Evolution of Antarctic Surface Mass Balance by high-resolution downscaling of LMDZ4 AGCM and contribution to sea-level change

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Ice2sea Open Forum 2 - 19, March 2011

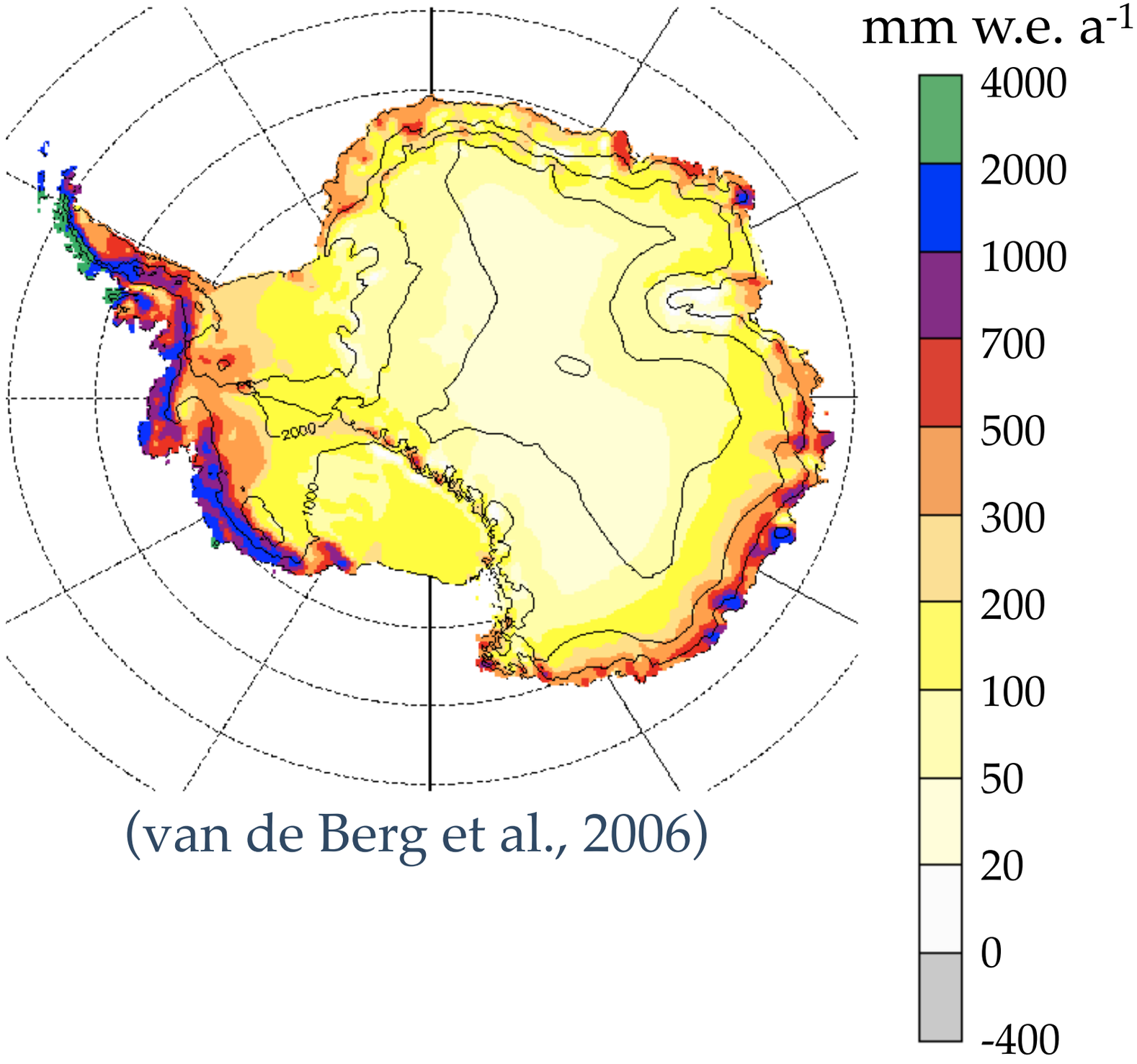
Antarctic Surface Mass Balance

- Coastal areas :

  snowy and windy

- Antarctic Plateau :

  cold and dry



(van de Berg et al., 2006)

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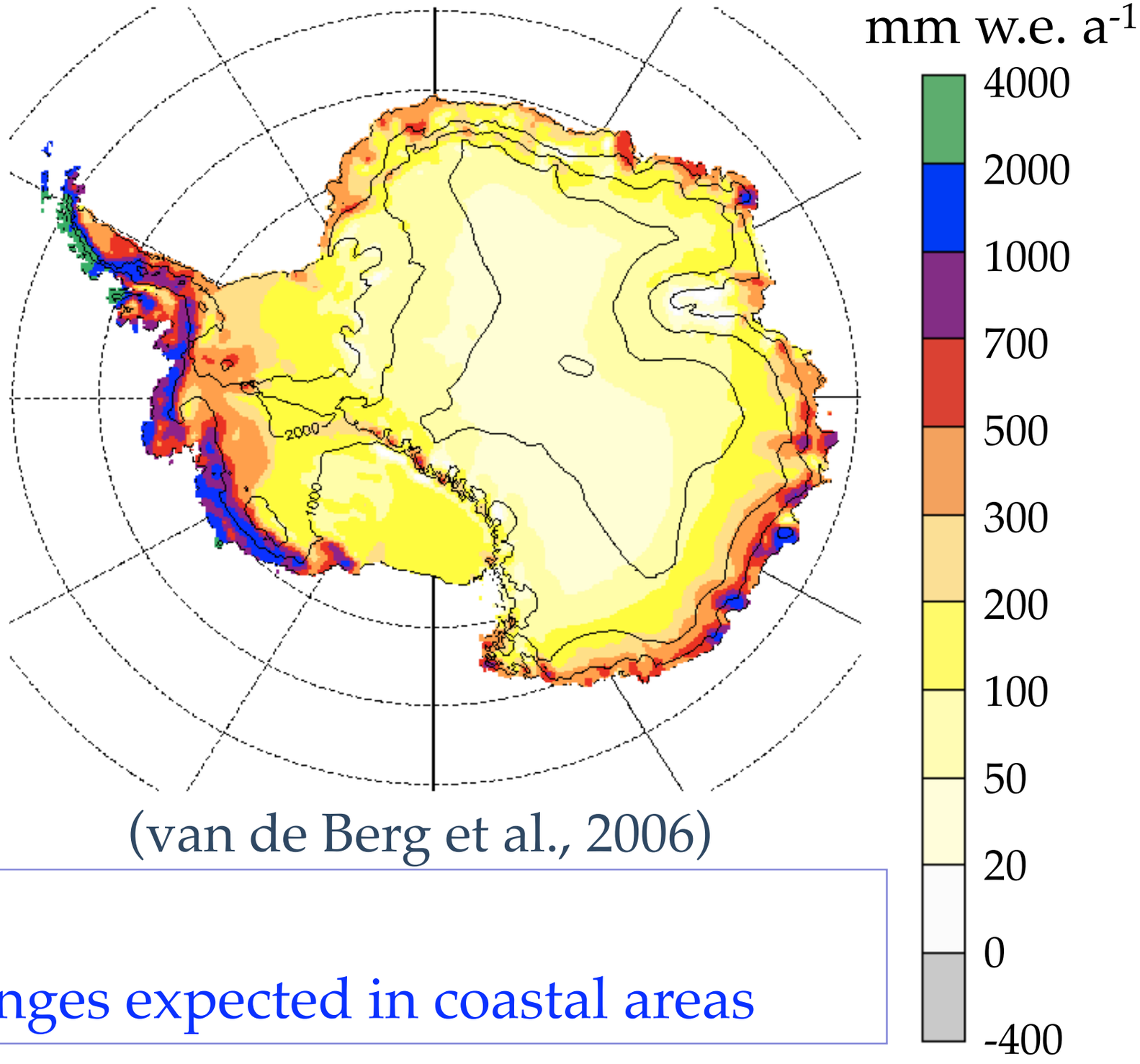

(van de Berg et al., 2006)

- 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

HiDEP

The HiDEP model

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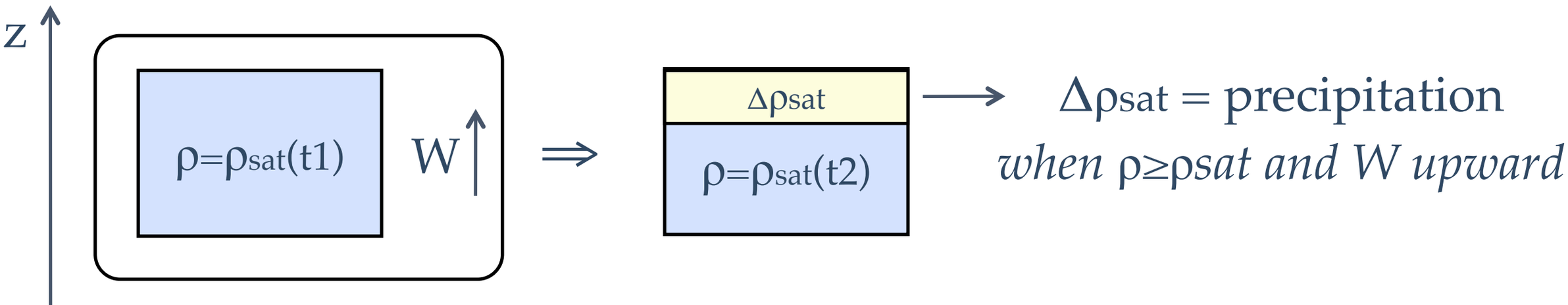
Precipitation downscaling : an orographic precipitation model

Upward wind → Adiabatic cooling → ρ_{sat} ↓



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

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

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

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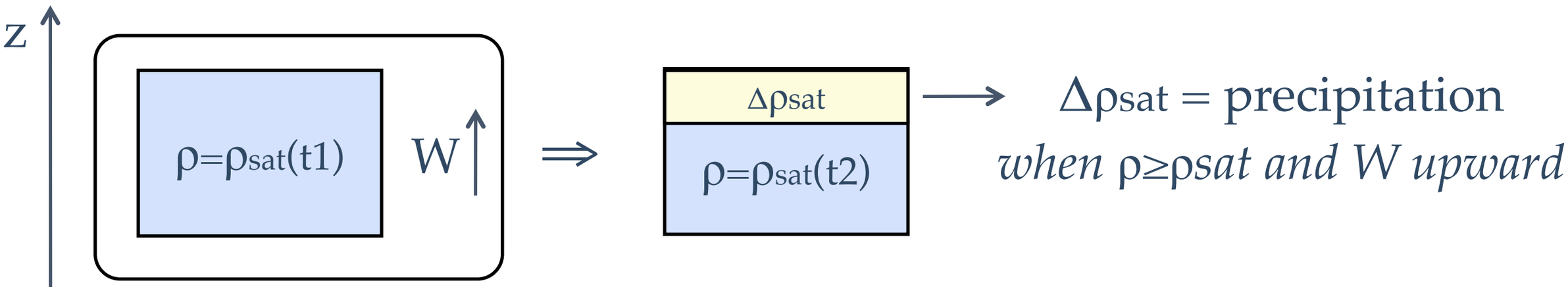

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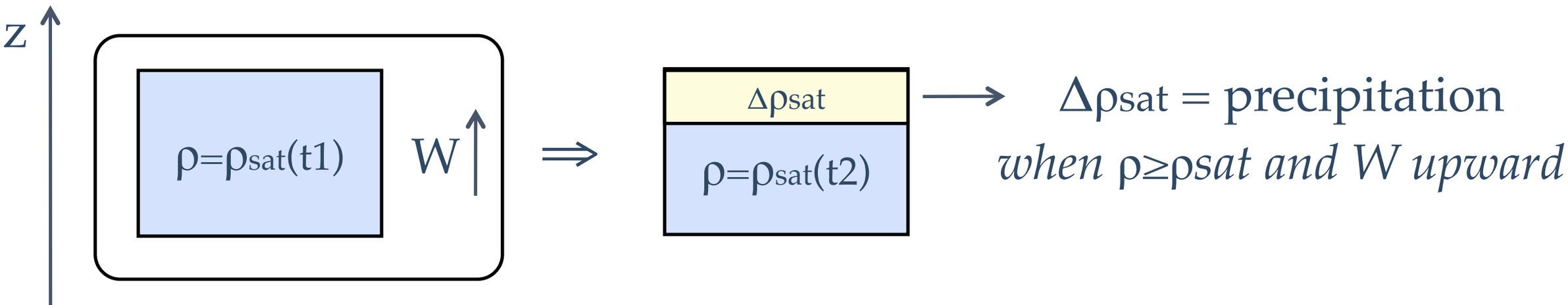

