Warm Boundary Layer Processes Working Group Updates

Co-chairs: Robert Wood and Yunyan Zhang

Land-Atmosphere Feedback Experiment (LAFE)

- Scientific objectives
  1. Examine similarity relationships (variances and fluxes) for u, T, q
  2. Use synergy of scanning lidars to map wind/temperature/humidity in the surface layer over different surface types
  3. Characterize the land-atmosphere feedback and moisture budget at SGP
  4. Verify LES runs and improve turbulence parameterizations used in mesoscale models
- Achievements
  - Campaign conducted August 2017; data in the ARM data archive (IOP section)
  - Documented evolution of the land-atmosphere feedback during the Aug 2017 solar eclipse
  - Modified similarity relationship for water vapor variance at z_i using both ARM obs and LES output
  - Richardson number-based surface layer scheme provides better consistency with observations than Monin-Obukhov similarity relationship
    - Analyzing scanning LAFE lidar data to extend this analysis throughout the entire surface layer
  - First simultaneous measurement of sensible and latent heat flux profiles at SGP
  - Developing methods to derive water vapor and temperature advection using profiling systems at SGP Central Facility and Extended Facilities

LAFE PIs: Volker Wulfmeyer and Dave Turner

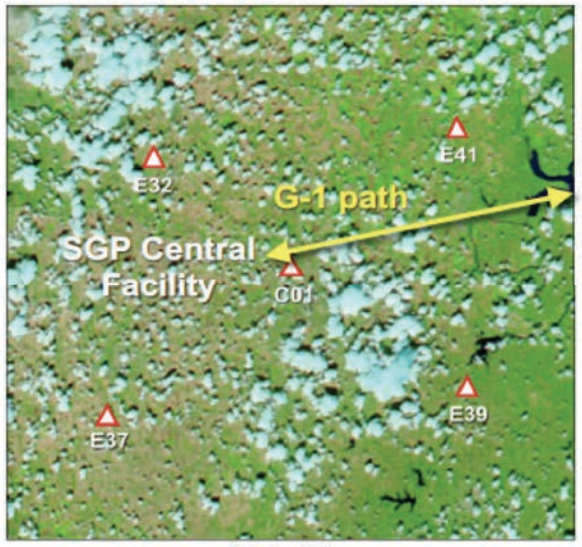
Talk at WBLP WG breakout [Thurs.]

Linking Land-Atmosphere Interations to Transitions in Convective Cloud Populations

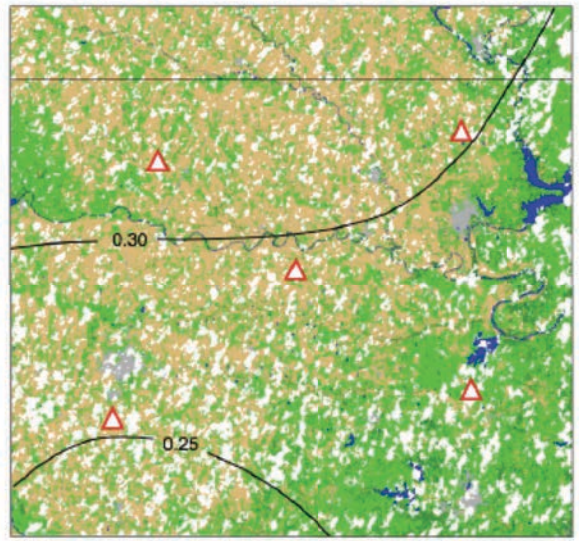
- **LES experiments** conducted (Δx = 100 m) to study the impact of variable land-atmosphere coupling on convective cloud populations observed on August 30, 2016 during HI-SCALE
- Model reproduces observed heterogeneity in clouds and shallow-to-deep transitions **only if realistic variations in soil moisture** are used. **Soil moisture** drives initial cloud fields, then **cold pools** become important during the afternoon.

- Need to account for variable (sub-grid) land-atmosphere interactions and cold pools in shallow convection parameterizations

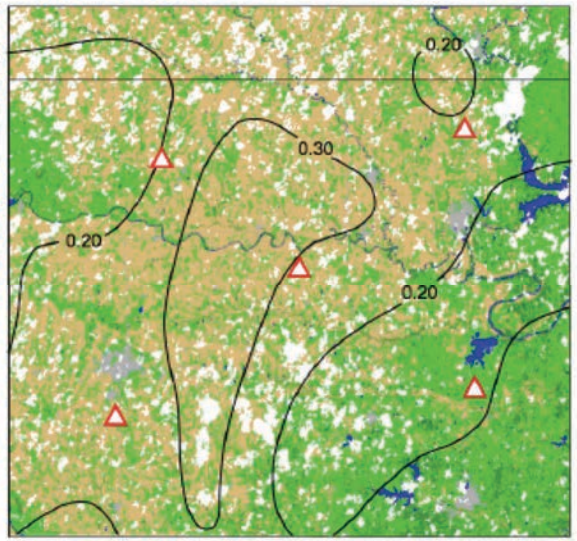
MODIS clouds ~1350 CST



Smooth Soil Moisture



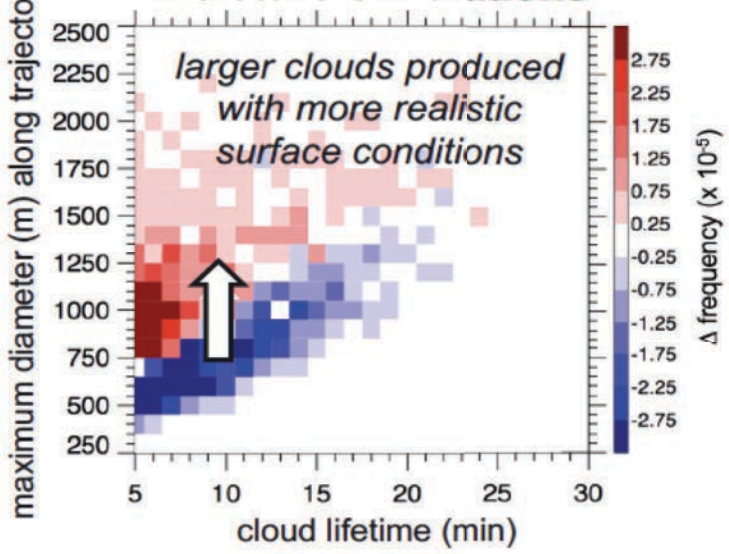
"Observed" Soil Moisture



120 km

black lines = soil moisture contours

Observed – Smooth Soil Moisture Simulations



Fast et al. (2019), Under revision in JAMES

The effect of land heterogeneity and background wind on shallow-to-deeper convection transition

