Droplet stochastic activation and spectrum broadening

in the presence of supersaturation fluctuations

Gustavo C. Abade[1], W. W. Grabowski[2], H. Pawłowska[1]

[1]University of Warsaw, Faculty of Physics, Institute of Geophysics, Warsaw, Poland

[2]National Center for Atmospheric Research, Boulder, USA

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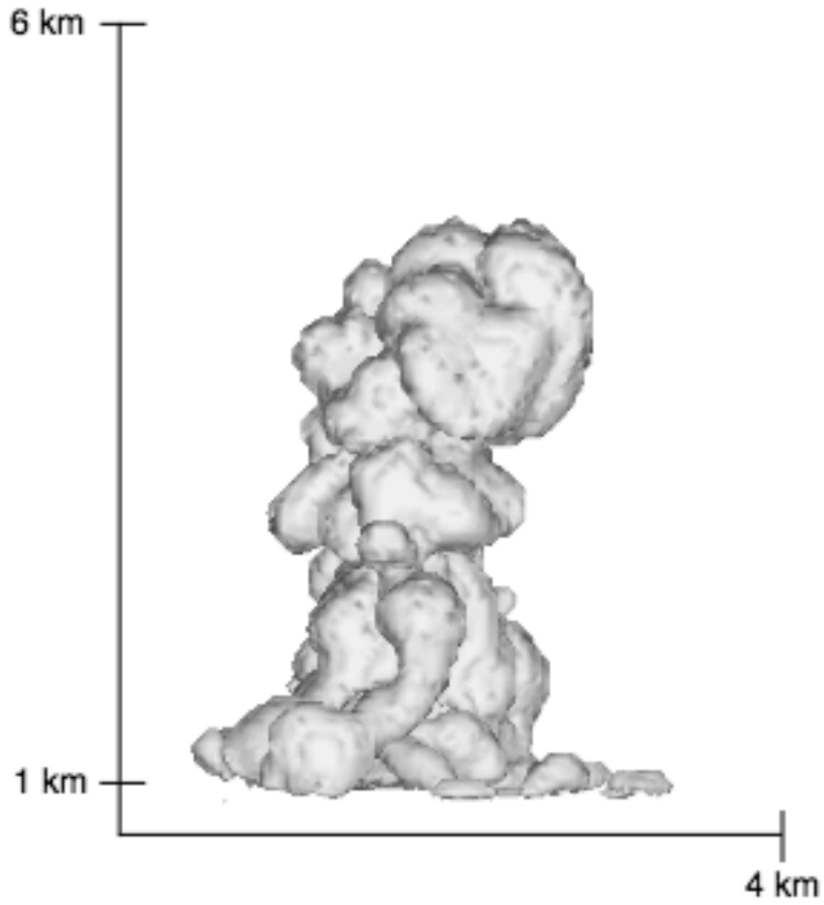
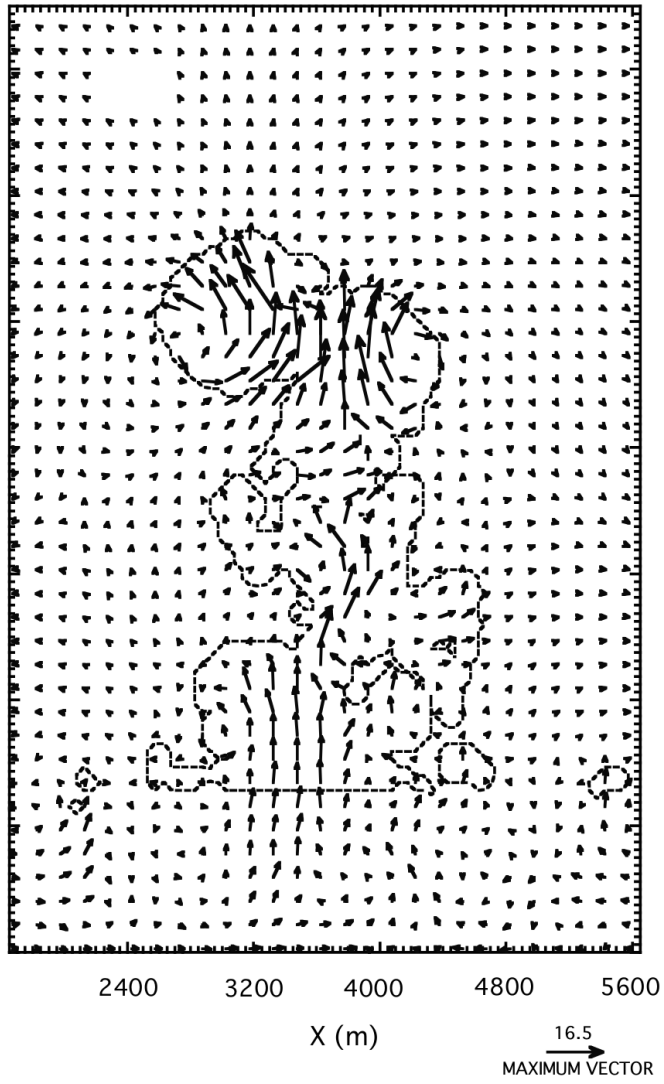
LES of cloud-scale flow

cloud updraft and interfacial instabilities (entraiment)





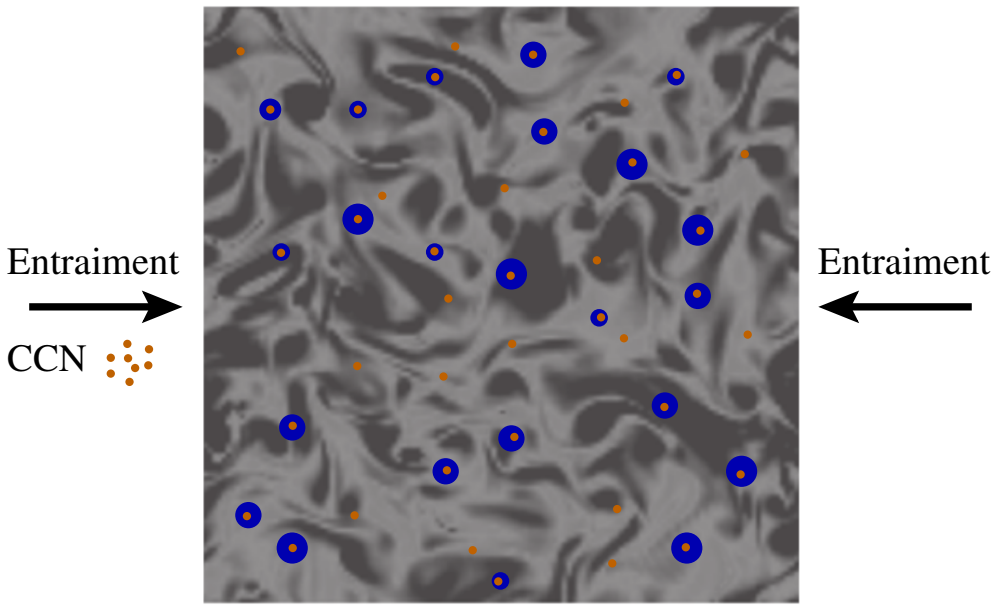
Lasher-Trapp *et al.*, QJRMS, **131** (2005)

