Partitioning of Water and Ice during 2 Nov 2016 of NAWDEX

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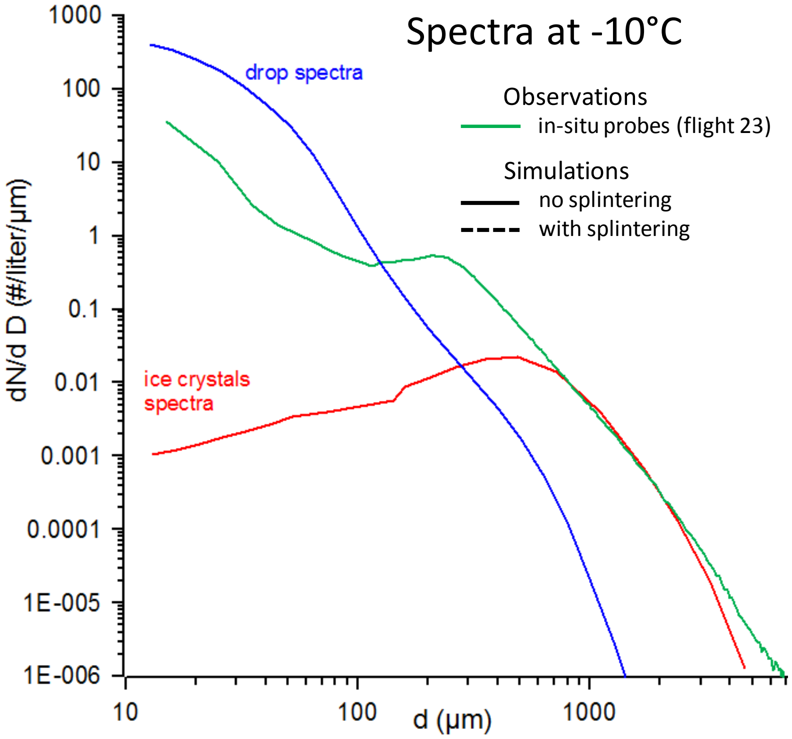
Objective: **understanding of the formation and the presence of the ICE phase in the temperature range from 0 °C to -25 °C**

Reasons for Ice Nucleation:

1. heterogeneous nucleation
   of existing drops and/or aerosol particles
   ➔ leads to an <u>extreme underestimation of ice crystals</u>
2. secondary ice multiplication
   ➔ only Hallet- Mossop splintering is well confirmed
   from lab measurements (-3 to -8 °C)
   other processes are suspected !

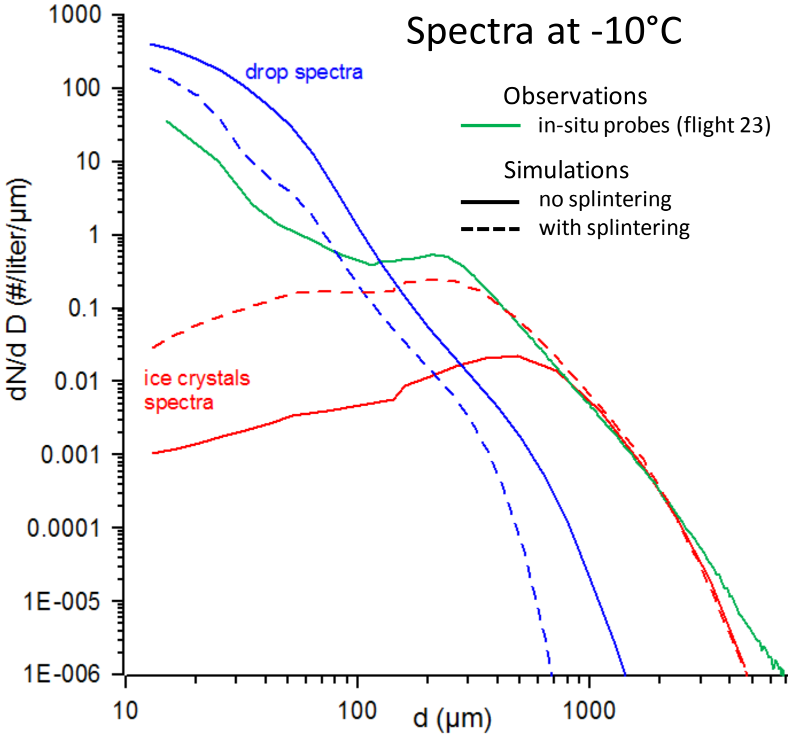
Example from the HAIC campaign over French-Guyana, May 2015
Results from bin modelling



► general result:

Ice crystal numbers for D < 500 µm are strongly underestimated and droplet numbers are too high

Example from the HAIC campaign over French-Guyana, May 2015
Results from bin modelling



► general result:

Ice crystal numbers for D < 500 µm are strongly underestimated   and
droplet numbers are too high

► adding splintering:

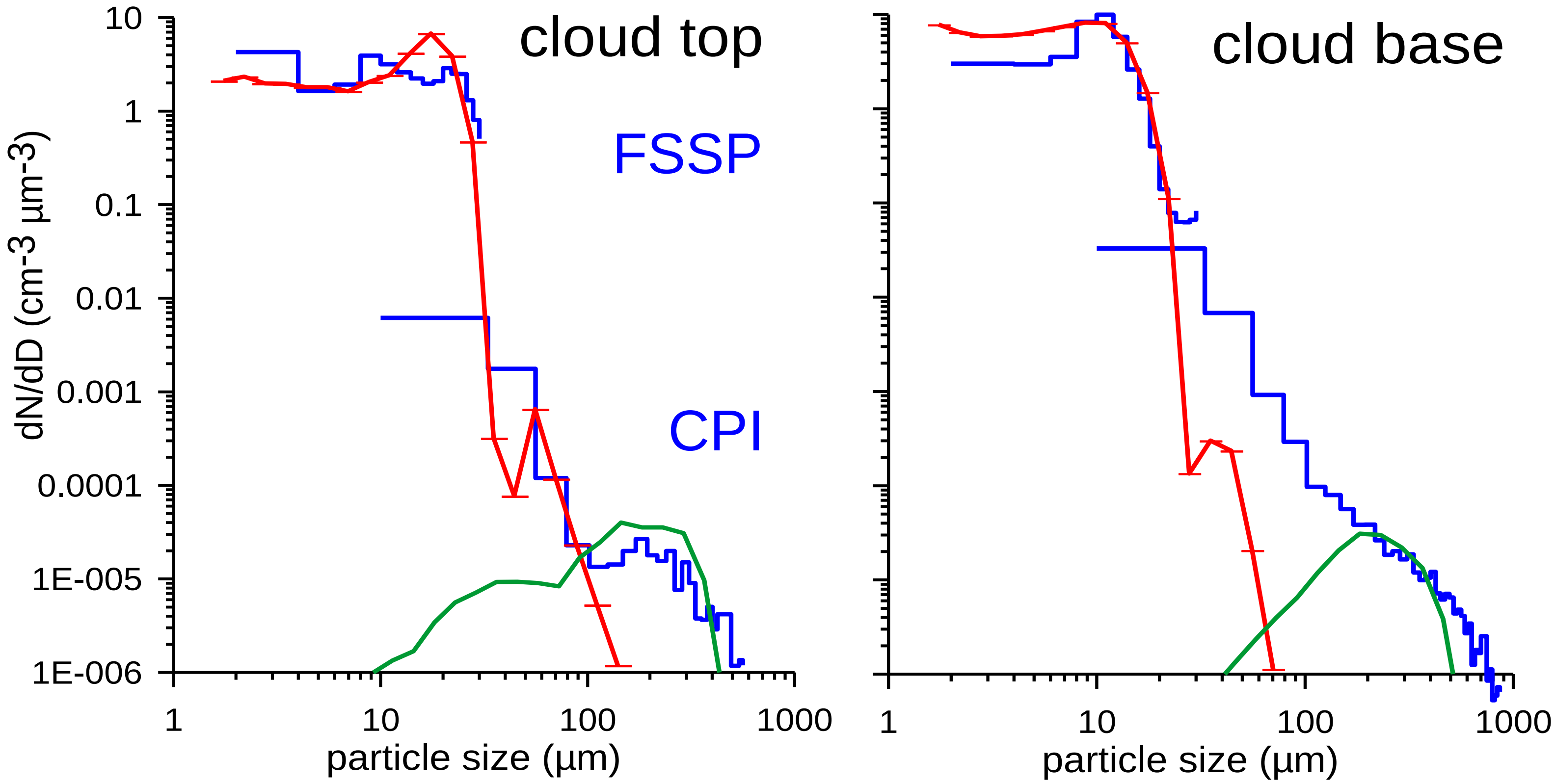
with splintering, the number concentration of ice crystals becomes comparable to the in-situ measurements down to diameters of 100 µm.

this hold for tropical clouds ➔

➔ **Arctic clouds:**

Example from <u>the ASTAR campaign over Spitsbergen</u> 2005

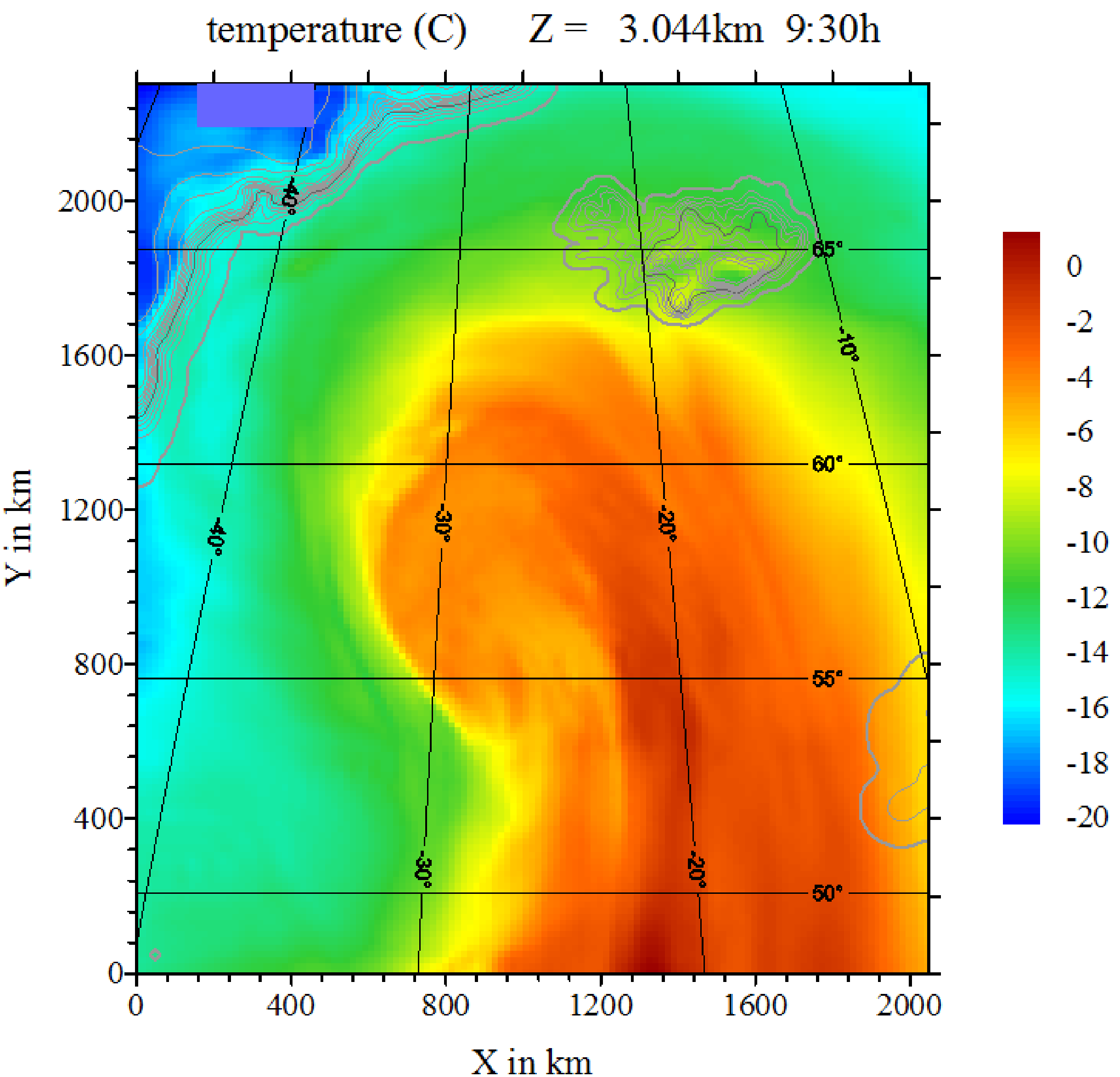
important cloud drop numbers from -8° to - 22°C



