Supplemental Material for

Recognition of two dominant modes of EASM and its thermal driving factors based on 25 monsoon indexes

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Text-S1 Classification of 25 monsoon EASM indexes

25 monsoon indexes have been selected in our analysis and the information of each index has been summarized in Table S1. Overall, the definitions of monsoon indexes exhibit large diversity. Some indexes are mainly based on the thermal driving factor of the monsoon. For example, land-sea thermal contrast has been used by *Guo (1983)* and *Shi et al. (1996)*. And some indexes are defined from the dynamical factors, such as circulation index used by *Wang and Fan (1999)* and *Zhang et al. (2003).* The combination of thermal and dynamical factors was also used by other researchers to define the monsoon indexes (*Liang et al., 1999；Zhang et al., 2002*). It is noted that various climate variables have been selected to define the monsoon index, however, different physical variables can be dependent to some extent due to the intrinsic nature of the EASM system. Are there any linkages among different monsoon indexes? And what the difference in capturing the main features of the summer monsoon by different monsoon indexes?

To reduce the uncertainty Firstly, three reanalysis datasets are used to calculate the selected 25 monsoon indexes. For most summer monsoon indexes, high monsoon indexes (strong summer monsoon) usually corresponds northward shift of the summer rainbelt and less rainfall in the Yangtze river basin. However, the original definitions of five monsoon indexes (WZCI、WWOI、JQCI、LTHI、WWLI) shows that high monsoon indexes are associated with more rainfall in the Yangtze river basin. For consistence, the five monsoon indexes have been multiplied by -1.0 in our study.

To recognize the possible linkages and difference among various monsoon indexes discussed, we put 25 monsoon indexes into a 5x5 matrix as shown in Fig. S1) and two dominant modes of various monsoon indexes have been extracted by the EOF analysis， which both pass the significance test proposed by *North et al. (1982)*. As shown in Fig. S1a-c, the two dominant modes of the EASM indexes from three reanalysis datasets shows generally similar spatial patterns. The first leading mode indicates that 20 indexes in the first lines exhibit consistent variations. However, the second leading mode of the EOF analysis suggest that the consistent variation of the no. 21-25 indexes (Fig. S1d-f). Overall, the selected 25 monsoon indexes can be classified into two categories, category I includes the 20 indexes in Table 1 but category II consists in 5 indexes with No. 21-25. We further checked calculate the correlation coefficients among 25 EASM indexes, which demonstrate the reasonability of the classification based on the EOF analysis.

Text-S2 Definitions of EAP index and EUP index

According to *Huang and Yan (1999)*, we calculated the EAP index by

$$I_{\mathrm{EAP}} = \mathrm{NOR}(-0.25Z'_{s(20°\mathrm{N},125°\mathrm{E})} + 0.50Z'_{s(40°\mathrm{N},125°\mathrm{E})} - 0.25Z'_{s(60°\mathrm{N},125°\mathrm{E})}),$$

in which Z' represents the 500hPa geopotential height anomaly at selected point, $Z'_s = Z'\sin 45°/\sin\varphi$ and φ is the latitude.

By following *Zou et al. (2013)*, the summer EU teleconnection index was calculated as follows:

$$I_{\mathrm{EU}} = \mathrm{NOR}(-0.25Z^*_{(55°\mathrm{N},20°\mathrm{E})} + 0.50Z^*_{(55°\mathrm{N},75°\mathrm{E})} - 0.25Z^*_{(52.5°\mathrm{N},110°\mathrm{E})})),$$

In which, Z^* represents the normalized 500hPa geopotential height at selected gird points.

