Multidecadal variability of North China aridity and its relationship to PDO during 1900-2010

Cheng Qian, Tianjun Zhou

Institute of Atmospheric Physics,
Chinese Academy of Sciences,
Beijing, China

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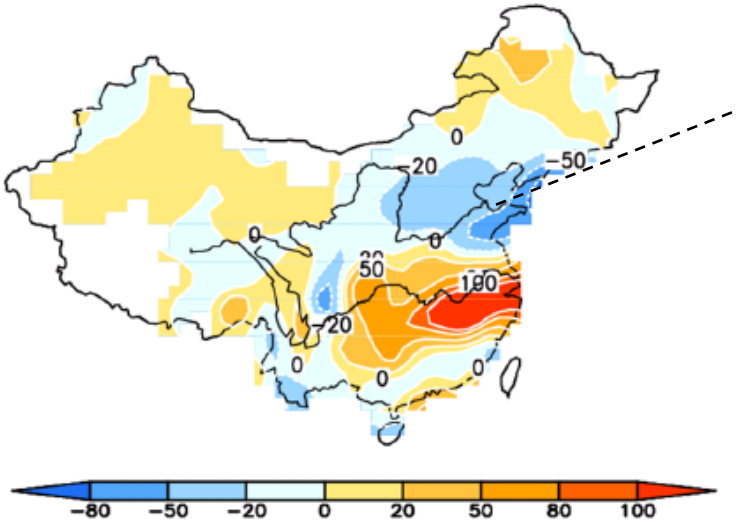
Background

North China is one of the main industrial and agricultural production bases in China; however, this area has been facing a severe drying trend in the second half of 20th century.

- Increasing drought in N. China
- Excessive rainfall in central China along the Yangtze River valley



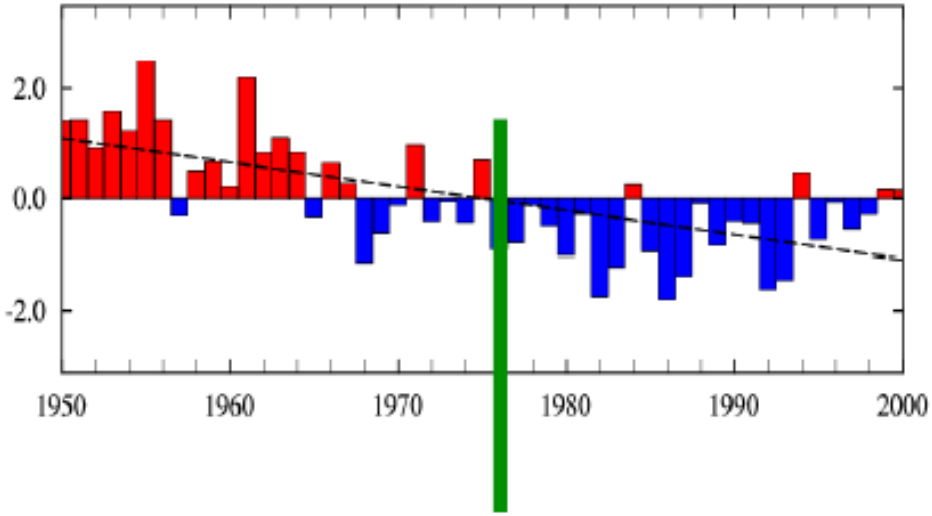
Trend of JJA rainfall in 1950-2000

the South-to-North Water Diversion Project to alleviate the water shortage problem in NC

Background

Previous studies have focused mainly on decadal-to-interdecadal timescale drought in North China since the 1950s (Hu et al. 2003; Gong et al. 2004; Dai et al. 2005; Yang et al. 2005; Ju et al. 2006; Ma 2007; Li et al. 2010), a period associated with a weakening of East Asian summer monsoon circulation leading to southern flooding and northern drought phenomenon.

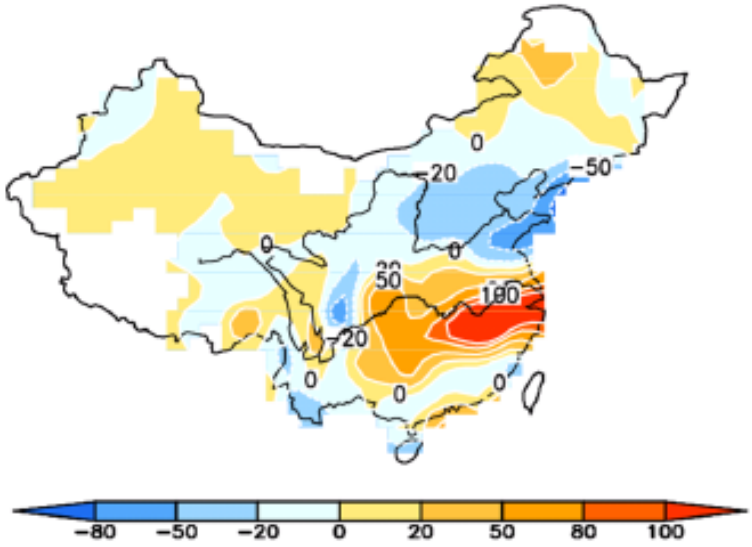
E. Asian Summer Monsoon Index



EASM experienced an interdecadal shift in late 1970s.

southern flooding and northern drought

- Increasing drought in N. China
- Excessive rainfall in central China along the Yangtze River valley



Trend of JJA rainfall in 1950-2000

Why “southern flooding - northern drought” ?

➢Natural variability

A phase transition of PDO (Yang et al. 2005; Ma 2007; Li et al. 2010) or recent warming of the tropical Pacific and Indian Oceans (Hu 1997; Chang et al. 2000; Yang 65 and Lau 2004; Zhou et al. 2006; Zhou et al. 2009b; Li et al. 2010).

➢Human activities

- increased aerosols from pollution (e.g.,Menon et al. 2002)
- human-induced land cover changes (e.g., Fu 2003).

Up to now:

no consensus has been reached thus far (Zhou et al. 2009) due to the short data length (1950-present)

Only a limited number of studies in China have extended analysis based on instrumental data to the entire 20th century

e.g. Ma and Shao (2006): statistical analysis of humidity index (1901-2002)
e.g. Zhang and Zhou (2011): statistical analysis of changes in global land monsoon precipitation during 1901-2002

- physical mechanisms?
- the role of multi-decadal climate variability in periods of 60–80 years (Schlesinger and Ramankutty 1994; Wu et al. 2011) or 50–70 years (Minobe 1997,1999) in dry–wet evolution in N. China?

