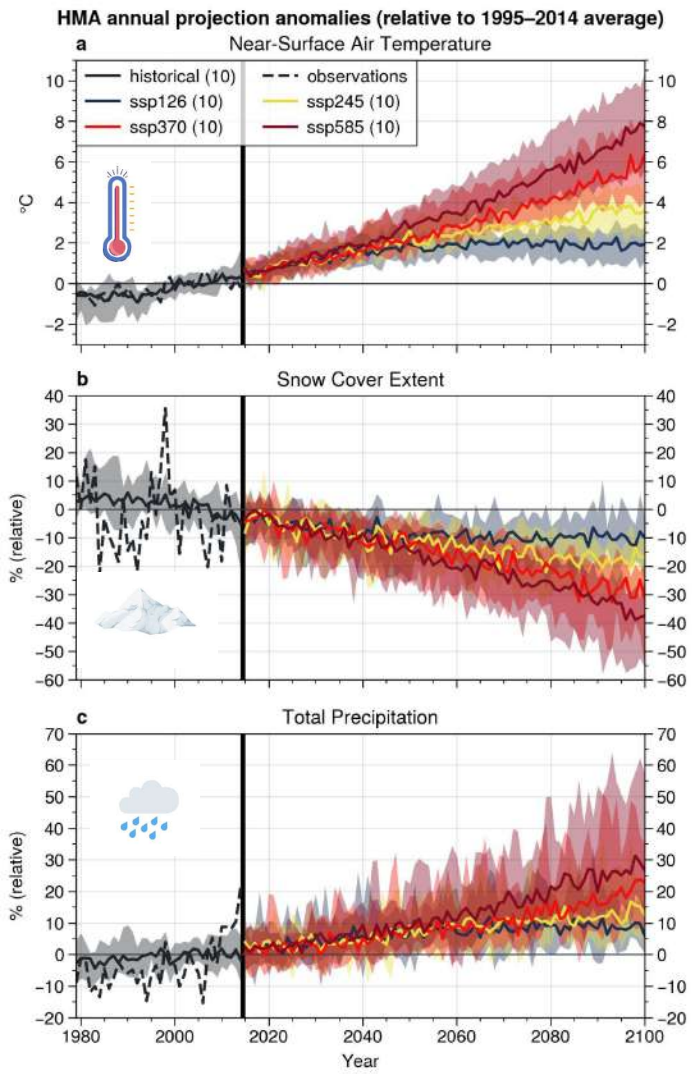

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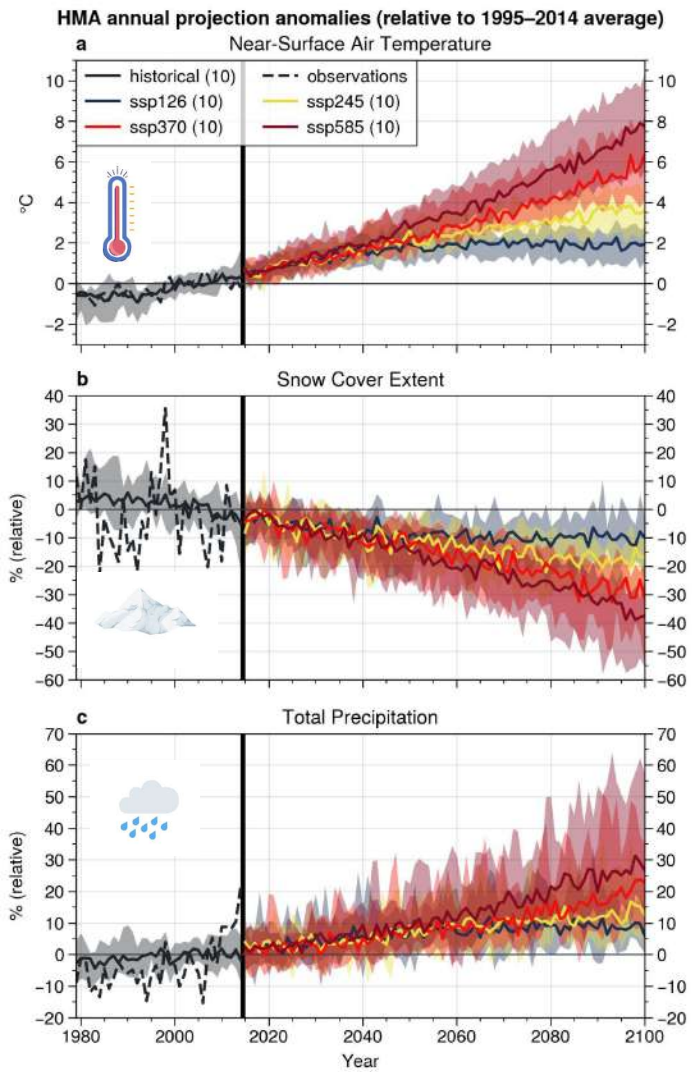
Projections



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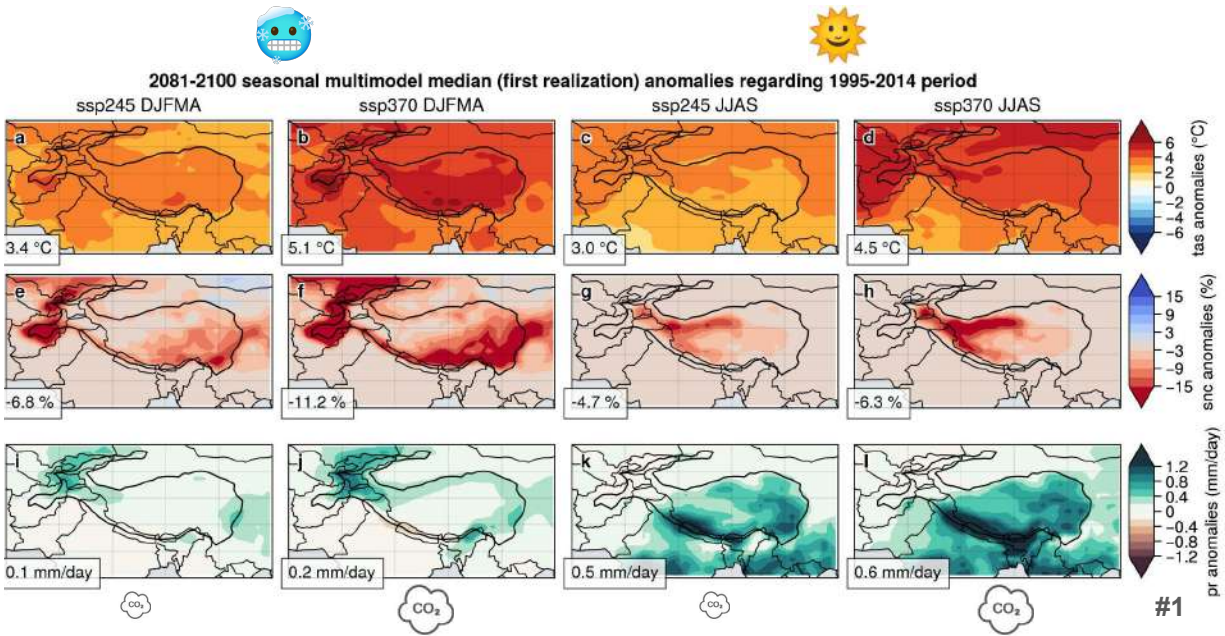

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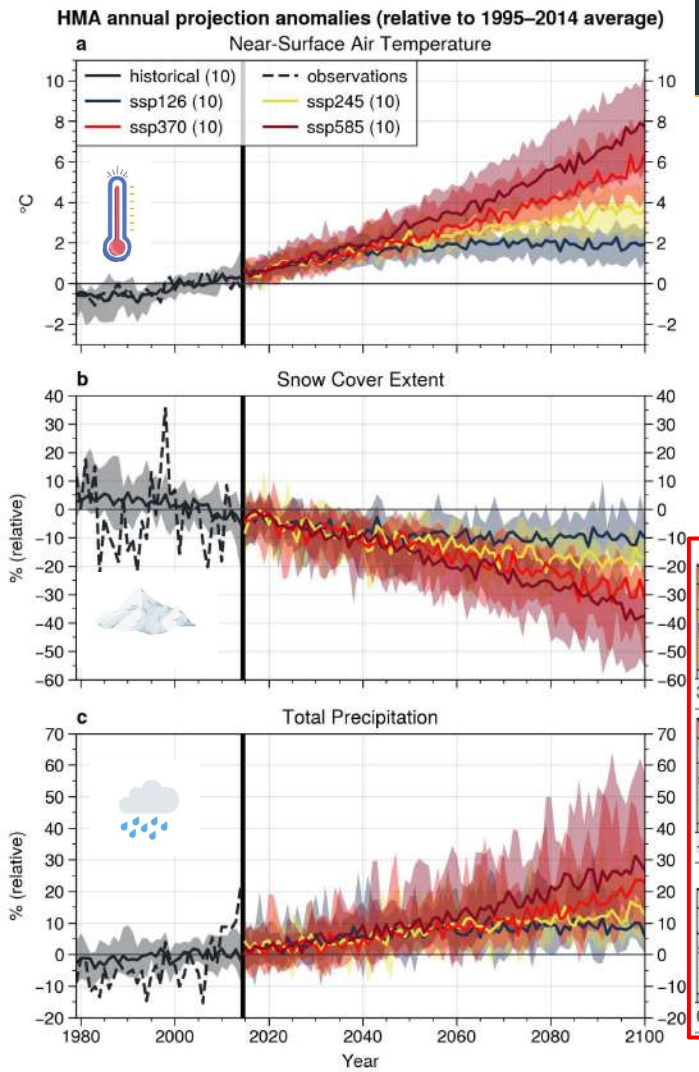

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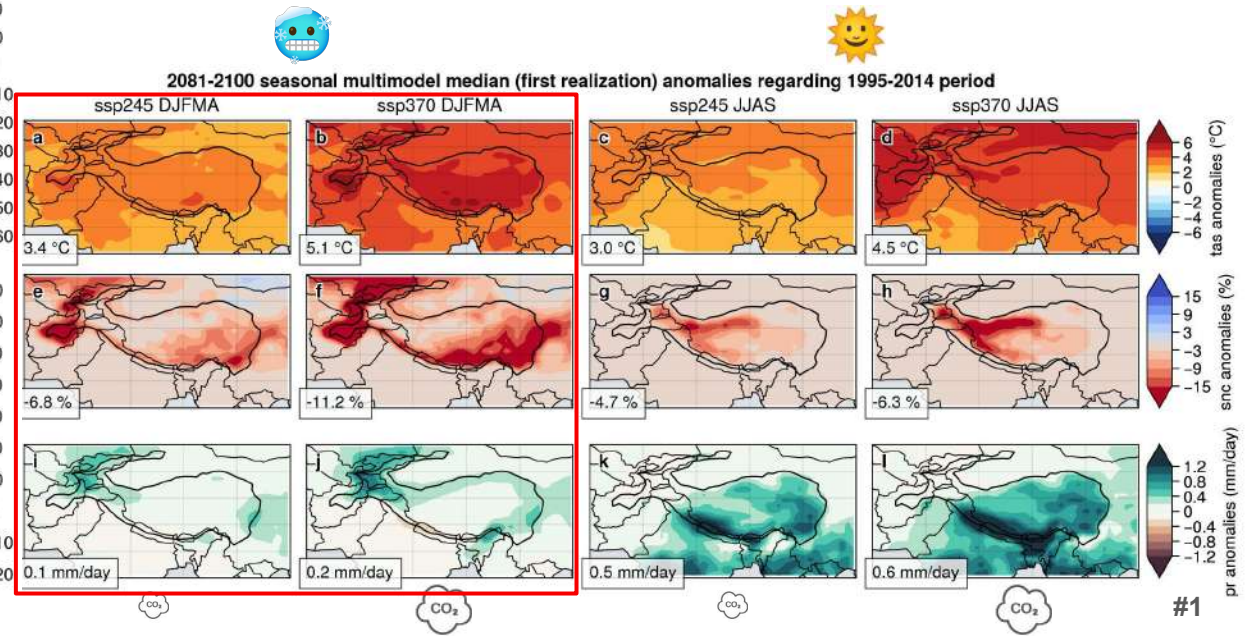

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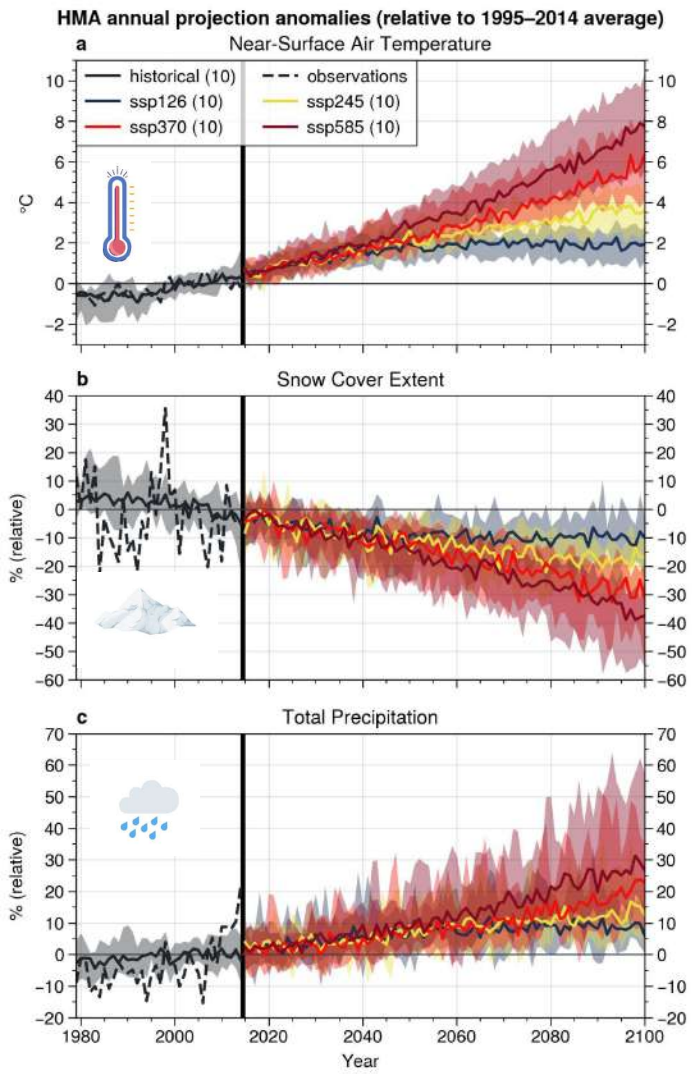

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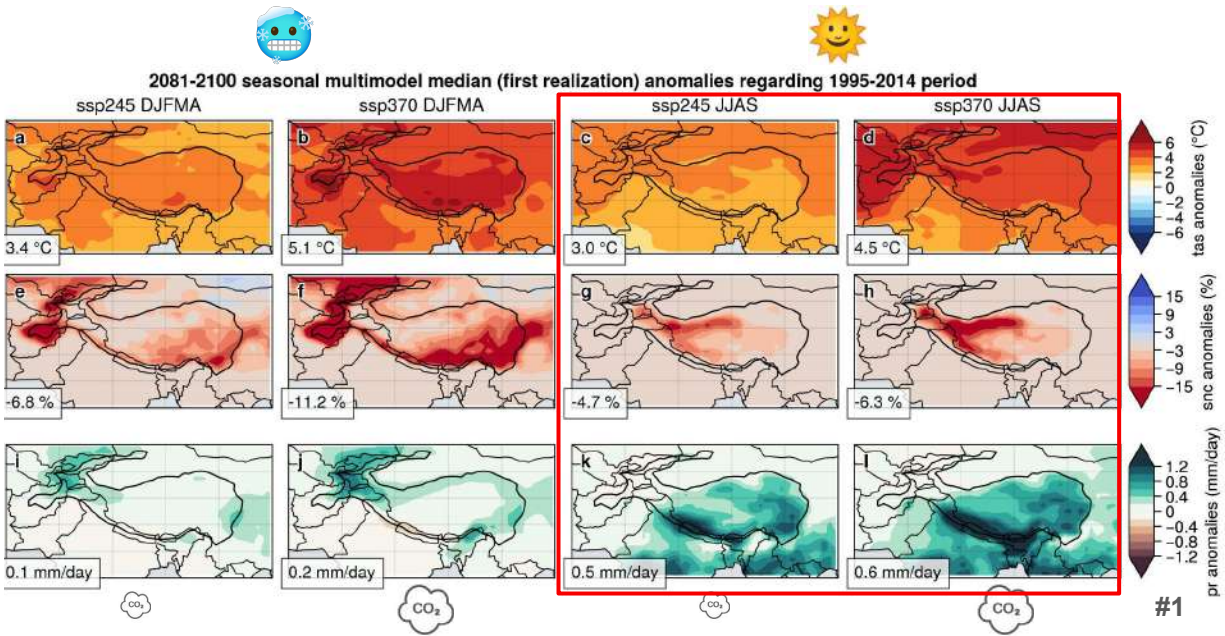

Take-home messages

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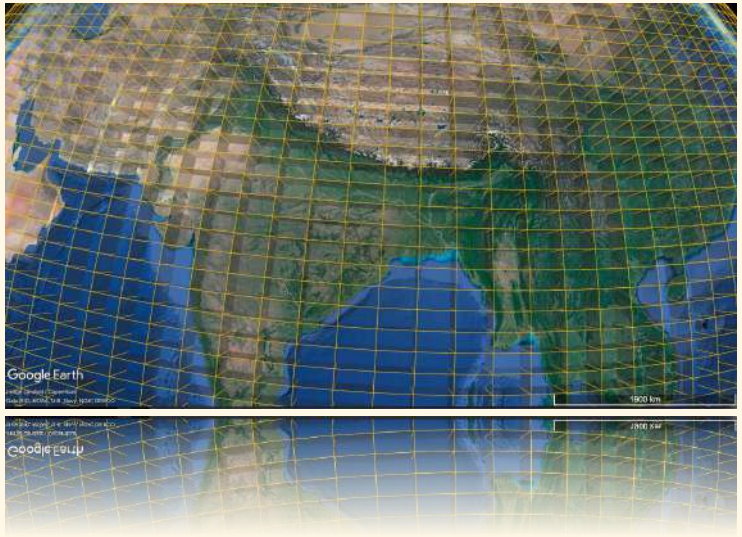
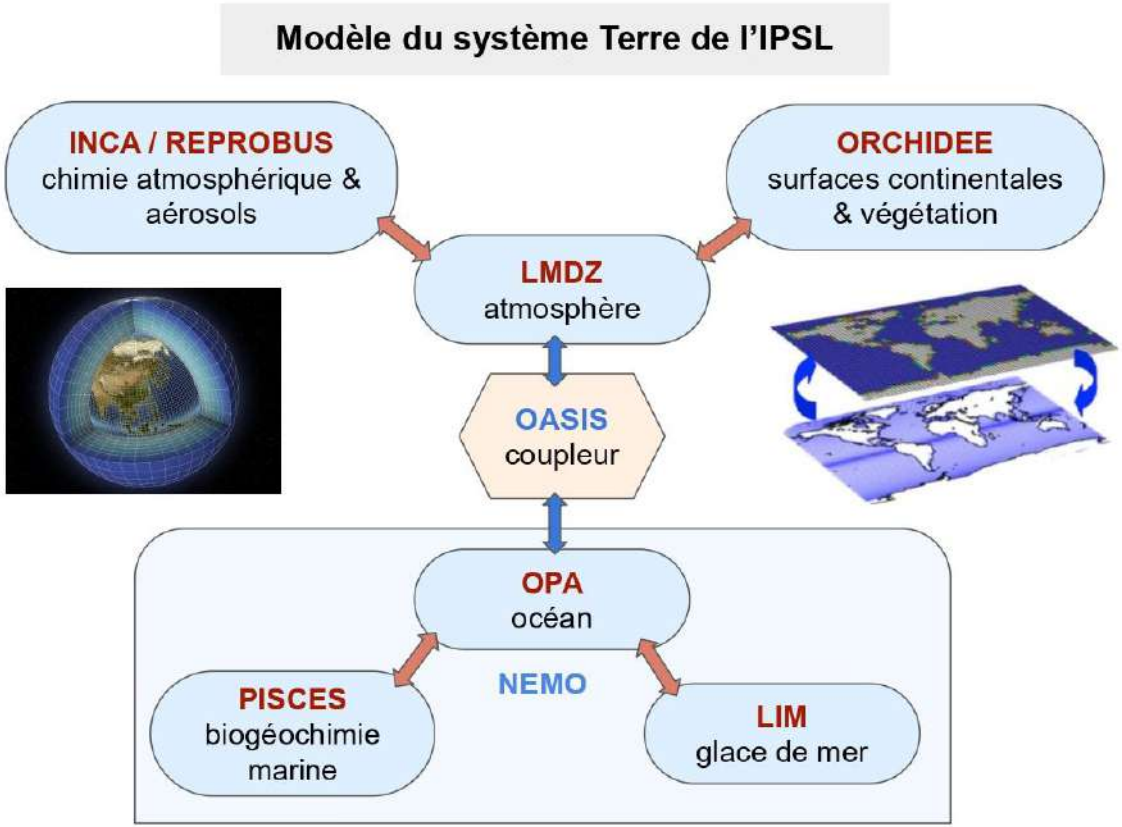
- Annual projections (2081-2100 with respect to 1995-2014 average with 10 GCMs):
  - median warming from 1.9 °C to 6.5 °C
  - relative median snc decrease from -9.4 % to -32.2 %
  - relative median pr increase from 8.5 % to 24.9 %

Partie #2

Description et évaluation du modèle de l'IPSL en HMA



Modèle du système Terre de l'IPSL



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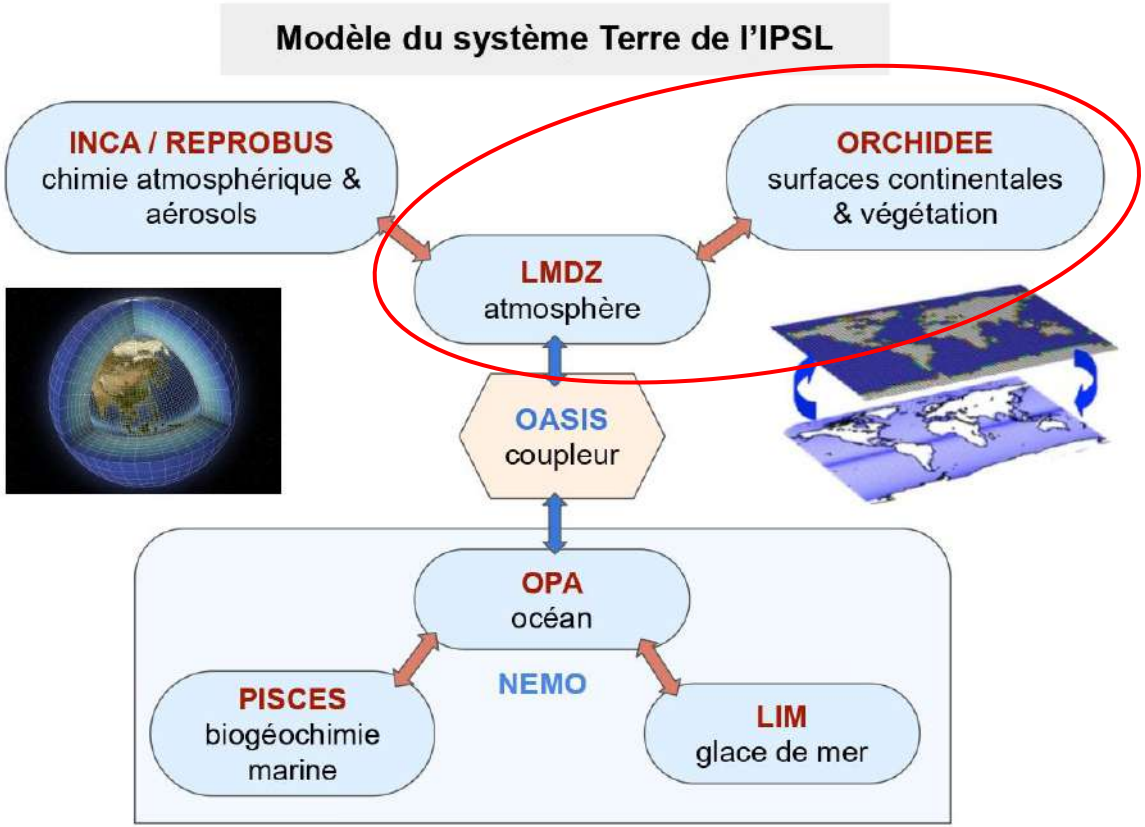

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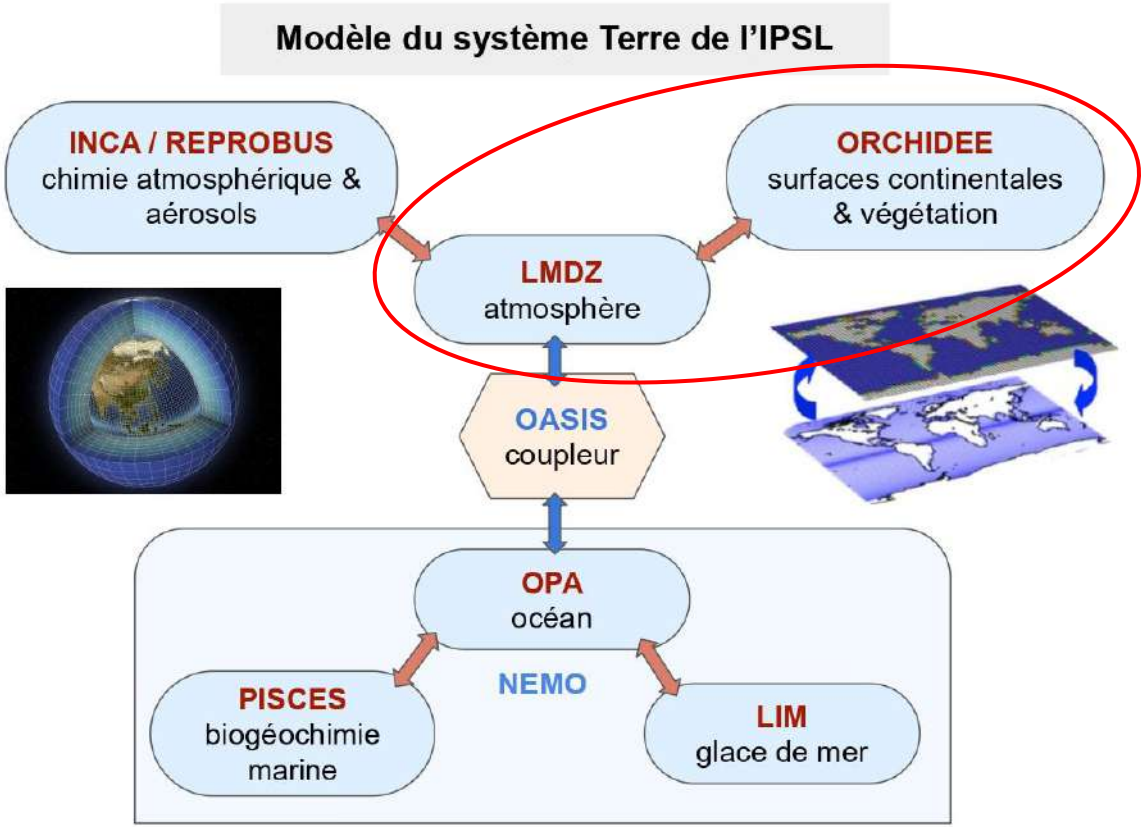
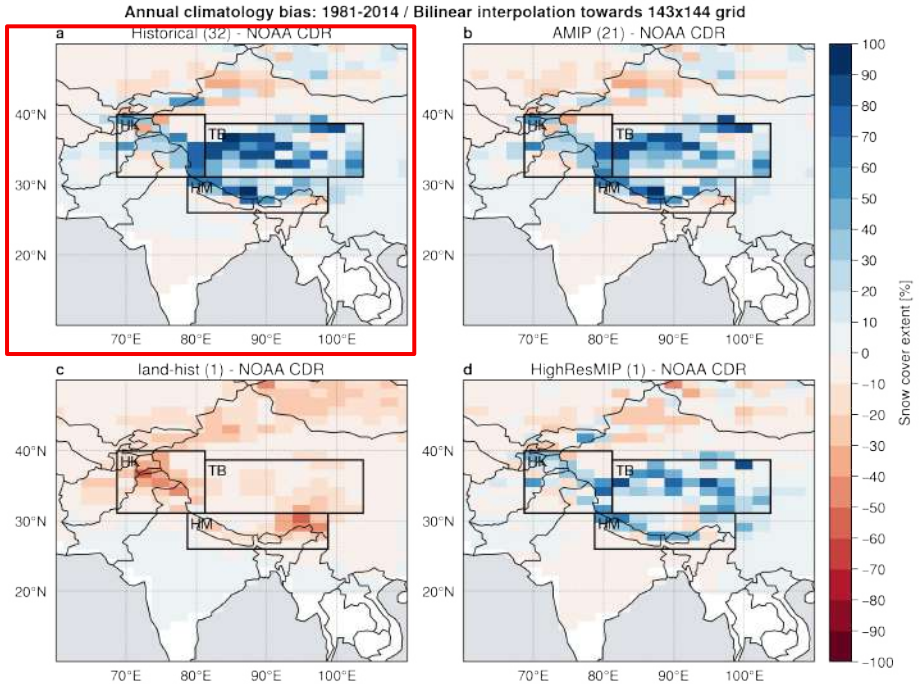
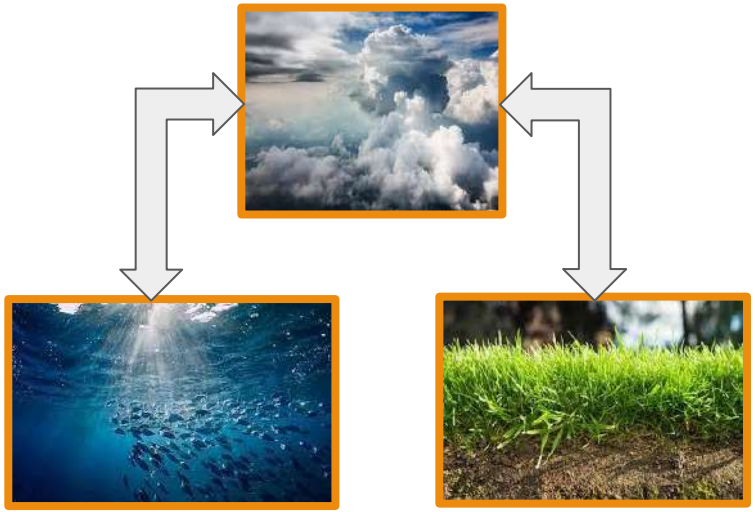


- Version 6A-LR (CMIP6) :
  - 144 x 142 (points de grille lon / lat)
  - ~ 2,5° x 1,25°
  - 79 couches verticales (jusqu'à ~80 km d'altitude)
  - pas de temps de la physique : 15 min
- Version 6A-HR (CMIP6) :
  - 360 x 180 (points de grille lon / lat)
  - ~ 0,5° x 0,5°
  - pas de temps de la physique : 3,75 min

IPSL-CM6A-LR: Historical, AMIP, land-hist / IPSL-CM6A-ATM-HR bias

Snow cover bias





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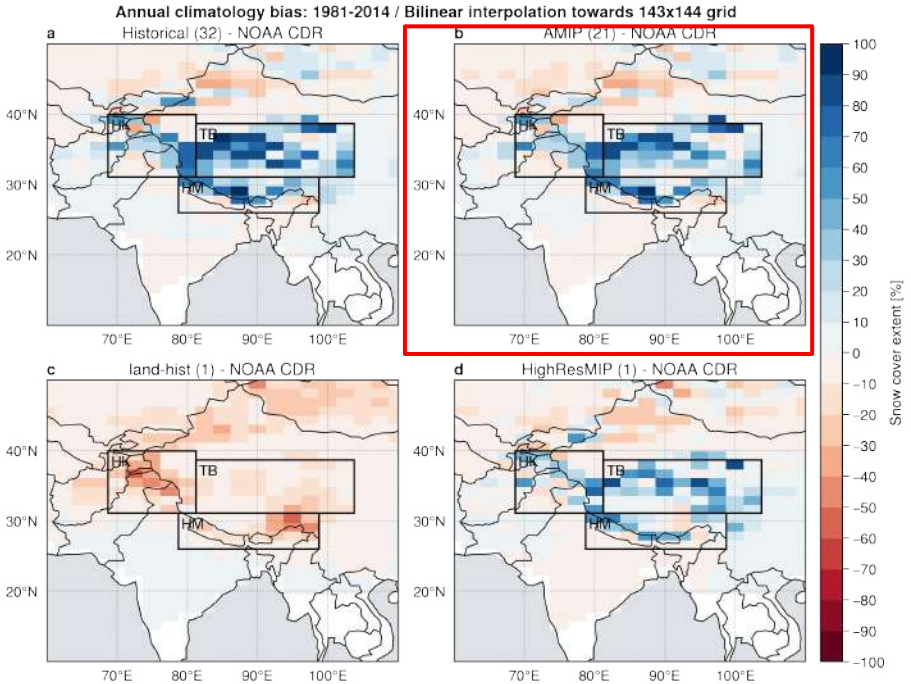
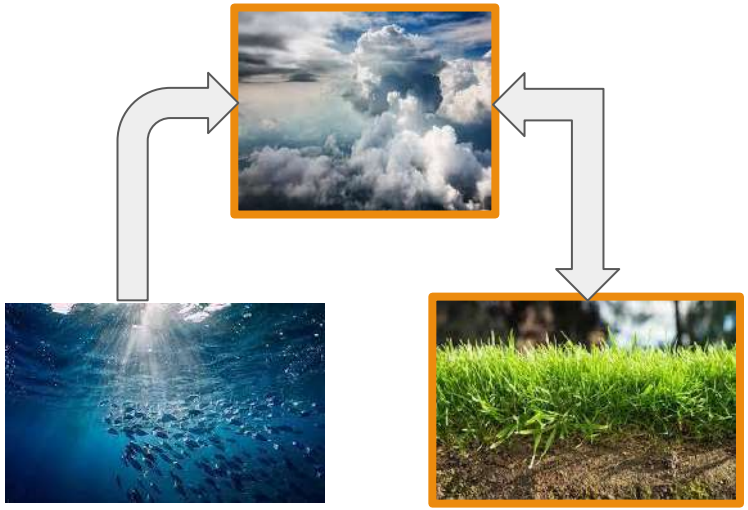
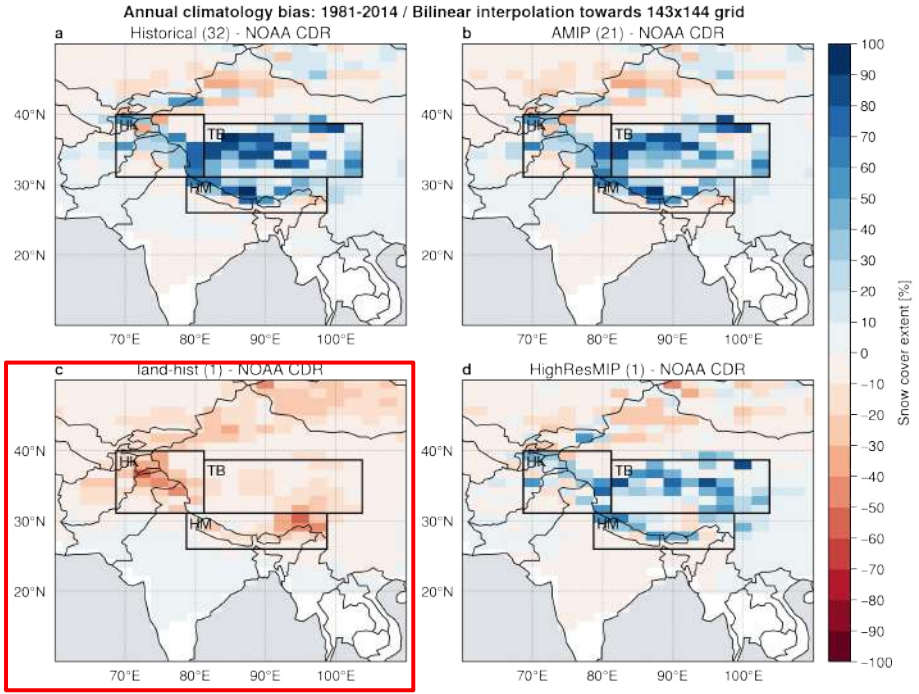
Snow cover bias

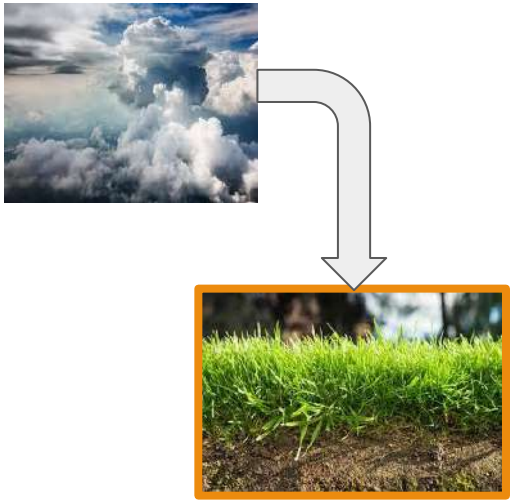




IPSL-CM6A-LR: Historical, AMIP, land-hist / IPSL-CM6A-ATM-HR bias

Snow cover bias





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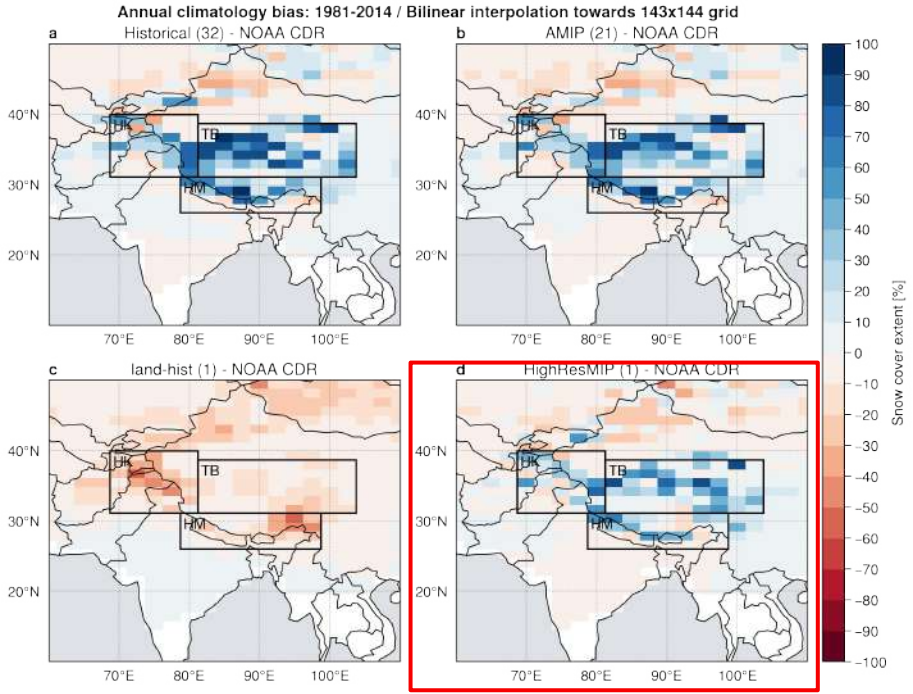
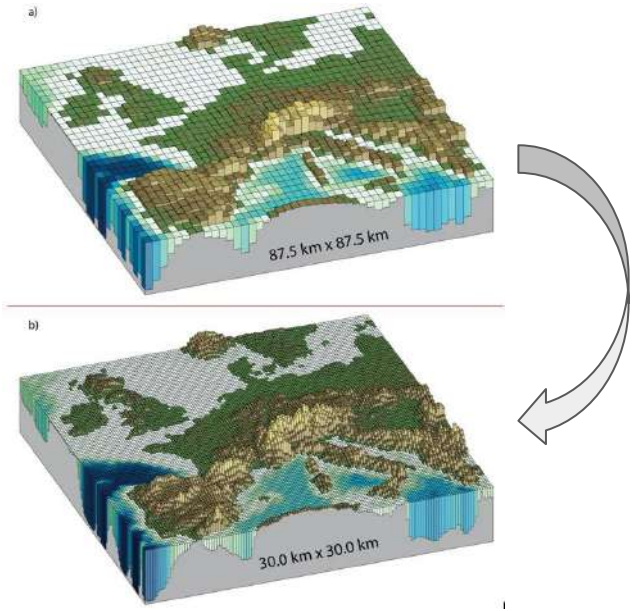
Snow cover bias





