Climate and Human History

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Thursdays, 2:00-4:00pm

Slides and other materials at:
http://www.stephan-matthiesen.de/en

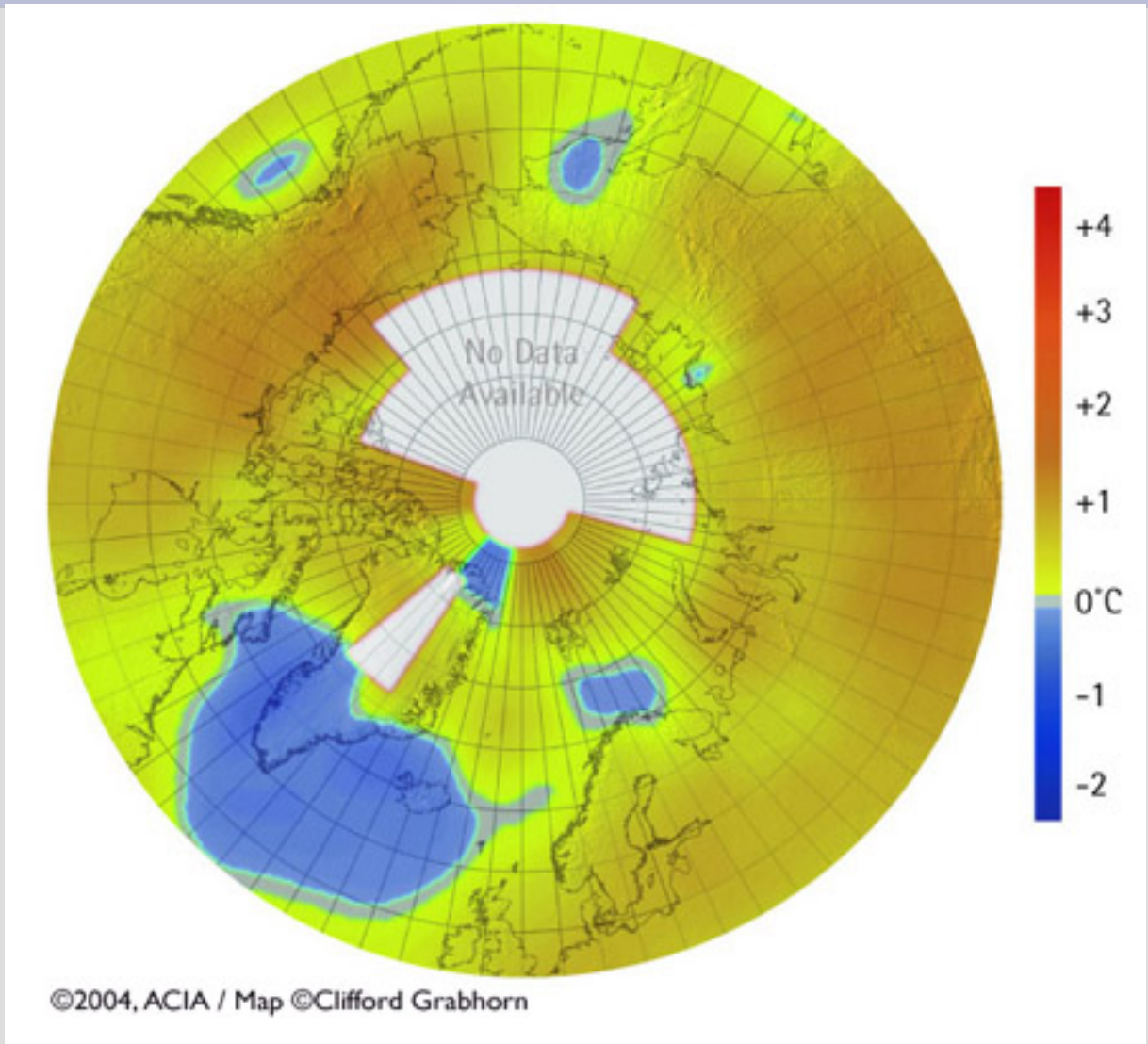
Climate and Human History

1. Climate and climate history
2. The Ice Age
3. Farming and City States
4. Rise and Fall of the Roman Empire
5. Tang and Maya in the 10th century
6. Mediaeval Optimum and Little Ice Age
7. El Niño through the ages
8. Miscellaneous topics
9. Current and future changes
10. Summary and re-cap

About me

Fieldwork in Sweden, Aug 2007

Arctic Change Observed 1954-2003



ACIA (2004): Arctic Climate Impact Assessment

About you

- Why did you decide to come to this course?
- Are there any civilisations or periods that you are particularly interested in?

