Impact of afforestation with Loblolly Pines in the Southeastern US on regional and global climate

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EARTH SCIENCES DIVISION

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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

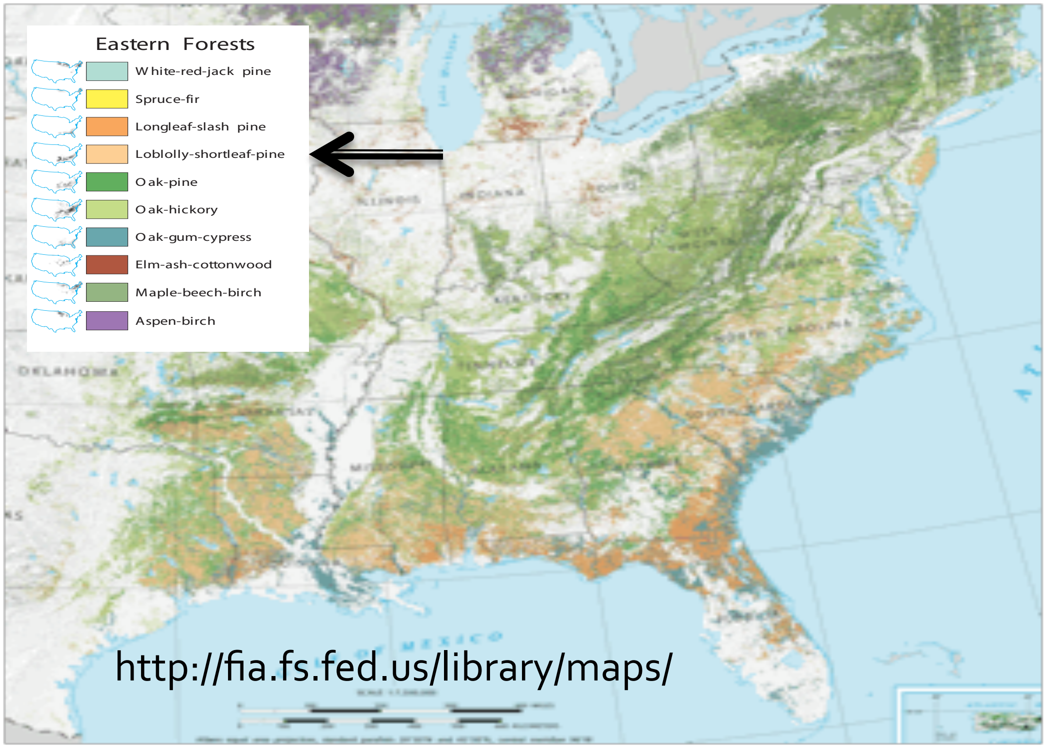
- LCC impacts the energy, radiation and hydrological budgets at regional to global scales.
- LCC due to expansion of biofuels may have non-trivial effects on climate through biophysical feedbacks.


- Growing perennial grasses (Miscanthus) instead of annual crops (maize) caused regional cooling of up to 1°C due to higher LAI, ET and rooting depth (Georgescu et al., 2009; Georgescu et al., 2011).
- Growing sugar cane crops on agricultural land cooled temperatures by almost 1°C due to enhanced ET and higher albedo (Loarie et al., 2011).

Loblolly Pine (Pinus taeda)

- 83% of the 45 million acres of plantation forest in the southern US are Loblolly pine (*Pinus taeda L.*; 75%) and Slash pine (*Pinus ellioti*; 25%) (Smith et al., 2002; Zhang and Polyakov, 2010).

