Heat waves over Europe: Identification and connection to large-scale circulation

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1. Motivation and objectives

- Heat waves have important impacts on our societies:
  - Increase in fatalities
  - Reduction of crop production
  - Endangering our ecosystems
  - Infrastructures put under stress
- To mitigate these impacts it is essential to:
  - Understand the underlying processes of heat waves
  - Assess the current predictive skill of S2S models
  - Develop an early warning system for heat waves
- This poster shows the first steps in understanding the main processes triggering heat waves

2. Data and Methodology

- Use of ERA5 re-analysis dataset 1979-2018[i] over extended summer period (April – October):
  - Daily mean 2 meter temperature (2mT)
  - Daily mean geopotential height at 500hPa (Z500)
  - Daily mean potential vorticity at 315K (PV)
- Identification of heat waves (Stefanon et al., 2012[ii], three steps):
  - For each grid point the 2mT should exceed the 90th percentile with respect to the 1979-2018 climatology
  - This threshold should be exceeded by at least 60% grid points within a circle of 170km radius
  - The previous conditions should be meet for at least 4 days
  - Separate Europe into 4 climatic regions and extract events that cover 40% or more of the region (cf. table below for regions and number of events)
- Circulation patterns:
  - Use Z500 composites of each heat wave pattern
- Previous evolution:
  - Use Hovmöller diagrams showing the evolution of Z500 from 180W to 180E for the 30 days prior to the event

Heat wave regions	Number of heat waves
Western Europe (WE)	13
North Sea (NS)	22
Russia (RU)	22
Eastern Europe (EE)	18

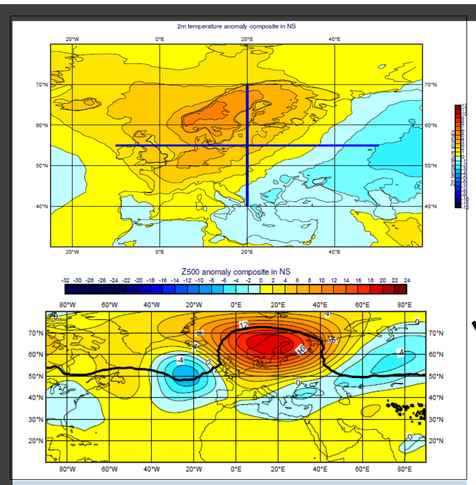
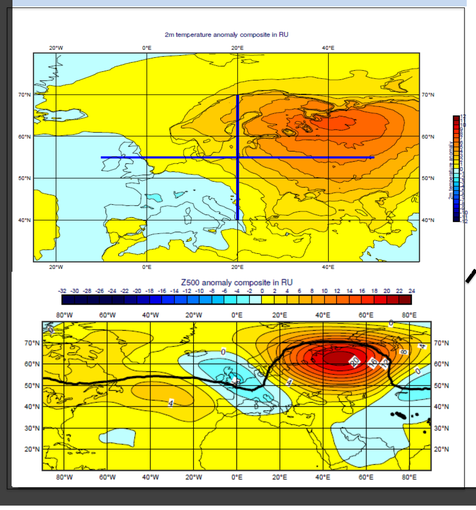


Fig. 1- 2: For NS (top) and RU (bottom) the heat wave centres are associated with a clear anti-cyclonic anomaly. Both show a omega like pattern with a cyclonic anomaly south-west and south-east of the heat wave centre.



3. Representation of each heat wave regions and their typical circulation patterns*

- Each top panel shows the 2mT anomaly compared to 90th percentile as colour shading with the cross representing how the regions are defined.
- Each bottom panel shows the Z500 anomaly compared to climatology as colour shading with the black line representing the 2PV unit margin
- The Hovmöller diagrams show the average temporal evolution of Z500 anomaly as colour shading for different latitudinal bands (WE and EE: 45 to 55N; NS: 55 to 65N; RU: 45 to 60N) 30 days prior to the heat wave.

