Processes contributing to skillful prediction of the summer 2003 European drought and heat wave 13 months in advance

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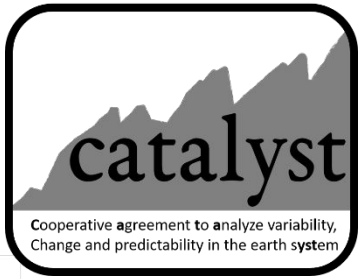
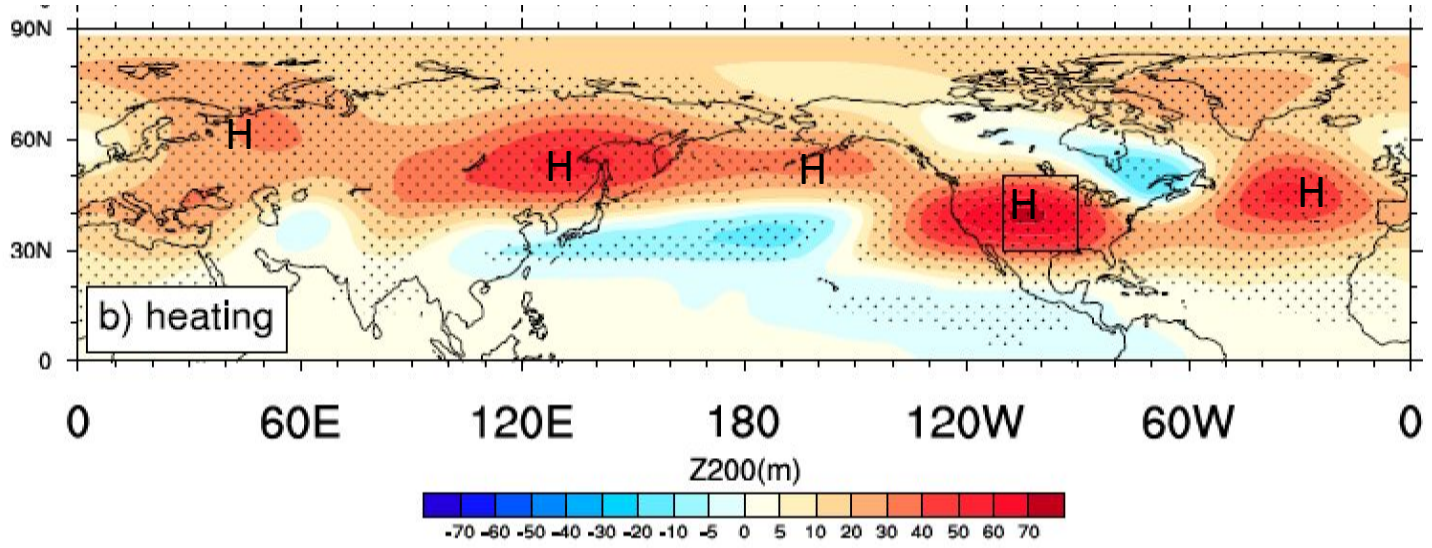
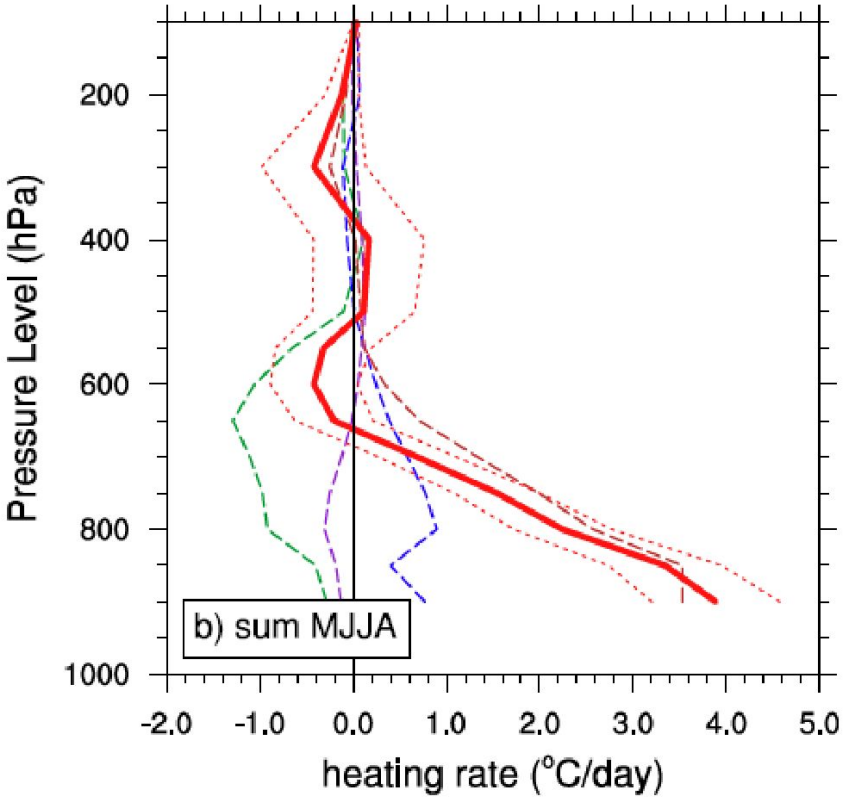
U.S. DEPARTMENT OF ENERGY
Office of Science
Biological and Environmental Research
Regional and Global Model Analysis



There is evidence that lower tropospheric heating from very dry soils and hot surface temperatures over the U.S. can drive a circumglobal wave-5 summer teleconnection pattern (Teng et al 2019)
that can connect heat extremes over the US to Europe on decadal timescales (Meehl et al., 2022)



