Selected specifics of double-moment microphysics

David Němec (CHMI, Prague)

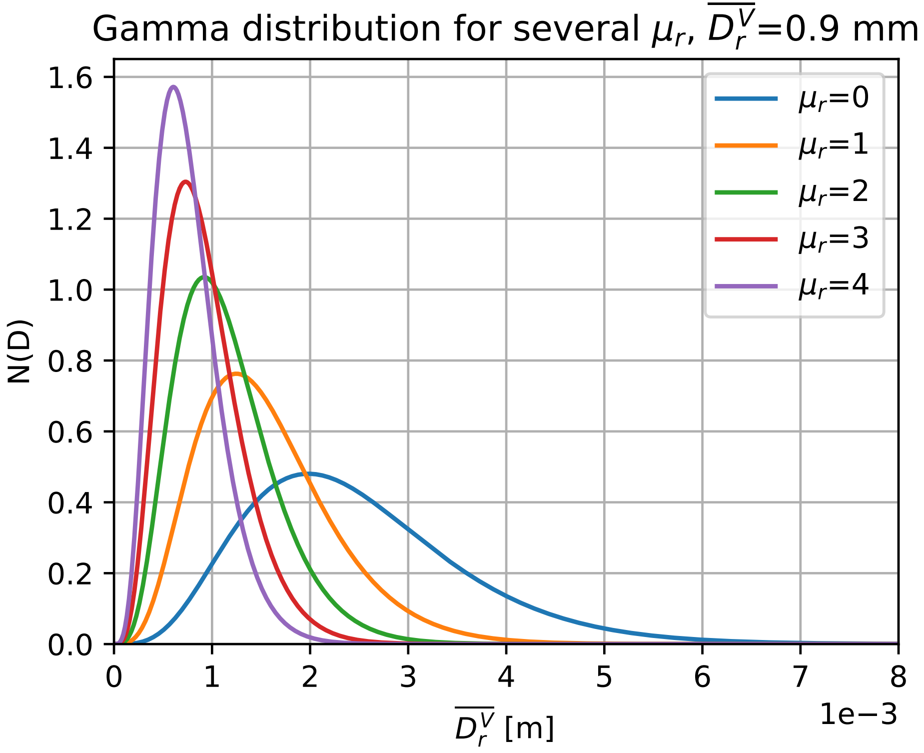
Czech Hydrometeorological Institute

Outline

- generalities and current status
- parameterization of cloud water
- rain sedimentation: the problem of excessive size-sorting
- rain self-collection and breakup: spike
- the choice of interpolator for rain
- ice phase: the devil in disguise

Towards 2-mom scheme in ALARO: generalities

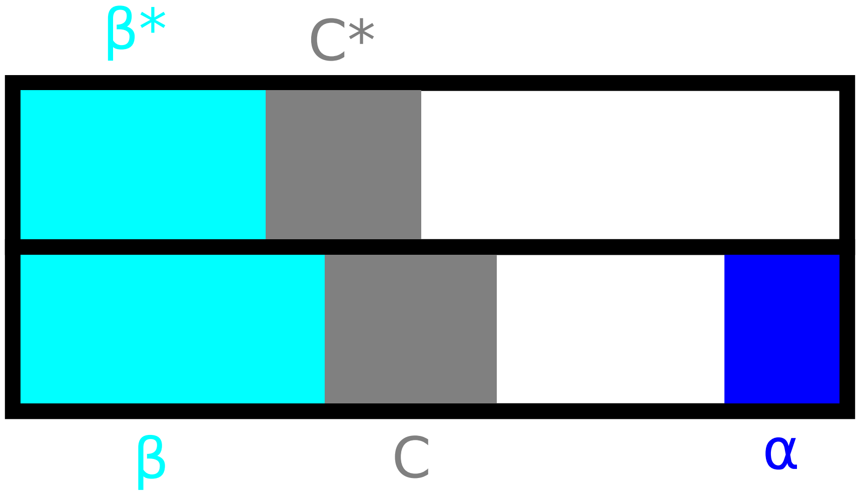
- 5 hydrometeors
- gamma size distributions
- 2-mom hydrometeors have 2 GFL fields: for q and N



Towards 2-mom scheme in ALARO: current status

- liquid phase ready for testing
- very beginning of ice phase
- cloud and preciptiation overlap/geometry
  - equal $\overline{D_r^V}$ in all four areas:

$$N_j = \frac{q_j}{q} N \tag{1}$$



Processes

- activation
- autoconversion
- collection
- self-collection + break-up
- evaporation + melting

Definition of a hydrometeor

mass: $$m(D) = aD^b \tag{2}$$

fall-speed: $$w(D) = cD^d \left(\frac{\rho_0}{\rho_a}\right)^f \tag{3}$$

size-distribution: $$n(D) = N\rho_a \frac{\lambda^{\mu+1}}{\Gamma(\mu+1)} D^\mu e^{-\lambda D} \; [m^{-4}] \tag{4}$$

slope parameter: $$\lambda(q, N, \mu, a, b) = \left[\frac{Na\Gamma(\mu+1+b)}{q\Gamma(\mu+1)}\right]^{\frac{1}{b}} \tag{5}$$

Parameterization of cloud water: Activation

- from CCN to droplet number concentration (N_l)
- based on Feingold and Heimsfield (1992)
- number of activated CCN based on T, w, and CCN concentration
- important for autoconversion
- loss N_l: self-collection
- N_l can(not) be diagnostical

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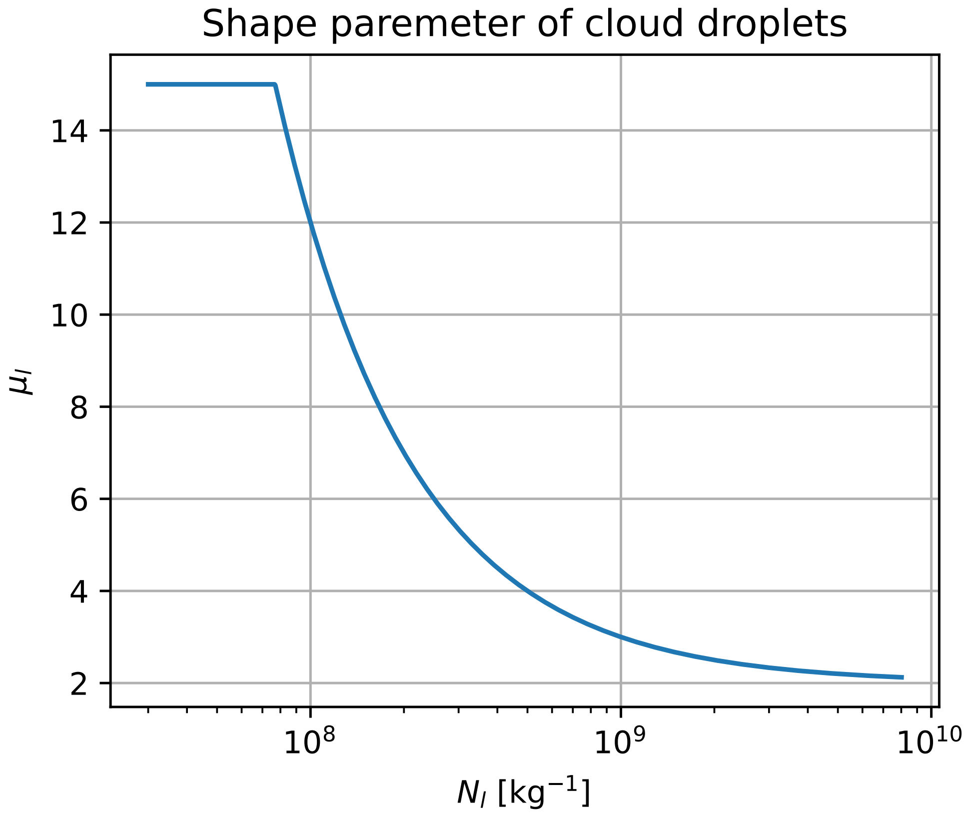
Shape parameter of cloud water