*Individual figures are shown larger in the following slides

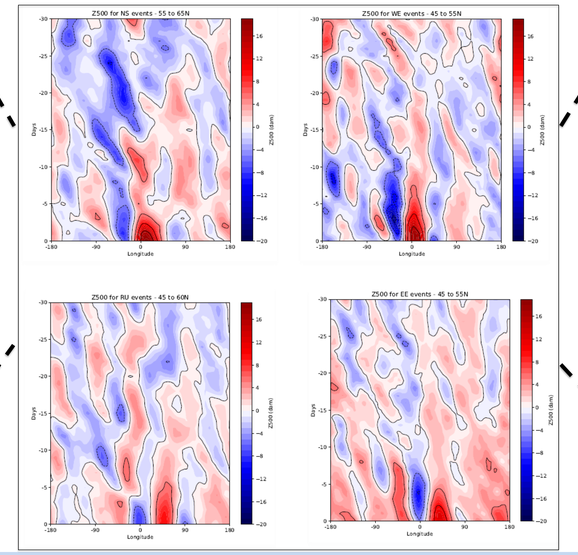


Fig. 5: In these figures we can observe the specific circulation patterns identified in figures 1 to 4. In addition we can see when the zonal flow is stopped into a blocking pattern. On average, the blocking configuration seems to amplify for 10 days prior to the heat wave. The early manifestation of these patterns shows that predicting heat waves at sub-seasonal scale has potential.

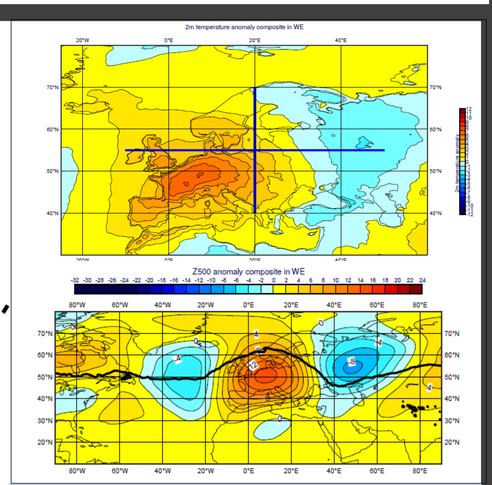
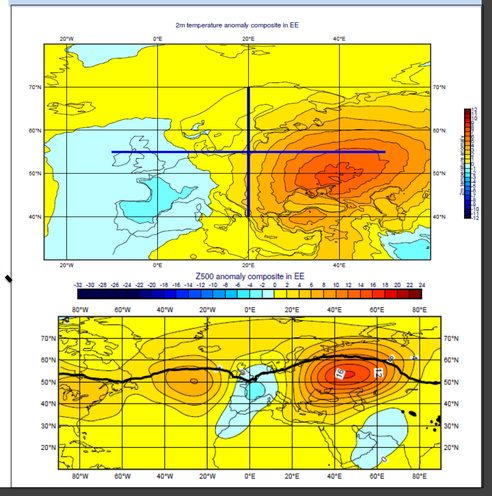


Fig. 3-4: For WE (top) and EE (bottom) the heat wave centres are associated with a clear anti-cyclonic anomaly. Both show a zonal pattern with a cyclonic anomaly west and east of the heat wave centre for WE and only west for EE.



4. Key results

- Each heat wave centre is associated with an anti-cyclone and a specific blocking configuration
- North/South divide: Omega blocking like configurations for regions of NS and RU, and dipole/tripole blocking configuration for WE and EE
- The relatively slow establishment of the ridge at Z500, shown in Fig. 5 suggests potential for the S2S predictions.
- The Hovmöller diagram for an individual heat wave event (not shown) shows the relevance of Rossby Wave Packets as one of the precursors.

5. Future challenges

- Closer look at the processes relevant for the heat wave development by analysing individual heat waves:
  - Effects of land surface conditions
  - Importance of climate drivers such as sea surface temperature anomalies and Madden-Julian Oscillation
- Identifying the relevant processes common to each of the 4 heat wave types
- Sensitivity to a warming climate

References:

- [i]Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS). https://cds.climate.copernicus.eu/cdsapp#!/home
- [ii]Stefanon M, Dandrea F, Drobinski P (2012) Heatwave classification over Europe and the Mediterranean region. Environ Res Lett 7. https://doi.org/10.1088/1748-9326/7/1/014023

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CAFE Climate Advanced Forecasting of sub-seasonal Extremes

This work is part of the Climate Advanced Forecasting of sub-seasonal Extremes (CAFE) project. The project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 813844.