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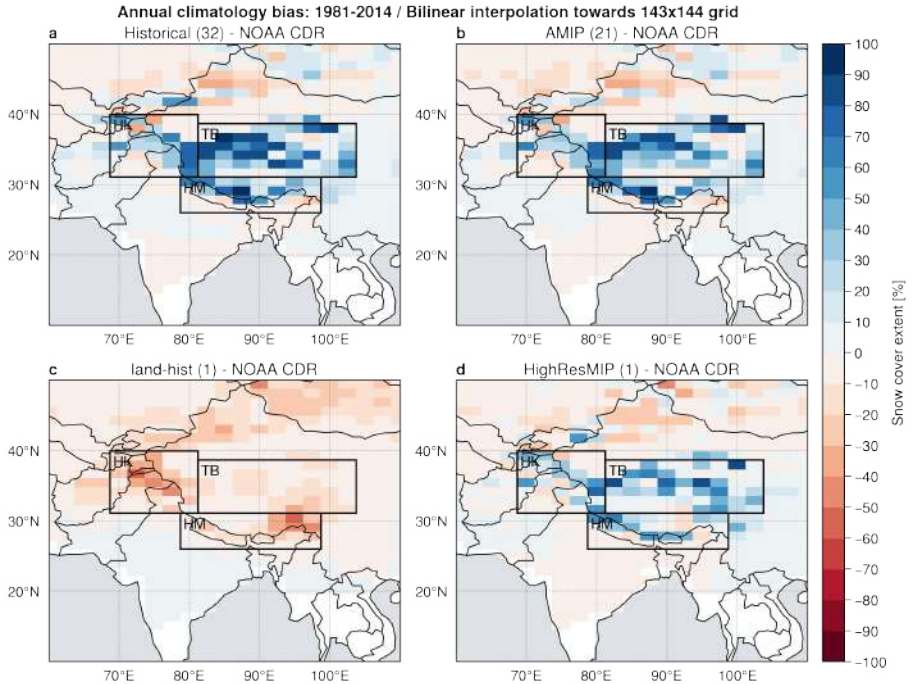
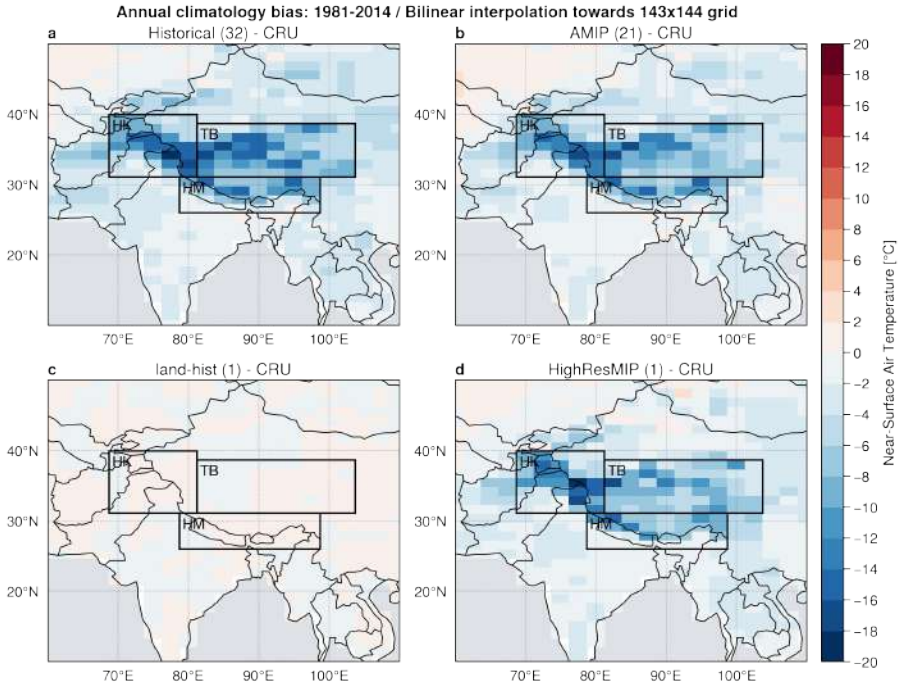


Temperature bias



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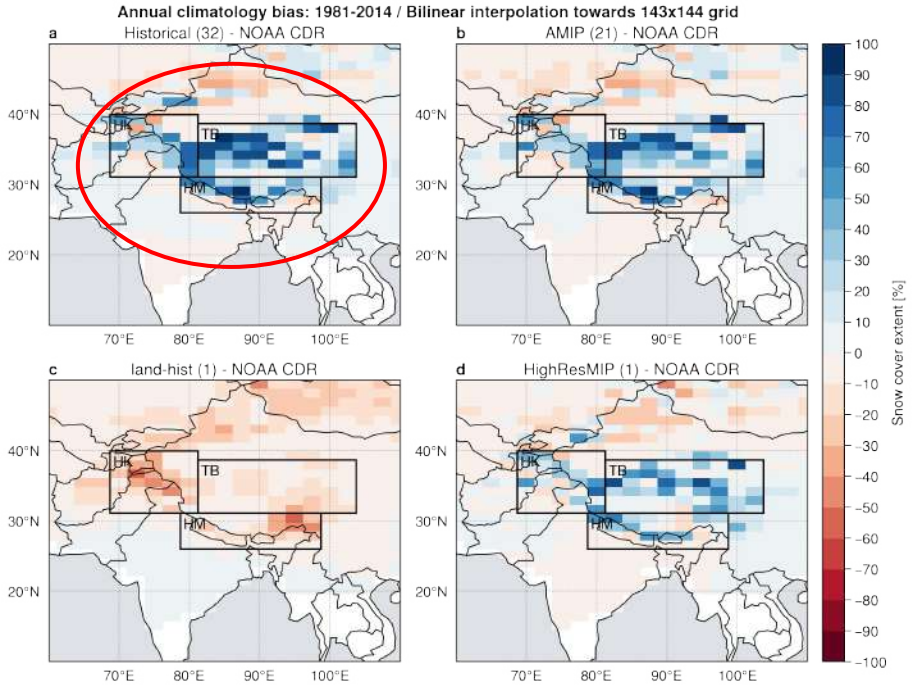
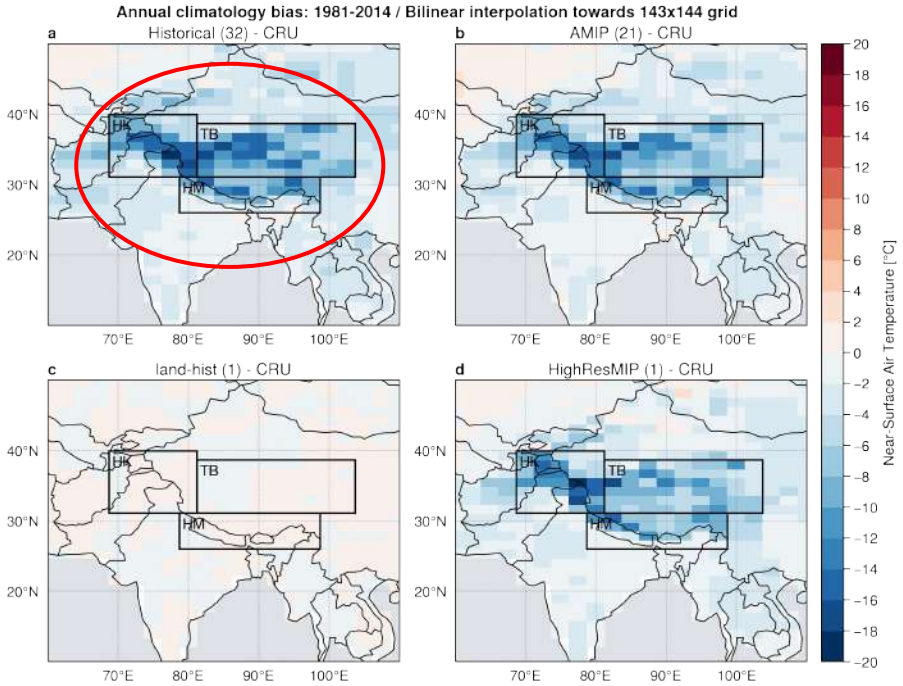
Snow cover bias



Temperature bias



- Large cold bias (up to -20 °C) and excess of snow cover (> 50 %) mainly located on the Tibetan Plateau

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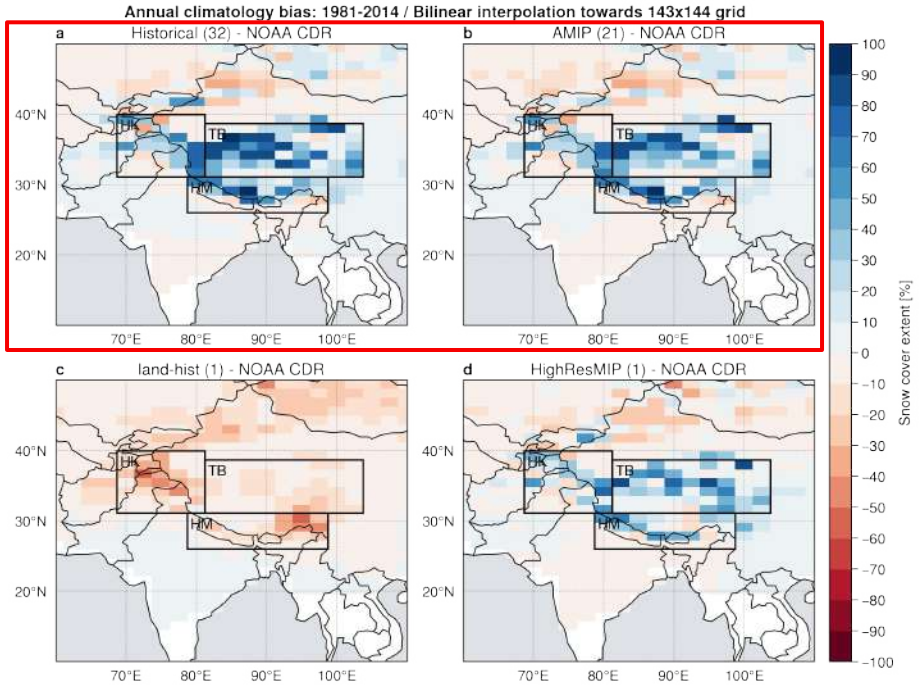
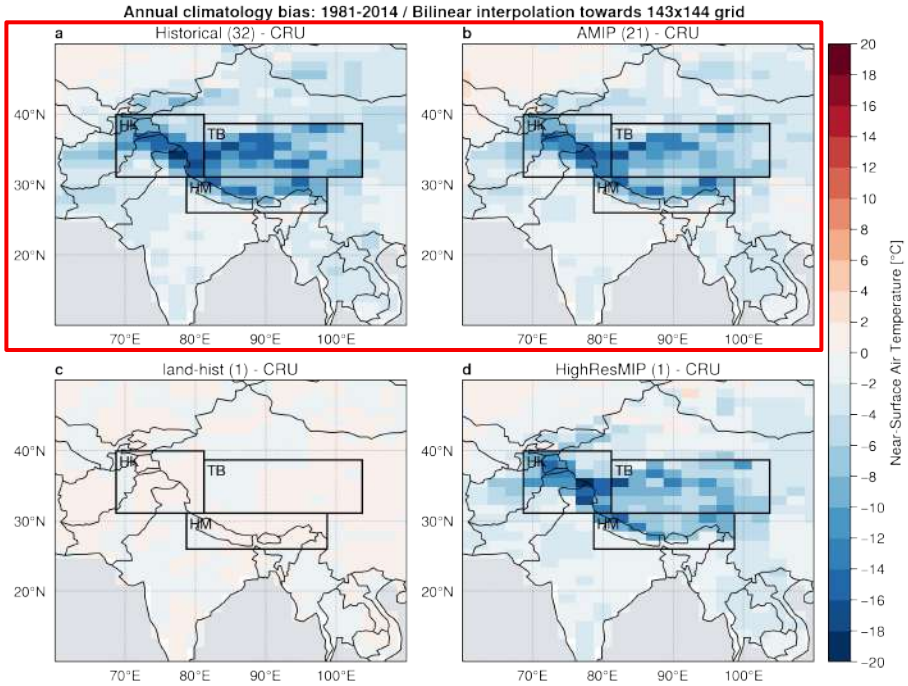
Snow cover bias



Temperature bias



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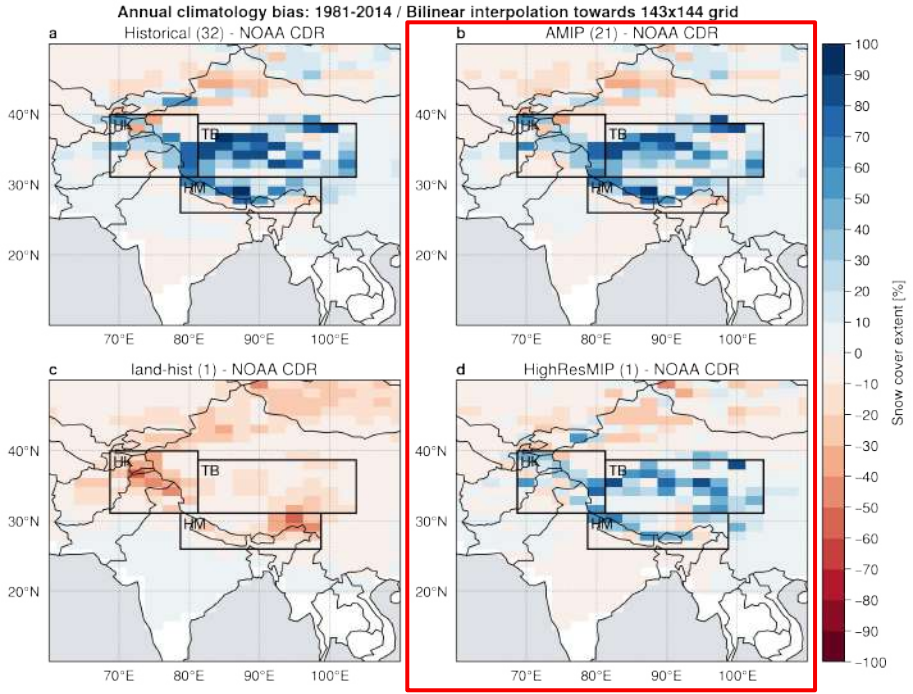
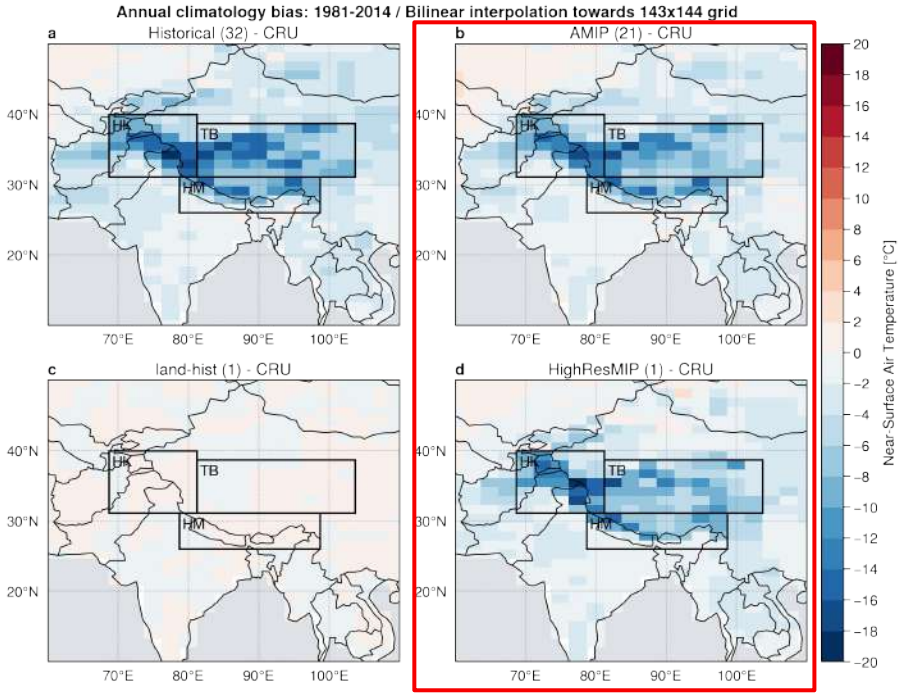


Temperature bias



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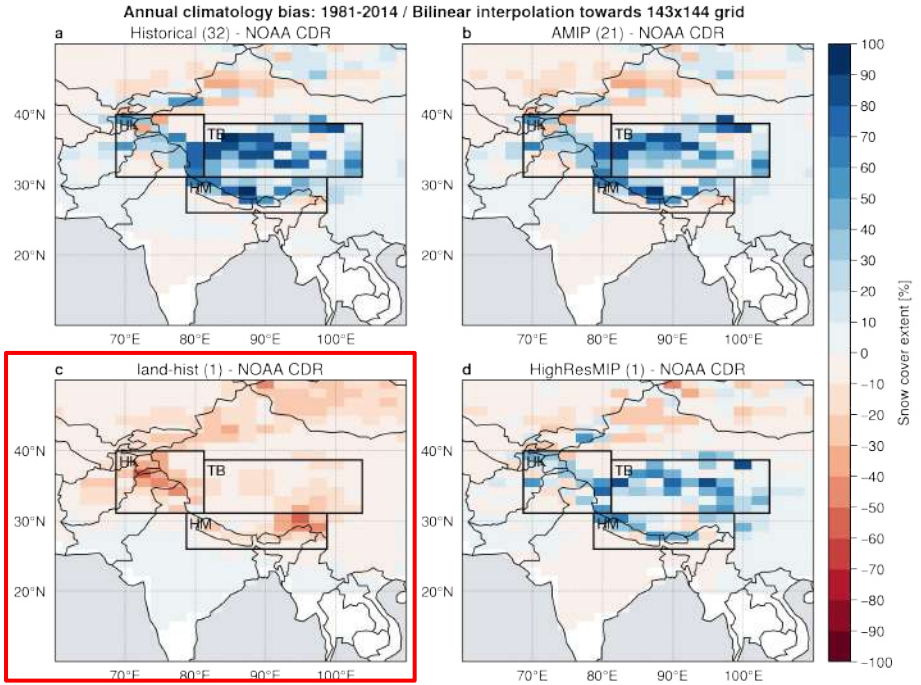
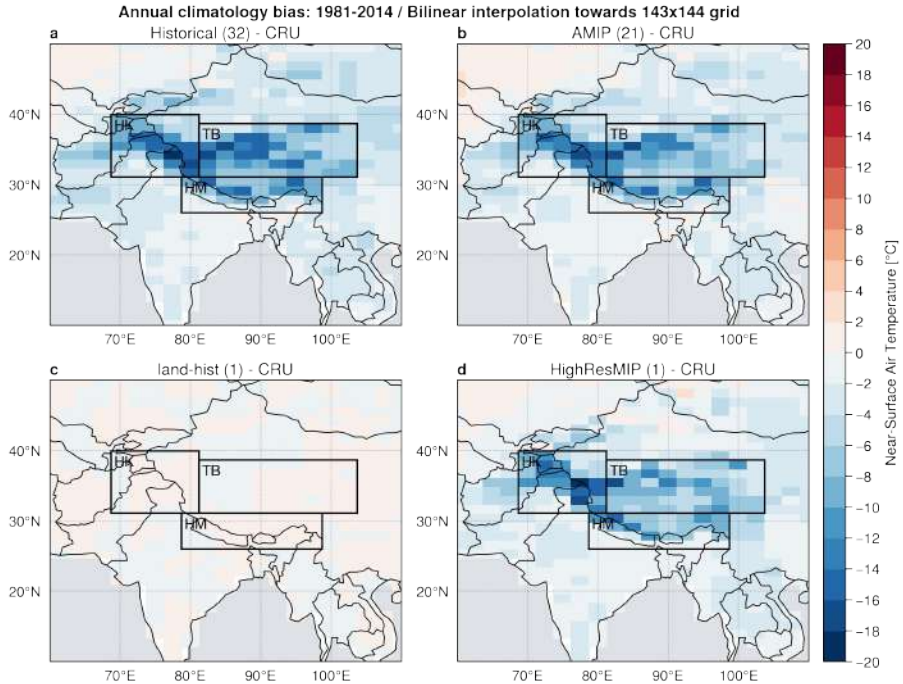
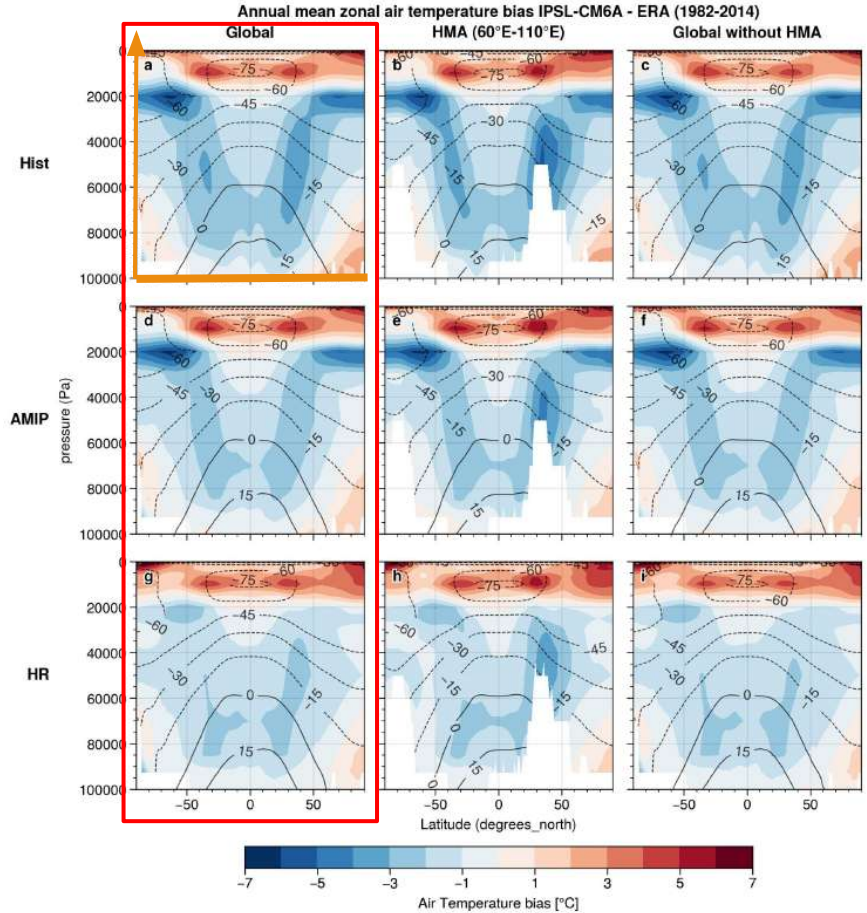


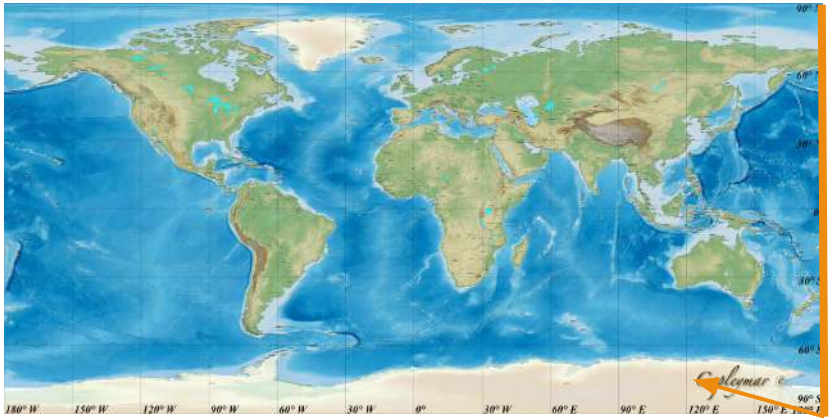
Temperature bias



- Large cold bias (up to -20 °C) and excess of snow cover (> 50 %) mainly located on the Tibetan Plateau
  - Historical / AMIP similar and reduced biases in HighResMIP
- land-hist slightly underestimate the snow cover (/!\ poor quality of atmospheric forcing? /!\)

Air Temperature zonal means bias global versus HMA





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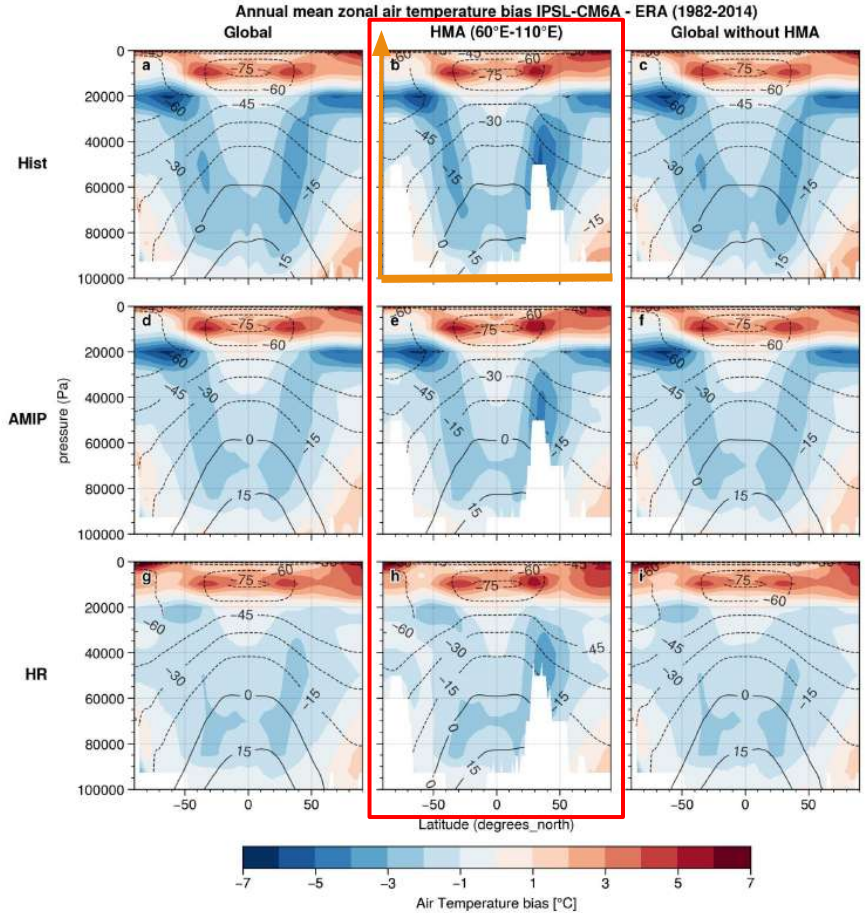

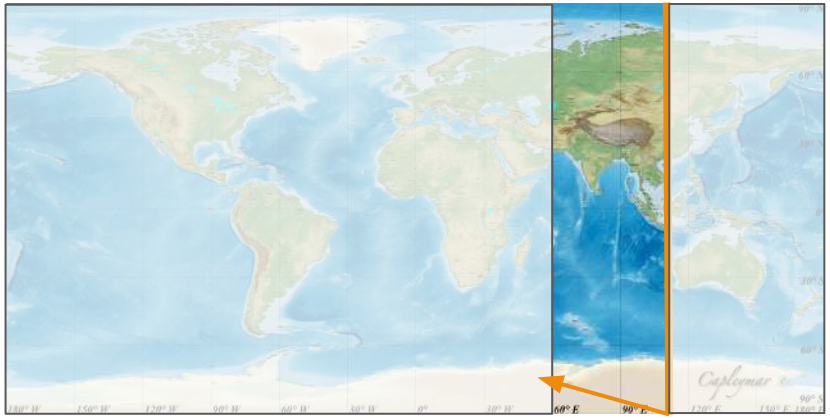

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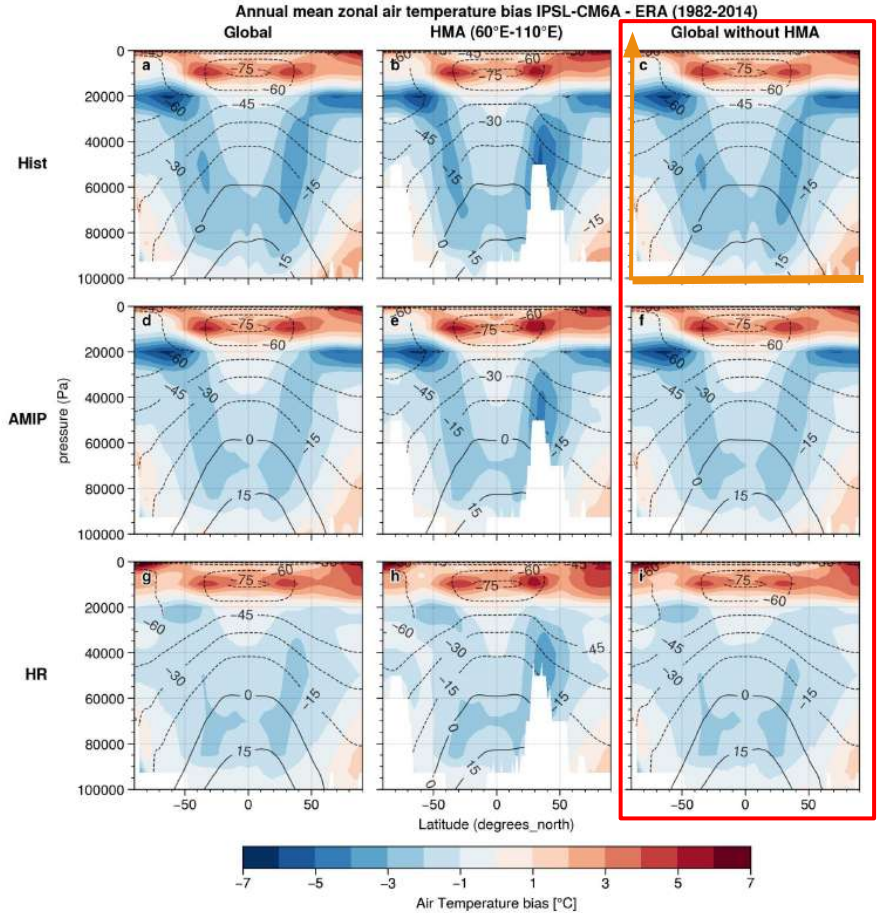

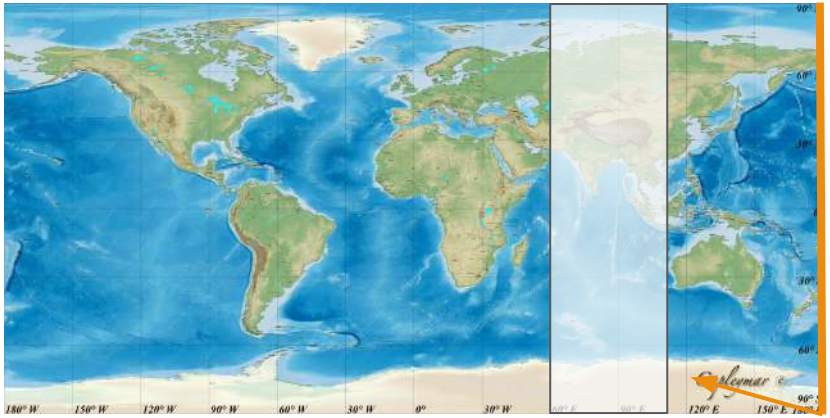

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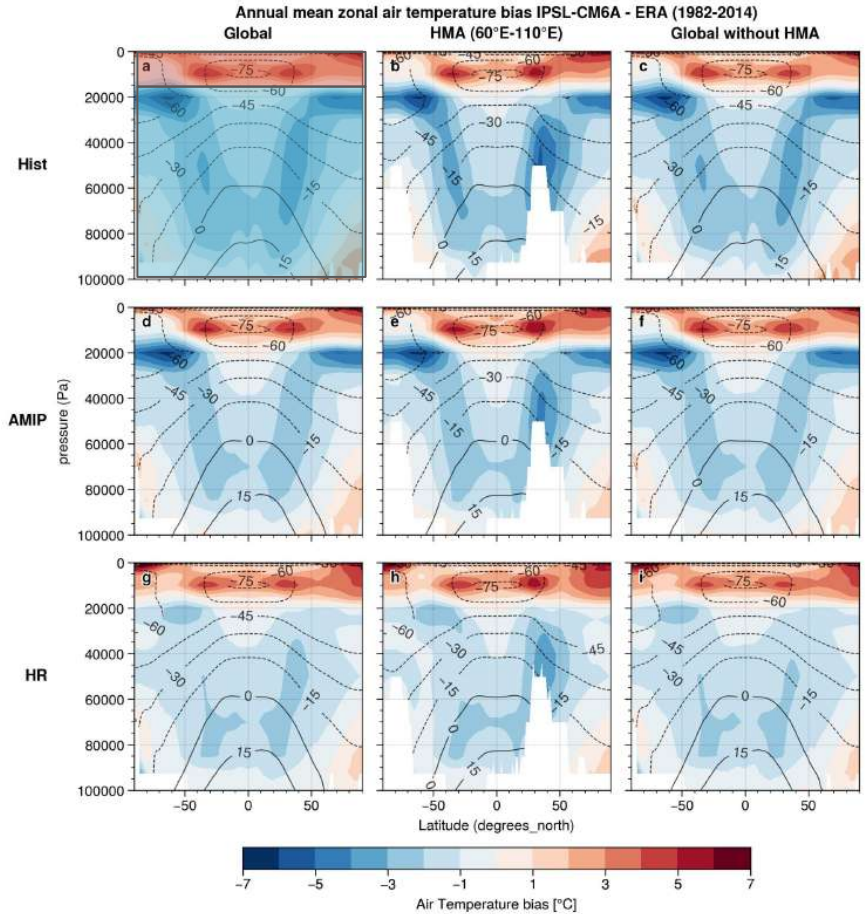
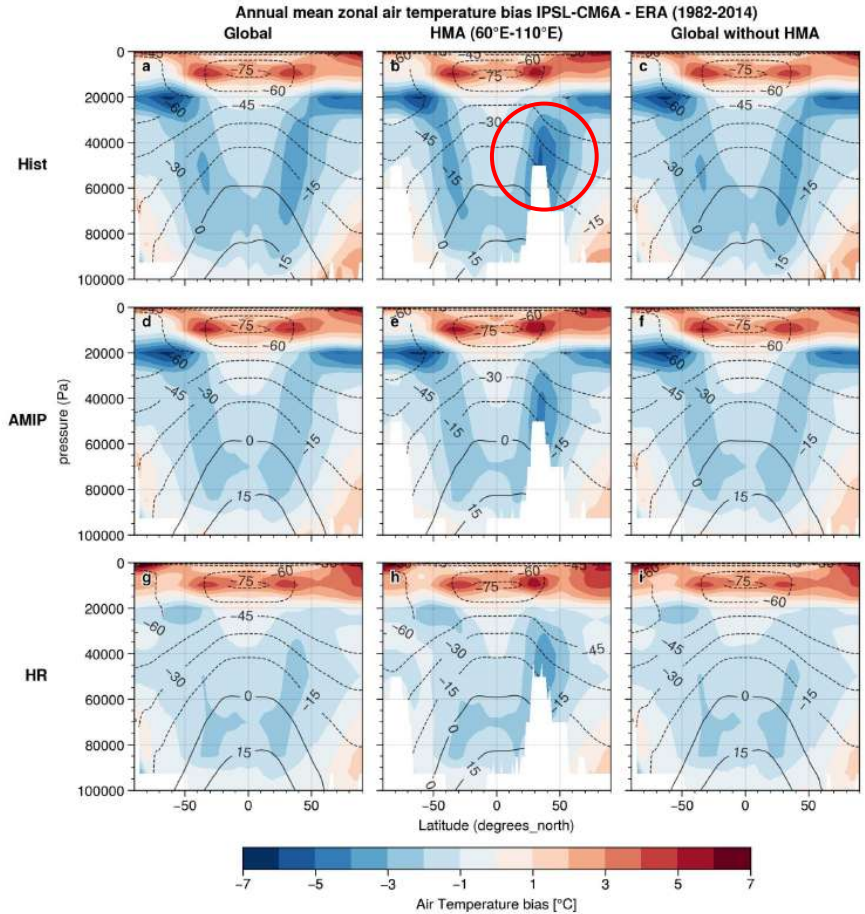


- Cold bias in troposphere and hot bias in stratosphere

Air Temperature zonal means bias global versus HMA



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  - HMA seems to amplify this bias

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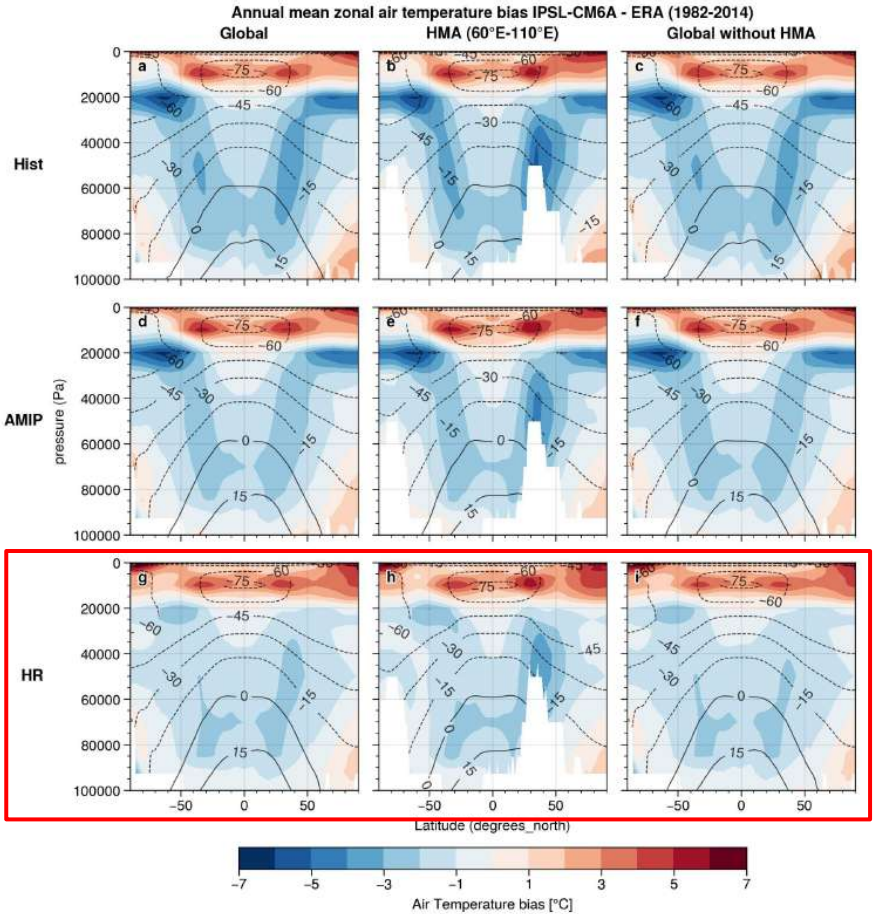

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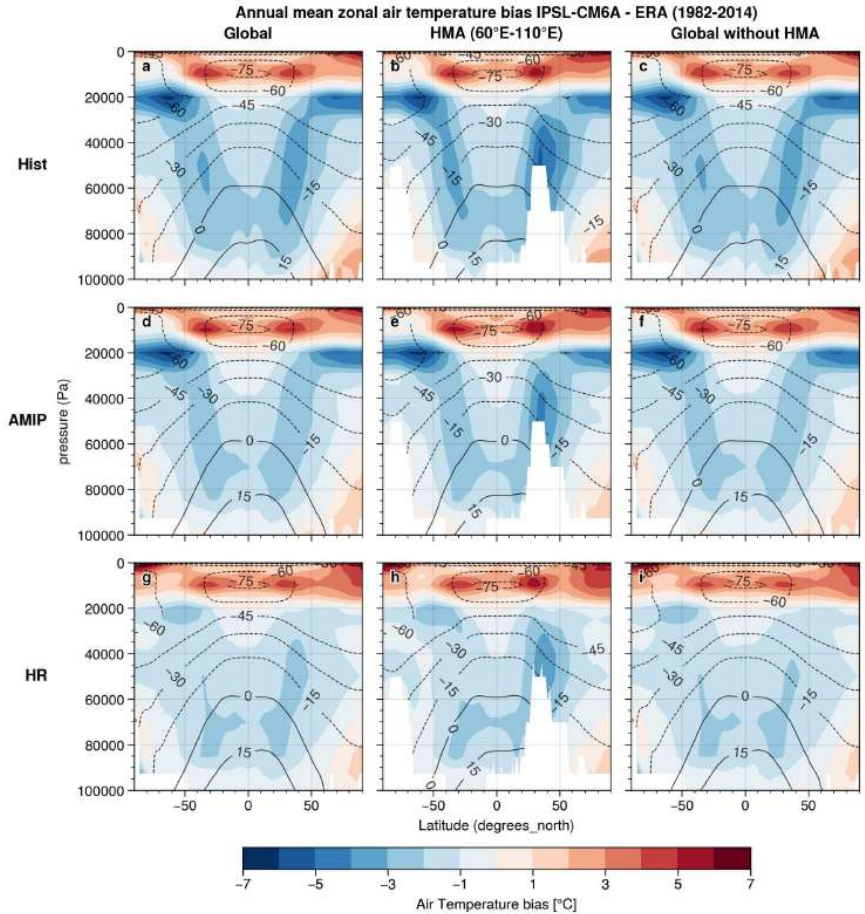

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Questions

1. Does the surface biases trigger tropospheric biases?
2. Are the tropospheric biases responsible of surface biases?

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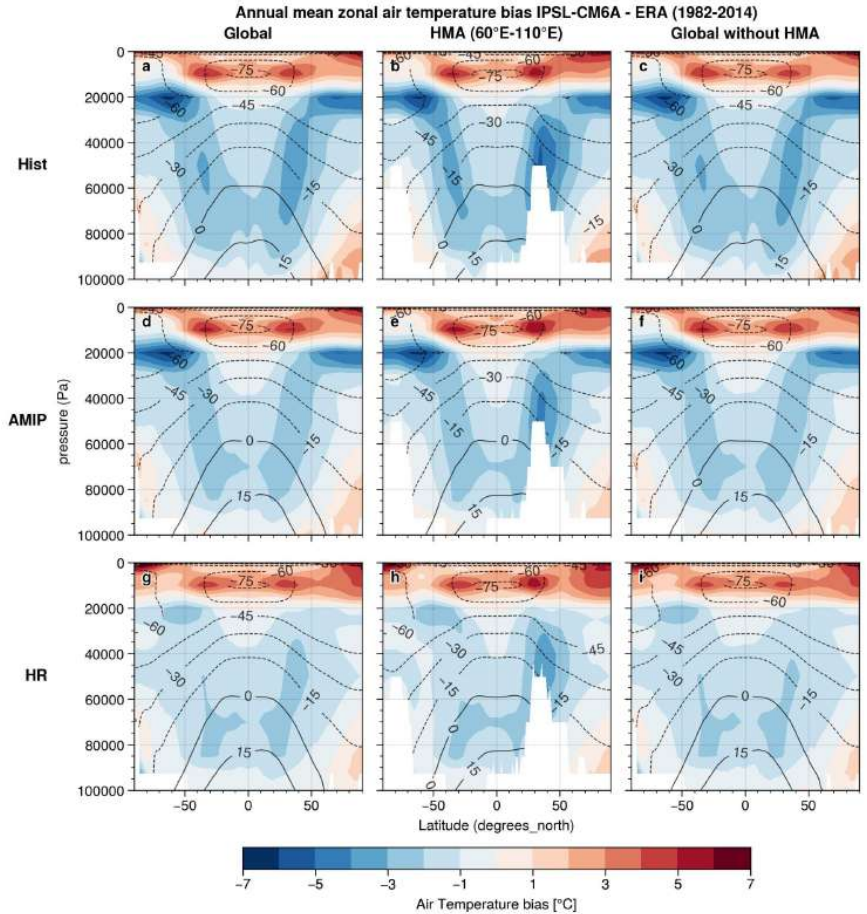

