AWACA

Atmospheric WAter Cycle over Antarctica

past, present & future

Antarctic Clouds: Evaluation of the LMDZ Atmospheric General Circulation Model using Satellite Observations

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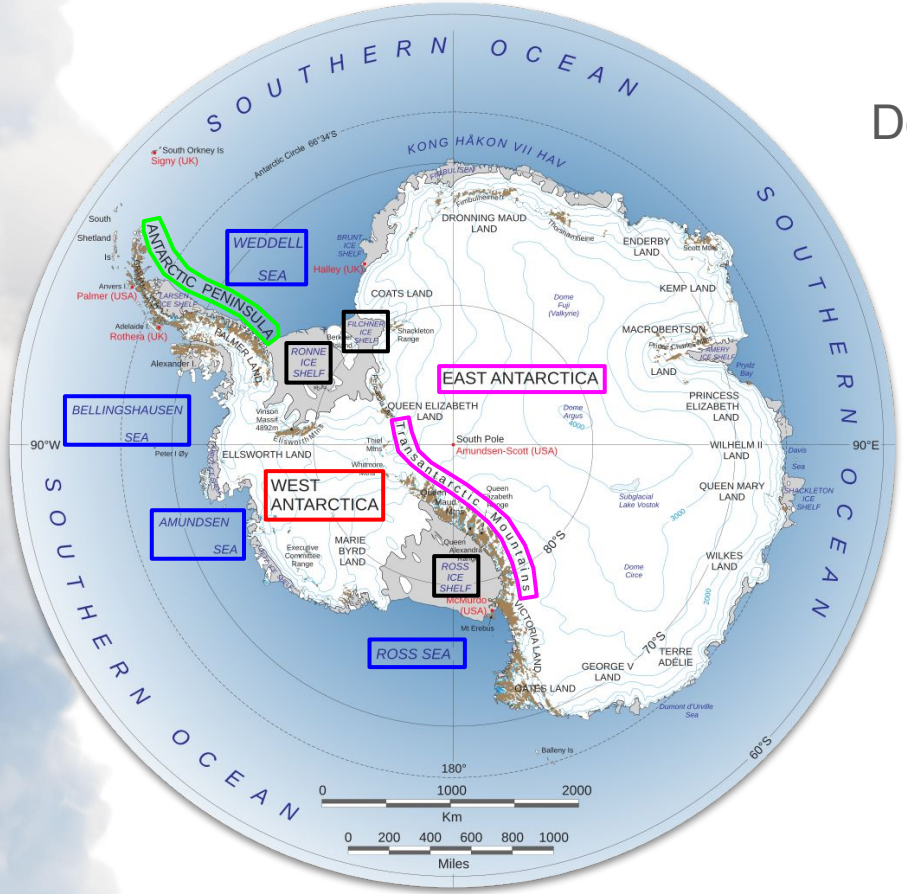
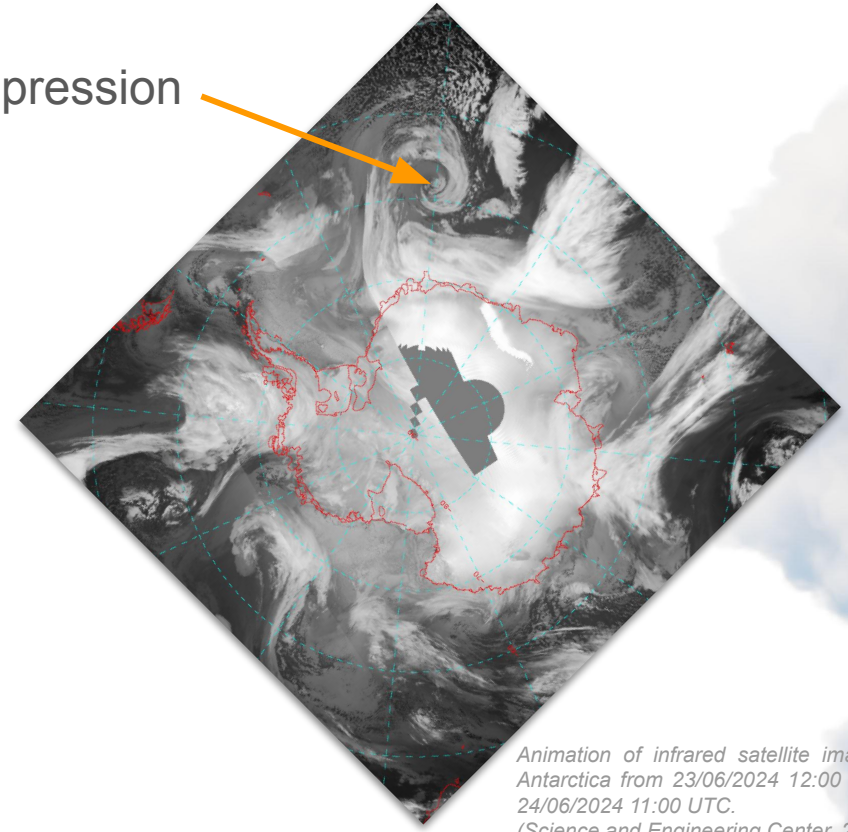
Antarctica and Its Climate



Map of Antarctica from the Landsat Image Mosaic of Antarctica Project

Depression



Animation of infrared satellite images of Antarctica from 23/06/2024 12:00 UTC to 24/06/2024 11:00 UTC.
(Science and Engineering Center, 2024)

Antarctica and Climate Change

Increase in precipitation

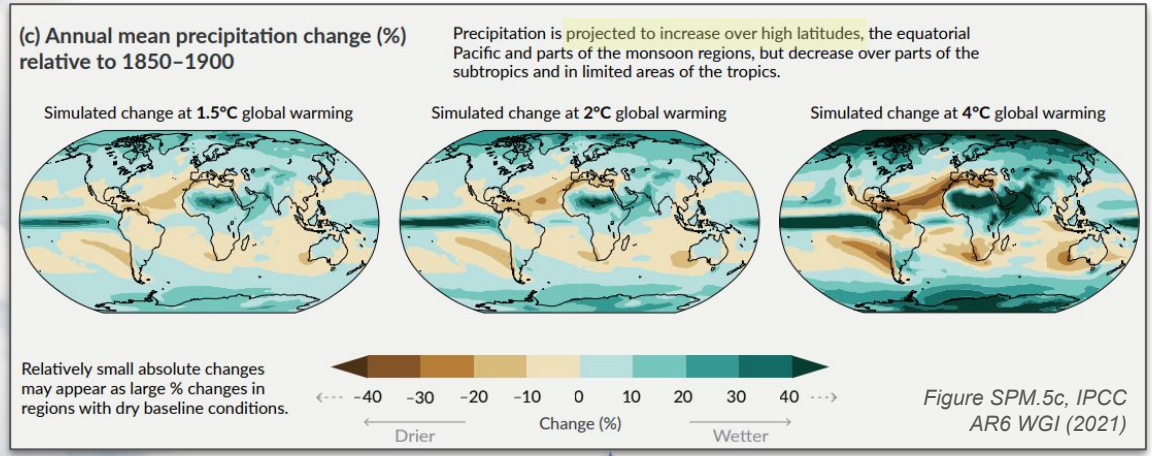


Figure SPM.5c, IPCC AR6 WGI (2021)

*"There is **high confidence** that **global mean precipitation** and evaporation **increase with global warming**, but the estimated rate is model-dependent."*

Citation IPCC (IPCC AR6 WGI, Chapter 8)

Sheet Mass Balance

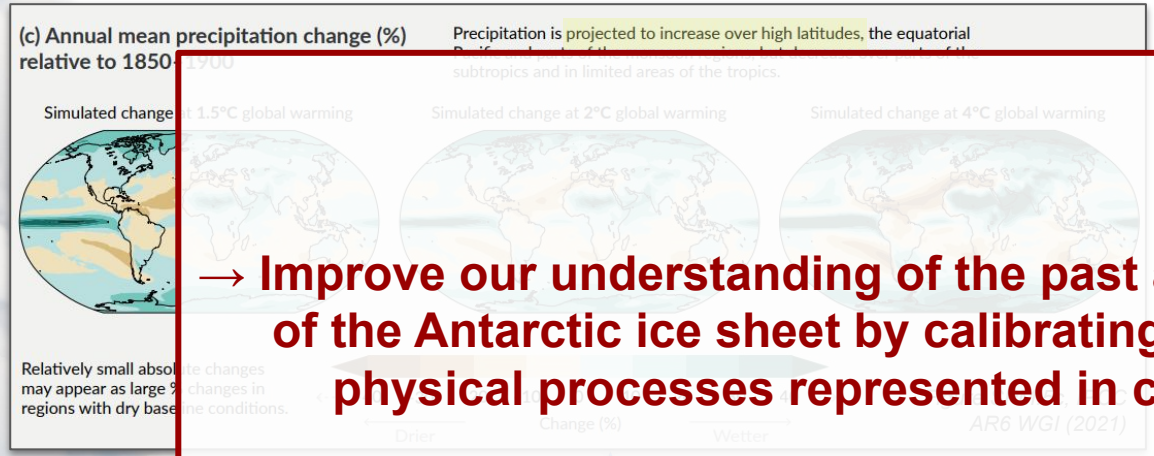
Global sea level

*"There is only **medium confidence** that the **future contribution of Antarctic SMB to sea level** this century will be **negative** under all greenhouse gas emissions scenarios."*

