40th AMS Conference on Radar Meteorology, August 31, 2023
Session 12A: Use of Radar Data for Numerical Weather Prediction and Analysis

Investigating the Microphysics of a Simulated Convective Event Using EMVORADO (PFO)

Raquel Evaristo, Prabhakar Shrestha and Silke Trömel

University of Bonn

Jana Mendrok, Ulrich Blahak

DWD

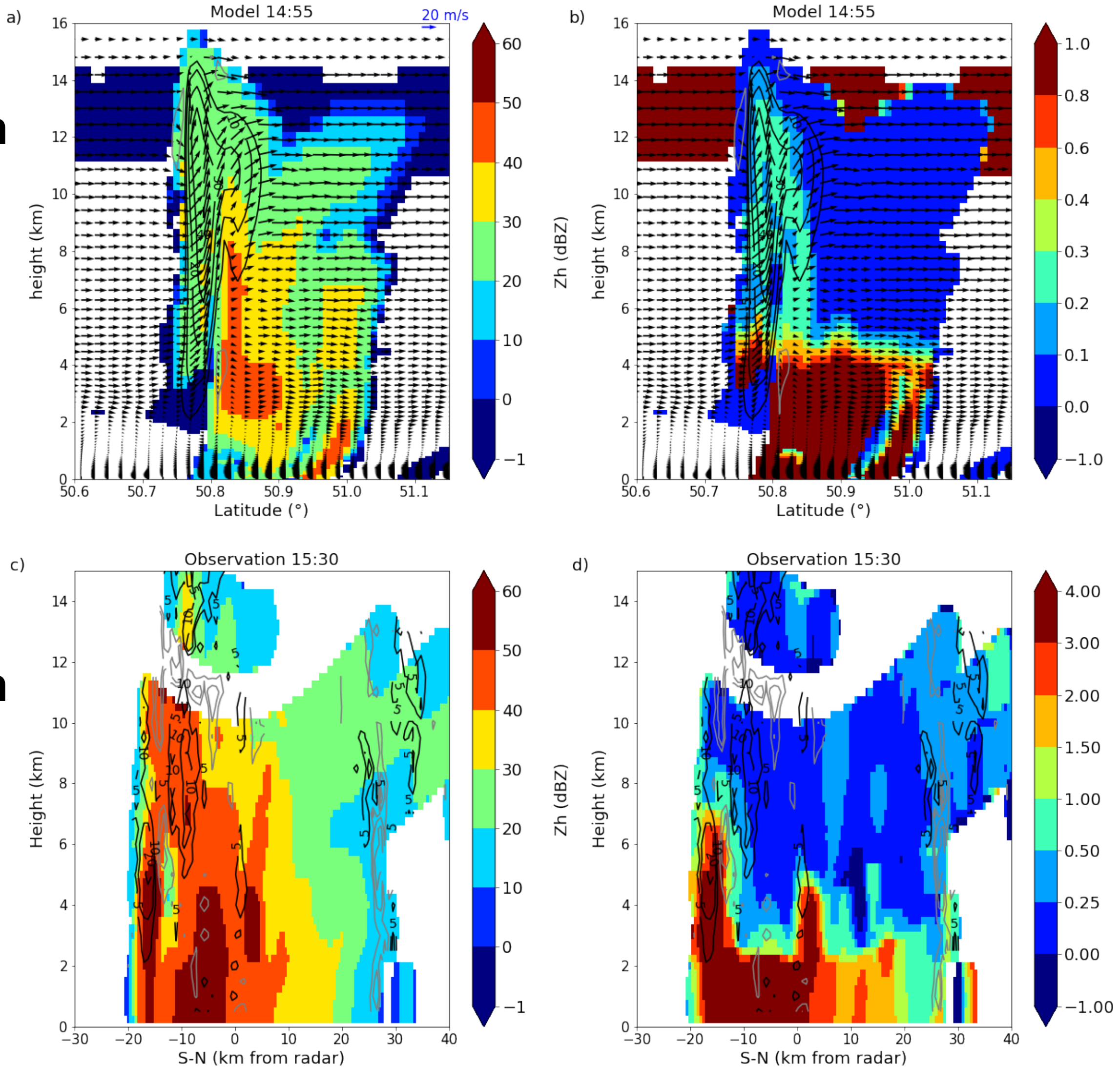
revarist@uni-bonn.de

Motivation

Simulation

Zh

Zdr



Observation

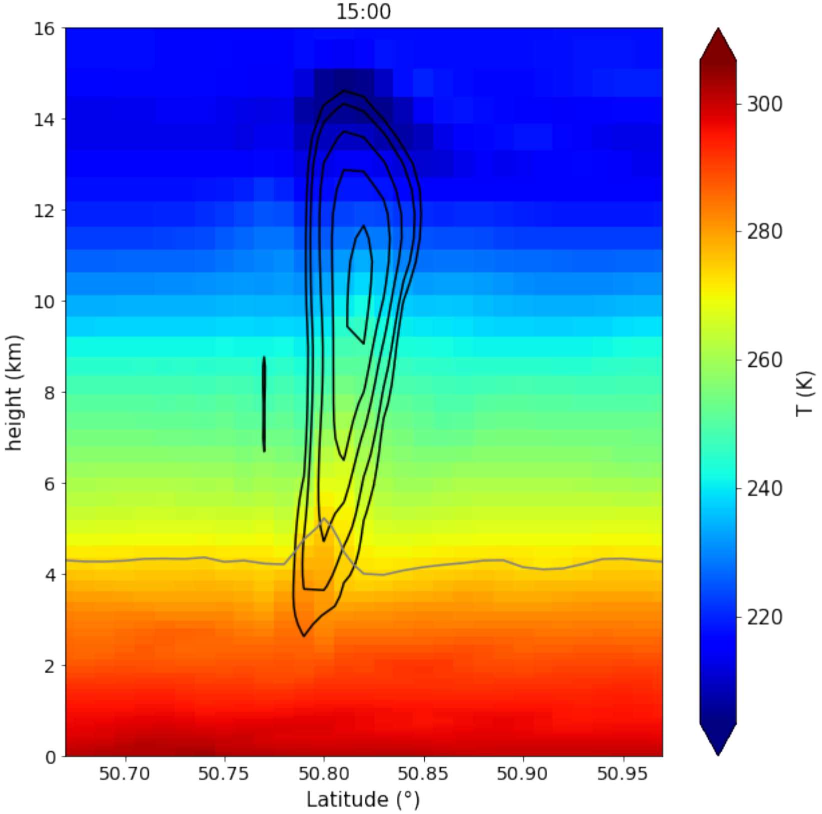
Zh

Zdr

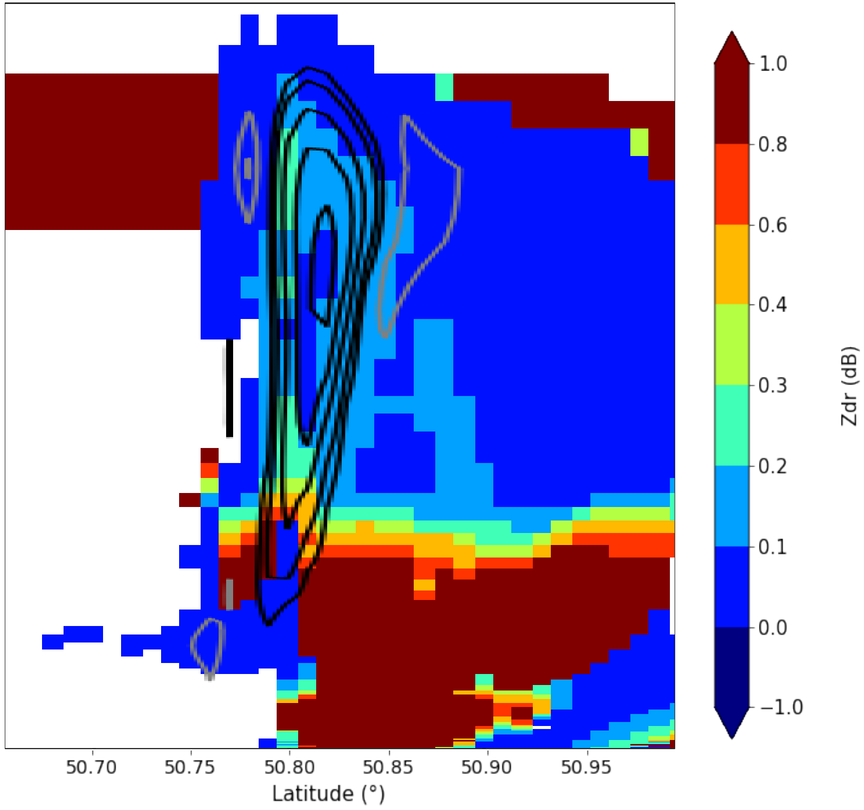
- Zdr columns are present but with significantly lower intensity
- Simulated updrafts were consistently stronger than the observed

Motivation

Temperature



Zdr



Values of Zdr ranging from 0.1 to 0.6 dB near the updraft

Contours updraft: 5, 10, 20, 30, 40 m/s

Objective

- Investigation the reason for low values of Zdr in the simulated Zdr column
- Why are Zdr columns not well represented?
    - Model
    - Forward Operator