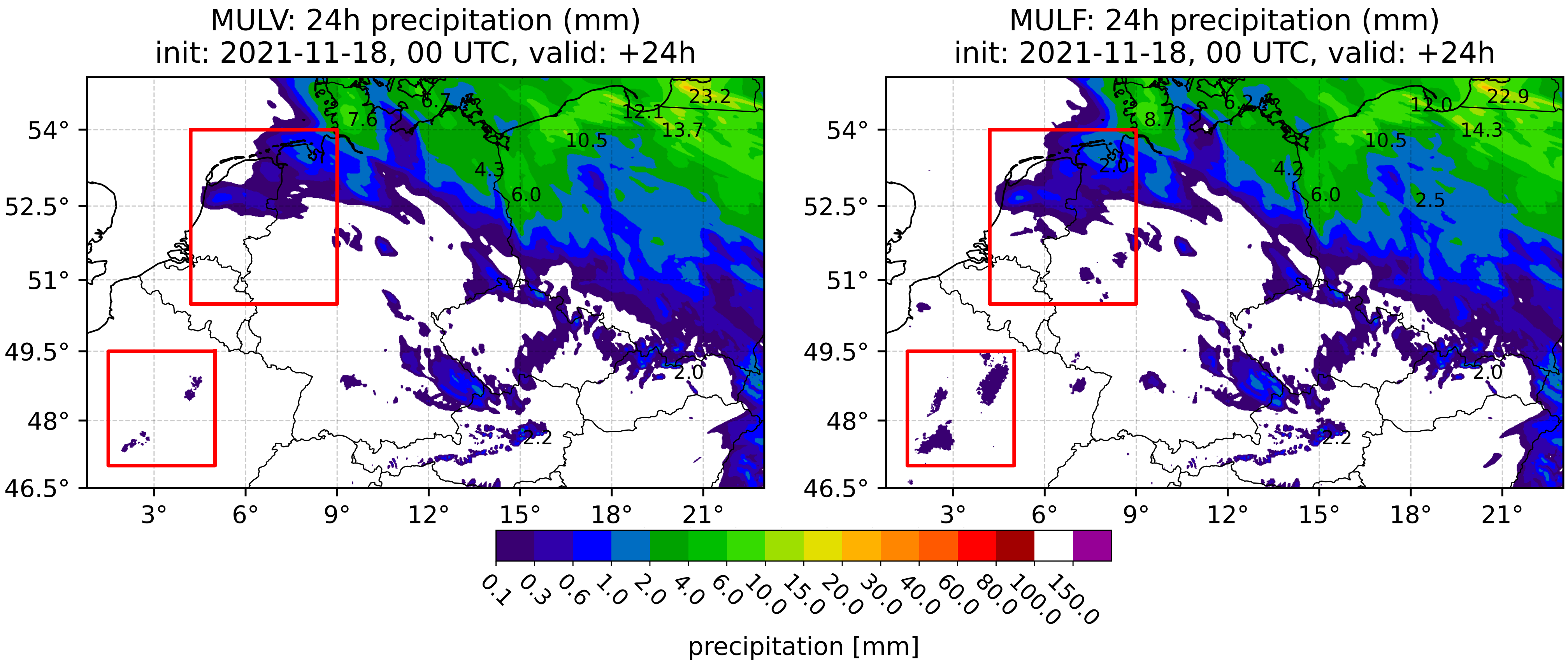
- as in the Thompson scheme (`MULV`):

$$\mu_l = \min\left(15, 2 + \frac{10^9}{N_l \rho_a}\right)$$

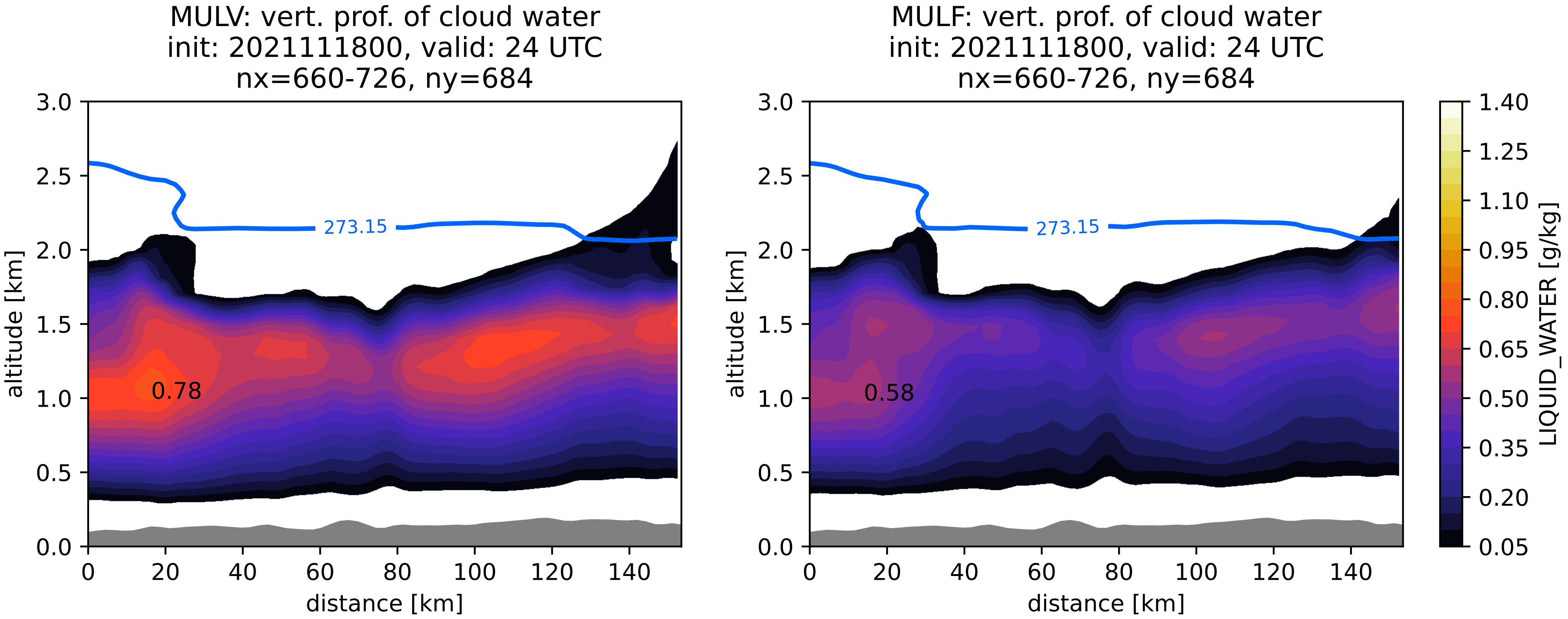
- fixed with $\mu_l = 2$ (`MULF`)