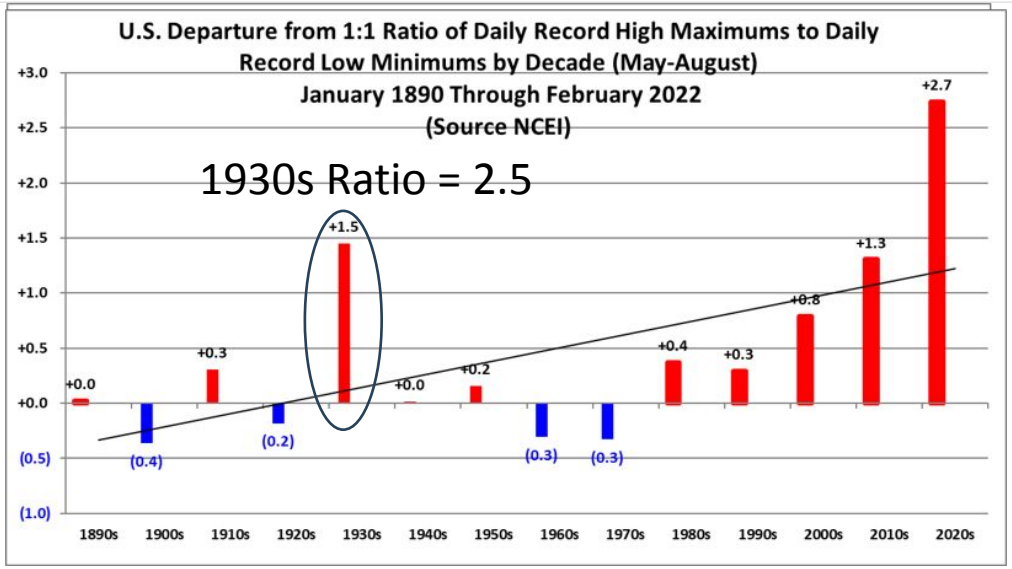


Teng et al. (2019) *J. Climate*, DOI: 10.1175/JCLI-D-18-0823.1

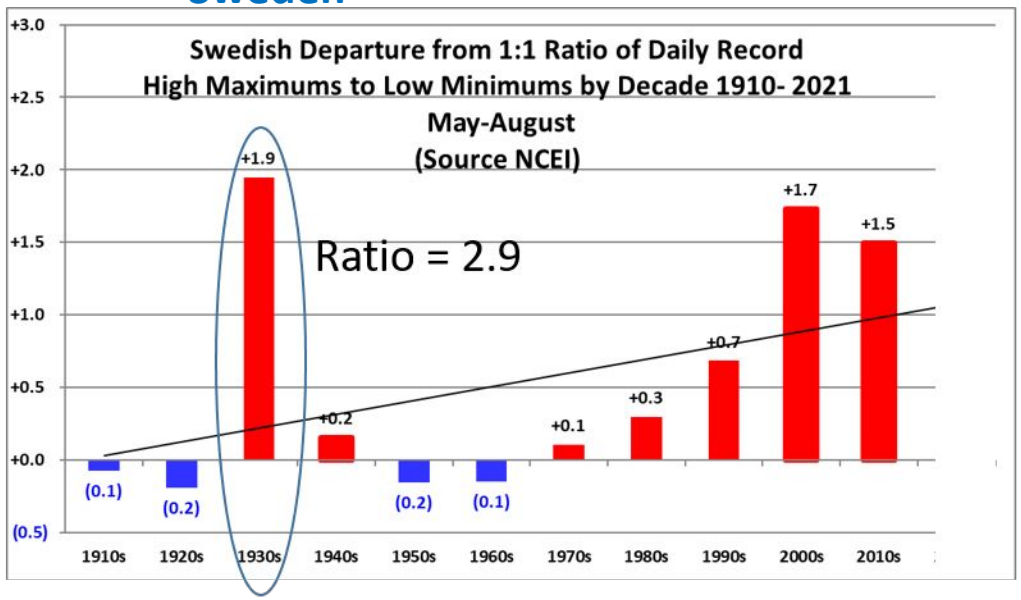
Meehl et al. (2022), *Nature Scientific Reports,* doi:10.1038/s41598-022-22262-5.

The U.S. Dust Bowl Drought was associated with heat extremes in the 1930s, but areas in Europe were anomalously warm during the 1930s and had relatively high records ratios indicative of extreme heat

