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How does the South Asian summer monsoon anomaly influence the interannual variations in precipitation over the South-Central Tibetan Plateau

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Outline

1. Background
2. Data and methods
3. Results
4. Summary

Outline

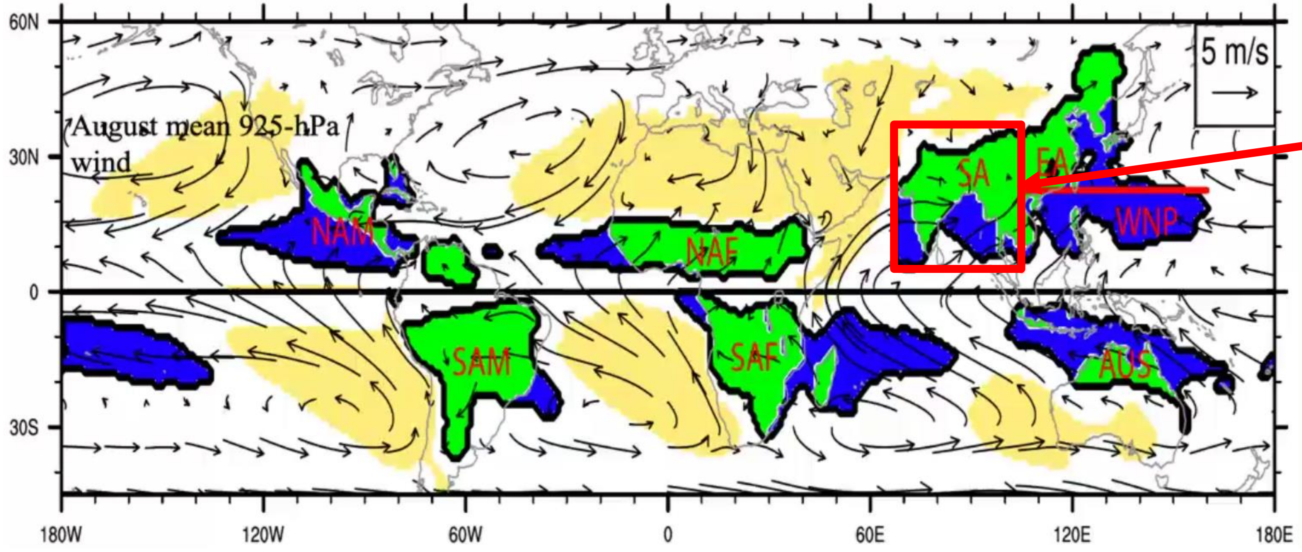
1 **Background**

2 Data and methods

3 Results

4 Summary

The South Asian summer monsoon (SASM) system anomaly causes precipitation extremes and serious disasters



South Asian summer monsoon region

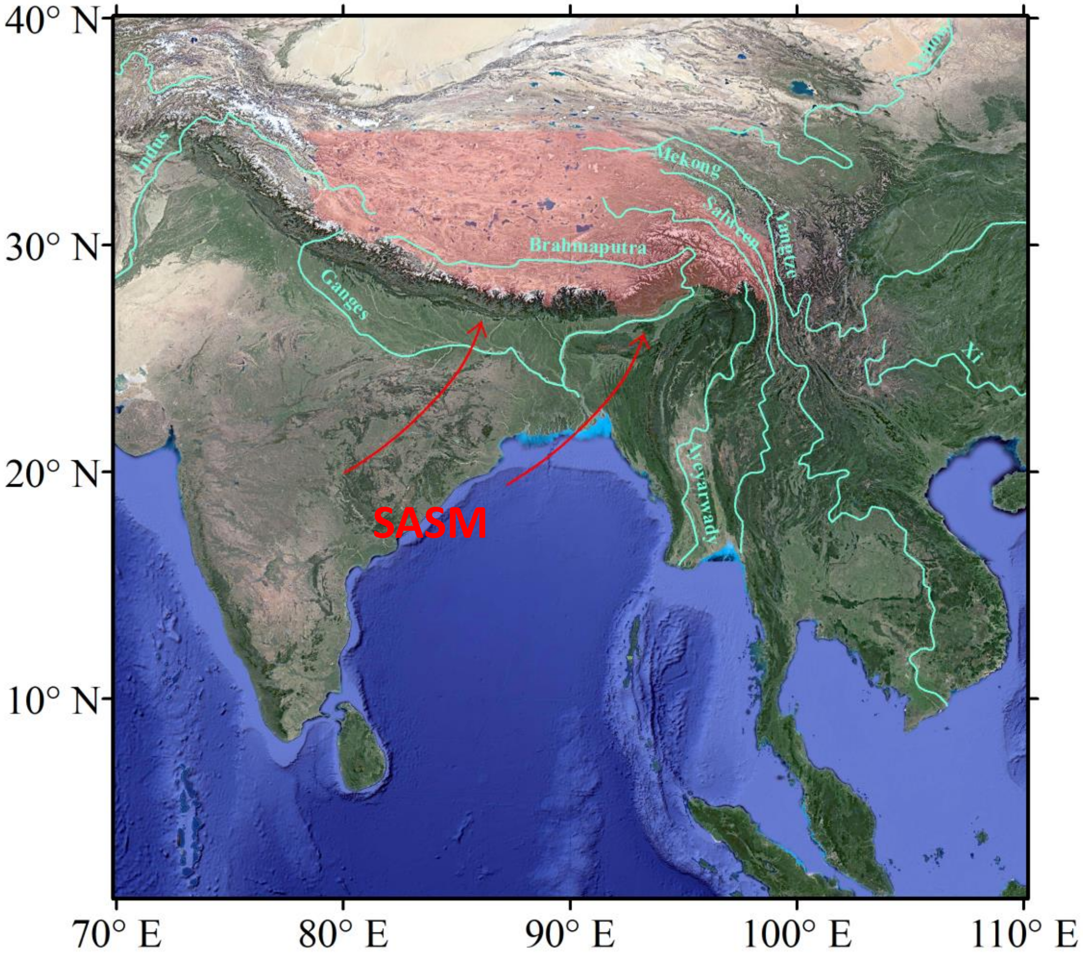
(Wang & Ding, 2008)

Floods

(Eos)

Droughts

Sustainable freshwater management and water disasters mitigation over the SCTP is of vital importance



The South-Central Tibetan Plateau (SCTP)
”Asian water tower”

Landslides

Mountain floods

Mudslides

Scientific question

(1) How do the **onset and demise** of the SASM control the **interannual variations** in precipitation over the SCTP?

