EXTREME SEASONS IN EUROPE: SUMMER 2007

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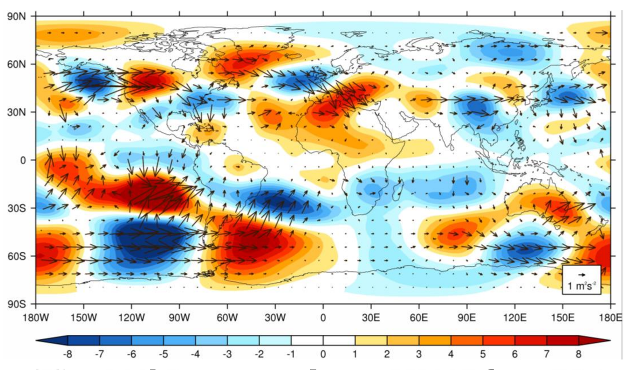
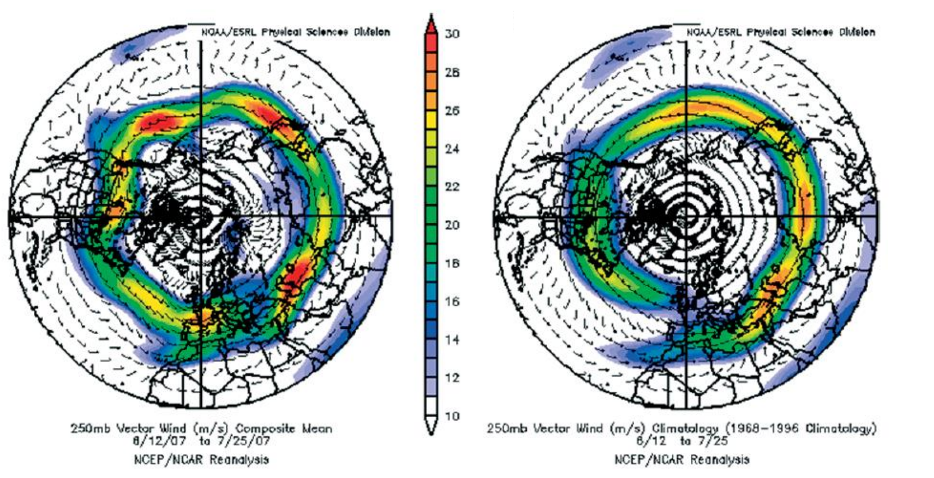
1. Motivation



Ψ' at 200hPa averaged over JJ2007 from ERA-Interim reanalysis (shading, units of 10^6 m^2s^{-1}) and horizontal component of wave activity flux (Takaya and Nakamura, 2001; arrows, units of m^2s^{-2})

- Wettest Summer in England and Wales since 1912.
- Persistent trough and equatorward displacement of the jetstream over the east Atlantic.
- Apparent phase-locking of mid-latitude anomalies.

(Blackburn et al., 2008)



The NH jet stream, shown by the strength and direction of the wind at 250hPa in ms^{-1}, time-averaged over the period 12th June to 25th July for (left) 2007 and (right) climatological average for 1968-1996 (Blackburn et al. 2008)

2. Idealised model

We use an adiabatic, multi-level, primitive equation atmospheric model that will be referred to as Dynamical Circulation Model (DCM). The model is run at a T42 horizontal truncation and 15 vertical levels with some concentration in the tropopause region as in Jin and Hoskins (1995).

A basic state flow, in general a 3D climatology, is maintained. Prescribed heating anomalies are then added and the model is integrated forward in time to obtain the direct, nonlinear, quasi-stationary response. The basic state considered was the June-August climatology from ERA-Interim (1989-2008).

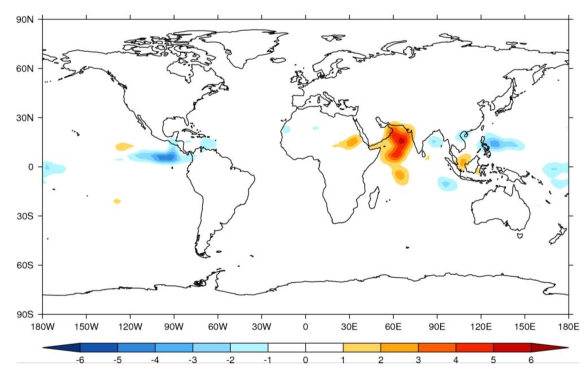
We use idealised tropical heating anomalies and heating patterns based on the observed OLR anomalies. In both cases the vertical profile is taken from Jin and Hoskins (1995). Heating anomalies are also constructed from observed (ERA-Interim) vertical motion anomalies, scaled by assuming that heating is balanced by adiabatic ascent.

