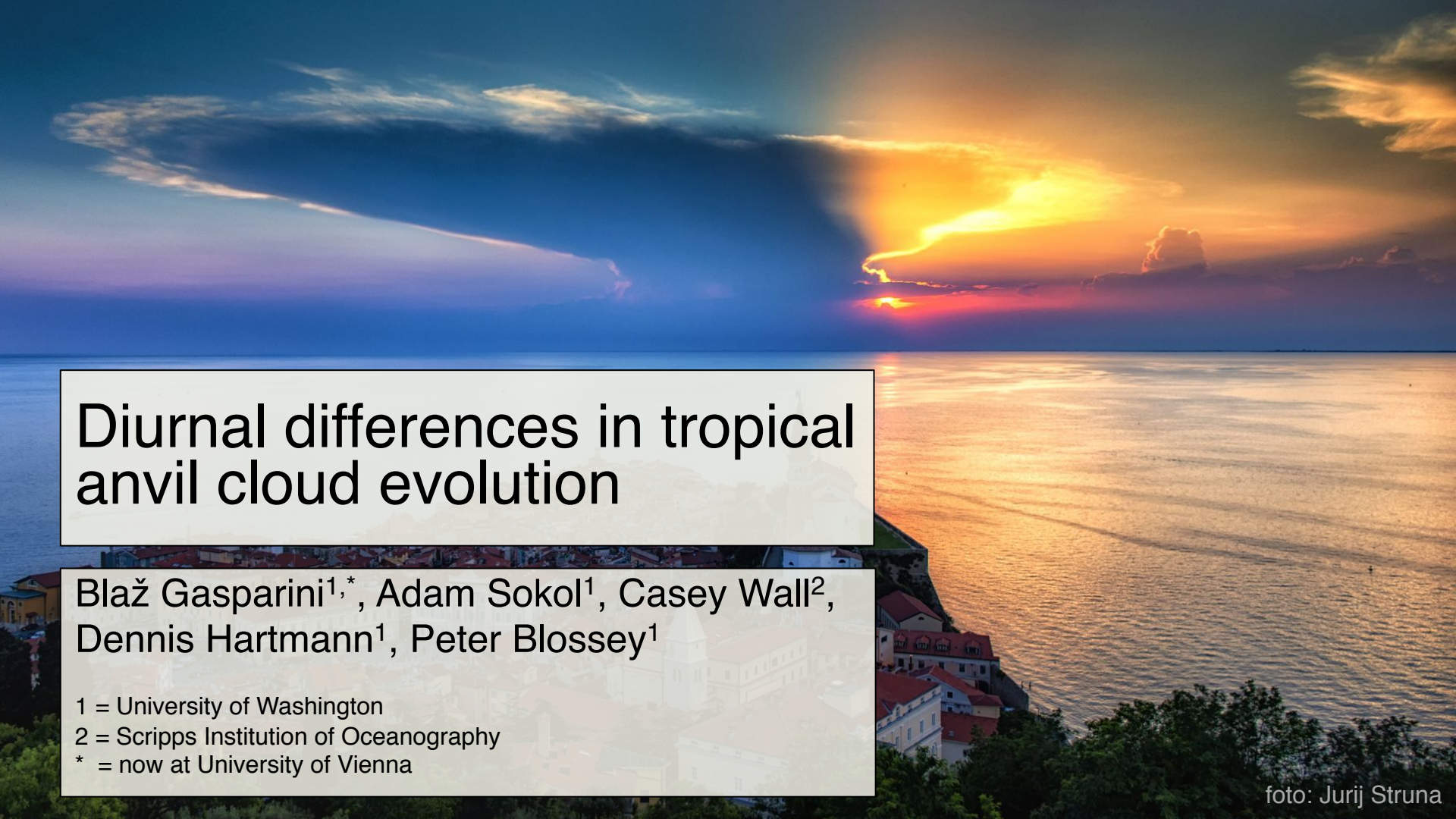


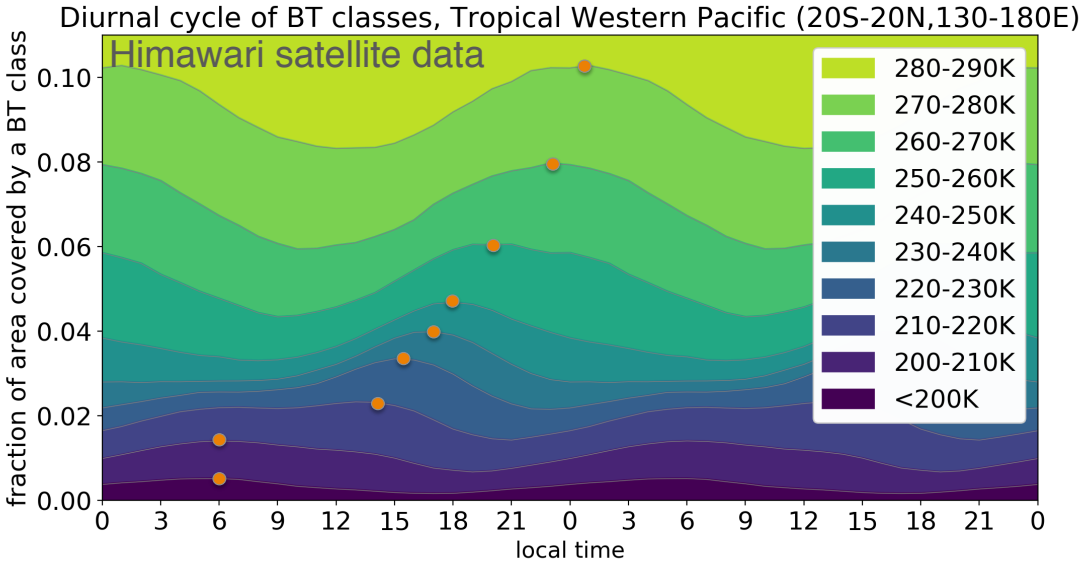
Diurnal differences in tropical anvil cloud evolution

Blaž Gasparini[1,*], Adam Sokol[1], Casey Wall[2], Dennis Hartmann[1], Peter Blossey[1]

1 = University of Washington
2 = Scripps Institution of Oceanography
* = now at University of Vienna

foto: Jurij Struna

