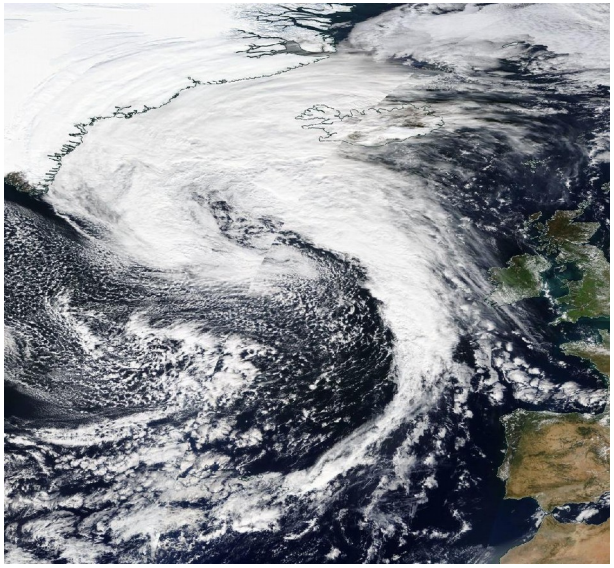
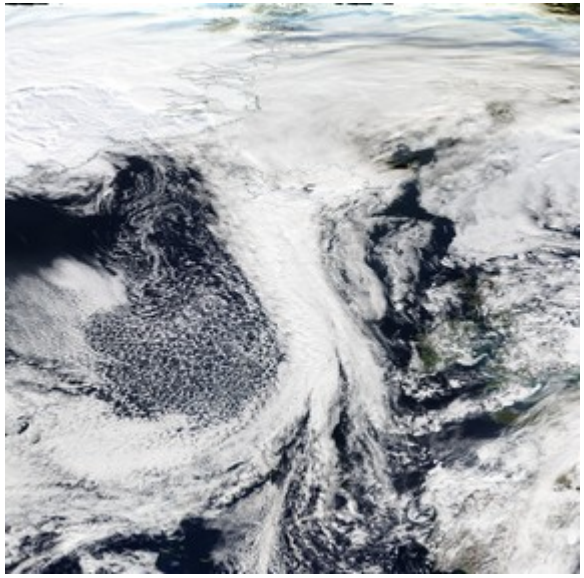
Impact of **different microphysics** on the **warm conveyor belt** of **extratropicals cyclones** observed during the **NAWDEX** campaign and on their associated **ridge building**



Stalactite cyclone (01 - 05/10/16)

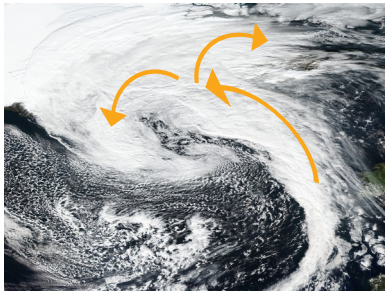


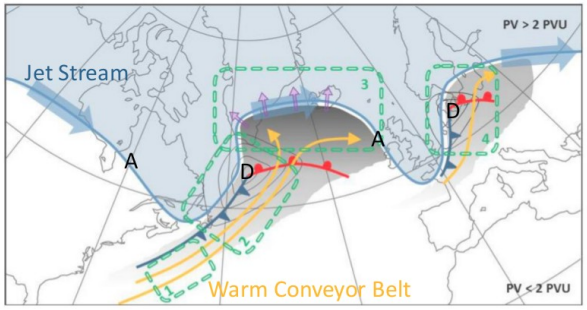
Thor ridge (12 - 15/10/16)

Marie Mazoyer (CNRM), Didier Ricard (CNRM), Gwendal Rivière (LMD), Philippe Arbogast (CNRM), Julien Delanoë (LATMOS), Benoit Vié (CNRM), Christine Lac (CNRM)

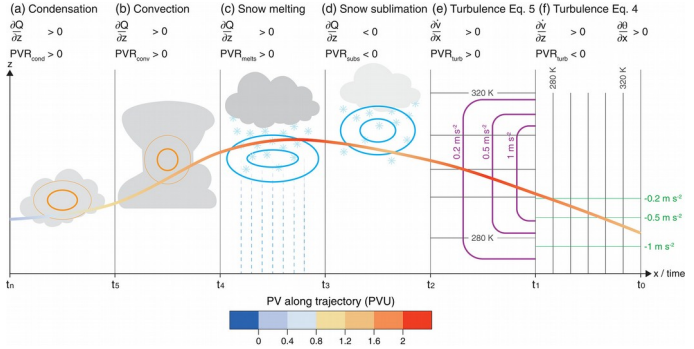
Why looking at microphysics on warm conveyor belt?

➢ **Warm conveyor belts** are **ascending cloudy air mass,** ahead of cold front, reaching jet stream level and impacting PV distribution





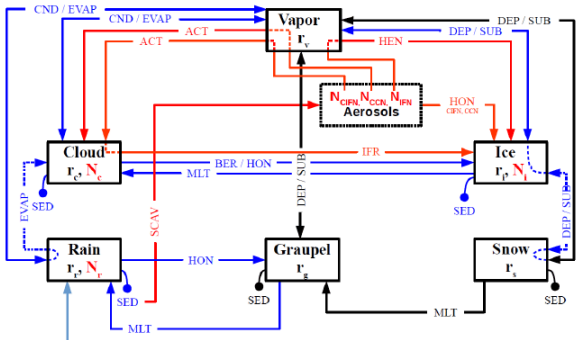
Schäfler et al, 2018



Attinger et al. , 2019

➢ Potential **misrepresentation of diabatic processes** through latent heat release **along WCBs** can lead to **PV error along the jet stream → Prediction error in NWP models** (Gray, 2014)

↳ Importance of **microphysical** processes (Joos and Wernli, 2012, Joos and Forbes, 2016)
But **lots of uncertainties** (Khain et al., 2015) in their representation



LIMA, microphysical processes

Scientific questions

I. How does the ridge building representation differ using two <u>distinct microphysical schemes</u> ?

ICE3 (r) vs LIMA (N, r)

II. Is that the same impact on <u>distinct extratropical cyclones</u> ?

Stalacticte cyclone (explosive) vs Thor ridge (moderate)

III. What if we play with the <u>parametrizations</u> ?

- Snow fallspeed
- Ice fallspeed
- Secondary ice production
- IFN (~ice) concentration
- Ice shape
- CCN (~droplets) concentration
- Supercooled droplets repartition
- Subgrid condensation scheme

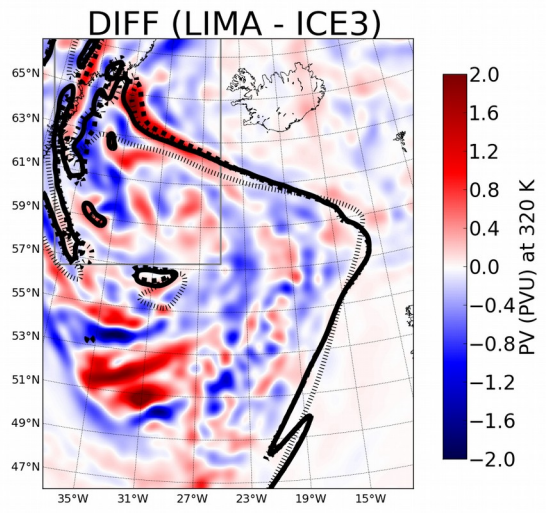
- Turbulence representation (1D to 3D)

➢ **Which configuration provides the <u>best representation</u> ?**

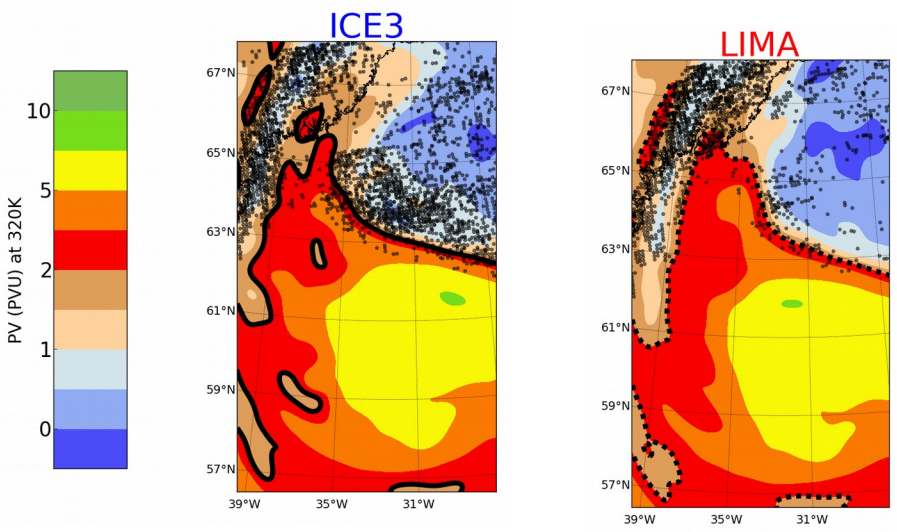
How does the ridge building representation differ using two distinct microphysical schemes ?

What did we learn from ‘Stalactite Cyclone’ study

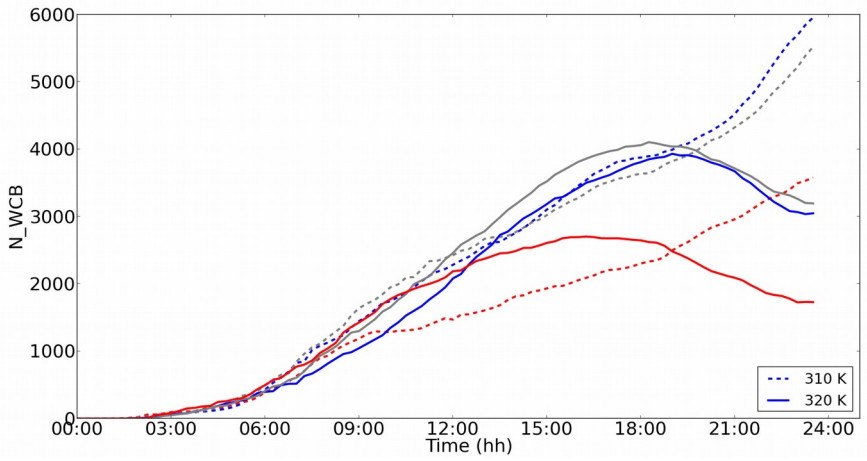
1- 2° Tropopause shift using ICE3 or LIMA after 24h



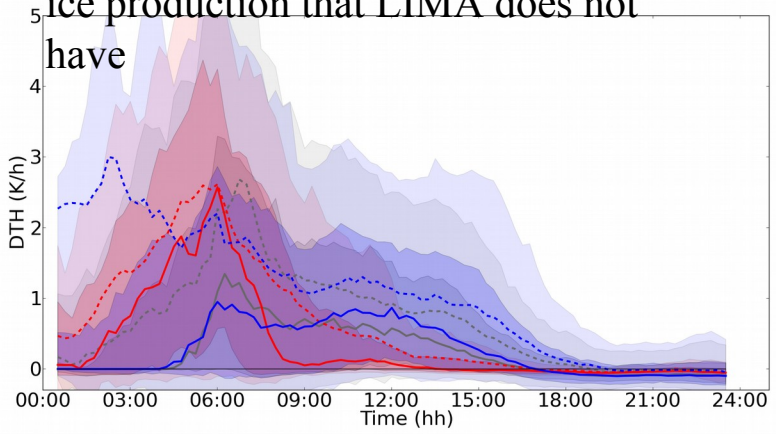
2- Due to WCB ‘power’



3- WCB ‘power’ evolves with time

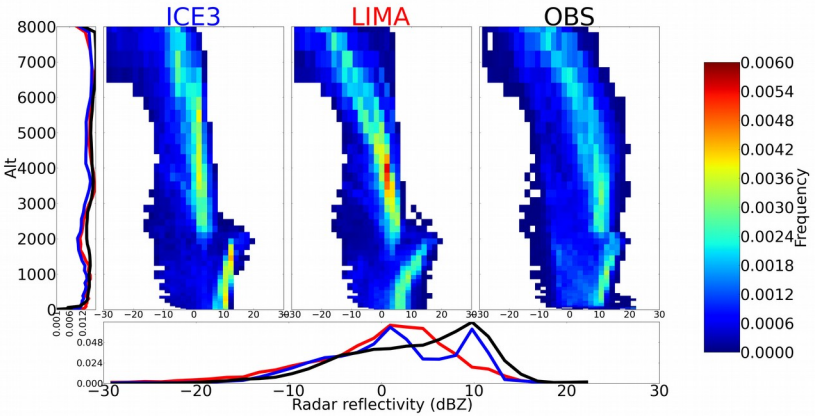


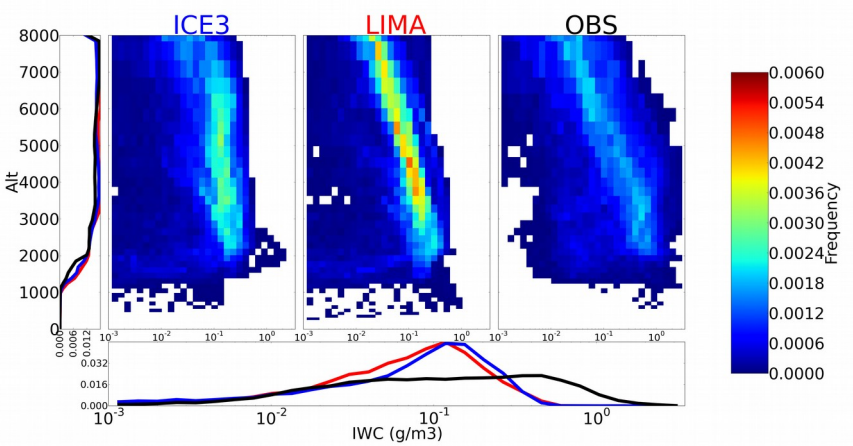
4- ICE3 higher number of trajectories Comes from a second ascent due to ice production that LIMA does not have



Which one is the closest to the obs ?