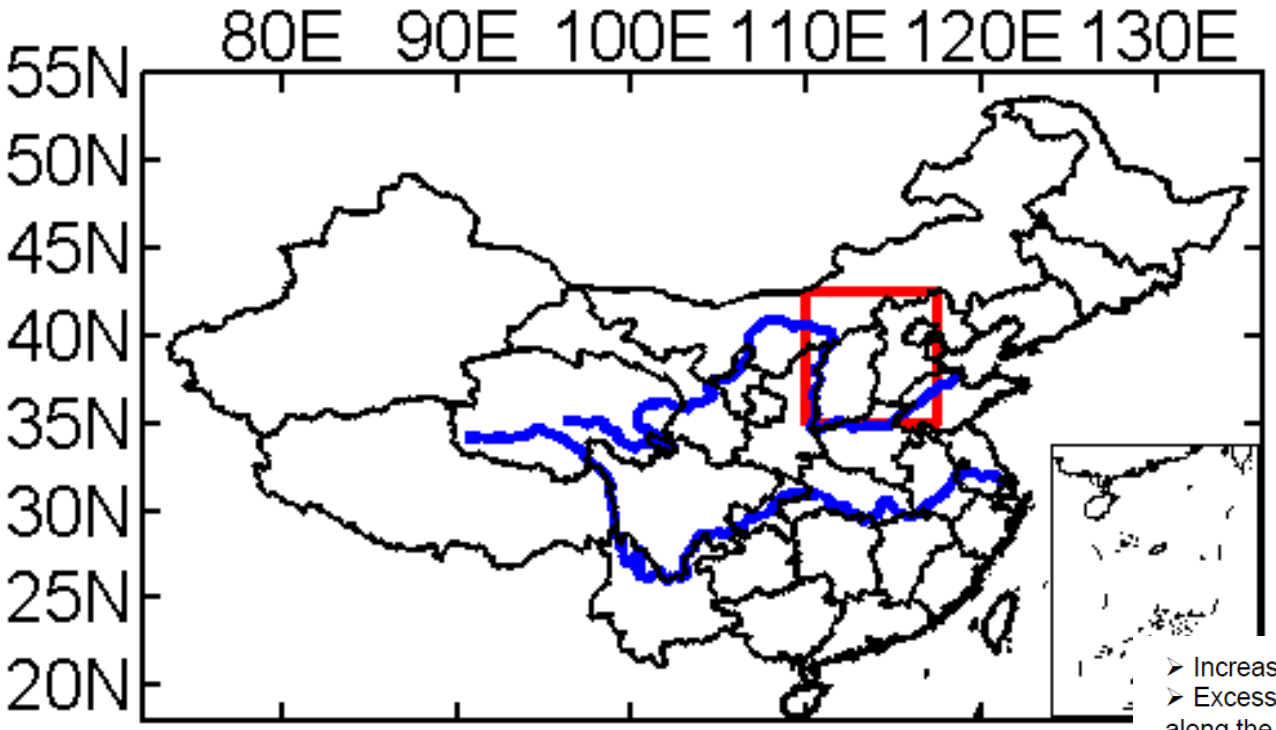
Aim of this study

to examine the evolution of dryness–wetness in North China during 1900–2010 and to investigate its relationship with PDO phase transition at the multi-decadal time scale.

Data

- Self-calibrated PDSI 1900－2010 (Dai et al. 2011)
- PDO index 1900－2010 (Mantua et al. 1997)
- Land Precipitation
  - Dai et al. 2011 (2.5x2.5) 1900-2010
  - GHCN v2 (5x5) 1900-2010
  - GPCC v6 (0.5x0.5) 1901- 2010 (Schneider et al. 2011)
  - CRU TS3.10.01 (0.5x0.5) 1901-2009 (Harris et al. 2013)
- Land T: **CRUTEM3** (Brohan et al. 2006) **CRU TS3.10** (Harris et al. 2013)
- 20th century Reanalysis (Compo et al. 2011)
- SST: HadISST (Rayner et al., 2003)

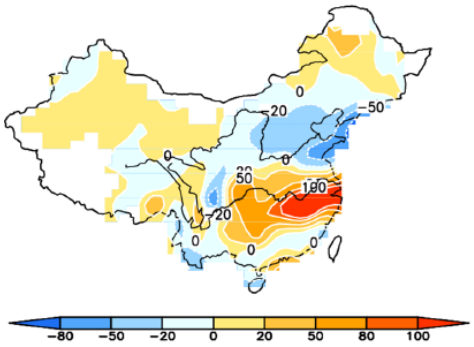
Research domain



(35~42.5°N，110~117.5°E)

An area underwent severe drying trend in the second half of 20th century.

- Increasing drought in N. China
- Excessive rainfall in central China along the Yangtze River valley

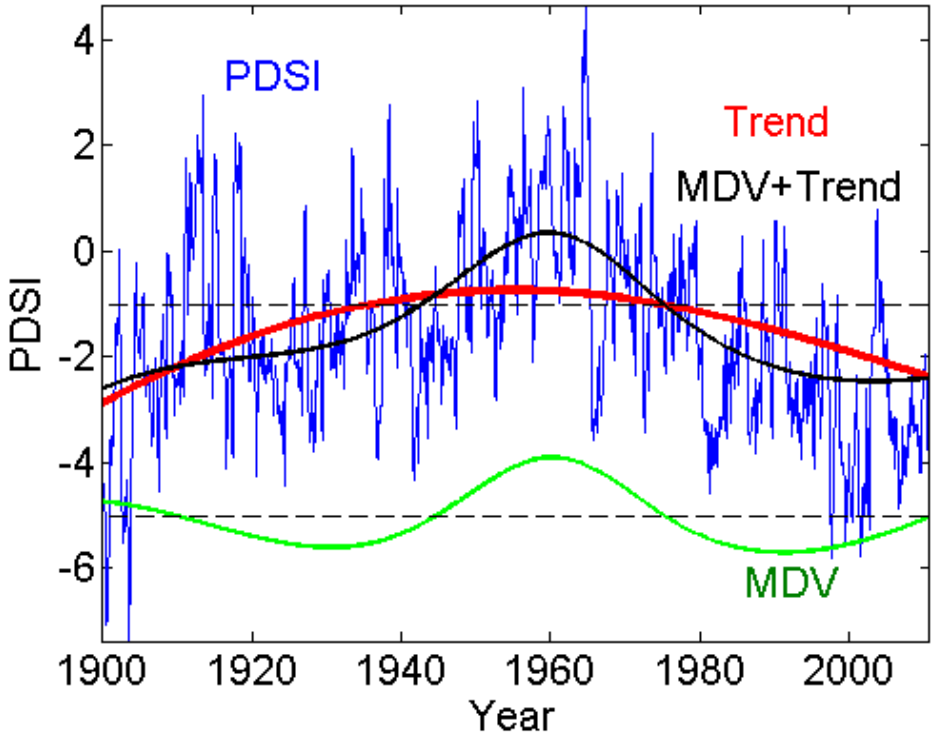


Trend of JJA rainfall in 1950-2000

Multidecadal variability and trend in drought-wet conditions of North China during 1900-2010

Classes for wet and dry periods based on PDSI value (Palmer 1965)

value	classes	value	classes
≥ 4.00	extremely wet	−1.00~−1.99	mild drought
3.00~3.99	very wet	−2.00~−2.99	moderate drought
2.00~2.99	moderately wet	−3.00~−3.99	severe drought
1.00~1.99	slightly wet	≤ − 4.00	extreme drought
0.99~−0.99	Normal		