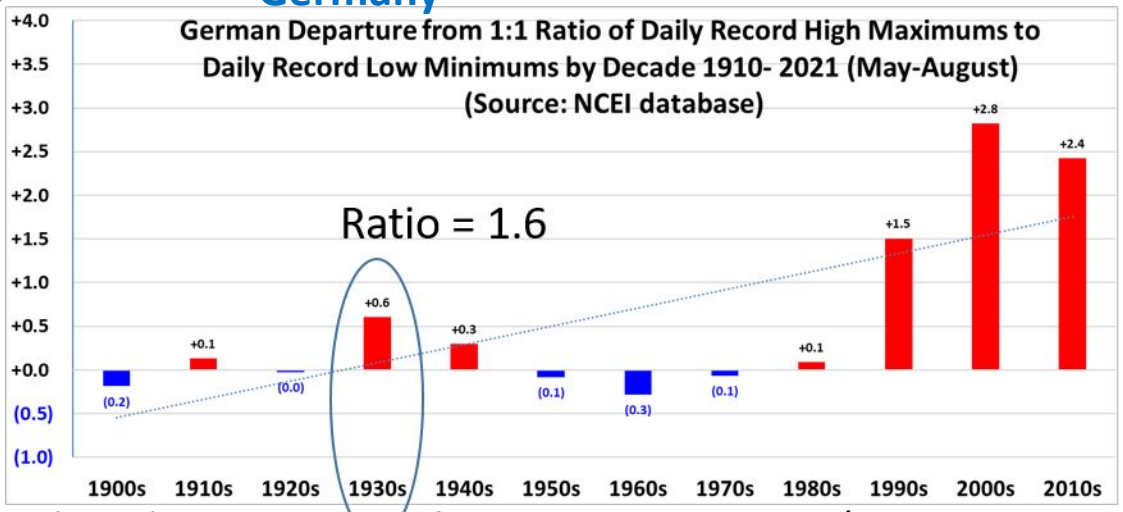
a) **U.S.**



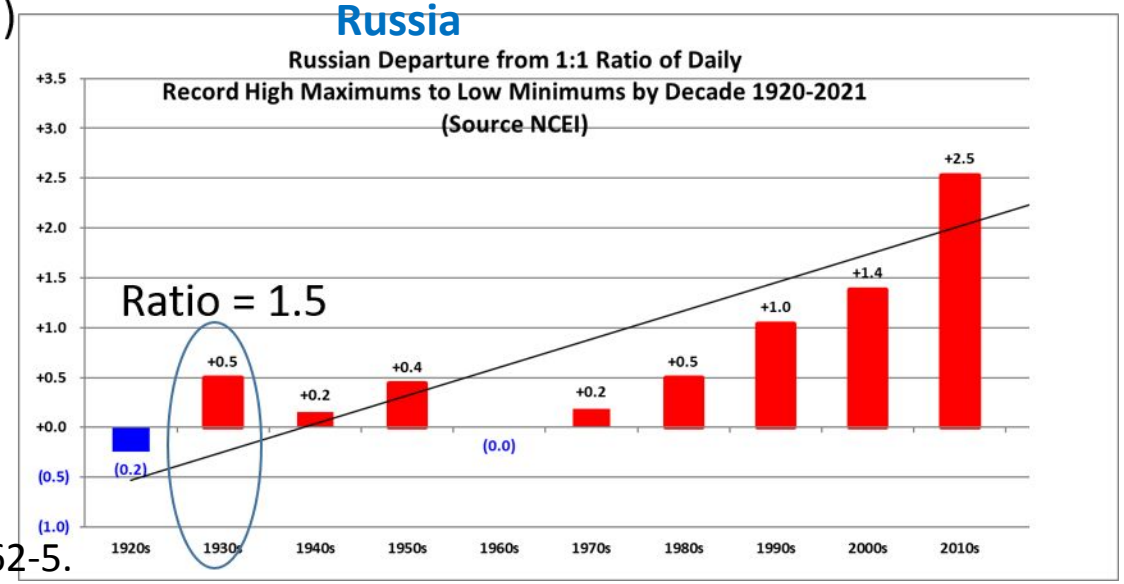
b) **Sweden**



c) **Germany**



d) **Russia**



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Could U.S. soil moisture anomalies provide predictive value for heat and drought conditions over Europe on interannual timescales?

Let’s try to predict the 2003 European heat and drought as a case study

Prior to the 2003 European heat/drought event, there was drought over the U.S. in 2002

The 2002 North American Drought was an exceptional and damaging drought which impacted the western United States. Denver was forced to impose water restrictions for the first time in over 20 years

https://en.wikipedia.org/wiki/2002_North_American_drought

https://www.carbonbrief.org/us-sees-alarming-increase-in-combined-heatwaves-and-droughts/

There was drought over the U.S. in 2002

and drought and excessive heat over the U.S. and Europe a year later

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In 2003, the western U.S. faced extreme dryness, with Washington recording its driest summer in history and Nevada its hottest. Colorado saw significant agricultural, tourism, and water-supply impacts, with 63 counties receiving federal disaster designations.

https://www.ncei.noaa.gov/access/monitoring/monthly-report/drought/200307

https://www.bsc.es/news/bsc-news/bsc-warns-the-risk-hot-and-dry-extremes-will-significantly-increase-the-coming-decades

Heat and drought were extreme in summer 2003 in Europe and resulted in an estimated 70,000 deaths. The drought was exacerbated by the heat.

https://hal.science/file/index/docid/884013/filename/hal-00884013.pdf

Case study to explore possible predictive value of U.S. soil moisture anomalies *initialized in May 2002 for JJA 2003 European drought and heat wave*

Test case: Initialized SMYLE hindcasts with CESM2

Initialized in May 2002, and analyzed for 13 month lead for JJA 2003

20 ensemble members

Ocean initialization: **FOSI**

Soil moisture initialization: **Land component of CESM SMYLE is initialized using the CLM output generated from an offline TRENDY (CRU-JRA55) forced land-only case; Soil moisture is initialized via land initial conditions**

Observed soil moisture: **ESA CCI** (https://climate.esa.int/en/projects/soil-moisture/)

Observed SSTs: **HadISST**

Observed atmospheric fields: **ERA5**

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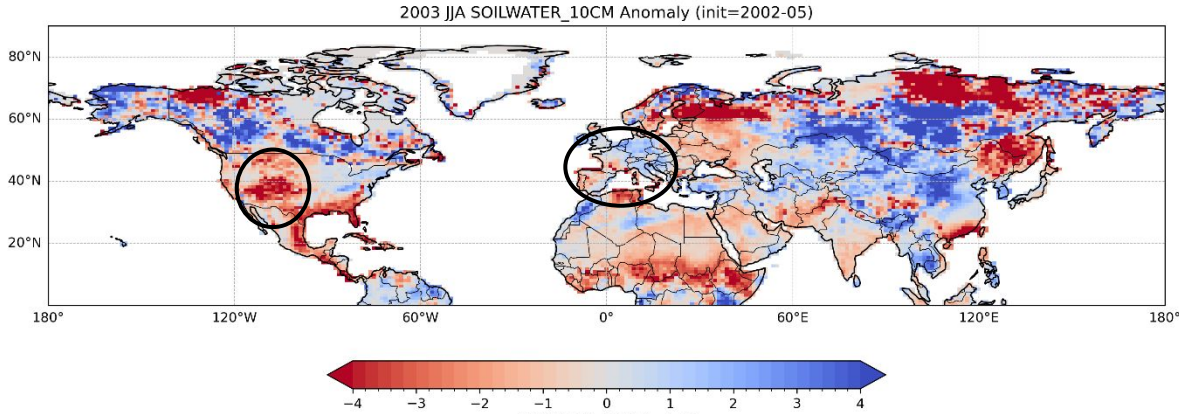
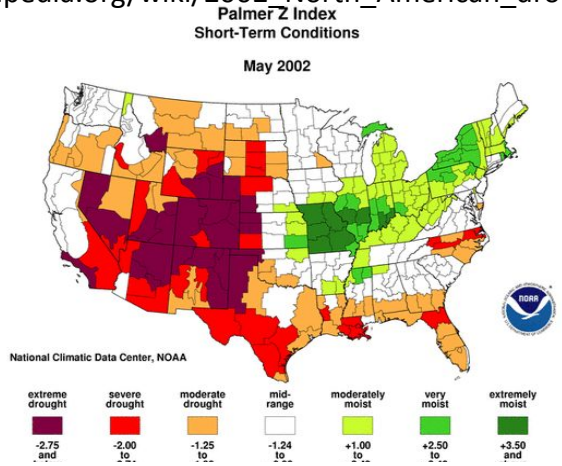
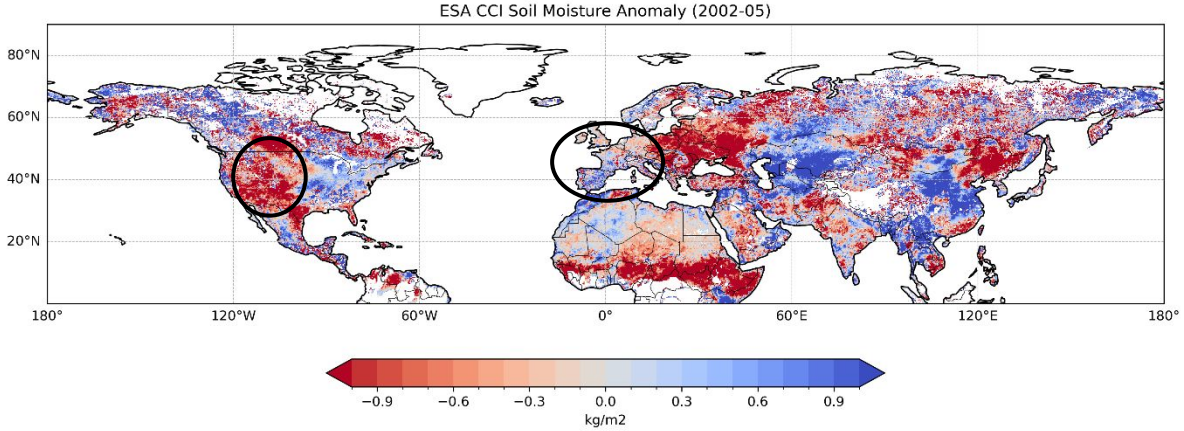
Initial state soil moisture anomalies May 2002