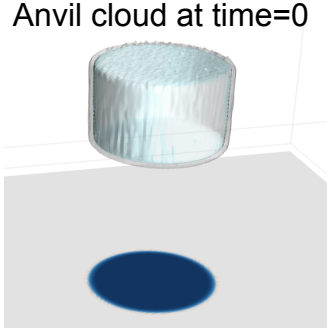
Substantial time gap between the peak in deep convective activity and the peak in anvil clouds



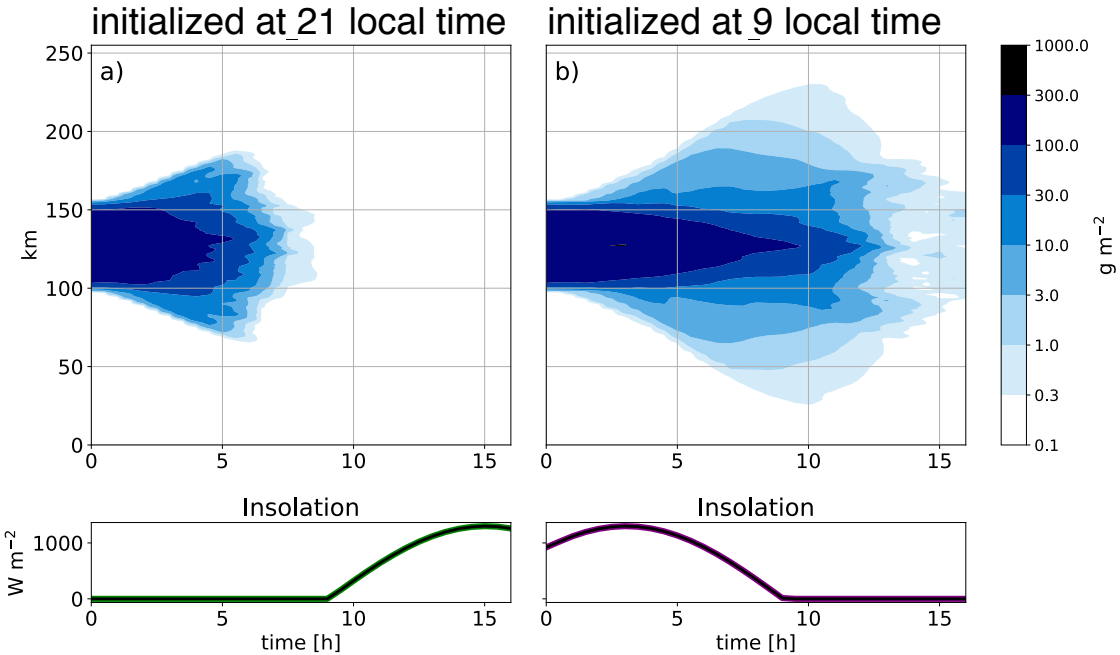
Lowest brightness temperature classes (=deep convection) peak in the early morning hours; warmer classes, typical of anvil clouds, peak in the afternoon hours