Simulations and Forward Operator

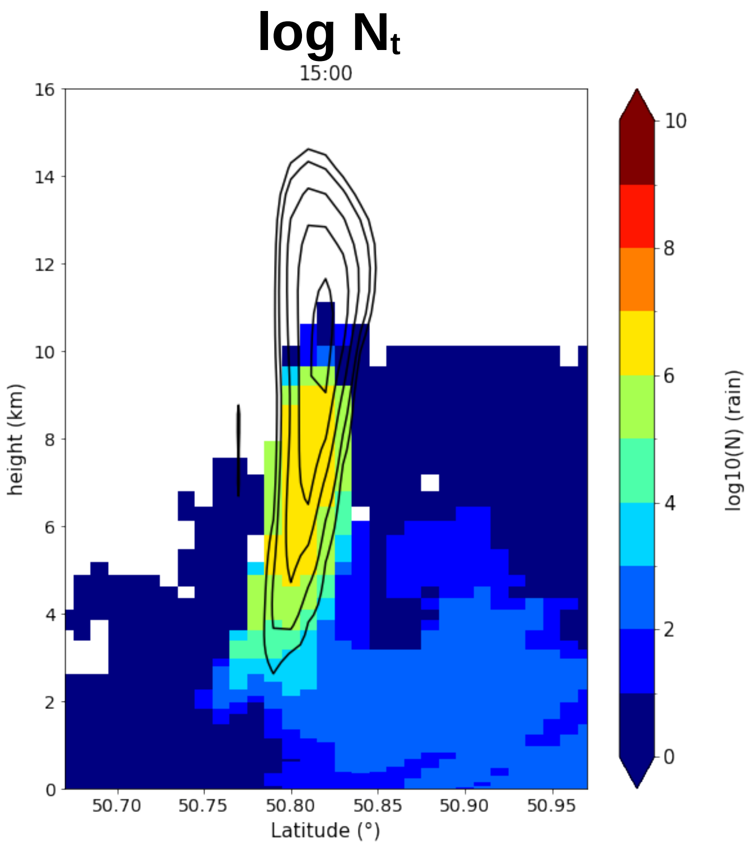
- A coupled model for the soil–vegetation–atmosphere
- The atmospheric component consists of the operational German weather forecast model COSMO (Consortium for Small-scale Modeling)
- two-moment bulk microphysics scheme (Seifert and Beheng, 2006)
- predicts the mass densities (q_x) and number densities (N_x)
- cloud droplets, rain, cloud ice, snow, graupel and hail particles
- PSD follows a modified Gamma distribution

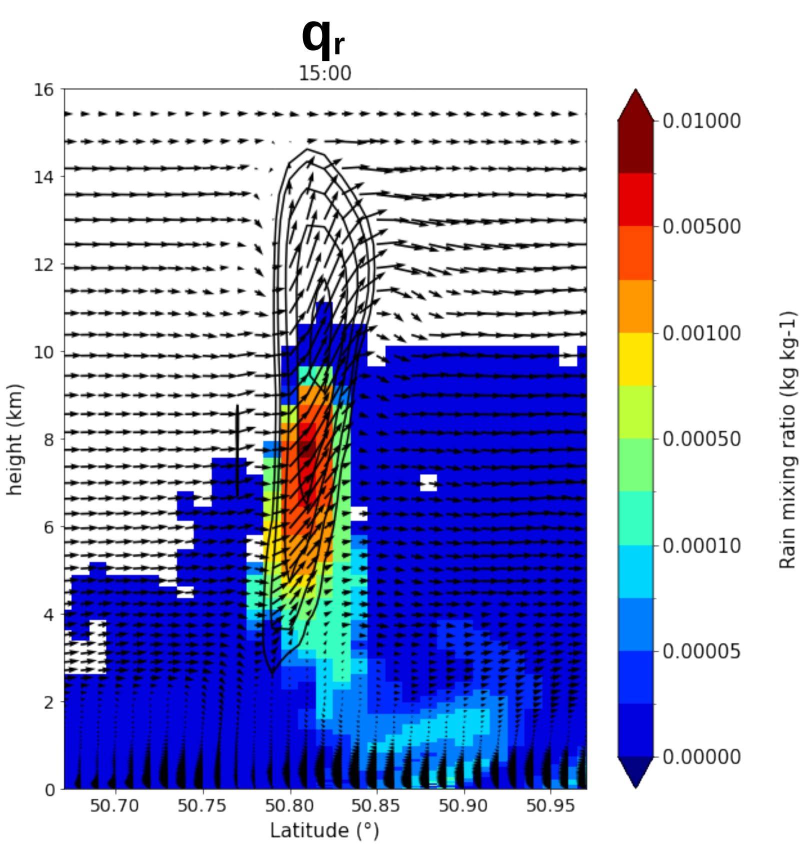
$$N(D) = N_0\, D^{\nu} \exp(-\lambda\, D^{\mu})$$

- Polarimetric extension of EMVORADO (Zeng et al., 2016)
- simulates the polarimetric radar variables at specified weather radar wavelengths (X-band – 3.2 cm)
- the hydrometeors are interpreted as homogeneous oblate spheroids in a T-matrix computation

For details see Shrestha *et al.* 2022
Atmos. Chem. Phys., 22, 7593–7618, 2022
https://doi.org/10.5194/acp-22-7593-2022

Simulated rain



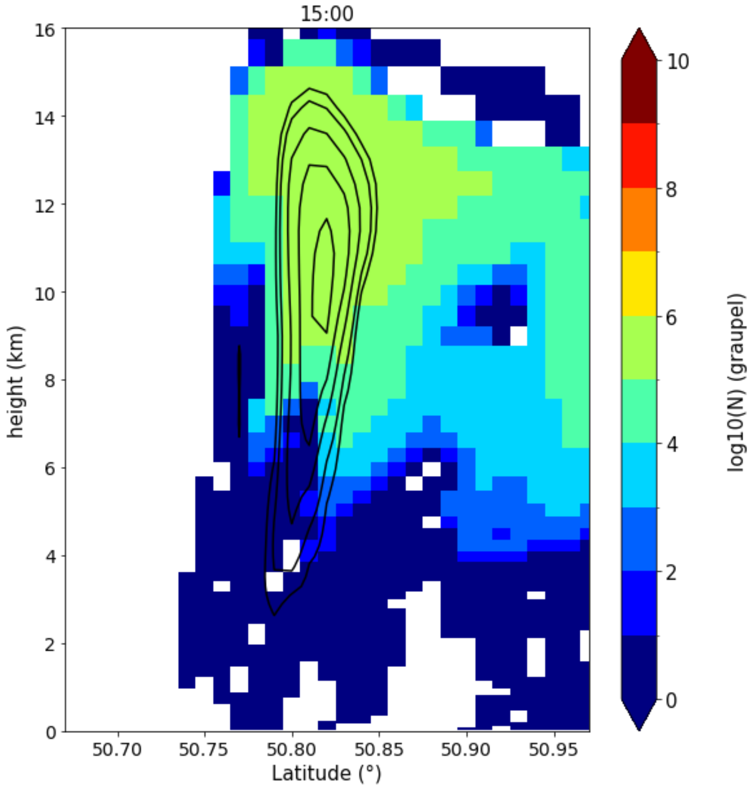


- Simulation of a hail producing convective storm
- Cross section through the convective core
- Well defined updraft (up to 40 m/s)
- High concentration of rain drops within the updraft
- High values of rain mixing ratio (up to 7.5 g/kg)
- Values of water content comparable to Zdr columns simulated with a spectral bin model (Kumjian *et al.* 2014, Ilotoviz *et al.* 2018)

