Investigation of cloud-PBL coupling for warm continental clouds and its applications

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Warm Boundary Layer Processes
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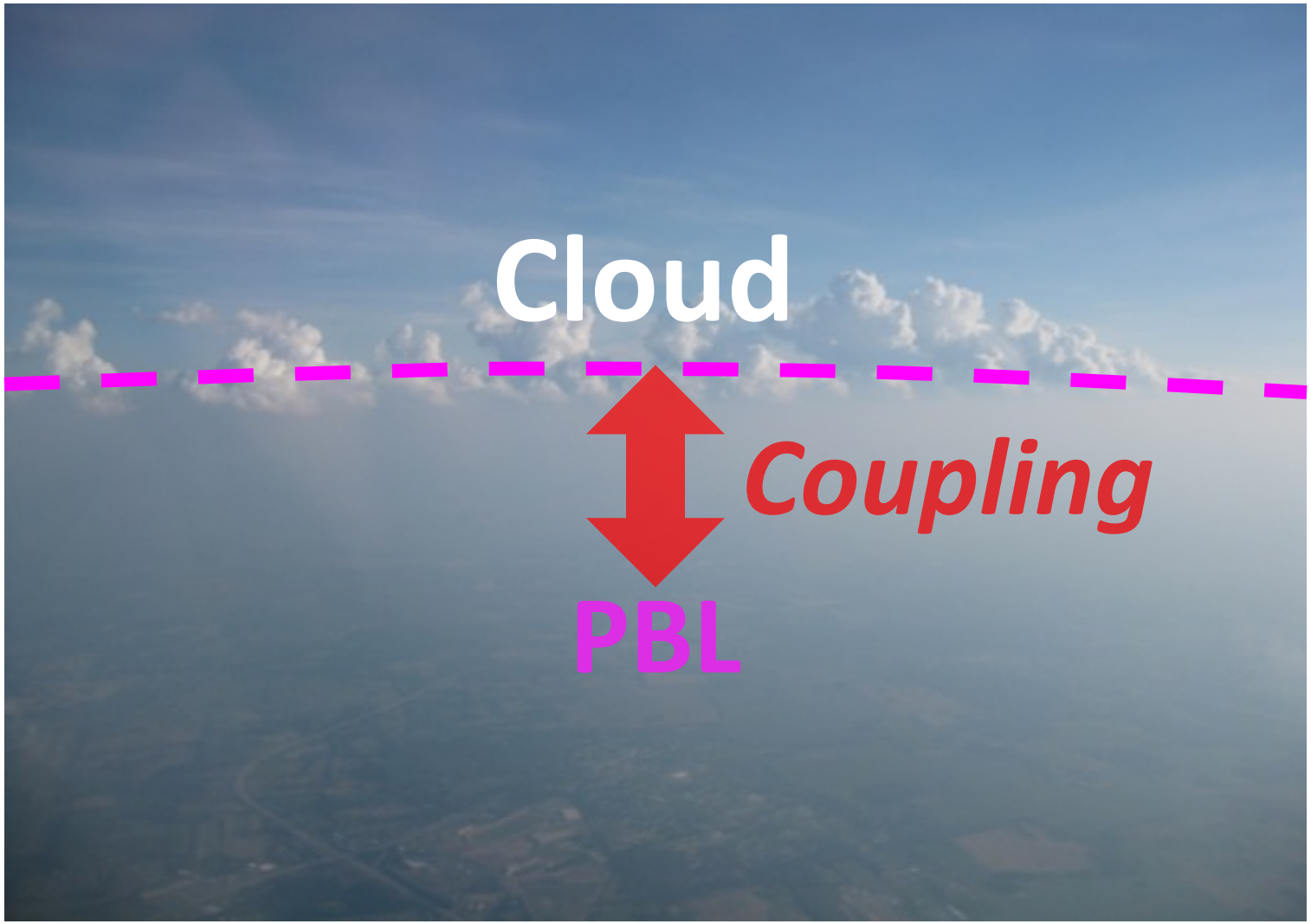
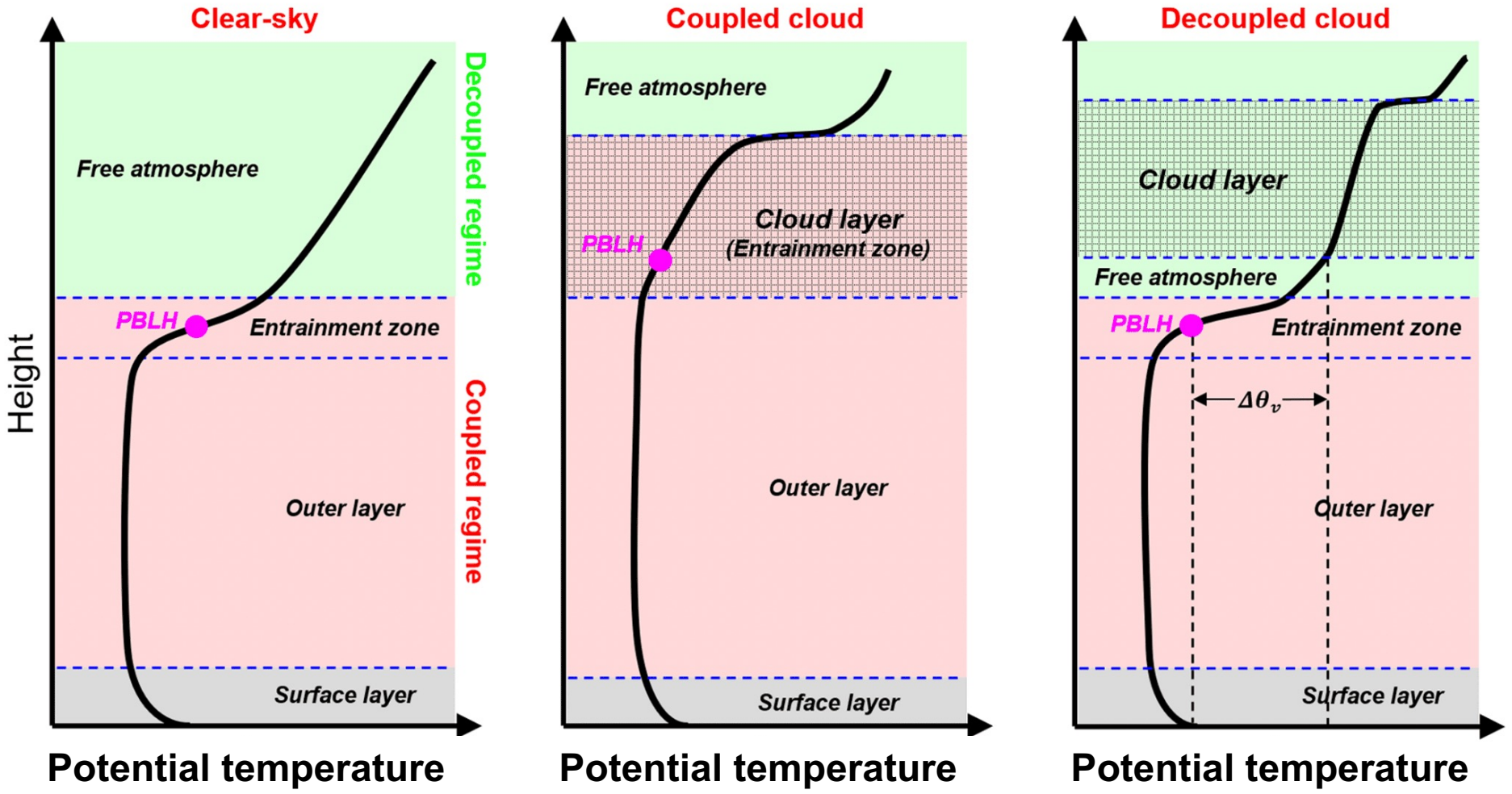
Introduction

