GEFÖRDERT VOM

FONA Research for sustainability

CLIMXTREME Climate Change and Extreme Events

Bundesministerium für Bildung und Forschung

POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

EGU General Assembly 2021

Session CL4.19 | Dynamics of the atmospheric circulation in past, present and future climates, 29.04.2021

Increased frequency of Eurasian double jets linked to summer heat extremes in Europe

Efi Rousi[1], Kai Kornhuber[2,3], Goratz Beobide Arsuaga[4,5], Fei Luo[6], Dim Coumou[6,7,1]

1 Potsdam Institute for Climate Impact Research
2 Earth Institute, Columbia University, New York, US 3 Lamont-Doherty Earth observatory, Columbia University, New York, US
4 International Max Planck Research School 5 Universität Hamburg
6 IVM-Institute for Environmental Studies, Free University of Amsterdam, Netherlands 7 Royal Netherlands Meteorological Institute (KNMI), De Bilt, Netherlands

Efi Rousi: rousi@pik-potsdam.de

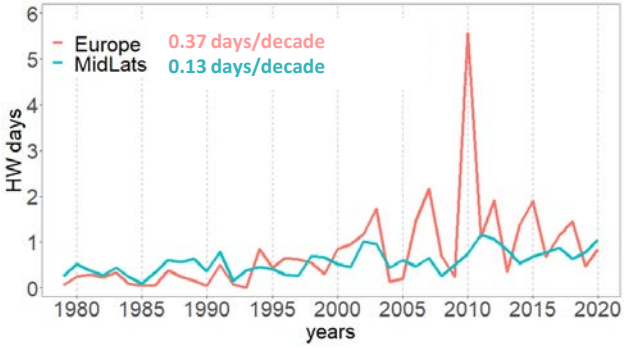
@syn_efou

Introduction - Motivation

- In recent decades Europe has faced an increase in devastating heatwaves, which is faster than in the rest of the midlatitudes. Why is that?
- Thermodynamic factors are important, but what is the contribution of large-scale atmosphere dynamics in summer?

→ Our hypothesis is that high latitude warming and decreased westerlies in summer result in more double jets over Eurasia and this could partly explain the increase in European heat extremes.

→ Our approach: we are adapting a dynamical perspective of those trends by looking at large scale circulation and changes in the zonal mean zonal wind in the upper atmosphere.



Rousi et al. (in preparation)

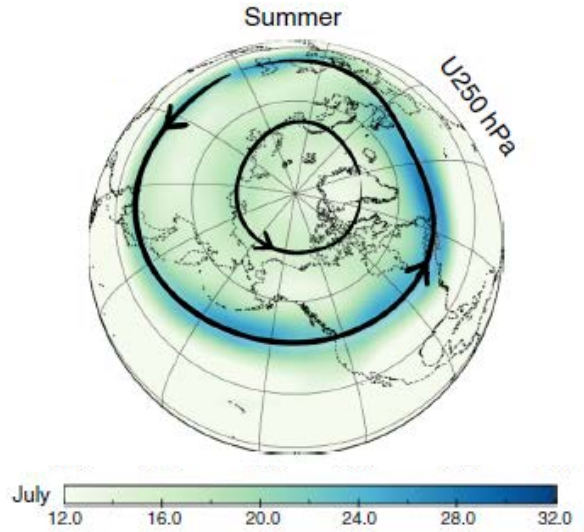


Figure 2b from Coumou et al. NatCom 2018

Research questions:

- Is there an increase of double jet states in summer?
- Are those states linked to more heat extremes in Europe?

Efi Rousi: rousi@pik-potsdam.de

Data - Reanalysis

- Era5 (daily) for July and August 1979-2020 (Hersbach et al. Q. J. R. Meteorol. Soc. 2020):
  - ✓Heatwave metrics with the use of Tmax (2m)
  - ✓surface temperature at 2m (T)
  - ✓ zonal (over Eurasia: 25W-180E) mean u wind at different pressure levels (800hPa – 100hPa)