Citation IPCC (IPCC AR6 WGI, Chapter 9.4.2.3)

Antarctica and Climate Change

Increase in precipitation



*"There is **high confidence** that **global mean precipitation** and evaporation **increase with global warming**, but the [illegible] **confident**."*
Citation IPCC (IPCC AR6 WGI, Chapter 8)

→ Improve our understanding of the past and future evolution of the Antarctic ice sheet by calibrating and refining the physical processes represented in climate models

Sheet Mass Balance

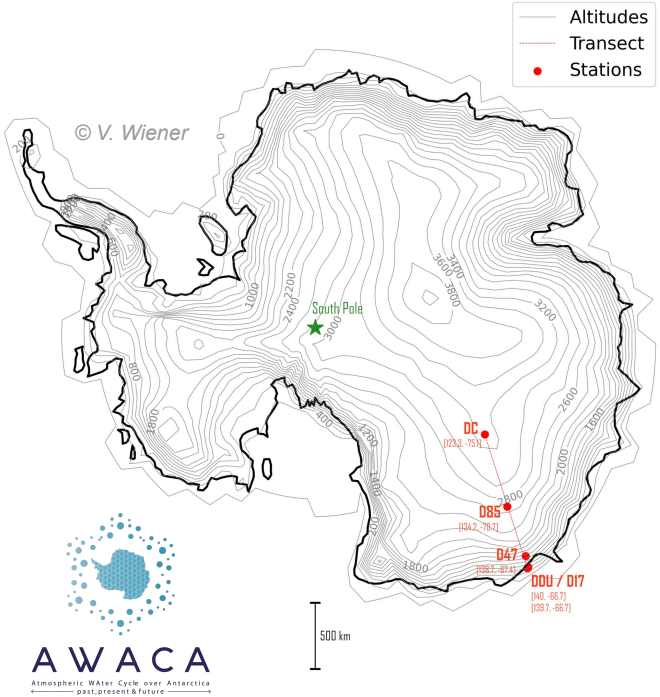
Global sea level

*"There is only **medium confidence** that the **future contribution of Antarctic SMB to sea level** this century will be **negative** under all greenhouse gas emissions scenarios."*
Citation IPCC (IPCC AR6 WGI, Chapter 9.4.2.3)

The AWACA project

https://awaca.ipsl.fr/

Scan Me



Observations in Antarctica are **rare**, especially along the coast and during summer.

AWACA involves the installation of:

- 4 autonomous observation platform units (OPUs)
- 4 meteorological towers, 7 meters high

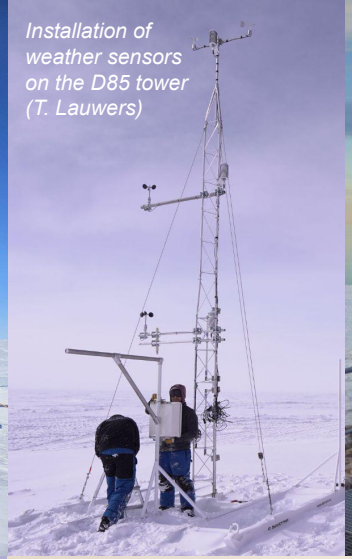
along a 1,100 km transect between the coastal Adélie Land and the Dome C Plateau.

The OPUs operate year-round and measure:

- condensed water in the atmosphere
- water vapor and isotopes of snowflakes

Additional instruments are located at the Dumont d'Urville (DDU) station.

OPU of D17 with the weather station (A. Berne)

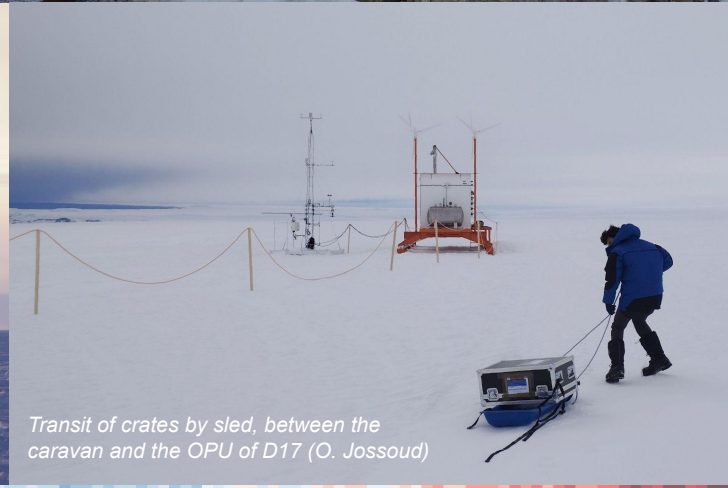


Installation of weather sensors on the D85 tower (T. Lauwers)

Wind profiler installed at Dumont d'Urville (A. Berne)

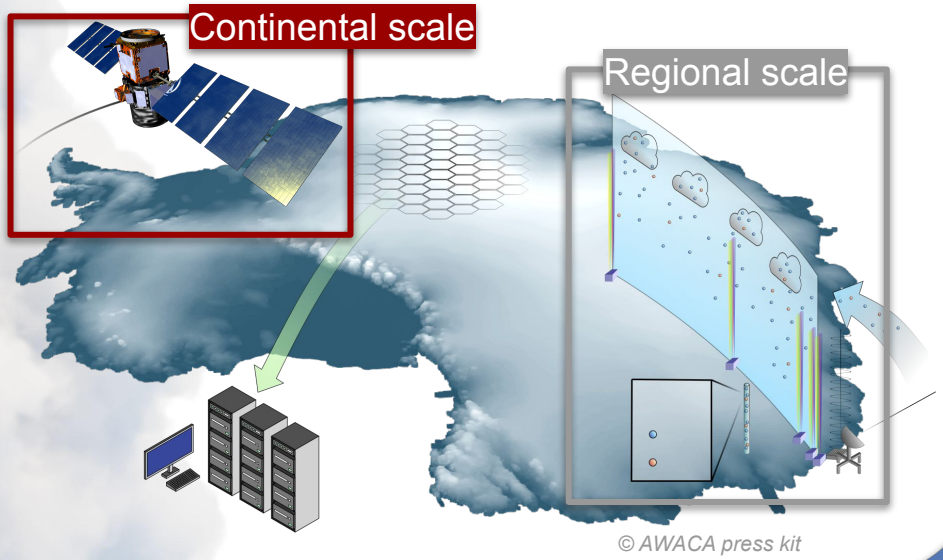
OPU of D85 north face (T. Lauwers)

OPU of D85 on its trailer with ski, photo taken at D47 (T. Lauwers)



Transit of crates by sled, between the caravan and the OPU of D17 (O. Jossoud)

Evaluating the representation of Antarctic clouds in LMDZ



© AWACA press kit

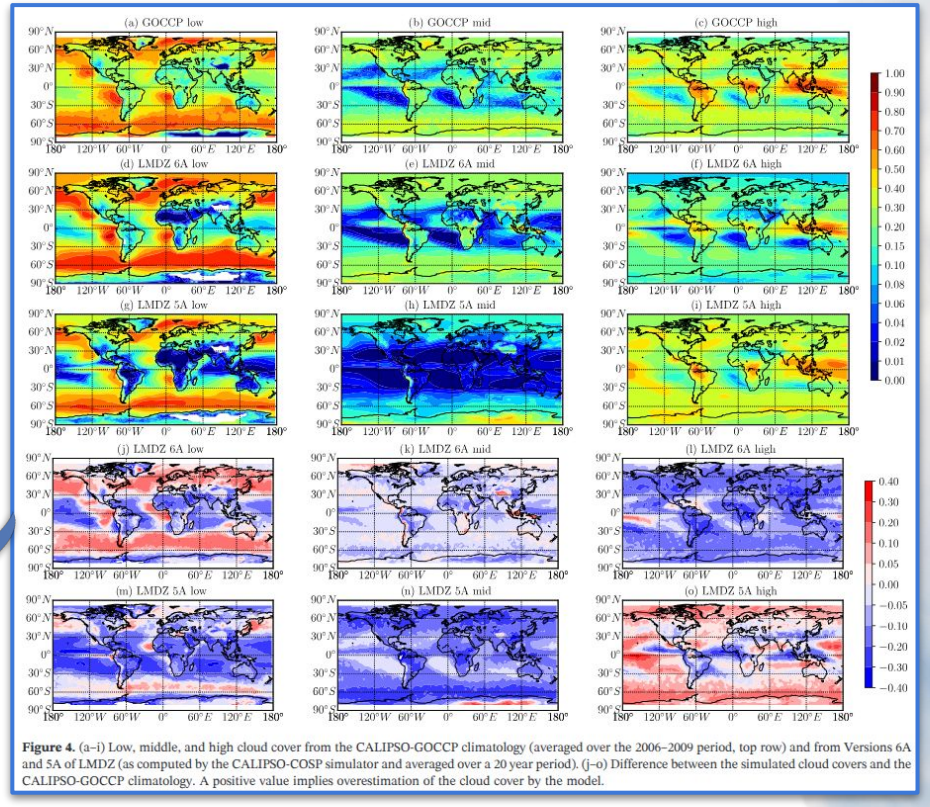


Figure 4. (a–i) Low, middle, and high cloud cover from the CALIPSO-GOCCP climatology (averaged over the 2006–2009 period, top row) and from Versions 6A and 5A of LMDZ (as computed by the CALIPSO-COSP simulator and averaged over a 20 year period). (j–o) Difference between the simulated cloud covers and the CALIPSO-GOCCP climatology. A positive value implies overestimation of the cloud cover by the model.