Climate and Climate History

Outline:

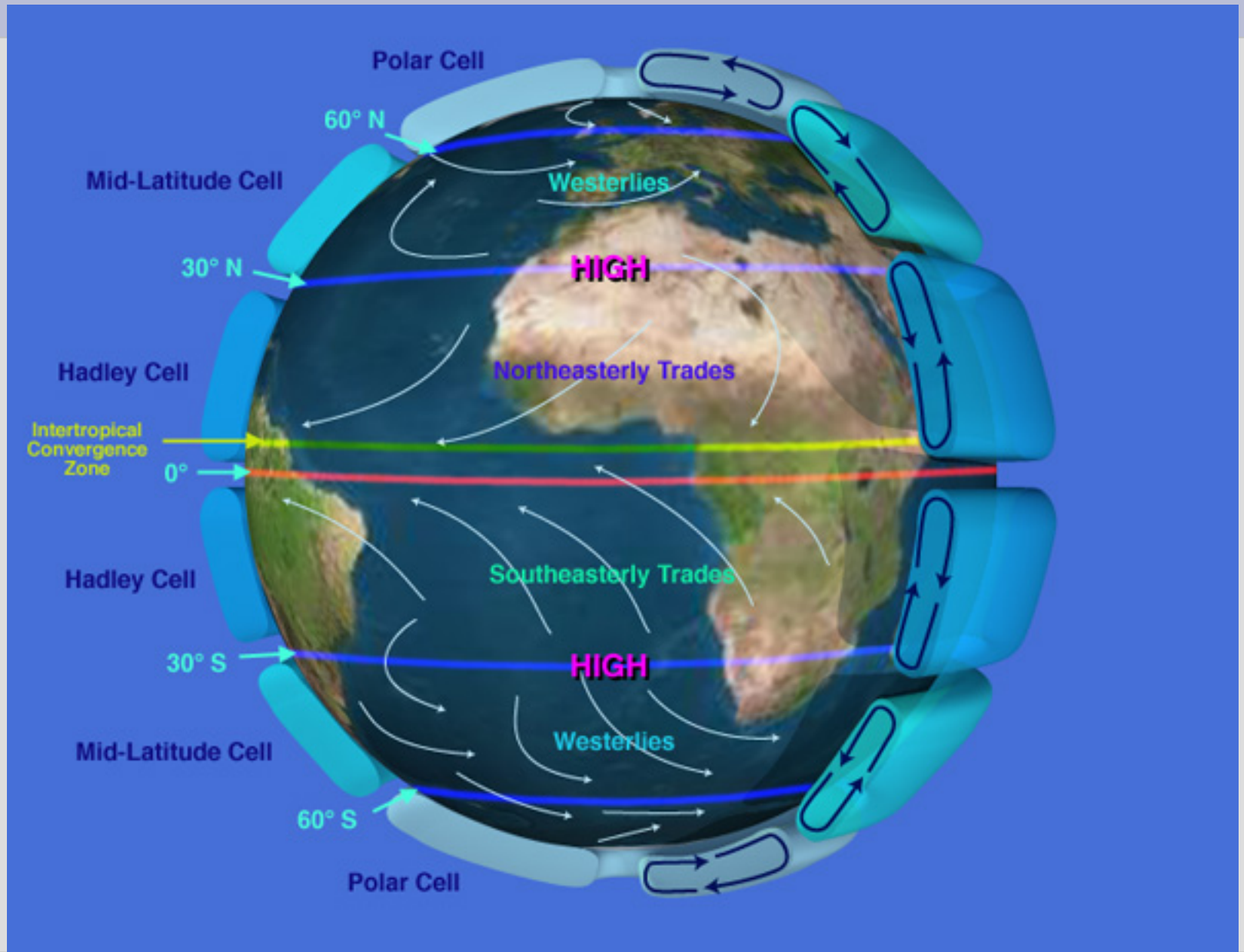
- The Climate System
- Methods for Reconstructing Past Climates
- Climate History

What is Climate?