(2) Is there an **asymmetric effect** of the SASM on SCTP precipitation between its onset and demise, and between its early and late onset (demise)?

(3) What are the **underlying mechanisms** that are responsible for the variations in interannual precipitation?

Outline

Data

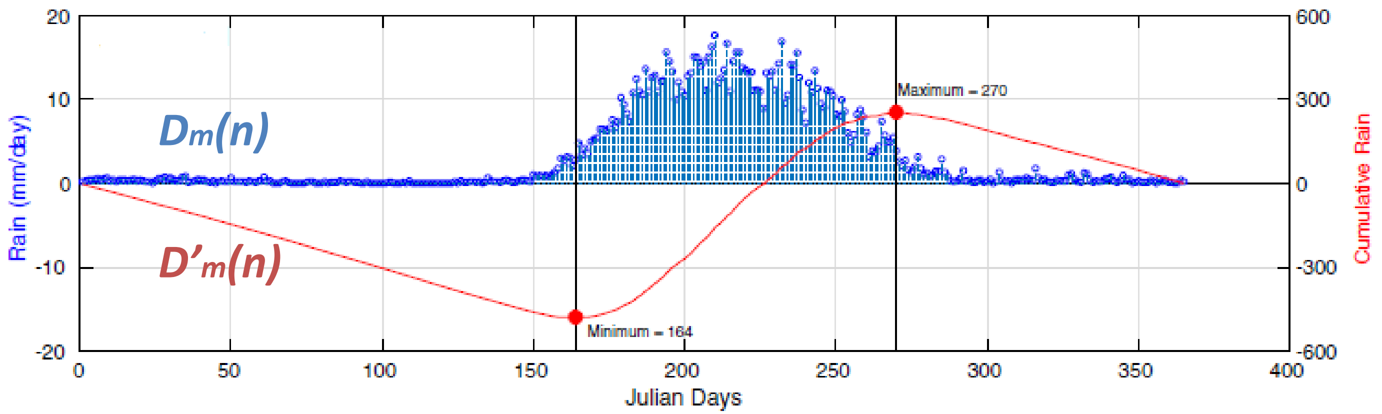
Dataset	Spatial Resolution	Periods	Data sources
CMA	80 stations	1979-2015	http://data.cma.cn/
APHRODITE	0.25° ×0.25°	1951-2015	http://www.chikyu.ac.jp/precip/products.html
CMAP	2.5° ×2.5°	1979-2015	https://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html
Chen	0.5° ×0.5°	1961-2010	https://rcg.gvc.gu.se/data/ChinaPrecip/index.htm
Zhao	0.5° ×0.5°	1961-2015	http://data.cma.cn/data/cdcdetail/dataCode/SURF_CLI_CHN_PRE_DAY_GRID_0.5.html
CRU	0.5° ×0.5°	1901-2015	https://crudata.uea.ac.uk/cru/data/hrg/
ERA5	0.25° ×0.25°	1979-2015	https://www.ecmwf.int/
GLDAS	0.25° ×0.25°	1948-2015	https://disc.gsfc.nasa.gov/datasets/GLDAS_NOAH025_M_V2.0/summary?keywords=GLDAS
GPCP	2.5° ×2.5°	1979-2015	https://www.esrl.noaa.gov/psd/data/gridded/data.gpcp.html
JRA55	0.562° ×0.562°	1958-2015	https://rda.ucar.edu/datasets/ds628.1/
NCEP-NCAR	1.875° ×1.904°	1948-2015	https://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.derived.html
SM	0.5° ×0.5°	2007-2015	http://hydrology.irpi.cnr.it/download-area/sm2rain-data-sets/
TRMM 34B3	0.25° ×0.25°	1998-2015	https://disc.gsfc.nasa.gov/datasets/TRMM_3B43_V7/summary?keywords=TRMM
IGSNRR	0.25° ×0.25°	1952-2013	http://hydro.igsnrr.ac.cn/public/vic_outputs.html

Data: 1979-2015

- Daily **APHRODITE** precipitation data
- Monthly **ERA5** reanalysis data

(Zhu & Sang, 2018)

