The ("Deeper") Convective parts of the LLNL ASR SFA & Yunyan Zhang's Early Career Research Project

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With additional contributions from

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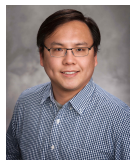
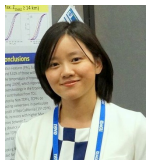




ASR Atmospheric System Research

ECRP DOE Early Career Research Program

Overview

- Our primary focus is on shallow clouds and convection over land and ocean
  - also land-atmosphere interaction & surface energy/water balance/temperature
- Extensive model evaluation (including DOE's E3SM large-scale model)

But our research does involve on deep convection over land …

- When does convection remain shallow and when and how does it go deep? We're often working in environments at the boundary between shallow and deep convection
- We are interested in the aggregate climate effects of all convection over warm season land on the coupled (land-atmosphere) energy and water cycles

For more info about the LLNL ASR SFA see: http://climate.llnl.gov/asr.html

Our Process Paradigm

Diurnally-paced surface-forced convection over land

Conceptually simple

Tough to represent in large-scale models

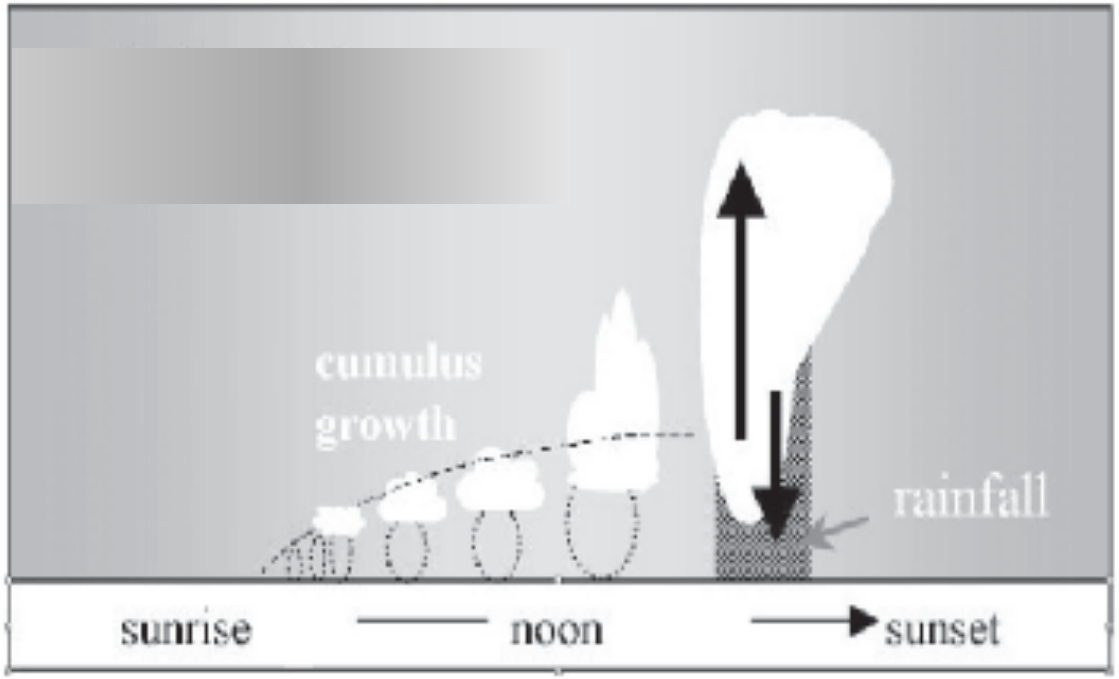
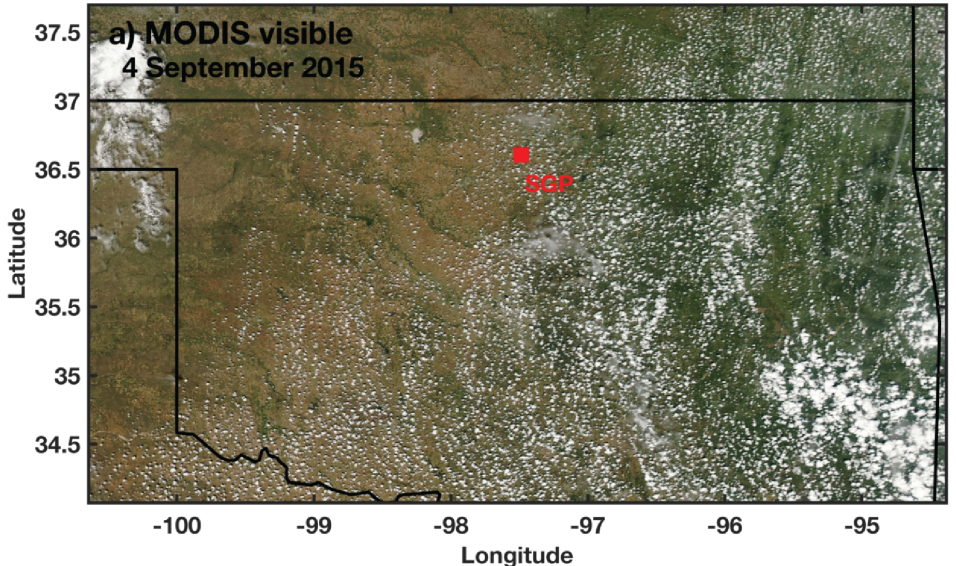


