



Assessing the cloud representation of two global atmospheric models using multiple overpasses of CloudSat-CALIPSO over an Arctic cyclone

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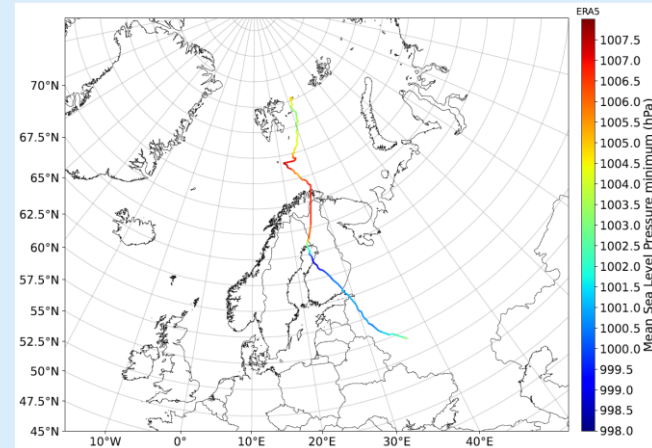
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Contact : meryl.wimmer@lmd.ipsl.fr

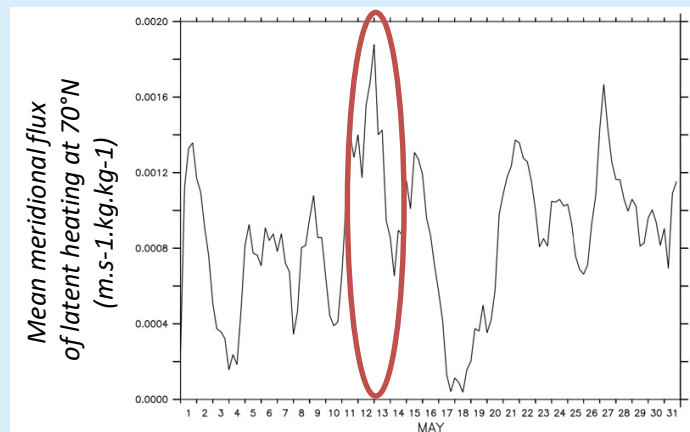
Study Case:

Arctic Cyclone in May 2019

- Born: 2019-05-09 in Russia
- End: 2019-05-16 near Svalbard
- Characteristics:
 - Long life
 - Small deepening (near 998hPa)
 - Brings humidity in Arctic Area
 - 20 overpasses of CloudSat and CALIPSO
 - Availability of DARDAR products and model simulation

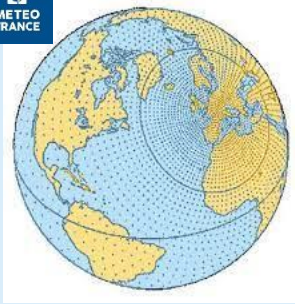


Minimum of MSLP during the Arctic cyclone trajectory (ERA5 data)



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

Atmospheric models



ARPEGE

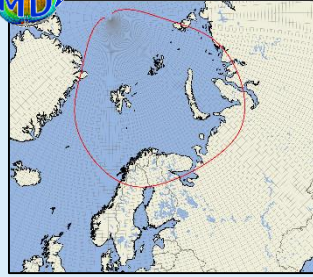
Resolution: 5-24km, 105 levels

Initialisation: 4DVar analysis
(2019-05-12 at 00UTC)

Type of simulation: “Free” Forecast

Simulations:

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



LMDZ

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

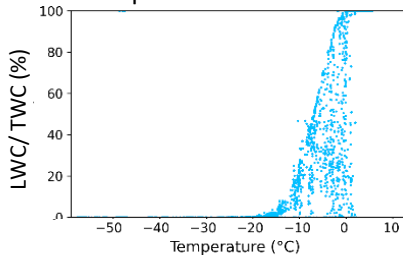
Initialisation: ERA5
(2019-05-12 at 00UTC)

Type of simulation: nudging to ERA5 outside the zoom with COSP simulator

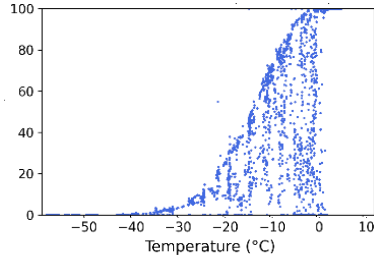
Simulations:

- CMIP7.1b version
- CMIP7.1b version $ratqs = \sqrt{\Delta x}$
- CMIP7.1b version $ratqs = \sqrt{\Delta x}$; liquid/ice partition function according to T and D

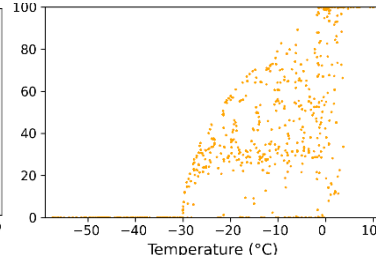
Operational ARPEGE



Modified ARPEGE



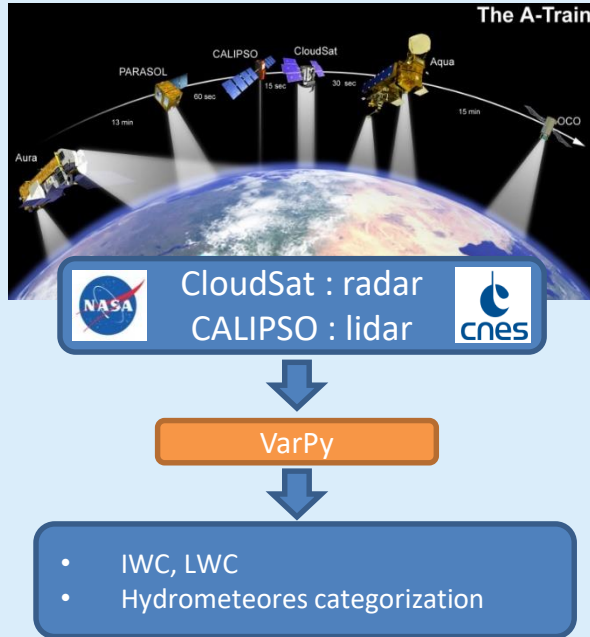
LMDZ



Outputs:

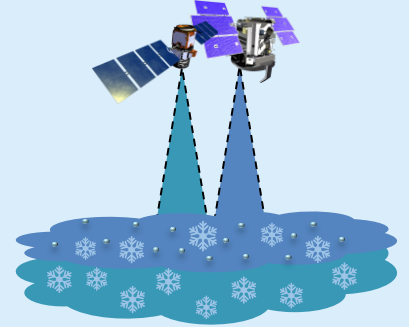
- time: 3h
- Lon x Lat : 0,5° x 0,5°
- 18 pressure levels (50hPa resolution)