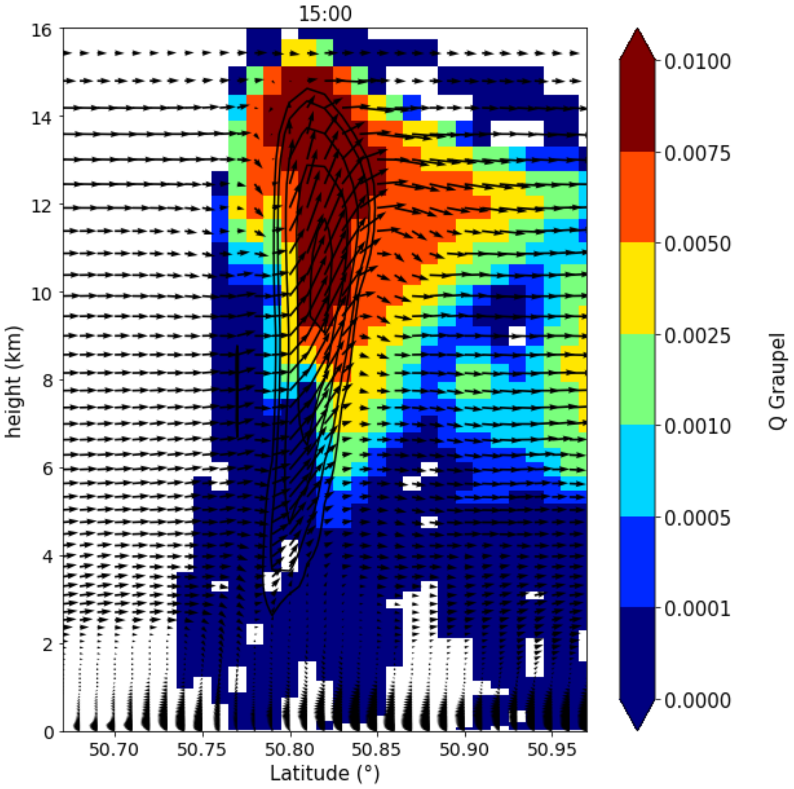
Contours updraft: 5, 10, 20, 30, 40 m/s

Simulated graupel

log N_t



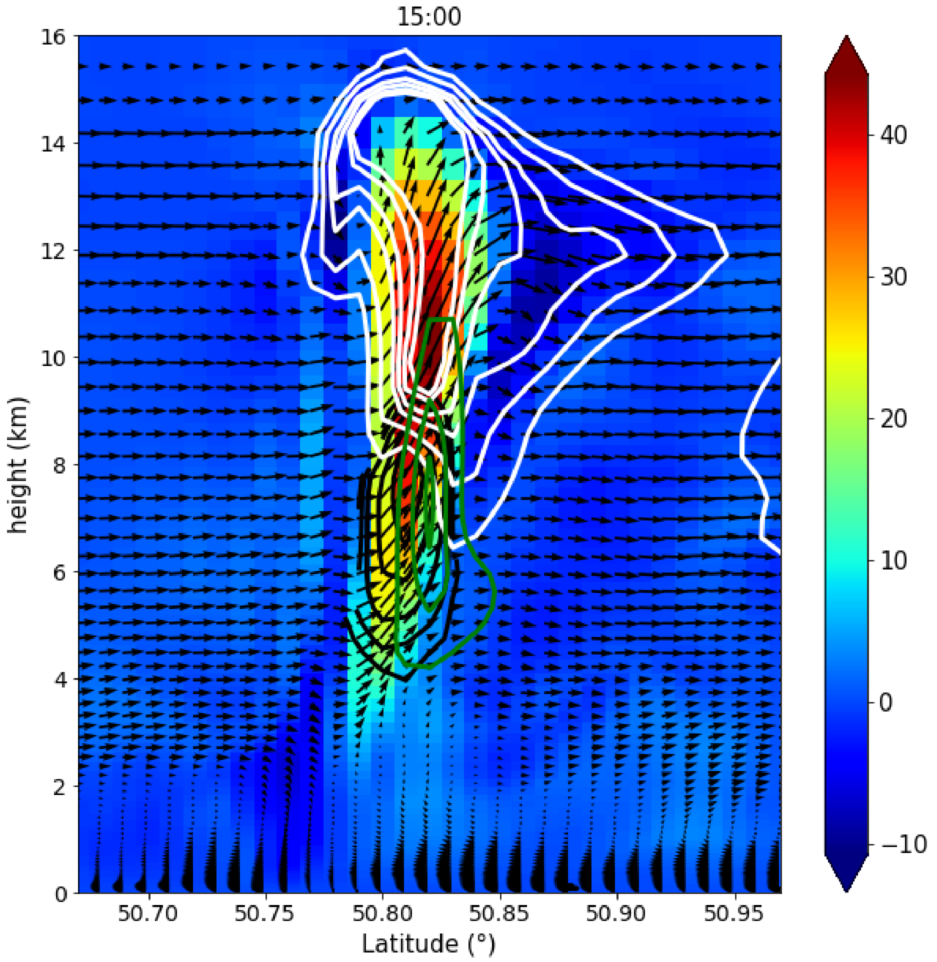
q_g



- Graupel number and mass increase within the updraft towards the top
- Maximum values of Nt and q_g towards the top, where rain mass decreases

Contours updraft: 5, 10, 20, 30, 40 m/s

Simulated q_r, q_g, q_h



Rain
Contours: 0.25, 0.5, 1, 2, 3 g/kg

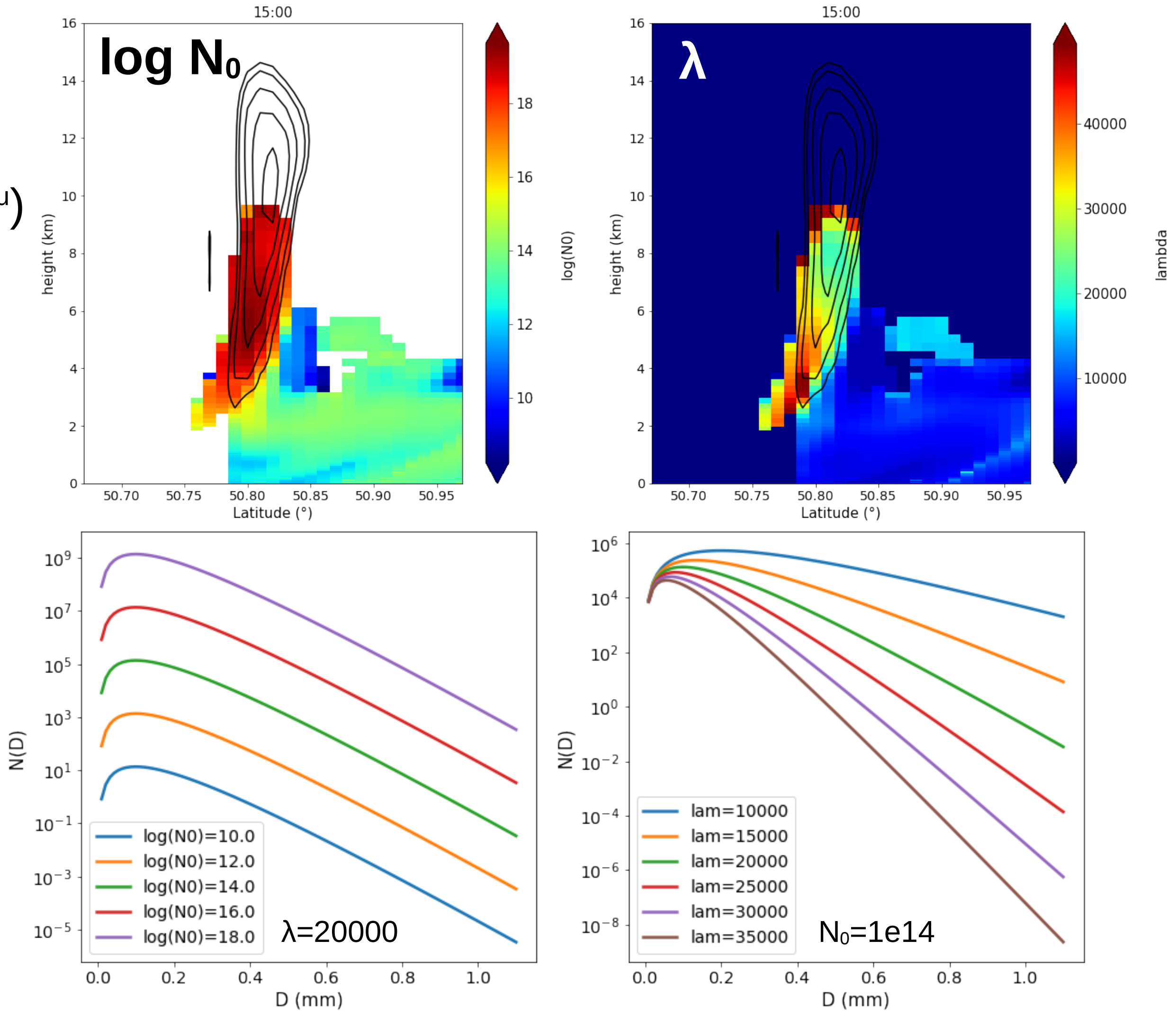
graupel
Contours: 2, 4, 6, 7, 8, 8.5 g/kg