Figure from Guichard et al, 2004



Shallow Convection @SGP
Using Days Fitting Our Paradigm

- Observational work
  - Cloud–controlling factors (RH, EF/Bowen ratio, inversion strength)
  - What do we learn from new observations (doppler lidar)?
- Modeling
  - Built a characteristic shallow cumulus modeling case (CASS) to test whether LES and large-scale models can properly simulate the ARM observations of shallow convection

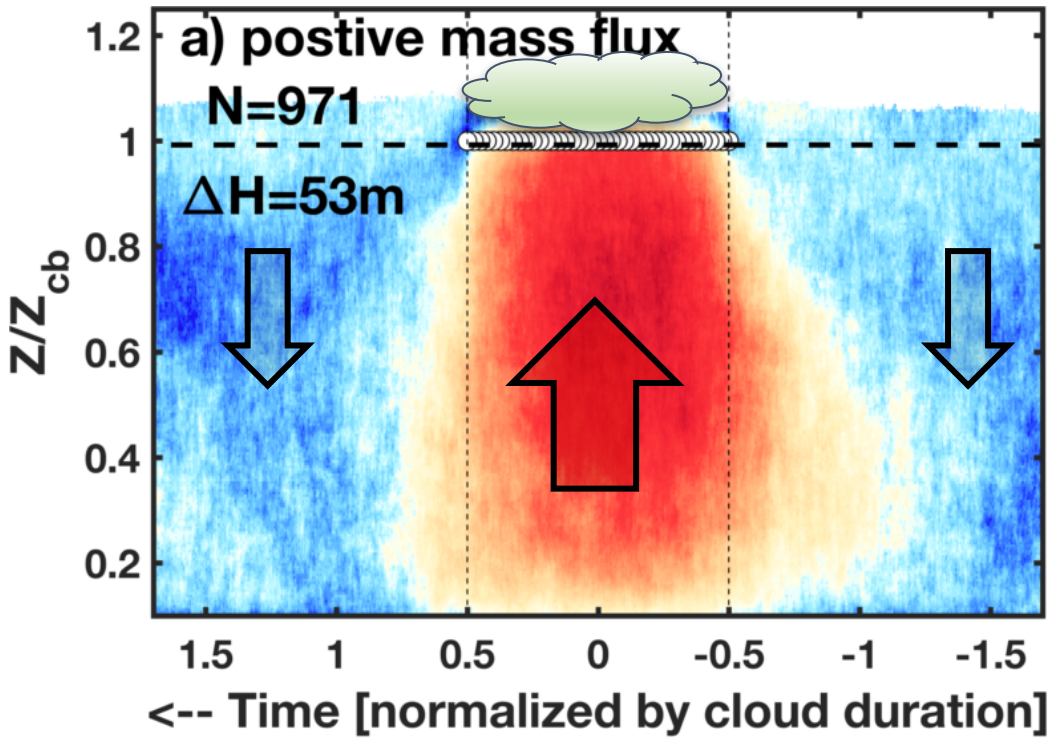
1. Zhang, Y., S. A. Klein, J. Fan, A. S. Chandra, P. Kollias, S. Xie, and S. Tang, 2017: Large-eddy simulation of shallow cumulus over land: A composite case based on ARM long-term observations at its Southern Great Plains site. *J. Atmos. Sci.*, **74**, 3229–3251, doi: 10.1175/JAS-D-16-0317.1.
2. Zhang, Y. and S. A. Klein, 2013: Factors controlling the vertical extent of fair-weather shallow cumulus clouds over land: Investigation from diurnal-cycle observations of the diurnal cycle collected at the ARM Southern Great Plains site. *J. Atmos. Sci.*, **70**, 1297–1315, doi: 10.1175/JAS-D-12-0131.1.

