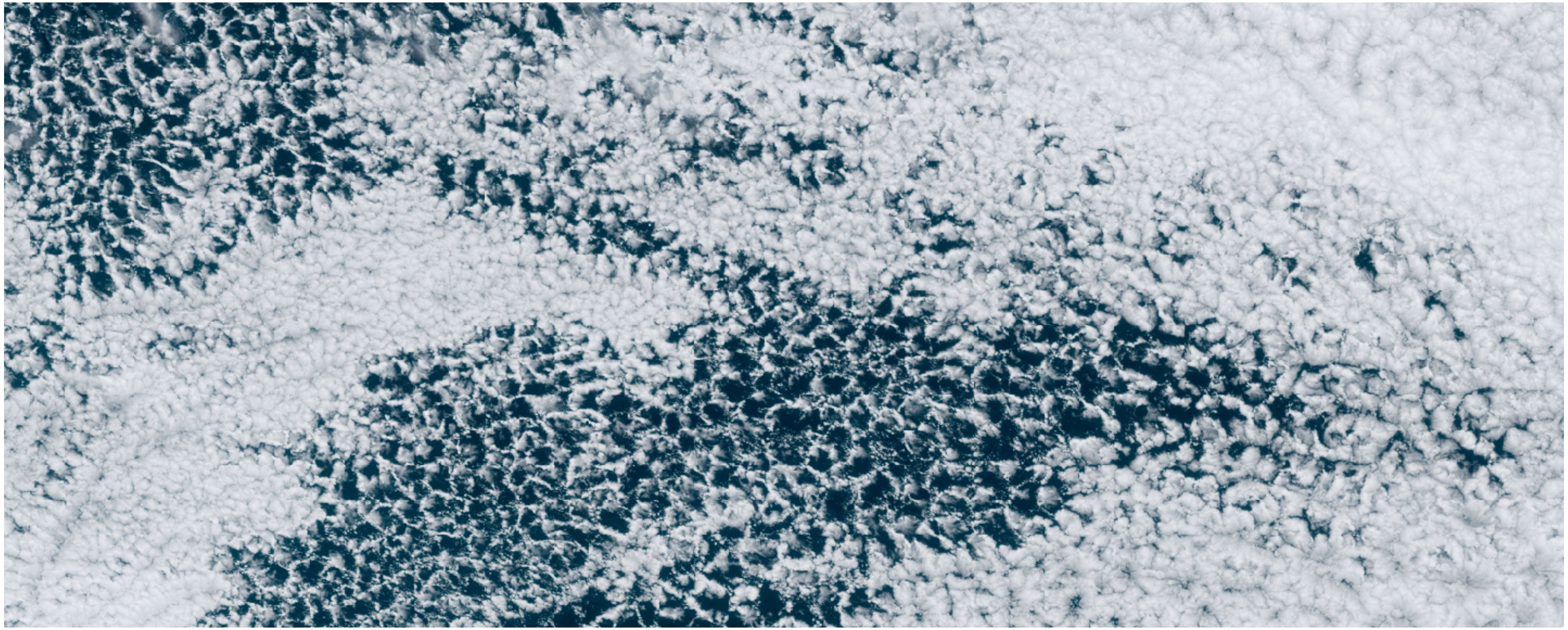
Self-organization of shallow clouds on the mesoscale

Franziska Glassmeier



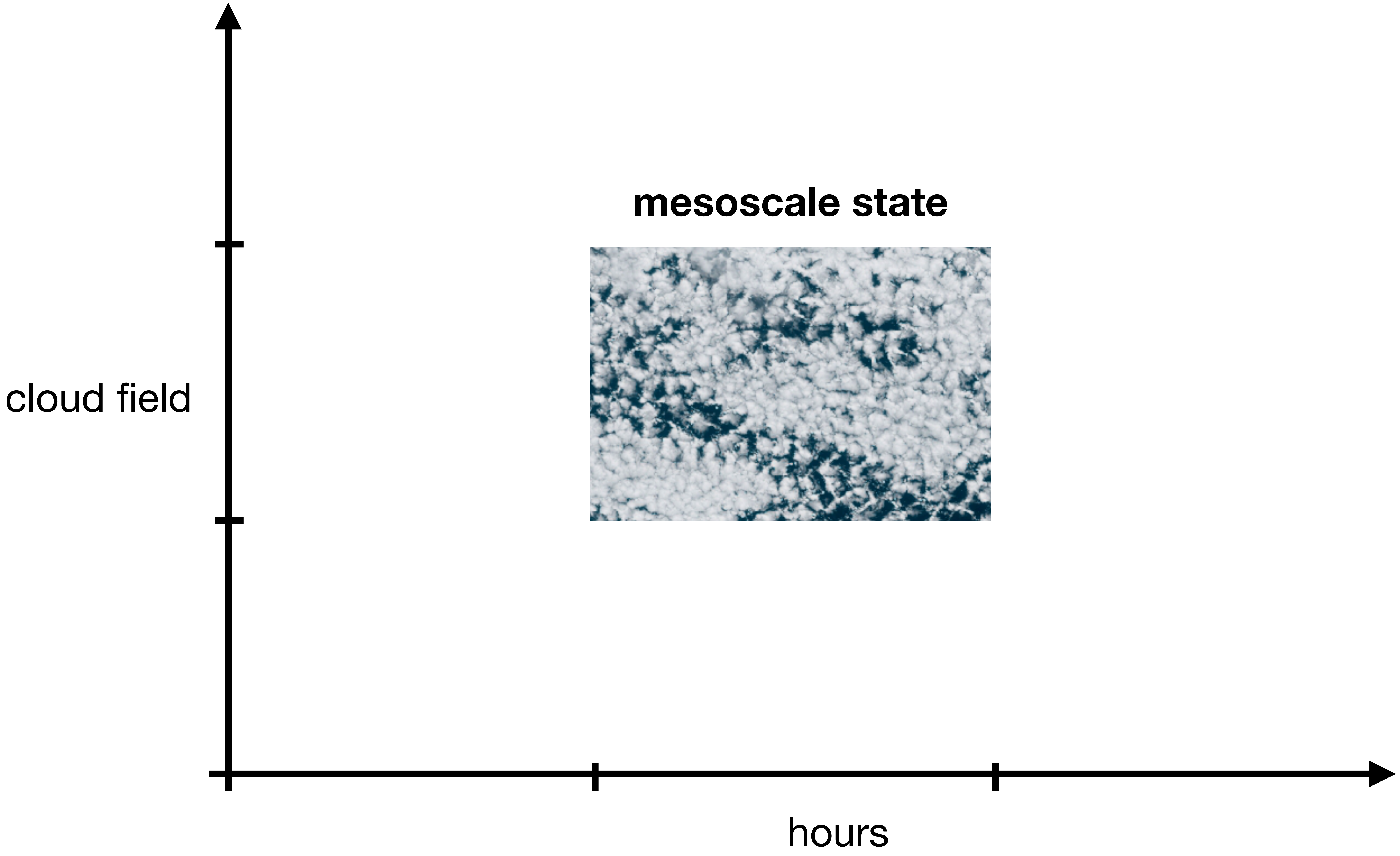
3rd Workshop on Cloud Organization - Training Session **Sep 4, 2023**