Method: Heatwaves

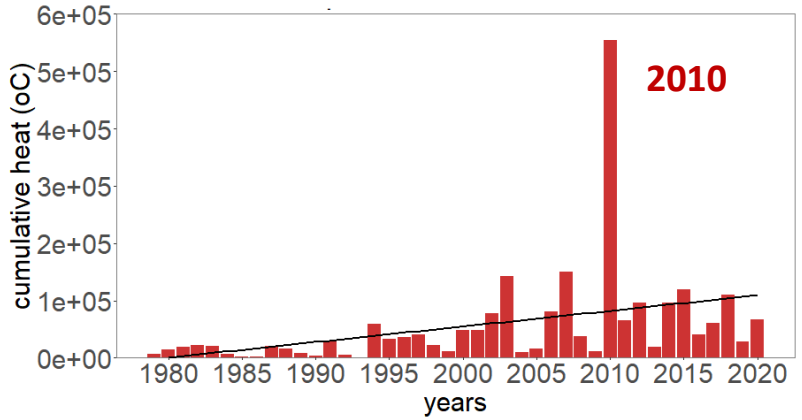
- Many different heatwave definitions exist depending on the region, the season, the scope of the study, etc.
- Here, a heatwave is defined by:
  - Temperature threshold: daily Tmax > 90th percentile based on 15-day window (Vogel et al. 2020)
  - Temporal extension: ≥ 6 consecutive days (Fischer & Schär 2010)
  - Spatial extension: ≥ 40.000km^2 within a 3.75° x 3.75° sliding window (Stefanon et al. 2012)

- Cumulative heat: integration of heat exceedance over the threshold for each heatwave event and for its whole spatial extent (Perkins-Kirkpatrick & Lewis 2020):

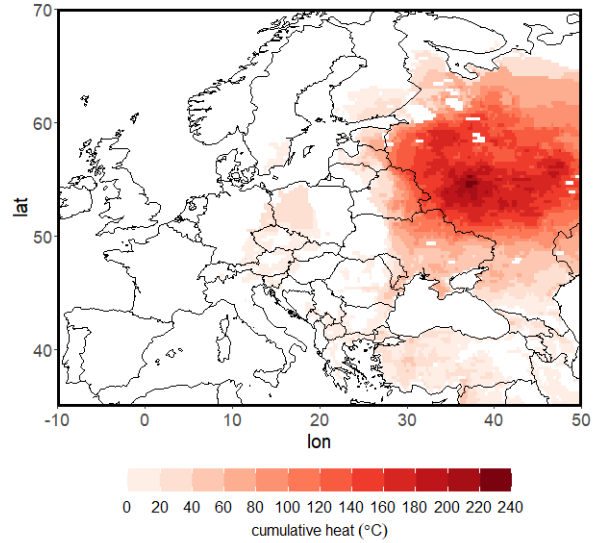
$$cumulative\ heat = \sum_{1}^{gp} \sum_{1}^{d} (Tmax - Tmax_{90th})$$

