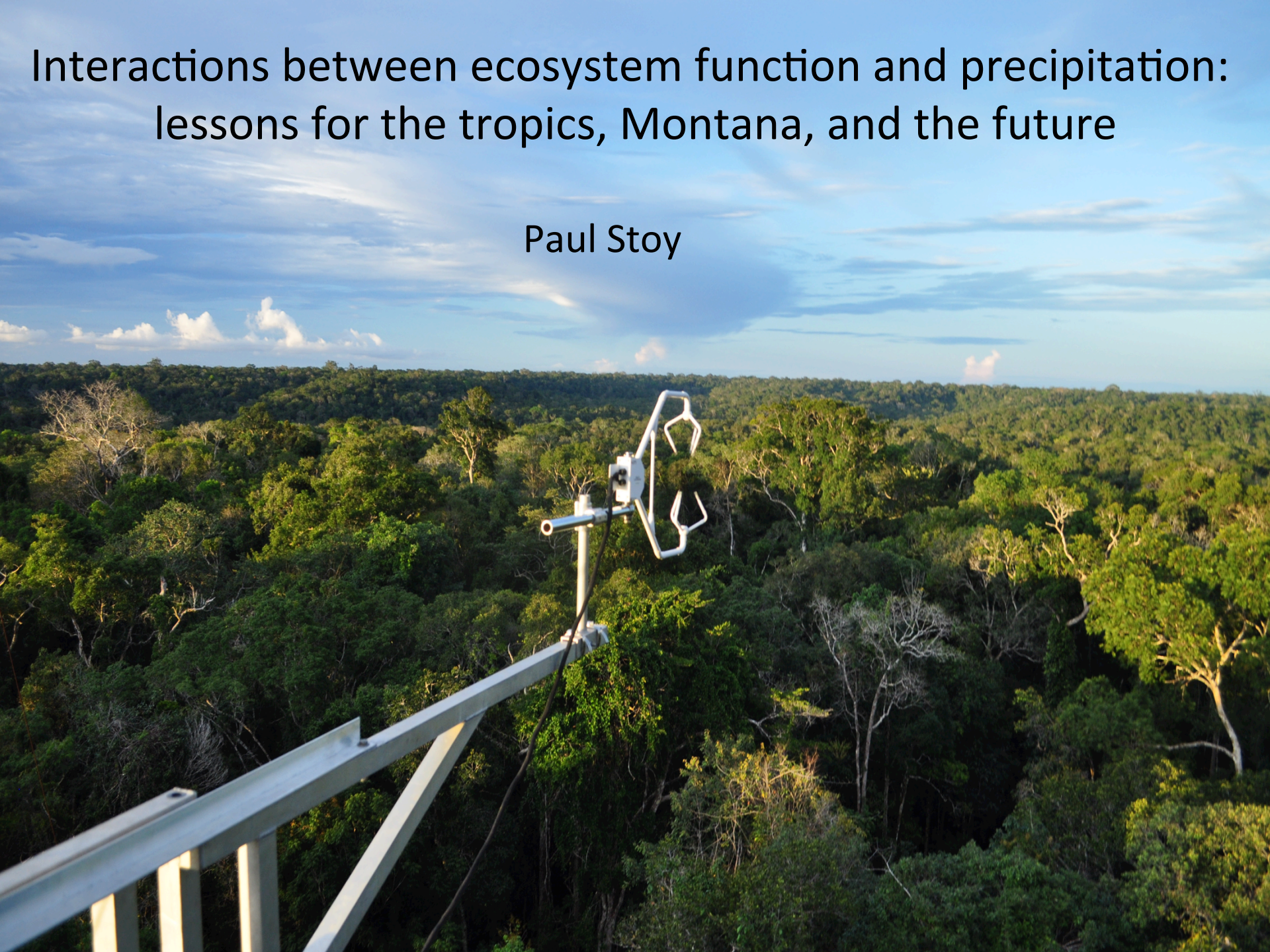
Interactions between ecosystem function and precipitation: lessons for the tropics, Montana, and the future

Paul Stoy



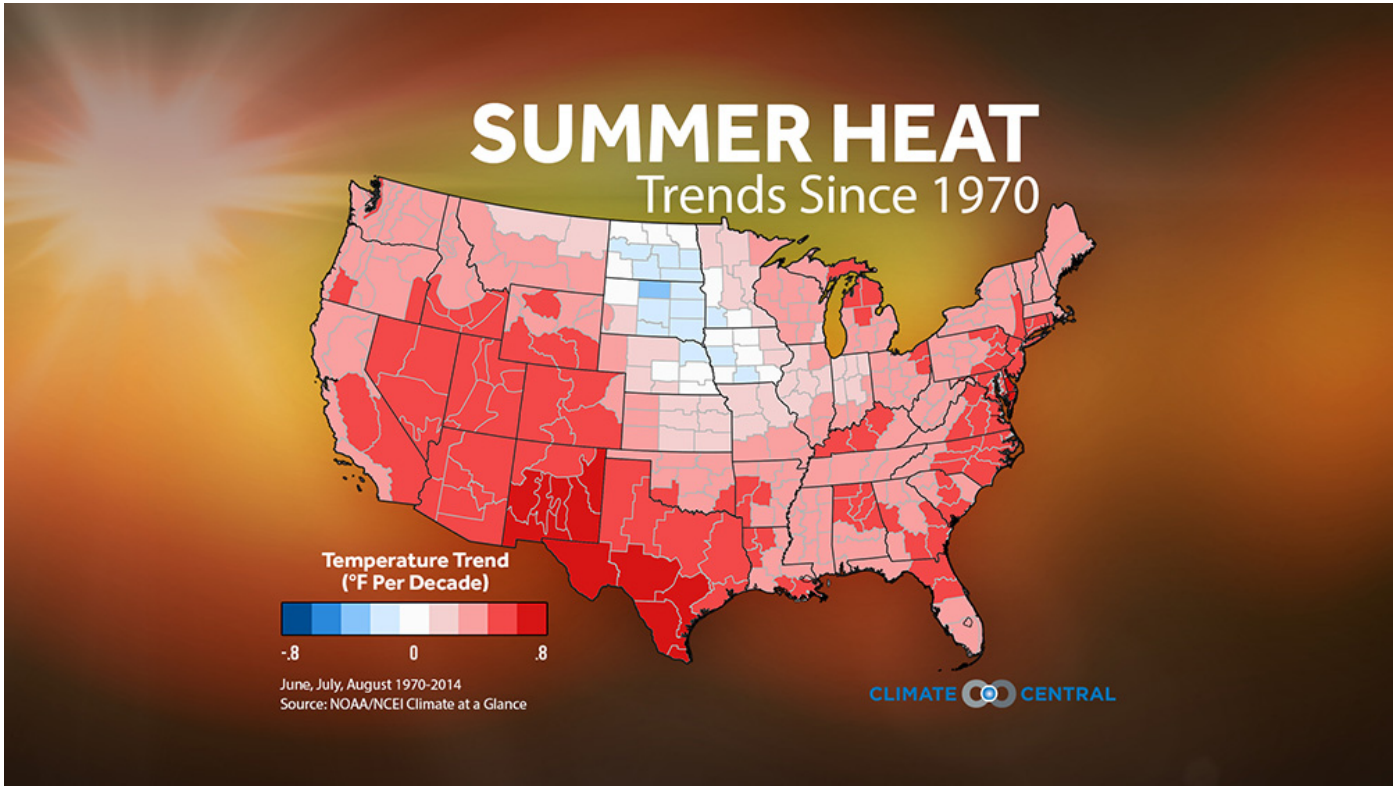
Acknowledgements

Marcelo Chamecki, Jose Fuentes, Tobias Gerken, Elizabeth Vick, Angela Tang, Kim Novick, Darren Ficklin, Ben Poulter, Perry Miller, Gabe Bromley, David Wood, Mallory Morgan, Bill Kleindl

What role do clouds play in the Earth system?
What is the role of the biosphere in controlling them?

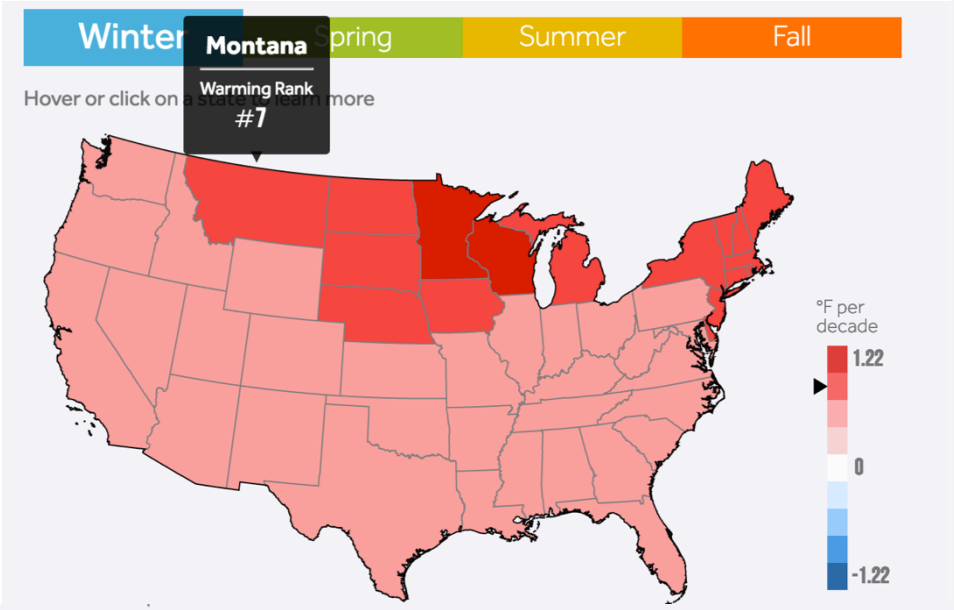
Motivating questions:

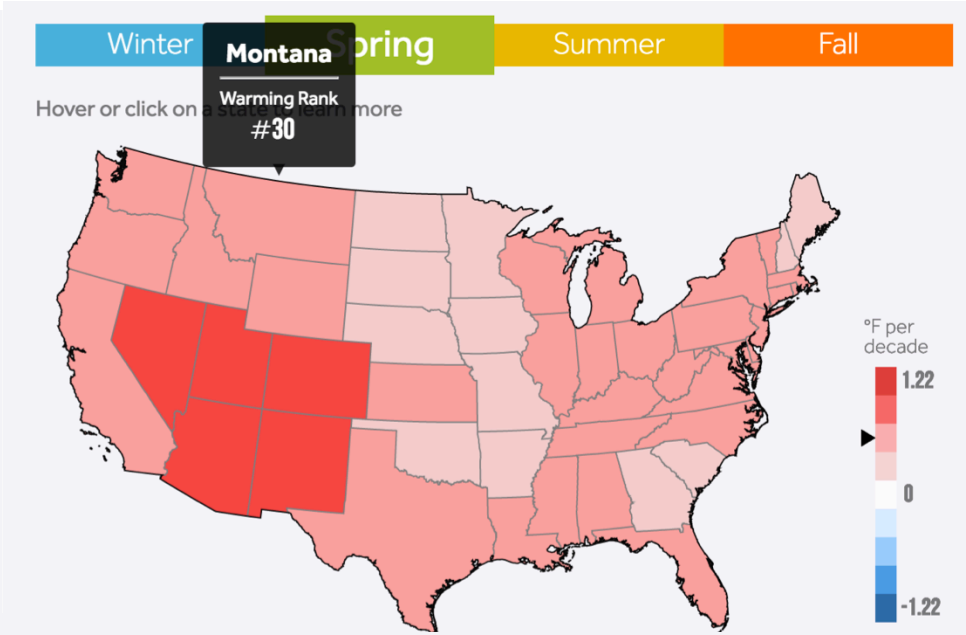
1) Why are parts of the northern North American Great Plains cooling?

