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Investigating Spatiotemporal Variation of Heatwave and its Association with Blocking in the Northeastern Asia

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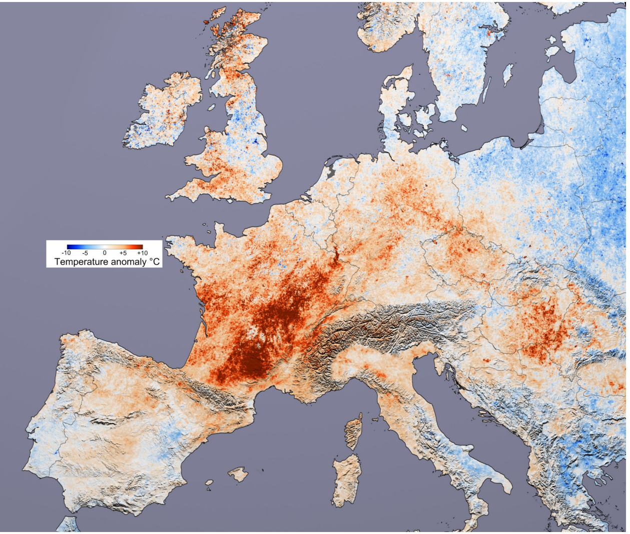
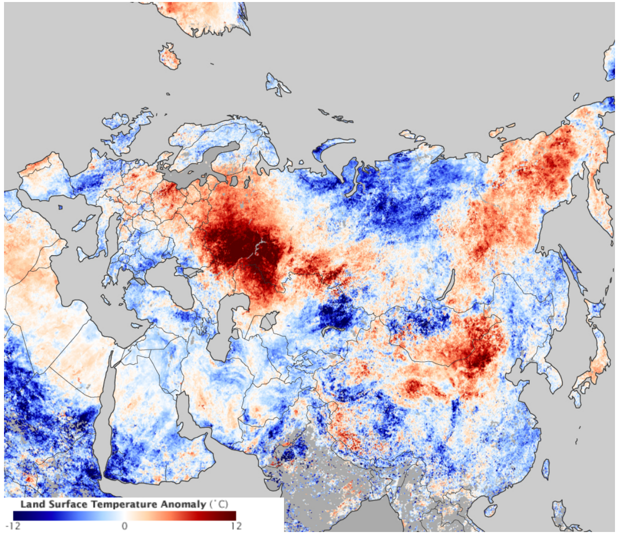
Motivation — *Impact of Heatwave*

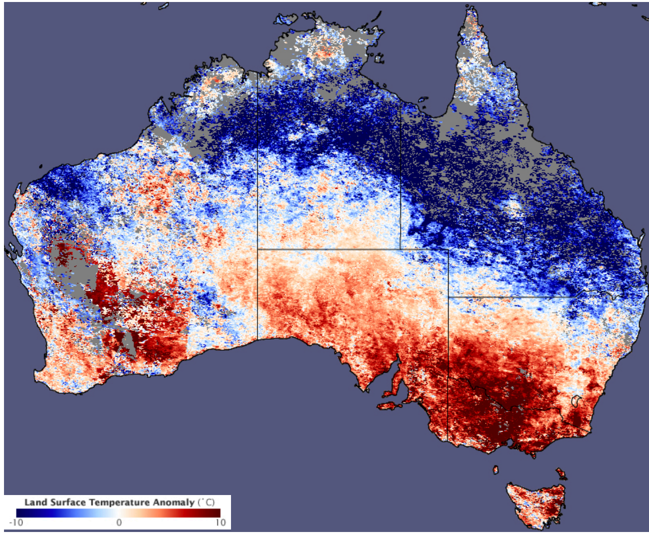
Human health | **Infrastructure** | **Ecosystems**