All simulations for NAWDEX, 2 Nov 2016, included “Hallet-Mossop ice multiplication”

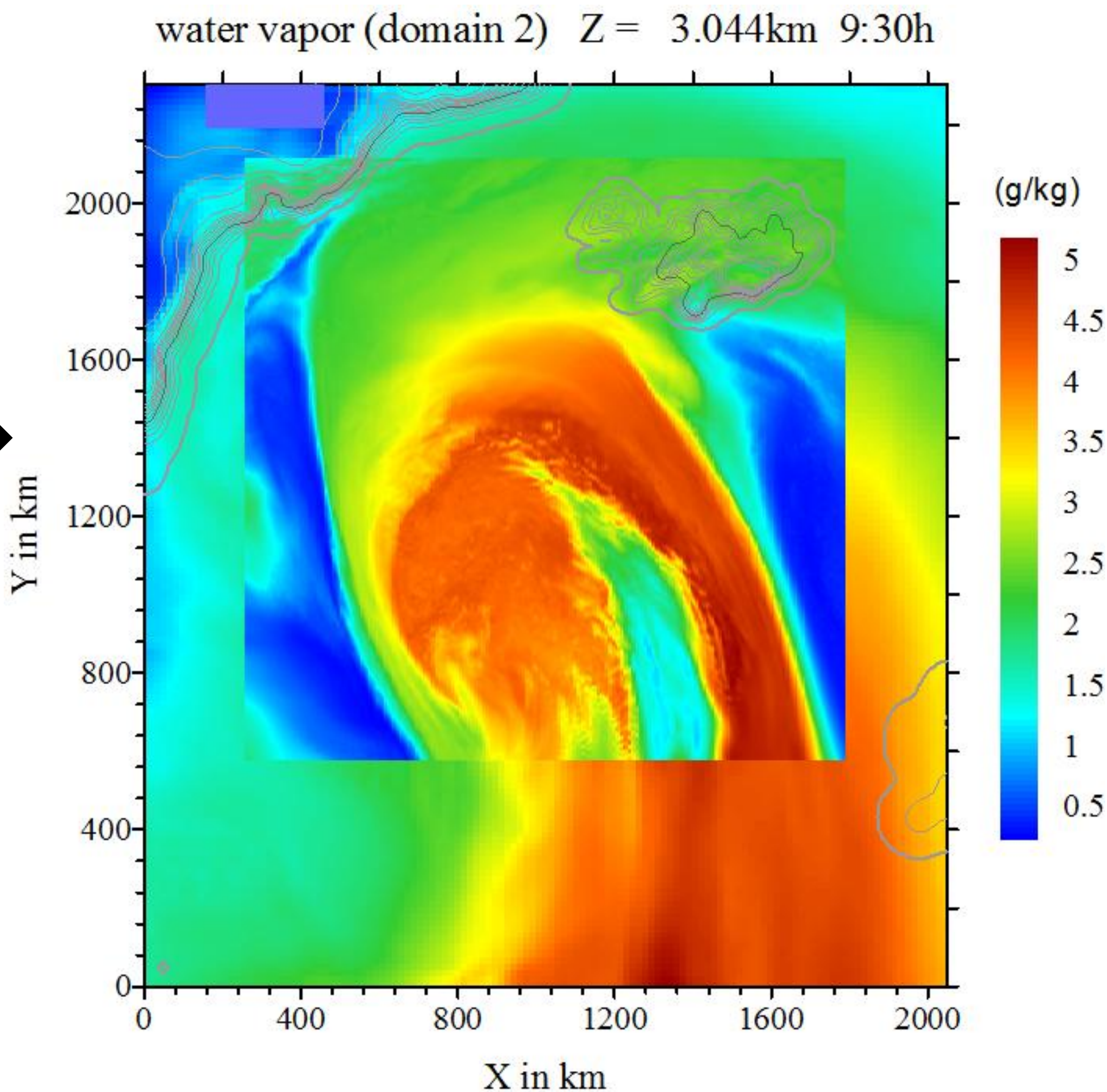
Model setup of the dynamic part: 16 km – 4 km – 1 km
- outmost domain –

Strong horizontal variability in temperature ➔



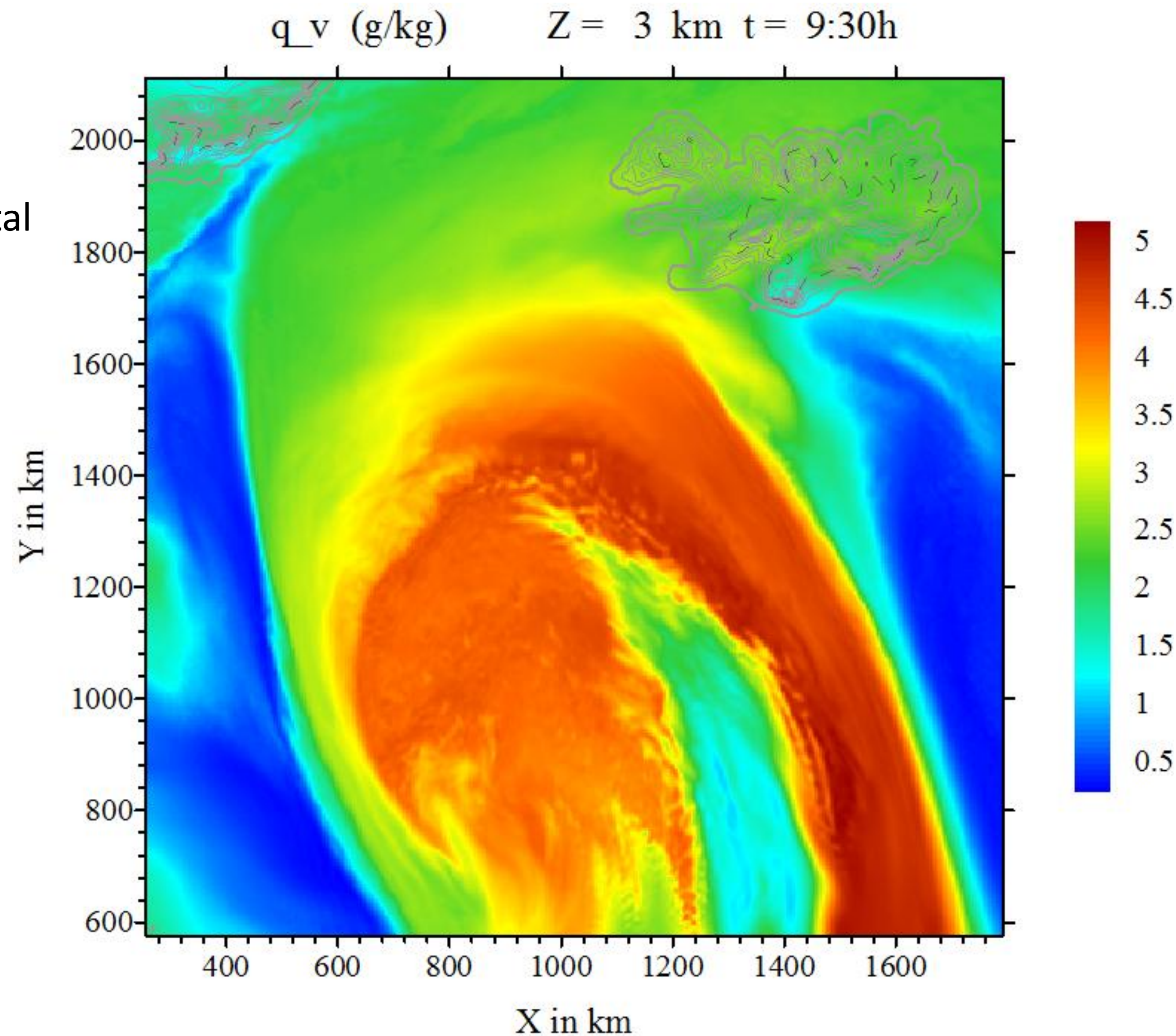
Model setup of the dynamic part: 16 km – 4 km – 1 km
2nd domain

Strong horizontal variability in temperature as well as in water vapor ➔



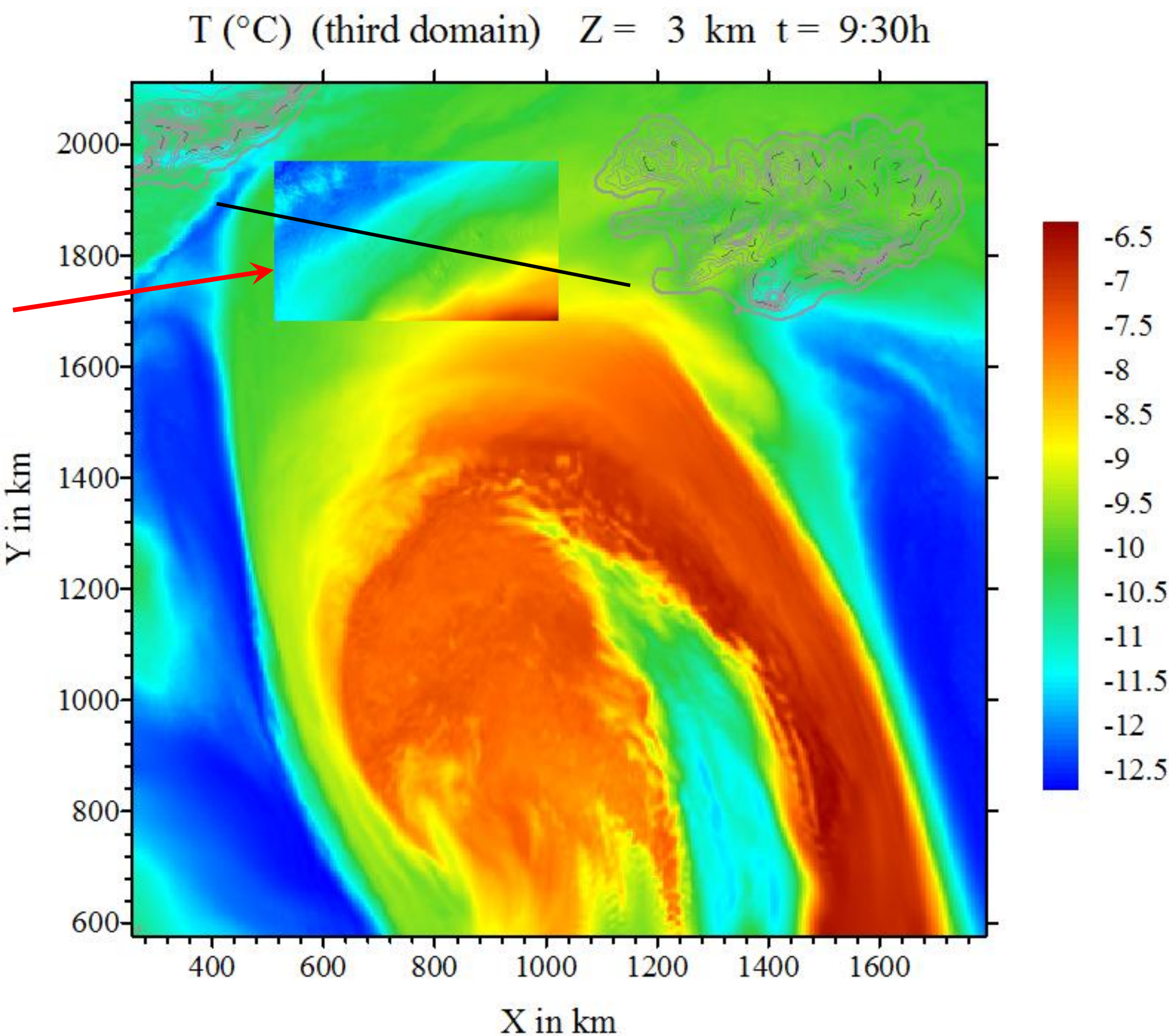
Model setup of the dynamic part: 16 km – 4 km – 1 km
2nd domain

