Assessing the cloud representation of ARPEGE and LMDZ using multiple overpasses of CloudSat-CALIPSO over an Arctic cyclone

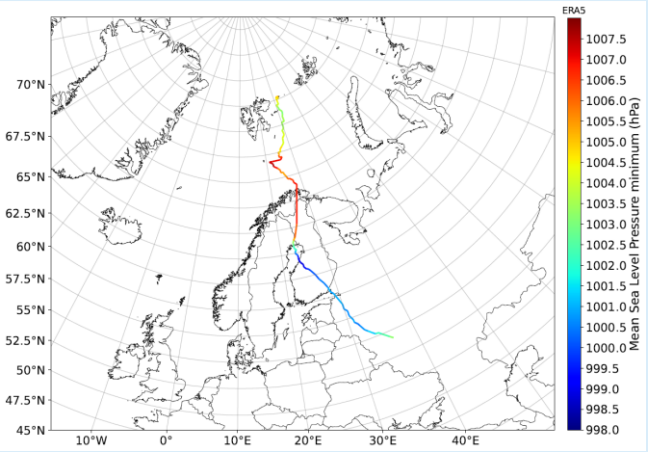
Meryl WIMMER[1,2],
Clémantyne AUBRY[3,4], Gwendal RIVIERE[2], Julien DELANOË[4], Éric BAZILE[5], Etienne VIGNON[2], Lukas HOFMANN[2]

[1] CNES, [2] LMD-CNRS, [3] DLR, [4] LATMOS, [5] CNRM / Météo-France & CNRS

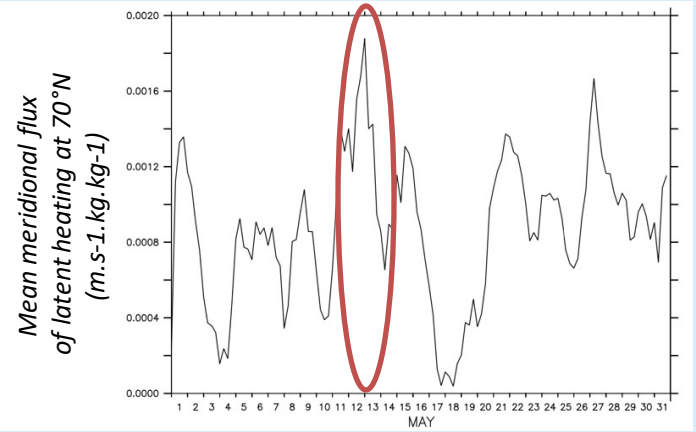
Contact : meryl.wimmer@lmd.ipsl.fr

Study Case:
Arctic Cyclone in May 2019

- Born: 05/09/2019 in Russia
- End: 05/16/2019 near Svalbard
- Arctic Cyclone characteristics:
  - Long life
  - Small deepening
  - Bring humidity in Arctic Area
  - Arctic Cyclone in the flight area of ATR42 during THINICE
  - 20 overpasses of CloudSat and CALIPSO
  - Availability of DARDAR products and ARPEGE forecasts

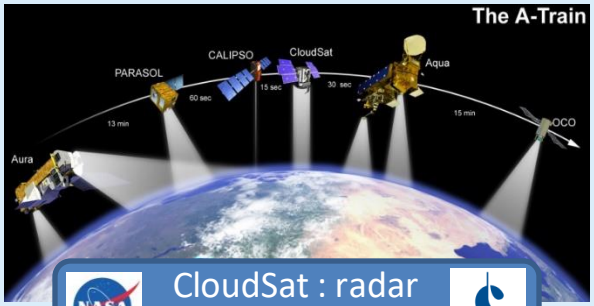


Minimum of MSLP during the Arctic cyclone trajectory (ERA5 data)



Mean meridional flux of latent heating at 70°N (ERA5 data)

VarPy: DARDAR products



CloudSat : radar
CALIPSO : lidar

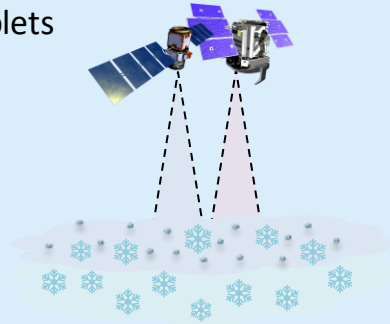
VarPy

- IWC, LWC
- Hydrometeores categorization

Delanoë and Hogan (2008, 2010), Clémantyne AUBRY's PhD

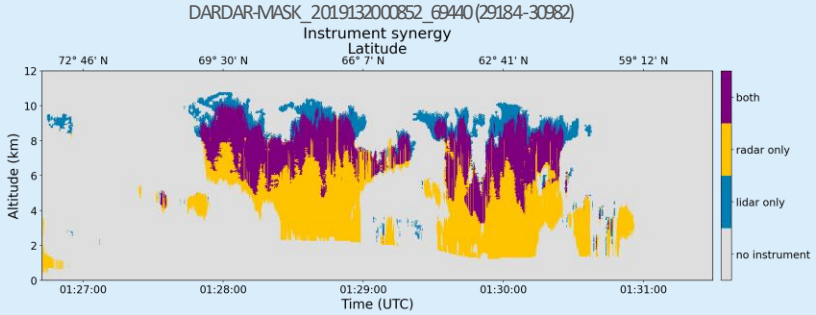
Lidar:

- Sensitive to concentration of small particules
- Detects small cristals and liquid droplets
- Use to determine LWC and IWC

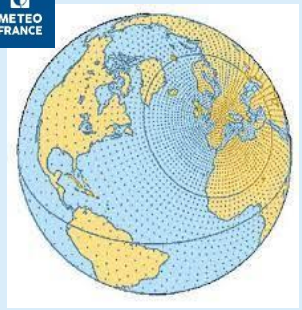


Radar:

- Sensitive to diameter of particules
- Detects ice cristals
- Use to determine IWC



Atmospheric models

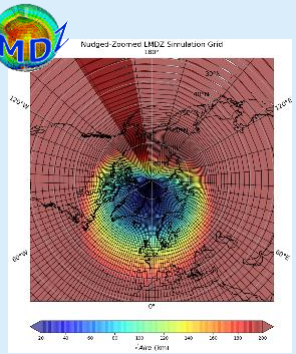


ARPEGE

Resolution: 5-24km, 105 levels

Initialisation: 4DVar (05/11/2019 at 0UTC)

Type of simulation: “Free” Forecast



LMDZ

Resolution: Zoom configuration with 50km in Svalbard, 95 levels

Initialisation: ERA5 (05/11/2019 at 0UTC)

