Precipitation in Antarctica : comparison between Cloudsat observations and the LMDz global climate model.

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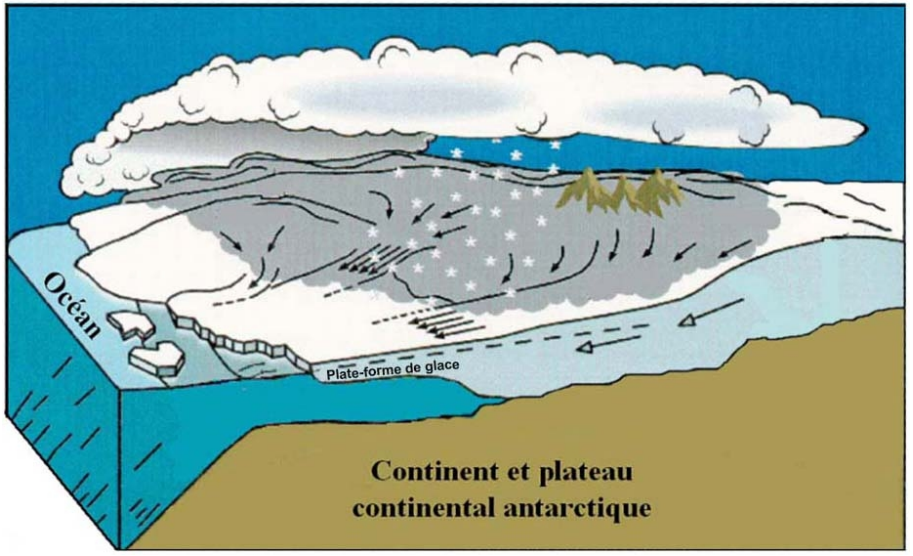
Introduction : Antarctica

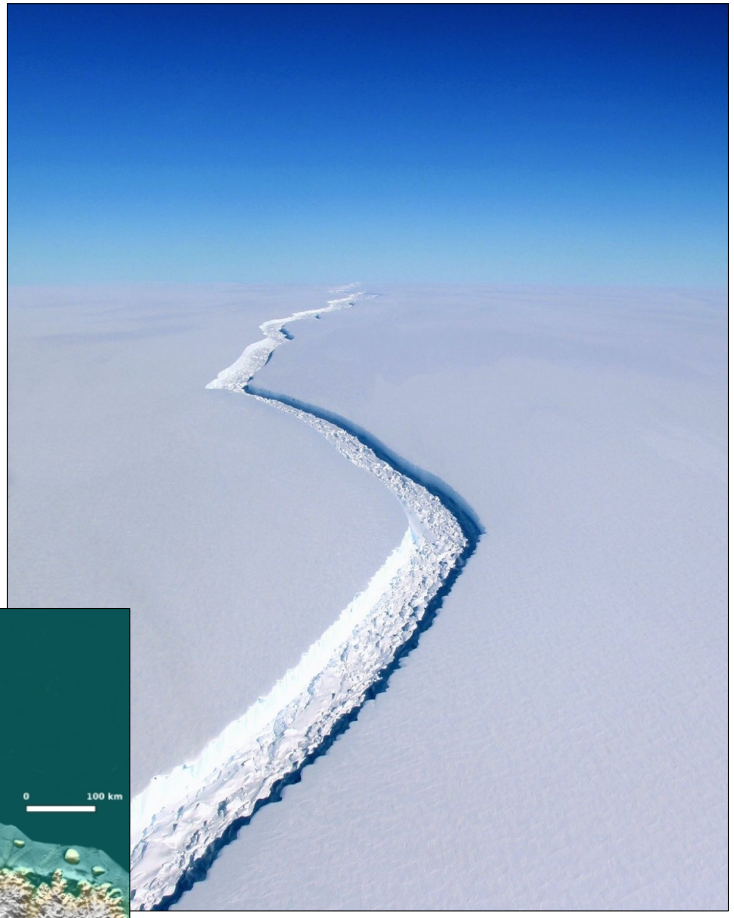
- Ressources :
  - 75 % of the global fresh water.
- Surface mass balance :
  - Snow precipitation and accumulation over the ice cap.
  - Glacier calving, sublimation and meltwater runoff.
  - Wind erosion and drifting snow.

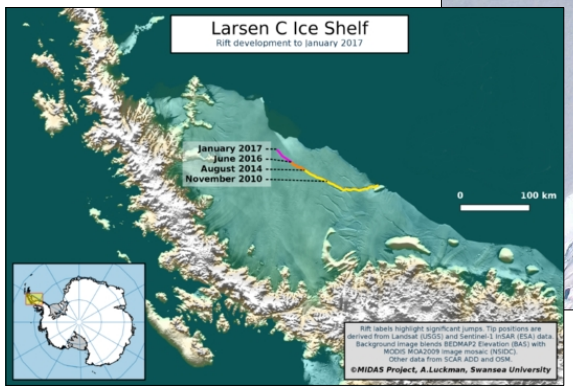


Introduction : global warming

- Consequences on the surface mass balance :
  - Snow accumulation changes.
  - Ice cap destabilization.

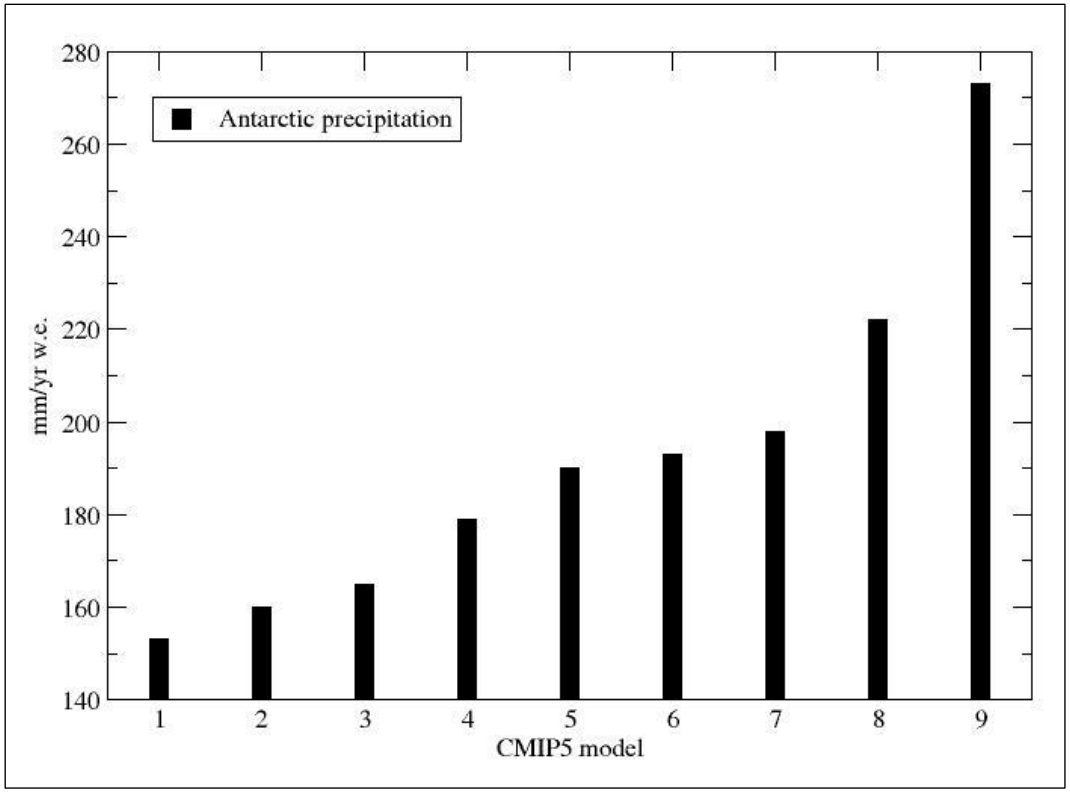
- Evolution of the ice-cap :
  - Constrain the contribution of the precipitation.





Role of precipitation in Antarctica

- Precipitation over Antarctica is mostly unknown.
- CMIP5 models predict a large range of precipitation.



Adapted from Palerme et al., 2014

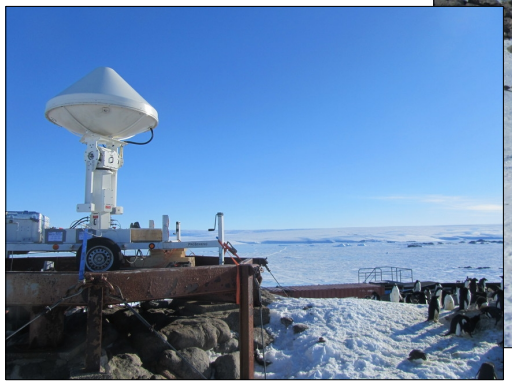
Introduction : the APRES3 project

- **A**ntarctic **P**recipitation, **Re**mote **S**ensing from **S**urface and **S**pace project from the National Research Agency.
- France-Switzerland collaboration.
- Meteorological project.