Result consistent with studies showing evidence for (1) a morning peak in MCS activity (e.g.: Gray and Jacobson, 1977, Nesbitt and Zipser, 2003) and (2) afternoon peak in anvil cloud cover (e.g. Feofilov and Stubenrauch, 2019, Chepfer et al., 2019, Sokol and Hartmann, 2020)

Day anvils are more persistent and widespread



Ice water path evolution

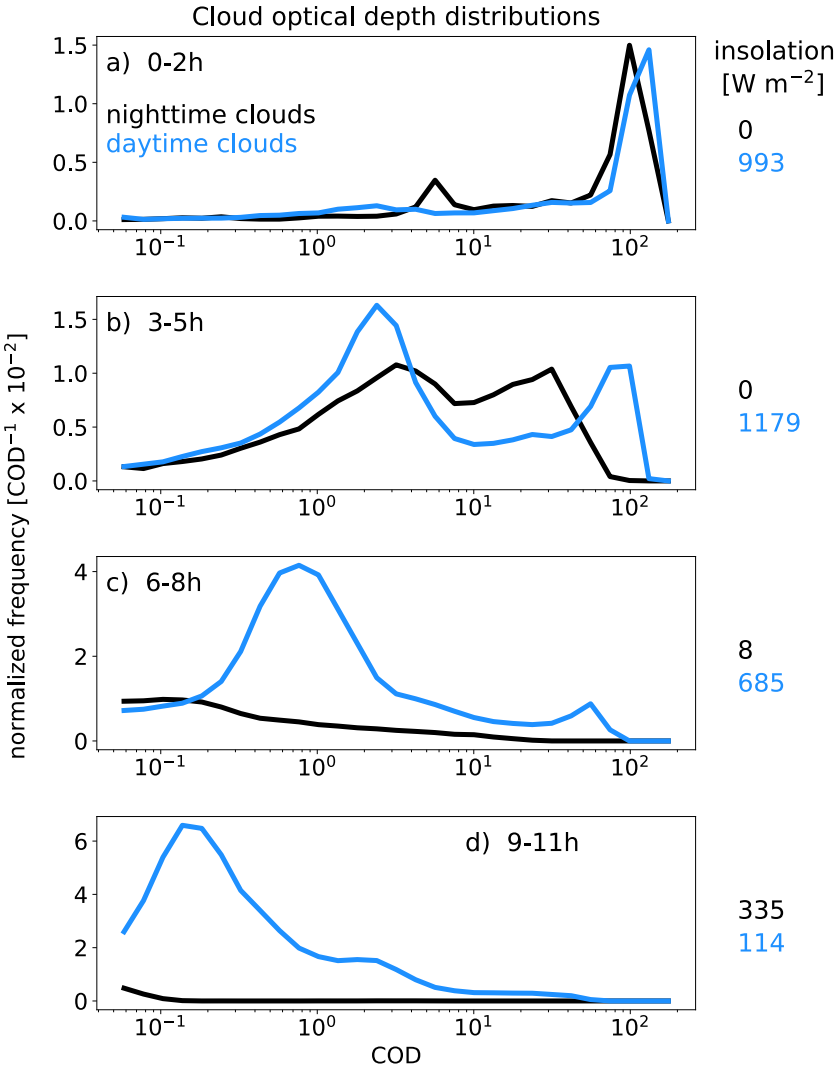


Idealized experiments with the SAM cloud resolving model (modified P3 microphysics)

Single cloud evolution pathways:

- Cloud initialized in the middle of the domain; representative of typical thick tropical anvil clouds
- Cloud can freely evolve after initialization

