The possible climatic causes of 2018 extreme heat event in South Korea

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IBS Center
for Climate Physics

Recent trend in heat waves over east Asia and their potential causes

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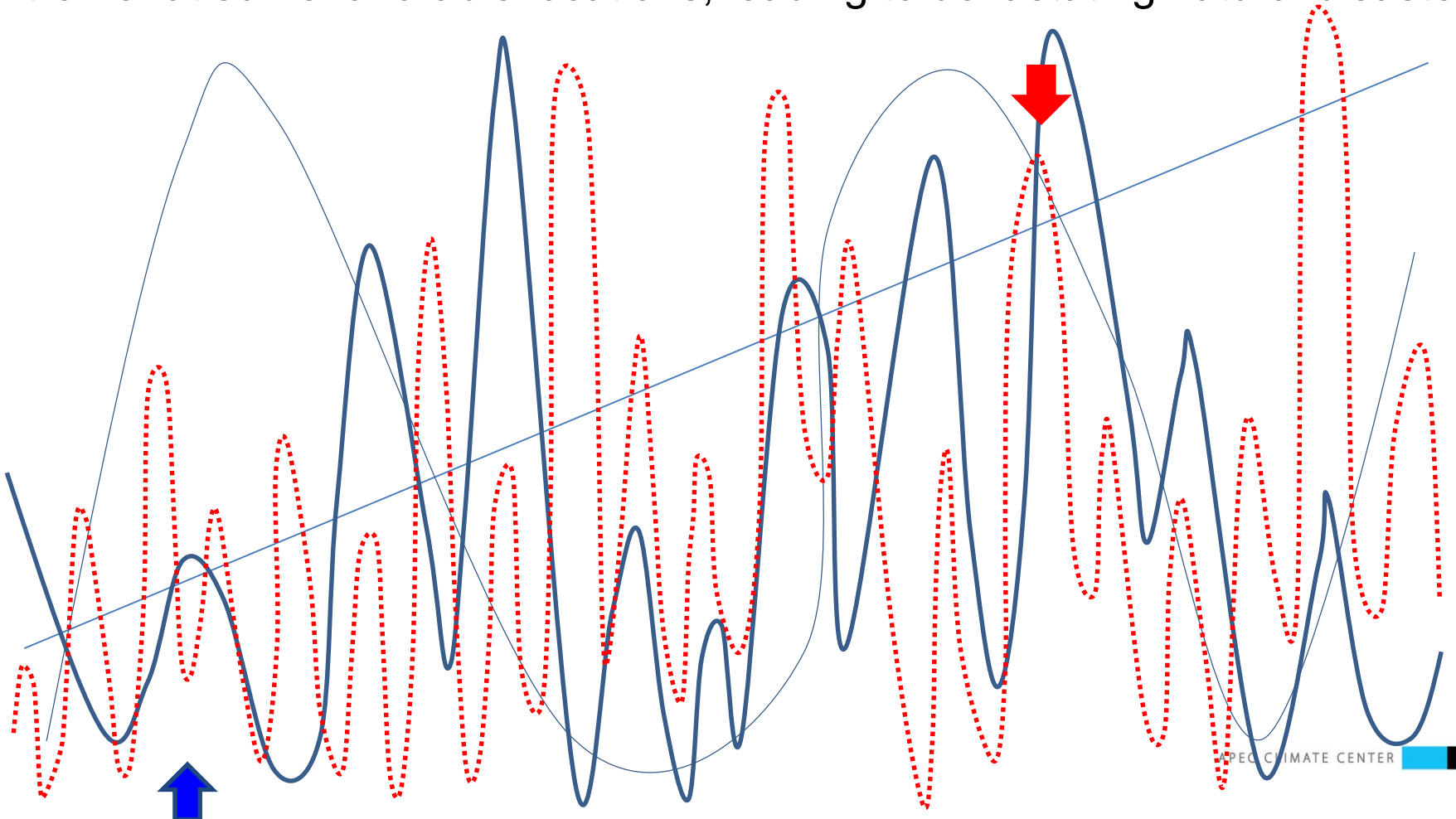
Oct. 30, 2018

Motivation: Extreme events ?

Phase locking of weather and climate or several climate events can become “extreme” at some favorable locations, leading to devastating natural disaster



Motivation: 2018 Hottest summer ?

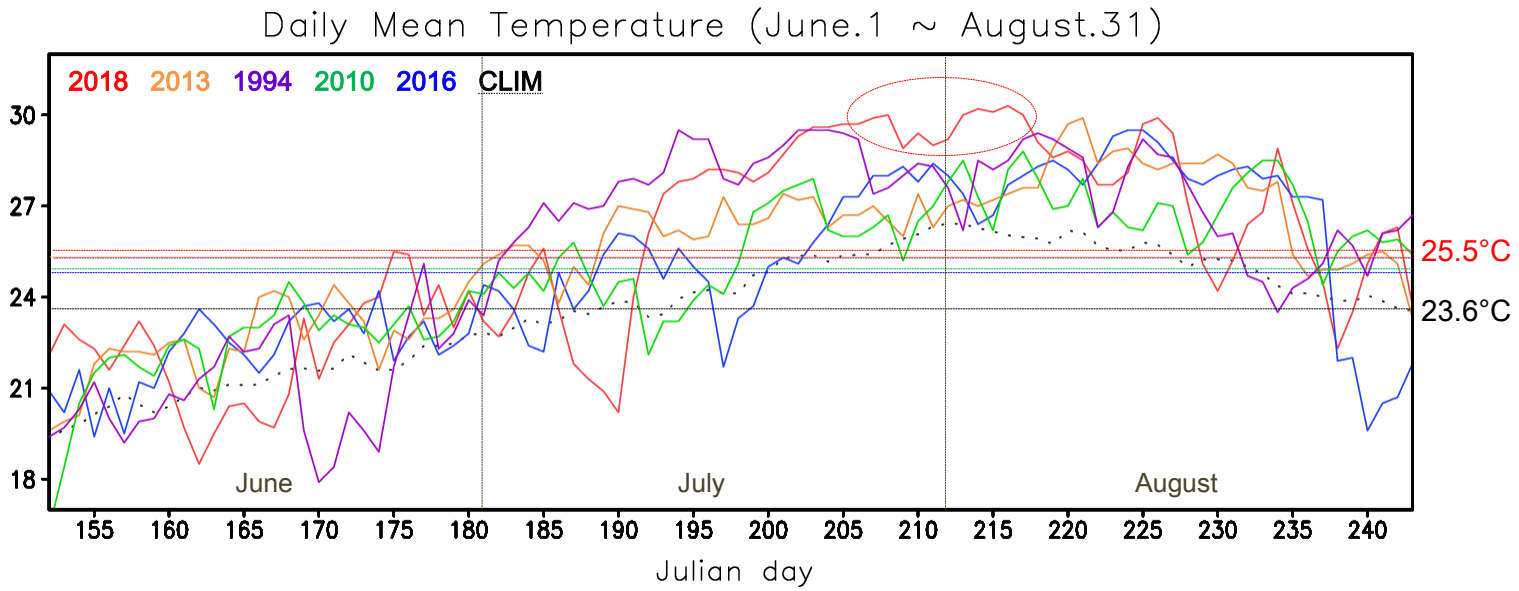
- During 1973~2018 (46 yr),

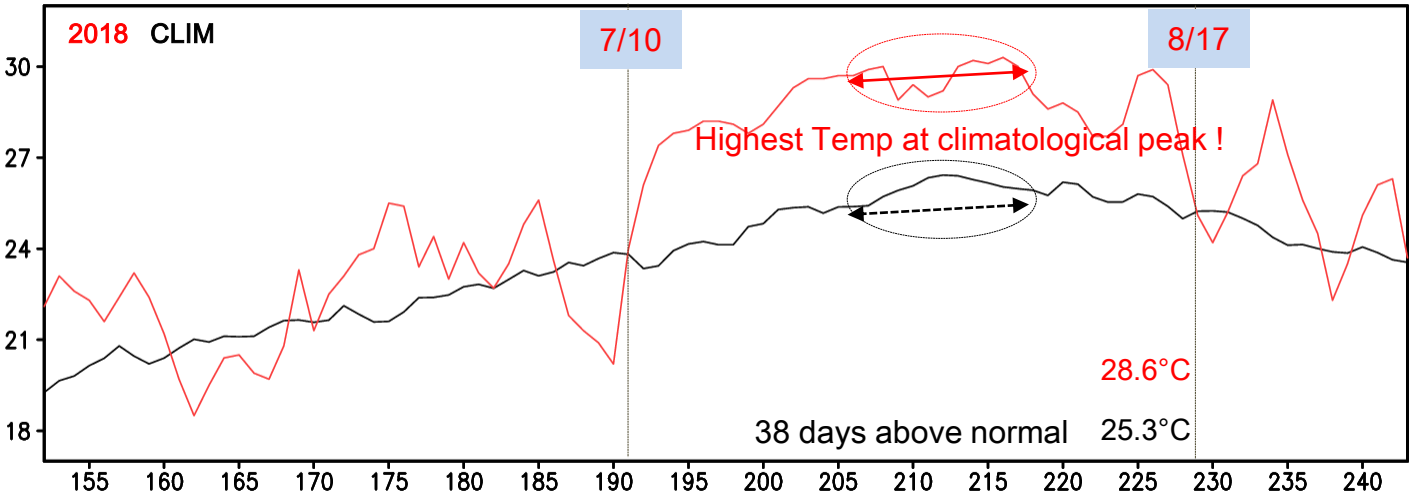
June 5th + July 2nd (1st 1994) + August 1st = JJA 1st Why?

- Data
  1. ERA Interim 1979 to 2018 (1.5x1.5, daily)
     First three harmonics, ENSO variability removed
     5-day moving avg.
  2. Surface air Temp (ave, max, min) and rainfall from KMA
  3. MODIS satellite evapotranspiration (8-day, monthly mean)

Motivation : Extreme hot summer in 2018

- 45 stations (South Korea)





2018 Hottest summer ?

- During 1973~2018 (46 yr),

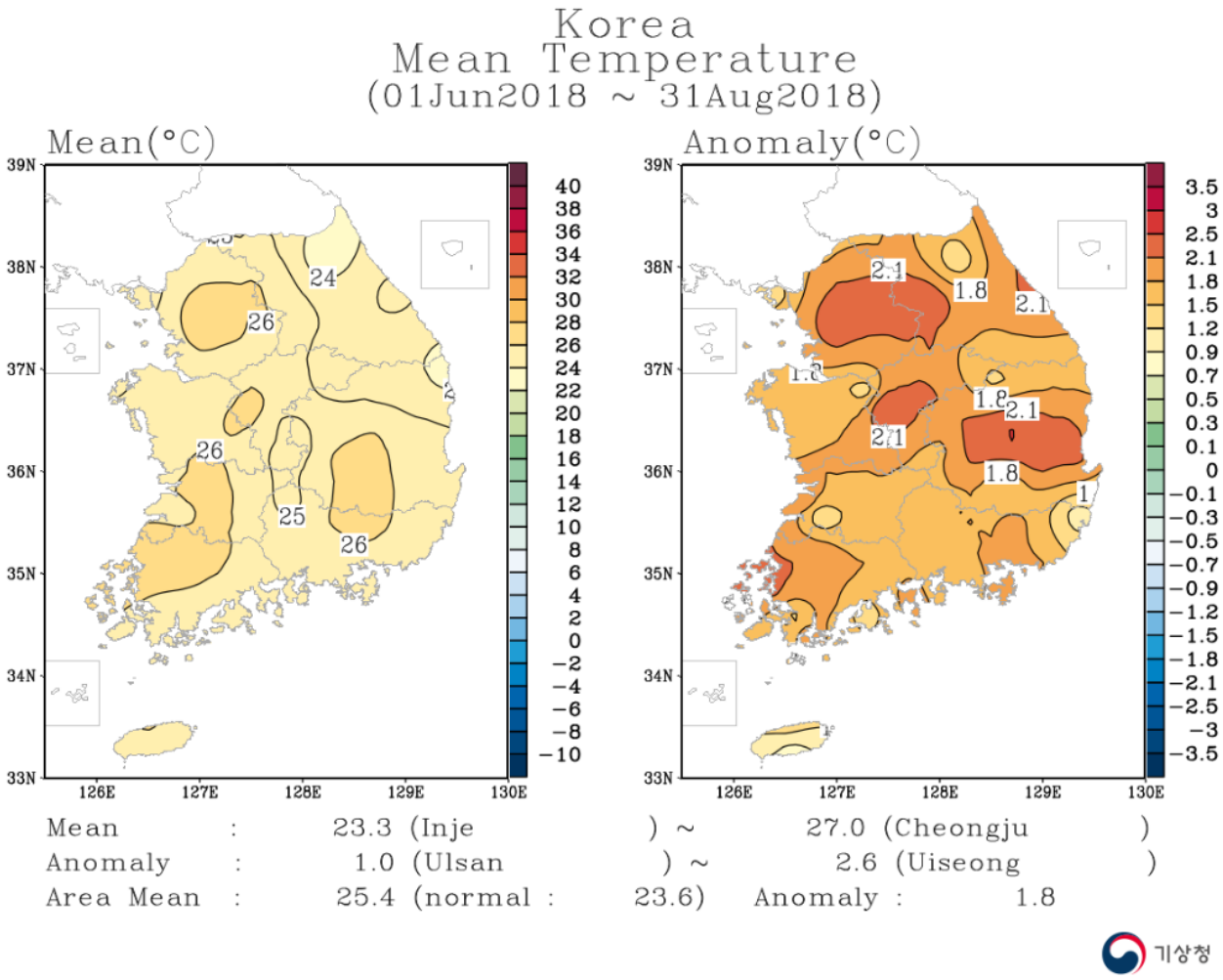
June 5th + July 2nd (1st 1994) + August 1st = JJA 1st Why?

Because,

Extreme high temp at the climatological peak !

