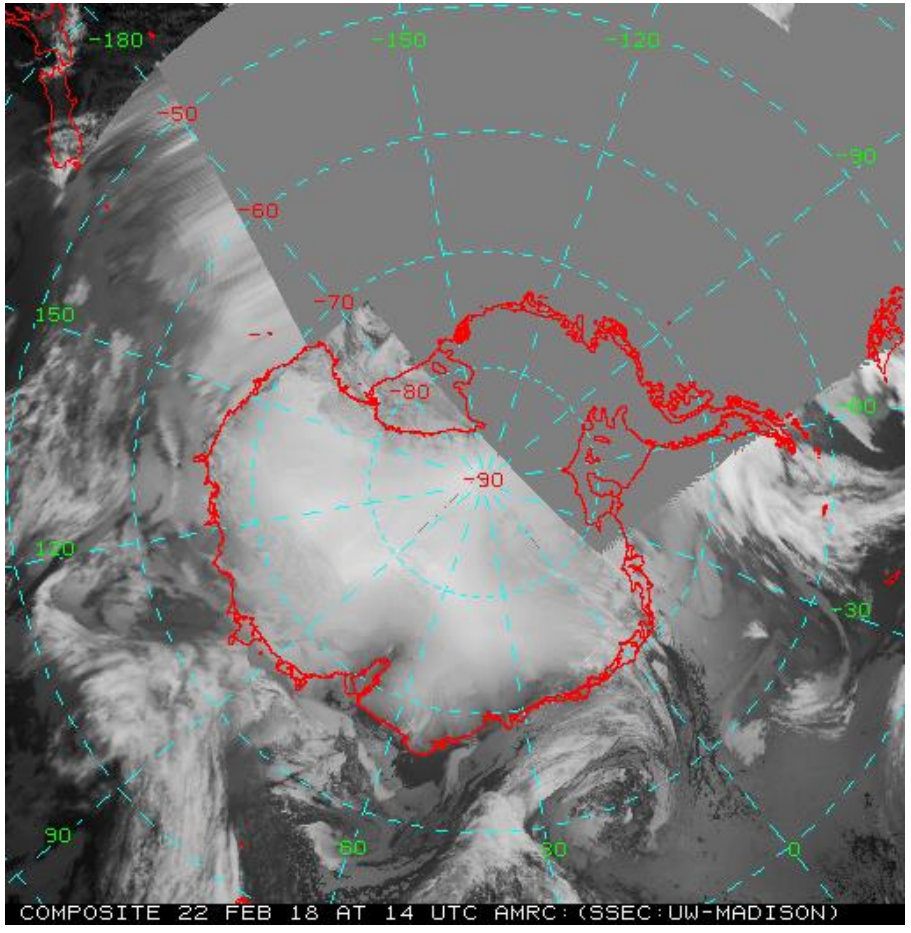
Evaluation of MAR and LMDz models with RADAR/LIDAR data at Dumont d'Urville, Antarctica : A precipitation study



A. Chemison [ab] , F. Lemonnier [*a] ,
H. Gallée [b] , G. Krinner [b] ,
C. Durán-Alarcón [b] , A. Teisseire [c] ,
B. Boudevillain [b] , A. Berne [d] ,
J.B. Madeleine [a] , C. Claud [a] ,
and C. Genthon [a]

a : LMD/IPSL, CNRS, Paris, France
b : IGE, CNRS/OSUG, Grenoble, France
c : Leibniz Institute for Tropospheric Research, Leipzig, Germany
d : EPFL, Lauzanne, Switzerland
* : florentin.lemonnier@lmd.jussieu.fr

APRES3 ANR LMD cnrs IGE Institut des géosciences de l'environnement UNIVERSITÉ Grenoble Alpes Sciences de l'environnement Institut Pierre Simon Laplace TROPOS Leibniz Institute for Tropospheric Research

Context

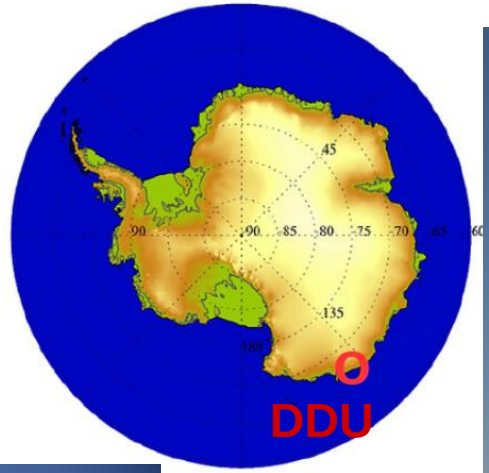
APRES3 Project: Dumont d'Urville Precipitation Characterization
This study: At Dumont d'Urville (DDU), Antarctica, February 2017

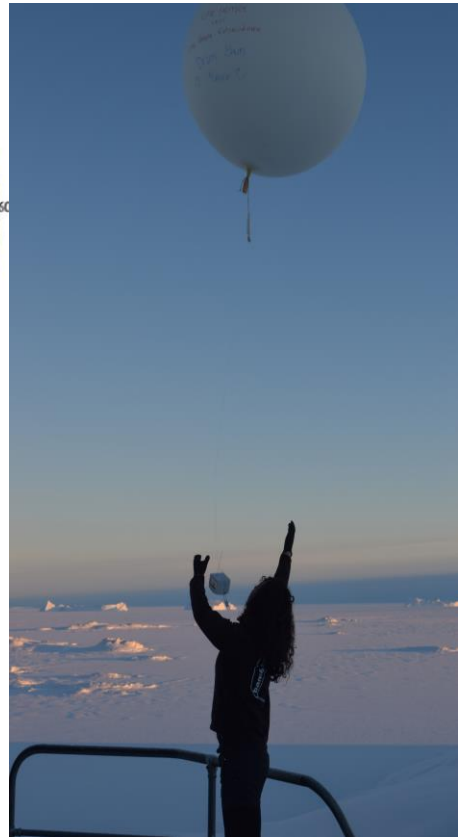
Data set:

