



12th Workshop on Antarctic Meteorology and Climate

Climate change in Antarctica : contribution of the Global Climate Model with a high regional resolution

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Special thanks: - Hubert Gallée, Antoinette Alias, Cécile Agosta, Vincent Favier & LMD team
- SCAR

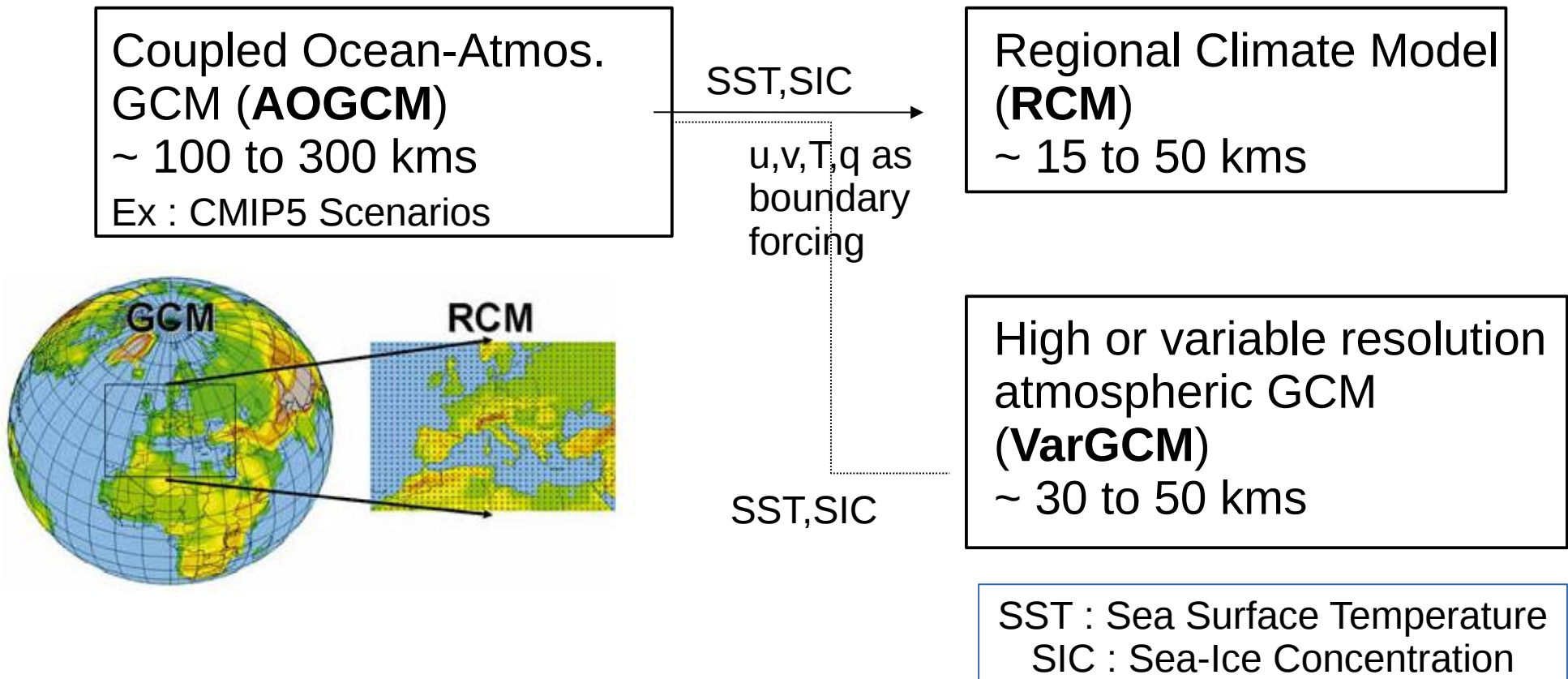
ANR ASUMA



NCAR, Boulder (CO) 16th June 2017

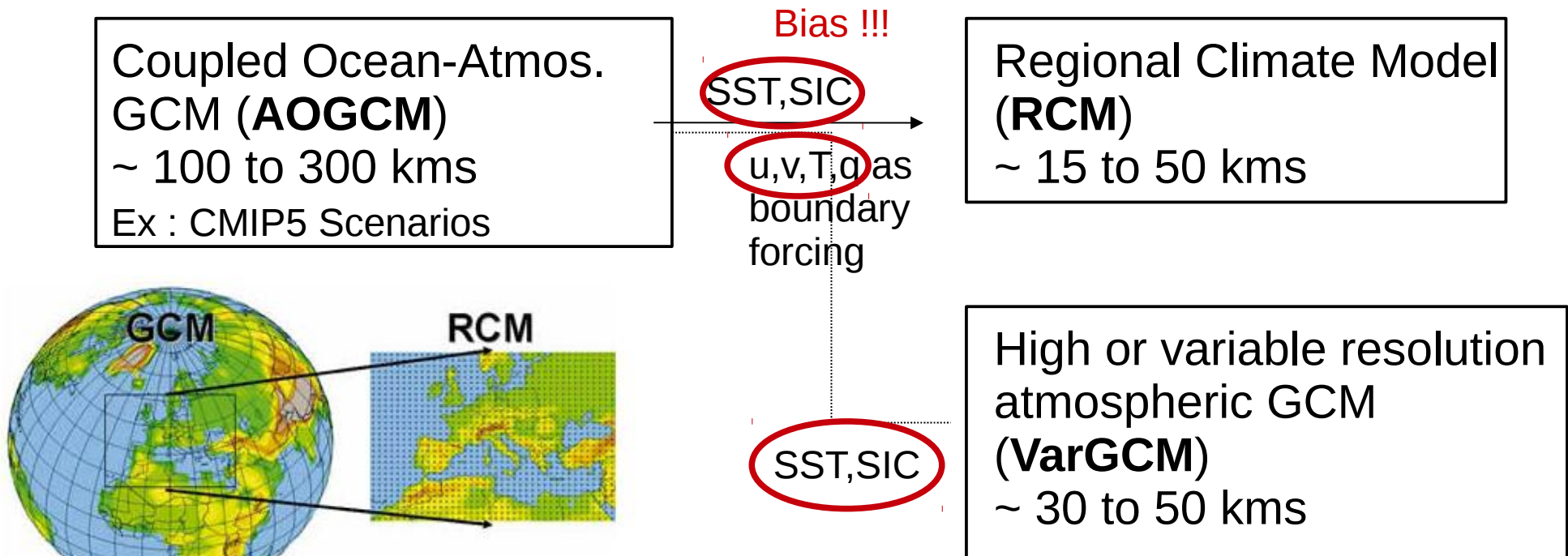
Introduction & context

- Classical methods for the **downscaling** of climate scenarios :