3. Methodologies

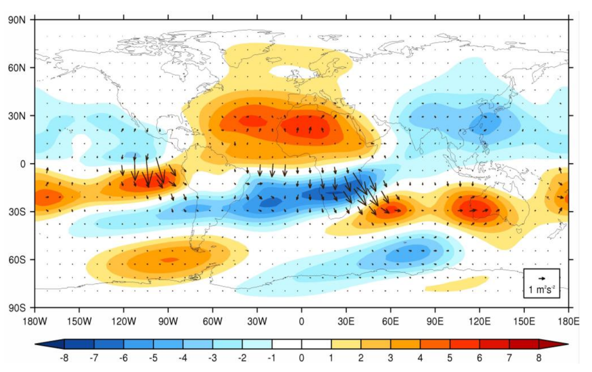
- Anomalous heating experiments based on observations/analyses: the model is forced with tropical heating anomalies, both idealised and based on the observed tropical OLR and tropical vertical motion anomalies.
- Relaxation/Nudging Technique: relaxation or nudging technique is a well established diagnostic technique in atmospheric sciences where aspects of the flow are drawn towards a reference state during the course of the time integration (Hoskins et al., 2012). In this technique the model variables are relaxed towards analyses in a target region that can initially be defined as the whole tropics, extra-tropics or the stratosphere.

It is important to stress the difference between forcing experiments and relaxation experiments: while forcing experiments try to give the origin of the anomalies, relaxation experiments show aspects of the flow that are crucial to get right in order to simulate other aspects.

4. Anomalous Heating Experiments

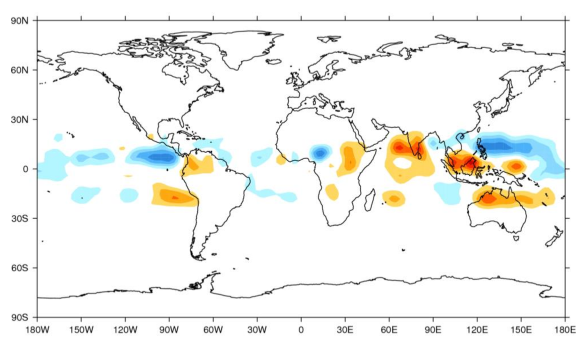


Heating anomalies derived from the observed June-July 2007 tropical OLR anomalies (units of 0.5 $Kday^{-1}$)

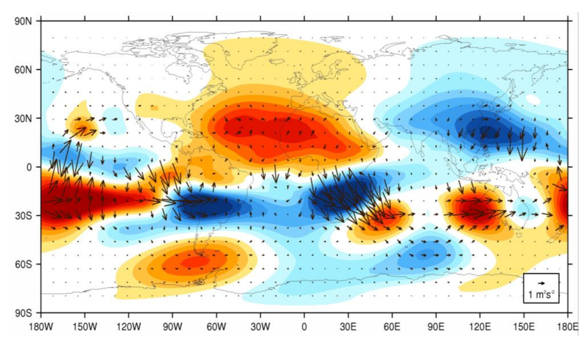


Ψ' anomalies at 200hPa averaged over days 20-30 (shading, units of 10^6 m^2s^{-1}) and horizontal component of wave activity flux (Takaya and Nakamura, 2001; arrows, units of m^2s^{-2})

- **Model forced with the observed June-July 2007 tropical OLR anomalies, scaled to give a heating.**
- The pair of cyclones over the East Pacific is reproduced but the anticyclone pair over Africa is stronger and more extensive than in observations. The extra-tropical anomalies in the NH are not replicated in this experiment.



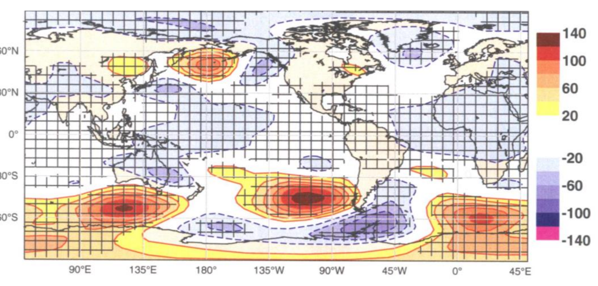
Heating anomalies derived from the observed June-July 2007 tropical vertical motion anomalies (units of 0.5 $Kday^{-1}$)