- Mid July to Mid August

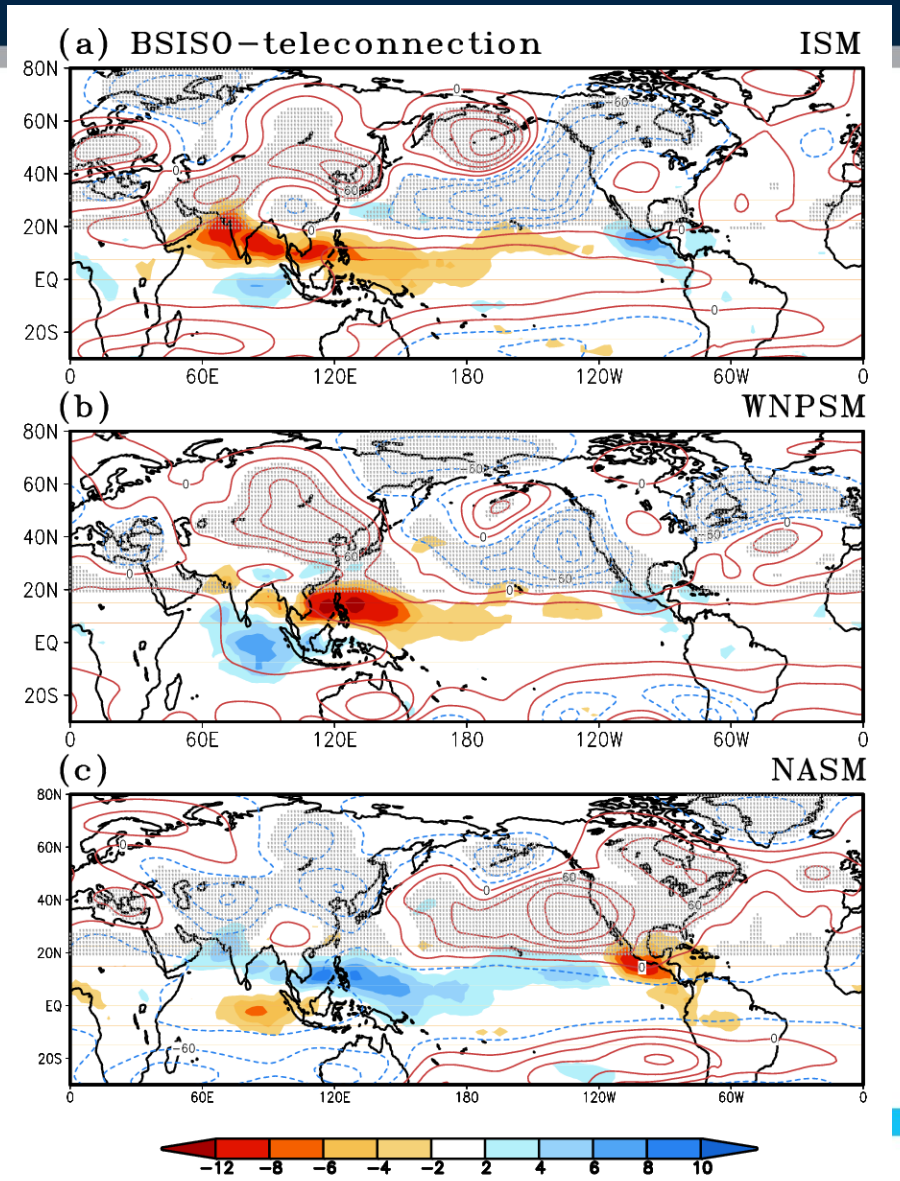
Is this local phenomena ?



Local
But
Not local ^^

Teleconnection

Fig. The regressed intraseasonal anomalies of OLR (shaded, in W/m^2) and GPH200 (contour, in gpm) against (a) ISM (b) WNPSM, and (c) NASM circulation indices defined based on Fig. 1. Dotted areas represent statistically signifi cant regions of GPH200 at 99% confidence level to the north of 20 °N by student's t-test.



NH Summer Monsoon Intraseasonal Index

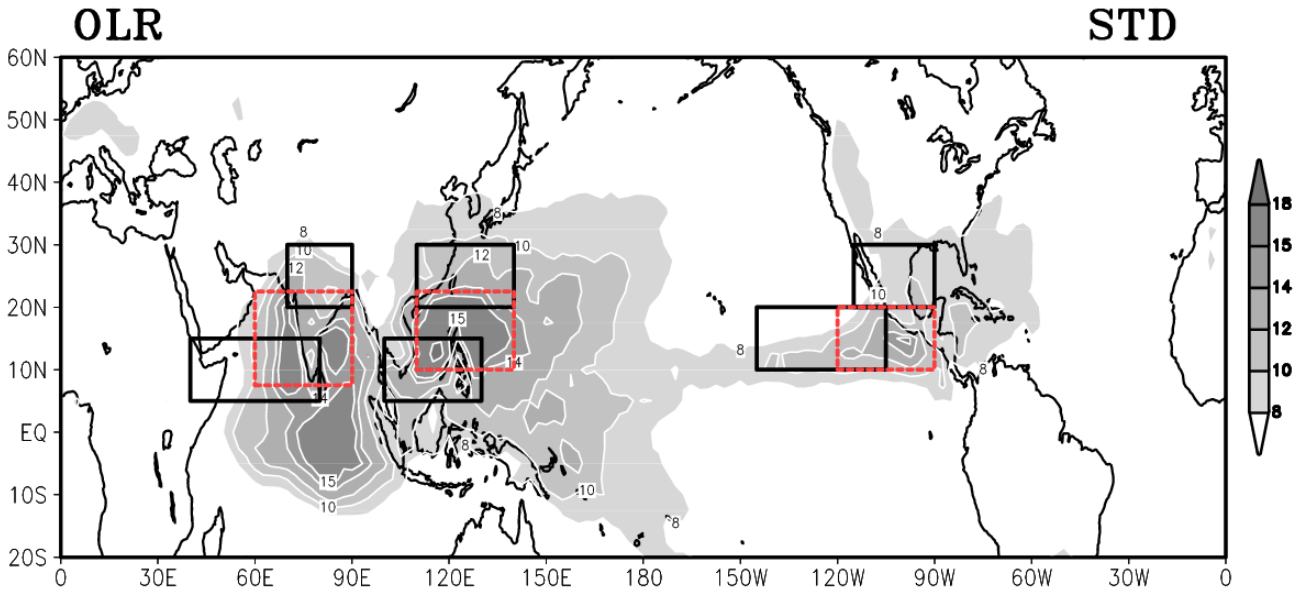


Fig. Standard deviation of the intraseasonal outgoing longwave radiation (OLR) anomaly during the boreal summer (June~September) from 1979 to 2010. The intraseasonal anomaly is defined as the daily data with the long-term mean removed and 30-60 day filtered using Lanczos band-pass filter. Black solid boxes indicate the location selected for each circulation monsoon indices: Indian Summer Monsoon, ISM, U850 (5°-15°N, 40°-80°E - 20°-30°N, 70°-90°E) Western North Pacific Summer Monsoon, WNPSM, U850 (5°-15°N, 100°-130°E - 20°-30°N, 110°-140°E) and North American Summer Monsoon, NASM U850 (7.5°-17.5°N, 125°-90°W - 20°-30°N, 115°W-80°W). Red dashed boxes indicate the location selected for each convective monsoon indices: C_ISM, OLR [7.5°-22.5°N, 60°-90°E], C_WNPSMI=OLR [10°-22.5°N, 110°-140°E], C_NASMI=OLR [10°-20°N, 120°-90°W]. The unit of OLR is W/m^2.

Moon et al. (2013) Teleconnections associated with Northern Hemisphere summer monsoon intraseasonal oscillation

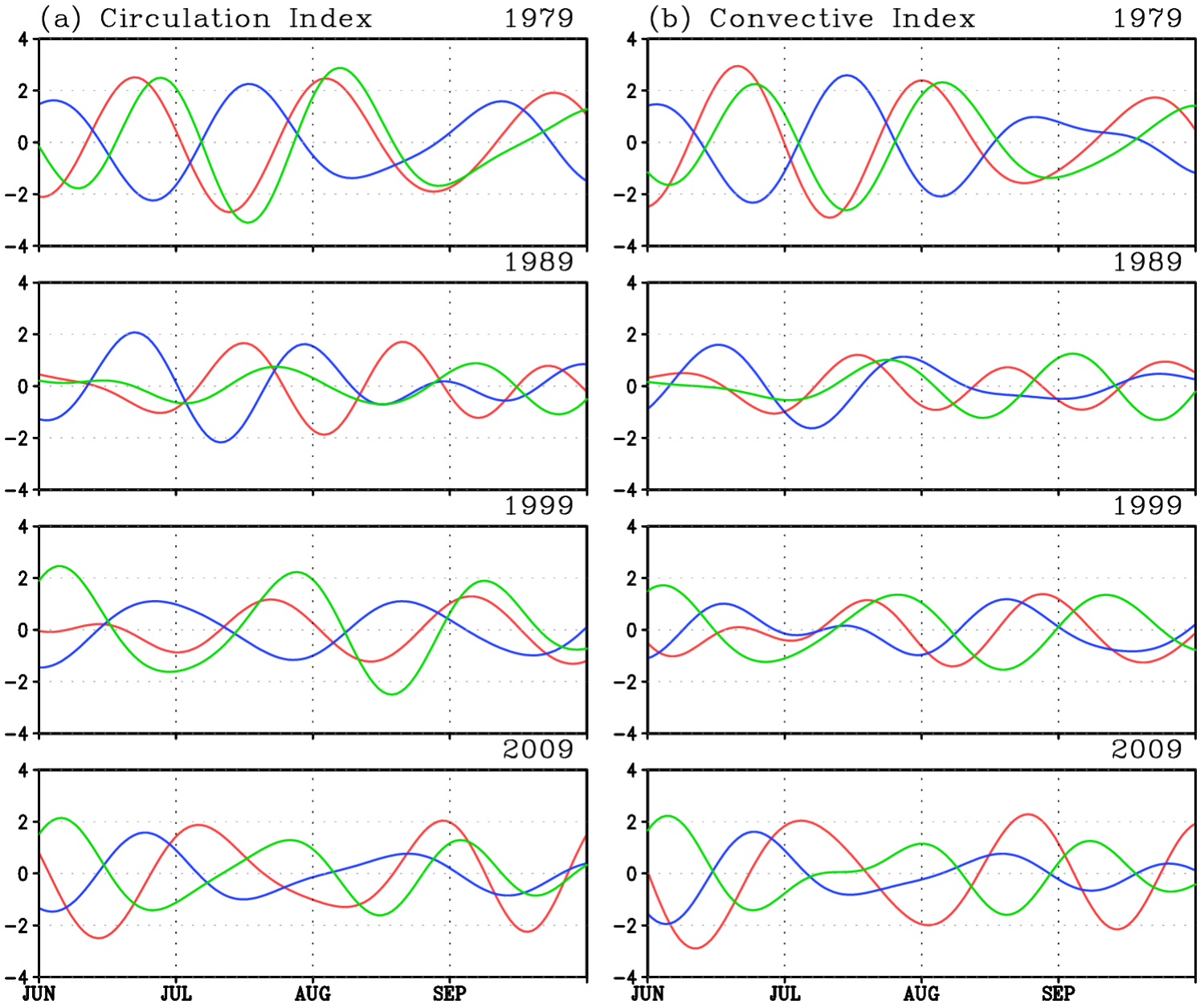
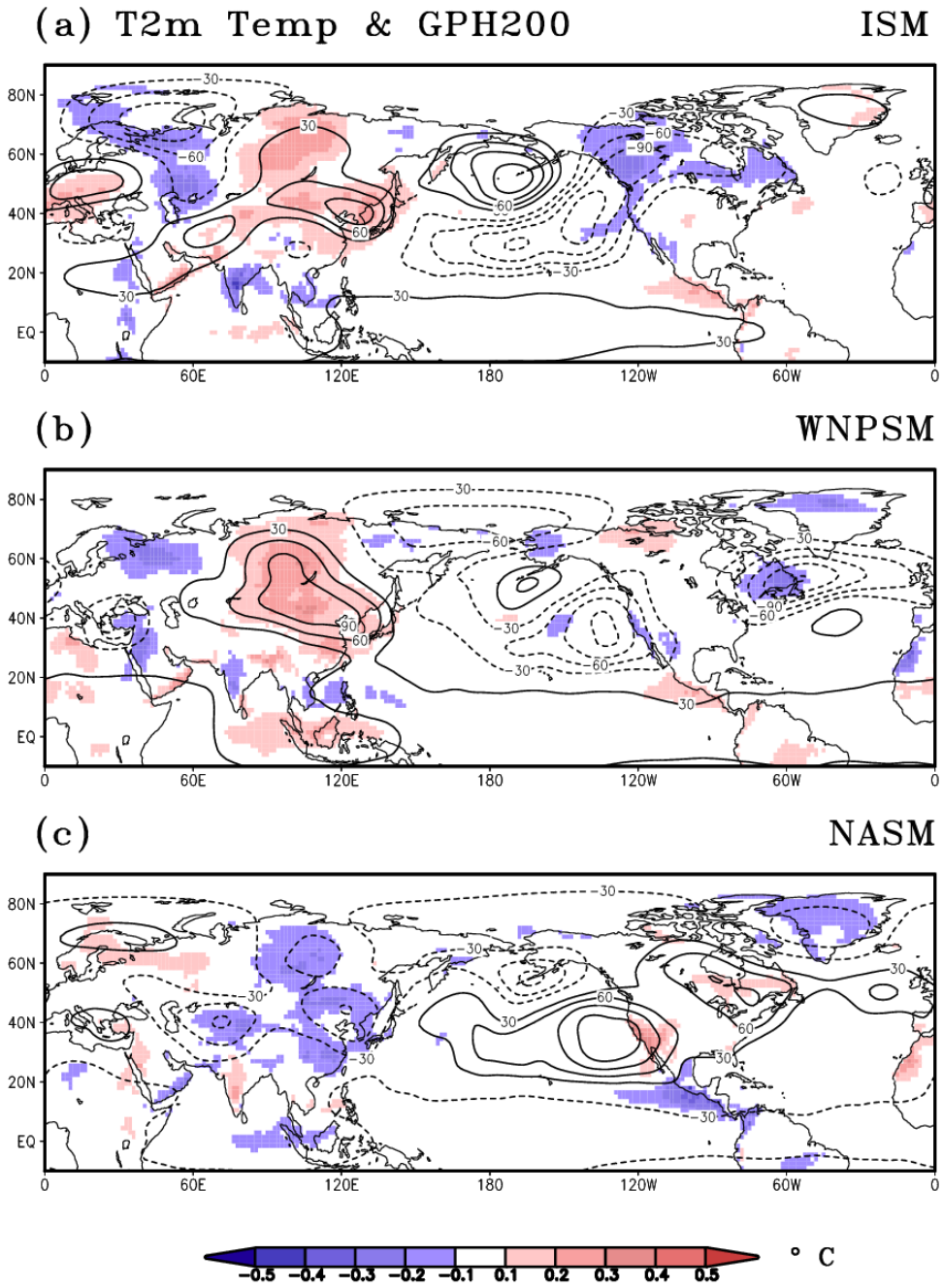
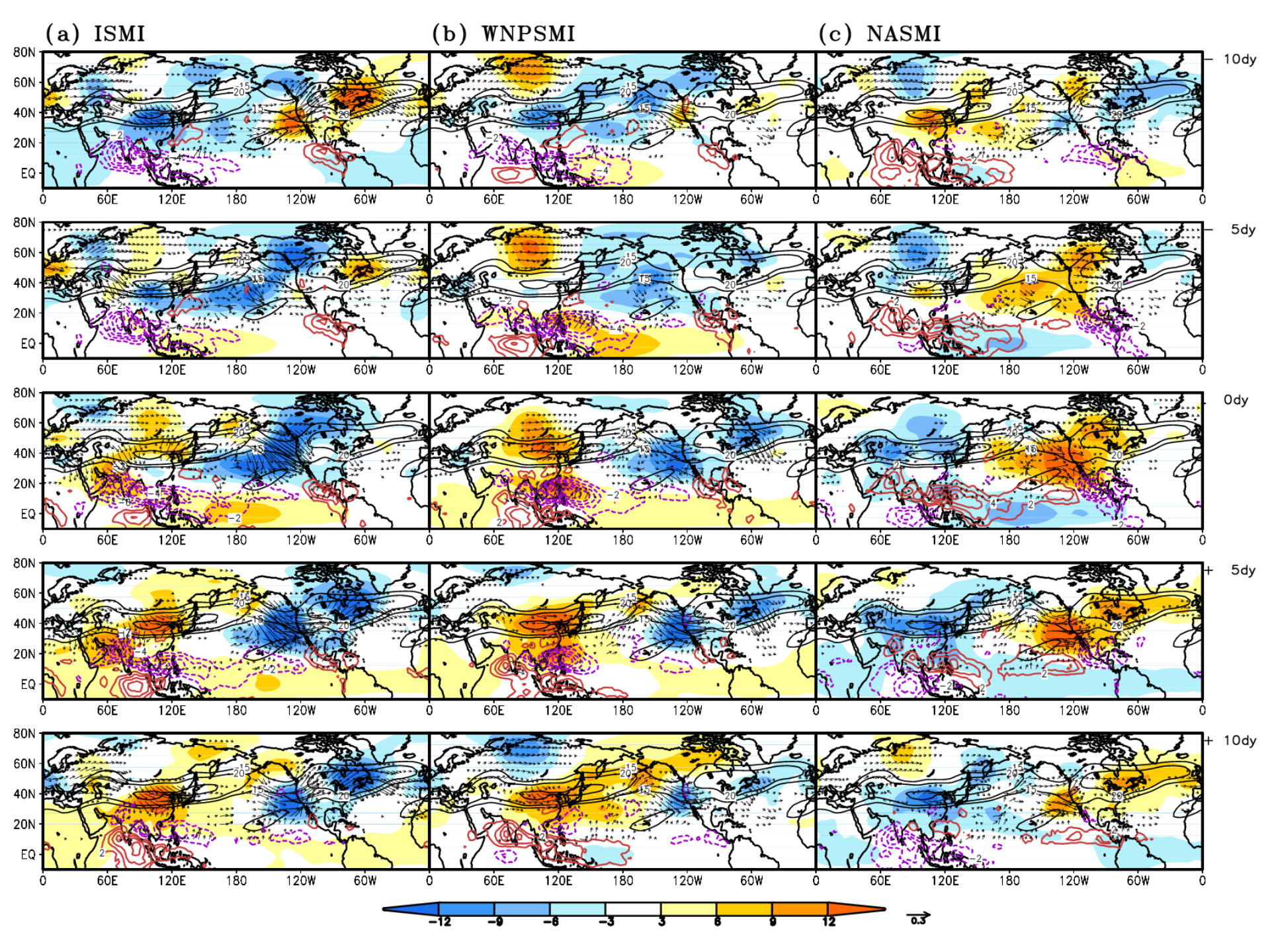


