JOHANNES GUTENBERG UNIVERSITÄT MAINZ

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Inhomogeneous cirrus clouds during the AIRTOSS-ICE campaign

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AIRTOSS-ICE Campaign

- May and September 2013 over North and Baltic Sea
- Collocated measurements of microphysics and radiation
- Sample inhomogeneous cirrus clouds
- Investigate the formation processes

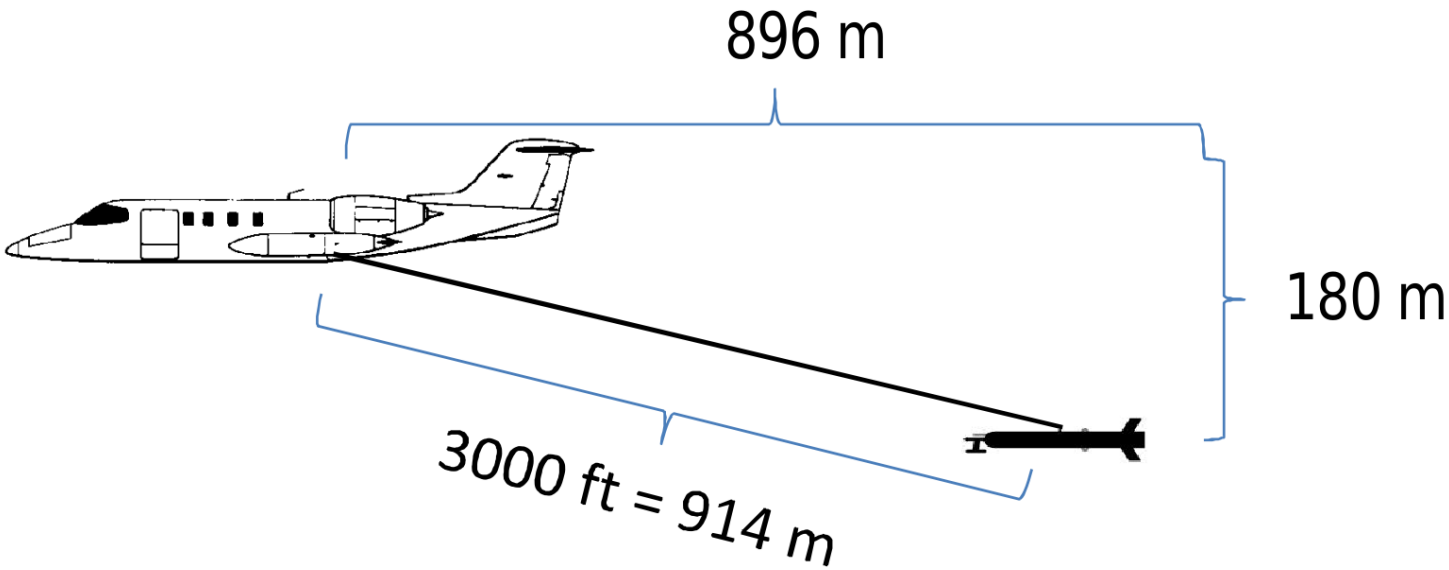

Figure: Learjet Airtoss configuration (Frey et al., 2009)

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Meteosat view 4th of September at 9.30 UTC

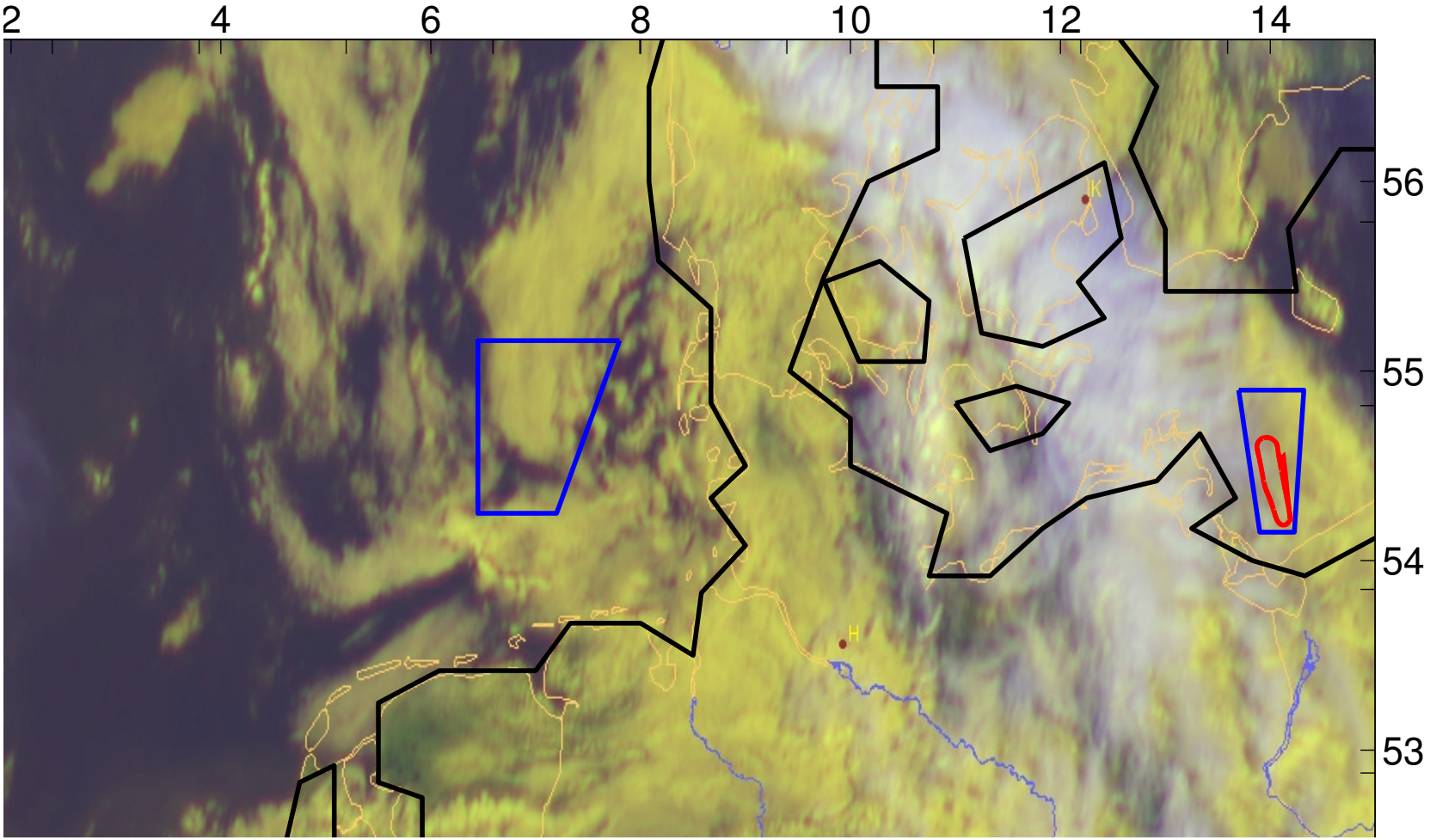
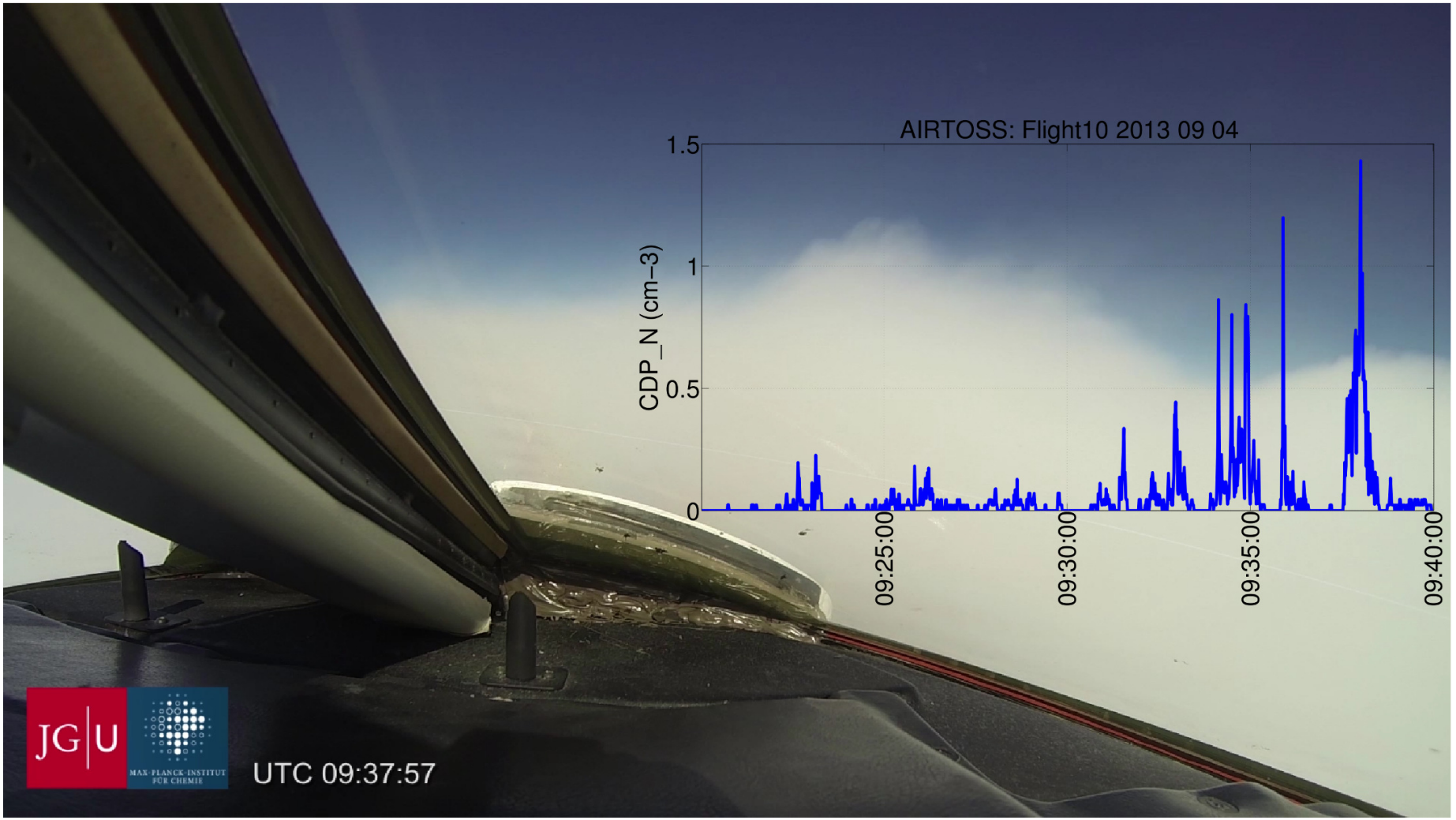


