Constraining unified parameterizations with long-term coincident cloud and turbulence observations

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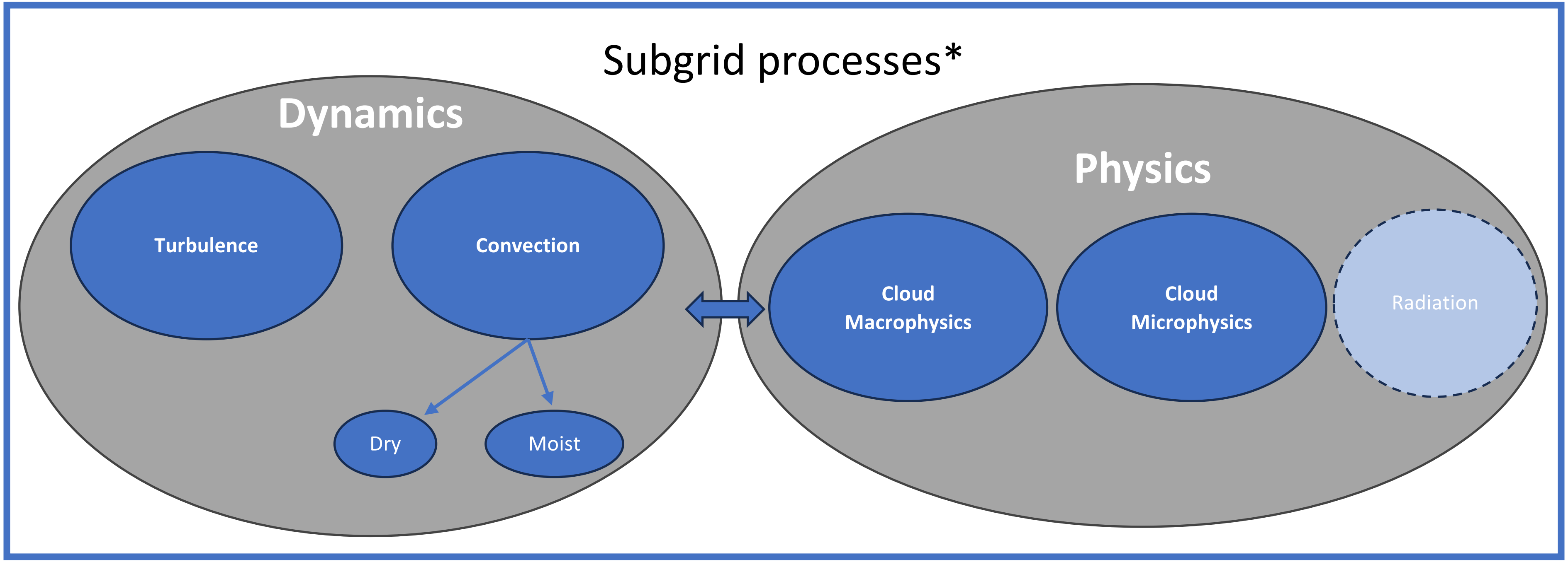
What does it mean to “unify” parameterizations?



* not an exhaustive list

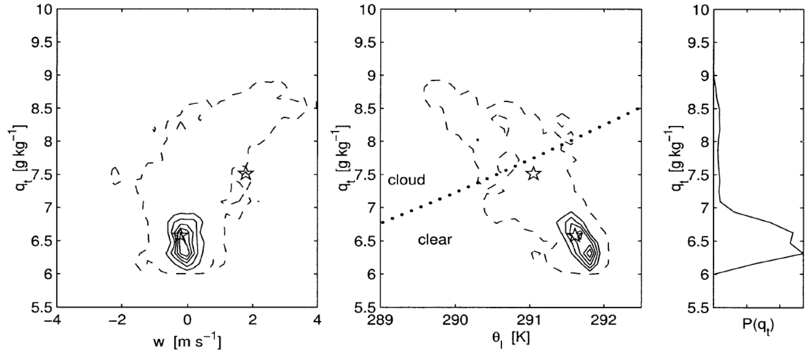
Unified parameterizations

- Degree of process unification varies widely from scheme to scheme, model to model
- Many modern schemes use simple assumed distributions to represent subgrid variability
- Examples: EDMF, CLUBB/SHOC

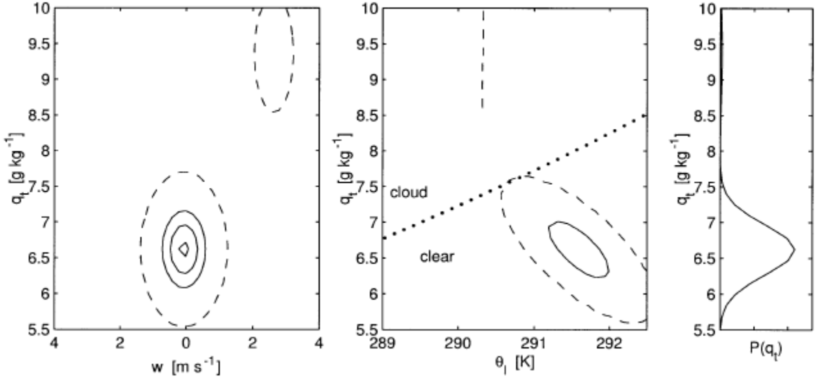
commonly used in NWP

used in ESMs

Aircraft transect of shallow Cu



CLUBB (double Gaussian)