Doppler Lidar Insights into Relationship of Sub-cloud Turbulence to Convection

Doppler lidar observations show greater updrafts speeds are associated wider and taller clouds.

Can Doppler Lidar observations yield insights into deeper convection?

Composite Doppler Lidar Vertical Velocity under Shallow Convection



Lareau, N. P., Y. Zhang, and S. A. Klein, 2018: Observed boundary layer controls on shallow cumulus at the ARM Southern Great Plains Site. *J. Atmos. Sci.*, **75**, 2235–2255, doi: 10.1175/JAS-D-17-0244.1.

Shallow to Deep Convection Transition Over Land

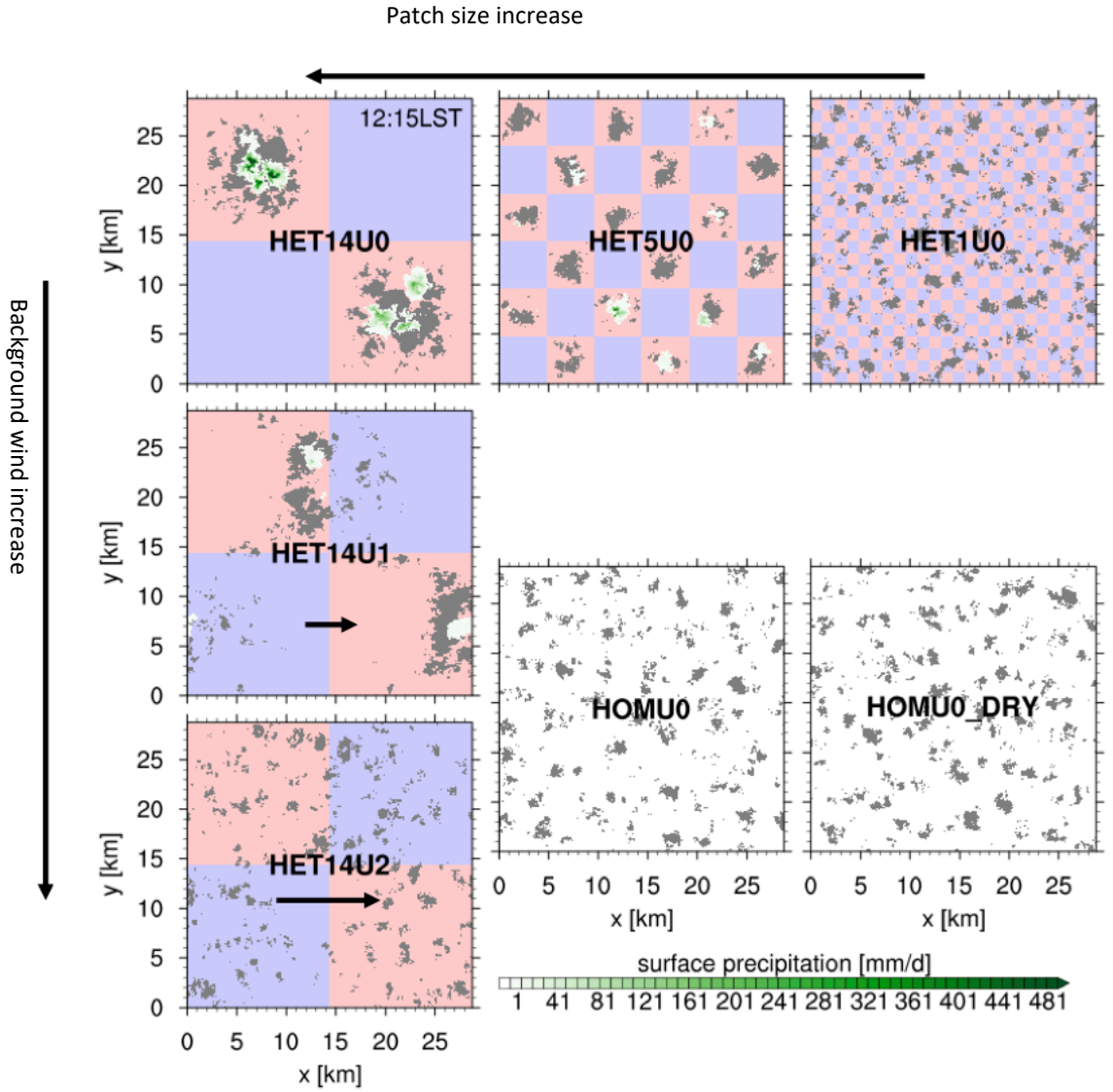
- We studied the transition in SGP observations a while back, but SGP is not ideal...
  - Deep convection is nocturnal not late-afternoon dominant
  - Thus there are not as many cases as we would like
- We're now examining into GoAmazon observations extensively
  - Lots of cases (Good)
  - Much more complicated environment
    - residual convection in morning condition
    - land-river breeze effect on location of shallow and deep convection
- Someday we'd like to have ARM observations from the South East USA where this transition is very common

