Improving the representation of major Indian crops in CLM5 using site-scale crop dataset

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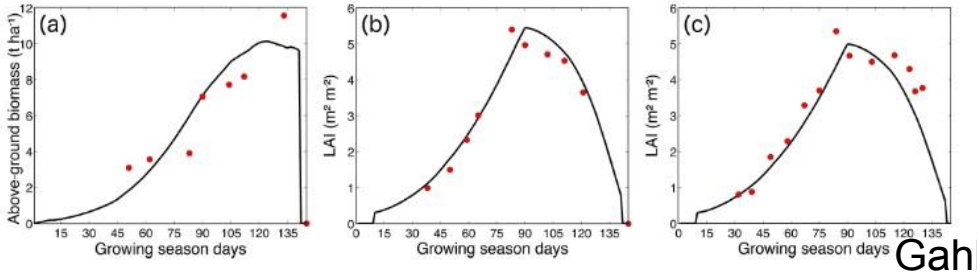
Major Indian crops in LSMs

(1)



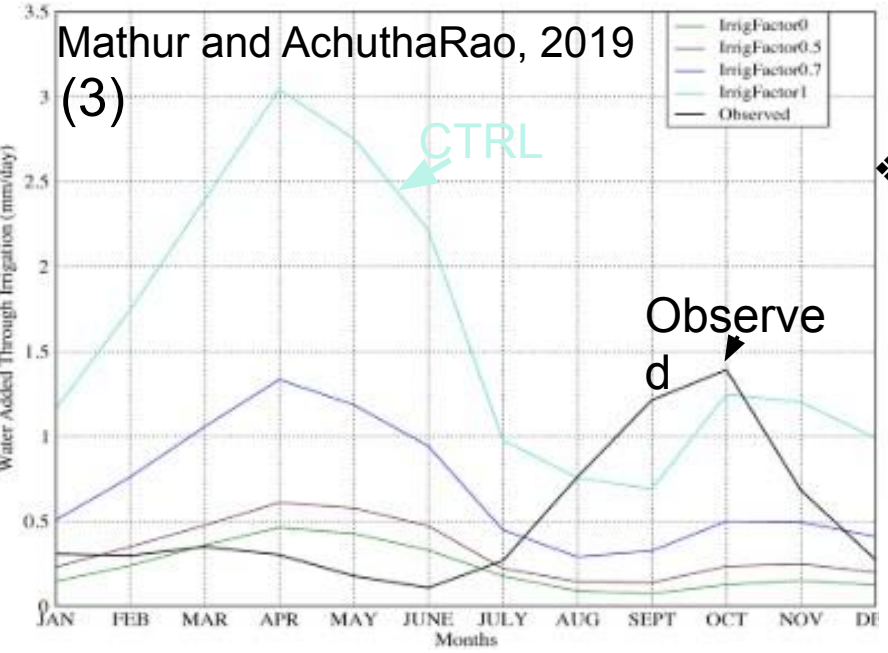
Gahlot et al., 2020

Figure 1. Model calibration and validation plots for the experimental wheat site at IARI, New Delhi. **(a)** Model calibration for above-ground biomass for the 2015–2016 growing season. **(b)** Model calibration for LAI for the 2015–2016 growing season. **(c)** The model-estimated LAI validated with site-measured data for the 2014–2015 growing season. The red dots are site-measured values and the black lines are ISAM-simulated values.

- Lack of openly accessible crop datasets for calibration and validation limits crop modelling studies in the Indian region (Gahlot et al., 2020).

Mathur and AchuthaRao, 2019

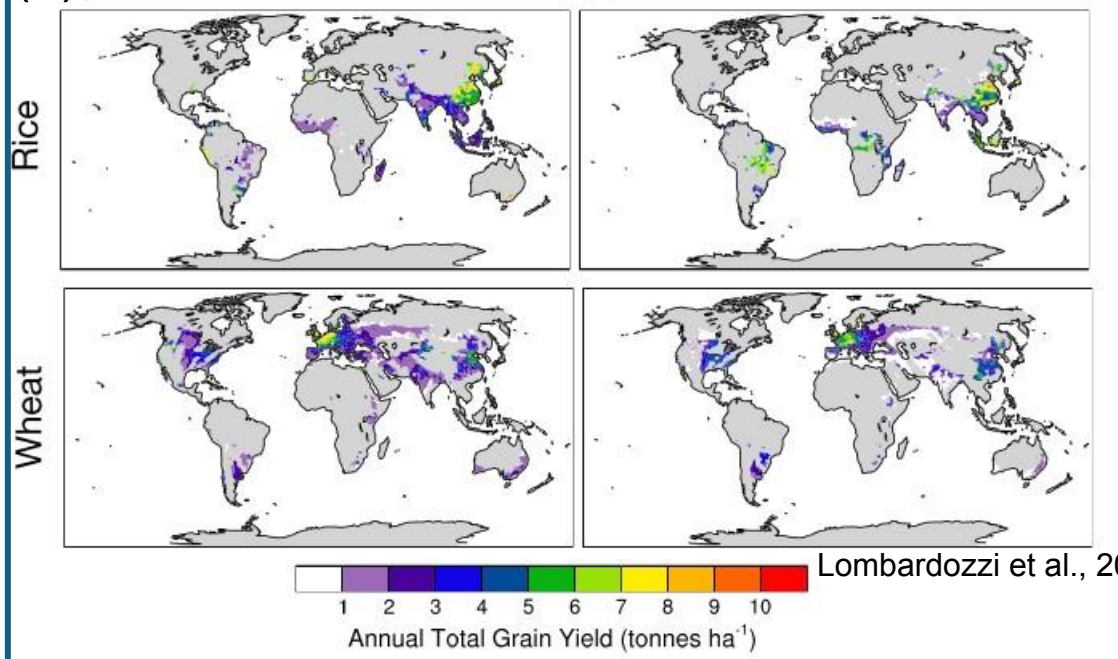
(3)



- Irrigation water added simulated by CLM for Indian region are far from observations

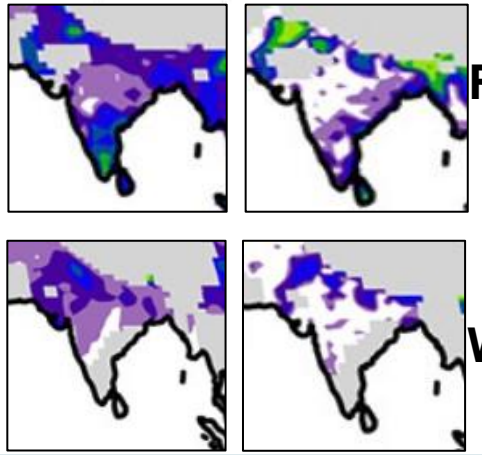
Fig. 12 Annual cycle climatology of irrigation water added (mm/day) in the different irrigation factor experiments shown along with observed estimates used in Cook et al. (2015) based on the work of Wisser et al. (2010). The data is shown only for grid cells where greater than 20% PFTs (Supplementary Figure S13) are irrigated crop types predominantly in the Indo-Gangetic plain