Objective

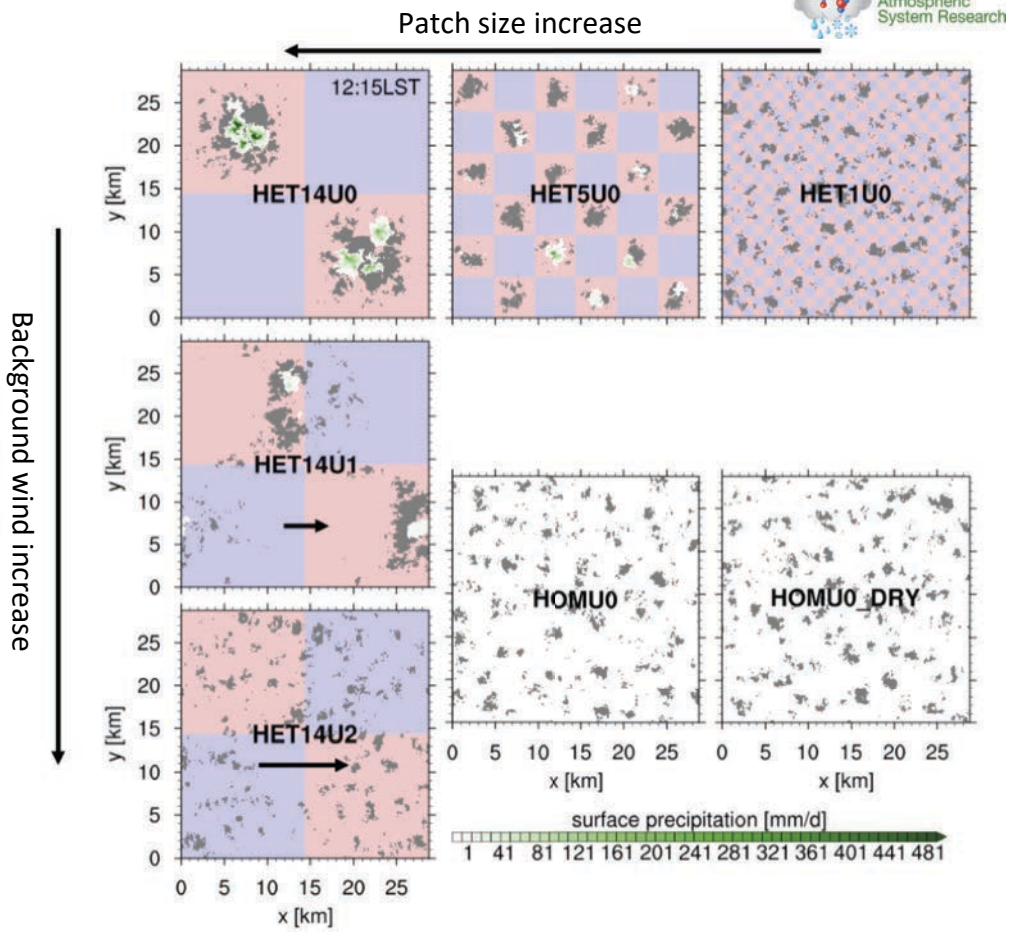
- Determine the threshold of heterogeneity length and background wind speed for triggering convection transition

Approach

- Large-Eddy Simulations (LES) based on the conditionally unstable shallow cumulus case
- Analyze the influence of the patch size and the background wind speed on PBL turbulence and thermodynamics characteristics as well as the cloud macrophysical properties
- Identify the processes that drive the convection transition

Impact

- Shallow-to-deeper convection transition occurs over DRY patch when the patch size > 5km and the background wind speed < 1.5 m/s



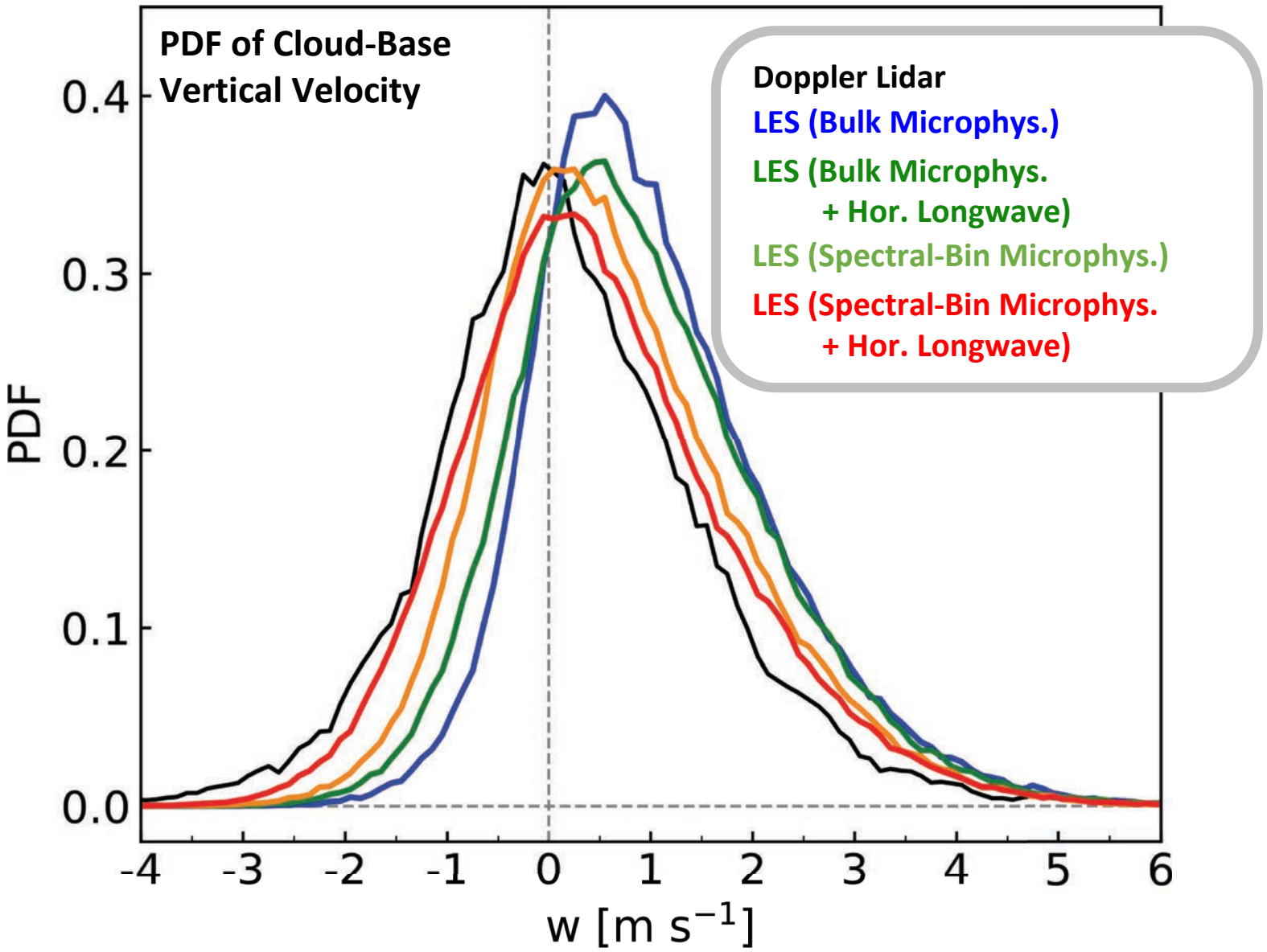
Spatial distribution of clouds (grey) and precipitation (white-green color scale) over various patch sizes and under different background wind speeds at midday. DRY (WET) patches are the squares in red (blue) color. Only non-precipitating, shallow clouds develop over homogeneous surface even with the low evaporative fraction of the DRY patch.