where
d = days
gp = grid points

European HW Cumulative Heat JA



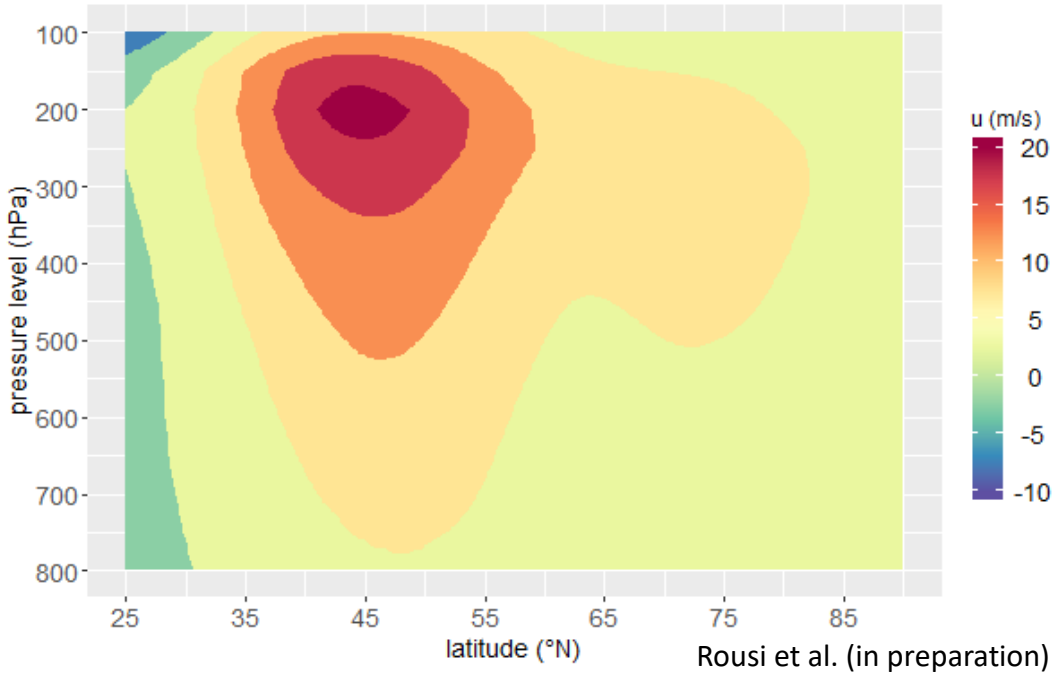
HW Cumulative Heat JA 2010



Rousi et al. (in preparation)

