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

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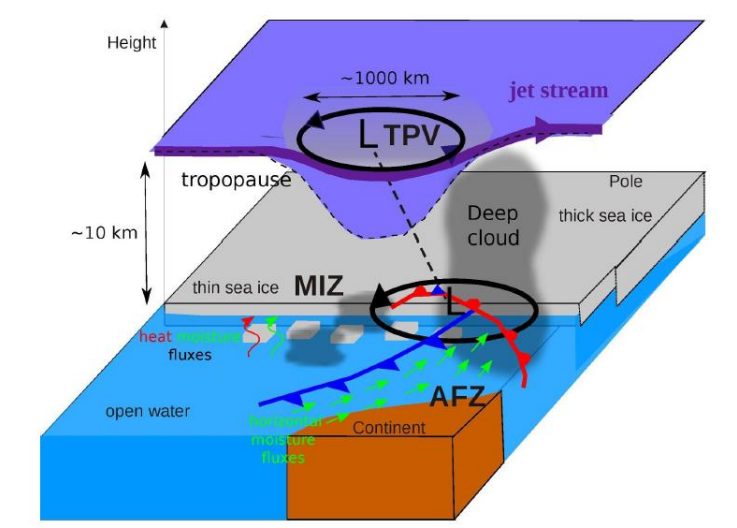
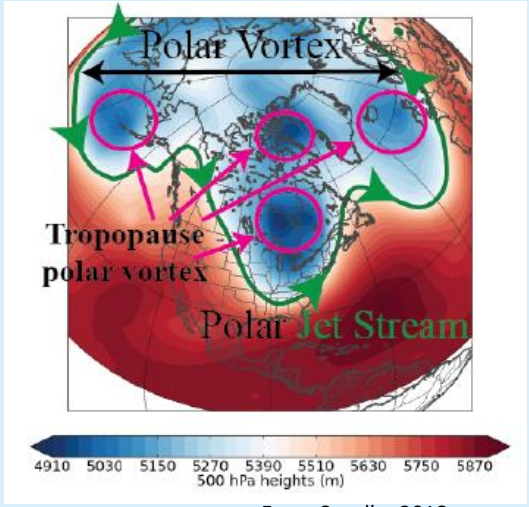
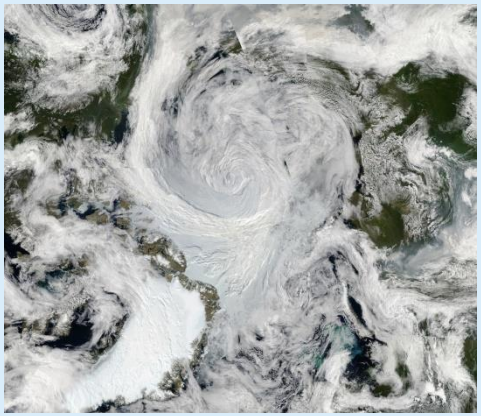
Arctic Cyclones

- Large-scale cyclone (1000km)
- Long duration (2 weeks)
- Not well known dynamics: baroclinic (AFZ) / barotropic (Tanaka et al. 2012)
- 1/3 of Arctic Cyclones linked to TPV (Gray et al. 2021)
- Impact on rapid sea ice loss in summer (ex: Simmonds et al. 2012)





From Cavallo, 2018



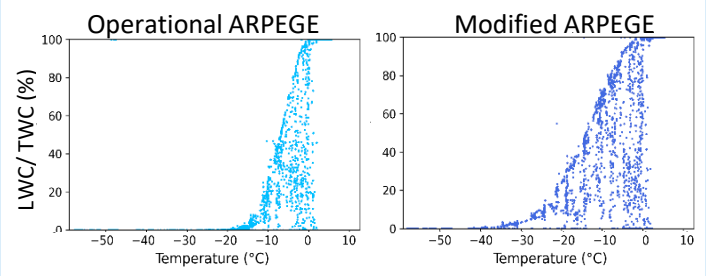
Great Arctic Cyclone 2/05/2012(MODIS)

Credit: NASA/Goddard/MODIS Rapid Response Team

Uncertainty in GCM 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), …)



Adapté de Ricaud et al., 2020

Uncertainty due to liquid/ice partition function:

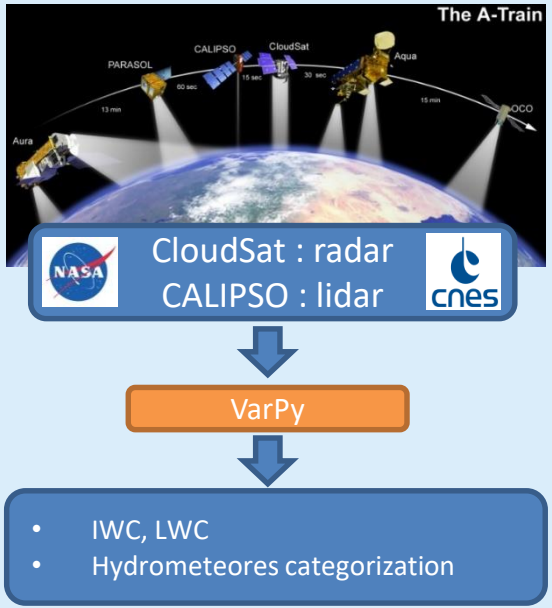
- Mazoyer et al (2023), Ricaud et al. (2020)

Problem: supercooled liquid water occurrence not linked only to temperature

Objective:

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

Observations: DARDAR products

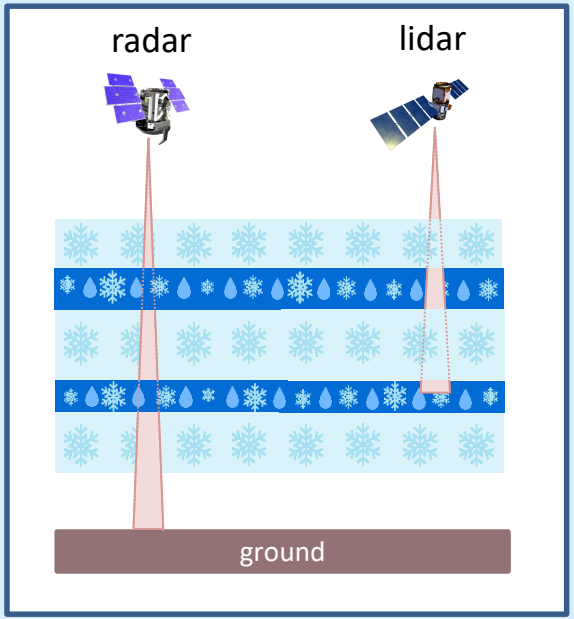


Radar:

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

Lidar:

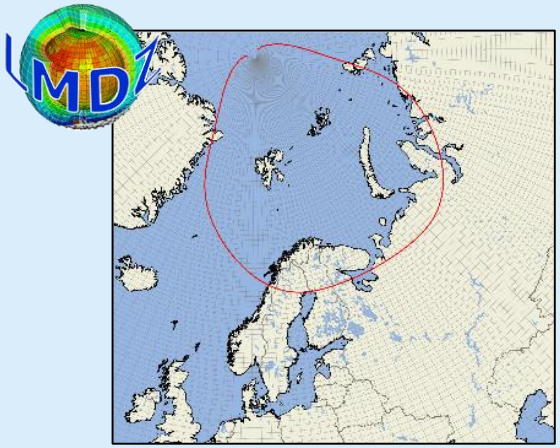
- Sensitive to concentration of small particules
- Detects small cristals and liquid droplets
- Use to determine LWC and IWC



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

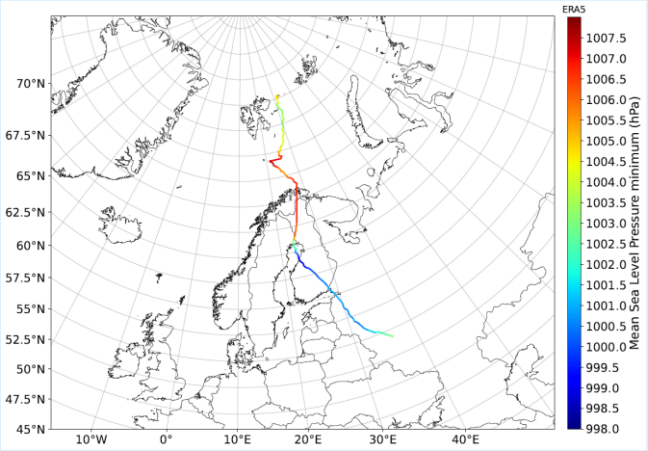


LMDZ (climate model)
Resolution: Zoom configuration with 50km in Svalbard, 95 levels
Initialisation: ERA5
Type of simulation: nudging to ERA5 outside the zoom with COSP simulator
Version: CMIP7.1b version