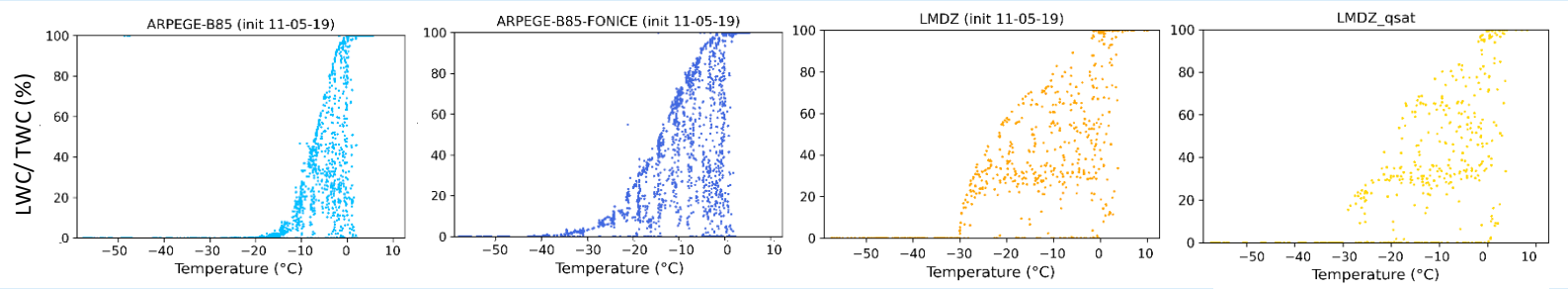
Type of simulation: nudging to ERA5 outside the zoom

Simulations:

- Operational liquid/ice partition function
- liquid/ice partition function tested in Ricaud et al. (2020)

Simulations:

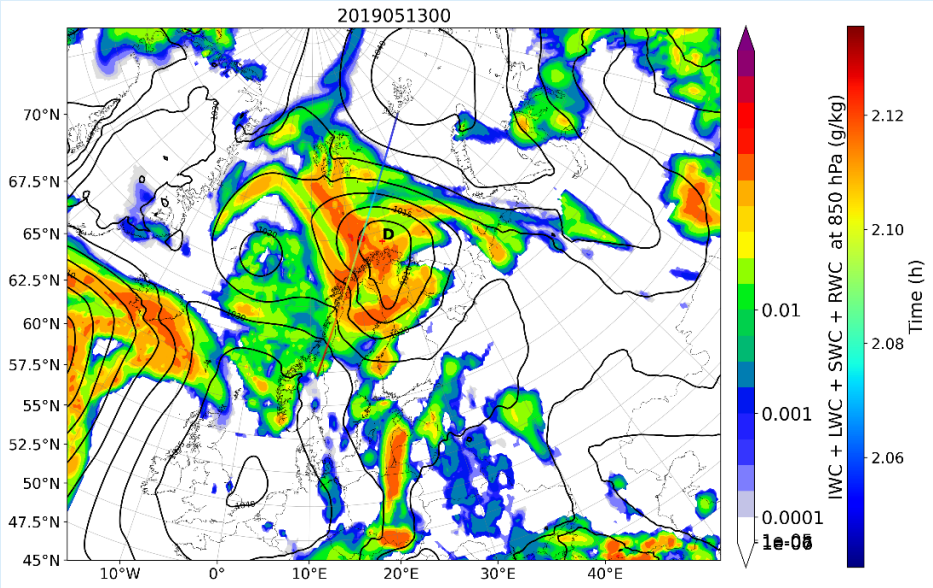
- CMIP5 version
- ratqs=0.002 (standard deviation of the sub-grid humidity distribution)



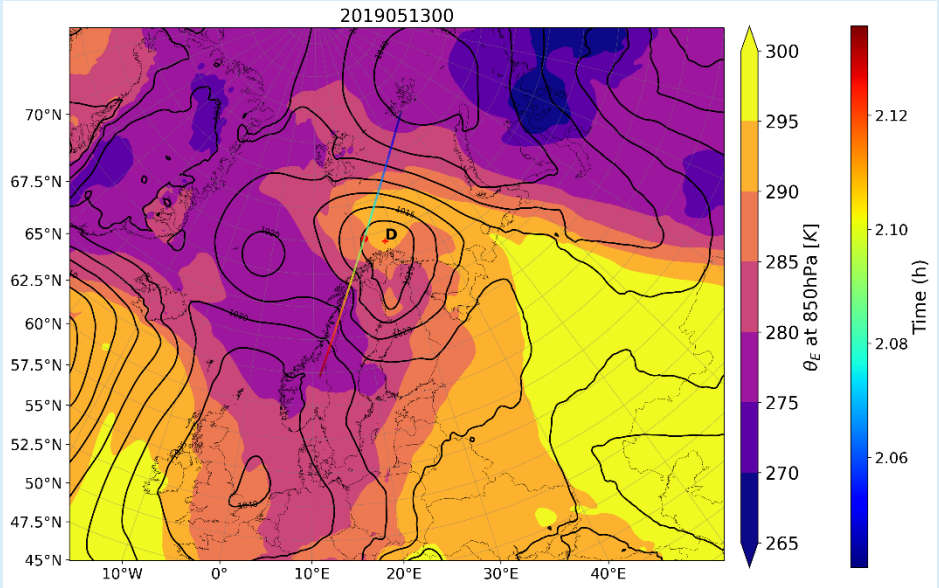
Outputs: time: 3h ; lonxlat : 0,5° x 0,5° ; 18 pressure levels

Example of one satellites overpass: 2019133004652_69455

ERA5 : 20190513 0UTC



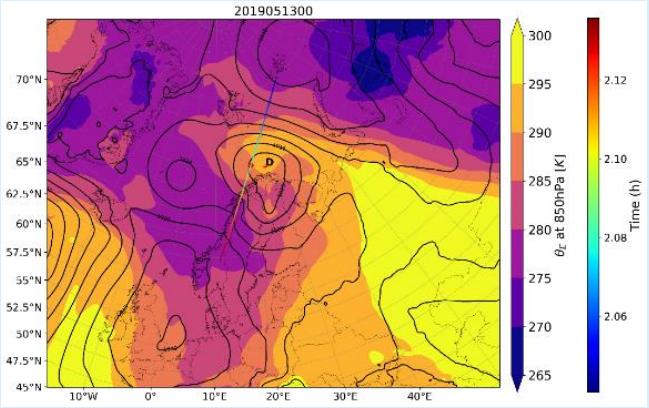
Shading: TWC at 850hPa (g.kg^{-1}) ; black contours: MSLP (hPa) ; coloured line: time along satellites overpass



