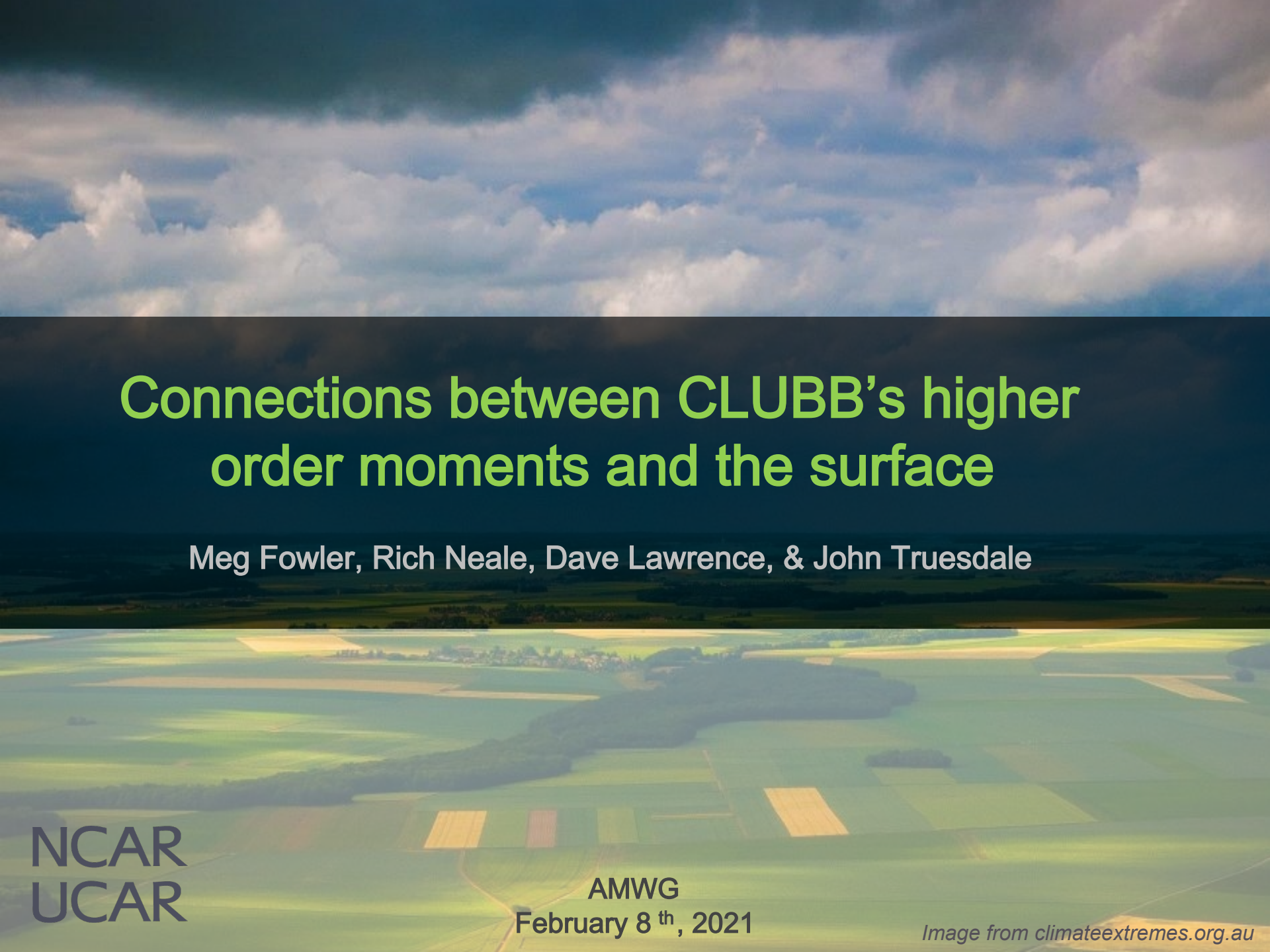


Connections between CLUBB's higher order moments and the surface

Meg Fowler, Rich Neale, Dave Lawrence, & John Truesdale

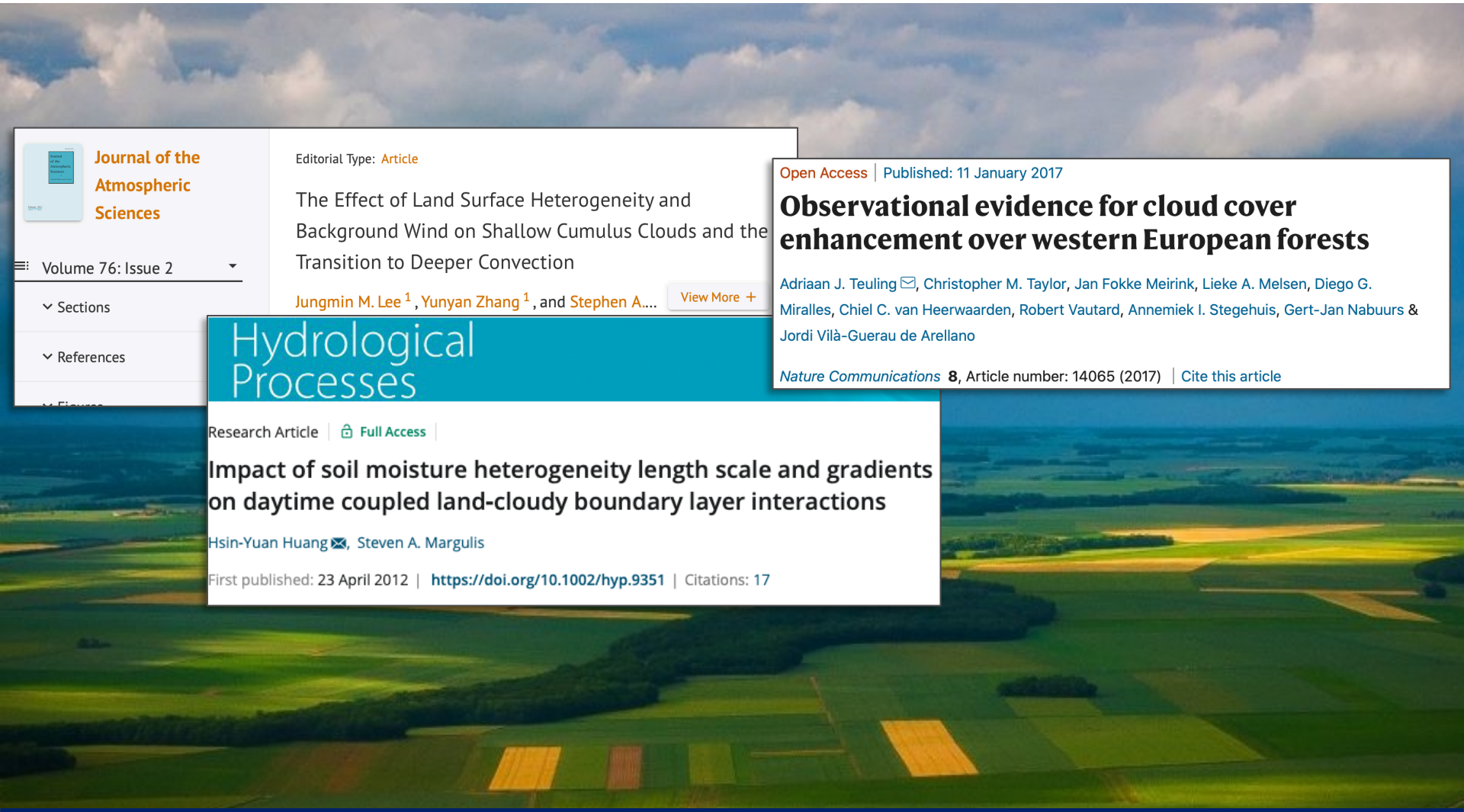
NCAR
UCAR

AMWG
February 8 th, 2021

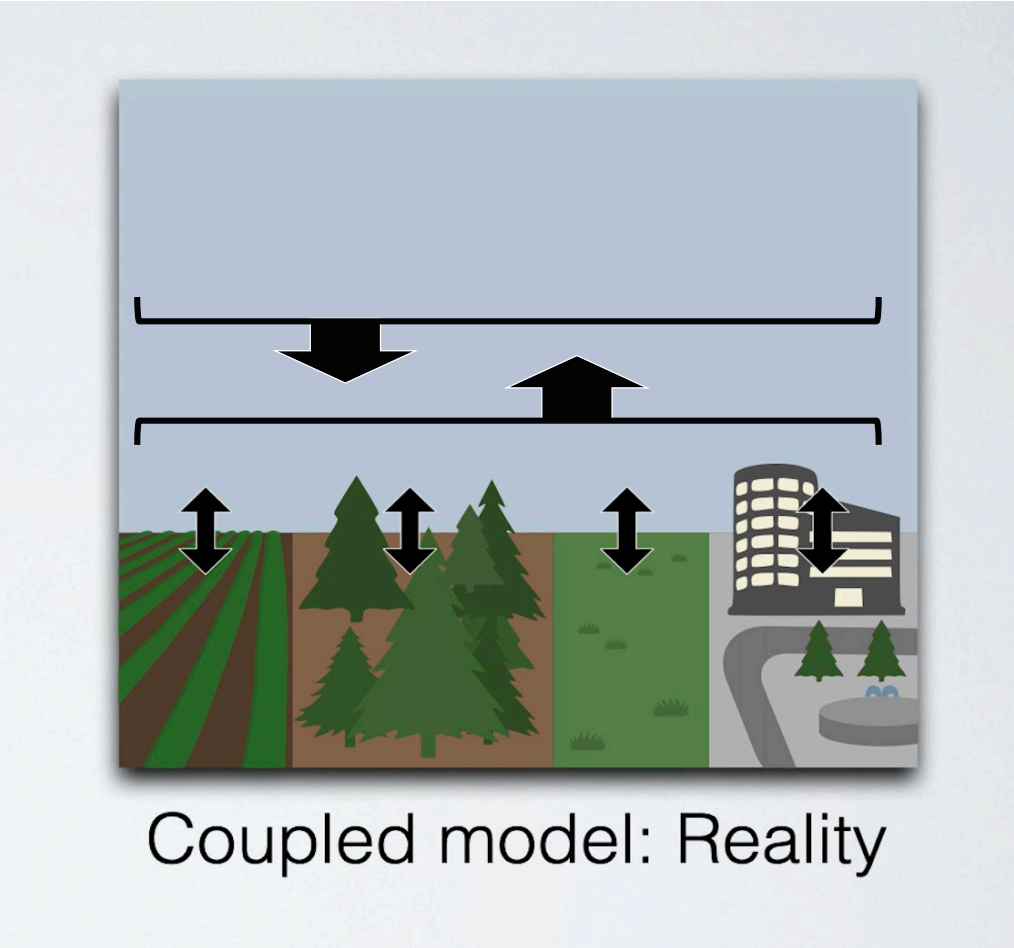
Image from climateextremes.org.au

In reality, there's a clear coupling between the land and atmosphere

From land perspective: heterogeneity matters



But coupled models don't communicate heterogeneity



Slide courtesy of Nate Chaney

One attempt at improvement: CLASP

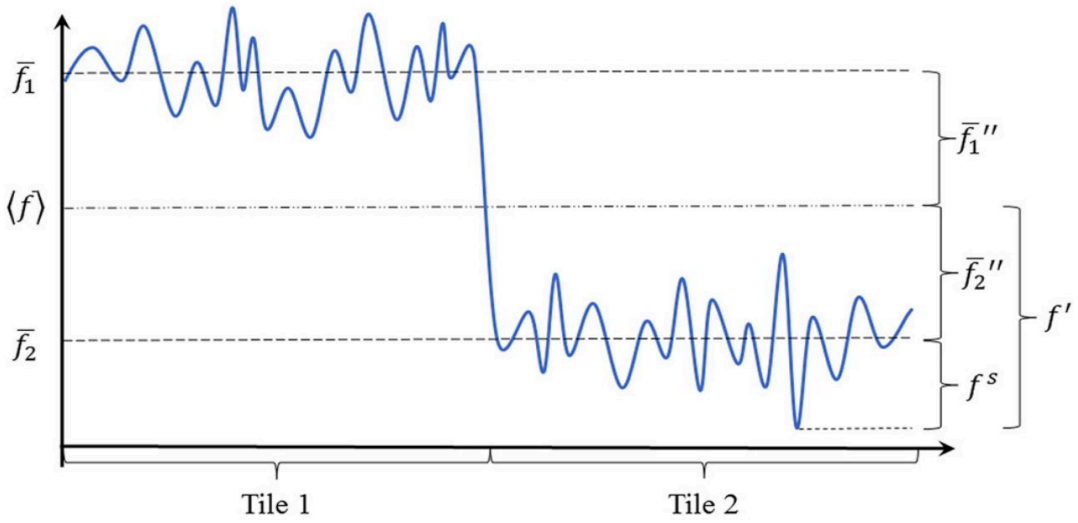
Coupling of Land and Atmospheric Subgrid Parameterizations

- Current goal: communicate subgrid heterogeneity that exists in CLM up to CAM

One attempt at improvement: CLASP

Coupling of Land and Atmospheric Subgrid Parameterizations