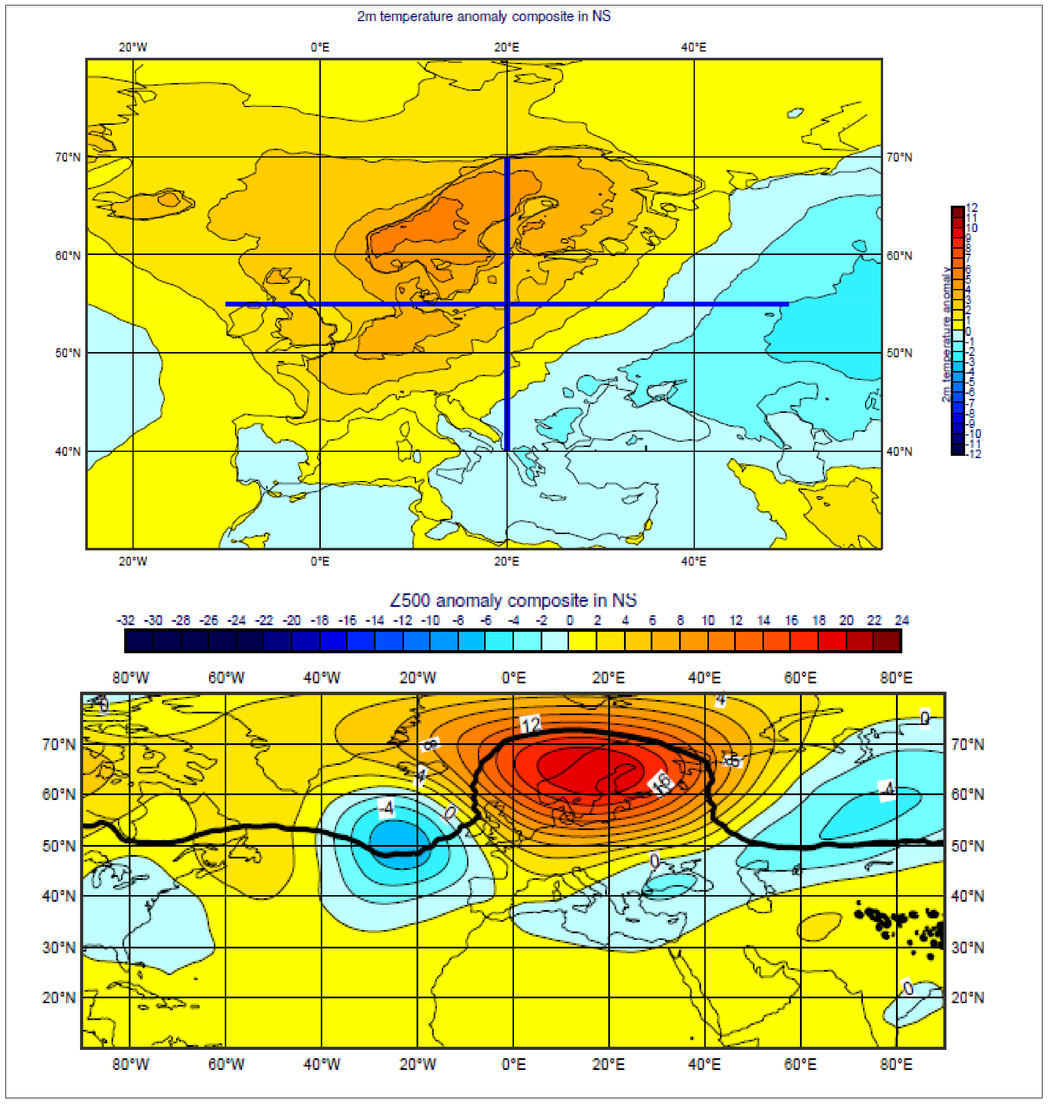

Figure 1

This figure shows the characteristics of the NS heat waves using composites. Both composites use the average of all days and all events coming from this category. Top panel uses 2mT anomaly (K) with reference to the 90th percentile and the bottom one uses the Z500 (dam) anomaly compared to climatology while the black line represents the 2PV unit margin.

