

# Land surface processes contributing to skillful prediction of the summer 2003 European drought and heat wave 13 months in advance

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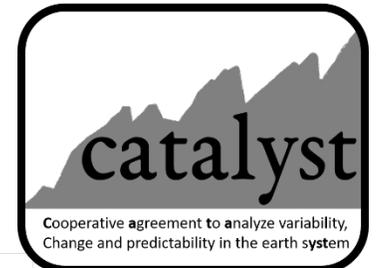
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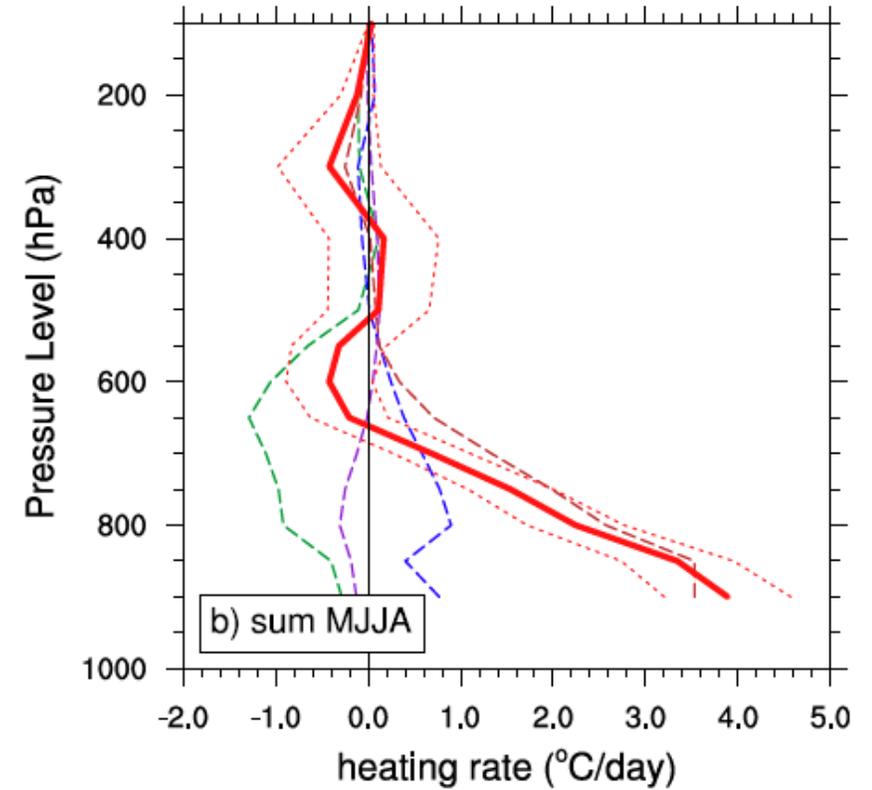
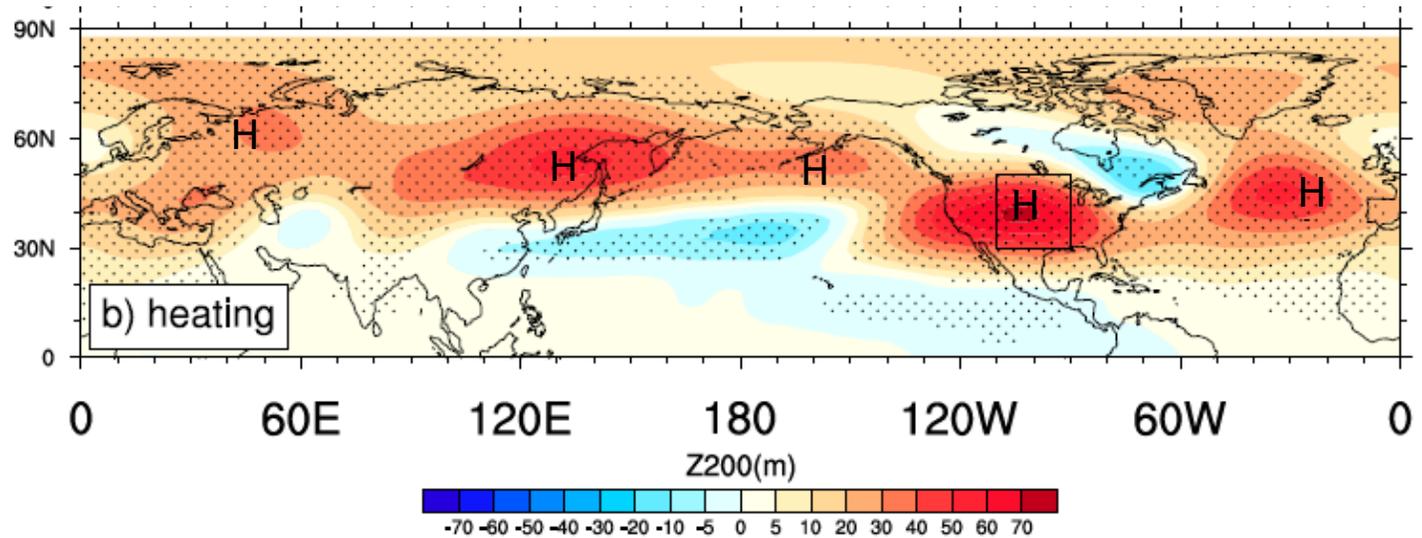
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Regional and Global Model Analysis