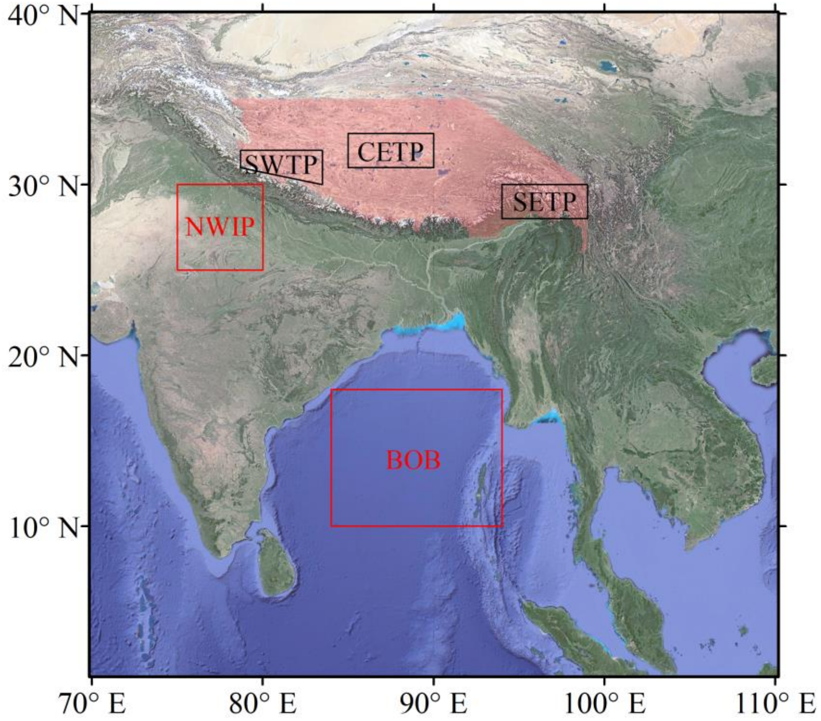
Definition of onset and demise times of the SASM system



$$D'_m(n) = \sum_{n=1}^{N}\left[D_m(n) - \overline{\overline{D}}\right]$$

$$\overline{\overline{D}} = \frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N} D_m(n)$$

(Noska & Misra, 2016)



Onset date (*OD*): the minimum value of *D'm(n)*, after the first four months and before the last three months of a year;

Demise date (*DD*): the maximum value of *D'm(n)*, after OD;

Season length (*SL*): the days from the *OD* to *DD*;

Seasonal precipitation (*SP*): the total amount of precipitation the between the *OD* and *DD.*

Moisture budget analysis

Moisture budget equation

$$P = -\frac{1}{g\rho}\int_0^{p_s} \nabla \cdot (Vq)\, dp - \frac{1}{g\rho}\int_0^{p_s} \frac{\partial(\omega q)}{\partial p} dp + E$$

