The Abdus Salam
International Centre for Theoretical Physics

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IAEA

2165-4

International MedCLIVAR-ICTP-ENEA Summer School on the Mediterranean Climate System and Regional Climate Change

13 - 22 September 2010

Paleo: Mediterranean paleoclimate evidence. Sources and reconstructions

XOPLAKI Elena

Cyprus Meteorological Service
L. Nikis 28, 1086 Lefkosia
Lefkosia
CYPRUS

Mediterranean paleoclimate evidence
Sources and reconstructions

Elena Xoplaki

University of Bern & The Cyprus Institute
elena.xoplaki@giub.unibe.ch

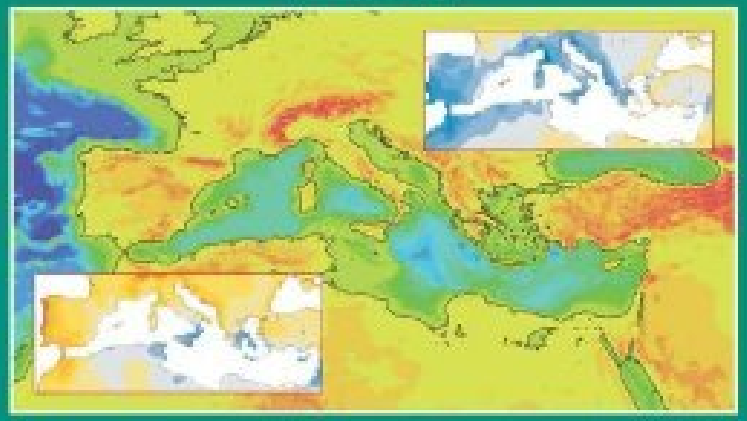
MedCLIVAR

Mediterranean Climate Variability

DEVELOPMENTS IN EARTH & ENVIRONMENTAL SCIENCES 4

MEDITERRANEAN CLIMATE VARIABILITY

P. LIONELLO, P. MALANOTTE-RIZZOLI AND R. BOSCOLO (EDITORS)



Mediterranean climate variability, 2006

Chapter 1

Mediterranean Climate Variability Over the Last Centuries: A Review

Jürg Luterbacher,[1] Elena Xoplaki,[1] Carlo Casty,[1] Heinz Wanner,[1] Andreas Pauling,[2] Marcel Küttel,[2] This Rutishauser,[2] Stefan Brönnimann,[3] Erich Fischer,[3] Dominik Fleitmann,[4] Fidel J. González-Rouco,[5] Ricardo García-Herrera,[5] Mariano Barriendos,[6] Fernando Rodrigo,[7] Jose Carlos Gonzalez-Hidalgo,[8] Miguel Angel Saz,[8] Luis Gimeno,[9] Pedro Ribera,[10] Manola Brunet,[11] Heiko Paeth,[12] Norel Rimbu,[13] Thomas Felis,[14] Jucundus Jacobeit,[15] Armin Dünkeloh,[16] Eduardo Zorita,[17] Joel Guiot,[18] Murat Türkes,[19] Maria Joao Alcoforado,[20] Ricardo Trigo,[21] Dennis Wheeler,[22] Simon Tett,[23] Michael E. Mann,[24] Ramzi Touchan,[25] Drew T. Shindell,[26] Sergio Silenzi,[27] Paolo Montagna,[27] Dario Camuffo,[28] Annarita Mariotti,[29] Teresa Nanni,[30] Michele Brunetti,[30] Maurizio Maugeri,[31] Christos Zerefos,[32] Simona De Zolt,[33] Piero Lionello,[33] M. Fatima Nunes,[34] Volker Rath,[35] Hugo Beltrami,[36] Emmanuel Garnier[37] and Emmanuel Le Roy Ladurie[38]

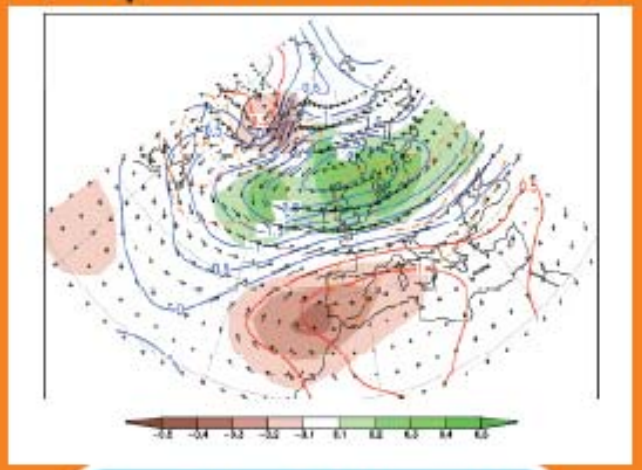
Symposium on

Climate Extremes
During Recent Millennia
and
their Impact on
Mediterranean Societies

13-16 September 2008
Athens Greece

Symposium

"Climate Extremes During Recent Millennia and their Impact on Mediterranean Societies"



National and Kapodistrian University of Athens
"Kostis Palamas" Building
Akadimias 48 & Sina, Athens
13–16 September 2008

Hosts

Organizers

Elena Xoplaki
University of Bern, Switzerland

Jürg Luterbacher
University of Bern, Switzerland

Ray Bradley
University of Massachusetts, USA

Henry Diaz
NOAA/ESRL, Boulder, USA

Malcolm Hughes
University of Arizona, USA

Thorsten Kiefer
PAGES, Bern, Switzerland

Ricardo García-Herrera
University Complutense, Madrid, Spain

Ercan Kahya
Istanbul Technical University, Turkey

Phil Jones
Climatic Research Unit, UK

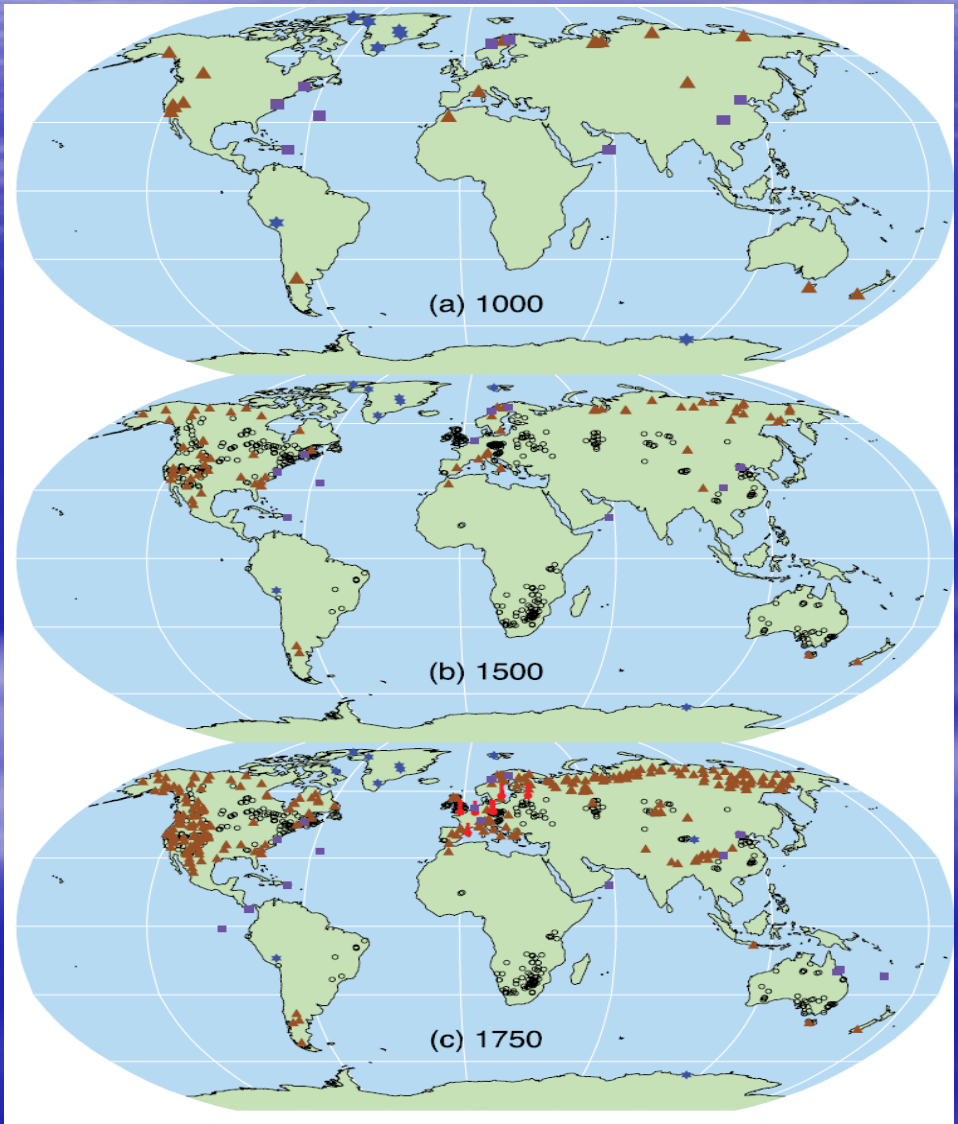
Christos Zerefos *Academy of Athens, University of Athens, Greece*

Types of climatic evidence

	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

Spatial distribution of proxies 1000, 1500 and 1750



- Measurements
- Tree ring information
- Borehole
- Ice
- Other proxies

Jansen et al., 2007, IPCC

Outline

- Natural proxies
- Documentary proxies
- Use and application of proxy information for the study of the Mediterranean past climate
- Conclusions

Natural proxies in the Mediterranean

Red Sea corals

High resolved proxy for temperature, aridity, SSTs

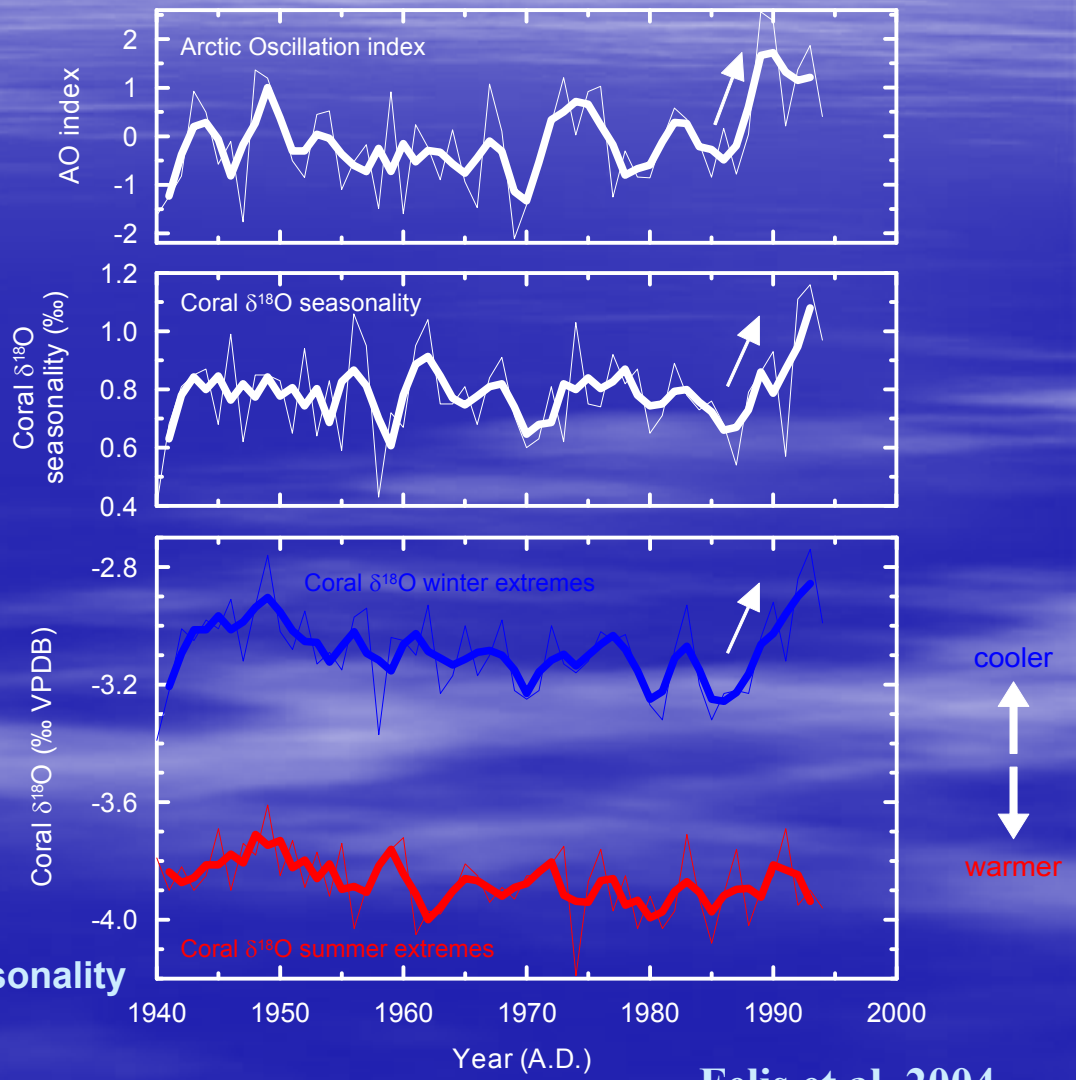
Thomas Felis

Red Sea corals

Modern reef (Gulf of Aqaba, northernmost Red Sea)

Thomas Felis

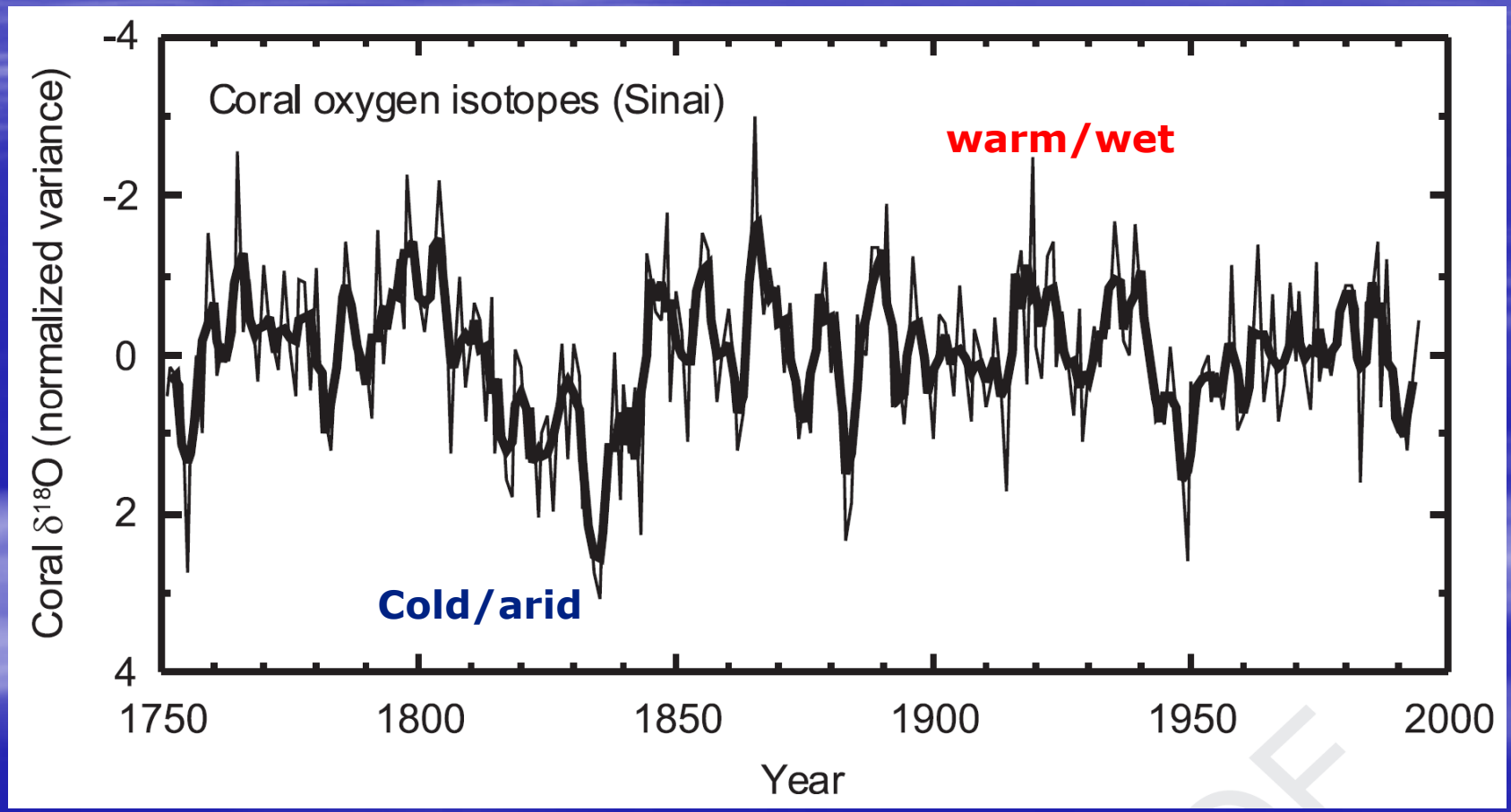
AO/NAO and coral d18O seasonality (northernmost Red Sea)



- **AO/NAO controls northernmost Red Sea seasonality through its control on winter temperatures**

Felis et al. 2004

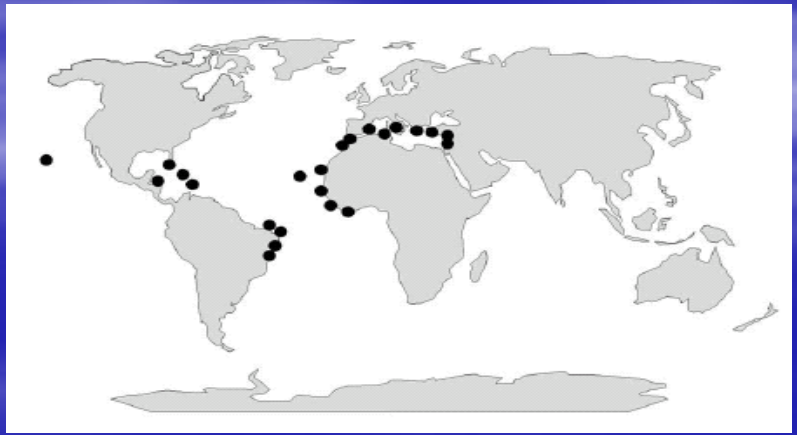
Corals in Red Sea



Felis et al. 2000

Vermetids

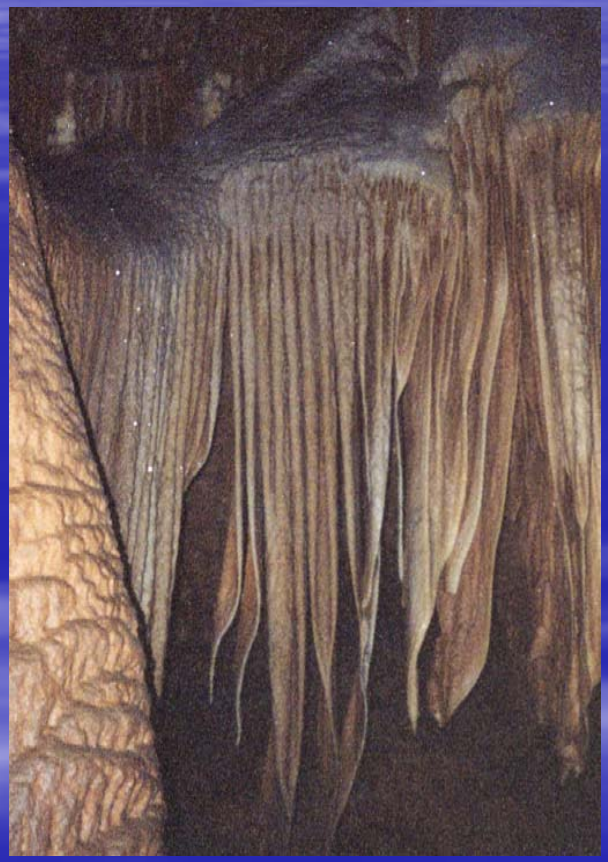
Non tropical corals, seasonal to multi-decadal proxy for sea-water chemistry, productivity, SSTs, sea level

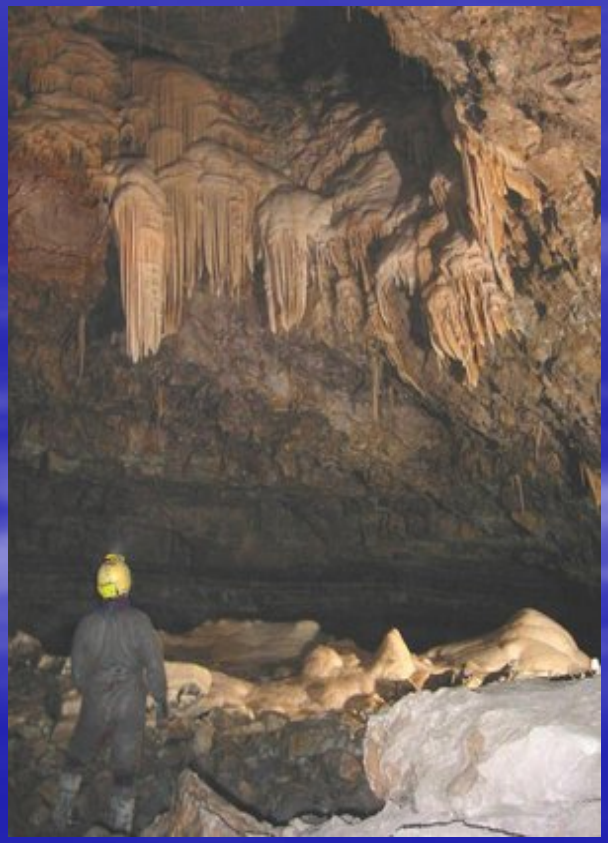


Silenzi et al. 2004
Montagna et al. 2006

Speleothems

Temperature or precipitation indicators of annual to decadal resolution





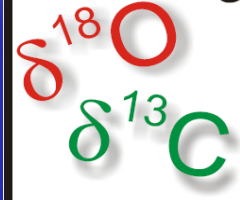
Central Alps, Italian Alps, Sardinia, Turkey, ...

