Monsoon variability and predictability associated with antecedent remote land surface temperature

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Backgrounds

ENSO, the single largest predictor explains ~25-30% seasonal ISMR variability. In the later phase of monsoon, in general ENSO-monsoon relationship is stronger.

What are the other sources of ISMR variability, predictability ?

The Asian monsoon is a giant inter-hemispheric circulation primarily initiated by the land-ocean temperature gradient. Land surface processes are important but less explored, partly due to a lack of observations

Initial phase of monsoon goes through dramatic changes in the land surface characteristic. Extremes on sub-seasonal components are also part of initial phase of monsoon, which can contribute to the seasonal mean and variability.

Predictability arising from land-atmosphere interactions could add to the seasonal monsoon predictability.

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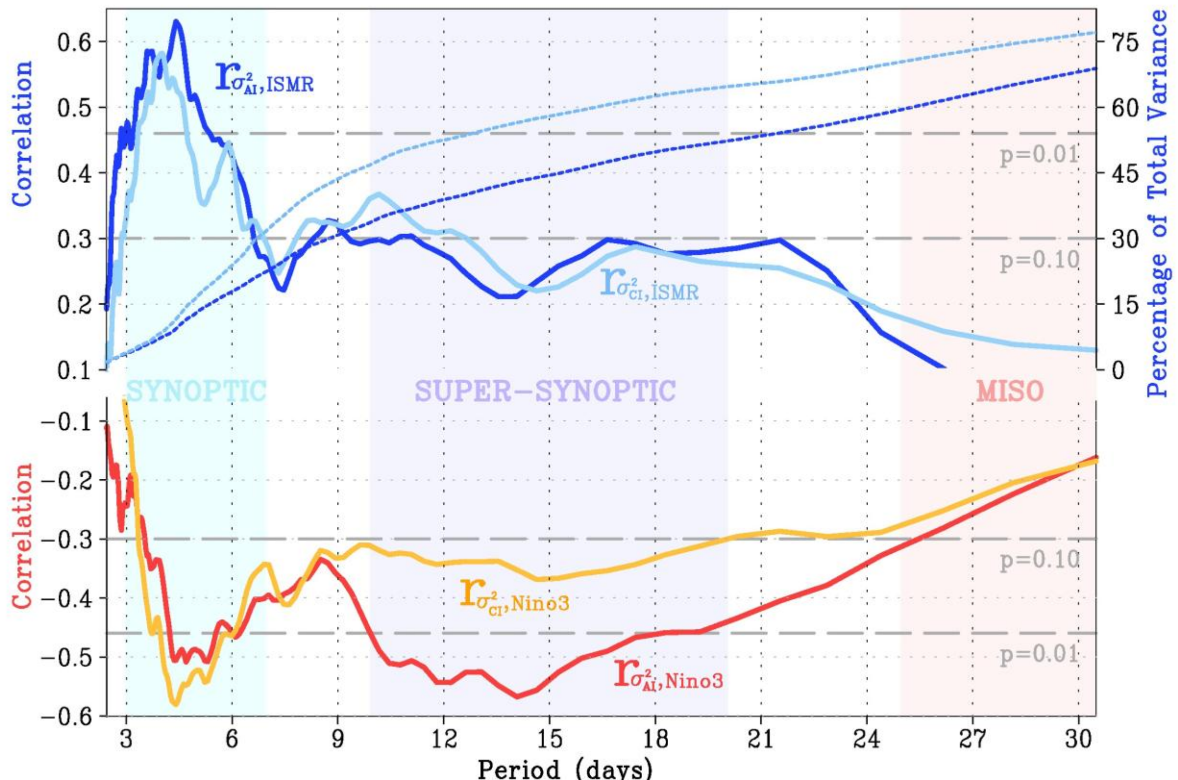
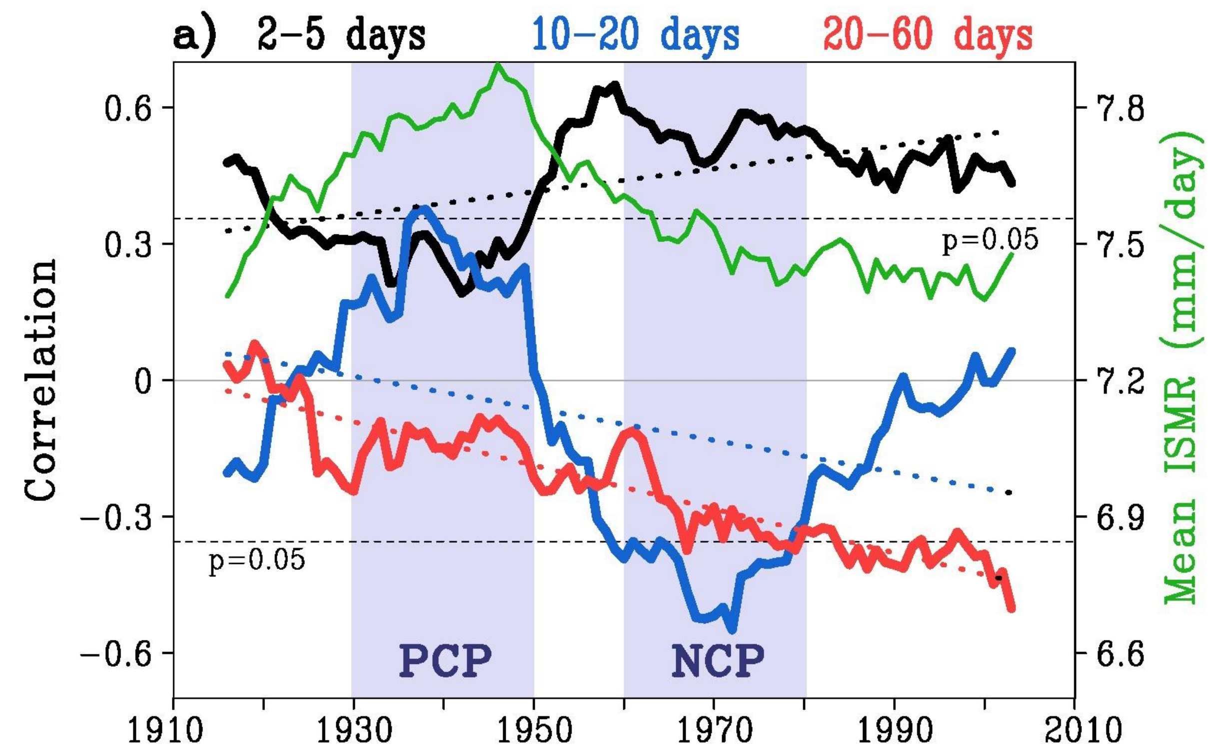
Su-seasonal components are linked with ISMR variability, predictability



Saha et al., 2019; JGR



Saha et al., 2021; GRL

➔ Synoptic activity have maximum contribution to the ISMR anomaly
➔ Synoptic and MISOs are part of predictive signal and not NOISE!
➔Model with poor simulation of synoptic system, unlikely to have better skill

JGR Atmospheres

COMMENT
10.1029/2020JD033037

This article is a comment on Saha et al. (2019), https://doi.org/10.1029/2018JD030082.

Key Points:

- The correlation between seasonal mean Indian rainfall and its subseasonal variance is sensitive to temporal and spatial domain
- The observed synoptic peak in the

Comment on “Unraveling the Mystery of Indian Summer Monsoon Prediction: Improved Estimate of Predictability Limit” by Saha et al.

Erik T. Swenson[1], Debanjana Das[1,2], and J. Shukla[1,3]

