Role of Tibetan Plateau in the Asian summer monsoon onset

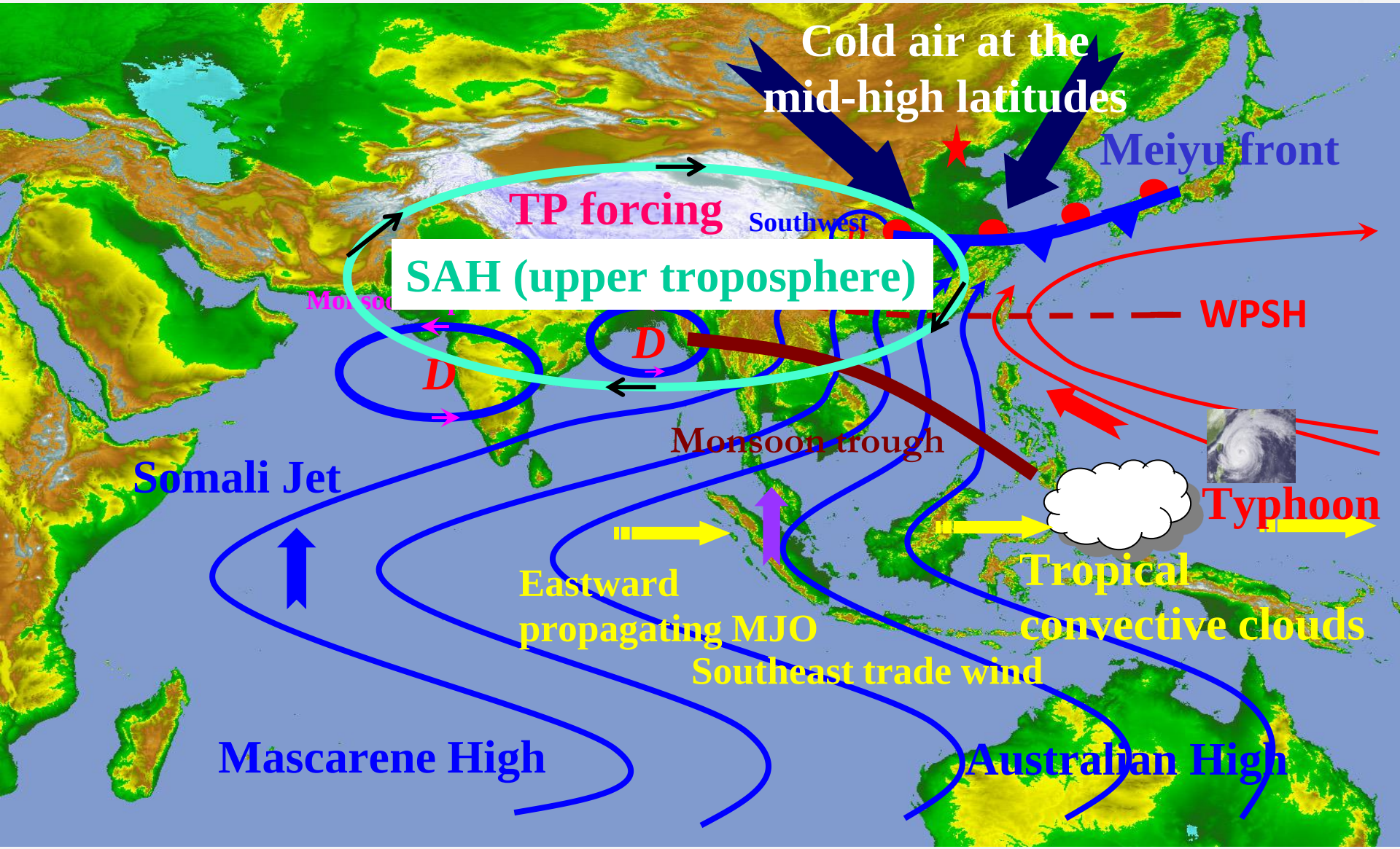
Boqi Liu

2.27-3.3 2017,Beijing

OUTLINE

1. Asian summer monsoon (ASM) onset process
2. Effect of Tibetan Plateau (TP) on the ASM circulation
3. Influences of TP on the ASM onset process:
4. Discussion: TP snow and ASM onset

Major Circulations of AASM



Definition of ASM onset dates

Asian summer monsoon onset criteria (ASMOC)

1. The upper tropospheric (500–200 hPa) MTG changes from negative to positive and remains positive for more than 10 days;
2. The wind direction change at 10-m height is greater than 100°;
3. The rainfall is steadily greater than 5 mm day^{-1} over the ocean and 3 mm day^{-1} over the land.

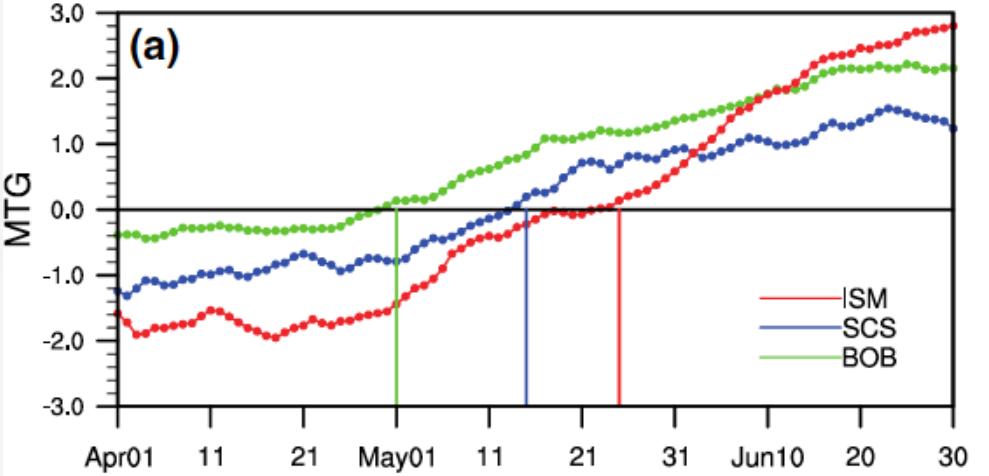


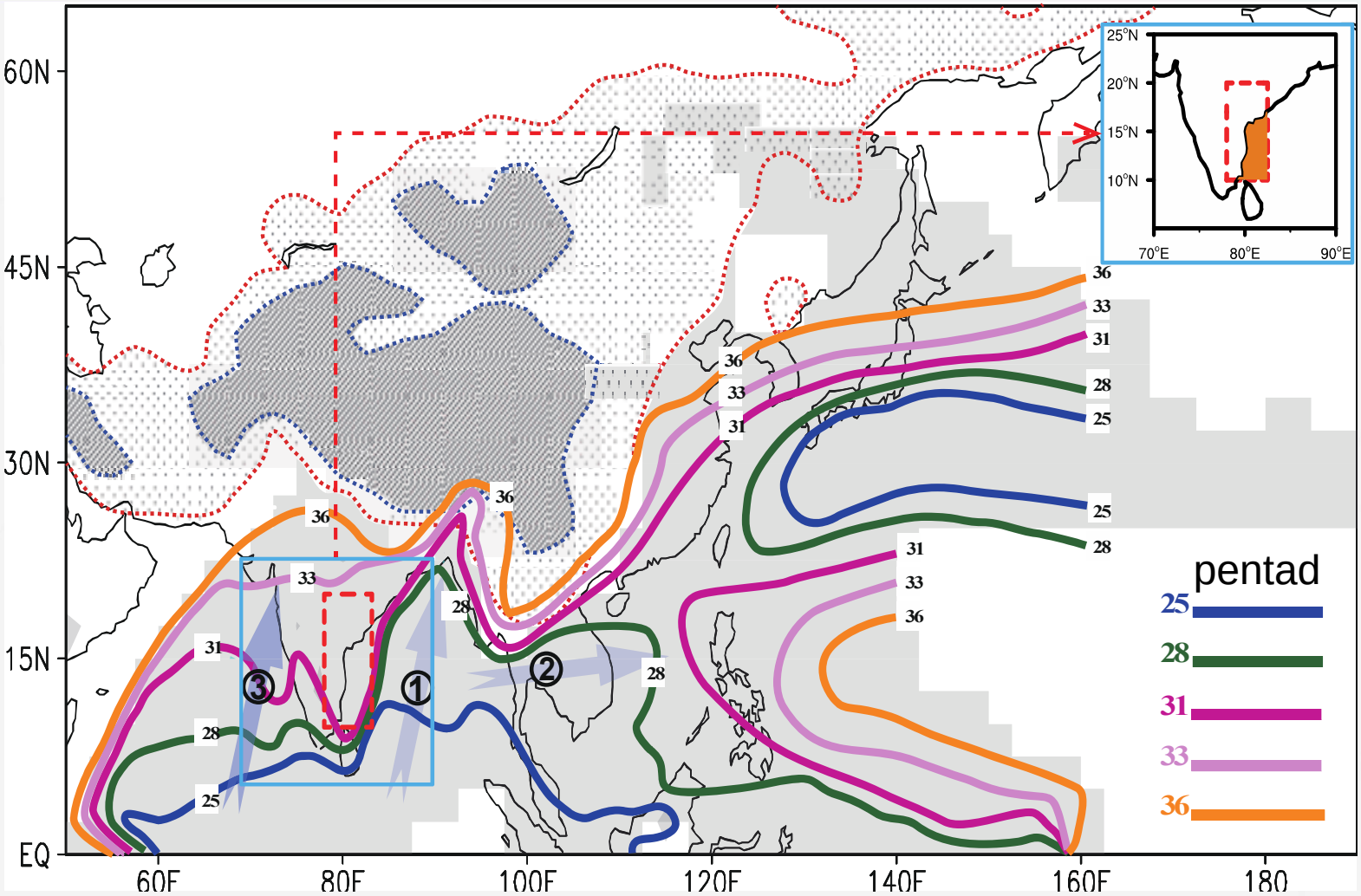
Table 1 Linear correlation coefficients of onset dates defined by the ASMOC in this study with others over the BOB, SCS, and India

BOB	
U850 (Mao and Wu 2007)	0.892
OLR (Mao and Wu 2007)	0.635
MTG (Mao and Wu 2007)	0.804
SCS	
Wang et al. (2004)	0.504
Wang and Wu (1997)	0.699
Tian and Wang (2010)	0.557
India	
Ananthakkrishnan and Soman (1988)	0.665
Wang and Wu (1997)	0.699
Taniguchi and Koike (2006)	0.739
Xavier et al. (2007)	0.678
Wang et al. (2009b)	0.734
Prasad and Hayashi (2005)	0.739

All values have passed the 99 % confidence level

[Liu et al., 2015, CD]

ASM onset process: transient characteristics



- Step 1: Bay of Bengal (BOB) summer monsoon onset
- Step 2: South China Sea (SCS) summer monsoon onset
- Step 3: Indian summer monsoon onset

