An Assessment of coupling of GFS model with SSiB Land surface model on regional Climate

by

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Outline

- **Coupling of SSiB2 model with Global Forecast System (GFS)**
- **Annually varying Land Use Land Cover Change (LULCC) maps**
- **Experimental setup**
- **Evaluation of LULCC impact on Temperature and rainfall.**

GFS-SSiB2 Model

- **In this study, we have adopted the National Centre for Environmental Prediction (NCEP) Global Forecast System (GFS).**
- **We set the spectral discretization of the NCEP GFS model at T62L28, which has about 200 km of grid spacing with 28 vertical levels.**
- **The NCEP GFS model is coupled with the second version of the Simplified Simple Biosphere land surface model (SSiB2).**

GFS-SSiB2 Model

- **The SSiB2 is a state-of-the-art vegetation biophysical model that includes photosynthesis in land surface processes while preserving energy, water, and momentum conservation at the atmosphere-land surface interface**

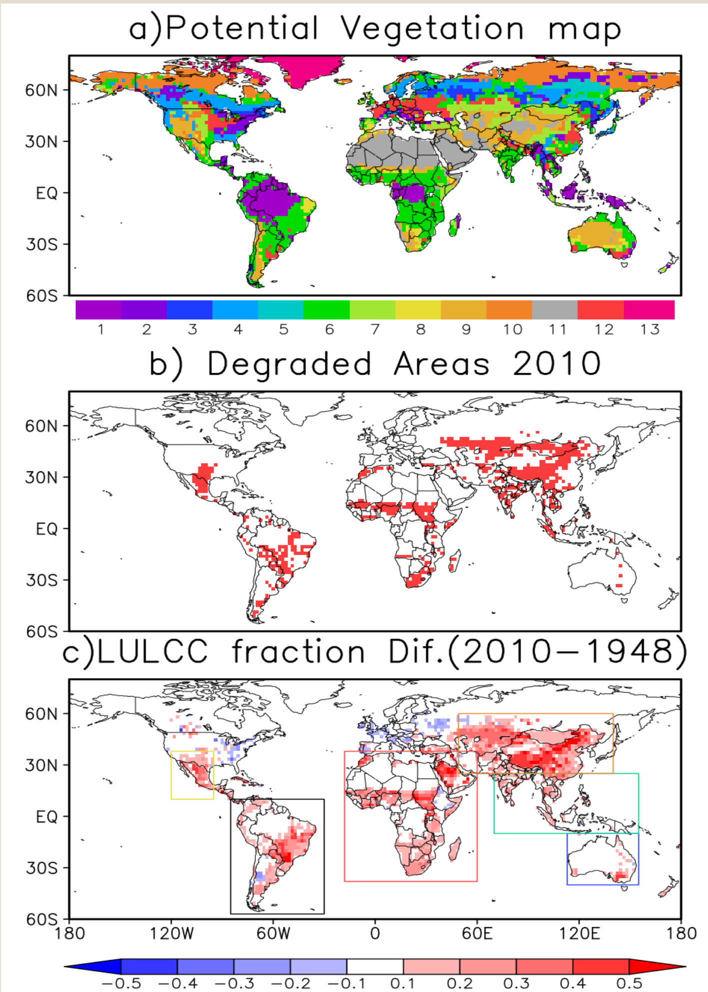
Annually varying Vegetation

- ✓ **LULCC is a gradual change with significant effect on regional and global weather and climate.**
- ✓ **Previous modeling studies implemented LULCC without gradual change, which may lead to unrealistic assessment of LULCC effect.**
- ✓ **In this study, we have implemented LULCC gradually (potential vegetation map updated annually) to assess the merits of this methodology.**

Experimental setup

- **We have conducted two experiments, one with a potential vegetation map without interannual variability(CTL) and another one with an annually varying vegetation map (LULCC experiment).**
- **In the LULCC experiment, the potential vegetation map is updated annually based on historical land use land cover re-constructed data (**Hurtt *et al.*, 2006, 2011)**.**