Observations: DARDAR products



Radar:

- Sensitive to diameter of particles
- Detects ice crystals
- Use to determine IWC



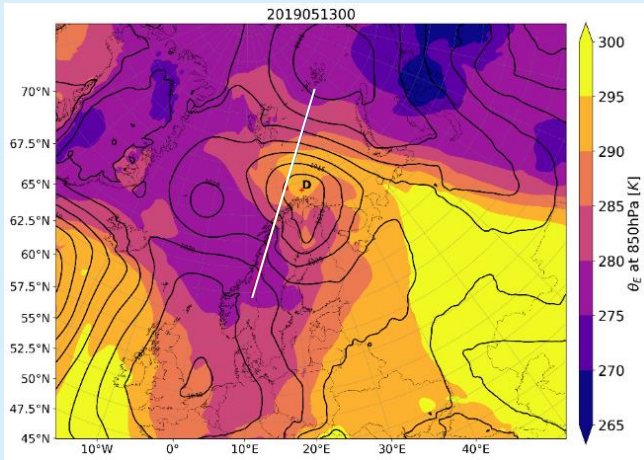
Lidar:

- Sensitive to concentration of small particles
- Detects small crystals and liquid droplets
- Use to determine LWC and IWC

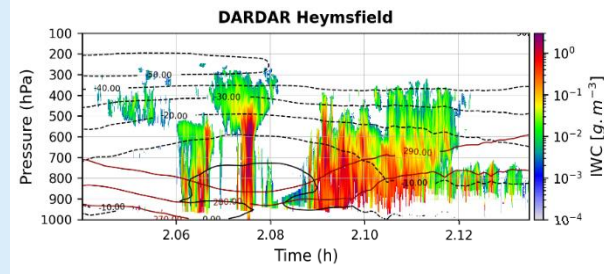
Example of one satellites overpass: #2019133004652_69455 crossing warm and cold front

DARDAR Products : 20190513 02UTC

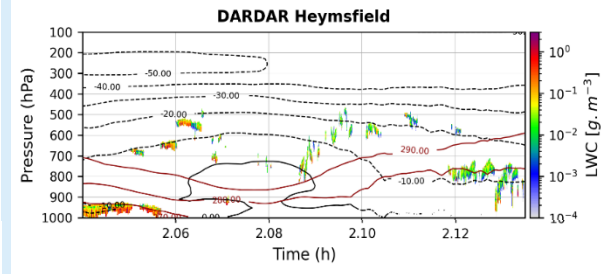
ERA5 : 20190513 00UTC



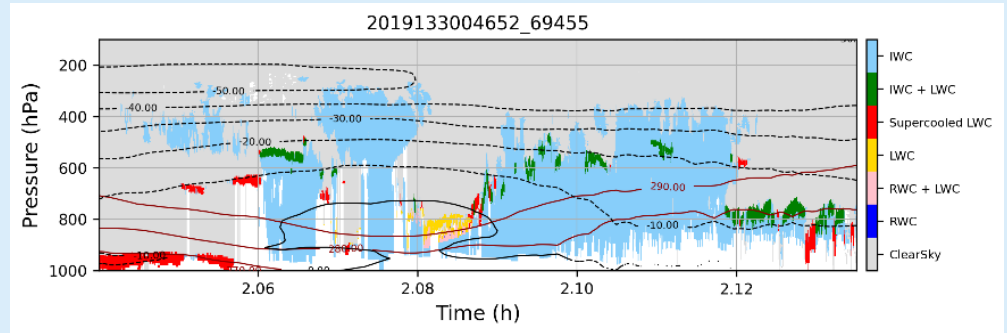
Shading: θ_E at 850hPa (K) ; black contours: MSLP (hPa) ;
white line: time along satellites overpass



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



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



Shading: Hydrometeors categorization ; black contours: Temperature ($^{\circ}\text{C}$) ; red contours: θ_E (K)

Comparison of IWC

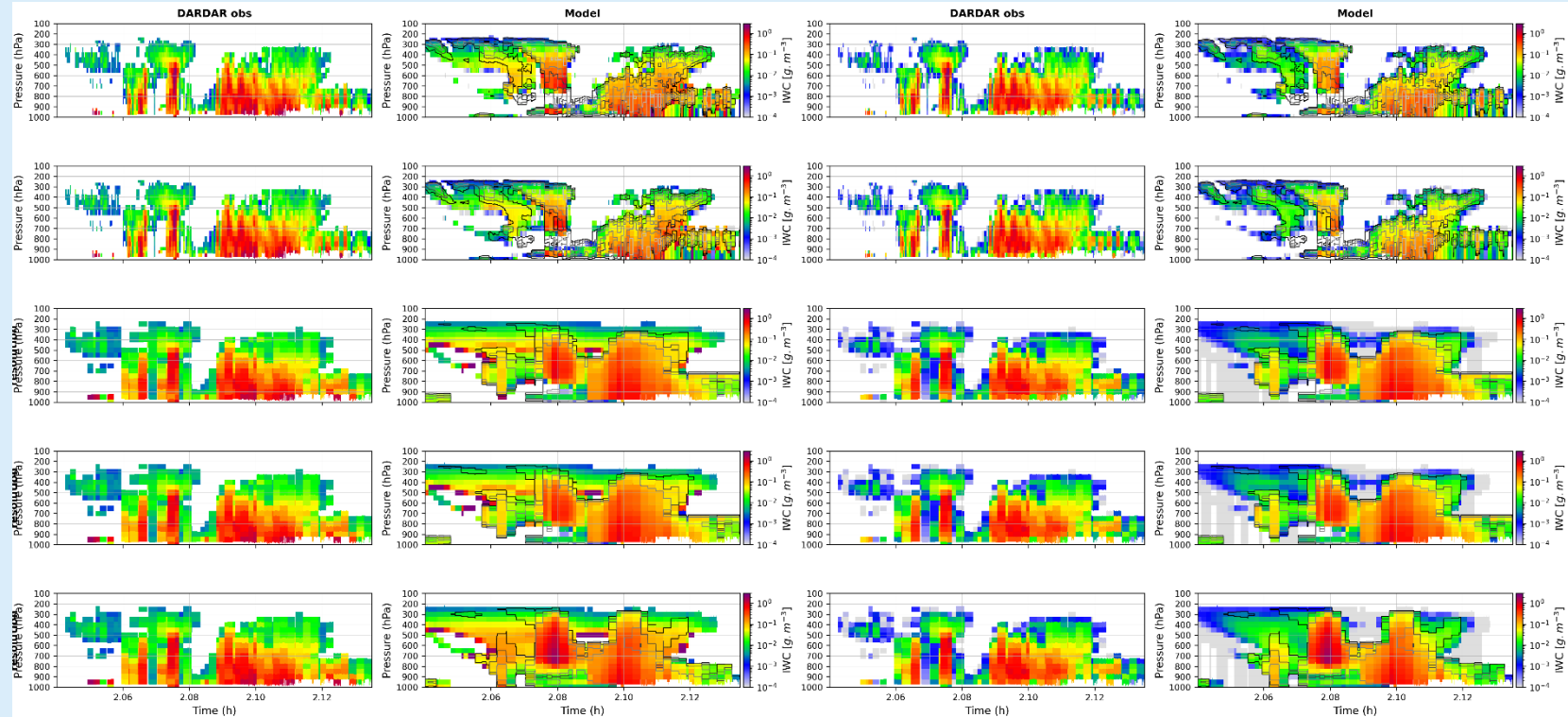
Shading: IWC (g.m^{-3}) ; black contours: Cloud Fraction at 2019-05-13 UTC