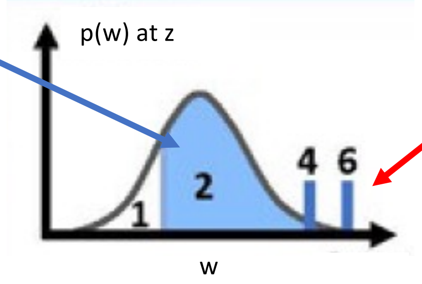
Larson et al. 2002 JAS

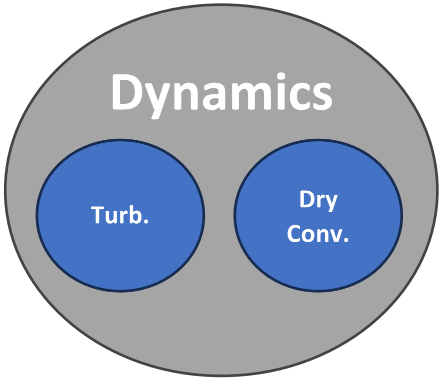
Eddy diffusivity-mass flux (operational)

$$\overline{\boldsymbol{w'\varphi'}} = \textbf{local mixing} + \textbf{convection}$$

$$\overline{w'\varphi'}\Big|_{ED} = -K(\bar{e})\frac{\partial\bar{\varphi}}{dz}$$

