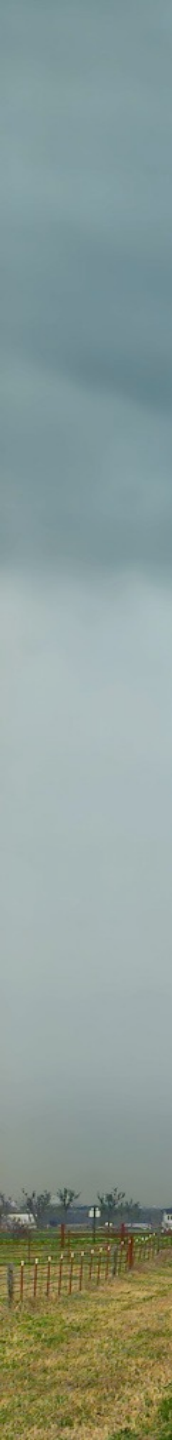


ASR
Atmospheric
System Research

Warm Boundary Layer Processes Working Group Updates

Rob Wood and Yunyan Zhang

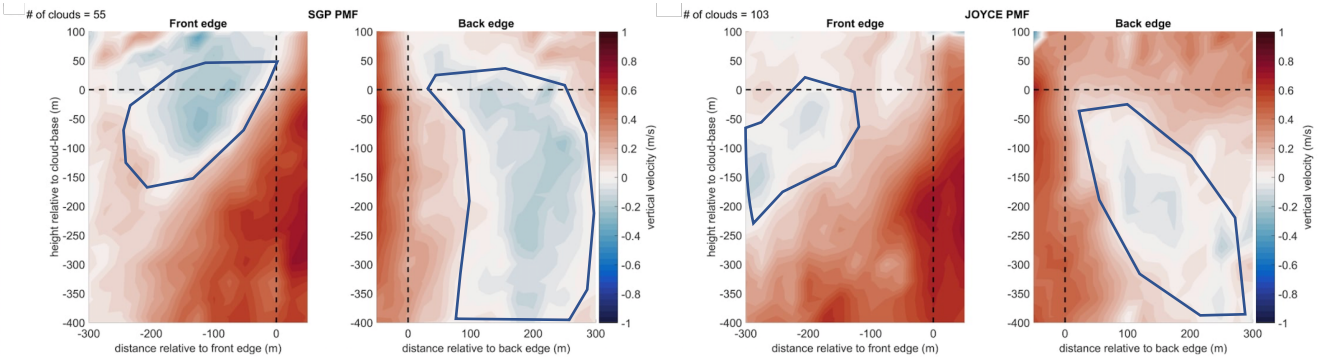
U.S. DEPARTMENT OF ENERGY

THIS WORK WAS PERFORMED UNDER THE AUSPICES OF THE U.S. DEPARTMENT OF ENERGY BY LAWRENCE LIVERMORE NATIONAL LABORATORY UNDER CONTRACT DE-AC52-07NA27344. LAWRENCE LIVERMORE NATIONAL SECURITY, LLC LLNL-PRES-823656