APRES3

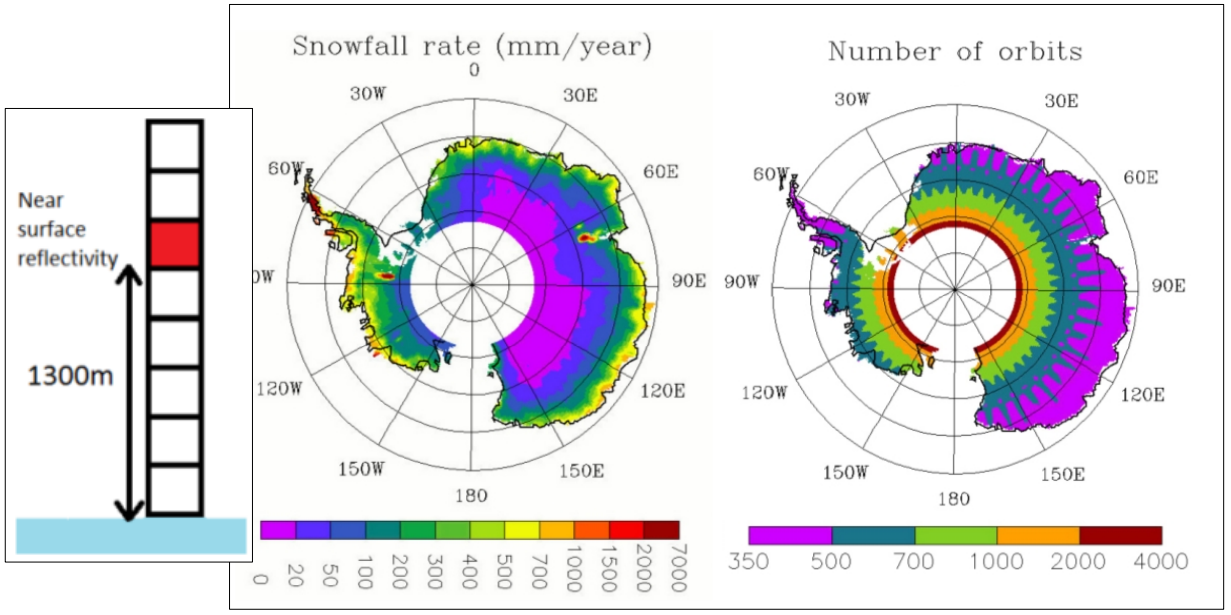
Introduction : the APRES3 project

- Two phases :
  - Snowfall observations.
    → Field campaigns and remote sensing observations.
  - Polar climate modeling.
    → With a global climate model (LMDz) and a mesoscale model (MAR, see poster X5.467).



Observations : CloudSat

- Earth observation satellite belonging to the A-train (NASA).
- Meteorological radar :
  - Clouds and precipitation observations.
  - Altitude limit for observation : ~ 1,2km.
  - 94 GHz frequency.



Haynes et al., 2009
Palerme et al., 2014

Observations : CloudSat

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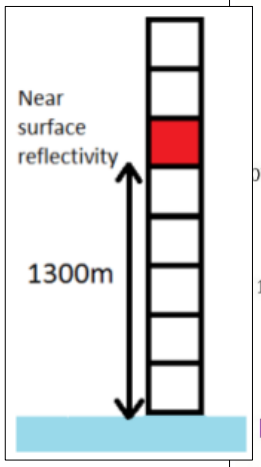
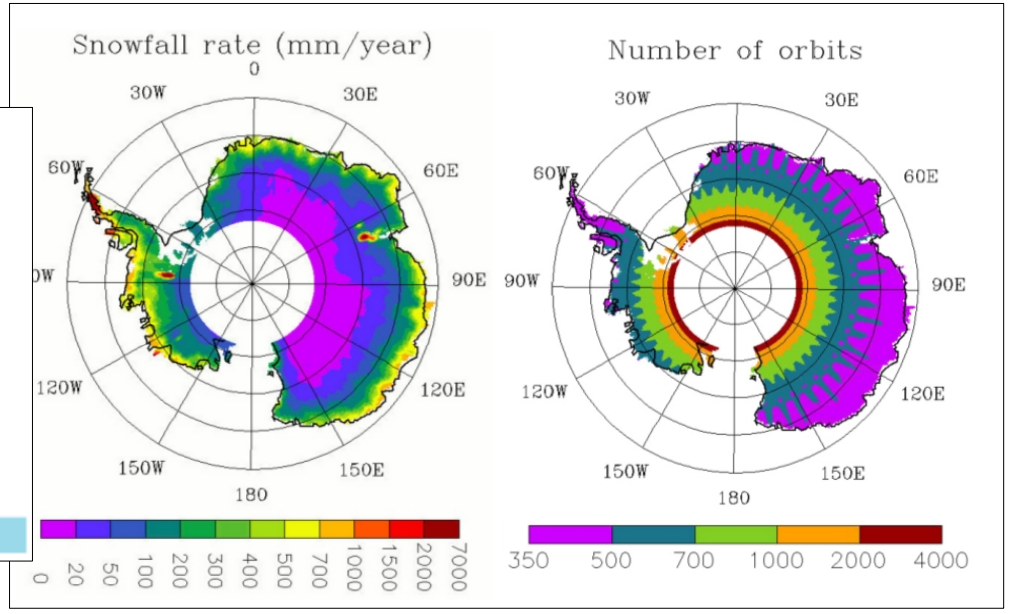
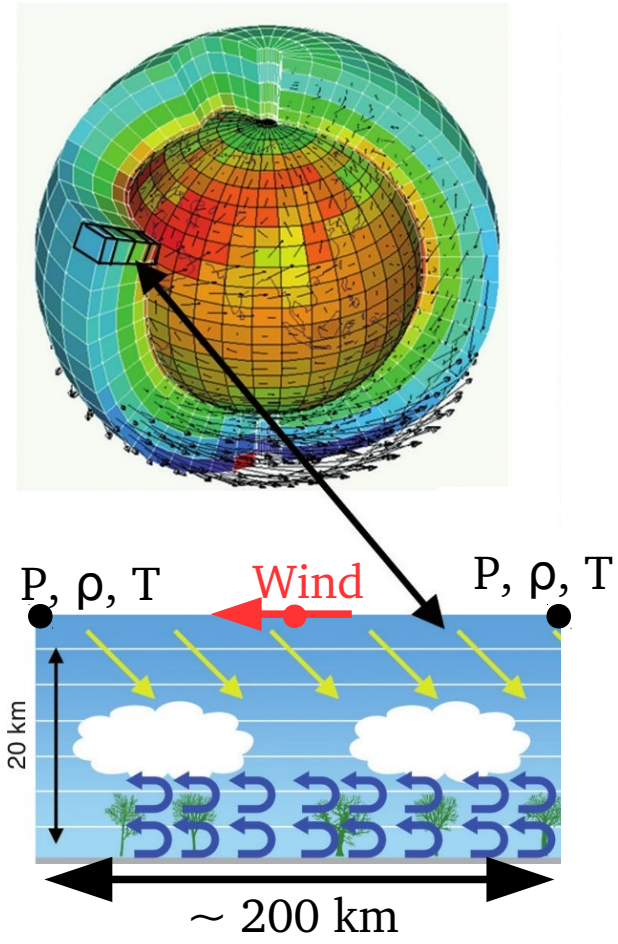
- Comparisons with the LMDz model.
  - Model validation ?
  - Precipitation modeling in agreement with data ?





Haynes et al., 2009
Palerme et al., 2014

IPSL-CM atmospheric model (LMDz)

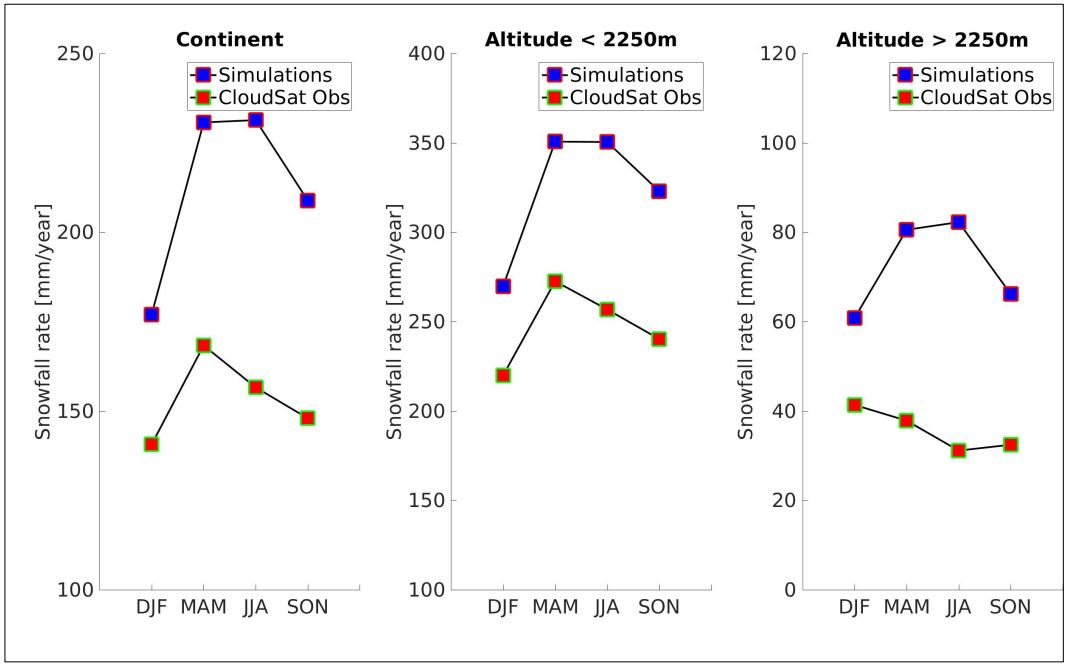


- Dynamical core.
  → Primitive hydrostatic equations of meteorology.
- Radiative transfer model.
  → RT equations (plane-parallel approximation).
- Physical parameterizations.
  → Large scale and shallow convection clouds.
  → Cloud scheme.
  → Conversion to rain and snowfall.