Hail
Contours: 0.1, 0.2, 0.3, 0.4, 0.5 g/kg

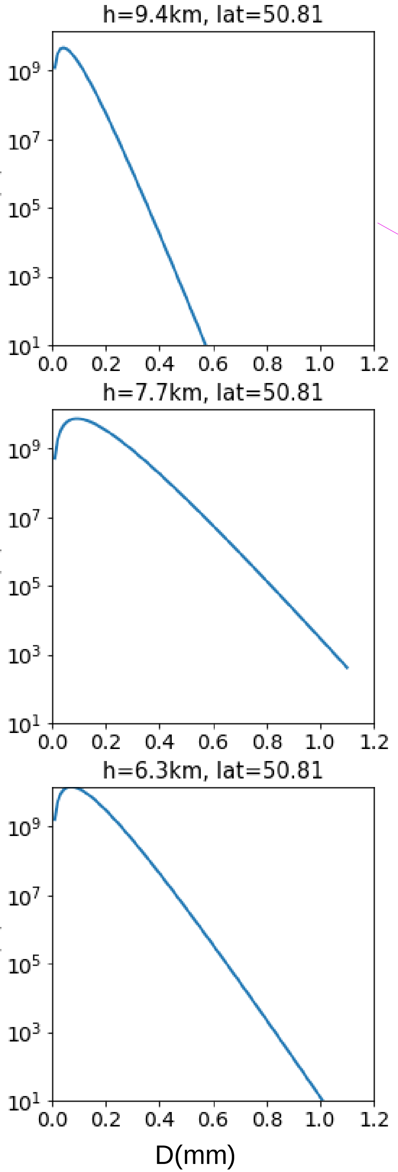
Parameters of the PSD for rain: N_0, λ

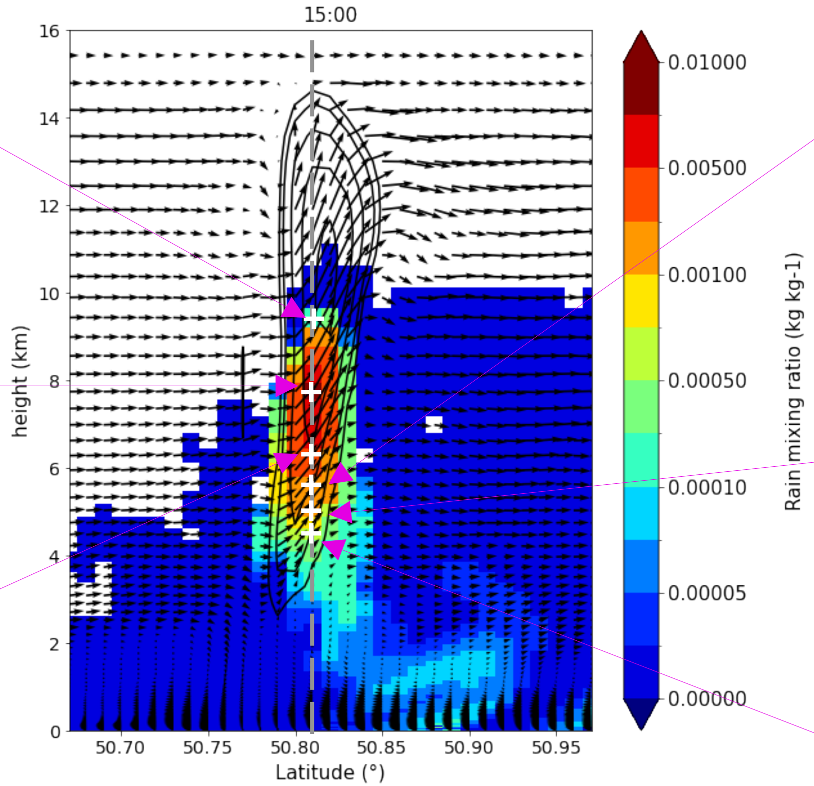
$N(D) = N_0\, D^{\nu}\ \exp(-\lambda\, D^{\mu})$

