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Supplement of

Short to sub-seasonal hydrologic forecast to manage water and agricultural resources in India

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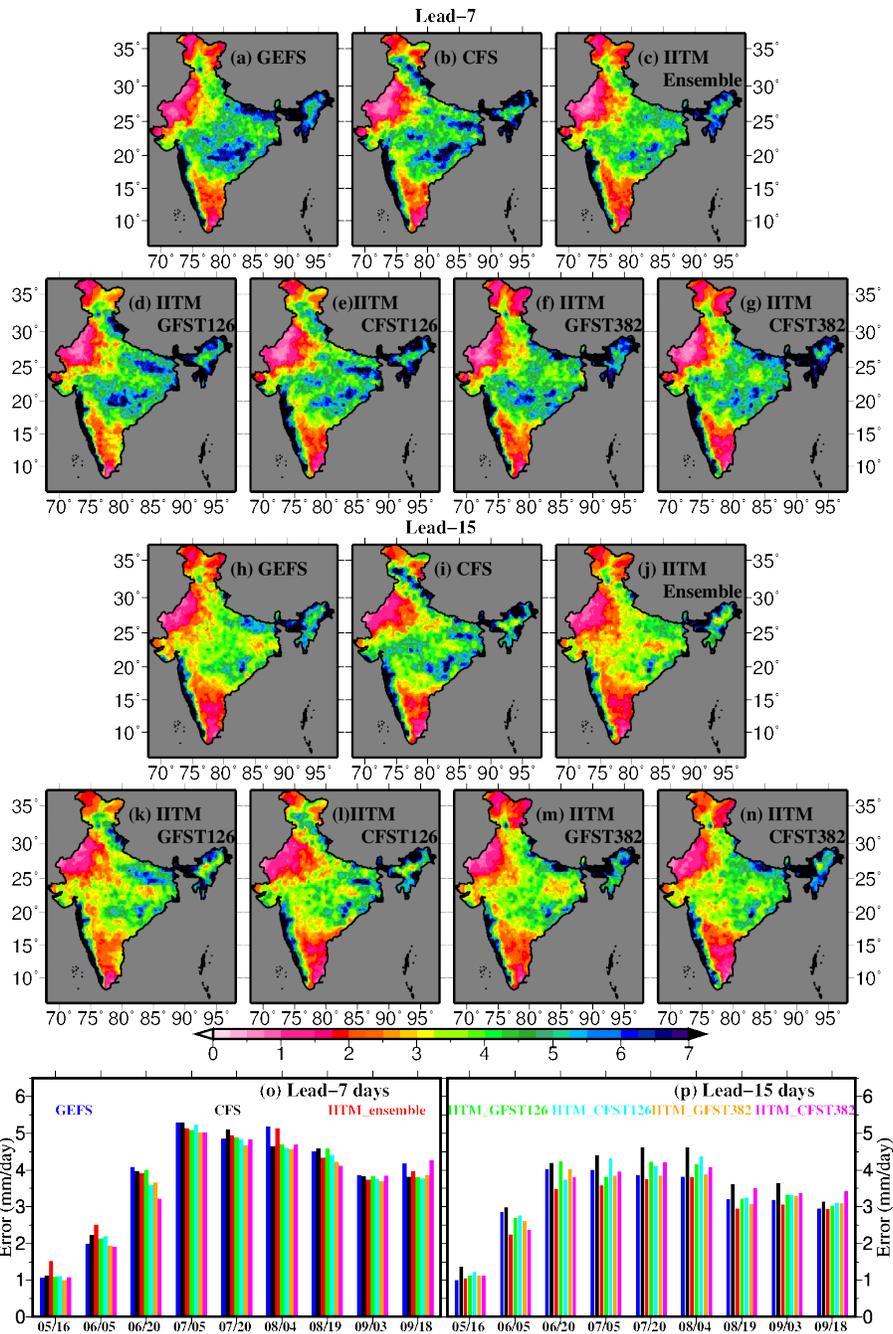


Figure S1: Median Absolute Error (MAE) in precipitation forecast as compared to observed (OBS) precipitation. (a) Error in precipitation forecast for accumulation period 7-days from GEFSv2 compared to OBS, (b) same as (a) but with CFSv2 (c) same as (a) but with IITM (multimodel, multiresolution) ensemble (d) same as (a) but with IITM GFST126, (e) same as (a) but with IITM CFST126, (f) same as (a) but with IITMCFST382, (g) same as (a) but with IITM GFST382. (h-n) same as (a-g) but for accumulation period 15 days. (o) area-weighted error in different forecast for accumulation period 7-days as compared to OBS for forecast initiated on different monsoon season dates (p) same as (o) but for accumulation period of 15 days. (period: 2001-2009). Plots were prepared using GMTv4.5.9.

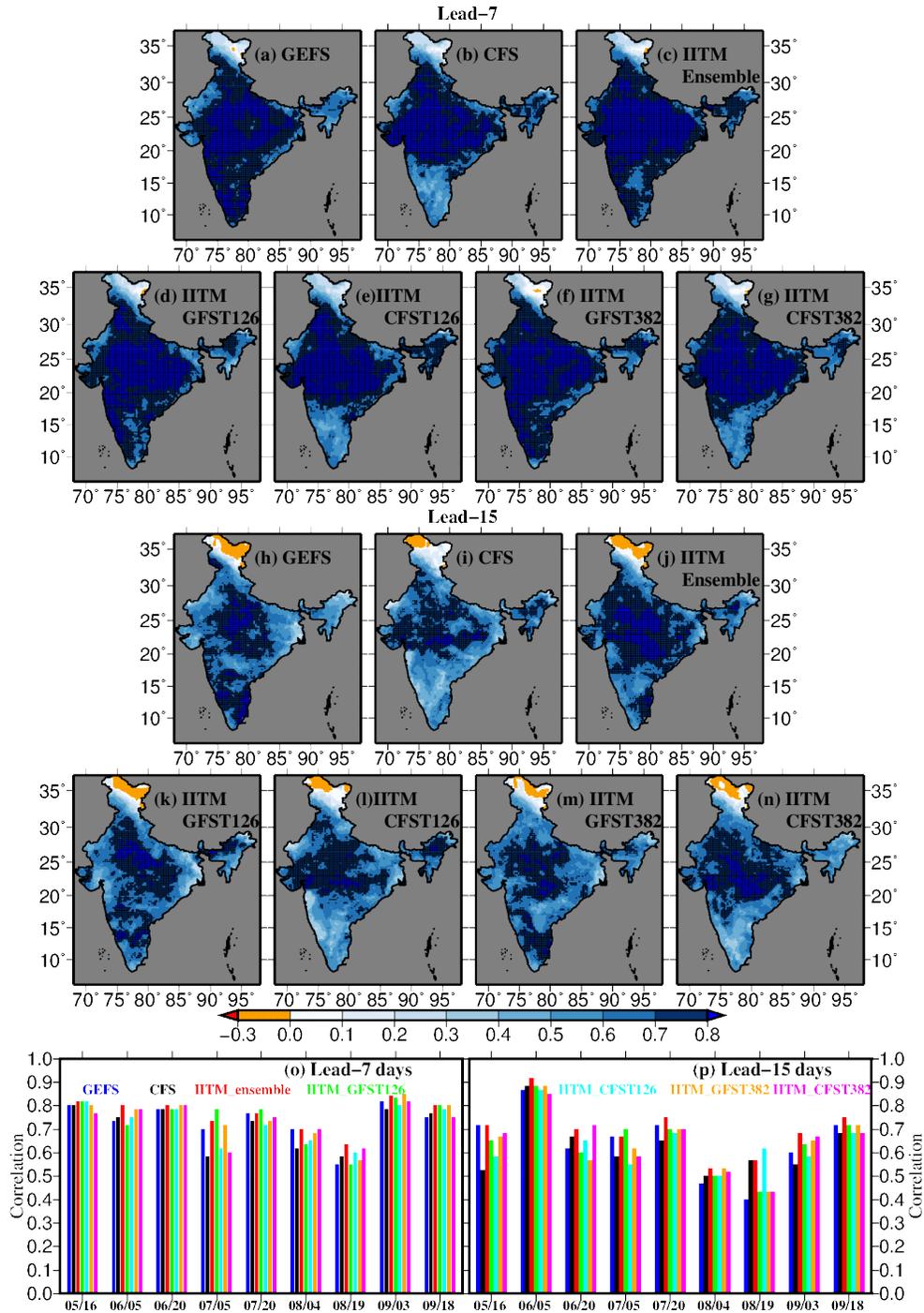


Figure S2: Correlation between daily maximum temperature (T_{max}) forecast and OBS T_{max} . (a) Correlation between T_{max} forecast from GEFSv2 averaged for accumulation period of 7-days and corresponding OBS, (b-g) same as (a) but with CFSv2, IITM ensemble, IITM GFST126, IITM CFST126, IITM GFST382, and IITM CFST382. (h-n) same as (a-g) but for accumulation period of 15 days. (o) all-India median correlation between different forecast for accumulation period of 7-days and corresponding OBS for forecast initiated on different dates (h) same as (g) but for accumulation period of 15 days. Plots were prepared using GMTv4.5.9.

