21st century high-resolution downscaling of Antarctic surface mass balance from global circulation models

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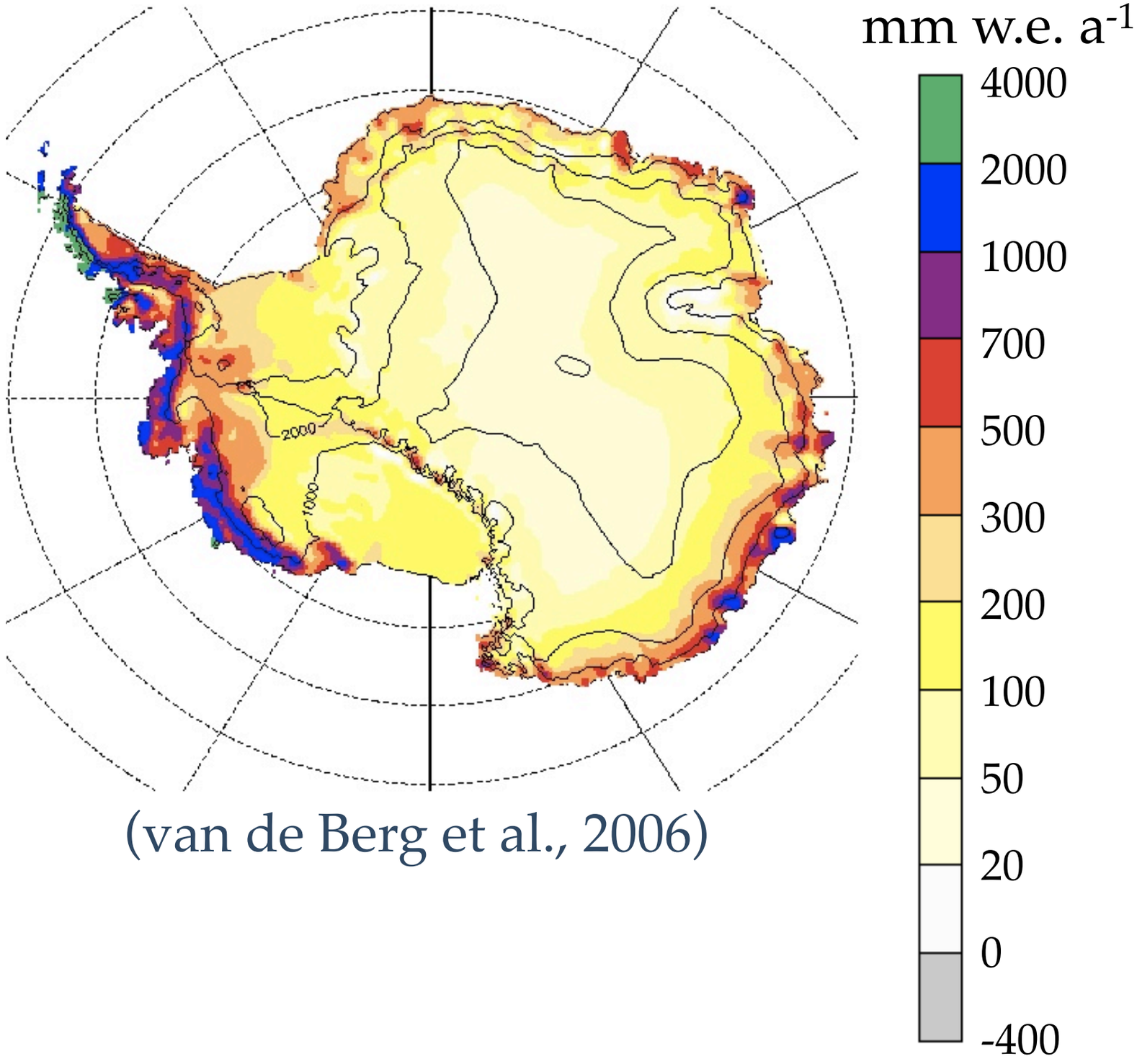
Antarctic Surface Mass Balance

- Coastal areas :

  snowy and windy

- Antarctic Plateau :

  cold and dry



(van de Berg et al., 2006)