Fig. Intraseasonal monsoon indices by (a) circulation and (b) convection defined in Fig. 1. Each year is from June 1st to September 30th. Each index is normalized by its standard deviation.



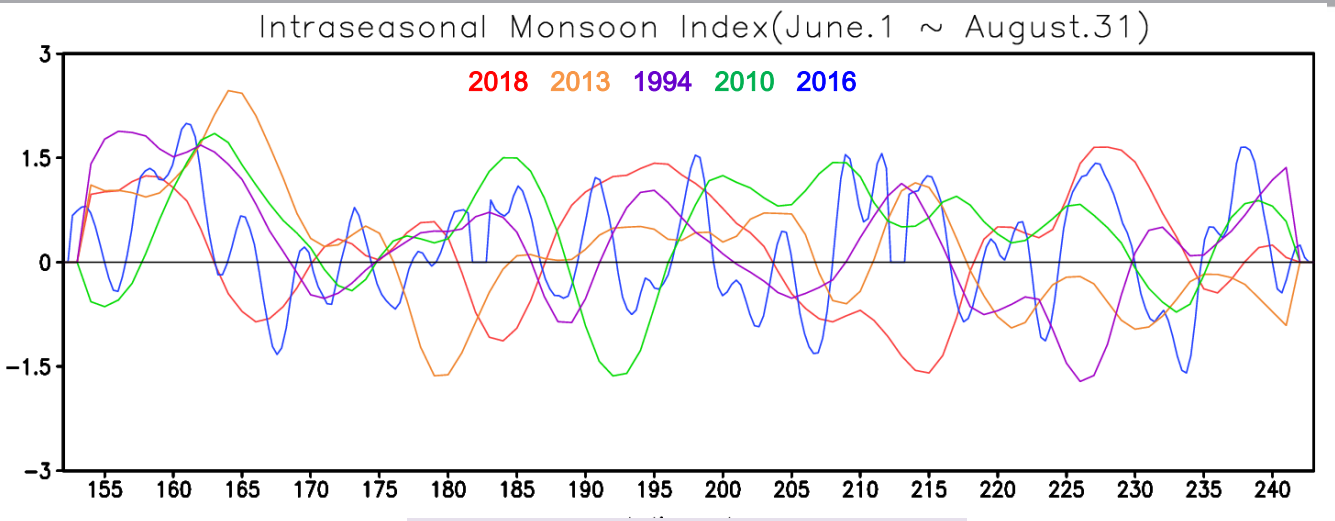
Temp tends to be increased both from ISM and WNPSM indices with high pressure anomaly

Fig. The regressed intraseasonal anomalies of 2m air temperature (T2m Temp, shaded) and GPH200 (contour) with reference to the (a) ISM (b) WNP SM, and (c) NASM indices. The unit of T2m Temp and GPH200 are °C and gpm, respectively.


(a) ISMI
(b) WNPSMI
(c) NASMI
10dy
5dy
0dy
-5dy
-10dy
80N
60N
40N
20N
EQ
0
60E
120E
180
120W
60W
-12
-9
-6
-3
3
6
9
12
0.3

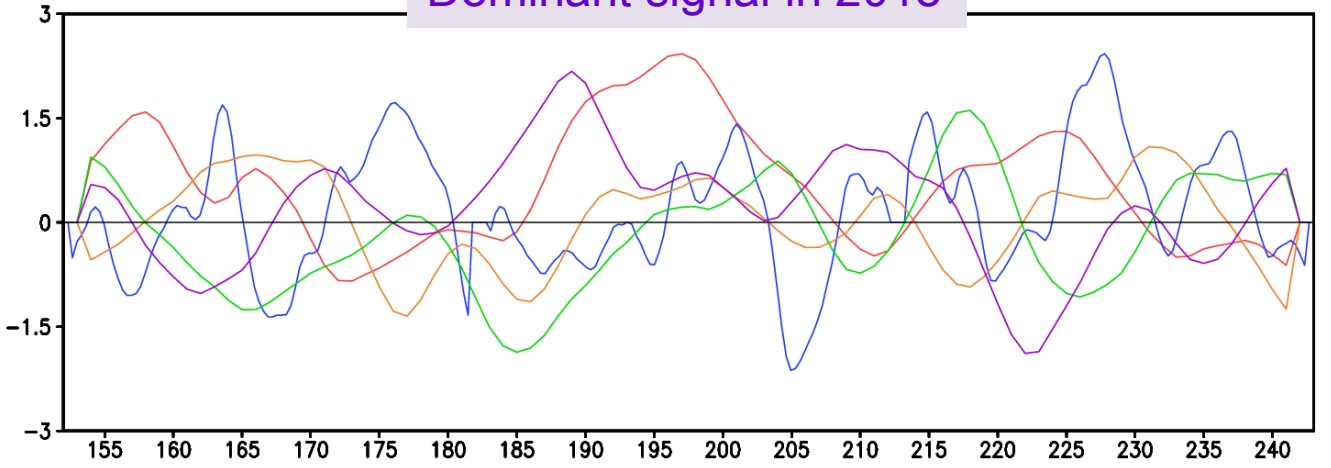
Application to 2018
Compare to other hot summers

Indian Summer Monsoon Index (ISMI)



Dominant signal in 2018

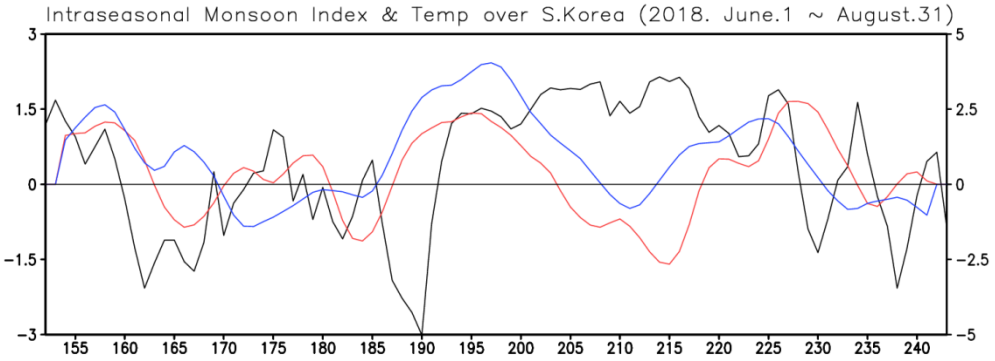
Western North Pacific Summer Monsoon Index (WNPSMI)



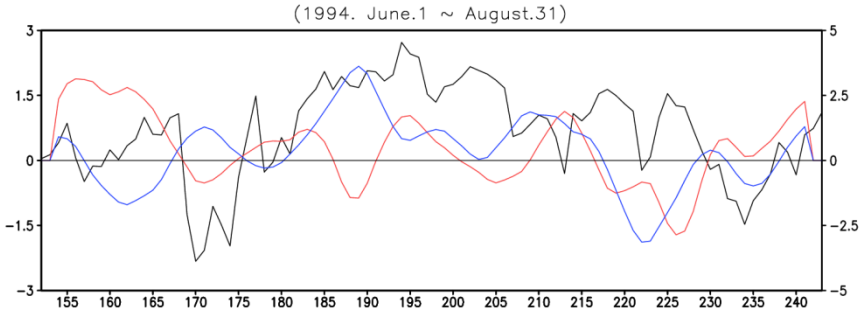
Intraseasonal Monsoon indices during top five hot summers (Jun.1 – Aug. 31)

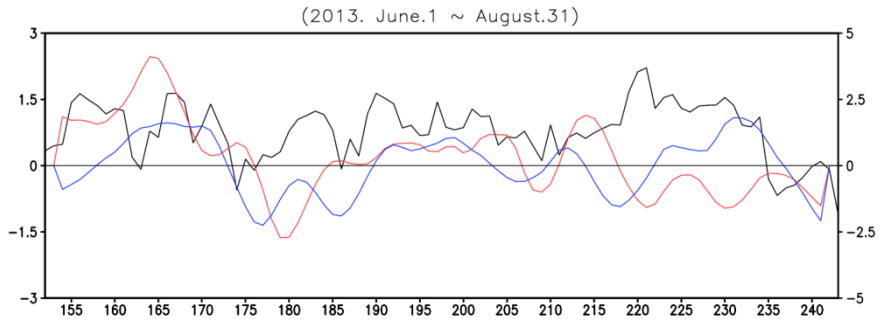
Tave_korea

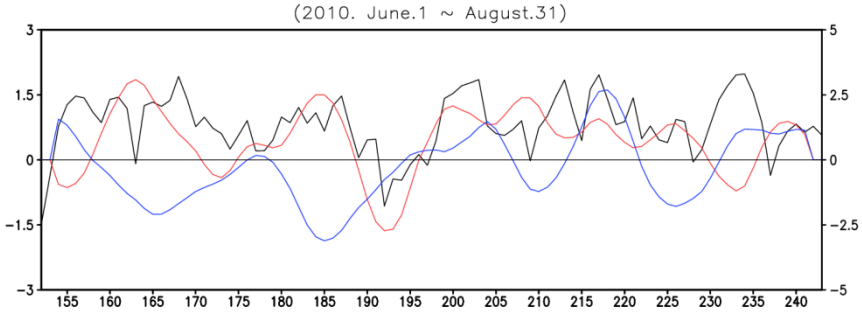
ISMI
WNPSMI
(5day mov- avg)

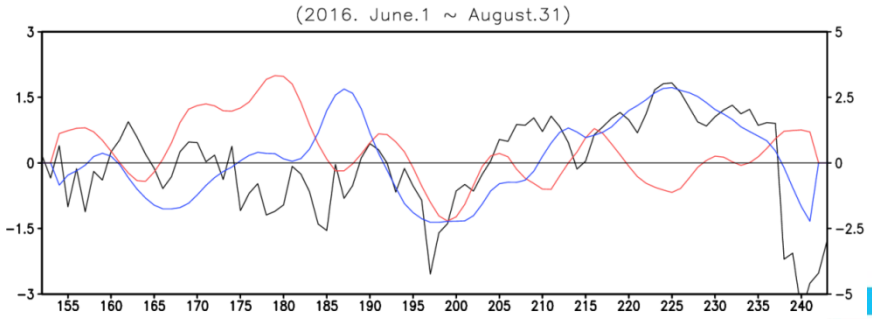


ISMI & WNPSMI in 2018
Both Stronger (simultaneously) and Longer duration compared to other hot summers !!



