2022 EGU meeting

Low-level radiative cooling in patterns of shallow convective organization

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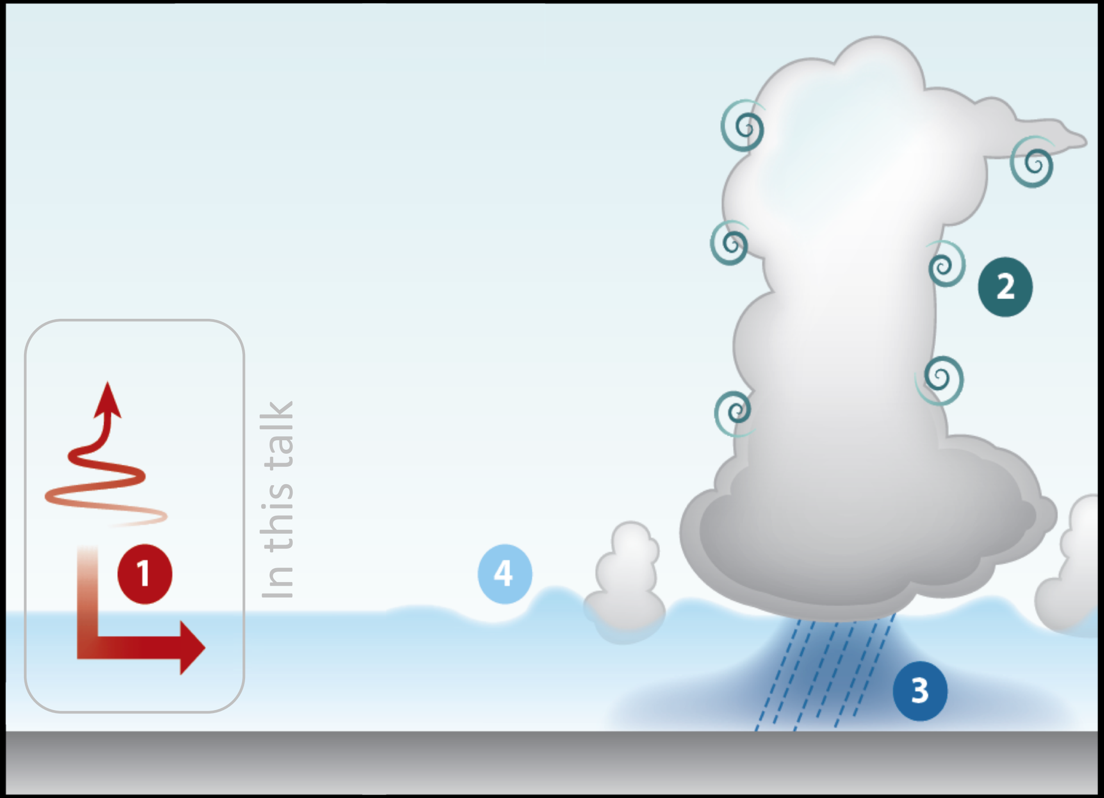