Subsiding Shells in Shallow Cumulus From Doppler Lidar and LES

Lucas A. McMichael and David B. Mechem, *University of Kansas*

Doppler Lidar Composites of Positive Mass-Flux Clouds



SGP Lidar – Northern Oklahoma

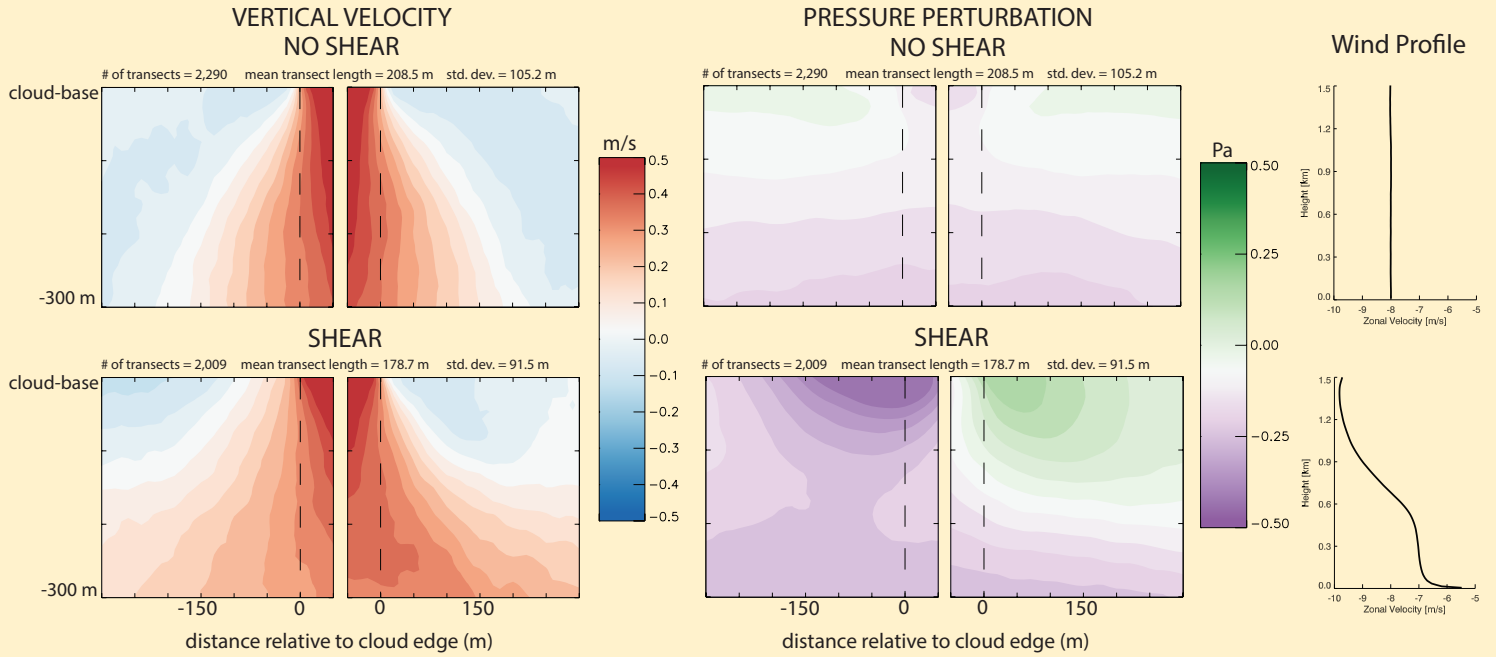
JOYCE Lidar – Western Germany

McMichael et al. (2020), GRL

- Asymmetric subsiding shell structure, with back-edge shells extending farther into the subcloud layer and front-edge updrafts gently sloping upward toward cloud base.
- A lidar emulation experiment with LES suggests that the asymmetry between front and back edges is not a result of transient cloud evolution.

Exploring Dynamics Behind The Asymmetry

- Sheared LES run reveals a more vertically oriented up-shear shell and gently sloping updraft on the down-shear side, as observed in lidar composites.
- A downward-directed PPGF may explain the more vertically oriented back-edge shell.
- Additionally, a substantial up-to-down-shear PPGF develops across the cloud.