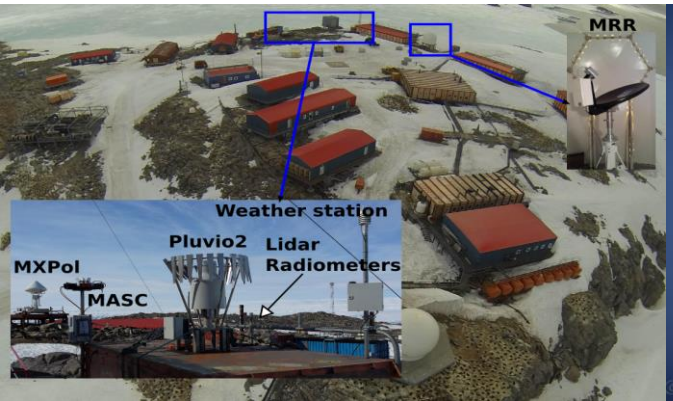
- LIDAR: backscatter and depolarization, from 10 m to 8 km, 1 measurement / min
- MRR: resolution 100 m, from 300 m to 3 km
- Radiosonde

Simulations:

- MAR: mesoscale complex model
- IPSL-LMDz: general circulation model







A first study : Clouds at Dumont d'Urville

Goal : Characterization of clouds with LIDAR / RADAR data

- Detection of the cloud base altitude
- Supercooled liquid water detection

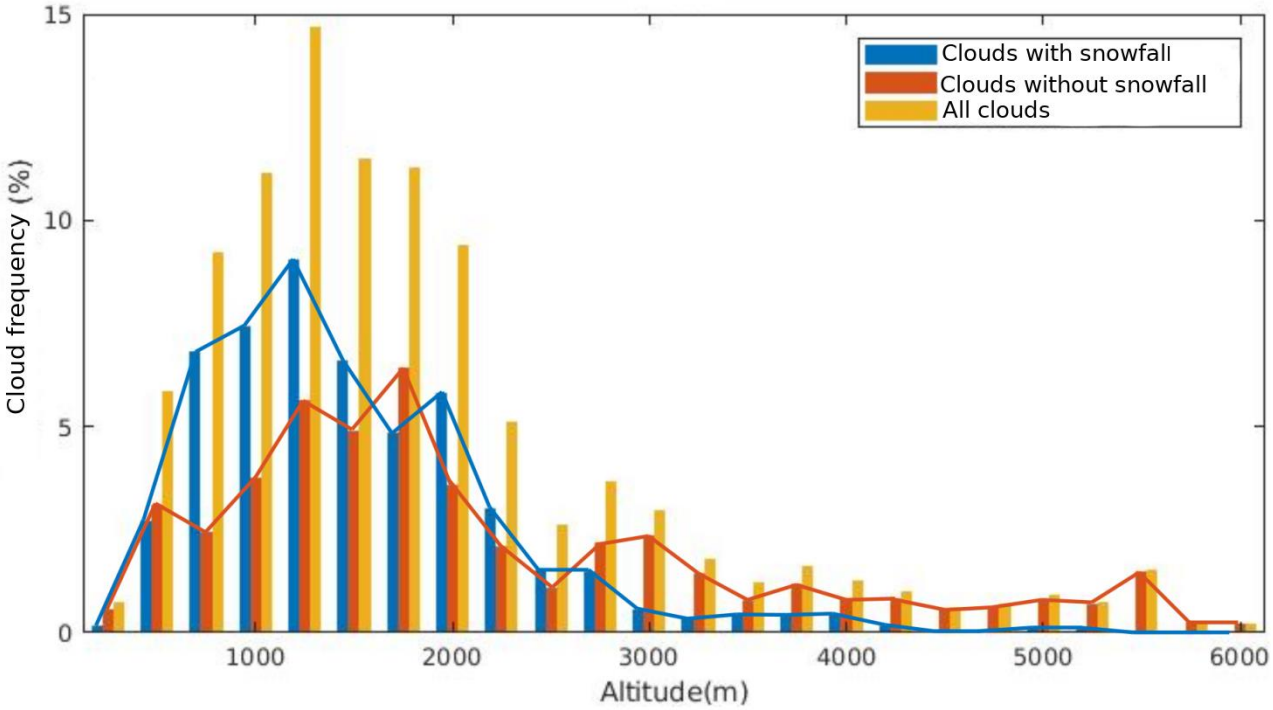
Results:

- Cloud cover : 64% of the month of February 2017

- Clouds without snowfall: 1 000 m at 3 000 m altitude

- Clouds with snowfall: 800m to 2 000m

Statistical analysis of cloud base altitude



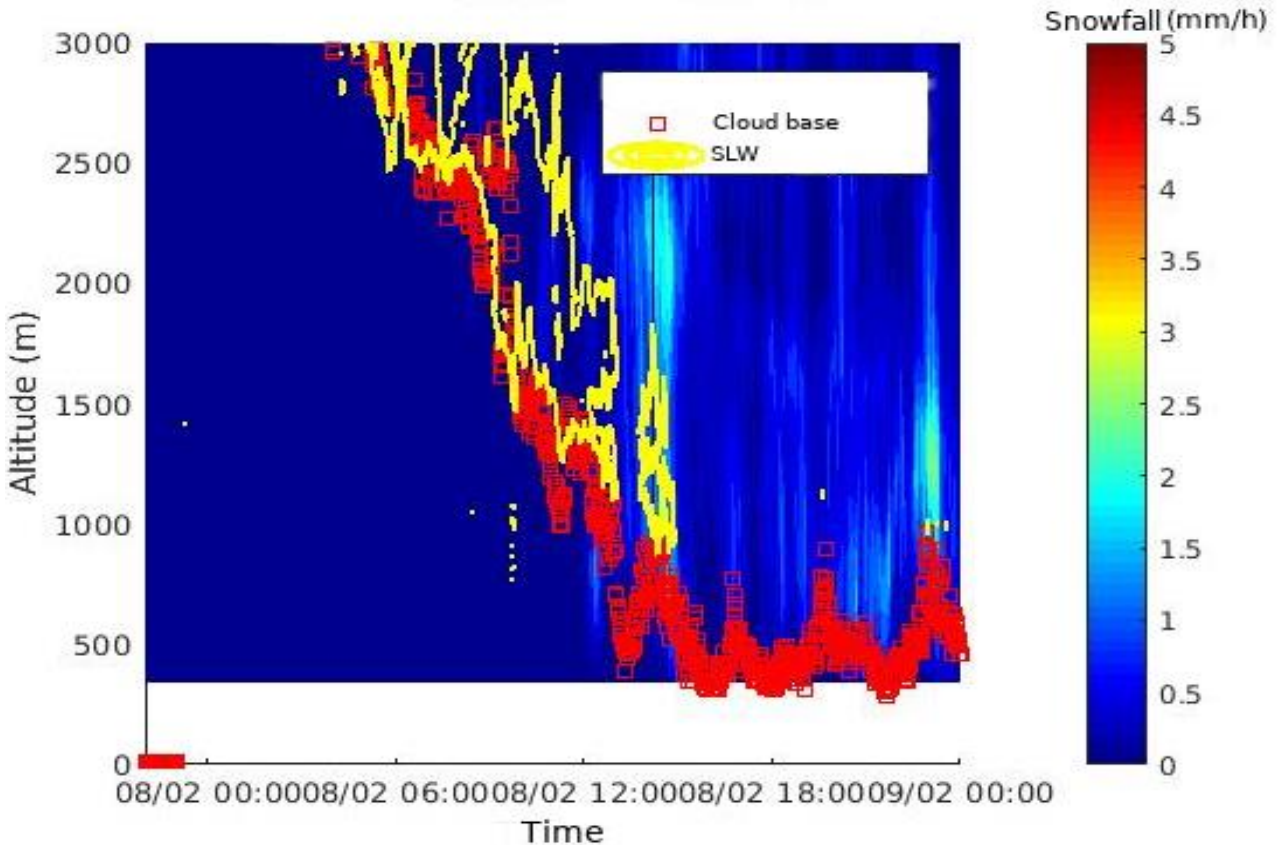
The altitude of clouds without snowfall is higher than clouds with snowfall

A first study : Clouds at Dumont d'Urville

Results:

- Evidence of supercooled water in clouds without precipitation
- Decrease then disappearance of supercooled liquid water when precipitation occurs: **Werger-Bergeron-Findeisen process**

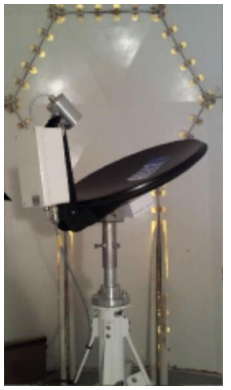
Cloud base and supercooled liquid water detection, with MRR



Observed scenario:

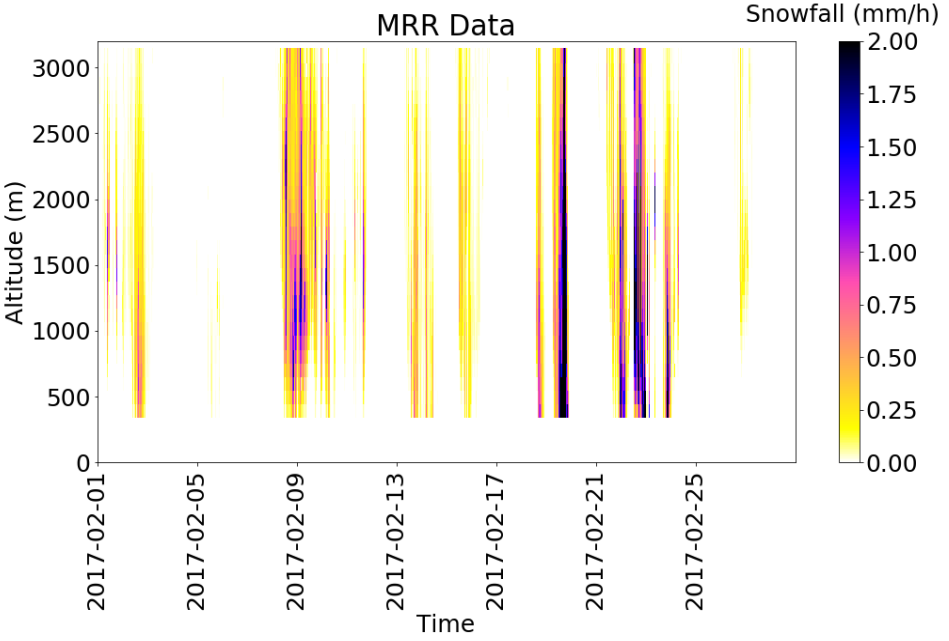
- Formation of the cloud at middle altitude
- Descent of the cloud
- Extinction of supercooled liquid water signal
- Appearance of snowfall under 1500m