Western Europe, 2003
Death: 70000



Russian, 2010
Death: 54000

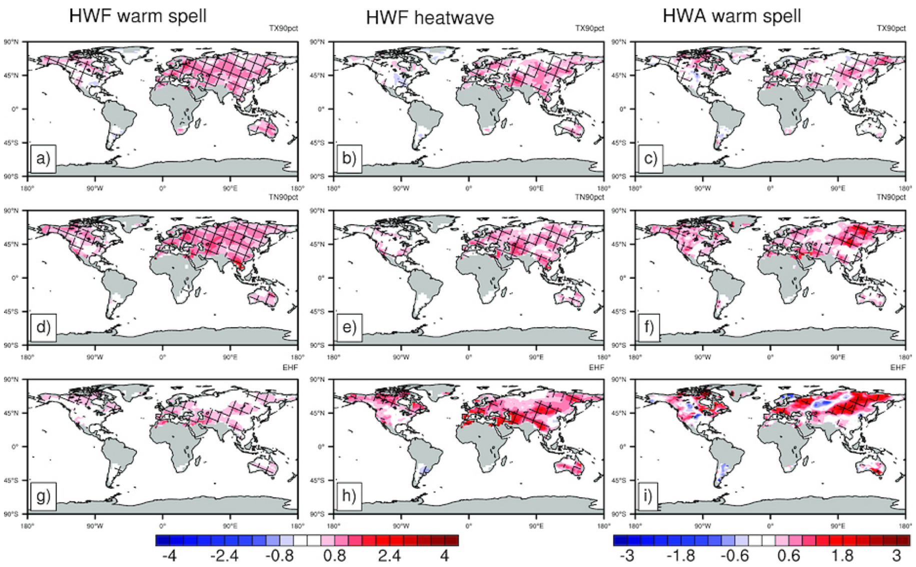


South Australia, 2009
Death: 374

Motivation — *Changes of Heatwave*

The increases in heatwave frequency, duration and intensity are extensively evidenced

(Frich et al., 2002; Alexander et al., 2006; Perkins et al., 2012; Perkins & Alexander, 2013; Steffen et al., 2014).

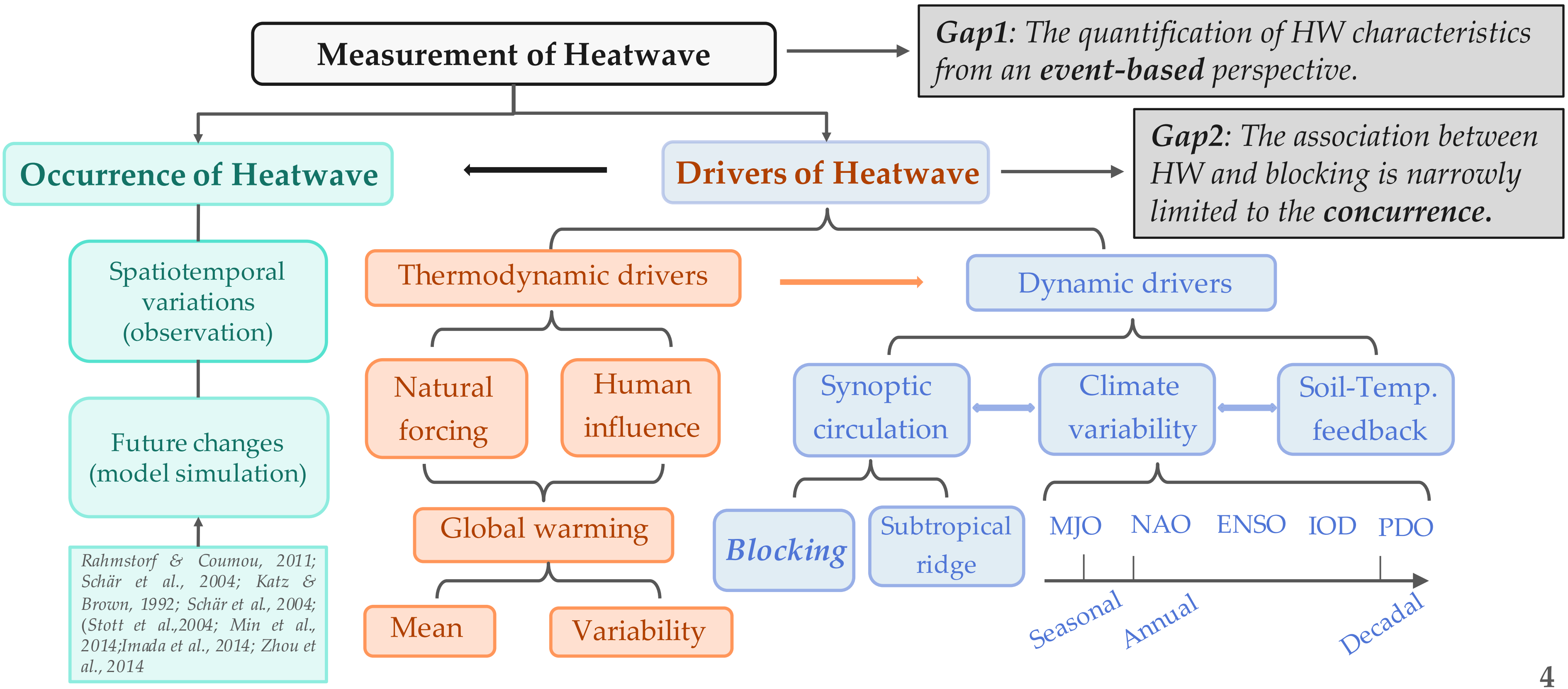


(Perkins et al., 2012)

- Global warming: + 0.95° compared to the mean of 20th century *(NOAA)*
- Mean shift **+** increasing variability of temperature *(Rahmstorf & Coumou, 2011; Schär et al., 2004; Katz & Brown, 1992; Schär et al., 2004)*
- Natural forcing **+ Human influence**

Increasing risk *(Stott et al.,2004; Min et al., 2014;Imada et al., 2014; Zhou et al., 2014)*

