Microphysics developments in AROME

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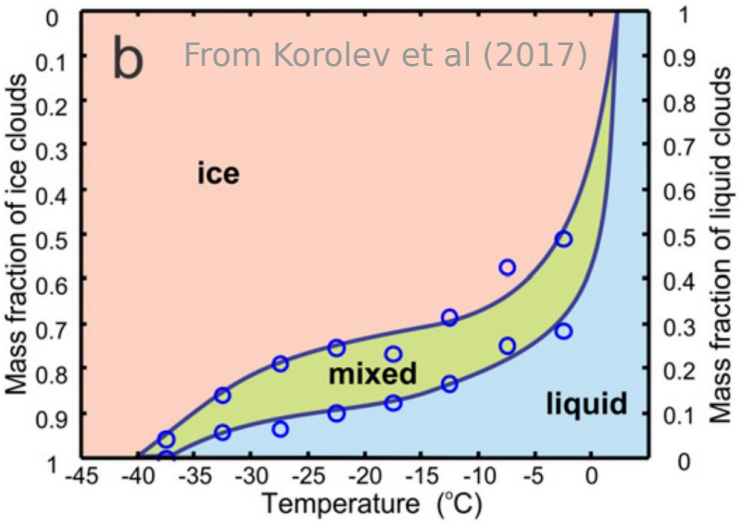
(ACCORD ASW, April 16th 2024)

Outline

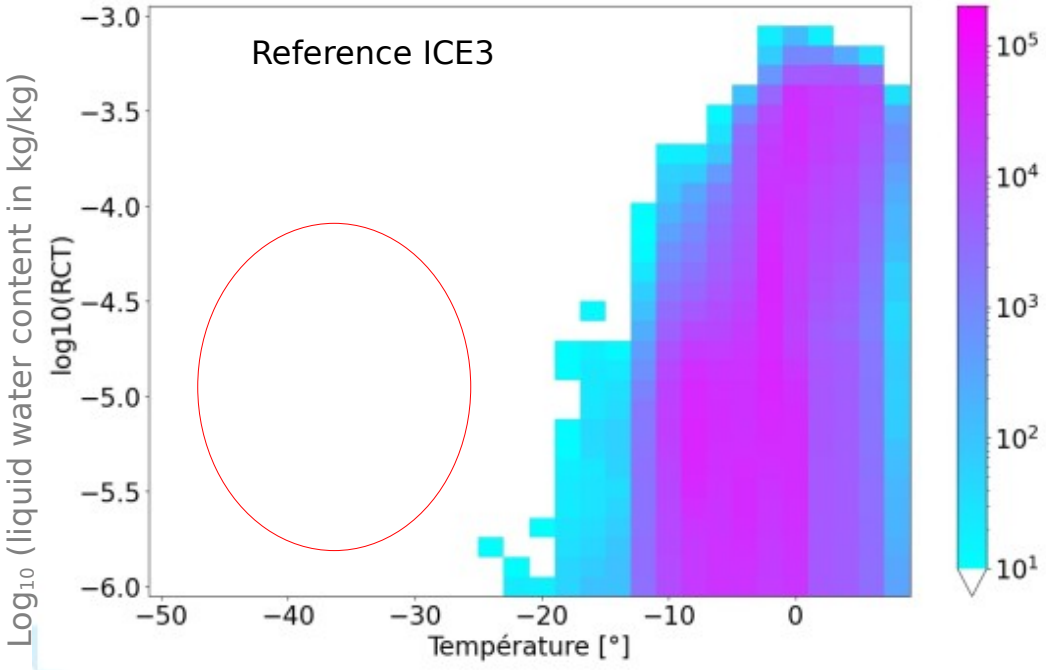
- Supercooled liquid water in ICE3
- Ongoing work in LIMA
- Cloud scheme and autoconversion consistency in ICE3

From ICICLE experiment

- Icing dedicated campain in 2019 over US Great Lakes area
- Oper ICE3 microphysics is not able to reproduce observations

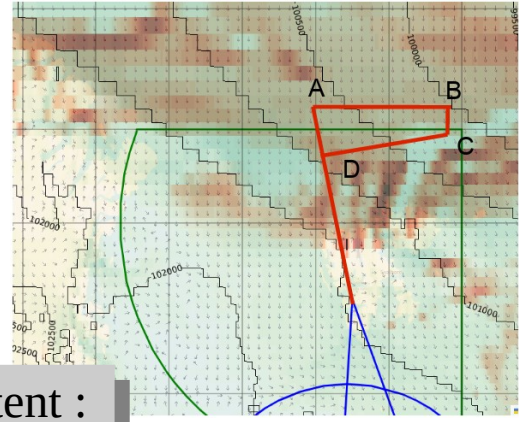


Number of grid boxes classified in bins of temperature and cloud liquid water content in an ICE3 simulation



(→ Courtesy R. Dupont)

From Rali-Thinice experiment

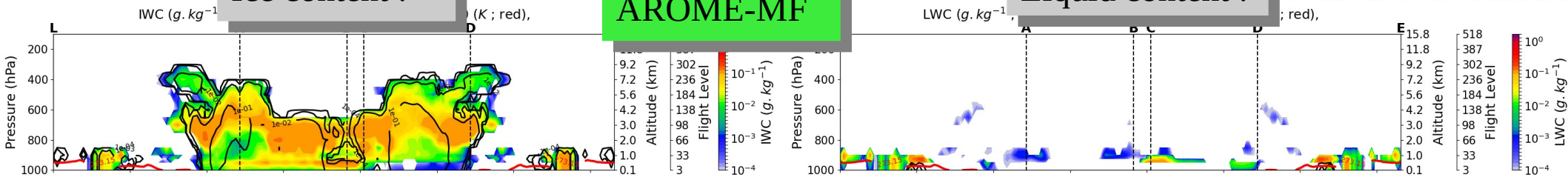


- Arctic clouds and polar lows field campain around Svalbard August 2022
- Not enough supercooled liquid water in AROME (ex Fl 53 25 August):

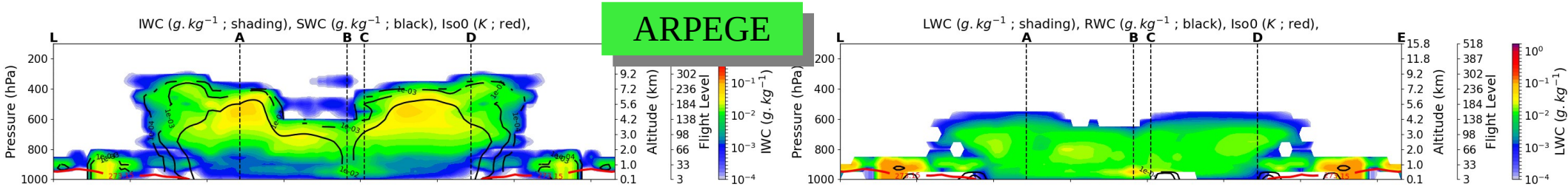
Ice content :

Liquid content :

