Expansion of Loblolly Pines for Bioenergy feedstock in the Southeastern US: Climate model insights

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16th Annual CESM Workshop

June 21, 2011

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BERKELEY LAB

One Billion Ton biomass target

- Large land conversion to perennial crops if market for bioenergy emerges.
- Acres harvested under DOE/USDA land use change scenario:

	Perennials
Moderate crop yield increase:	35 million acres
High crop yield increase:	55 million acres

- USDA/DOE assumes woody feedstock comes from additional forests planted on marginal agricultural land and pasture land.

Land Cover Change

- LCC impacts the energy, radiation and hydrological budgets at regional to global scales.
- LCC due to expansion of biofuels may have non-trivial effects on climate through biophysical feedbacks.

- Perennial grasses (Miscanthus) caused regional cooling (up to 1°C) compared to annual crops (maize) due to higher LAI, transpiration and rooting depth (Georgescu et al., 2009; Georgescu et al., 2011).
- Remote-sensing data showed growing sugar cane crops on agricultural land cooled temperatures by almost 1°C due to enhanced ET and higher albedo (Loarie et al., 2011).

Motivation

- Native Loblolly Pines are the prime candidate for plantation bioenergy in the Southeast US (Kline and Coleman, 2010).

- In this work we quantify the effects of woody crops for biofeedstock production on regional and hemispheric climate under a plausible 21st century deployment scenario in the SE US.

Methodology

- To represent Loblolly pine (LP) in CCSM4 we optimized PFT physiology parameters to minimize observed versus predicted differences in energy fluxes.
- We used observations from the AmeriFlux Duke Forest Loblolly site for the period 2003-2009.

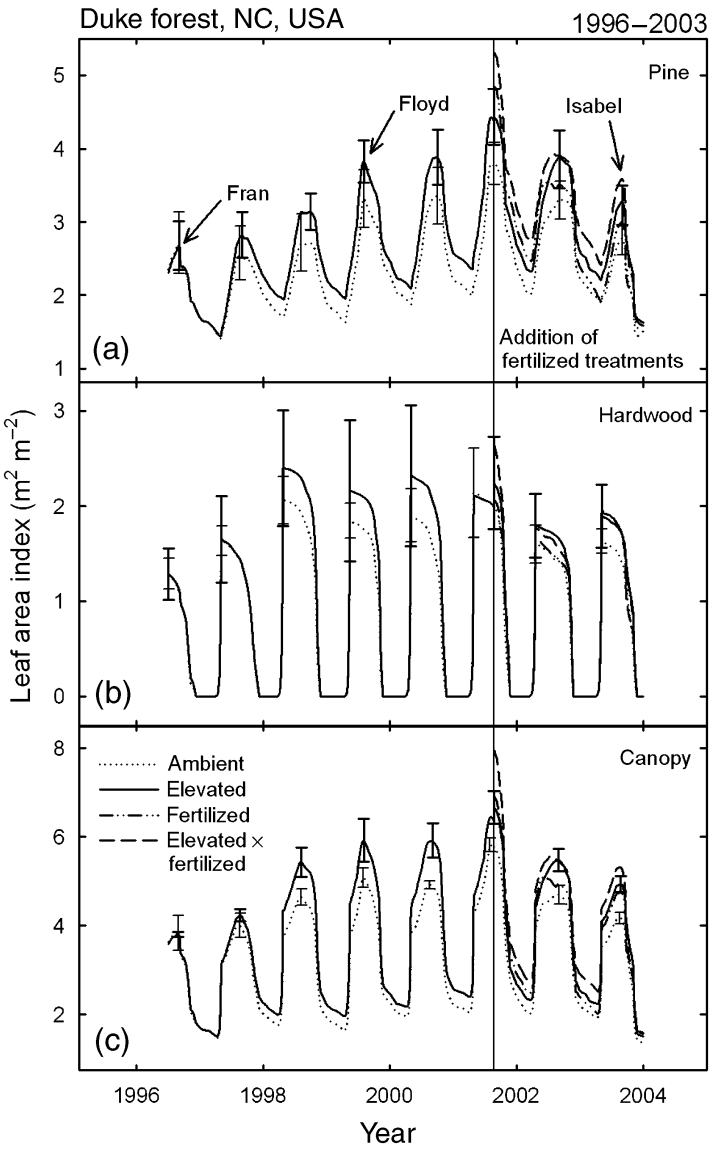
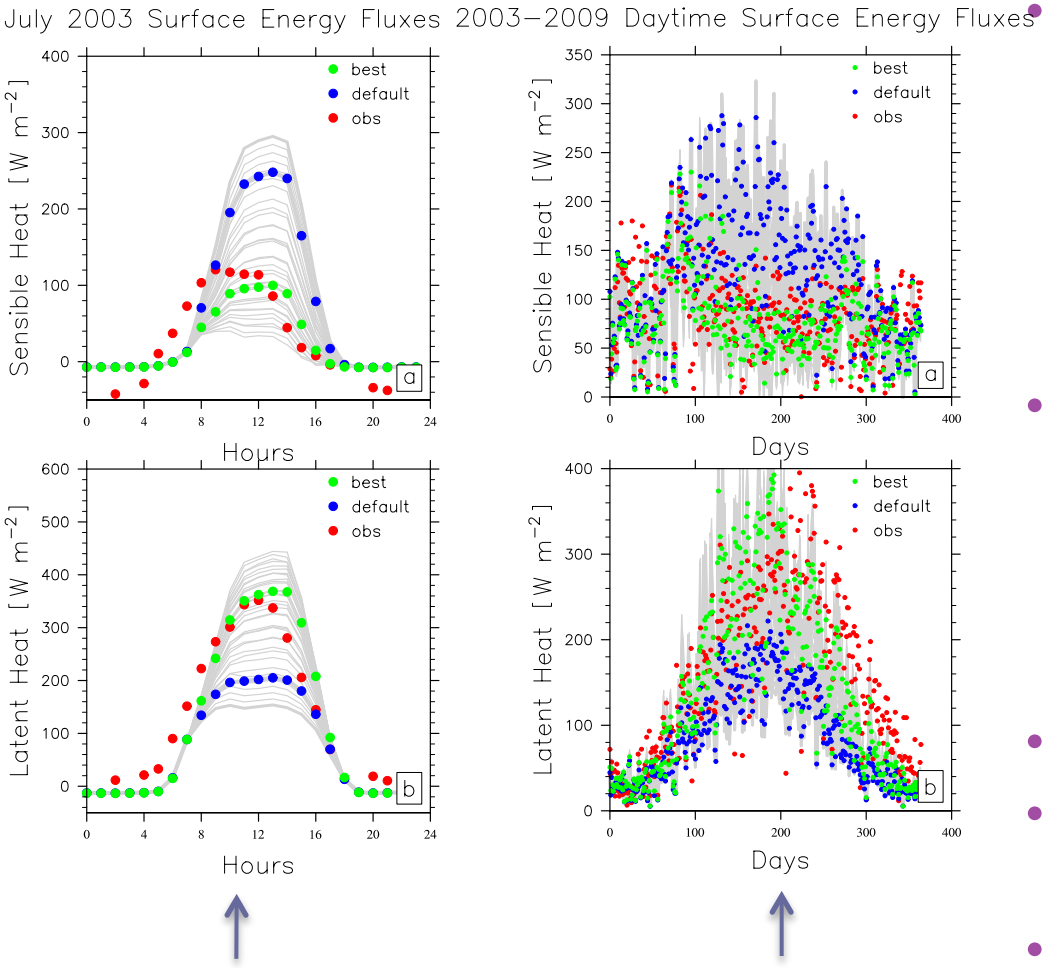


