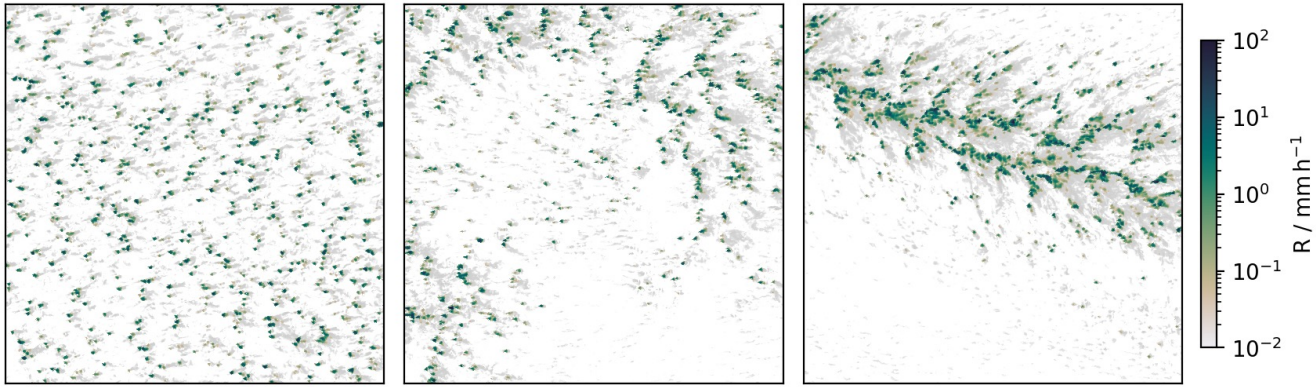
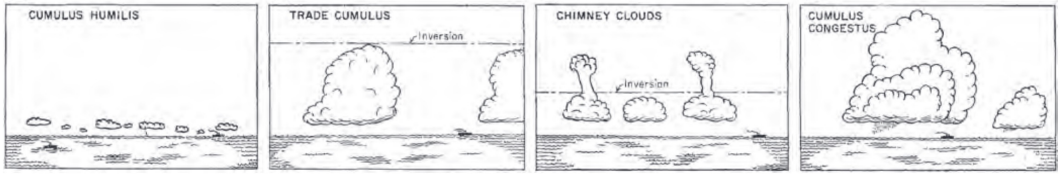
How pathways to precipitation vary with spatial organization in LES simulations of the trades



Jule Radtke, Raphaela Vogel, Felix Ament (UHH), Ann Kristin Naumann (MPI-M)

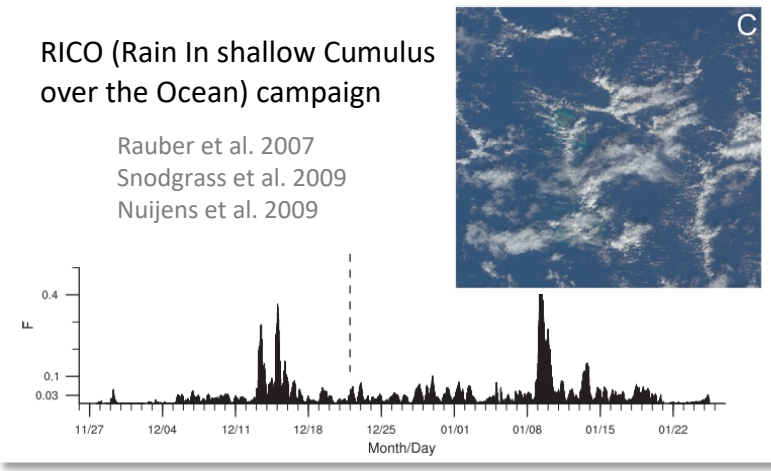
Trade wind clouds – commonly precipitate and organize into a variety of spatial structures



Different cloud types in the trades, taken from Riehl (1954)

RICO (Rain In shallow Cumulus over the Ocean) campaign

Rauber et al. 2007
Snodgrass et al. 2009
Nuijens et al. 2009



Do we miss a cloud feedback component?

(Bony et al. 2020)

What is the relationship between precipitation and spatial organization in the trades?

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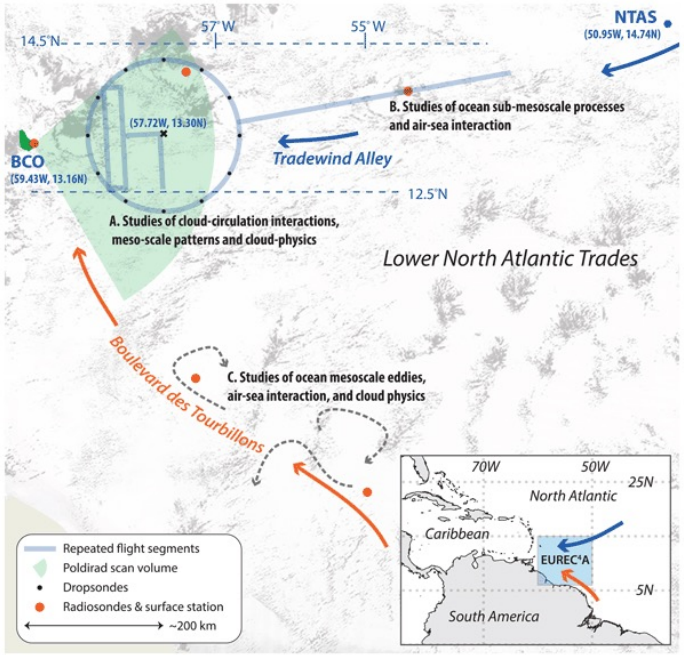
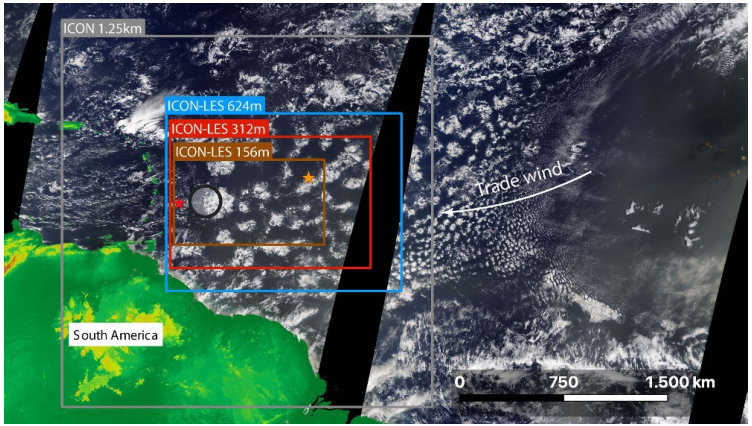