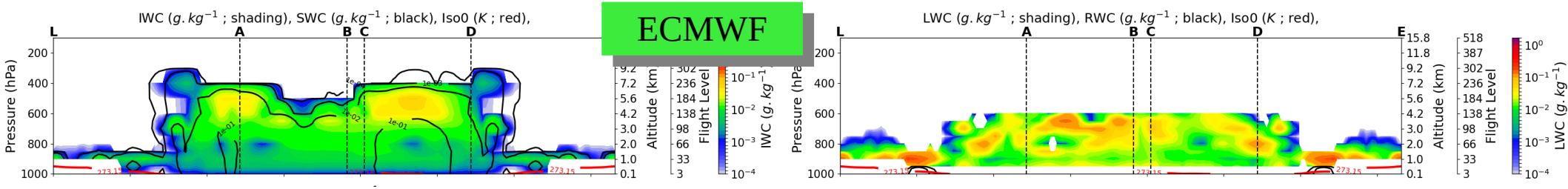
AROME-MF



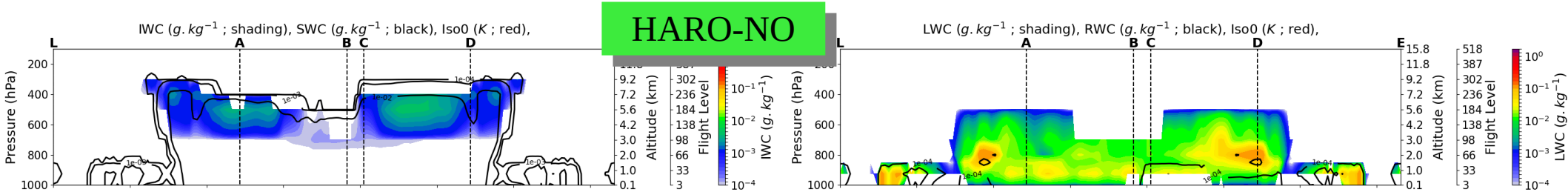
ARPEGE



ECMWF

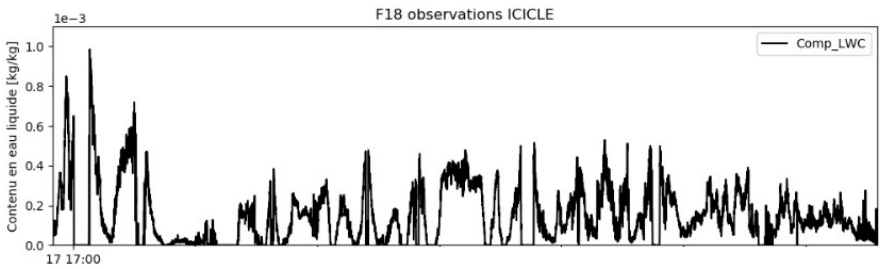


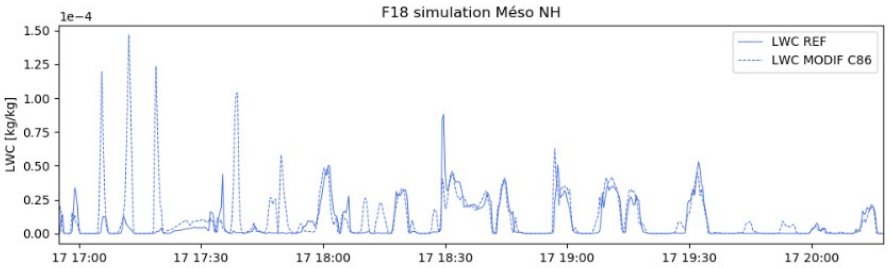
HARO-NO

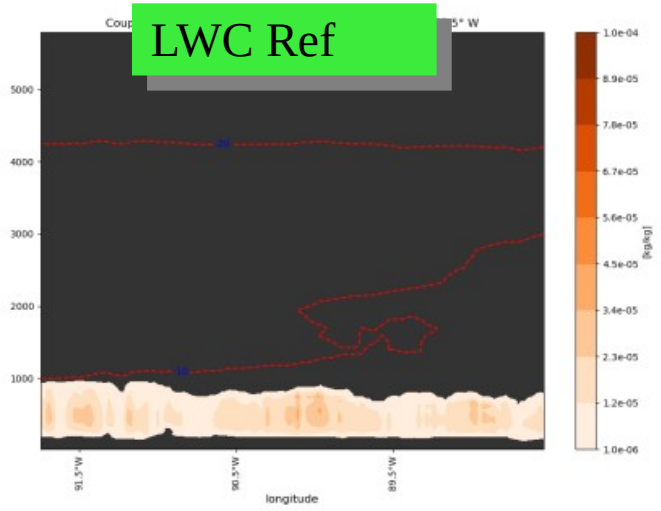


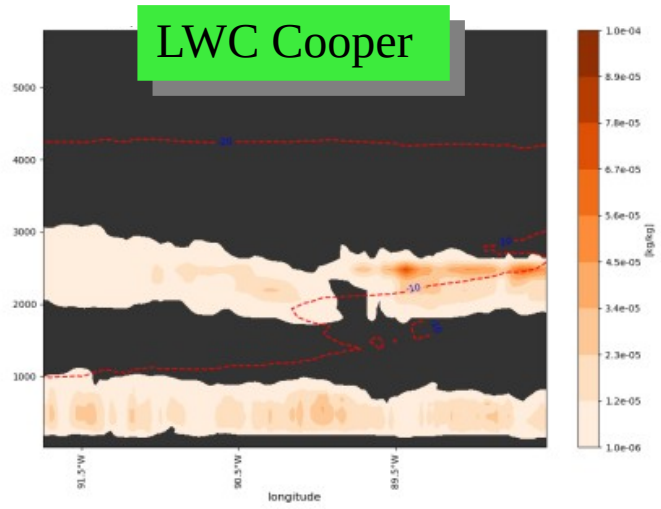
ICE3 modifications

- Introduction of some modifications from ICE-T reducing ice nucleation (Engdahl et al.,2020) :
  1) Heterogeneous nucleation : Cooper (1986) instead of Meyers (1992)
  → Less easy to form ice (Meyers : as soon as SSi>100 %, whatever T, in Cooper,addition of T and SSi thresholds (T< -12°C et SSi>125 %))









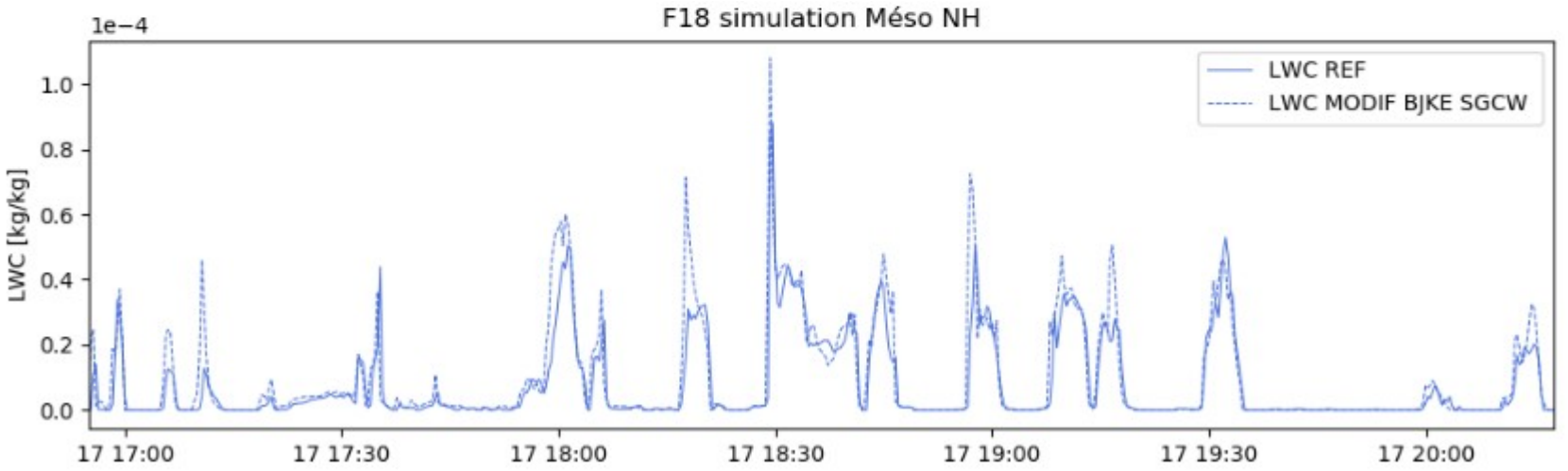
2) Immersion ice nucleation process added following Bigg (1956) as in Thompson et al. (2008), as a complement to Cooper (which is only valid for IceNuclei nucleation).

- 1) +2) remains < Meyers

(→ Courtesy Rémi Dupont)

ICE3 modifications

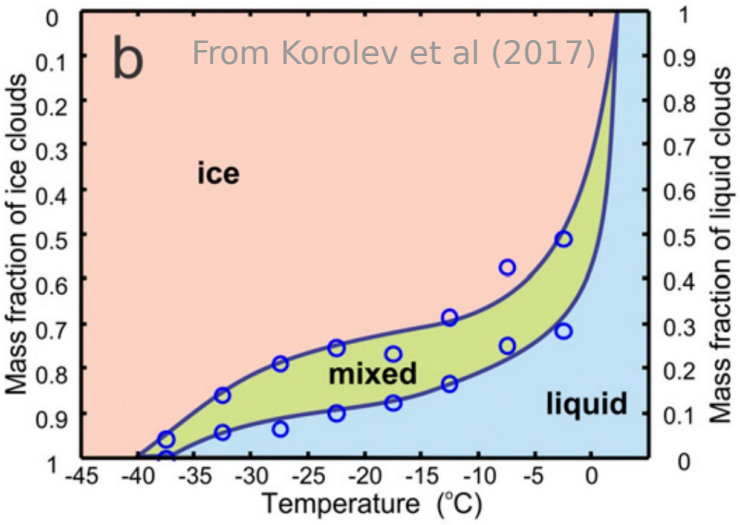
- Decrease collection processes (Engdahl et al.,2020, from Thompson et al. 2008) :
  → Snow and graupel will collect less liquid water as part of snow collecting water is converted into graupel
  → Less impact than ice nucleation modifications