μ, ν: Constant for each hydrometeor type

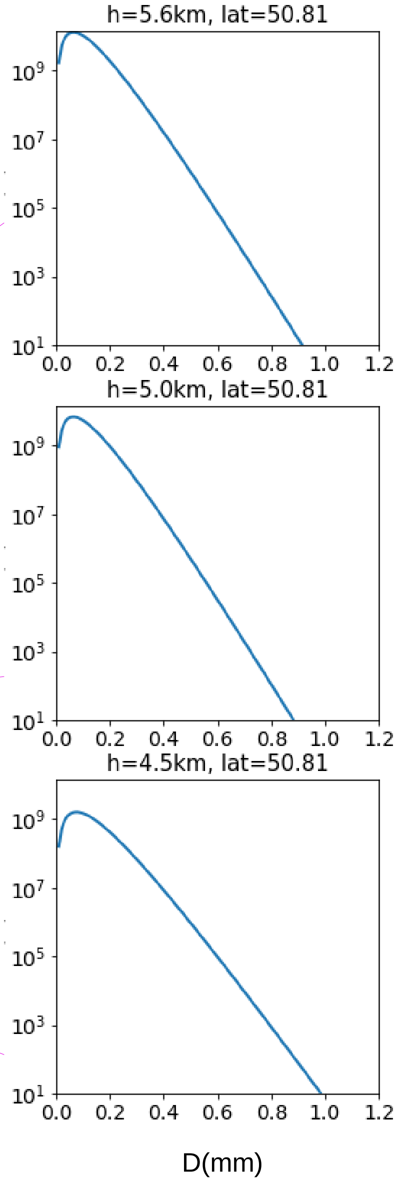


DSD within the updraft

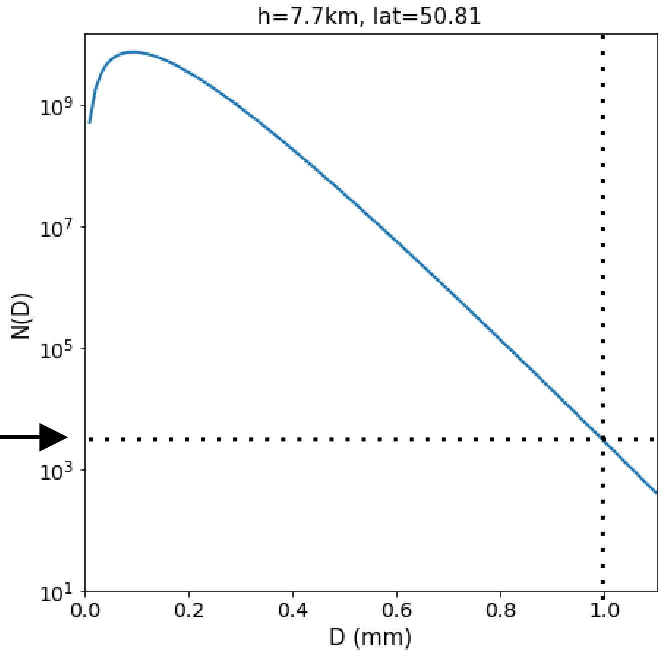




W contours: 5, 10, 20, 30, 40 m/s

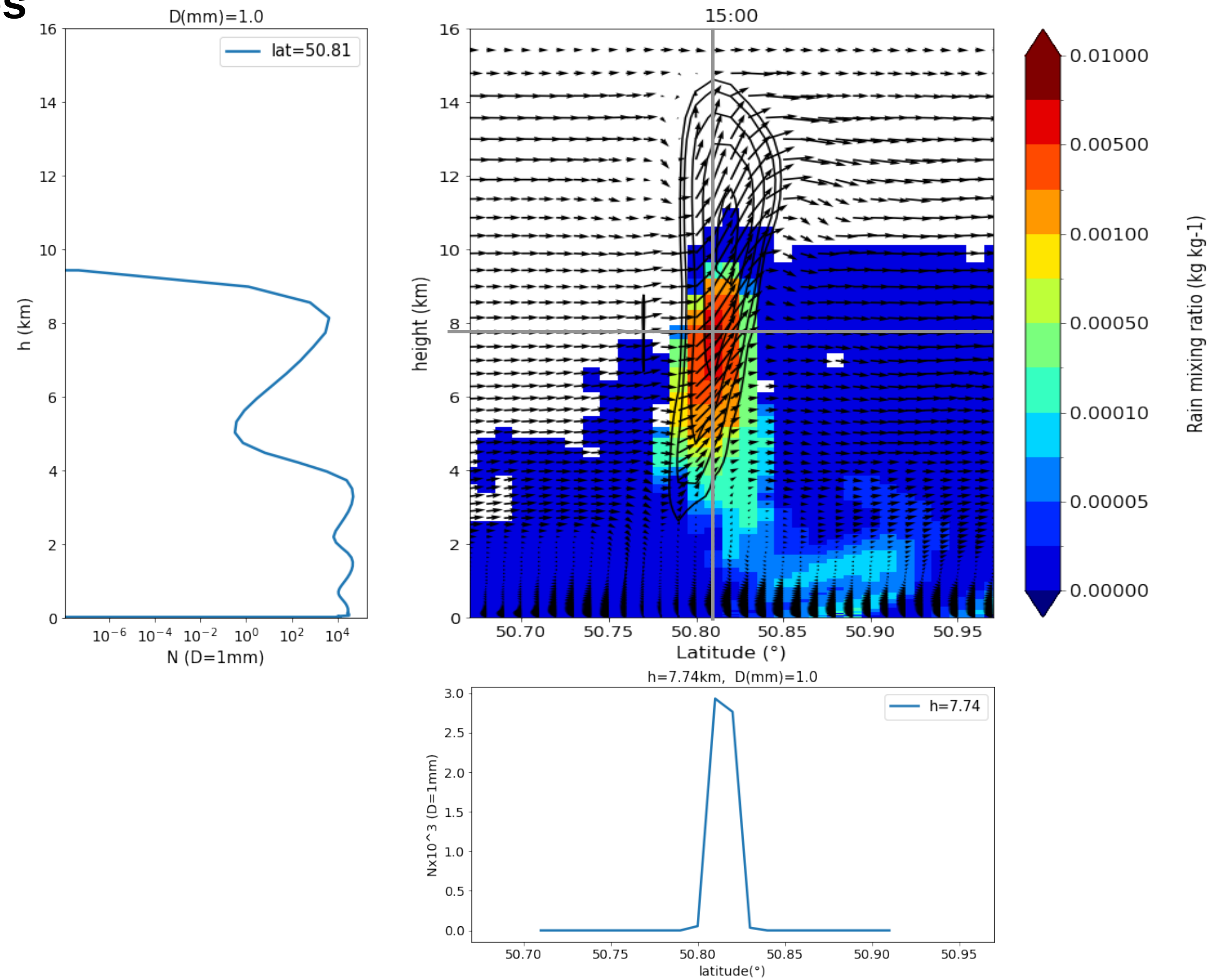


Number of large particles

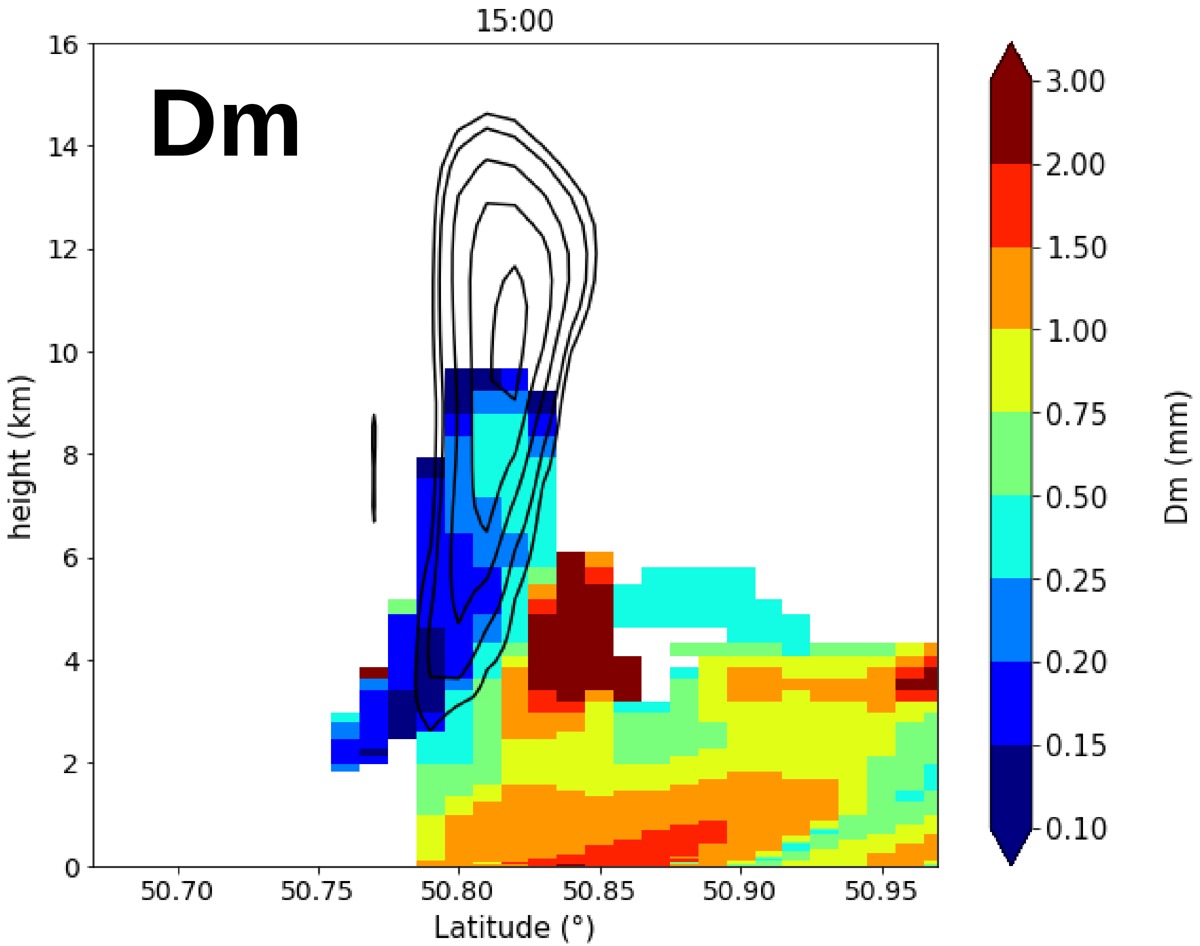


N at D=1mm

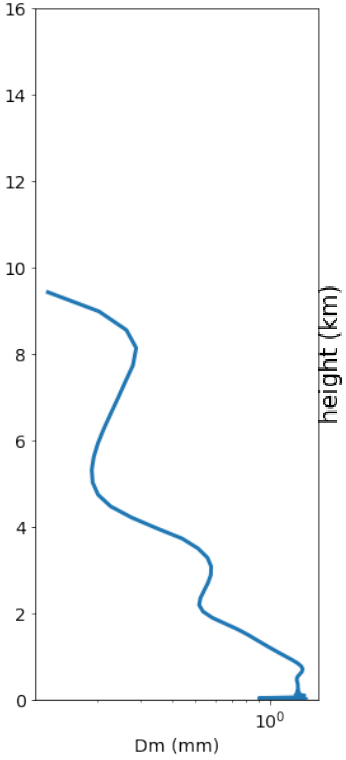
Number of large particles

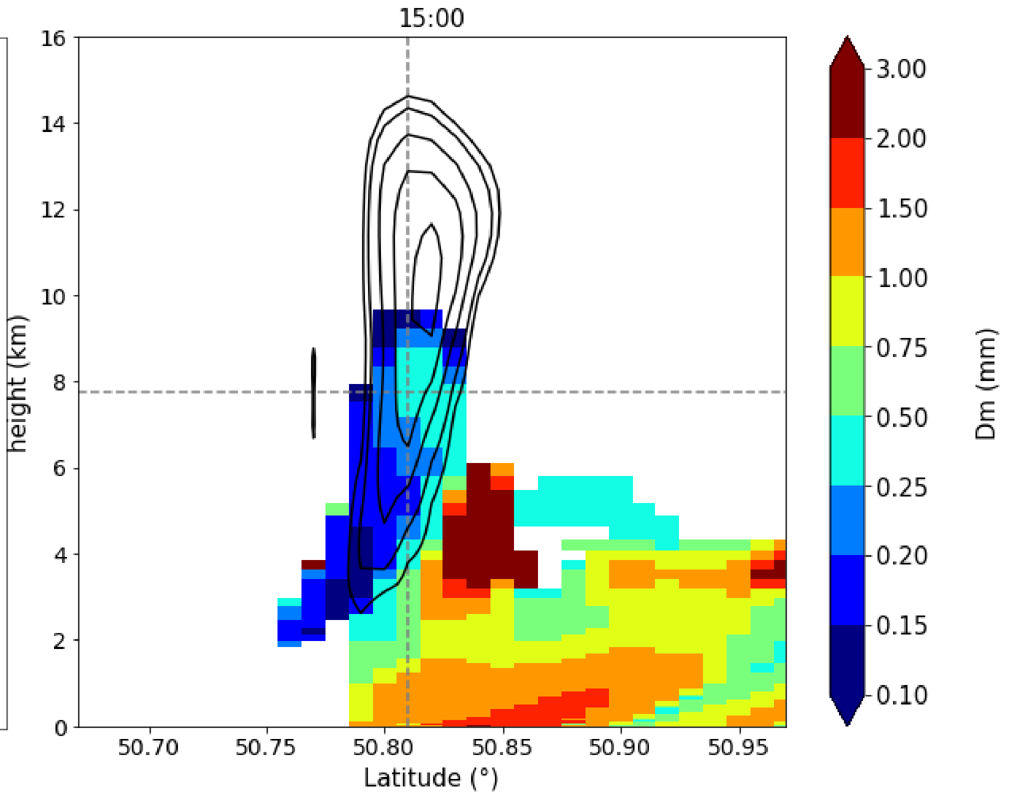


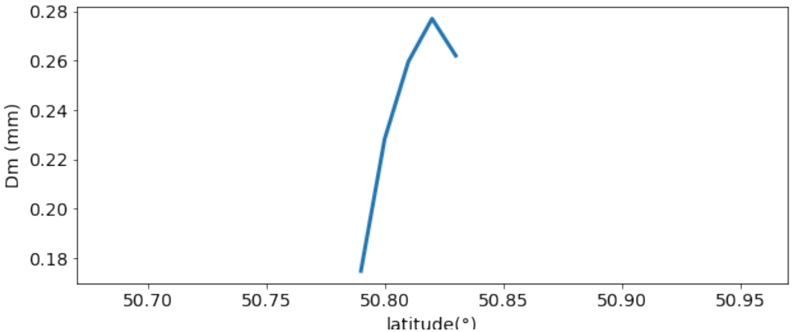
Mean volume diameter rain Dm



Mean volume diameter rain Dm

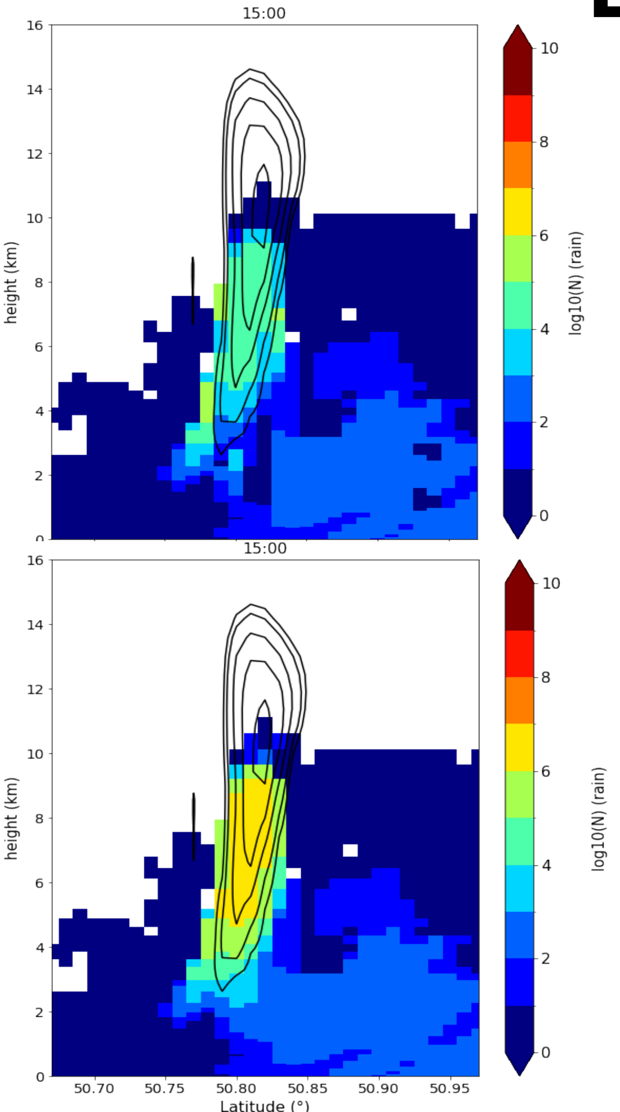




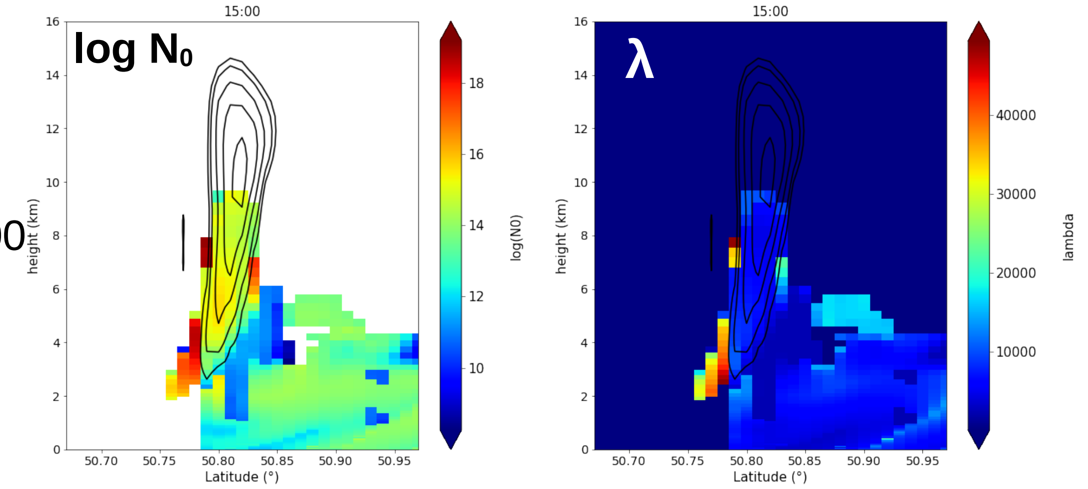


Max Dm~0.28mm

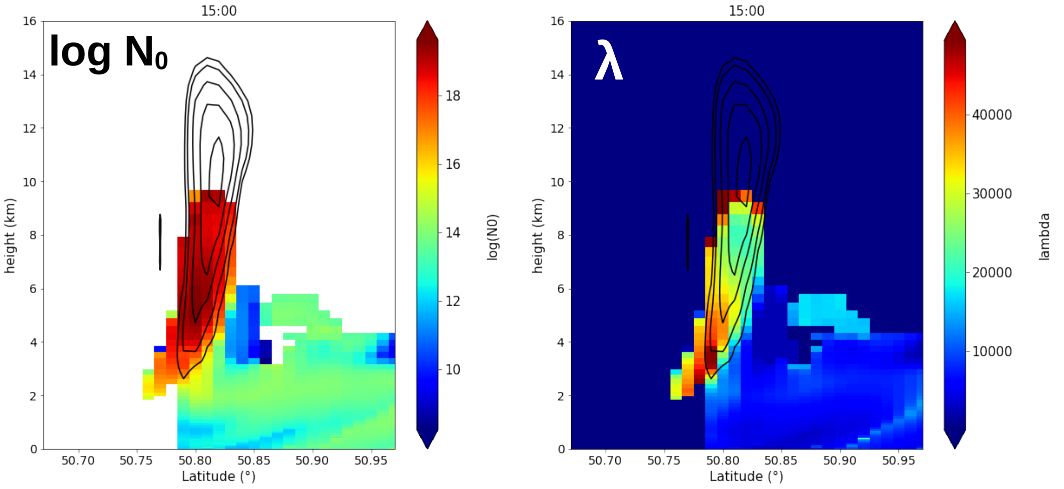
Decreased rain Nt