$$\overline{w'\varphi'}\Big|_{MF} = \sum a_i w_i \varphi_i'$$

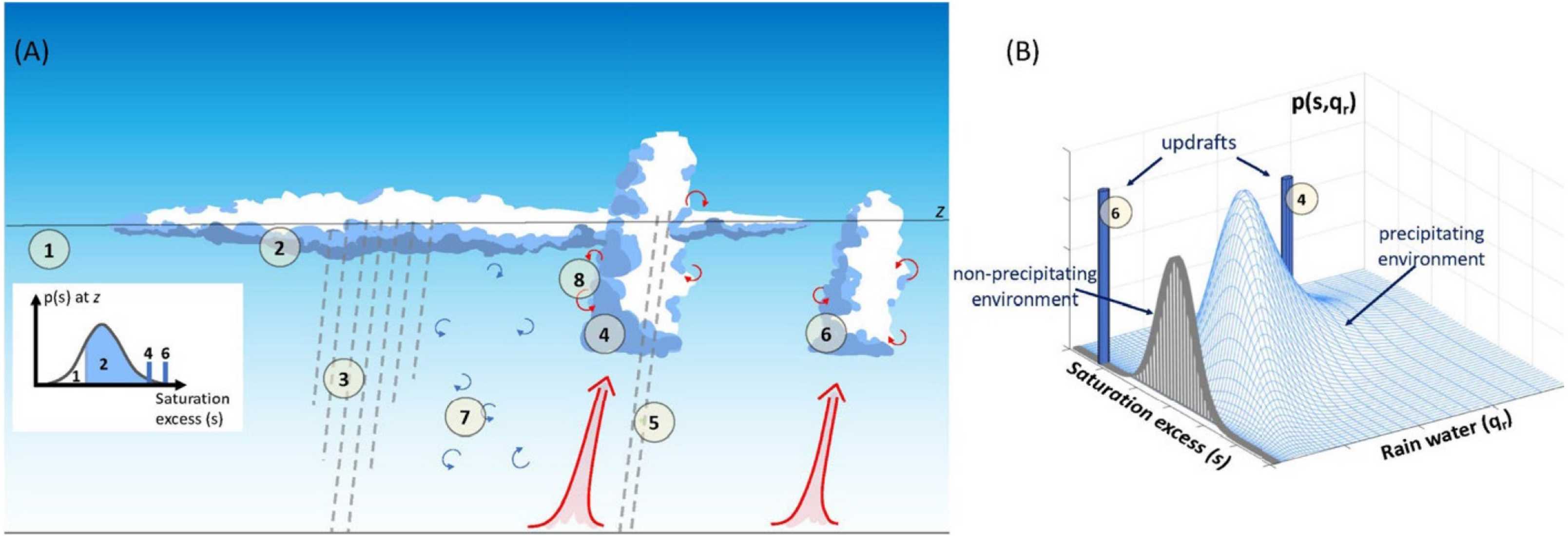




e.g., Siebesma et al. 2007

Suselj et al. 2022 JAMES

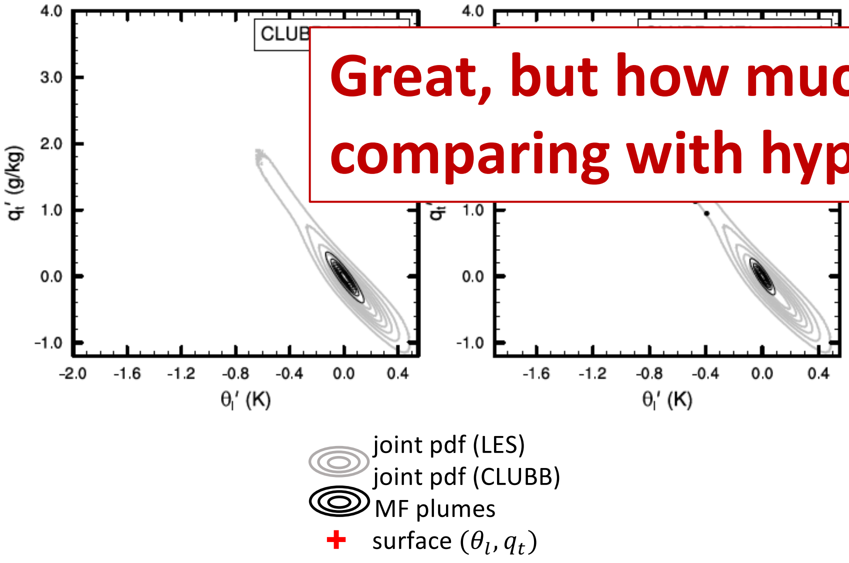
Eddy diffusivity-mass flux (fully loaded)



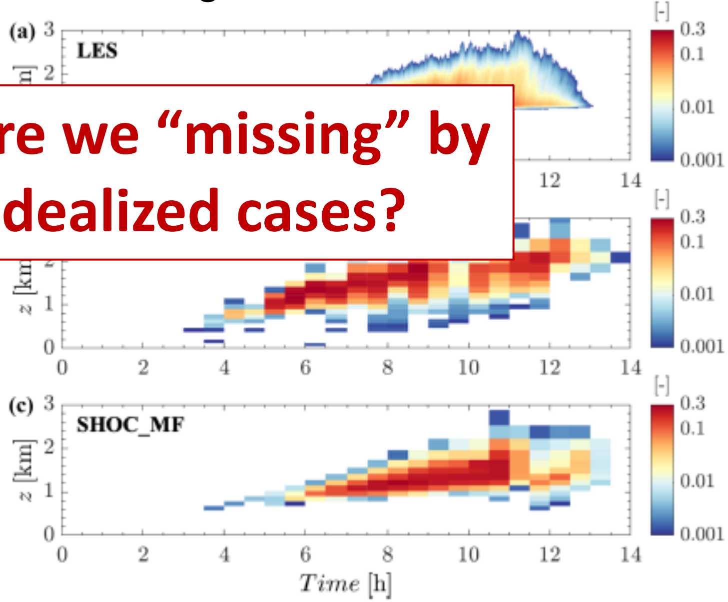
(1)	Cloud-free environment (unsaturated part of the JPDF)	(2)	Stratiform cloud (Saturated part of the JPDF)
(3)	Stratiform precipitation	(4)	Precipitating updraft (Dirac delta PDF)
(5)	Convective precipitation	(6)	Non-precipitating updraft
(7)	Non-convective turbulence	(8)	Entrainment for the updrafts

Validating results: model (SCM) vs. model (LES)

Joint distributions of θ_l and q_t



Time-height curtains of cloud cover



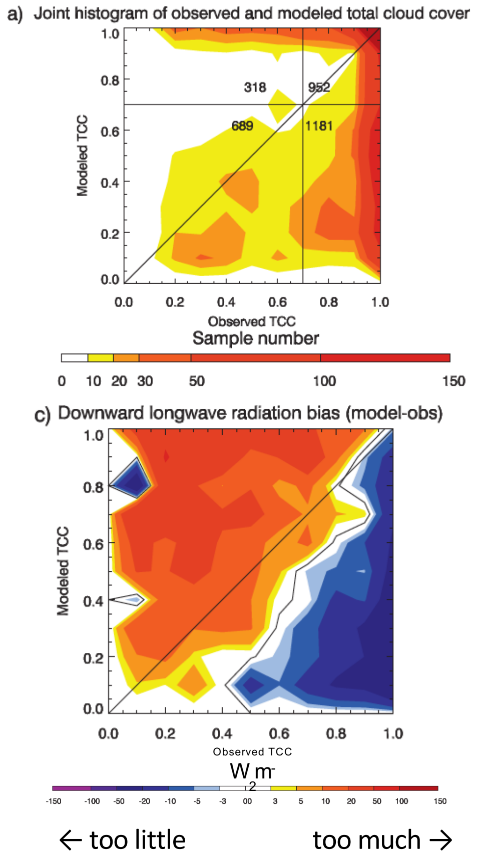
Great, but how much are we "missing" by comparing with hyper-idealized cases?