Speleothem-based climate reconstructions

Dominik Fleitmann

Uranium Series Dating

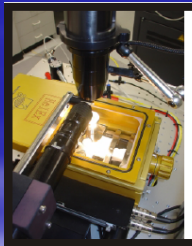
Back to ~400.000 kyr B.P. (Before Present)
Absolute ages
Small age uncertainties



Oxygen and carbon isotopes

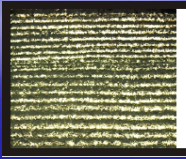
"Environmental isotopes"
Oxygen isotope ratios in speleothems directly reflect climate (e.g., Amount of rainfall)

Carbon isotope ratios often reflect the type of vegetation above the cave



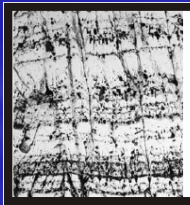
Trace Elements

Sub-monthly resolution possible
Mg, Na, K, Sr, Ba concentrations in speleothem calcite often reflect climate
S reflects atmospheric sulfur contents of the atmosphere



Annual Band Thickness

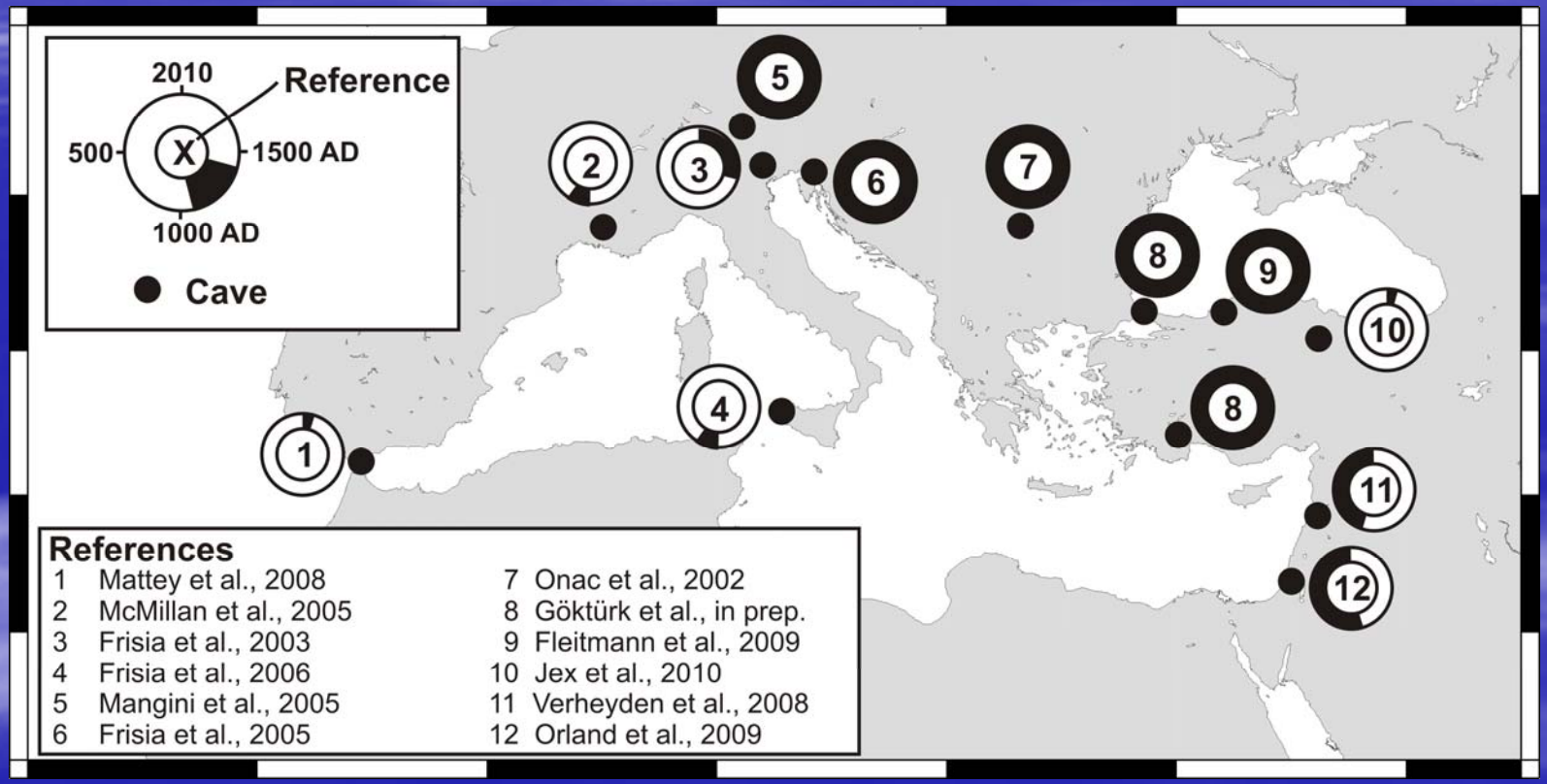
"Tree rings"
Thickness reflects amount of precipitation



Speleothem Fluid Inclusions

Trapped groundwater and precipitation
Noble gas concentrations and Hydrogen isotopic compositon.
Paleotemperatures & Atmospheric gas conc.

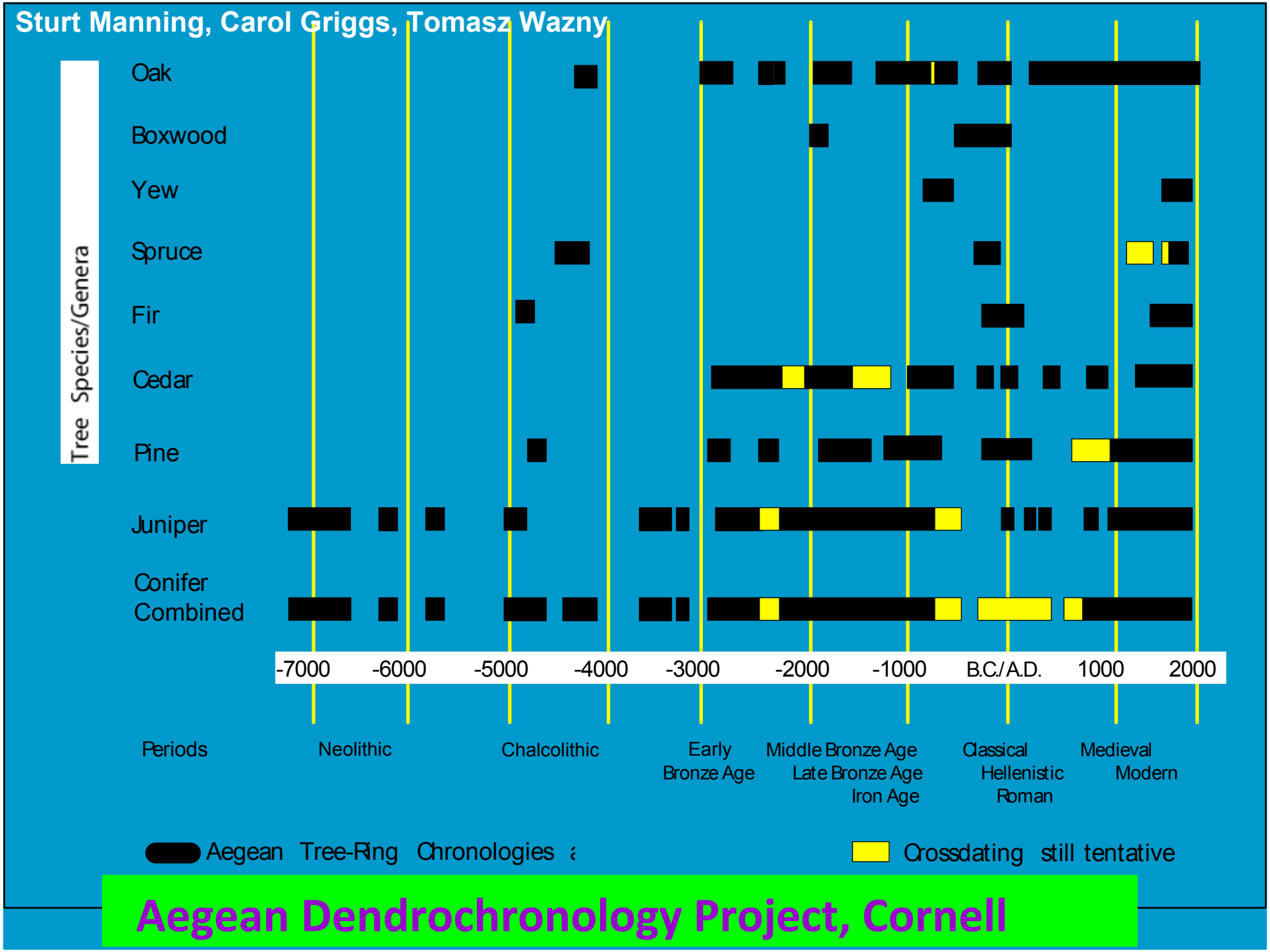
Speleothem-based climate reconstructions



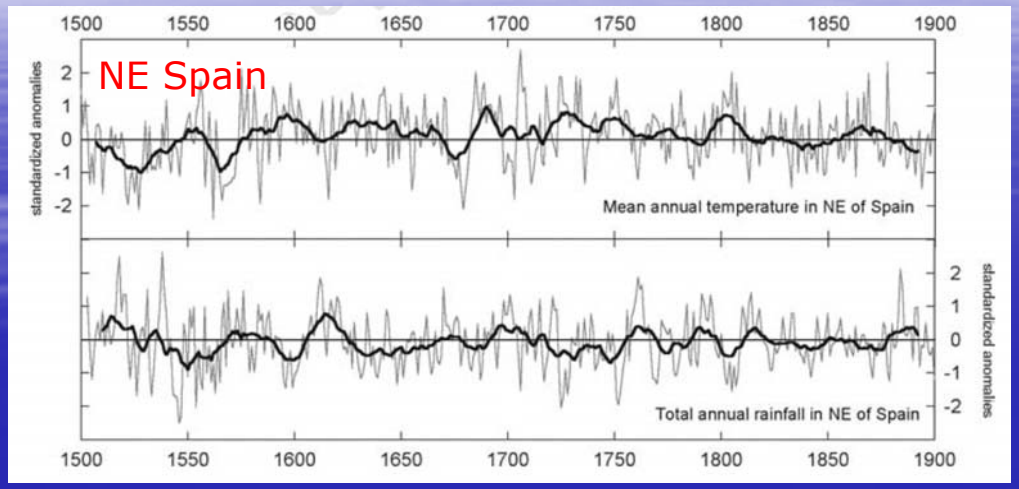
Dominik Fleitmann

Tree rings

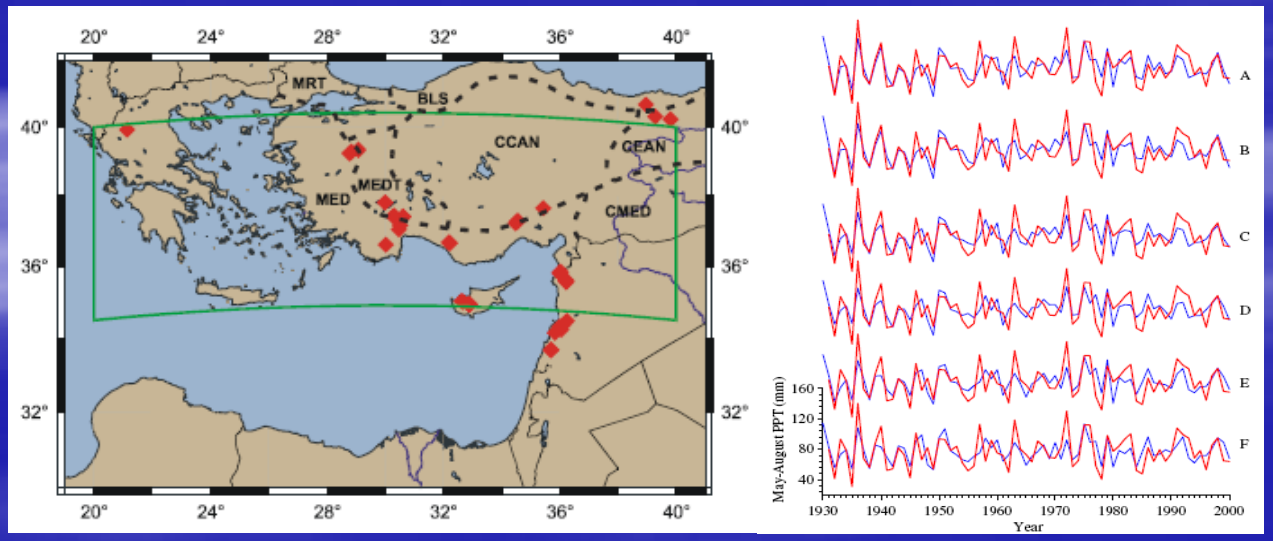
Tree rings provide information on summer temperature (Scandinavia / Alps) or precipitation (Mediterranean)


Sturt Manning, Carol Griggs, Tomasz Wazny
Tree Species/Genera
Oak
Boxwood
Yew
Spruce
Fir
Cedar
Pine
Juniper
Conifer Combined
-7000
-6000
-5000
-4000
-3000
-2000
-1000
B.C./A.D.
1000
2000
Periods
Neolithic
Chalcolithic
Early Bronze Age
Middle Bronze Age
Late Bronze Age
Iron Age
Classical
Hellenistic
Roman
Medieval
Modern
Aegean Tree-Ring Chronologies
Crossdating still tentative
Aegean Dendrochronology Project, Cornell

Tree ring-based climate reconstructions

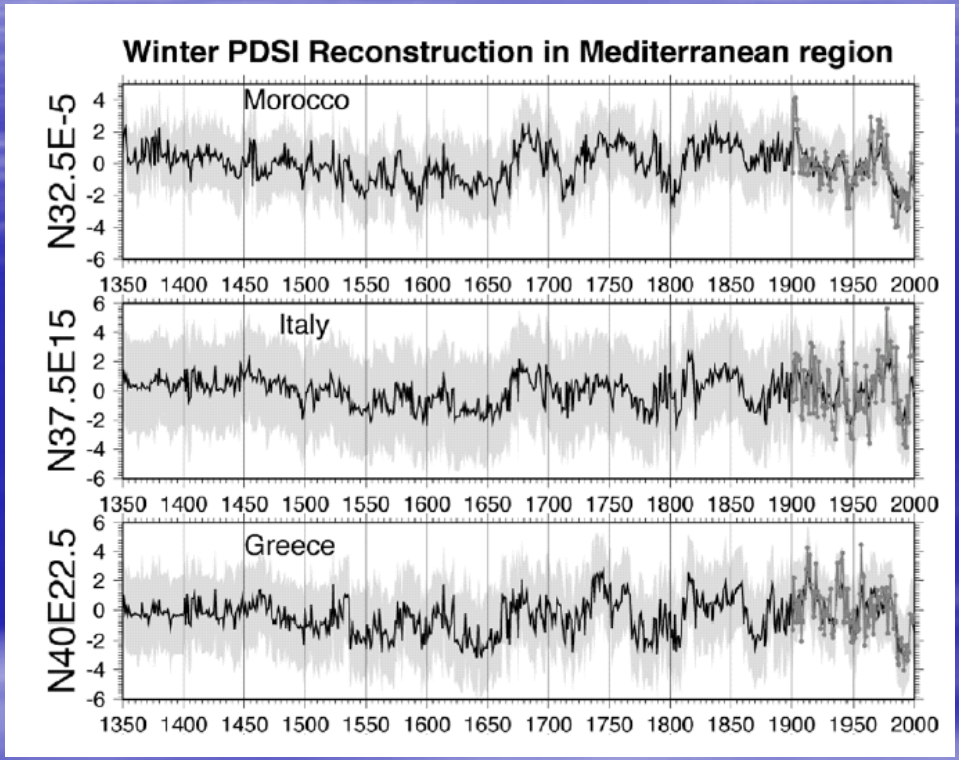


Saz 2004

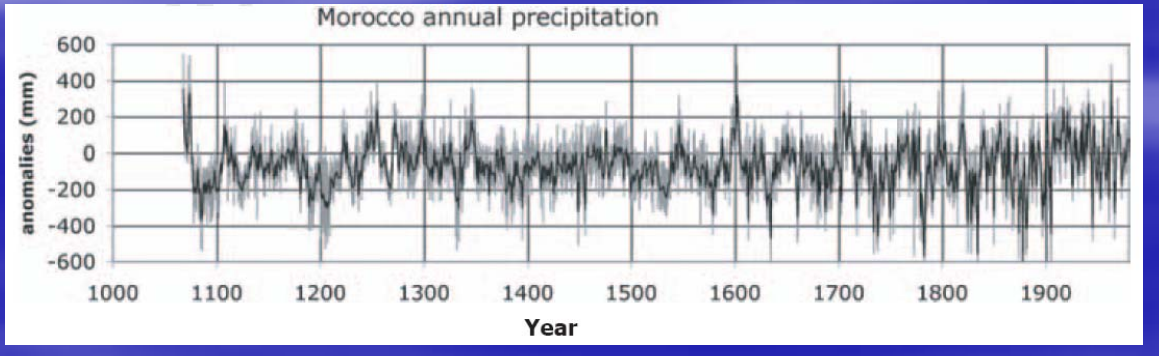


Touchan et al. 2005

Tree ring-based climate reconstructions

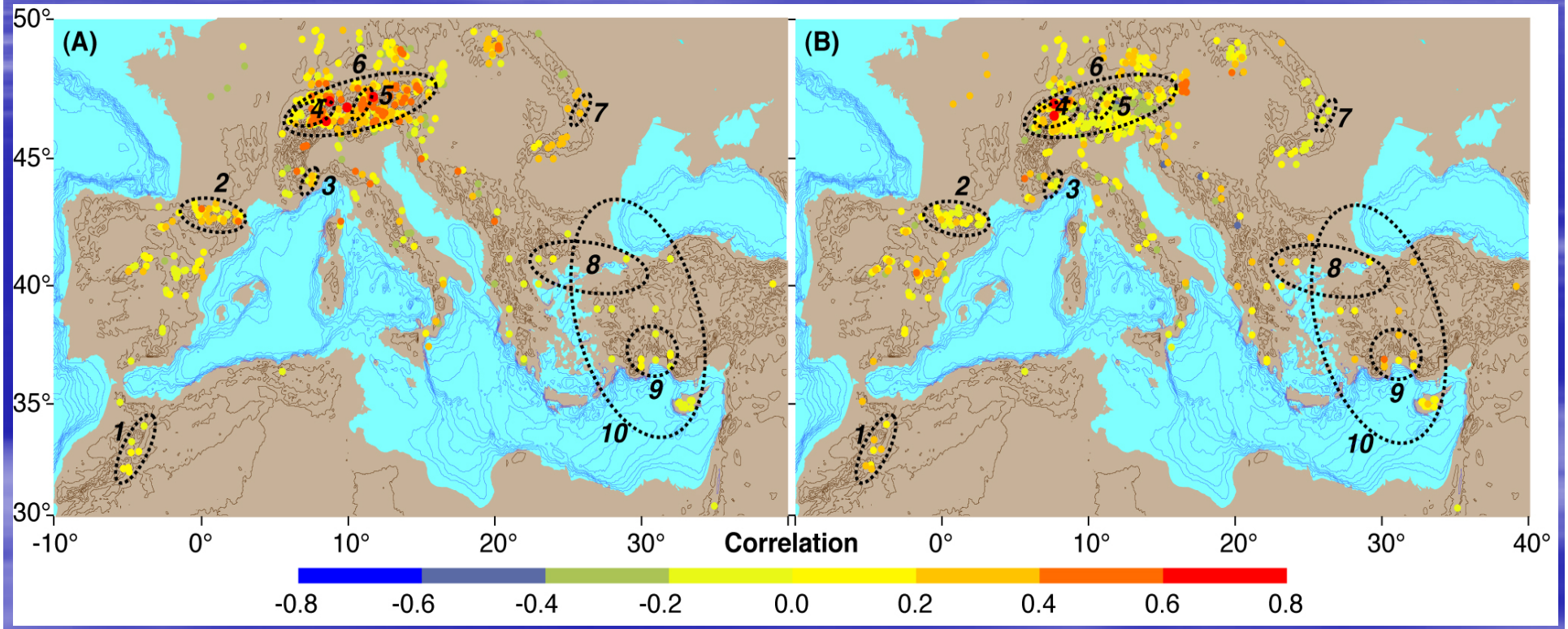


Guiot et al. 2005



Till and Guiot 1990

Spatial distribution of 847 tree ring width sites and correlation with JJA temperature (left) and precipitation (right)