Strong horizontal variability in water vapor

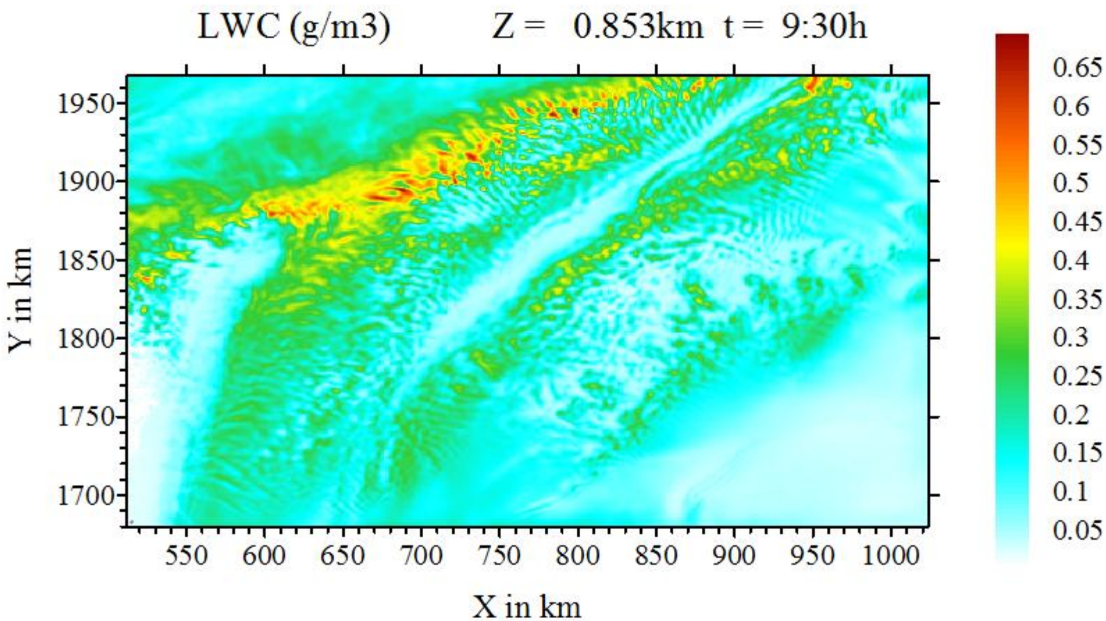


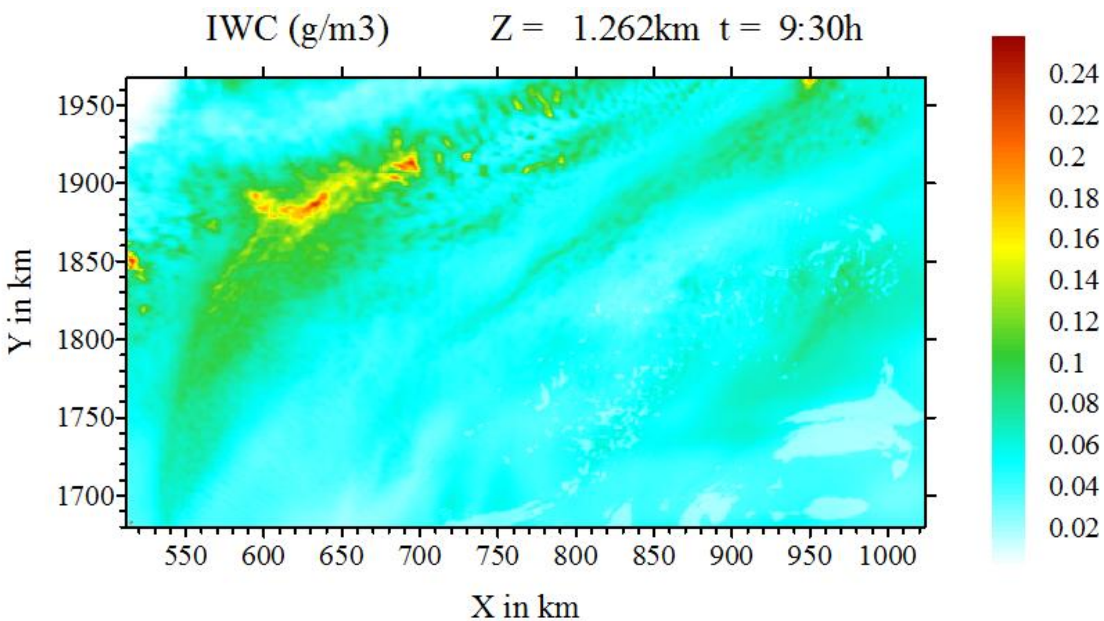
Model setup of the dynamic part: 16 km – 4 km – 1 km
3rd domain (for the morning flight)

temperature field of the 3rd domain



Results for the 3rd domain (morning flight)

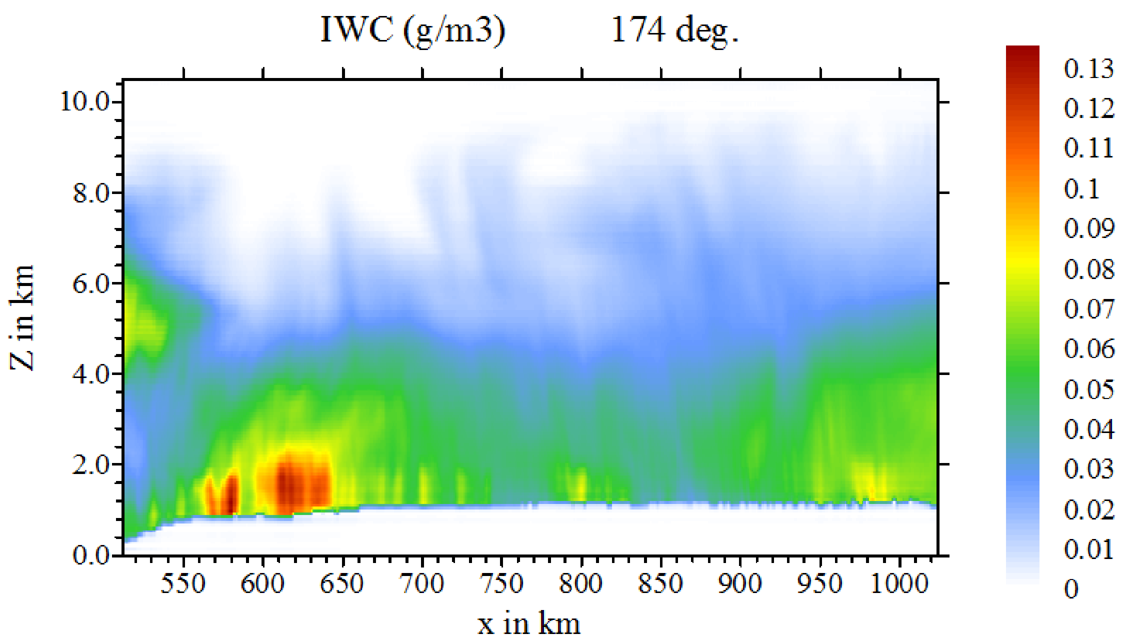




Due to the directional wind shear in the lower 2 km the formation of warm clouds is favored in the lowest layers up to 3 km with important LWC

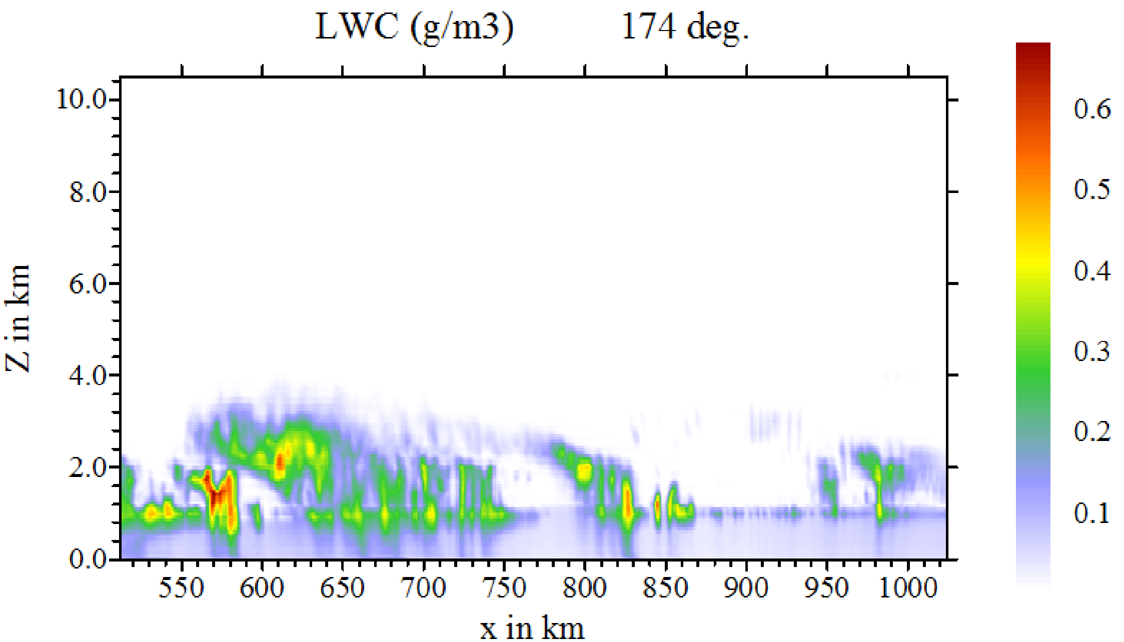
IWC in general weak with < 0.1 g m^{-3}.
Only in regions of “shallow convection” IWC becomes stronger

Results for the 3rd domain (morning flight)



