Seminar University of Brno, Dept of Geography, October 2013

From proxy data to large-scale paleo reconstructions; new insights on past and present European summer temperature over the past 2500 years

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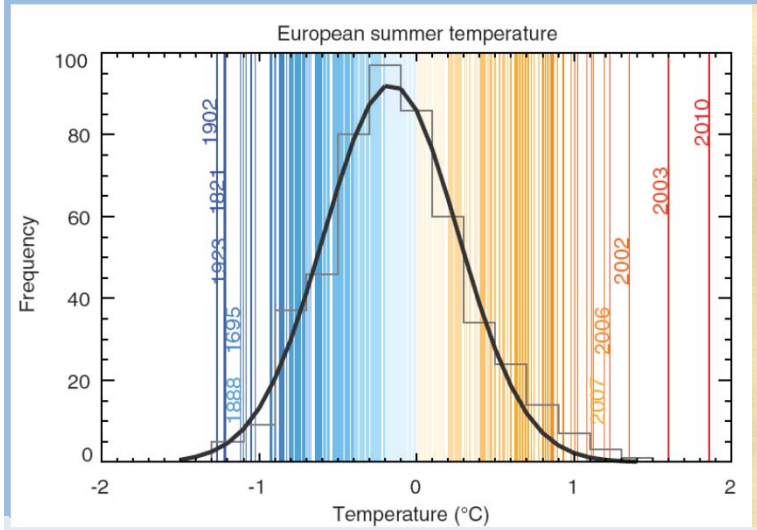

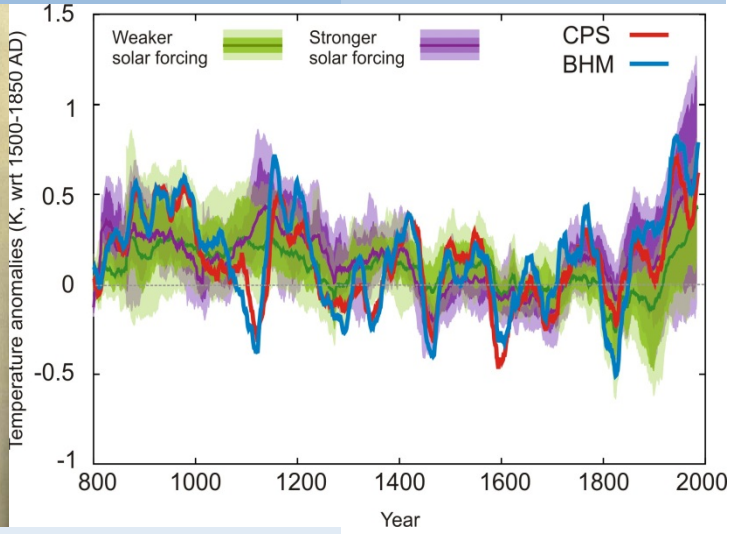

Department of Geography Justus Liebig University of Giessen

- University established 1607, one of the oldest in Germany
- Approx. 70 km north of Frankfurt
- > 23000 students
- Department of Geography was funded in 1864
- Currently 1000 students (Bachelor, Master, PhD and teachers)
- 6 Professorships
  - Geomorphology/soil sciences (physical Geography)
  - Climatology (physical Geography)
  - Economy Geography
  - Anthropo Geography
  - Regional Planning
  - Geography didactics and pedagogics

Leading research questions addressed in this seminar

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- How can we reconstruct climate before the instrumental period?
- How did European summer temperature vary over the past two millennia and how reliable are those reconstructions?
- What are the natural variations of European summer temperature back to Roman times?
- Is the current warmth and warming trend exceptional in the context of the past two millennia?
- What is the influence of human and natural forcing on past European summer temperature?
- The exceptional warm summers of 2003 and 2010; is there evidence for similar past extremes?

→ Importance of Palaeoscience for global change research

Importance of Palaeoscience for Global Change Research

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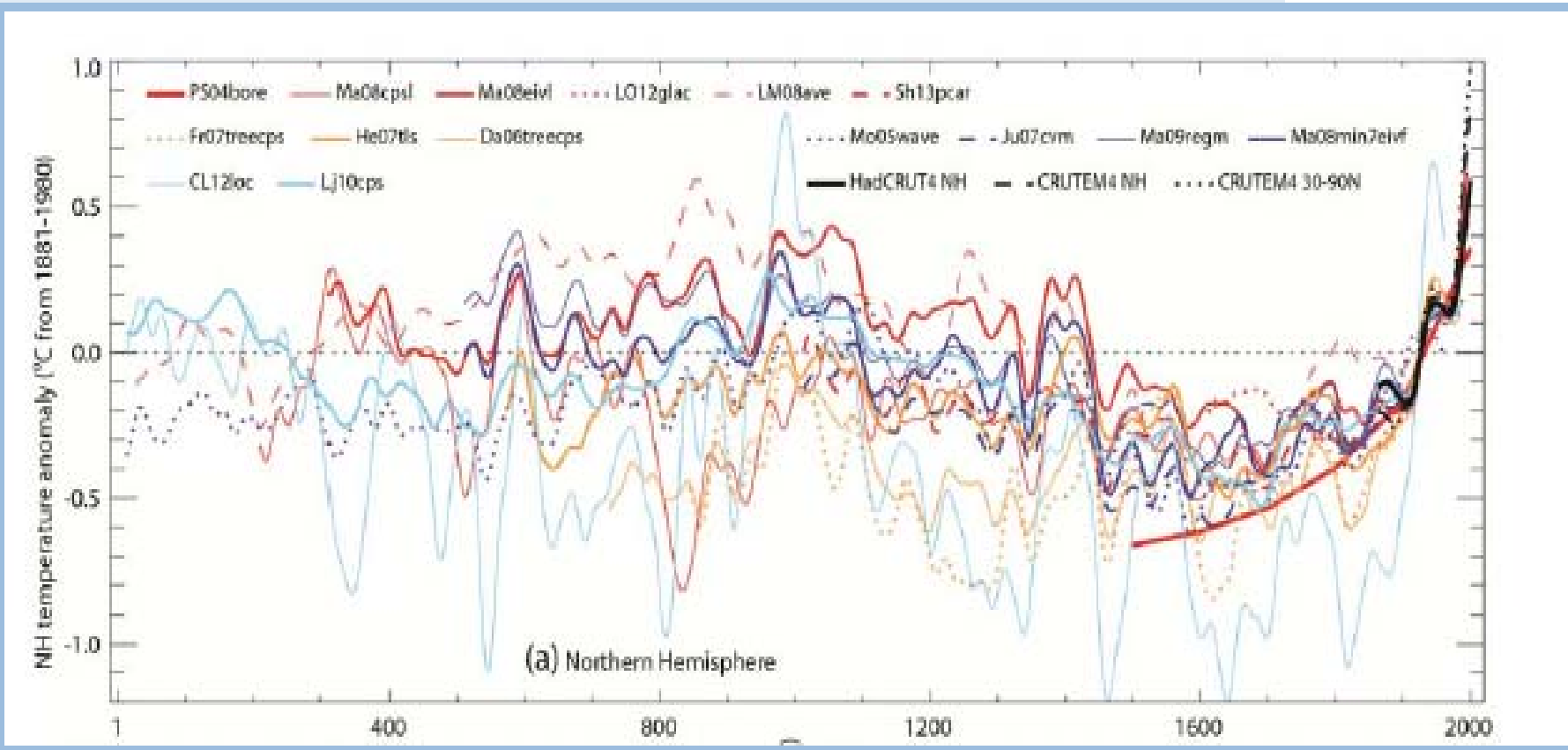
- Palaeoscience is the study of climate and environmental processes in the past prior to the existence of instrumental records
- In order to better understand current climate changes and to project future scenarios, knowledge of the past is imperative
- The palaeorecord evidence in concert with modelling of past scenarios provides a quantitative understanding of past Earth System variability and the underlying processes
- The past does not provide a prescriptive guide to the future but can form the basis for an evaluation of present day trends, future probabilities, uncertainties and likely human consequences

(PAGES 2009)

AR5 IPCC 2013: Northern Hemisphere temperature variations back to AD 1



→ NH mean reconstructions do not provide information about seasonal and spatial variations

IPCC AR5 2013, chapter 5

Global summer temperature anomalies 2012

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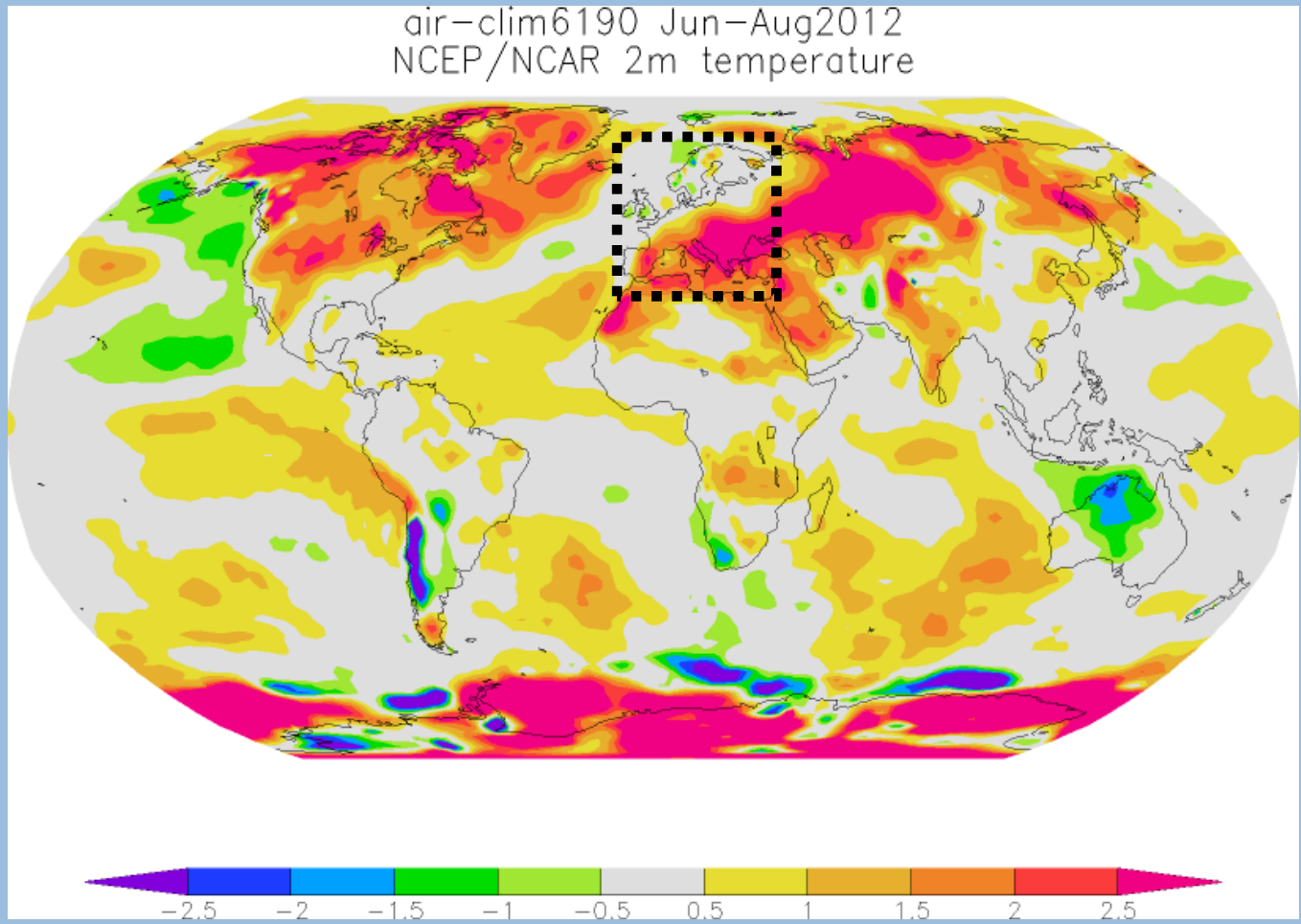