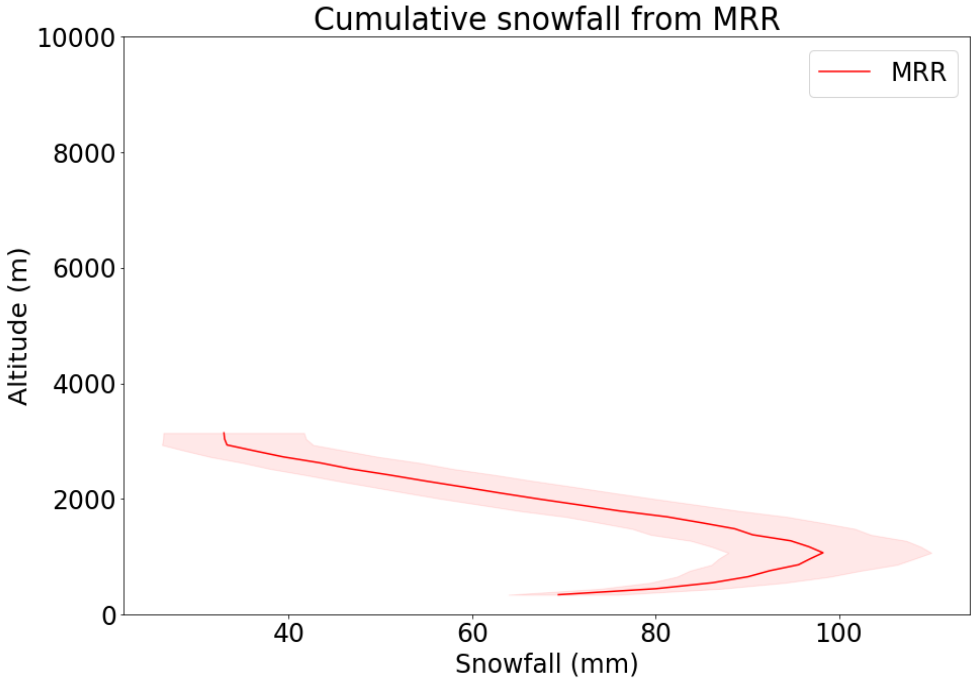
The new study :
Evaluation of MAR and LMDz models with RADAR/LIDAR data at Dumont d'Urville, Antarctica, A precipitation study



For this study we analyze the precipitation over DDU, during the February 2017 period
Goal : Comparison of climate simulations with the observations obtained by the MRR

MRR :
- **28 levels** from 341m to 3141m : every 100 m
- Step time : 1min





We sum the precipitation to make a cumulative profil of the vertical structure over the entire month of February 2017.
The red interval corresponds to a 95% confidence interval.

MAR : Meso scale complex model

Horizontal resolution: 2 – 40 km → 5 and 25 km

Dynamic time: 6 min

Spin up: 4 months

Highly developed microphysics:

- autoconversion
- nucleation
- Bergeron-Findeisen process
- blown snow
- accretion
- re-evaporation
- ...

Nudging parameters, with ERA-Interim reanalysis, in sponge area :

- Wind
- Humidity
- Temperature

MAR : Microphysical process

Symbol	Microphysical process
P_{dqvw}	Condensation of water vapor to form cloud water Evaporation of cloud water
P_{ihm1}	Homogenous freezing of cloud water to form cloud ice
P_{ihm2}	Homogeneous deposotion of water vapor to form cloud ice
P_{ihet}	Heteregoneous ice nucleation
P_{isub}	Sublimation of ice
P_{idw}	Depositional growth of cloud ice at expense of cloud water
P_{imlr}	Melting of cloud ice to form cloud water
P_{raut}	Autoconversion of cloud water to form rain
P_{saut}	Autoconversion (aggregation) of cloud ice to form snow
P_{racw}	Accretion of cloud water by rain
P_{sacw}	Accretion of cloud water by snow
P_{saci}	Accretion of cloud ice by snow
P_{raci}	Accretion of cloud ice by rain to form snow
P_{iacr}	Accretiion of rain by cloud ice to form snow
P_{sacr}	Accretion of rain by snow
P_{sfr}	Probalistic freezing of rain to form snow
P_{smlt}	Melting of snow to form rain
P_{racs}	Accretion of snow by rain
P_{sdep}	Depositional growth of snow
P_{revp}	Evaporation of rain
P_{ssub}	Sublimation of snow
P_{rsed}	Rain fallout
P_{ssed}	Snow fallout

Cumulative of snowfall : MAR and MRR

MAR, Sensitivity test on the vertical resolution :