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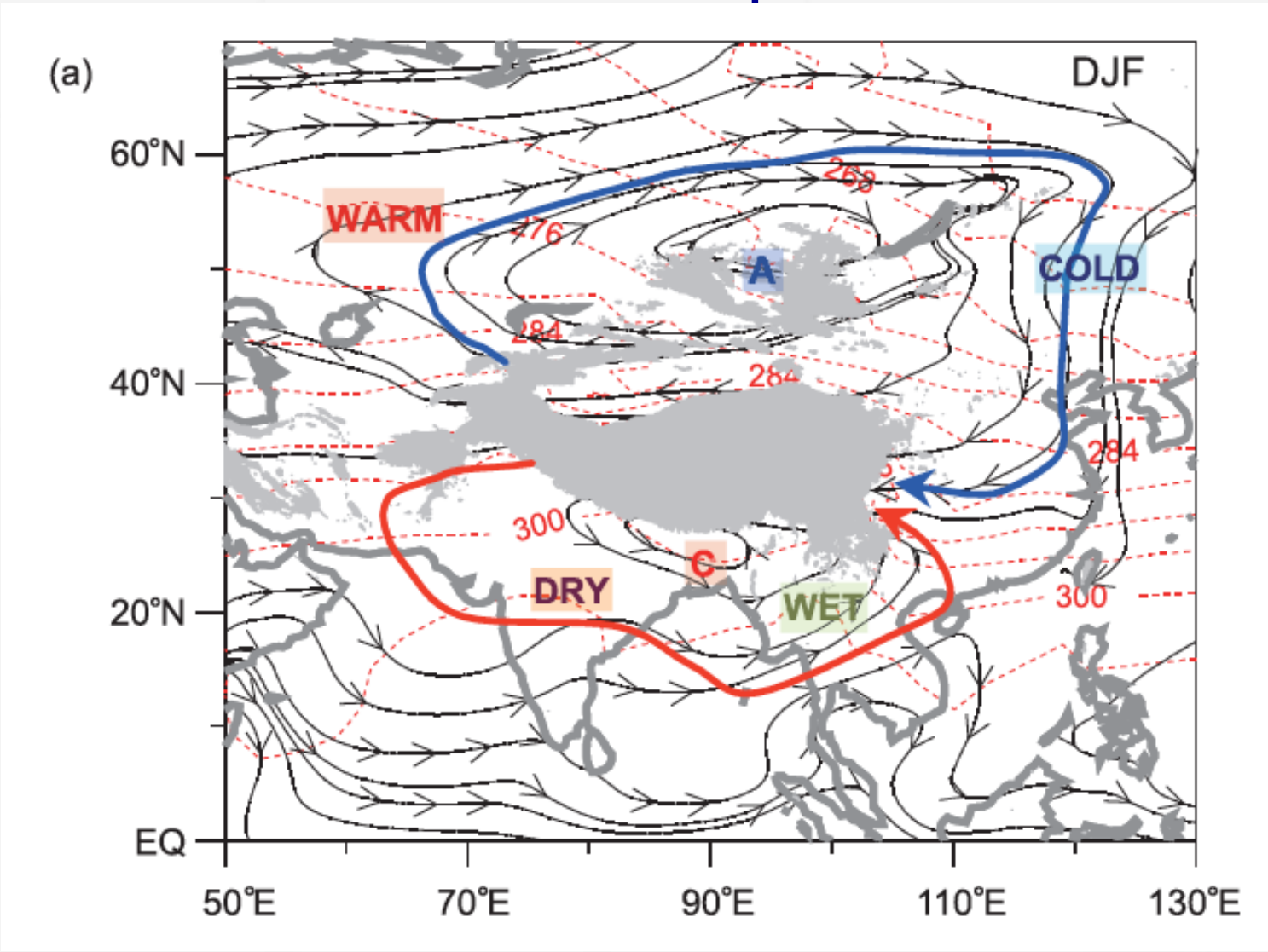
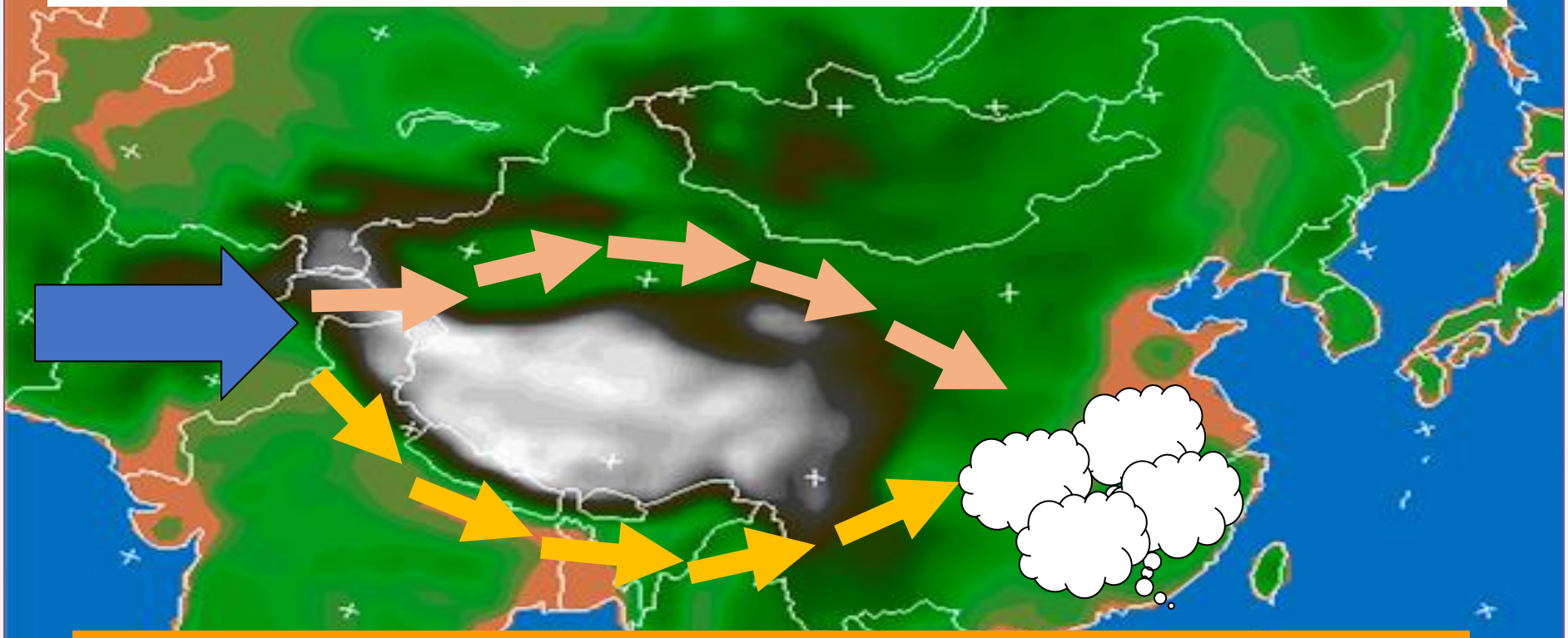
Mechanical effect of TP on the ASM circulation

Boreal winter： TP-Dipole circulation



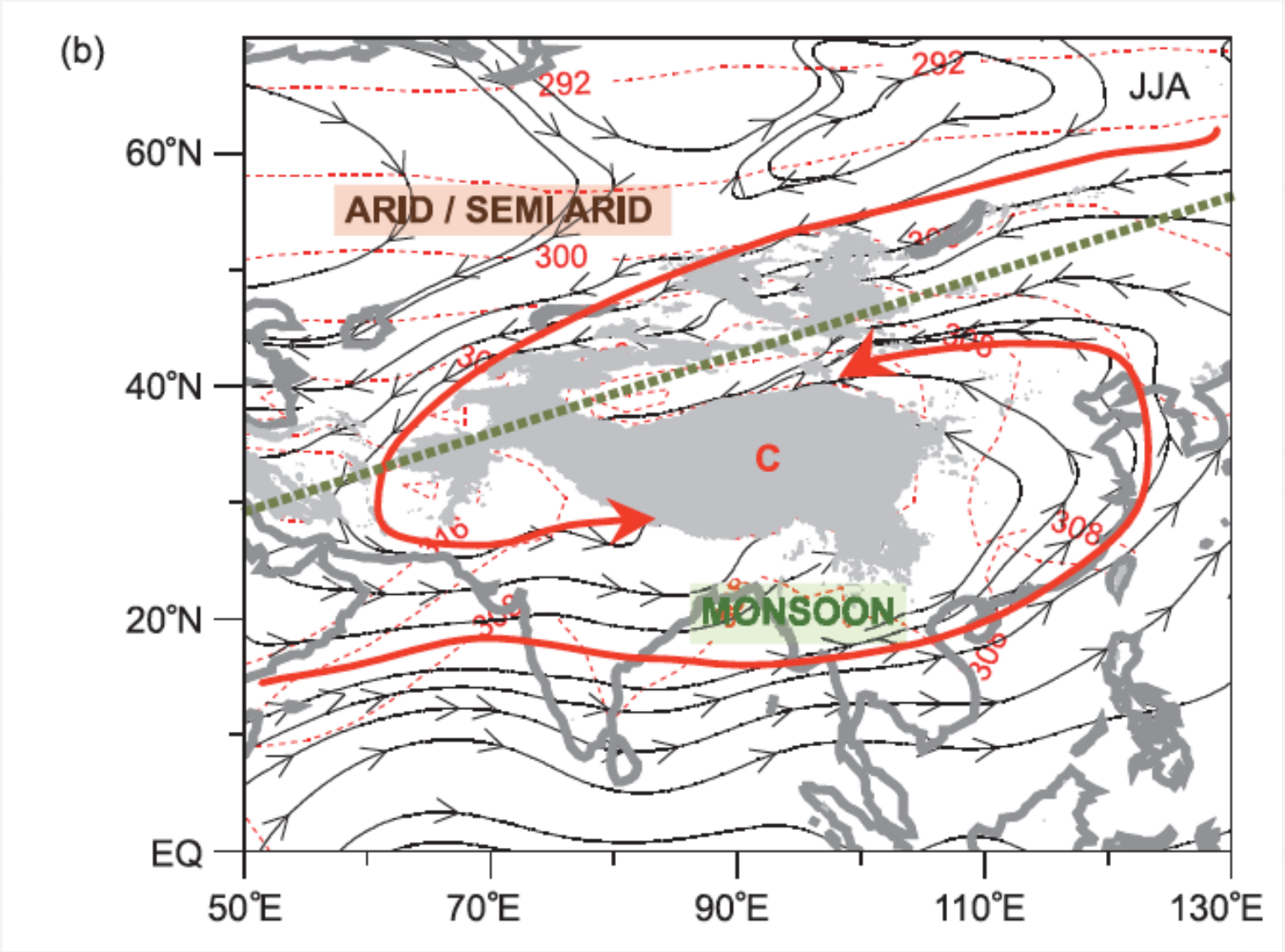
Spring permanent rainfall (SPR) only exists over East Asia, why?



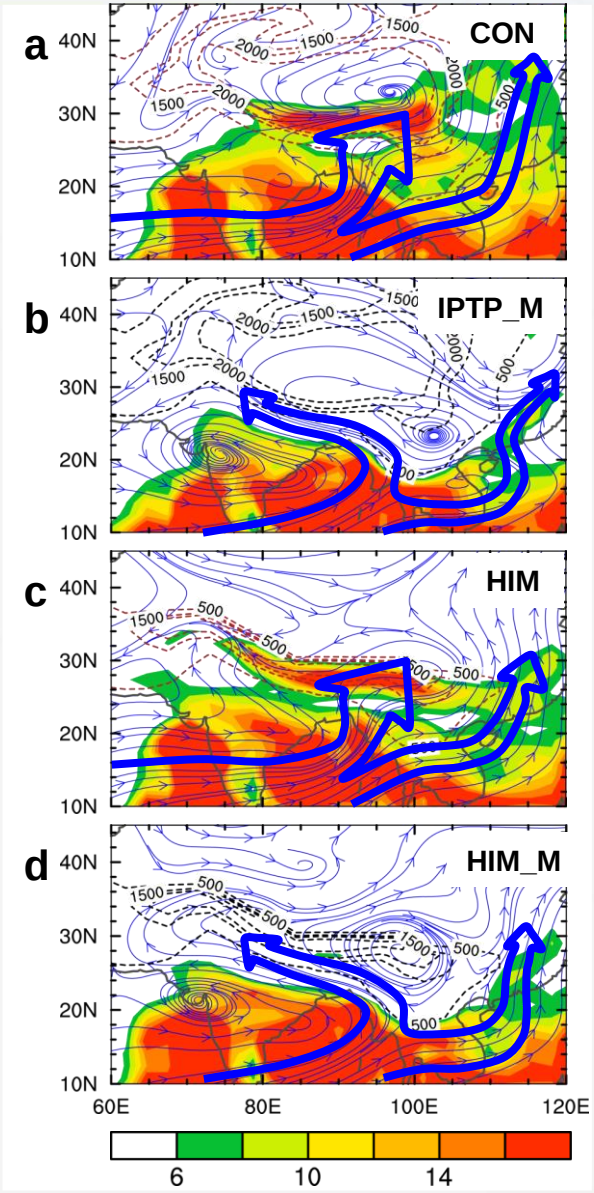
TP-Dipole circulation could produce the low-level convergence over the South China in boreal spring to form the SPR.