- Current goal: communicate subgrid heterogeneity that exists in CLM up to CAM
- Compute surface higher order moments for CLUBB in CLM



$$f = \langle \overline{f} \rangle + \overline{f}'' + f^s$$

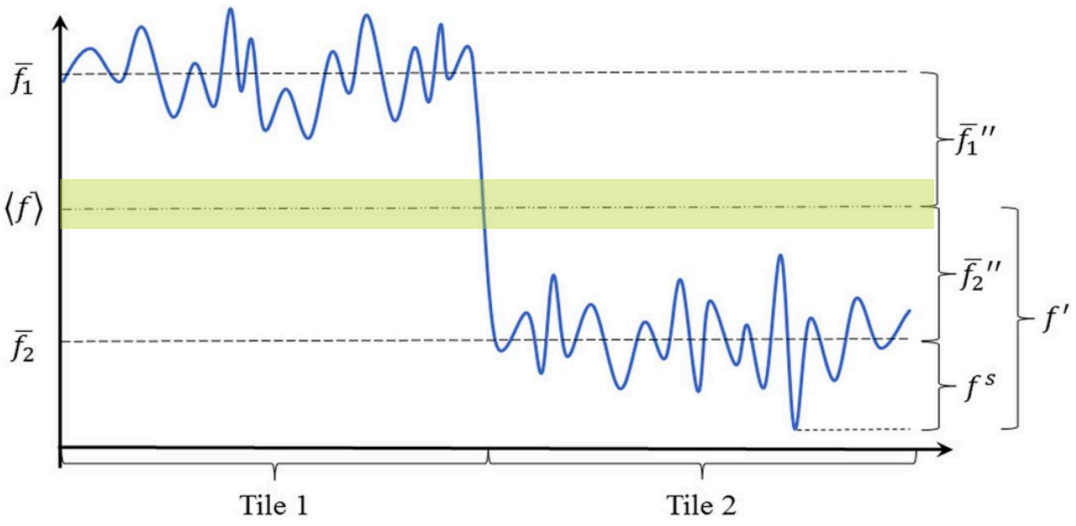
Machulskaya & Mironov, 2018

One attempt at improvement: CLASP

Coupling of Land and Atmospheric Subgrid Parameterizations

- Current goal: communicate subgrid heterogeneity that exists in CLM up to CAM
- Compute surface higher order moments for CLUBB in CLM

Gridcell Mean



$$f = \langle \overline{f} \rangle + \overline{f}'' + f^s$$

Machulskaya & Mironov, 2018

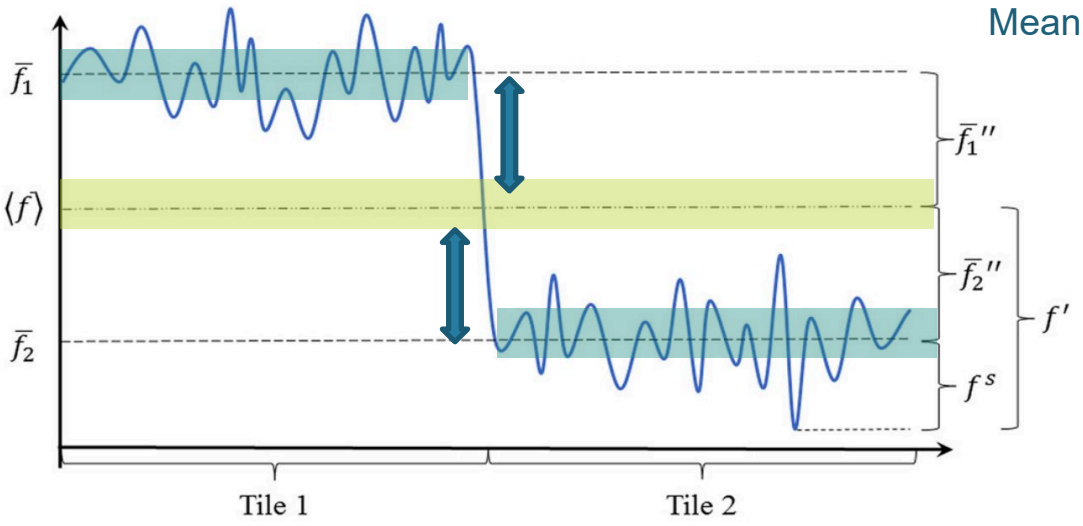
One attempt at improvement: CLASP

Coupling of Land and Atmospheric Subgrid Parameterizations

- Current goal: communicate subgrid heterogeneity that exists in CLM up to CAM
- Compute surface higher order moments for CLUBB in CLM