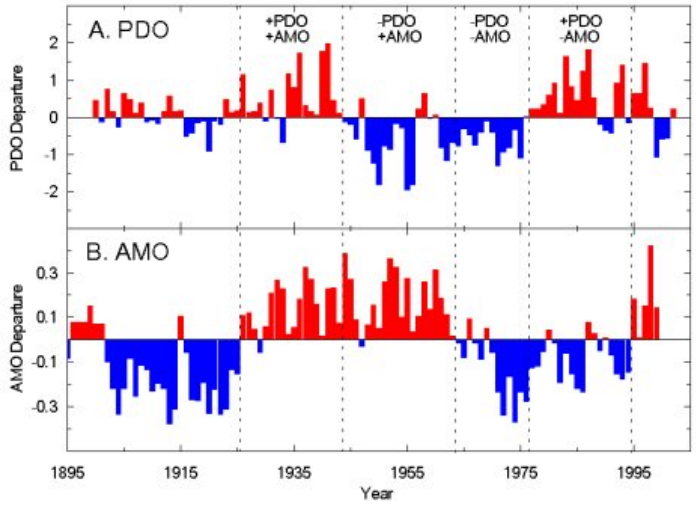


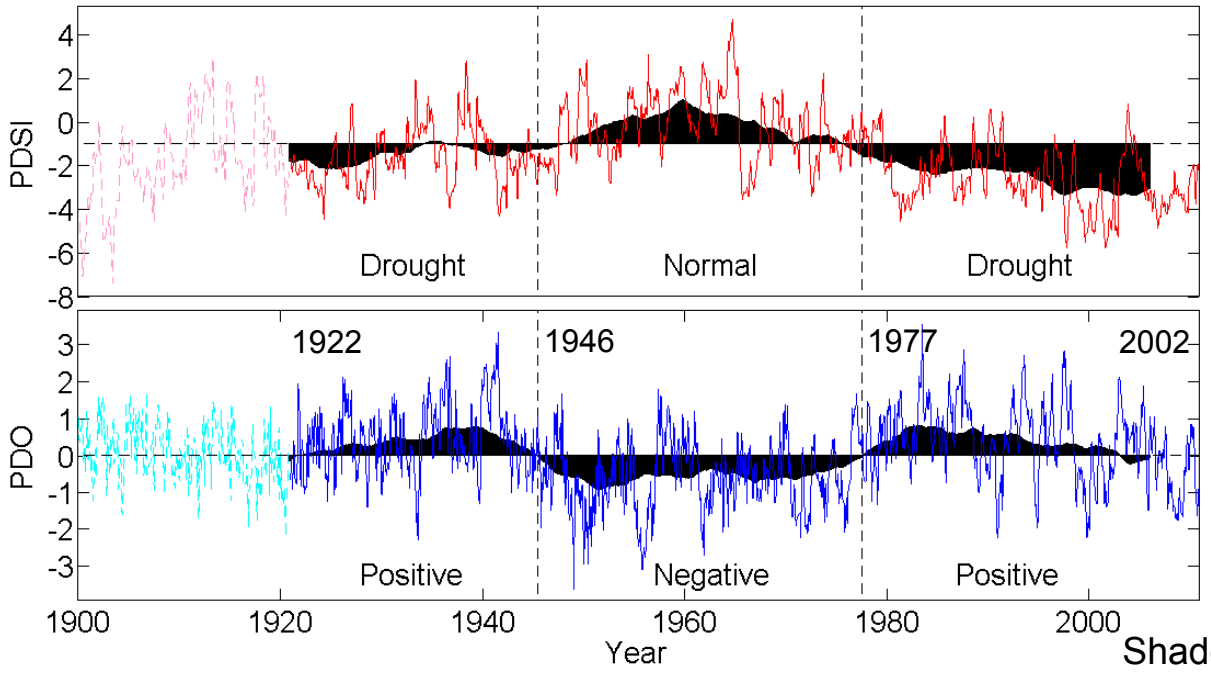
1900-1959: wetting
1960-2010: drying

1960-1990's drying: about 70% from MDV

50-70 yr (~56)

Drought-wet conditions in North China & PDO

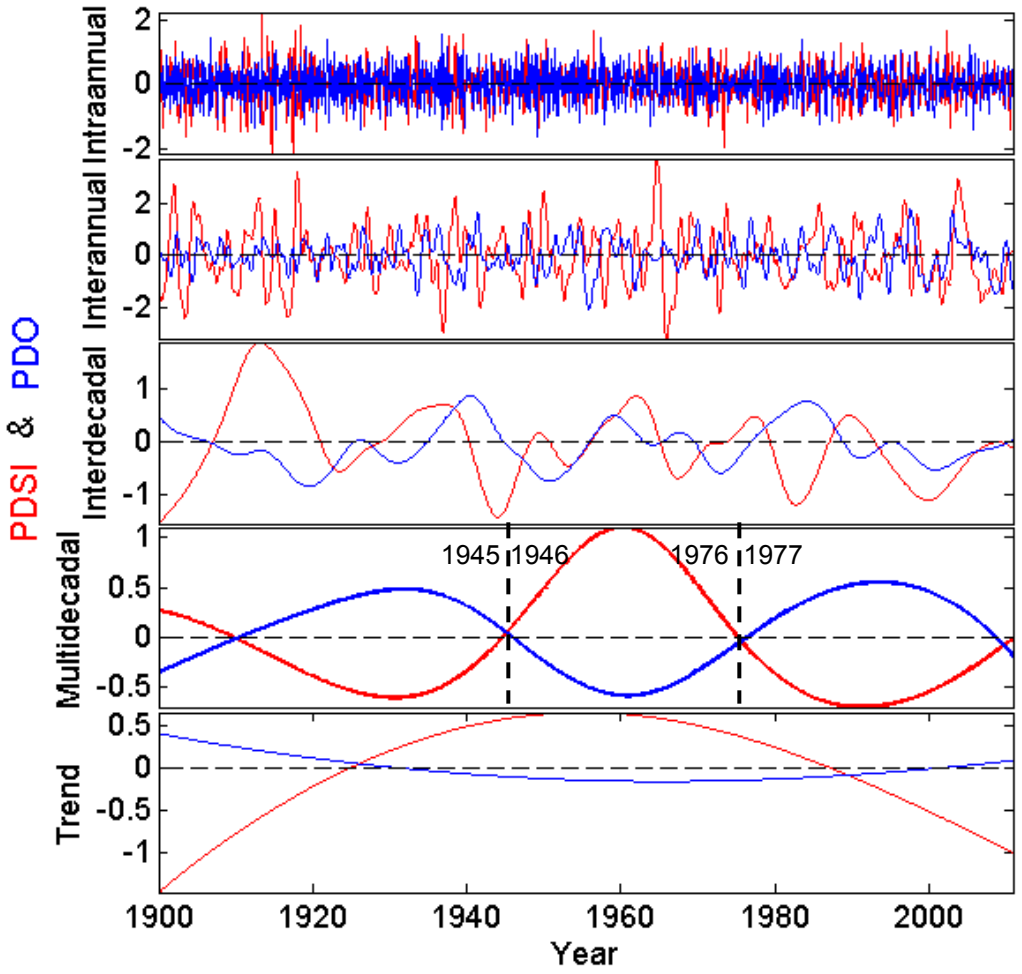




Shaded: 11-yr running mean

Negatively correlated with PDO, but phase mismatch with AMO

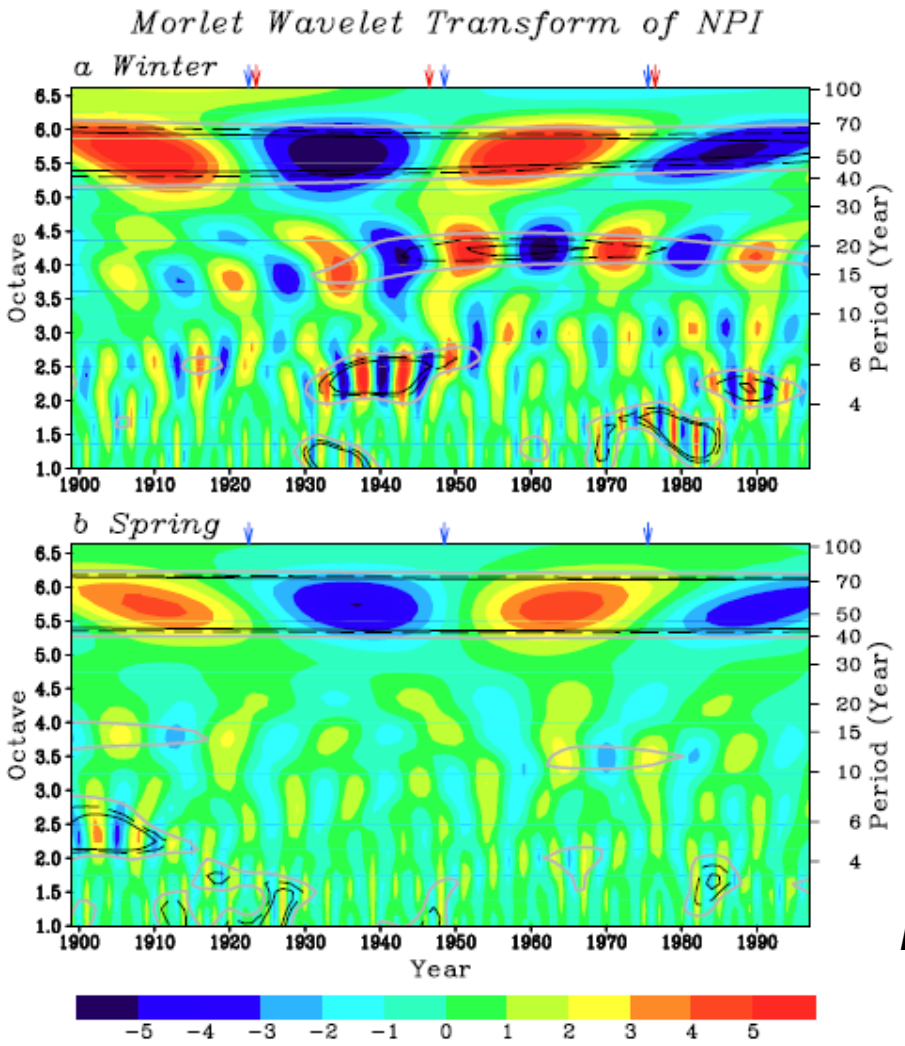
Multi-timescale analysis of NC-PDSI and PDO by EEMD