IWC_{in} : DARDAR at model resolution

IWC_{in} : model resolution

IWC : DARDAR at model resolution

IWC : model resolution



ARPEGE
(oper)

ARPEGE
(-40)

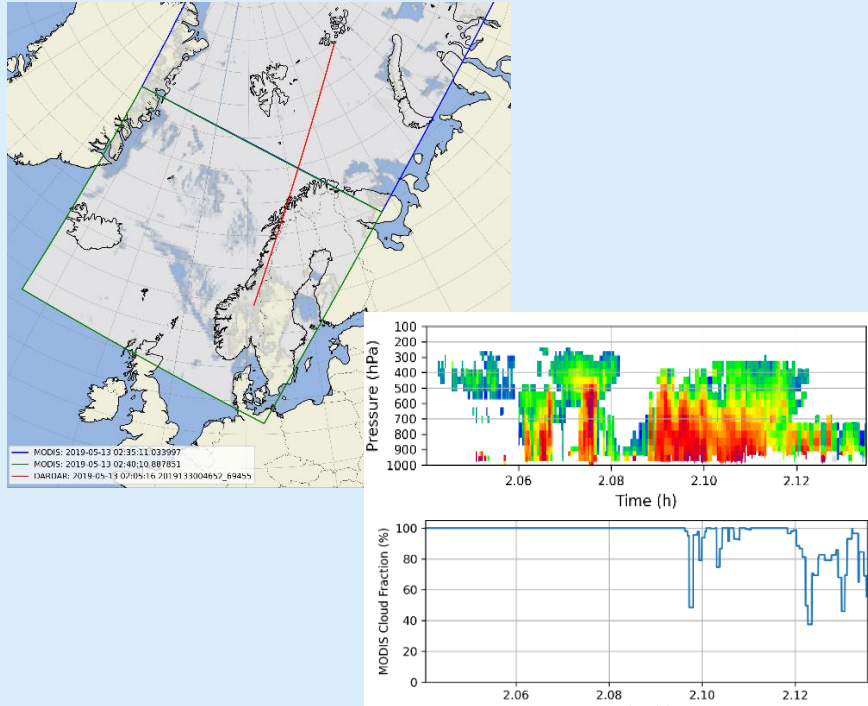
LMDZ
(CTRL)

LMDZ
(ratqs)

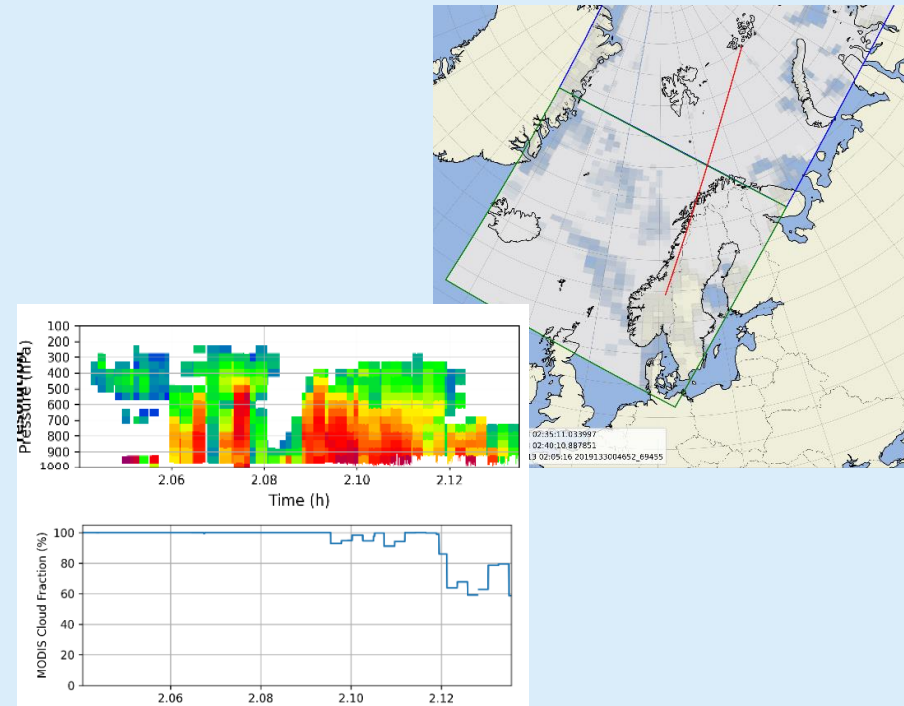
LMDZ
(ratqs + f(T,D))

Are the DARDAR observations representative of the grid box ?

