Evaluating Arctic clouds representation in two global atmospheric models with DARDAR: focus on clouds in an Arctic cyclone

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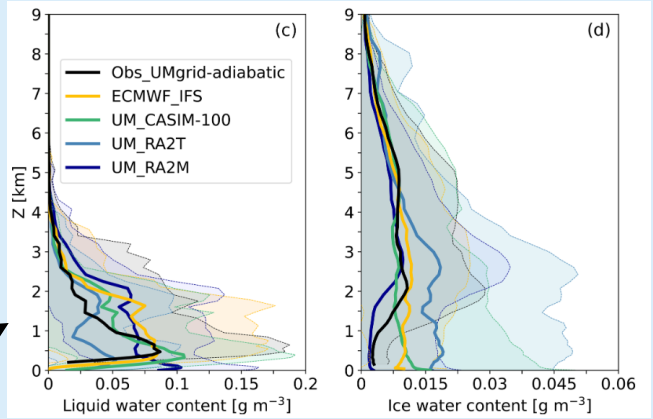
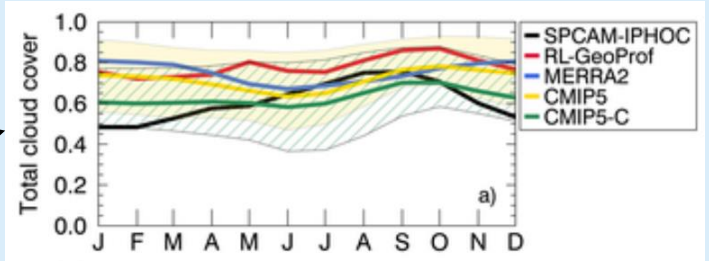
Evaluation of cloud parameterization using satellite products

Many studies on evaluation of cloud parameterizations by comparing to satellite/field campaign



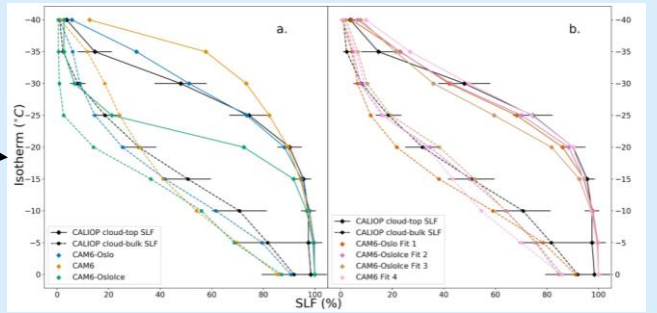
<u>Focus on Arctic clouds :</u>

- Comparison of surface radiation, TWC, CF, IWC, LWC between IFS+UM and CloudNet during Arctic Ocean 2018 expedition (Young et al (2022))



- Comparison of annual cloud cover and vertical distribution of clouds between MMF and Radar-Lidar Geometrical Profile Product (Li et al (2019))

- Fitting of time scale and INP in Nordic Earth System Model V2 to adjust liquid/ice partition function using CALIOP (Shaw et al. (2022))



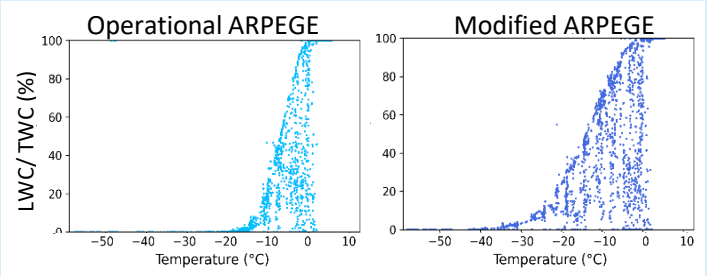
Uncertainty on the liquid/ice partition function

Liquid/Ice partition function in mixed-phase clouds:

- Allows supercooled liquid water at negative temperature
- Generally only depends on temperature
- Different functions for each model
- Error in supercooled liquid water generate precipitation and temperature bias in polar region (Pithan et al. (2014), …)

Uncertainty due to liquid/ice partition function:

- Mazoyer et al (2023)
- Ricaud et al. (2020)



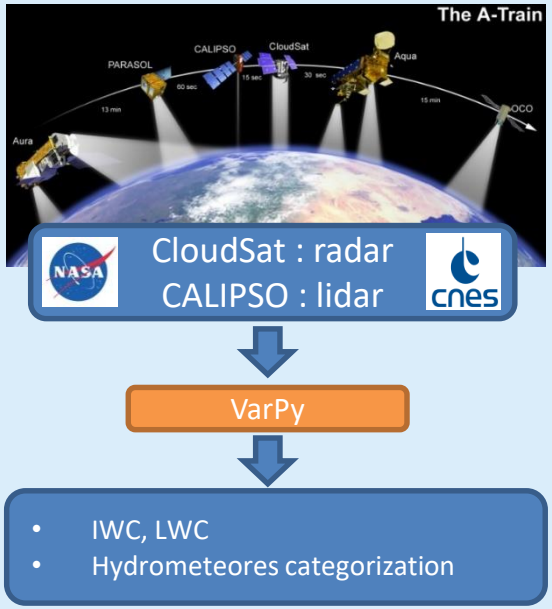
<u>Problem</u>:

- supercooled liquid water occurrence not linked only to temperature

<u>Objective</u>:

- find and test other predictors of supercooled liquid water using active remote sensing technics

Observations: DARDAR products

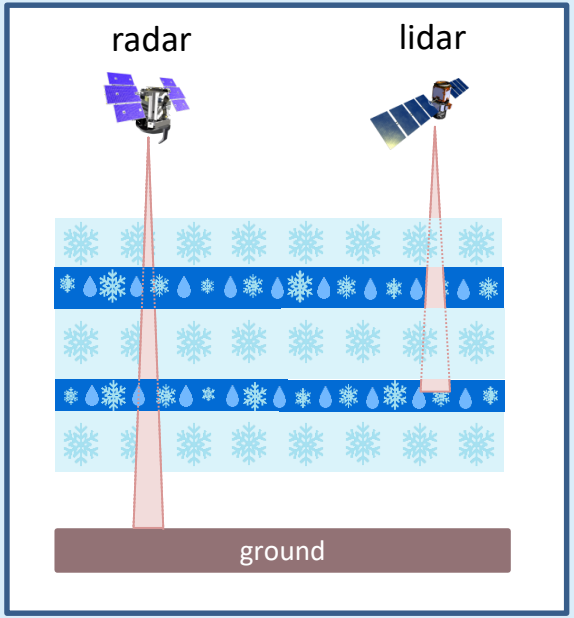


Radar:

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

Lidar:

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



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

Atmospheric models

ARPEGE (NWP model)

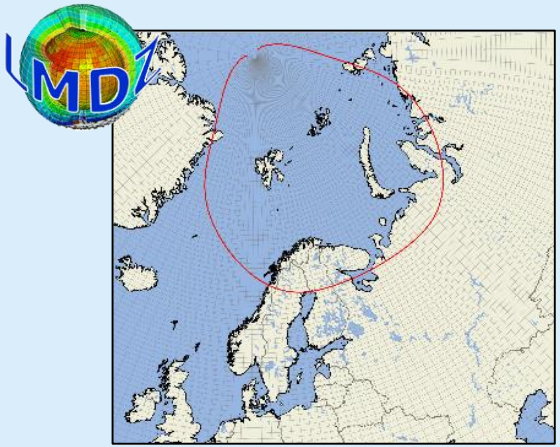
Resolution: 5-24km, 105 levels

Initialisation: 4DVar analysis

Type of simulation: “Free” Forecast

Version:

- Operational
- Modified FONICE as in Ricaud et al (2020)



LMDZ (climate model)

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

Initialisation: ERA5

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

Version:

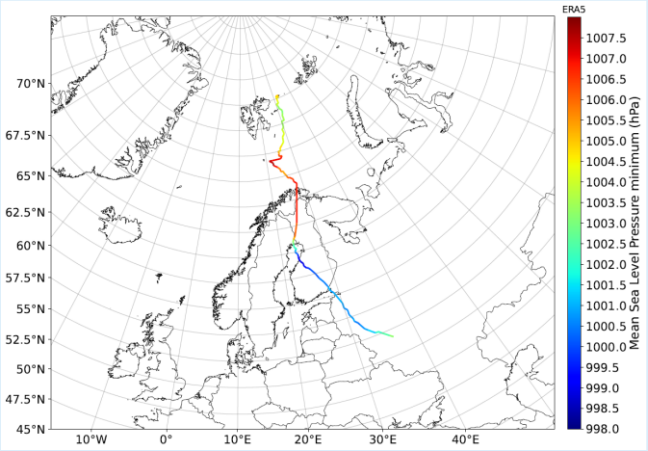
- CMIP7.1b version
- Liquid/ice partition function: $f(T, d_{top})$

Outputs:

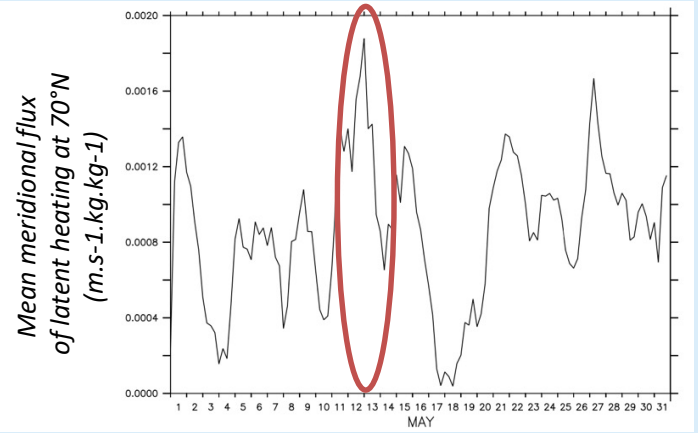
- time: 3h
- Lon x Lat : 0,5° x 0,5°
- 18 pressure levels (50hPa resolution)

Study Case:
Arctic Cyclone in May 2019

- Born: 2019-05-09 in Russia
- End: 2019-05-16 near Svalbard
- Characteristics:
  - Long life
  - Brings humidity in Arctic Area
- Data:
  - Availability of satellites products and model simulation
  - 18 overpasses of CloudSat and CALIPSO
  - Simulation initial time: 20190512 at 0UTC