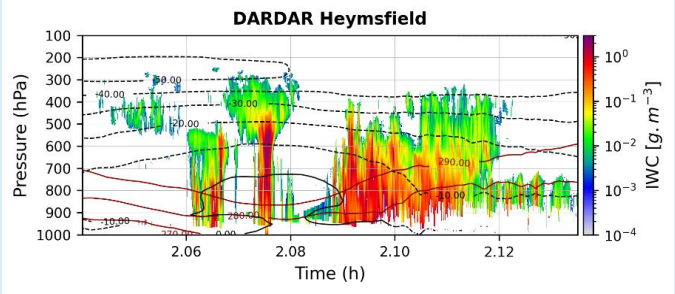
Shading: θ_E at 850hPa (K) ; black contours: MSLP (hPa) ; coloured line: time along satellites overpass

Overpass #2019133004652_69455 : crossing cold and warm front

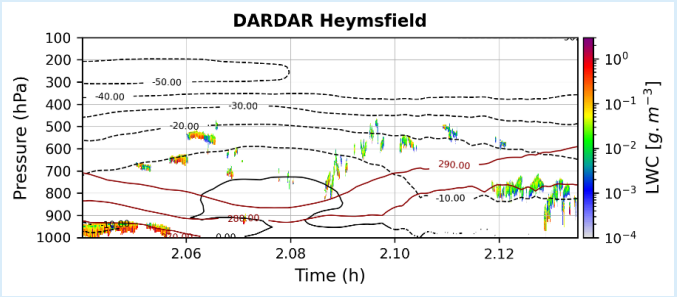
DARDAR Data



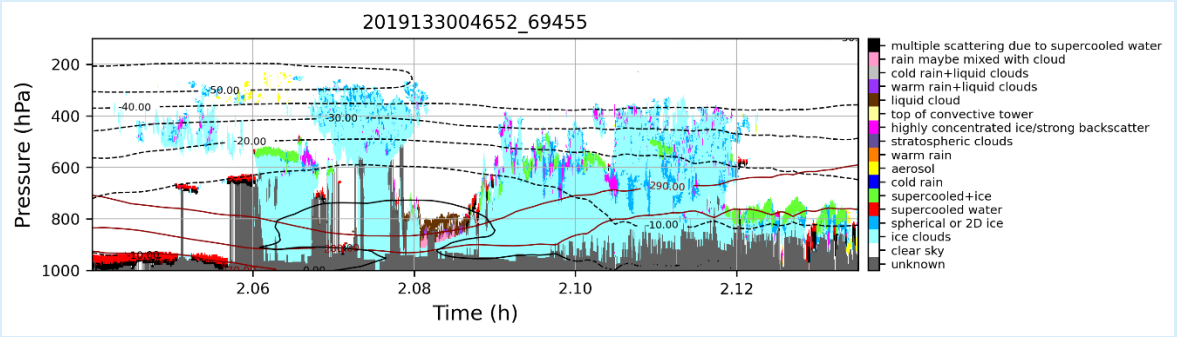
Shading: θ_E at 850hPa (K) ; black contours: MSLP (hPa) ; coloured line: time along satellites overpass



Shading: IWC ($g.m^{-3}$) ; black contours: Temperature (°C) ; red contours: θ_E(K)



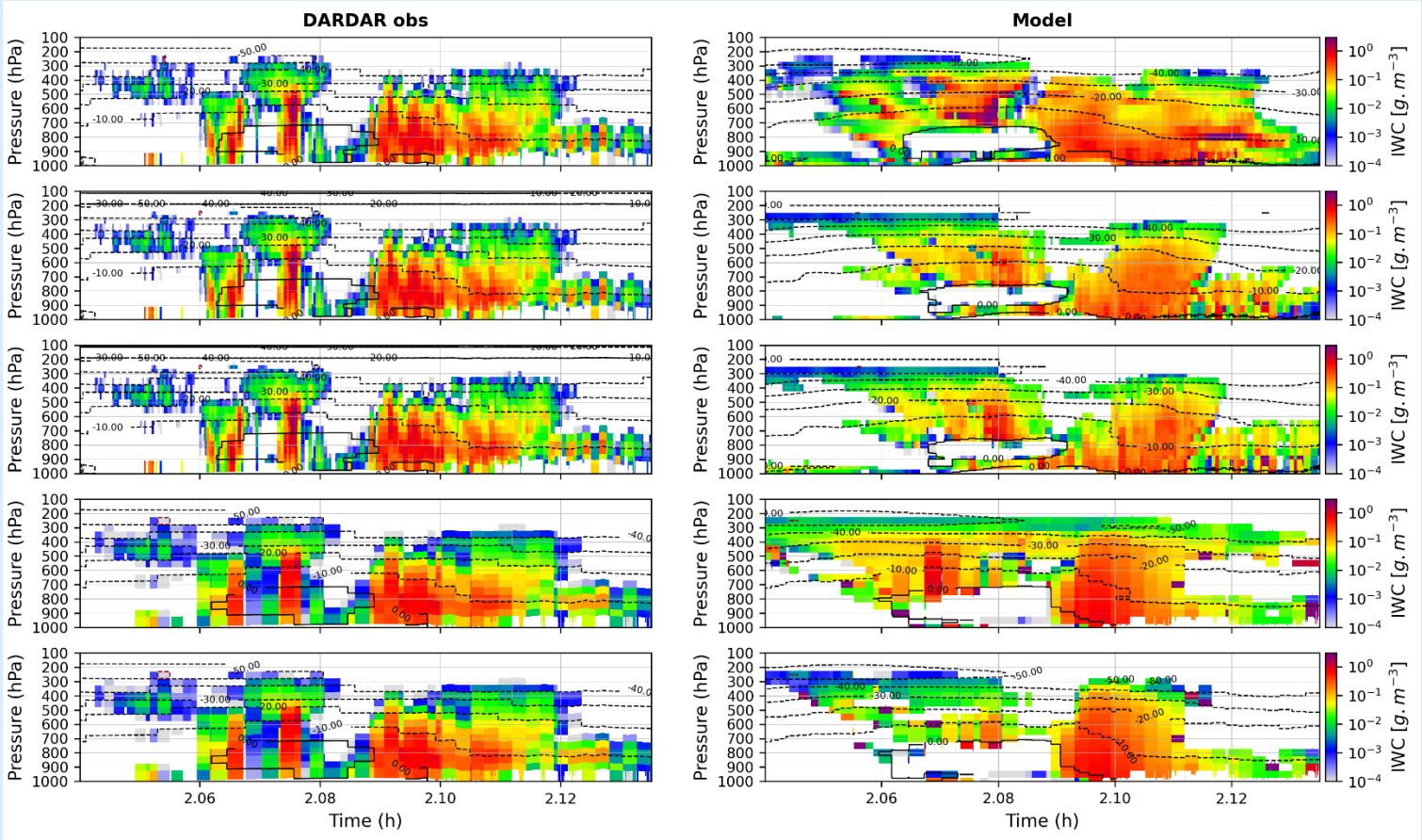
Shading: LWC ($g.m^{-3}$) ; black contours: Temperature (°C) ; red contours: θ_E(K)