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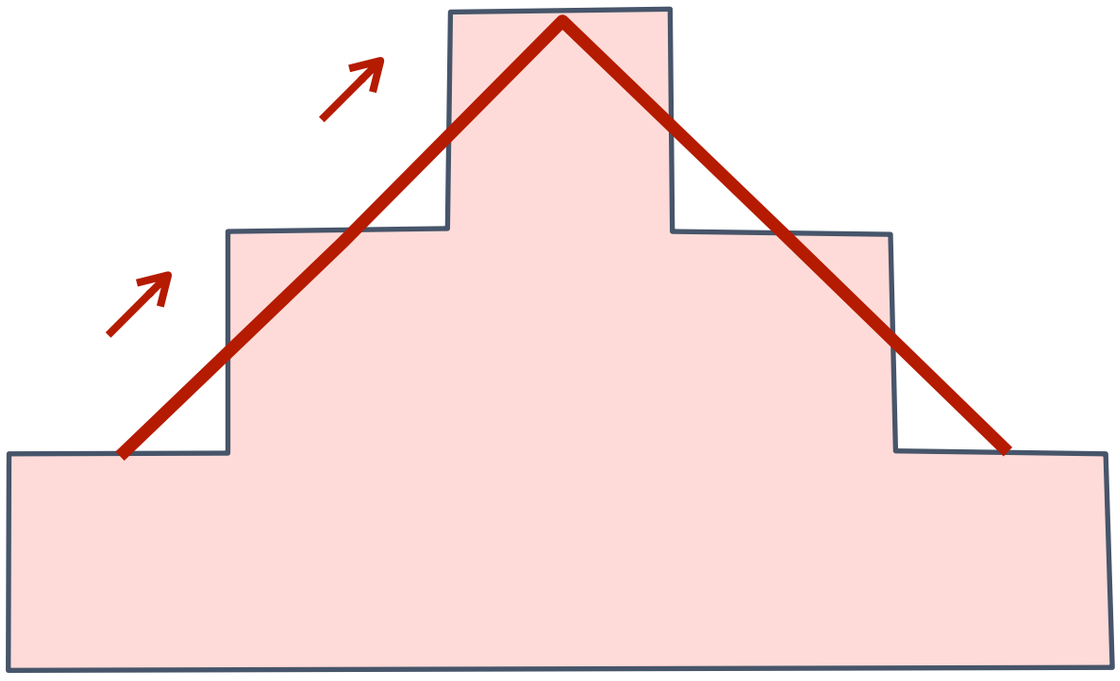
Orographic precipitation : Determination of the vertical wind W

At the surface : the wind is tangent to the topography



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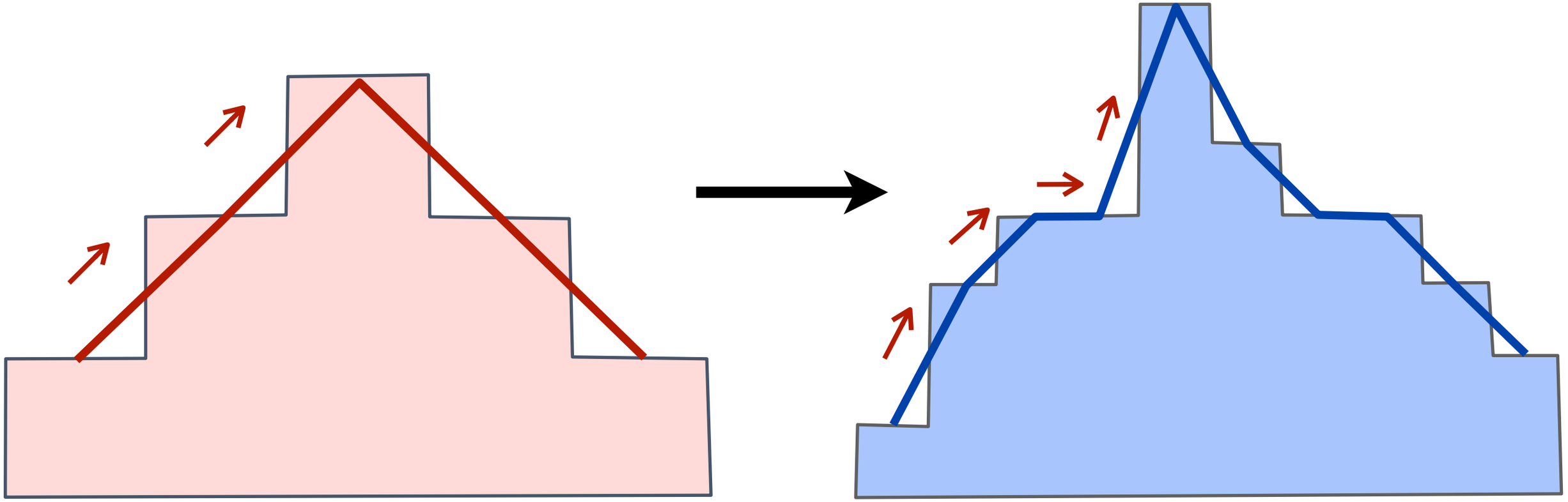

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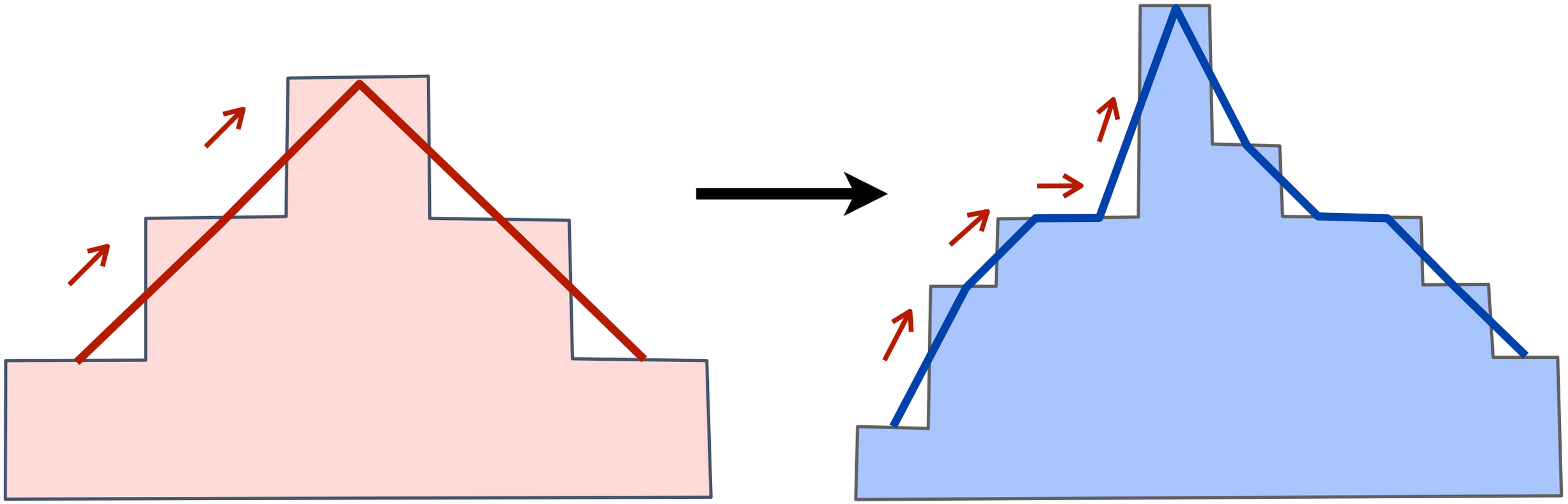
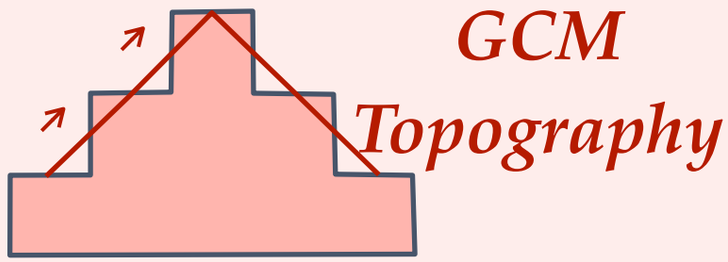


➙ Computation for W : resolution of mountain gravity wave

Total precipitation : Orographic + Non-Orographic

GCM Grid (~50 km res.)



GCM Precipitation

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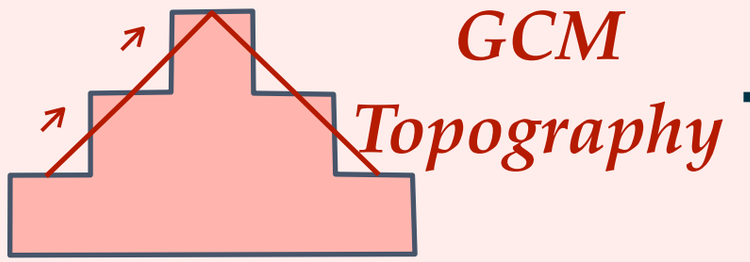

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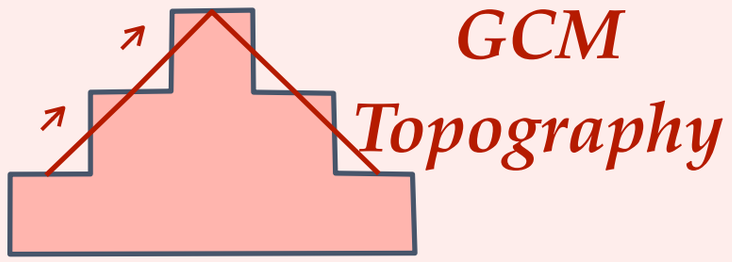

GCM Topography

Interpolation

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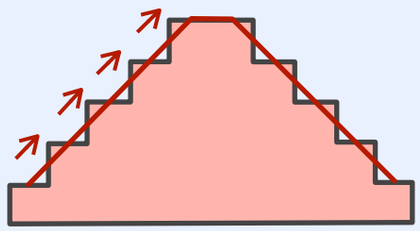

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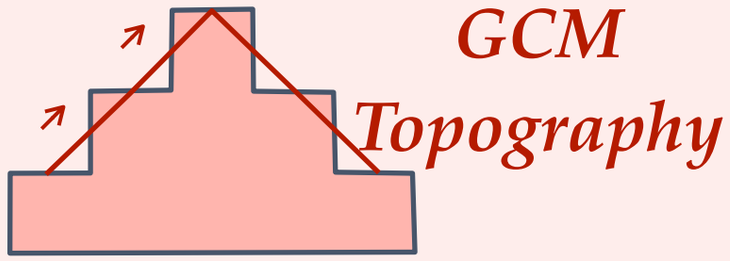

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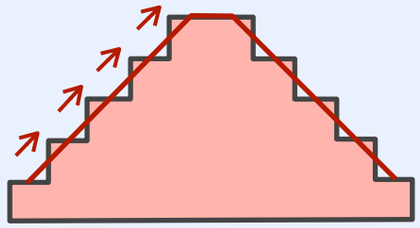

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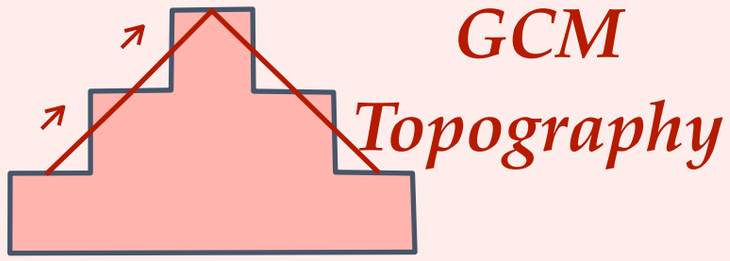

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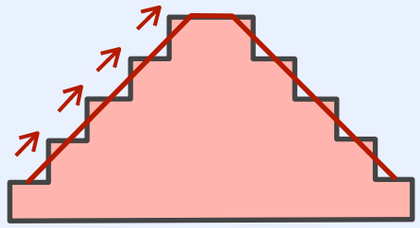

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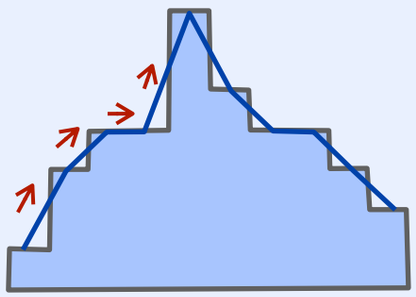

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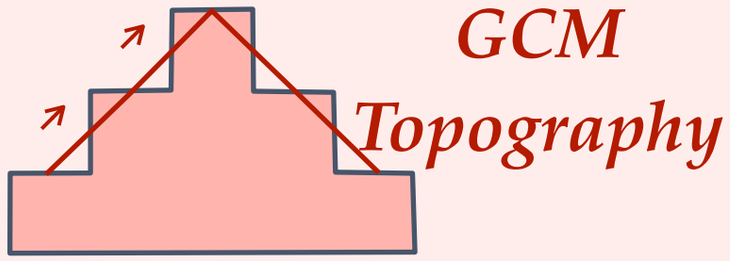