Result consistent with the observational study by Wall et al., 2020



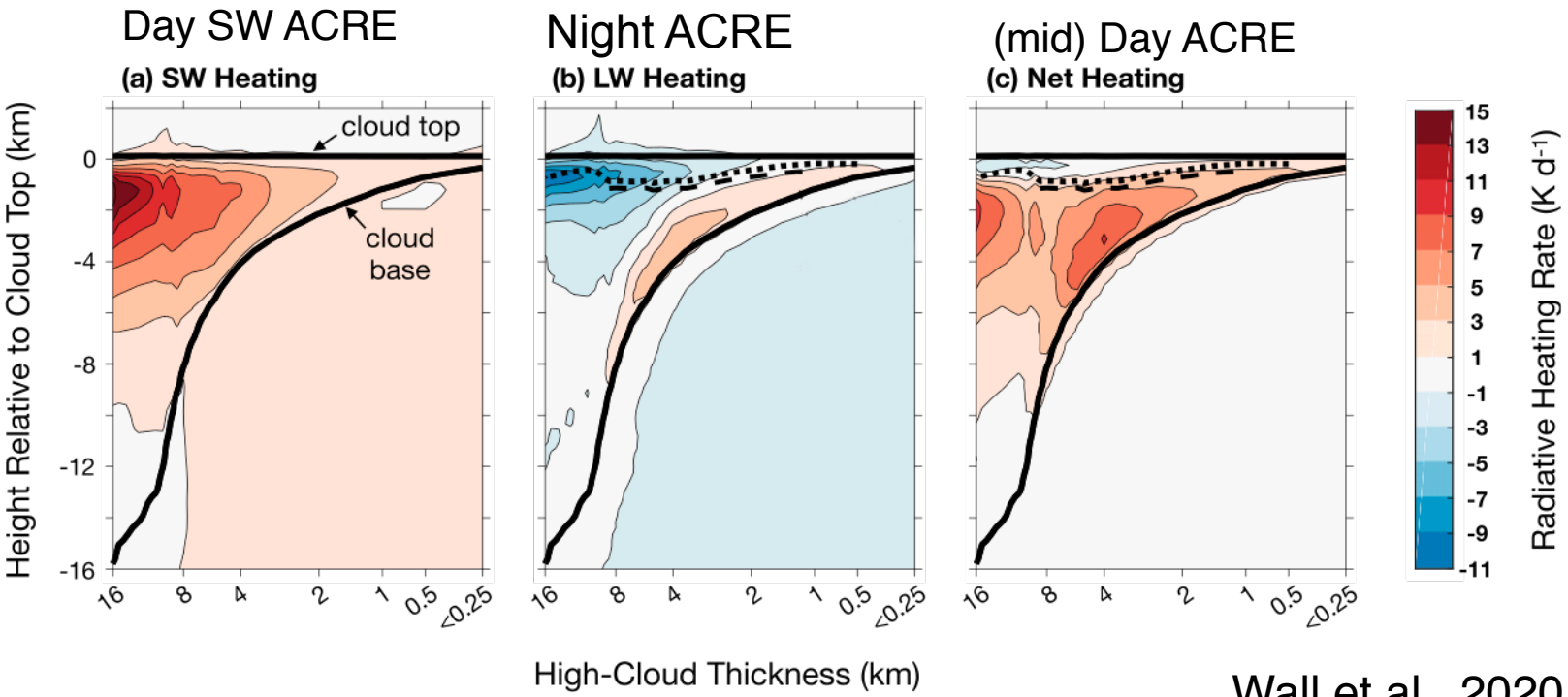
Day anvils thicker compared with night anvils

Comparison of simulated clouds by their corresponding cloud age.
Nighttime composite includes anvils initialized between 19 and 23 LT; daytime composite includes anvils initialized between 7 and 11 LT.

What processes are driving such differences?