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Table S1 Description of 25 EASM indexes used in this study

No.	Indexes	Definition	Reference
1	PSNI	$I=\sum_{i=1}^{i=17}(H_{i,150°E}-H_{i,110°E})$, i is the latitude between 10°N and -50°N with an interval of 2.5°, H is summer 500hPa geopotential height	*Peng et al. (2000)*
2	ZZI	$I=\frac{1}{n}\sum_{i=30}^{i=40}P^*_{i,160°E}-\frac{1}{n}\sum_{i=40}^{i=50}P^*_{i,110°E}$, i is the latitude (°N), n is the gird number between the upper and lower limits of the latitude, P^* is the normalized summer sea level pressure	*Zhao and Zhou (2005)*
3	GQYI	$I=\frac{I_t}{\frac{1}{n}\sum_{t=1}^{n}I_t}$, $I_t=\sum_{j=1}^{12}\sum_{i=1}^{5}\mathrm{IF}(P_{tji,110°E}-P_{tji,160°E}\le -5hPa, P_{tji,110°E}-P_{tji,160°E}, 0)$, t represent time in years, j is the month, i is the latitude between 10°N and -50°N with an interval of 10.0° and P is sea level pressure (SLP)	*Guo (1983)*
4	SZWI	$I=\sum_{i=1}^{7}(P^*_{i,160°E}-P^*_{i,110°E})$, i represents the latitude between 20°N and -50°N with an interval of 5.0°, P^* is normalized summer SLP	*Shi et al. (1996)*
5	ZHWI	$I=I_1^*+I_2^*$, $I_1=\sum_{i=10}^{50}(P_{i,160°E}-P_{i,110°E})$, $I_2=\frac{1}{n\times m}\sum_{i=0}^{10}\sum_{j=100}^{130}(U_{850hPa,ij}-U_{200hPa,ij})$, I is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, P is sea level pressure and U is zonal wind, * means normalized variable	*Zhu et al. (2000)*
6	DXZI	$I=\sum_t\sum_{i=5}^{20}\sum_{j=105}^{120}\mathrm{IF}(U_{tij}>0,\sqrt{U_{tij}^2+V_{tij}^2},0)$, t represents the month from May to July, i is the latitude, j is the longitude, U and V are 850hPa zonal wind and meridional wind, respectively	*Dai et al. (2000)*
7	WDJI	$I=\frac{1}{n\times m}\sum_{i=0}^{20}\sum_{j=105}^{120}(U'_{850hPa,ij}-U'_{200hPa,ij})$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, U' is summer zonal wind departure	*Wang et al. (1998)*
8	LWYI	$I=\frac{V_{sw}-1.0}{a}+\frac{235-R}{b}$, $V_{sw}=\frac{1}{n\times m}\sum_{i=5}^{20}\sum_{j=105}^{120}\frac{U_{ij}+V_{ij}}{\sqrt{2}}$, $R=\frac{1}{n\times m}\sum_{i=5}^{20}\sum_{j=105}^{120}r_{ij}$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, U and V represents summer 850hPa zonal and meridional wind, respectively. r is the outgoing longwave radiation (OLR), a = 1m/s, b = 10W/m^2	*Liang et al. (1999)*
9	ZLYI	$I=\frac{X_1-\overline{X_1}/1.9}{\sigma_{X1}}+0.65\frac{X_2-\overline{X_2}/3.8}{\sigma_{X2}}$, $X_1=\frac{1}{k}\sum_{i=5}^{20}\sum_{j=105}^{120}\mathrm{IF}(0\le\arctan\frac{V_{ij}}{U_{ij}}\le 70°,\sqrt{U_{ij}^2+V_{ij}^2},0)$, $X_2=\frac{1}{n\times m}\sum_{i=5}^{20}\sum_{j=105}^{120}(240-r_{ij})$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude k is the total grid number that the wind direction is between 200° and 270° in the selected region. U and V represents summer 850hPa zonal and meridional wind, respectively. r is OLR, $\overline{X}$ and σ_x is the climatology and the standardized deviation of variable X, respectively.	*Zhang et al. (2002)*
10	LTHI	$I=\frac{1}{n\times m}\sum_{i=22.5}^{27.5}\sum_{j=105}^{120}Q'_{ij}-\frac{1}{n\times m}\sum_{i=35}^{40}\sum_{j=105}^{115}Q'_{ij}$, $Q=\frac{1}{g}\int_{300}^{P_s}qv\mathrm{d}p$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, P_s, q and v means summer surface pressure, specific humidity and 850hPa meridional wind, respectively. Q' is the departure of Q.	*Liang et al. (2007)*
11	HXSI	$I=\frac{1}{n\times m}\sum_{i=0}^{10}\sum_{j=100}^{130}(U'_{850hPa,ij}-U'_{200hPa,ij})$, i is the latitude, j is the longitude, n and m	*He et al.*