Shading: Hydrometeors categorization ; black contours: Temperature (°C) ; red contours: θ_E (K)

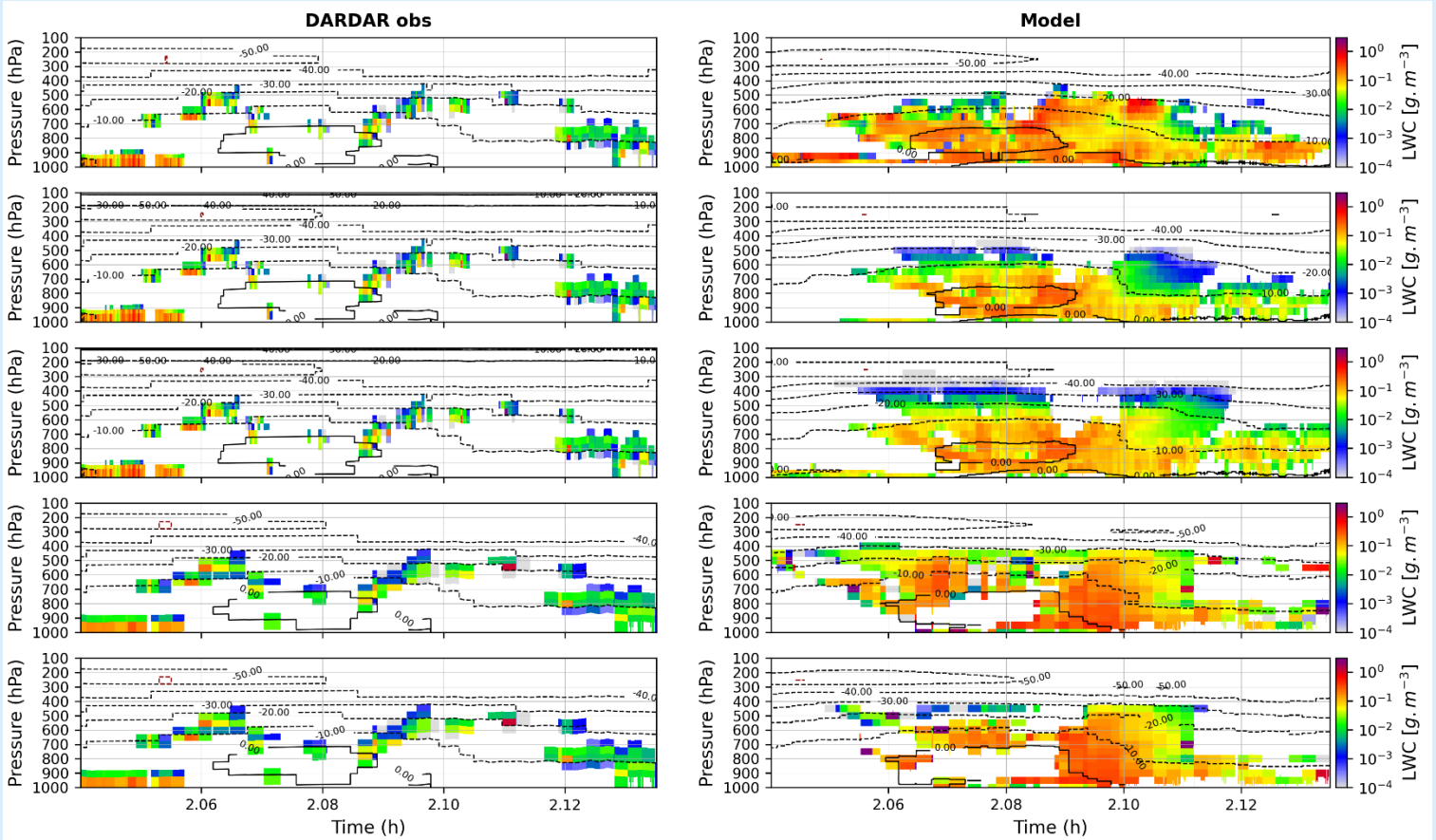
IWC

Shading: IWC ($g.m^{-3}$) ; black contours: Temperature (K) at 05/13/2019 0UTC



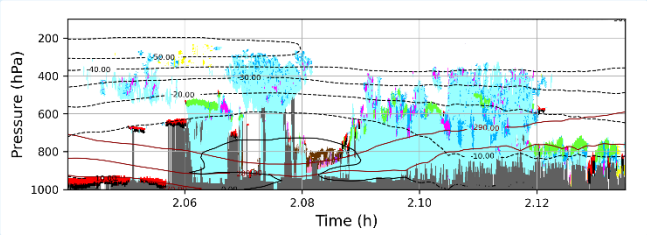
LWC

Shading: IWC ($g.m^{-3}$) ; black contours: Temperature (K) at 05/13/2019 0UTC

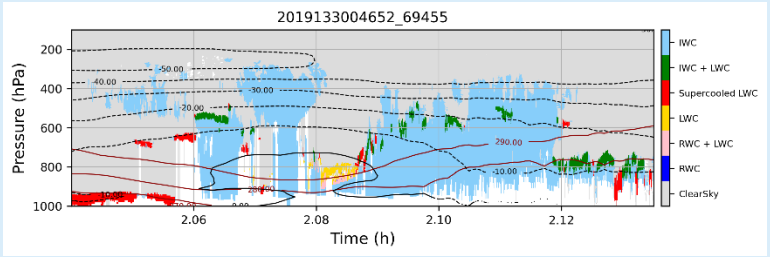


Comparison of hydrometeors categorization

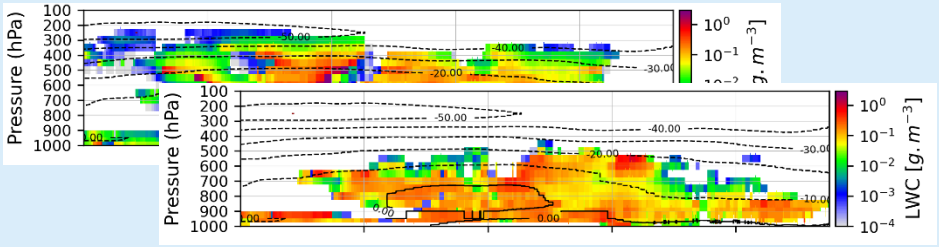
DARDAR's categorization



multiple scattering due to supercooled water	Supercooled LWC
rain maybe mixed with cloud	RWC + LWC
cold rain+liquid clouds	RWC + LWC
warm rain+liquid clouds	RWC + LWC
liquid cloud	LWC
top of convective tower	IWC
highly concentrated ice/strong backscatter	IWC
stratospheric clouds	Nan
warm rain	RWC
aerosol	Nan
cold rain	RWC
supercooled+ice	IWC + LWC
supercooled water	Supercooled LWC
spherical or 2D ice	IWC
ice clouds	IWC
clear sky	Clear Sky
unknown	Nan

