



# Connections between CLUBB's higher order moments and the surface

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

NCAR  
UCAR

AMWG  
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*Image from [climateextremes.org.au](http://climateextremes.org.au)*

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



# From land perspective: heterogeneity matters



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- Sections
- References

Editorial Type: **Article**

The Effect of Land Surface Heterogeneity and Background Wind on Shallow Cumulus Clouds and the Transition to Deeper Convection

Jungmin M. Lee<sup>1</sup>, Yunyan Zhang<sup>1</sup>, and Stephen A.... [View More +](#)

[Open Access](#) | Published: 11 January 2017

## Observational evidence for cloud cover enhancement over western European forests

Adriaan J. Teuling [✉](#), Christopher M. Taylor, Jan Fokke Meirink, Lieke A. Melsen, Diego G. Miralles, Chiel C. van Heerwaarden, Robert Vautard, Annemiek I. Stegehuis, Gert-Jan Nabuurs & Jordi Vilà-Guerau de Arellano

*Nature Communications* **8**, Article number: 14065 (2017) | [Cite this article](#)

## Hydrological Processes

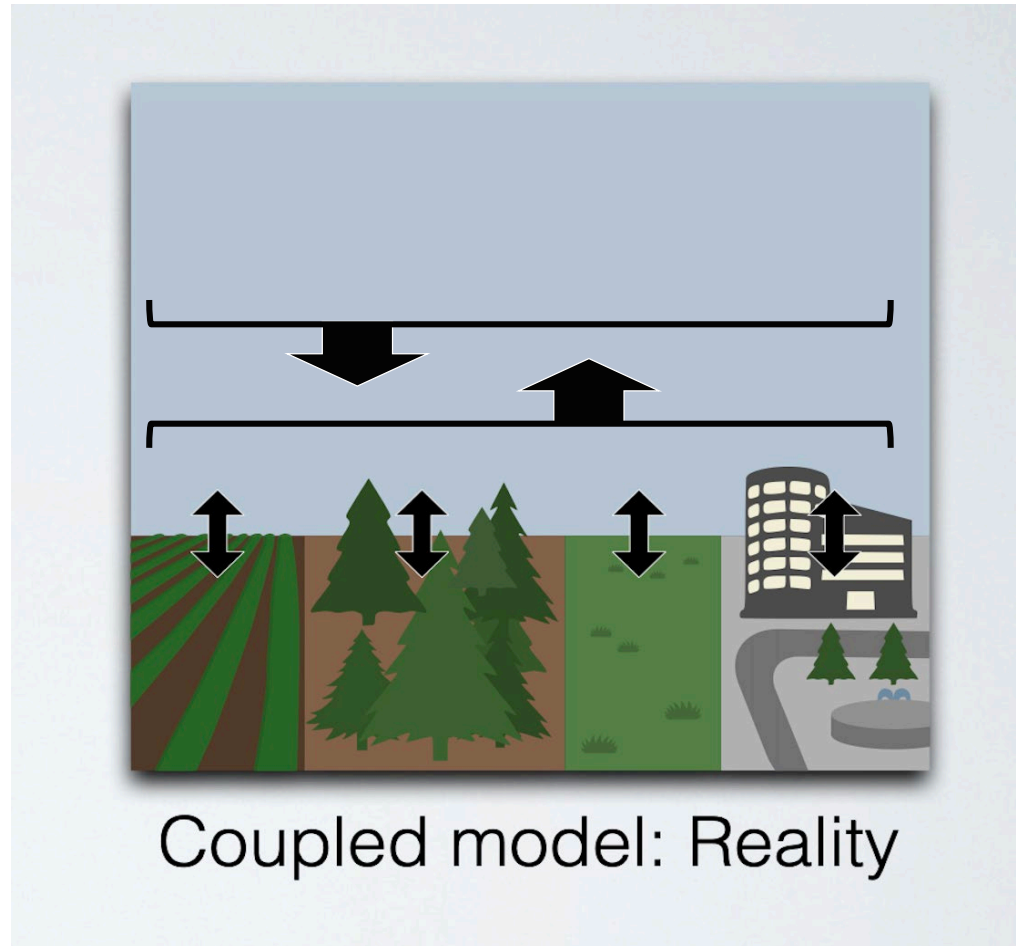
Research Article | [Full Access](#)

### Impact of soil moisture heterogeneity length scale and gradients on daytime coupled land-cloudy boundary layer interactions

Hsin-Yuan Huang [✉](#), Steven A. Margulis

First published: 23 April 2012 | <https://doi.org/10.1002/hyp.9351> | Citations: 17

# But coupled models don't communicate heterogeneity



*Slide courtesy of Nate Chaney*

# One attempt at improvement: CLASP

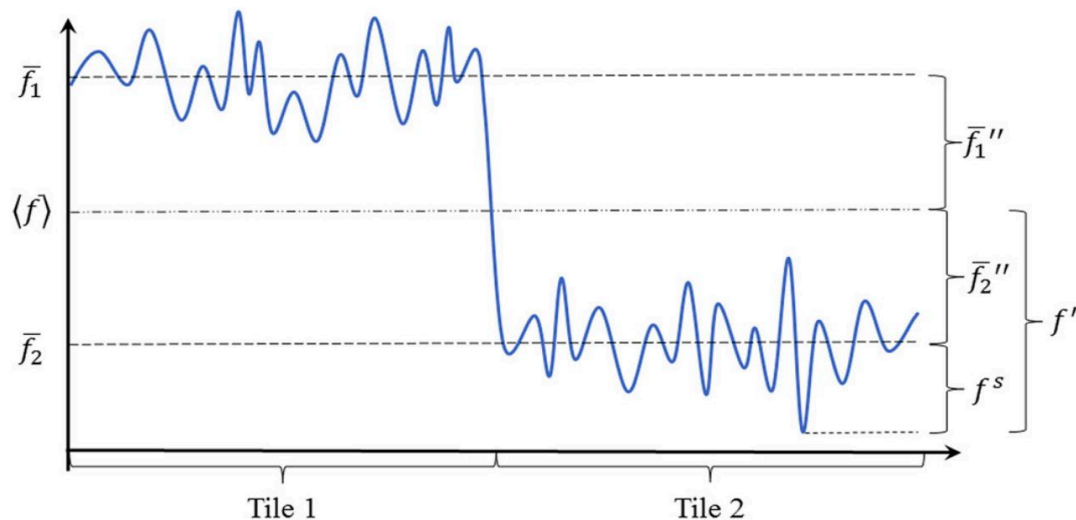
Coupling of Land and Atmospheric Subgrid Parameterizations

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

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Coupling of Land and Atmospheric Subgrid Parameterizations

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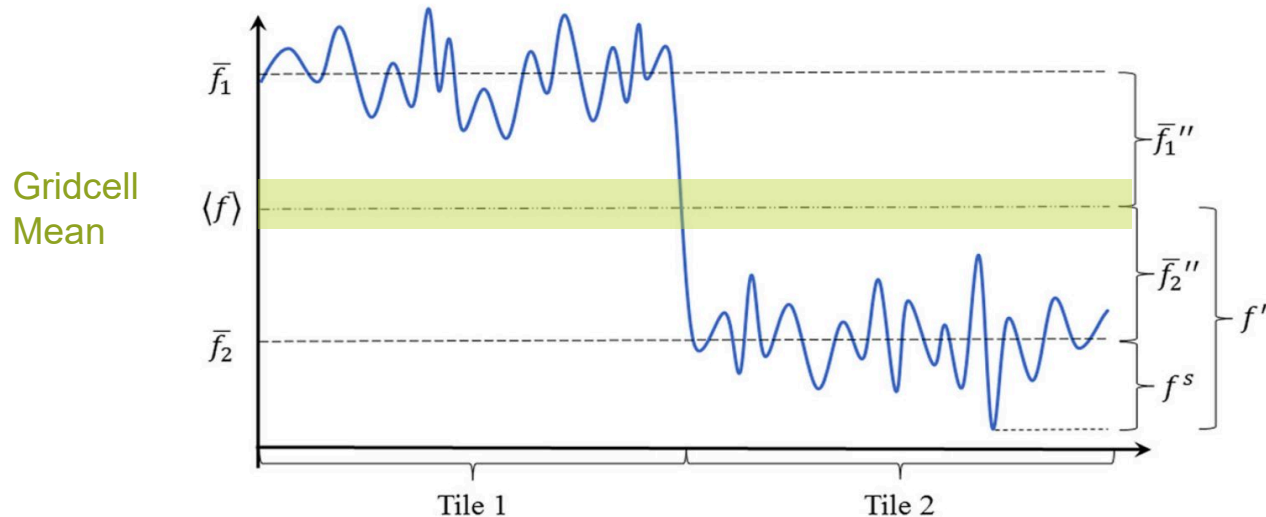
$$f = \langle f \rangle + \bar{f}'' + f^s$$