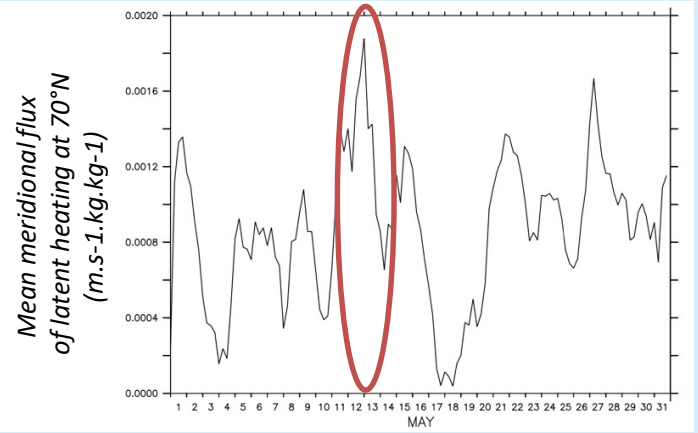
Outputs:
- time: 3h
- Lon x Lat : 0,5° x 0,5°
- 18 pressure levels (50hPa resolution)

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)

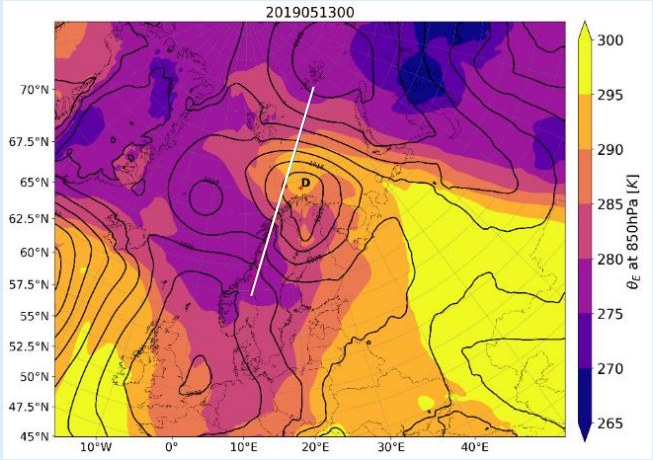


Mean meridional flux of latent heating at 70°N (ERA5 data)

Example of one satellites overpass:

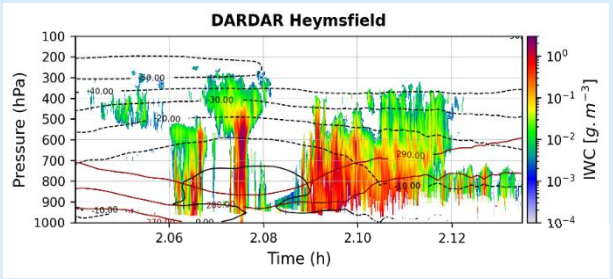
#2019133004652_69455 crossing warm and cold front

ERA5 : 20190513 00UTC

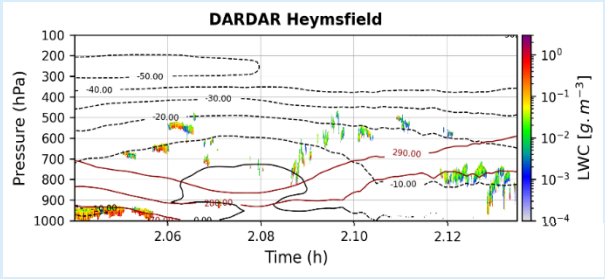


Shading: θ_E at 850hPa (K) ; black contours: MSLP (hPa) ;
white line: time along satellites overpass