Microphysical variability

at sub-grid scales (SGS)

- $S = \langle S \rangle + S'$
- Mixing
- Activation/deactivation
- Super-droplets

LES grid box



Stochastic activation

Köhler curve and potential

$$r\frac{\mathrm{d}r}{\mathrm{d}t} = D\left(S - \frac{A}{r} + \frac{B}{r^3}\right)$$

$$x \equiv r^2 \qquad S = \langle S \rangle + S'$$

$$\frac{\mathrm{d}x}{\mathrm{d}t} = -\frac{\partial V}{\partial x} + 2DS'$$

Abade, Grabowski and Pawlowska, JAS (2018)

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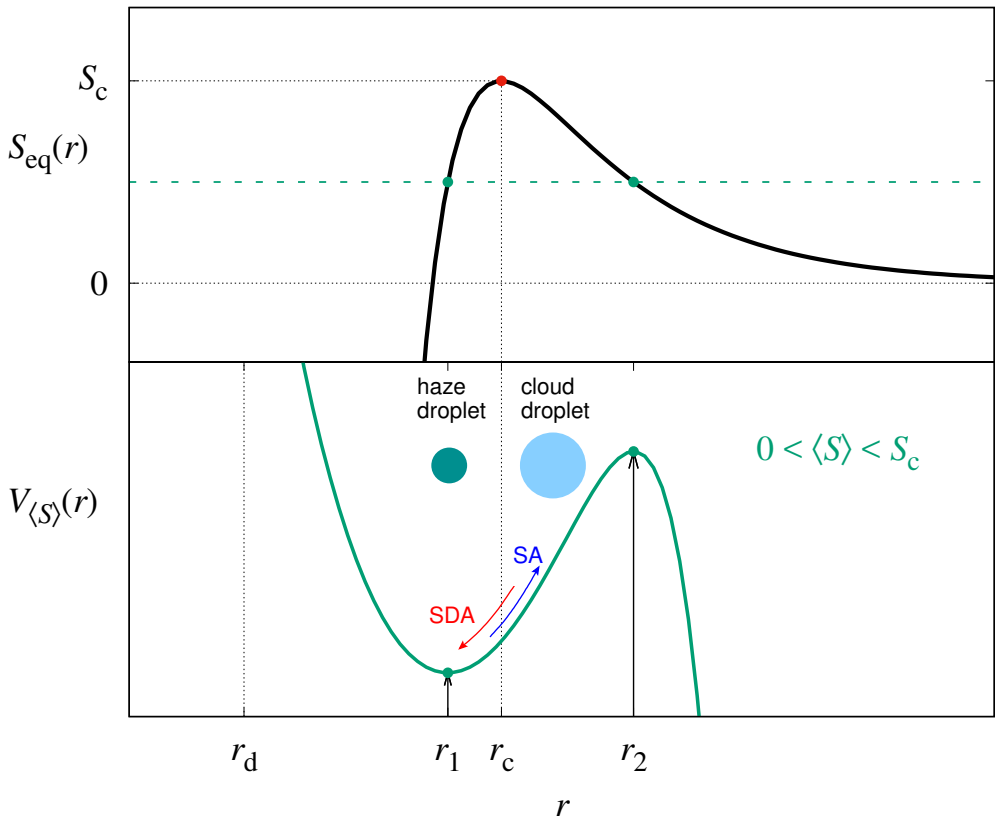

Abade, Grabowski and Pawlowska, JAS (2018)