Witte et al. 2022 MWR

Chinita et al. 2023 GMD

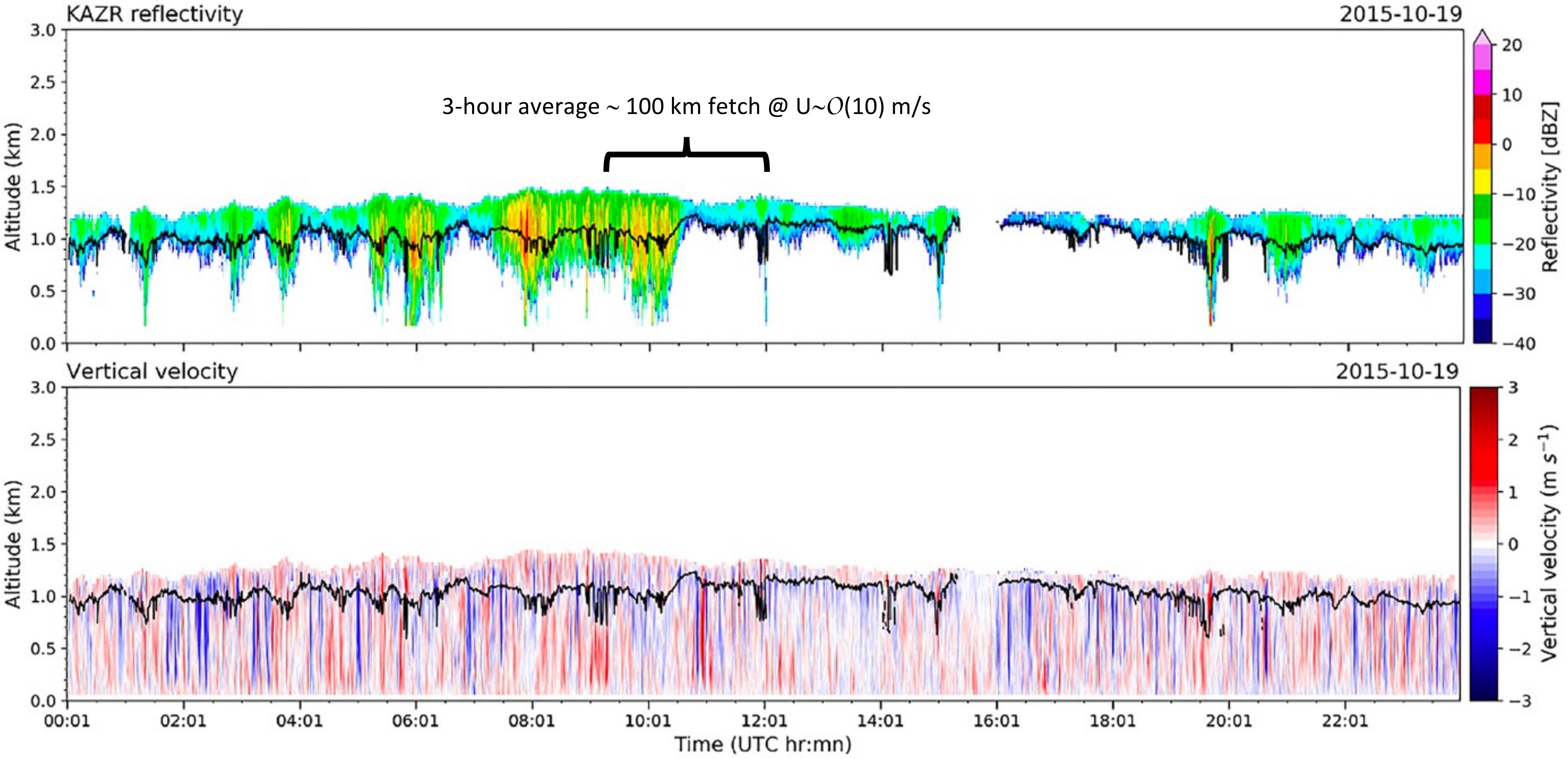
Validating results: model (SCM/3D) vs. obs

- Data from ENA observatory precursor was used to evaluate low clouds in IFS (Ahlgrimm and Forbes 2014)
- Improvements to microphysics and Cu triggering led to reduced radiation biases in 3D model
- Lack of value-added retrievals (i.e., of *w*) limited their analysis to cloud cover and radiation properties

