European drought during the last two millennia

from reconstructions and model simulations.

EGU2020-19963

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EGU2020 Display 08.05.2020

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Information to be provided to introduce the chat:

Presenter: J. Fidel González Rouco

This presentation analyses EU drought in climate reconstructions (OWDA) and model simulations of the CESM-Last Millennium Ensemble

We find that:

- EU drought can be objectively structured into regions of ~ uncorrelated long term variability
- Some of these regions exhibit megadroughts through the last millennium
- CESM LME reproduces a comparable array of drought regions including a comparable behaviour of extreme drought.
- Extreme drought does not seem to be related to external forcing.

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Outline

1. Motivation
2. Reconstruction and model ensemble
3. Method
4. Regionalization
5. Regional long term variability and extremes
6. Conclusions

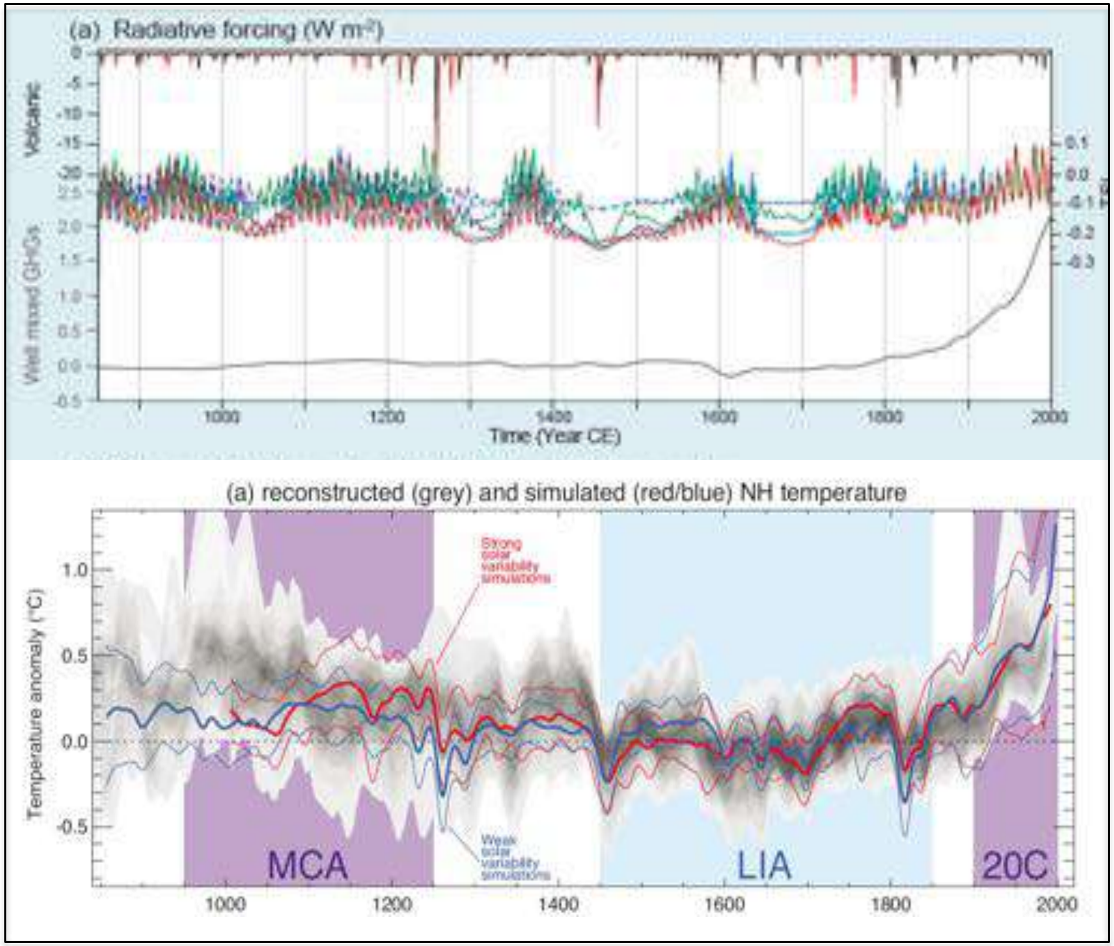
Motivation: reconstructed & simulated LM temperatures

Comparison of LM model simulations and reconstructions shows broad agreement and a cuasi-linear response of temperature to external forcing changes (Fernández-Donado et al 2013).

Uncertainties in modelling stem from uncertainties in boundary conditions (external forcing) and from structural model uncertainties.