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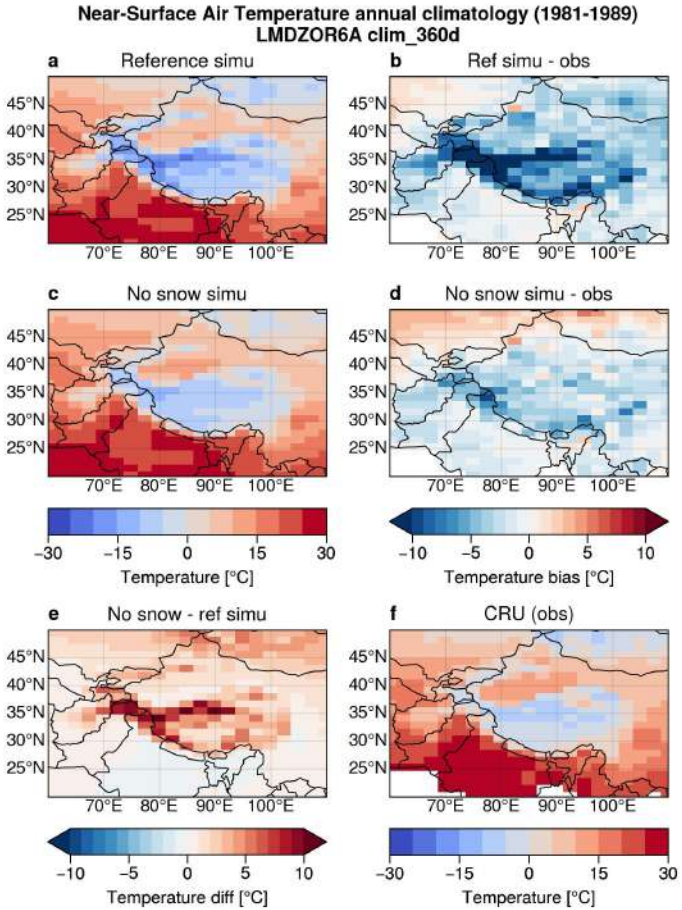
Experiments

1. Experience without snow
2. Nudged experiments (temperature and wind)

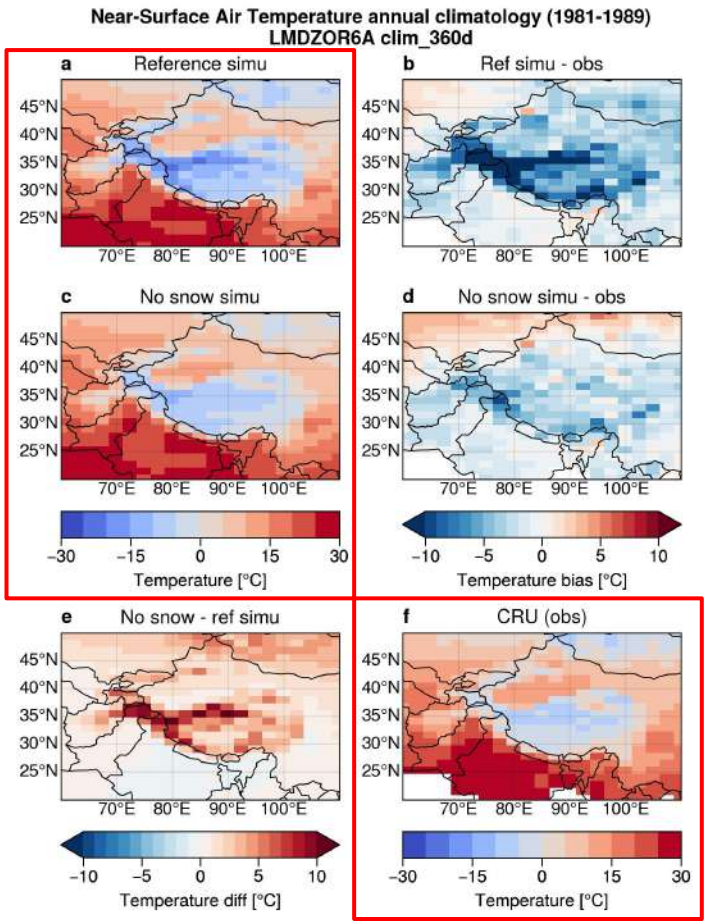
Impact de la surface : expérience sans neige



Impact de la surface : expérience sans neige

avec neige

sans neige

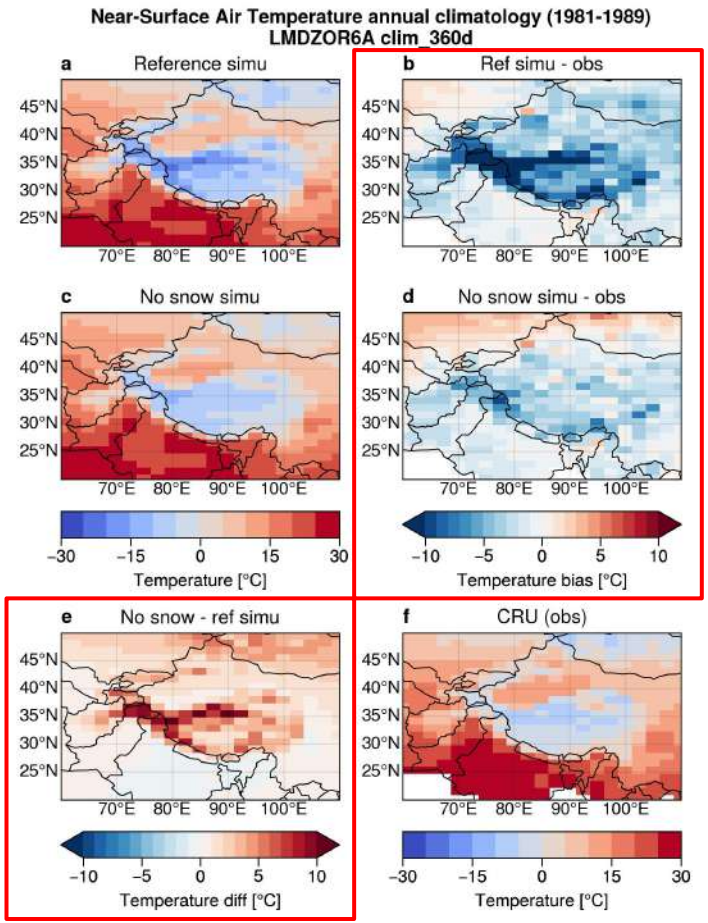


obs

Impact de la surface : expérience sans neige

avec neige

sans neige



obs

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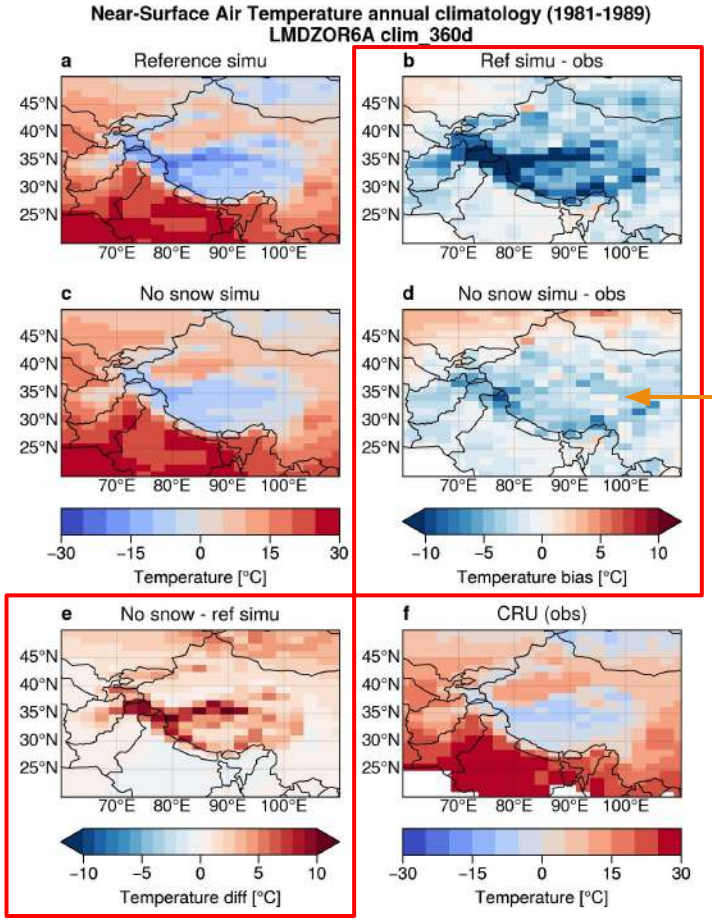


avec neige

sans neige

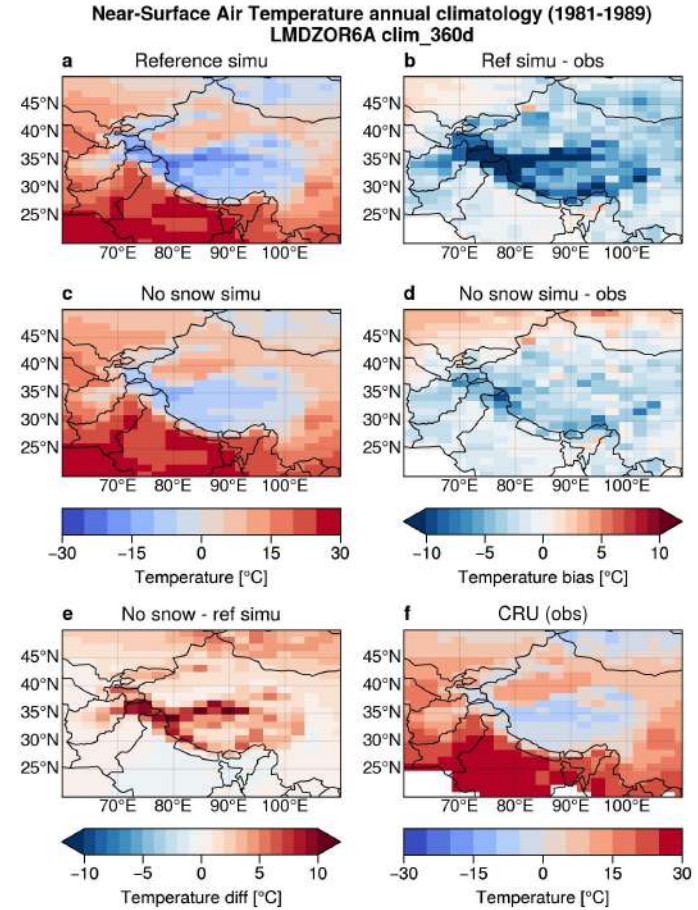
obs

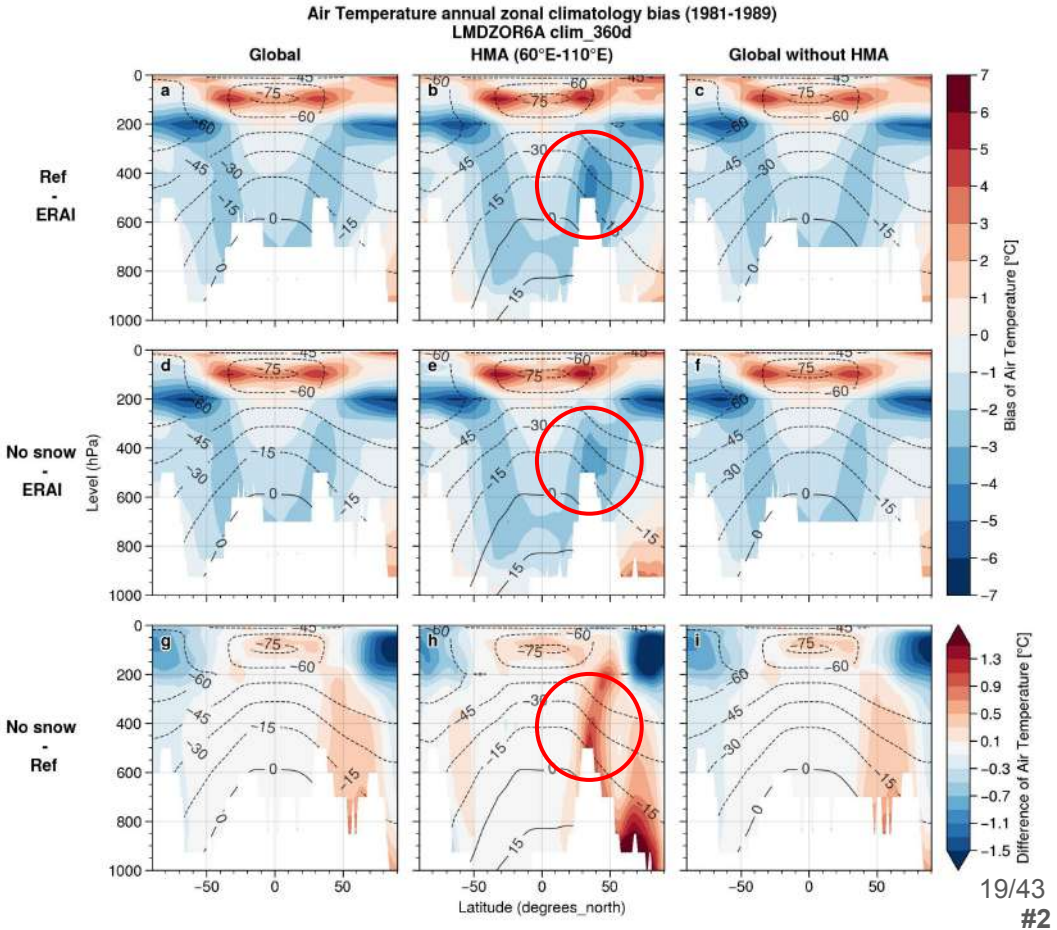
bias froid persistant même sans neige!

Impact de la surface : expérience sans neige

avec neige

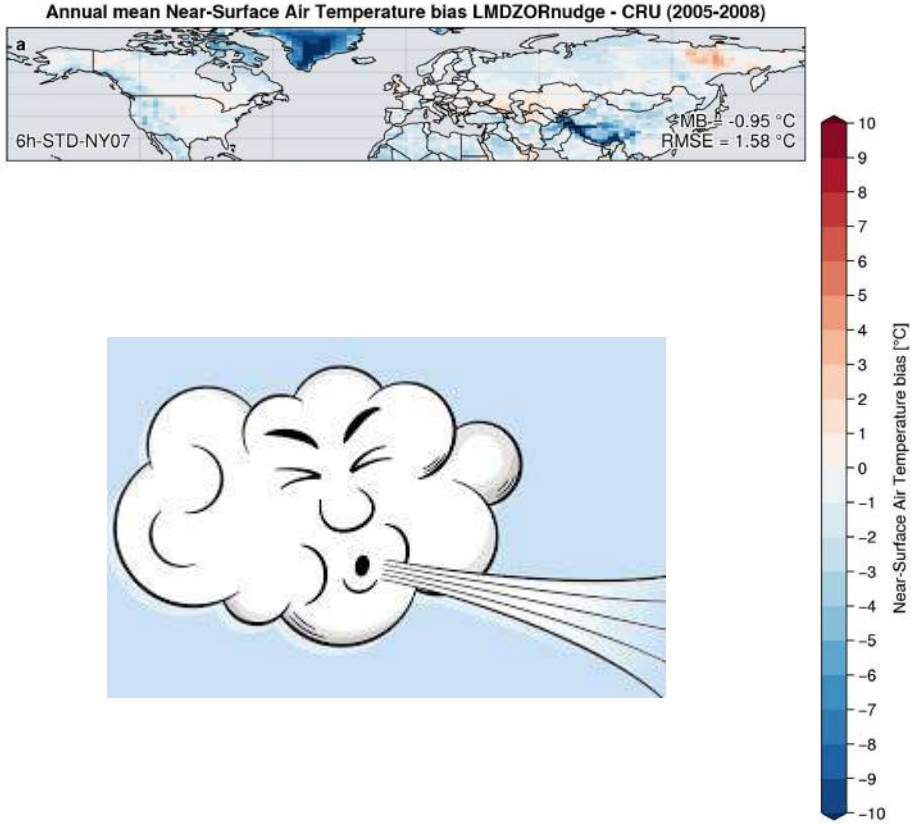
sans neige

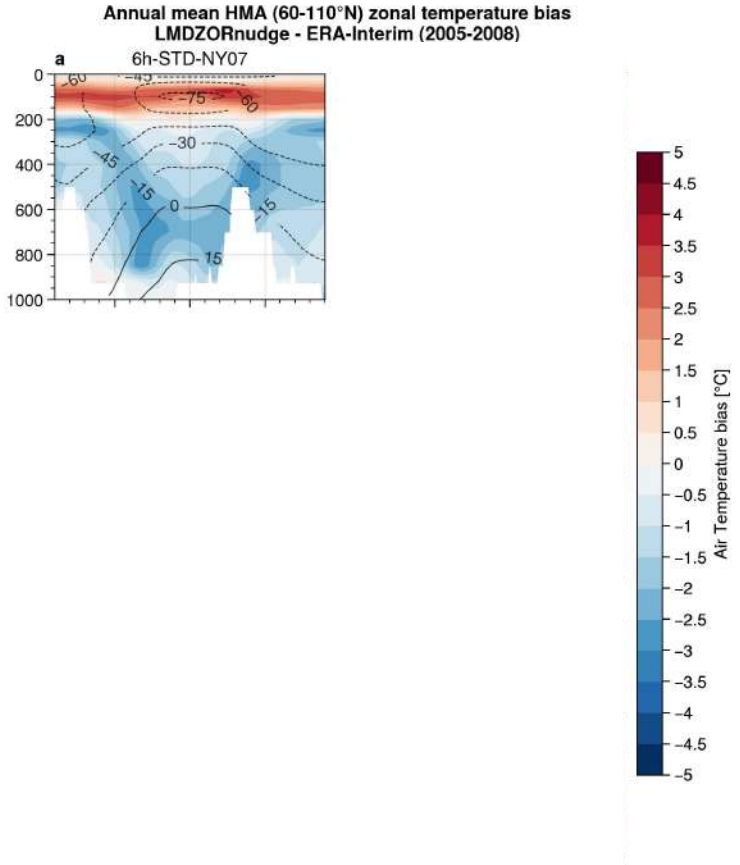




Réduction du biais troposphérique : expérience guidées

6h u, v

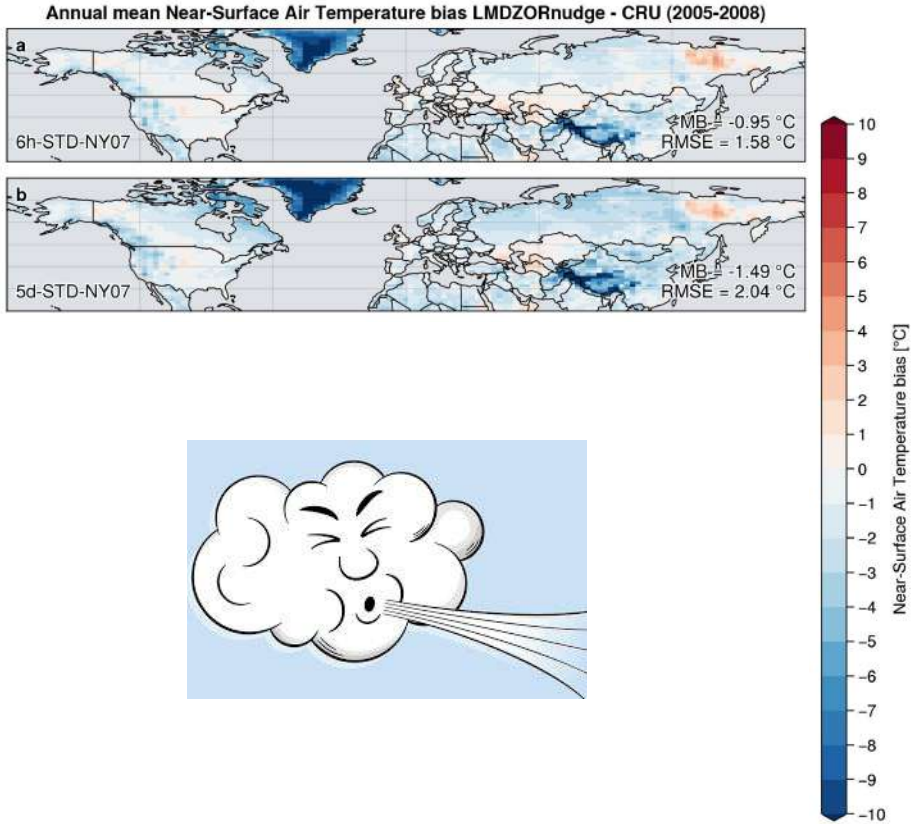


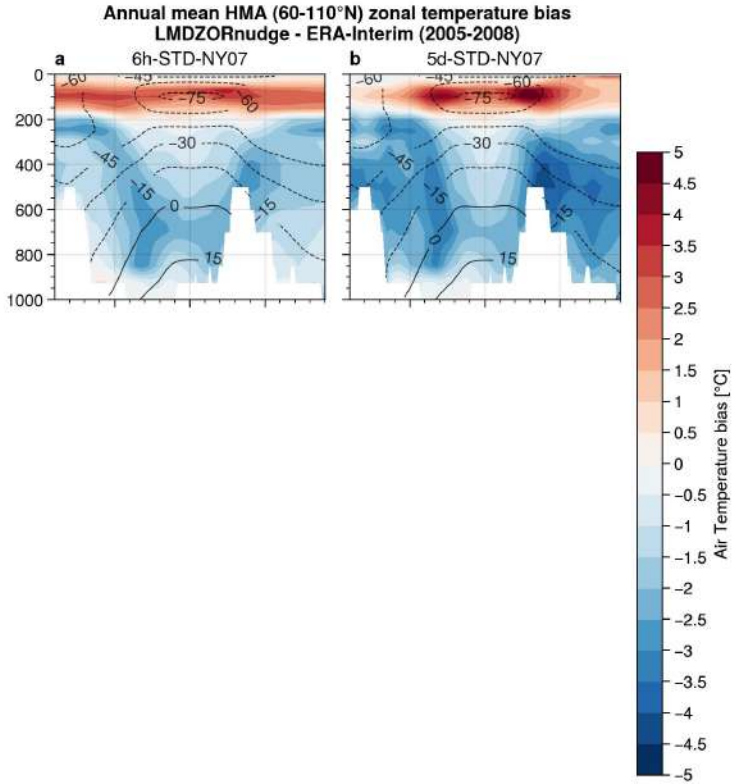


Réduction du biais troposphérique : expérience guidées

6h u, v

5j u, v



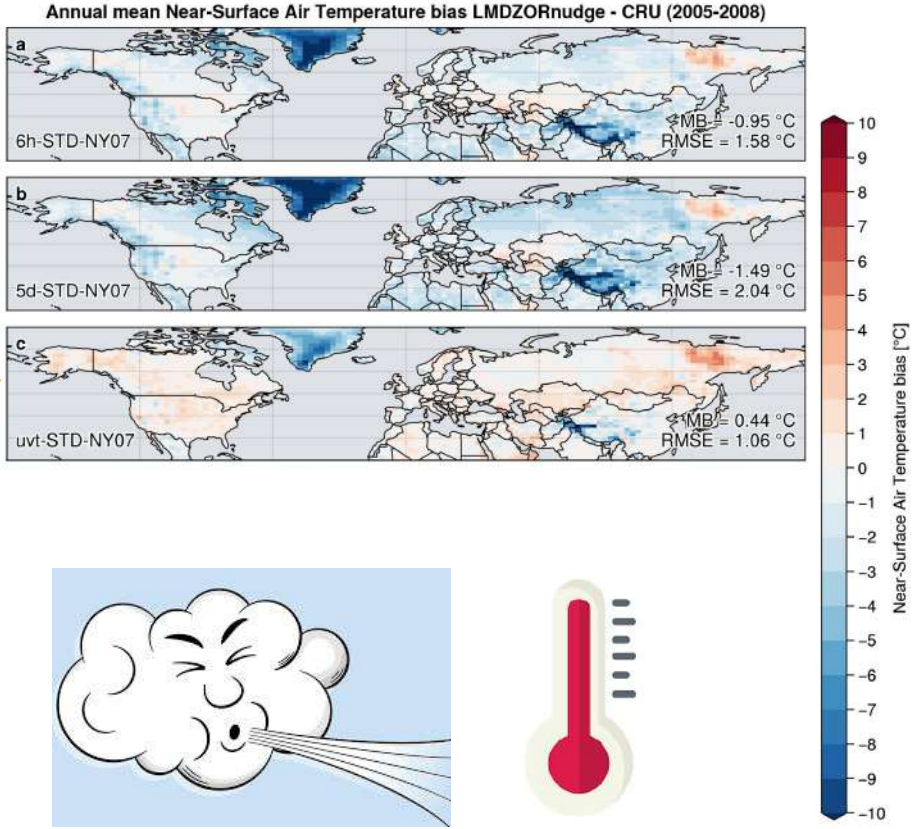


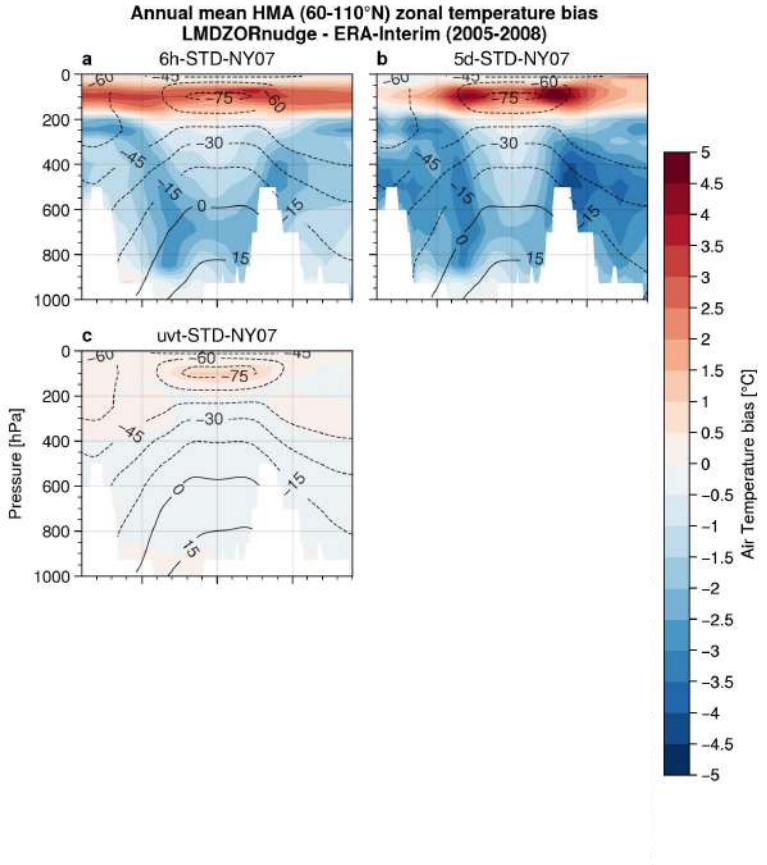
Réduction du biais troposphérique : expérience guidées

6h u, v

5j u, v

3h u, v, T





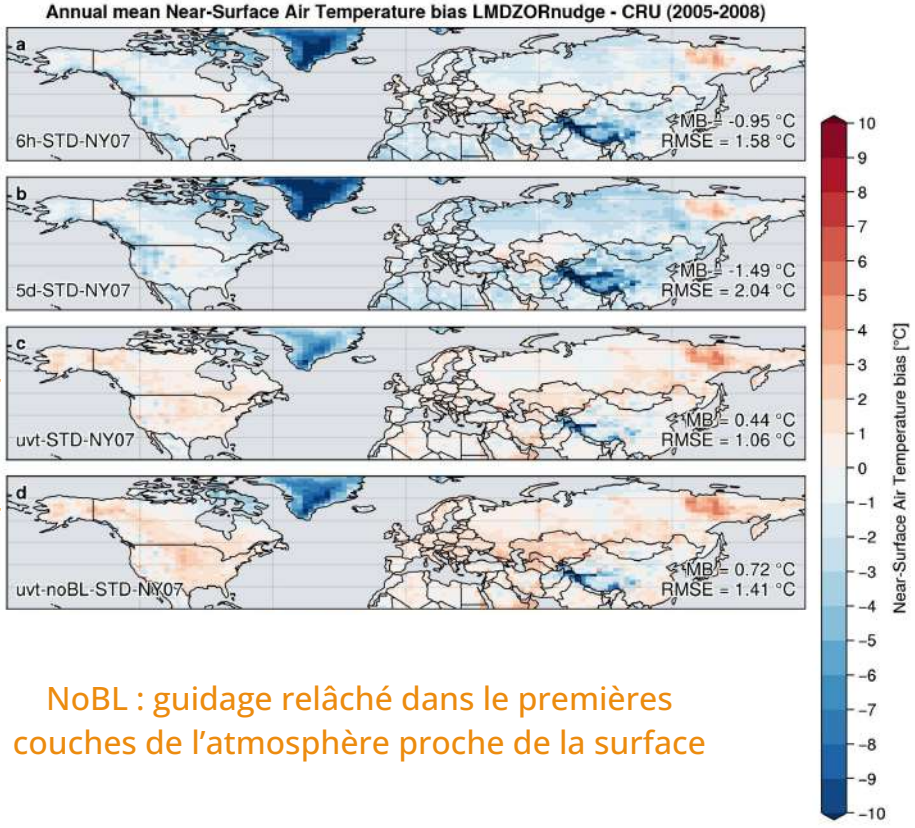
Réduction du biais troposphérique : expérience guidées

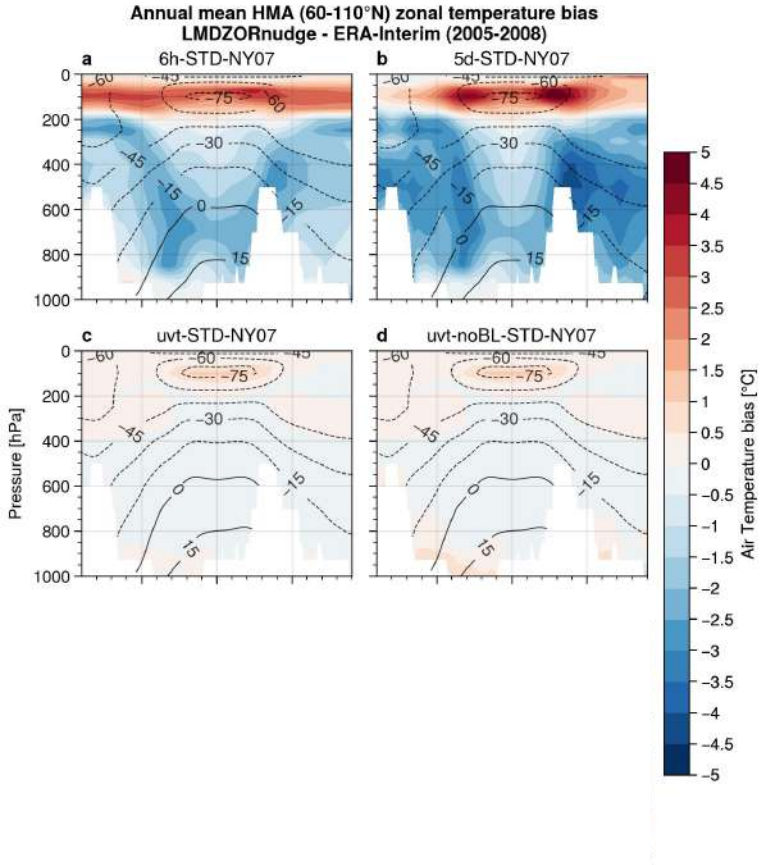
6h u, v

5j u, v

3h u, v, T

3h u, v, T NoBL





NoBL : guidage relâché dans le premières couches de l'atmosphère proche de la surface

Réduction du biais troposphérique : expérience guidées

6h u, v

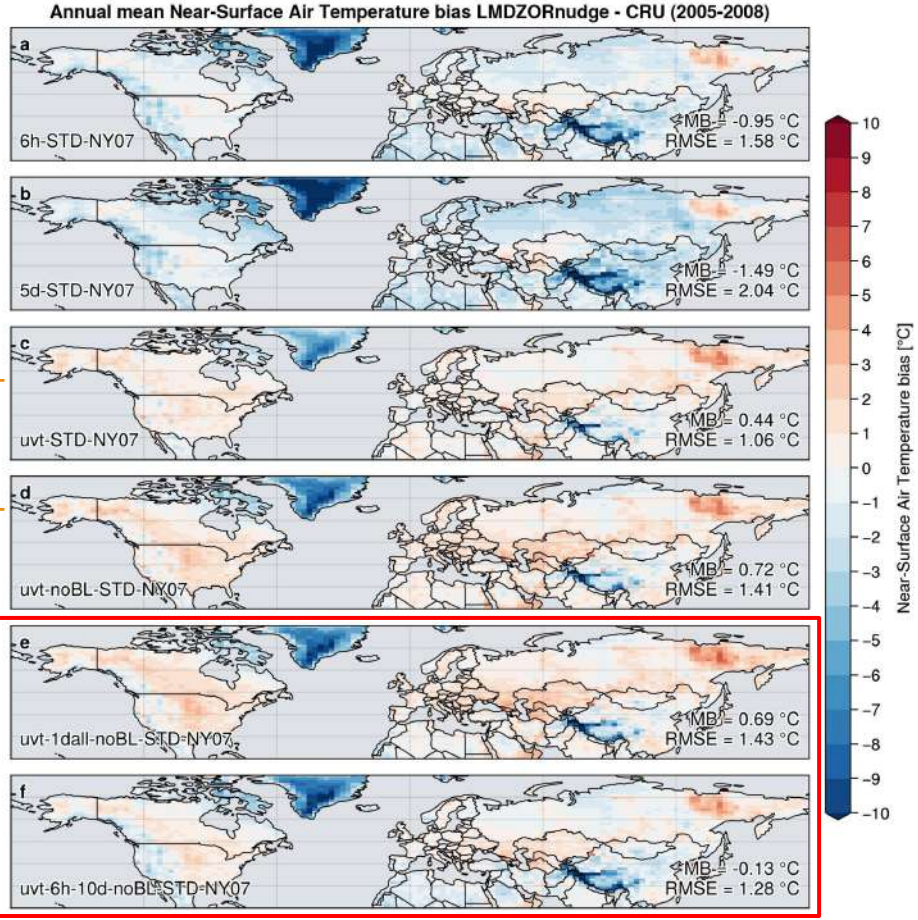
5j u, v

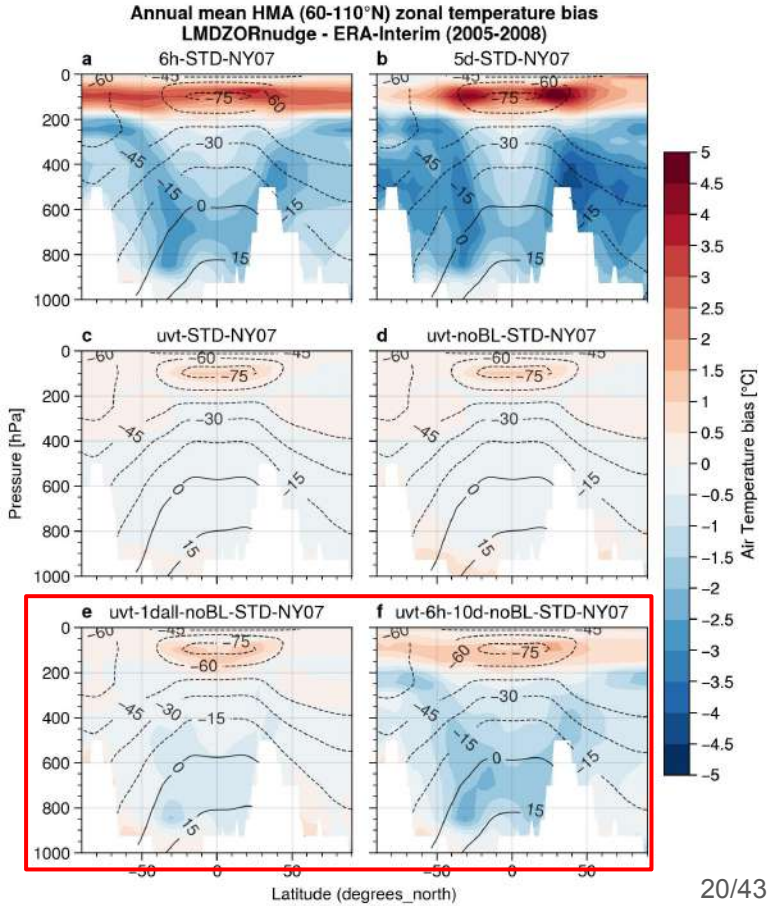
3h u, v, T

3h u, v, T NoBL

1j u, v, T NoBL

6h u, v, 10j T NoBL





Réduction du biais troposphérique : expérience guidées

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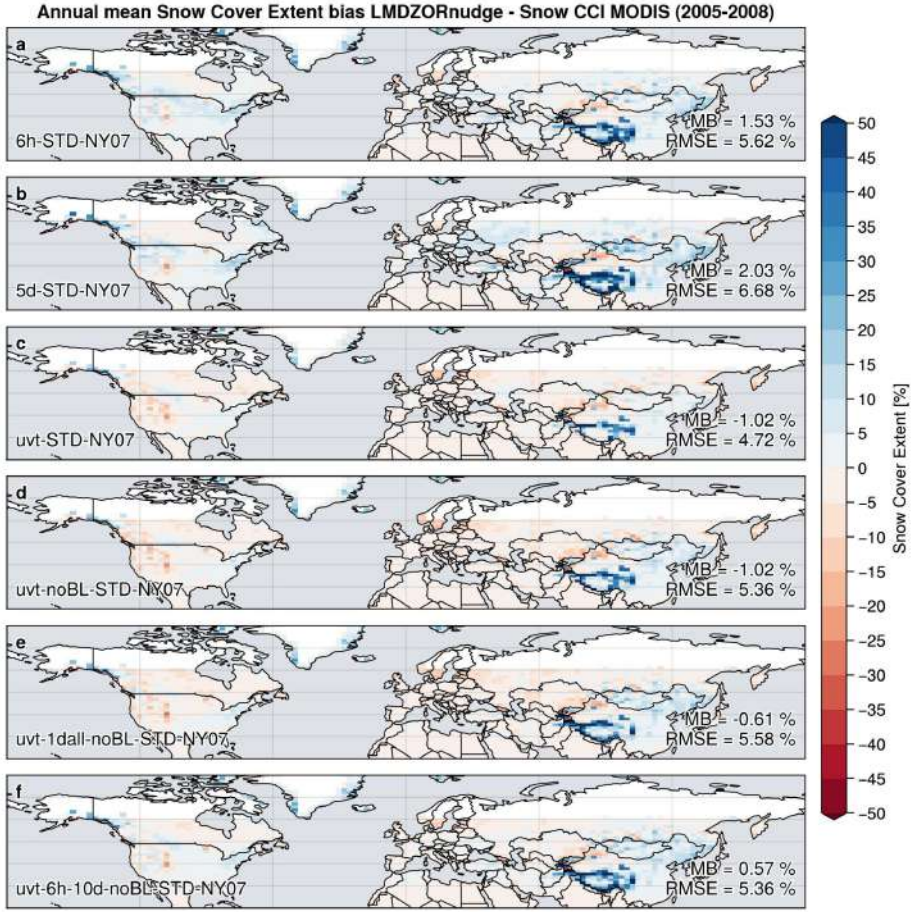
5j u, v