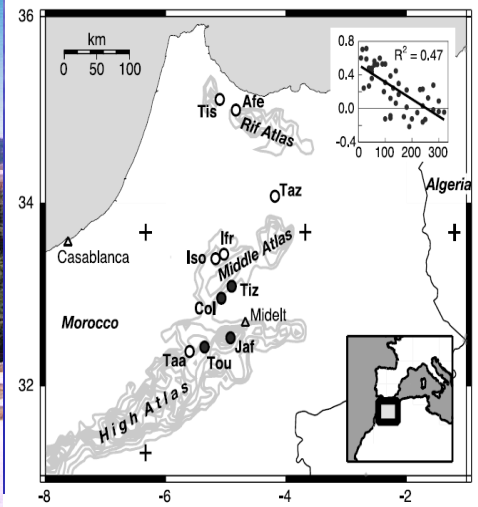


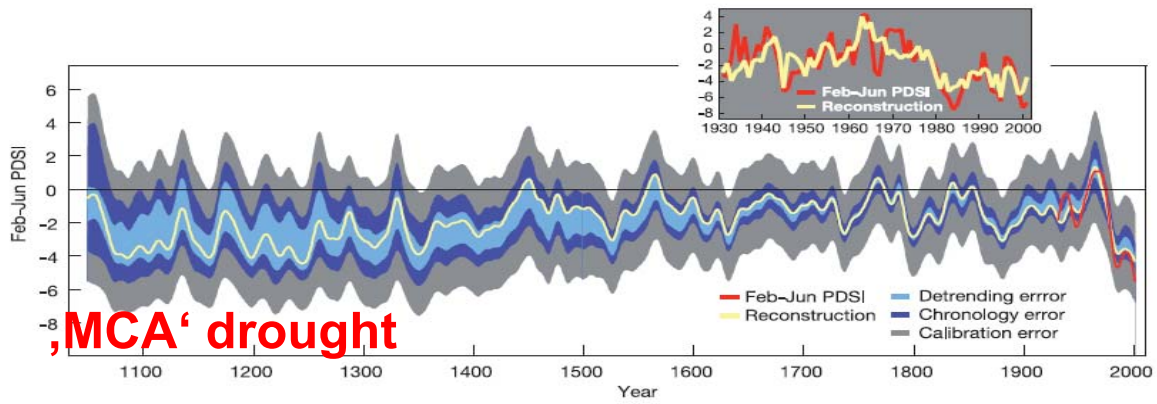
→ Pyrenees and Alpine sites reflect summer temperatures

→ Sites in the south reflect hydroclimatic evidence (seasonal dependent)

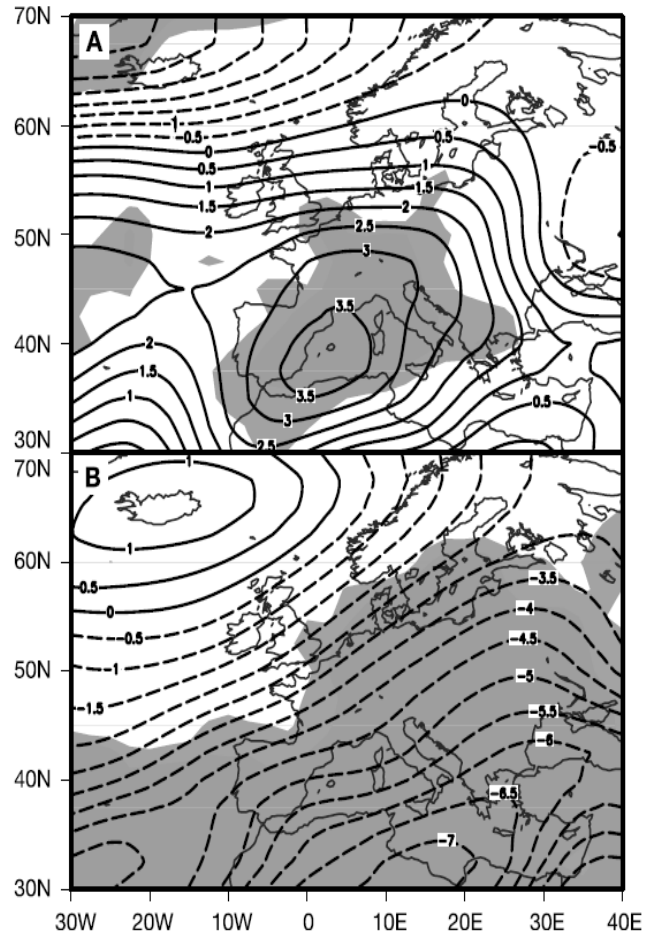
Luterbacher et al. 2011; Büntgen, pers. comm.

Drought reconstructions in Morocco based on Altas Cedar trees; drought during MCA



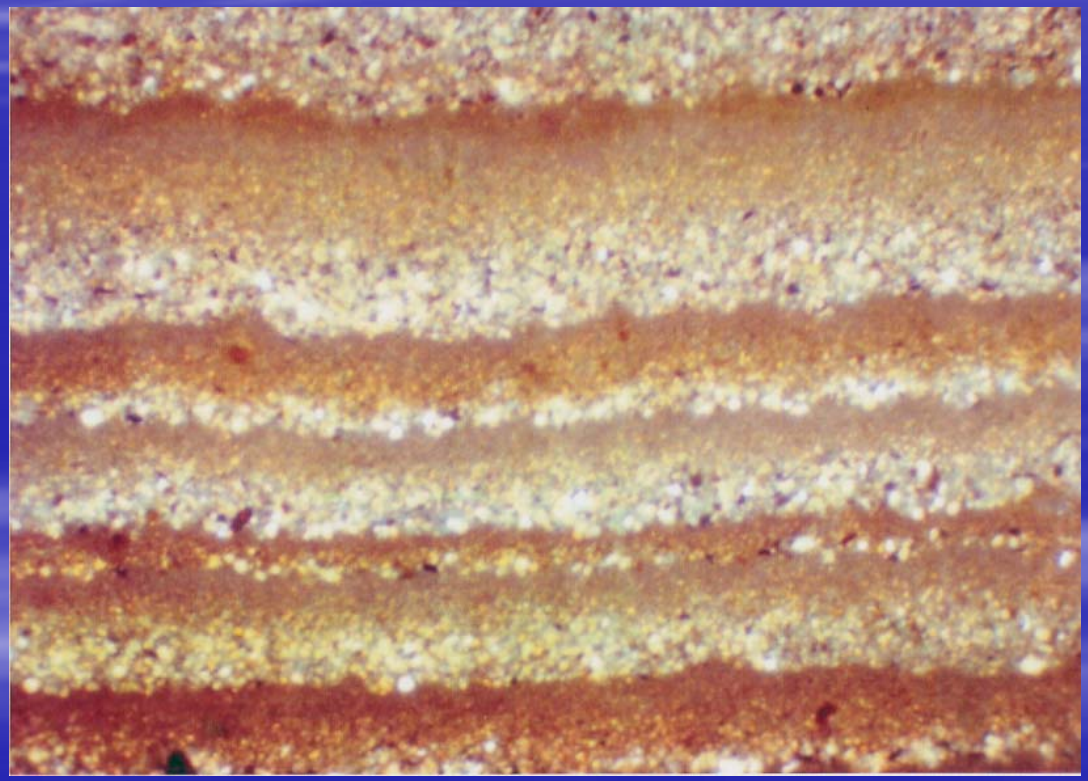


‚MCA' drought



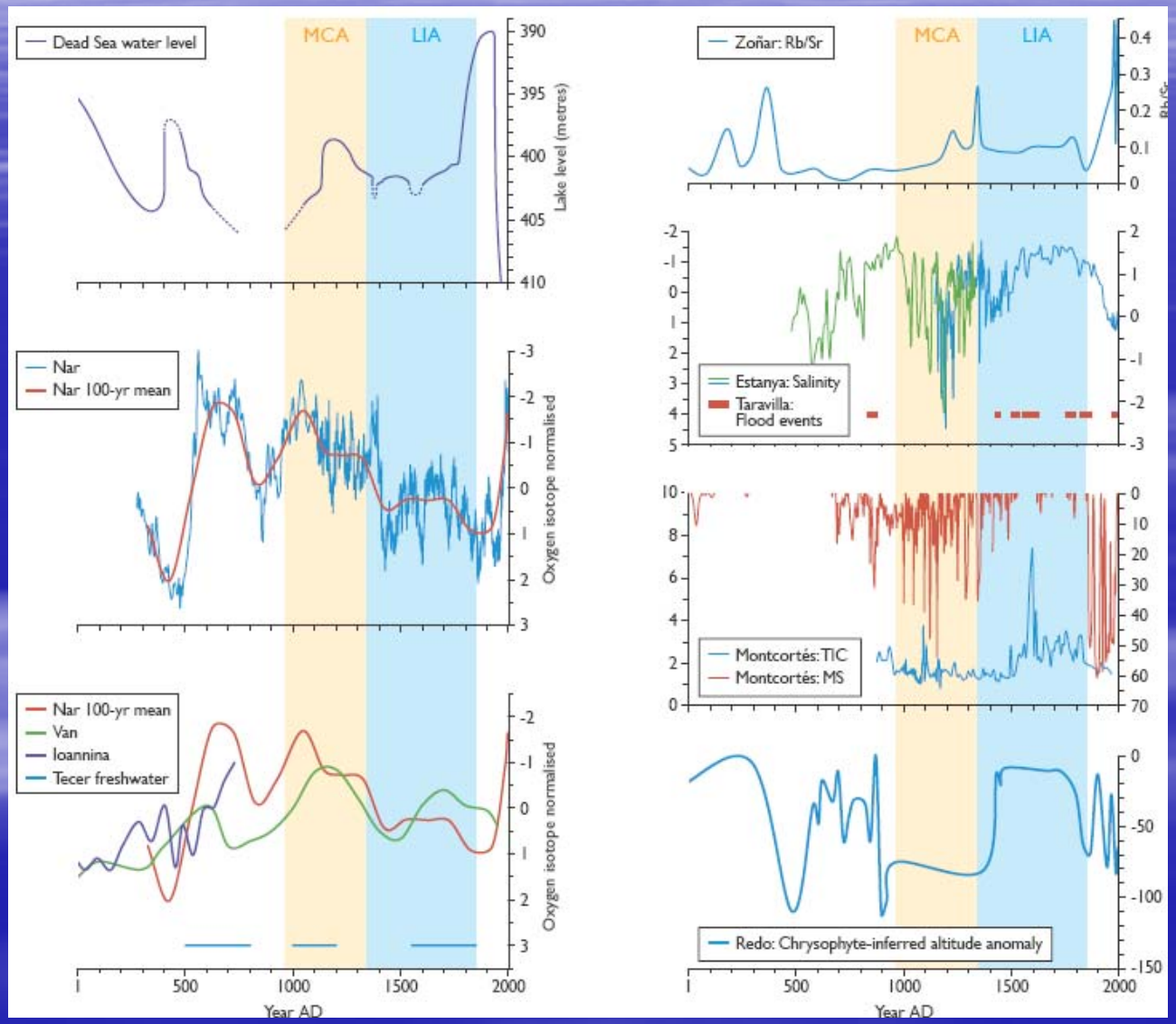
Esper, Luterbacher, Xoplaki et al. 2007

Varved sediments



Ray Bradley

Lake sediments from the Mediterranean

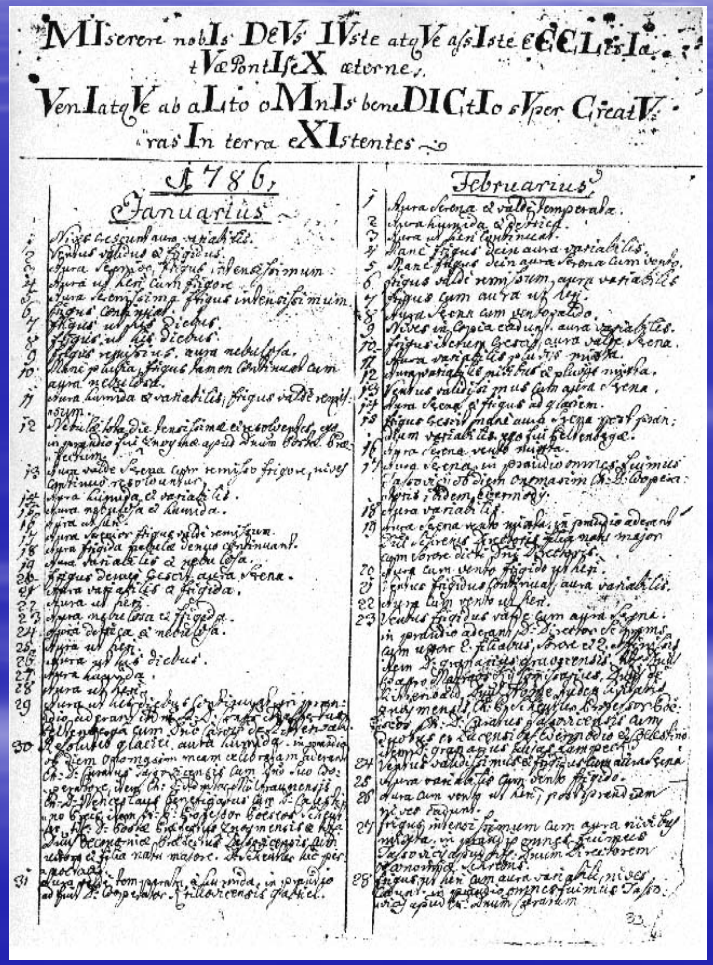


Tinner et al. in prep.


Documentary proxies in the Mediterranean

Documentary data to study past climate

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


MIserere nobIs DeVs IVste atqVe aVsIste eCCLesIa
tVæ PontIfeX æterne.
VenIatqVe ab aLto oMnIs bene DICtIo sVper CreatVras In terra eXIstentes.

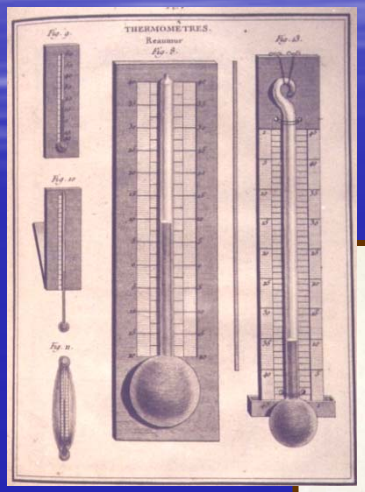
1786.

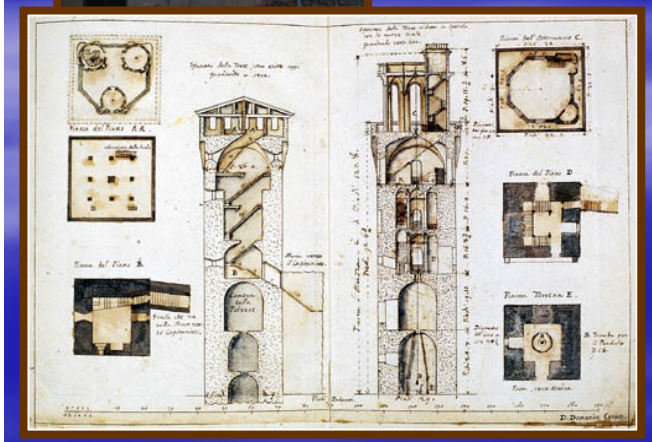
Januarius

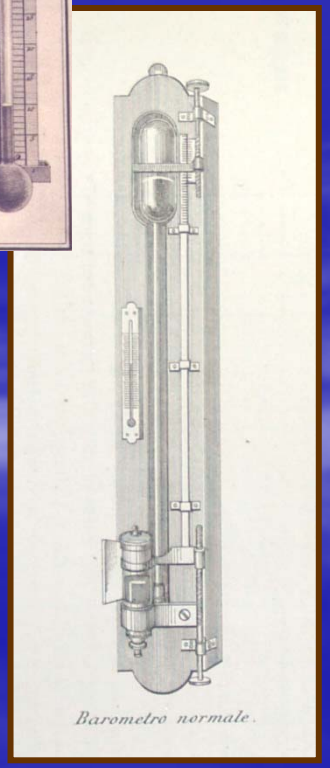
Februarius

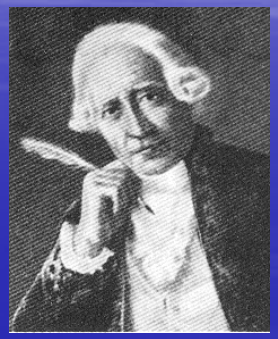
Pfister 1999, Brazdil et al. 2005

Documentary sources containing climate information





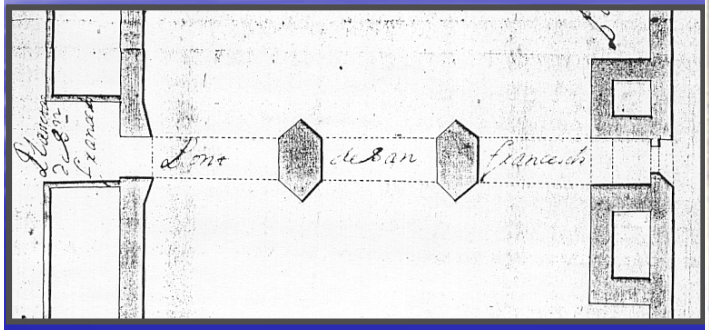




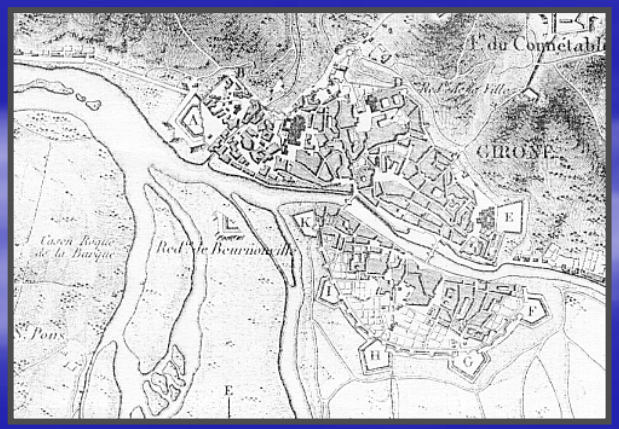
Earliest continuous diary dates in Spain: F. Salvà, Barcelona, January 1780

Barriendos, pers. comm.