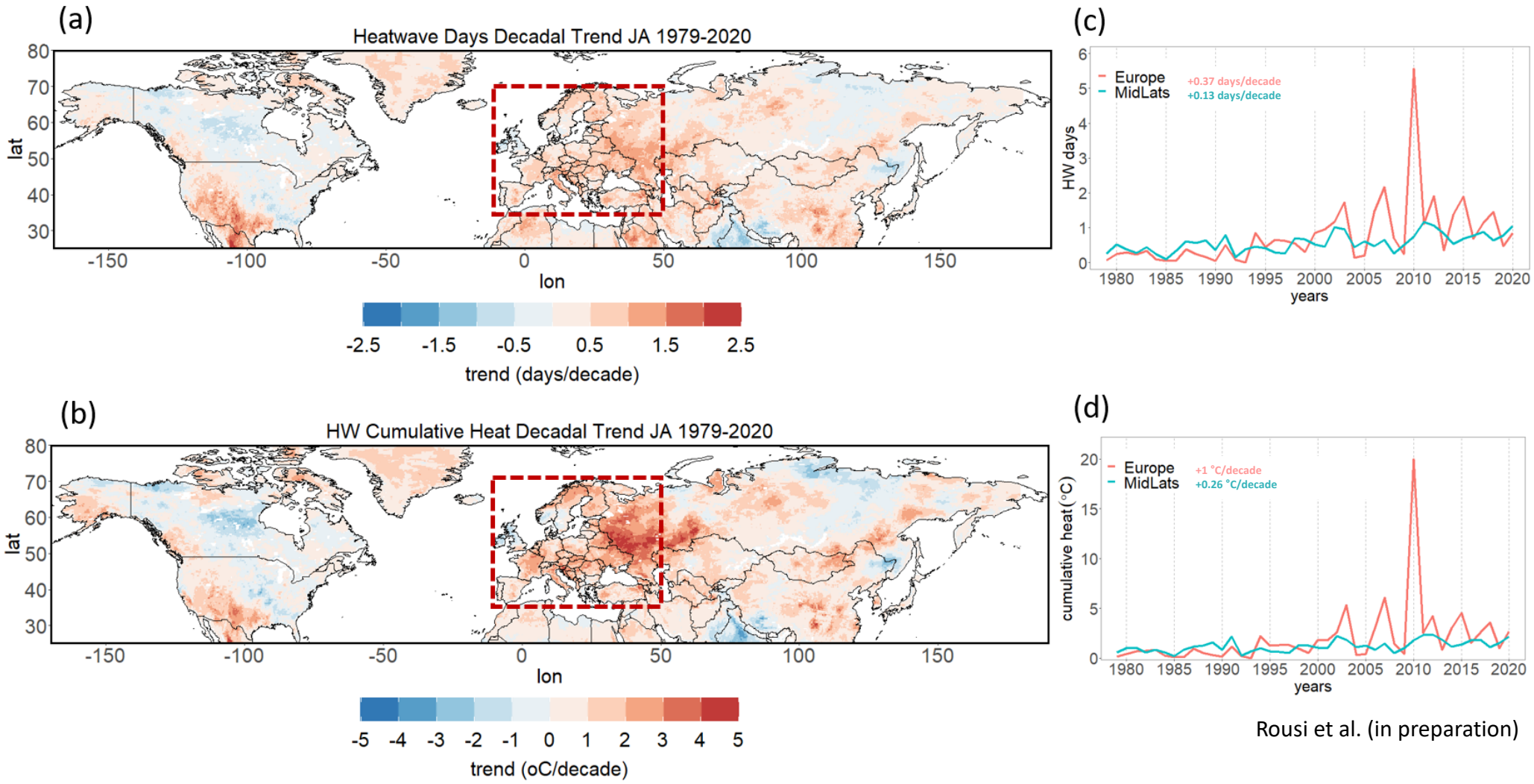
Method: Double jets

- Self-Organizing Maps (SOMs; Kohonen 2001; Rousi et al. 2015; 2020) to identify summer double jet regimes (Sasi - Master Thesis, 2020).
- Applied on vertical pressure levels of the zonal (over Eurasia) mean u wind.



Climatology (JA 1979-2020) of zonal u wind at different pressure levels

Results: Heatwave trends

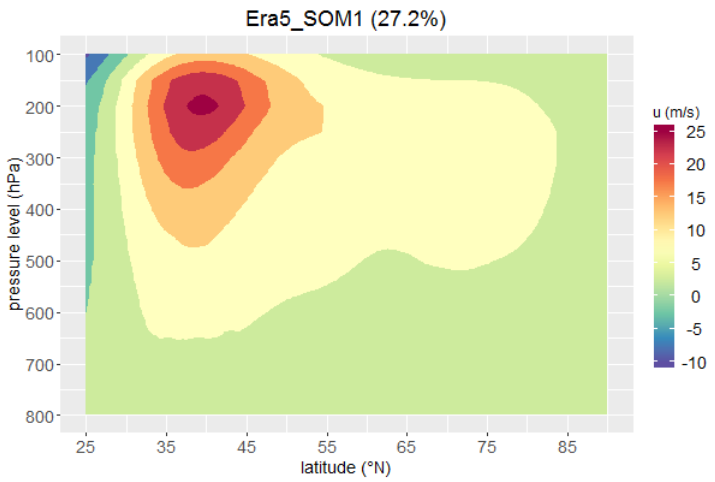


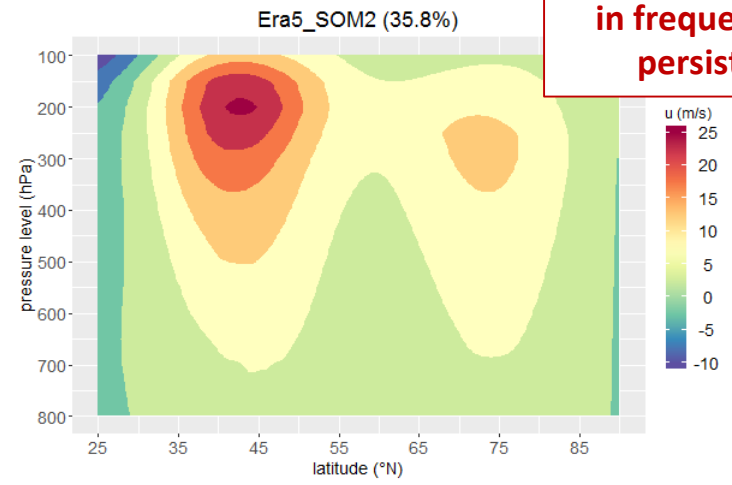
Rousi et al. (in preparation)