Research Focus & Gaps



Methods – *Heatwave Index*

- **Data**: CPC global air temperature data, 0.5°×0.5°, Observation
- **Study period**: 1979-2017
- **Study area**: 35°N–75°N, 70°E–160°E (Northeastern Asia)
- **HW index**: ≥ 3 days, when Tamax ≥ 90^{th} quantile of 15 moving-day;
- **Grid basis**: 0,1,0,0,1…

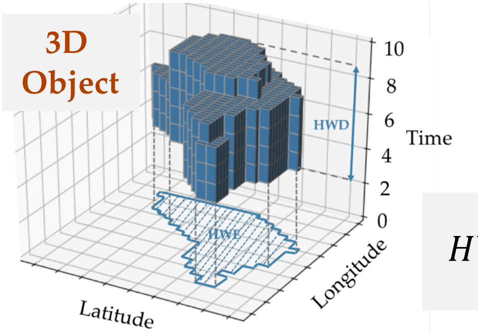
- **HW event identification**
  - Connectivity
  - Overlap ratio ≧ 0.4
  - At least 3 days.
  - HWD, HWE, HWV,HWI

T1

0	1	0
0	1	0
1	0	1

T2

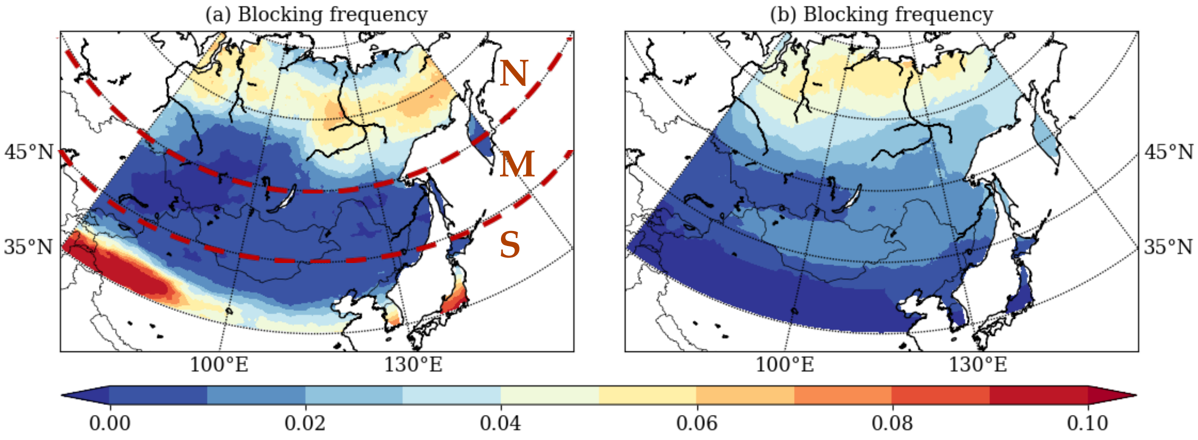
0	1	0
1	1	0
1	0	0



$$HWI = \frac{T_d - T_{15d90p}}{T_{15d75p} - T_{15d25p}}$$

Methods – *Blocking Index*

- **Two leading blocking indices:**
  - **TM index**: Meridional gradient of Z_{500} *(Tibaldi & Molteni,1990; Scherrer et al., 2006, 2-D TM90)*
  - **PV index**: Vertically (500-150hpa) averaged Potential Vorticity (PV) *(Schwierz et al., 2014; APV*)*



- **TM/PV index**: two/one high frequency bands

North region: 55° - 75°N
South region: 45°- 55°N
Middle region: 35°- 45°N

Methods – *Association Analysis*

1. Concurrent association between HW and blocking

- P(heatwave): JJA climatology of HW frequency;
- P(heatwave | blocking) : HW frequency under blocking days.

$$\boldsymbol{HWF_{anom}} = \frac{P(heatwave|blocking)}{P(heatwave)}$$

- Significant test: Monte Carlo test (0.05 level)
- Sensitivity test: Different thresholds for PV index, and TM index