Lee, J. M., Zhang, Y and Klein, S. A., The effect of land surface heterogeneity and background wind on shallow cumulus clouds and the transition to deep convection, *J. Atmos. Sci.*, **76**, 401–419, https://doi.org/10.1175/JAS-D-18-0196.1

Reconciling Differences Between Large-Eddy Simulations (LES) and Doppler-Lidar Observations of Continental Shallow Cumulus Cloud-Base Vertical Velocity

S. Endo, D. Zhang, A. Vogelmann, P. Kollias, K. Lamer, M. Oue, W. Gustafson, H. Xiao, D. Romps

Poster #17
Session B2 [Wed]



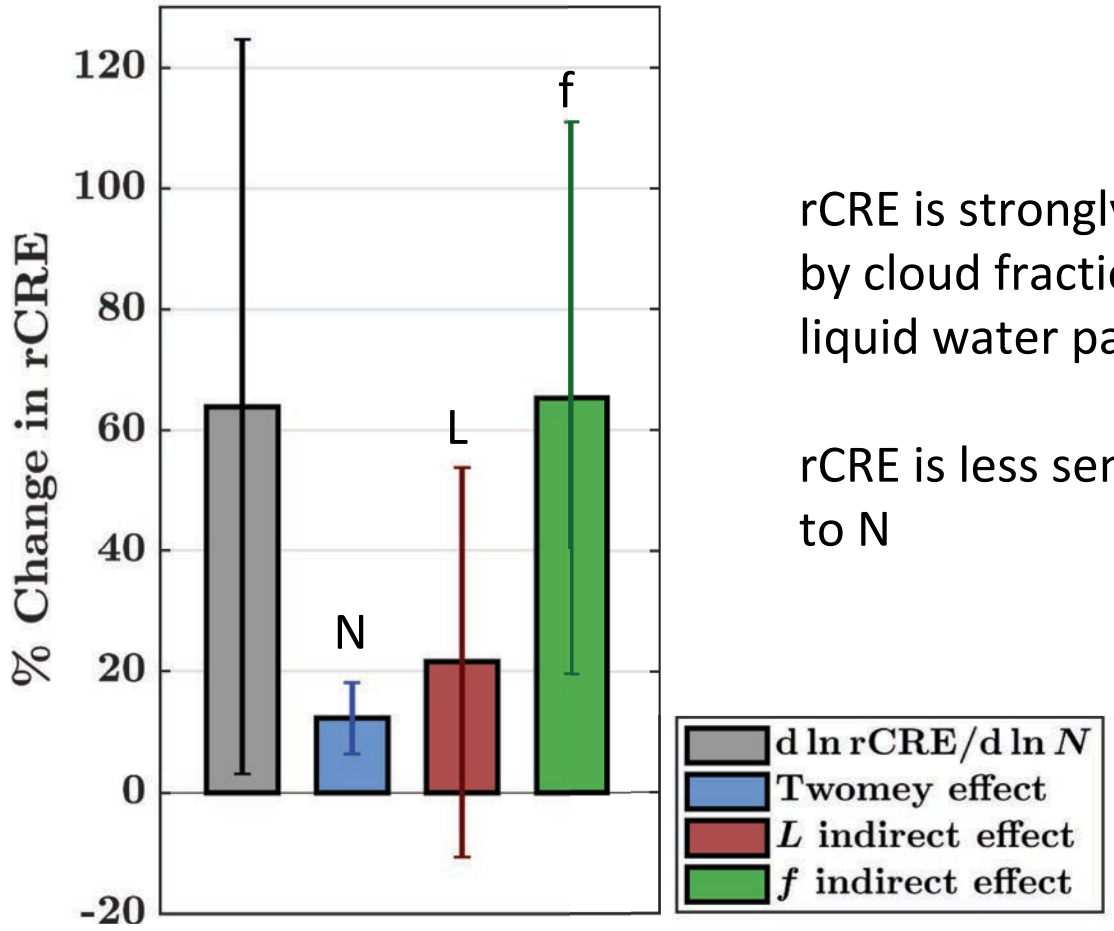
- The 5-site Doppler Lidar statistics suggests that **the LES have insufficient downdrafts,** which is insensitive to various numerical, physical, or dynamical choices.

- The LES can more closely reproduce observations after improving the model physics to use:

  spectral-bin microphysics and **horizontal longwave radiation.**

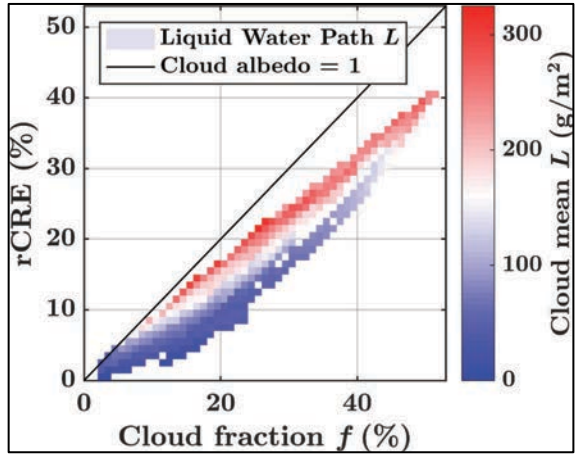
  Both modify the cloud buoyancy and velocity structure near cloud edges, particularly when **used together**.

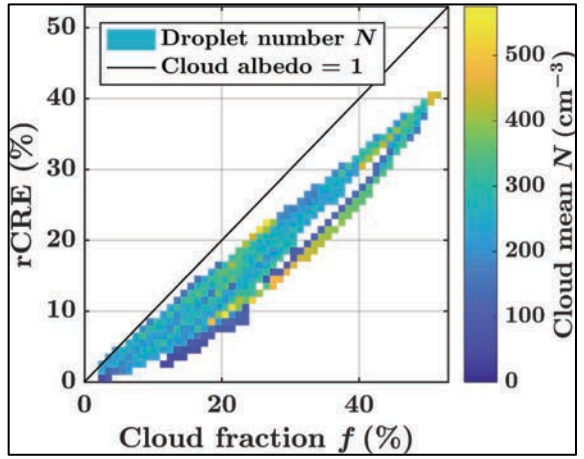
Decomposing Aerosol-Cloud Interactions at SGP: LASSO modeling



rCRE is strongly driven by cloud fraction f and liquid water path L

rCRE is less sensitive to N





Ian Glenn (NOAA /CIRES/CU Boulder)

Poster #32
Session B2 [Wed]