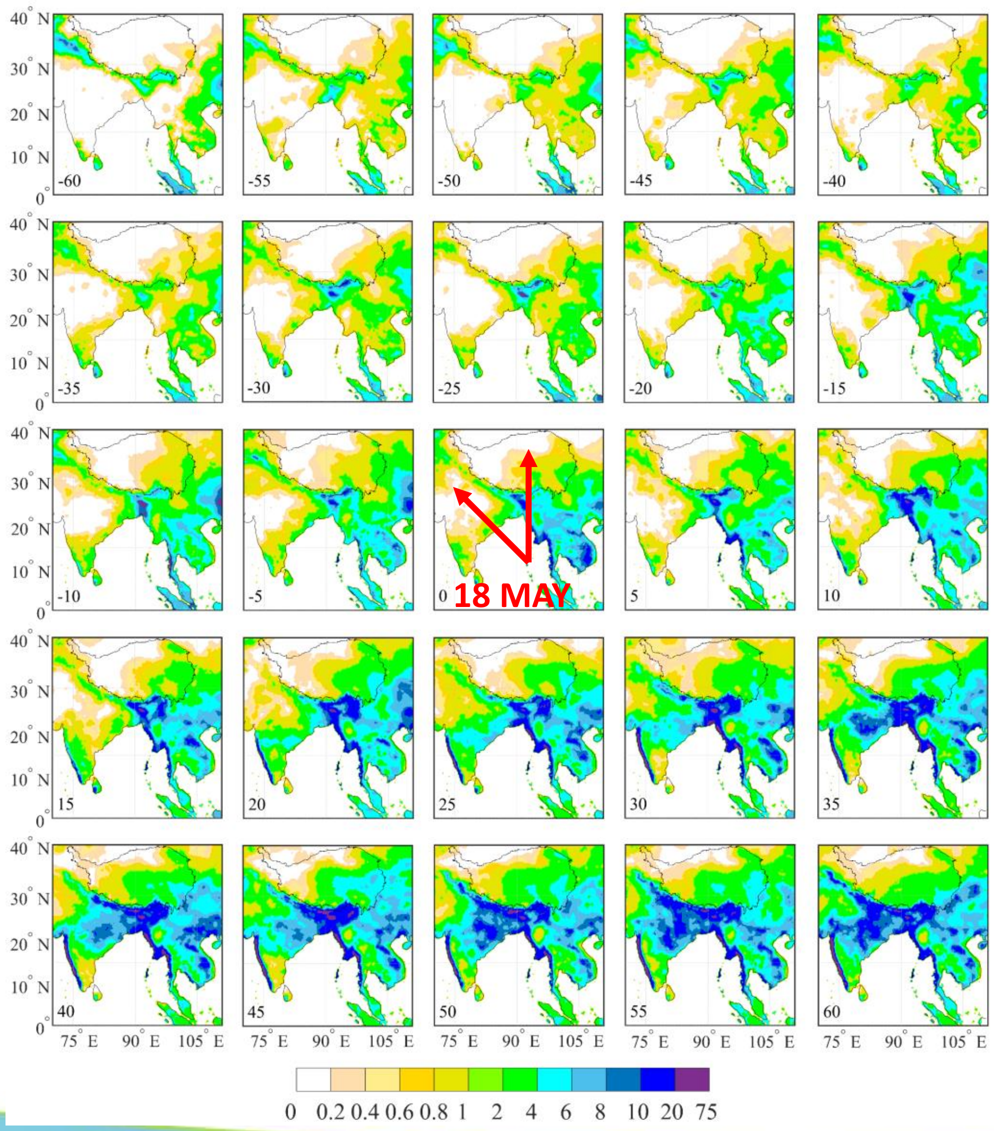
Decomposition

$$\underbrace{P'}_{\text{Precipitation}} = \underbrace{-\frac{1}{g\rho}\int_0^{p_s} \nabla \cdot (\overline{V} q')\, dp}_{\text{Horizontal thermodynamic component}} \underbrace{-\frac{1}{g\rho}\int_0^{p_s} \nabla \cdot (V' \overline{q})\, dp}_{\text{Horizontal dynamic component}} \underbrace{-\frac{1}{g\rho}\int_0^{p_s} \frac{\partial(\overline{\omega} q')}{\partial p} dp}_{\text{Vertical thermodynamic component}} \underbrace{-\frac{1}{g\rho}\int_0^{p_s} \frac{\partial(\omega' \overline{q})}{\partial p} dp}_{\text{Vertical dynamic component}} + \underbrace{E'}_{\text{Evaporation}}$$

Outline

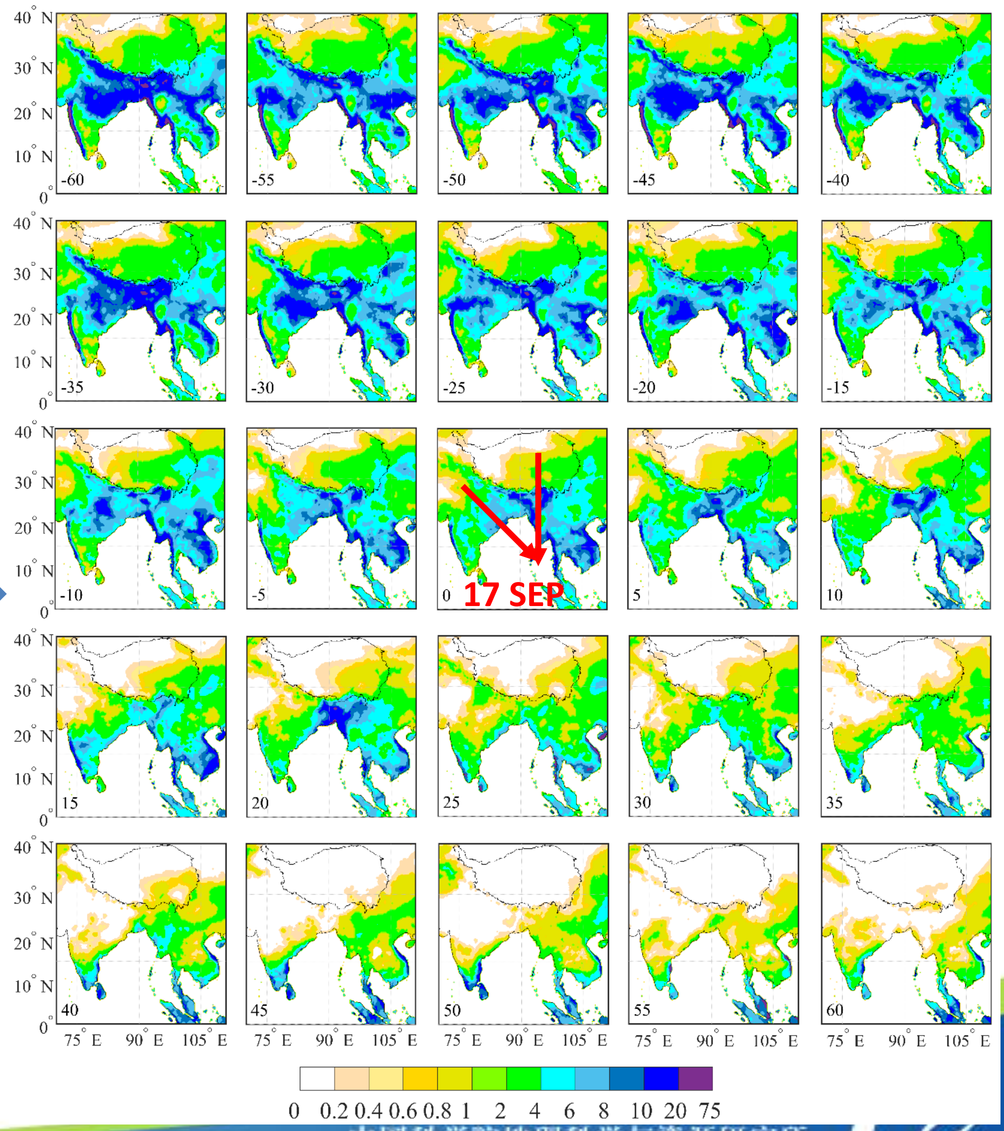
The SASM system controls the evolution of the precipitation over the SCTP