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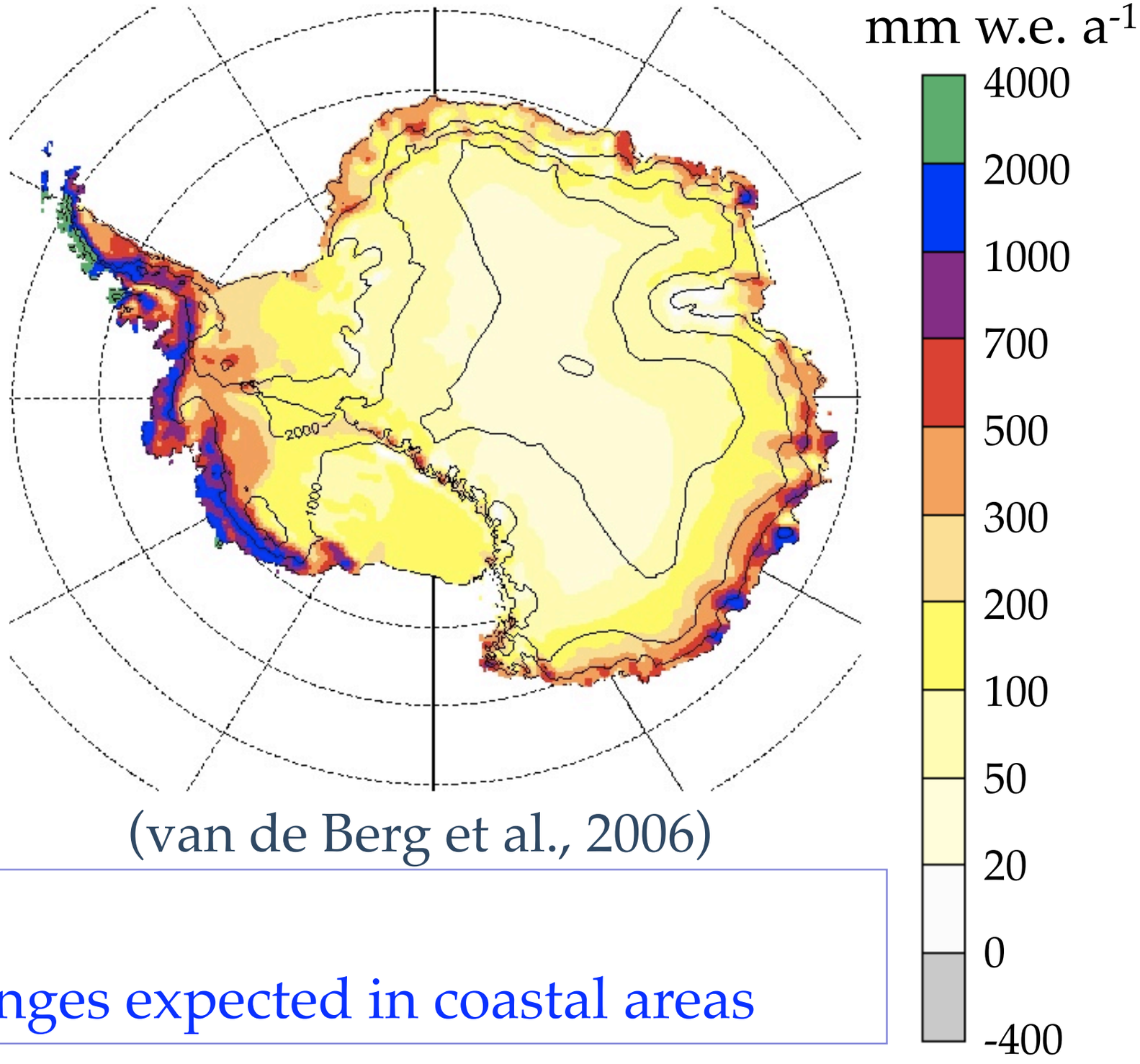


(van de Berg et al., 2006)

- Climate models:

  major SMB changes expected in coastal areas

SMB Downscaling : Why ?

SMB estimation

Precipitation, Sublimation, Melting, Refreezing, Blowing snow

Spatial extent

Antarctica (5600 km x 5600 km)

Time extent

~800 yrs (1980-2200 * 2 Scenarios * 2 Boundary conditions)

GCM resolution : ~ 60 km → Required resolution : ≤ 15 km

→ Reduced computation time needed

The HiDEP model

High-Resolution Downscaling of surface Energy balance and Precipitation

INPUTS (~50 KM RESOLUTION)

GCM Outputs :
P, T, Qv, U, V, W

3D Fields
Time step : 6H

Surface Fields
Time step : 3H

High-resolution topography

Precipitation

HiDEP

Surface Energy Balance

OUTPUTS (15 KM RES.)

$Rain_{HIDEP}$

$Snow_{HiDEP}$

$Sublimation_{HIDEP}$

$Melting_{HiDEP}$

$Refreezing_{HiDEP}$

Precipitation downscaling : an orographic precipitation model

Upward wind → Adiabatic cooling → ρ_{sat} ↓

Integration of the Clausius-Clapeyron equation **at saturation** :

