Antarctic precipitation in the LMDz and MAR climate models : comparison to CloudSat retrievals and improvement of cold microphysical processes

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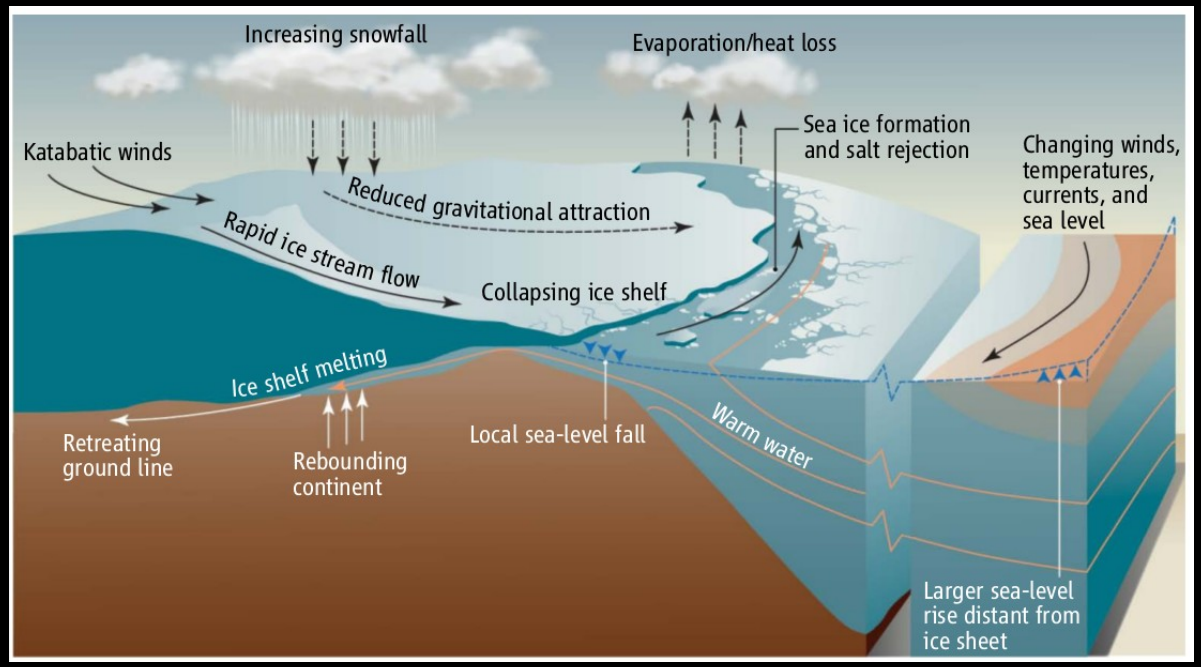
[3] With special thanks to A. Idelkadi, L. Mellul, L. Fita, J.-Y. Grandpeix, I. Musat, F. Hourdin, C. Rio

APRES3 project, french National Research Agency*
**Antarctic Precipitation, REmote Sensing from Surface and Space*

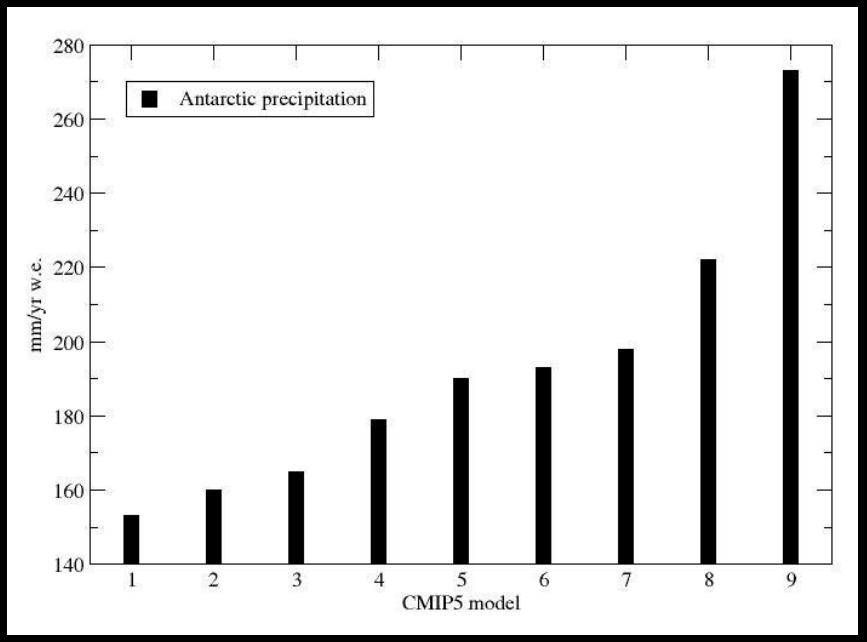
Role of precipitation in Antarctica

$$\Delta M_{T_0}^{T} = \int_{T_0}^{T} \mathrm{SMB}\, dt - \int_{T_0}^{T} D\, dt \text{ , where } \mathrm{SMB} = P - \mathrm{SU} - \mathrm{ER} - \mathrm{RU}$$

Total mass change (ΔM), surface mass balance (SMB), ice discharge (D), precipitation (P), sublimation (SU), drifting snow erosion (ER), and meltwater runoff (RU)



[Willis & Church, 2012]



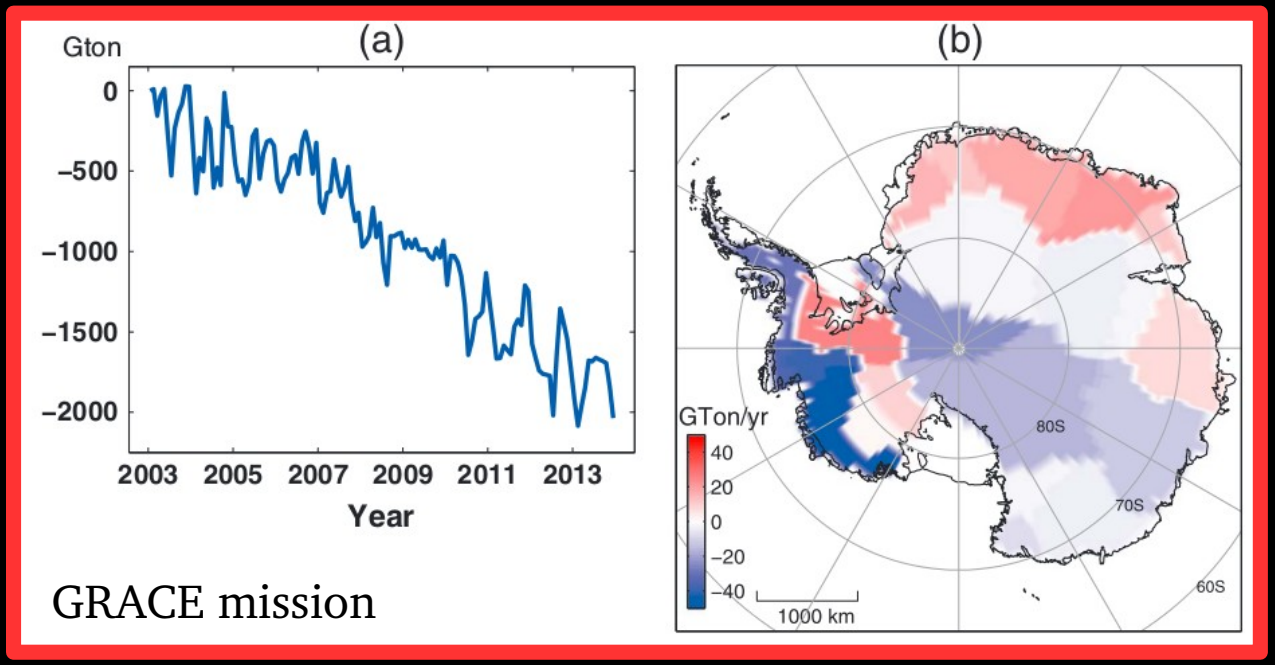
[adapted from Palerme et al., 2014]