Figure: High clouds in blueish white and low clouds in yellow

High number concentrations in cloud tops

Figure: Cloud tops seen out of the learjet front window

High number concentrations in cloud tops



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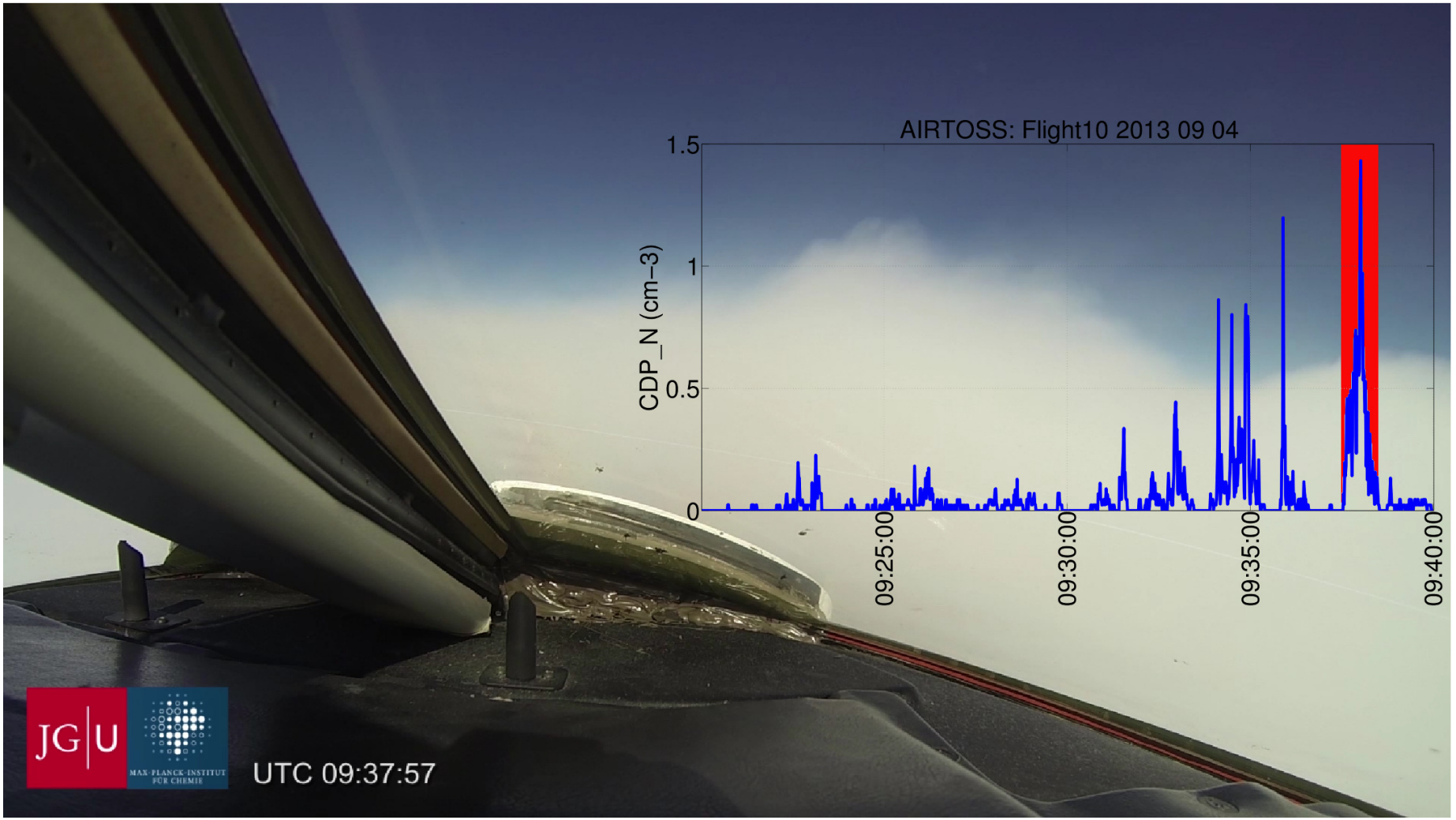

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Trajectory latitude and longitude