**MODIS Cloud Fraction
at ARPEGE resolution**

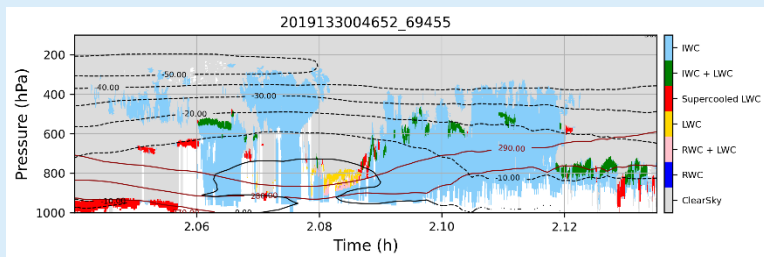
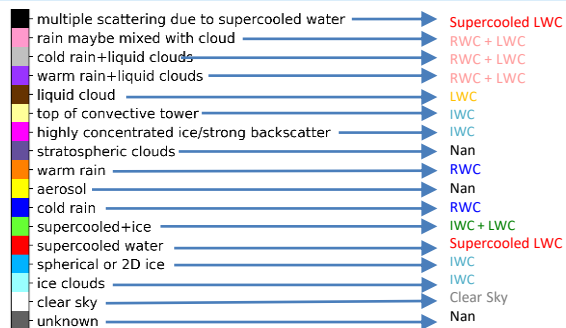
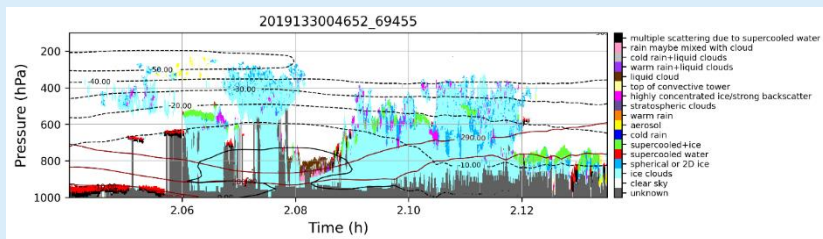


**MODIS Cloud Fraction
at LMDZ resolution**



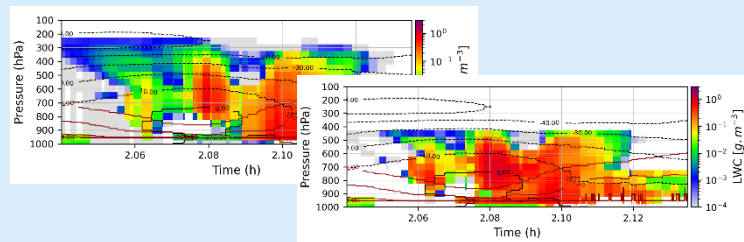
Comparison of hydrometeors categorization

DARDAR's categorization: simplification



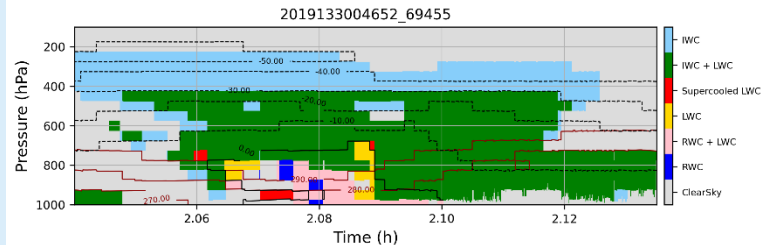
Shading: Hydrometeors categorization ;
black contours: Temperature ($^{\circ}\text{C}$) ;
red contours: θ_E (K)

Model categorization (ex : LMDZ)



Threshold: 90%

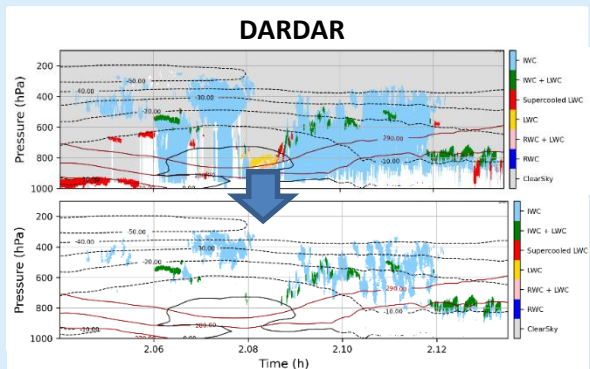
- 90% of TWC is rain → RWC
- 90% of TWC is liquid cloud → LWC
- 90% of TWC is liquid cloud at $T < 0^{\circ}\text{C}$ → Supercooled LWC
- 90% of TWC is ice or snow → IWC
- From 10% to 90% of TWC is ice/snow and liquid cloud → IWC + LWC
- From 10% to 90% of TWC is rain and liquid cloud → RWC + LWC
- $\text{TWC}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



Over-representation of ice in mid-troposphere in observation

Observations :

Keep data only where there are signals from radar and lidar simultaneously, namely :



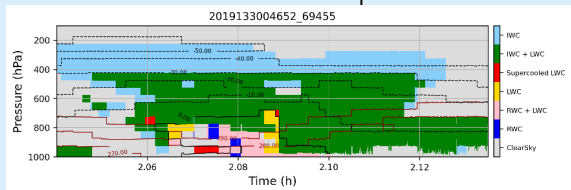
Models (ex: LMDZ CTRL) :

Delete datas where:

- $IWC < 5 \times 10^{-2} g.m^{-3}$
- $LWC > 1 \times 10^{-1} g.m^{-3}$

Validation with COSP simulator:

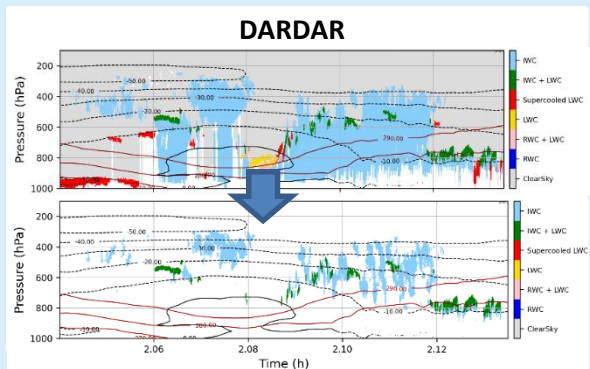
- $Z < -28dBZ$
- $b_{scat} < 1 \times 10^{-7} m^{-1}.sr^{-1}$



Over-representation of ice in mid-troposphere in observation

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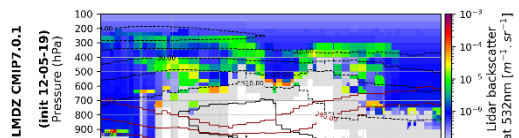
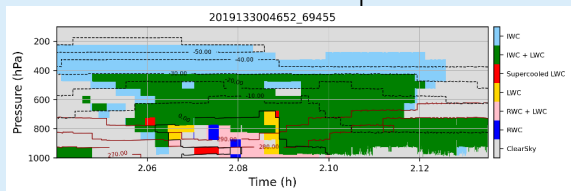
Models (ex: LMDZ CTRL) :

Delete datas where:

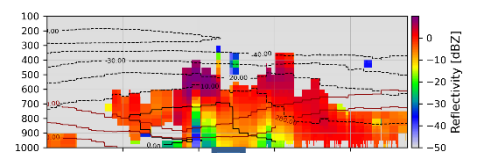
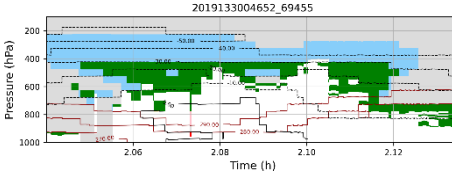
- $IWC < 5 \times 10^{-2} g.m^{-3}$
- $LWC > 1 \times 10^{-1} g.m^{-3}$

Validation with COSP simulator:

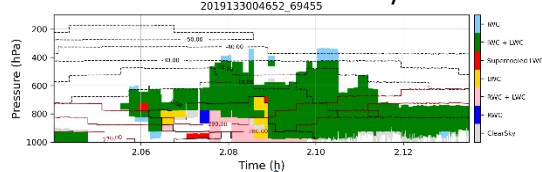
- $Z < -28dBZ$
- $bscat < 1 \times 10^{-7} m^{-1}.sr^{-1}$



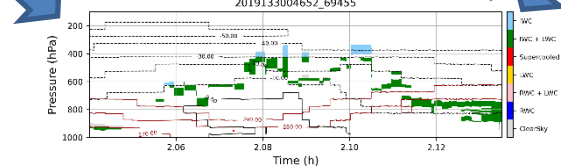
Mask on lidar backscatter



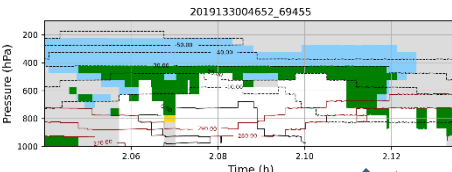
Mask on radar reflectivity



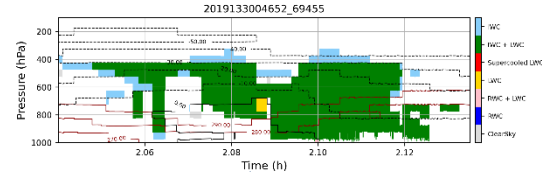
Mask on backscatter and reflectivity



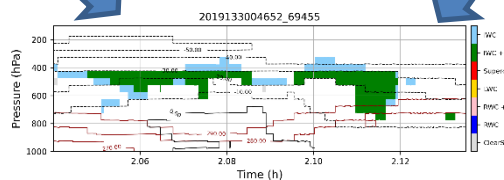
Mask on LWC



Mask on IWC

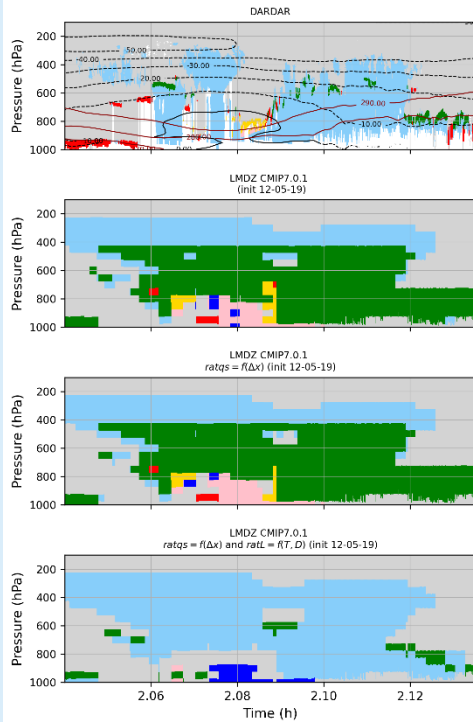


Mask on WC

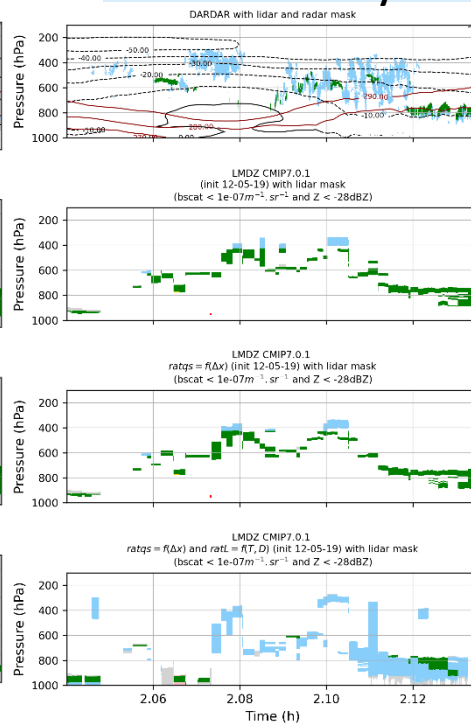


Mask on COSP/ water content

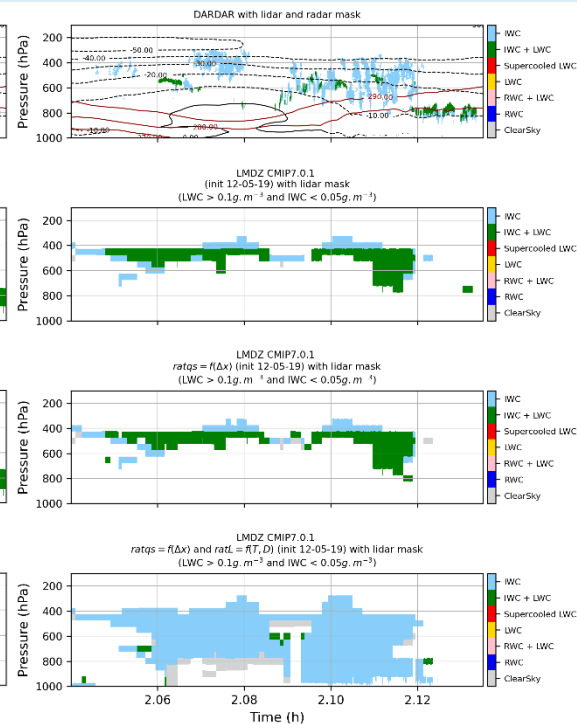
No mask