Less weak precipitation with variable μ_l



Higher liquid water content with variable μ_l



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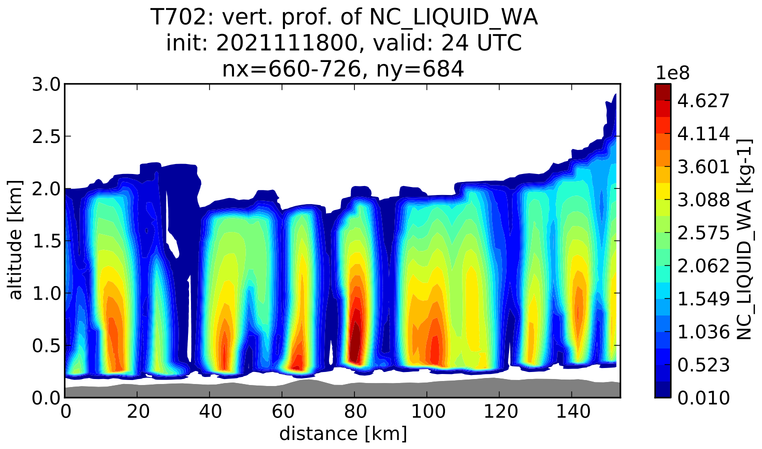
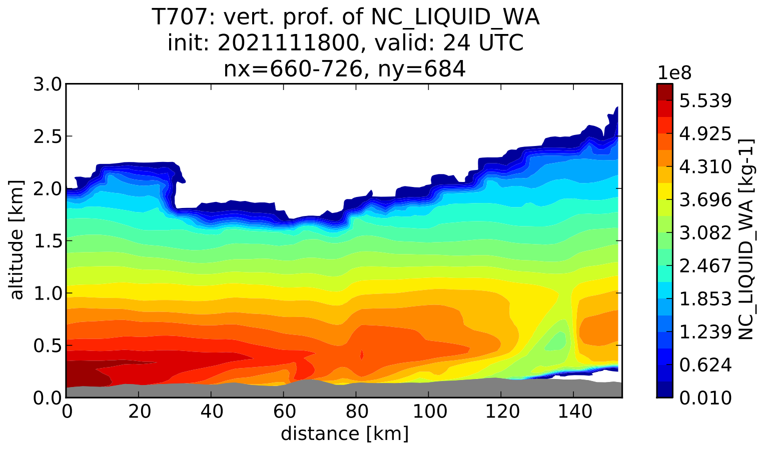
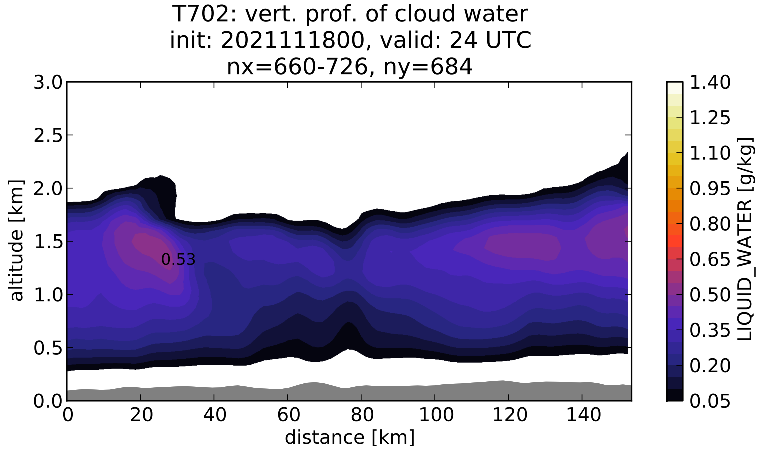
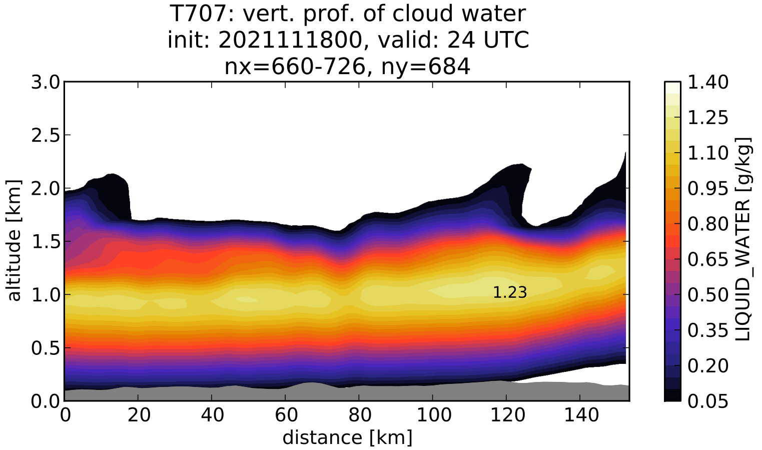
What if N_l is not prognostical (left)?









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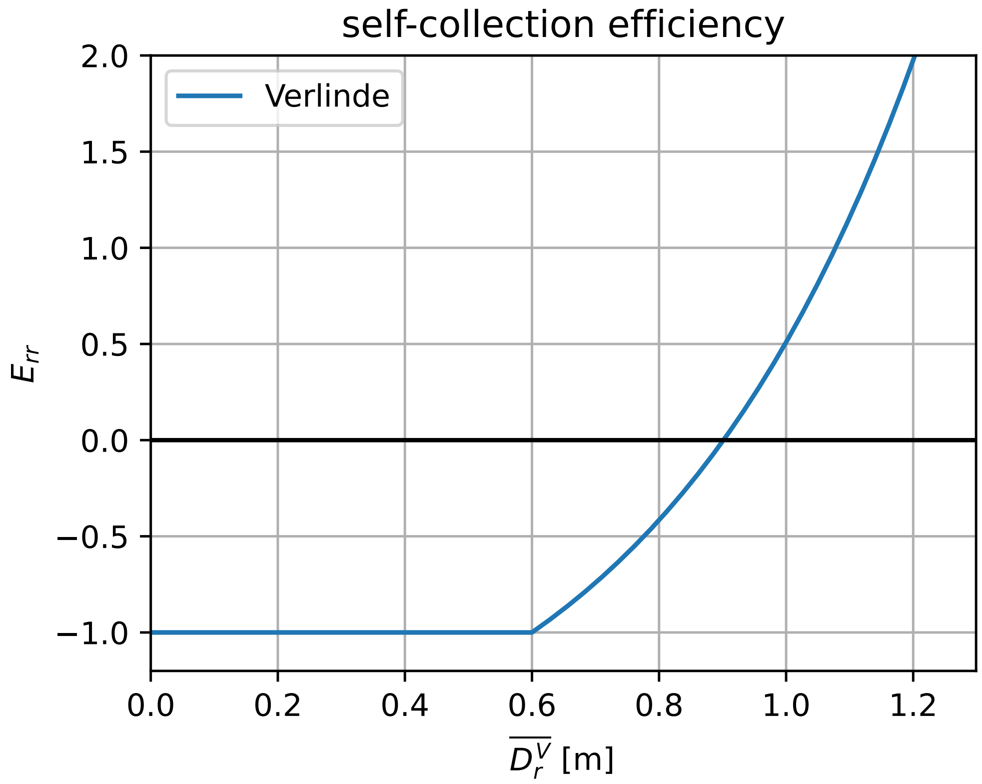
Self-collection and breakup of raindrops