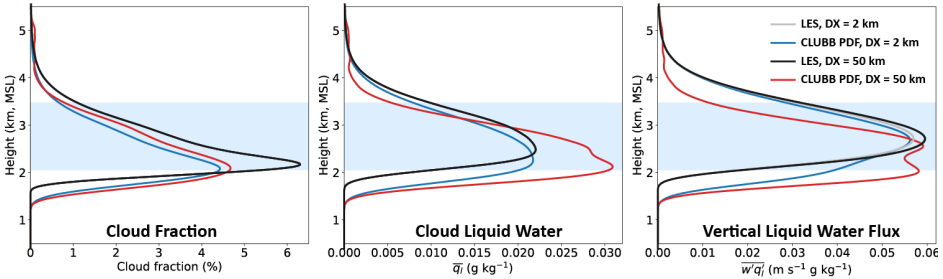
← Shear vector

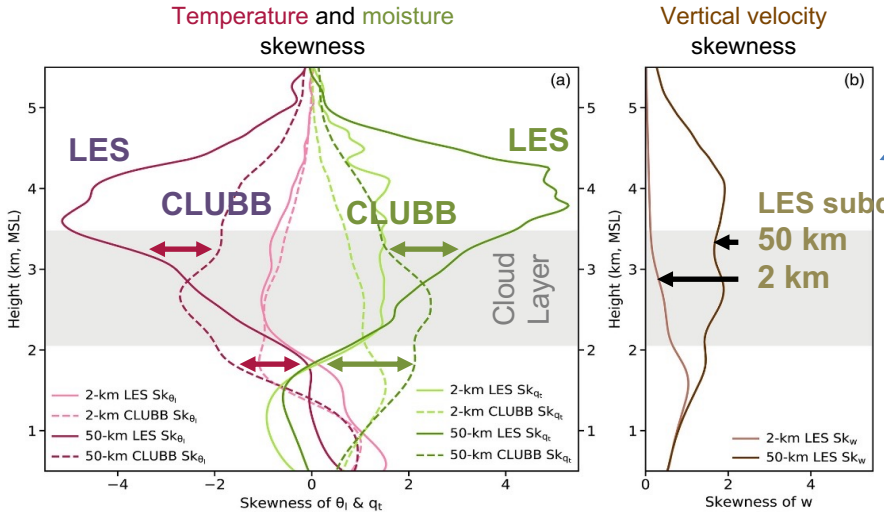
Poster Tues. 3-4 p.m.

This work has been supported by U.S. Department of Energy Atmospheric Systems Research Grant DE-SC0016522.

Representing horizontal moisture variability in a shallow cloud layer

Shallow Convection at SGP (12-14 CST, August 30, 2016)
LES vs CLUBB assumed PDF





- We compare cloud and turbulence statistics from **large-domain LES of shallow convection** from HI-SCALE field campaign with those produced by **CLUBB's assumed PDF** (with input statistics taken from the same LES) for horizontal scales 2–100 km.
- CLUBB's assumed PDF produces significant **biases in cloud properties**, including cloud fraction, cloud water mixing ratio and liquid water flux, especially near the **cloud top and base** and at low horizontal resolutions (> 25 km).
- These biases are mainly caused by misrepresentation of the **skewness** in temperature and moisture horizontal variability.
- More and better observations of the vertical structure of the shallow clouds as well as their horizontal variability are needed to develop and improve coupled cloud and turbulence parameterizations.

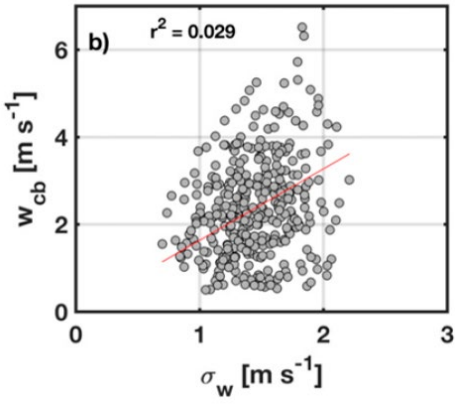
Huang, M., Xiao, H., Wang, M., & Fast, J. D. "Assessing CLUBB PDF closure assumptions for a continental shallow-to-deep convective transition case over multiple spatial scales." *Journal of Advances in Modeling Earth Systems,* **12,** e2020MS002145. (2020). [DOI: 10.1029/2020MS002145]

Sub-cloud turbulence explains cloud-base updrafts for ShCu ensemble

Youtong Zheng* and Zhanqing Li, U. of Maryland. *Now at Princeton/GFDL

Motivation: Sub-cloud turbulent kinetic energy has been used to parameterize the cloud-base updraft velocity (w_b) in cumulus parameterizations. Its validity has never been proved in observations.