Courtesy: Prof. W. Brune, https://www.e-education.psu.edu/meteo300/node/711

Cloud-PBL Coupling



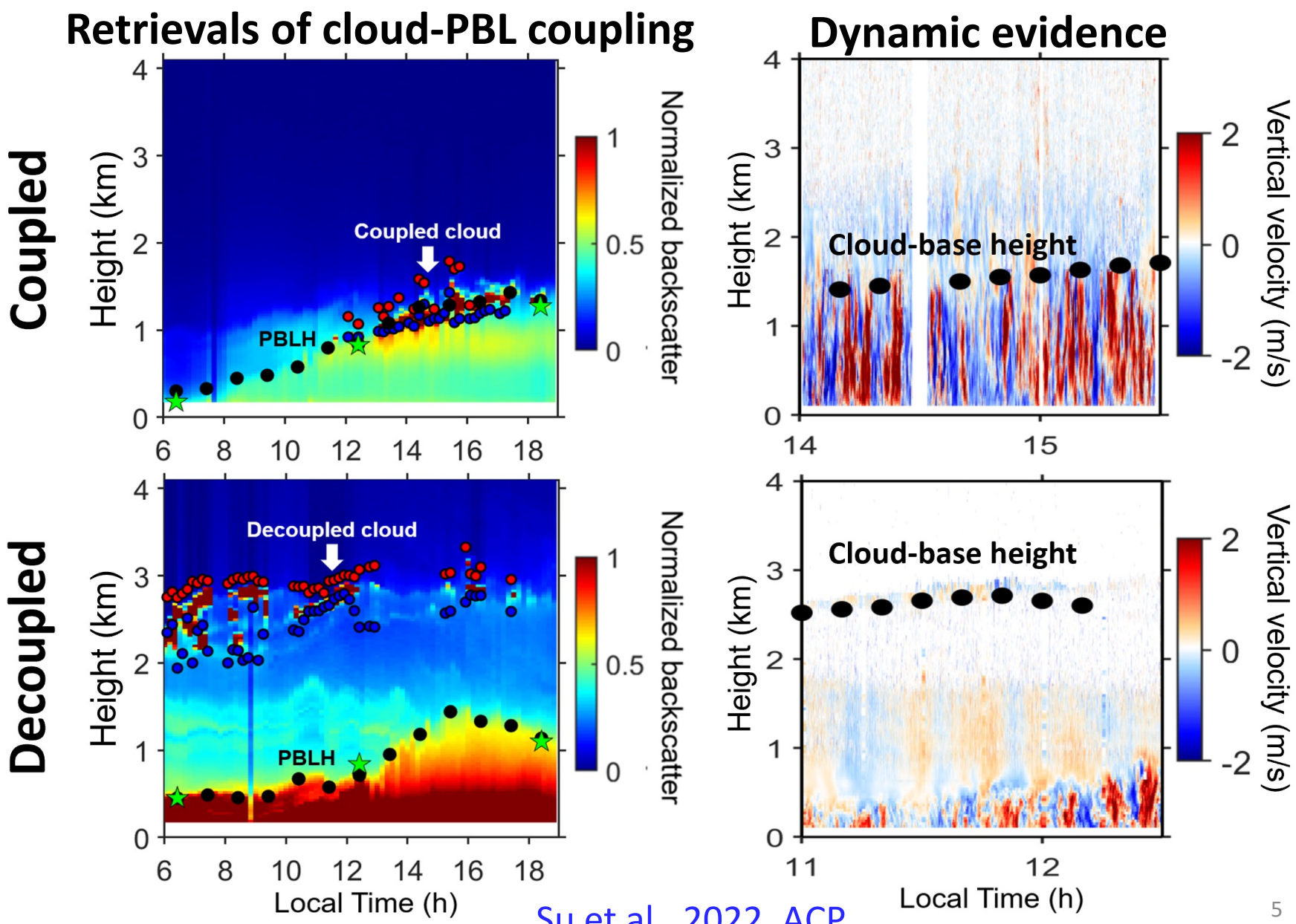
What is the fundamental difference between coupled and decoupled clouds?



Cloud-PBL coupling is equivalent to cloud-surface coupling over land.

Su et al., 2022, ACP

Identification of cloud-PBL coupling



Su et al., 2022, ACP

Highlight in the 2022 DOE ARM Annual Report

Cloud-Land Coupling Examined at Southern Great Plains Observatory

Cloud-Land Coupling Examined at Southern Great Plains Observatory

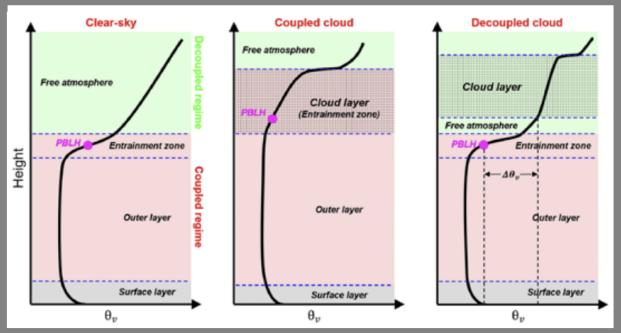
Connections between the surface and clouds are important for understanding how clouds develop. Most previous work on these connections has centered on oceans rather than land. Data from ARM's Southern Great Plains atmospheric observatory allowed researchers to study the coupling between clouds and land.