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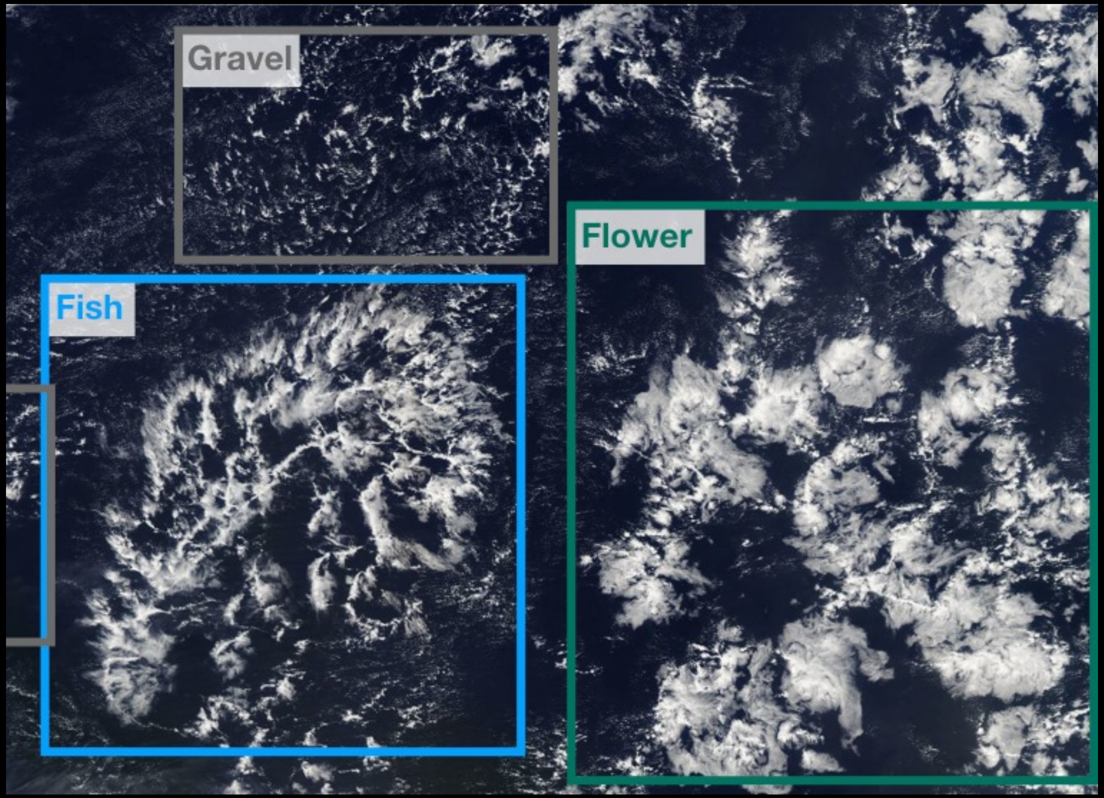


Radiative feedback strength consistent with simulations of deep aggregation

Clear-sky longwave cooling in moisture space

Signal needed

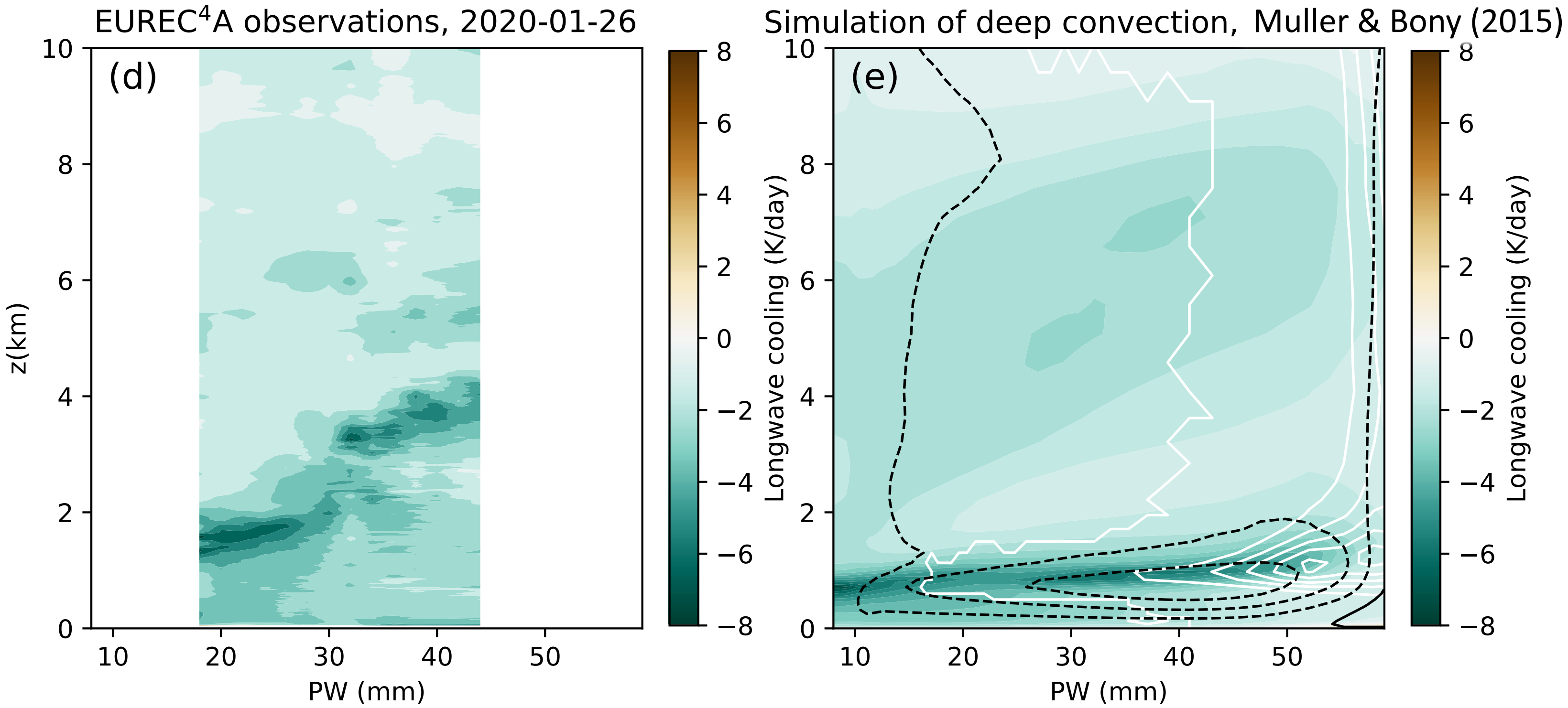
- *Horizontal differences in radiative cooling between dry and moist areas, **mainly controlled by longwave cooling in clear sky***