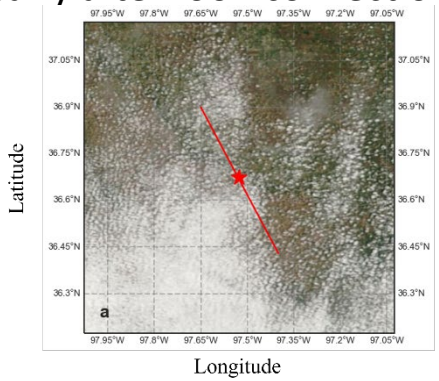
Contrary evidence: some observations show they are not correlated for **single cumuli**:



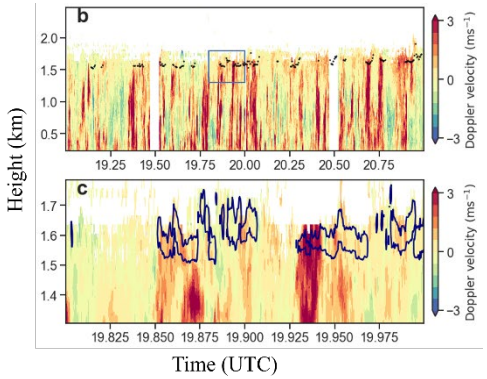
Lareau et al., 2018, JGR

Our argument: w_b of **single cumuli** is different from w_b of **cumulus ensemble.** Correlation occurs for cumulus ensemble, not single cumuli.

Methodology: We use Doppler lidar data from SGP. We develop a **new** lidar sampling methodology to measure w_b of a ShCu ensemble by taking advantage of the stationarity and ergodicity of early afternoon convection.

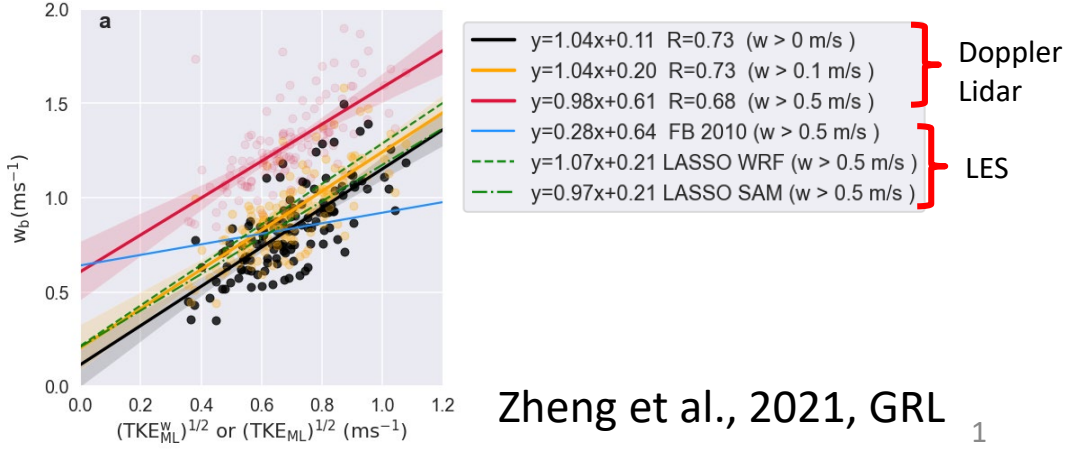


MODIS image



Doppler lidar image

Results: **Sub-cloud TKE explains >~50% of w_b in both Doppler lidar and LASSO LES**