Global-scale findings *(Madeleine et al., 2020)*

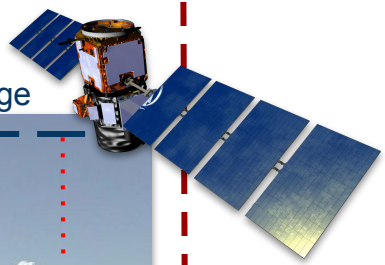
- Improved distribution of low and medium clouds, overestimated cover at high latitudes
- Underestimated high-level cover

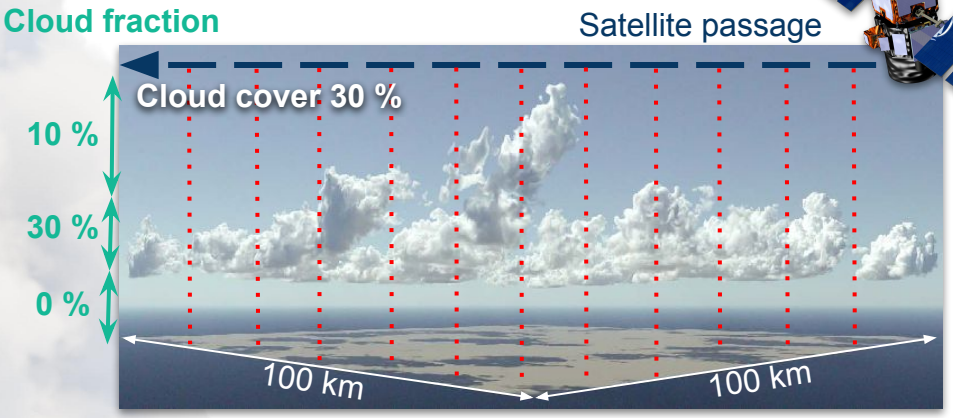
What about Antarctica?

- Bias between LMDZ-simulated data and CALIPSO satellite observations
- Testing the origin of the observed biases

CALIPSO satellite

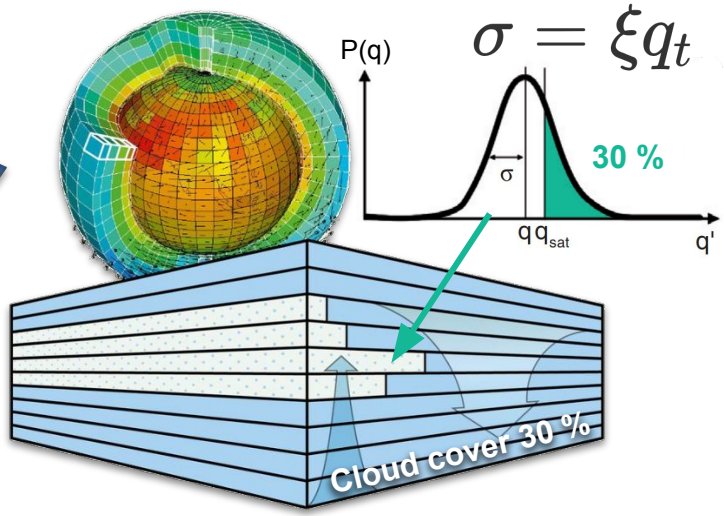
Artist's view of the CALIPSO satellite (NASA)





A pass of the CALIPSO satellite with laser shots from the CALIOP lidar, adapted from Hourdin (2024).

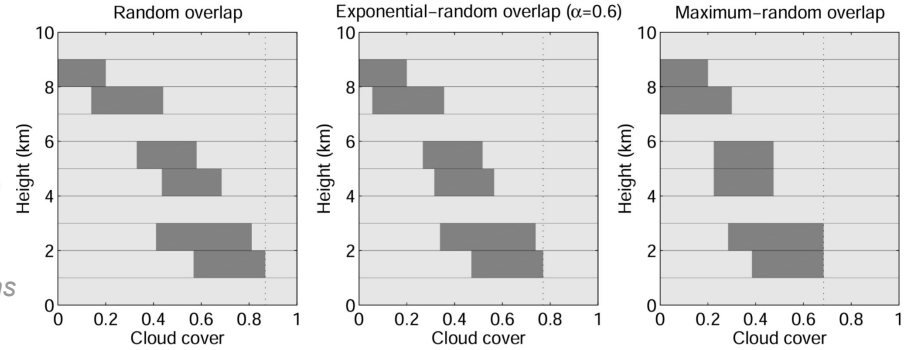
LMDZ climate model



The different vertical levels of LMDZ and a cloud distribution calculated by the model, adapted from Hourdin (2024)

2 key variables:
- cloud fraction (3D)
- cloud cover (2D)

Cloud overlap assumptions



3 possible overlap assumptions (Hogan and Shonk, 2008)

Simulation configuration, time period, common grid

Global LMDZ nudged simulation

- LMDZ 6a version
- AMIP CMIP6 (prescribed SST and sea ice)
- Land surface coupling with ORCHIDEE
- Nudged in wind and temperature
- Includes COSP simulator
- Grid 144 (lon) x 142 (lat) x 79 (levels)

Satellite CALIPSO

- GOCCP product
- Grid 180 (lon) x 90 (lat) x 40 (levels)

Time period

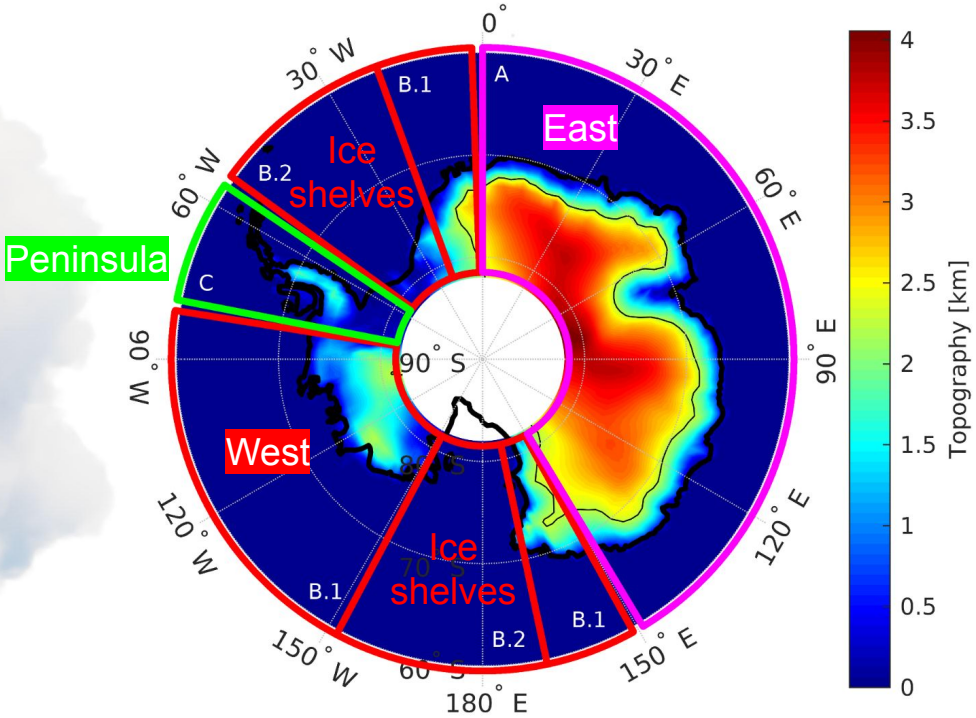
2011-2020
(excluding 2016)

Common grid
(interpolated)