Introduction & context

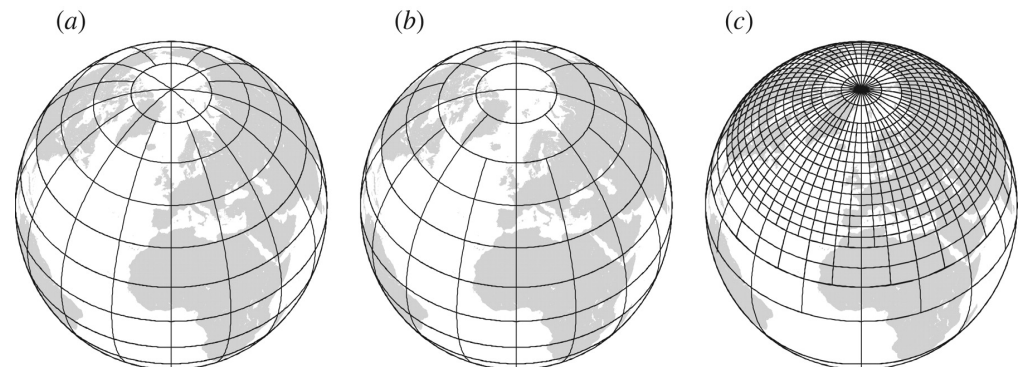
- Classical methods for the **downscaling** of climate scenarios :



Contribution of VarGCM ?

Introduction & context

- Contribution of VarGCM for downscaling future climate scenarios ?
 - Directly **downscale & bias-correct** oceanic forcings from coupled models scenarios
 - Do not depend on the **reliability of the forcing** at its lateral boundary
 - Bias correction of **systematic errors on atmospheric general circulation**



Introduction & context

- **Importance of oceanic forcings**
 - Large influence on **polar climates**
 - More and more future climate scenarios **downscaling with bias-corrected future SST (and SIC)** Ashfaq *et al.*, 2010 ; Krinner *et al.*, 2008 ; Hernandez-Diaz *et al.*, 2016
 - Future scenarios in Antarctica : more sensitive to **future oceanic boundary conditions** than to **future GHG concentrations** Krinner *et al.*, 2014

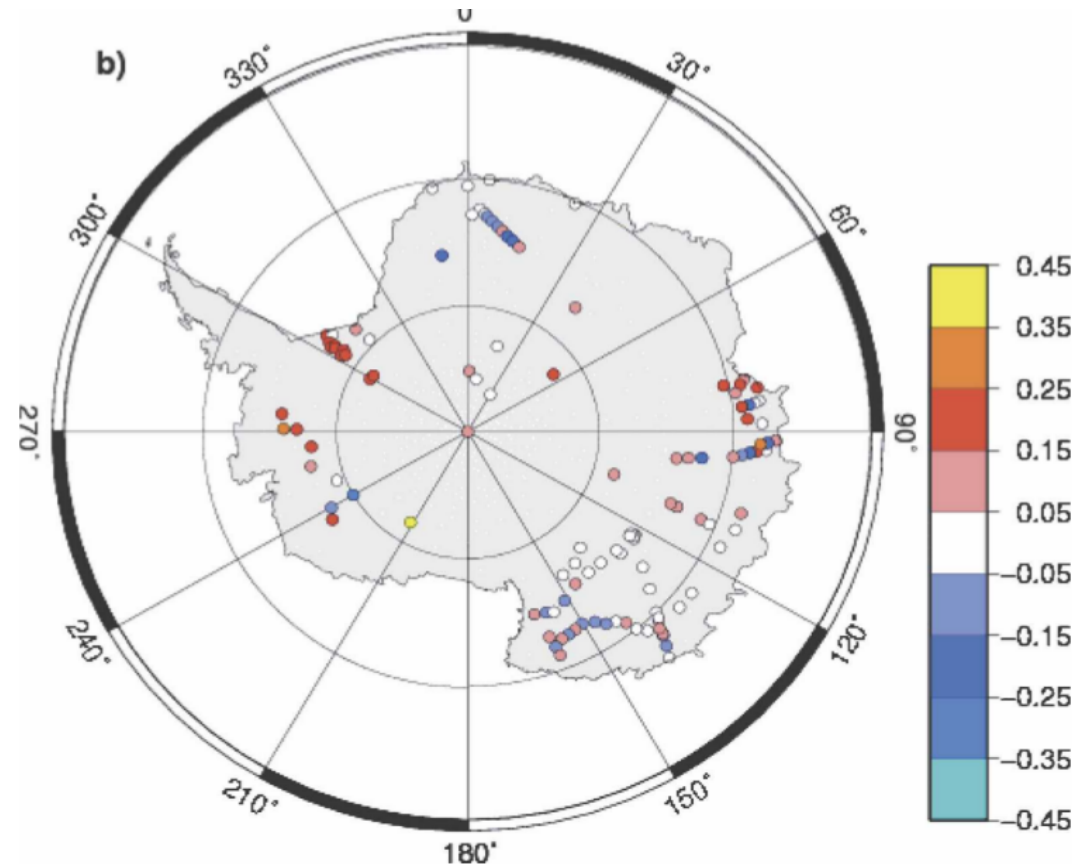


FIG. 5. Surface mass balance skill (between 0 and 1; dimensionless). (a) Simulation O20; (b) difference between O20 and S20.

Krinner *et al.*, 2008. Difference in Surface mass balance skill between simulation forced by observed SST/SIC and GCM SST/SIC

Outline



I. Model evaluation on present climate : **LMDZ**

1. Bias-correction of atm. circulation (LMDZv5)
2. Improving surface climate representation (LMDZv6)

II. Perspectives & Conclusion

I. Model evaluation : present climate*

LMDZv5 (CMIP5 version)

* AMIP sim. : forced by observed SST and SIC (pcmdi)

- **High resolution** configuration
 - 360 lon * 142 lat
 - 3x zoom south of 60°S
 - ~ **45 kms** resolution over Antarctica
 - Considerable computational cost
 - Same bias structure as low resolution simulations

- **Low resolution** test configuration
 - 96 lon * 95 lat
 - 2x zoom south of 60°S
 - ~ **125 kms** resolution over Antarctica

- 3 simulations :
 - Free
 - Nudged : u,v,T adjusted on ERA-Int every 6h / BL not guided
 - Bias-corrected

I. Model evaluation : present climate*

LMDZv5 (CMIP5 version)

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- **High resolution** configuration
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3 simulations :

- Free
- Nudged : u, v, T adjusted on ERA-Int every 6h / BL not guided

- Bias-corrected

??