Fig 5 from McCarthy et al. (2007)

Improved daytime energy fluxes



Diurnal cycle

10am-4pm average flux

- We altered two parameters that influence photosynthesis:
  - Flnr – fraction of leaf N in Rubisco enzyme
  - Mp – slope of conductance to photosynthesis relationship
- We ran a 36-member ensemble (gray) varying each parameter 6 times [(flnr = 0.05-0.1), (mp = 5-10)]
- Observations in red
- Default NET (blue): flnr = 0.05, mp = 6
- Loblolly pine (green): flnr = 0.05, mp = 10

Experimental design

	Name	LAI	LCC
1.	PD Loblolly (old LAI)	Default NET LAI	Replaced NET in SE US with Loblolly Pine.
2.	PD Loblolly	Duke Forest Loblolly LAI	Same as 1.
3.	Future Loblolly	Same as 2.	Same as 1. In addition we converted C_4 grasslands to Loblolly Pines in the SE US.
4.	CTL	Default LAI	PD land cover (NET in SE US).

- We use a data ocean model and CN is off ("f_2000" compset)
- All simulations are integrated for 60 years with static land cover. Averages and statistical significance are calculated using the last 40 years of simulation.

Loblolly Pine (Pinus taeda)

http://fia.fs.fed.us/library/maps/

Results: JJA Heat fluxes

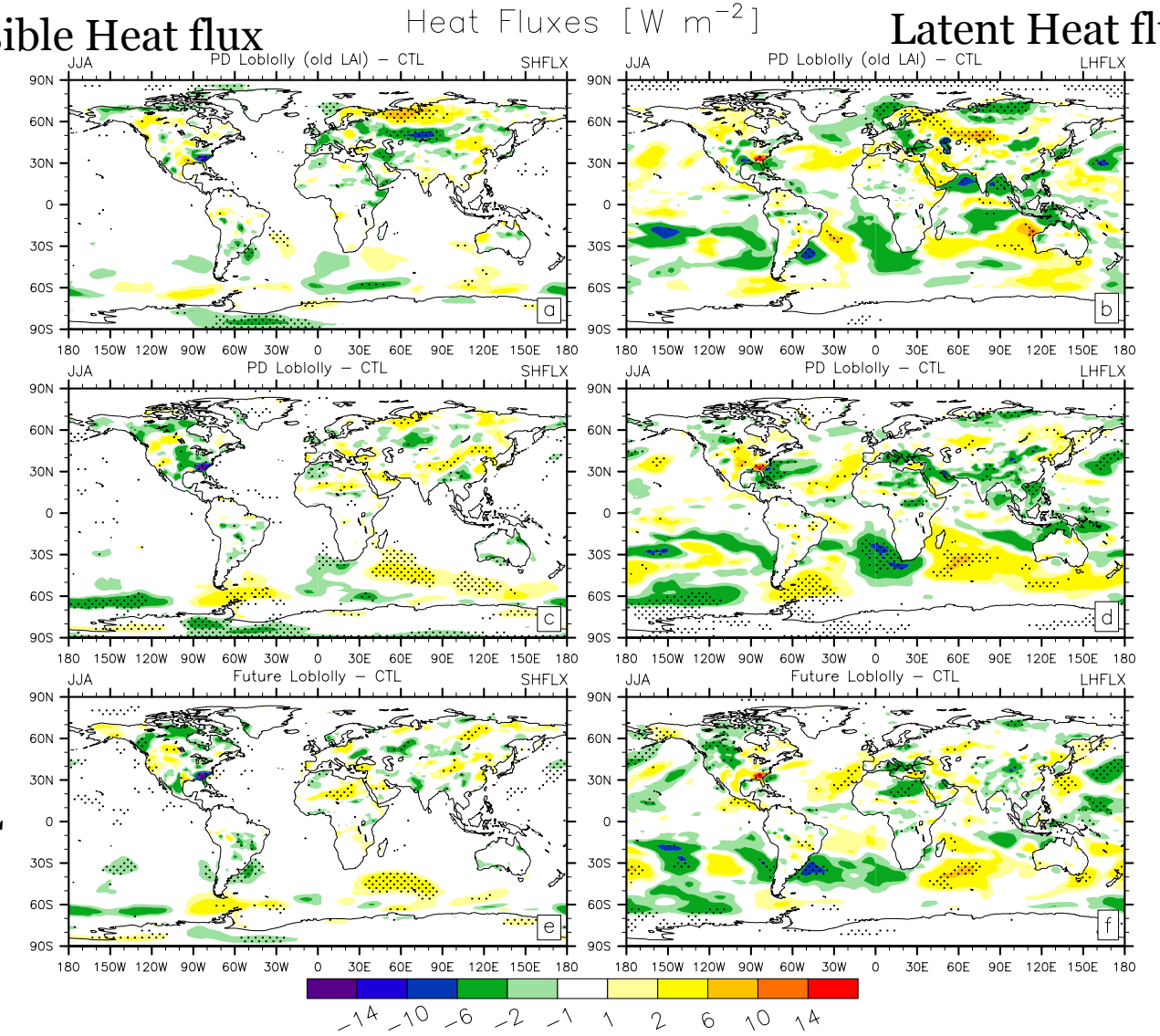
Sensible Heat flux

Latent Heat flux

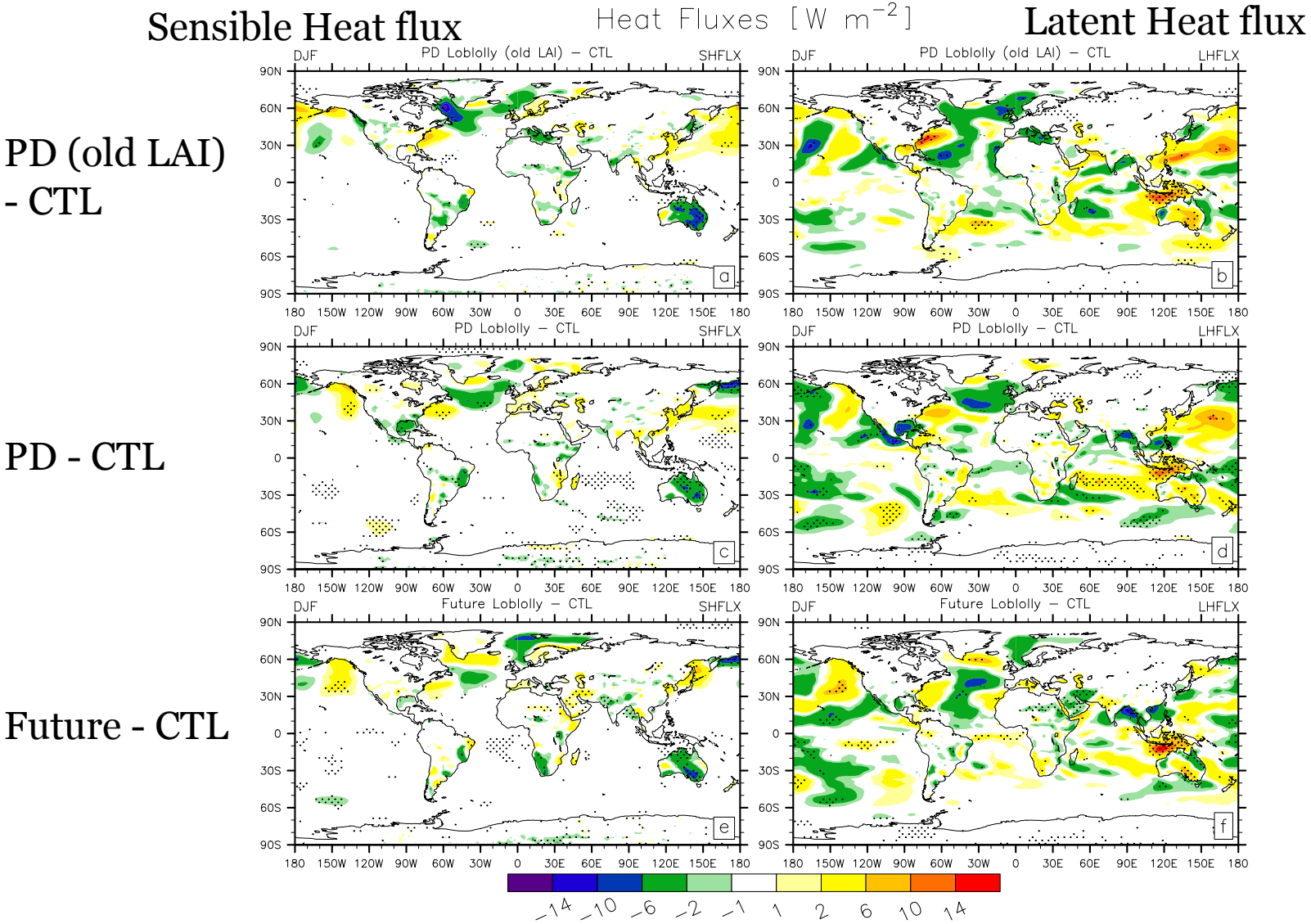
PD (old LAI) - CTL

PD - CTL

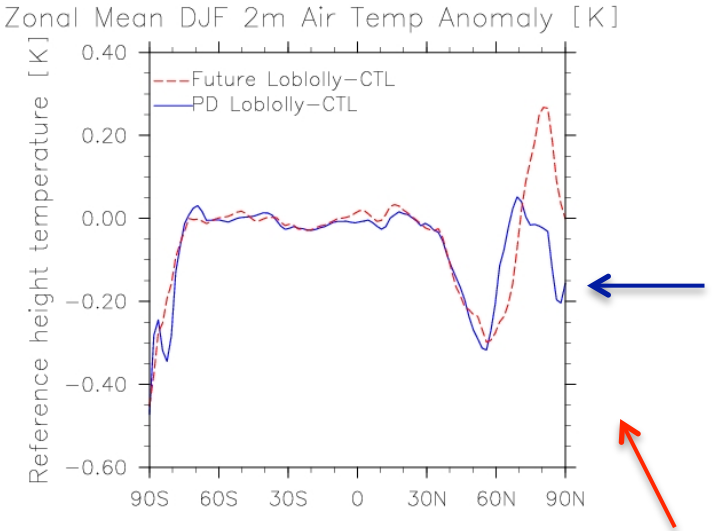
Future - CTL

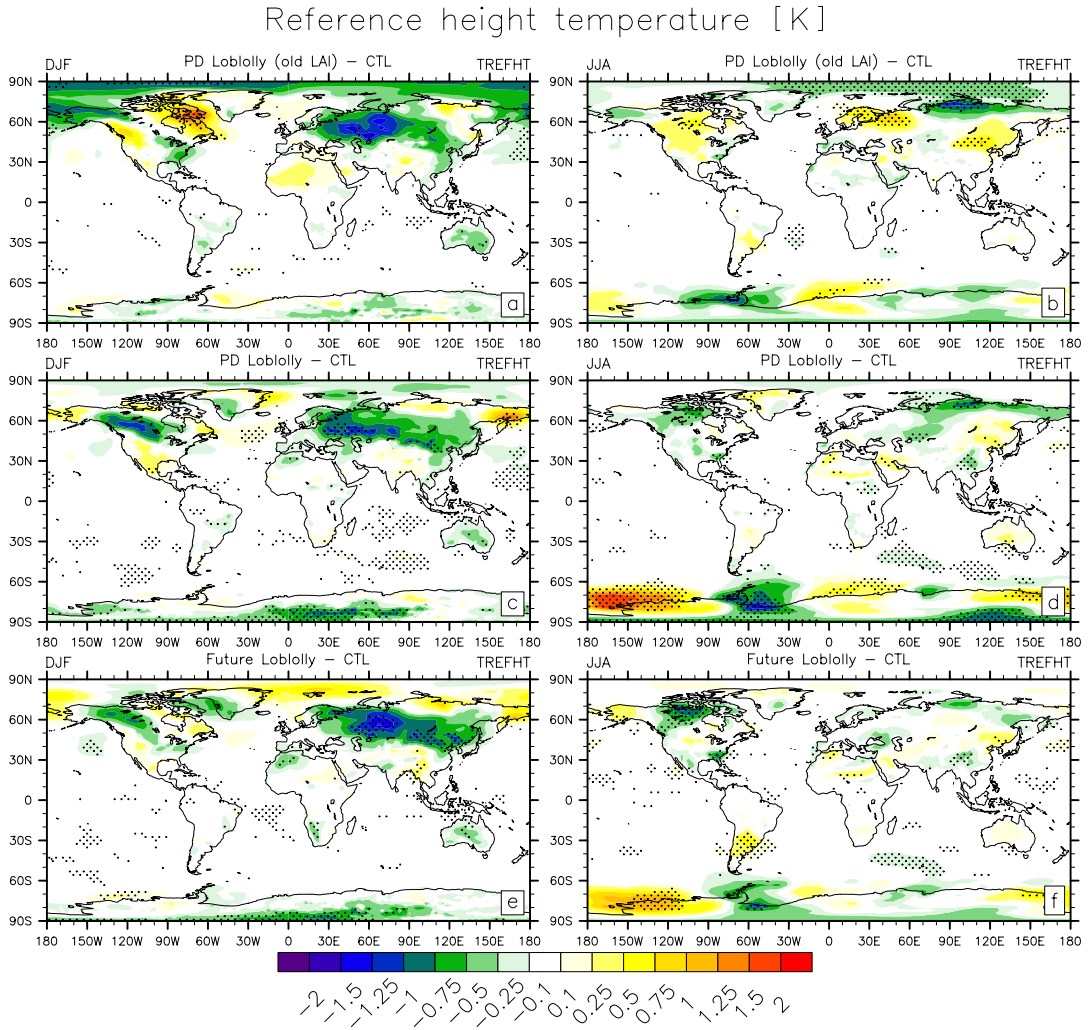