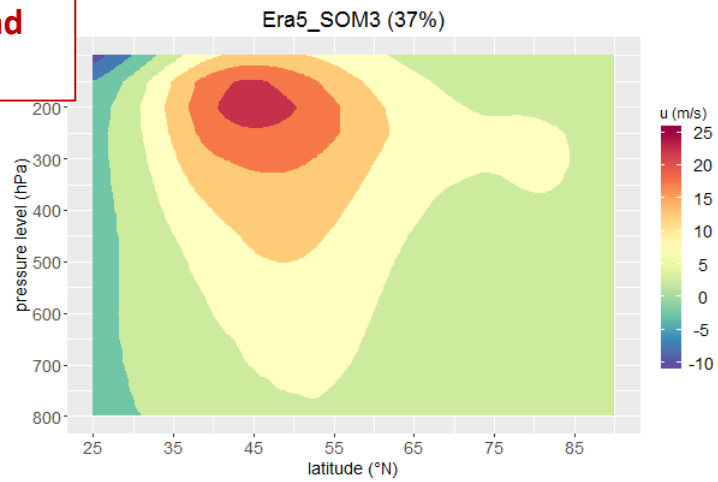
Results: SOMs of jet stream states

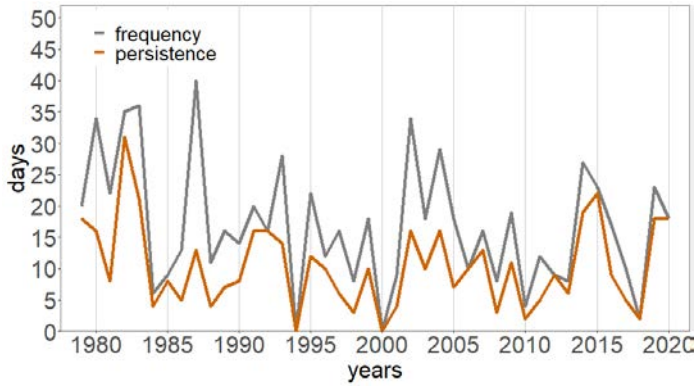
Double Jets (= two wind maxima and a minimum in between) increasing in frequency and persistence

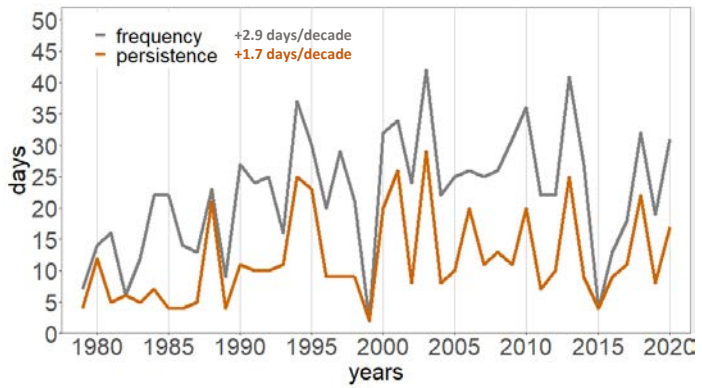
Single jet

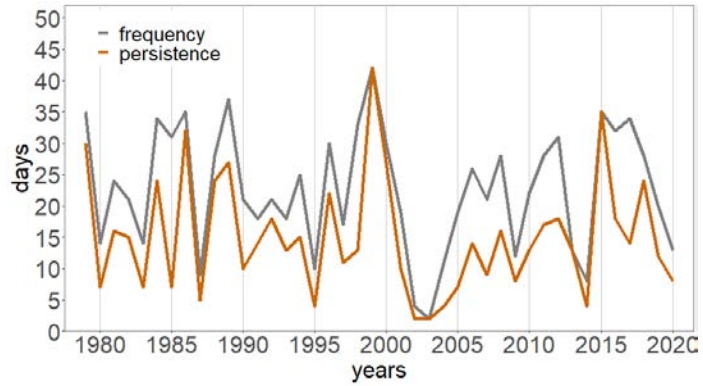












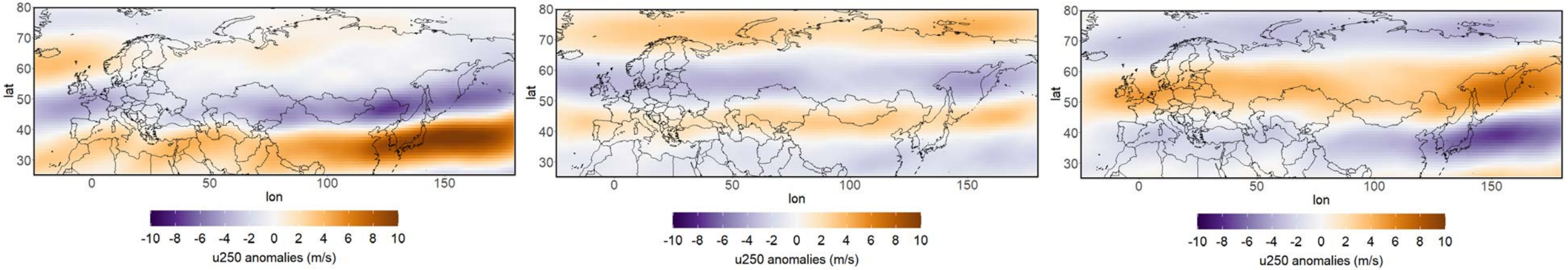
Rousi et al. (in preparation)