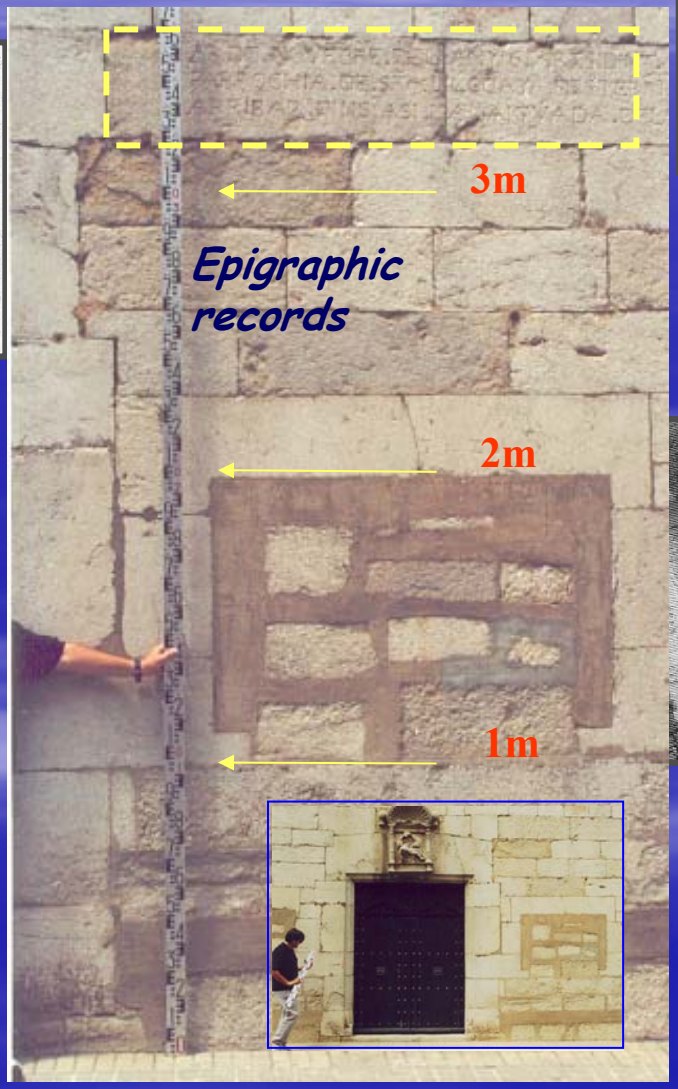
Other documentary sources



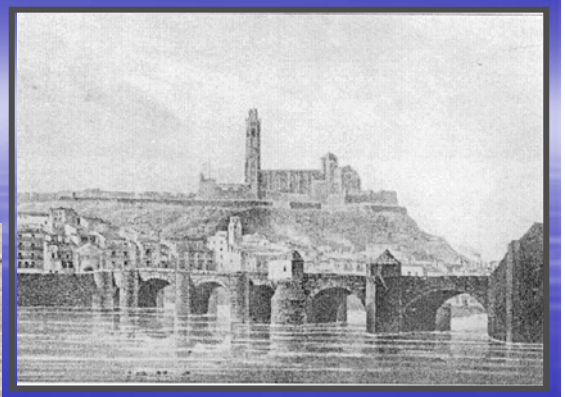
Files and plans of public works



Early cartography



Epigraphic records

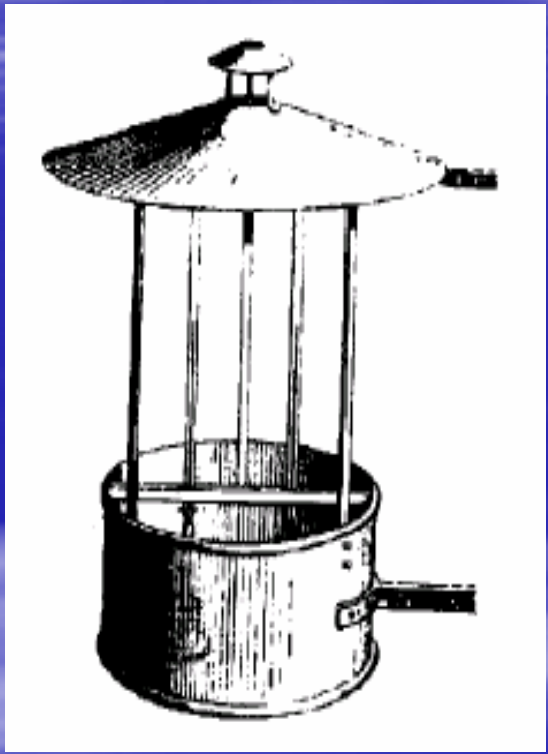


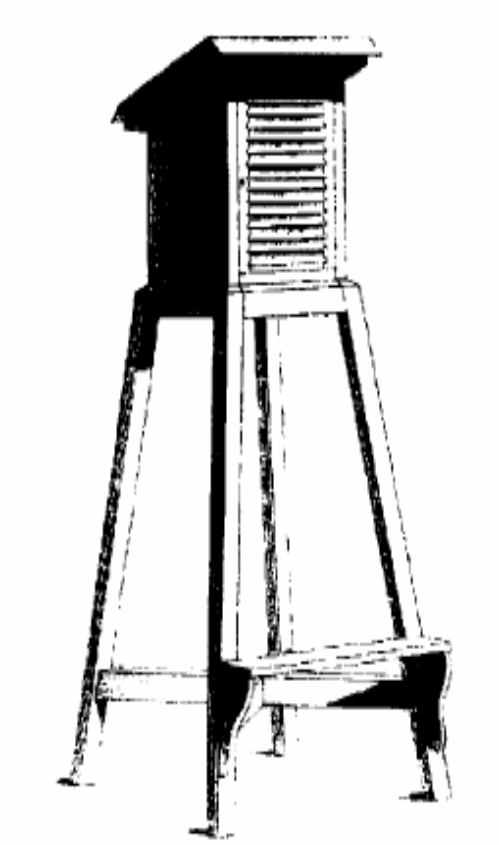
Old pictures

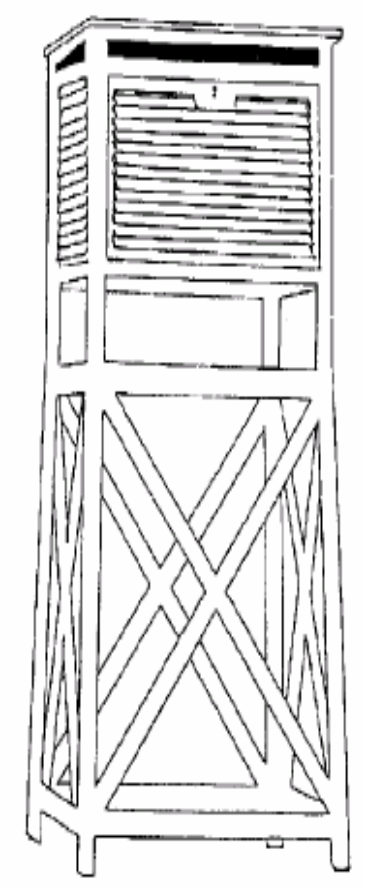
Early photography

Eduardo Rama

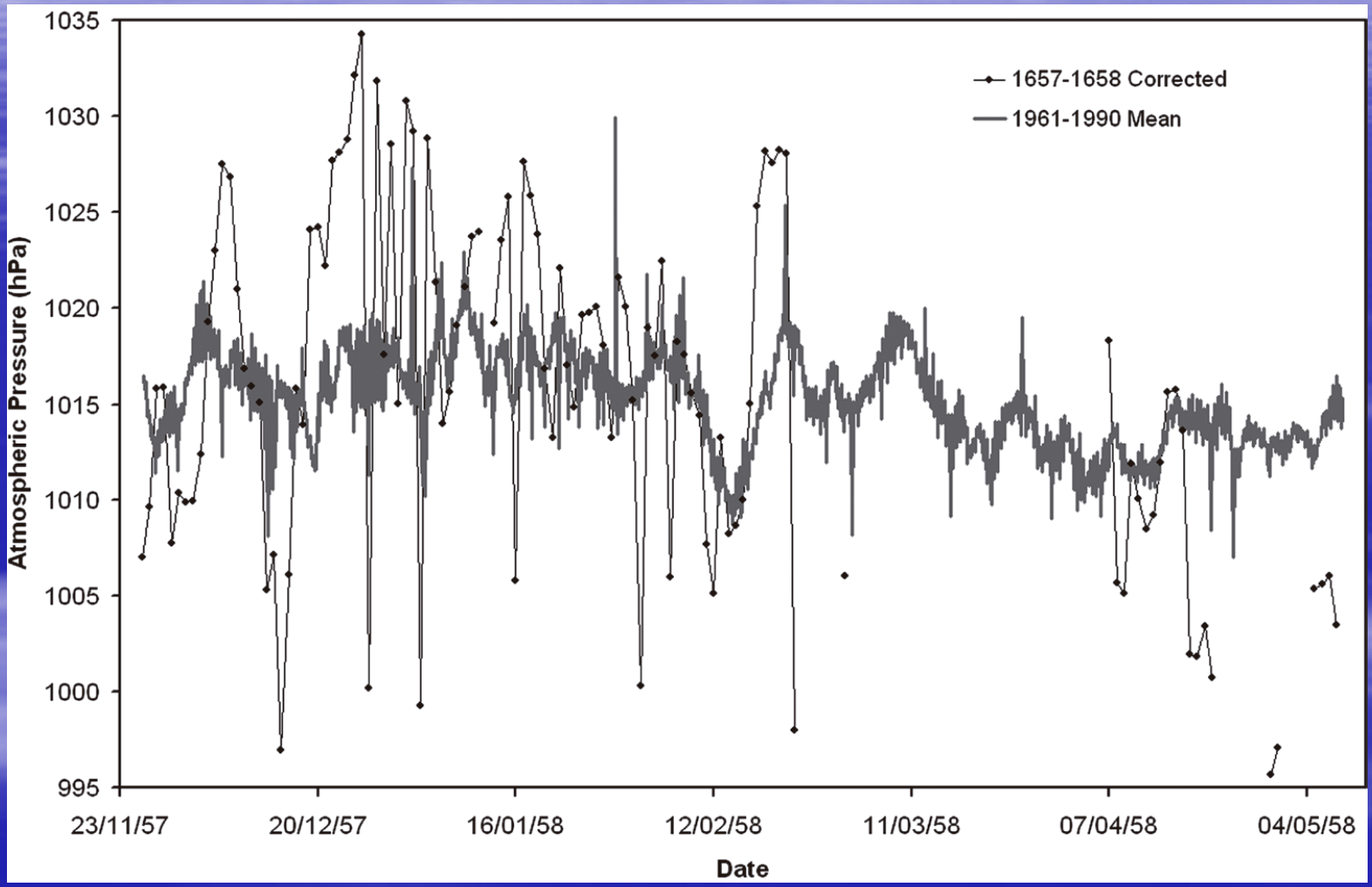
Early instruments





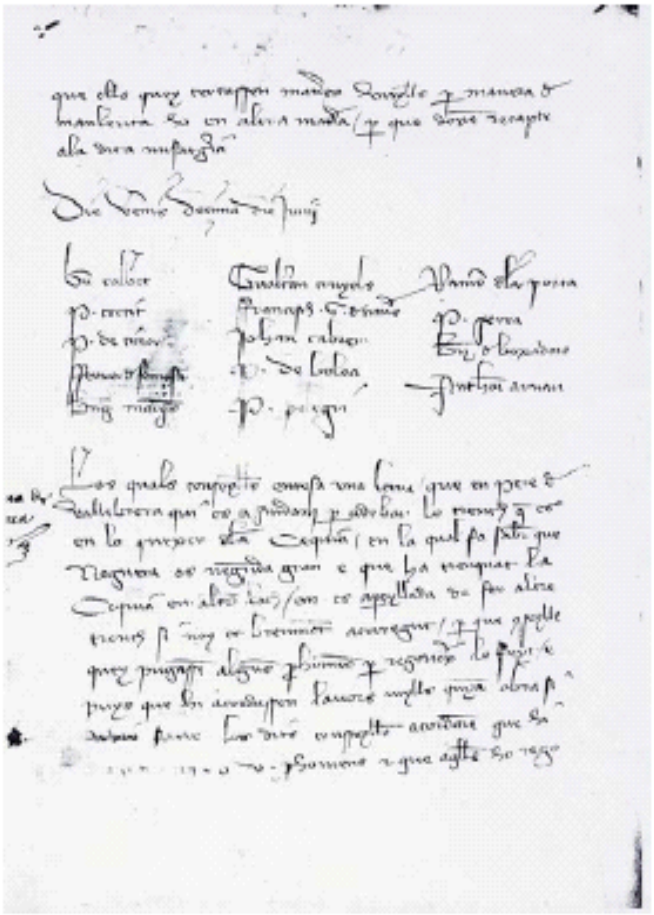


Pisa pressure; November 1657 - May 1658



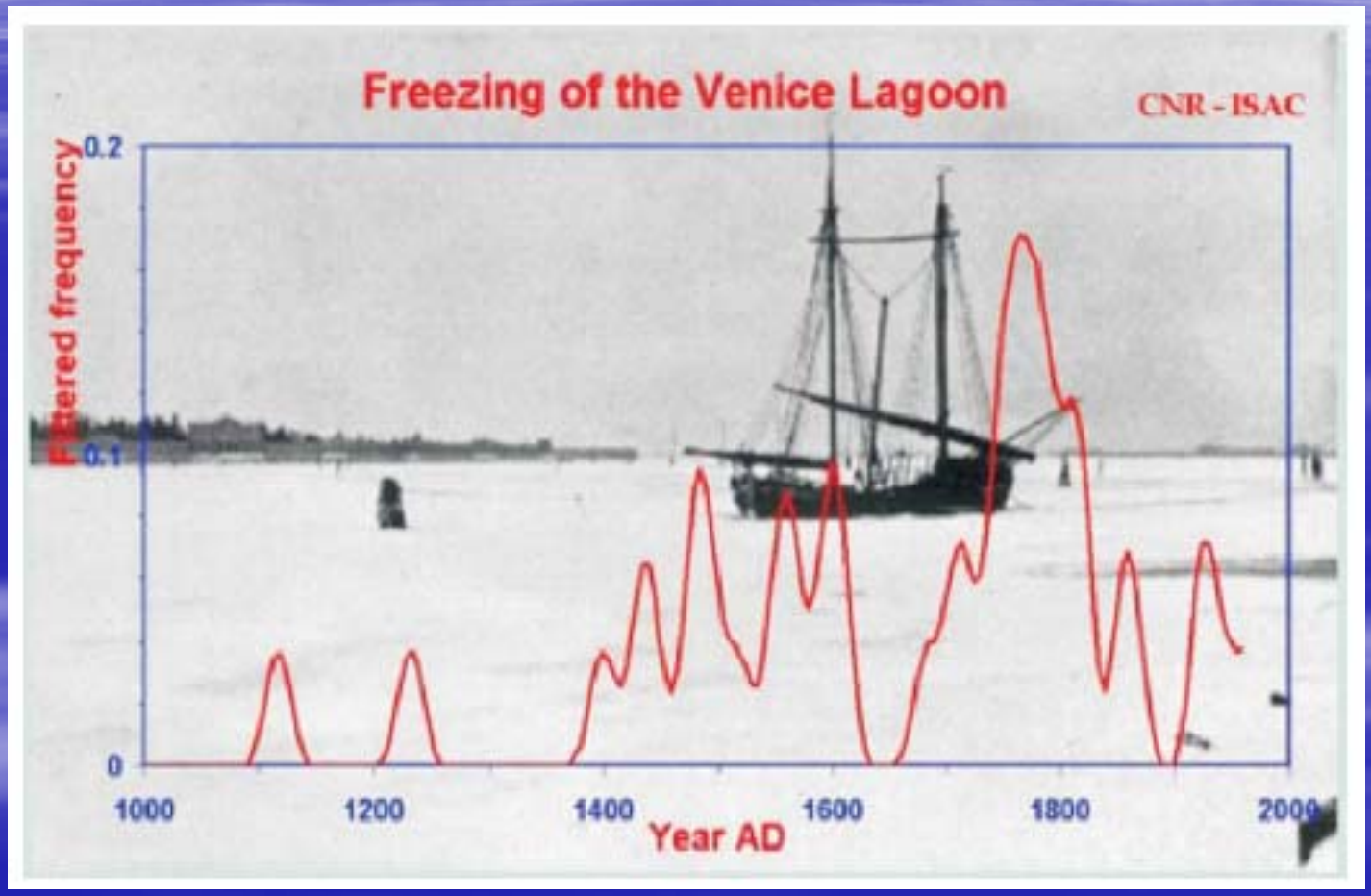
Camuffo et al. 2010

Damage report in irrigation Barcelona (left) & Barcelona flood 1862 (right)



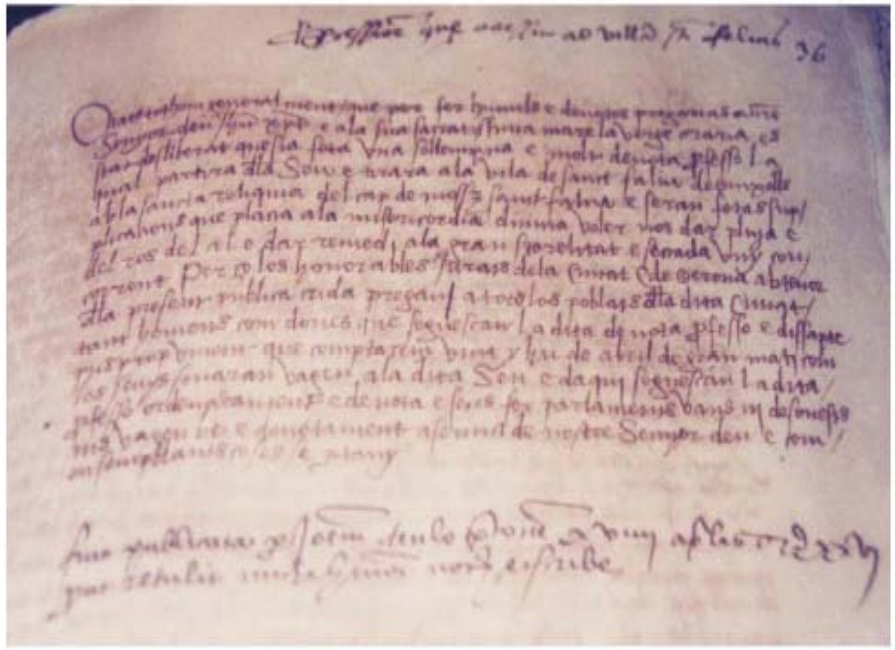
Luterbacher et al. 2006

1000-yr of the Venice lagoon freezing



Camuffo 1997

Rogation ceremony



Girona, April 1642 Saint Narcisus first bishop in Girona

Luterbacher et al. 2006

1907 – 2007, 100 years from the Segre flood

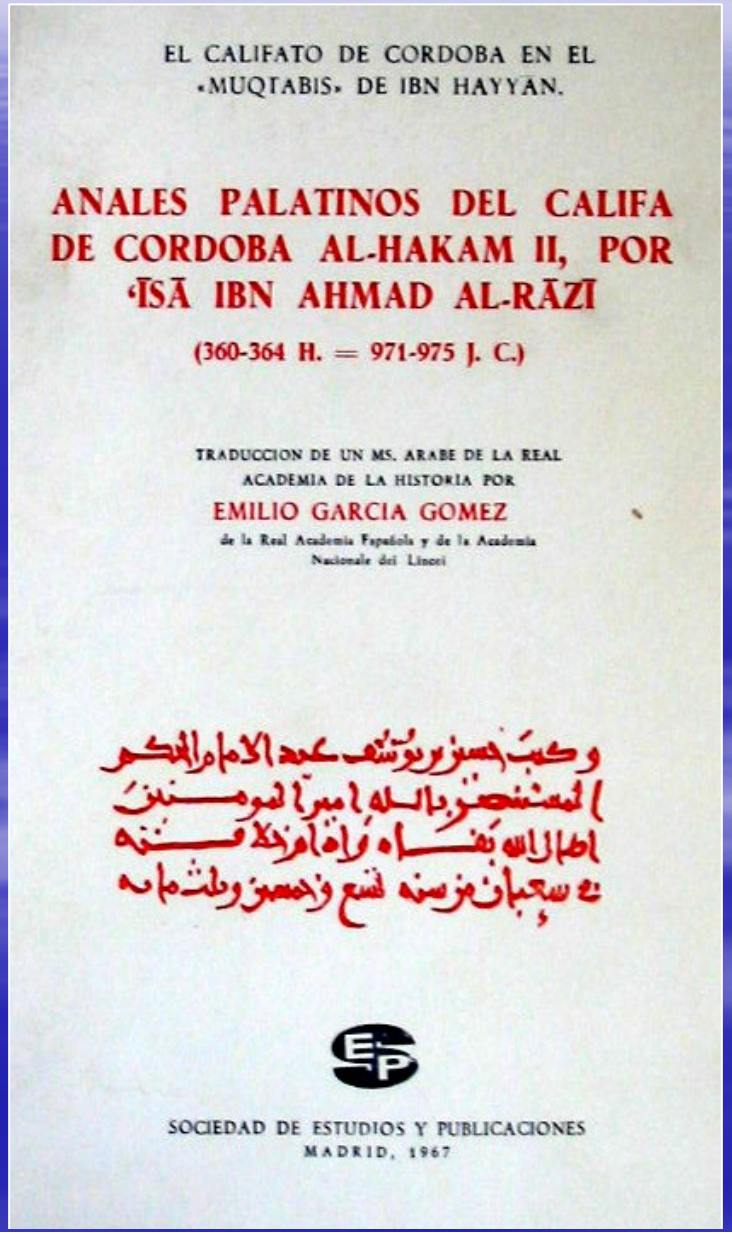
Barriendos, pers. comm.