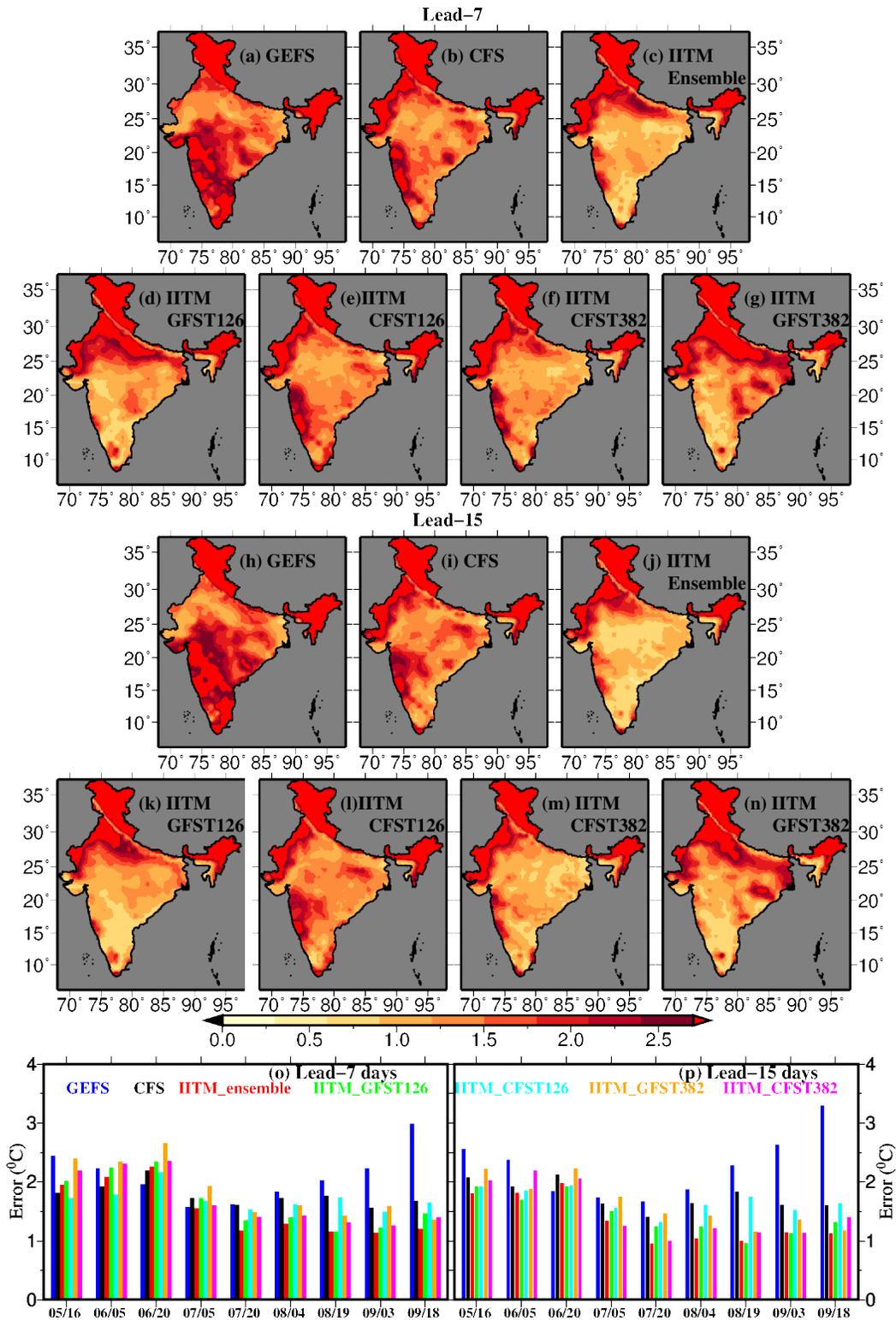


Figure S3: same as Figure 2 but MAE instead of correlation. Plots were prepared using GMTv4.5.9.

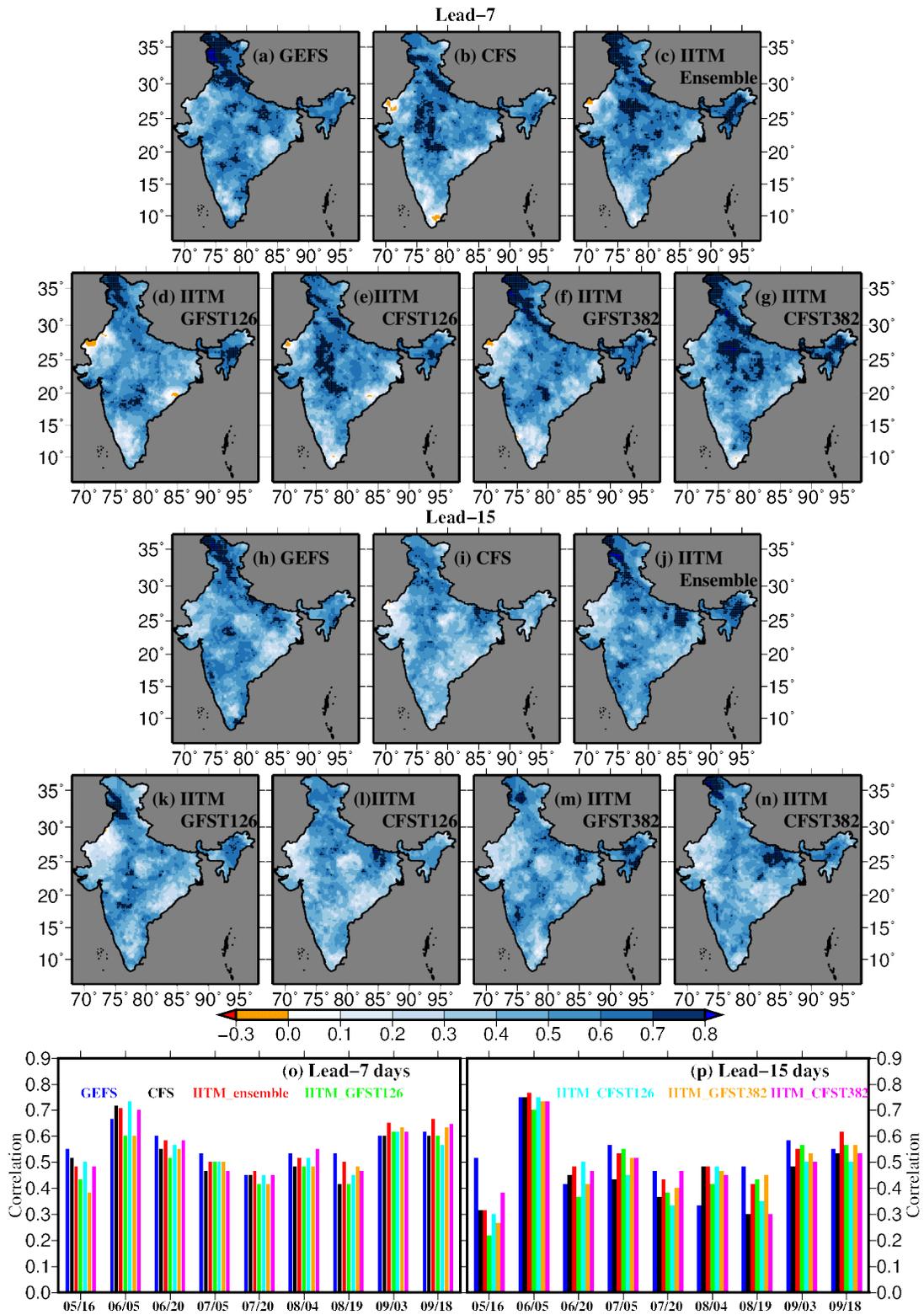


Figure S4: Same as Figure2 but for minimum temperature (Tmin). Plots were prepared using GMTv4.5.9.

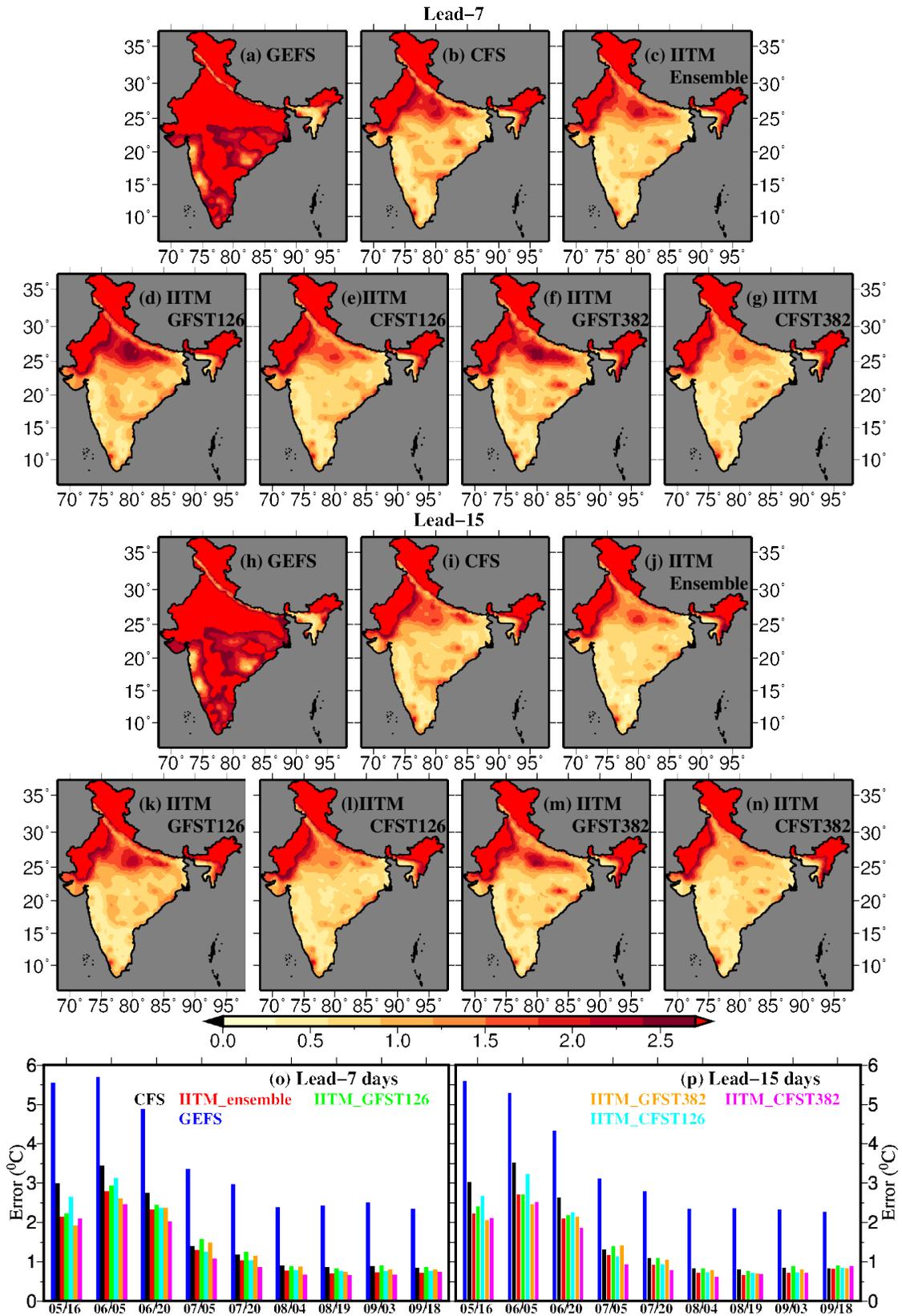


Figure S5: Same as Figure 3 but shows MAE in Tmin. Plots were prepared using GMTv4.5.9.

