NCAR UCAR | CESM COMMUNITY EARTH SYSTEM MODEL

2016 WINTER WORKING GROUP MEETINGS

COLA / AOES Land Group

Climate Simulations with Respect to Land Cover Change in CLM45 and CLM50

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Outline

- CLM4.5 and CLM5.0 land cover change sensitivity experiments
- Observed climatic impacts of land cover change
- Validation of CLM using FLUXNET

Question #1

- Can CLM4.5 and CLM5.0 reasonably represent the impacts of land cover change on surface temperature?

CESM sensitivity experiment

Name	ATM	LND	Land Cover
Ctrl_45_off	Qian et al. (2006)	CLM4.5 (CESM-1.2.2)	PFTs in 1850
BareSoil_45_off			Remove all PFTs
AllGrass_45_off			Replace all non-grass PFTs with grass
Ctrl_50_off	Qian et al. (2006)	CLM5.0 (CAM55CLM50hydro)	PFTs in 1850
BareSoil_50_off			Remove all PFTs
AllGrass_50_off			Replace all non-grass PFTs with grass

Metric for Biogeophysical Feedback

- the surface energy balance:

$$R_n = S + LW_{in} - \varepsilon\sigma T_s^4 = H + LE + G$$

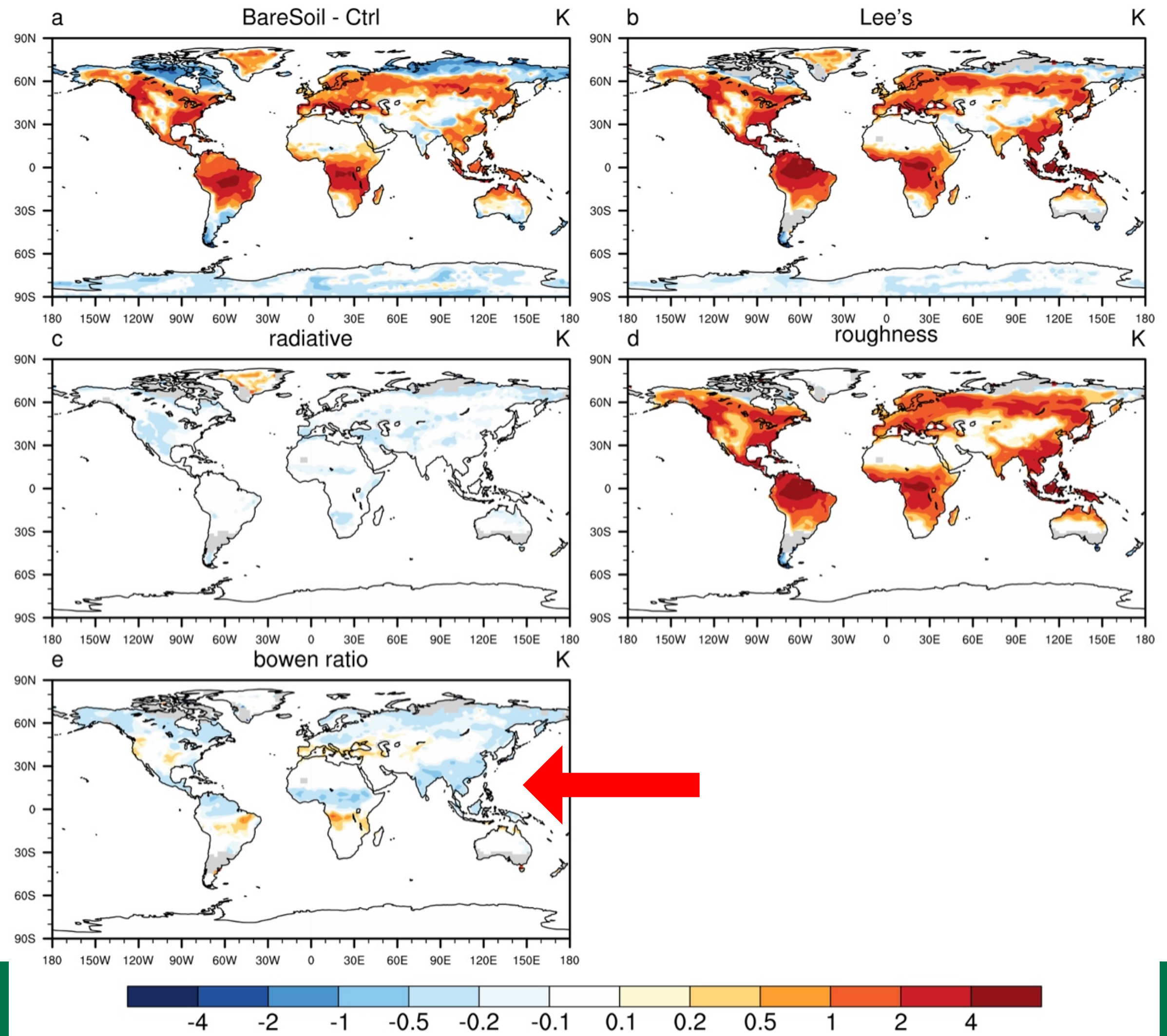
- intrinsic biophysical mechanism (Lee et al., 2011):

$$\Delta T_s \approx \frac{\lambda_0}{1+f}\Delta S + \frac{-\lambda_0}{(1+f)^2}R_n\Delta f_1 + \frac{-\lambda_0}{(1+f)^2}R_n\Delta f_2$$

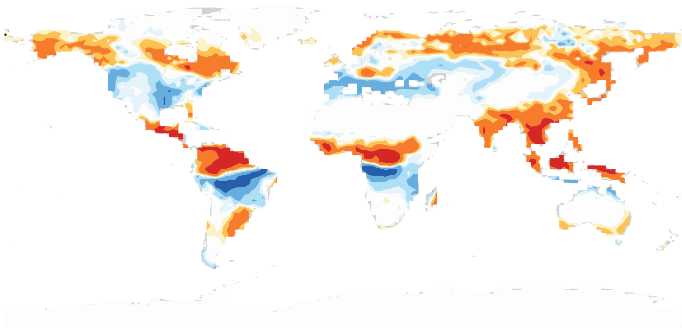
albedo effect | surface roughness effect | Bowen ratio effect

$$f = \frac{\rho C_p}{4\sigma T_a^3 r_a}\left(1 + \frac{1}{\beta}\right) \qquad \Delta f_1 = -\frac{\rho C_p}{4\sigma T_a^3}\left(1 + \frac{1}{\beta}\right)\frac{\Delta r_a}{r_a^2} \qquad \Delta f_2 = -\frac{\rho C_p}{4\sigma T_a^3 r_a}\frac{\Delta \beta}{\beta^2}$$

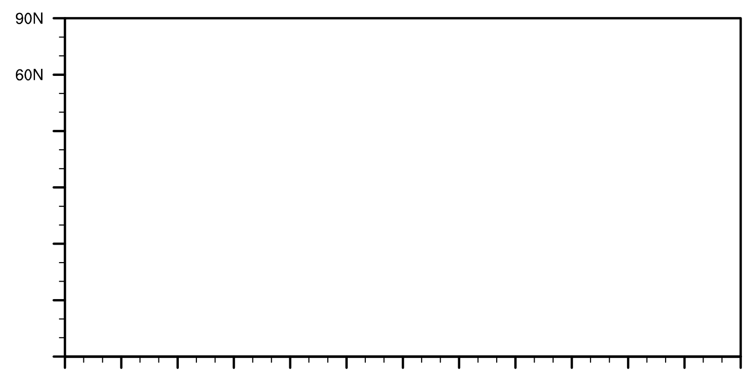
T_{surf} Change in BareSoil (CLM45)

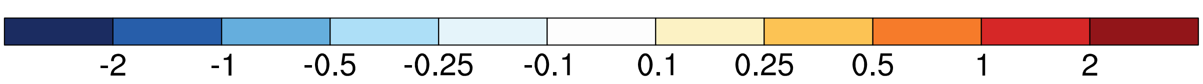


ET Change in BareSoil (CLM45)