Land use land cover change

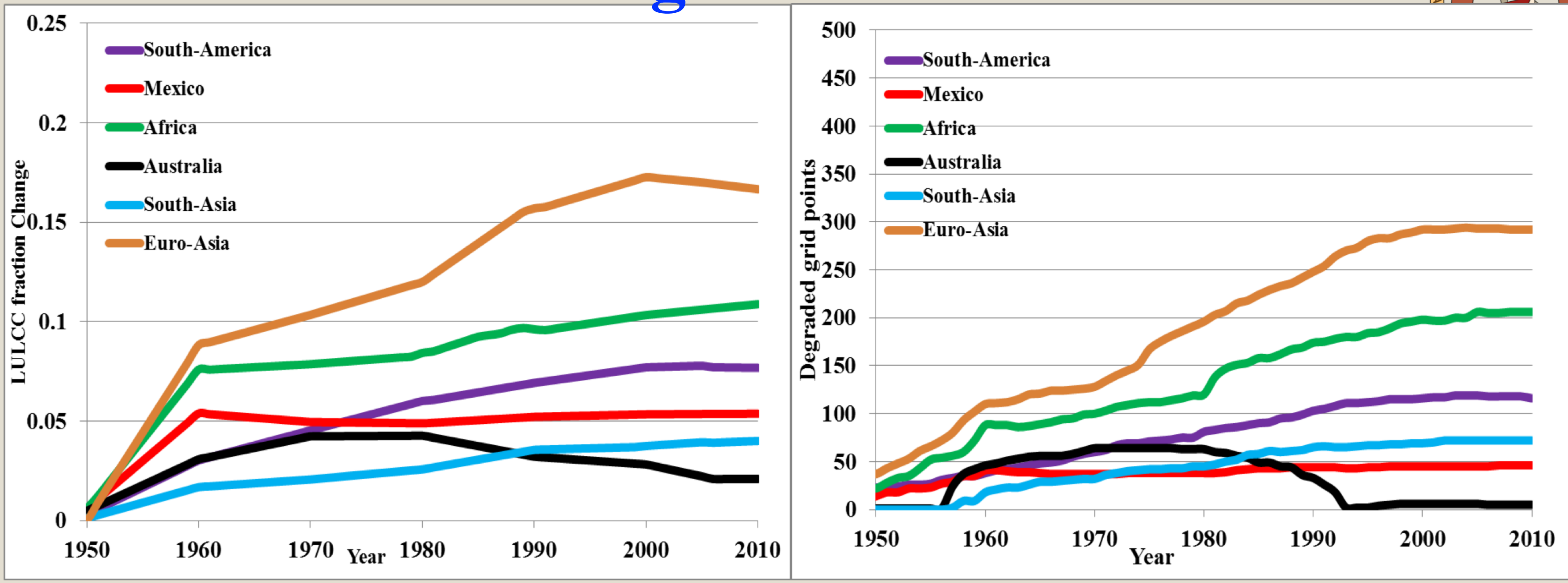


S.No	Description
1	Tropical rainforest
2	broadleaf deciduous trees
3	broadleaf and needle leaf trees
4	needle leaf evergreen trees
5	needle leaf deciduous trees
6	broadleaf trees with ground cover
7	Grass land
8	broadleaf shrubs with ground cover
9	broadleaf shrubs with bare soil
10	dwarf trees with ground cover
11	bare soil
12	Crops
13	Ice

- **Potential vegetation map used in this study (a; see Table for vegetation types), degraded areas in the year 2010 in the LULCC experiment (b) and LULCC fraction difference between 1948 and 2010 (c).**
- ***We have implemented annually varying vegetation map***

*Ref# **Nagaraju C.,** and Y. Xue; An assessment of potential climate impact during 1948-2010 using historical land use land cover change maps, International journal of climatology, Apr 2020. https://doi.org/10.1002/joc.6621*

LULCC Changes Vs Number of Grids

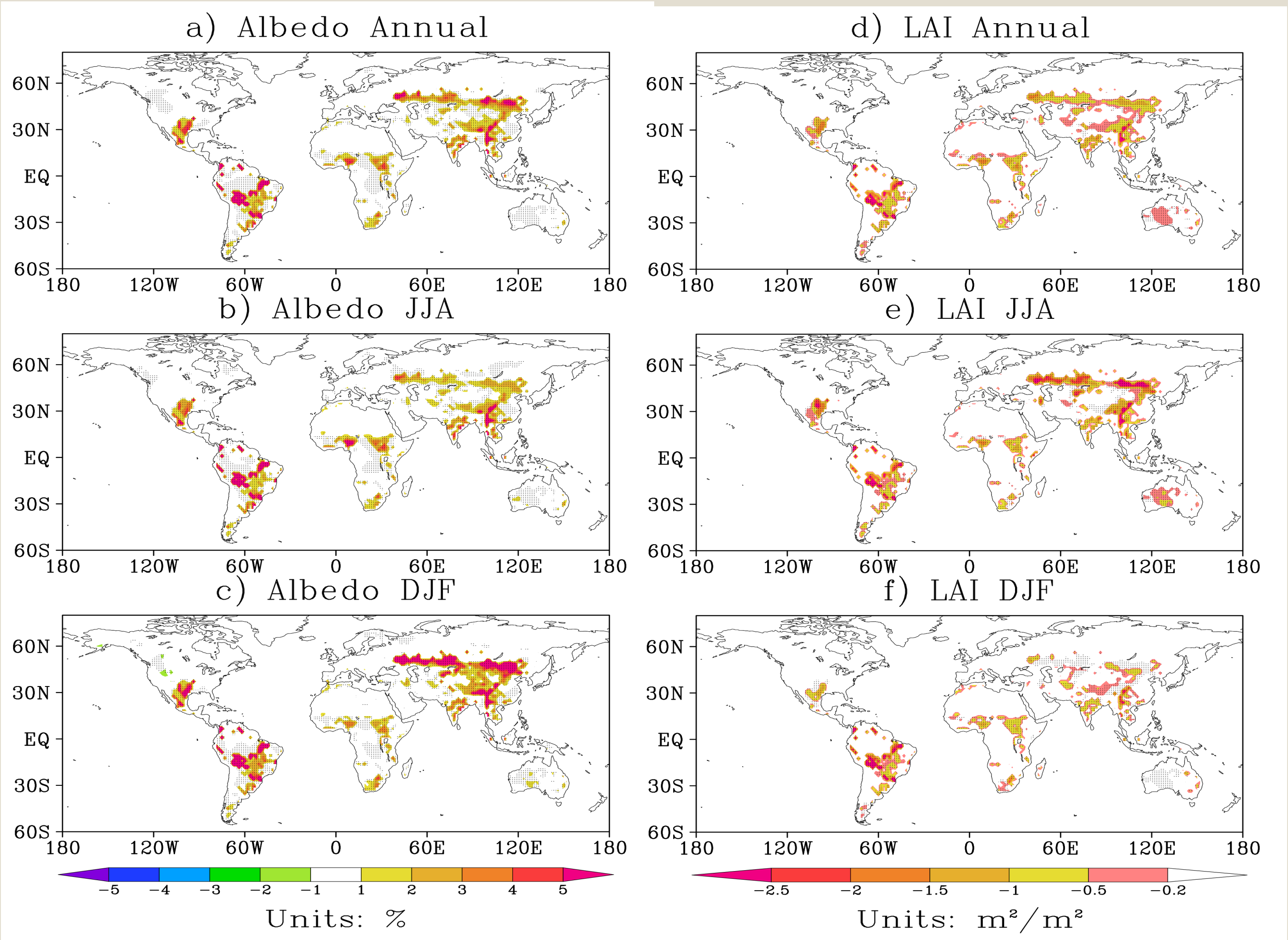


Time series of LULCC fraction difference (left panel) relative to the 1948 for each area specified in the figure 1 and changes in the number of grid points degraded in each region (right panel) from 1950 to 2010.