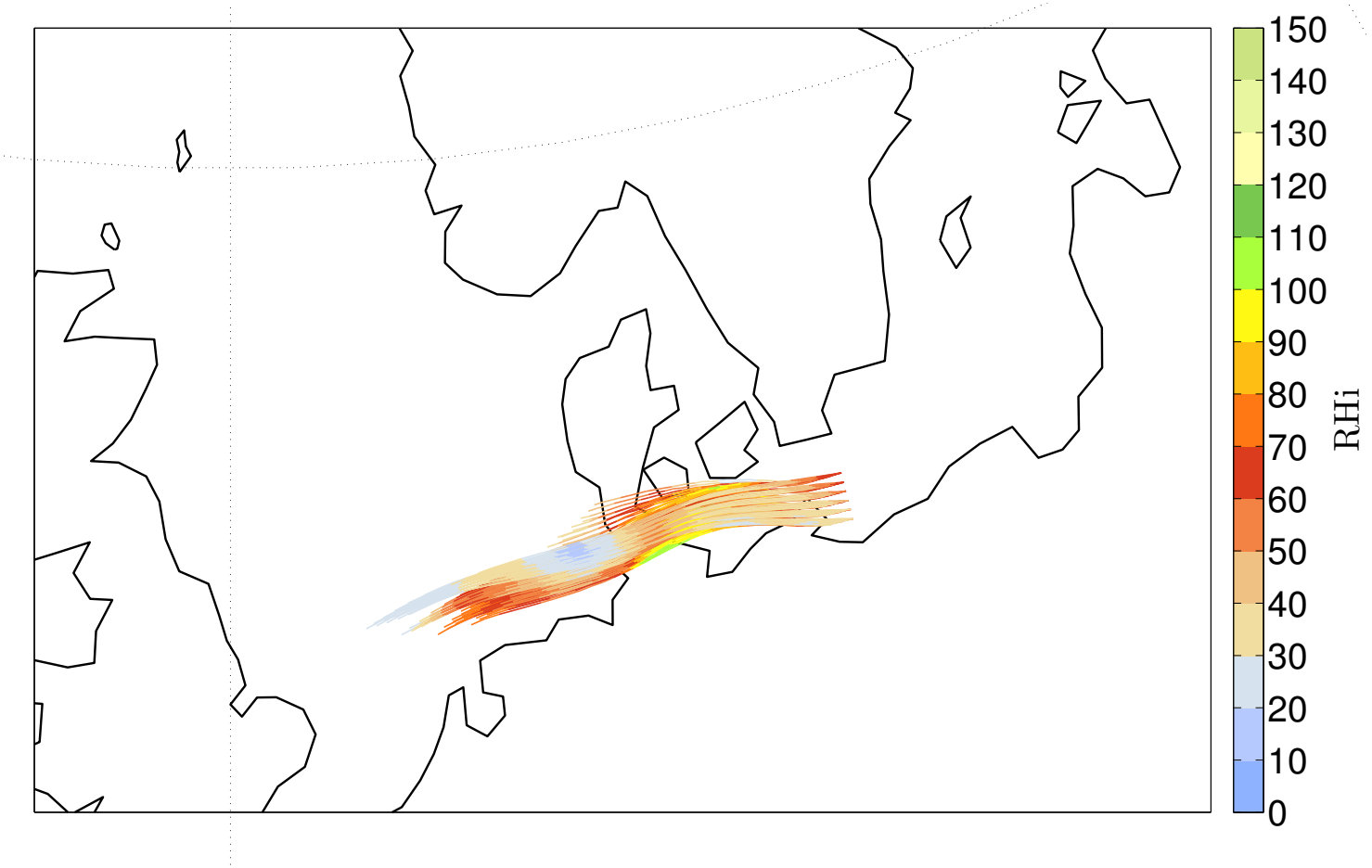


Figure: Lagranto (Wernli and Davies, 1997) backward trajectories

Trajectory height

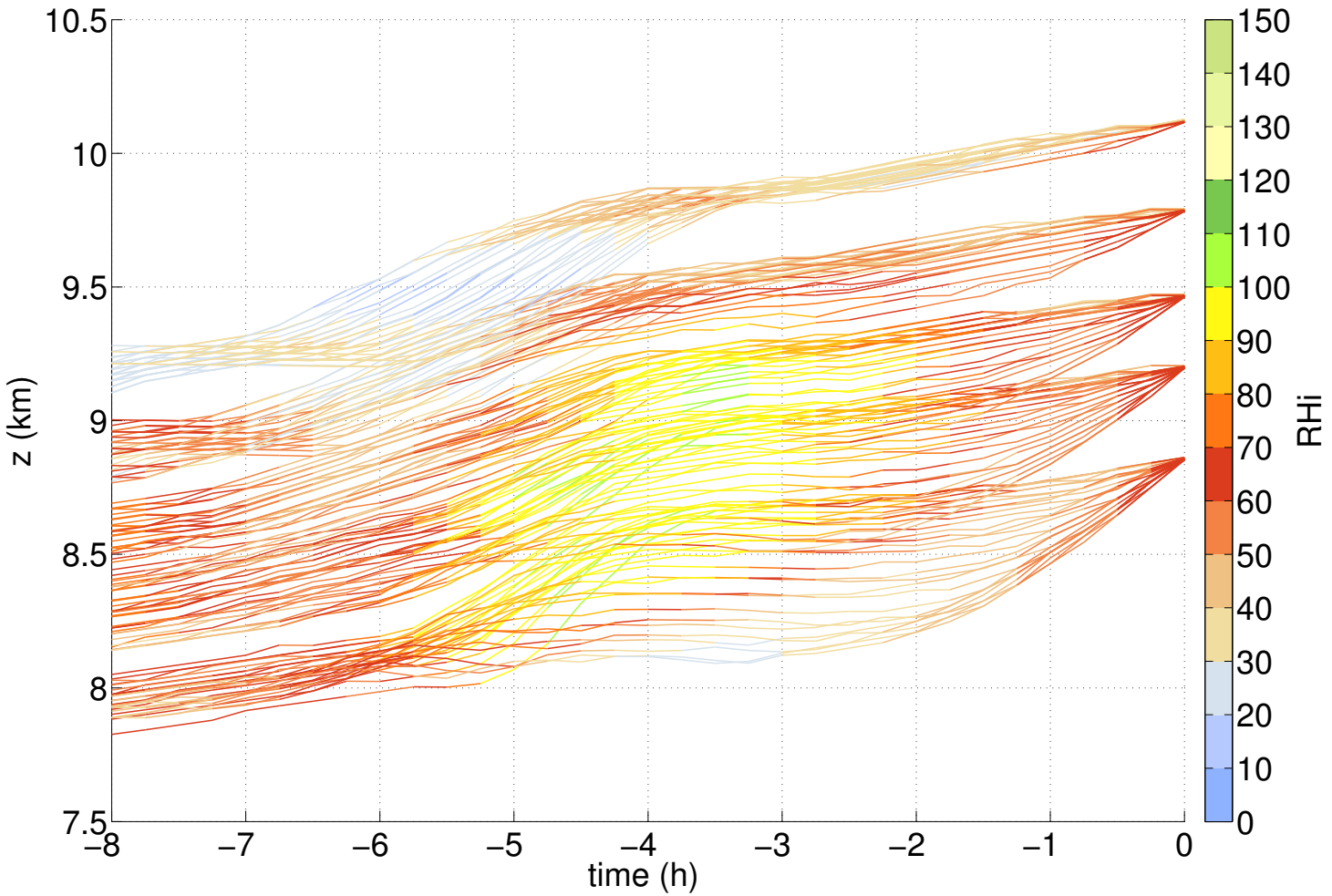


Figure: Height of trajectories colored with RHi

Microphysical Model

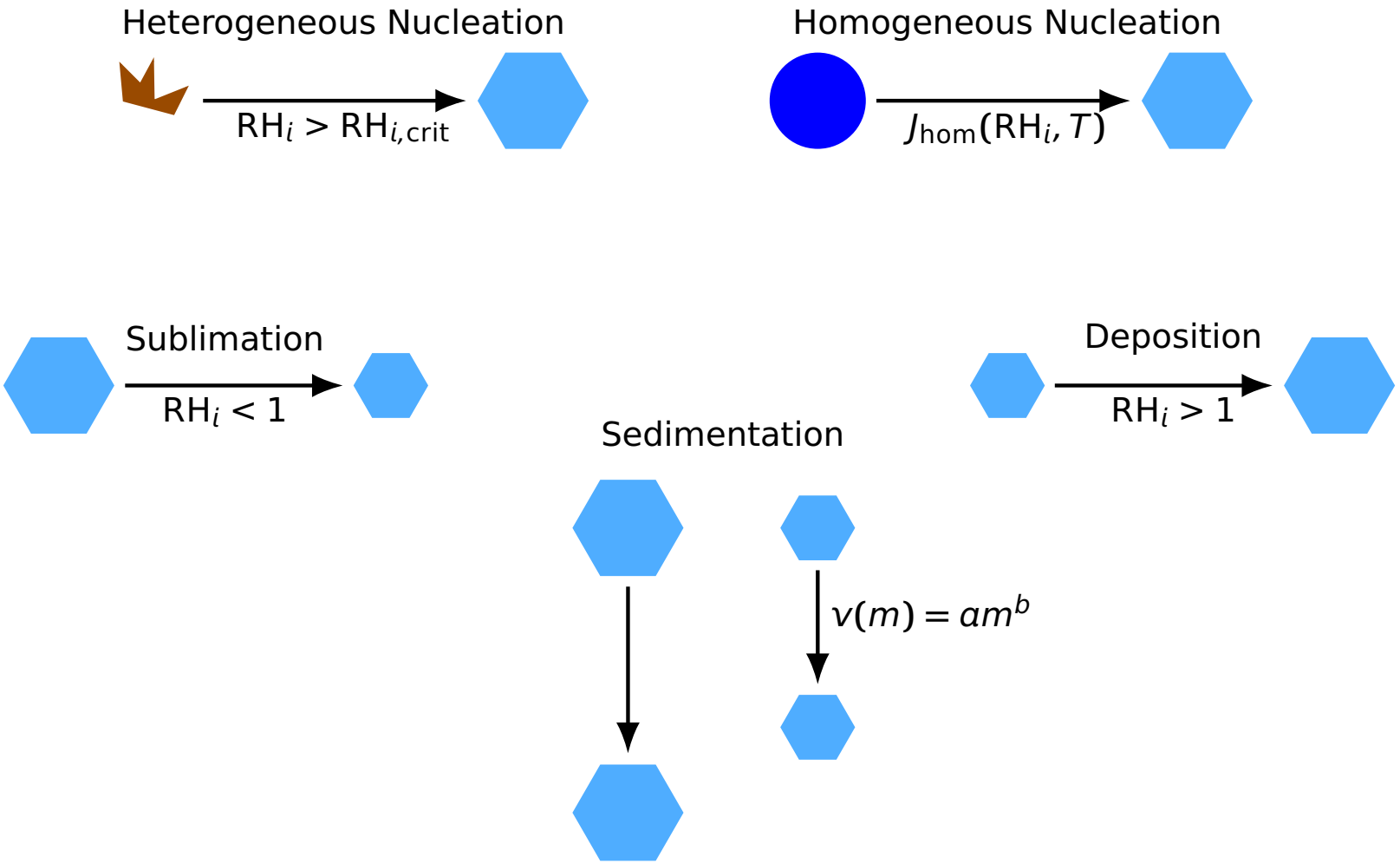


Figure: Microphysics in the model (Spichtinger and Gierens, 2009)

EULAG (Prusa et al., 2008)

- Version solves the anelastic equations.
- Split in environmental state and deviation: $\psi' = \psi - \psi_e$

Mass conservation

$$\nabla \cdot (\rho_0 \, \mathbf{u}) = 0$$