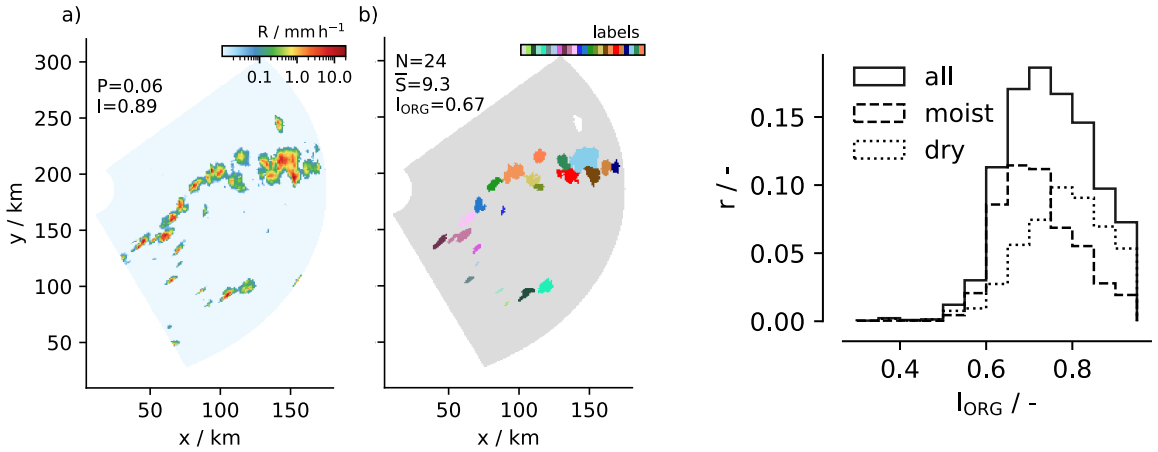
EUREC4A Field Campaign
January, February 2020



What is the relationship between precipitation and spatial organization in the trades?

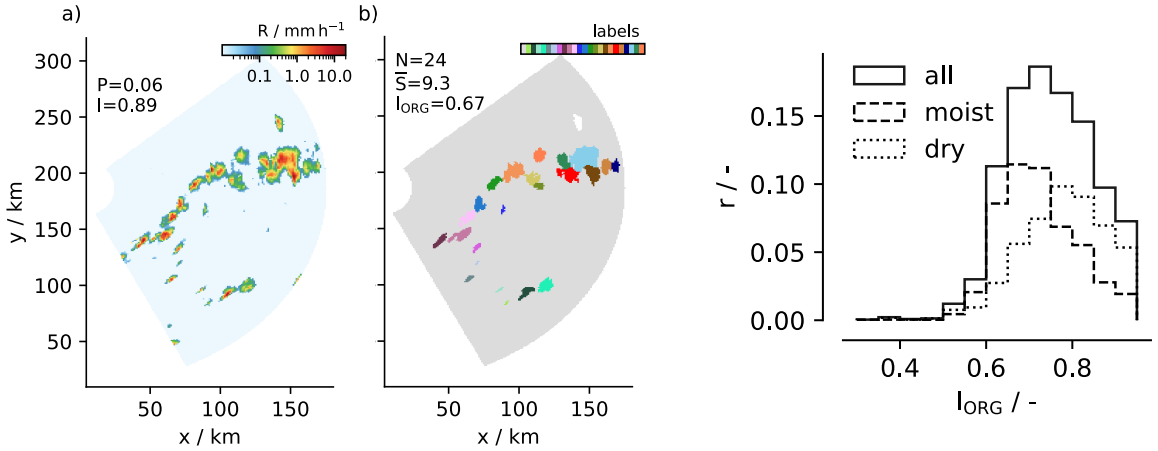
- Scenes with precipitation are almost always clustered

Radtke et al. (2022), QJRMS



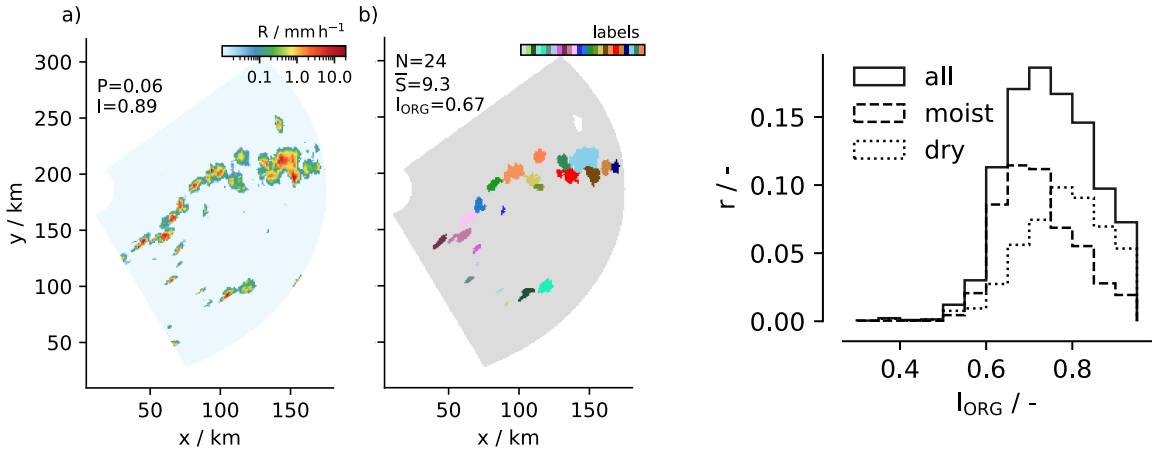
What is the relationship between precipitation and spatial organization in the trades?

- Scenes with precipitation are almost always clustered, but precipitation varies mainly independently from the cells' degree of clustering.
  Radtke et al. (2022), QJRMS