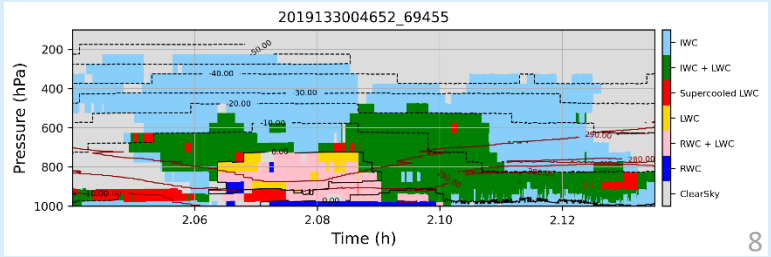


Model categorization (ex : ERA5)



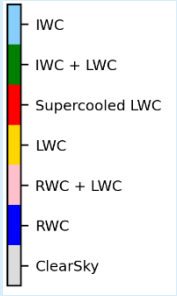
Threshold: 90%

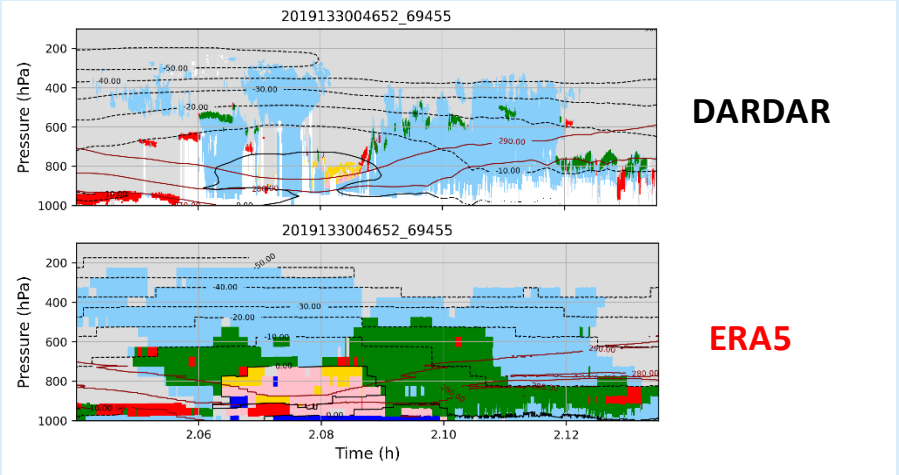
90% of TWC is rain	RWC
90% of TWC is liquid cloud	LWC
90% of TWC is liquid cloud at T<0°C	Supercooled LWC
90% of TWC is ice or snow	IWC
From 10% to 90% of TWC is ice/snow and liquid cloud	IWC+LWC
From 10% to 90% of TWC is rain and liquid cloud	RWC+LWC
TWC < $10e^{-7}$g/m^3	Clear Sky



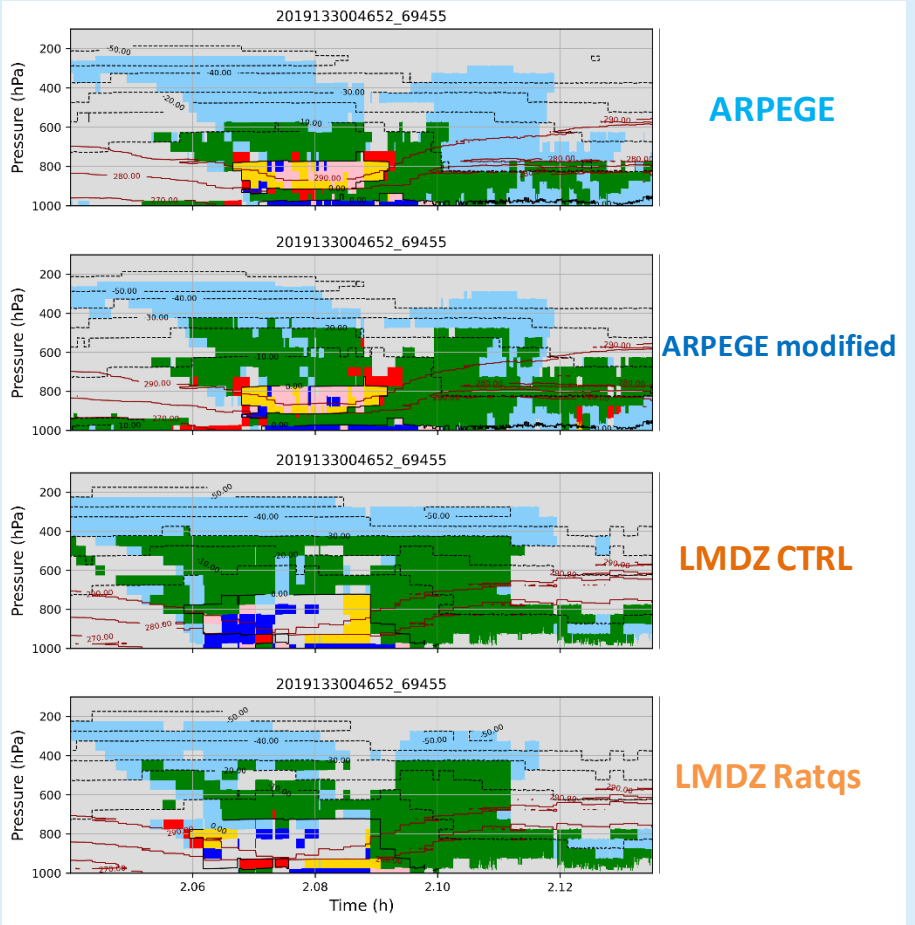
Shading: Hydrometeors categorization ; black contours: Temperature (°C) ; red contours: θ_E (K)

Sensitivity to ice/liquid partition function

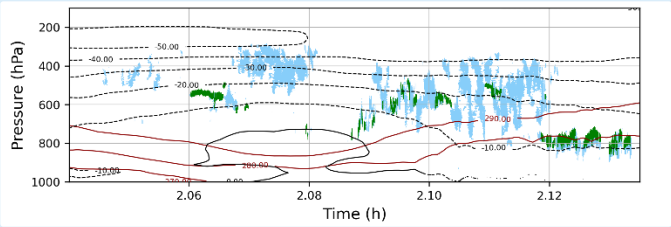




Shading: Hydrometeors categorization ;
black contours: Temperature (°C) ;
red contours: θ_E (K)