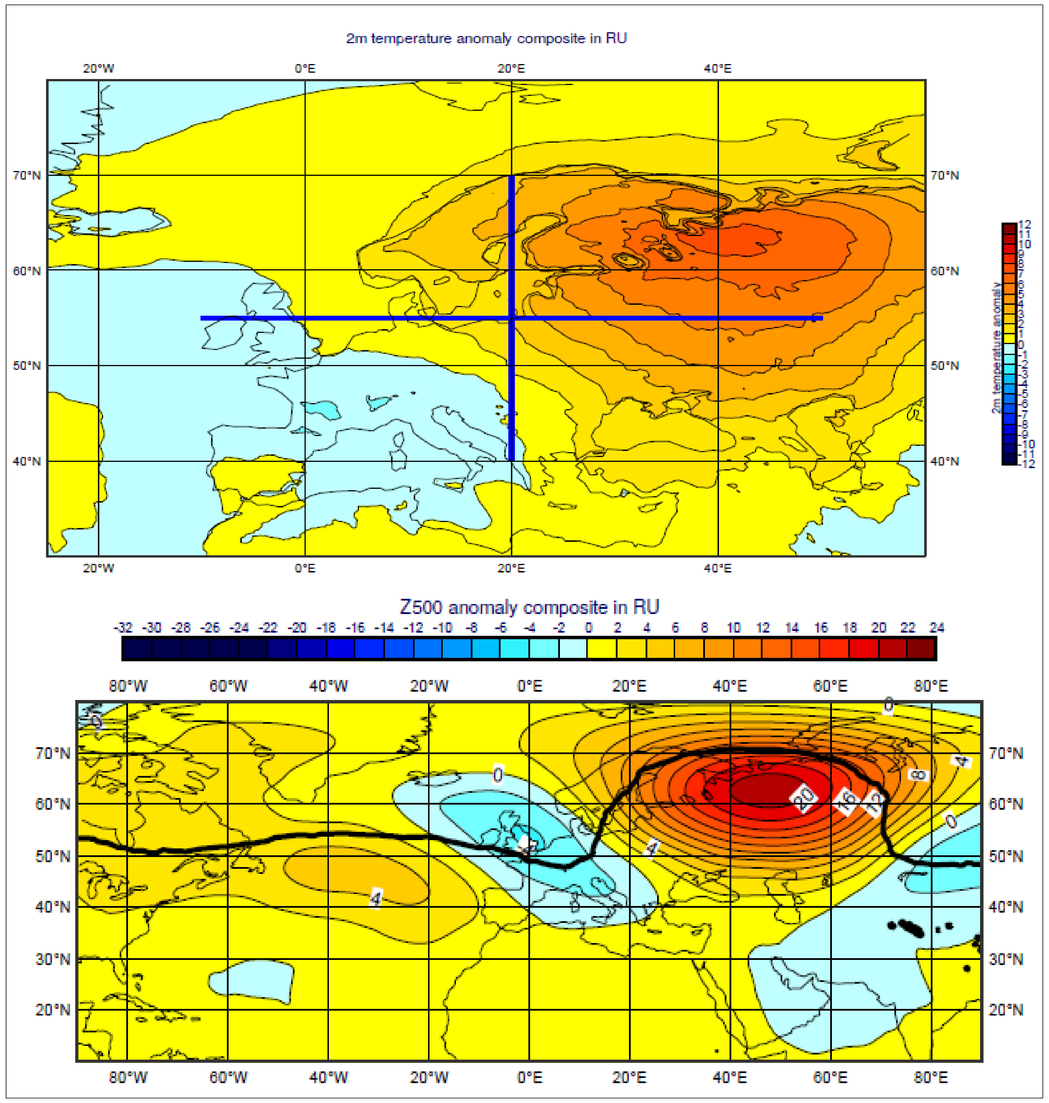

Figure 2

This figure shows the characteristics of the RU heat waves using composites. Both composites use the average of all days and all events coming from this category. Top panel uses 2mT anomaly (K) with reference to the 90th percentile and the bottom one uses the Z500 (dam) anomaly compared to climatology while the black line represents the 2PV unit margin.