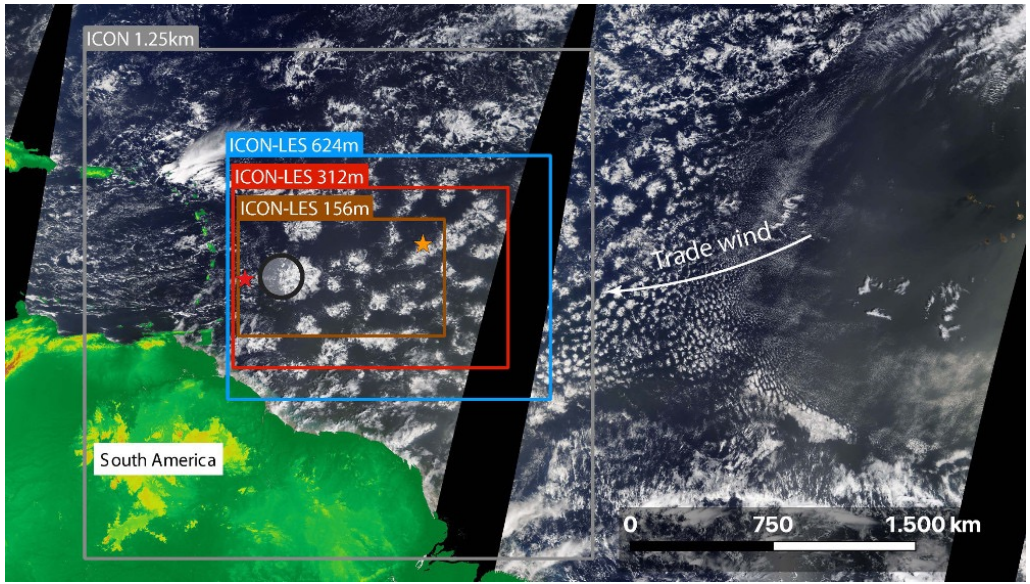
What is the relationship between precipitation and spatial organization in the trades?

- Could spatial organization be a process to maintain precipitation in very different environments, enabling or creating different pathways to precipitation?



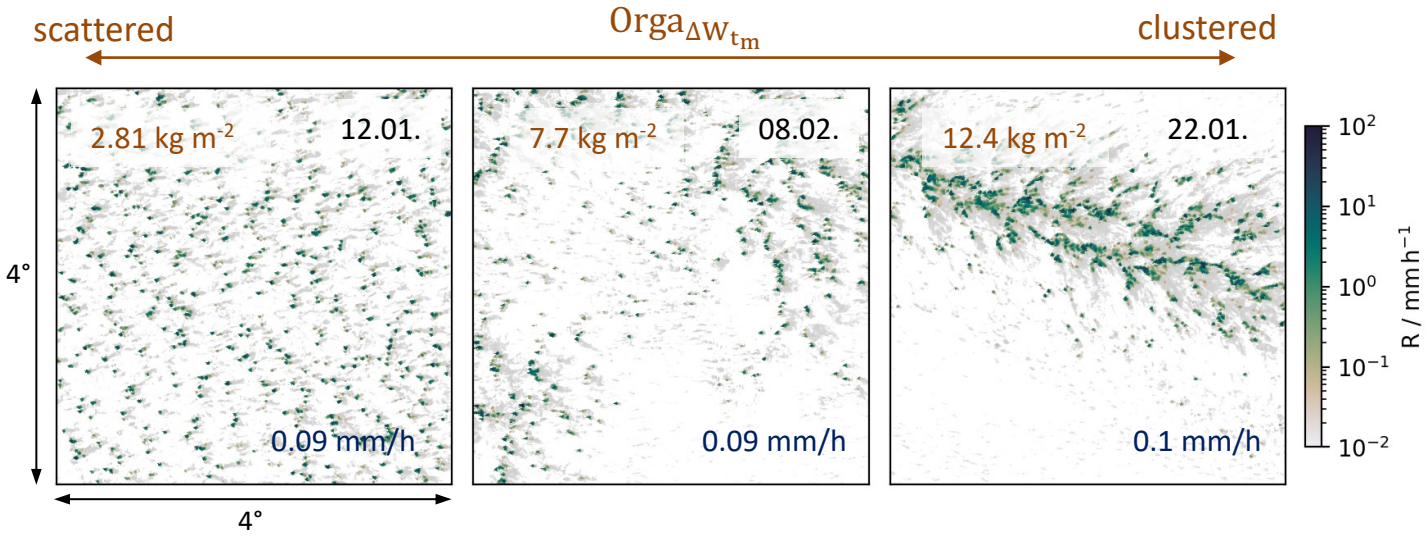
How do pathways to precipitation differ with organization?

Large Domain ICON LES Simulations*, 600m gridspacing



* by Hauke Schulz

How do pathways to precipitation differ with organization?



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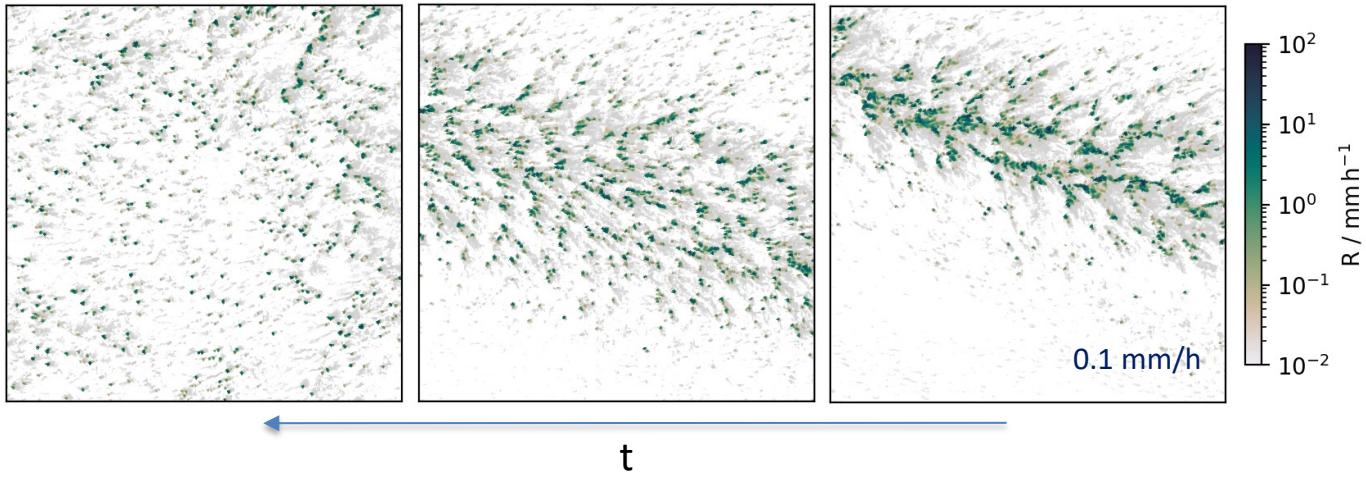
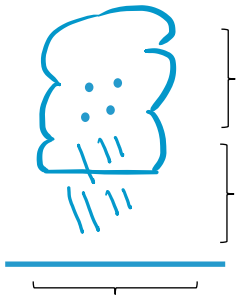


How do pathways to precipitation differ with organization?

$$P = A \cdot \frac{P}{A}$$

Precipitation | Production | Sedimentation Efficiency



A - Autoconversion (+Accretion) (cloud > rain water)