- **A methodology had been developed to convert the LULCC fraction map with 1° resolution to the GCM grid points in which only one dominant type was allowed.**

- **Comprehensive evaluations were conducted to ensure the consistence of the trend of the original LULCC fraction change and that the trend of the fraction of grid point changes over different regions.**

Albedo & LAI difference

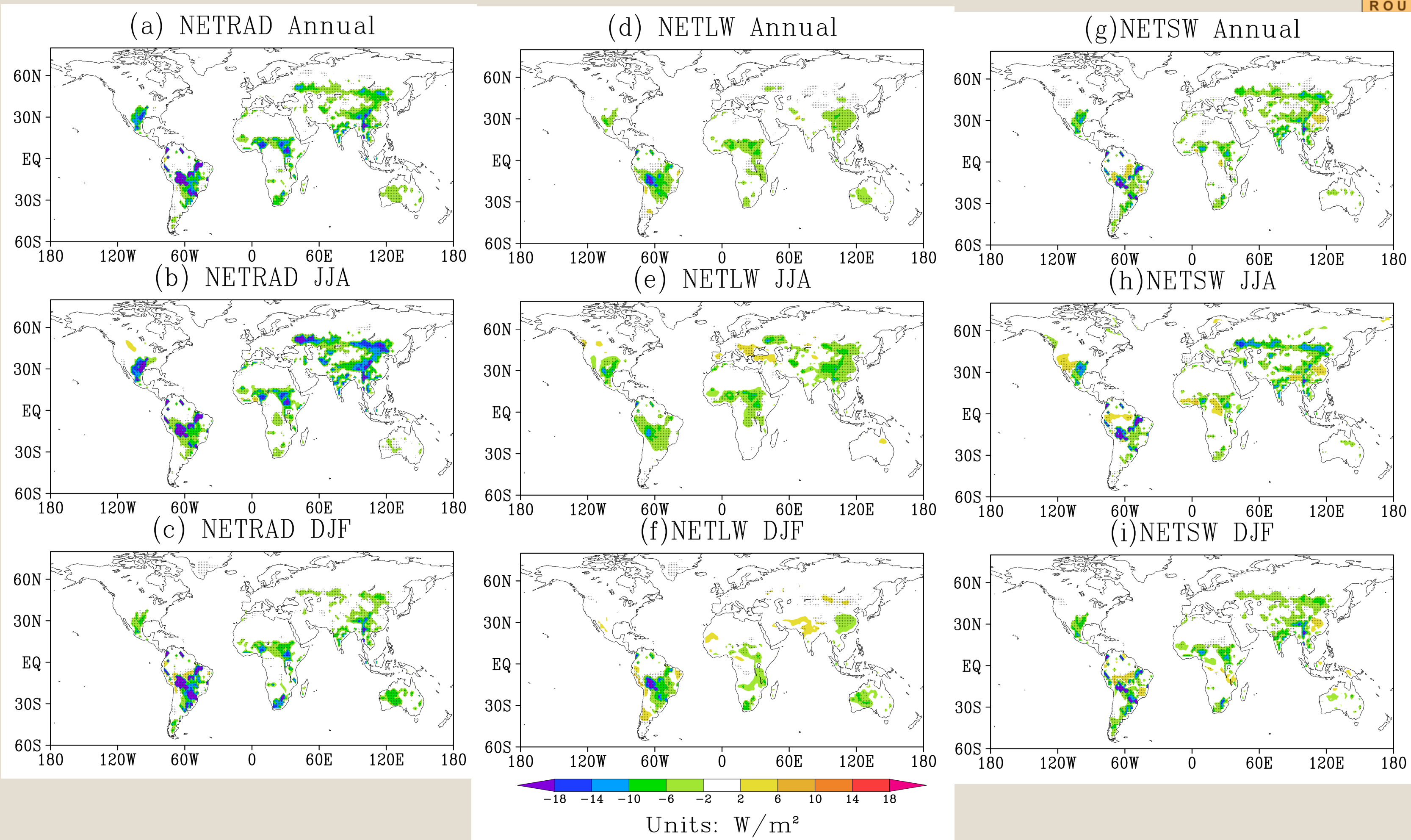


LULCC simulated Albedo difference (%; left column) and leaf area index (LAI) (m2 /m2) difference (LULCC – CTL; right column) for annual, JJA and DJF seasons averaged from 1948 to 2010. The stippled region in the figure indicates that the anomalies are significant at 95% based on two tailed Student's t -test

	Variable name	Units	Mean (CTL simulation)	Diff (LULCC-CTL)
Annual	Albedo	%	27.66	3.24
	Leaf Area Index	m^2/m^2	2.12	-1.0
	Net Surf. Radiation	W/m^2	93.68	-10.9
	Latent Heat	W/m^2	47.38	-8.91
	Sensible Heat	W/m^2	39.92	-2.11
	Ground Heat	W/m^2	0.48	0.12
	Surf. Temperature	K	289.78	0.44
	Precipitation	mm/day	2.76	-0.32