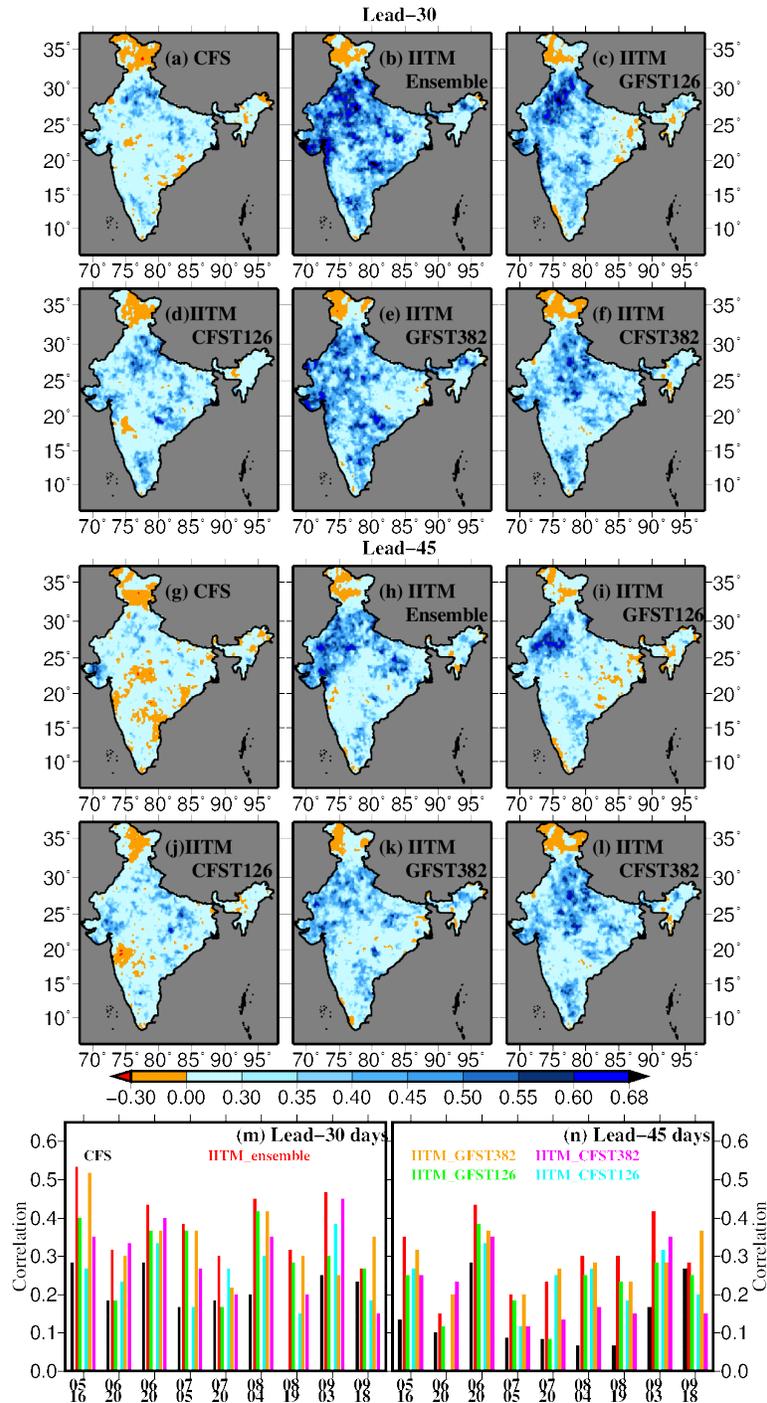


Figure S6: Correlation between precipitation forecast and observed precipitation (OBS). (a) Correlation between precipitation forecast from CFS2 for accumulation period of 30-days and corresponding OBS, (b-f) same as (a) but for IITM ensemble, IITM GFST126, IITM CFST126, IITM GFST382, and IITM CFST382, respectively. (g-l) same as (a-f) but for accumulation period of 45 days. (m) all-India median correlation between different forecast for accumulation period of 30-days and corresponding OBS for forecast initiated on different dates (n) same as (m) but for accumulation period of 45 days lead. (period: 2001-2009). Plots were prepared using GMTv4.5.9.

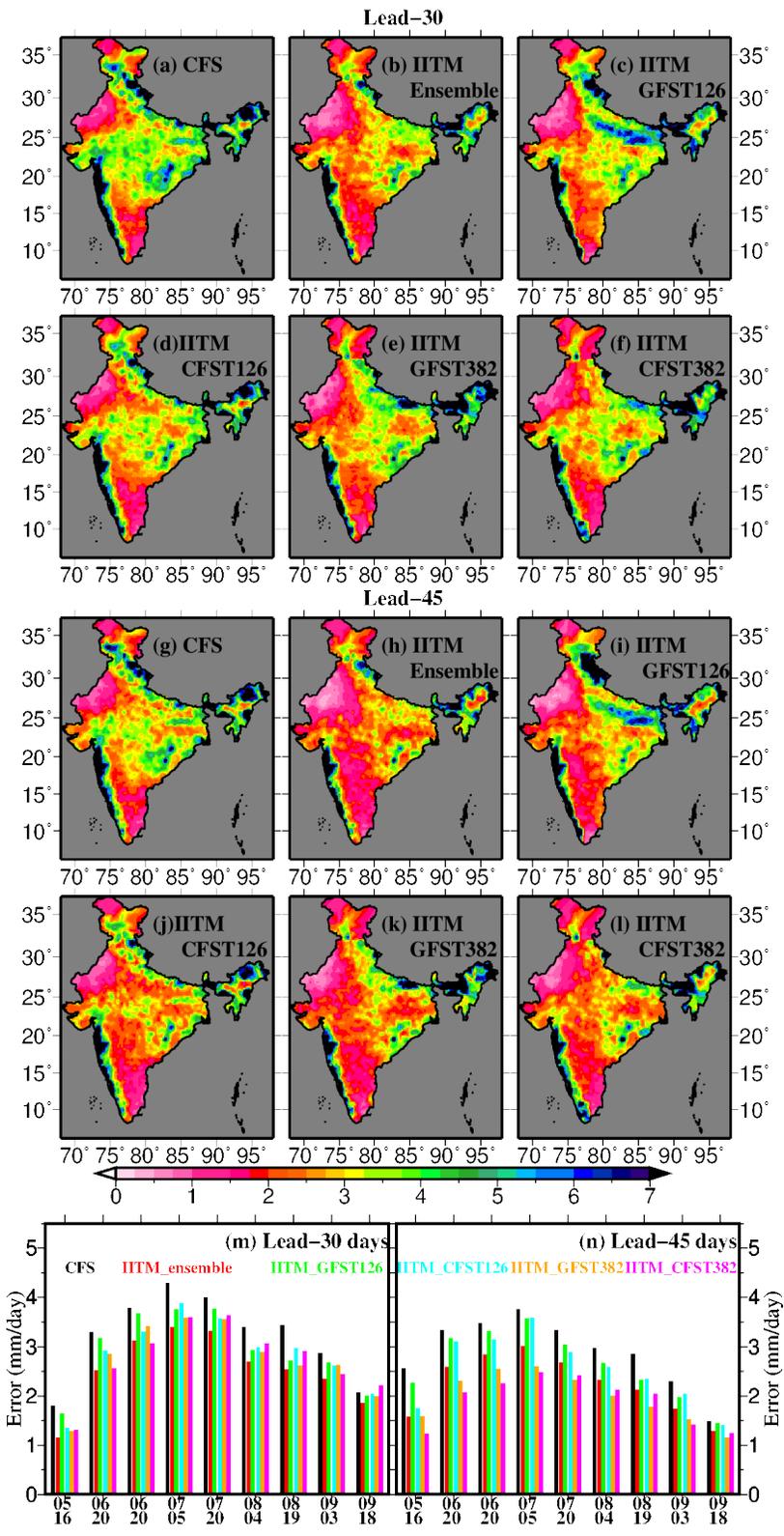


Figure S7: Same as Fig.6 but using MAE instead of correlation. Plots were prepared using GMTv4.5.9.