Large differences in ACRE between (mid)day and night

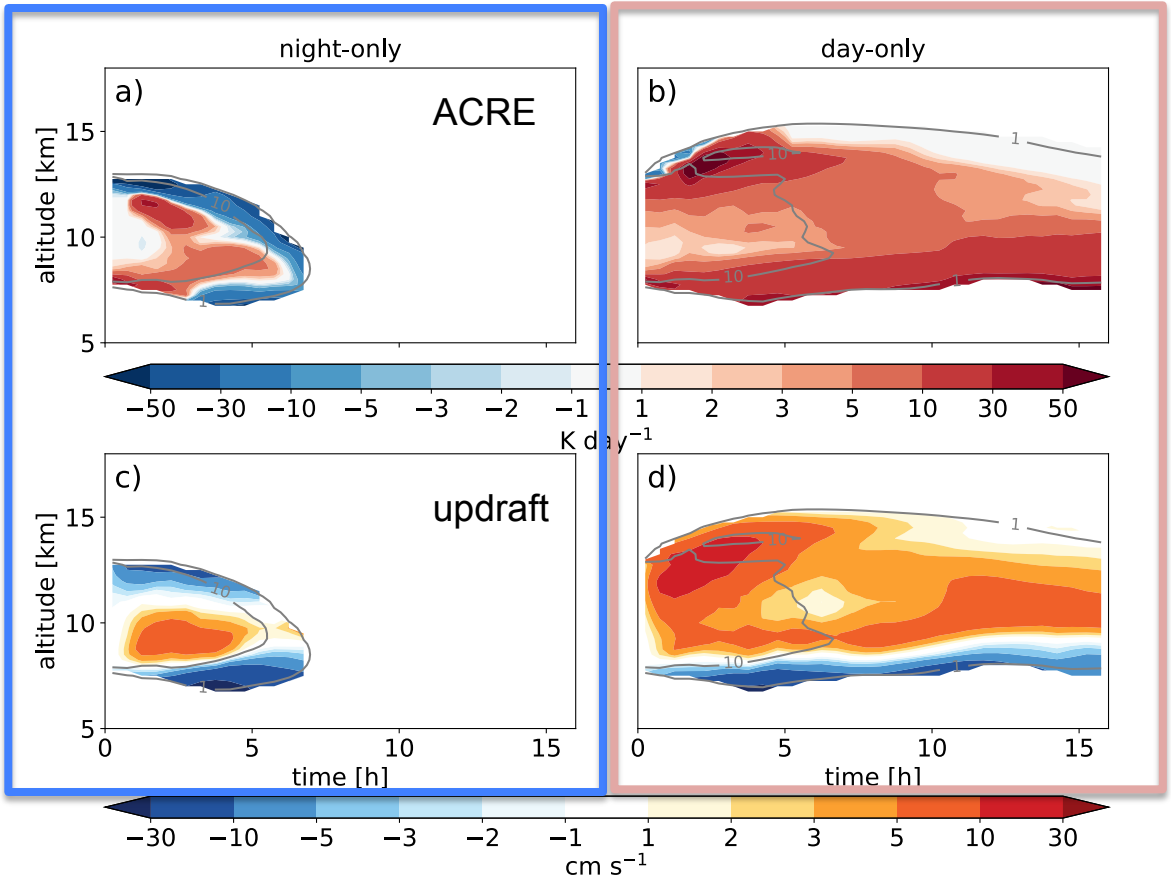
ACRE=atmospheric cloud radiative effects, referring to both the cloud part of the LW and SW heating and cooling within the atmospheric column



Wall et al., 2020

Heating rate derived from CCCM dataset (CloudSat-CALIPSO profiles, afternoon overpass)

