The Role of the Ocean for the Development of Heat Waves over Europe

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Motivation

Heat waves are becoming more and more severe under the changing climate conditions that we already observe. Frequency and duration of heat waves are very likely to further increase under future climate conditions over most land areas. To improve the predictability of such extreme events, it is getting more and more important to understand their driving mechanisms better.

Although earlier work hints at a connection between **North Atlantic (NA) sea surface temperatures (SSTs)** and the occurrence of European heat waves, the role of the ocean in shaping heat waves is not fully understood.

Here, we investigate the effect of the **2018 NA SST pattern**, which was characterized by negative subpolar North Atlantic SST anomalies, on European heat wave magnitude and duration.

We want to answer the question whether such an oceanic anomaly pattern would favor heat wave conditions over Europe by affecting large-scale jet stream dynamics.

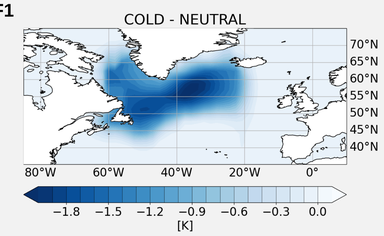
Model Experiments

We use ECHAM6 time slice experiments employing the daily 2018 SST and sea ice pattern as a boundary forcing. We compare this experiment with a complementary simulation in which the negative SST anomaly was removed.

ECHAM6 simulations:

- T63L95
- AMIP-like setup
- time slice 2018 conditions (SSTs, sea ice, GHGs, aerosols, land use)
- ensemble of 100 model years per experiment
- 2 experiments: COLD & NEUTRAL
- small-scale, day-to-day SST variability same in both experiments

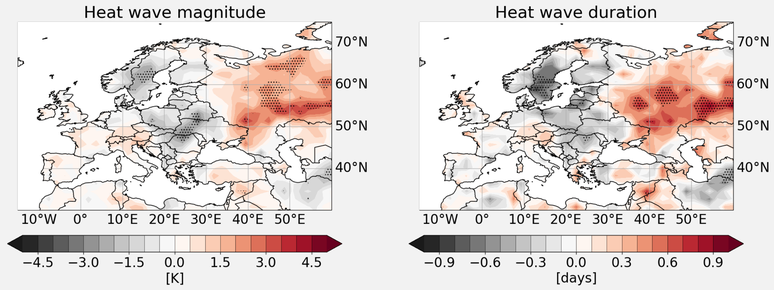
F1



COLD → With cold SST anomaly
NEUTRAL → Without cold SST anomaly

Heat Waves Statistics

F2 **COLD** minus **NEUTRAL**



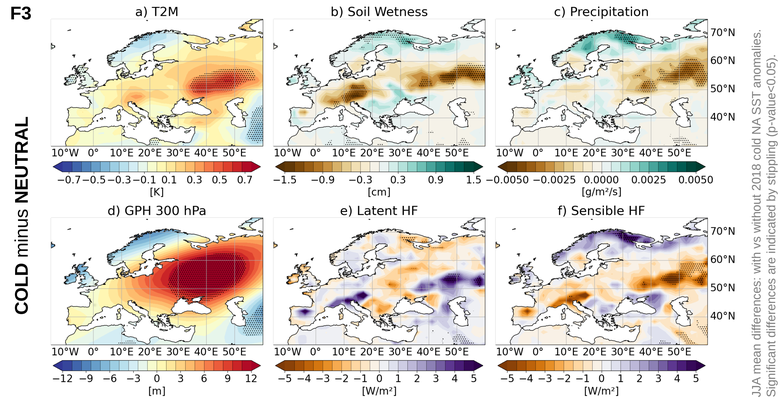
Heat waves are defined as days with maximum temperatures (T2M) above a 90th percentile threshold defined over a 30 day window. Only heat waves that occur in JJA and last for at least 3 days are considered. The magnitude is defined as the cumulated difference between T2M and the 90th percentile threshold. Significant differences are indicated by stippling (p-value<0.05).

The region affected most by the difference in SST forcing in our model setup is the **easternmost part of the European continent**.

Heat wave statistics (F2) indicate **stronger and longer lasting heat waves** in that region.

Soil Moisture Feedback

F3



Under cold NA SST anomalies:

- High max. temperatures (a) in eastern Europe coincide with depleted soil wetness (b)

Lack in soil wetness …

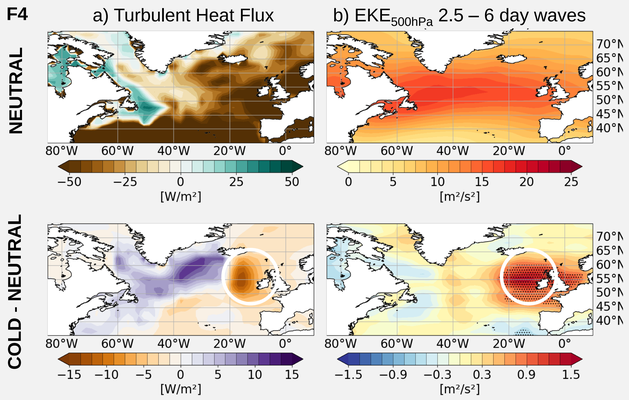
- is due to a high pressure anomaly (d) and associated decrease in precipitation (c)
- leads to a reduced latent heat release and therefore reduced cooling (e)
- further increases T2M (a), which is also indicated by increased sensible heat release (f)

Positive Feedback favoring the occurrence of temperature extremes (F2 and F3)

How can North Atlantic SSTs influence European Temperatures?

GPH anomaly favors heat wave conditions over western Russia (F3). How are NA SST anomalies connected to that?

F4



JJA season only. Significant differences are indicated by stippling (p-value<0.05).

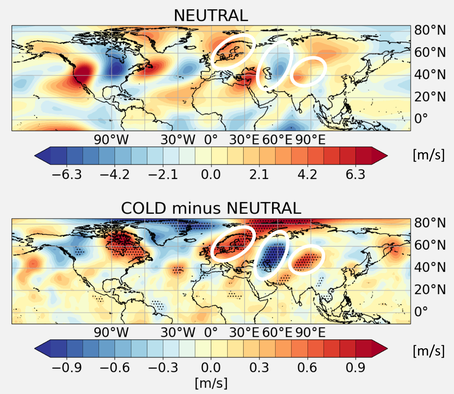
Difference in SST forcing leads to different turbulent heat flux release from the ocean to the atmosphere (F4a).

Stronger heat flux in eastern NA is connected to higher values in eddy kinetic energy at 500 hPa (F4b).

Enhanced wave structure with cold NA SST anomaly promotes high pressure over the continent (F5).

high EKE can feed back onto the prevailing GPH fields and enhance the summer wave pattern further down stream

F5 **JJA v-wind at 300 hPa**



Significant differences are indicated by stippling (p-value<0.05).

2018 cold NA SST anomalies are associated with an **enhanced turbulent heat flux release** in the eastern NA ocean. This leads to **higher EKE** of 2.5 to 6 day waves at 500 hPa that can feed back onto the prevailing GPH fields during summer. In our low-resolution model setup, this **enhances the high pressure anomaly** over the easternmost part of the European continent **favoring extreme temperature conditions** there. The anomalous temperature conditions are strengthened by **a positive soil moisture feedback** in that region.

NOTE: The exact location of the GPH anomaly is specific to ECHAM6 biases in its climatological wave representation at the here-used resolution. The importance is on the consistency of the downstream response over the European continent.

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