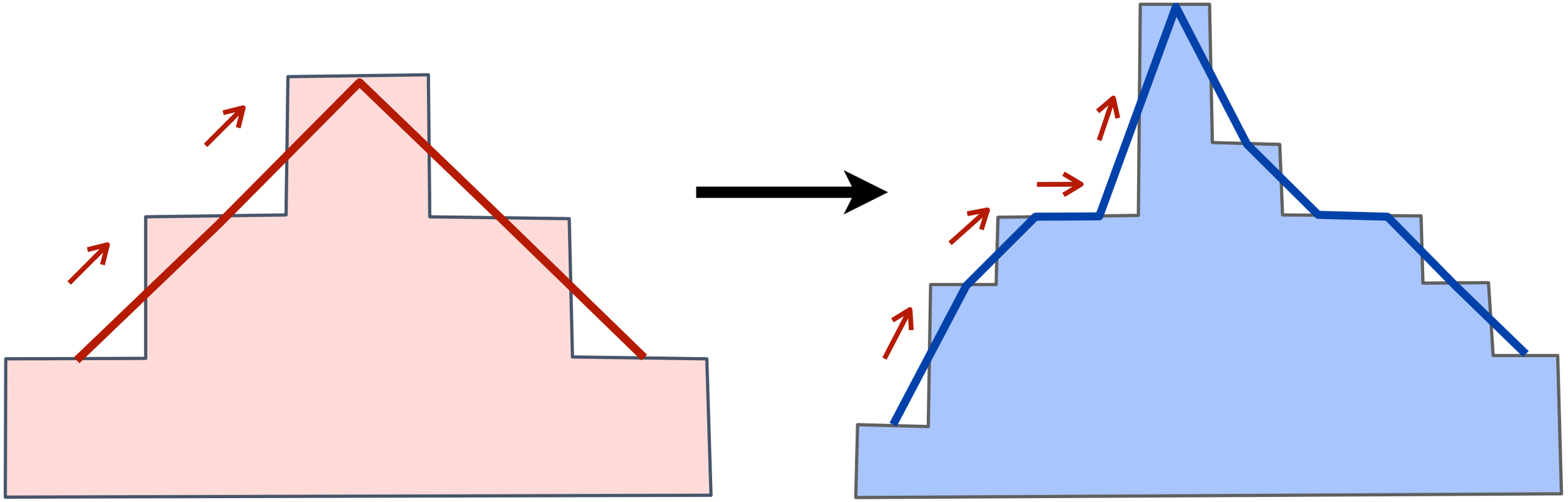
$$\text{Precipitation rate} = \Delta\rho_{sat} / \Delta t = \boldsymbol{F}\,(\rho_{sat}, T, P) \times W$$

when $\rho \geq \rho_{sat}$ *and W upward*

Orographic precipitation : Determination of the vertical wind W

At the surface : the wind is tangent to the topography

➙ new vertical wind at the surface



➙ Computation for W : resolution of mountain gravity wave

Total precipitation : Orographic + Non-Orographic

Low-res. NON-Orographic Precipitation

Low-res. Total Precip. *(Interpolated from GCM)*

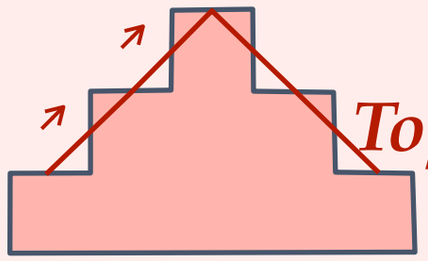
– Low-resolution Orographic Precip.

+ High-resolution Orographic Precip.

High-resolution Total Precip.

Total precipitation : Orographic + Non-Orographic

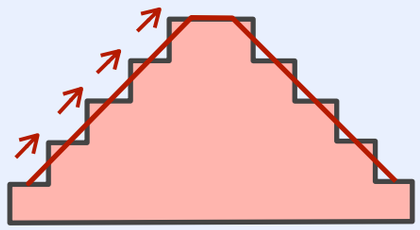
GCM Grid (~50 km res.)



GCM Topography

Interpolation

HiDEP Grid (15 km res.)



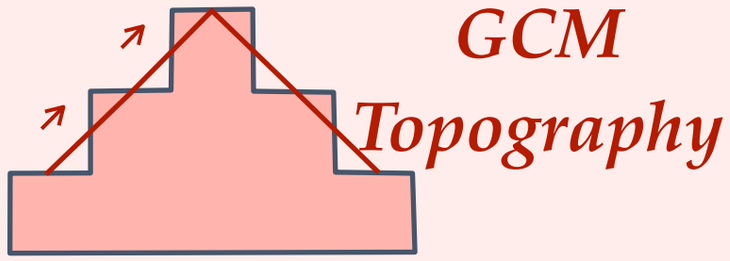
GCM Interpolated Topography

Low-res. Oro. Precip.

GCM Precipitation

Total precipitation : Orographic + Non-Orographic

GCM Grid (~50 km res.)



Interpolation

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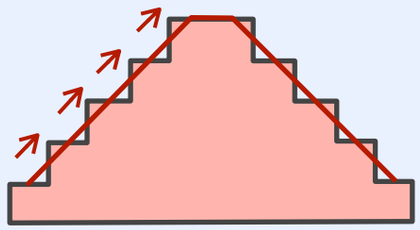

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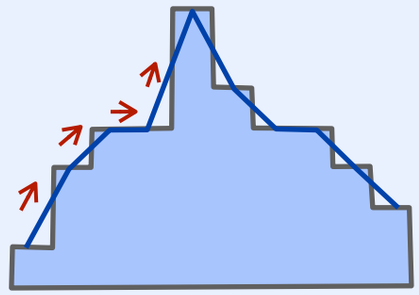

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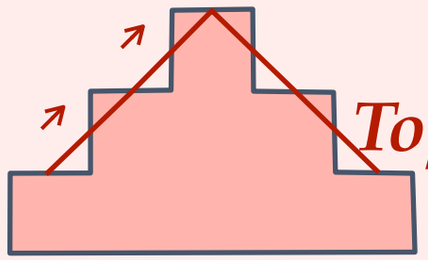