Mechanism

- Low radiative cooling (1-2km) in dry areas can feed a surface density current *[Shamekh et al. (2020)]*
- Cooling below the inversion (3-4km) may stabilize the diverging air and reinforce circulations [Stevens et al. (2017)]

Dataset

[Albright, Fildier, Touze-Peiffer et al. (2020)]

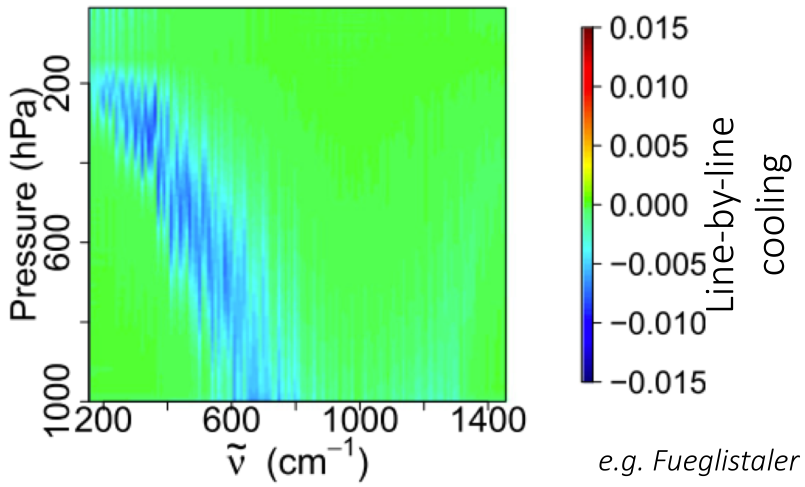


In which situations do we expect large radiative cooling ?

What controls the peak longwave cooling ?

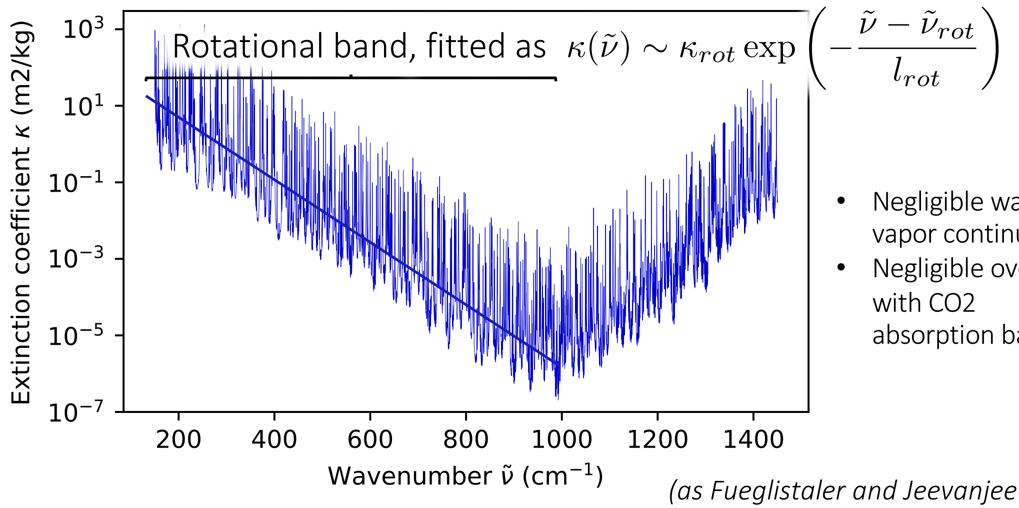
Assumptions invoked in the derivation

(1) *Cooling-to-space* approximation $$\frac{dF_{\tilde{\nu}}}{d\tau_{\tilde{\nu}}} \approx -B_{\tilde{\nu}}(T)e^{-\tau_{\tilde{\nu}}}$$



e.g. Fueglistaler and Jeevanjee (2020ab)
(using smooth zonally-averaged profiles)

