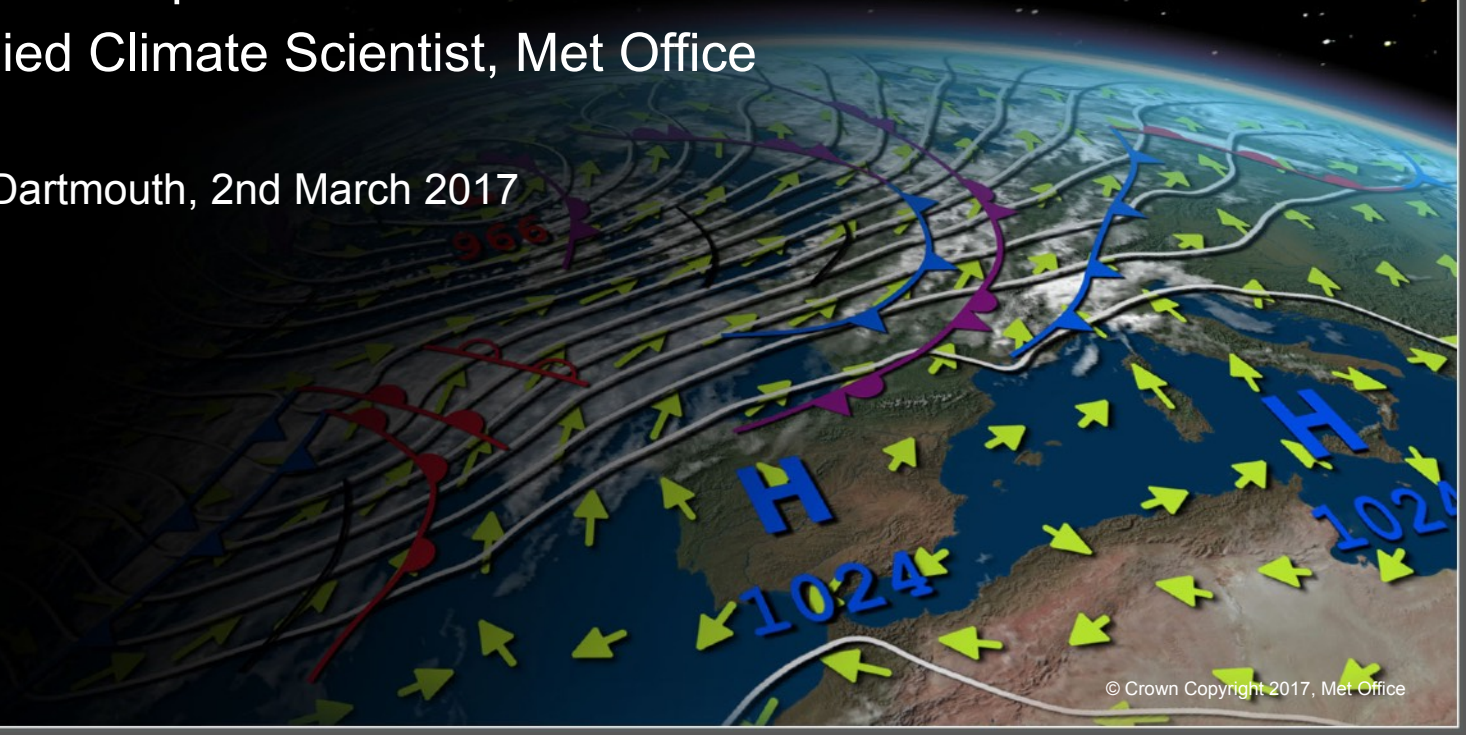
Climate in the Classical Era

Hamish Steptoe
Applied Climate Scientist, Met Office

U3A Dartmouth, 2nd March 2017

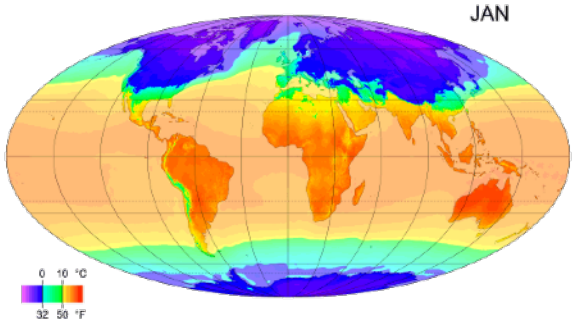


Preface

What is weather and climate

Climate is what you expect, weather is what you get

- Andrew John Herbertson (1901)



Weather is how you choose your outfit, climate is how you choose your wardrobe

- Unattributed

Met Office
Hadley Centre

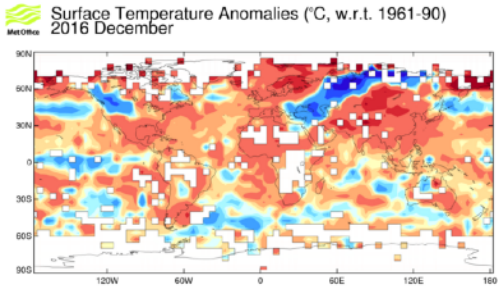
Context

... a look at our present weather and climate

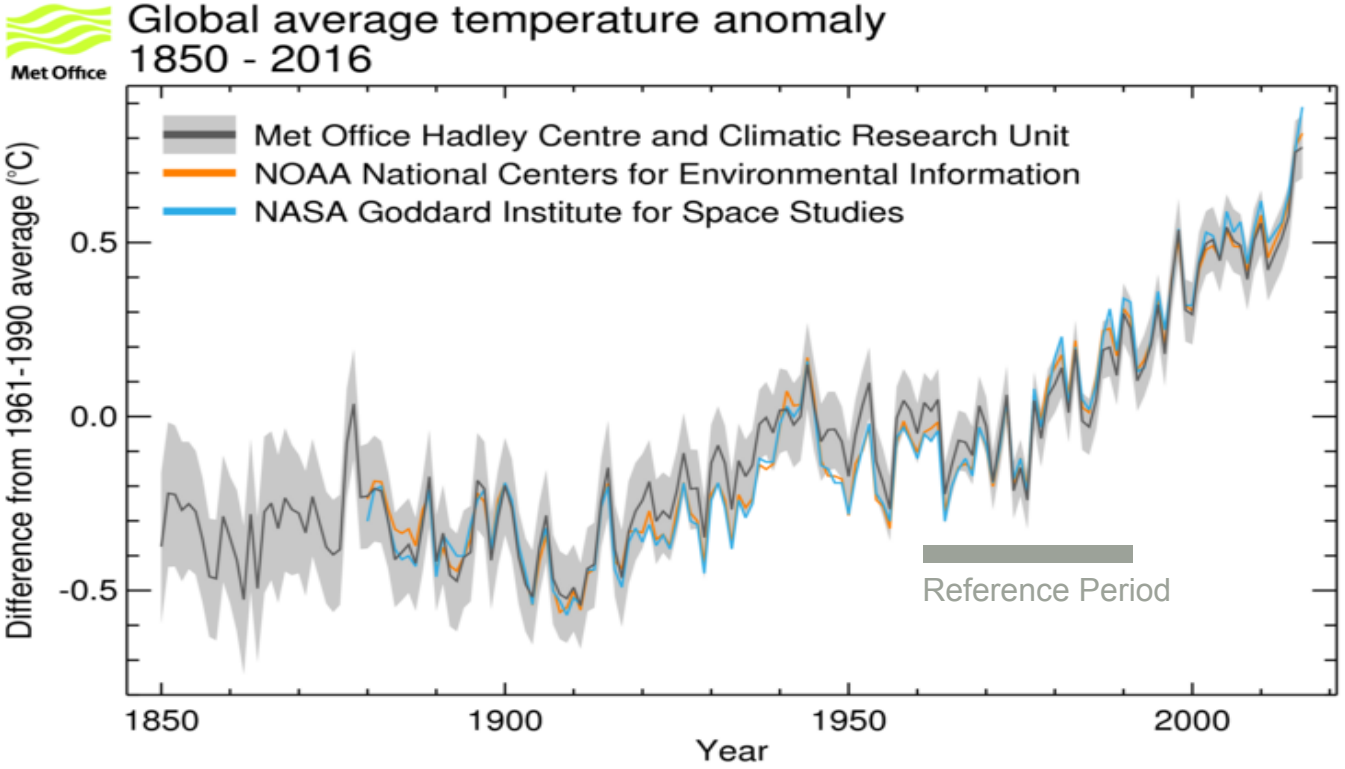
Present Climate

Combined land-surface and sea-surface temperature

→ Global average



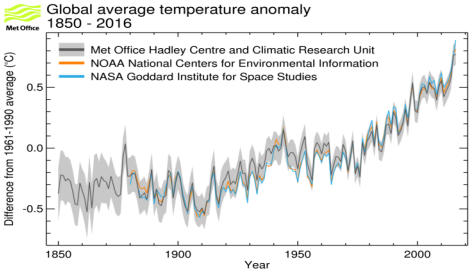
Data available: www.metoffice.gov.uk/hadobs/hadcrut4