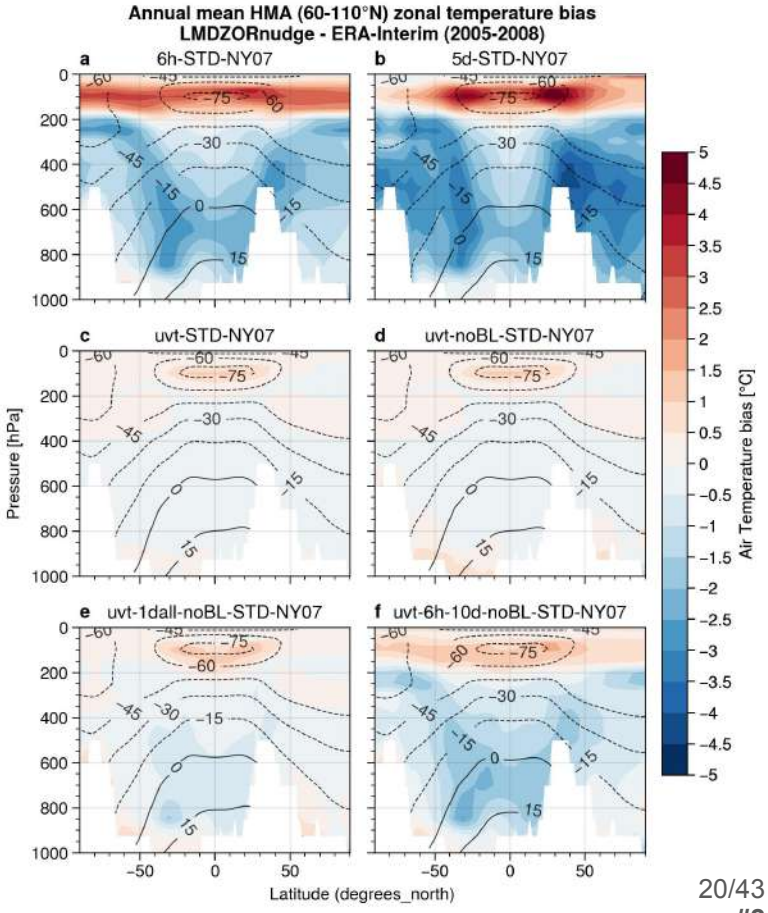
3h u, v, T

3h u, v, T NoBL

1j u, v, T NoBL

6h u, v, 10j T NoBL





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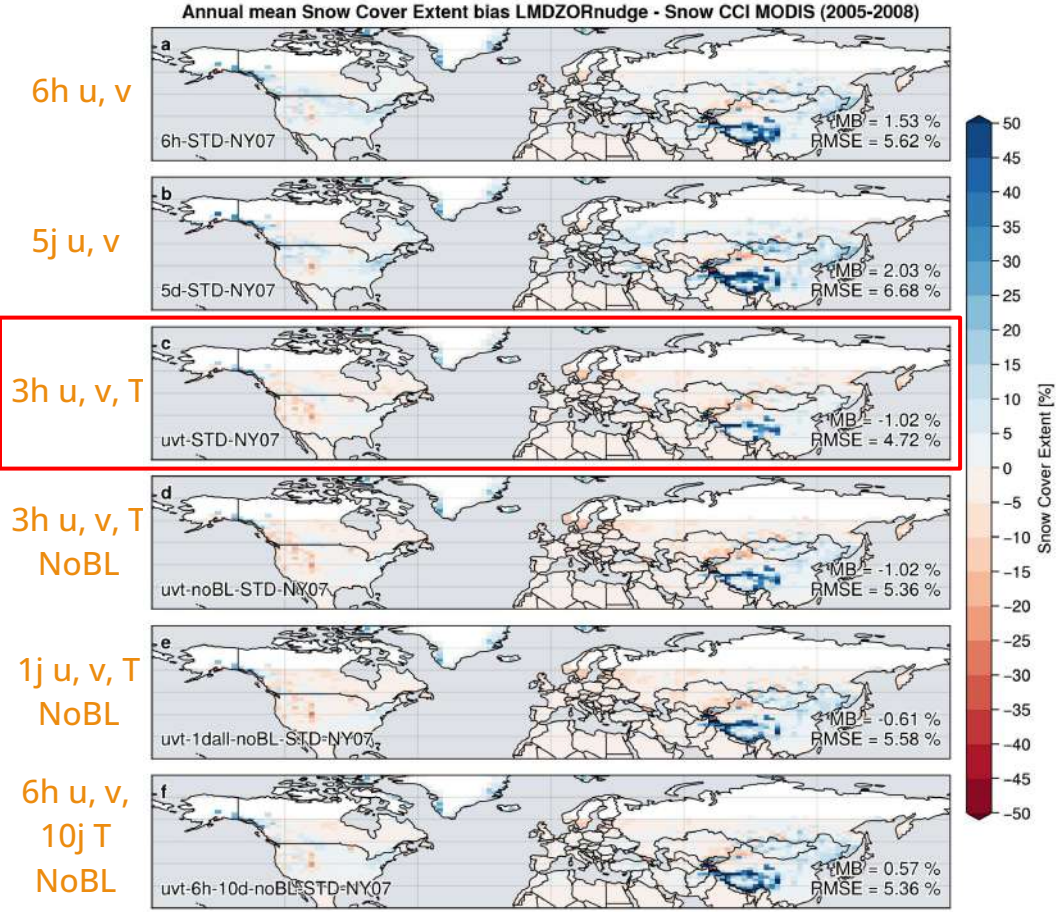
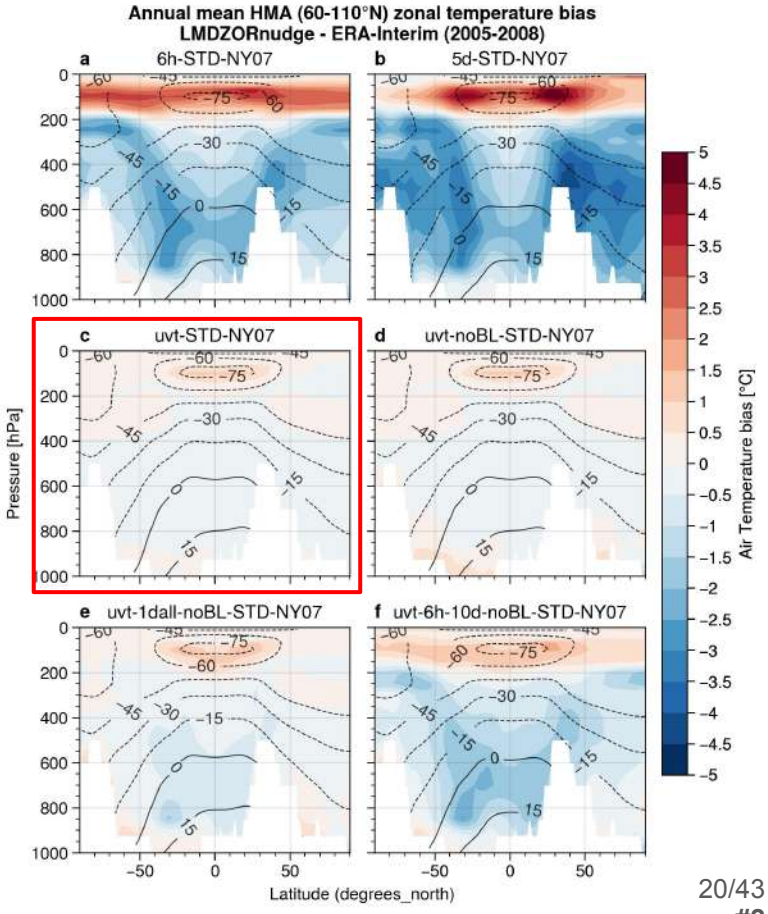




Réduction du biais troposphérique : expérience guidées

6h u, v

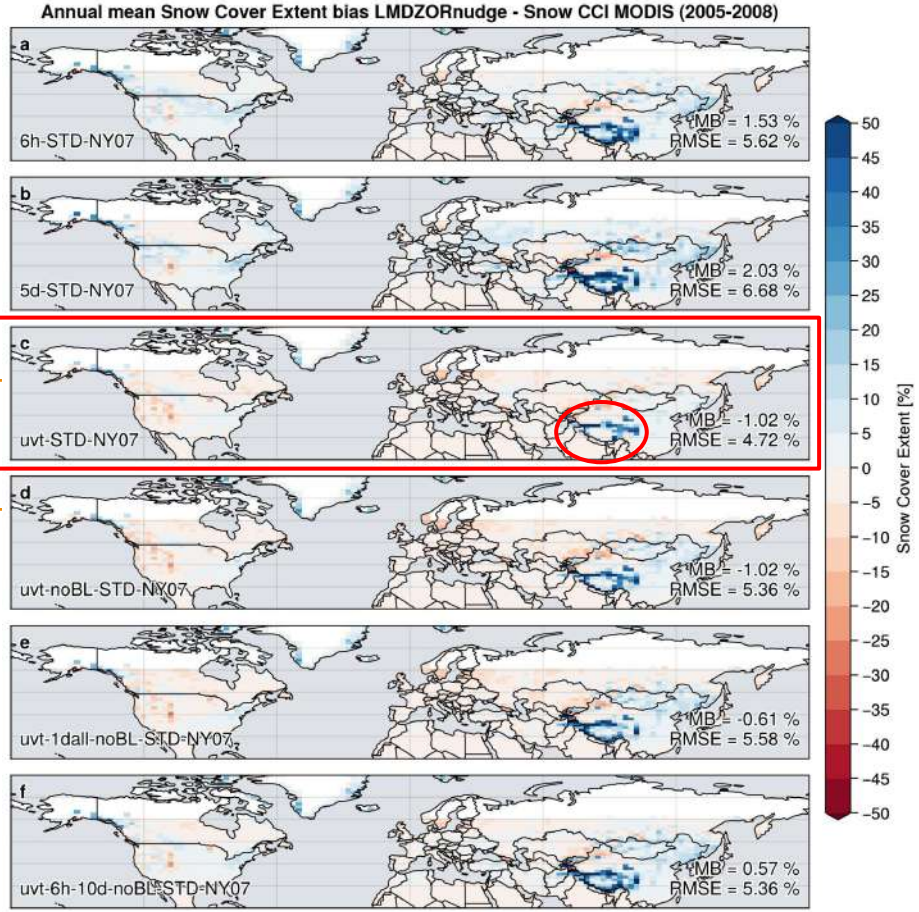
5j u, v

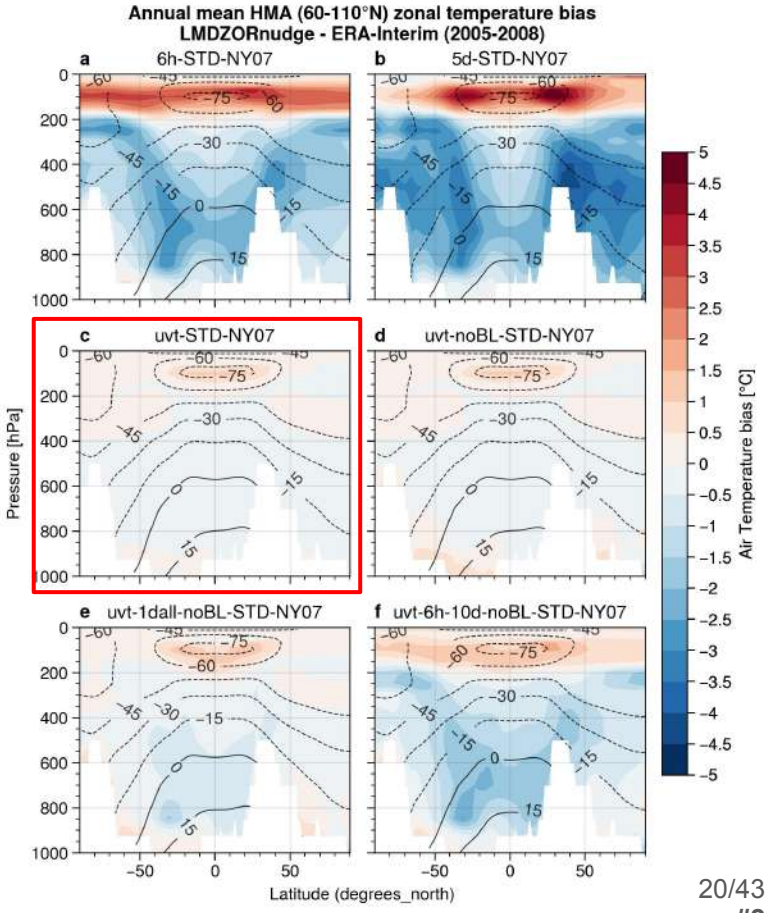
3h u, v, T

3h u, v, T NoBL

1j u, v, T NoBL

6h u, v, 10j T NoBL





Take home messages

- Surface biases don’t seem to be the source of the tropospheric biases

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Take home messages

- Surface biases don't seem to be the source of the tropospheric biases
  - Tropospheric biases amplify surface biases
- Surface biases seem to have distinct cause of the tropospheric biases

- Snow cover biases seem partly related to the topography

- Other important possible causes (not investigated):
cloud cover, albedo, aerosols, boundary layer processes, etc.

Partie #3

Paramétrisation de la couverture de neige en région de montagne


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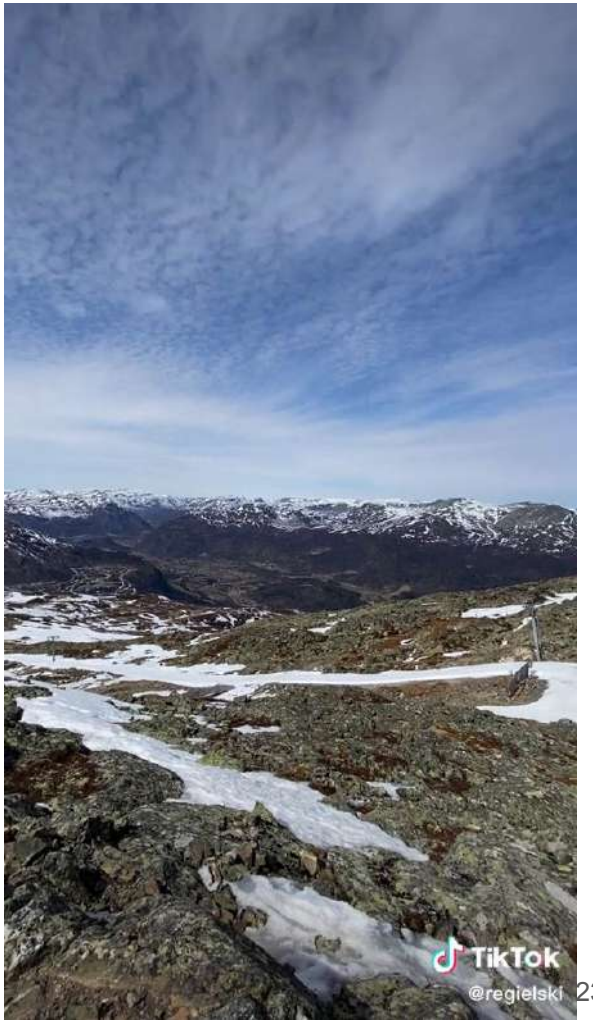

TikTok
@regielski

Snow cover over mountainous areas in global climate models

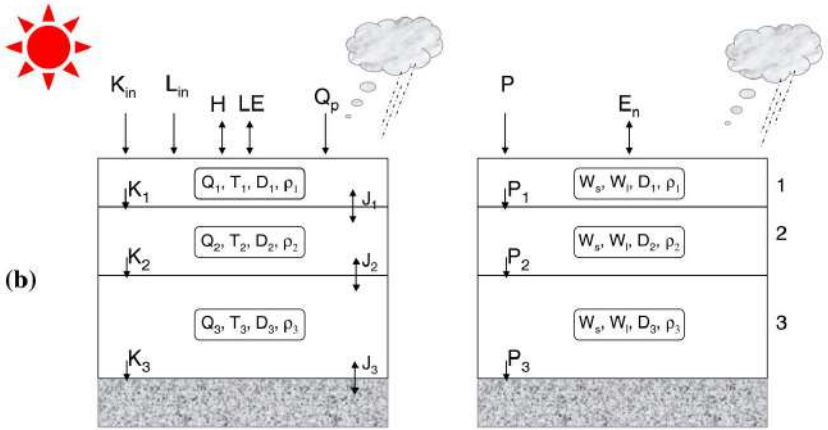
IPSL-CM6A

How do we compute the snow cover fraction (SCF) in global climate models?

&

How does the SCF evolves over mountainous areas?

Snow scheme



K_{in} (short wave radiation), **L_{in}** (longwave radiation), **H** (sensible heat flux), **LE**(latent heat flux), **J** (conduction heat flux), **Q** (snow layer heat content), **Q_p**(advective heat from rain and snow), **W** (snow layer SWE), **W_l** (snow layer liquid water content), **D** (snow layer depth), **ρ** (snow layer density) , **P** (precipitation), **E_n** (evaporation)

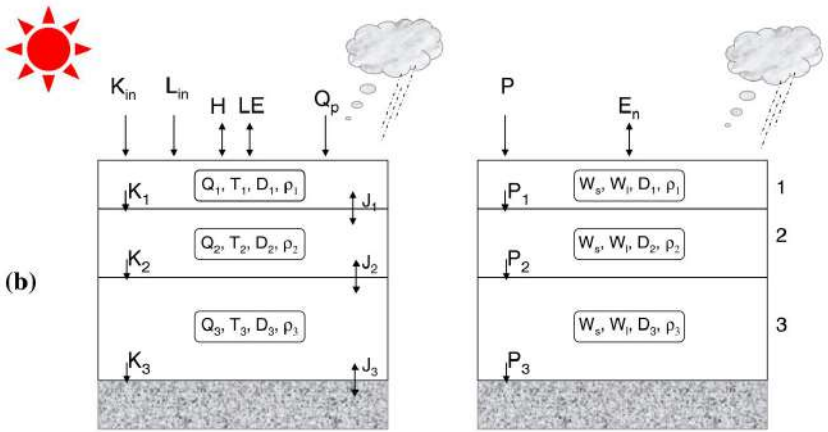
snow scheme in the ORCHIDEE land surface model (Wang et al., 2013)

Snow Depth

Snow Water Equivalent

Snow Density

Snow scheme



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Snow Density

Snow Cover Fraction

Snow cover parameterizations

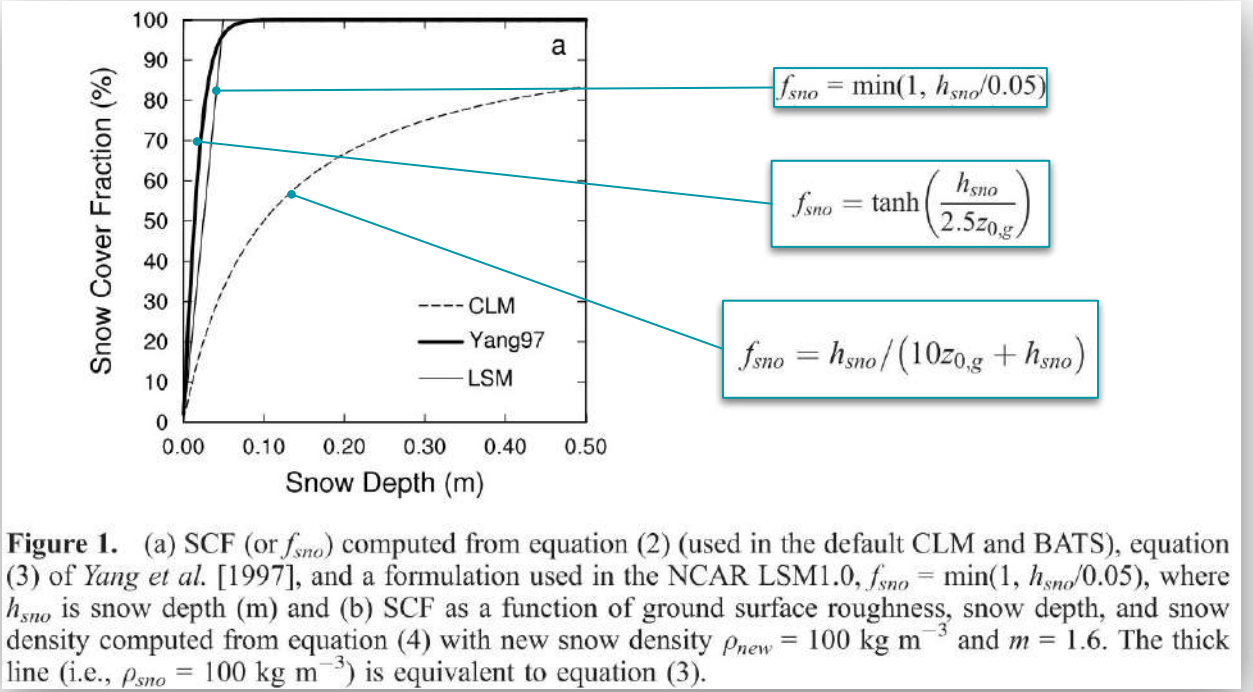

Figure 1. (a) SCF (or f_{sno}) computed from equation (2) (used in the default CLM and BATS), equation (3) of *Yang et al.* [1997], and a formulation used in the NCAR LSM1.0, $f_{sno} = \min(1, h_{sno}/0.05)$, where h_{sno} is snow depth (m) and (b) SCF as a function of ground surface roughness, snow depth, and snow density computed from equation (4) with new snow density $\rho_{new} = 100$ kg m^{-3} and $m = 1.6$. The thick line (i.e., $\rho_{sno} = 100$ kg m^{-3}) is equivalent to equation (3).

Niu and Yang (2007)

Snow Cover parameterization: Niu and Yang (2007) - NY07

$$f_{sno} = \tanh\left(\frac{h_{sno}}{2.5 z_{0g}(\rho_{sno}/\rho_{new})^m}\right)$$

Snow Density

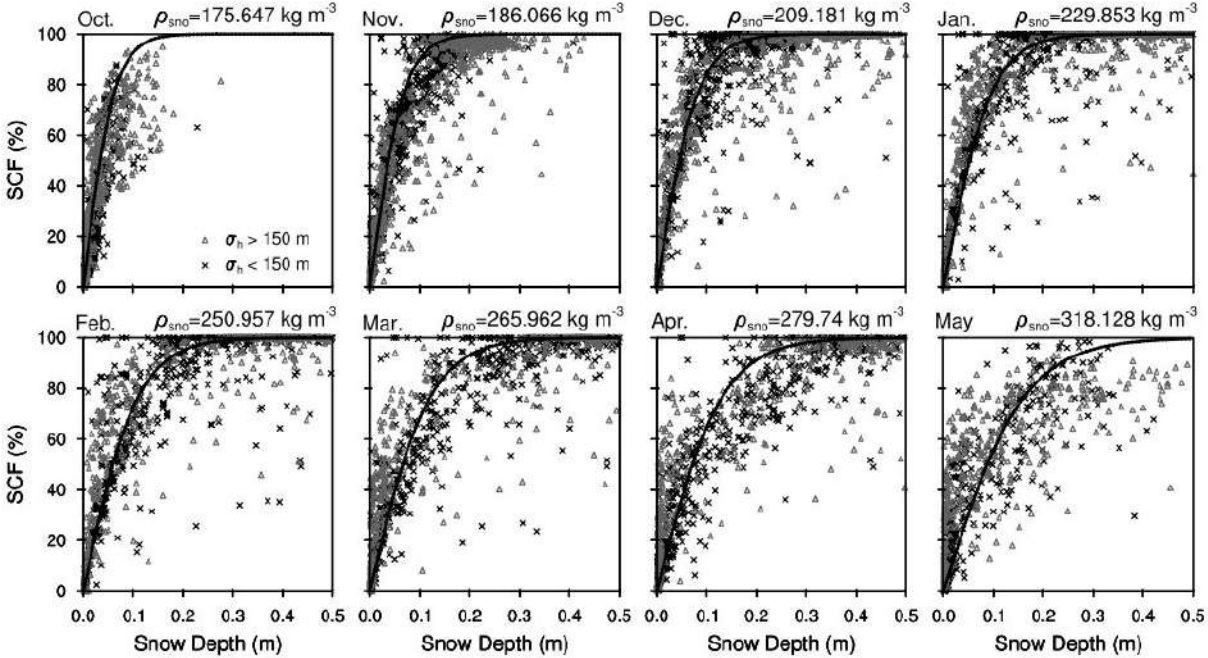

Figure 2. Relationship between AVHRR SCF (%) and CMC snow depth (m) in 1° × 1° grid cells of major NA river basins including the Mackenzie, Yukon, Churchill, Fraser, St. Lawrence, Columbia, Colorado, and Mississippi from October to May. The darker crosses stand for 1° × 1° grid cells where the standard deviation of topography $\sigma_h < 150$ m, and the lighter triangles stand for 1° × 1° grid cells where $\sigma_h > 150$ m. The fitted lines are computed from equation (4) ($m = 1.6$) with the mean snow densities shown above each frame.

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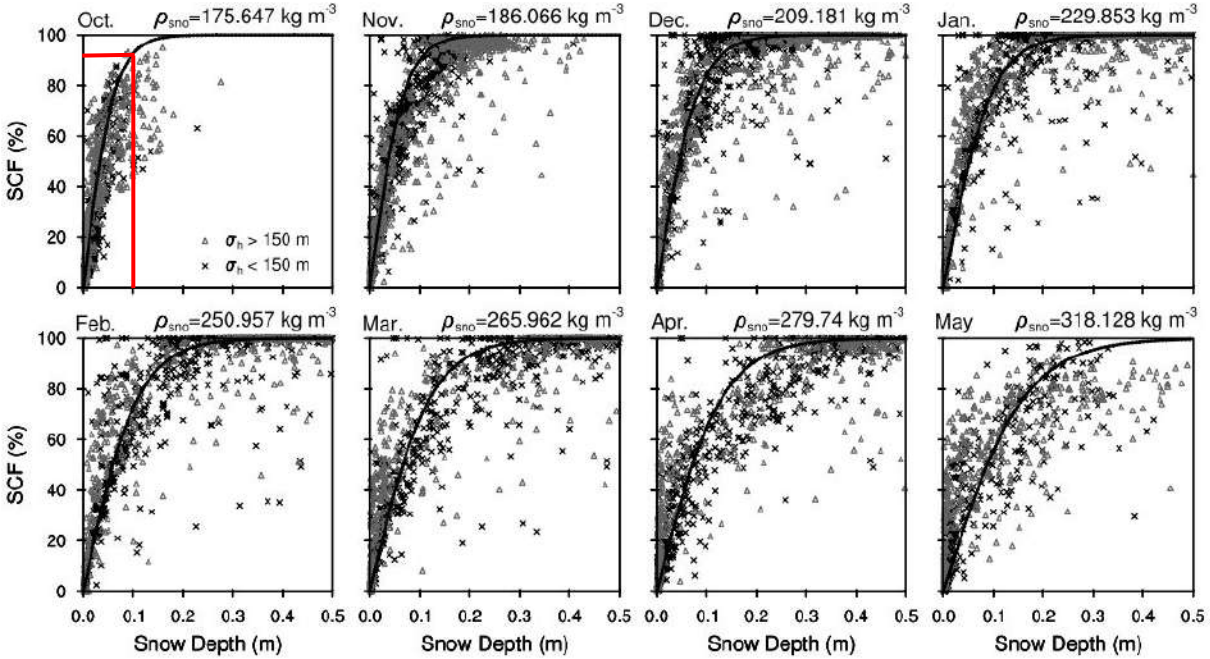

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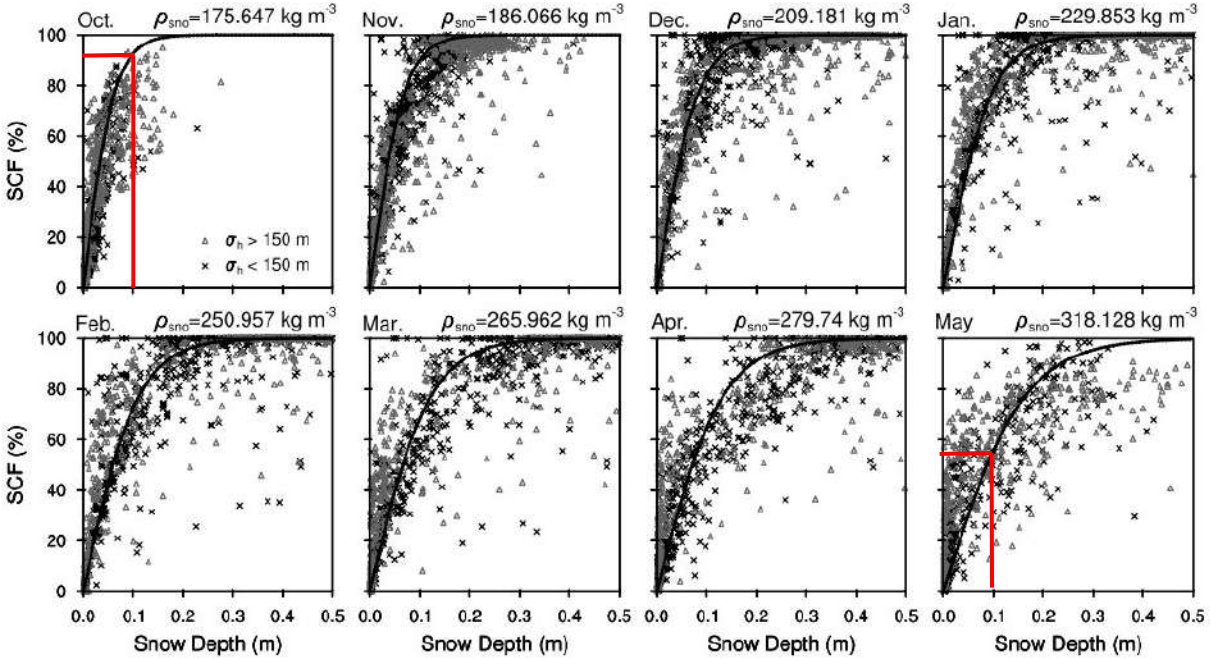

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Snow cover micro to macro

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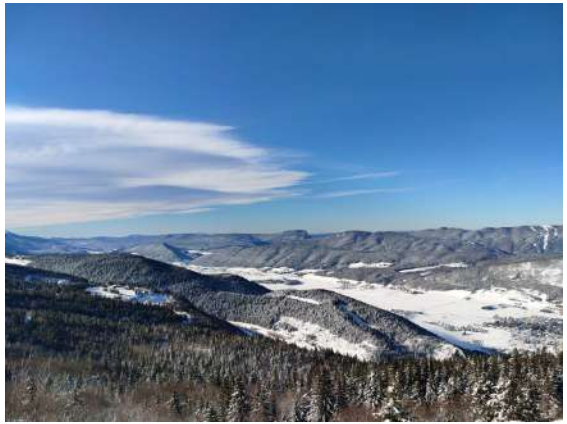
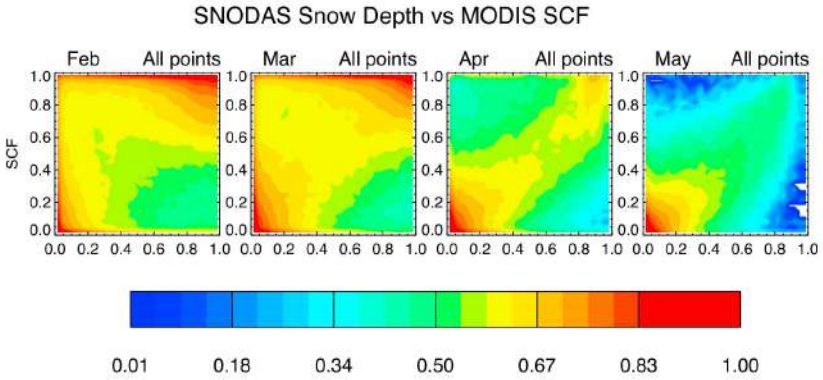


Snow cover in mountainous area: Swenson & Lawrence (2012) - SL12



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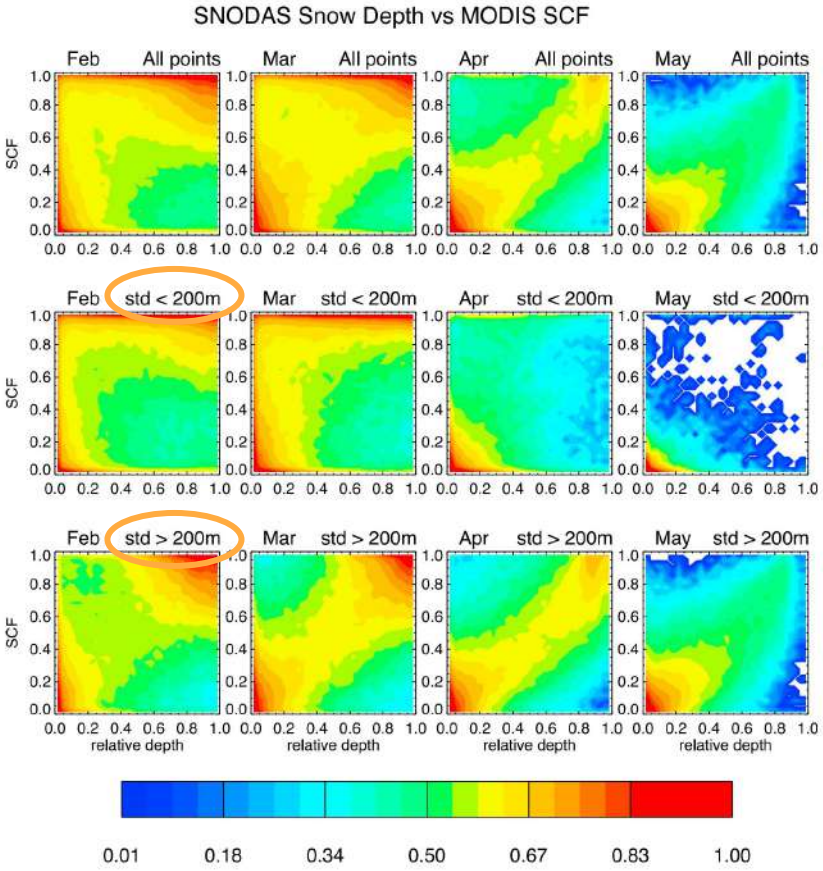
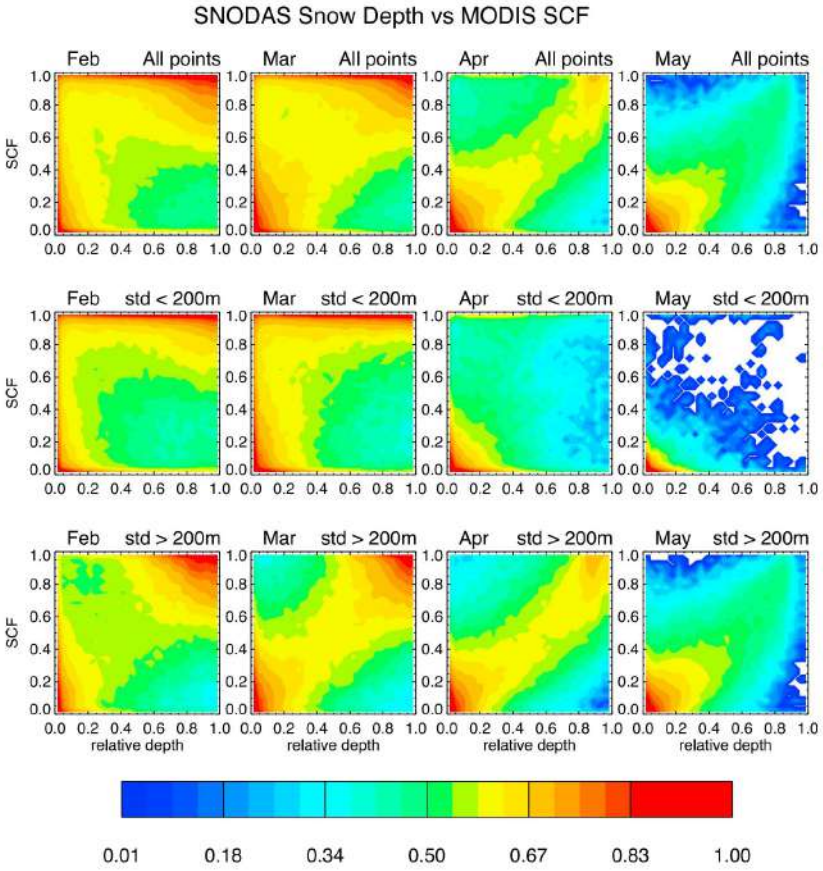


Swenson & Lawrence (2012)

Snow cover in mountainous area: Swenson & Lawrence (2012) - SL12



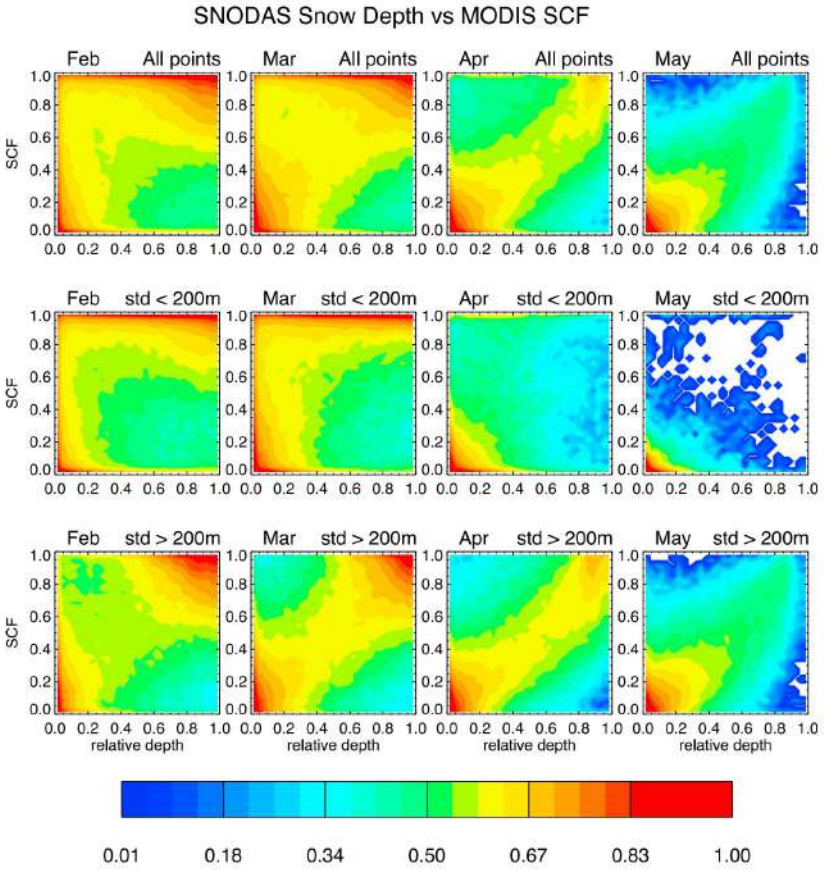
Swenson & Lawrence (2012)

Standard deviation of topography (σ_{topo}) in SCF parameterization first introduced by Douville et al. (1995), then Roesch et al. (2001), etc.

$$SCF = 1 - \left[\frac{1}{\pi}\text{acos}\left(2\frac{SWE}{SWE_{max}} - 1\right)\right]^{N_{melt}}$$

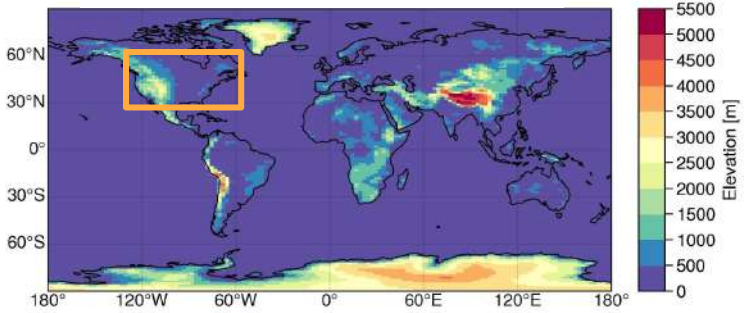
$$N_{melt} = \frac{200}{\max(30, \sigma_{topo})}$$

Snow cover in mountainous area: Swenson & Lawrence (2012) - SL12

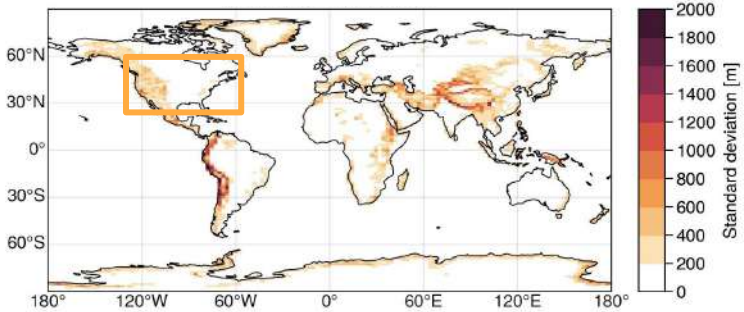


Swenson & Lawrence (2012)

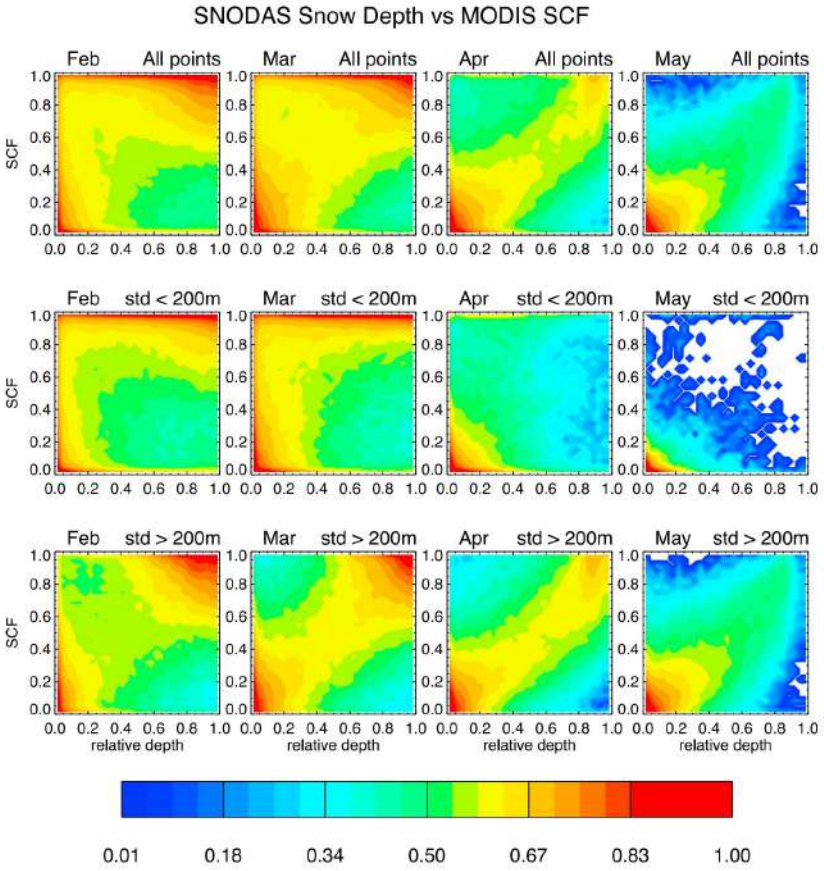
Elevation



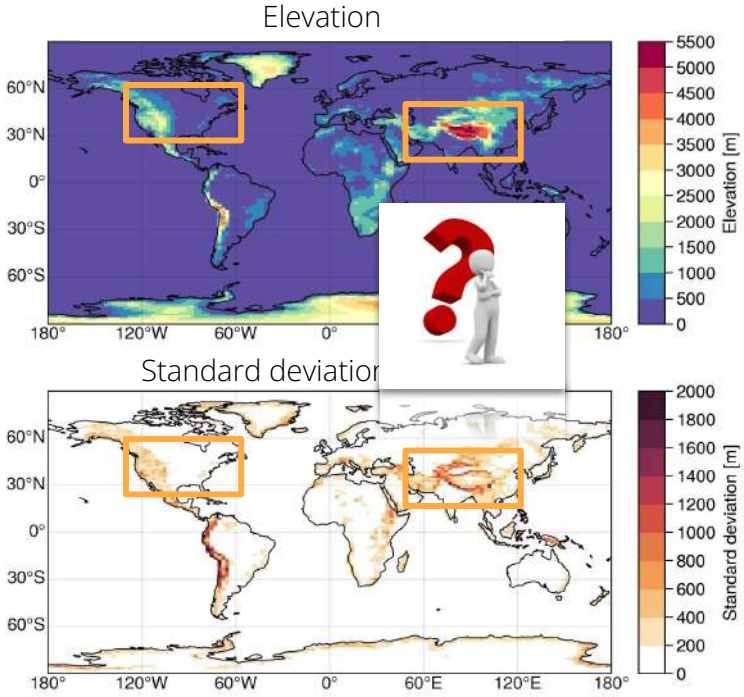
Standard deviation of elevation



Snow cover in mountainous area: Swenson & Lawrence (2012)



Swenson & Lawrence (2012)

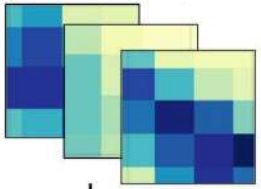


“Estimating the spatial distribution of snow water equivalent (SWE)
in mountainous terrain is currently
the most important unsolved problem in snow hydrology.”