Results: DJF Heat fluxes



Results: 2m Air Temperature

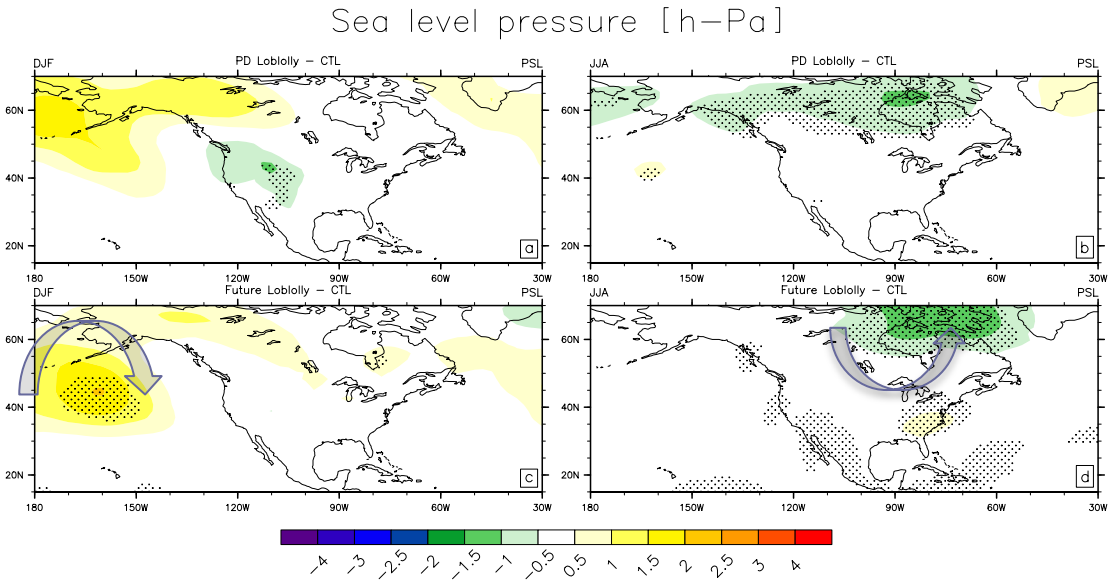




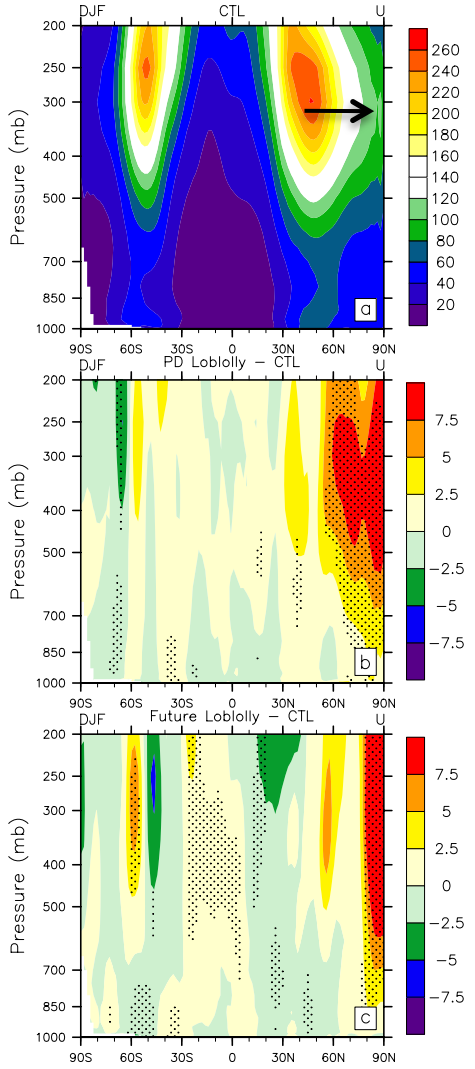
- Cooling of a quarter degree between 40-70°N due to the addition of Loblolly pine.

Results: Circulation changes

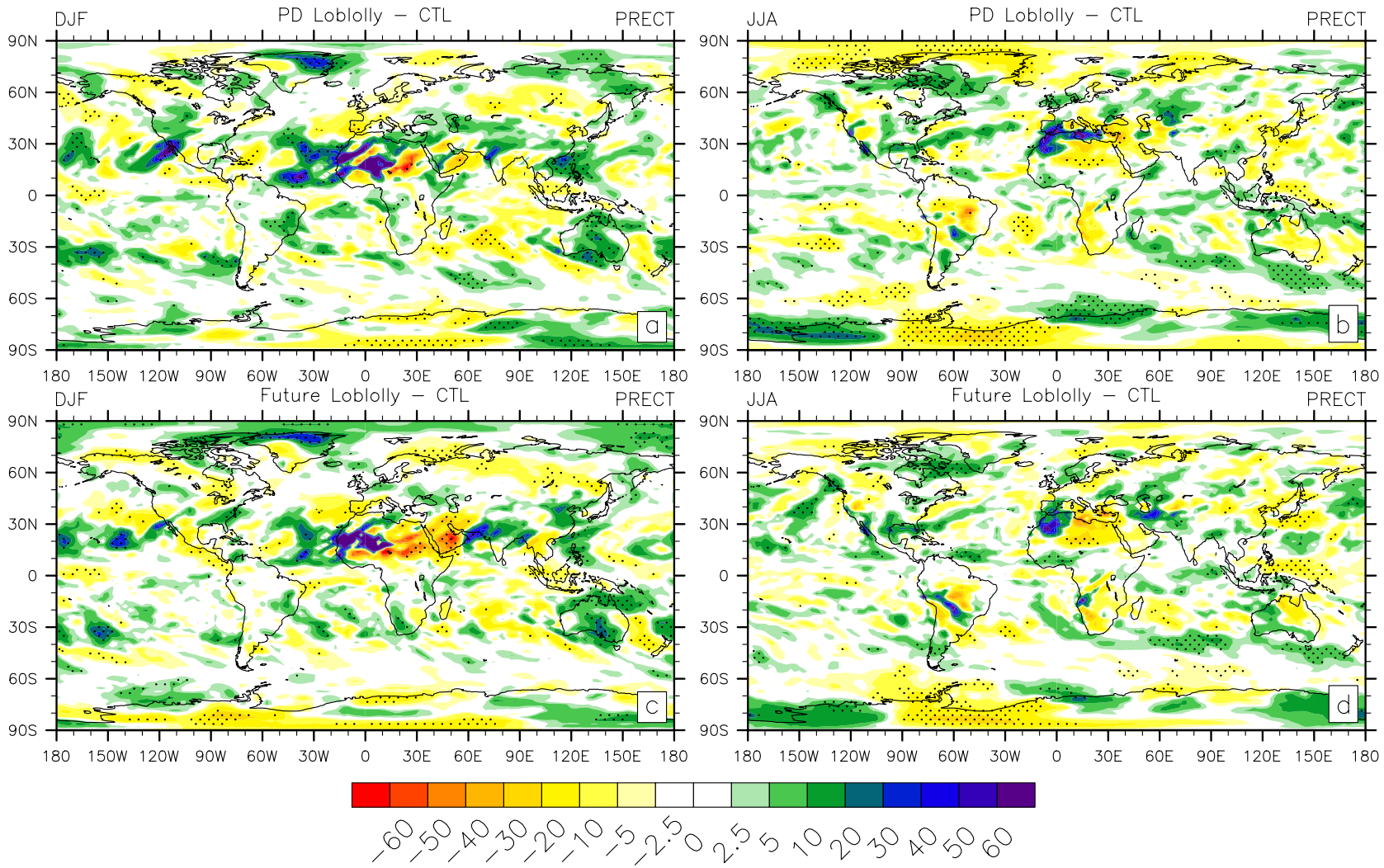
- Aleutian low is slightly weakened during DJF.
- Eddy kinetic energy averaged longitudinally shows increase in Northern Hemisphere suggesting northward shift in storm tracks.