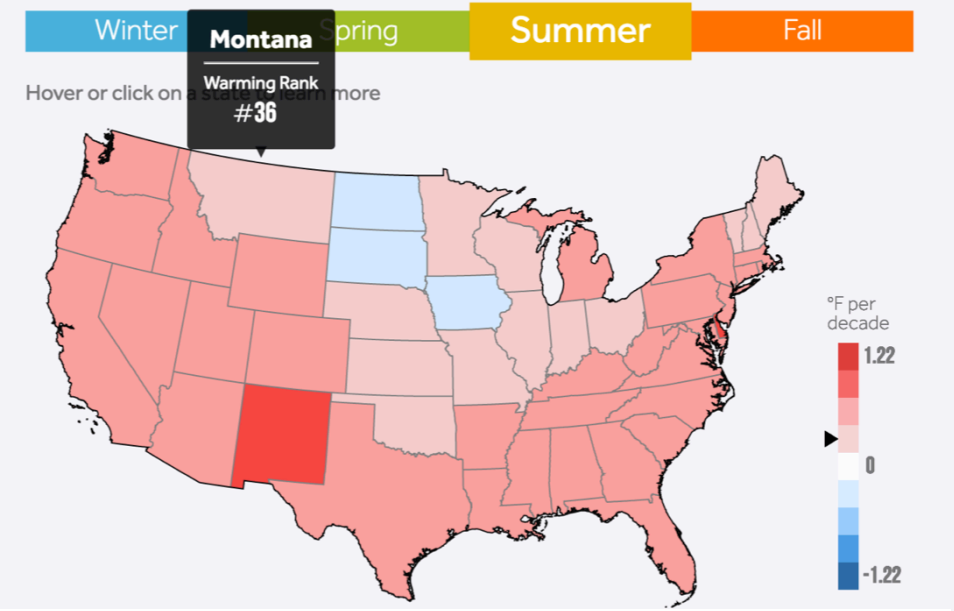


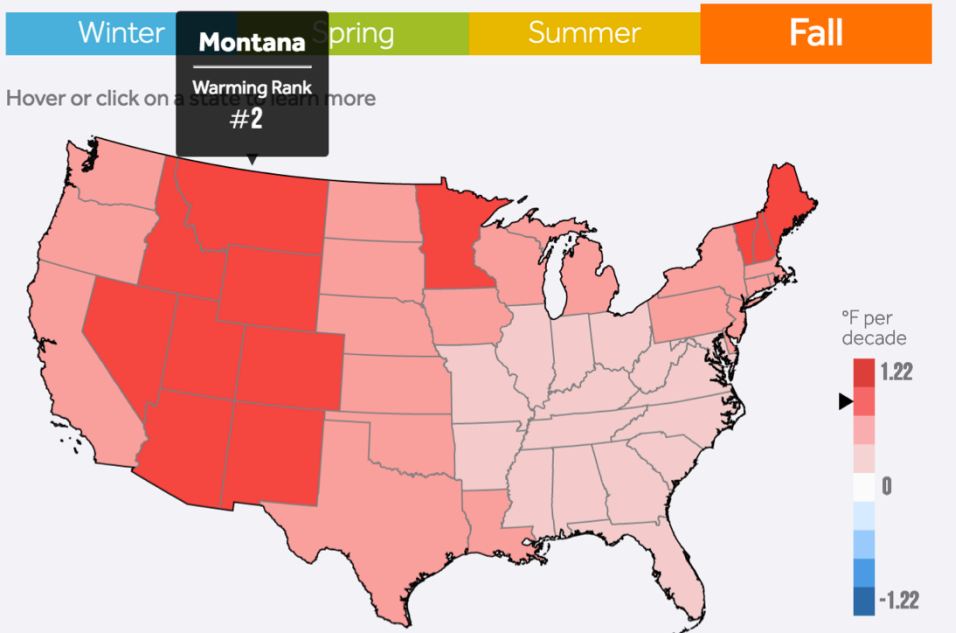
Motivating questions:

2) Why is it only during summer?



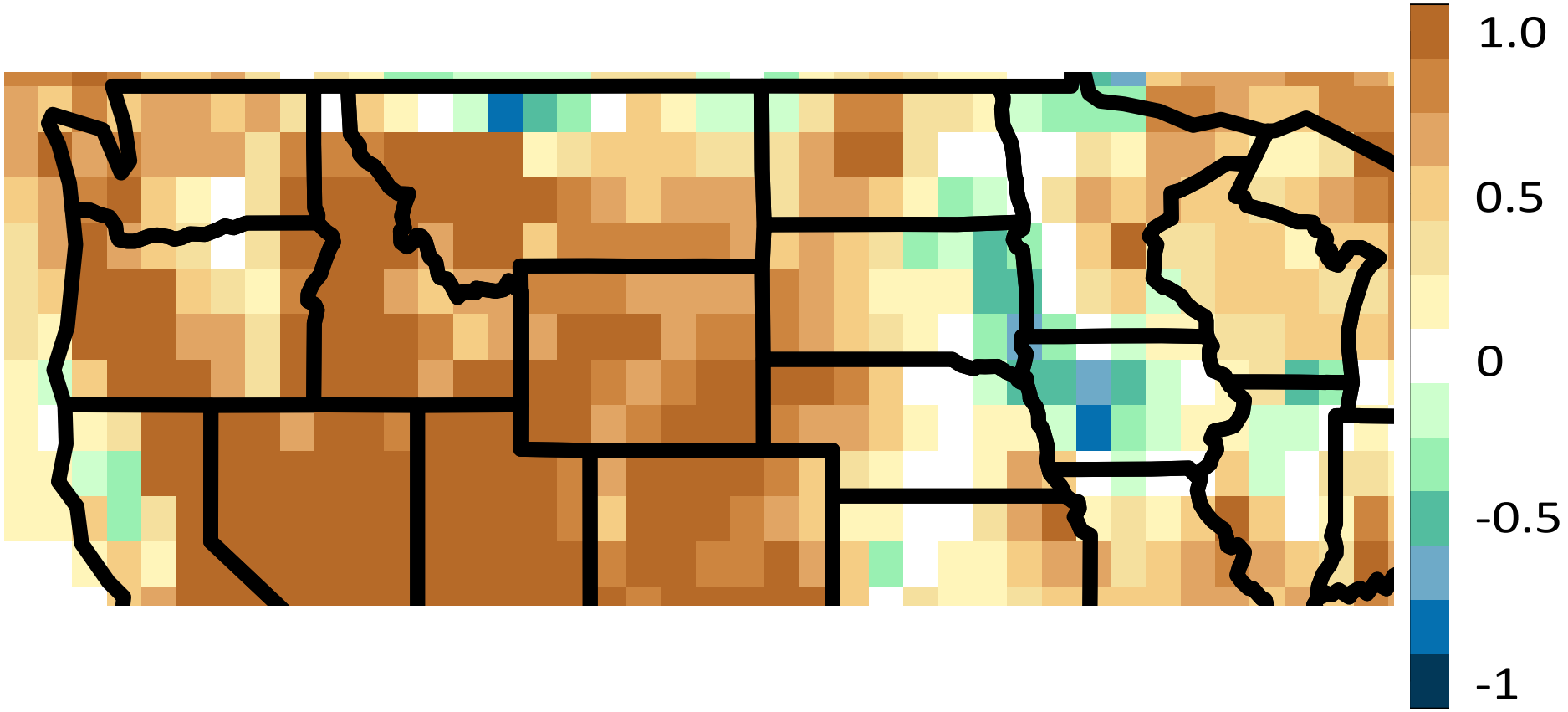






Motivating questions:

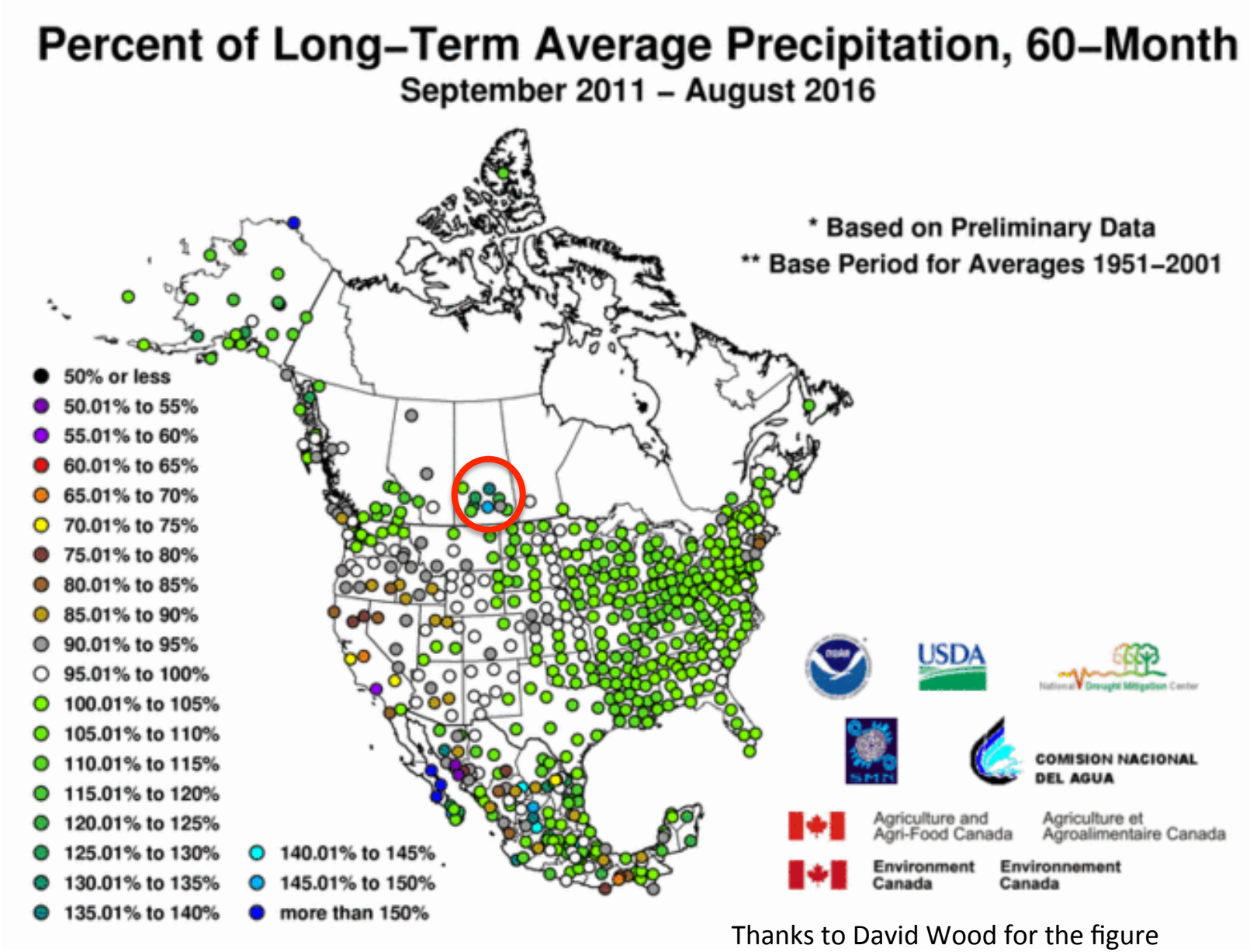
3) How is Montana affected?



Sheffield et al. (2006) Princeton Global Forcings dataset

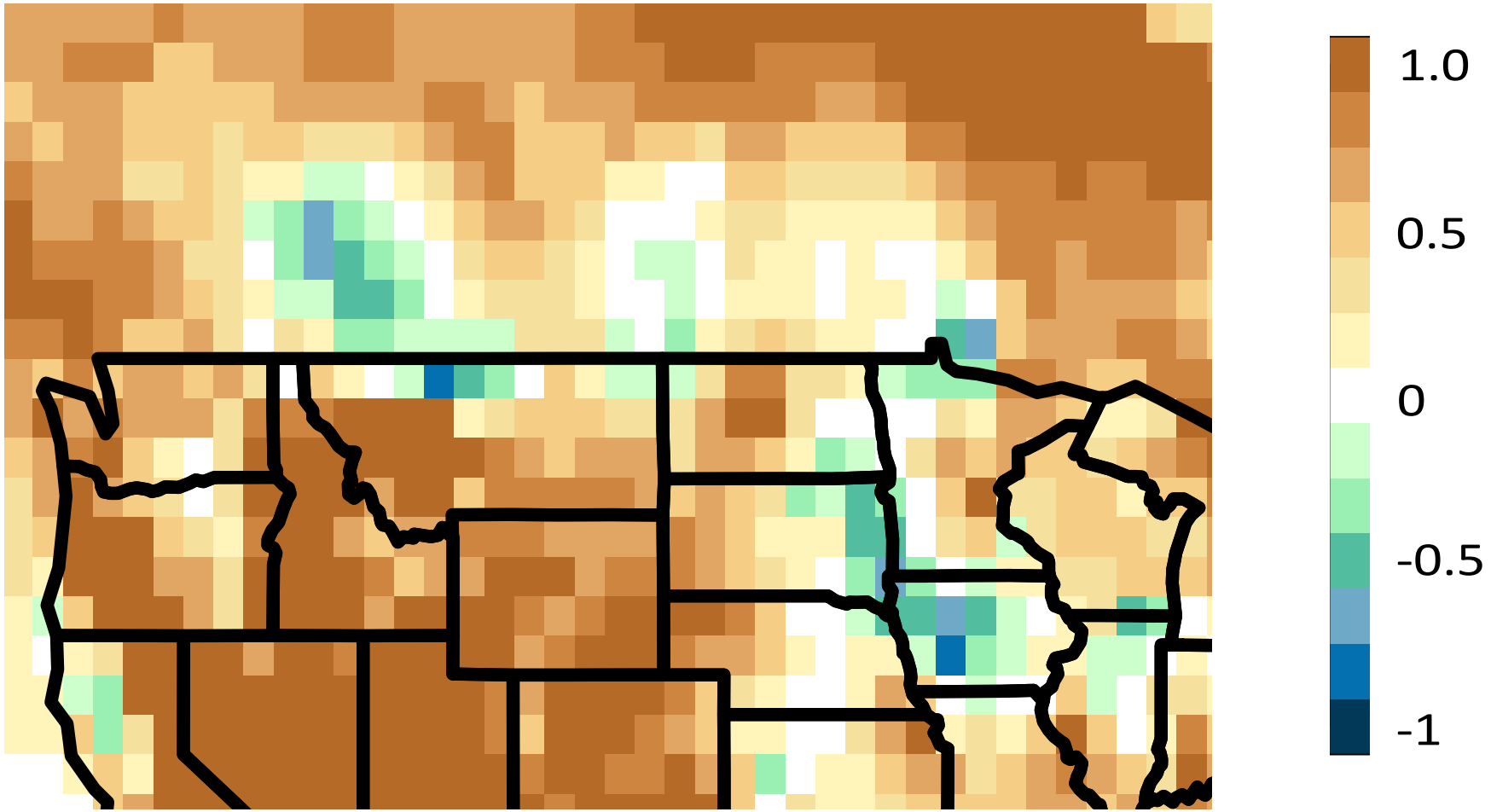
Motivating questions:

4) Is there a large country to our north?