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

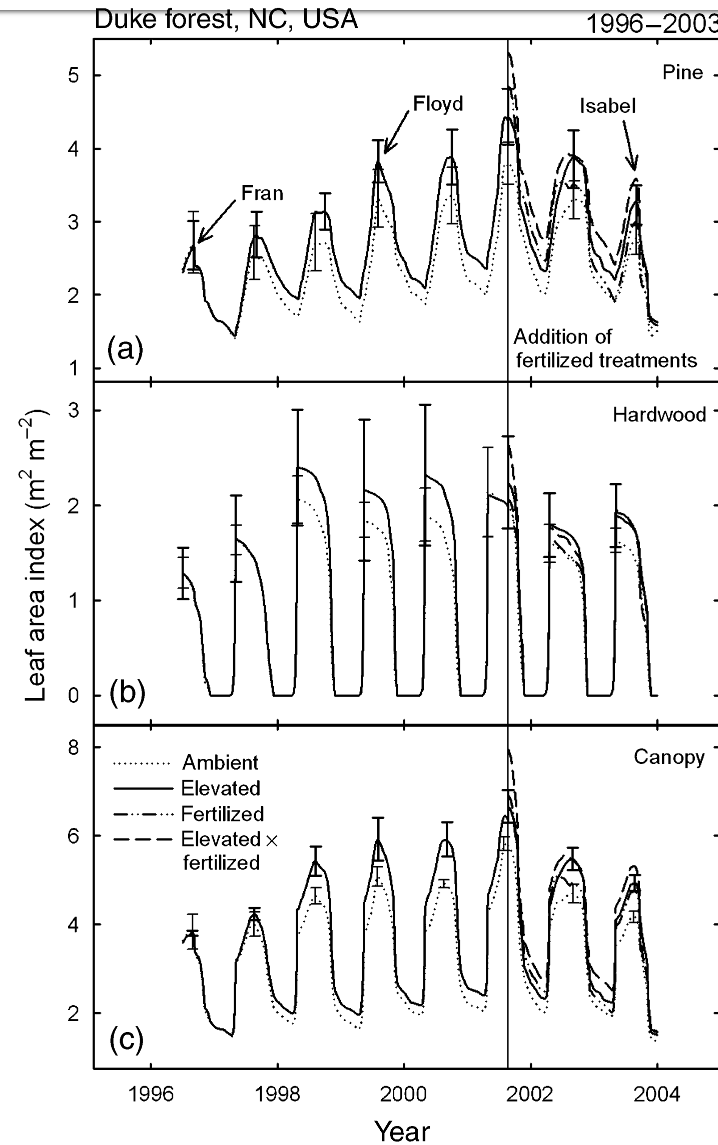


Motivation

Fig 5 from McCarthy et al. (2007)

- CLM4 has a single plant functional type (PFT) that represents temperate needleleaf evergreen trees (NET), which has a flat seasonal LAI with almost no difference between winter and summer values.

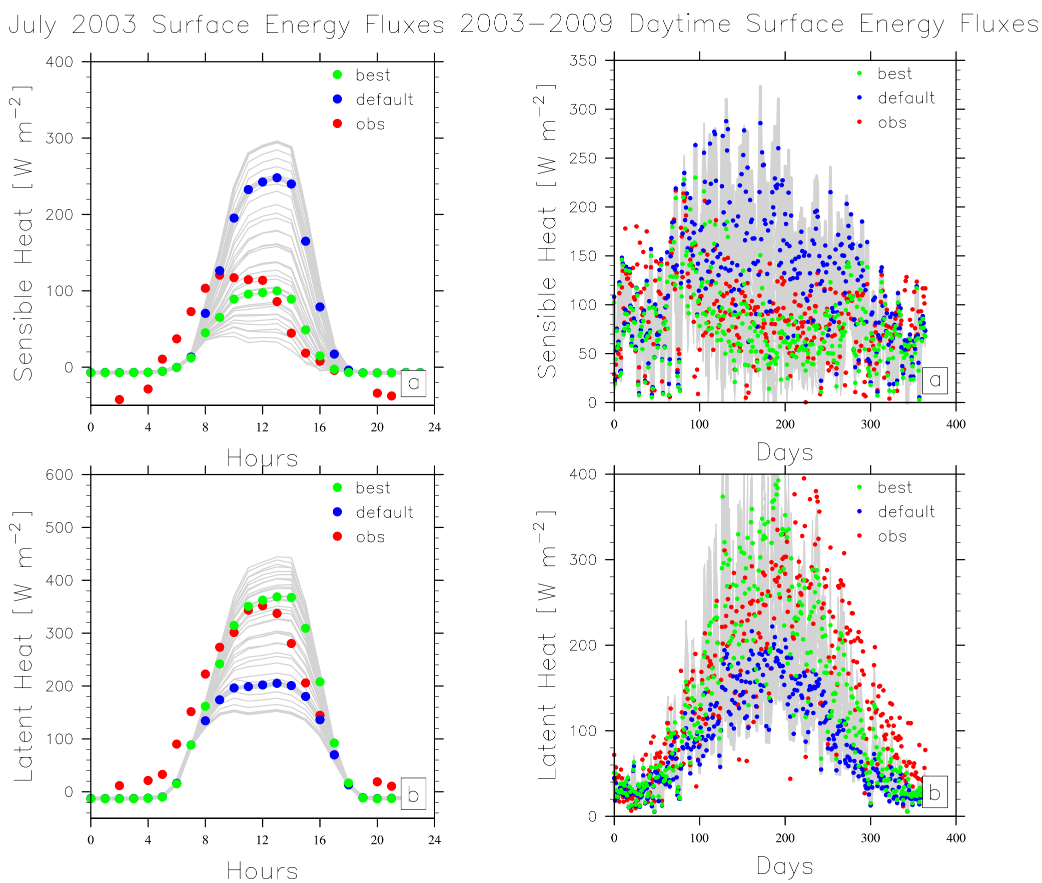
- LP has a relatively rapid 18-month needle turnover rate for evergreen species that yields a seasonally-varying leaf area index (LAI).