I. Model evaluation : present climate

**Atmospheric bias correction in a GCM :
Use climatology of the model drift in the
nudged simulation to correct “free”
simulation**

Nudging:

$$\frac{\partial X}{\partial t} = F(X) - \frac{1}{\tau} (X - X_R)$$

Bias correction:

$$\frac{\partial X}{\partial t} = F(X) + G$$

where G is the empirical bias correction

$$G = -\frac{1}{\tau} \overline{(X - X_R)}^{AC}$$

G ~ **Daily climatology** of the **model drift**
with respect to the reanalysis

GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L18803, doi:10.1029/2012GL052815, 2012

The impact of model fidelity on seasonal predictive skill

V. V. Kharin¹ and J. F. Scinocca¹

Tellus (2005), 57A, 575–588

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TELLUS

**Reduction of systematic errors by empirical model
correction: impact on seasonal prediction skill**

By A. GULDBERG^{1*}, E. KAAS¹, M. DÉQUÉ², S. YANG¹ and S. VESTER THORSEN¹,

¹Climate Research Division, Danish Meteorological Institute, Lyngbyvej 100, DK-2100 Copenhagen Ø, Denmark;

²Météo-France, Centre National de Recherches Météorologiques, 42 Avenue Coriolis,

F-31057 Toulouse Cedex, France

Application for future climate scenario ?
→ Demonstrate **stationarity** of climate
model biases (Krinner & Flanner, 2017
(*subm.*))

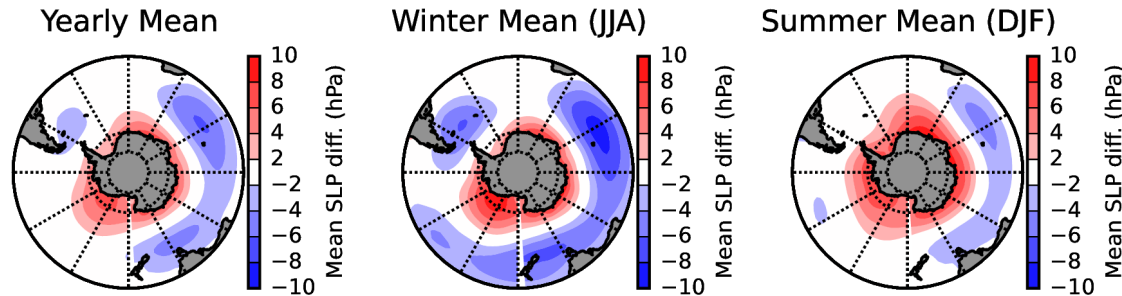
Nudged simulations : u,v,T above the
atmospheric boundary layer

I. Model evaluation : present climate

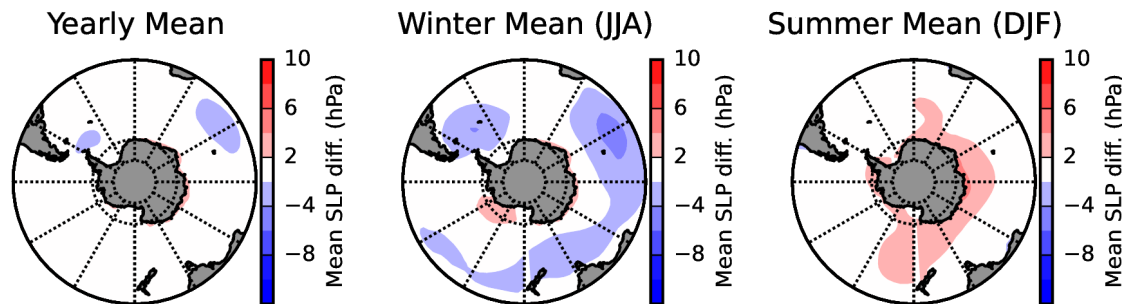
LMDZv5 (CMIP5 version)

General circulation : comparisons with ERA-Interim

Free LMDZv5 - ERA-Int : Sea level Pressure (hPa)



Corrected LMDZv5 - ERA-Int : Sea level Pressure (hPa)



Model biases on general circulation are (almost) completely removed in the bias-corrected simulation

1981-2000 Mean

I. Model evaluation : present climate

LMDZv5 (CMIP5 version)



Surface climate : comparisons with ERA-Interim ?

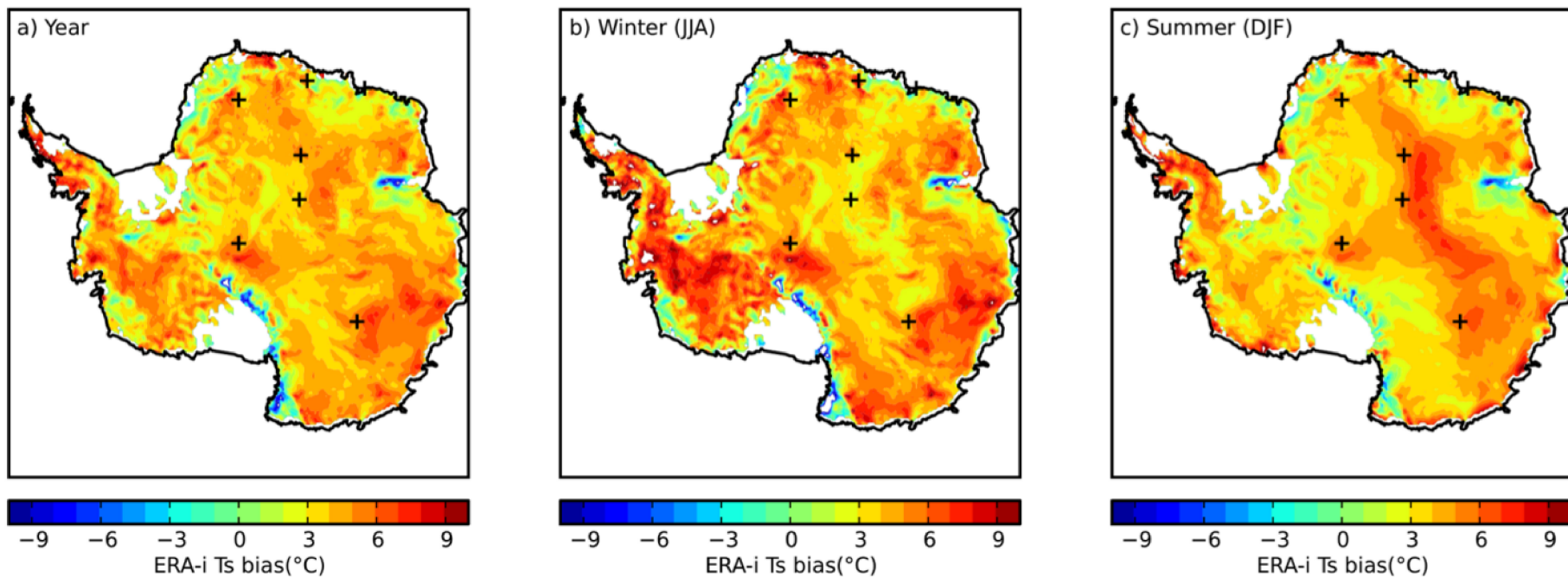


Fig 3. Freville *et al.*, 2014 : ERA-Interim bias with respect to MODIS clear-sky surface temperatures