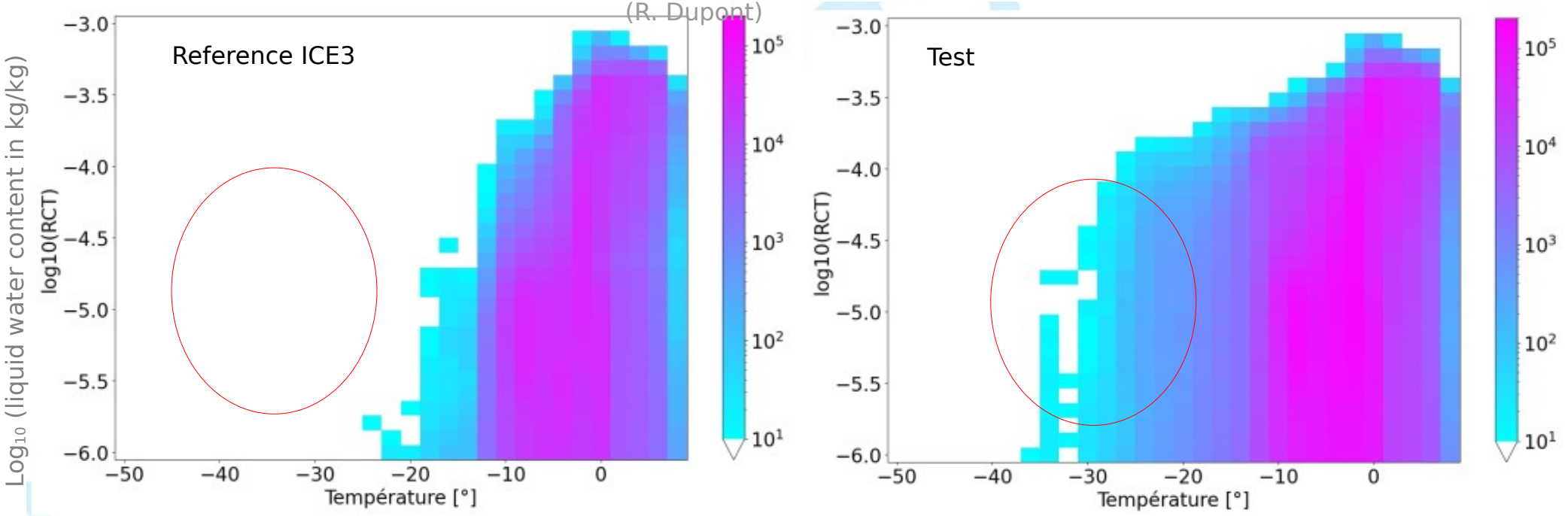
(→ from Rémi Dupont)

Results from ICICLE experiment

- Oper model microphysics is not able to reproduce observations
- Some promising results with modifications...

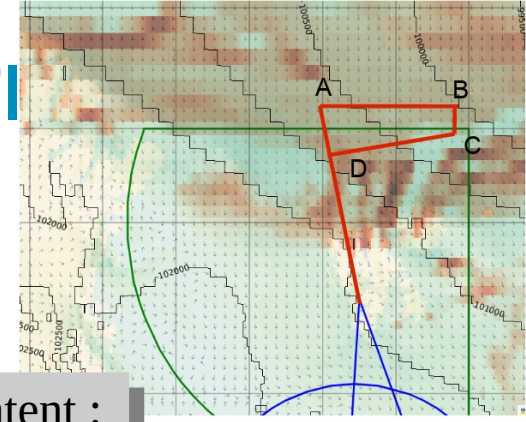


Number of grid boxes classified in bins of temperature and cloud liquid water content in an ICE3 simulation (R. Dupont)



Results from Rali-Thinice (25 August Fl

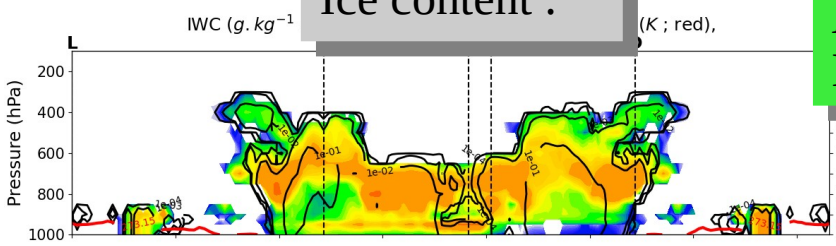
- Lower IWC, more LWC but still < HARO-NO

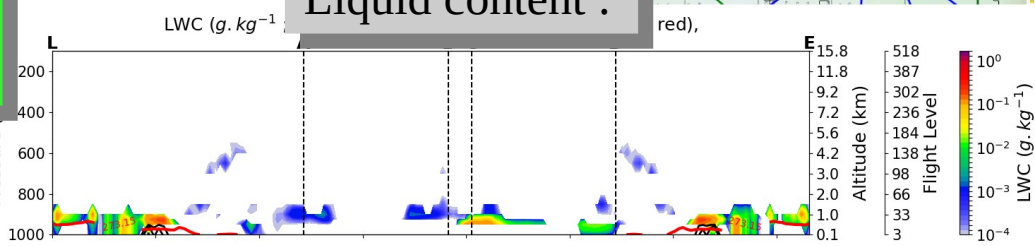


Ice content :

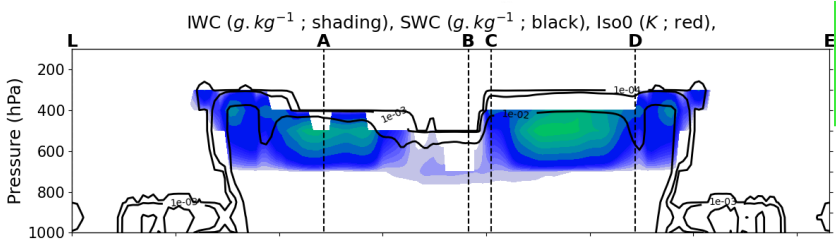
Liquid content :