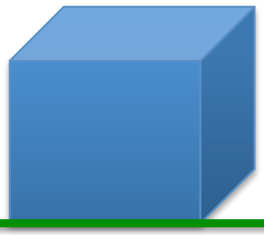
Thanks to David Wood for the figure

…and are parts of it cooling in summer, too?

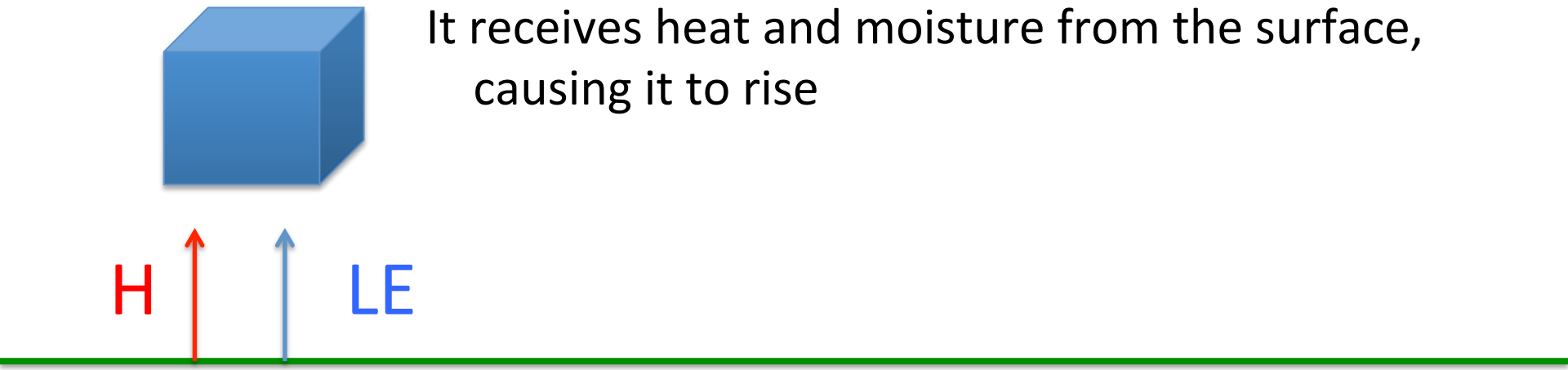


These changes may be due to surface-atmosphere interactions

Background: Imagine an imaginary parcel of air

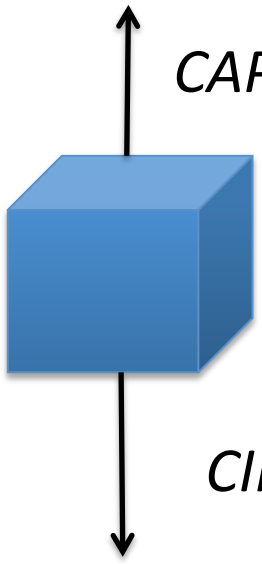


Imagine an imaginary parcel of air



It receives heat and moisture from the surface, causing it to rise

Imagine an imaginary parcel of air



CAPE: Convective available potential energy (J/kg)

As it rises, it is subjected to forces

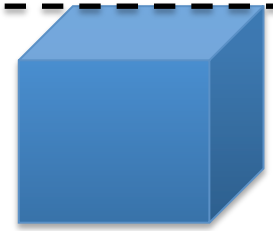
CIN: Convective inhibition "anti-CAPE" (J/kg)

Imagine an imaginary parcel of air

The height at which it condenses is called the *Lifted condensation level (LCL)*

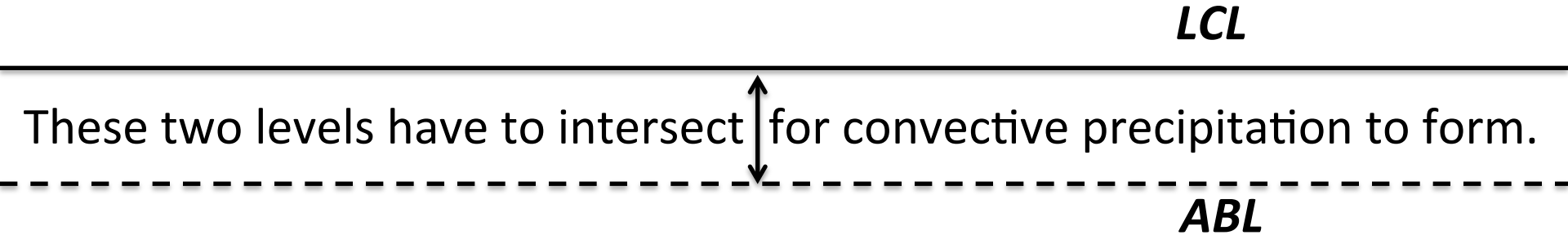
$$PV = nRT$$

Imagine an imaginary parcel of air



The maximum height that it reaches under the Influence of the surface alone is the *Atmospheric boundary layer (ABL) height*

Imagine an imaginary parcel of air



Have these processes changed over the past 4-5 decades in MT?

Observations

In the Canadian Prairies over the past 4 decades,
Summer Tmax: - 1 °C trend
Precip: + 10 mm/decade trend
-6 W m^{-2} summer forcing!
Anthropogenic warming +2.5 W m^{-2}

Gameda et al., (2007)
Betts et al. (2013 a,b)

Why? Fallow reduction?

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-6 W m^{-2} summer forcing!

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Gameda et al., (2007)
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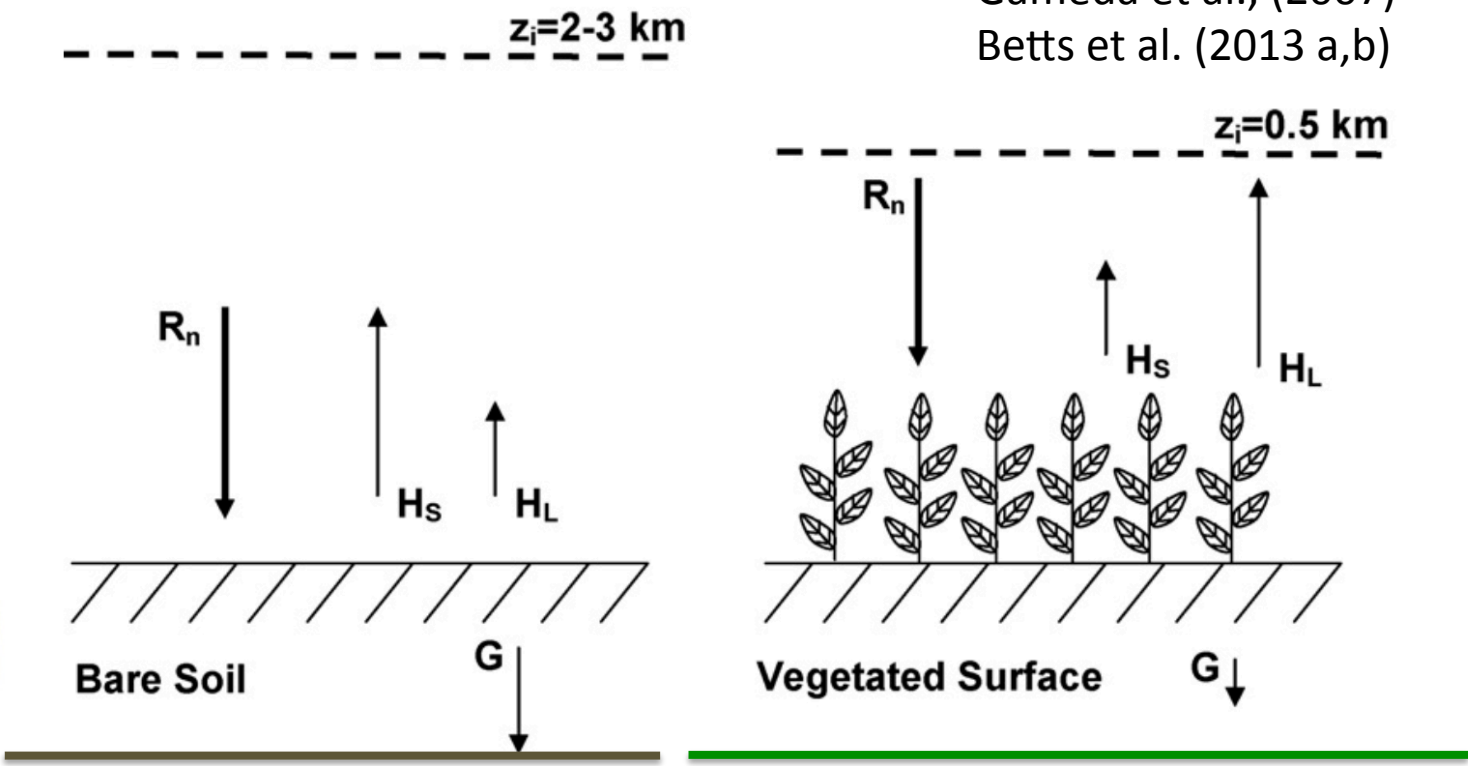
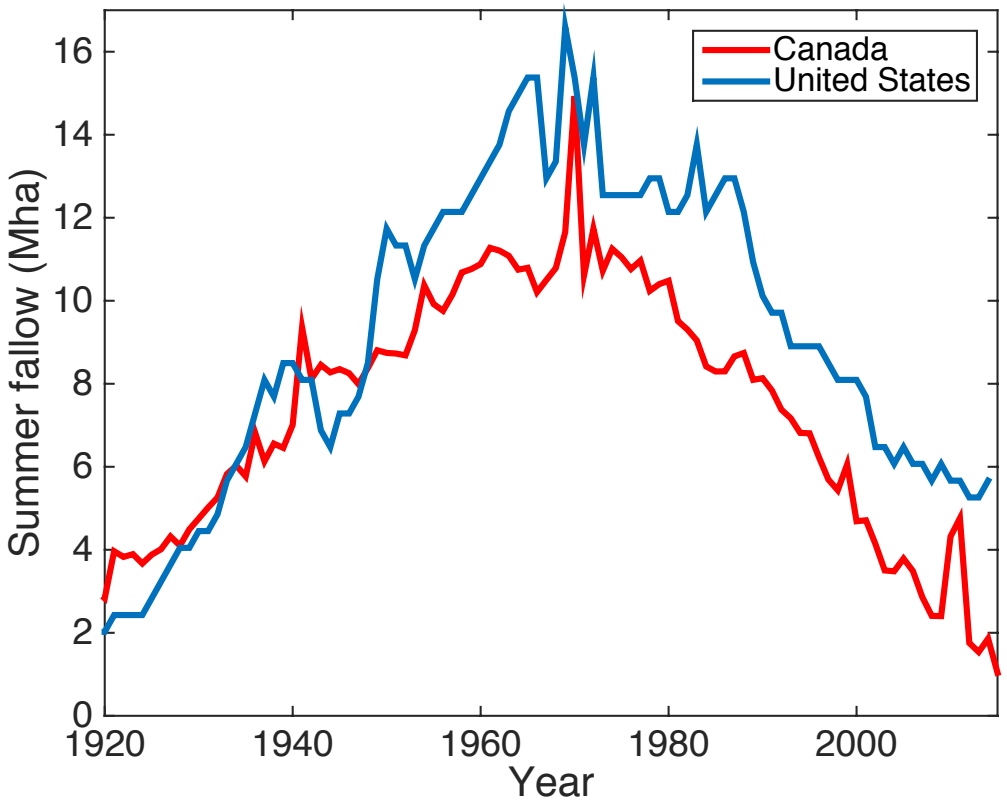
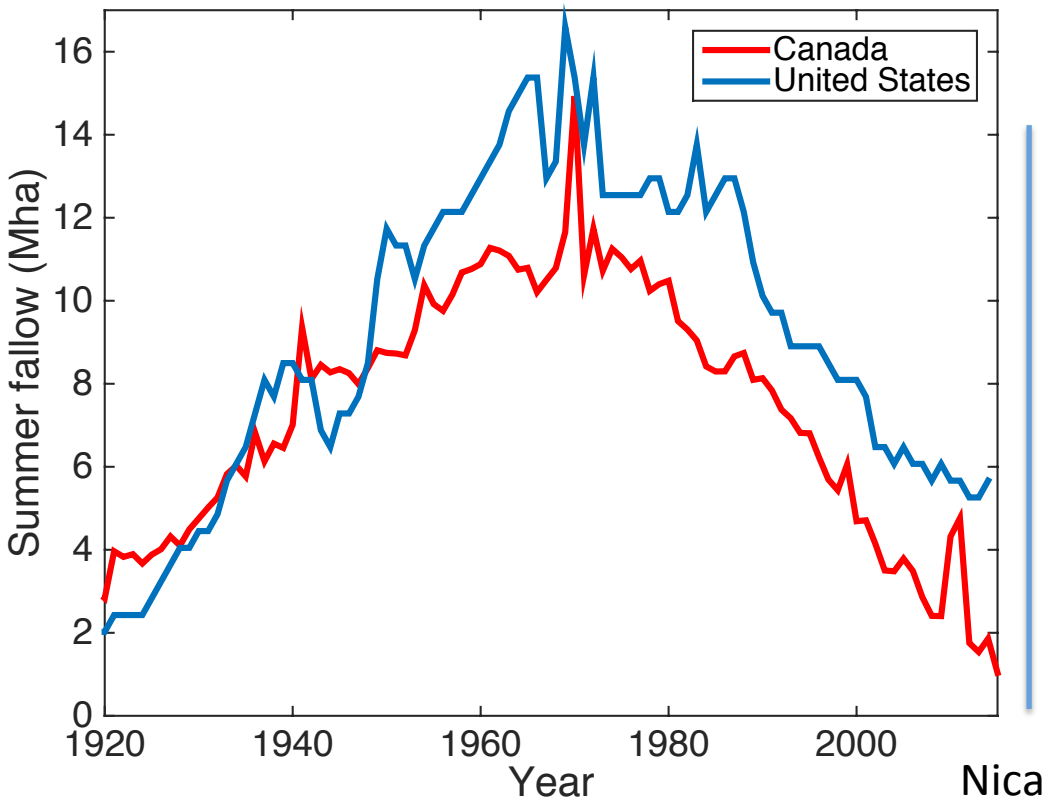