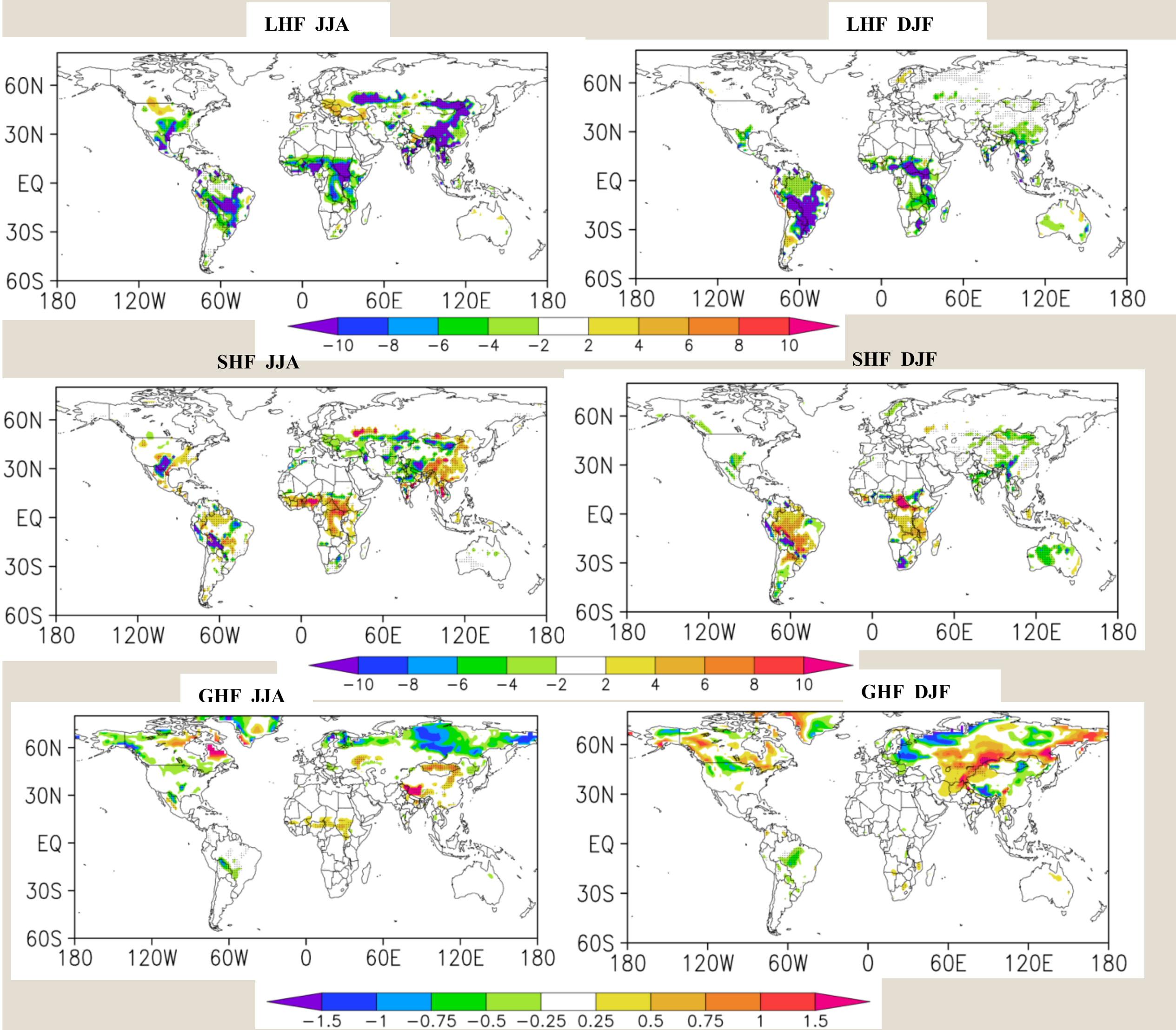
Annual mean surface variables and their difference between LULC and CTL averaged from 1948 to 2010 over global land.

Differences in Radiation



LULCC simulated net radiation (left column), net longwave radiation (middle column) and net shortwave radiation (right column) differences (LULCC − CTL) for annual, JJA and DJF season