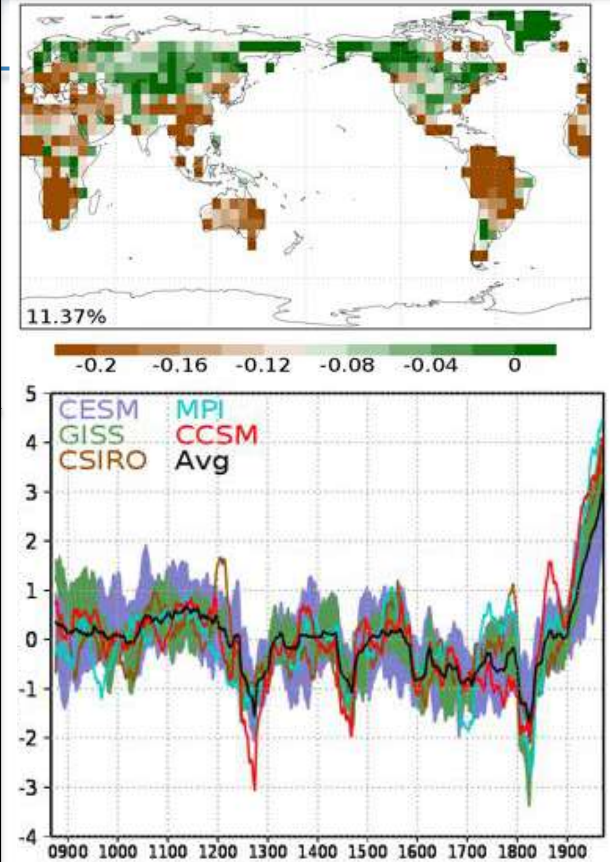
Uncertainties in reconstructions stem from proxy issues, spatial and temporal sampling

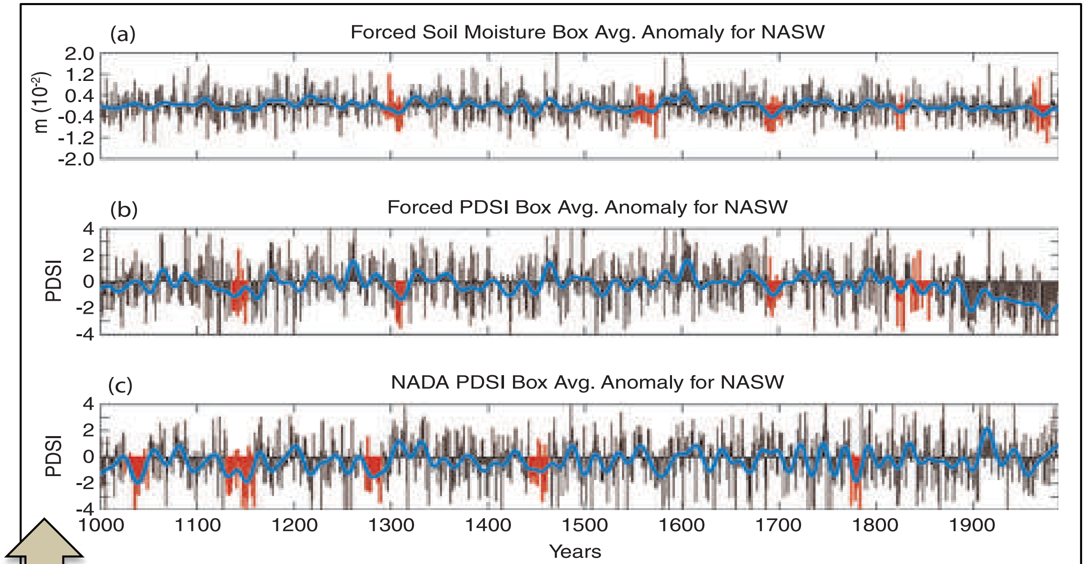
Stocker et al., 2013



Motivation: simulated hydroclimate responses

Roldan et al (2020) compare temperature and hydroclimate responeses in the PMIP3 ensemble of simulations suggesting that dynamics and precipitation show global coordinated responses to external forcing changes.
The Figure shows the 1st EOF and PC of scPDSI in simulations of the PMIP3 LM ensemble. Note changes through the MCA, LIA and industrial period as well as volcanic cooling