*Machulskaya  
& Mironov, 2018*

# One attempt at improvement: CLASP

Coupling of Land and Atmospheric Subgrid Parameterizations

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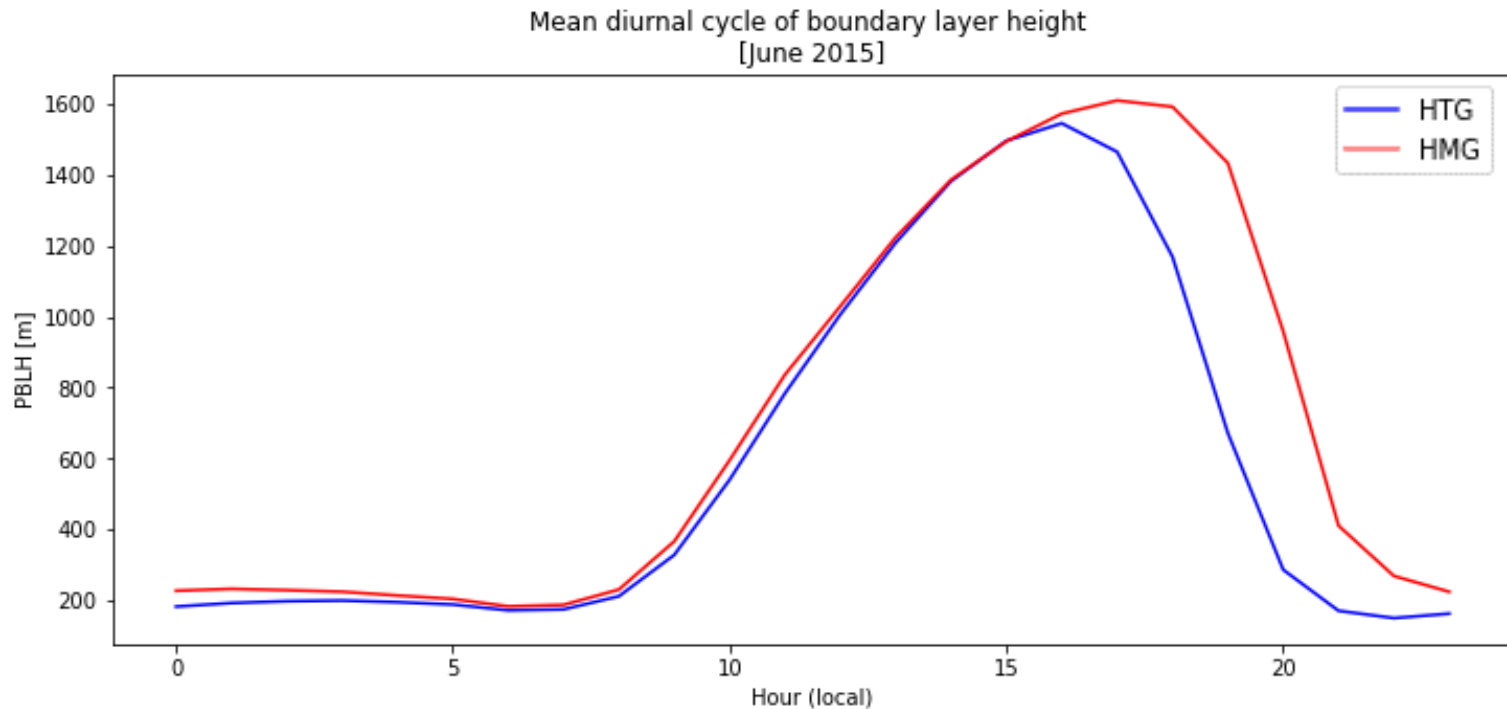


# What impact does this have on the atmosphere?

- 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.)

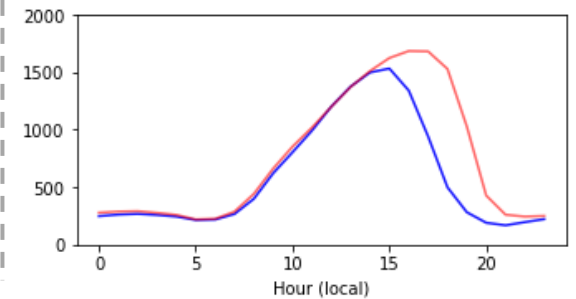
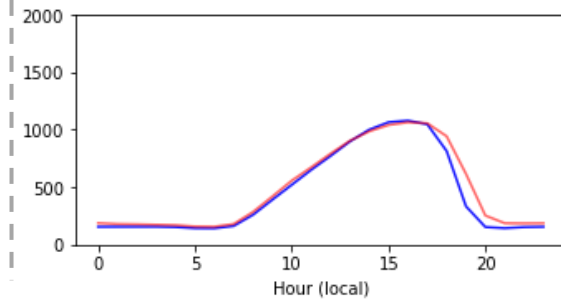
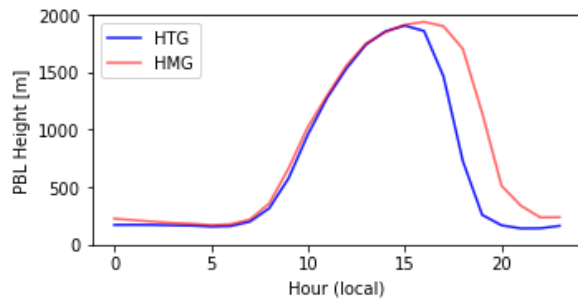
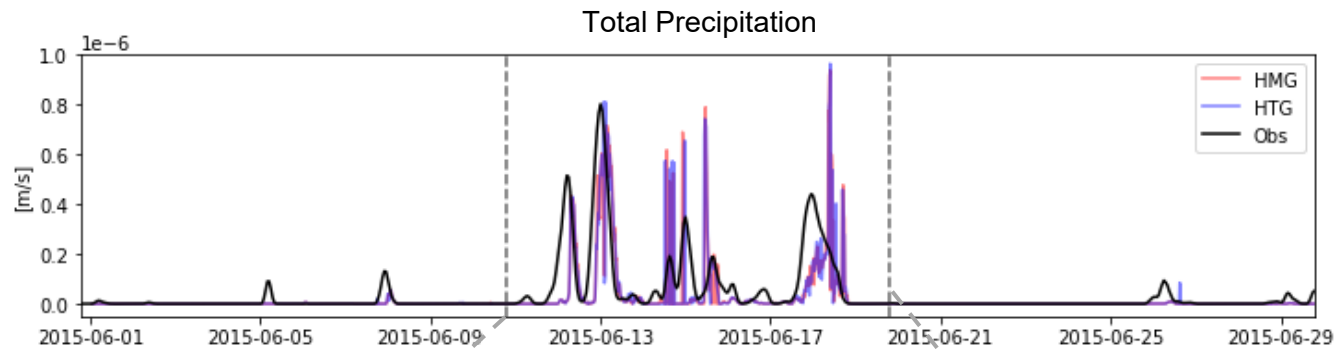
# What impact does this have on the atmosphere?