DARDAR Products : 20190513 02UTC



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



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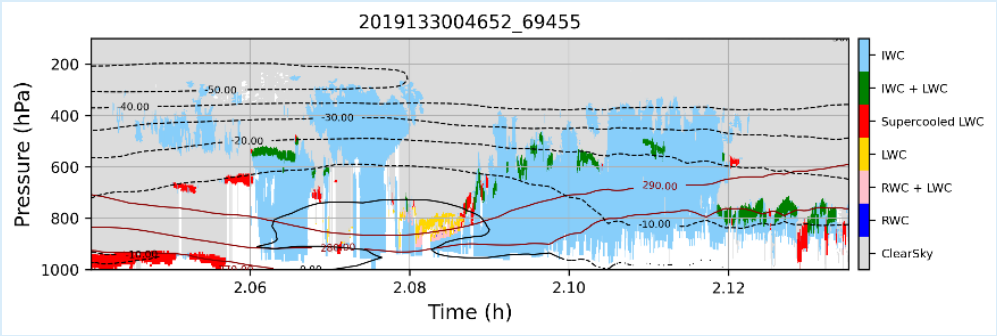
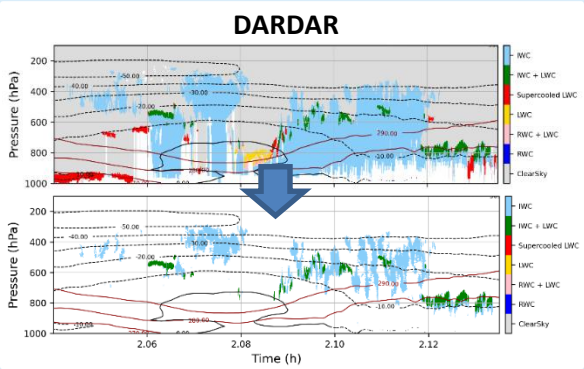
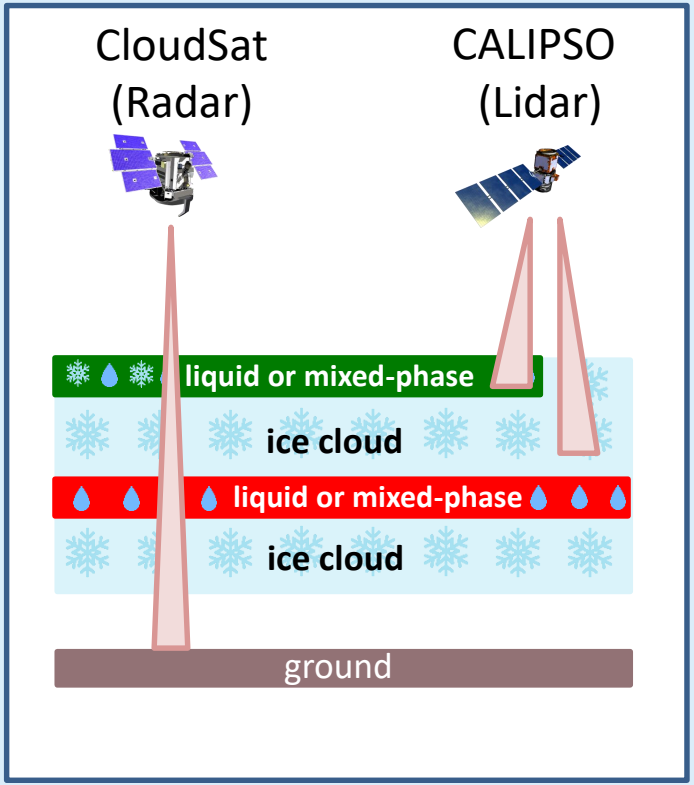


Shading: Hydrometeors categorization ; black contours: Temperature (°C) ; red contours: θ_E (K)