Tile Mean

Gridcell Mean



$$f = \langle \overline{f} \rangle + \overline{f}'' + f^s$$

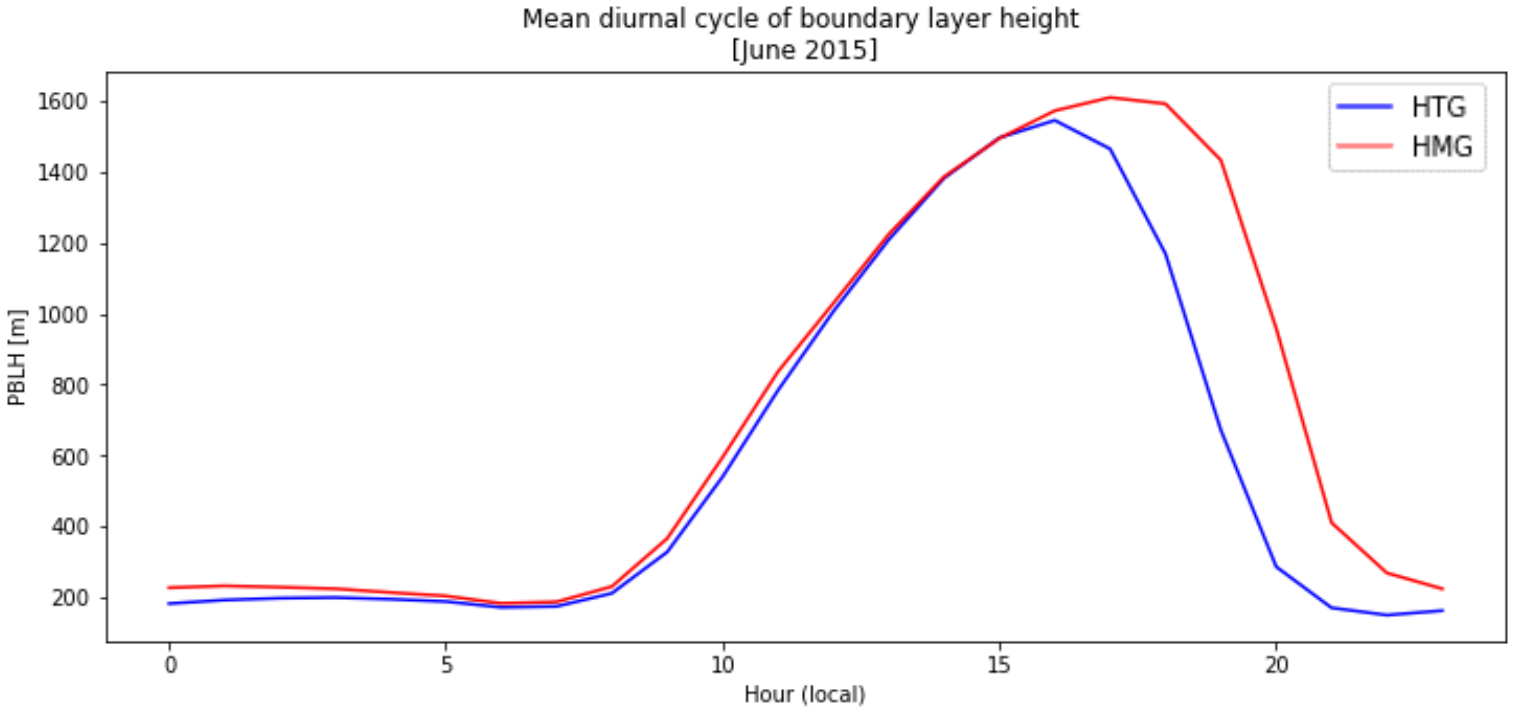
Machulskaya & Mironov, 2018

What impact does this have on the atmosphere?

- SCAM simulations:
  - One month (June 2015) run at the Southern Great Plains ARM site, with 64 vertical levels
  - Homogeneous (HMG) and heterogeneous (HTG) forcing based on offline HydroBlocks run
  - Prescribed surface high order moments (variances, covariances, etc.)

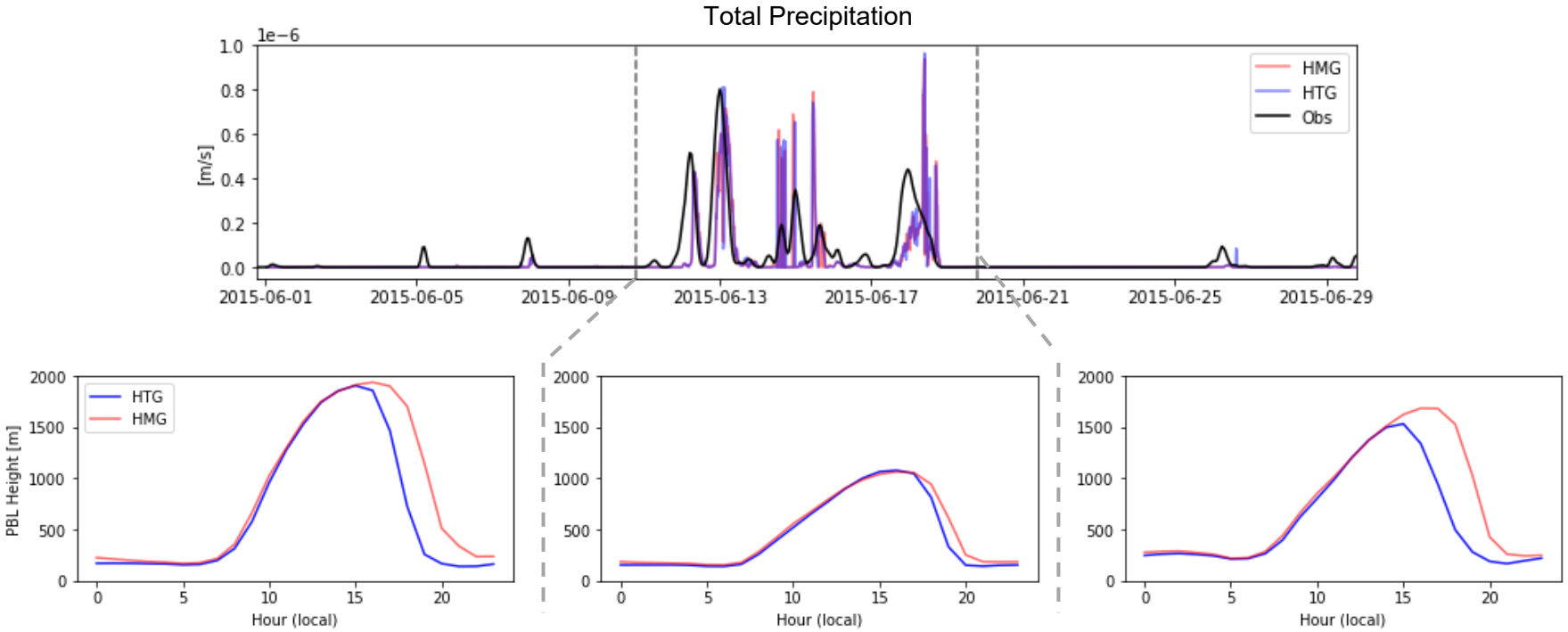
What impact does this have on the atmosphere?

- Land heterogeneity results in a lower peak PBLH



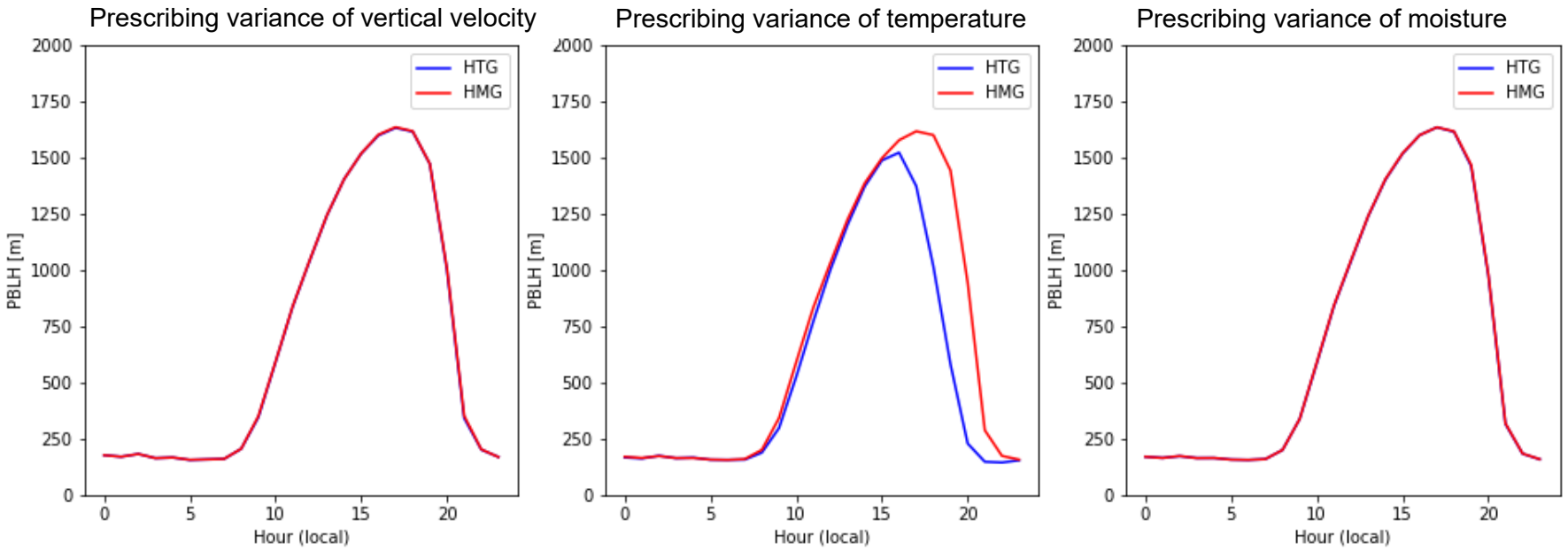
What impact does this have on the atmosphere?

- Land heterogeneity results in a lower peak PBLH
- Particularly noticeable during dry periods



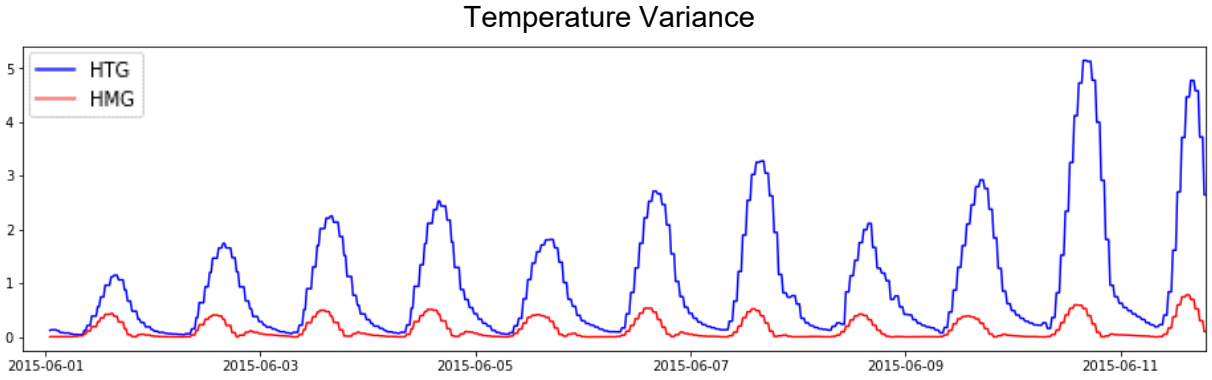
What's behind that difference in PBL evolution?