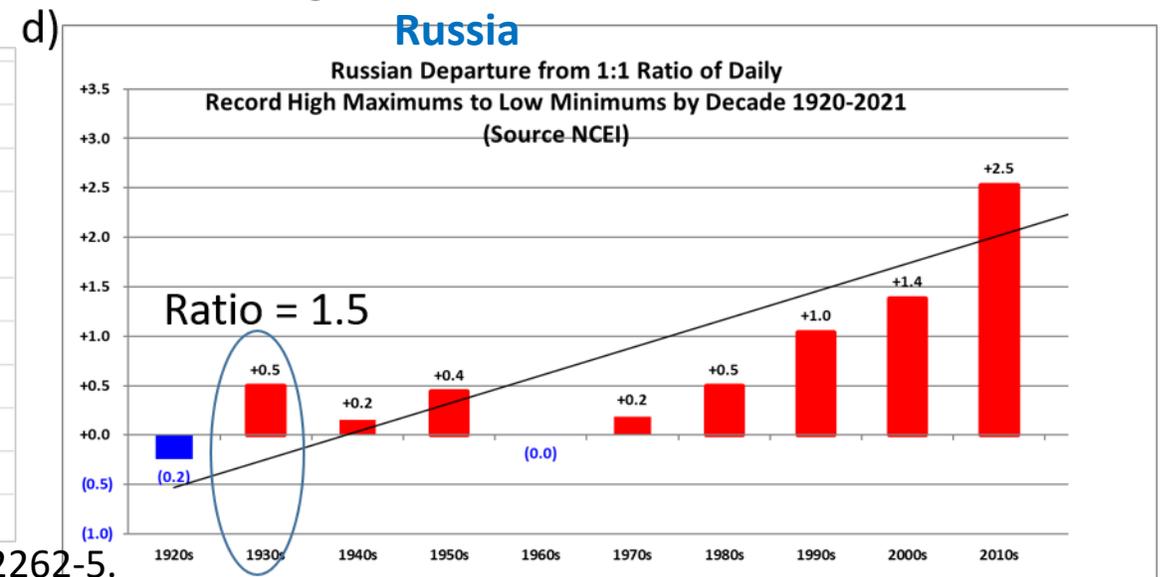
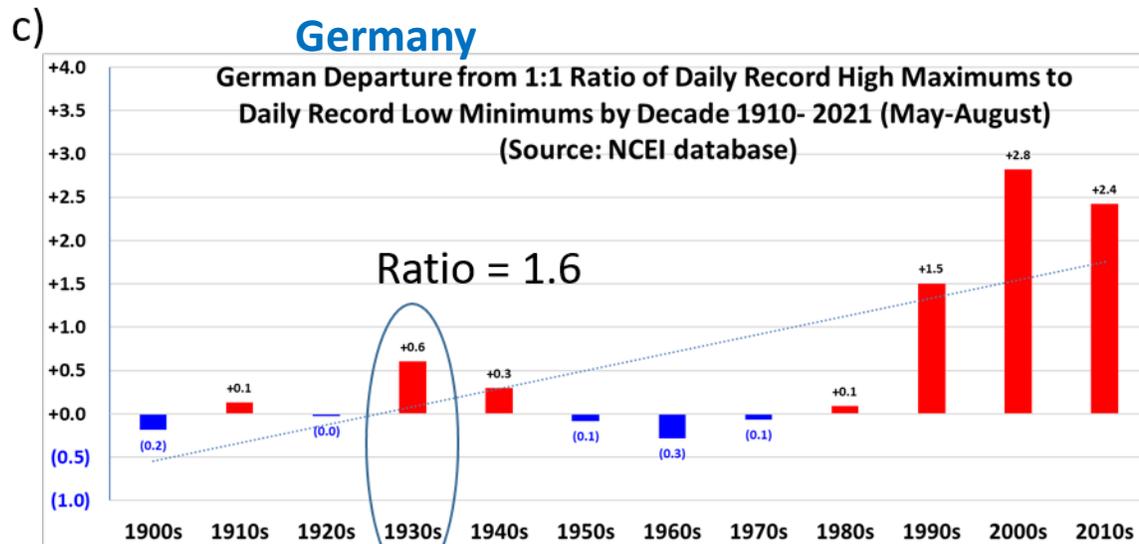
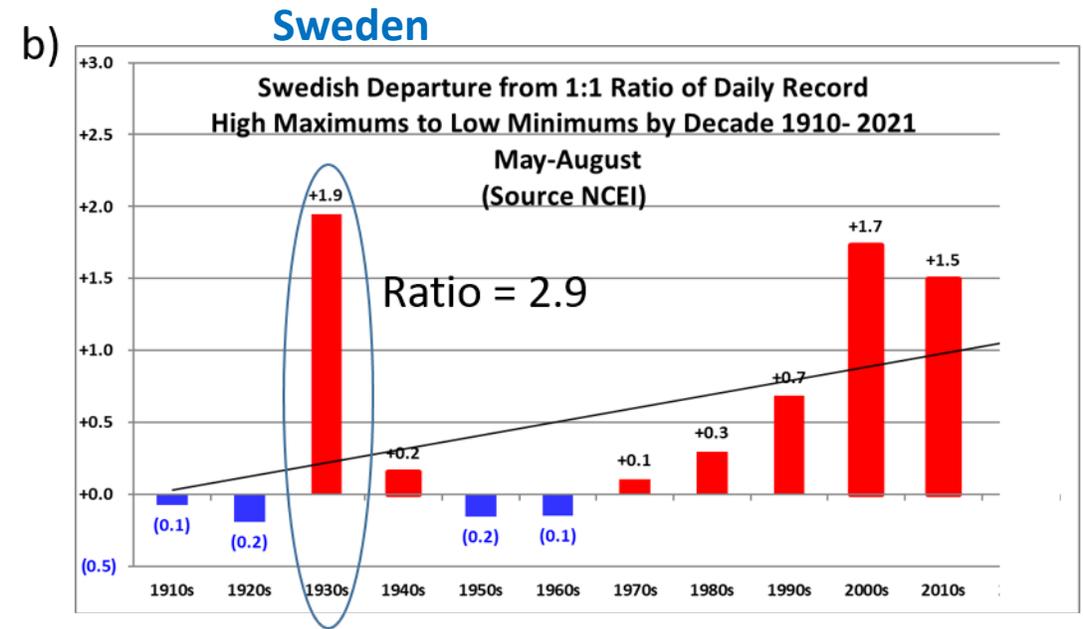
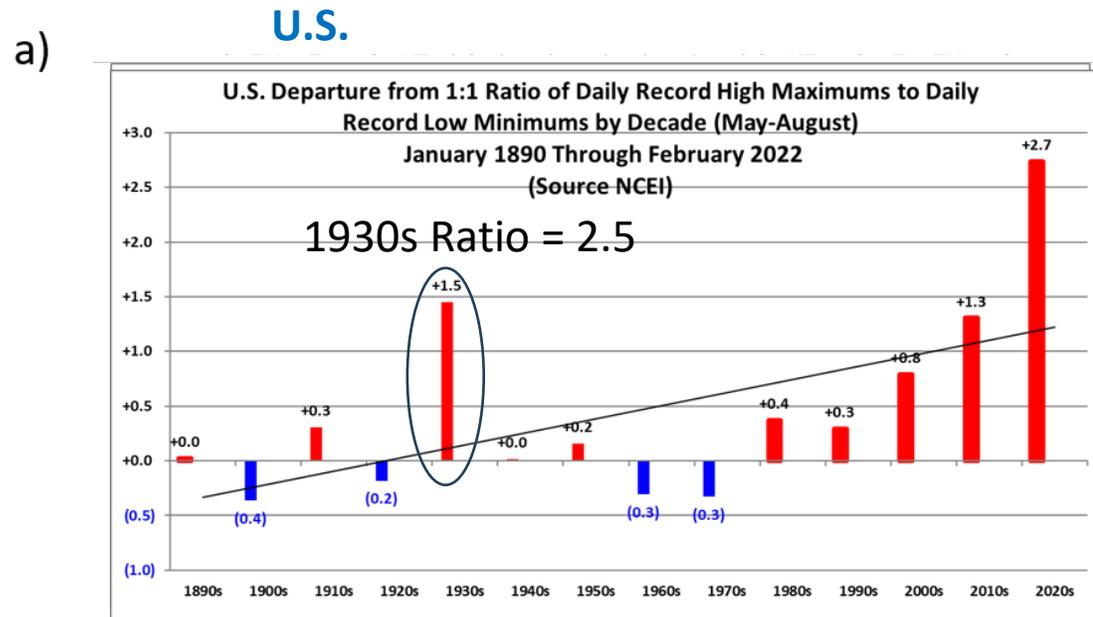
There is evidence that lower tropospheric heating from very dry soils and hot surface temperatures over the U.S. can drive a circumglobal wave-5 summer teleconnection pattern (Teng et al 2019) that can connect heat extremes over the US to Europe on decadal timescales (Meehl et al., 2022)