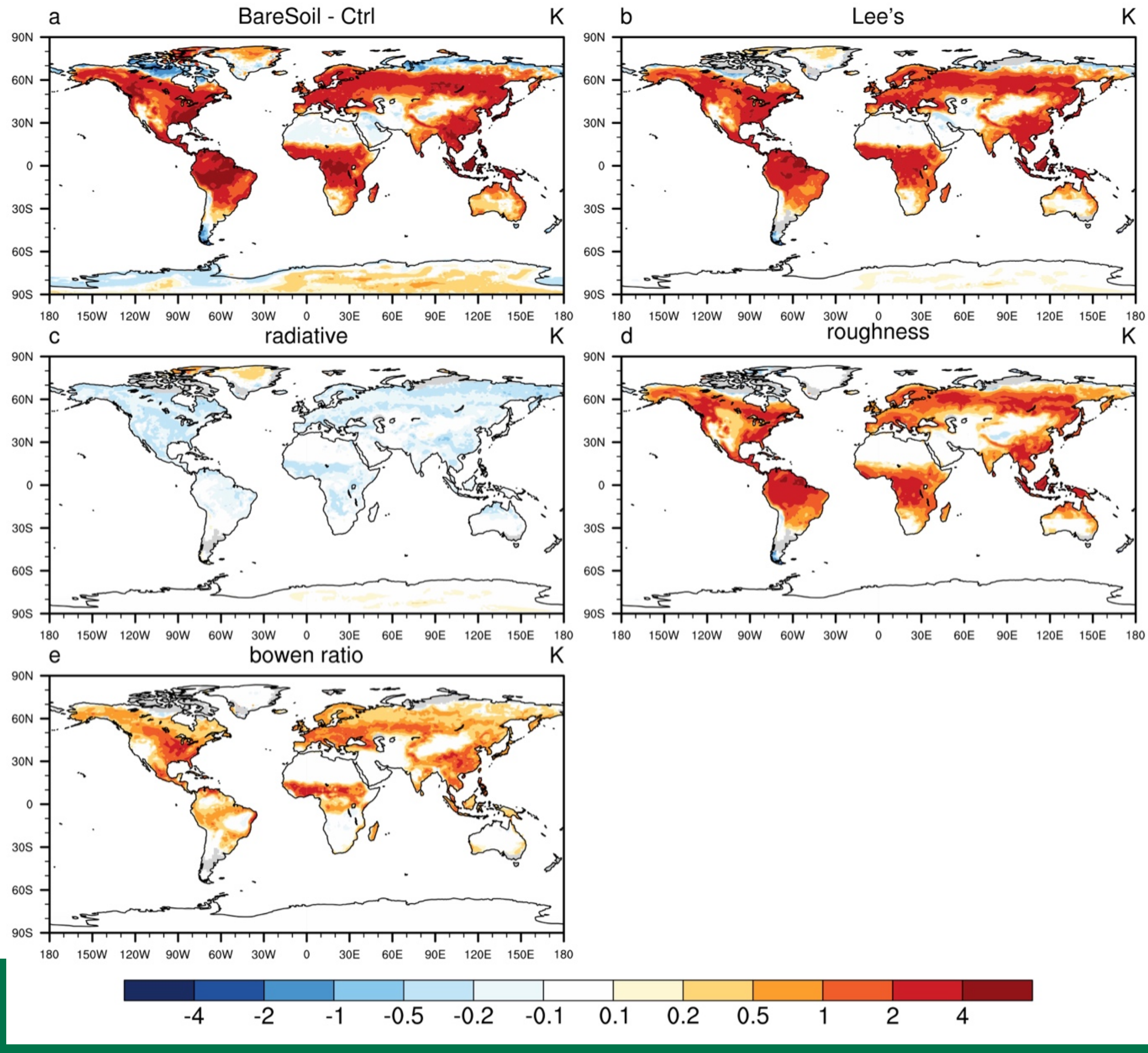


?

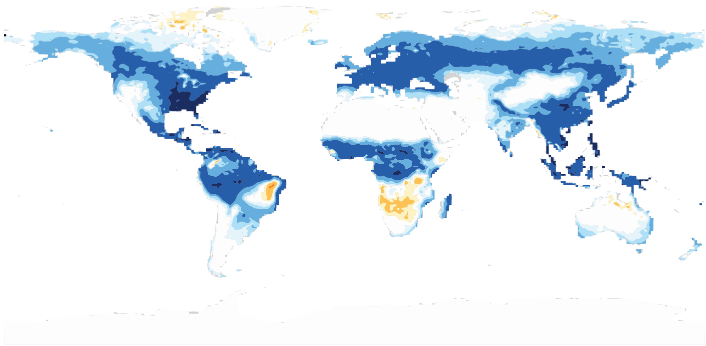


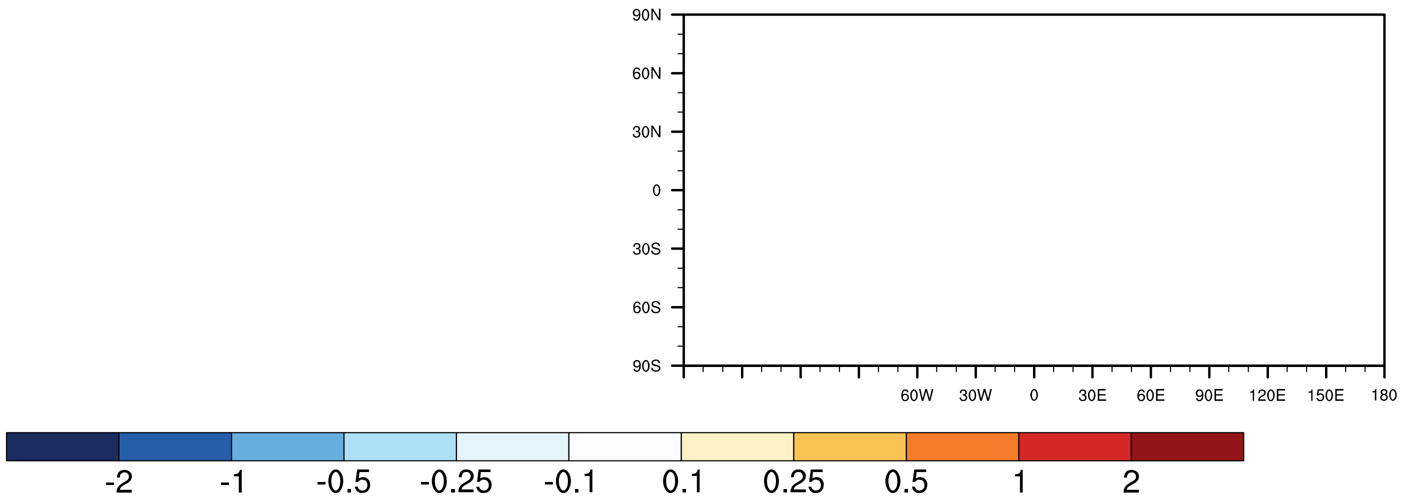


T_{surf} Change in BareSoil (CLM50)

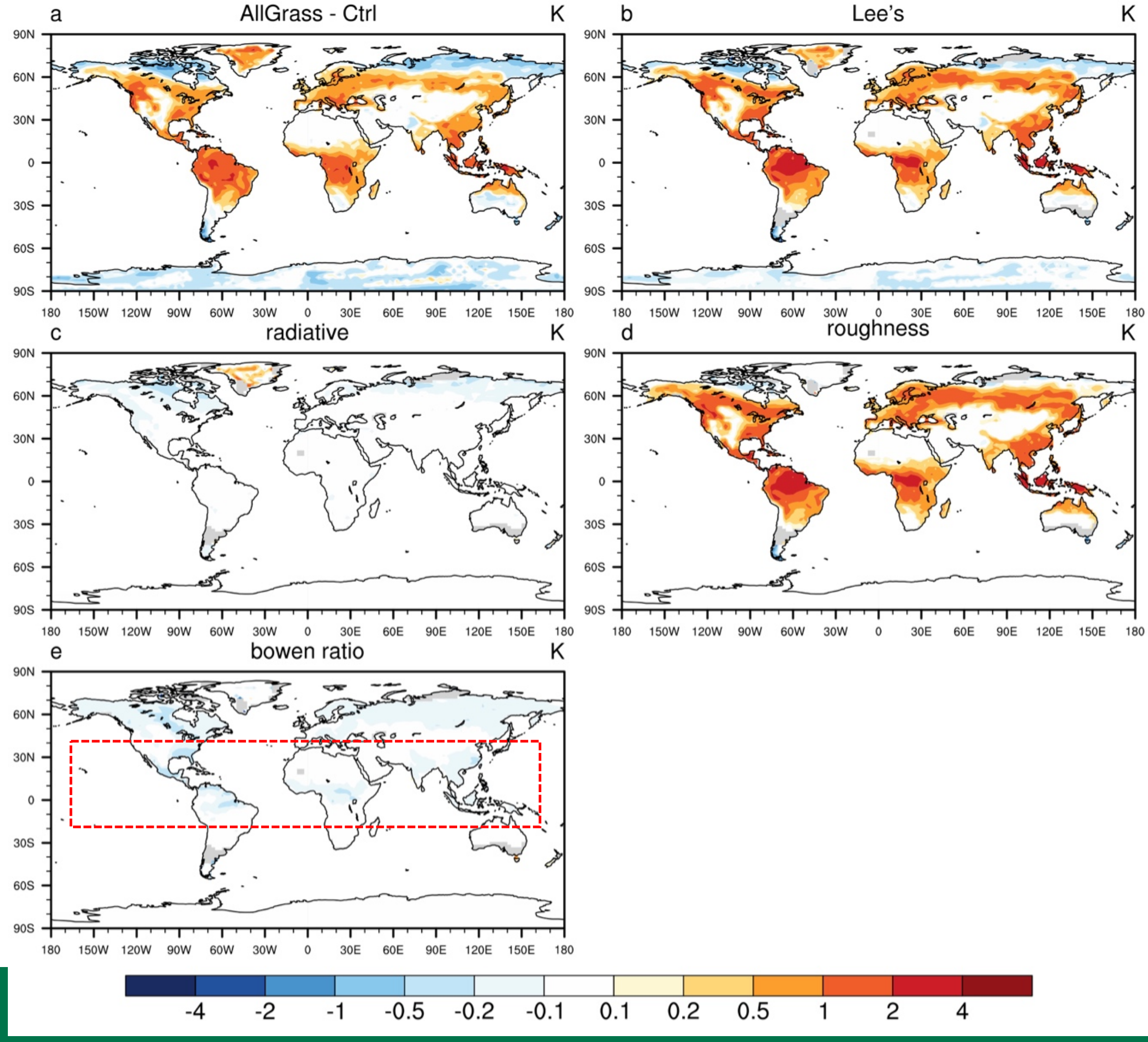


ET Change in BareSoil (CLM5)