(2) *Smoothing* of water vapor absorption lines



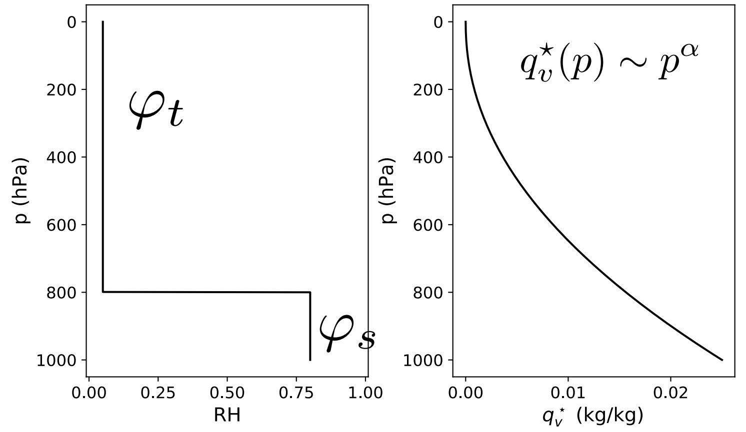
- Negligible water vapor continuum
- Negligible overlap with CO2 absorption bands

(as Fueglistaler and Jeevanjee (2020b))

(3) Little variation in extinction coefficient with height: *separation of variables* between spectral properties and the vertical distribution of water in the column

$$\tau(\tilde{\nu}, p) \approx \kappa(\tilde{\nu})W(p)$$

(4) *Idealization of thermodynamic profiles* (final step only)



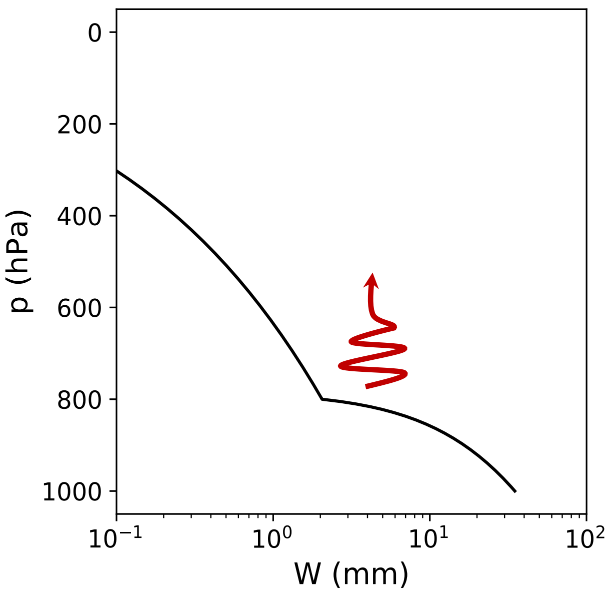
Simple spectral theory explains the height and magnitude of cooling peaks

Theory branching on Jeevanjee&Fueglistaler (2020b)