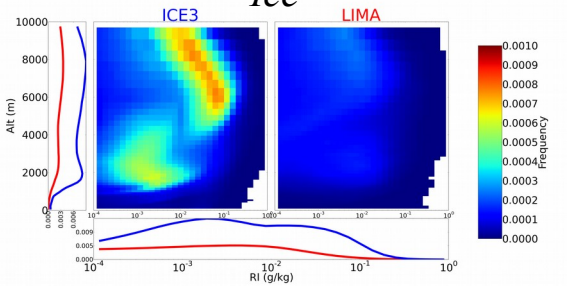
5- ICE3 and LIMA do not have enough cold species. LIMA has a good vertical repartition.
ICE3 more higher values in altitude



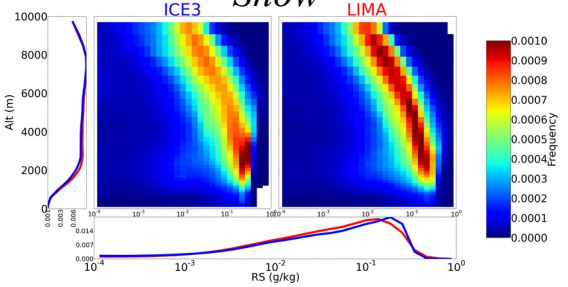


6- Different hydrometeor repartitions. LIMA less ice but more graupel and snow for LIMA.
ICE3 supercooled droplets but LIMA no.

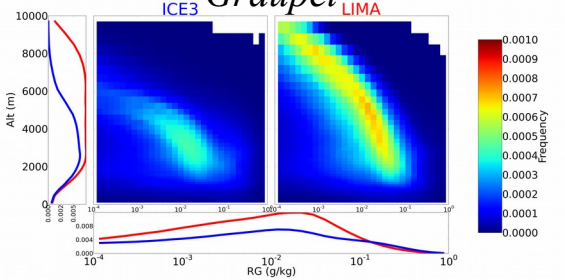
Ice



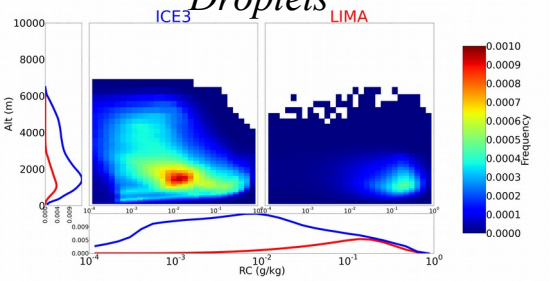
Snow



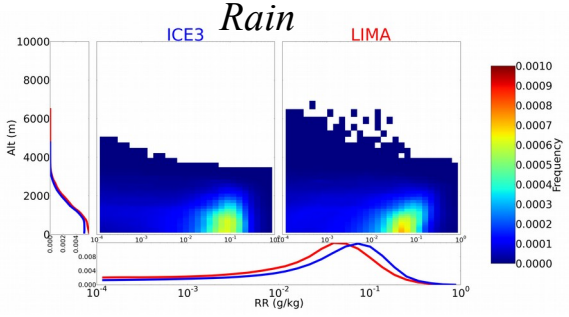
Graupel



Droplets



Rain



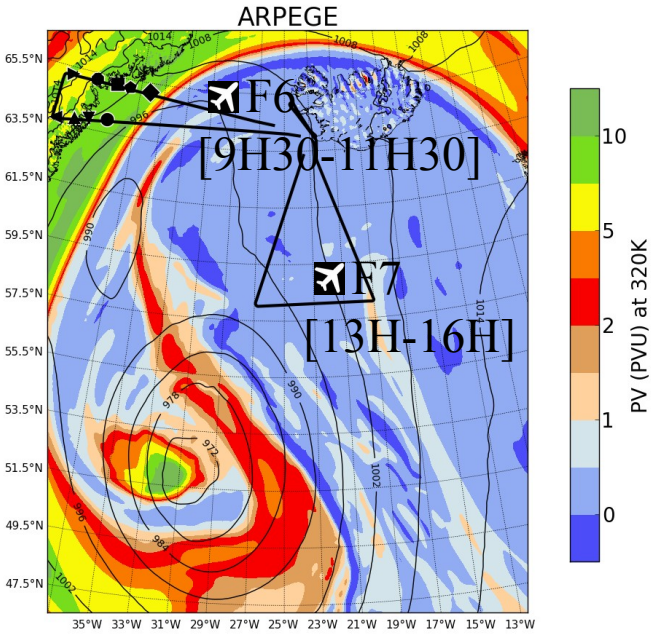
Is that the same impact on distinct extratropical cyclones ?

Cases studies from the Nawdex campaign

1) Explosive **'Stalactite' cyclone**
01 – 04/10/2016

Formation of a **Scandinavian blocking** that last for several weeks

Focus on 02/10/2016 :
- Ridge amplification by the WCB
- Two flights of the Falcon-20



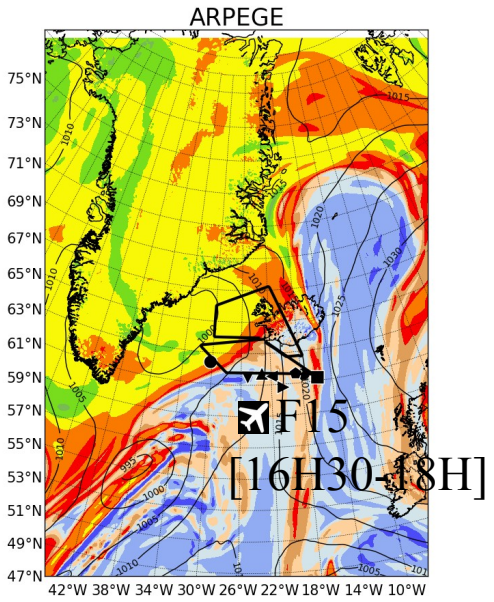
00:00 02/10/2016

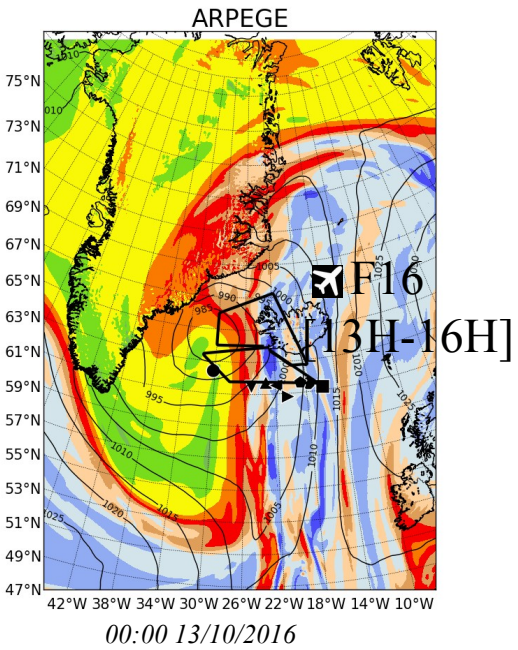
Cases studies from the Nawdex campaign

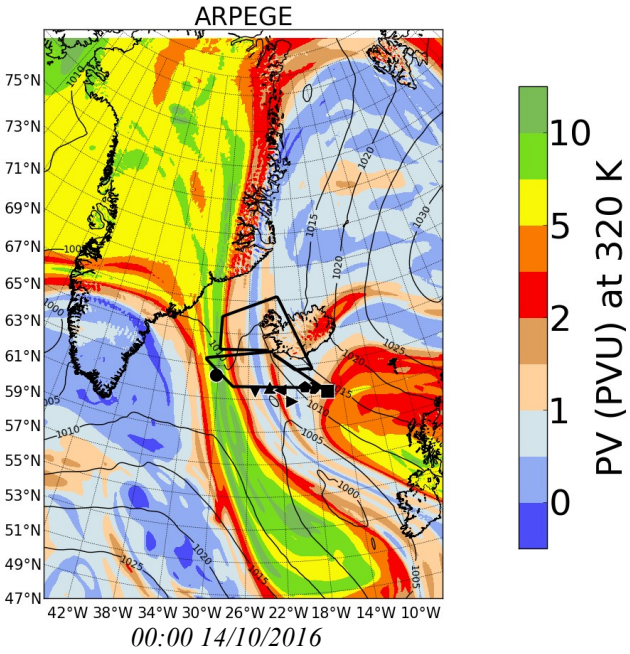
2) Moderate **'Thor' ridge**
12-15/10/2016

Large amplification of the block previously formed with the Scandinavian cyclone

Focus on 12-13/10/2016 :
- Ridge amplification by the WCB
- Two flights of the Falcon-20







Numerical experiments / comparison with observation

Méso-NH model :

- Output : every 15min
- CI and forcing : Global operational model ARPEGE
- ΔXΔY → **2.5 km*2.5 km** (explicit convection)
- Radar simulator colocated with the flight at the same time and satellite simulator
- Inline backward trajectories computation

Meso-NH
mesoscale non-hydrostatic model

Flights of French Safire Falcon :

- Airborne RADAR and LIDAR (Z, IWC, U) (retrieved from variational algorithm; Delanoë and Hogan, 2008)
- Dropsondes F6 (P, T, U, RH)
- Meteosat (Tbrightness)

2 cases : Stalactite cyclone (24 h from 02/10/16 00:00)
Thor ridge (72 h from 12/10/16 00:00)

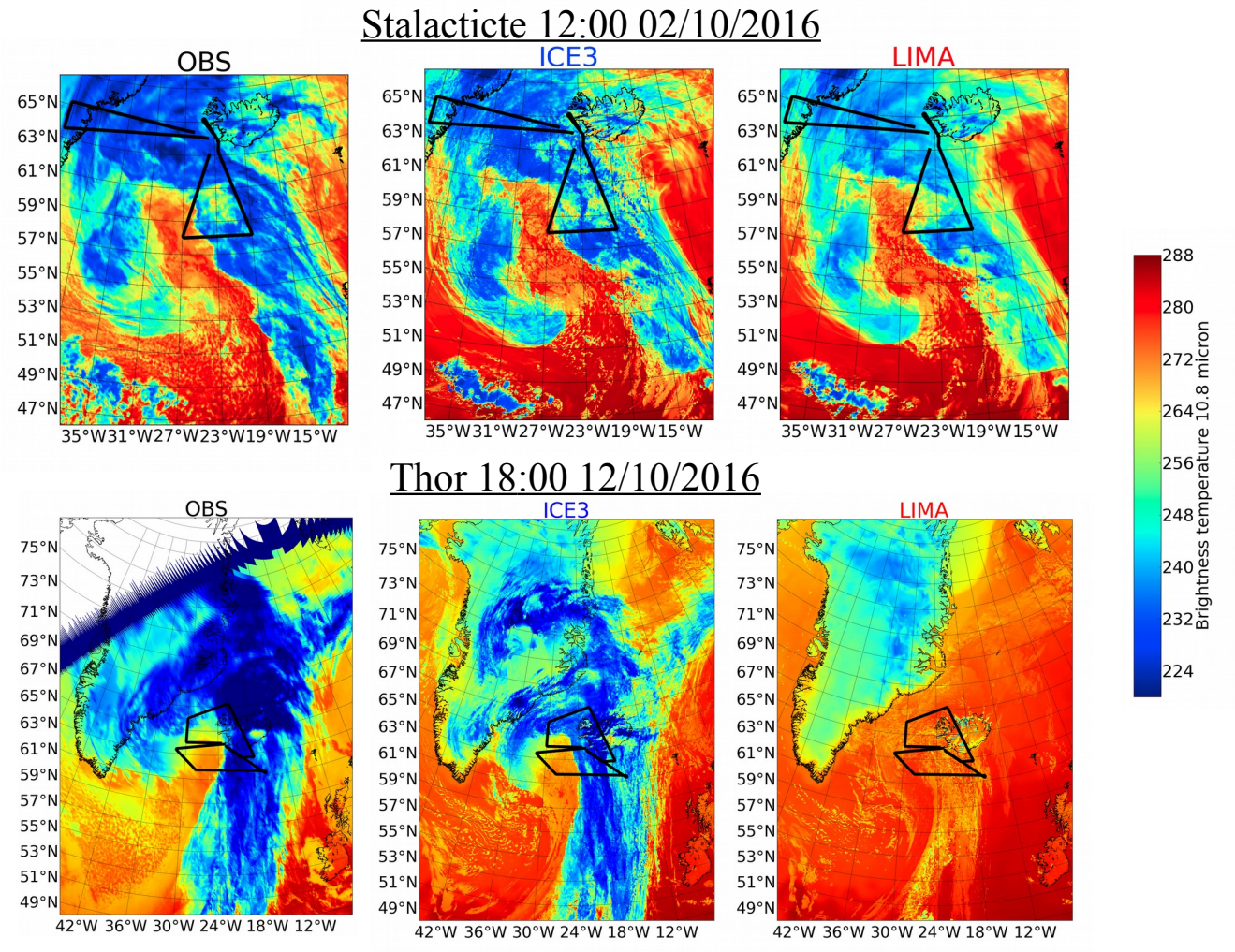
*

2 simulations : ICE3 (Pinty and Jabouille, 1998)
LIMA (Vié et al, 2016)

And sensibilities tests

Is the cloud structure well represented ?