Effect of ACRE-driven dynamics: the basics

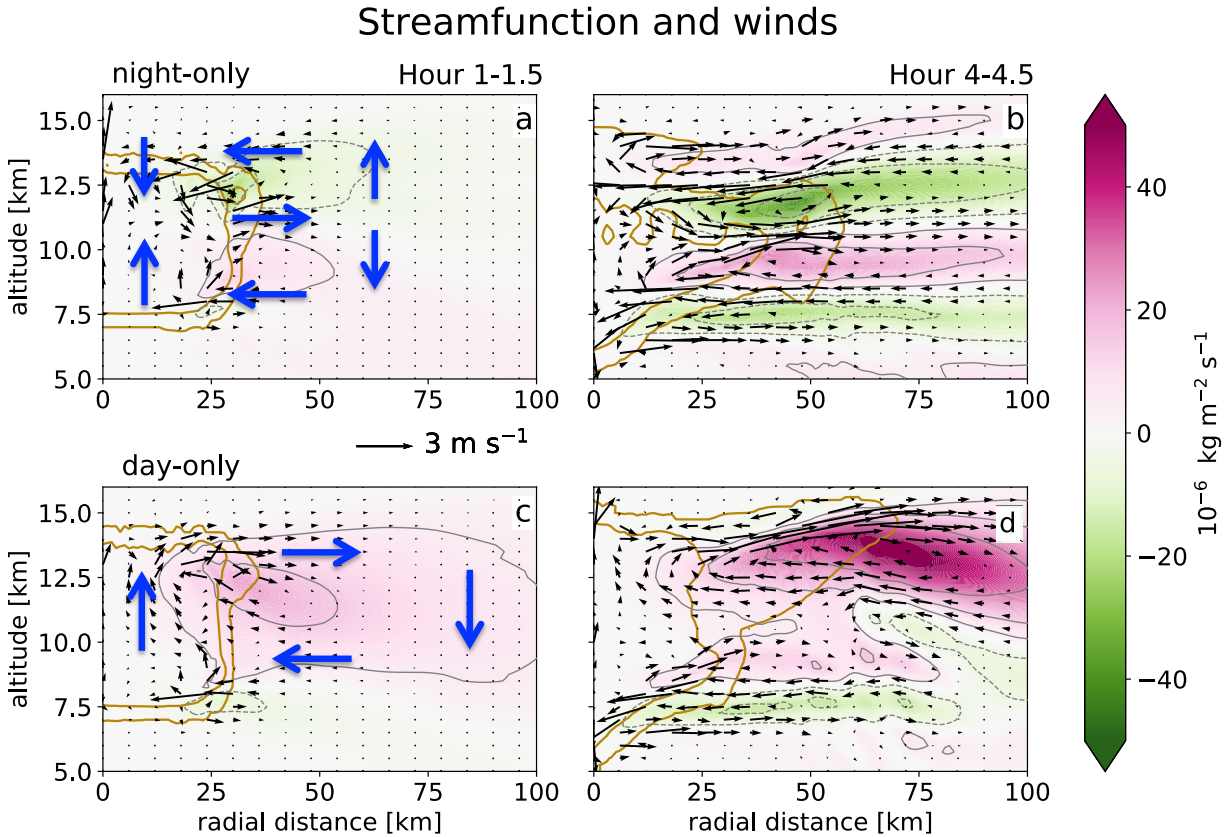


- Cloud lofting in the day
- Cloud sinking in the night

SAM simulations of “cloud in the middle of the domain” with no insolation (night-only) and constant mid day insolation (1300 W m^{-2}, day-only)

Consistent with the results of:
Ruppert and Hohenegger, 2018
Ruppert and Klocke, 2019