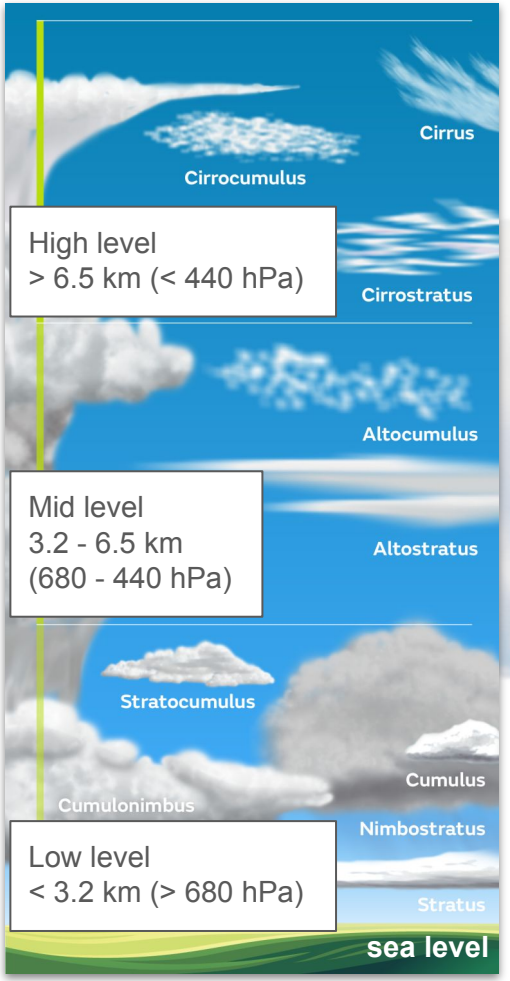
144 x 90 x 40

CMIP *Climate Model Intercomparison Project*
AMIP *Atmospheric Model Intercomparison Project*
GOCCP *General Circulation Models Oriented Cloud CALIPSO Product*
COSP *Cloud Feedback Model Intercomparison Project (CFMIP) Observation Simulator Package*

Study areas and cloud cover



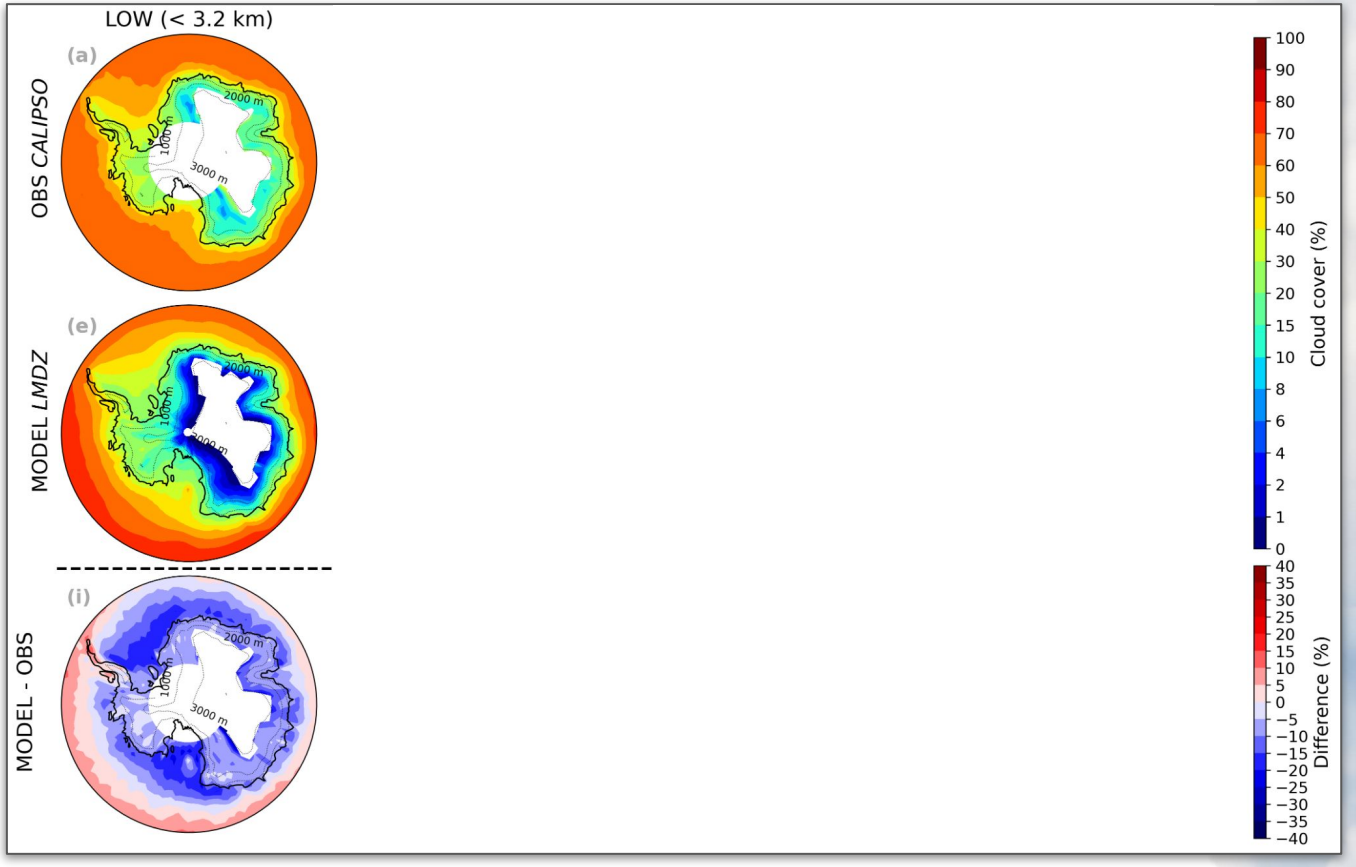
Topography of the Antarctic ice sheet and the four studied areas, adapted from Lemonnier (2019).



Cloud cover altitudes, based on the ISCCP classification. Adapted from the Met Office.