- Land heterogeneity results in a lower peak PBLH



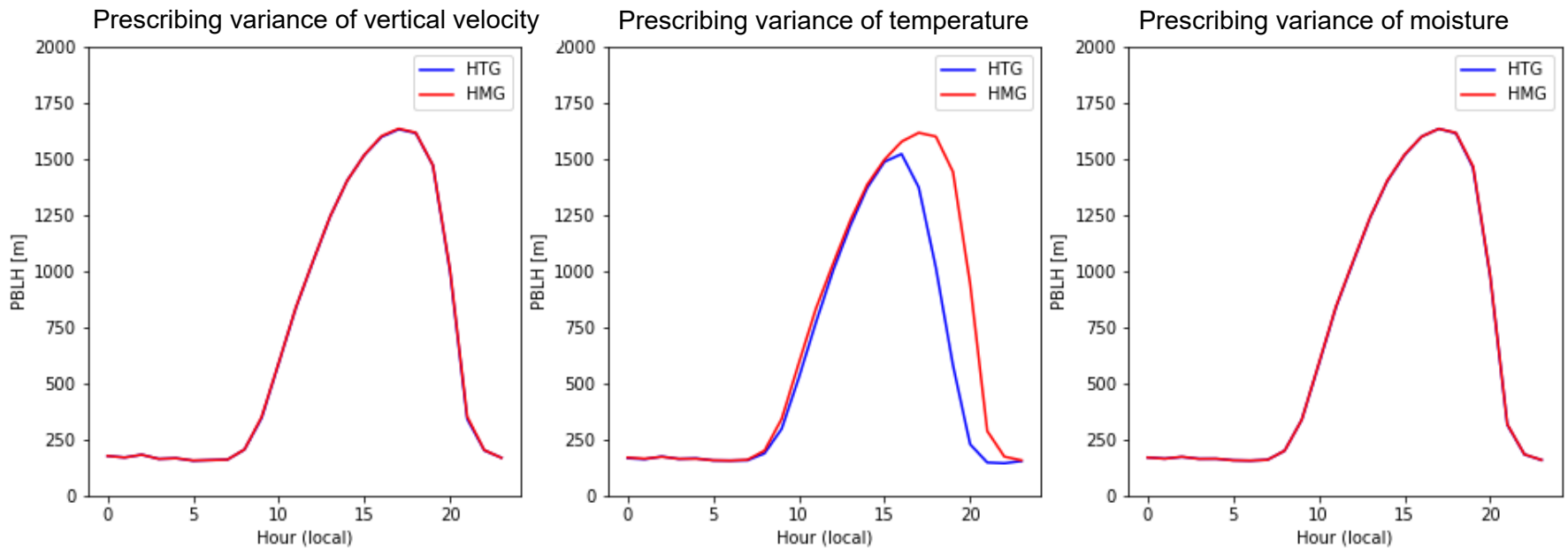
# What impact does this have on the atmosphere?

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



# What's behind that difference in PBL evolution?

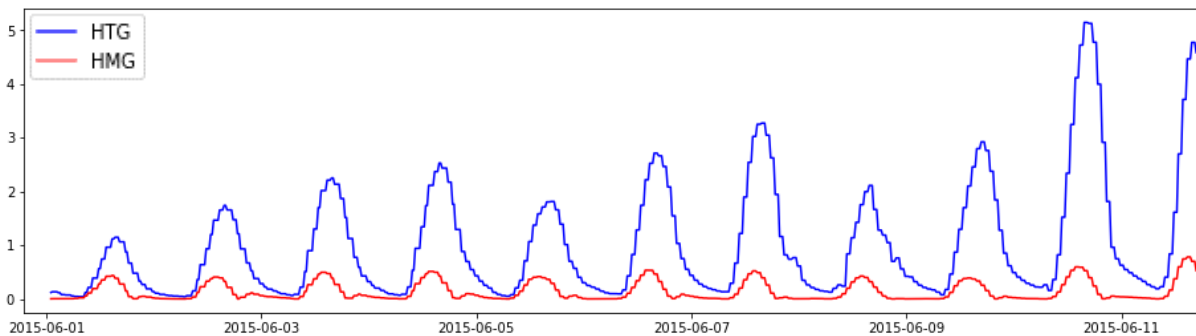
- Originally prescribing *all* surface moments – but they don't all act equally



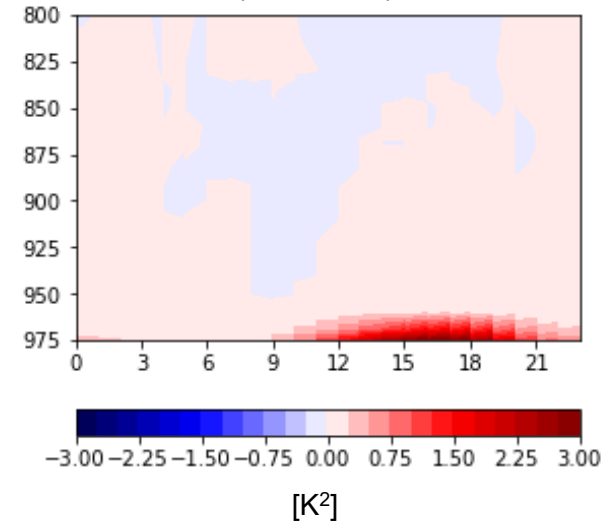
# What's behind that difference in PBL evolution?

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

Temperature Variance



Temperature Variance Difference (HTG-HMG)



Averaged over early dry period,  
June 1-11

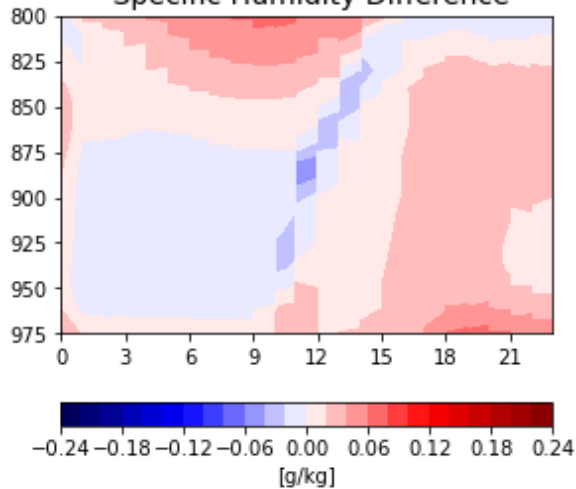
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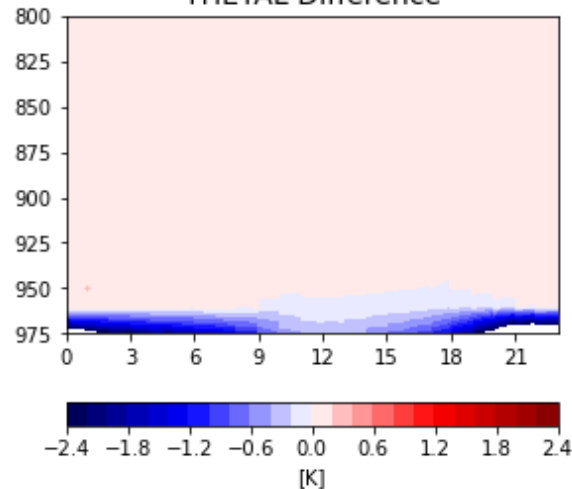
(HTG-HMG)

Early Period

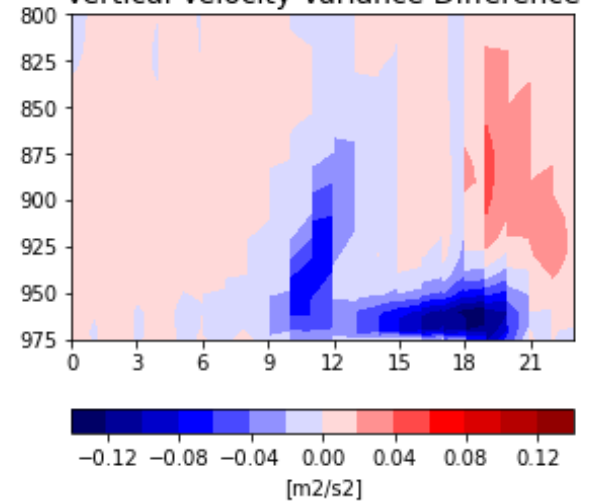
Specific Humidity Difference



THETAL Difference



Vertical Velocity Variance Difference



# 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

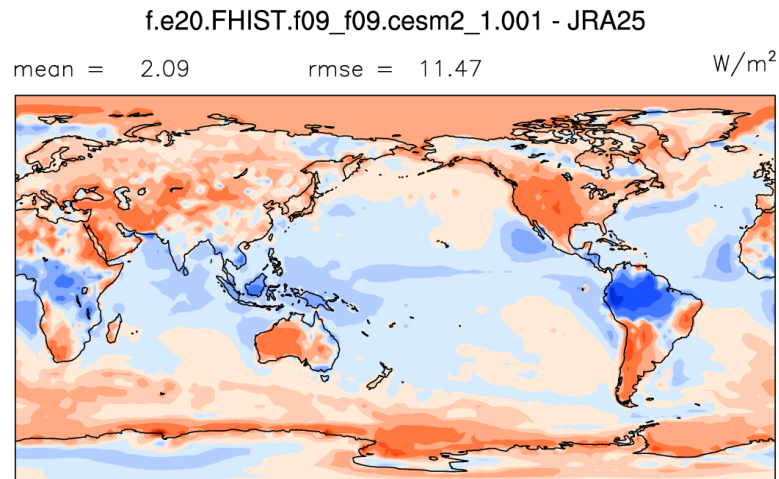
From atmospheric perspective: can we leverage information in CLUBB to improve surface fluxes?