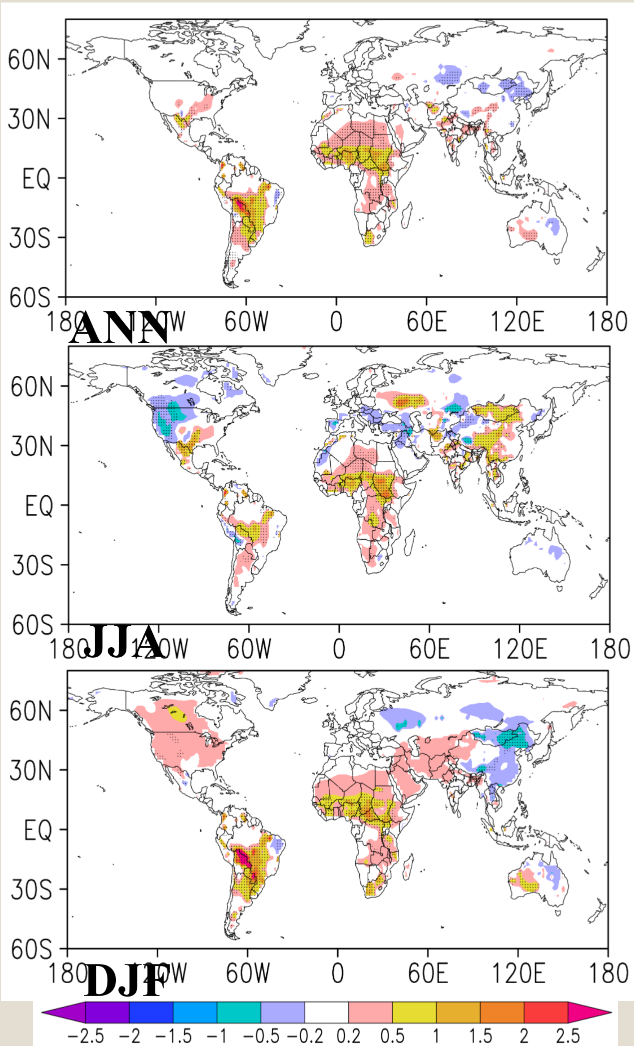
Changes in the surface fluxes



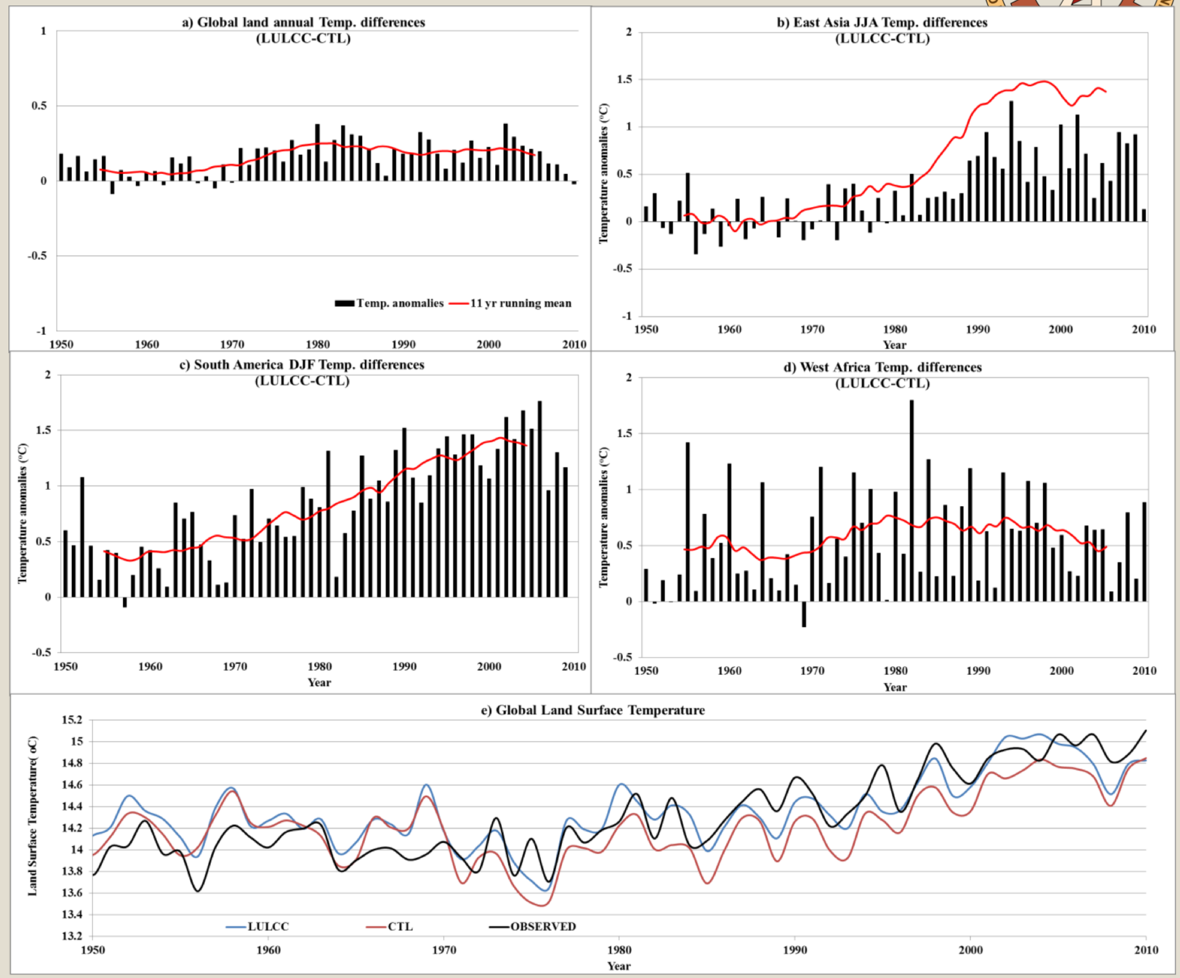
Latent heat flux reduced due to decrease in Leaf Area Index (LAI) and land degradation

Latent heat Flux (LHF), Sensible heat Flux (SHF) and Ground heat Flux (GHF) differences (LULCC-CTL) for JJA (left column) and DJF (right column) season averaged from the 1948 to 2010. The stippled region in the figure indicates that the anomalies are significant at 95 % based on two tailed Student's t-test.

Temperature Changes



Surface temperature anomalies (LULCC-CTL) for annual (upper panel), JJA (middle panel) and DJF (lower panel) seasons averaged from 1948 to 2010.

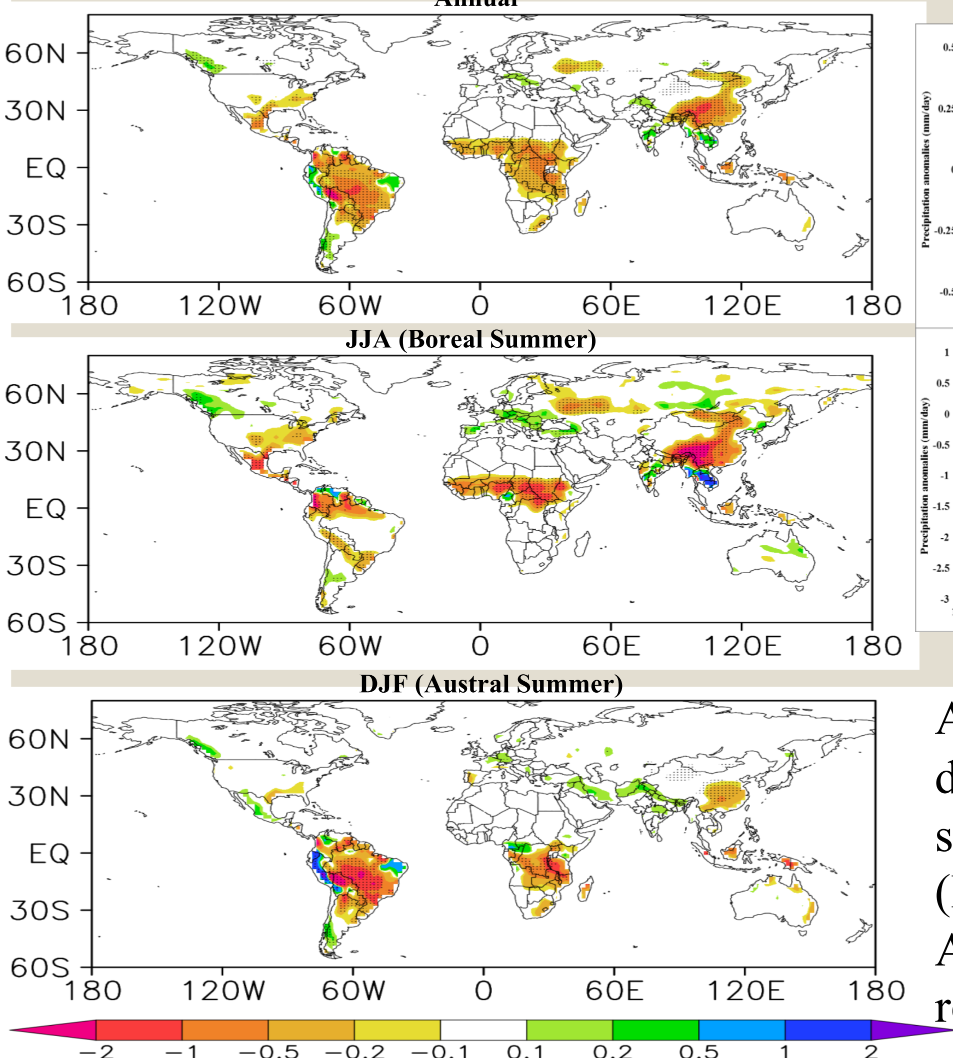


Annual global land mean surface temperature difference (LULC-CTL)(a); the summer surface temperature difference (LULC-CTL) over East Asia (b), South America(c) West Africa(d), respectively. The red line in the figures a-d denotes 11 year running mean of anomalies. The comparison of global annual land surface temperature simulation with observation (e).