Cooling height

is set by the maximum in *water vapor path lapse rate*

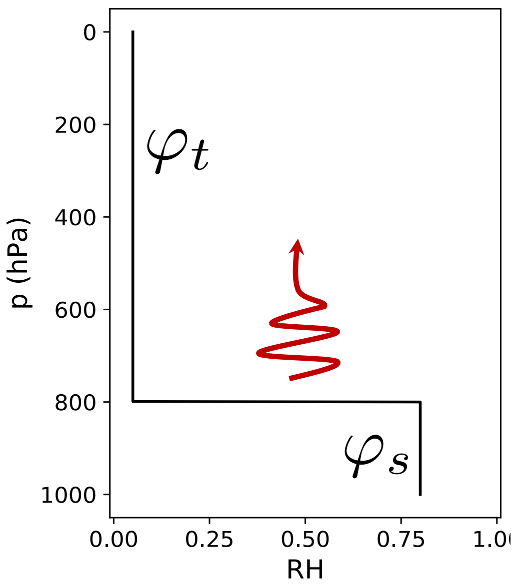
$$\beta = \frac{d\ln W}{d\ln p}$$

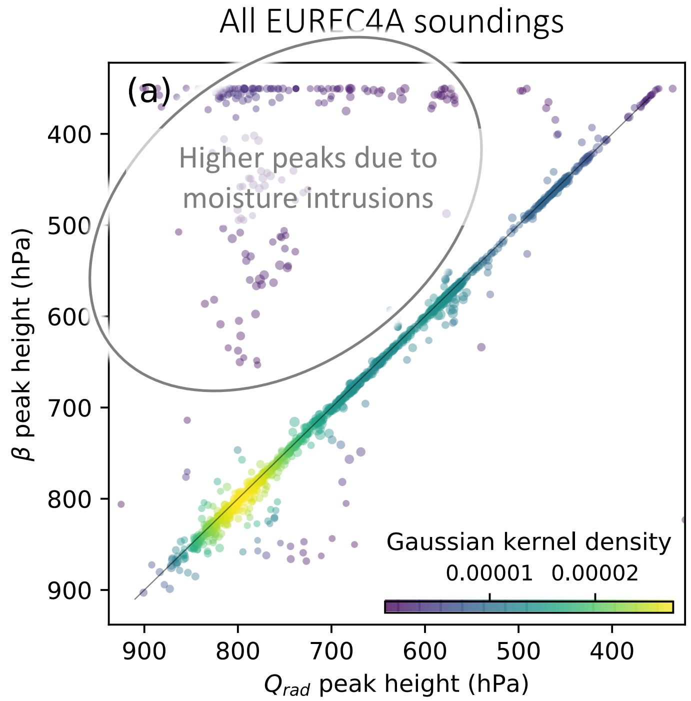


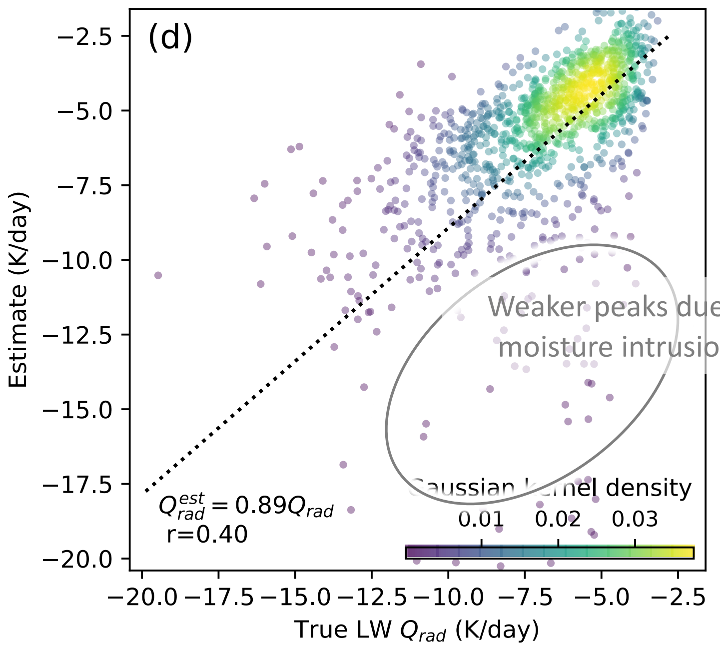
Cooling magnitude

is proportional to the ***ratio** of relative humidity* in the boundary layer and the free troposphere

$$Q^* \approx -\frac{g}{C_p}\frac{1+\alpha}{p^*}\frac{\varphi_s}{\varphi_t}\pi\tilde{B}\frac{\Delta\nu}{e}$$