Arabic chronicles

Annals “palatinos”

Different meteorological notices appear in the document written by the Arab historian Al-Razi narrating the most outstanding events of the caliphate of Cordoba in the period 971-975. The chronicles of al-Razi report numerous weatehr related events. The most important are those related to agriculture- heavy rains, storms, hurricane force winds, hail, and frost. Also cited are the floods of the River Guadalquivir because of their great social impact.

Jose Vaquero


EL CALIFATO DE CORDOBA EN EL
«MUQTABIS» DE IBN HAYYAN.

ANALES PALATINOS DEL CALIFA DE CORDOBA AL-HAKAM II, POR ʿĪSĀ IBN AHMAD AL-RĀZĪ

(360-364 H. = 971-975 J. C.)

TRADUCCION DE UN MS. ARABE DE LA REAL ACADEMIA DE LA HISTORIA POR

EMILIO GARCIA GOMEZ

de la Real Academia Española y de la Academia Nacional del Lincei

SOCIEDAD DE ESTUDIOS Y PUBLICACIONES
MADRID, 1967

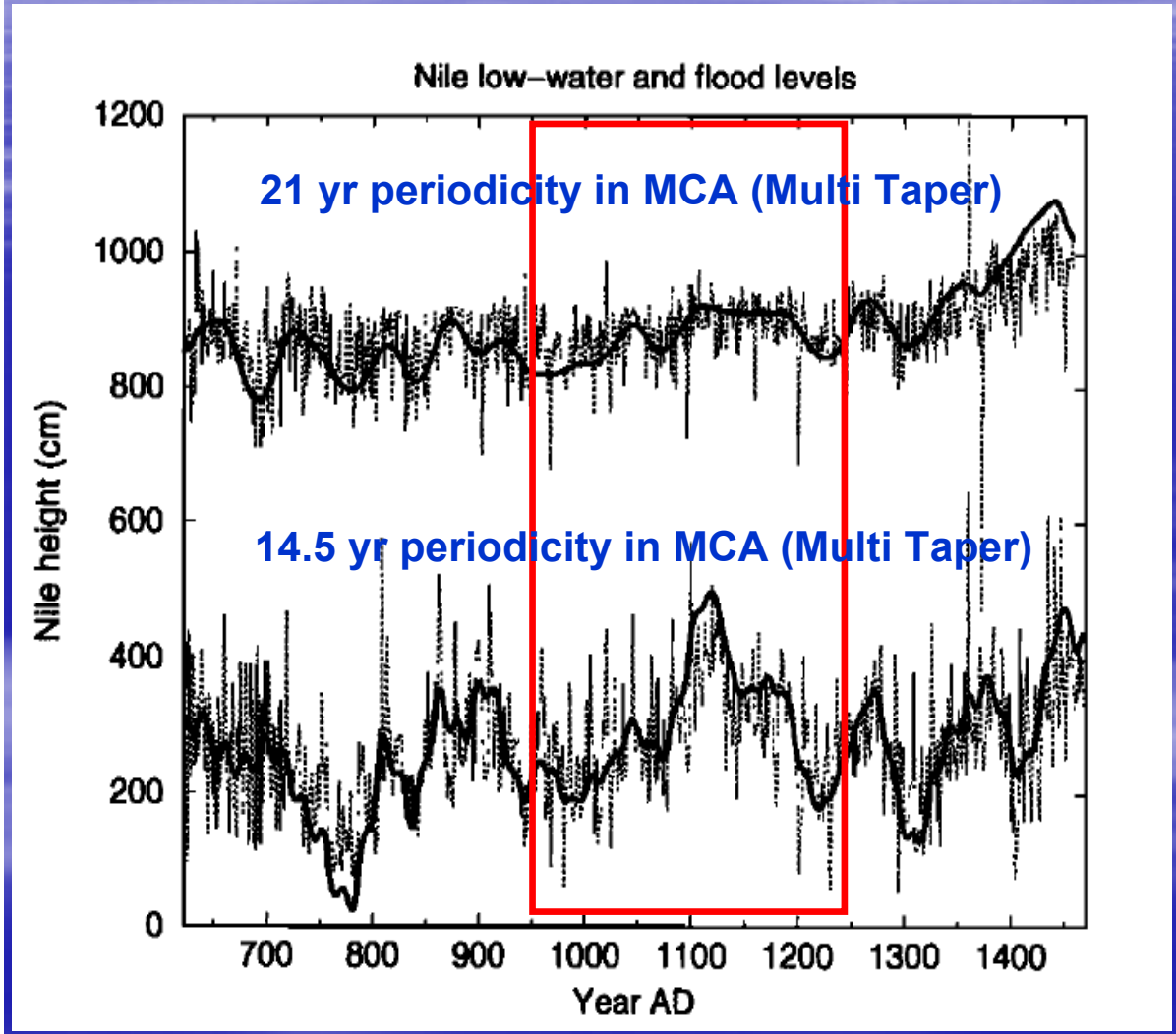
Nilometer
(instrument that measures the height of the Nile waters during its periodical flood)

Pharaonic and medieval Egypt depended solely on winter agriculture and hence on summer floods. The rise of the waters of the Nile was measured regularly from the earliest times.

compiled the annual maxima and minima of the water level recorded at nilometers, back to the 7th century.

Luigi Mayer, R. Brown
Historic Gallery, Pall Mall 1802

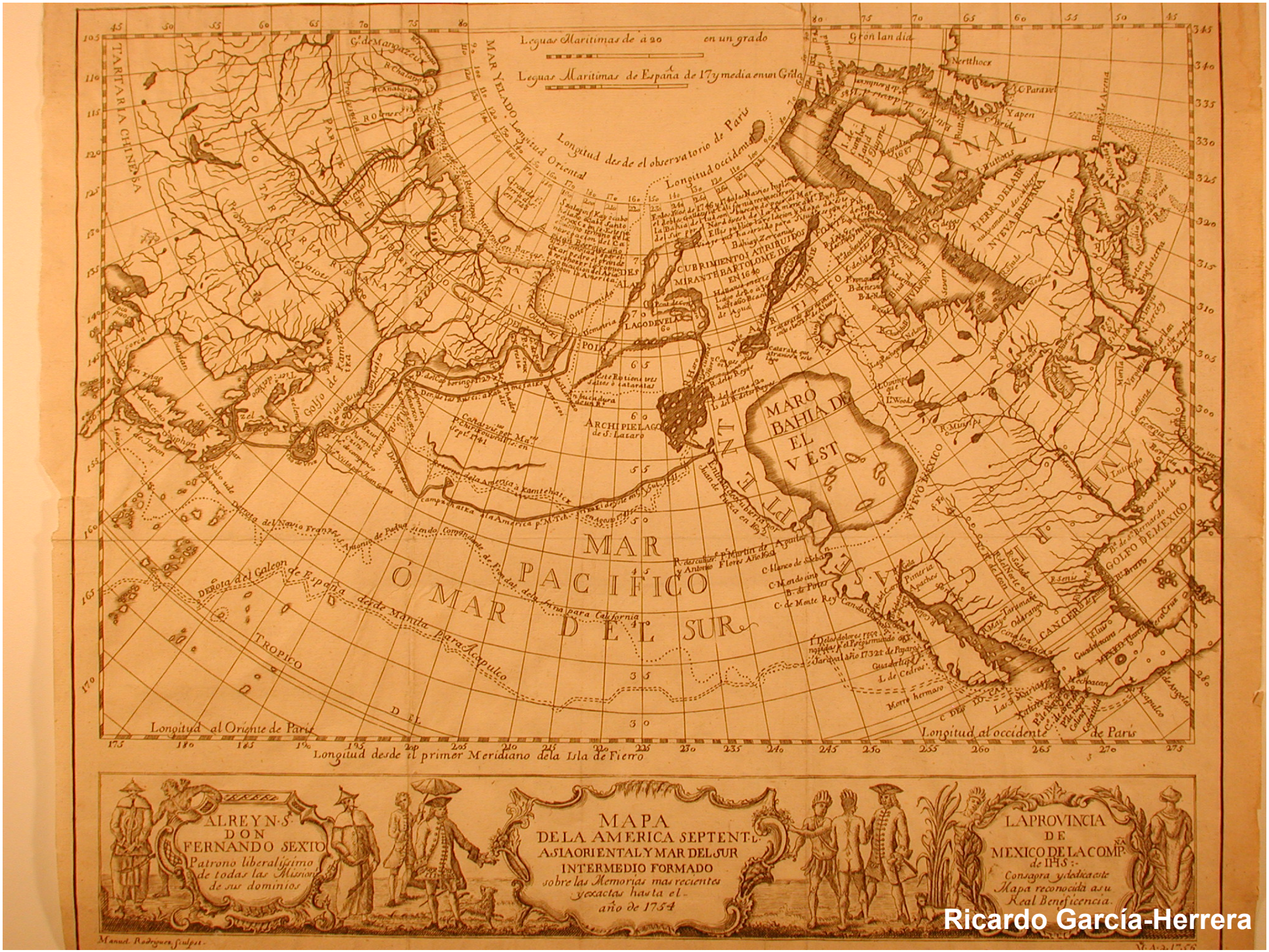
Annual record of flood (above) and low-water (below) at Roda Island, Cairo, based on Nilometer



MCA (~950-1250) characterised by a low variability in flood record and low proportion of weak nile floods

Record suggest that MCA was a period during which periodicities possibly linked to solar periods ‚lose' their temporal stability

De Putter et al. 1999

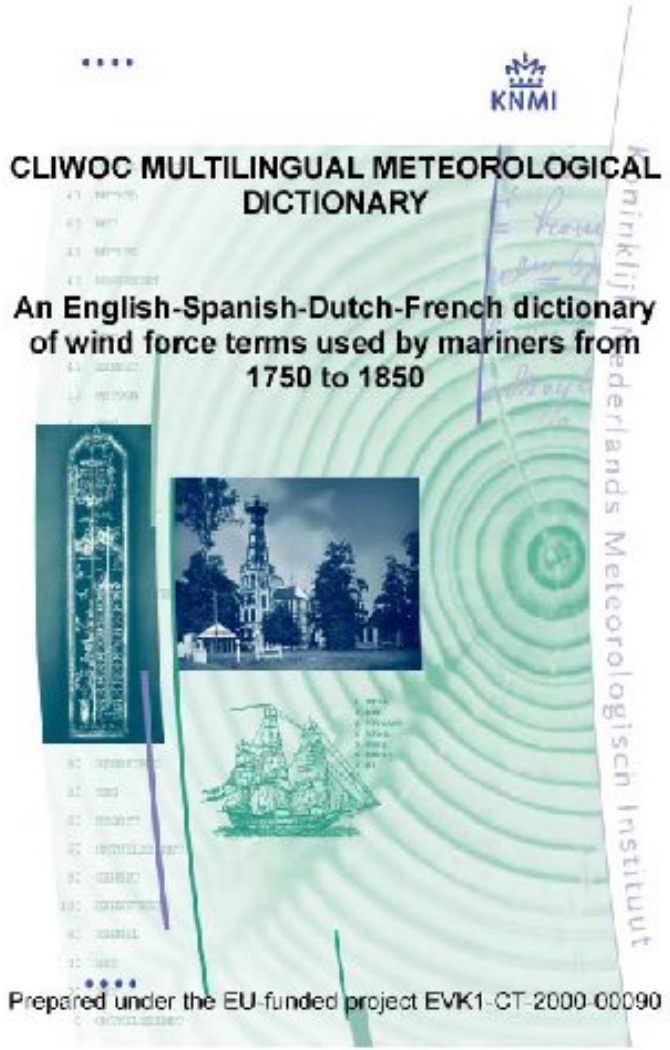


Del Viernes 5. al Savado 6. de Agosto de 1796. De C.....

Hs	M	B.	Rum.	Ab.	Vient.	Fuerz.	Mar	Caris.	Aparejo.	R.o Corr.s	Dis.	N.	S.	E.	O.
1	4	,	E.5°N.	,	O.	Galeno	P.SO	Acelg.s°	Gar.s 1. rizo Juan.s y alas	88°,,, 1°	47.2	1..	.....	47.2	
2	4	2	,	,	ONO.	,	O.yno	,	Vd. Estay degat.s y puño maior						
3	4	1½	,	,	,	,	,	Brumg.s	,						
4	4	3½	,	,	NO.	,	,	,	,						
5	4	5.	,	,	,	,	,	Soldado y	,						
6	4	6½	,	,	,	,	,	achub.do	,						
7	4	1½	,	,	P.Val.	,	,	,	Vd. menos Sobre Mez.a						
8	3.	6.	,	,	O.	,	,	,	Frinq.te y Gar.s 1. riso.						
9	4	6.	,	,	,	Rectas	,	Pdamp.s	Vd. mas Estai gar.a y el Su.°						
10	3.	1.	,	,	,	fugad.s	,	al 12 ½	,						
11	1.	6.	,	,	,	repeti	,	y aurés.no	Frinquete y Garias.						
12	2.	6.	,	,	,	das	,	,	Vd. Gar.s arriadas						
13	5.	,	E.¼.NE.	,	SO.	Fresco	Entem	Aguacer.s	Vd. Gar.s à ½ Mast.°	81.45. 1°	1o....	1.3½	.....	1o....	
14	5.	,	,	,	,	fugad.s	tradas	,	,						
15	6.	,	SE.¼.S.	,	SW.	rzeias	segun	,	Se aferró d Vel.° y se arrio	53.15. 2°	6.....		5..4	.5..	
16	3	6.	,	SE.	N.	Cstr.s	el V.to	,	las Gavias.	38.15. 2°	3..6.	.....	2.5½	2.4	
17	1.	3½	S.S.E.	¼S.	NE¼n.	,	NO.	,	,	53.15. 2°	2.3½	.....	1.4	2.....	
18	1.	,	,	,	,	Casi	N.	Serrado-	,						
19	1	2½	E.NE.	,	SO.	Calma	,	con aguas	Fré 2. Garias 1. riso Tué Pl.	73.3o 1°	2o.5.	6.6½	.....	19.3½	
2o	2.	6½	,	,	OSO.	Bon.a	,	y celax.n	de la maior y Estay de Gav.e						
21	3.	3.	,	,	,	Fresq.to	NO.	gruesa°	Vd. menos d Juan.s de Proa						
22	3.	6.	,	,	ONO.	,	,	,	el Sort.e Garias en 1. rizo.						
23	4.	4.	,	,	NO.	,	,	,	,						
24	4	3.	,	,	,	,	,	,	,						
Var.n NE. 3.°												9. 3. 7. 6½ 1. 3½	7. 6½	86. 2½	

Lat.d S.a Alt.a N.	Dif.a Lat.	Lat.d Lleg.a	Lat.d obs.a N.	Dif.a Ver.	Longd. S.a Or.l Cz	Dif.a Ap. E	Longd. Or.l C.	R.o Nav.o	Dist.
13. 32'. 9'	1'. 32.	13°. 33.39	15°.34'.55	2'. 46.	14°. 18. 32'.	1°. 28. 3'.	141°. 47'. 2'.	89°. ..	86 ½

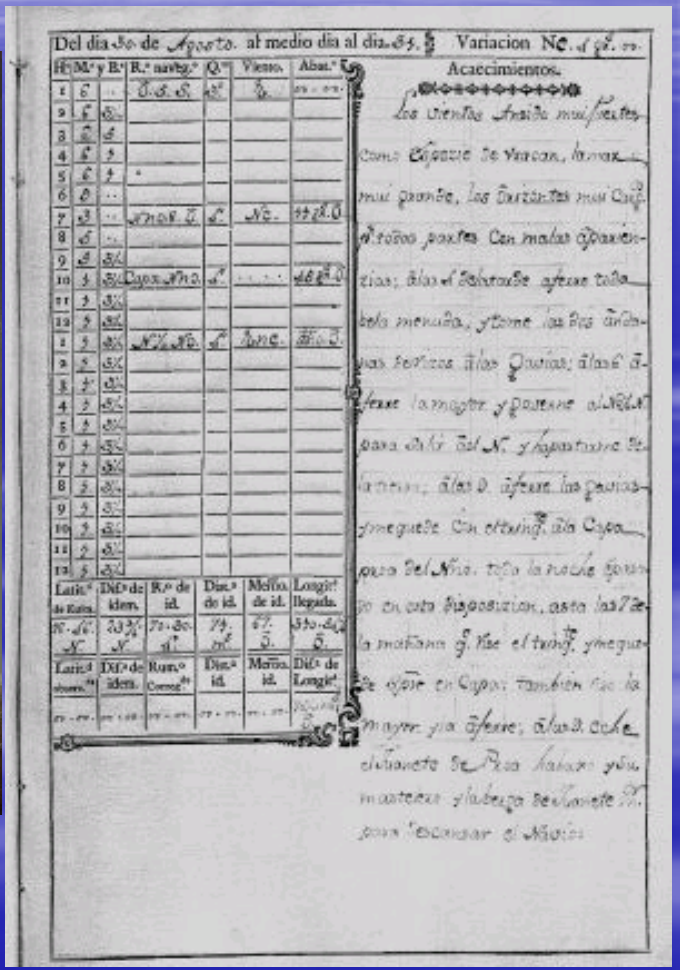
Empezamos esta singladura con V.to Galeno y el tiempo de buen semblante y empezando à variar al NO. fue yendose à chubascado de feo caris y à las 7. llovió al N. que despidio algunas fugadas Rejas desde cuia hora empezaron los Relampagos en el 1.° 4.° y 3.° 4.te variando, el V.to del N. al O. con Rejas fugadas al NO. y haviendo formado al ONO una Turn.a à las 11 ¼ entro el V.to recio al NO. con fuertes aguaceros y fugadas y apoco abonanzo el V.to al O. y SO. y continuando los relampagos al NE. fue tomando el Caris peor semblante, y à las 1 h.s que bolvio aventar el O. y NO. empezò à tronar con mucha fuerza cerrandose todo con fuertes aguaceros llamando de pronto el V.to al NE. con Rejas fugadas interrumpidas de y haviendo mediado el V.to à las 3. empezò el V.to acceder cesando la lluvia y aclarando algo lo horizontes y al amanecer estava llov.do hasta las 6 ½ y.e noto el V.to SO.