Mask on backscatter and reflectivity



Mask on IWC and LWC

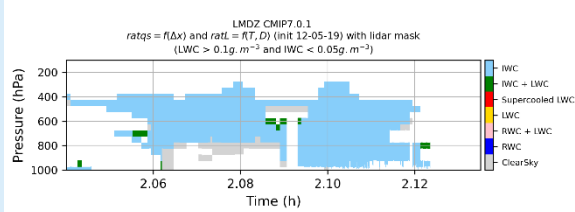
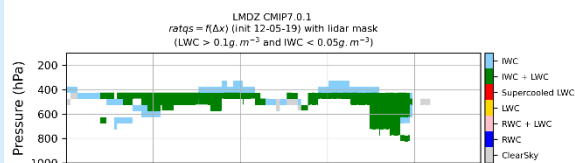
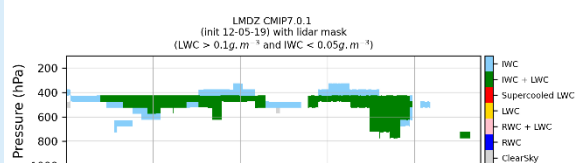
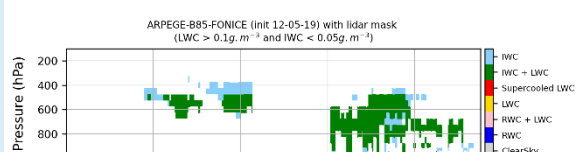
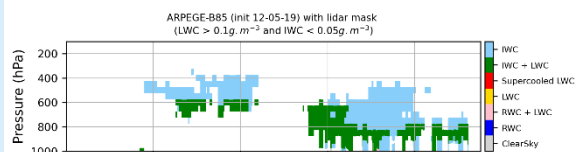
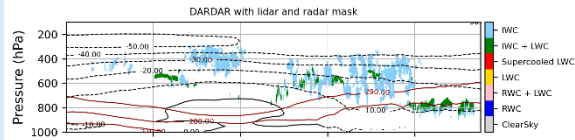
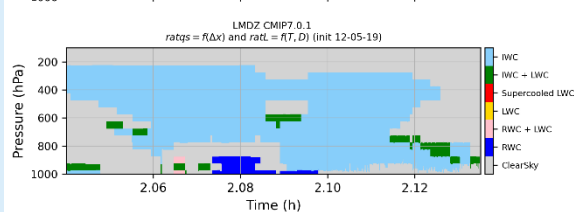
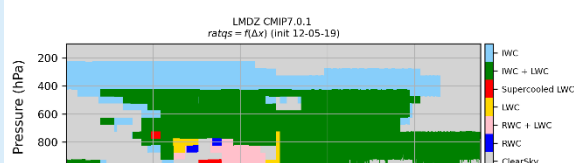
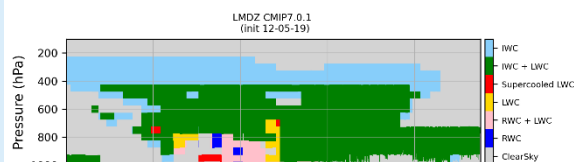
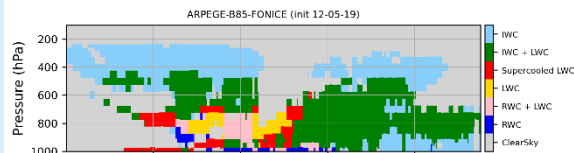
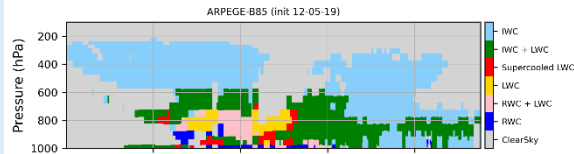
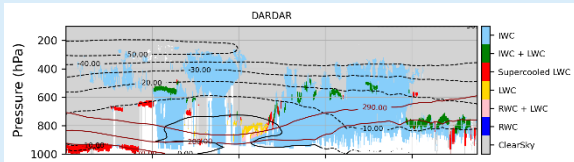


DARDAR

LMDZ
(CTRL)

LMDZ
(ratqs)

LMDZ
(ratqs + $f(T, D)$)



DARDAR

ARPEGE
(oper)

ARPEGE
(-40)

LMDZ
(CTRL)

LMDZ
(ratqs)

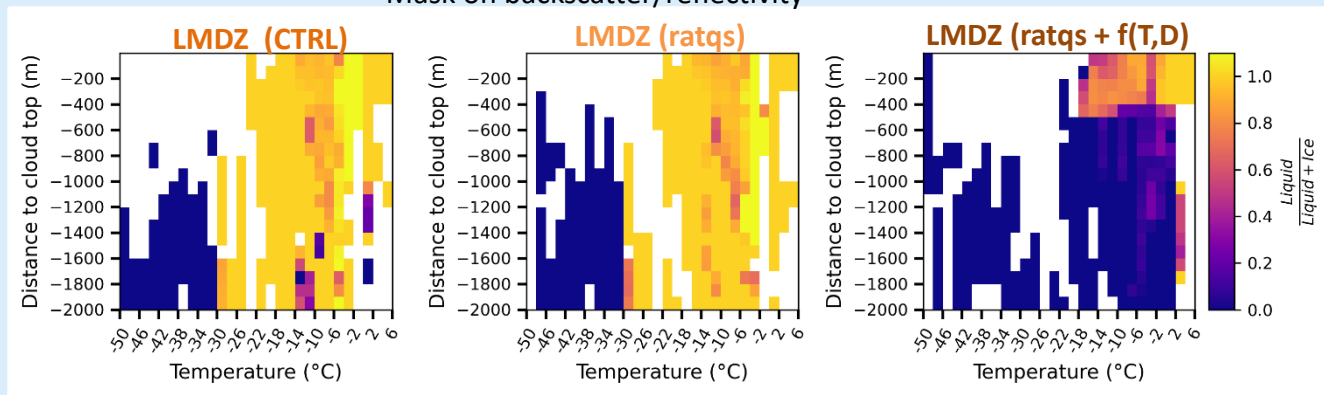
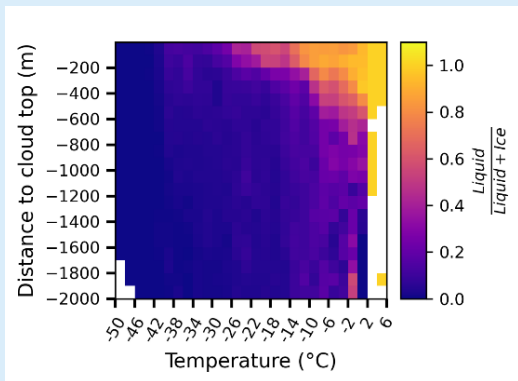
LMDZ
(ratqs + $f(T, D)$)