Stochastic activation

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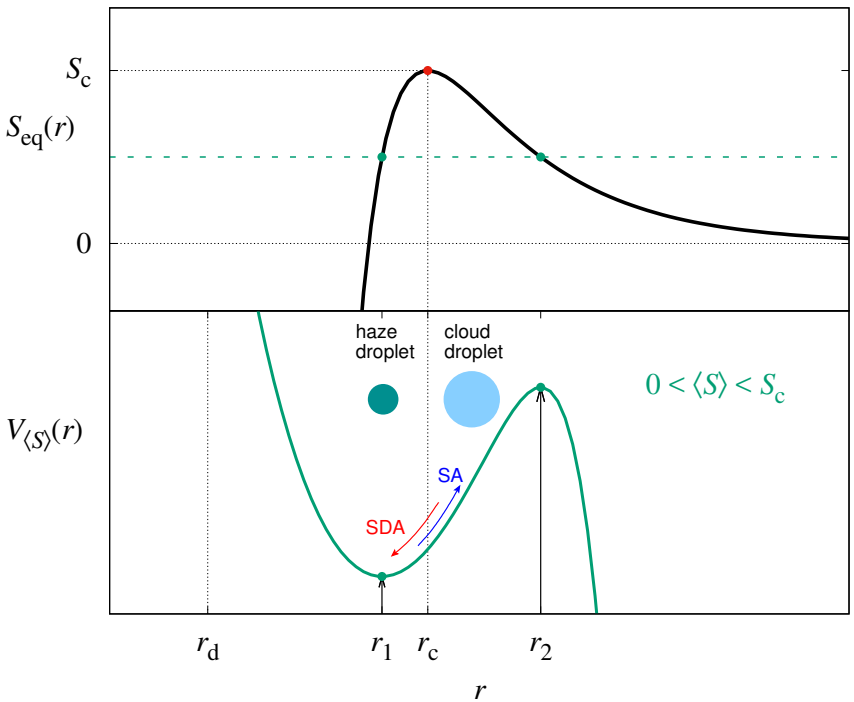
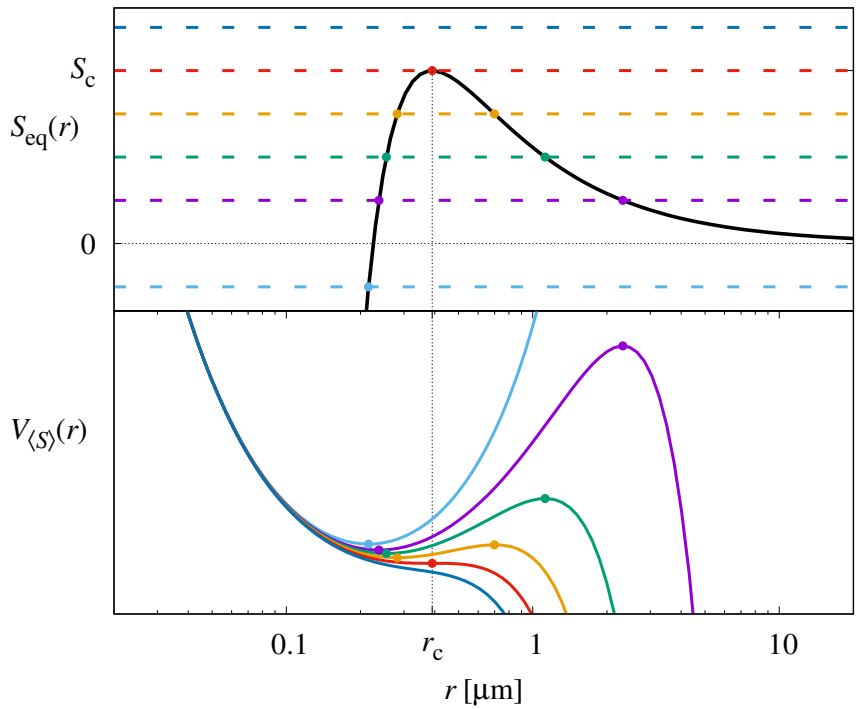
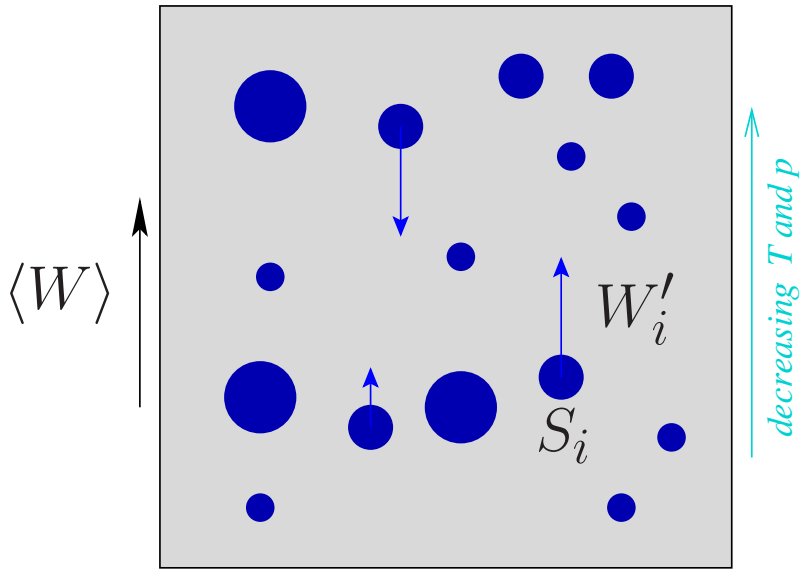


Feedback mechanism



Abade, Grabowski and Pawlowska, JAS (2018)

Supersaturation and velocity fluctuations



$$\frac{\mathrm{d}S_i'}{\mathrm{d}t} = -\frac{S_i'}{\tau_S} + aW_i'(t)$$

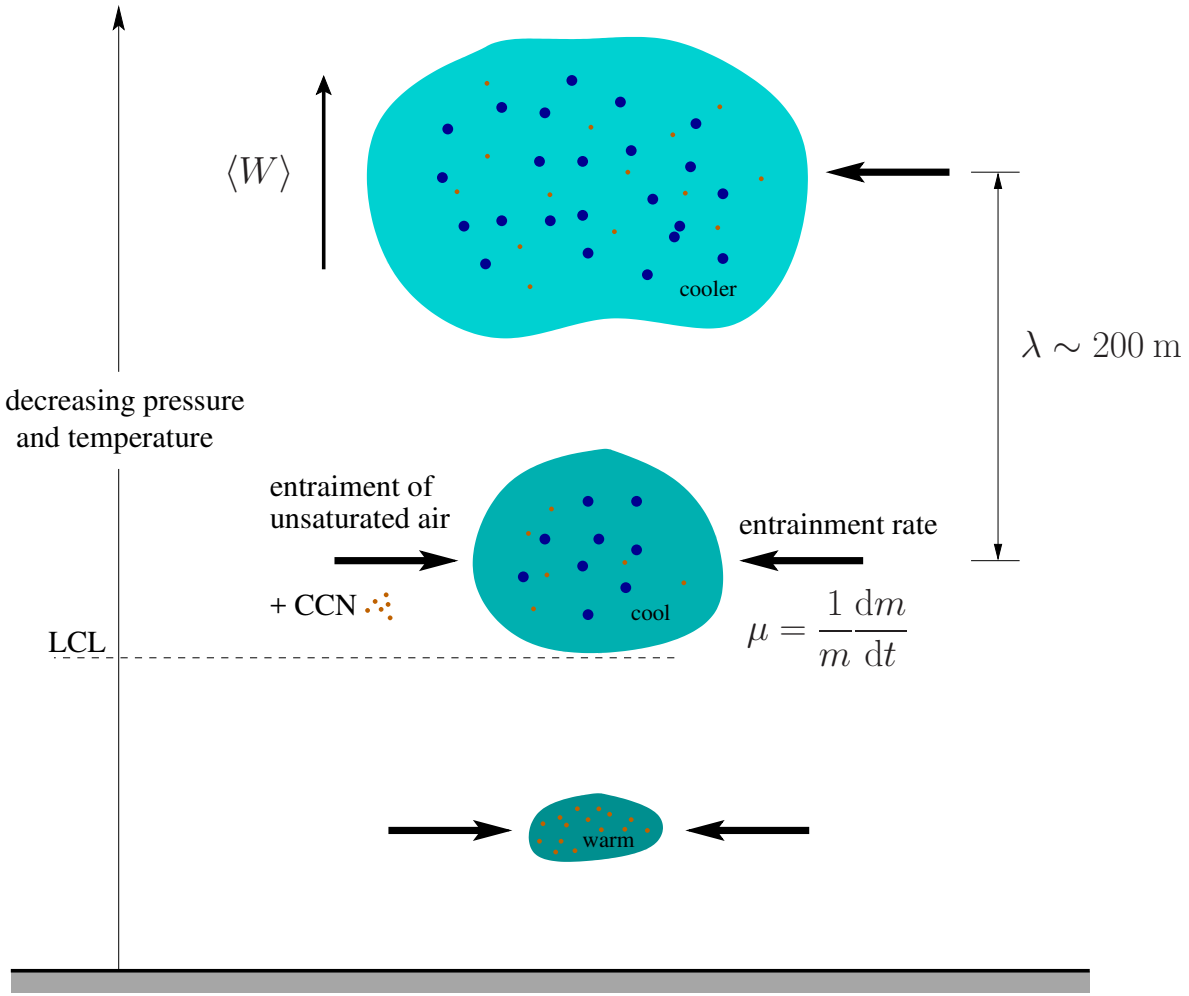
τ_S – condensation and mixing

- Statistical model for $W'(t)$

Grabowski and Abade, JAS, **74** (2017)