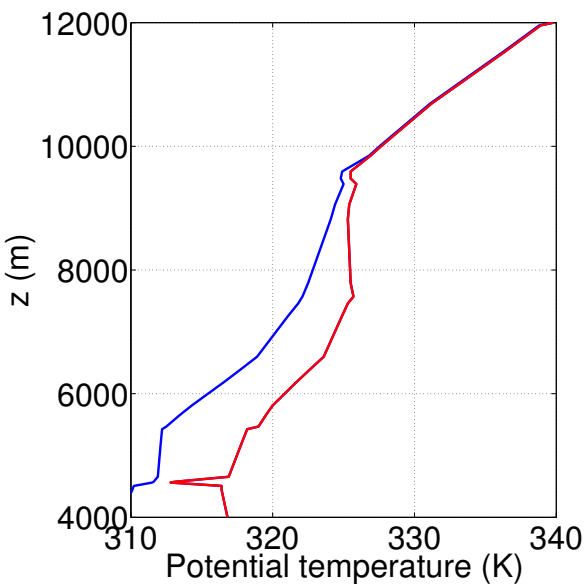
Momentum conservation

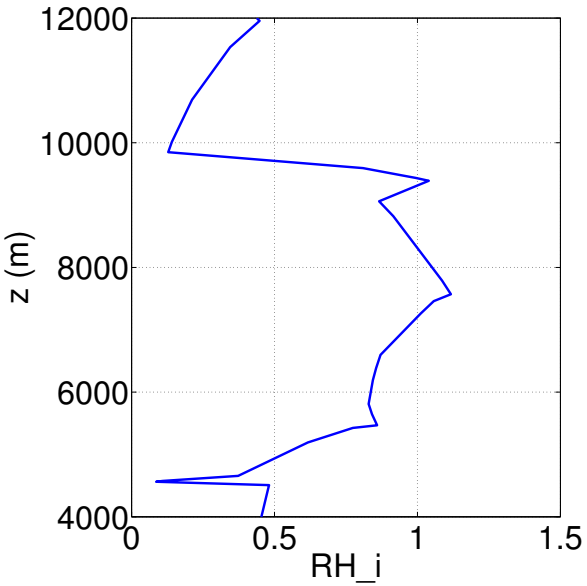
$$\frac{\mathrm{d}\mathbf{u}}{\mathrm{d}t} = -\nabla \left(\frac{p}{\rho_0} \right)' - \mathbf{g} \frac{\Theta'_d}{\Theta_0}$$

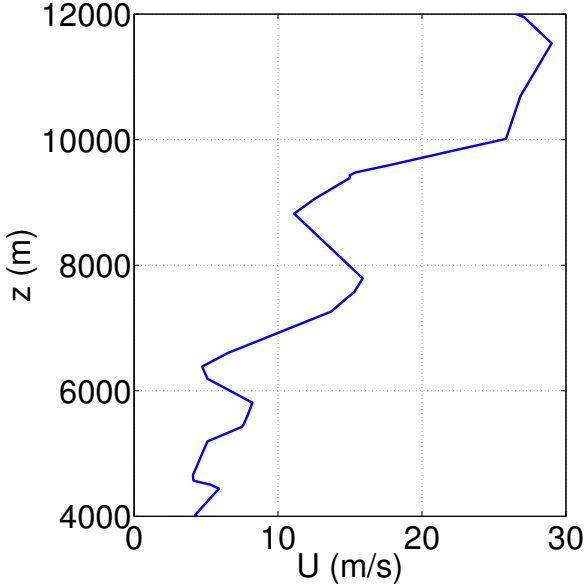
Energy conservation

$$\frac{\mathrm{d}\Theta'}{\mathrm{d}t} = -\mathbf{u} \cdot \nabla \Theta_e + F_\Theta$$

Sounding and idealized profiles







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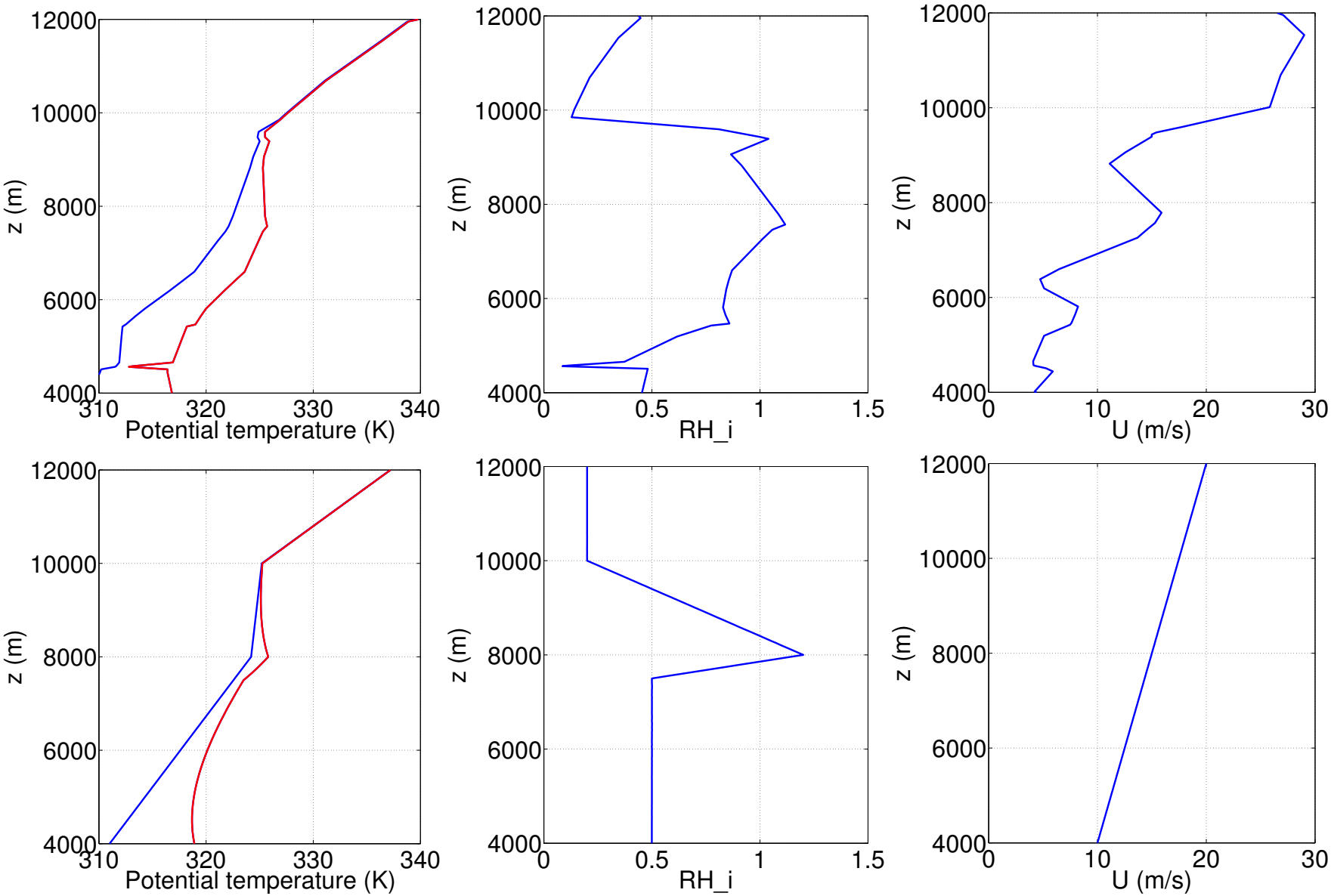