Data VS LMDz model

- Bad agreement in annual mean precipitation over the **2007-2010** period :
  - LMDz snowfall rate LMDz : 212 mm/yr.
  - CloudSat snowfall rate : 153 mm/yr.
- Important bias :
  - Overestimation of precipitation.
  - Wrong seasonal variability of the high continental shelf.

Resolution : 144x142 points grid
79 vertical levels
Free climate simulation



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General question

What is the origin of the differences between the LMDz model and data ?

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→ Improve the parameterization controlling the snowfall over Antarctica. ←

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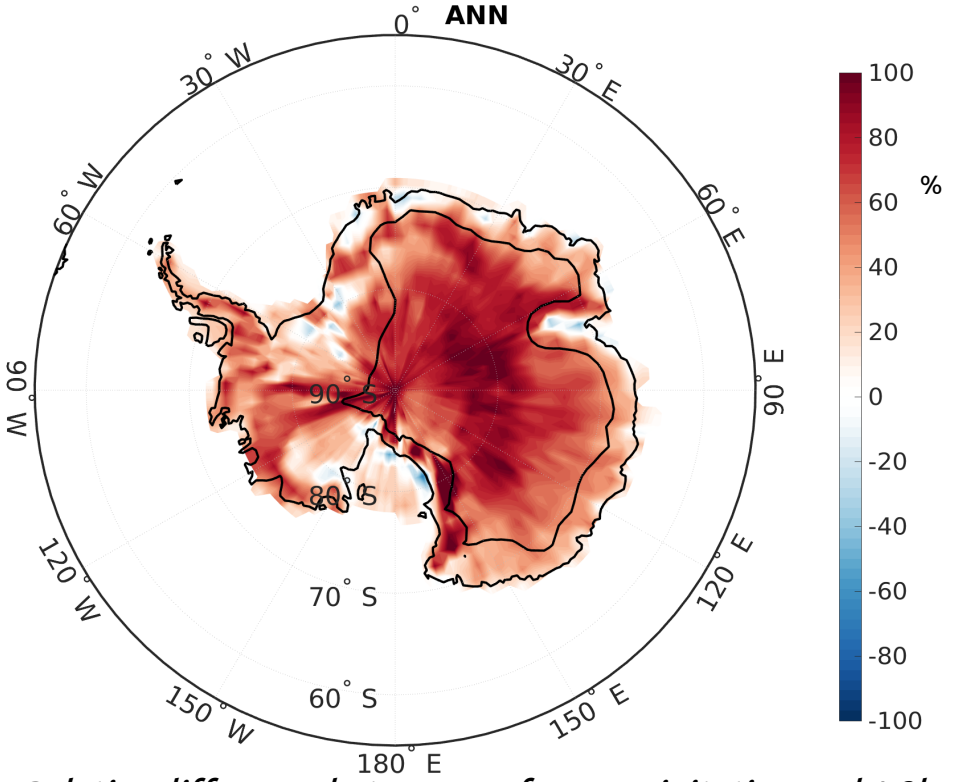
Selection of a vertical level to compare the LMDz model with CloudSat data.

Surface precipitation VS 1,2 km high precipitation

- Precipitation detection limit by CloudSat radar : 1,2 km.



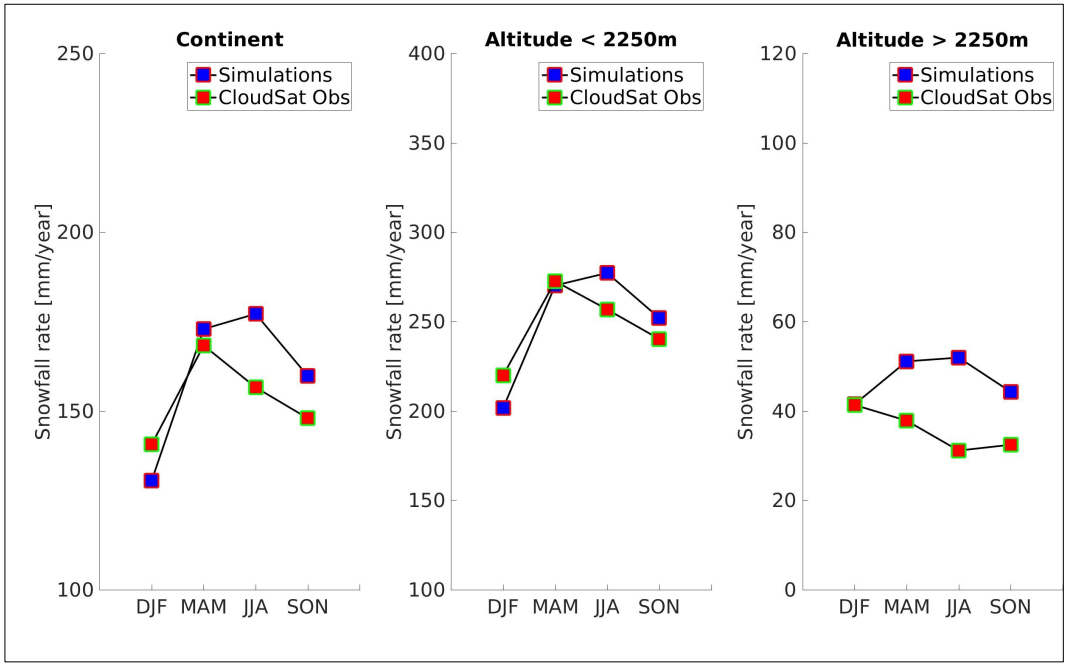
Relative difference between surface precipitation and 1,2km-high precipitation – Free climate simulation in annual mean.

Reevaporation by the katabatics winds processes : <u>see poster X5.465</u>

Data VS LMDz model

- Good agreement in annual mean on the period **2007-2010** :
  - LMDz snowfall rate : **160 mm/yr**.
  - CloudSat snowfall rate : 153 mm/yr.

Resolution : 144x142 points grid
79 vertical levels
Free climate simulation



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General question

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Comparison of simulations averaged over the 2007-2010 period.

Used simulations

- Free climate simulation – sea surface temperature and sea ice imposed.
- Nudged simulations – relaxation term toward ERA-I reanalysis with a time constant τ of 3 hours.

$$\frac{\partial u}{\partial t} = \frac{\partial u}{\partial t}_{GCM} + \frac{u_{analysis} - u}{\tau}$$

$$\frac{\partial v}{\partial t} = \frac{\partial v}{\partial t}_{GCM} + \frac{v_{analysis} - v}{\tau}$$

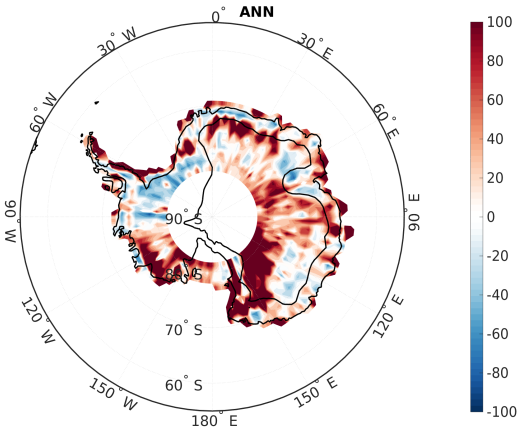
τ Time constant for the relaxation of the model wind toward analyses

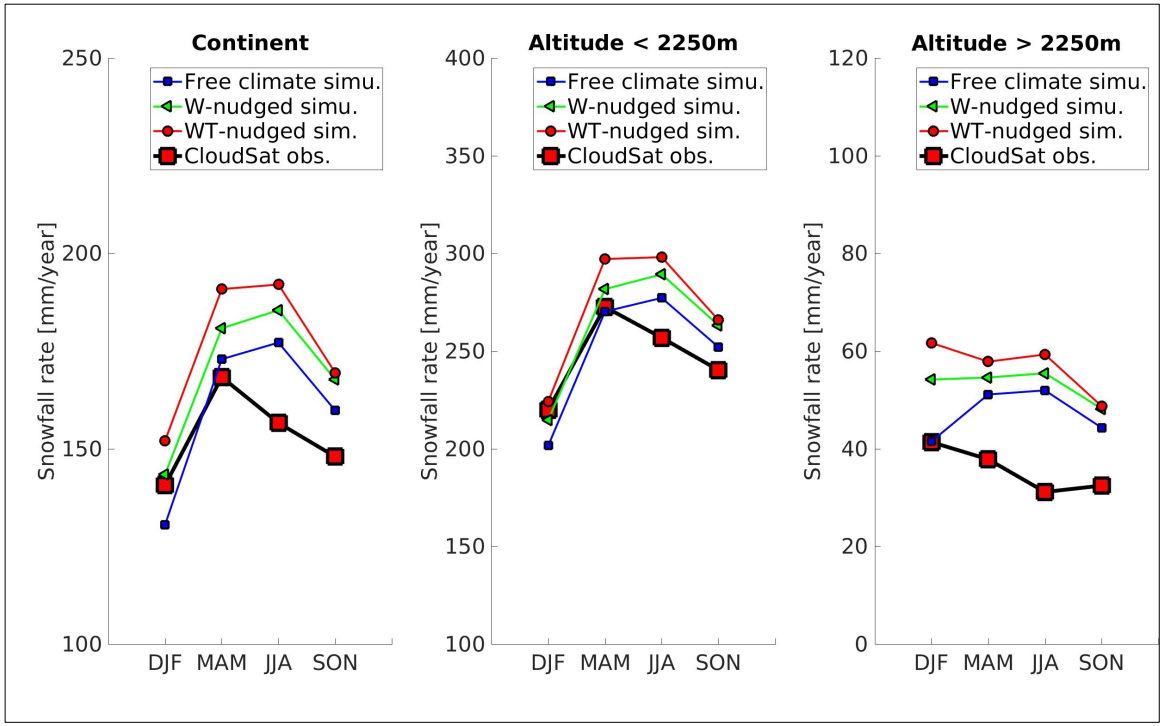
Coindreau, 2007

Comparison of the simulations

Free climate simulation :

- Wrong seasonal variability over the high continental shelf.
- Good agreement of the precipitation rate in annual mean.