Approaching Greenland the 0°C level drops from 1.2 km to < 0.8 km

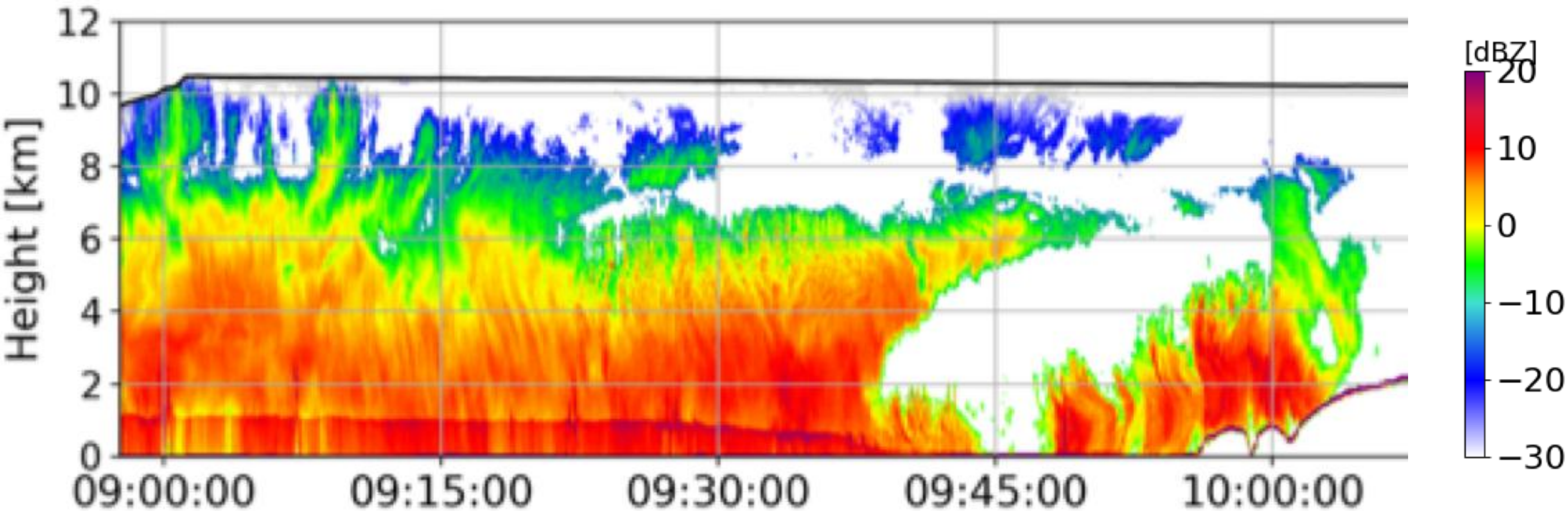
IWC above 4-5 km remains quite low

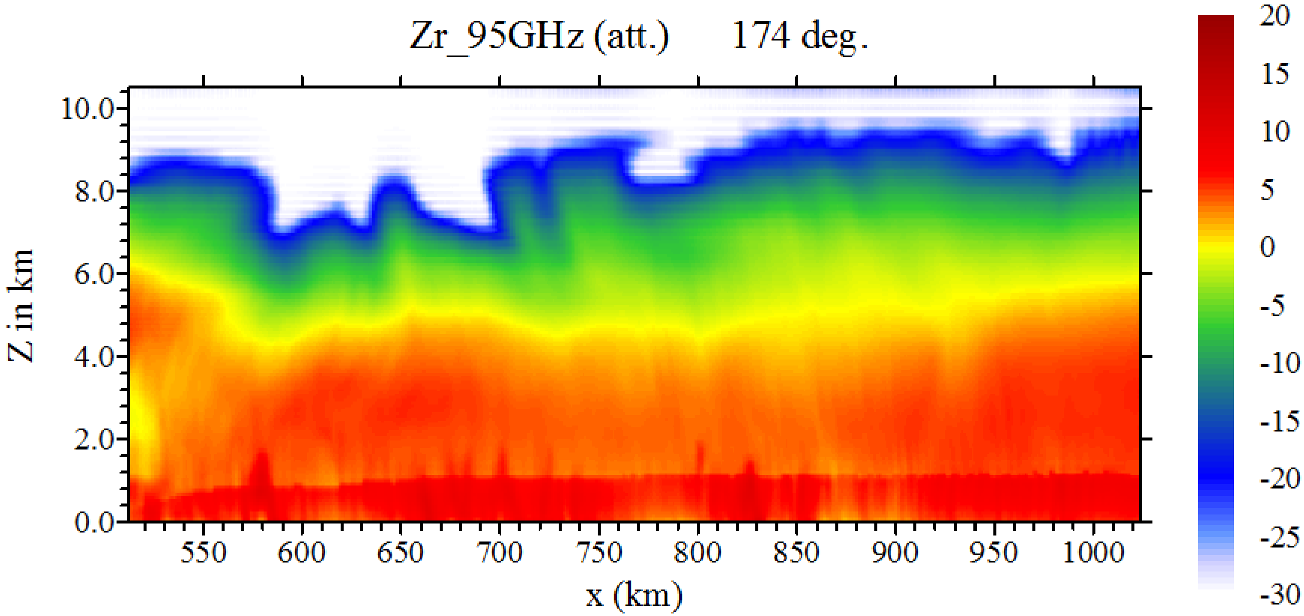


The vertical distribution of LWC shows quite patchy patterns.

Spots with high LWC allow the presence of higher values in IWC.

Comparison with RASTA (morning flight)





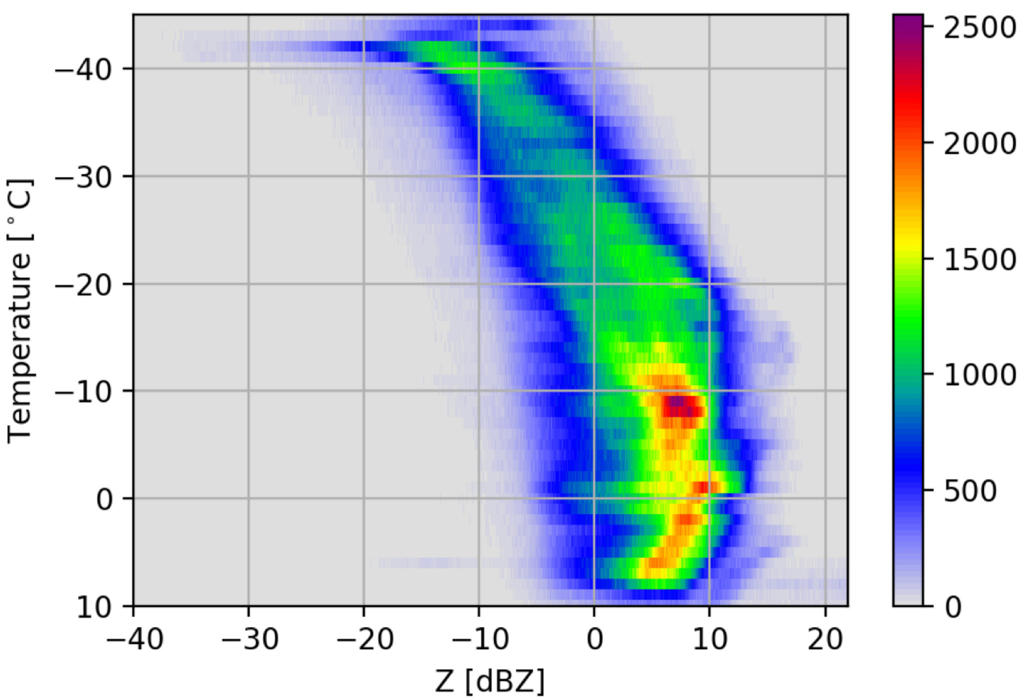
Z95 GHz calculated from the modeled drop and crystal spectra, using the relationship:

$$mass_{bin} = 0.0454\ D_{bin}^{2.05}$$

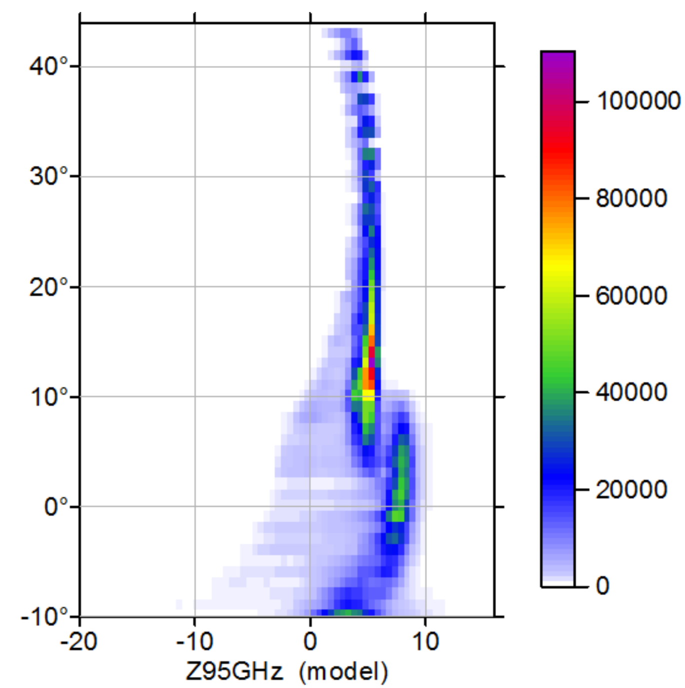
Comparison with RASTA (morning flight)

CFADS for Z95GHz

Delanoë et al. NAWDEX meeting (2019)

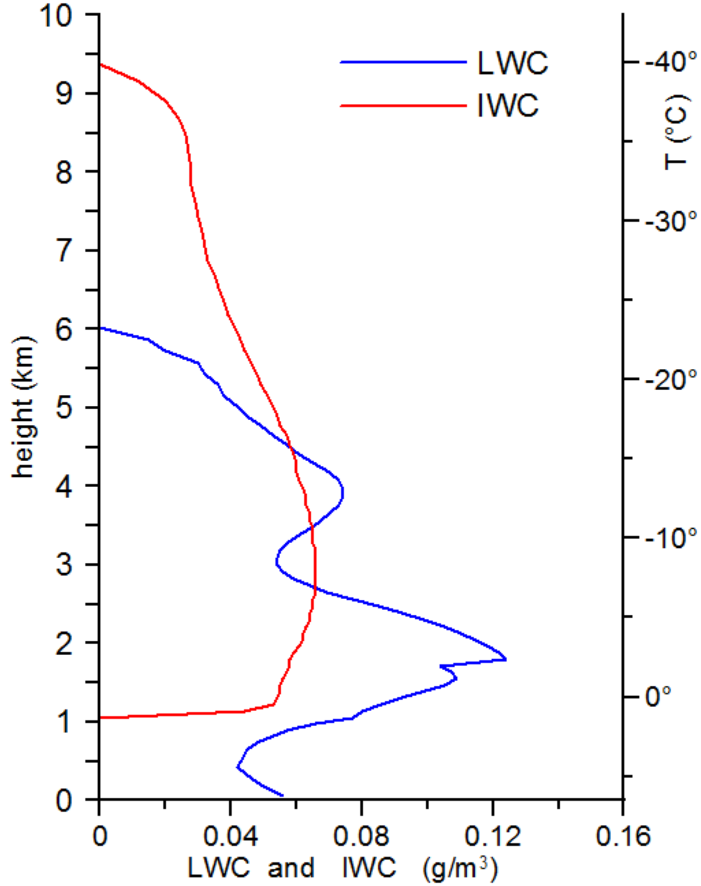


Calculated from the simulated particle spectra
(strongly dependent on the mass-diameter assumption)