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



**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://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>

**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>



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



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

# **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-JRAv2) 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/>)

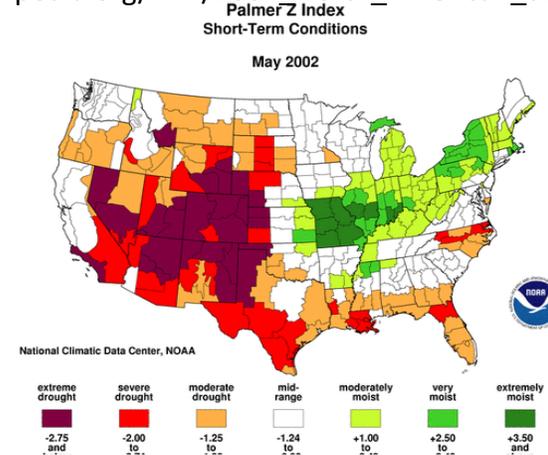
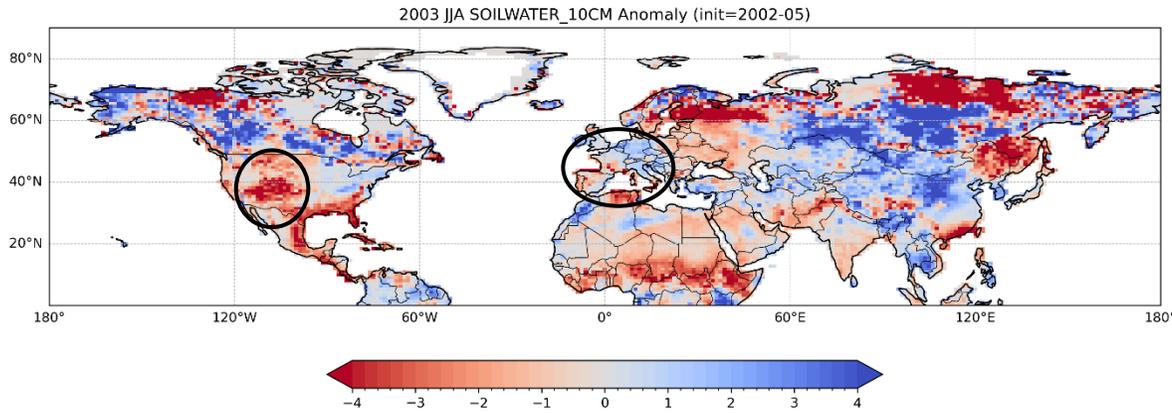
**Observed SSTs: HadISST**