Results: composites for SOM jet states

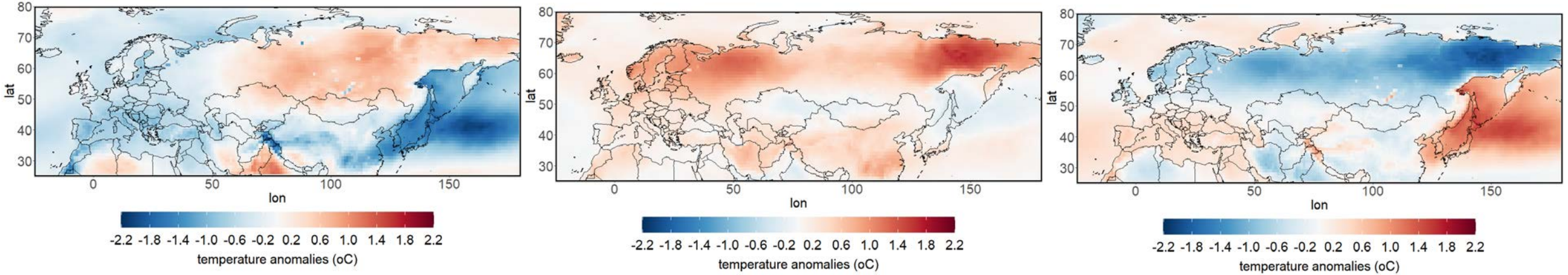
Double Jets linked to weaker winds over north-central Europe and to higher temperatures

Single jet

u250



Temperature

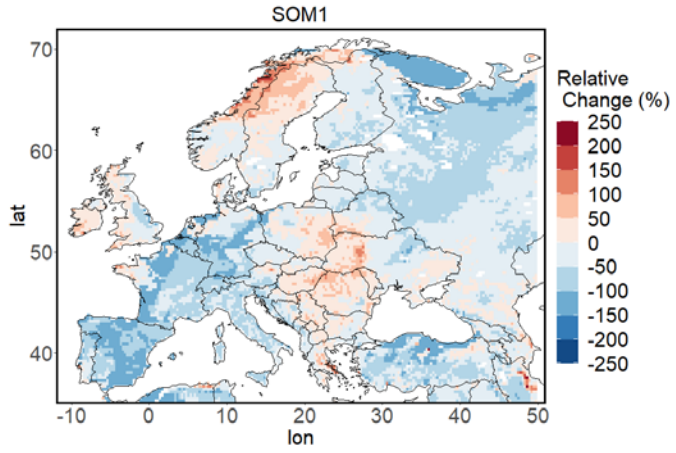


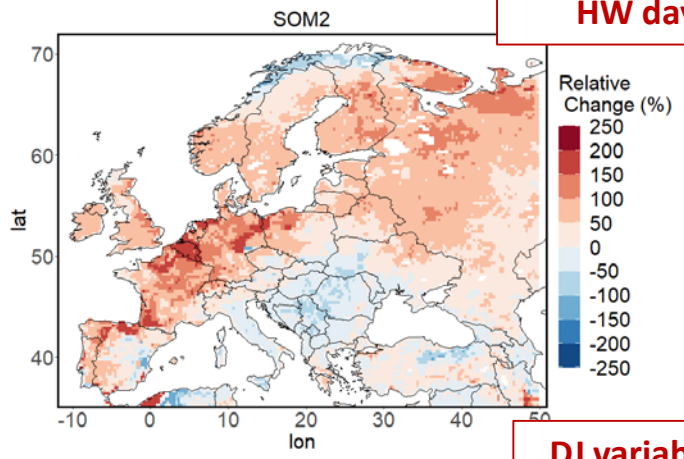
Rousi et al. (in preparation)

