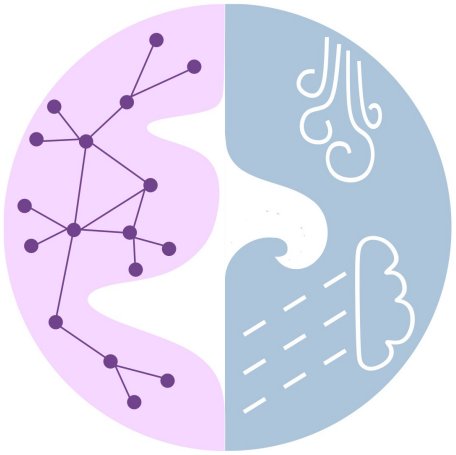

machine learning in climate science

Collaborative impact of the NAO and atmospheric blocking on European heatwaves, with a focus on the hot summer of 2018

Julia Hellmig

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LETTER

Collaborative impact of the NAO and atmospheric blocking on European heatwaves, with a focus on the hot summer of 2018

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NAO and Atmospheric Blocking

1

- What is the NAO and Atmospheric Blocking?
- What are their interconnections?

Research Question, Data and Methods

2

- Research Question
- Data
- Methods

Results

3

- Summer heatwave 2018
- MSAT anomalies
- Geopotential height anomalies
- Evolution of the EB
- Wind anomalies

Discussion and Summary

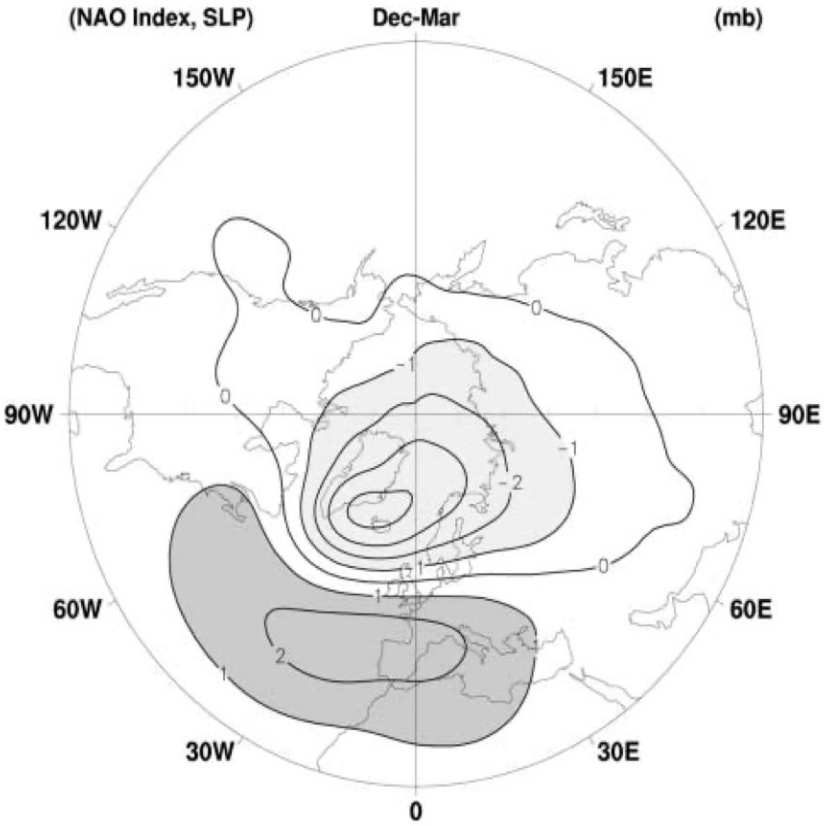
4

- Conclusion
- My take home message

Outline

North Atlantic Oscillation (NAO)

- Pressure difference between the icelandic low and the azores high
- Positive NAO: large difference in pressure
- Negative NAO: small difference in pressure