Effect of ACRE-driven dynamics: Role of the circulation near cloud top

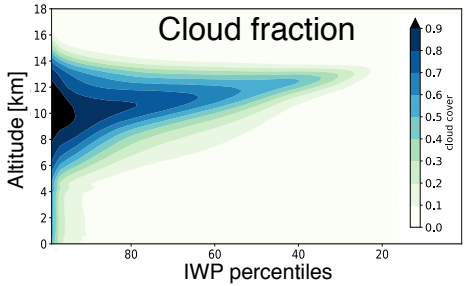


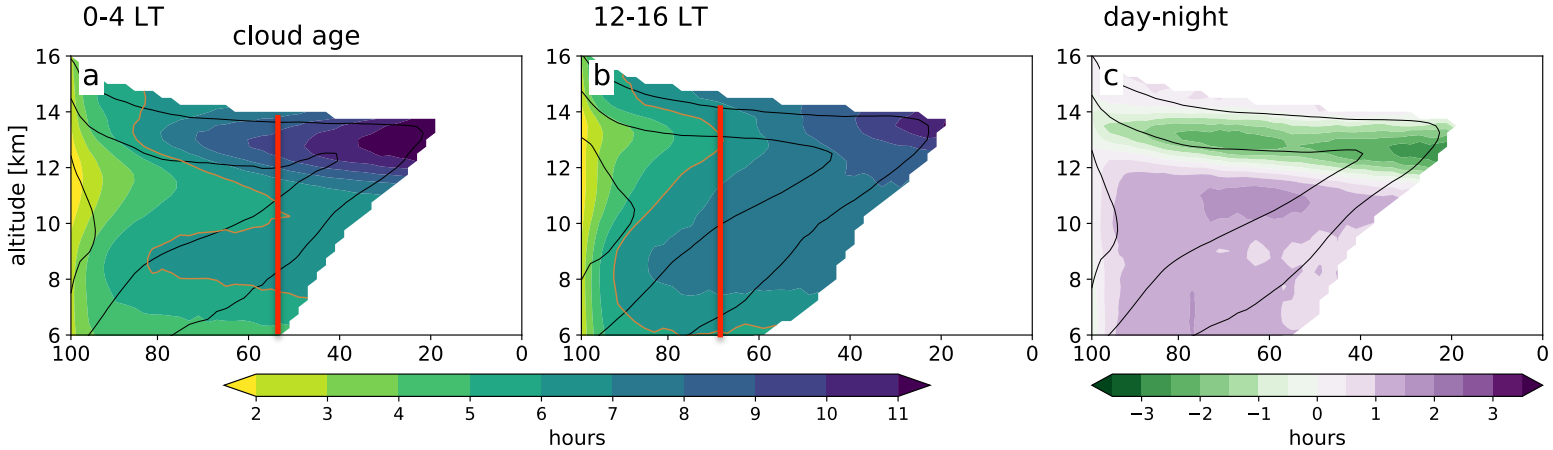
"Squeezing" and spreading of the cloud

Lofting and spreading of the cloud

Radiative-convective equilibrium simulations agree with the idealized experiments

- Non-aggregated convection
- Realistic diurnal cycle of insolation
- Results binned by ice water path (IWP)



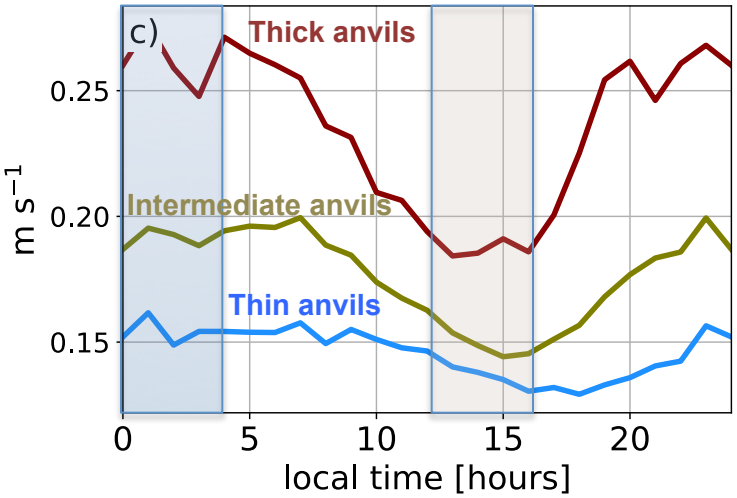


Day anvils evolve (reach lower IWP/IWP percentiles) slower compared with night anvils as highlighted by the 6 hour isochrone

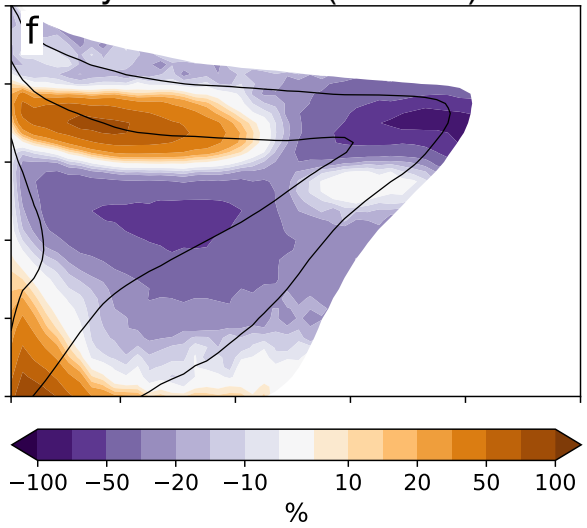
Day anvils: cloud top not sedimenting much when thinning
More+younger clouds at higher altitudes

More turbulence within anvils in the night; however, more ice crystals near cloud top in the day

Standard deviation of vertical velocity (in-cloud)