**Observed atmospheric fields: ERA5**

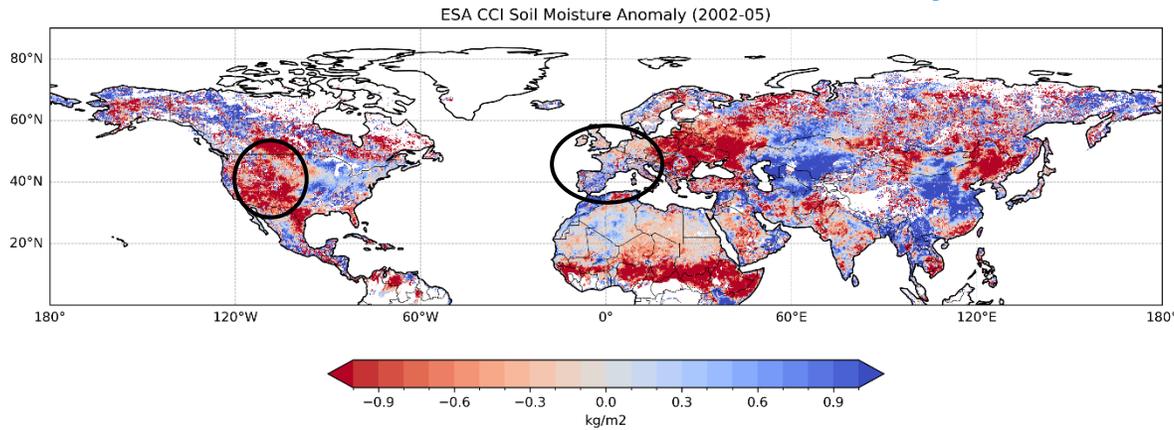
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## Initial state soil moisture anomalies May 2002



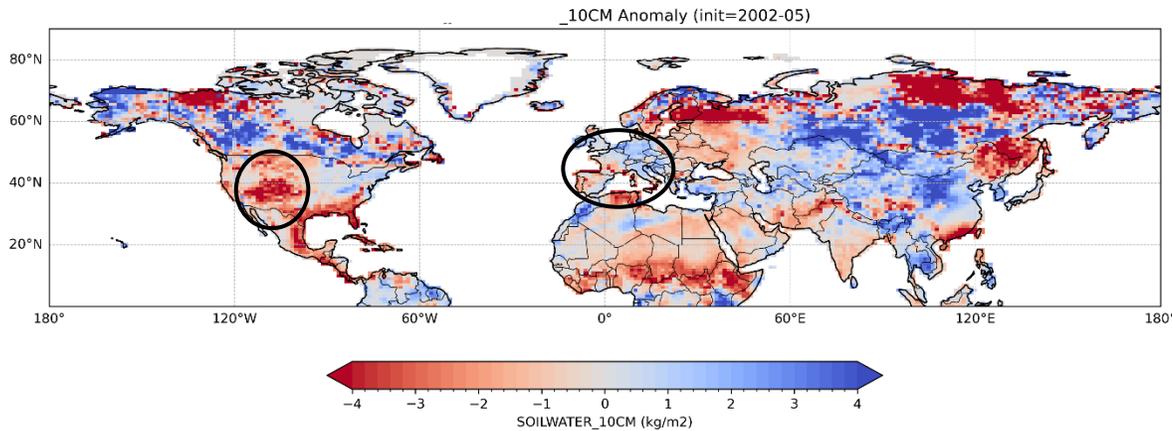
## Observed soil moisture anomalies May 2002



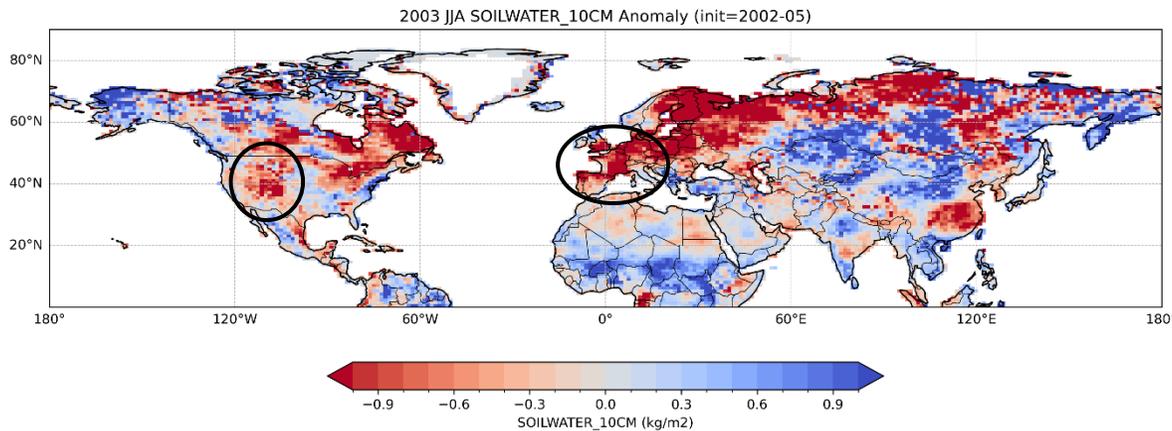
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### Initial state soil moisture anomalies May 2002