How big is 14 Mha?



14 Mha

How big is 14 Mha? (International version)



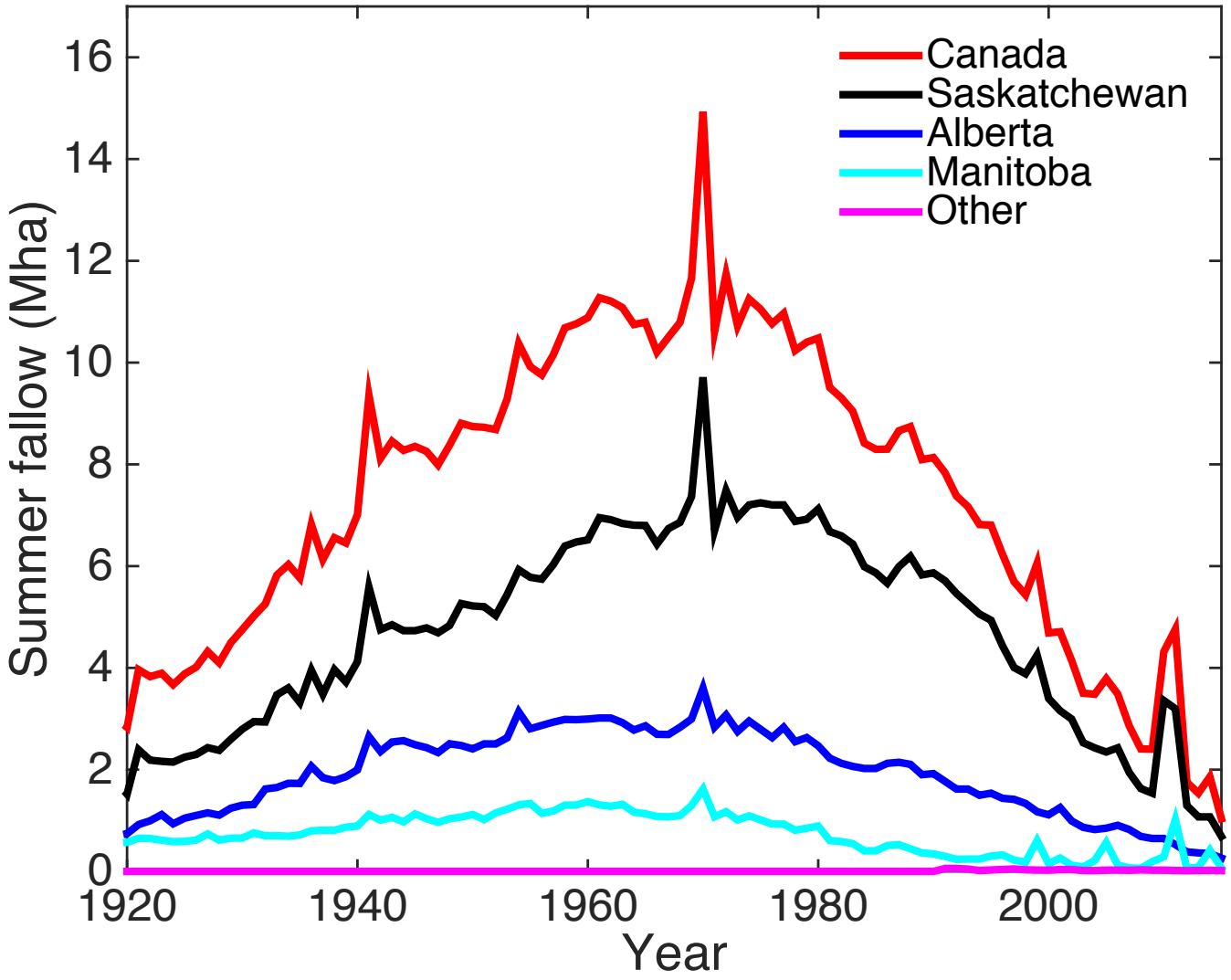
2 x

14 Mha

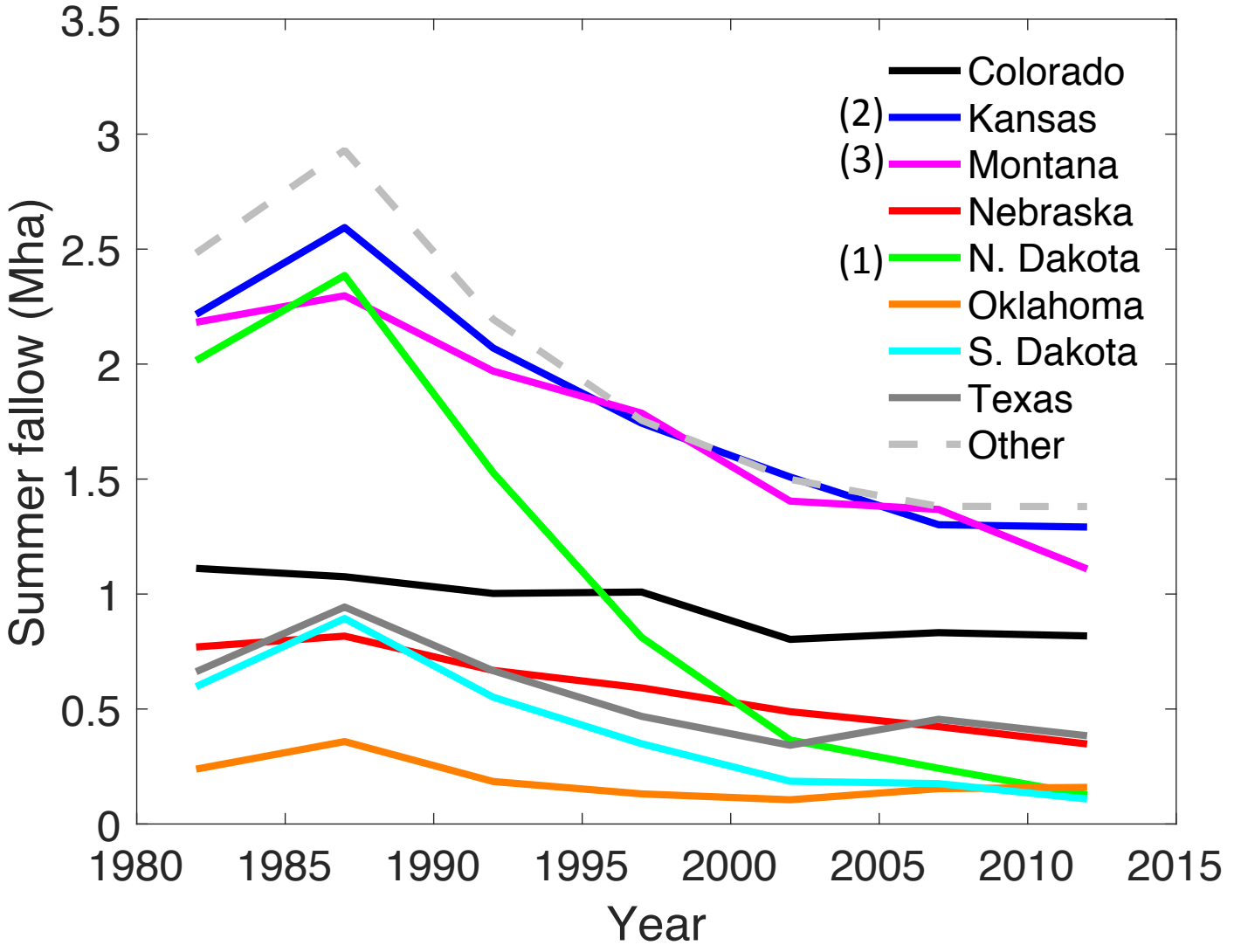
Nicaragua = 13 Mha
Bangladesh = 14.7 Mha
Tunisia = 16 Mha
Uruguay = 17.6 Mha