I. Model evaluation on present climate

LMDZv5 (CMIP5 version)

Surface climate : comparisons with MAR-RCM

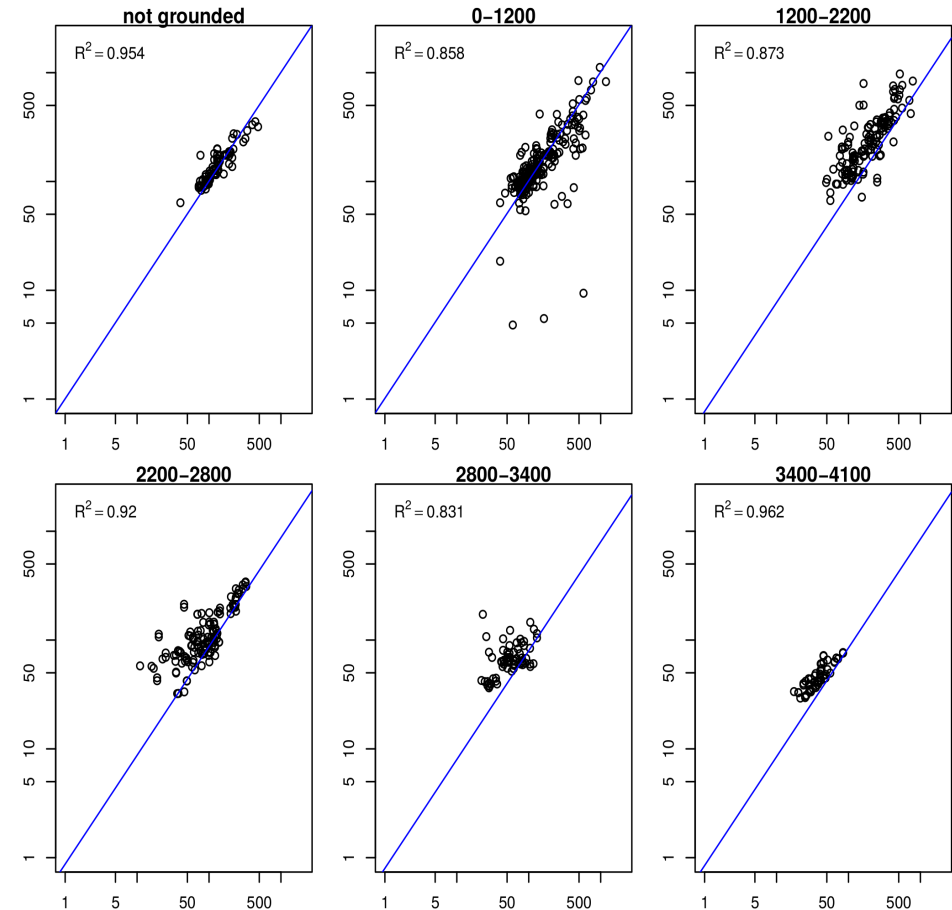
MAR-RCM :

Not an observation but ...

- ERA-Interim driven
- Complex **snow model** (CROCUS) and physics adapted to polar regions
- 35 kms horizontal resolution
 - Fair reference for less skilled GCM over Antarctica

SMB comparison from MAR and OBS

Altitude weighted



Comparison between MAR modelled and Observed (SAMBA data base, Favier *et al.*, 2013) surface mass balance (mmWe) per altitude classes (m) 12

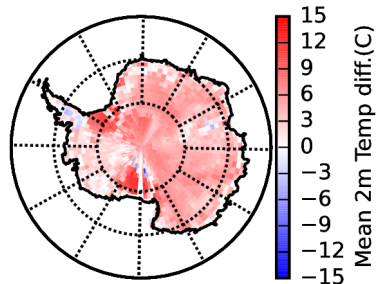
I. Model evaluation on present climate

LMDZv5 (CMIP5 version)

Surface climate : comparisons with MAR-RCM

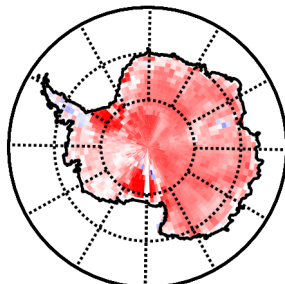
Free LMDZv5 - MAR-ERA-Int : 2m Temperature (1981-2000)

Yearly Mean



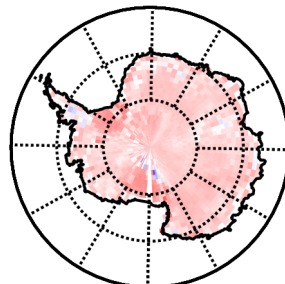
MAE (C) : 4.8
BIAS (C) : 4.6

Winter Mean (JJA)



MAE (C) : 6.5
BIAS (C) : 6.4

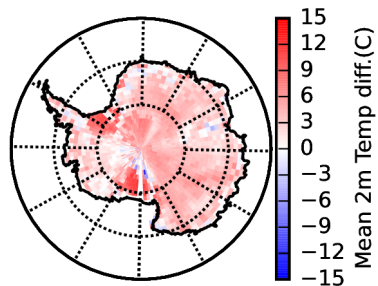
Summer Mean (DJF)



MAE (C) : 3.0
BIAS (C) : 2.9

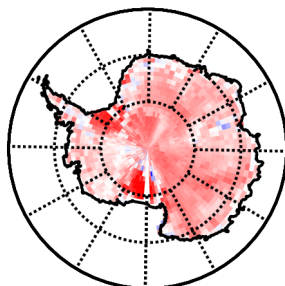
Corrected LMDZv5 - MAR-ERA-Int : 2m Temperature (1981-2000)

Yearly Mean



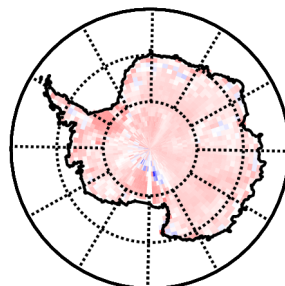
MAE (C) : 3.9
BIAS (C) : 3.6

Winter Mean (JJA)



MAE (C) : 5.1
BIAS (C) : 4.9

Summer Mean (DJF)



MAE (C) : 2.3
BIAS (C) : 2.0

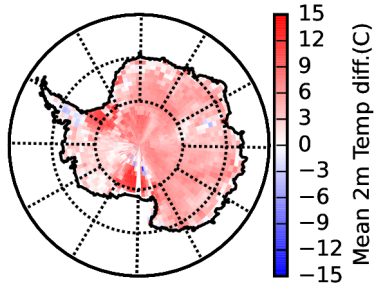
I. Model evaluation on present climate

LMDZv5 (CMIP5 version)