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

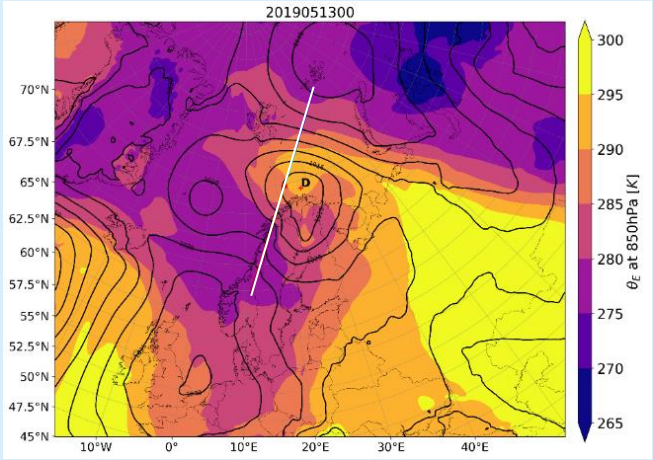


Mean meridional flux of latent heating at 70°N (ERA5 data)

Example of one satellites overpass:

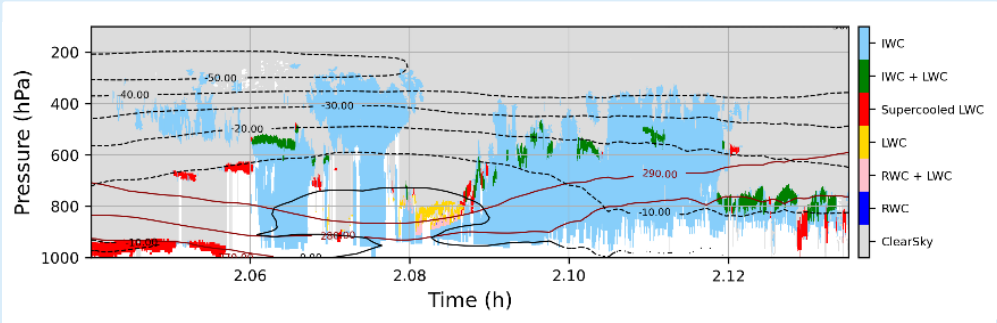
#2019133004652_69455 crossing warm and cold front

ERA5 : 20190513 00UTC

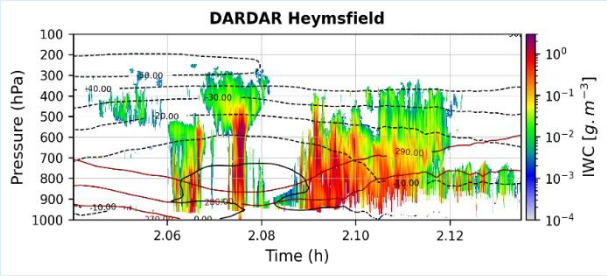


Shading: θ_E at 850hPa (K) ; black contours: MSLP (hPa) ;
white line: time along satellites overpass

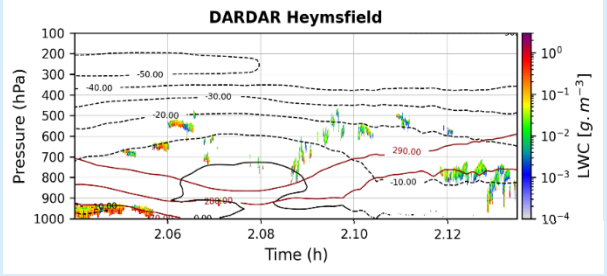
DARDAR Products : 20190513 02UTC



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



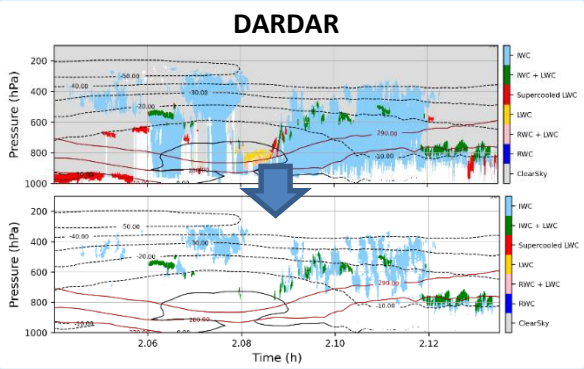
Shading: IWC (g.m^{-3}) ;
black contours: Temperature (°C) ; red contours: θ_E(K)