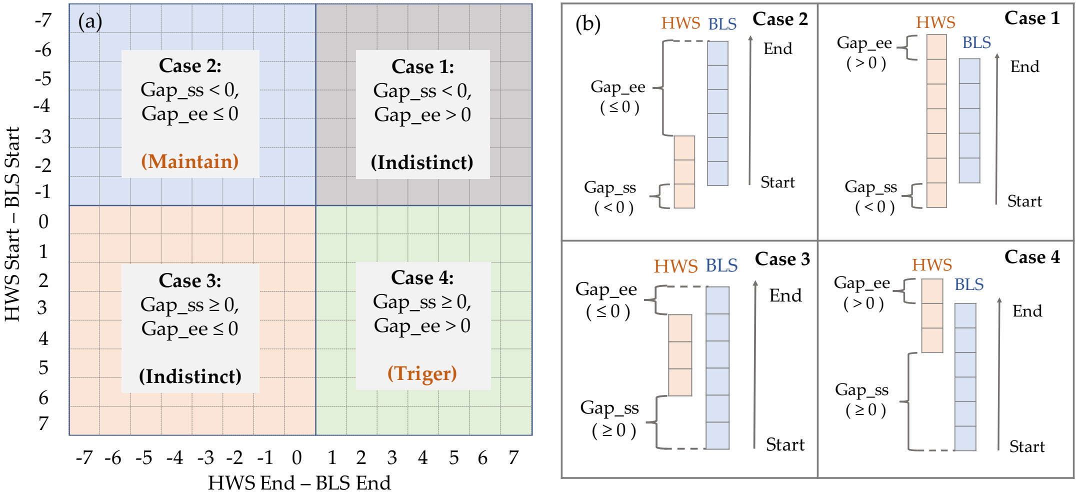
Methods – *Association Analysis*

2. Temporal association with time lags

- HWS/BLS: consecutive HW/BL days are grouped into one sequence (HWS/BLS)
- Gap_ss, Gap_ee: The gap between the start/end date of HWS and BLS

Cold extremes often occurs days after the onset of blocking (Buehler et al., 2011)

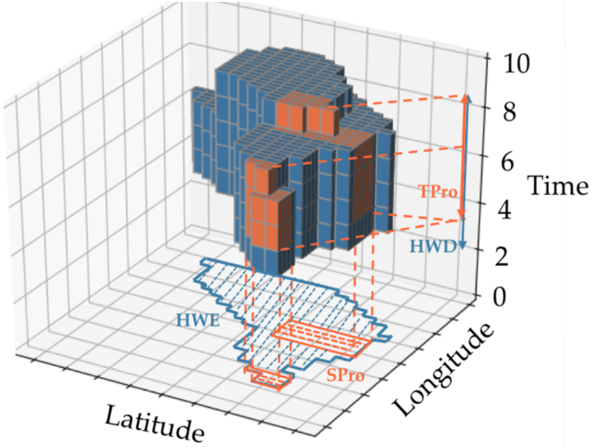
- Role of blocking: Triger? Maintain?



Methods – *Association Analysis*

3. Blocking impact on the characteristics of HW event

- Blocking related HW event **(BRH)** VS. unrelated HW event **(BURH)**
- **Ks test**: examine the significance of the difference between ECDFs



$$R_{HWD} = \frac{Tpro}{HWD},\ R_{HWE} = \frac{Spro}{HWE},$$
$$MDEOR = (R_{HWD} + R_{HWE})/2$$

(larger overlapped parts – larger MDEOR)

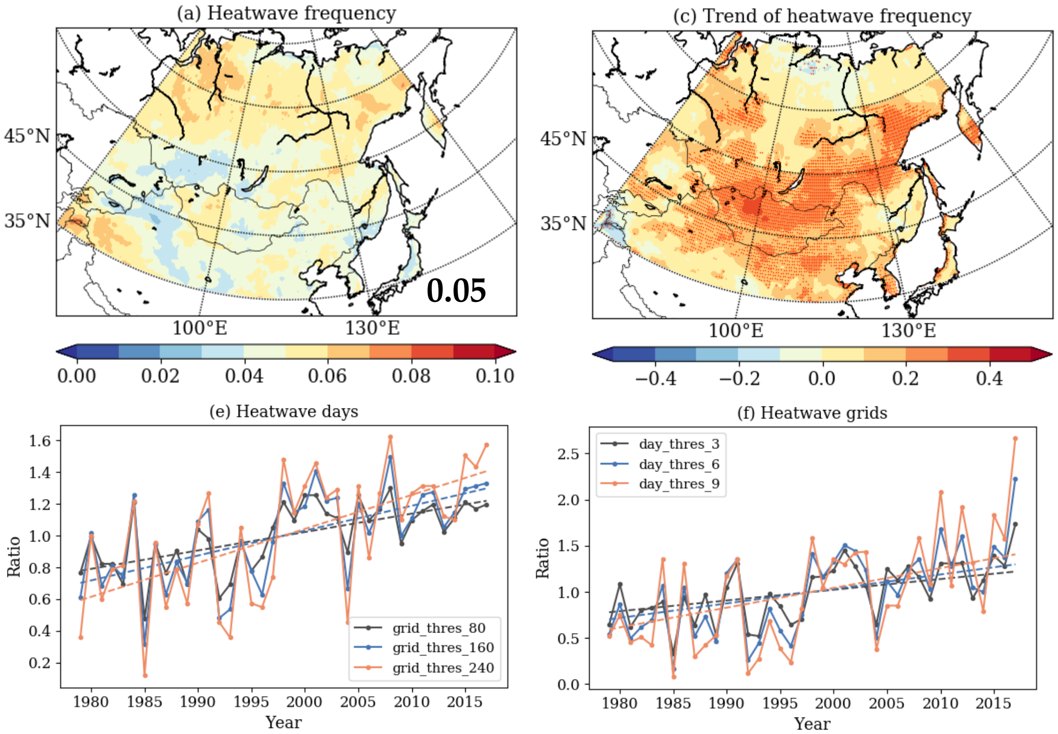
BRH: MDEOR > Rx

BURH: MDEOR ≤ Rx

Rx: 0, 0.2, 0.4, 0.6, 0.8

Results – *Increase of Heatwave*

Increase in heatwave occurrence based on both grid and event bases.