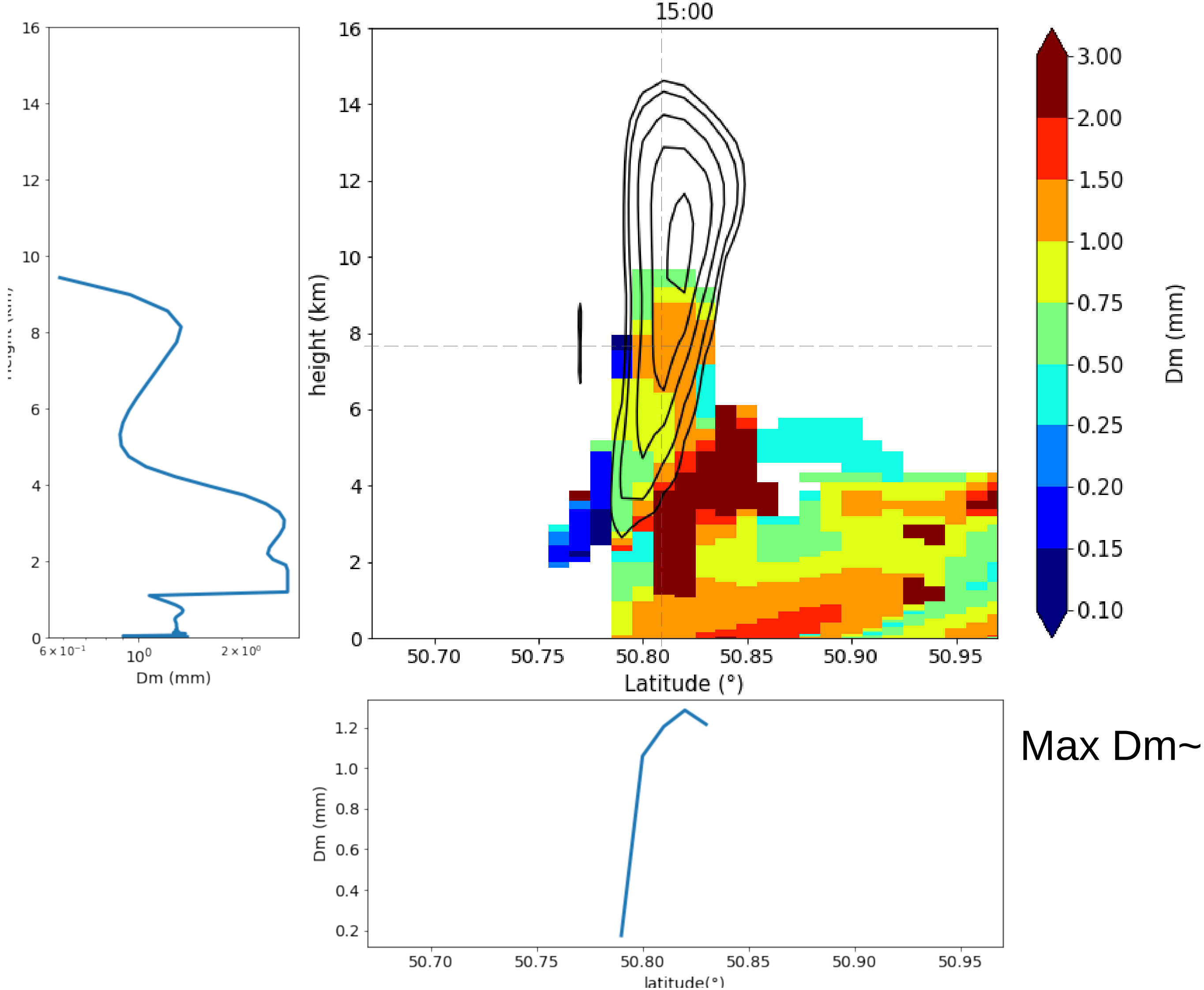
Nt (rain) /100



original



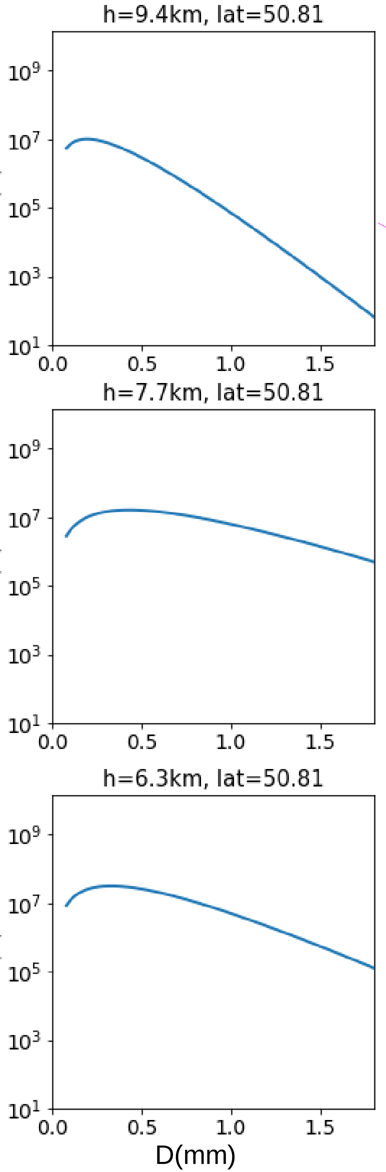
Mean volume diameter rain Dm

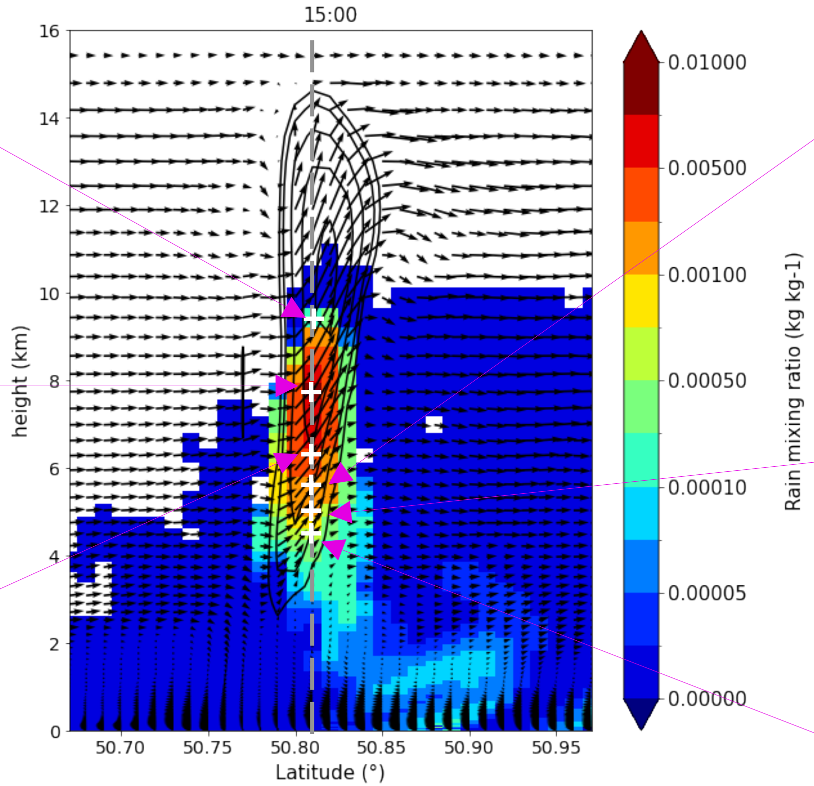


Max Dm~1.3 mm

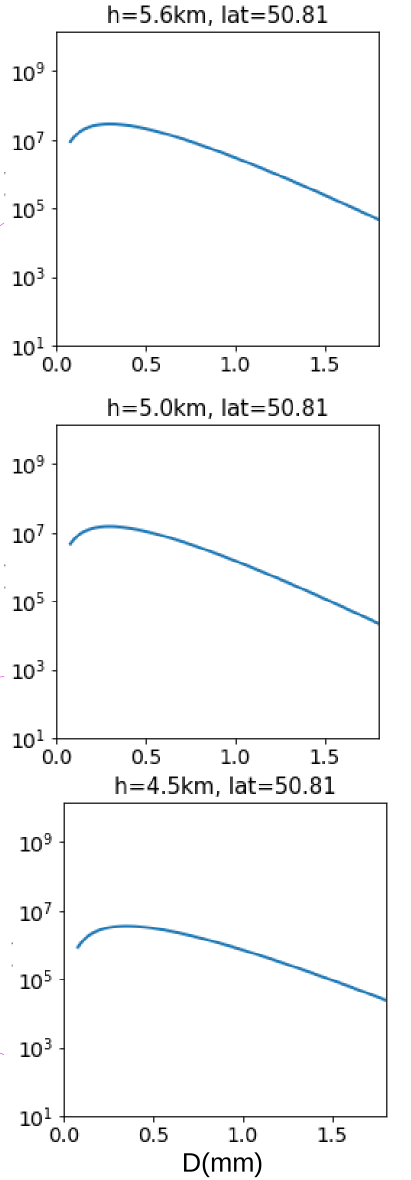
DSD within the updraft

With Nt (rain) /100



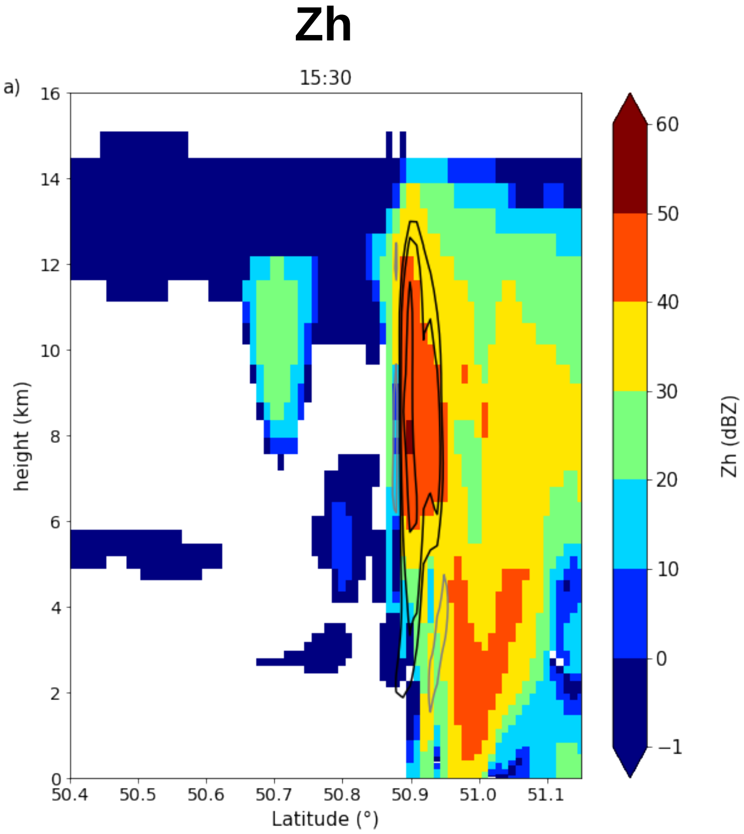


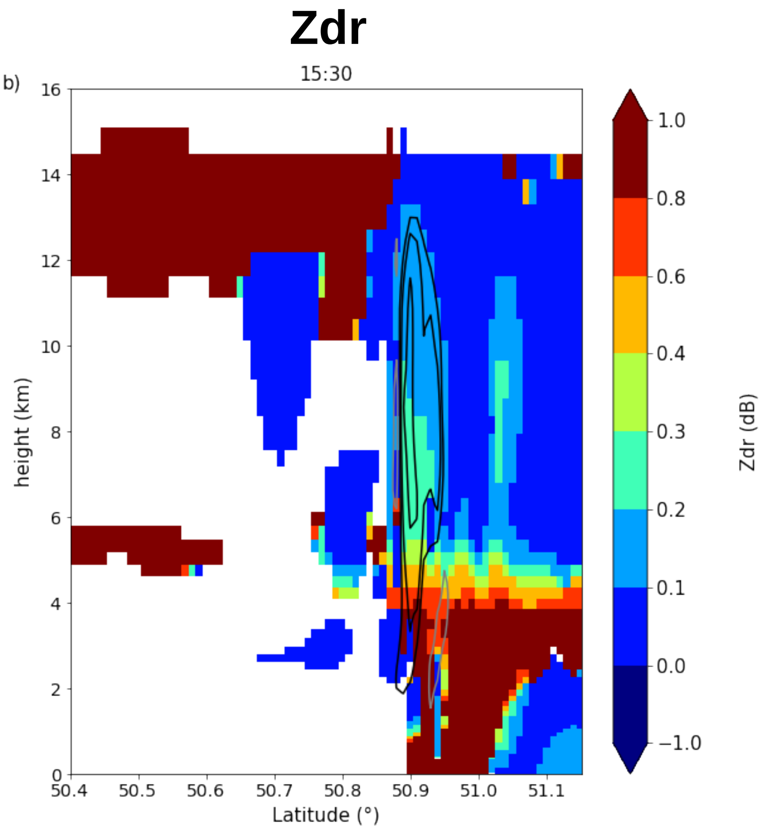
W contours: 5, 10, 20, 30, 40 m/s



30 minutes later: 1530UTC

Simulation

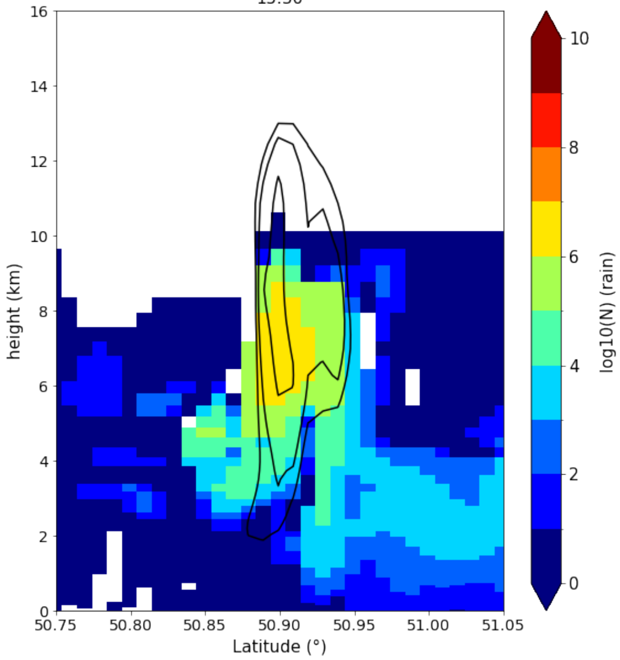




Values of Zdr ranging from 0.1 to 0.4 dB

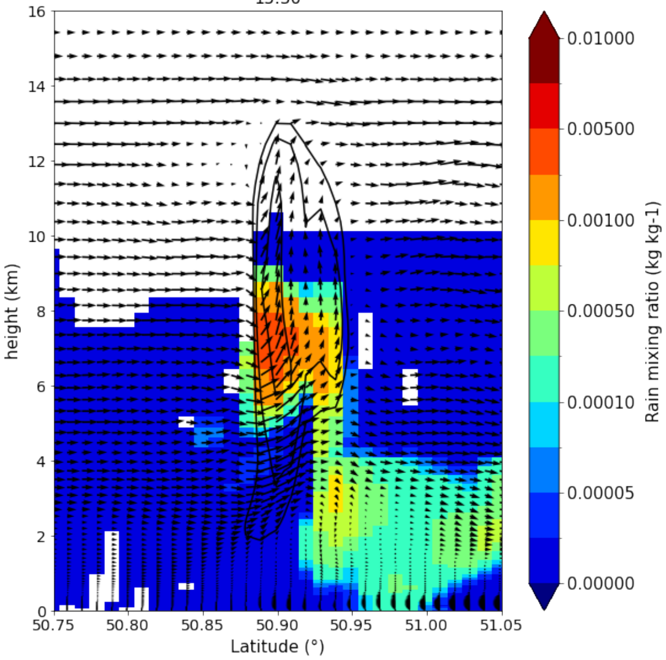
30 minutes later: 1530UTC

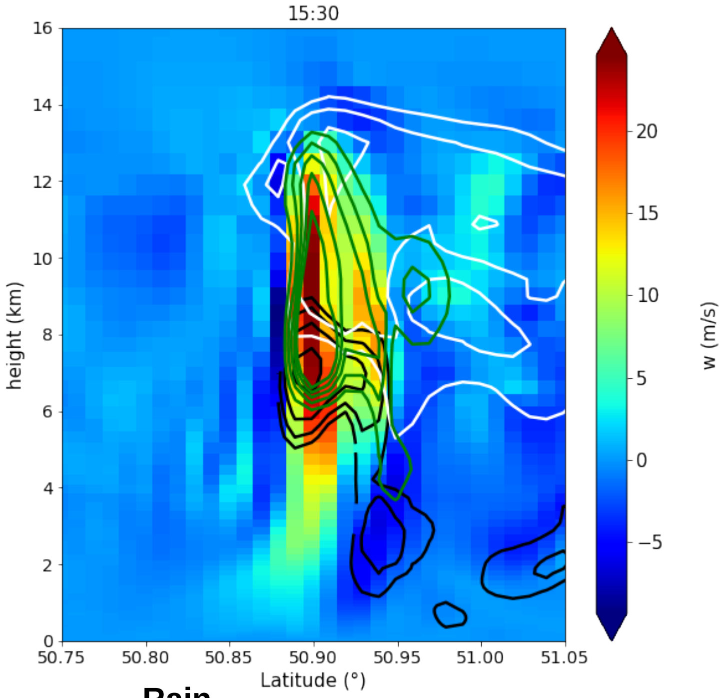
log N_t



Contours updraft: 5, 10, 20, 30, 40 m/s