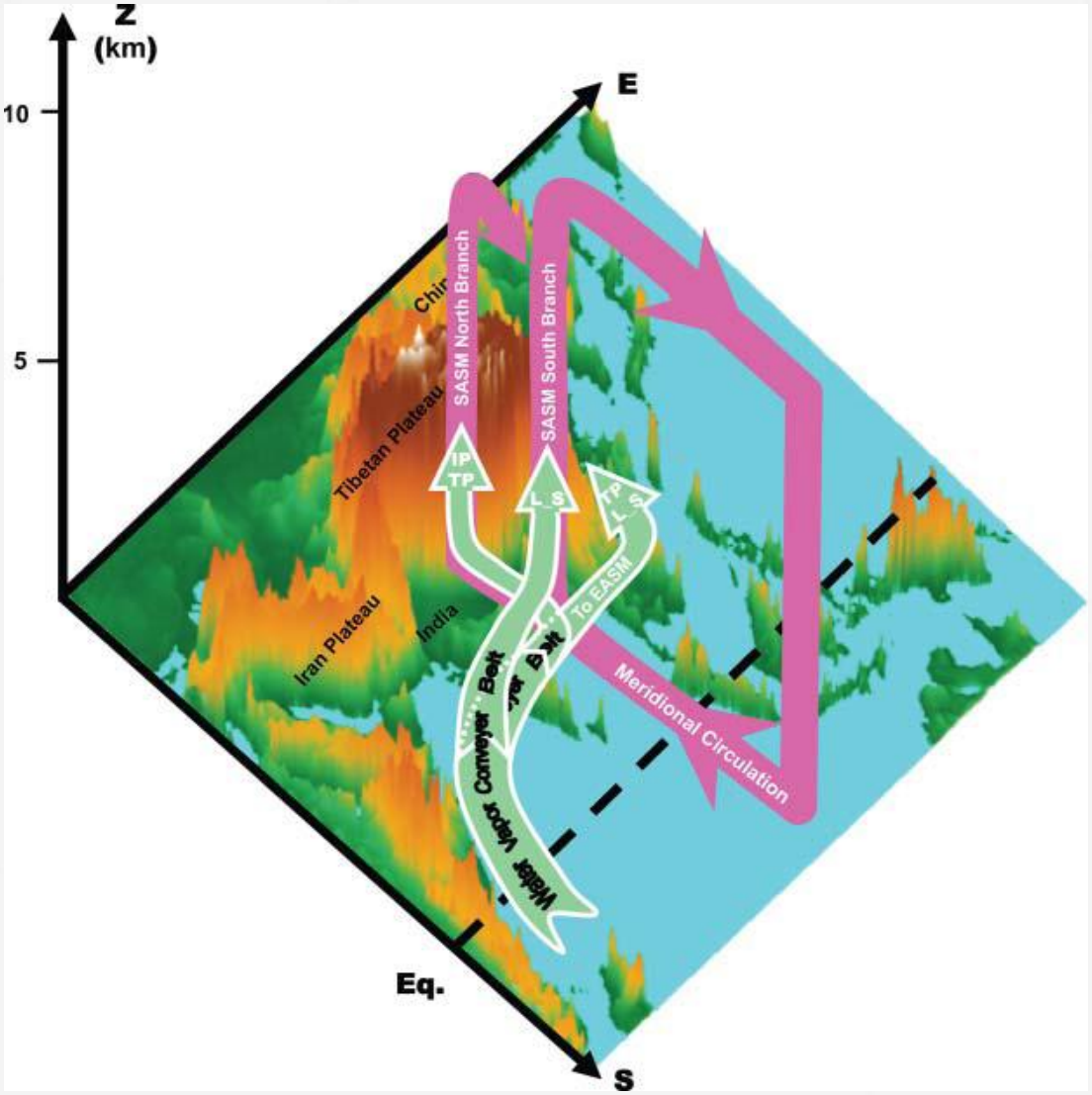
[Wan and Wu, 2005; Wu et al., 2007]

TP becomes a heat source in boreal summer



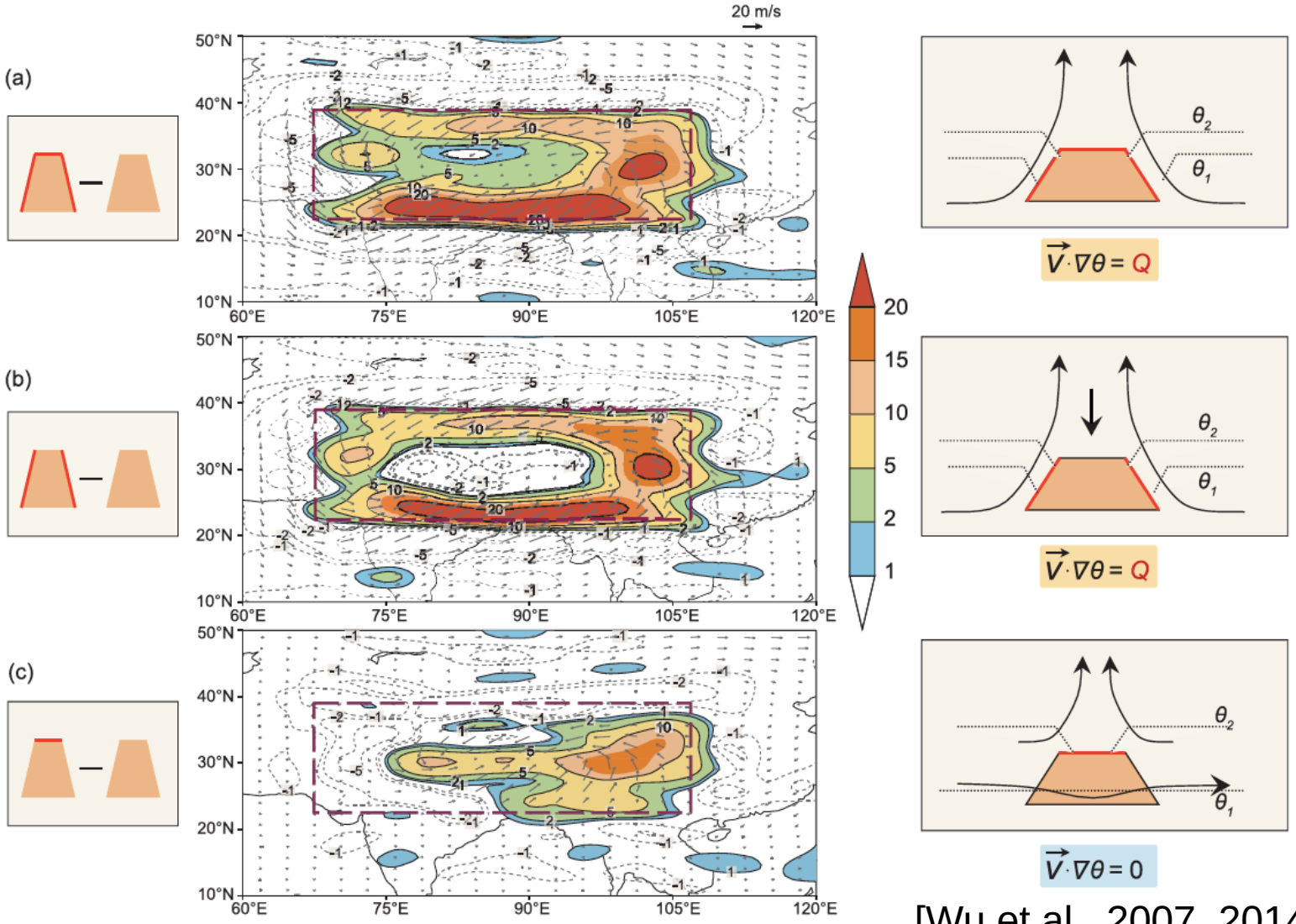
Thermal effect of TP on the ASM circulation





(Wu et al., 2012 Scientific Reports)

Effects of sensible heating on the southern slope of TP as an air pump



[Wu et al., 2007, 2014]

Figure 2. Distributions of difference in wind (vectors, m s^{-1}) and vertical velocity ($-\omega$, shading, 10^{-2} Pa s^{-1}) at the $\sigma = 0.991$ surface between the two perpetual July experiments: (a) ALLSH–NOSH, (b) SLPSH–NOSH, and (c) TOPSH–NOSH, with the dashed rectangle indicating the prescribed mountain base. Left panels indicate the experiment designs and right panels are interpretations of the relevant mechanisms, with orange shading representing mountain and heavy red bar denoting the imposed surface sensible heating. See the text for details [56].

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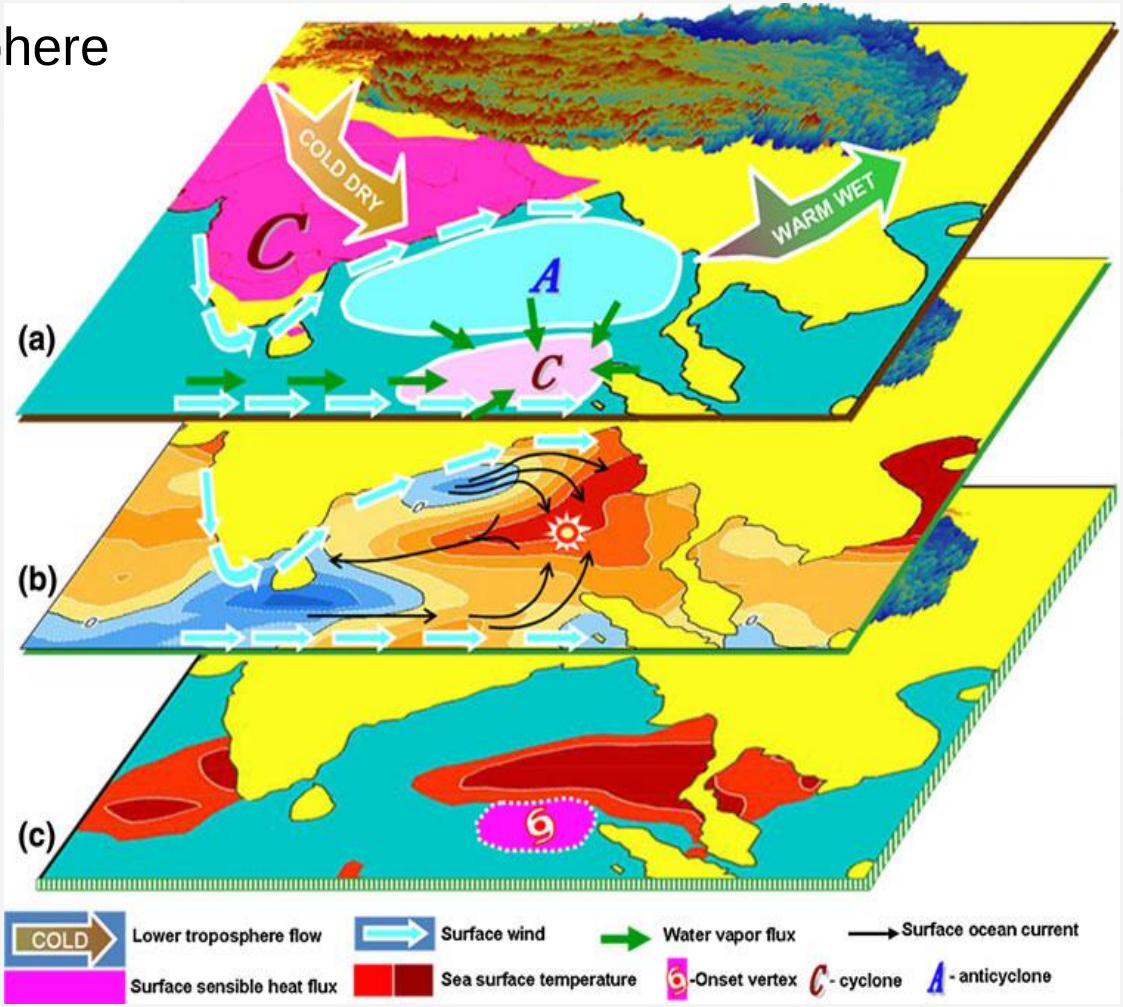
Why the ASM starts over the BOB in early May?