NCEP/NCAR

Arctic Sea Ice Extent

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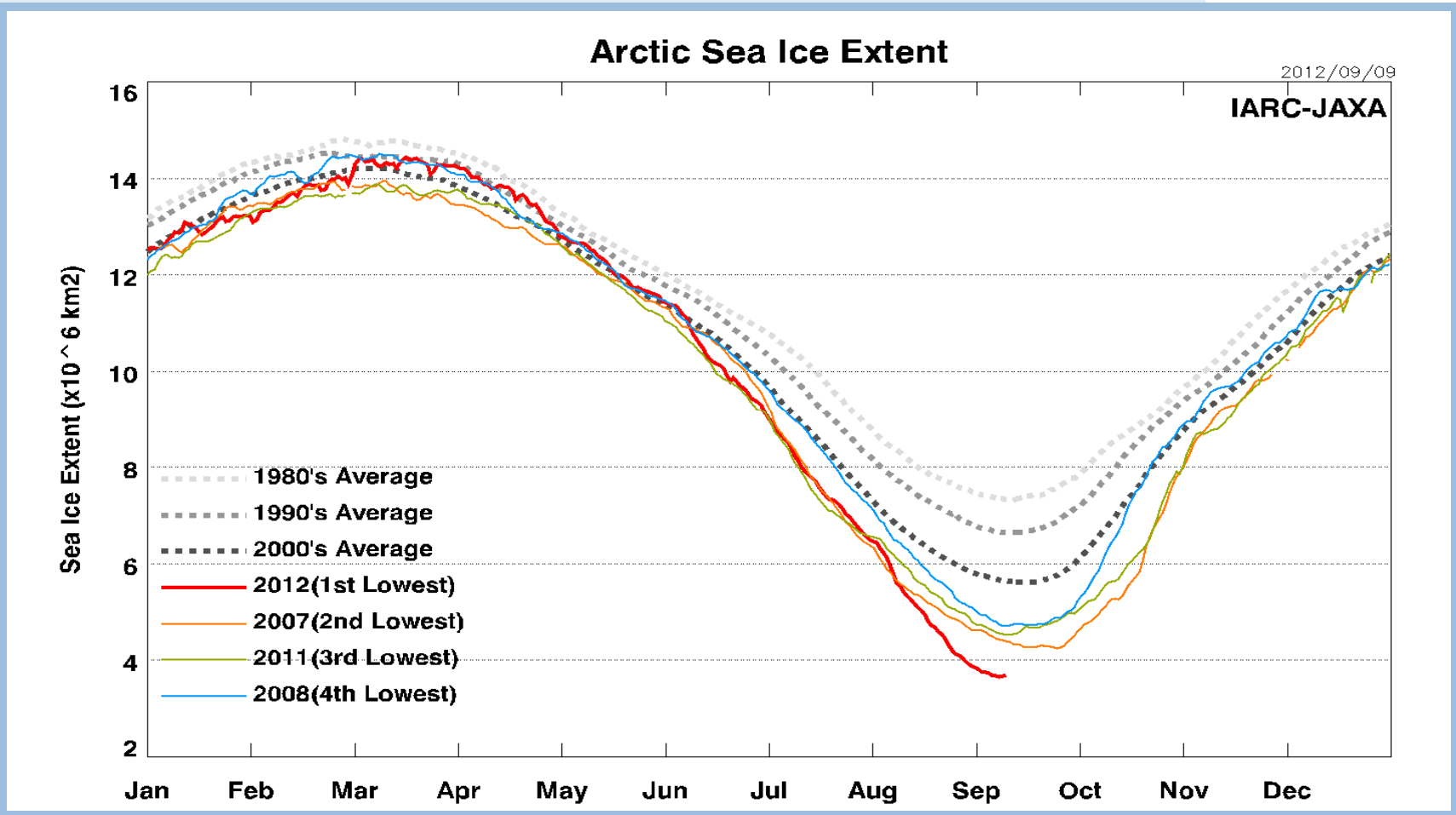

The 2007 minimum record of sea ice extent was broken on 24, August, 2012

Summer temperature change within the instrumental period

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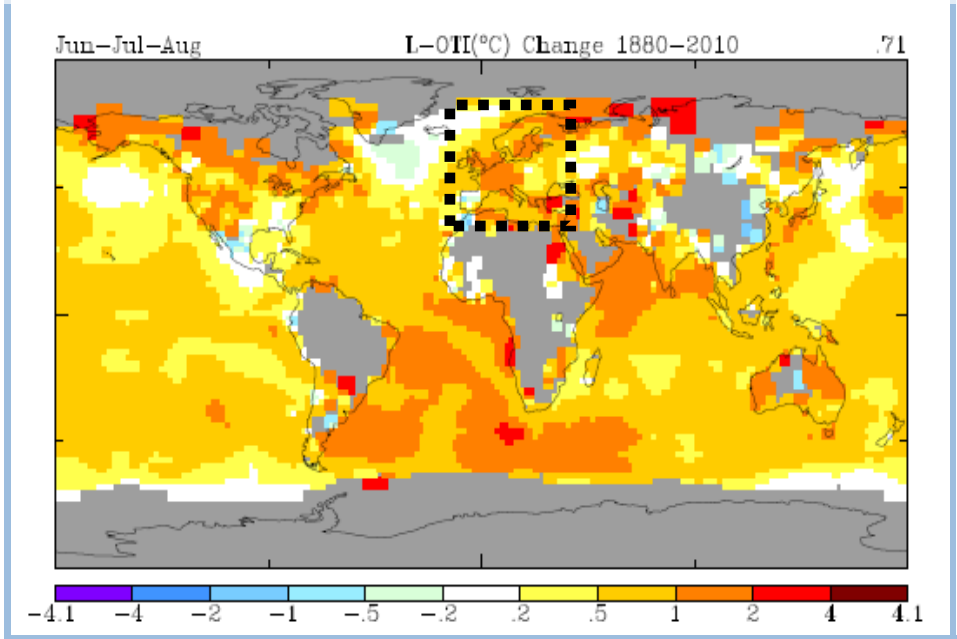