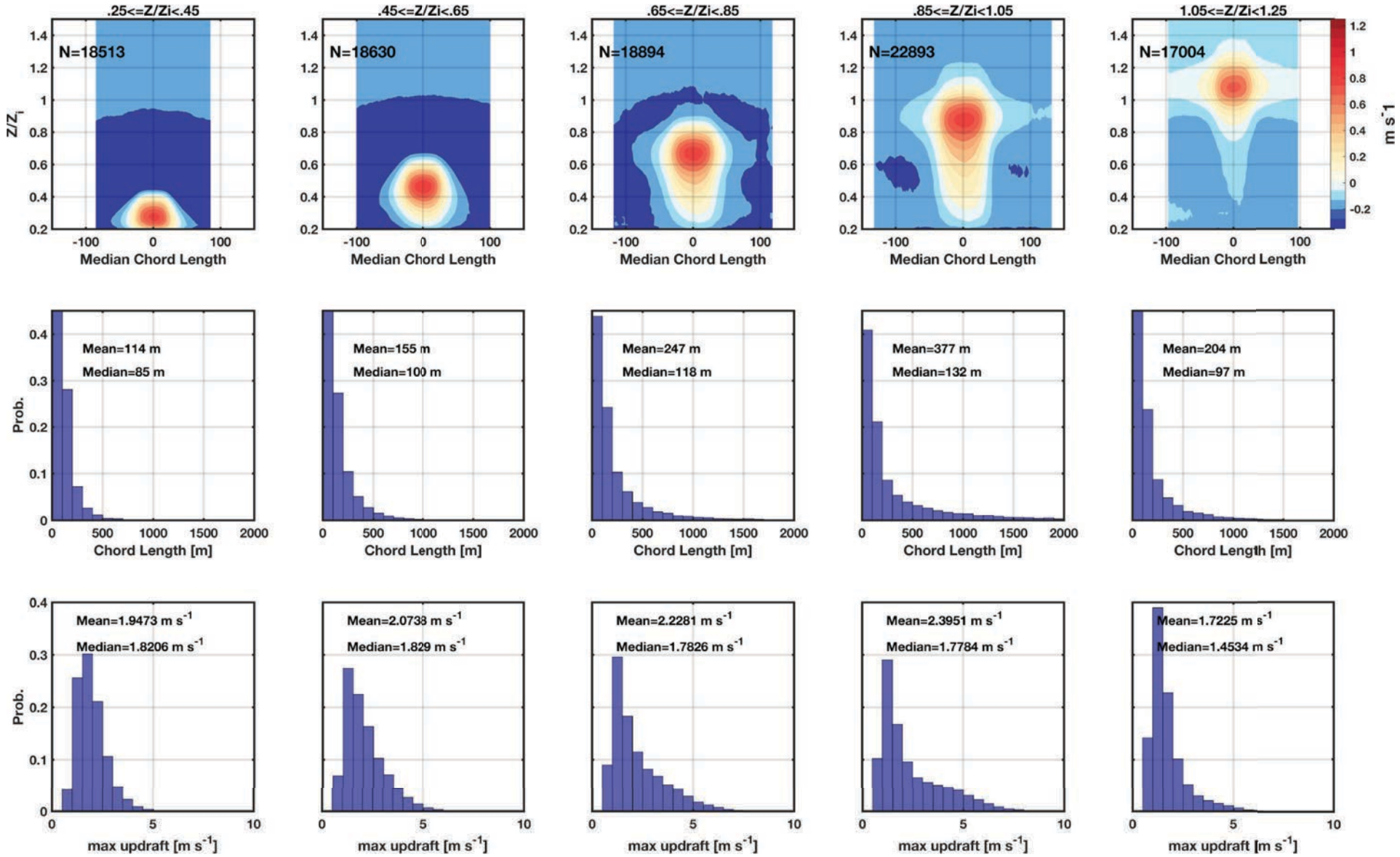
Results based on16 simulation days 2015-2018

The power of ARM Doppler Lidar statistics

Composite vertical velocity for updrafts at different normalized heights (z/z_i).

PDFs of chord lengths

PDF of vertical velocity



Poster #37
Session B2 [Wed]

Neil Lareau [U Nevada, Reno]

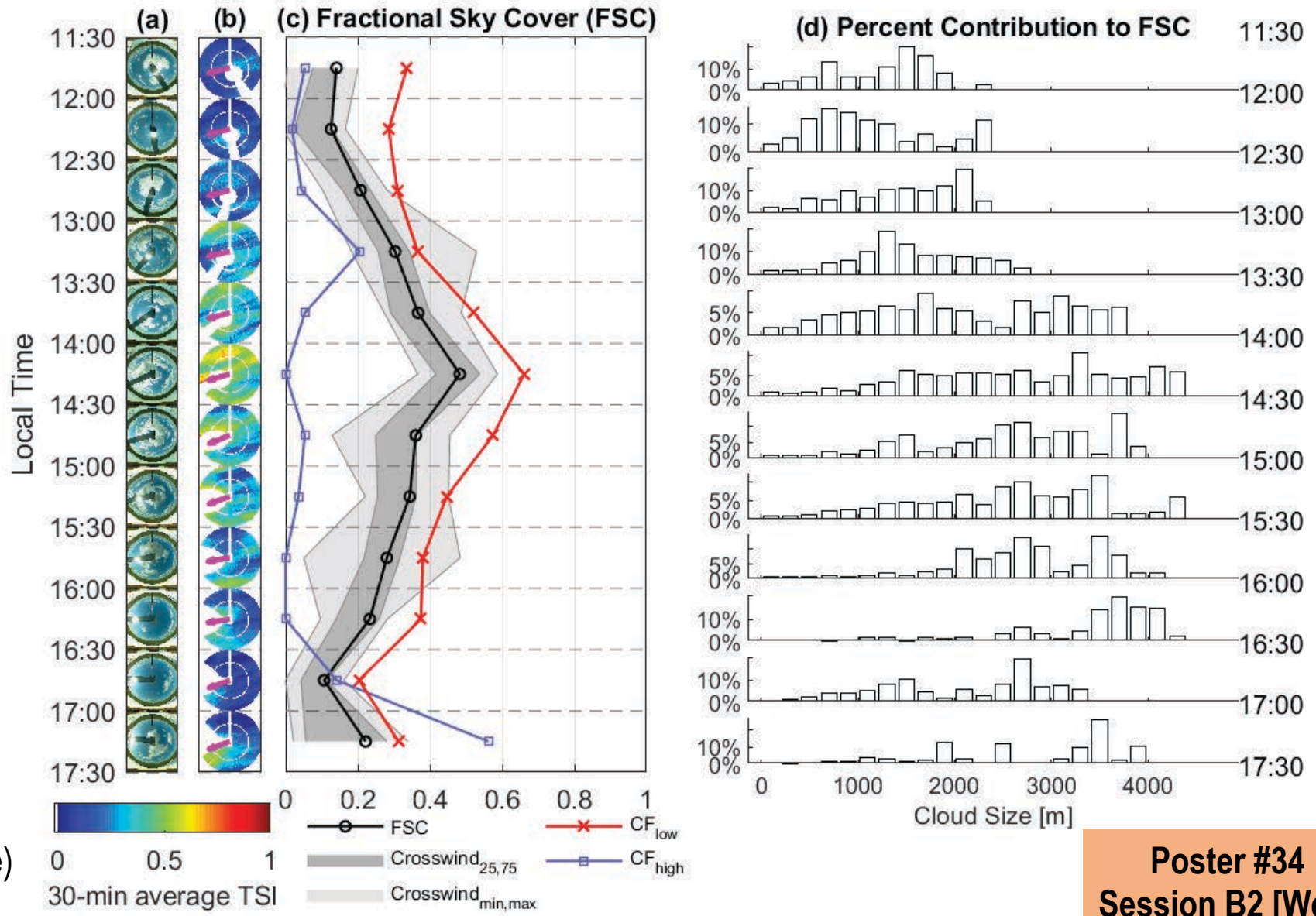
Diurnal cycle of cloud size at SGP

Comparisons of cloud cover estimates from active ground-based remote sensing and all-sky images for identified summertime single-layer shallow cumulus events 2000-2017 at SGP are presented in quick-look figures (a-c).