		represents the grid number between the upper and lower limits of the latitude and the longitude, U' is summer zonal wind departure	*(2002)*
12	WFI	$I=\frac{1}{n\times m}\sum_{i=5}^{15}\sum_{j=90}^{130}U'_{ij}-\frac{1}{n\times m}\sum_{i=22.5}^{32.5}\sum_{j=110}^{140}U'_{ij}$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, U' is summer 850hPa zonal wind departure	*Wang and Fan (1999)*
13	WWLI	I is defined by the first principle component acquired by multi-variables EOF analysis on six meteorological variables including summer rainfall, zonal wind and meridional winds at 850hPa and 200hPa, sea level pressure over (0°-50°N,100°-140°E).	*Wang et al. (2008)*
14	LZI	$I=\frac{1}{n\times m}\sum_{i=10}^{40}\sum_{j=110}^{140}(\frac{\|\|\overline{V_{1ij}}-\overline{V_{tij}}\|\|}{\|\|\overline{V}_{ij}\|\|}-2)$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, $\overline{V_1}$ is the climatological 850hPa wind vector in January, $\overline{V}$ represents the difference in the climatological 850hPa wind vector (January minus July), $\overline{V_t}$ is summer 85hPa wind vector for year t. $\|\|A\|\|=\left[\iint_s \|A\|^2\,dS\right]^{1/2}$, S represents the horizontal area of the selected region.	*Li and Zeng (2002)*
15	ZTCI	$I=\frac{1}{n\times m}\sum_{i=10}^{20}\sum_{j=100}^{150}U'_{ij}-\frac{1}{n\times m}\sum_{i=25}^{35}\sum_{j=100}^{150}U'_{ij}$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, U' is summer 850hPa zonal wind departure.	*Zhang et al. (2003)*
16	WLI	$I=\frac{V_{sw}-\overline{V_{sw}}}{\sigma_v}-\frac{R-\bar{R}}{\sigma_r}$, $V_{sw}=\frac{1}{n\times m}\sum_{i=10}^{20}\sum_{j=110}^{120}\frac{U_{ij}+V_{ij}}{\sqrt{2}}$, $R=\frac{1}{n\times m}\sum_{i=10}^{20}\sum_{j=110}^{120}r_{ij}$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, U and V represents summer 850hPa zonal and meridional wind, respectively. r is the outgoing longwave radiation (OLR), $\bar{X}$ and σ_x is the climatology and the standardized deviation of variable X, respectively.	*Wu and Liang (2001)*
17	WZCI	$I=\frac{1}{n\times m}\sum_{i=17.5}^{27.5}\sum_{j=105}^{130}V'_{ij}-\frac{1}{n\times m}\sum_{i=32.5}^{40}\sum_{j=105}^{130}V'_{ij}$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, V' is summer 850hPa meridional wind departure.	*Wang et al. (2001)*
18	YQI	$I=\frac{1}{n\times m}\sum_{i=10}^{20}\sum_{j=105}^{120}\rho_{ij}^{-1}(\zeta_a)_{ij}\cdot\nabla(\theta_{se})_{ij}$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, ρ, ζ_a and θ_{se} represents the air density, absolute vorticity and equivalent potential temperature.	*Yao and Qian (2001)*
19	ZHI	$I=\frac{1}{n\times m}\sum_{i=-10}^{10}\sum_{j=100}^{140}(V'_{850hPa,ij}-V'_{200hPa,ij})$, i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude,, V' is summer meridional wind departure.	*Zhou et al. (2003）*
20	LZhI	$I=\frac{\Delta D}{\sqrt{\sum(\Delta D_k)^2/K}}$, $\Delta D=\frac{1}{n\times m}\sum_{i=7.5}^{17.5}\sum_{j=105}^{125}(D_{850hPa,ij}-D_{200hPa,ij})$, k、i is the latitude, j is the longitude, n and m represents the grid number between the upper and lower limits of the latitude and the longitude, D is the divergence.	*Li and Zhang (1999)*
21	WYI	$I=\frac{1}{n\times m}\sum_{i=10}^{40}\sum_{j=110}^{140}(U'_{850hPa,ij}-U'_{200hPa,ij})$, which i and j represent the latitude and longitude, n and m denote the grid numbers of latitude and longitude between the upper and lower limits, U' is summer zonal wind anomaly.	*Webster and Yang (1992)*
22	HYI	$I=-0.25Z'_{s(20°N,125°E)}+0.50Z'_{s(40°N,125°E)}-0.25Z'_{s(60°N,125°E)}$, $Z'_s=Z'\sin45°/\sin\varphi$, Z' is the departure of the summer 500hPa geopotential height at certain grid, φ is the	*Huang and Yan (1999)*