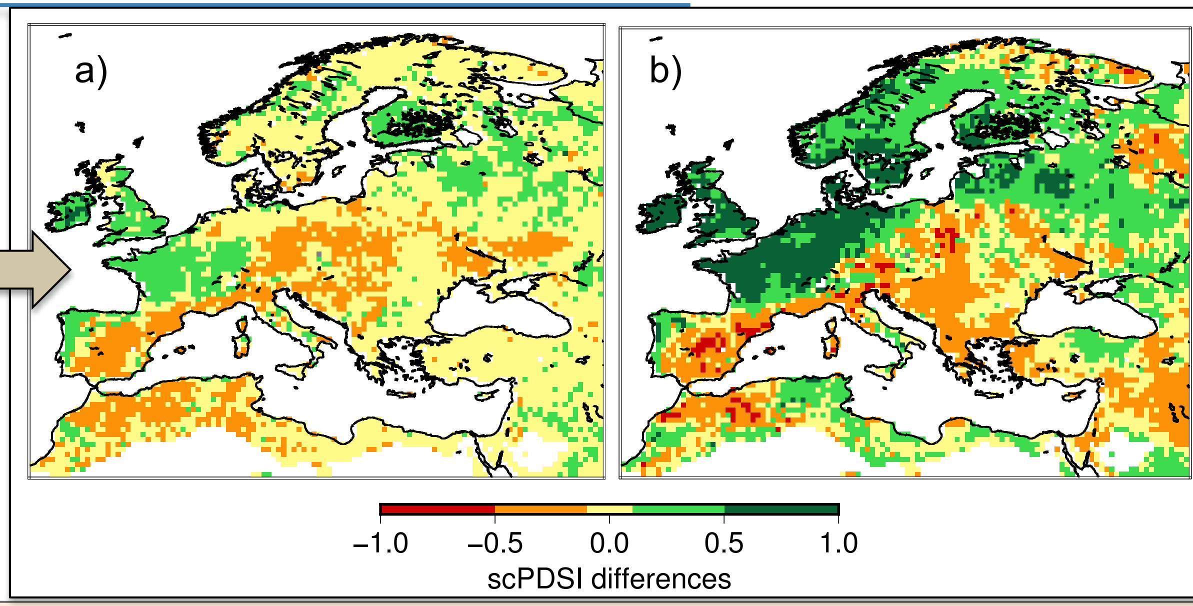
An example at regional scales (Coats et al 2013) where reconstructed PDSI from North American SW is analysed in comparison to LM model simulations. Large extremes (megadroughts) occur in the reconstructions and model but do not follow the timing external forcing and suggests a role of internal variability

Questions:

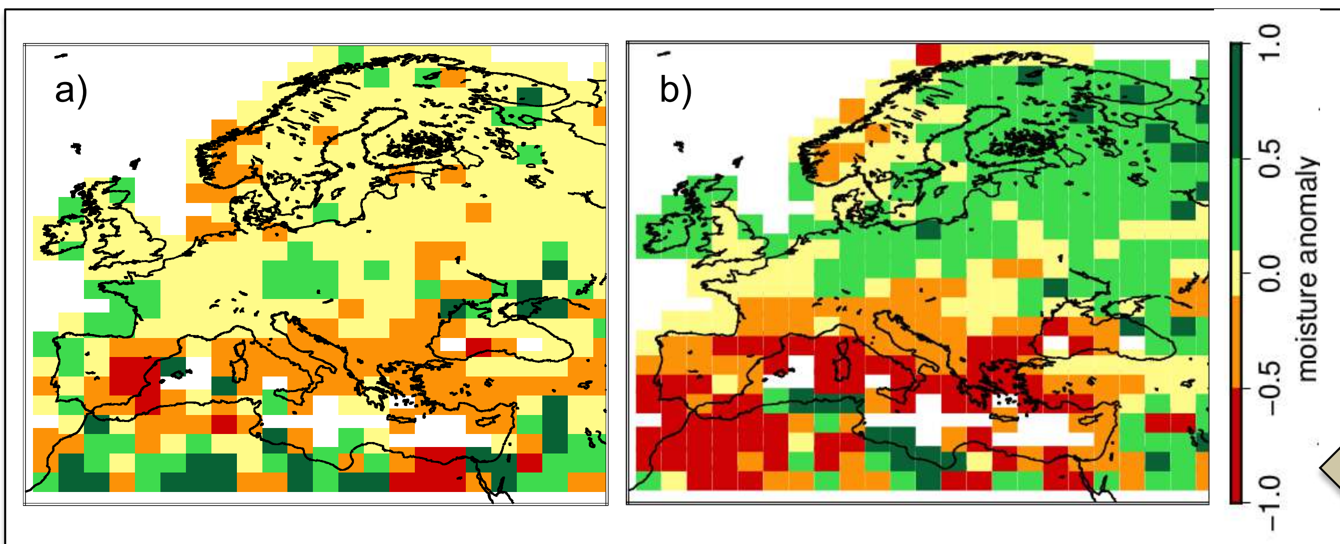
- ***What is the behaviour of spatial/temporal variability over Europe during the LM?***
- ***Are there large drought extreme episodes ~ megadrougts?***
- ***Does it follow external forcing changes?***

Reconstruction & model ensemble

The OWDA scPDSI JJA (Cook et al., 2015) dendro based reconstruction has been used. Differences between: a) the MCA (950-1250 CE) and LIA (1450-1850 CE); b) the historical period (1851-2005 CE) and the LIA. OWDA shows a drier Mediterranean in the MCA and Hist.