15 Mha (Canada) + 11 Mha (U.S.) = 26 Mha = *bigger than the UK!*

The largest changes are in Saskatchewan…

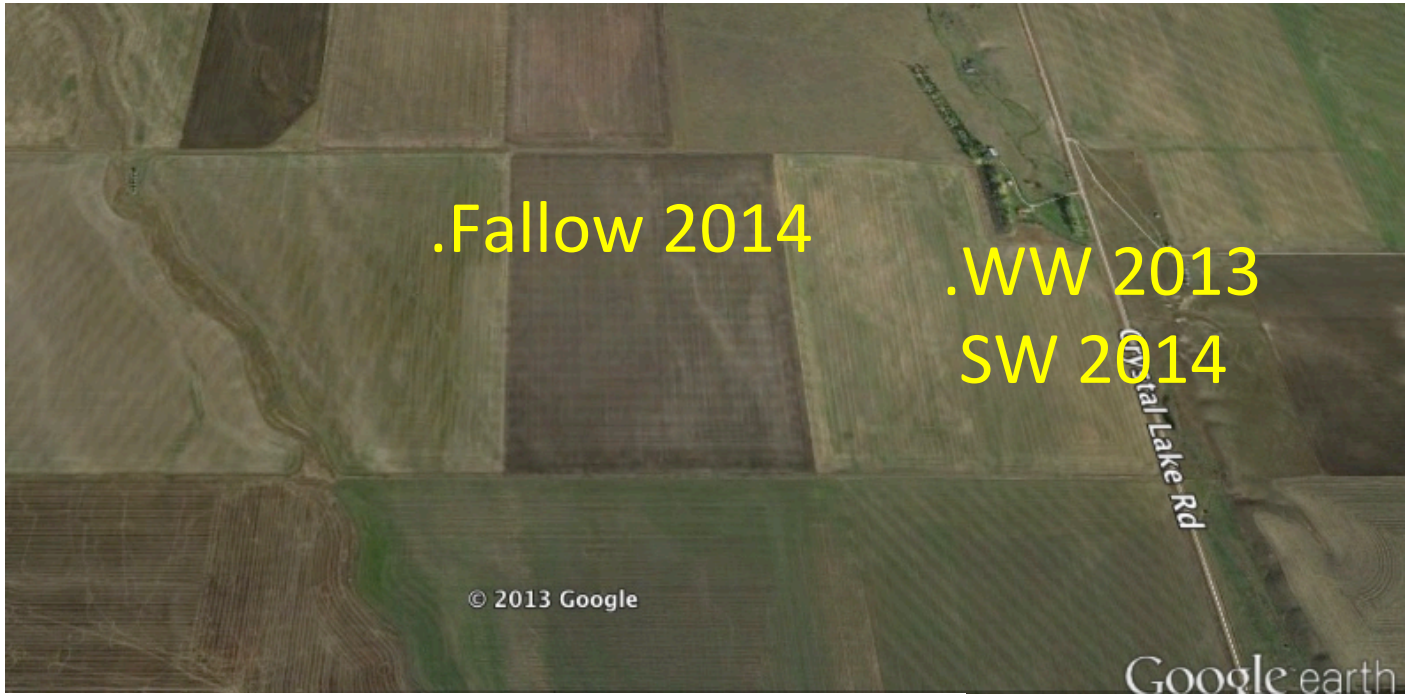


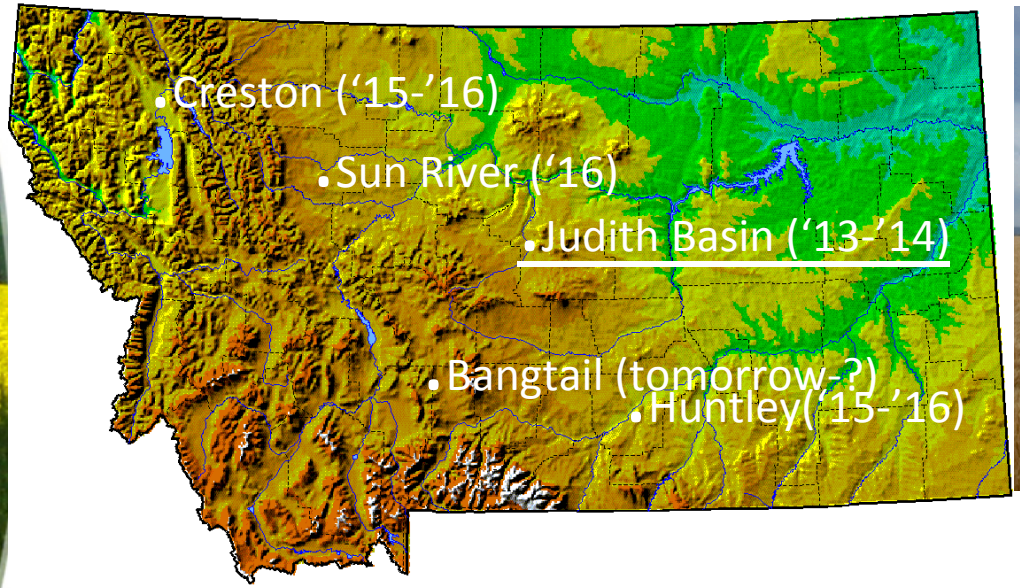
…and North Dakota.



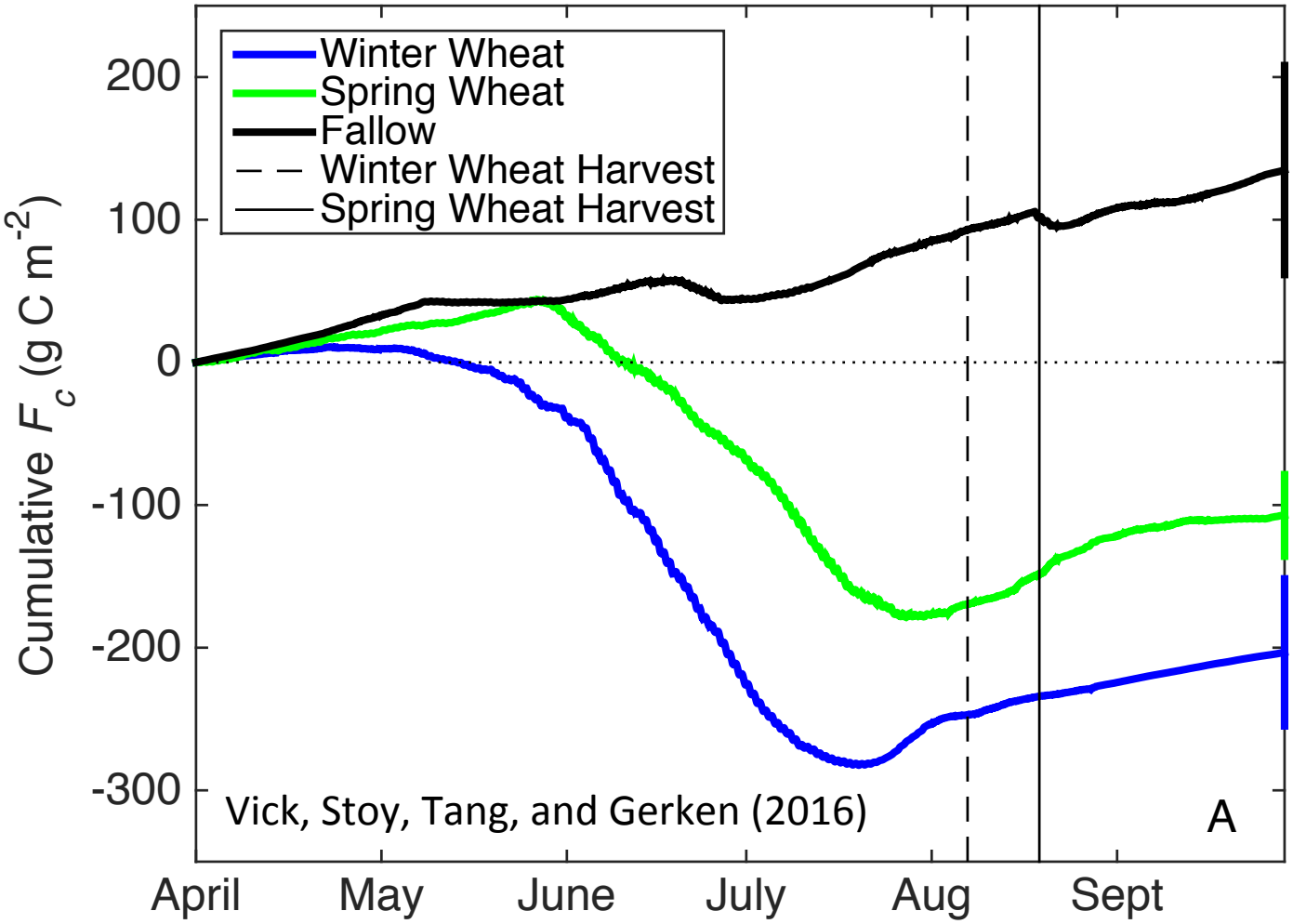
Is this a win-win-win scenario for regional climate, soil conservation, and income?

What are the carbon, water, and heat consequences of fallow?

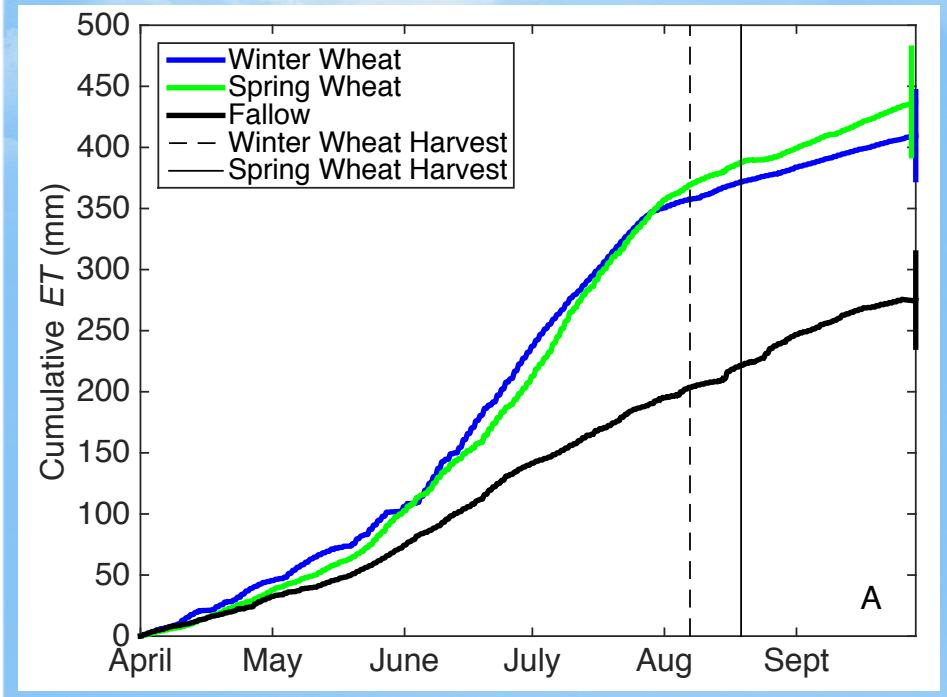




Carbon uptake or loss depend on crop management

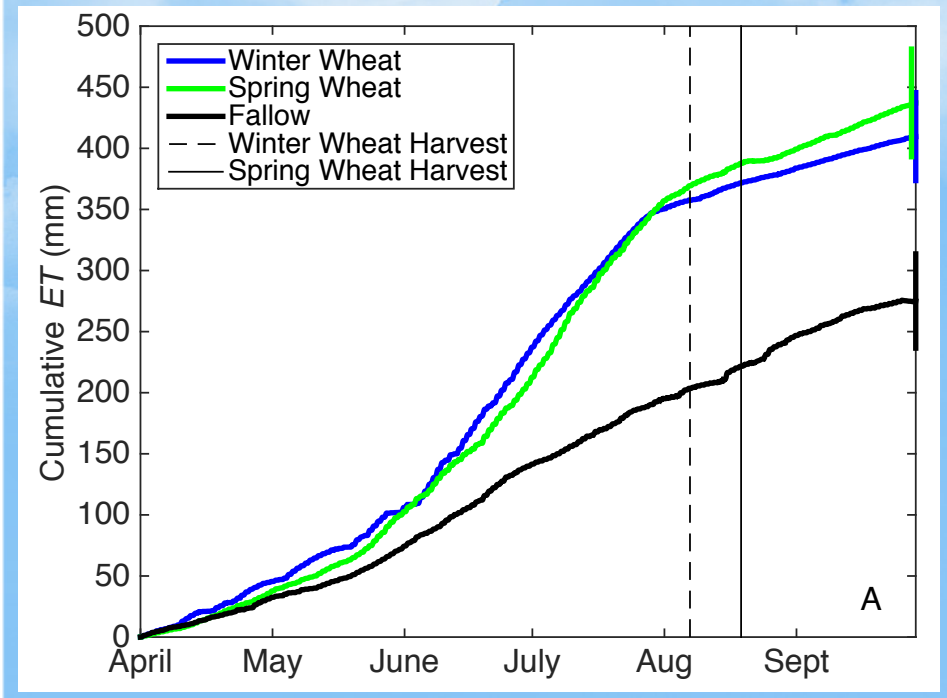


Latent Heat

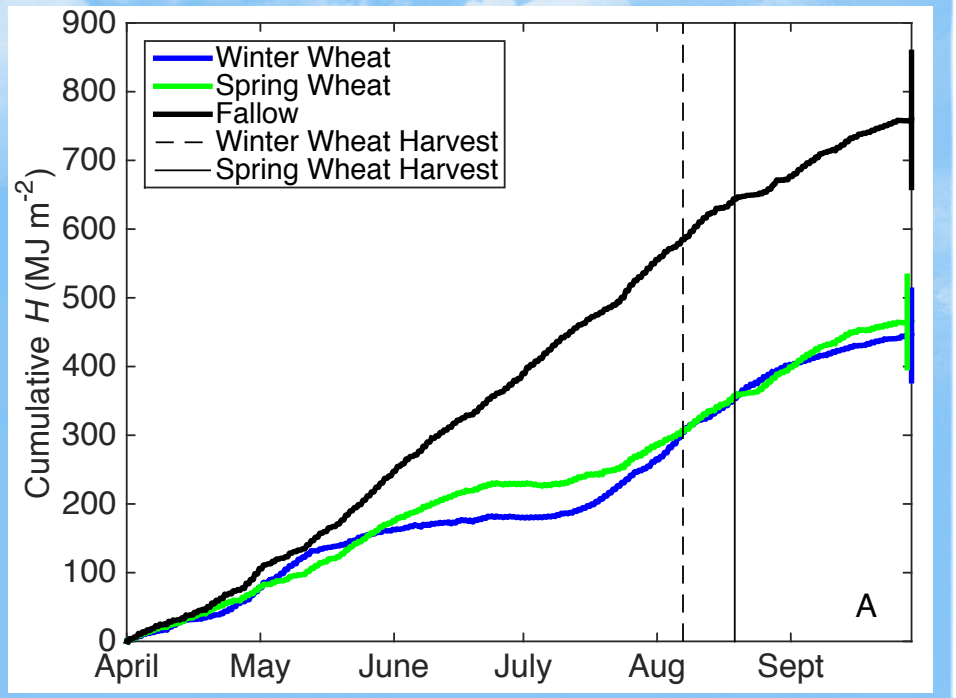


Vick, Stoy, Tang & Gerken (2016)