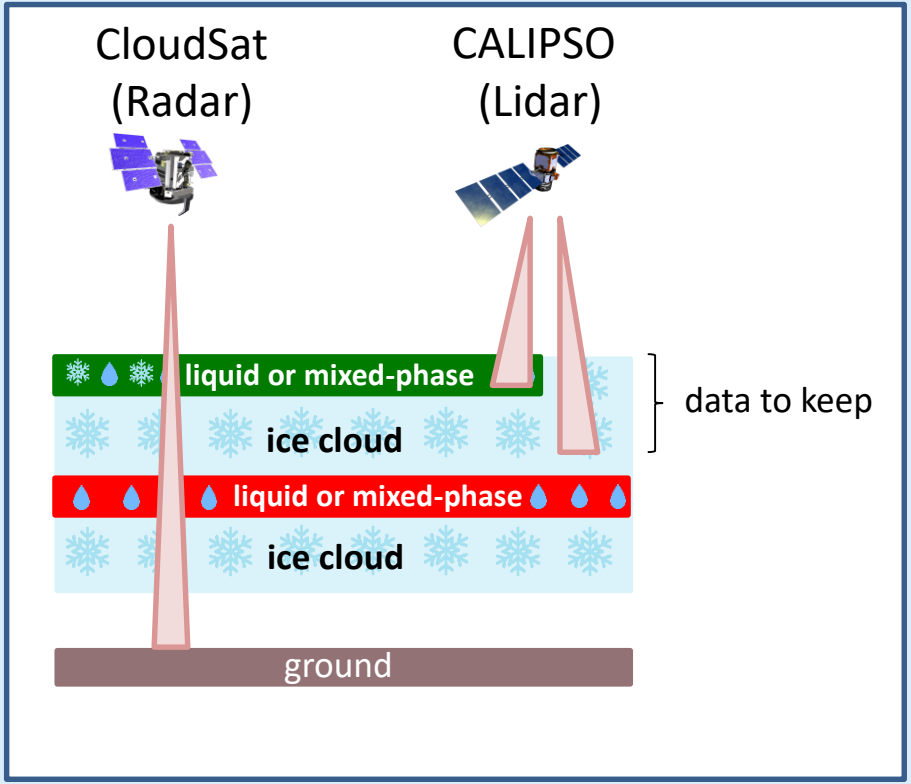


Shading: LWC (g.m^{-3}) ;
black contours: Temperature (°C) ; red contours: θ_E(K)

Over-representation of ice in mid-troposphere in observation

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





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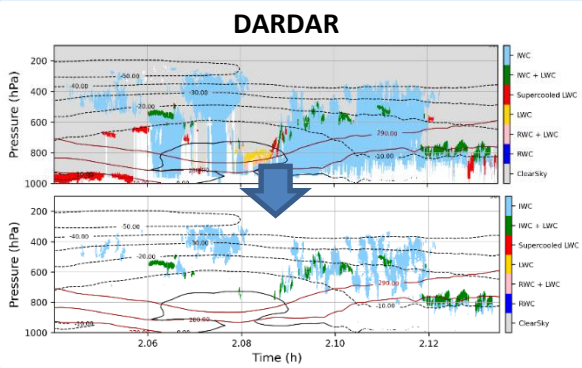
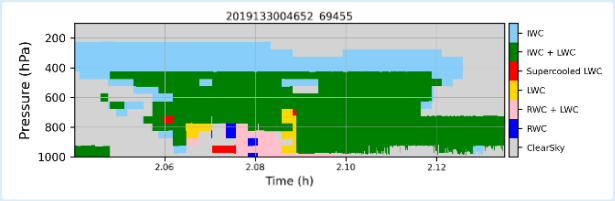
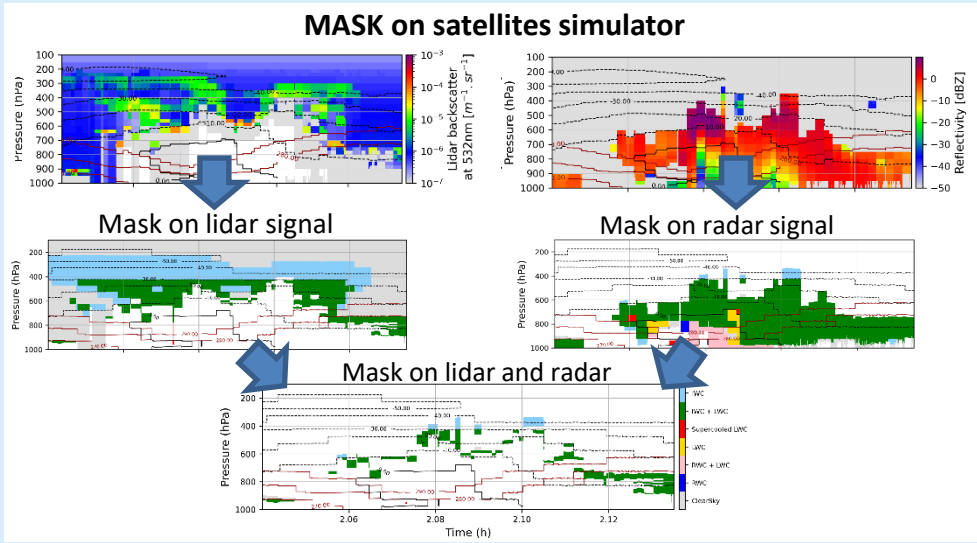