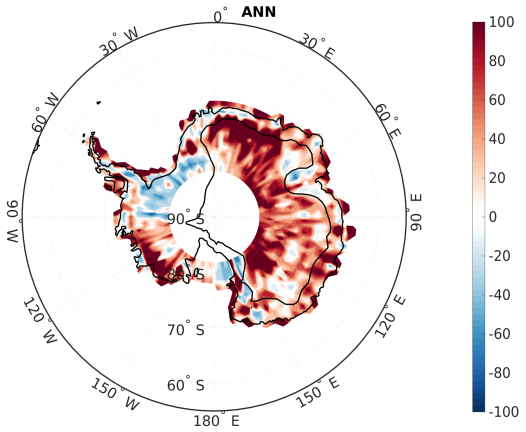


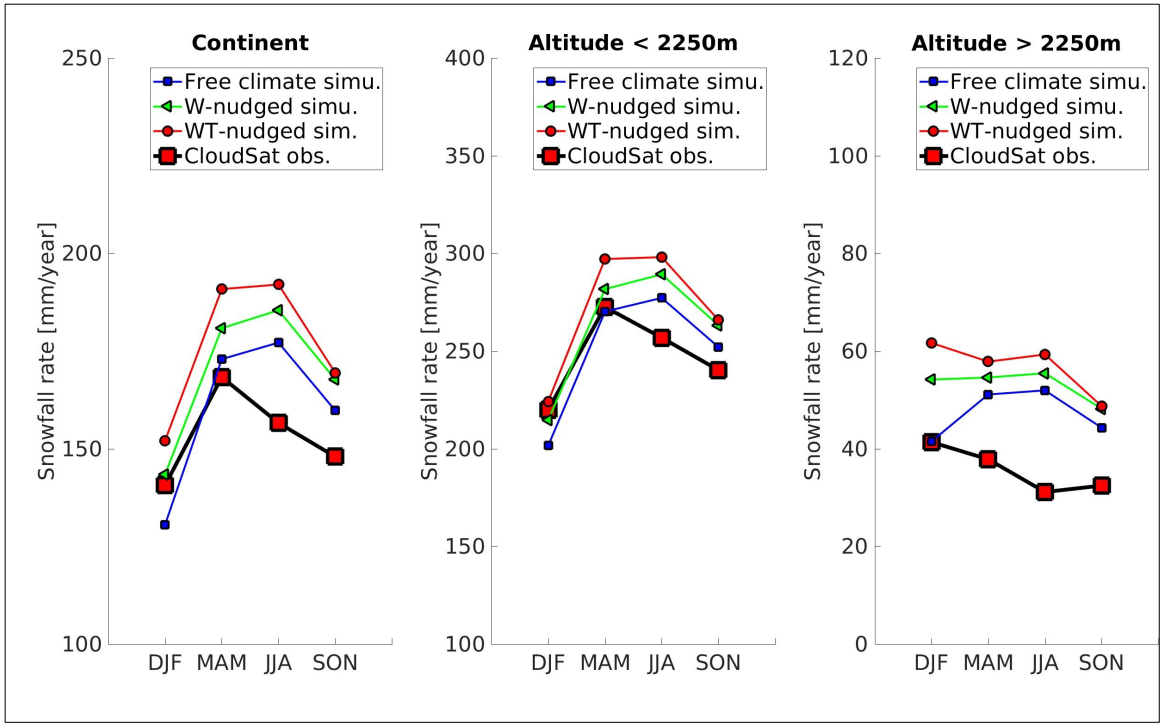
Relative difference of snowfall rate between LMDz and CloudSat.

Comparison of the simulations

W-nudged simulation :

- Good seasonal variability of coastal precipitation between LMDz model and data.
- High continental shelf precipitation overestimation.





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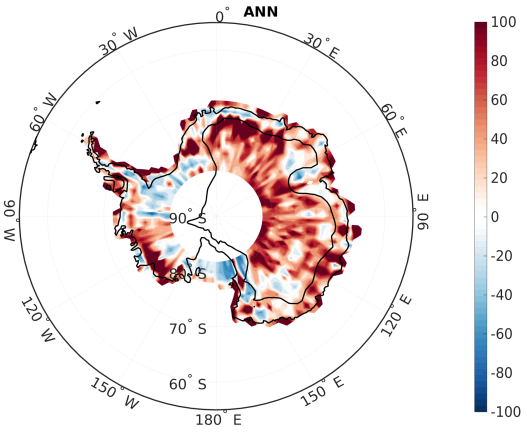

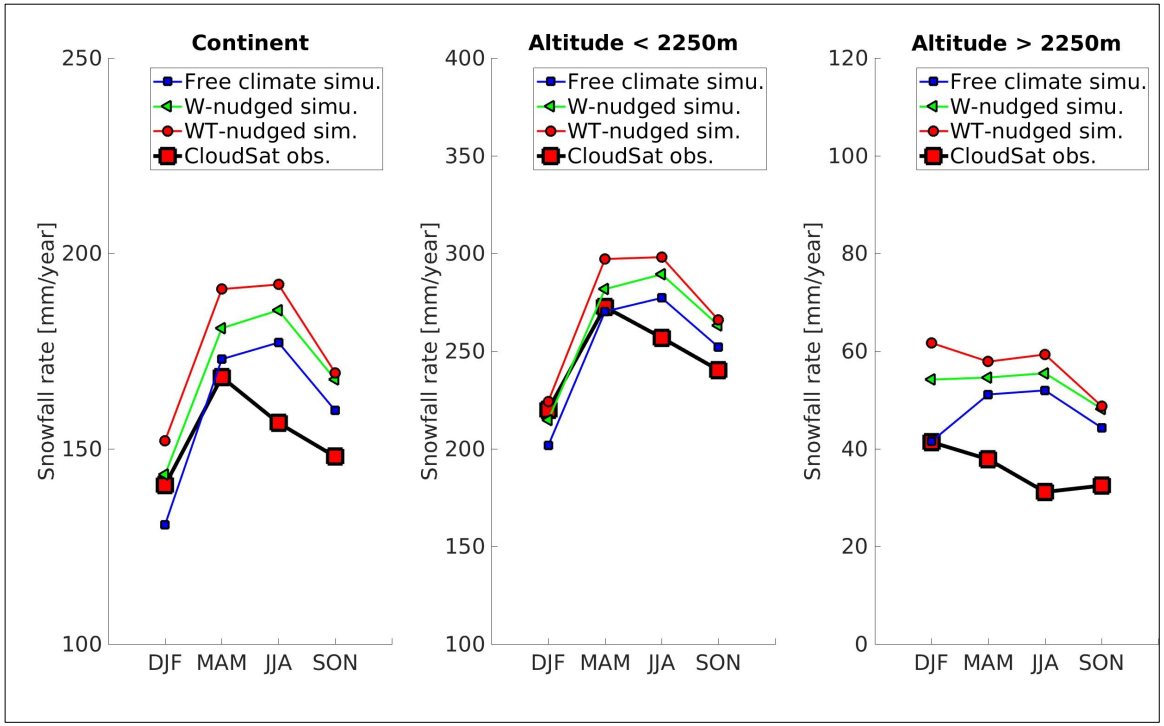

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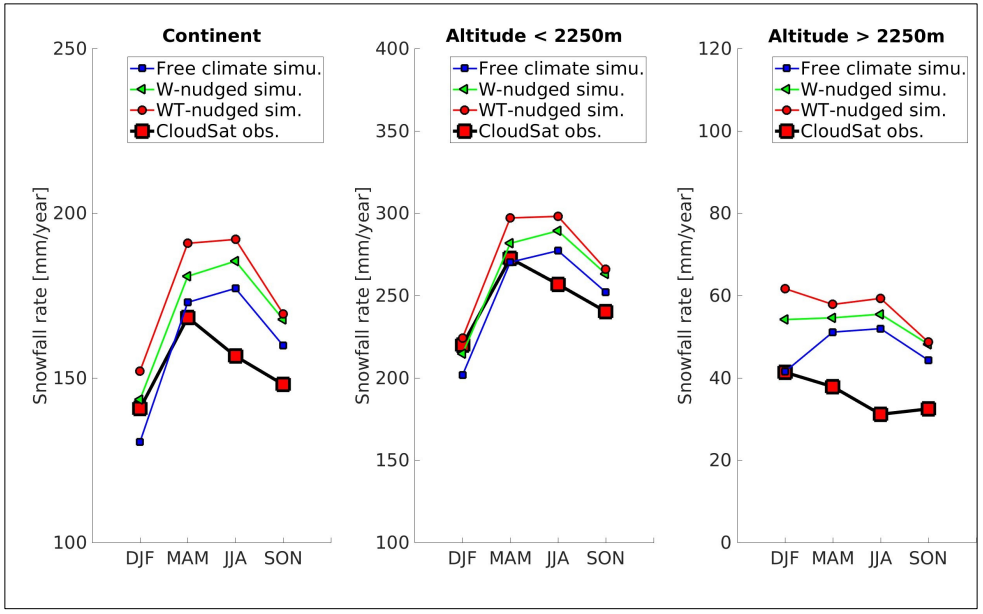

Free climate simulation :

- Coastal precipitation in good agreement.
- Wrong seasonal variability over the high continental shelf.