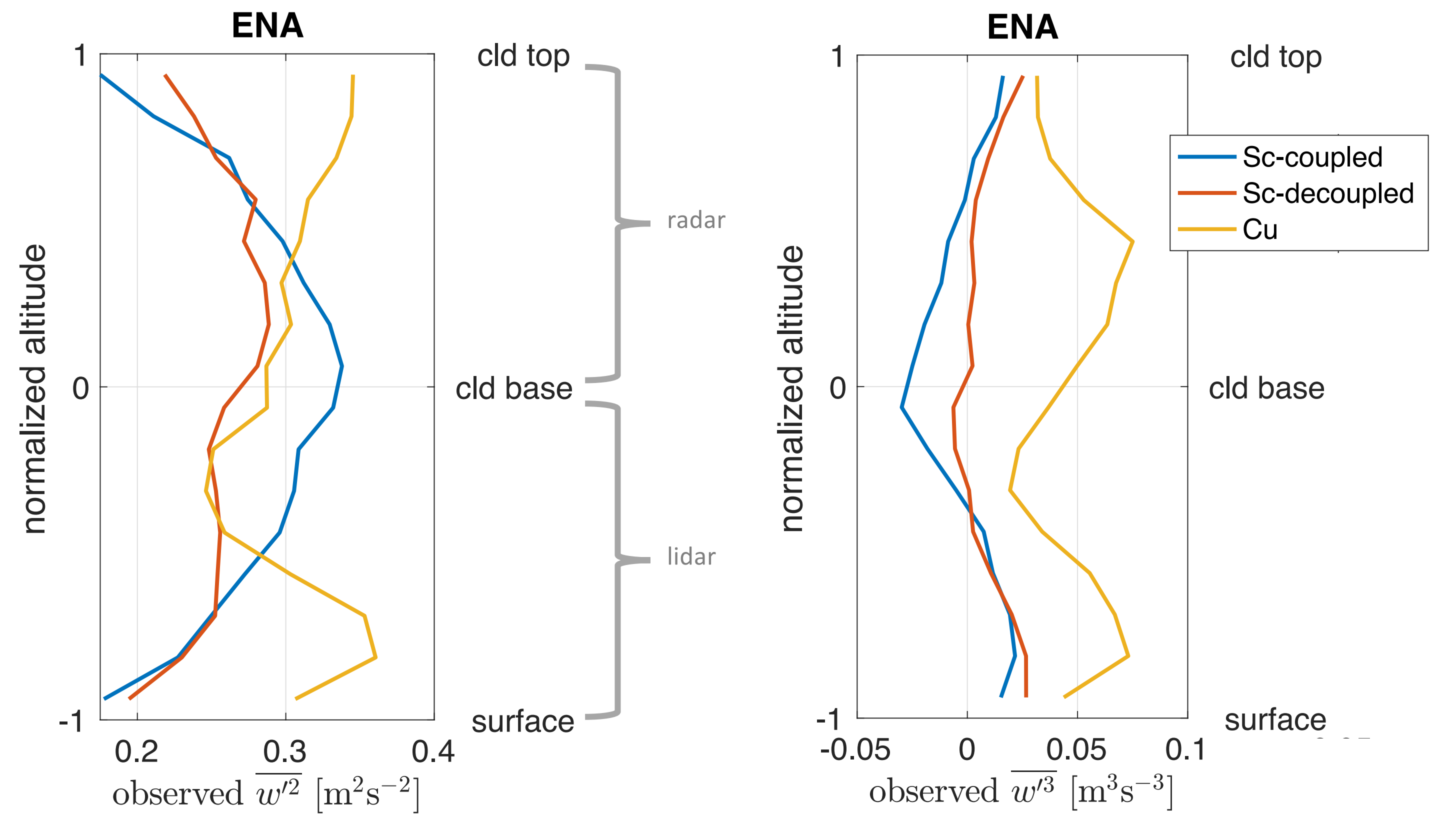


ENA observatory

- Graciosa Island, Azores, Portugal
- US DOE long-term remote sensing site
- Main sensors used:
  - zenith-pointing Doppler lidar
  - zenith-pointing Ka-band radar
  - 3-channel microwave radiometer
- Main retrieved variables:
  - radar reflectivity
  - retrieval fraction (proxy for cloud fraction)
  - vertical velocity
  - integrated water paths (vapor, cloud, rain)
- Vertical velocity retrievals available from 8 OCT 2015 to 28 AUG 2017
- ~2400 hours of PBL cloud observations