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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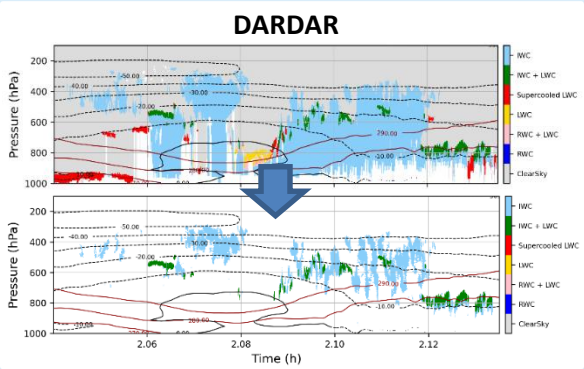
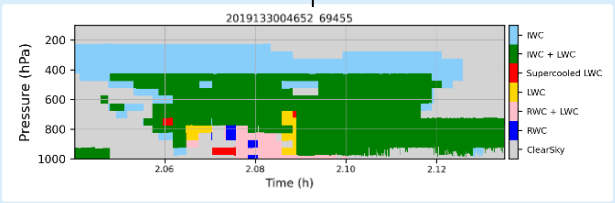
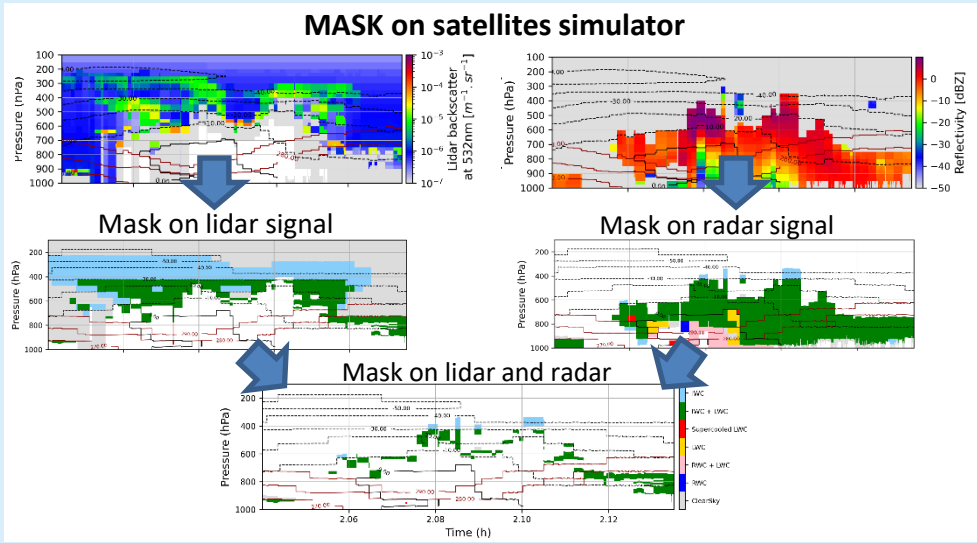
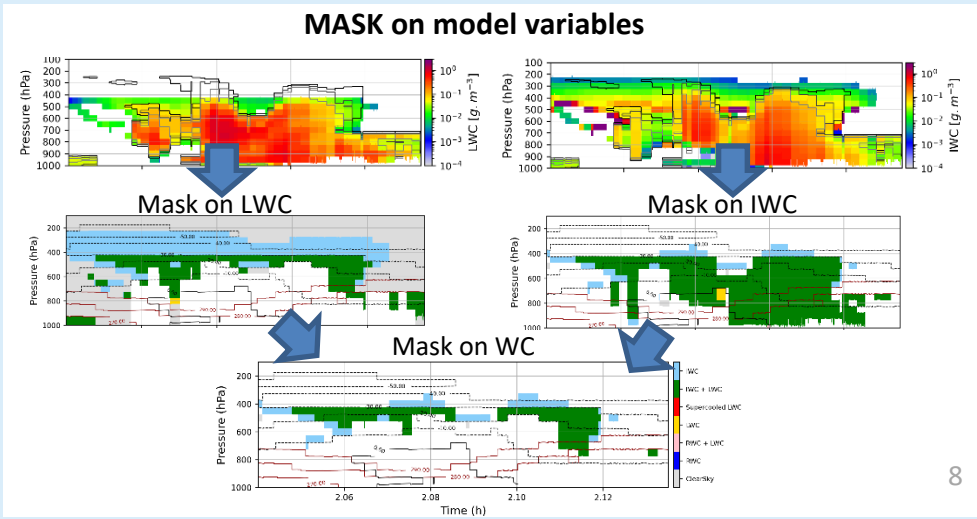


Models (ex: LMDZ CTRL):
Delete datas where:
- $IWC < 5 \times 10^{-2} g.m^{-3}$
- $LWC > 1 \times 10^{-1} g.m^{-3}$

Validation with COSP simulator:
- $Z < -28 dBZ$
- $bscat < 1 \times 10^{-7} m^{-1}.sr^{-1}$