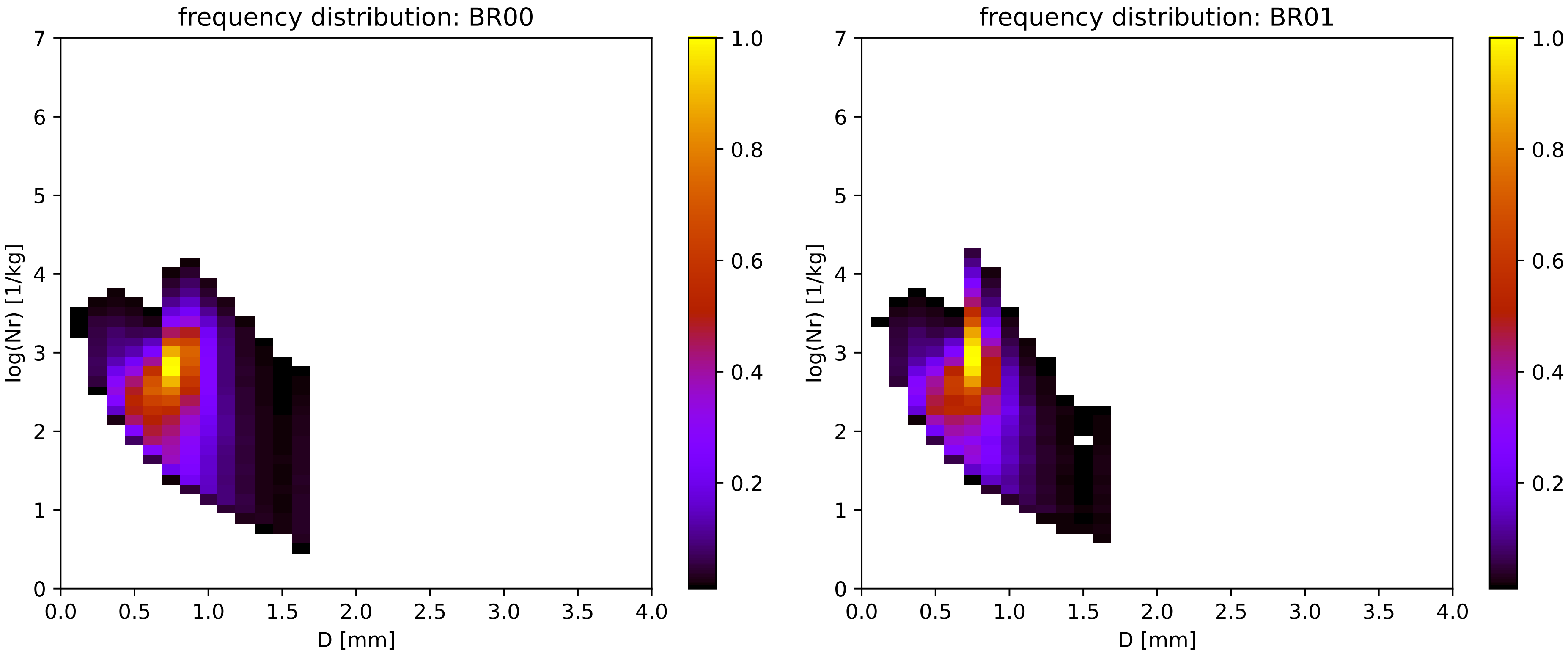
- change N_r, not q_r
- formula: Beheng (1994):

$$\left(\frac{dN_r}{dt}\right)_{sc} = 8E_{rr}N_r q_r \rho_a$$

- efficiency: Verlinde (1992)



Frequency distribution of sizes and the “spike”



Size sorting

- number-weighted and mass-weighted fall speeds:

$$w_N = \frac{\int\limits_0^\infty w(D)n(D)dD}{\int\limits_0^\infty n(D)dD}, \qquad w_m = \frac{\int\limits_0^\infty w(D)n(D)m(D)dD}{\int\limits_0^\infty n(D)m(D)dD} \tag{6}$$

- their ratio:

$$\frac{w_m}{w_N} = \frac{\Gamma(\mu+1)}{\Gamma(\mu+1+d)} \frac{\Gamma(\mu+1+b+d)}{\Gamma(\mu+1+b)} \overset{\text{b=3}}{=} \frac{\sum\limits_{i=1}^{3}(\mu+i+d)}{\sum\limits_{i=1}^{3}(\mu+i)} \tag{7}$$