➢ **Cloud top structure** : Meteosat, brightness temperature 10.8 µm & RTTOV for Méso-NH



➡

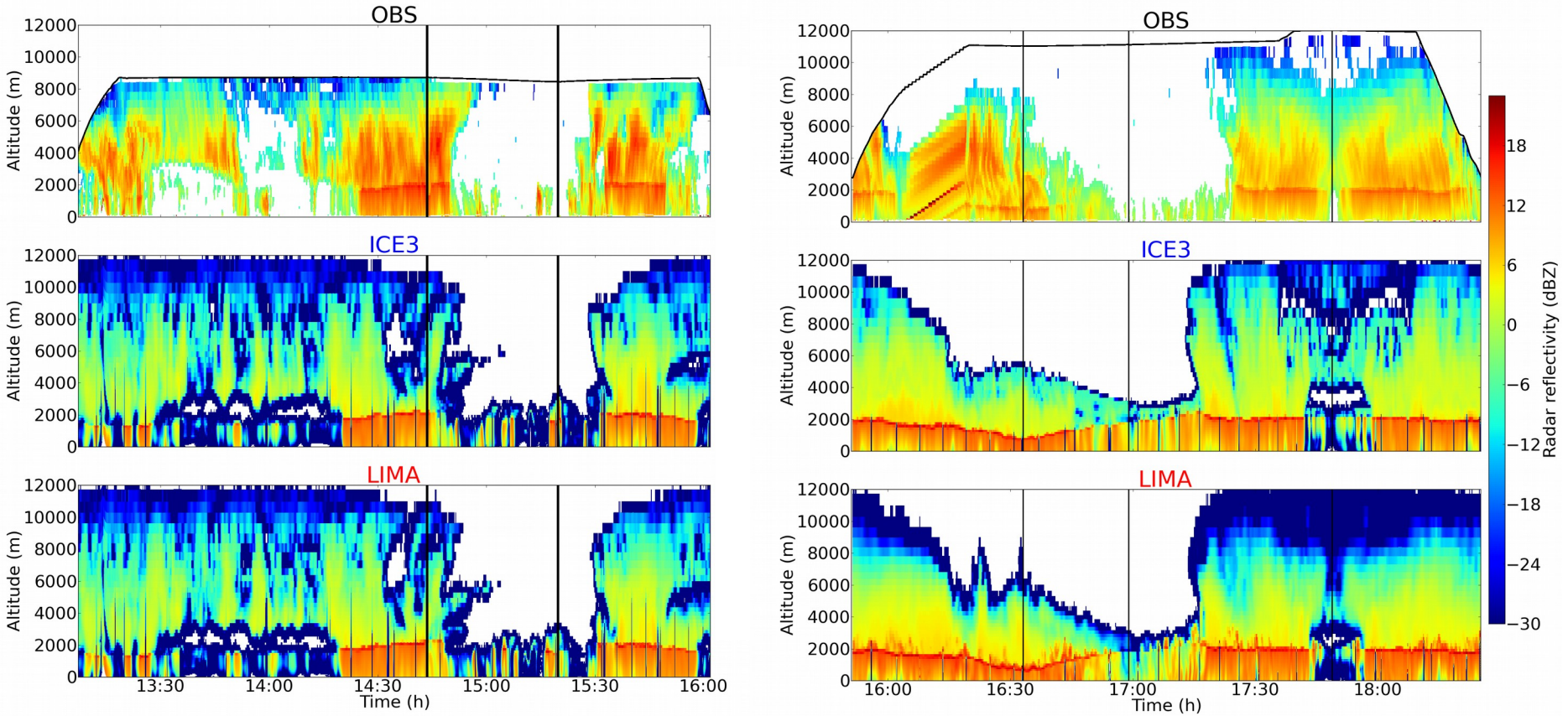
- **[Stalacite]&[Thor] Good location of the WCB**
- [Stalacite]&[Thor] Cloud top warmer (→ lower) in the model runs
- Far more pronounced on Thor → specialy with LIMA

What about microphysical representation ?

➢ **RALI (RASTA radar + LIDAR)** : Reflectivity and IWC under the flight path

Stalacticte, ascending part of the WCB

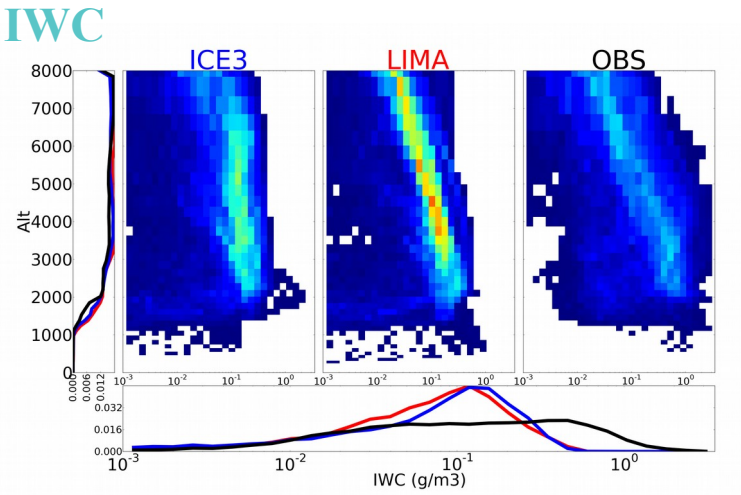
Thor, ascending part of the WCB



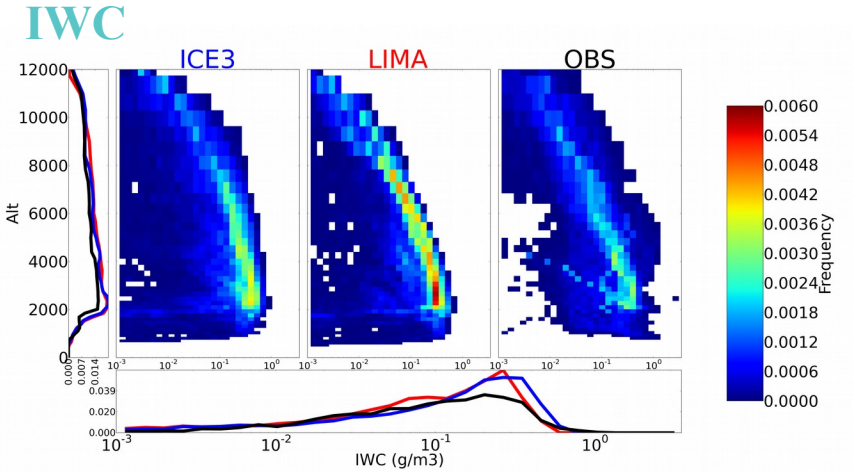
- [Stalactite]&[Thor] Quite a good location of radar structure and melting layer
- [Stalactite]&[Thor] Large underestimation of simulated reflectivity for the mixed or/and cold phases
- [Stalactite]&[Thor] Far more pronounced on updrafts
- [Stalactite]&[Thor] ICE3 higher reflectivity at higher level
- **[Stalactite]&[Thor] Similar behavior**

How are distributed the hydrometeors (solid and liquid) ?

Stalactite, ascending part of the WCB



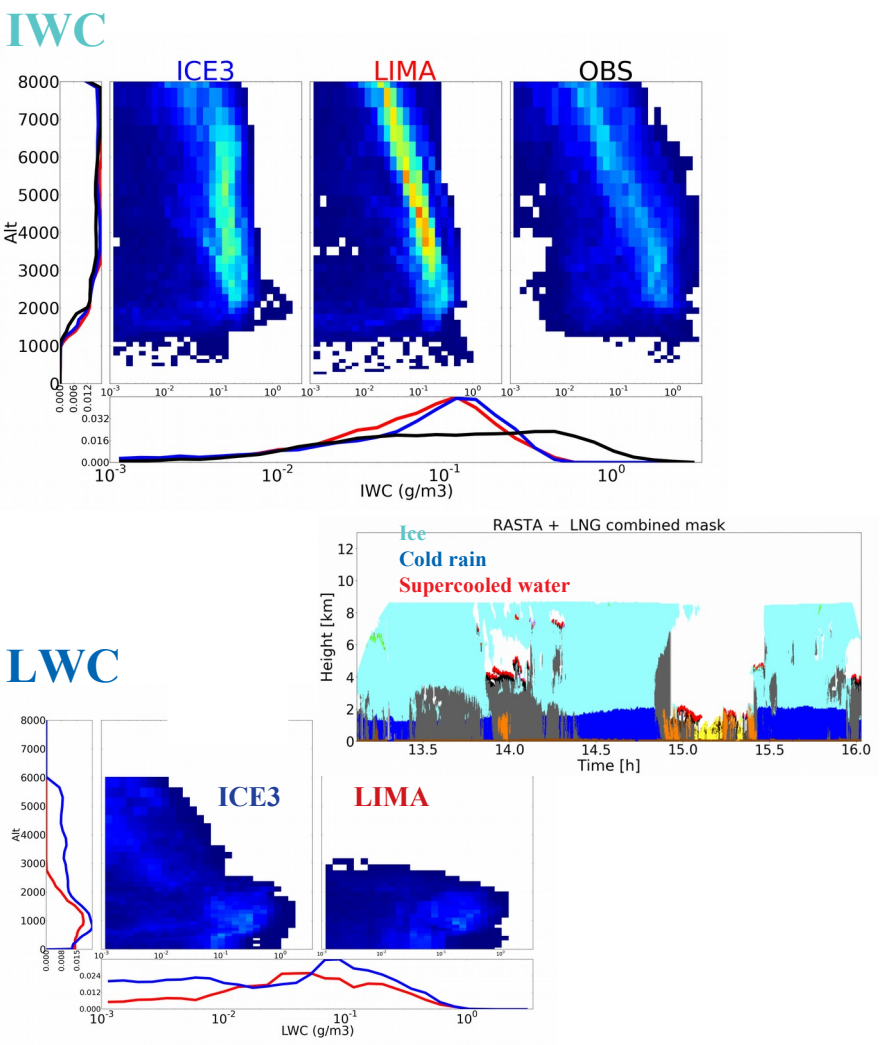
Thor, ascending part of the WCB

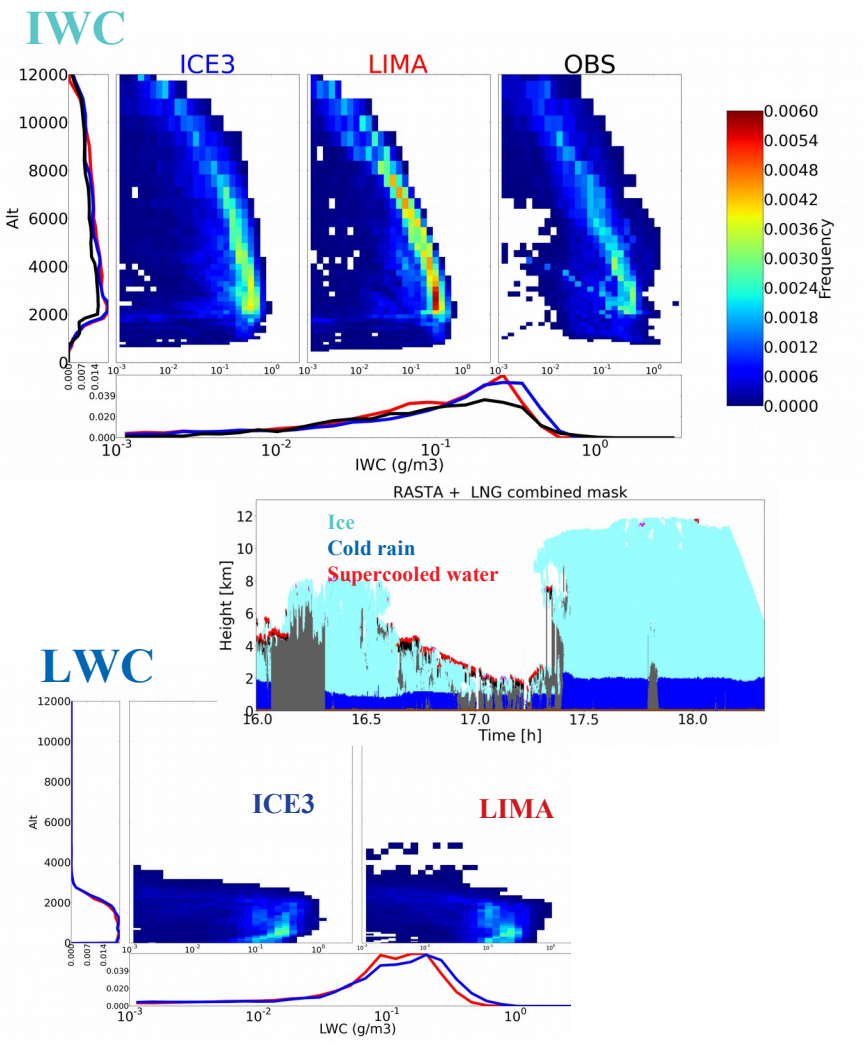


How are distributed the hydrometeors (solid and liquid) ?