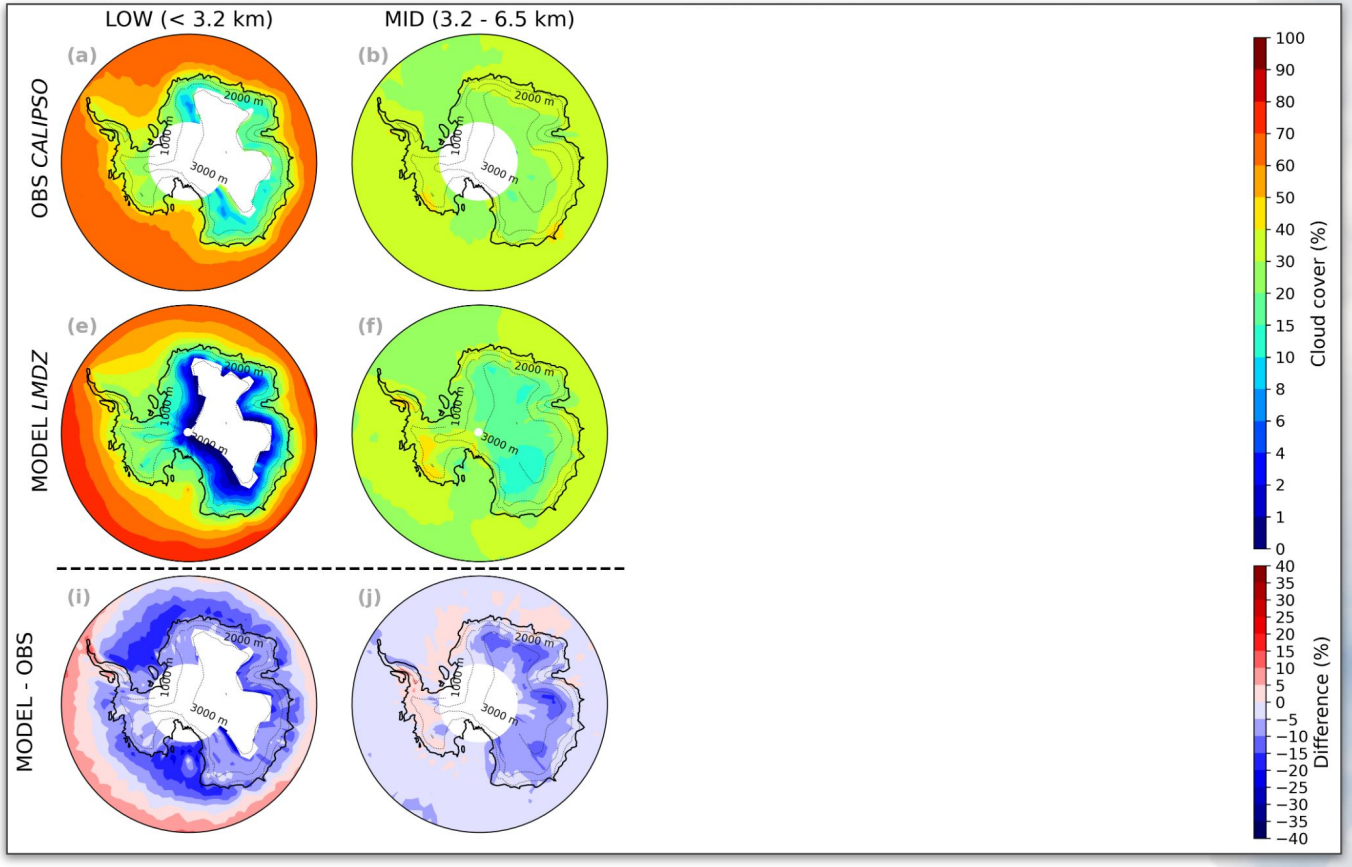
Cloud cover climate maps

	Austral ocean	Continent
Low		



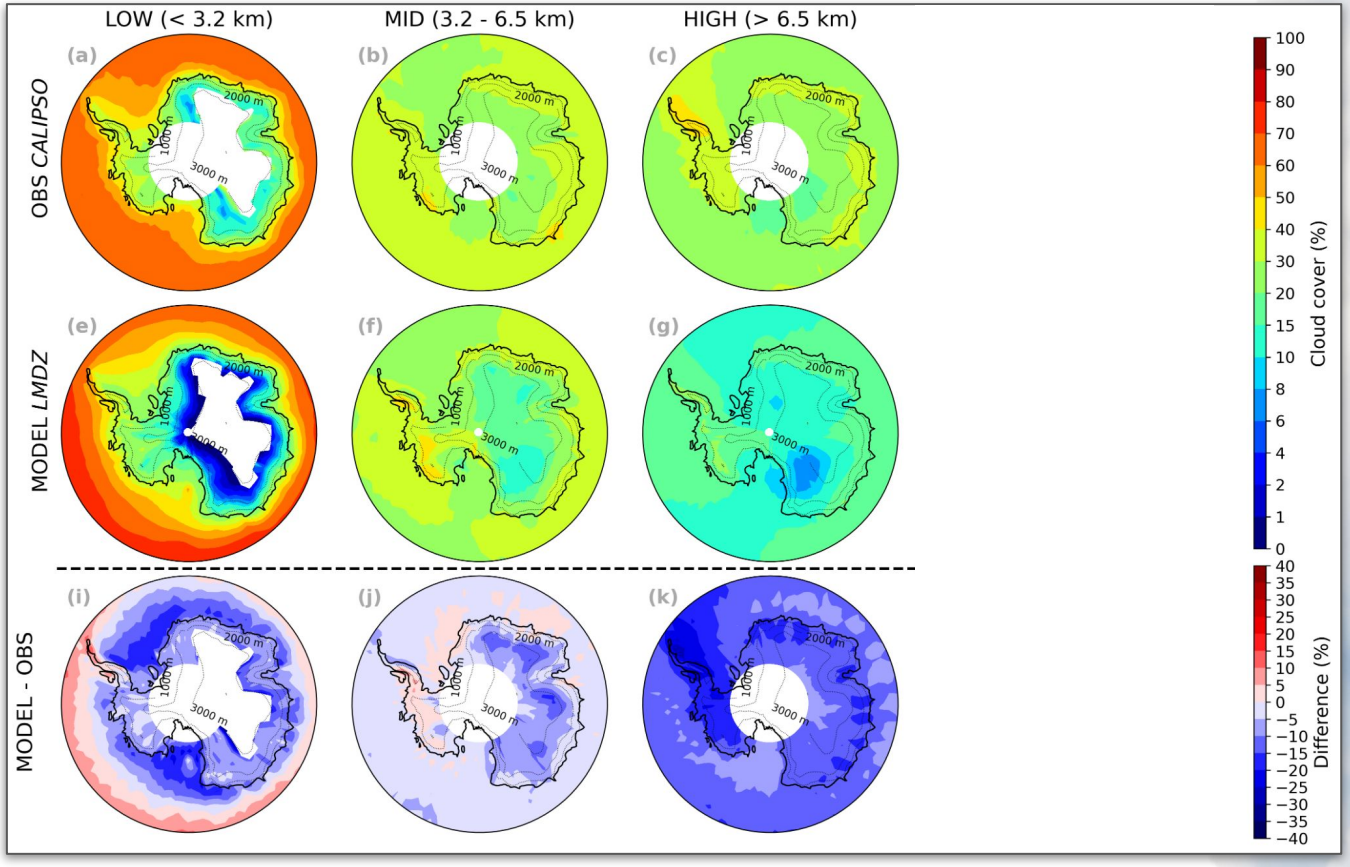
Cloud cover climate maps

	Austral ocean	Continent
Mid		
Low		



Cloud cover climate maps

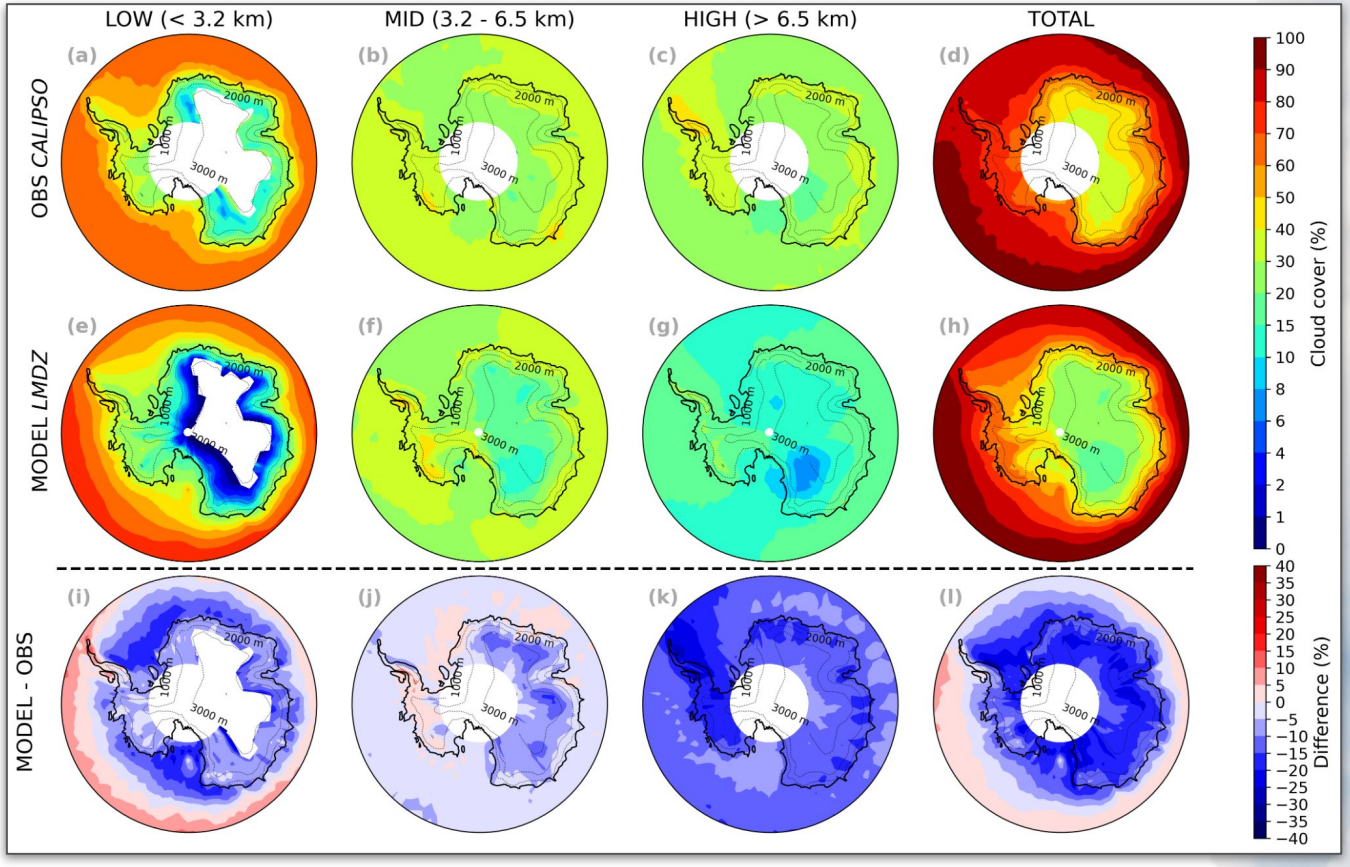
	Austral ocean	Continent
High		
Mid		
Low		