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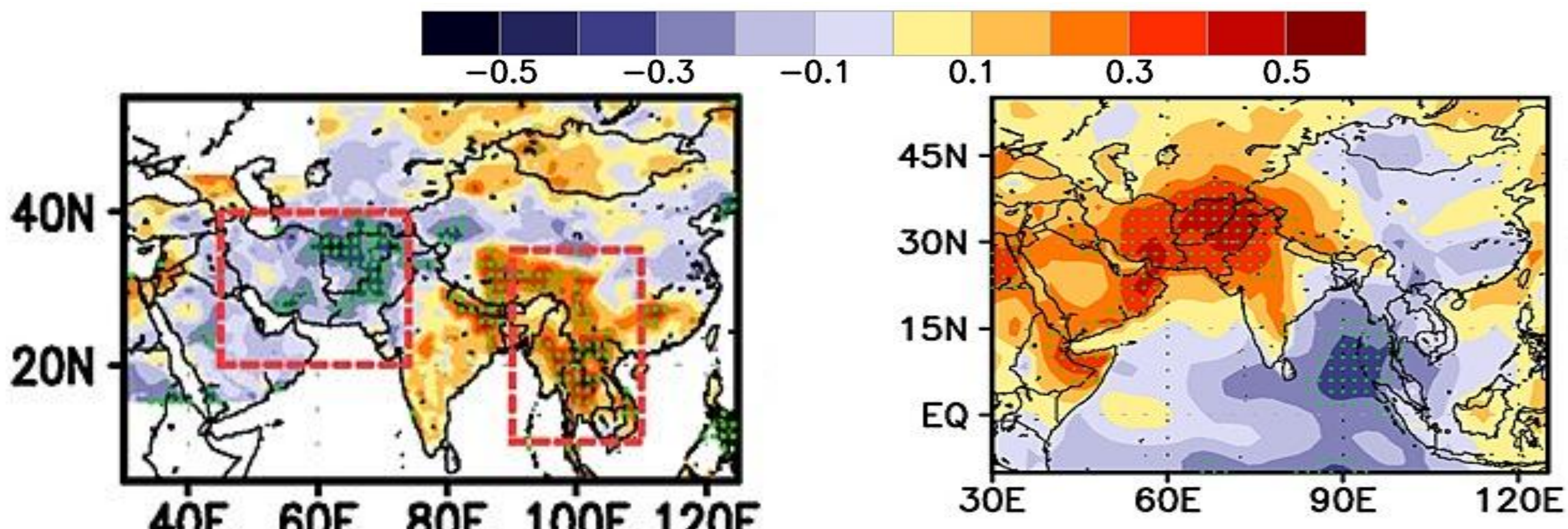
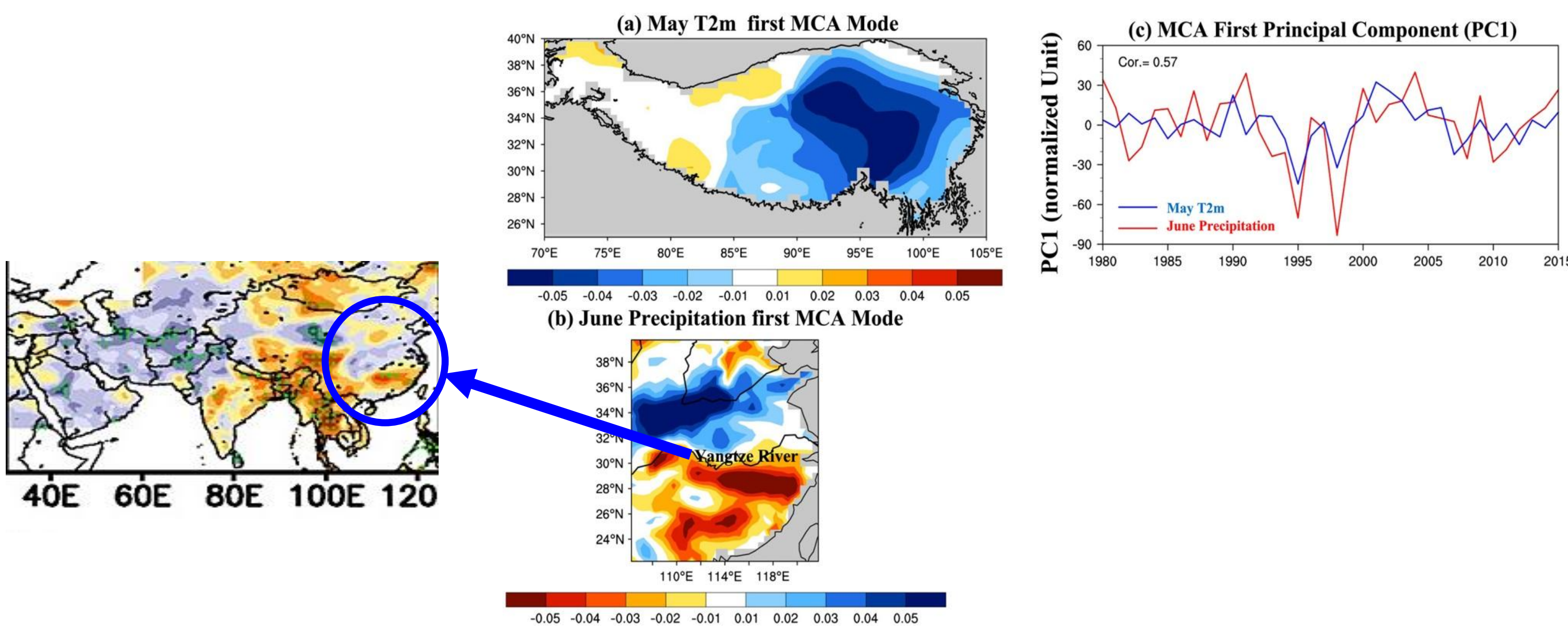
Independent Studies on Effects of Tibetan Plateau on Monsoon



Central India averaged June rainfall is correlated with April-May rainfall

Central India average June rainfall is correlated with April-May 2m temp

Rai et al., 2015, JGR



Xue et al., 2018; JGR

MCA over East Asia. (a and b) Spatial patterns of MCA1 for May T2 m over TP and June precipitation over East Asia, respectively. (c) PC1 of MCA during 1980–2015 for May T2 m (blue line) and June precipitation (red line). a–c are expressed in normalized unit.

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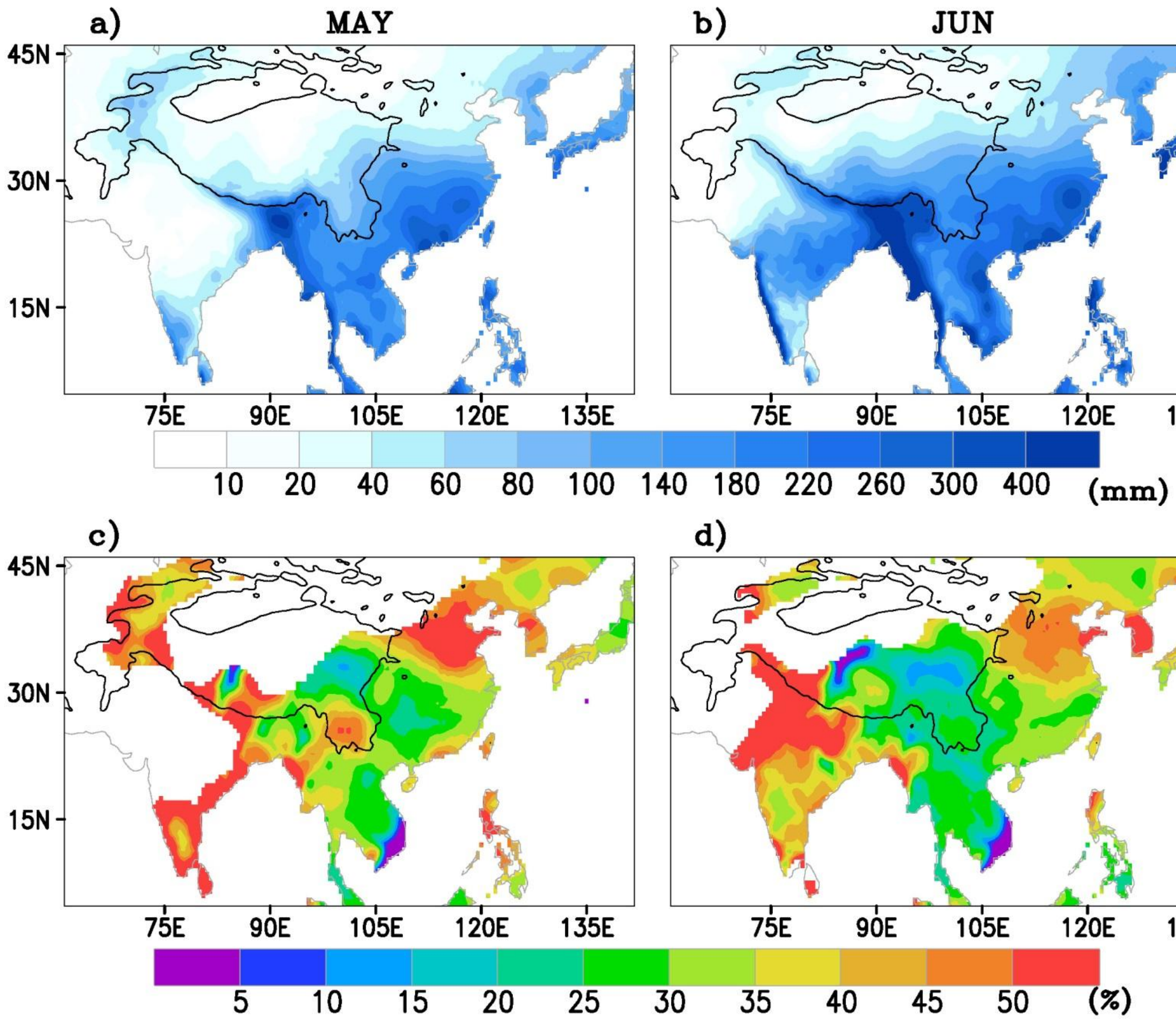
Mean & Variability in the First Phase of Asian Monsoon

Mean

SD



Climatological mean (1901–2019) accumulated rainfall (*in mm*) during **a)** May and **b)** June from CRU. The interannual standard deviation of monthly rainfall with respect of mean (in %) during **c)** May and **d)** June. Height of 1.5 km topography shown by thin black contour.

The Asian summer monsoon is an inter-hemispheric circulation system, initially driven by north-south land-ocean temperature gradient.