Stalactite, ascending part of the WCB

Thor, ascending part of the WCB

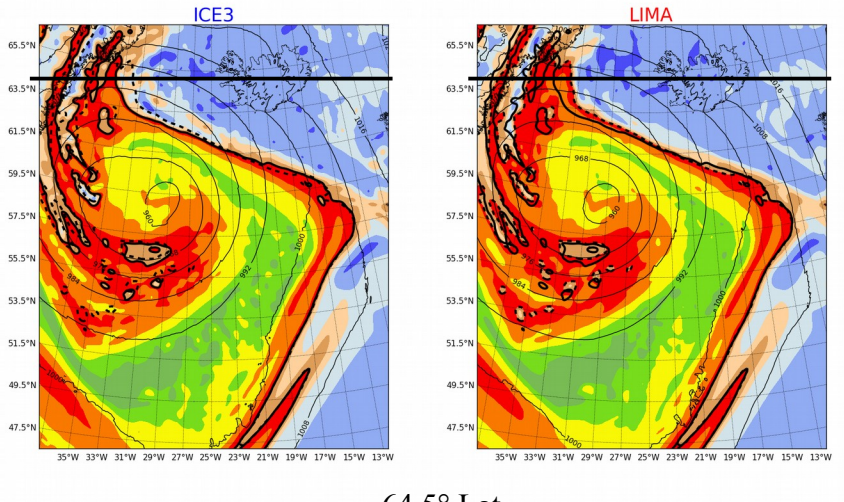




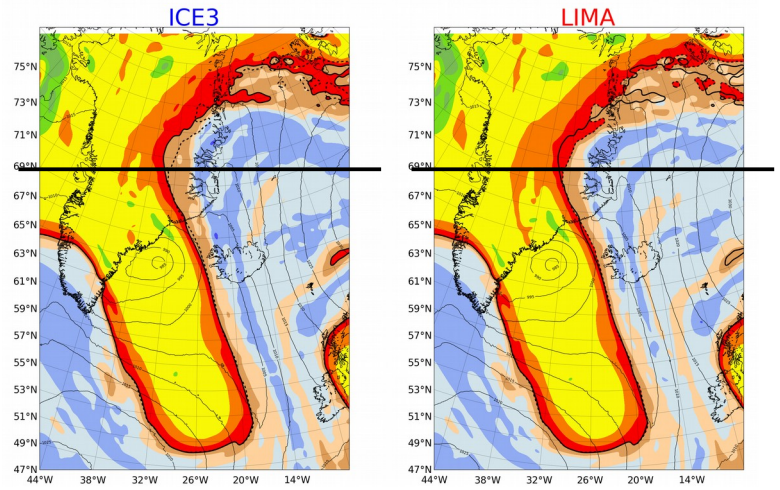
- **IWC, underestimation with Stalactite et overestimation with Thor** (!)
- [Stalactite]&[Thor] with LIMA correct hydrometeor distribution
- Due to the snow. Then ICE3 more ice and LIMA more graupel (quasi no ice).
- No supercooled droplets except for Stalactite with ICE3

Is there any impact on the ridge building ?

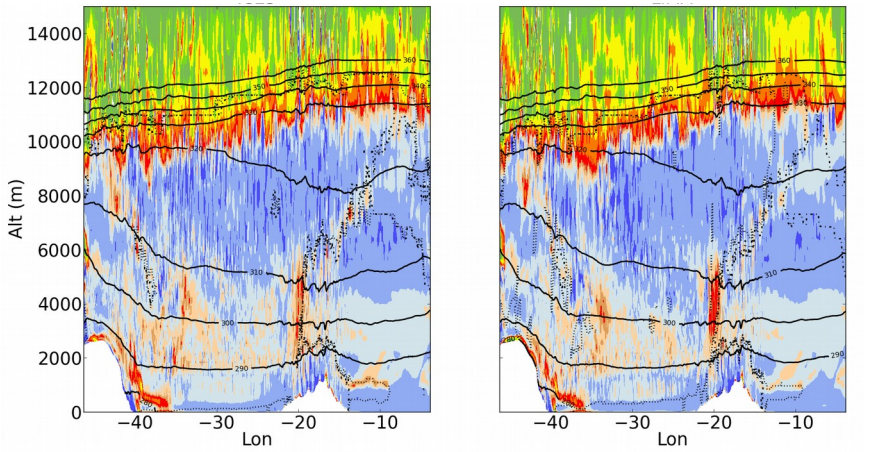
Stalacticte, PV at 320K (03/10 00:00), after 24h



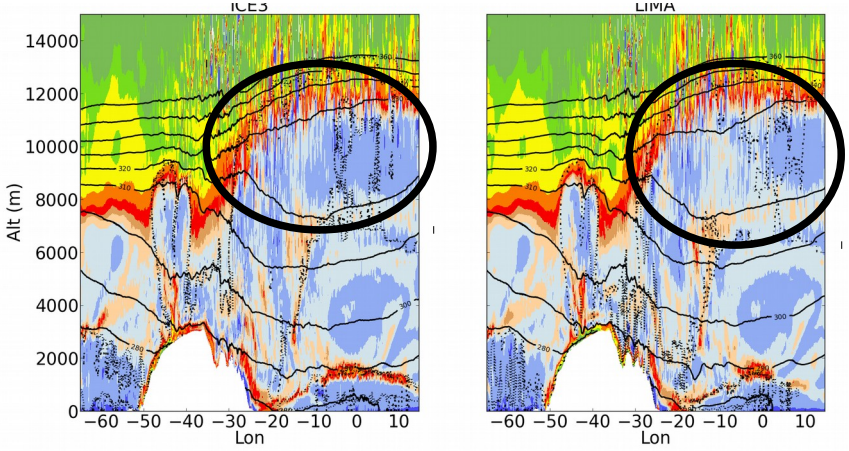
Thor PV, at 320K (13/10 12:00), after 36h



64.5° Lat



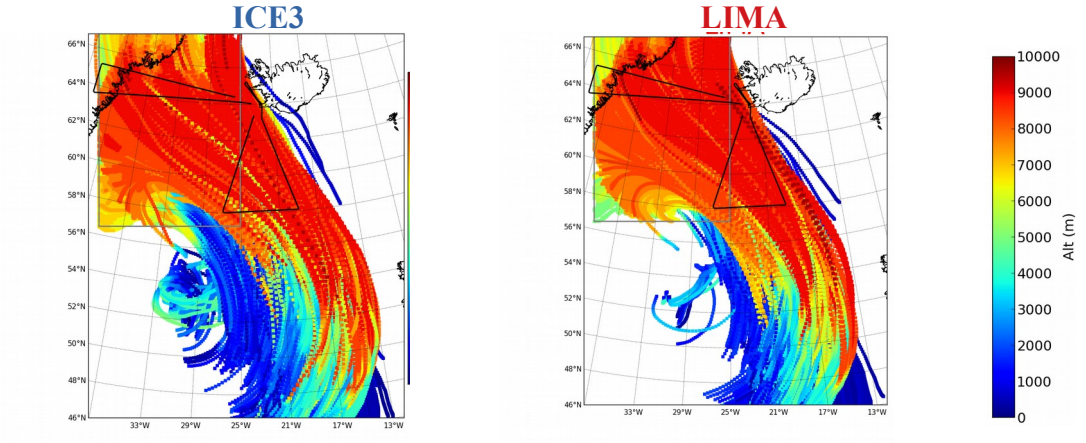
69° Lat



- [Stalactite] 2° tropopause shift between ICE3 and LIMA
- [Thor] Isentropes and PV values differ into the ridge
- **[Stalactite]&[Thor] Ridge more pronounec with ICE3, Stalactite → Tropopause location**
  Thor → PV values into the ridge

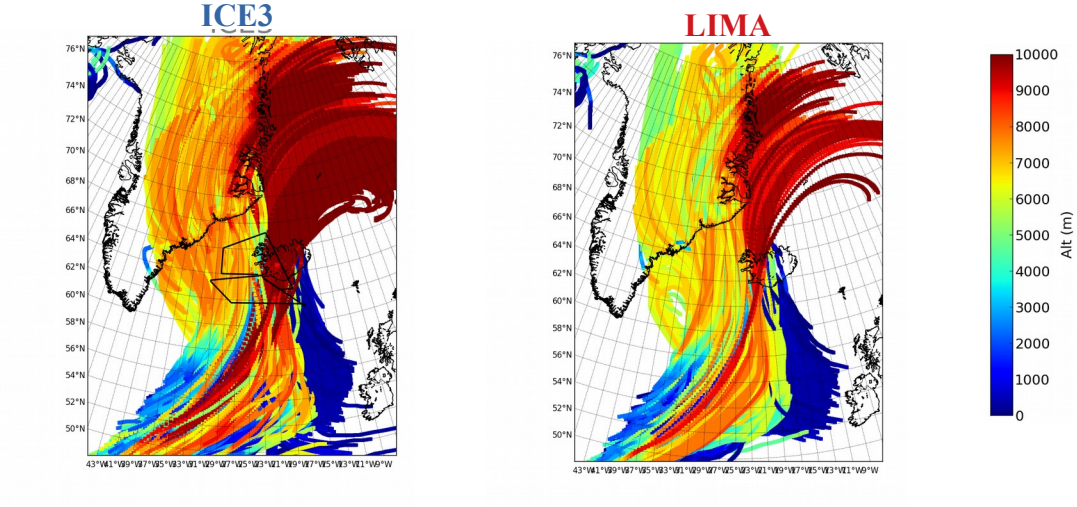
So, lets look at the WCB

- **[Stalactite]** 24h backward WCB trajectories from **03/10/16 00:00 from grey box** (168 960 meshes) ascending 300 hPa in 24h



LIMA
43 % less
trajectories

- **[Thor]** 36h backward WCB trajectories from **13/10/16 12:00 from all domain** (810 000 meshes) ascending 450 hPa in 36h