Model Setup

Fixed parameters

- vertical grid spacing $dz = 50\,\mathrm{m}$
- horizontal grid spacing $dx, dy = 100\,\mathrm{m}$
- time step $dt = 1\ \mathrm{s}$
- horizontal extension $0 \leq x \leq 25\,\mathrm{km}$
- vertical extension $4\,\mathrm{km} \leq z \leq 14\,\mathrm{km}$

Varied parameters

- Large scale ascent rate $3 \leq w \leq 5\,\mathrm{cms}^{-1}$
- Number of Ice Nuclei $\mathrm{IN} = 0, 10, 100\,\mathrm{L}^{-1}$
- Wind profile
- Temperature profile
- RH_i profile

Objective PDF Comparison (Bhattacharyya, 1943)

If p_i is the probability density of distribution P in bin i and q_i for distribution Q, then $\sqrt{p_i \cdot q_i}$ is the geometric mean of the two.

$$BC = \sum_i \sqrt{p_i \cdot q_i}$$

$$0 \leq BC \leq 1$$

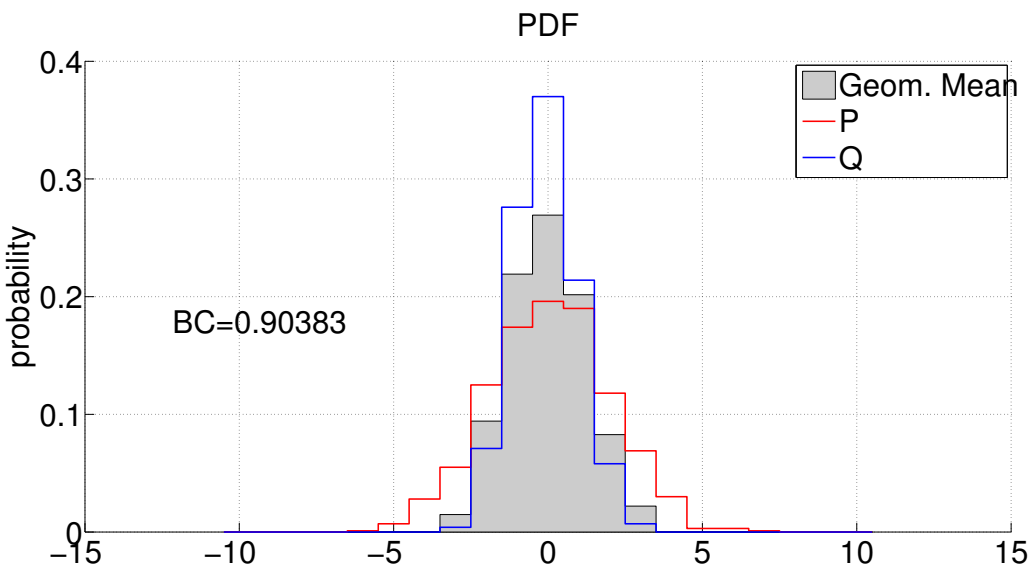

Figure: Random normal pdf distributions

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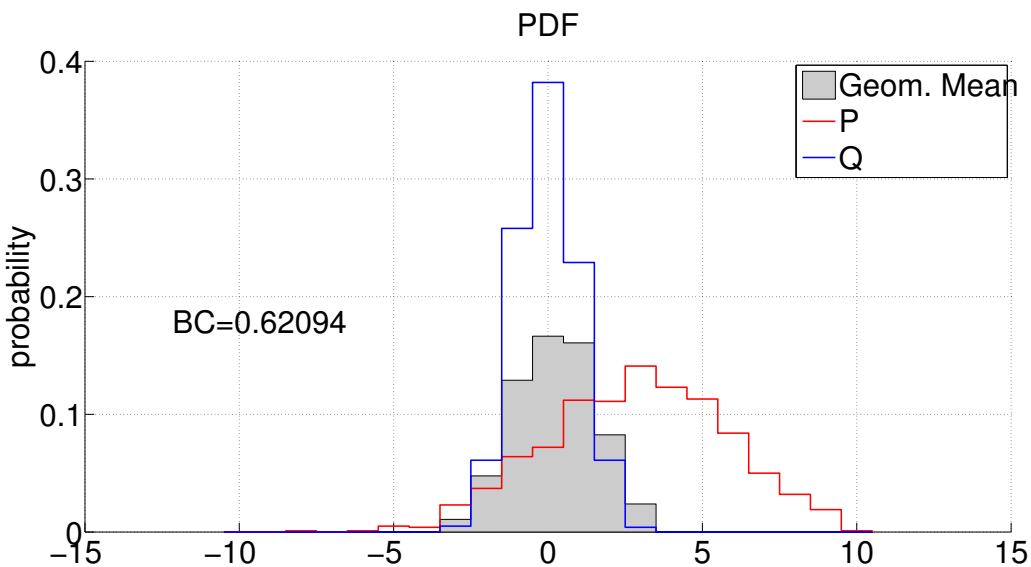