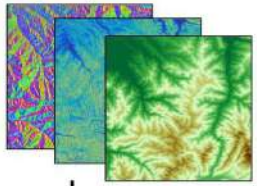
Dozier et al. (2016)

High Mountain Asia UCLA Daily Snow Reanalysis (HMASR)

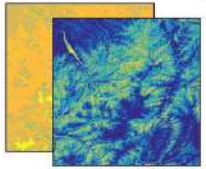
Meteorological forcing
(Precip., air temp., radiation, etc.)
e.g. MERRA-2



Topographic data
(DEM, slope, aspect, etc.)
e.g. SRTM, ASTER



Landcover data
(landcover, forest cover fraction, etc.)
e.g. MODIS, GLCF, AVHRR

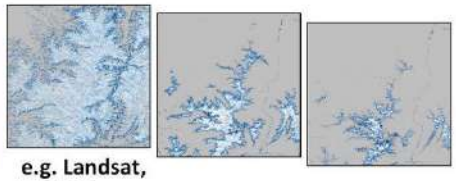


Forcing downscaling/uncertainty
(Girotto et al., 2014a, b)

Resampling to uniform or multi-resolution model grid
(Baldo and Margulis, 2017)

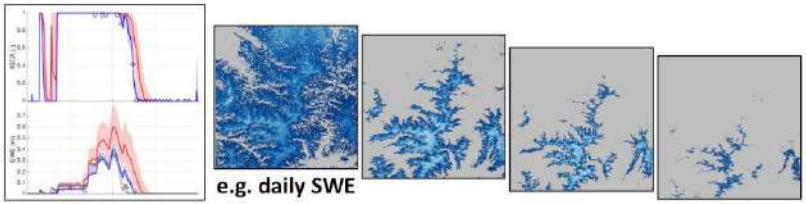
Generation of prior (open-loop) estimates
- Parameter uncertainty
- Land Surface Model-Snow Depletion Curve [LSM-SDC]
- Prior fSCA/SWE and other snow-related estimates

Fractional Snow Covered Area (fSCA) Observations (Cortés et al., 2014; Painter et al., 2009)



e.g. Landsat, MODIS

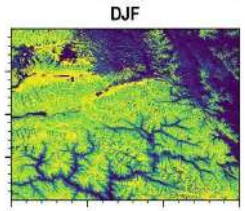
Reanalysis step
- Bayesian update; condition prior estimate on remotely-sensed fSCA
- Using Particle Batch Smoother (PBS; Margulis et al., 2015)
- Joint Landsat+MODSCAG assimilation
- Posterior SCA/SWE and other snow estimates (along with posterior parameters/forcings)

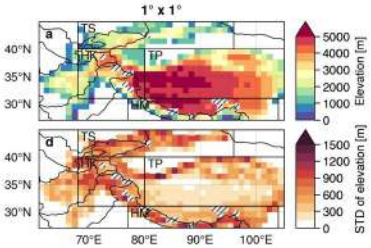


e.g. daily SWE

Margulis et al. (2019)

HMASR -> snow cover parameterizations

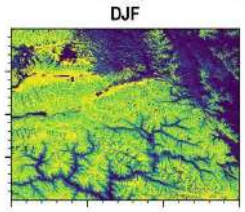


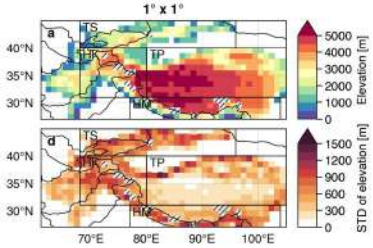


HMASR
SD / SWE / density
+ STD topo
at 1°x1°

SCF

HMASR -> snow cover parameterizations





HMASR
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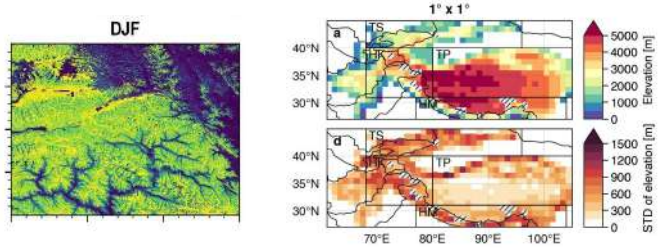
SCF

R01 (Roesch et al., 2001)

$$\mathrm{SCF} = 0.95 \cdot \tanh(100 \cdot \mathrm{SWE}) \sqrt{\frac{1000 \cdot \mathrm{SWE}}{1000 \cdot \mathrm{SWE} + \varepsilon + 0.1 \cdot \sigma_z}}$$

HMASR -> snow cover parameterizations



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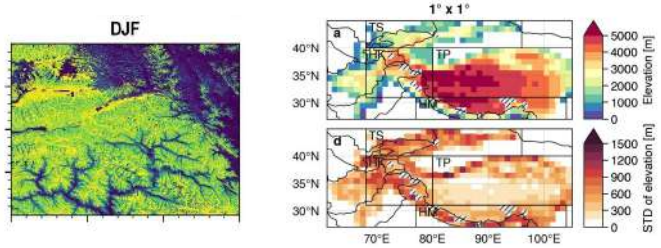
$$SCF = 1 - \left[\frac{1}{\pi}\text{acos}\left(2\frac{SWE}{SWE_{max}} - 1\right)\right]^{N_{melt}}$$

$$N_{melt} = \frac{200}{\max(30, \sigma_{topo})}$$

$$SWE_{max} = \frac{2 \cdot SWE}{\cos\left[\pi(1 - SCF)^{1/N_{melt}}\right] + 1}$$

HMASR -> snow cover parameterizations



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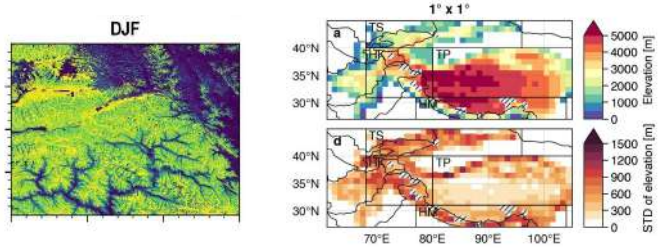

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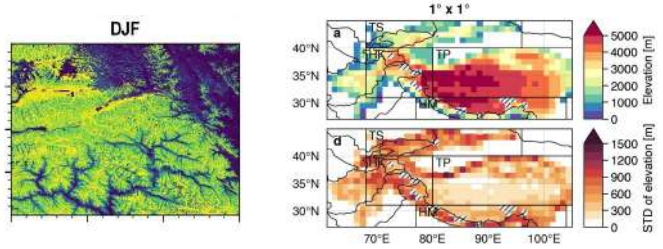
HMASR -> snow cover parameterizations



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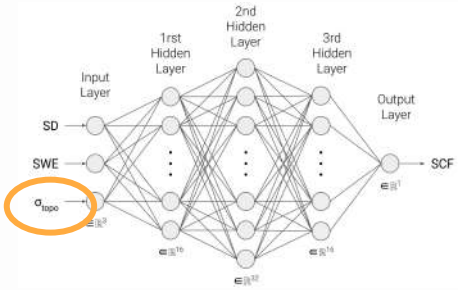
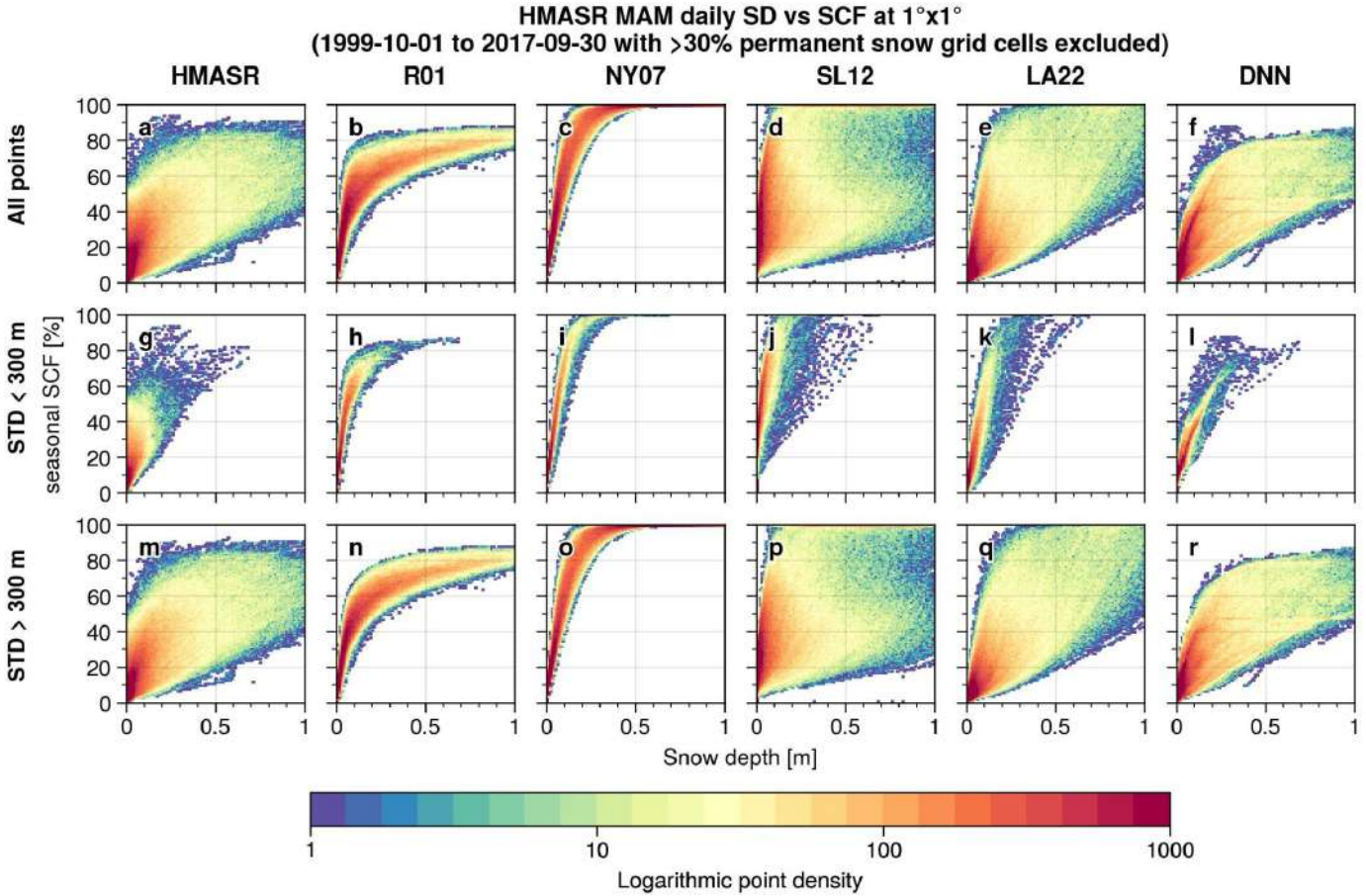
DNN (deep neural network)



Histograms of the daily HMASR seasonal SCF and SD



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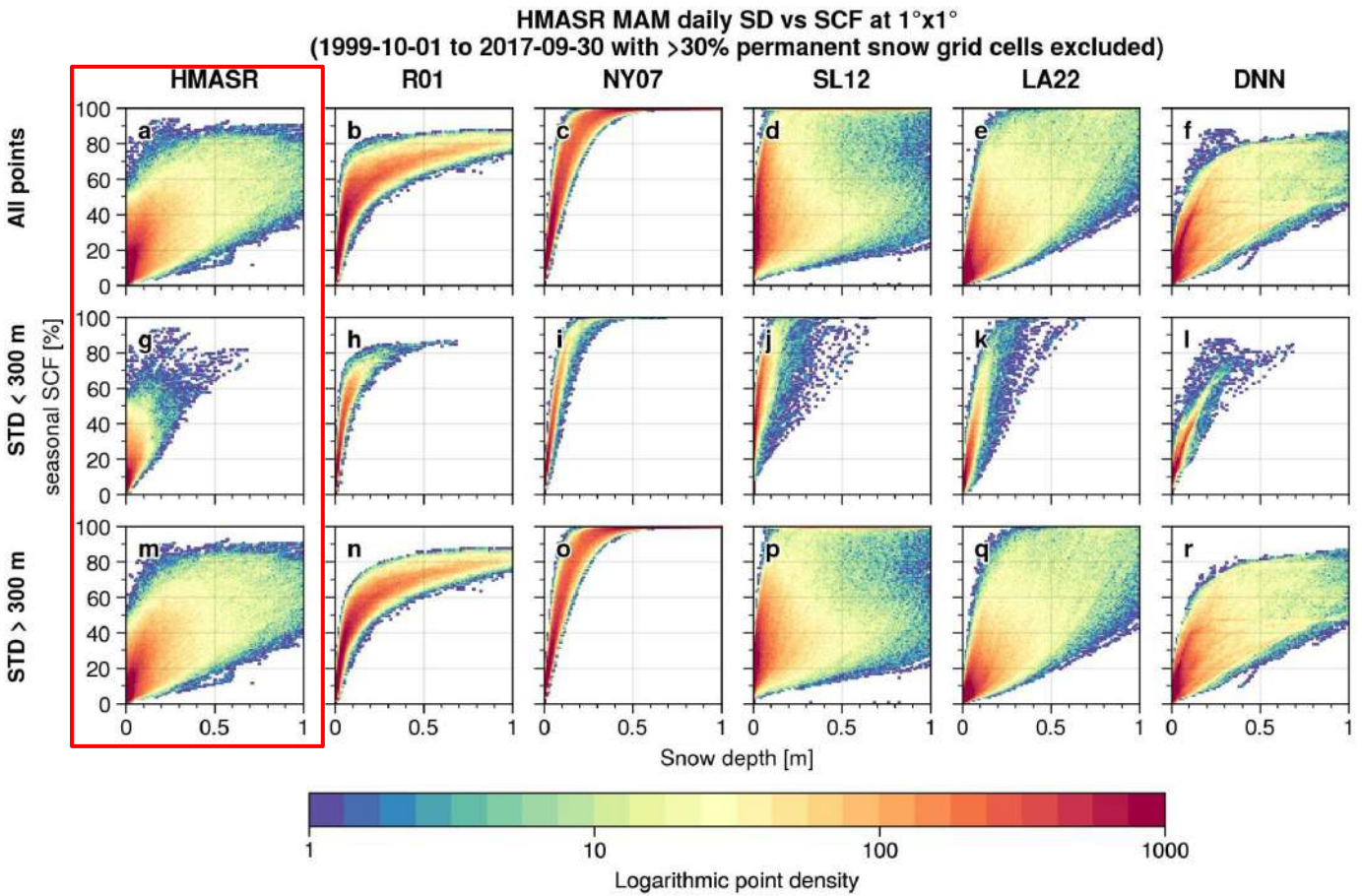

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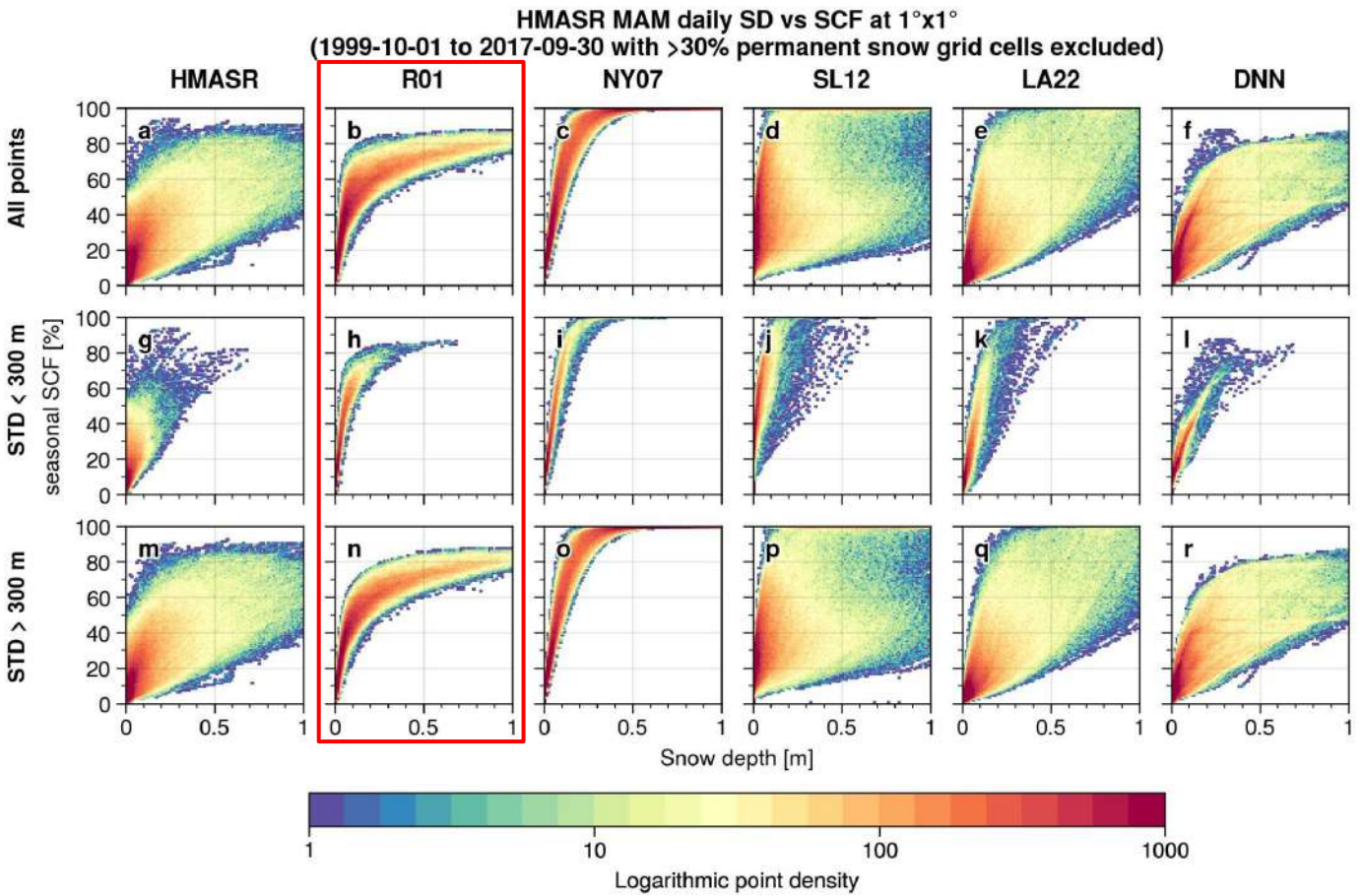

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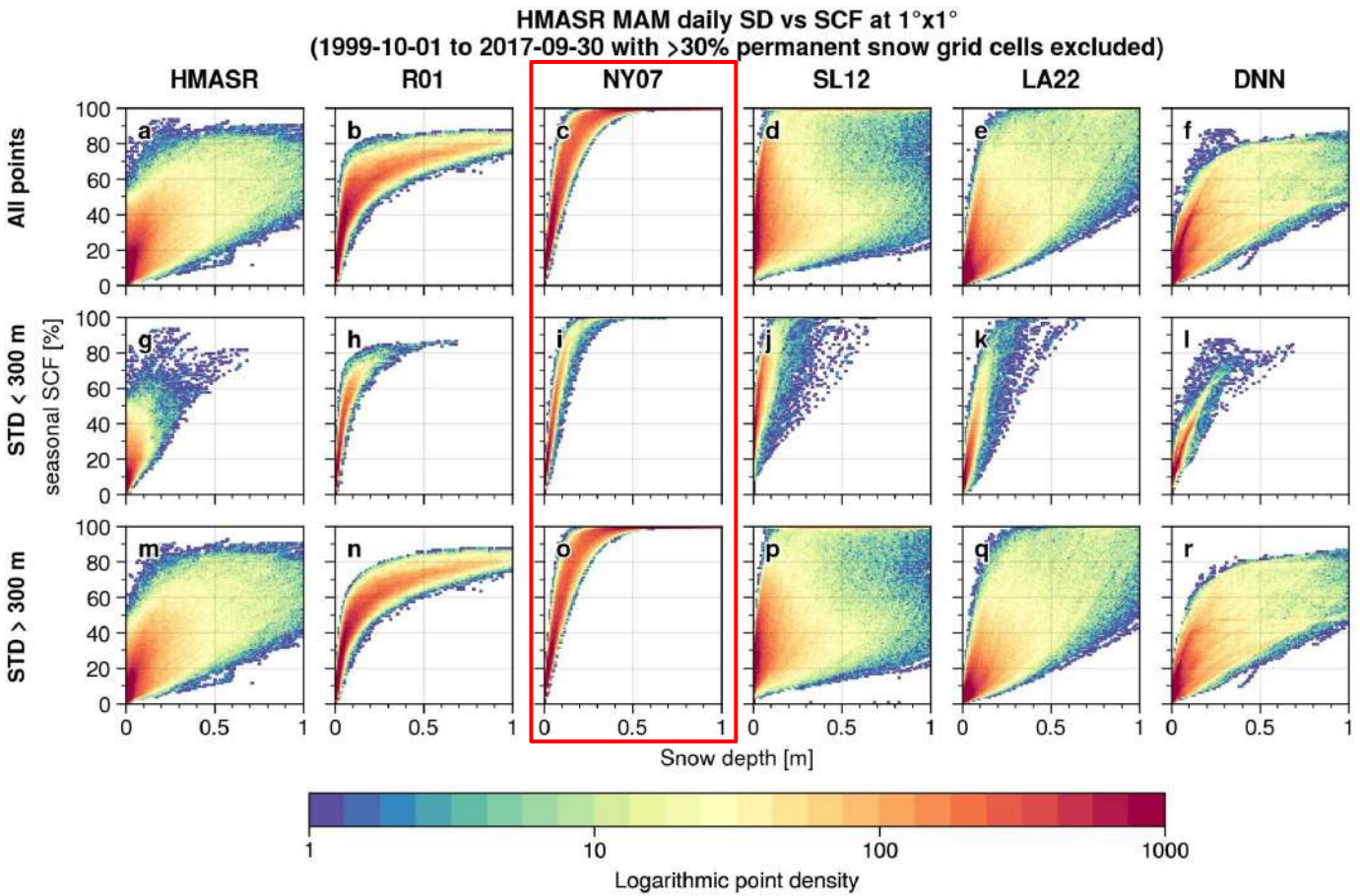

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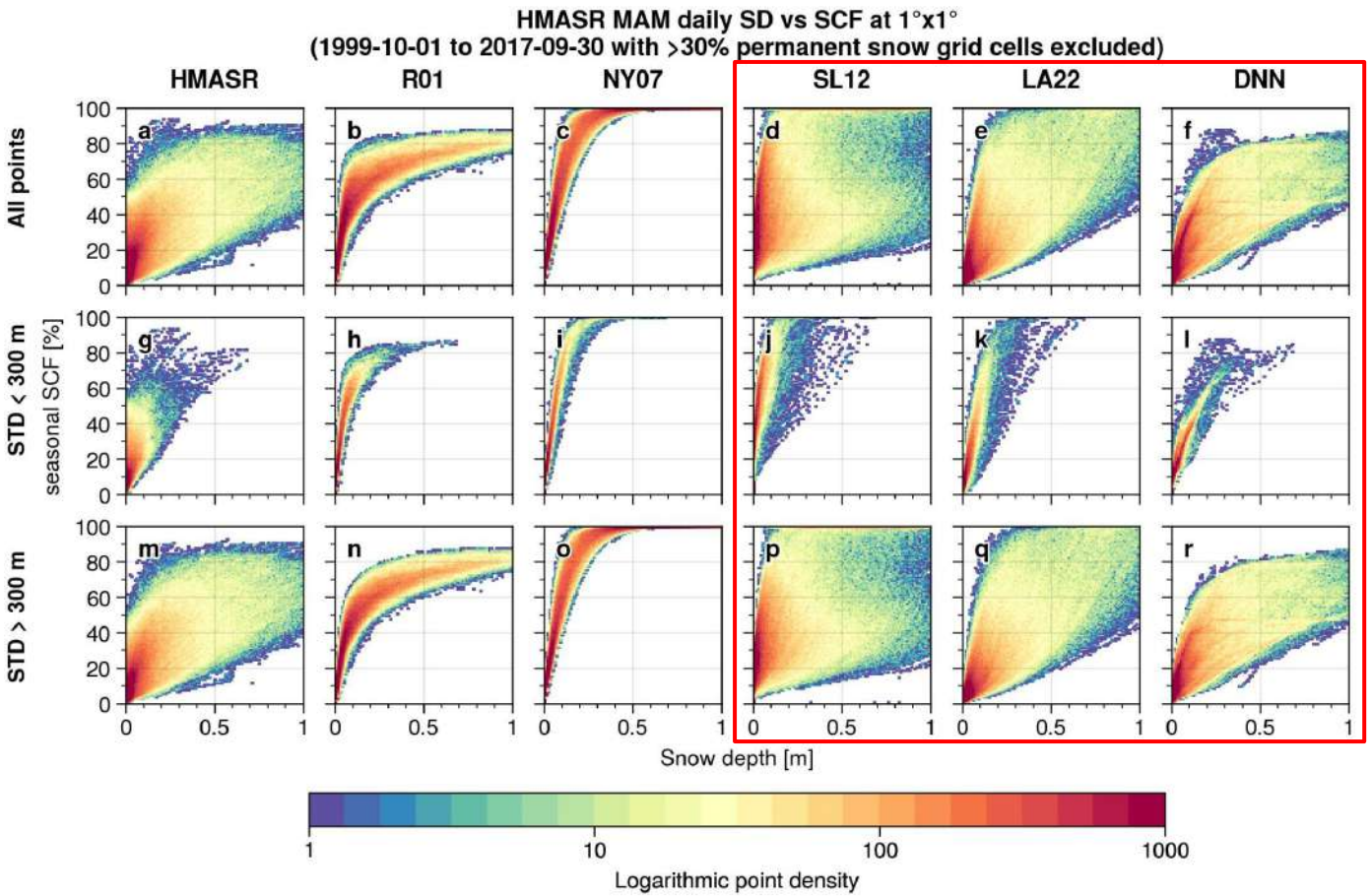
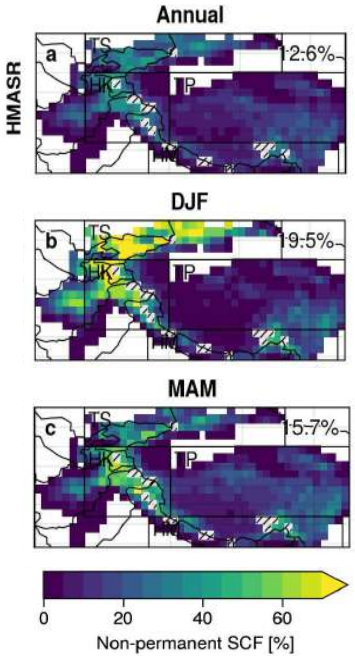
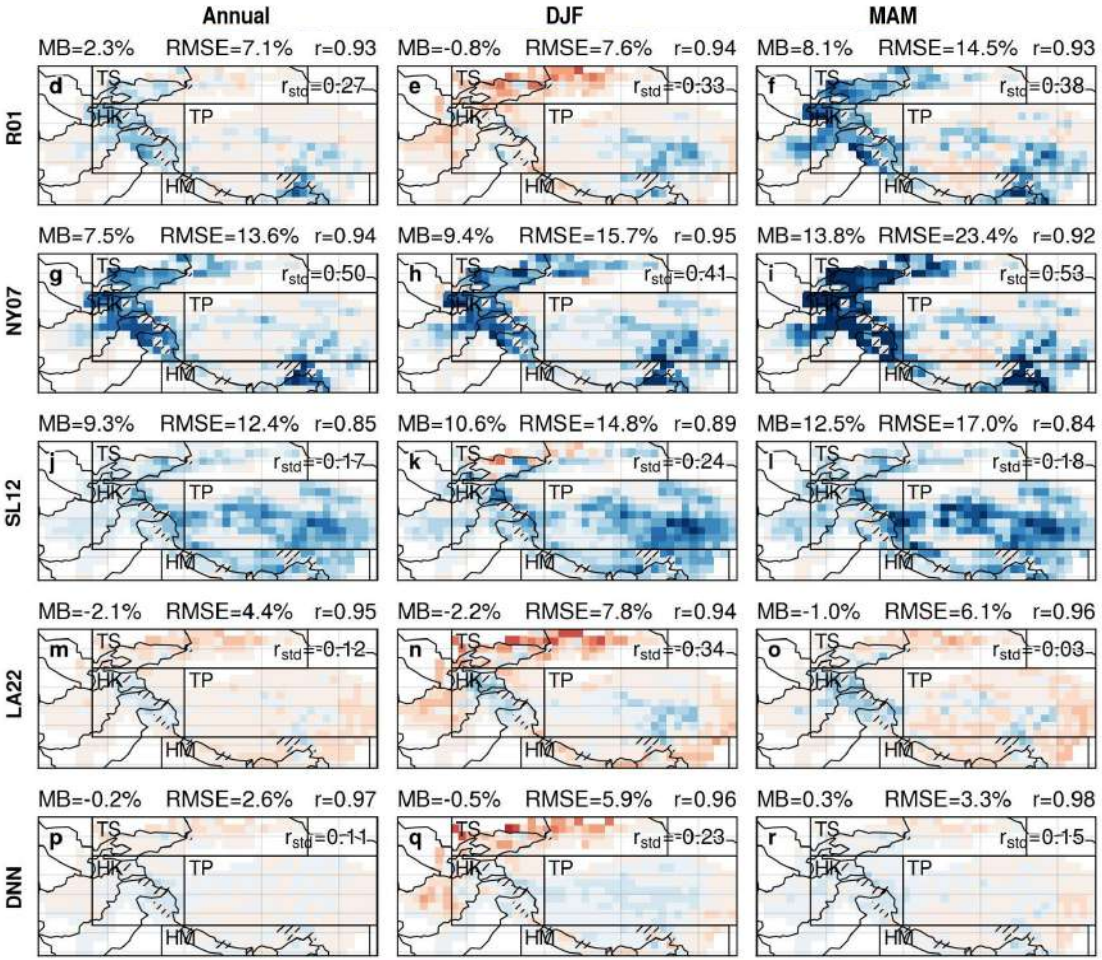
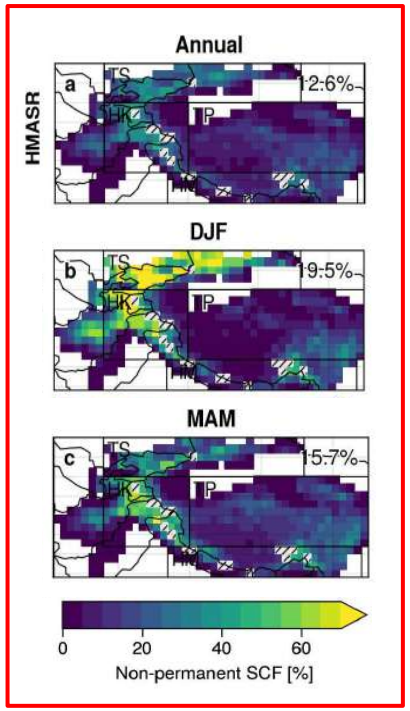


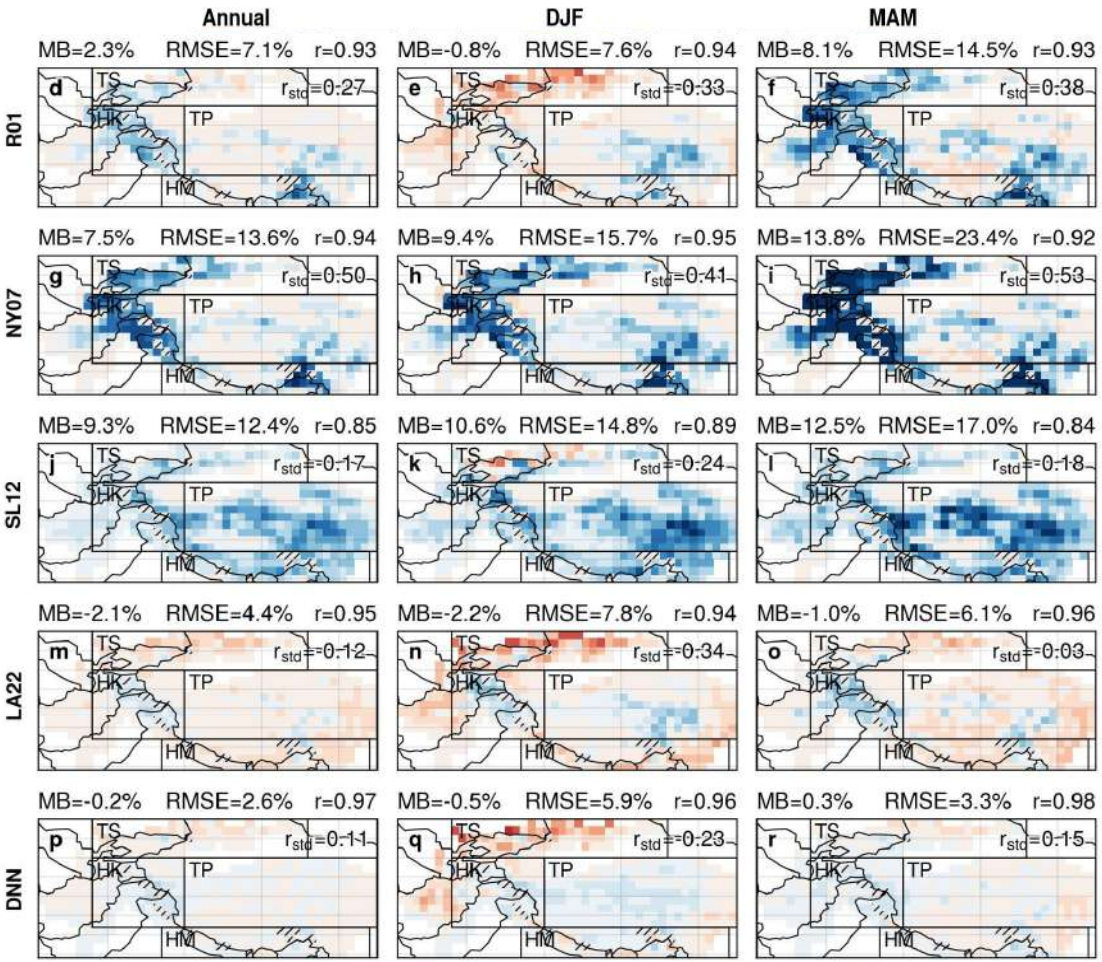
HMASR -> snow cover parameterizations



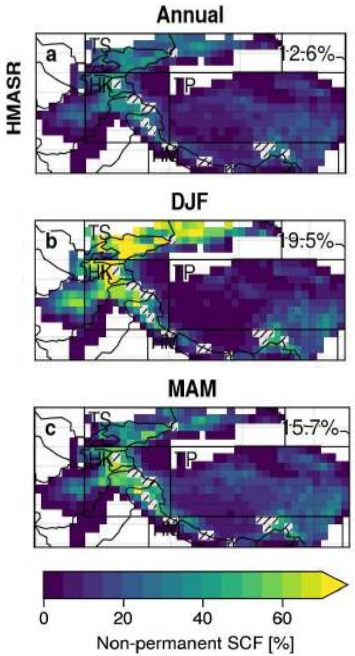


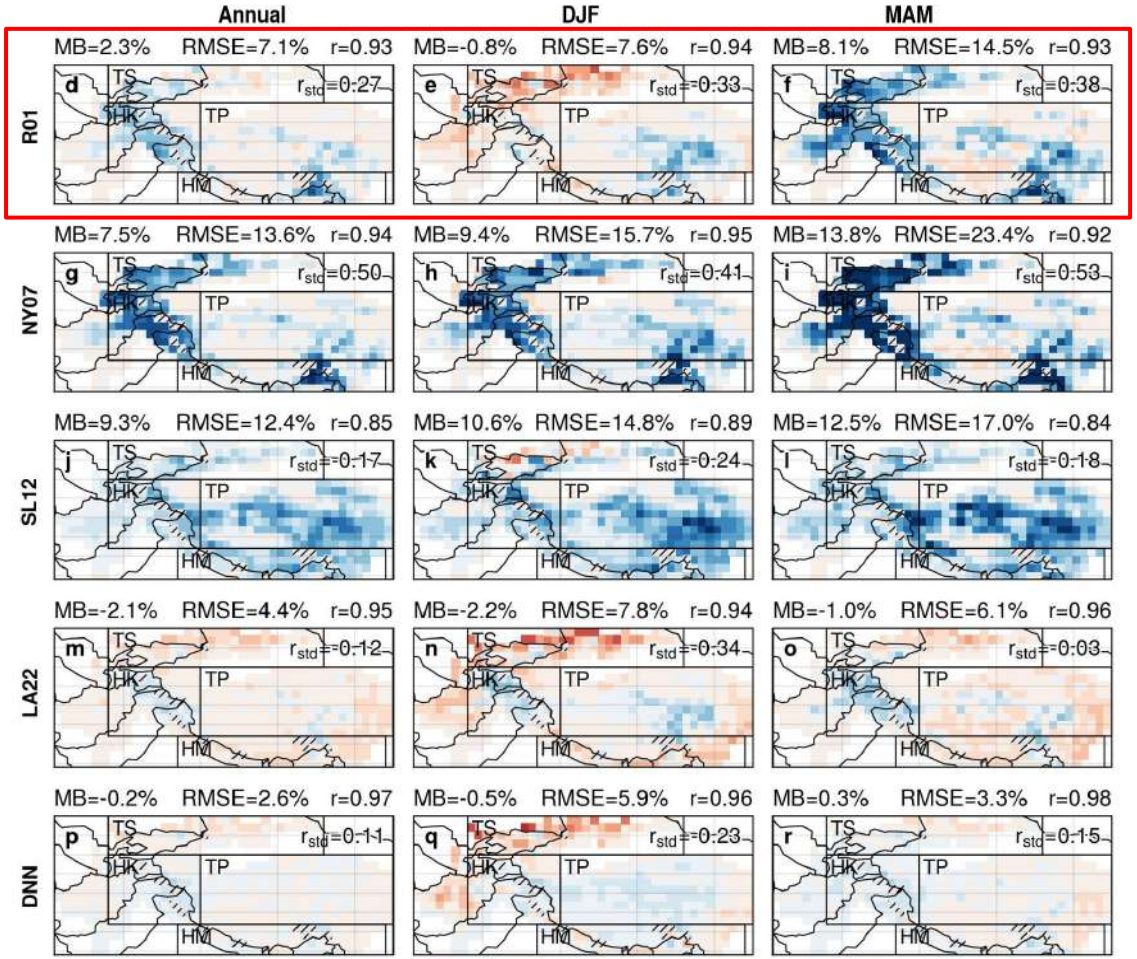
HMASR -> snow cover parameterizations





HMASR -> snow cover parameterizations





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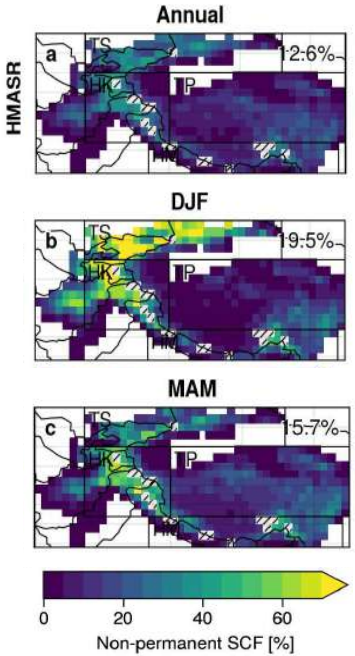

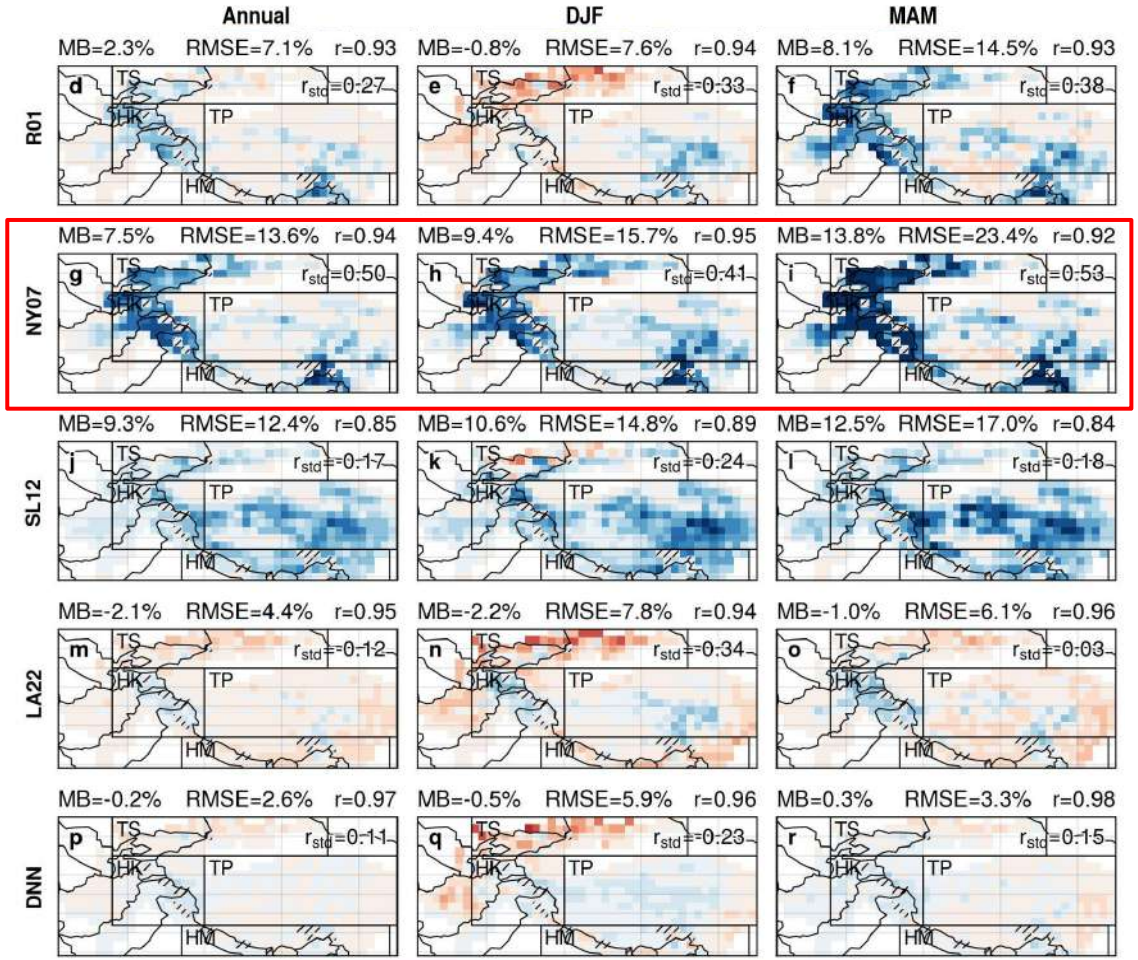

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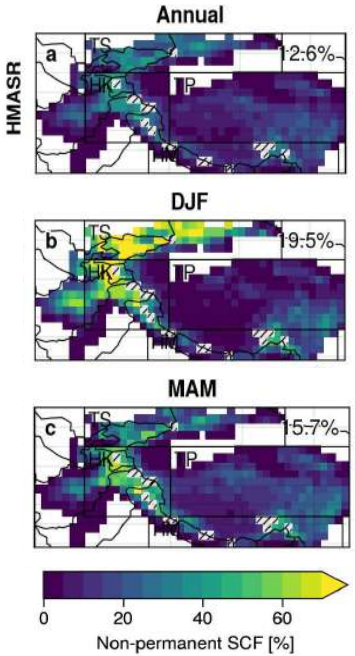