Entraining cloud parcel

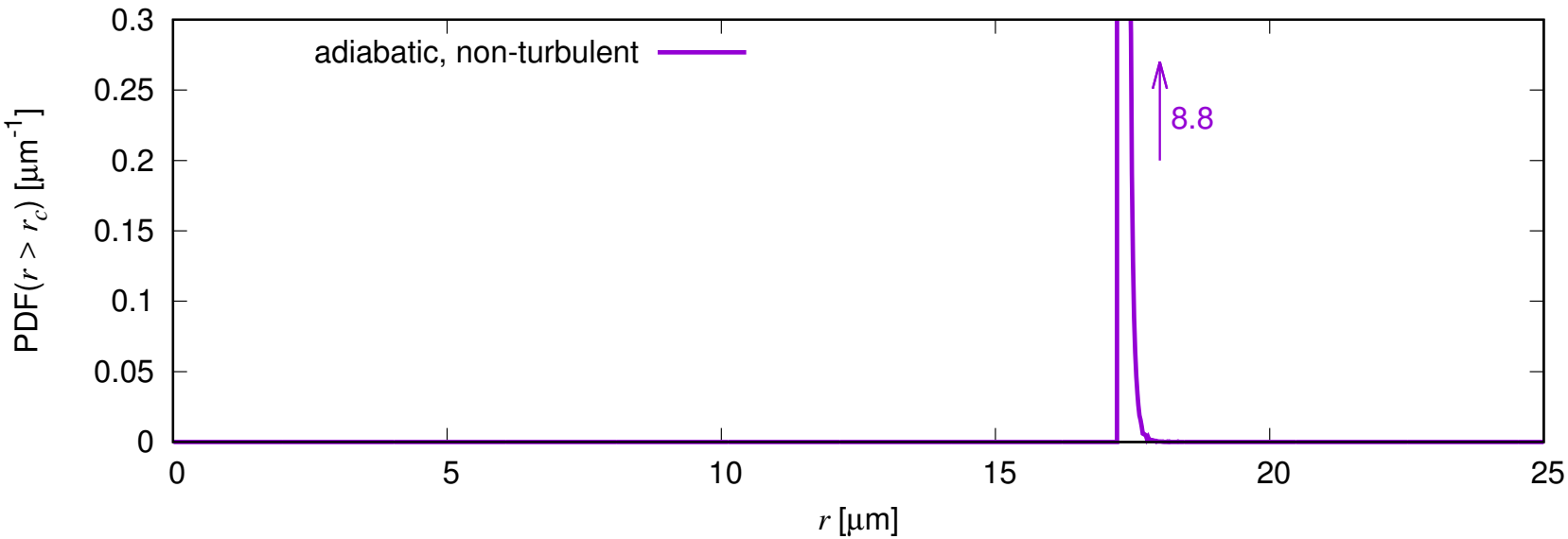
stochastic entrainment events



Krueger *et al.*, JAS, **54** (1997); Romps and Kuang, JAS, **67** (2010)

Droplet-size distribution

after a 1-km parcel rise



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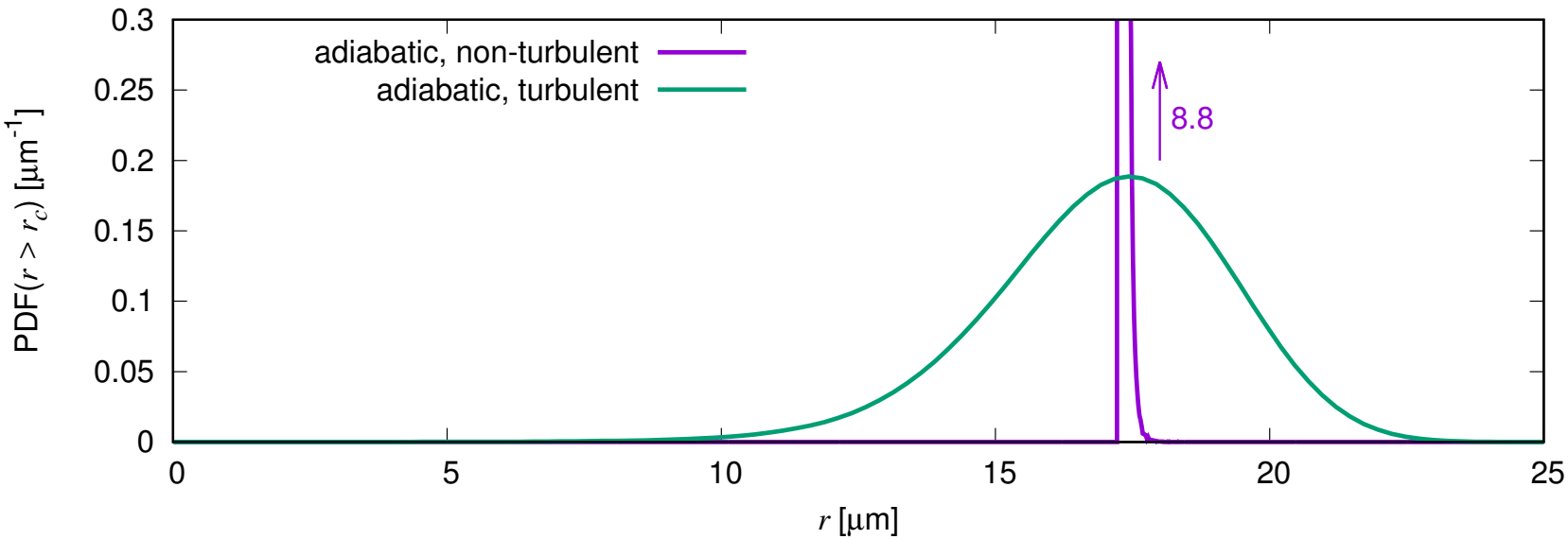