- **Grid basis:**
  - Increasing trend for HWDys at almost all grids
- **Event basis**: (connectivity)
  - Persistent, extensive and intense heatwave events have become more frequent

Results – *Increase of Heatwave*

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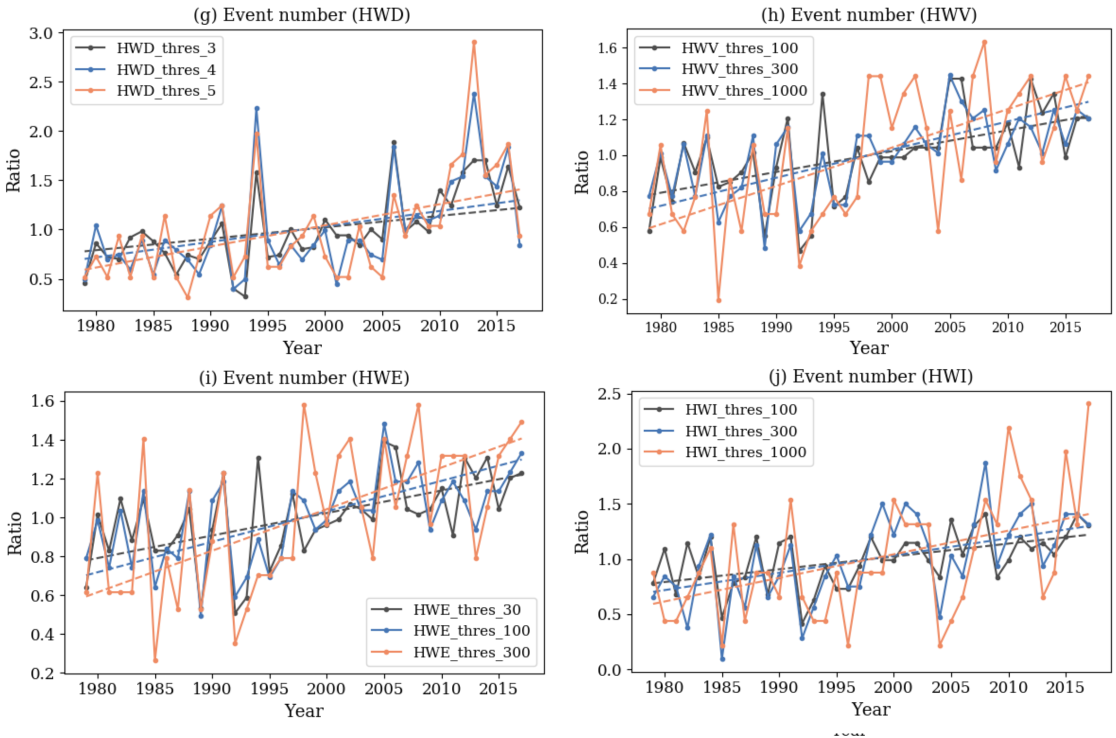

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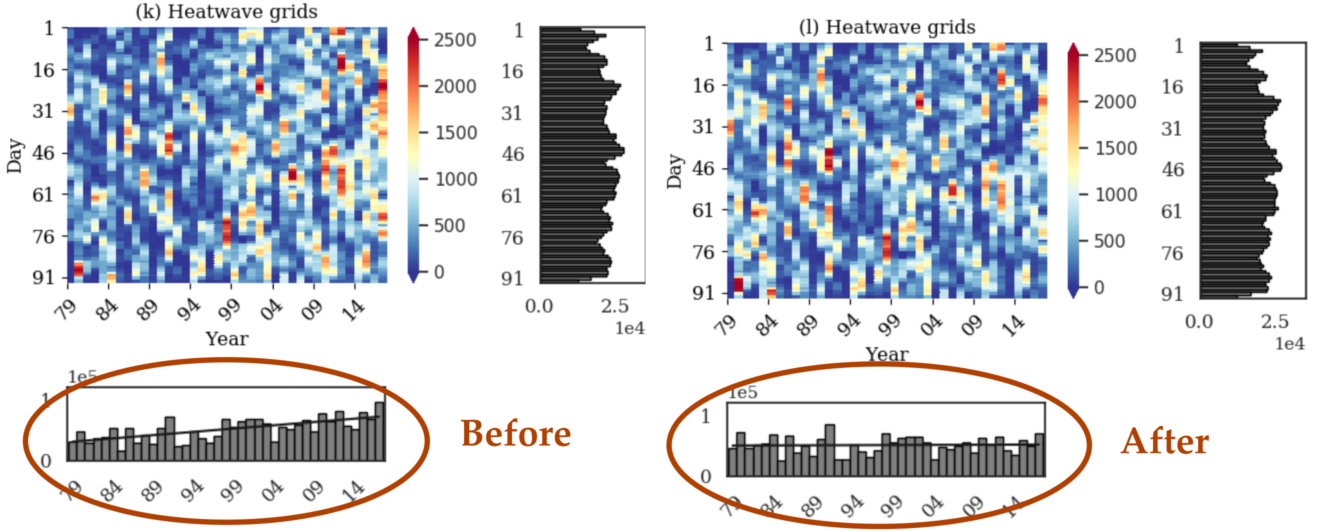
Results – *Role of Global Warming*

The increase of HW occurrence is highly correlated with global warming.