TU Delft


Peru
2023-06-12 16:30:20 UTC
CIRA
RAMMB

"Cloud organization" is a mesoscale characteristic:

state of the constellation of clouds in a cloud field



Mesoscale cloudiness dominates cloud-climate uncertainty:

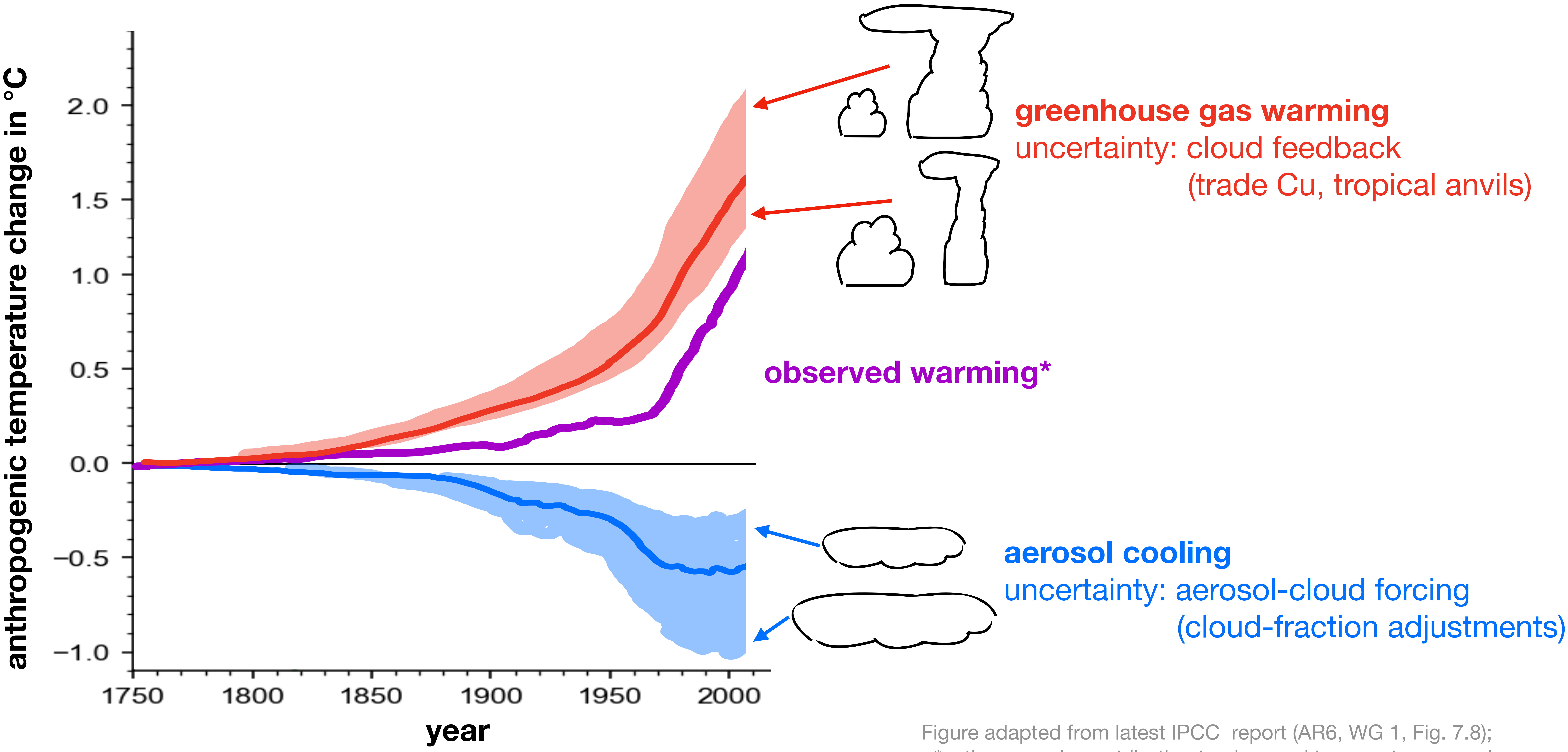
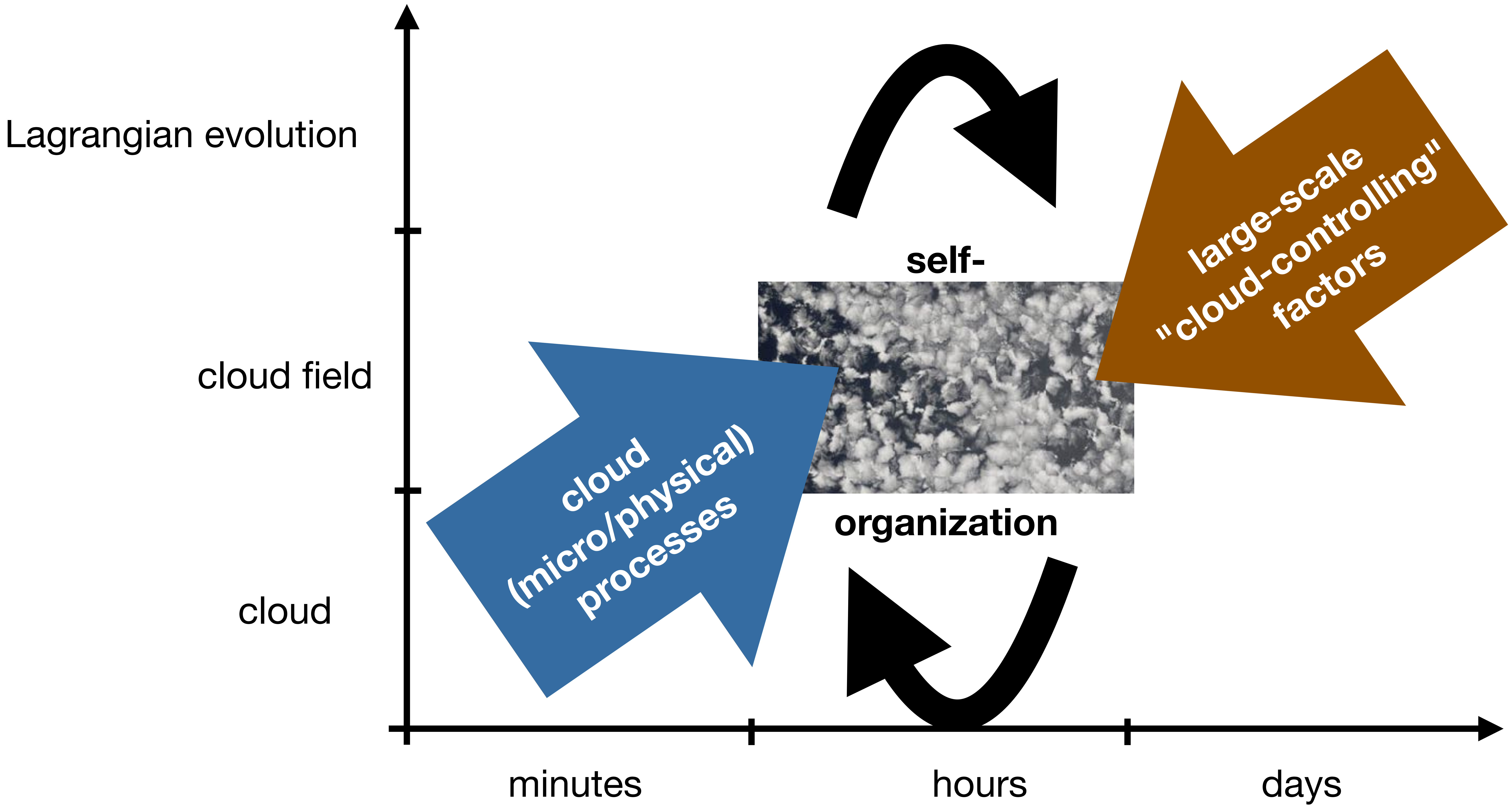