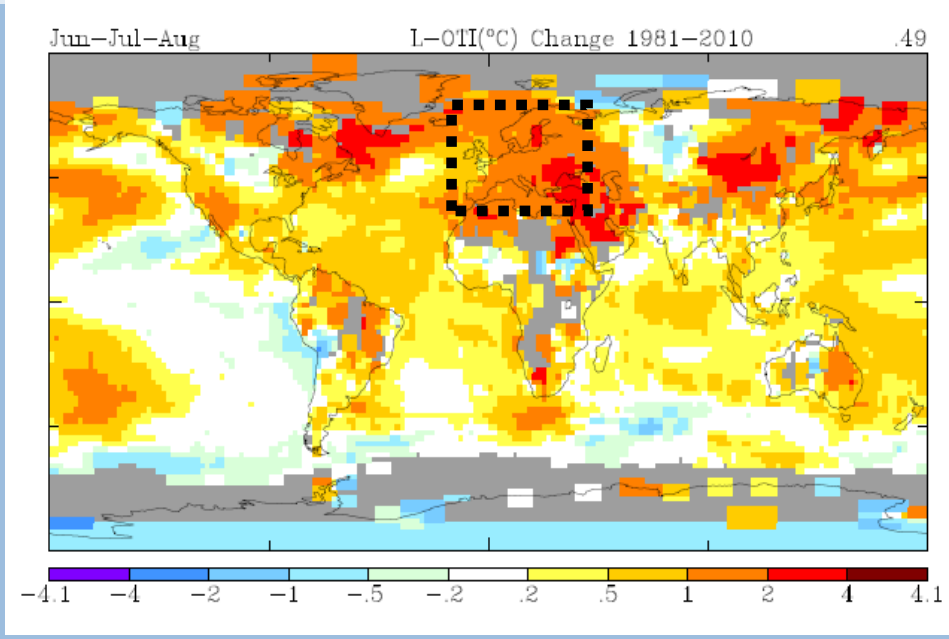

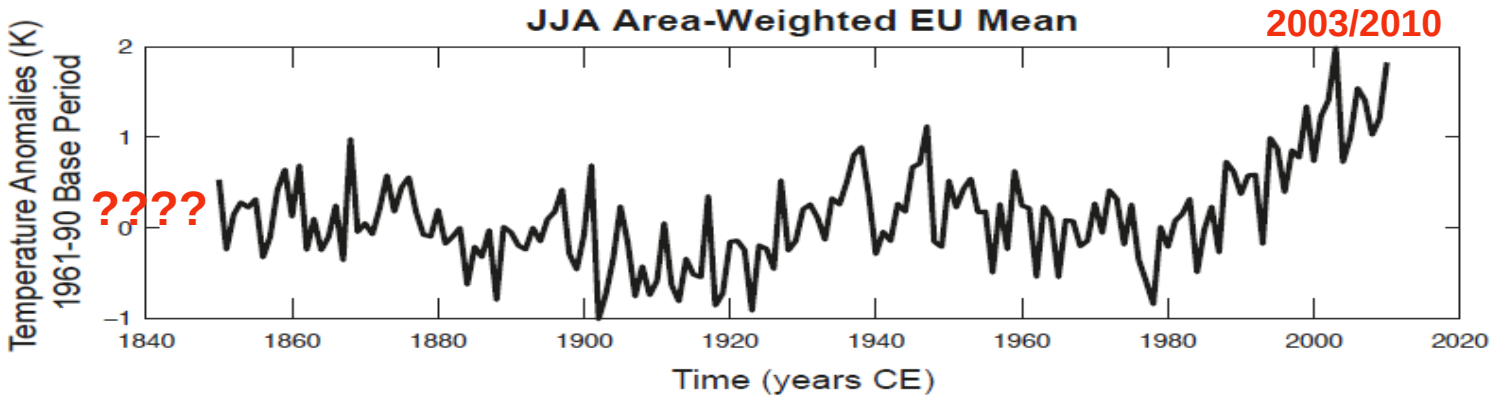

GISS NASA
CRU

Continental temperature change 19th and 20th century

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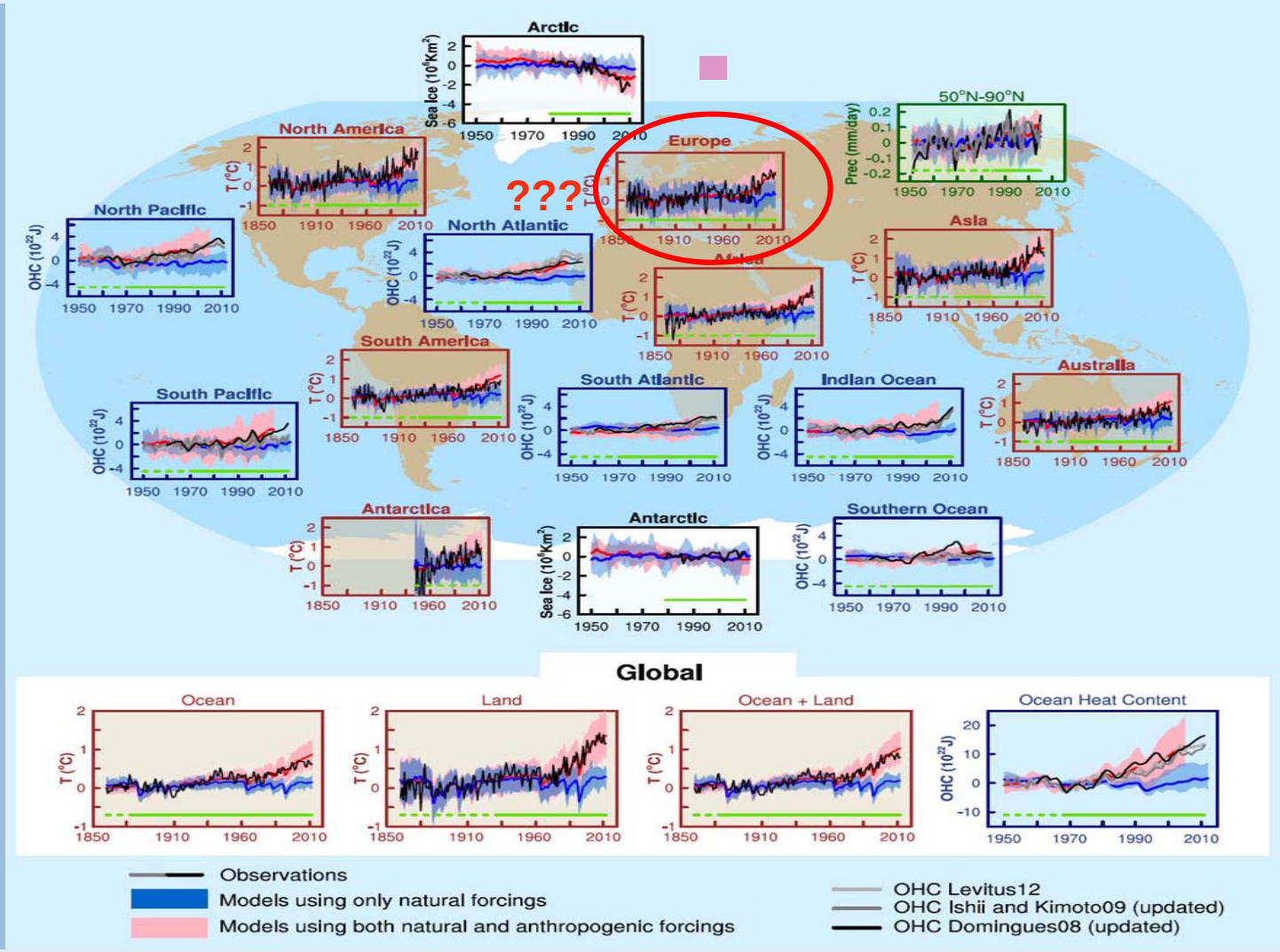

IPCC AR5 2013, chapter 10

PAGES Initiative, 2000 years of high resolution continental climate reconstructions

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Proxies used for climate reconstructions

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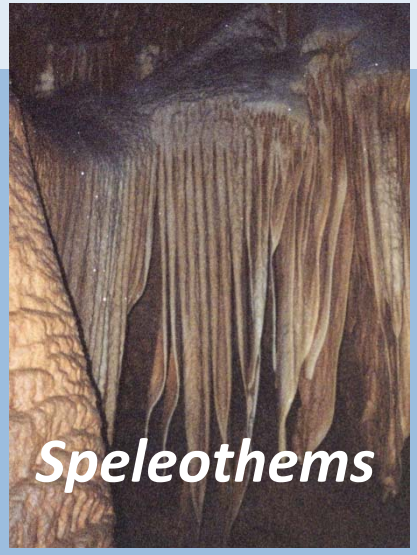

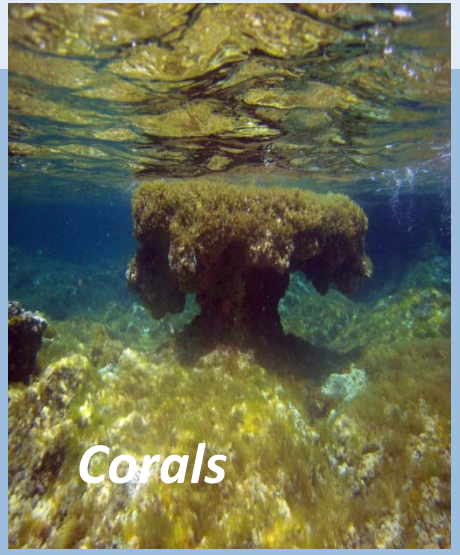

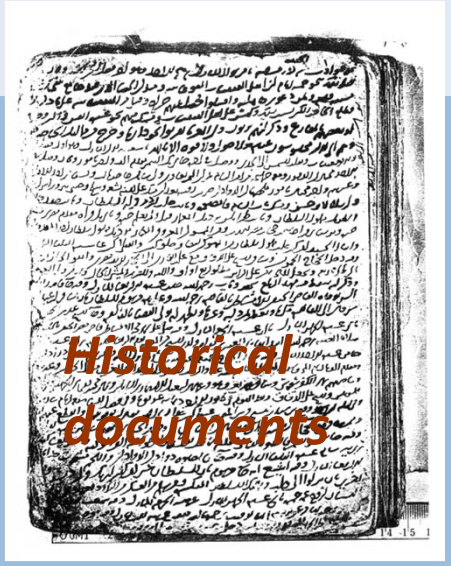

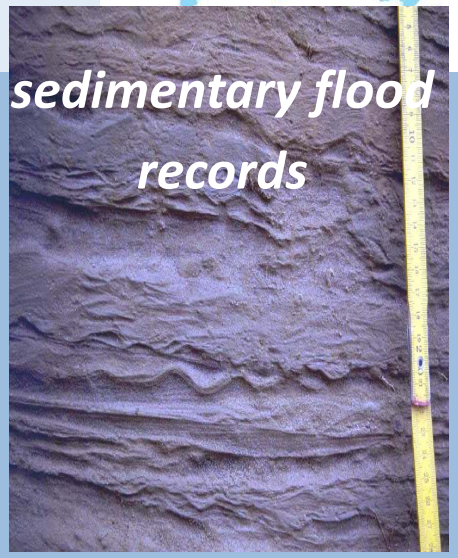

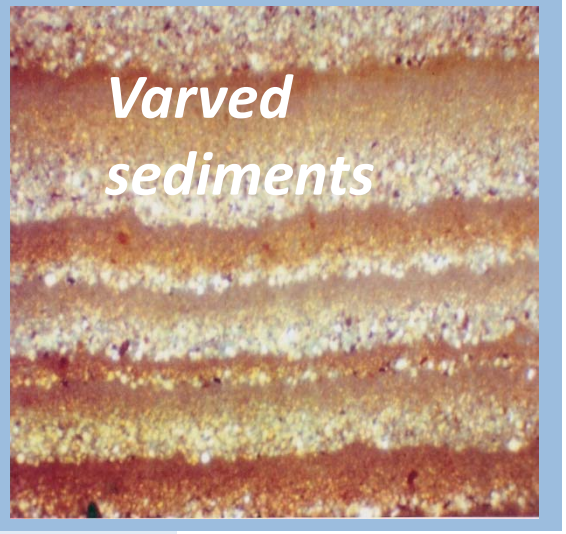

Bradley 1999

Types of climatic proxies

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	Natural Archives		Societal Archives		
Direct Data - Measurements - …			Historical documents	*Descriptions* - Weather diaries - Natural disasters - …	*Measurements* - Temperature, precipitation, pressure - …
Indirect or proxy data	*Organic* - Tree rings - …	*Inorganic* - Ice cores - Boreholes - Varves		*Organic* - Phenological data - (Grape) Harvest - …	*Inorganic* - Flood marks - Icing and break-ups - Duration of snow cover …
				Religious Sources - Inscriptions, Paintings	- Rogation processions - …

Pfister 1999

Early instrumental measurements

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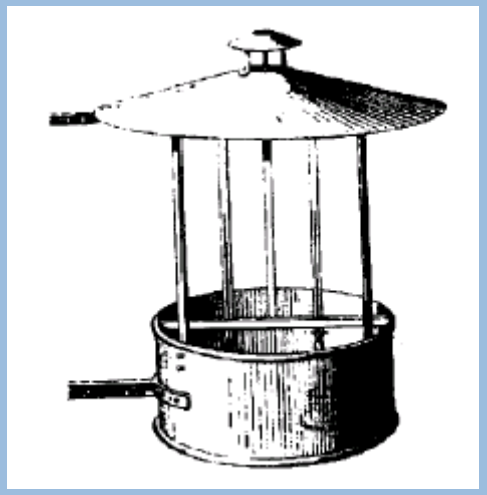