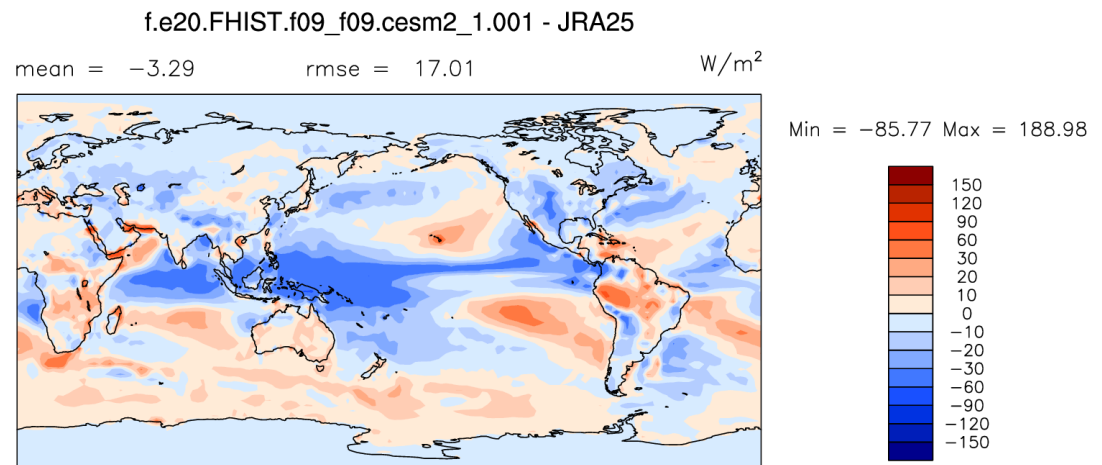


# Known biases in surface fluxes around the world

SHFLX Bias  
(1979-2005)

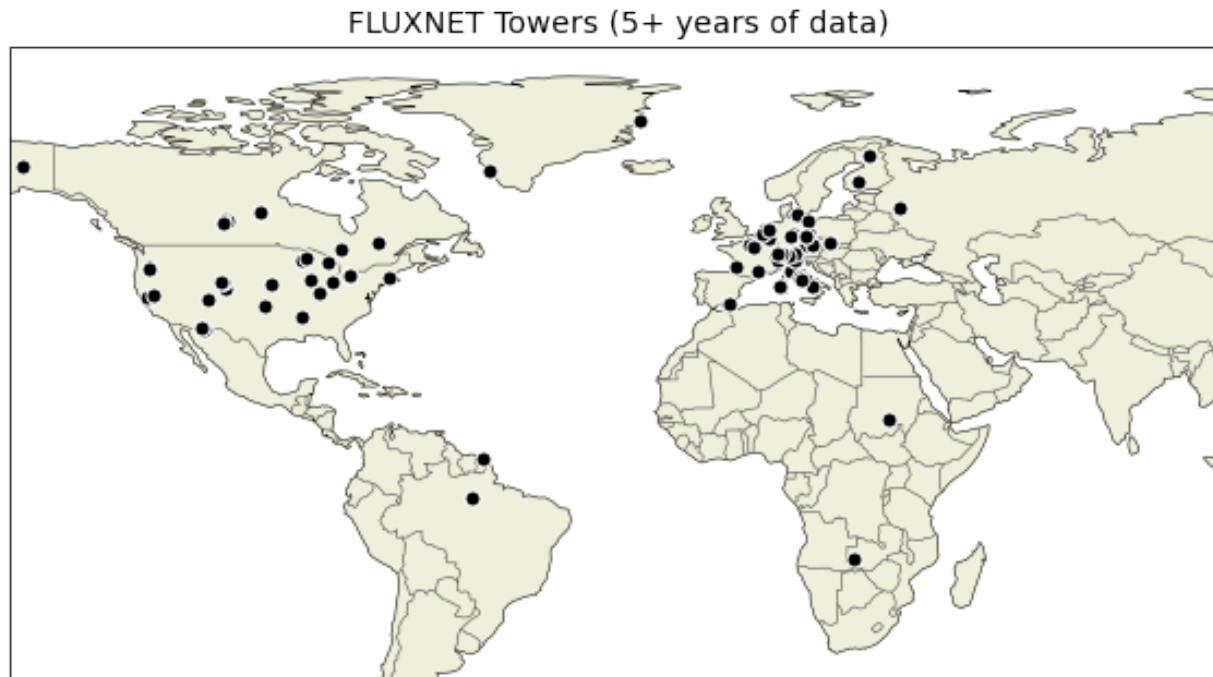


LHFLX Bias  
(1979-2005)



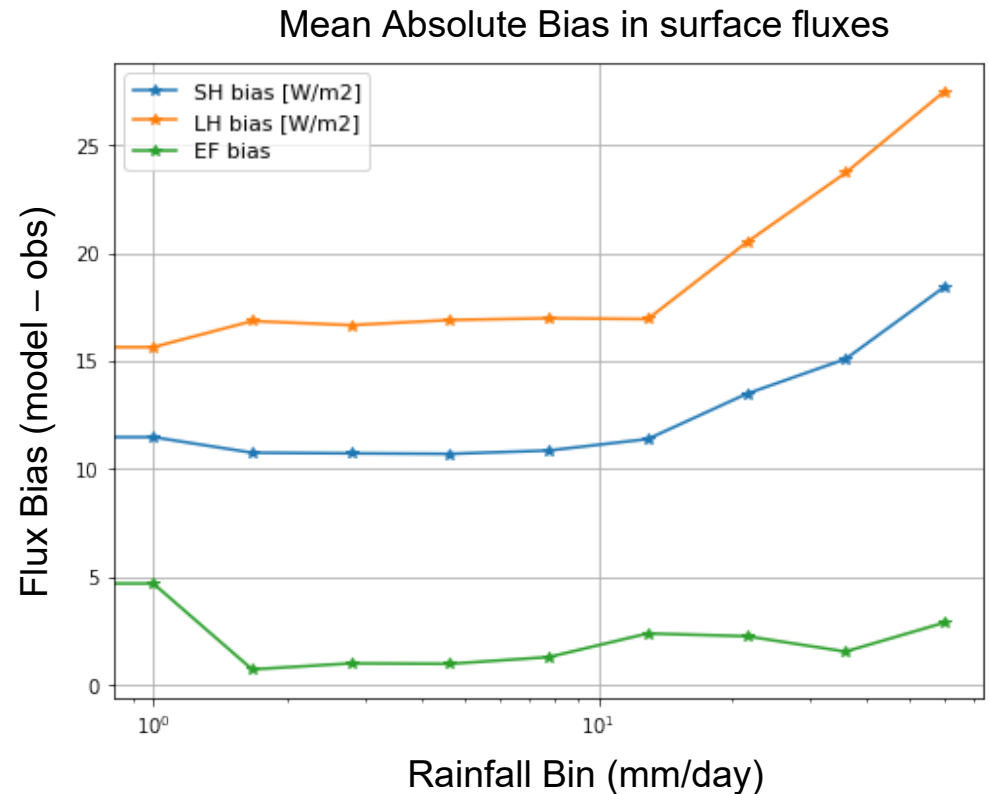
# Can we say more about where/when biases are most pronounced?