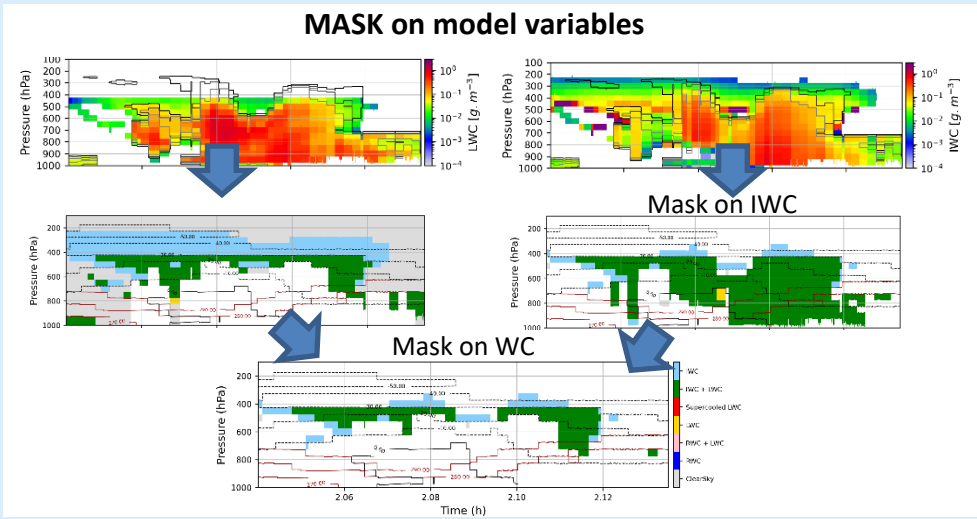
Models (ex: LMDZ CTRL):

Delete data where:

- COSP : $Z < -28dBZ$ and bscat $< 1 \times 10^{-7} m^{-1}.sr^{-1}$
- w/o COSP : $IWC < 5 \times 10^{-2} g.m^{-3}$ and $LWC > 1 \times 10^{-1} g.m^{-3}$







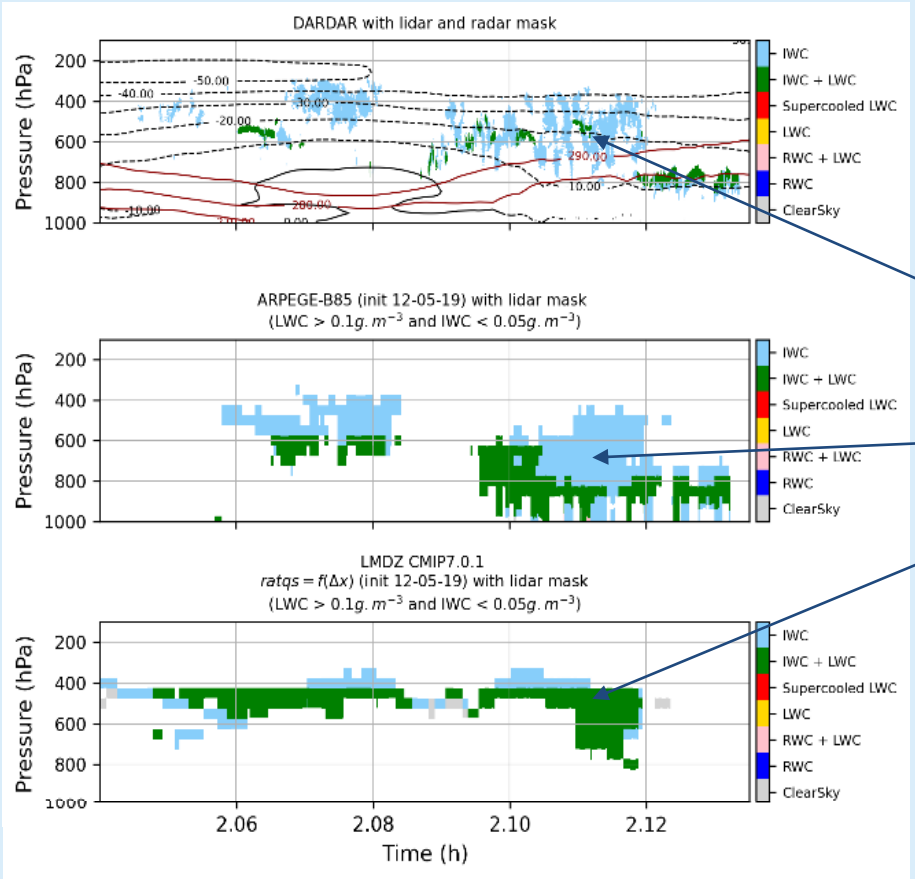
Comparison of mixed-phase and ice occurrences

mask on water content

DARDAR

ARPEGE

LMDZ



Ice clouds

Mixed phase clouds

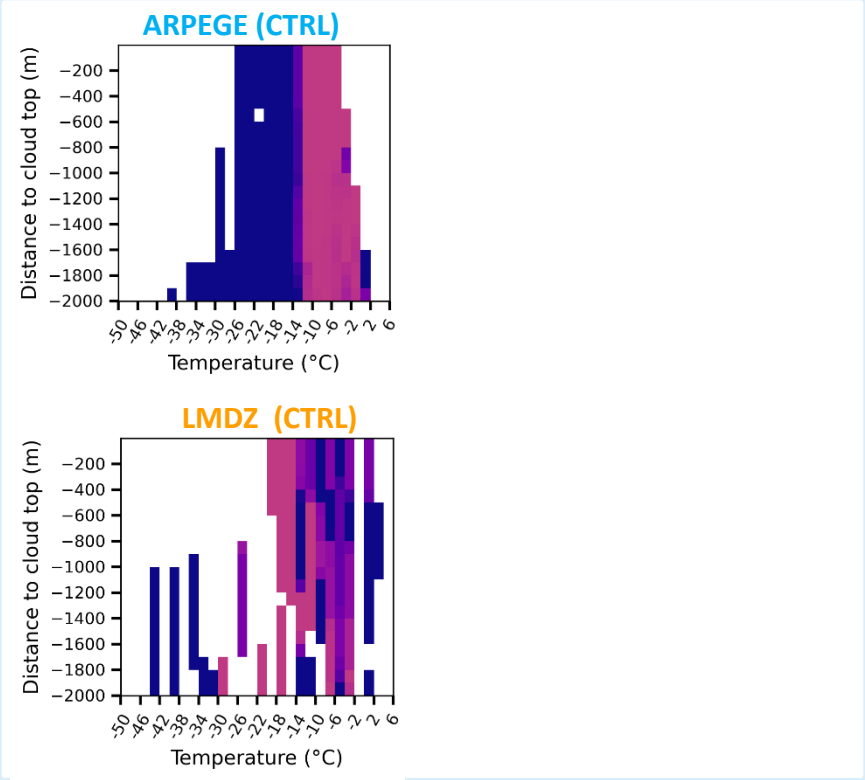
- Models do not produce mixed phase in top of clouds
- Better representation of mixed-phase with ARPEGE
- Mixed phase at too high altitude with LMDZ