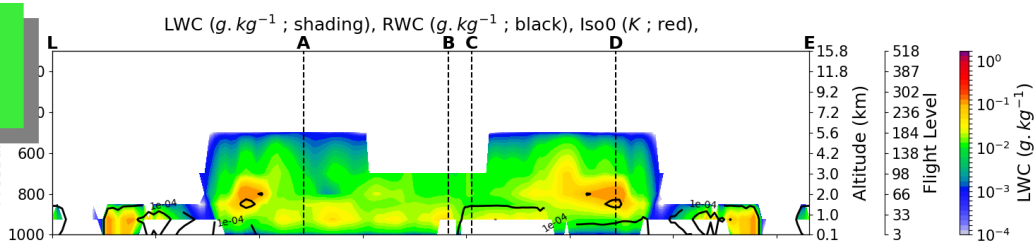
AROME-MF



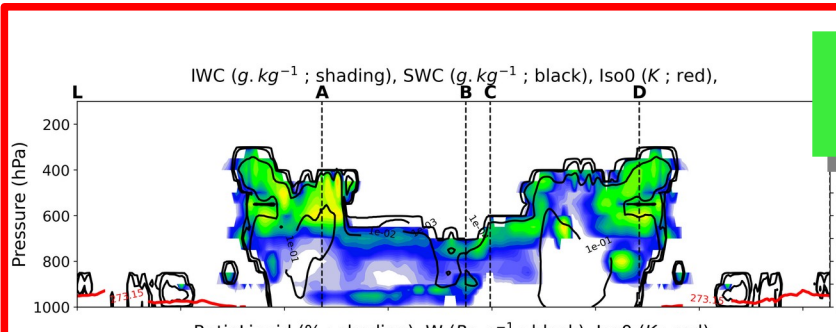


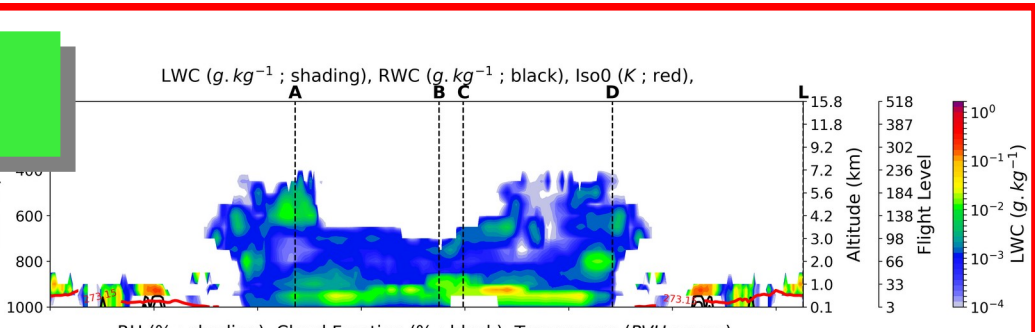
HARO-NO



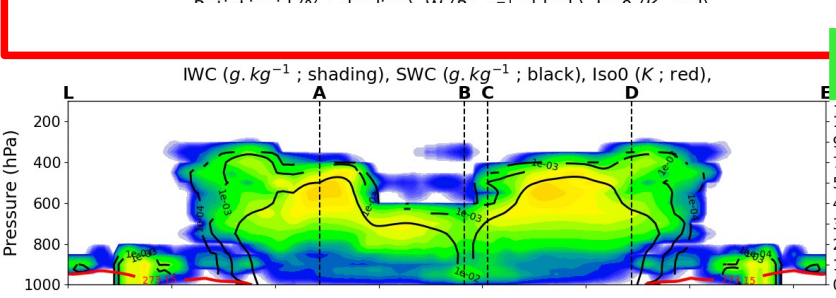


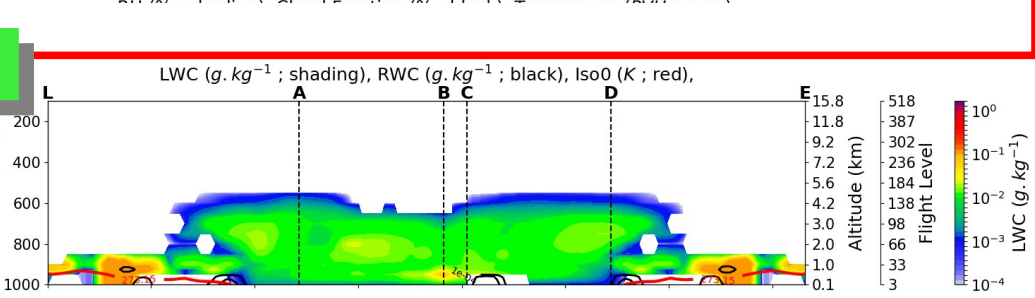
AROME-TEST





ARPEGE



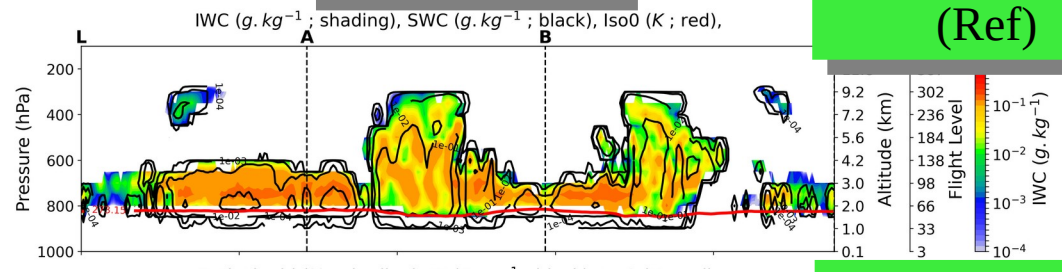


Rali-Thinice : August 06th flight

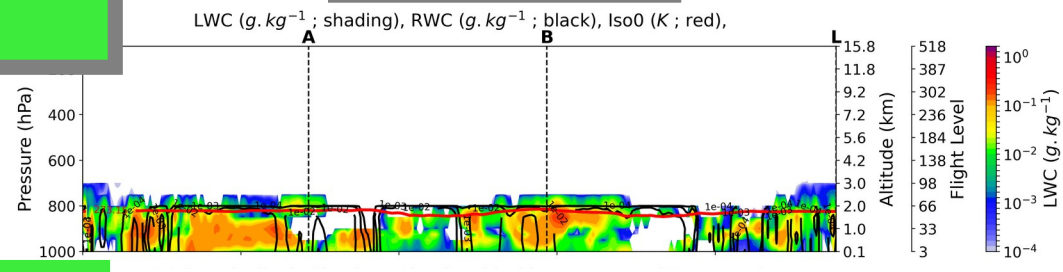
- More LWC, less IWC, with strong values at some cloud tops

Ice content :

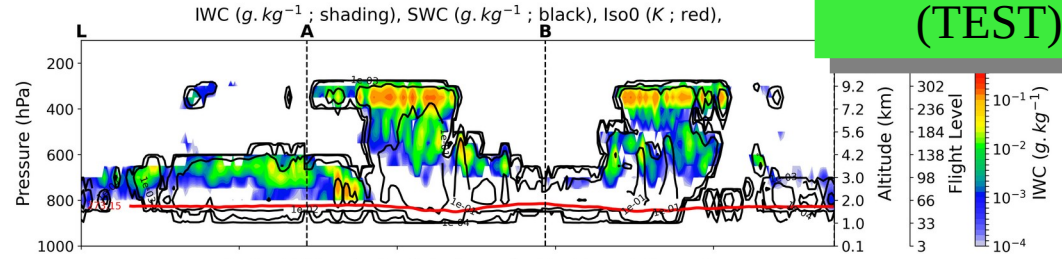
AROME-MF (Ref)

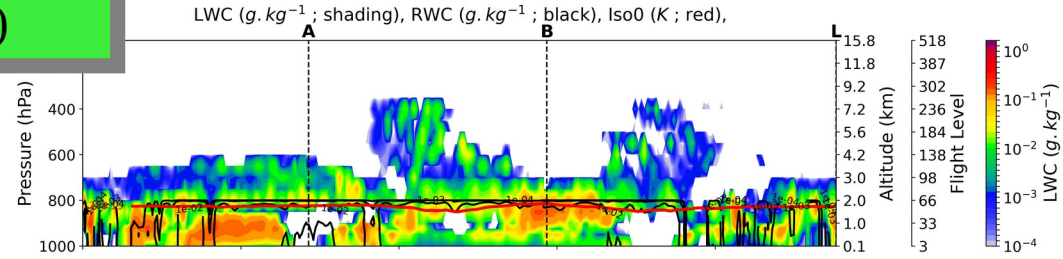


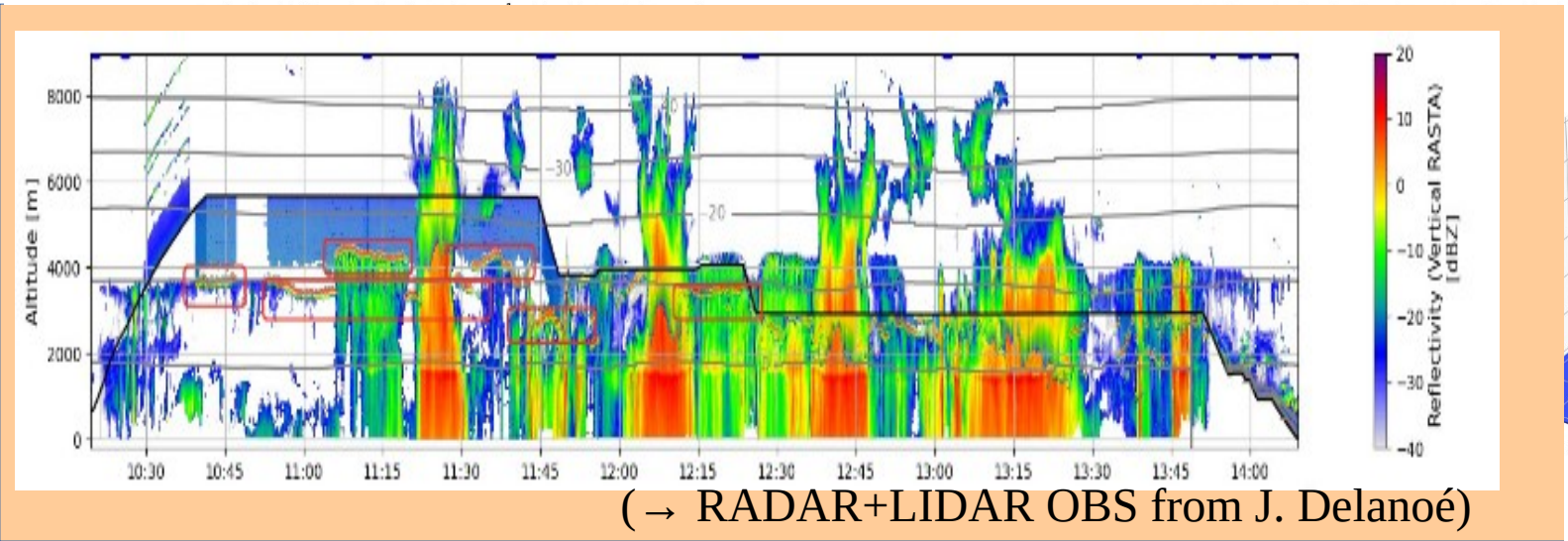
Liquid content :

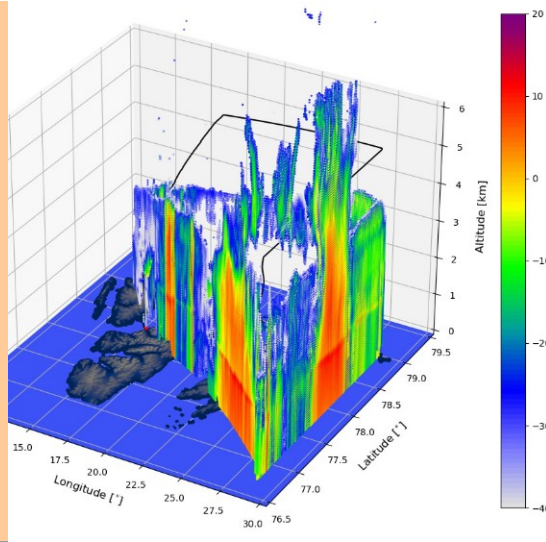


AROME-MF (TEST)