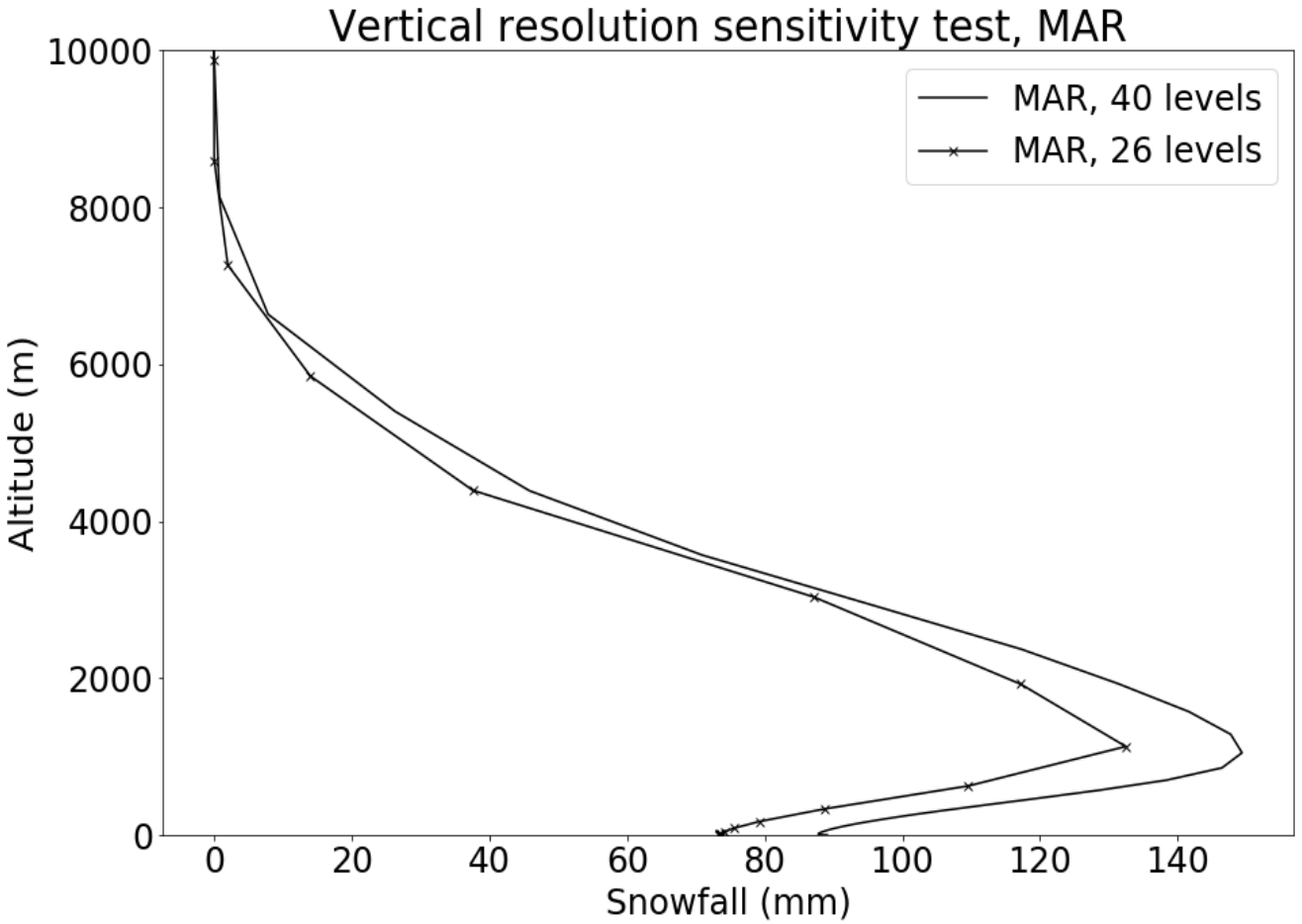
- MAR: 26 vertical levels from 0,17m to 17860m, **5 levels** from 333m to 3034m
- MAR: 40 vertical levels from 0,17m to 19545m, **12 levels** from 309m to 3568m

- The altitude of maxima in precipitation rates is the same

- Slight increase in cumulative snowfall with 40 levels resolution

- MAR's vertical resolution has a small effect on simulated precipitation

- 40 levels: higher accuracy



Cumulative of snowfall : MAR and MRR

MAR, sensitivity test on the simulation **horizontal resolution** (MAR 40 levels):

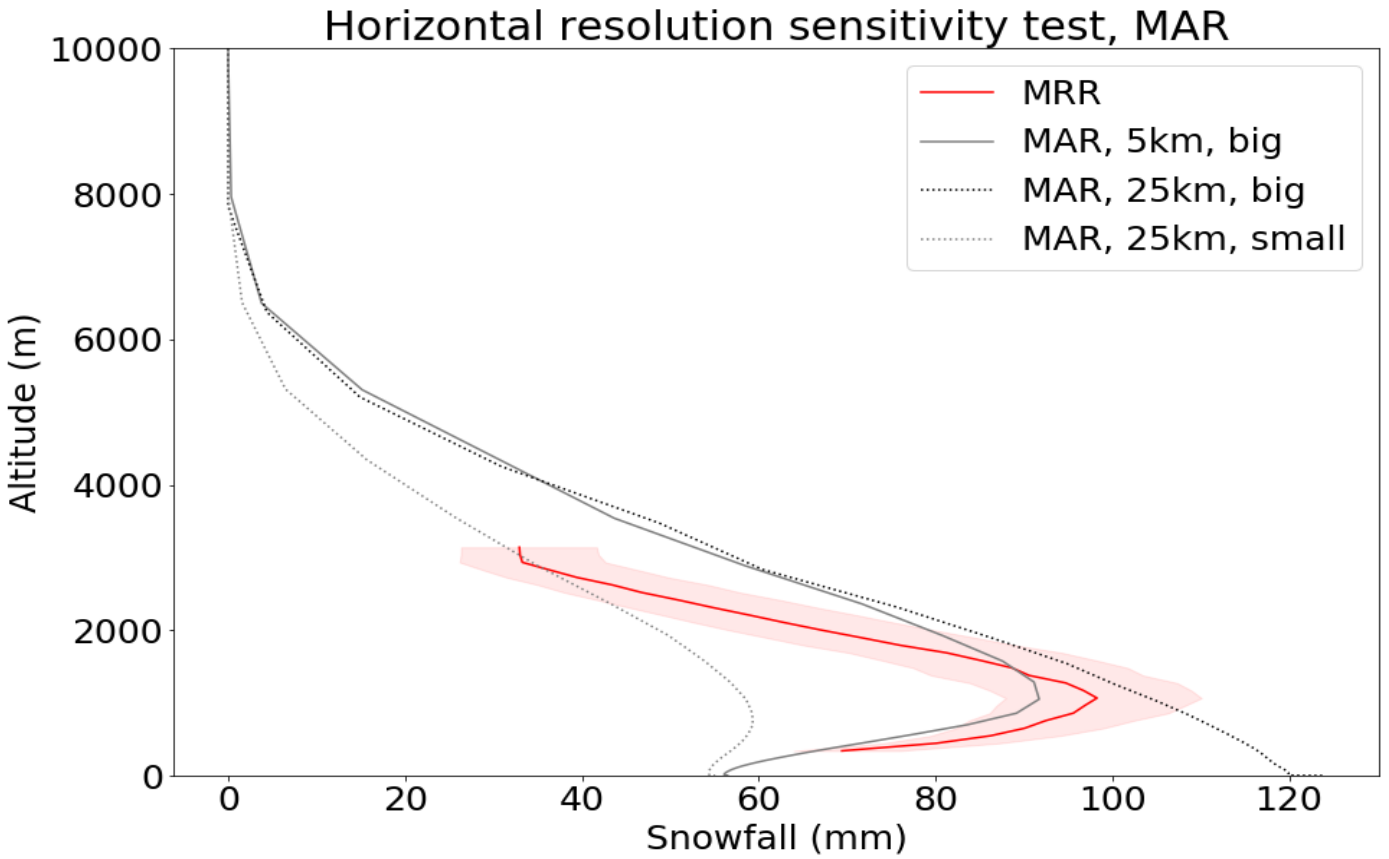
- MAR 5 km ‘big’: 1000 km domain free of nudging, resolution 5 km or **200 grid points**
- MAR 25 km ‘big’: 1000 km domain free of nudging, resolution 25 km or **40 grid points**
- MAR 25 km ‘small’: 250 km domain free of nudging, resolution 25 km or **10 grid points**