Onset Phase



Evolution of climatological daily precipitation

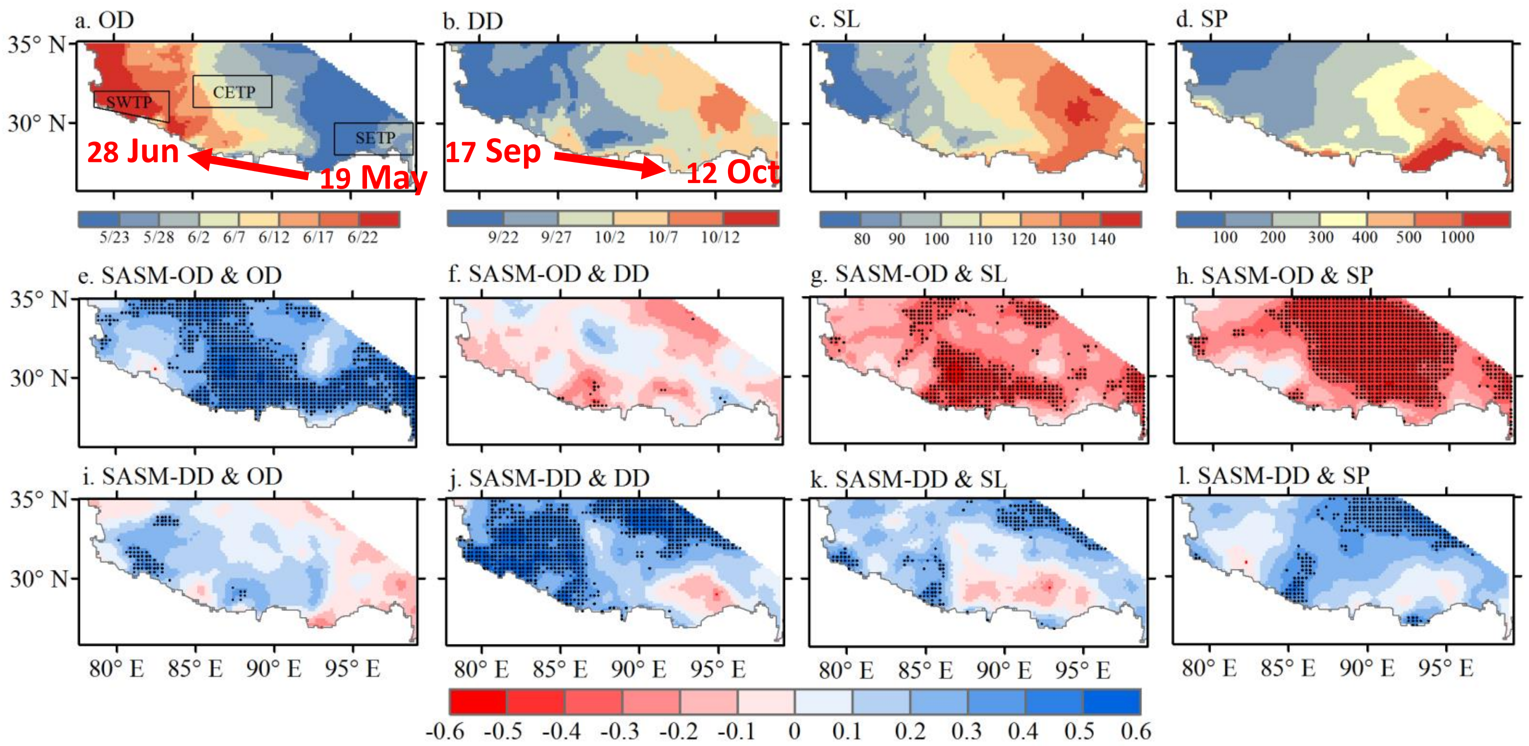
Demise Phase



Associations between the interannual variations of the SASM and precipitation over the SCTP

Climatology

Correlations



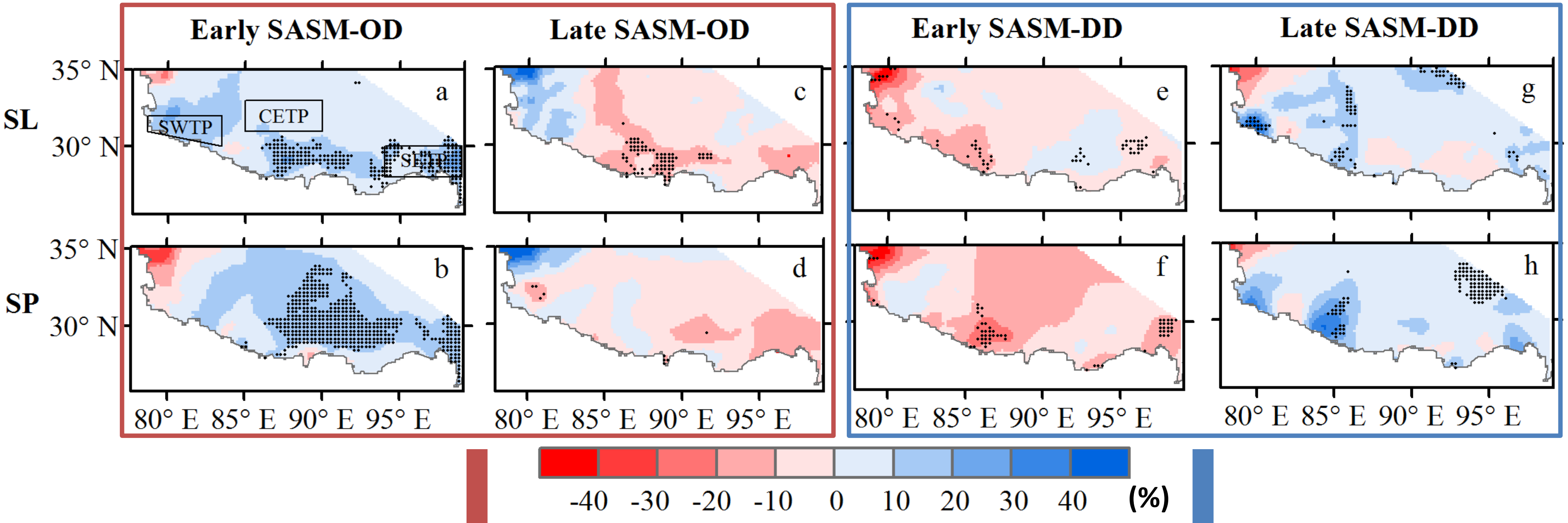
- The propagation, duration, and total amount of precipitation over the SCTP is closely connected with the evolution of SASM, but with **significant spatial heterogeneity**.
- The associations of interannual variations in precipitation with the **SASM-onset** (**SASM-demise**) is stronger in the **SETP and CETP** (**SWTP and CETP**).