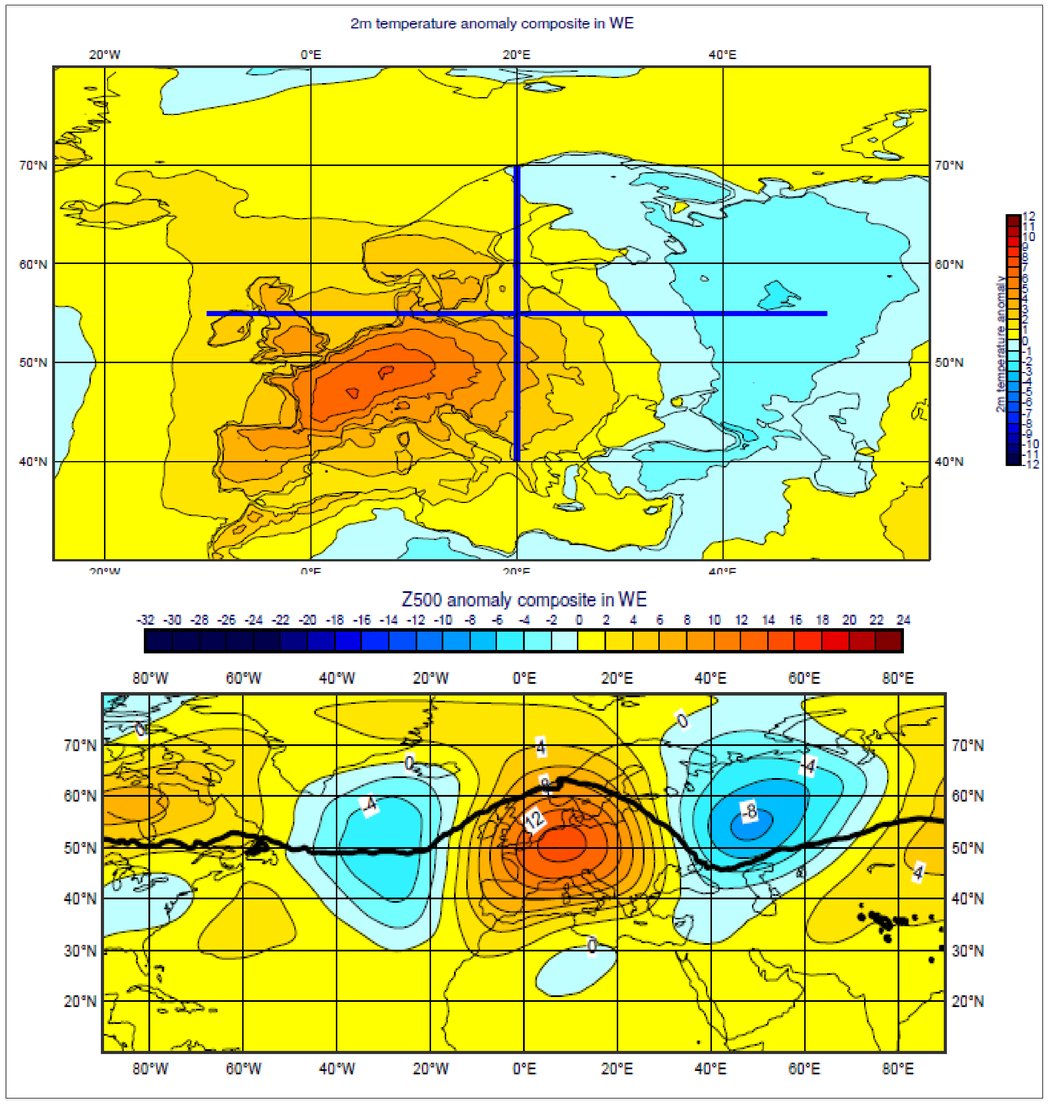

Figure 3

This figure shows the characteristics of the WE heat waves using composites. Both composites use the average of all days and all events coming from this category. Top panel uses 2mT anomaly (K) with reference to the 90th percentile and the bottom one uses the Z500 (dam) anomaly compared to climatology while the black line represents the 2PV unit margin.