Recent mass changes

$$\Delta M_{T_0}^{T} = \int_{T_0}^{T} \mathrm{SMB}\, dt - \int_{T_0}^{T} D\, dt \text{ , where } \mathrm{SMB} = P - \mathrm{SU} - \mathrm{ER} - \mathrm{RU}$$

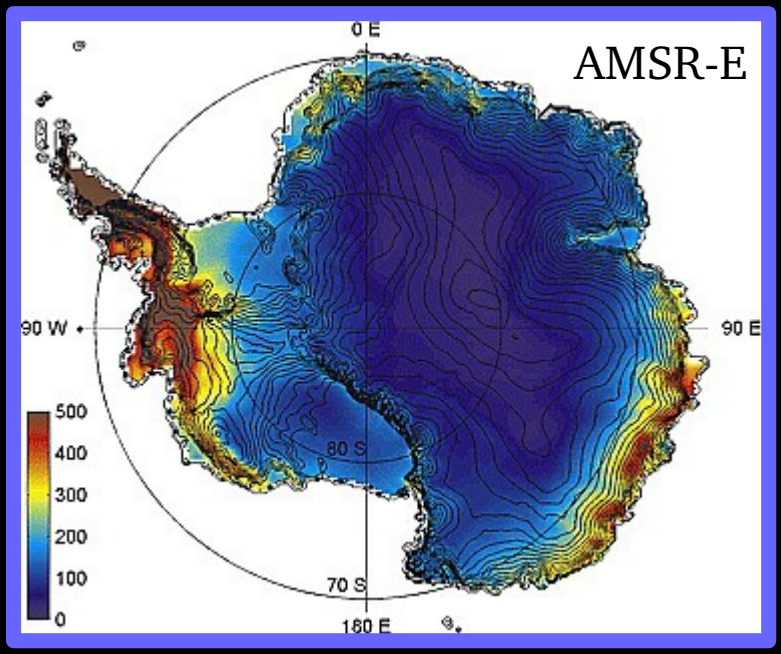
? → **APRES3 project**

Total mass change (ΔM), surface mass balance (SMB), precipitation (P)



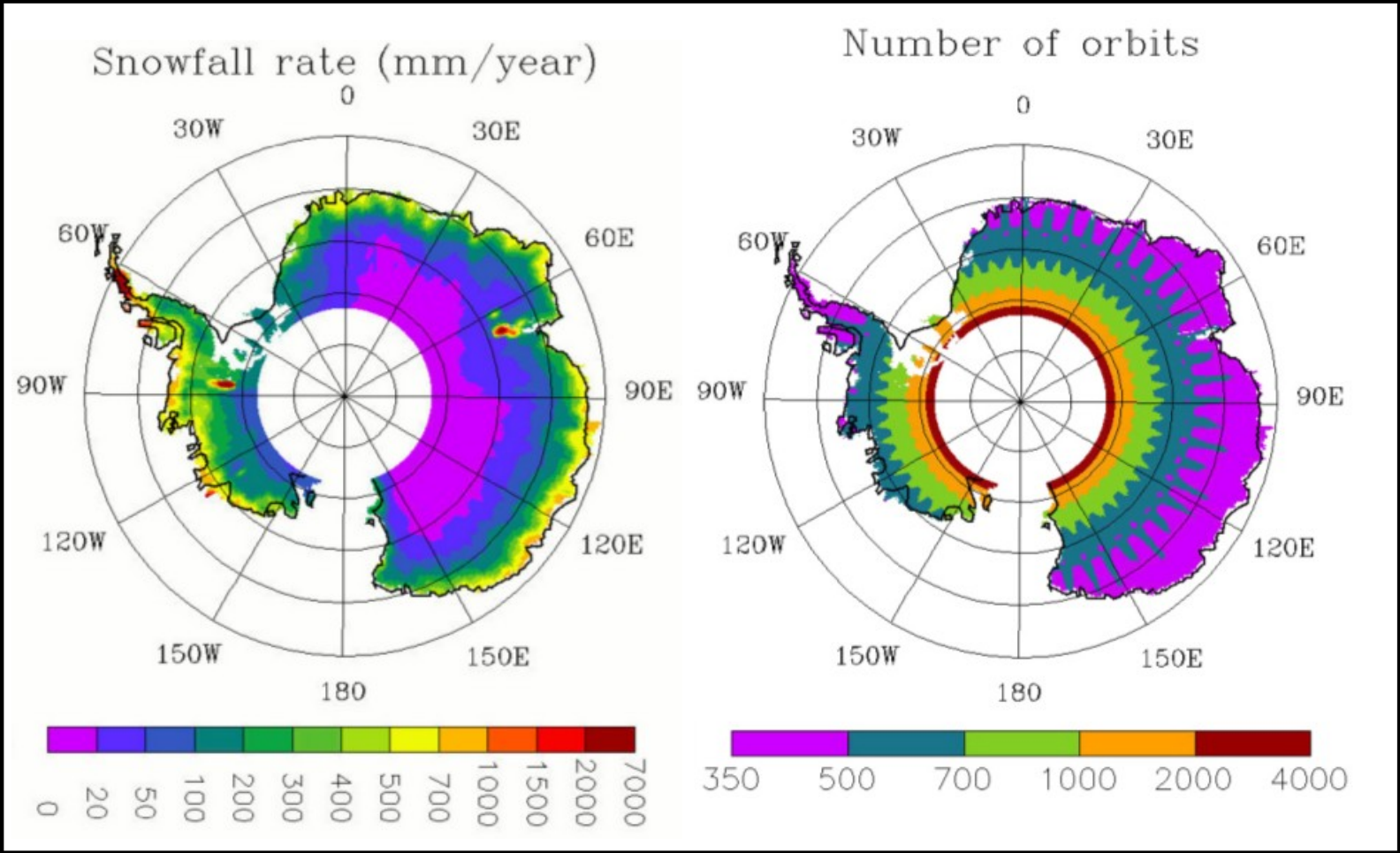
GRACE mission

Mean mass balance in GTon/yr [Seo et al., 2015]

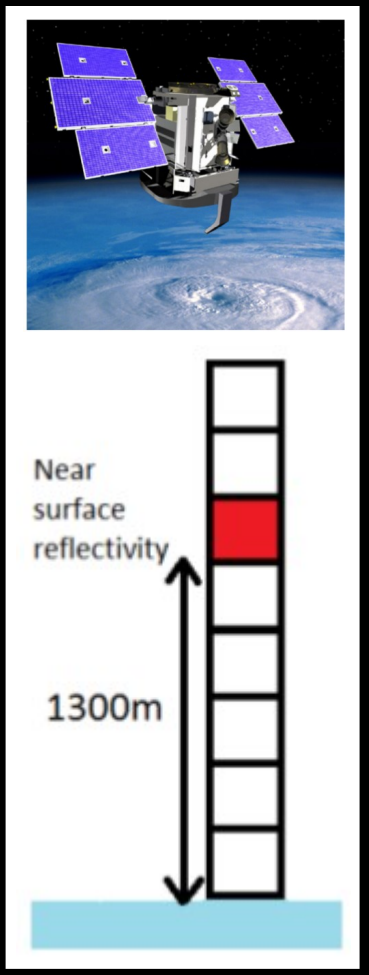


Snow accumulation in mm/yr [Arthern et al., 2006]