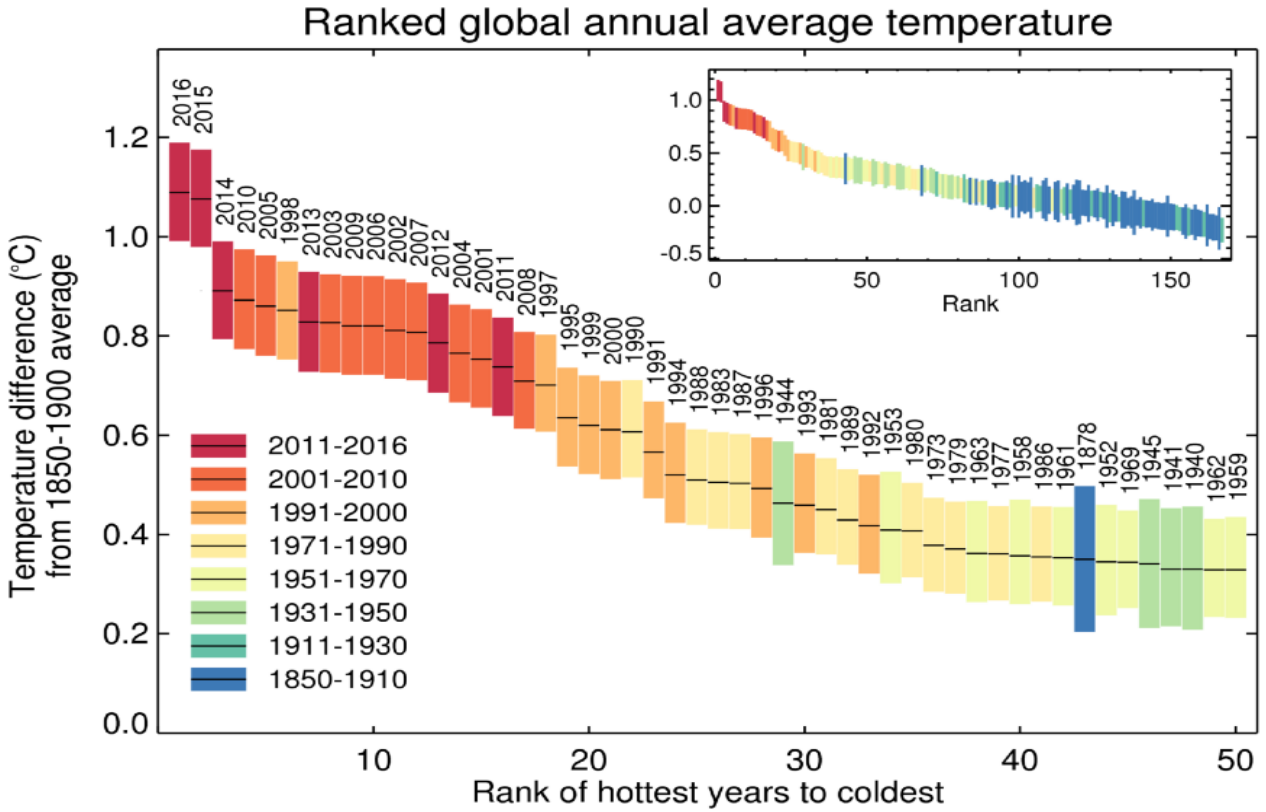
Present Climate

Combined land-surface and sea-surface temperature

→ Global average



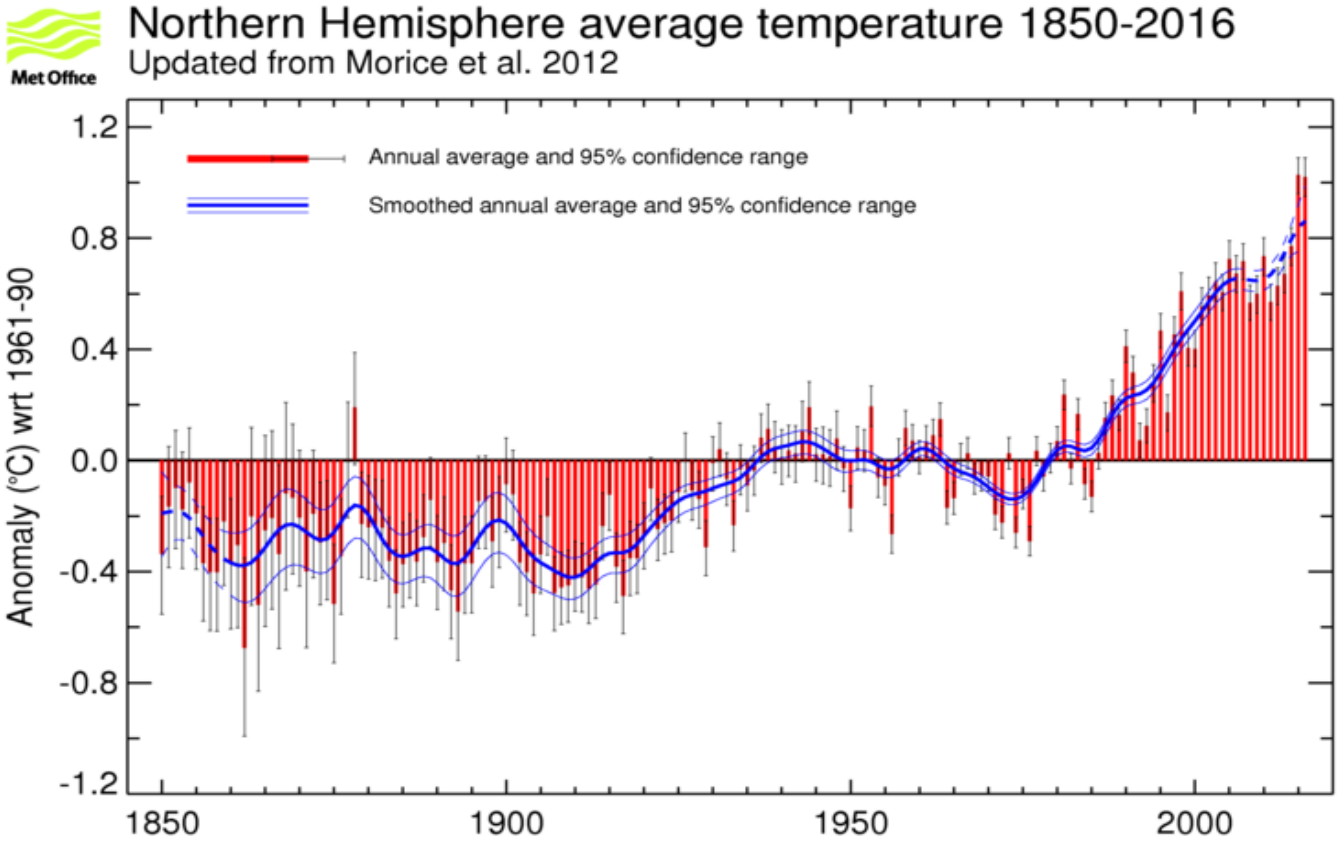
Data available: www.metoffice.gov.uk/hadobs/hadcrut4