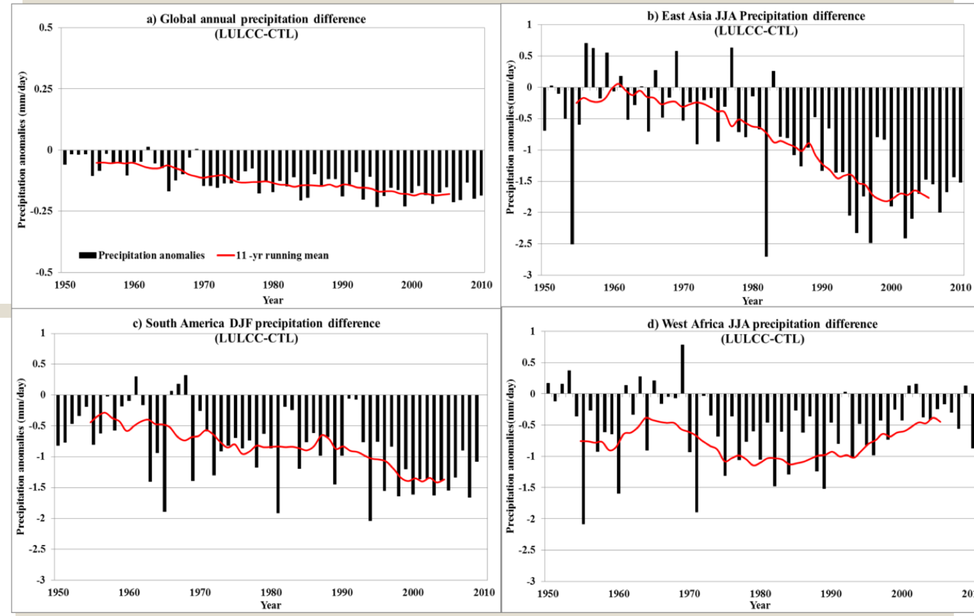
Season	Region	CTL Correlation(R)	ΔR (LULCC-CTL)	CTL RMSE(σ)	Δ σ (LULCC-CTL)
Annual	Global Land	0.77	0.06	0.27	-0.06
	East Asia	0.29	0.18	0.86	-0.01
	West Africa	0.58	0.07	0.59	0.06
	South America	0.65	0.11	1.08	-0.49

Comparisons of annual mean surface temperature (K) from1948 to 2010 between CRU data and simulations over different regions

Precipitation Changes



Global Rainfall difference (LULCC-CTL) for ANN, JJA and DJF season averaged from 1948 to 2010.

