The Future Summer Climate in Europe

The Role of Hadley Circulation and Lapse-Rate Changes

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Motivation & Goal

Climate projections commonly show an enhanced summer warming in the Mediterranean known as Mediterranean amplification.

Our goal is to determine **which processes are responsible for the Mediterranean amplification?**

Conclusions

The Mediterranean amplification is **mainly caused by lapse-rate changes**, which are weaker in the Mediterranean compared to the rest of Europe.

Changes in the **Hadley circulation have a negligible influence** on the future European summer climate.

Method

An ensemble of 3 **regional climate simulations** is used to simulate the end of century warming assuming RCP8.5. The ensemble mean is analyzed. By performing simulations with modified lateral boundary conditions we can **separate the influence of different contributing processes** to climate change.

Summer Warming Separated Into Four Contributions

The Mediterranean amplification is clearly visible in the **full climate change signal**. The full climate change signal is the sum of the four contributions on the right hand side.

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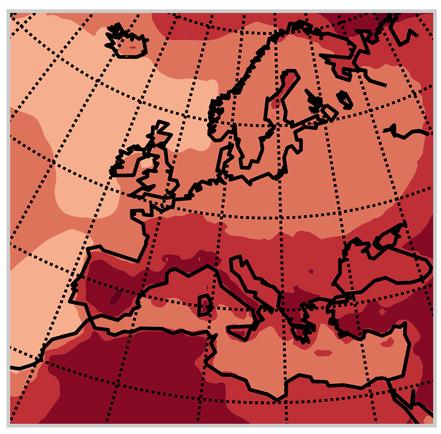

The **thermodynamic** contribution is responsible for most of the warming but does not induce the Mediterranean amplification.

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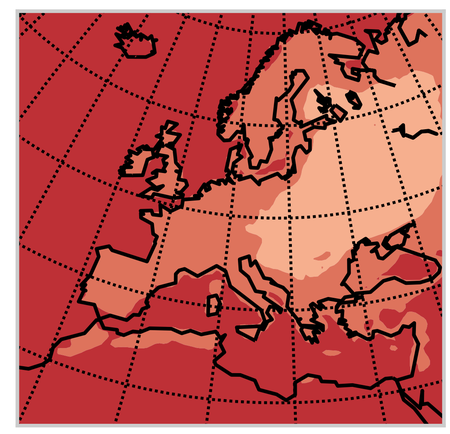

The contribution of **zonal mean circulation and stratification changes** is responsible for the Mediterranean amplification! It includes **Hadley circulation** and **lapse-rate changes**.

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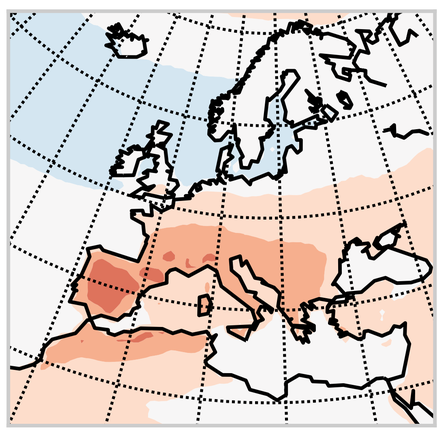

The **3D structure of circulation changes** over Europe is not important for the Mediterranean amplification.

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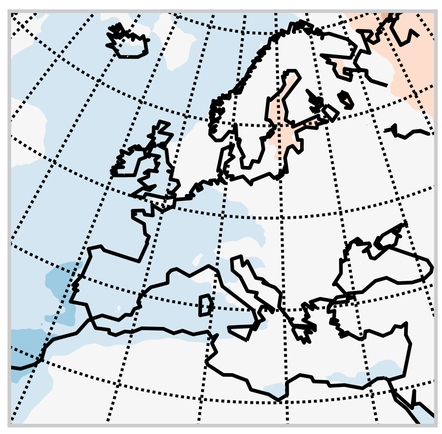
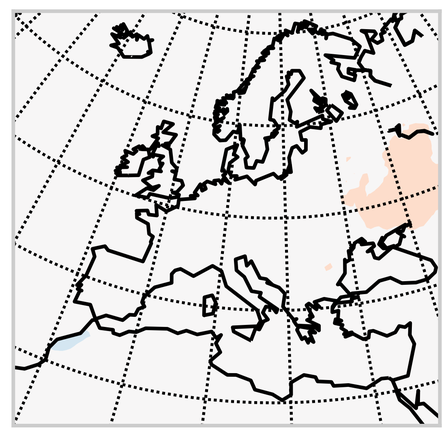
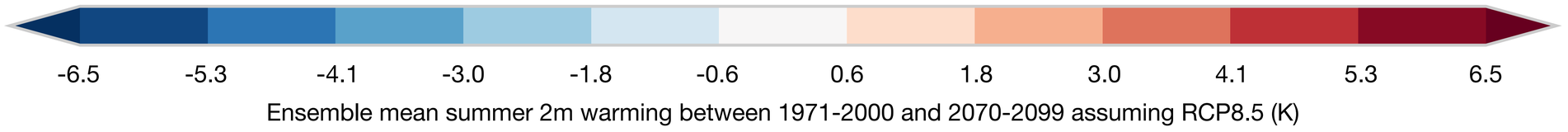


Frequency changes in **baroclinic eddies** have a surprisingly small influence on the European summer climate.