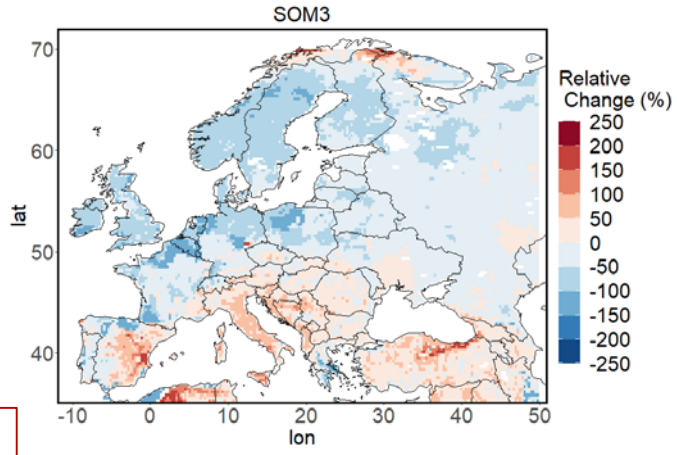
Results: Heatwaves and SOM jet states

HW days: relative change compared to climatology

Double Jets linked to more HW days

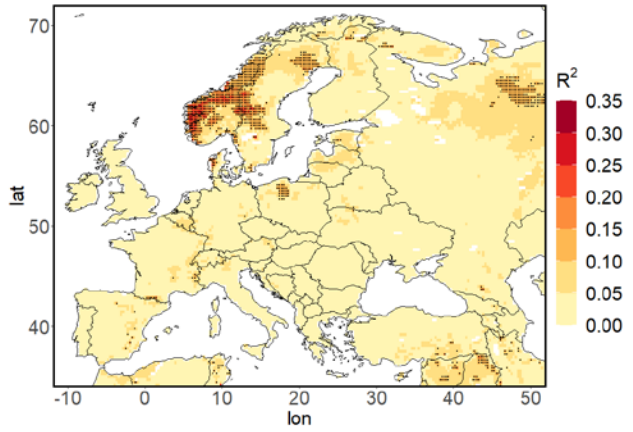


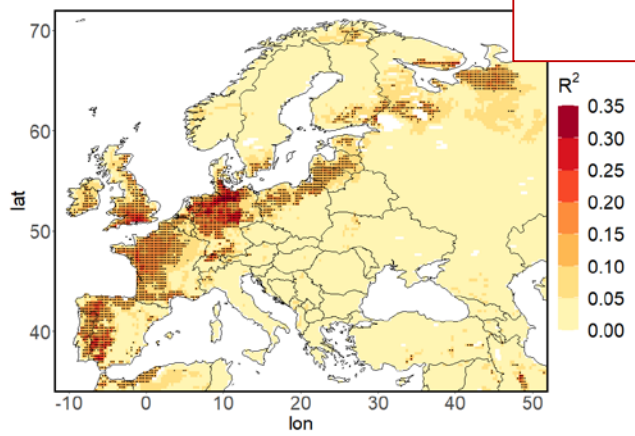


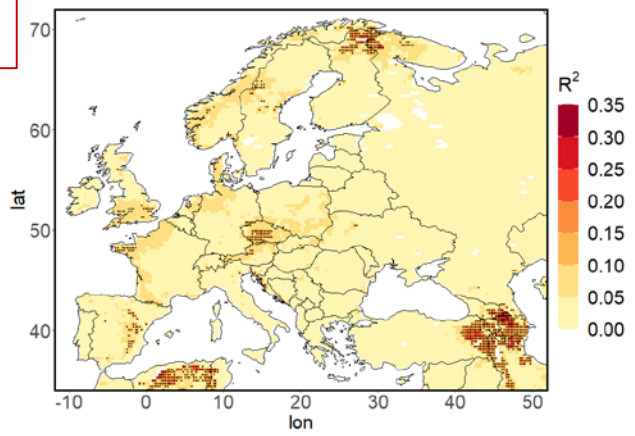


HW days: linear regression on SOMs persistence

DJ variability explains large part of HW variability over W. Europe

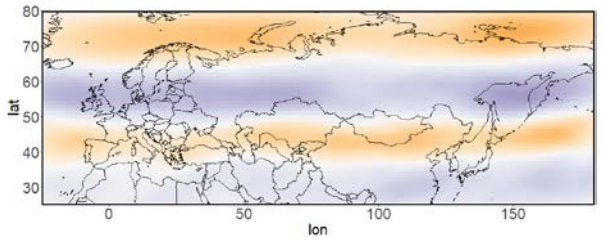


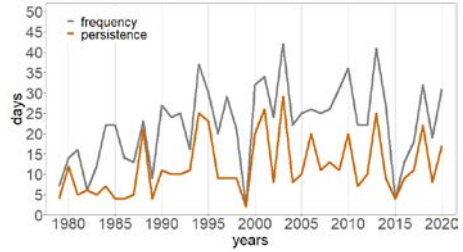


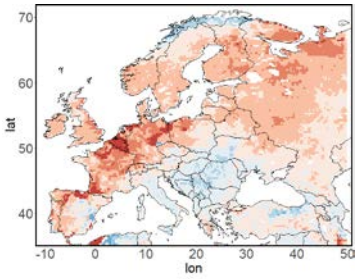


Rousi et al. (in preparation)

Conclusions





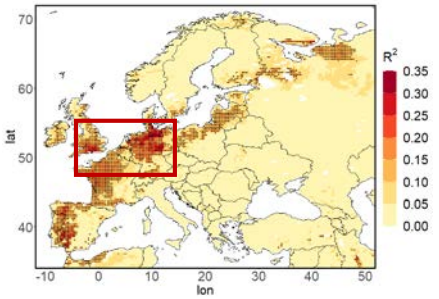


Summer (JA) double jets:

- increase in frequency and persistence
- are linked to increased temperature and heatwaves over western, central and northern Europe
- are found as dominant states before and during intense heatwaves

Summer double jet frequency and persistence:

- explain up to 35% of HW variability over Western Europe
- their increase may explain up to 50% (17%) of the HW increase in W. Europe (Europe)



→ Changes in the jet stream seem to be important for variability and trend of HWs over W. Europe

Ways forward:

- What do climate models show?
- What causes the increase in summer double jets?

Thank you for your interest!

References

Coumou, D., G. Di Capua, S. Vavrus, L. Wang, and S. Wang, 2018: The influence of Arctic amplification on mid-latitude summer circulation. Nat. Commun., 9, 2959, https://doi.org/10.1038/s41467-018-05256-8.

Fischer, E. M., and C. Schär, 2010: Consistent geographical patterns of changes in high-impact European heatwaves. Nat. Geosci., https://doi.org/10.1038/ngeo866.