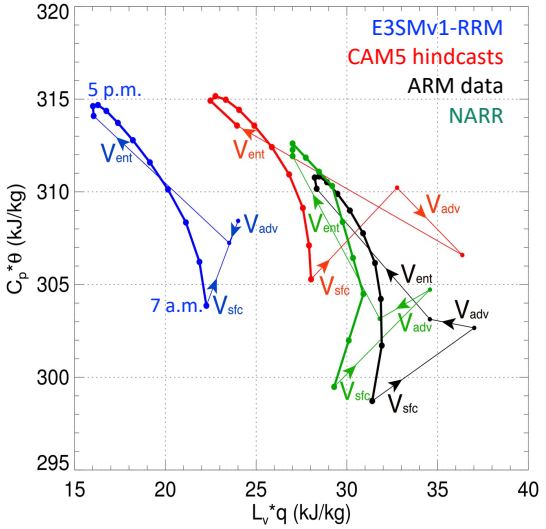


Zheng et al., 2021, GRL

Land-Atmosphere Coupling at Southern Great Plains

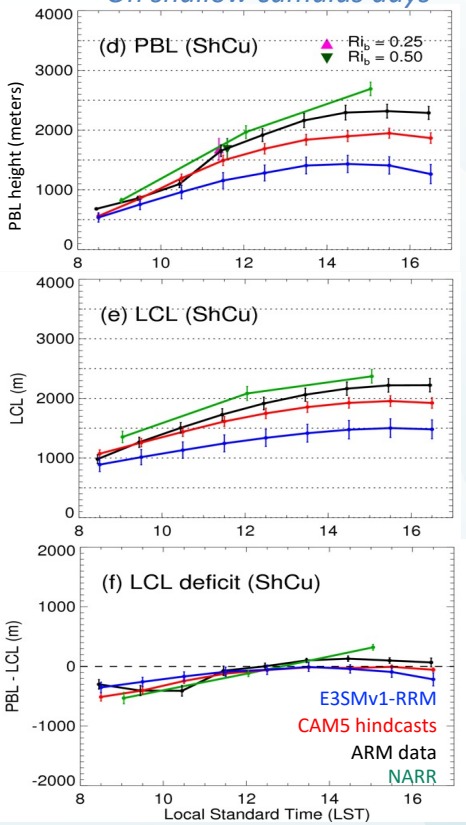
Use ARM data to assess the performance of climate models in representing the interactions between land surface, planetary boundary layer (PBL) and clouds

Mixing diagram on clear-sky days



- Longterm ARM SGP data are used to evaluate CAM5 hindcasts and E3SMv1 Regionally Refined Model (RRM) nudged runs. An analysis framework based on locally generated convective regimes is established to attribute model biases in land-atmosphere coupling to initial morning conditions, large-scale advections, and parameterized boundary layer and convective processes. Compared with ARM observations:
  - On clear-sky days, CAM5 overestimates entrainment drying while E3SMv1-RRM underestimates surface evaporation.
  - On shallow cumulus days, clouds are formed in models with weaker PBL growth and more humid morning conditions.
  - On deep convection days, simulated convections are triggered more often by elevated instabilities with a relatively stable lower troposphere especially in E3SMv1 RRM runs.

On shallow cumulus days



Tao, C., Y. Zhang and Co-authors, 2021: Land-atmosphere coupling at the US Southern Great Plains: A comparison on local convective regimes between ARM observations, reanalysis, and climate model simulations. *J. Hydrometeor.,* 22 (2), 463-481, https://doi.org/10.1175/JHM-D-20-0078.1

DOE Early Career Research Program

ARM

ASR Atmospheric System Research

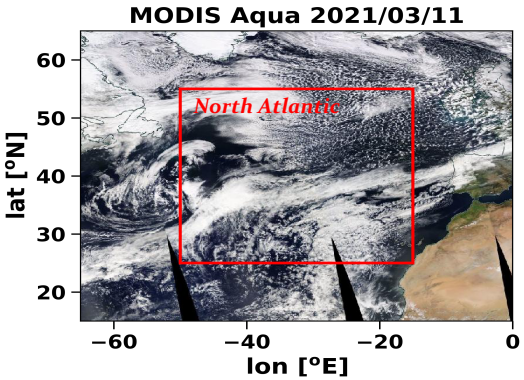
See Poster, Tao et al, Thurs. 3-4 p.m.

National Nuclear Security Administration

Sea Surface Temperature Control on the Brightness of Marine Clouds over the North Atlantic Ocean

Xiaoli Zhou[1,2], Jianhao Zhang[1,3], Graham Feingold[1]

[1]NOAA CSL, [2]CIRES, [3]NRC



- ***Dataset and Methods***

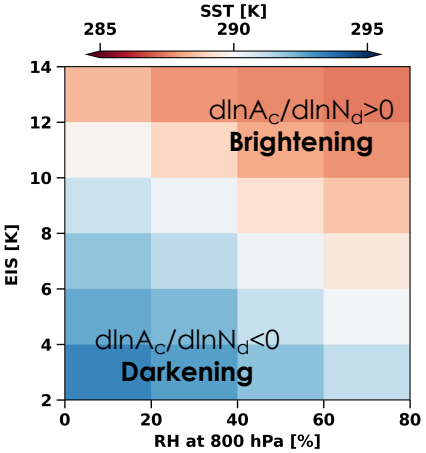
2003-2011 (8 years)