Stochastic Environmental Research and Risk Assessment, R.J.Greatbatch, 2000, Springer Verlag

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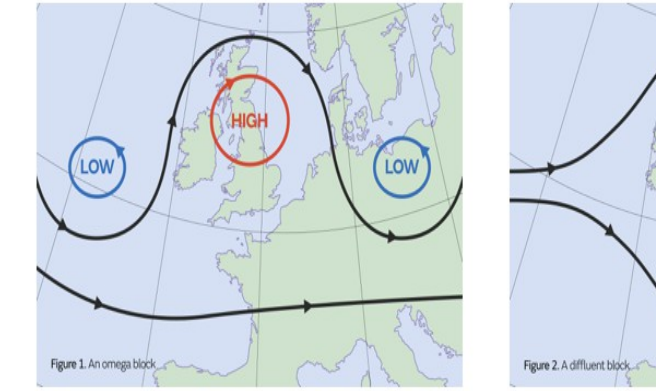
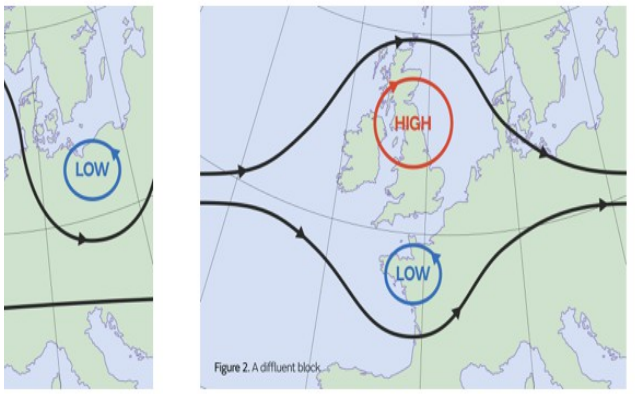
Atmospheric Blocking

- Nearly stationary atmospheric fields of high pressure
- Cause the area of the block to have the same kind of weather for a longer period of time
- Blocking events are a main cause for heatwaves in europe





Taken from: https://uip.primavera-h2020.eu/storymaps/atmospheric-blockings

Interplay between Atmospheric Blocking, heatwaves and NAO

- Summer heatwaves over Europe are closely related to blocking events
- NAO^+ events favour the occurrence of European blocking (EB) events
- NAO^+ related EB events are stronger and more persistent
- NAO^+ related EB events cause long lived extreme cold events in winter

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Research Question

- To what extend was the summer heatwave of 2018 related to atmospheric blocking over Europe?
- Does the NAO^+ related atmospheric blocking affect characteristics of summer heatwaves in Europe?

Data

- Daily maximal surface air temperature (MSAT) and daily precipitation
- Between 1979 and 2018, summer, over Europe
- Historical simulations generated from 15 different CMIP6 models

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Methods

Blocking:

- detection method of Tibaldi and Molteni
- Blocking event is considered related to an NAO^+ event if the lag 0 day of the EB lies within the lifetime of an NAO^+ event

NAO index:

- obtained from the National Oceanic and Atmospheric Administration/ Climate Prediction Center

Heatwaves:

- land only, MSATI (MSAT index) anomalies
- A heatwave is defined if the MSATI exceeds the 90^{th} percentile for at least three consecutive days