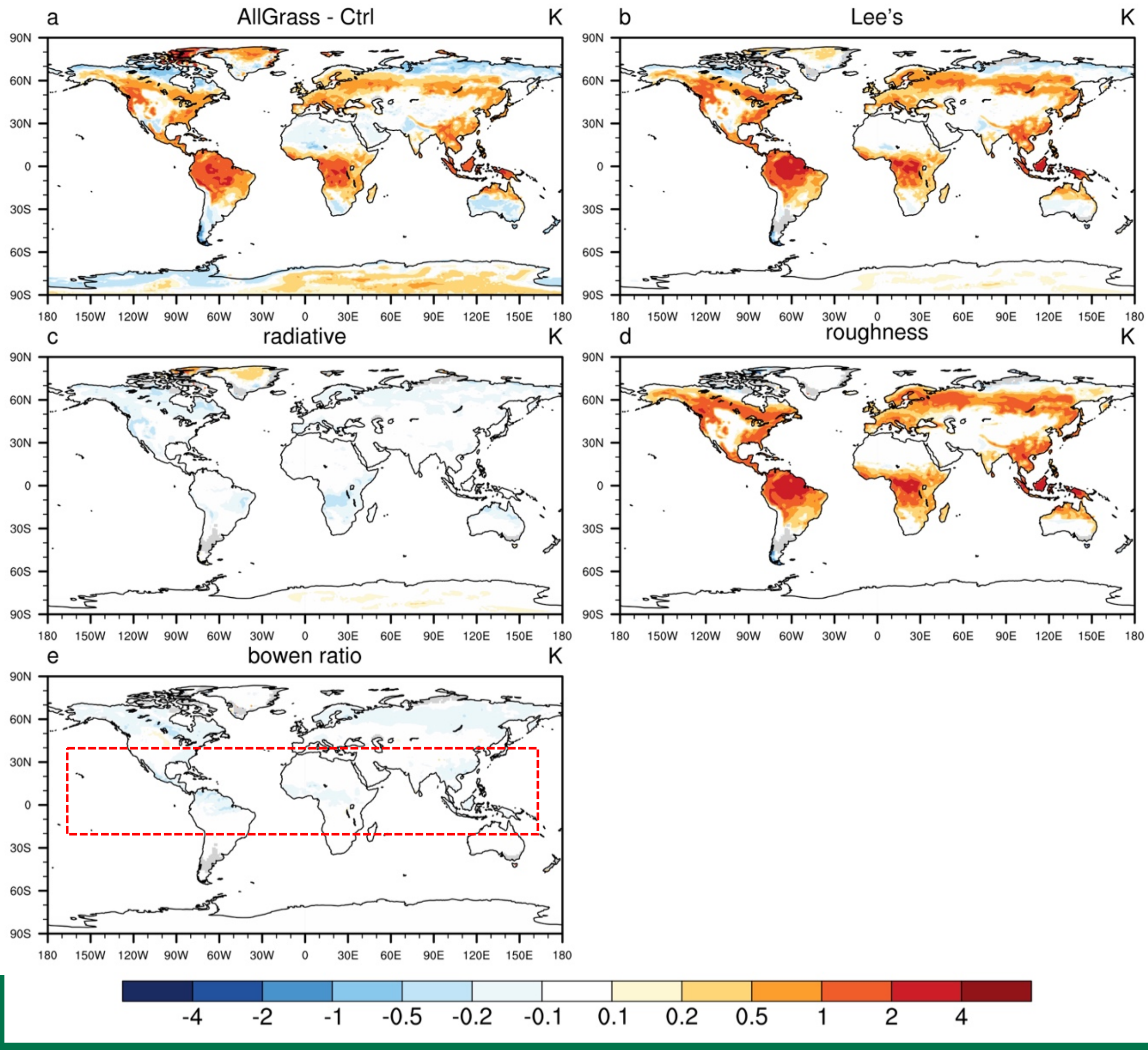




T_{surf} Change in AllGrass (CLM45)

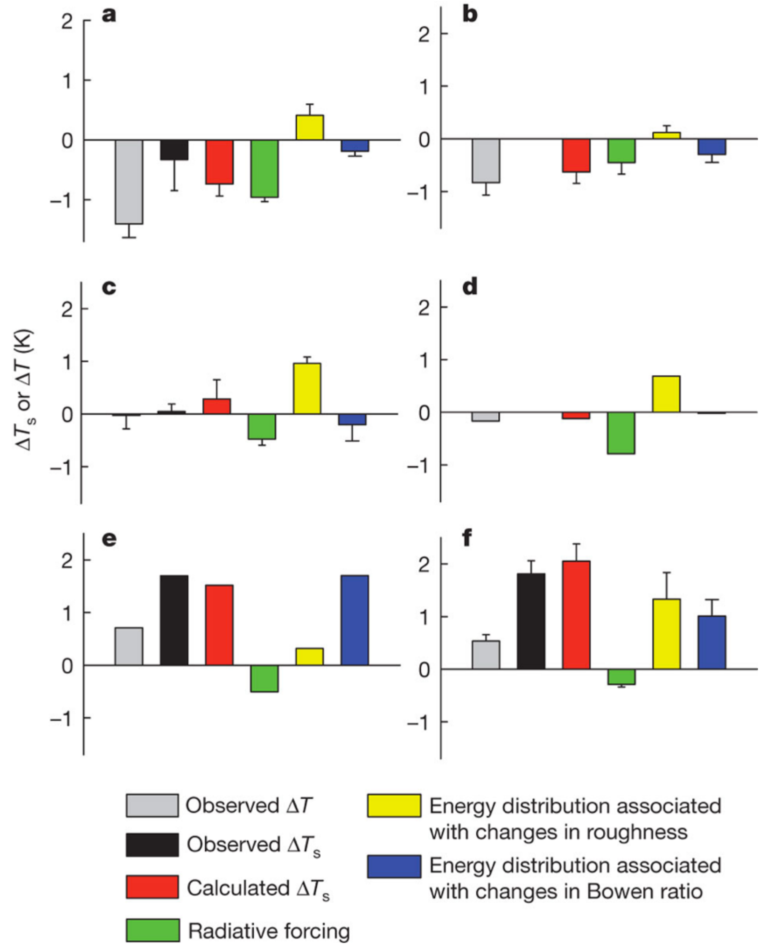


T_{surf} Change in AllGrass (CLM5)