CloudSat CPR precipitation

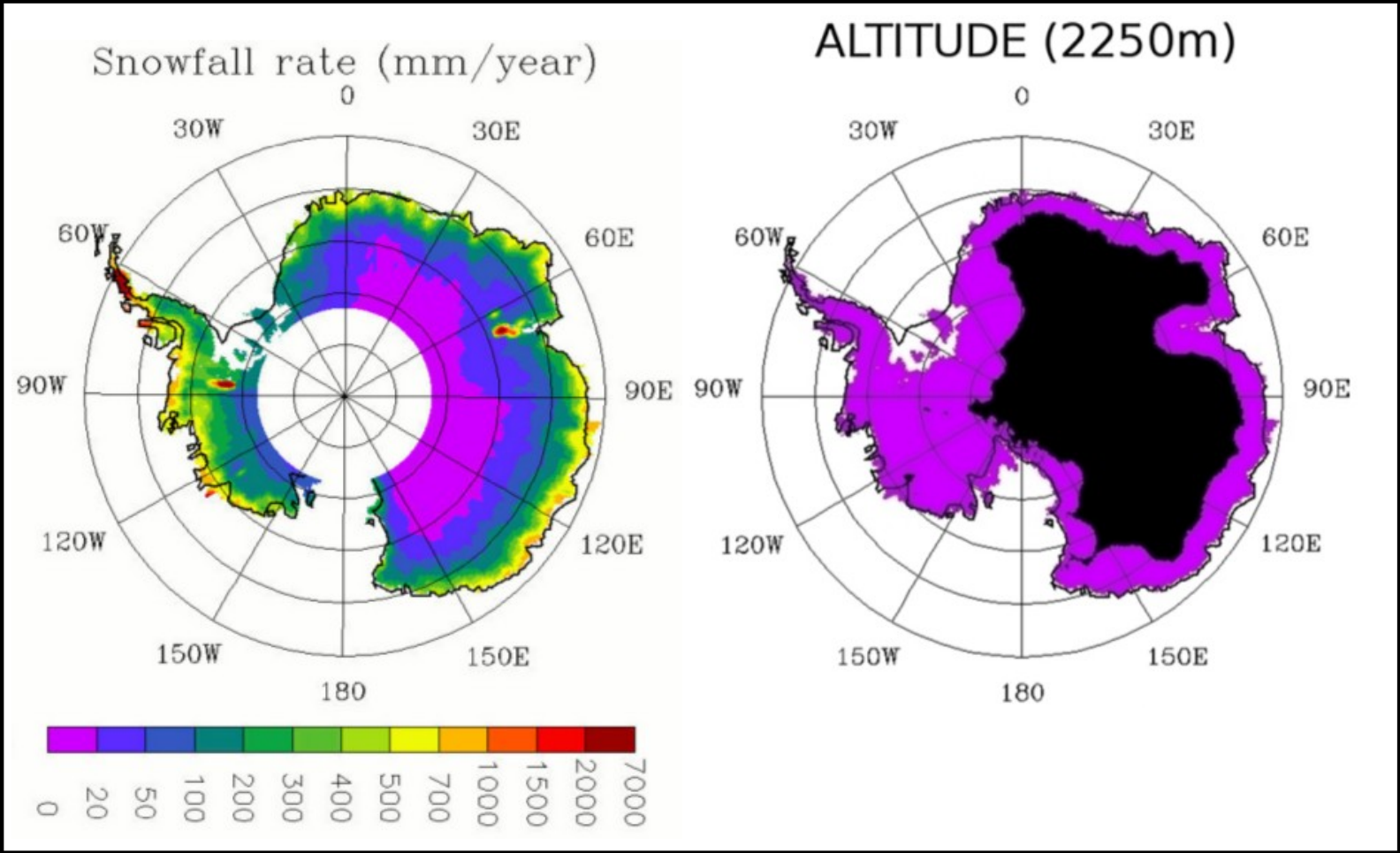


Snowfall rate over Antarctica derived by Palerme et al., 2014



2C-SNOW-PROFILE product [Haynes et al., 2009 ; 2013]

CloudSat CPR precipitation



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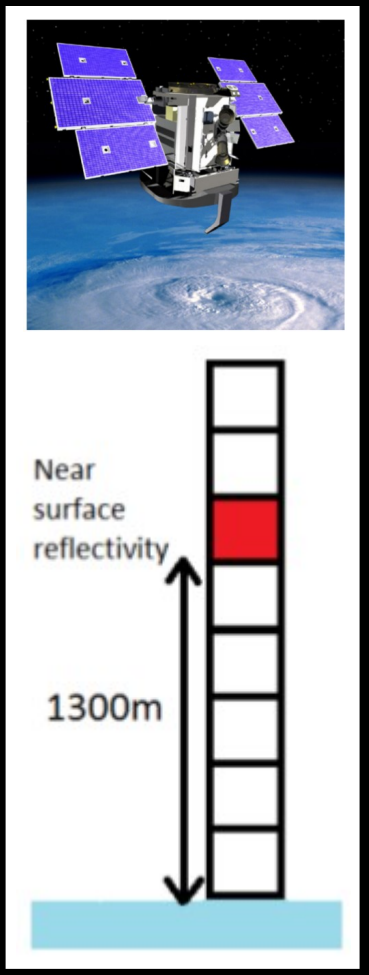

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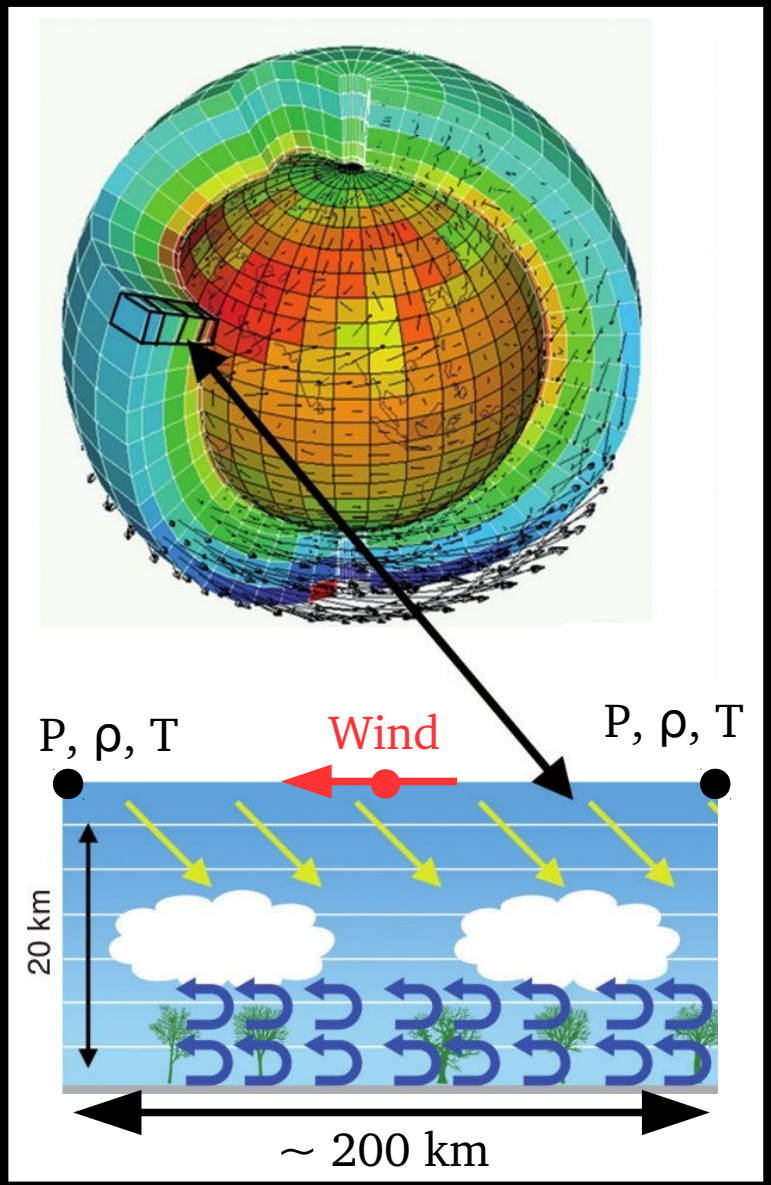
IPSL-CM atmospheric model (LMDz)



→ **Dynamical "core"**

Primitive hydrostatic equations of meteorology

→ **Radiative transfer model**

RT equations (plane-parallel approximation)

→ **Physical "parameterizations"**

Processes not resolved by the model grid (turbulence, clouds and precipitation, convection)