(2) FAO-Earthstat CLM5



Lombardozzi et al., 202

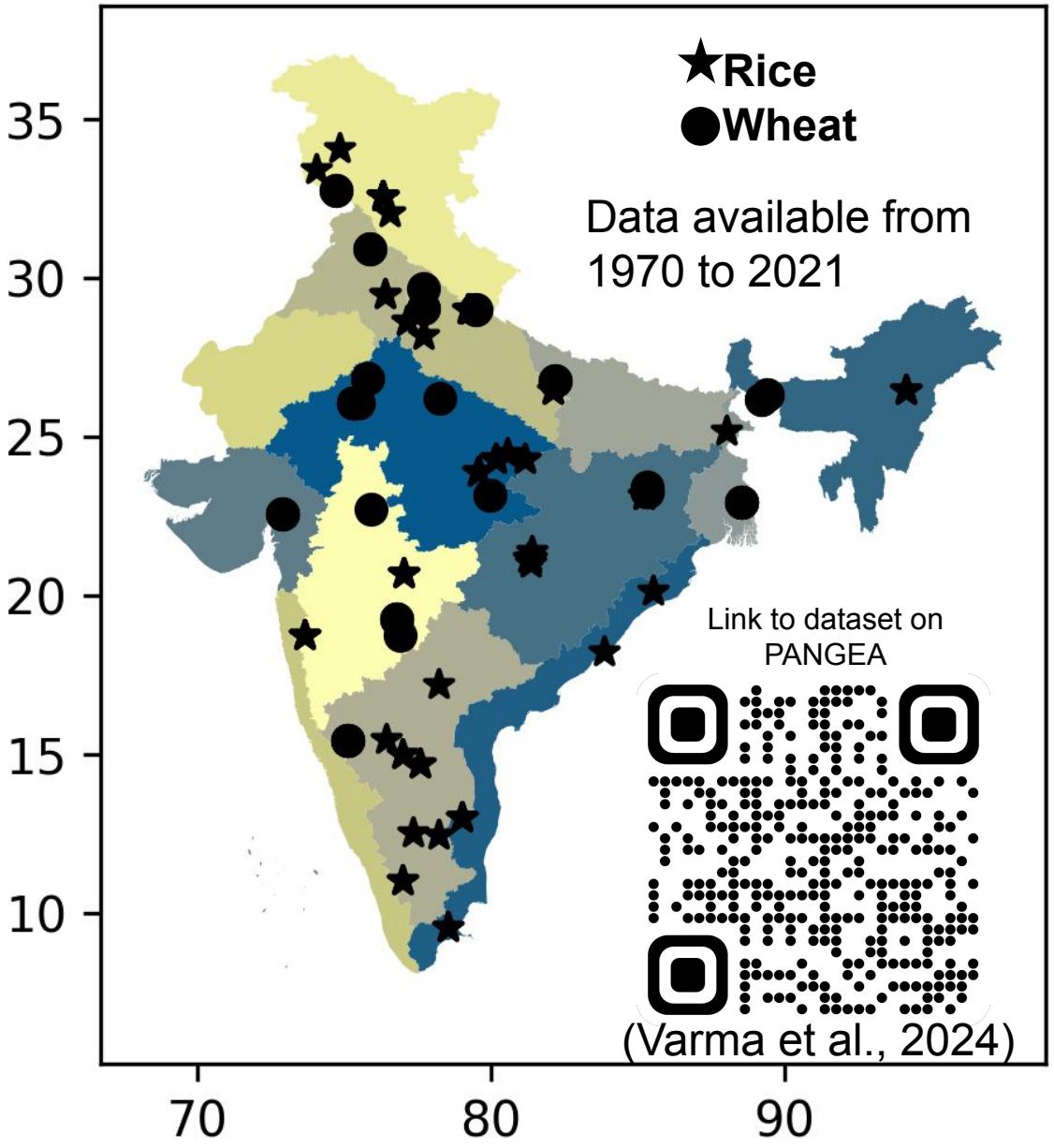
- Major Indian crop yield estimates in CLM5 have large biases compared to FAO observation data (Lombardozzi et al., 2020).



Rice

Wheat

Crop dataset from experimental agricultural site



- Site-scale observations of Indian crops are very rarely available for public access.
- Students at agricultural institutes across India conduct experiments on Indian crops and report their results (Veeranjaneyulu, 2014).
- To fill the gap of crop data on Indian crops, we started to assemble data on wheat and rice in a formatted, machine-readable format that can be downloaded and used for model development. The data is available on the PANGEA data repository (Varma et al., 2024) .

Crop Parameters extracted

Leaf Properties
Leaf Area Index
Leaves/hill
Mean leaf area

Above ground biomass
Total Dry Matter
Shoot Dry Matter
Stem dry matter
Crop growth rate (g/m2/day)

Irrigation
Irrigation requirement (mm)
Crop water use efficiency (kg ha mm-1)
water use efficiency (kg ha-1mm-1)
Total evapotranspiration (mm)

Yield
Grain Yield (q/ha)
Harvest Index (%)
1000-Test Weight (g)
Straw Yield (q/ha)

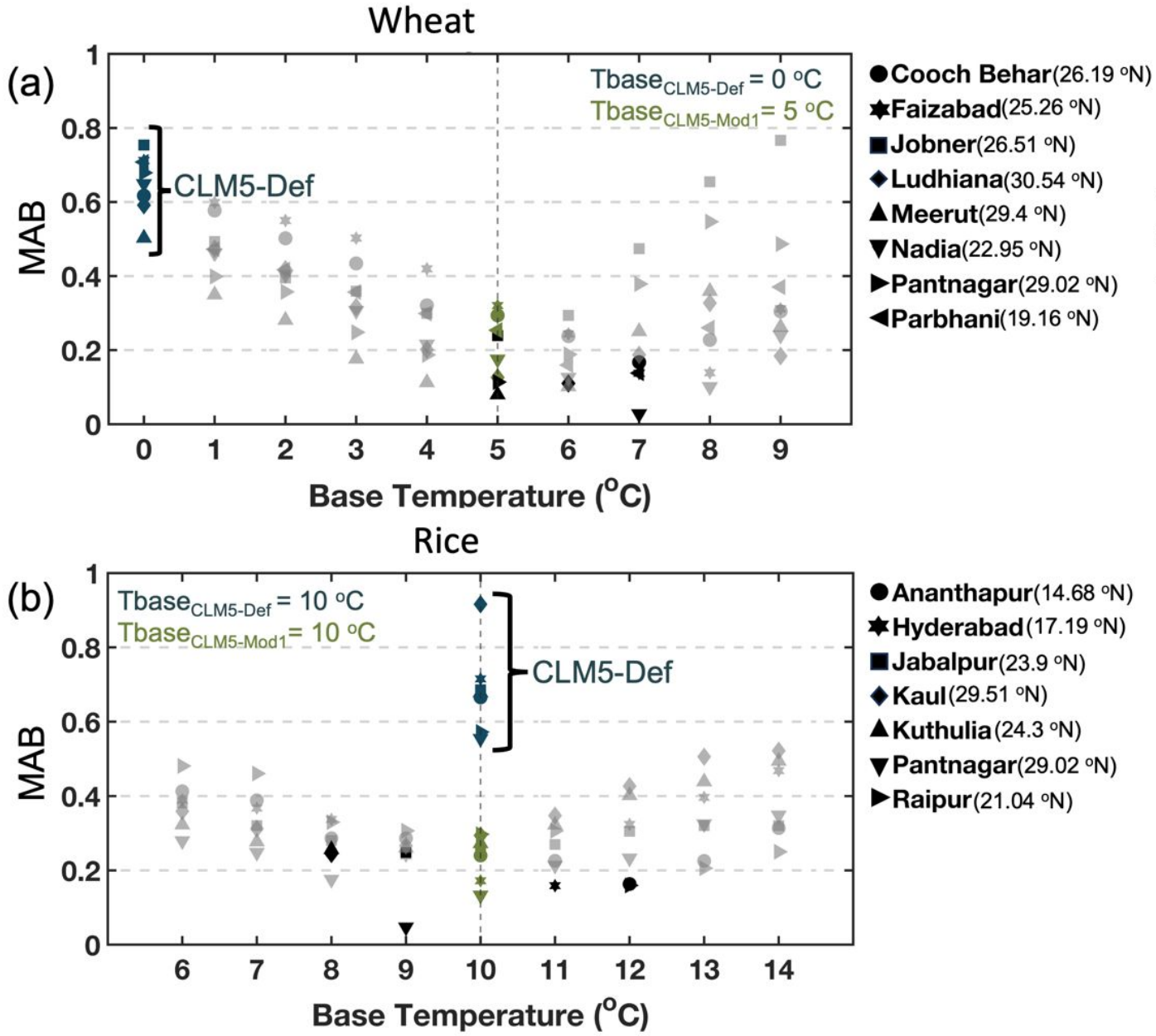
Root parameters
Total Root Length (cm)
Root volume (cm3)