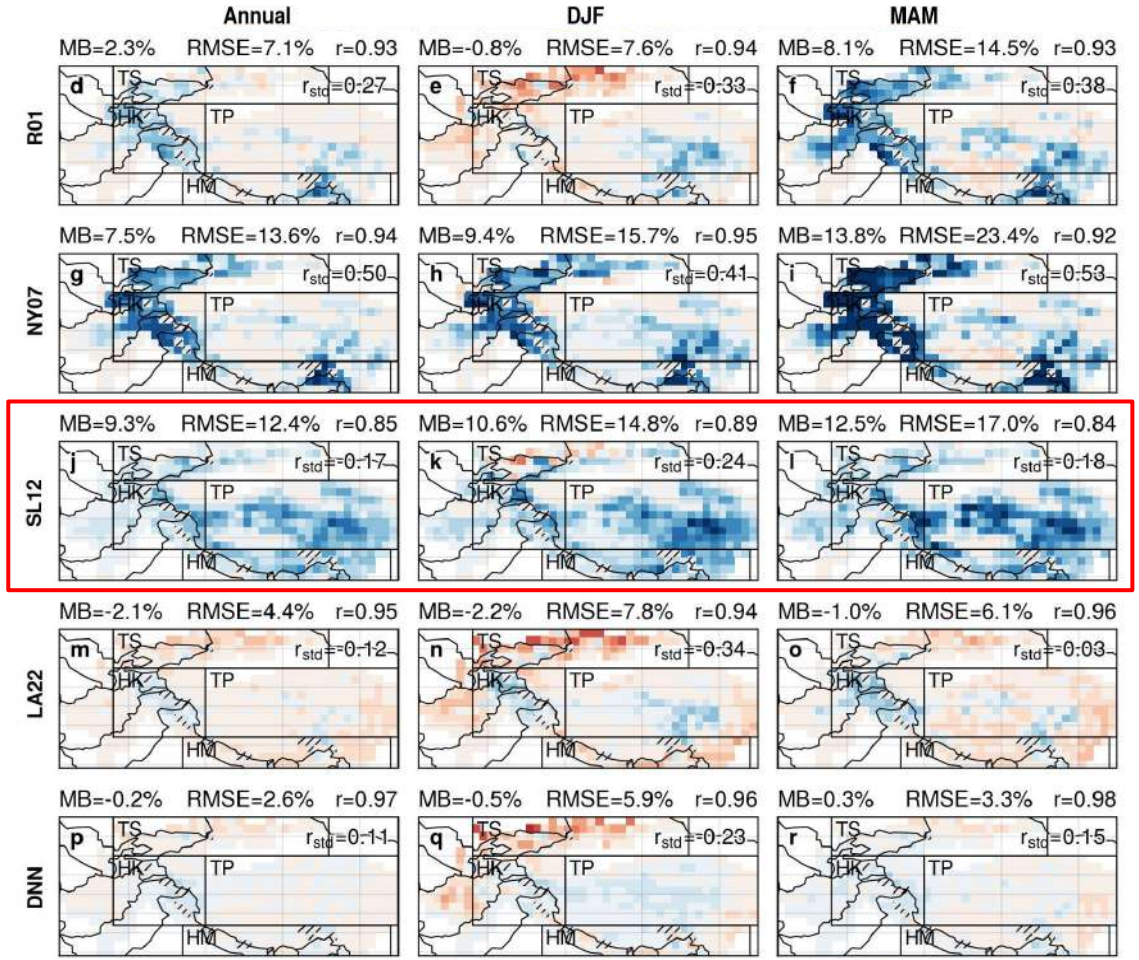

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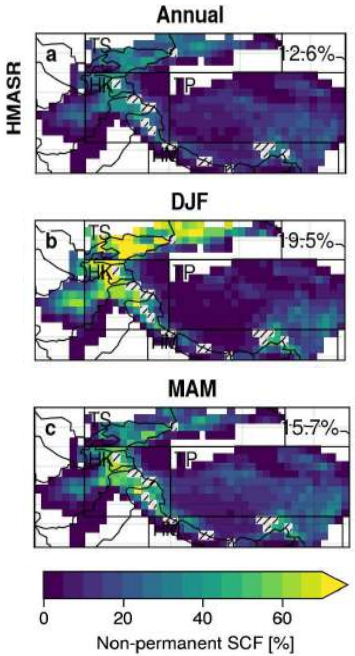
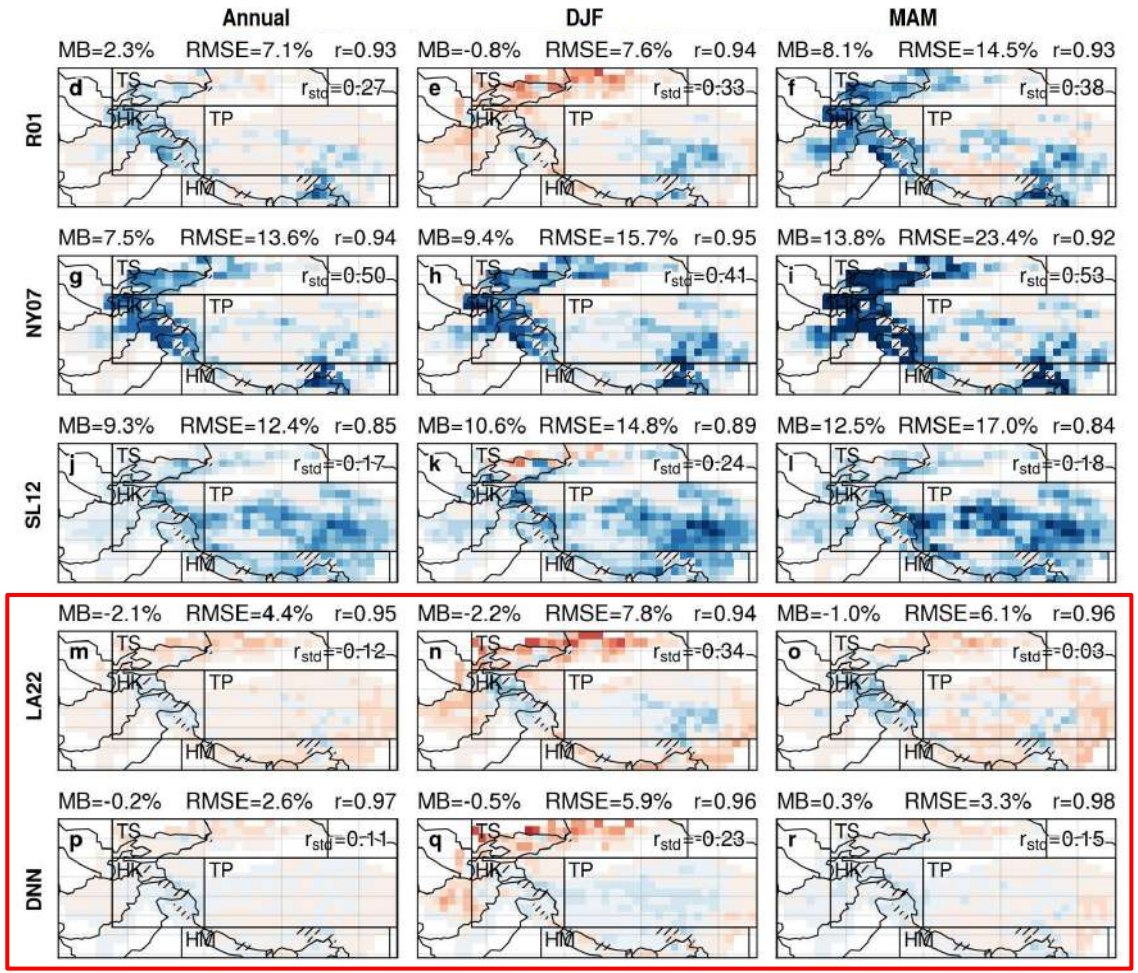
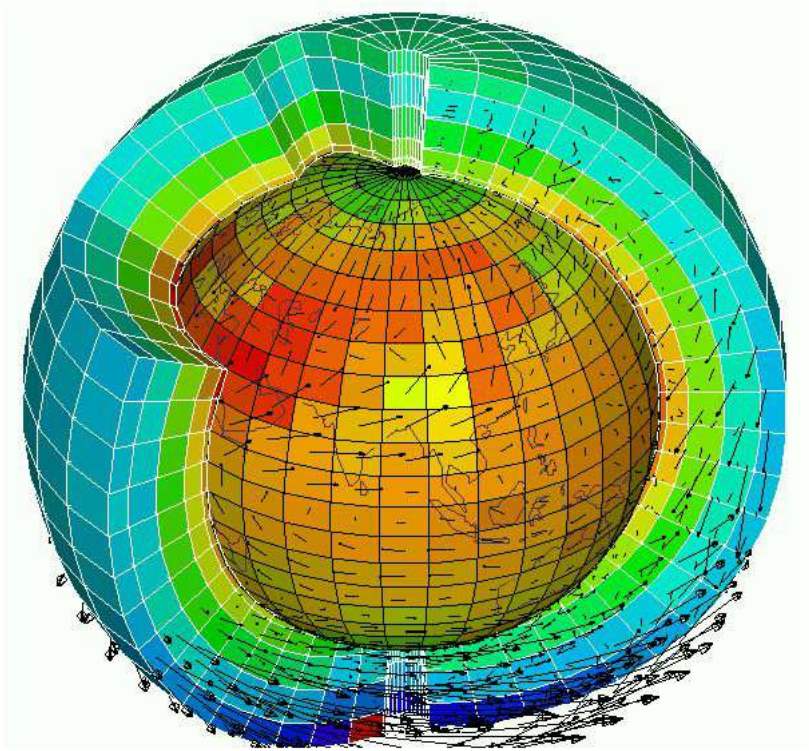




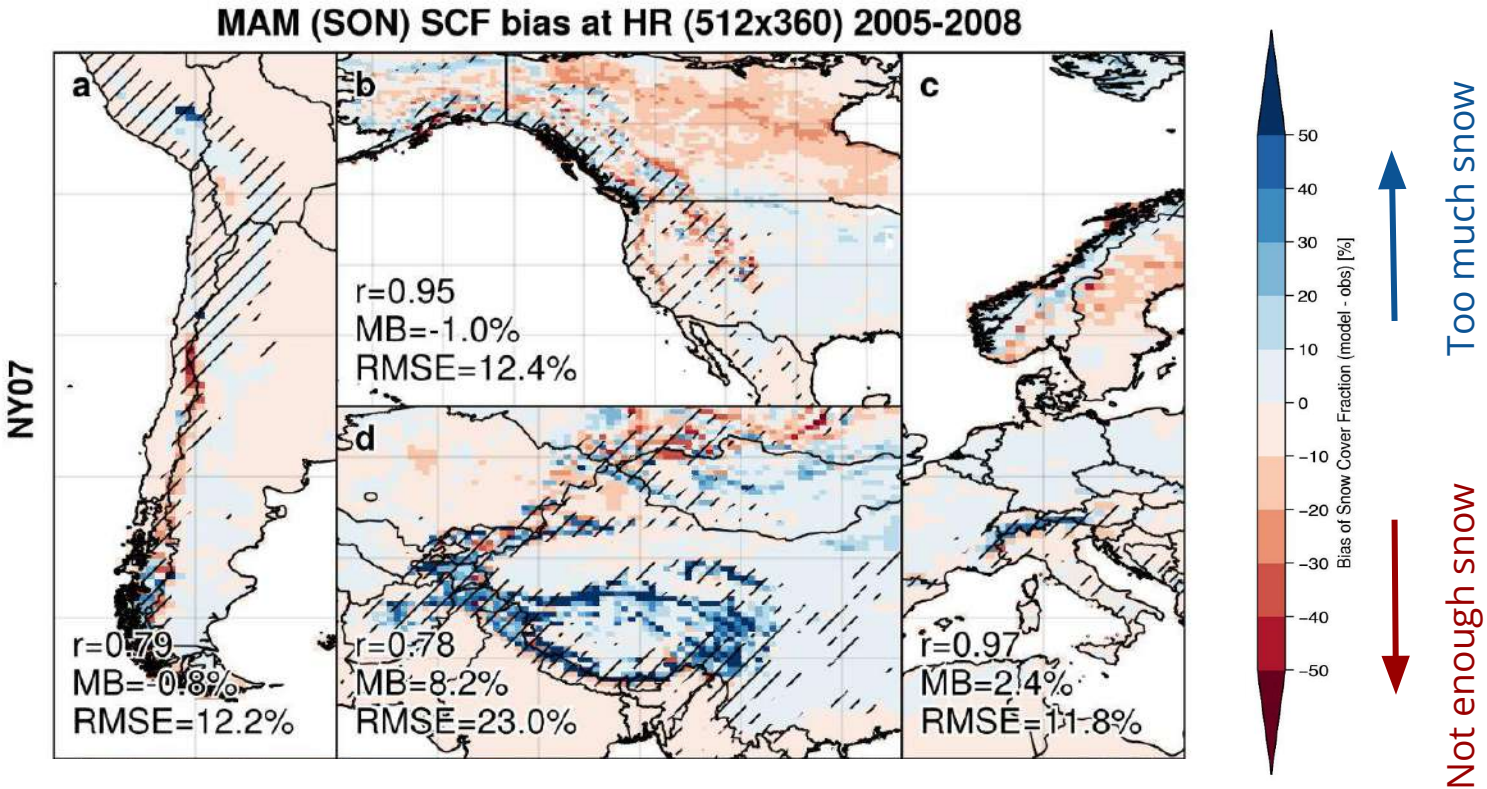
Application in GCM (LMDZ/ORCHIDEE)



- Nudged land-atmosphere coupled simulations (LMDZ/ORCHIDEE)
- 2 resolutions:
  - LR 144x142 (~100/200 km)
  - HR 512x360 (~50 km)
- 2005-2008 (2004 spin-up)
- NY07, LA22, and SL12 parameterizations
- Snow CCI MODIS observational reference

Spring snow cover bias

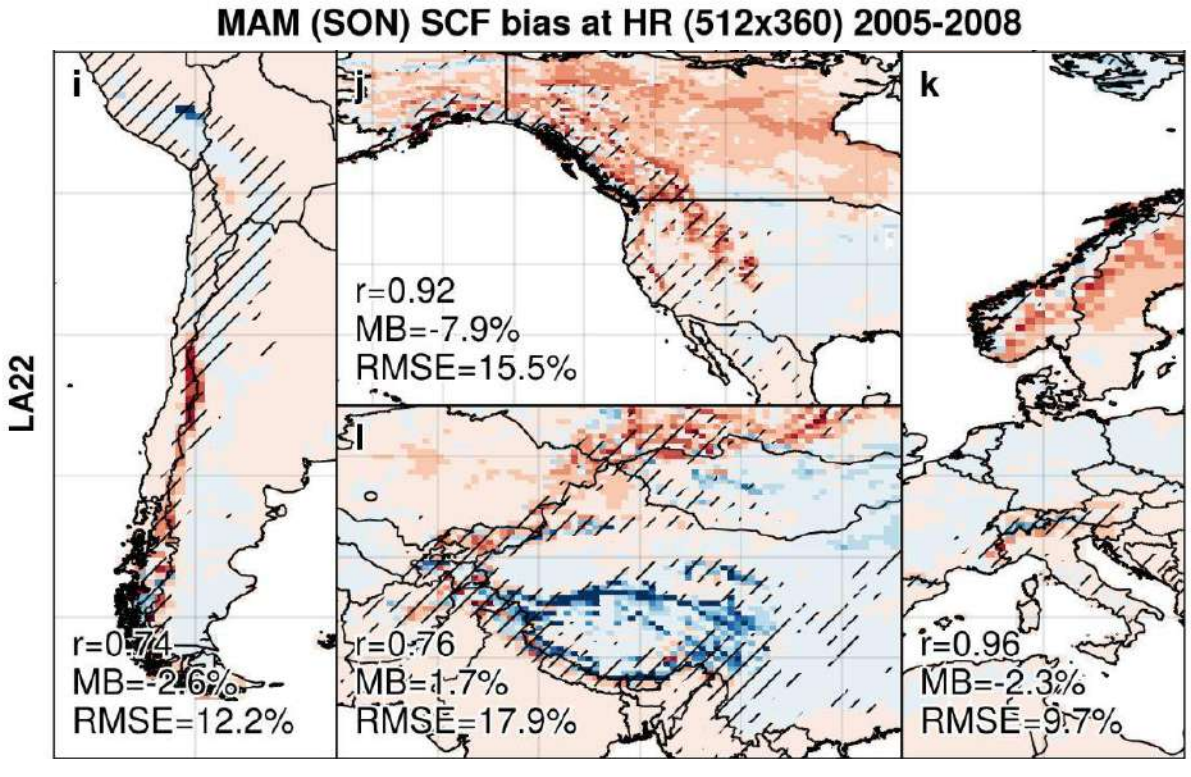
Reference
(Niu and Yang, 2007)



Application in GCM (LMDZ/ORCHIDEE)

Spring snow cover bias

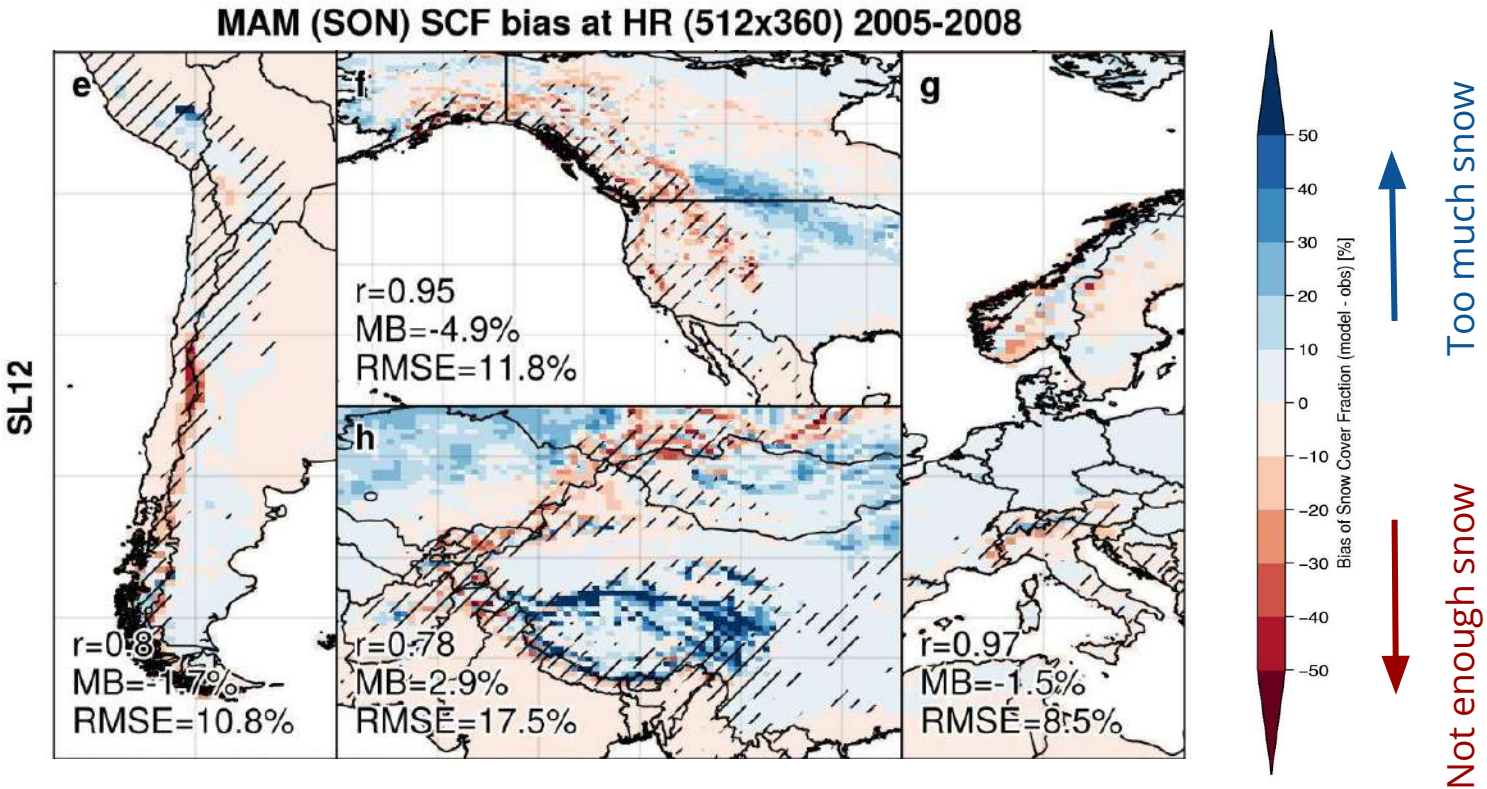
New LA22
(based on NY07)



Application in GCM (LMDZ/ORCHIDEE)

Spring snow cover bias

New SL12
(Swenson and Lawrence, 2012)



Take home messages

- Taking into account the sub-grid topography in SCF parameterization seems essential over mountainous areas (Swenson and Lawrence, 2012 ; Miao et al., 2022 ; Lalande et al., in prep)
- Other processes might be involved in current biases over HMA:
  - precipitation (orographic drag; e.g, Wang et al., 2020) / aerosol deposition on snow (e.g., Usha et al., 2020) / boundary layer (e.g., Serafin et al., 2020) / tropospheric cold bias, etc.
- Further calibration -> other regions / datasets (+ other variables, forested areas?, etc.) +
  ↳Crucial need of snowfall, SD/SWE observations over mountainous areas!
- Limitation over permanent snow areas? (glaciers, etc.)
  - elevation bands (e.g., Walland and Simmonds, 1996; Younas et al., 2017)
- Other parameterizations not tested, e.g.: Liston (2004), Helbig et al. (2021), etc.
- Deep learning very promising for such parameterizations (+ help to test the influence of other parameters)

Conclusion et perspectives générales

#1 Étude multi-modèle CMIP6 des changements climatiques en HMA

Objectif : Étudier et quantifier les changements climatiques en HMA à l'aide de modèles de circulation générale (GCMs) et de jeux d'observations.

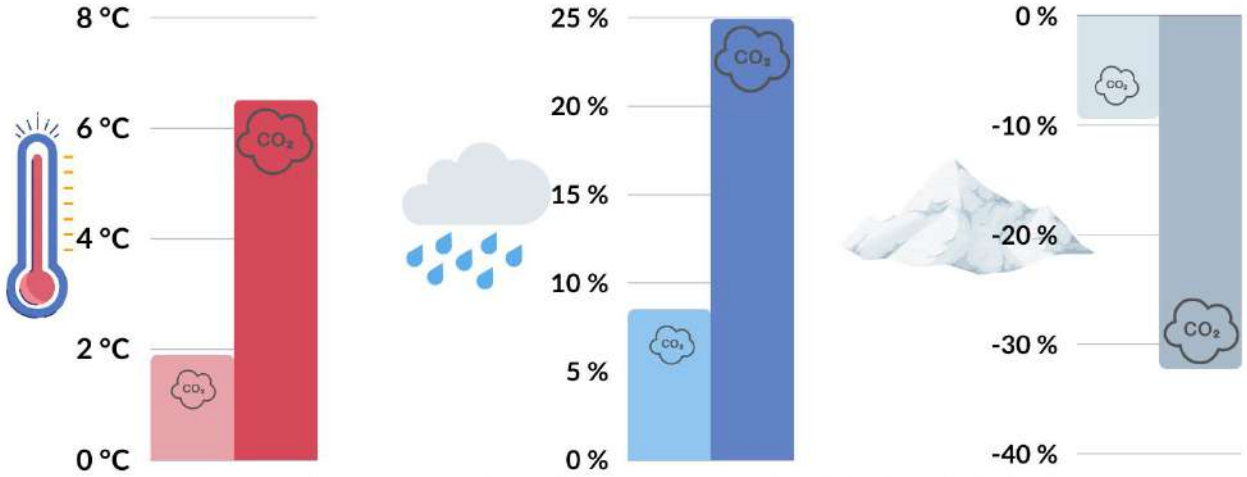
- Biais froid toujours présent dans la plupart des modèles CMIP6 en HMA
- Pas de lien évident entre biais et tendances -> certains modèles biaisés sont capables de reproduire les tendances passées.
- L'origine des biais semble différent d'un modèle à l'autre (même si biais froid et surestimation de couverture de neige coïncide pour la plupart des modèles)
- La résolution des modèles n'améliore pas systématiquement les performances...
  ↳Besoin d'améliorer les GCMs sur les régions de montagnes
- Enjeux sociaux-économiques et environnementaux importants en HMA
- D'autres variables peuvent être impliquées... (couverture nuageuse, aérosols, couche limite, T500,...)

#1 Étude multi-modèle CMIP6 des changements climatiques en HMA

Objectif : Étudier et quantifier les changements climatiques en HMA à l'aide de modèles de circulation générale (GCMs) et de jeux d'observations.

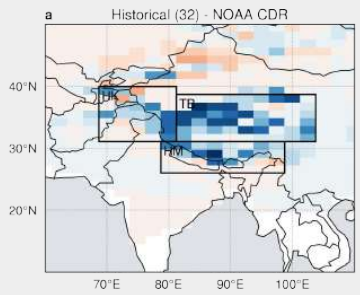
RÉCHAUFFEMENT EXACERBÉ DANS LES HAUTES MONTAGNES D'ASIE

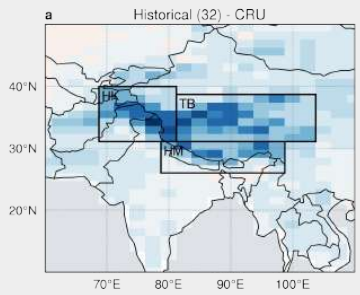
Changements de température, précipitations et couverture de neige à la fin du siècle par rapport à la période récente 1995-2014 en fonction des scénarios de basses ou hautes émissions de gaz à effet de serre.

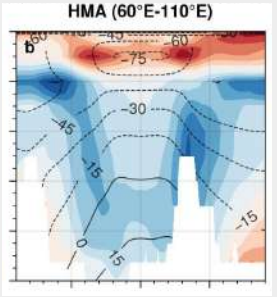


Source: Climate change in the High Mountain Asia in CMIP6 (Lalande et al., 2021)

#2 Description et évaluation du modèle de l'IPSL en HMA







- Expérience sans neige : les biais de surface ne semblent pas être à l'origine des biais troposphériques.
- Expérience guidées : les biais de surface semblent avoir une cause distincte des biais troposphériques.
- Les biais troposphériques amplifient les biais de surface
- Les biais de la couverture neigeuse semblent en partie liés à la topographie.
- Autres causes possibles importantes (non étudiées) : couverture nuageuse, albédo, aérosols, processus de la couche limite, etc.

#3 Paramétrisation de la couverture de neige en région de montagne

Objectif : Améliorer la représentation de la couverture de neige en région de montagne dans les GCMs.

- La prise en compte de la topographie sous-maille dans la paramétrisation de SCF semble essentielle sur les zones montagneuses (Swenson et Lawrence, 2012 ; Miao et al., 2022 ; Lalande et al., en prép.)
- Permet de réduire les biais de couverture de neige et de température en HMA (+ sur les Alpes - autres massifs)
- D'autres processus sont certainement également impliqués dans les biais en HMA
- Calibration -> autres régions / jeux de données (+ autres variables, zones forestières, etc.)
  + ↳Besoin crucial d'obs de precip neigeuse, SD/SWE sur les zones montagneuses !
- Deep learning très prometteur pour de telles paramétrisations (+ pour tester l'influence d'autres paramètres).

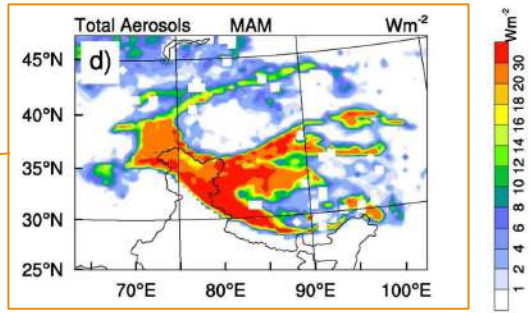
Perspectives : conseils SCF CMIP6 -> CMIP7 LMDZ/ORCHIDEE

- Implémenter SL12 et LA22 (en plus de NY07) et conserver un switch pour passer d'une version à l'autre pour déterminer la meilleure en fonction des configurations (+ ML sur du long terme).
- Envisager une calibration directement dans le modèle (dès lors que l'on pas — encore — d'obs fiables sur les régions montagneuses).
  ↳ /!\ compensations de biais ≠ couplé ou non /!\
- Lorsque + de jeux de données revenir sur une calibration + physique
- Approfondir simulations ORCHIDEE offline pour déterminer les incertitudes liées aux jeux de forçages
- Regarder ce qu'il se passe dans les zones de forêt
- En couplé : /!\ biais tropo /!\ -> impact sur l'ensemble des surfaces continentales

Perspectives : conseils SCF CMIP6 -> CMIP7 LMDZ/ORCHIDEE

- Amélioration de la représentation de l'albédo de la neige incluant le dépôt d'aérosols (ex., Warren and Wiscombe, 1980; Kokhanovsky and Zege, 2004; Wang et al., 2020b)

Fig. 7 Usha et al. (2020)



Le sable du Sahara a partiellement recouvert le manteau neigeux de plusieurs stations des Pyrénées, comme ici à la station de Piau (Hautes-Pyrénées), le 15 mars 2022. | BASTIEN ARBERET / AFP

Perspectives : conseils SCF CMIP6 -> CMIP7 LMDZ/ORCHIDEE

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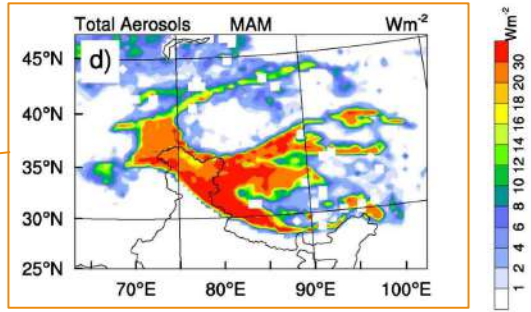
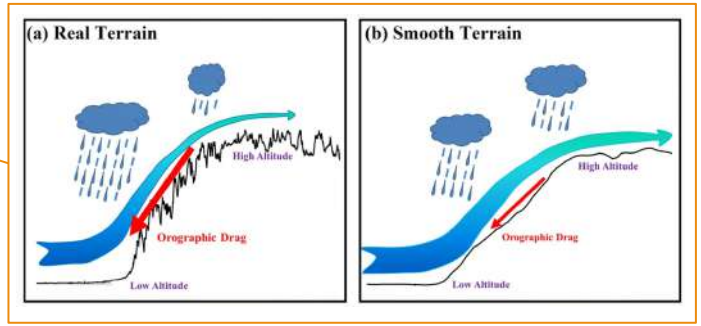


- Trainée orographique de petite échelle

Fig. 5 Wang et al. (2020)



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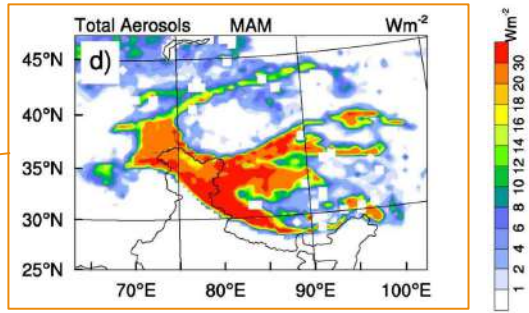

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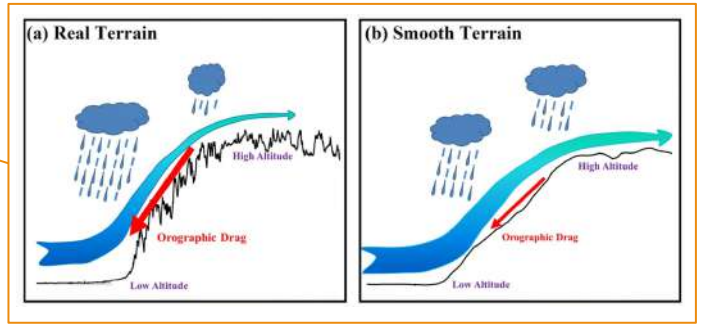
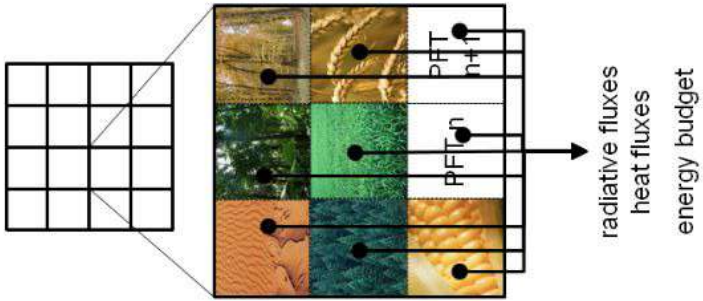


- Amélioration du calcul du bilan d'énergie de surface



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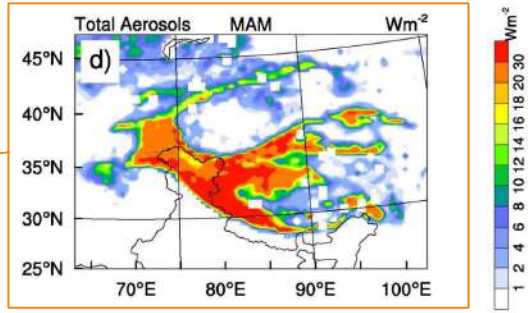

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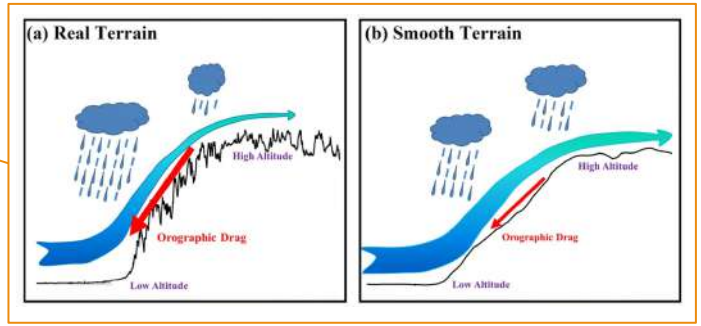
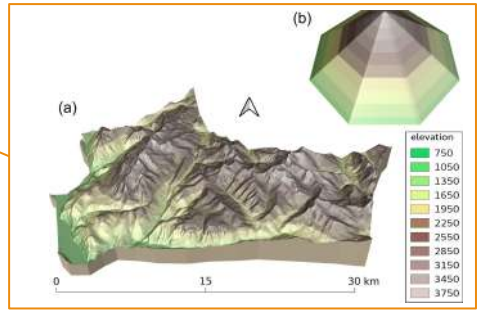


- Amélioration du calcul du bilan d'énergie de surface

- Bandes d'altitudes et couplage neige-glace

Fig. 3 Vernay et al. (2022)



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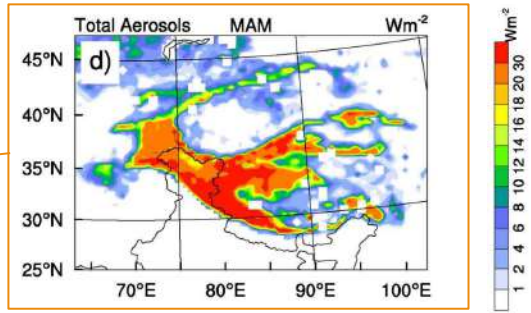

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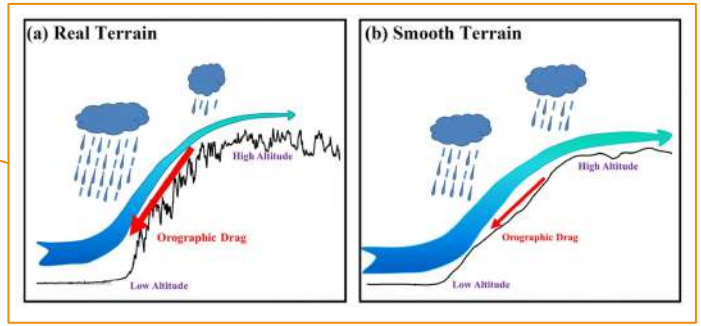

- Amélioration du calcul du bilan d'énergie de surface

- Bandes d'altitudes et couplage neige-glace

- Couche limite en zone de montagne (Wekker and Kossmann, 2015; Serafin et al., 2020)

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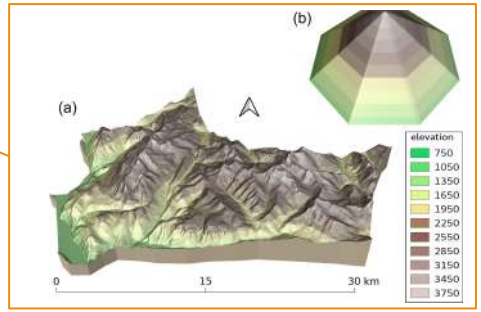
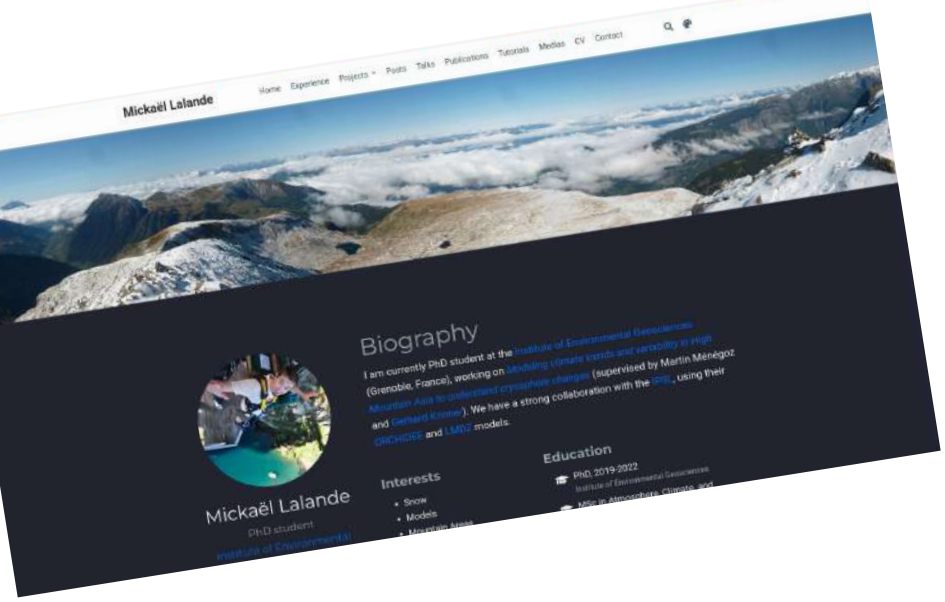


Merci à tous pour votre attention !