South Asian & East Asian monsoon are not independent completely.

Is there a common mode of variability in the first phase of the Asian summer monsoon associated with land-surface heating over the elevated region of Tibetan plateau ?

IWM-8

EOFs of June Rainfall (1901-2019)

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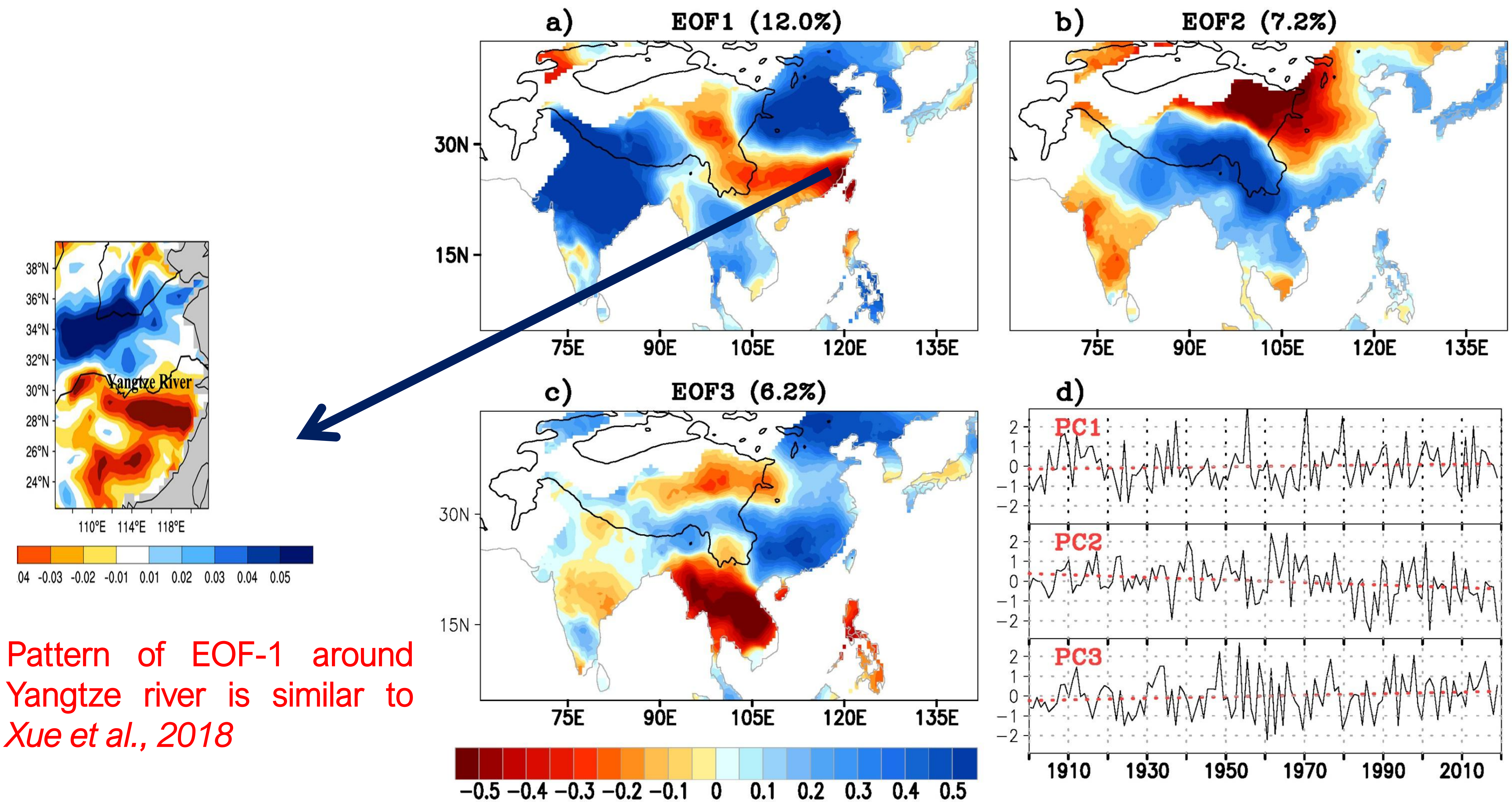
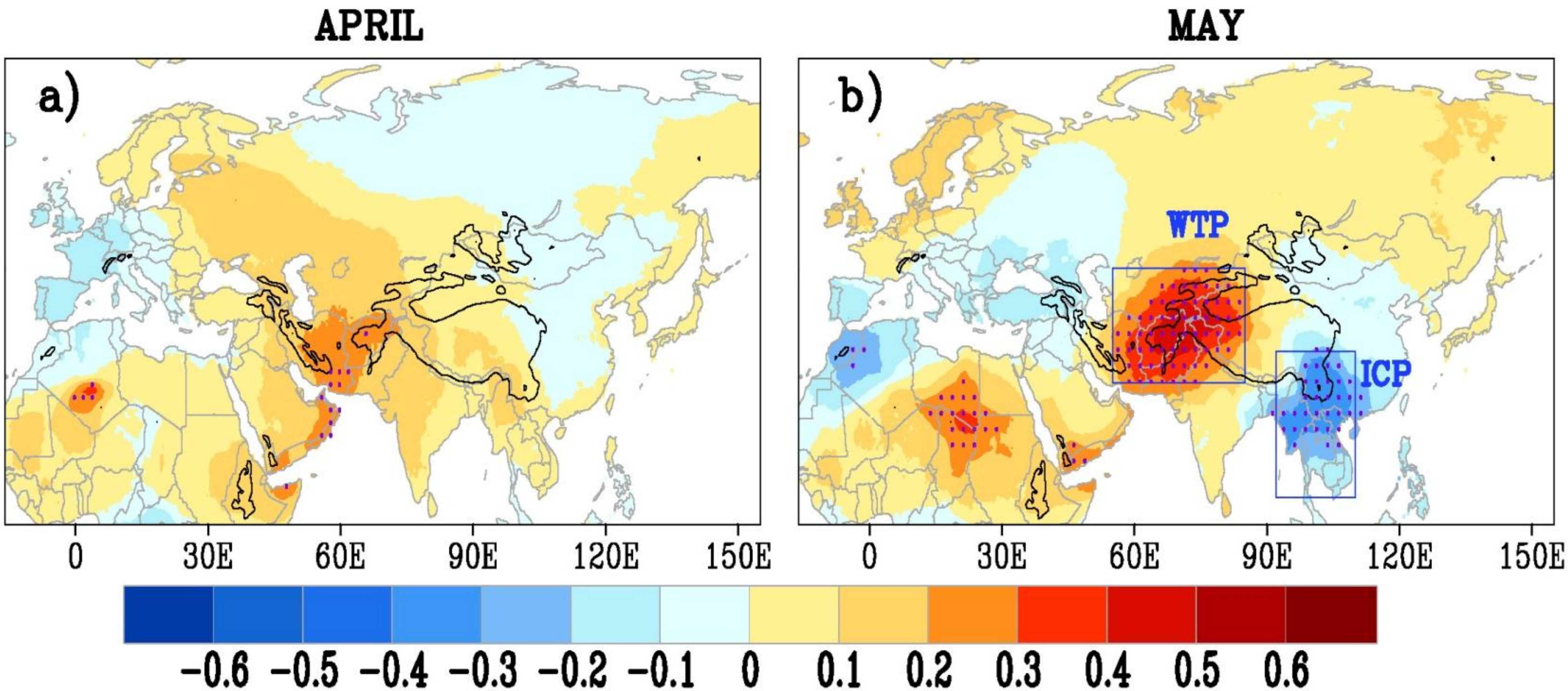


Pattern of EOF-1 around Yangtze river is similar to *Xue et al., 2018*

First three EOFs and PCs of June rainfall from CRU (1901–2019). The percentage of total variance explained by individual EOFs are given in the sub-figure captions.

Saha, Xue et al., 2023; Clim. Dyn.

Teleconnection of Dominant Precipitation Mode



PC1 is correlated (1901–2019) with surface air temperature (2 m) during **a)** April and **b)** May.