Figure adapted from latest IPCC report (AR6, WG 1, Fig. 7.8);
*anthropogenic contribution to observed temperature record

"Cloud organization" is a multiscale phenomenon:




Peru

Mesoscale self-organization:

emerges from small-scale processes
is not enforced, but modulated, by larger scales

Self-organization of stratocumulus cells:

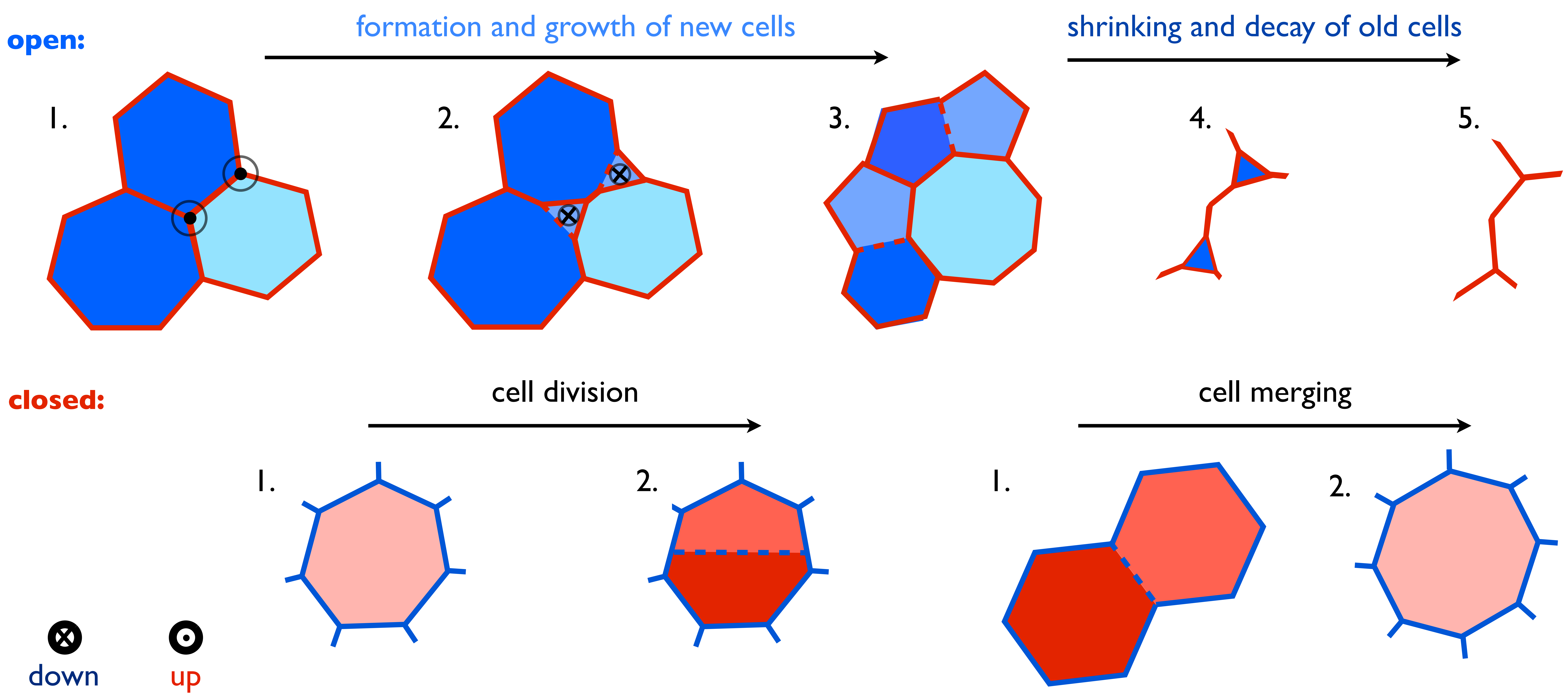
[Sketch:
Glassmeier & Feingold,
PNAS, 2017]

closed cells:
high aerosol ~> no rain

open cells:
low aerosol~> rain

Cellular network description of self-organization:

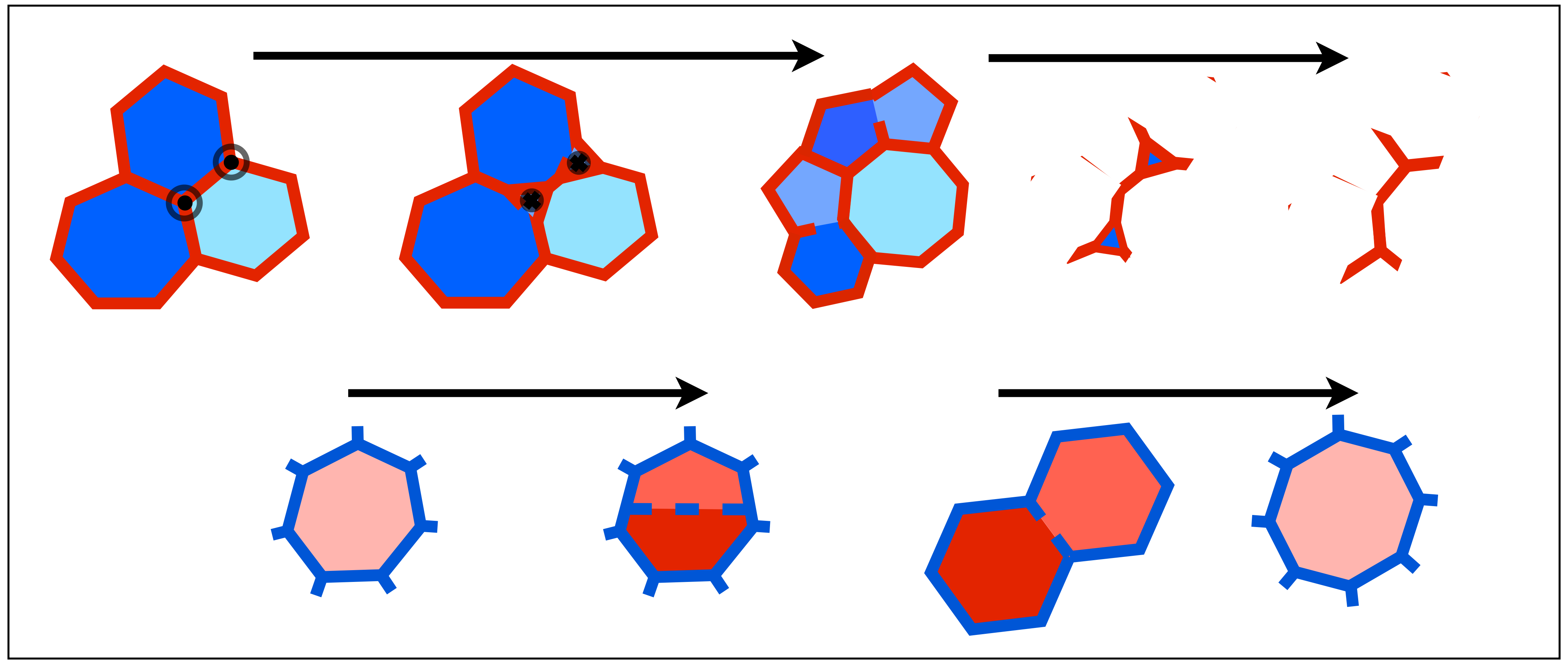
[Glassmeier & Feingold, PNAS, 2017]