		latitude	
23	WWOI	$I=\frac{1}{n\times m}\sum_{i=20}^{30}\sum_{j=110}^{140}V'_{ij}-\frac{1}{n\times m}\sum_{i=30}^{40}\sum_{j=110}^{140}V'_{ij}$, *i* is the latitude, *j* is the longitude, *n* and *m* represents the grid number between the upper and lower limits of the latitude and the longitude, V' is summer 850hPa meridional wind departure.	*Wang et al. (2001)*
24	JQCI	$I=\frac{V_{sw}-\overline{V_{sw}}}{\sigma_v}-\frac{R-\bar{R}}{\sigma_r}$, $V_{sw}=\frac{1}{n\times m}\sum_{i=22.5}^{32.5}\sum_{j=112.5}^{135}\frac{U_{ij}+V_{ij}}{\sqrt{2}}$, $R=\frac{1}{n\times m}\sum_{i=22.5}^{32.5}\sum_{j=112.5}^{135}r_{ij}$, in which *I* and *j* represent the latitude and longitude, *n* and *m* denote the grid numbers of latitude and longitude between the upper and lower limits, *U* and *V* denote summer 850hPa zonal and meridional wind velocity, *r* is outgoing long-wave radiation (OLR), *X and* σ_x represents the climatology and the standard deviation.	*Ju et al. (2005)*
25	CWYI	$I=-\frac{1}{n\times m}\sum_{i=20}^{i=25}\sum_{j=115}^{j=130}H^*_{ij}+\frac{1}{n\times m}\sum_{i=40}^{i=45}\sum_{j=140}^{j=150}H^*_{ij}-\frac{1}{n\times m}\sum_{i=60}^{i=65}\sum_{j=110}^{j=135}H^*_{ij}$, in which *i* and *j* represent the latitude and longitude, *n* and *m* denote the grid numbers of latitude and longitude between the upper and lower limits, H^* is the normalized summer 500hPa geopotential heights.	*Cai et al. (2009)*