50-70-yr (~56)

Variance contribution of 50-70-yr variability: PDSI (13.1%); PDO (16%)

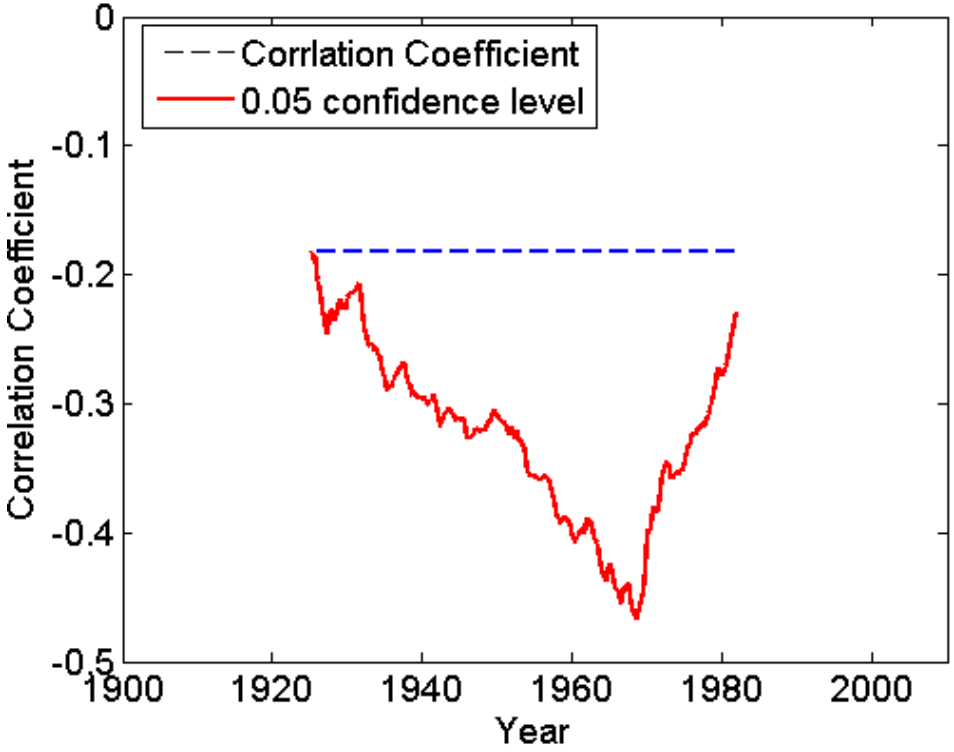
50-70-yr multi-decadal variability in North Pacific



The NPI is defined as the area-averaged Sea Level Pressure (SLP) anomaly in the region 160°E−140°W, 30−65°N.

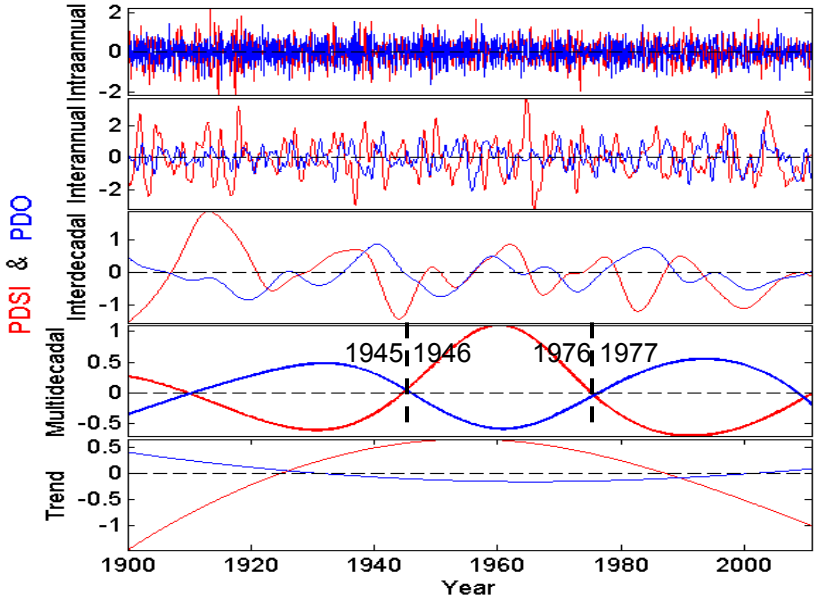
Stability of the relationship between NC-PDSI and PDO at multi-decadal scale