Modification of liquid/ice
partition function:
not better

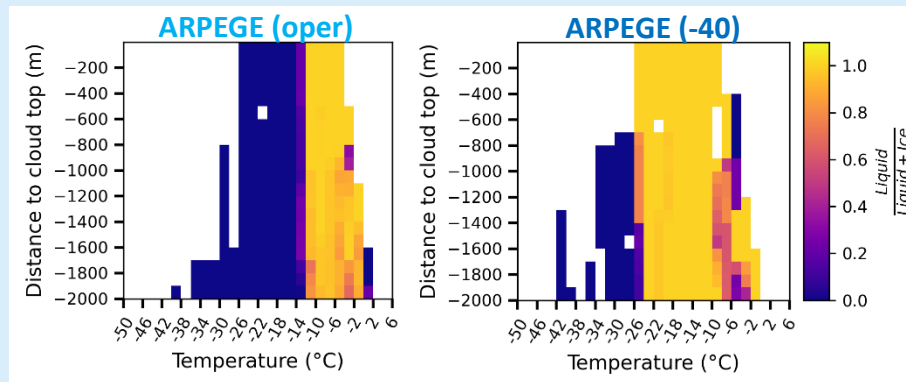
Modification of liquid/ice
partition function:
- Better results
- but problem with mask on
water content

Ice/liquid partition function on occurrence: according to temperature and distance to cloud top Statistics on all satellite overpasses

Mask on backscatter/reflectivity



Mask on water content



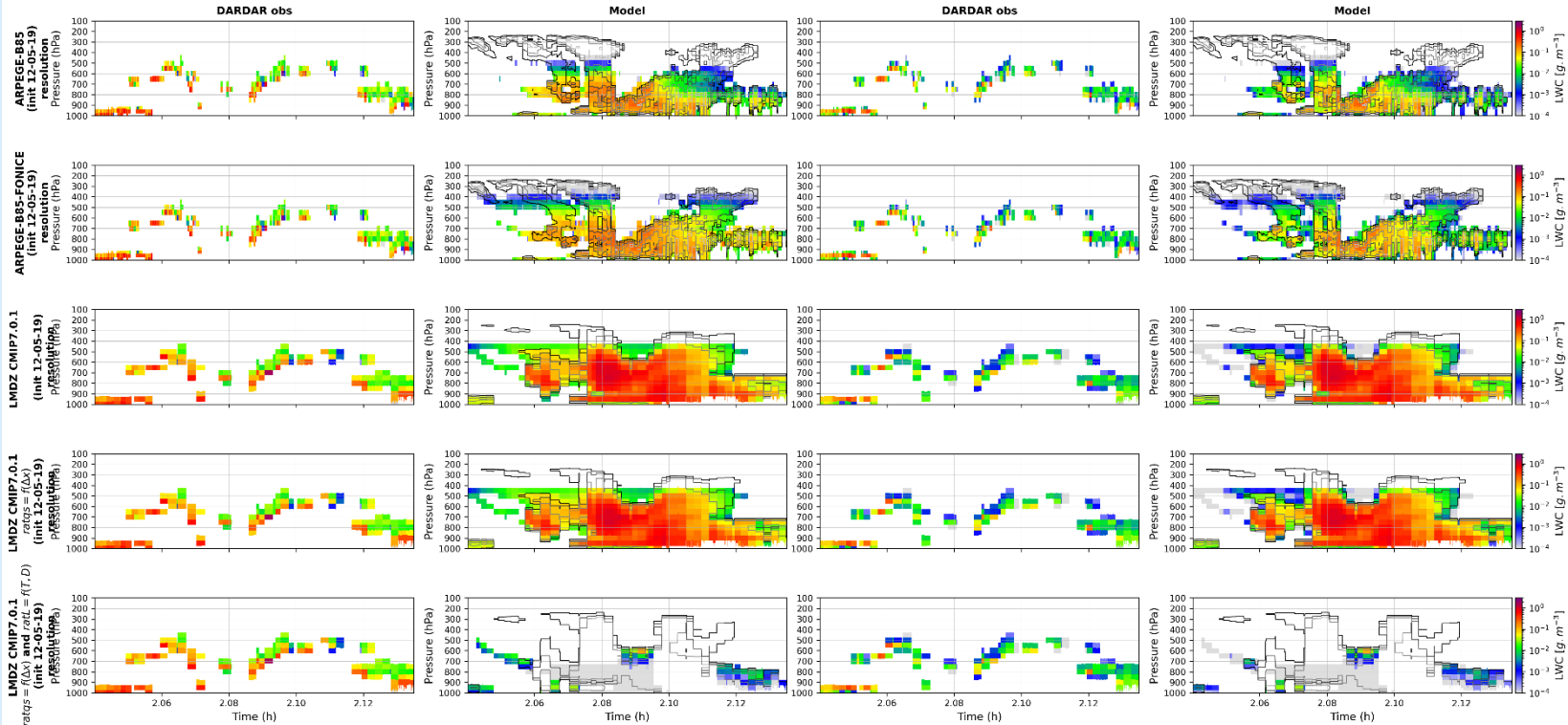
Comparison of LWC

LWC_{in} : DARDAR at model resolution

LWC_{in} : model resolution

LWC : DARDAR at model resolution

LWC : model resolution



ARPEGE
(oper)

ARPEGE
(-40)

LMDZ
(CTRL)

LMDZ
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LMDZ
(ratqs + f(T,D))