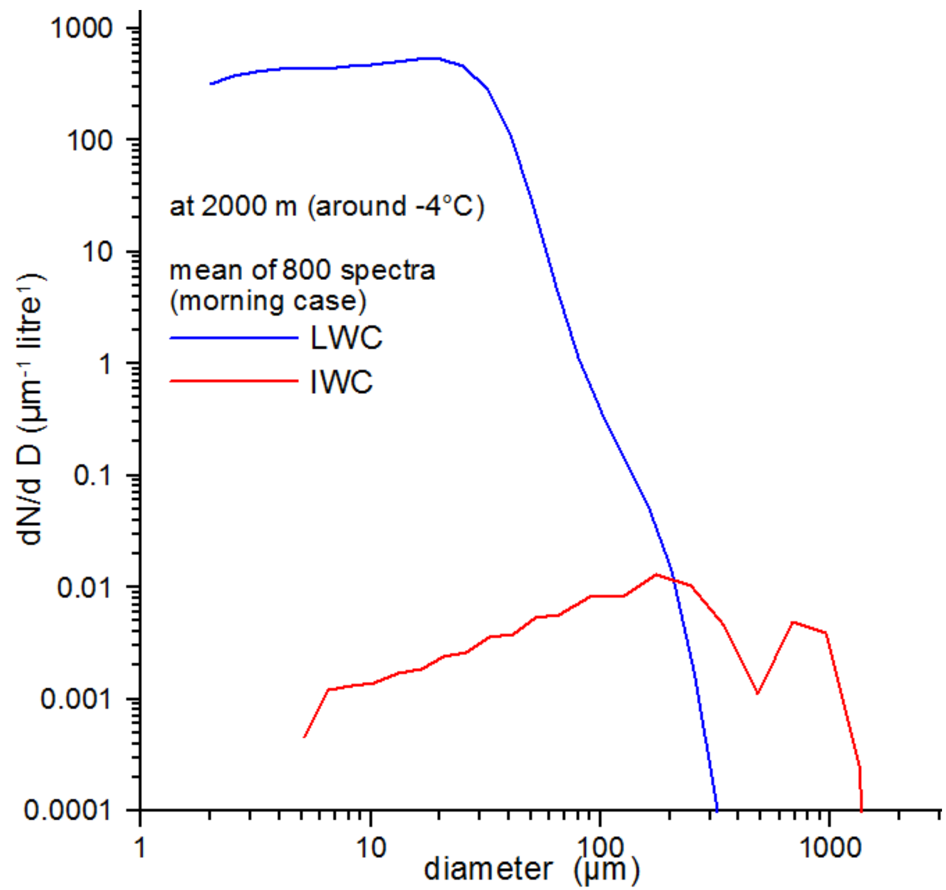
Resulting vertical profiles of LWC and IWC

below Rasta retrieval and MESOnh results



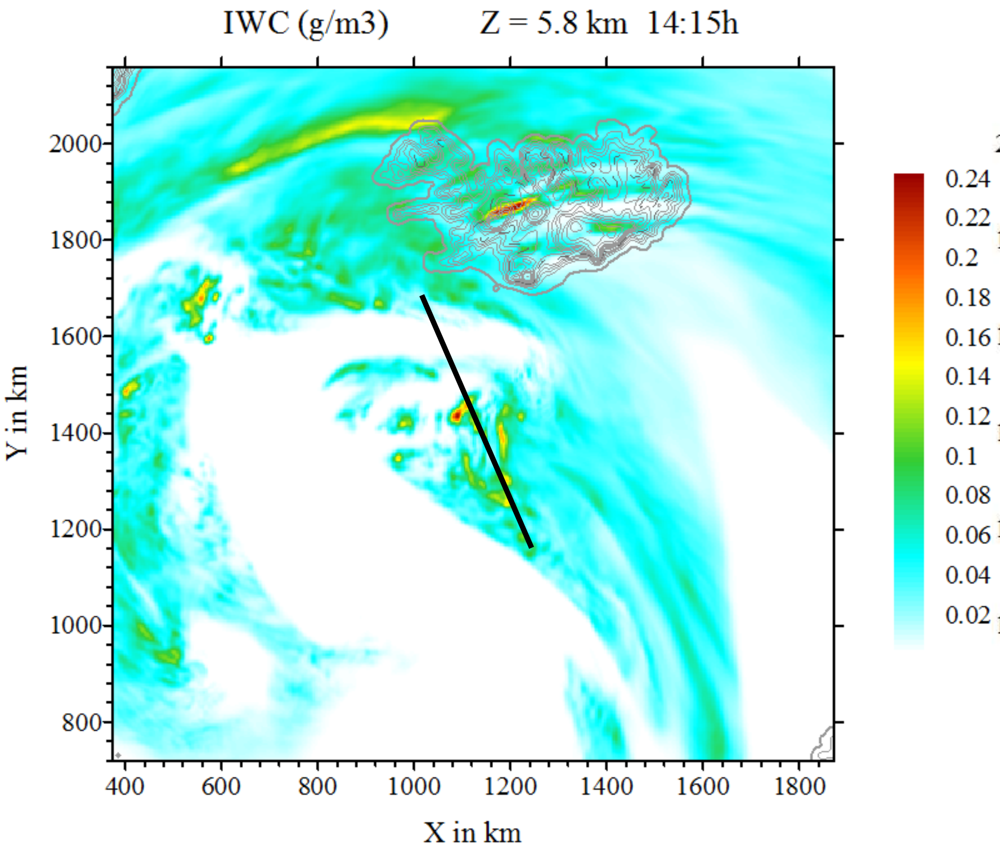
Simulated droplet and crystal spectra at 9:30

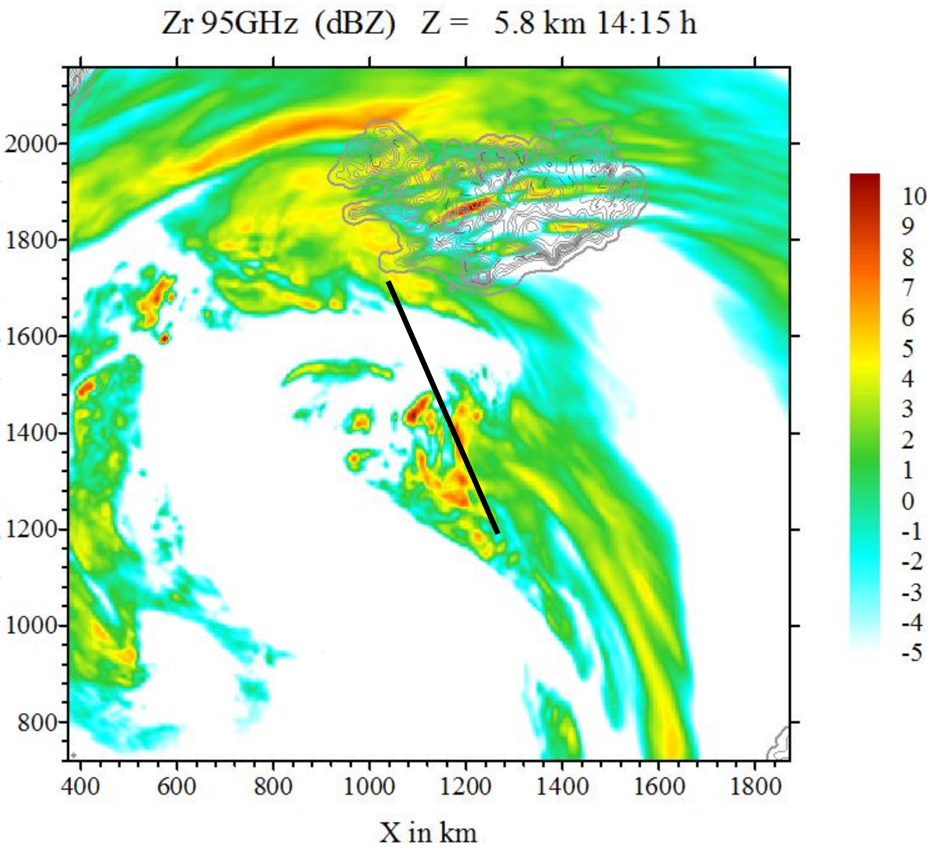
The liquid cloud phase remains also dominant in elevated layers



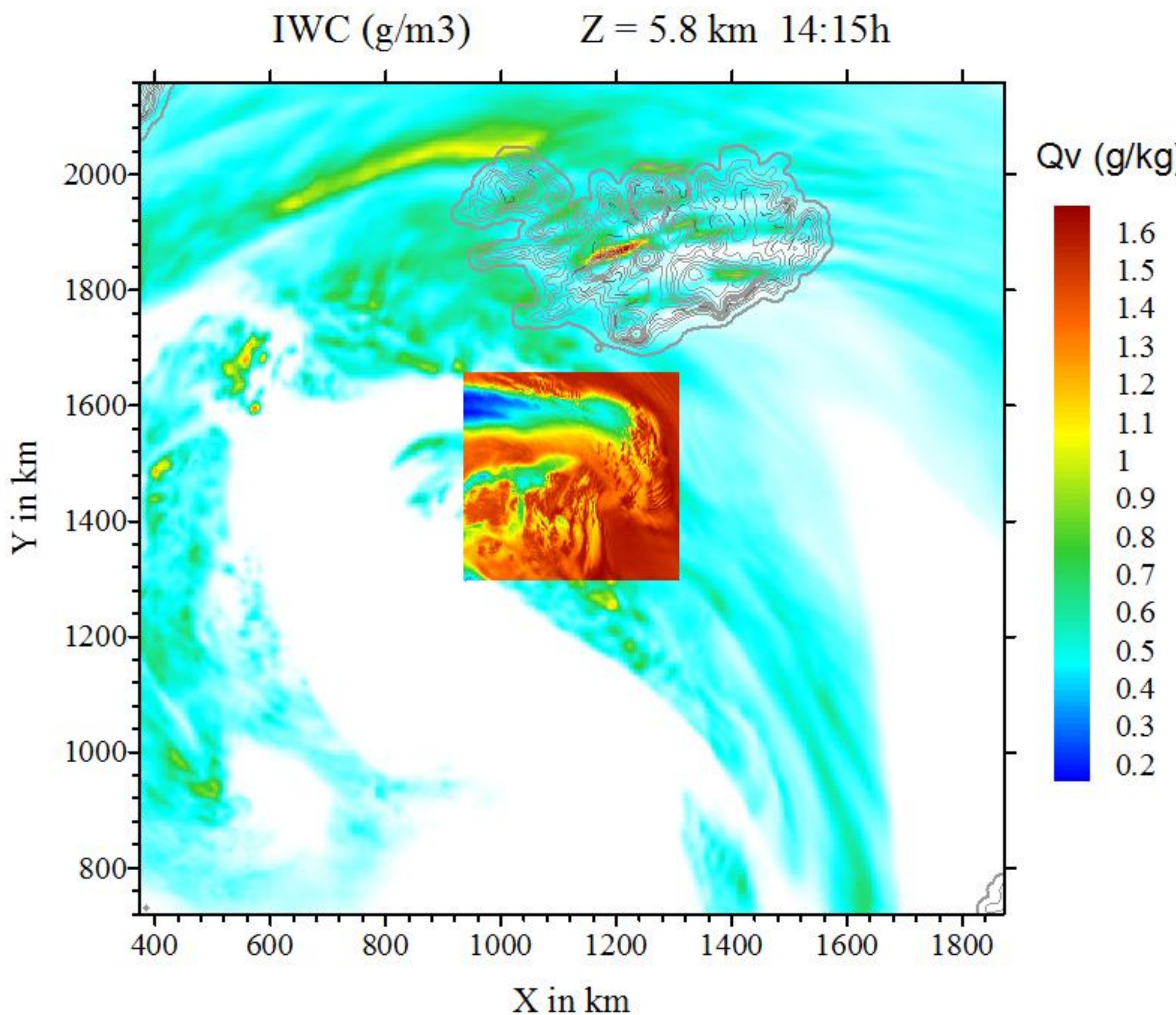
Model set-up (afternoon flight) : 14.4 km – 3.6 km -0.9 km 2nd domain

During 13:30 – 15:00 h a strong "cloud gap" appeared during the overpass of CloudSat