Present Climate

HadCRUT4 global temperature record

→ Northern Hemisphere average

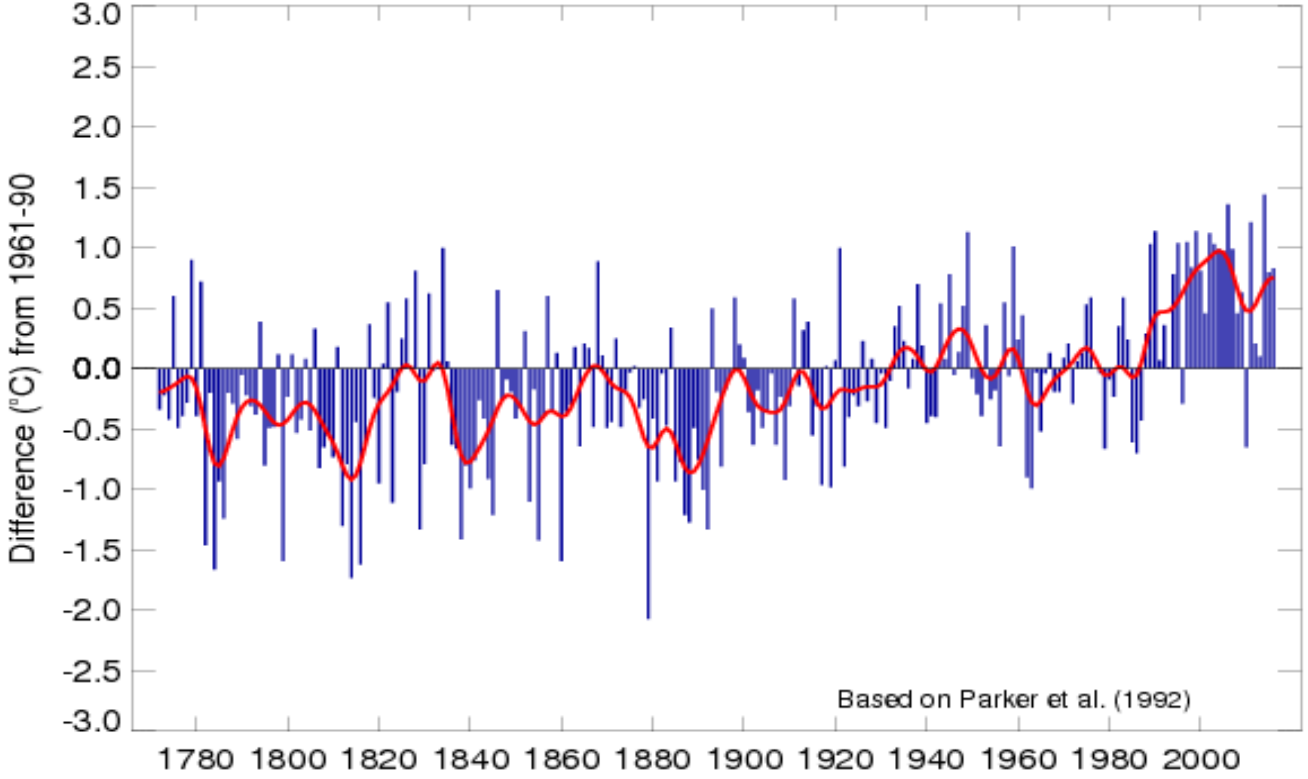


Met Office
Hadley Centre

Present Climate

HadCET
central England
temperature record

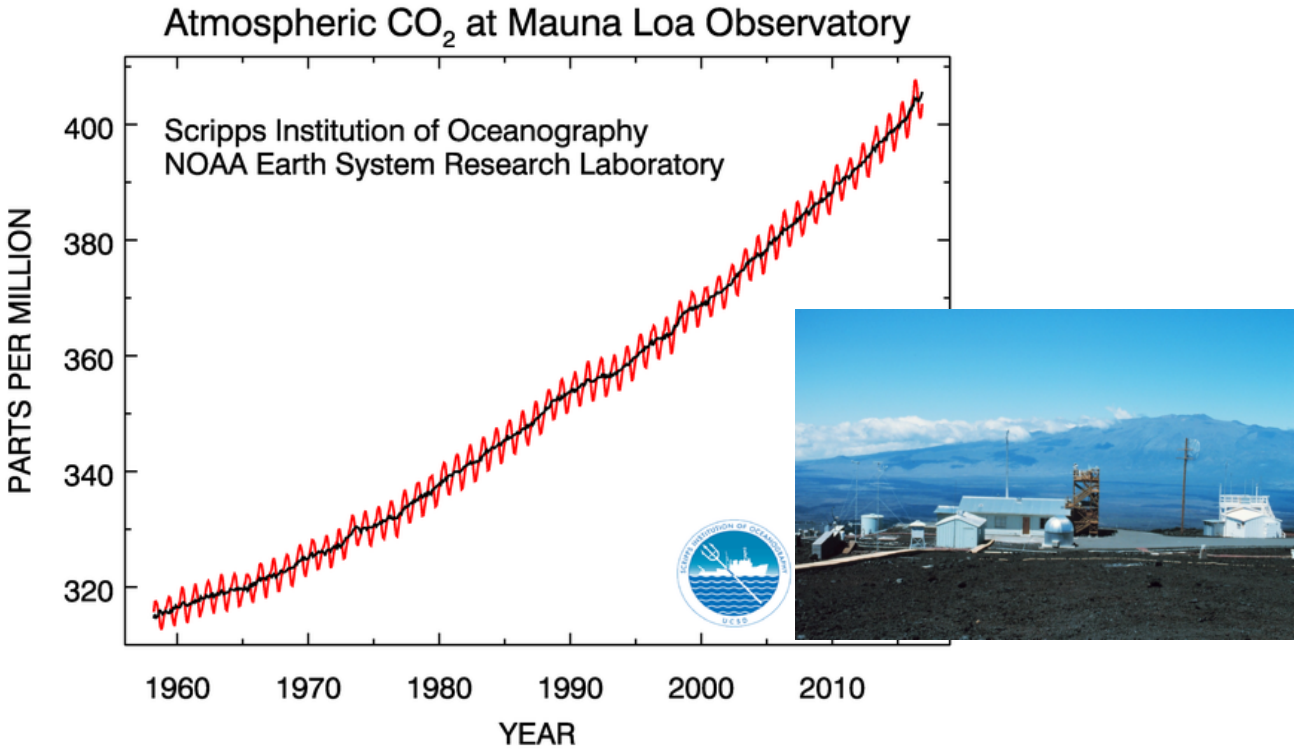
Longest instrumental
record of temperature
in the world



Present Climate

Atmospheric CO2 Mauna Loa Observatory, Hawaii (3,400m amsl)

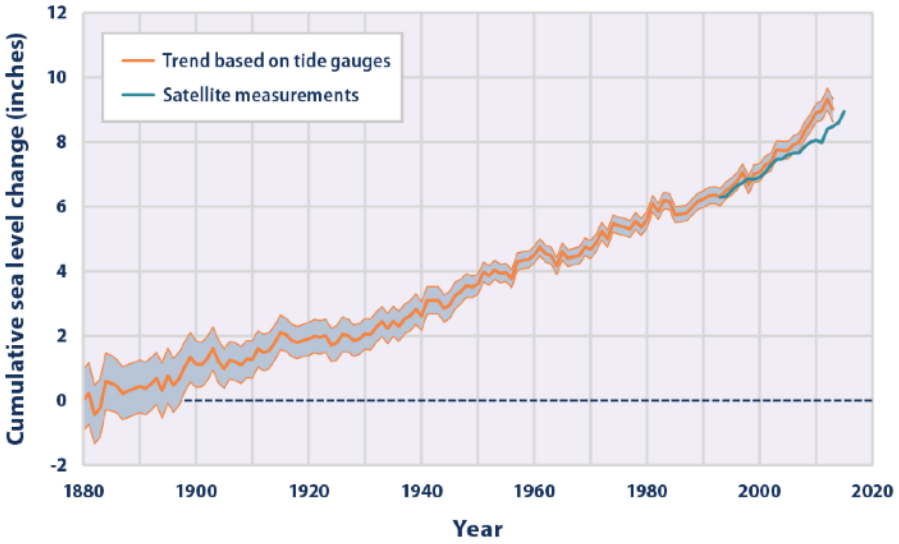
Available at: https://www.esrl.noaa.gov/gmd/ccgg/trends/



Present Climate

Met Office
Hadley Centre

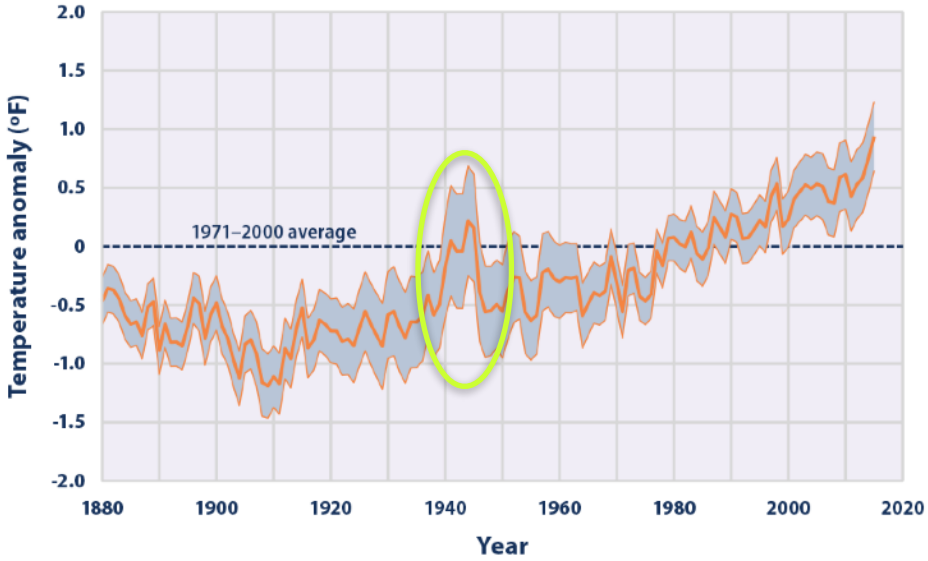
Global Average Absolute Sea Level Change, 1880–2015



Data sources:
- CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2015 update to data originally published in: Church, J.A., and N.J. White. 2011. Sea-level rise from the late 19th to the early 21st century. Surv. Geophys. 32:585–602. www.cmar.csiro.au/sealevel/sl_data_cmar.html.
- NOAA (National Oceanic and Atmospheric Administration). 2016. Laboratory for Satellite Altimetry: Sea level rise. Accessed June 2016. http://ibis.grdl.noaa.gov/SAT/SeaLevelRise/LSA_SLR_timeseries_global.php.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Average Global Sea Surface Temperature, 1880–2015



Data source: NOAA (National Oceanic and Atmospheric Administration). 2016. Extended reconstructed sea surface temperature (ERSST.v4). National Centers for Environmental Information. Accessed March 2016. www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst.

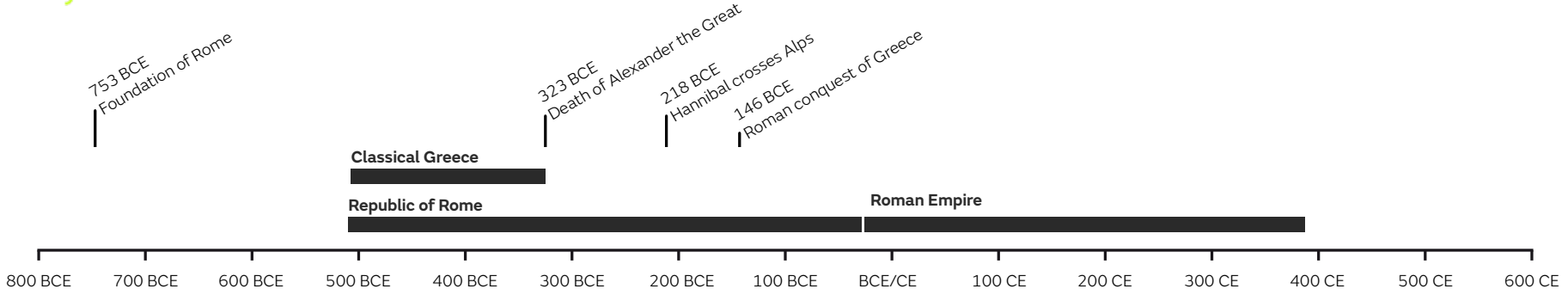
For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Present Climate

- Natural variability has a larger impact year to year than climate change, but…
- We're living in a time of significant climate variability
- NH average temperatures have risen ~1°C in the last 30-40 years
- Human activities are having a noticeable impact

Met Office
Hadley Centre

Timeline



(mainly for my benefit…)

Met Office
Hadley Centre

Timeline

753 BCE
Foundation of Rome

323 BCE
Death of Alexander the Great

218 BCE
Hannibal crosses Alps

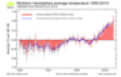
146 BCE
Roman conquest of Greece

Classical Greece

Republic of Rome

Roman Empire

800 BCE | 700 BCE | 600 BCE | 500 BCE | 400 BCE | 300 BCE | 200 BCE | 100 BCE | BCE/CE | 100 CE | 200 CE | 300 CE | 400 CE | 500 CE | 600 CE



Classical Antiquity

1000 BCE | BCE/CE | 1000 CE | 2000 CE

1960
First weather satellite

Met Office
Hadley Centre

So…

(the contents of this talk)

- Paleoclimate: how do we look at climate of the deep past?
- How does our present climate compare to the climate of Classical Antiquity?
- How has weather and climate shaped Classical history?