Nudged boundary layers: 6 grid points

- MAR 25 km big: too much precipitation on the surface → **no katabatic wind simulated**

- MAR 25 km small: not enough precipitation → **area too small for stabilization**

- MAR 5 km big: good snowfall simulation → **fine and efficient resolution**

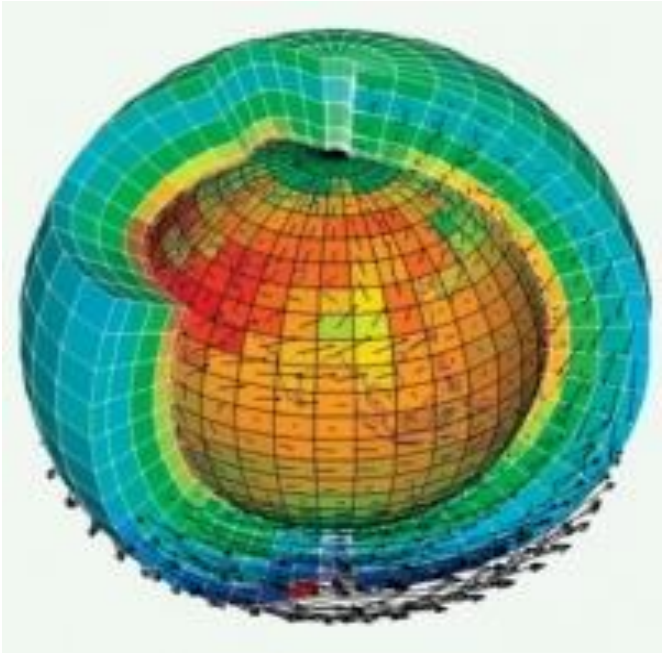


LMDz : Global Climate Model

Physical equation in agreement with CMIP6 IPSL simulations

- Horizontal resolution: 25 km
- Dynamic time step: 3 min 45
- Spin up: 3 months
- Domain free of nunging : 250 km → 10 grid points

Representation of LMDZ model in 3D



Microphysics :

- autoconversion
- sedimentation velocity
- sublimation

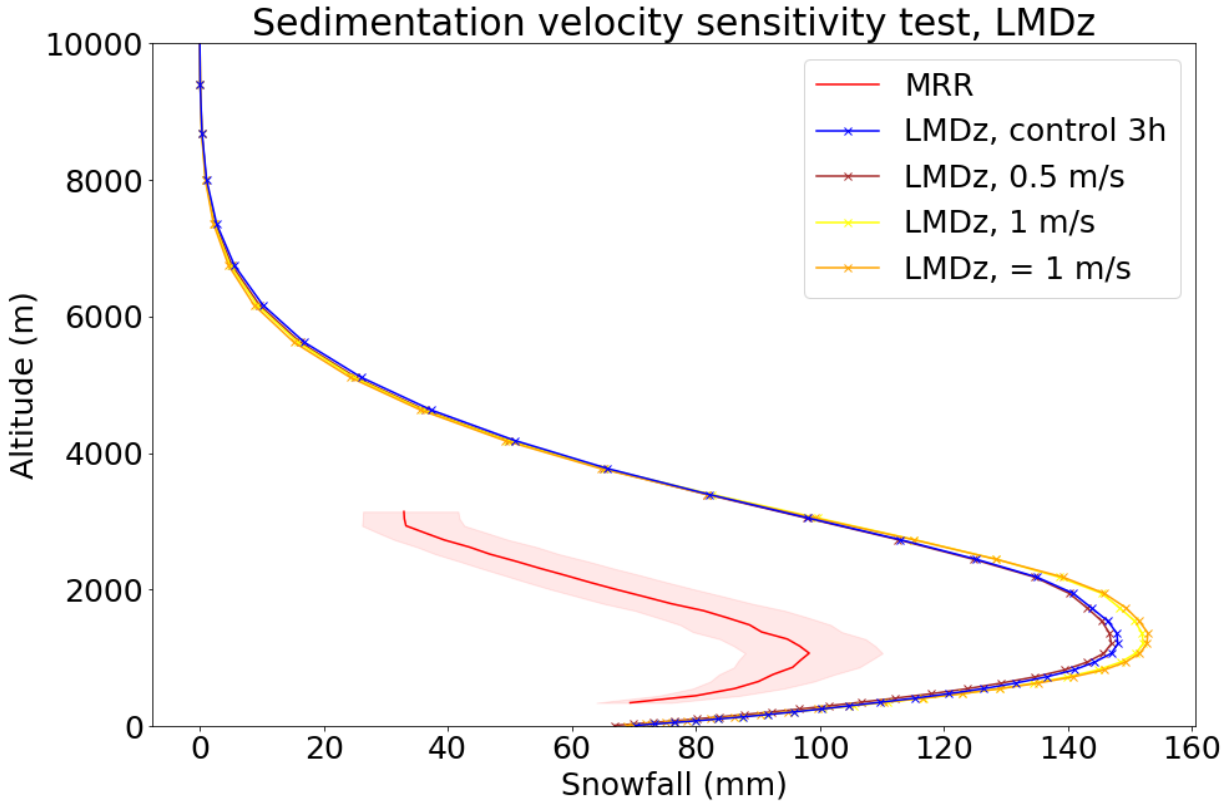
Nudging parameters, with ERA-Interim reanalysis :