W-nudged simulation :

- Good seasonal variability of coastal precipitation between LMDz model and data.
- High continental shelf precipitation overestimation.

WT-nudged simulation :

- Good seasonal variability of coastal precipitation between LMDz model and data.
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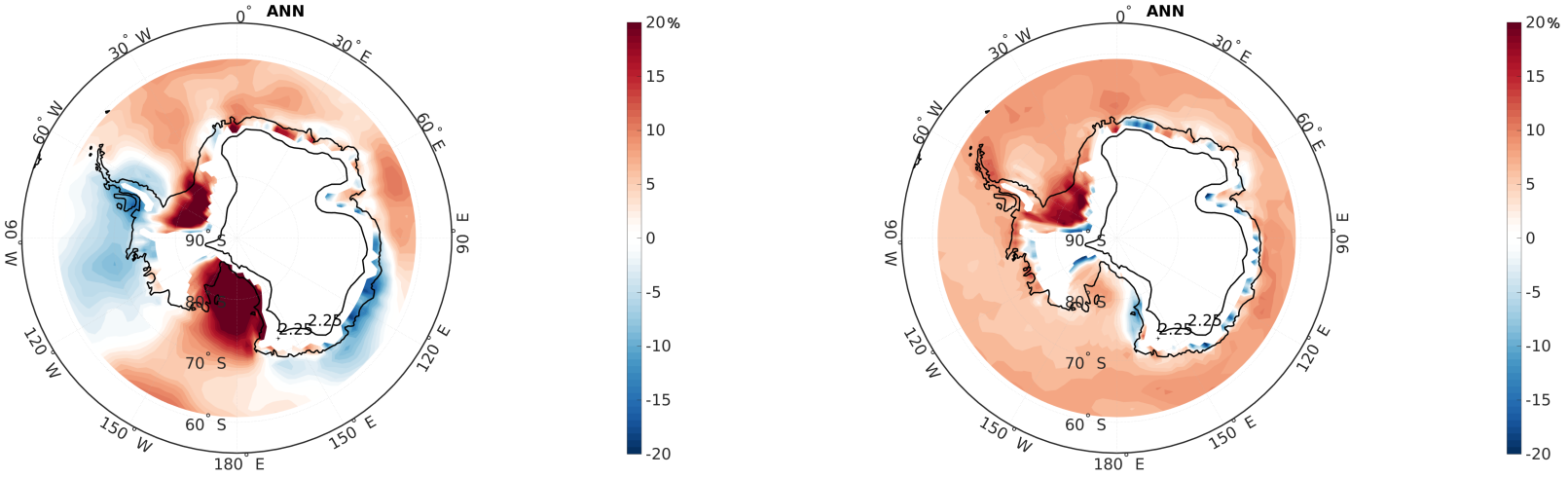
Comparison of the simulations

- Precipitation over the lowlands in Antarctica is mainly controled by the temperature and the specific humidity.

  → Biases in the model are localized over the ice-shelves.
  → The model is overly moist when the dynamics is nudged.



Free climate simulation *W-nudged simulation*

Relative difference in specific humidity at 850 hPa between LMDz model and ERA-I reanalysis.

Conclusions

- The nudged simulations replicate well the seasonal variability of the precipitation over the whole continent.
- The LMDz model overestimates the precipitation due to a positive bias of specific humidity.

Outlooks

- Study a humidity-nudged simulation to verify the precipitation rate and the seasonal cycle in the model.
- Consider new data obtained with the last field campaign which give access to the vertical profiles of snowfall over one full year.
- Analysis of the precipitation at small scale using the zoomed model, and comparison with the Dumont D'Urville's observations.

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→ Improve the parameterizations of cloud ice to snow conversion and snowfall.

Thank you for your attention !

Please see other posters on the project :

→ X5.465 / J. Graziolo : low-level precipitation sublimation on the coasts of East Antarctica.

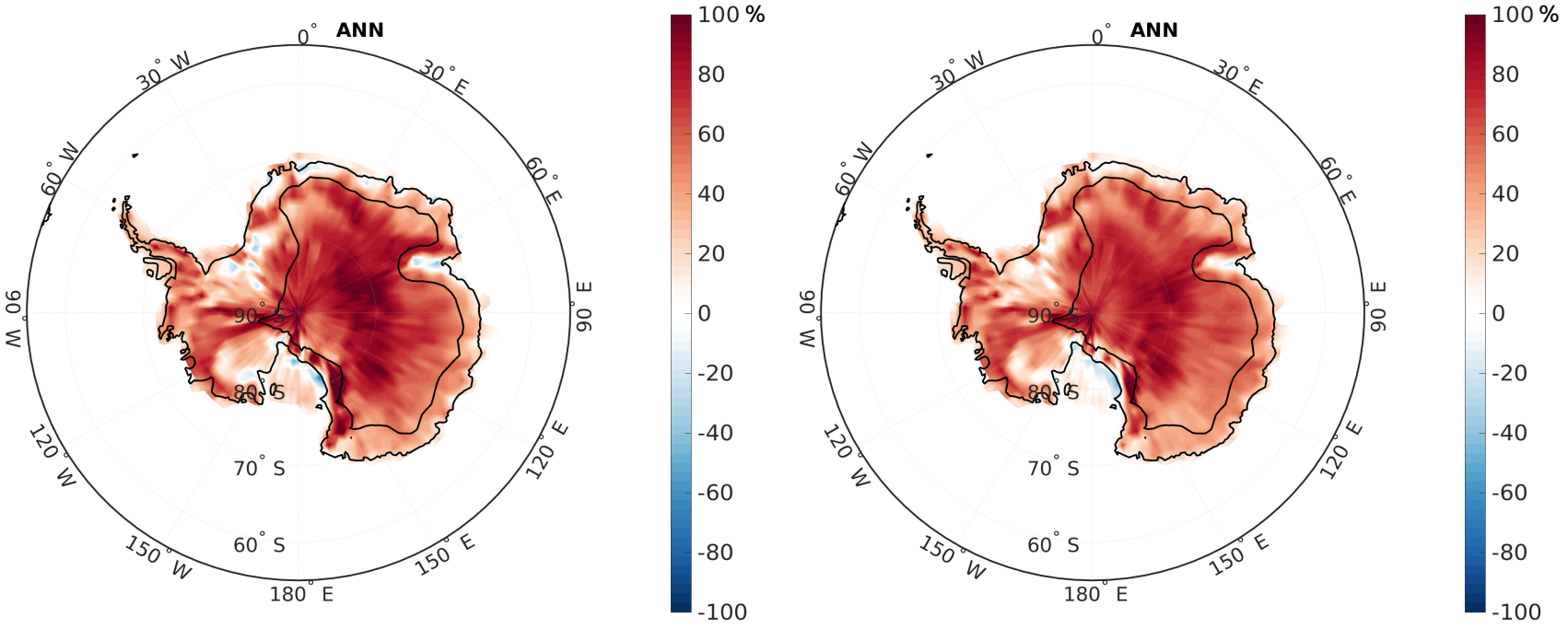
→ X5.467 / H. Gallee : snow precipitation in Adelie Land, Antarctica. MAR validation using data from a meteorological radar.

More at :
http://apres3.osug.fr

APPENDIX

Comparison of the simulations

- The nudging in wind strangles katabatic winds and suppresses the coastal reevaporation.

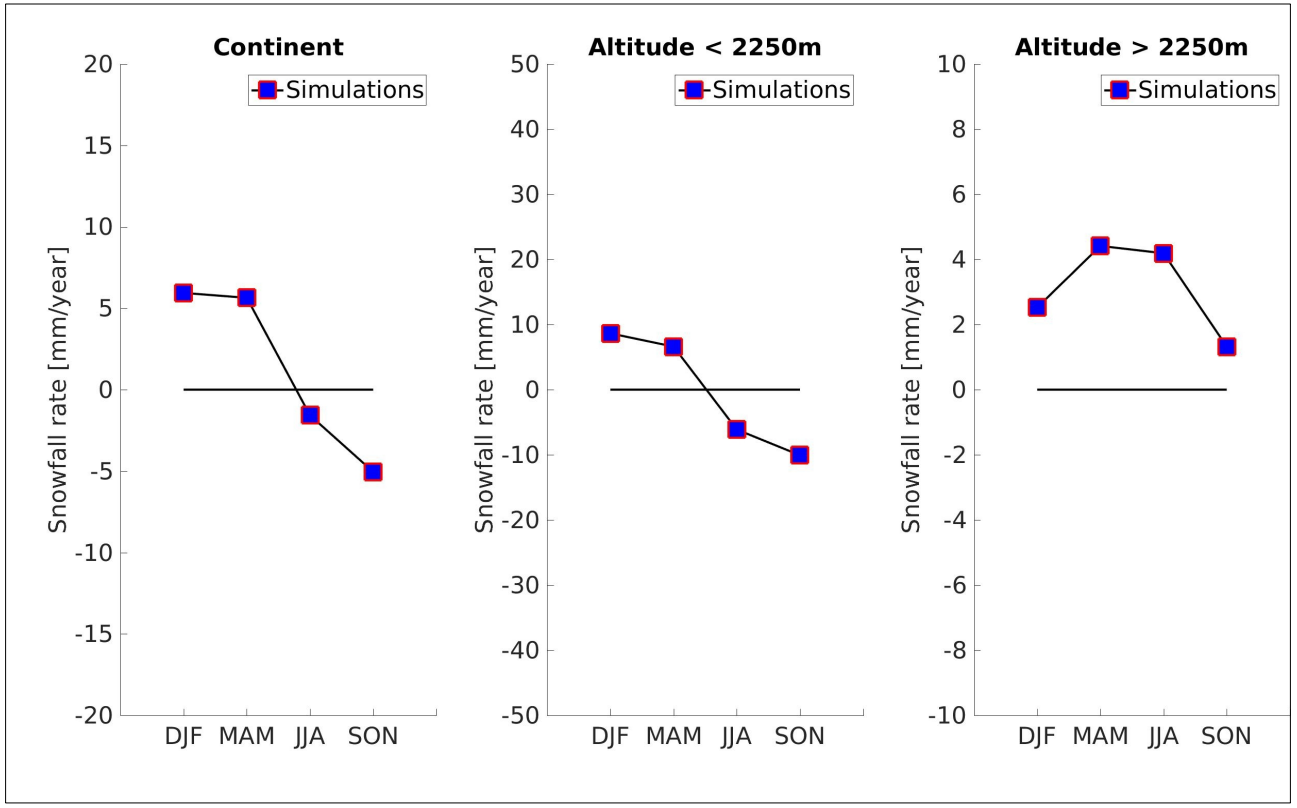


Relative difference between surface precipitation and 1,2km-high precipitation

Free climate simulation in annual mean.