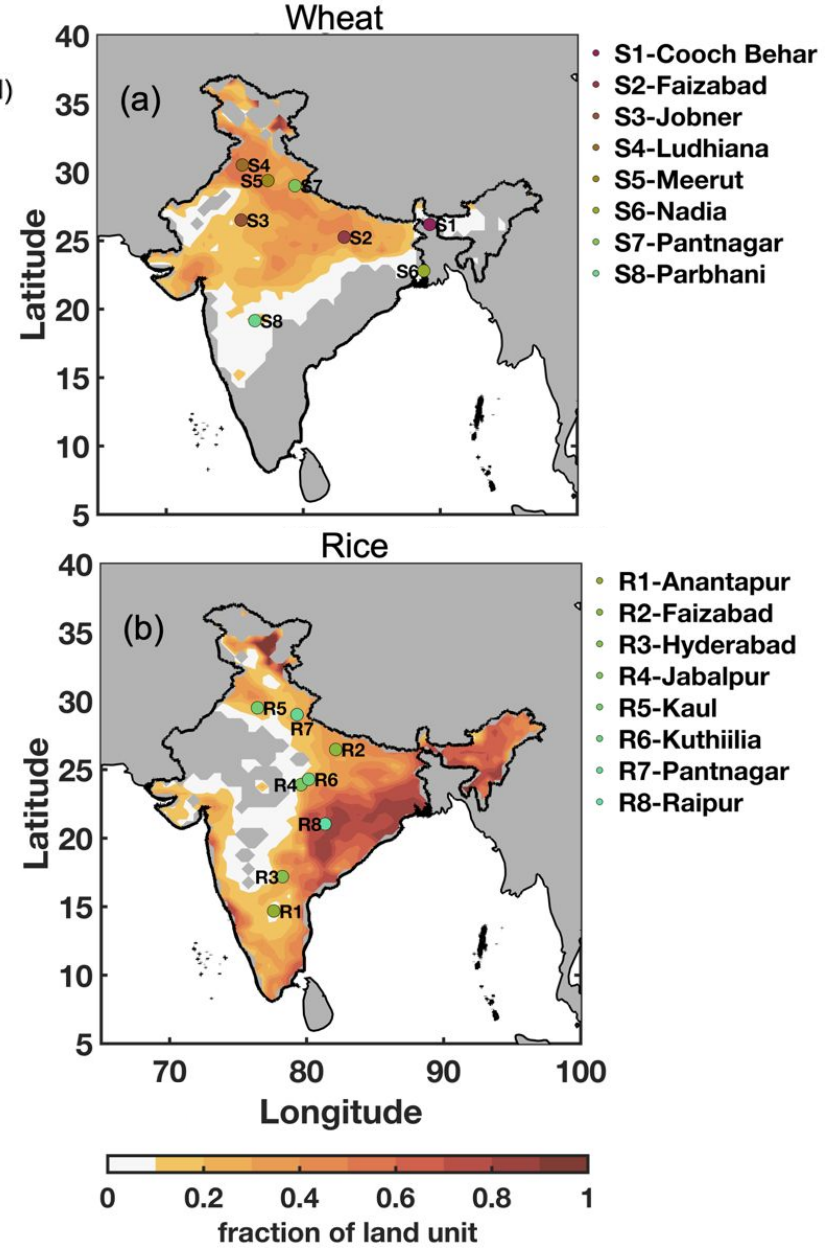
Wheat and rice in CLM5

- The current study uses the CLM5 model with the data atmosphere model (DATM).
- The GSWP3 atmospheric data is used for the simulations.
- We ran CLM5 at two different spatial resolutions from 2000 to 2014:
  - site-scale simulations to calibrate the crop module, and
  - regional simulations to compare the calibrated model against remote sensing data and derived surface flux data.

Parameter	Description (units)	Wheat		Rice	
		CLM5_Def	CLM5_Mod1	CLM5_Def	CLM5_Mod1
min_NH_planting_date	Minimum planting date for the Northern hemisphere (MMDD)	401	1115 (calibrated in this study)	101	701 (calibrated in this study)
max_NH_planting_date	Maximum planting date for the Northern hemisphere (MMDD)	615	1231 (calibrated in this study)	228	815 (calibrated in this study)
min_planting_temp	Average 5 day daily minimum temperature needed for planting (K)	272.15	283.15 (Rao et al., 2015)	283.15	294.15 (Kumar et al., 2023)
planting_temp	Average 10-day temperature needed for planting (K)	280.15	290.15 (Asseng et al., 2016; Mukherjee et al., 2019)	294.15	300.15 (Jat et al., 2019)
baset	Base Temperature (ºC)	0	5 (Mukherjee et al., 2019; Mehta and Dhaliwal, 2023)	10	10 (Thakur et al., 2022)
grnfill	Grain fill parameter	0.6	0.6	0.4	0.65 (calibrated in this study)
hybgdd	Growing Degree Days for maturity (°C-days)	1700	1700	2100	2100
baset_mapping	Switch to turn on/off the latitudinal variation in baset in tropics	'constant'	'constant'	'constant'	'constant'

Wheat and rice in CLM5





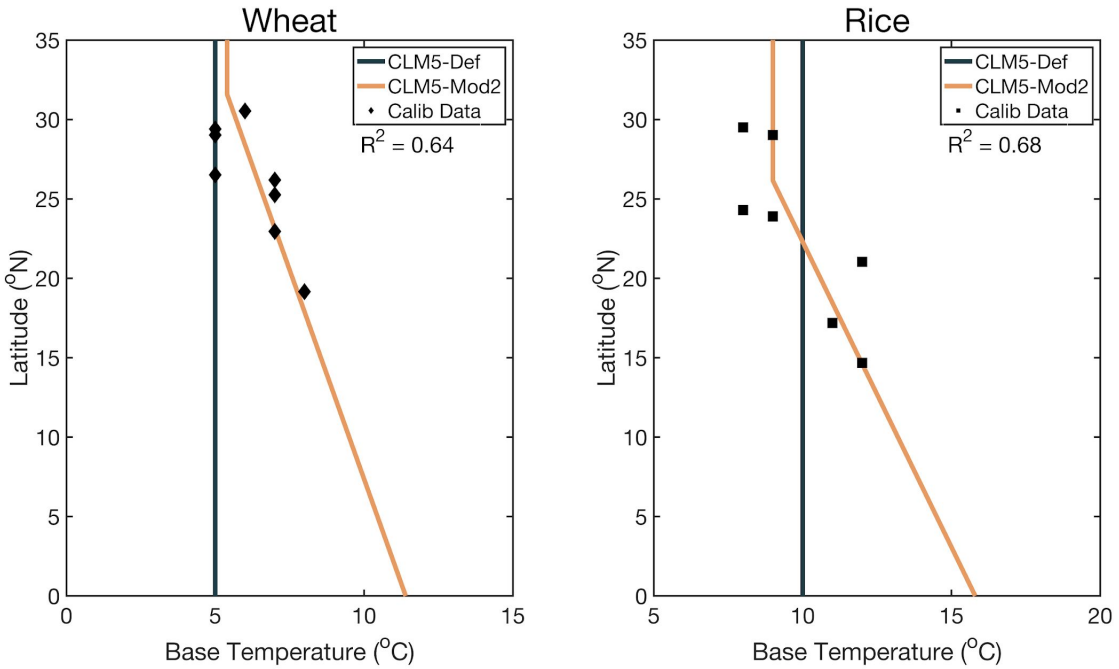
Wheat and rice in CLM5

$$Tbase_{lat} = Tbase + latvary_{intercept} - \min\{latvary_{intercept}, latvray_{slope} * |latitude|\}$$