GCM Topography

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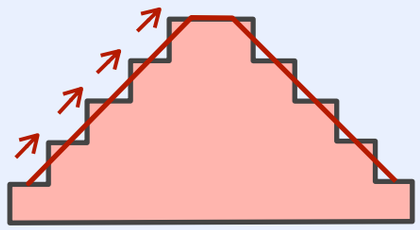

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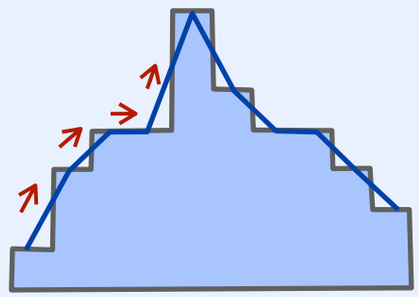


High-res. Topography

High-res. Oro. Precip.

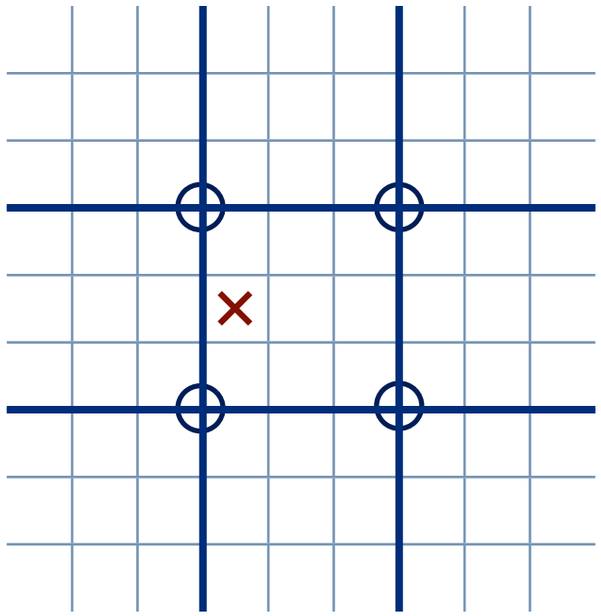
GCM Precipitation

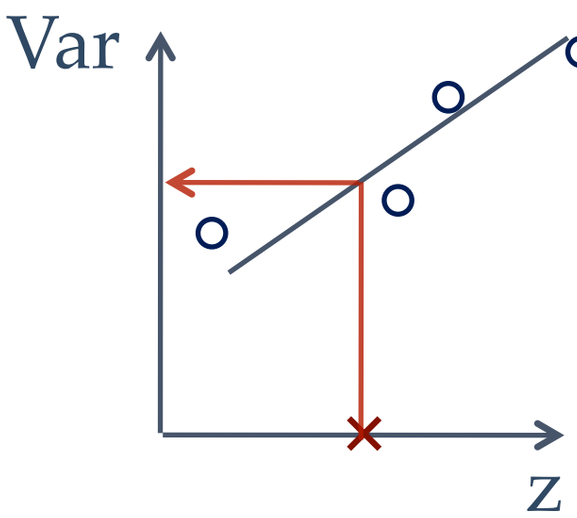
Interpolation

Low-res. Total Precip. (Oro. + Non-Oro.)