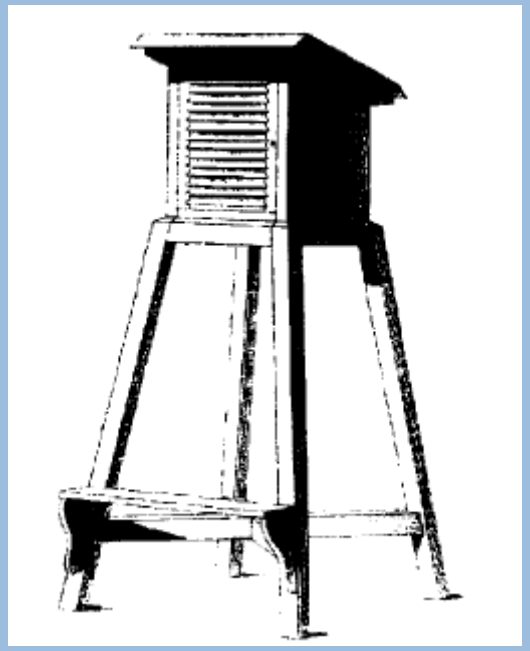

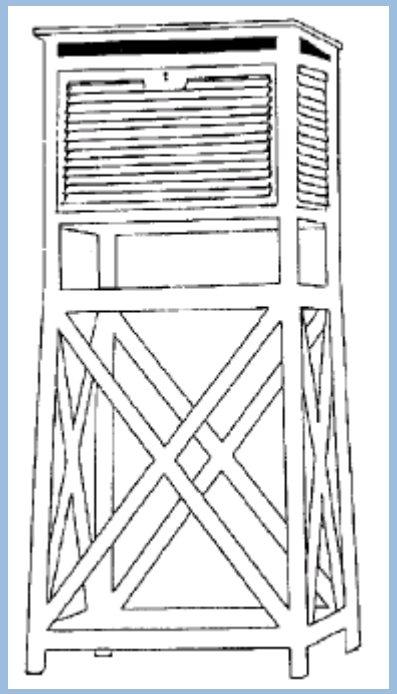

Nordli et al. 1997

Documentary evidence, different sources

- **narrative sources** (annals, chronicles, memories)
- **visual daily weather records**
- **personal correspondence**
- **newspapers**
- **scientific papers**
- **epigraphic records**
- **economic records** (books of accounts, correspondence, about natural disasters)

Brazdil et al. 2005 ff; Dobrovolny et al. 2010ff; Pfister et al 2008

Central European summer temperature reconstruction 1500-2000 using documentary & instrumental information

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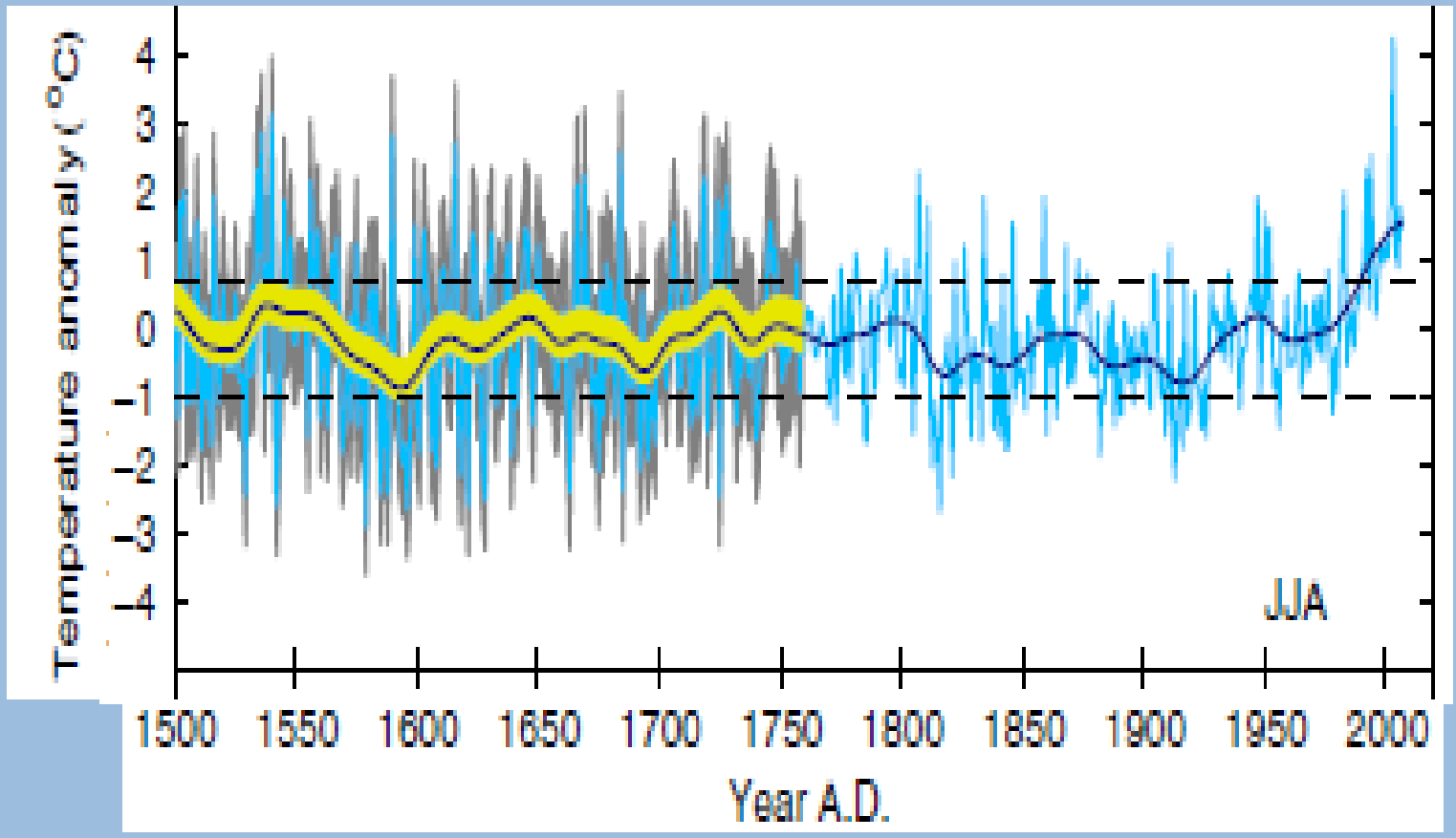

Dobrovolny et al. 2010

Documentary evidence, Grape harvest data → past summer temperature (France, Switzerland, Austria)

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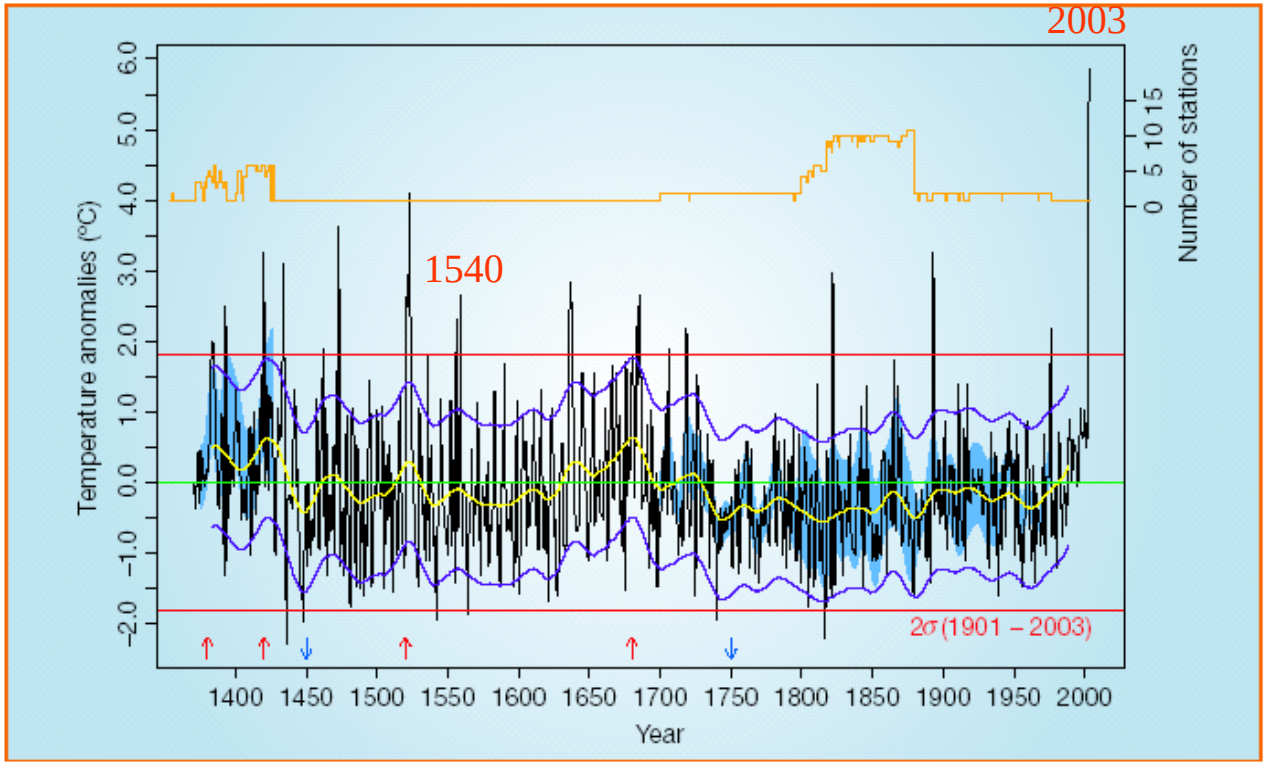

Chuine et al. 2004

Types of climate proxies

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Pfister 1999

Natural archives, Glacier Nigardsbreen (western Norway)