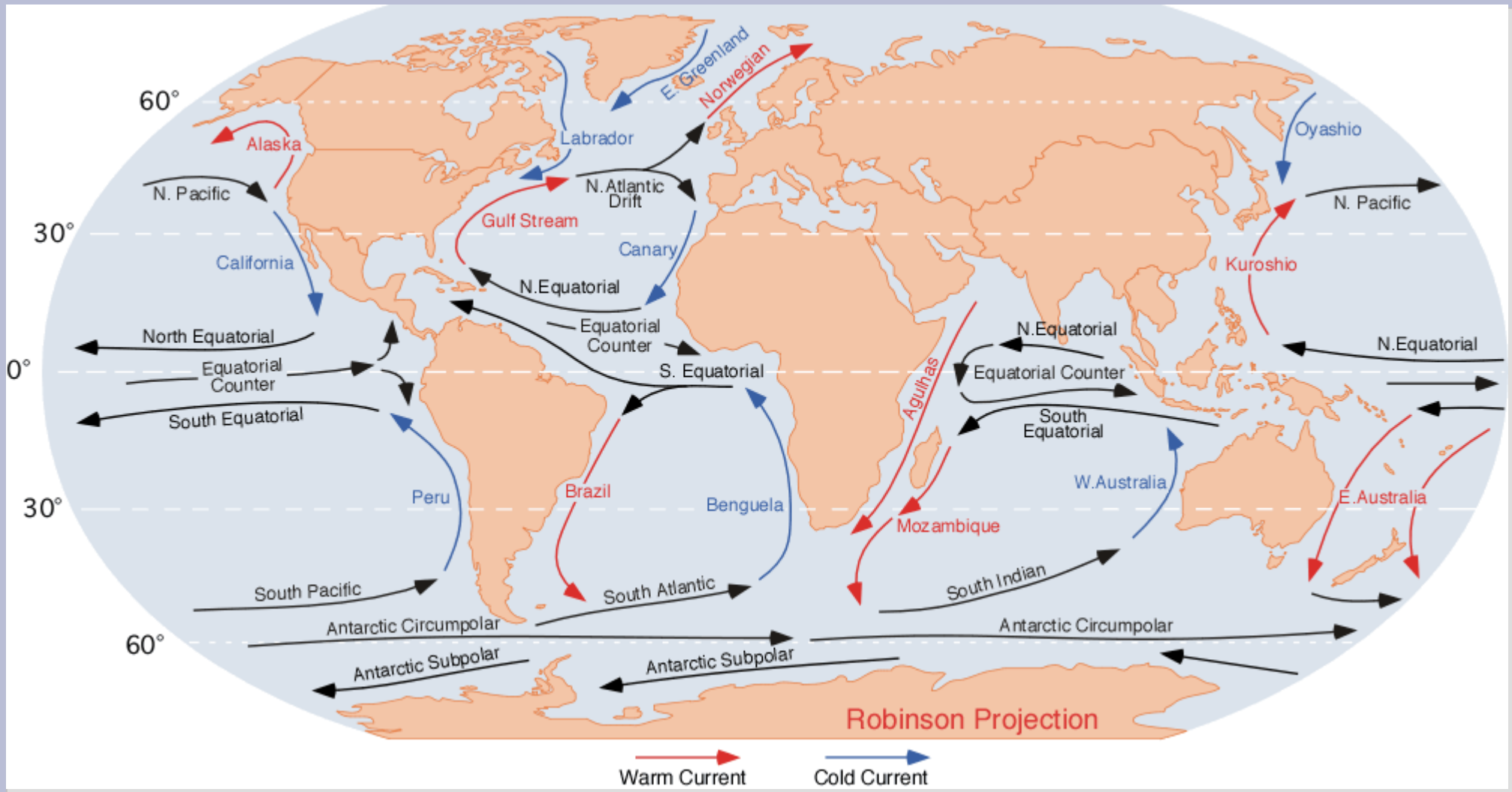
“average weather”:
“Climate represents (...) the accumulation of daily and seasonal weather events (the average range of weather) over a long period of time.”

[Ahrens (2002): Meteorology Today]