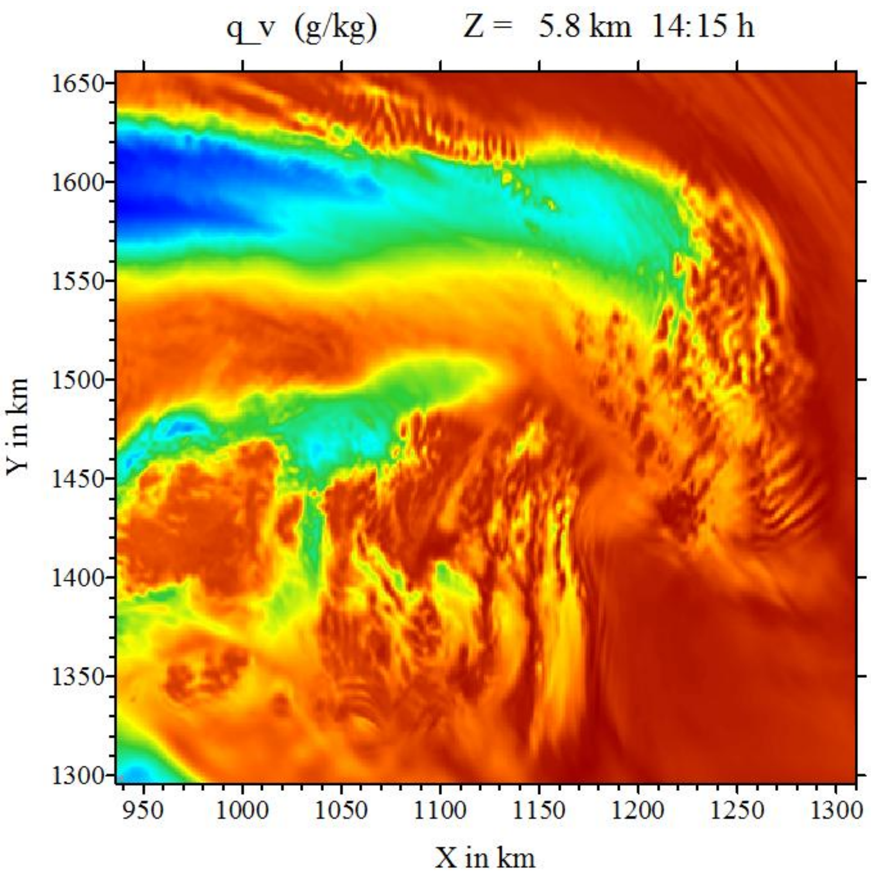
Model set-up (afternoon flight) innermost domain

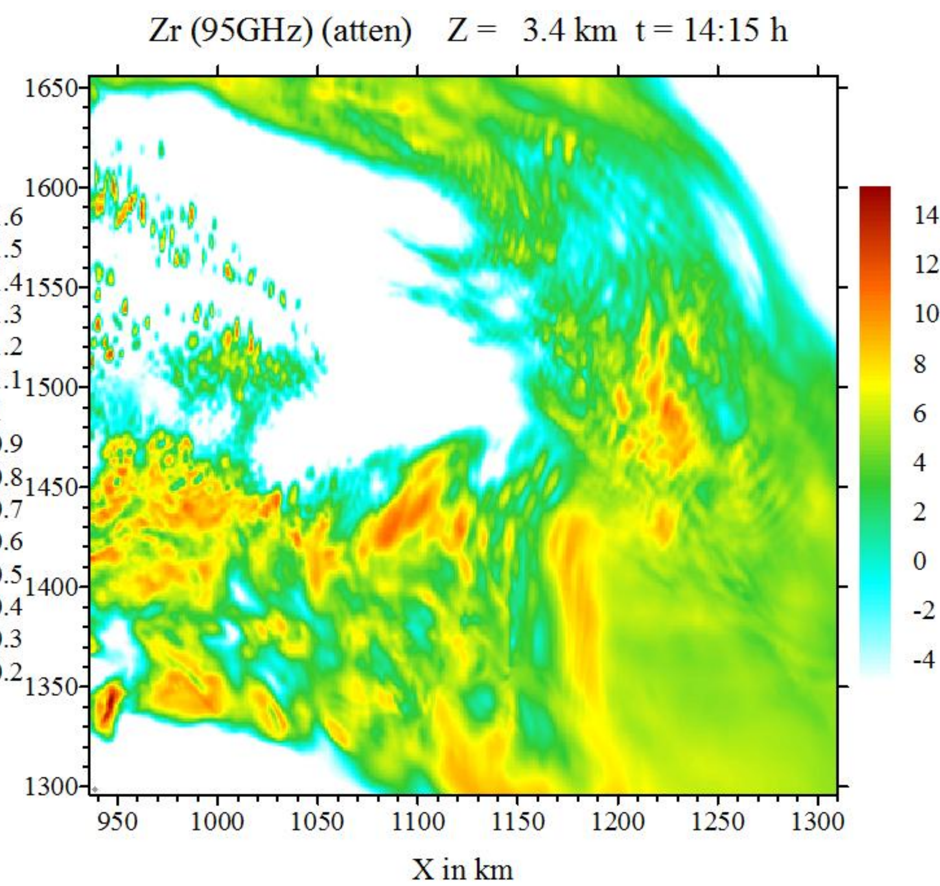


Results for the 3rd domain (afternoon flight)

Origin of the “cloud gap during the Cloudsat:

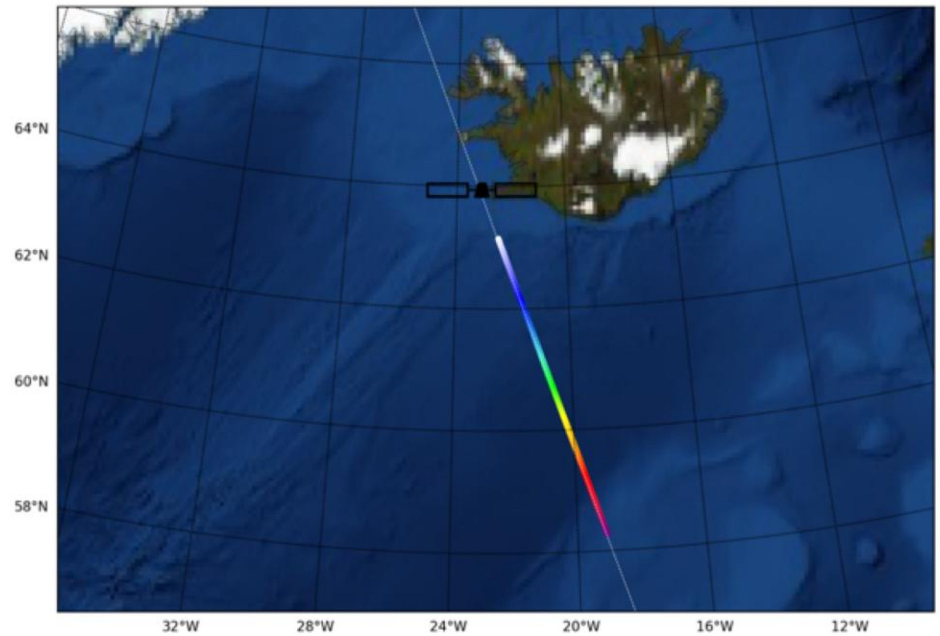
Intrusion of dry air inside the warm scector



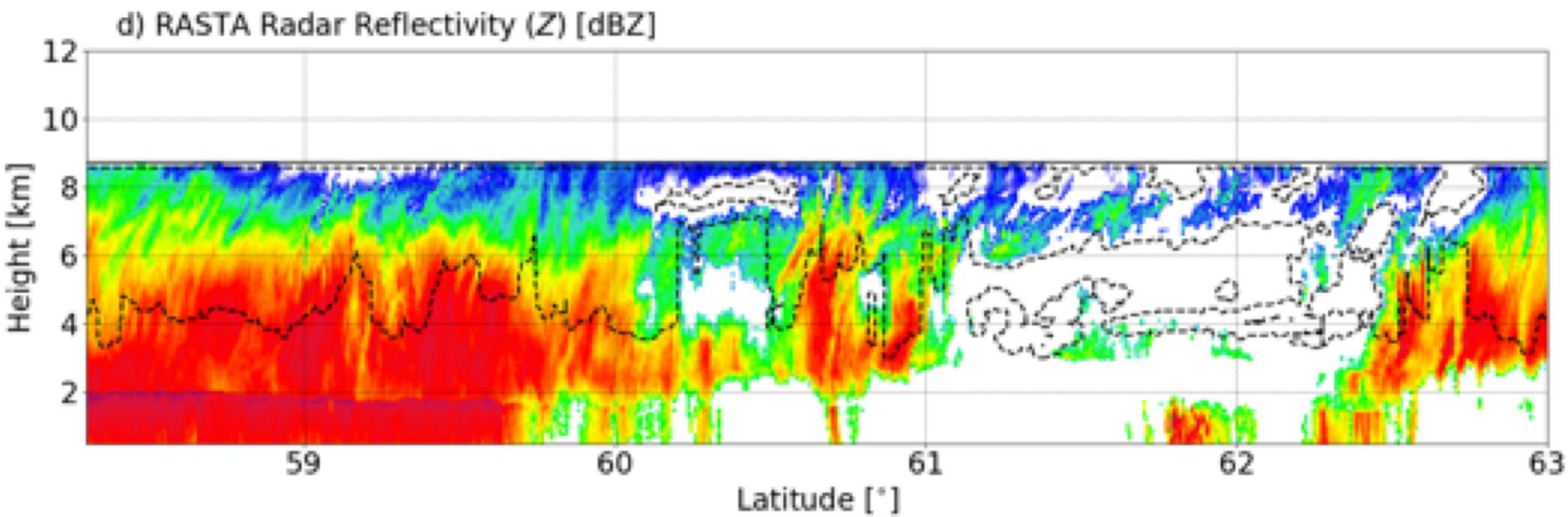


afternoon flight:

Rasta - CloudSat



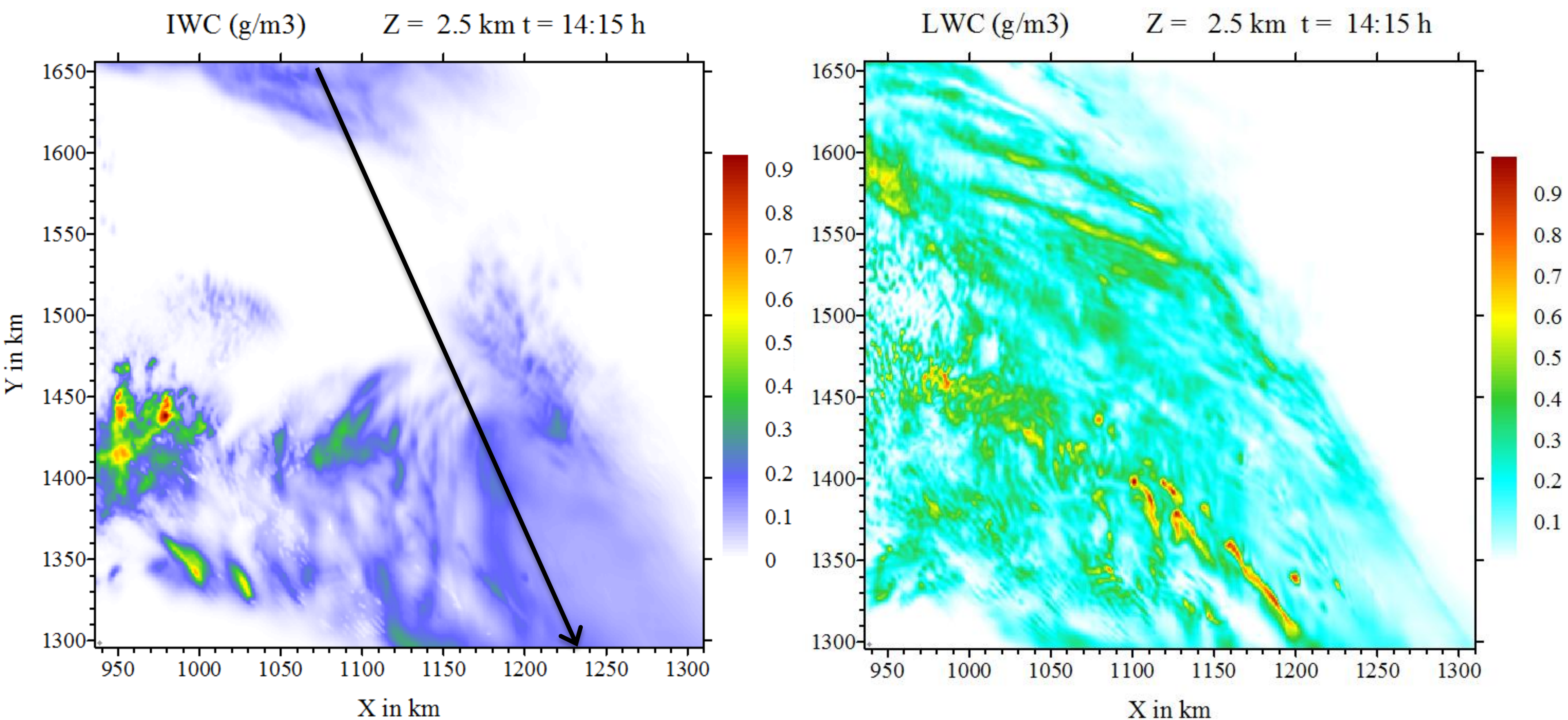
Figures: Delanoë et al.
NAWDEX meeting (2019)