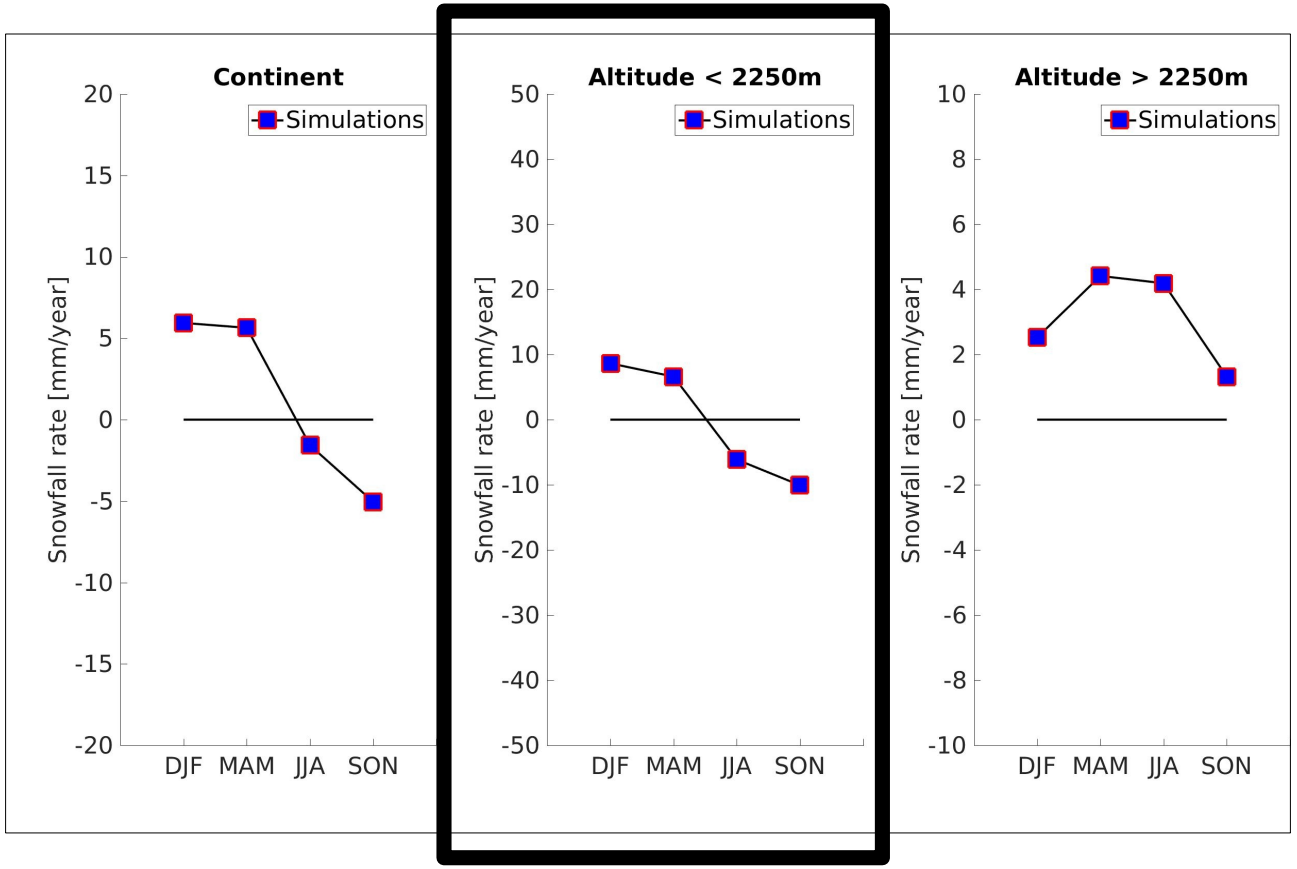
Wind nudged simulation in annual mean.

Nudged AMIP simulations comparison



Difference between wind-nudged AMIP and wind-temperature-nudged simulations.

Nudged AMIP simulations comparison – coastal area



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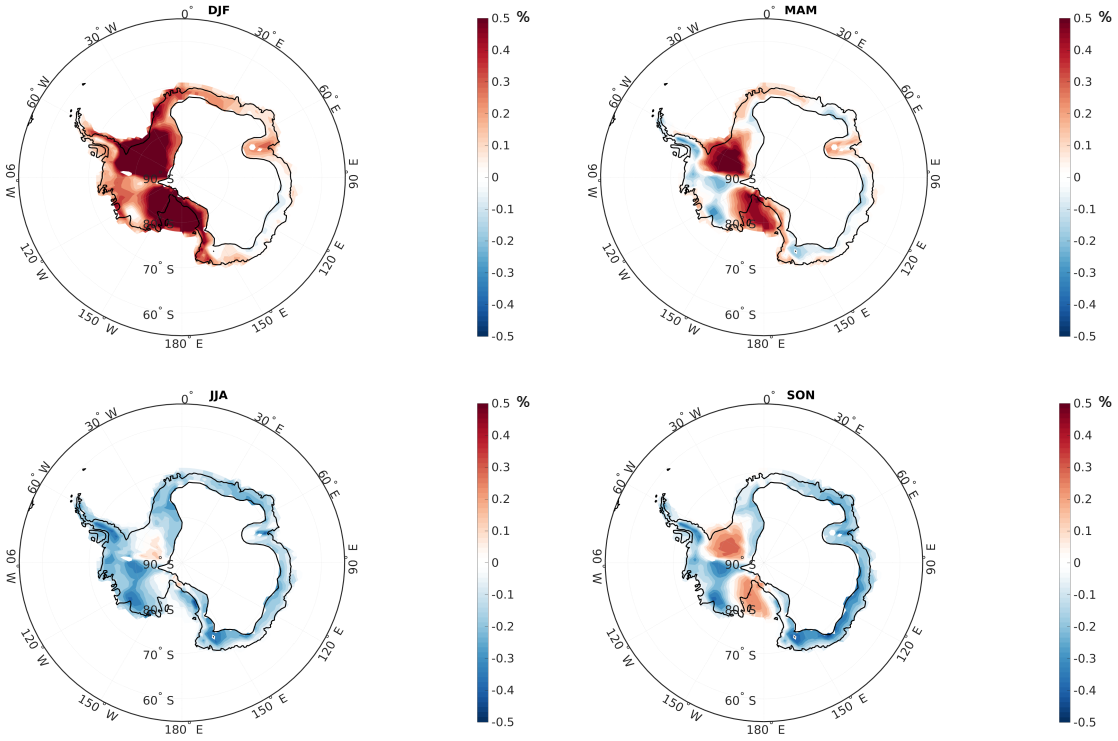
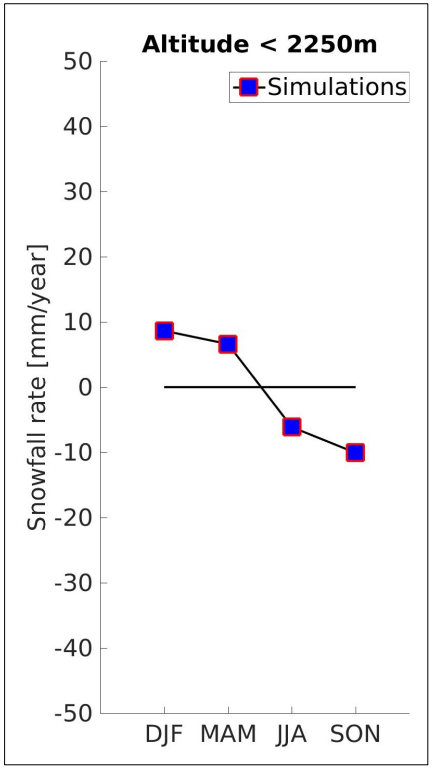
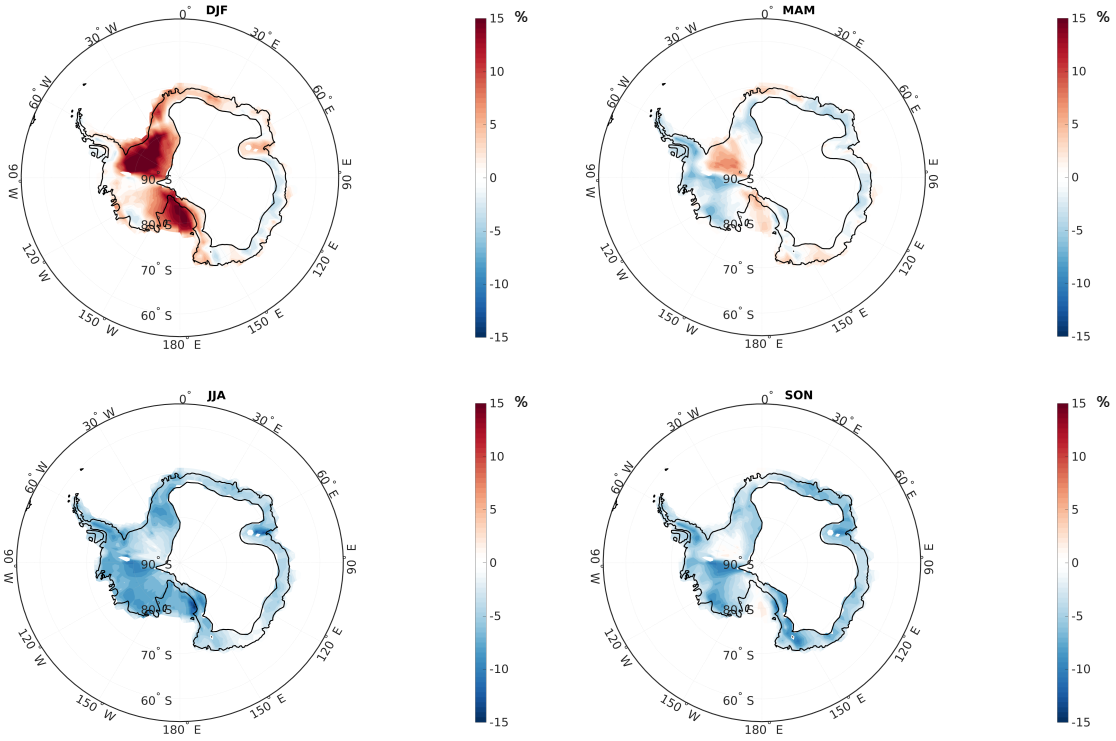
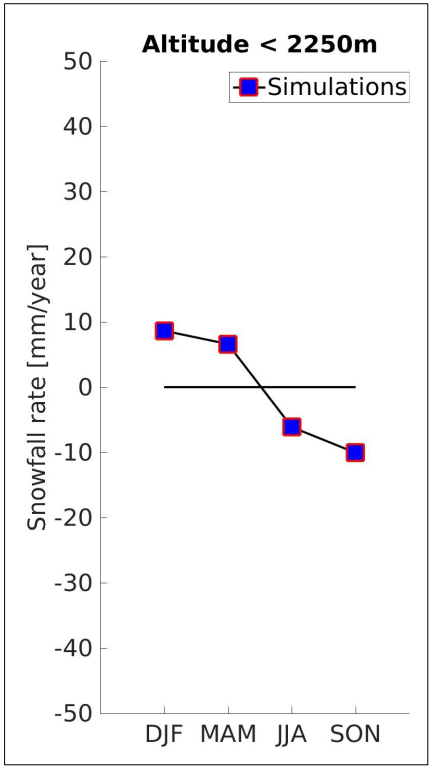