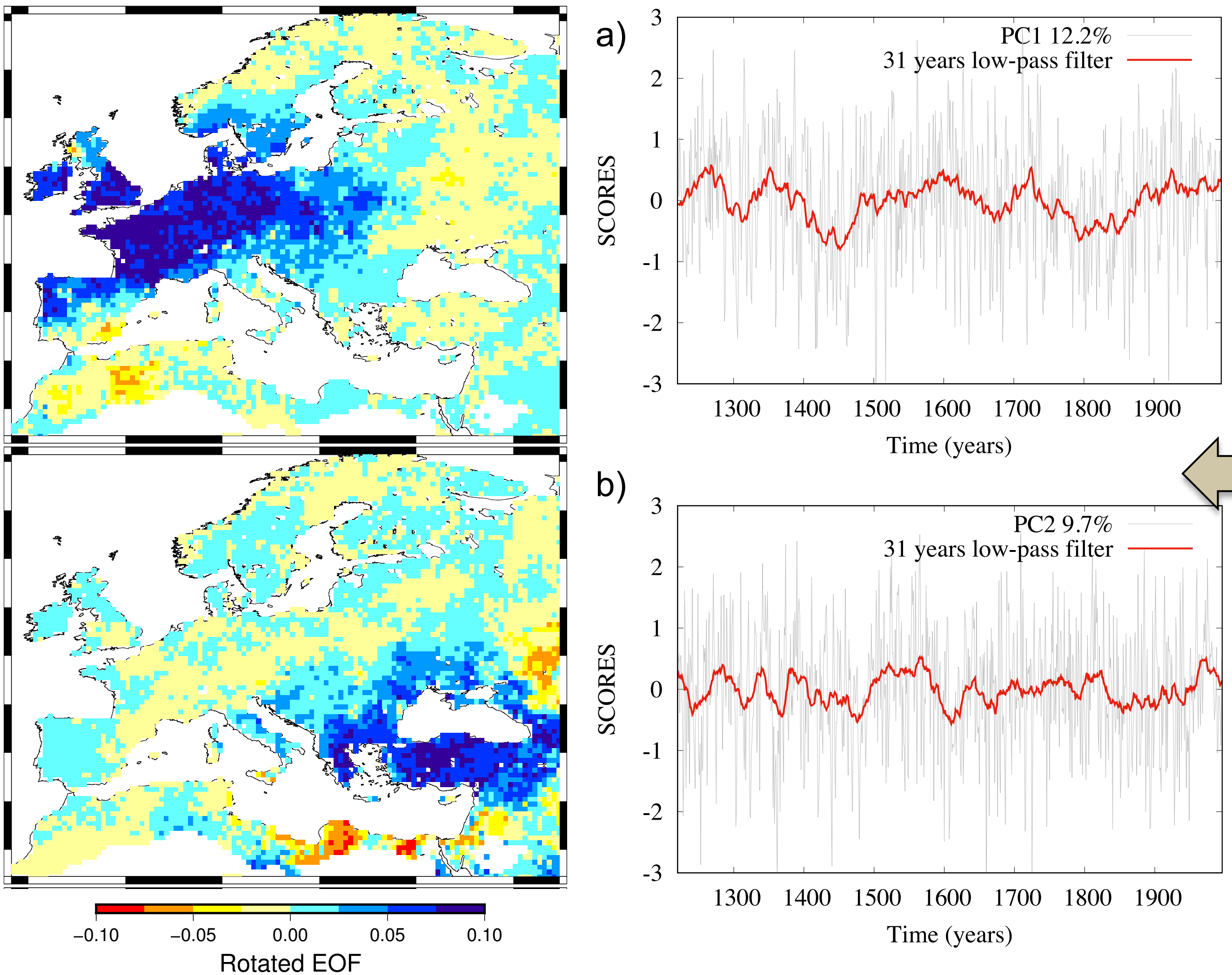
NCAR CESM-LME (Otto-Bliesner et al., 2016) 13 experiments from the All Forcing ensemble. Simulations were driven with LM external forcing PMIP3 specifications (Schmidt et al 2011). JJA soil moisture (kg/m^2) is considered.



MCA-LIA (a) and HIST-LIA (b) for the All-Forc_1 run shows drier MCA and HIST in the Mediterranean, consistent with OWDA. Similar response is obtained for the other runs.

Method

Rotated Principal Component Analysis, using VARIMAX rotation, is used to define regions of ~ uncorrelated variability in the OWDA and in the CESM-LME (e.g. Jiménez et al 2008)



Examples of the 1st (a) and second (b) rotated EOFs and their corresponding PCs for 1200 CE – present in OWDA.

Rotated PCs show larger loadings over specific regions, like Atlantic EU (1st mode) or around the Black Sea (2nd mode).

7 PCs (not significantly correlated) were retained. Regions are identified by stablishing a threshold isoline level in rotated EOFs.

The behaviour of rEOFs in CESM-LME is comparable in its statistics (not shown).