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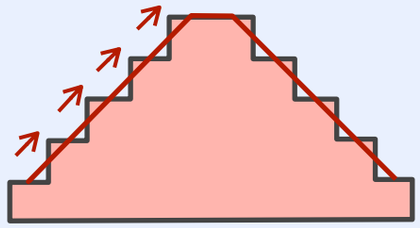

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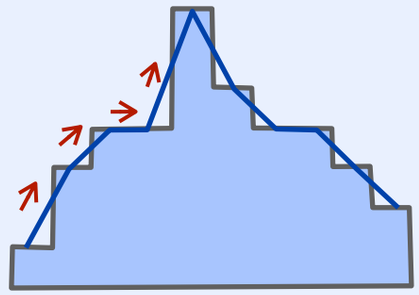

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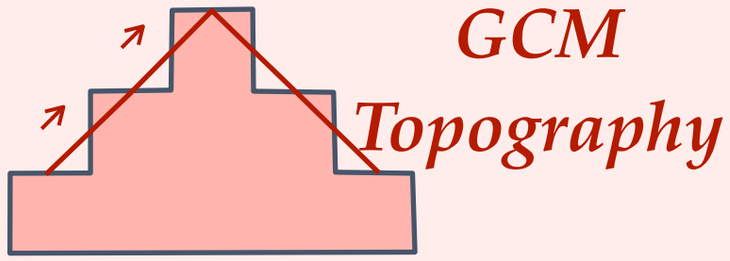

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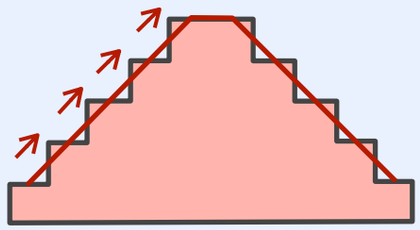

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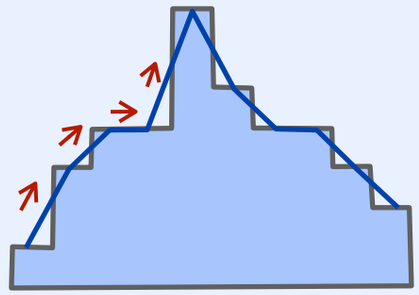

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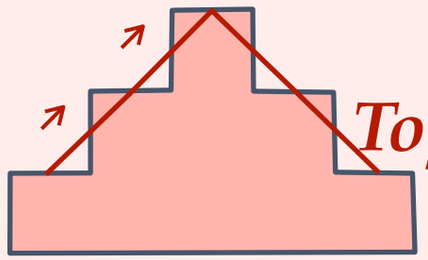

GCM Topography

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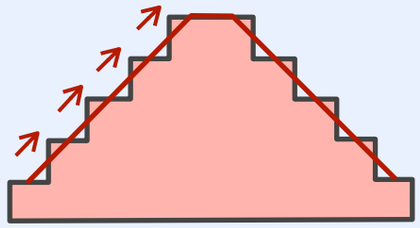
HiDEP Grid (15 km res.)



GCM Interpolated Topography

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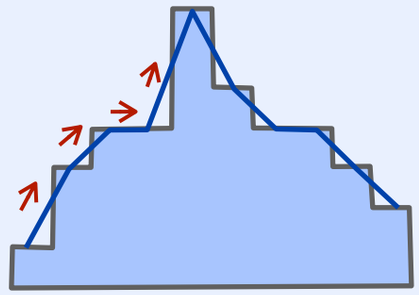


High-res. Topography

High-res. Oro. Precip.

GCM Precipitation

Interpolation

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

Total precipitation : Orographic + Non-Orographic

Low-res. NON-Orographic Precipitation

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

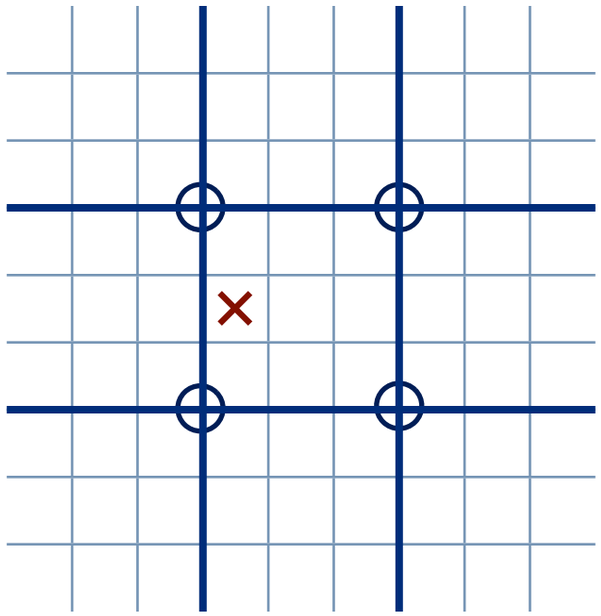
– Low-resolution Orographic Precip.

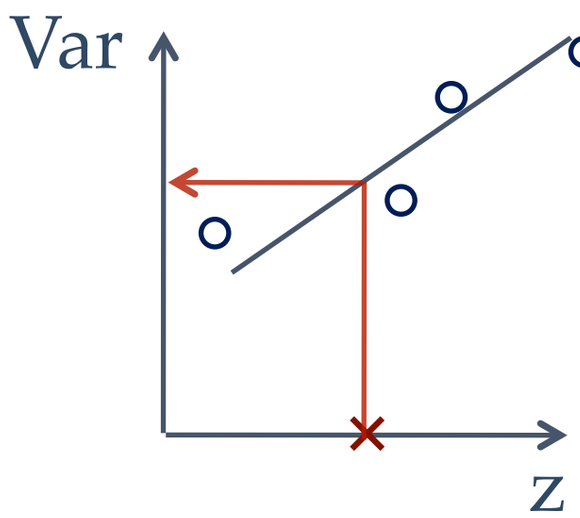
+ High-resolution Orographic Precip.

High-resolution Total Precip.

Surface Energy Balance

Extrapolation of GCM surface fields against the topography





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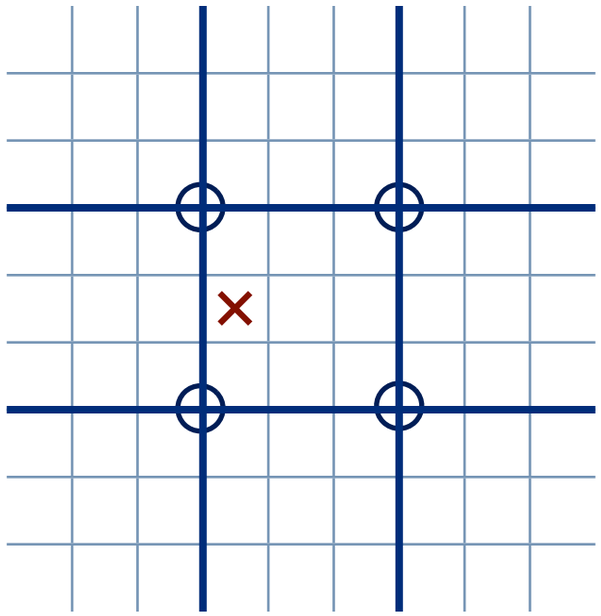
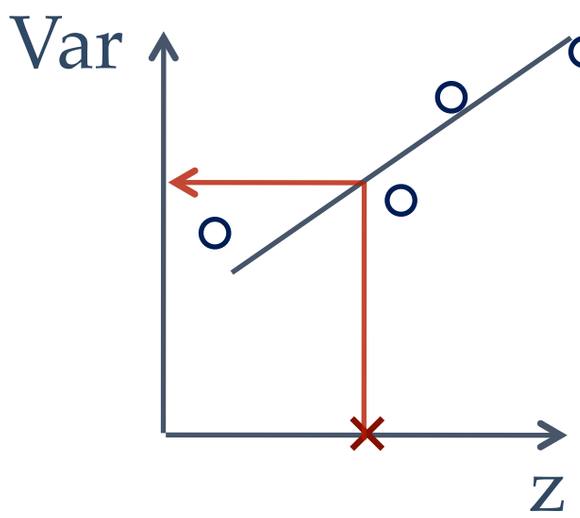
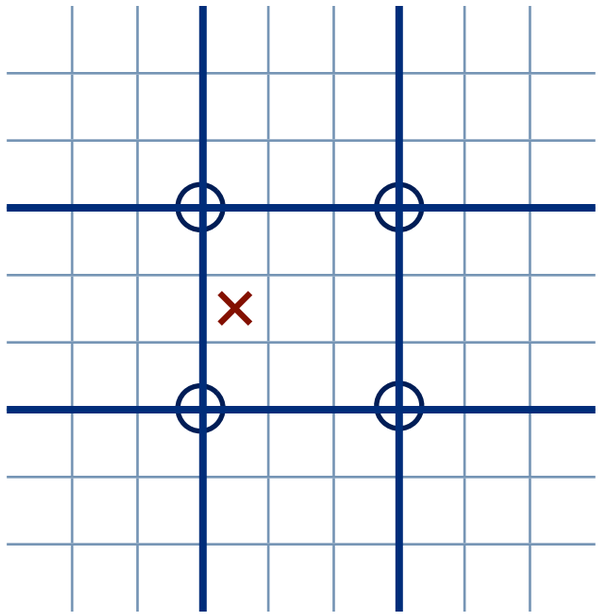