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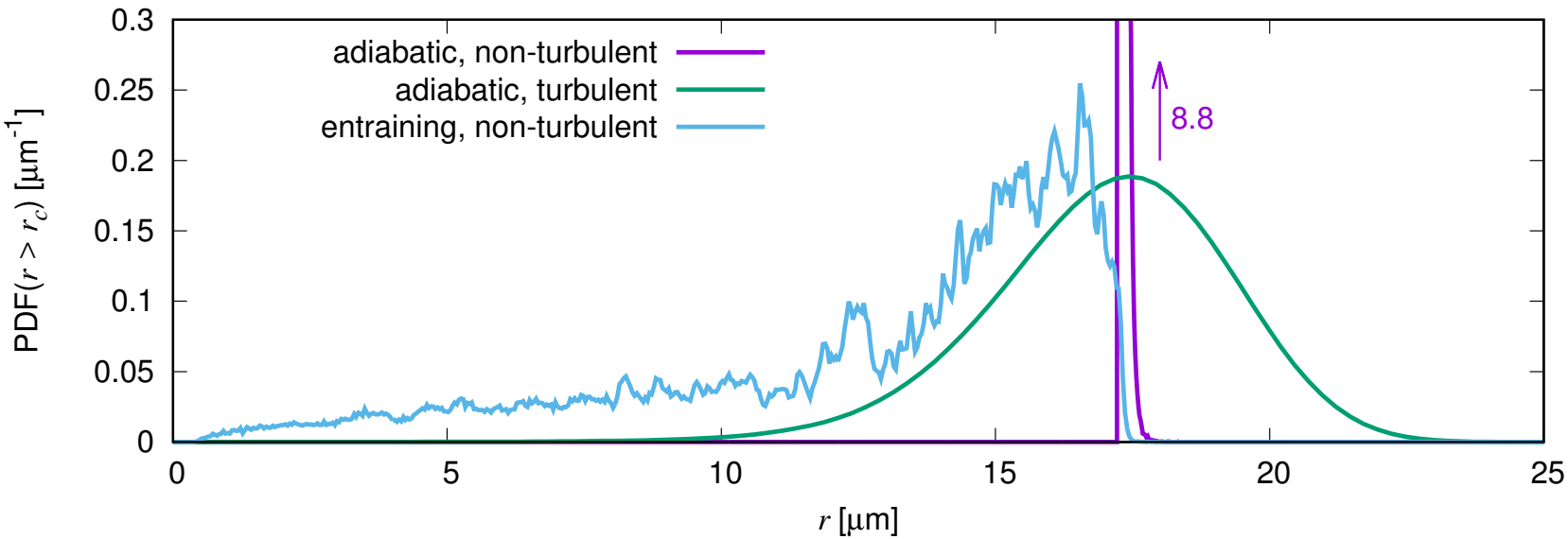

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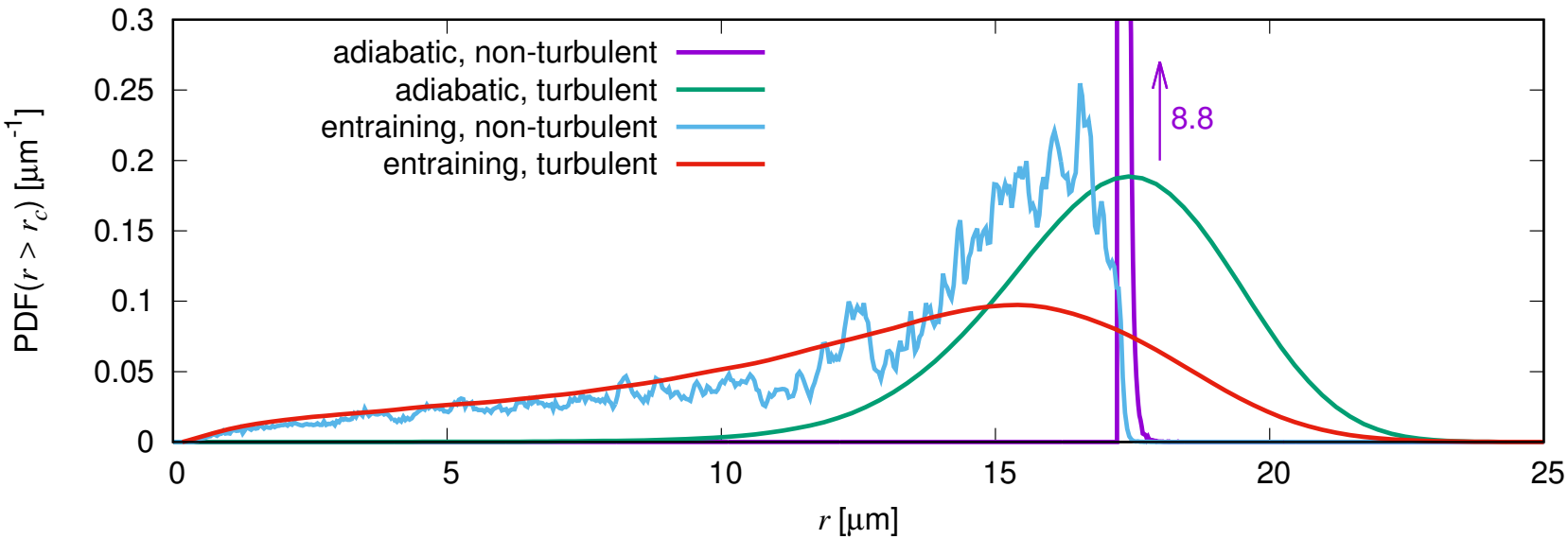