- 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](mailto:mdfowler@ucar.edu)

# High order moments in CLUBB:

## *The math*

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

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

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

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

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

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

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

$$\overline{v'_s \theta'} = 0; \quad \overline{u'_s \theta'}/Q_0$$

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

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

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

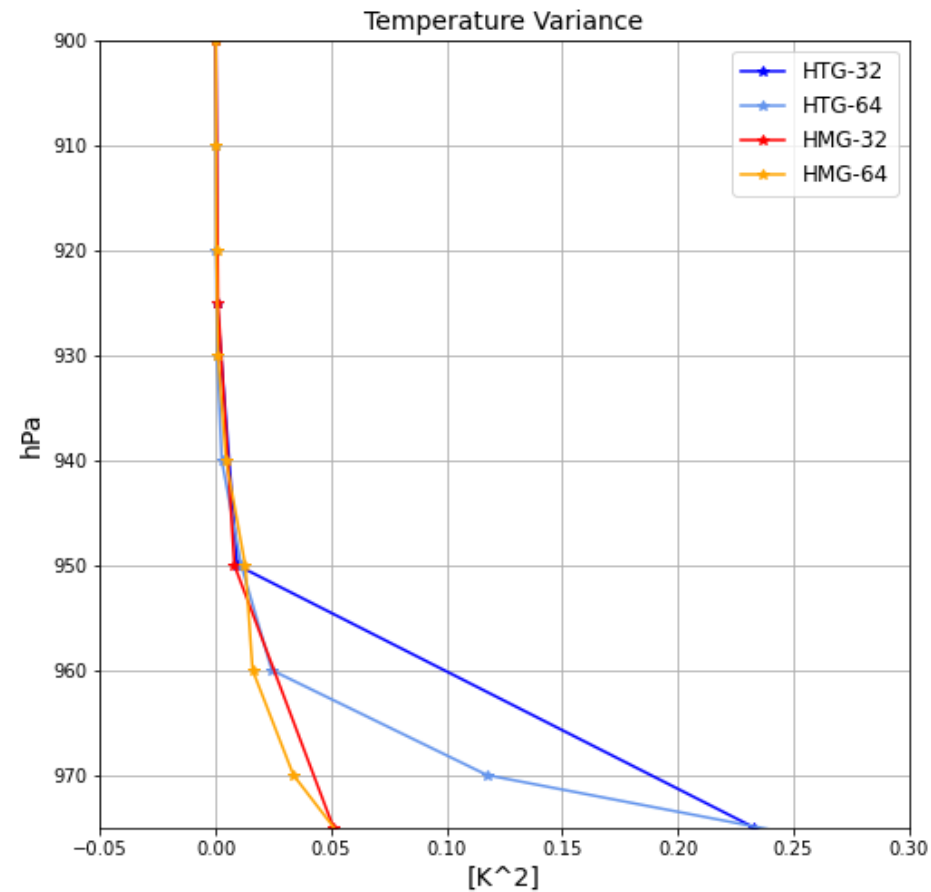
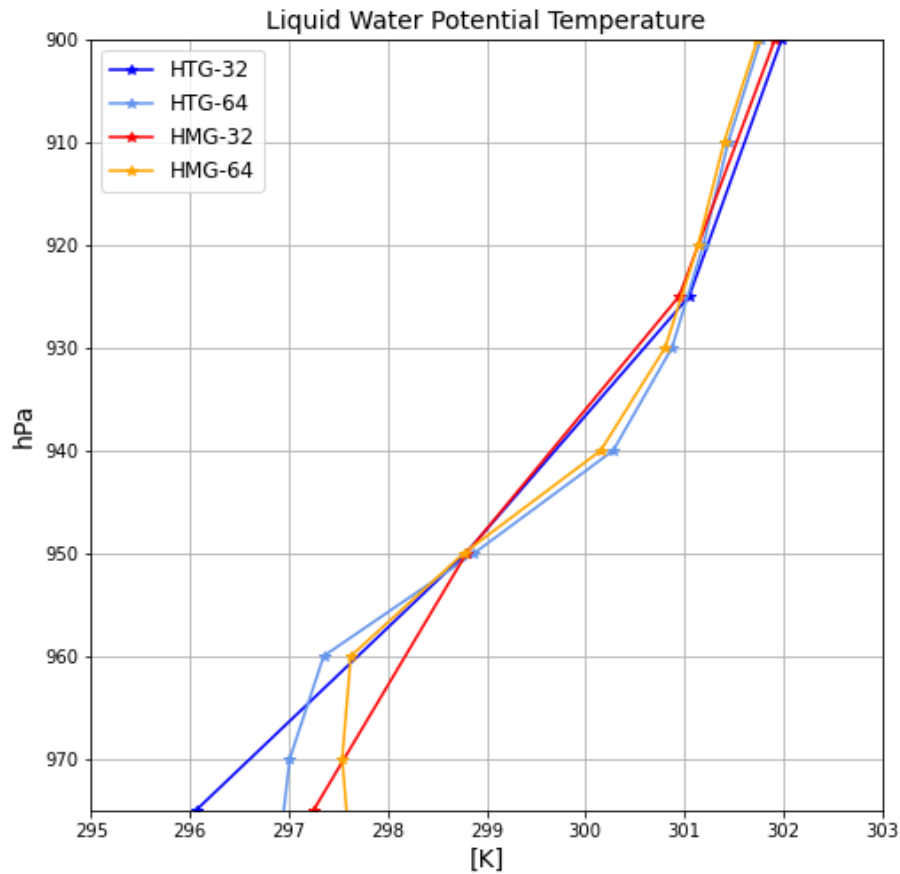
$$\overline{w'^2} = \begin{cases} [1.75 + 2(-\zeta)^{\frac{2}{3}}]u_*^2, & \zeta < 0 \\ 1.75u_*^2, & \zeta > 0. \end{cases}$$

André et al., 1978

# What impact does this have on the atmosphere?

## *Single day case study – resolution matters*

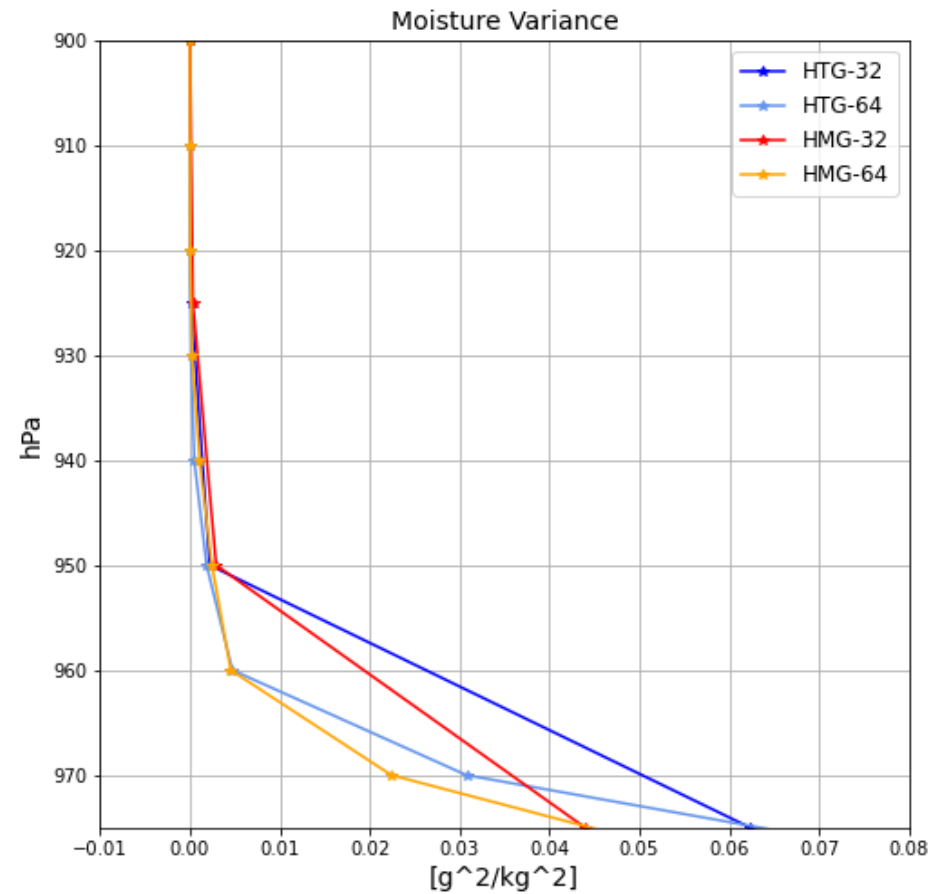
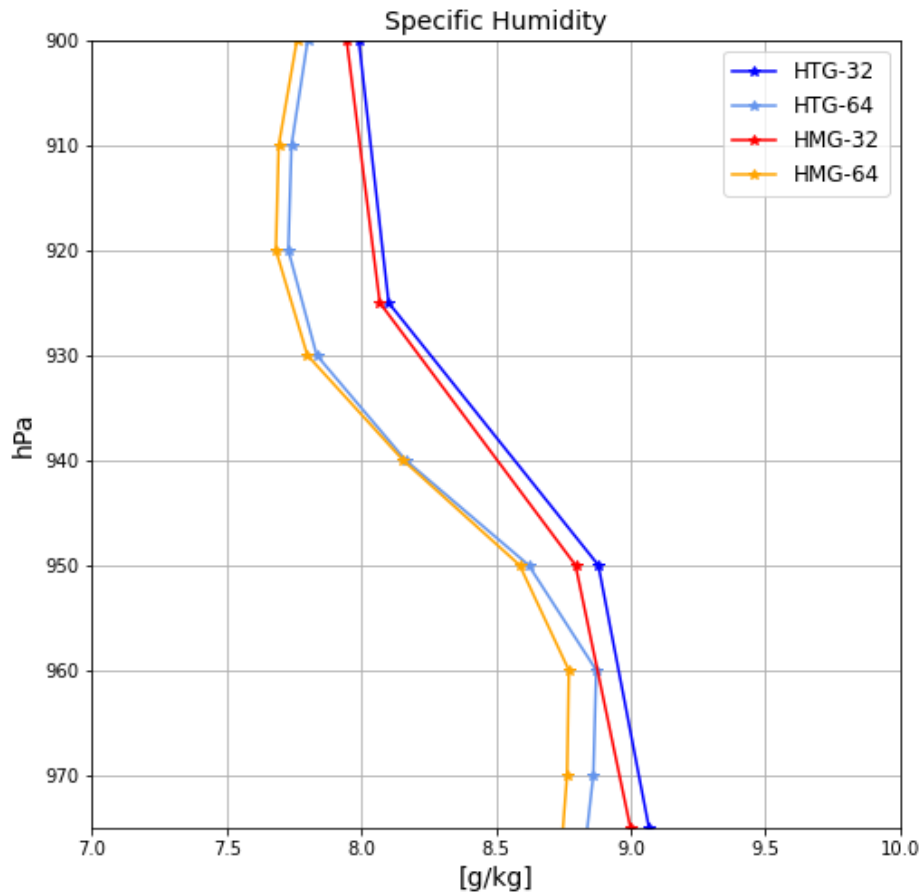
8-10a Local Mean