Surface Energy Balance

Extrapolation of GCM surface fields against the topography





Surface Scheme

↓

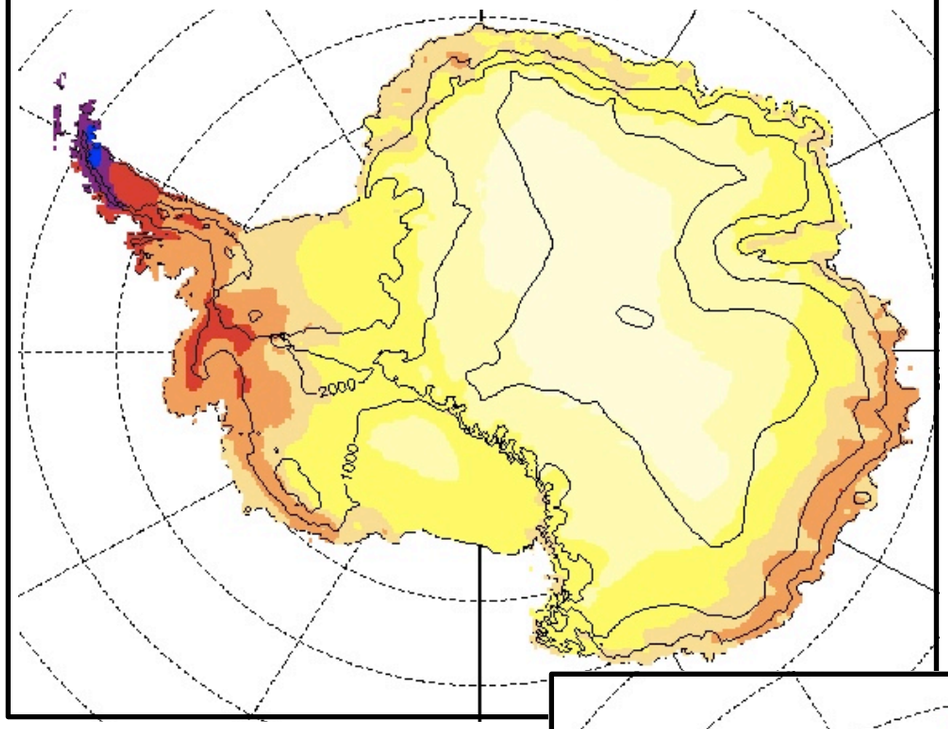
Sublimation

Melting

Refreezing

Application to LMDZ4 : 1980-2007

Arthern et al, 2006