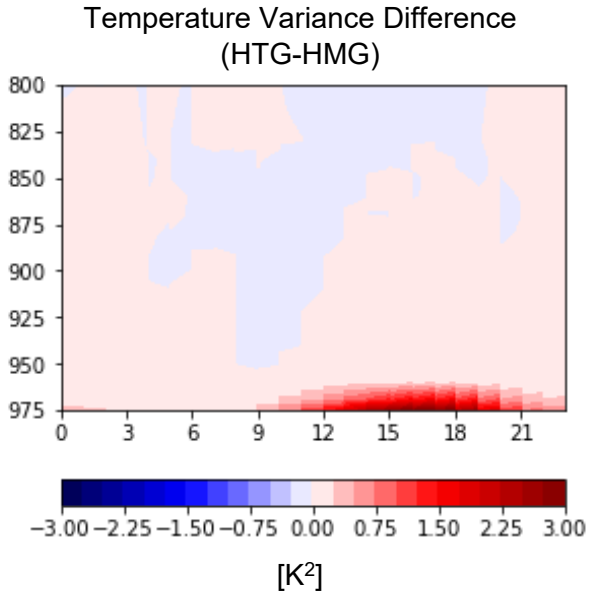
- Originally prescribing *all* surface moments – but they don't all act equally



What's behind that difference in PBL evolution?

- The impact of prescribing temperature variance at the surface doesn't stay confined to just the surface or to one field

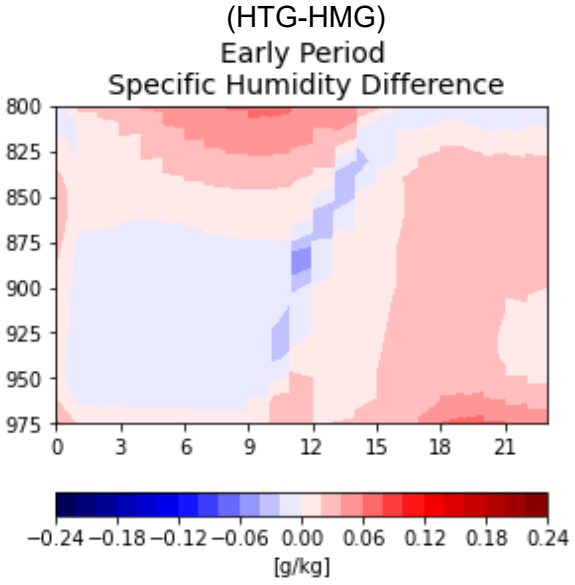


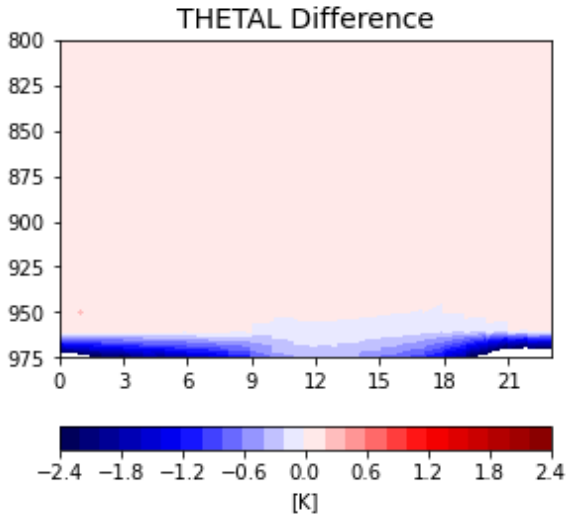


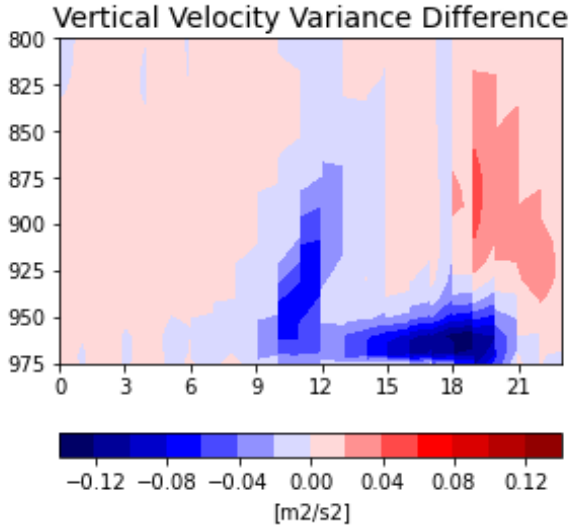
Averaged over early dry period, June 1-11

What's behind that difference in PBL evolution?

- The impact of prescribing temperature variance at the surface doesn't stay confined to just the surface or to one field







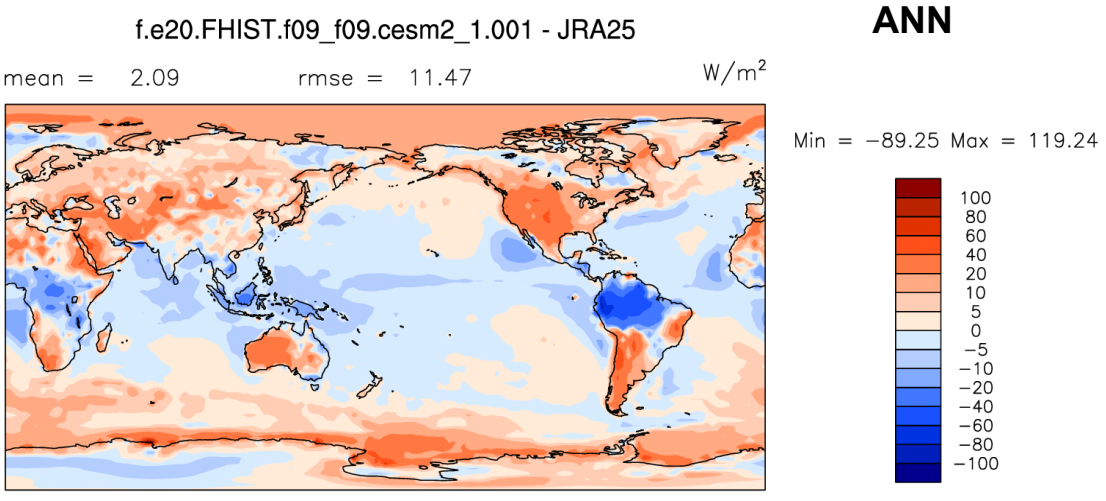
Land heterogeneity can have big impacts on the near -surface atmosphere

- Ongoing work to integrate this into CLM and assess impacts on CAM at regional and global scales

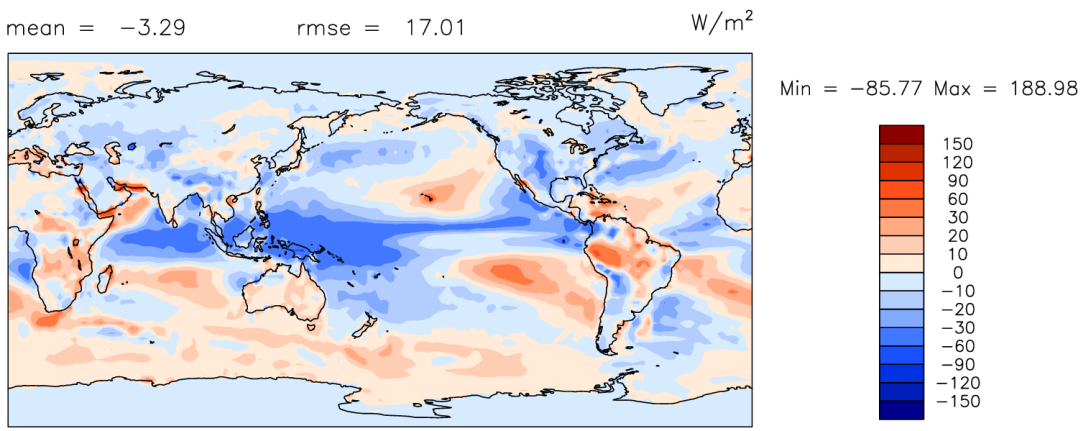
From atmospheric perspective: can we leverage information in CLUBB to improve surface fluxes?