TEMPERATURE – Good agreement in the correlation between precipitation and temperature.
→ Dipole with ice-shelves.

Nudged AMIP simulations comparison – coastal area



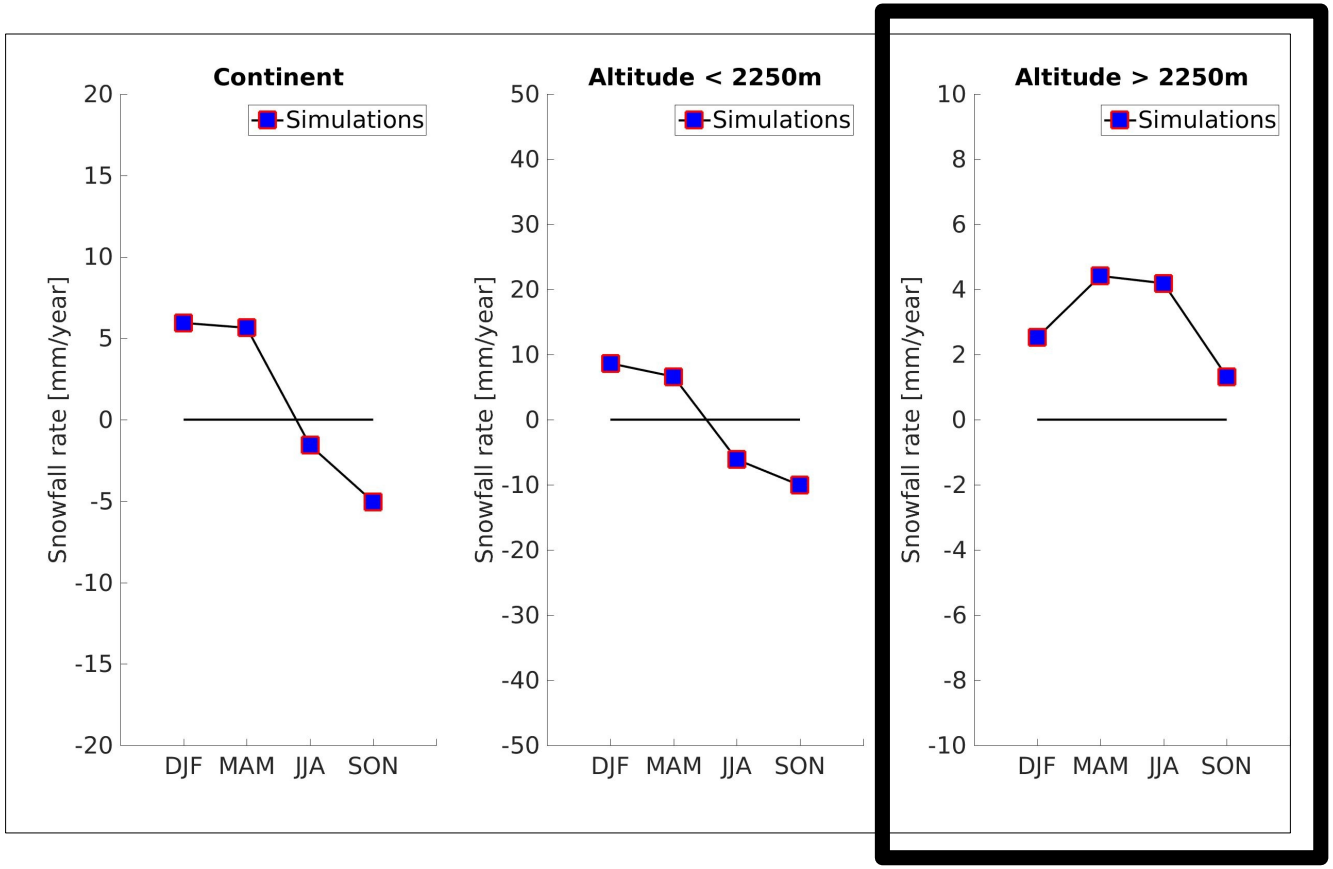


HUMIDITY – Good correlation between precipitation and humidity.

Nudged AMIP simulations comparison – coastal area

- Precipitation over the lowlands in Antarctica are mainly regulated by the temperature and the specific humidity.
- Bias in the model are localized over the ice-shelves.