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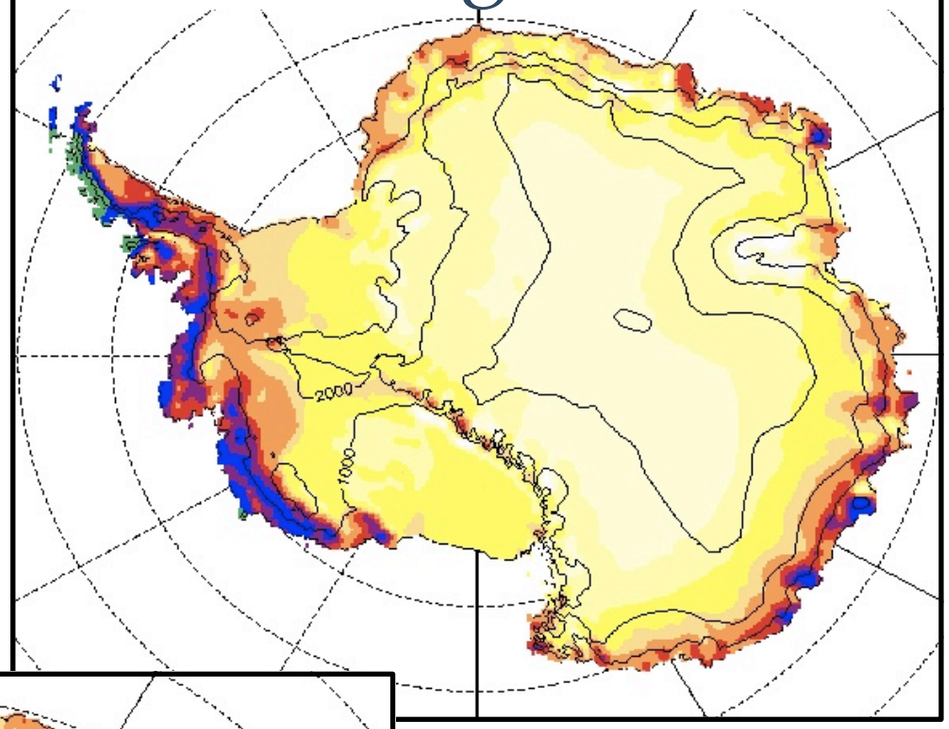
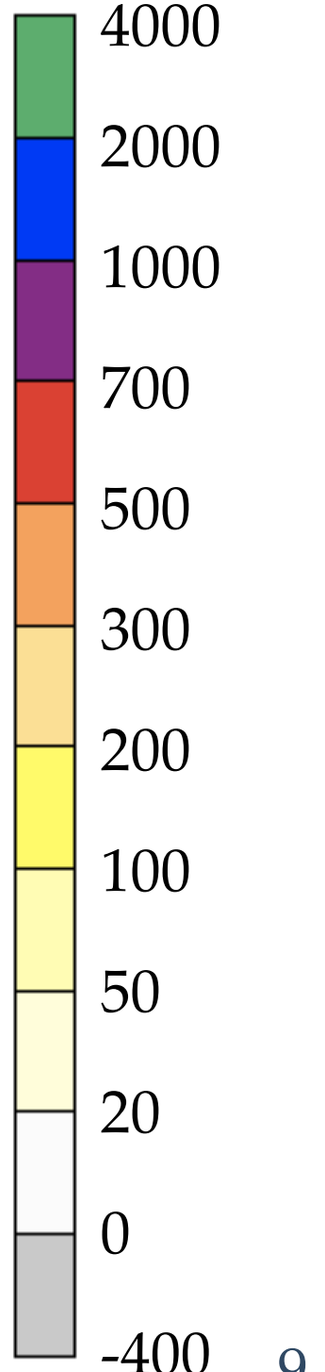
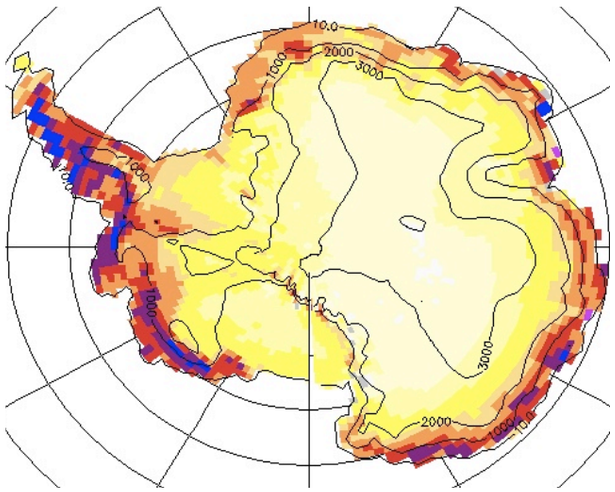
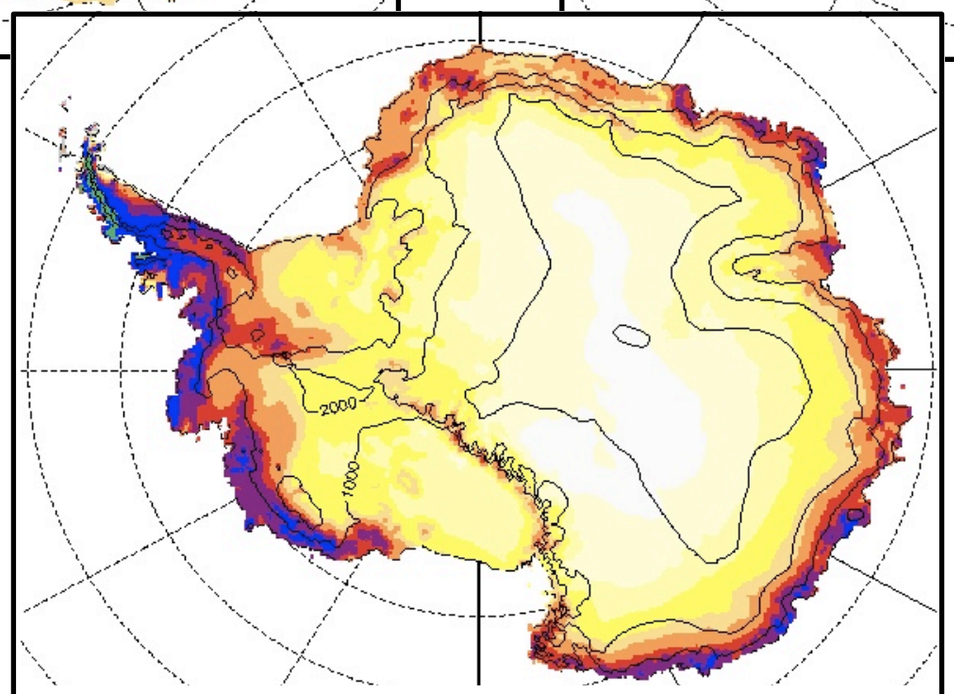