Predictive network model vs LES cell arrangement:

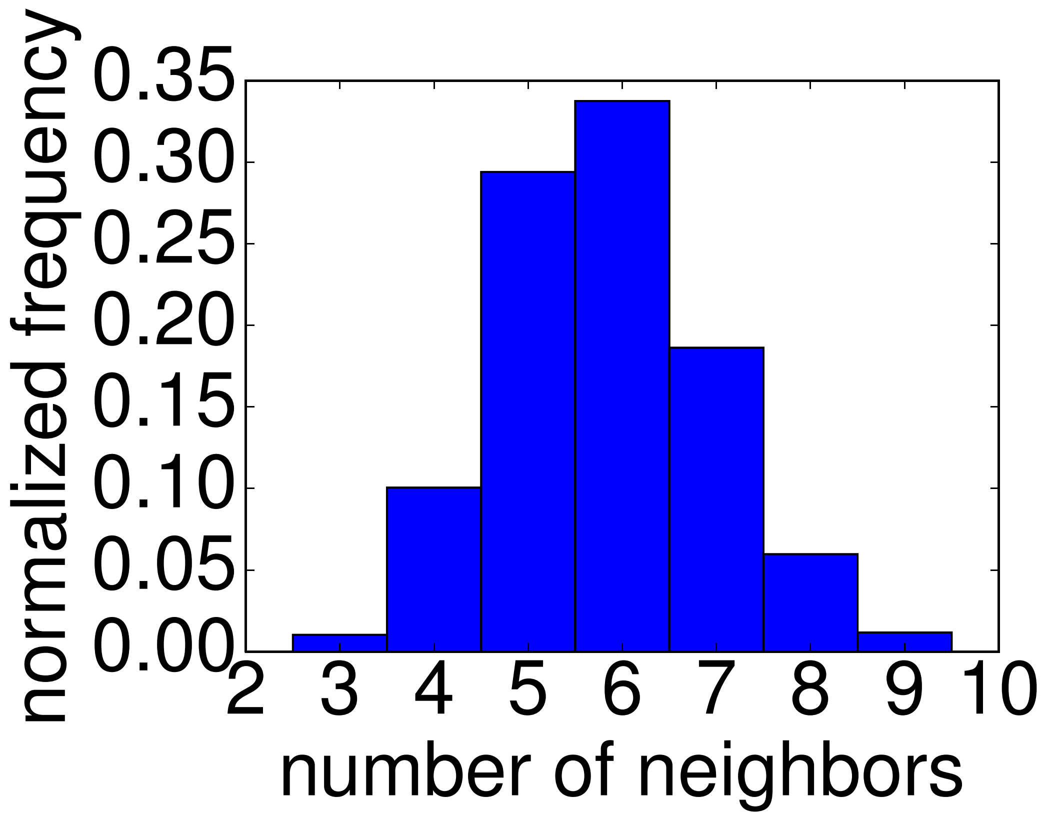
[Glassmeier & Feingold, PNAS, 2017]

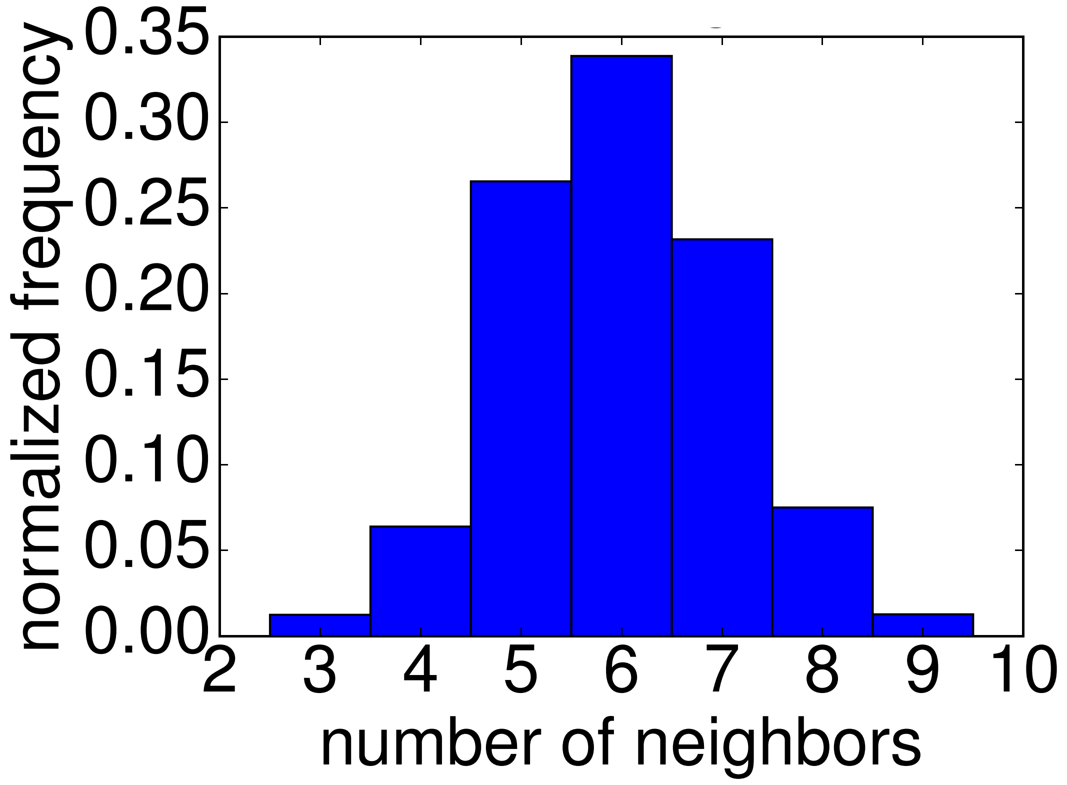
initial cellular network →



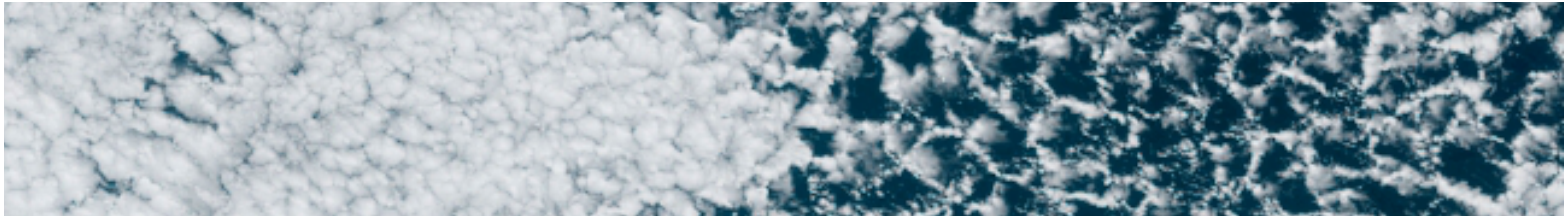
→ steady-state network shaped by rules

	LES	network model
variance of neighbor distribution	1,8	1,3
"large surrounded by small"	yes	yes