CERES (MODIS): Cloud properties, cloud albedo

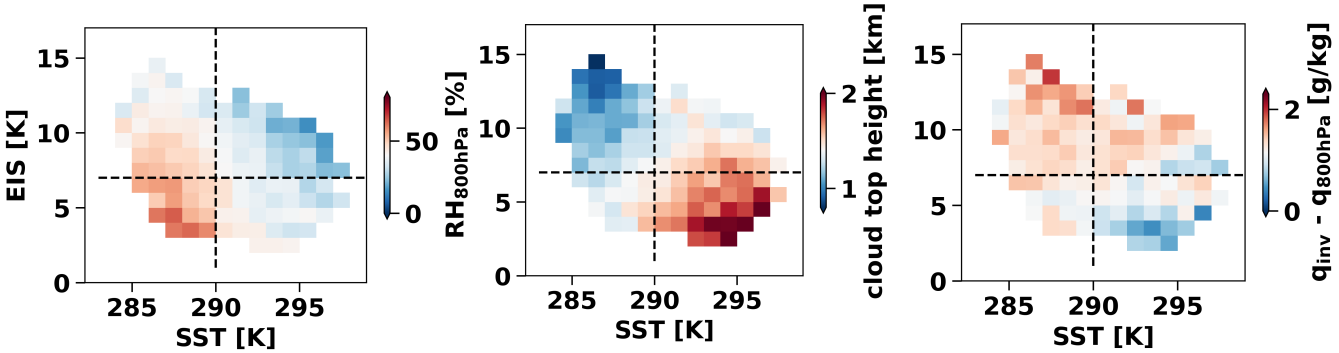
AMSR-E: rain rate

ERA5: SST, 3D temp. & specific humidity, aerosol mass

Compute in-cloud average cloud and environmental properties, albedo susceptibility ($dlnA_c/dlnN_d$) in 2°x2° scene (CF_{scene}>0.25)



SST has a strong control on the brightness of marine clouds over the North Atlantic Ocean by modulating lower tropospheric stability and free troposphere relative humidity.



- Darkening is facilitated by lower RH at 800 hPa and deeper PBL.
- We anticipate a more frequent occurrence of less reflective clouds (warming effect) over the North Atlantic with global warming or with the strengthening phase of the Atlantic meridional overturning circulation.

See Poster, Feingold et al., Weds. 2-3 p.m.

xiaoli.zhou@noaa.gov

Investigation of entrainment mixing processes in stratocumulus clouds with high-resolution digital holography

Objective

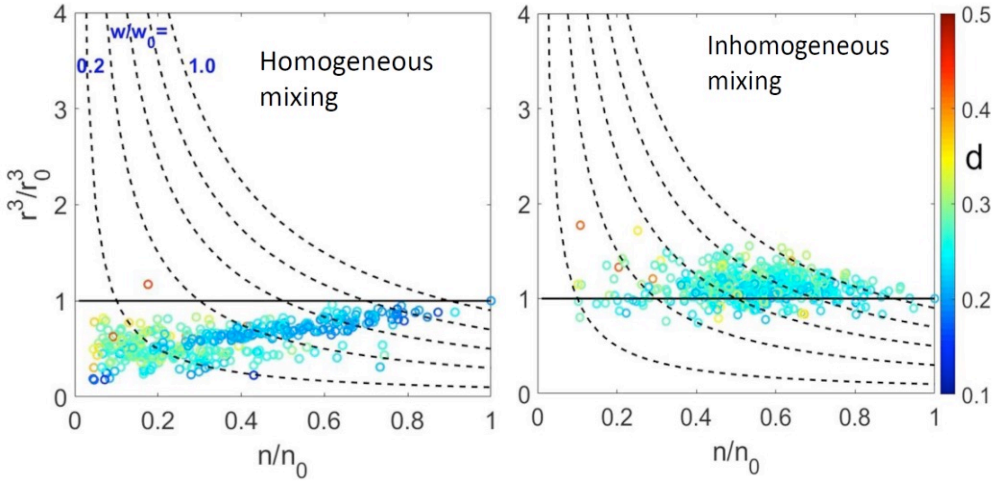
- Study the vertical variation of turbulent entrainment-mixing processes in marine stratocumulus clouds with high-resolution digital holography.