PC-1 of June rainfall is strongly correlated with May 2m air temperature over Western Tibetan Plateau (WTP) and Indo-China Peninsula region

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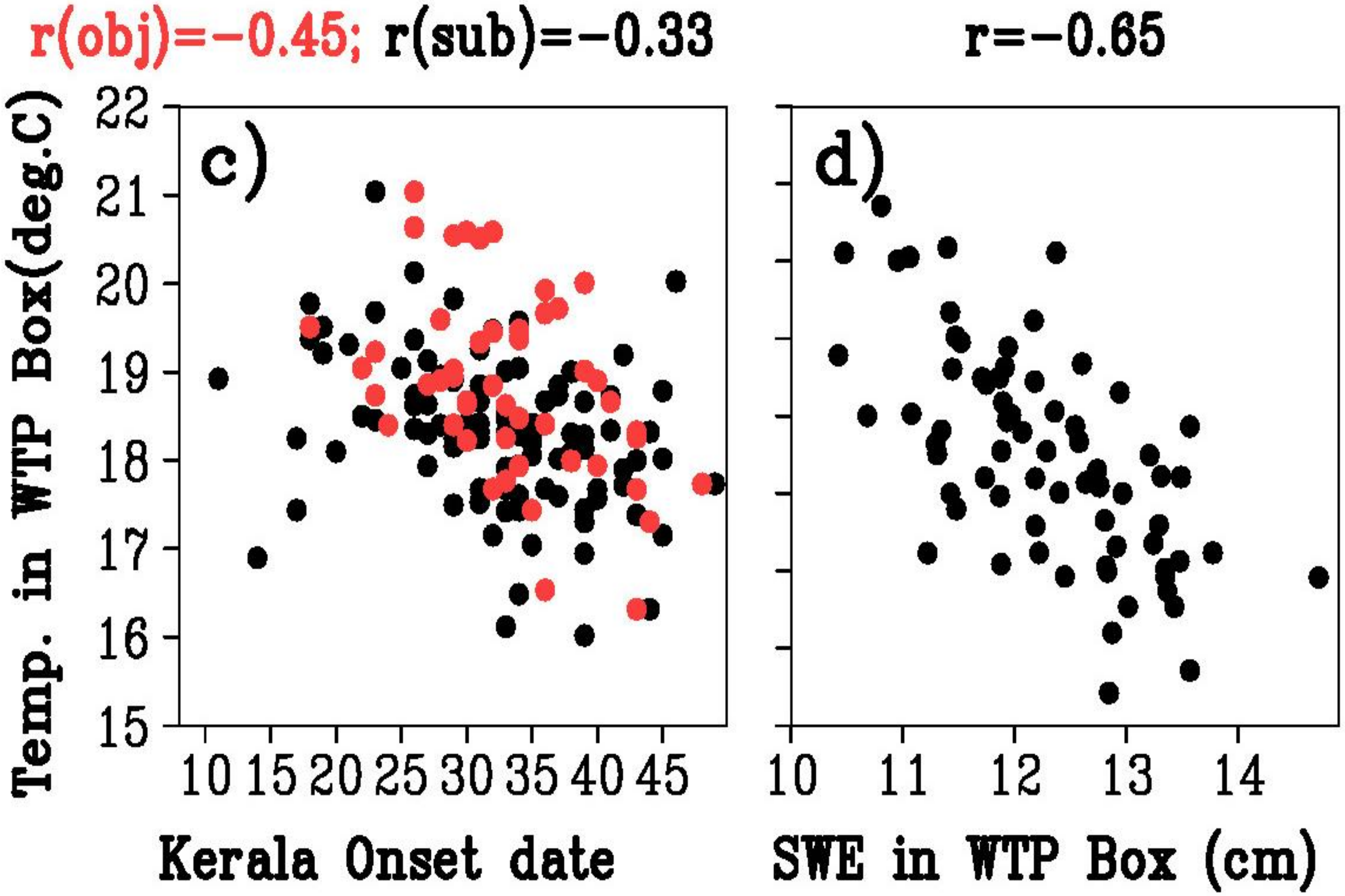
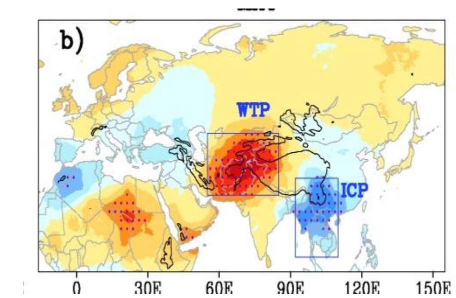
Teleconnection of Dominant Precipitation Mode



WTP box averaged temperature Vs **c)** monsoon onset date over Kerala based on IMD's subjective (black), objective (red) criteria, **d)** snow water equivalent averaged over WTP box during May

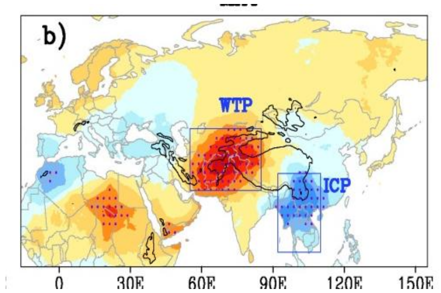


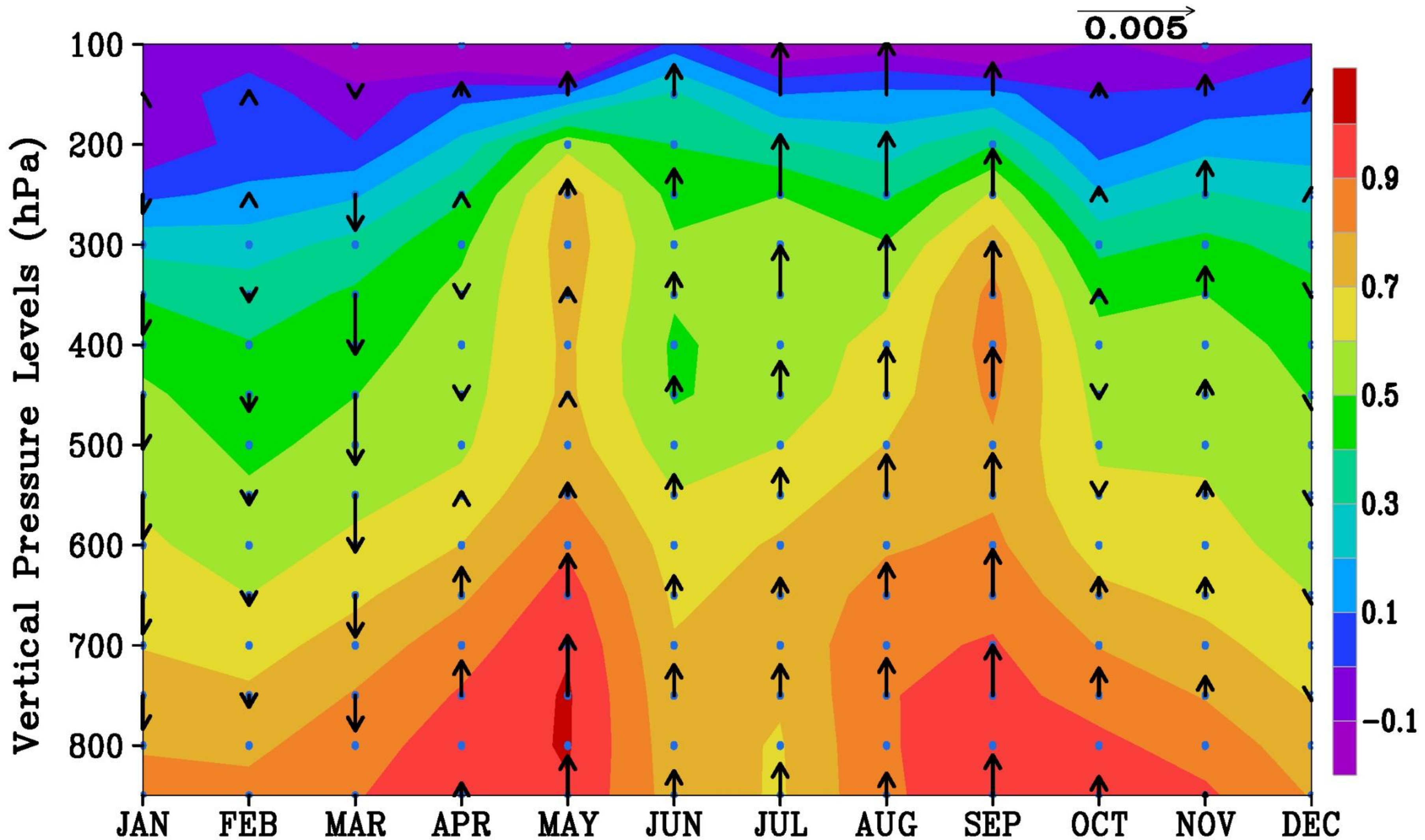
During May, 2m air temperature is inversely correlated with SWE over WTP region (r=-0.65), suggesting role of land-surface processes on atmospheric temperature anomaly

Monsoon onset date over Kerala (southern tip of India) is inversely related with WTP averaged 2m air temperature of May.

Local LST forcing on the atmosphere

Is there any link between WTP surface temp. and tropospheric temperature ?





Monthly WTP surface temperature is correlated (color shade) and regressed (arrow) with the air temperature and Omega in the vertical levels (1901–2015) respectively.

Strong ascending motion in association with WTP surface temperature, particularly during spring and autumn suggest sensible heating of the troposphere by elevated land surface.