Nudged AMIP simulations comparison – high area



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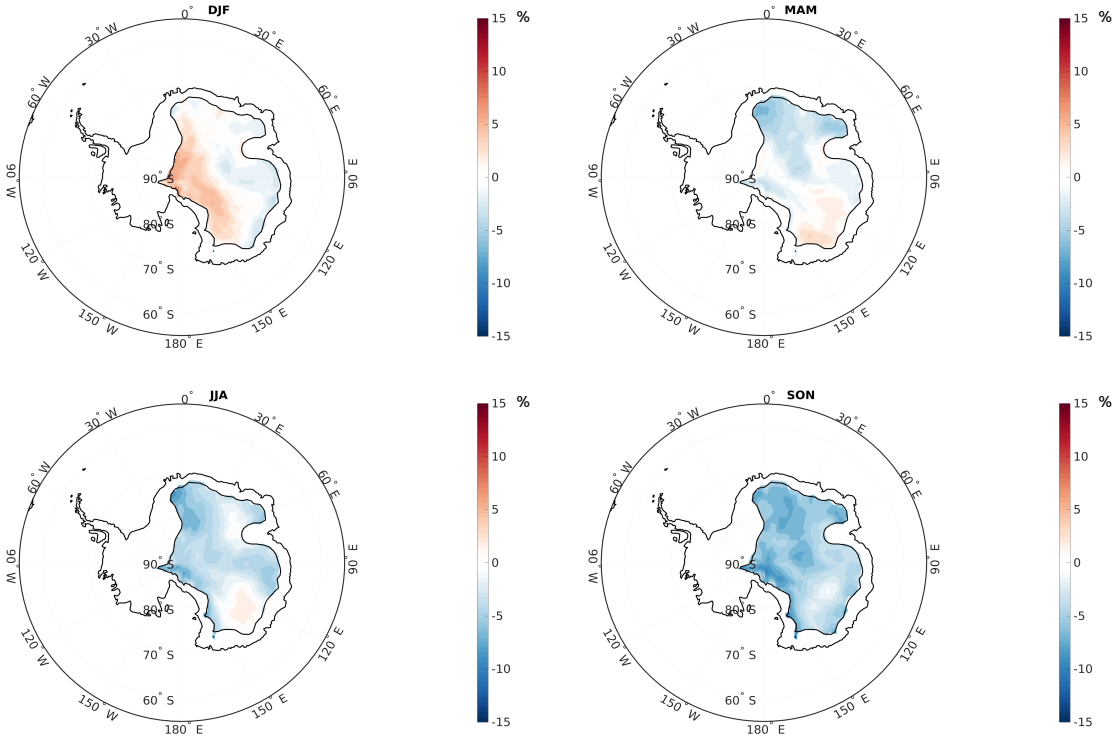
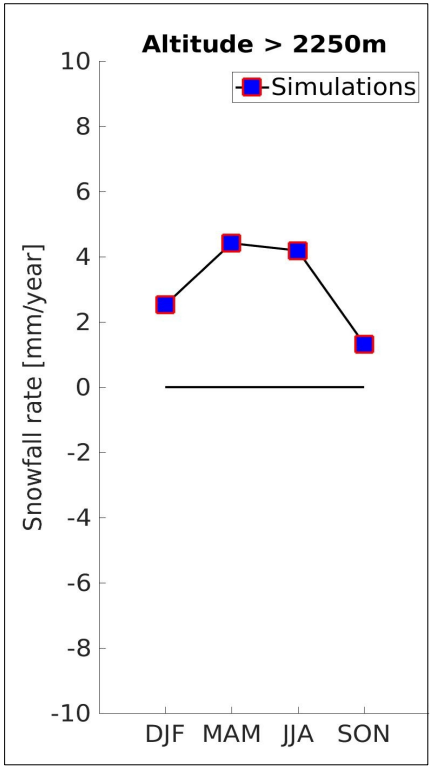
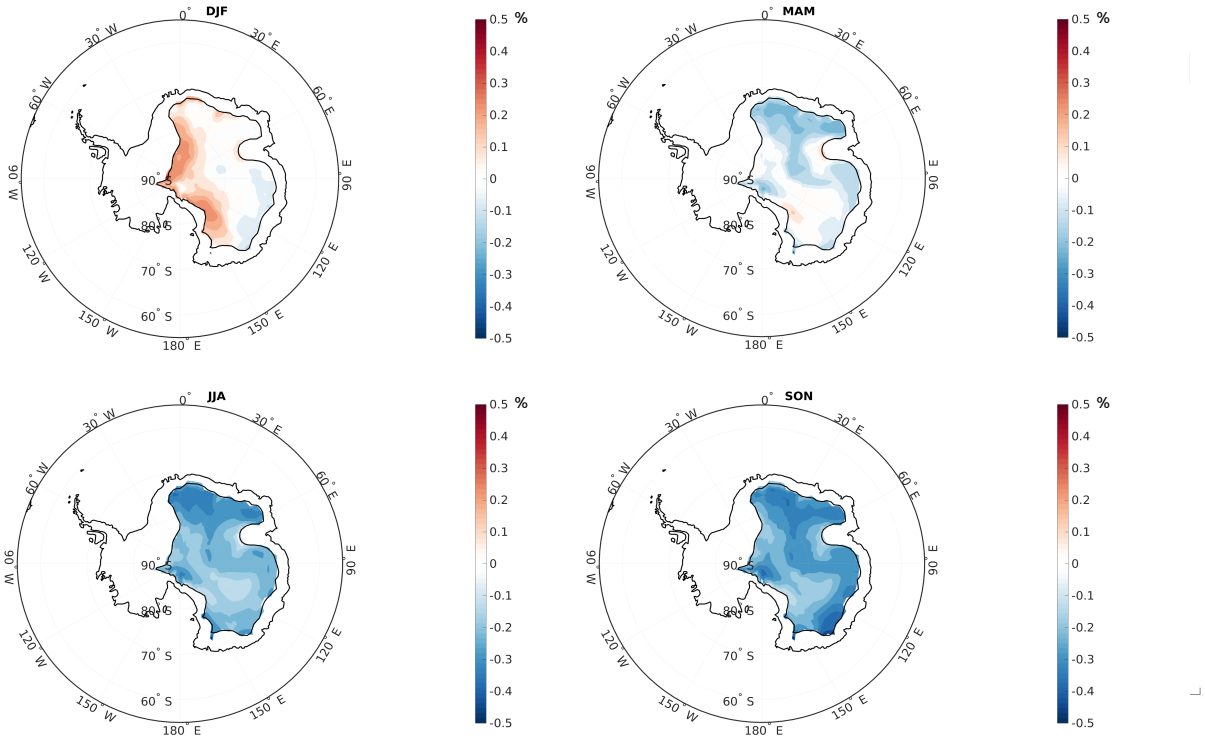
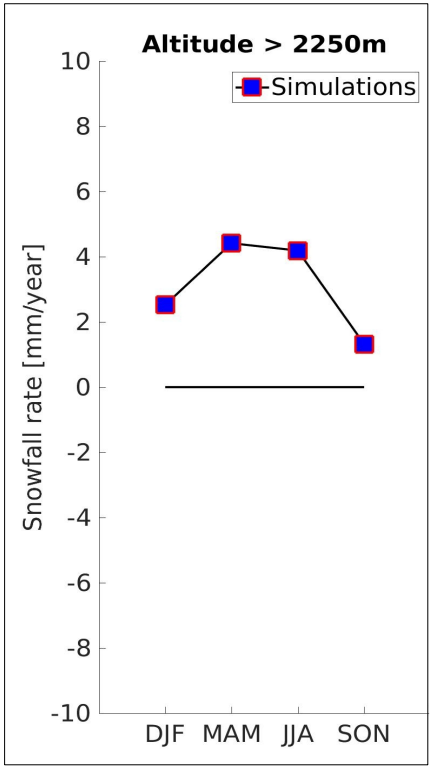




HUMIDITY – Any correlation between precipitation and humidity.

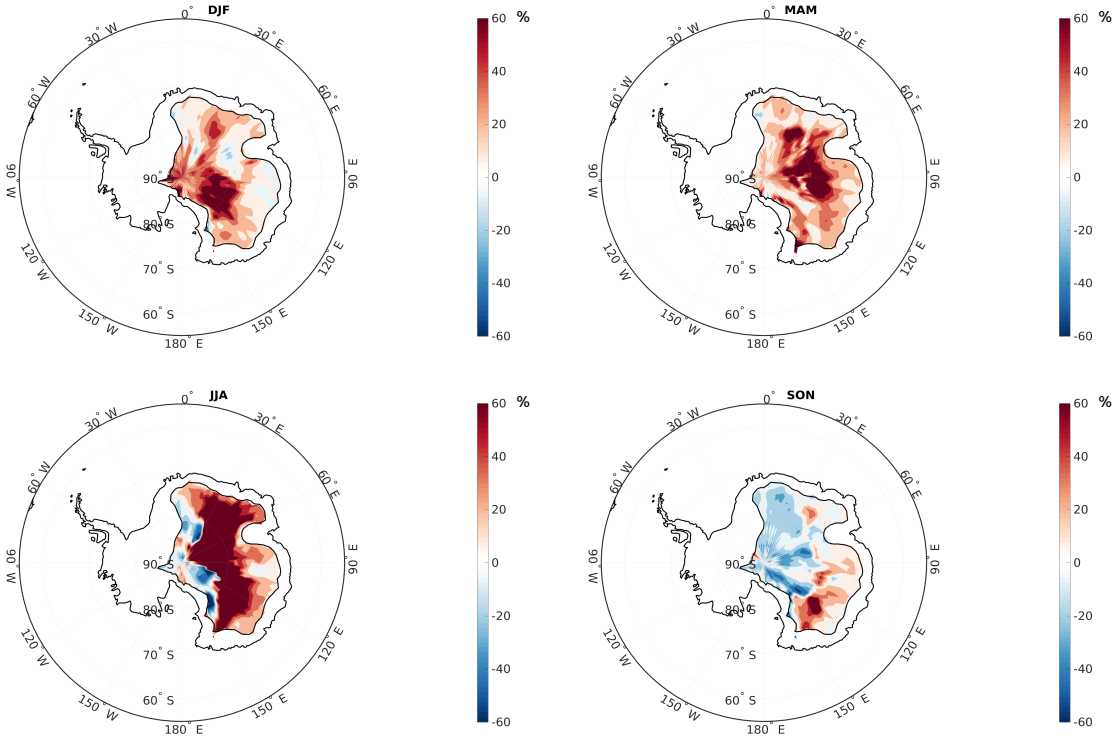
Nudged AMIP simulations comparison – high area

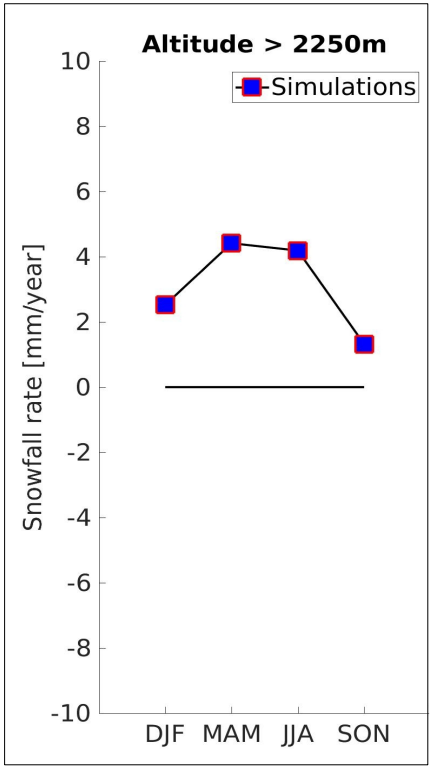




TEMPERATURE – Any correlation between precipitation and temperature.

Nudged AMIP simulations comparison – high area





CLOUDS WATER – Strong correlation between precipitation and clouds content water.

→ Absence of any correlation in the lowlands.