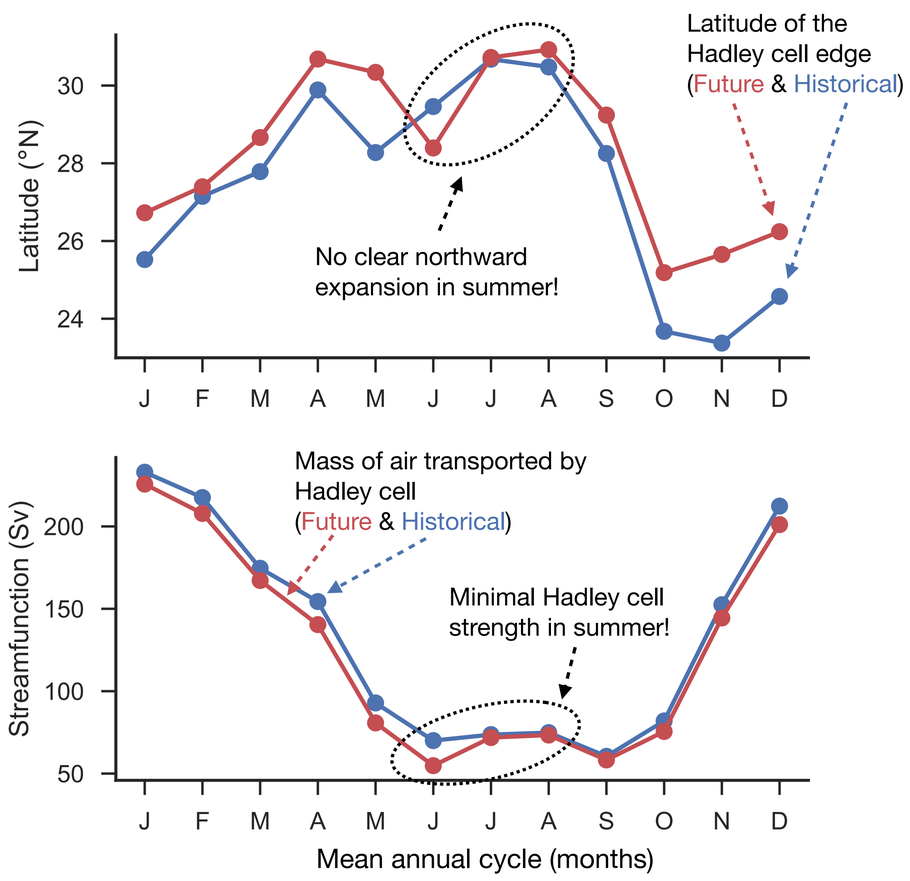




Ensemble mean summer 2m warming between 1971-2000 and 2070-2099 assuming RCP8.5 (K)

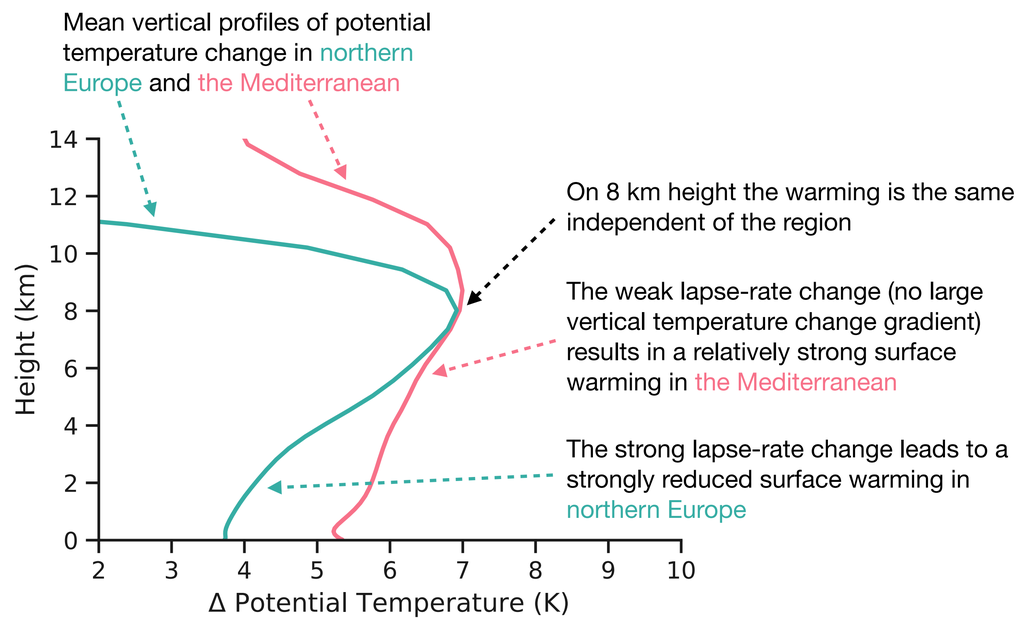
Hadley Circulation Changes

A northward expansion of the Hadley cell could explain the Mediterranean amplification, since the subtropical climate zone would reach further north. However, we can see in the figure below, that the Hadley circulation south of Europe **does not expand northwards and is very weak in summer**.



Lapse-Rate Changes

In a warming climate, the atmosphere warms less at the surface compared to higher altitudes. This is referred to as lapse-rate change. **Different lapse-rate changes** depending on the region **determine the strength of the surface warming** in summer in Europe as show in the figure below.



The regionally different lapse-rate changes are likely caused by **differences in moisture availability**. Lapse-rate changes are caused by moist-adiabatic vertical motions in a warmer climate. In the dry Mediterranean, moist-adiabatic vertical motions are uncommon which leads to weak lapse-rate changes. The strong lapse-rate changes in northern Europe are caused by more frequent moist-adiabatic vertical motions.

Get the full story

Brogli, R., N. Kröner, S.L. Sørland, D. Lüthi and C. Schär, 2019: The Role of Hadley Circulation and Lapse-Rate Changes for the Future European Summer Climate. Journal of Climate, 32, 385-404

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