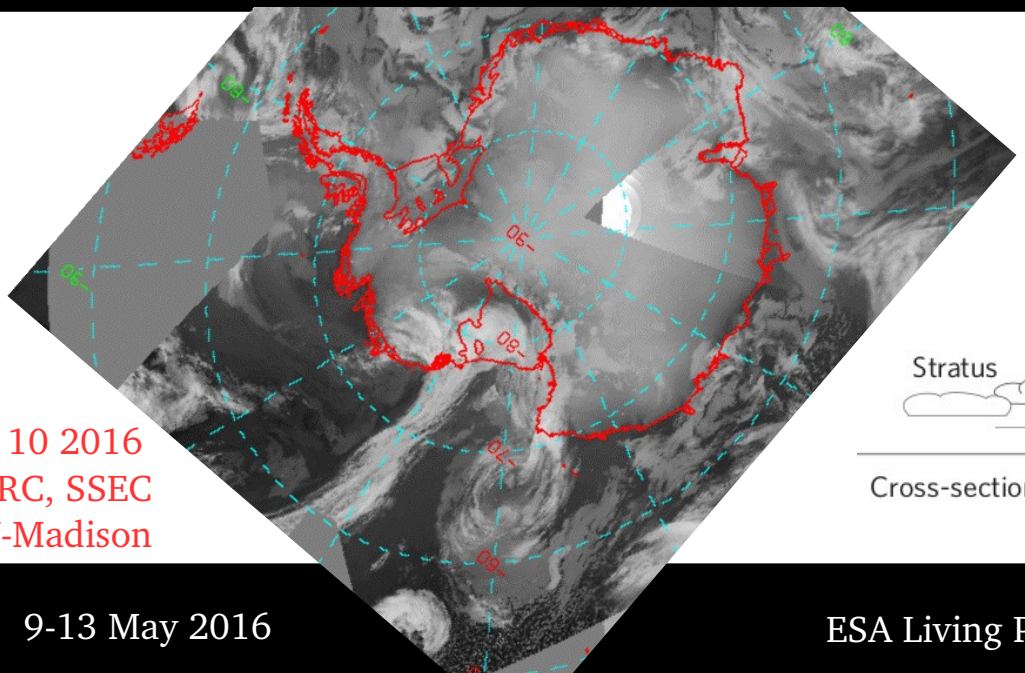
© IPSL

Towards the IPSL-CM6 model

- Improvement of the temperature dependency of **supercooled water droplets** (based on observations by Doutriaux-Boucher & Quaas 2004; Cesana & Chepfer 2013);
- Addition of the **latent heat of melting / freezing**;
- Improved the **conversion of liquid precipitation to solid precipitation**;
- Precipitation mass flux $(\rho w_{iw} q_{iw})$ computed using ice particle fall velocity

$w_{iw} = \gamma_{iw} w_0$ with $w_0 = 3.29(\rho q_{iw})^{0.16}$ and γ_{iw} a tuning coefficient

[Zender and Kiehl, 1997 ; Heymsfield and Donner, 1990]



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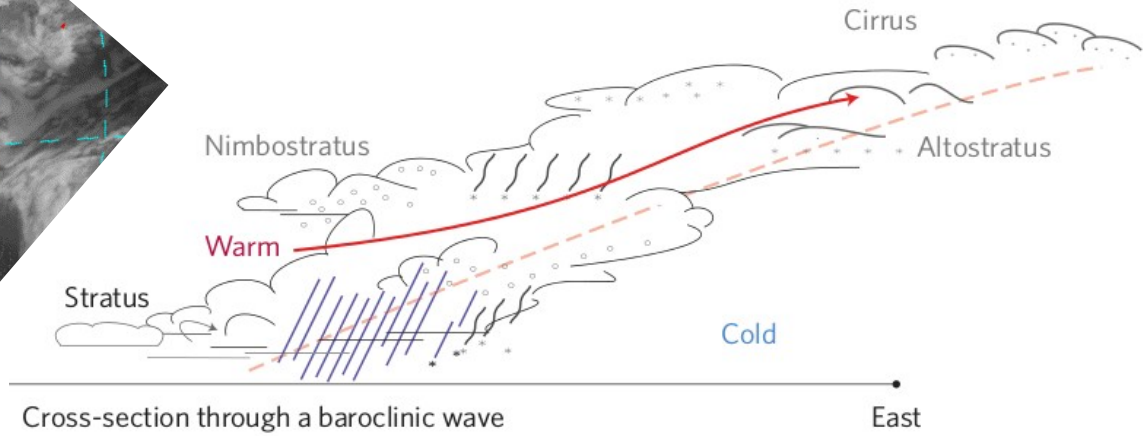
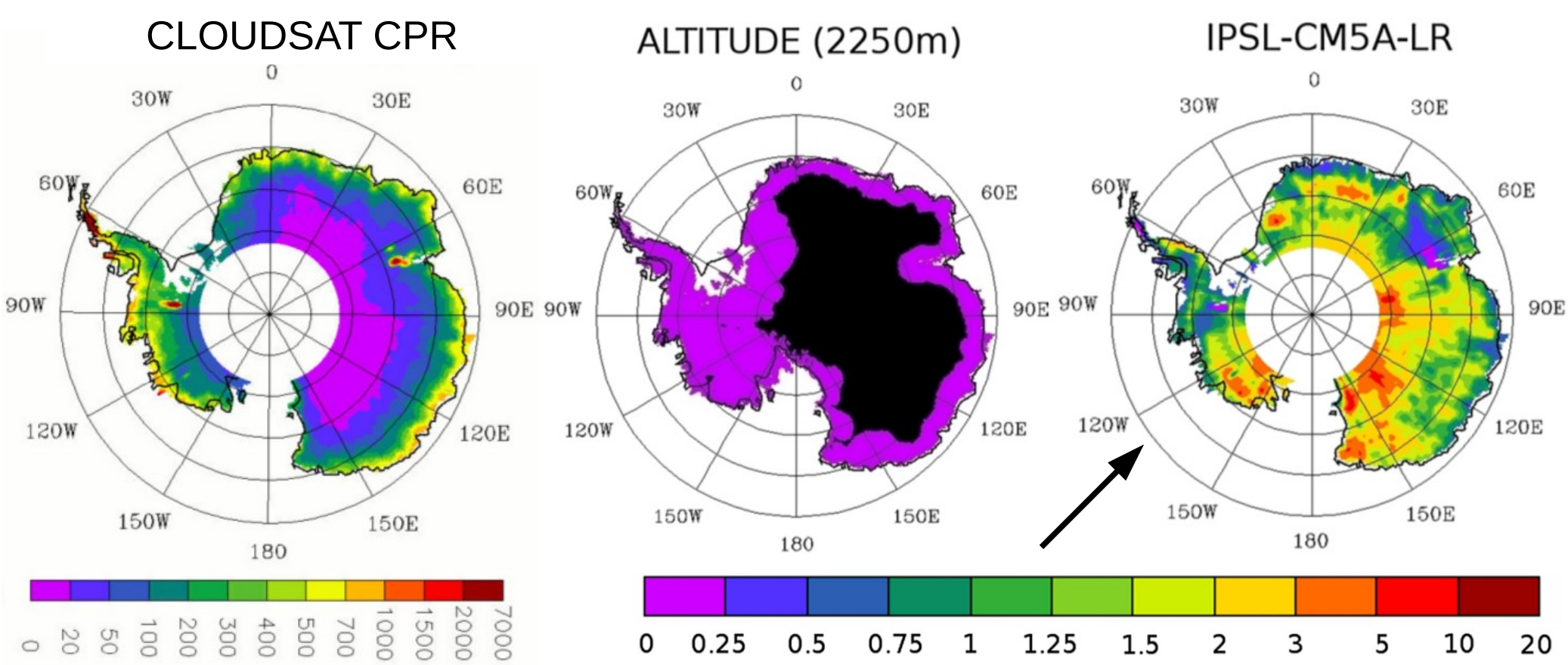