Over-representation of ice in mid-troposphere in observation



DARDAR

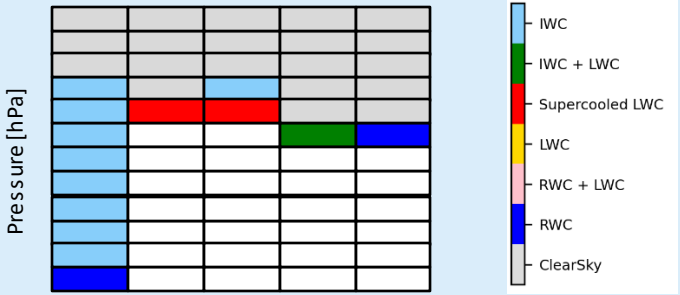
Observations :

Delete some data in order to keep data only where there are signals from radar and lidar simultaneously, namely :

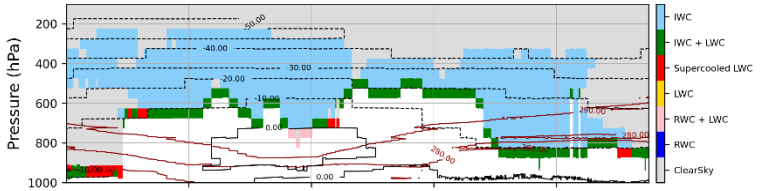
- where lidar signal is extinguished or attenuated
- where there is a clutter in radar signal

Models :

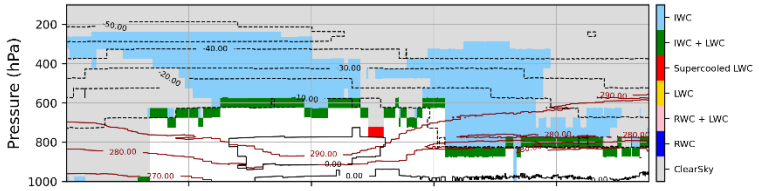
Simplified simulator to represent lidar signal attenuation



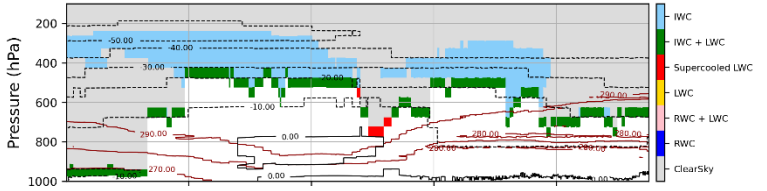
ERA5



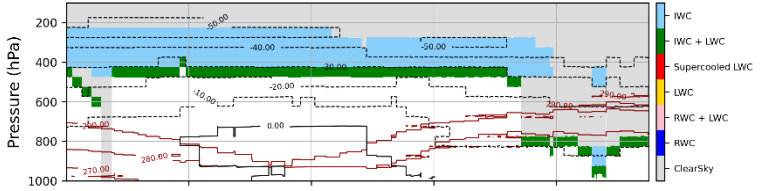
ARPEGE



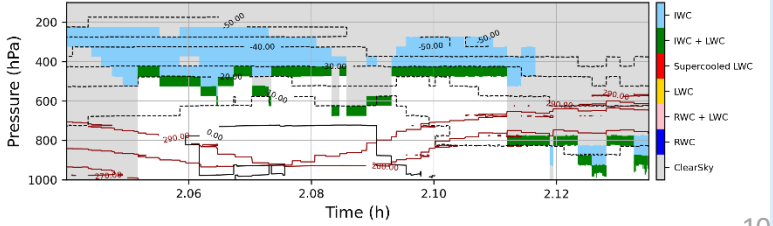
ARPEGE modified



LMDZ CTRL



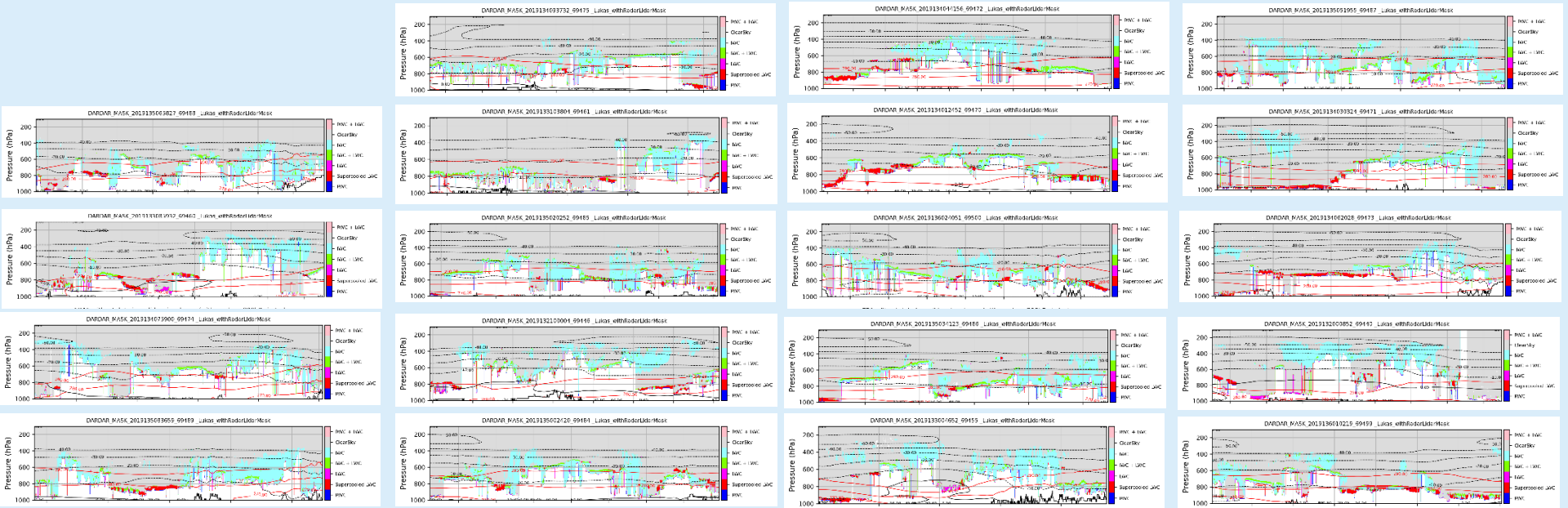
LMDZ Ratqs



Ice/liquid partition function on occurrence: statistics on all overpasses

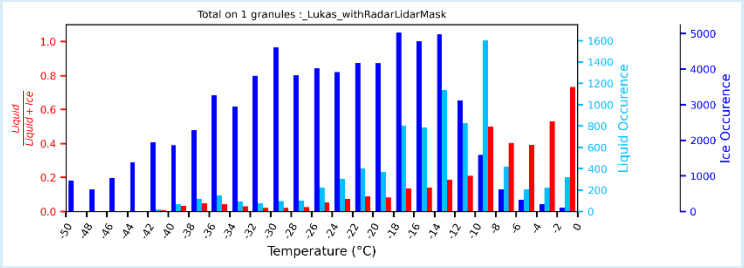
$$r = \frac{Liquid\ Occurrences}{Liquid + Ice\ Occurrences}$$