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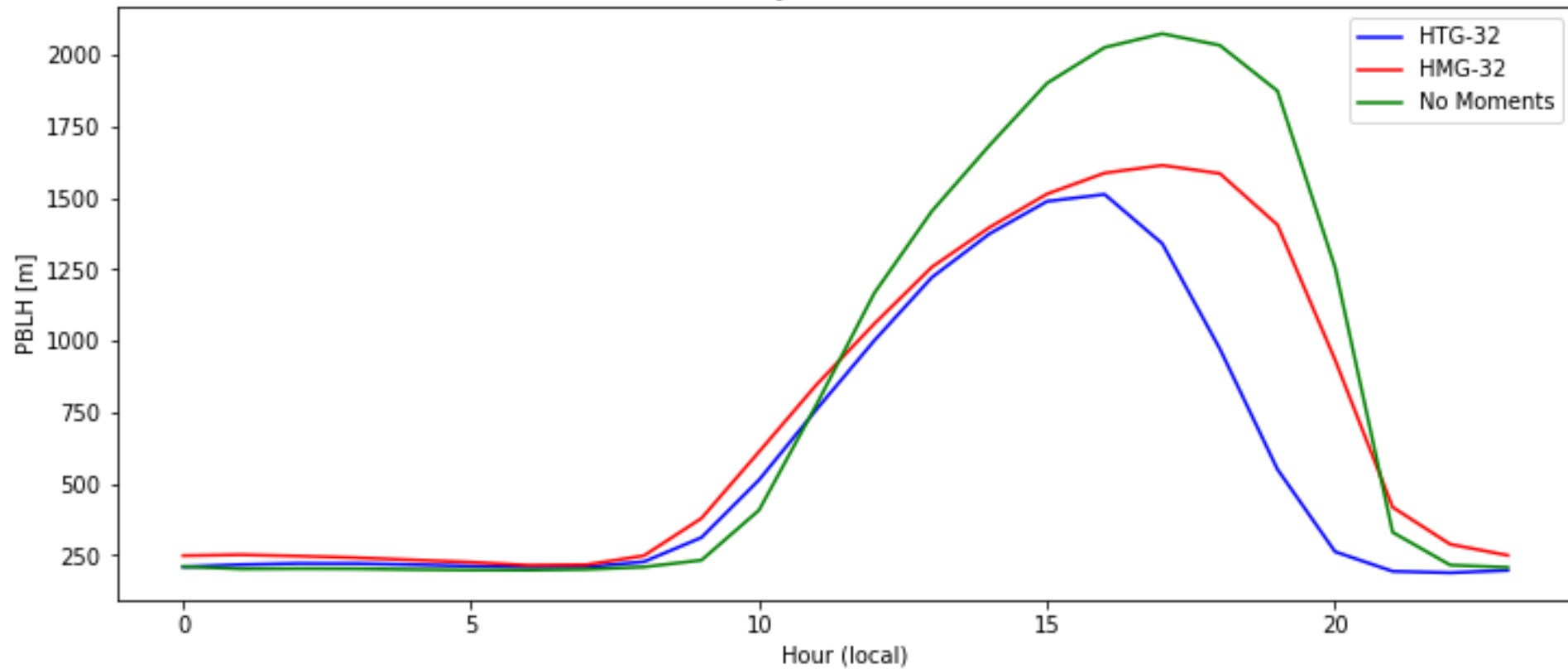
## *Single day case study – resolution matters*

8-10a Local Mean



# If no moments prescribed at the surface?

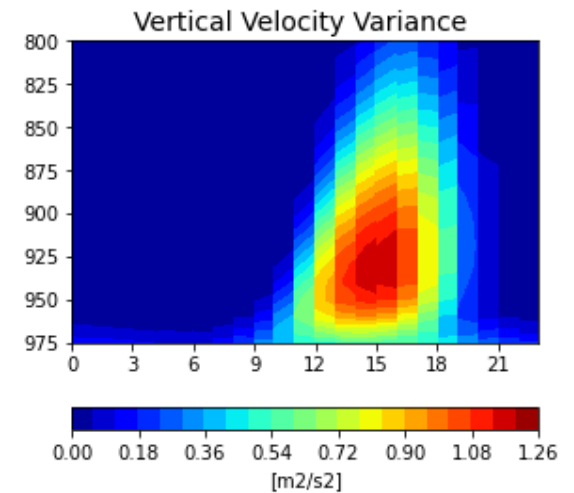
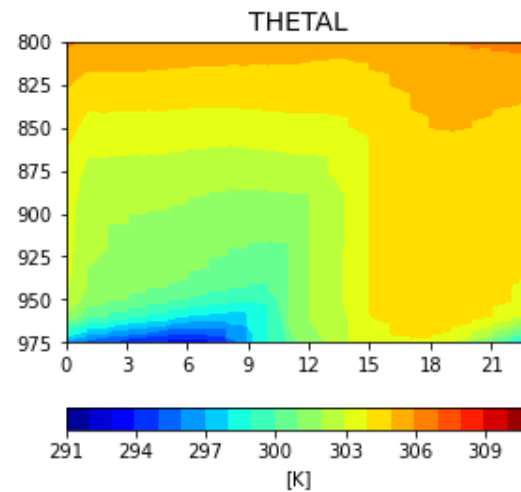
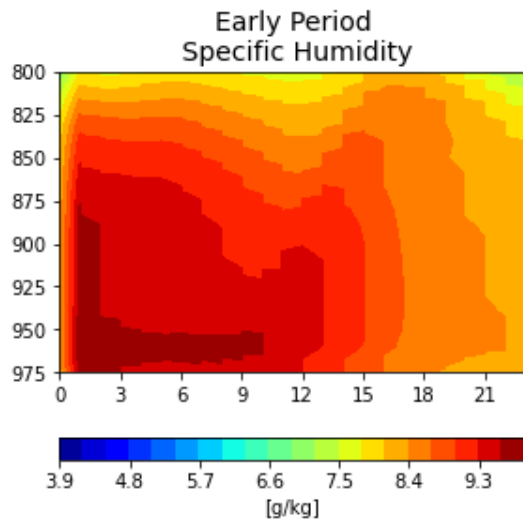
Mean diurnal cycle of boundary layer height  
[June 2015]