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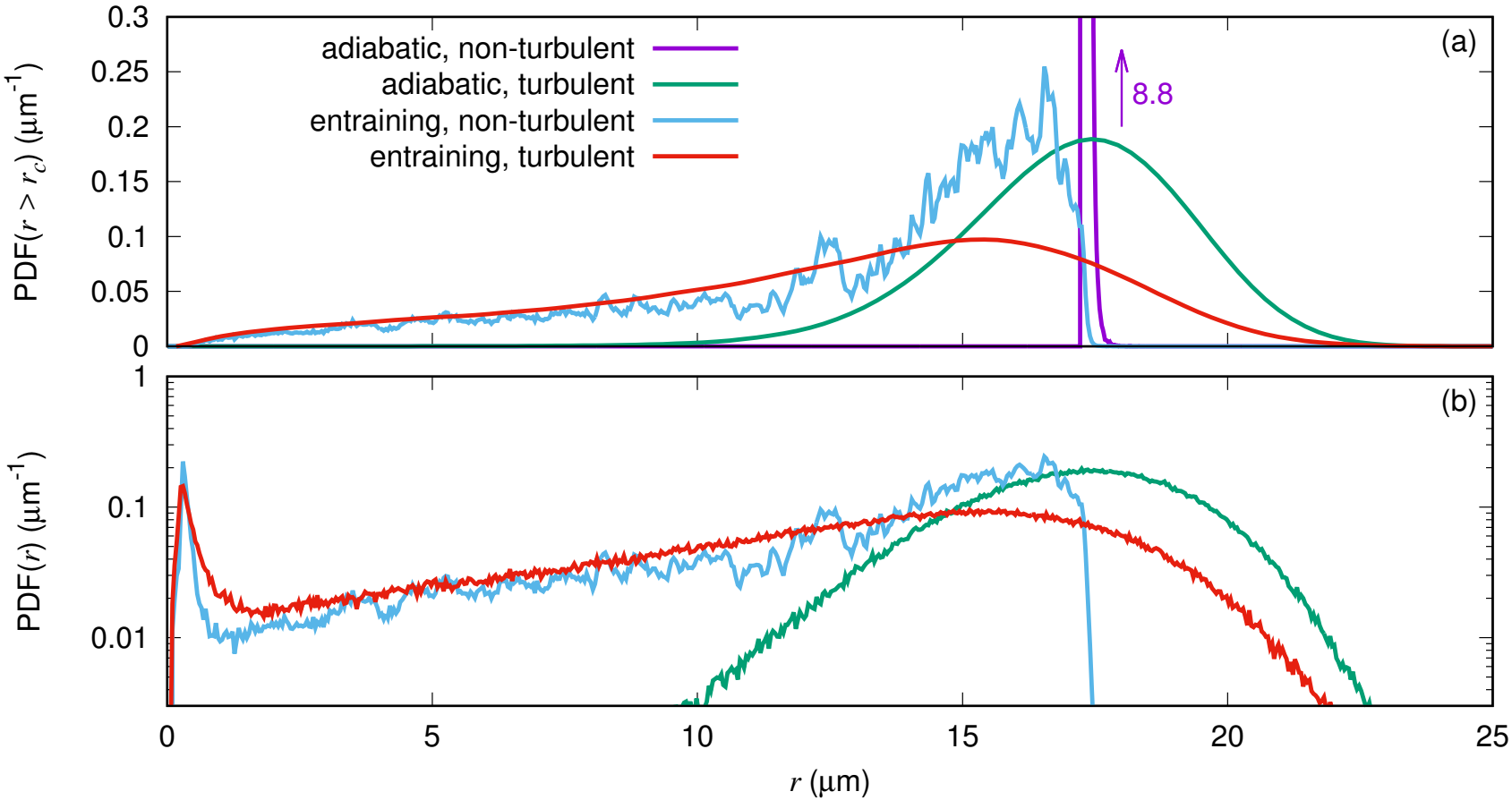
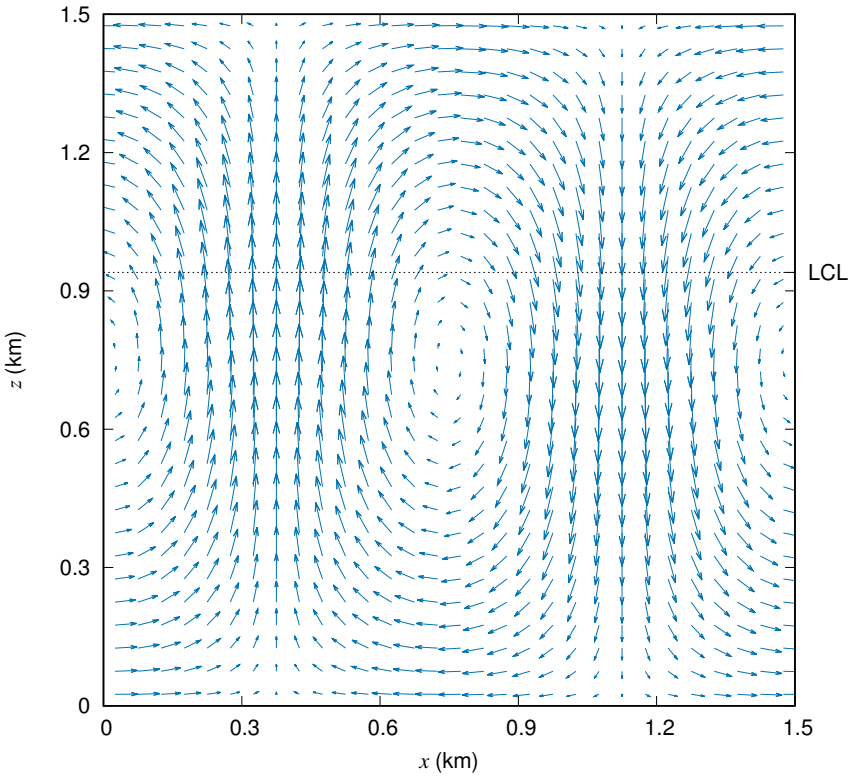
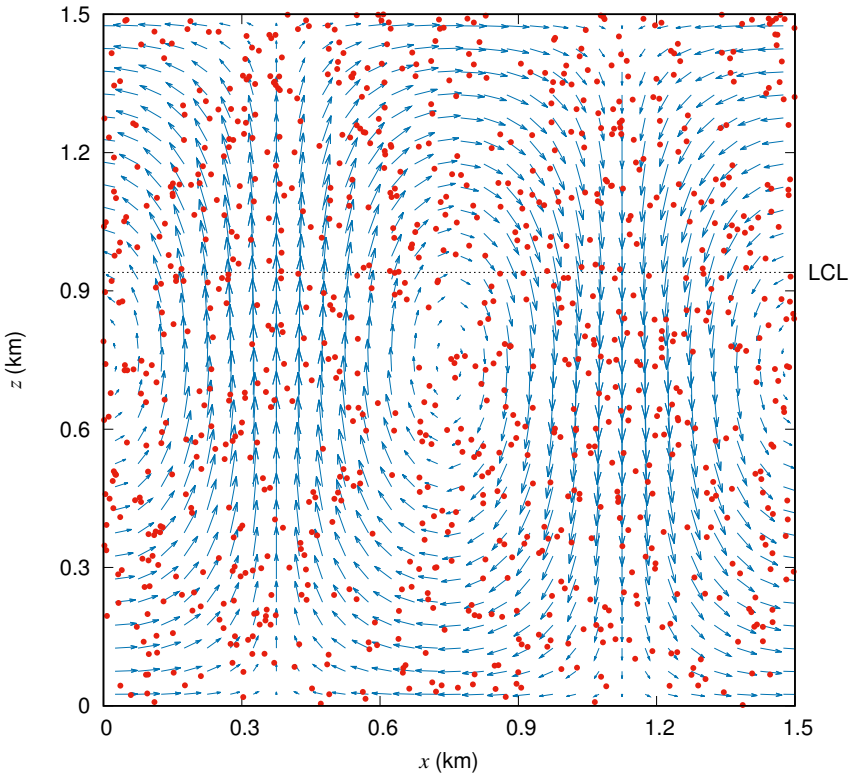