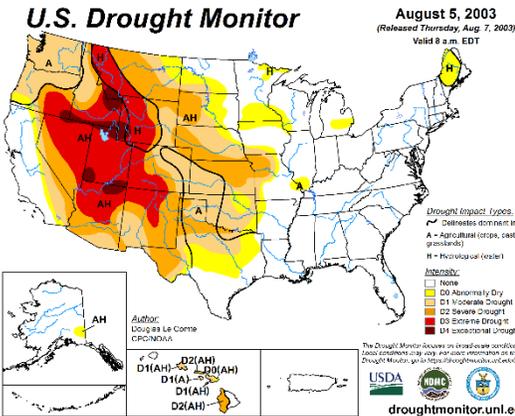
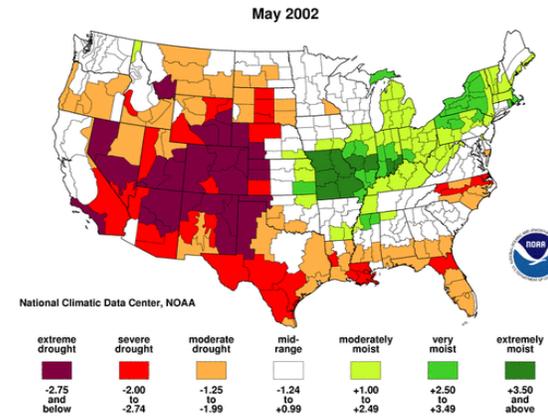
### 13 month lead predicted soil moisture JJA 2003



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>

Palmer Z Index  
Short-Term Conditions

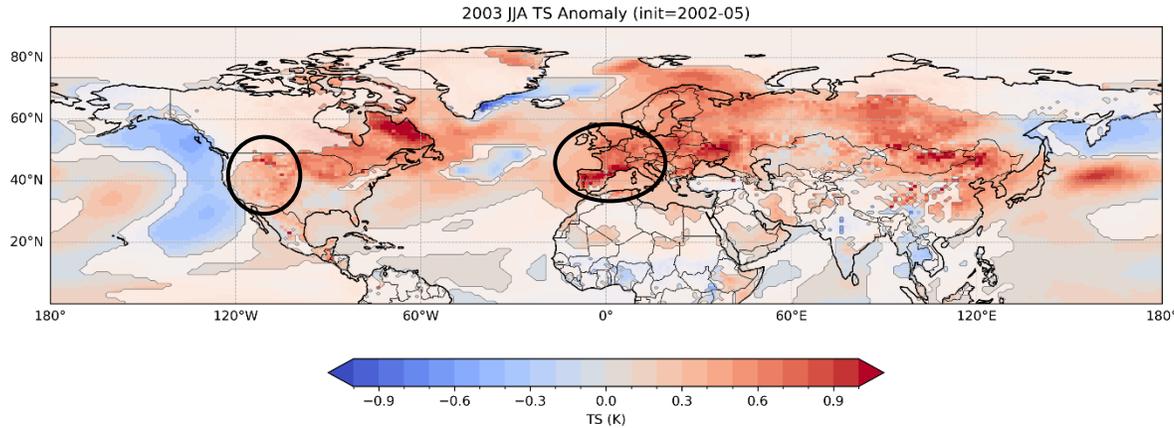


A 2003 drought across western and central portions of the U.S. caused major losses to agriculture

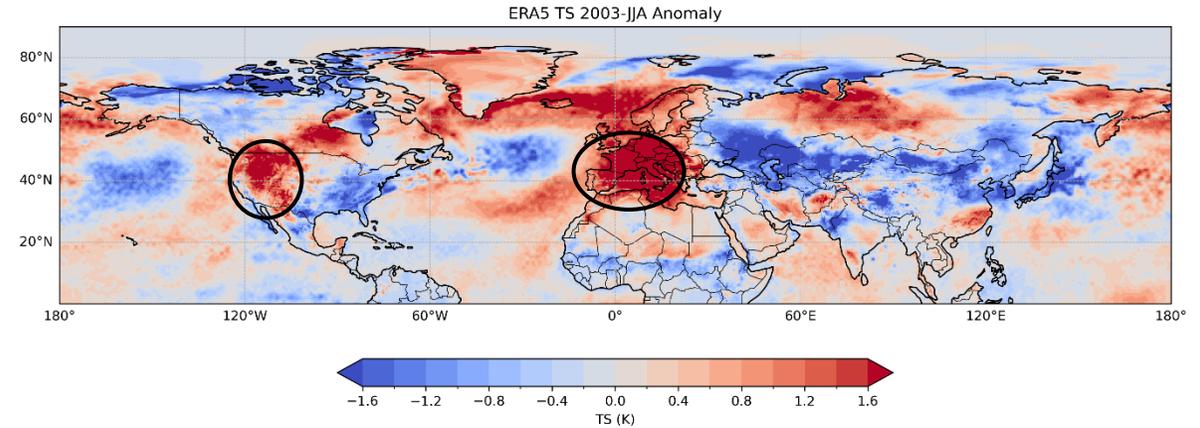
<https://www.aarp.org/events-history/costliest-heat-waves/>