Figure: Random normal pdf distributions

Probability for ice particle numbers

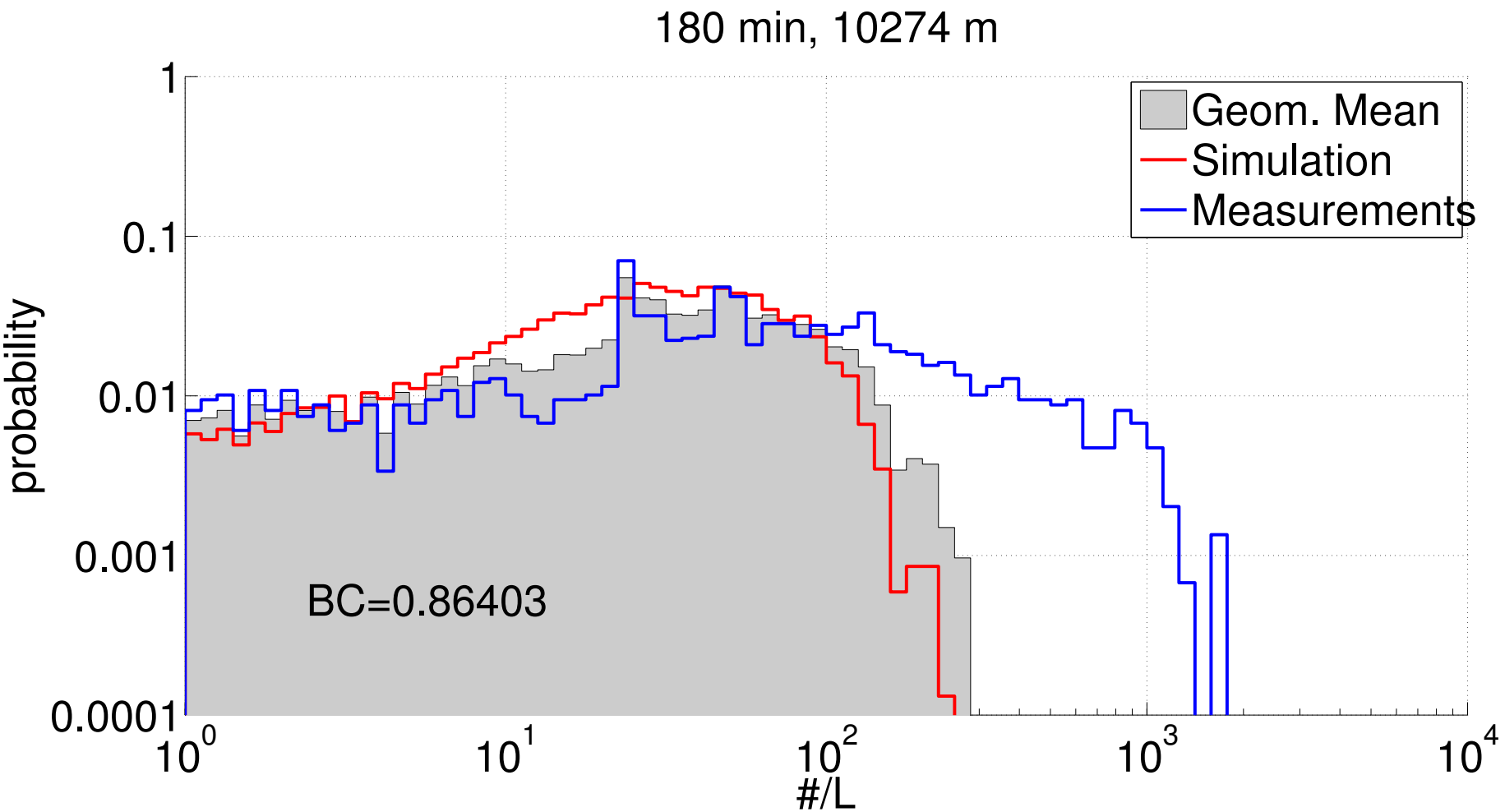
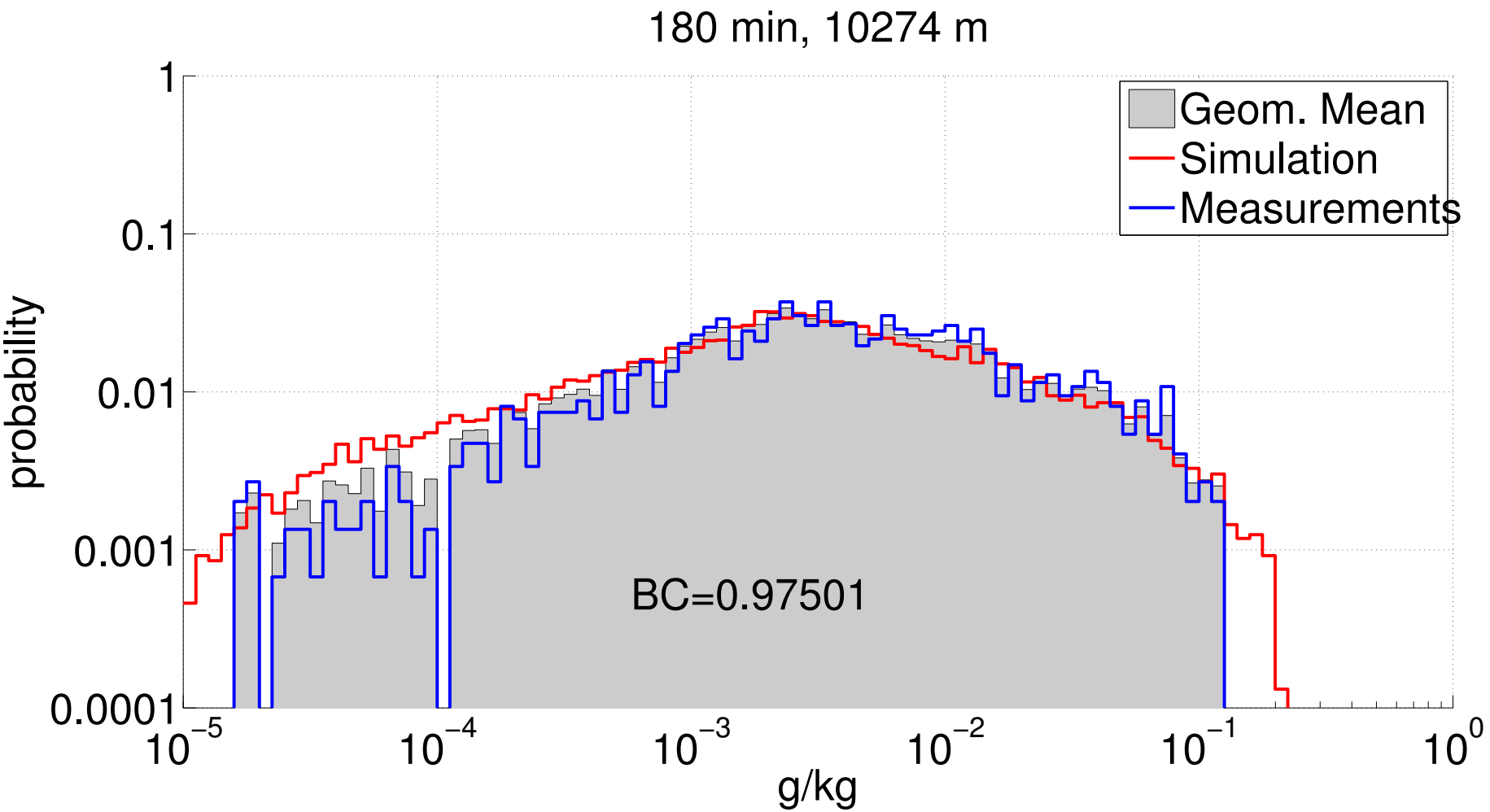


Figure: Ice number of measurements compared to simulations

Probability for ice particle mass



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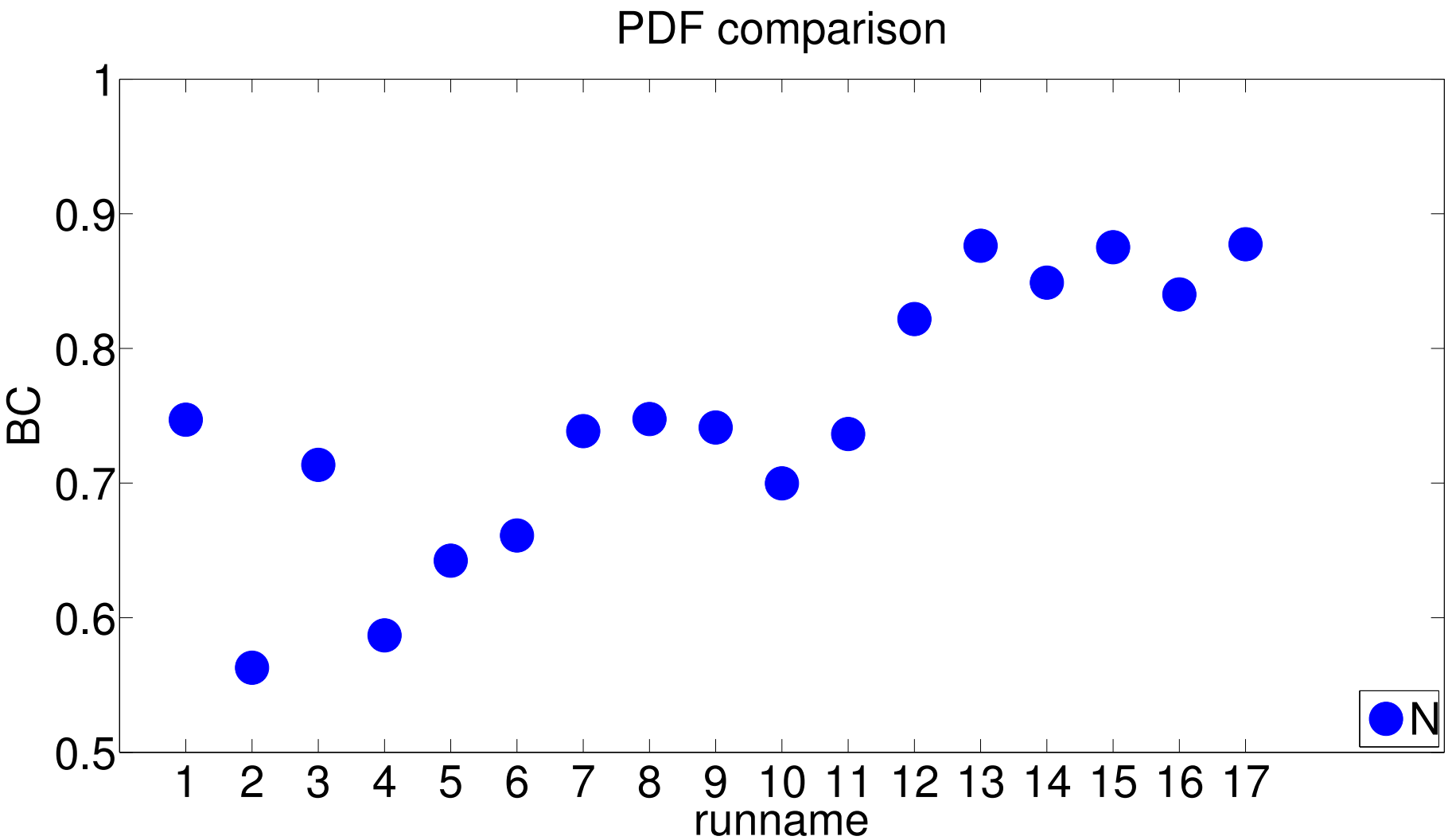