Known biases in surface fluxes around the world

SHFLX Bias
(1979-2005)

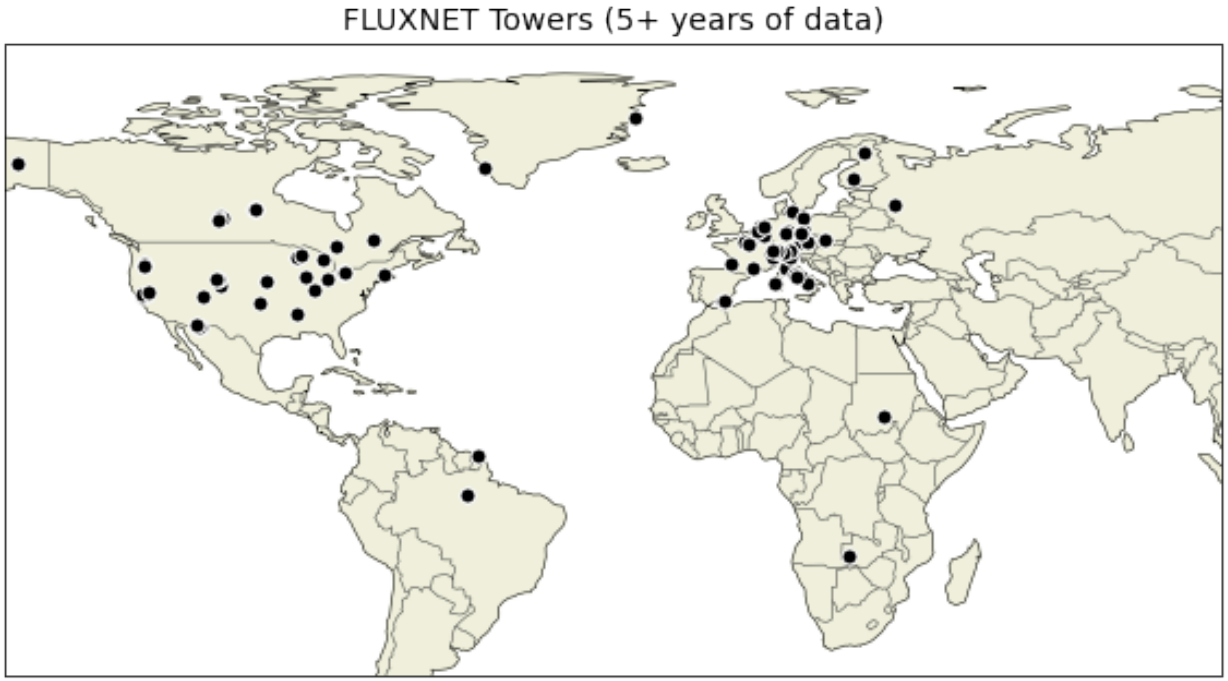


LHFLX Bias
(1979-2005)



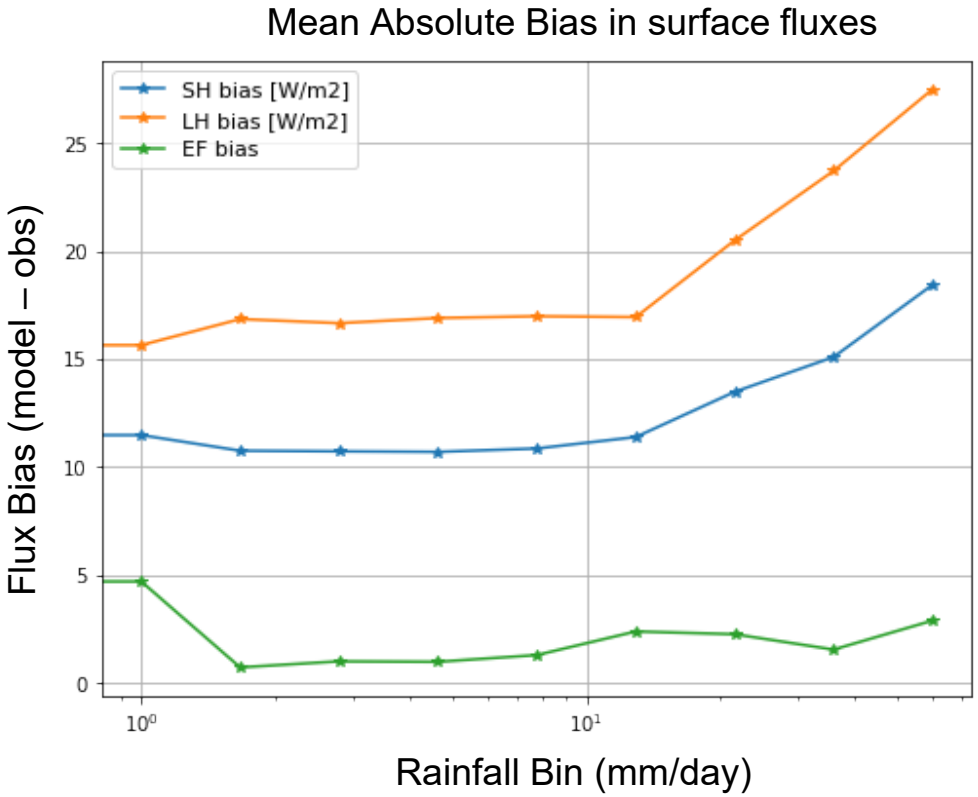
Can we say more about where/when biases are most pronounced?

- Compare AMIP run against observations from ~115 FLUXNET towers



Presence of rain influences bias magnitude

- Days with rainfall of certain amounts in observations vs. CAM6
- Biases in SHFLX and LHFLX increase at higher rain amounts
  - Evaporative fraction biases may be largest for drizzle-type events instead



Ultimate goal:

Communication of subgrid heterogeneity between the atmosphere and the surface

mdfowler@ucar.edu

High order moments in CLUBB:

The math

$$\overline{w'^2} = \begin{cases} u_*^2\left[1.75 + 2(-\zeta)^{\frac{2}{3}}\right], & \zeta < 0 \\ 1.75u_*^2, & \zeta > 0 \end{cases}$$

$$\overline{\theta'^2} = \begin{cases} Q_0^2/u_*^2(4(1-8.3\zeta)^{-2/3}), & \zeta < 0 \\ Q_0^2/u_*^2(4), & \zeta > 0 \end{cases}$$

$$\overline{q'^2} = \begin{cases} H_0^2/u_*^2(4(1-8.3\zeta)^{-2/3}), & \zeta < 0 \\ H_0^2/u_*^2(4), & \zeta > 0 \end{cases}$$

$$\overline{\theta' q'} = \sqrt{\overline{\theta'^2}}\sqrt{\overline{q'^2}}$$

André et al., 1978

$$\overline{u_S' w'} = -u_*^2; \quad \overline{v_S' w'} = \overline{u_S' v_S'} = 0; \quad \overline{w'\theta'} = Q_0; \quad \overline{w' q'} = H_0$$

$$\overline{\theta'^2}(u_*^2/Q_0^2) = \overline{\theta' q'}(u_*^2/Q_0 H_0) = \overline{q'^2}(u_*^2/H_0^2)$$

$$= \begin{cases} 4(1-8.3\zeta)^{-\frac{1}{3}}, & \zeta < 0 \\ 4, & \zeta > 0 \end{cases}$$

$$\overline{v_S'\theta'} = 0; \quad \overline{u_S'\theta'}/Q_0$$

$$= \begin{cases} -3.7(1-15\zeta)^{-\frac{1}{3}}(1-9\zeta)^{-\frac{1}{3}}, & \zeta < 0 \\ -3, & \zeta > 0 \end{cases} \quad (29)$$

$$\overline{u_S'^2} = \begin{cases} 4u_*^2 + 0.3w_*^2, & Q_0 > 0 \\ 4u_*^2, & Q_0 < 0 \end{cases}$$

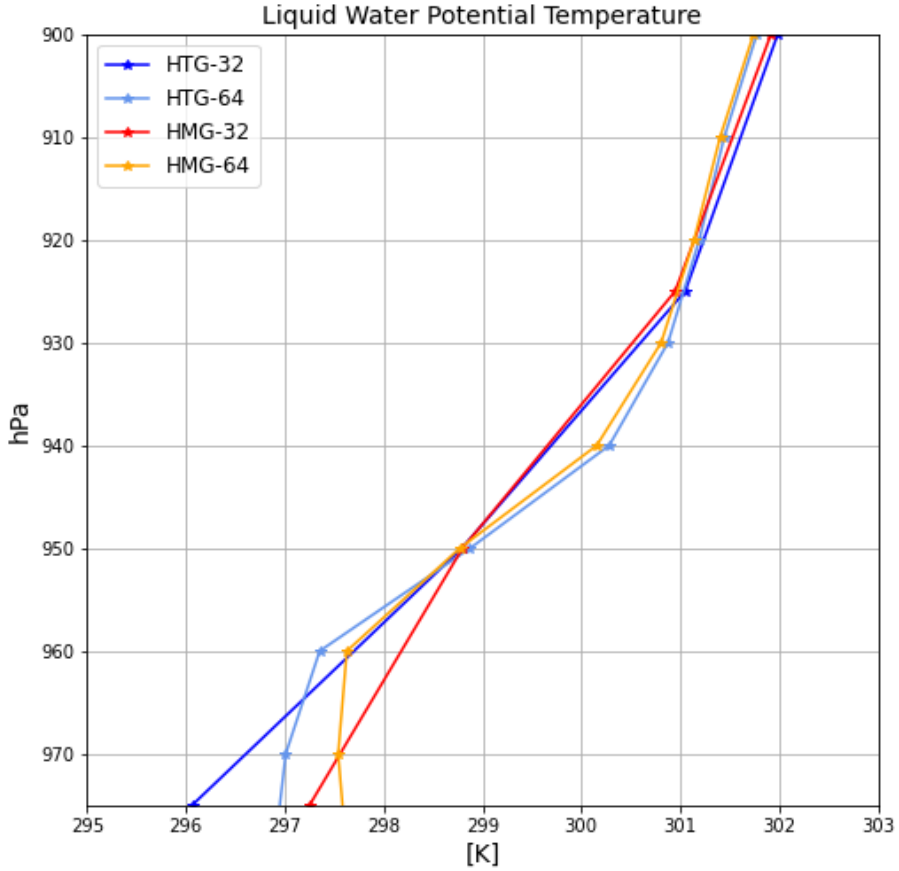
$$\overline{v_S'^2} = \begin{cases} 1.75u_*^2 + 0.3w_*^2, & Q_0 > 0 \\ 1.75u_*^2, & Q_0 < 0 \end{cases}$$