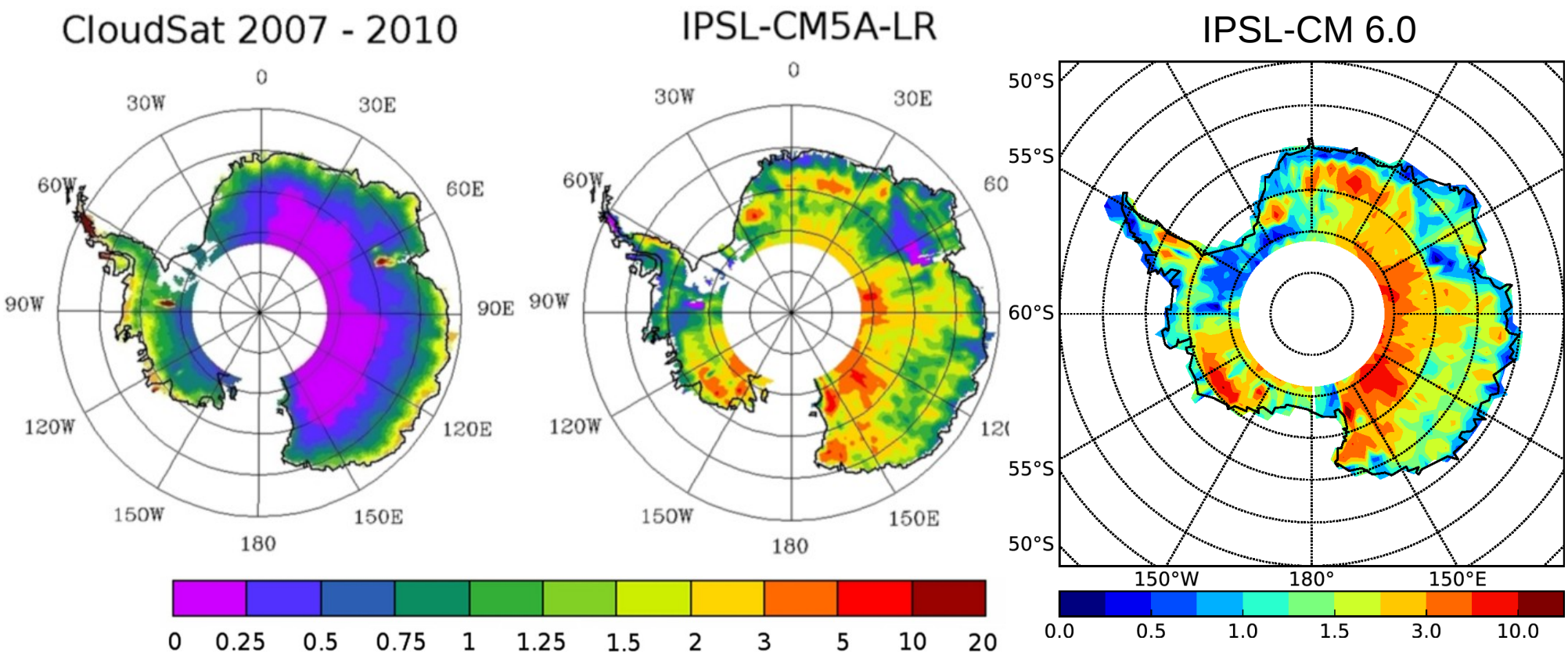
[Bony et al. 2015]

Comparison to CMIP5 models



Ratio of the snowfall rate simulated by the IPSL-CM5A model to the CloudSat snowfall rate [Palerme et al. 2016]

Results of IPSL-CM 6.0



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NEW SIMULATION

Nudged AMIP simulations

AMIP (Atmospheric Model Intercomparison Project) simulations :
Simulations are forced by observed sea surface temperatures and sea ice fractions

Ice sheet surface properties:
→ Ice thermal inertia set to 2000 J K^{-1} m^{-2} $s^{-1/2}$
→ Albedo set to 0.77

Nudged simulations : relax the GCM dynamical variables to ECMWF reanalysis data (Coindreau et al., 2007) using :

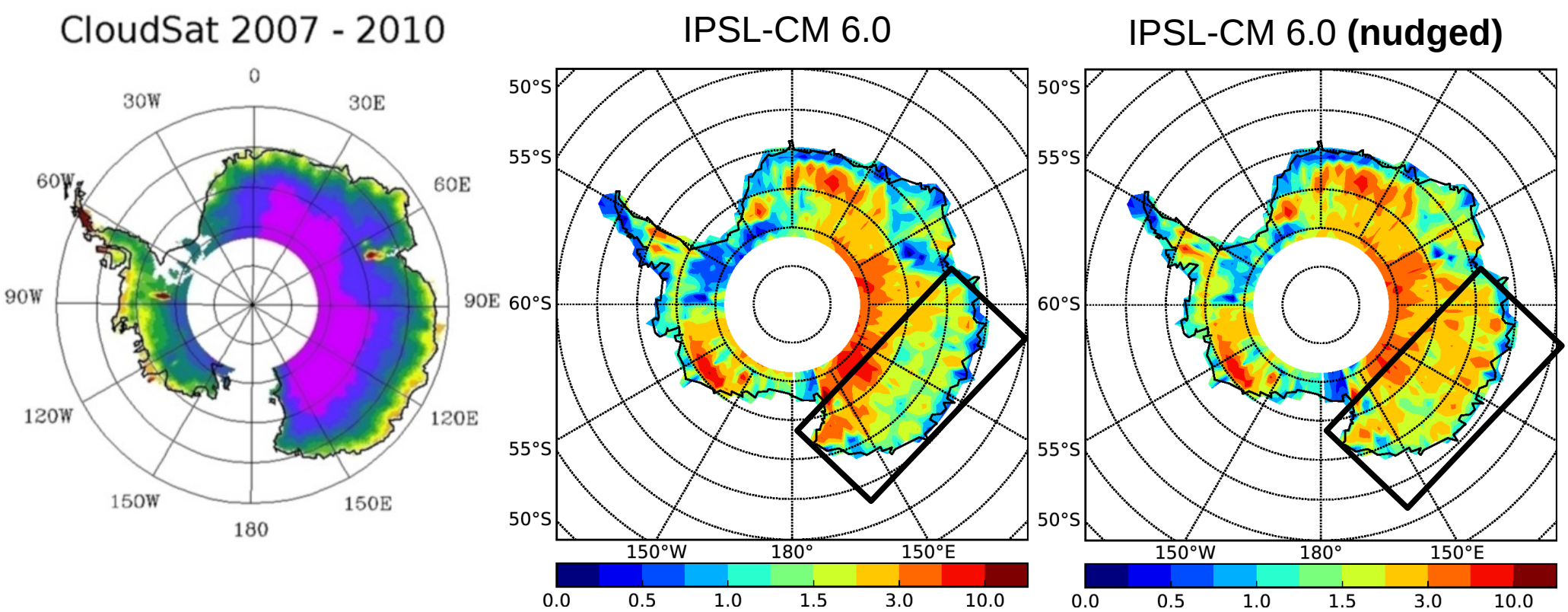
$$\frac{\partial u}{\partial t} = \frac{\partial u}{\partial t}_{GCM} + \frac{u_{analysis} - u}{\tau}$$

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

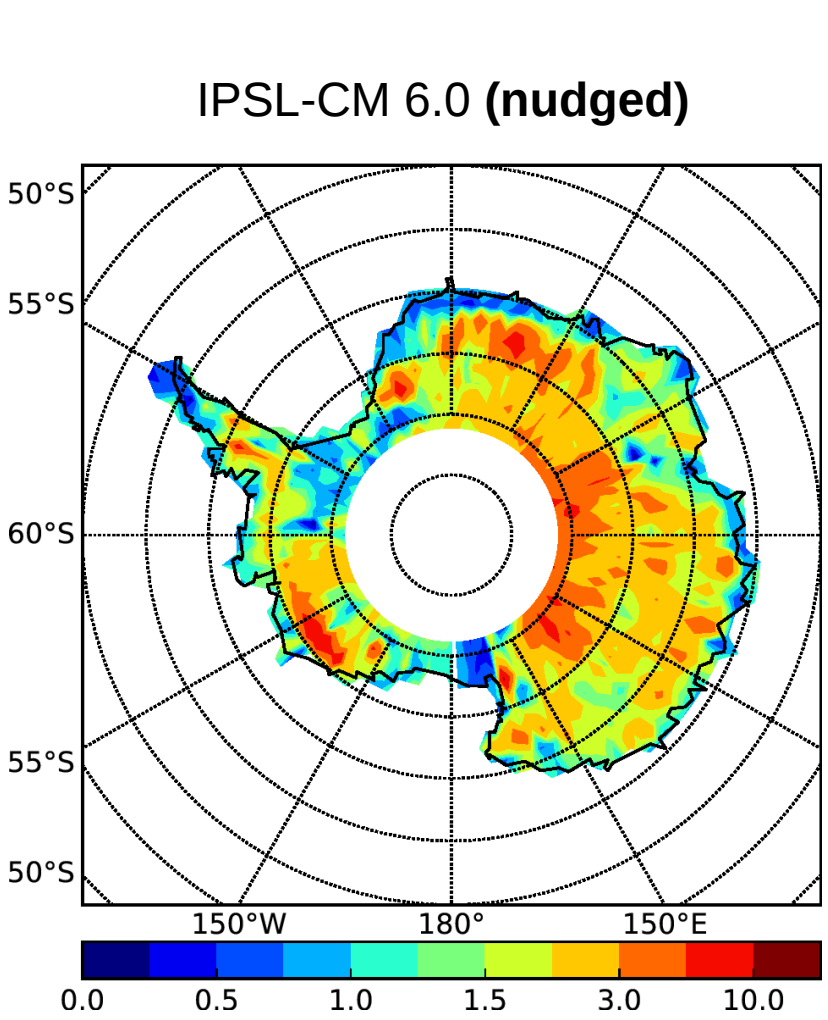
τ Time constant for the relaxation of the model wind toward analyses