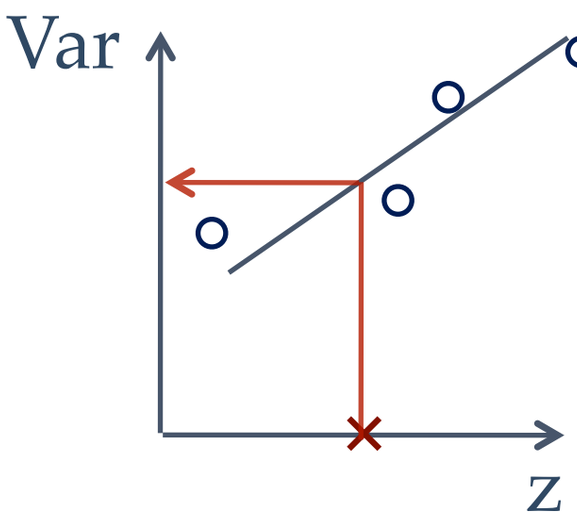


Surface Scheme

Surface Energy Balance

Extrapolation of GCM surface fields against the topography





Surface Scheme

↓

Sublimation

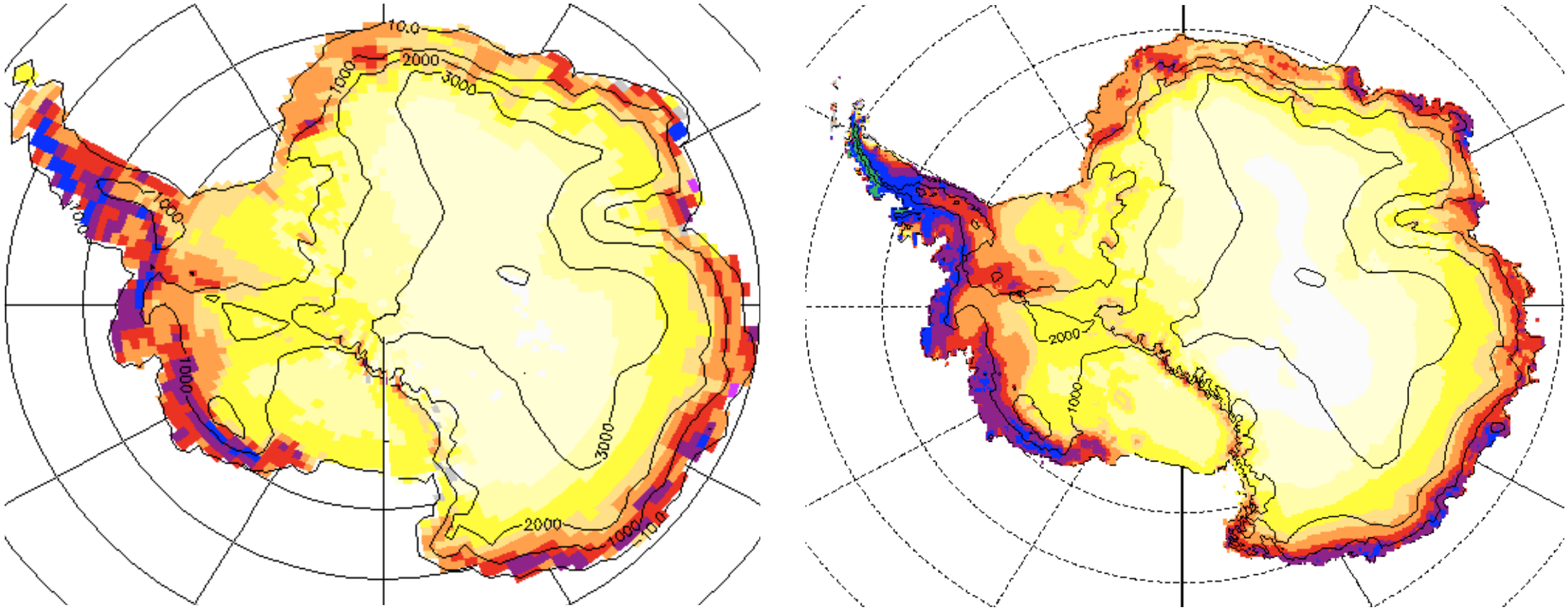
Melting

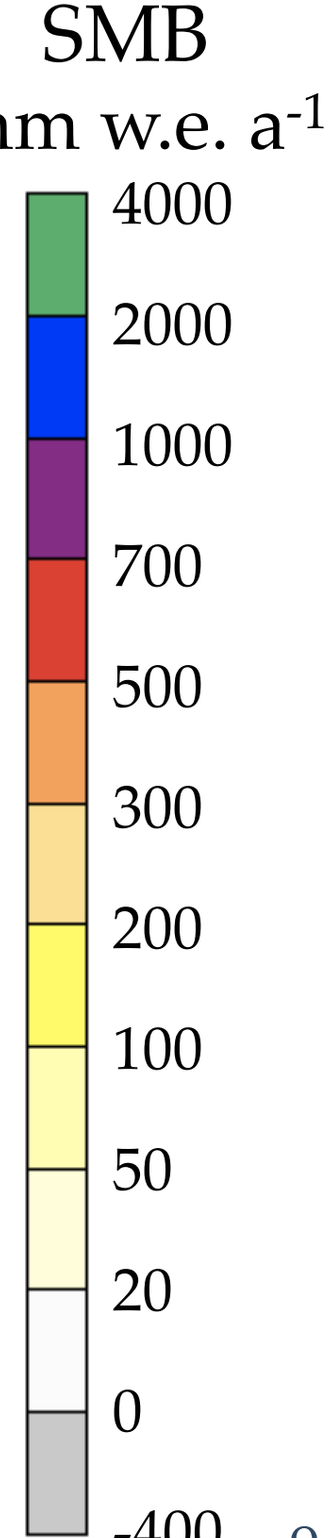
Refreezing

Application to LMDZ4 : 1980-2007

LMDZ4

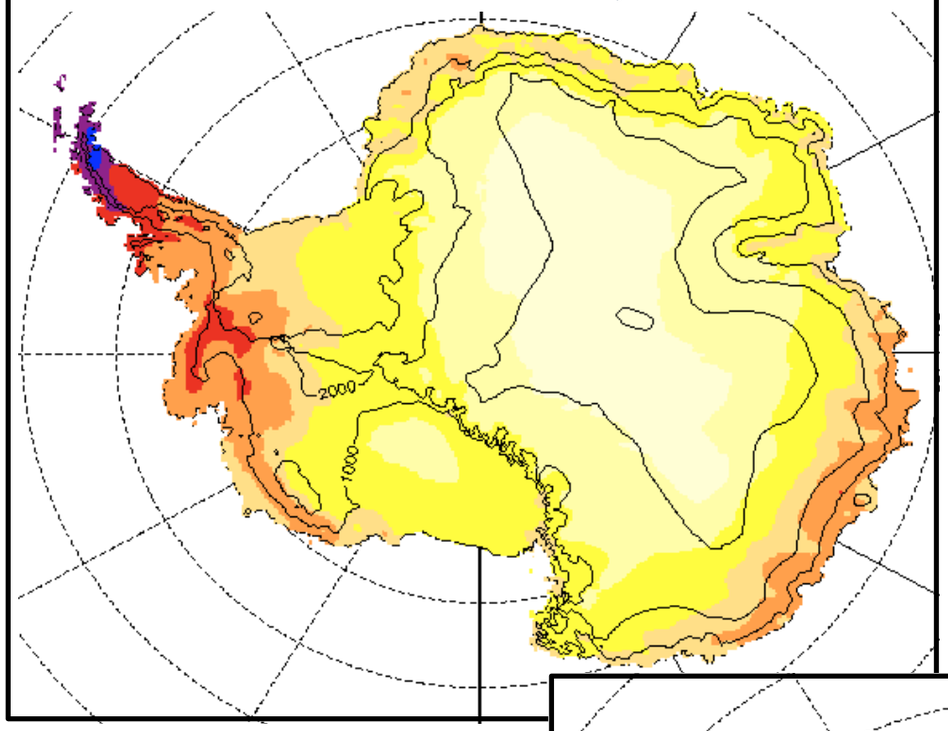
HiDEP-LMDZ4





Application to LMDZ4 : 1980-2007

Arthern et al, 2006



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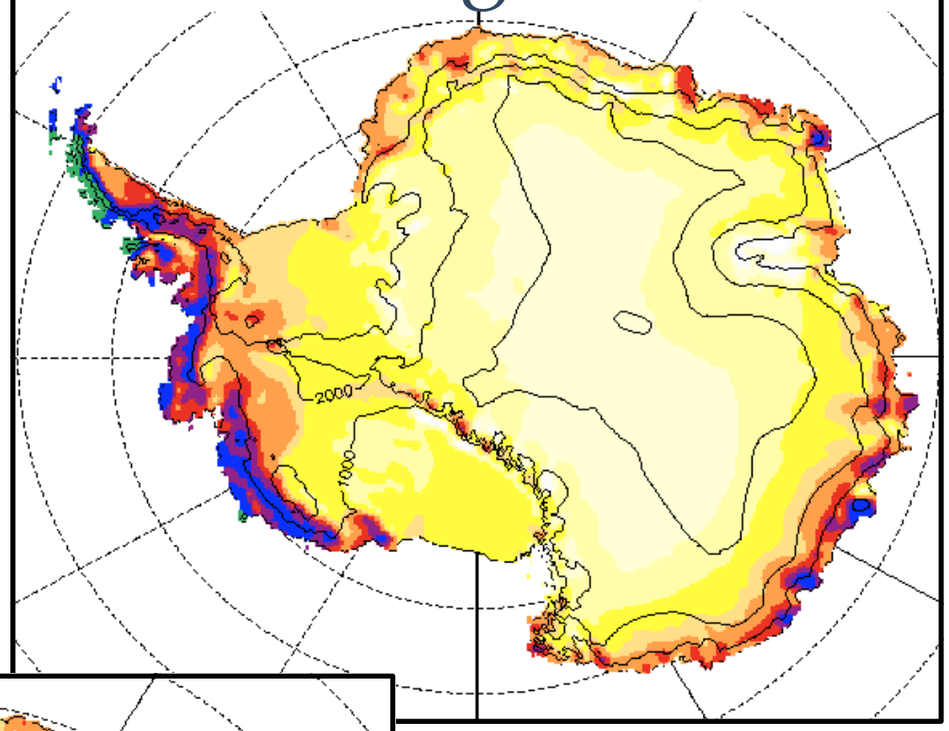
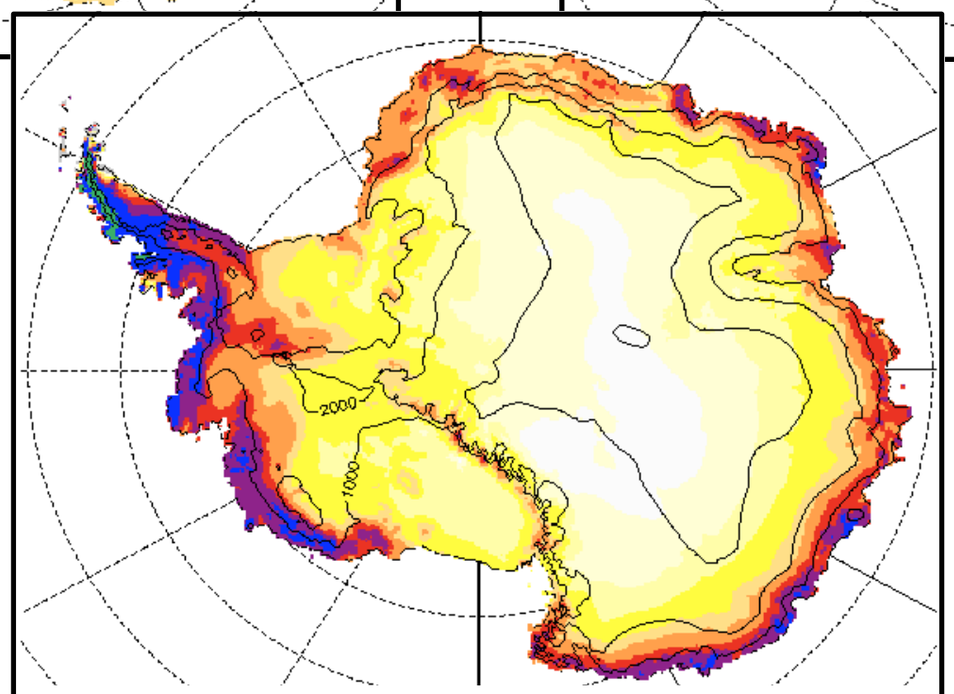
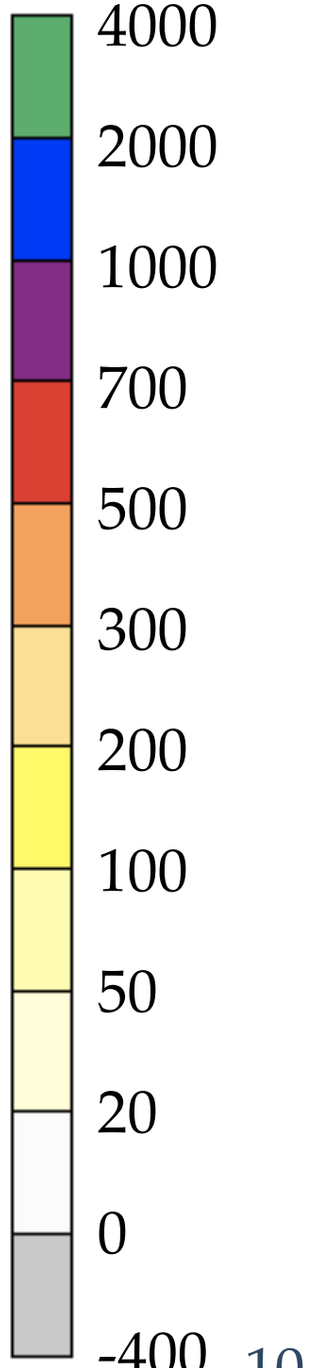