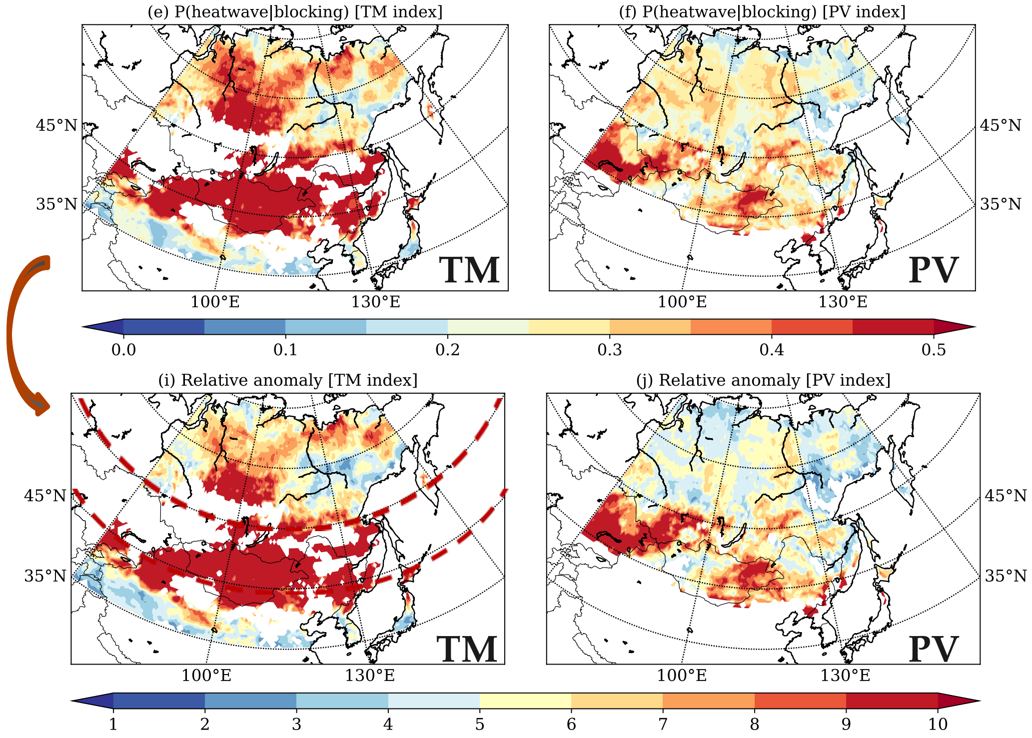


The number of HW grids before/ after remove the trend of TMP at each grid

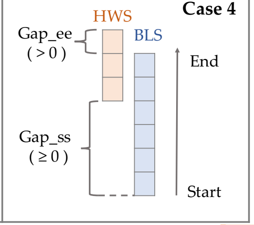
- **Before**
  - Increasing trend
- **After**
  - No trend
  - Highly correlated

Results – *Concurrent Association*

Concurrence: blocking favors the occurrence of HW.