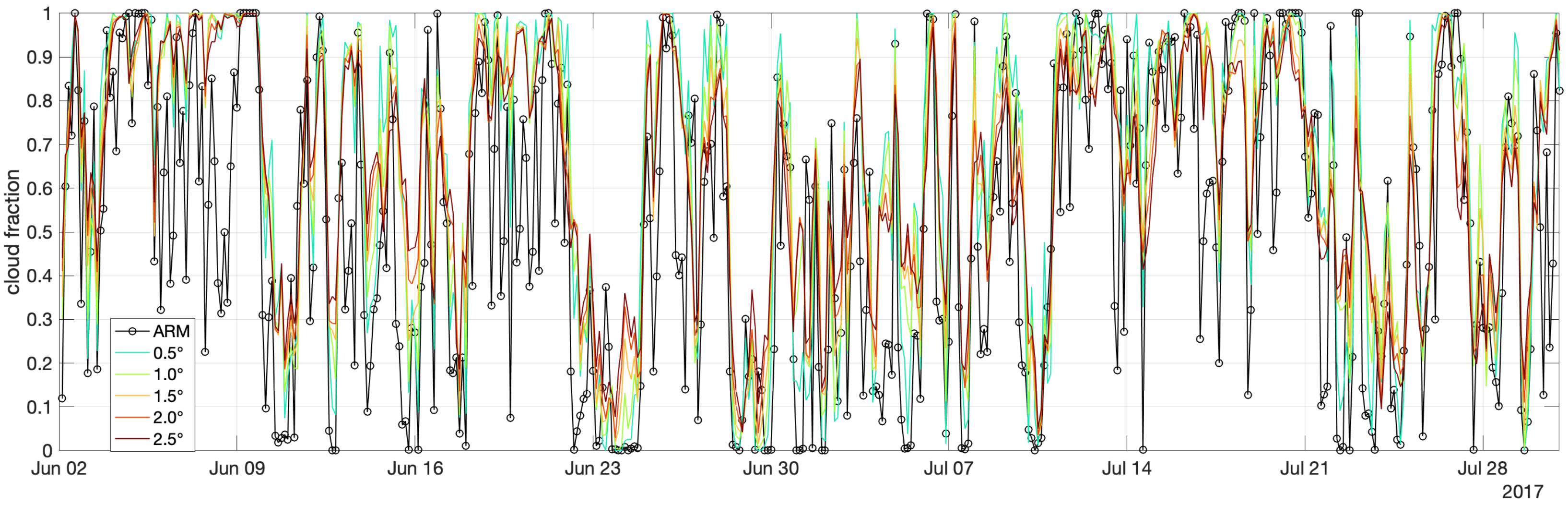


Jeong et al., 2022 JGR



ENA
1
0
-1
0.2
0.3
0.4
normalized altitude
observed $\overline{w'^2}$ $[\mathrm{m^2 s^{-2}}]$
cld top
cld base
surface
radar
lidar
ENA
1
0
-1
-0.05
0
0.05
0.1
normalized altitude
observed $\overline{w'^3}$ $[\mathrm{m^3 s^{-3}}]$
cld top
cld base
surface
Sc-coupled
Sc-decoupled
Cu

Retrieval fraction is a decent proxy for cloud cover



ARM: KAZR 3-hour retrieval fraction

Shaded curves: 3-hour average of 15-min Meteosat SEVIRI cloud fraction

Experimental setup

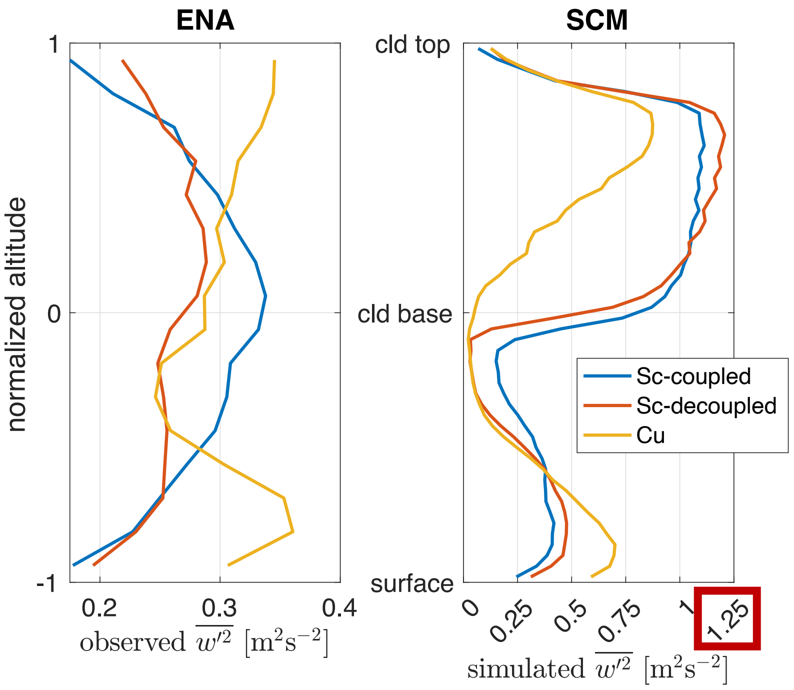
- JPL EDMF in standalone single column mode (Suselj et al. 2022) coupled to RRTMG