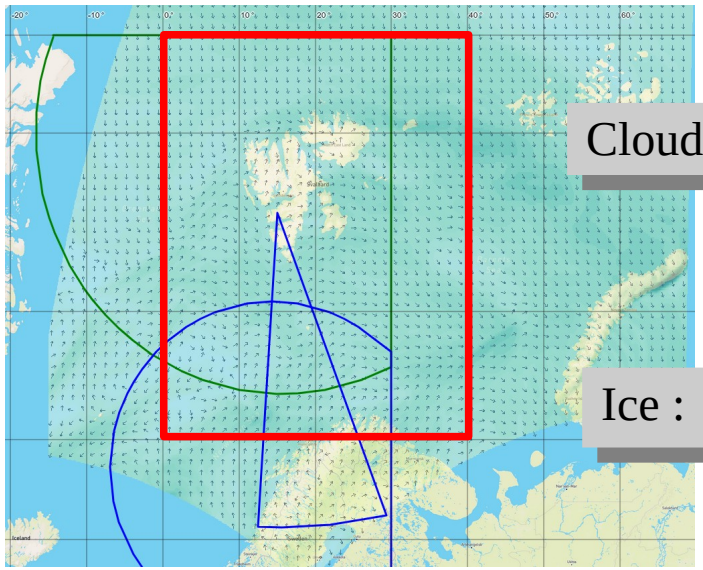




(→ RADAR+LIDAR OBS from J. Delanoé)

August 25th 2022, mean vertical profiles

- ICE3_Ref,
  ICE3_Test,
  HARO-NO

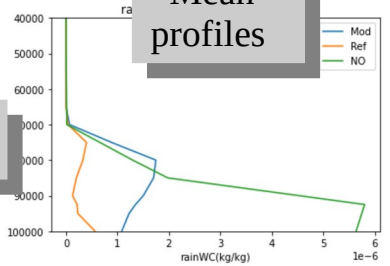


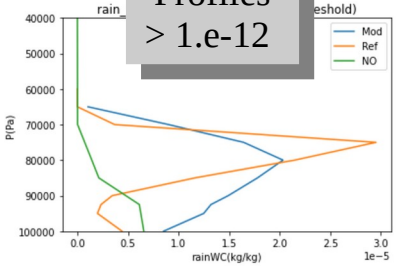
Mean profiles

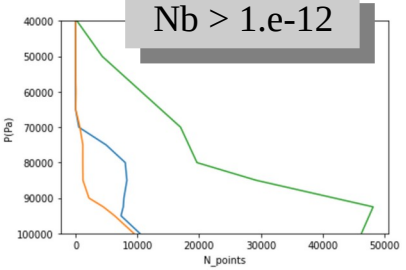
Profiles > 1.e-12

Nb > 1.e-12

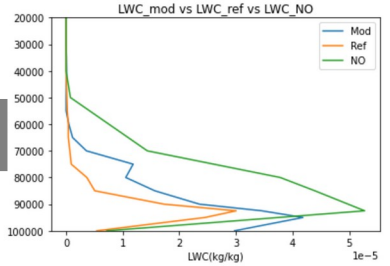
Rain :

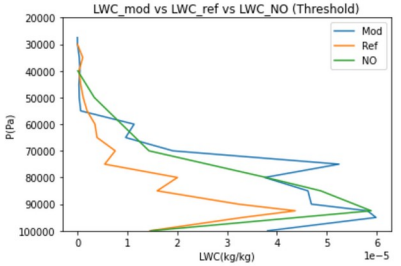


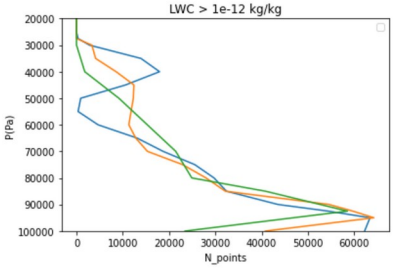




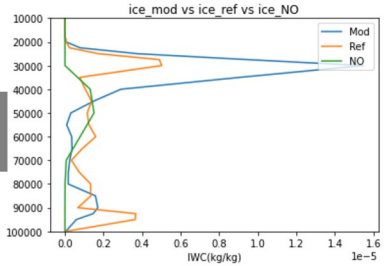
Cloud :

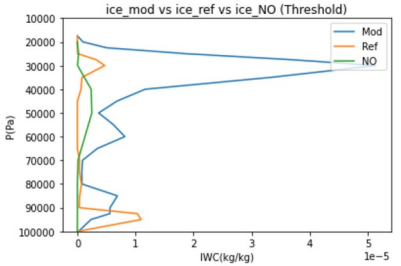


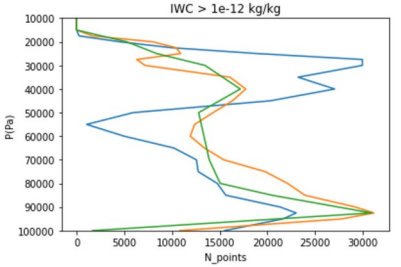




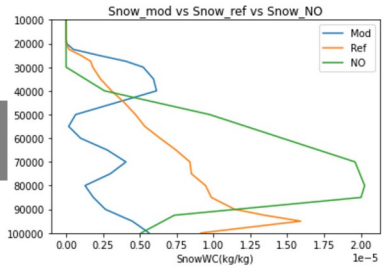
Ice :

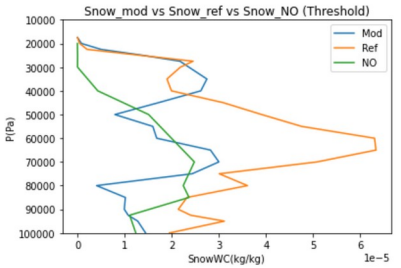


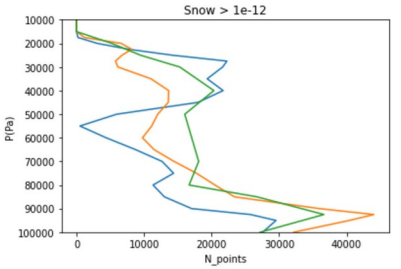




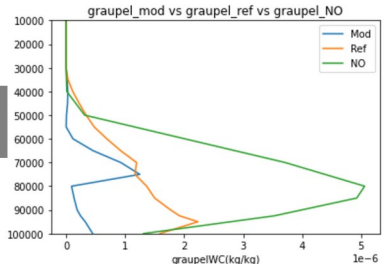
Snow :

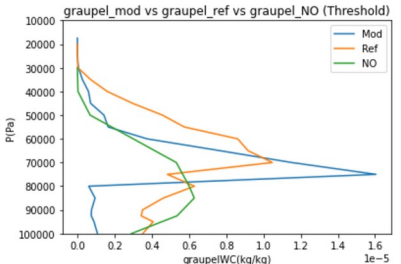


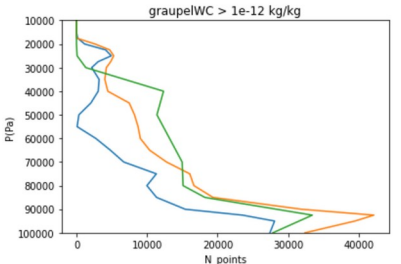




Graupel :