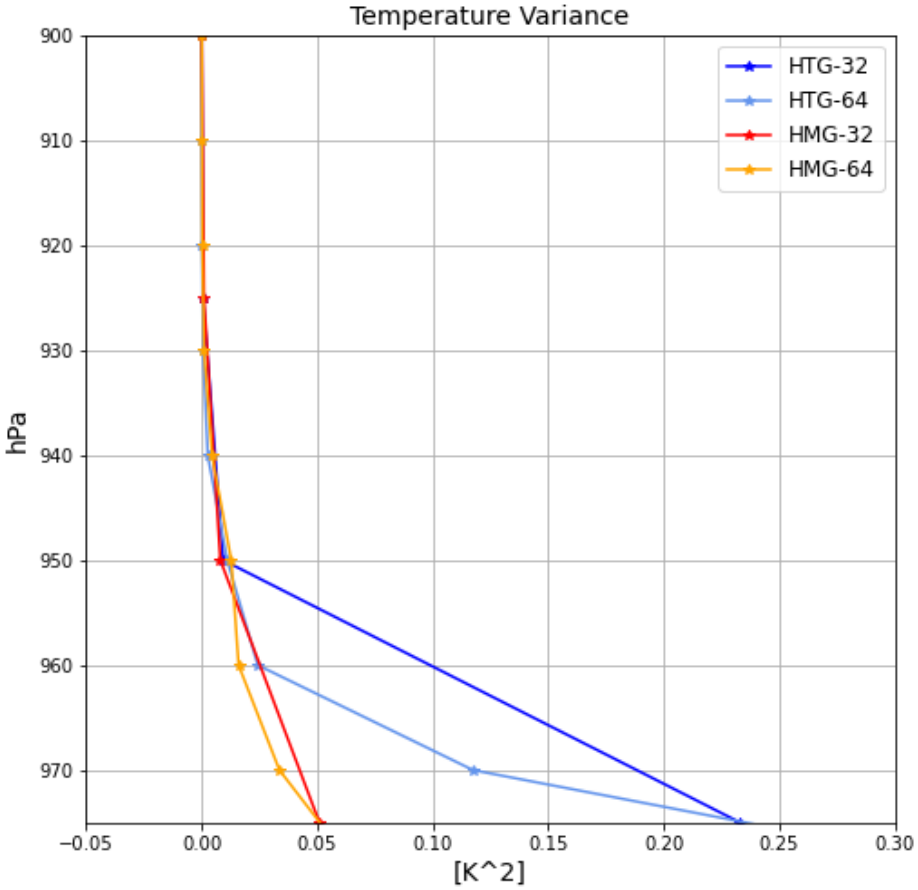
$$\overline{w'^2} = \begin{cases} [1.75 + 2(-\zeta)^{\frac{1}{3}}]u_*^2, & \zeta < 0 \\ 1.75u_*^2, & \zeta > 0. \end{cases}$$

What impact does this have on the atmosphere?

*Single day case study – **resolution matters***

8-10a Local Mean

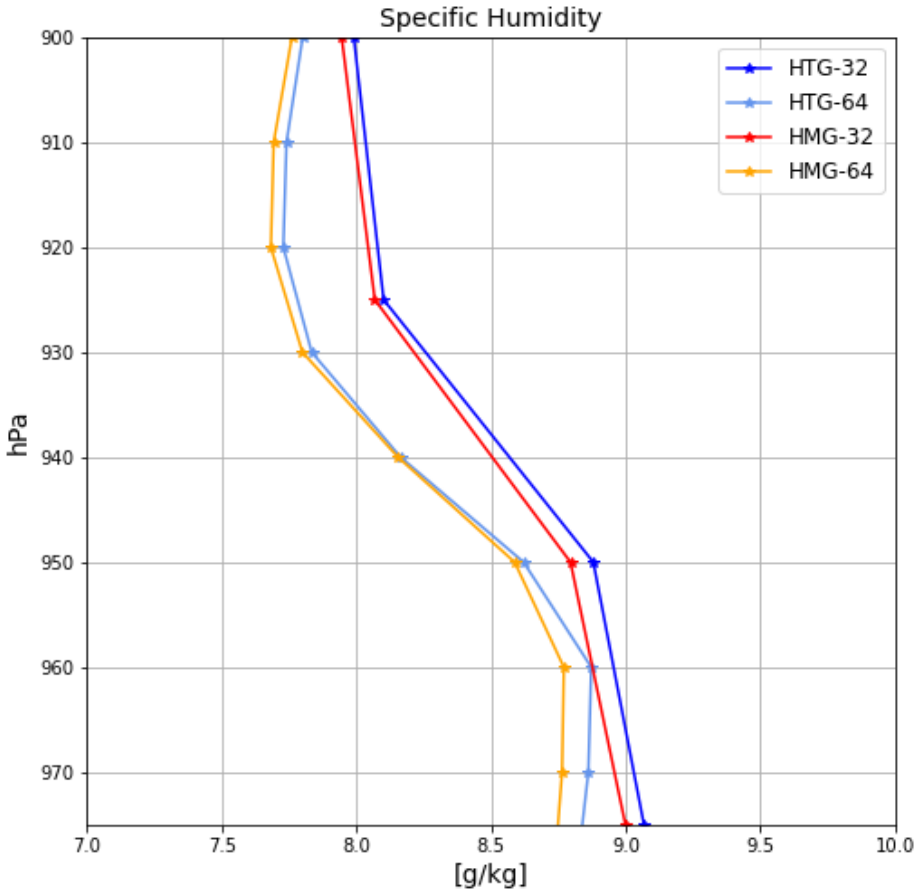


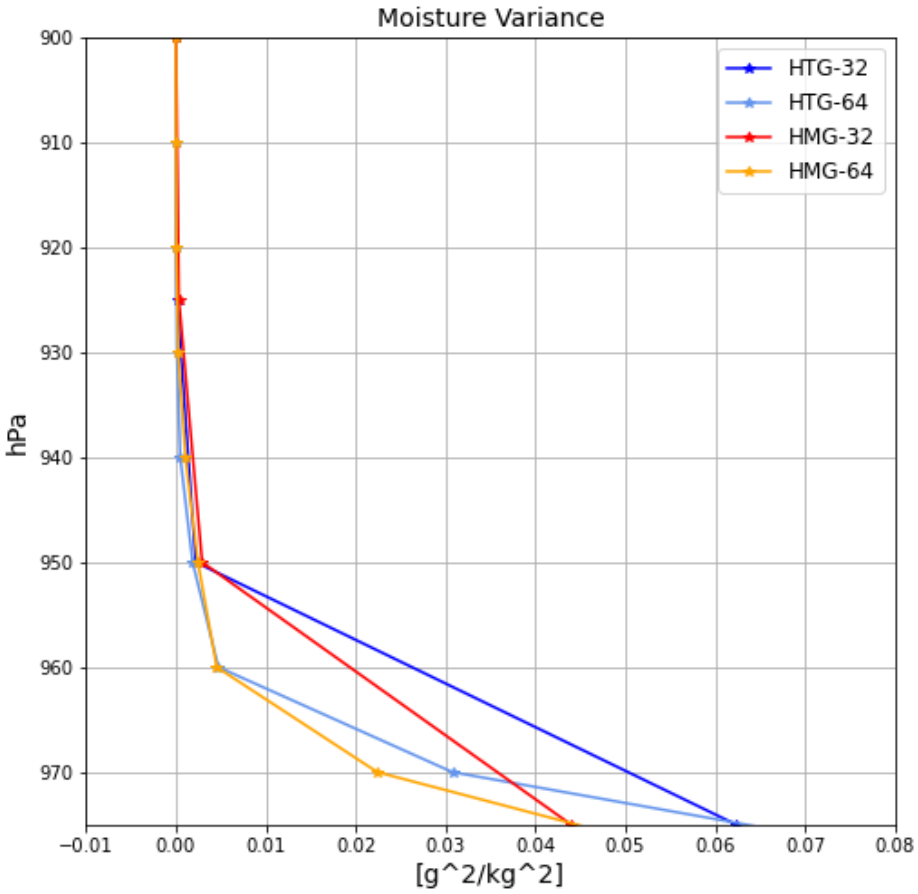


What impact does this have on the atmosphere?

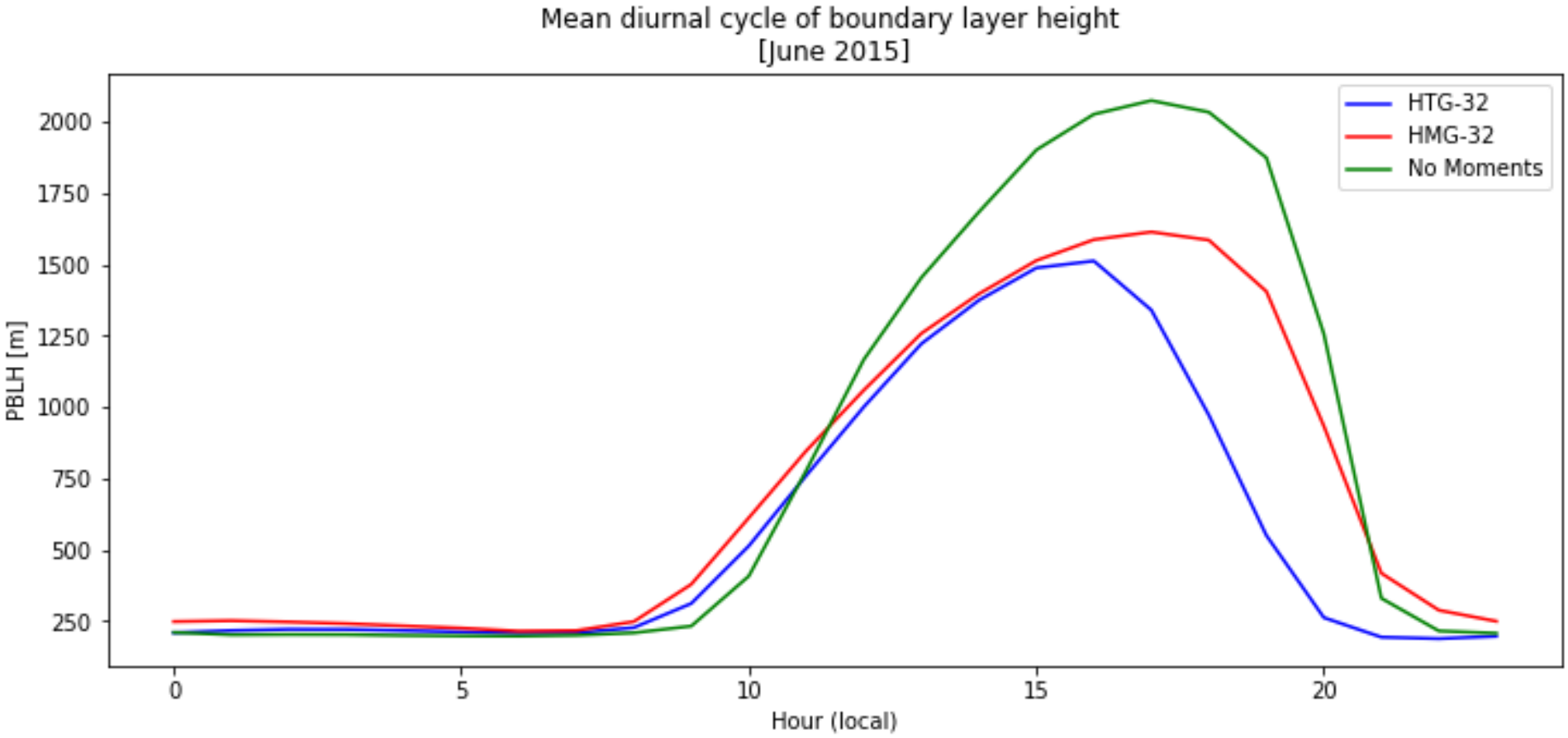
*Single day case study – **resolution matters***