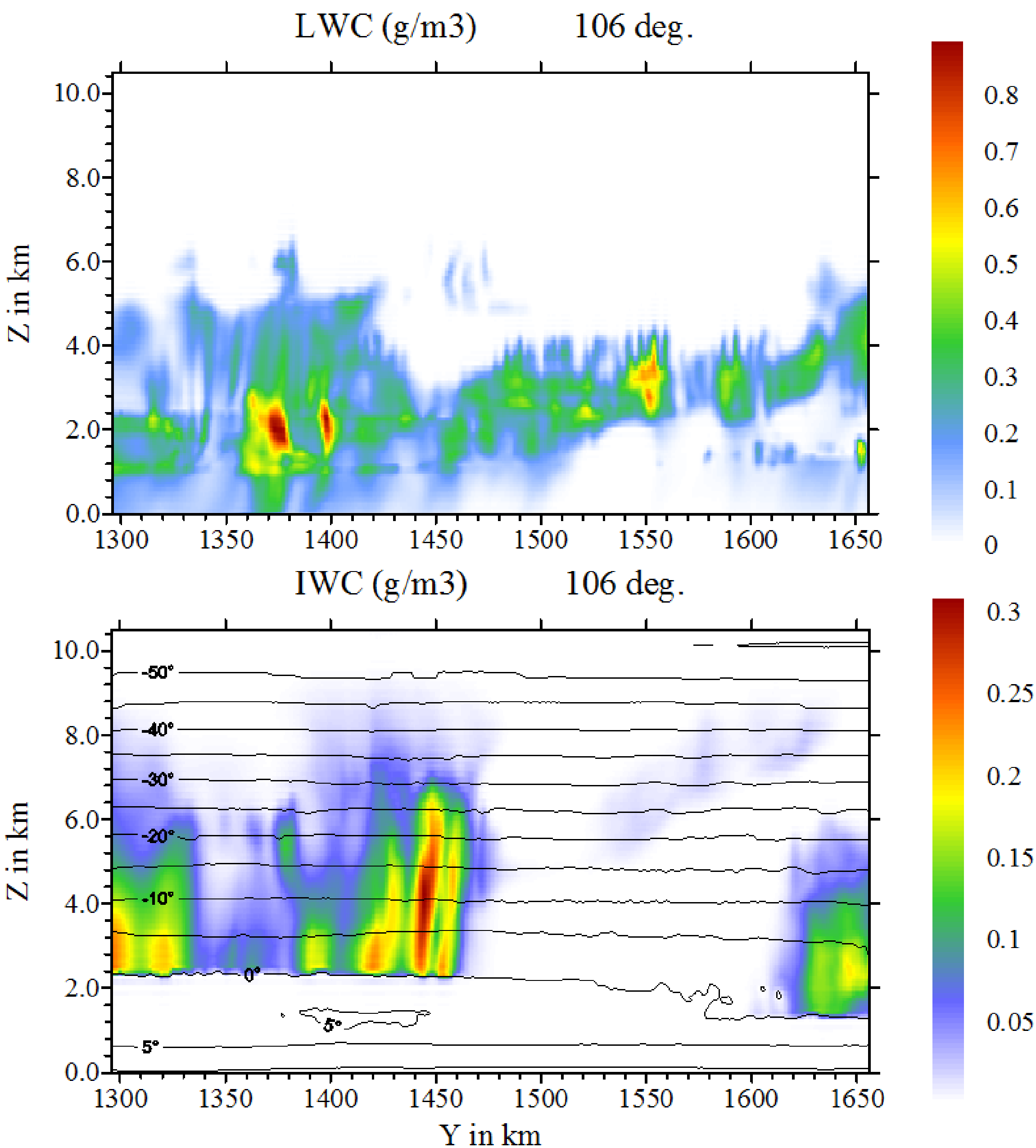
Results for the 3rd domain (afternoon flight): comparing LWC and IWC

Horizontal cross section at 2.5 km for IWC and LWC : strong values occur for both inside the warm-sector

The orientation of the cloud band gives the location of the advancing warm-front



Results for the 3rd domain (afternoon flight)

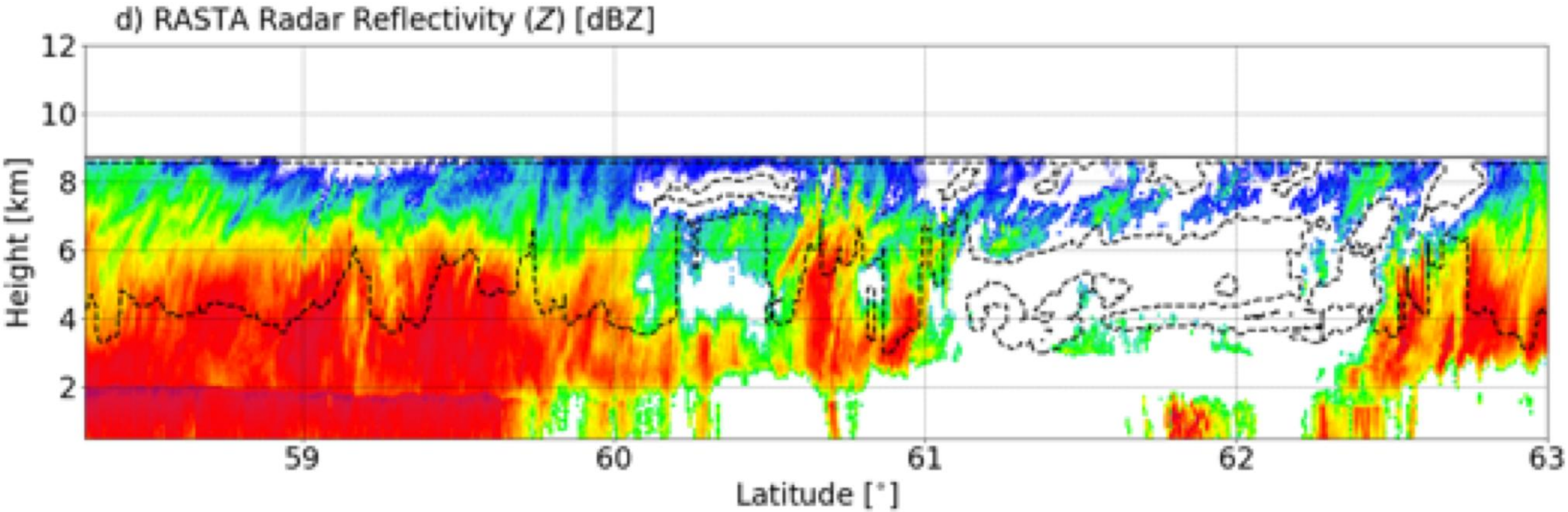


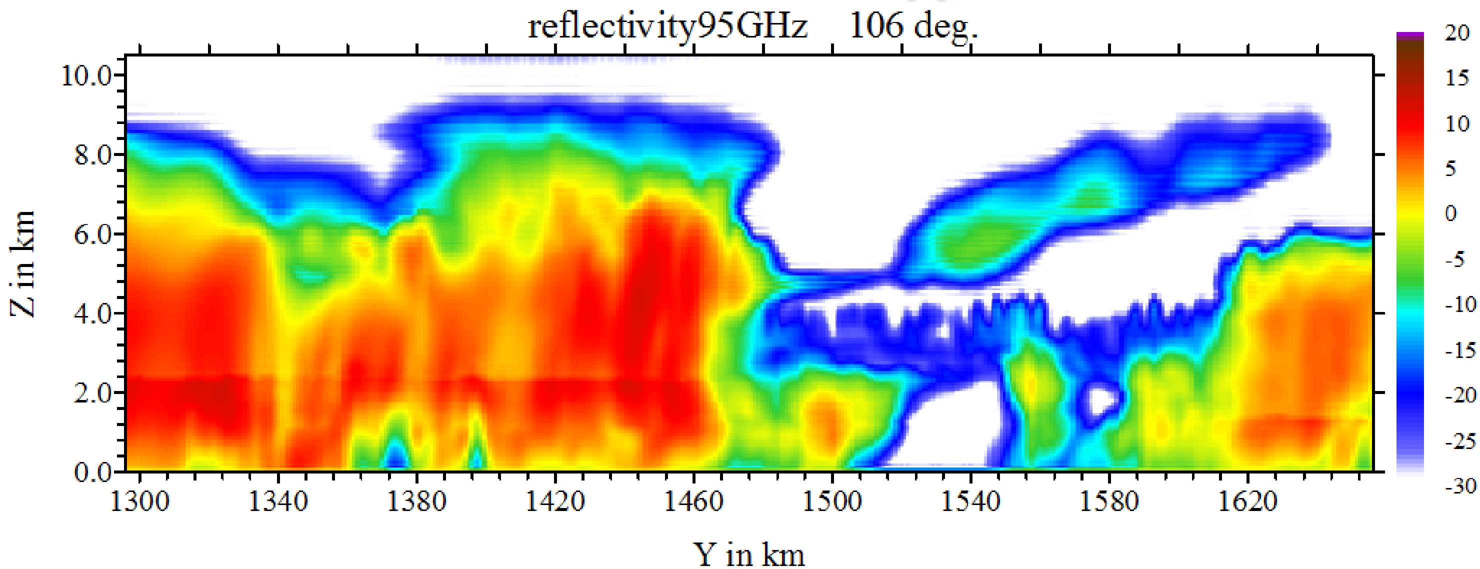
Significant increase in the vertical extension of the LWC

IWC also increases especially in the southern part (y < 1450 km)

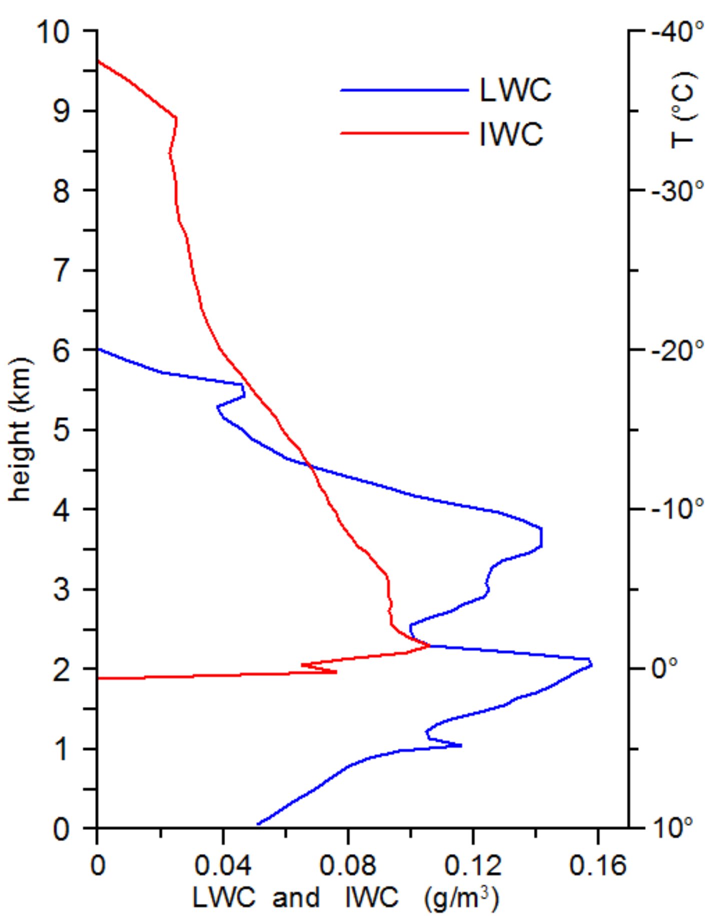
The change in the temperature structure of the cloud field is emphasized by the 0° level, which is at 1.2 km next to Iceland (y=1650 km) and at 2.4 km inside the warmsector