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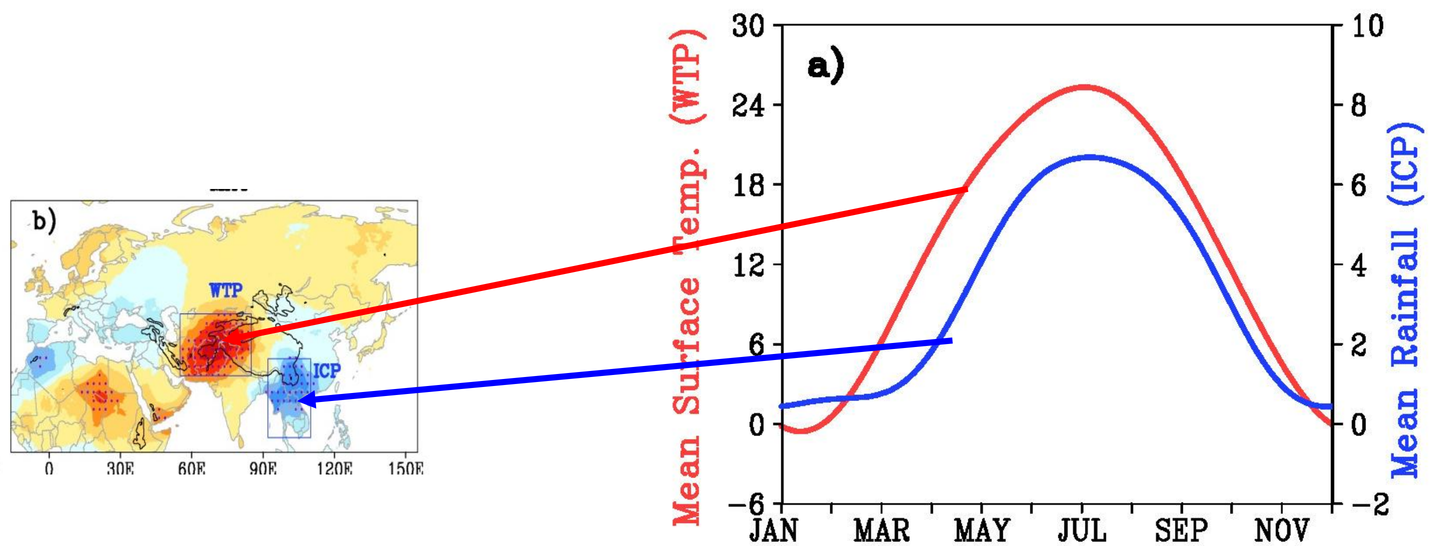
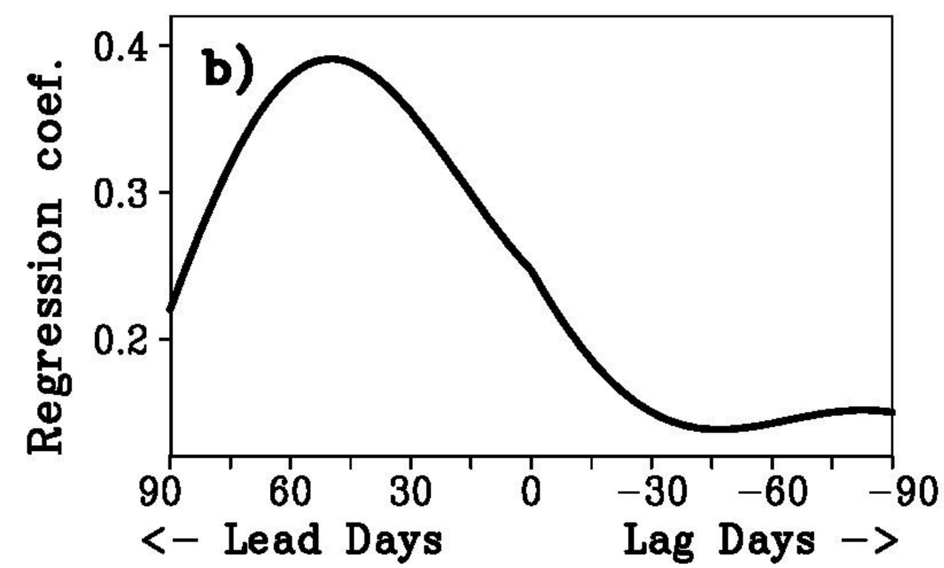
ObsLink between BoB Convection & WTP LST

Which one is the real cause ? WTP temperature or convection over ICP/BoB ?



Climatological mean smooth annual cycle of WTP averaged 2m air temp. (red) and ICP averaged rainfall (blue)



Lead-lag regression suggests that WTP surface temp. leads ICP rainfall by ~50 days

Warmer (colder) troposphere owing to land-surface heating (cooling) over WTP region enhances (decreases) rainfall over ICP and part of East Asia in May, which eventually cool (warm) surface temperature.

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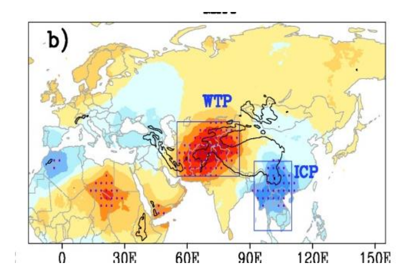
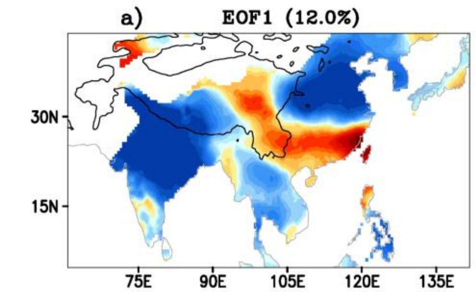
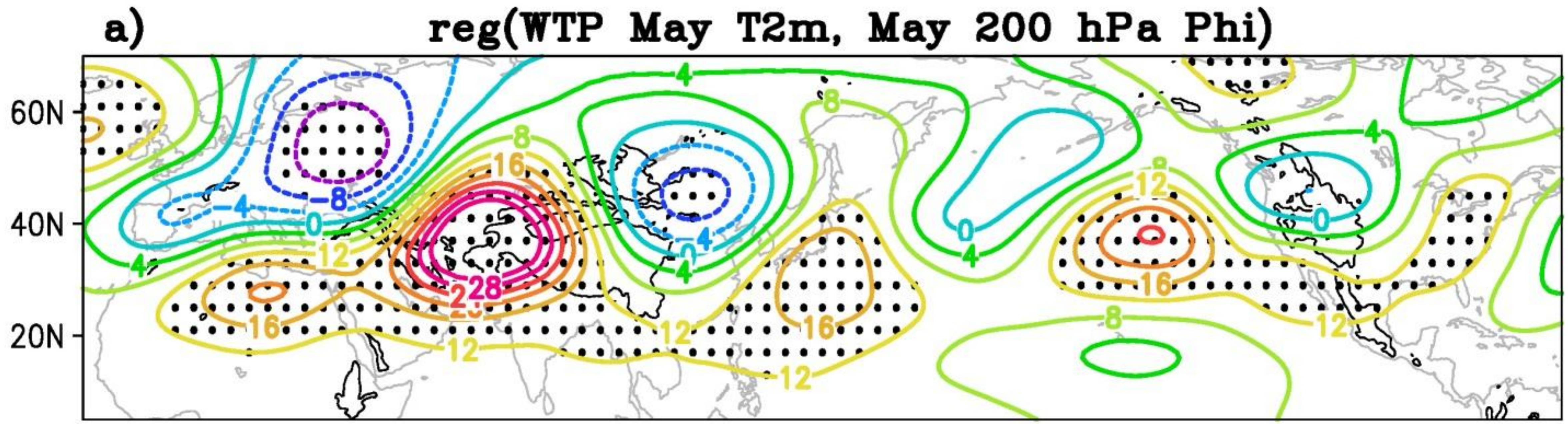
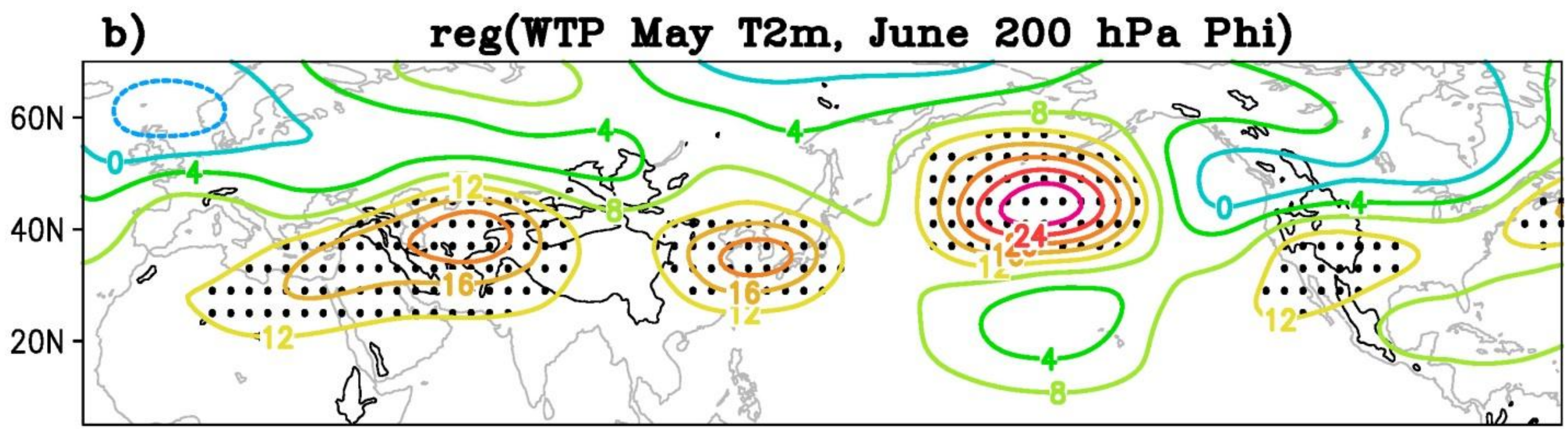
Eastward Stationary Wave Associated with WTP LST

How such rainfall pattern is created by WTP temp anomaly ?