8-10a Local Mean



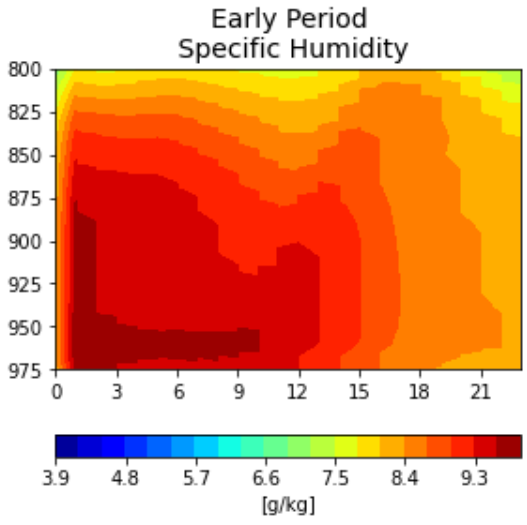


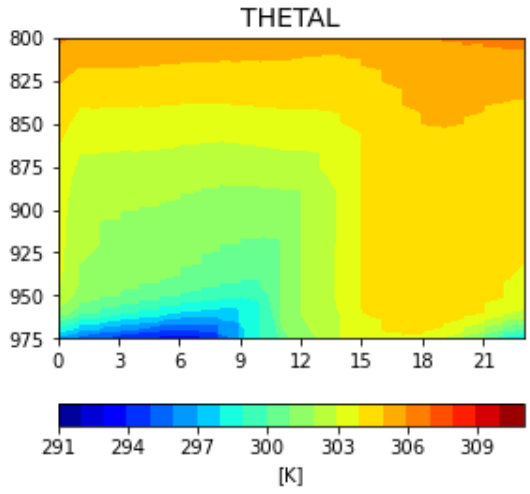
If no moments prescribed at the surface?