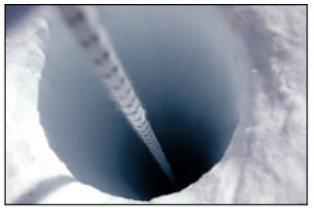
Met Office
Hadley Centre

Introduction to Palaeoclimatology

"Study of ancient climates, prior to the widespread availability of instrumental records" ~ NOAA

Palaeoclimatology

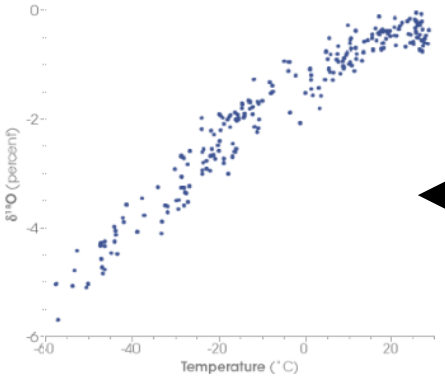
- We don’t have instrumental records, so we use proxy records:
  - Ice & sediment cores
  - Tree rings
  - Speleothems (Caves)
  - Coral & sclerosponges

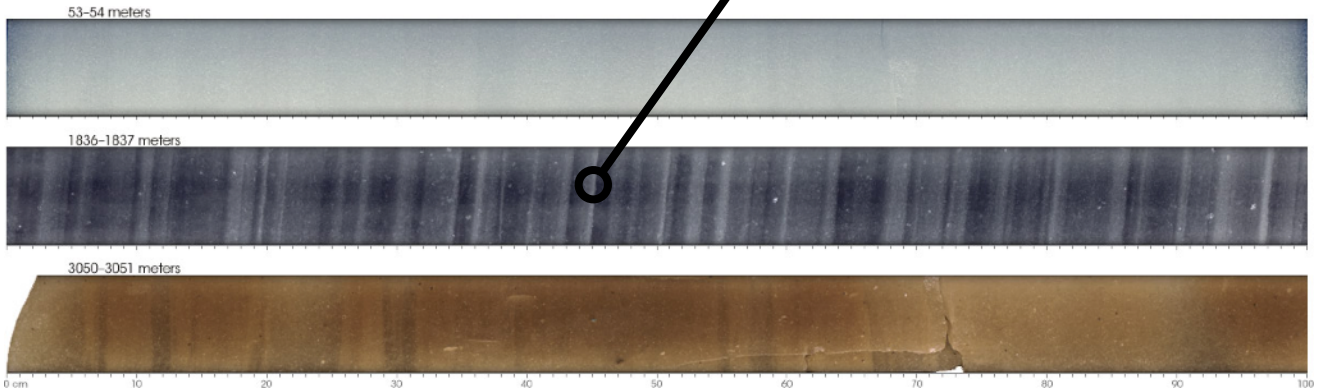


Palaeoclimatology

http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores/

- Oxygen is one of the most significant keys to deciphering past climates.
- Ratio of ^{16}O to ^{18}O in water changes with the climate

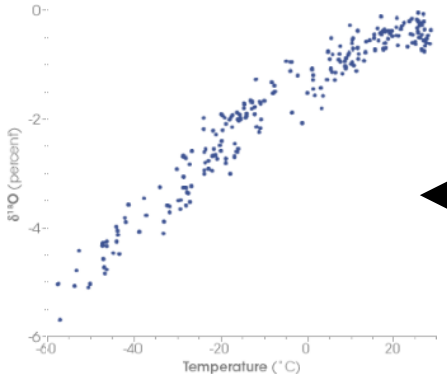


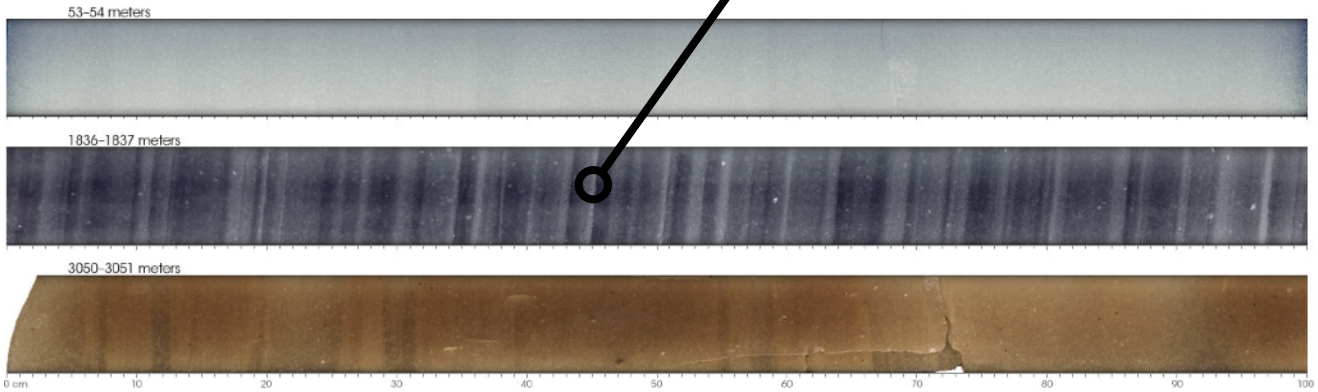


Palaeoclimatology

http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores/

- Evaporation and condensation are the two processes that most influence the ratio of heavy oxygen to light oxygen in the oceans.

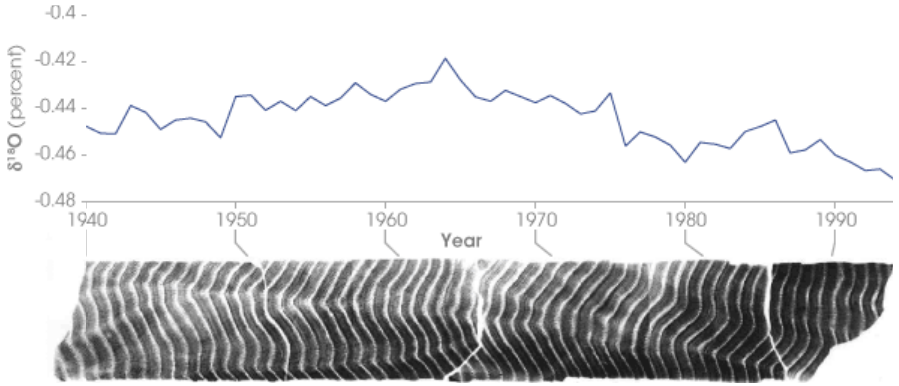




Palaeoclimatology

http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores/

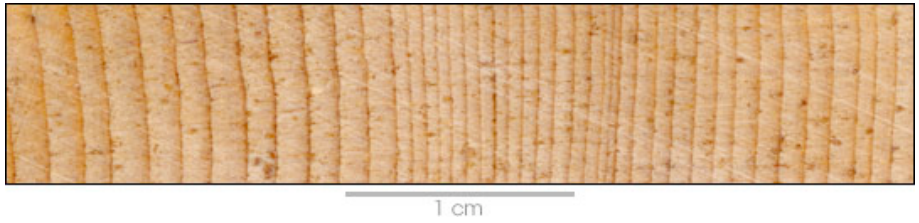
- O isotopes also exist in corals.
- Ratio of $^{16}O/^{18}O$ in coral depends on water temperature
- Corals also capture strontium/calcium which is also determined by temperature.
- Coral growth rings and radioisotopic (eg. ^{14}C) dating can precisely date (calibrate) isotope ratios



Palaeoclimatology

http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores/

- Spacing of tree rings (growth cycles) depend on rainfall
- But in areas where rainfall is plentiful, rings can give indication of temperature or other events



Forest fire record

..so how do these compare to our timeline?