SMB
mm w.e. a^{-1}





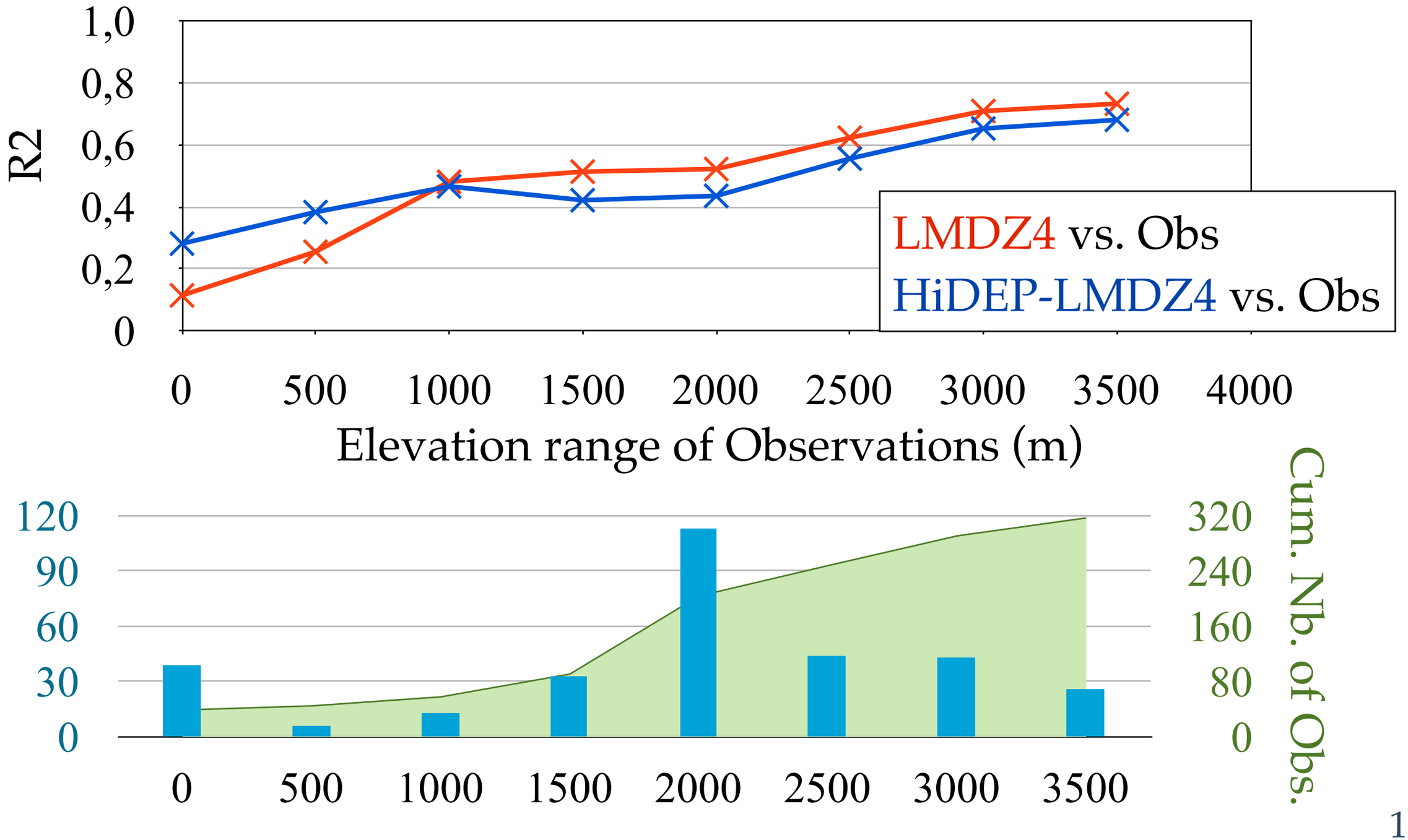
LMDZ4



HiDEP-LMDZ4

Validation with a quality-controlled SMB data-set (Magand et al., 2007) : 90° – 180°E

R2 weighted by the number of observation in LMDZ4 grid boxes



Validation with a quality-controlled SMB data-set (Magand et al., 2007) : 90° – 180°E

Extension of the data quality-control to the rest of Antarctica :

Work in progress at LGGE

(In charge : Soazig Parouty, Vincent Favier)

Grounded SMB 1980-2007

Present SMB (1950-2000) :

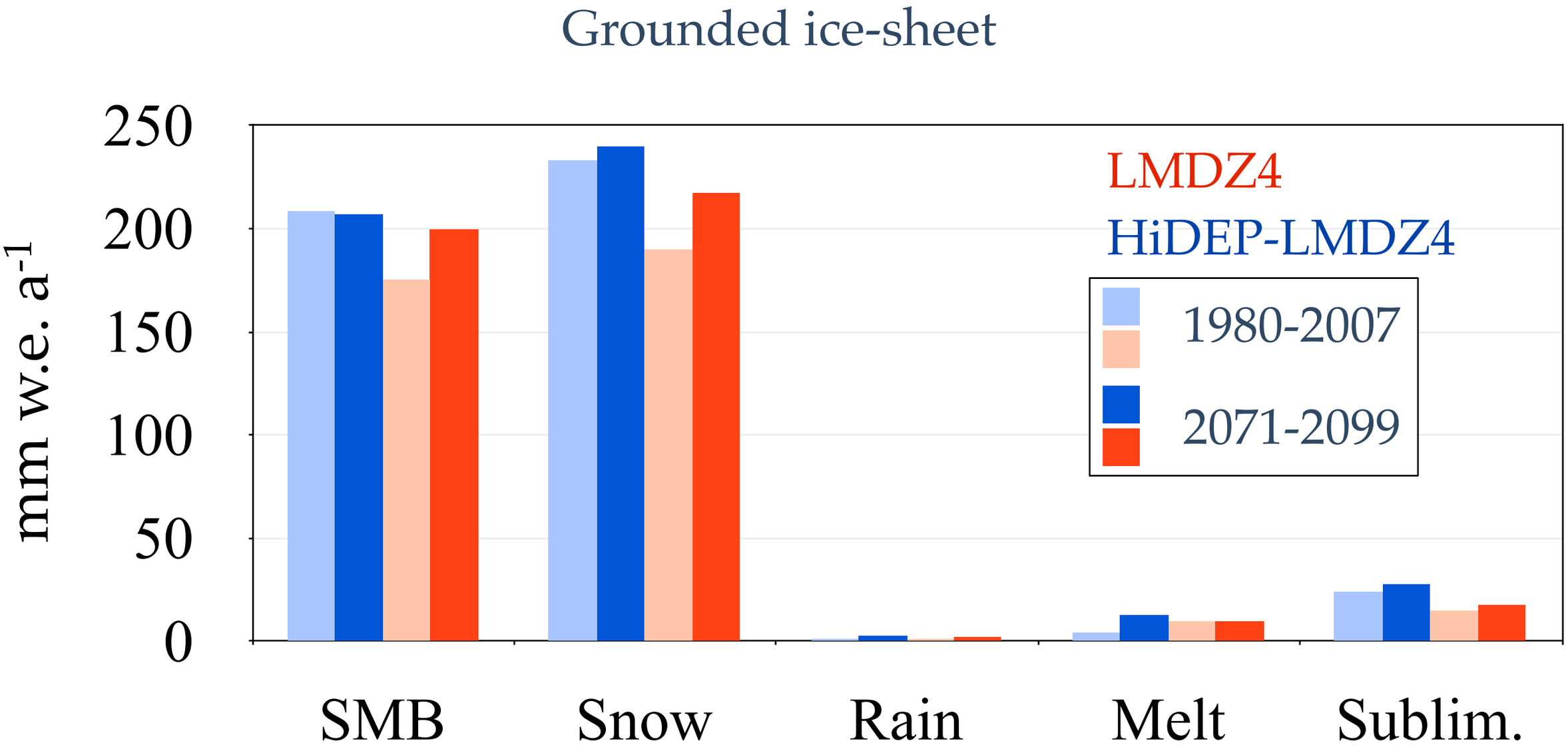
- Range : 4.1 to 6.4 mm a^{-1} sea level equivalent (Monaghan et al., 2006)