Lower troposphere

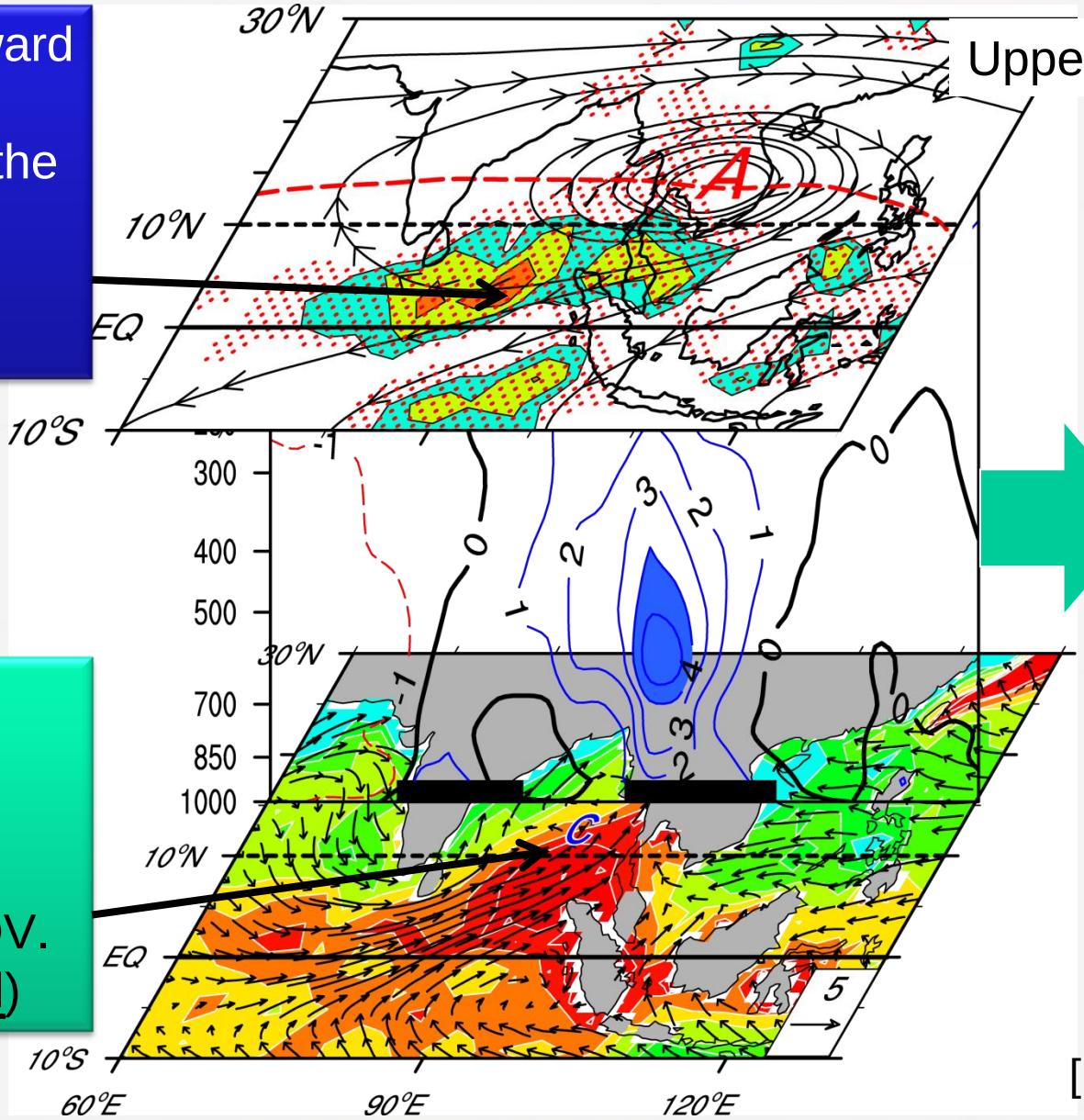


TP effect on the low-level circulation and the formation of BOB warm pool before ASM onset

[Wu et al., 2012]

Why the ASM starts over the BOB in early May?

Upper: westward extending of SAH causes the divergence-pumping. (**trigger**)

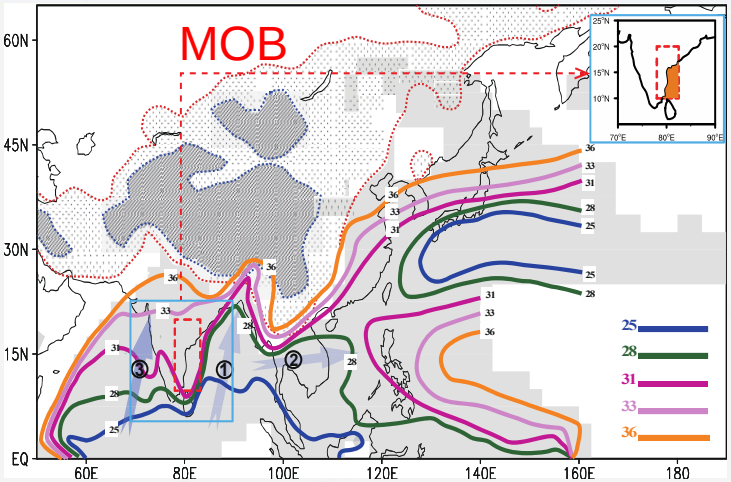


Lower: BOB spring warm pool provides eddy kinetic energy to MOV. (**background**)

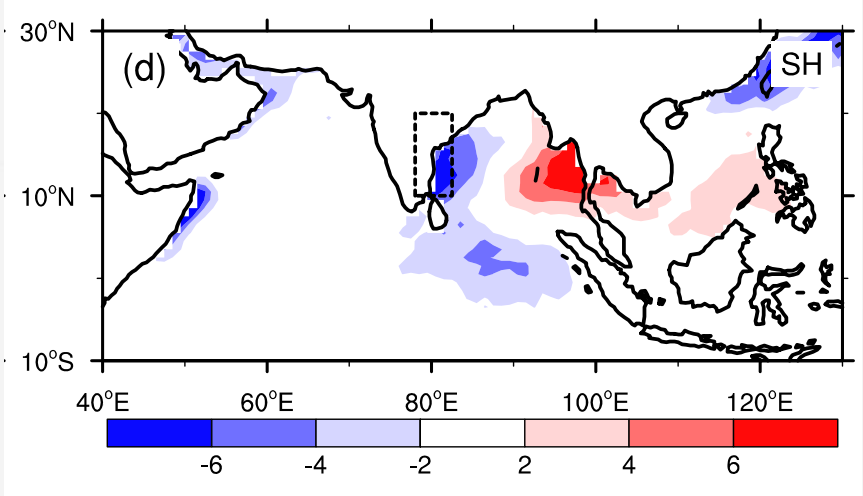
BOB MOV forms and the ASM builds up.

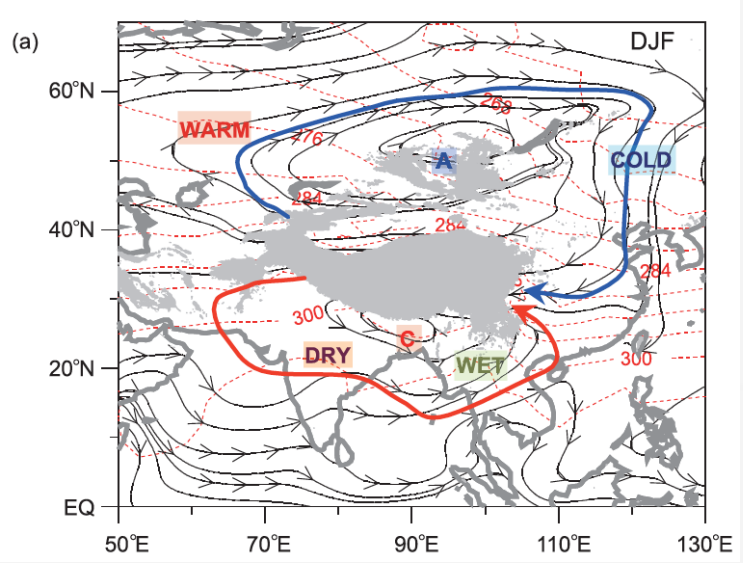
[Liu et al., 2013]