In research published by *Atmospheric Chemistry and Physics* in January 2022, scientists simultaneously measured the planetary boundary-layer height and coupled states under cloudy conditions. A lidar-based method developed by the researchers relies on the planetary boundary-layer height, lifted condensation level (the altitude at which a moist but unsaturated air parcel becomes saturated), and cloud base height to identify cloud coupling.

As coupled and decoupled clouds have distinct features, the new method offers an advanced tool to separately investigate them. Researchers generated a 20-year climatology by using the method.

Reference

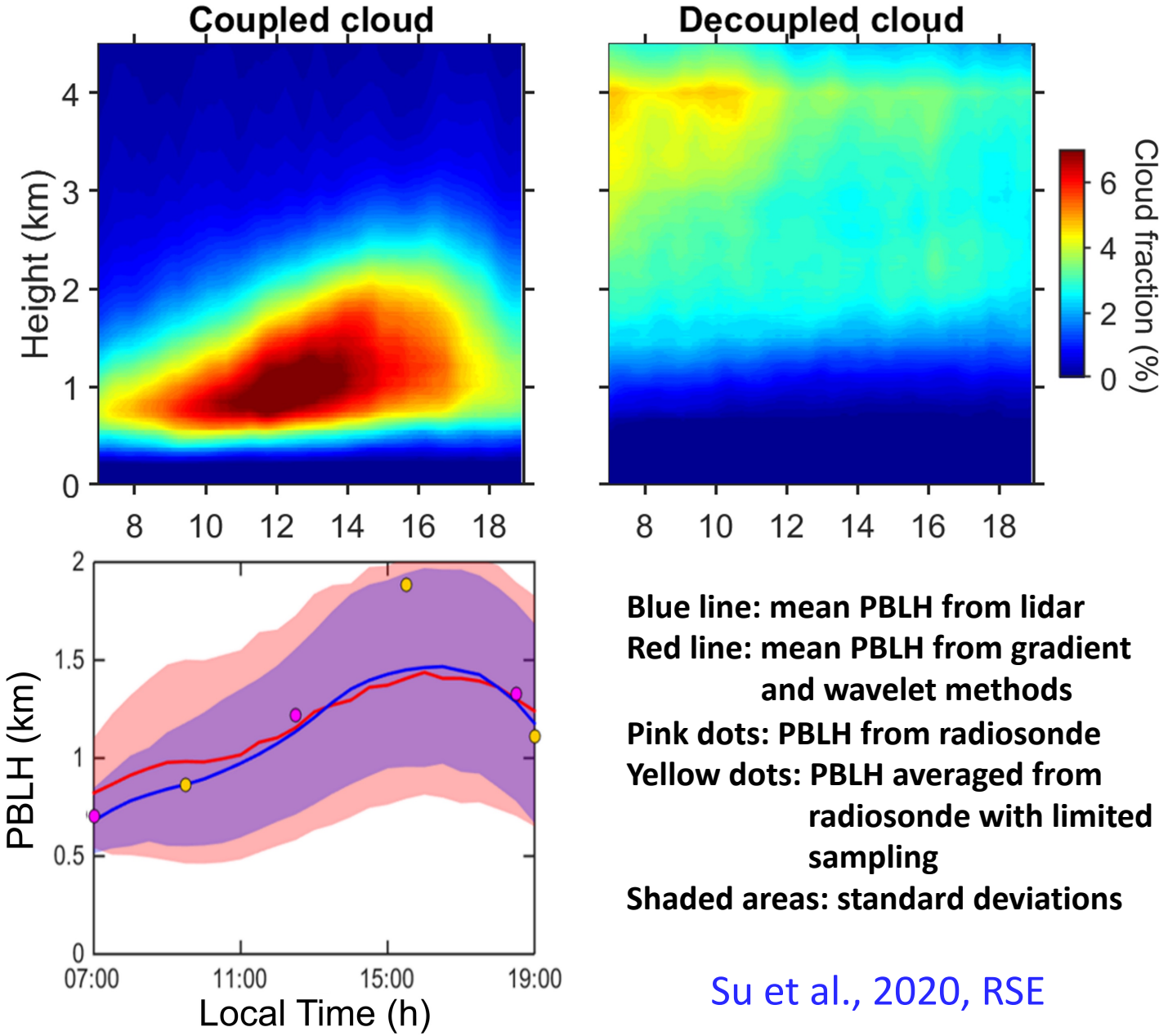
Su T, Y Zheng, and Z Li. 2022. "Methodology to determine the coupling of continental clouds with surface and boundary layer height under cloudy conditions from lidar and meteorological data." *Atmospheric Chemistry and Physics* 22(2):1453-1466, https://doi.org/10.5194/acp-22-1453-2022.