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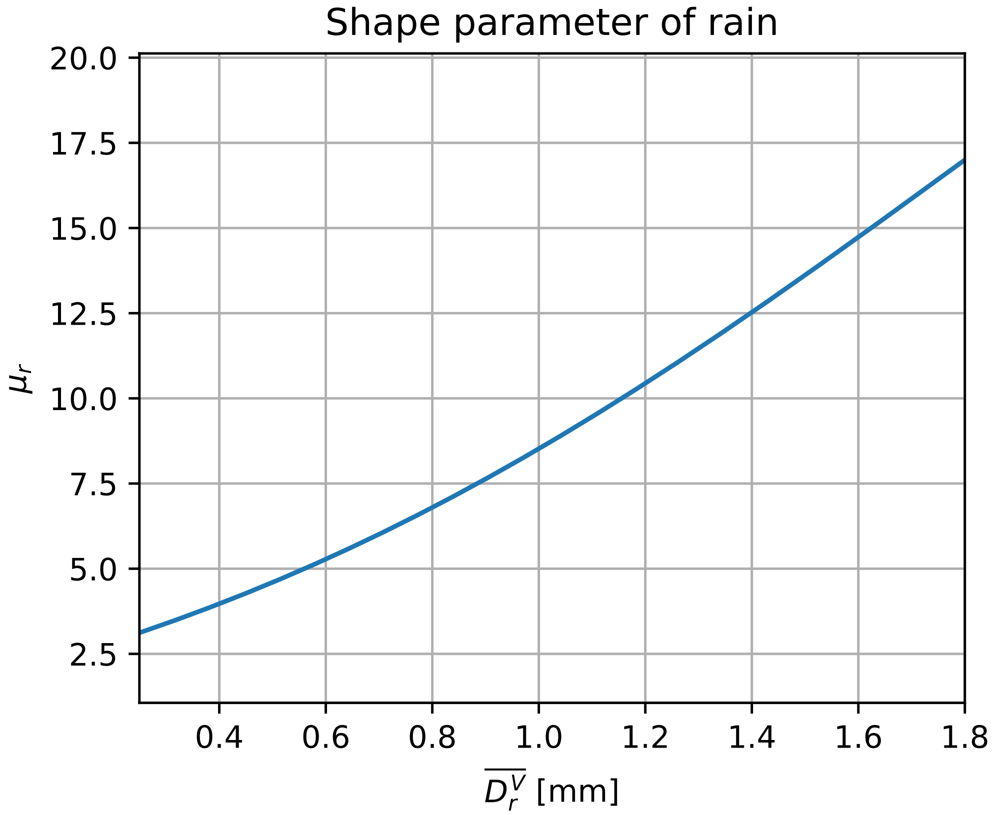
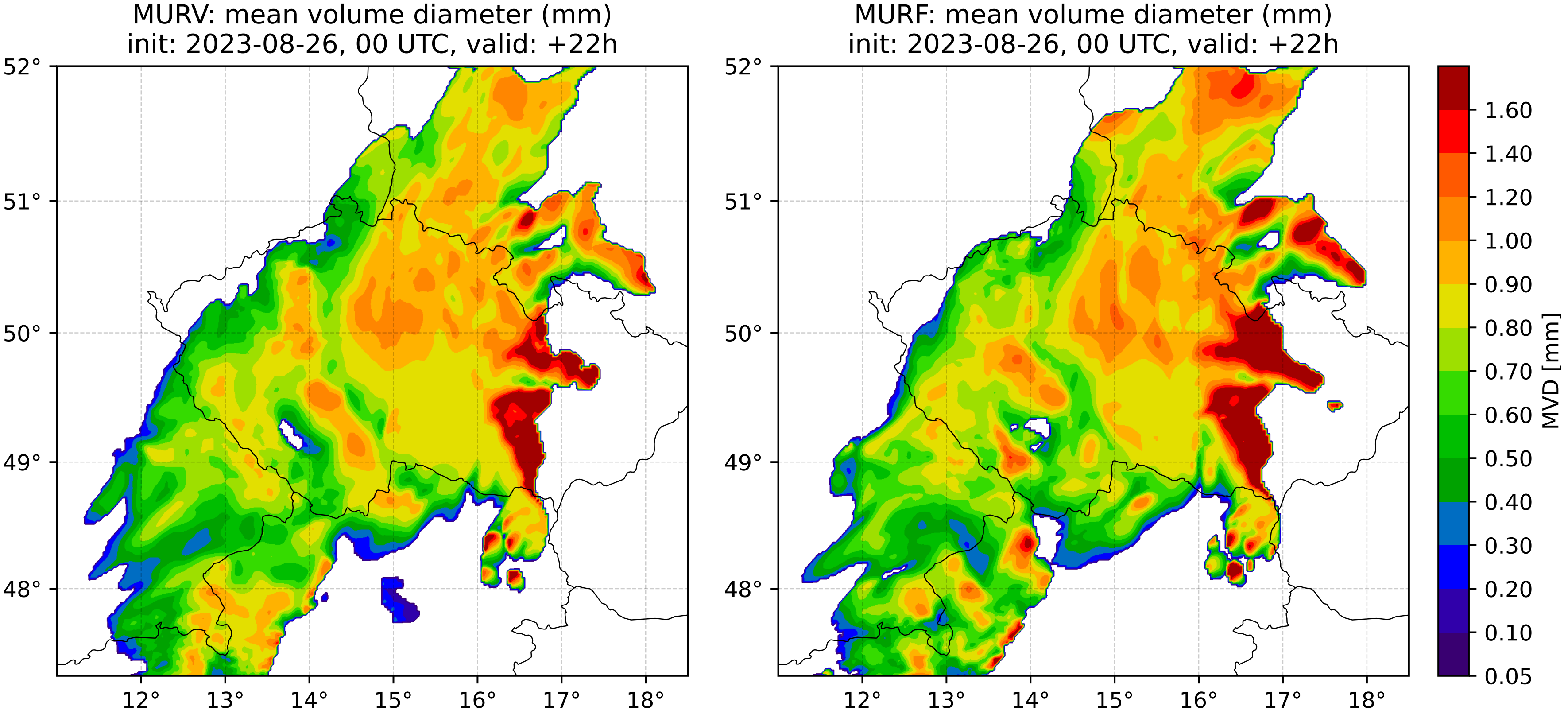
Self-collection and breakup of raindrops

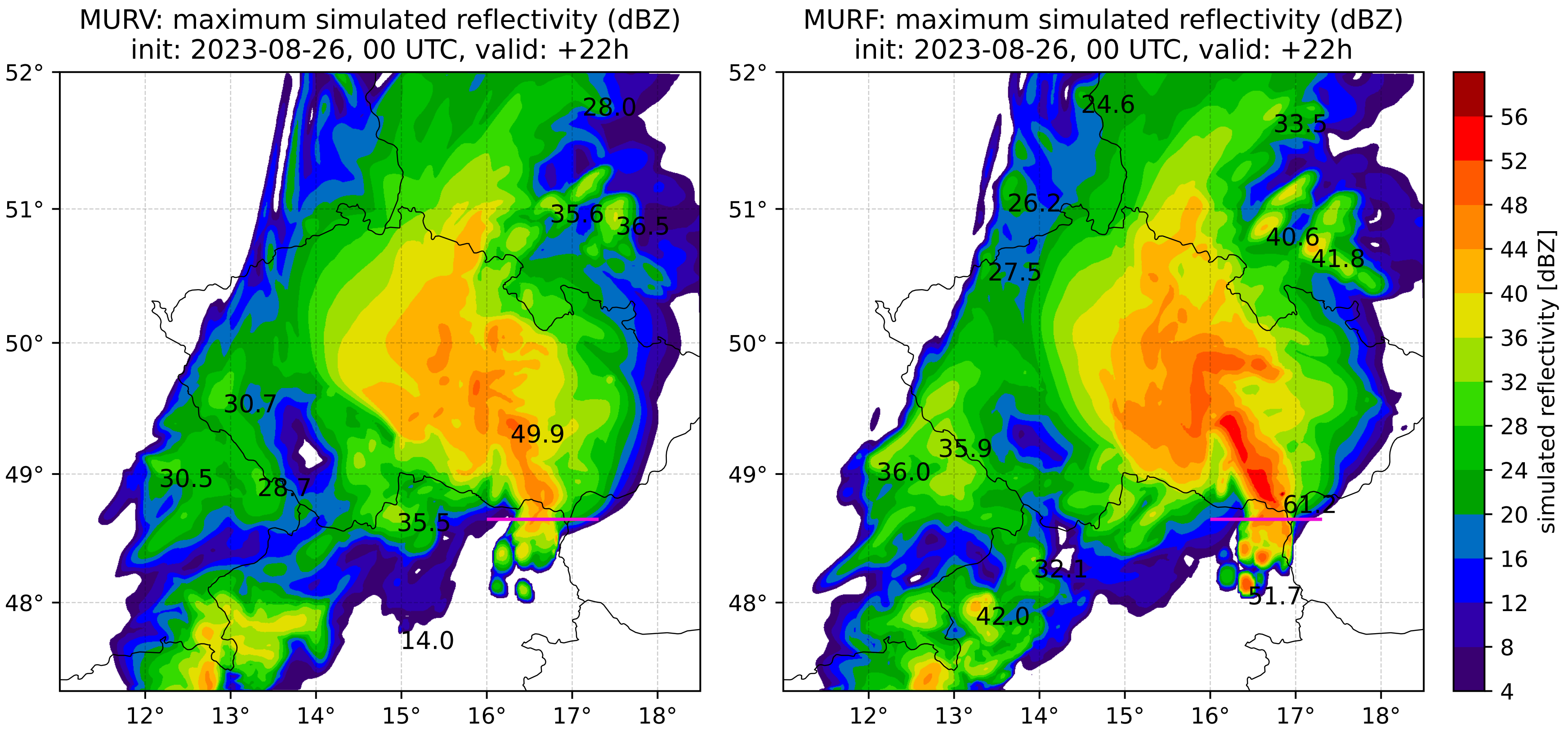
- for tests: Milbrandt, 2005: `MURV`
- fixed with $\mu_r = 1$: `MURF`