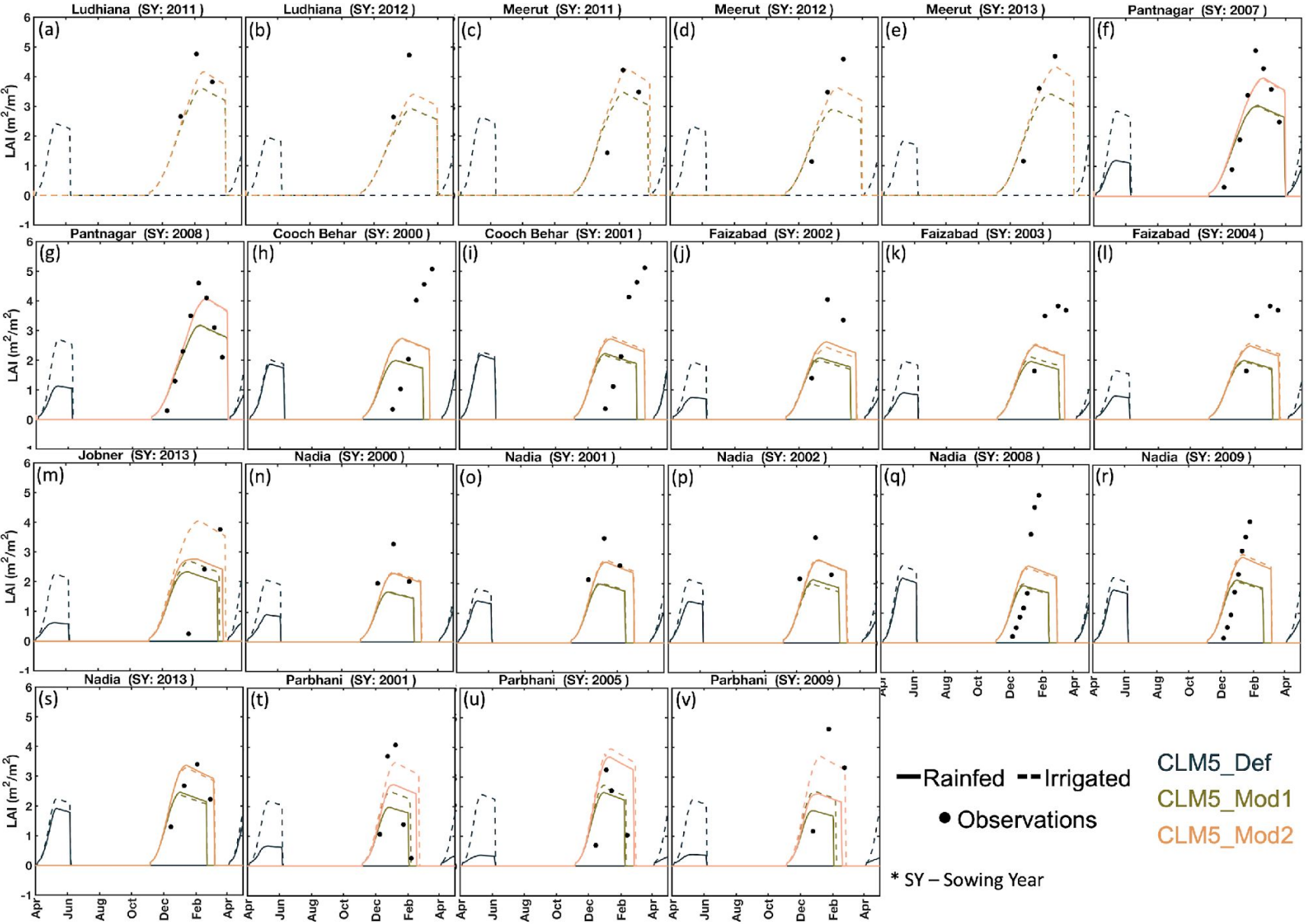
Crop	Site Name	Latitude [°N]	Base temperature @ lowest bias [°C]
Wheat	Parbhani	19.16	8
	Nadia	22.95	7
	Faizabad	25.26	7
	Cooch Behar	26.19	7
	Jobner	26.51	5
	Pantnagar	29.02	5
	Meerut	29.40	5
	Ludhiana	30.54	6
Rice	Anantapur	14.68	12
	Hyderabad	17.19	11
	Raipur	21.04	12
	Jabalpur	23.90	9
	Kuthulia	24.30	8
	Pantnagar	29.02	9
	Kaul	29.51	8

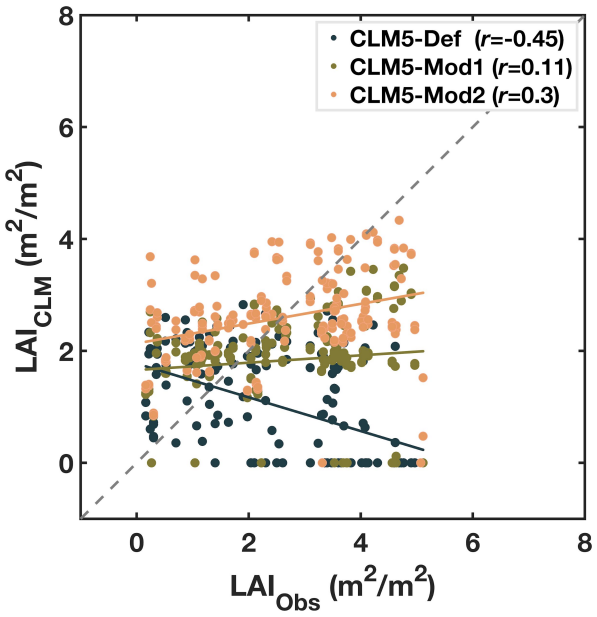
Parameter name	Wheat		Rice	
	CLM5_Def	CLM5_Mod2	CLM5_Def	CLM5_Mod2
baset	0	5.4**	10	9**
latvary_intercept	12	6**	NA	6.8**
latvary_slope	0.4	0.19*	NA	0.26*

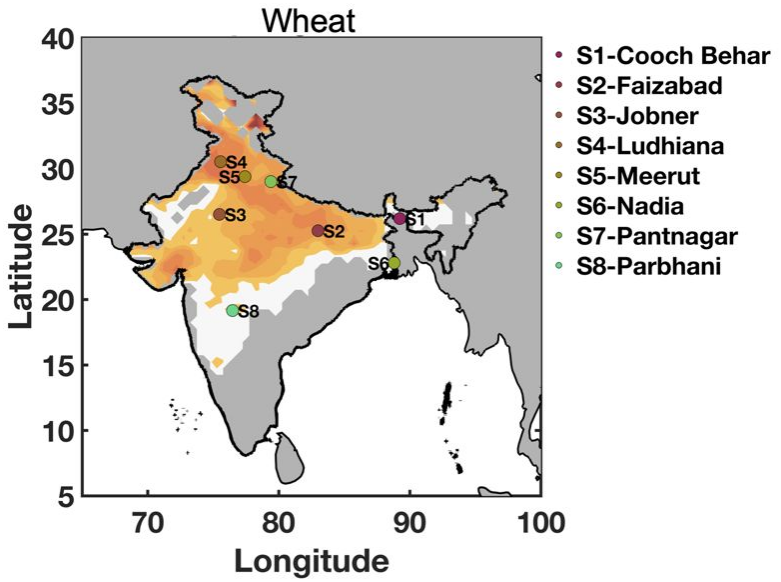
* significant at p<.05 ** significant at p<.01