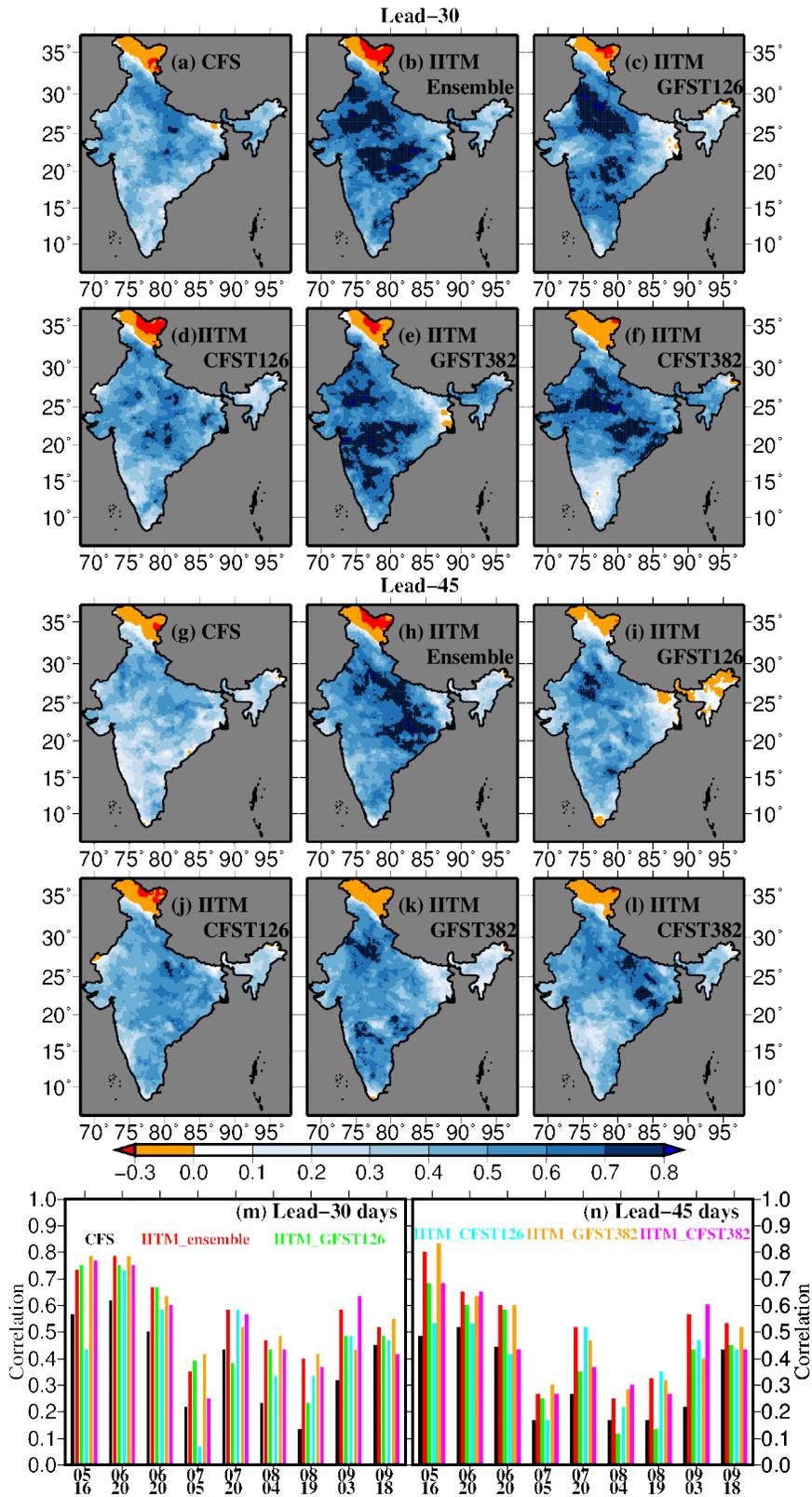


Figure S8: Same as Fig. 6 but correlation of Tmax instead of precipitation. Plots were prepared using GMTv4.5.9.

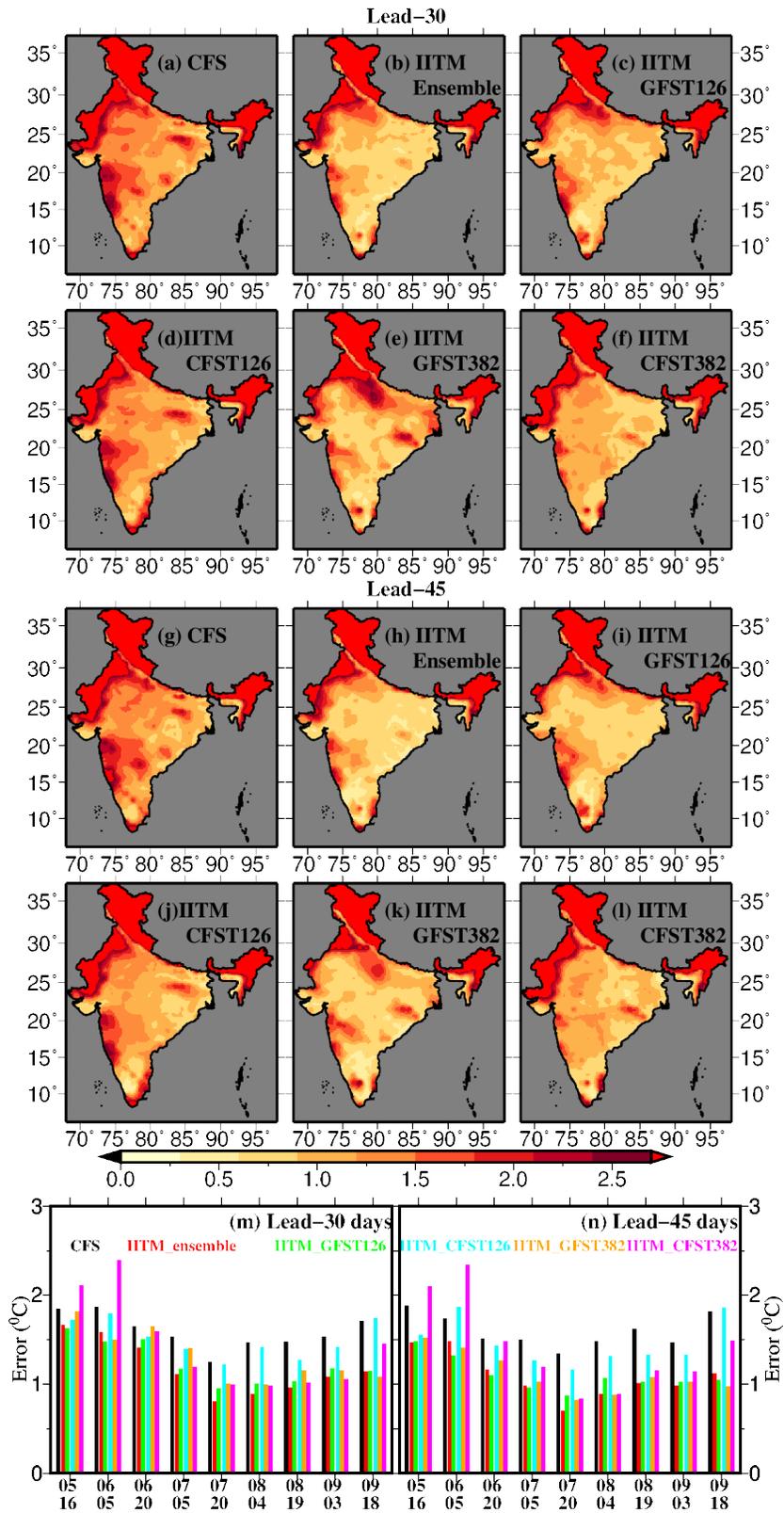


Figure S9: Same as Figure 6 but shows MAE in T_{max} instead of correlation in precipitation. Plots were prepared using GMTv4.5.9.

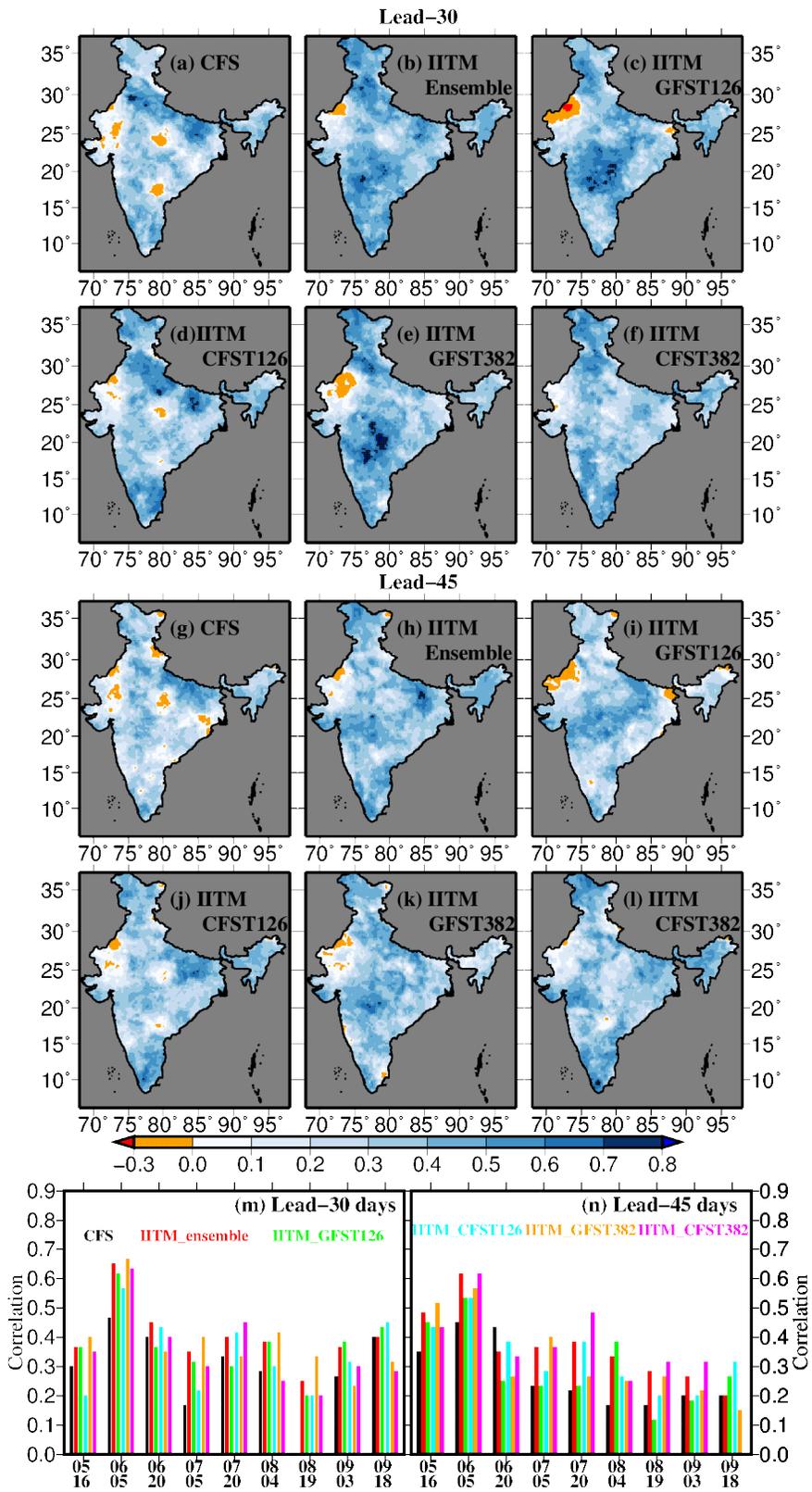


Figure S10: same as Figure 6 but shows correlation in T_{min} instead of precipitation. Plots were prepared using GMTv4.5.9.