55-yr (660 months) running correlation



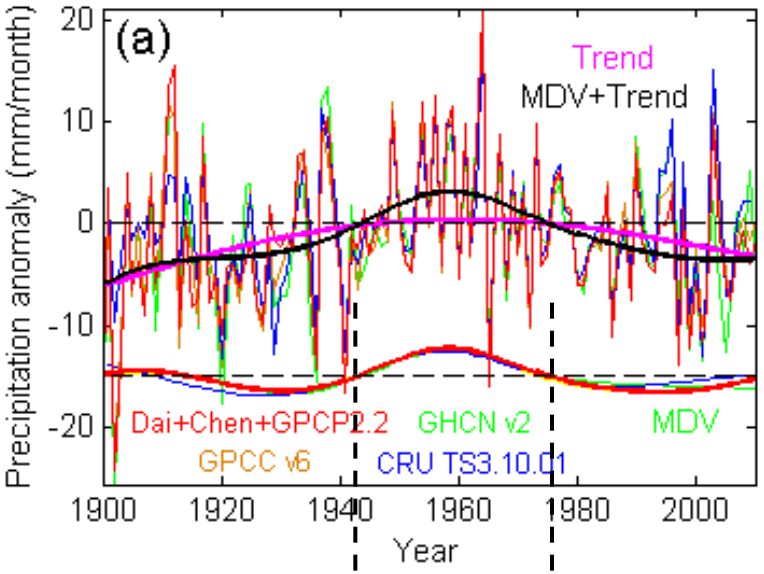
EDOF: 117

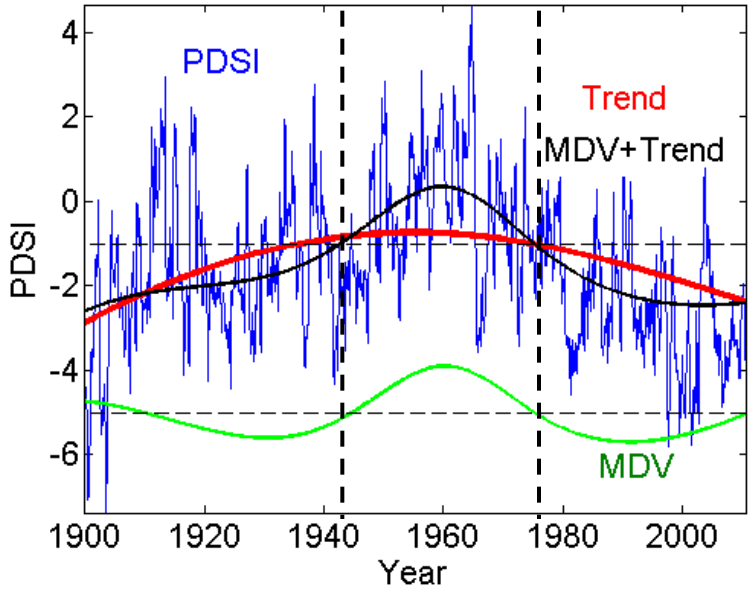
The inverse relationship is stable



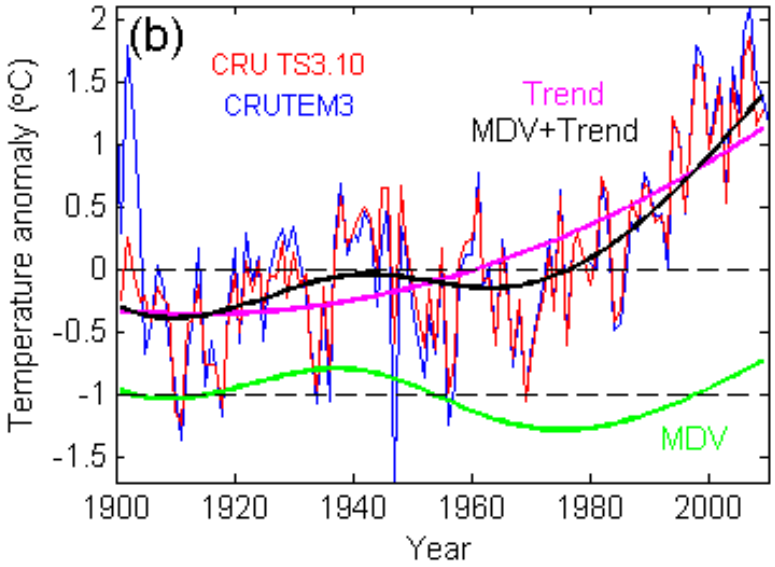
Role of precipitation and temperature

Annual Precipitation





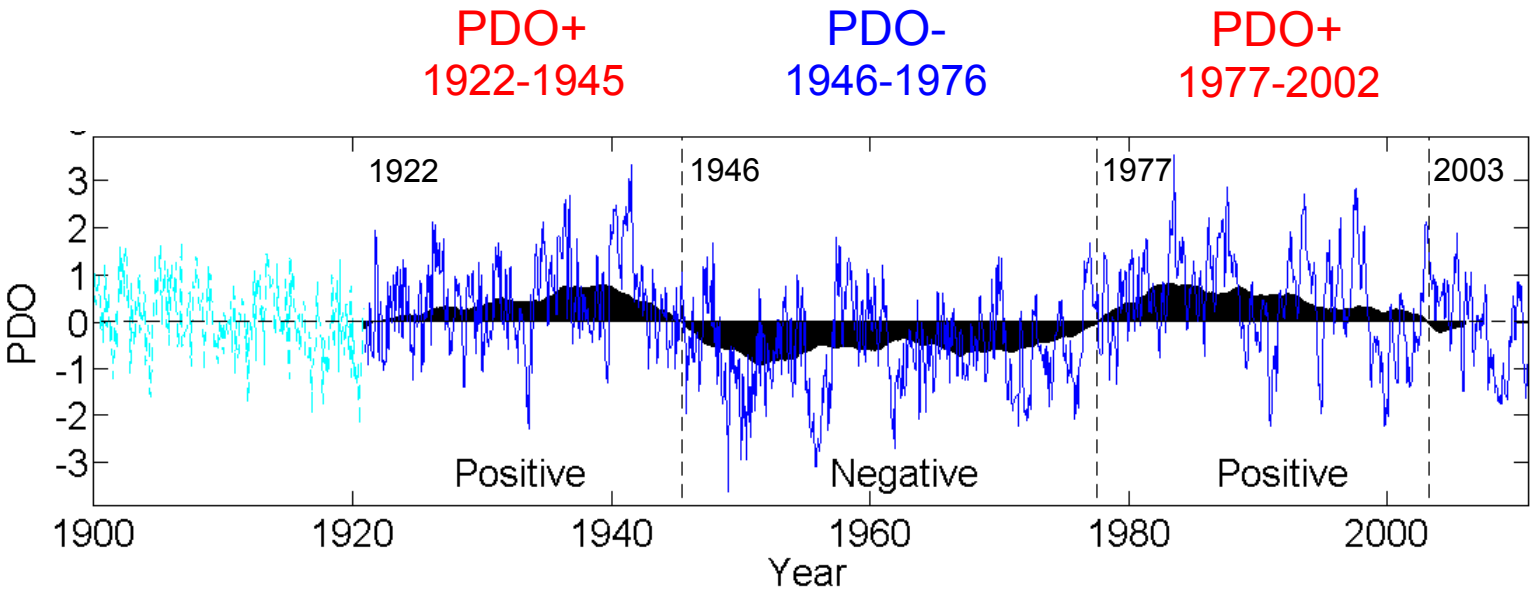
Annual Temperature



the MDV in NC-PDSI is dominated by precipitation

2/3 annual precipitation is from JJA

PDO phase


PDO+
1922-1945
PDO-
1946-1976
PDO+
1977-2002
1922
1946
1977
2003
Positive
Negative
Positive
PDO
3
2
1
0
-1
-2
-3
1900
1920
1940
1960
1980
2000
Year