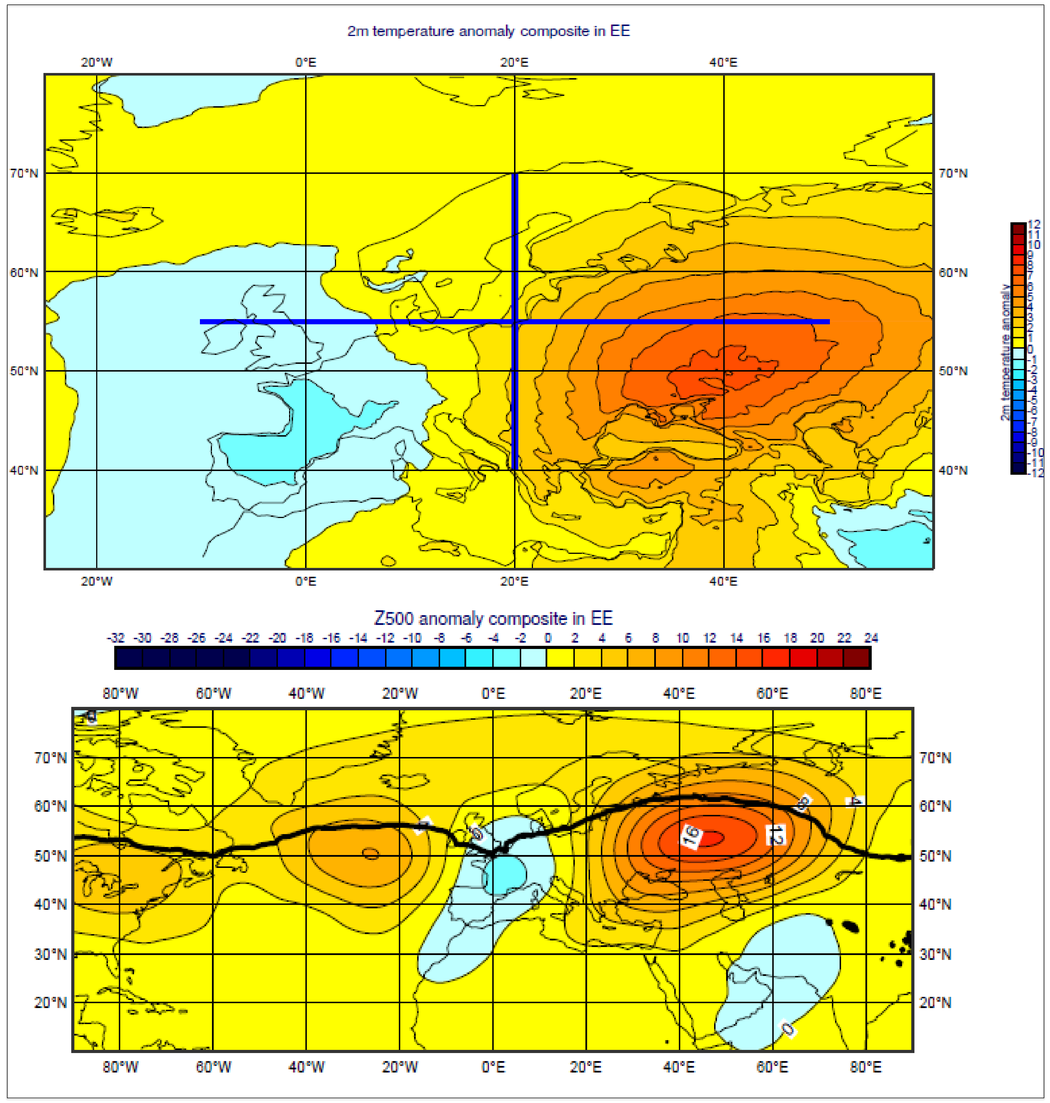

Figure 4

This figure shows the characteristics of the EE heat waves using composites. Both composites use the average of all days and all events coming from this category. Top panel uses 2mT anomaly (K) with reference to the 90th percentile and the bottom one uses the Z500 (dam) anomaly compared to climatology while the black line represents the 2PV unit margin.