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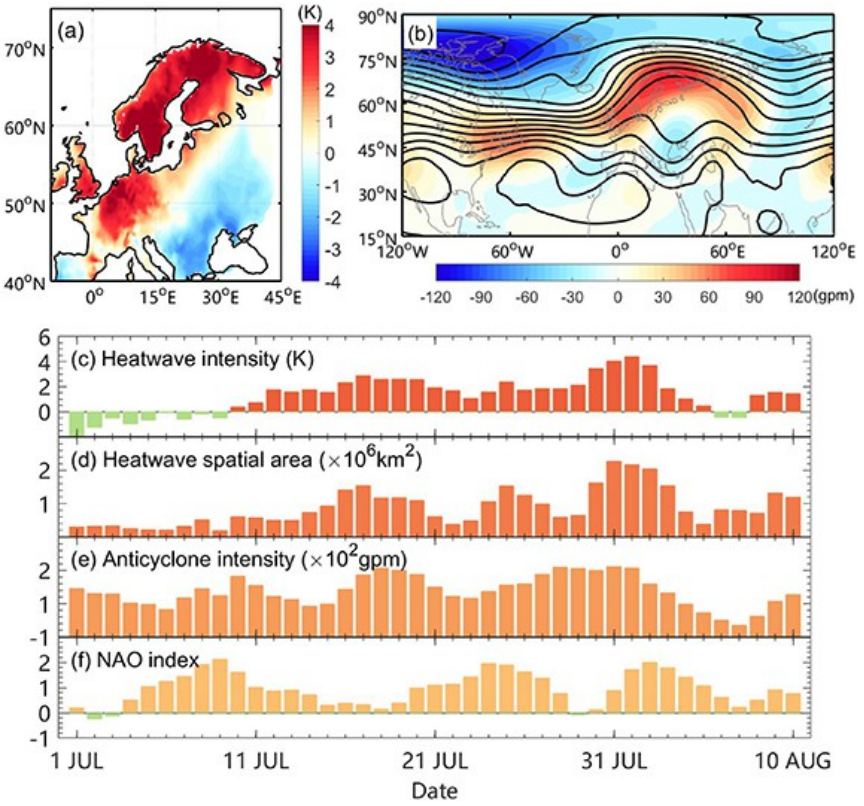
Analysis of the 2018 summer heatwave over Europe:

- Two heatwaves
- One blocking event
- Three NAO$^+$ events
-



Analysis of EB and NAO$^+$ events from data between 1979 and 2018 (and CMIP 6 model data)

Table 1. Number of NAO$^+$-related EB events, NAO$^+$-unrelated EB events and NAO$^+$ events without EB, and characteristics (number, frequency, average lifetime, average spatial area, and average intensity) of related heatwaves derived from E-OBS 19.0. (These numbers are expressed as events per decade.) The frequency of heatwave refers to the possibility of a heatwave when a NAO$^+$/EB event occurs. The comparable numbers for the mean of the CMIP6 historical simulations are presented in parentheses. The periods covered are 1979–2018 and 1980–2010 for E-OBS 19.0. and CMIP6 historical simulations, respectively.

	NAO$^+$ events without EB	NAO$^+$-unrelated EB events	NAO$^+$-related EB events
Number of NAO$^+$/EB events (/decade)	17.00 (18.95)	20.50 (15.46)	8.25 (7.20)
Number of heatwaves (/decade)	2.25 (1.85)	4.75 (4.88)	3.75 (2.86)
Frequency of heatwaves	13.24% (9.76%)	23.17% (31.57%)	45.45% (39.72%)
Average lifetime of heatwaves (days)	4.33 (5.00)	5.00 (5.59)	6.87 (6.90)
Average spatial area of heatwaves (10^6 km^2)	1.77 (2.10)	1.95 (2.30)	1.97 (2.32)
Average intensity of heatwaves (K)	3.04 (2.78)	3.38 (3.01)	3.64 (3.27)