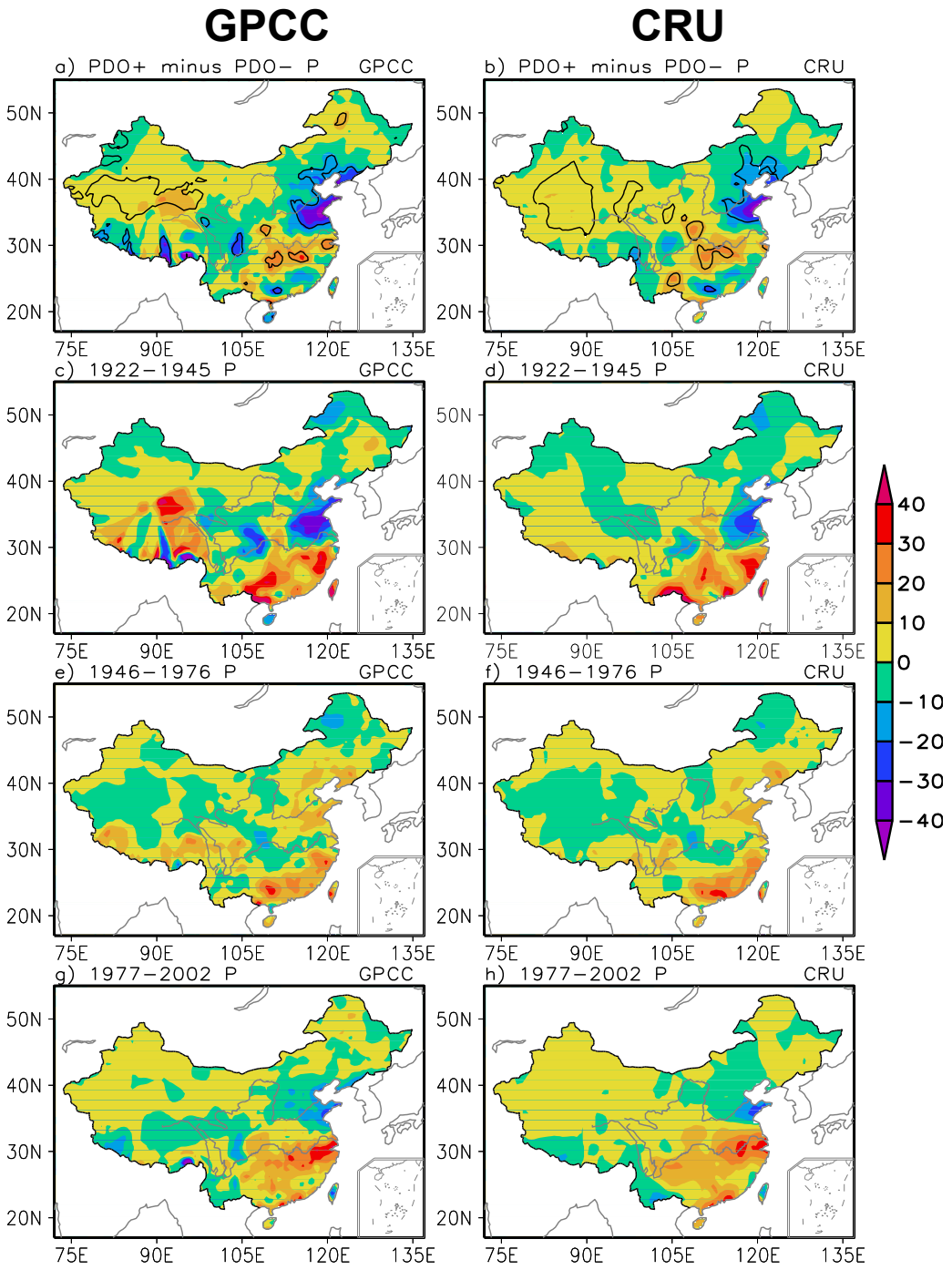
JJA precipitation

PDO+ minus PDO-
North China drought

PDO+ (1922-1945)
North China drought

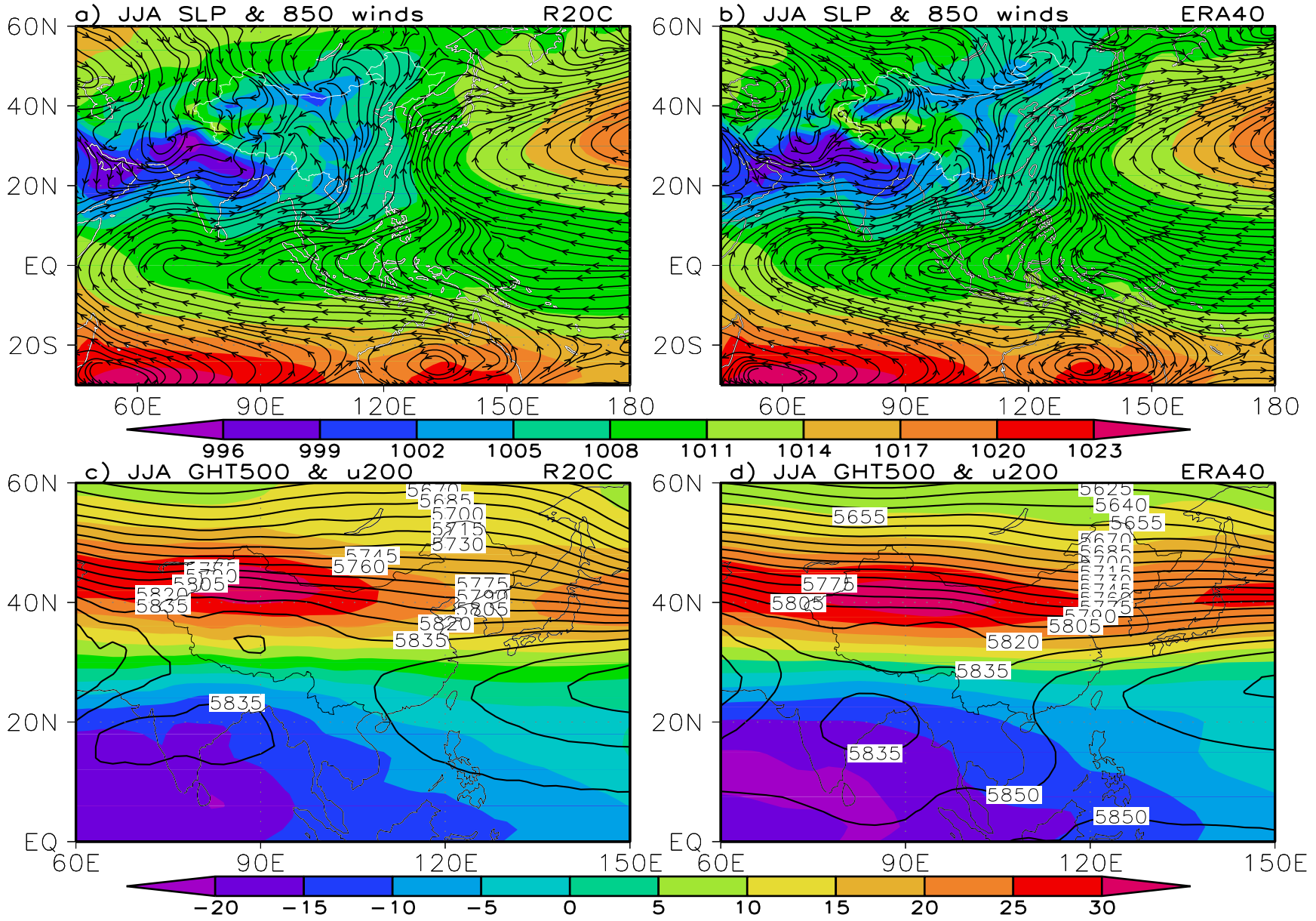
PDO- (1946-1976)
North China wet

PDO+ (1977-2002)
North China drought



1961-1990 JJA climatology

20CR v2 V.S. ERA-40

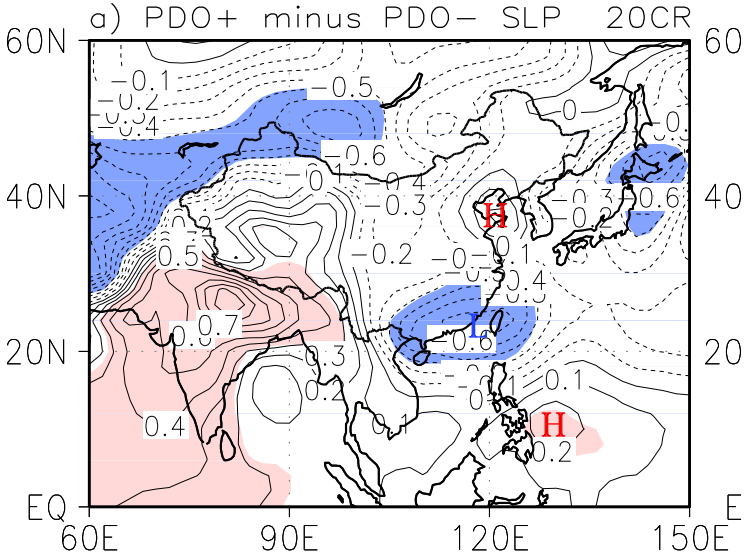


PDO+ (1922-1945 & 1977-2002) minus PDO- (1946-1976) 20CR v2

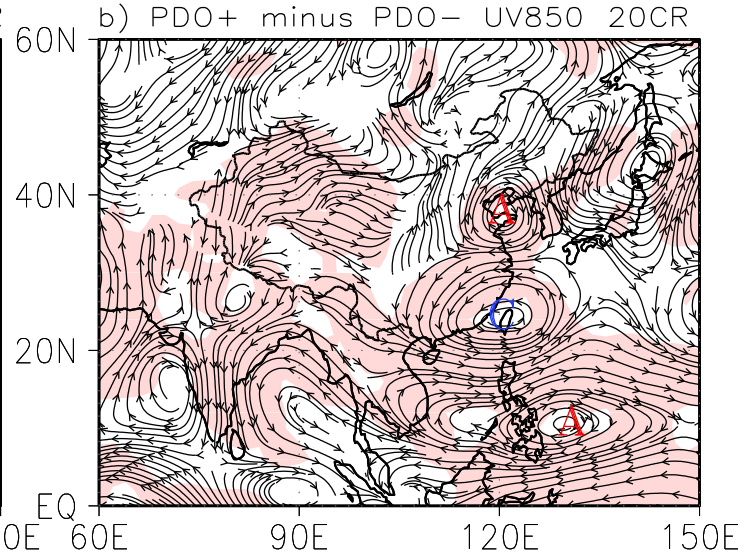
PDO modulates NC-PDSI by

Way 1: PJ / EAP pattern-like wave train
Way 2: Land-sea thermal contrast

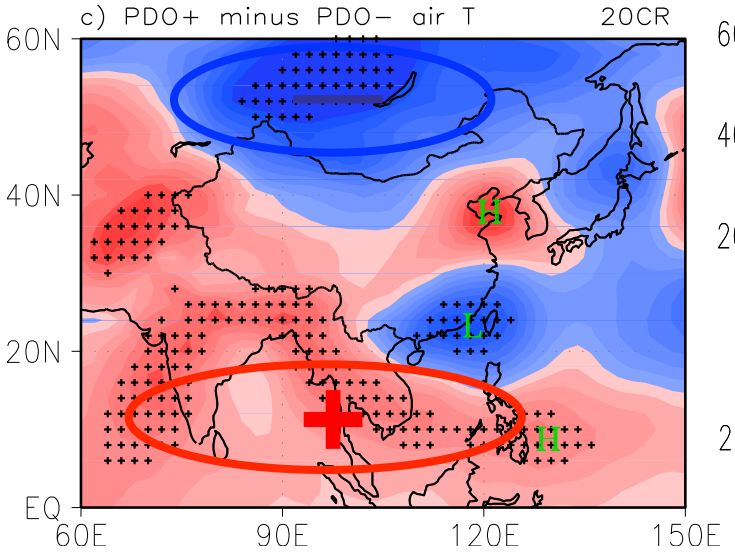
JJA SLP



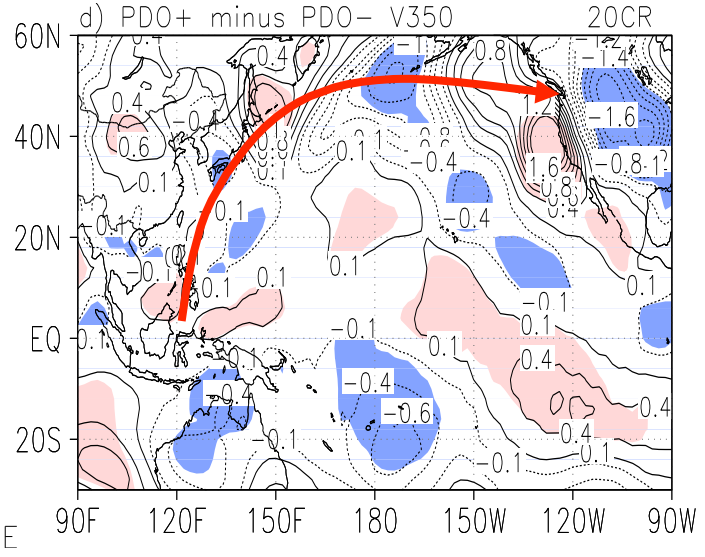
JJA 850 hPa winds



JJA 1000-500 hPa air T

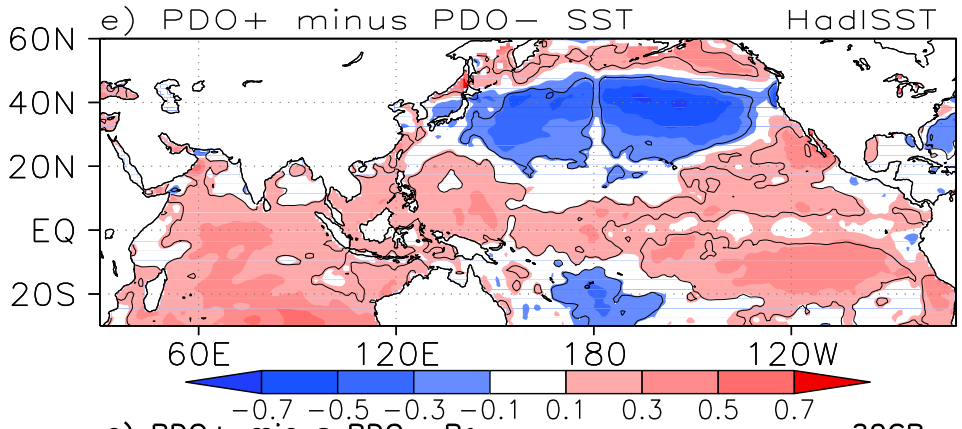