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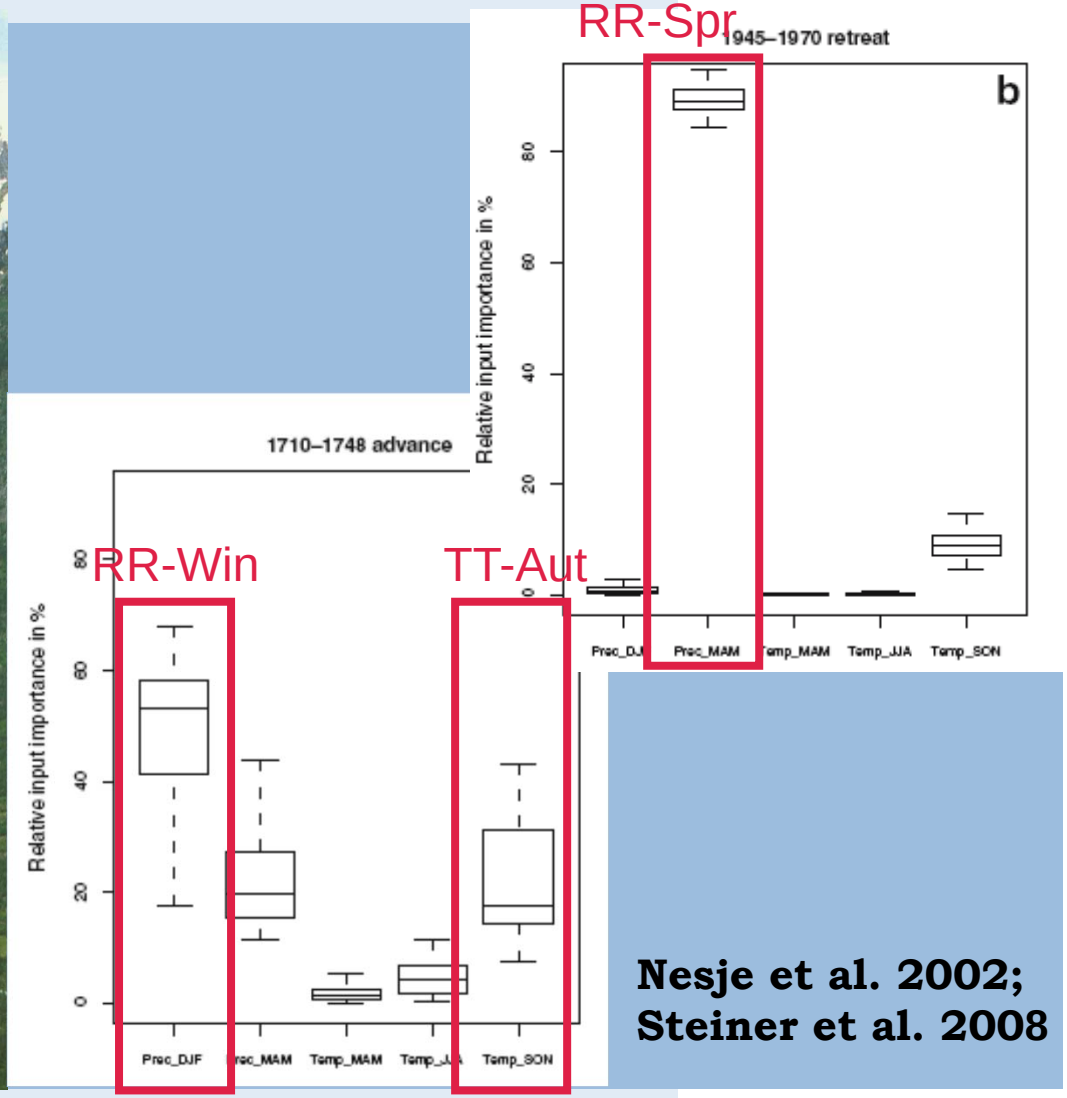

Nesje et al. 2002; Steiner et al. 2008

Natural archives, Tree rings

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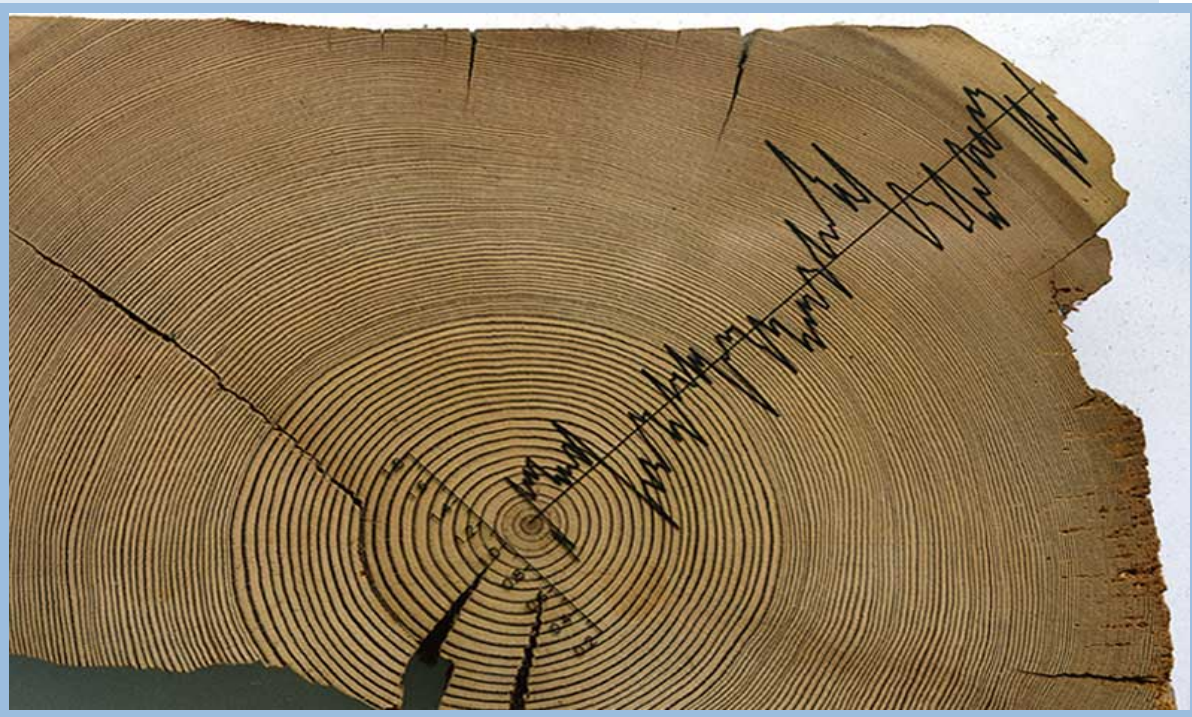

Climate information from:
tree ring width; wood morphological changes throughout the growing season (early and late wood; tree density); isotopic components

Tree rings can provide information on summer temperature (Scandinavia/Alps) or precipitation (Mediterranean, UK)

Maximum Late Wood Density derived from northern Scandinavian Pinus sylvestris trees → summer temperature reconstruction

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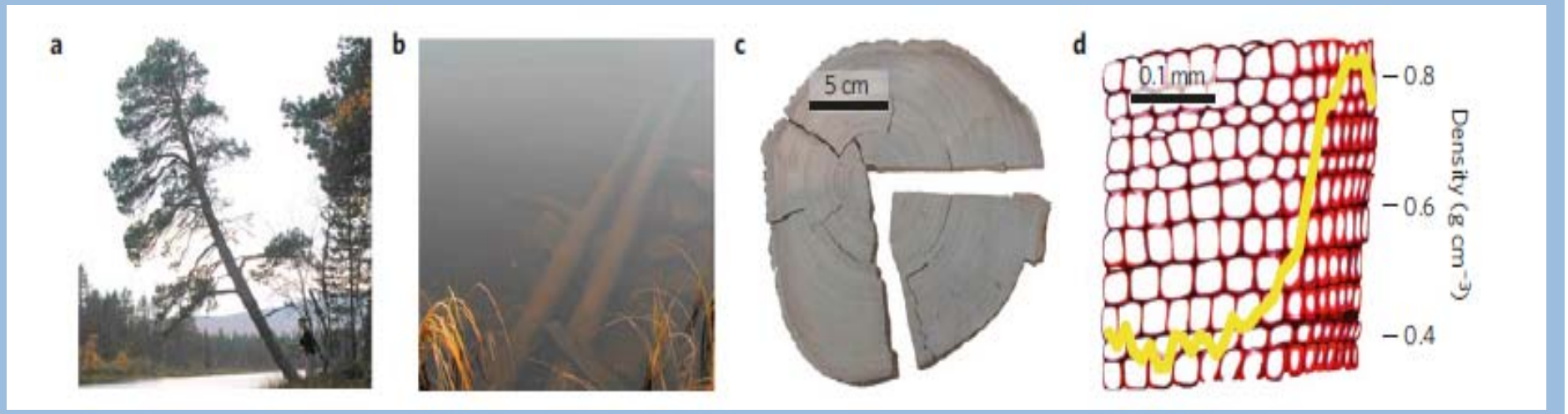

Esper, Luterbacher et al. 2012, Nature C C

Summer temperature and precipitation in central Europe BC 500 to today

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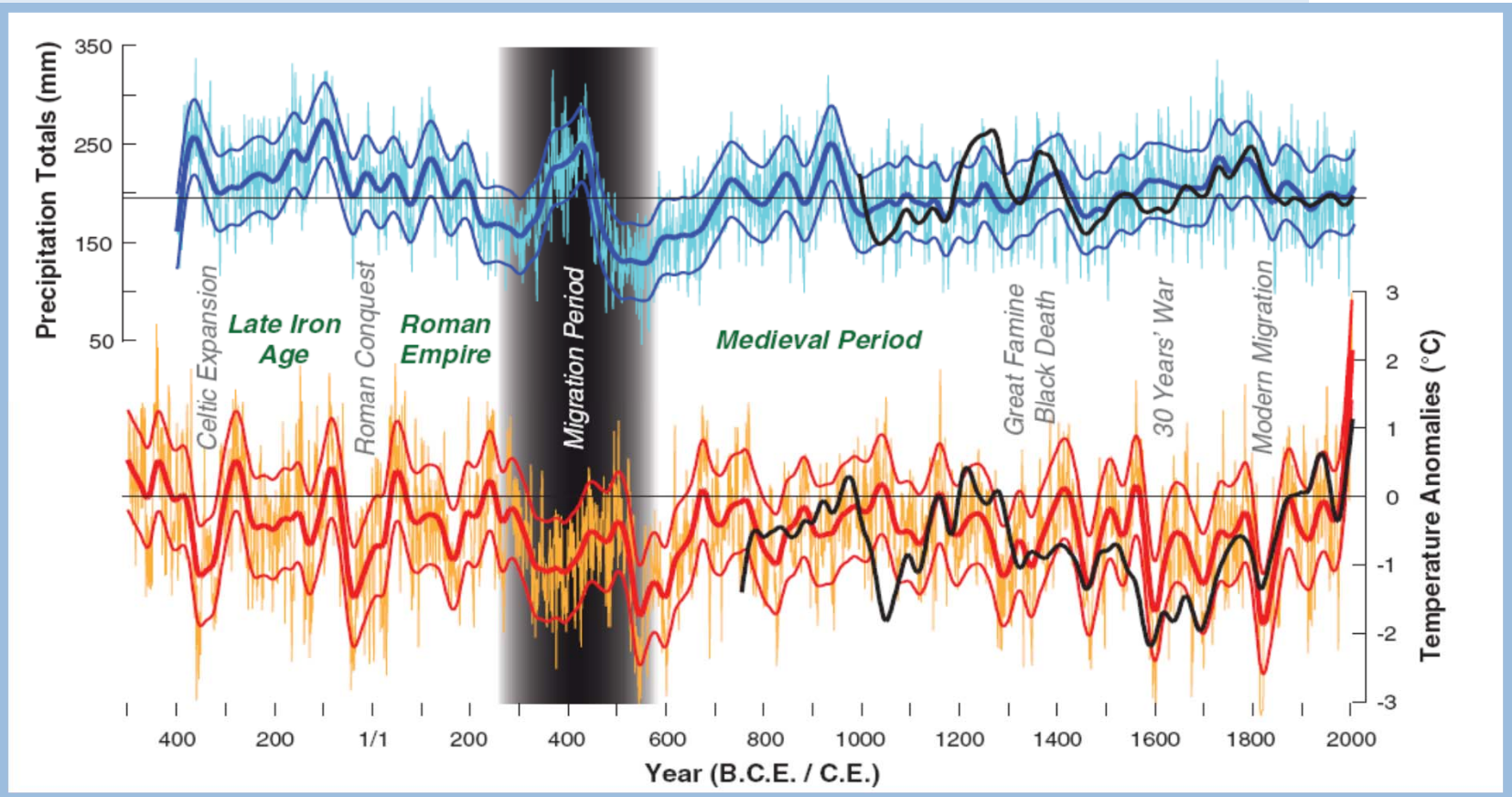