Methodology

- We examine the biogeophysical effects of biofuel feedstock production on regional and hemispheric climate under a plausible 21st century deployment scenario in the Southeastern United States (SUS).
  - Land area between 30-40°N and 70-100°W
- To represent Loblolly pine in CLM4 we optimized PFT physiology parameters to minimize observed versus predicted differences in energy fluxes.
- We use observations from the AmeriFlux Duke Forest Loblolly site (Stoy et al., 2006; Novick et al., 2009).
- Representing the seasonal changes in photosynthesis and stomatal conductance is critical for modeling energy fluxes of ecosystems (Xu and Baldocchi, 2003).

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 prescribed SSTs and no CN cycling ("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.

Results: JJA Heat fluxes

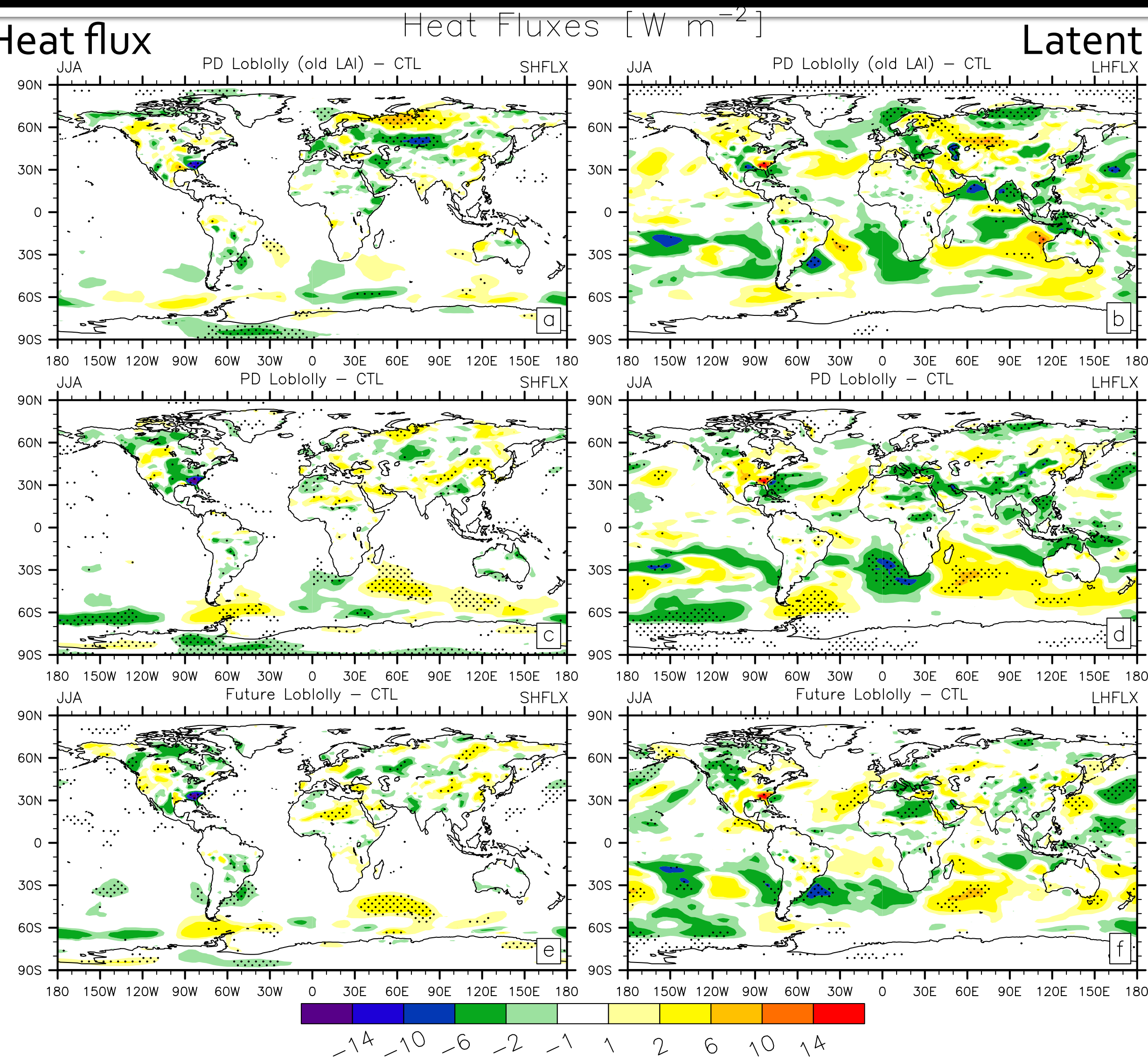
Sensible Heat flux

Latent Heat flux

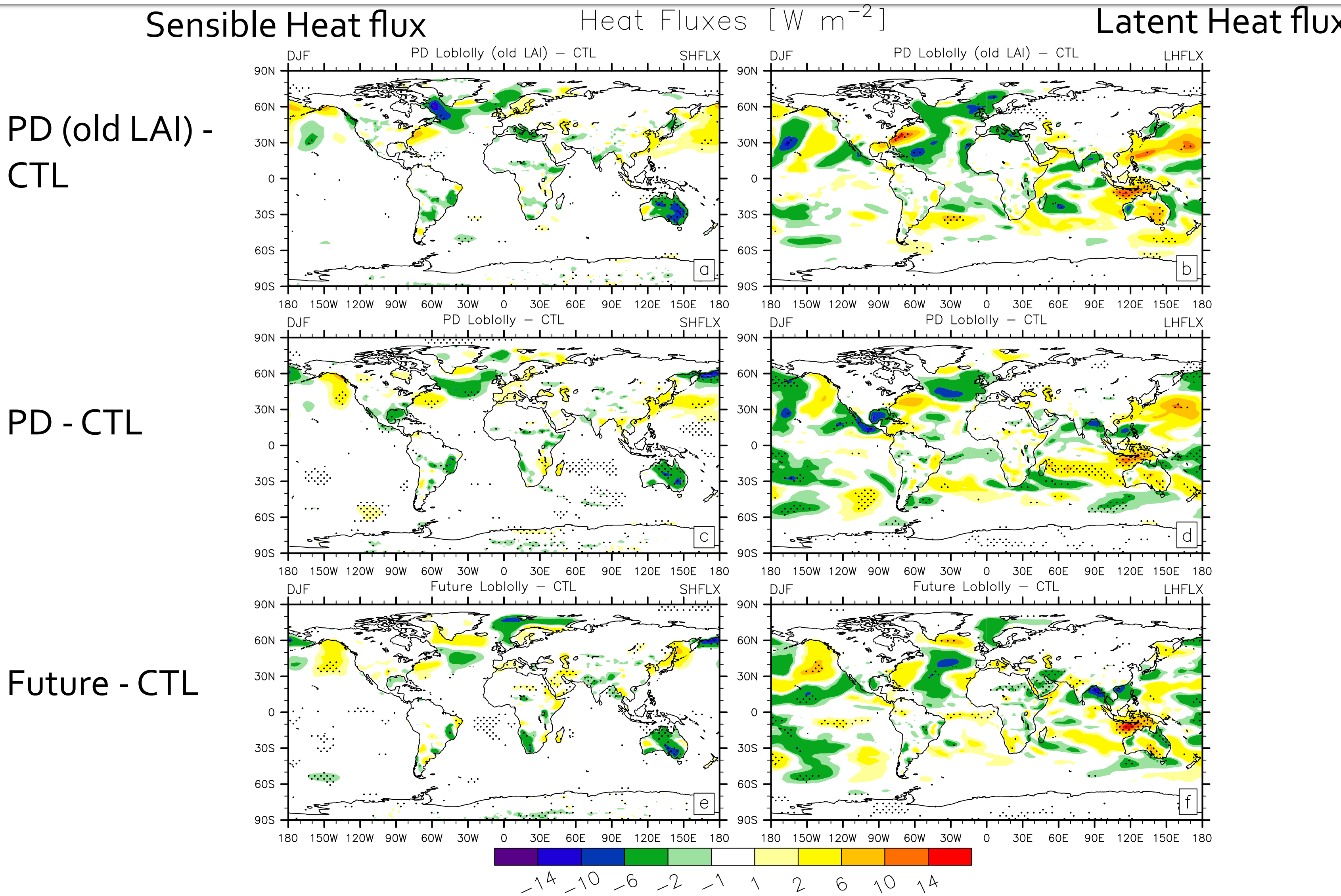
PD (old LAI) - CTL

PD - CTL

Future - CTL



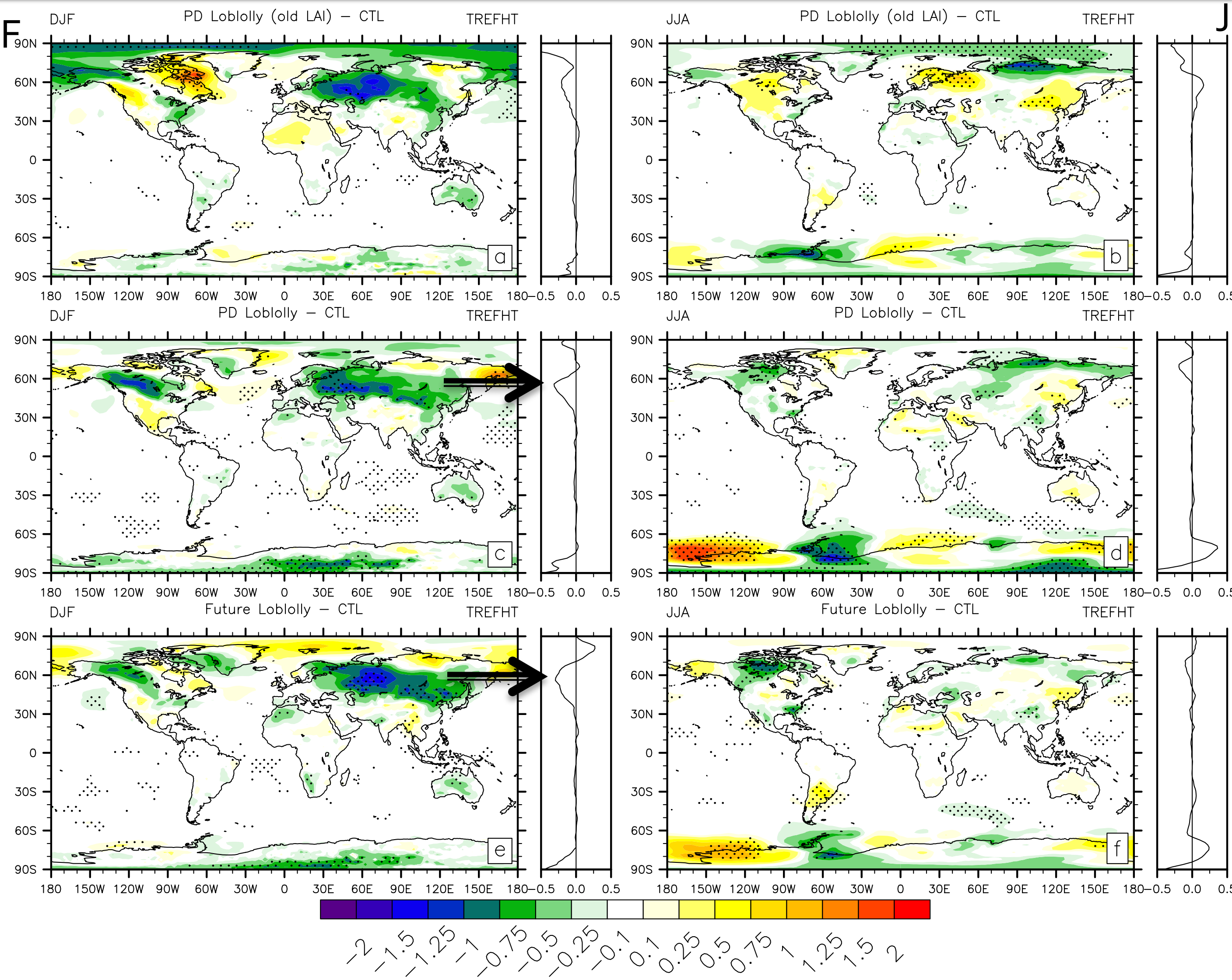
Results: DJF Heat fluxes