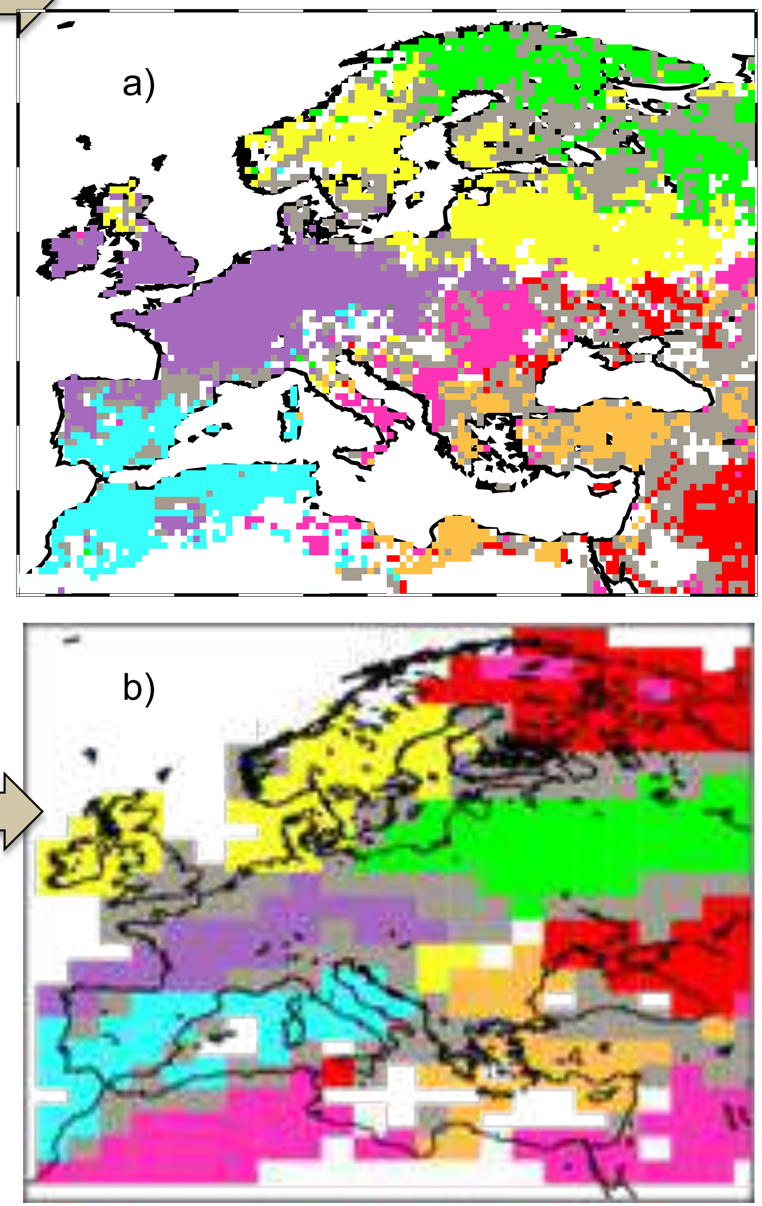
Regionalization: reconstruction and model

Resulting objective classification of regions in the OWDA (a) and in CESM-LM from the first seven VARIMAX rotated EOFS: purple (NWE); orange (TG); green (SL); red (ME); yellow (BS); blue (WM); and pink (BS). Grey areas represent zones of overlap for various regions

Table 1: Regions and acronyms resulting in the analysis of OWDA

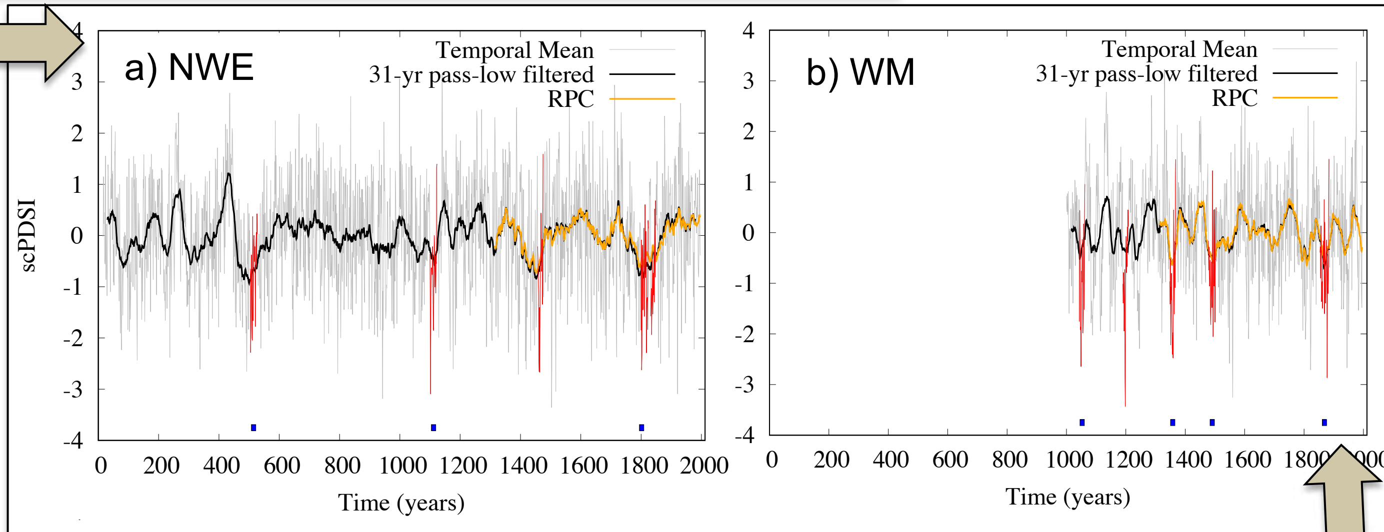
Region REOF	Name (Acronym)
1	North-Western Europe (NWE)
2	Turkey-Greece (TG)
3	Sápmi-Lapland (SL)
4	Middle East (ME)
5	Baltic Sea (BaS)
6	Western Mediterranean (WM)
7	Black Sea (BS)