Zonally averaged eddy KE

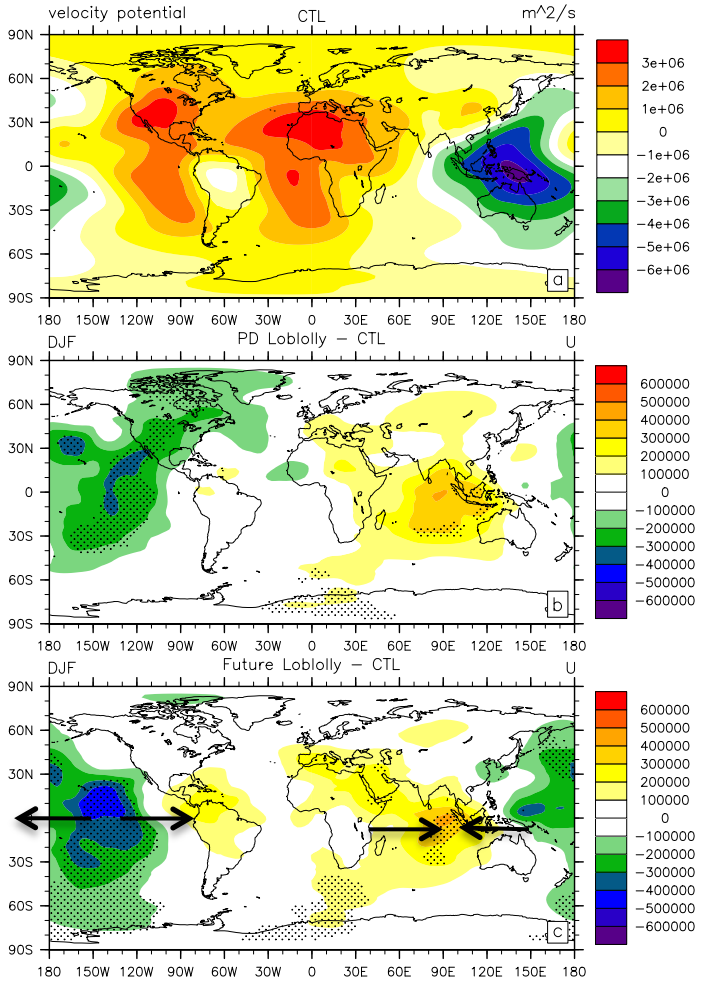


Results: Global precipitation anomaly (% change)



Results: Atmospheric divergence

DJF Velocity Potential 300 h-Pa



- Southern Hemisphere changes may result from the vorticity transport set up by perturbed large-scale divergence [Chase et al., 2000].
- Transport of vorticity by the divergent field is an effective transport mechanism, especially for tropical-extratropical teleconnections [Sardeshmukh and Hoskins, 1987].

Conclusions

- Our new optimized Loblolly PFT resulted in decreased sensible heat flux and increased latent heat flux compared to the NET PFT.
- Cooling over the SE US was largest in summer.
- Northern Hemisphere cooling between 40-70°N is largest in winter.
- Changes in the Aleutian low may alter storm tracks in the Northern Hemisphere.
- Perturbations in atmospheric divergent field may lead to teleconnections in the Southern Hemisphere due to vorticity advection.

References and Pictures

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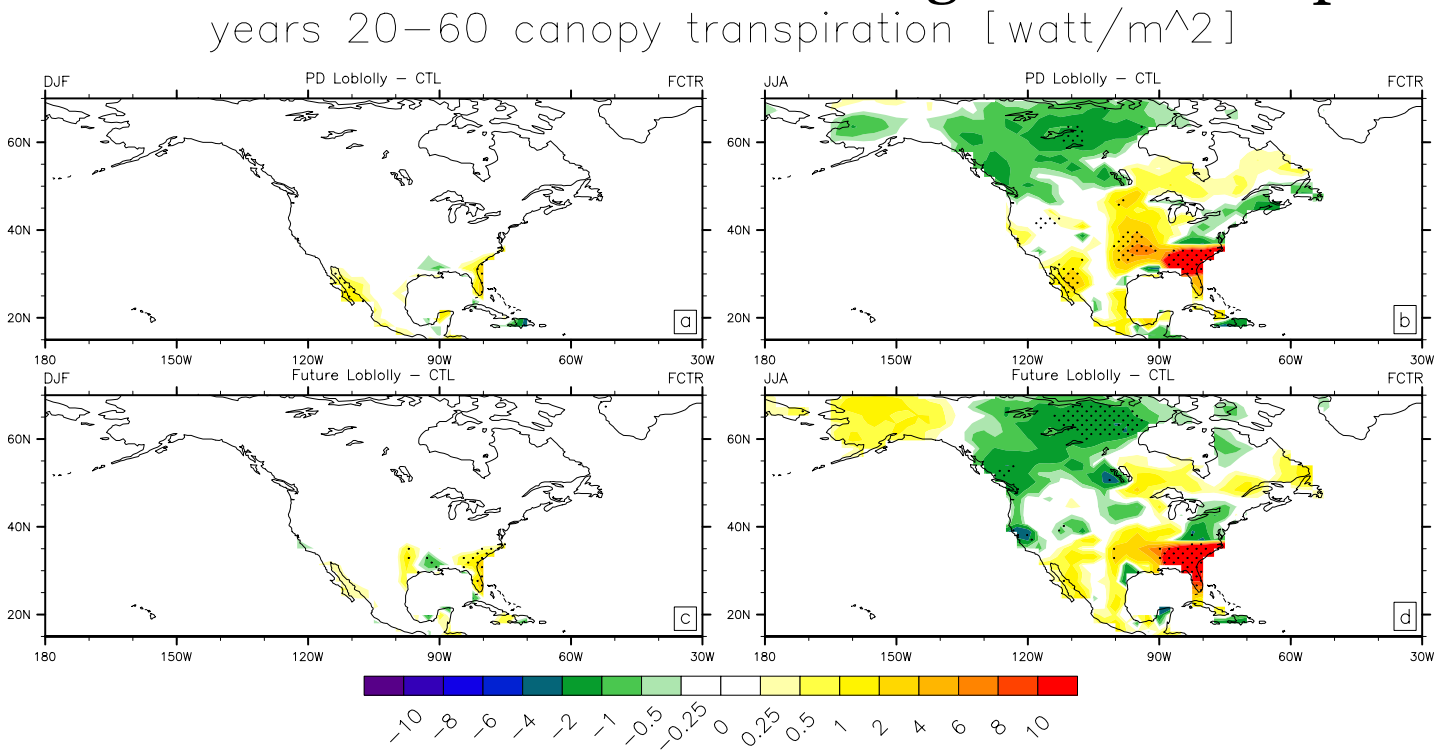
- Sardeshmukh P.D. and B.J. Hoskins, 1987: The generation of global rotational flow by steady idealized tropical divergence. J. Atmos. Sci., 45, 1228-1251.
- Slide 3: http://agronomyday.cropsci.illinois.edu/2005/Tour_D/Fuel/
- Slide 3: http://sites.google.com/site/sugarcanepm/pre-harvest-burning
- Slide 4: Connor, K.F., ed. 2006. Gen. Tech. Rep. SRS-92, USDA