Observed soil moisture anomalies May 2002



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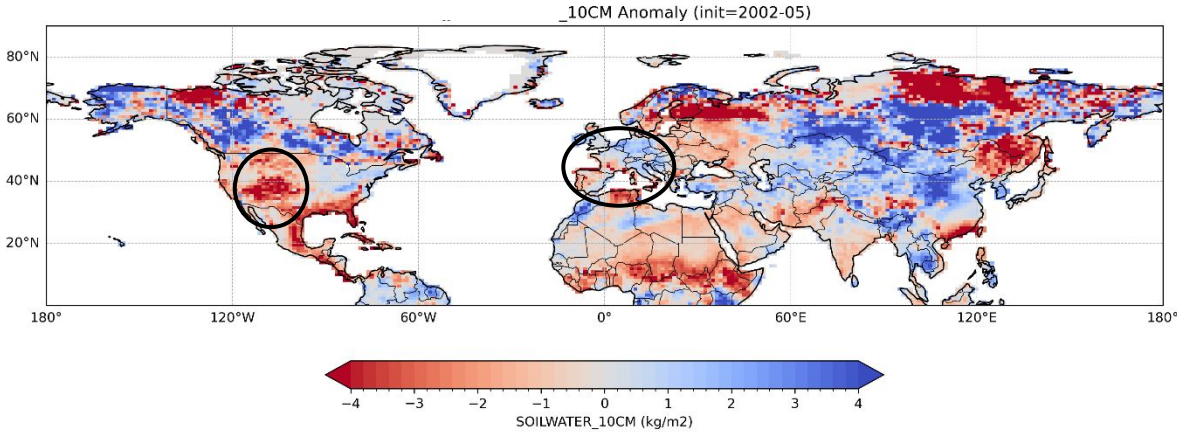
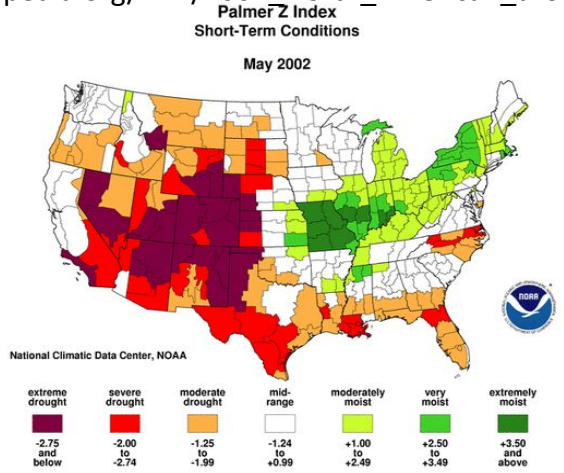
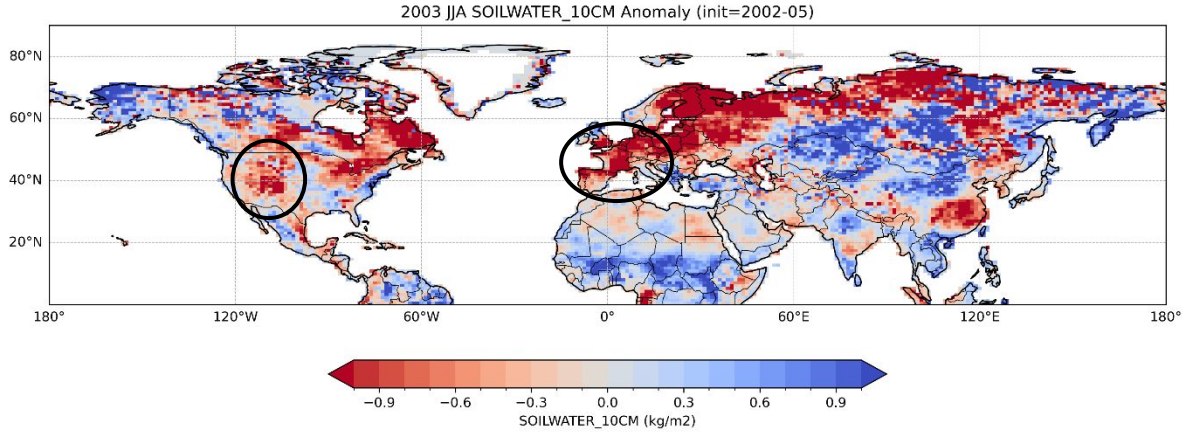
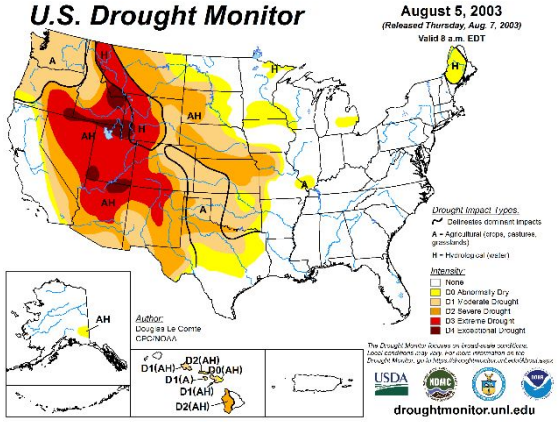