Monsoon onset barrier: a product of TP forcing

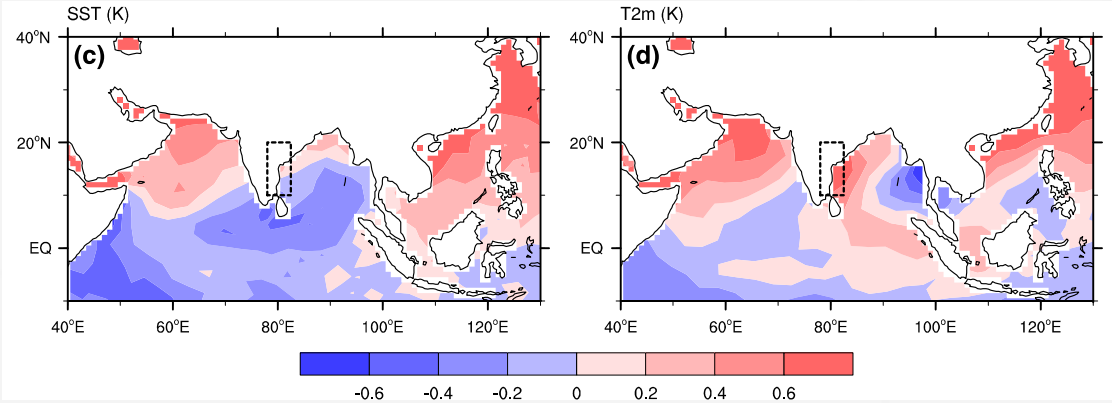


Sensible heating variation during BOBSM onset



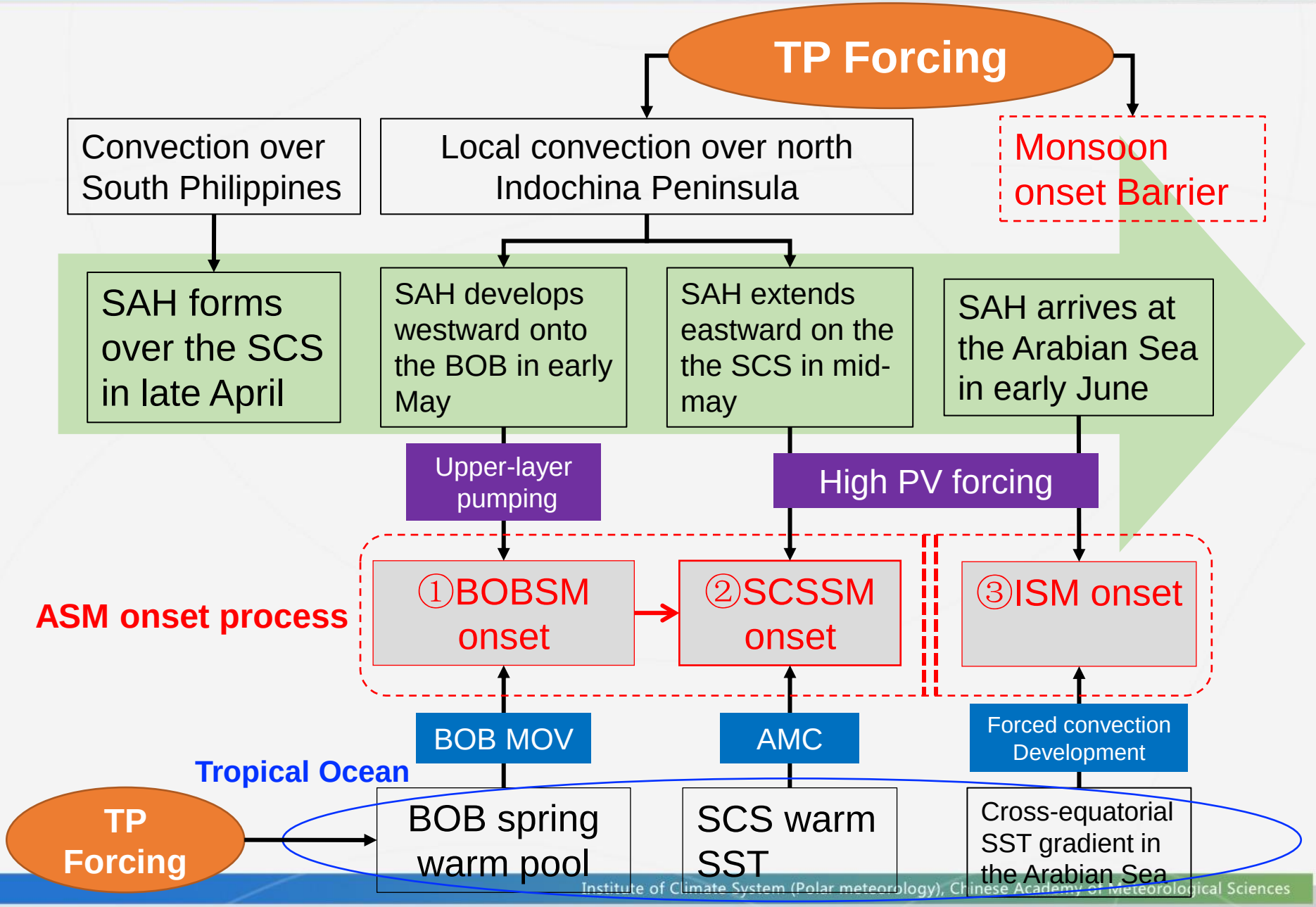


TP-Dipole circulation

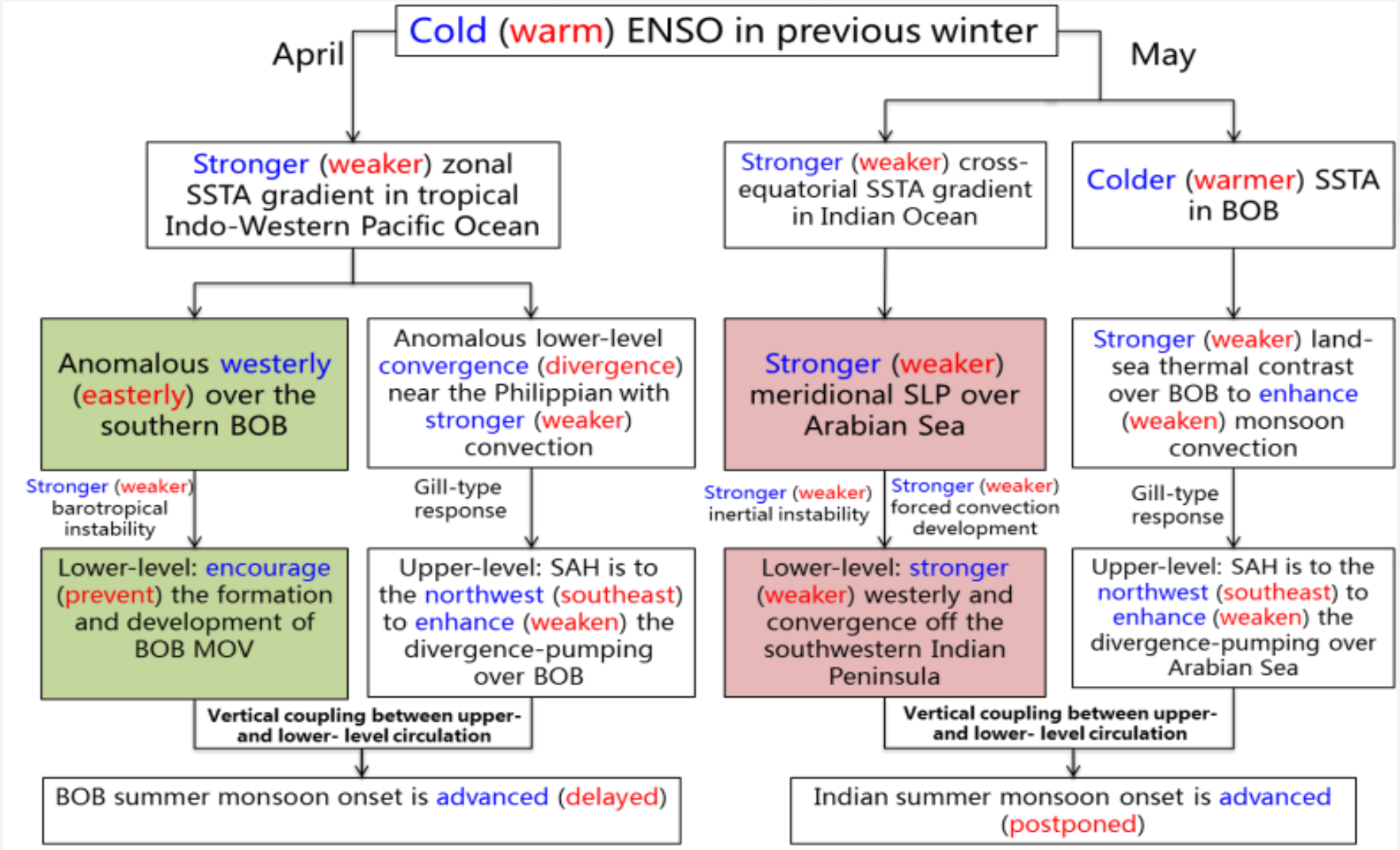


[Liu et al., 2015]

Impacts of TP and tropical ocean on the ASM onset process



Interannual timescale: ENSO event is important for the onset time of ASM

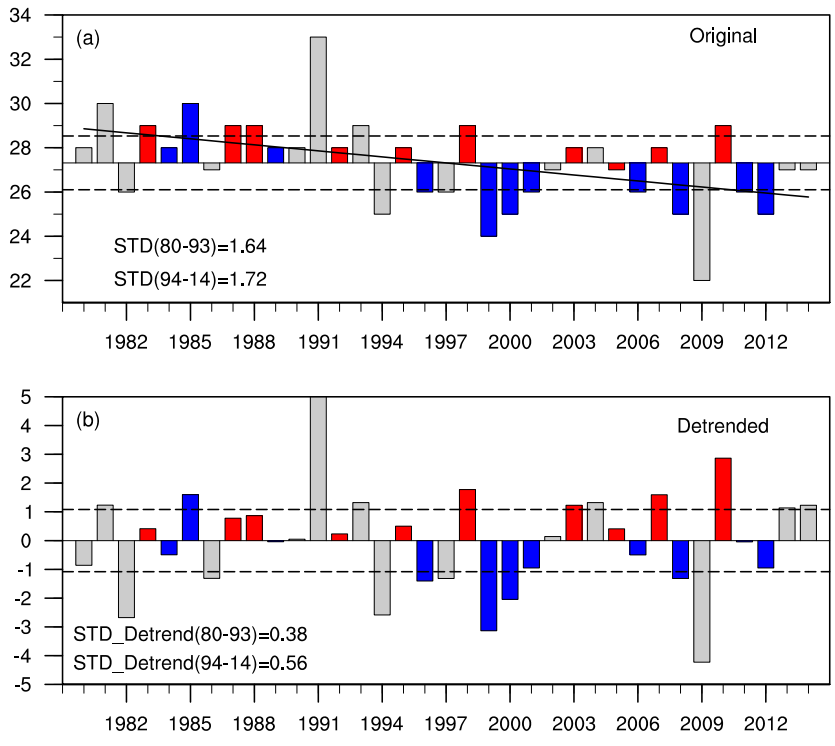


For the BOB and Indian summer monsoon onset

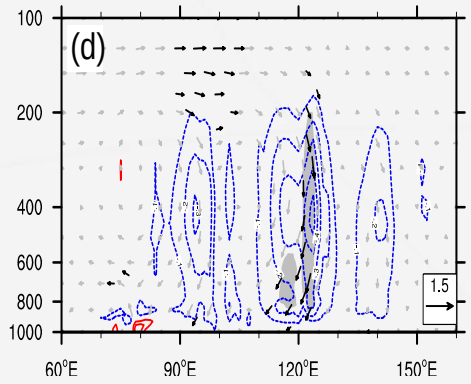
[Liu et al., 2015]

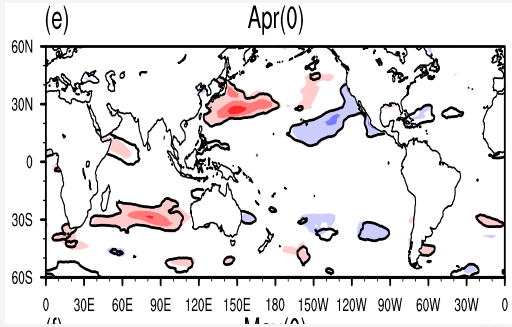
As for the SCS summer monsoon, its interannual variation of its onset time is affected by the ENSO events the after 1993/94, before which it depends on the SST anomalies in the southern Indian Ocean.

For the SCS summer monsoon onset

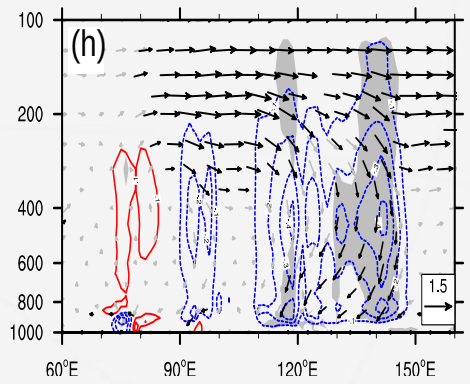


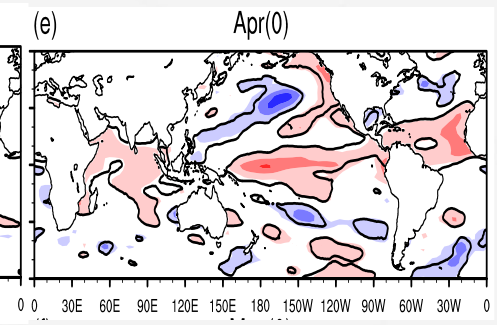
Before 1993/94



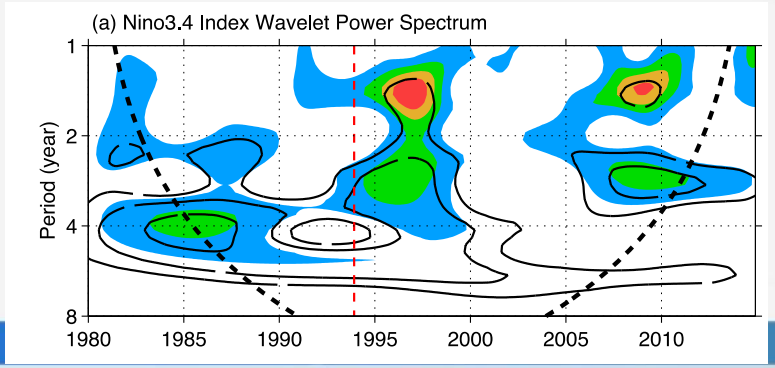


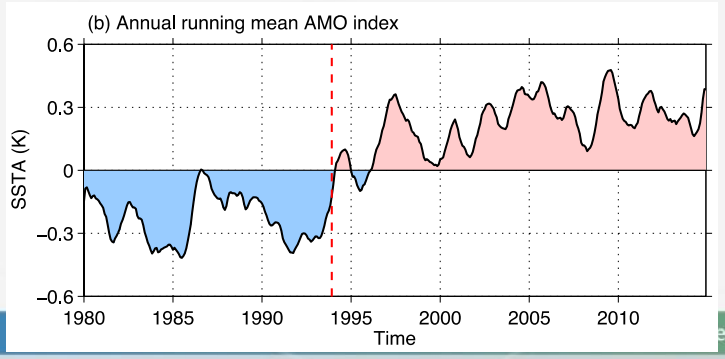
After 1993/94





Possible reason: Interdecadal variation of ENSO events





[Liu et al., 2016]

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Uncertainty in the TP snow datasets

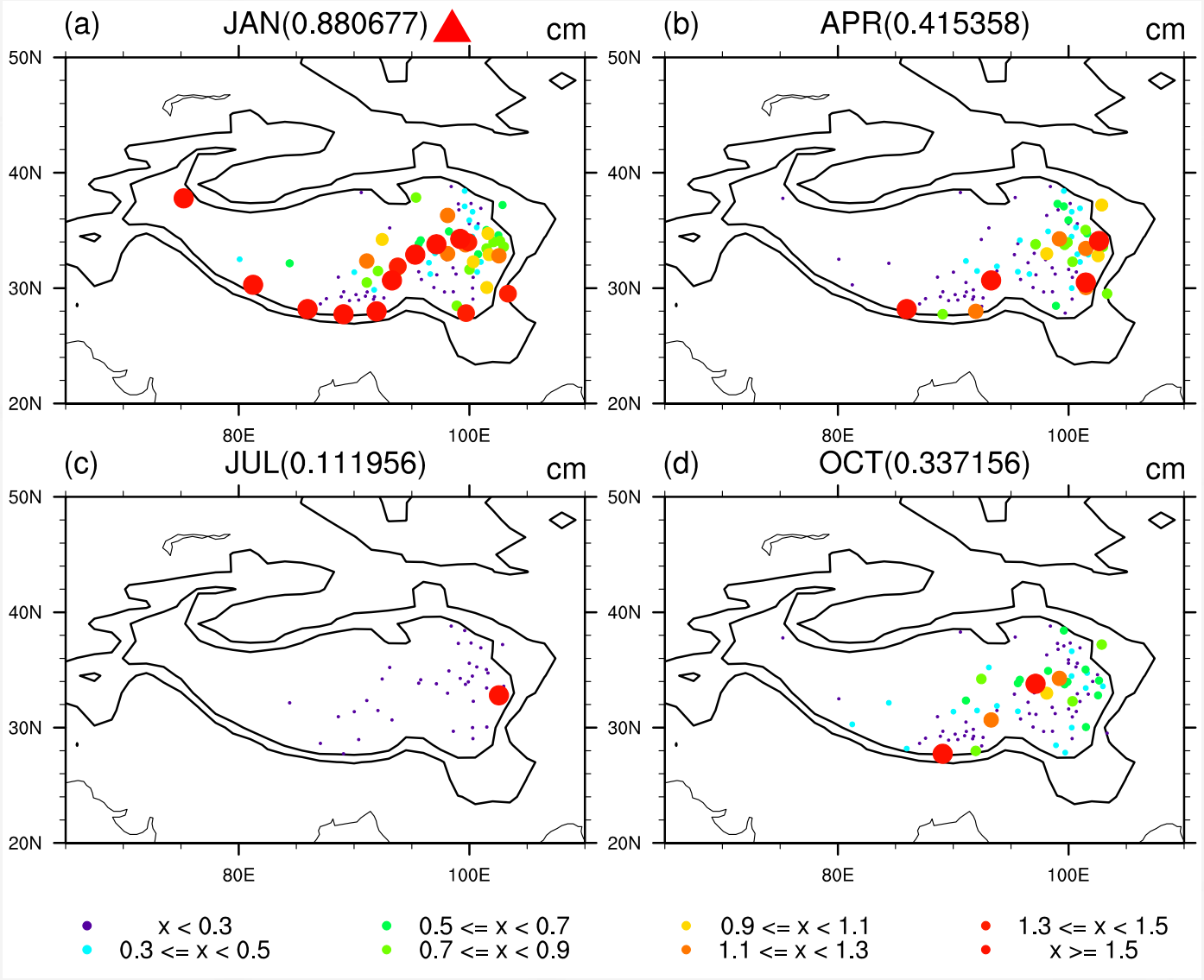
TP region: 70-105E, 25-40N, above 3000m

Data	Spatial Resolution	Period	Temporal Resolution	Data Source
Station Snow depth	92 stations	1951-2013	Daily/monthly	CMA
Station Max Snow depth	92 stations	1951-2013	monthly	CMA
Station Snow cover days	92 stations	1951-2013	monthly	CMA
Snow water equivalent	25km	197811-200705	monthly	NSIDC (SMMR SSM/I)
Snow Cover	25km	196611-201112	weekly	NSIDC (weekly NOAA Charts)
Snow Cover	89*89	196611-201405	monthly	Rutgers University Global Snow Lab(NOAA)
Snow depth	0.25*0.25	1979-2011	daily	CAREERI,CAS (SMMR SSM/I AMSR-E)

Large discrepancy among the existed datasets.