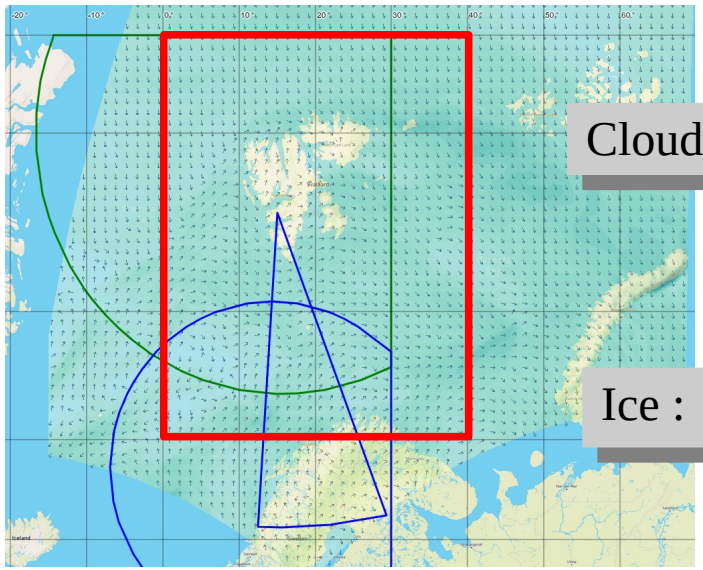






August 25th 2022, mean vertical profiles

- ICE3_Ref,
  ICE3_Test,
  HARO-NO

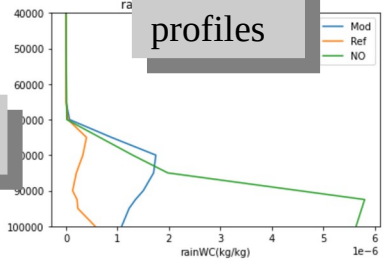


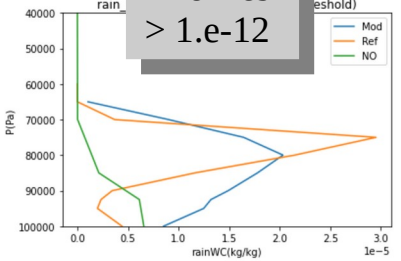
Mean profiles

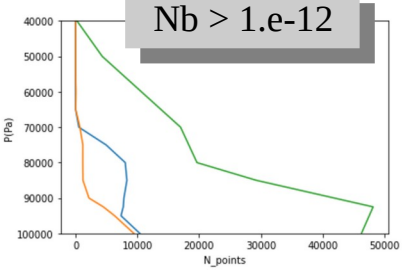
Profiles > 1.e-12

Nb > 1.e-12

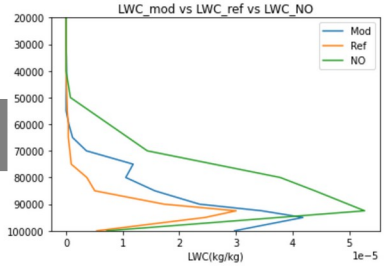
Rain :

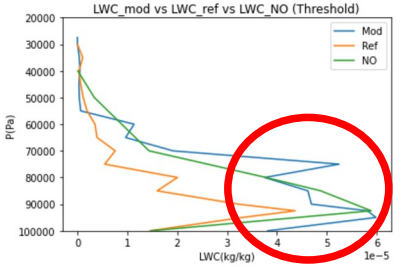


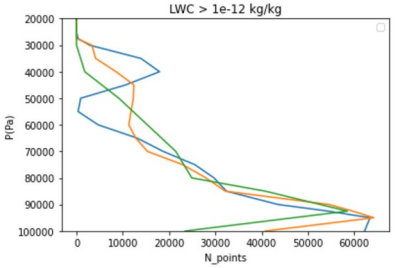




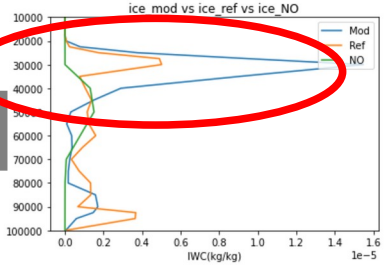
Cloud :

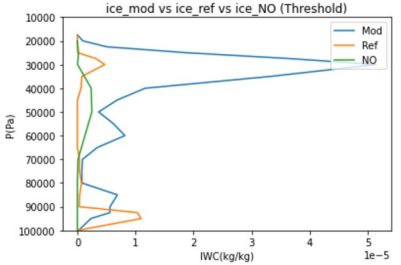


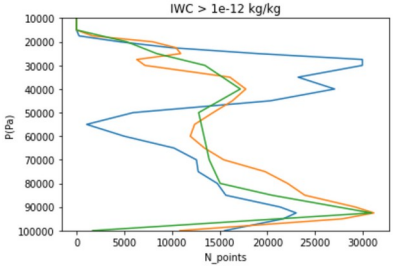




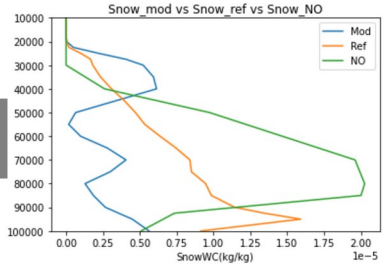
Ice :

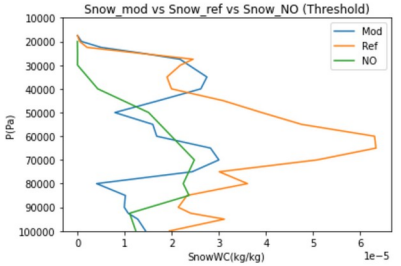


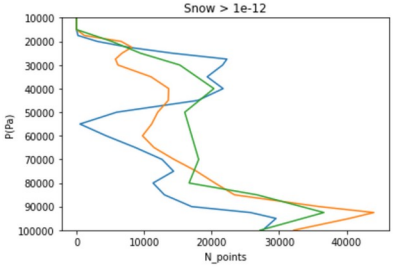




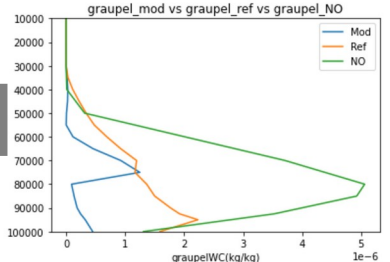
Snow :

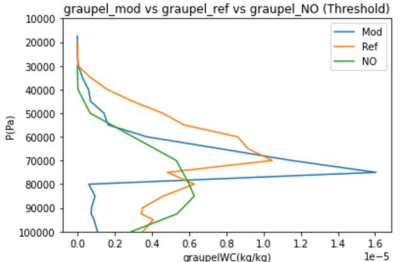


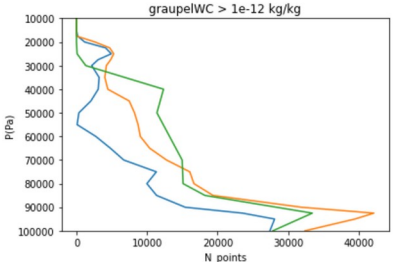




Graupel :