13 month lead predicted soil moisture JJA 2003





Heat and drought were extreme in summer 2003 in Europe. The drought was exacerbated by the heat.

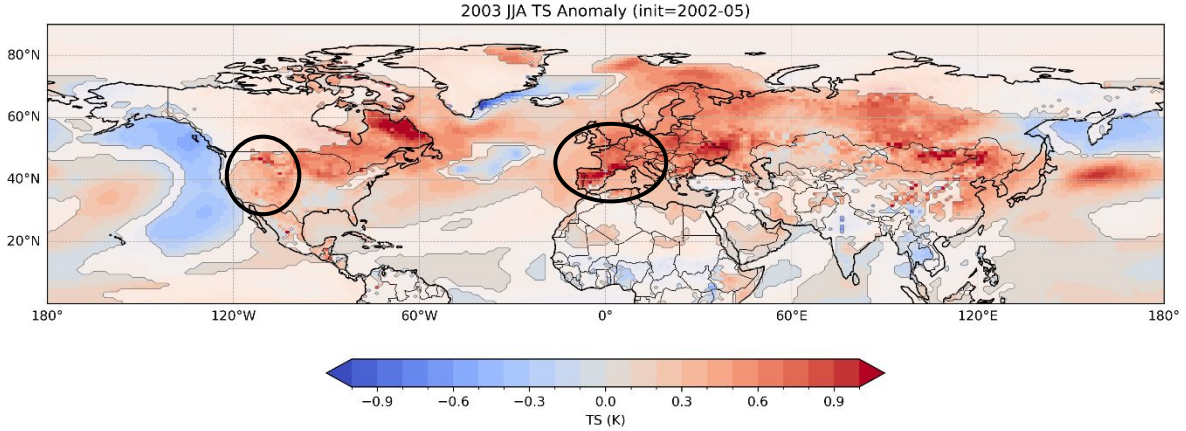
https://hal.science/file/index/docid/884013/filename/hal-00884013.pdf

A 2003 drought across western and central portions of the U.S. caused major losses to agriculture

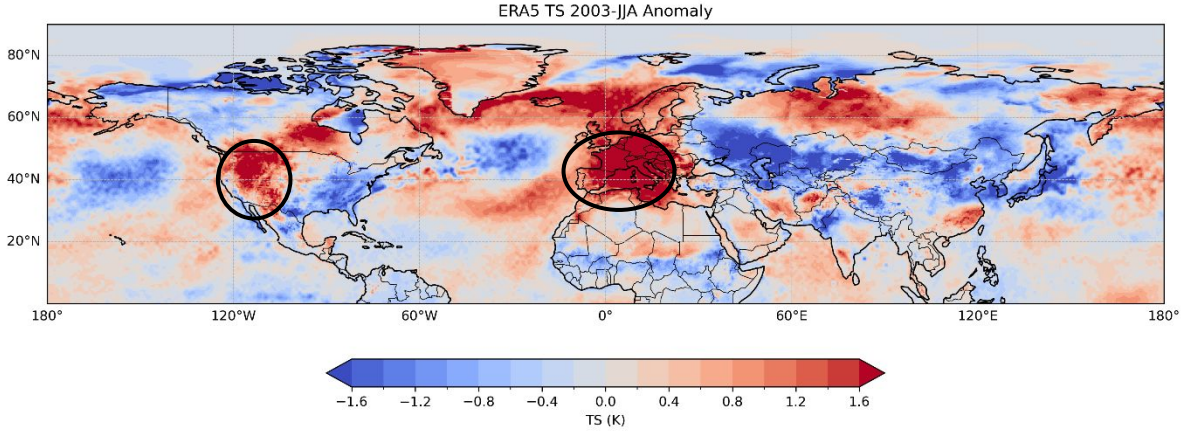
https://www.aarp.org/events-history/costliest-heat-waves/