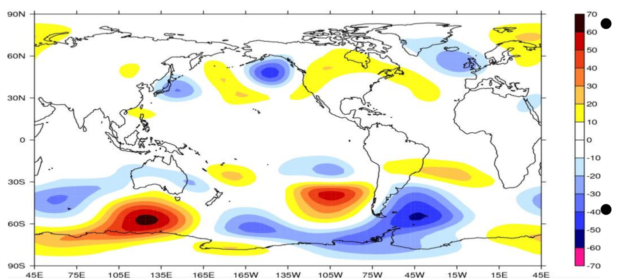
Ψ' anomalies at 200hPa averaged over days 20-30 (shading, units of 10^6 m^2s^{-1}) and horizontal component of wave activity flux (Takaya and Nakamura, 2001; arrows, units of m^2s^{-2})

- **Model forced with the observed June-July 2007 tropical vertical motion anomalies, scaled to give a heating.**
- Overall the response is similar to that obtained with the scaled tropical OLR anomalies but with a larger amplitude.

5. Tropical Relaxation Experiments

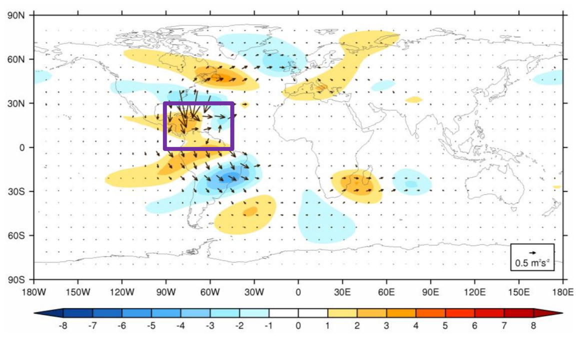


Z' anomalies at 500hPa in response to tropical relaxation obtained with the ECMWF's GCM (units of meters) (Hoskins et al., 2012)

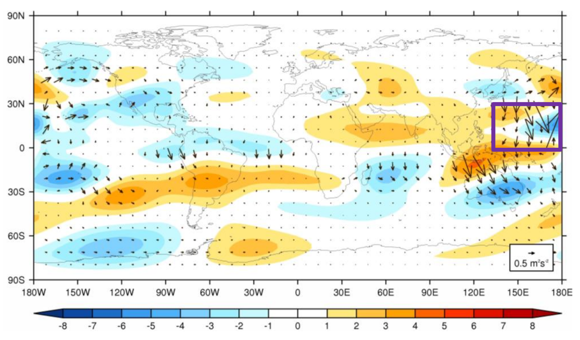


Z' anomalies at 500hPa averaged over days 20-30 in response to tropical relaxation obtained with the DCM (units of meters)

- **Response to tropical relaxation (30ºN-30ºS) by the ECMWF's GCM and the DCM.**
- The response obtained to tropical relaxation in a single model run with the DCM, an idealised model with very simple physics, is similar to that obtained in an ensemble of seasonal forecasts with the ECMWF's model, a state-of-the-art GCM.