New TSI-derived ***cloud size*** contribution to cloud fraction shows the evolution of the cloud field through the day.

Quick-look images and data available in ARM archive: PI-datasets / Kleiss. DOI: 20 10.5439/1523254.
See Riley et al. (2019) AMT Discussions.

Jessica Kleiss (Lewis and Clark College)

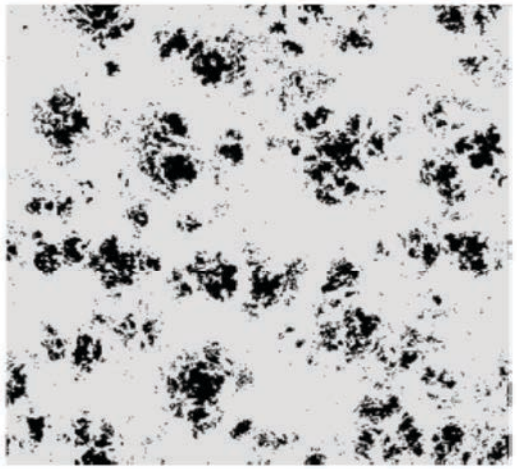


Poster #34
Session B2 [Wed]

Powerlaw scaling in the internal variability of cumulus cloud size distributions based on LASSO simulations at SGP

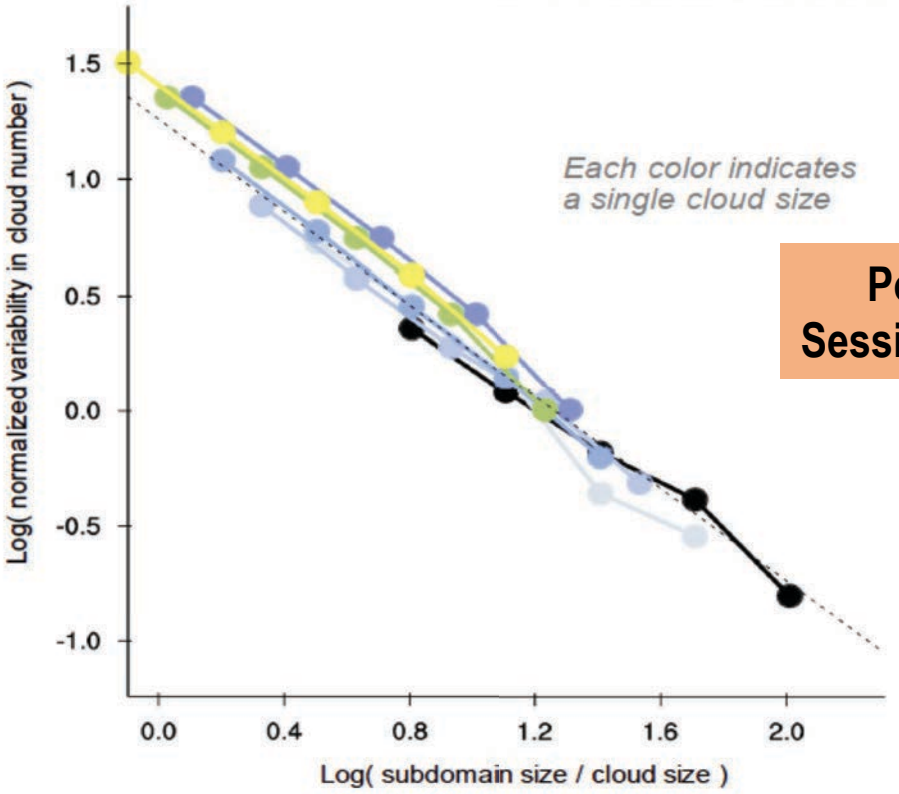
Roel Neggers, Philipp Griewank, Thijs Heus

LES cloud mask on 18 May 2016, 5pm



Question: How does the variability in the number of cumulus clouds depend on the size of the (sub)domain of sampling?

Neggers, Griewank and Heus (JAS, 2019)
doi:10.1175/JAS-D-18-0194.1



Poster #33
Session B2 [Wed]

Answer:

- For unorganized cumulus, a strong powerlaw scaling is found between the normalized variability and the ratio of subdomain size to cloud size.
- Spatial organization reduces the exponent for small clouds, enhancing their variability in larger domains
- The results suggest a new metric for spatial organization B_{org} which is useful for stochastic cumulus parameterizations

This work is funded by grant DE-SC0017999 of DOE's ASR program

Observing clouds in 4D with multi-view stereo

- A ring of 6 cameras installed at the SGP site on a 6-km circle centered on the Central Facility
- The cameras are arranged in pairs, which perform stereo reconstruction from all sides
- The resulting Clouds Optically Gridded by Stereo (COGS) product is a gridded cloud field with a 50-m spatial resolution and a 20-s temporal resolution

Citation: Citation: D.M. Romps and R. Oktem, “Observing clouds in 4D with multi-view stereo photogrammetry,” Bulletin of the American Meteorological Society, vol. 99, no. 12, 2575-2586, 2018, DOI: 10.1175/BAMS-D-18-0029.1

Talk at WBLP WG breakout [Thurs.]

Aerosol and Cloud Experiments - Eastern North Atlantic (ACE-ENA)

- Two IOPs: June 21-July 20, 2017 (summer) and January 11-February 20, 2018 (winter)
- Comprehensive in-situ characterizations of boundary layer and lower FT structures, and aerosol, low clouds, and precipitation under representative meteorological conditions
- Synergy between the in-situ measurements onboard the G-1 and the ongoing measurements at the ENA site
- Ongoing studies on the properties and interactions of aerosol, clouds, and precipitation, and validation and improvements of ground-based retrieval algorithms
- **ACE-ENA Breakout session (1:30-3:30pm, today)** and **overview presentation on Thursday morning (8:00 am)**

Large-scale drivers of clouds and precipitation at the ENA for subsidence regimes

C. M. Naud, J. F. Booth, K. Lamer

Clouds:
Cloud base, top heights (a), or cloud top temperature correlate best with:

$$M = \theta_{skin} - \theta_{800hPa}$$

$\Rightarrow$ both surface forcing and inversion strength matter.
C.f. McCoy et al (2017): M =f(EIS, ΔT_{surf})

Precipitation:
rain shaft depth /base height, rate at 500 m, rain to cloud fraction (b) (~ freq. of precipitation) correlate best with (albeit noisier):