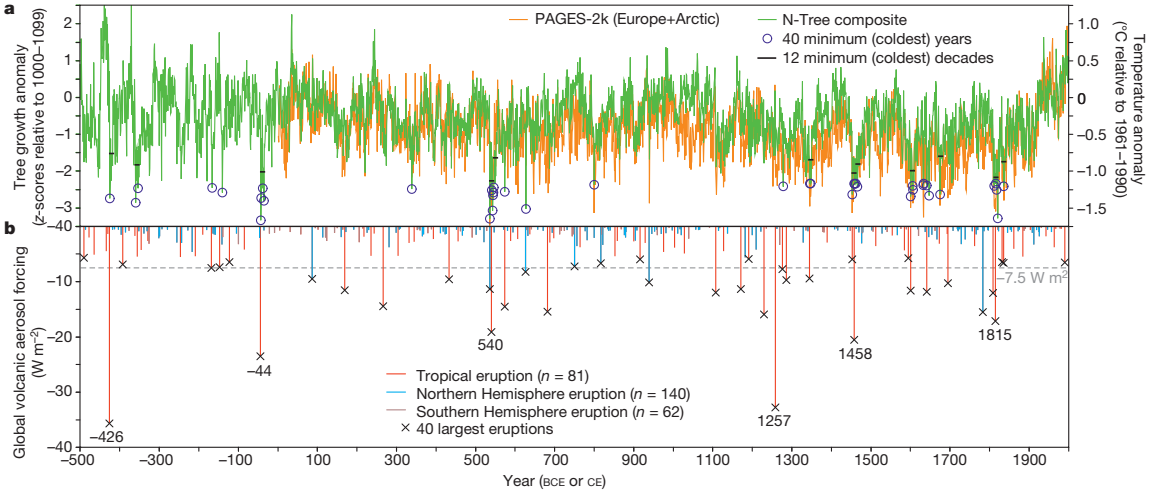
Met Office
Hadley Centre

The Climate of Classical Antiquity

www.metoffice.gov.uk

The Climate of Classical Antiquity

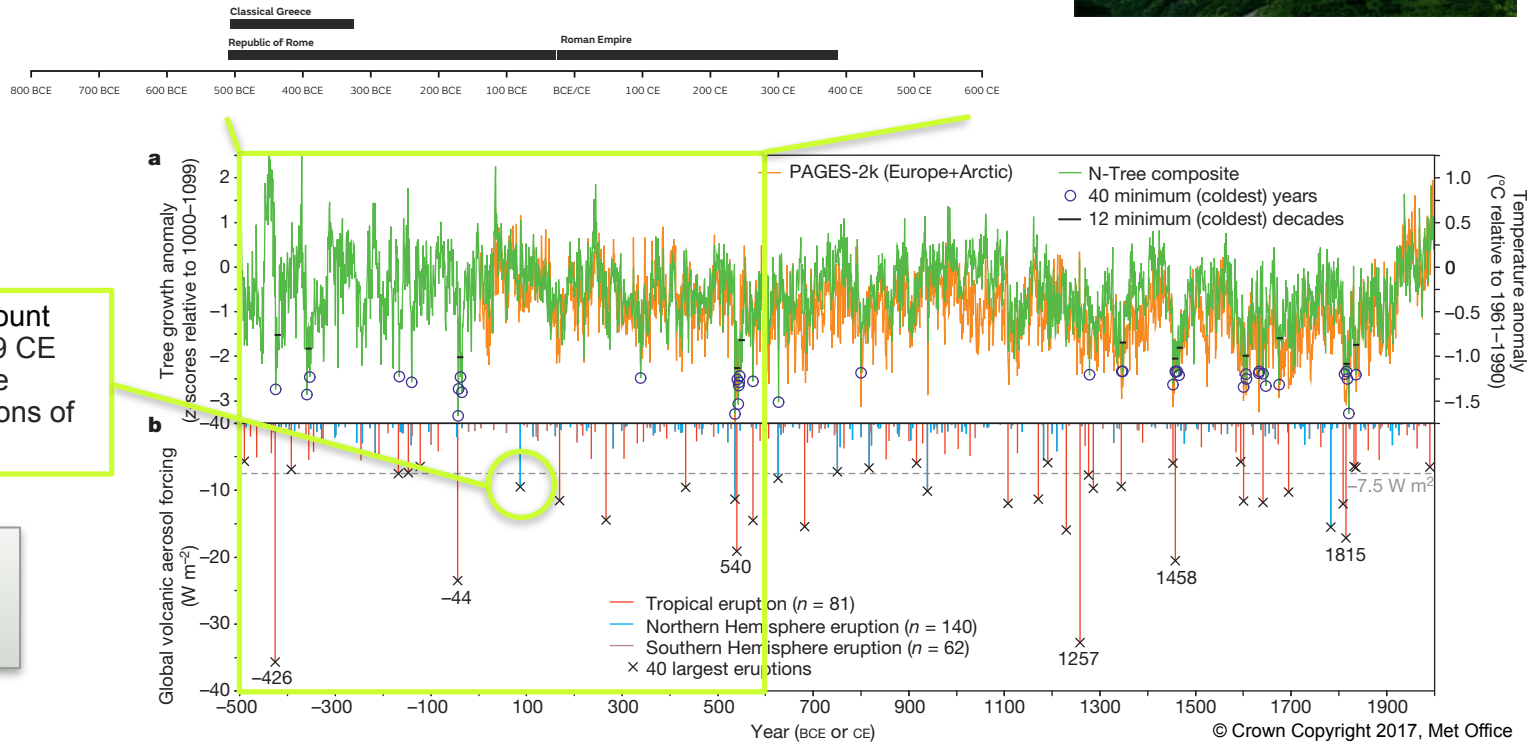
- Volcanic eruption reconstruction based on Greenland & Antarctica ice-core proxies
- Based on sulphur concentrations



Sigl, M. et al. Timing and climate forcing of volcanic eruptions for the past 2,500 years. Nature 523, 543–549 (2015).

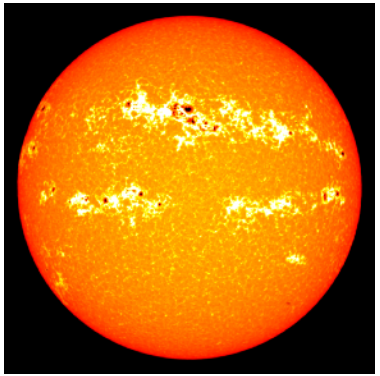
The Climate of Classical Antiquity

Eruption of Mount Vesuvius in 79 CE was one of the smaller eruptions of this period

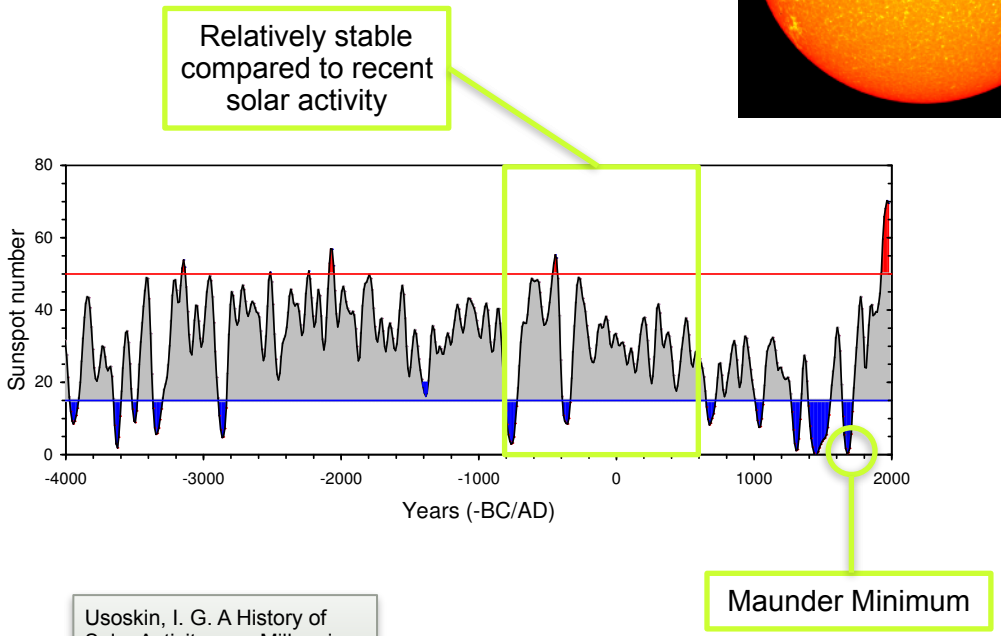


Sigl, M. et al. Timing and climate forcing of volcanic eruptions for the past 2,500 years. Nature 523, 543–549 (2015).

The Climate of Classical Antiquity



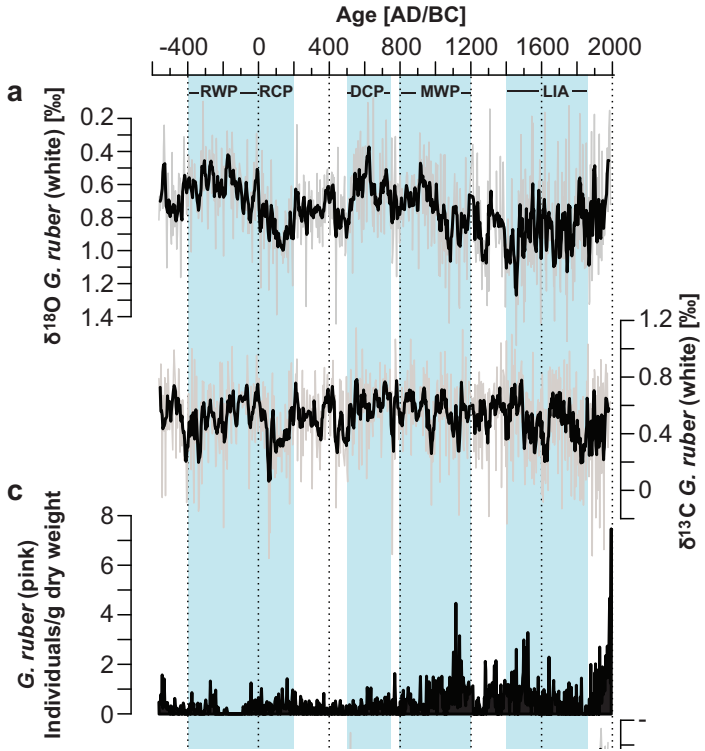
- Sun spot activity indicates sun activity.
- Reconstructed from ^{14}C and geomagnetic records
- Occurrence of minima/ maxima is not driven by long-term cyclic variability, but by a chaotic process
- Sunspot activity unlikely to have any major influence on Classical Climate

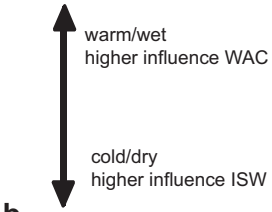


Usoskin, I. G. A History of Solar Activity over Millennia. Living Rev. Solar Phys. 10, 1–94 (2013).