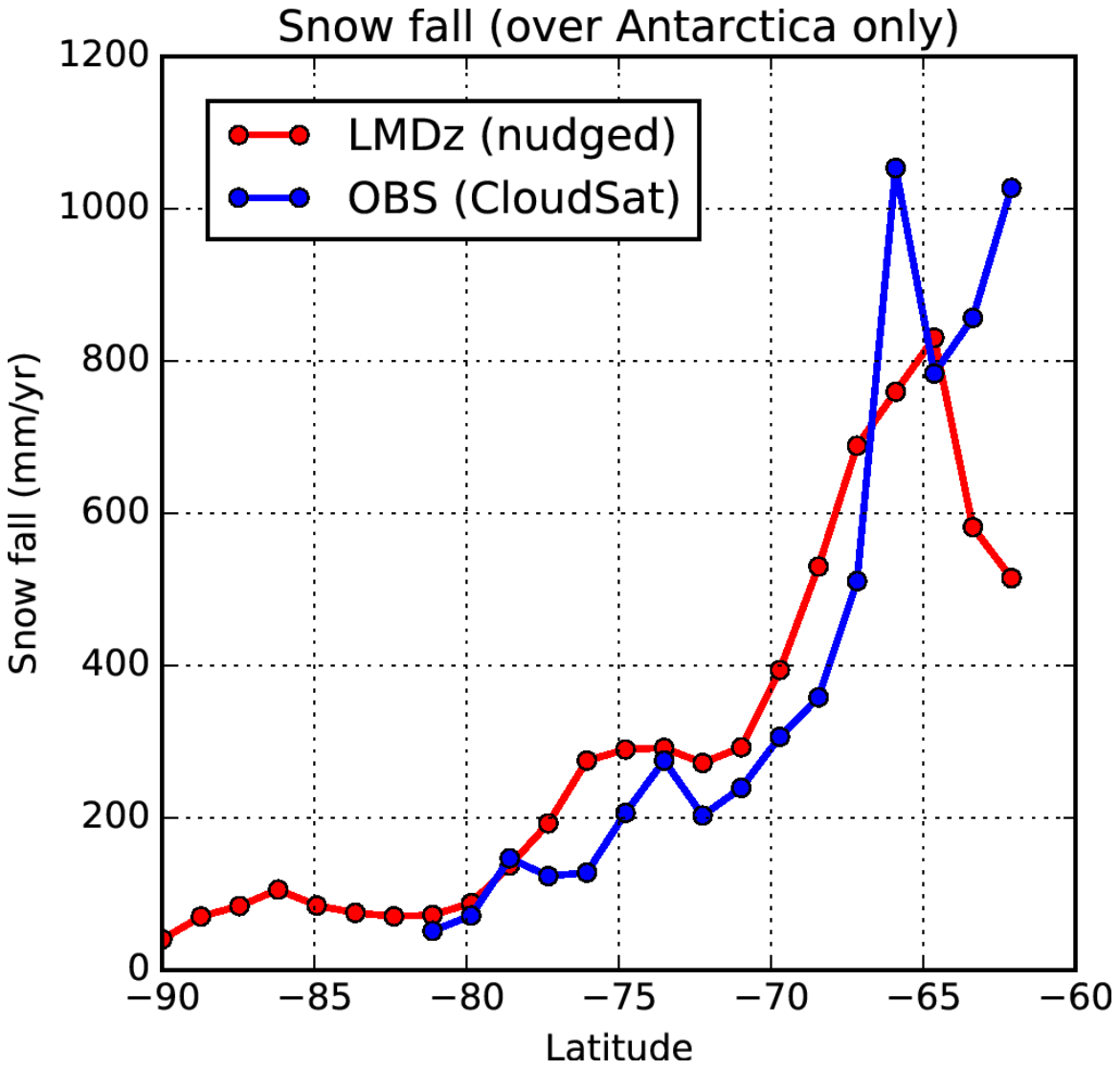
$u_{analysis}$ $v_{analysis}$

Comparison to nudged simulations

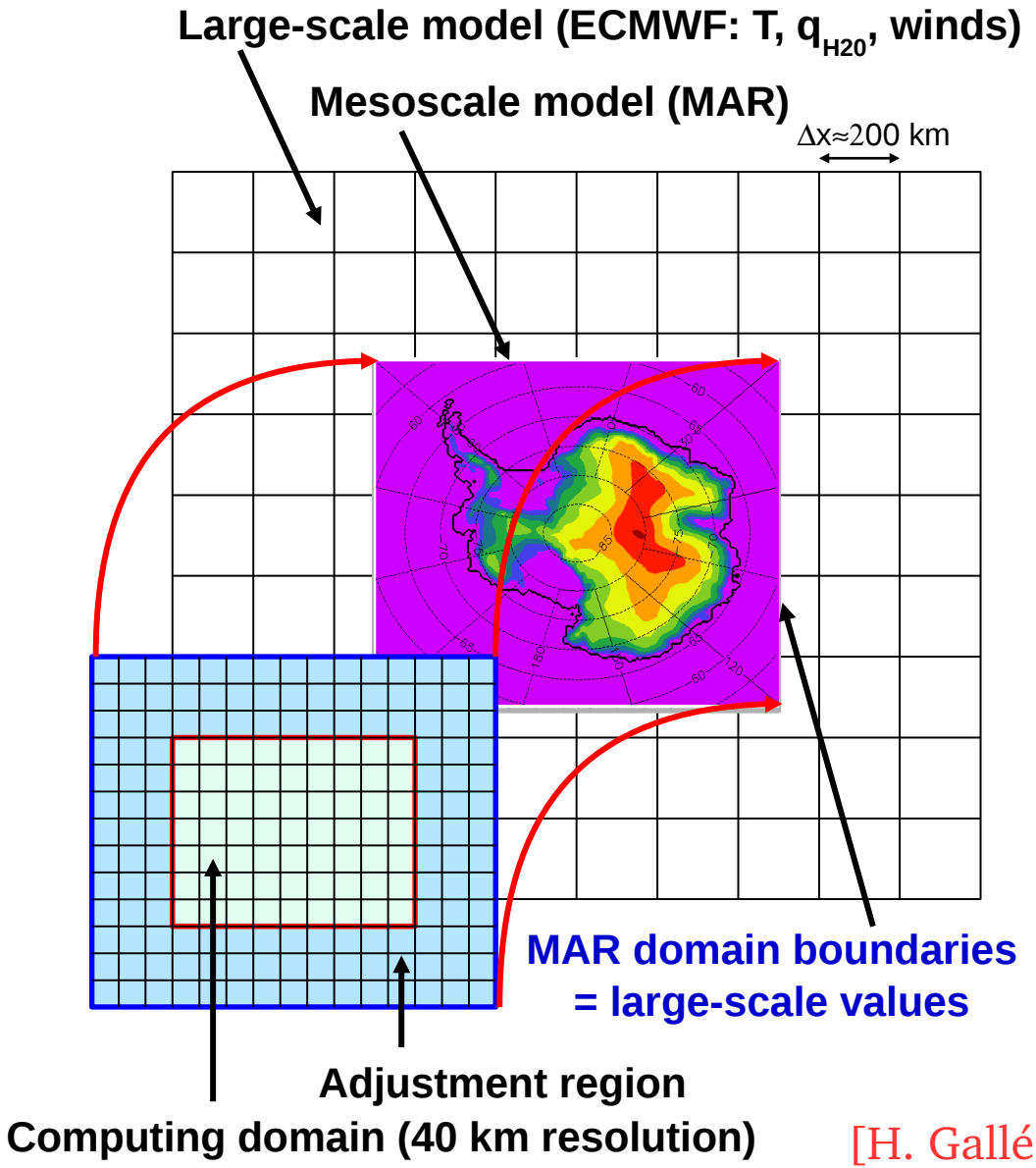


Zonal mean over the continent



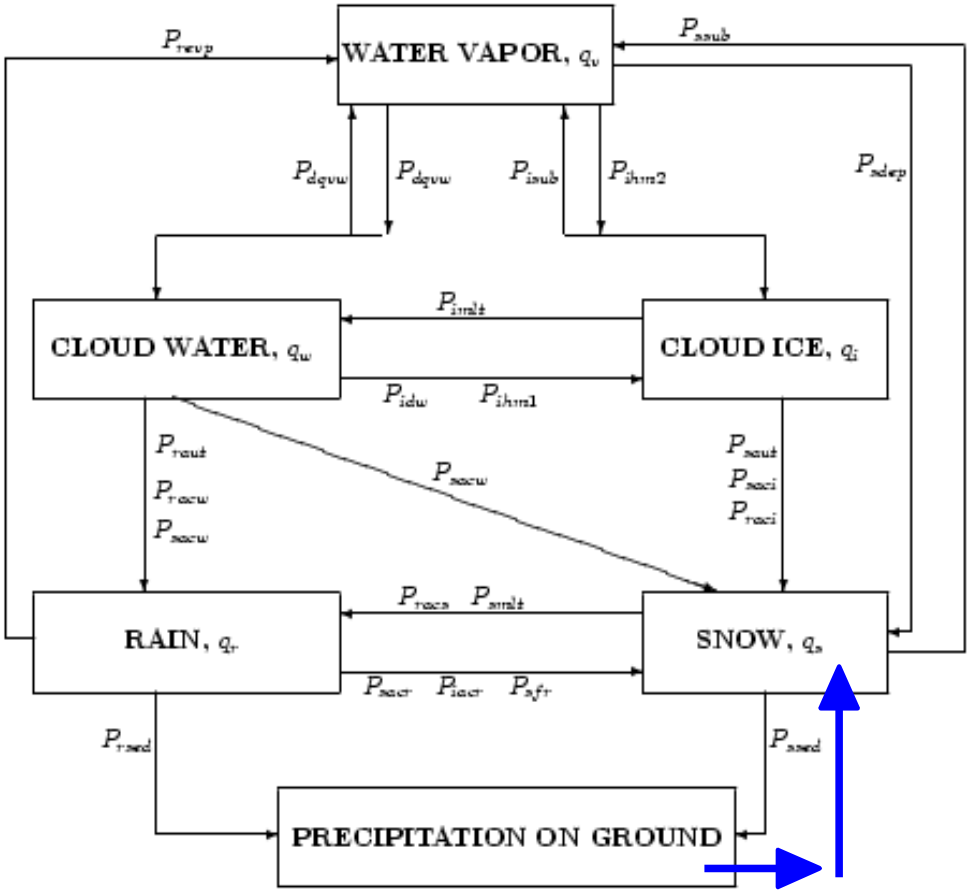