13 month lead JJA 2003 prediction: hot and dry over the U.S. and Europe

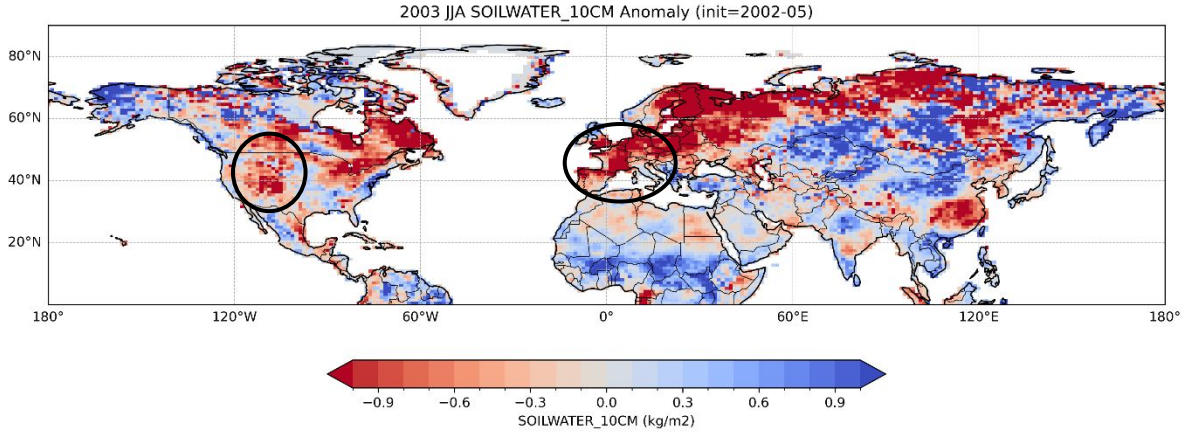
Predicted surface temperature anomalies



Observed surface temperature anomalies



Predicted soil moisture anomalies



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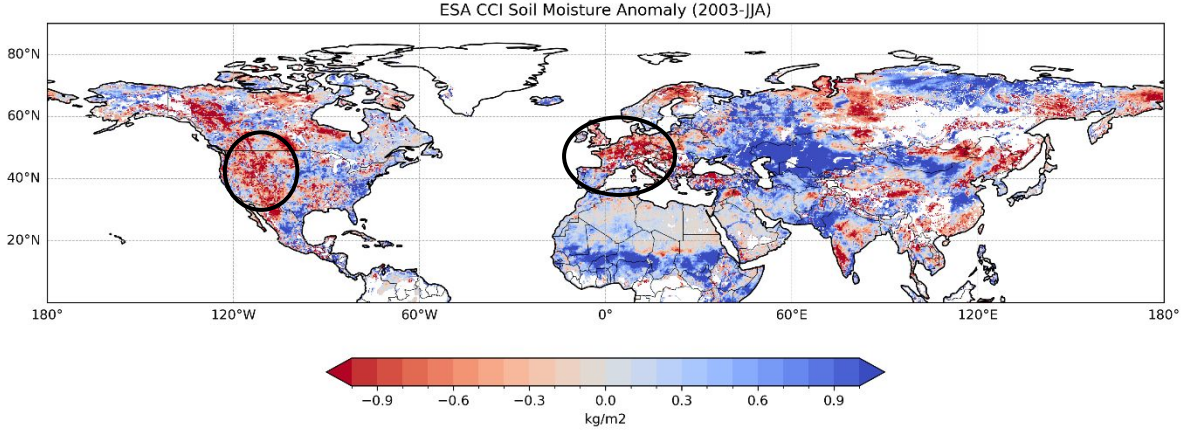
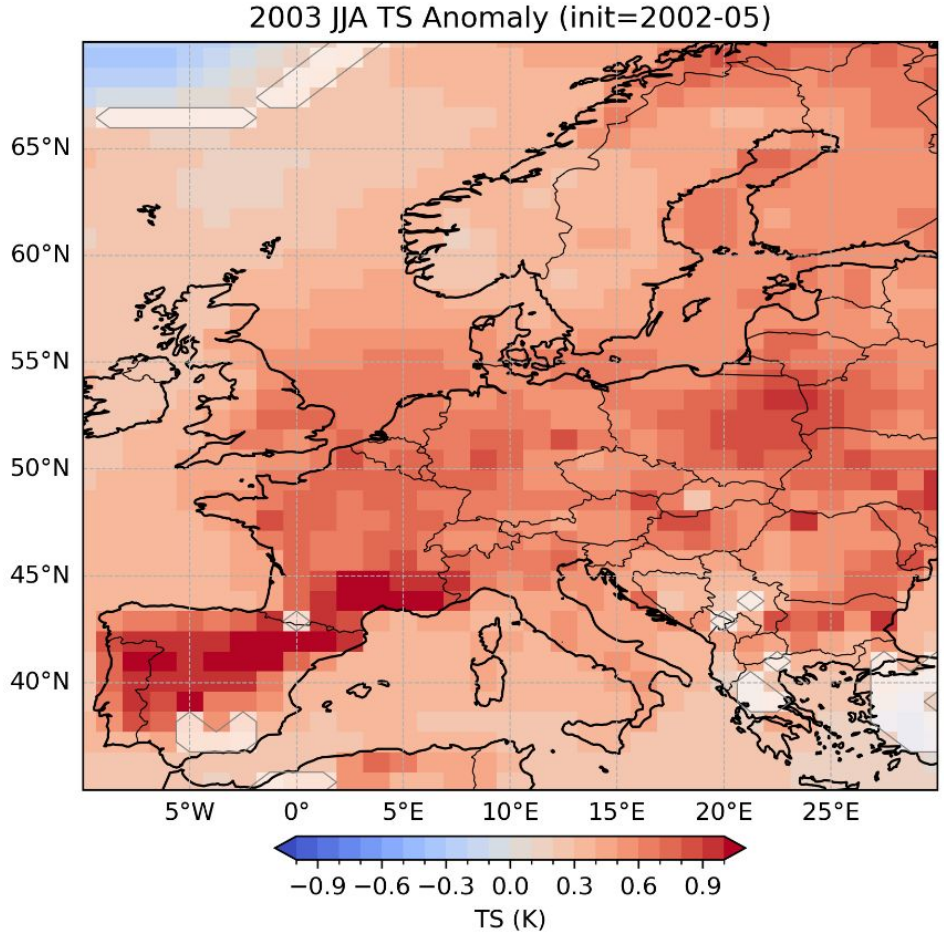