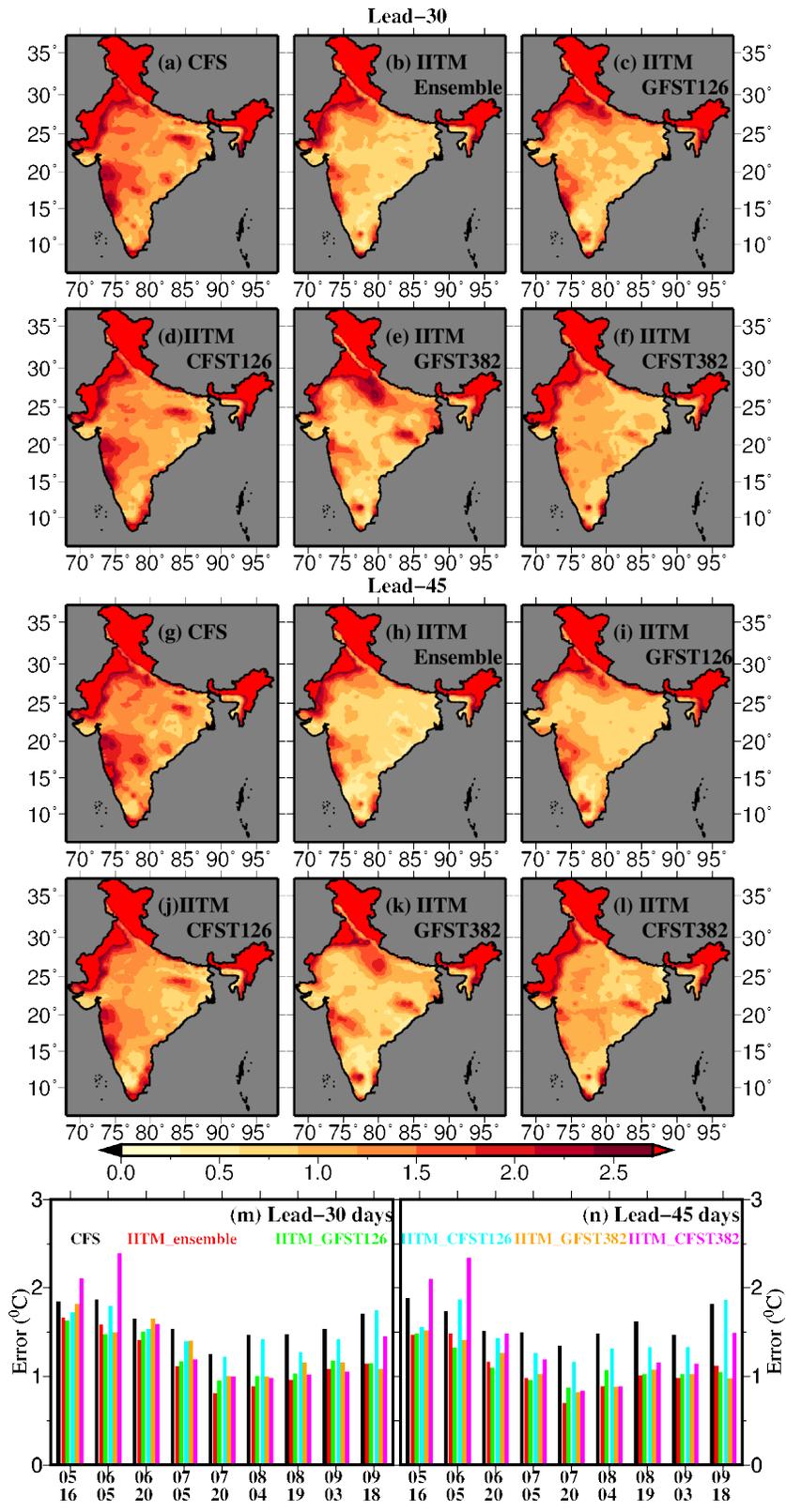


Figure S11: same as Figure 6 but shows MAE in T_{min} instead of correlation in precipitation. Plots were prepared using GMTv4.5.9.

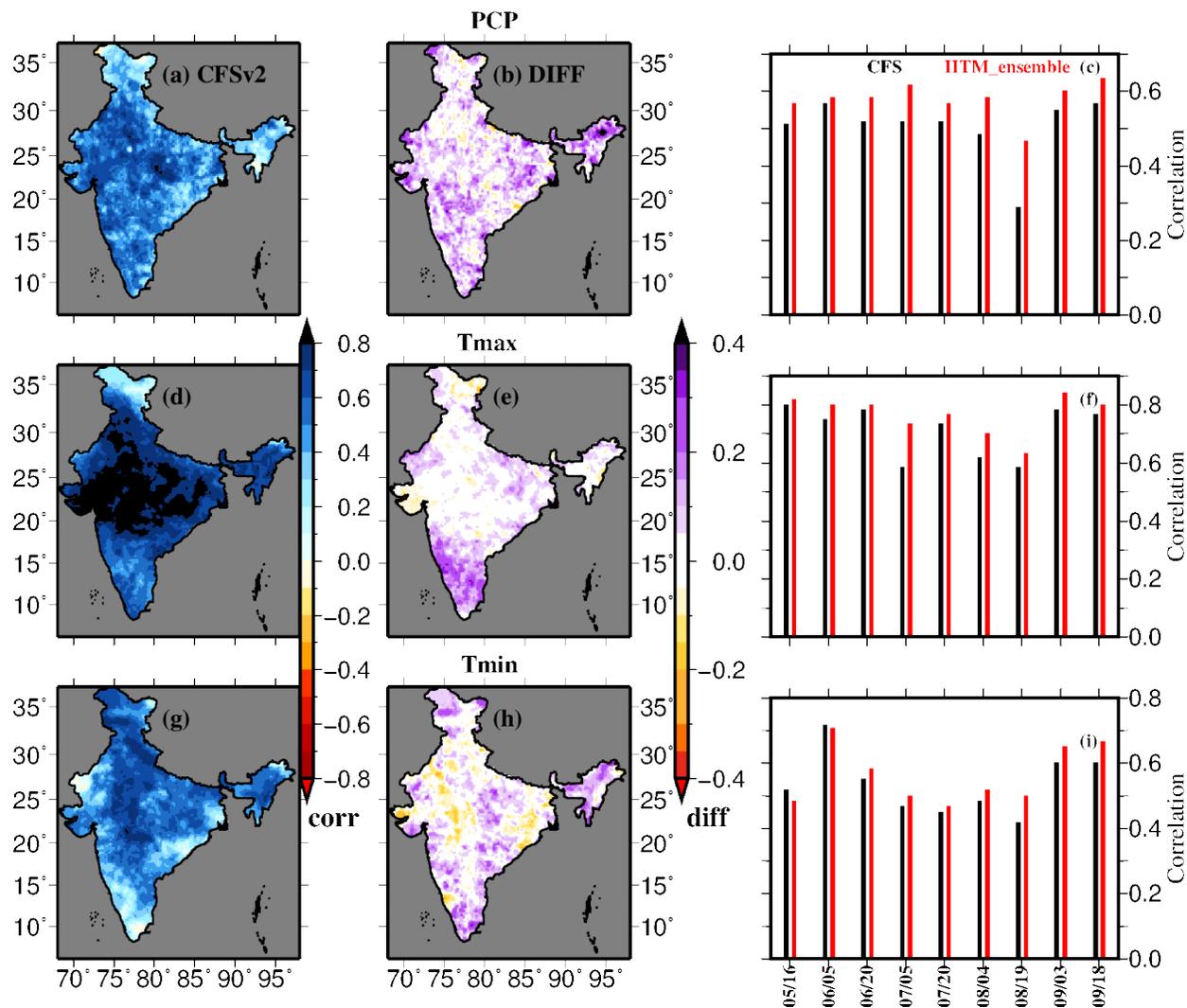


Figure S12: Correlation of forecast for accumulation period of 7-days lead with corresponding observations. (a) correlation of precipitation forecast from CFS with OBS (b) Change in correlation of precipitation forecast from IITM-ensemble with OBS as compared to (a). Correlation in (a) and (b) are median of different forecast dates during the monsoon season. (c) all-India weighted median correlation for forecast initiated on different forecast dates. (d-f) is same as (a-c) but for daily maximum temperature and (g-i) is same as (a-c) but for daily minimum temperature. Plots were prepared using GMTv4.5.9. Observed data were obtained from IMD. Forecast data were obtained from CFSv2 and IITM.