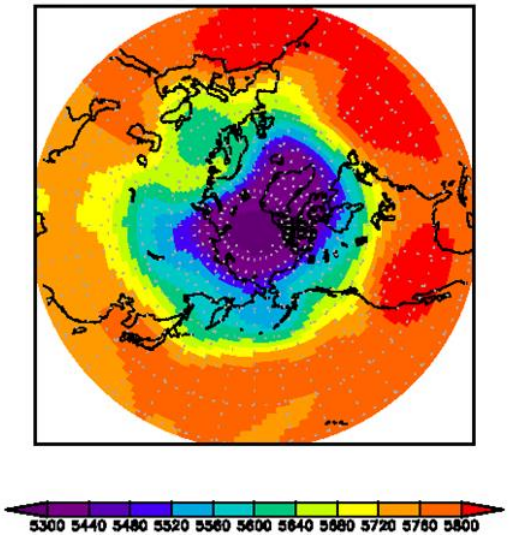




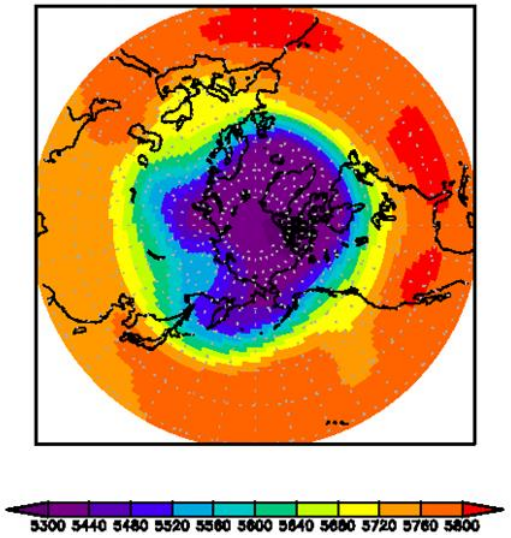


Geopotential height at 500 hPa

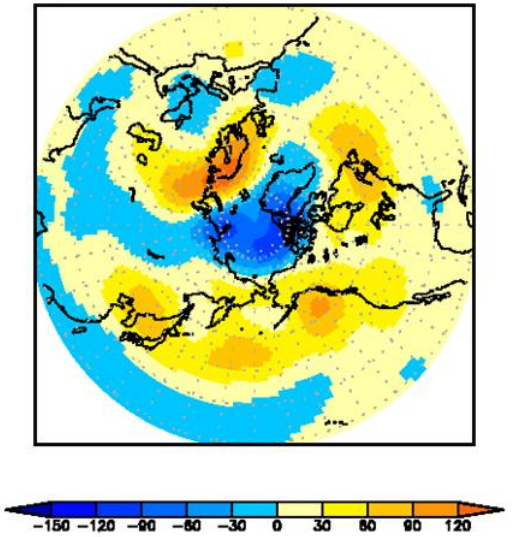
JULY_mean [2018]



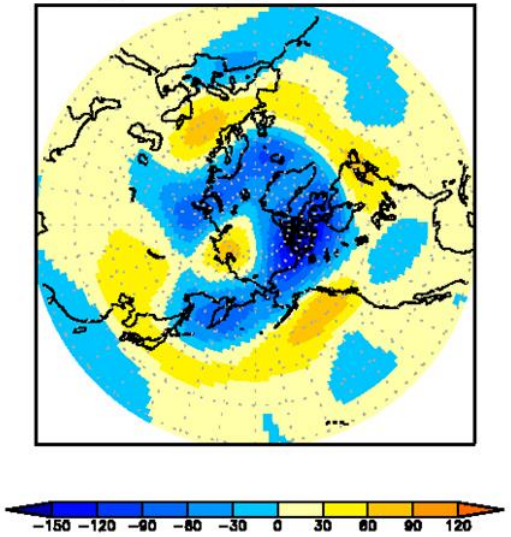
AUGUST_mean [2018]



JULY_anomaly [2018]



AUGUST_anomaly [2018]

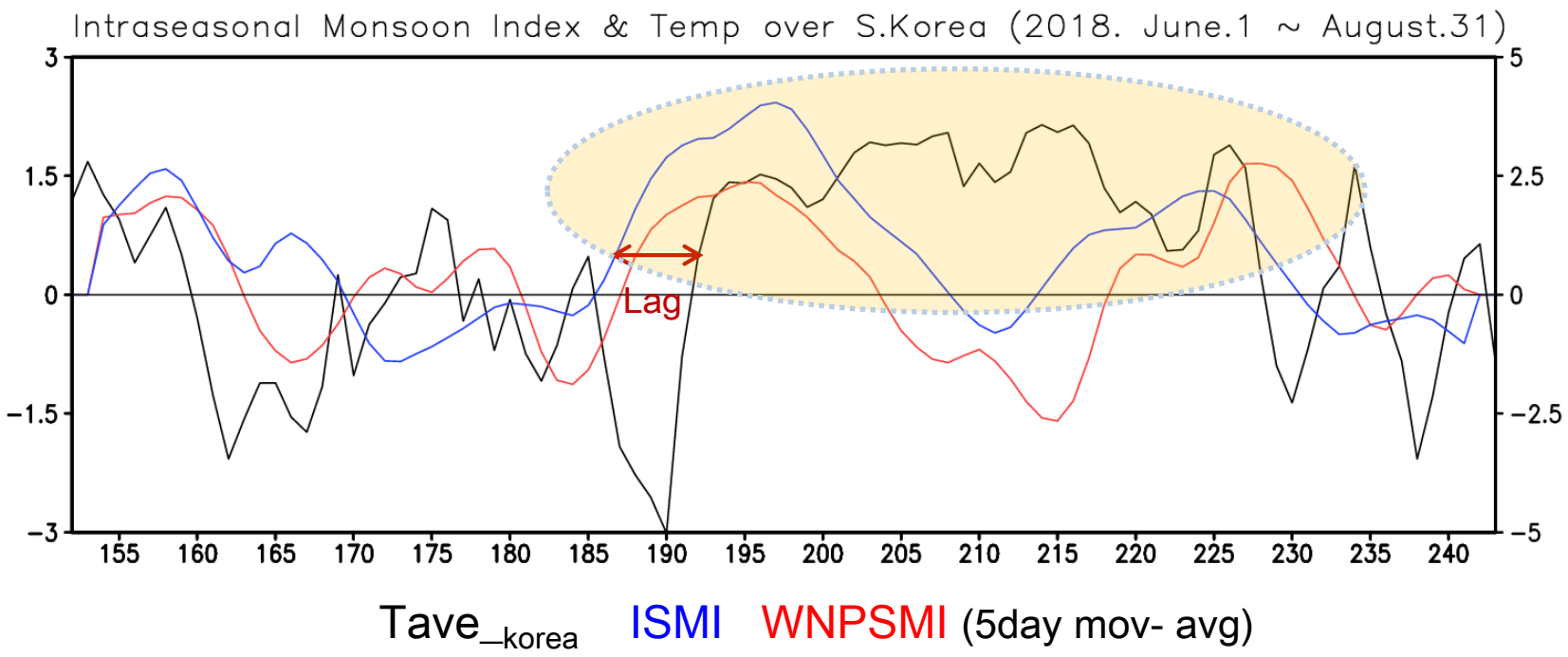


North-South Blocking structure

High pressure A. persist through July and August

data : geopotential height from ERA-INTERIM

Application to 2018

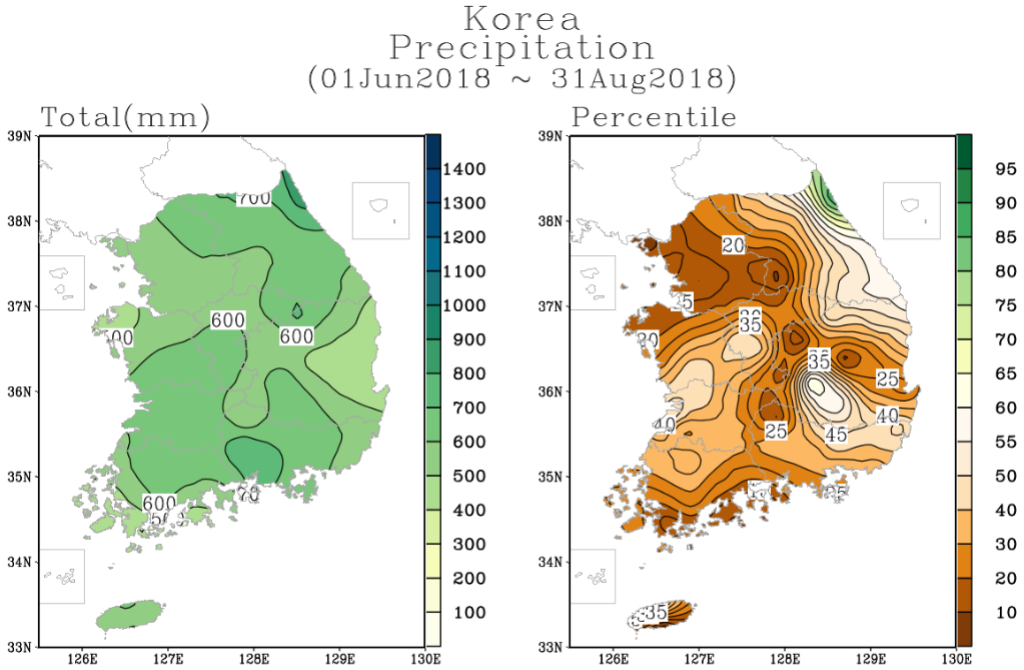


Dominant signal in 2018 especially WNPSMI persist with the above normal temp !

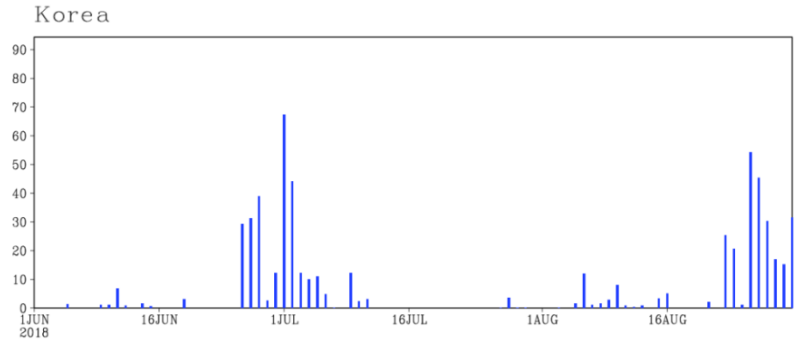
? Weakening WNPSMI but still high temperature, why?

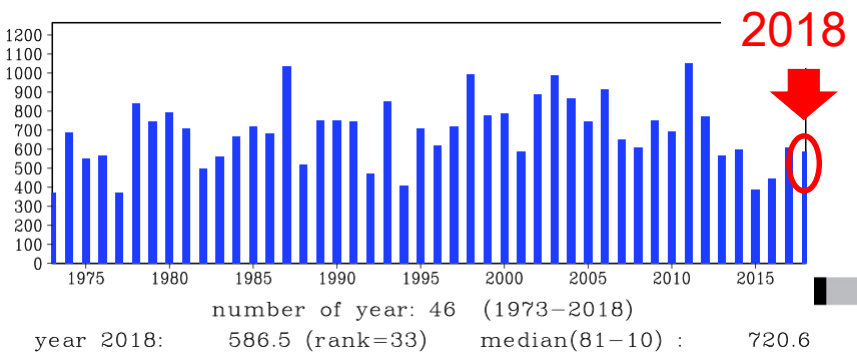
2018 Rainfall over S. Korea (33th/46yrs)

Below normal year

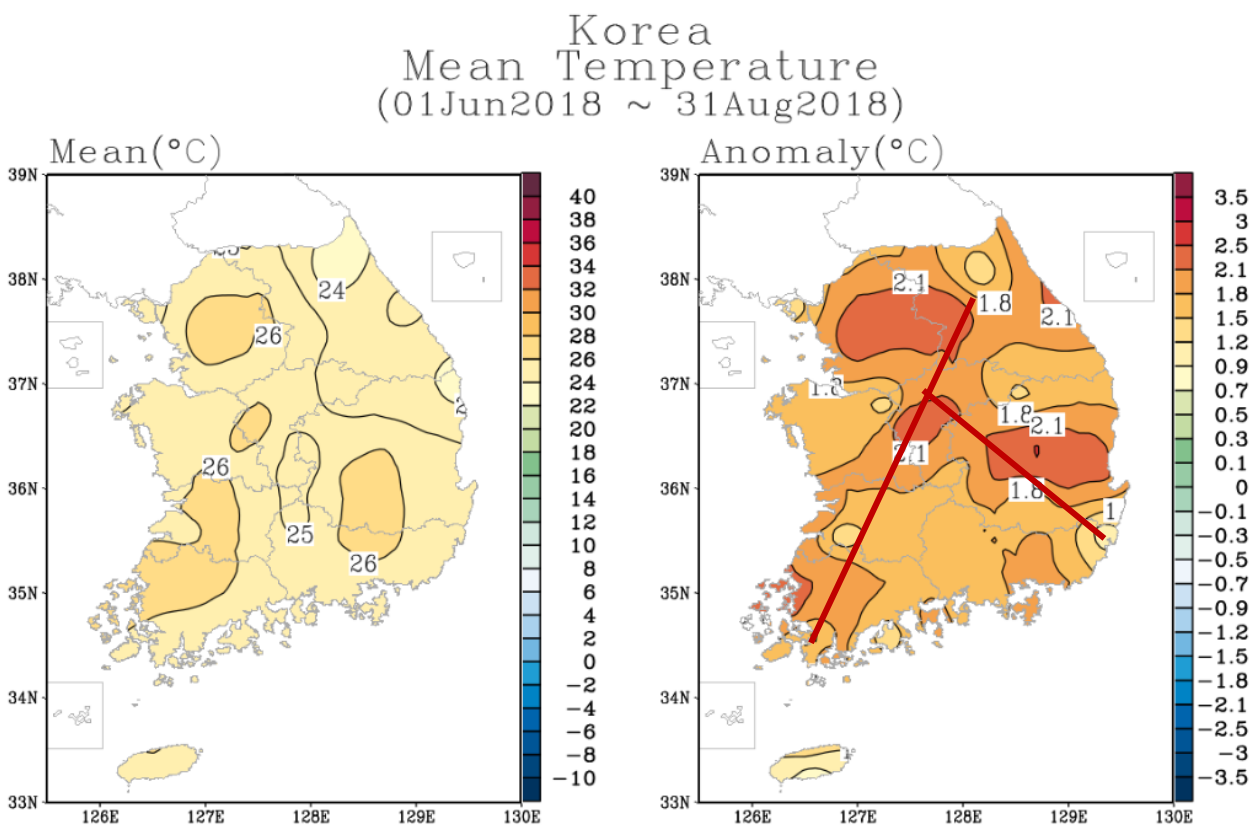


Dry Surface !