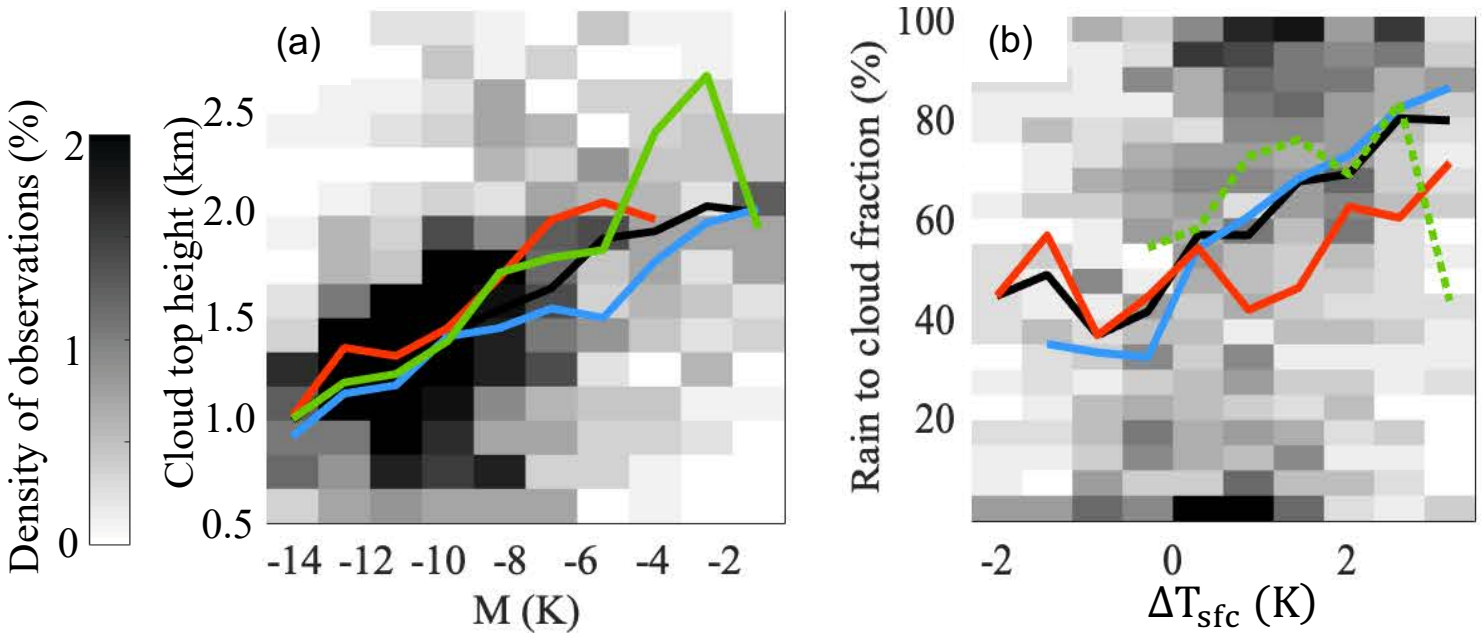
$$\Delta T_{surf} = T_{skin} - T_{surfAir}$$

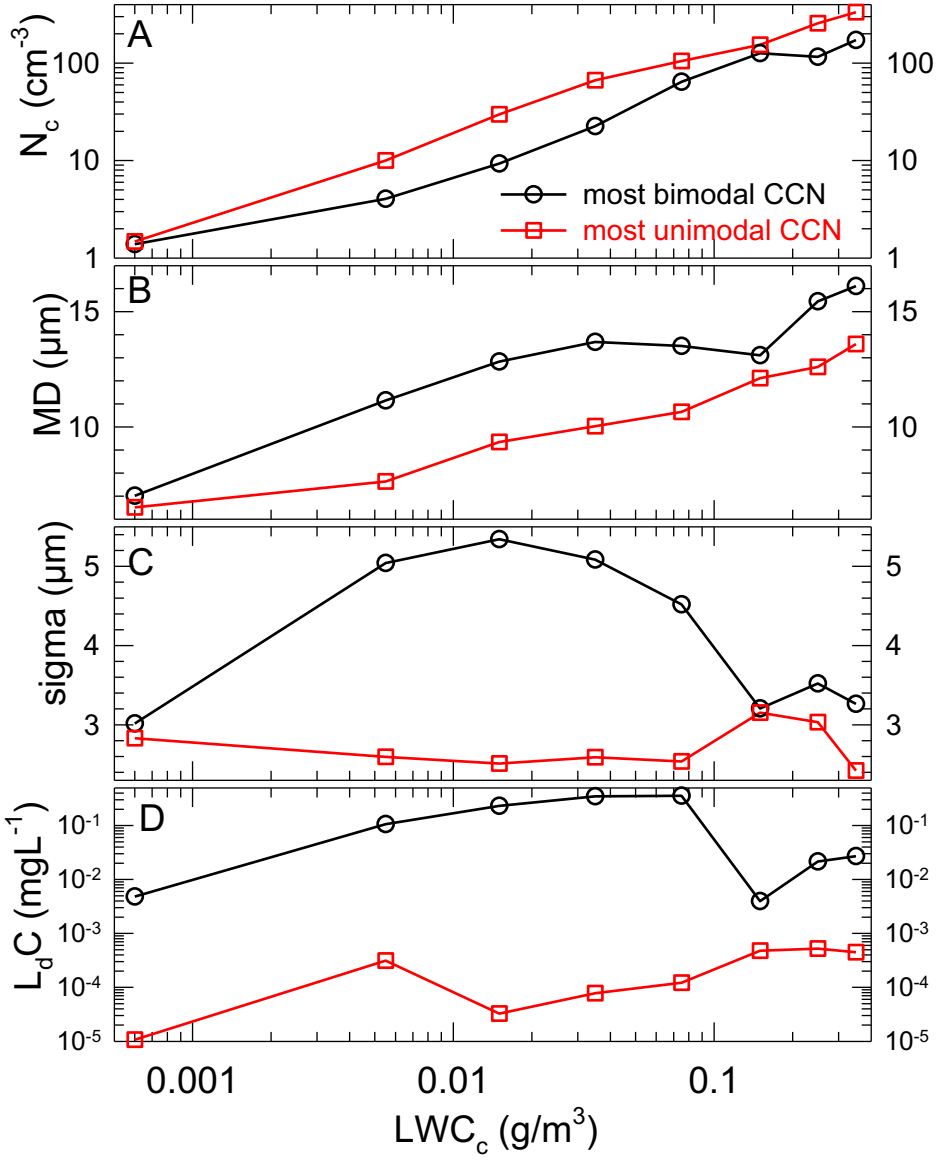
=> surface forcing dominates
c.f. new drizzle PI product, c.f. Lamer et al., poster 5.30 pm Wednesday

Three different subsidence regimes:
$Subsidence_{North}$ = subsidence with Northerly wind
$Subsidence_{South}$ = subsidence with Southerly wind
$Subsidence_{PCF}$ = subsidence after the passage of a cold front

Lines: relation per regime for mean per 2K (a)/0.5K (b) bins

Poster #40
Session B2 [Wed]





Caption. (**a**) cloud droplet concentration, N_c, (**b**) cloud droplet mean diameter, MD, (**c**) cloud droplet spectral width, sigma, σ, **(d)** drizzle LWC, from 2DC (L_dC) against cloud droplet liquid water content (LWC_c) bins in small low altitude cumulus clouds in the Caribbean ICE-T project.

These cumulus results are opposite of MASE stratus (Hudson et al. 2018). Cloud processing enhanced both AIE in stratus but suppressed AIE in cumuli.

D shows conversion of cloud water to drizzle at intermediate LWC_c.