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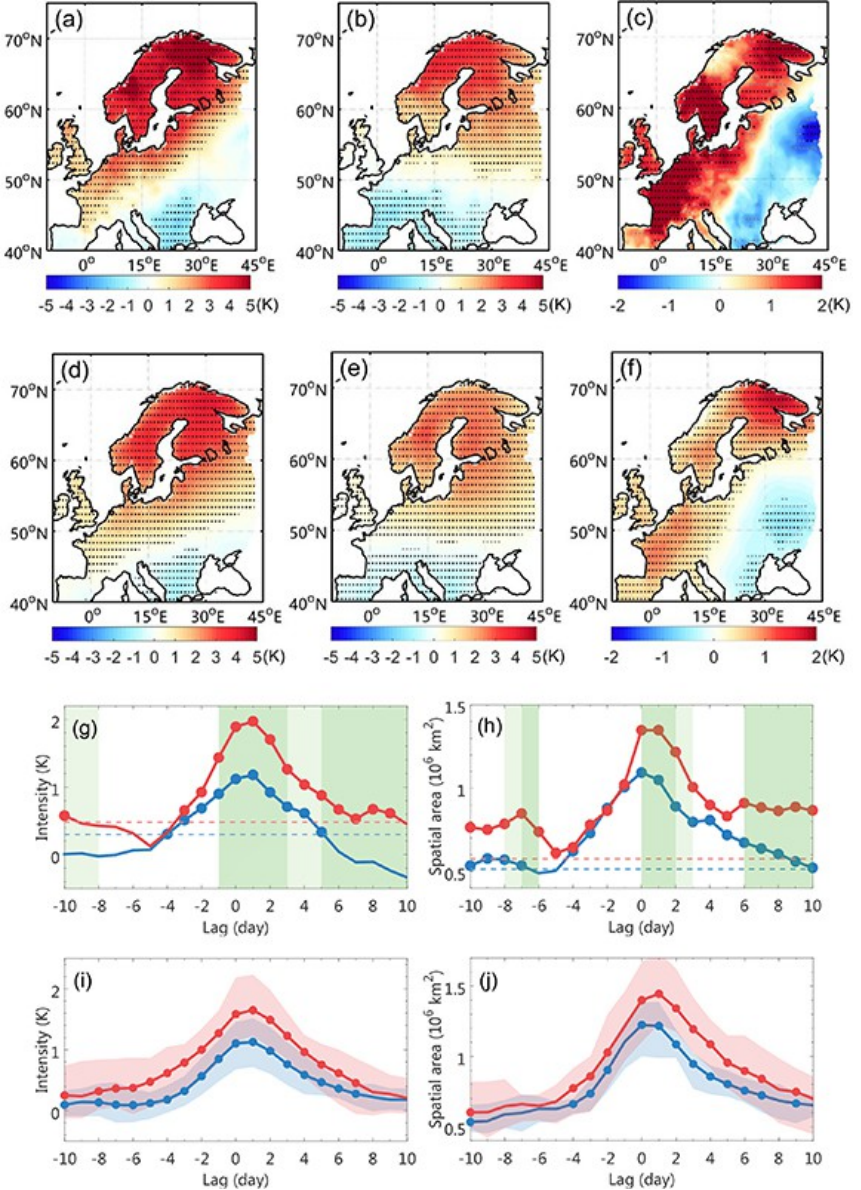
MSAT anomalies on Lag 0 day

- Spatial distribution and intensity differs between NAO⁺ related and unrelated EB heatwaves
- NAO⁺ related EB events cause north-west heatwaves
- NAO⁺ unrelated EB events cause north-east heatwaves
- NAO⁺ related EB event heatwaves have higher intensitives and are larger



