1000 years of droughts

Mechanisms behind climate changes

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SUMMARY

Variations in solar activity and volcanic eruptions are some of the main factors contributing to shape the evolution of climate. During the last millennium, the contribution of these external factors was influential for the occurrence of the so called Medieval Climate Anomaly (MCA; ca. 950-1250) and Little Ice Age (LIA; ca. 1450-1850), periods respectively characterised by higher and lower temperatures in most regions of the Earth.

The impact of external forcings on drought occurrence is not evident, and it is in general considered that it is more affected by short-term variations caused by the internal dynamics of the climate system. However, several studies based on reconstructed data suggest that periods of MCA and LIA also had an opposite behavior with regard to the hydrology for some particular regions. Most of these regions are located around equator, where displacements of the Intertropical Convergence Zone (ITCZ) could explain a different behaviour for MCA and LIA, and in extratropical areas, probably affected by expansions and contractions of the Hadley cell.

To obtain a global view of droughts over the last millennium, and to go deeper into the mechanisms explaining these events, several analyses have been performed. Firstly, maps of wet and dry regions during MCA and LIA have been obtained from an exhaustive compilation of published records. The collected information refers to precipitation, moisture, lake levels and river flows, and it is based on data from tree rings, marine and lake sediments, speleothems, ice cores and documentary sources. Secondly, analyses based on simulations from different climate models have been performed to evaluate whether the spatial patterns obtained from reconstructed data are also present in results from model simulations.

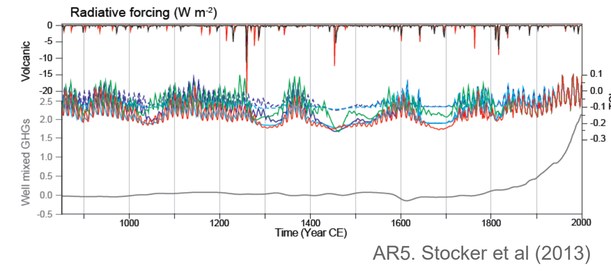
These analyses allow to understand how droughts are linked to variations in global temperature, and to identify which regions are more susceptible to suffer this kind of events in response to external forcing.

MOTIVATION

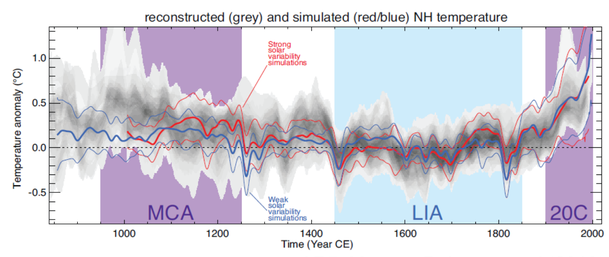
Temperatures of the last millennium were mainly characterised by three different periods:

- Medieval Climate Anomaly (MCA)
  ca. 950 to 1250 CE
- Little Ice Age (LIA)
  ca. 1450 to 1850 CE
- Industrial Era
  ca. 1850 CE to present

Did these periods also exist on hydroclimate?



AR5. Stocker et al (2013)



AR5. Masson-Delmotte et al (2013)

What are the available sources?

Reconstructions

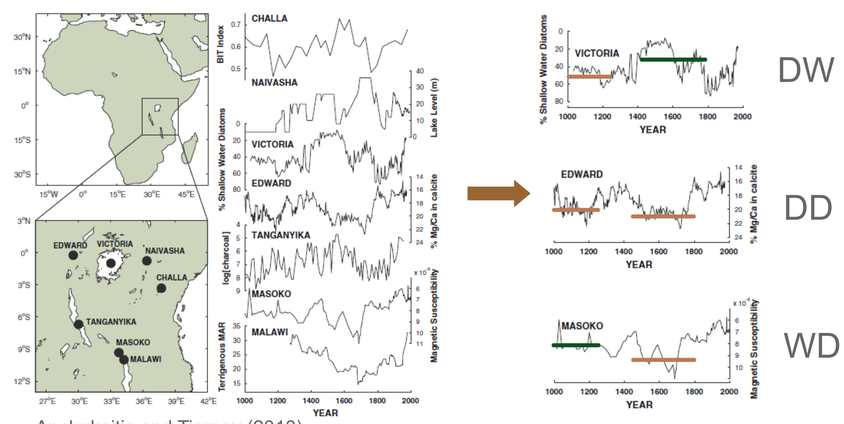
117 studies based on:

- Tree rings
- Marine and lake sediments
- Speleothems
- Ice cores
- Documentary sources.