2-D kinematic simulations



- Prescribed flow $\mathbf{u}(\mathbf{r})$
- Balance equations for entropy and water vapor
- Super-droplets
- $\epsilon = 10^{-3}\ \mathrm{m^2\ s^{-3}}$ everywhere

2-D kinematic simulations



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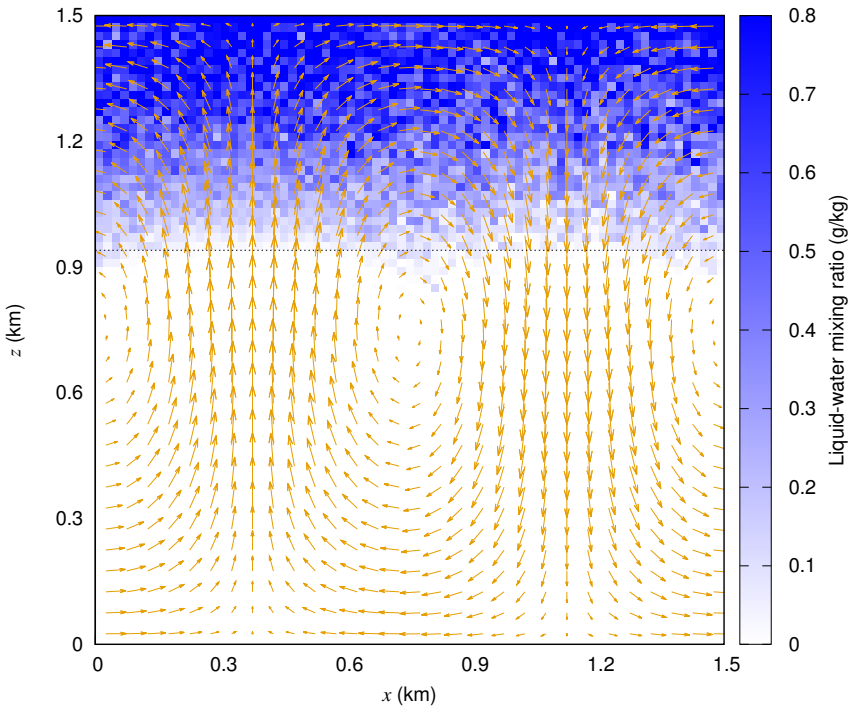
2-D kinematic simulations

Droplet-size PDF



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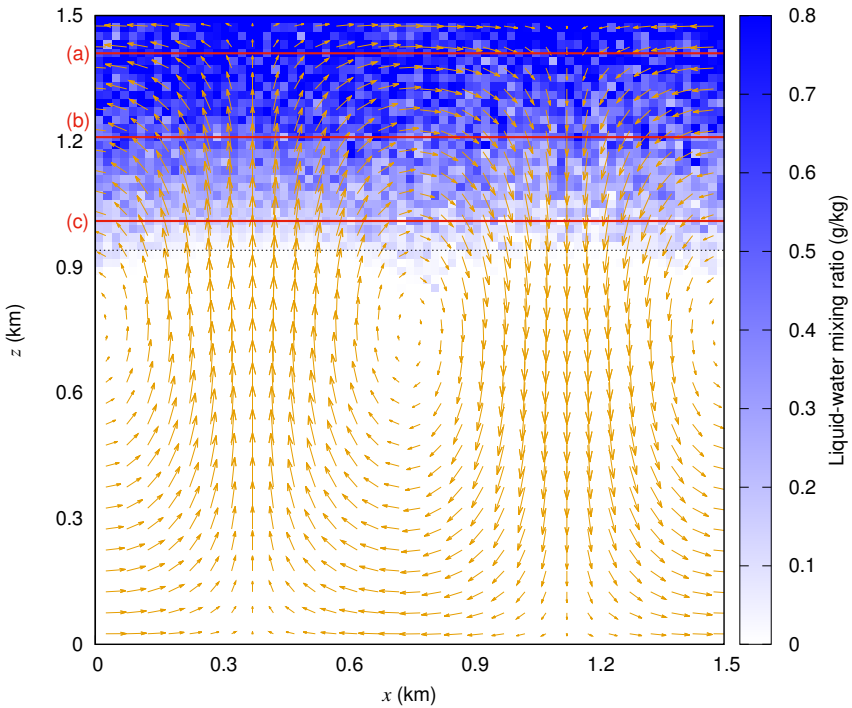