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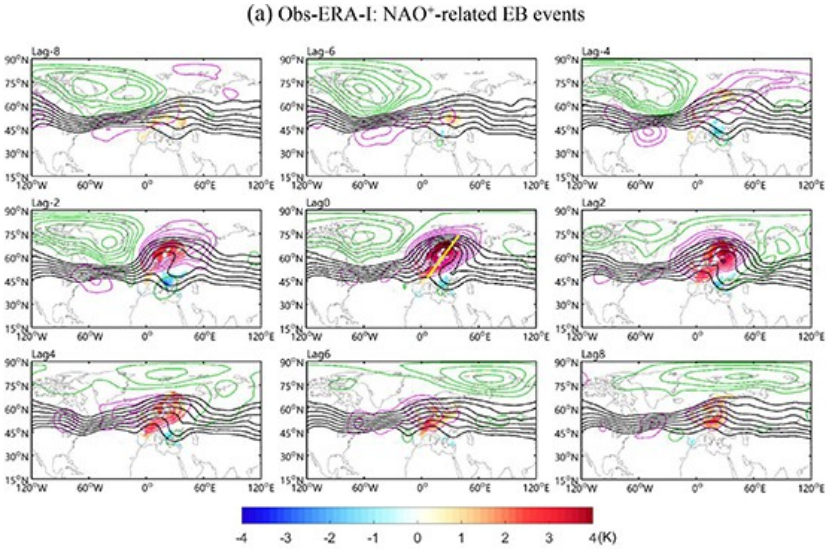
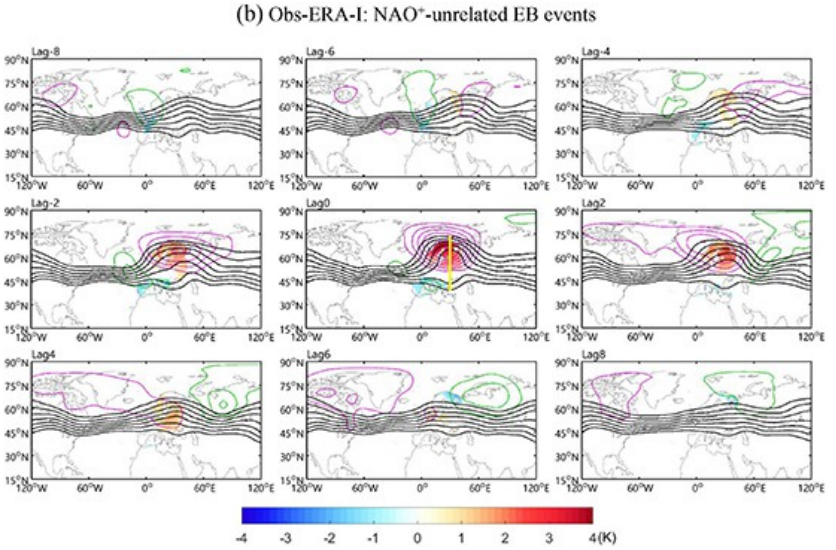
Geopotential height anomalies from lag -8 day to lag 8 day for observed data

- EB tilt to the south west for NAO+ related EB events
- No tilt for NAO+ unrelated EB events