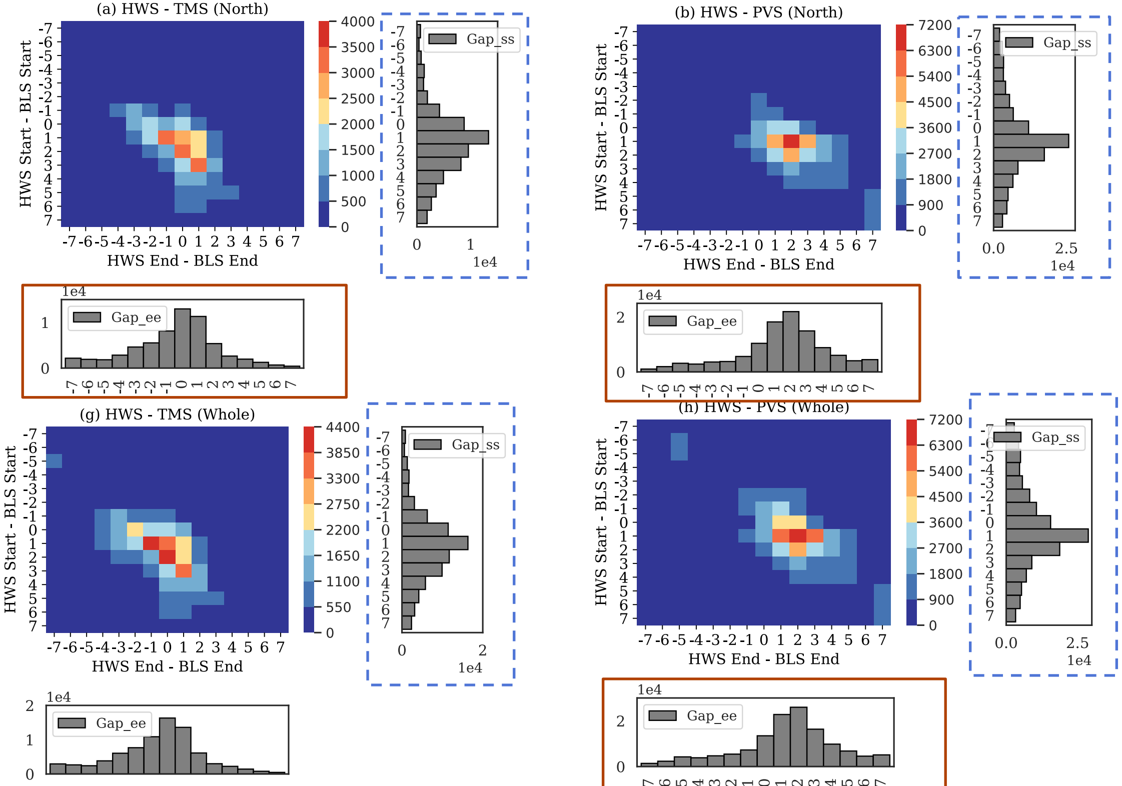


- ✓ **P(heatwave | blocking) > 0.3 VS. P(heatwave) < 0.1** – blocking **favors** the occurrence of HW
- ✓ $HWF_{anom} = \frac{P(heatwave|blocking)}{P(heatwave)}$
  - North: 7 (TM), 5 (PV)
  - South: 3 (TM), no blocking (PV)
  - Middle: barely no blocking
- ✓ **TM index**: stronger concurrence



Results – *Temporal Association*

Blocking is more necessary to trigger HW than maintain it.



- **North region**
  - Gap_ee/Gap_ss
    Negatively skewed
- **Whole region**
  - Gap_ss
    Negatively skewed
  - HW starts/ends no earlier than blocking.

Results – *Temporal Association*

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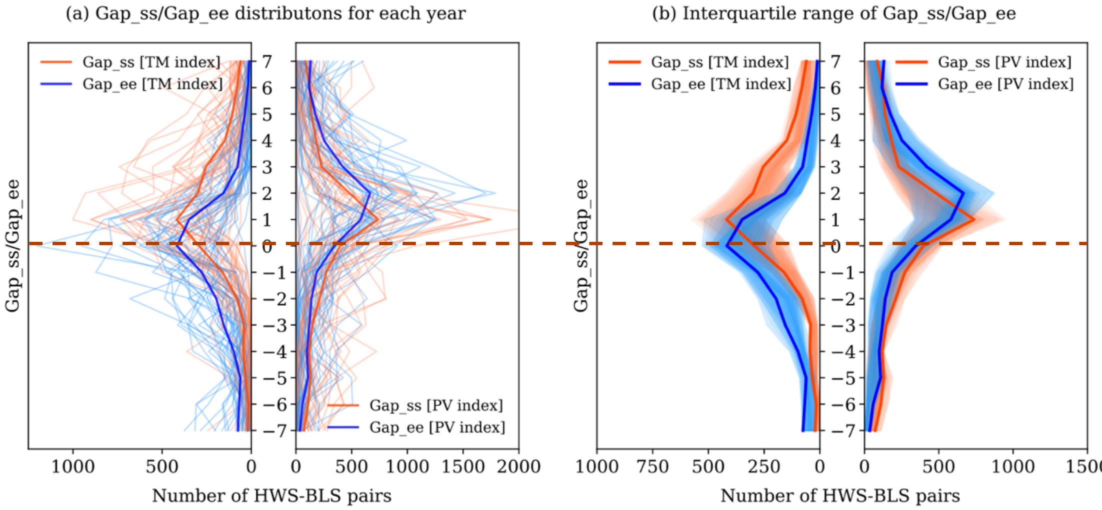
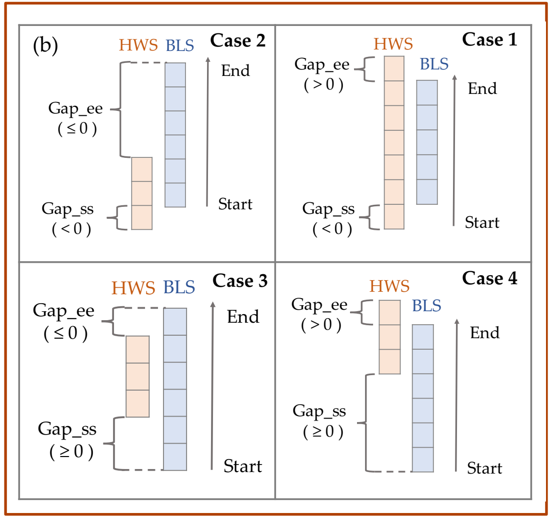


- Variability of Gap_ss/Gap_ee
  - Whole region
  - ✓ Year-to-year variability
  - ✓ HW starts/ends no earlier than blocking
  - ✓ Narrow interquartile range (IQR)

Results – *Temporal Association*

Blocking is more necessary to trigger HW than maintain it.