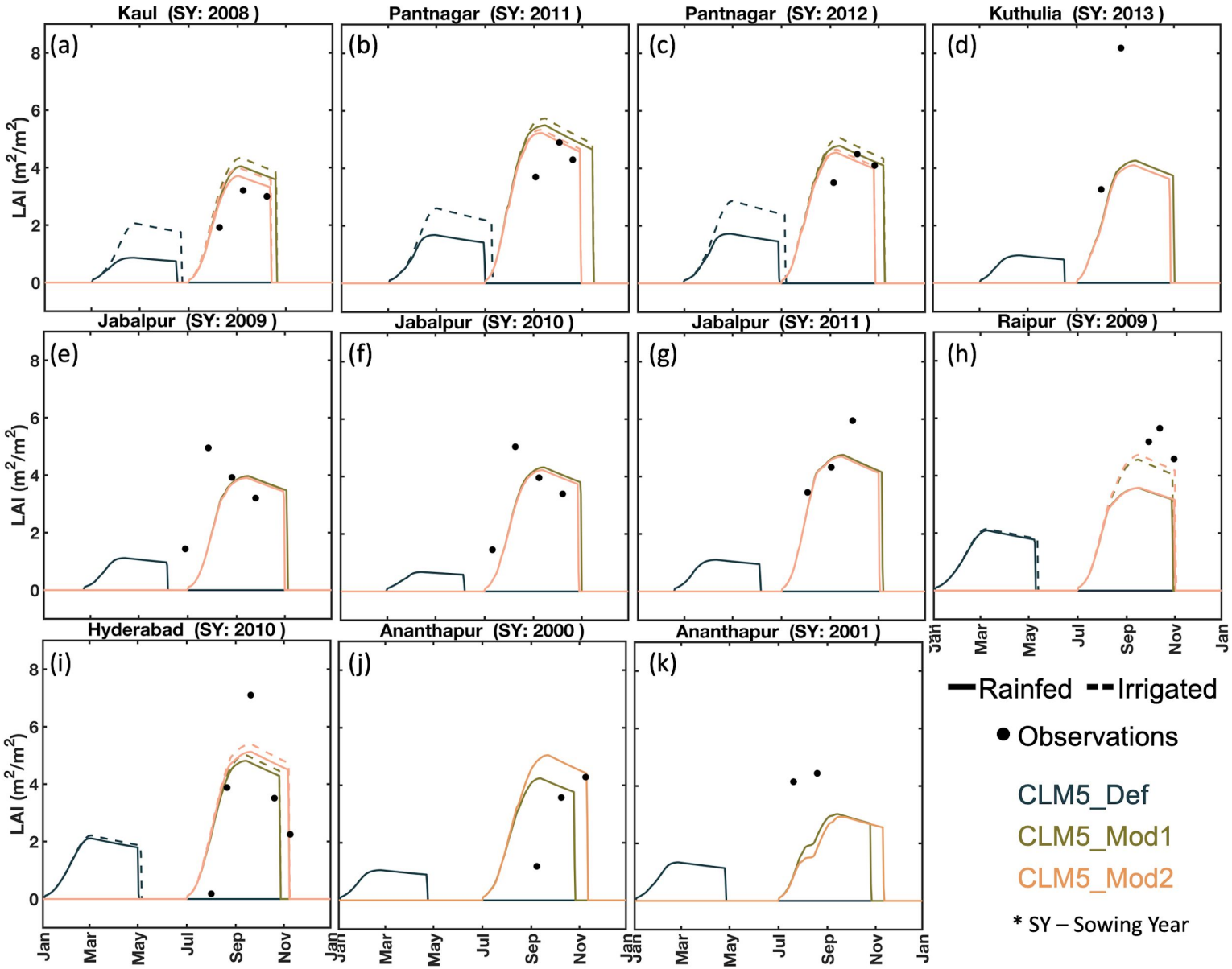
Results: Wheat at site-scale

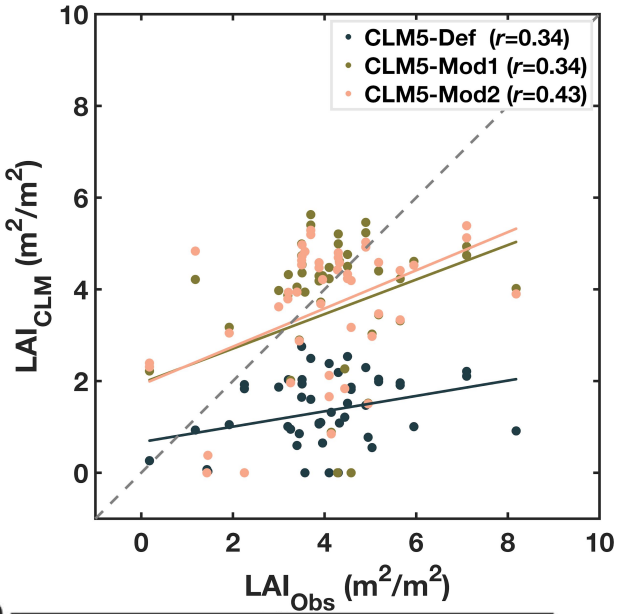


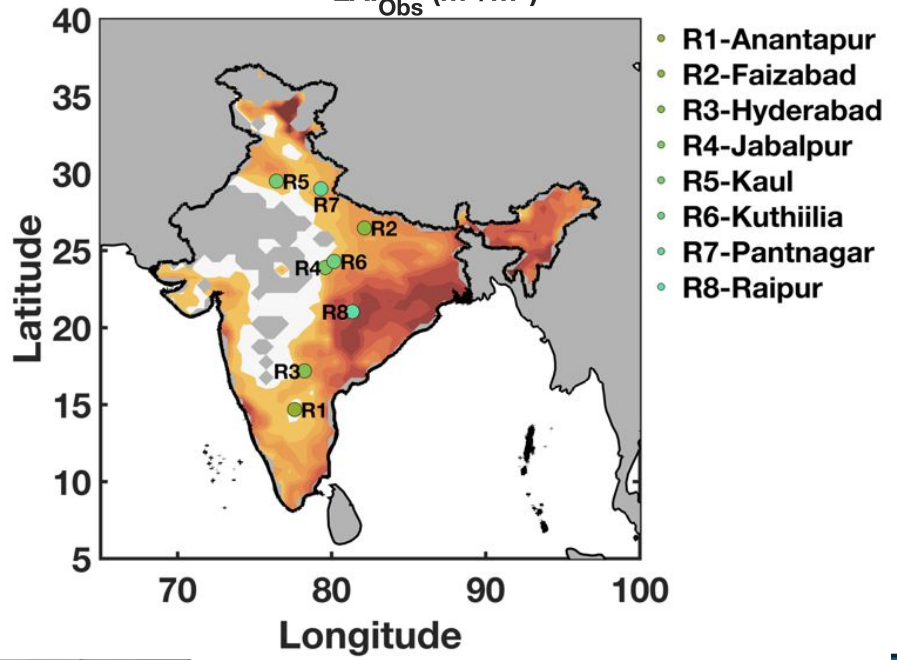




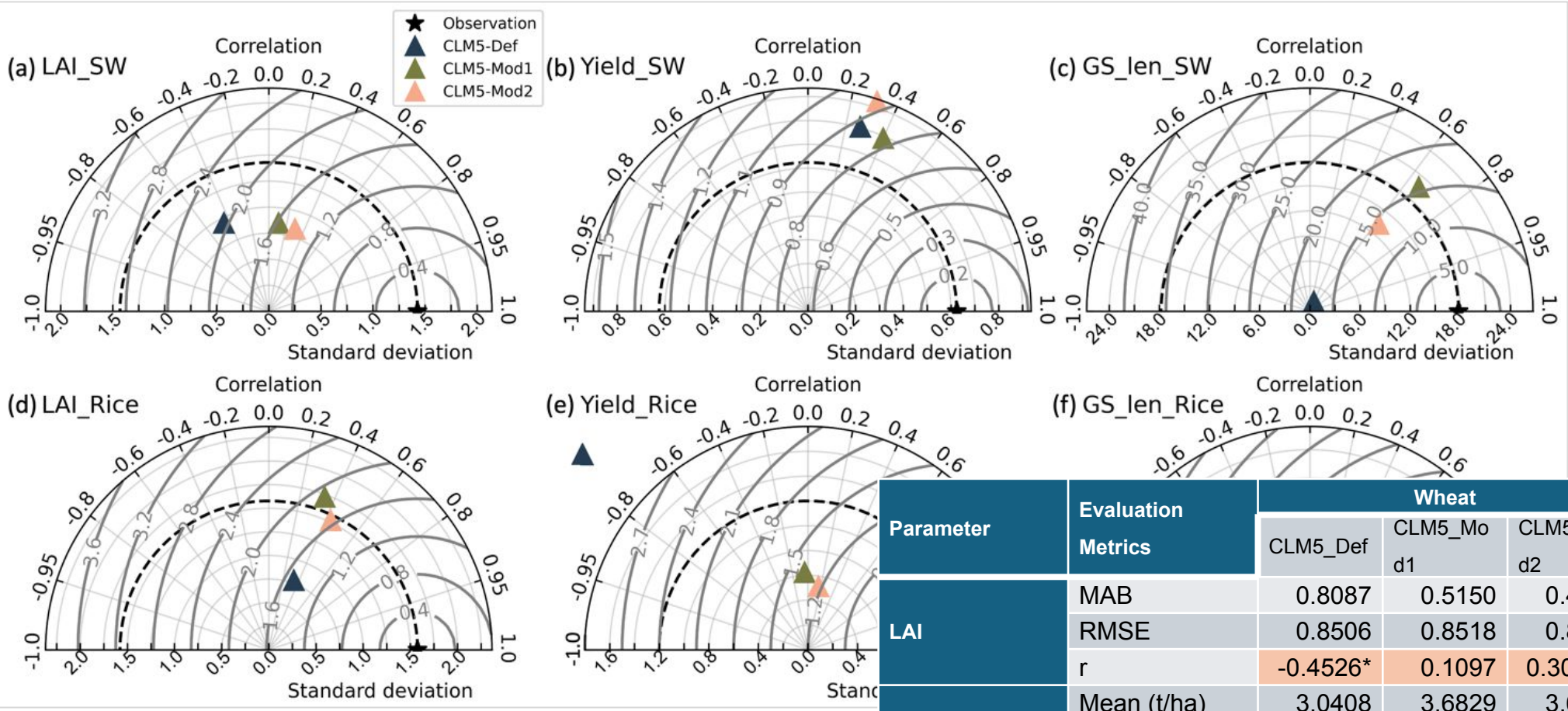
Results: Rice at site-scale







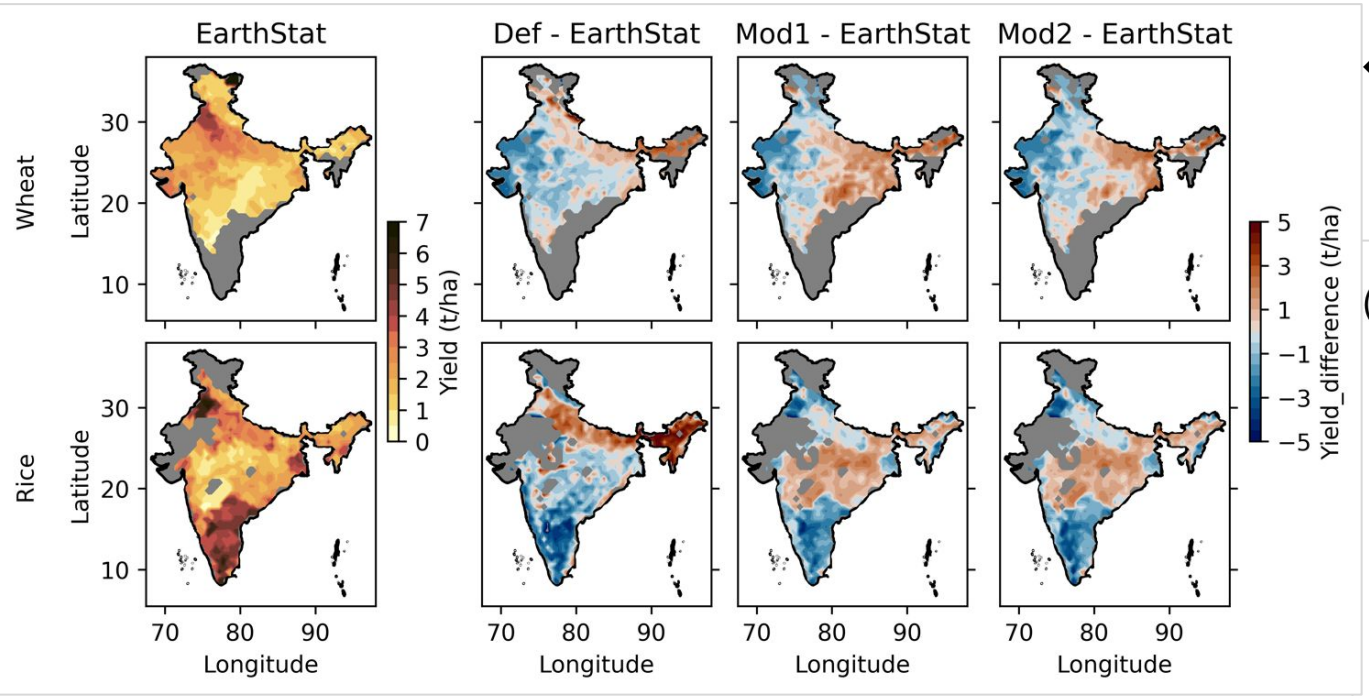
Results: Wheat and Rice at site-scale



- Yield in rice crop has seen the largest improvement.
- Growing season length in wheat was just 68.77 days on an average across sites as simulated in default case.

Parameter	Evaluation Metrics	Wheat			Rice		
		CLM5_Def	CLM5_Mod1	CLM5_Mod2	CLM5_Def	CLM5_Mod1	CLM5_Mod2
LAI	MAB	0.8087	0.5150	0.4293	0.6640	0.3872	0.3430
	RMSE	0.8506	0.8518	0.8312	0.7453	1.6352	1.3843
	r	-0.4526*	0.1097	0.3041**	0.3374*	0.3445*	0.4322**
Yield	Mean (t/ha)	3.0408	3.6829	3.6836	2.6159	3.5079	3.4327
	MAB	0.2460	0.1488	0.1907	0.6988	0.2969	0.2917
	RMSE	0.8713	0.7901	0.9659	1.6330	0.6487	0.5308
	r	0.2734	0.3995	0.3132	-0.7560*	-0.0412	0.1638
Growing season length	Mean (days)	68.77	125.86	136.23	114.33	123.33	121.33
	MAB	0.4680	0.1054	0.0980	0.0712	0.0814	0.1007
	RMSE	1.2073	15.2178	10.6807	7.7250	8.9504	10.8272
	r	0.3731	0.6592**	0.6187**	0.2541	0.3965	-0.0712