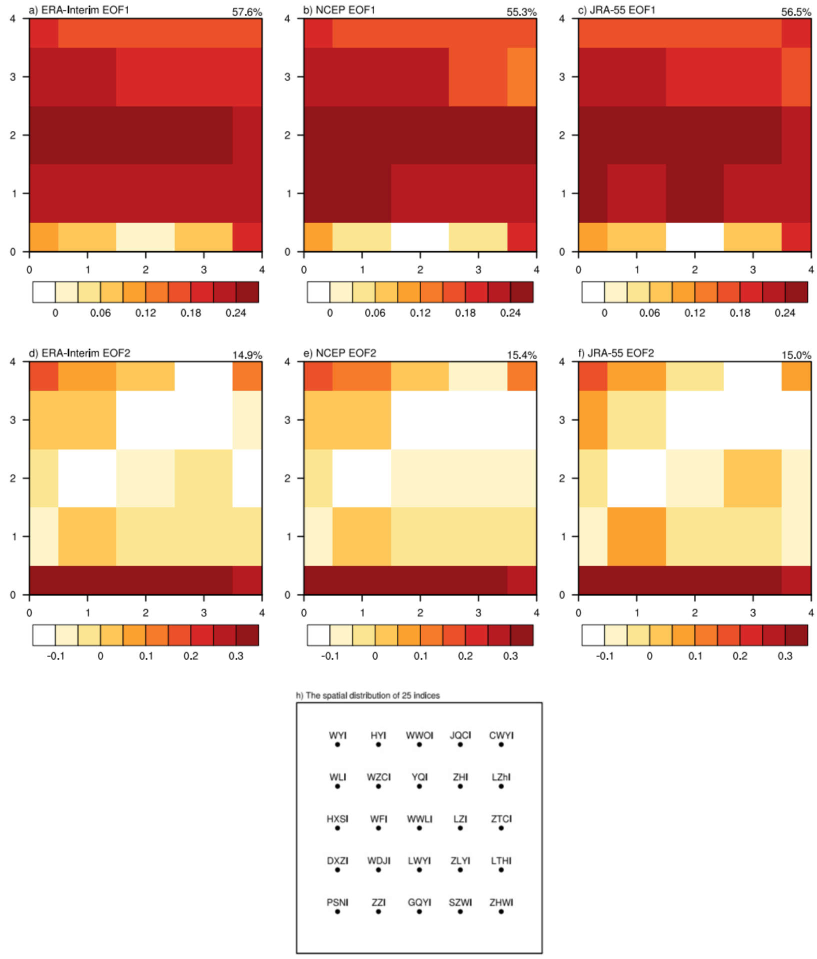

Fig. S1 The distribution of the first (a-c) and second (d-e) leading modes of EOF analysis of 25 EASM indexes as well as the spatial location of EASM indexes (g), in which (a) and (d) are from ERA-Interim, (b) and (e) NCEP, (c) and (f) JRA-55.

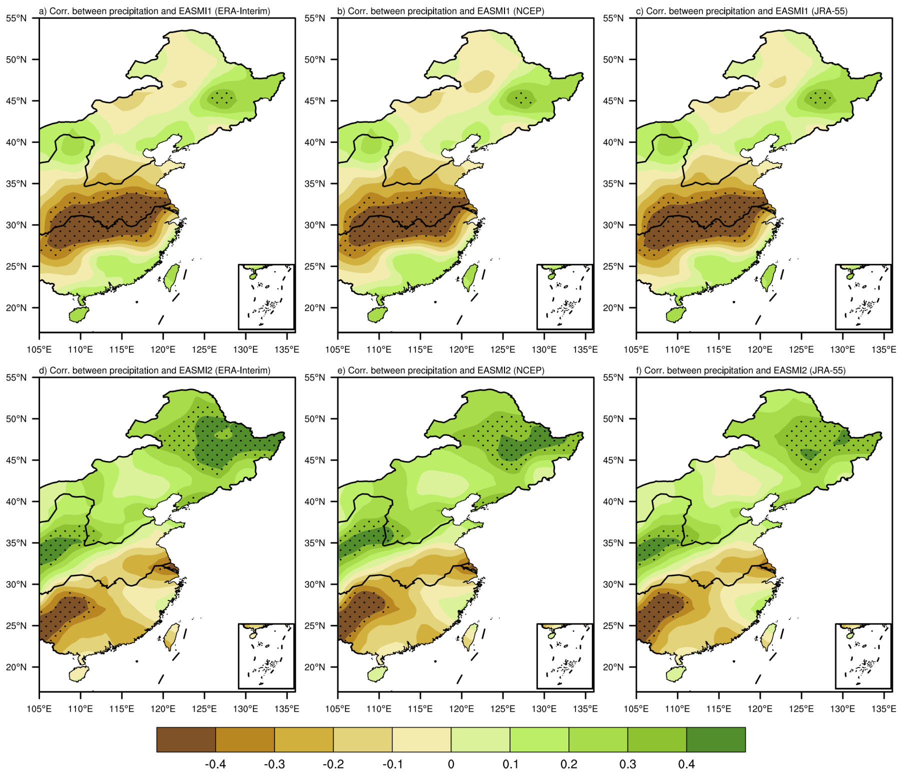

Fig. S2 Geographic distribution of correlation bewteen summer rainfall in eastern China and I_{EASMI1} (a-c) / I I_{EASMI2} (d-f), in which (a) and (d) are from the ERA-Interim, (b) and (e) NCEP, (c) and (f) JRA-55. The dotted area shows the regions where the correlation is statistically significant at 5% level.