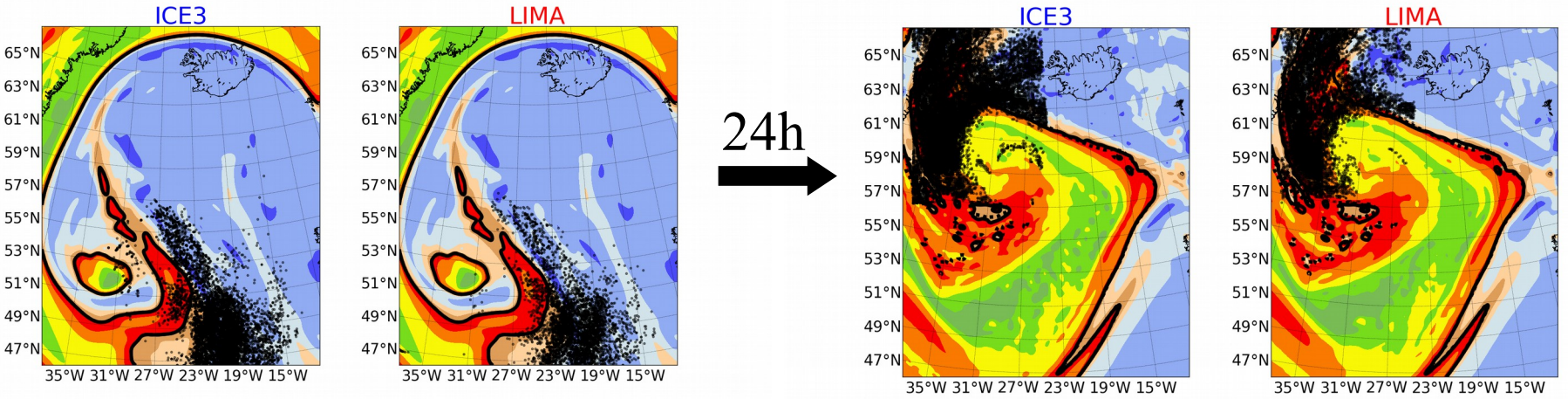


LIMA
55 % less
trajectories

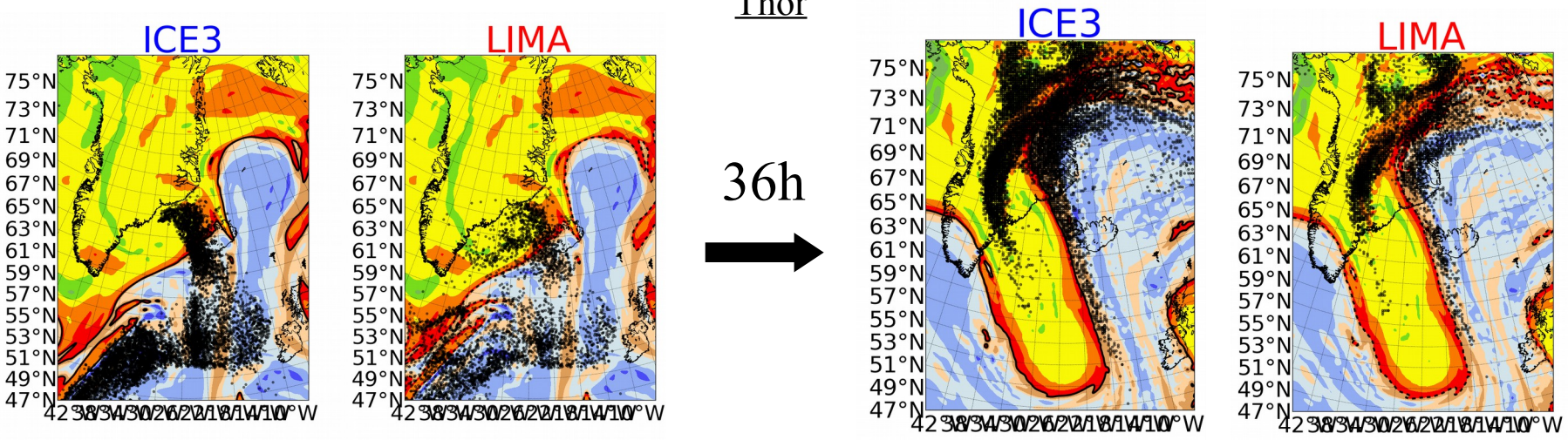
➡ **Thor&Stalactite, similar WCB activity difference between ICE3 and LIMA**

So, where do they come from and where do they arrive ?

Stalactite



Thor



Thor&Stalactite, WCB arrive close to the tropopause
Thor with ICE3 MORE trajectories into the ridge

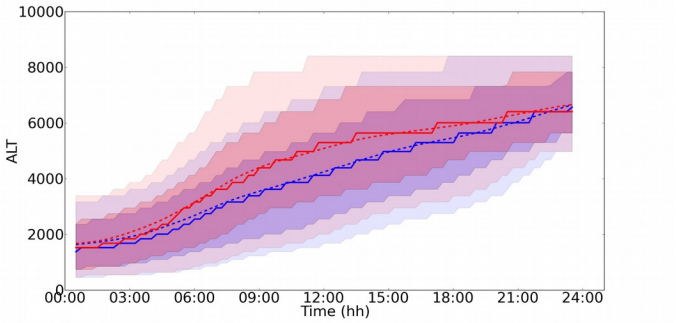
How are they evolving ?

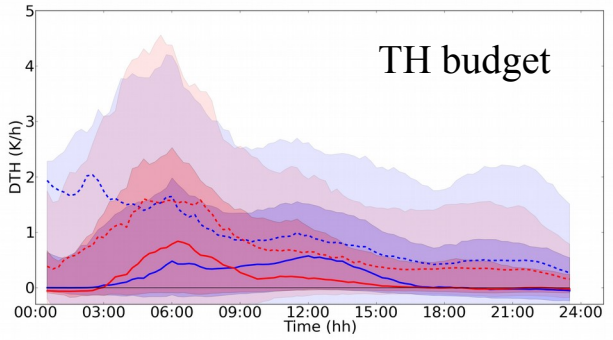
LIMA
ICE3

Mean
Median

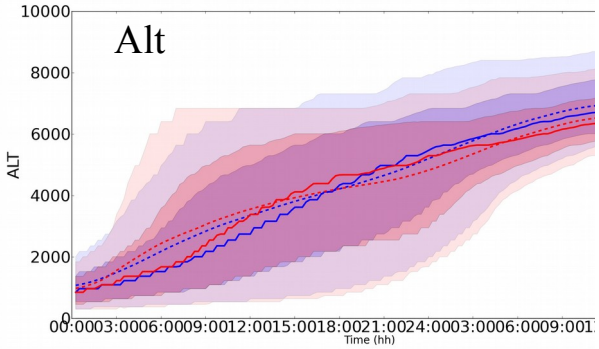
Stalactite (24h)

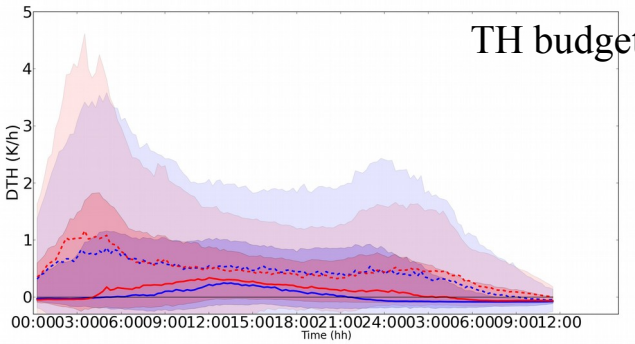
Alt





Thor (36h)





➡ **[Stalactite]&[Thor] LIMA, Faster ascension at the beginning with LIMA but then higher slopes with ICE3**

Is that the same impact on distinct extratropical cyclone ?

- **Yes, ridge more pronounced with ICE3 than LIMA**
  ICE3 produces more IWC than LIMA

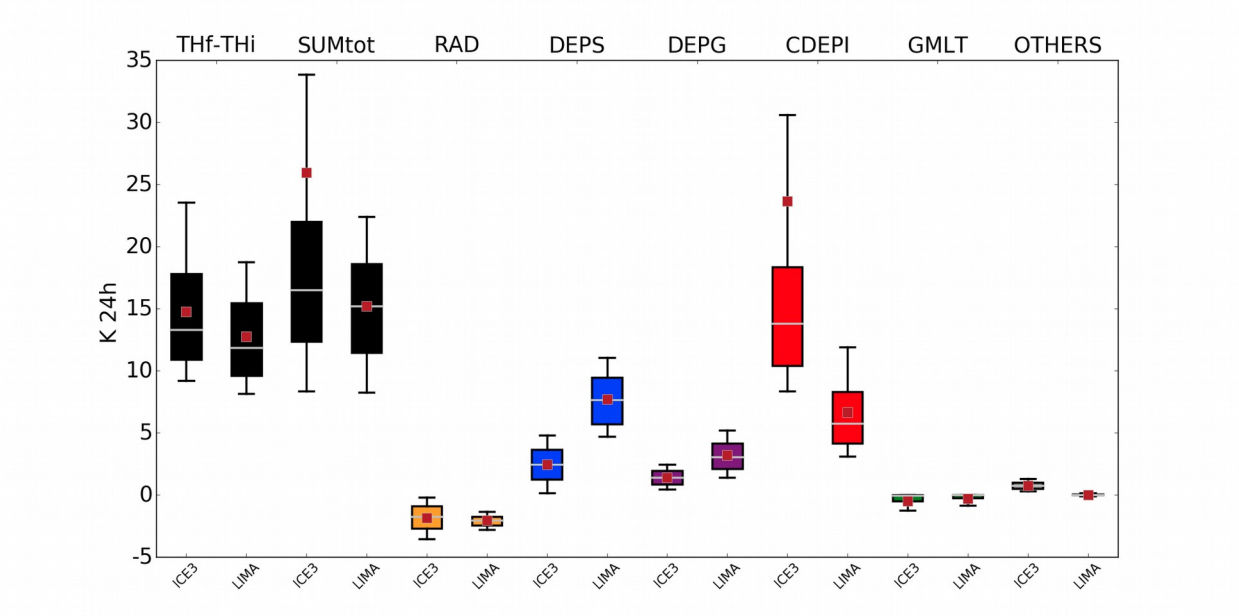
- But, Stalactite → Tropopause shift
  Thor → lower PV values in the ridge

  Ascent differs
  Theta budget differs

  Thor produces more IWC than the obs but Stalactite does not

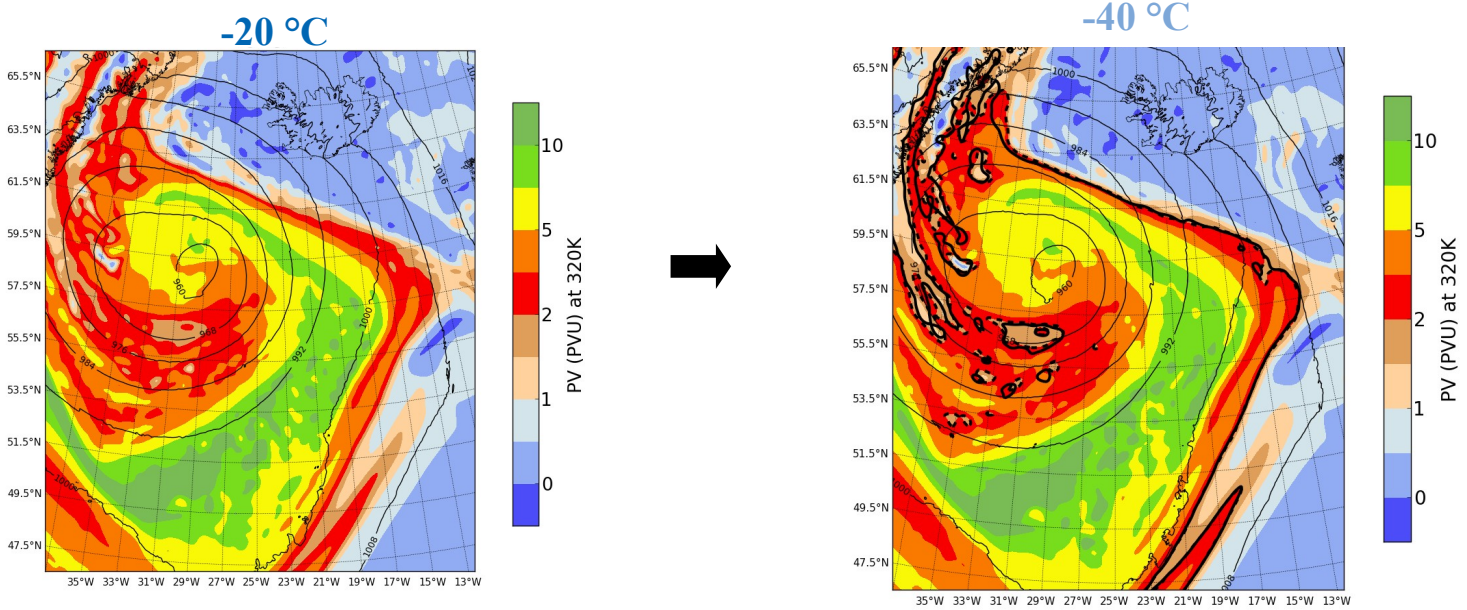
What if we play with the parametrizations ?

Stalactite

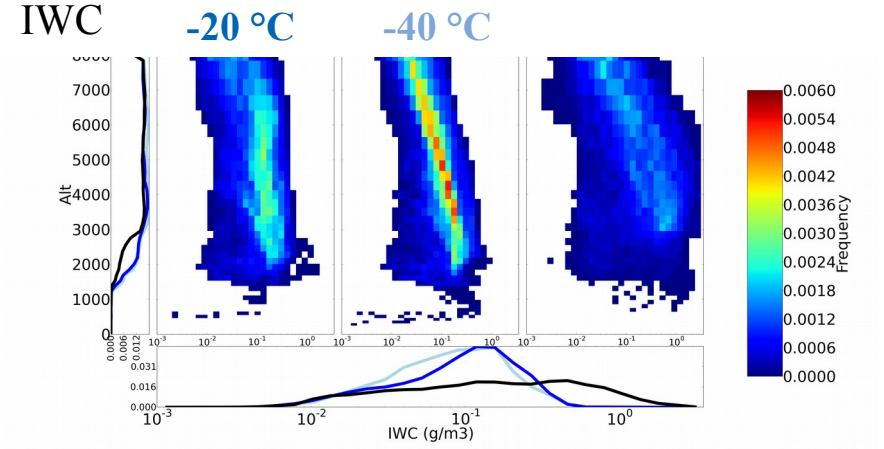


On supercooled water

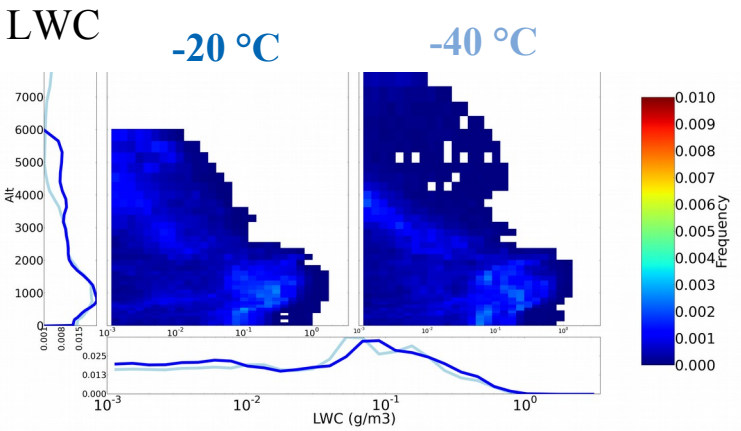
- No with LIMA but with presence with ICE3 till -20°C
- Litterature existence till -40°C