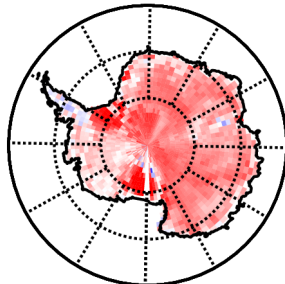
Surface climate : comparisons with MAR-RCM

Free LMDZv5 - MAR-ERA-Int : 2m Temperature (1981-2000)

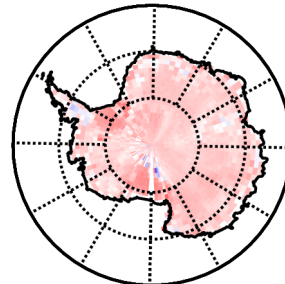
Yearly Mean



Winter Mean (JJA)



Summer Mean (DJF)



MAE (C) : 4.8
BIAS (C) : 4.6

MAE (C) : 6.5
BIAS (C) : 6.4

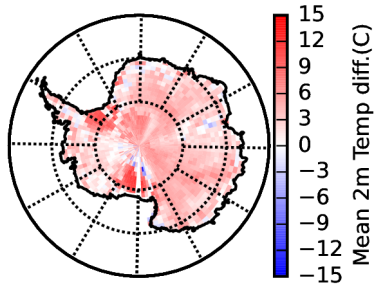
MAE (C) : 3.0
BIAS (C) : 2.9

	Year	JJA	DJF
Admundsen-Scott	4.9	5.9	3.3
Vostock	7	9.9	2.8
Dumont D'Urville	-5.6	-5.4	-5.4
Mc Murdo	-2.3	-1.6	-1.9

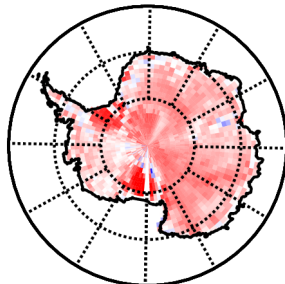
Tab : Bias on 2m T° LMDZv5 corrected simulation with monthly READER obs

Corrected LMDZv5 - MAR-ERA-Int : 2m Temperature (1981-2000)

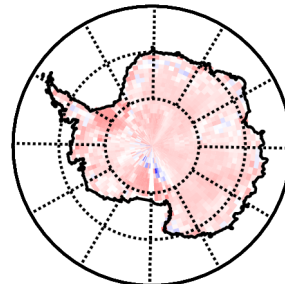
Yearly Mean



Winter Mean (JJA)



Summer Mean (DJF)



MAE (C) : 3.9
BIAS (C) : 3.6

MAE (C) : 5.1
BIAS (C) : 4.9

MAE (C) : 2.3
BIAS (C) : 2.0

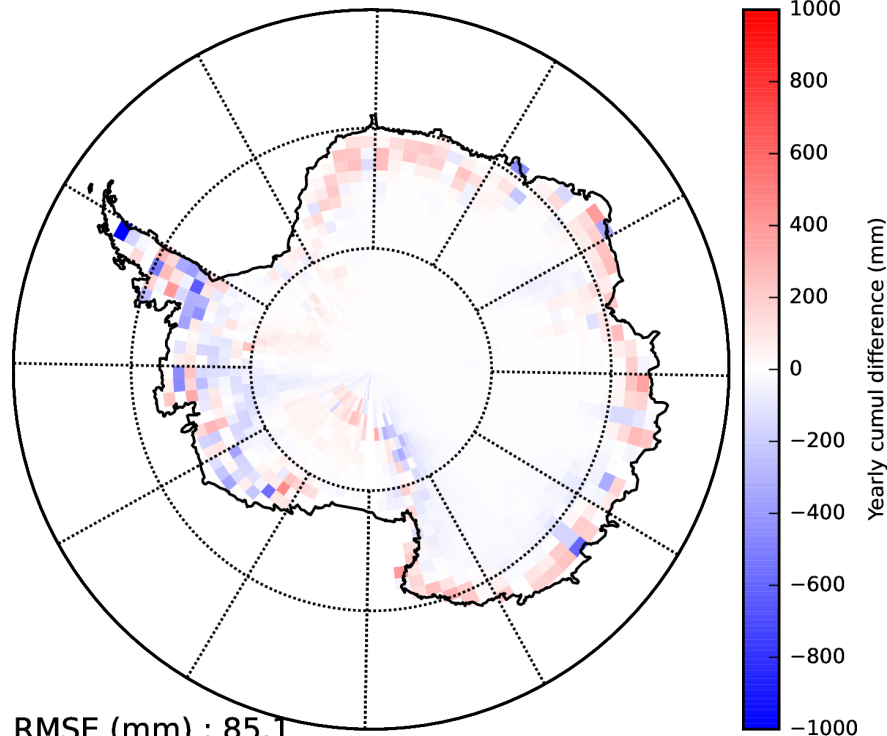
Correction of general circulation errors improve slightly the modeling of T2m but the **warm bias mainly in winter** remains considerable

I. Model evaluation : present climate

LMDZv5 (CMIP5 version)

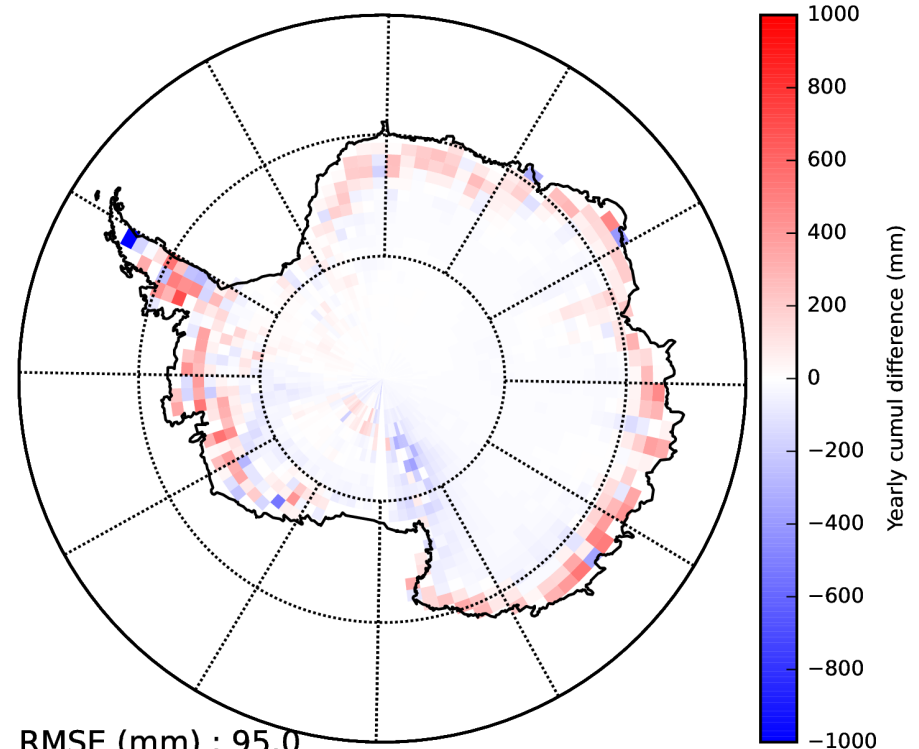
Precipitations and surface mass balance : comparisons with MAR-RCM