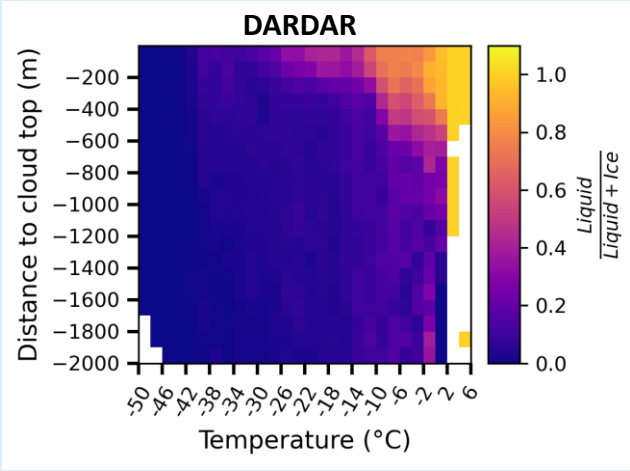
Shading: Hydrometeors categorization ; black contours: Temperature (°C) ; red contours: θ_E (K)

Ice/liquid partition function on occurrence: according to temperature and distance to cloud top

Statistics on all satellite overpasses

Mask on water content





Under-estimation at T< -40°C

Under-estimation at - 15°C <T< 0°C and 0m<d<600m

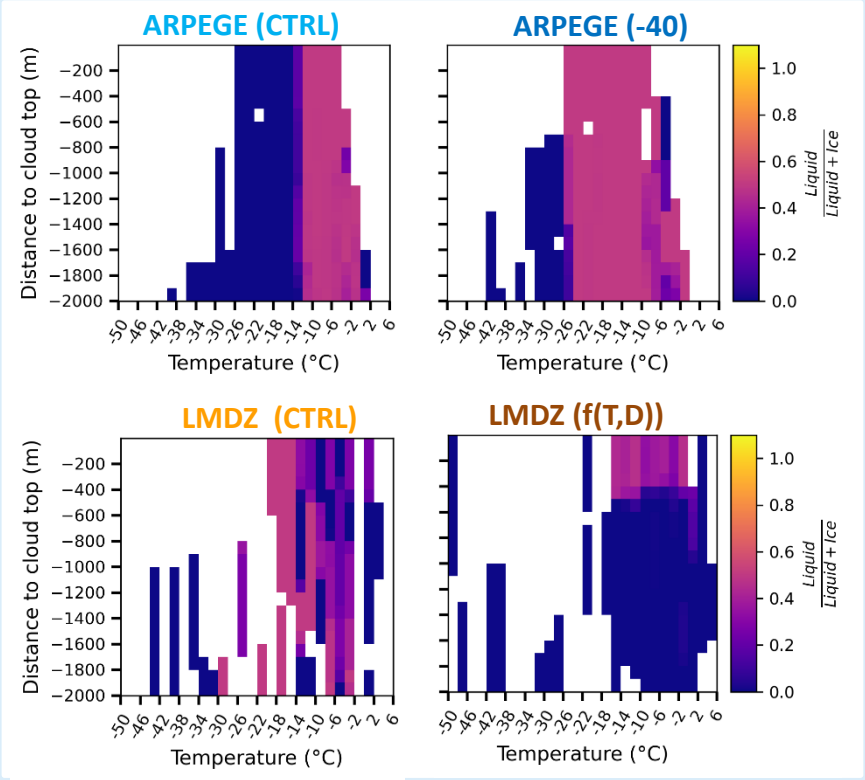
Over-estimation at - 15°C <T< 0°C and 600m<d<2000m

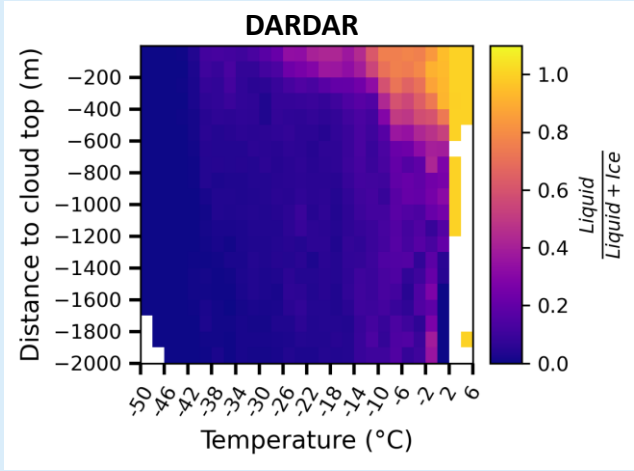
No dependence on d

Ice/liquid partition function on occurrence: according to temperature and distance to cloud top