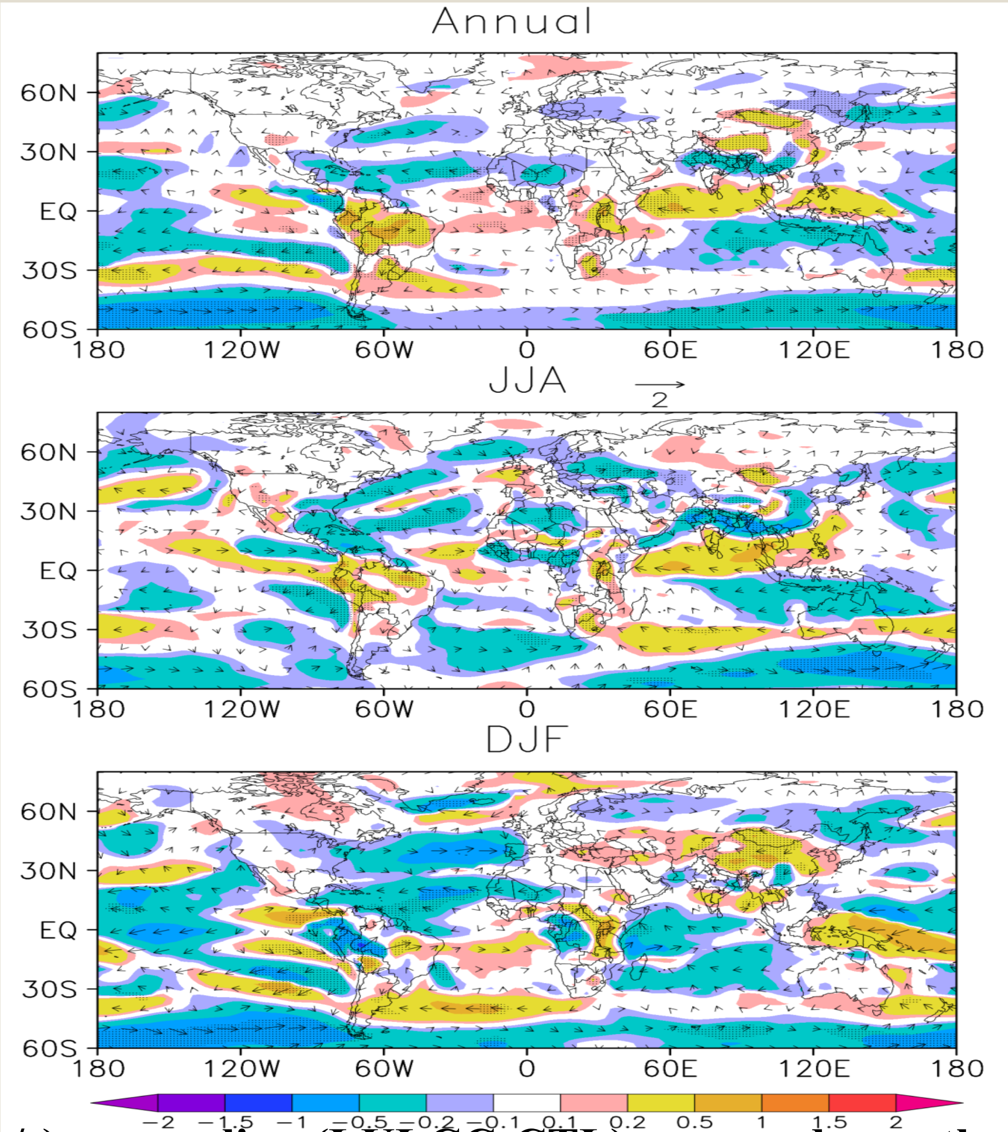


Annual global land mean precipitation difference between LULC and CTL(a); the summer surface temperature difference (LULC-CTL) over East Asia (b), South America(c) West Africa(d), respectively. The red line in the figures a-d denotes 11 year running mean of anomalies.

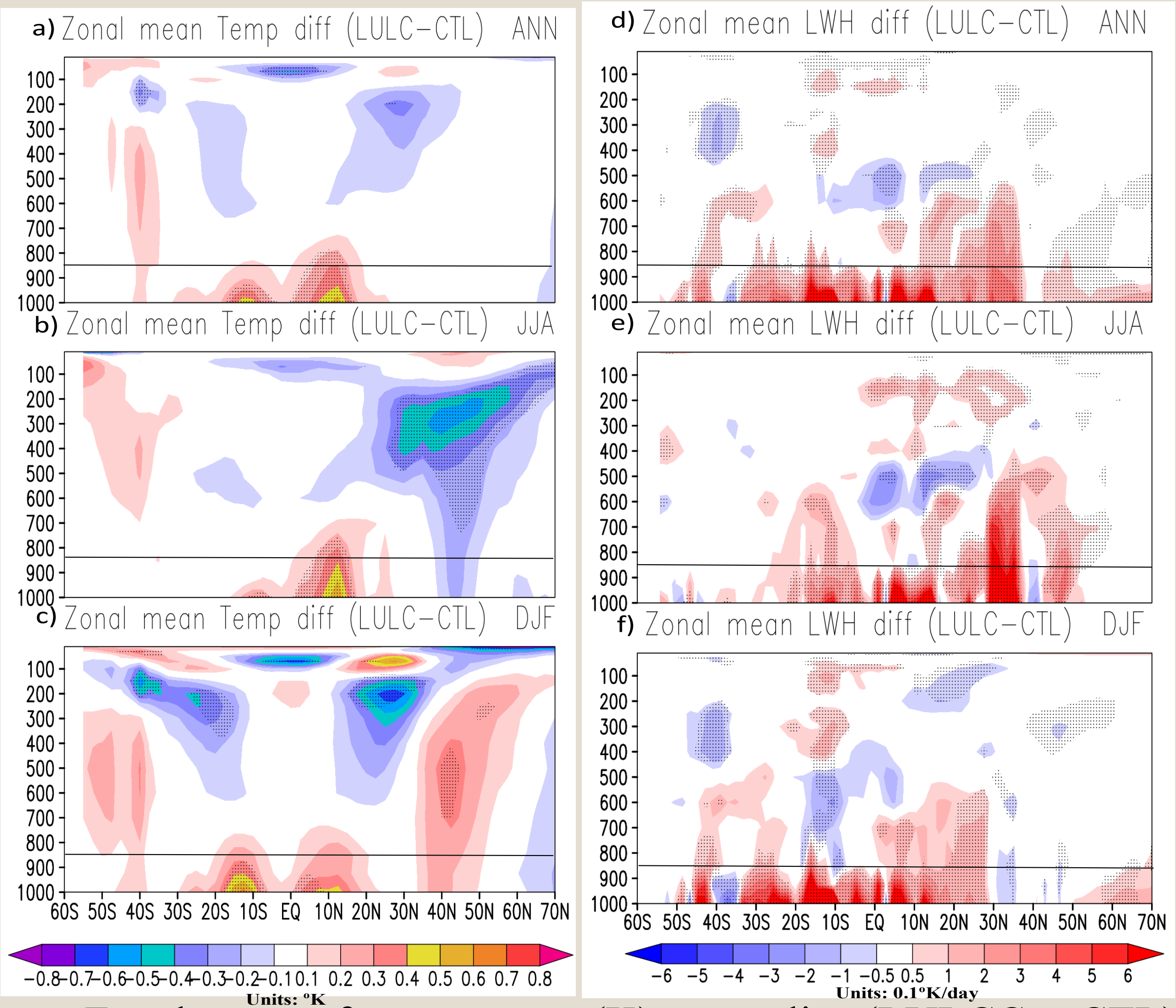
Seasonal mean of surface variables and their difference between LULC and CTL averaged from1948 to 2010 for various regions.

Region	Variable	Mean (CTL simulation)		Diff (LULCC-CTL)	
		JJA	DJF	JJA	DJF
East Asia	Albedo (%)	24.93	28.45	3.01	3.02
	Leaf Area Index (m^2/m^2)	2.82	1.71	-1.14	-0.51
	Net Surf. Radiation(W/m^2)	148.92	33.39	-12.8	-5.18
	Latent Heat (W/m^2)	102.57	22.91	-16.71	-2.89
	Sensible Heat (W/m^2)	43.15	7.99	3.66	-2.5
	Ground Heat (W/m^2)	1.6	-0.14	0.25	0.21
	Surf. Temperature (K)	295.03	272.02	0.56	-0.32
	Precipitation (mm/day)	8.83	1.08	-1.11	-0.16
West Africa	Albedo (%)	27.66	28.99	2.11	1.36
	Leaf Area Index (m^2/m^2)	1.15	1.37	-0.47	-0.46
	Net Surf. Radiation (W/m^2)	120.23	59.52	-7.64	-5.35
	Latent Heat (W/m^2)	51.23	15.53	-10.33	-3.06
	Sensible Heat (W/m^2)	72.53	43.84	2.46	-2.17
	Ground Heat (W/m^2)	-3.27	0.39	0.23	-0.12
	Surf. Temperature (K)	302.82	296.31	0.82	0.71
	Precipitation (mm/day)	3.69	0	-0.72	0
South America	Albedo (%)	22.2	21.51	5.58	5.78
	Leaf Area Index (m^2/m^2)	3.28	3.31	-1.63	-1.83
	Net Surf. Radiation (W/m^2)	92.06	171.56	-17.01	-24.23
	Latent Heat (W/m^2)	43.51	93.34	-11.21	-21.56
	Sensible Heat (W/m^2)	42.34	58.84	-5.62	-2.61
	Ground Heat (W/m^2)	0.82	-0.84	-0.18	-0.06
	Surf. Temperature (K)	293.22	298.36	0.34	1.61
	Precipitation (mm/day)	0.7	6.48	-0.13	-1.2