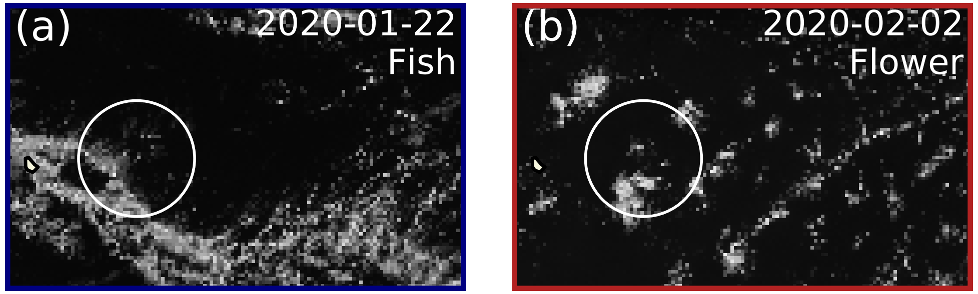




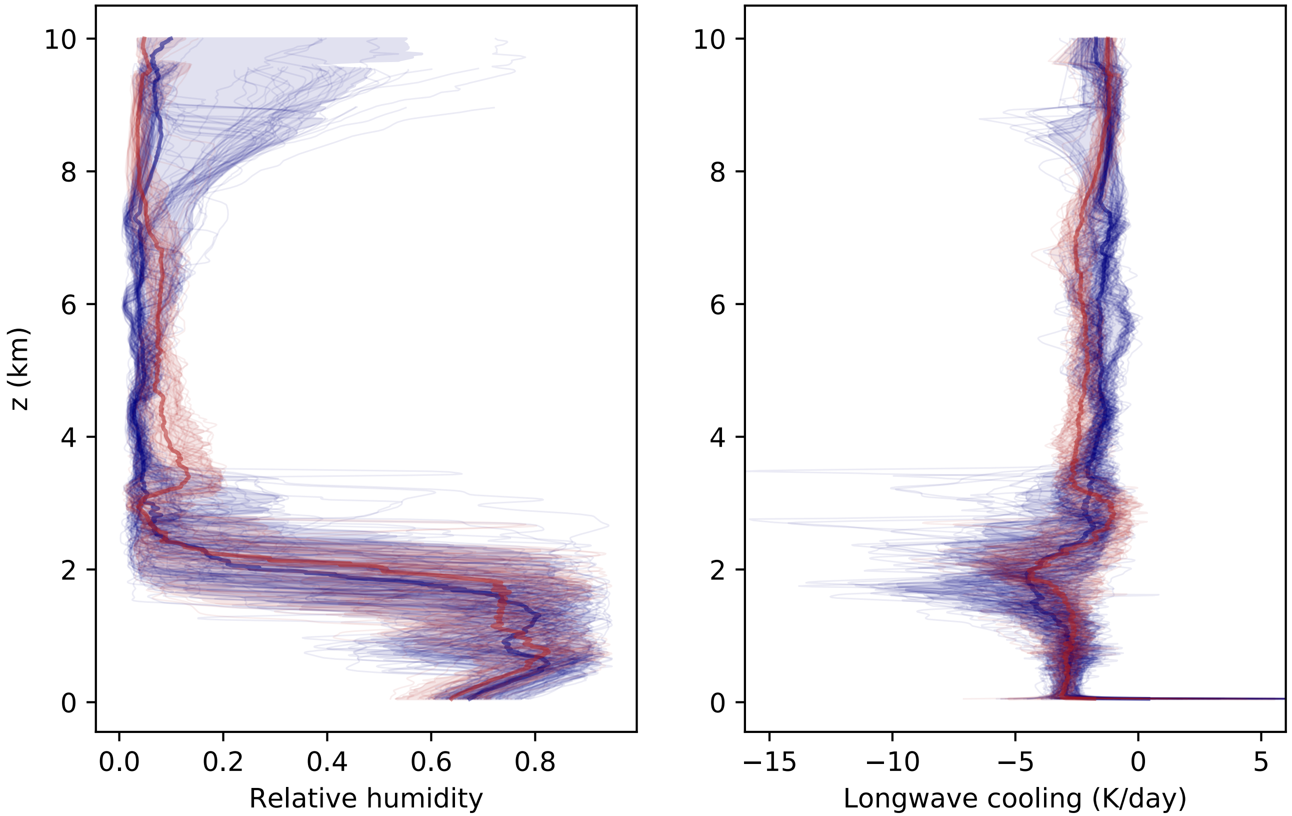


An example, comparing Fish and Flower patterns

- Drier free troposphere for this Fish case
- Some difference here may come from cloud-top detrainment and shorter spacing between Flowers