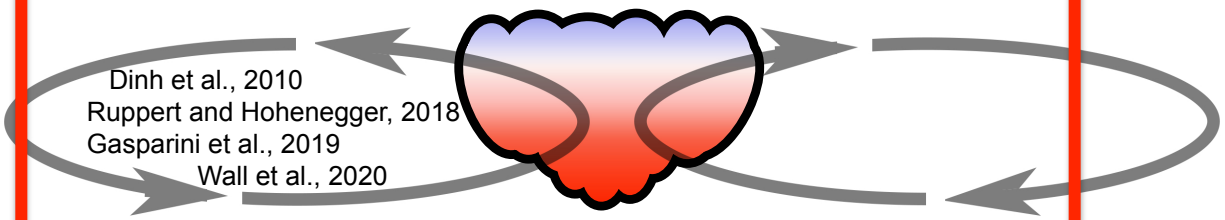
Day – Night,
Ice crystal number (in-cloud)



=> ice nucleation within anvils is of secondary importance compared with the SW-driven ascent that counteracts ice crystal sedimentation in the diurnal anvil clouds

What keeps anvils aloft for so long?

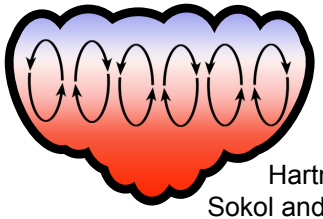
a) Mesoscale circulation



Dinh et al., 2010
Ruppert and Hohenegger, 2018
Gasparini et al., 2019
Wall et al., 2020

Mesoscale updraft within anvils =>
(partially) counteracts sedimentation of ice crystals

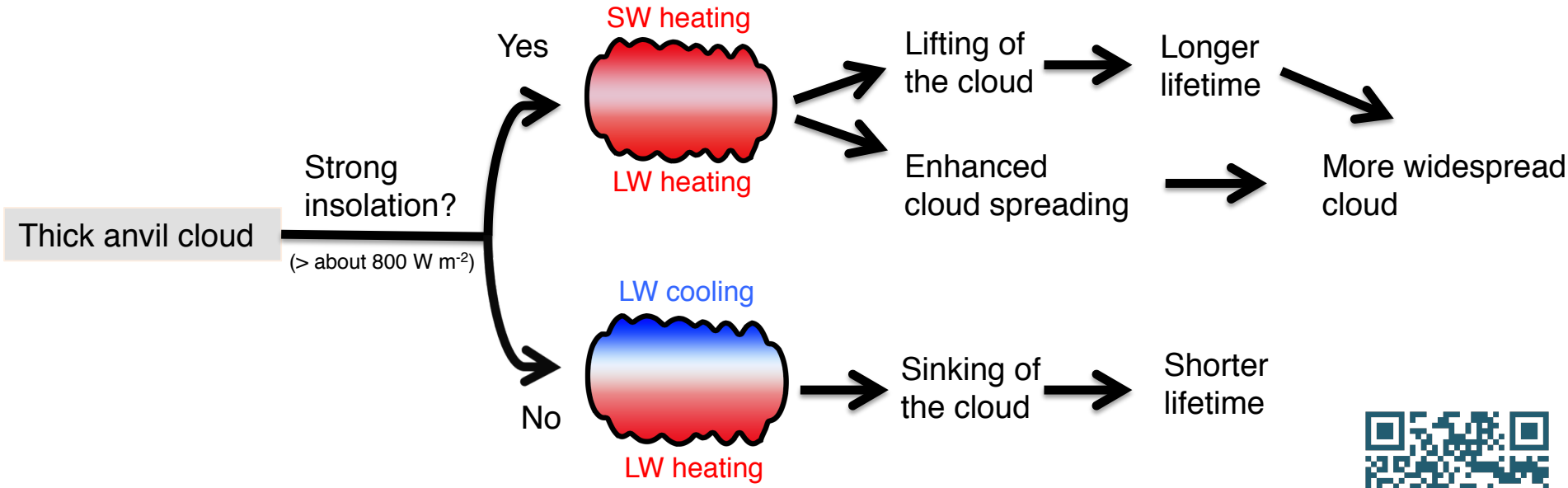
b) In-cloud convection



Hartmann et al., 2018
Sokol and Hartmann, 2020

Turbulence generates new ice crystals
=> smaller than those from deep conv.
=> Slower sedimentation

Mechanism summary: Anvil cloud evolution pathways depends on the insolation in their initial lifetime stage



Manuscript in review for JClim, available at:
https://www.essoar.org/doi/abs/10.1002/essoar.10506580.1

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