Latent Heat



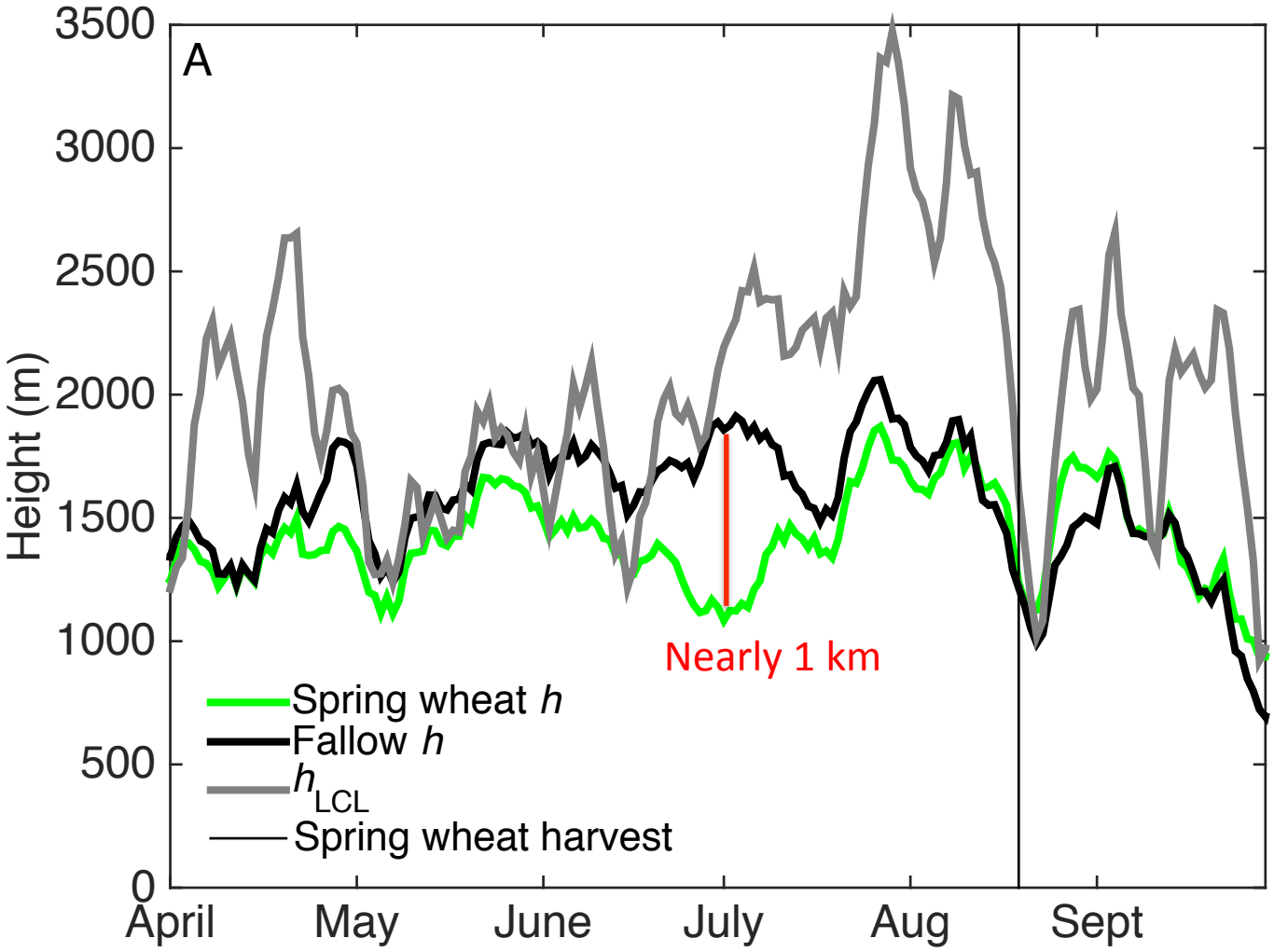
Sensible Heat



Parcels of air that interact with the fallow field are more buoyant

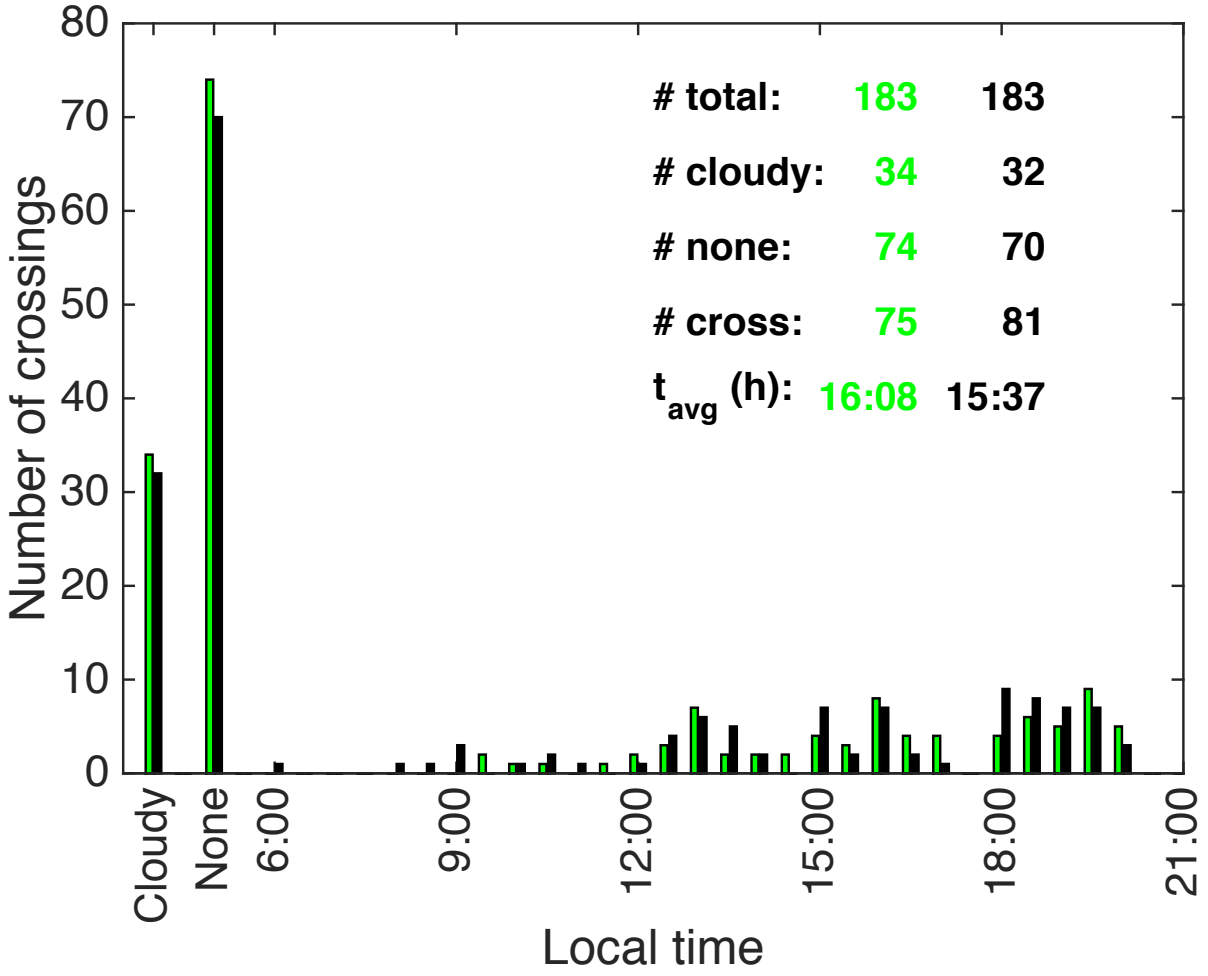
Vick, Stoy, Tang & Gerken (2016)

Consequences for atmospheric boundary layer development



Vick, Stoy, Tang & Gerken (2016)

More ABL – LCL crossings under **fallow** than **spring wheat** (in model world)



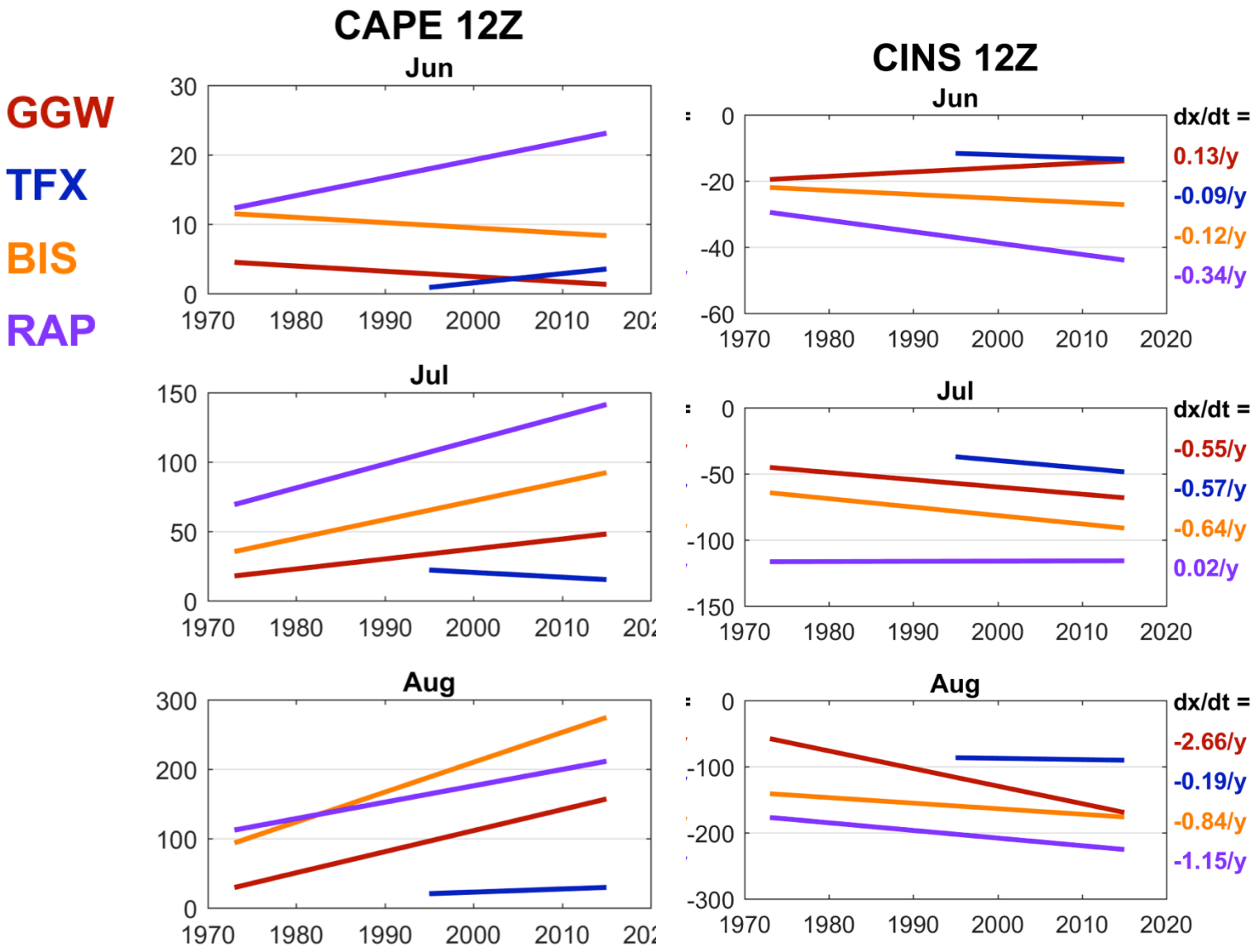
Betts et al. (2013) noted a 7% increase in RH.