Free LMDZv5 - MAR-ERA-Int : 1980-2000 Yrly Mean
Total precipitation



RMSE (mm) : 85.1
MAE (mm) : 42.6
m BIAS (mm) : -2.3

Nudged LMDZv5 - MAR-ERA-Int : 1980-2000 Yrly Mean
Total precipitation



RMSE (mm) : 95.0
MAE (mm) : 46.5
m BIAS (mm) : 3.5

1981-2000 Mean

I. Model evaluation : present climate

LMDZv5 – Intermediate conclusions

- **Bias-correction** using nudged simulation is a convenient way to correct model **systematic errors** on general atmospheric circulation
- LMDZv5 **errors on Antarctic surface climate** limit its application for the study of Antarctic climate and climate change
 - Simulations with **LMDZv6 (CMIP6 version)**
 - 2 simulations (low resolution) :
 - Free
 - Nudged : u,v,T adjusted on ERA-Int every 6h / BL not guided

Main changes in LMDZ6

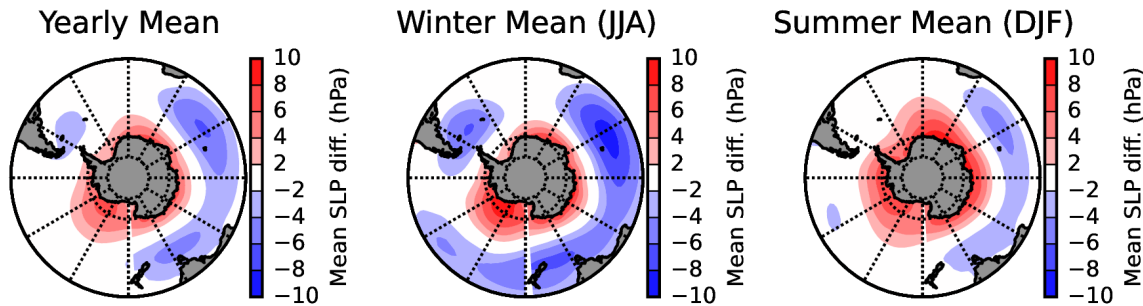
- 39 → 79 vertical levels
- RRTM radiative scheme
- New physic (Boundary layer, precipitations...)

I. Model evaluation : present climate

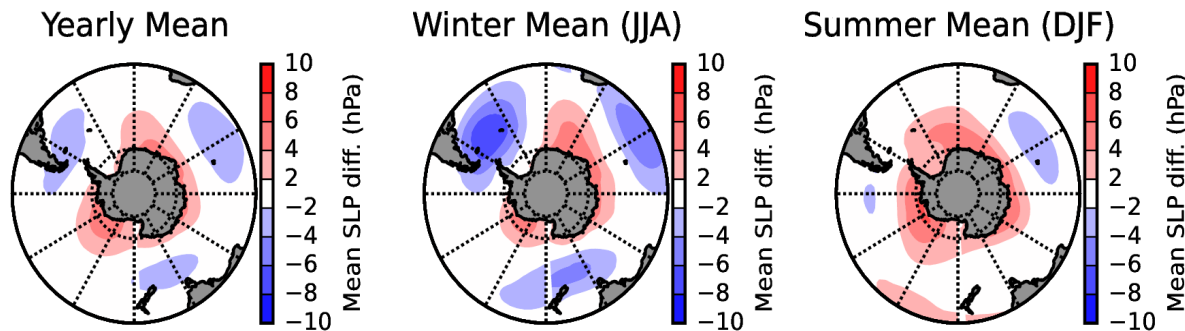
LMDZv6 (CMIP6 version)

General circulation : comparisons with ERA-Interim

Free LMDZv5 - ERA-Int : Sea level Pressure (hPa)



Free LMDZv6 - ERA-Int : Sea level Pressure (hPa)



Model bias structure is similar but bias magnitude is greatly reduced

1981-2000 Mean

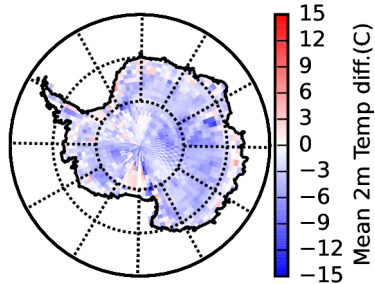
I. Model evaluation : present climate

LMDZv6 (CMIP6 version)

Surface climate : comparisons with MAR-RCM

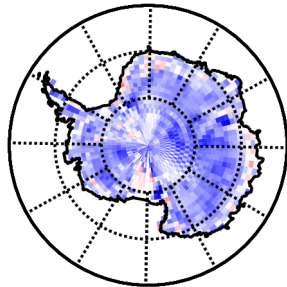
Free LMDZv6 - MAR-ERA-Int : 2m Temperature (1981-2000)

Yearly Mean



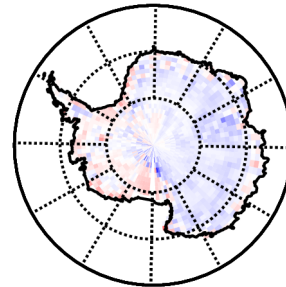
MAE (C) : 3.3
BIAS (C) : -2.9

Winter Mean (JJA)



MAE (C) : 5.2
BIAS (C) : -5.0

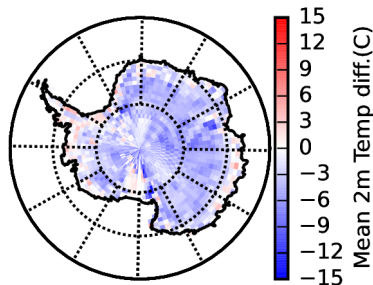
Summer Mean (DJF)



MAE (C) : 1.3
BIAS (C) : -0.6

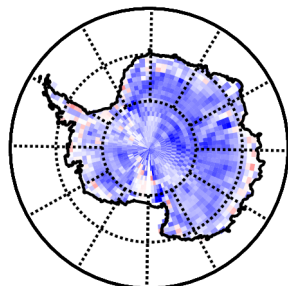
Nudged LMDZv6 - MAR-ERA-Int : 2m Temperature (1981-2000)