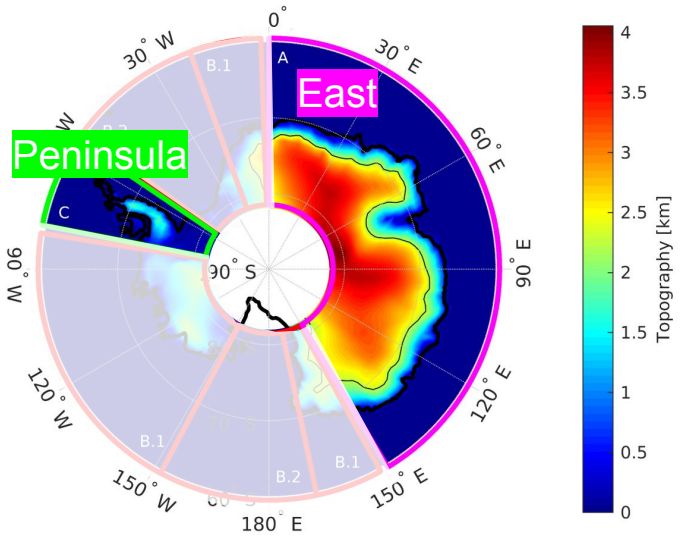
Cloud cover climate maps

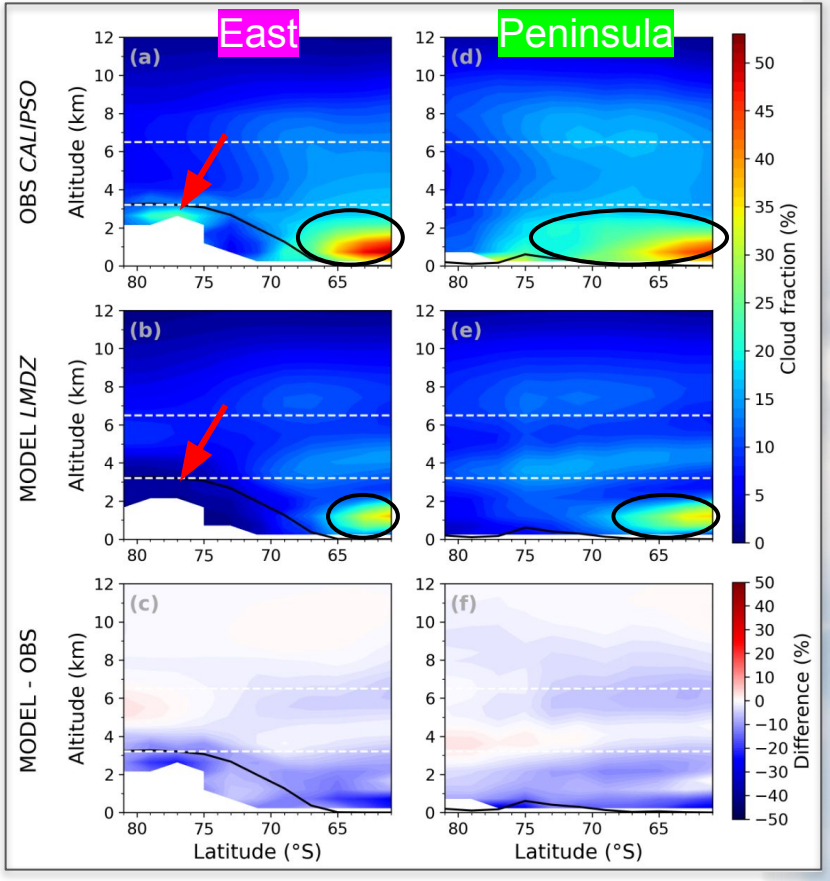
	Austral ocean	Continent
High		
Mid		
Low		

coasts/continent



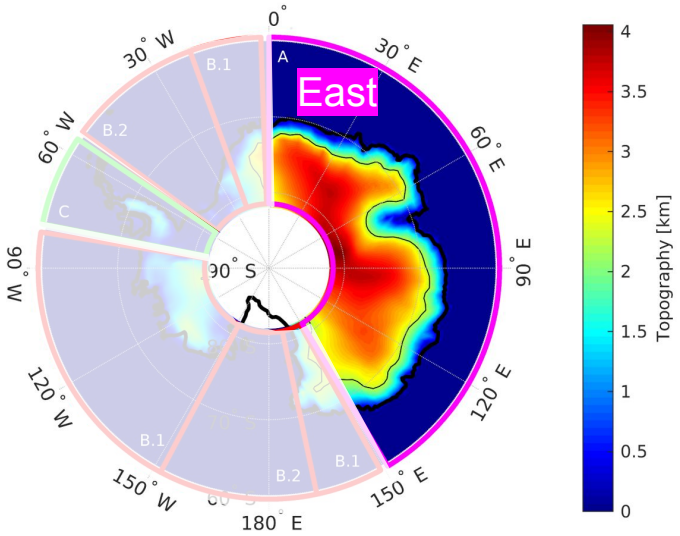
Low clouds over the coasts

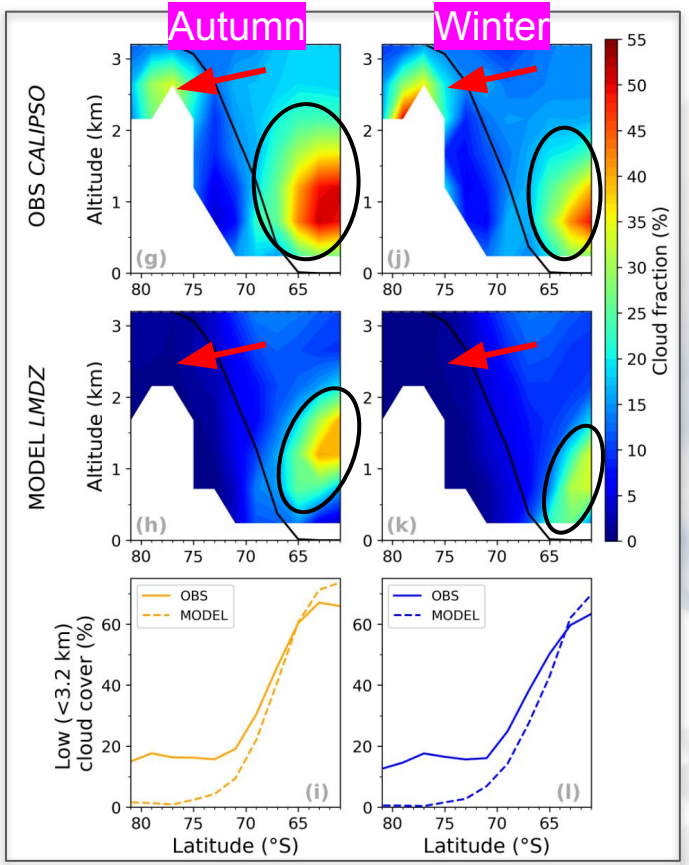




- Good altitude
- Lack of fraction
- Difficulty reaching the coasts
- On East shelf, complete absence of fraction

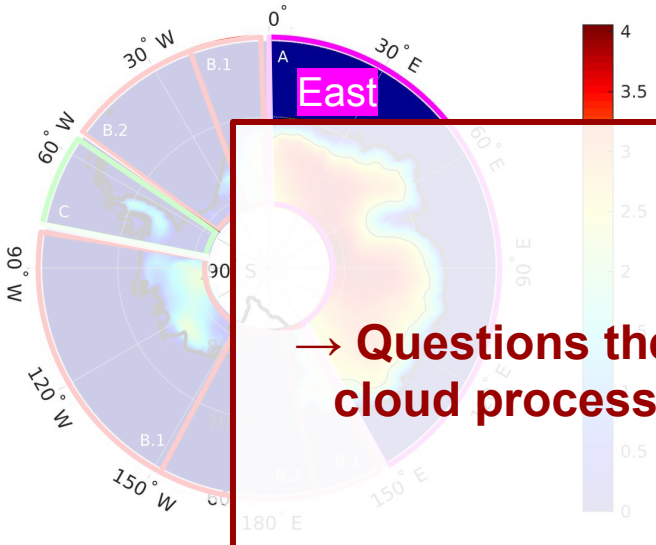
Low clouds over the East in Autumn and Winter

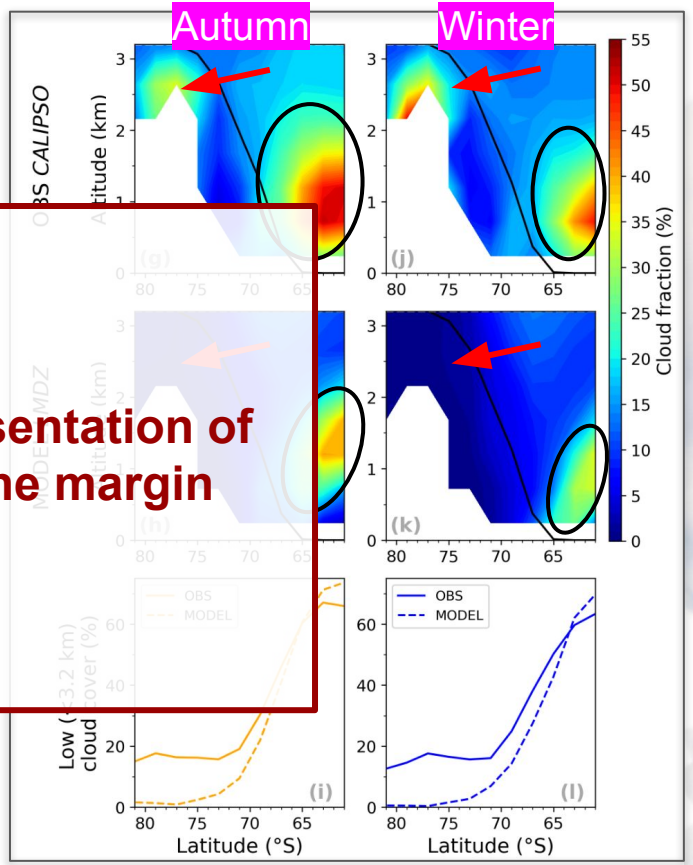




- Clouds over the Transantarctic Mountains in autumn and winter are not modeled
- Incorrect cloud altitude in autumn and winter
- Cloud fraction decreases near the coasts
- Bias also present in cloud cover