Hersbach, H. et al., 2020: The ERA5 global reanalysis. Q J R Meteorol Soc. https://doi.org/10.1002/qj.3803

Kohonen, T., 2001. Self-organizing Maps, third edition. Springer, Berlin.

Perkins-Kirkpatrick, S. E., and S. C. Lewis, 2020: Increasing trends in regional heatwaves. Nat. Commun., 11, 1–8, https://doi.org/10.1038/s41467-020-16970-7.

Rousi, E., Anagnostopoulou, C., Tolika, K., Maheras, P., 2015: Representing teleconnection patterns over Europe: A comparison of SOM and PCA methods. Atmos Res 152:123–137 . https://doi.org/10.1016/j.atmosres.2013.11.010

Rousi, E., Rust, H.W., Ulbrich, U., Anagnostopoulou, C. 2020: Implications of Winter NAO Flavors on Present and Future European Climate. Climate 8:13 . https://doi.org/10.3390/cli8010013

Sasi, K.,2020: Influence of northern hemisphere spring snow cover extent , soil moisture and surface temperature on high latitude warming and propagation of mid-latitude summer double jet streams. Master Thesis. University of Amsterdam.

Stefanon, M., F. D'Andrea, and P. Drobinski, 2012: Heatwave classification over Europe and the Mediterranean region. Environ. Res. Lett., 7, 014023, https://doi.org/10.1088/1748-9326/7/1/014023.

Vogel, M. M., R. Orth, F. Cheruy, S. Hagemann, R. Lorenz, B. J. J. M. van den Hurk, and S. I. Seneviratne, 2017: Regional amplification of projected changes in extreme temperatures strongly controlled by soil moisture-temperature feedbacks. Geophys. Res. Lett., 44, 1511–1519, https://doi.org/doi:10.1002/2016GL071235.