Mickaël Lalande
Home Experience Projects Posts Talks Publications Tutorials Medias CV Contact
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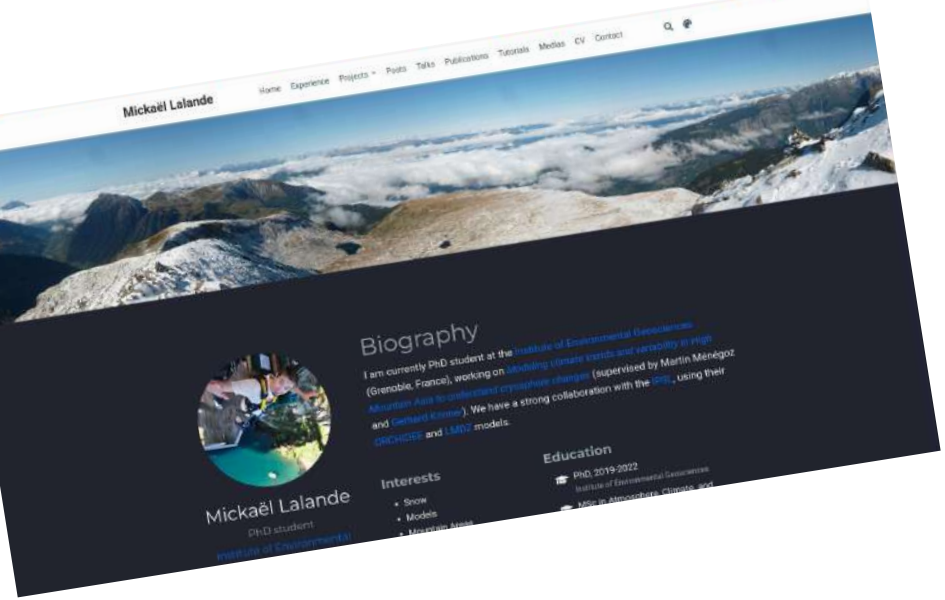
PhD, 2019-2022
Institute of Environmental Geosciences
Interests
Snow
Models
Mickaël Lalande
PhD student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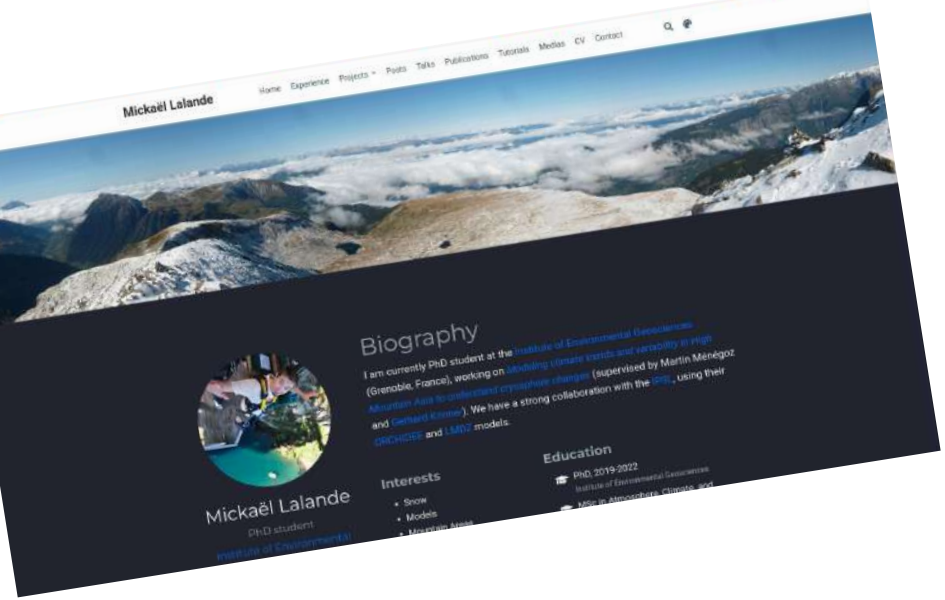
Science et Climat


#1
Le pouvoir réfléchissant de la Terre !
L'ALBEDO


#2
NIVEAU DES MERS
PASSÉ
PRÉSENT
FUTUR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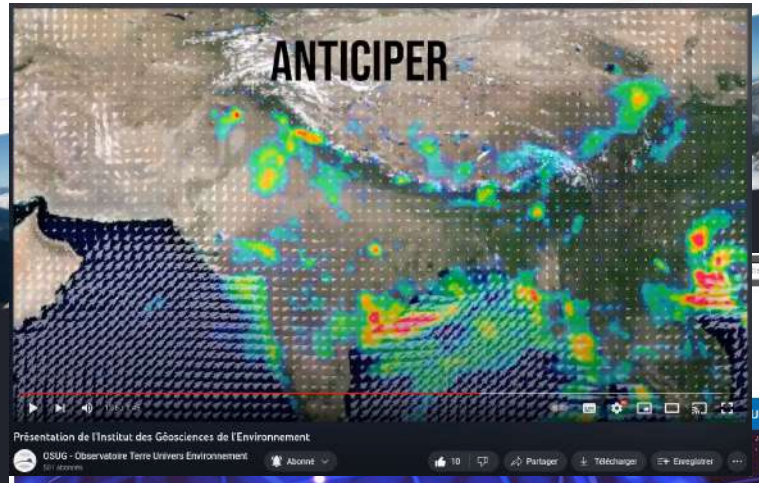
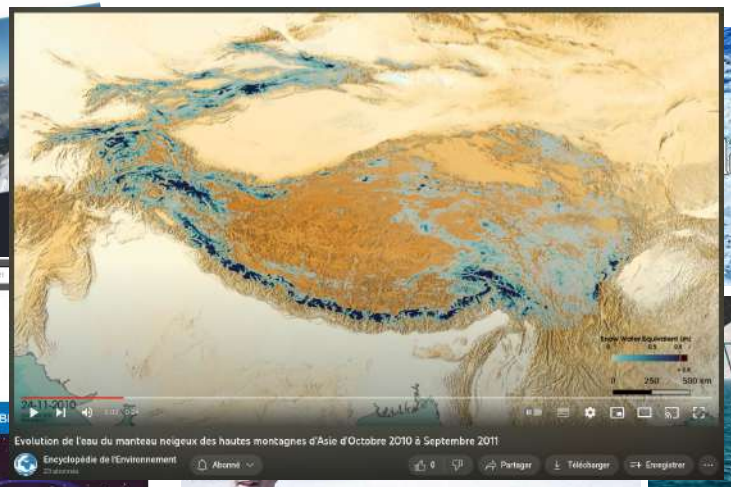
INTERVIEW #1
OÙ EN EST-ON DU RÉCHAUFFEMENT CLIMATIQUE ?
Gerhard Krinner


ANTICIPER
Présentation de l'Institut des Géosciences de l'Environnement
OSUG - Observatoire Terre Univers Environnement


Evolution de l'eau du manteau neigeux des hautes montagnes d'Asie d'Octobre 2010 à Septembre 2011
Encyclopédie de l'Environnement


L'ALBEDO


VEAU DES MERS
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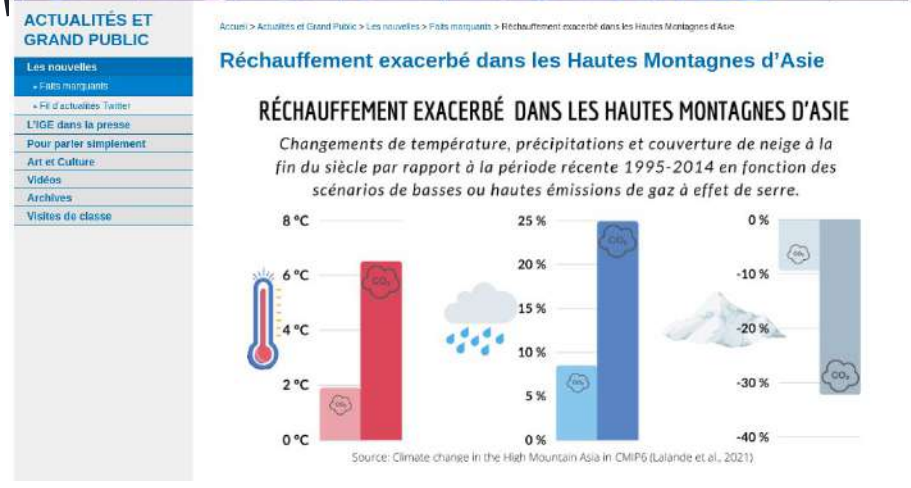
ACTUALITÉS ET GRAND PUBLIC
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Faits marquants
Fil d'actualités Twitter
L'IGE dans la presse
Pour parler simplement
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Vidéos
Archives
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Accueil > Actualités et Grand Public > Les nouvelles > Faits marquants > Réchauffement exacerbé dans les Hautes Montagnes d'Asie
Réchauffement exacerbé dans les Hautes Montagnes d'Asie
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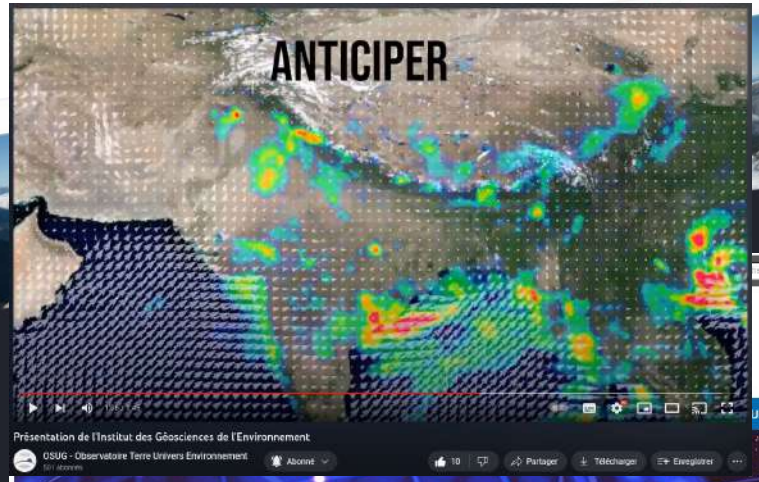
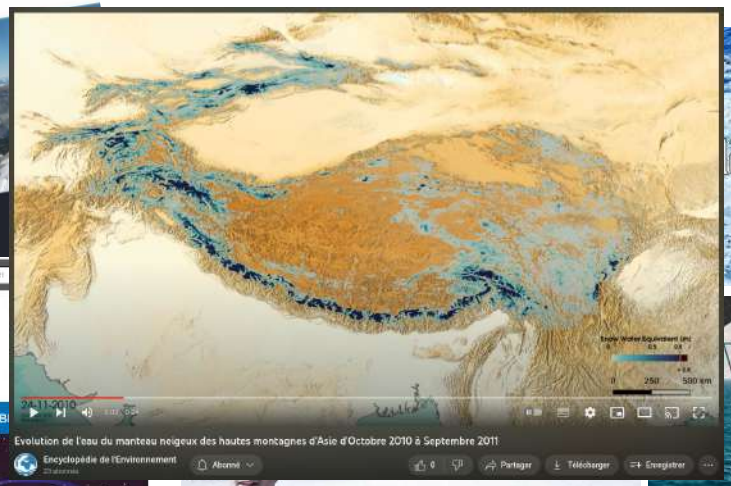
8 °C
6 °C
4 °C
2 °C
0 °C
25 %
20 %
15 %
10 %
5 %
0 %
0 %
-10 %
-20 %
-30 %
-40 %
Source: Climate change in the High Mountain Asia in CMIP6 (Lalande et al., 2021)


INTERVIEW #1
OÙ EN EST-ON DU RÉCHAUFFEMENT CLIMATIQUE ?
Gerhard Krinner

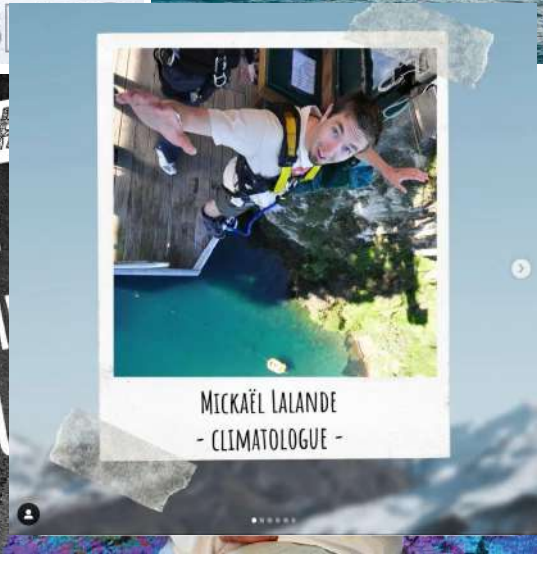

ANTICIPER
Présentation de l'Institut des Géosciences de l'Environnement
OSUG - Observatoire Terre Univers Environnement

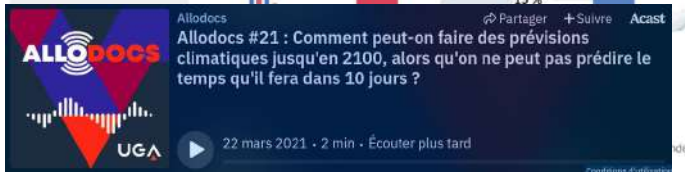

Evolution de l'eau du manteau neigeux des hautes montagnes d'Asie d'Octobre 2010 à Septembre 2011
Encyclopédie de l'Environnement


VEAU DES MERS
PASSÉ
PRÉSENT


LE RECHAUFFEMENT
CLIMATIQUE
EN COURS EST-IL
DU A
L'HOMME ?


T'FAIS UNE THÈSE ?
DIMINUTION DE L'ENNEIGEMENT DANS LES HAUTES MONTAGNES D'ASIE


MICKAËL LALANDE
- CLIMATOLOGUE -


Allodocs
Partager
Suivre
Acast
Allodocs #21 : Comment peut-on faire des prévisions climatiques jusqu'en 2100, alors qu'on ne peut pas prédire le temps qu'il fera dans 10 jours ?
22 mars 2021 · 2 min · Écouter plus tard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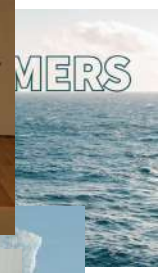
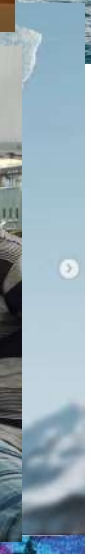
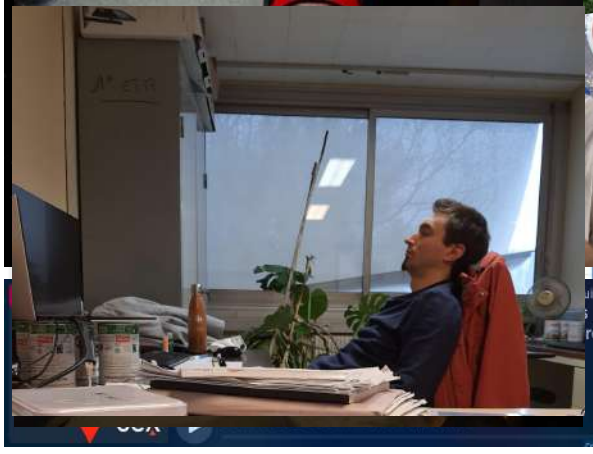

MERS










Mickaël Lalande

SOCIAL NETWORKS

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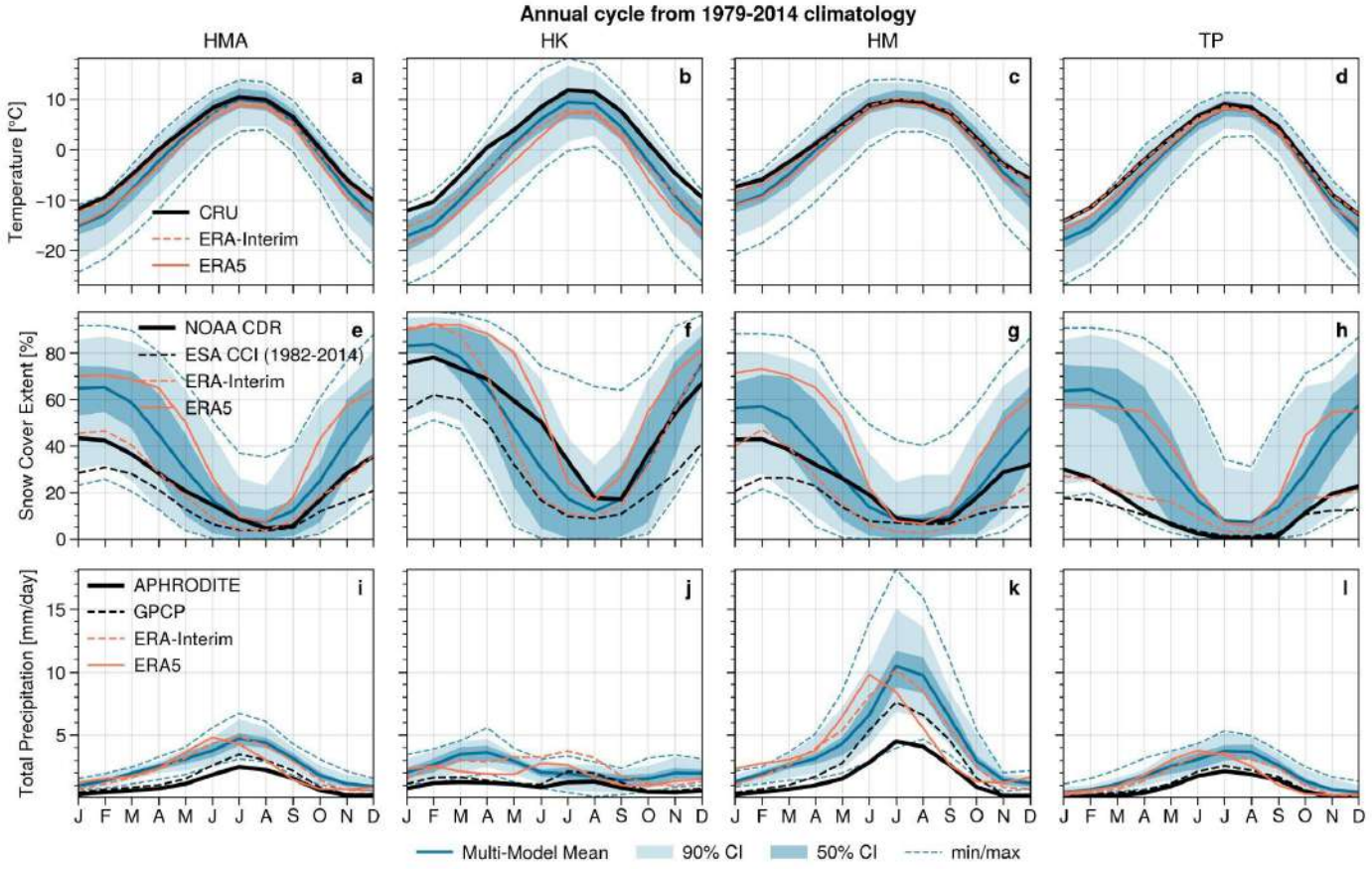
Supplementary materials

CMIP6 models

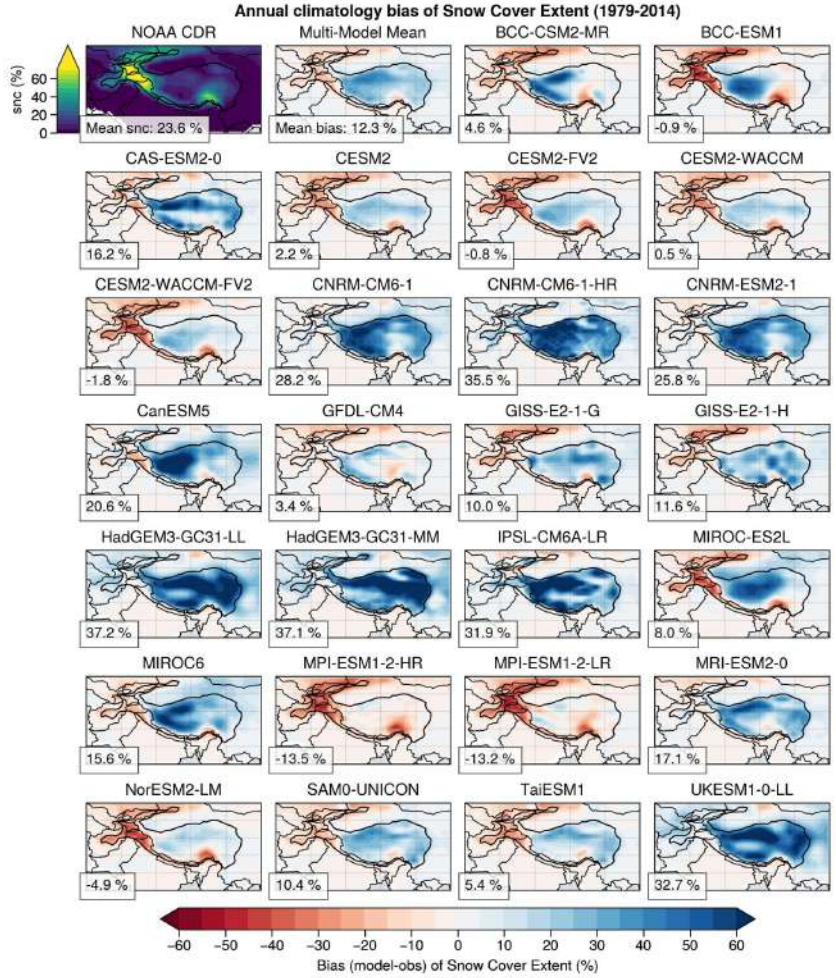
CMIP6 institute	CMIP6 model	Resolution (lonxlat)	Grid	Calendar	Member	SSP
BCC	BCC-CSM2-MR	1.1°x1.1°	gn	365_day	r1i1p1f1	
	BCC-ESM1	2.8°x2.8°				
CAS	CAS-ESM2-0	1.4°x1.4°	gn	365_day	r4i1p1f1	
NCAR	CESM2	1.2°x0.9°	gn	noleap	r1i1p1f1	
	CESM2-FV2	2.5°x1.9°				
	CESM2-WACCM	1.2°x0.9°				
	CESM2-WACCM-FV2	2.5°x1.9°				
CNRM-CERFACS	CNRM-CM6-1	1.4°x1.4°	gr	gregorian	r1i1p1f2	
	CNRM-CM6-1-HR	0.5°x0.5°				
	CNRM-ESM2-1	1.4°x1.4°				
CCCma	CanESM5	2.8°x2.8°	gn	365_day	r3i1p2f1	
NOAA-GFDL	GFDL-CM4	1.2°x1.0°	gr1	noleap	r1i1p1f1	
NASA-GISS	GISS-E2-1-G	2.5°x2.0°	gn	365_day	r1i1p1f1	
	GISS-E2-1-H					
MOHC	HadGEM3-GC31-LL	1.9°x1.2°	gn	360_day	r1i1p1f3	
	HadGEM3-GC31-MM	0.8°x0.6°				
IPSL	IPSL-CM6A-LR	2.5°x1.3°	gr	gregorian	r1i1p1f1	
MIROC	MIROC-ES2L	2.8°x2.8°	gn	gregorian	r1i1p1f2	
	MIROC6	1.4°x1.4°			r1i1p1f1	
MPI-M	MPI-ESM1-2-HR	0.9°x0.9°	gn	proleptic_gregorian	r1i1p1f1	
	MPI-ESM1-2-LR	1.9°x1.9°				
MRI	MRI-ESM2-0	1.1°x1.1°	gn	proleptic_gregorian	r1i1p1f1	
NCC	NorESM2-LM	2.5°x1.9°	gn	noleap	r2i1p1f1	
SNU	SAM0-UNICON	1.2°x0.9°	gn	noleap	r1i1p1f1	
AS-RCEC	TaiESM1	1.2°x0.9°	gn	noleap	r1i1p1f1	
MOHC, NIMS-KMA	UKESM1-0-LL	1.9°x1.2°	gn	360_day	r1i1p1f2	

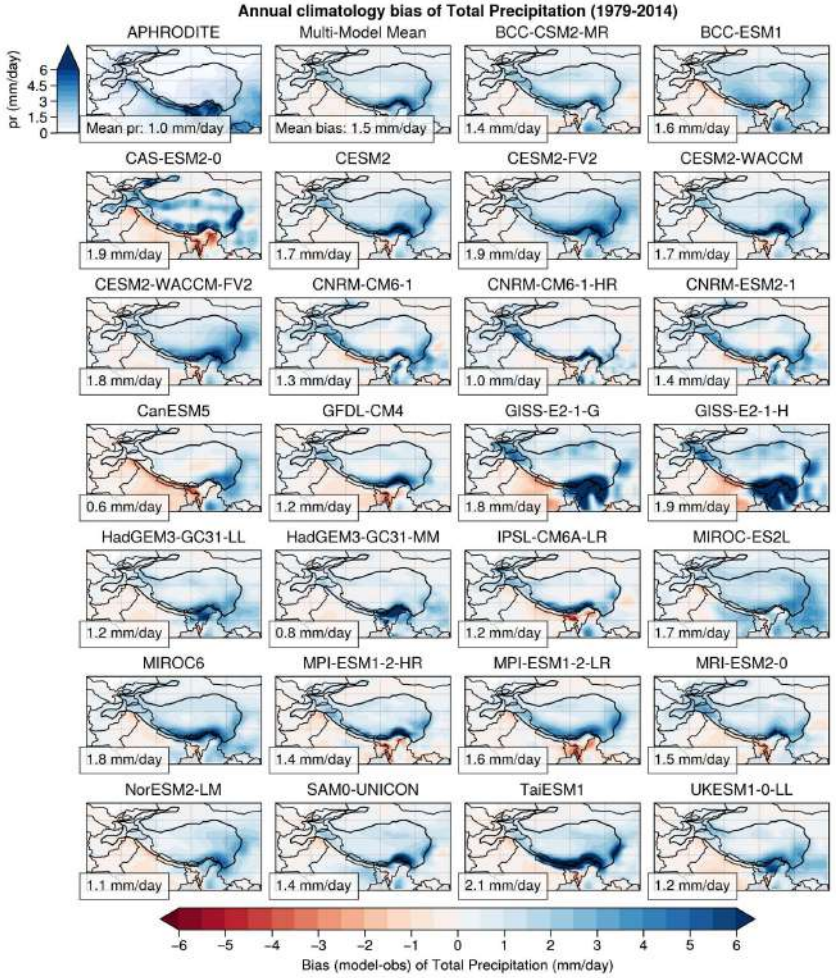
tas, snc and pr annual cycles

- stronger biases in winter for tas (~2/3°C) and snc (~20%) over HMA
- large snc spread -> difficulty to simulate snc in complex topography areas
- ERA5 bias similar to models -> no assimilation >1500m (Orsolini et al., 2019)
- pr obs lower than models -> snow undercatch issues by rain gauge (e.g. Jimeno-Saez et al., 2020)

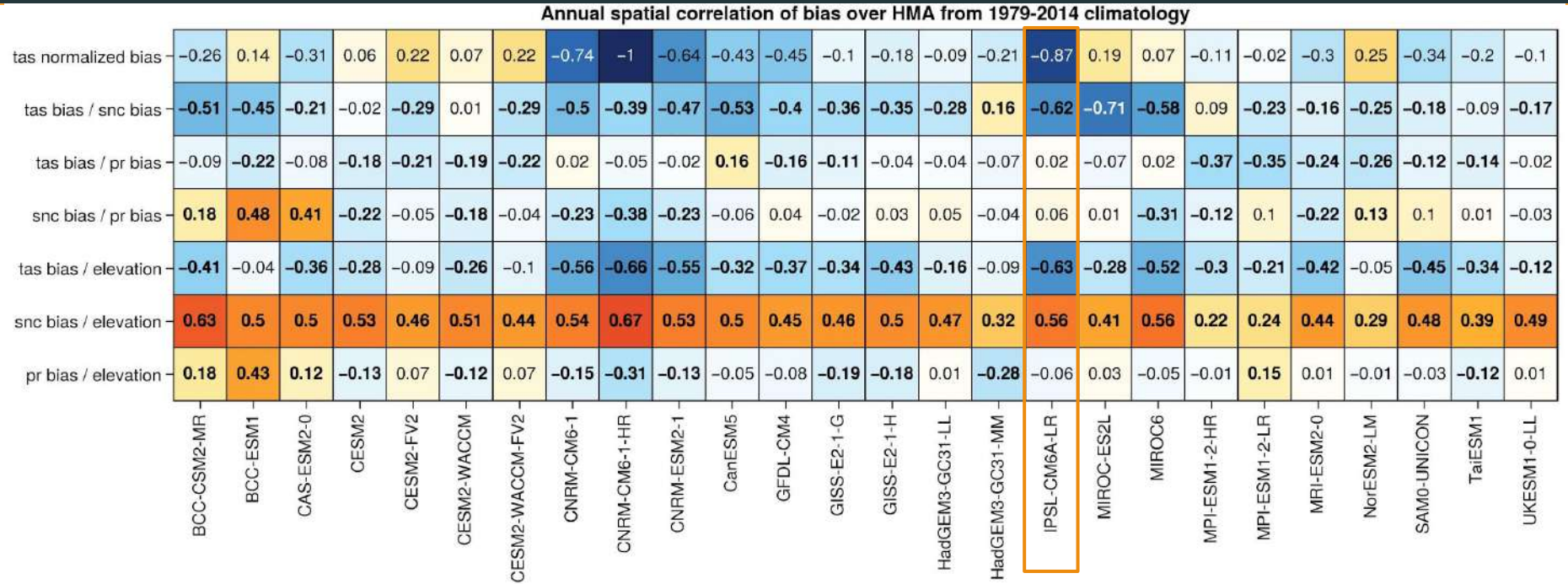


Historical bias analysis





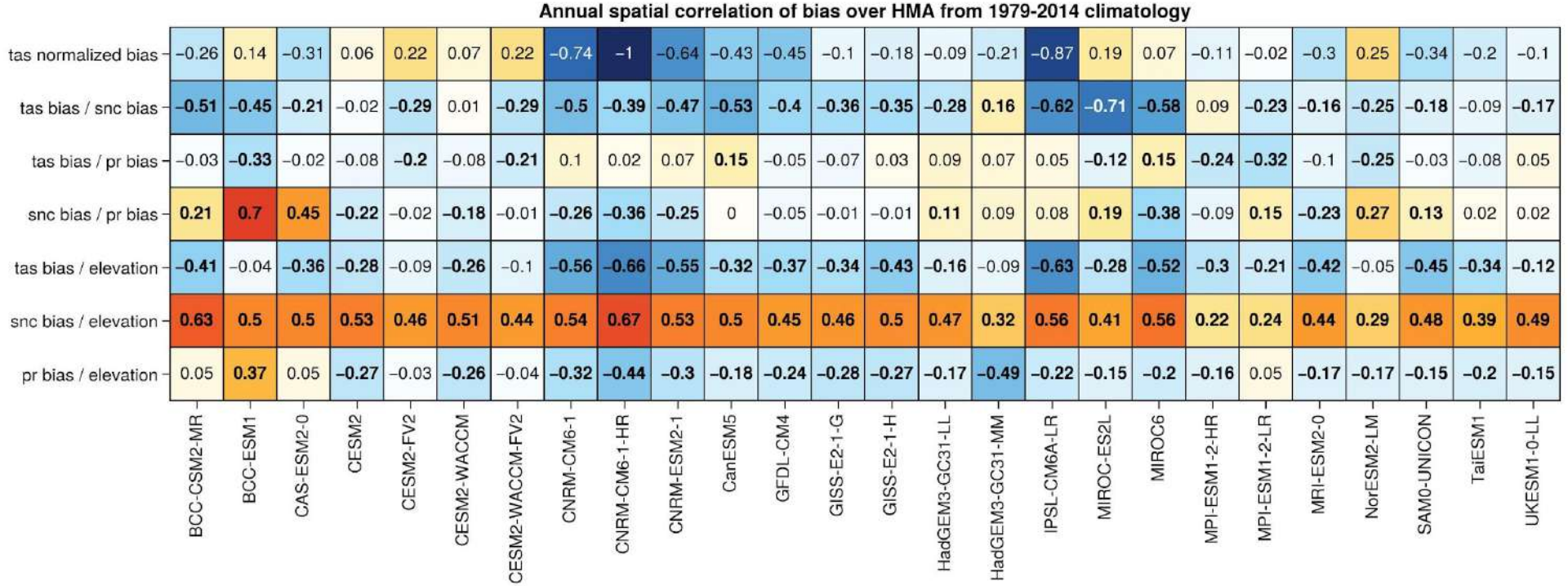
Bias spatial correlation



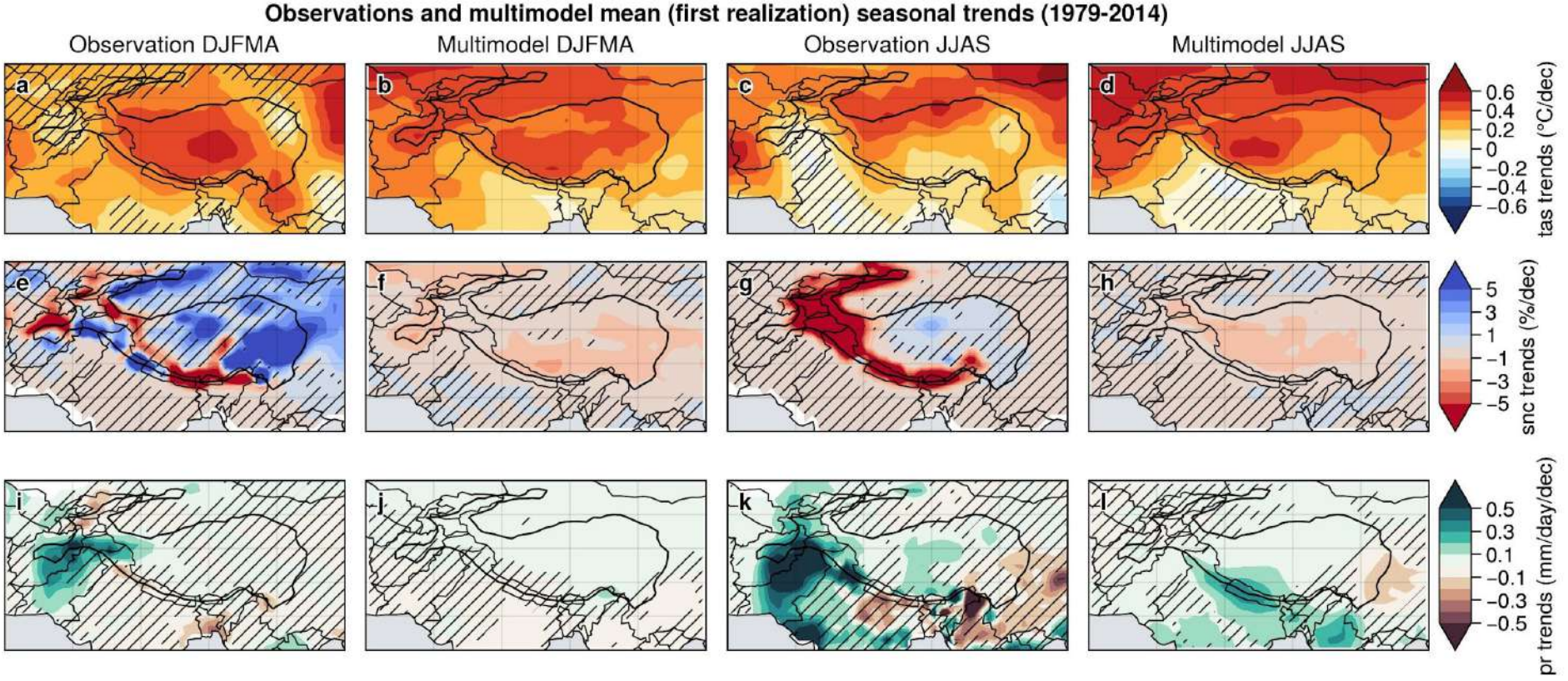
- Significant negative correlations between tas and snc biases
- Less obvious for pr (/!\ APHRODITE underestimate solid precip /!\ -> more negative correlation)
- Correlations between tas/snc biases with elevation -> difficulty representing physical processes at high elevation?

Are trends impacted by overall biases?

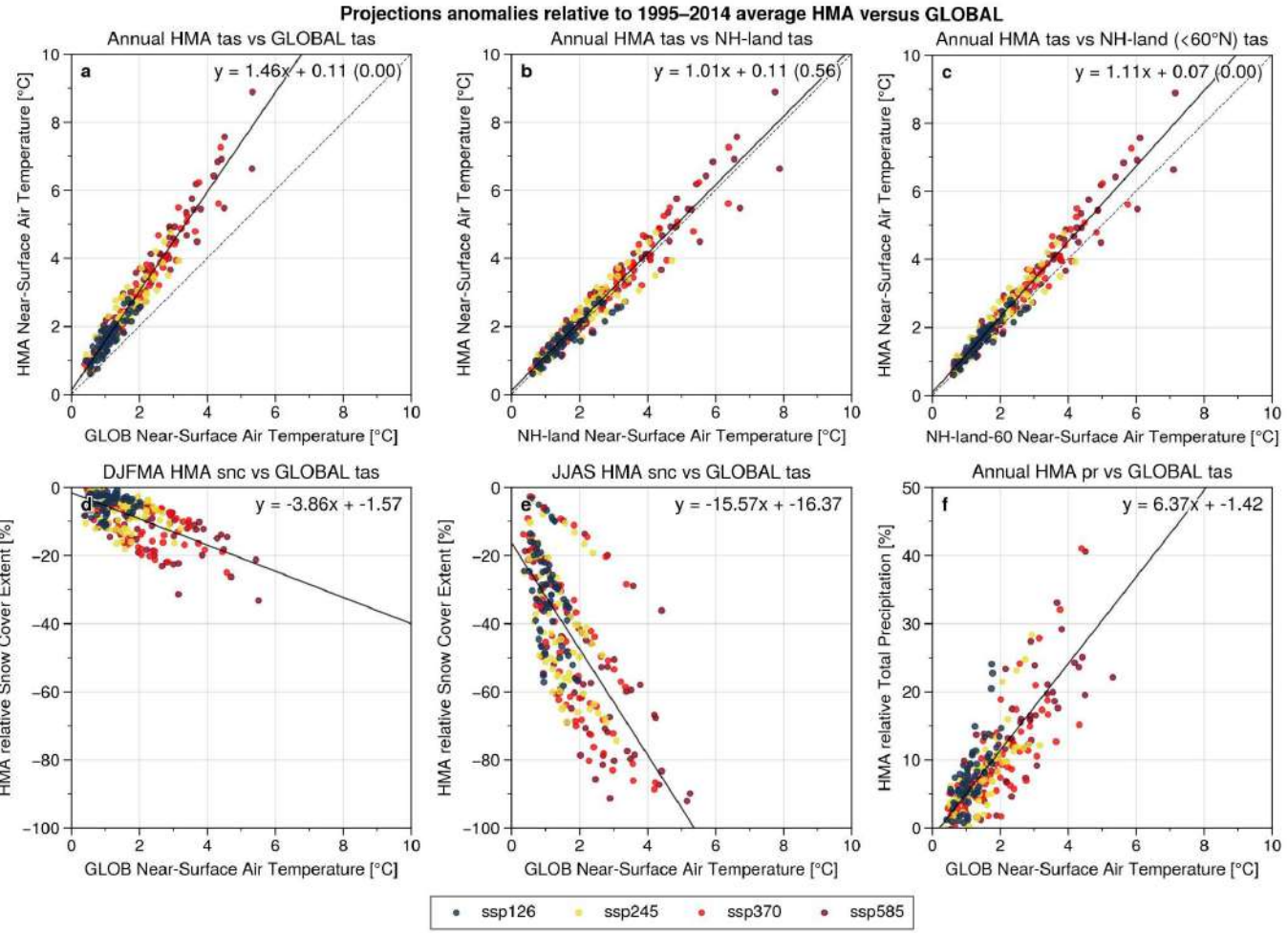
Bias spatial correlation (GPCP)



Historical trends analysis



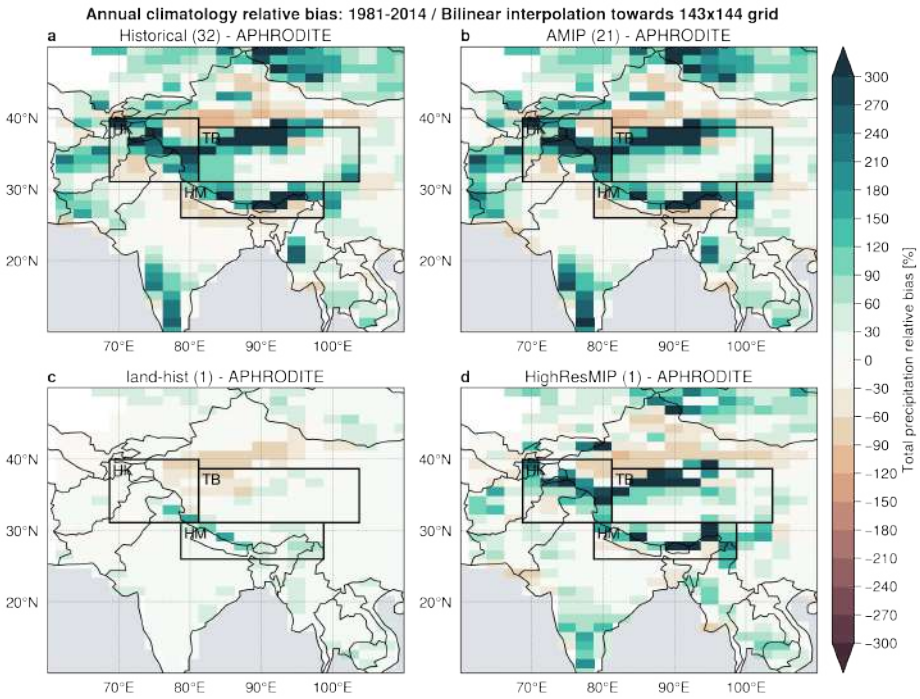
HMA versus global



- HMA is warming faster as the rest of the world ?
- 10% faster… compared to NH (without Arctic)
- ~ 4% relative snc loss per 1° C GSAT in winter (linear)
- In summer almost all snc disappear in worst scenario (not linear)
- ~ 6 % relative more pr per 1°C GSAT

IPSL-CM6A-LR: Historical, AMIP, land-hist / IPSL-CM6A-ATM-HR bias

Total precipitation **relative** bias

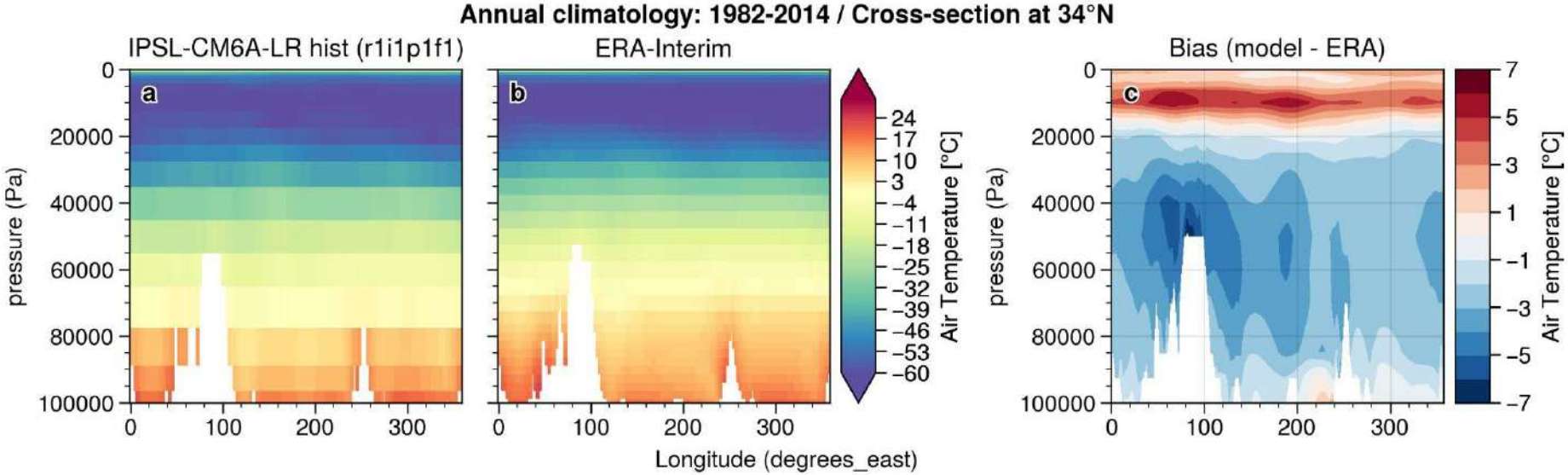


BUT...