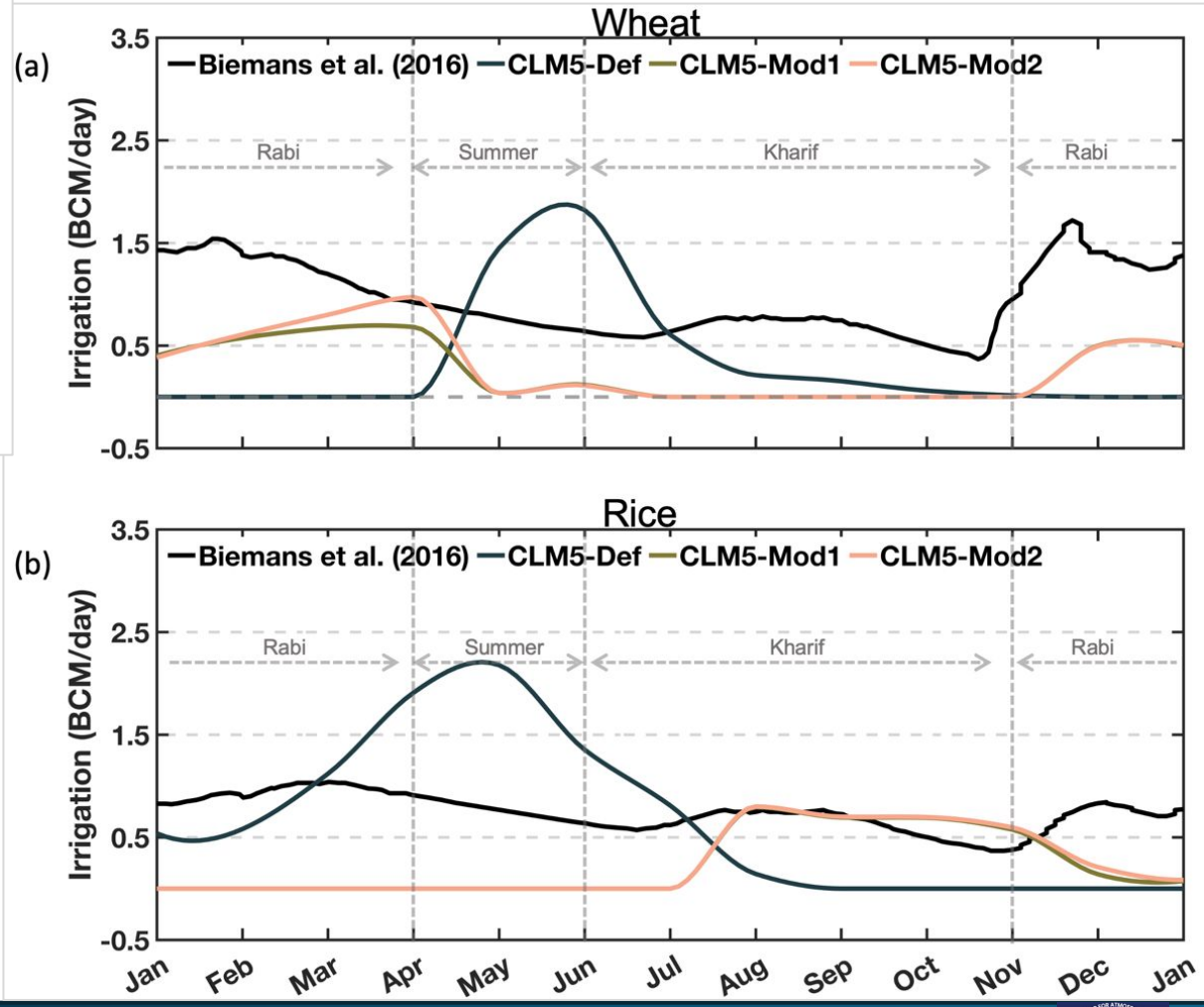
Results: Wheat and Rice at regional scale



- The unexpected peak in irrigation found in Mathur and AchuthaRao. (2019) is the result of wrong cropping patterns of wheat and rice in India. This error in simulating irrigations patterns is reduced in the modified cases.

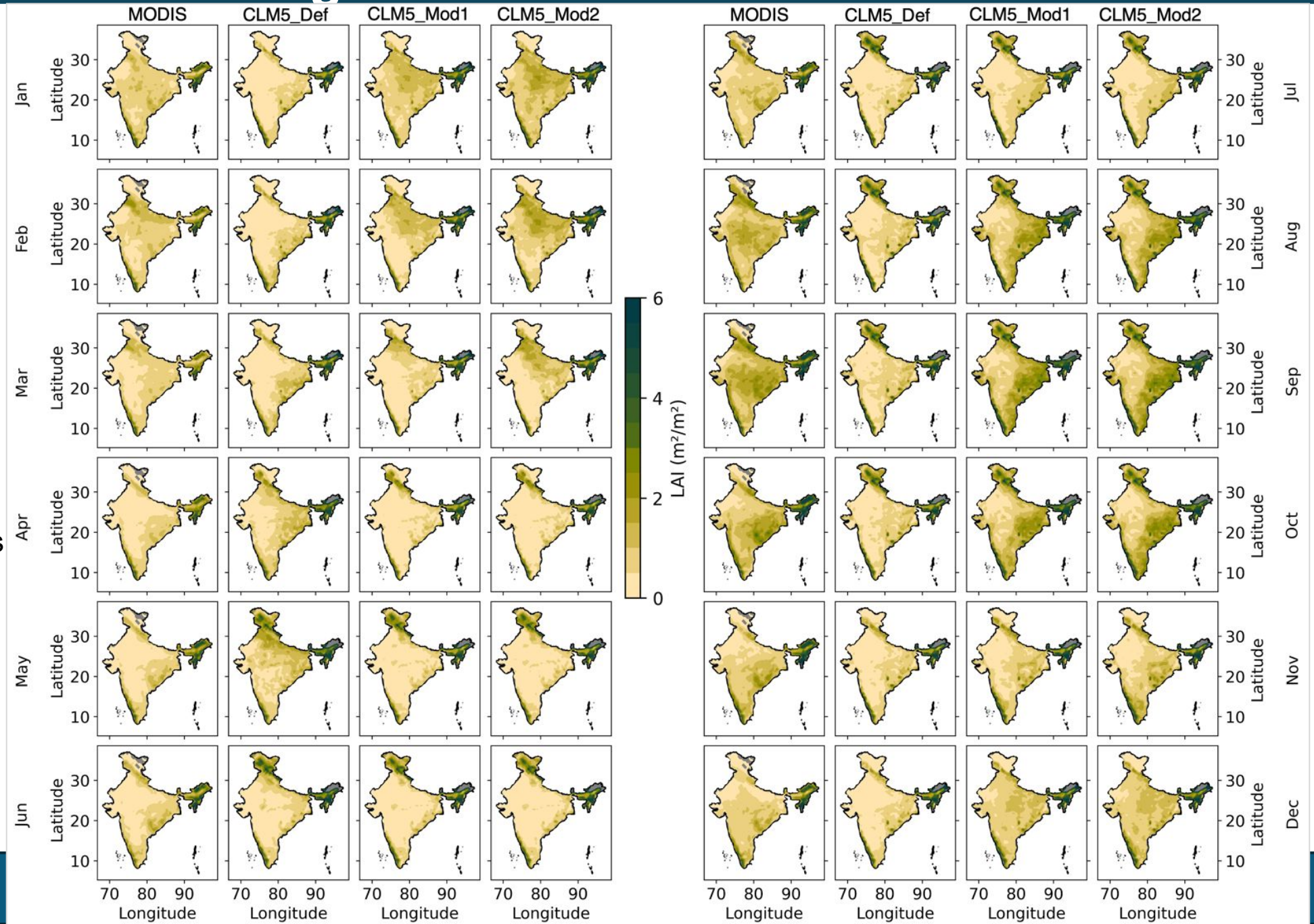
- The amount of water added through irrigation has reduced by 25% in the case of wheat and nearly 60% in the case of rice growing regions.

- Considerable improvement in yield projections of rice in the modified cases.