Results: 2m Air Temperature

DJF

JJA

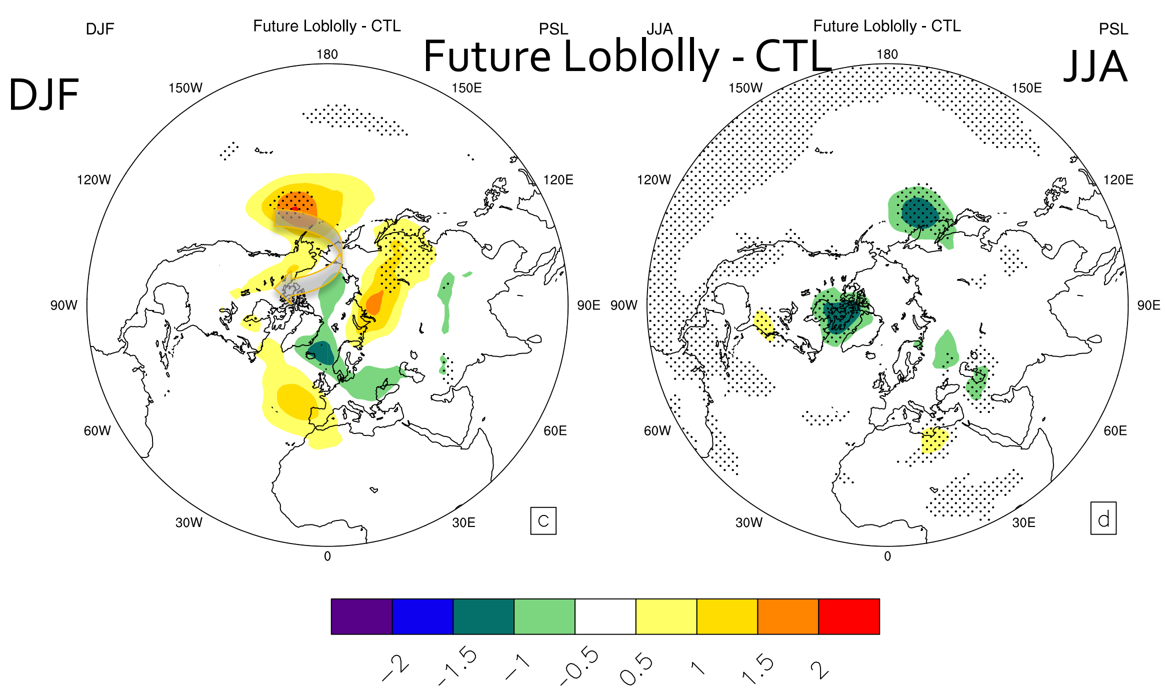


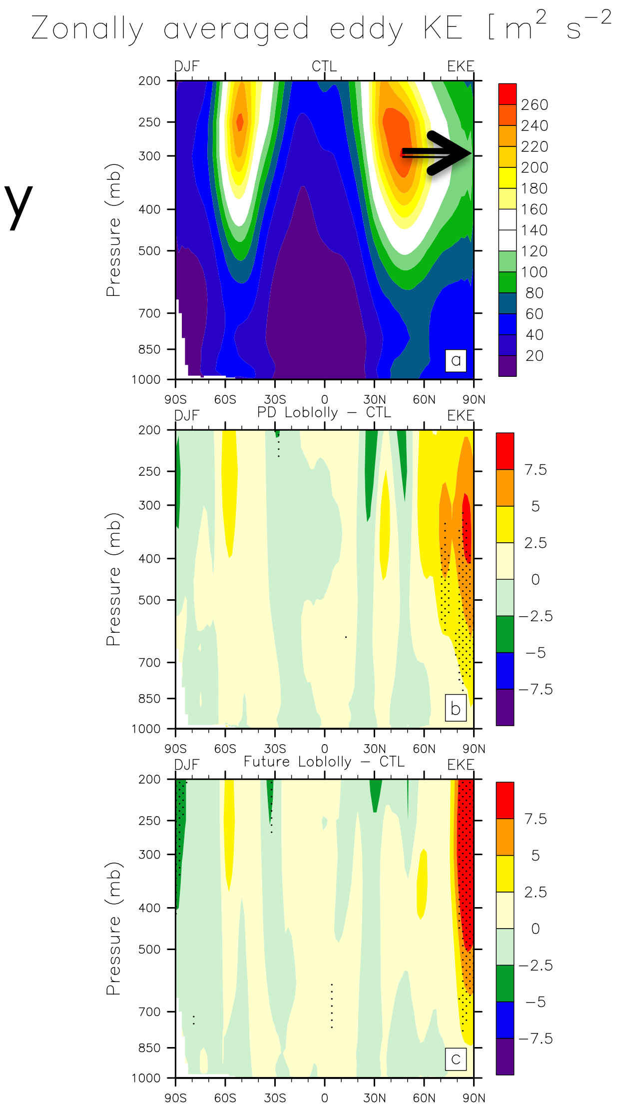
- DJF cooling of 0.25°C between 40-70°N.

Results: Circulation changes

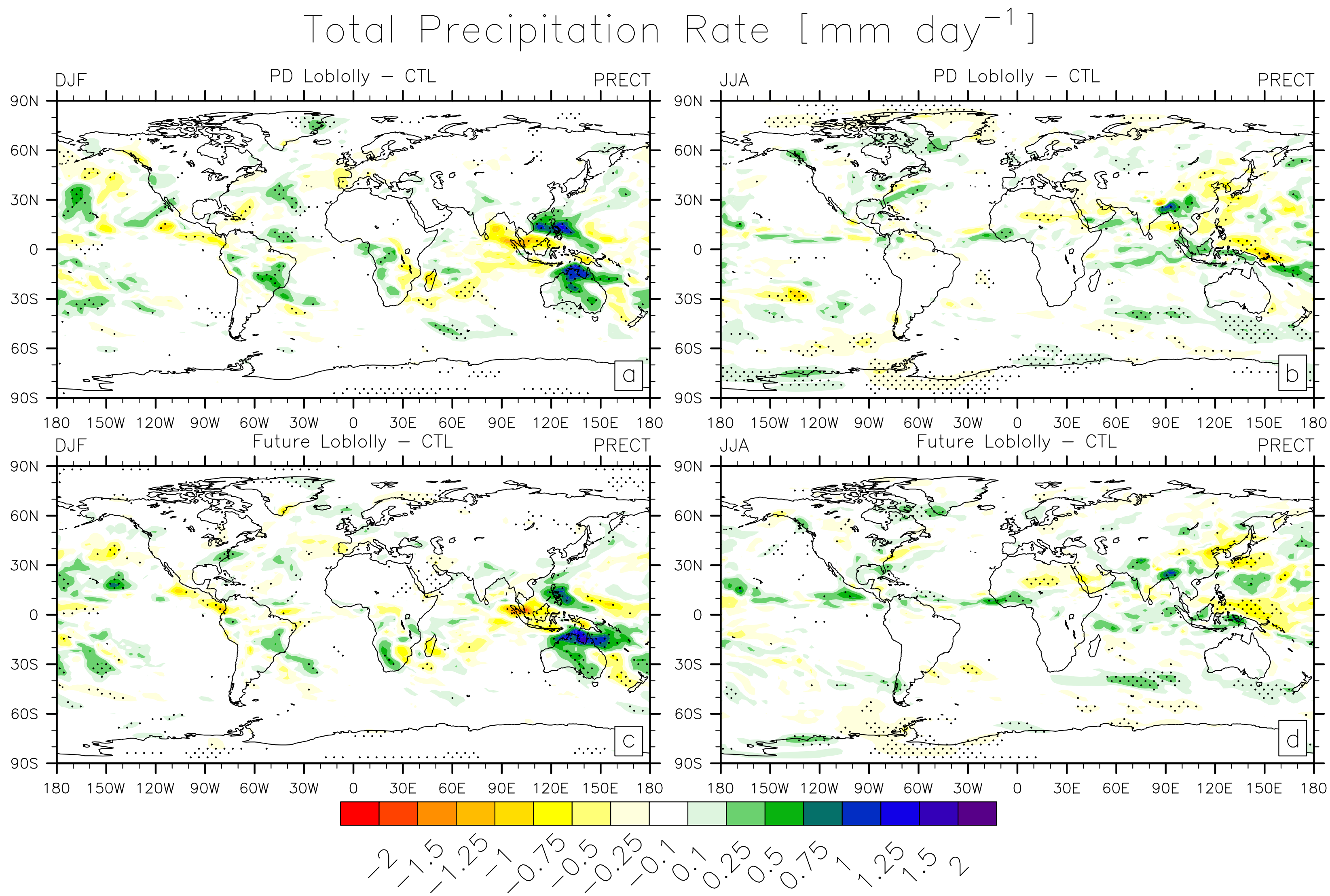
- Aleutian low is weakened during DJF.