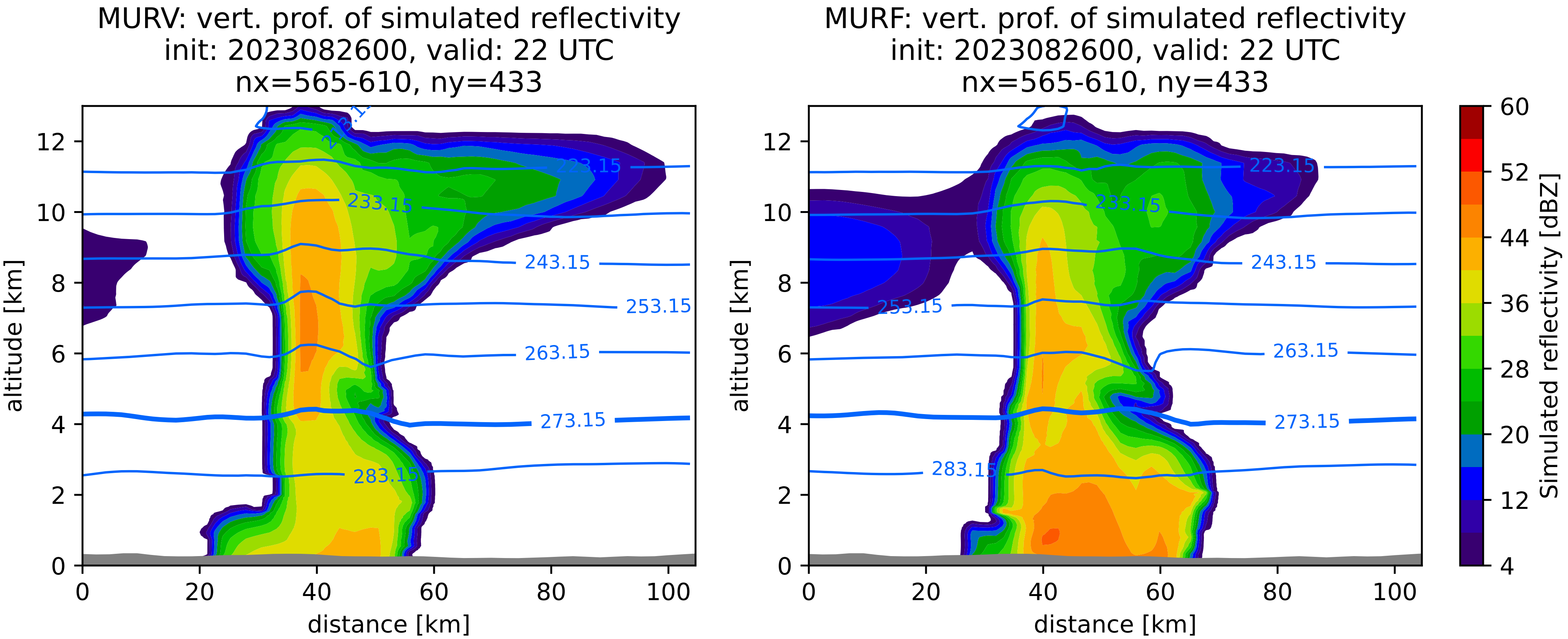
Mean volume diameter: left with variable μ_r



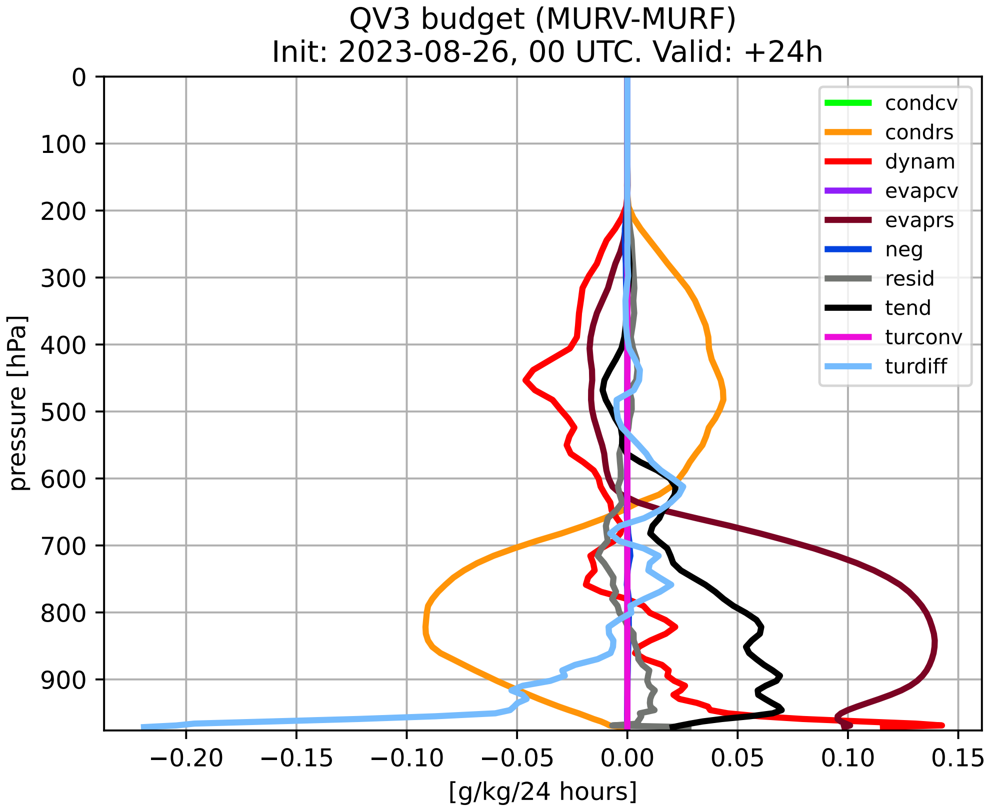
Simulated reflectivity: left with variable μ_r