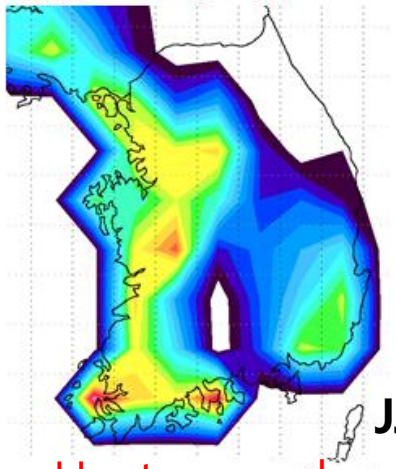


Is this local phenomena ?



Tropical night days

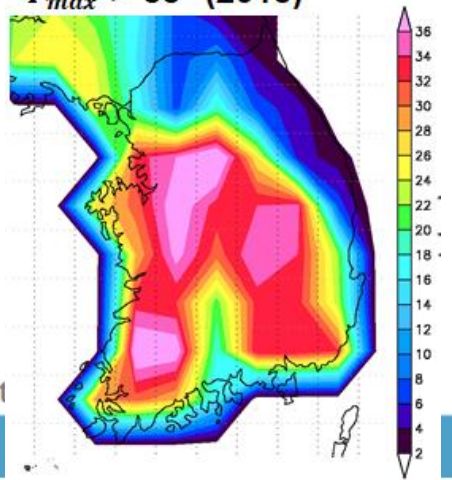
$T_{min} > 25°$ (2018)



JJA

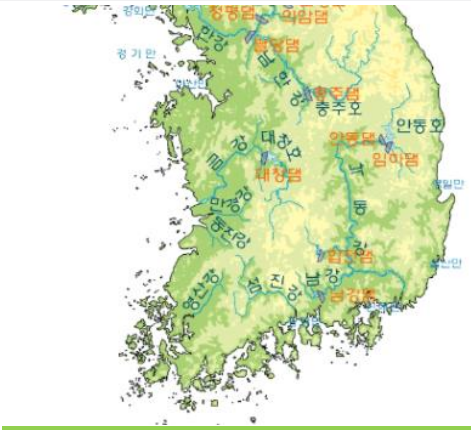
Heat wave days

$T_{max} > 33°$ (2018)

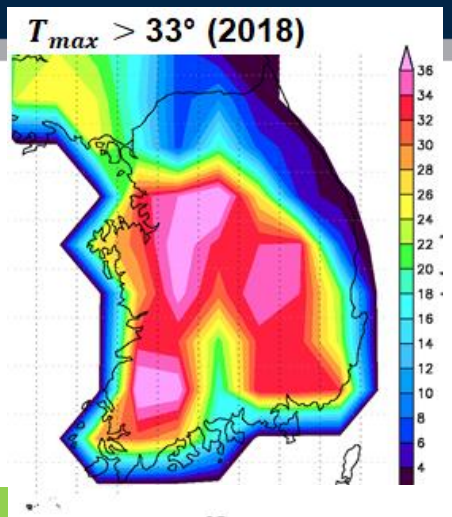


data : Maximum and Minimum temperature (CPC), evapotranspirat

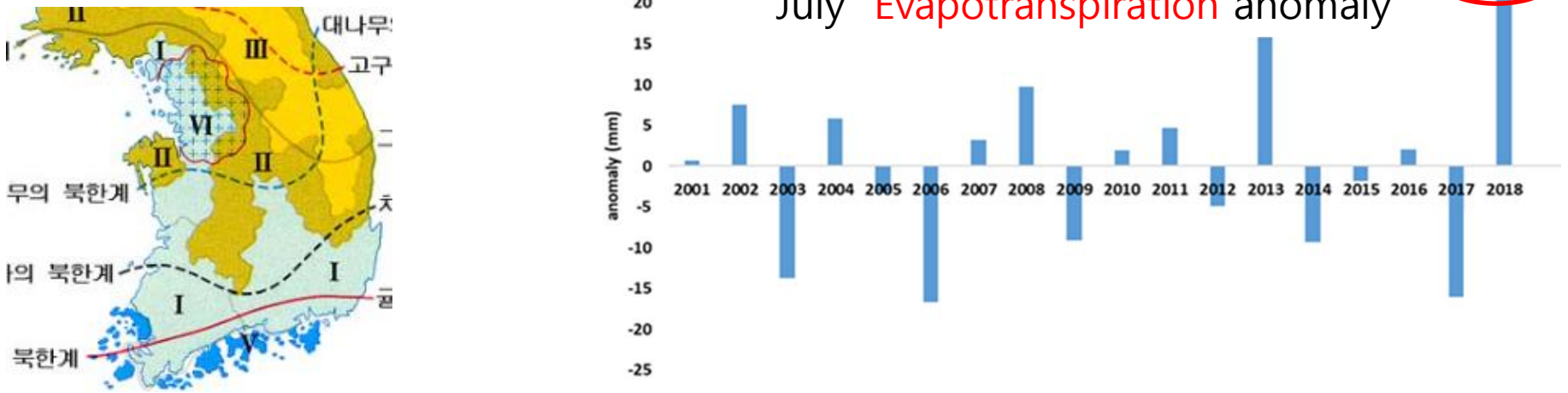
Is this local phenomena ?



Main rivers and streams



2018 -
Largest loss of moisture from the surface !



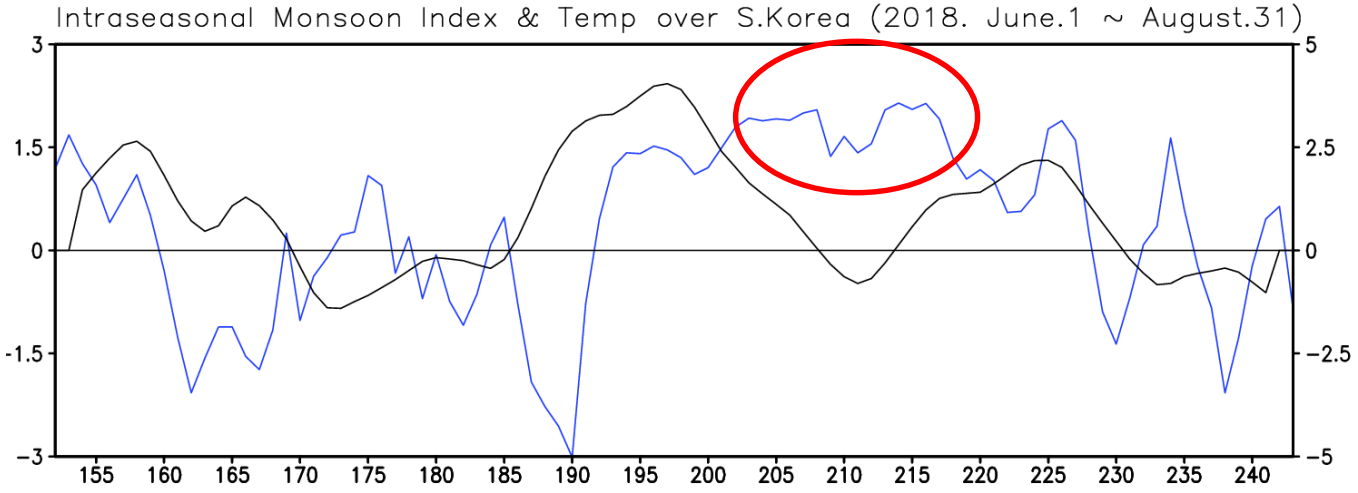
Paddy(Agriculture) field

data : Maximum and Minimum temperature (CPC), evapotranspiration (MODIS)

Is this local phenomena ? Local

Tave_korea
WNPSMI

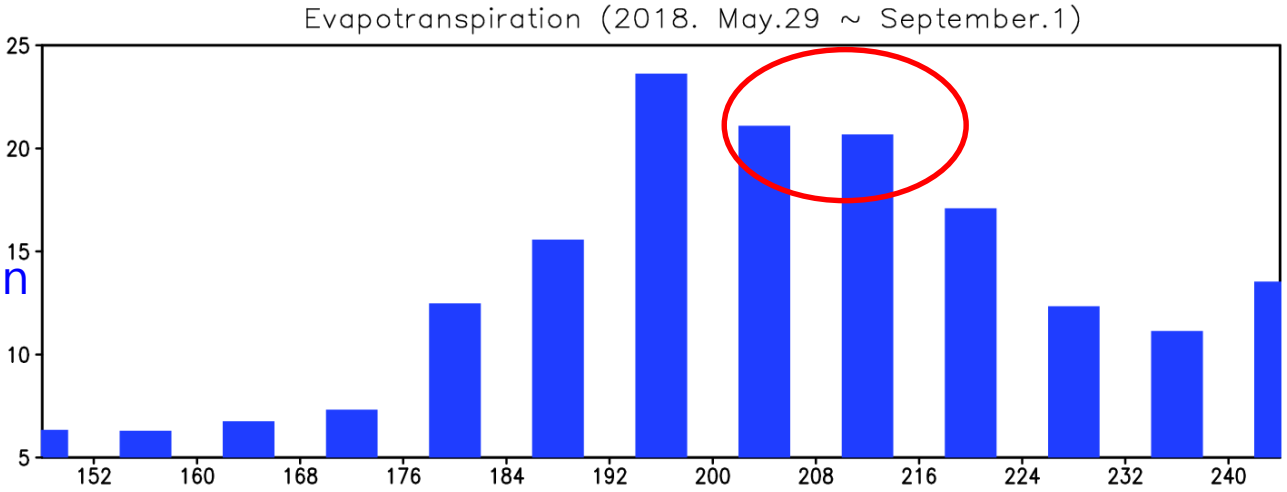
5-day mov. Avg.



EvapoT_

Arable land

8-day mean



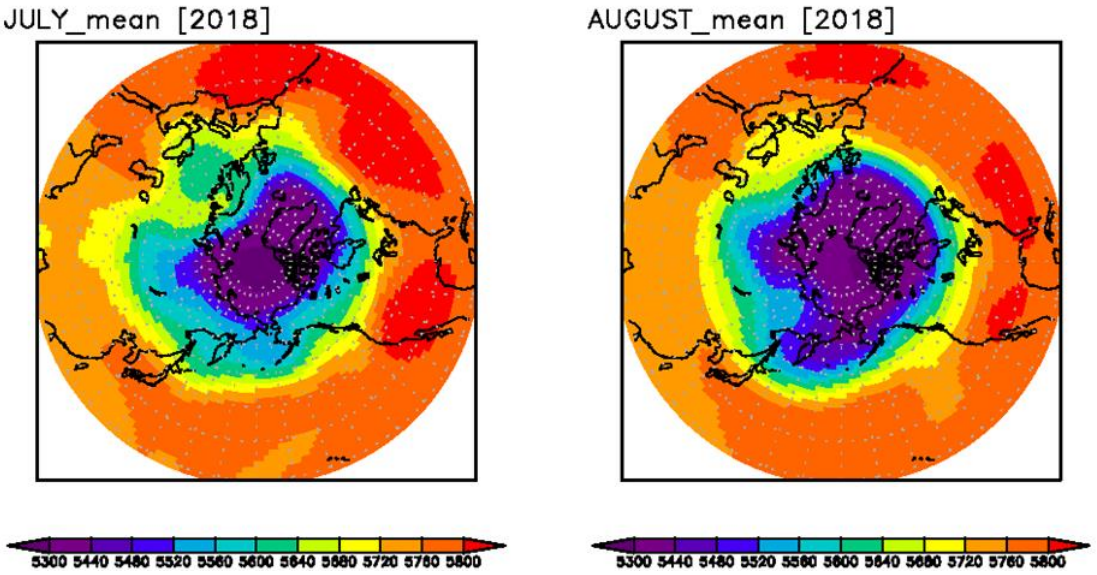
Geopotential height at 500 hPa

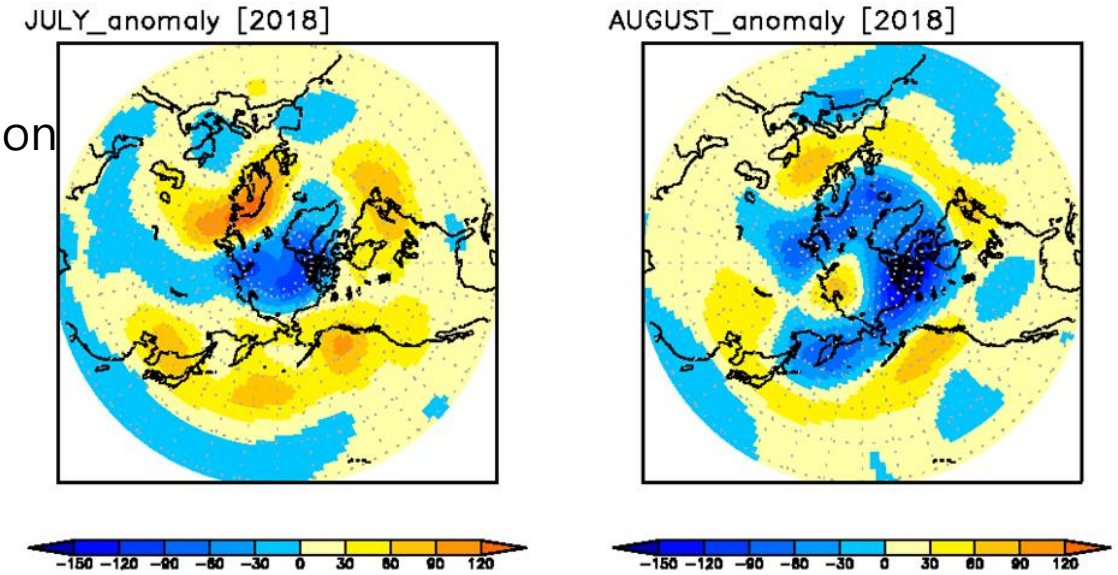
North-South
Blocking structure

High pressure A.
Restrict
precipitation to
be formed

Lots of moisture
in the atmosphere
and
Surface dry condition
maintained the
heat wave

(Local effect)





data : geopotential height from ERA-INTERIM

Conclusion

- 2018 Summer (JJA) was recorded as the hottest summer during 47 years (1973~2018)
  - Above normal temperature maintained around 37 days at the climatological maximum period in 2008 summer
  - Tropical nights were 35 days (T_{min} < 25°)
    Heat wave days were 40 days (T_{max} > 33°)

- Among the plausible causes,
  - Non-local effect :
    Strong high pressure anomaly initiated over Korea from the teleconnection pattern produced by strong convection both from India to western North Pacific ISO.
    Compared to other hot summers, the forcing was strong and steady.