Provide information about:

- Precipitation
- Moisture
- Level of lakes
- River flows

Were the MCA and LIA drier or wetter than the average?



Anchukaitis and Tierney (2013)

DW

DD

WD

Climate models

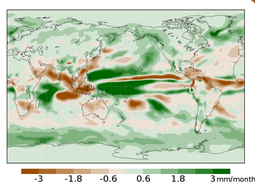
Different models have been used:

- ECHO-G (2 simulations; González-Rouco et al., 2009)
- CESM-LME (10 simulations; Otto-Bliesner et al., 2015)

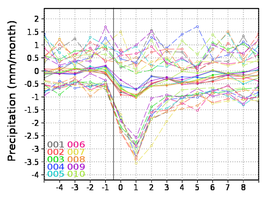
Allow to analyse many variables:

- Temperature
- Sea Level Pressure
- Horizontal wind
- Precipitation
- Soil moisture

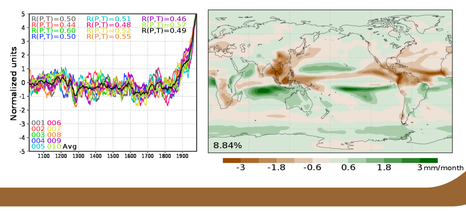
Composites for MCA-LIA
(multicentennial changes)



Composites for the years after volcanic eruptions
(interannual changes)

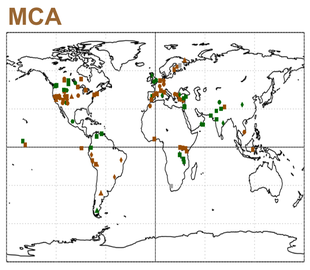


Principal Component analysis
(multidecadal and above changes)



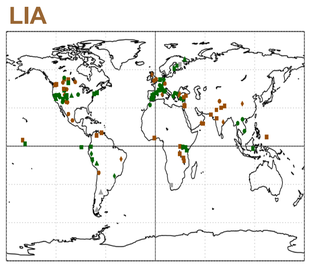
What do they show?

MCA

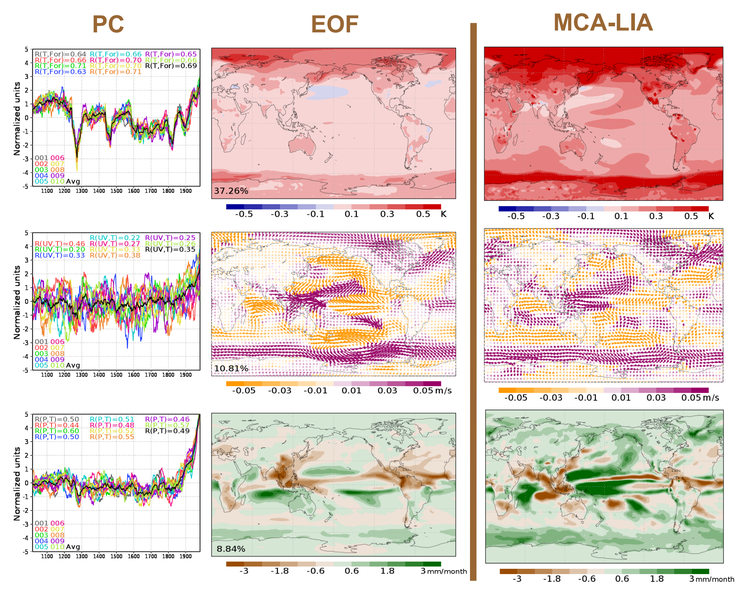


Brown: Period drier than average.
Green: Period wetter than average.
Grey: Period drier or wetter depending on the season.