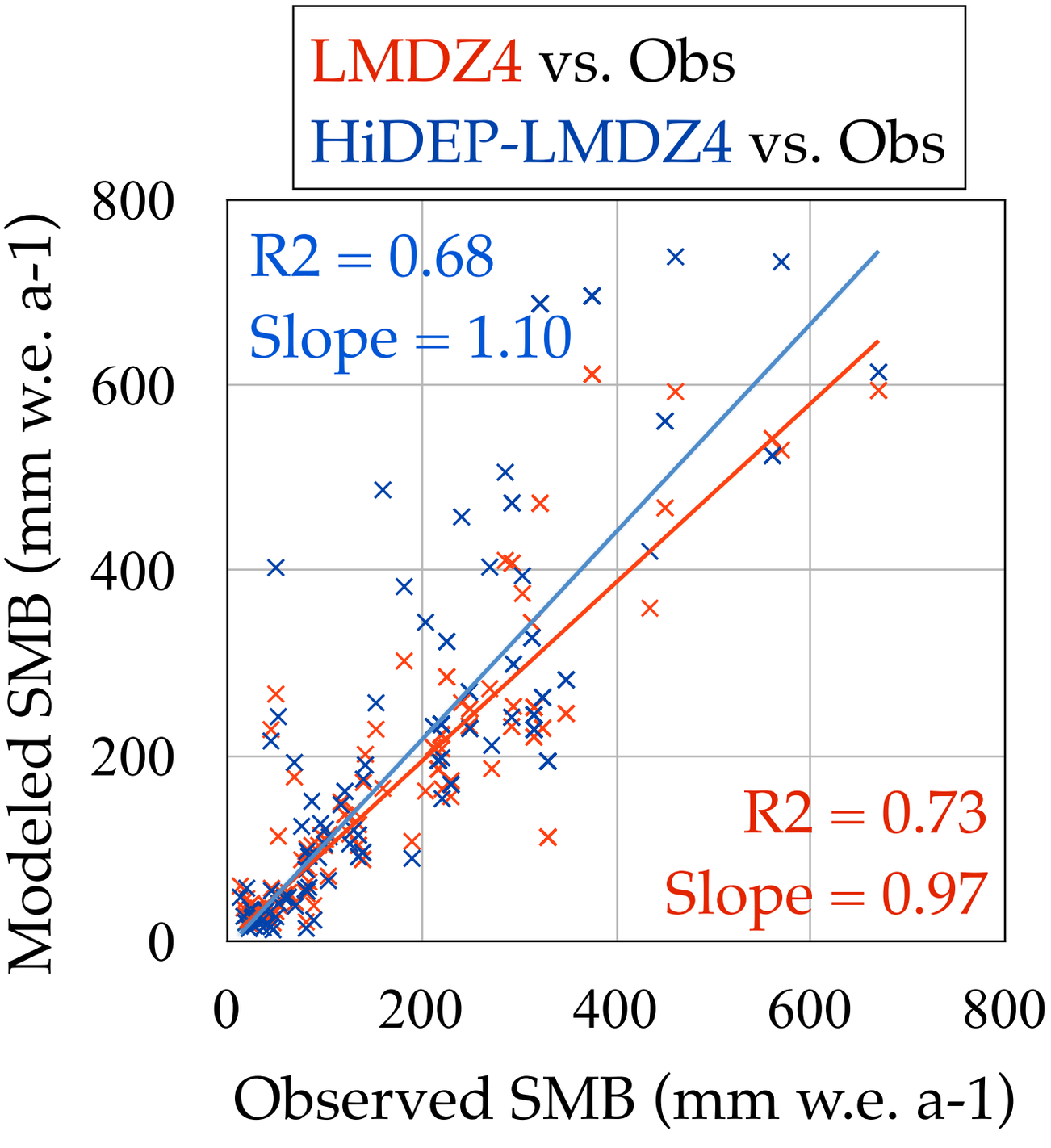
HiDEP-LMDZ4

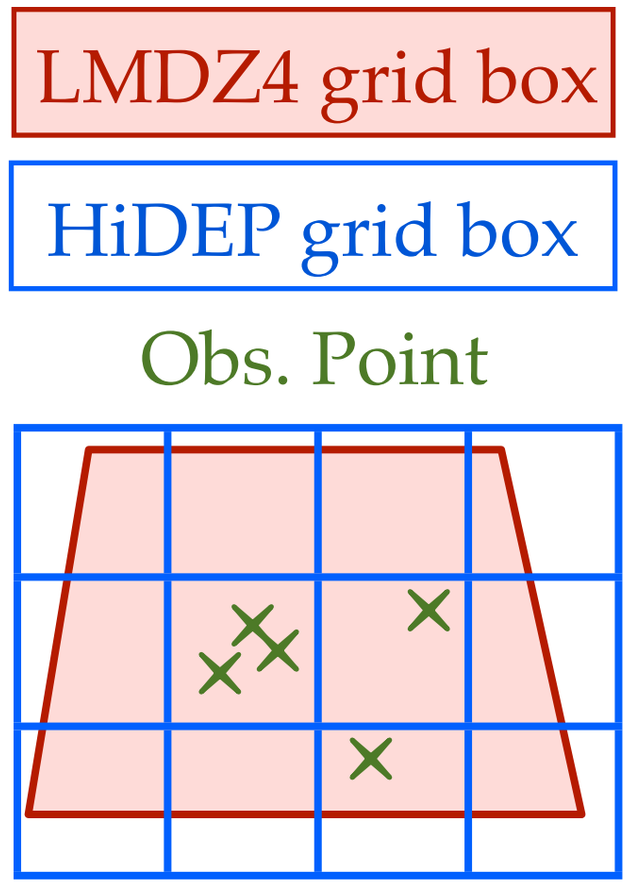


SMB
mm w.e. a^{-1}



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

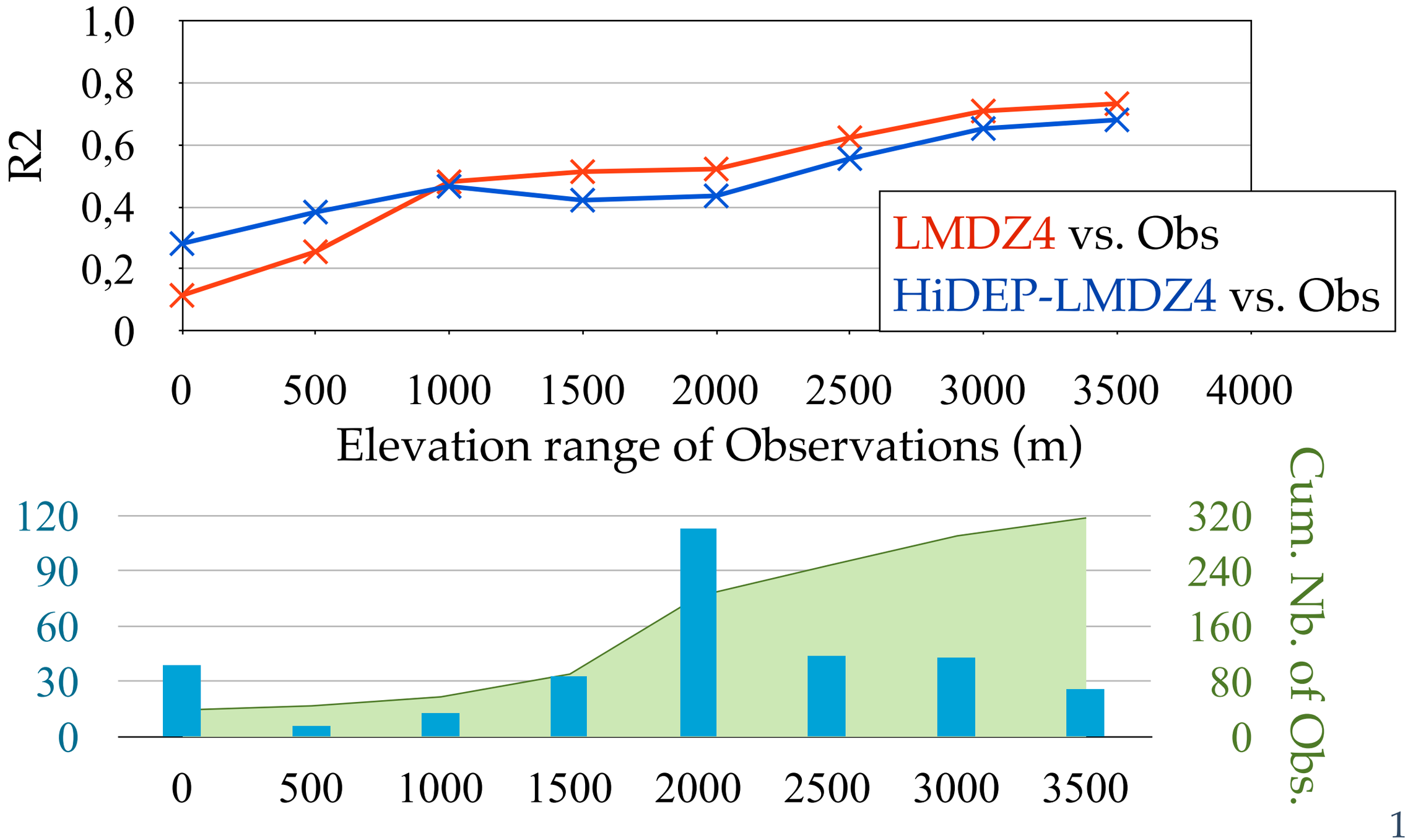




Average :
in each LMDZ4 Box
1 Obs ↔1 HiDEP Box

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



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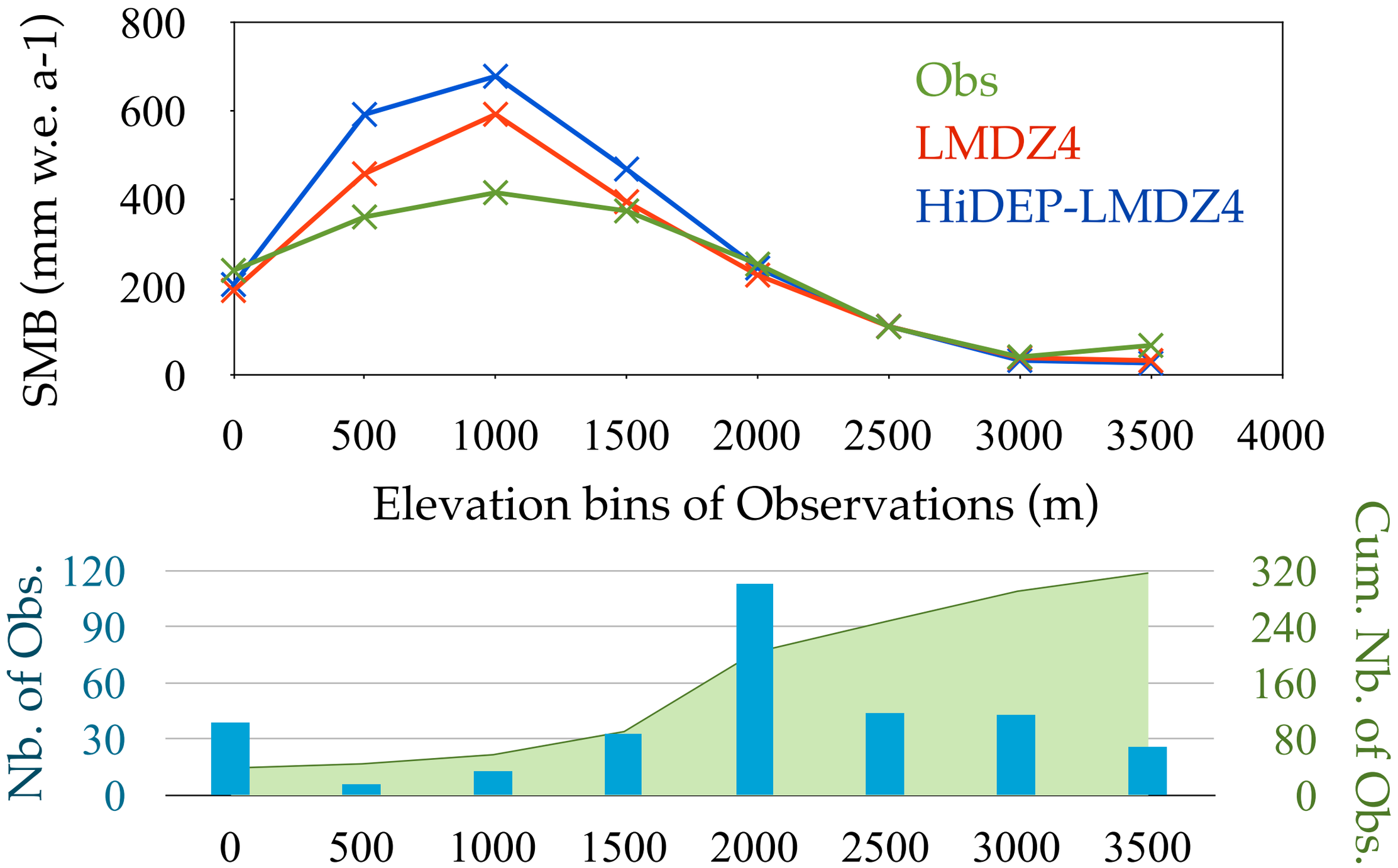

Validation with a quality-controlled SMB data-set (Magand et al., 2007)

Extension of the data quality-control to the rest of Antarctica : Work in progress at LGGE

For further information, you can contact Soazig Parouty

Grounded SMB 1980-2007

LMDZ4 P-E

175.2 mm a^{-1} = kg m^{-2} a^{-1}

⇔ 2159 Gt a^{-1}

⇔ 6.0 mm a^{-1} sea level equivalent

HiDEP-LMDZ4 SMB

208 mm a^{-1} = kg m^{-2} a^{-1}

⇔ 2410 Gt a^{-1}

⇔ 6.7 mm a^{-1} sea level equivalent

Present SMB (1950-2000) :

- Range : 1475 à 2331 Gt a^{-1} [Monaghan et al., 2006]

Conclusion

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

  Partial validation for present :

  - Downscaled SMB close to LMDZ4 SMB performance
  - Increase the wet bias of LMDZ4 in coastal areas

BUT lack of field data in (crucial) coastal areas

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Runing :

- HiDEP-LMDZ4 for :

Just Finished

		Scenario	
		A1B	E1
LMDZ4 Boundary Conditions	HadCM3	**21C**	21C & 22C
	ECHAM5	21C	21C

Outlook

Further validation :

- Extended quality-controlled data set over all Antarctica
- Coastal-to-plateau transects

Model development in progress :

- MAR Surface Scheme
- Humidity advection


Thank you
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Validation with a quality-controlled SMB data-set (Magand et al., 2007)

Quality criteria defined of the basis of :

1 - Essential information available : location, time period, method

2 - Quality rating of SMB measurement methods

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Applied to the **90° – 180°E Antarctic sector** :

Review of references compiled by Vaughan and Russell (1997)