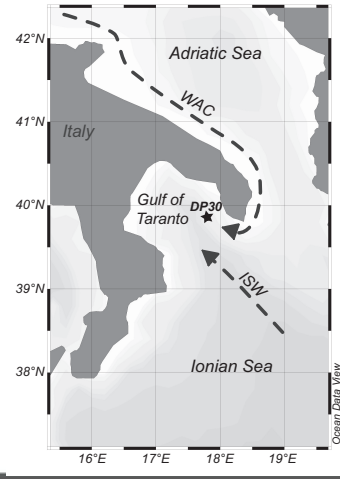
The Climate of Classical Antiquity

- A study of carnivorous shallow-water planktonic foraminifera - isotope analysis of ^{18}O and ^{13}C
- These give an indication of <u>temperature, salinity & nutrient availability → proxy for sea/ocean circulation</u>





b



Grauel, A.-L. et al., Climate of the past 2500 years in the Gulf of Taranto, central Mediterranean Sea: A high-resolution climate reconstruction based on ð 18O and ð 13C of Globigerinoides ruber(white). The Holocene 23, 1440–1446 (2013).

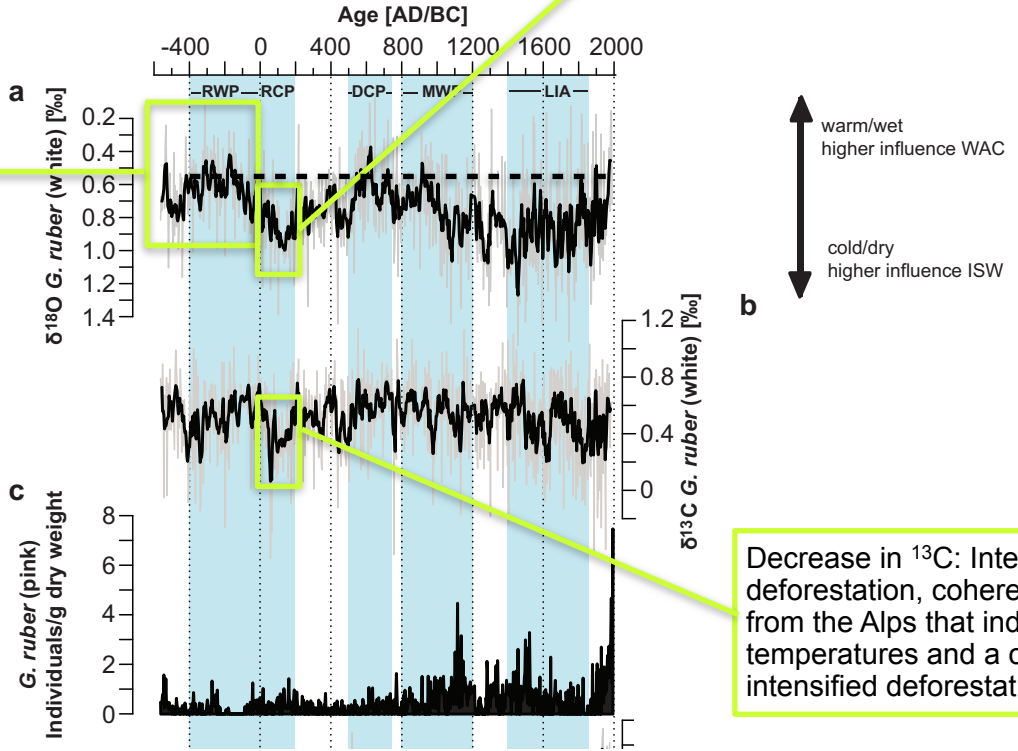
ISW = Ionian Surface Water

WAC = West Adriatic Current

The Climate of Classical Antiquity

Increase in ^{18}O: Move to more saline, less nutrient rich conditions, decrease in WAC

Low values ^{18}O indicating a higher influence of the less saline, nutrient-rich WAC and a trend to a lower depth habitat of the species reflecting generally wetter and warmer conditions during this time interval, compared to today.

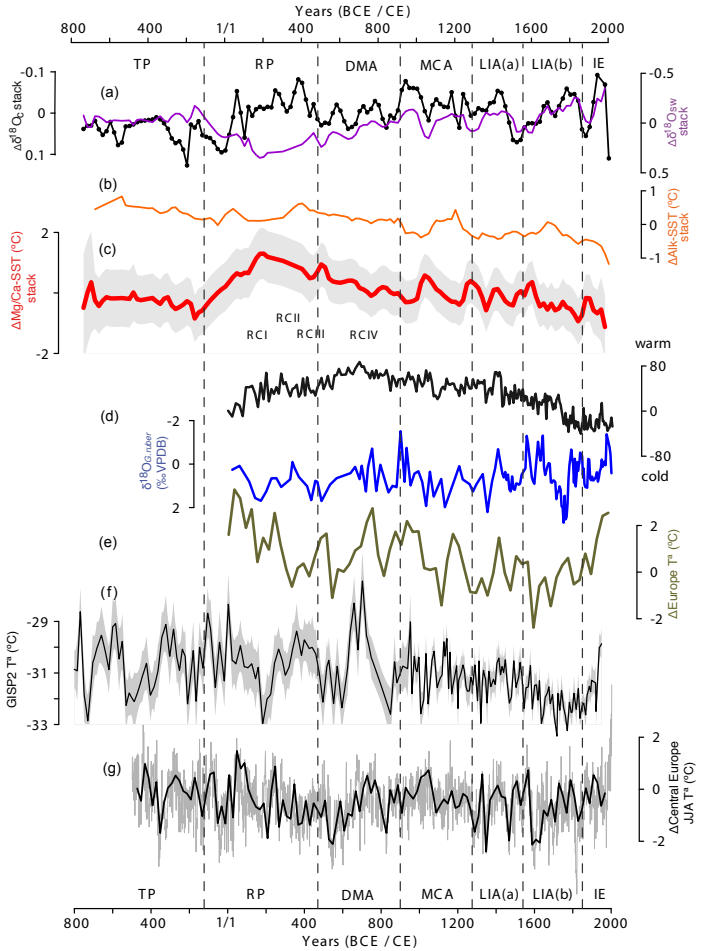


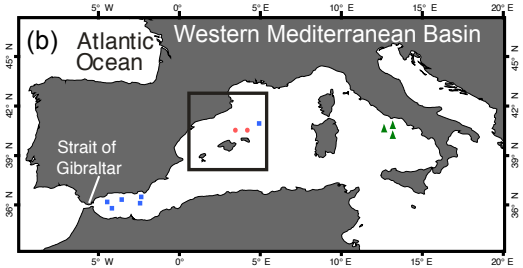
Decrease in ^{13}C: Intensified deforestation, coherent with pollen data from the Alps that indicate higher temperatures and a continuing and intensified deforestation.

Grauel, A.-L. et al., Climate of the past 2500 years in the Gulf of Taranto, central Mediterranean Sea: A high-resolution climate reconstruction based on δ 18O and δ 13C of Globigerinoides ruber(white). The Holocene 23, 1440–1446 (2013).

The Climate of Classical Antiquity

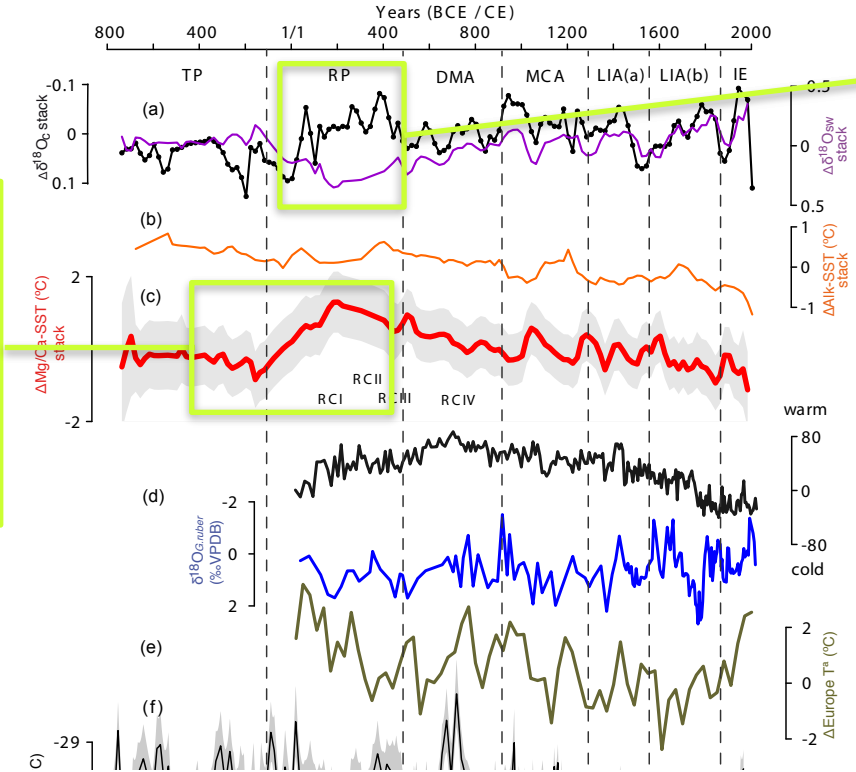
- Sediment Cores in Western Med. Basin
- Multiple proxies used, including foraminifera
- Gives indication of evaporation–precipitation balance and sea surface temperatures





Cisneros, M. et al. Sea surface temperature variability in the central-western Mediterranean Sea during the last 2700 years: a multi-proxy and multi-record approach. Clim. Past 12, 849–869 (2016).