Büntgen et al. 2011

Schematic diagram of the methodology used to reconstruct past climate

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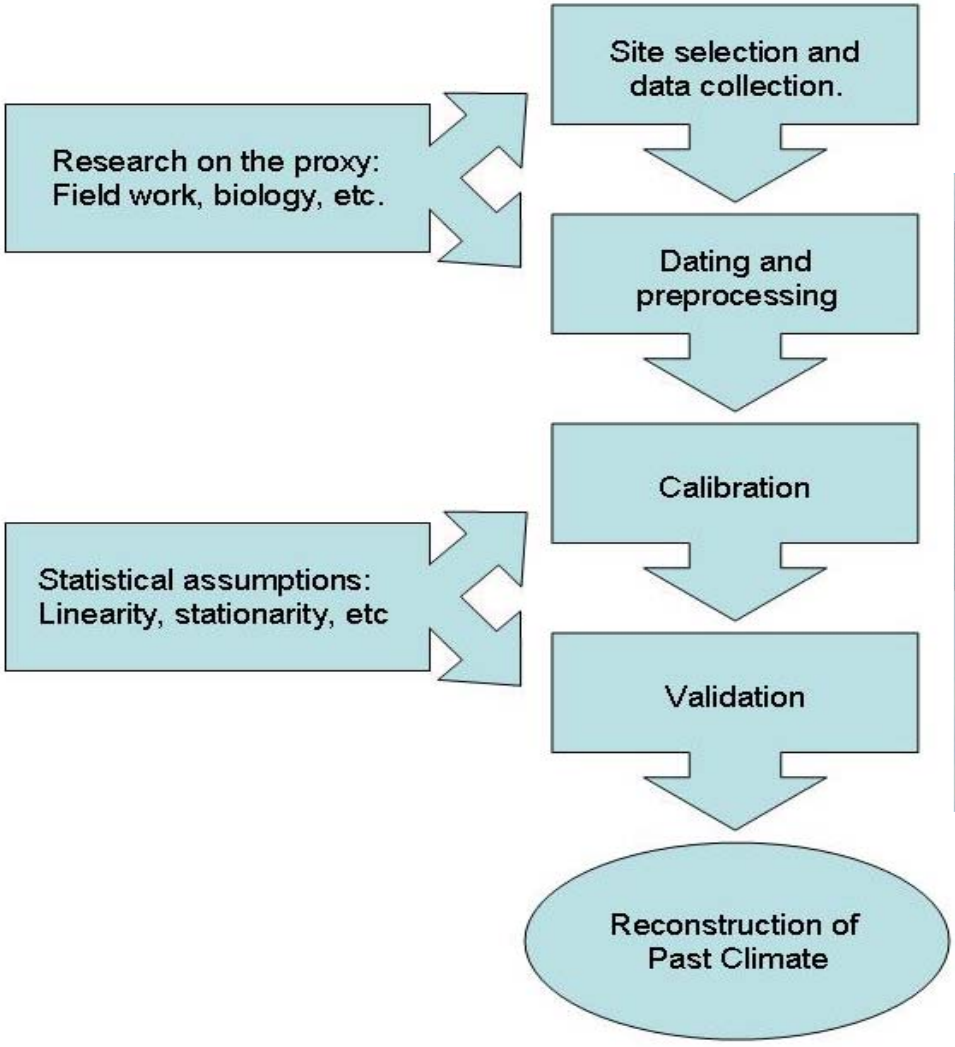
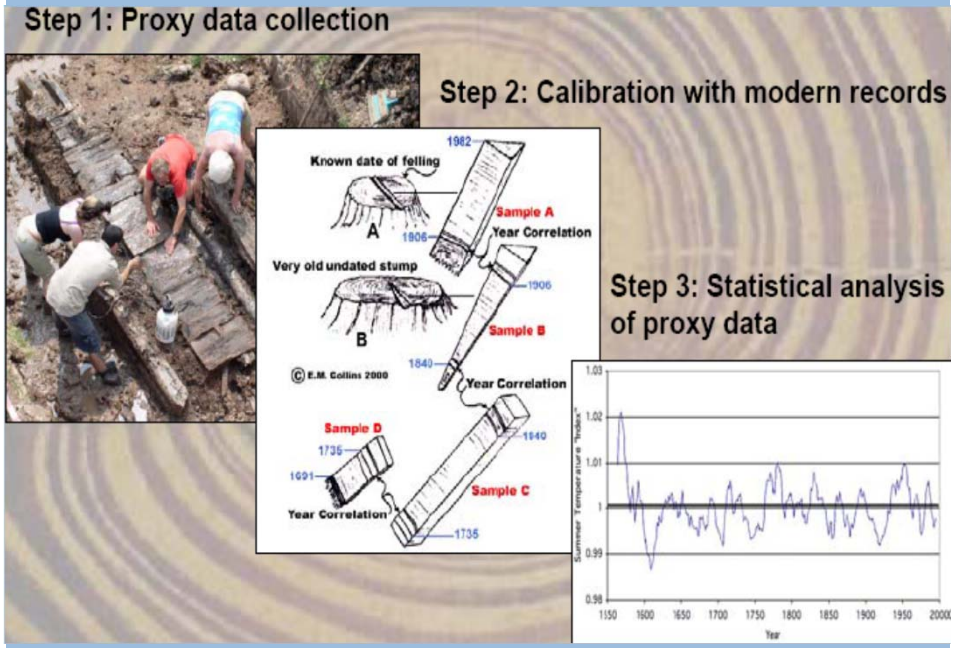
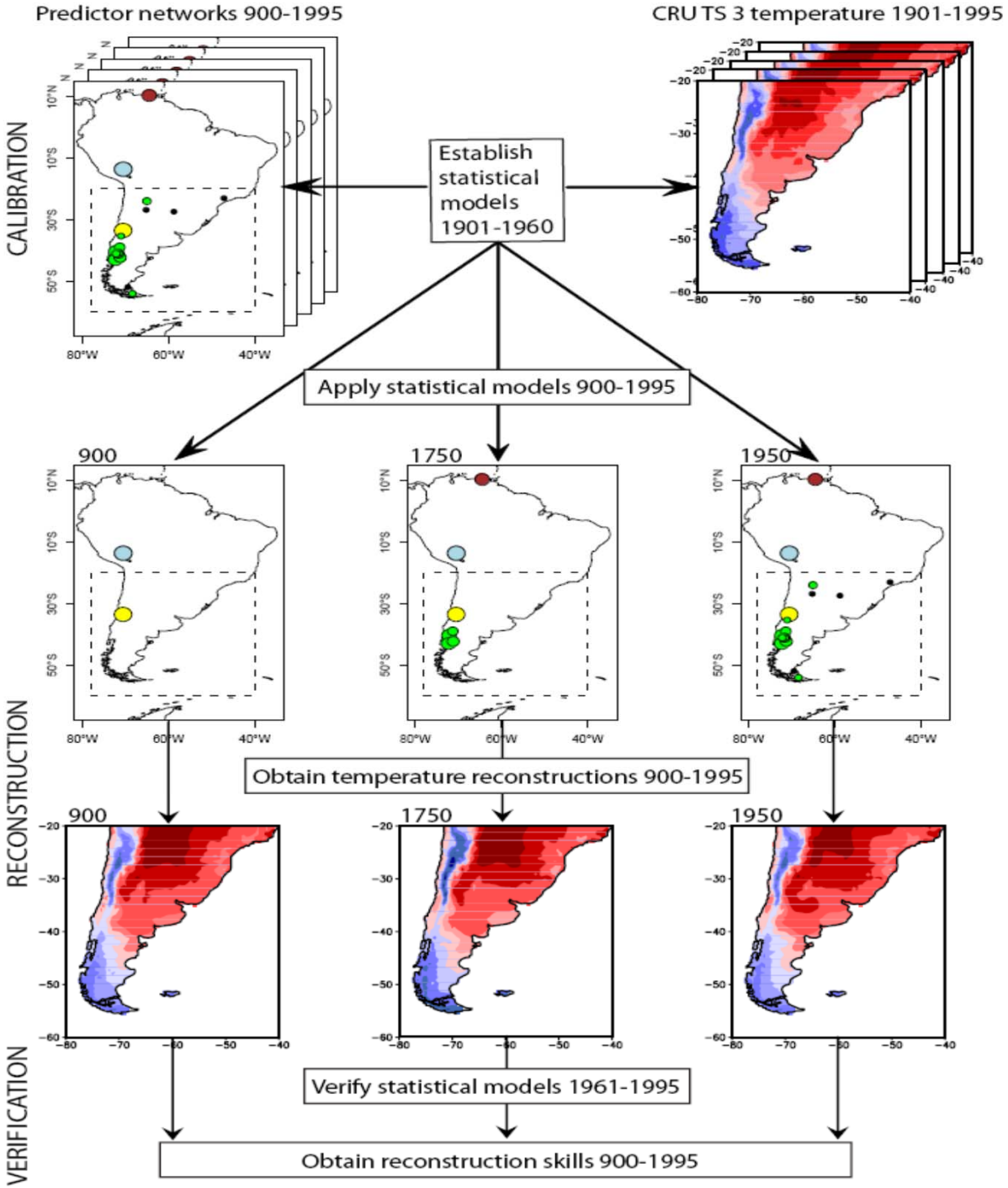




NRC 2006



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Neukom 2010

Detection and attribution of past and present European summer temperature

- …is the European temperature variability prior to the 20th century really '*fundamentally a consequence of unforced variability*'? (Bengtsson et al., 2006)
  → their argument is based on the consistent variability for short timescales in an unforced AOGCM control simulation and continental reconstruction

- We apply D&A methods to seasonally reconstructed European land areas back to AD 1500
  → separate externally driven variability from internal fluctuations
  → Quantify the role of external forcing

Fingerprint method : estimates contribution of forced fingerprint (multimodel mean) to reconstructions

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Multiple regression:

Fingerprint f_i: $T_{proxy}(t) = \sum_{forcings} a_i (f_i(t) + noise) + noise$

1-signal: multimodel mean response (tls estimate, ie variability noise in fingerprint and reconstruction considered)

[3 signal (GHG + aerosol; volcanic; solar): Energy Balance Model simulation in response to forcing i]

- The uncertainty of the fit is estimated by superimposing samples of internal climate variability from the climate model and unexplained variance from the reconstruction
- Estimate of climate variability: from model runs after subtracting a scaled all forcings EBM run; compared to residual in reconstructions

Hegerl, Luterbacher et al. 2011, Nat. Geosci.