Limited Area Model



Microphysics scheme

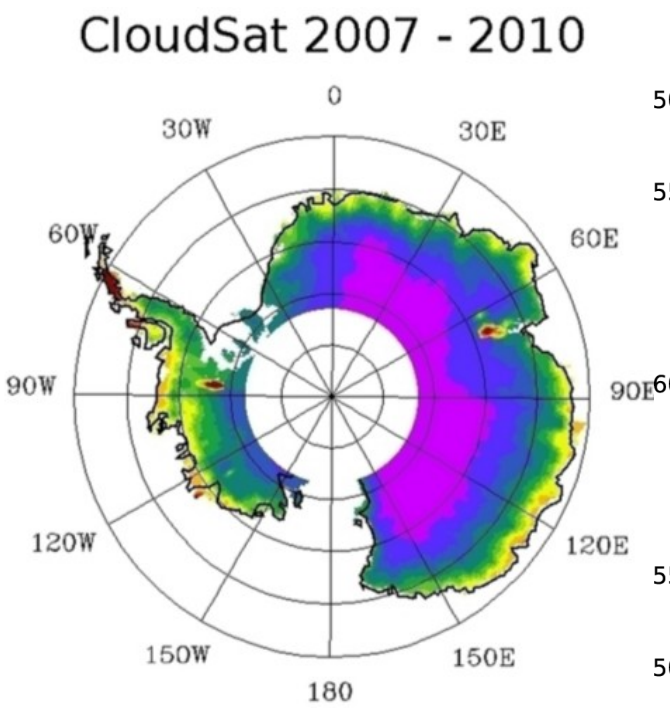
(6 pronostic equations)

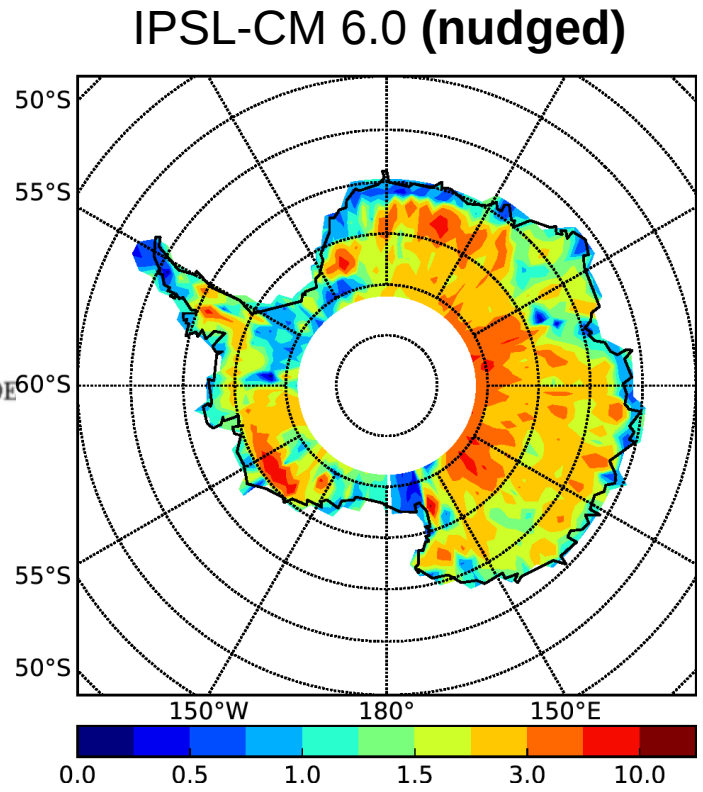


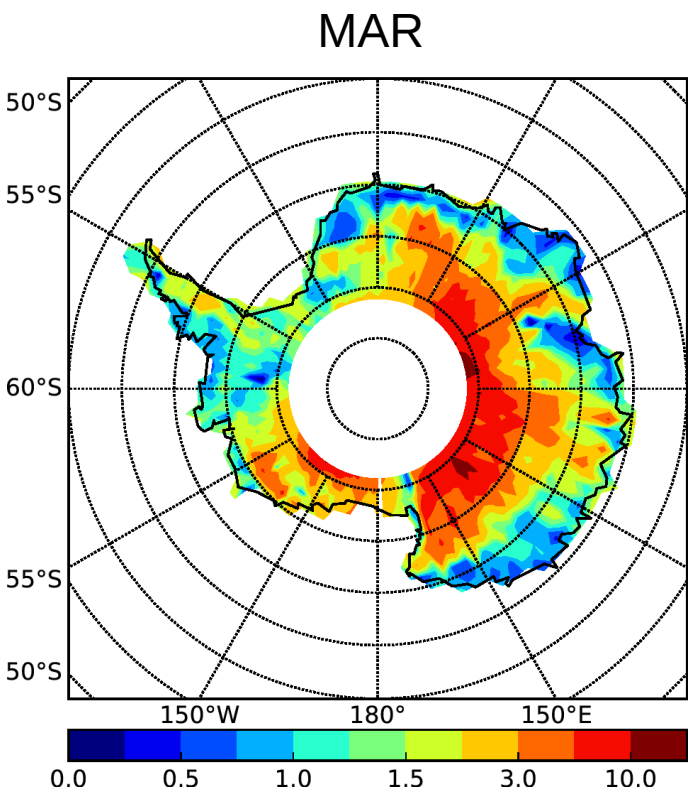
[H. Gallée & I. V. Gorodetskaya, 2010]