The Climate of Classical Antiquity



~2°C warming of SSTs - reflects warmer climate. Higher (steric) sea level also likely (maybe as much as 20mm) but this is complicated subject…

this change (over ~250 yrs) is equivalent to the change in sea surface temperature we've seen between 1900 to 2000

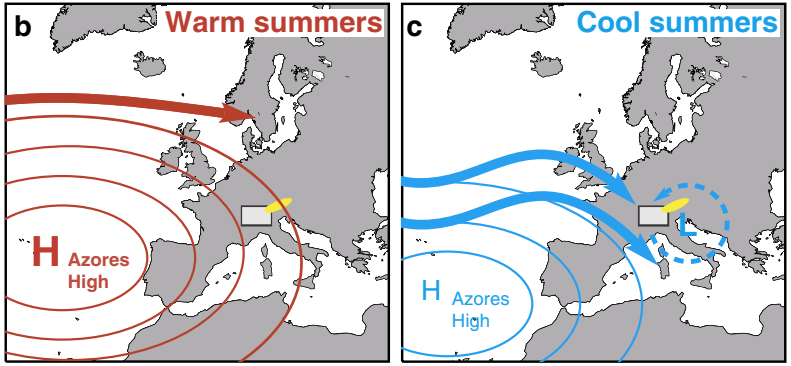
Elevated evaporation-precipitation (also seen in Alps) could result in increased precipitation elsewhere in Europe (e.g Spain).

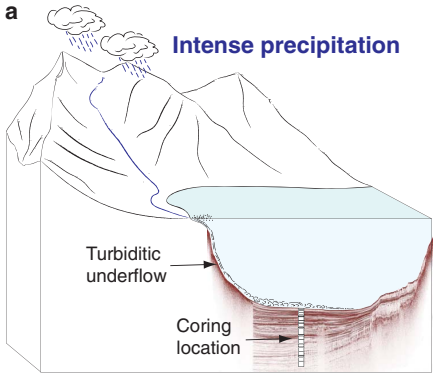
↑E-P = more evaporation that precipitation = drier conditions

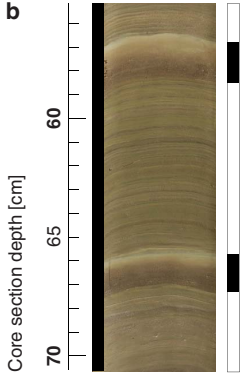
Cisneros, M. et al. Sea surface temperature variability in the central-western Mediterranean Sea during the last 2700 years: a multi-proxy and multi-record approach. Clim. Past 12, 849–869 (2016).

The Climate of Classical Antiquity

- Sediment cores from across Switzerland for Alpine flood reconstruction
- These give an indication of <u>summer</u> conditions and European storm tracks





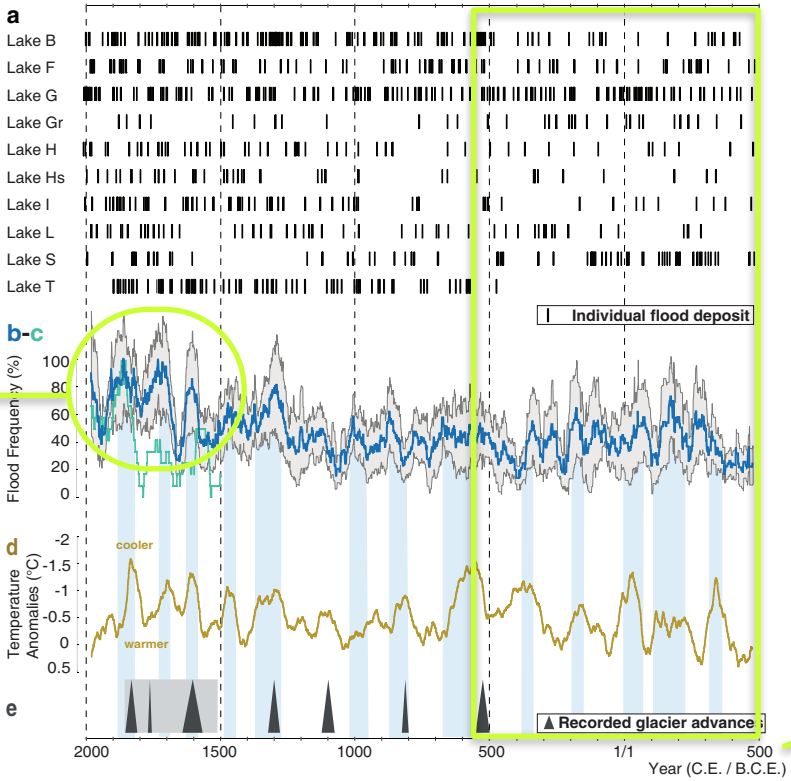


Glur, L. et al. Frequent floods in the European Alps coincide with cooler periods of the past 2500 years. Scientific Reports 3, 1–5 (2013).

The Climate of Classical Antiquity

Summer Conditions

Alpine flood frequency slightly higher in recent times



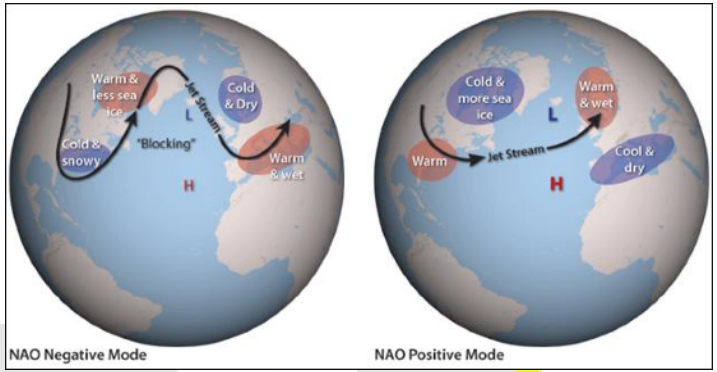
Decreased occurrence of westerly storm tracks during warmer summers decrease the frequency of flood events in the Alps but this pattern of less frequent intense precipitation events with warmer summers is regional in nature

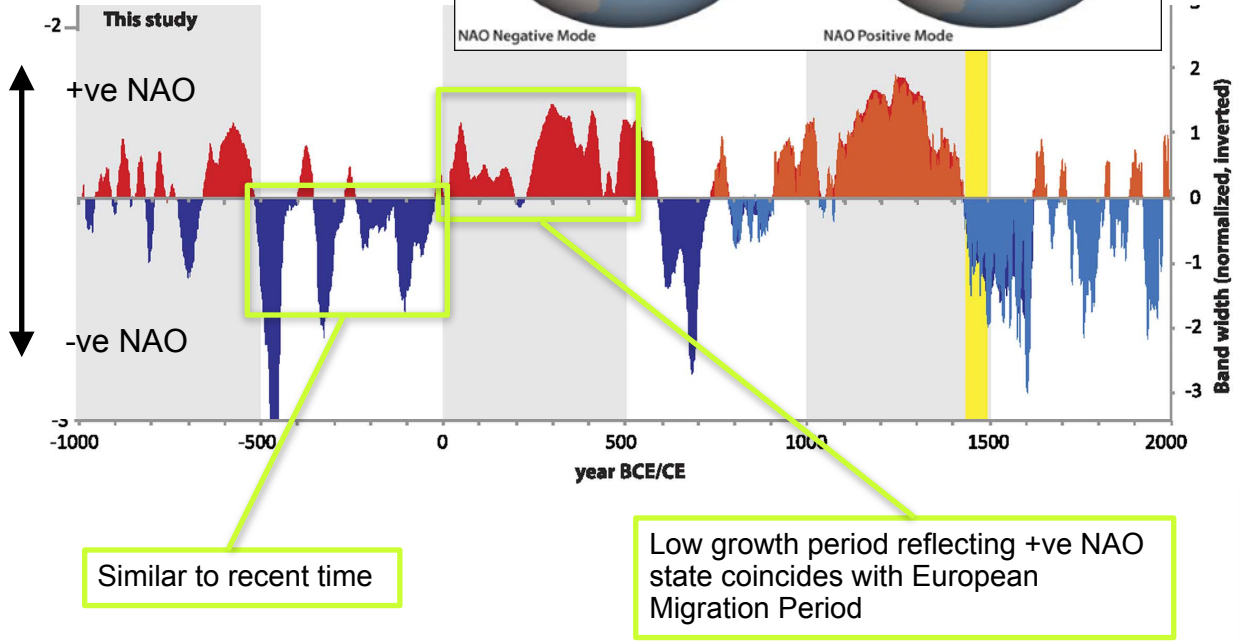
N.B. Change in axis direction!

Glur, L. et al. Frequent floods in the European Alps coincide with cooler periods of the past 2500 years. Scientific Reports 3, 1–5 (2013).