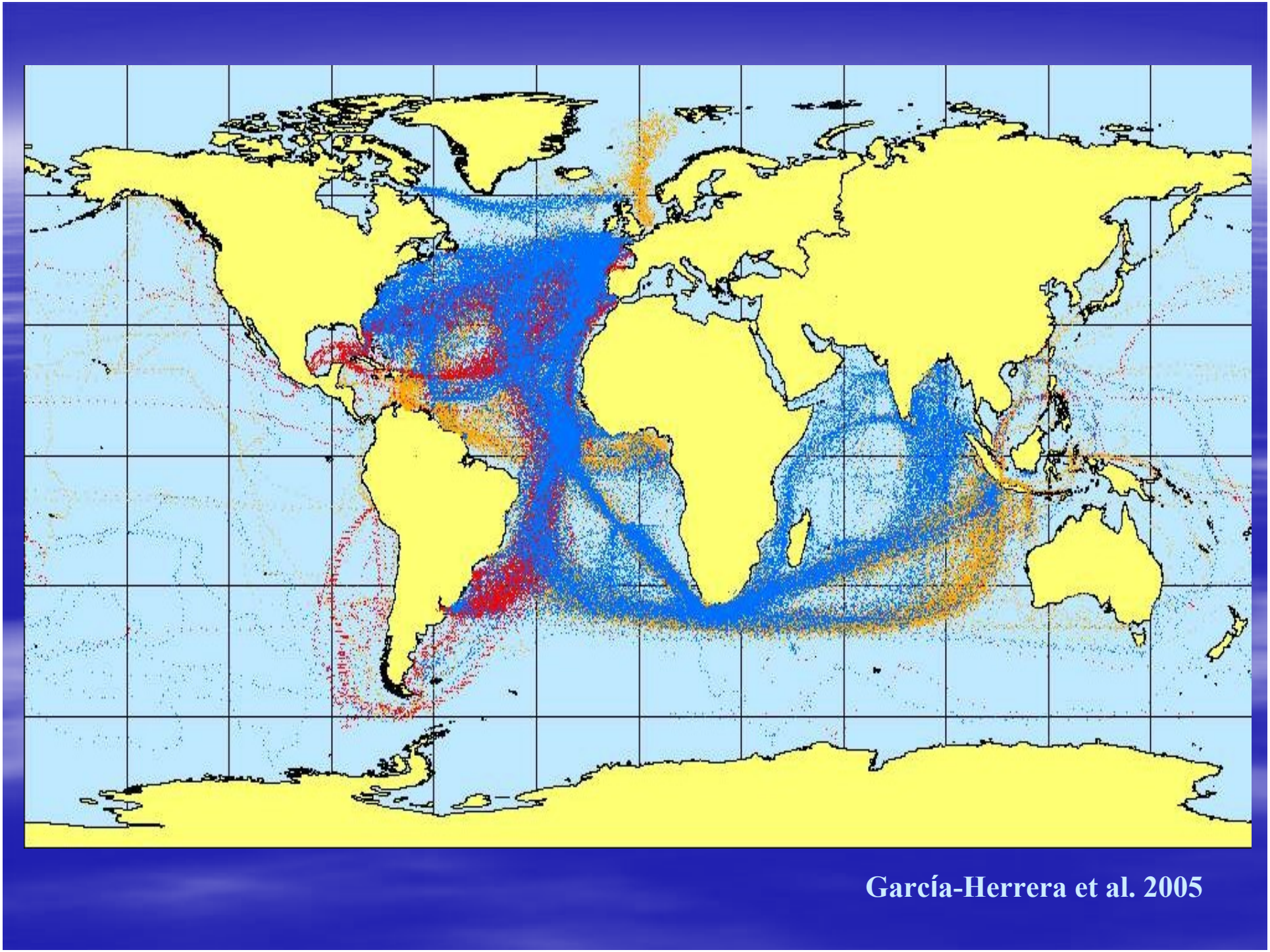
Ricardo García-Herrera

Ship log data – CLIWOC

Copyright: Nicholas Pocock's painting of the East India Company's Hindostan.
By courtesy (until 2013) of the National Maritime Museum, Greenwich (UK)
http://icoads.noaa.gov/reclaim/images/BHC1097_Pocock_E_Indiaman.jpg



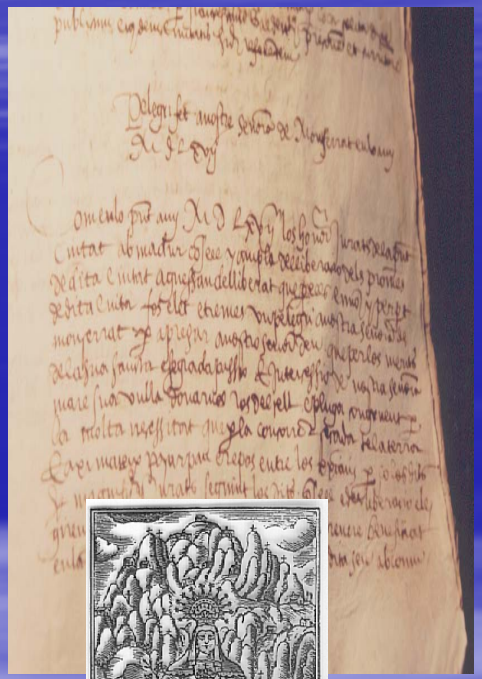
http://www.ucm.es/info/cliwoc/logbooks.htm

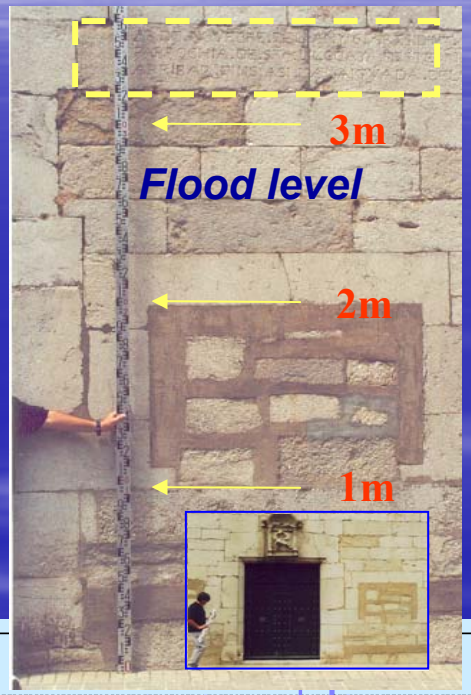


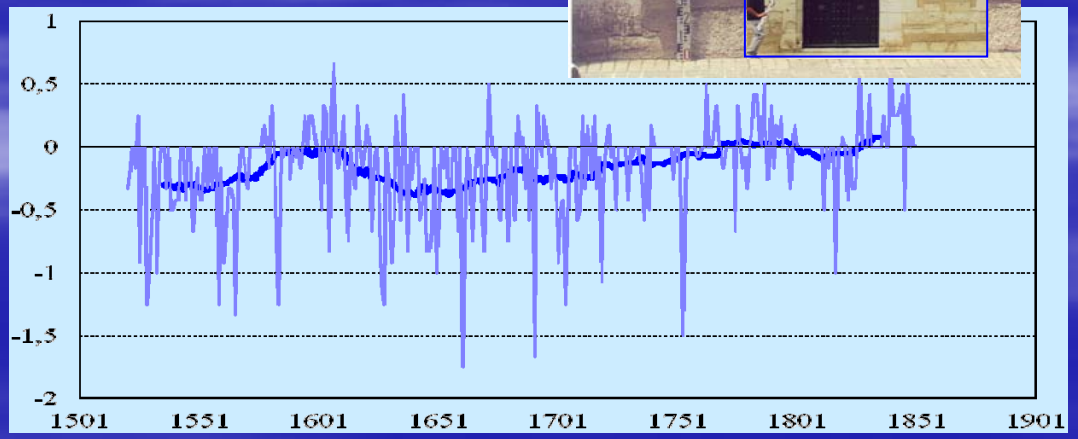
García-Herrera et al. 2005

Use and application of proxy information for the study of the Mediterranean past climate

Combination of documentary data to reconstruct precipitation, Barcelona 1501-1851

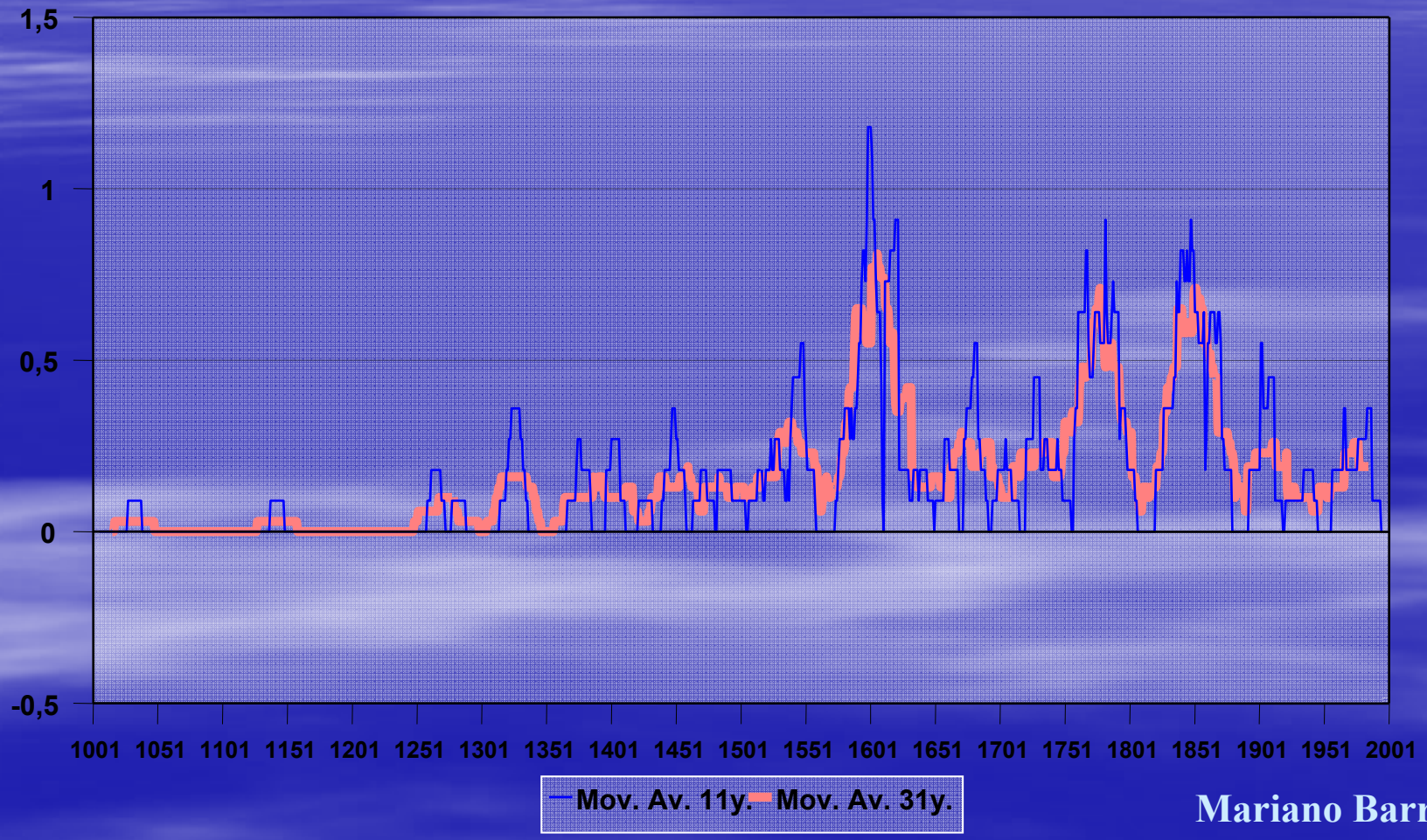






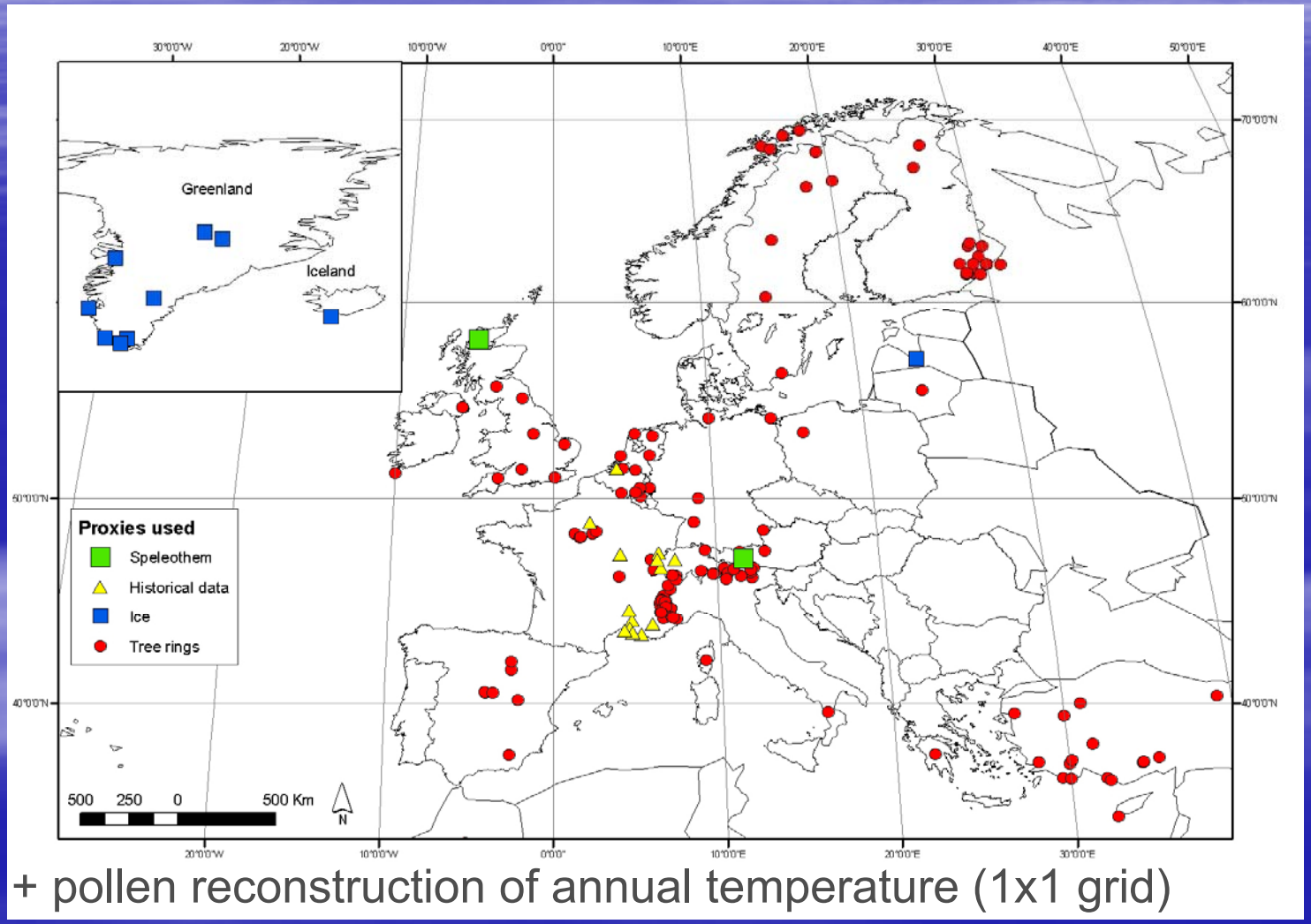
Rodrigo & Barriendos 2008

Number of catastrophic floods in Catalonia



Mariano Barriendos

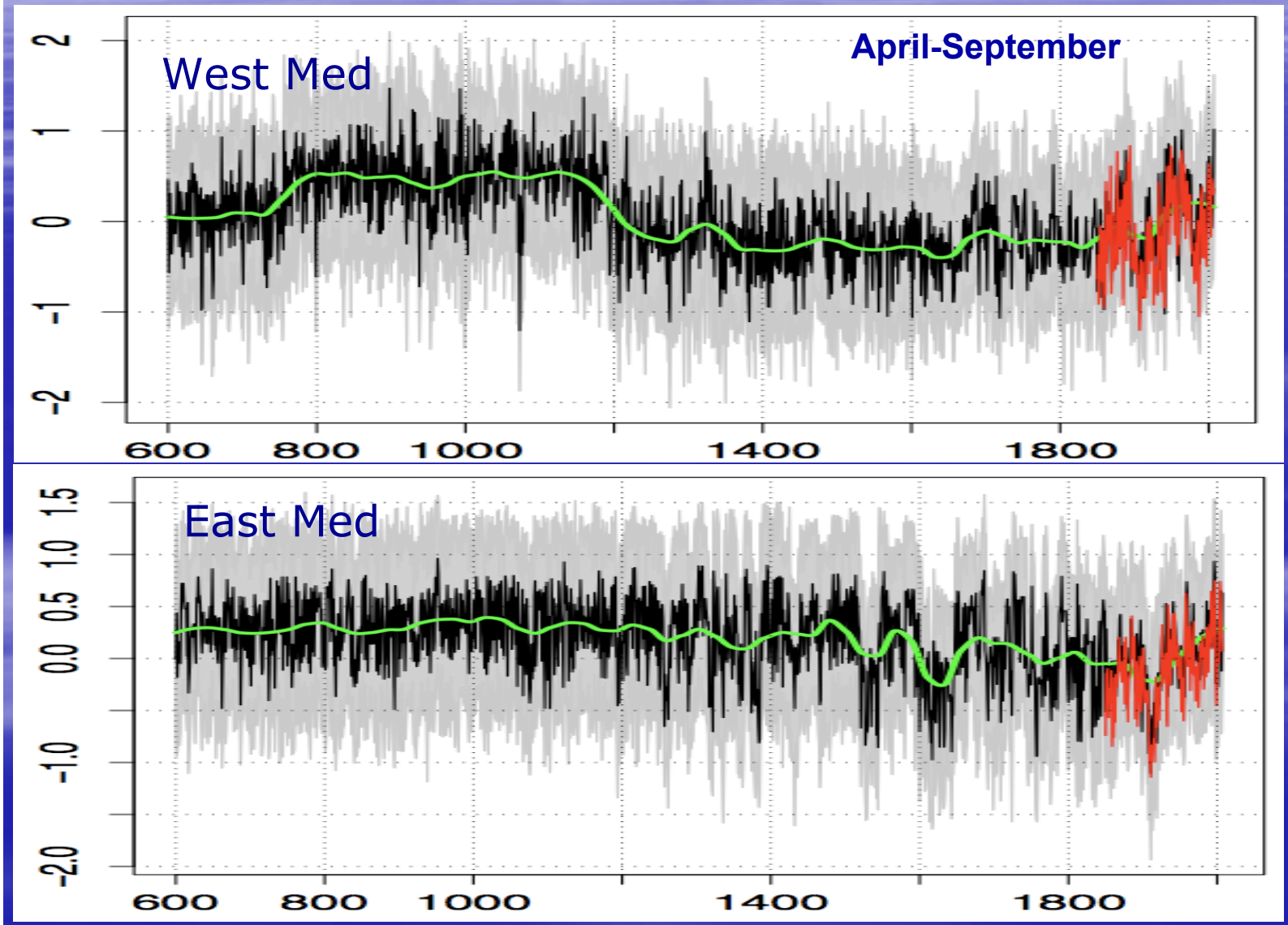
Location of proxies



+ pollen reconstruction of annual temperature (1x1 grid)