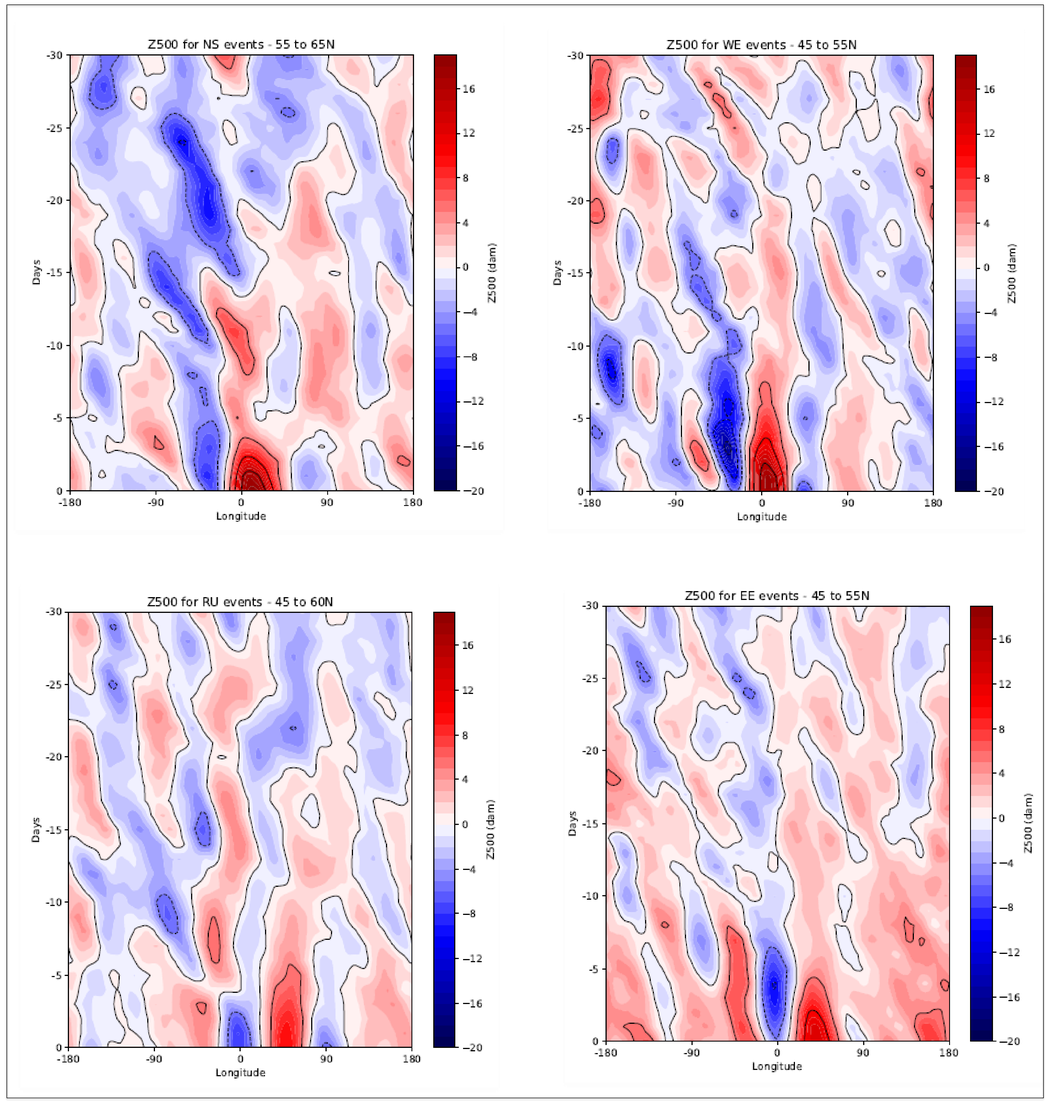

Figure 5

The four panels are Hovmöller diagrams showing the average evolution of the Z500 anomaly (dam) for each heat wave category for the 30 days prior to the events. Each value represents an average over all cases of the category and over the selected latitudinal band. The selected bands are:

- 55 to 65N for NS
- 45 to 60N for RU
- 45 to 55N for WE and EE