The anomalous SASM causes spatial heterogeneous and asymmetric precipitation changes over the SCTP

Composite difference

Monsoon season length

Monsoon seasonal precipitation



Early (late) SASM-onset leads to **longer** (shorter) monsoon season length, and **increase** (decrease) in precipitation amount

Early (late) SASM-demise leads to **shorter** (longer) monsoon season length, and **decrease** (increase) in precipitation amount

The anomalous SASM causes spatial heterogeneous and asymmetric precipitation changes over the SCTP

Region	Phase	Onset Date		Demise Date		Monsoon Season Length		Seasonal Precipitation	
		Date (Julian Day)	Absolute Change (Days)	Date (Julian Day)	Absolute Change (Days)	Days	Relative Change (%)	Amount (mm)	Relative Change (%)
SETP	Climatology	140 (19 May)		274 (30 September)		135		667.19	
	Early Onset	130	-10	275	1	145	7.96	741.83	11.19
	Late Onset	150	10	275	1	125	-7.36	585.63	-12.22
	Early Demise	141	1	273	-1	133	-1.29	628.41	-5.81
	Late Demise	138	-2	282	8	144	6.89	715.49	7.24
CETP	Climatology	153 (1 June)		267 (23 September)		114		226.22	
	Early Onset	143	-9	262	-4	119	4.69	259.29	14.62
	Late Onset	155	3	267	0	111	-2.32	223.30	-1.29
	Early Demise	152	-1	264	-3	112	-1.44	194.32	-14.10
	Late Demise	153	0	275	8	122	7.34	242.96	7.40
SWTP	Climatology	169 (17 June)		261 (17 September)		91		287.43	
	Early Onset	159	-11	258	-1	100	10.26	301.13	4.76
	Late Onset	165	-4	261	1	96	5.63	295.48	2.80
	Early Demise	155	-14	236	-24	80	-11.30	260.04	-9.53
	Late Demise	166	-3	279	19	113	24.40	345.87	20.33

23.41%

13.05%

15.91%

21.50%

1.96%

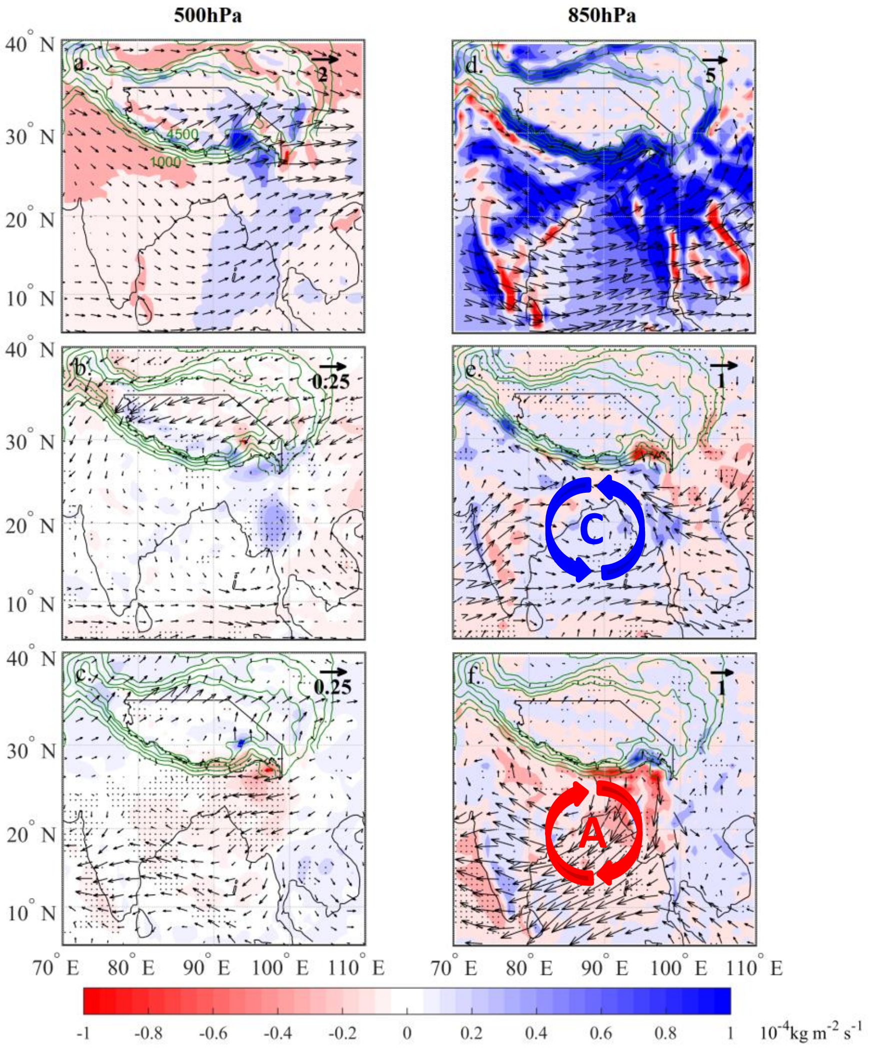
29.86%

Changes of WV generated by anomalous SASM activities dominate the interannual SCTP-precipitation variations