Wind difference

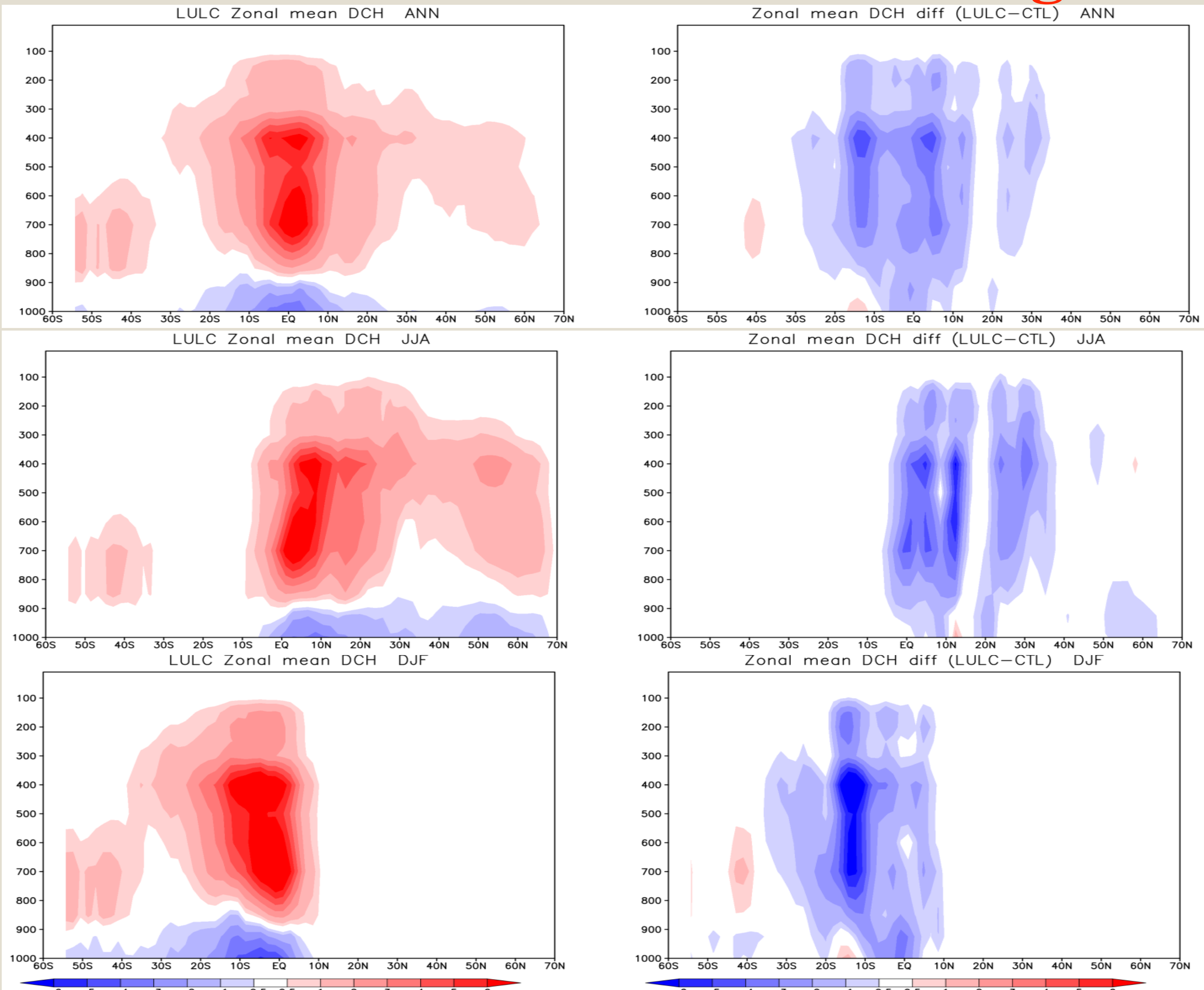


850hPa wind (m/s) anomalies (LULCC-CTL) averaged over the 1948 to 2010 for Annual, JJA and DJF seasons.



Left column: Zonal mean of temperature (K) anomalies (LULCC − CTL) for annual (upper panel), JJA (middle panel) and DJF (lower panel) seasons averaged from 1948 to 2010. Right column: Same as left column but for long wave heating rate (0.1 K/day) anomalies. The stippled region in the figure indicate that the anomalies are significant at 95% based on two tailed Student's t-test. The black horizontal line represents the 850 hPa level

Zonal mean of convective heating rate



LULCC simulated Deep convective heating rate (K/day) seasonal mean (left column) and difference (0.1K/day, LULCC – CTL; right column) averaged from 1948 to 2010.

Conclusions

- We have degraded the potential vegetation classification map progressively relative to the vegetation distribution conditions in 1948 based on LULCC fraction data.
- Evaluated the impact of LULCC on temperature and precipitation from 1948-2010.
- Evapotranspiration also reduced because of reduction in vegetation fraction which led to less cloud fraction due to less moisture availability in the atmosphere which led to decrease (by allowing more longwave radiation to escape) in net longwave radiation at the surface.

- **The simulated results with this LULCC map with interannual variation show improvement in interannual temperature and precipitation variability and reduction in bias, which suggests the role of LULCC in the climate system.**

Thank you

for your attention

For questions and comments

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