Yearly Mean



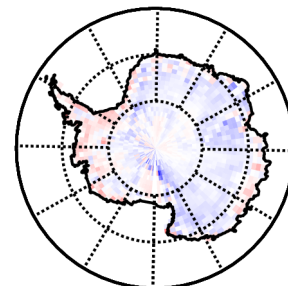
MAE (C) : 3.5
BIAS (C) : -3.2

Winter Mean (JJA)



MAE (C) : 5.5
BIAS (C) : -5.2

Summer Mean (DJF)



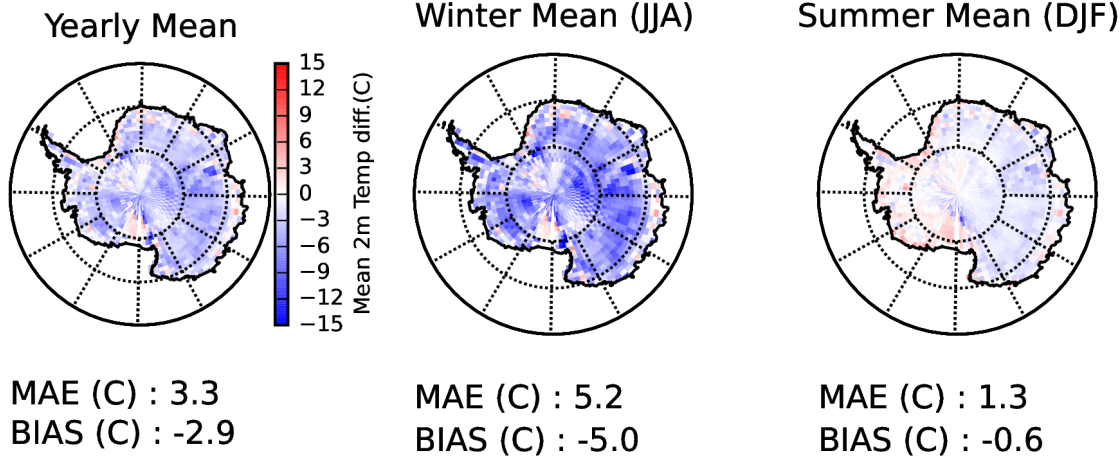
MAE (C) : 1.2
BIAS (C) : -0.5

I. Model evaluation : present climate

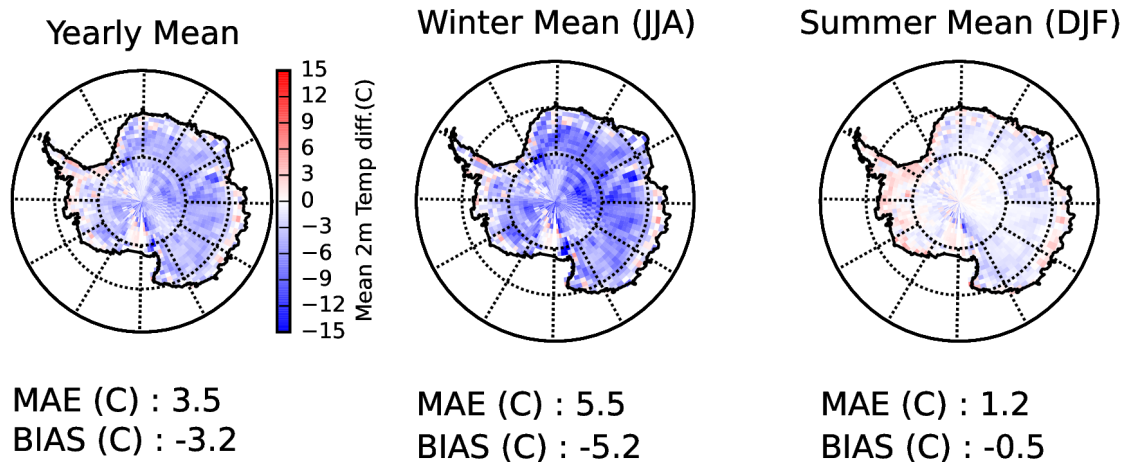
LMDZv6 (CMIP6 version)

Surface climate : comparisons with MAR-RCM

Free LMDZv6 - MAR-ERA-Int : 2m Temperature (1981-2000)



Nudged LMDZv6 - MAR-ERA-Int : 2m Temperature (1981-2000)



	Year	JJA	DJF
Admundsen-Scott	-1.9	-4.2	0.98
Vostock	-1.8	-4.1	-0.27
Dumont d'Urville	-11.9	-12.8	-10.1
Mc Murdo	-12.6	-17.1	-5.9

Tab : Bias on 2m T° LMDZv6 nudged simulation with monthly READER obs

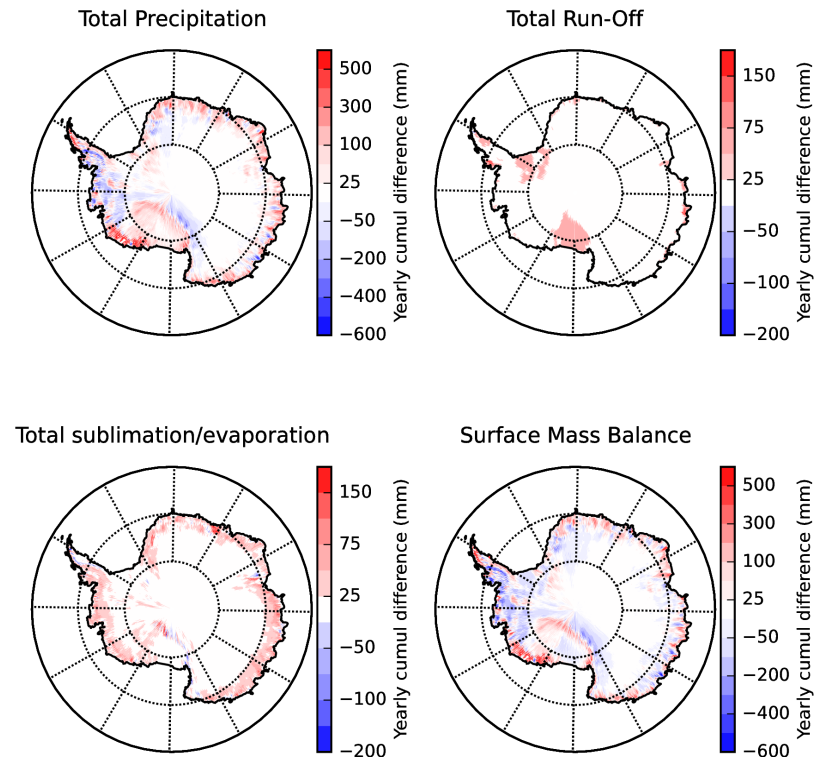
- **Summer T°** : ok !
- **Winter T2m** is now ~ 5°K to cold on the Antarctic Plateau
→ Need further calibration
- **≠** between **nudged** and **free** simulation reduced

II. Perspectives

Other work

- Bias correction methods for oceanic forcing boundary conditions for atmospheric models, J. Beaumet *et al.* (*in prep*)
- Running and evaluating high resolution simulation with ARPEGE GCM (MeteoFrance)

ARPEGE - MAR-ERA-Int : 1980-2010 Surface Mass Balance



II. Perspectives

LMDZv6

- Integration of new **developments** on **stable boundary layers** (Vignon *et al.*, *J. Geoph. Res.*, 2017) into CMIP6 version (June 2017) → further calibration + researches on gravity waves
- Perform high resolution simulations and validate with observations (READER & SAMBA) data base or high resolution data set (MAR, CROCUS run, MODIS surface T°)
- Projections with empiric bias correction (oceanic forcing and model systematic errors on atmospheric circulation)

Cordex

- Contribute to Antarctic Cordex with high resolution simulations from LMDZ and ARPEGE

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 READER data base : <https://legacy.bas.ac.uk/met/READER/background.html>

Thanks ! Questions ?