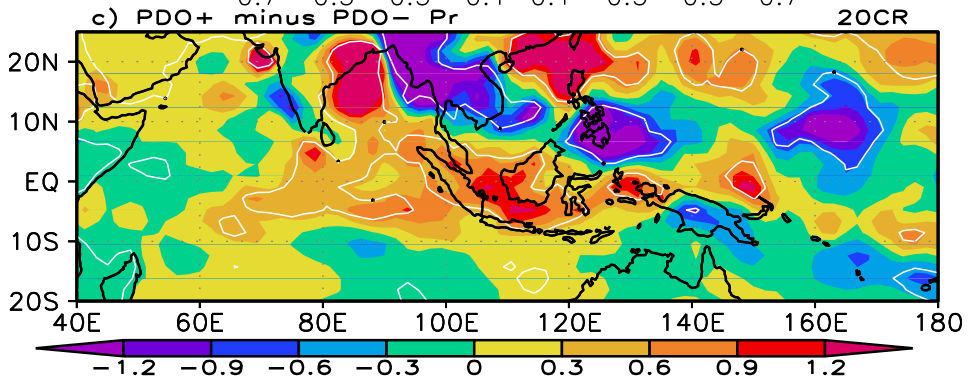
JJA V350



PDO+ (1922-1945 & 1977-2002)
minus PDO- (1946-1976)

JJA SST & 20CR Precipitation





Wave train propagation

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Local Hadley circulation

deficit precipitation and anticylone near Phillipines

I Warm West Pacific SSTA

②

II Warm Indian Ocean SSTA

①

convection and Kelvin wave response

#Jin and Hoskins 1995; Hu and Huang 2009

②Hu 1997

①Yang et al .2007GRL, Li et al. 2008JC, Xie et al. 2009JC, Wu et al. 2009JC

*Huang and Sun 1992

PDO+ (1922-1945 & 1977-2002) minus PDO- (1946-1976) 20CR v2

PDO modulates NC-PDSI by

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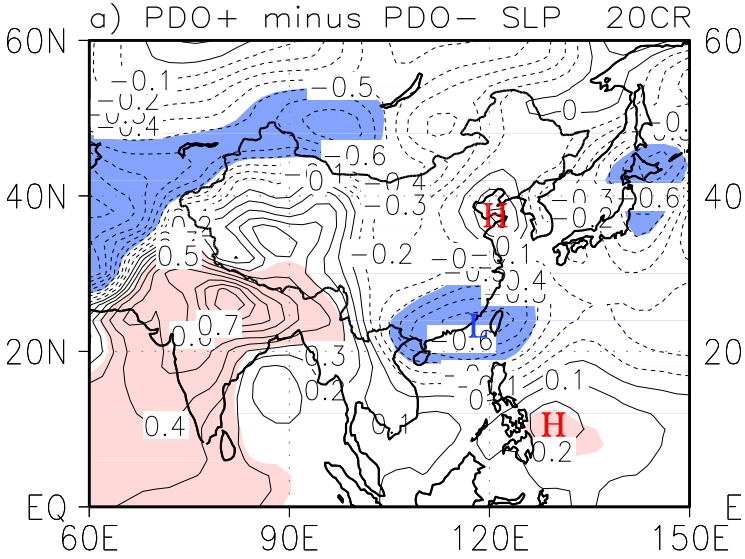
Way 2: Land-sea thermal contrast