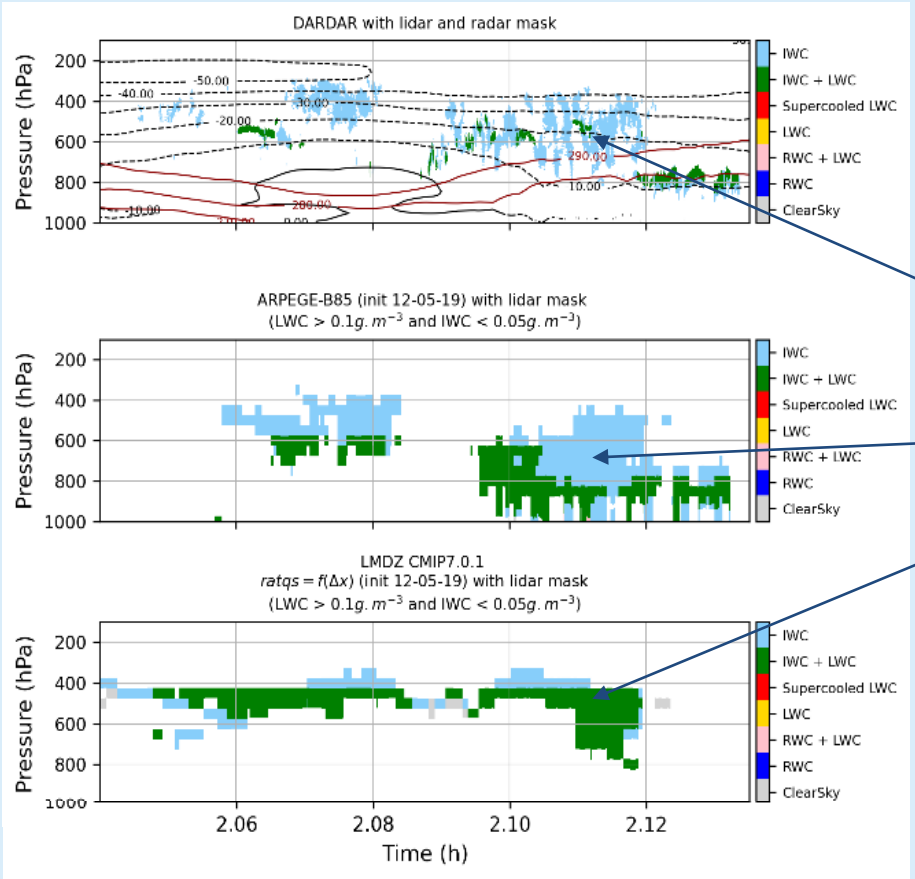
Comparison of mixed-phase and ice occurrences

mask on water content

DARDAR

ARPEGE

LMDZ



Ice clouds

Mixed phase clouds

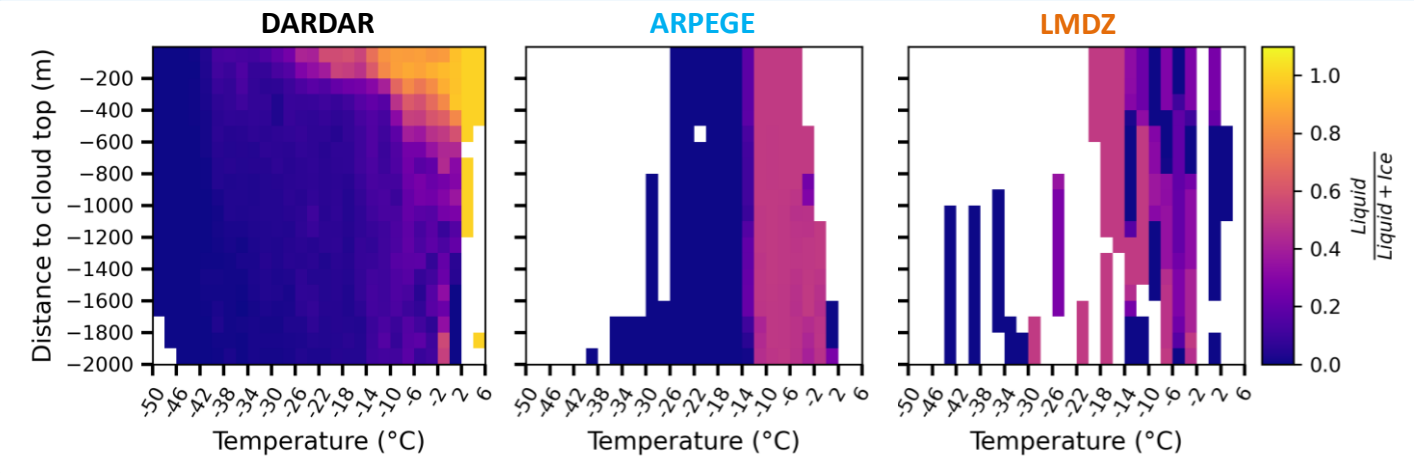
- Models do not produce mixed phase in top of clouds
- Better representation of mixed-phase with ARPEGE
- Mixed phase at too high altitude with LMDZ