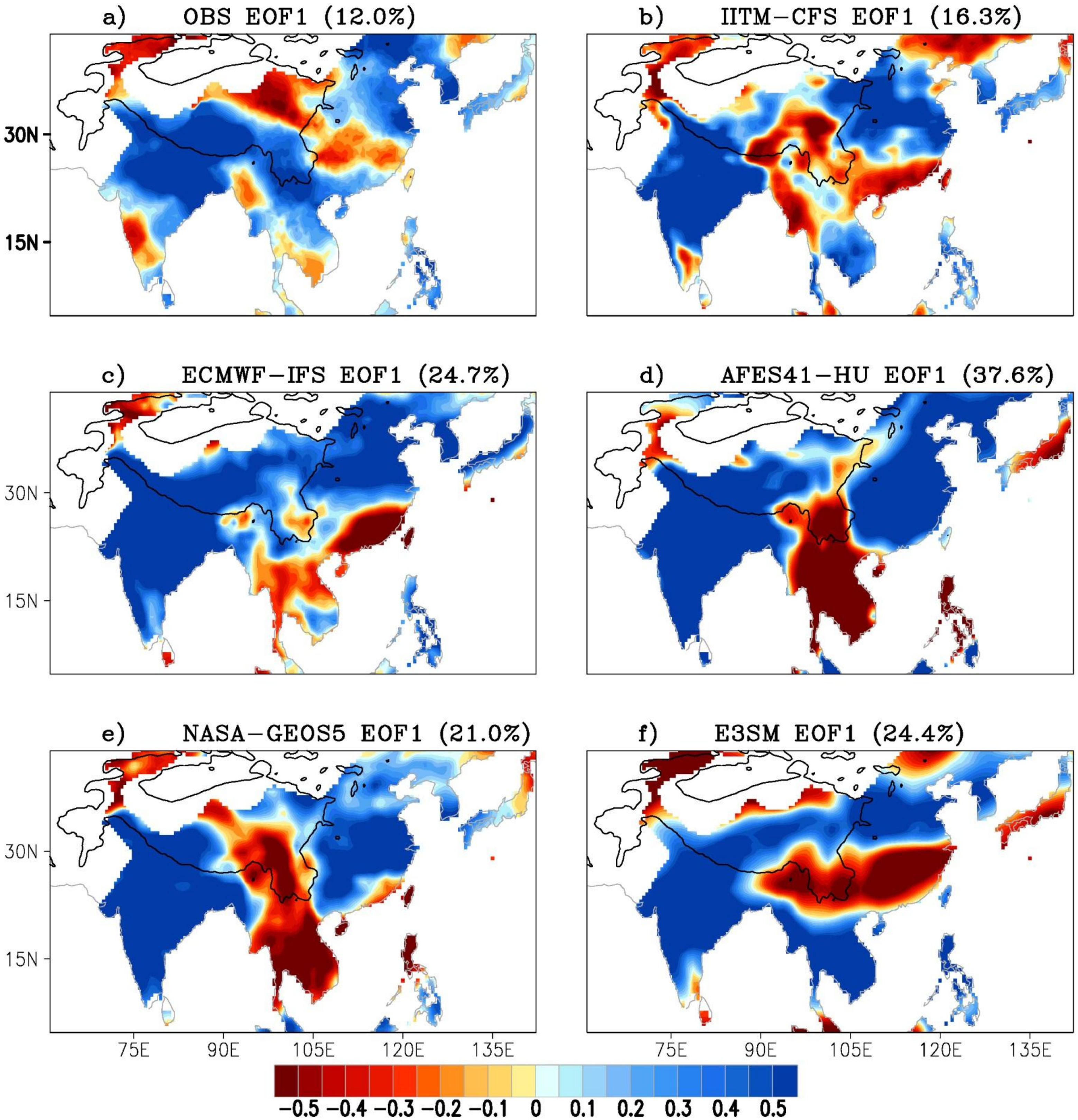




Wave Train due to WTP averaged LST (1901-2015)

EOF-1 in June Precipitation: Models vs Observations

How good are model in simulation these observed relationship ?



Under GEWEX, "Impact of Initialized Land Surface Temperature and Snowpack on Sub-seasonal to Seasonal Prediction phase I" (LS4P-I; Xue et al. 2021) was launched. Reforecast of 30 years (1981-2010) from five models are used.

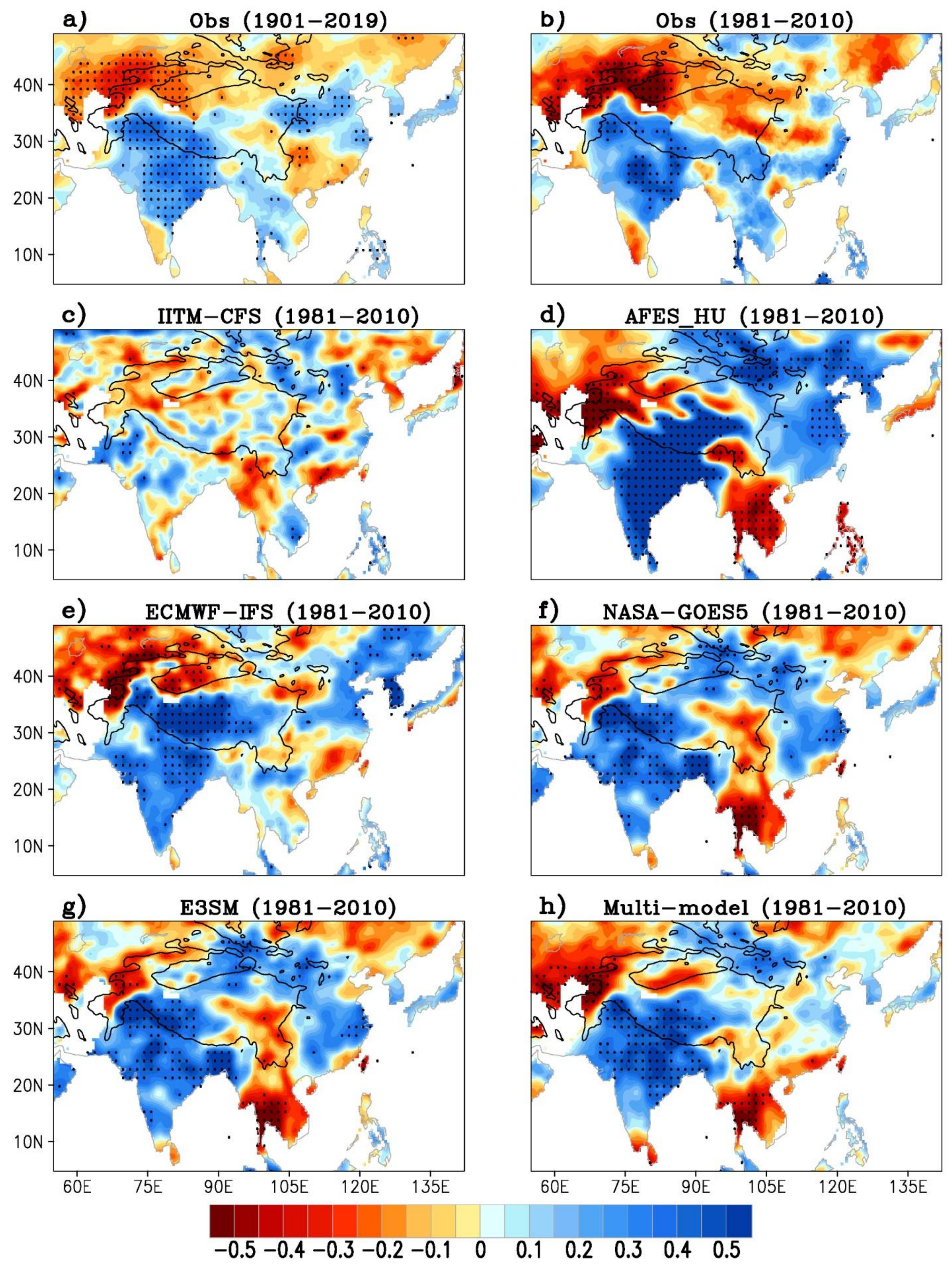
Models are correctly reproduce observed phases over South Asia, but fails over ICP and around Yangtze river.