JJA 2003 13 month lead prediction shows elevated heat over Europe

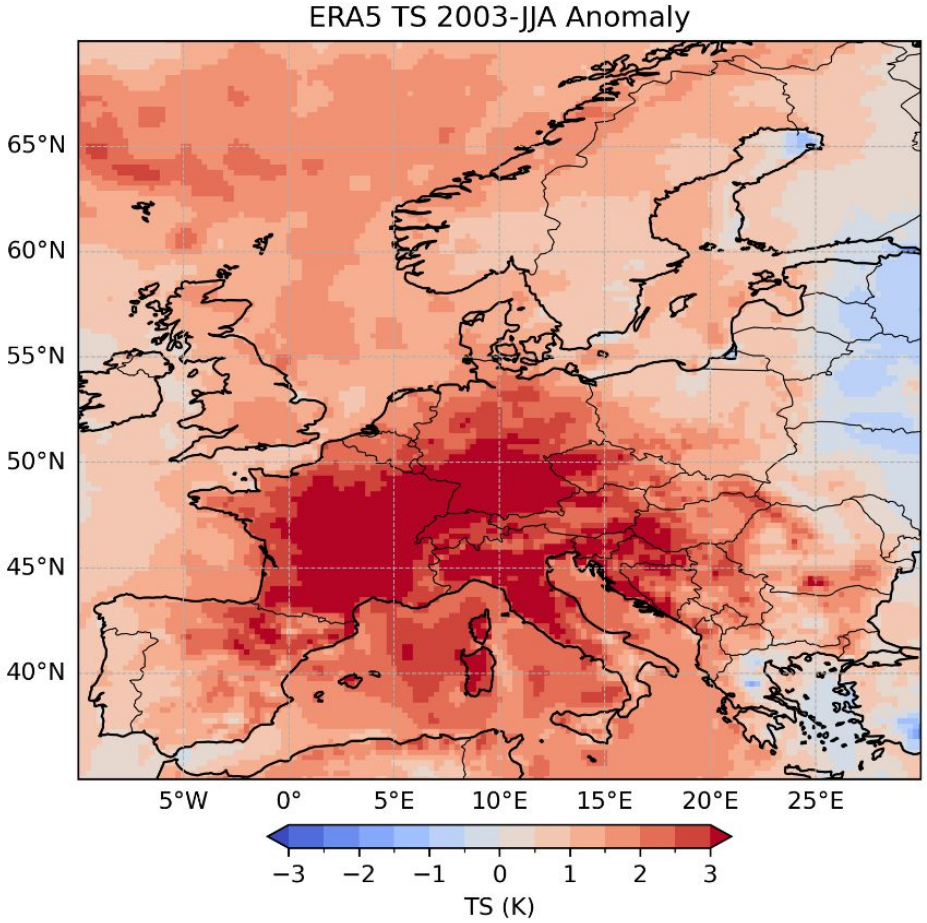
--predicted surface temperature anomalies about half of those observed

--centered over Spain and southern France; largest observed temperature anomalies farther north and east

Predicted surface temperature anomalies



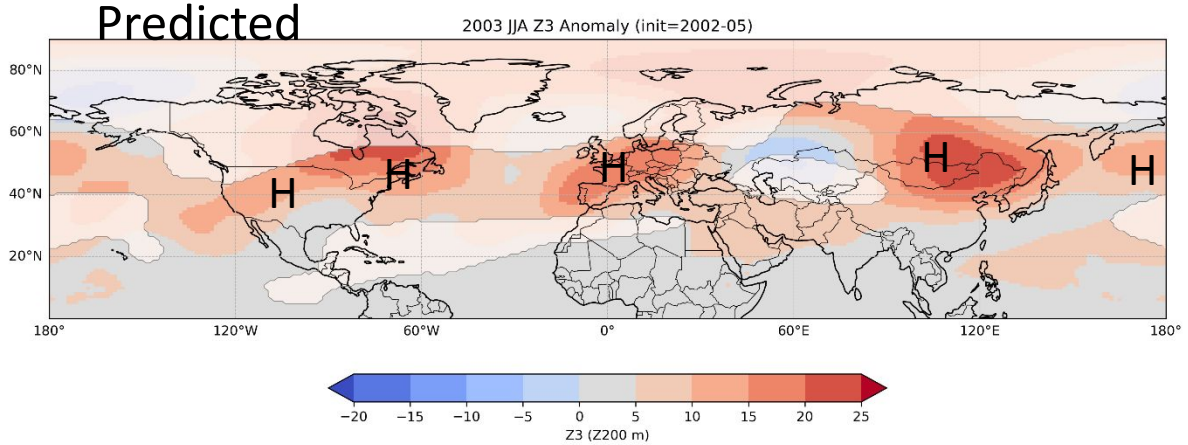
Observed surface temperature anomlaies



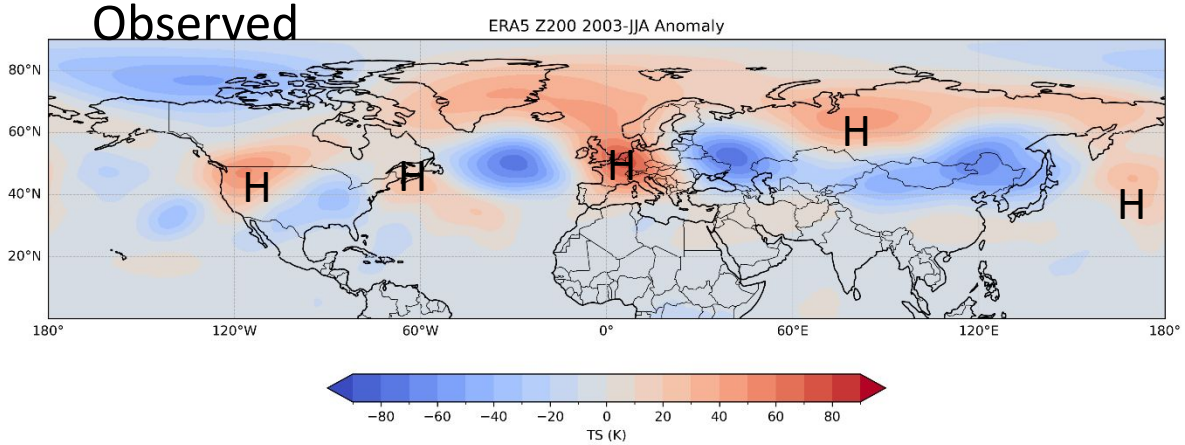
What is connecting the heat and drought over the U.S. to European heat and drought?