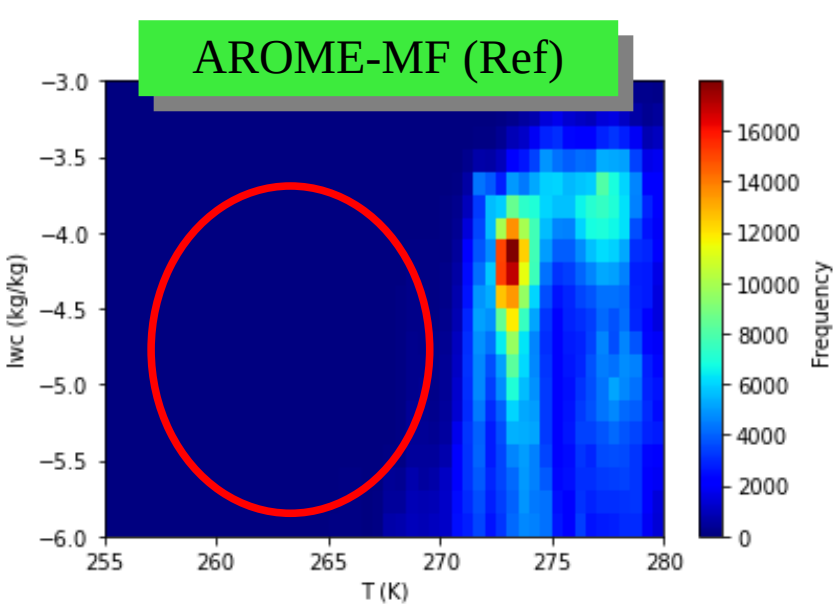


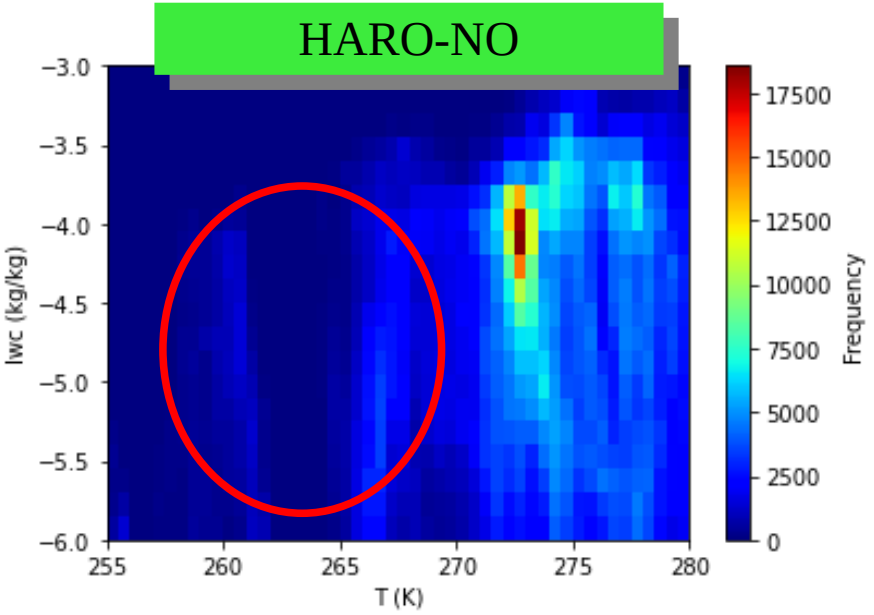


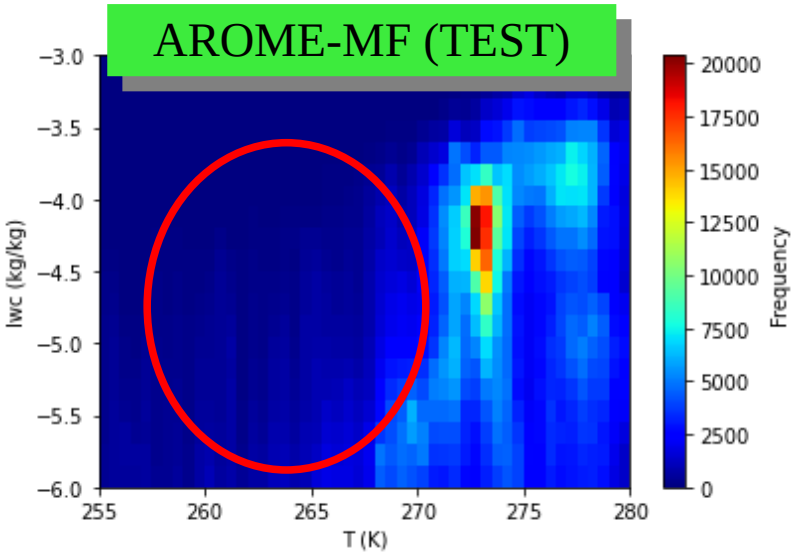
- LWC close between Test and NO
- More ice on high clouds in ICE3

August 6th, 2022

- More LWC in TEST
  (Ongoing work of Laurent Oungre at MF Feb-July 2024)







METEO FRANCE

August 6th, 2022

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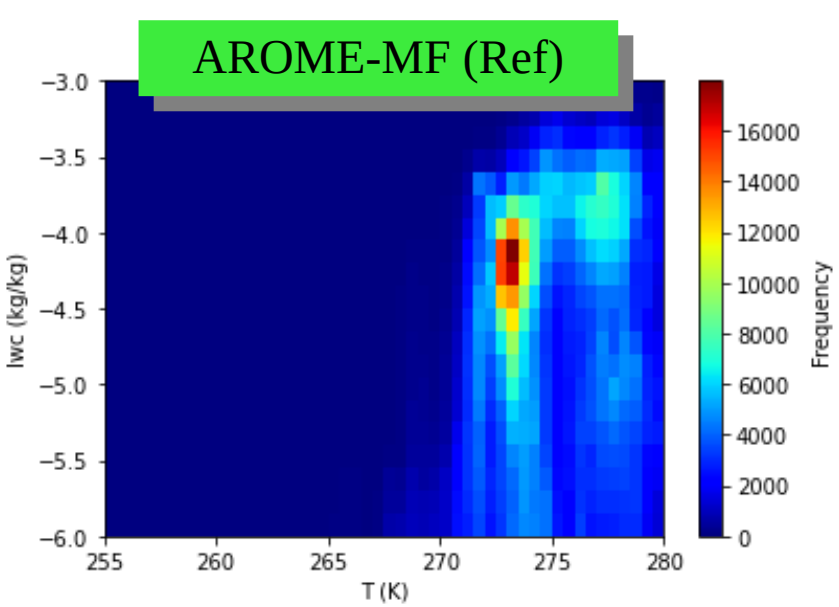
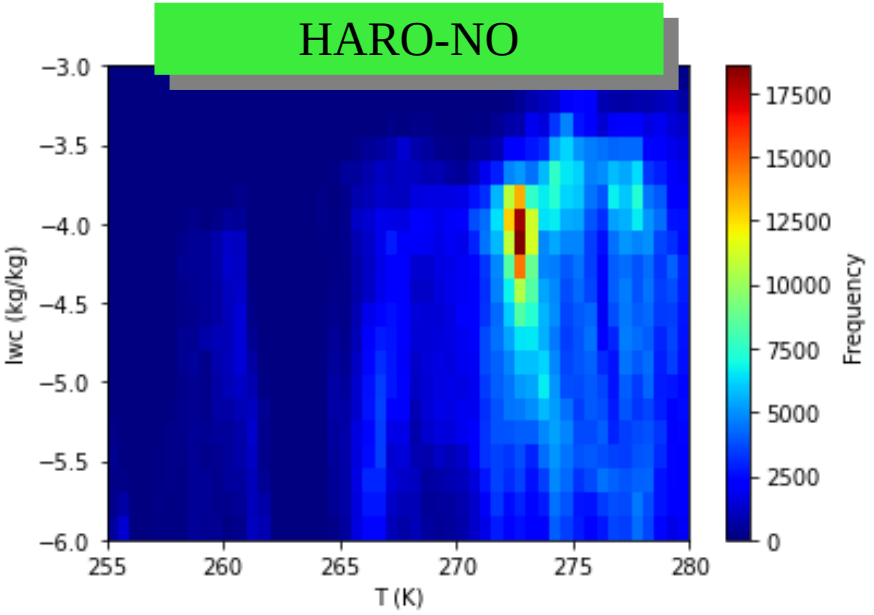
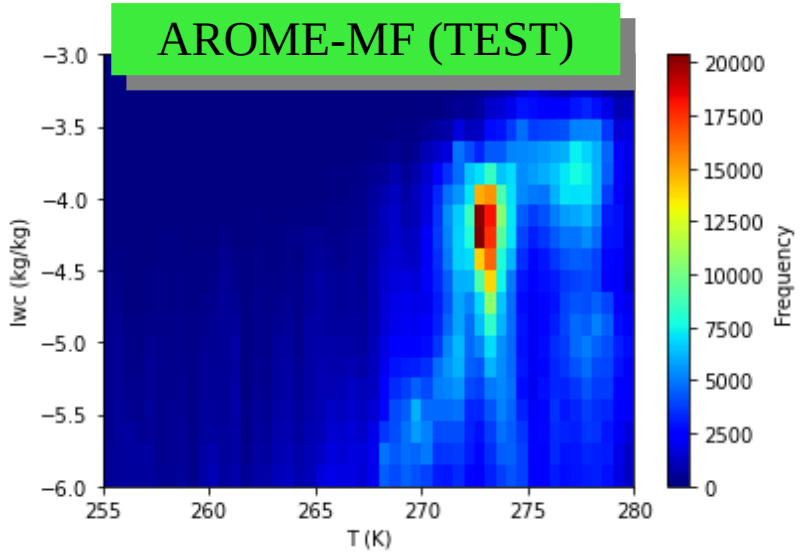




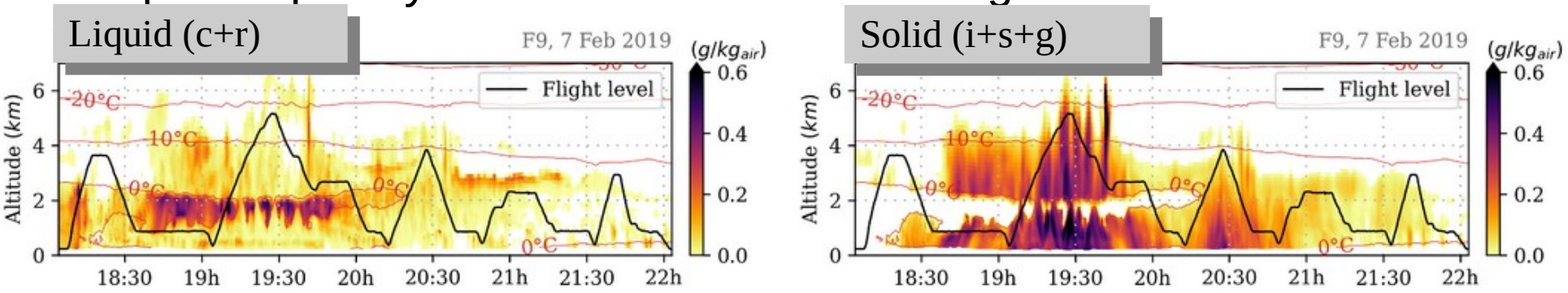


- Next steps : DDHs analysis
- Quantitative comparison with observations

METEO FRANCE

LIMA freezing rain *vs.* Graupel (ICICLE)