Analyzing data from the MOSAiC expedition, scientists noted a difference in ice-nucleating particle concentration scales between different temperatures. Error bars represent standard deviation. (*Copyrighted image from the journal.***)**

One of nine studies highlighted in the Annual Report

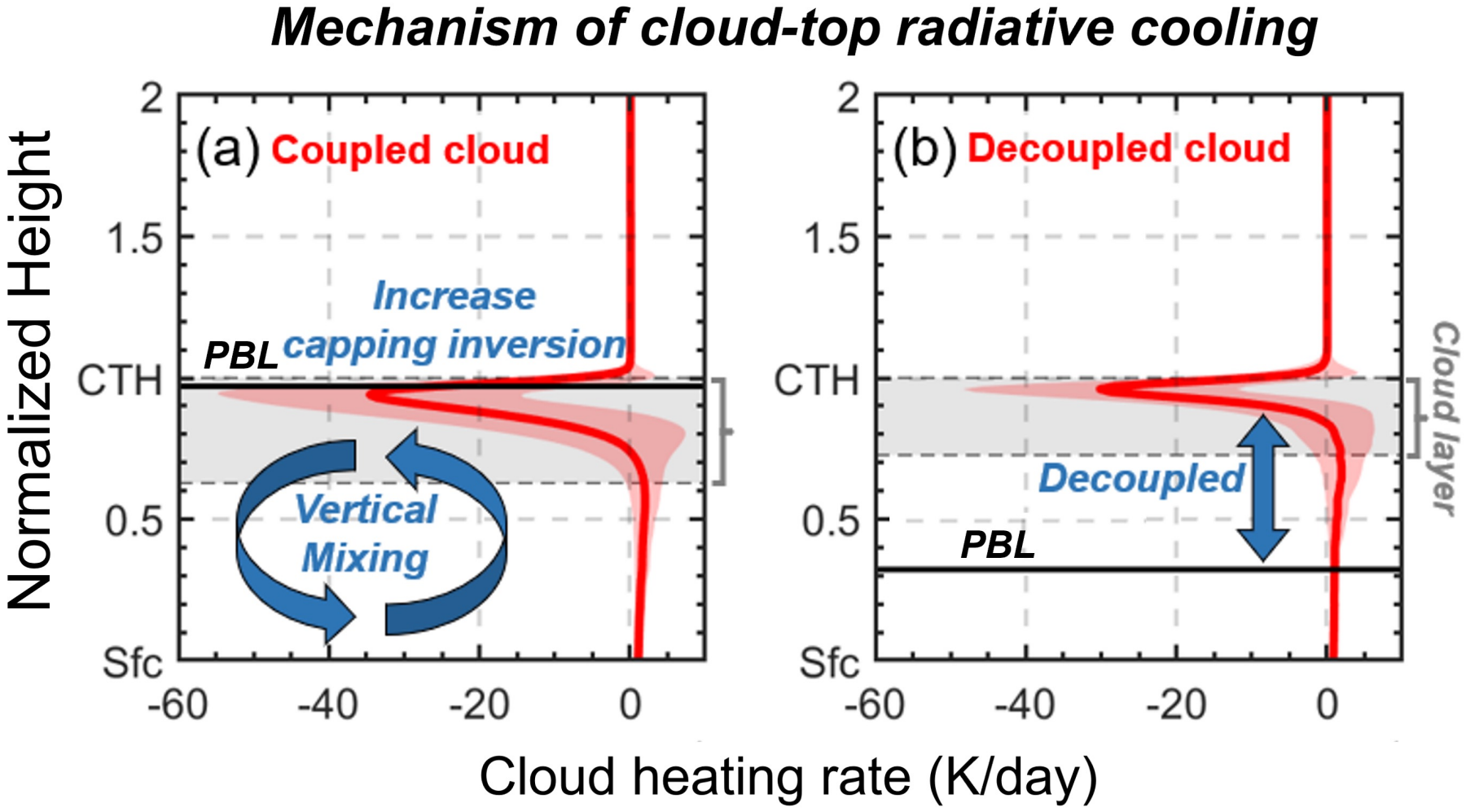
Cloud-PBL coupling leads to a strong interaction