Observed T_{surf} change

open land - forest



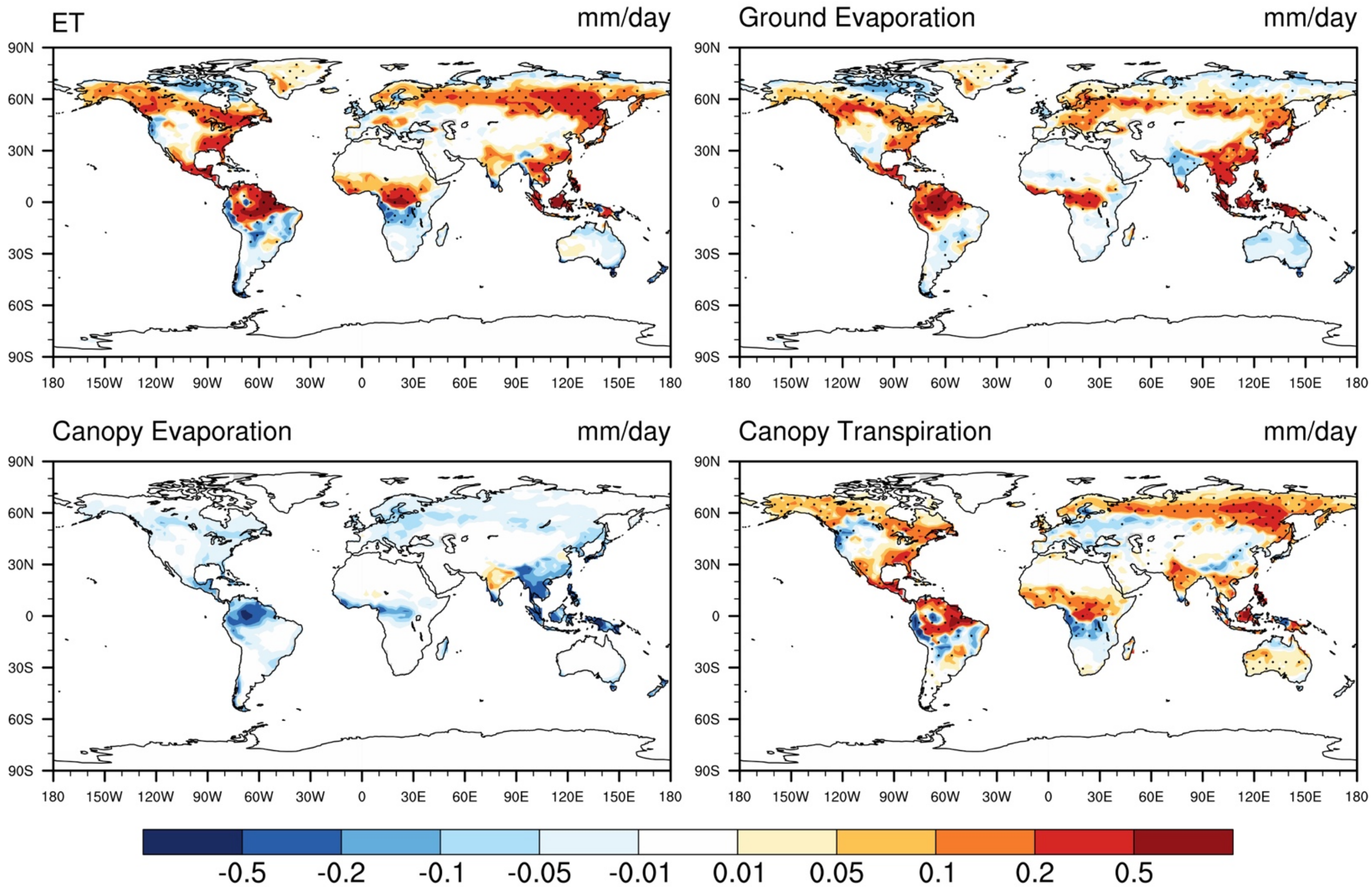
boreal

temperate

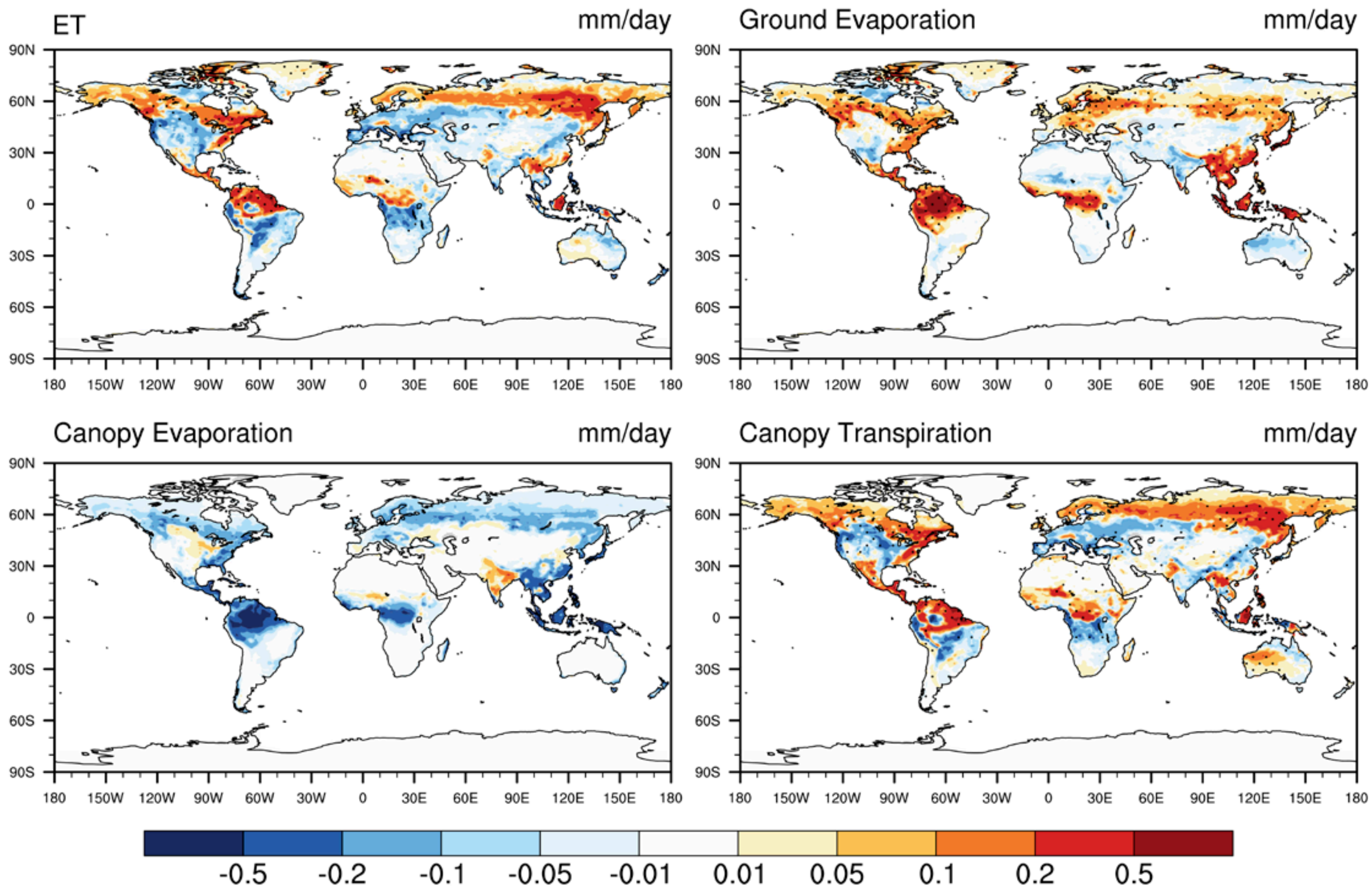
tropical

(Lee et al., 2011)

ET Change in AllGrass (CLM45)



ET Change in AllGrass (CLM5)



Question #2

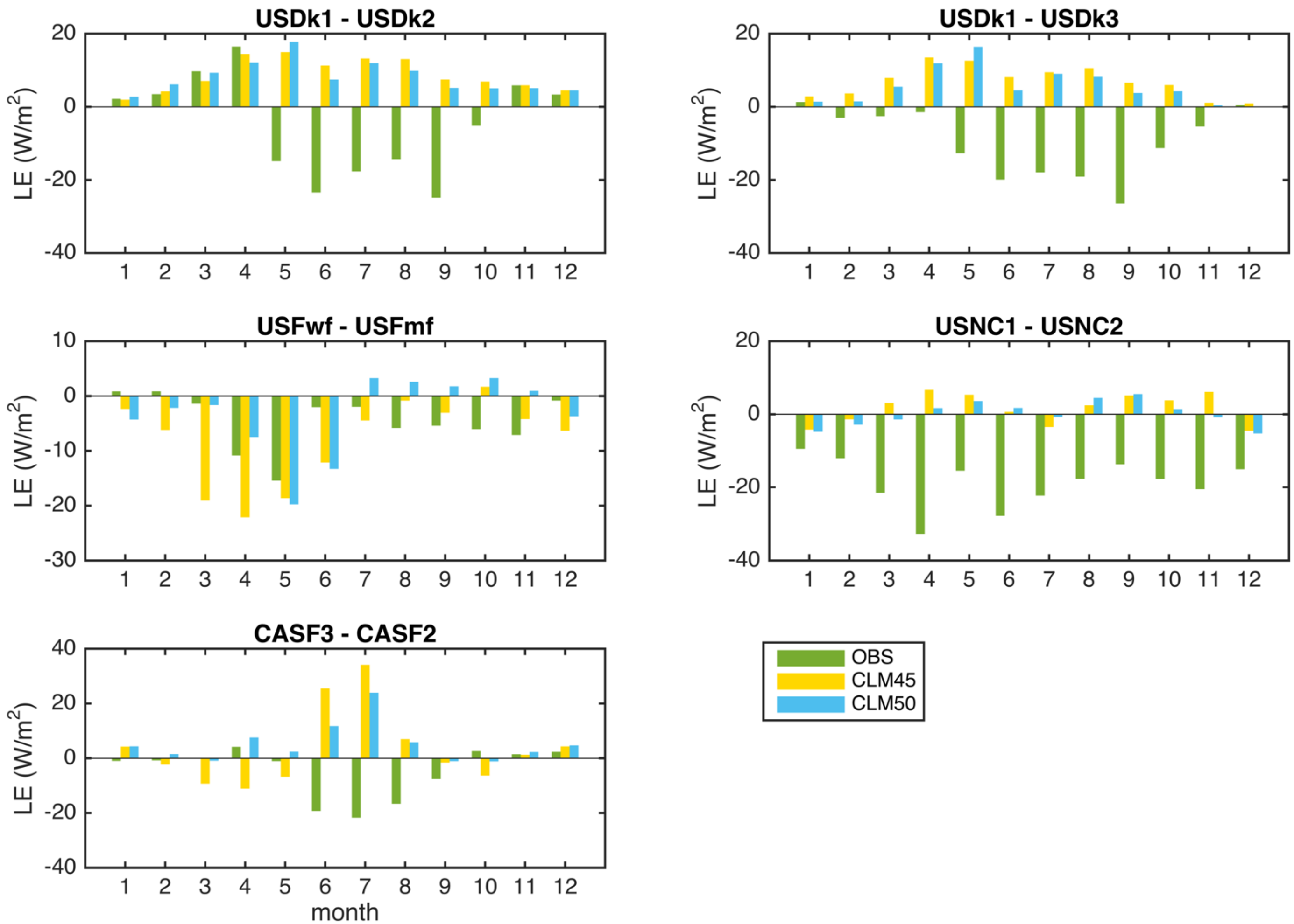
- Can CLM4.5 and CLM5.0 capture the observed impacts of land cover change on ET at paired FLUXNET sites?