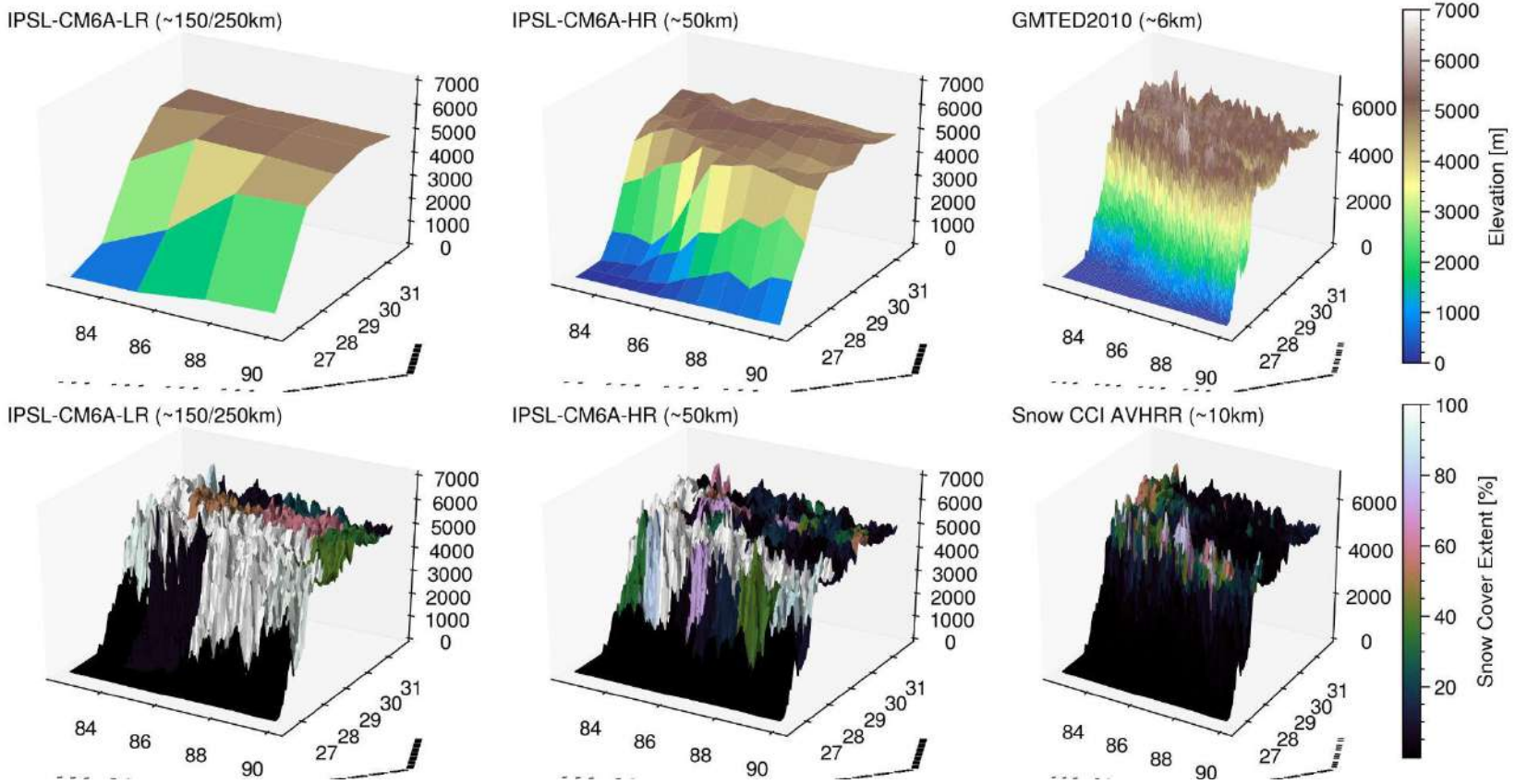
All in situ stations and satellite data tends to **underestimate** the **snow** component!

- The in situ station and satellite data, as well as their combinations, have difficulties in detecting the snow component of precipitation. (Palazzi et al., 2013)
- An independent validation with observed river flow confirms that the water balance can indeed only be closed when the high altitude precipitation on average is more than twice as high and in extreme cases up to a factor of 10 higher than previously thought. (Immerzeel et al., 2015)
- Gao et al. (2020) montrent qu'en raison de grandes incertitudes dans les ensembles de données de forçage atmosphériques sur les régions montagneuses (en particulier pour les précipitations), des biais importants liés à la neige sont présents.

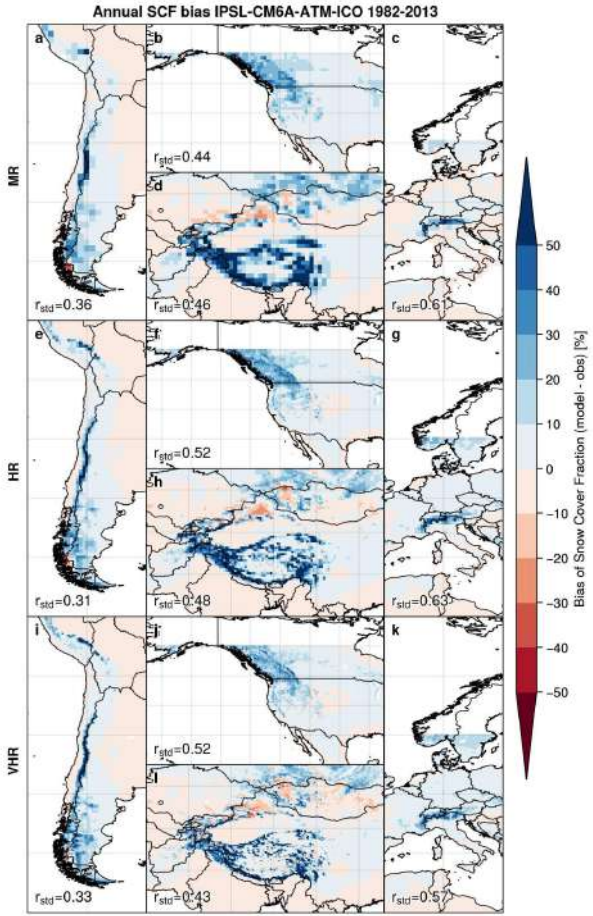
Air Temperature meridional cross-section means bias

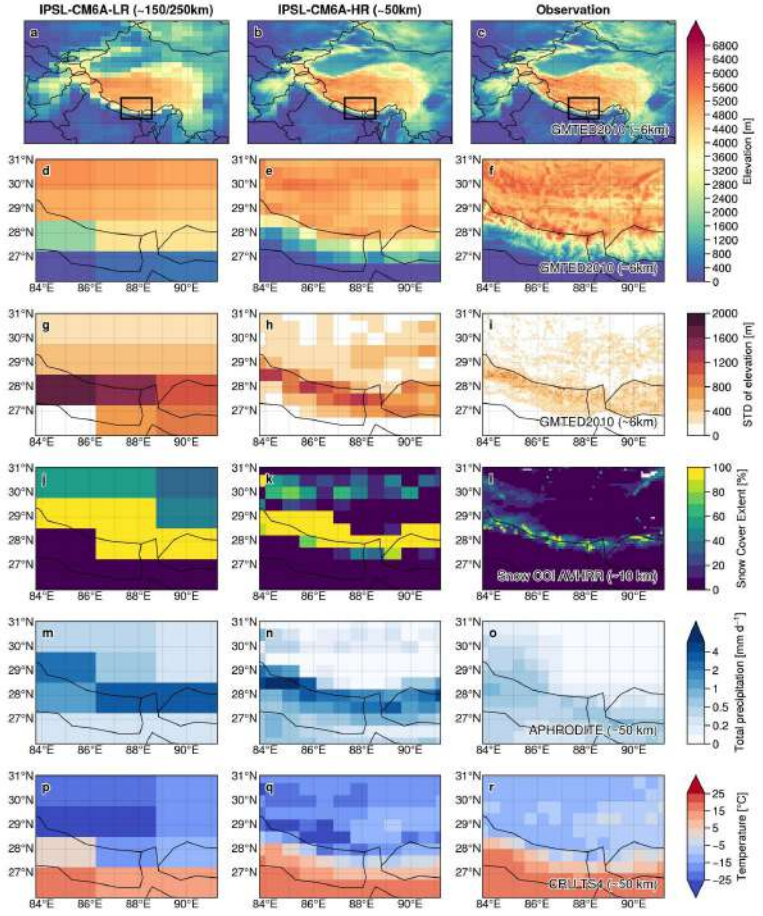


Lien avec la topographie ?

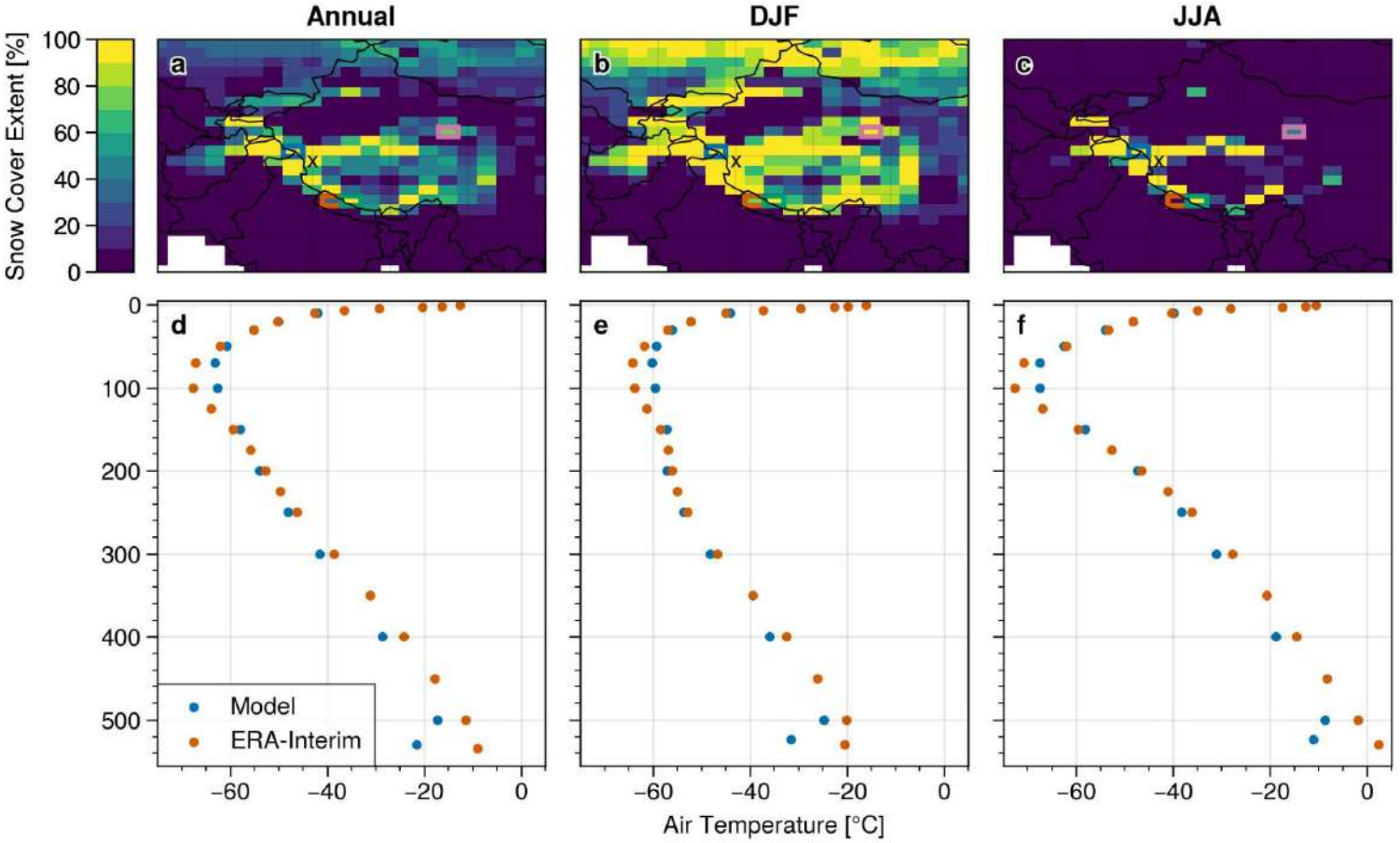


Influence de la résolution

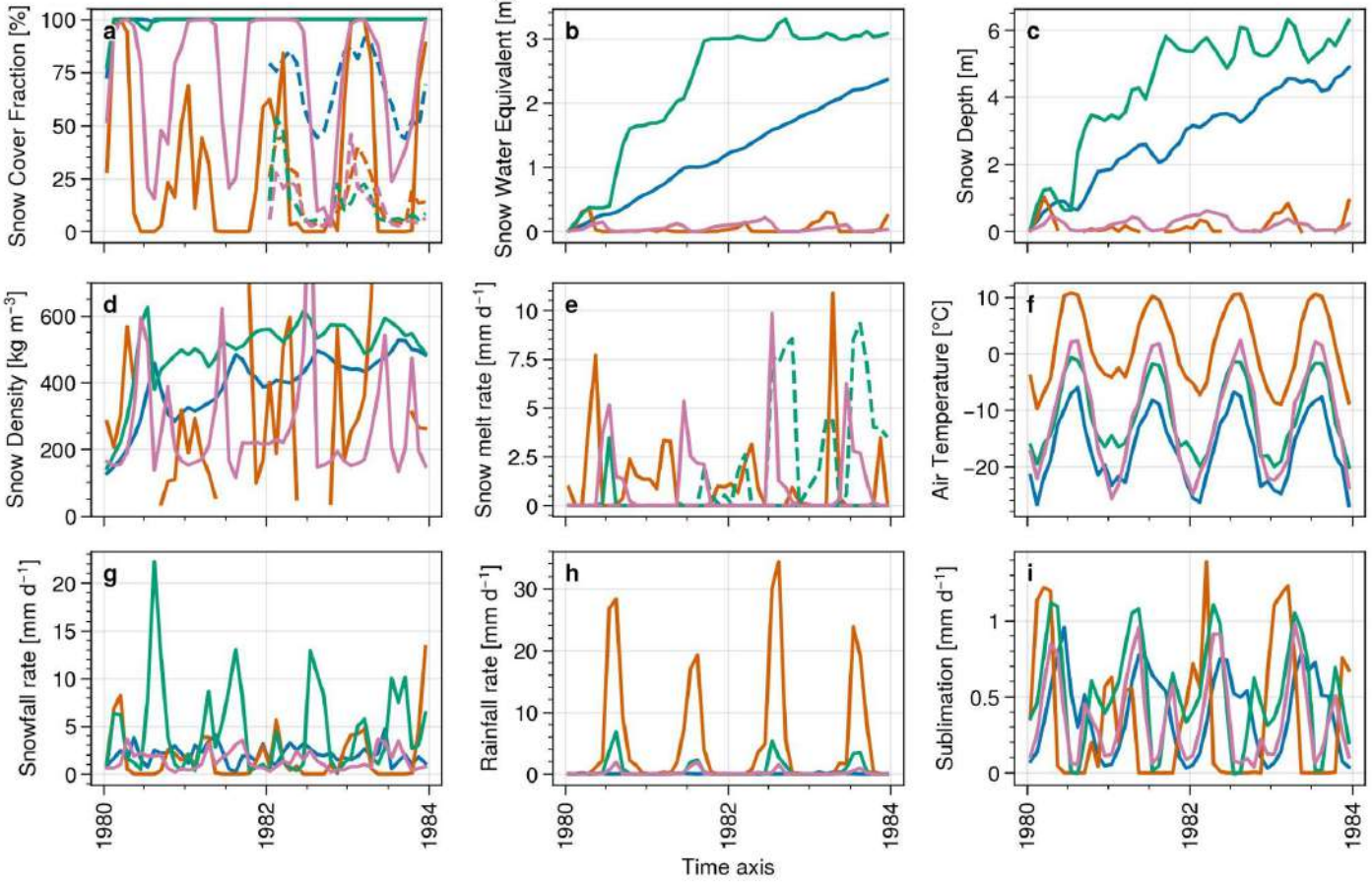




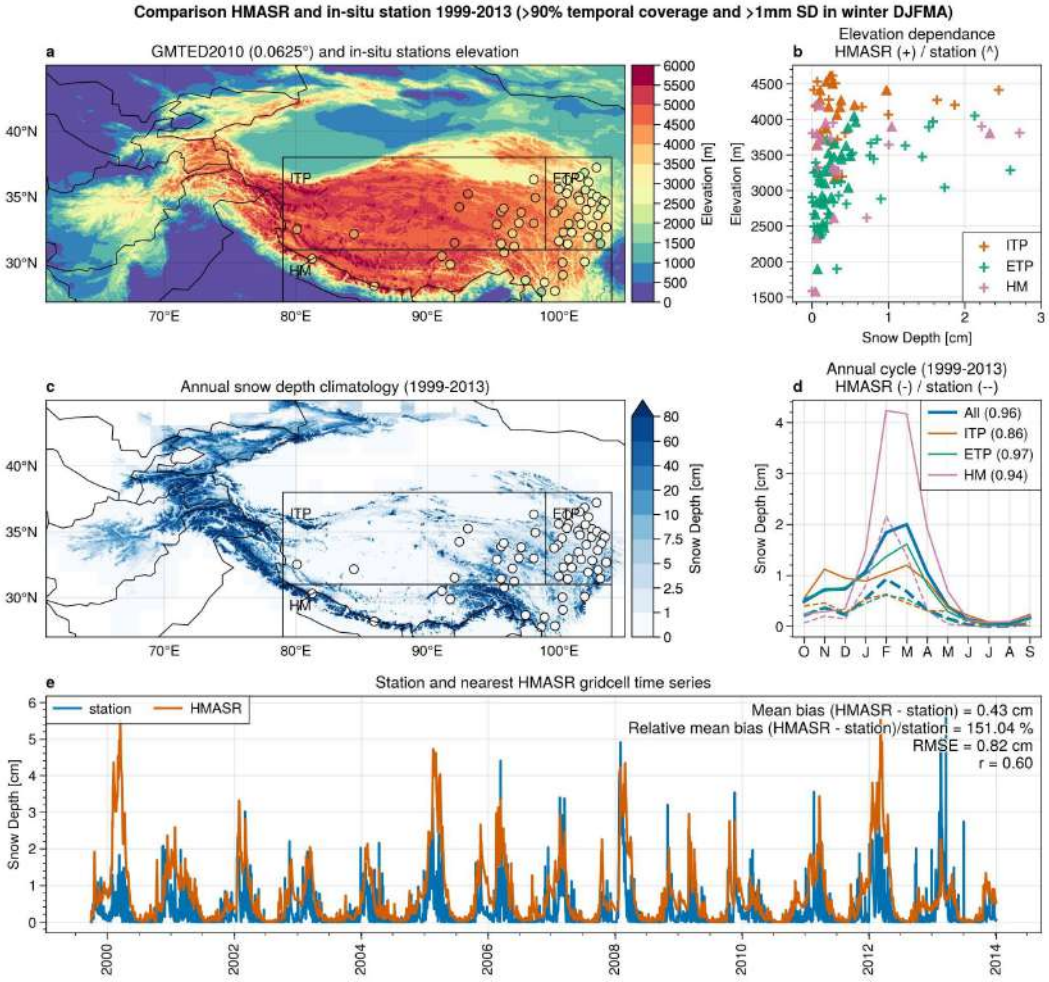
Neige permanente



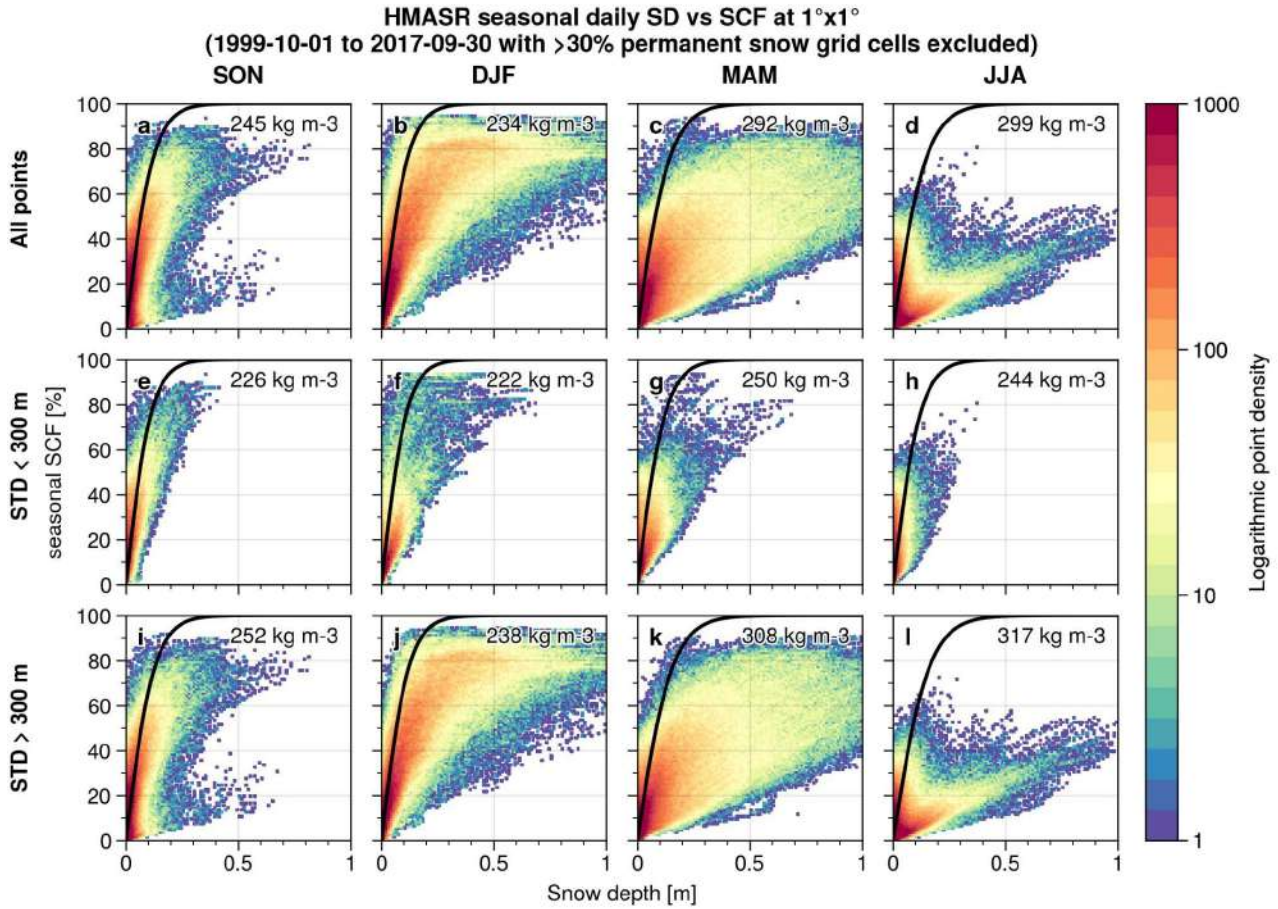
Neige permanente



High Mountain Asia UCLA Daily Snow Reanalysis (HMASR)



High Mountain Asia UCLA Daily Snow Reanalysis

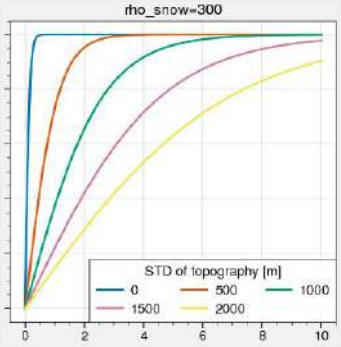


Other snow cover parameterizations

Niu and Yang (2007) custom

$$F = \tanh\left(\frac{d}{2.5 z_{0g}(\rho_{snow}/\rho_{new})^{m}}\right)$$

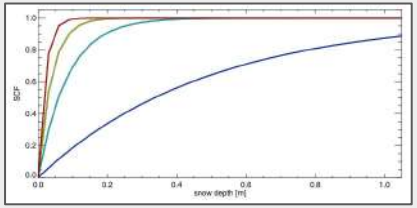
STD topo



Swenson and Lawrence (2012)

Accumulation

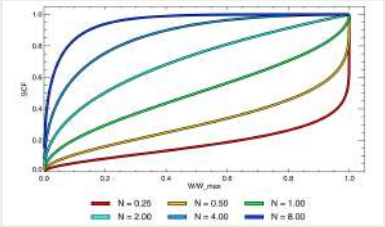
$$F_{N+1} = 1 - (p_{N+1})(p_N) = 1 - (1 - s_{N+1})(1 - F_N)$$



Depletion

$$F = 1 - \left[\frac{1}{\pi}\operatorname{acos}\left(2\frac{W}{W_{\max}} - 1\right)\right]^{N_{melt}}$$

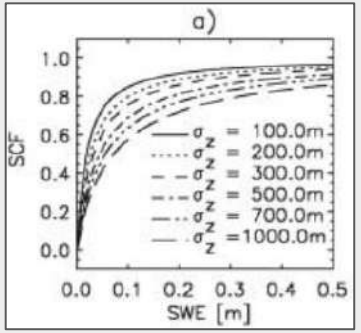
$$N_{melt} = \frac{200}{\sigma_{topo}}$$



Roesch et al. (2001)

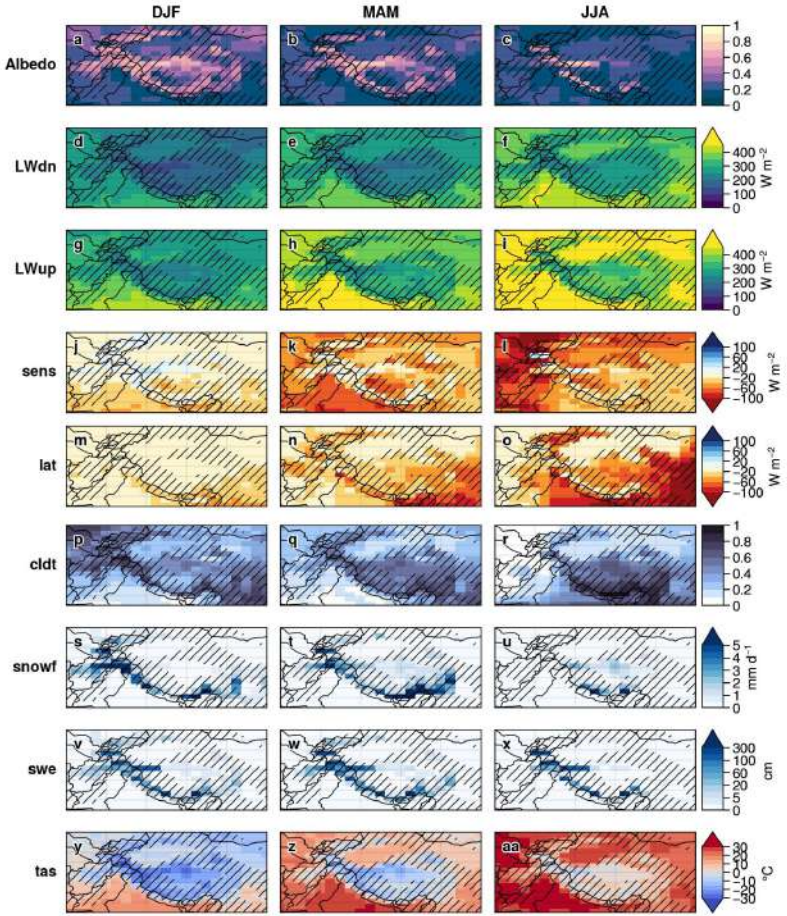
Mountainous areas

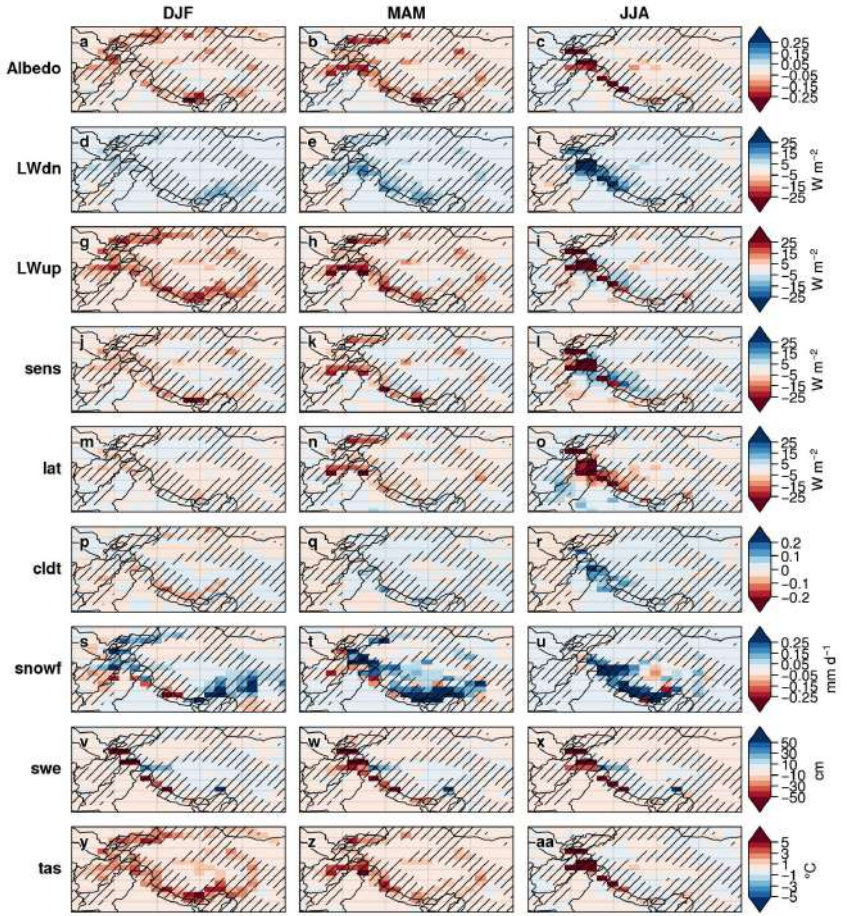
$$f_s = 0.95 \cdot tanh(100 \cdot S_n)\sqrt{\frac{1000 \cdot S_n}{1000 \cdot S_n + \epsilon + 0.15\sigma_z}}$$



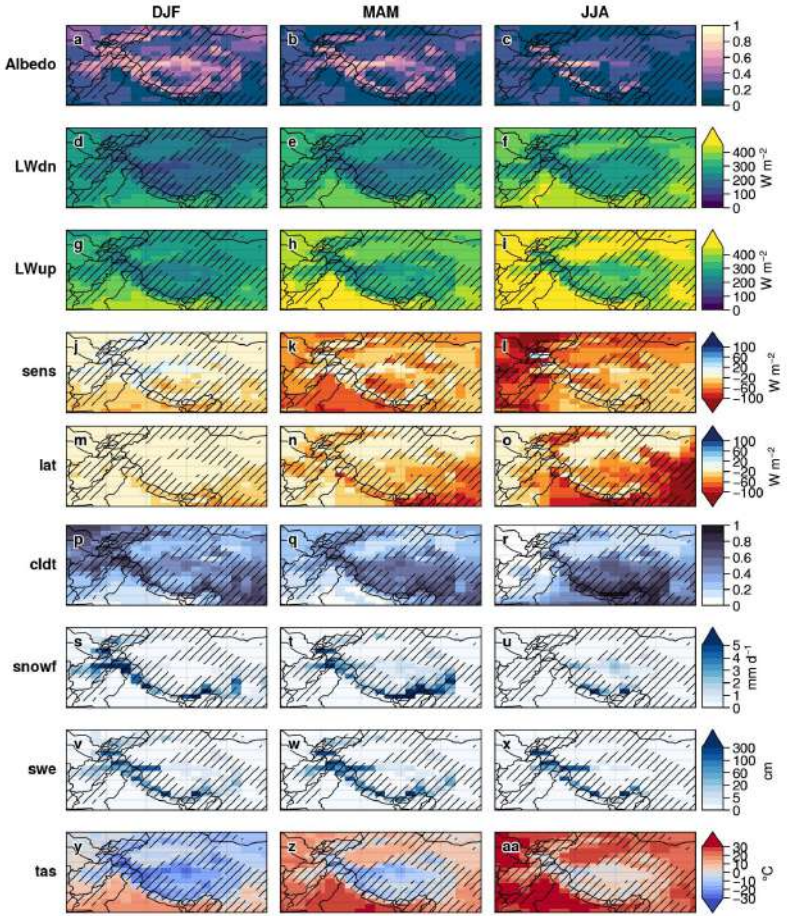
Depends only on SWE so no hysteresis

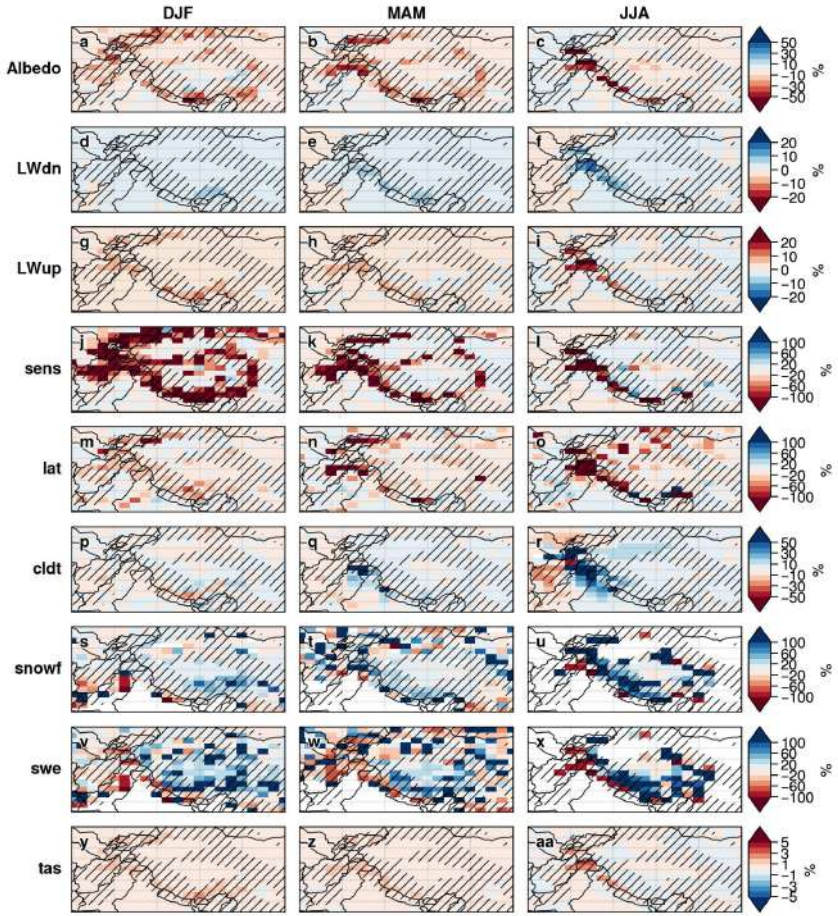
Feedbacks (LA22 - NY07)



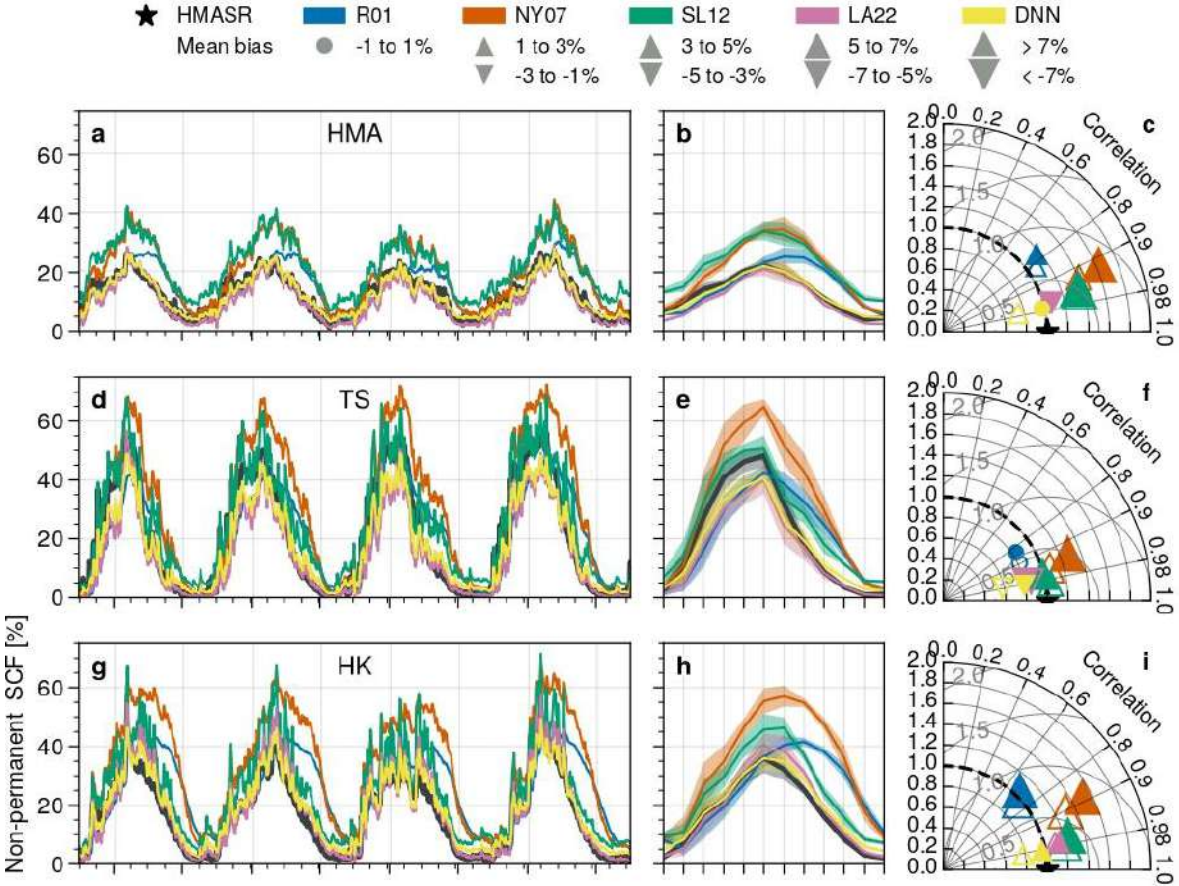


Feedbacks (LA22 - NY07)/NY07

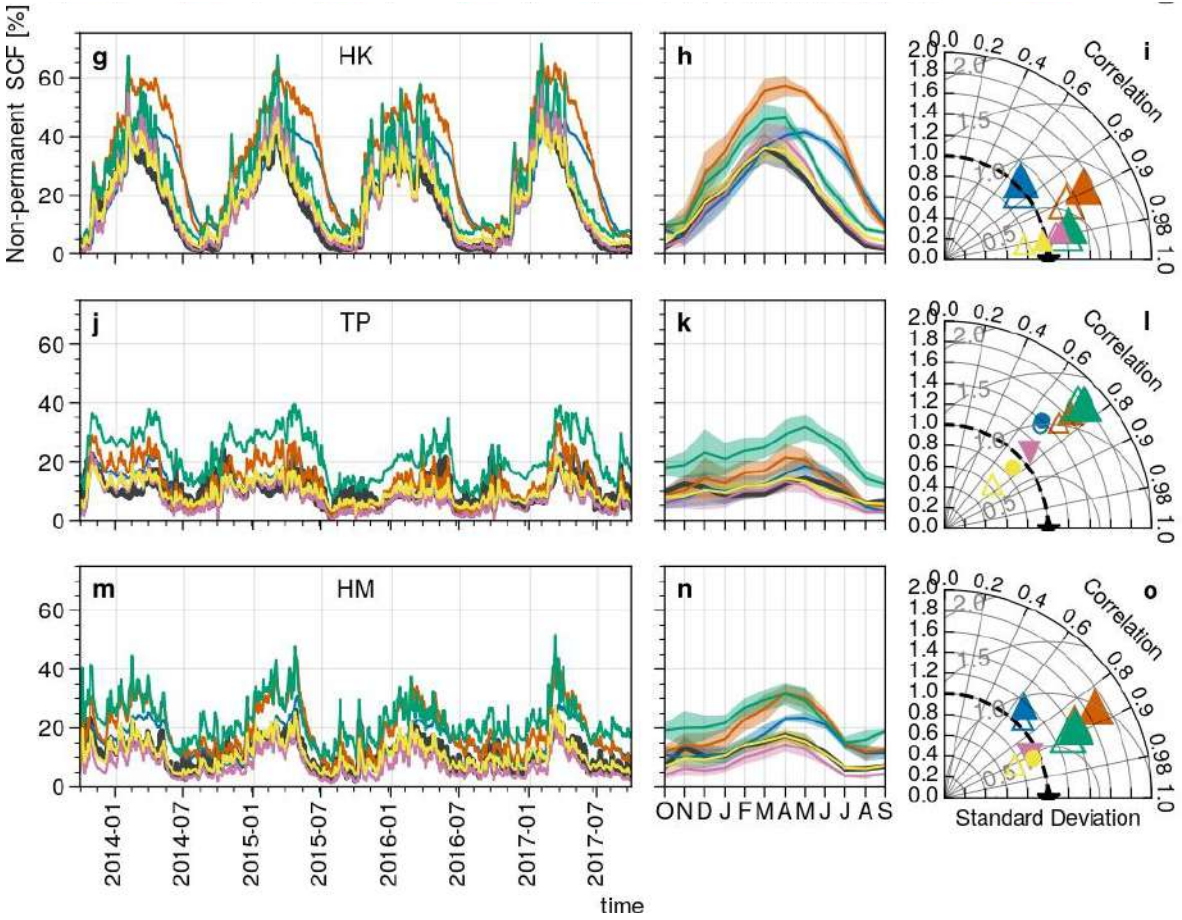




Time series


HMASR
Mean bias
R01
-1 to 1%
NY07
1 to 3%
-3 to -1%
SL12
3 to 5%
-5 to -3%
LA22
5 to 7%
-7 to -5%
DNN
> 7%
< -7%
a
HMA
b
c
Correlation
d
TS
e
f
g
HK
h
i
Non-permanent SCF [%]

Time series


g
HK
h
i
j
TP
k
l
m
HM
n
o
Non-permanent SCF [%]
0
20
40
60
2014-01
2014-07
2015-01
2015-07
2016-01
2016-07
2017-01
2017-07
time
O N D J F M A M J J A S
Correlation
Standard Deviation
0.0
0.2
0.4
0.6
0.8
0.9
0.98
1.0
0.5
1.0
1.5
2.0