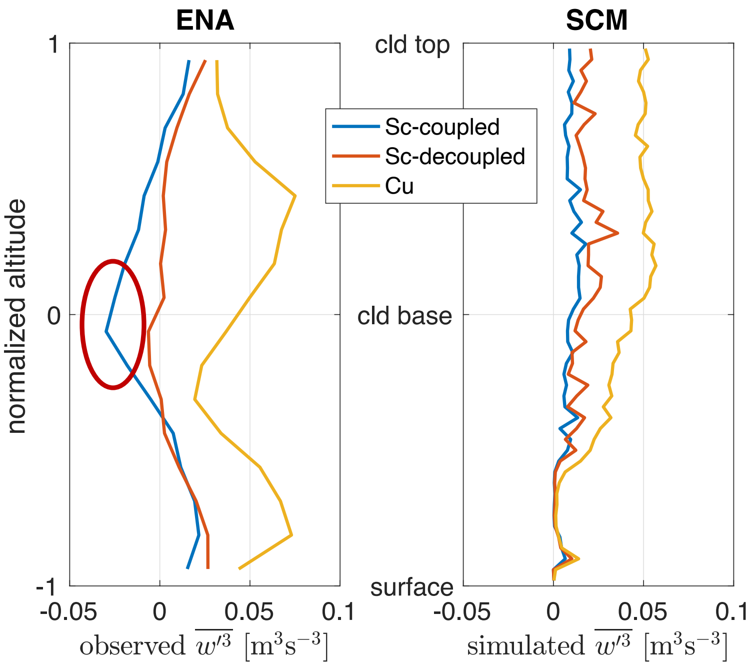
- MERRA-2 reanalysis for surface fluxes and initial conditions
  (also tried ERA5 – inversion height often biased too low)

- 802 three-hour simulations of low clouds, subjectively categorized as coupled/decoupled stratocumulus (Sc) or shallow cumulus (Cu)

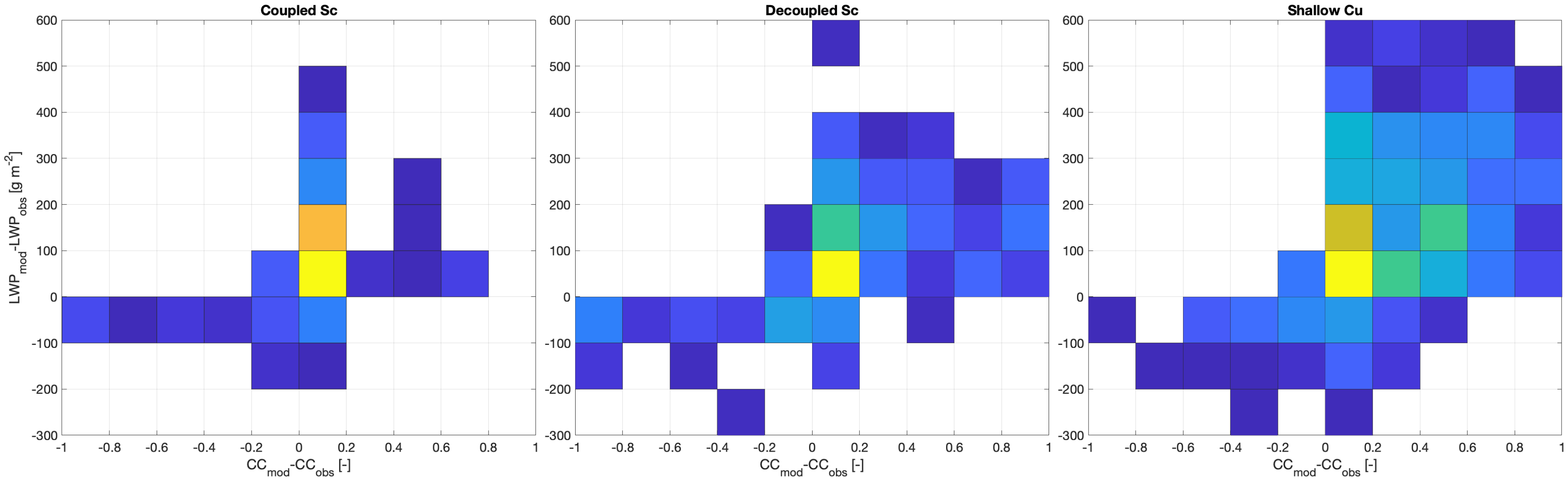
- Compare output with 3-hour averaged ENA observations