Self-organization of stratocumulus thickness:



[Sketch:
Glassmeier & Feingold,
PNAS, 2017]

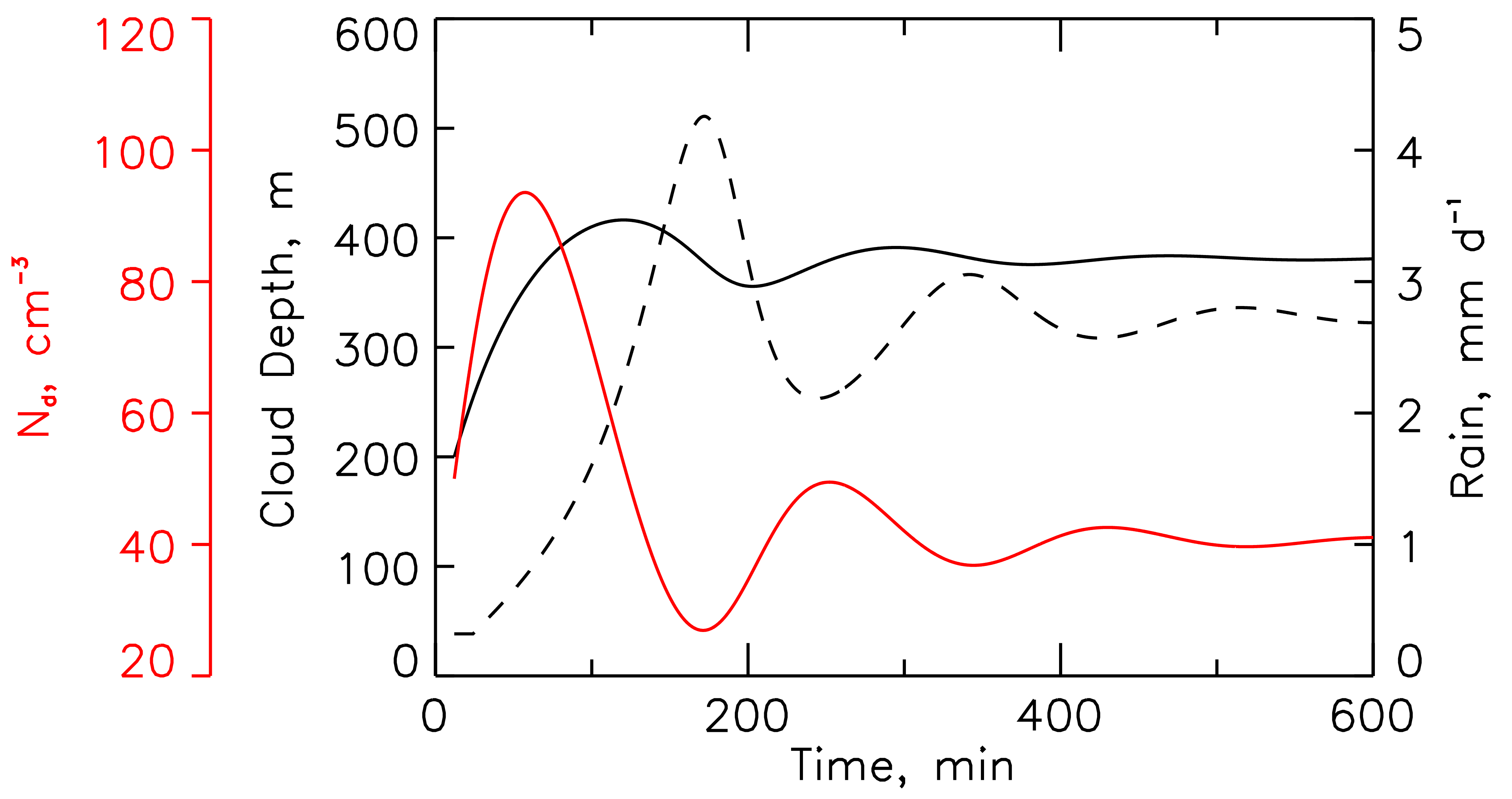
closed cells:
high aerosol ~> no rain

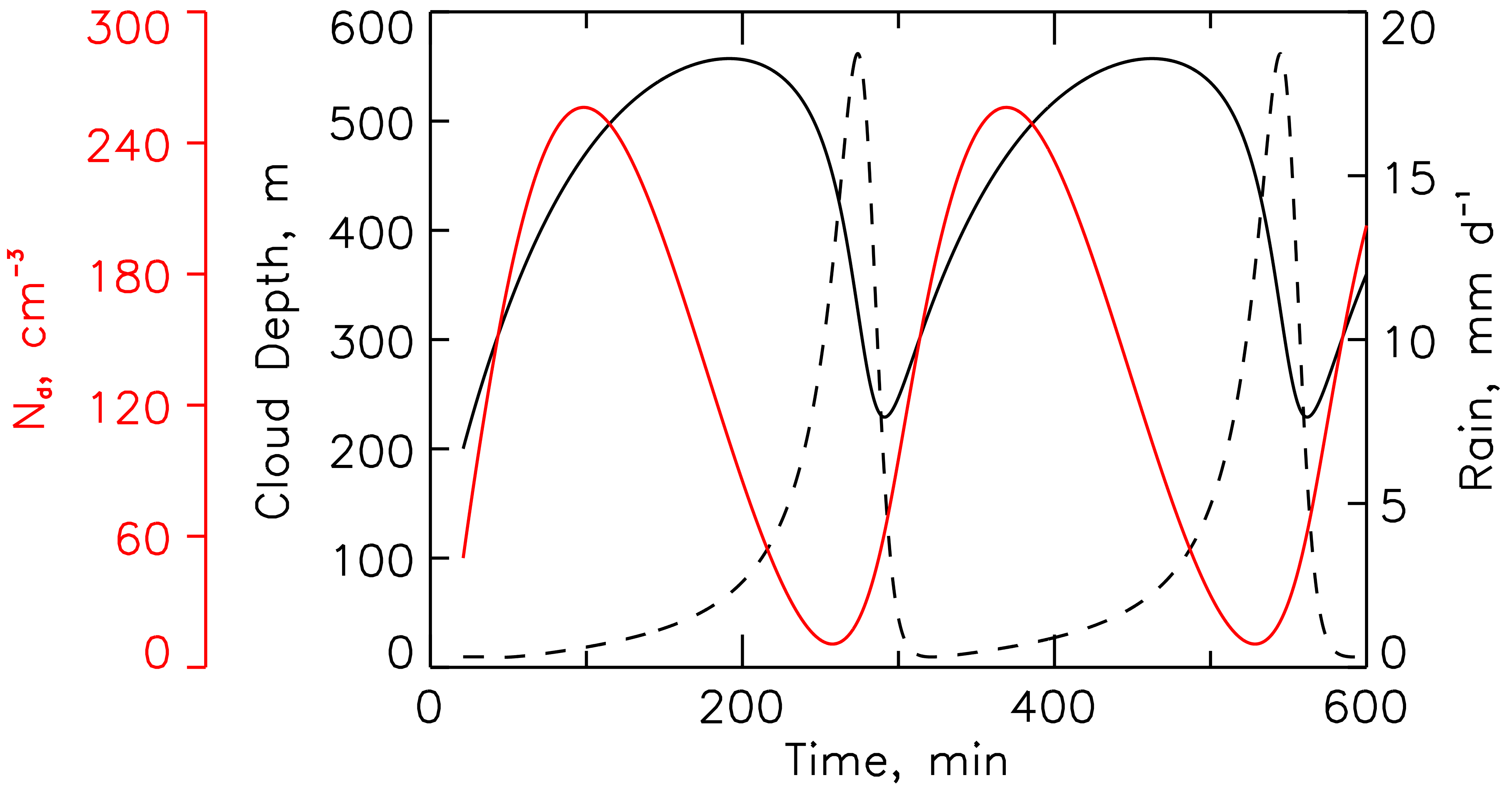
open cells:
low aerosol~> rain

Predator-prey model for stratocumulus:

[Koren & Feingold, *PNAS*, 2011; Koren et al., *Chaos*, 2017]

$$\frac{\mathrm{d}H}{\mathrm{d}t} = \underbrace{\frac{H_0 - H}{\tau_H}}_{\text{cloud...}} \underbrace{- \frac{\alpha}{\sqrt{N}} H^2(t-T)}_{\text{...feeds rain}}$$