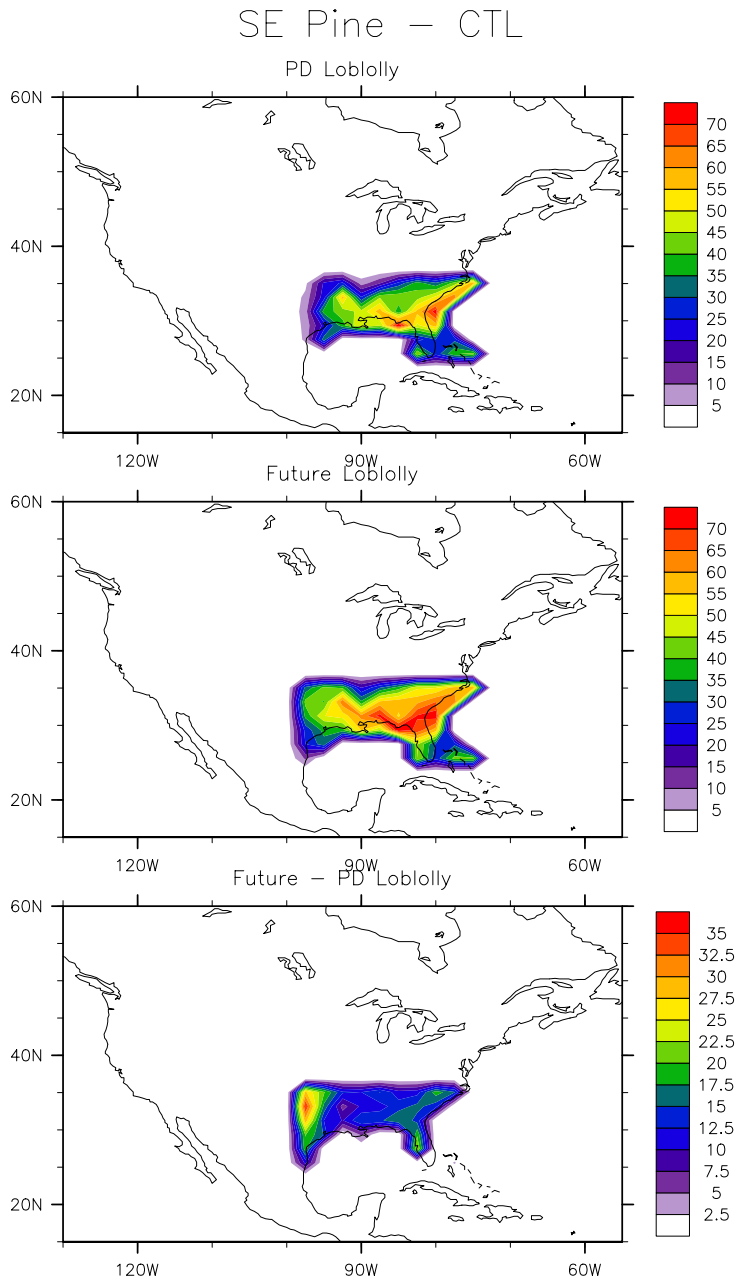
THANKS!

Results: Canopy transpiration

- Higher transpiration over SE US during the summer is due to physiology changes and not LAI changes.
- Development of Low Pressure over Northern Canada results in greater low level cloud cover – which reduces the short wave radiation at the surface leading to less transpiration.