C and D show how greater σ enhanced drizzle,
and that largest drizzle may be reducing MD (B) and σ.

Hudson, J.G., S. Noble, & S. Tabor, 2018: CCN spectral shape and stratus cloud and drizzle microphysics. *J. Geophys. Res. Atmos.,* **123**, 9635-9651. http://doi.org/10.1029/2017JD027865

Poster #4
Session A1 [Tues]

ARM SWS to study the clear-cloud transition zone and mixing processes

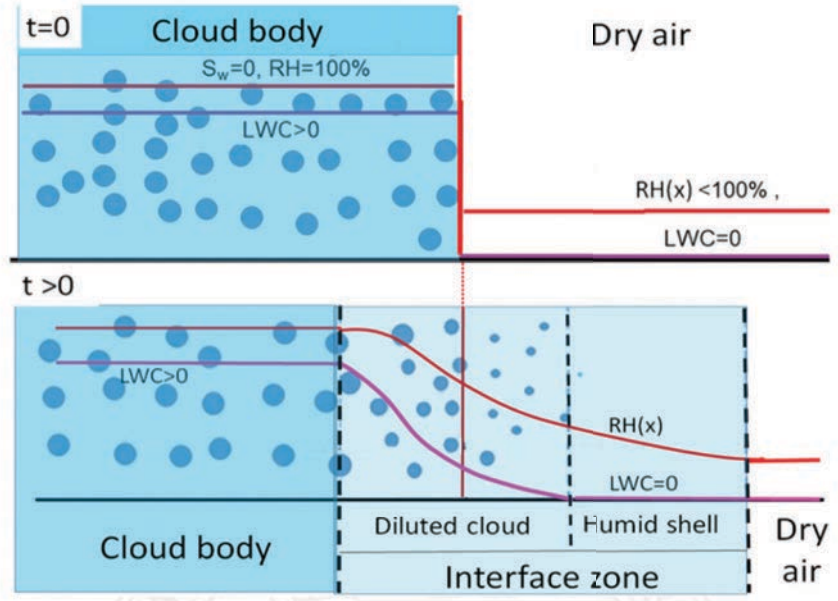
A. Marshak (GSFC), G. Wen (USRA), W. Yang (USRA), A. Khain (Hebrew University of Jerusalem)

- The Transition Zone (TZ) between cloudy and clear air is a region of **strong aerosol-cloud interactions** where aerosol CCN **humidify** and **swell** when approaching the cloud, while cloud drops **evaporate** and **shrink** when moving away from the cloud.

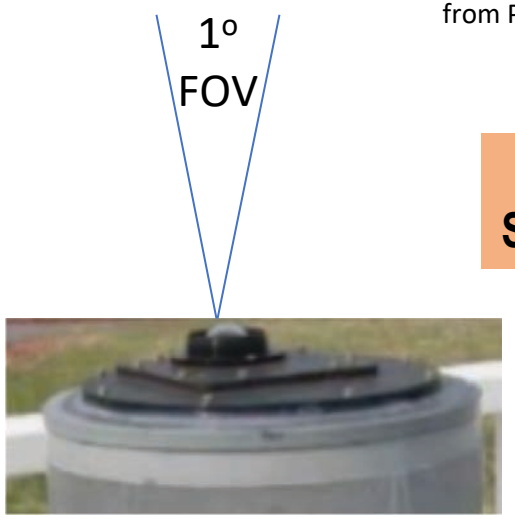
- The difference between homogeneous and inhomogeneous mixing is attributed to the **different timescales of mixing and evaporation.**

- To analyze mixing processes with ground-based spectral observations in the TZ we developed a new "**spectral invariant**" approach.

- Using the spectral invariant method to analyze **ARM SWS** radiance measurements at the SGP and during the MAGIC campaign we found that over ocean the effective radius remains unchanged within a significant fraction of dilution zone, despite decrease in LWC at cloud edge. These results confirm theoretical simulations by Pinsky and Khain (2018).



from Pinsky and Khain, JAS 2018

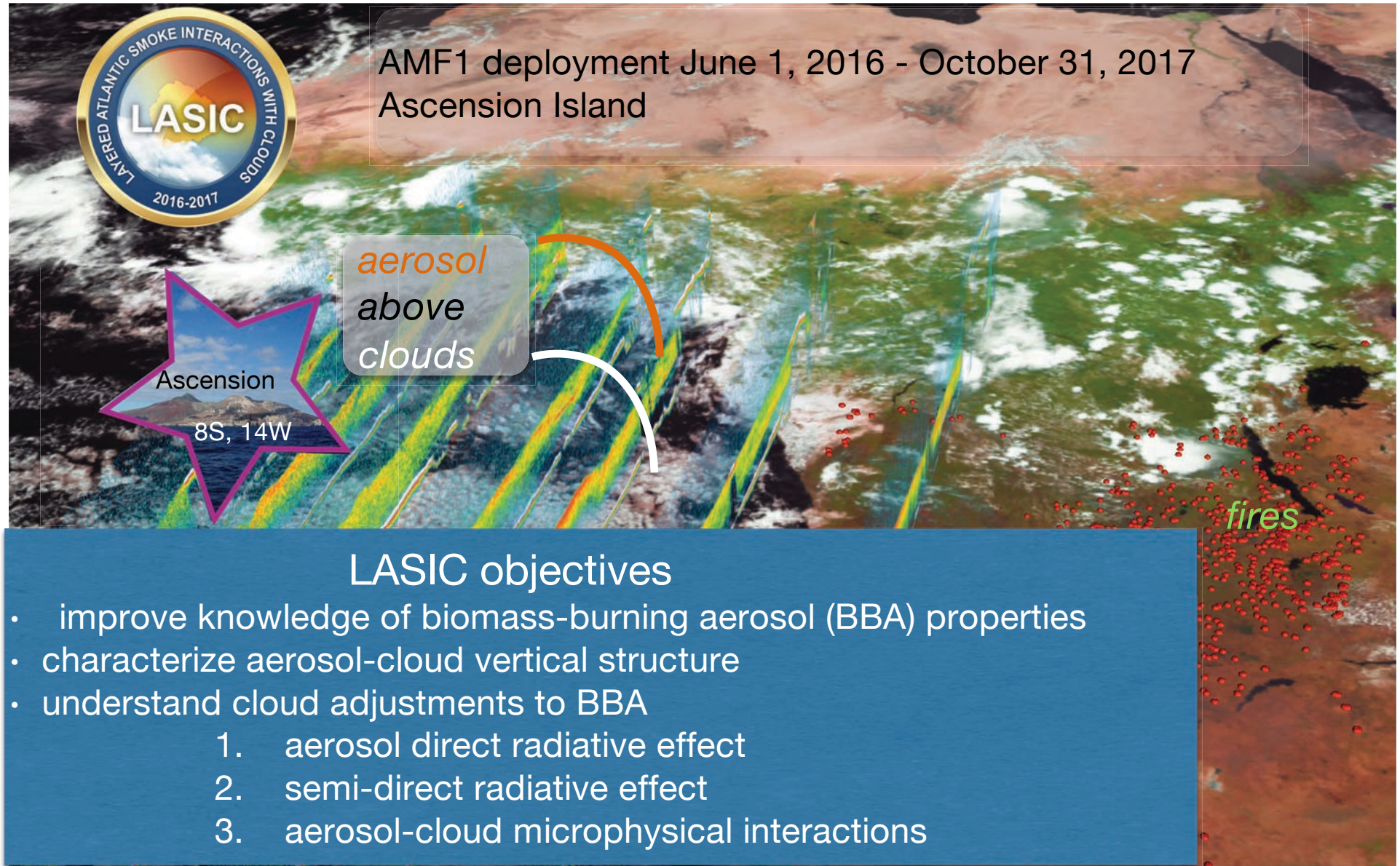


Poster #12
Session B2 [Wed]