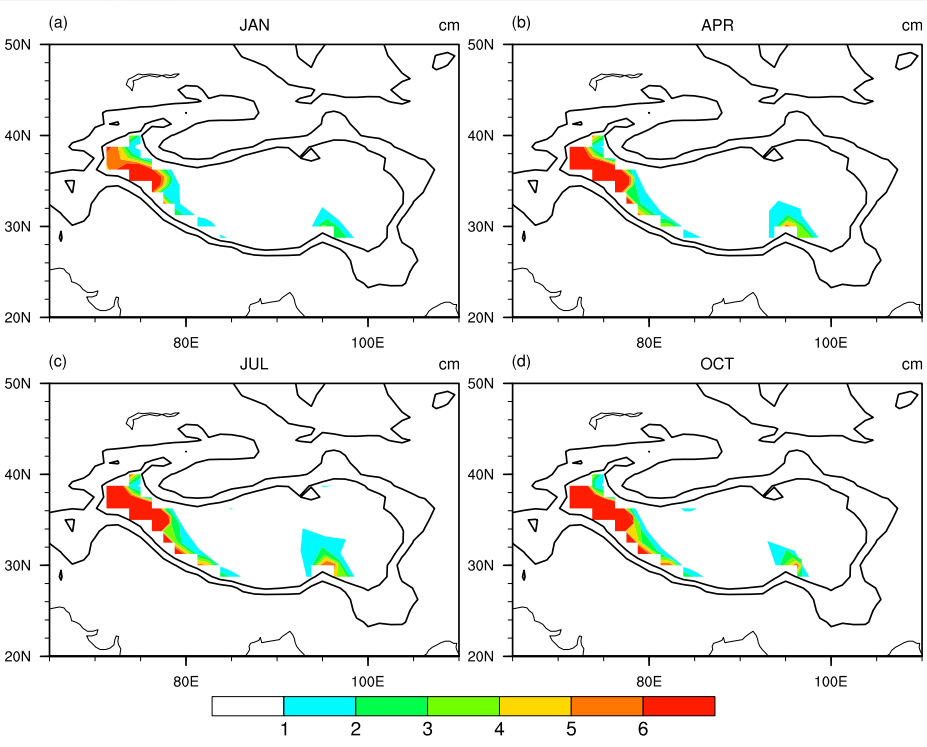
Seasonal cycle of snow depth over the TP

Station observation (92 stations)

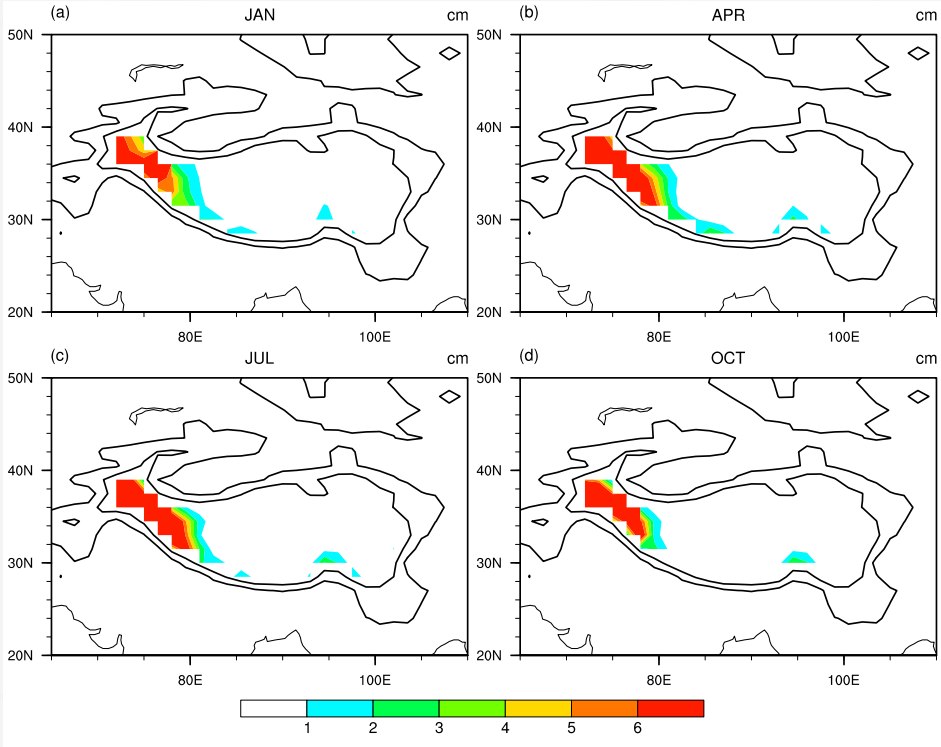


Seasonal cycle of snow depth over the TP

JRA-55

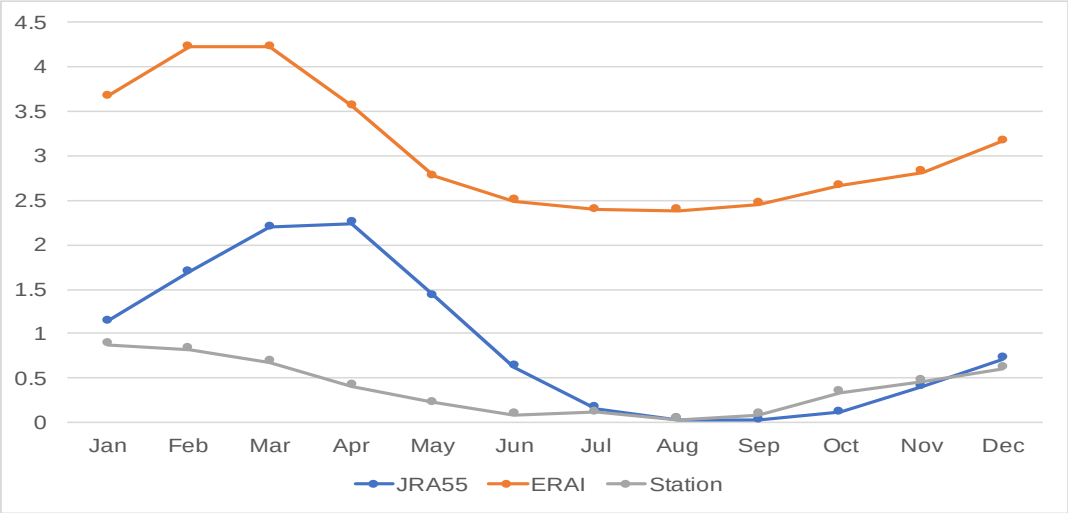


ERA-Interim

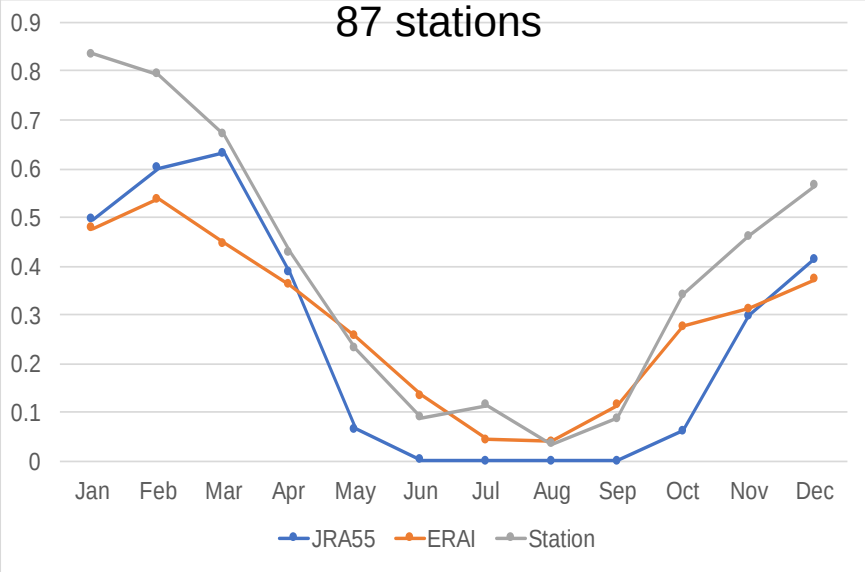


Seasonal cycle of snow depth over the TP

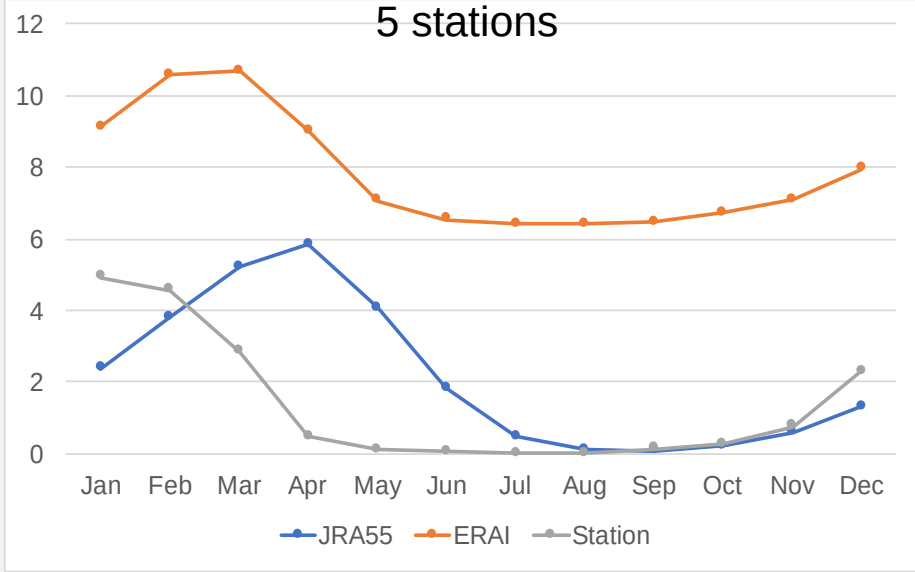
Total TP: 70-105E, 25-40N, above 3000m, 92 stations