+ New results from recent field campaigns

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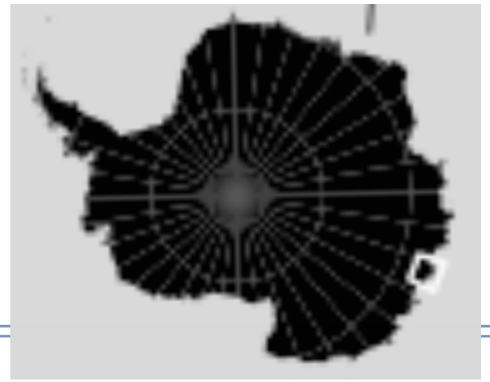
+ New results from recent field campaigns

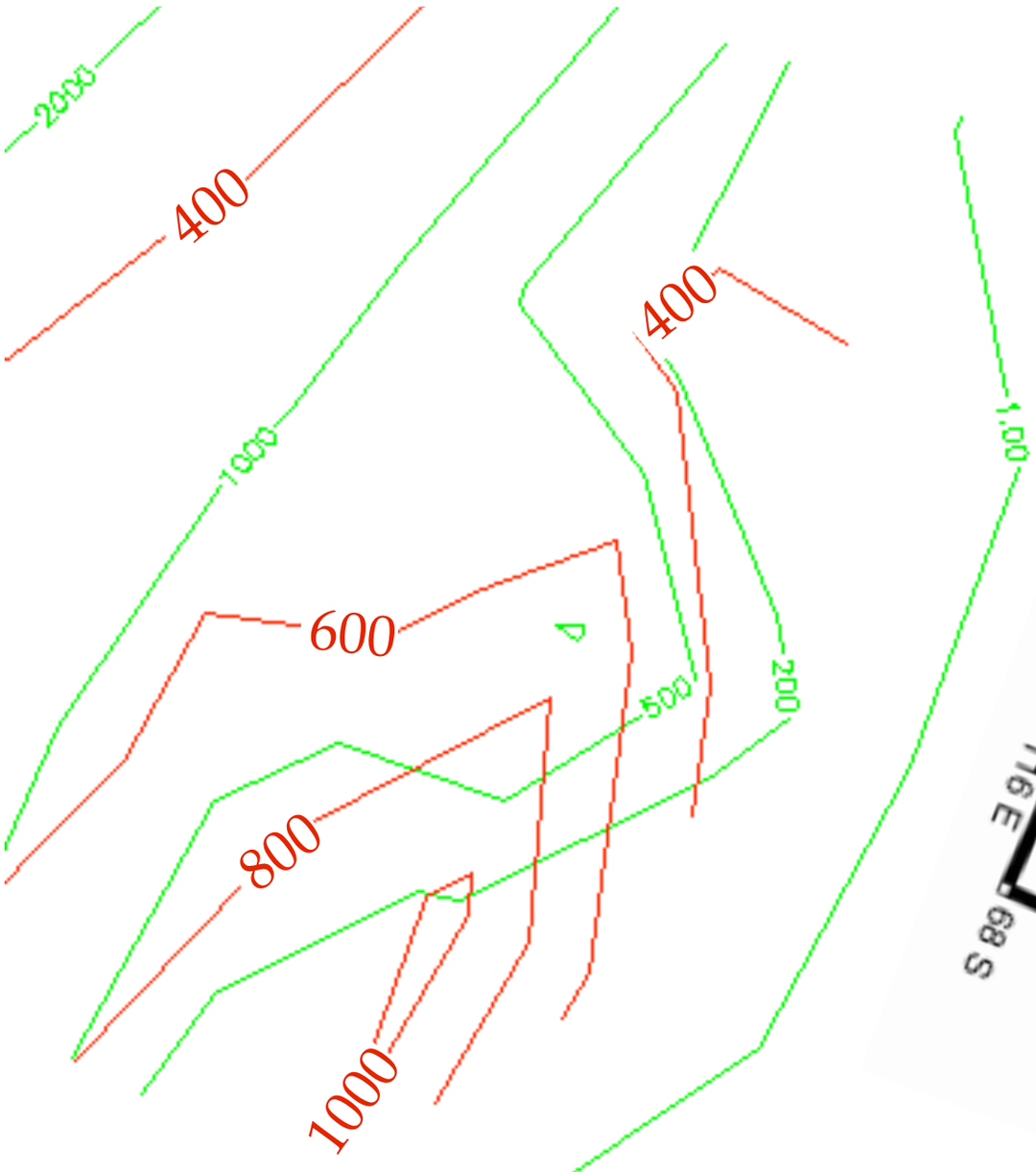
➜ Quality-controlled data set for the **1950–2005 time period**

- Reduction in density and coverage
- BUT reduced uncertainties compared to other compilations

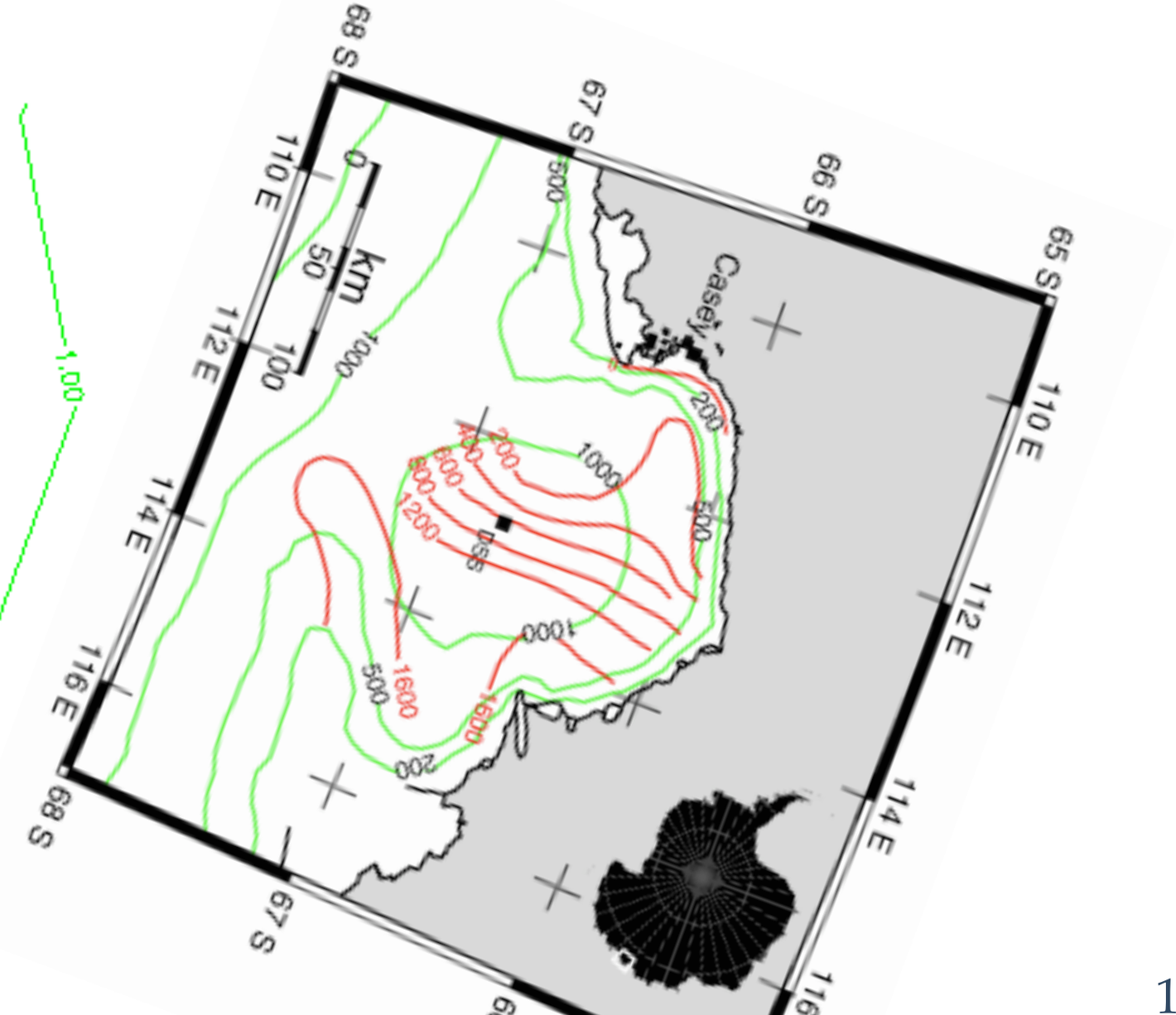
Law Dome



LMDZ4
SMB 1980-2007



Climatologie SMB
van Ommen et al., 2004



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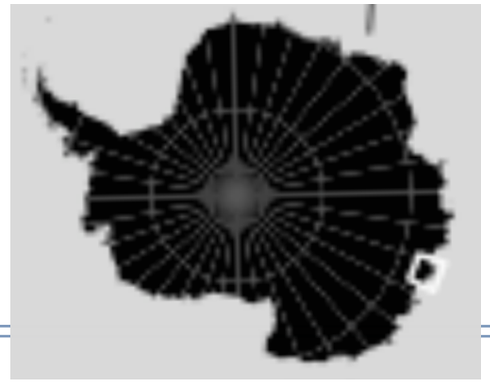
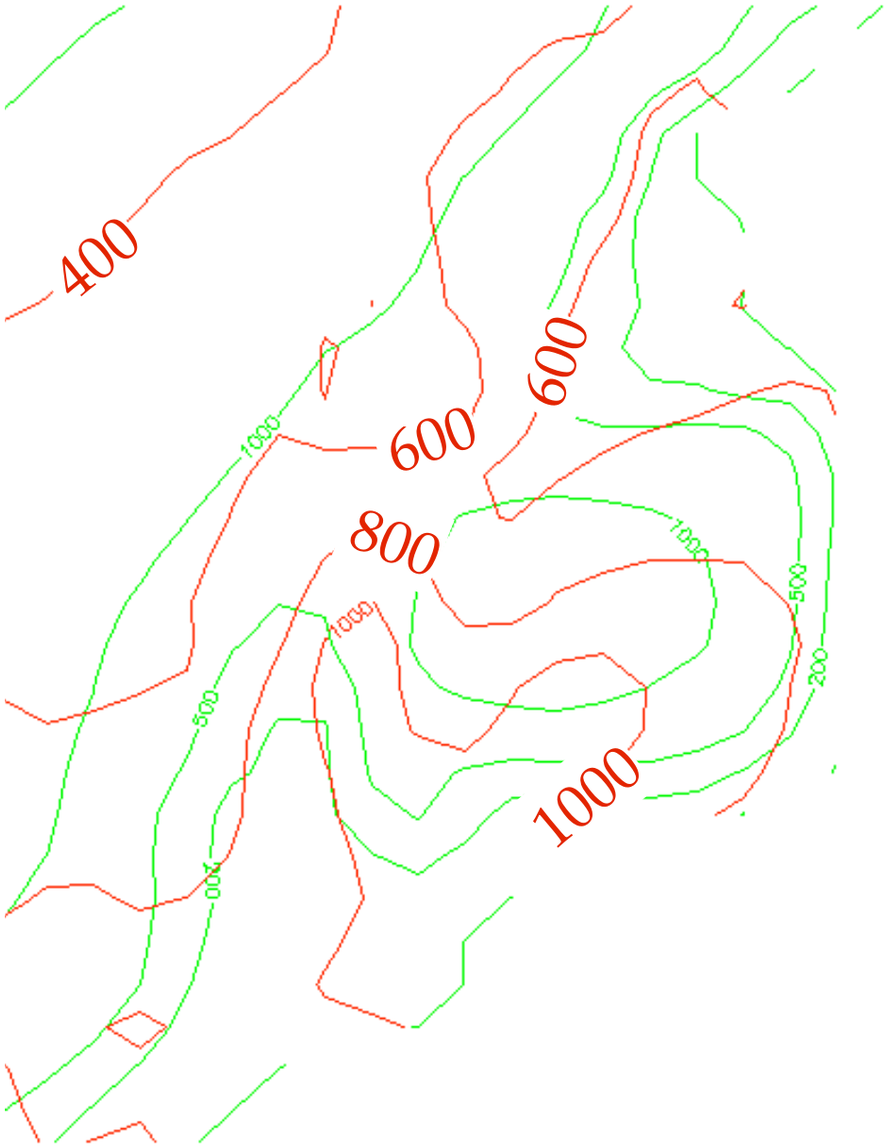
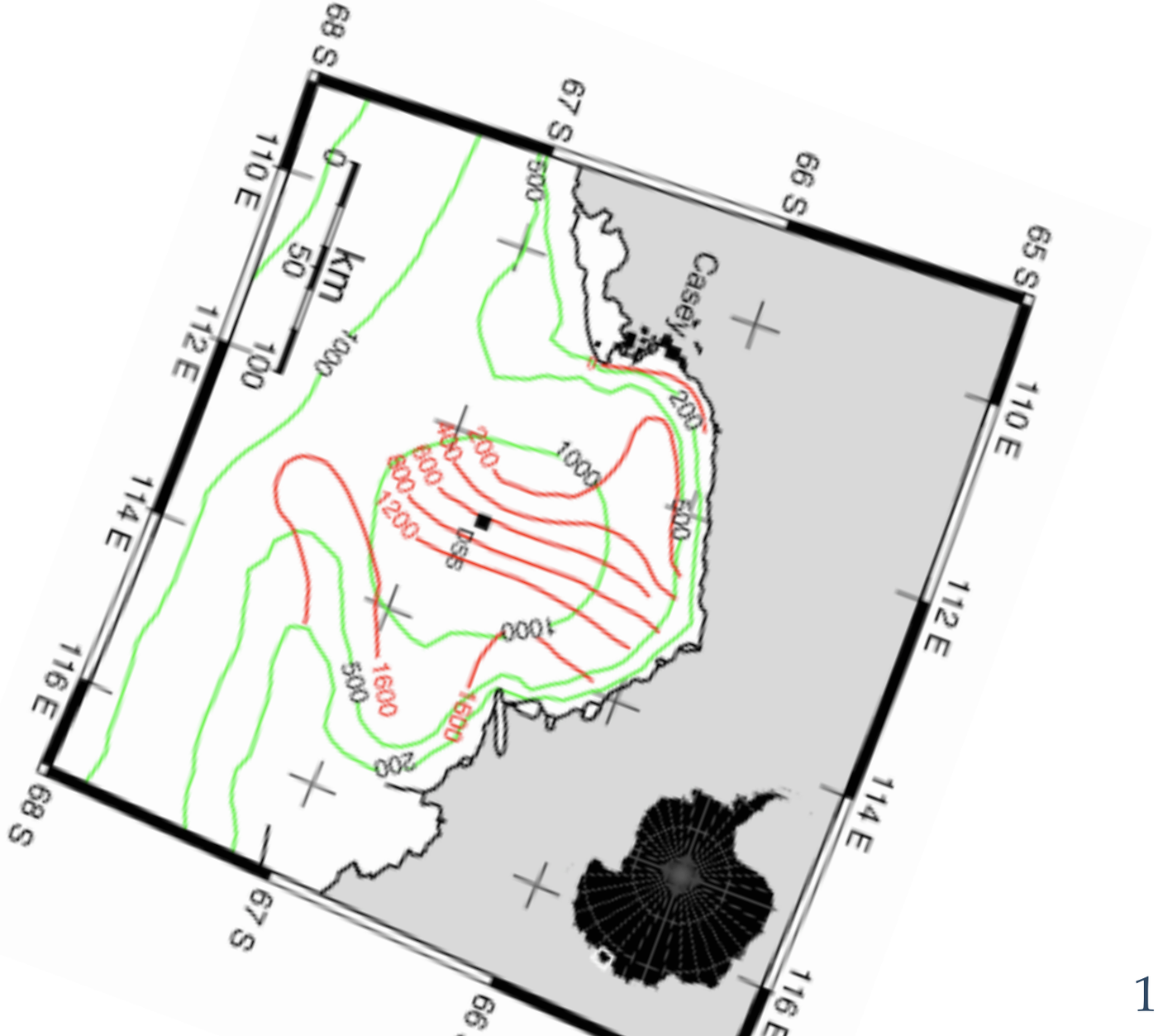