source: GoogleEarth

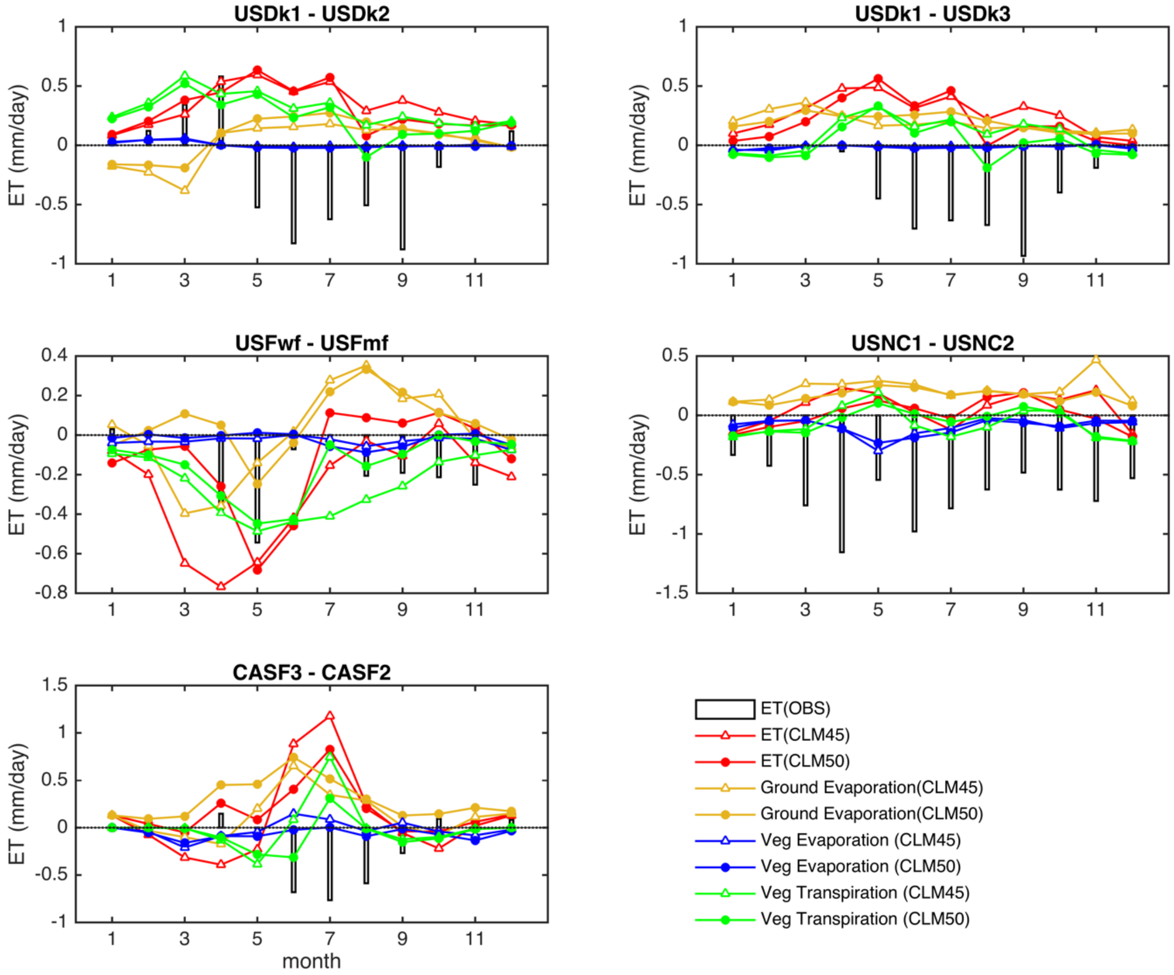
FLUXNET paired sites

Pair	Period	Location	Name	Latitide	Longitude	Elevation (m)	Land cover	Separation (km)
1	2001-5	Duke Forest, NC	US-DK1	35.9712	-79.0934	168	grassland	0.69
			US-Dk2	35.9736	-79.1004	168	deciduous broadleaf	
2	2001-5	Duke Forest, NC	US-DK1	35.9712	-79.0934	168	grassland	0.78
			US-Dk3	35.9782	-79.0942	163	evergreen needleleaf	
3	2006-10	Flagstaff, AZ	US-Fwf	35.4454	-111.7718	2270	grassland	33.84
			US-Fmf	35.1426	-111.7273	2160	evergreen needleleaf	
4	2006	Albemarle, NC	US-NC1	35.8118	-76.7119	5	open shrub	4.04
			US-NC2	35.8030	-76.6685	5	evergreen needleleaf	
5	2004	Boreal, SK	CA-SF3	54.0916	-106.0053	540	open shrub	19.90
			CA-SF2	54.2539	-105.8775	520	evergreen needleleaf	

LE change


USDk1 - USDk2
USDk1 - USDk3
USFwf - USFmf
USNC1 - USNC2
CASF3 - CASF2
LE (W/m²)
month
OBS
CLM45
CLM50
1 2 3 4 5 6 7 8 9 10 11 12

Change in ET components



Question #3

- How is the performance of CLM45 and CLM50 using the Protocol for the Analysis of Land Surface Models (PALS)?

The Plumbing of Land Surface Models: Benchmarking Model Performance

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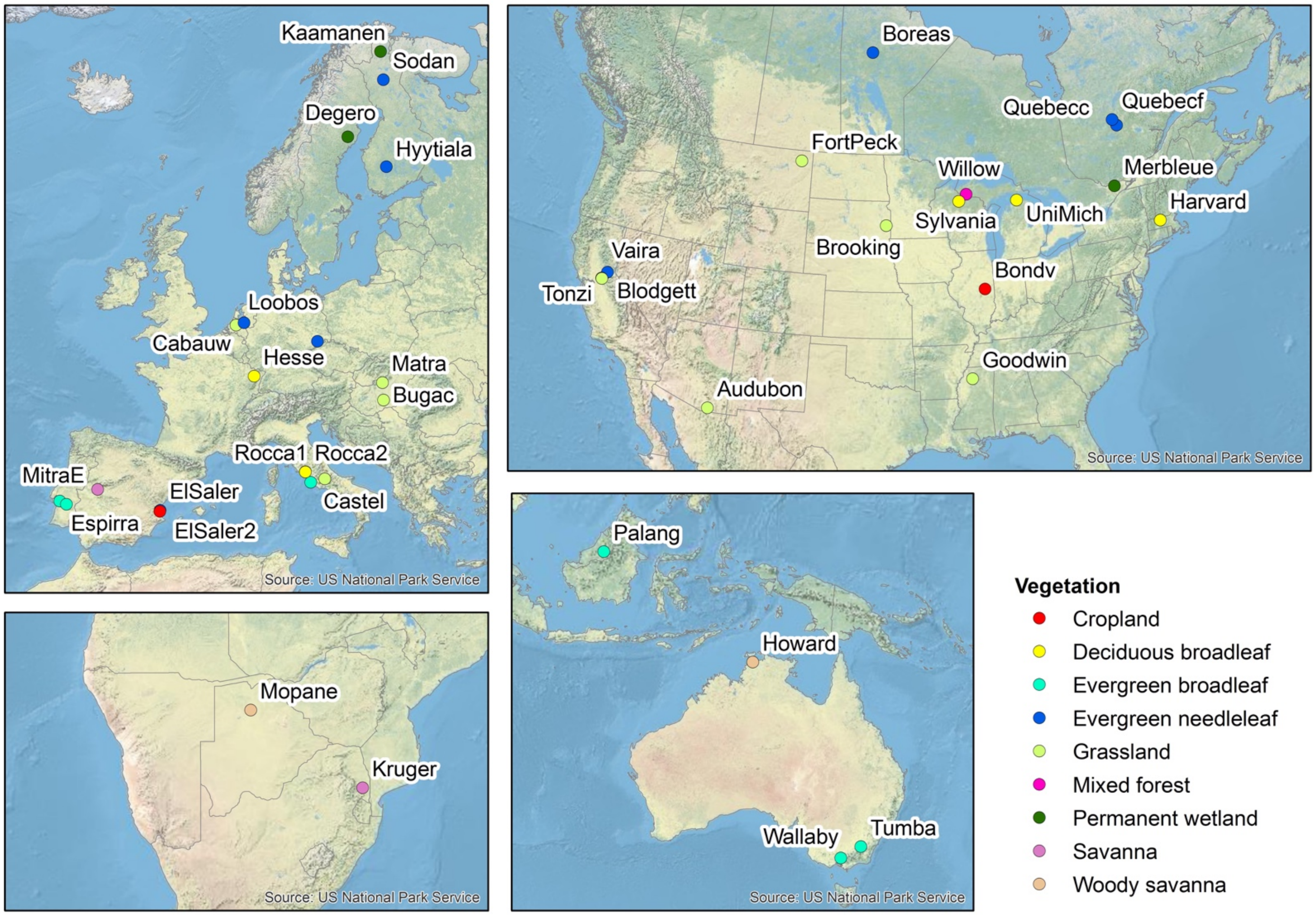
ABSTRACT

The Protocol for the Analysis of Land Surface Models (PALS) Land Surface Model Benchmarking Evaluation Project (PLUMBER) was designed to be a land surface model (LSM) benchmarking intercomparison. Unlike the traditional methods of LSM evaluation or comparison, benchmarking uses a fundamentally different approach in that it sets expectations of performance in a range of metrics a priori—before model simulations are performed. This can lead to very different conclusions about LSM performance. For this study, both simple