Eastern TP: 85-105E, 25-40N, above 3000m, 87 stations

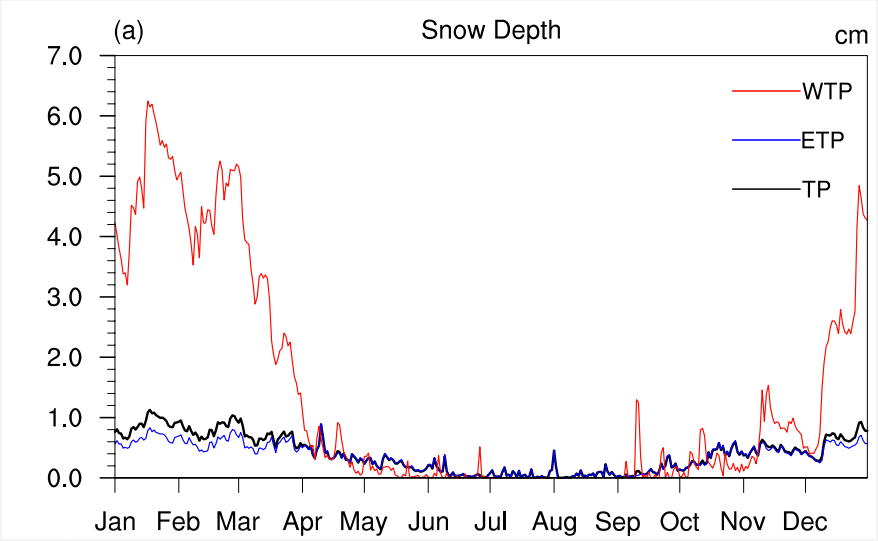


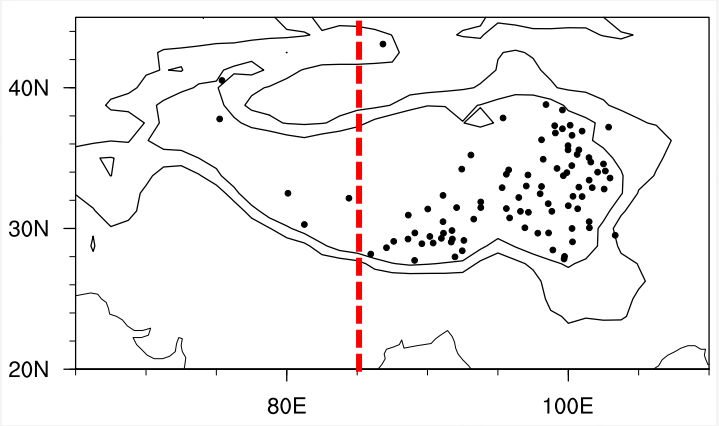
Western TP: 70-84E, 25-40N, above 3000m, 5 stations



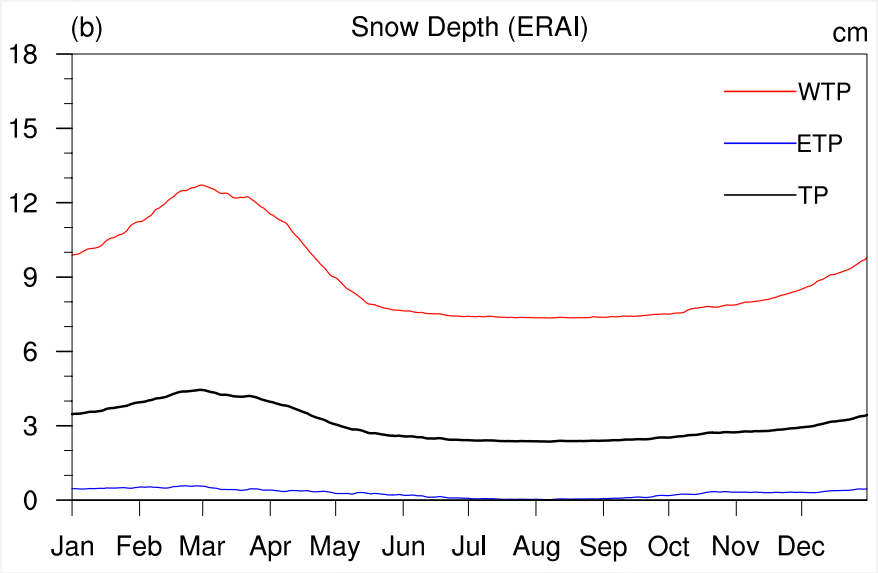
Seasonal cycle of snow depth over the TP