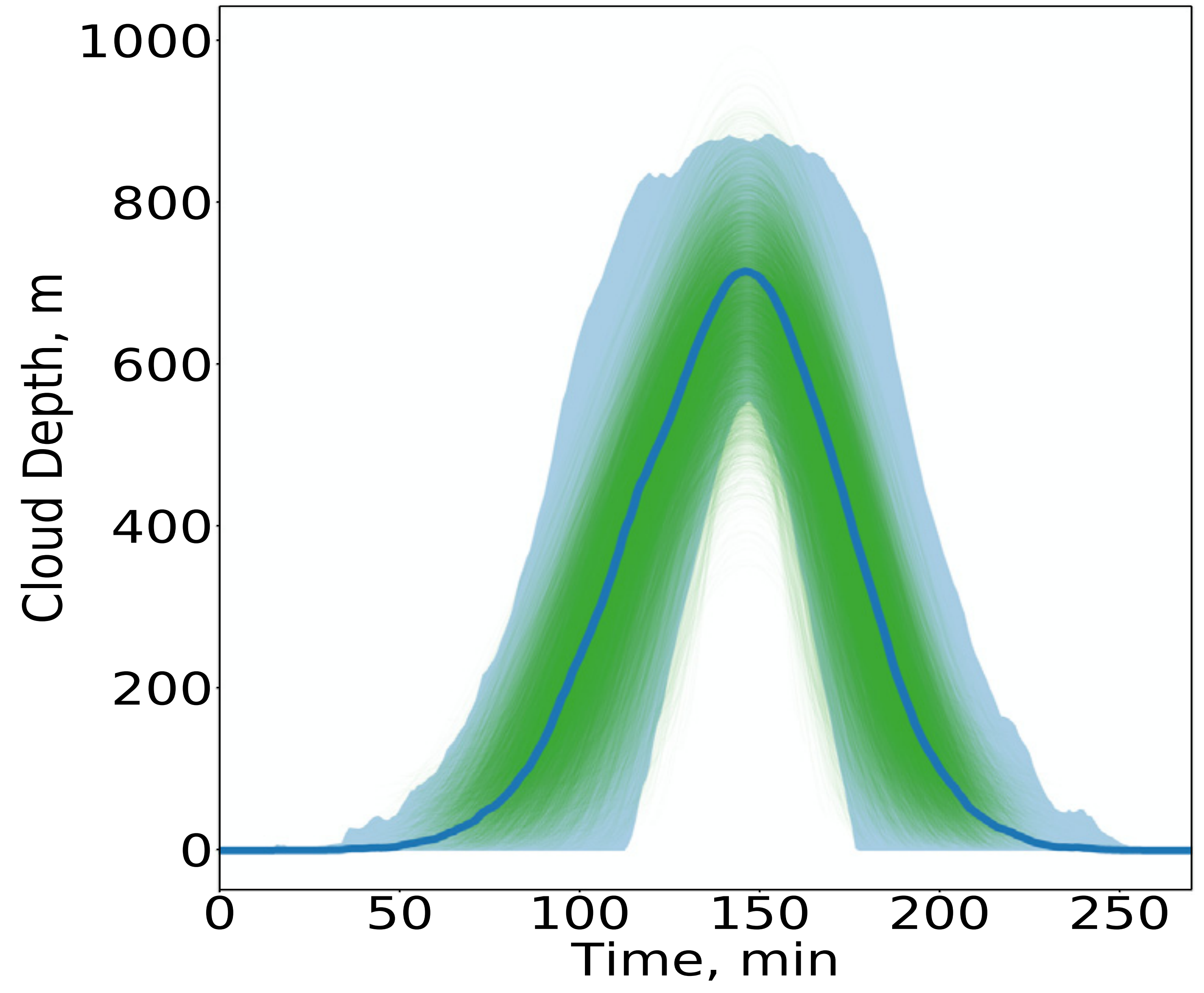


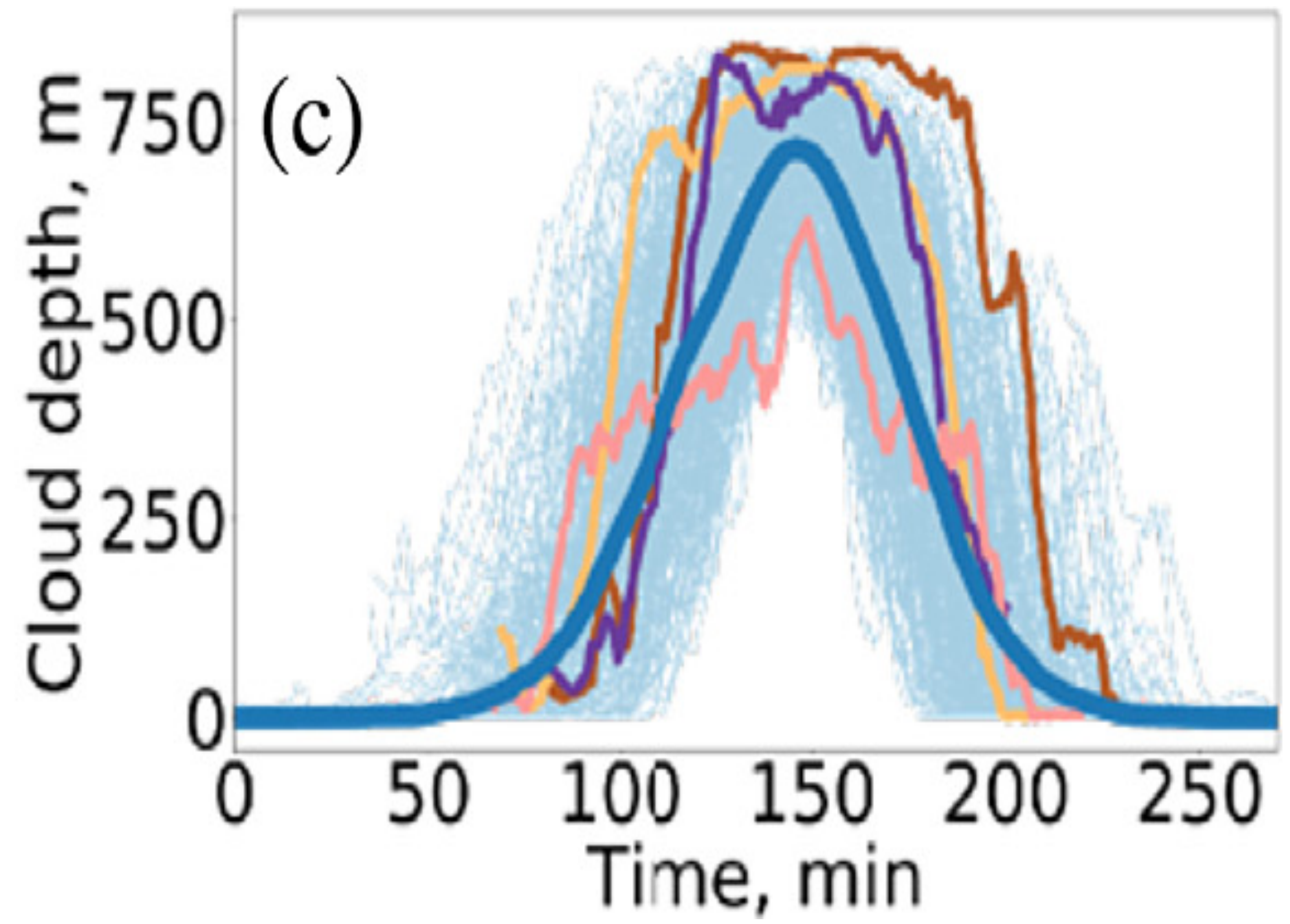
Predator-prey vs LES oscillations:

[Lunderman et al., *Physica D*, 2020]

$$\frac{\mathrm{d}H}{\mathrm{d}t} = \underbrace{\frac{H_0 - H}{\tau_H}}_{\text{cloud...