Wintering of J. Charcot expedition, Graham Land, 1905

Annex

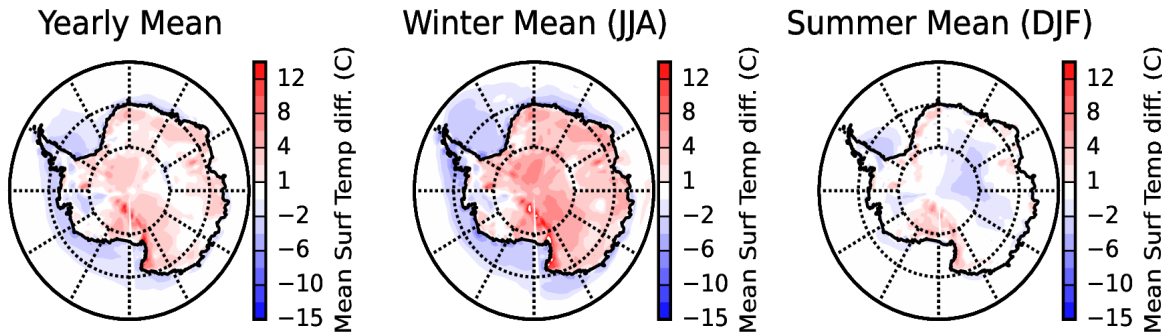
I. Model evaluation on present climate

LMDZv5 (CMIP5 version)



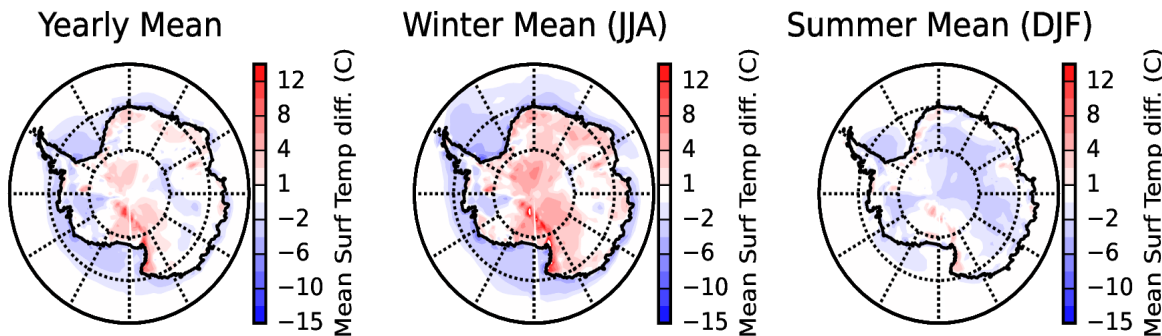
Surface climate : comparisons with ERA-Interim

Free LMDZv5 - ERAi : Surface Temperature (C)



Correction of the general circulation errors improve slightly the modeling of surface temperatures but the **warm bias in winter** remains considerable

Corrected LMDZv5 - ERAi : Surface Temperature (C)



1981-2000 Mean

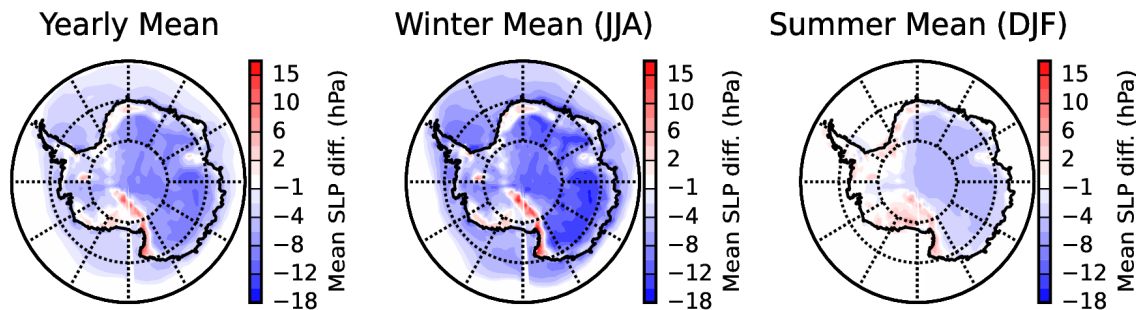
I. Model evaluation : present climate

LMDZv6 (CMIP6 version)

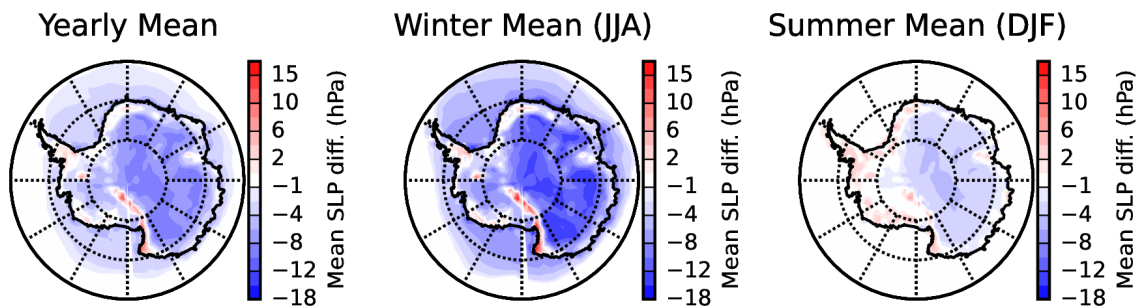


Surface climate : comparisons with ERA-Interim

Free LMDZv6 - ERA-Int : Surface Temperature (C)



Nudged LMDZv6 - ERA-Int : Surface Temperature (C)



1981-2000 Mean

- Summer surface temp. : ok !
- Winter surface temp. Is now probably $> 5^{\circ}\text{K}$ to cold on the Antarctic Plateau
→ Need further verifications and understandings of LMDZ6 unusual bias structure