Comparison of LWC

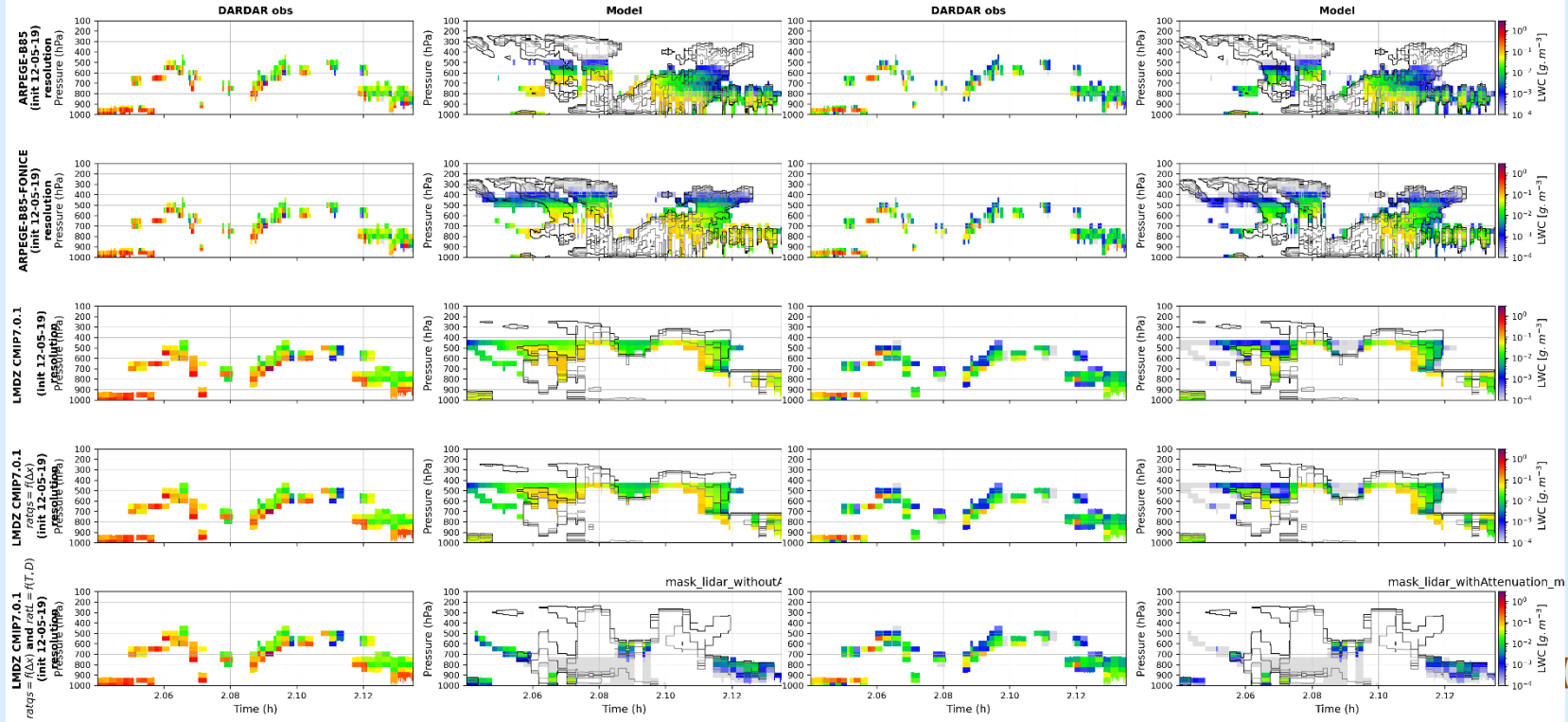
Mask on LWC

LWC_{in} : DARDAR at model resolution

LWC_{in} : model resolution

LWC : DARDAR at model resolution

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ARPEGE
(oper)

ARPEGE
(-40)

LMDZ
(CTRL)

LMDZ
(ratqs)

LMDZ
(ratqs + f(T,D))

Conclusion and outlooks

Conclusion:

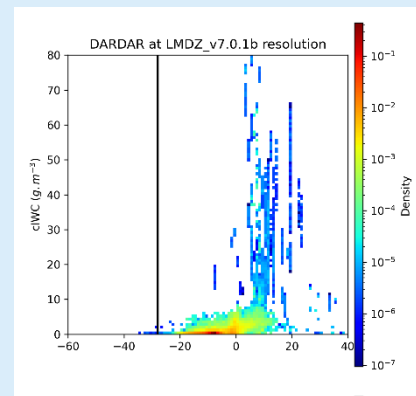
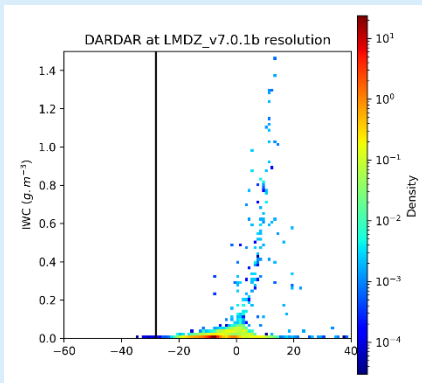
- Higher **IWC** with **LMDZ**, but IWC_{in} too high ? ARPEGE better in shape
- Higher **LWC** with **LMDZ** CTRL, LMDZ better in shape (due to mask ?)
- Liquid water **occurrences**:
 - Over-estimation at moderate negative temperature (-20° - 0°)
 - Under-estimation at very negative temperature (-40°C)
 - Models do not consider a dependence on **distance to cloud top**
 - **Better** with function depending on temperature and **distance to cloud top**
- Changing the **ice/liquid partition function in ARPEGE**:
 - Decreases IWC
 - Allows supercooled liquid water at higher altitude
- Changing the **ice/liquid partition function in LMDZ**:
 - Increases IWC
 - Too small LWC but well placed

Outlooks:

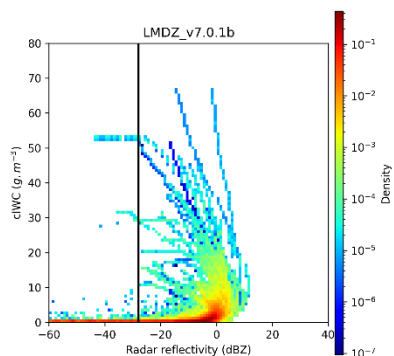
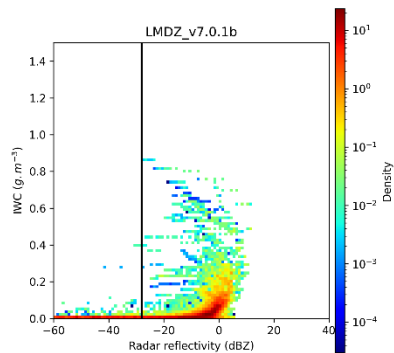
- Better estimate IWC and LWC **threshold** for mask on water content
- Look at ice/liquid partition function according to **content** and not only occurrences -> Clémantyne ?
- Validate the percent use for model categorization

Better estimate threshold on LWC and IWC

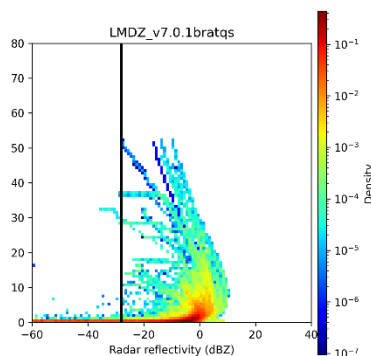
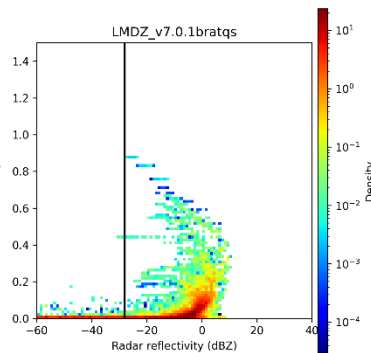
DARDAR



**LMDZ
(CTRL)**



**LMDZ
(ratqs)**



**LMDZ
(ratqs + f(T,D))**