Simulated reflectivity: left with variable μ_r



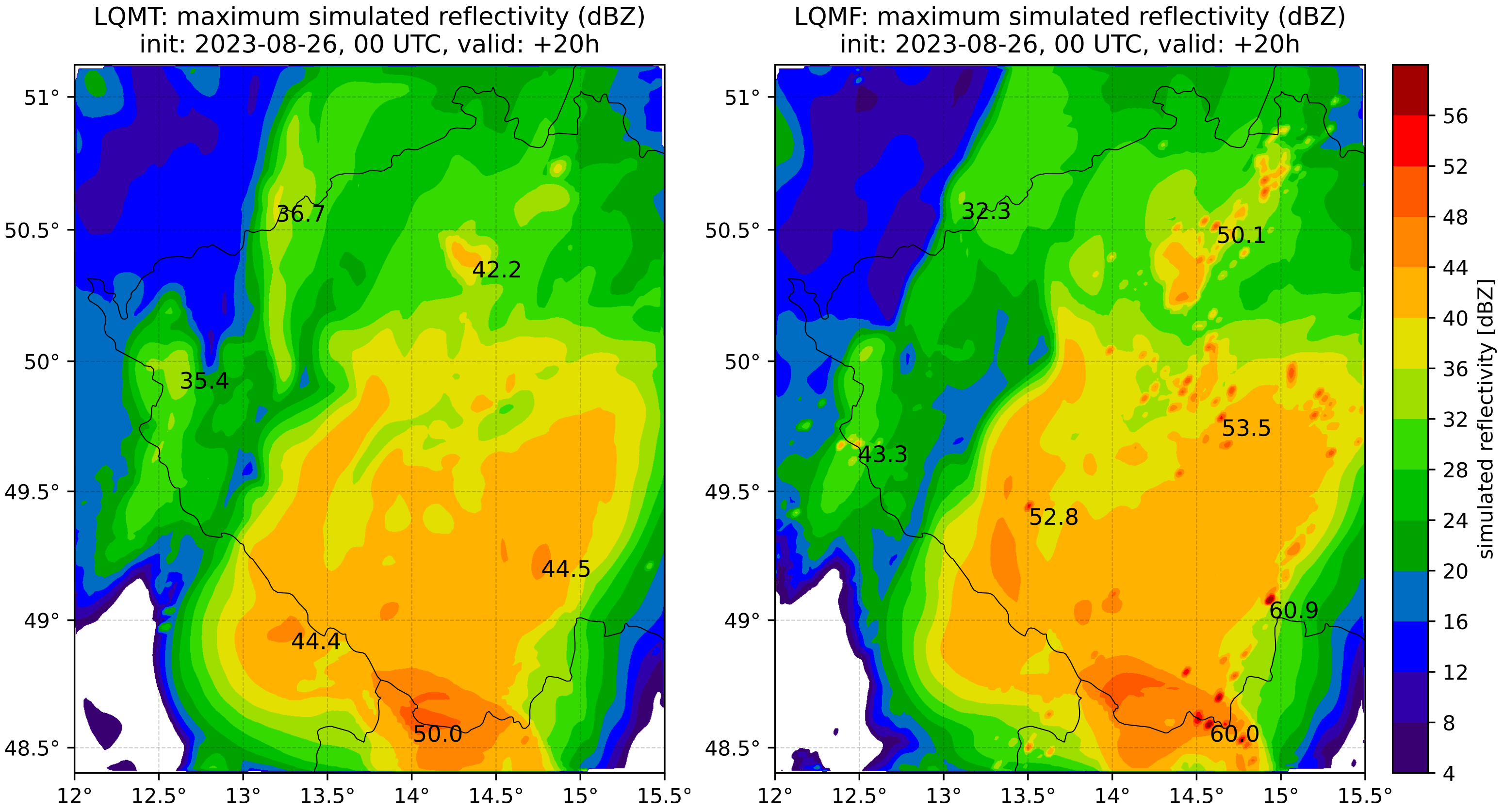
Water vapour budget difference (MURV-MURF)



Overshoots/undershoots due to interpolations

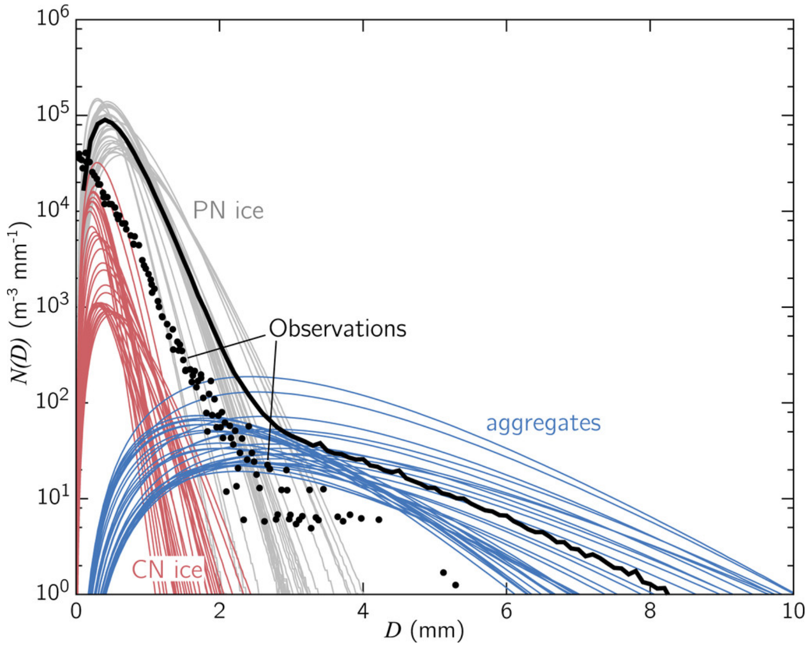
- overshoots/undershoots without shape-preserving option
- using shape-preserving option (`%LQM=.T.`) for rain (N_l, q_l) solves it
- but its precision is lower
- when used only for rain, low impact on results
- but perceptible when for all hydrometeors

Reflectivity pimples



Ice phase: the devil in disguise

- what is cloud ice and what is snow?
- shape of snow?
- density of graupel?
- values of sticking efficiencies?
- size-distributions
- phase split



Source: Jensen, A. A., Harrington, J. Y., & Morrison, H. (2018).