Resulting distribution of EU regions obtained by the 1st 7 rotated EOF of the All Forcing CESM-LME ensemble. Some regions are comparable to those in OWDA, but not identical. The color distribution does not intend therefore a 1to1 correspondence. Grey stands for regions of overlap. Details of the construction of the regions from the ensemble not shown here.



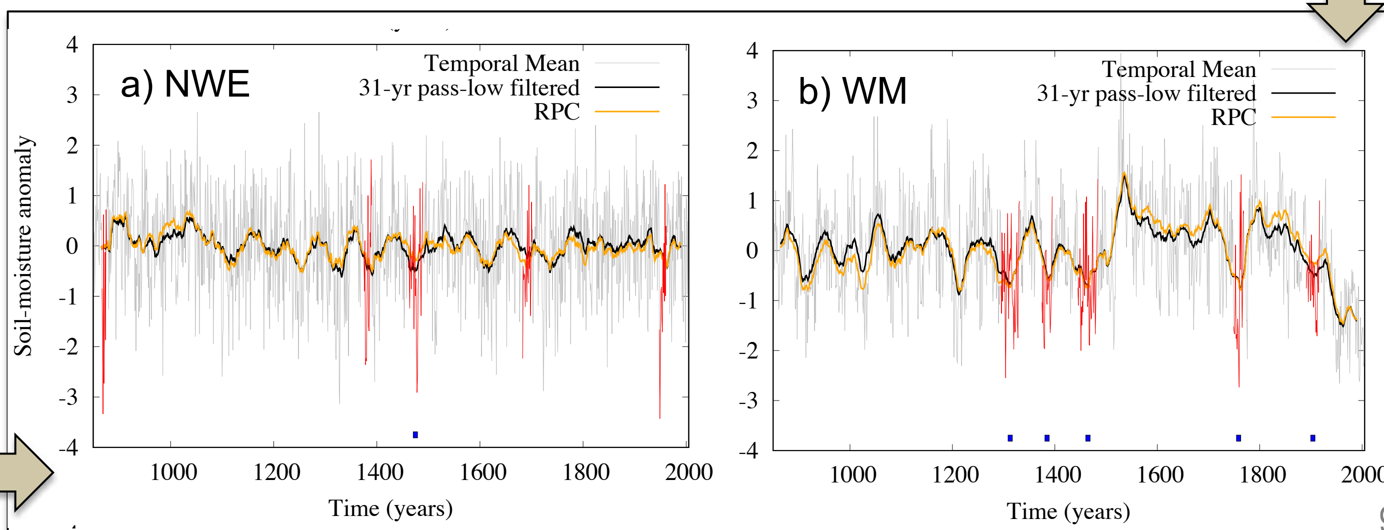
Regional long term variability and extremes

Examples of time series of scPDSI mean in two regions (NWE and WM, see Table 1). The rotated PC (orange) is shown for comparison with the mean scPDSI in the region (black) after 1300 CE. Regional series are uncorrelated. The mean is calculated for the pre-1300 period for the regions with availability of data.