Conclusion

- Among the plausible causes,
  - Local effect :
    Evapotranspiation increased 23.5mm than climatology
    Precipitation was low and 80% of the climatology during July 2018.
    => Surface dry, Atmosphere wet environment

- Persistent and continuous tropical night with much moisture in the atmosphere could cause record breaking extreme hot days to occur

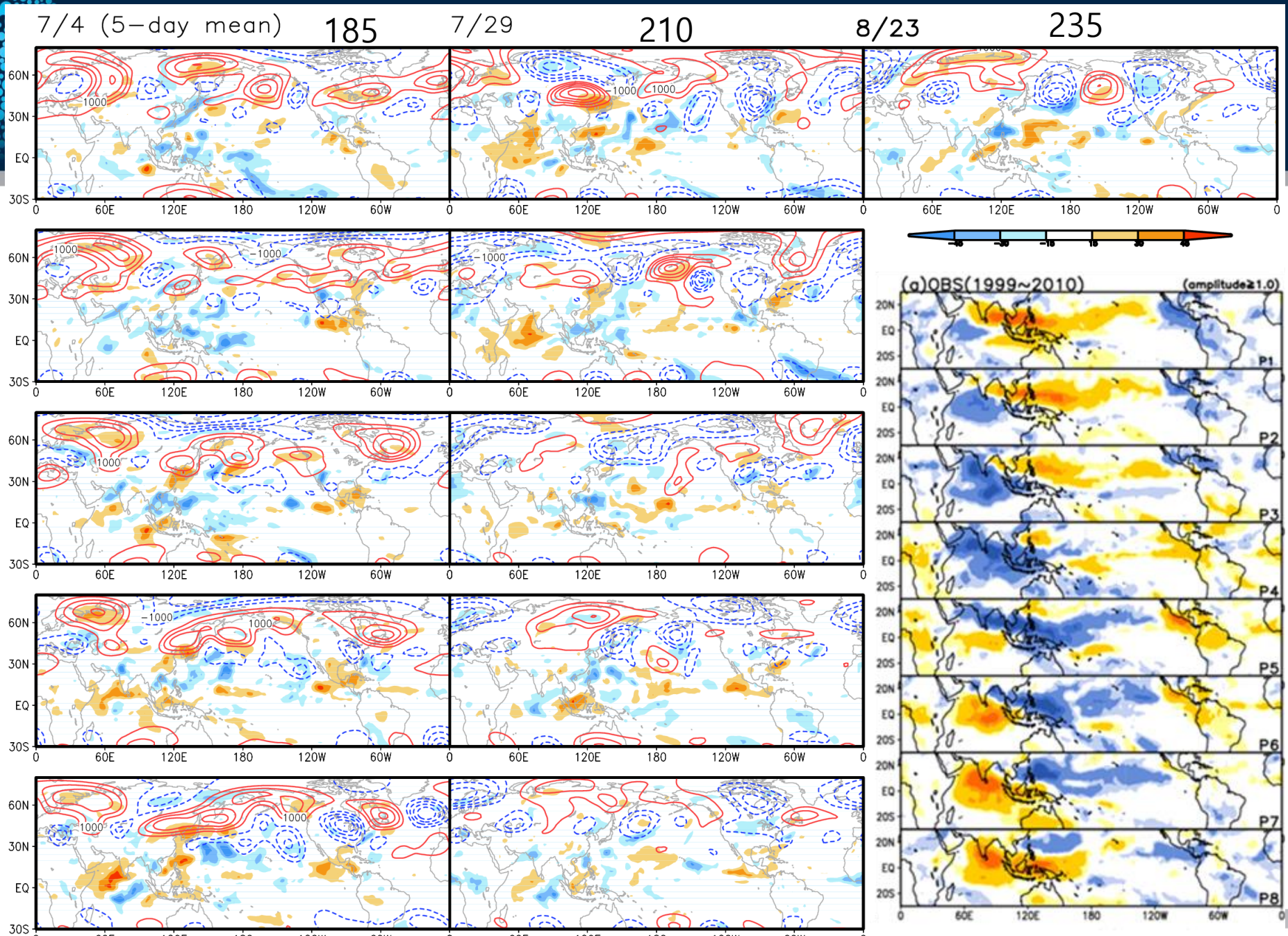
Possible climatic causes (Kim and others at KMS Meeting)

- Global Warming
- ENSO variability
- Active convective forcing over the WNP
- Tibetan Plateau High
- Natural atmospheric variability with blocking event
- Dry land surface processes
- Reduced ice and snow
- North-south dipole
- Local factors
- Stationary wave trains
- Anomalous atmospheric planetary waves
- CGT
- North Atlantic SST

+

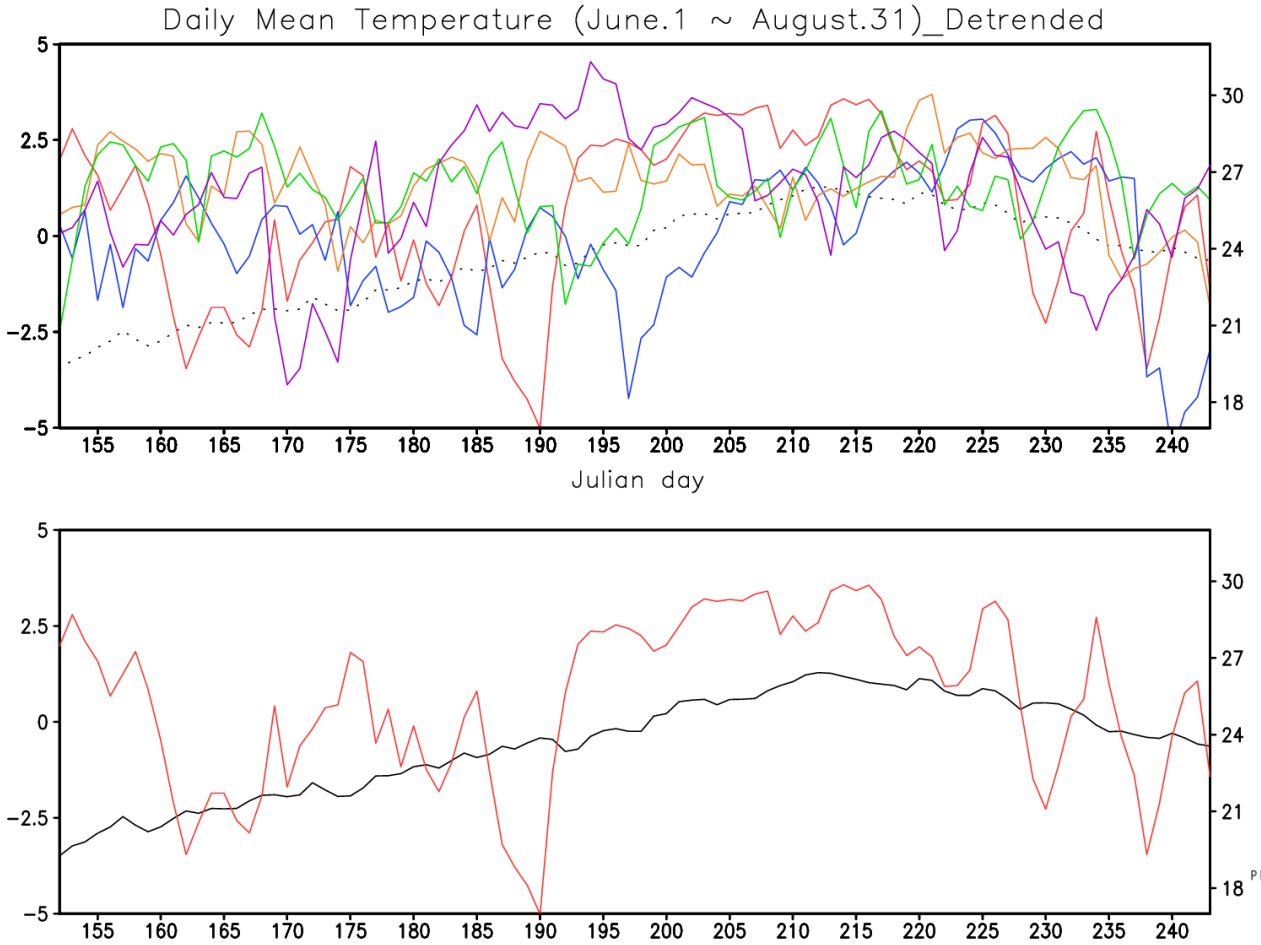
- MJO/BSISO with local effect

Thank you for your attention !


7/4 (5-day mean)
185
7/29
210
8/23
235
60N
30N
EQ
30S
0
60E
120E
180
120W
60W
1000
-1000
(a)OBS(1999~2010)
(amplitude≥1.0)
20N
EQ
20S
P1
P2
P3
P4
P5
P6
P7
P8

Discussion

Global Warming ?
After detrending, still 2018 highest ?



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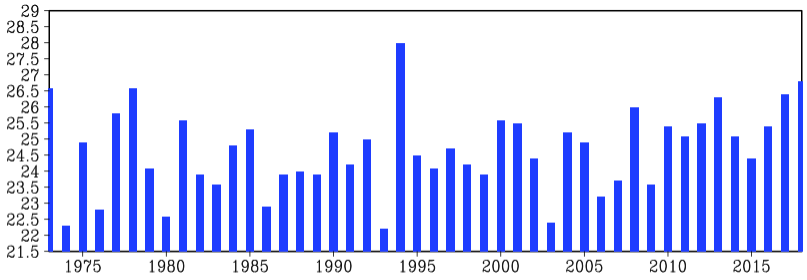
July

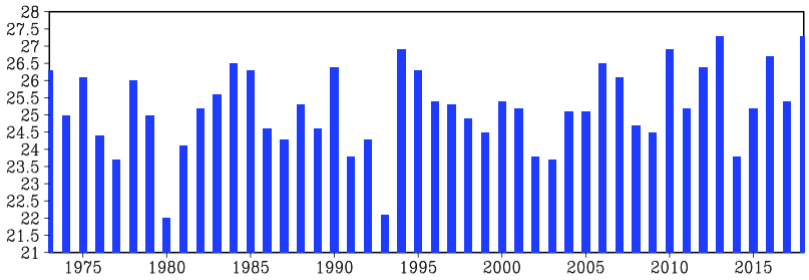


number of year: 46 (1973-2018)

year 2018: 26.8 (rank=2) normal(81-10) : 24.5

rank(01)	1994	28.0	rank(24)	1997	24.7
rank(02)	2018	26.8	rank(25)	1995	24.5
rank(03)	1978	26.6	rank(26)	2015	24.4
rank(04)	1973	26.6	rank(27)	2002	24.4
rank(05)	2017	26.4	rank(28)	1998	24.2
rank(06)	2013	26.3	rank(29)	1991	24.2
rank(07)	2008	26.0	rank(30)	1996	24.1
rank(08)	1977	25.8	rank(31)	1979	24.1
rank(09)	2000	25.6	rank(32)	1988	24.0
rank(10)	1981	25.6	rank(33)	1999	23.9
rank(11)	2012	25.5	rank(34)	1989	23.9
rank(12)	2001	25.5	rank(35)	1987	23.9
rank(13)	2016	25.4	rank(36)	1982	23.9
rank(14)	2010	25.4	rank(37)	2007	23.7
rank(15)	1985	25.3	rank(38)	2009	23.6
rank(16)	2004	25.2	rank(39)	1983	23.6
rank(17)	1990	25.2	rank(40)	2006	23.2
rank(18)	2014	25.1	rank(41)	1986	22.9
rank(19)	2011	25.1	rank(42)	1976	22.8
rank(20)	1992	25.0	rank(43)	1980	22.6
rank(21)	2005	24.9	rank(44)	2003	22.4
rank(22)	1975	24.9	rank(45)	1974	22.3
rank(23)	1984	24.8	rank(46)	1993	22.2