IWC



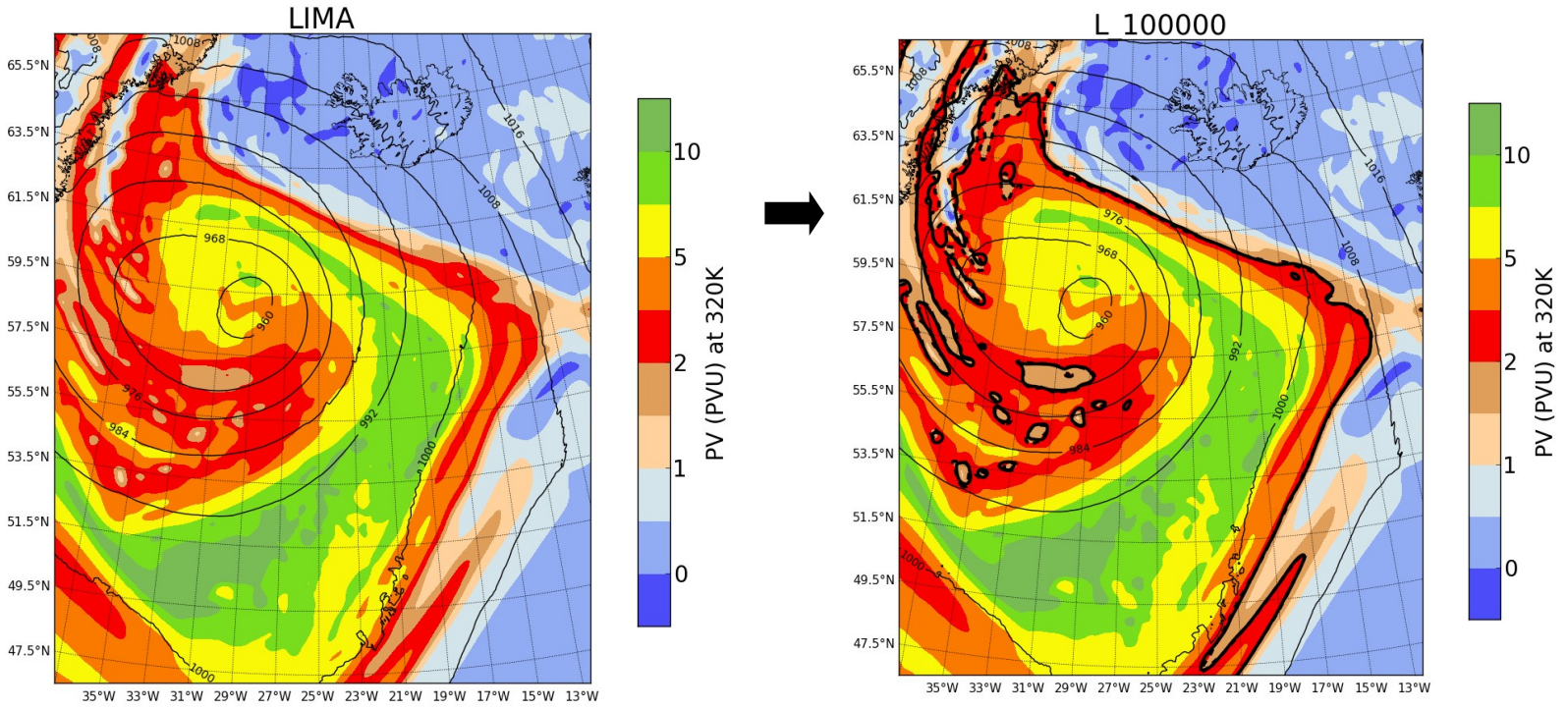
LWC



[-40°C] Improvement in the hydrometeor distribution
Hydrometeor distribution closest to LIMA [snow,graupel,ice]
But slight tropopause east shift

On IFN concentration

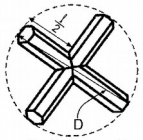
- LIMA, from 10000 #/L to 100 000 #/L

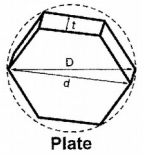


➡ Very little changes on the rigde building
It could have had an impact through radiation

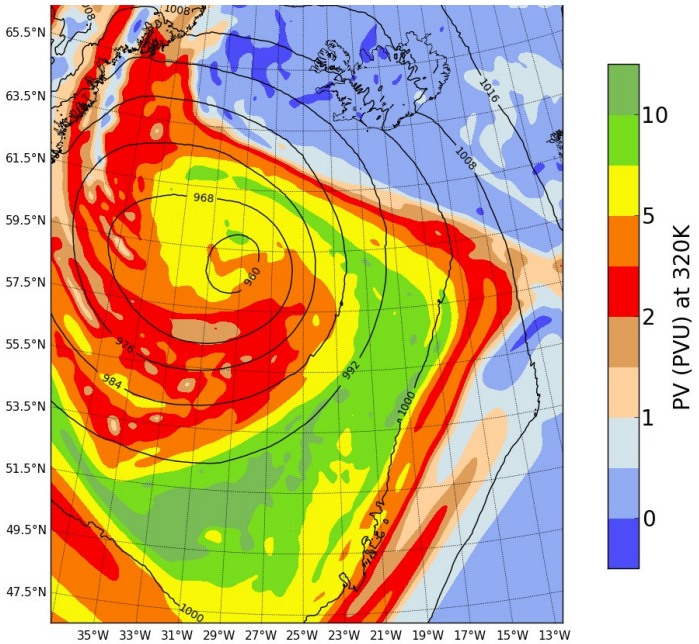
On crystal shape

- LIMA, from plates to bullet rosettes

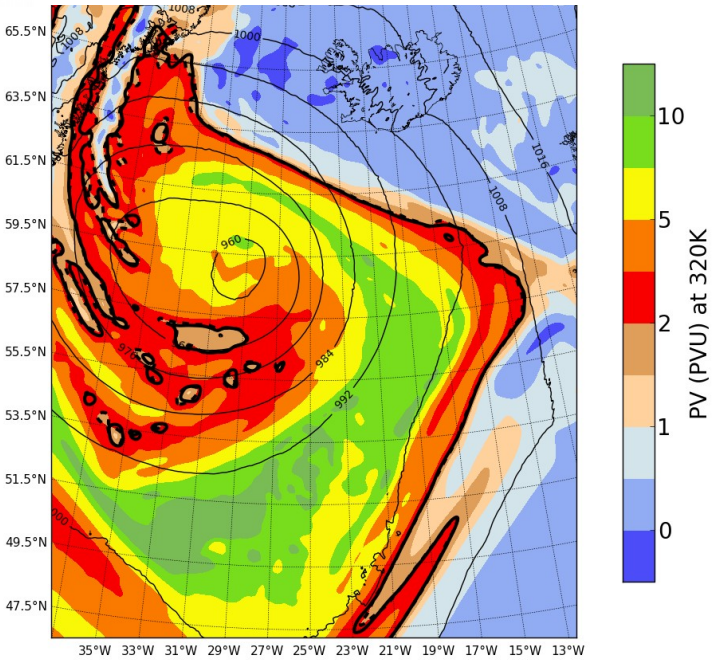




PLATES



Bullet rosettes

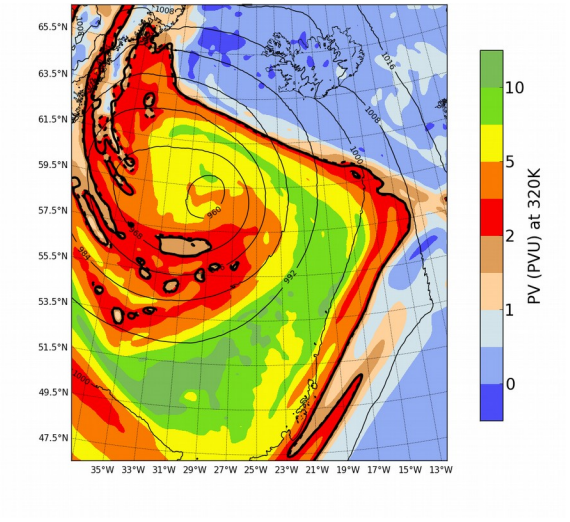


➡ Very little changes on the rigde building
Could have had an impact through radiation and vapor deposition

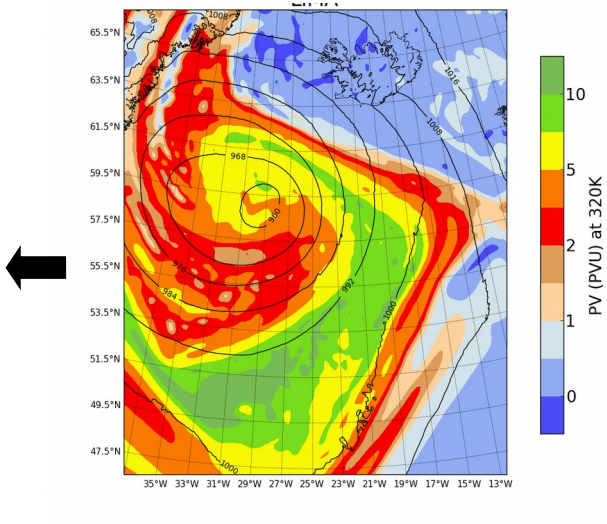
On CCN concentration

- LIMA, from 300 #/cm-3 to 3 000 #/cm-3
- LIMA, from 300 #/cm-3 to 100 #/cm-3

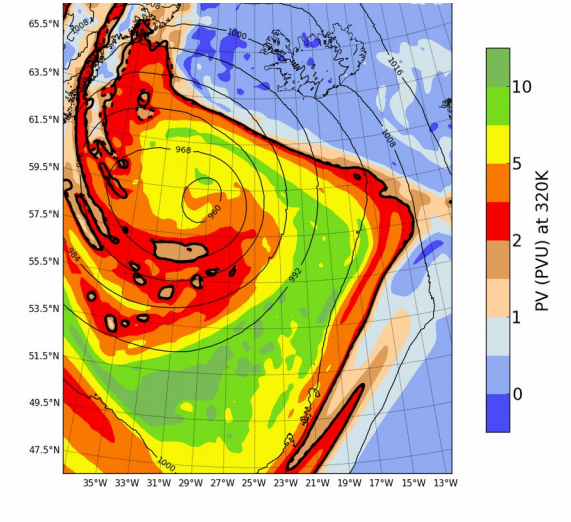
100 #.cm-3



300 #.cm-3



3000 #.cm-3

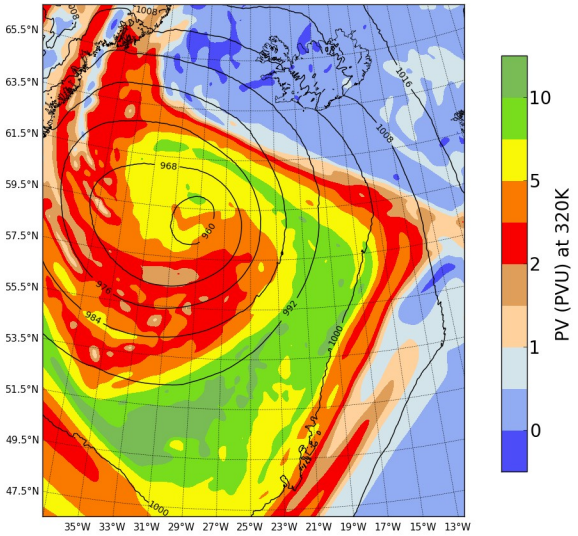


➡ Very little changes on the rigde building
Could have had an impact through invigoration

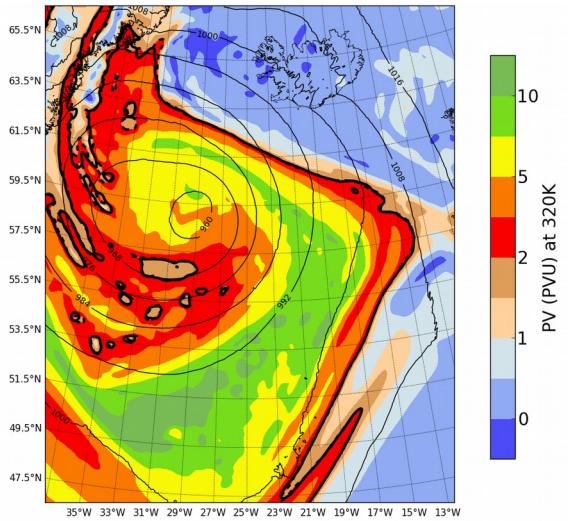
To improve the IWC represention, on snow fallspeed

- LIMA, fallspeed / 2

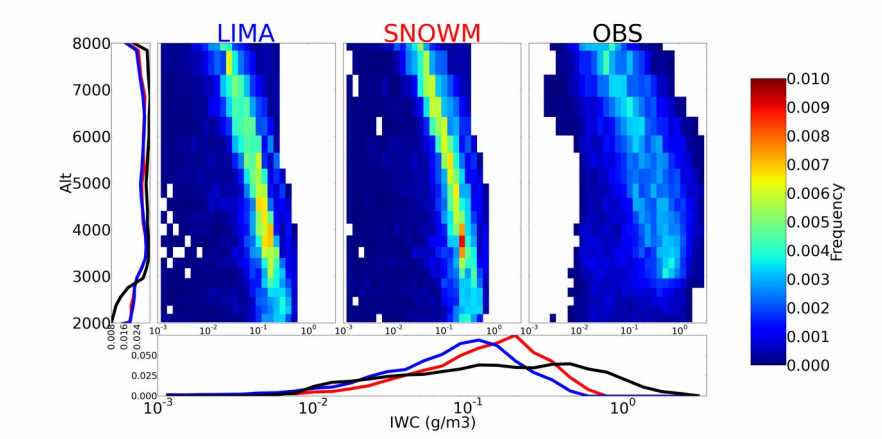
/1.