Sedimentation $\frac{P}{A} = 1 - \frac{E}{A}$

E - Evaporation

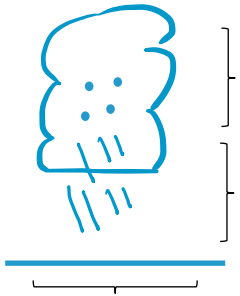
P - Precipitation

(following Langhans et al., 2015)

How do pathways to precipitation differ with organization?

$$\frac{P}{W_{\mathrm{L}}} = \frac{A}{W_{\mathrm{L}}} \cdot \frac{P}{A}$$

Precipitation Efficiency | Production Efficiency | Sedimentation Efficiency



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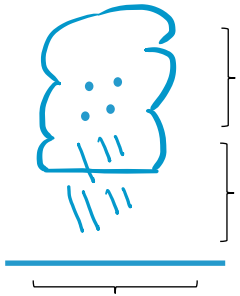
Precipitation Efficiency	Production Efficiency	Sedimentation Efficiency
$\boldsymbol{\varepsilon_{\mathrm{P}}}$	$\boldsymbol{\varepsilon_{\mathrm{conv}}}$	$\boldsymbol{\varepsilon_{\mathrm{sed}}}$



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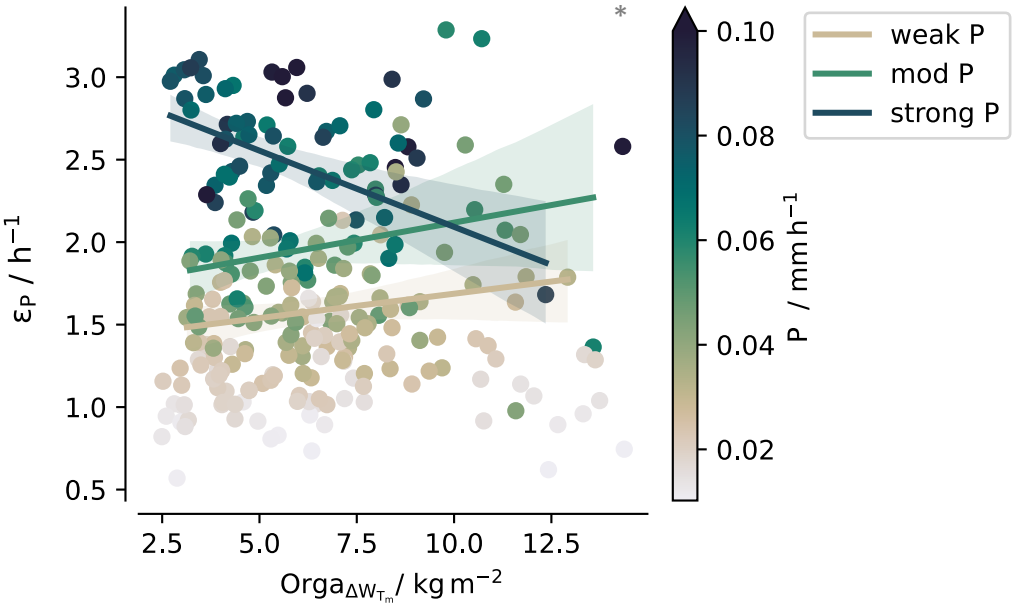
How efficient is cloud water returned to the surface as precipitation?



* 24 h averages of tracked precipitation process

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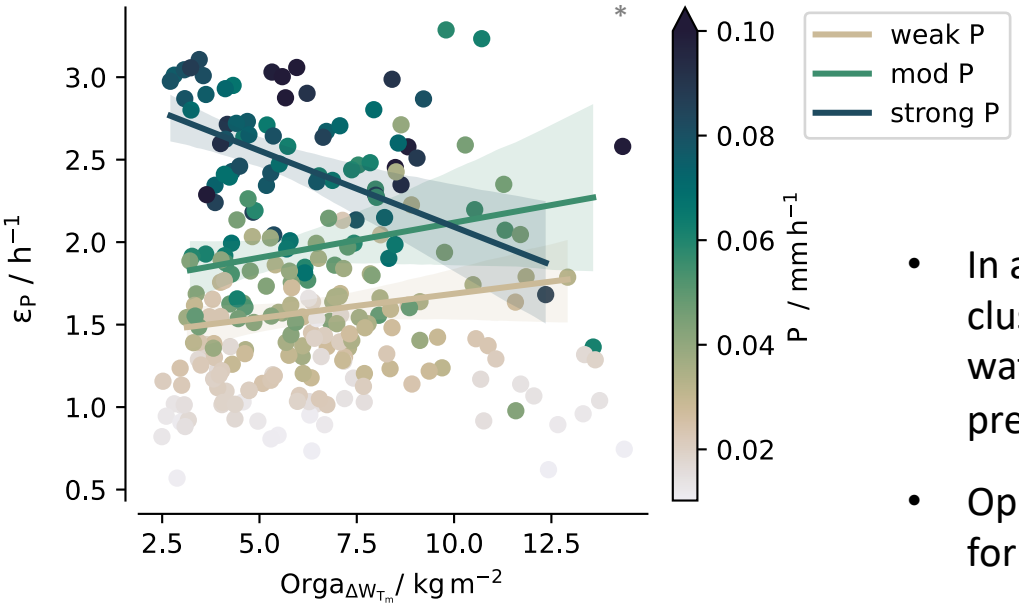
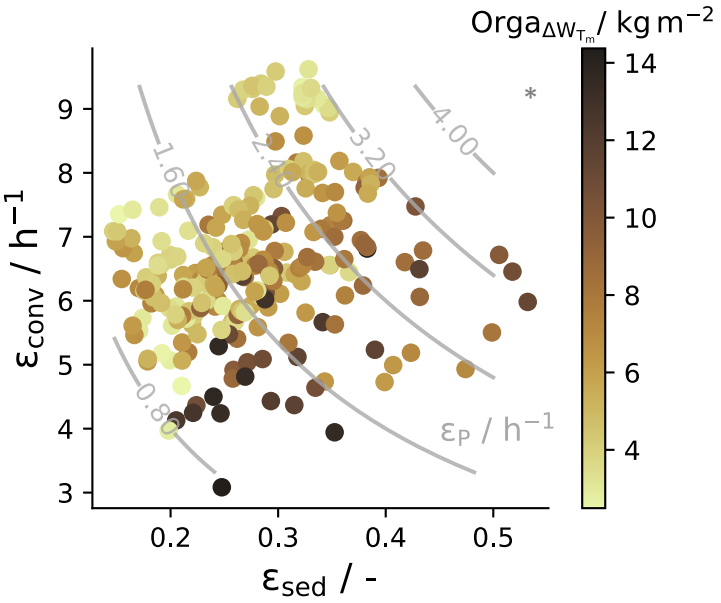