Explained variance in EOF-1 is higher in all models except IITM-CFS

Teleconnection of rainfall (June) with WTP LST (MAY)

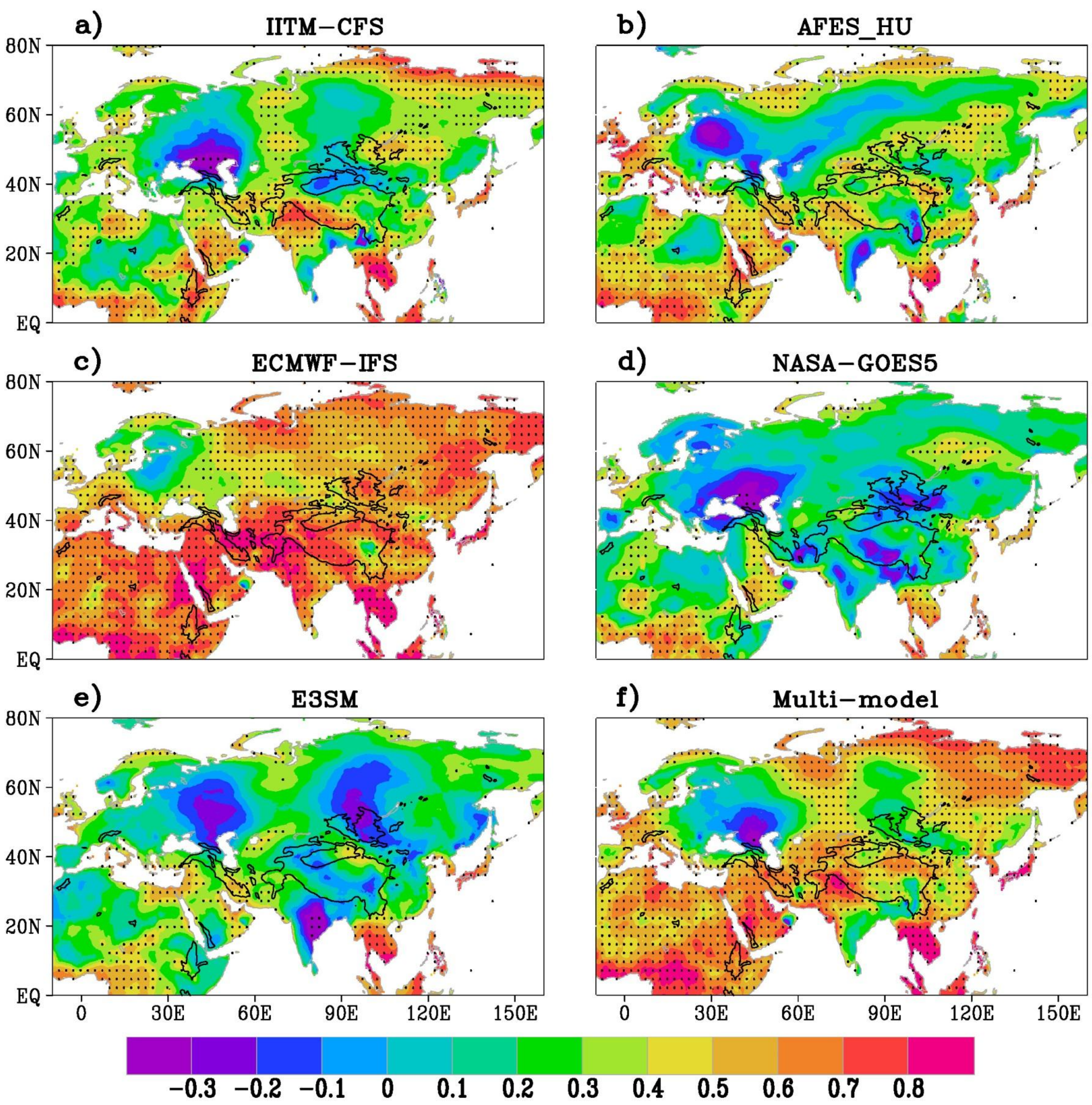
Reforecast of 30-yaers from five models were available

Most of the models reproduce observed relationship for South Asia (except IITM-CFS), but fails over East Asia (except IFS).



IWM-8

Skill in 2m Air Temperature (May)



Poor to moderate skill in surface 2m air temperature of May, including WTP region by all models (except IFS)..

Saha, Xue et al., 2023; Clim. Dyn.

Conclusions

A dominant mode of variability in June rainfall over the entire Asian summer monsoon (ASM) region is identified.

This mode is found to be linked with the spring (April, May) land surface temperature (LST) of the areas centred around the Western Third Pole (WTP).

A strong relationship of LST with snow water equivalent, vertical winds and tropospheric temperature over WTP suggests a seminal role of land surface processes in the first phase of ASM variability.

The observed dominant modes and their teleconnections are also investigated in the 30-years re-forecast by five global coupled climate models participating in the "Impact of Initialized Land Surface Temperature and Snowpack on Sub-seasonal to Seasonal Prediction phase I" project (LS4P-I).

While most models faithfully reproduce the observed link of June rainfall over South Asia with the remote LST, all models fail to capture the same over east Asia. In general, models show a significant bias in simulating the LST and the dominant modes of rainfall variability, which may have significant impact on sub-seasonal and seasonal prediction.

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Thank You!

Climate Dynamics
https://doi.org/10.1007/s00382-023-06709-7

A dominant mode in the first phase of the Asian summer monsoon rainfall: role of antecedent remote land surface temperature

Subodh Kumar Saha[1] · Yongkang Xue[2] · Sujith Krishnakumar[1] · Ismaila Diallo[3] · Yashas Shivamurthy[1] · Tetsu Nakamura[4] · Qi Tang[5] · Hemantkumar S. Chaudhari[1]

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EOF of June Rainfall (1901-2019)