Regional processes might be important.

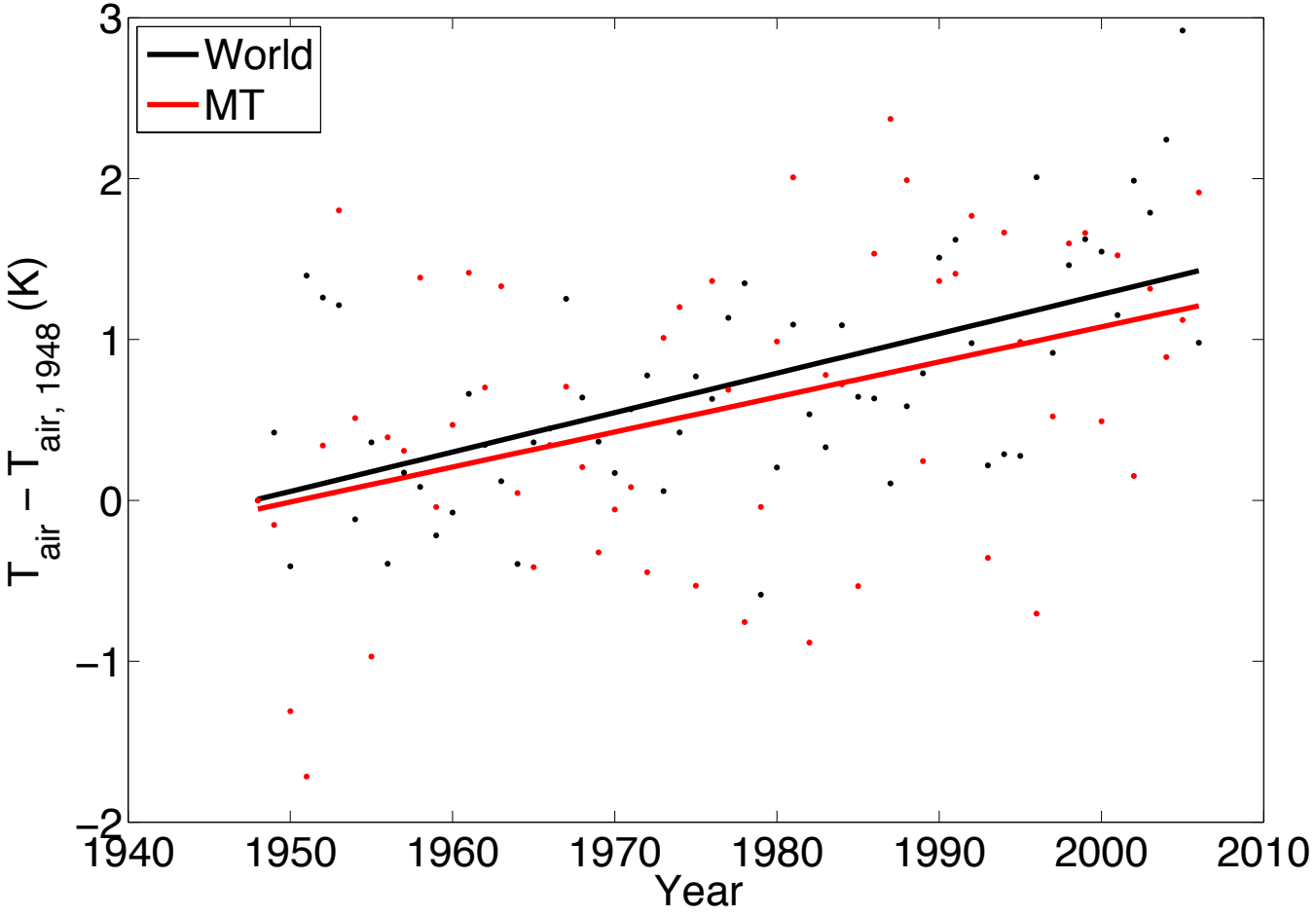
What about convective energy?

Atmospheric profiles compiled by the UWY Atmospheric Soundings Database

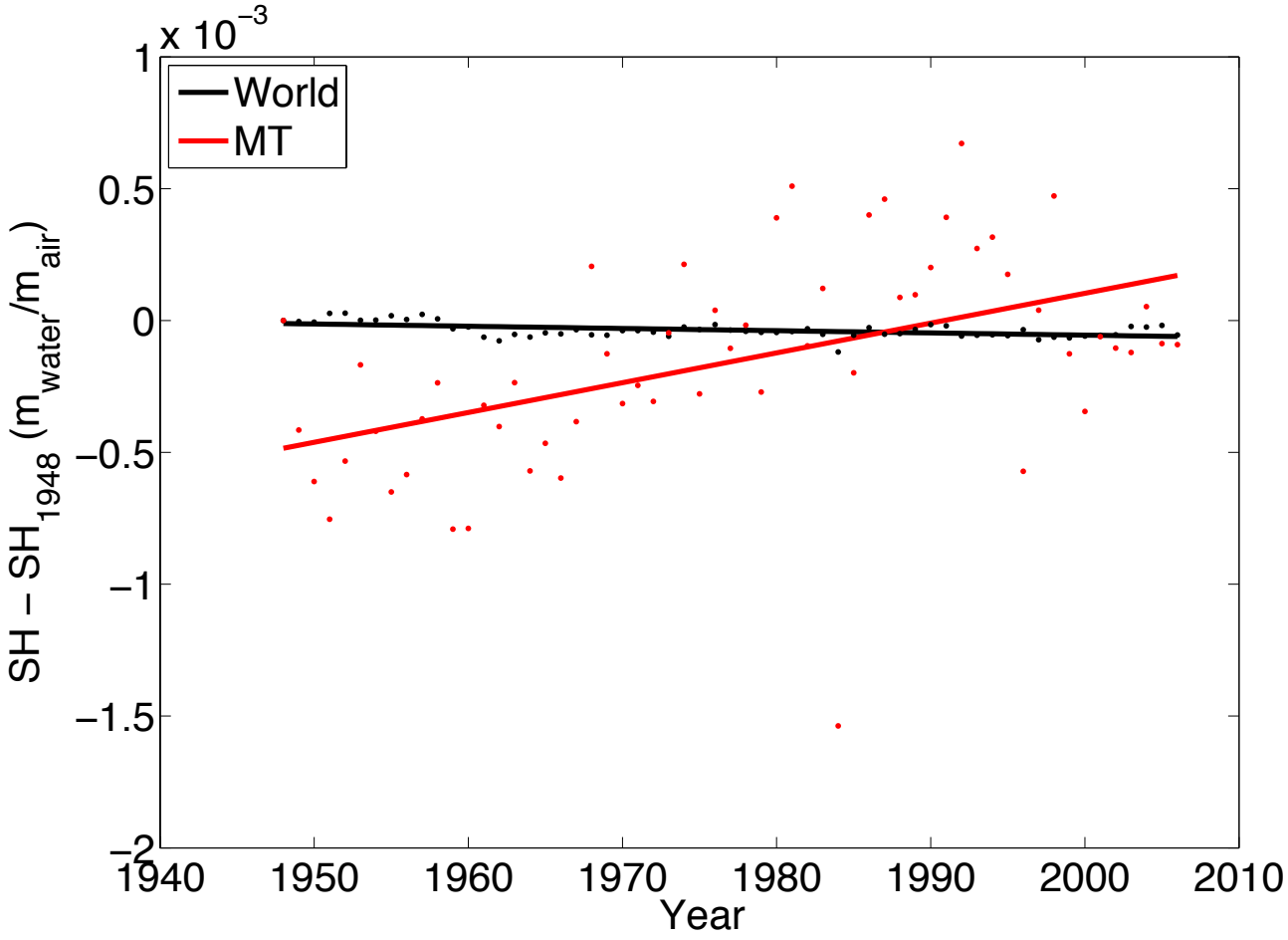
CAPE and CIN in the morning



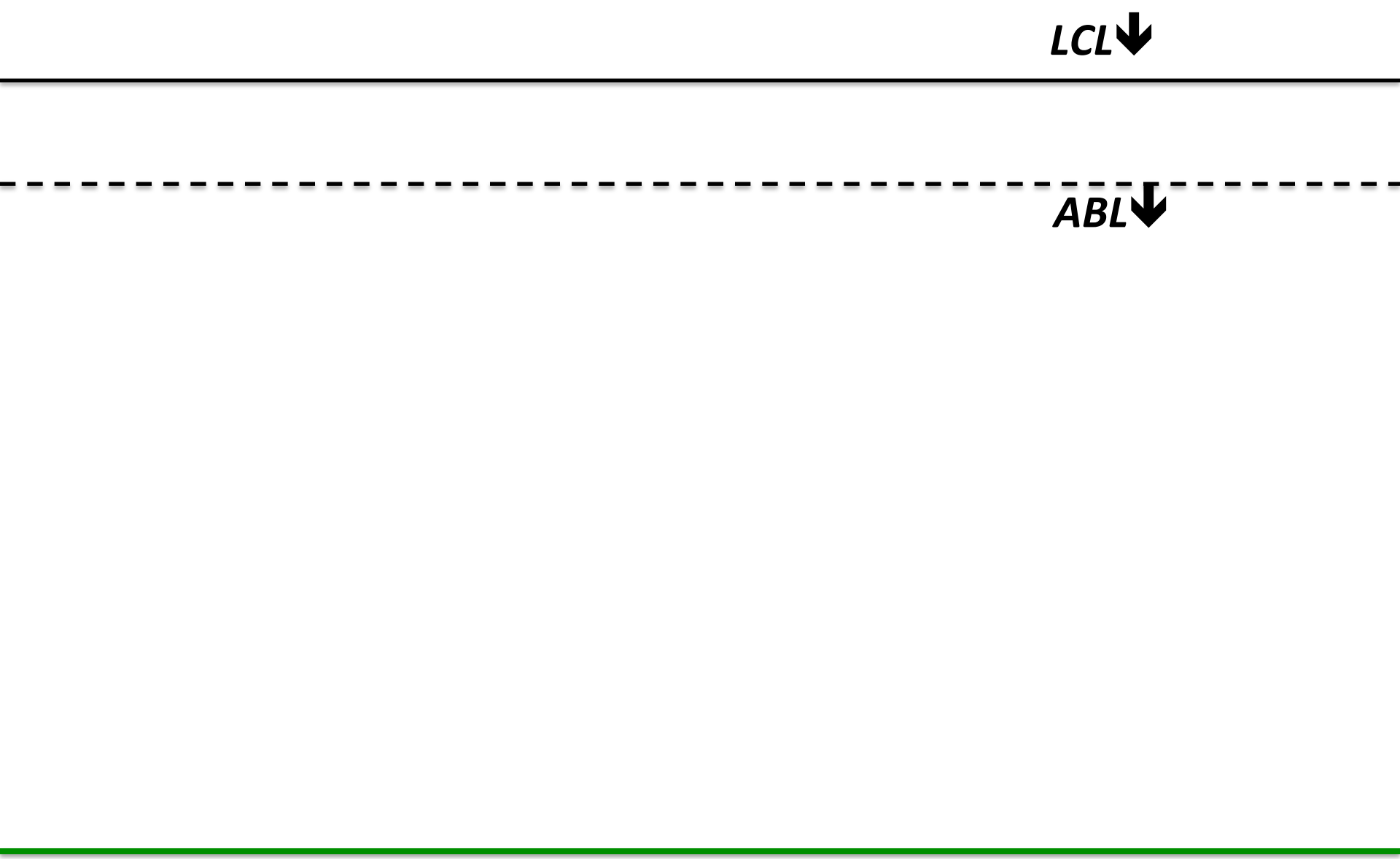
Montana is warming at the same rate as the rest of the globe