- In a precipitation-rich regime, the more clustered a scene the less efficiently cloud water is returned to the surface as precipitation
- Opposite for a moderate, weak dependence for a weak precipitation regime

* 24 h averages of tracked precipitation process

In clustered convection rain is less efficiently produced, but sediments more efficiently than in scattered convection



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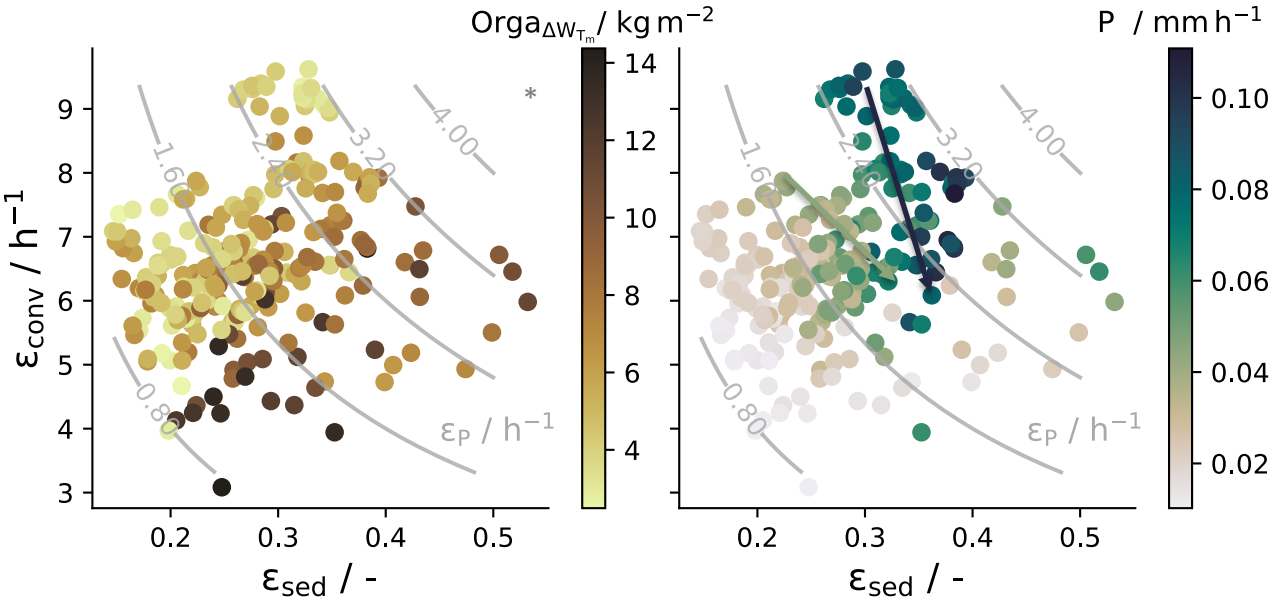

… how both balance out differs with Precipitation regime

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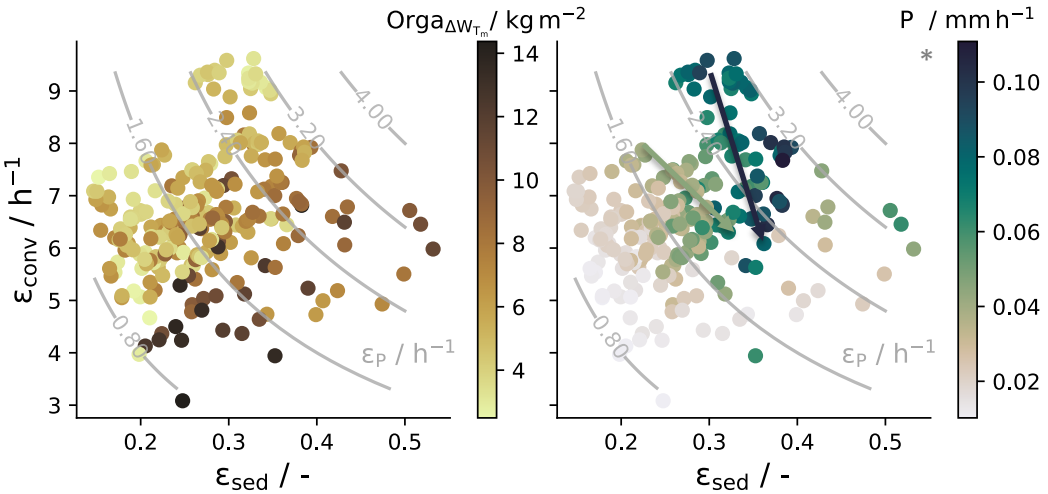