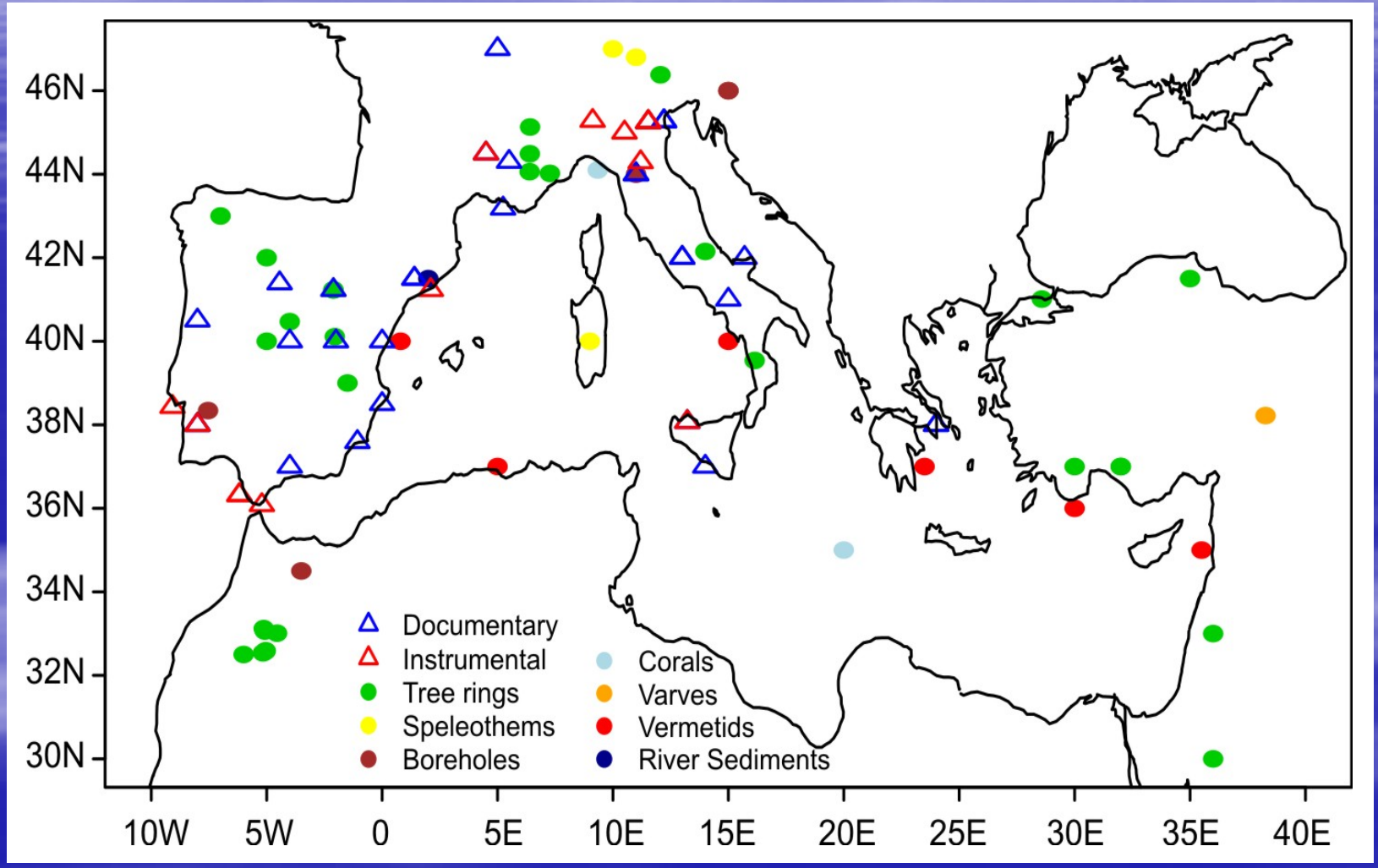
Guiot et al. 2010

Mediterranean temperature reconstructions



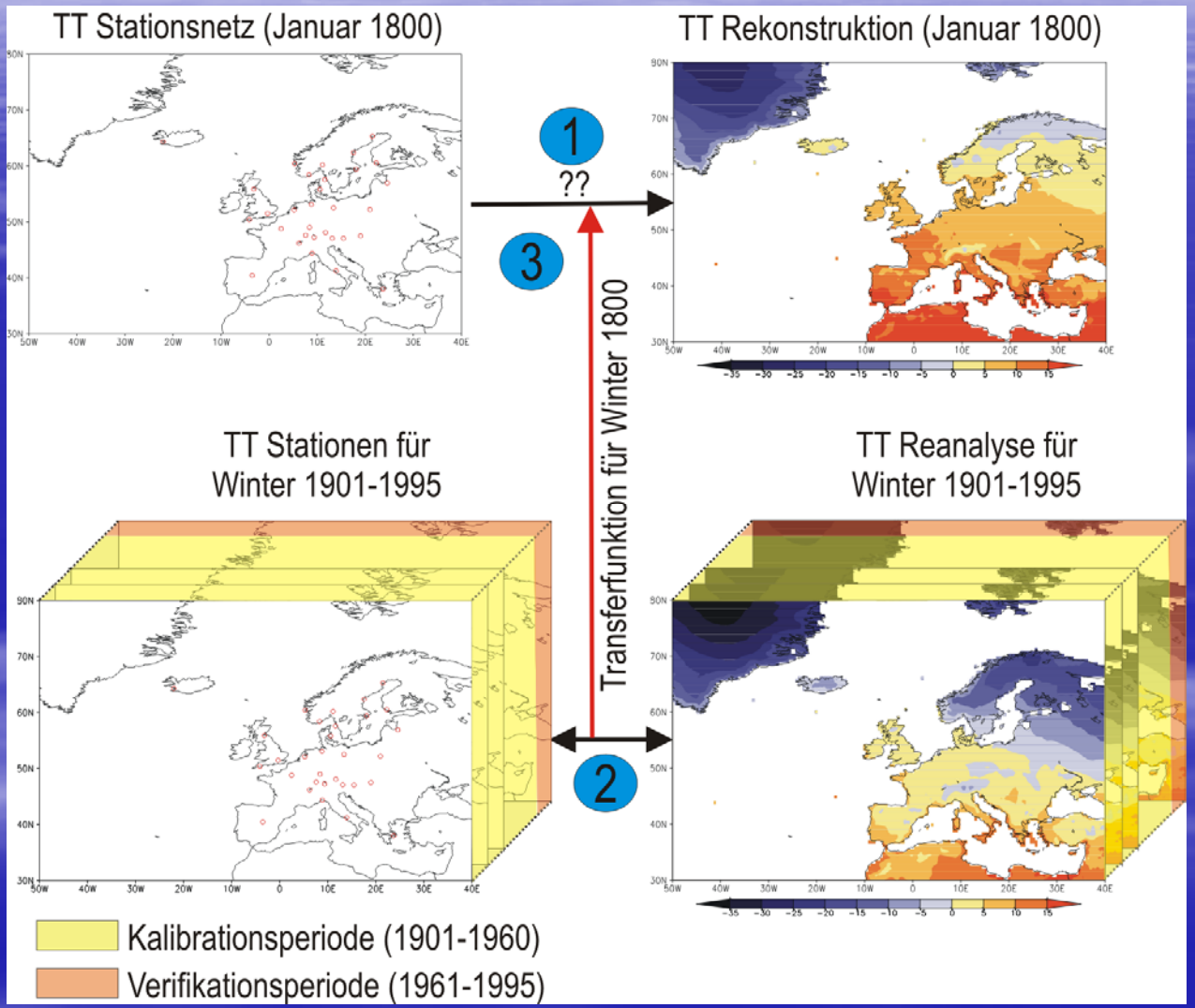
Guiot et al. 2010

Distribution of proxies (documentary & natural) over the Mediterranean area



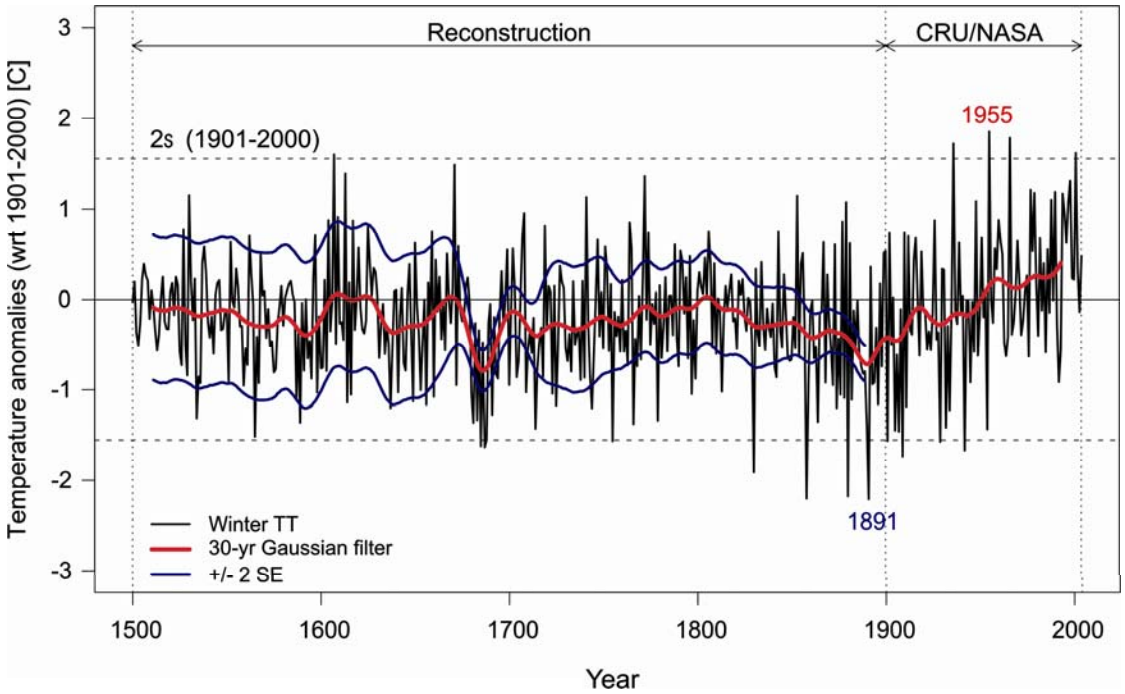
Luterbacher et al. 2006, updated

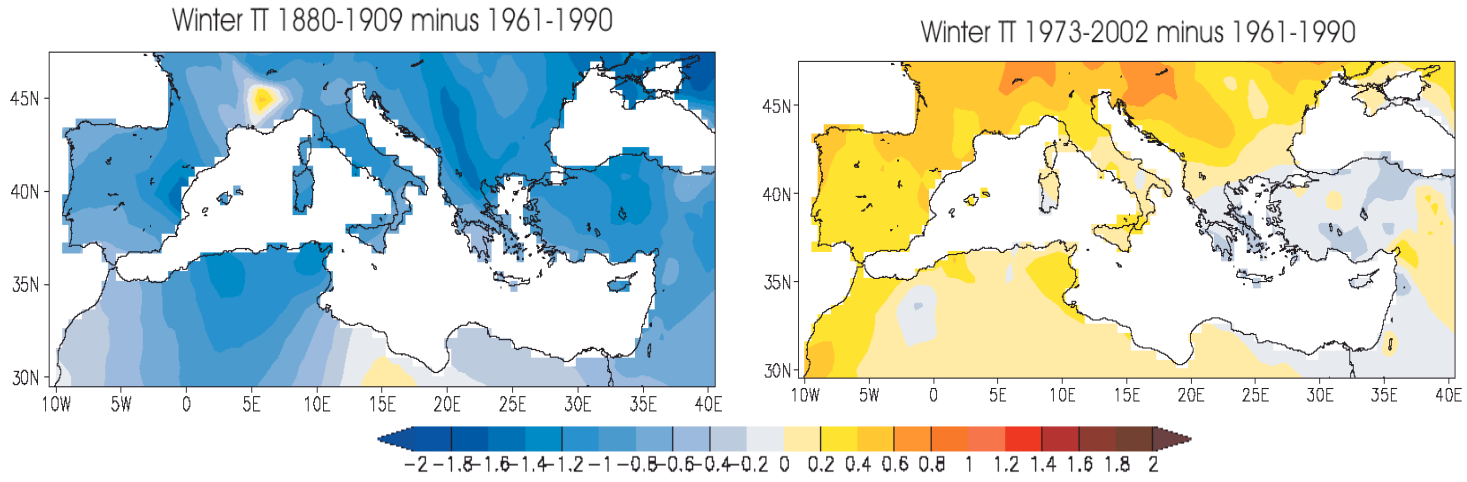
Reconstruction methodology (PCA-multivariate regression)