PALS sites

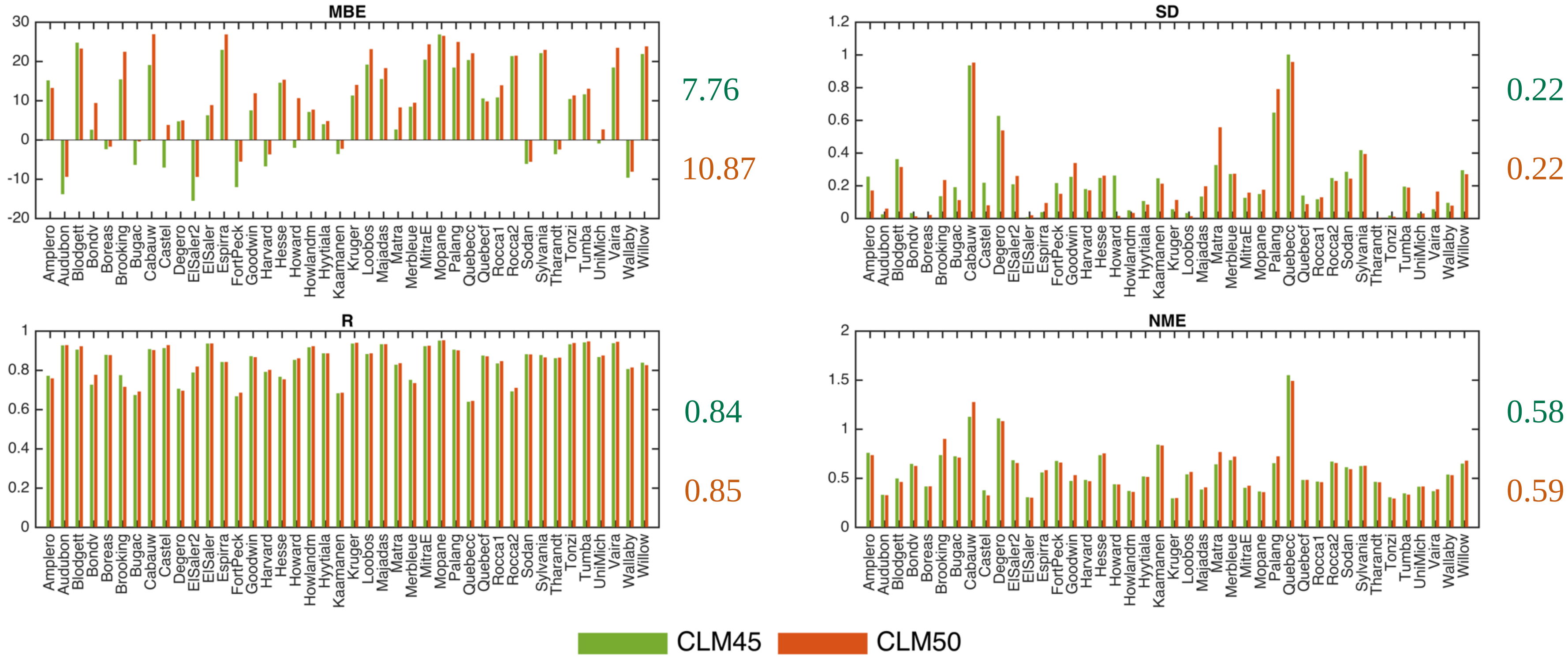

Kaamanen
Sodan
Degero
Hyytiala
Loobos
Cabauw
Hesse
Matra
Bugac
Rocca1
Rocca2
MitraE
ElSaler
Castel
Espirra
ElSaler2
Source: US National Park Service
Boreas
Quebecc
Quebecf
FortPeck
Willow
Merbleue
Harvard
Sylvania
UniMich
Brooking
Vaira
Bondv
Tonzi
Blodgett
Goodwin
Audubon
Source: US National Park Service
Mopane
Kruger
Source: US National Park Service
Palang
Howard
Wallaby
Tumba
Source: US National Park Service
Vegetation
Cropland
Deciduous broadleaf
Evergreen broadleaf
Evergreen needleleaf
Grassland
Mixed forest
Permanent wetland
Savanna
Woody savanna

Statistical Metrics

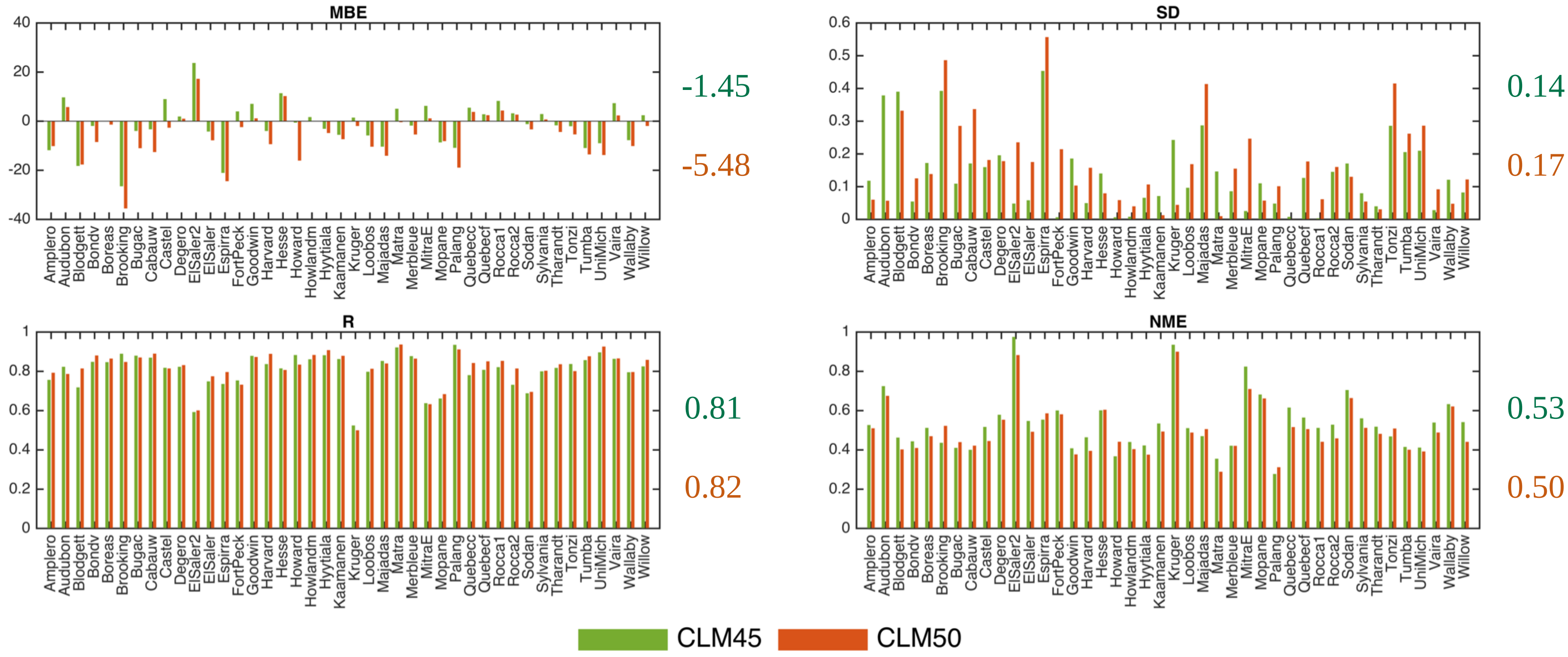
Common statistical measures	
Mean bias error (MBE)	$\frac{\left[\sum_{i=1}^{n}(M_i - O_i)\right]}{n}$
Standard deviation (SD)	$\left\| 1 - \frac{\sqrt{\frac{\sum_{i=1}^{n}(M_i - \overline{M})^2}{n-1}}}{\sqrt{\frac{\sum_{i=1}^{n}(O_i - \overline{O})^2}{n-1}}} \right\|$
Correlation coefficient (r)	$\frac{n\sum_{i=1}^{n}(O_i M_i) - \left(\sum_{i=1}^{n} O_i \sum_{i=1}^{n} M_i\right)}{\sqrt{\left[n\sum_{i=1}^{n} O_i^2 - \left(\sum_{i=1}^{n} O_i\right)^2\right]\left[n\sum_{i=1}^{n} M_i^2 - \left(\sum_{i=1}^{n} M_i\right)^2\right]}}$
Normalized mean error (NME)	$\frac{\sum_{i=1}^{n}\|M_i - O_i\|}{\sum_{i=1}^{n}\|\overline{O} - O_i\|}$

(Best et al. 2015)