Blue line: mean PBLH from lidar
Red line: mean PBLH from gradient and wavelet methods
Pink dots: PBLH from radiosonde
Yellow dots: PBLH averaged from radiosonde with limited sampling
Shaded areas: standard deviations

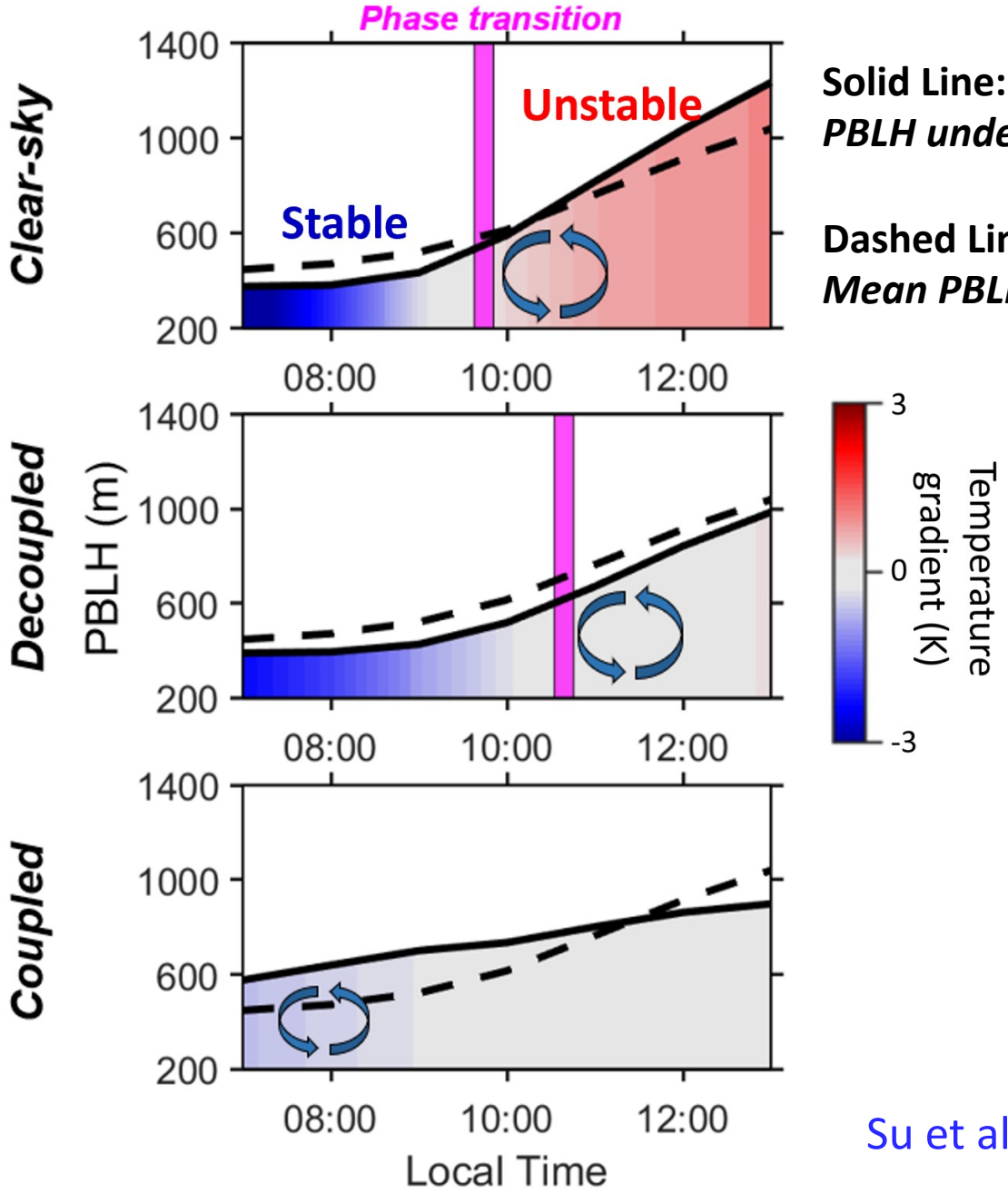
Su et al., 2020, RSE

Cloud-PBL coupling affects PBL stability



Su et al., 2023, GRL

Cloud-PBL coupling alters PBL diurnal cycles

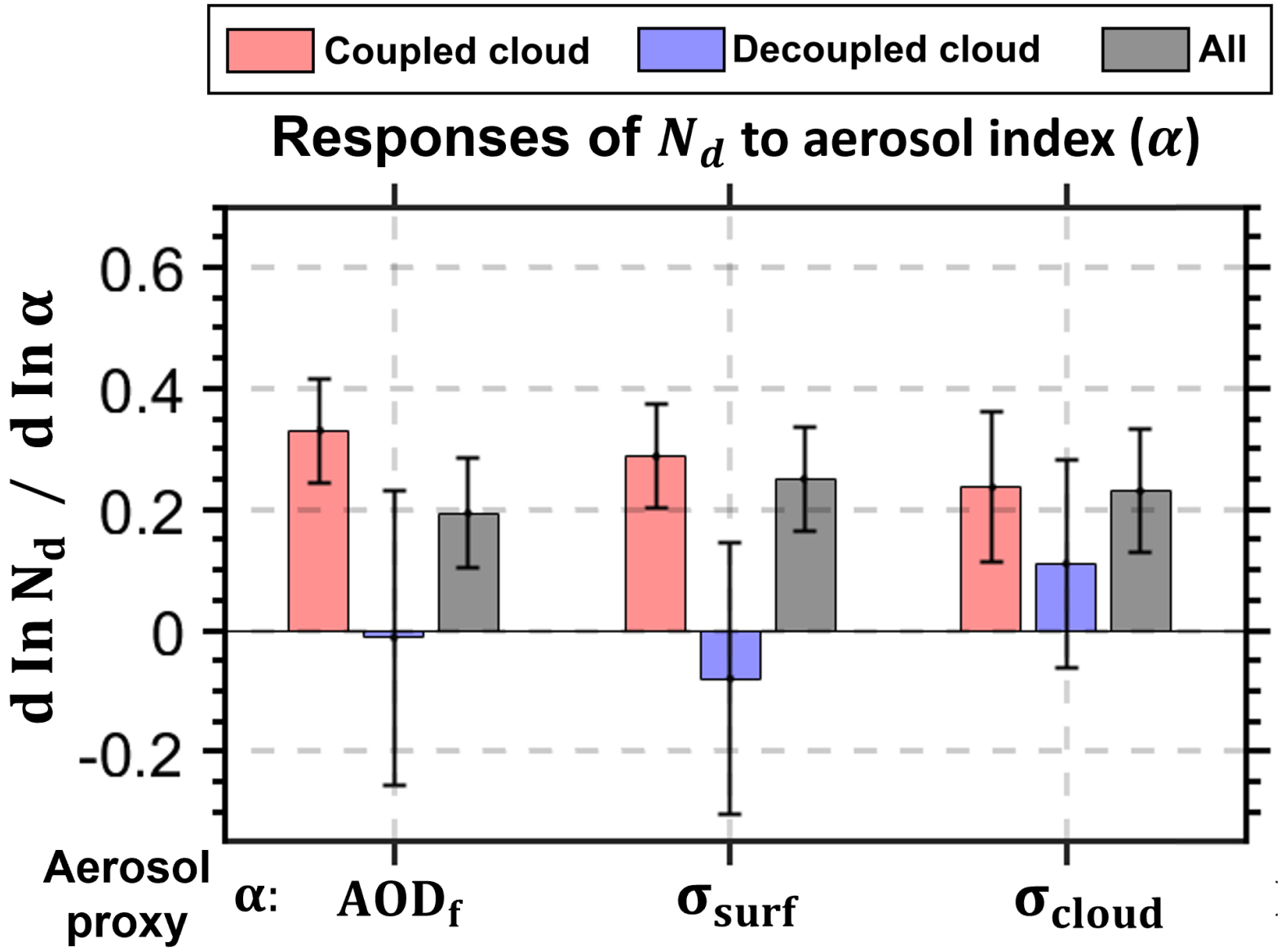


Solid Line:
PBLH under different conditions

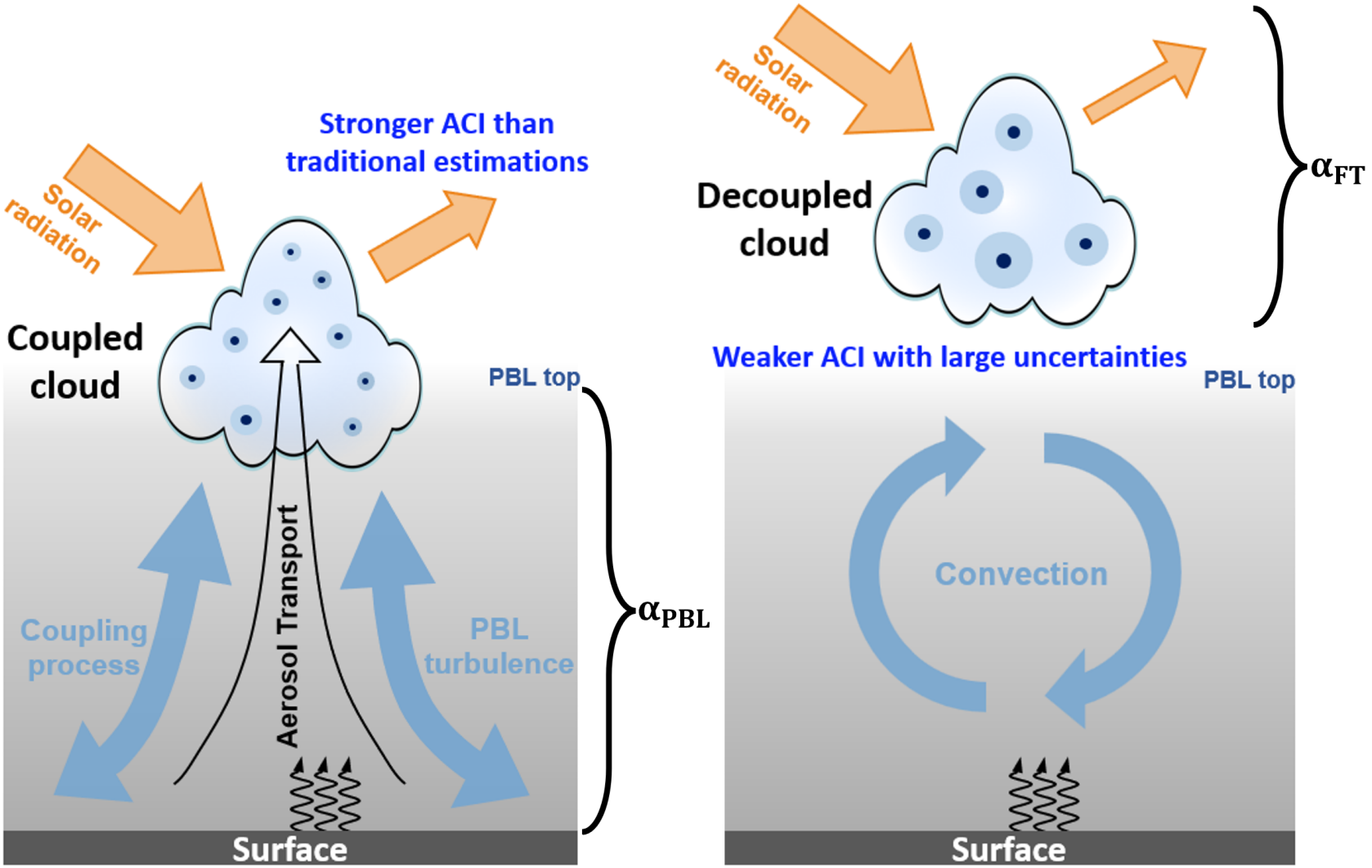
Dashed Line:
Mean PBLH for all cases

Su et al., 2023, GRL

Cloud coupling changes responses of clouds to aerosols



Neglecting cloud coupling results in an underestimation of aerosol-cloud interactions



Su et al., under review

Take-Home Messages

- **We have developed a lidar-based method to determine cloud-PBL coupling over land.** (Su et al., 2020, RSE; Su et al., 2022, ACP)

- **Our study reveals that the coupling process between clouds and the PBL can largely change the PBL diurnal cycle.** (Su et al., 2023, GRL)

- **Our findings underscore the impact of cloud-surface coupling on ACI, potentially advancing our ability to constrain aerosol indirect radiative effects.** (Su et al., under review)

Publications

Su, T., Li, Z., and Zheng, Y., 2023. Cloud-surface coupling alters the morning transition from stable to unstable boundary layer. *Geophys. Res. Lett.*

Su, T., Zheng, Y., and Li, Z., 2022. Methodology to determine the coupling of continental clouds with surface and boundary layer height under cloudy conditions from lidar and meteorological data. *Atmos. Chem. Phys.*

Su, T., Li, Z., and Kahn, R., 2020. A new method to retrieve the diurnal variability of planetary boundary layer height from lidar under different thermodynamic stability conditions. *Remote Sens. Environ.*