Pair Type	Sub-region	Case 1	Case 2	Case 3	Case 4
HWS-PVS	North	8617	19607	12826	**69971**
	Middle	4155	7079	1792	**7175**
	South	640	**1284**	89	799
	Total	13412	27970	14644	**77945**
HWS-TMS	North	1023	9578	**30359**	22583
	Middle	306	1065	**1121**	1091
	South	224	3283	**7325**	2407
	Total	1553	13926	**38805**	26081



Results – *Temporal Association*

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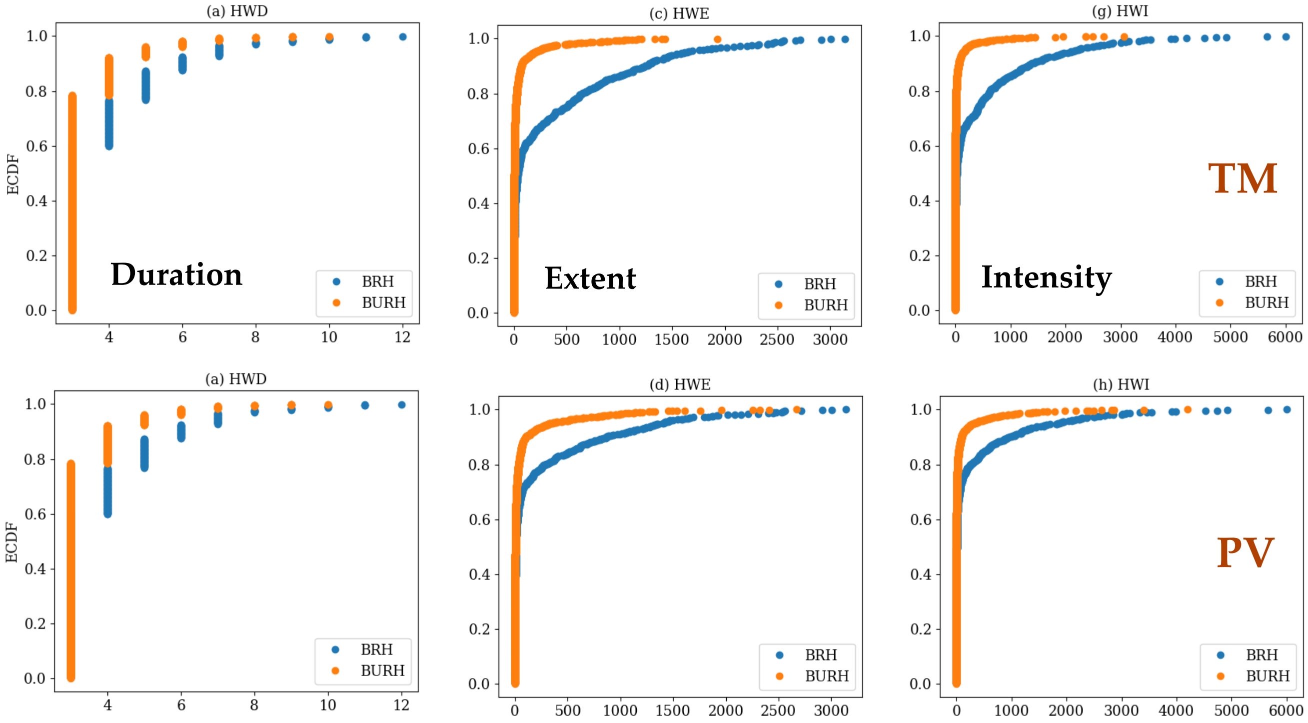
- For **HWS-PVS**:
  - Case 4 is the dominant
- For **HWS-TMS**
  - Case 3
  - Case 4 outnumbers the other cases

Results – *Blocking Impact on HW Events*

BRH, more likely to be persistent, extensive and intense



- North, MDEOR ≧ 0.2

✓ **Significant** difference ($P < 0.05$)

✓ **Robust**, with different MDEOR thresholds, three sub-regions

Conclusions

1) Persistent, extensive and intense HW has become more frequent in the Northeastern Asia, especially those associated with blocking.

2) Blocking favors heatwave occurrence based on both indices. And TM-based blocking exhibits stronger concurrence with HW.

3) Blocking is more of a favorable environmental condition to trigger heatwave than maintain it.

Thank you for your attention!