- wind: every 3 hours
- humidity: every 12 hours
- temperature: every 12 hours

Cumulative snowfall : LMDz and MRR

LMDz sensitivity test on the **sedimentation velocity,** 3h averaged**:**

- LMDz 0.5 m/s: the fall speed **tends to 0.5 m/s,** depending on pressure and temperature
- LMDz 1 m/s: the speed of fall **tends to 1 m/s,** depending on pressure and temperature
- LMDz = 1m/s: the fall speed **is equal to 1 m/s**
- LMDz control: **control** simulation



If the fall speed is increasing, the precipitation maximum increases slightly but not significantly.

Too much snowfall is simulated

Sensitivity tests on re-evaporation show also an almost zero impact of this phenomenon on precipitation.

LMDz sensitivity test on dissipation

Dissipation is a numerical calculation in GCMs.
It **keeps the model stable**. It dissipates temperature and wind excess.

$$\frac{\partial \varphi}{\partial t} = dyn(\varphi) + phy(\varphi) + F(\varphi)$$

Temperature/wind with time

Dyn : dynamical process

Phy : physical process

***F* : dissipation**

Sensibility test on :
- time
- frequencies : High frequencies + Low frequencies

Examples : Large-scale advection Precipitation autoconversion

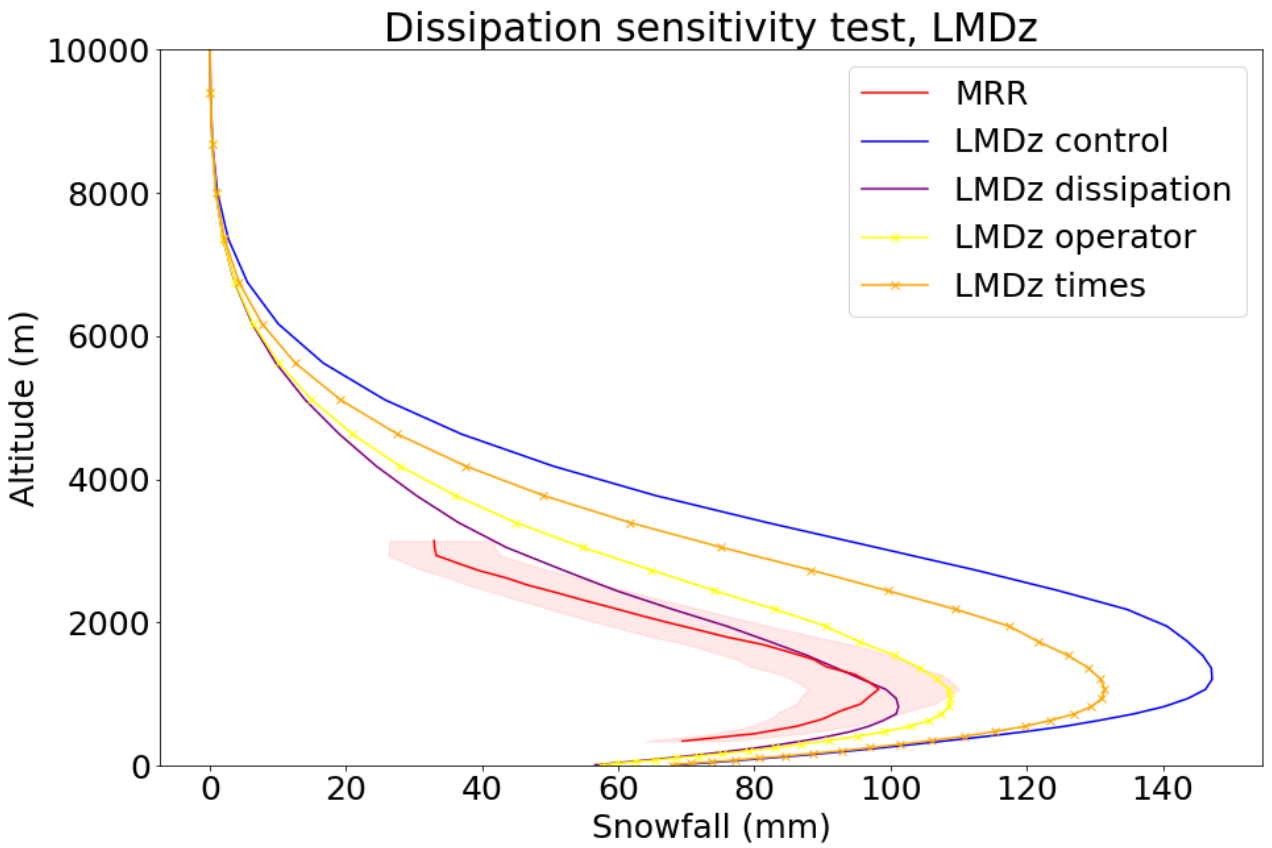
Cumulative of snowfall : LMDz and MRR

LMDz sensitivity test on **dissipation**:

- LMDz **control**: the high and low frequencies are dissipated with a time step of 75 s