Findings

- Entrainment-mixing behavior changes from homogeneous near cloud base to inhomogeneous near cloud top.
- The variation in relative humidity of the entrained air is key to entrainment mixing.
- Vertical variation of the entrainment-mixing behavior can be explained by covariations in microphysics, turbulence & thermodynamics.

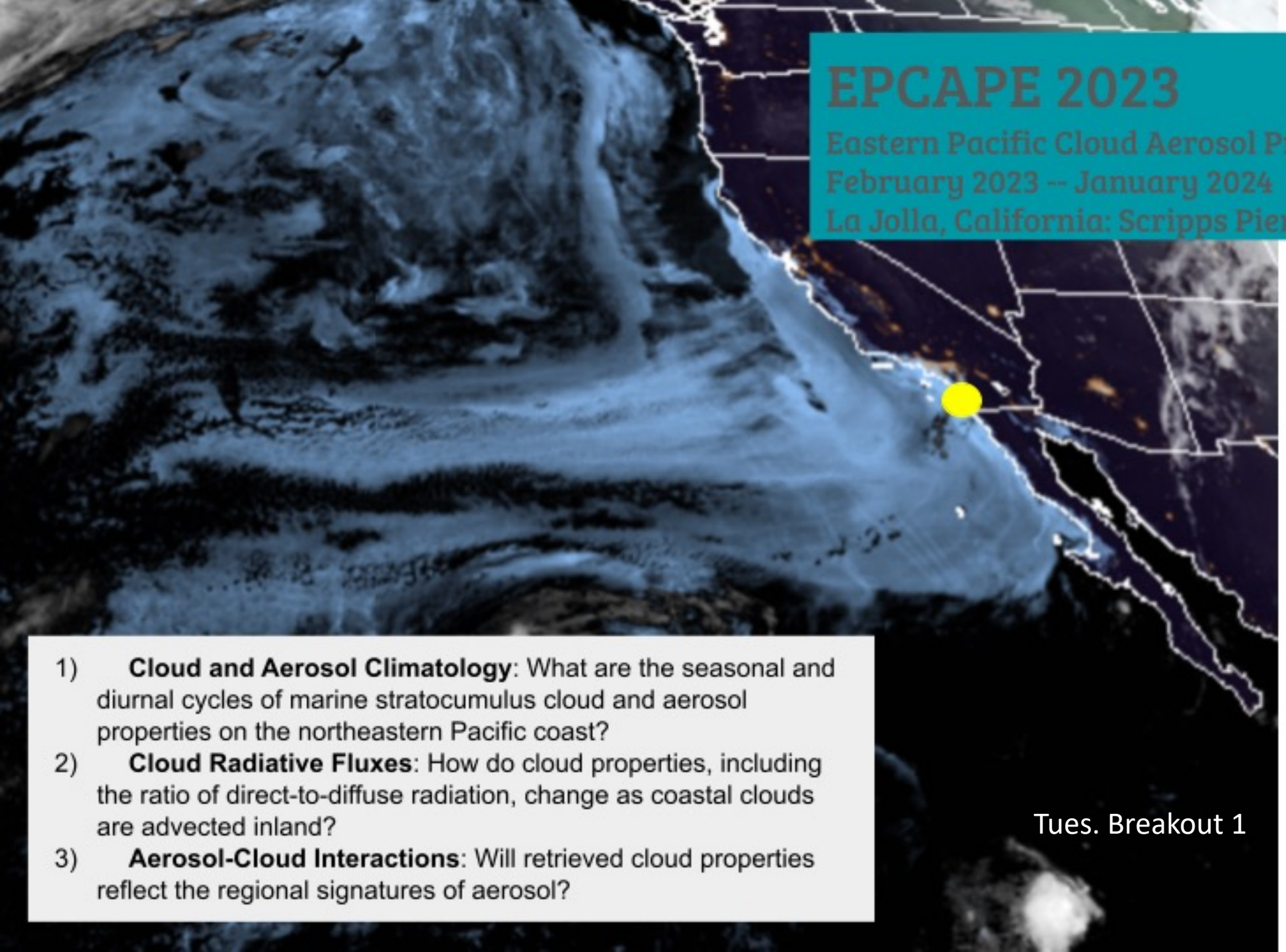
Impact

- High-resolution 3D digital holography helps resolve a long-standing challenge of resolving the dependence of entrainment-mixing mechanisms on sampling scale.