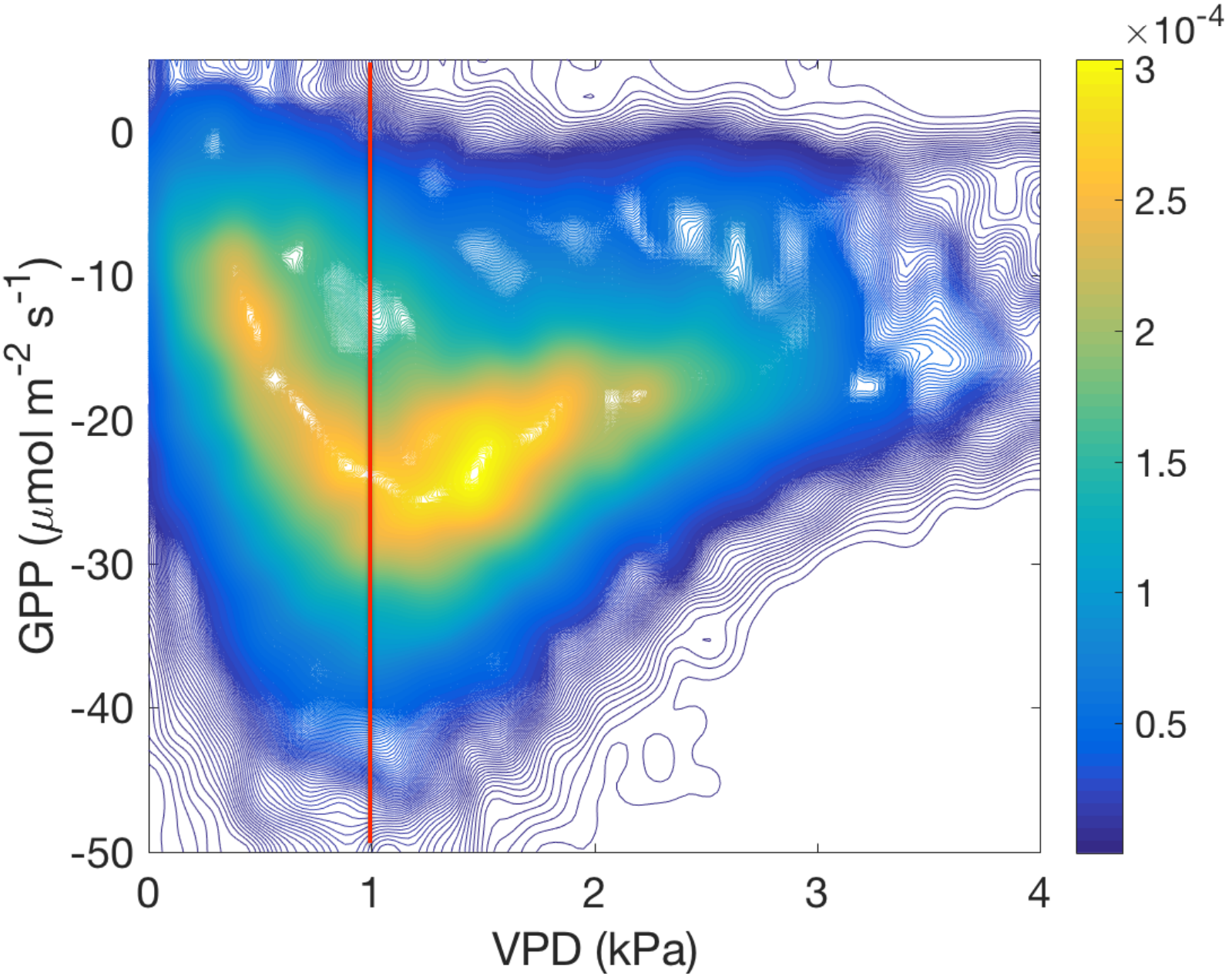
Montana's air is getting more humid



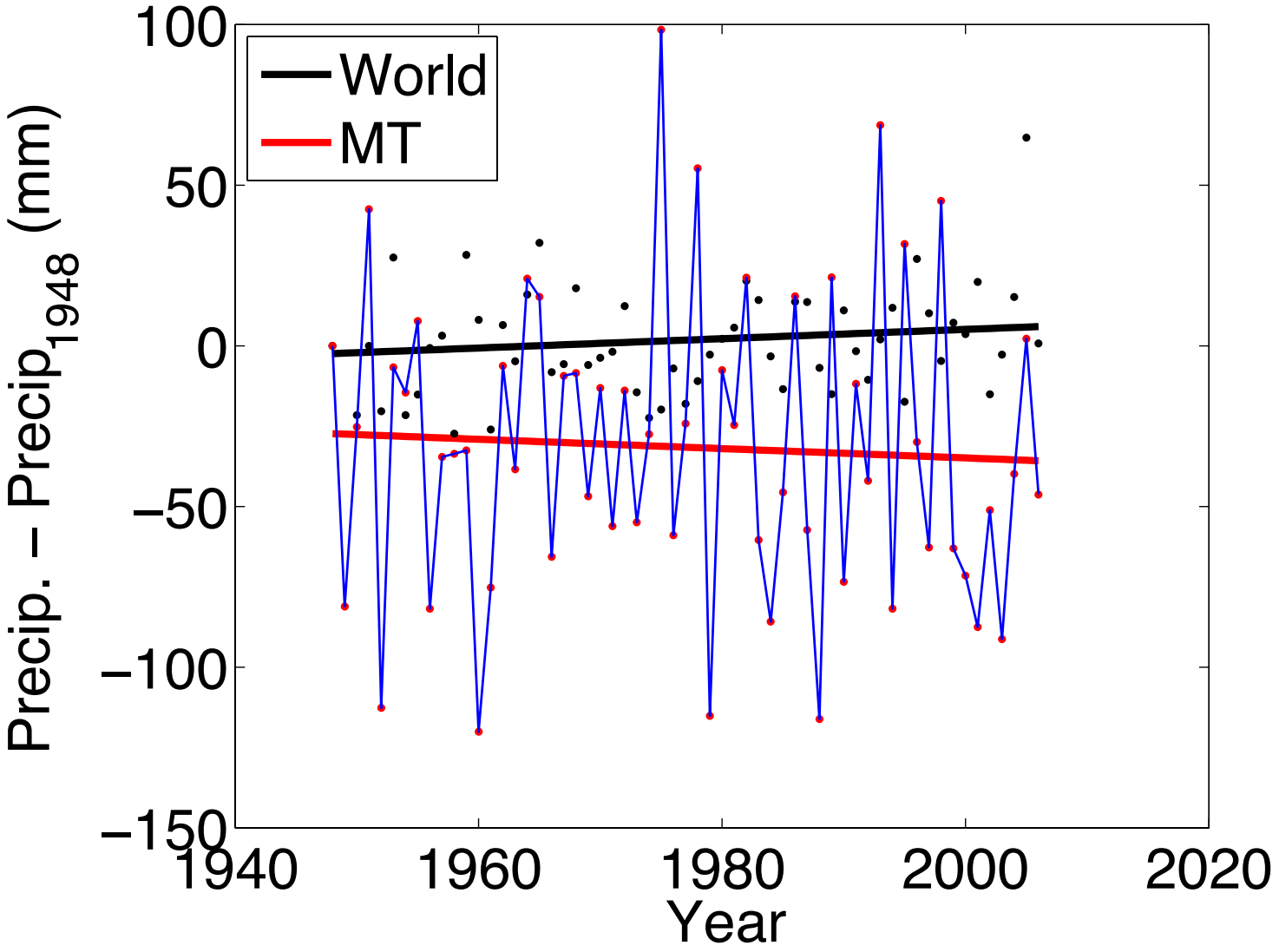
Both LCL & ABL will decrease under cooler & more humid conditions



Plants are sensitive to atmospheric dryness



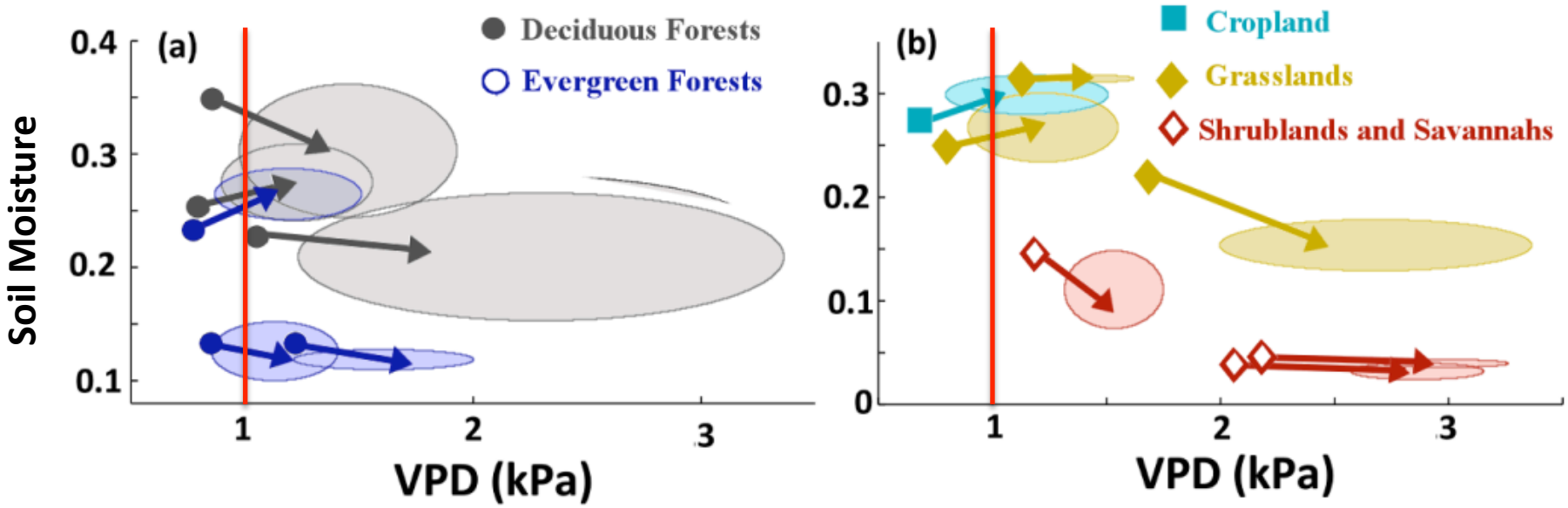
MT *versus* global precipitation trends



Sheffield et al. (2012) Little change in global drought over the past 60 years. Nature doi:10.1038/nature11575

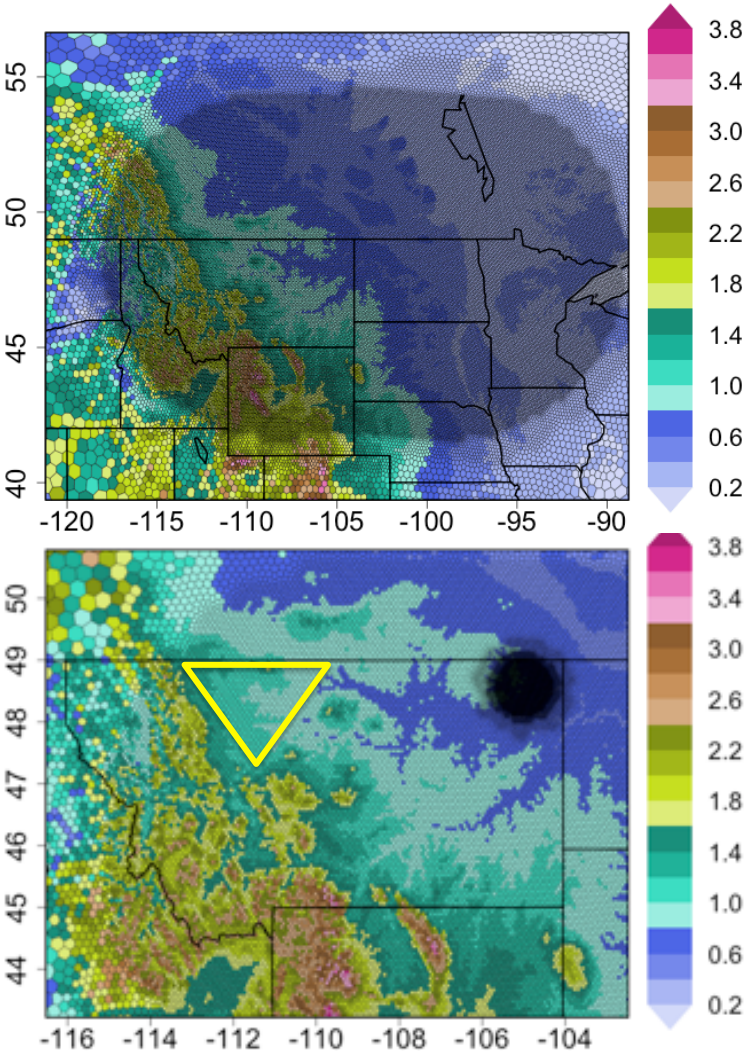
Climate change will increase the importance of atmospheric constraints on carbon and water fluxes in terrestrial ecosystems

Soil moisture changes are less certain



Novick, Ficklin, Stoy et al. (2016) *Nature Climate Change*
(mean of 10 GCMs for 38 FLUXNET sites in North America)

Future work: Regional climate modeling & fallow attribution:



Are there emergent properties of this coupled human/natural system?