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



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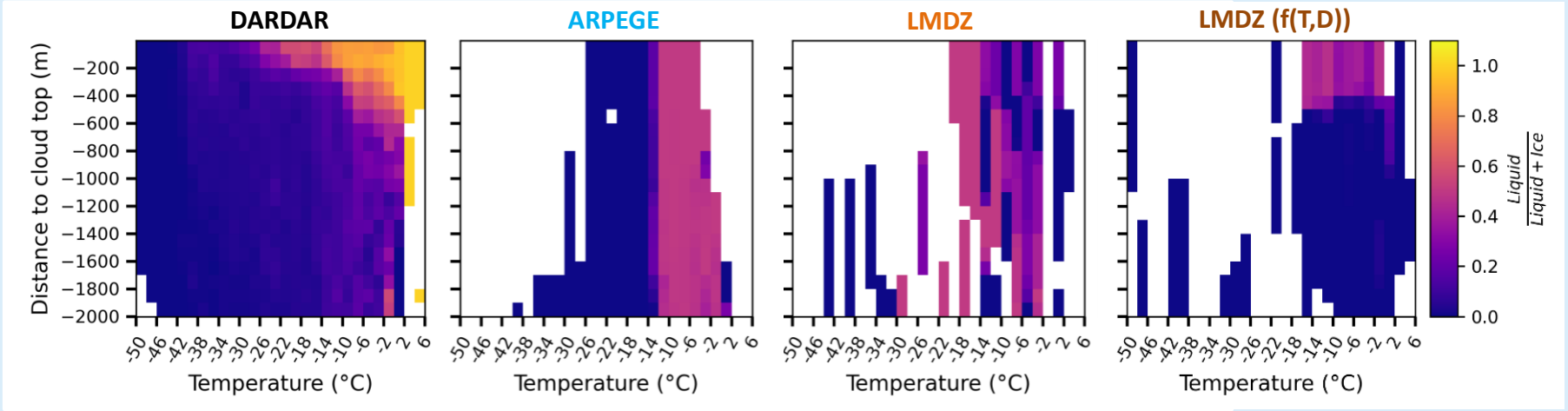
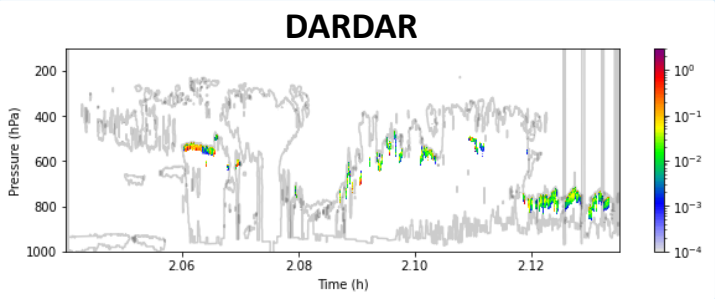
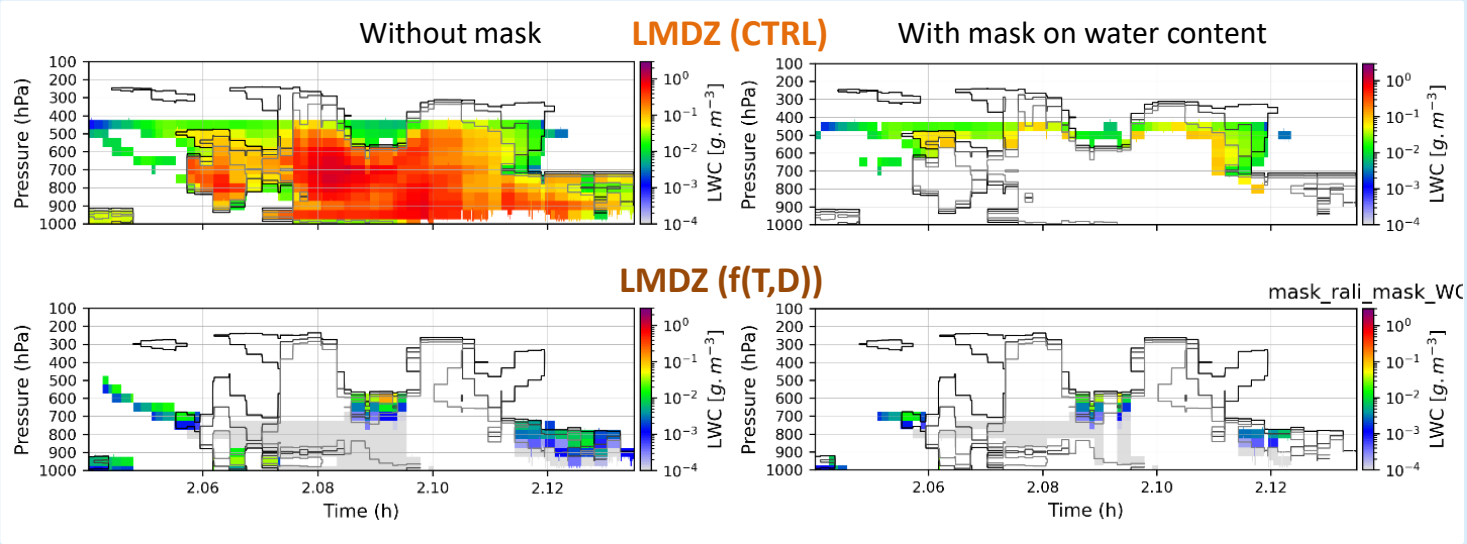