- Graupel frequently forecast instead of freezing rain below warm fronts



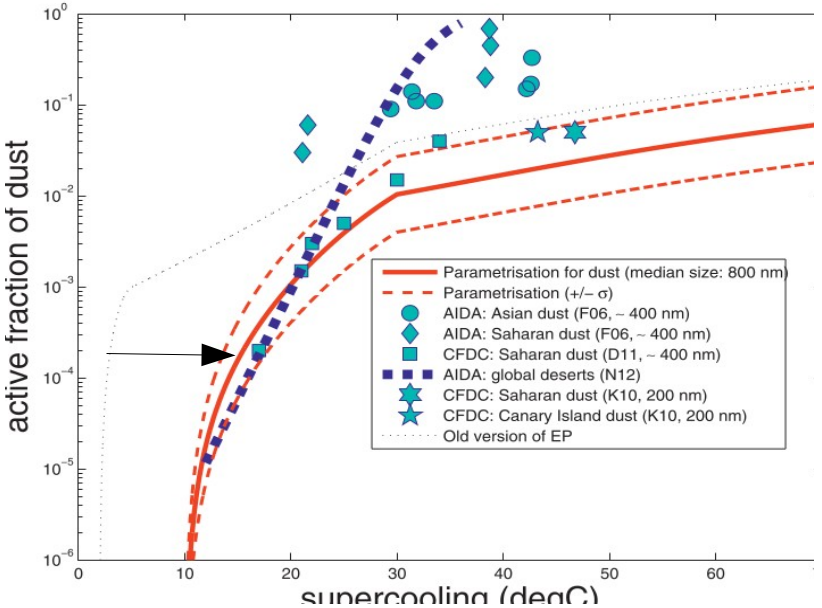
- Fast contamination by graupel and/or snow from cold regions around
  - Advection of small contents of graupel followed by unrealistic fast growth, and so on
  - PSD errors + collection processes unsuitable for small hydrometeors (= small contents)
  - Problem solved with a threshold on snow and graupel, but not satisfying

➔ Working on a collision efficiency based on the diameter, and preventing the snow and graupel from being too small (*M. July-Wormit PHD*)

Heterogeneous ice nucleation : Phillips 2008 → 2013

- Phillips' revised parameterization (2013) reduces ice nuclei activation, especially at not-too-cold temperatures (0°C → -20°C)

Ex for Dusts IFN :



- More realistic, but produces even less ice
  - → Ongoing evaluation on ICICLE lake effect clouds
  - → To be used with secondary ice production (cf next slide) for general cases / convection ?

Secondary ice production in LIMA (available in PHYEX)

- 2 new secondary ice production mechanisms

RDSF

Droplet fragmentation during freezing a

Splintering during riming (Hallett-Mossop process) b

CIBU

Fragmentation during ice-ice collision c

Ice fragmentation during thermal shock d

Fragmentation during sublimation e

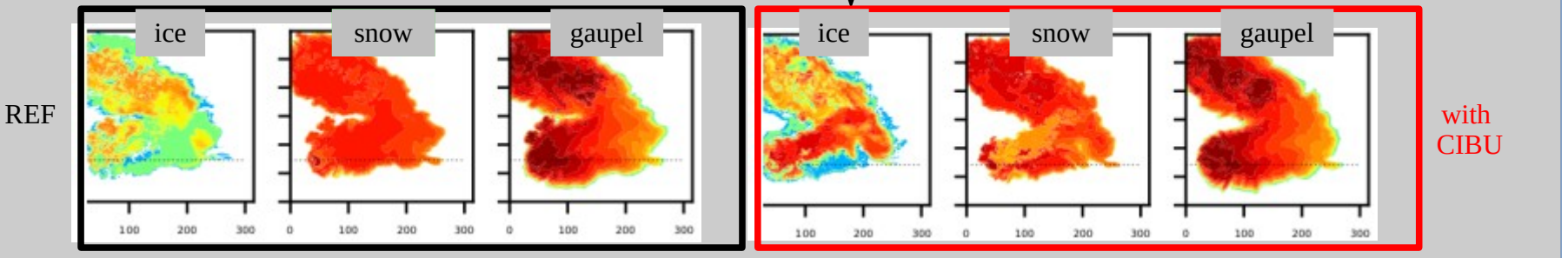
Activation of INP in transient supersaturation f

(Korolev and Leisner, 2020)

→ More ice

(MesoNH idealized supercell case)

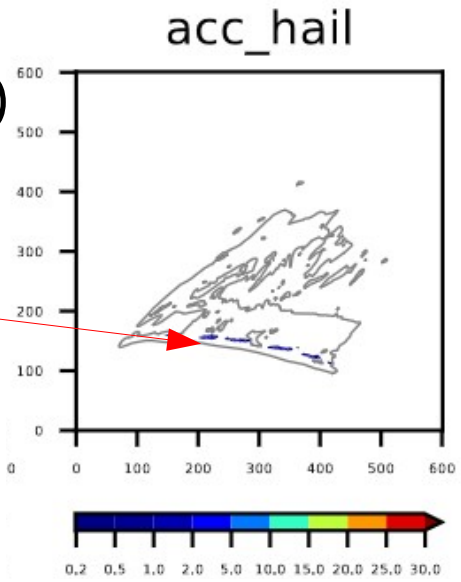
t=140 min, level 65



Microphysics : LIMA news (available in PHYEX)

- More flexible choice for each variable (1 or 2-moments)

Full 2-moments with hail :
realistic hail along supercell track
(idealized supercell)



- Under tests/validation in CY49T1 (full 1-moment, 2-moments only for liquid...)

Consistency between the cloud scheme and the autoconversion process

- **<u>Present hypothesis for the cloud scheme:</u>**
  - the ‘σ_s‘ computed by the turbulence represents the subgrid variance of the departure to saturation ‘s’
  - cloud content and fraction are computed by an analytical relation derived from simulations (Chaboureau & Bechtold 2002)

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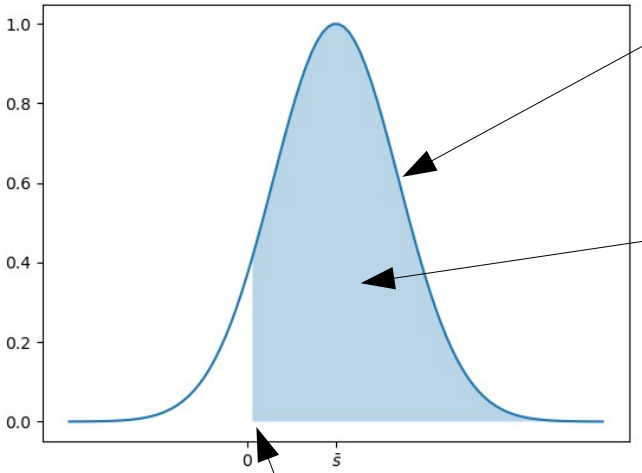
→ **This is not consistent :**

- cloud should stay on its fraction for the autoconversion
- the σ_s computed by the turbulence **is** the variance of 's'
- as long as the adjustement process is used, the distribution function of the cloud content (for the autoconversion) should be the tail of the distribution used for the adjustment

Consistency between the cloud scheme and the autoconversion process



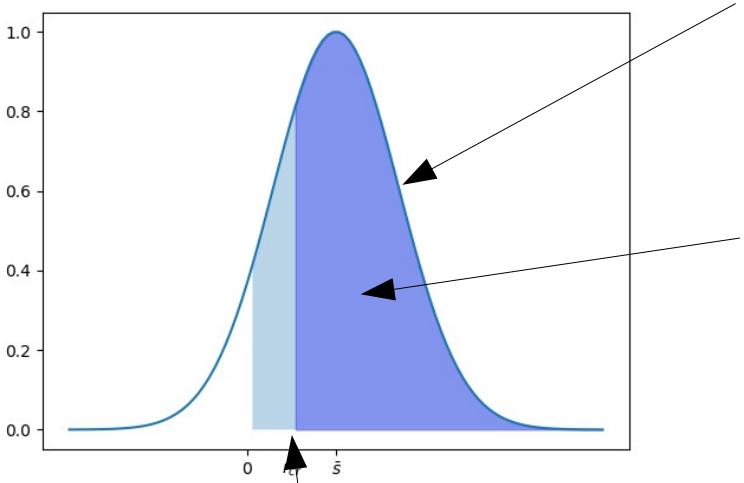
Adjustment PDF

$$CF = \int_0^{+\infty} G(s)\,ds$$

$$\bar{r}_c = \int_0^{+\infty} sG(s)\,ds$$

Saturation threshold

Consistency between the cloud scheme and the autoconversion process



- Prerequisites: “true” PDF:
  - replacement of the analytical relations by a Gaussian PDF in the adjustment (ongoing evaluation for entering next e-suite in 49t1, by S. Riette)
  - replacement of the DIRE scheme of the shallow convection by another Gaussian PDF (bi-Gaussian scheme). Ongoing development and evaluation on 1D cases (MUSC) by A. Marcel (PhD student)
- Need evaluation and maybe tuning of the autoconversion threshold

Summary / Outlooks

- Improvments for more supercooled liquid water in ICE3
  (→ comparisons with Harmonie-Arome and observations will continue)

- More flexible LIMA available in PHYEX
  (→ more validation/tests required)

- More consistency inside ICE3 (one step for 49T1_op)

Thanks for your attention !
any questions ?

Y. Seity, S. Antoine, S. Riette, B. Vié

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