Climatology

Early onset

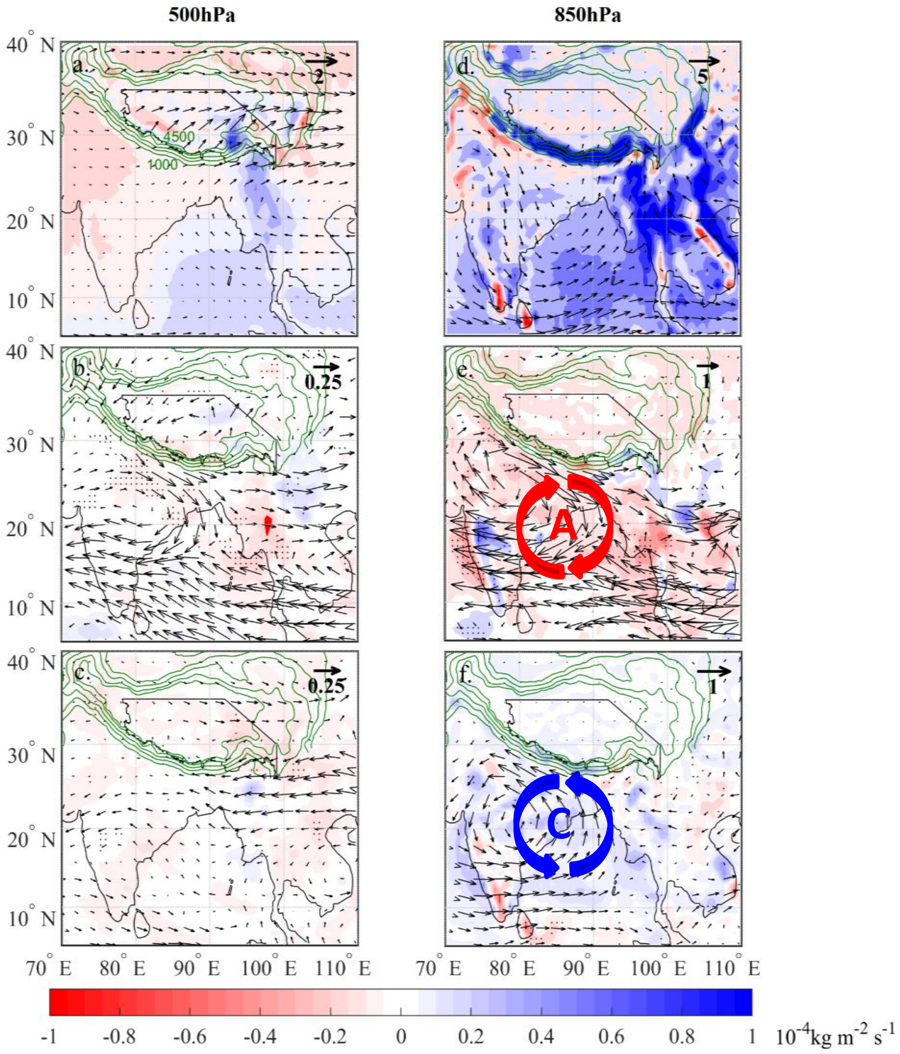
Late onset



Climatology

Early demise

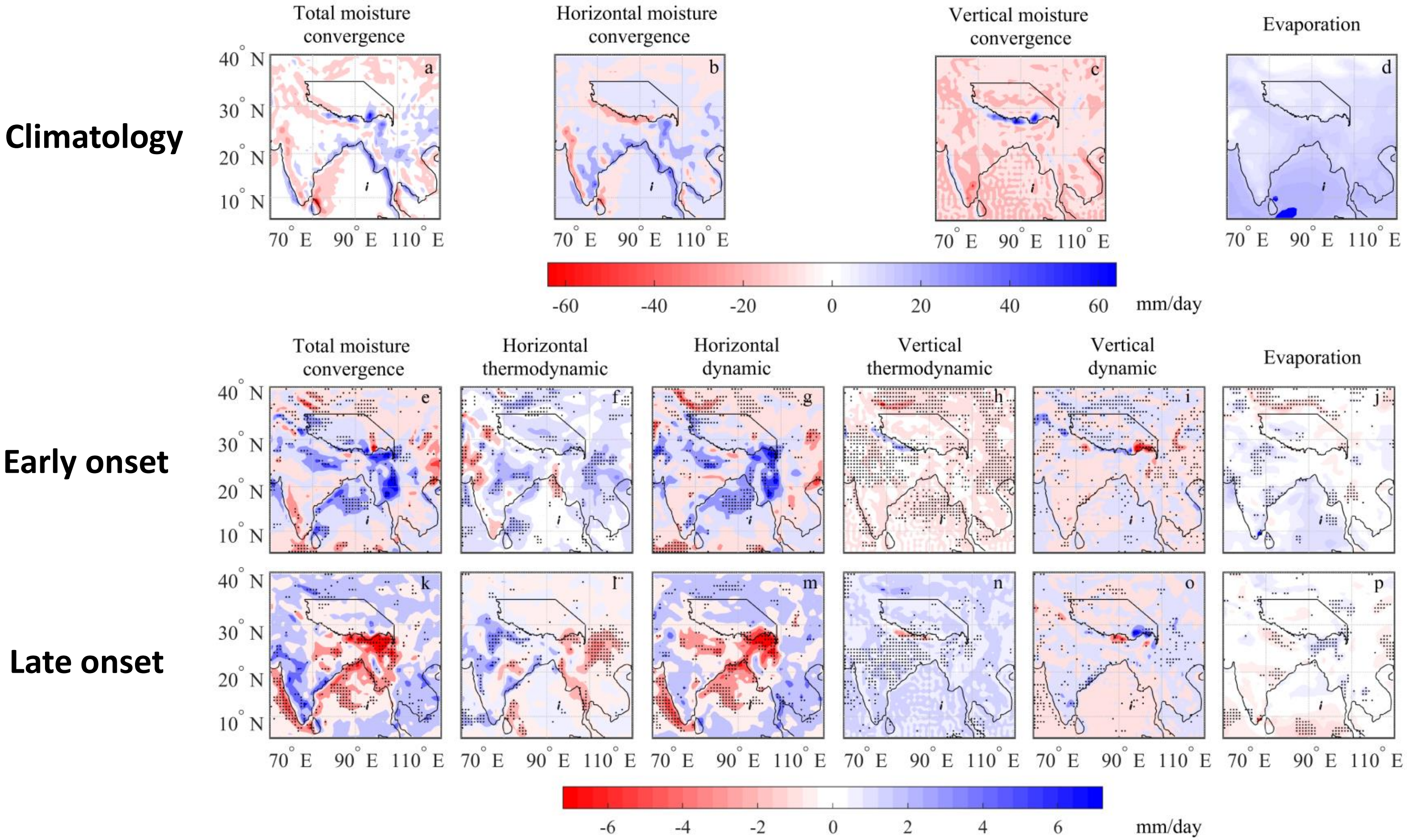
Late demise



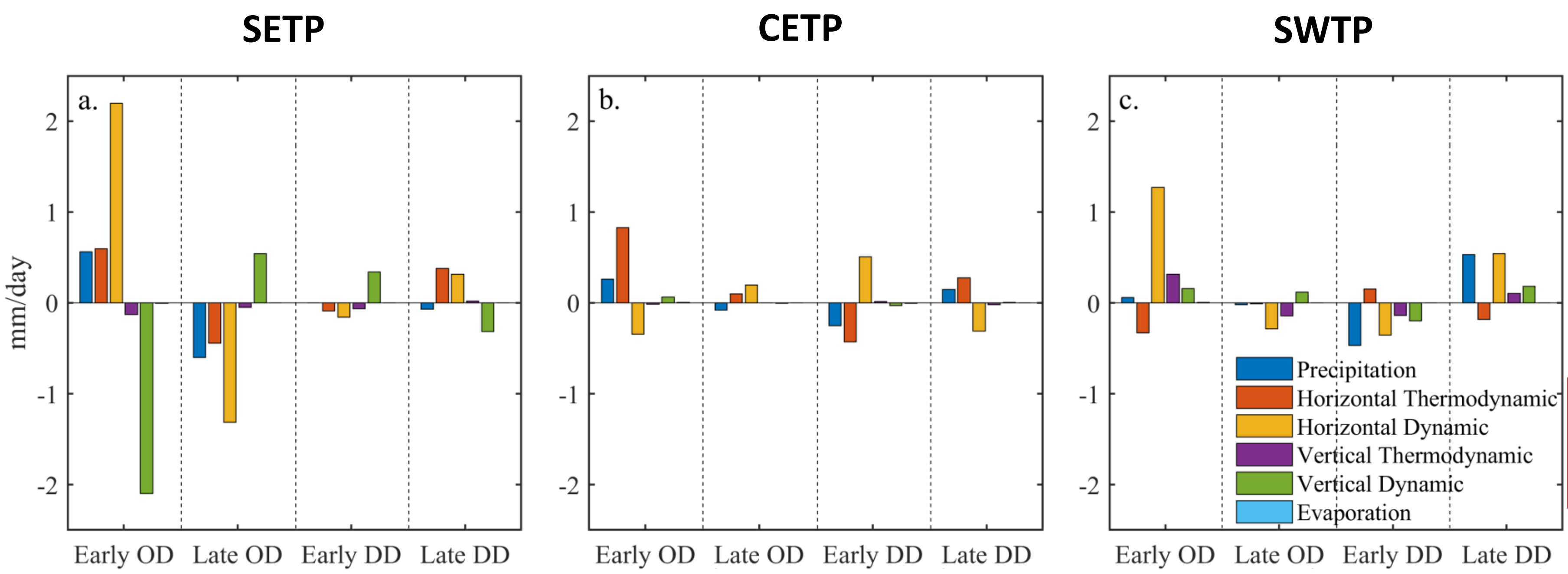
The horizontal (vectors) and vertical (shadings) water vapor (WV) flux

Thermodynamic and dynamic mechanisms governing the interannual SCTP-precipitation variations

Moisture convergence (MC) decomposition



Spatial heterogeneous and asymmetric changes of the MC components explain the SASM effects on precipitation



Horizontal Thermodynamic: HTD
Horizontal Dynamic: HD
Vertical Thermodynamic: VTD
Vertical Dynamic: VD

HTD+HD+VD		HTD+HD		HTD+HD+VTD+VD	
2.40	0.53	0.63	0.76	0.59	0.86

Large (small) changes in the MC reasonably explain the **larger** (smaller) precipitation anomalies in the anomalous SASM-onset years versus those in the SASM-demise years in the **SETP** (CETP and SWTP).

Outline

Summary

- The water vapor transport and its changes generated by the anomalous **SASM** activities, combined with the **topographic effect**, control the precipitation **propagation** and its **anomaly** across the SCTP.
- There are **asymmetric effects** of the SASM with topography on the precipitation between onset and demise, and between early and late onset (demise) of the SASM, along with evident spatial heterogeneity.
- The results presented here would be helpful to improve our understanding of the SASM-precipitation relationship over the SCTP and guide the **freshwater resources management and water-related disasters mitigation** in this region and its surrounding areas.

Thank you!

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Zhu, Y., Sang, Y. F., Chen, D., Sivakumar, B., & Li, D. (2020). Effects of the South Asian summer monsoon anomaly on interannual variations in precipitation over the South-Central Tibetan Plateau. Environmental Research Letters, 15(12), 124067.

Zhu, Y. X., & Sang Y. F. (2018). Spatial variability in the seasonal distribution of precipitation on the Tibetan Plateau [in Chinese]. Progress in Geography, 37(11), 1533–1544.