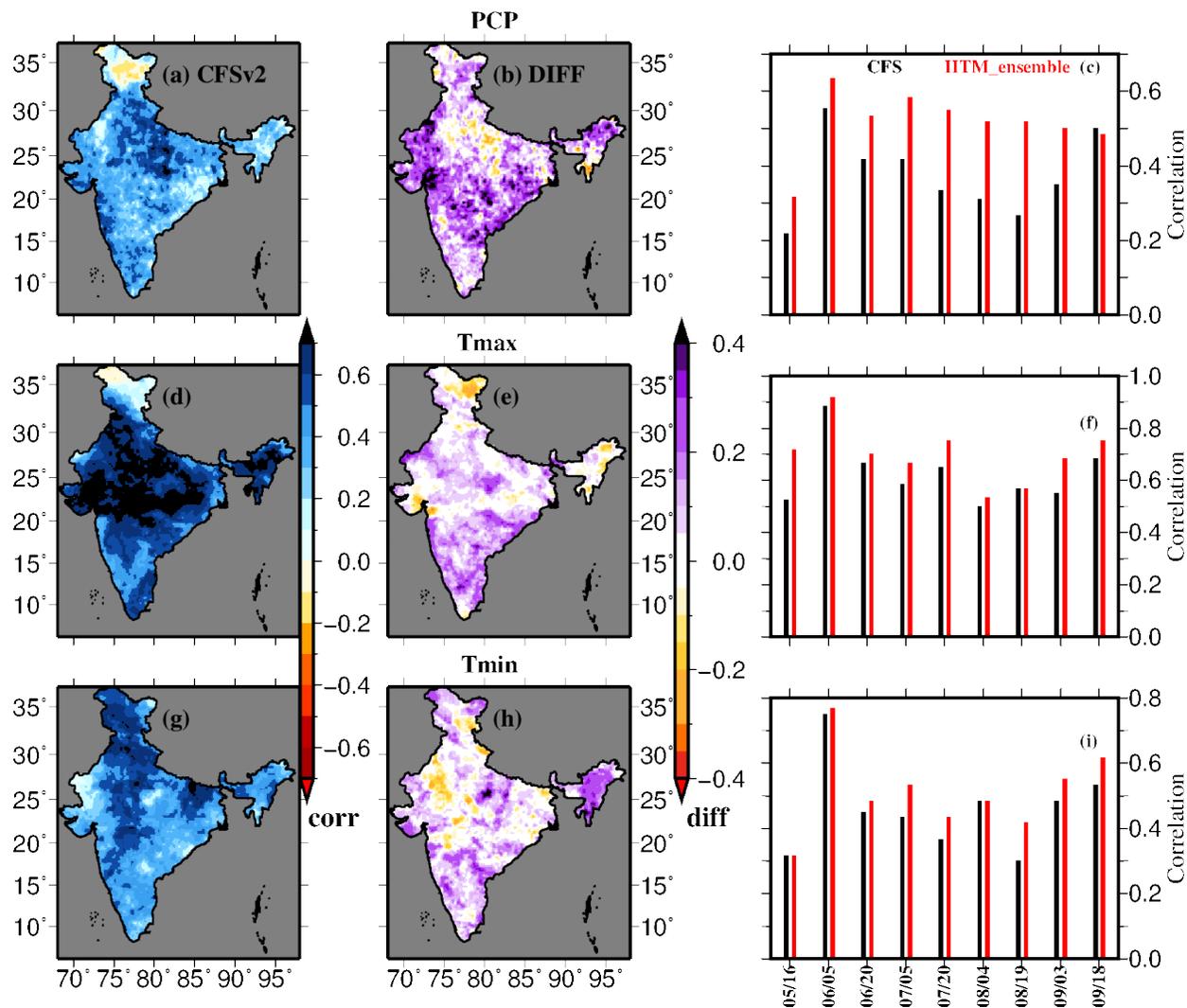


Figure S13: Correlation of forecast for accumulation period of 15-days lead with corresponding observations. (a) correlation of precipitation forecast from CFS with OBS (b) Change in correlation of precipitation forecast from IITM-ensemble with OBS as compared to (a). Correlation in (a) and (b) are median of different forecast dates during the monsoon season. (c) all-India weighted median correlation for forecast initiated on different forecast dates. (d-f) is same as (a-c) but for daily maximum temperature and (g-i) is same as (a-c) but for daily minimum temperature. Plots were prepared using GMTv4.5.9. Observed data were obtained from IMD. Forecast data were obtained from CFSv2 and IITM.

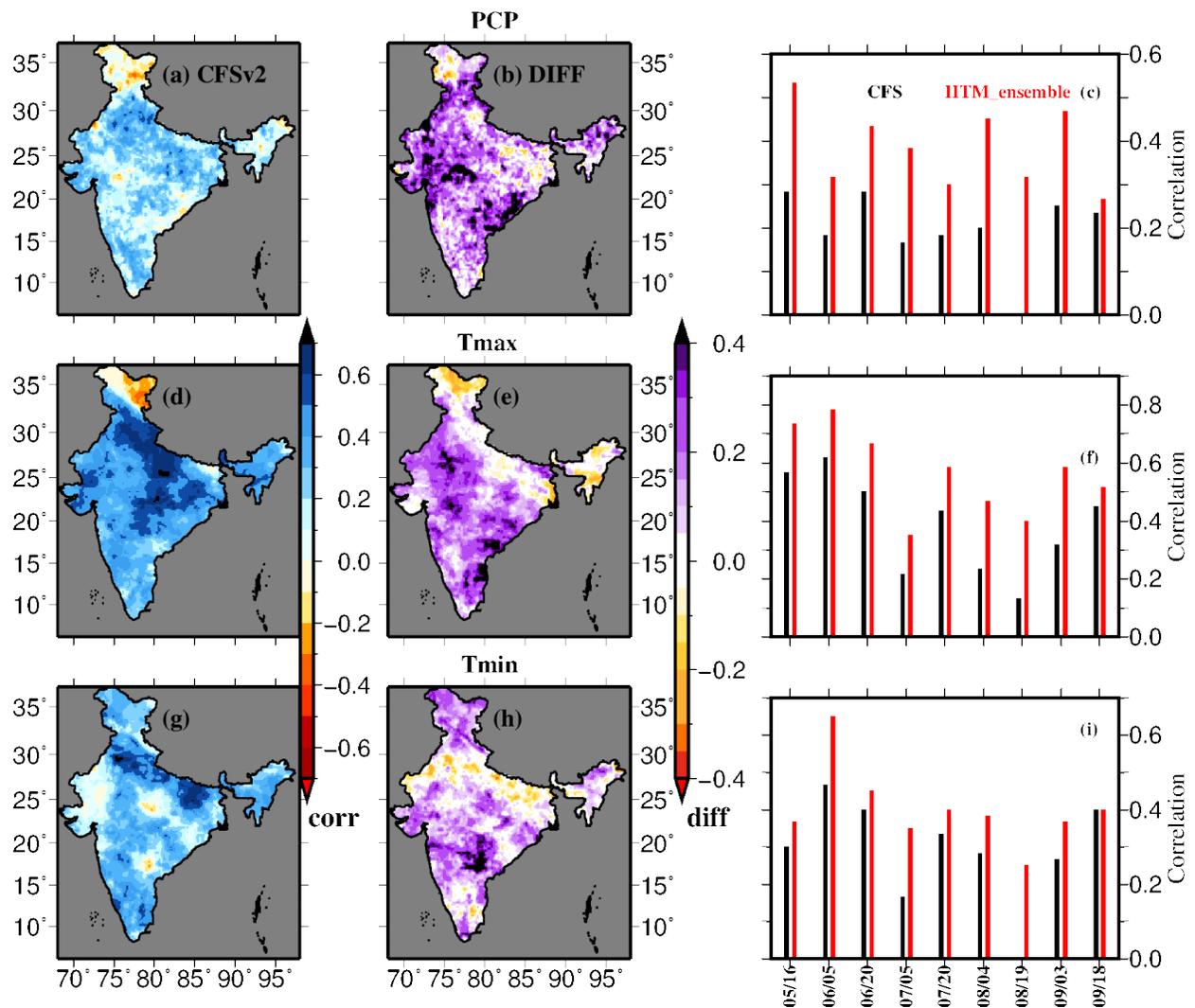


Figure S14: Correlation of forecast for accumulation period of 30-days with corresponding observations. (a) correlation of precipitation forecast from CFS with OBS (b) Change in correlation of precipitation forecast from IITM-ensemble with OBS as compared to (a). Correlation in (a) and (b) are median of different forecast dates during the monsoon season. (c) all-India weighted median correlation for forecast initiated on different forecast dates. (d-f) is same as (a-c) but for daily maximum temperature and (g-i) is same as (a-c) but for daily minimum temperature. Plots were prepared using GMTv4.5.9. Observed data were obtained from IMD. Forecast data were obtained from CFSv2 and IITM.