- LMDz **operator**: only high frequencies are dissipated
- LMDz **time**: the dissipation time is increased → 150s
- LMDz **dissipation**: all tests are cumulated

- LMDz_time: **slight drop in precipitation**
- LMDz_operator: **significant decrease in snowfall**
- LMDz_dissipation: **very significant decrease in snowfall**

The dissipation strongly impacts the simulated precipitation → We are working on it !



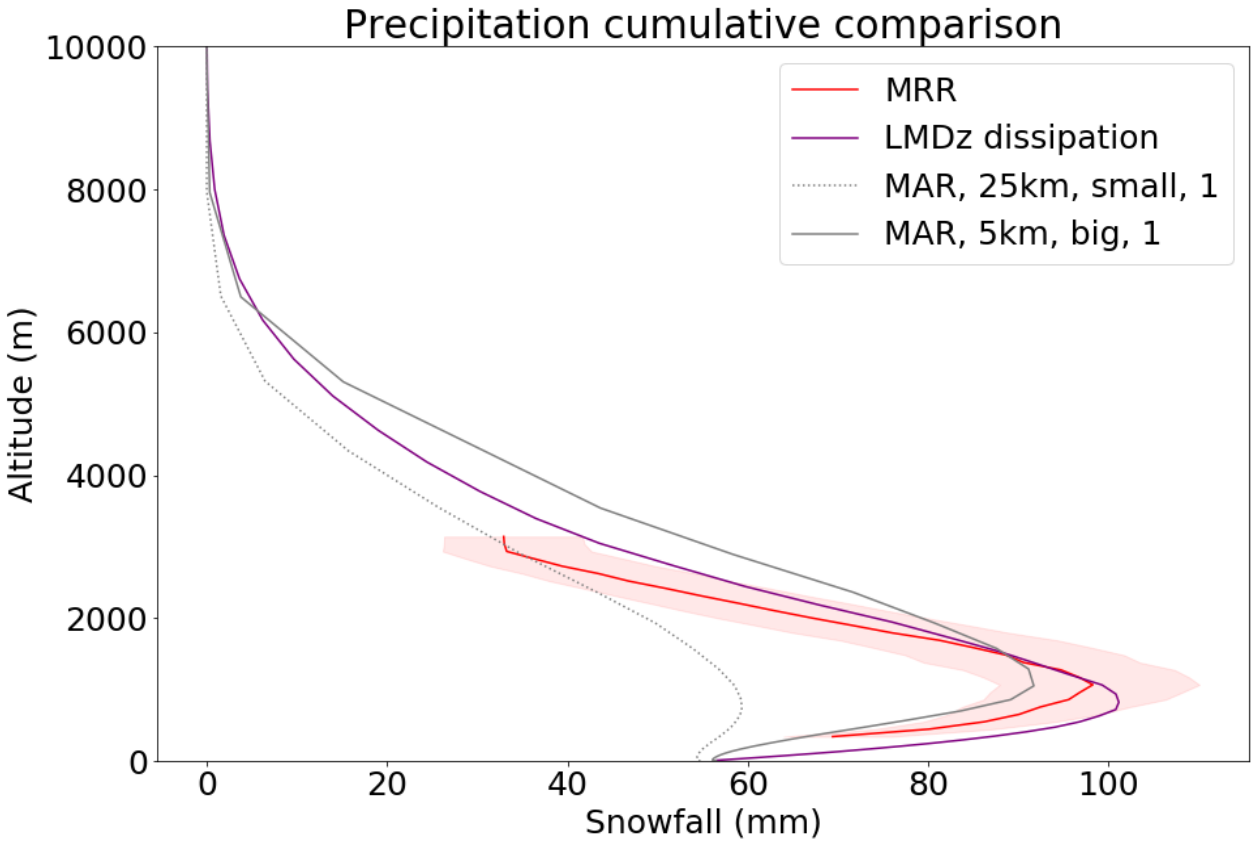
Discussion of results

To compare MAR and LMDz they must have the same domain and the same resolution, which is the case only for the simulation 'small' 25 km from MAR. But this simulation, unlike LMDz, does not simulate enough precipitation: the domain is too small for the mesoscale phenomena to take place.

MAR needs a large area and / or fine resolution to simulate near-reality precipitation

→ It would be interesting to make a large domain simulation: 1000km with LMDz in order to compare it with the 'big' simulation, 25km from MAR.

→ Dissipation strongly impacts precipitation in LMDz, so it is an important parameter to correctly predict climate in Antarctica.



Thank you for your attention !

If you have any specifics questions, please contact :

- Florentin Lemonnier : florentin.lemonnier@lmd.jussieu.fr
- Alizée Chemison : alizee.chemison@univ-grenoble-alpes.fr