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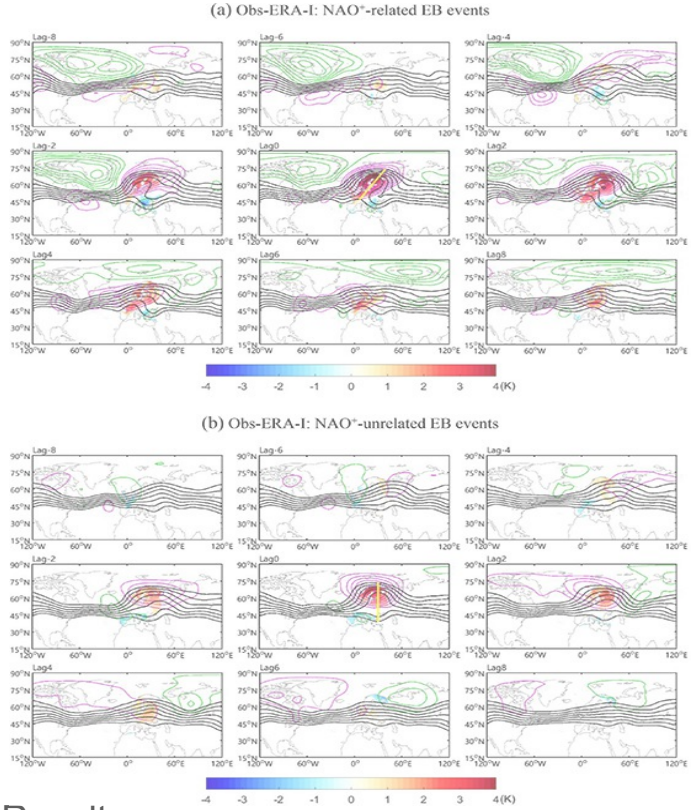
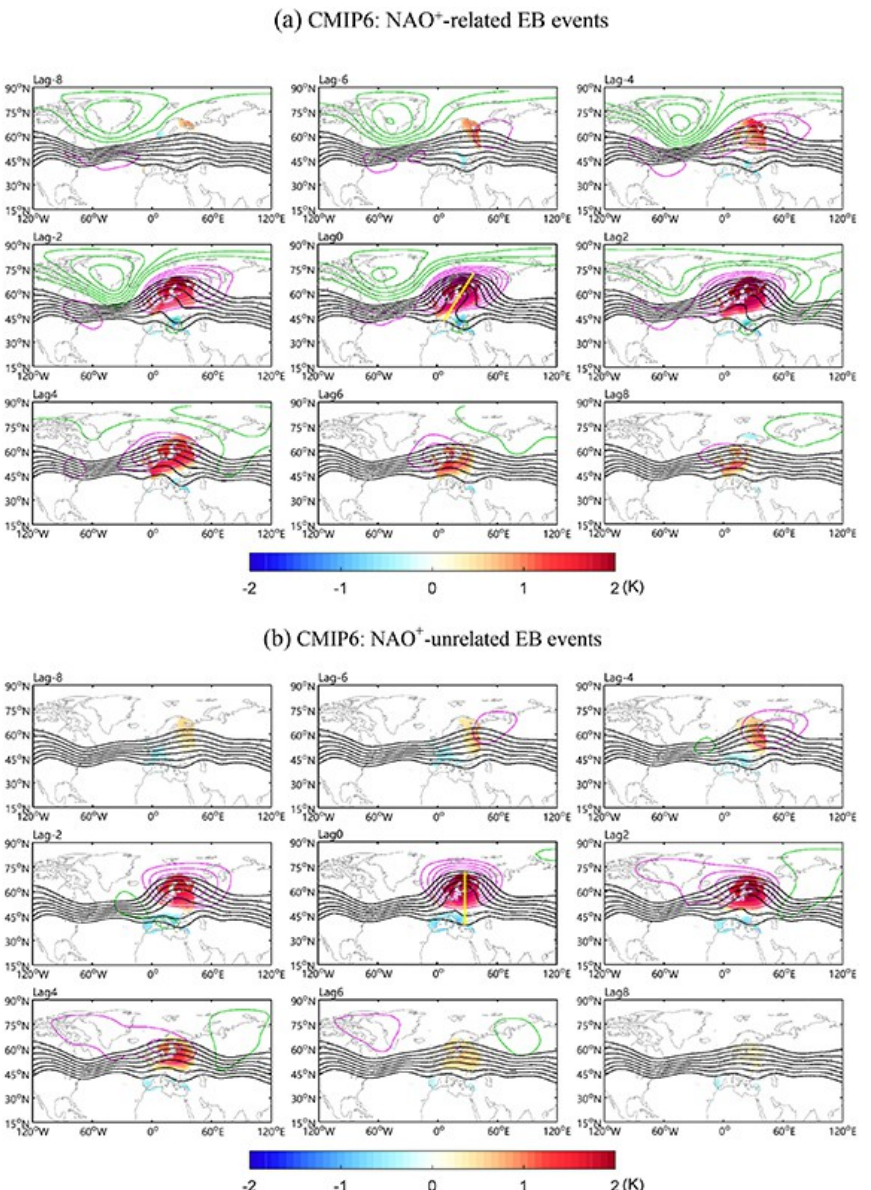
Geopotential height anomalies from lag -8 day to lag 8 day for model data