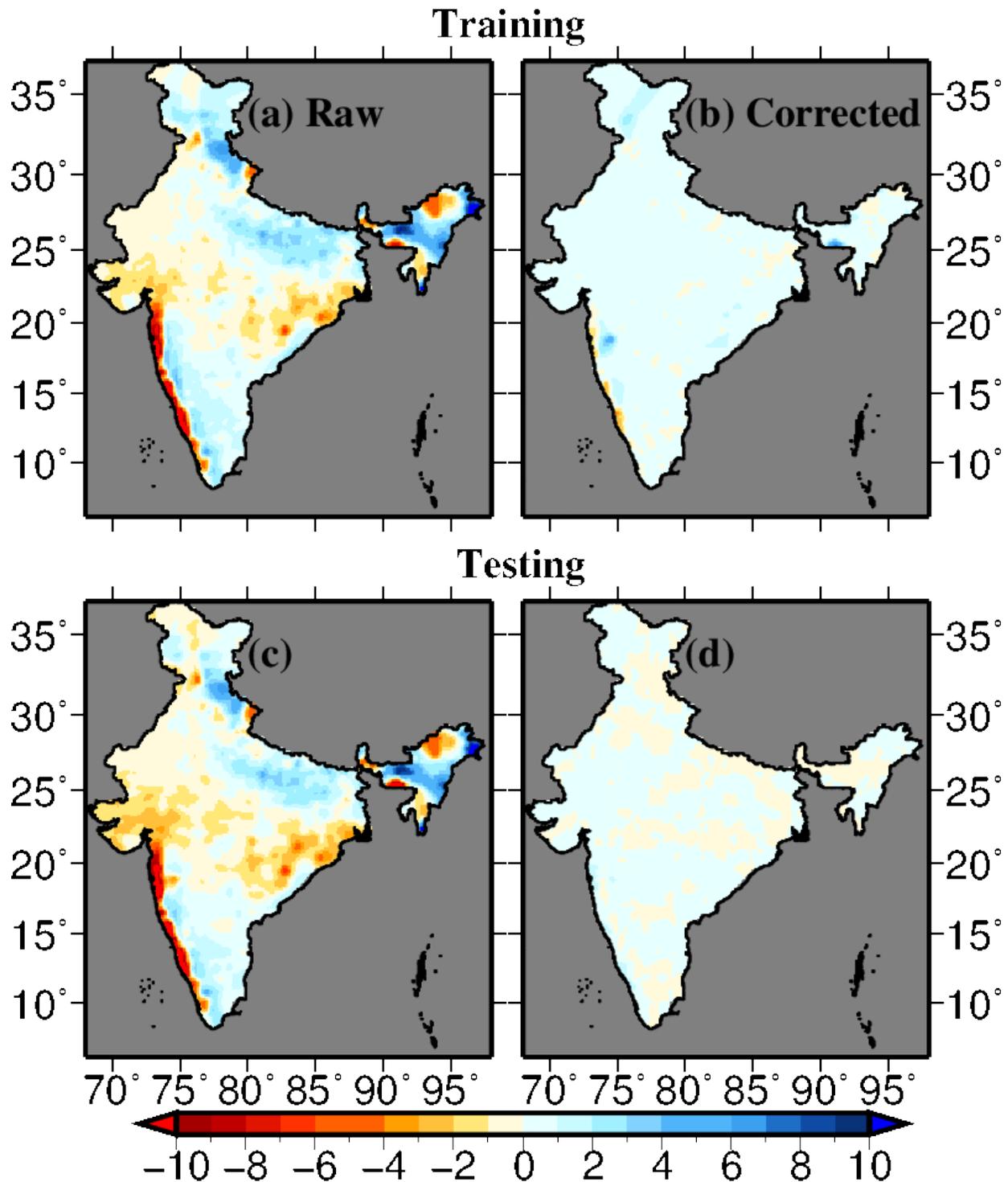


Figure S15: Median (of multifold trials and forecast dates) bias (mm/day) in forecast (accumulated for 45 days) from IITM-ensemble before and after correction. (a and b) Median bias (mm/day) in precipitation forecast before and after correction, respectively during training years (9 years). (c and d) same as (a and b) but for testing year (1 year) . Plots were prepared using GMTv4.5.9.

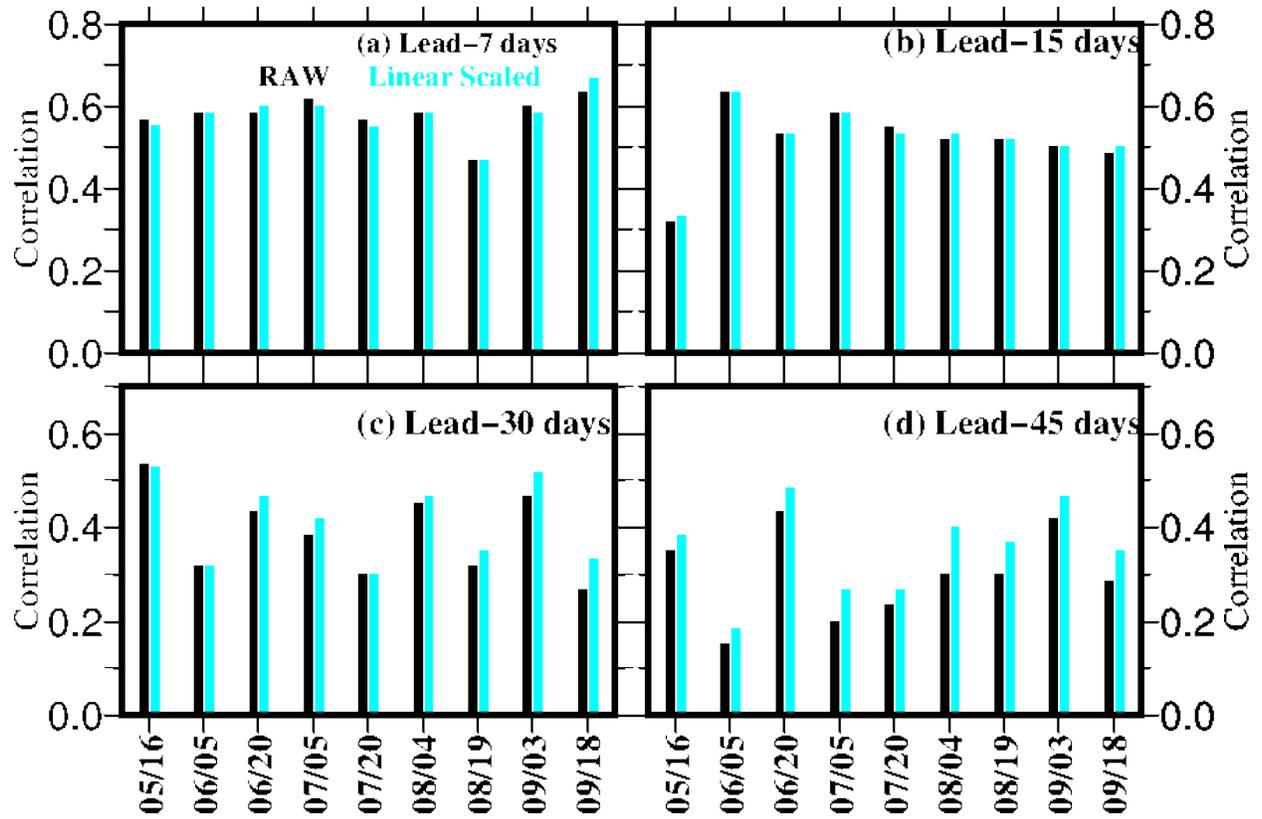


Figure S16: Comparison of all-India median correlation between raw precipitation prediction from IITM-ensemble and OBS (green color) and bias-corrected precipitation prediction from IITM-ensemble and OBS (black color) for different forecast dates during the monsoon season and at different leads. Plots were prepared using GMTv4.5.9.

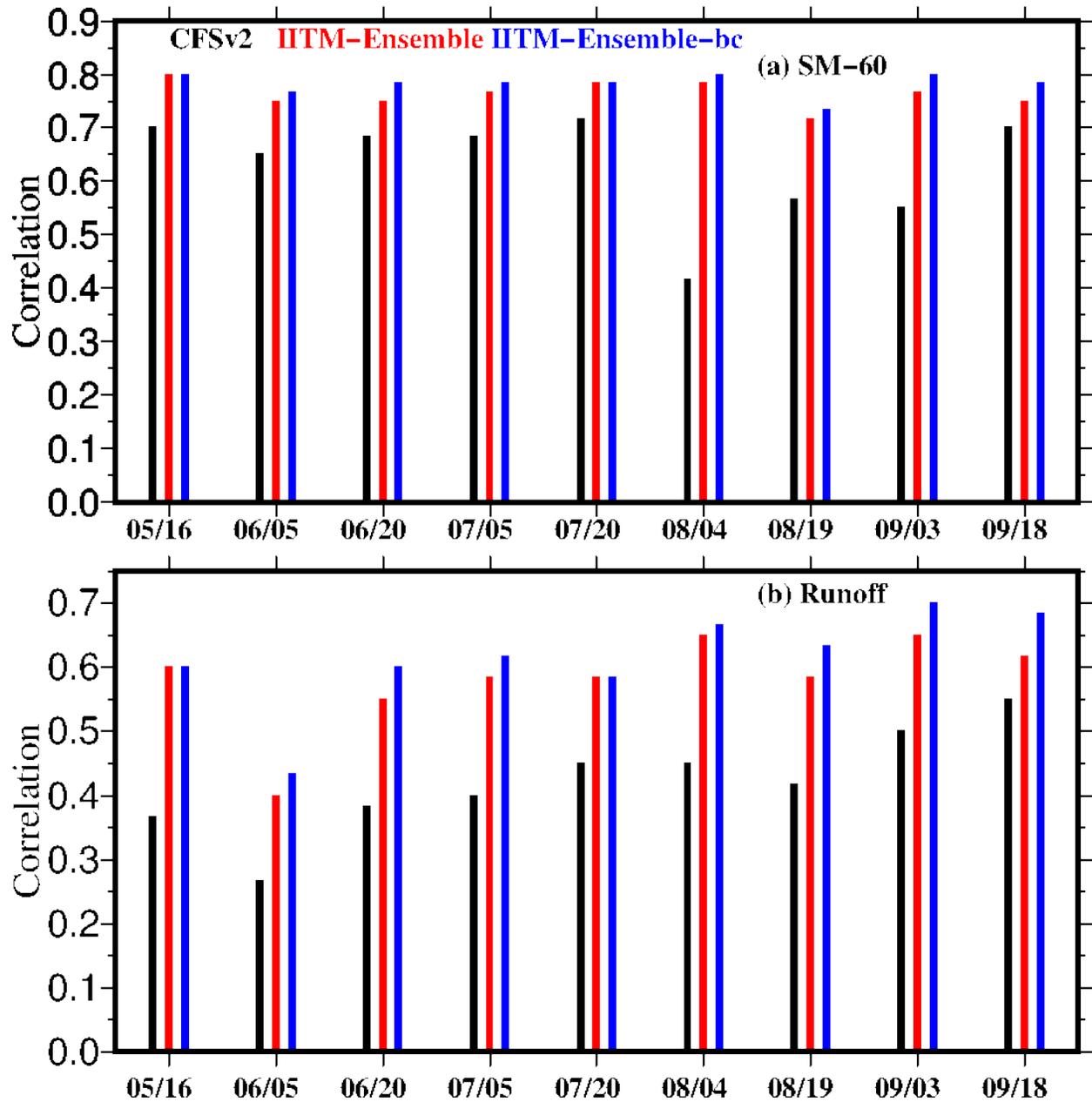


Figure S17: All-India median correlation of runoff and root zone soil moisture (60 cm) predicted using VIC and forecast with that simulated using VIC and OBS forcings for forecast dates during the monsoon season. Period: 2001-2009. Plots were prepared using GMTv4.5.9.