LMDZ4 P-E	175.2 mm w.e. a^{-1} = kg m^{-2} a^{-1} ⇔ 6.0 mm a^{-1} sea level equivalent

HiDEP-LMDZ4 SMB	208.6 mm w.e. a^{-1} = kg m^{-2} a^{-1} ⇔ 6.7 mm a^{-1} sea level equivalent

Projection for the 21st century (A1B)

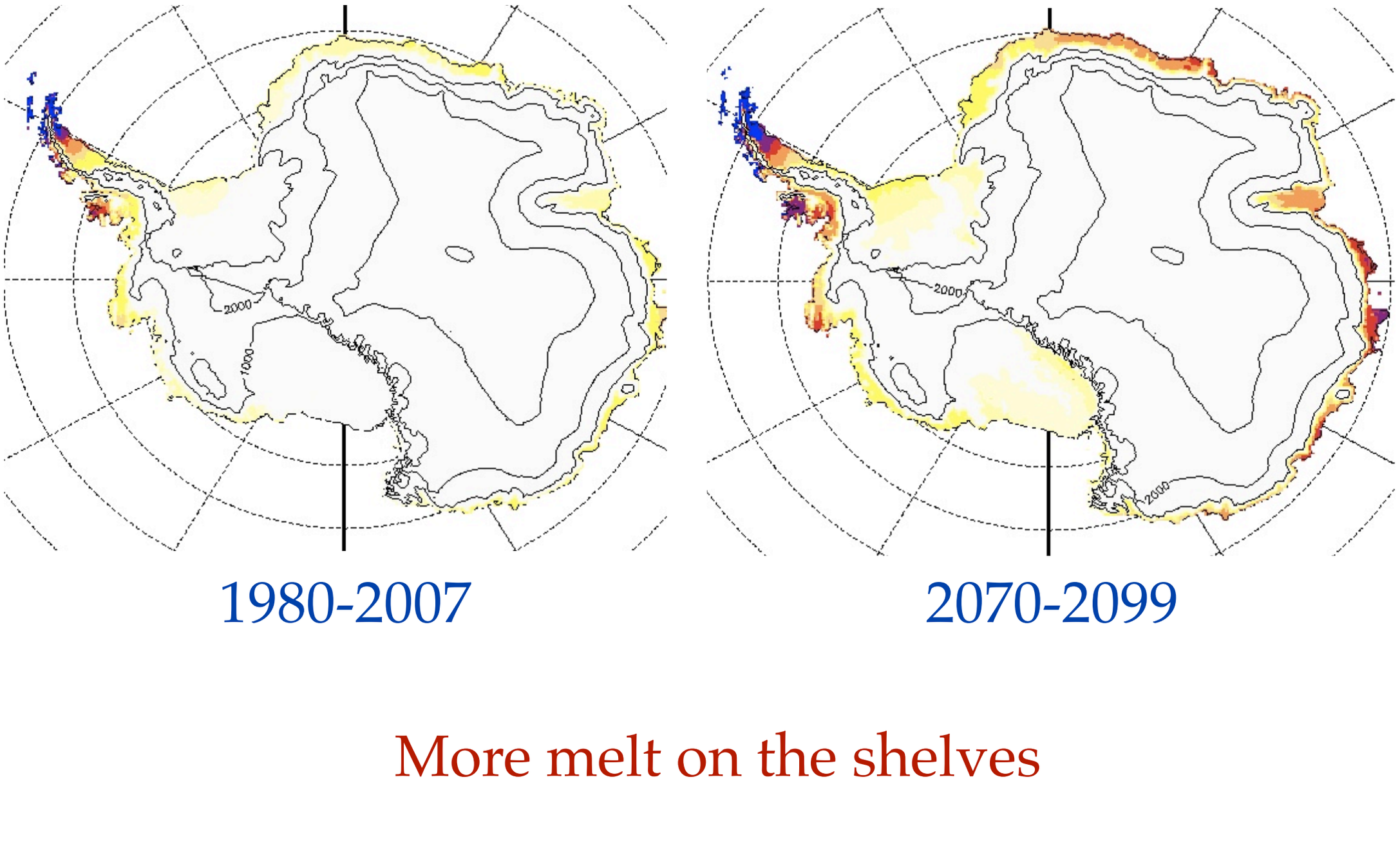
First results



Projection for the 21st century (A1B)

First results

Melt HiDEP



1980-2007

2070-2099

More melt on the shelves

Conclusion

- High-resolution SMB (15 km) obtained from LMDZ4 downscaling

  Partial validation for present :

  - Increased performance Downscaled SMB close to LMDZ4 SMB

    BUT lack of field data in (crucial) coastal areas

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Further validation :

- Extended quality-controlled data set over all Antarctica

Model development in progress :

- More detailed Surface Scheme


Thank you
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