Statistics on all satellite overpasses

Mask on water content





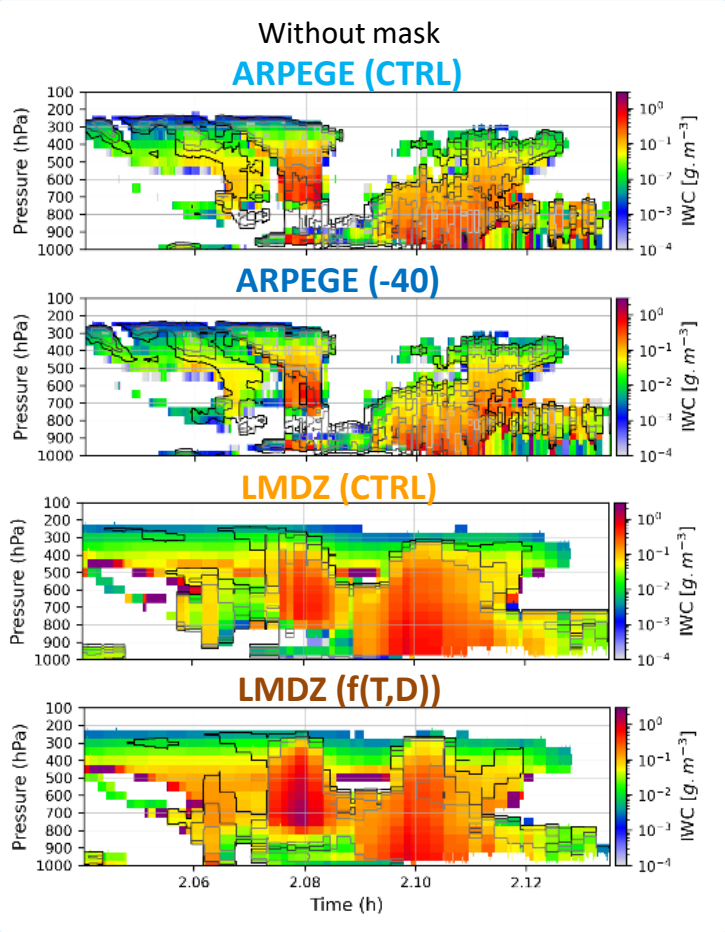
Under-estimation at T< -40°C

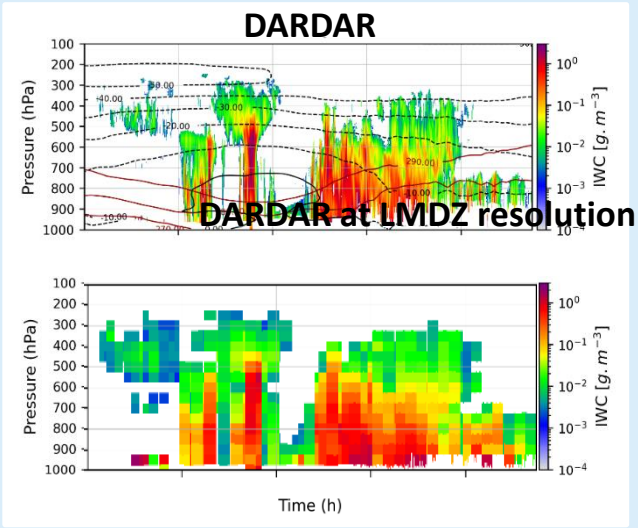
Under-estimation at - 15°C <T< 0°C and 0m<d<600m