}} \underbrace{- \frac{\alpha}{\sqrt{N}} H^2(t-T)}_{\text{...feeds rain}}$$

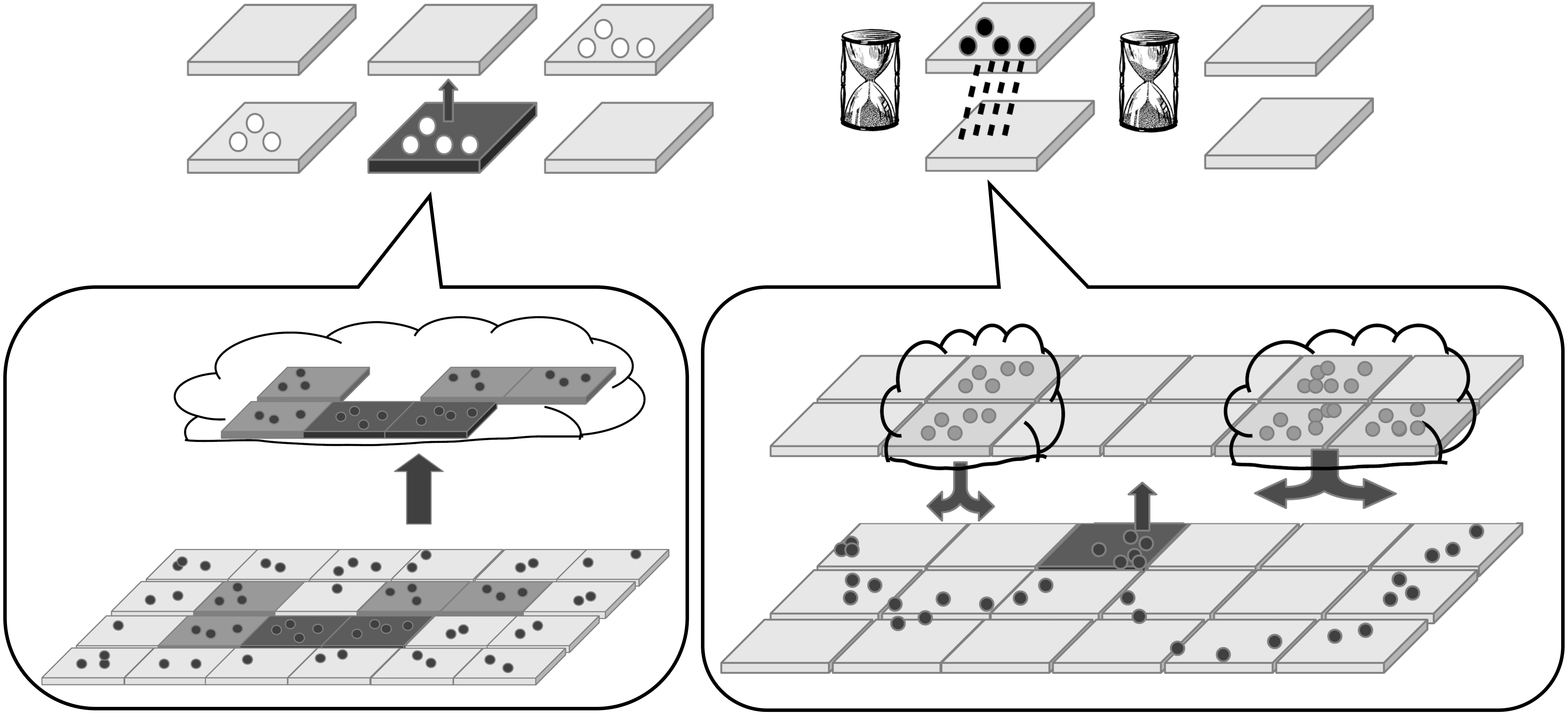
$$H_0 = 2063\,\mathrm{m}$$
$$\tau_H = 120\,\mathrm{min}$$
$$T = 33\,\mathrm{min}$$