Contribution of external forcing to reconstructed European summer temperature

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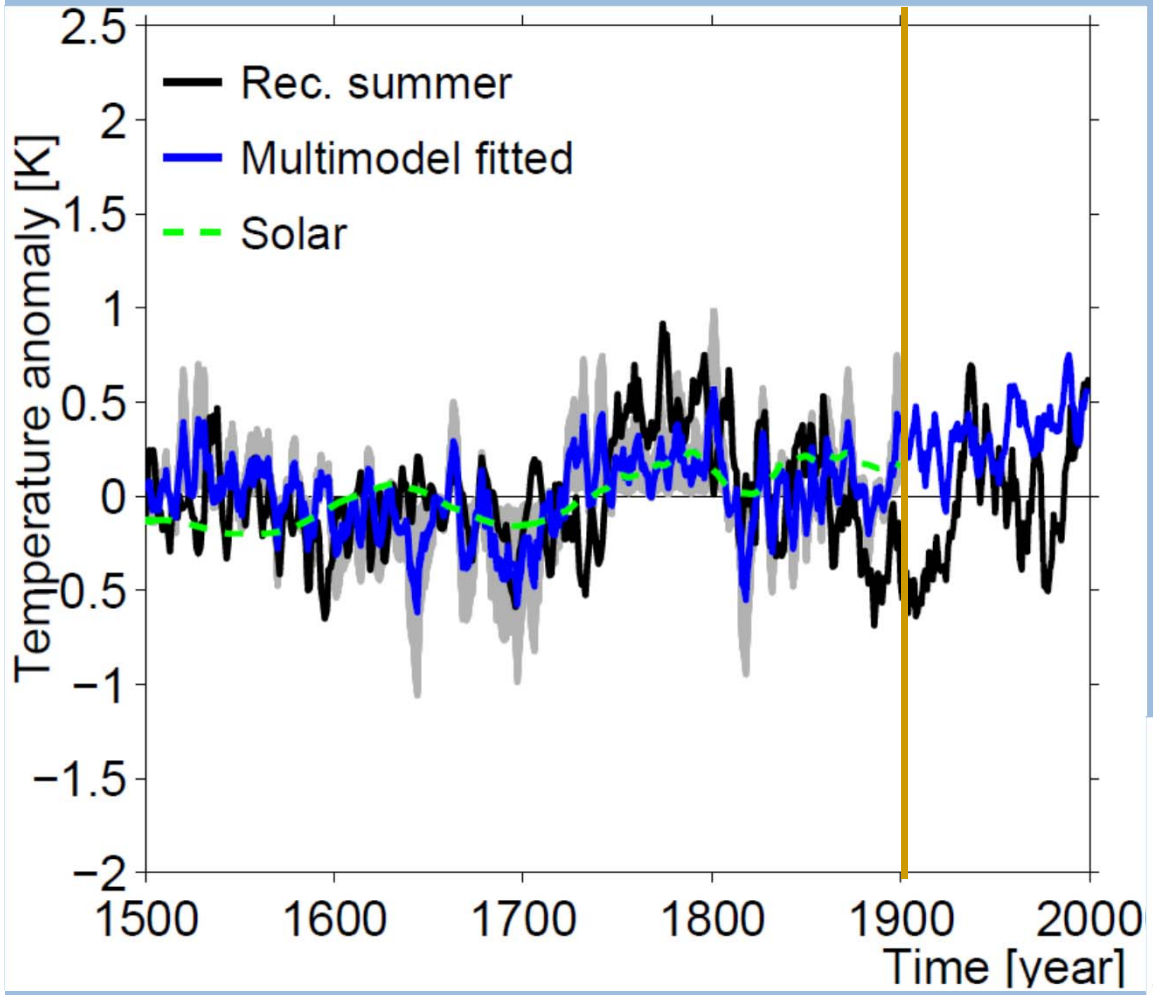
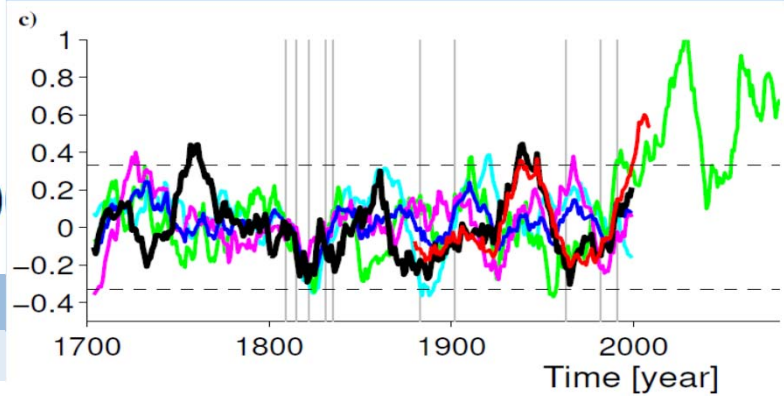


- Role of solar forcing not detectable for whole record, not robust over time
- Post 1970 acceleration of summer warming is unusual and likely caused by anthropogenic influences (Christidis et al. 2011)
- Solar influence on European summer temperatures remains speculative



Response to volcanic eruptions in summer temperature for 17 past eruptions

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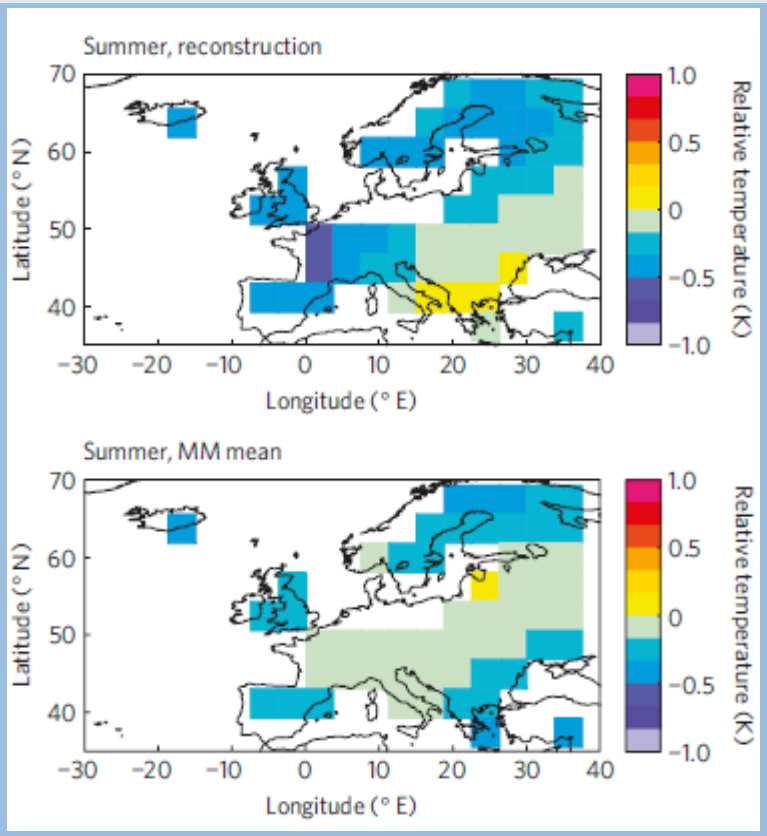
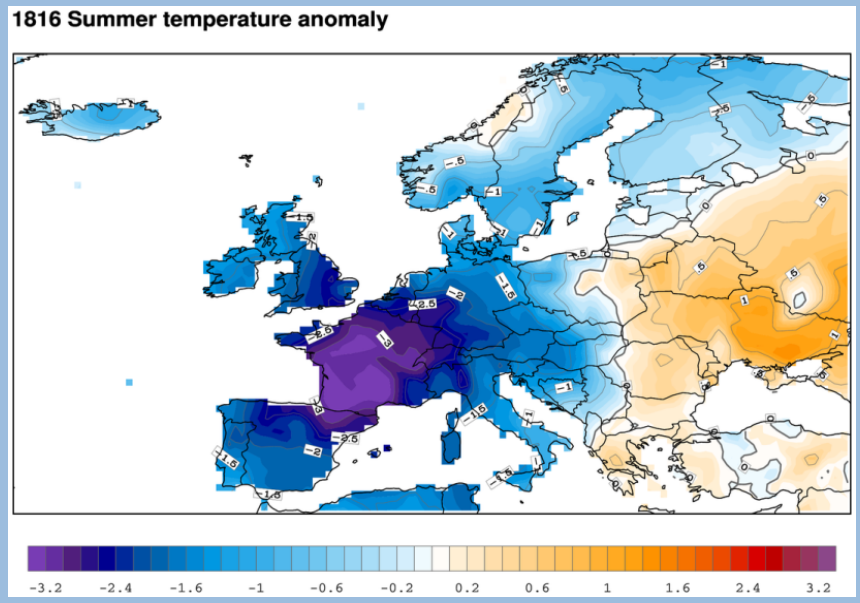
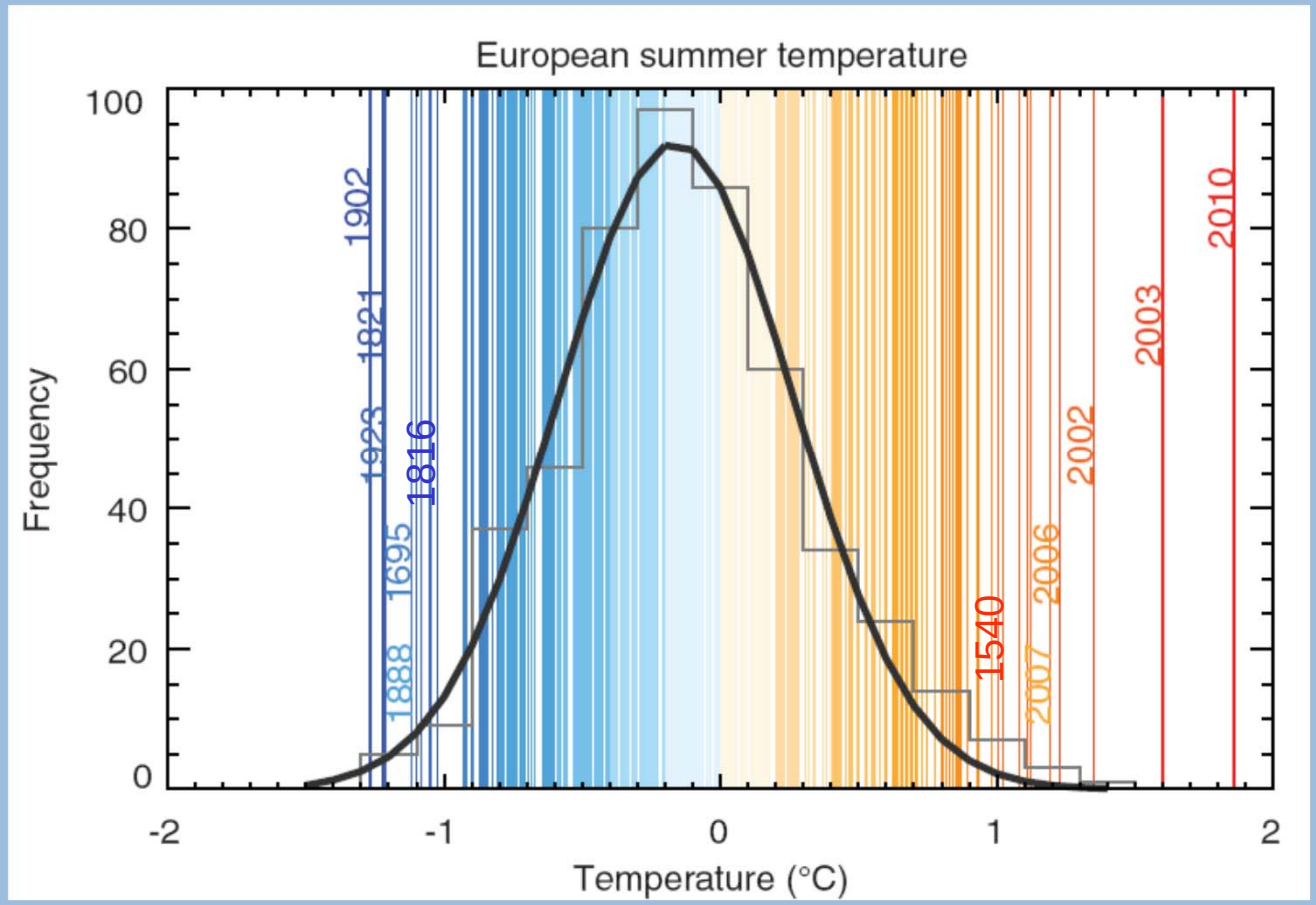