Sensible heat flux



Latent heat flux

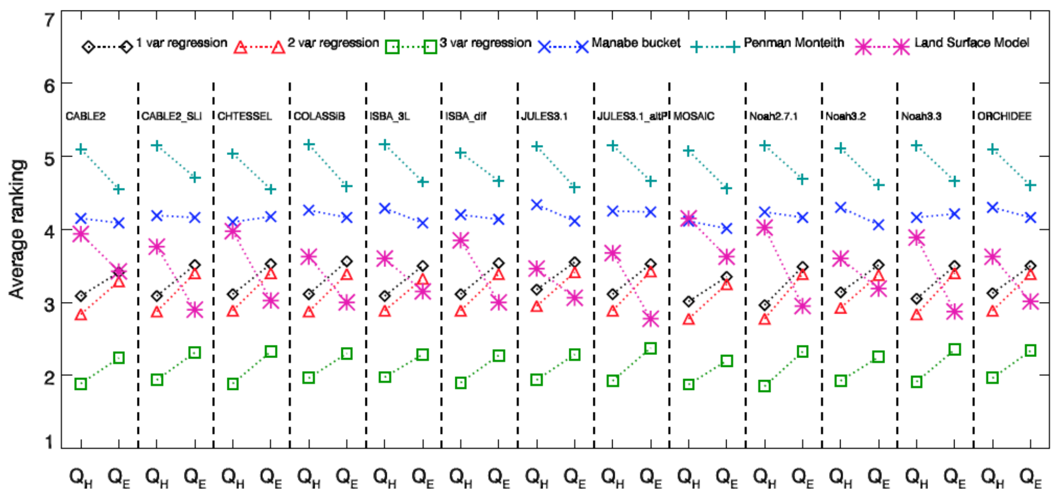


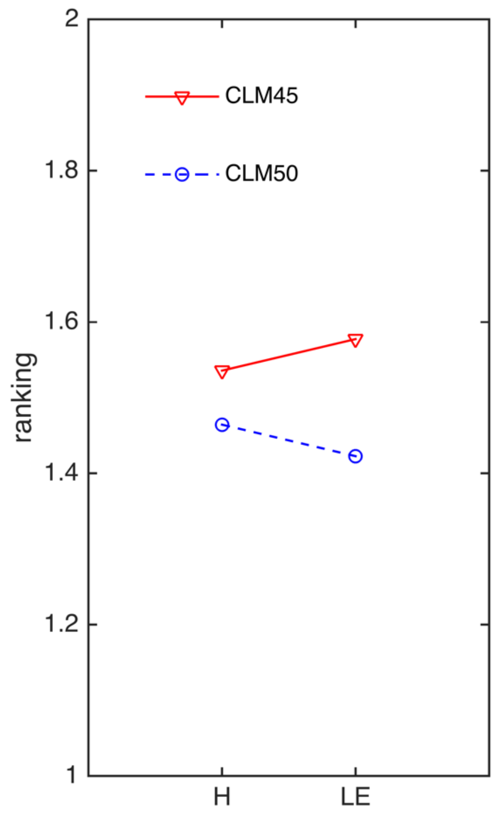
Ranking the models

$$\overline{R_i} = \frac{1}{n_s n_t} \sum_{j=1}^{n_s} \sum_{k=1}^{n_t} R_{i_{jk}}$$

(Best et al. 2015)

- n_s is the number of sites
- n_t is the number of metrics
- R_{ijk} is the rank of model at site j for metric k (1 or 2)





Conclusion

- CLM5.0 shows improved performance in bare soil sensitivity experiment.
- Both CLM4.5 and CLM5.0 have a good agreement with flux tower data, and CLM5.0 shows a little bit improvement (variability better, biases worse).
- Something is still missing in terms of climatic sensitivity of land cover/land use change (deforestation).

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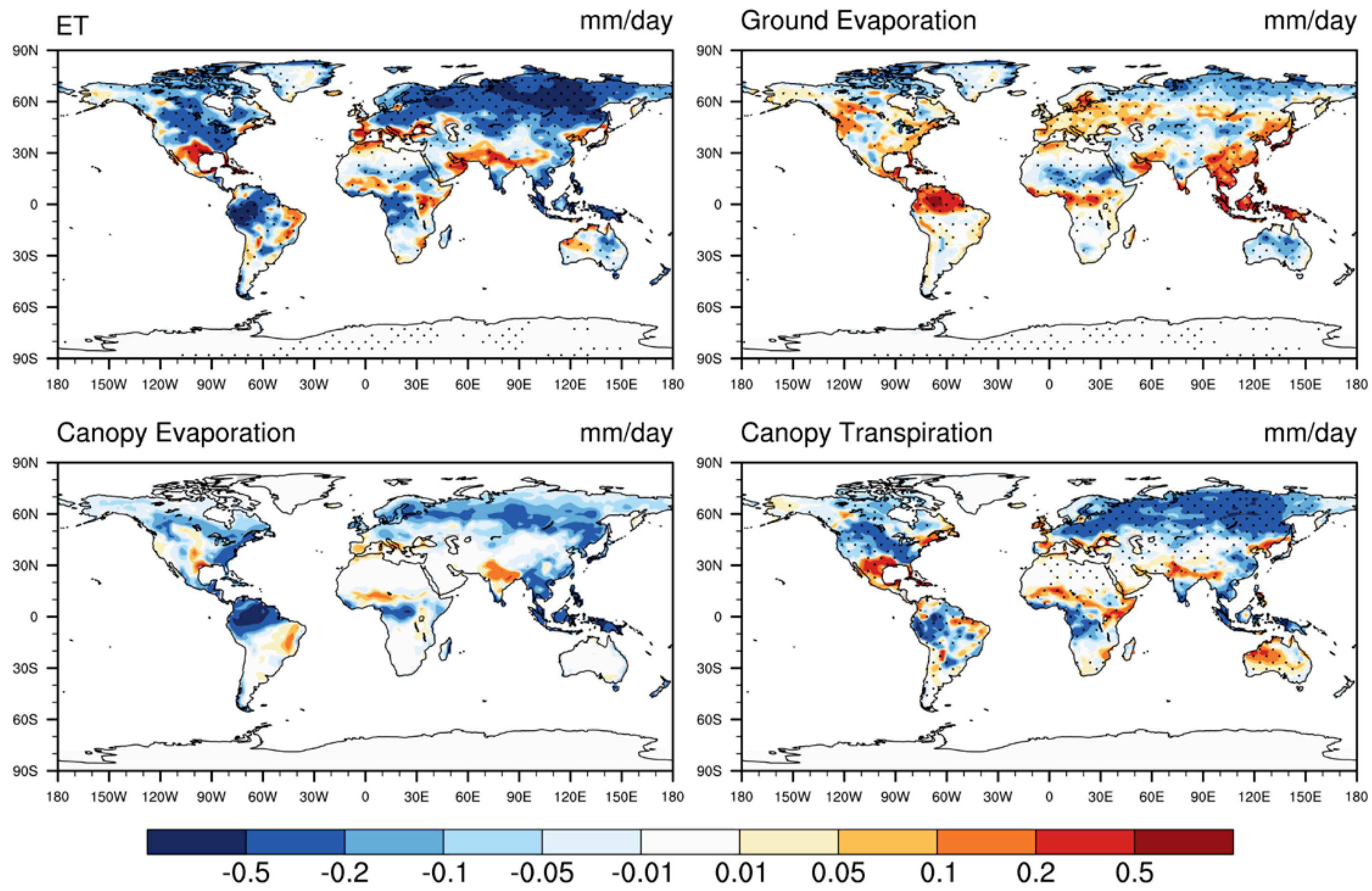
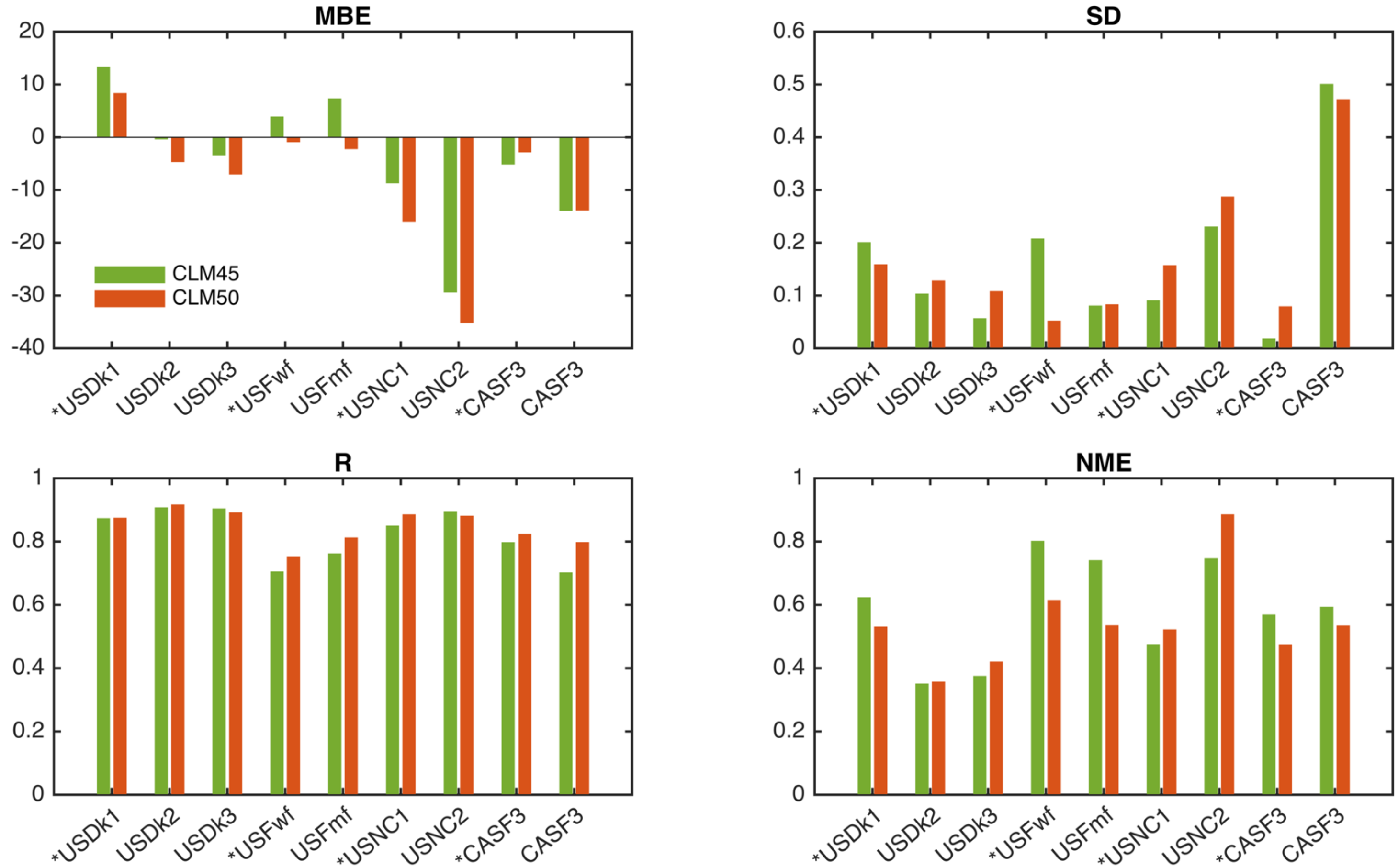
ET Change in AllGrass (CLM5 coupled)