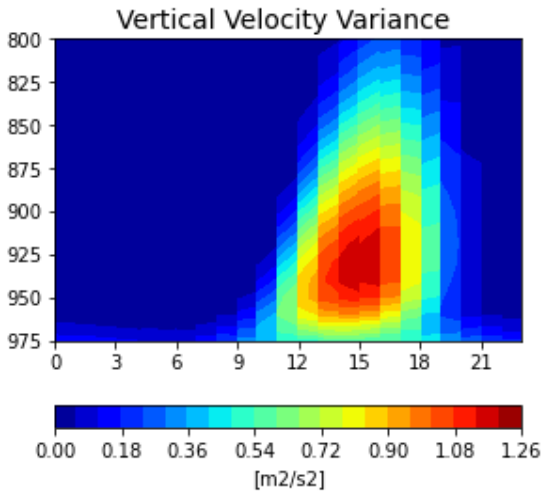


HTG Time/Height Plots: Early dry period

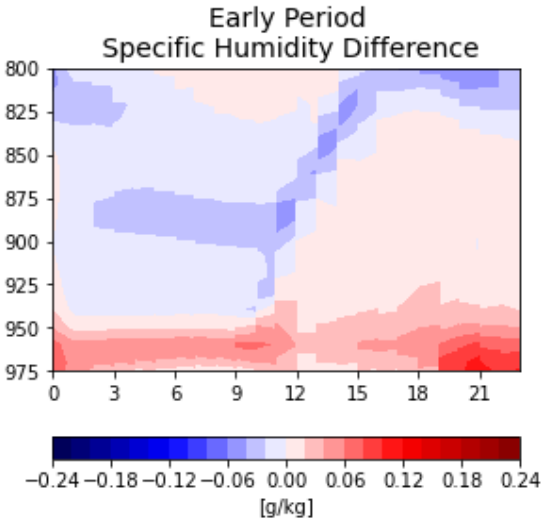
- All surface moments prescribed

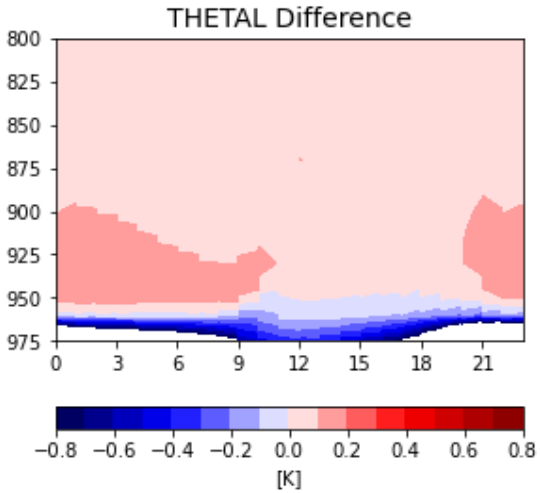


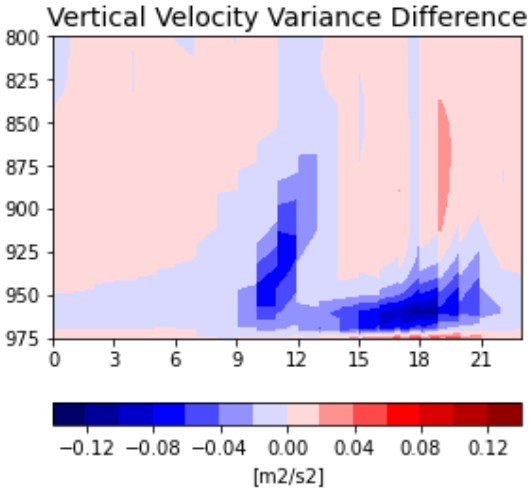




HTG-HMG
All surface moments prescribed



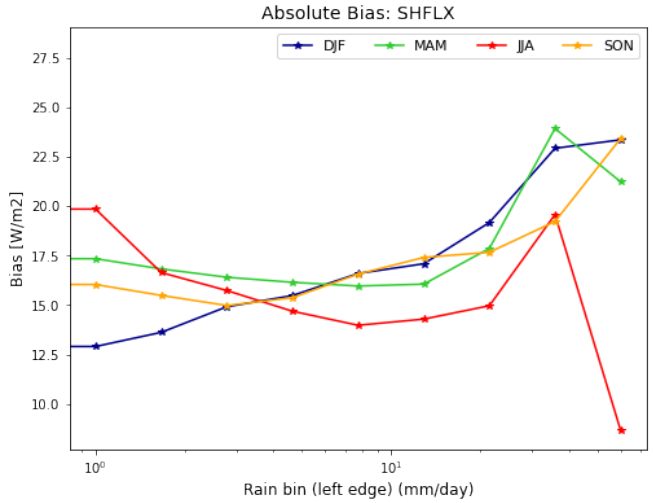


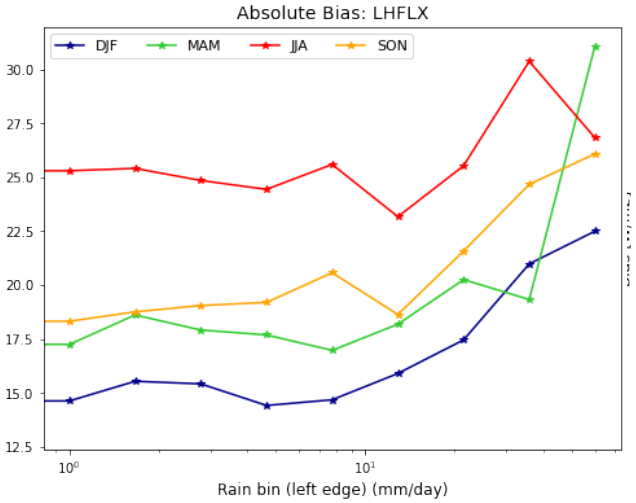


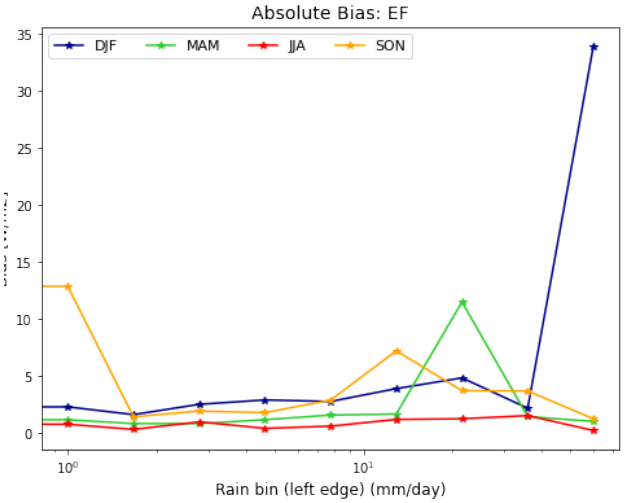
HTG-HMG
W'^2 only prescribed

FLUXNET Tower Comparisons

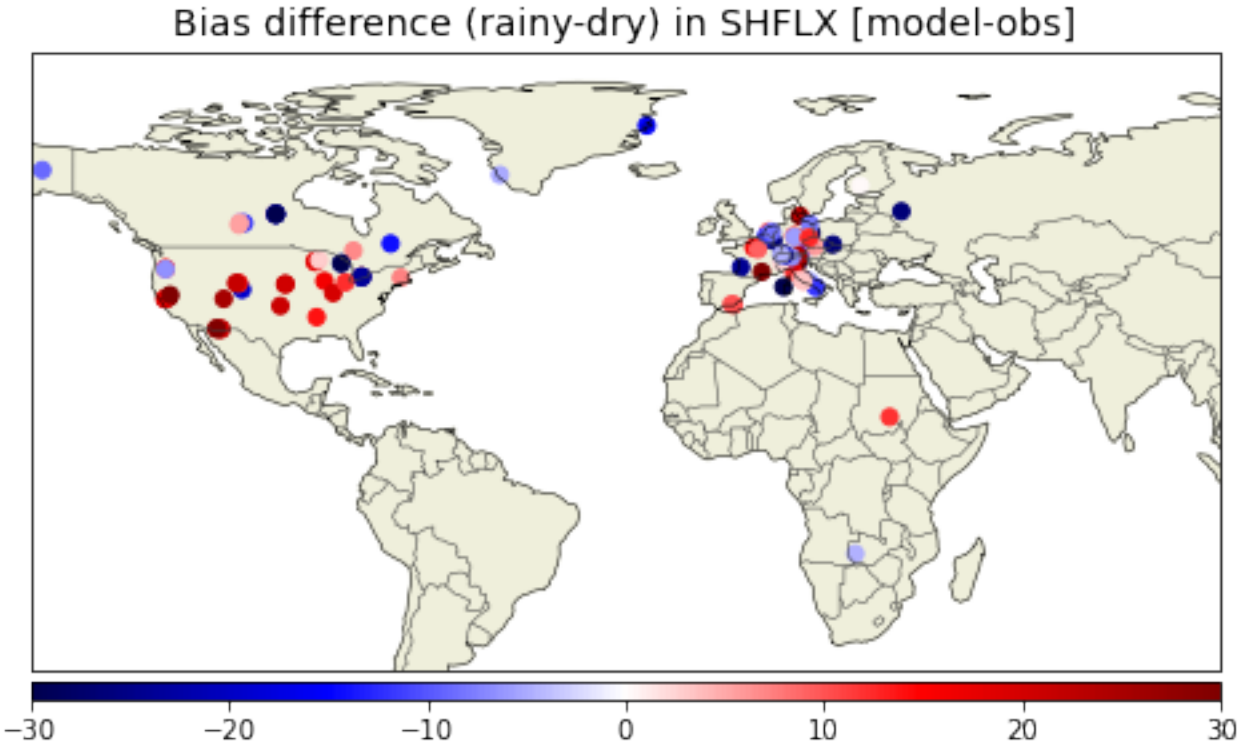
- Model data: 2000-14
- FLUXNET data: Varies by station, but all within 1992-2014



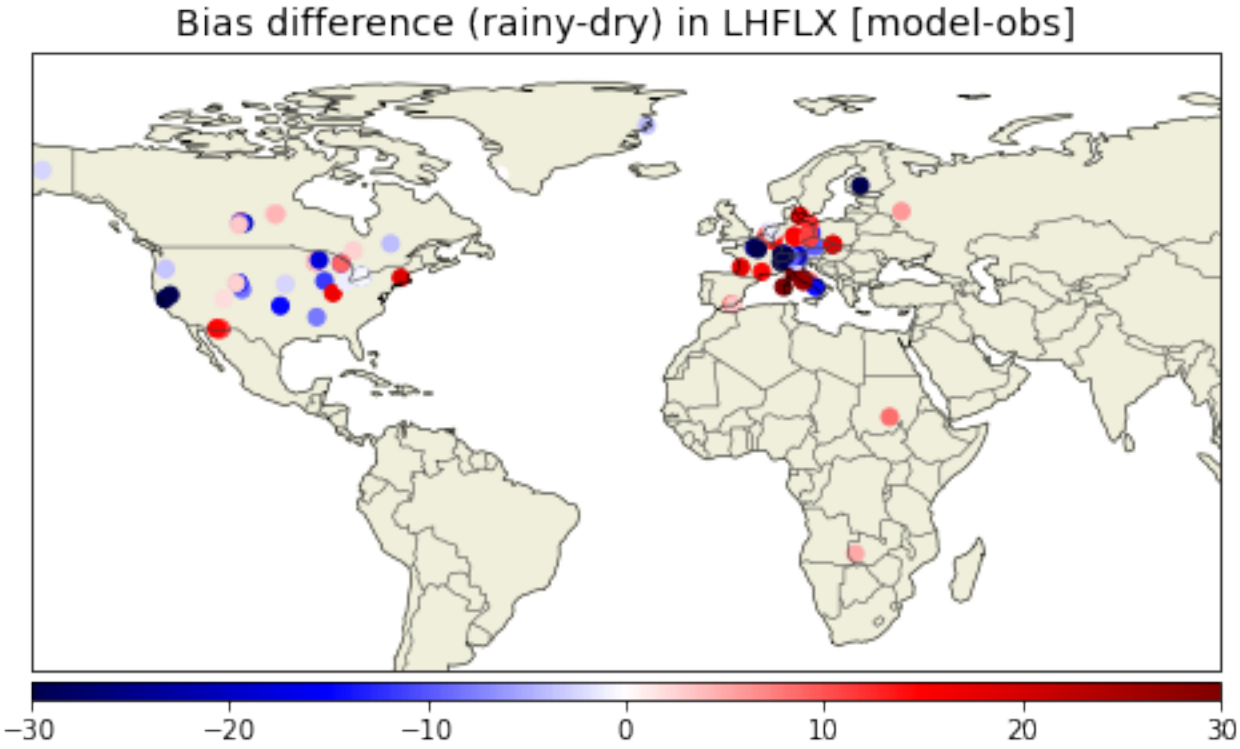




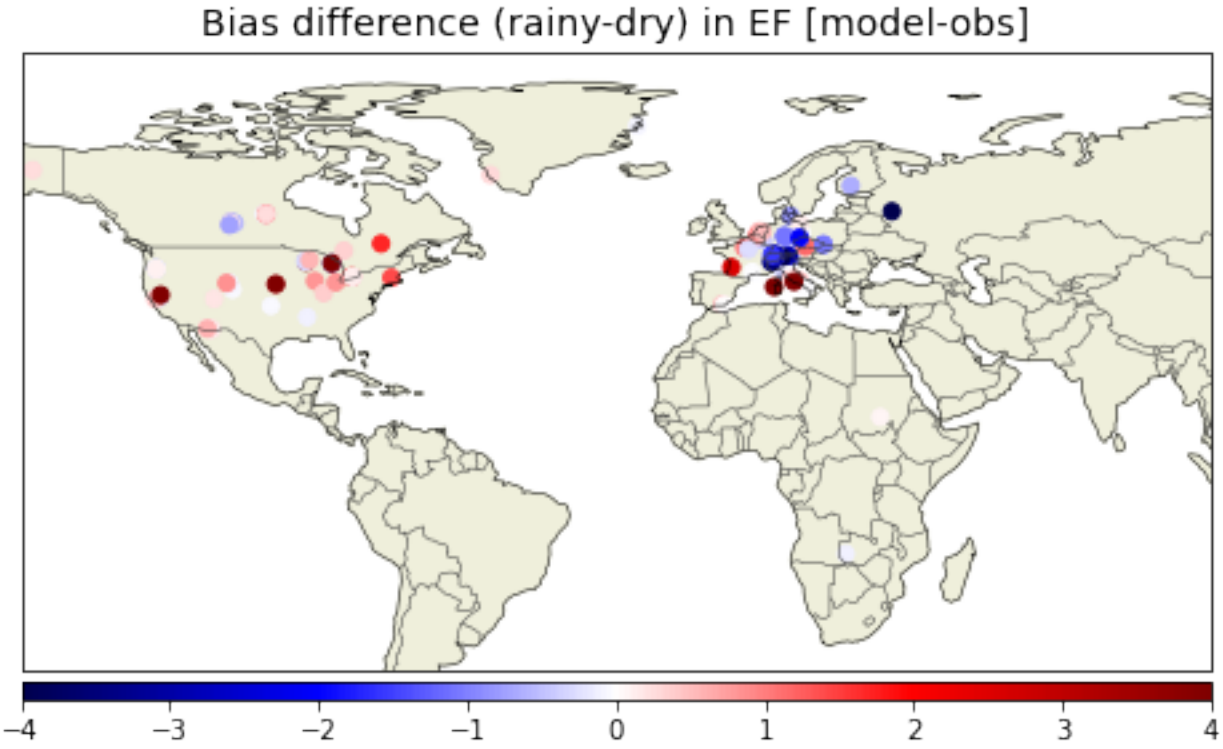
FLUXNET Comparison:
Rain vs. Dry Days (spatial biases)



FLUXNET Comparison:
Rain vs. Dry Days (spatial biases)



FLUXNET Comparison:
Rain vs. Dry Days (spatial biases)



FLUXNET Comparison: Correlation Coefficients