Turbulence results

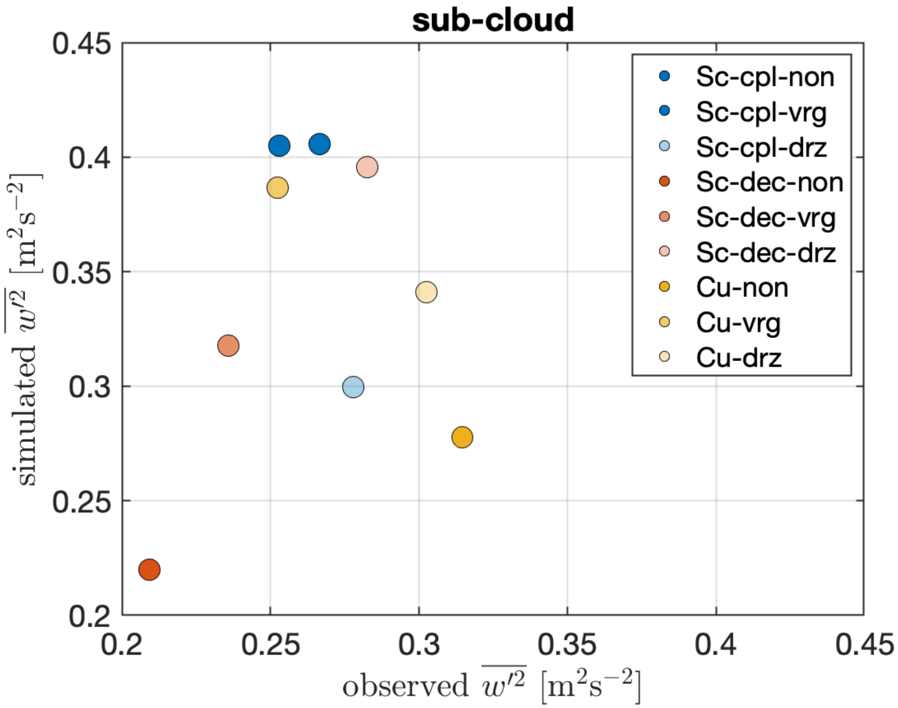




Cloudiness results



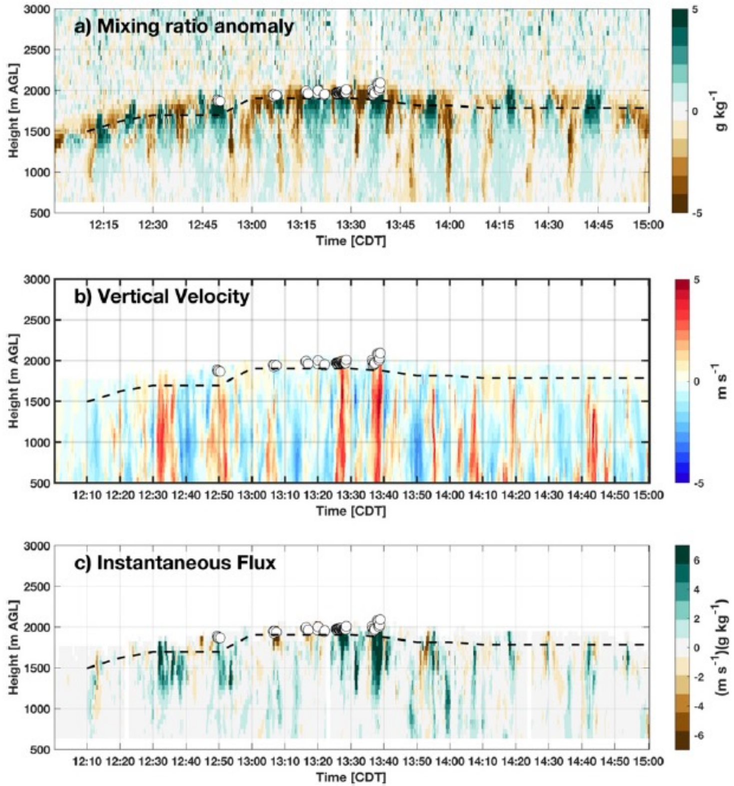
Microphysics-dynamics coupling



- Drizzle impacts on decoupled Sc are handled with skill
- Observed Cu and coupled Sc respond to precipitation differently than simulations
- Decreasing $\overline{w'^2}$ with increasing drizzle could be due to lack of cold pool representation (focus of ongoing work)

Obs Wish List: Turbulent Fluxes

- Fluxes are the fundamental quantity predicted by subgrid dynamics schemes
- Retrievals exist (RL+DL) but are limited to sub-cloud layer, unclear if operable in rain
- Complicated to automate processing (case selection, noise removal, data gaps, etc.)
- Can framework be extended for SH flux too?



Lareau 2020

Summary

- The JPL EDMF overpredicts turbulence intensity in the cloud layer and underpredicts $\overline{w'^2}$ in the sub-cloud layer
- Cloud cover is reproduced well for Sc, overpredicted for Cu
- LWP overpredicted for all cloud types – likely due to $\overline{w'^2}$ producing overly broad supersaturation variance
- “Missing” skewness, subcloud $\overline{w'^2}$ may be caused by lack of downdrafts in EDMF and poor microphysics-dynamics coupling
- The comparison framework presented here is easily adapted for any model output format (most easily to an SCM, e.g., CCPP)