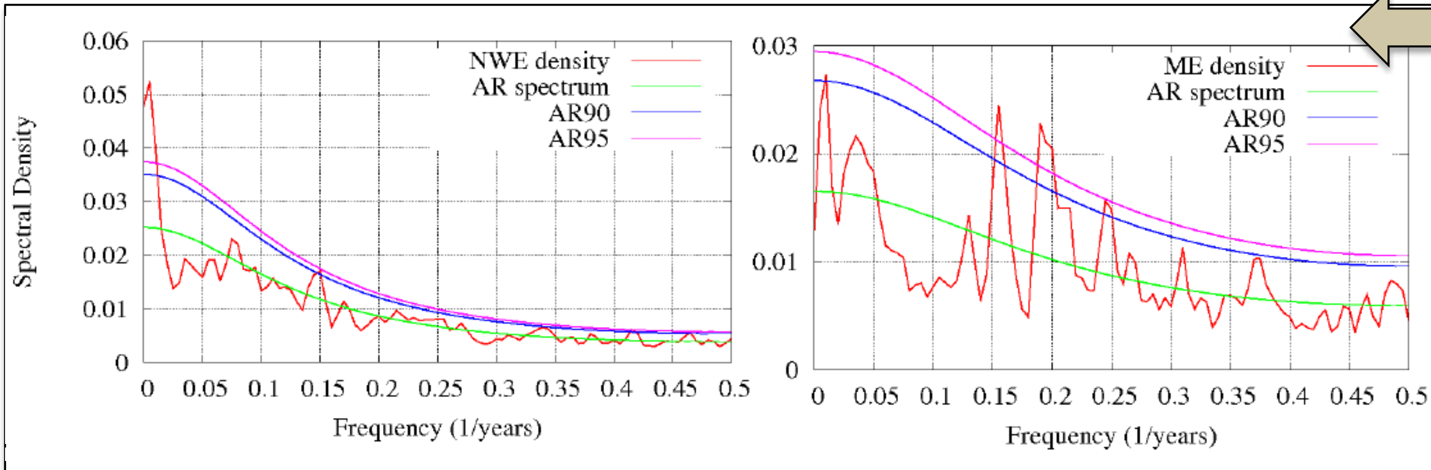


Droughts are calculaed as events that start after two consecutive years of scPDSI/soil moisture anomalies and end after two consecutive years of positive anomalies. Megadroughts are here droughts > 20 yrs. Red coloured intervals and dots indicate the ocurrence of megadroughts.

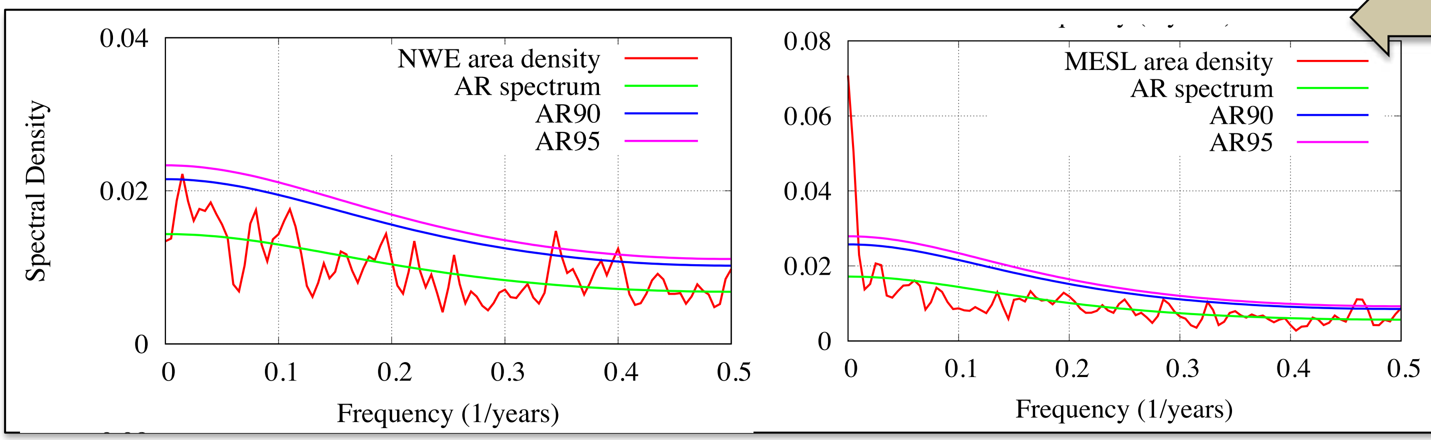
As in the top panel for the All-Forcing_1 CESM-LME experiment. Megadroughts occur both in the reconstructions and simulations but with different timing and thus not related to external forcing conditions in an evident way.



Regional long term variability and extremes



Examples of normalized spectra of OWDA scPDSI in two regions (NWE and ME, see Table 1). Spectral behaviour is also different for the different regions.