Snow Erosion

Comparaison CloudSat/MAR







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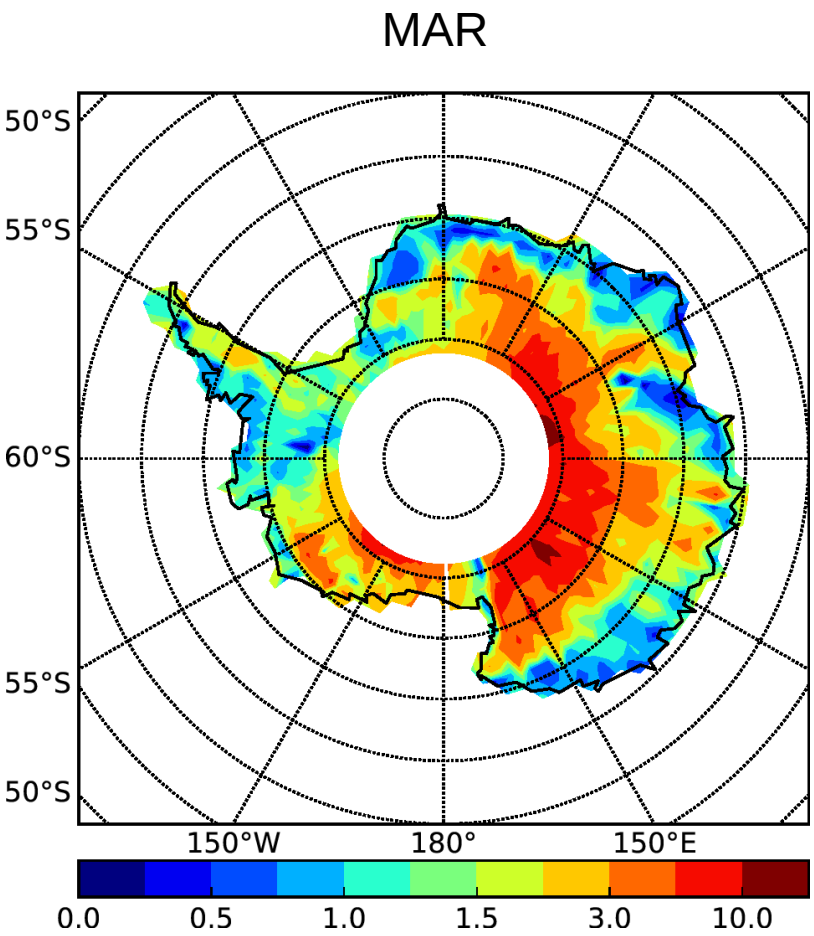

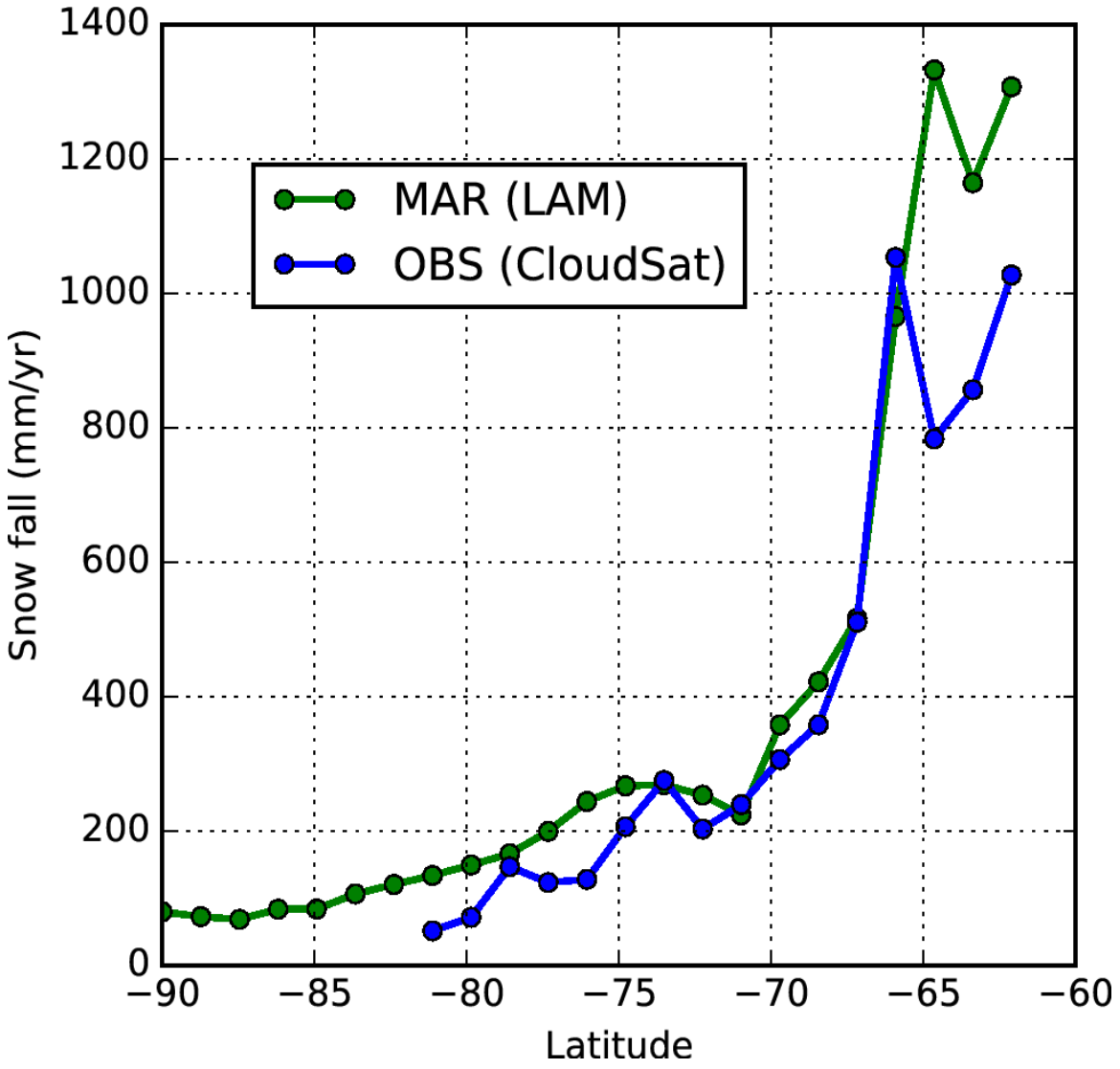

Conclusions

LMDz model	MAR model
• Overestimate precipitation over the whole continent • Does not come from the dynamics • Possibly due to high humidity over ocean	• Good agreement in the coastal areas • Overestimate snowfall in the interior of the continent (but CloudSat might miss low altitude precipitation)

Ongoing work

- Inclusion of more **satellite data** in the analysis
- Improvement of the **parameterization** of cold precipitation in the LMDz/GCM
- Comparison of the **CloudSat CPR data to ground-based radar observations**
- Simulation of particular **precipitation events** using both the forced LAM and GCM
- This is all part of the APRES3 project : **http://apres3.osug.fr**
- Looking forward to **EarthCare CPR and Doppler profiles.**

See other posters on the project:
→ **CRYO-158 (R23) / J. Grazioli :** Precipitation in Dumont D'Urville (Antarctica) from in-situ measurements and remote sensors
→ **ATMO-152 (R92) / C. Genthon :** Antarctic Precipitation : Remote Sensing from Surface and Space (APRES3)