- Eddy kinetic energy averaged longitudinally shows increase in Northern Hemisphere suggesting northward shift in storm tracks.



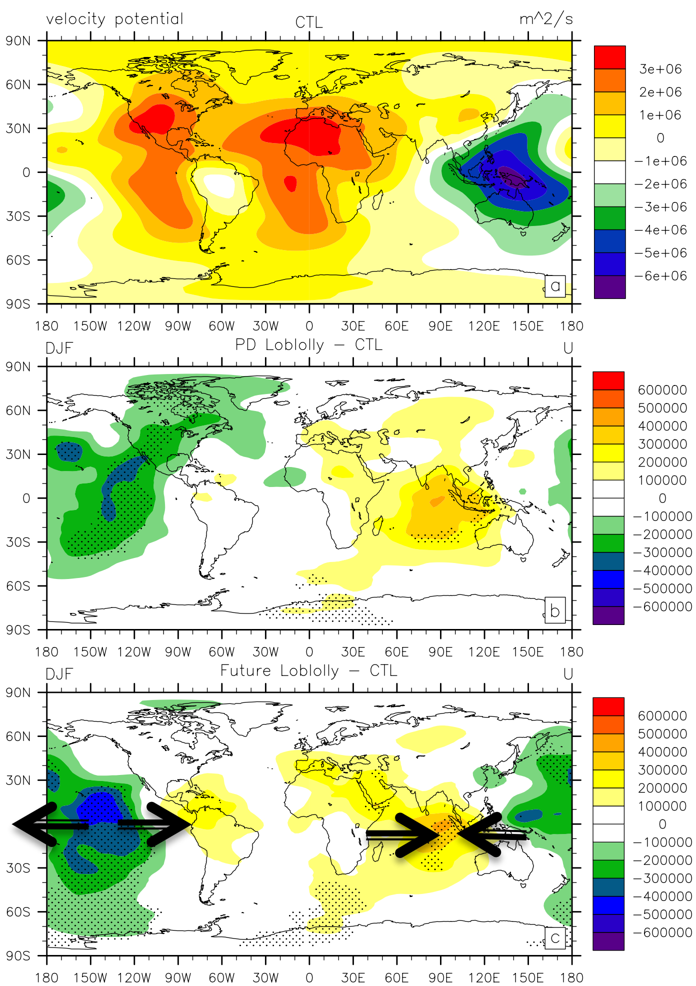


Results: Global precipitation anomaly



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 decreases sensible heat flux and increases latent heat flux compared to the NET PFT.
- Local cooling over the SUS is largest in summer.
- Remote cooling is largest in winter between 40-70°N.
- Weakening of 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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