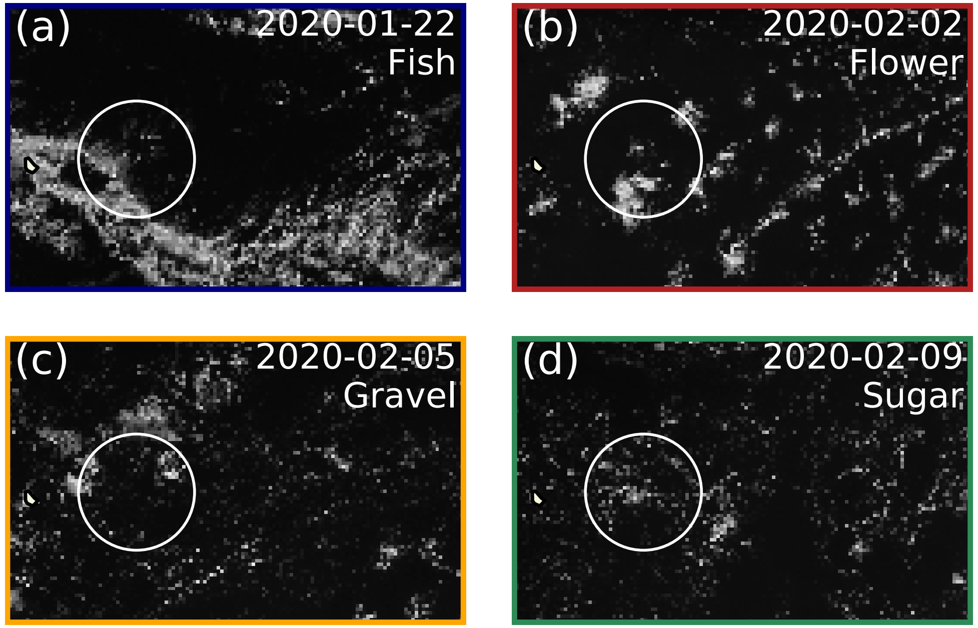


$$Q^* \approx -\frac{g}{C_p}\frac{1+\alpha}{p^*}\frac{\varphi_s}{\varphi_t}\pi\tilde{B}\frac{\Delta\nu}{e}$$