August

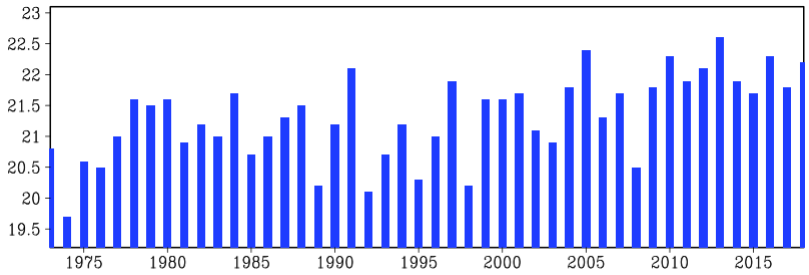


number of year: 46 (1973-2018)

year 2018: 27.3 (rank=1) normal(81-10) : 25.1

rank(01)	2018	27.3	rank(24)	2001	25.2
rank(02)	2013	27.3	rank(25)	1982	25.2
rank(03)	2010	26.9	rank(26)	2005	25.1
rank(04)	1994	26.9	rank(27)	2004	25.1
rank(05)	2016	26.7	rank(28)	1979	25.0
rank(06)	2006	26.5	rank(29)	1974	25.0
rank(07)	1984	26.5	rank(30)	1998	24.9
rank(08)	2012	26.4	rank(31)	2008	24.7
rank(09)	1990	26.4	rank(32)	1989	24.6
rank(10)	1995	26.3	rank(33)	1986	24.6
rank(11)	1985	26.3	rank(34)	2009	24.5
rank(12)	1973	26.3	rank(35)	1999	24.5
rank(13)	2007	26.1	rank(36)	1976	24.4
rank(14)	1975	26.1	rank(37)	1992	24.3
rank(15)	1978	26.0	rank(38)	1987	24.3
rank(16)	1983	25.6	rank(39)	1981	24.1
rank(17)	2017	25.4	rank(40)	2014	23.8
rank(18)	2000	25.4	rank(41)	2002	23.8
rank(19)	1996	25.4	rank(42)	1991	23.8
rank(20)	1997	25.3	rank(43)	2003	23.7
rank(21)	1988	25.3	rank(44)	1977	23.7
rank(22)	2015	25.2	rank(45)	1993	22.1
rank(23)	2011	25.2	rank(46)	1980	22.0

June

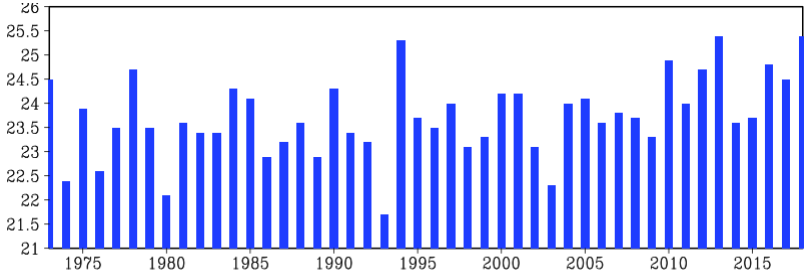


number of year: 46 (1973–2018)

year 2018: 22.2 (rank=5) normal(81–10) : 2

rank(01)	2013	22.6	rank(24)	2006	21.3
rank(02)	2005	22.4	rank(25)	1987	21.3
rank(03)	2016	22.3	rank(26)	1994	21.2
rank(04)	2010	22.3	rank(27)	1990	21.2
rank(05)	2018	22.2	rank(28)	1982	21.2
rank(06)	2012	22.1	rank(29)	2002	21.1
rank(07)	1991	22.1	rank(30)	1996	21.0
rank(08)	2014	21.9	rank(31)	1986	21.0
rank(09)	2011	21.9	rank(32)	1983	21.0
rank(10)	1997	21.9	rank(33)	1977	21.0
rank(11)	2017	21.8	rank(34)	2003	20.9
rank(12)	2009	21.8	rank(35)	1981	20.9
rank(13)	2004	21.8	rank(36)	1973	20.8
rank(14)	2015	21.7	rank(37)	1993	20.7
rank(15)	2007	21.7	rank(38)	1985	20.7
rank(16)	2001	21.7	rank(39)	1975	20.6
rank(17)	1984	21.7	rank(40)	2008	20.5
rank(18)	2000	21.6	rank(41)	1976	20.5
rank(19)	1999	21.6	rank(42)	1995	20.3
rank(20)	1980	21.6	rank(43)	1998	20.2
rank(21)	1978	21.6	rank(44)	1989	20.2
rank(22)	1988	21.5	rank(45)	1992	20.1
rank(23)	1979	21.5	rank(46)	1974	19.7

JJA



number of year: 46 (1973–2018)

year 2018: 25.4 (rank=1) normal(81–10) : 23.6

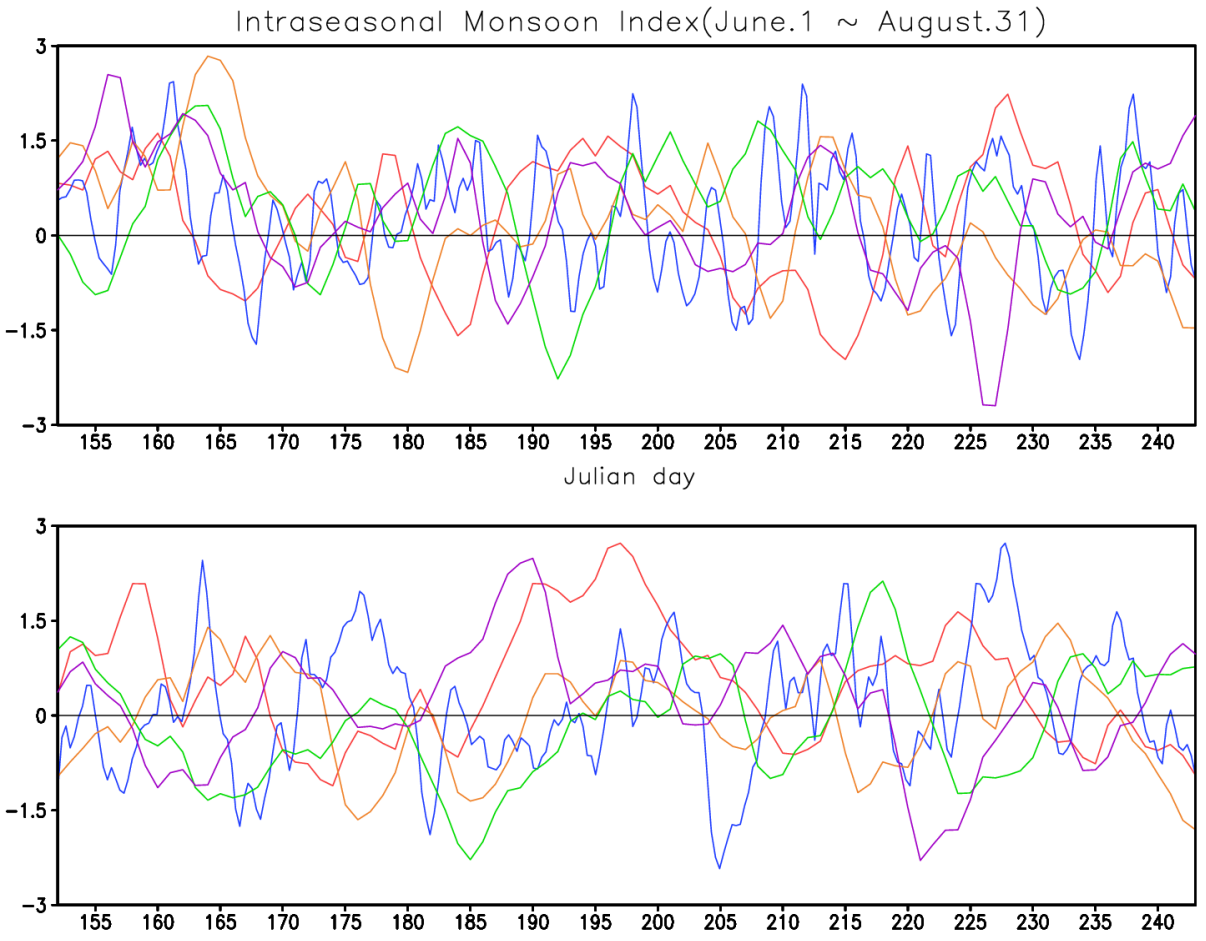
rank(01)	2018	25.4	rank(24)	2014	23.6
rank(02)	2013	25.4	rank(25)	2006	23.6
rank(03)	1994	25.3	rank(26)	1988	23.6
rank(04)	2010	24.9	rank(27)	1981	23.6
rank(05)	2016	24.8	rank(28)	1996	23.5
rank(06)	2012	24.7	rank(29)	1979	23.5
rank(07)	1978	24.7	rank(30)	1977	23.5
rank(08)	2017	24.5	rank(31)	1991	23.4
rank(09)	1973	24.5	rank(32)	1983	23.4
rank(10)	1990	24.3	rank(33)	1982	23.4
rank(11)	1984	24.3	rank(34)	2009	23.3
rank(12)	2001	24.2	rank(35)	1999	23.3
rank(13)	2000	24.2	rank(36)	1992	23.2
rank(14)	2005	24.1	rank(37)	1987	23.2
rank(15)	1985	24.1	rank(38)	2002	23.1
rank(16)	2011	24.0	rank(39)	1998	23.1
rank(17)	2004	24.0	rank(40)	1989	22.9
rank(18)	1997	24.0	rank(41)	1986	22.9
rank(19)	1975	23.9	rank(42)	1976	22.6
rank(20)	2007	23.8	rank(43)	1974	22.4
rank(21)	2015	23.7	rank(44)	2003	22.3
rank(22)	2008	23.7	rank(45)	1980	22.1
rank(23)	1995	23.7	rank(46)	1993	21.7

Application to 2018 Case study..
Compare to other hot summers

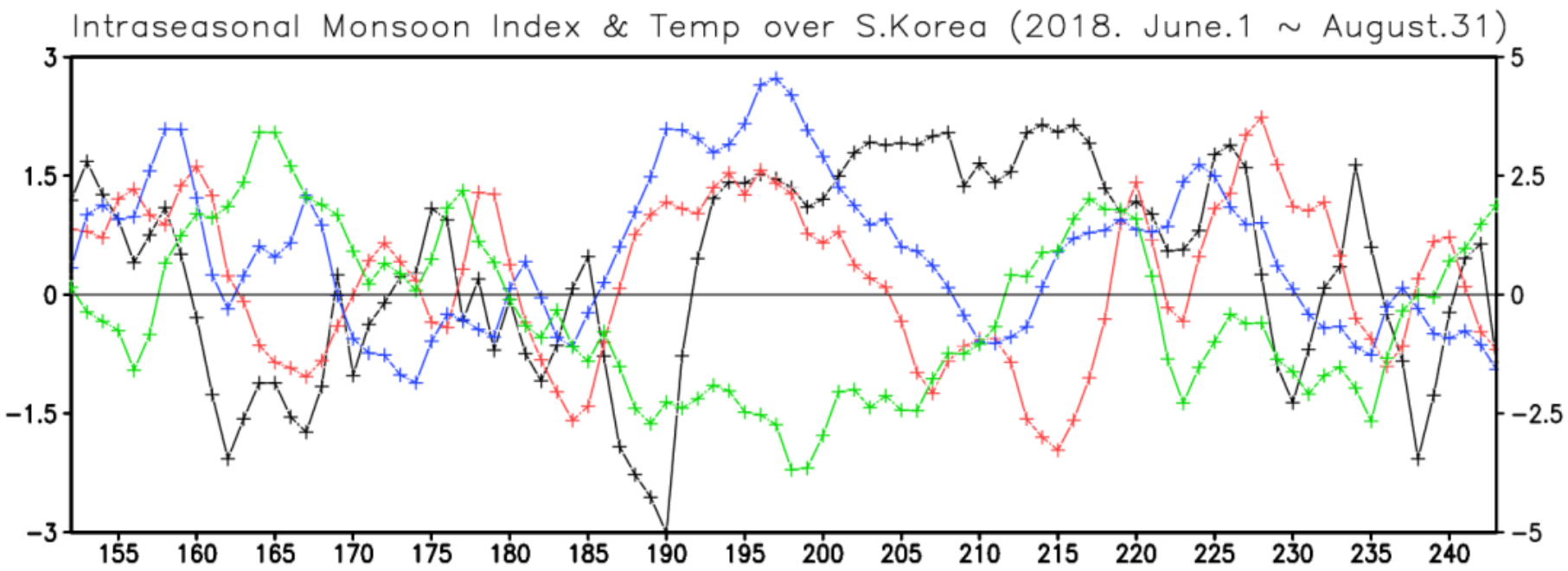
No 5-d mov

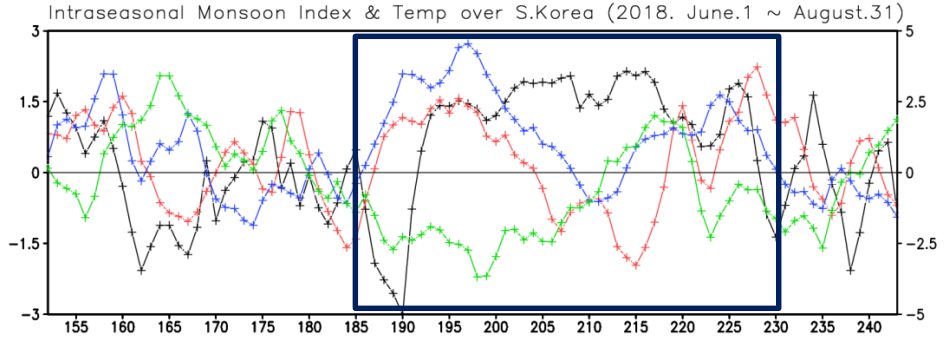
Mean structure different
1994: July
2018: Early August
2013, 2010 : Late August

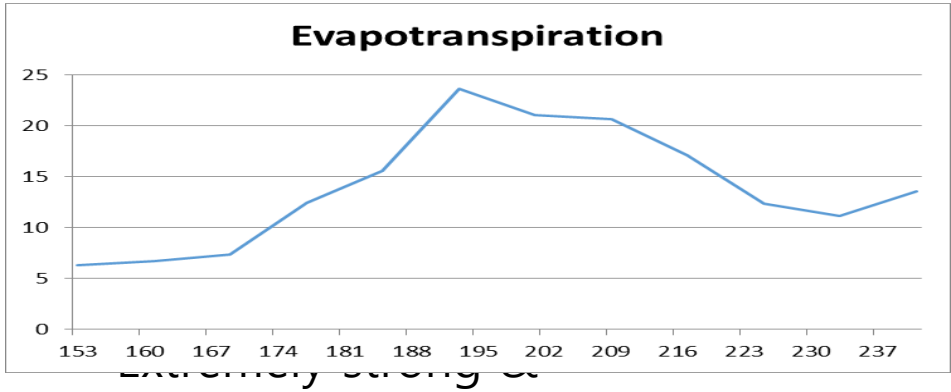
Intraseasonal ....
Duration
2013 > 1994 > 2018 > 2016 > 2010