DARDAR

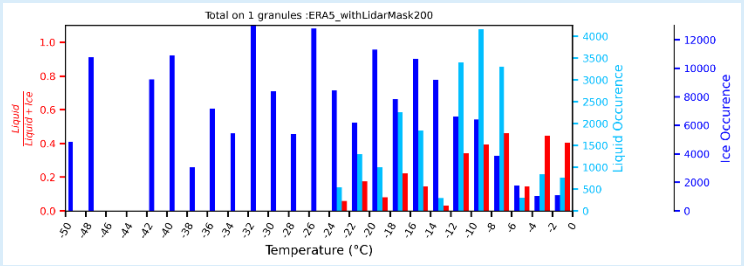


Ice/liquid partition function on occurrence: Predictor : Temperature

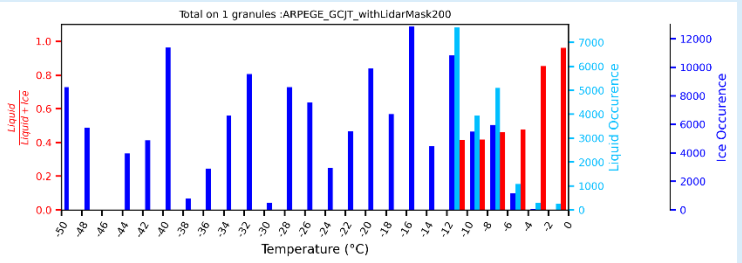
DARDAR



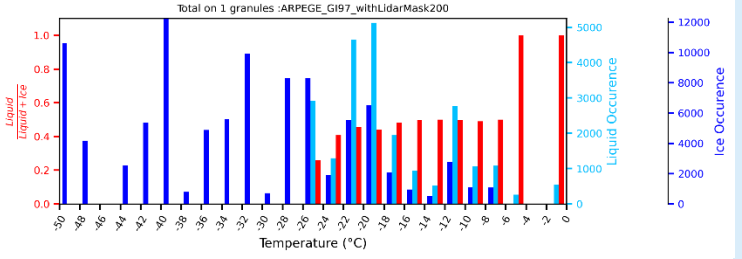
ERA5



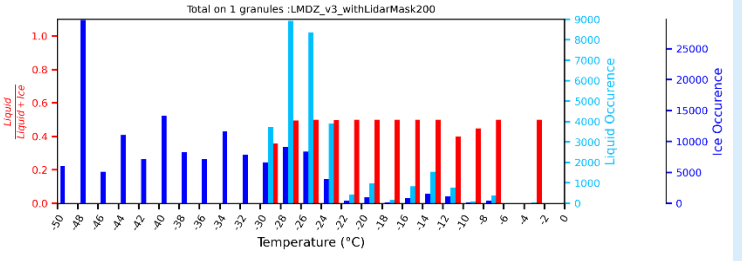
ARPEGE



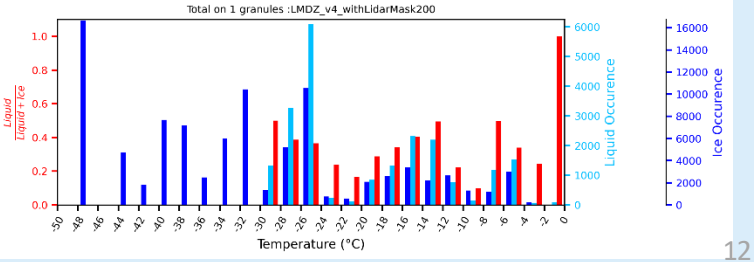
ARPEGE modified



LMDZ CTRL

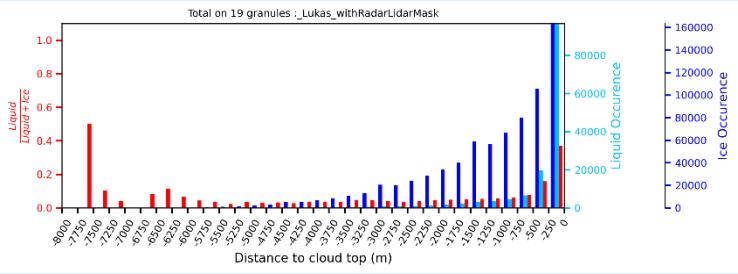


LMDZ Ratqs

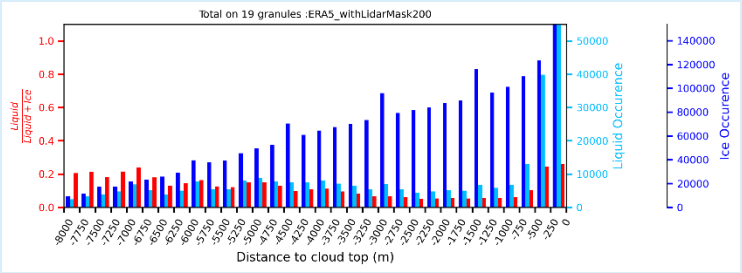


Ice/liquid partition function on occurrence: Predictor : Distance to cloud top

DARDAR



ERA5



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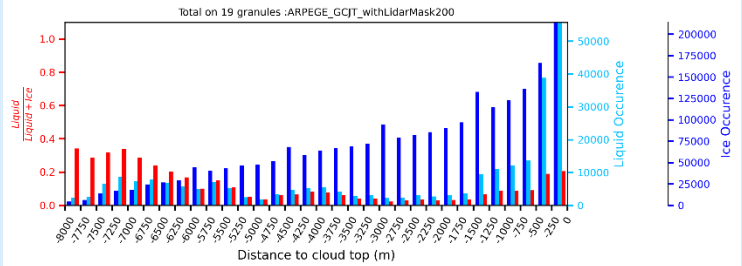