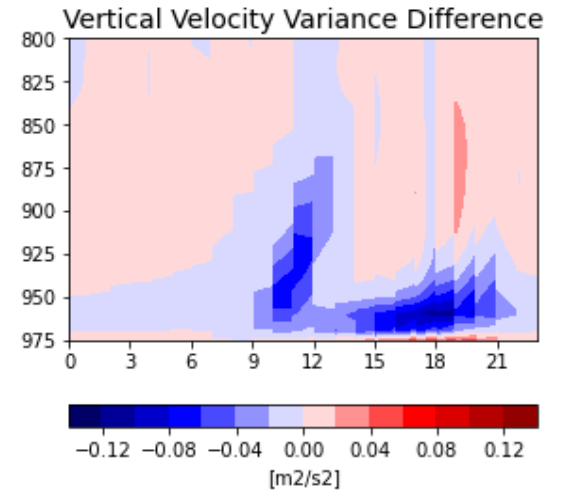
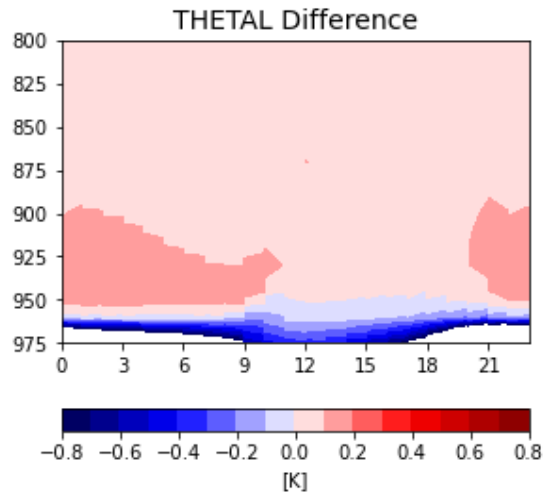
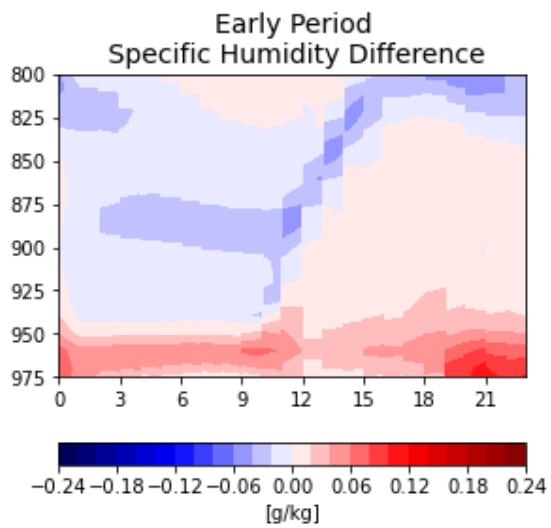
# HTG Time/Height Plots: Early dry period