Low clouds over the East in Autumn and Winter

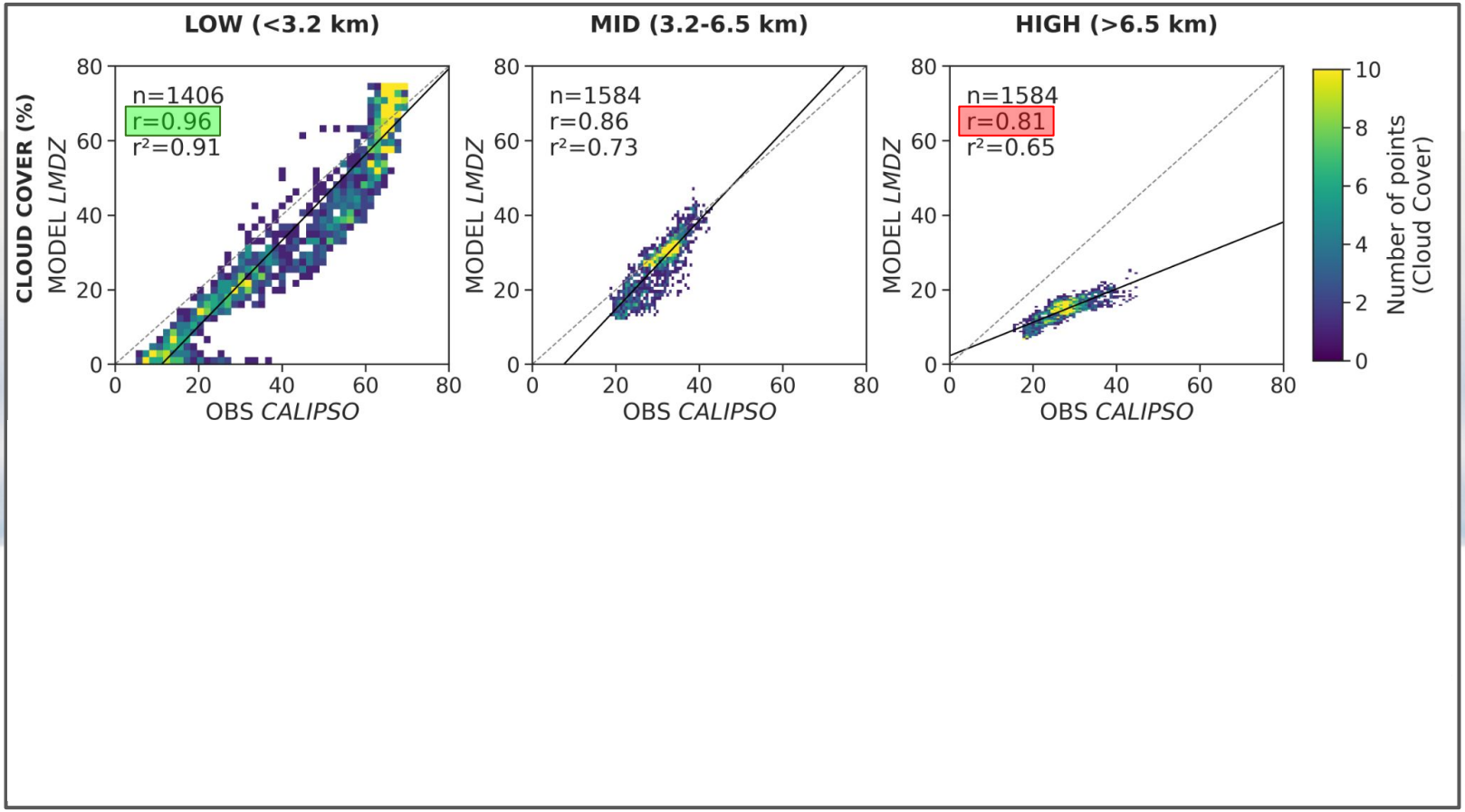




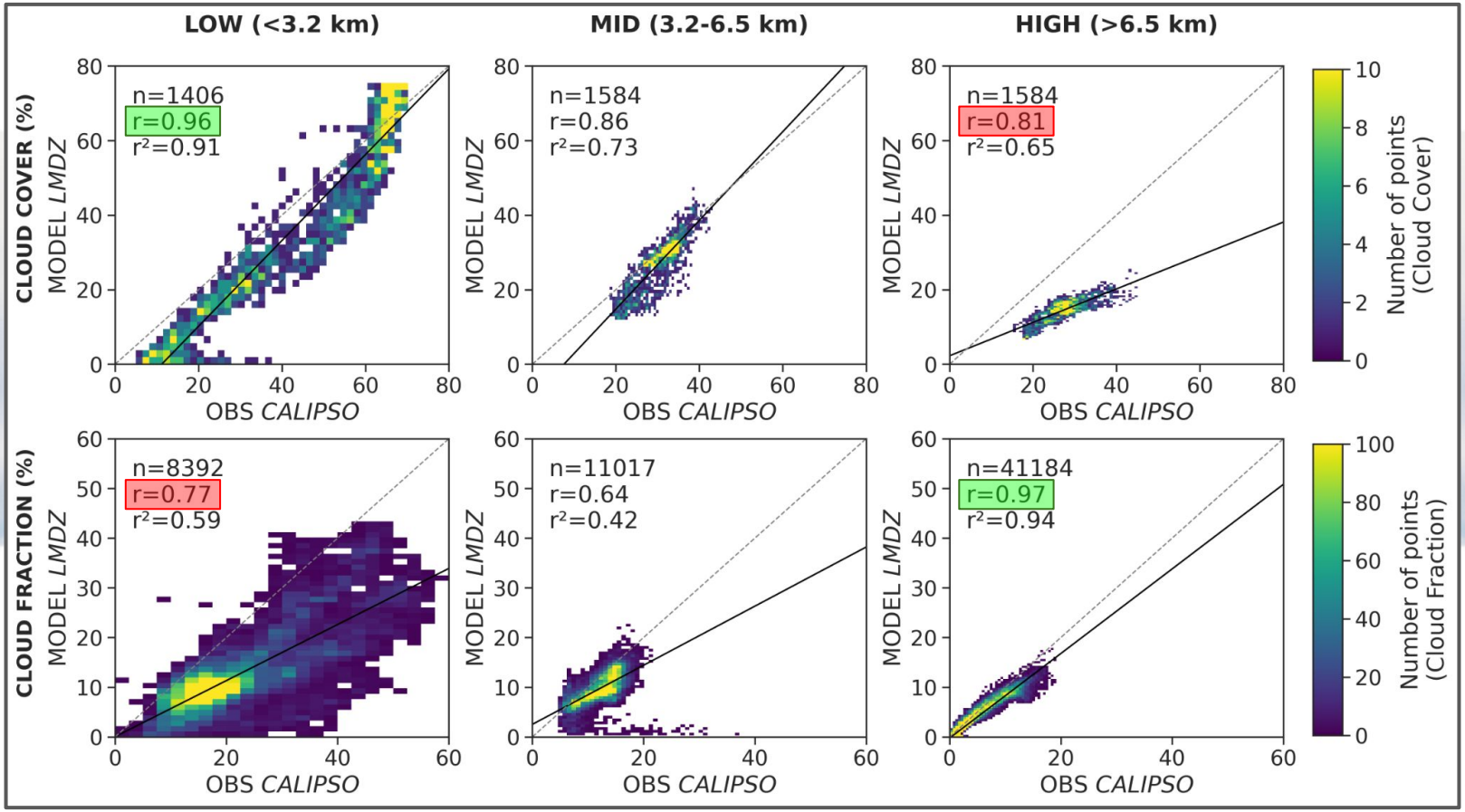
→ **Questions the representation of cloud processes on the margin**

- Clouds over the Transantarctic Mountains in autumn and winter are not modeled
- Incorrect cloud altitude in autumn and winter
- Cloud fraction decreases near the coasts
- Bias also present in cloud cover