→ Spatial pattern of multi-model volcanic fingerprint can be detected in the first 2 summers
→ Similar temperature anomalies as for reconstructions
→ Significant summer cooling after volcanoes, strongly expressed 1816 after Tambora

Fischer, Luterbacher et al. 2007; Hegerl, Luterbacher et al. 2011

European summer mean temperature distribution



Barriopedro, Luterbacher et al. 2011

Summer temperature anomalies 2003 and 2010 (wrt 1961-1990) and 'preconditions'

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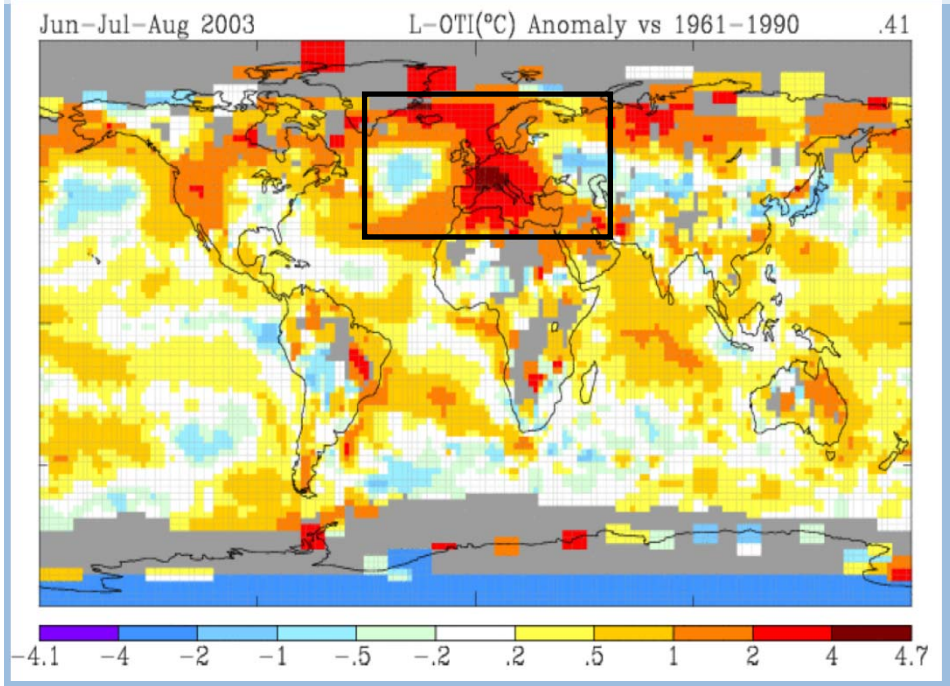

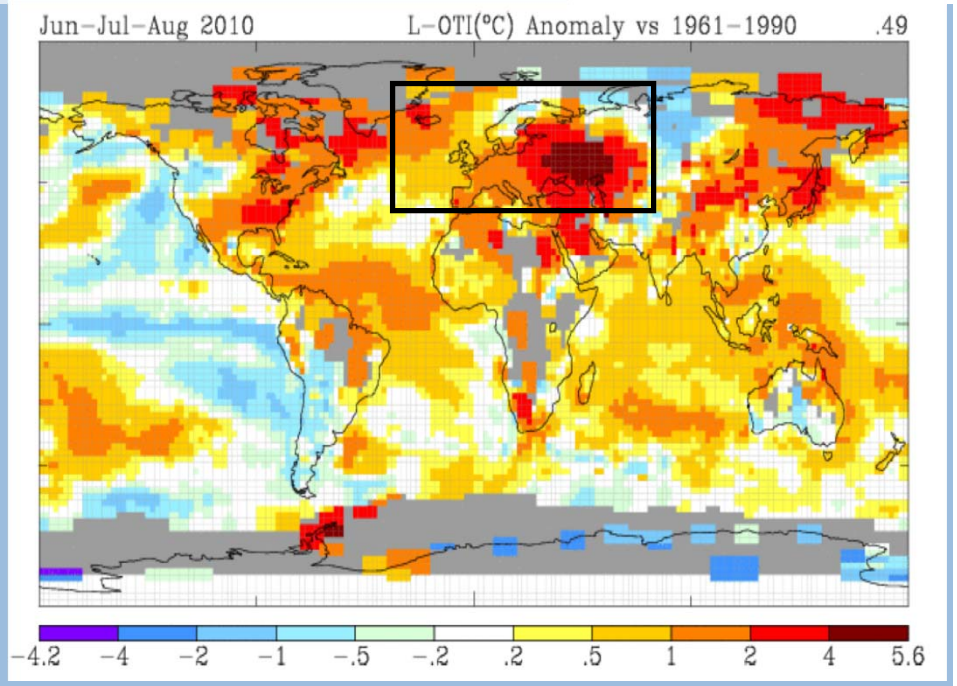

→ Extremly dry in spring and early snow melting period in the Arctic
→ strong and fast drying of the soil
→ persistent Omega-situations, subsidence, weak winds and/or warm air advection, strong insolation and reduced latent heat flow (no moisture); downstream floodings in Pakistan

GISS/NASA; Barriopedro et al. 2011

Balance after the hot summers of 2003 and 2010

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2003

- >70000 heat related death
- Actual total loss: 1300 Mio USD
- Large crop yield loss and shortage of animal feed in widespread Europe
- Widespread forest fires
- High fish mortality in central Europe
- Heat, drought, ozone and fine dust pollution led to health problems
- Problems with energy supply
- Record melting of Alpine glaciers Volume loss of 10 %

2010

- >55000 heat related death
- Actual total loss: 3600 Mio USD
- 25% less crop yield in W Russia
- Widespread forest fires in western Russia
- 2500 destroyed houses
- Heat, drought, ozone and fine dust pollution led to health problems
- Problems with energy supply

(Münchener Re Insurance, 2011; Emergency Control Ministry of Russia)

Possible explanations for the exceptional heat summers of 2003 and 2010

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- **Controversial discussions**
- Stott et al. (2004, Nature) → '*human influence on climate has doubled the risk of such an event*'
- Dole et al. (2011, GRL): 2010 Heatwave was "*mainly natural in origin*"
- Rahmstorf und Coumou (2011, PNAS): 2010 heatwave: "*with a probability of 80% "the 2010 July heat record would not have occurred" without the large-scale climate warming since 1980, most of which has been attributed to the anthropogenic increase in greenhouse gas concentrations*
- Otto et al. (2012, GRL): based on ensemble experiments, both is possible, depending on the research question

Conclusions

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- Europe offers a broad spectrum of different proxy information to reconstruct past climate
- European summers were warm during Roman & Medieval times. Cooler summers were experienced 14th-19th centuries
- The current warmth and warming trend are unusual, but not unprecedented in the context of natural climate variability over the past two millennia
- 2003 & 2010 are unusual, but not unprecedented (± 1K uncertainties) → 1540, a disaster beyond all expectations
- Good agreement between reconstructions and palaeo models → Evidence for a better agreement with the palaeo model ensemble using strong total solar irradiance
- Tropical volcanism trigger changes in dynamics, summer cooling 1 and 2 years after the eruption ('year without a summer')