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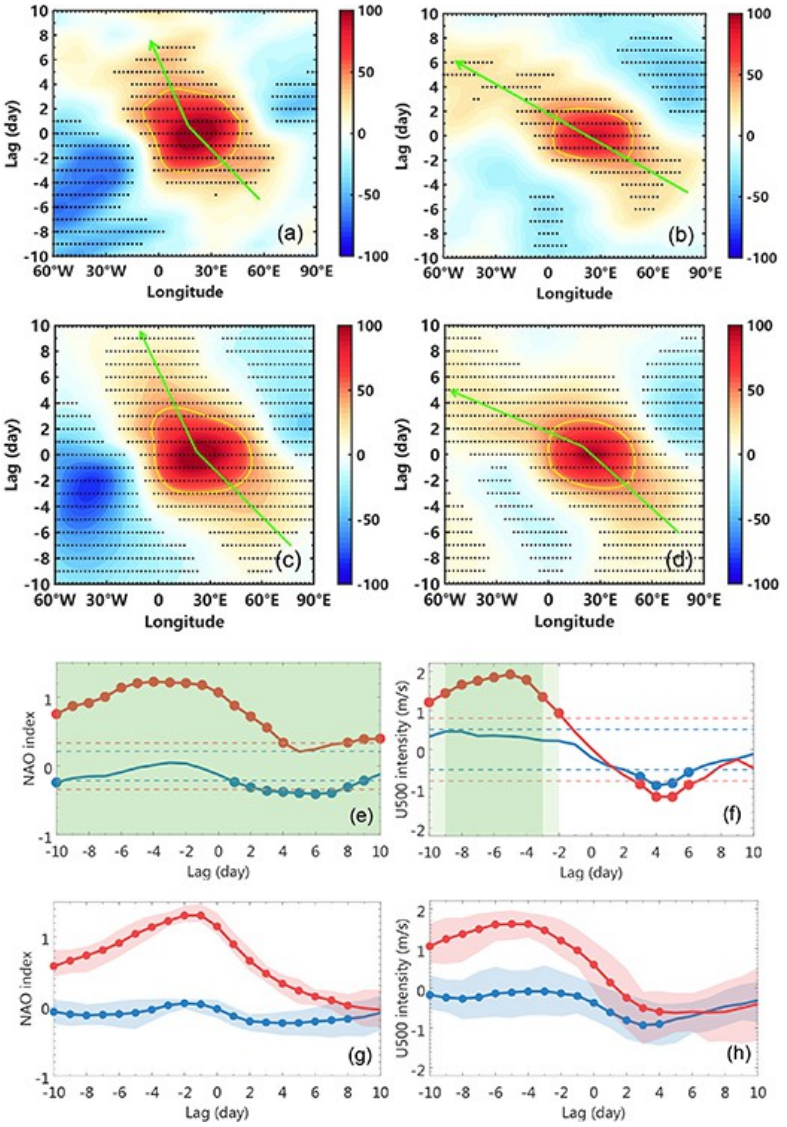
Time-longitude evolution of geopotential height anomalies

- EB event associated with NAO⁺ event persists longer than NAO⁺ unrelated EB event
- Travelling speed of NAO⁺ related EB events is slower than of NAO⁺ unrelated EB events