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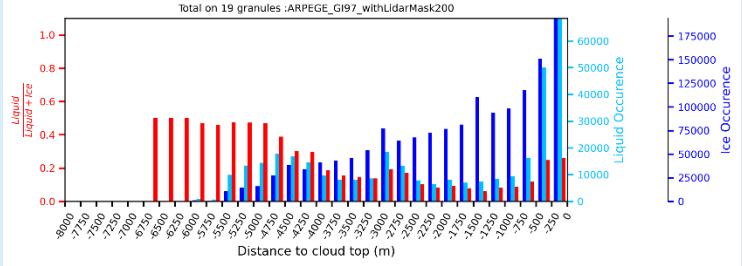
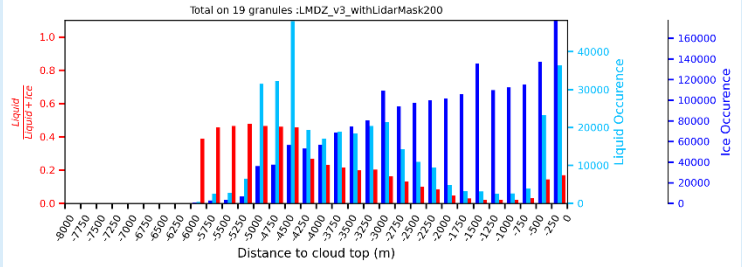
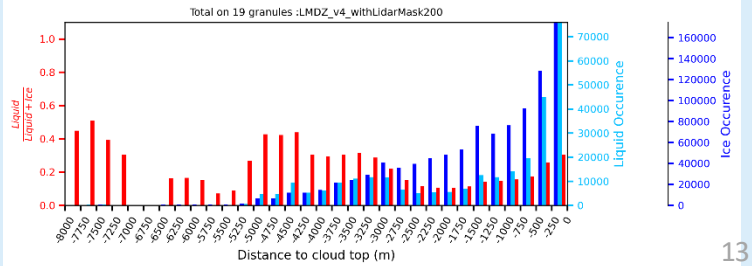


LMDZ CTRL

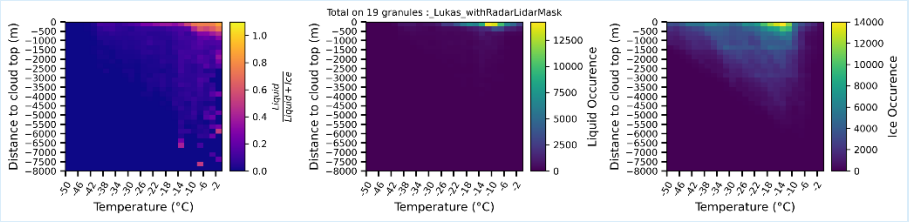


LMDZ Ratqs

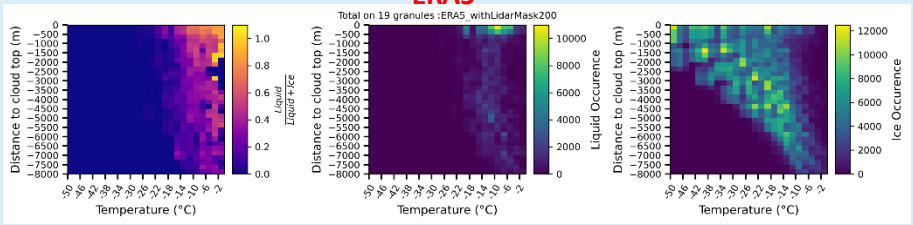


Ice/liquid partition function on occurrence: Predictor : T and D

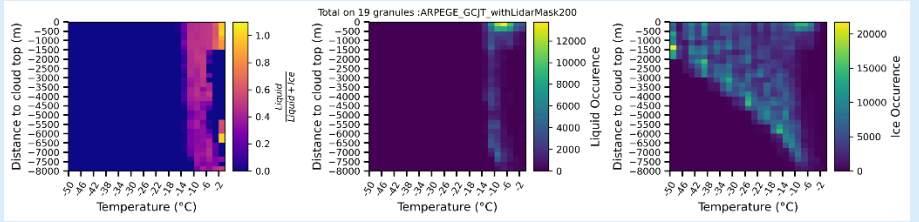
DARDAR



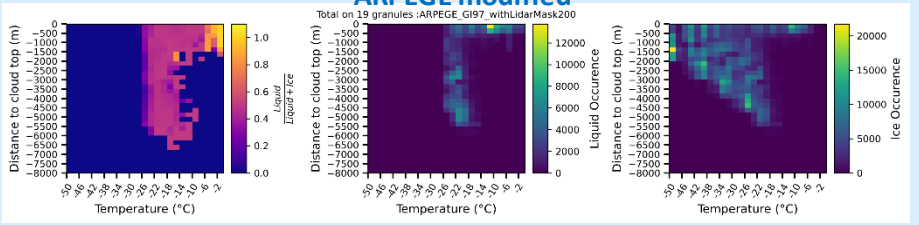
ERA5



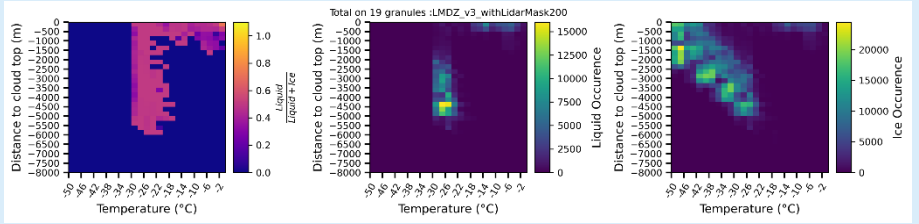
ARPEGE



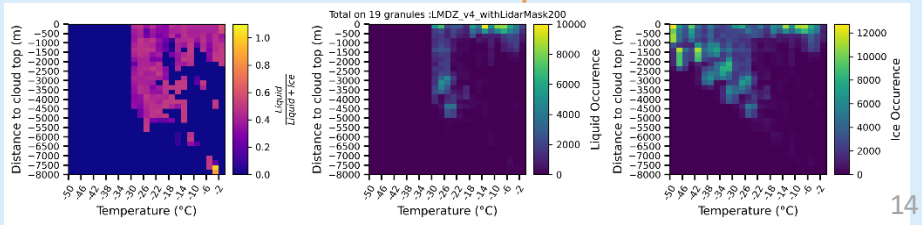
ARPEGE modified



LMDZ CTRL



LMDZ Ratqs



Conclusion

- No model predicts such thin supercooled liquid water structure
- Ice/Liquid water partition function allowing supercooled liquid water at lower temperature does not give a better representation of supercooled liquid water -> need to consider distance to cloud top
- IWC+SWC:
  - Higher IWC with LMDZ, more close to DARDAR observation
  - ARPEGE: Changing the ice/liquid partition function increases IWC
  - LMDZ: Changing ratqs value better represents IWC in high altitude
- LWC:
  - Models very far away from observation
  - ARPEGE: Changing the ice/liquid partition function does not affect LWC but allows supercooled liquid water at higher altitude
  - LMDZ: Changing ratqs value gives less supercooled liquid water in high altitude
- Liquid water occurrences:
  - Over-estimation at low temperature (-20° - 0°)
  - Under-estimation at very negative temperature (-40°C)
  - Over-estimation of distance to cloud top

Outlooks

- Make statistics with all post-processed overpasses
- Look at ice/liquid partition function according to content and not only occurrences
- Use of a CloudSat-CALIPSO simulator in LMDZ (COSP) to validate/verify the simplified simulator of lidar signal attenuation in models
- Verify the distance to cloud top is not due to lidar signal attenuation
- Look at LMDZ simulation with a new ice/liquid partition function depending on T and D

Thank you for your attention