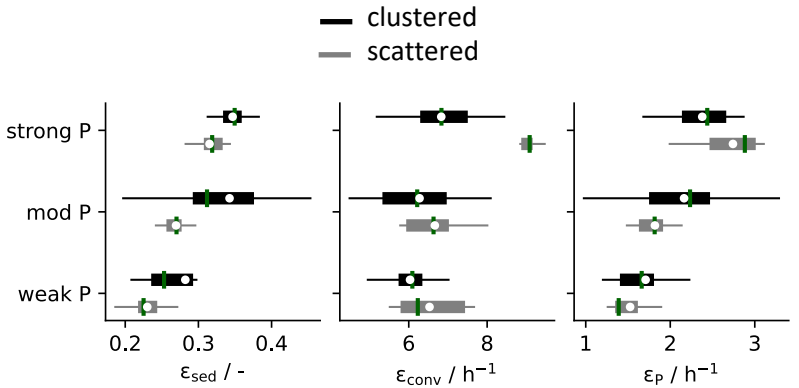

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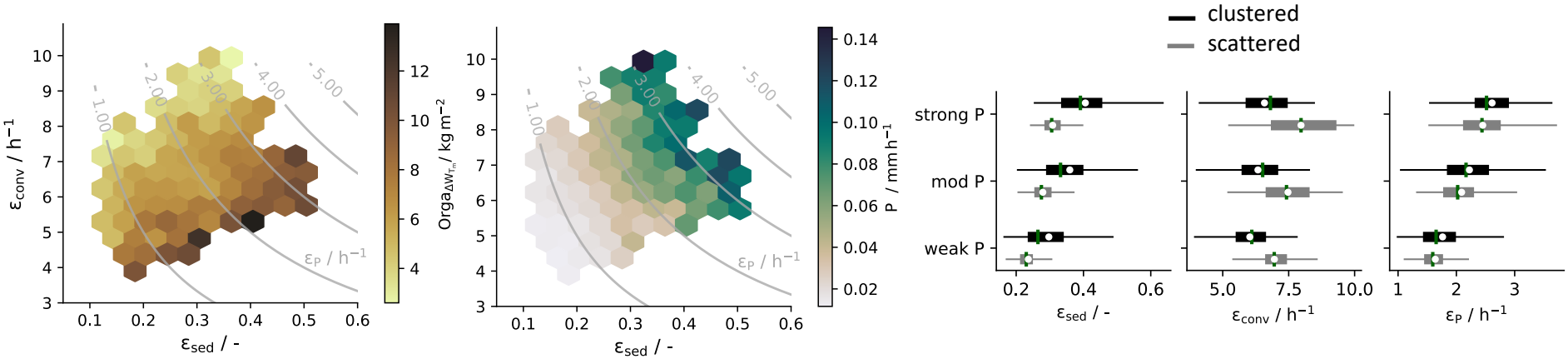
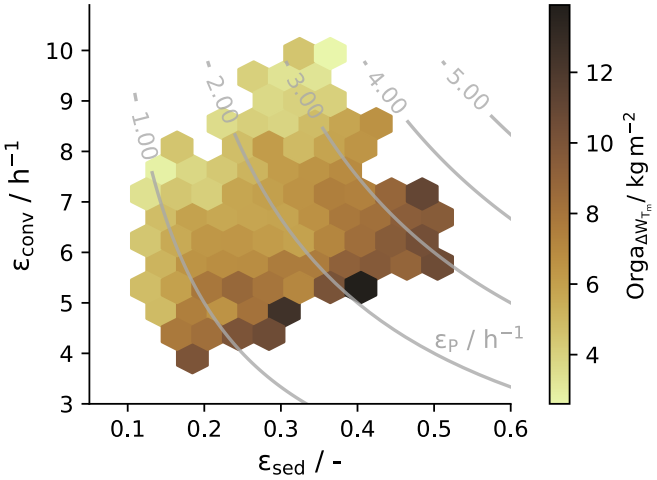


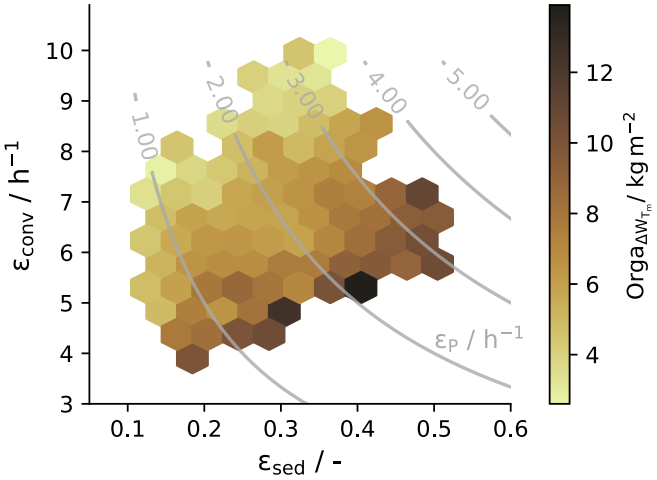
… Locally, not tracked, $\varepsilon_{\mathrm{conv}}$ and $\varepsilon_{\mathrm{sed}}$ balance out – precipitation efficiency and organization vary mainly independently

In clustered convection rain is less efficiently produced, but sediments more efficiently than in scattered convection



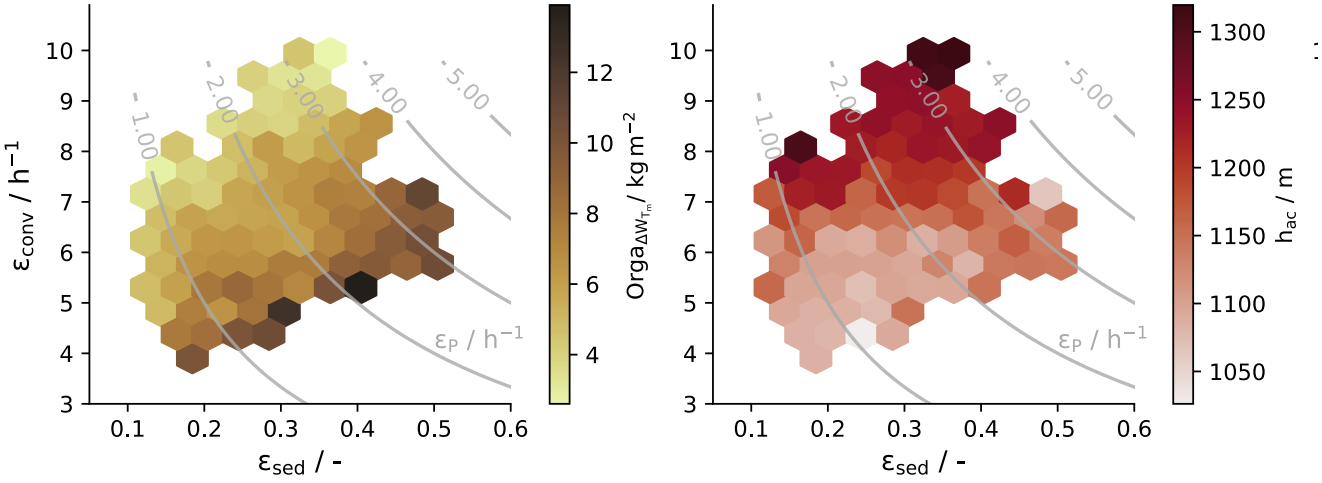
… because

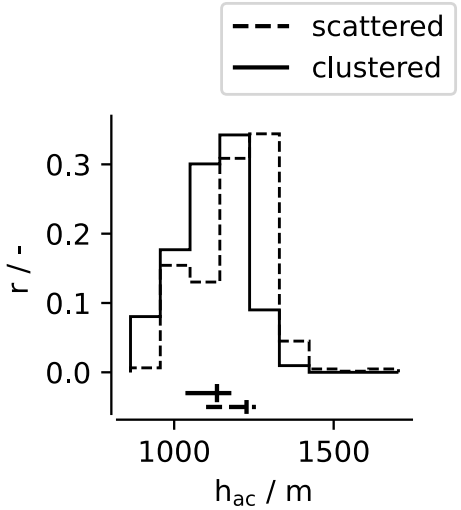
In clustered convection rain is less efficiently produced, but sediments more efficiently than in scattered convection



… because rain is produced at and thus falls from lower altitudes ?