/2.



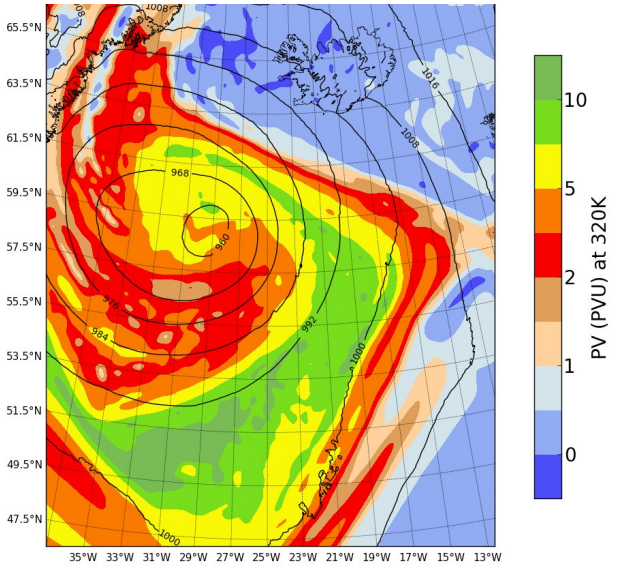
Ascending part of the WCB



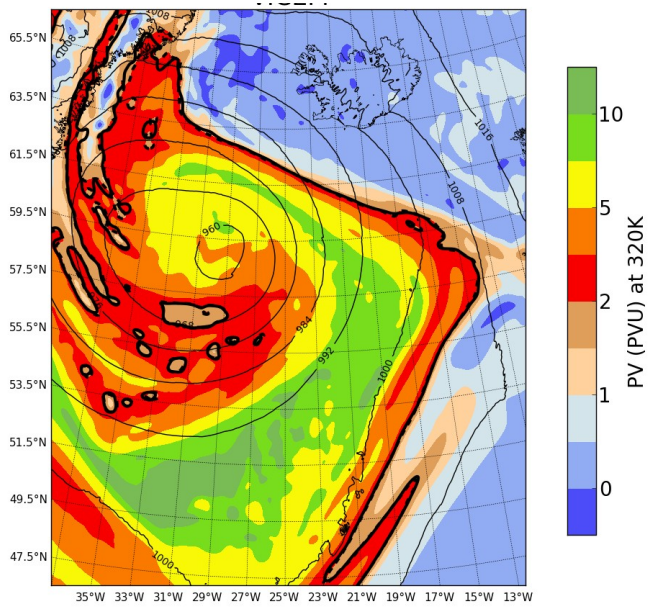
To improve the IWC represention, on ice fallspeed

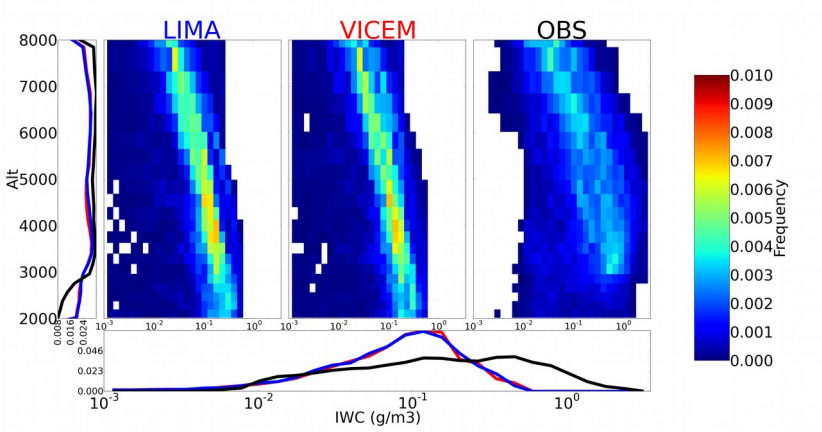
- LIMA, fallspeed / 2

/1.



/2.

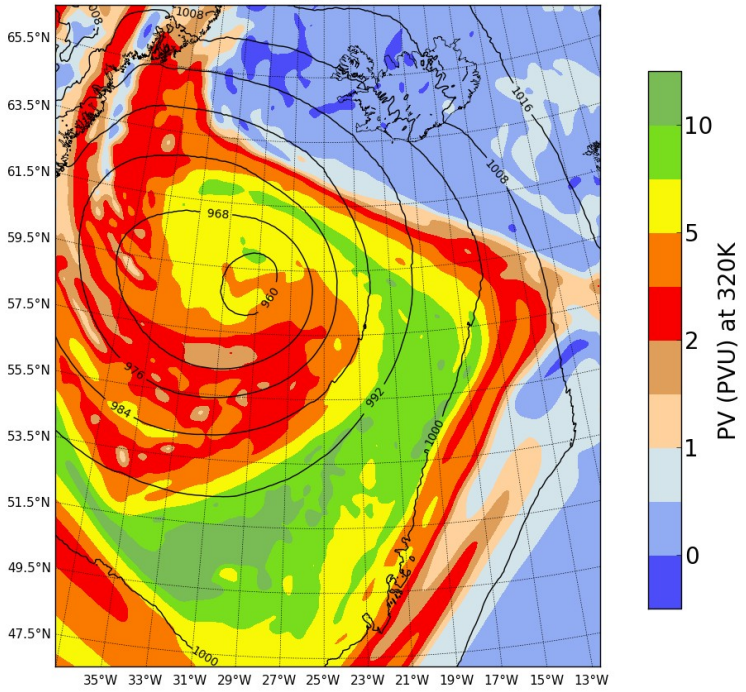




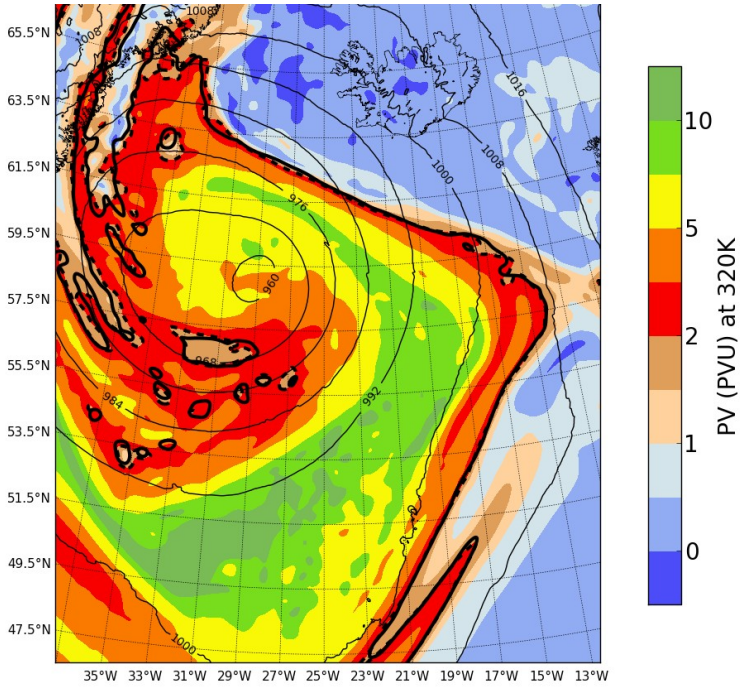
On turbulence parameterization – mixing length

- **LIMA**
- 1D vs 3D
- From BL89 (distance a parcel of air having the initial TKE of the level can travel upwards and downwards) to Deardoff (Larger vortex of the mesh)

1D BL89



3D DEARDOFF

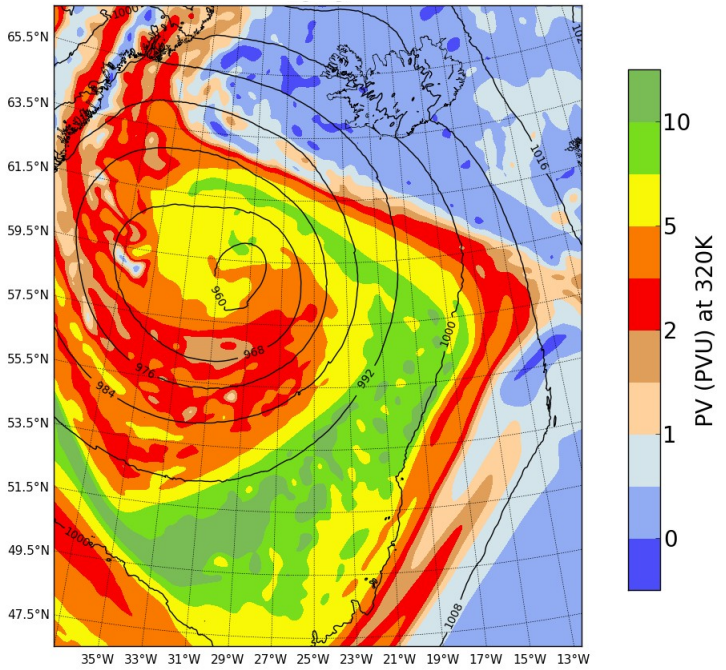


➡ Very little changes on the rigde building
Slight impact on LWC but mostly on the wind through friction

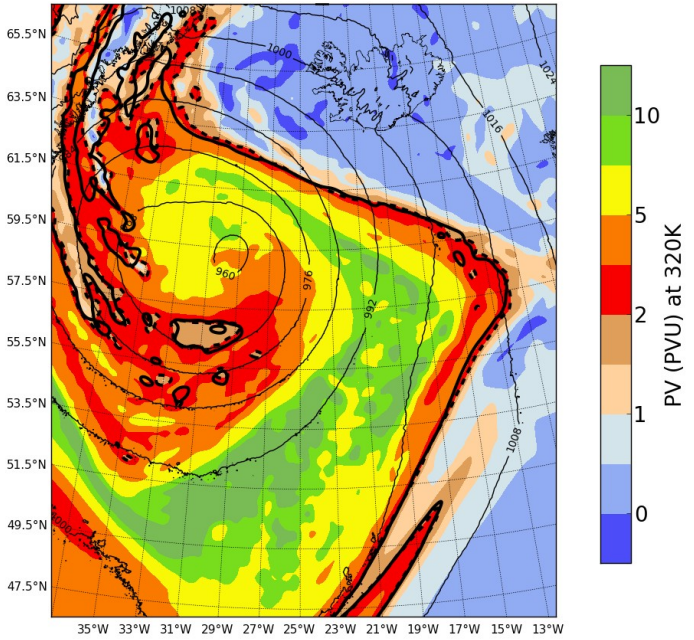
On turbulence parameterization – mixing length

- **ICE3**
- 1D vs 3D
- From BL89 (distance a parcel of air having the initial TKE of the level can travel upwards and downwards) to Deardoff (Larger vortex of the mesh)

1D BL89



3D DEARDORFF



➡ More change on the ridge building than with LIMA
Slight impact on LWC but mostly on the wind through friction

Conclusions

I. How does the ridge building representation differ using two distinct microphysical schemes ?

→ Using the 1 moment scheme ICE3 rather than the 2 moments LIMA, the ridge is more pronounced
→ ICE3 produces more ice but less snow and graupel
→ ICE3 gets a second ice peak production that LIMA does not have
→ This second peak is responsible for an increase in trajectory number with ICE3

II. Is that the same impact on distinct extratropical cyclone ?

→ Either on the explosive Stalactite or on the moderate Thor, the ridge is more built with ICE3
→ On the Stalactite it concerns more a tropopause shift and lower PV values on the Thor
→ Differences in number of trajectories between ICE3 and LIMA are observed with Stalactite and Thor
→ Higher ascent at the beginning with LIMA but higher slopes then with ICE3 for the two cyclones