200 hPa height anomalies show a wave 5 circumglobal teleconnection pattern in the 13 month prediction and observations for JJA 2003

Predicted

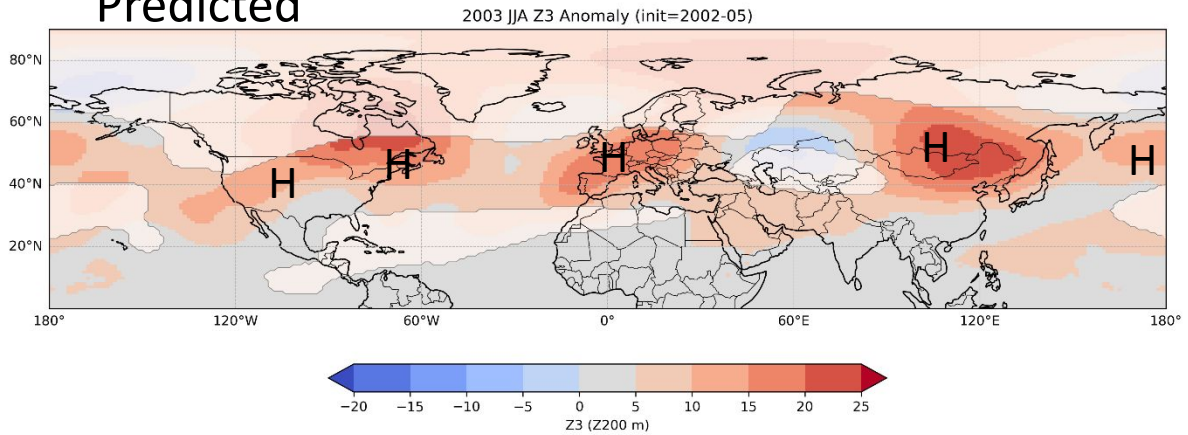


Observed

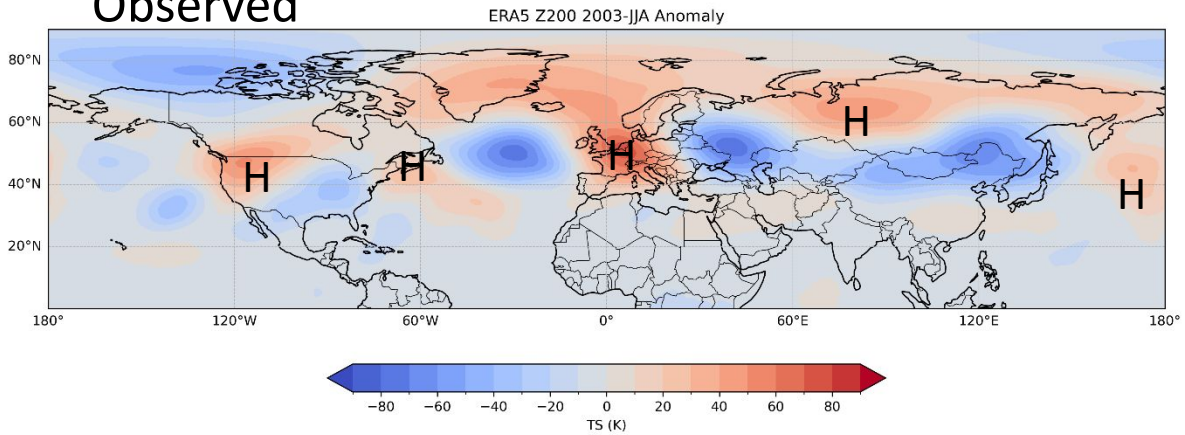


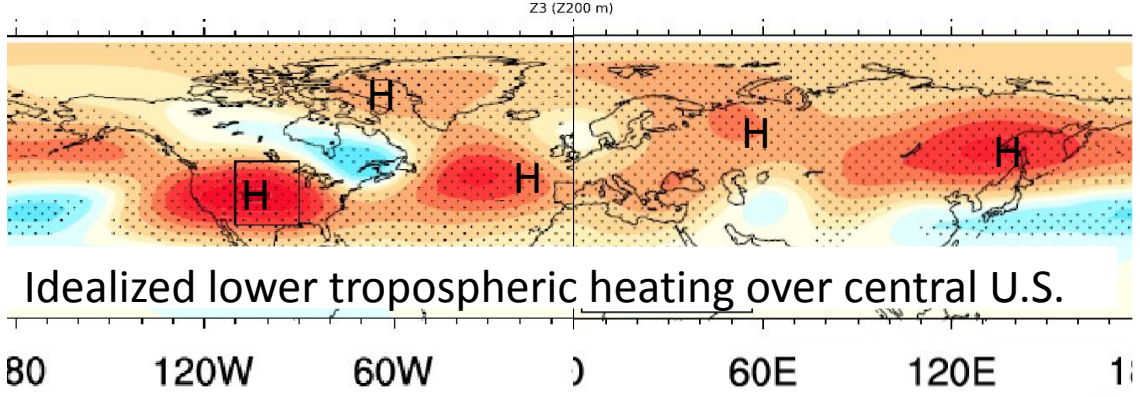
200 hPa height anomalies show a wave 5 circumglobal teleconnection pattern in the 13 month prediction and observations for JJA 2003 that provide predictive value for U.S. heat and drought for European heat and drought a year later

Predicted



Observed





This wave 5 circumglobal teleconnection pattern can be related to an idealized lower tropospheric heating experiment over the Great Plains (Teng et al 2019) **that connected the Dust Bowl heat extremes to European heat extremes** (Meehl et al., 2022)

Summary

Previous work demonstrated that very dry soils and associated heat extremes over the U.S. during the Dust Bowl in the 1930s can be connected via a circum-global wave-5 summer teleconnection pattern to heat extremes in Europe on decadal timescales

Could this connection also exist on interannual timescales to provide predictive value from U.S. drought to subsequent European drought and heat a year later?

Initialized hindcast case study to predict the 2003 European heat and drought:

Initialized negative soil moisture anomalies in the western U.S. in the model in May 2002 are comparable to observed soil moisture anomalies in May 2002, but there are no negative soil moisture anomalies over Europe in May 2002 in either the model initial state or observations

Initialized 13-month lead prediction for summer 2003 shows U.S. soil moisture anomalies persisted to produce surface heat, a circum-global wave-5 teleconnection pattern with an anomalous high over Europe, and anomalous heat and drought over Europe in JJA 2003