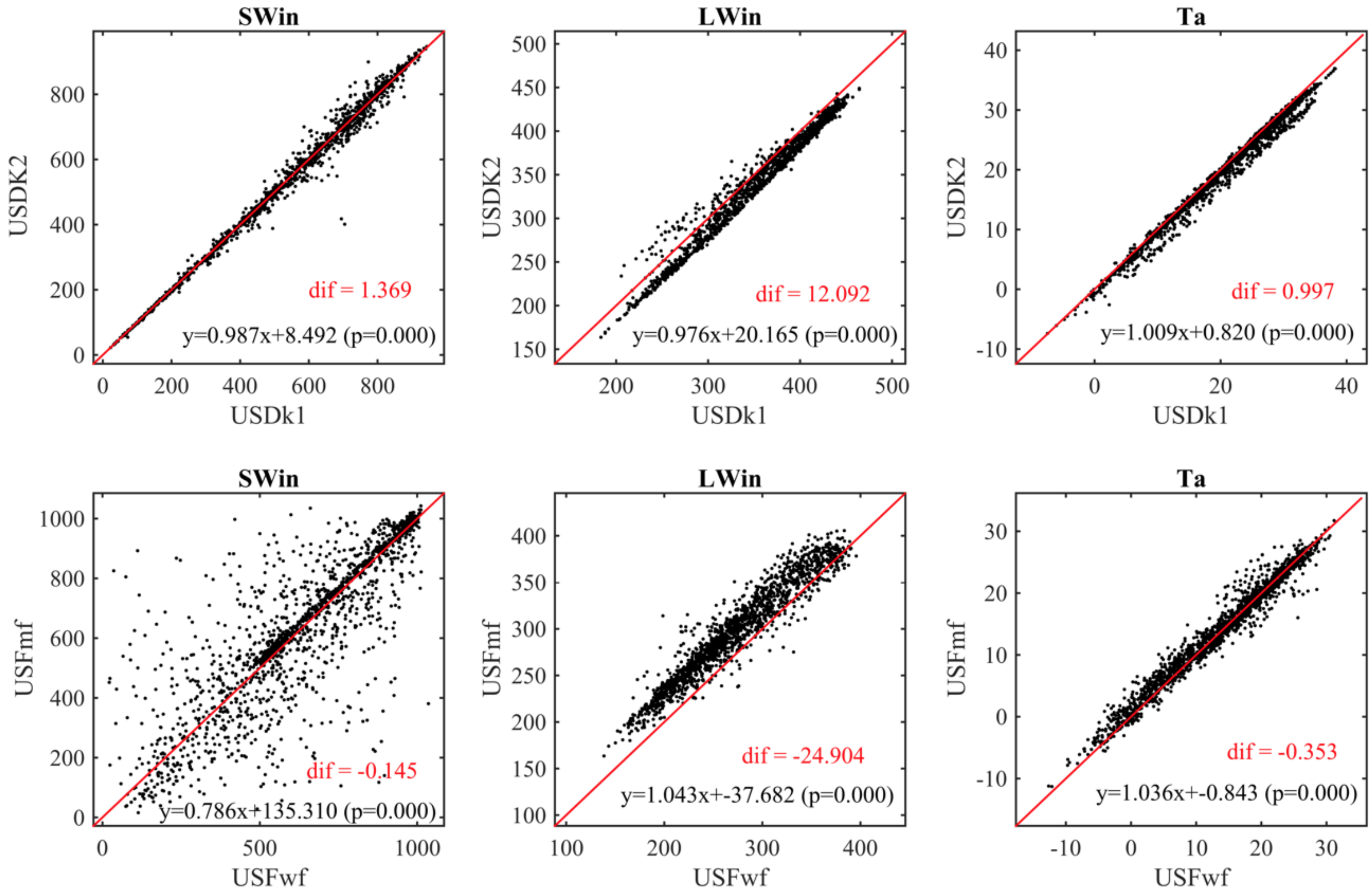


ET simulation



* open land (grassland or shrub)

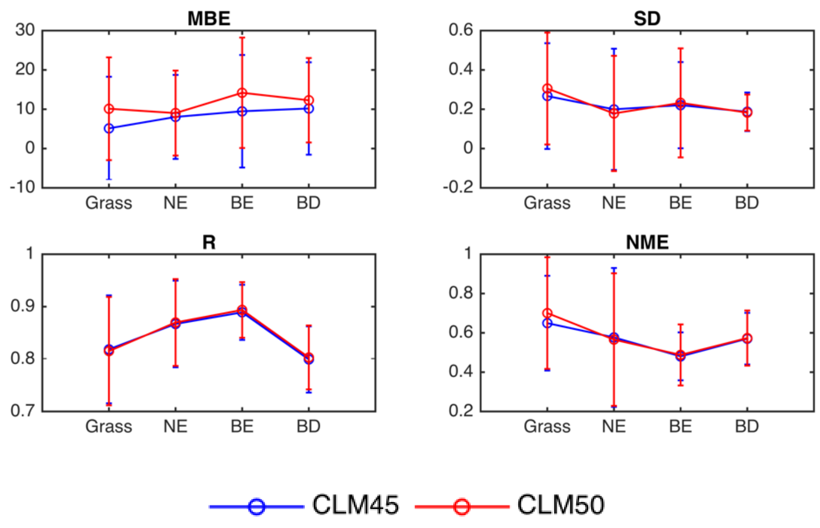
Forcing



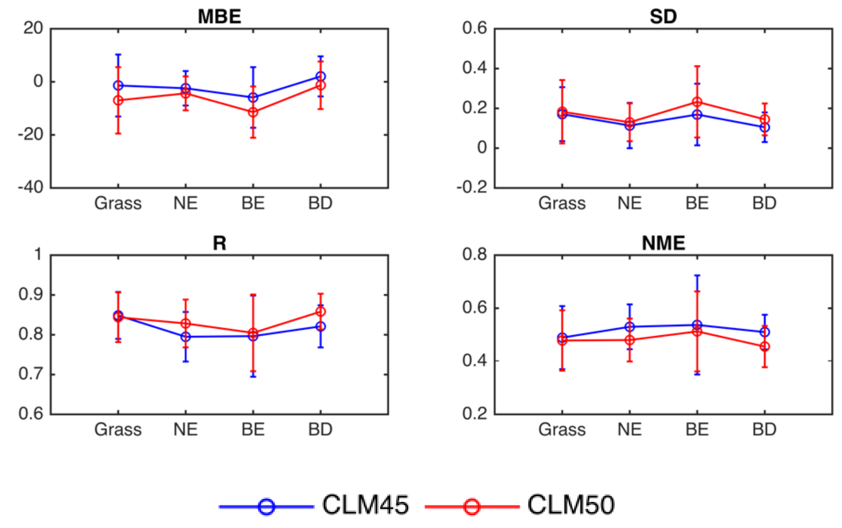
SWin
USDK2
USDk1
dif = 1.369
y=0.987x+8.492 (p=0.000)
LWin
USDK2
USDk1
dif = 12.092
y=0.976x+20.165 (p=0.000)
Ta
USDK2
USDk1
dif = 0.997
y=1.009x+0.820 (p=0.000)
SWin
USFmf
USFwf
dif = -0.145
y=0.786x+135.310 (p=0.000)
LWin
USFmf
USFwf
dif = -24.904
y=1.043x+-37.682 (p=0.000)
Ta
USFmf
USFwf
dif = -0.353
y=1.036x+-0.843 (p=0.000)

Land Cover Types

Sensible Heat Flux



Latent Heat Flux



Grass: grassland (9); **NE**: needleleaf evergreen forest (10); **BE**: broadleaf evergreen forest (6); **BD**: broadleaf deciduous forest (6)