1. Zhang Y. and **S. A. Klein**, 2010: Mechanisms affecting the transition from shallow to deep convection over land: Inferences from observations of the diurnal cycle collected at the ARM Southern Great Plains site. *J. Atmos. Sci.*, **67**, 2943–2959, doi: 10.1175/2010JAS3366.1.
2. See poster by Yang Tian at 2019 ARM/ASR Science Team meeting

Land-Surface Forcing of Convective Type Selection

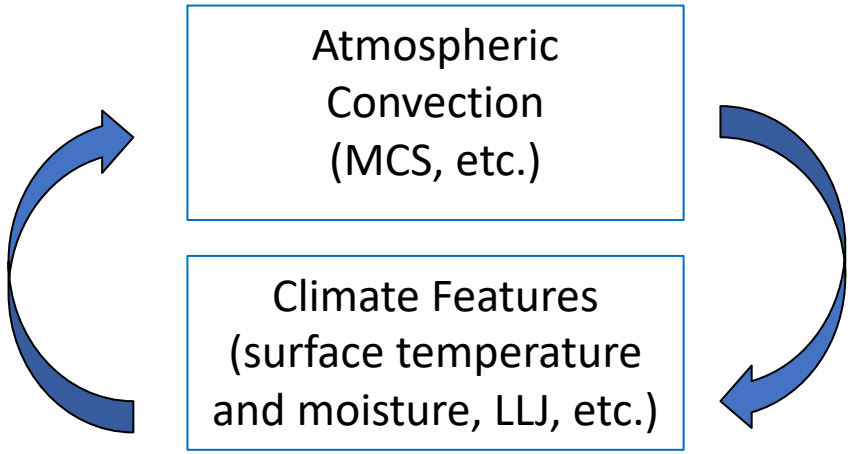
LES show that realistic variations in the Bowen ratio can induce transitions to deeper convection but only if organized at large scales (>10 km) and very low mean wind speeds (< 2 m/s)

Separate work analyzing observed coupling of land-surface to convection type across the SGP domain



1. Lee, J. M., Y. Zhang and S. A. Klein, 2018: The effect of land surface heterogeneity and background wind on shallow cumulus clouds and the transition to deeper convection. *J. Atmos. Sci.*, **76**, 401–419, doi: 10.1175/JAS-D-18-0196.1.
2. Tao, C., Y. Zhang, S. Tang, Q. Tang, H.-Y. Ma, S. Xie, and M. Zhang, 2019: Large-scale moisture budget and land-atmosphere coupling over US Sothern Great Plains from the ARM long-term observations. *J. Geophys. Res.-Atm.*, submitted.

Aggregate Effects of Convection on Land-Atmosphere Water/Energy Cycles



- We have focused the physical processes causing surface warm biases in summertime climate over Central USA using ARM SGP and other observations (CAUSES project, joint with MetOffice)
- In large-scale & regional models, surface temperature biases are due to:
  - Too much solar radiation absorbed at the surface
  - Overestimated Bowen ratio
- Solar radiation biases at SGP are due primarily to underestimated radiative effects from deep convective clouds
- We're now moving on to examine convection permitting models – which *might* do better because they can simulate MCS's responsible for 50% of summer rain in the Central USA

1. Ma, H.-Y., et al., 2018: CAUSES: On the role of surface energy budget errors to the warm surface air temperature error over the Central U. S.. *J. Geophys. Res.-Atm.*, **123**, 2888–2909, doi: 10.1002/2017JD027194.
2. Van Weverberg, K., et al., 2018: CAUSES: Attribution of surface radiation biases in NWP and climate models near the U. S. Southern Great Plains. *J. Geophys. Res.-Atm.*, **123**, 3612–3644, doi: 10.1002/2017JD027188.