q_r





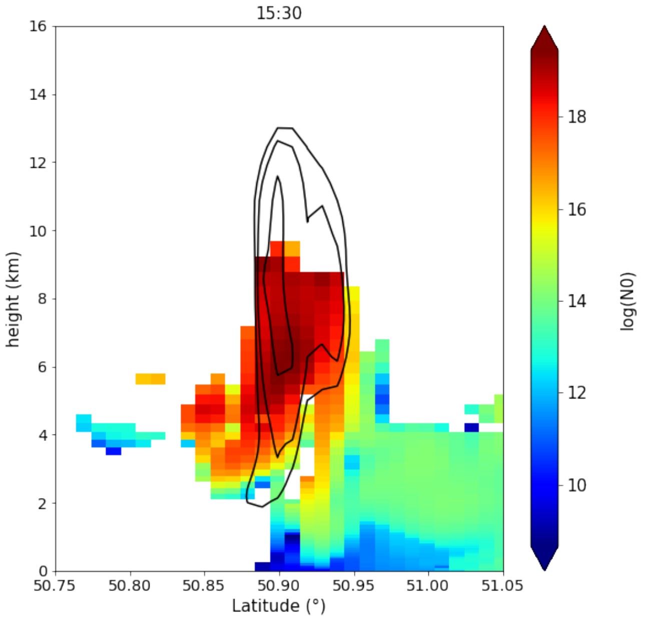
Rain
Contours: 0.25, 0.5, 1, 2, 3 g/kg

graupel
Contours: 2, 4, 6, 7, 8, 8.5 g/kg

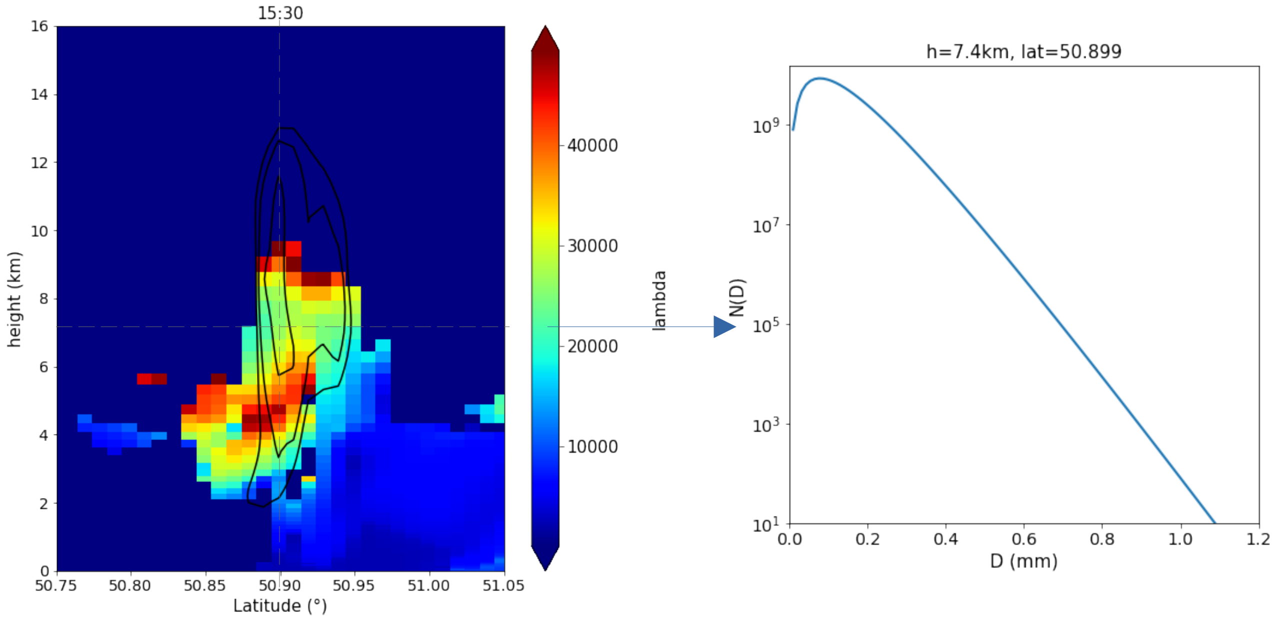
Hail
Contours: 0.5, 0.75, 1., 1.25, 1.5 g/kg

30 minutes later: 1530UTC

log N_0



λ



Conclusion

- The intensity of Zdr column is severely underestimated in the simulated event, this was verified in 2 other events
- Updraft intensity is stronger than the updrafts retrieved from DualDoppler analysis and seems reasonable for the specific event
- There is a maxima of qr within the updraft with high values (> 7.5 g/kg)
- The assumed DSD shows a large number of small drops and a reduced number of larger drops - Dm values are too low, maximum of ~0.28mm
- Reducing Nt for rain in the convective core results in a decrease in λ, a DSD shift to larger drop sizes and larger Dm.
- Sensitivity study in Shrestha *et al.* 2022 using a narrower cloud droplet size distribution in the model (changing the fixed parameters μ and ν) achieved some improvements in Dm (0.5-1mm) and Zdr intensity in the convective core.

Shrestha, P., Mendrok, J., Brunner,D:, 2022: Aerosol characteristics and polarimetric signatures for a deep convective storm over the northwestern part of Europe – modeling and observations. Atmos. Chem. Phys., 22, 14095–14117. https://doi.org/10.5194/acp-22-14095-2022