Mixing diagrams showing normalized cloud droplet number concentration on the x axis and normalized cloud droplet volume on the y axis, where the normalization is relative to the least diluted sample denoted by subscript "0". The dotted line represents constant liquid water content (w) line with the ratio of w/w_0 corresponding to the ratio of w in the hologram to that of the least diluted sample. Each data point represents the mean droplet volume and number concentration for each hologram during a cloud segment and is colored by the corresponding relative dispersion of droplet population in the hologram (d). The left and right compare the mixing diagrams near cloud base and near cloud top, respectively.

Desai N., Liu Y., Glienke S., Shaw R.A., Lu C., Wang, J. and Gao S. 2021: Vertical variation of turbulent entrainment mixing processes in marine stratocumulus clouds using high resolution digital holography. JGR-Atmospheres, 126, e2020JD033527. https://doi.org/10.1029/2020JD033527



EPCAPE 2023

Eastern Pacific Cloud Aerosol Precipitation Experiment
February 2023 -- January 2024
La Jolla, California: Scripps Pier and Mt. Soledad

1) **Cloud and Aerosol Climatology**: What are the seasonal and diurnal cycles of marine stratocumulus cloud and aerosol properties on the northeastern Pacific coast?
2) **Cloud Radiative Fluxes**: How do cloud properties, including the ratio of direct-to-diffuse radiation, change as coastal clouds are advected inland?
3) **Aerosol-Cloud Interactions**: Will retrieved cloud properties reflect the regional signatures of aerosol?

Tues. Breakout 1

Persistent offshore stratocumulus interacting with coastal range provides more than 6 months of frequent cloud conditions.

Workshop Summary (June 10-11, 2021)

Improving Understanding of Land-Atmosphere Interactions through Integration of Surface Flux and Atmospheric Boundary Layer Measurements

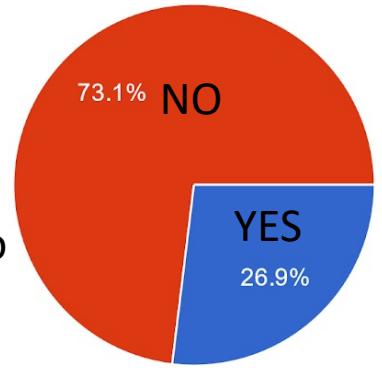
https://ameriflux.lbl.gov/community/ameriflux-meetings-workshops/land-atmosphere-interaction-workshop-overview/

Great Attendance

413 registered
281 (=68%) attended
> 5.5hrs per attendee
51 survey responses
97% yes on feeling inclusive
98% yes on next meeting

Good Outreach

Have you received DOE Funding for research related to this workshop?



1. What are the high-priority research questions that can be addressed with existing measurements (e.g., data from AmeriFlux sites with collocated instrumentation for boundary layer measurements, or nearby radiosonde/profile measurements)?
2. What new boundary layer measurements should be prioritized, and where? What are the cutting-edge research questions that could be addressed with these new measurements?
3. What is needed to increase interdisciplinary collaboration between ecologists/biogeoscientists and atmospheric scientists? How can we best share tools that are necessary to process, analyze, and interpret boundary layer measurements?
4. How can this kind of collaboration improve predictive understanding of biosphere-atmosphere interactions and land-atmosphere coupling?

More detailed report and discussion at Breakout 3, Thursday

Community inputs are needed for CPMSG Matrix on Shallow Cloud Microphysics and Boundary Layer Structure

The goal of CPMSG is to develop and maintain this public list of measurements or analysis gaps that require either specific additional investments or integration of PI or external data or codes, as well as a method for engaging community support.

Google doc link sent via wblp email list. Please contact Christine Chiu or Po-Lun Ma