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

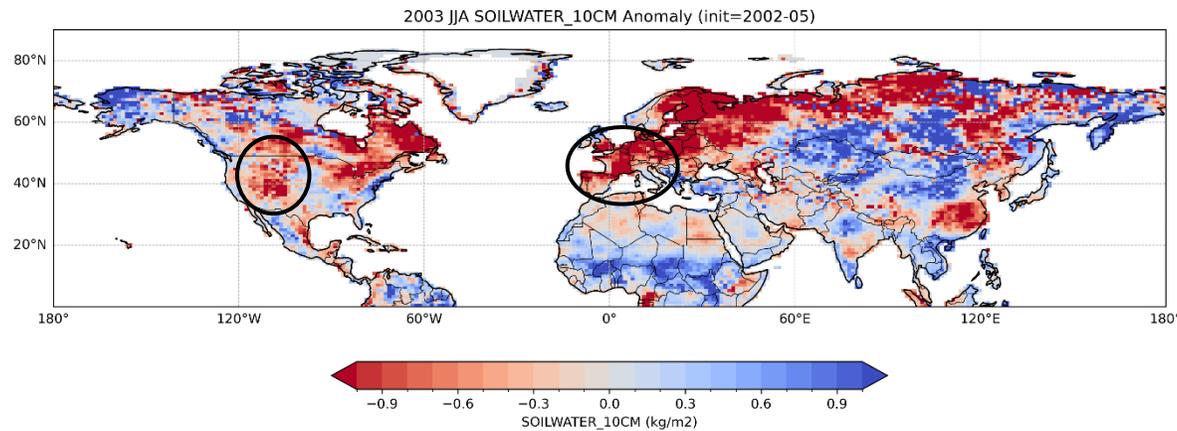
## Predicted surface temperature anomalies



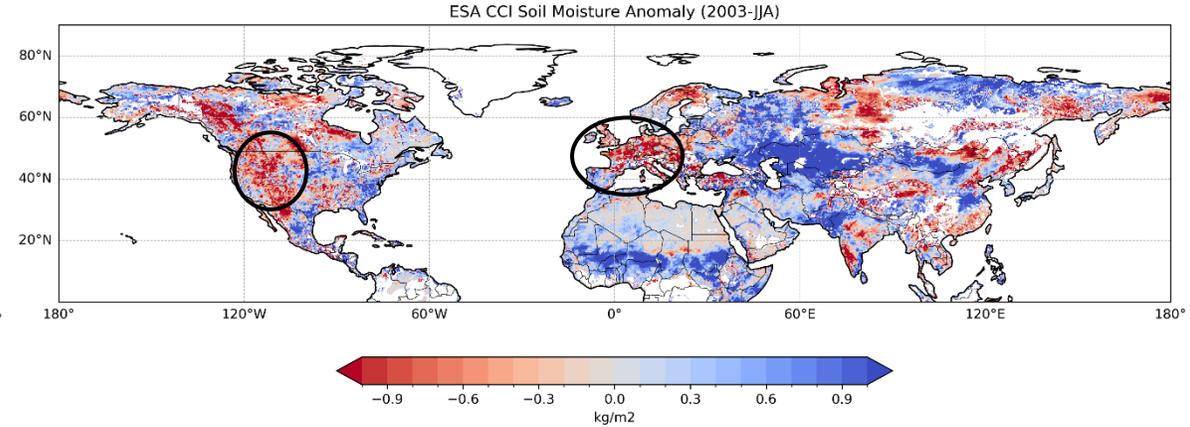
## Observed surface temperature anomalies



## Predicted soil moisture anomalies



## Observed soil moisture anomalies

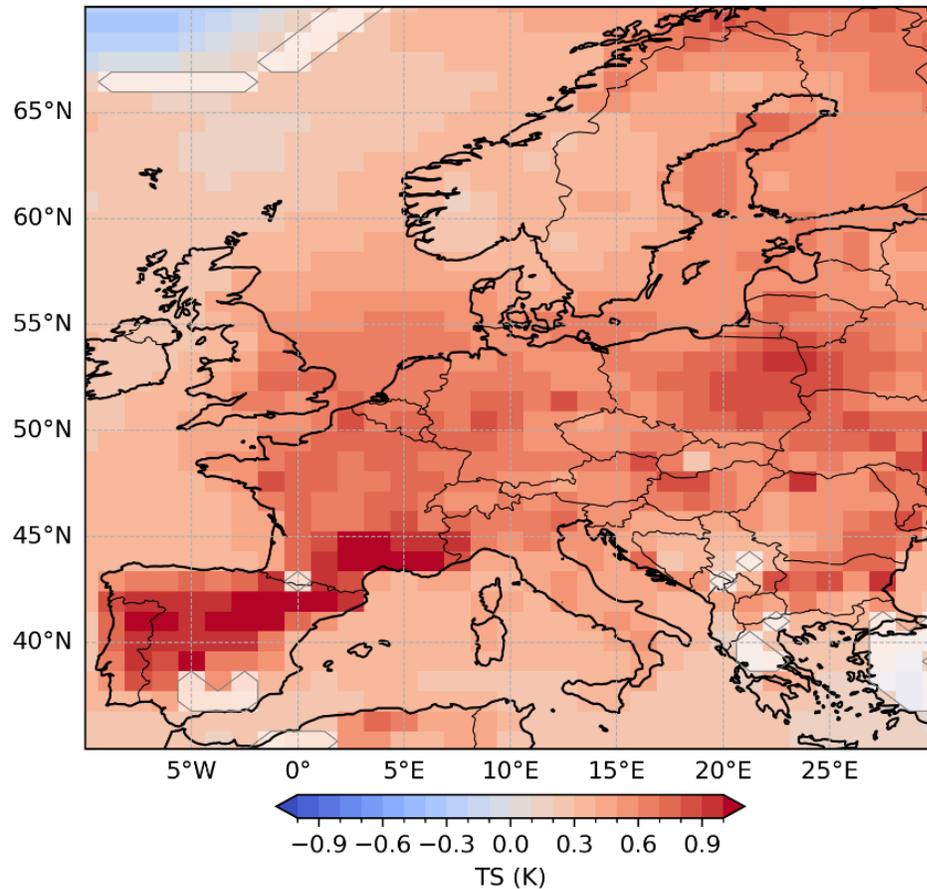


## JJA 2003 13 month lead prediction shows elevated heat over Europe

- predicted surface temperature anomalies about half of those observed
- centered over Spain and southern France; largest observed temperature anomalies farther north and east