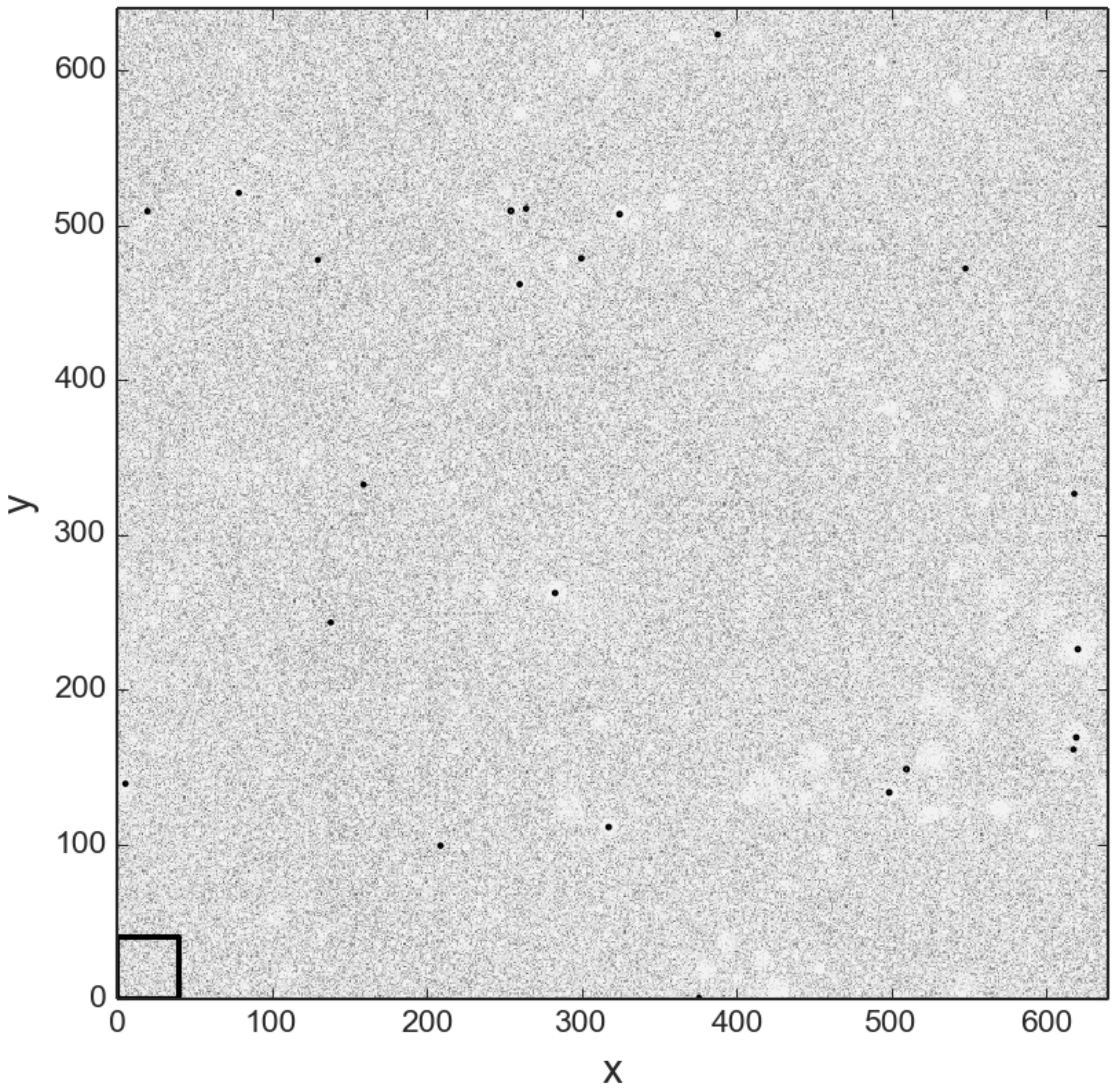
Intermediate complexity model for cellular convection:

[Böing, Math. Clim. Weather Forecast., 2016]

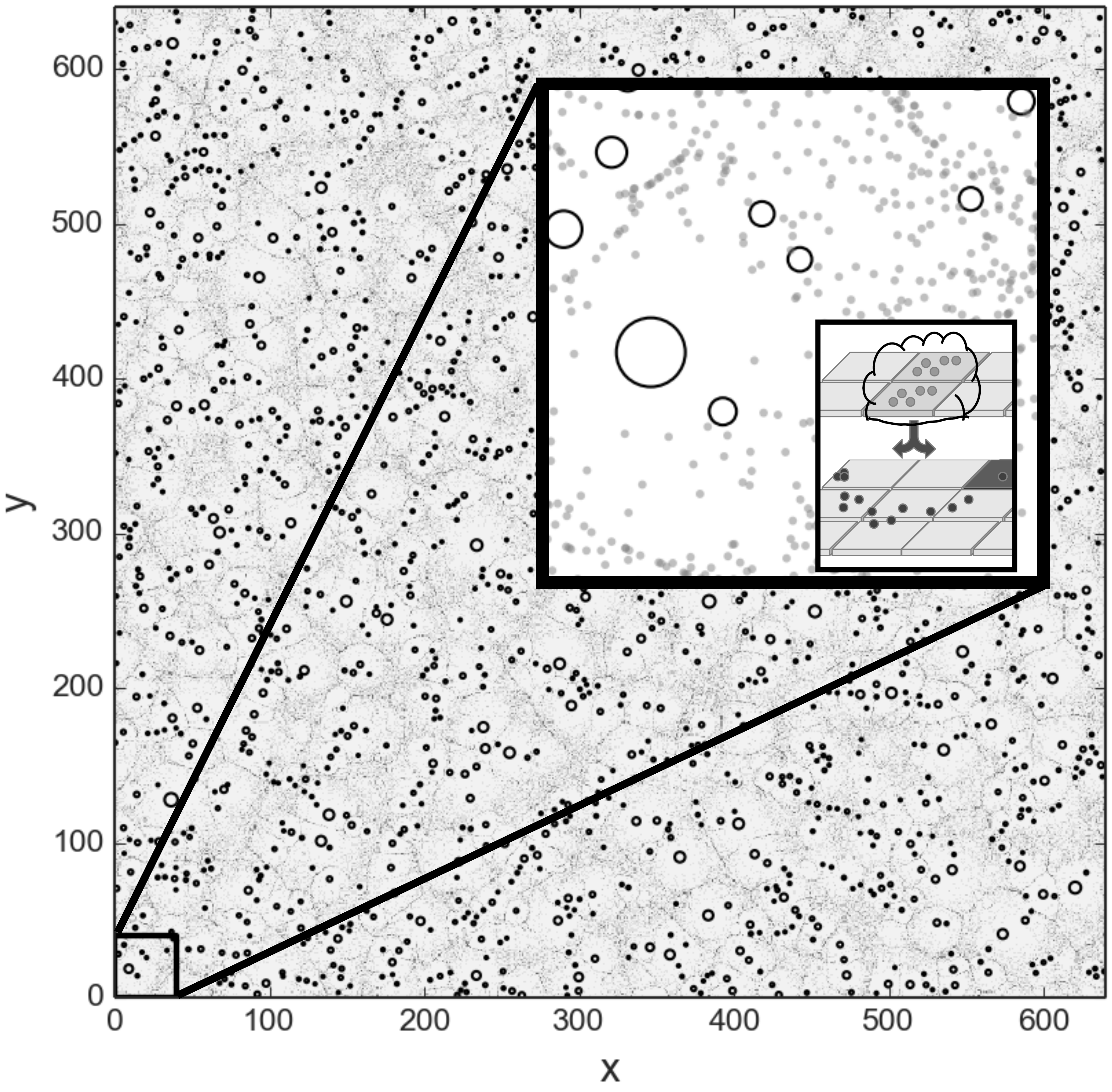


[Böing, Math. Clim. Weather Forecast., 2016]

cold-pool suppression:
no cells



cold pools:
cellular convection



Concluding questions:

- What's the minimum number of clouds to get organization?
- What's the role of cloud controlling factors for organization?
- What's the role of N in the predator-prey model?
- What's a useful degree of complexity for a toy model?
- Do we have to understand self-organization to reduce cloud-climate uncertainty?