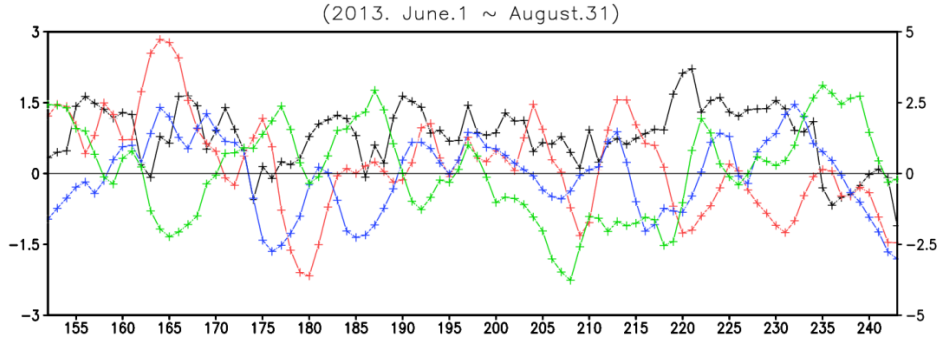


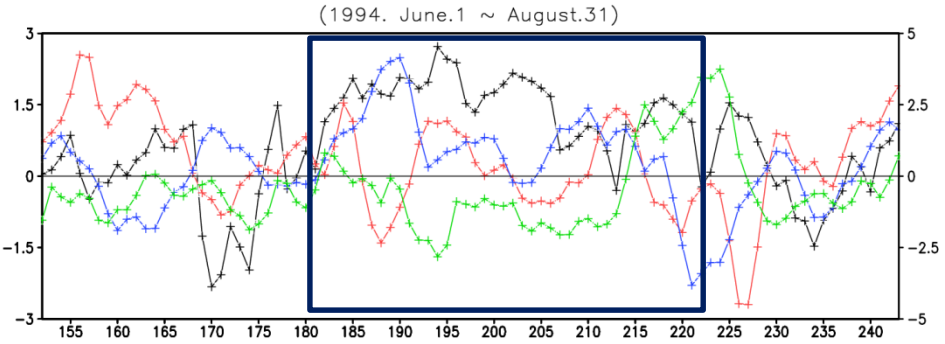
Application to 2018 Case study..
Compare to other hot summers

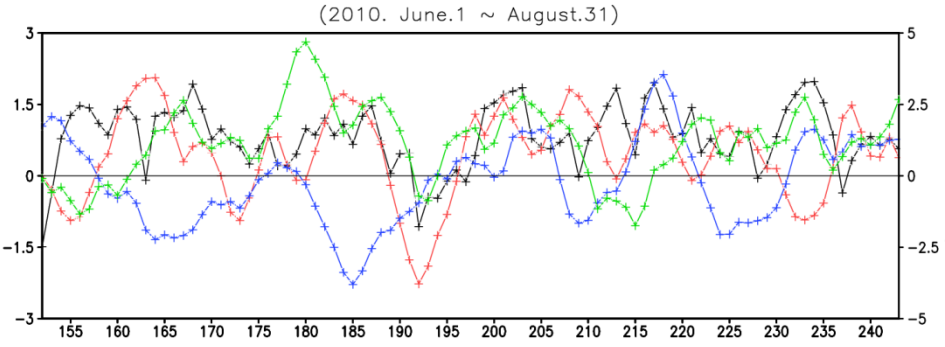


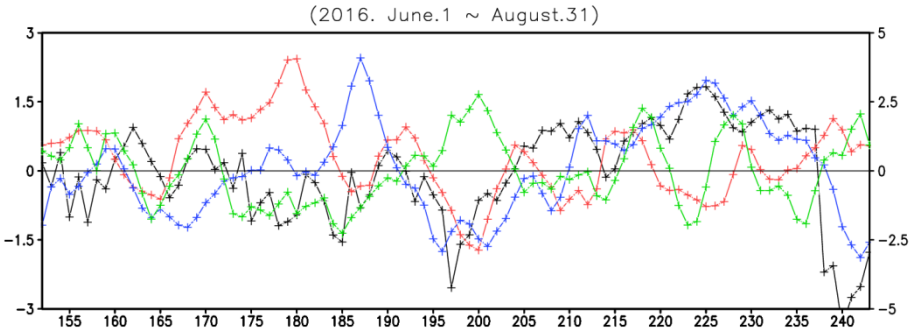












extended duration of Western North Pacific summer monsoon index during 2018 summer hot days !

Strong Indian summer monsoon index + WNPSMI

IBS Center
for Climate Physics

Recent trend in heat waves over east Asia and their potential causes

Kyung-Ja Ha[1*], Ye-Won Seo[1], Ji-Hye Yeo[1], Yang-Won Lee[2], Nari Kim[2] and Ye-Seol Yoon[2]
Pusan National University[1] , IBS Center for climate Physics (ICCP)[1*], Research Center for climate Sciences (RCCS)[1*], Pukyong National University[2]

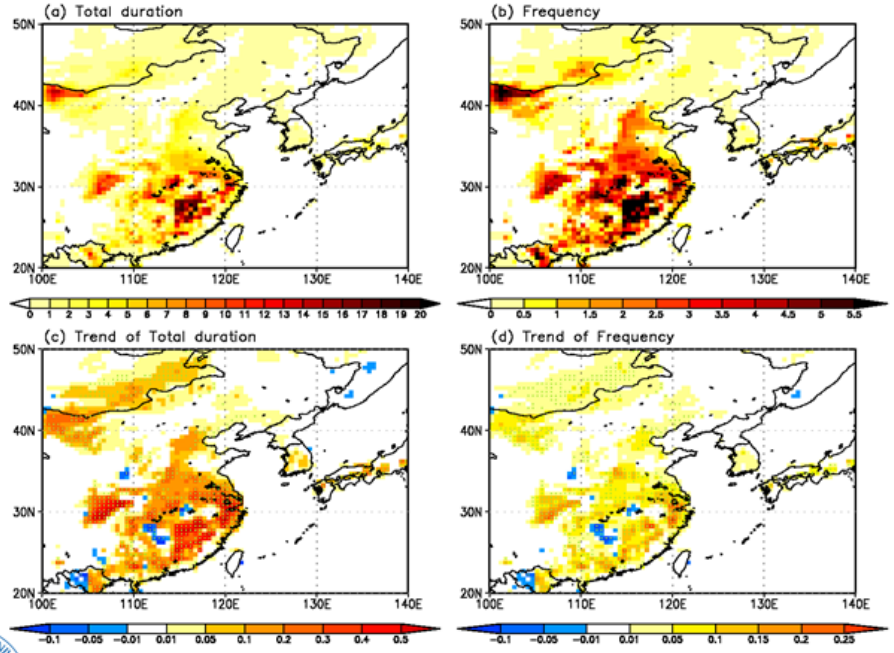
Oct. 30, 2018

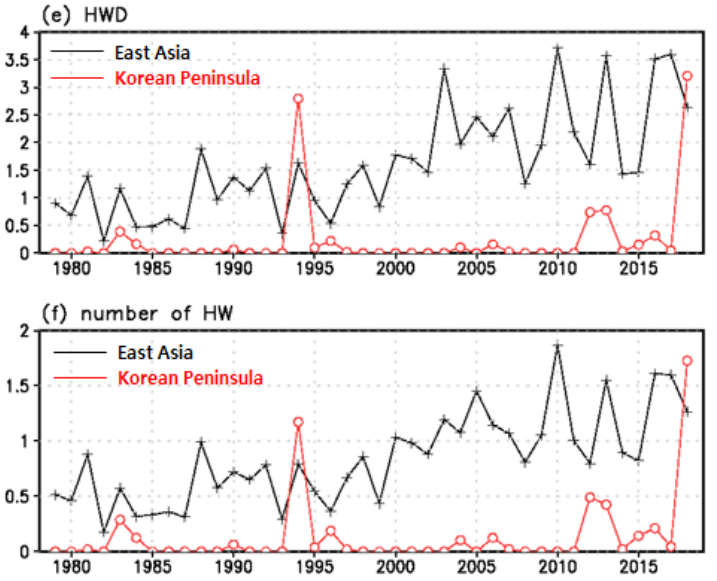
Heat waves

Heatwave definition

T_{max} ≥ 35 °C for ≥ 3 days from Jun-August (JJA)

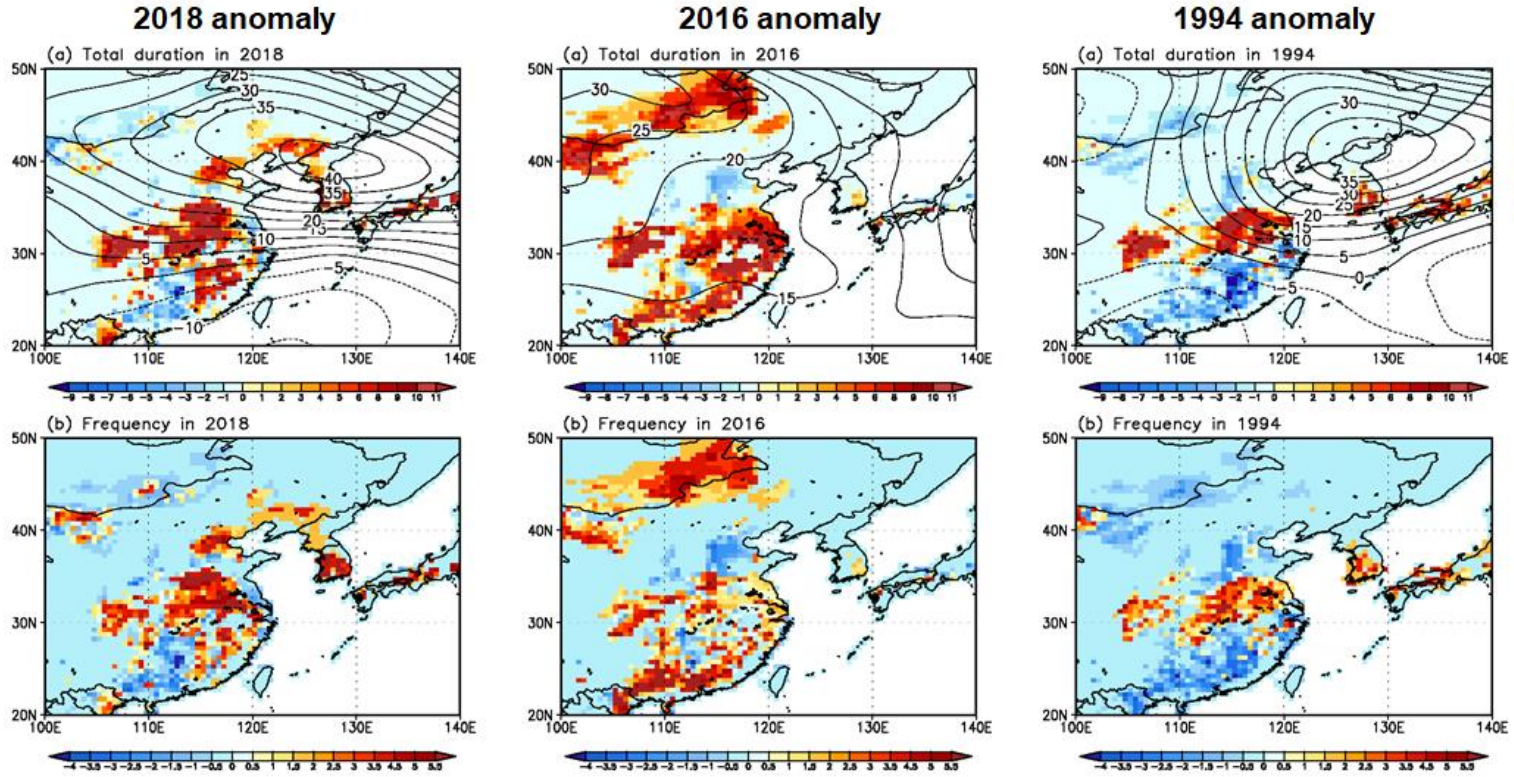
(Huang et al. (2010), Tong et al. (2010), Nitschke et al. (2011), Williams et al. (2012), Sun et al. (2014)





data : maximum temperature from CPC

Case of heat waves



Contour : geopotential height at 500 hPa anomaly at heat waves days (unit: gpm)

data : maximum temperature (CPC), geopotential height (ERA-INTERIM)

Conclusion

- 최근 extreme weather의 영향에 대한 중요성이 크게 대두되고, 이 중 Heat wave는 East Asia (EA)에서 증가추세에 있으며, 한국은 heat wave의 발생이 episodic하며 2018년이 1994년에 비하여 최고기온의 증가가 뚜렷함.

- 2016년은 EA에서 남과 북의 두 개의 강한 heat waves는 대륙성 고기압의 발달로 인한 것이며, 2018년과 1994년의 heat wave 사례는 한반도 북쪽으로 발달된 고기압 아노말리가 뚜렸하며 2018년에는 북쪽 고기압과 남쪽으로 발달된 저기압 아노말리에 의한 정체성을 가지는 Modon-like blocking의 요인을 메커니즘으로 볼 수 있음. 이러한 현상으로 2018년이 1994년에 비하여 지속성이 유지될 수 있었음.

- 특히, 2018년 7월의 증발산양은 평년대비 23.5mm 가 증가하면서 강수량은 평년대비 80% 감소하였으며, 이로 인하여 지표는 건조, 대기는 습윤한 환경을 조성함. 한반도에서는 6월~8월 동안 열대야 일수 (T_{min} < 25°)는 최대 35일, 폭염 일수 (T_{max} > 33°)는 최대 40일로 나타남. 수증기 효과와 열대야의 지속이 폭염일수가 이례적으로 지속되는데 영향을 미친 것으로 판단됨.