Figure: PDF similarity of various simulations compared to measurements

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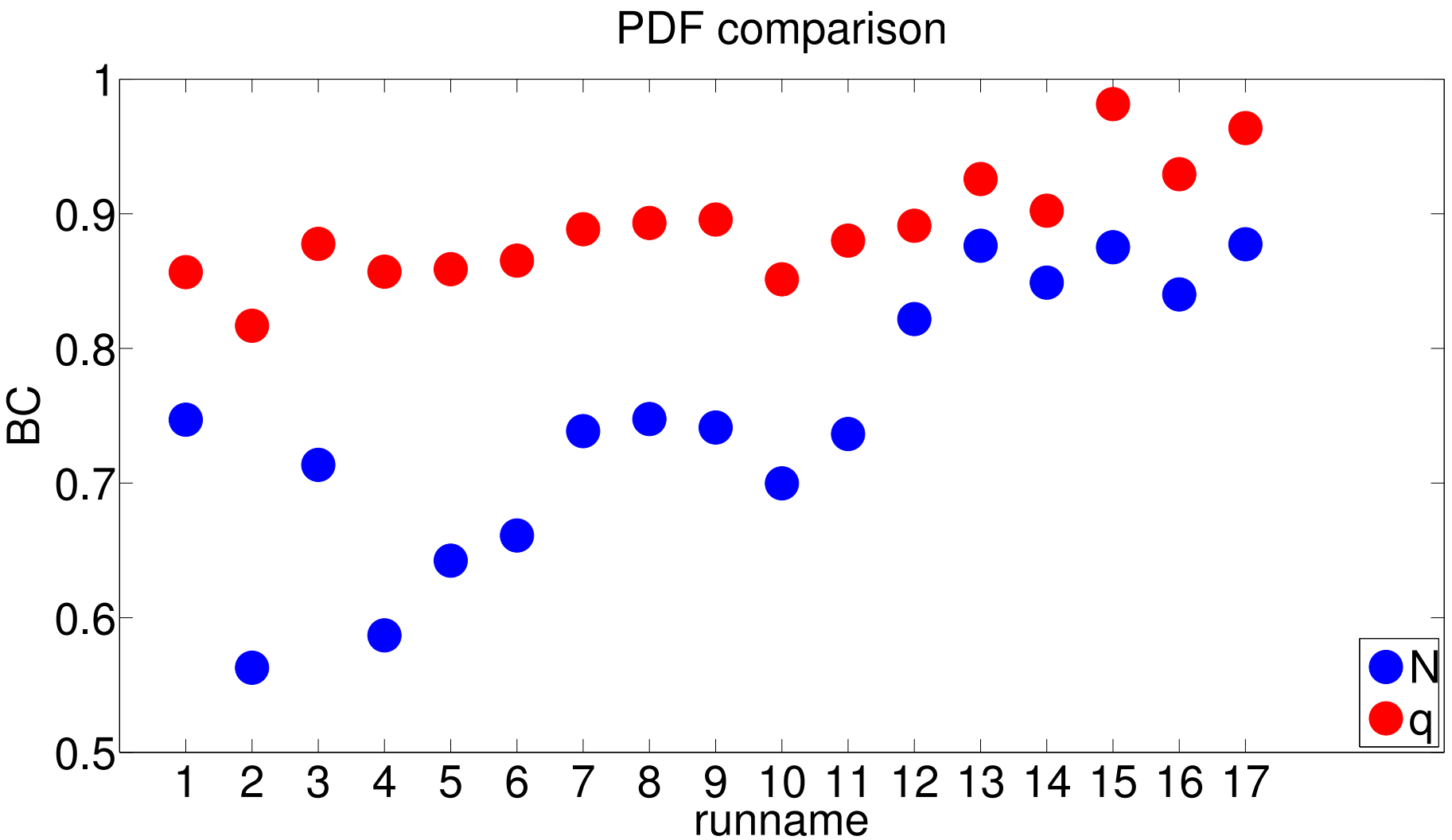

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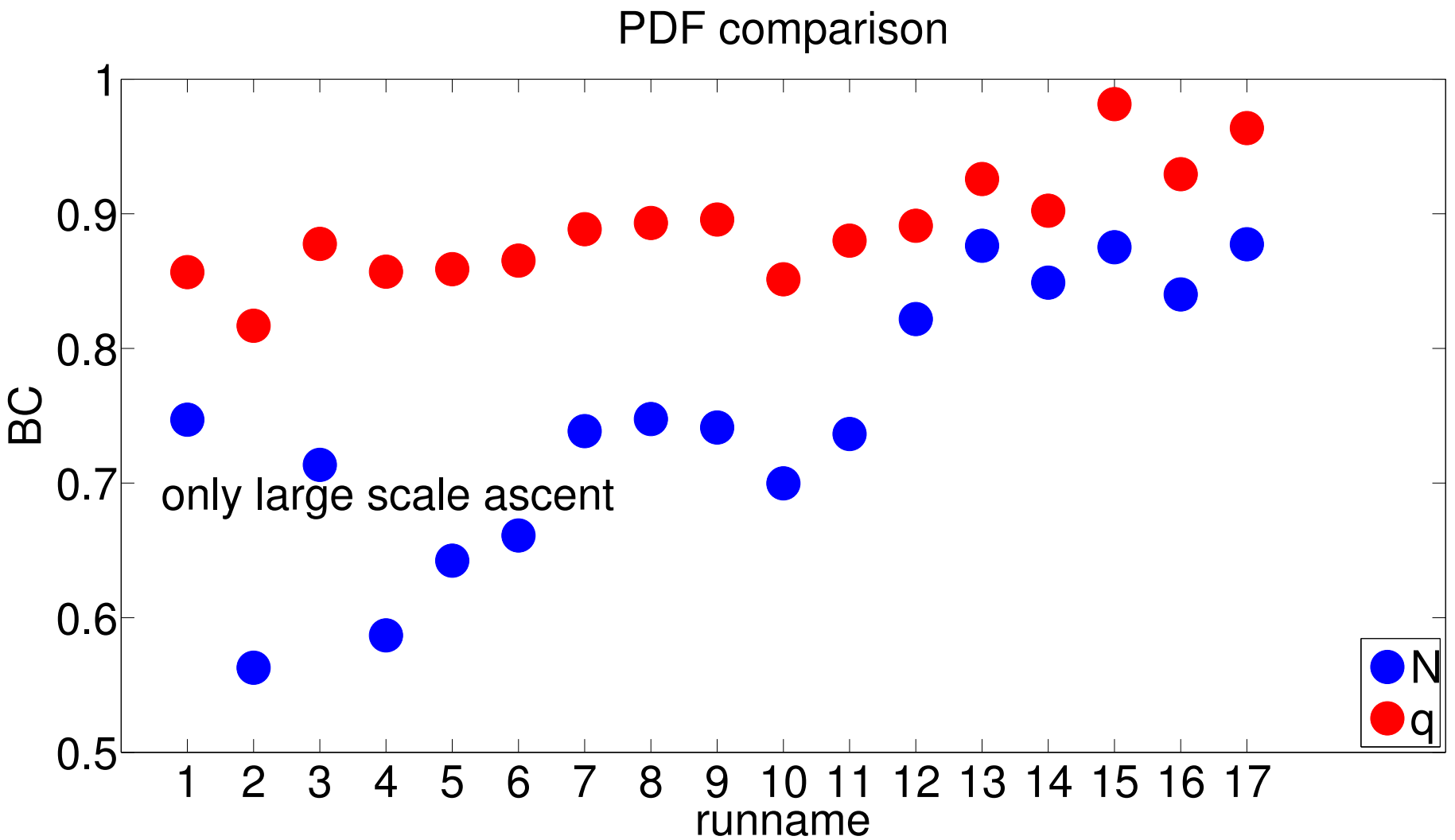