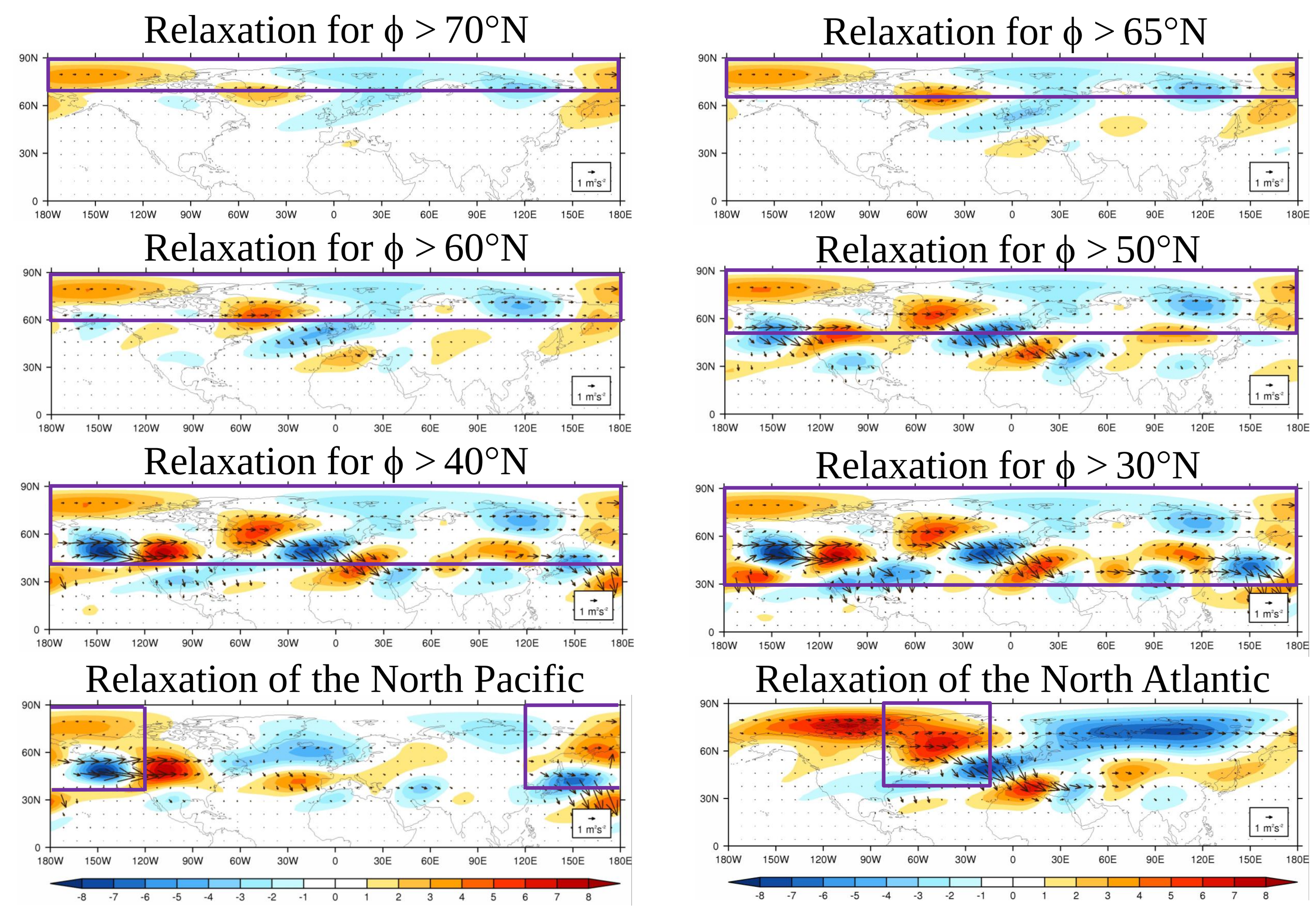
Ψ' anomalies at 200hPa (shading, units of 10^6 m^2s^{-1}) averaged over days 20-30 in response to the relaxation of the Caribbean region and horizontal component of wave activity flux (Takaya and Nakamura, 2001; arrows, units of m^2s^{-2})



Ψ' anomalies at 200hPa (shading, units of 10^6 m^2s^{-1}) averaged over days 20-30 in response to the relaxation of the West Pacific and horizontal component of wave activity flux (Takaya and Nakamura, 2001; arrows, units of m^2s^{-2})

- Relaxing the flow in the Caribbean region (0-30°N, 90°W-45°W) on a time-scale of 10h gives a wavetrain across the North Atlantic with a trough over the UK.
- The DCM's response to a relaxation of the flow in the West Pacific (0-30°N, 135°E-180°E) on a time-scale of 10h comprises a wavetrain across the North Pacific in phase with that observed.

6. Extra-tropical Relaxation Experiments



Ψ' anomalies at 200hPa averaged over days 20-30 in response to the relaxation of different extra-tropical regions (shading, units of 10^6 m^2s^{-1}) and horizontal component of wave activity flux (Takaya and Nakamura, 2001; arrows, units of m^2s^{-2})

- **Response to relaxation of the extra-tropics on a time-scale of 10h.**
- When the flow in the Arctic polewards of 65°N (or even 70°N) is relaxed towards analyses the wavetrain over Europe is reproduced although with a very small amplitude. This suggests that the anomalies in the Arctic may have contributed to the European anomalies, a result that is consistent with other studies such as Balmaseda et al. (2010).
- The response to the relaxation of the North Pacific gives a weak low pressure over the UK whereas when the North Atlantic is relaxed the anomalies over north-western Europe are similar to those observed.

7. Conclusions

We have investigated a recent extreme season in Europe, the wet summer of 2007, using analysis of observations, atmospheric analyses and experiments using an idealised model.

The results showed that tropical thermal anomalies alone do not give the right tropical and extra-tropical responses: despite being able to reproduce some of the observed tropical and subtropical features, the model failed to replicate most of the extra-tropical anomalies, in particular in the Northern (summer) Hemisphere.

Relaxation experiments showed that it is crucial to correctly simulate upstream anomalies in the extra-tropics. In line with other studies, the observed anomalies in the Arctic region in this season were also found to be important for the European anomalies.

References

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