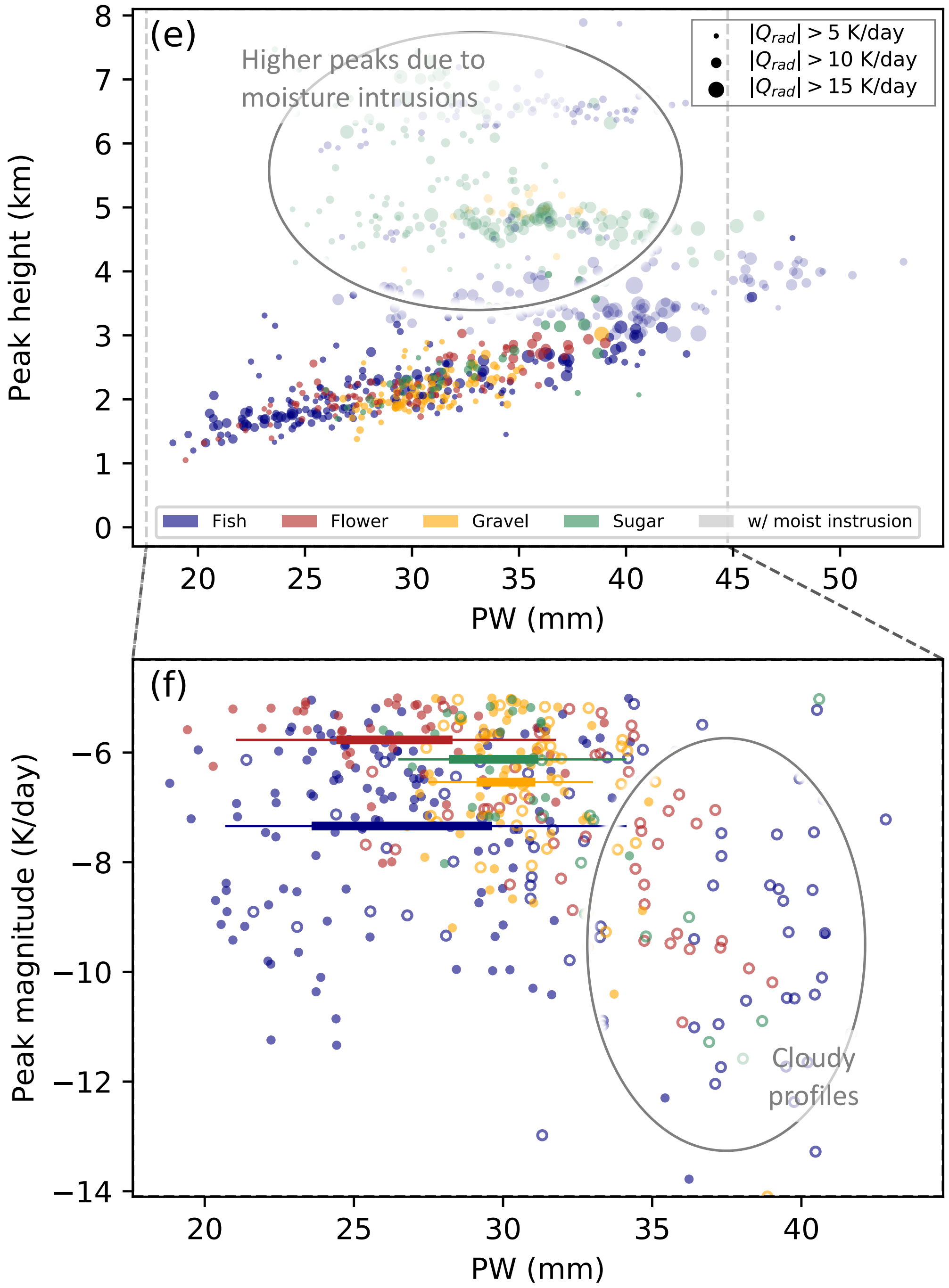


Comparing all shallow organization patterns

- Radiative cooling differences between dry and moist areas are seen for all patterns and at various heights
- Flower and Fish reach the lowest cooling peaks in the driest columns

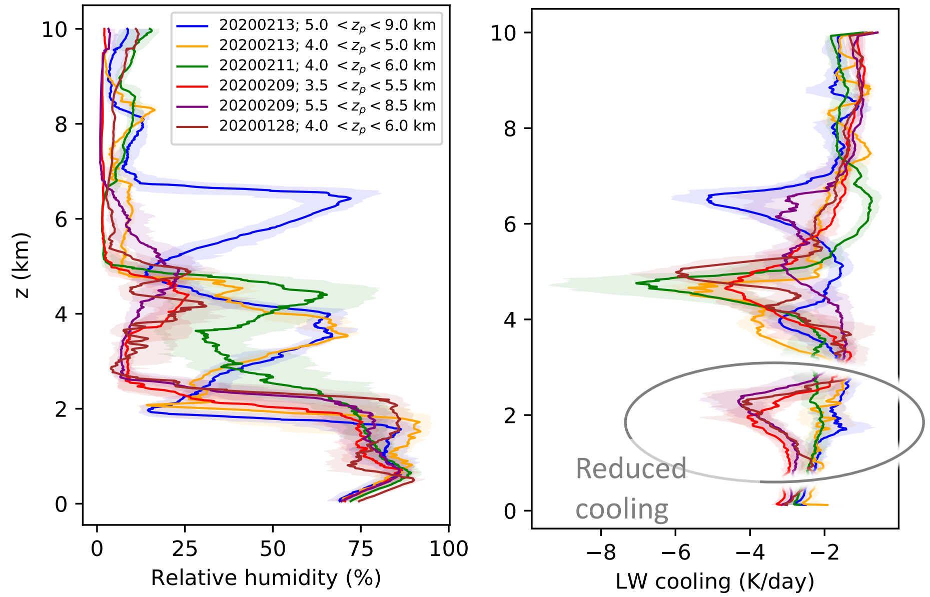


- Fish shows stronger longwave cooling in clear air and the widest spatially coherent dry areas: Fish are the best candidates for radiatively-driven self-aggregation.



Possible extensions to the theory

(a) *Include "shading" by moist intrusions* (seen on 4 days in EUREC^{4}A)



Intrusion "shading" depends on the amount of water added and on its height (this vertical distribution is not included yet in the theory)

Two assumptions to relax to account for these:

- Vertically-uniform κ
- Cooling-to-space approximation (energy exchanges between layers)

(b) *Include the shortwave diurnal cycle*

- Roughly balances longwave cooling at mid-day
- A similar approach could be used

(c) *Account for cloud radiative effects*

- Much more complex
- Would only enhance the contrast in cooling between dry and moist regions

Thank you!

- EUREC^{4}A observations show **strong longwave cooling** peaks, comparable with simulations of deep aggregation
- **Peak height** is controlled by the hydrolapse, **peak magnitude** is controlled by the ratio of free-tropospheric and boundary layer RH
- **Moist intrusions** can significantly dim low-level cooling for both geometric and spectroscopic reasons
- **Fish** (and Flower?) patterns may be most subject to the radiative feedback

References

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