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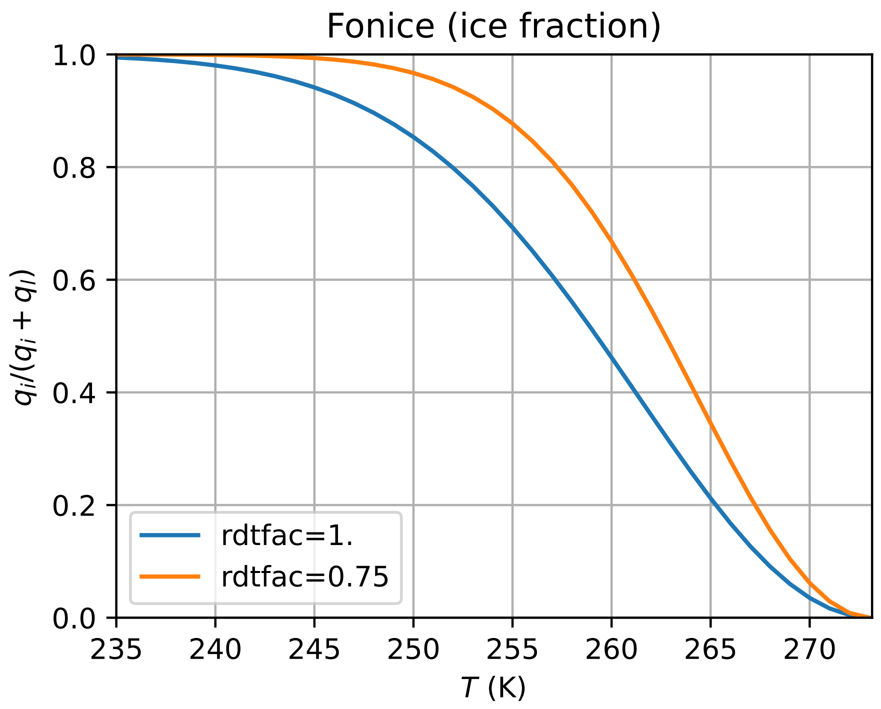
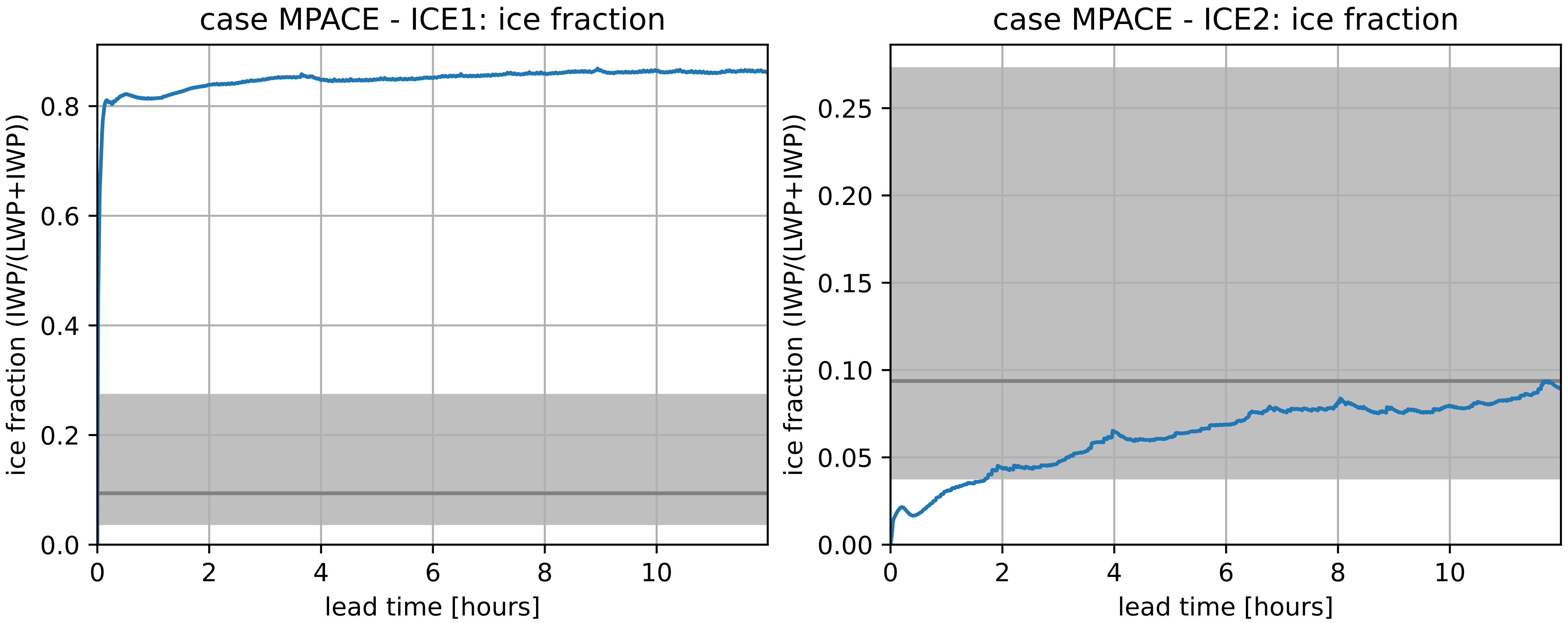
Phase split

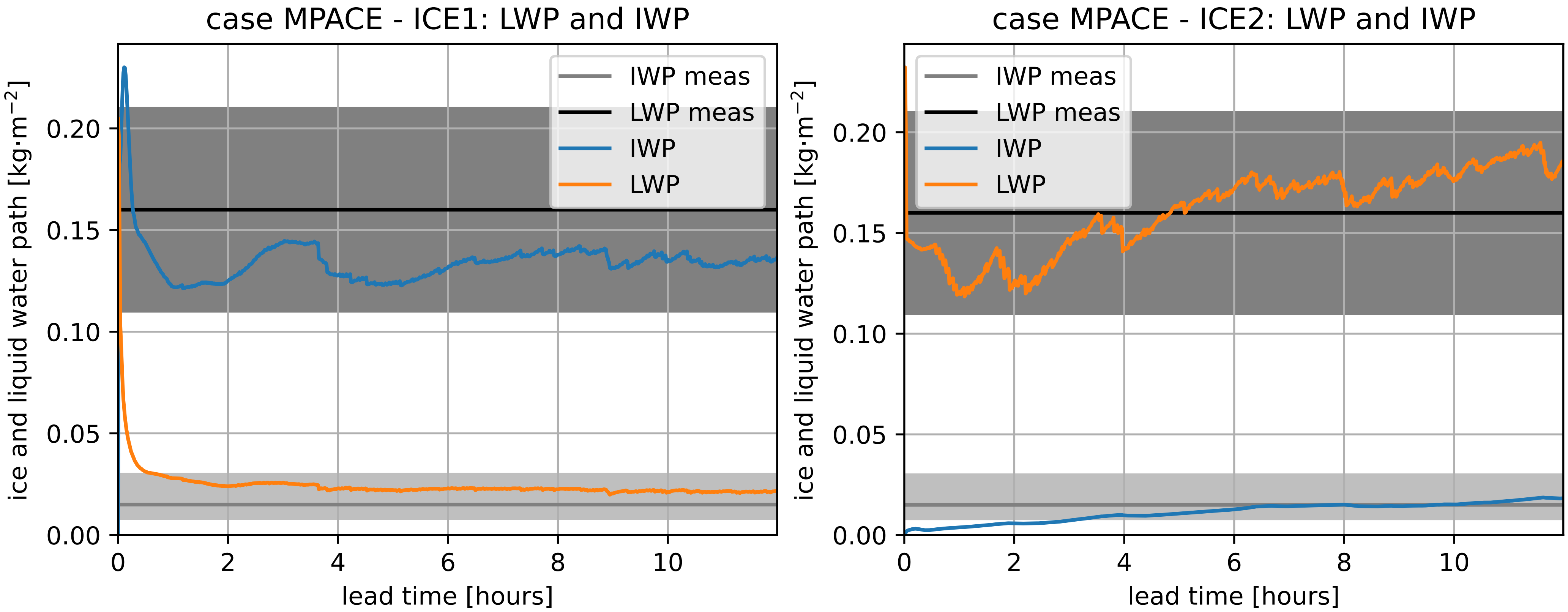
- current split between cloud particle phases by $\texttt{FONICE} = f(T)$
- with CAMS we “know” IFNs



MPACE results: ice fraction



MPACE results: LWP and IWP



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Conclusion and outlook

- liquid phase ready for testing
- higher μ_r reduces excessive size-sorting
- using `LQM`
- ice phase: very first tests and finding suitable parameterizations

References

- Jensen, A. A., Harrington, J. Y., & Morrison, H. (2018). Impacts of ice particle shape and density evolution on the distribution of orographic precipitation. Journal of the Atmospheric Sciences, 75(9), 3095-3114.

Thank you for your attention

David Němec

david.nemec@chmi.cz

Czech
Hydrometeorological
Institute