In clustered convection rain is less efficiently produced, but sediments more efficiently than in scattered convection

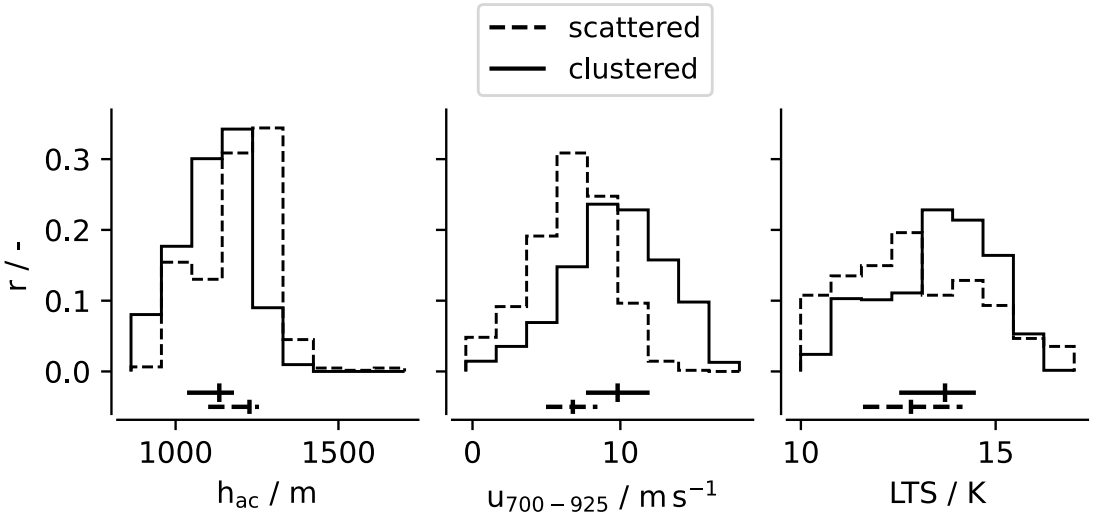




Similar to Lutsko and Cronin, 2018

… because rain is produced at and thus falls from lower altitudes ?

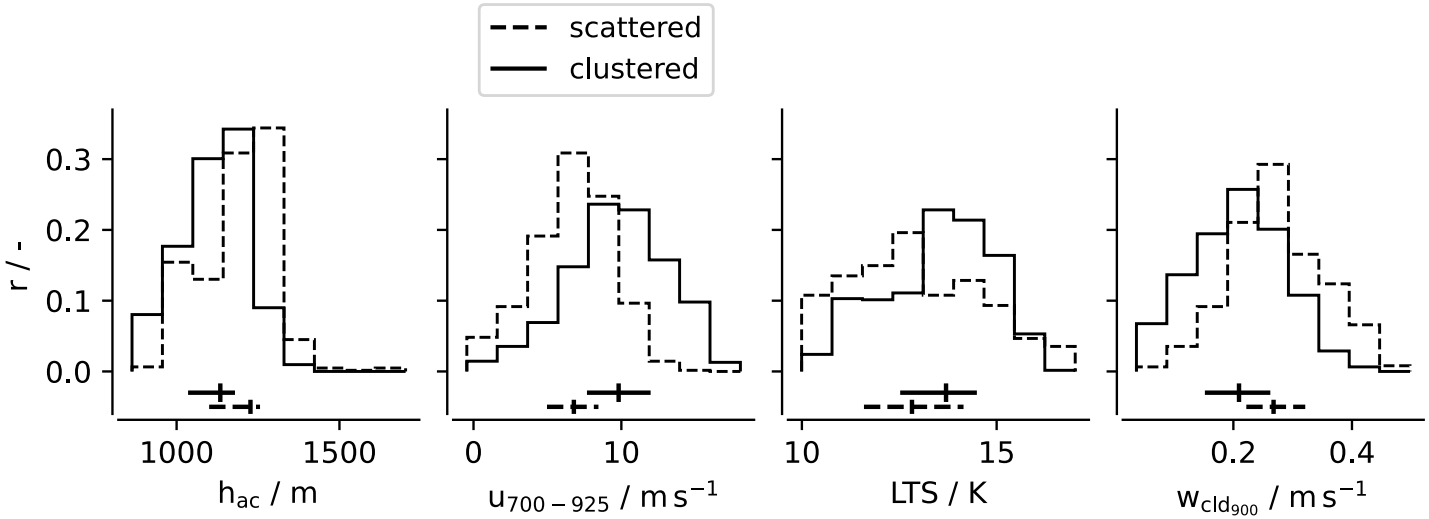
In clustered convection rain is produced at lower altitudes …



… because clouds are more sheared?

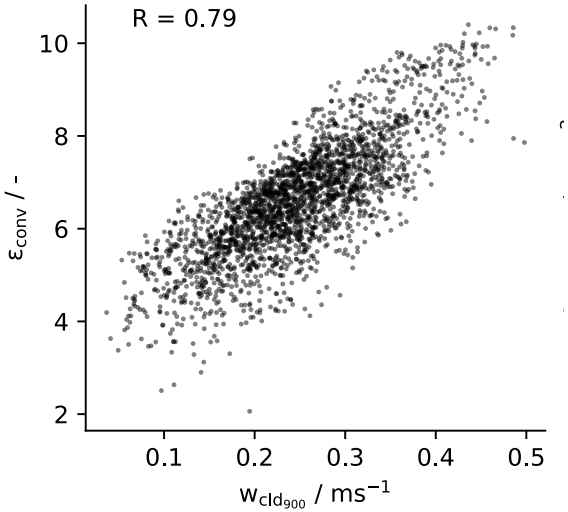
… and conditions more stable?

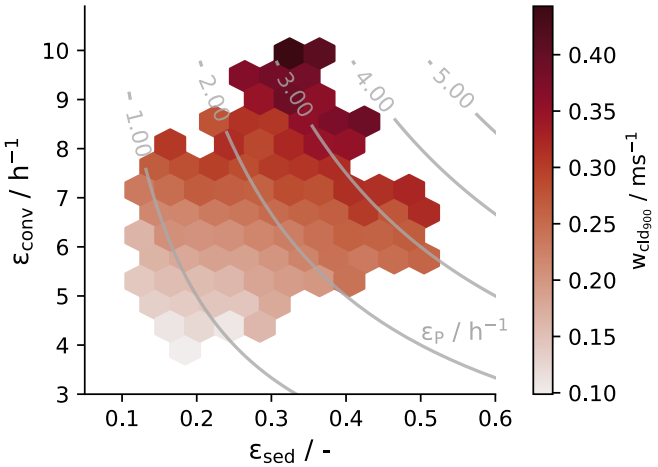
In clustered convection updrafts are weaker and rain is produced at lower altitudes