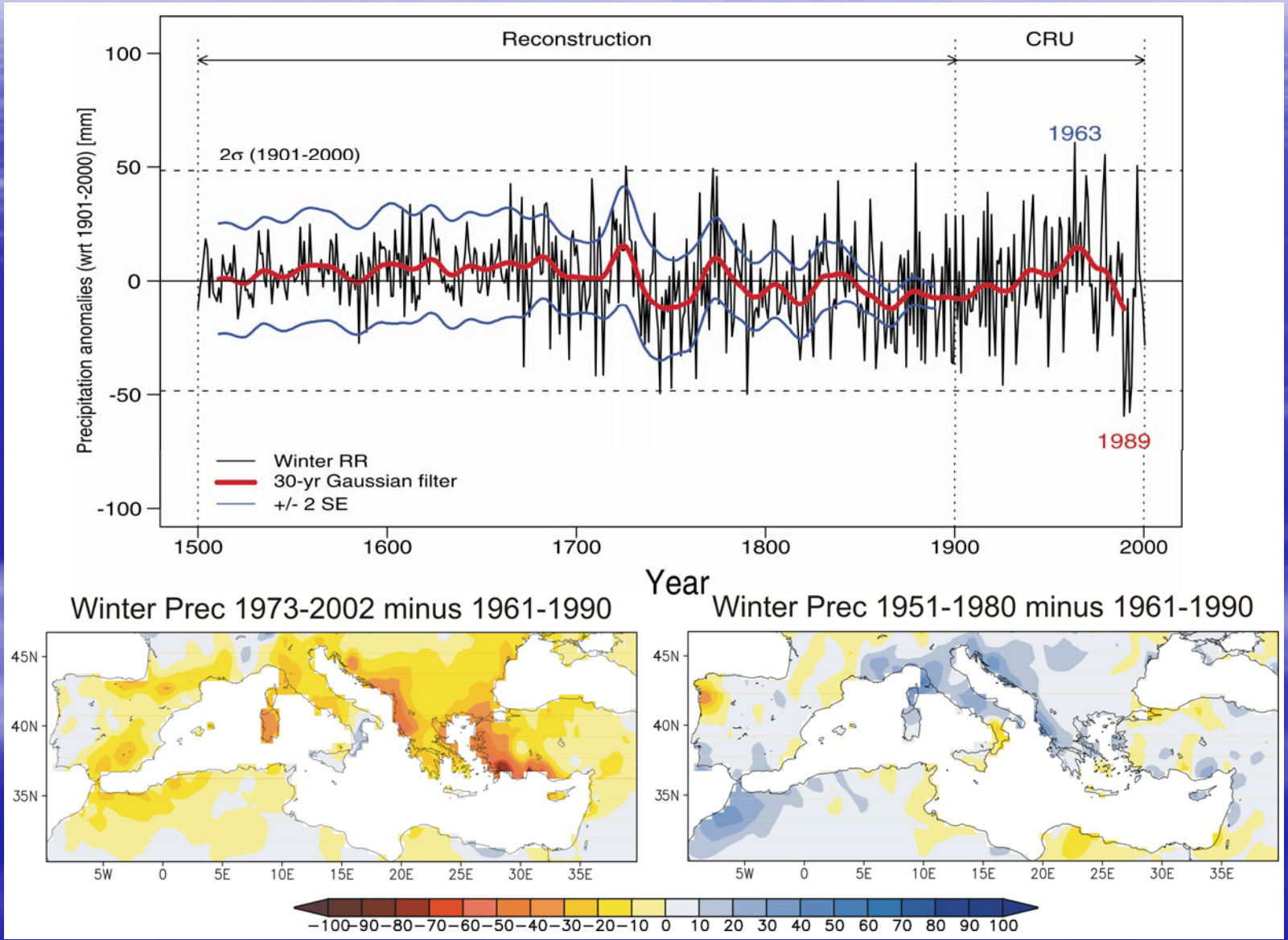
Luterbacher et al. 2004

Mediterranean winter temperature from 1500

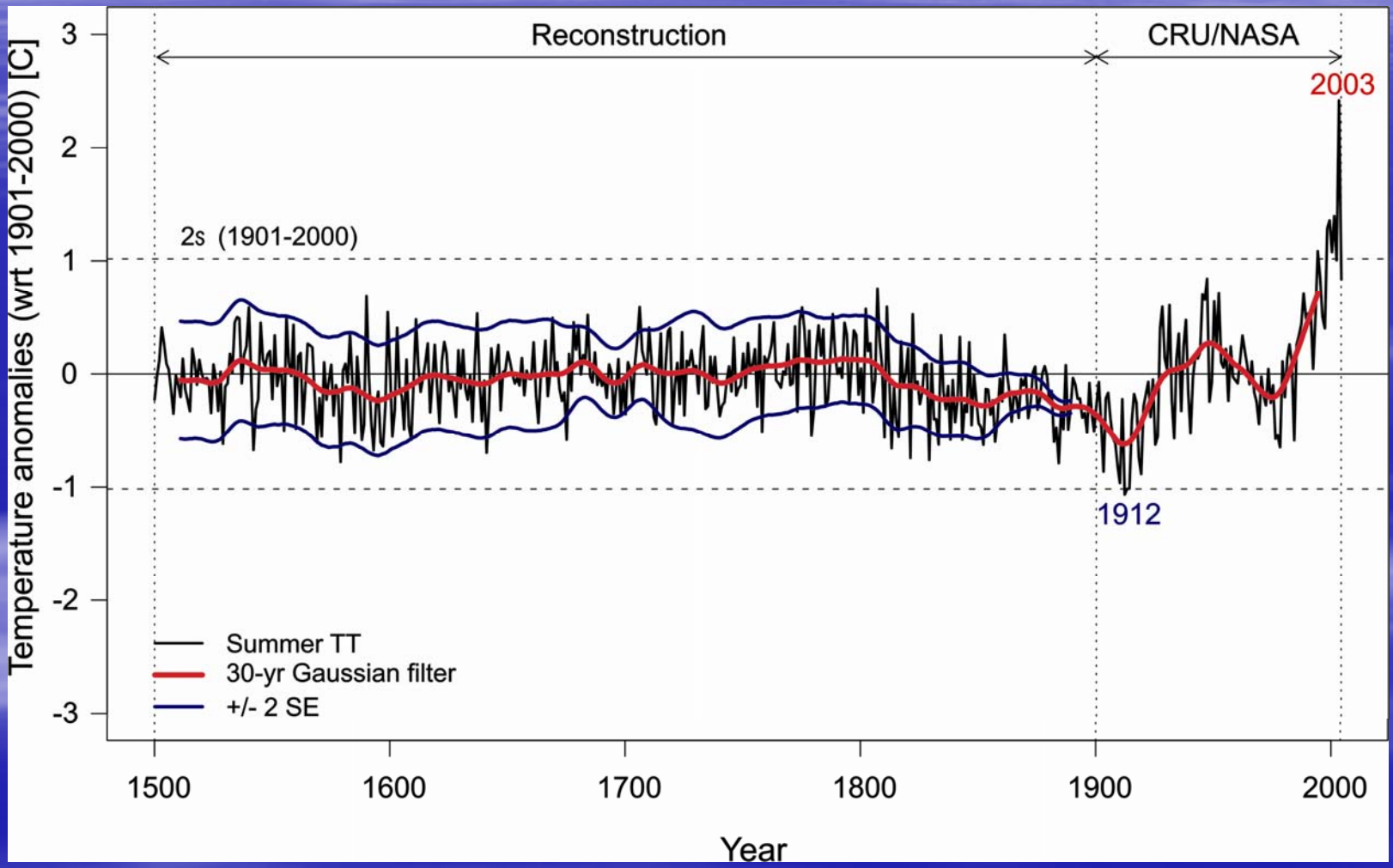




Mediterranean winter precipitation from 1500

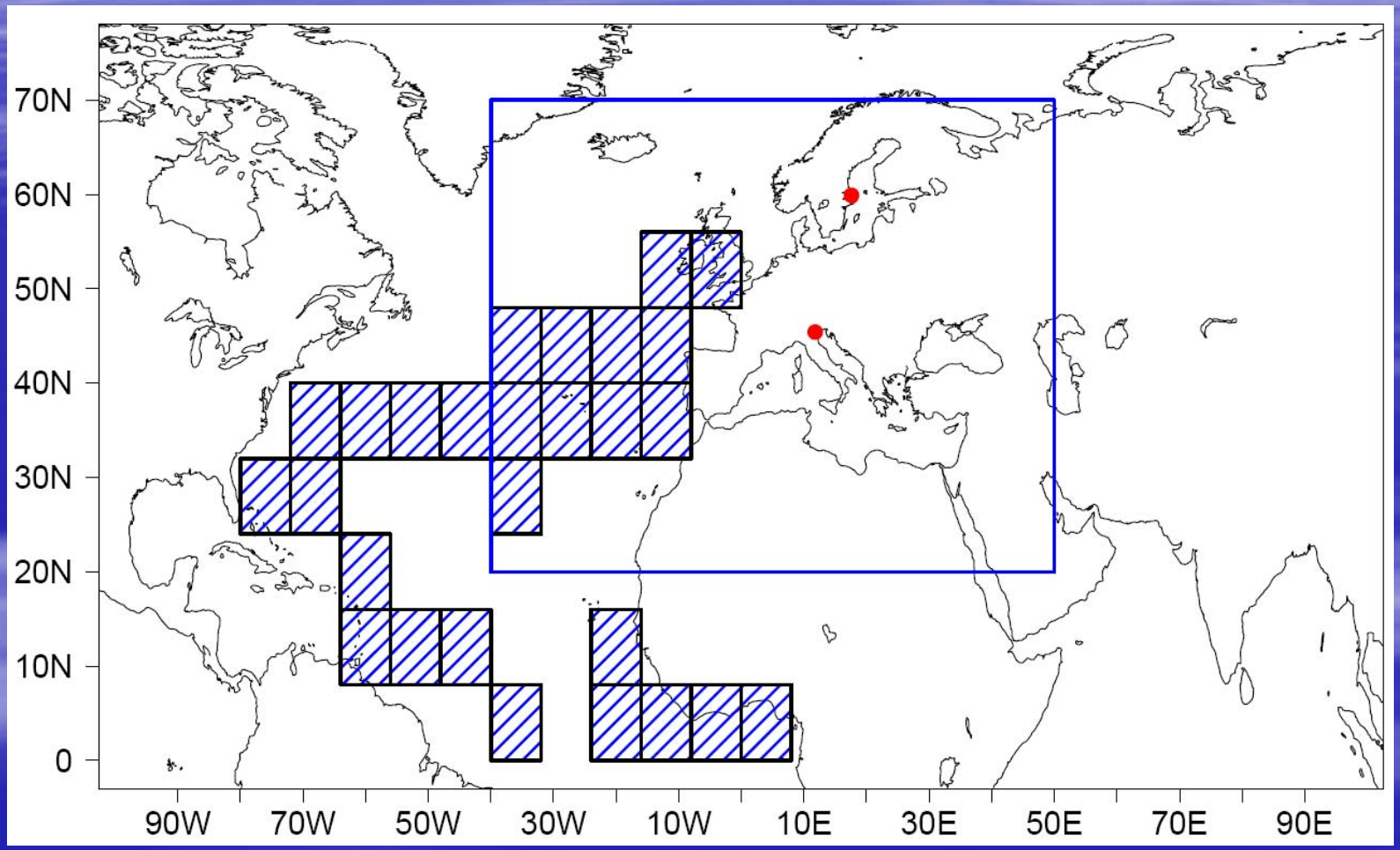


Mediterranean summer temperature from 1500



Luterbacher et al. 2004, updated

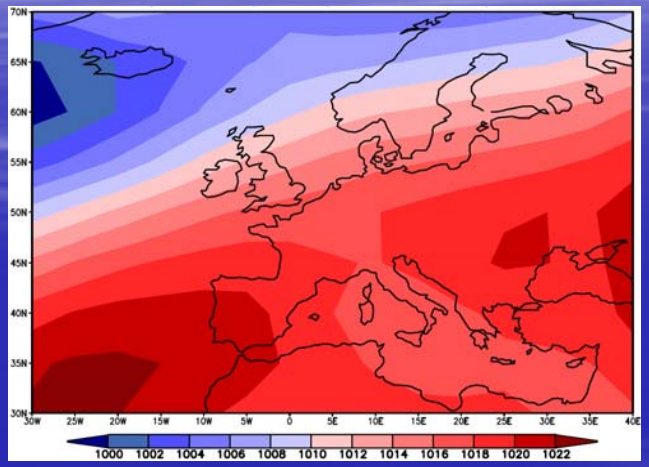
Reconstruction: Winter 1753

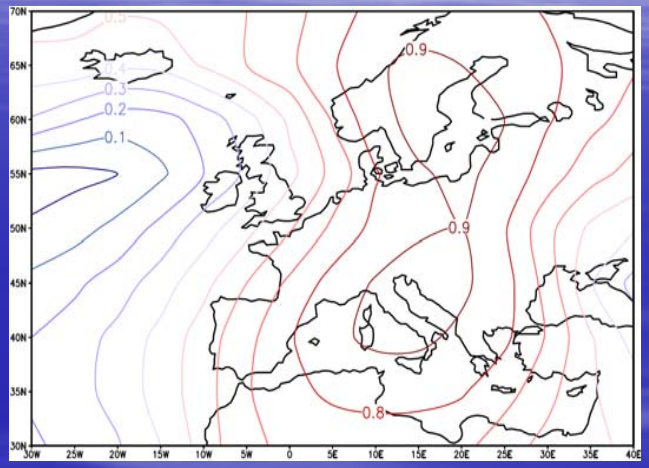


Küttel et al. 2010

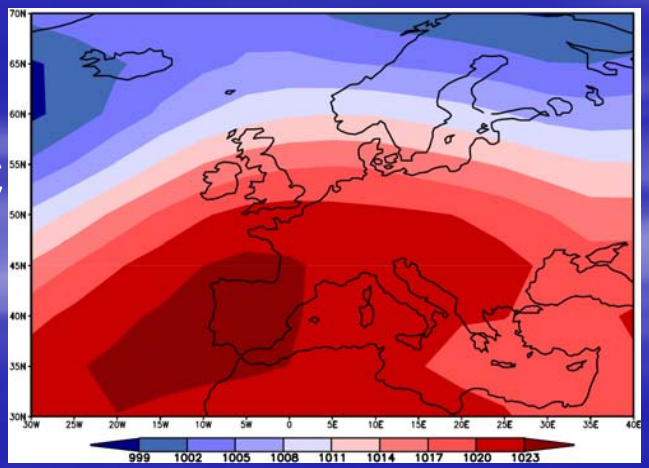
Reconstruction: Winter 1753

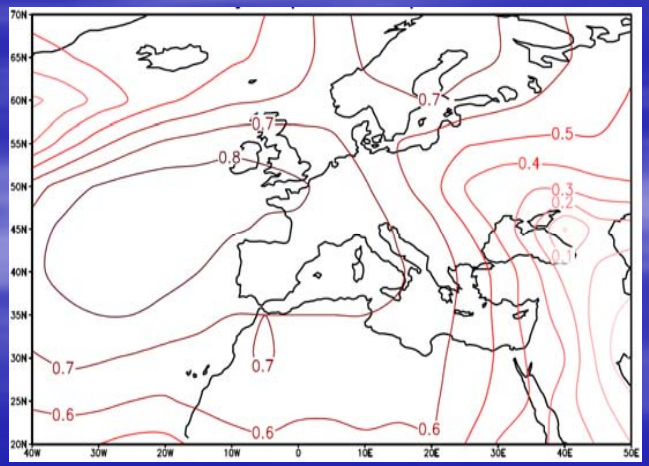
Instr only





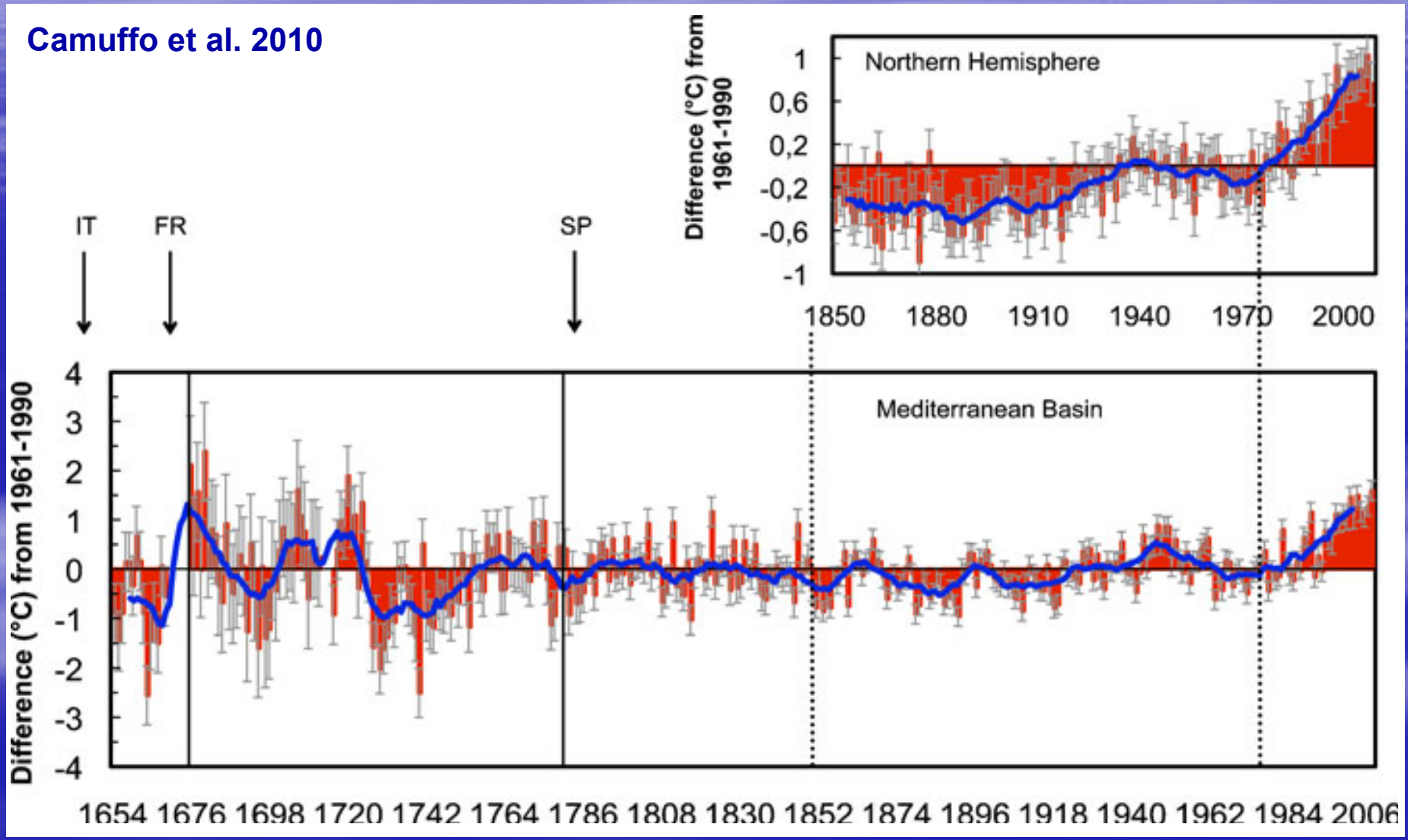
Instr & CLIWOC



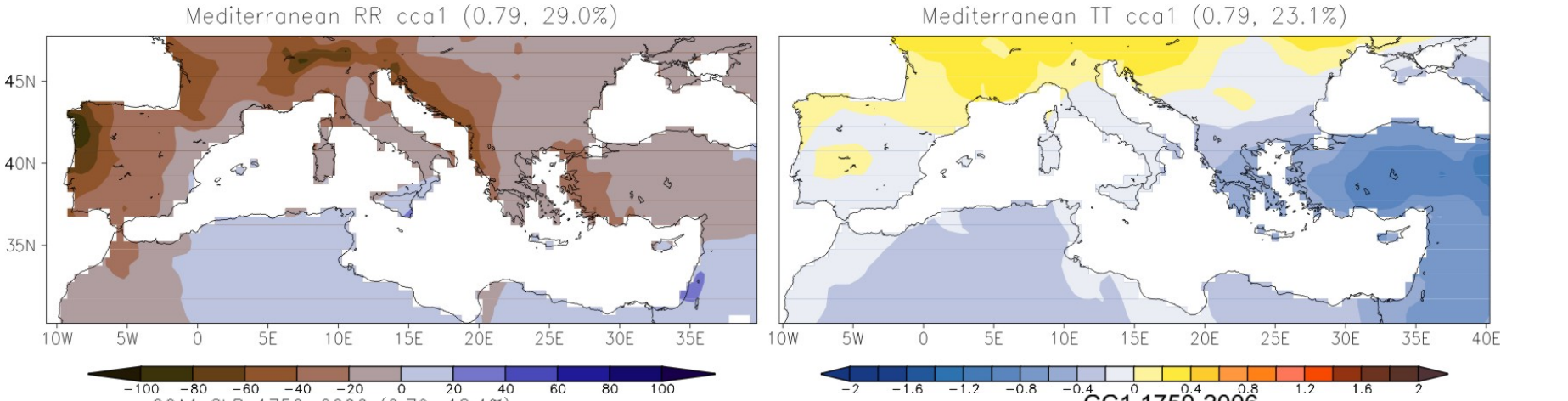


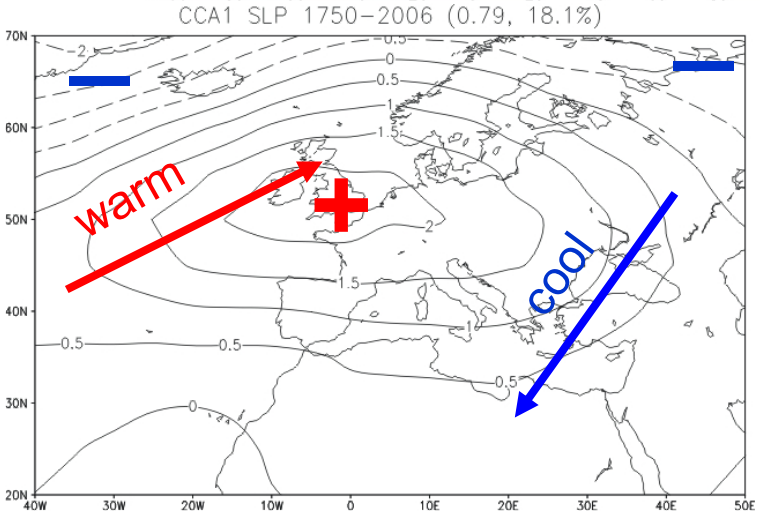
Küttel et al. 2010

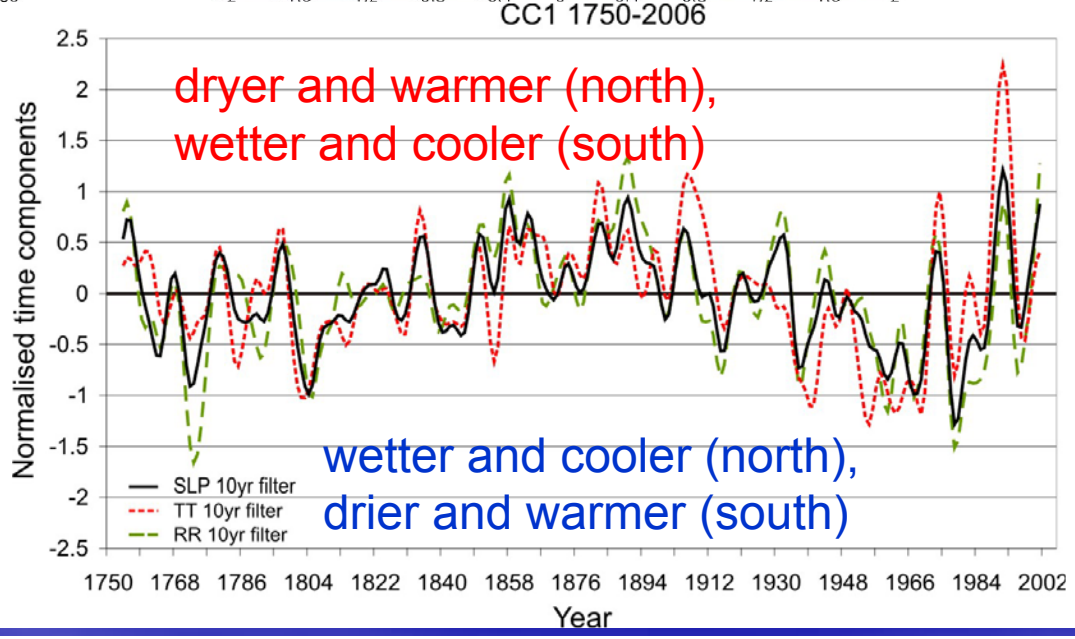
Annual Mediterranean temperature reconstruction



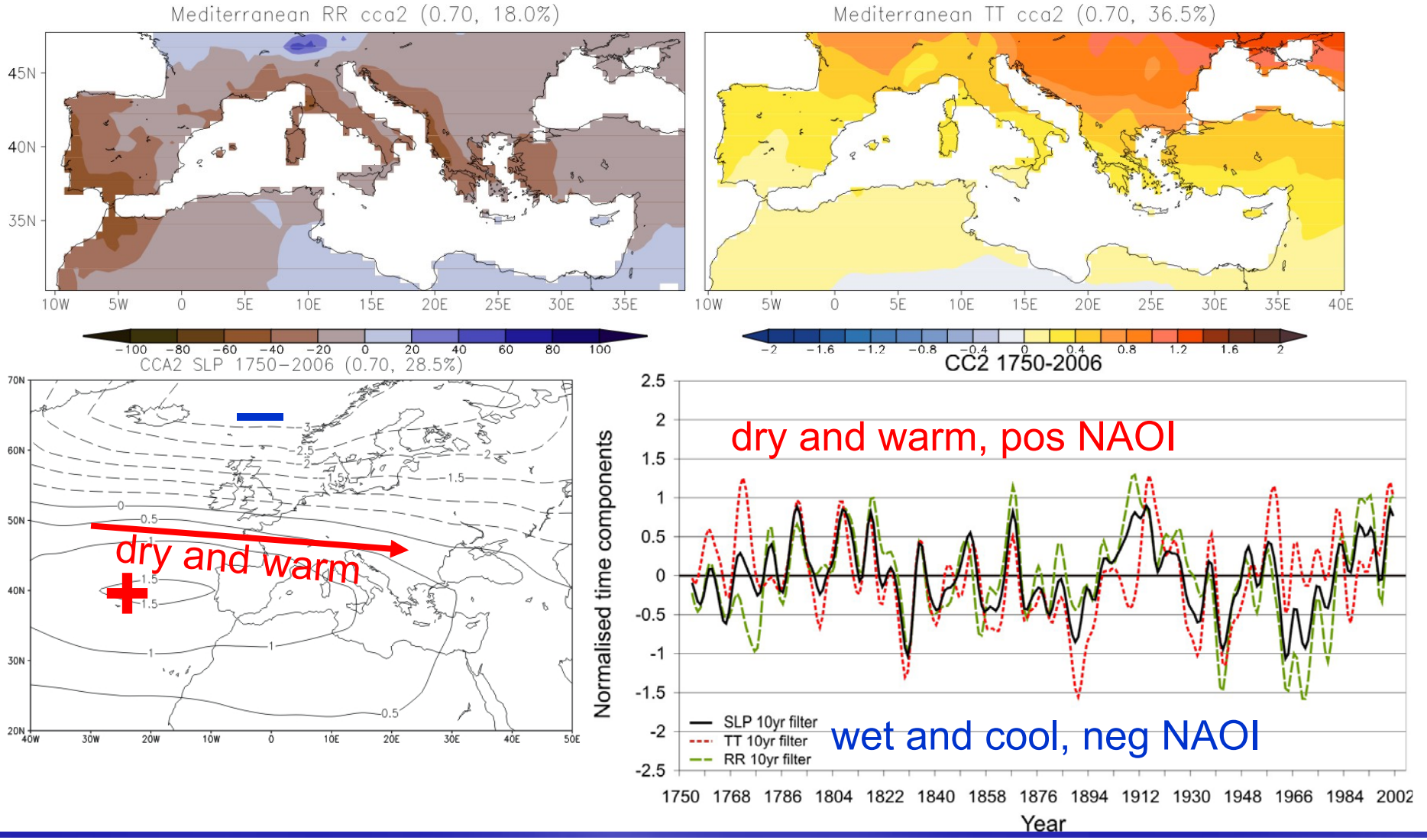
CCA1, 1750-2006
The EA/WRUS-like pattern







CCA2, 1750-2006
The NAO-like pattern



Conclusions

- The Mediterranean offers a broad spectrum of long instrumental, documentary and natural proxies
- Additional high quality and high resolution records are needed
- Multiproxy reconstructions allow insight in spatial and temporal details about past climate variations and related atmospheric circulation
- Future research should focus on developing stronger integration and exchange between the paleo-data researchers and dynamical/modelling communities


Thank you very much
for your attention!