Comparison with RASTA (afternoon flight)

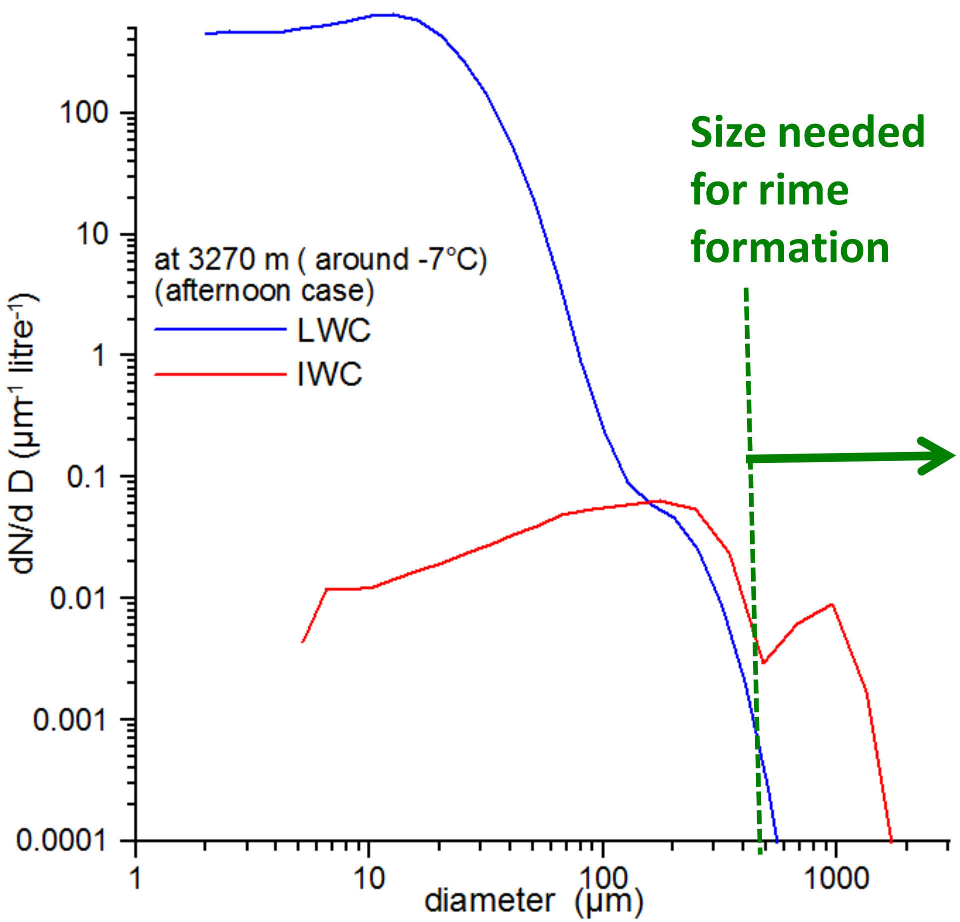




Resulting vertical profiles of LWC and IWC

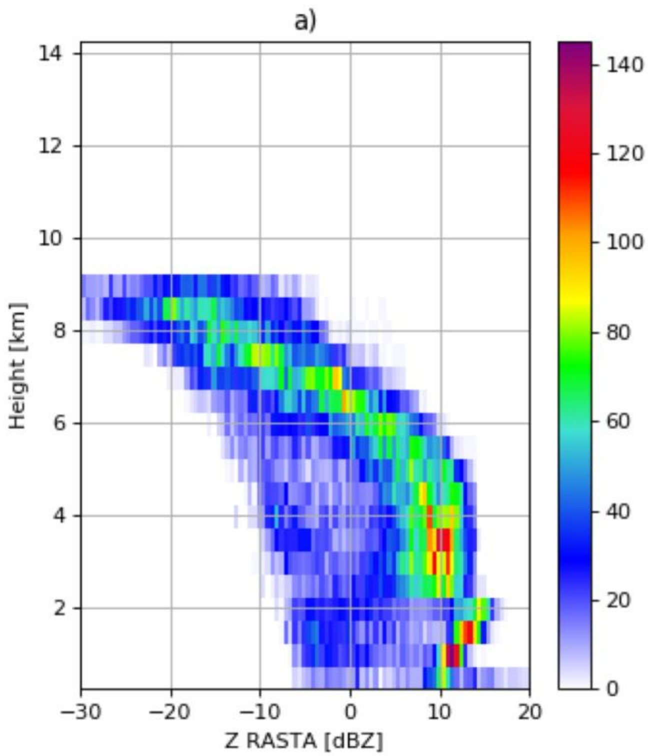


Simulated droplet and crystal spectra at 14:15

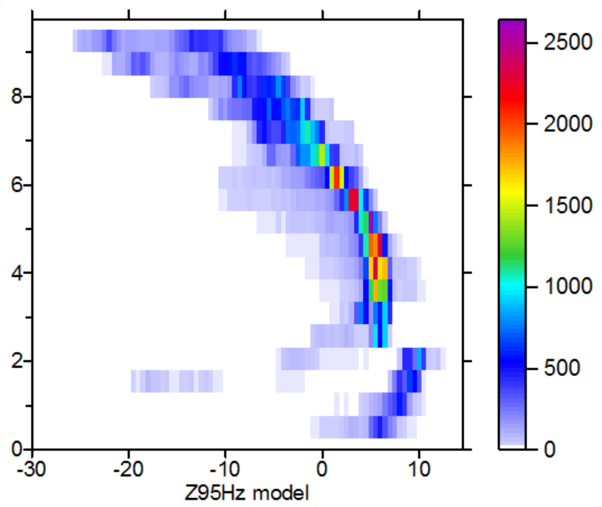


CFADS for Z95GHz

Delanoë et al. NAWDEX meeting (2019)



Calculated from the simulated particle spectra



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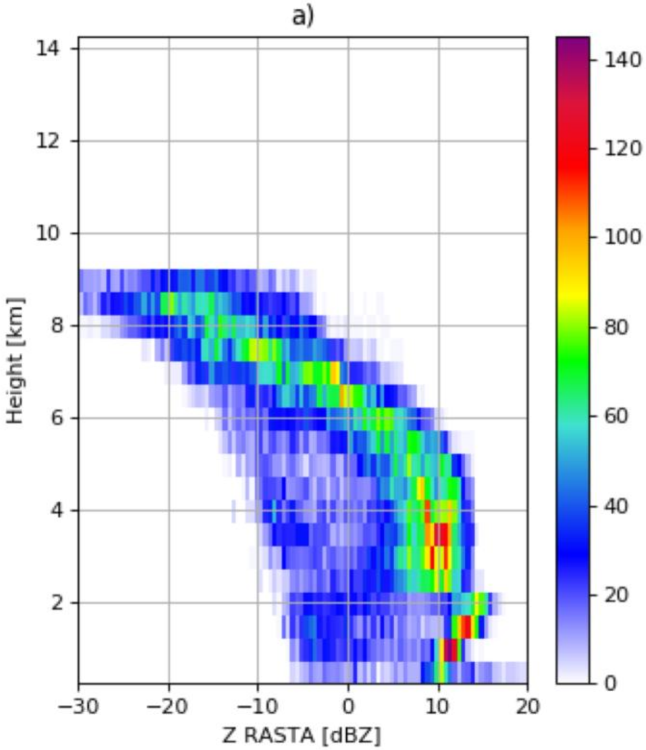

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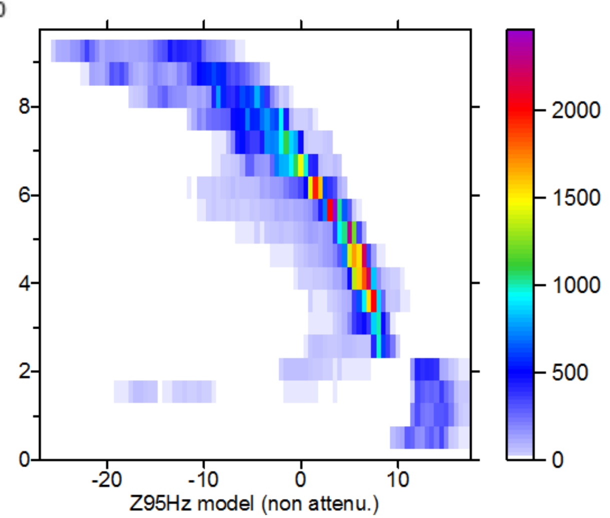


Conclusions:

still large uncertainties in the quantification of IWC and LWC in the layers from 0°C to -20°C

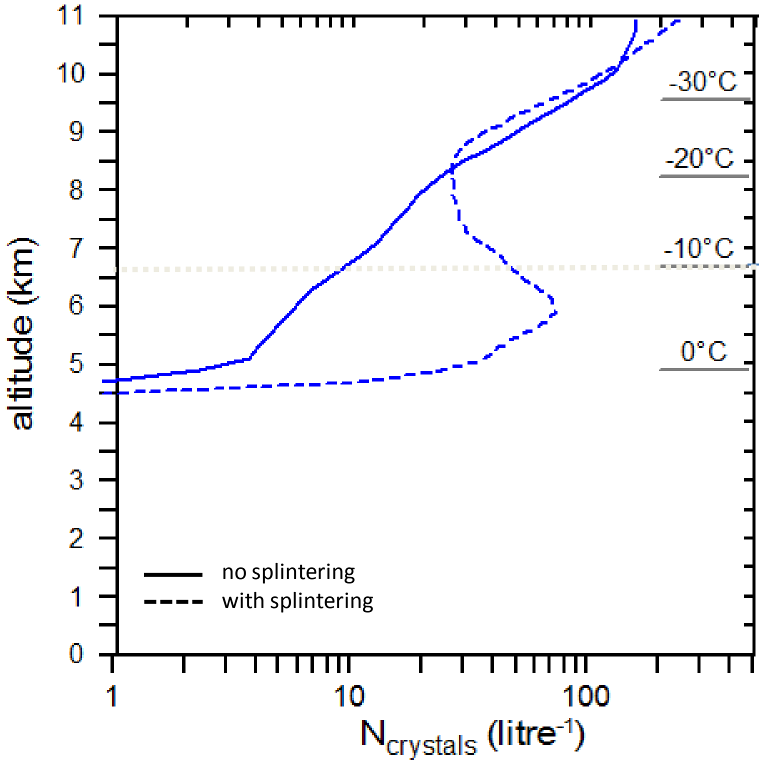
Splintering is quite ineffective when large drops and large crystals are not formed (compare to arctic clouds)

Modeled spectra need the comparison with in-situ observations

Next steps:

Running another case where in-situ observations are available (contacting the British group)

Adding further mechanisms for secondary ice multiplication (?)



altitude (km)
0
1
2
3
4
5
6
7
8
9
10
11
1
10
100
$N_{crystals}$ (litre^{-1})
-30°C
-20°C
-10°C
0°C
no splintering
with splintering