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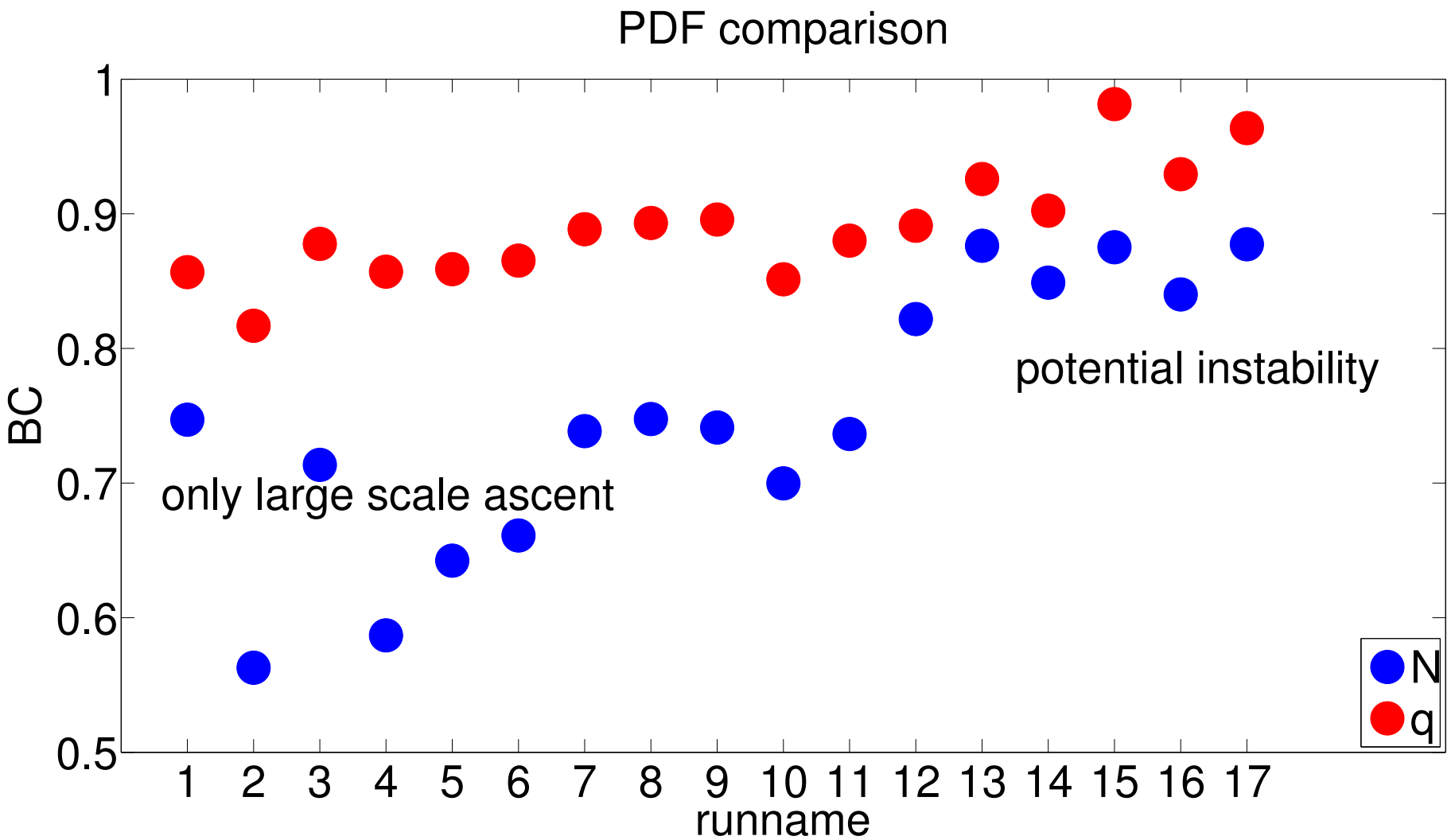

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Ice particle number concentration

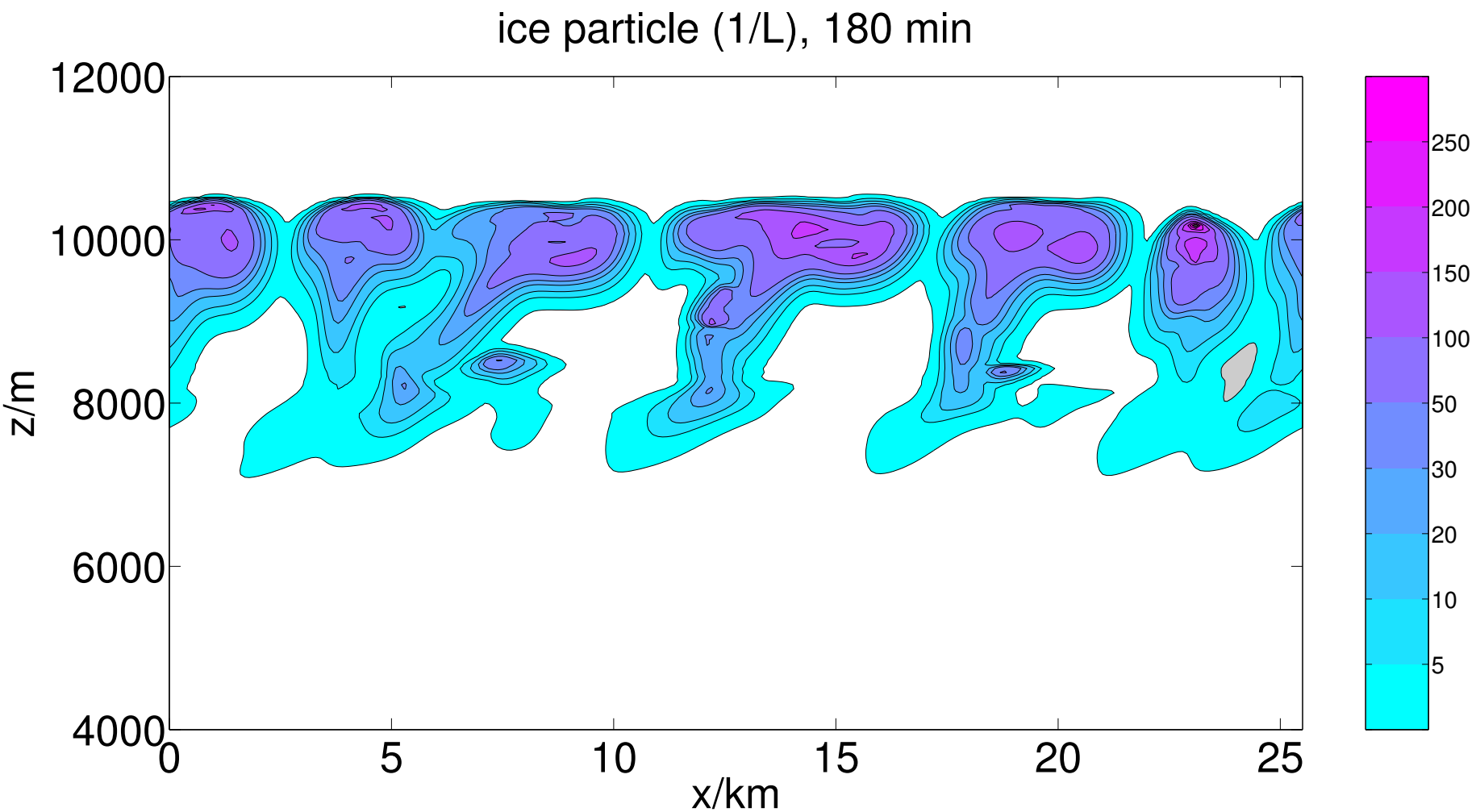

Figure: Contours of ice particle number concentrations

Summary

- Inhomogeneous cirrus sampled
- Variation from 10 to 1000 particles per liter on small scale
- Large scale motion shows only small and continuous updraft
- Small scale motion needed to explain measurements
- Sounding shows potentially unstable layer
- Parameter space explored with simulations
- Simulations statistically compared to measurements
- Scenario with shallow convection matches measurements best

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Thank you for attending

References I

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