JJA SLP



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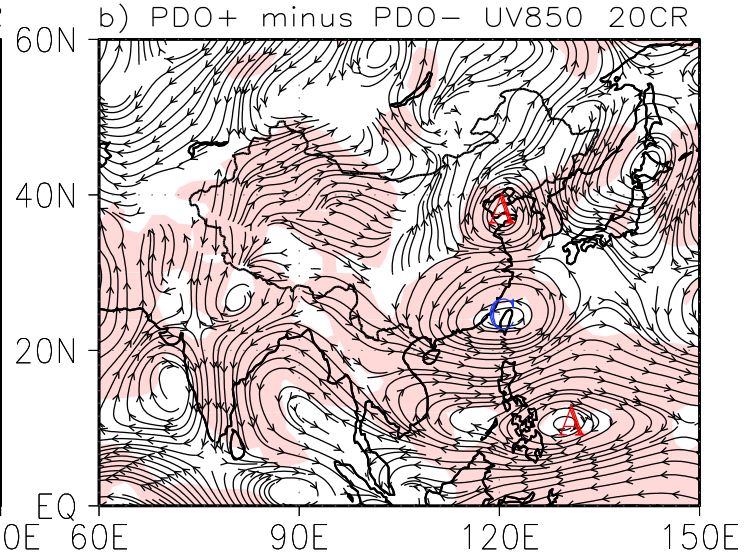
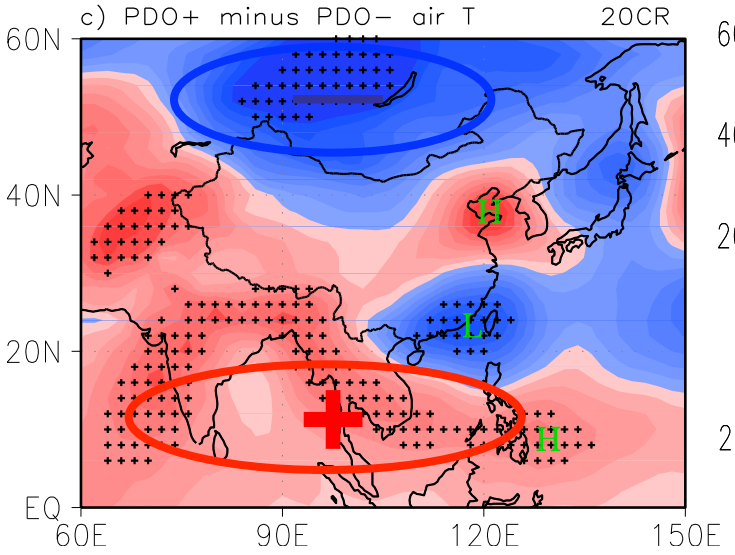
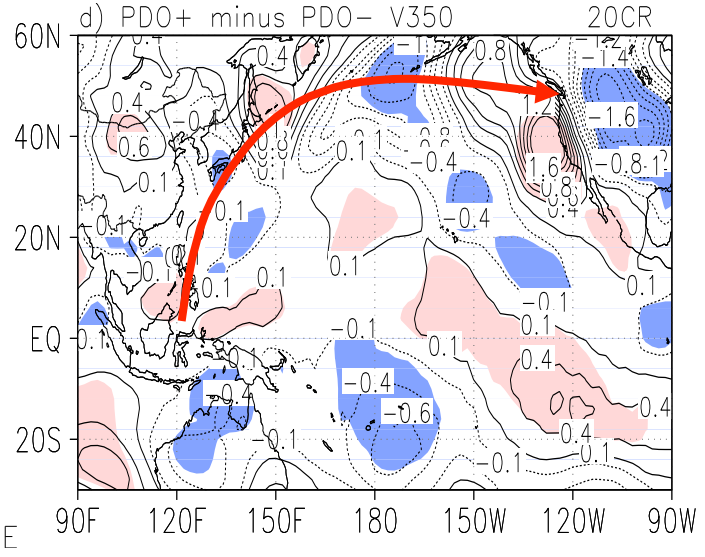


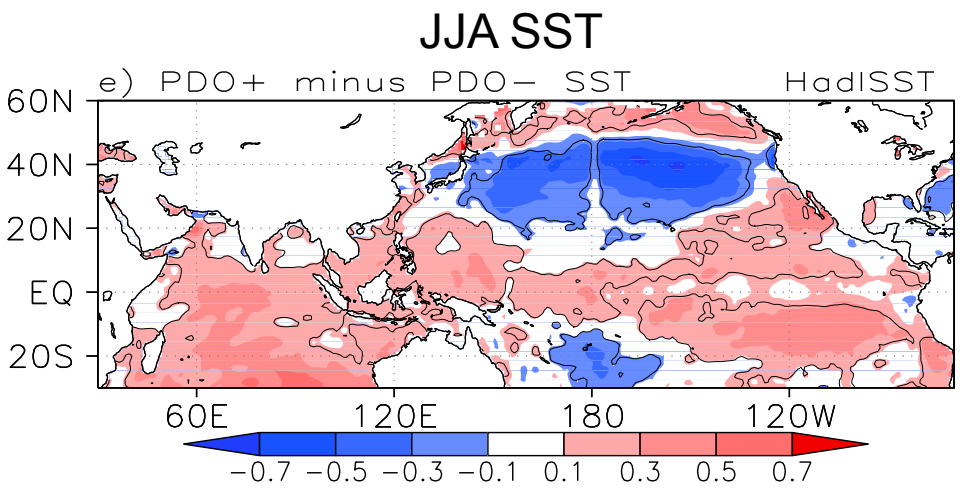
JJA 1000-500 hPa air T

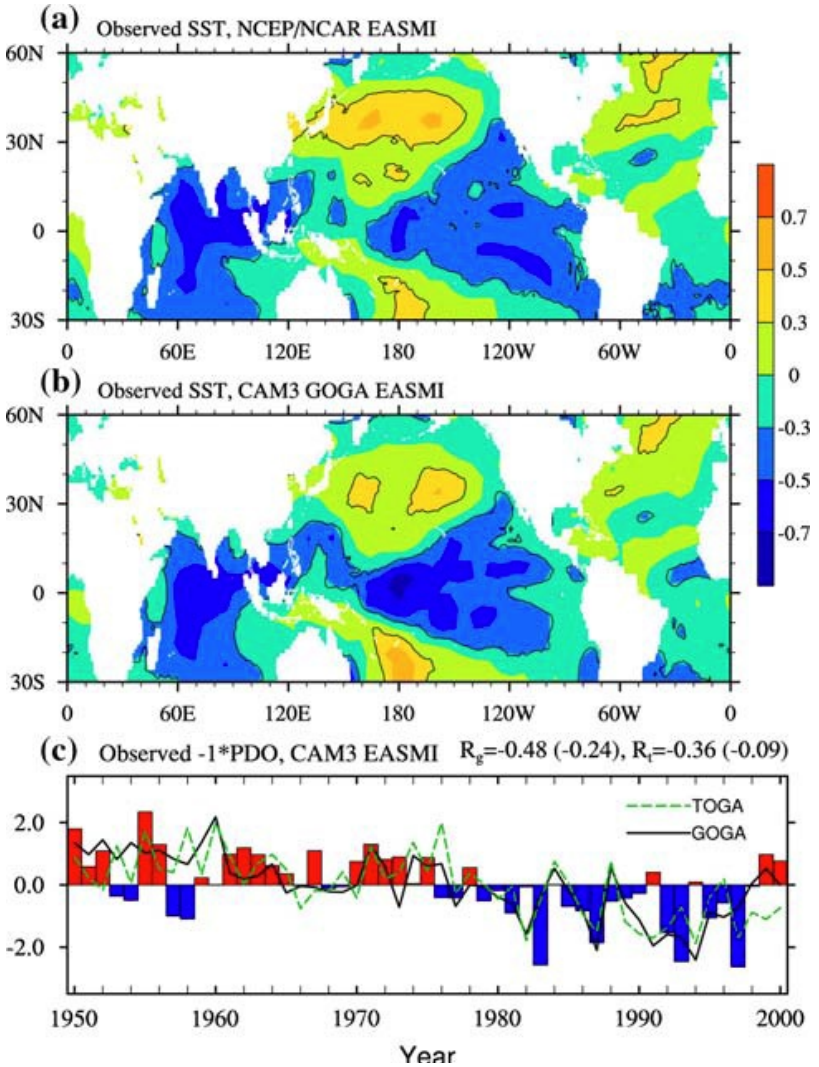


JJA V350



PDO+ (1922-1945 & 1977-2002)
minus PDO- (1946-1976)





Li, Dai, Zhou, 2010 Clim. Dyn.

Summary

- A transition from significant wetting to significant drying is detected around 1959/60. Approximately 70% of the drying trend during 1960–1990 originates from 50–70-yr multi-decadal variability related to Pacific decadal oscillation (PDO) phase changes.

- The PDSI in North China is statistically negatively correlated with the PDO index, particularly at the 50–70-yr timescale, and is also stable during 1900-2010. This result is a useful implication for 10–30 year decadal prediction.

- PDO modulates JJA precipitation in North China by:

- Way 1: affecting an anomalous Pacific–Japan/East Asian–Pacific pattern-like teleconnection, which may develop locally in response to the PDO-associated warm sea surface temperature anomalies in the tropical Indo–Pacific Ocean. North China is dominated by an anomalous high pressure system at mid–low levels and an anticyclone at 850 hPa, which are favorable for dry conditions.
- Way 2: affecting the land–sea thermal contrast.

Thank you for your attention !

E-mail: qianch@tea.ac.cn

Qian, C., and T. Zhou, 2013: Multidecadal variability of North China aridity and its relationship to PDO during 1900-2010. J. Climate. doi:10.1175/JCLI-D-13-00235.1, in press.

Comments and suggestions please