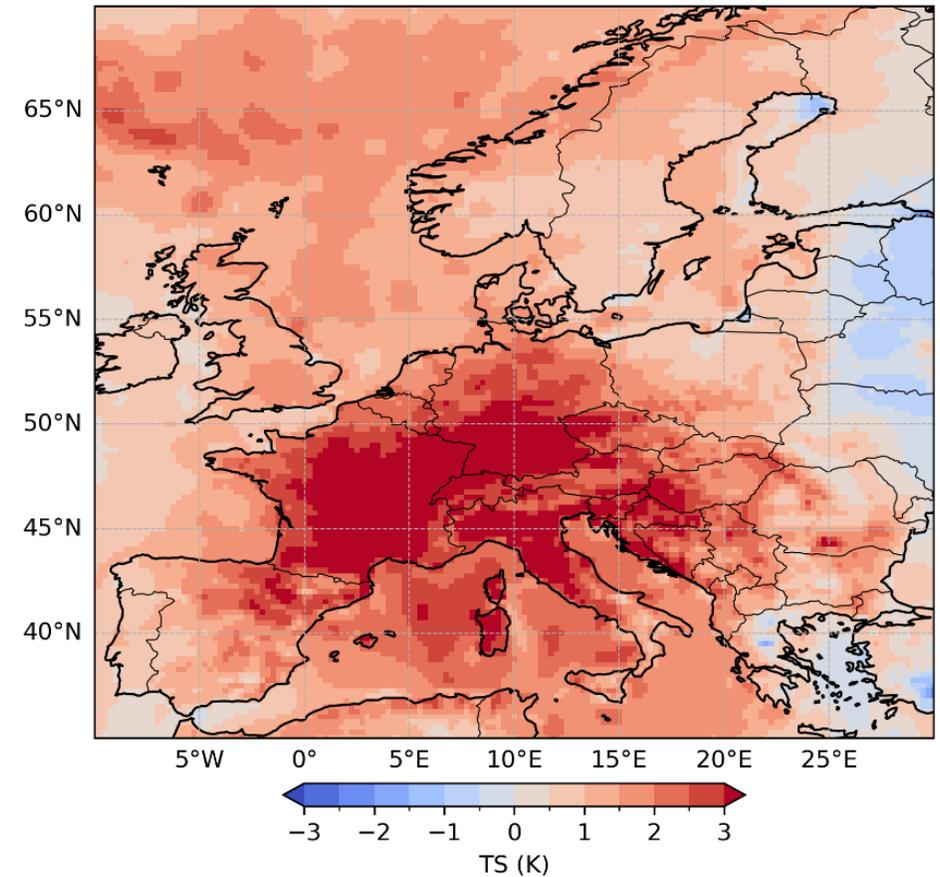
### Predicted surface temperature anomalies

2003 JJA TS Anomaly (init=2002-05)



### Observed surface temperature anomalies

ERA5 TS 2003-JJA Anomaly

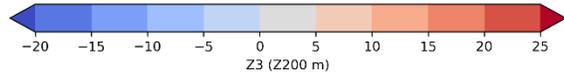
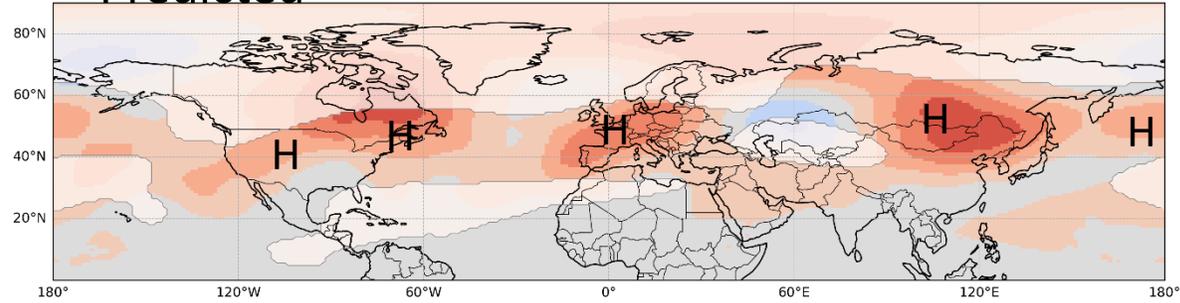