LIA

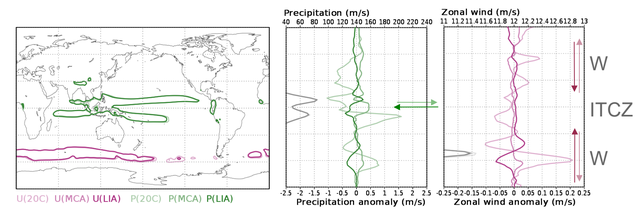


Circles: Tree-rings.
Squares: Sediments.
Diamonds: Speleothems.
Triangles: Others (ice cores, documentary, multiproxy).



How is that explained?

The major changes are located in the ITCZ and around the Westerlies.



Analyses suggest that there is a mechanism that transmits the influence of external forcing from temperature to hydroclimate.

Temperature

~40% of explained variance

Periods of MCA and LIA with higher and lower temperatures.

Dynamics (e.g. winds)

~20% of explained variance

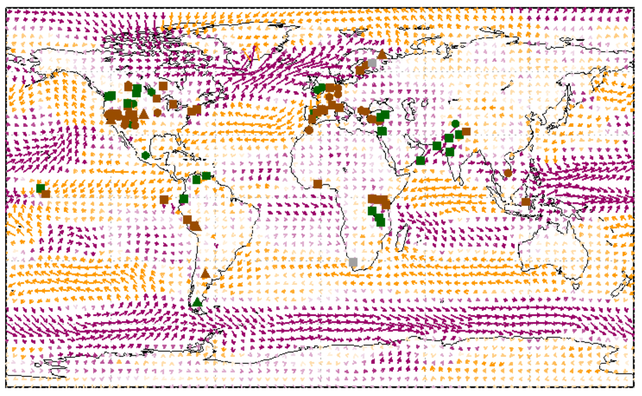
Expansion of Hadley cell and latitudinal displacements of westerlies.

Hydroclimate (e.g. precipitation)

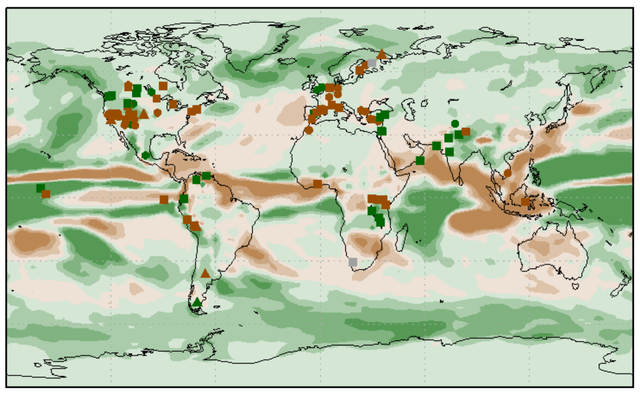
~10% of explained variance

Alteration of modes of variability (e.g. SAM, NAO).

Horizontal wind for MCA-LIA (simulations)
Hydroclimate during MCA (reconstructions)



Precipitation for MCA-LIA (simulations)
Hydroclimate during MCA (reconstructions)



West.

ITCZ

West.

CONCLUSIONS

1) Periods of MCA and LIA were mainly defined in temperatures, but some studies based on reconstructions also show these periods in hydroclimate.

2) A compilation of studies based on reconstructions has been performed, to generate maps of hydroclimate for MCA and LIA.

3) Analyses based on simulations have been performed, including EOFs and composites for MCA and LIA. These analyses suggest a mechanism that transmits the influence of external forcing from temperature to hydroclimate.

Temperature (~40%):	Periods of MCA and LIA
Dynamics (~20%):	Expansion of Hadley cell and displacement of westerlies
Hydroclimate (~10%):	Alteration of modes of variability (e.g. SAM, NAO)

4) Even if there are differences for several regions, simulations and reconstructions show similar spatial patterns. The areas more affected by droughts during MCA and LIA are those affected by expansions and contractions of Hadley cell and latitudinal displacements of westerlies.

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