The Climate of Classical Antiquity

- Stalagmites record gives indication of winter conditions
- Dry(ish)/warm conditions → high CO_2 production → limestone disolution → increase stalagmite growth

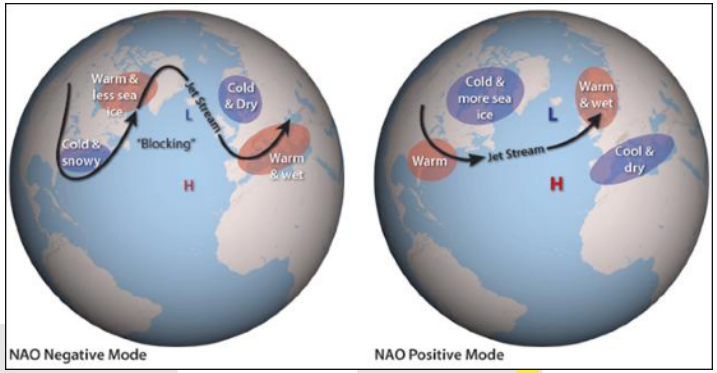


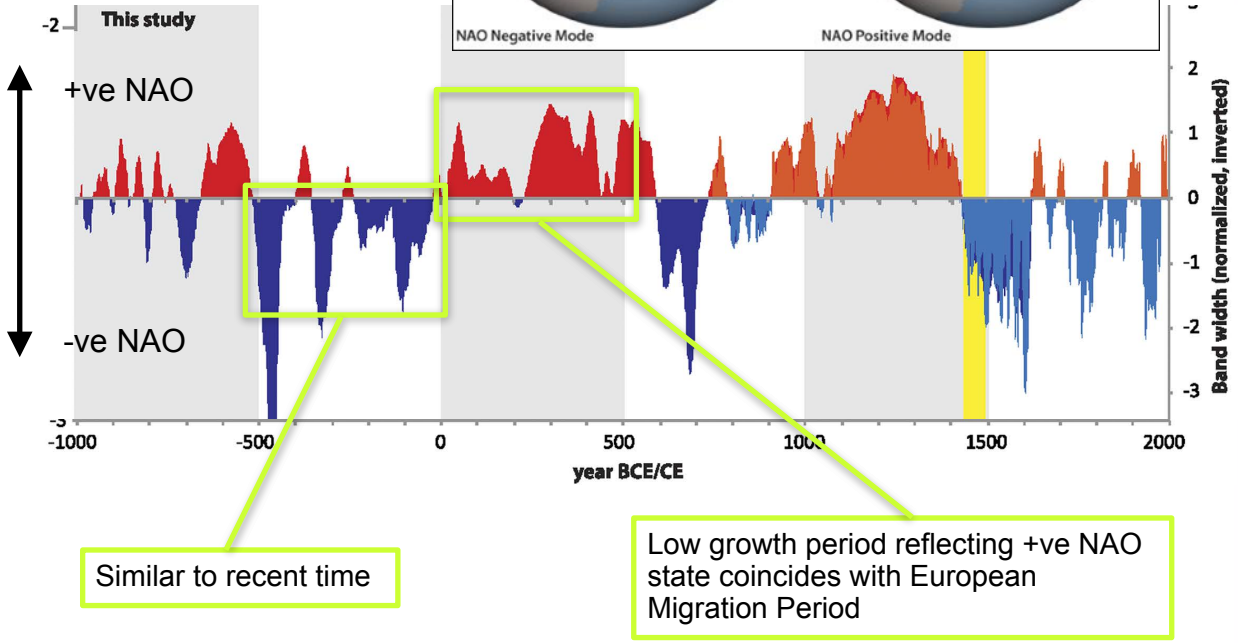


Baker, A., Hellstrom, J. C., Kelly, B. F. J., Mariethoz, G. & Trouet, V. A composite annual-resolution stalagmite record of North Atlantic climate over the last three millennia. Scientific Reports 1–8 (2015)

The Climate of Classical Antiquity

- NAO influence is not uniform over Europe
- +ve NAO = above-(modern) normal temp across northern Europe and often below-(modern) normal temperatures across southern Europe and the Middle East.
- Also associated with above-normal precipitation over northern Europe and Scandinavia and below-normal precipitation over southern and central Europe.

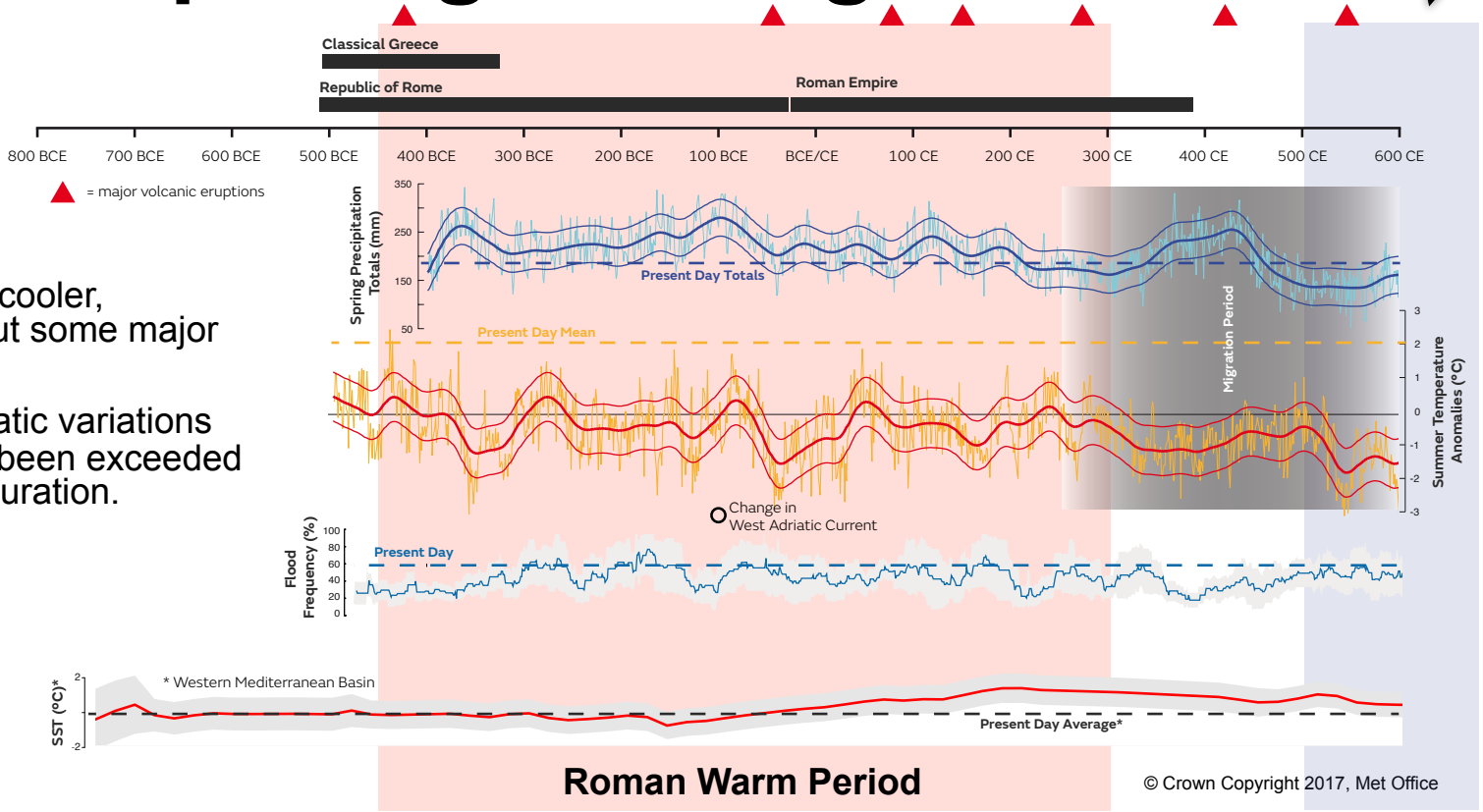




Met Office
Hadley Centre

So…putting it all together

Dark Ages Cold Period



- In general, climate cooler, frequently wetter but some major forcing events
- Modern hydro-climatic variations may have at times been exceeded in magnitude and duration.

Büntgen, Ulf, et al. "2500 years of European climate variability and human susceptibility." *Science* 331.6017 (2011): 578-582.

and previous references

Met Office
Hadley Centre

How has weather and climate shaped Classical history?

Shaping history…

Attribution of major events to climate is difficult!

but …

- Stable climate conditions coincide with Hannibal's crossing of the Alps and the eventual rise of the Roman Empire
- Wet and warm summers occurred during periods of Roman and medieval prosperity.
- Increased climate variability from ~250 to 600 C.E. coincided with the demise of the western Roman Empire and the turmoil of the Migration Period.

Büntgen, Ulf, et al. "2500 years of European climate variability and human susceptibility." *Science* 331.6017 (2011): 578-582.

McCormick, M. et al. Climate Change during and after the Roman Empire: Reconstructing the Past from Scientific and Historical Evidence. Journal of Interdisciplinary History 43, 169–220 (2012).

Final points…

- We cannot use a simplistic model of climatic determinism to explain cultural persistence, but…
- Historically, human adaptation has happened slower than climate change
- Even today, temperature depresses current U.S. maize yields by ~48% & warming since 1980 has elevated conflict risk in Africa by ~11%

Carleton, T. A. & Hsiang, S. M. Social and economic impacts of climate. Science 353, (2016).

Met Office
Hadley Centre

What is the point of History?

"History doesn't repeat itself, but it rhymes."

From a climate science point of view:
Looking at the past is a key component of helping us understand how to predict the future.
It forms the basis of assessing our climate modelling capability.

From a more general view:
… (over to you!)

Can we use our understanding of the past, to better ourselves today?

Met Office
Hadley Centre

Thank you
Any Questions?

hamish.steptoe@metoffice.gov.uk