# What is connecting the heat and drought over the U.S. to European heat and drought?

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

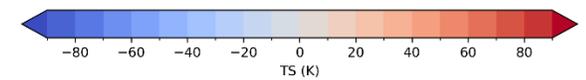
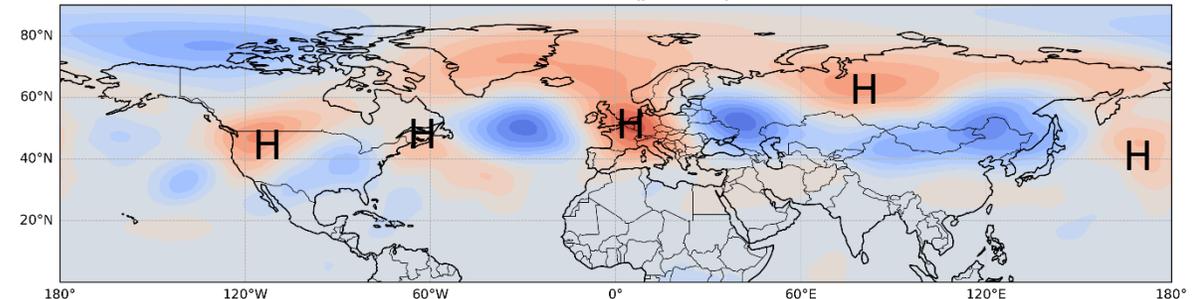
Predicted

2003 JJA Z3 Anomaly (init=2002-05)



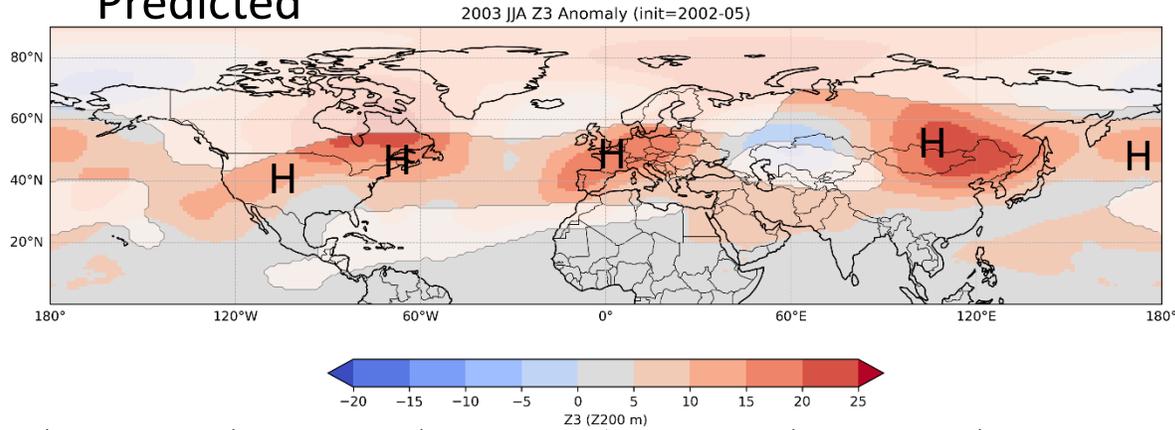
Observed

ERA5 Z200 2003-JJA Anomaly

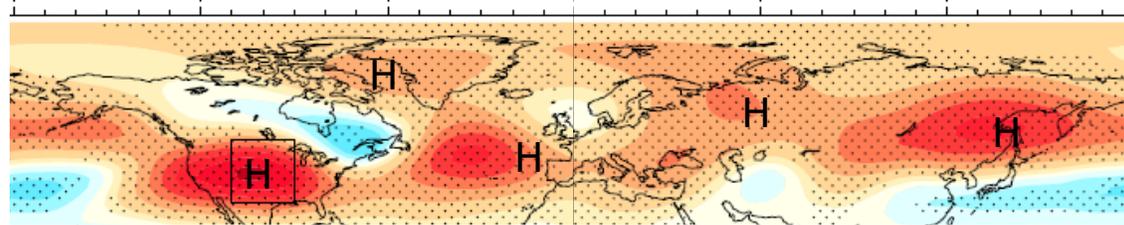
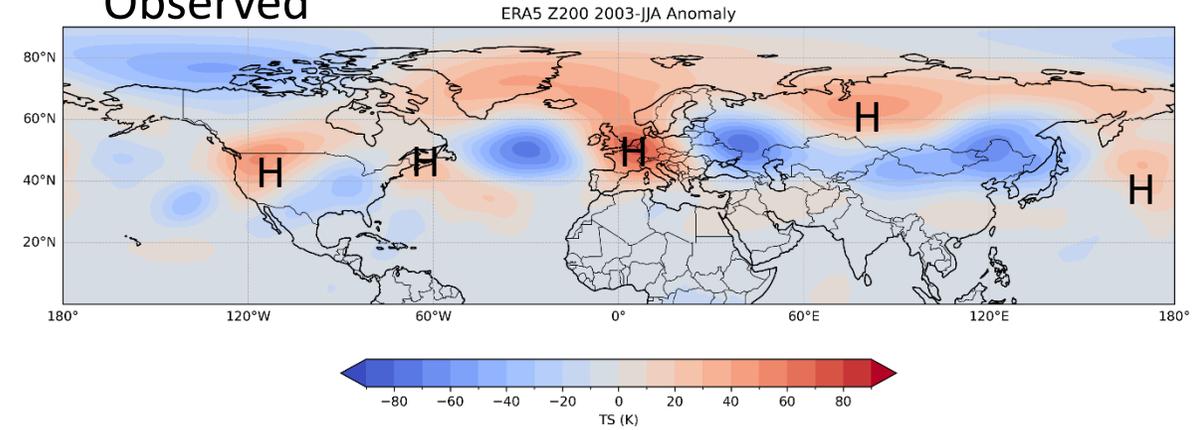


# 200 hPa height anomalies show a wave 5 circumglobal teleconnection pattern in the 13 month prediction and observations for JJA 2003 that provide predictive value for U.S. heat and drought for European heat and drought a year later

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**