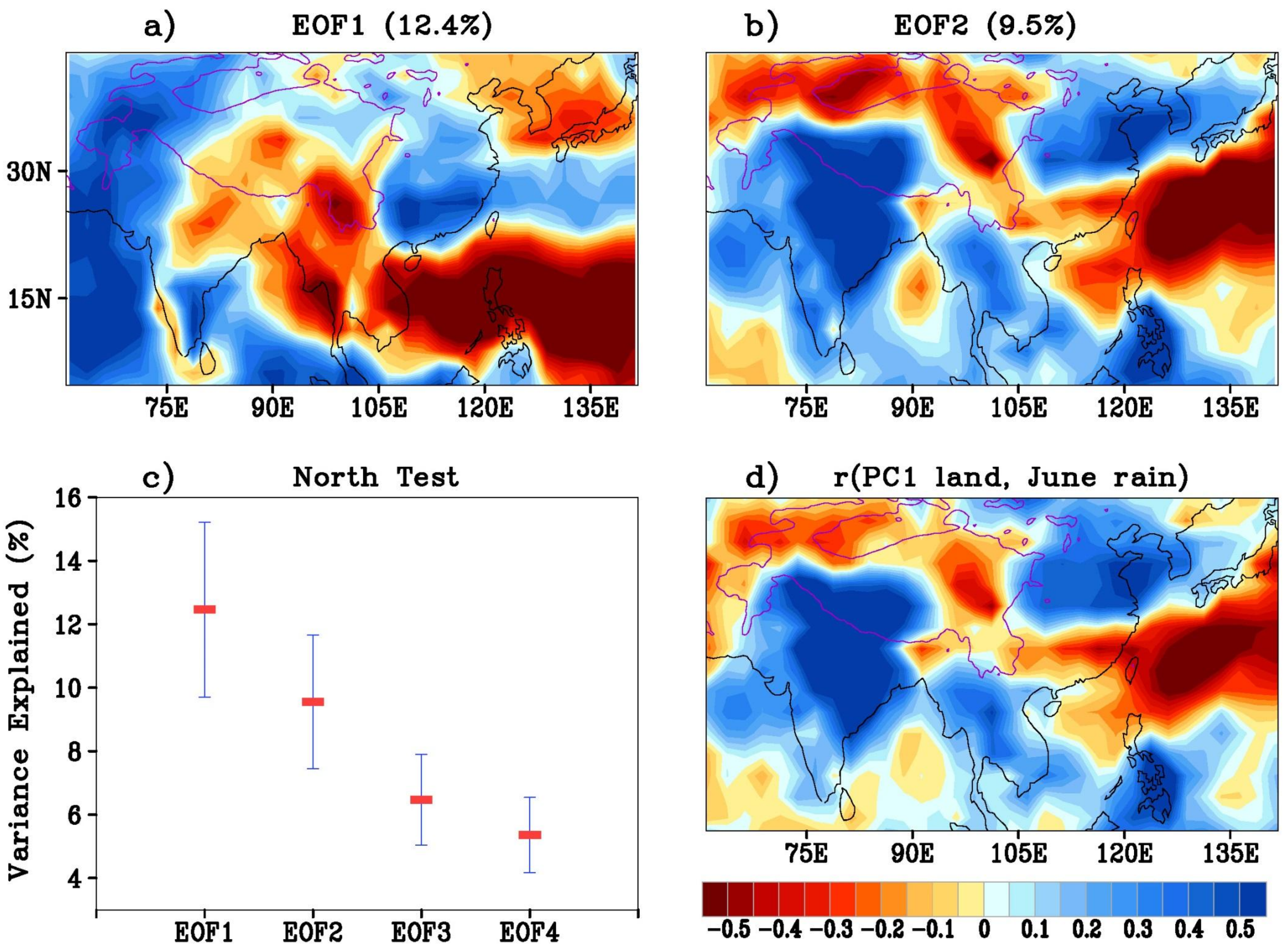
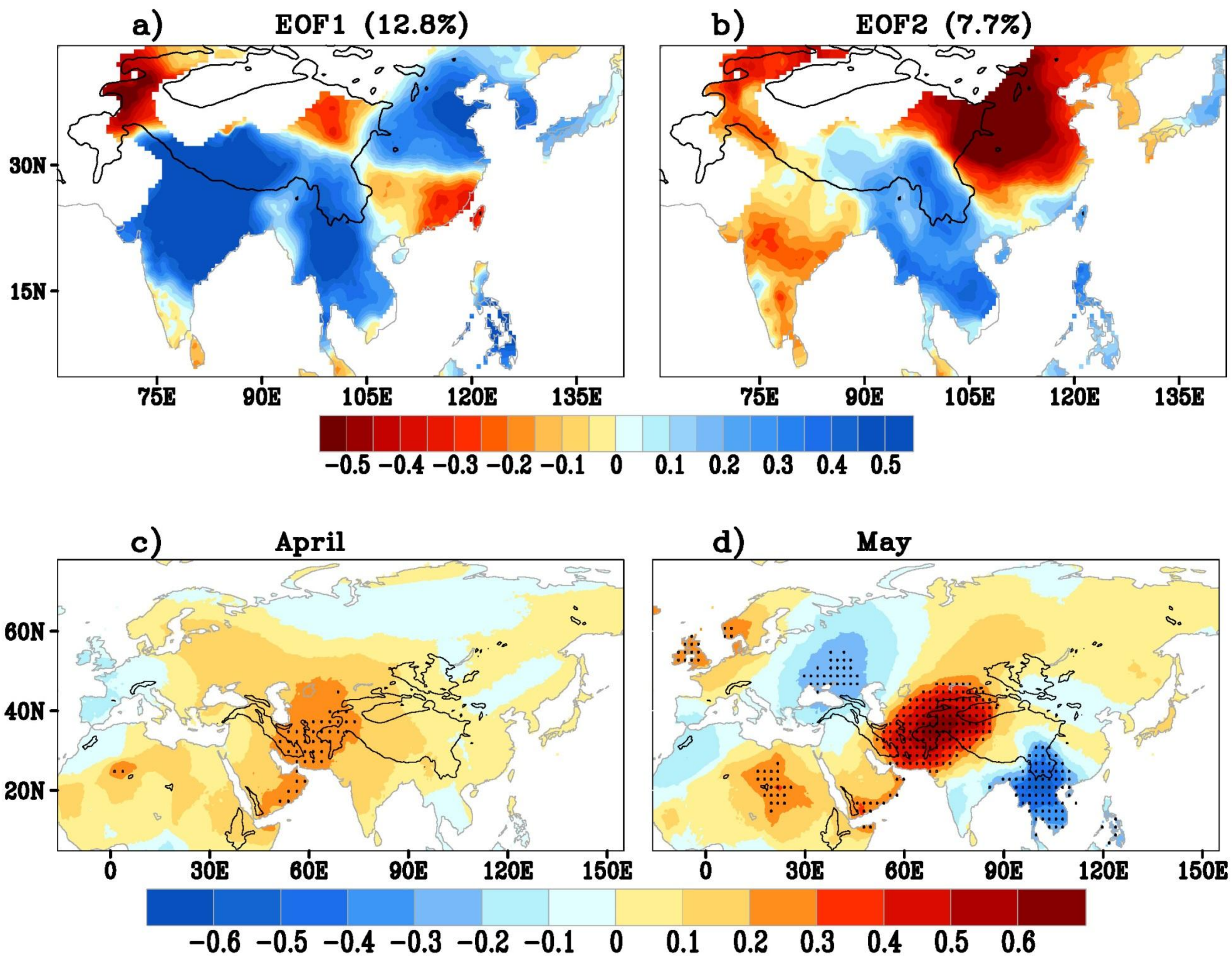


Fig. S1 First two dominant EOF mode **(a,b)** using GPCP rainfall of the month June during 1979-2019 (41-years). **c)** North test, suggesting first two EOFs are clearly separated. **d)** PC1 of land-only rainfall (Figure 2) is correlated with GPCP rainfall (June).

Dominant Modes & Teleconnection in May-June Rainfall



EOFs in May-June rainfall (1901-2019)

PC1 correlated with T2m air temperature

May to June averaged rainfall shows similar EOF patterns to that of June rainfall.

PC-1 of May-June rainfall has teleconnection pattern with 2m air temperature, which is similar to that using PC-1 of June rainfall

Large-scale moisture flux and tropospheric temperature

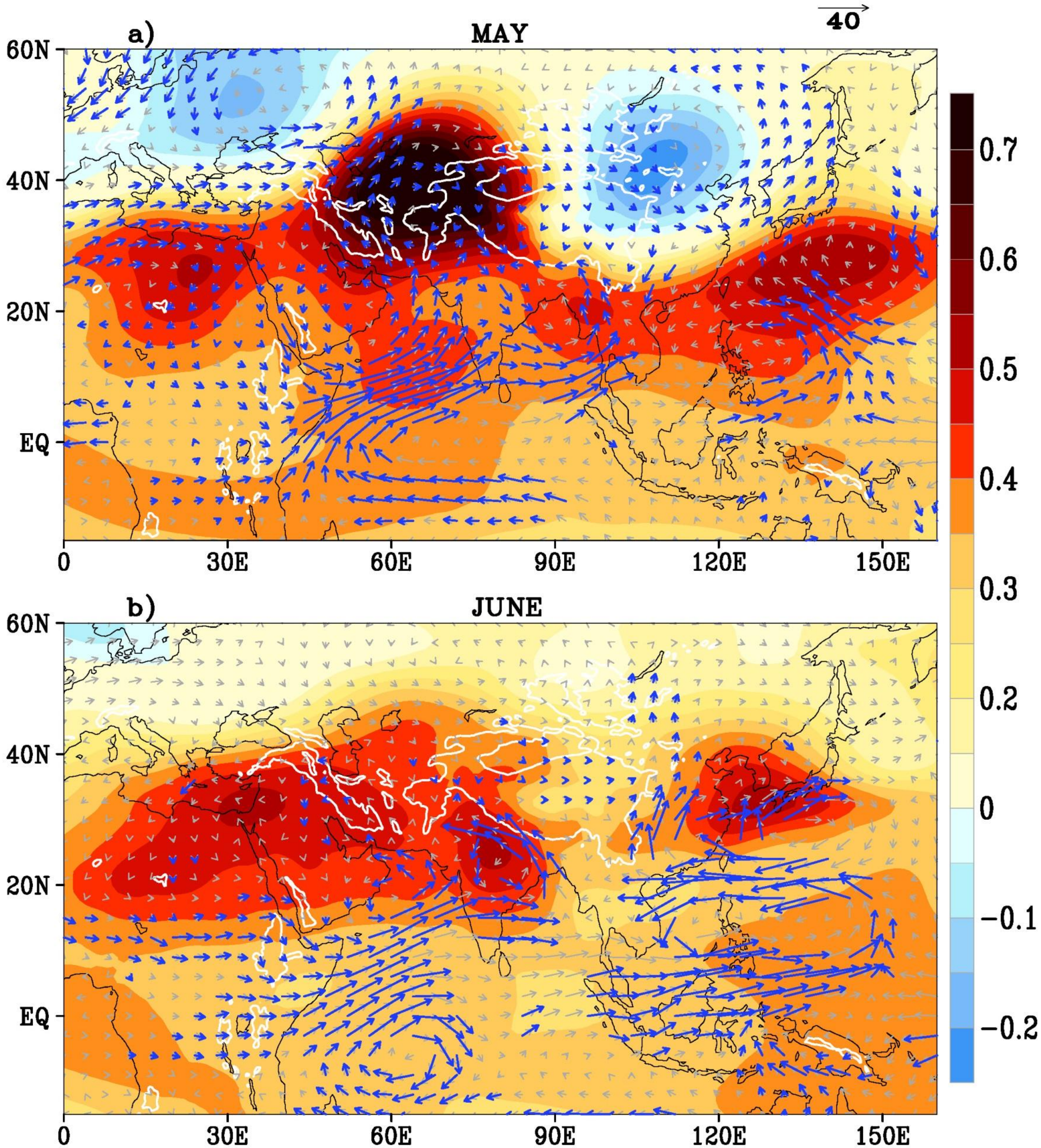


Fig. 5 Relationship of WTP surface temperature with large scale tropospheric temperature (average of 600–200 hPa) and vertically integrated moisture fluxes (surface to 200 hPa). WTP averaged surface temperature during May is correlated (regressed) with tropospheric temperature (moisture flux) of the month **a)** May and **b)** June. Correlations (shaded plot) above 0.18 are significant at above 95% level. Regressed moisture fluxes (vectors) significant at above 95% are marked by blue colors