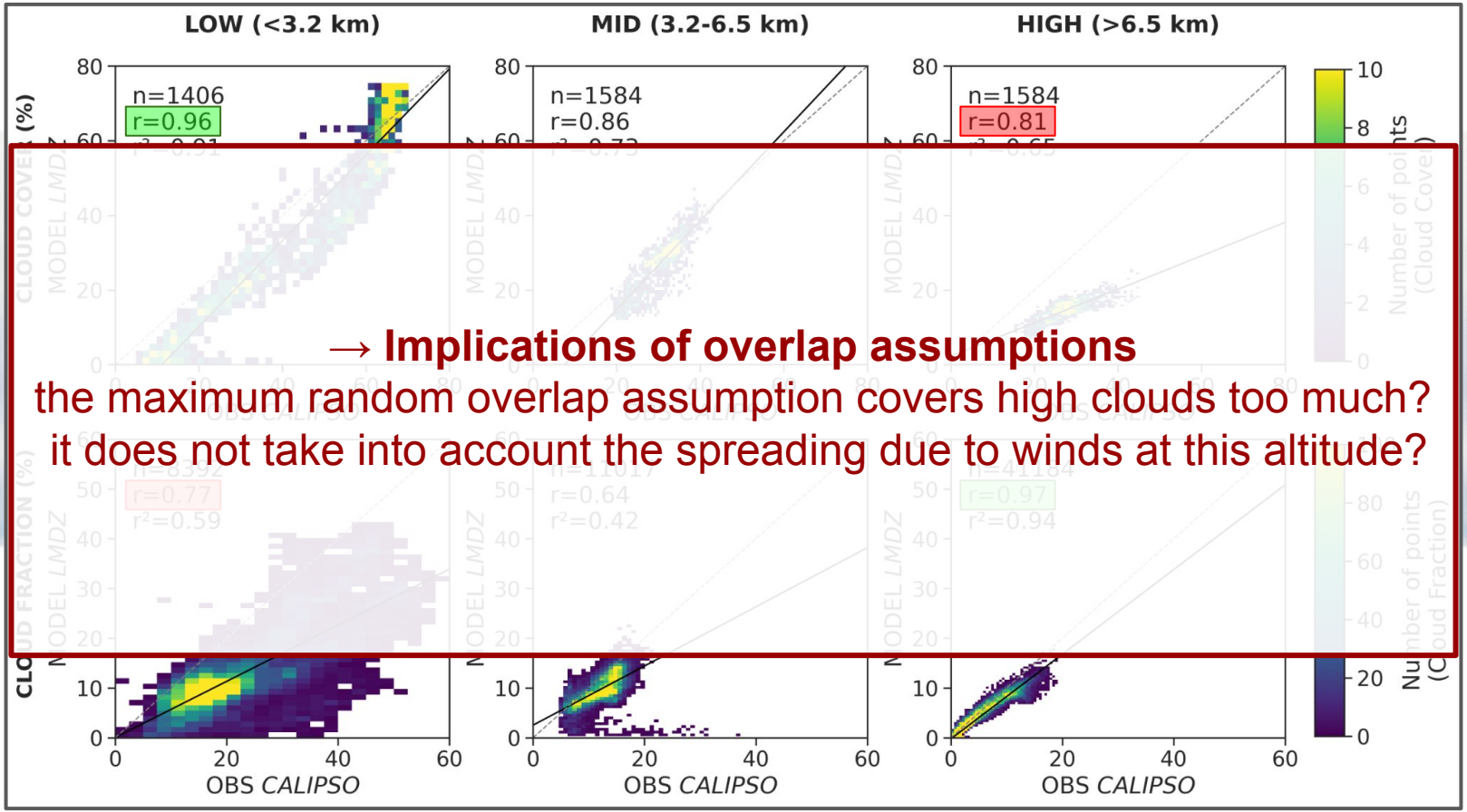
Correlation of observed and simulated cloud cover/fraction



Correlation of observed and simulated cloud cover/fraction



Correlation of observed and simulated cloud cover/fraction



→ **Implications of overlap assumptions**

the maximum random overlap assumption covers high clouds too much?

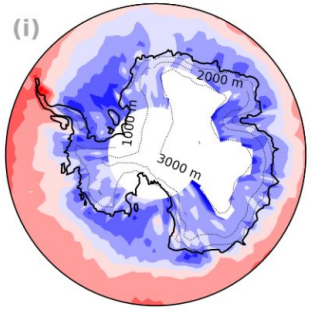
it does not take into account the spreading due to winds at this altitude?

Summary & perspectives

1 OROGRAPHIC CHALLENGE

Not enough low clouds on the coasts and platforms

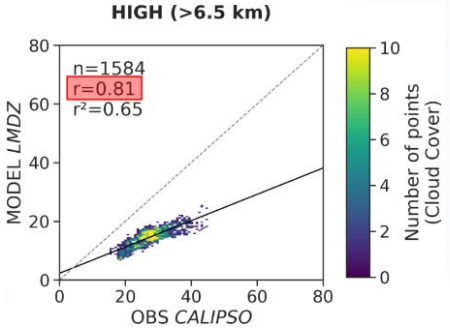
- ➔ check the 2m-temperature on the ice shelves
- ➔ need to modeling leads?
- ➔ everything precipitate before reaching the coast?



2 OVERLAP ASSUMPTIONS

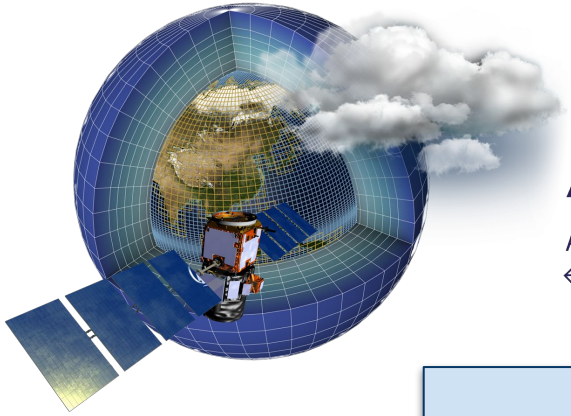
Maybe the maximum random overlap assumption do not spread high clouds enough

- ➔ sensitivity experience by changing the overlap assumption (insert a wind dependency?)



Long-term perspectives:

moving to a regional scale (*ICOLMDZLAM*) with new parameterizations (*mixed-phase, precipitation*) to evaluate clouds with AWACA field data



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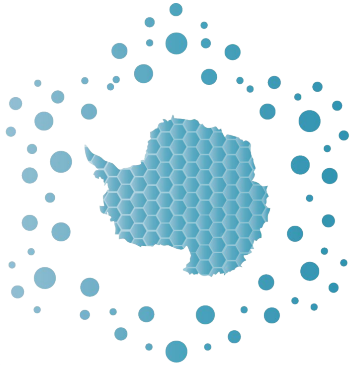

Thank you for your attention.

Your questions are welcome!

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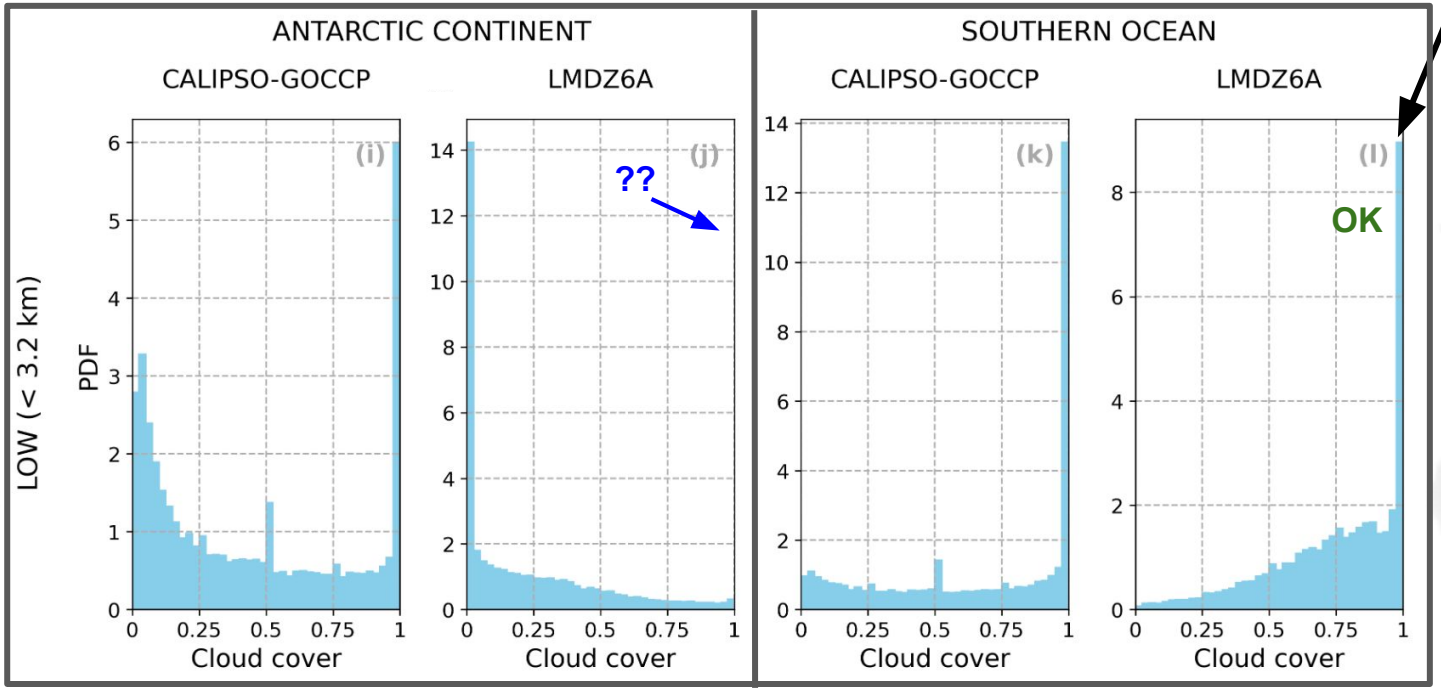
Funded by the European Union

Modeling of very cloudy clouds

Very covering stratocumulus?



➢ Over the continent, there is no 100% cloud cover in the model.

NB: on this figure the LMDZ simulation isn't nudged

Dry environment → all or nothing?

Cloud fraction