HiDEP-LMDZ4
SMB 1980-2007

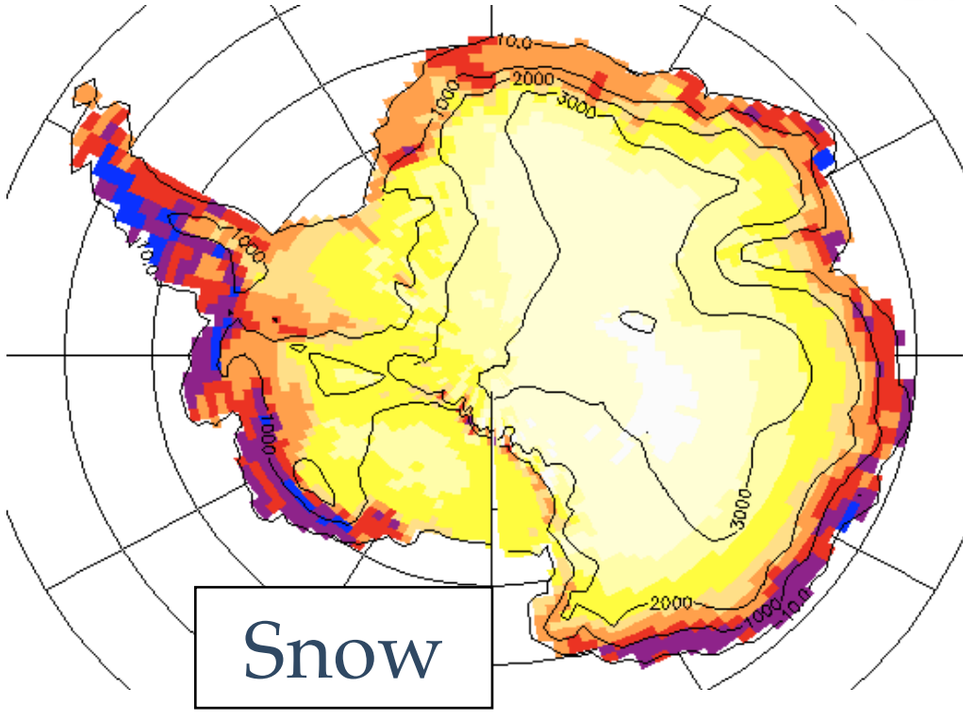


Climatologie SMB
van Ommen et al., 2004

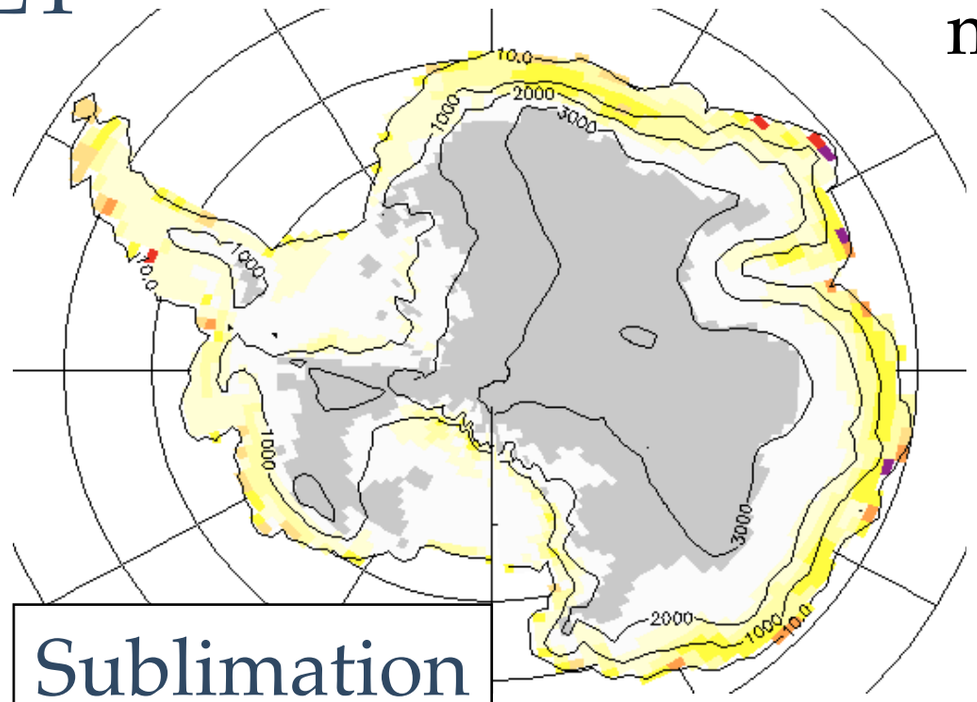


Application to LMDZ4 : 1980-2007

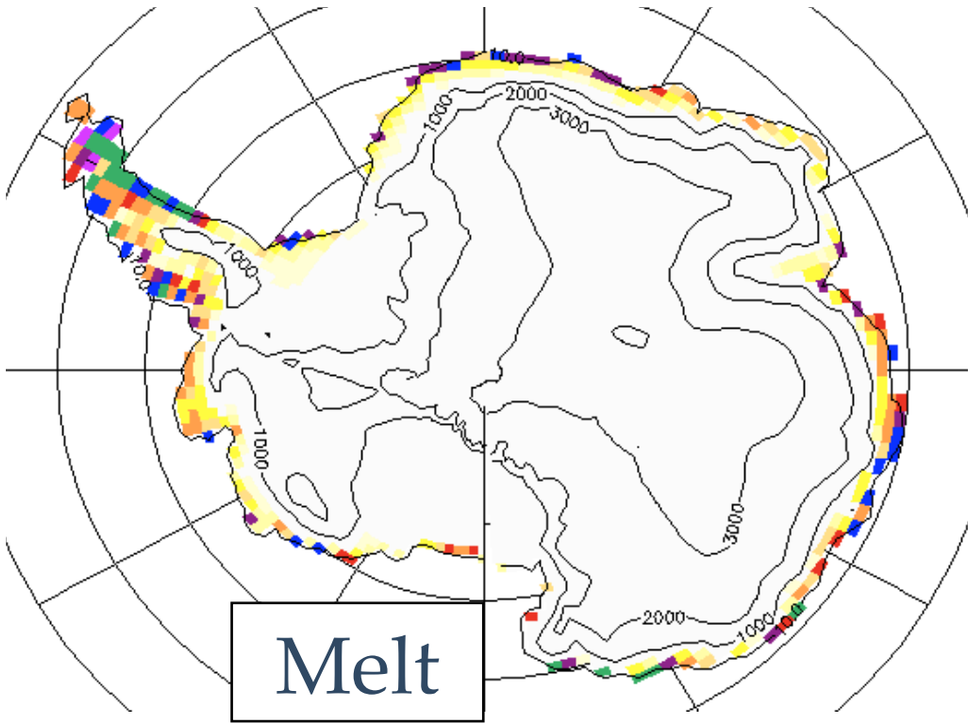
LMDZ4



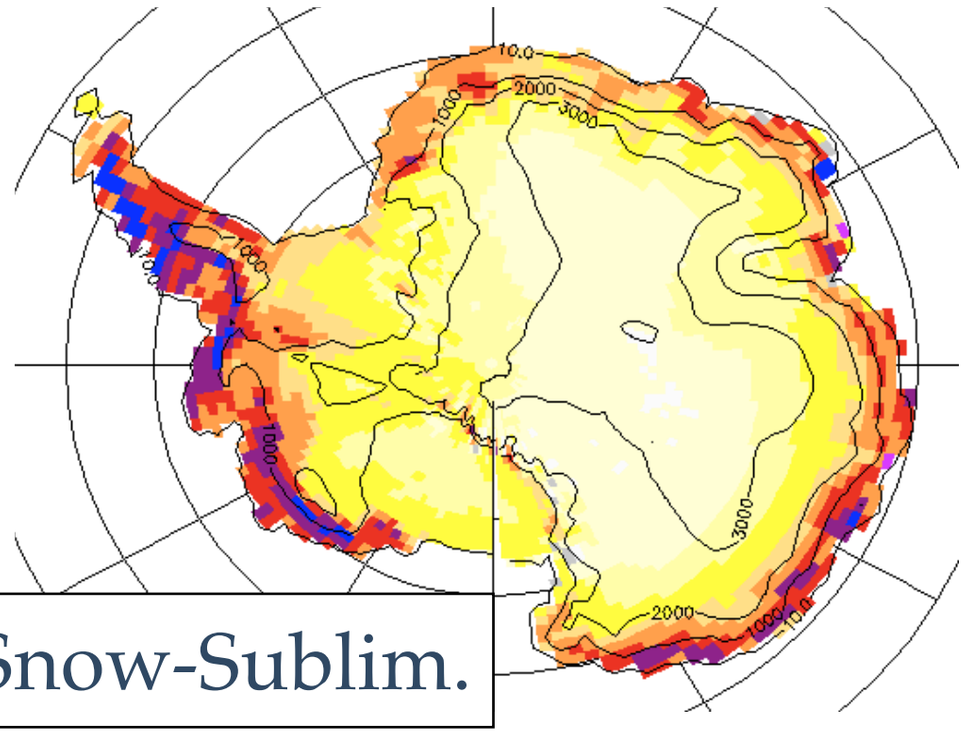
Snow



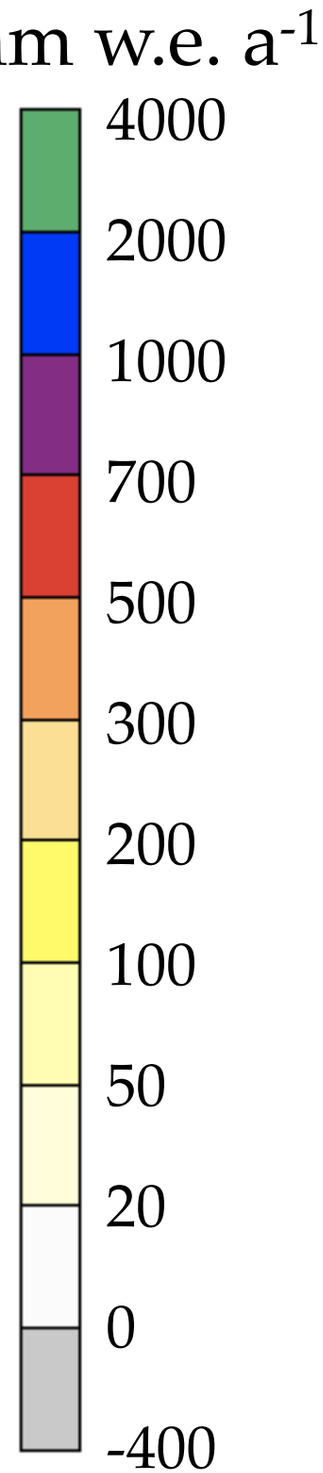
Sublimation



Melt

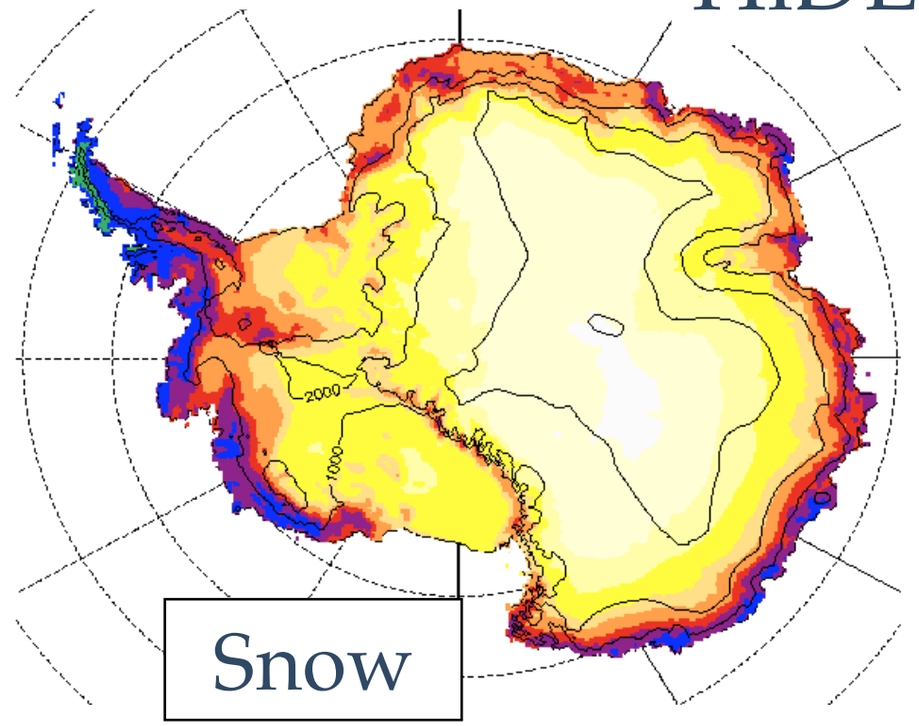


Snow-Sublim.

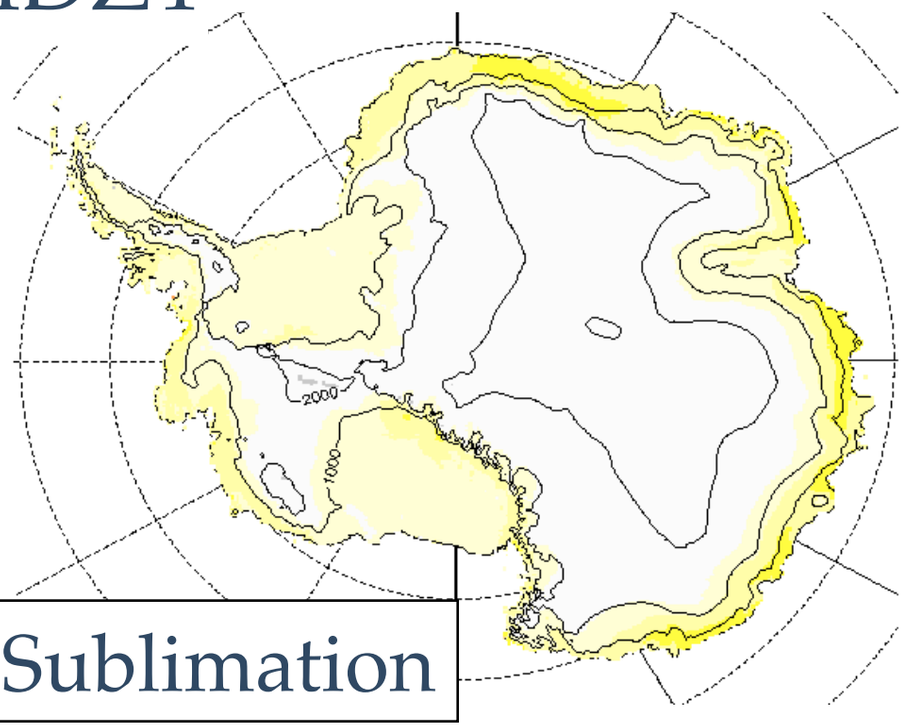


Application to LMDZ4 : 1980-2007

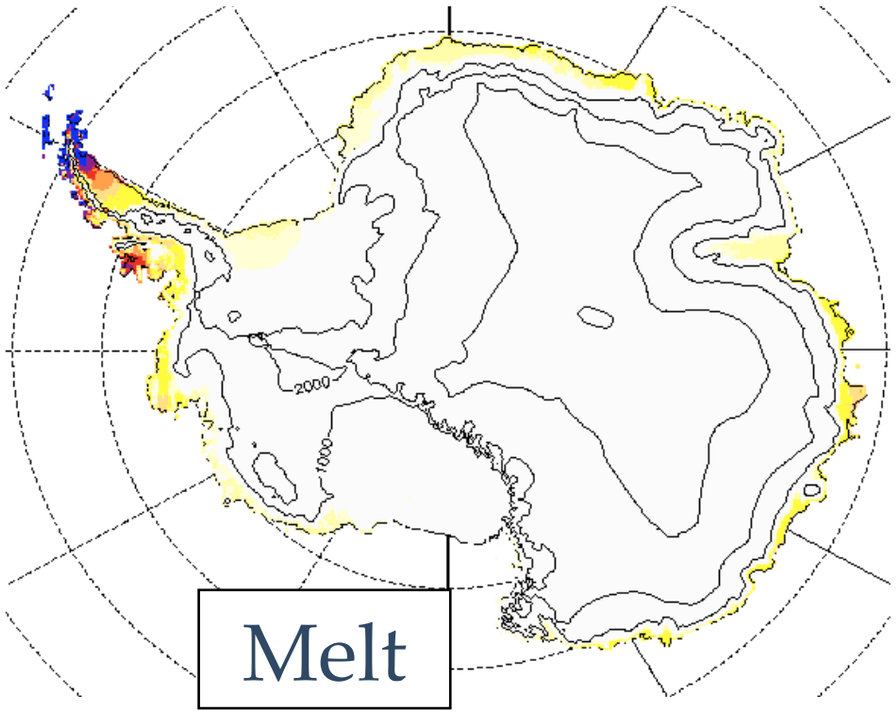
HiDEP-LMDZ4



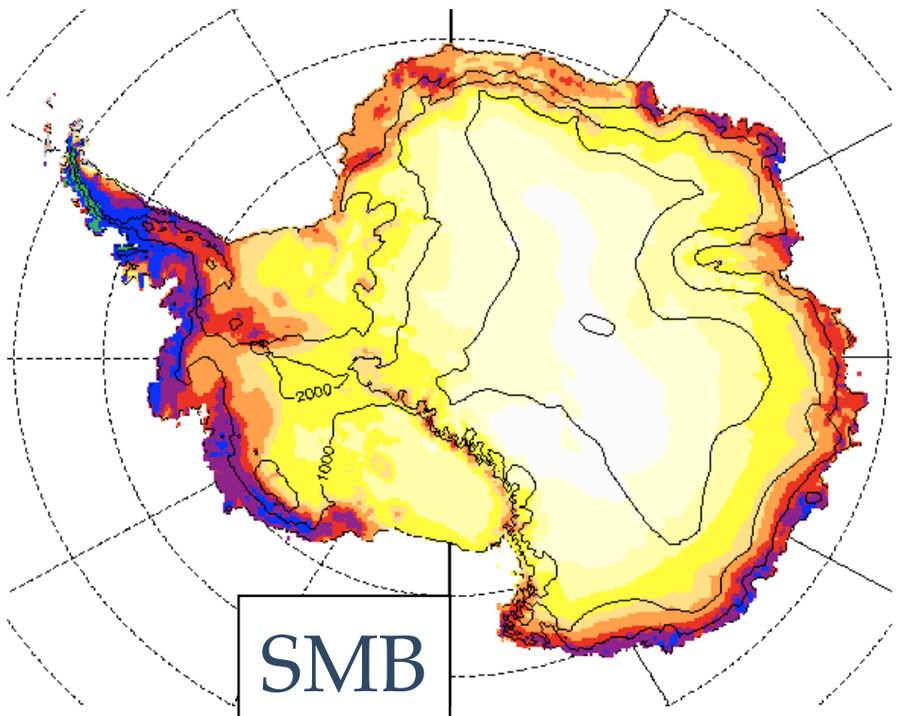
Snow



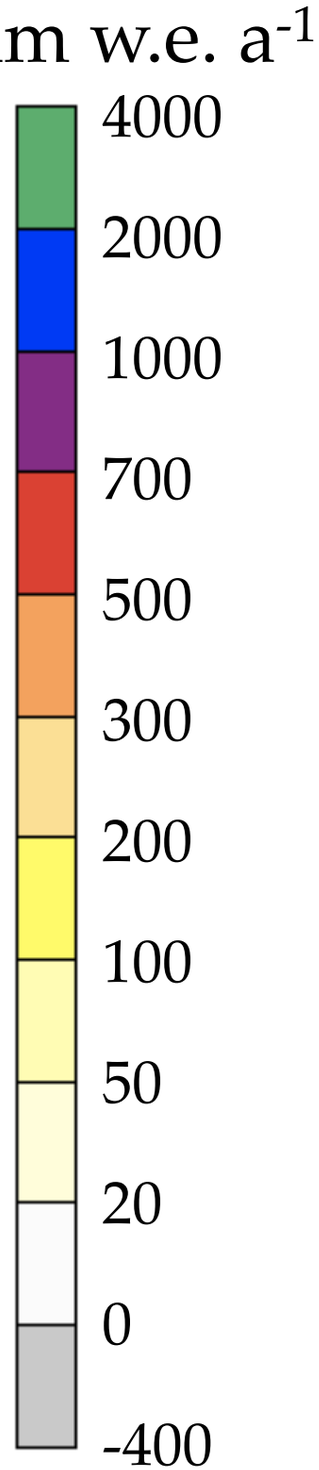
Sublimation



Melt



SMB



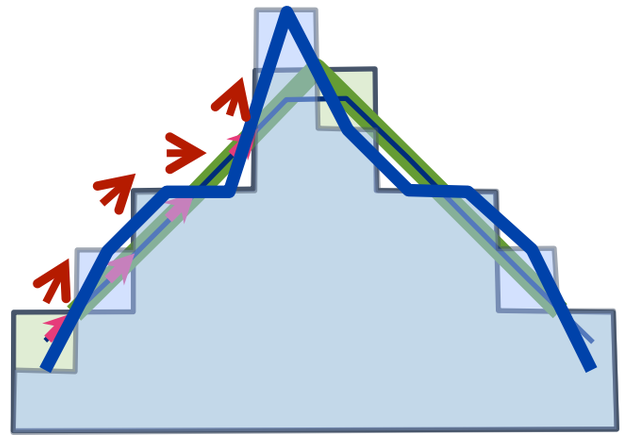
Désagrégateur de précipitation
Limites du désagrégateur de précipitation

Pas de dynamique (coûteux en temps de calculs)

- Pas de rétro-action de la physique sur la dynamique
- Pas de contournement du relief
- Pas d'effet de blocage

Orographic precipitation : Determination of the vertical wind W

Momentum equation
+ Continuity equation
+ Thermal dynamic equation
+ Steady adiabatic, inviscid, no-rotating flow



+ Hypothesis to simplify and linearize the equations :
  - Small perturbations around the hydrostatic equilibrium
  - Horizontal wind >> Vertical wind
  - Mean values slowly varying horizontally
  - 2D
  - Scorer parameter $l(z)=f(T(z),P(z))$ slowly varying

➔ Wave equation on W (Mountain gravity wave) : W_G