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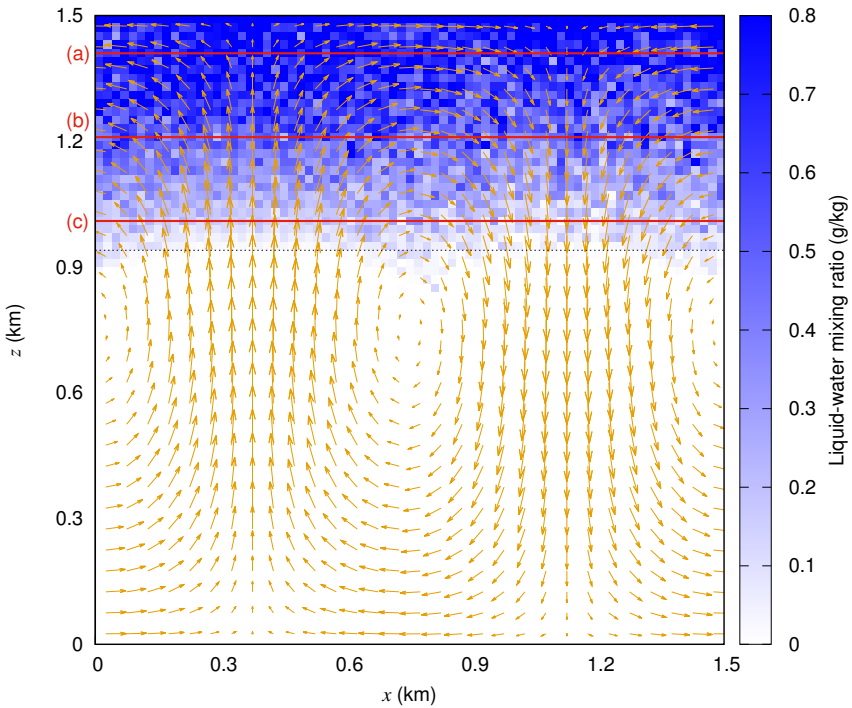
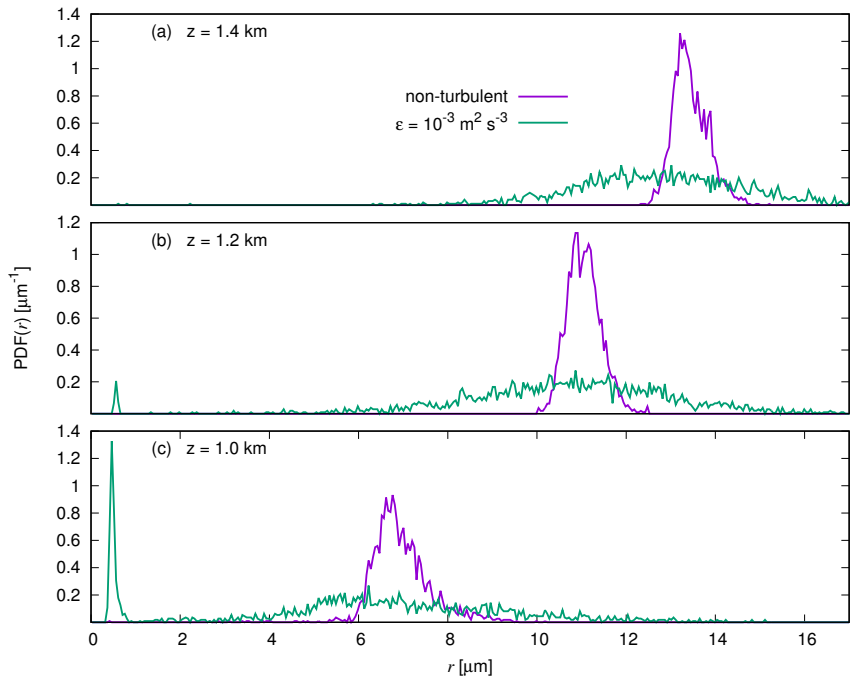
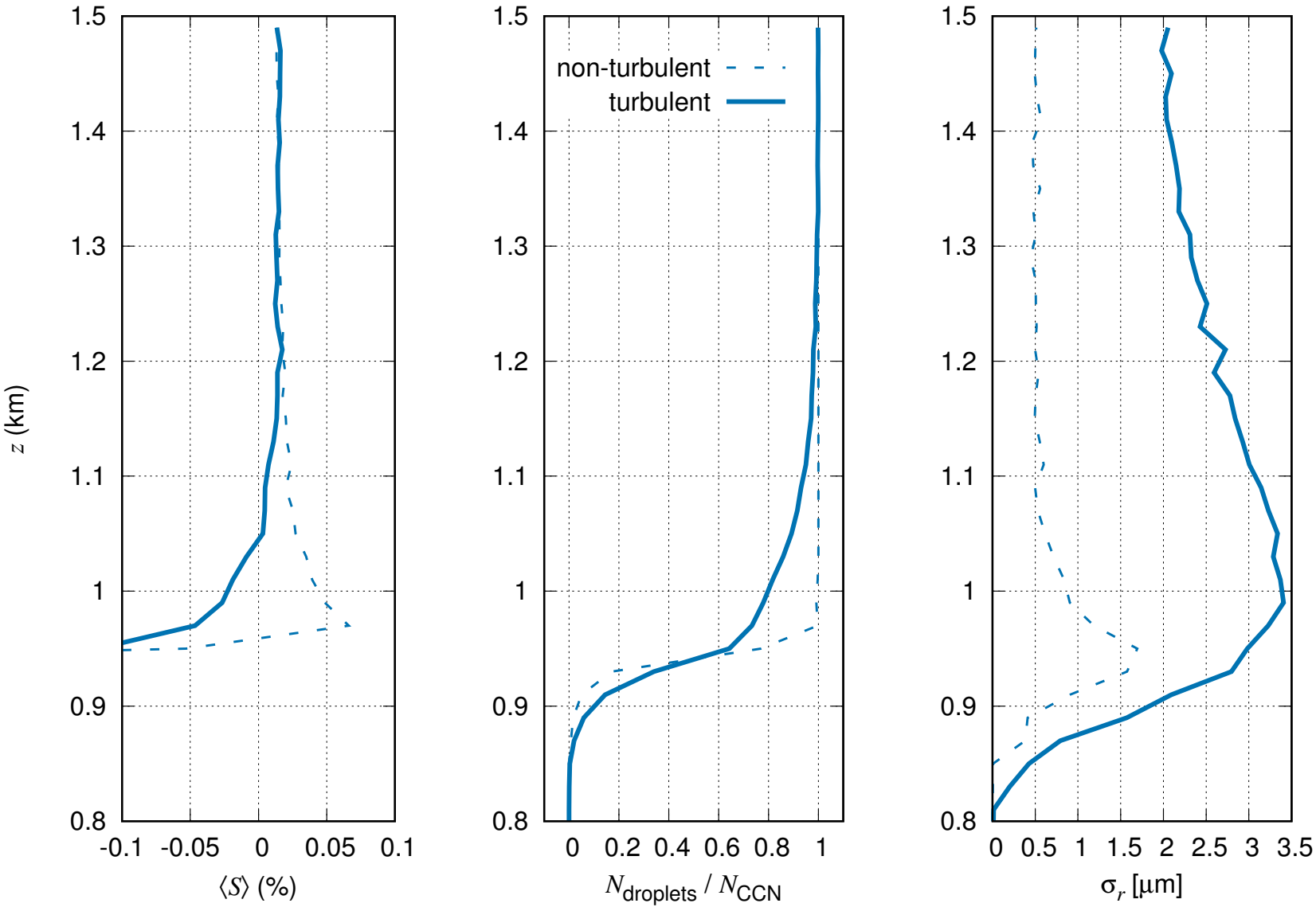




Microphysical profiles

horizontally averaged



Summary and outlook

- Simple model to mimic SGS variability
- Straightforward for super-droplets, difficult for bin microphysics
- Important for rain development through collision/coalescence
- Thermodynamic feedback: extends the distance of activation
- Future: couple the SGS scheme with dynamic LES

Acknowledgements

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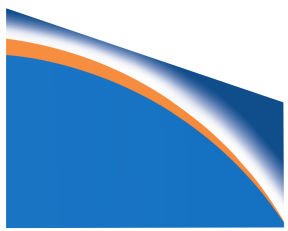
NATIONAL SCIENCE CENTRE
POLAND



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