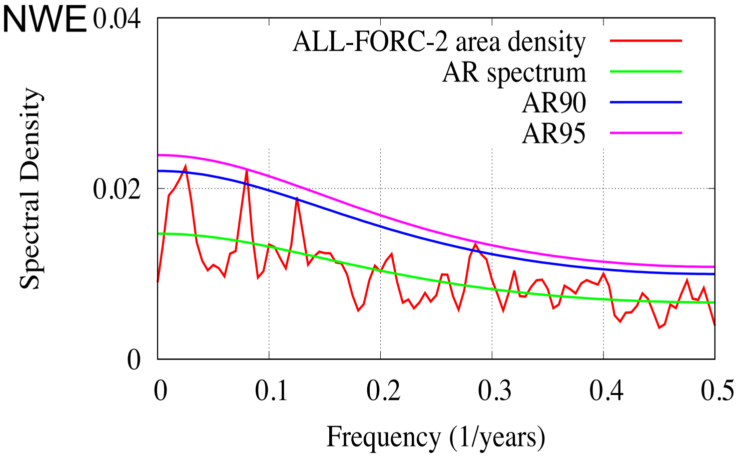


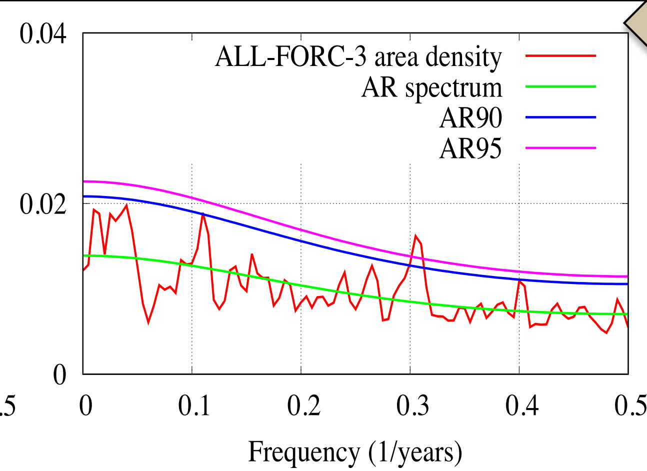
As in the top panel, examples of normalized spectra for the corresponding regions in All-Forcing_1 CESM-LME ensemble. Simulated spectral behaviour changes inter-regionally.

Spectral behaviour, i.e. the statistics of time variability in the frequency domain change from region to region and in the reconstructions and also relative to the climate model.

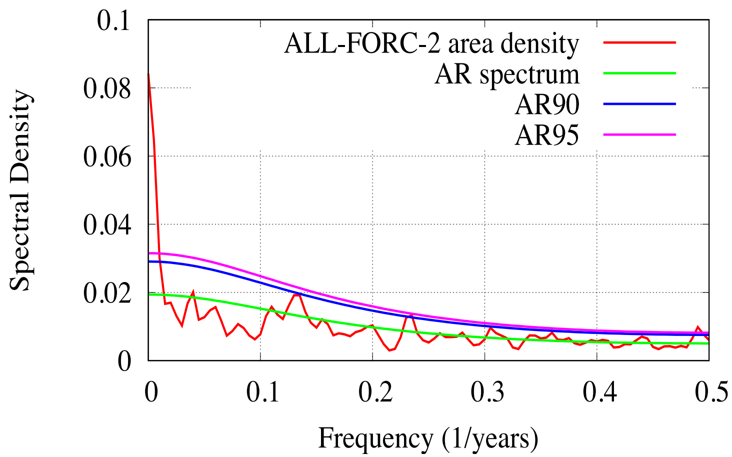
Regional long term variability and extremes

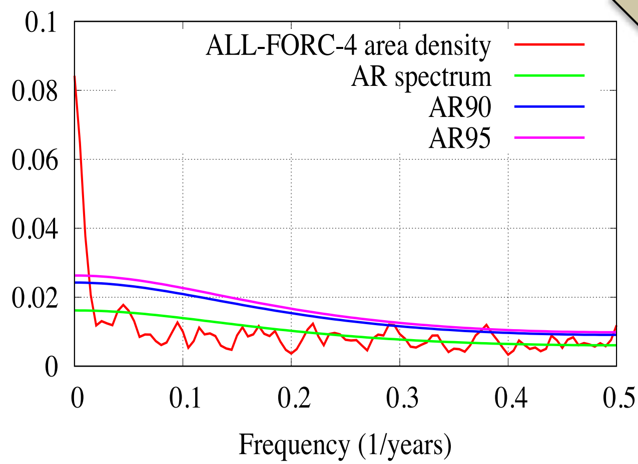
NWE





Examples of normalized spectra for the NWE region in All-Forcing_2 and 3 ensemble members





Examples of normalized spectra for the NWE region in All-Forcing_2 and 4 ensemble members

Spectral behaviour, i.e. the statistics of time variability in the frequency domain change from region in the climate model, but are compable for each region across simulations

Conclusions

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- → EU drought can be objectively structured into regions of ~ uncorrelated long term variability
- → Some of these regions exhibit megadroughts through the last millennium
- → CESM LME reproduces a comparable array of drought regions
- → The temporal and spectral characteristics of drought are inter-regionally different in the reconstructions and in the model simulations.
- → The spectral characteristics of drought are similar for a given region in the different model simulations.
- → Megadroughts occur in the reconstructions and in the model simulations.
- → Megadrought timing is different across regions and across model simulations. Thus, it does not respond to forcing in an evident way.

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Acknowledgements

Most of this work has been developed in the Master Thesis of MALC and NGC under the supervision of JFGR.

Authors gratefully acknowledge the IIModels (CGL2014-59644-R) and GreatModelS (RTI2018-102305-B-C21) projects.