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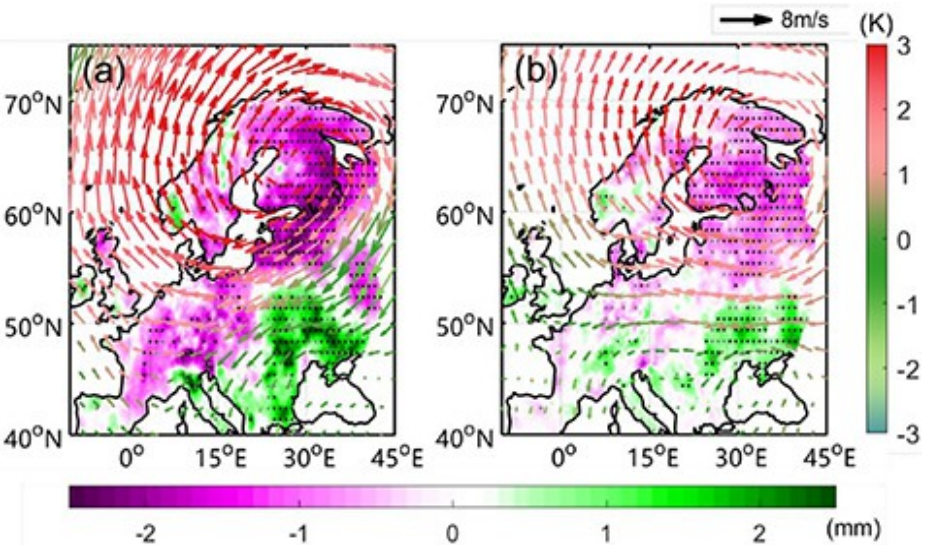
Wind and precipitation anomalies at lag 0 day

- Tilted EB events cause southerly winds to the west
- Stronger precipitation anomalies during NAO^+ related EB events



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Conclusion

- Heatwave of 2018 is associated with a atmospheric blocking event and three NAO^+ events
- NAO^+ patterns upstream of an atmospheric blocking event have influences on the
  - Shape
  - Intensity
  - Duration of heatwaves

Personal Take Home Message

- Heatwaves are caused by different atmospheric phenomena depending on the spatial location
- Different atmospheric events are all somehow connected to each other and influence each other

Literature

Muyuan Li *et al* 2020 *Environ. Res. Lett.* **15** 114003

R.J.Greatbatch, The North Atlantic Oscillation in Stochastic Environmental Research and Risk Assessment, 2000, Springer Verlag

Tibaldi and Molteni Index

- One dimensional blocks
- Blocking event: More than five contigous meridian lines are blocked for a day and this consists for at least three days
- Z500 = geopotential height

$$GHGS = \frac{Z500(\varphi_0) - Z500(\varphi_S)}{\varphi_0 - \varphi_S},$$

$$GHGN = \frac{Z500(\varphi_N) - Z500(\varphi_0)}{\varphi_N - \varphi_0}.$$

where $\varphi_N = 80°\mathrm{N} + \Delta$, $\varphi_S = 40°\mathrm{N} + \Delta$, and $\varphi_0 = 60°\mathrm{N} + \Delta$, and $\Delta = -5°, 0°$ or $5°$. If $GHGS > 0$ and $GHGN < -10$ gpm (deg. lat.)$^{-1}$ for any one of the three values of , blocking is defined to have happened at this longitude.

Model	EB events	NAO^+ events	NAO^+-related EB events	NAO^+-unrelated EB events	NAO^+ events without EB
ACCESS-CM2	52	80	22	30	60
BCC-CSM2-MR	87	73	27	60	49
BCC-ESM1	60	84	19	41	68
CanESM5	69	75	23	46	55
CESM2	68	82	23	45	61
CESM2-WACCM	61	75	20	41	56
EC-Earth3	68	77	23	45	54
FGOALS-g3	83	75	22	61	55
GEDL-CM4	86	78	26	60	49
IPSL-CM6A-LR	86	79	25	61	56
MIROC6	82	81	26	56	57
MPI-ESM1-2-HR	72	79	20	52	60
MPI-ESM1-2-LR	45	89	14	31	76
MRI-ESM2-0	84	86	28	56	59
NorESM2-MM	51	85	17	34	66
Average number of all the models	70.27	79.87	22.33	47.93	58.73