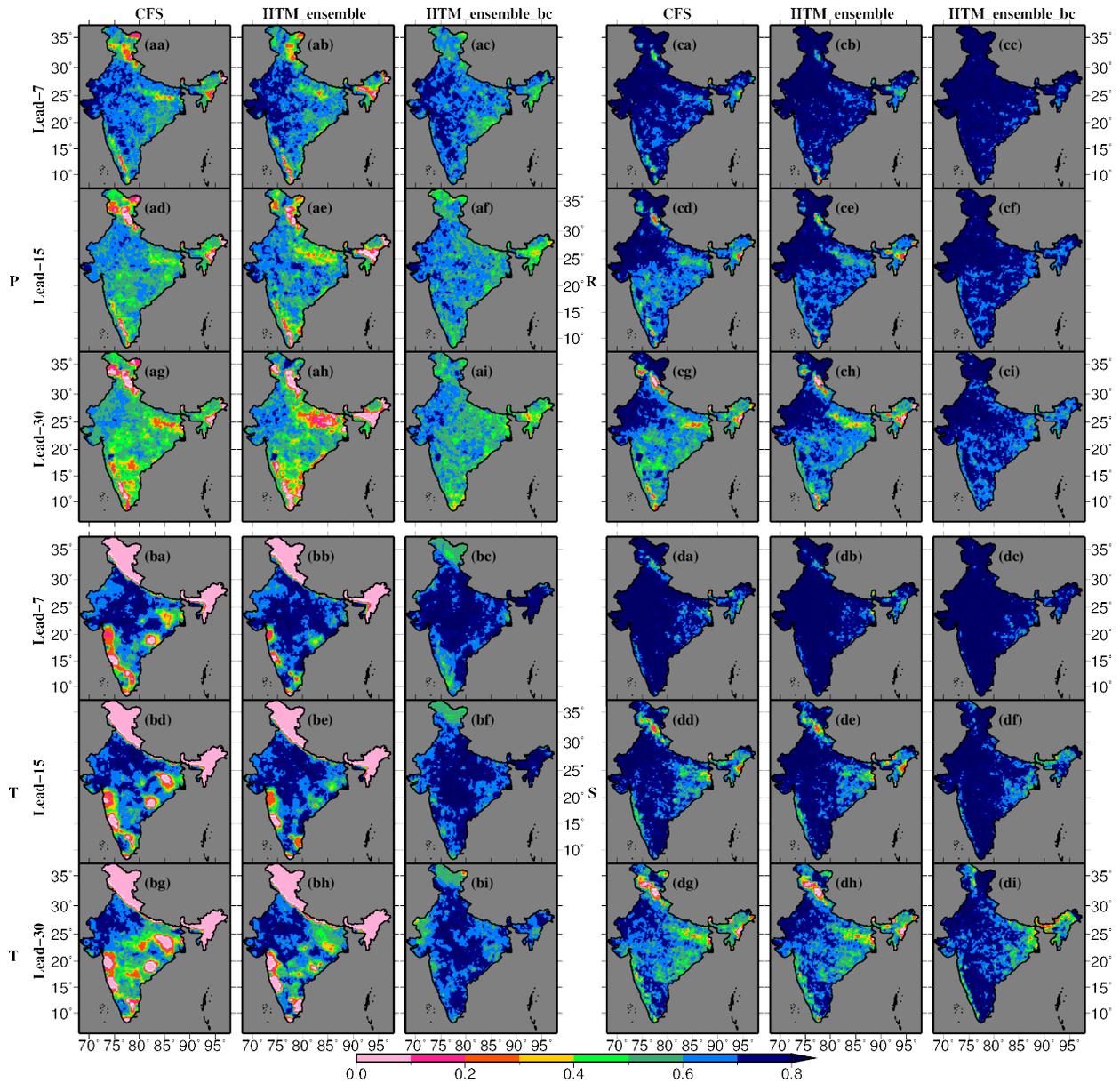


Figure S18: Critical Success Index (CSI, averaged for forecast dates) of predicting anomalies w.r.t observed anomalies. Anomalies for particular year were predicted w.r.t. observed climatology. (aa,ad,ag) shows precipitation anomalies predicted by CFSv2 (ab,ae,ah) IITM-ensemble, and (ac,af,ai) by bias-corrected IITM-ensemble for accumulation period of 7,15, and 30 days respectively. (ba-bi) same as (aa-af) but for average (during accumulation period) mean temperature. (ca-ci) same as (aa-ai) but for runoff. (da-di) same as (aa-ai) but for root zone soil moisture. Plots were prepared using GMTv4.5.9.

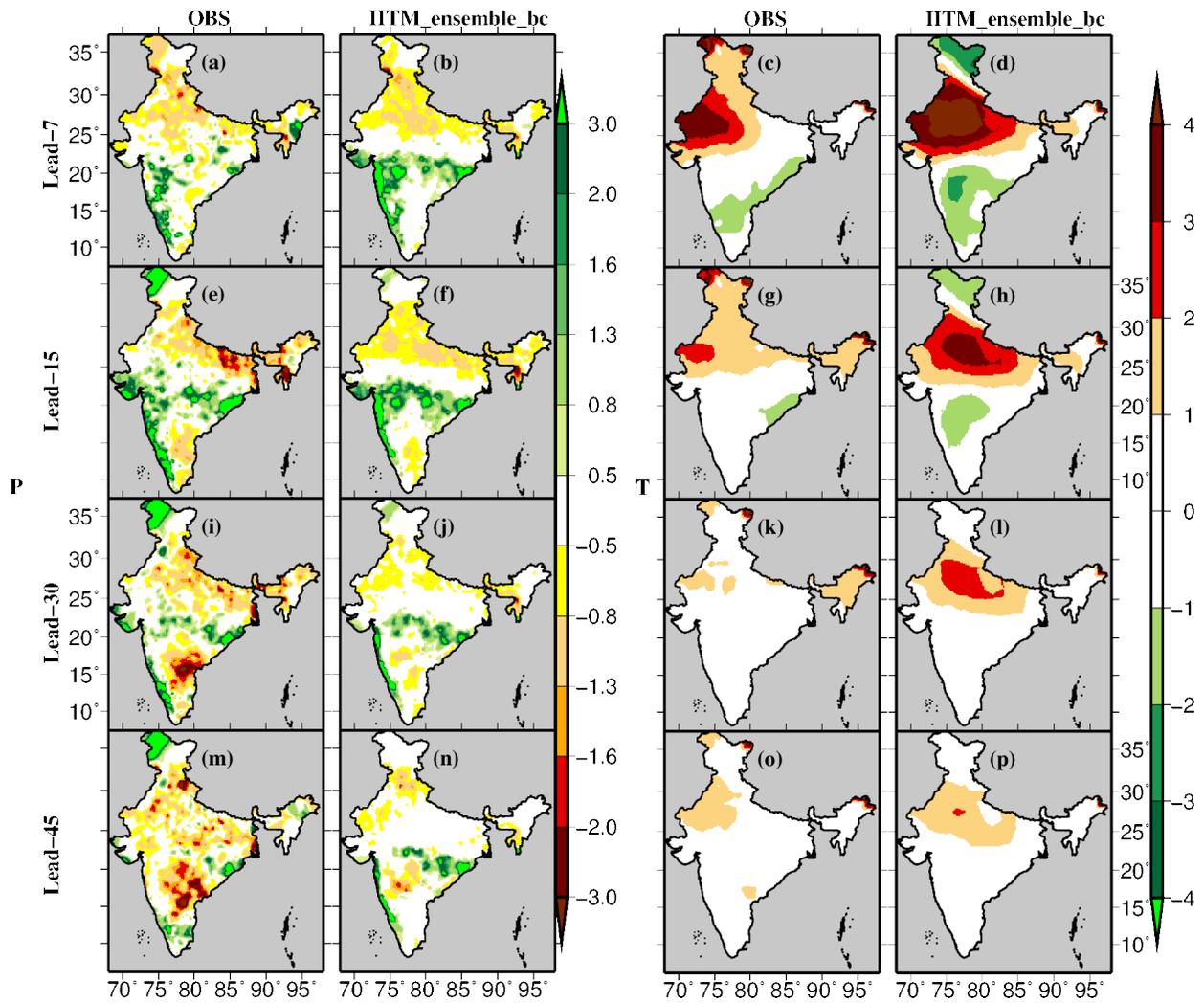


Figure S19: Forecast of anomalies initiated on 5th July, 2009 for accumulation period of 7, 15, 30, and 45 days of meteorological variables. (a) Observed (standardized) anomalies in precipitation runoff for accumulation period of 7 days (a) anomalies in forecasted precipitation using IITM-ensemble for accumulation period of 7 days. (c and d) same as (a and b) but shows anomalies in temperature for accumulation period of 7 days. (e-h), (i-l), (m-p) same as (a-b) but for 15, 30, and 45 accumulation period. Plots were prepared using GMTv4.5.9.

Table S1: Comparison of median skill (of considered forecast dates and of all-India) of different predicted variables for different forecast products.

		lead	GEFSv2	CFSv2	IITM_ensemble	IITM_GFST126	IITM_CFST126	IITM_GFST382	IITM_CFST382
Rain	Correlation	7	0.55	0.52	0.58	0.55	0.53	0.57	0.57
		15	0.50	0.35	0.52	0.43	0.42	0.47	0.47
		30		0.20	0.38	0.30	0.27	0.35	0.33
		45		0.10	0.30	0.25	0.25	0.28	0.17
	MAE(mm/day)	7	2.86	2.50	2.62	4.00	3.77	2.55	2.85
		15	2.62	2.82	2.36	3.32	3.30	2.53	2.77
		30		2.70	2.10	2.93	2.97	2.32	2.34
		45		2.39	1.90	2.66	2.58	1.99	2.07
Tmax	Correlation	7	0.75	0.75	0.80	0.78	0.75	0.78	0.75
		15	0.67	0.58	0.70	0.65	0.62	0.65	0.68
		30		0.43	0.58	0.48	0.47	0.52	0.57
		45		0.27	0.53	0.43	0.43	0.47	0.43
	MAE (°C)	7	2.0	1.7	1.3	1.5	1.7	1.6	1.4
		15	2.3	1.6	1.2	1.3	1.6	1.5	1.3
		30		1.5	1.1	1.2	1.4	1.2	1.2
		45		1.5	1.0	1.1	1.3	1.0	1.2
Tmin	Correlation	7	0.55	0.52	0.52	0.50	0.52	0.50	0.55
		15	0.52	0.45	0.48	0.43	0.48	0.47	0.47
		30		0.30	0.38	0.37	0.32	0.35	0.30
		45		0.22	0.35	0.25	0.32	0.27	0.33
	MAE	7	3.0	1.2	1.0	1.2	1.0	1.2	0.9
		15	2.8	1.1	0.9	1.1	0.9	1.0	0.9
		30		1.2	0.9	1.0	1.1	1.0	0.8
		45		1.2	1.1	1.1	1.1	1.0	1.0