daily result, climatology

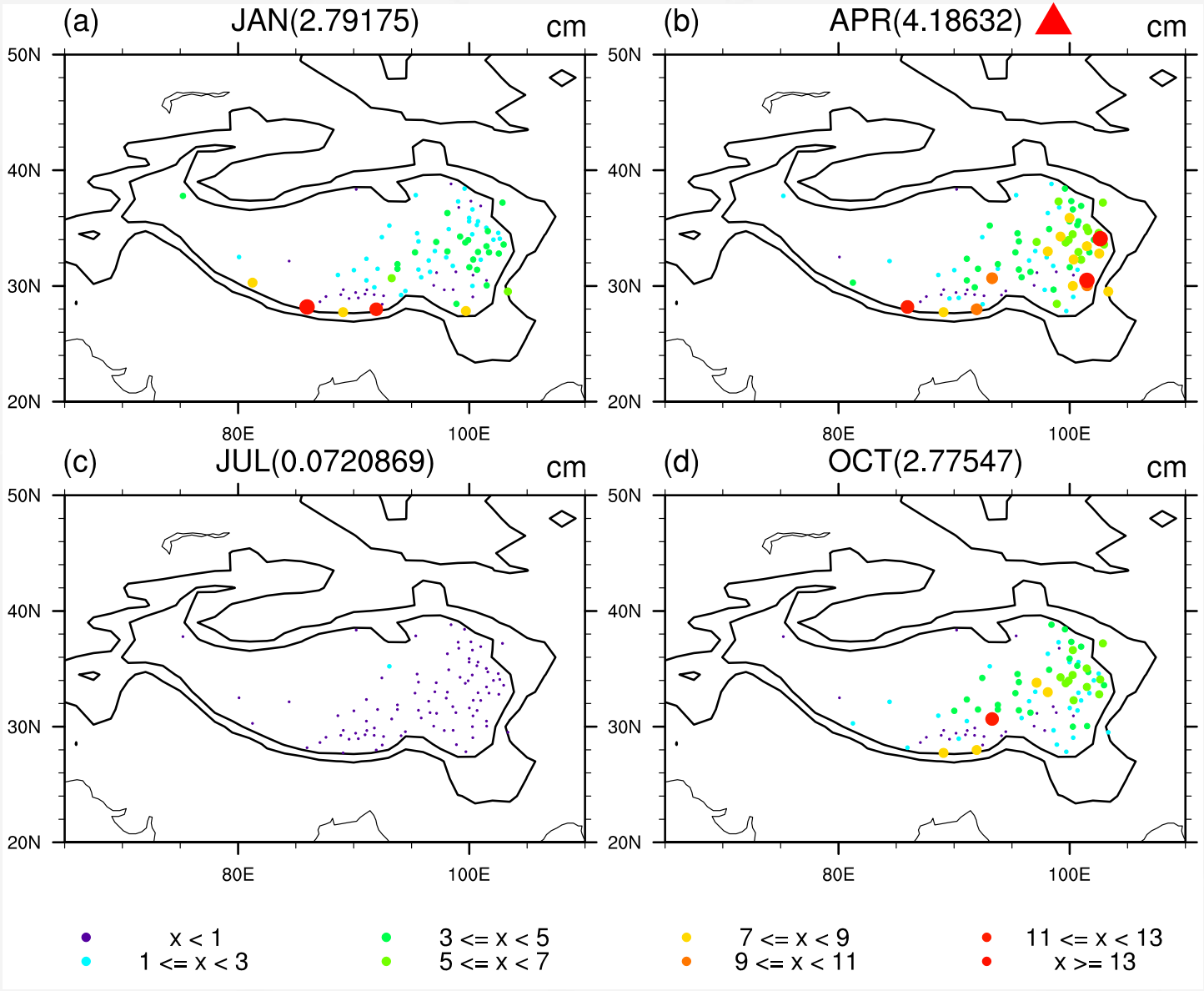




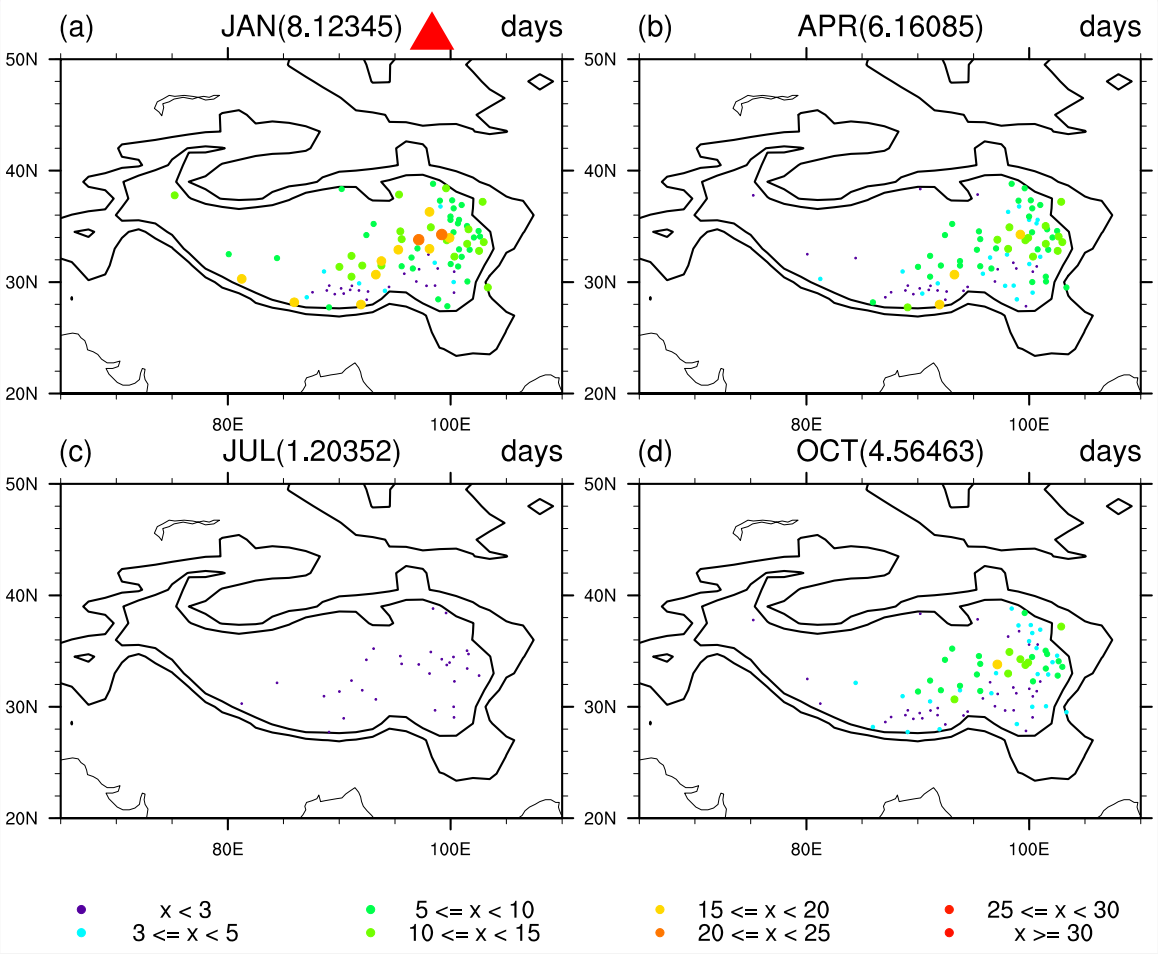
Observing time: 08:00 Beijing time



Seasonal cycle of monthly max snow depth over the TP

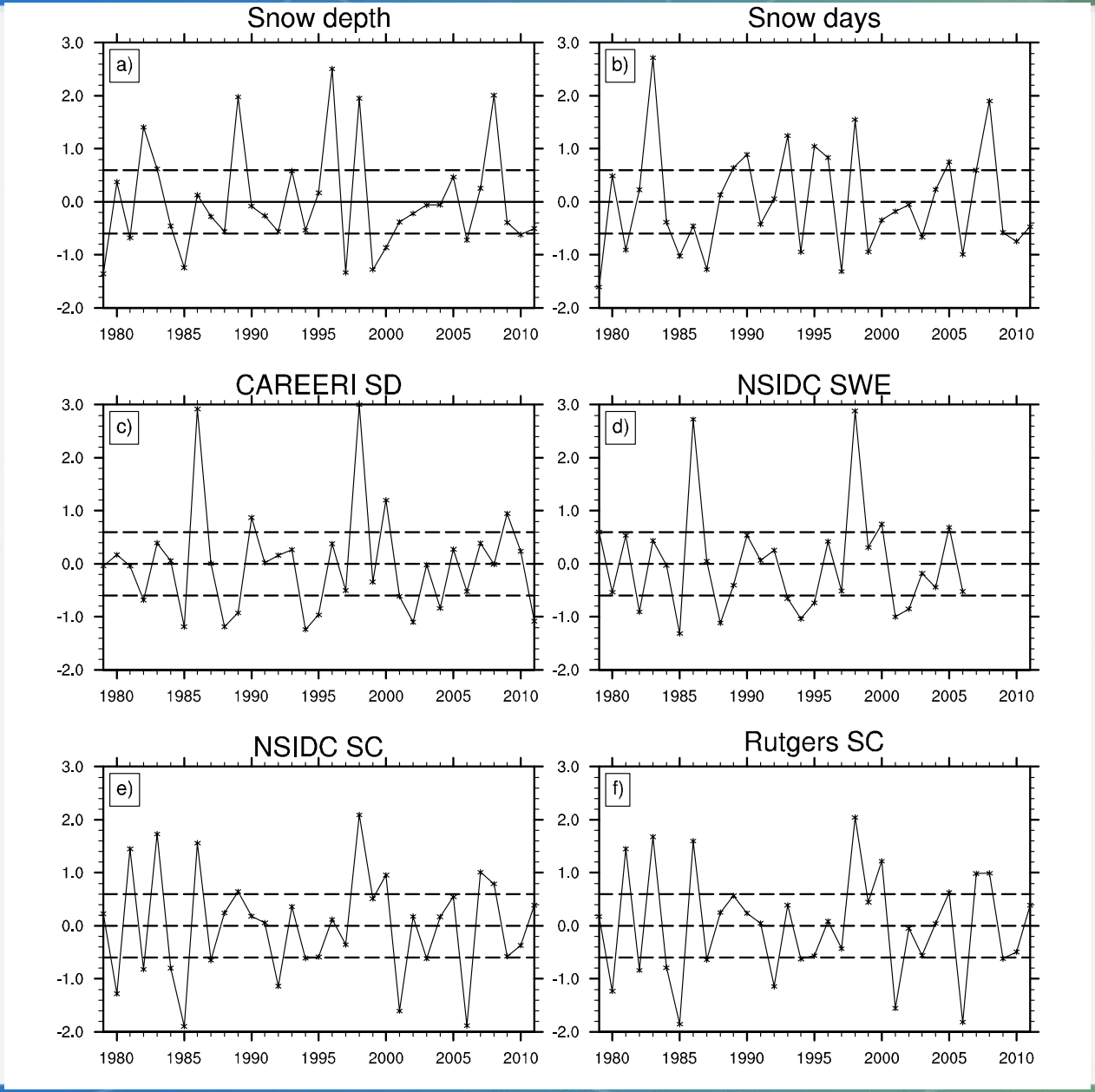


Seasonal cycle of monthly snow cover days over the ETP



Definition of snow cover for the station observation:
Snow (including graupel, granular snow and ice particles) covers more than 50% of the ground seen from the weather station.
In Chinese:
雪（包括霰、米雪、冰粒）覆盖地面达到气象站四周能见面积一半以上。

How to identify the high and low snow years over the ETP?

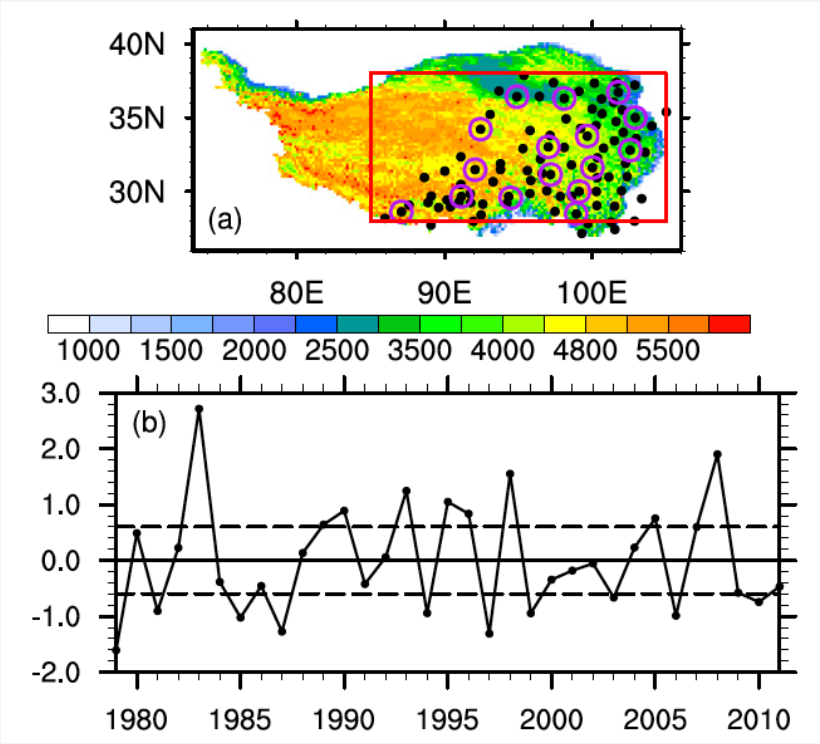


Dataset	Above normal	Below normal
Snow depth	1981/82 1982/83 1988/89 1995/96 1997/98 2007/08	1978/79 1980/81 1984/85 1996/97 1998/99 1999/00 2005/06 2009/10
Snow days	1982/83 1988/89 1989/90 1992/93 1994/95 1995/96 1997/98 2004/05 2007/08	1978/79 1980/81 1984/85 1986/87 1993/94 1996/97 1998/99 2002/03 2005/06 2009/10
CAREERI SD	1985/86 1989/90 1997/98 1999/00 2008/09	1981/82 1984/85 1987/88 1988/89 1993/94 1994/95 2000/01 2001/02 2003/04 2010/11
NSIDC SWE	1985/86 1997/98 1999/00 2004/05	1981/82 1984/85 1987/88 1992/93 1993/94 1994/95 2000/01 2001/02
NSIDC SC	1980/81 1982/83 1985/86 1988/89 1997/98 1999/00 2006/07 2007/08	1979/80 1981/82 1983/84 1984/85 1986/87 1991/92 1993/94 2000/01 2002/03 2005/06
Rutgers SC	1980/81 1982/83 1985/86 1997/98 1999/00 2004/05 2006/07 2007/08	1979/80 1981/82 1983/84 1984/85 1986/87 1991/992 1993/94 2000/01 2005/06 2008/09
N≥3	1982/83 1988/89 1997/98 2004/05 2007/08	1981/82 1984/85 1986/87 1993/94 2000/01 2005/06

High or low snow year appears at least in 3 datasets.

Possible approaches of TP snow in the previous winter on the ASM onset: the snow–albedo and snow–hydrology feedbacks

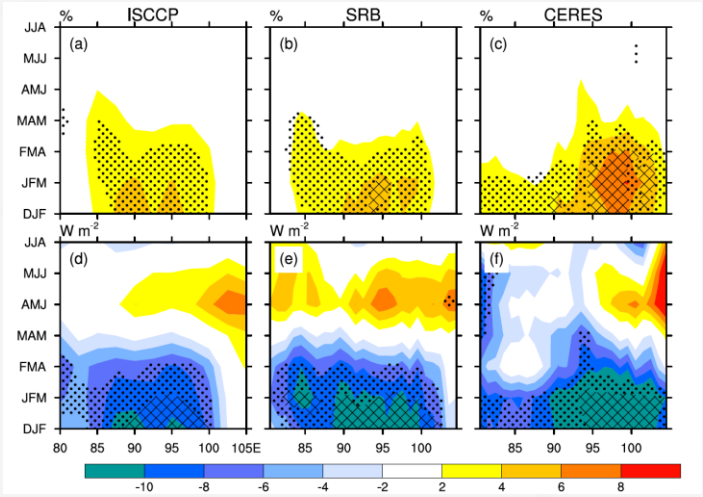
Number of snow cover days (NSCDs) in boreal winter



snow–albedo

Albedo

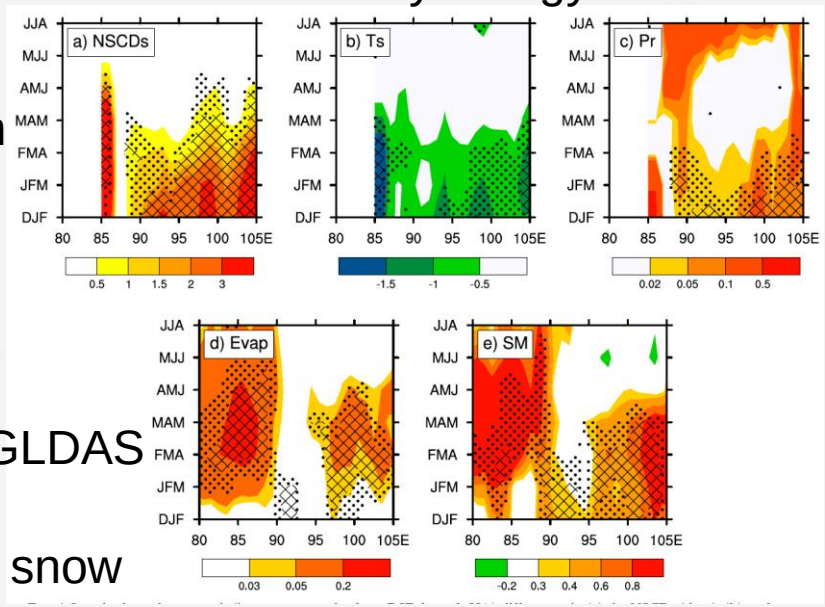
SW



snow–hydrology

Station

GLDAS



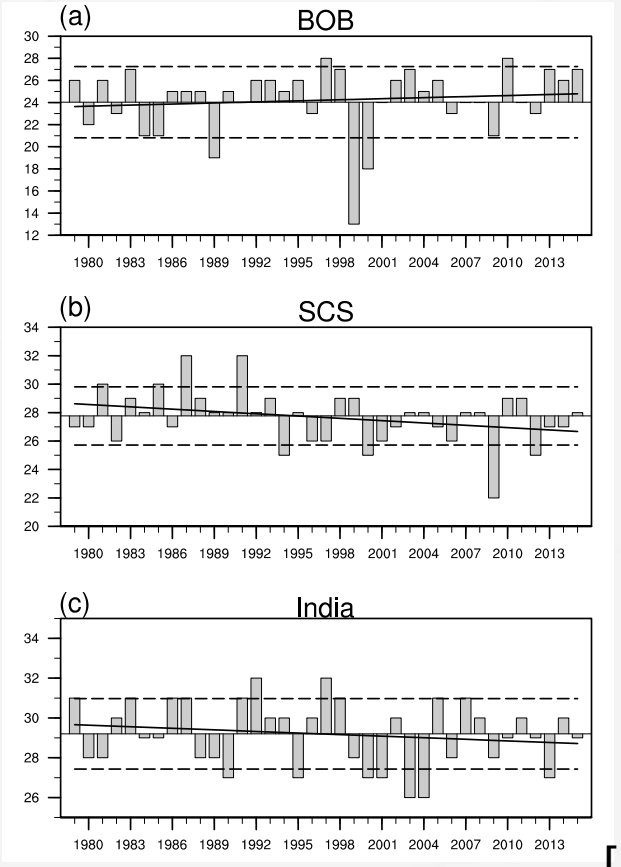
High snow – low snow

Cited from Xiao and Duan, 2016, JC

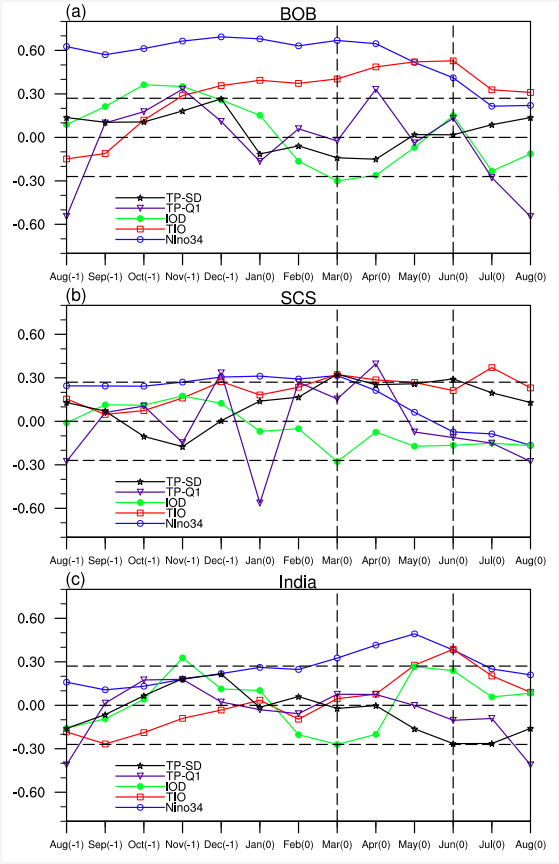
Unsolved issues

1. Seasonal evolution of TP snow from boreal winter to summer and its relationship with the formation of TP heating source.
2. Modulation of TP snow on the ASM onset time on the interannual timescale, as well as its collaboration with the tropical oceanic influences.

ASM onset dates



Multi factors influencing the ASM onset



[JRA55 dataset]

Thanks for your time,
and welcome comments.