- All surface moments prescribed



# HTG-HMG

## All surface moments prescribed

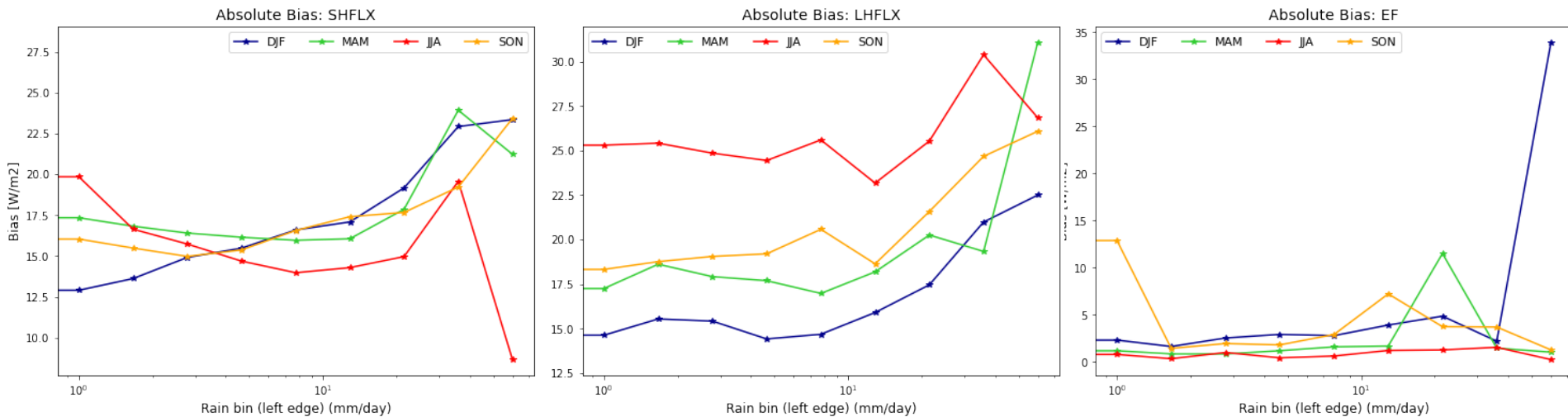


# HTG-HMG

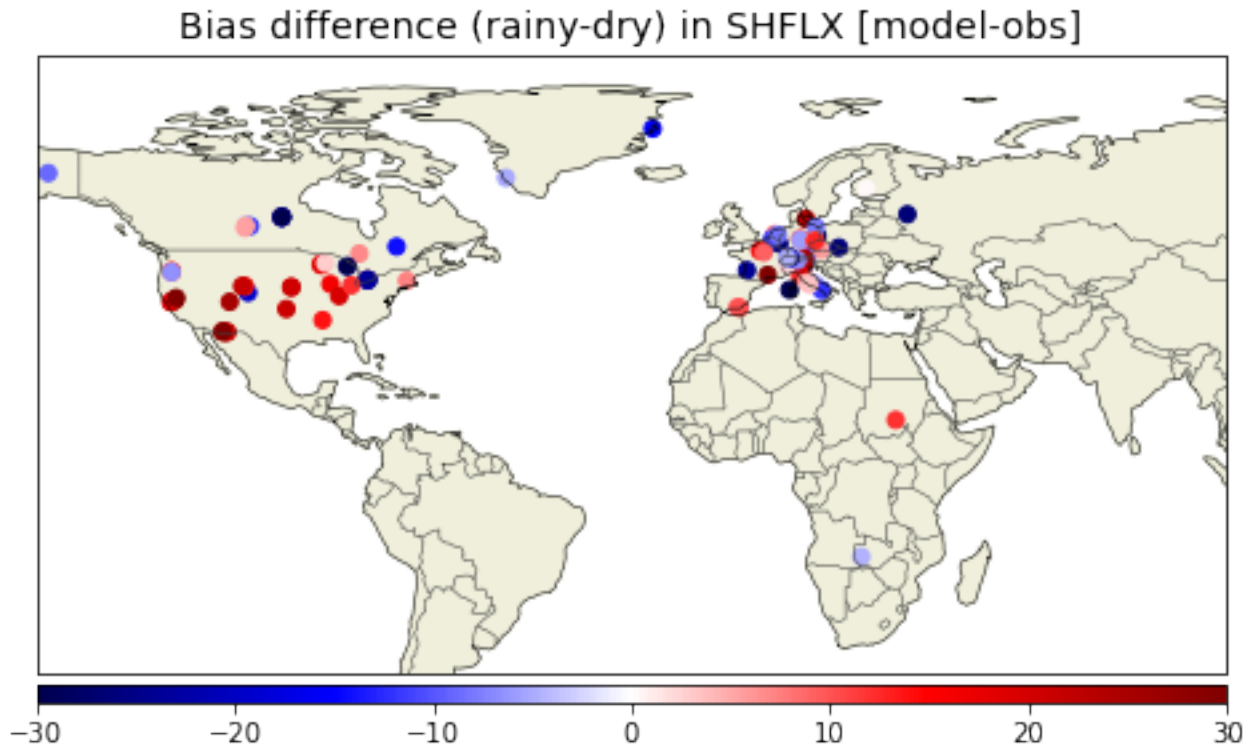
$W'^2$  only prescribed

# FLUXNET Tower Comparisons

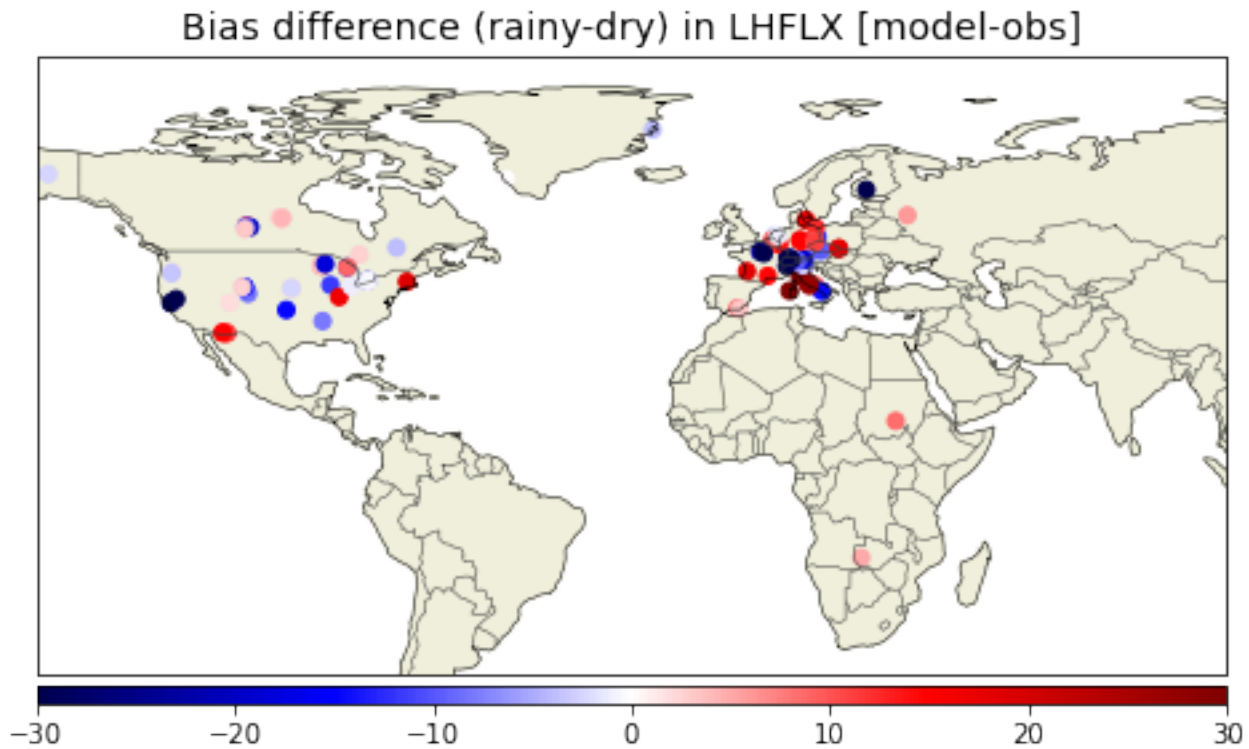
- Model data: 2000-14
- FLUXNET data: Varies by station, but all within 1992-2014



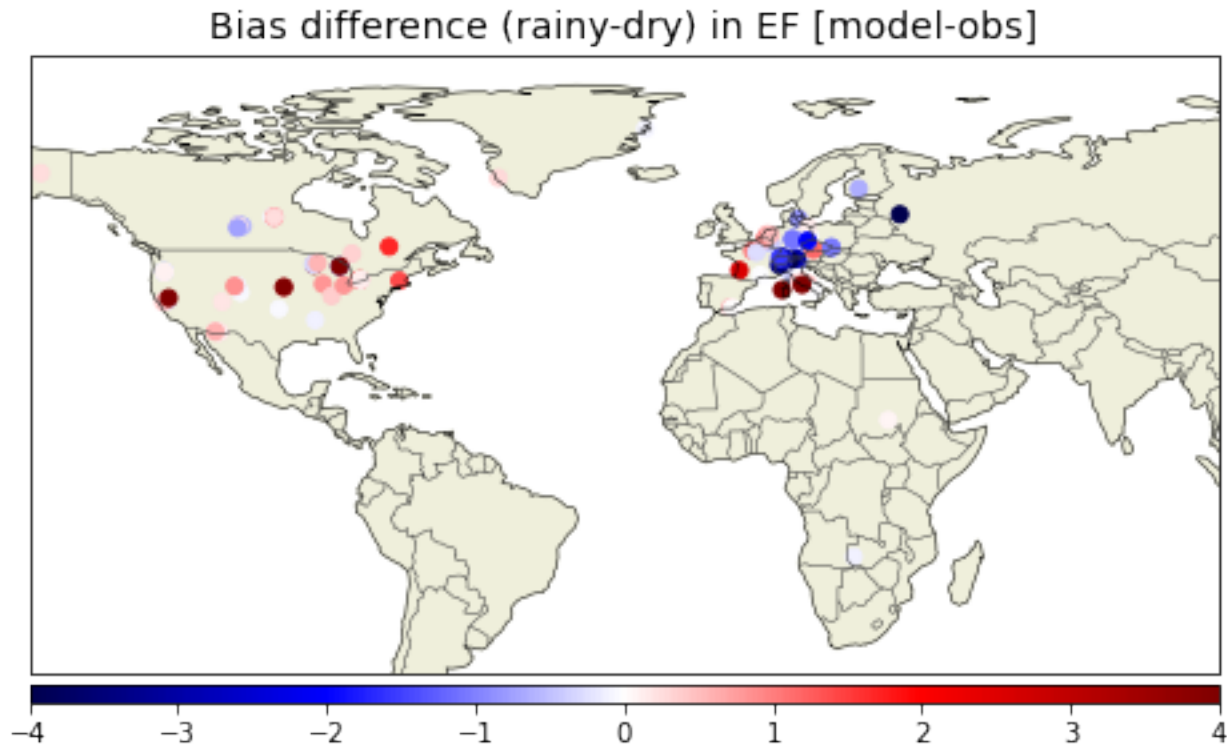
# FLUXNET Comparison: Rain vs. Dry Days (spatial biases)



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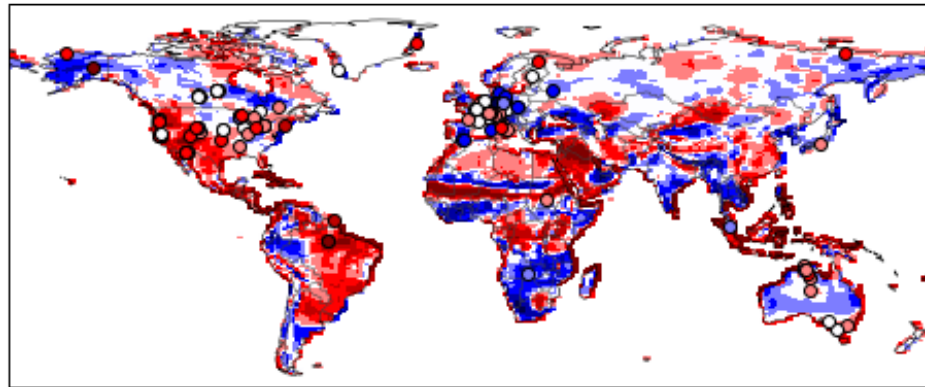


# FLUXNET Comparison: Rain vs. Dry Days (spatial biases)

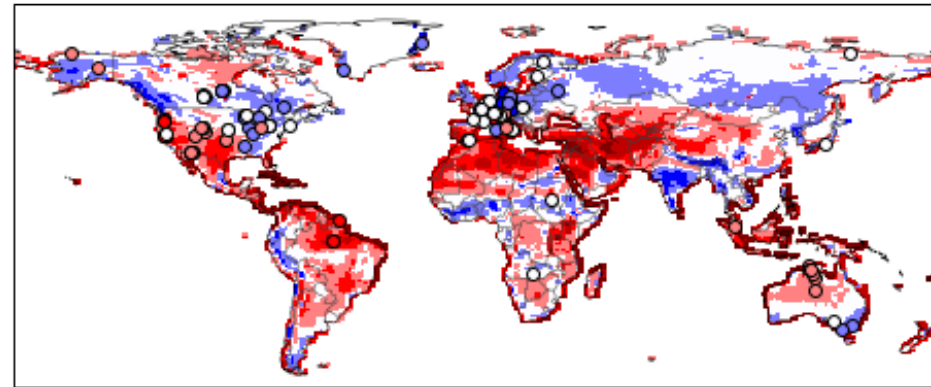


# FLUXNET Comparison: Correlation Coefficients

Correlation Coefficient [Monthly; JJA]:  
WindSpeed vs. SHFLX+LHFLX



Correlation Coefficient [Daily; JJA]:  
WindSpeed vs. LHFLX+SHFLX



-0.9 -0.6 -0.3 0.0 0.3 0.6 0.9 -0.9 -0.6 -0.3 0.0 0.3 0.6 0.9