Over-estimation at - 15°C <T< 0°C and 600m<d<2000m

No dependence on d

Comparison of IWC_{in}



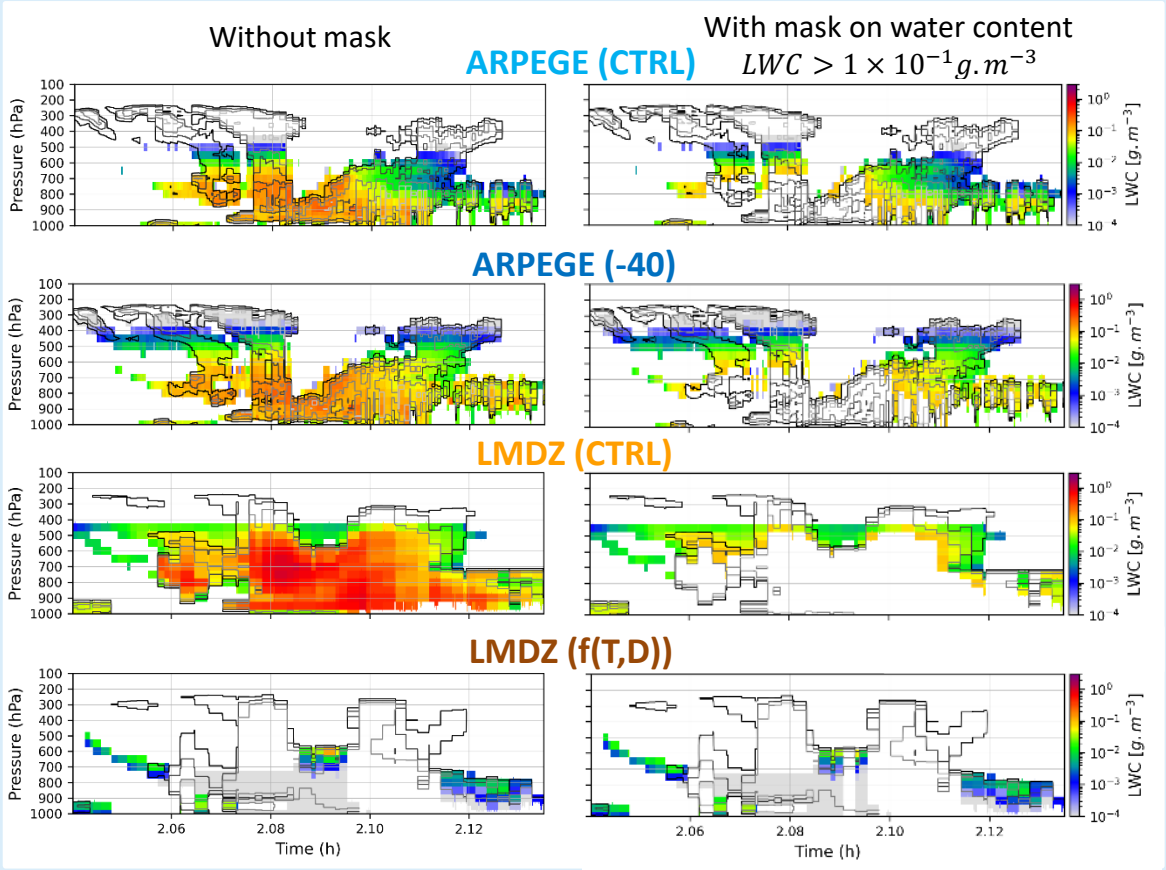


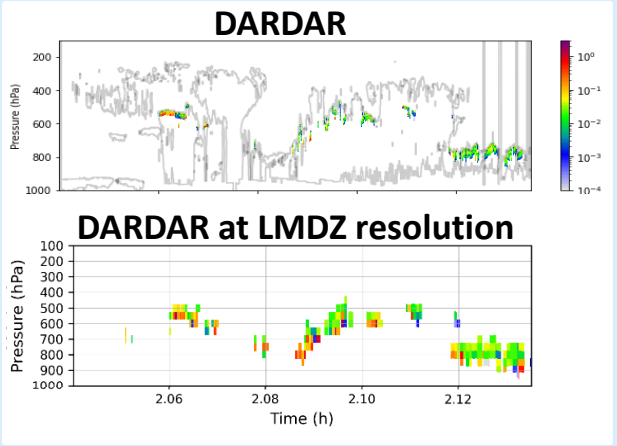
Modification of liquid/ice partition function:

- ARPEGE : IWC decreases
- LMDZ : IWC increases
- True for 18 satellite overpasses

Shading: IWC ($g.m^{-3}$) ; black contours: Cloud Fraction (%) at 2019-05-13 0UTC

Comparison of LWC_{in}





Modification of liquid/ice partition function:

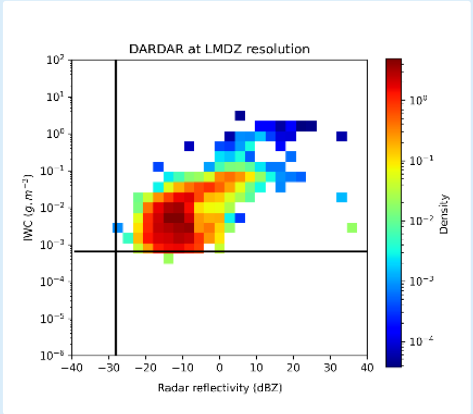
- ARPEGE: LWC at too high altitude
- LMDZ: LWC well localized but too small

Shading: LWC ($g.m^{-3}$) ; black contours: Cloud Fraction; at 2019-05-13 0UTC

Main results outlooks

Conclusion:

- Cannot compare directly models and DARDAR: need a post-processing on mask to focus on proper area
- Liquid water **occurrences**:
  - Under-estimation at very negative temperature (< -40°C)
  - Under-estimation at moderate negative temperature (- 15°C , 0°C) and low distance to cloud top (0-600m)
  - Over-estimation at moderate negative temperature (- 15°C , 0°C) and high distance to cloud top (600-2000m)
  - Models do not consider any dependence on **distance to cloud top**
  - **Better** with function depending on temperature and **distance to cloud top**
- Better **IWC** and **LWC** with **LMDZ**
- Changing the **liquid/ice partition function in ARPEGE**:
  - Decreases IWC
  - Allows supercooled liquid water at higher altitude
- Changing the **liquid/ice partition function in LMDZ**:
  - Increases IWC
  - Too small LWC but well localized



Outlooks:

- Better estimate IWC and LWC **threshold** for mask on water content

Thank you for your attention