Comparison of LWC

LMDZ (f(T,D)) : LWC well localized but too small





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

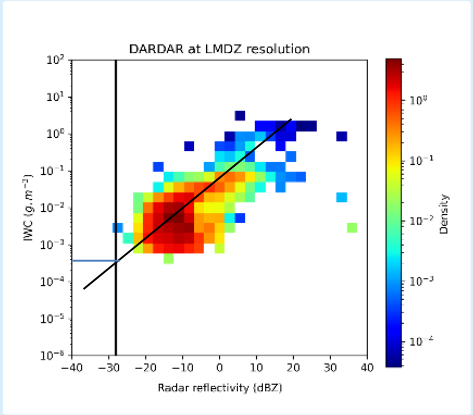
Main results outlooks

Conclusion:

- Case study to prepare the THINICE field campaign (2022)
- Liquid water **occurrences**:
  - Under-estimation at moderate negative temperature (- 15°C , 0°C)
  - Over-estimation at negative temperature (- 40°C , - 15°C)
  - Under-estimation at very negative temperature (>-40°C)
  - 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

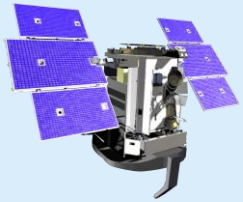
CloudSat and CALIPSO out of order

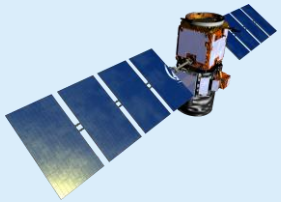
CALIPSO : 28/04/2006 – 15/12/2023

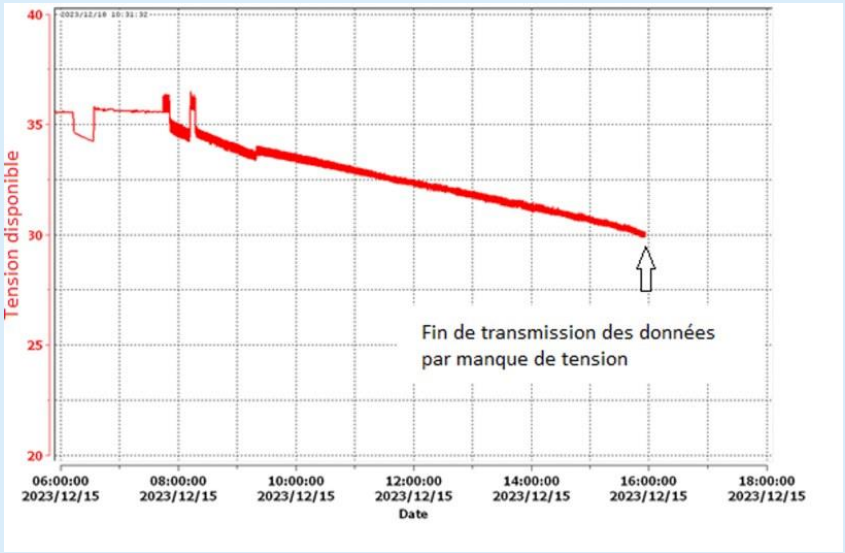
Lidar’s end : 01/08/2023

CloudSat : 28/04/2006 – 04/2024

Radar’s end : 20/12/2023







Last signal from CALIPSO