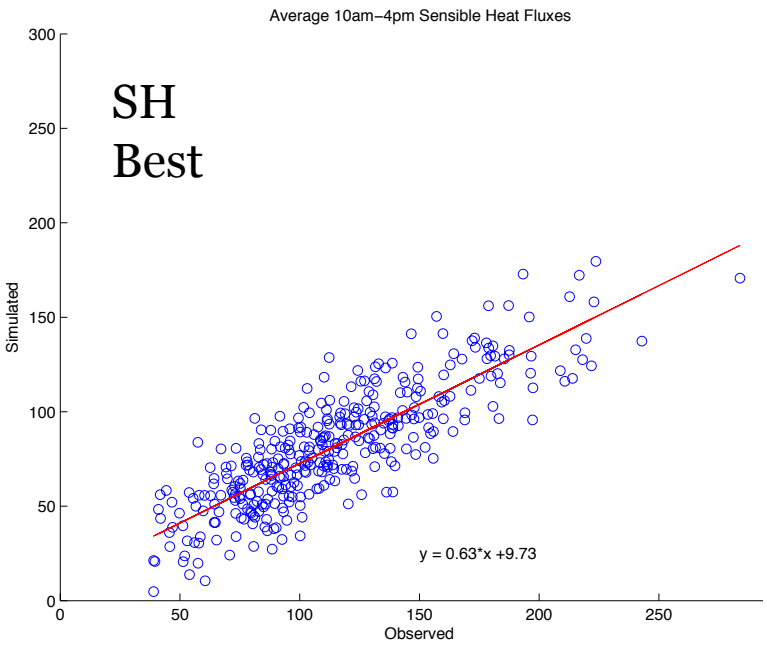


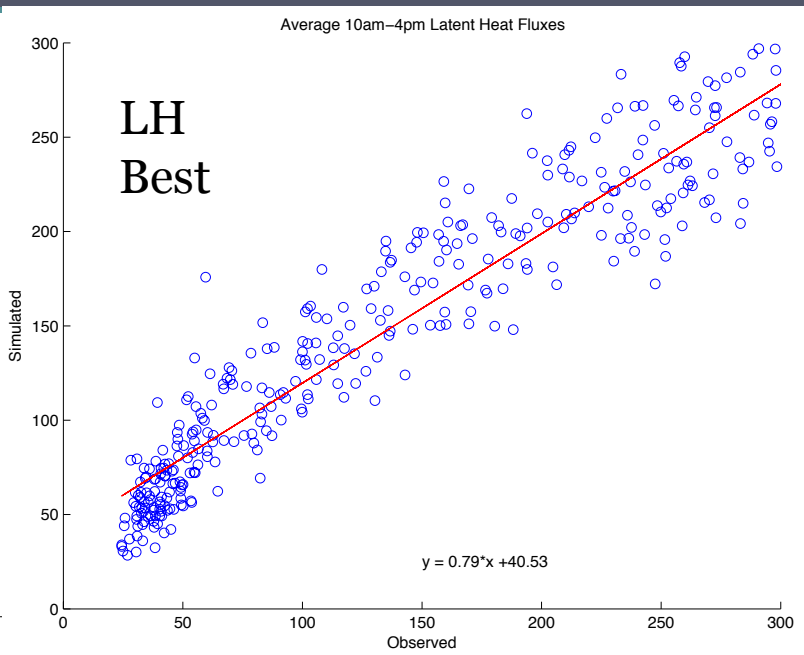
LCC

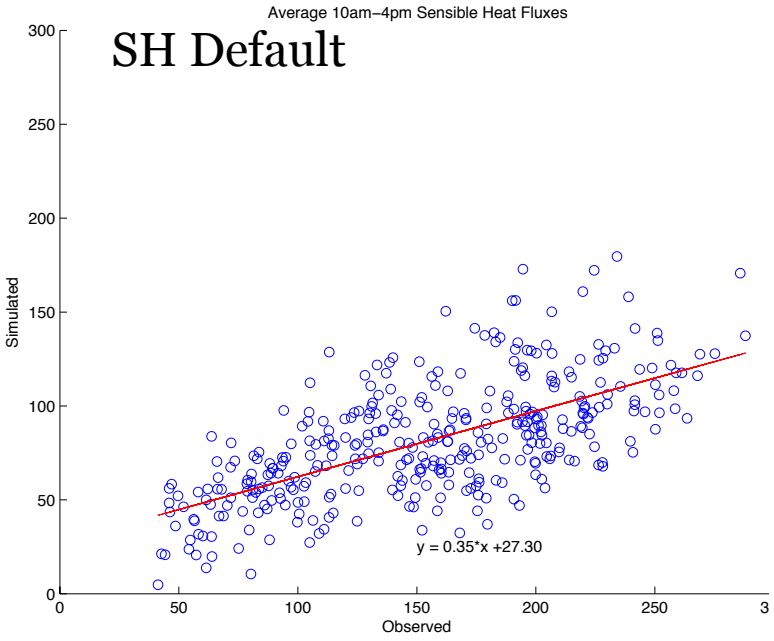


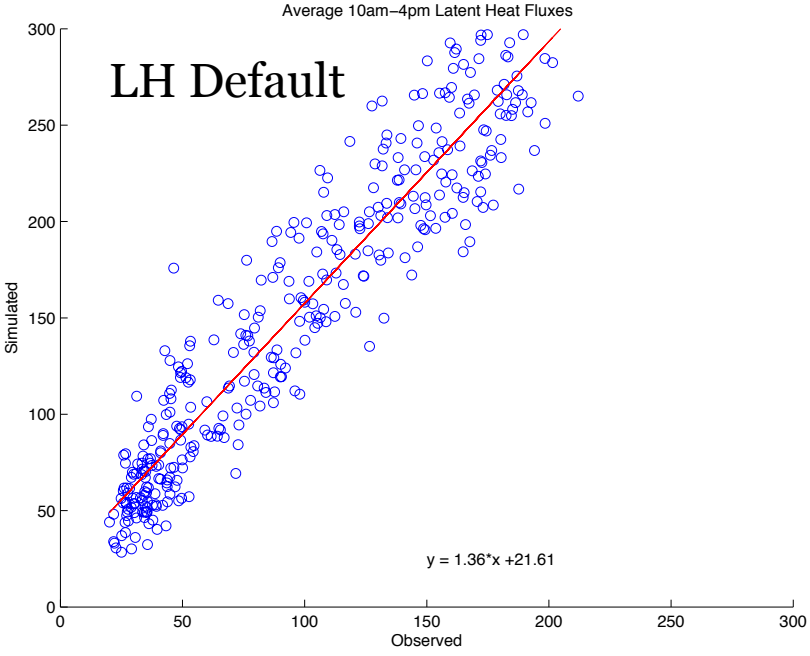
PD temperate
NET distribution

PD temperate
NET distribution
+ C4 grasslands


Average 10am–4pm Sensible Heat Fluxes
SH
Best
Simulated
Observed
y = 0.63*x +9.73
0
50
100
150
200
250
300


Average 10am–4pm Latent Heat Fluxes
LH
Best
Simulated
Observed
y = 0.79*x +40.53
0
50
100
150
200
250
300


Average 10am–4pm Sensible Heat Fluxes
SH Default
Simulated
Observed
y = 0.35*x +27.30
0
50
100
150
200
250
300


Average 10am–4pm Latent Heat Fluxes
LH Default
Simulated
Observed
y = 1.36*x +21.61
0
50
100
150
200
250
300

Figure

Results: Atmospheric divergence

JJA Velocity Potential 300 h-Pa