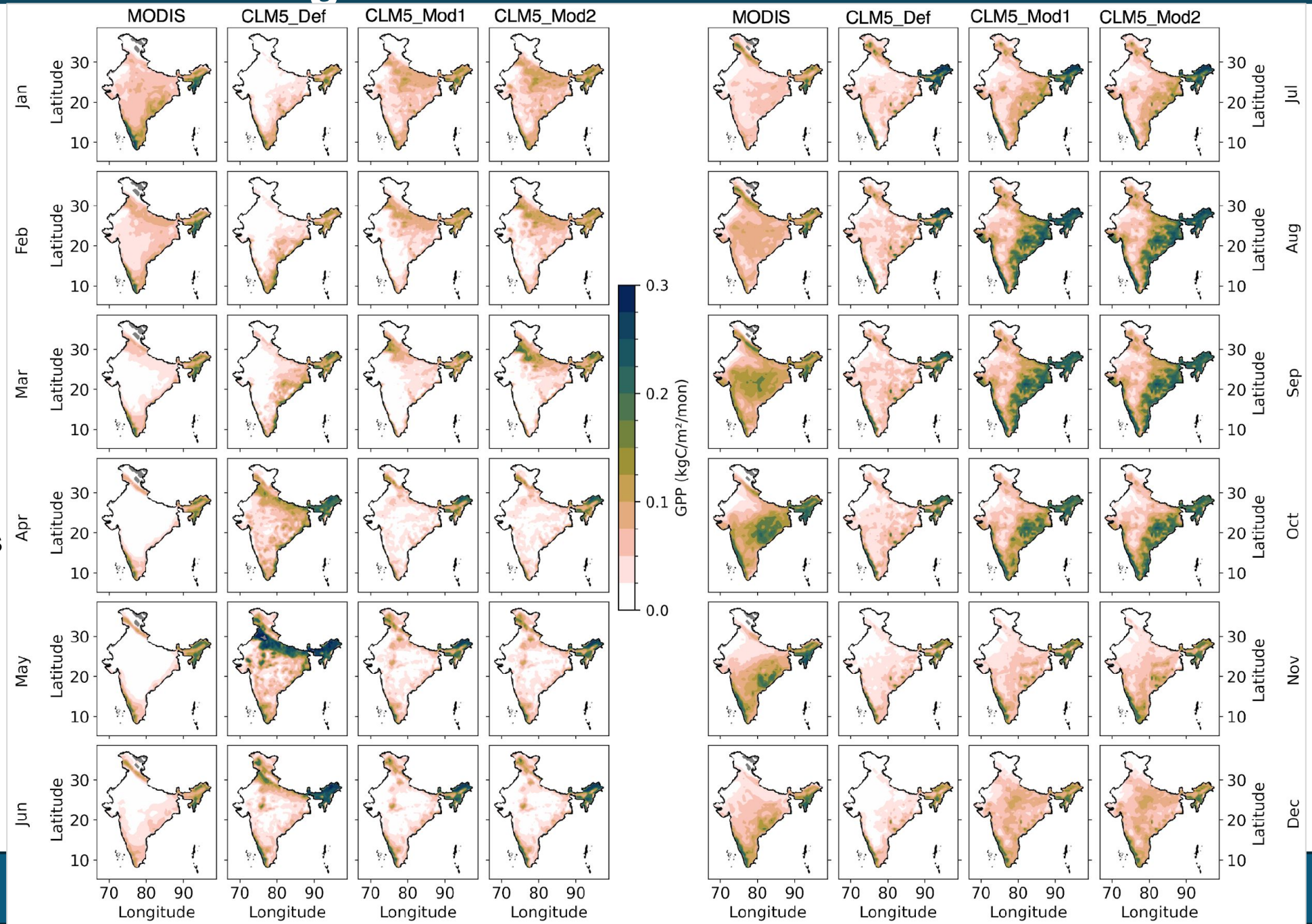
Results: CLM5 at regional scale - LAI

Spatial variation of LAI simulated by CLM5 against MODIS data. The data shows the monthly LAI averaged over 2000-2014.

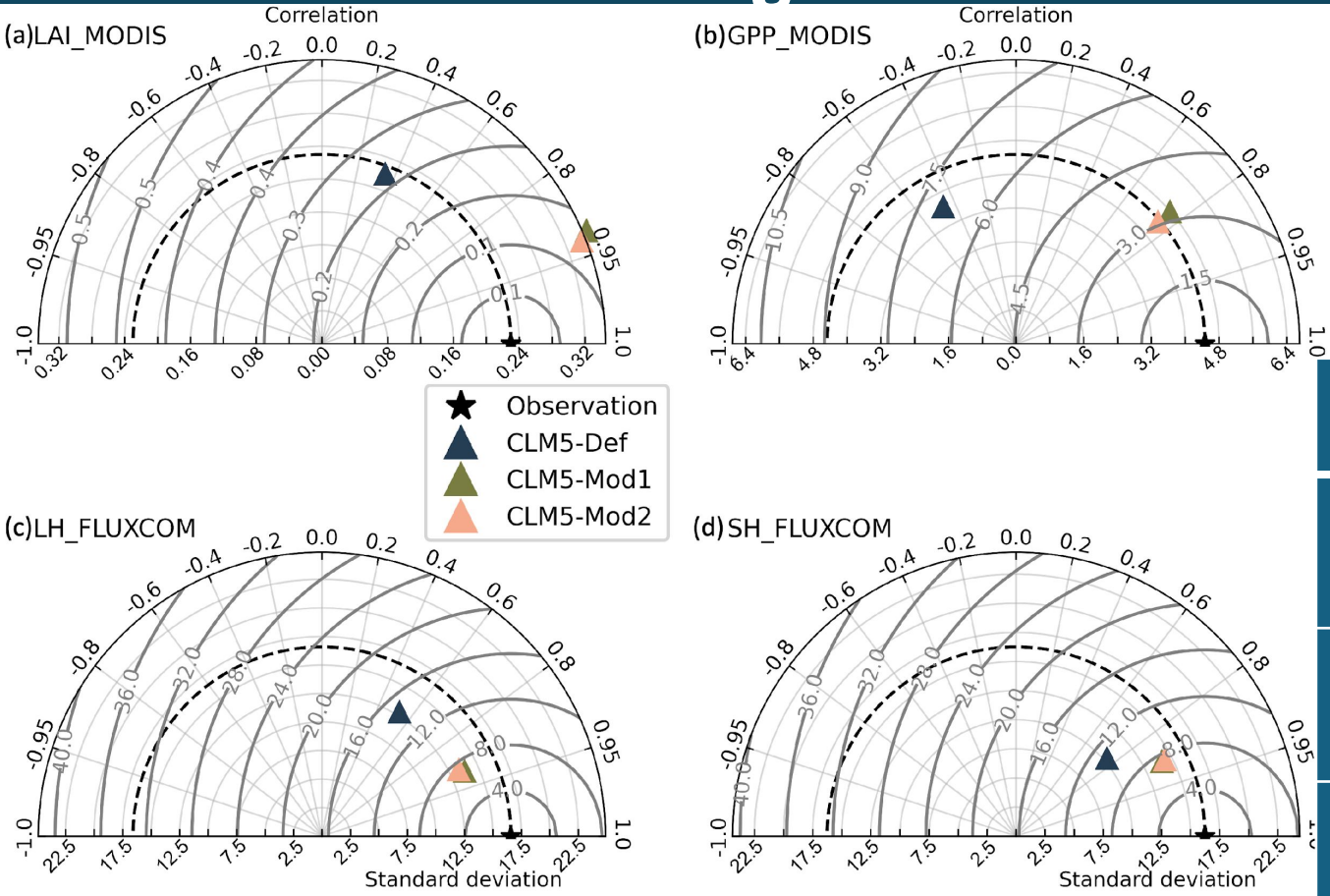


Results: CLM5 at regional scale - GPP

Spatial variation of LAI simulated by CLM5 against MODIS data. The data shows the monthly LAI averaged over 2000-2014.



Results: CLM5 at regional scale



Parameter	Evaluation Metrics	CLM5_Def	CLM5_Mod1	CLM5_Mod2
LAI	MAB	0.1911	0.2390	0.3099
	RMSE	0.2011	0.1380	0.1246
	r	**0.3530***	**0.9200***	**0.9307***
GPP	MAB	0.5141	0.2435	0.2359
	RMSE	3.2511	3.1188	2.8887
	r	**-0.4653***	**0.7607***	**0.7585***
LH	MAB	0.2733	0.2192	0.2062
	RMSE	10.9445	5.8659	5.7292
	r	**0.5259**	**0.9052**	**0.9038**
SH	MAB	0.2320	0.1785	0.1895
	RMSE	6.6510	6.3690	6.6357
	r	**0.7646***	**0.8930***	**0.8877***

Take Home

- Current study is an example on how the accurate representation of regional crops improves the carbon, energy and water fluxes simulated by land surface model.

- The crop parameters should be defined at grid level instead of defining globally to allow for regional variability.

!! Special thanks to Peter Lawrence.

Thank

https://knreddy.online/