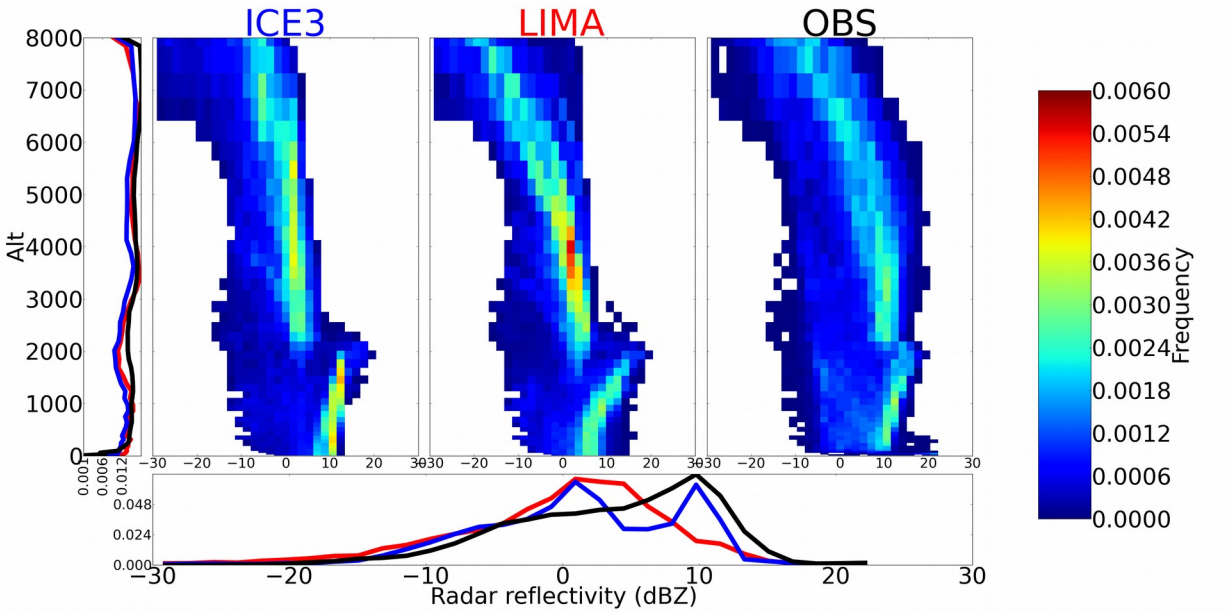
III. What if we play with the parametrizations ?

→ Very little impact
→ Highest impact when playing with the supercooled droplets

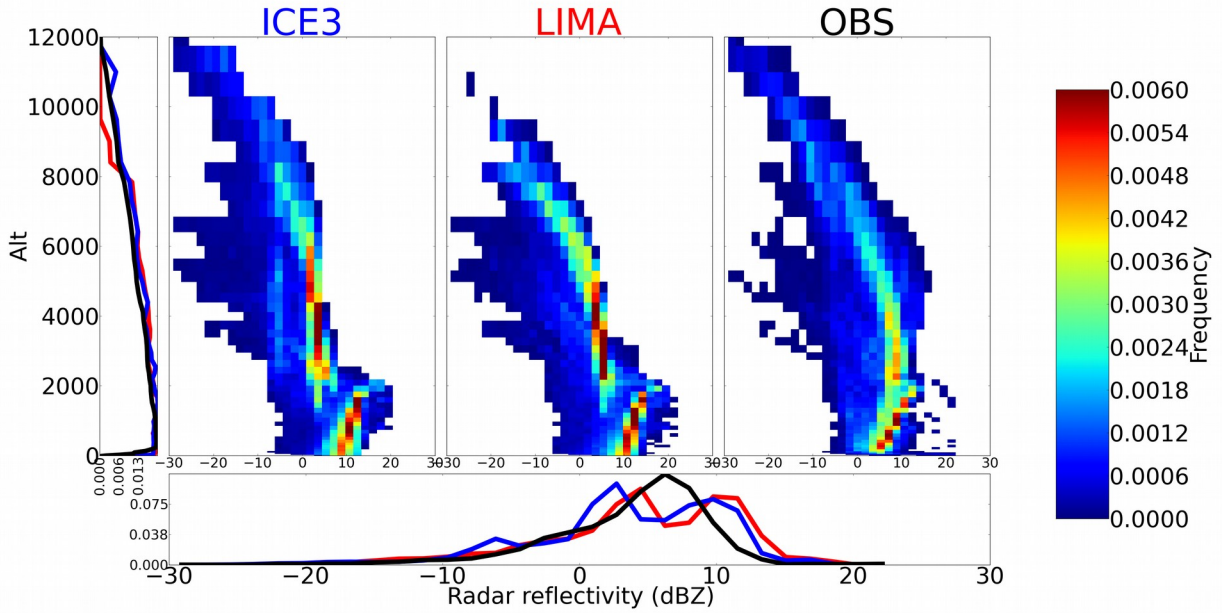
➢Which configuration provides the best representation ?

→ ICE3 when changing the snow fallspeed (but that could be due to the snow mass-diameter relationship that is supposed to be far from observations..)

Stalacticte, ascending part of the WCB



Thor, ascending part of the WCB



ICE3 (Used in French NWP)

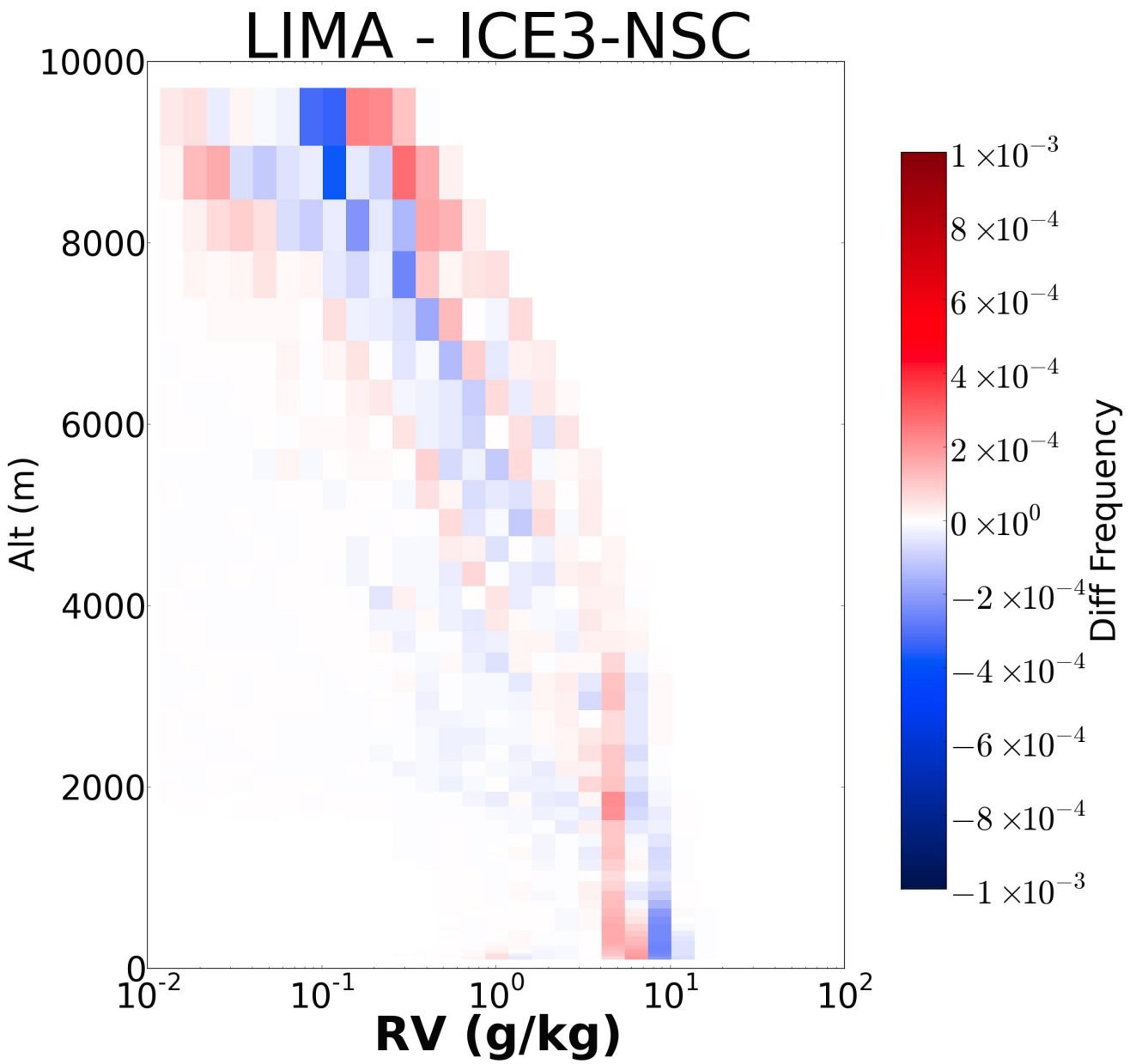
- Hydrometeor **mixing ratio pronostic** (one-moment scheme)
- **Cold phase (and mixed) : deposition of all vapor in excess**
- **Subgrid condensation scheme** (allow to consider condensate in a mesh with RH < 100%)
- **Conversion ice/snow depends on the ice mixing ratio**

$\neq$

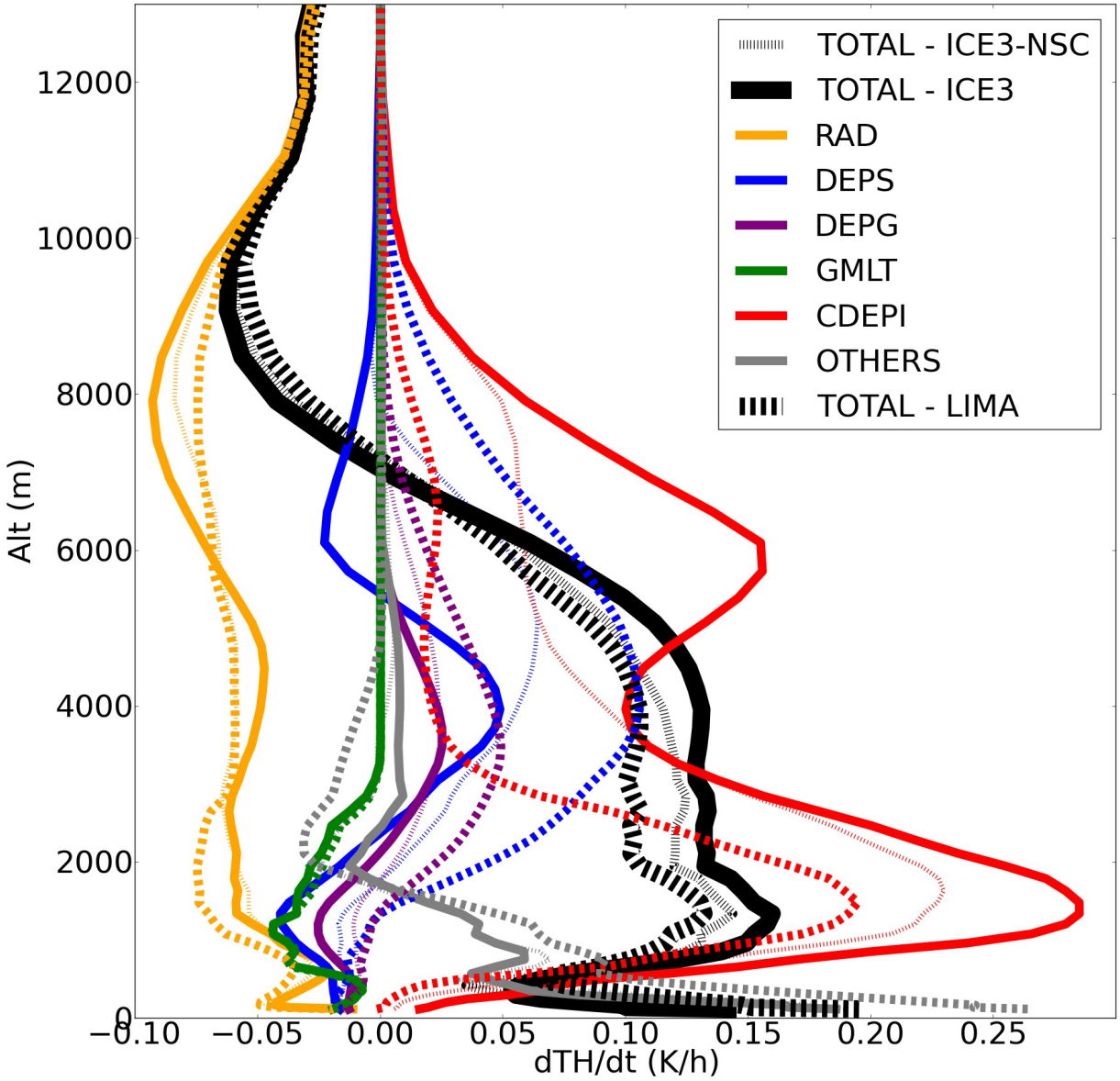
LIMA

- Hydrometeor **mixing ratio and concentration pronostics** (two-moments scheme)
- **Cold phase (and mixed) : explicit transfert mass**
- **All or nothing cloud in a mesh**
- **Conversion ice/snow depends on a threshold diameter for the ice**

Difference of vapor mixing ratio distribution



Vertical evolution of TH budget (mean on the whole domain at different time steps)



Dropsondes from F6