ARM SWS

Shortwave-absorbing aerosols and their interactions with clouds
e.g. Layered Atlantic Smoke Interactions with Clouds (LASIC)
but not limited to LASIC

Breakout session 5: Wednesday 1:30-3:30. Brookside room



LASIC objectives

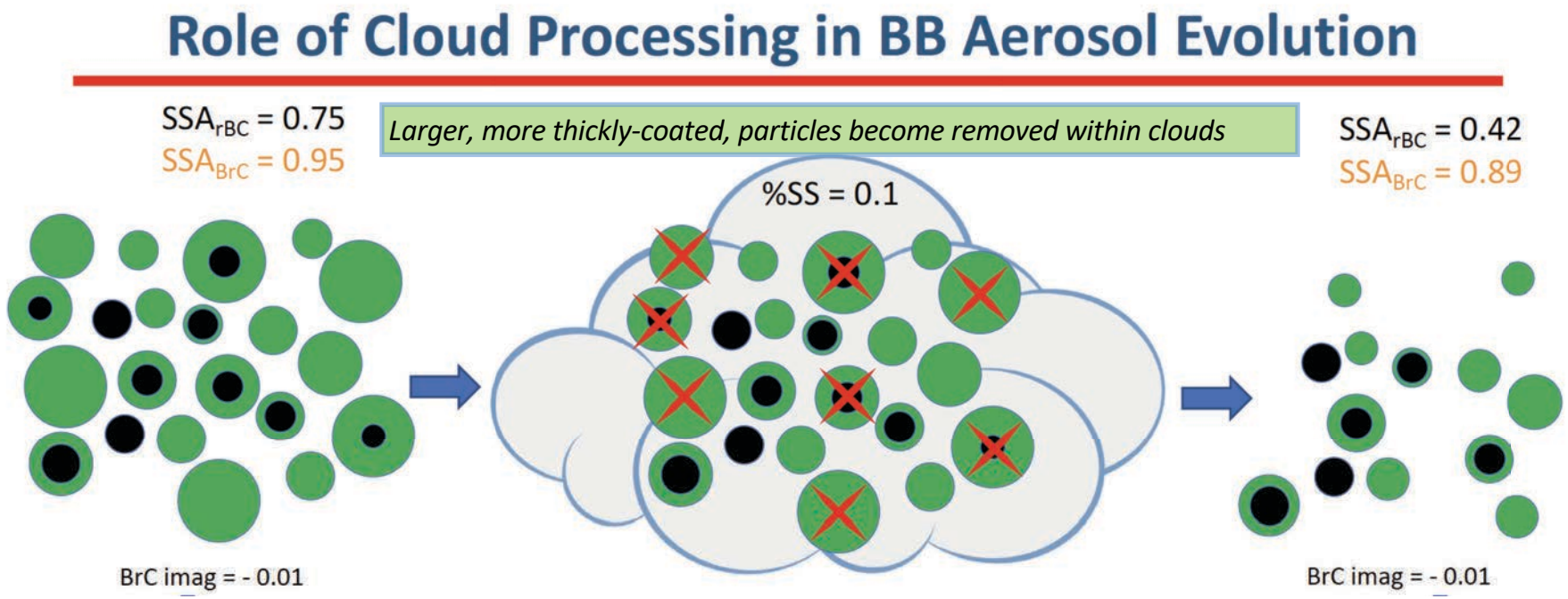
- improve knowledge of biomass-burning aerosol (BBA) properties
- characterize aerosol-cloud vertical structure
- understand cloud adjustments to BBA
    1. aerosol direct radiative effect
    2. semi-direct radiative effect
    3. aerosol-cloud microphysical interactions

How does the boundary layer biomass-burning aerosol become more absorptive?

Nephelometer+PSAP measurements at ASI indicate a (green) single-scattering-albedo of ~0.8 in the PBL, confirmed by Aerodyne CAPS-SSA –

lower than measured near fire sources

Scientific sleuthing by Art Sedlacek et al suggesting…..



Potential impact on shortwave absorption in the boundary layer and aerosol semi-direct effects

WBLP-Focused Breakout Sessions

Tuesday 1:30-3:30	Aerosol and Cloud Experiments in the Eastern North Atlantic (ACE-ENA) [*Salon C*]	*Jian Wang, Jason Tomlinson, Beat Schmidt*
Tuesday 1:30-3:30	LASSO Update and Discussion: Expansion Beyond Shallow Convection v [*White Flint*]	*Bill Gustafson, Andrew Vogelmann, Jim Mather*
Wednesday 10:30-12:30	Marine cloud-topped boundary layer processes: cloud, aerosol, drizzle and turbulence [*Salon C*]	*Xue Zheng, Robert Wood*
Wednesday 1:30-3:30	Evaluation of Measurement Needs to Address Cloud and Precipitation Science Issues [*Salon C*]	*Jim Mather*
Wednesday 1:30-3:30	Upcoming Arctic campaigns (MOSAiC, COMBLE) [*White Flint*]	*Bart Geerts, Matt Shupe, Mikhail Ovchinnikov*
Wednesday 1:30-3:30	Shortwave-absorbing aerosols and their interactions with clouds [*Brookside*]	*Paquita Zuidema, Art Sedlacek, Allison Aiken*
Thursday 10:30-12:30	MICRE/MARCUS and Southern Ocean Activities [*Brookside*]	*Roger Marchand*
Thursday 10:30-12:30	How ARM Meets the Needs of ASR Science Goals (Panel Discussion) [*Salon C*]	*Shaocheng Xie, Jennifer Comstock, Jim Mather*
Thursday 1:30-4:00	Warm boundary layer processes Working Group Breakout [*Salon C*]	*Rob Wood, Yunyan Zhang*

AGENDA for WBLP Working Group Meeting (Thursday 1:30-4:00pm)

Science talks (1:30 to 2:15)

1. Stereophotogrammetry and COGS, David Romps
2. LAFE and DIAL updates, Dave Turner

Breakout summaries (2:15 to 3:00, ~5 minutes each)

ACE-ENA (Jian Wang)
Marine cloud-topped boundary layer processes: cloud, aerosol, drizzle and turbulence (Xue Zheng and Rob Wood)
MICRE/MARCUS and Southern Ocean Activities (Roger Marchand)
Shortwave-absorbing aerosols and their interactions with clouds (Paquita Zuidema)
Land-Atmosphere Interaction (Larry Berg and Yunyan Zhang)
LASSO (Bill Gustafson or Andrew Vogelmann)

ARM infrastructure updates (3:00 to 3:15, Shaocheng Xie)

Discussion (3:15 to 3:45)