Helfer et al. 2020: shear keeps clouds shallower by weakening updrafts

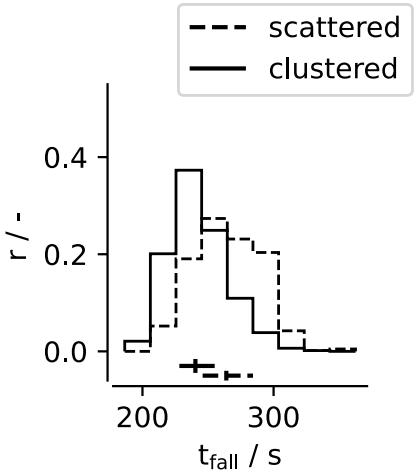
In clustered convection updrafts are weaker and rain is produced at lower altitudes …





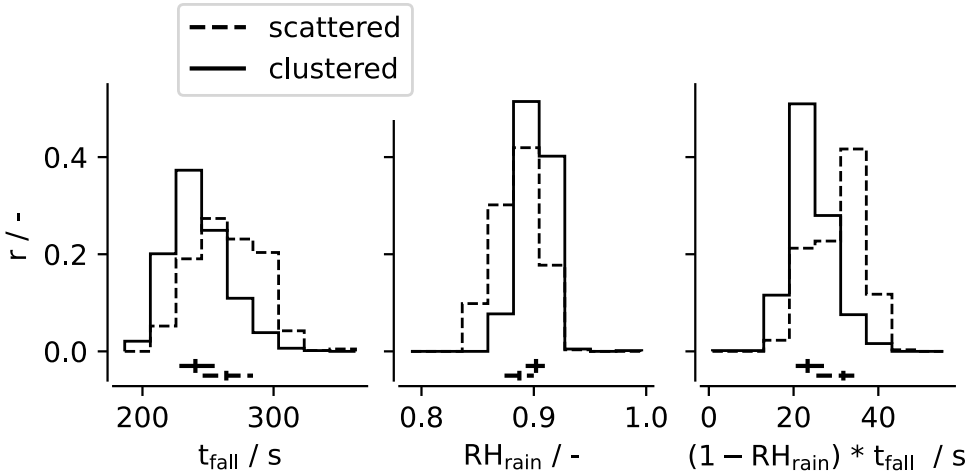
… so that rain is less efficiently produced than in scattered convection (?)

In clustered convection rain falls in less time (from lower altitudes)

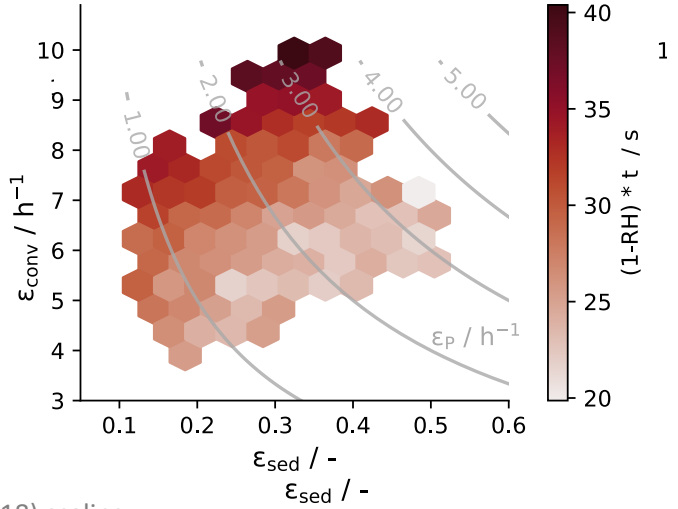


$t_{fall} = h_{ac} / w,\ w \sim qr$

In clustered convection rain falls in less time (from lower altitudes) through moister areas



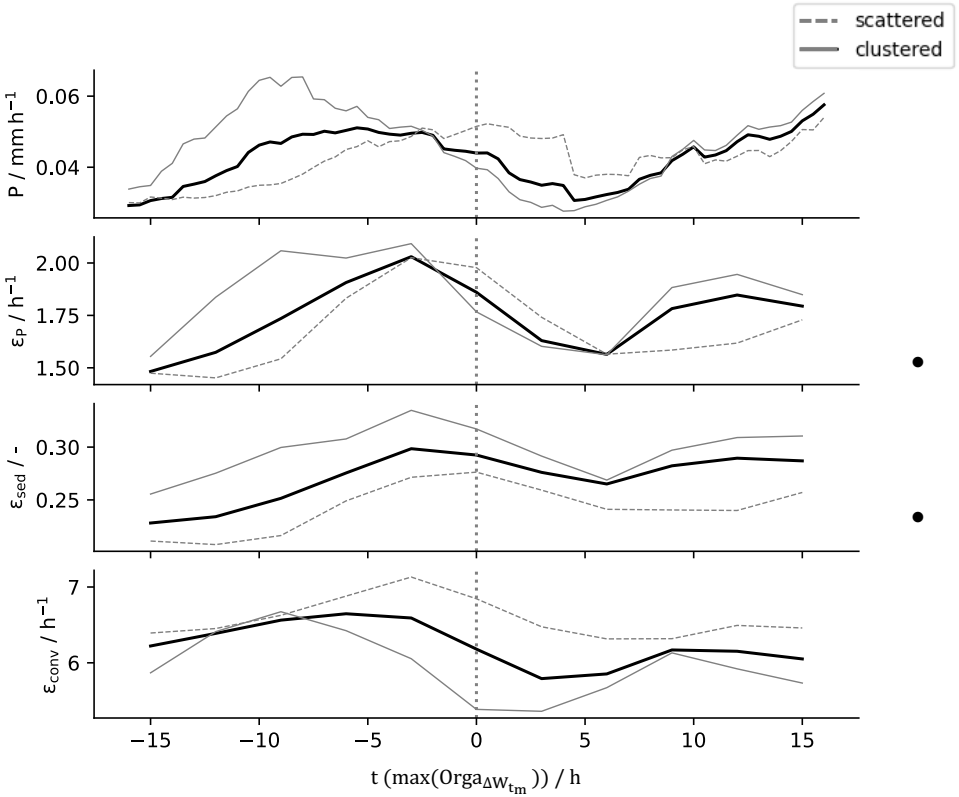
$t_{fall} = h_{ac} / w$, $w \sim qr$



* Lutsko and Cronin (2018) scaling

… so that rain sediments more efficiently than in scattered convection (?)

How does the evolution of precipitation (efficiency) differ with organization?



- In clustered convection precipitation (efficiency) maximizes before organization
- Conversion efficiency maximizes before sedimentation efficiency

Conclusions

- In clustered convection, rain is less efficiently produced, but sediments more efficiently than in scattered convection.
- … possibly because rain is produced in weaker updrafts at and thus falls from lower altitudes and through moister environments.
- These effects mostly balance out, however, tracking a scene, the 24h averaged precipitation efficiency for a high precipitation regime decreases with organization suggesting internal feedbacks?
- Spatial organization is associated with different pathways to precipitation.