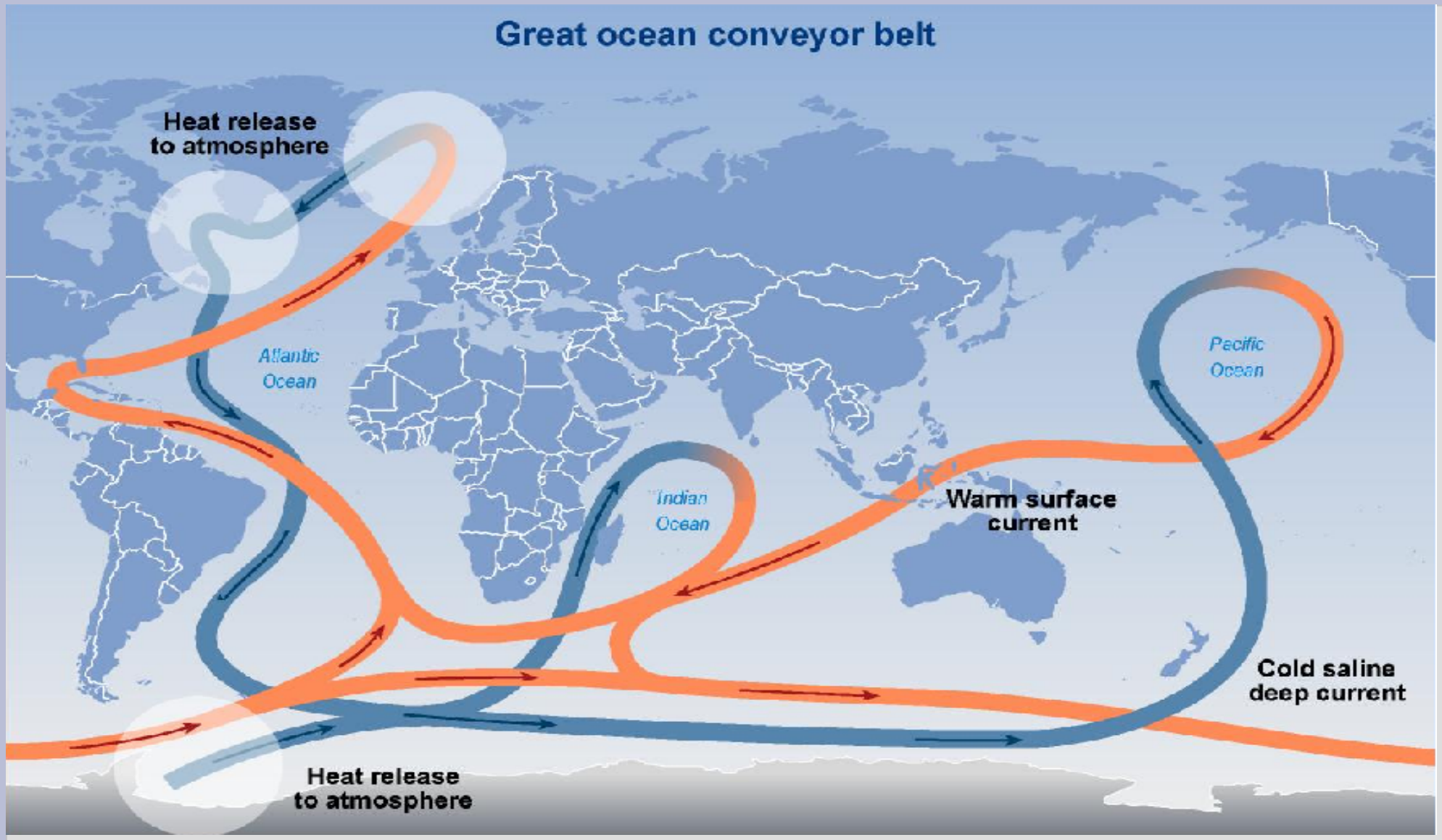
Atmospheric Circulation



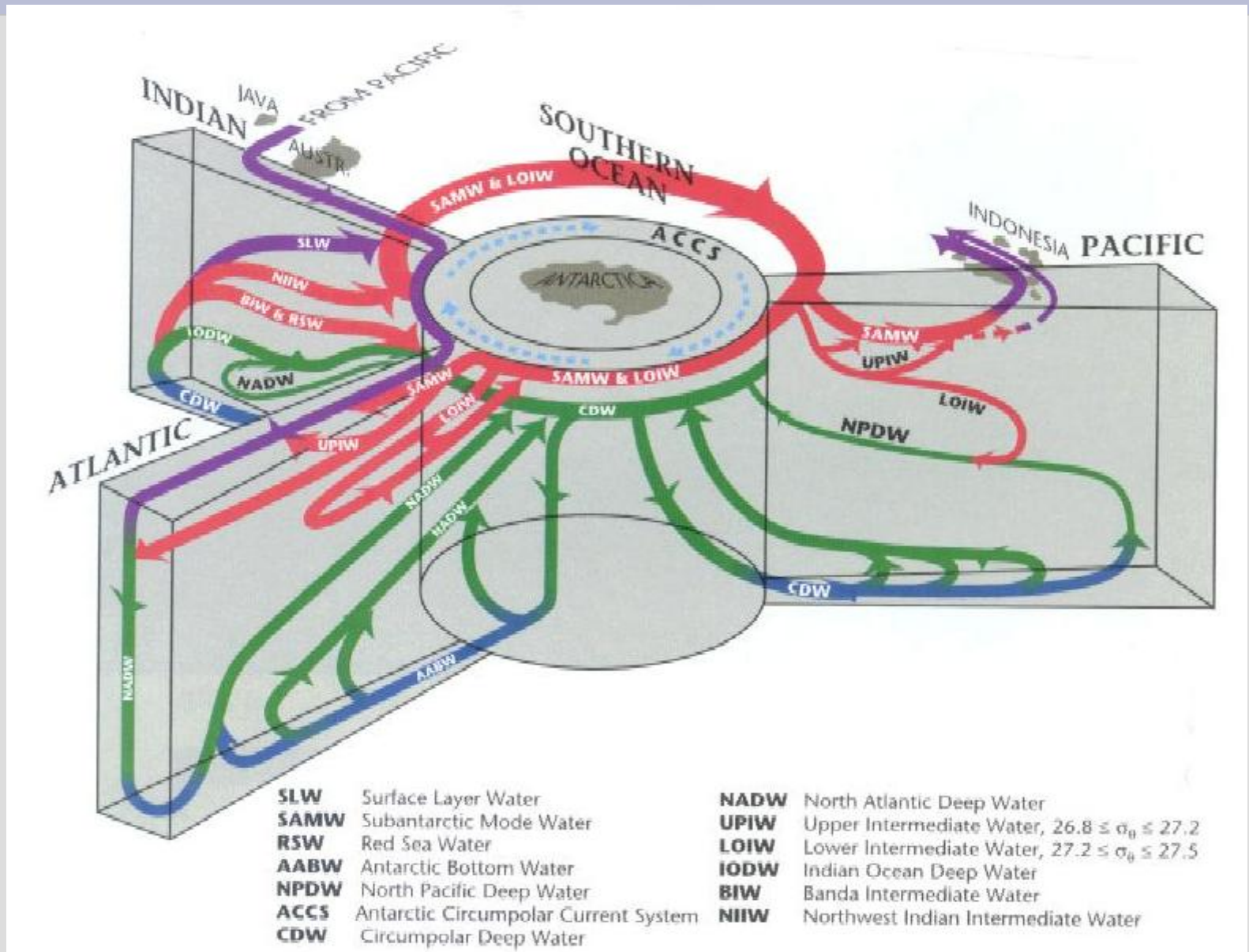
Ocean currents



Thermohaline Circulation

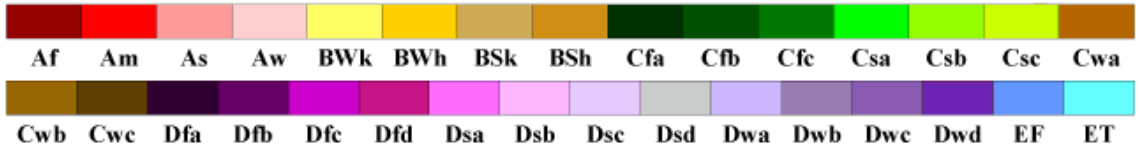


A different view of the thermohaline circulation



World Map of Köppen−Geiger Climate Classification

updated with CRU TS 2.1 temperature and VASClimO v1.1 precipitation data 1951 to 2000



Main climates
- A: equatorial
- B: arid
- C: warm temperate
- D: snow
- E: polar

Precipitation
- W: desert
- S: steppe
- f: fully humid
- s: summer dry
- w: winter dry
- m: monsoonal

Temperature
- h: hot arid
- k: cold arid
- a: hot summer
- b: warm summer
- c: cool summer
- d: extremely continental
- F: polar frost
- T: polar tundra

Resolution: 0.5 deg lat/lon

Version of April 2006

http://gpcc.dwd.de
http://koeppen-geiger.vu-wien.ac.at

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006: World Map of Köppen-Geiger Climate Classification updated. *Meteorol. Z.*, **15**, 259-263.

http://koeppen-geiger.vu-wien.ac.at/

A: **equatorial**: all months above 18°C
B: **arid**
C: **warm temperate**: coldest month > -3°C
D: **snow**: coldest month < -3°, warmest > 10°C
E: **polar**: warmest month < 10°C

W: desert
S: steppe
f: fully humid
s: summer dry
w: winter dry

h: hot arid
k: cold arid
a: hot summer
b: warm summer
c: cool summer
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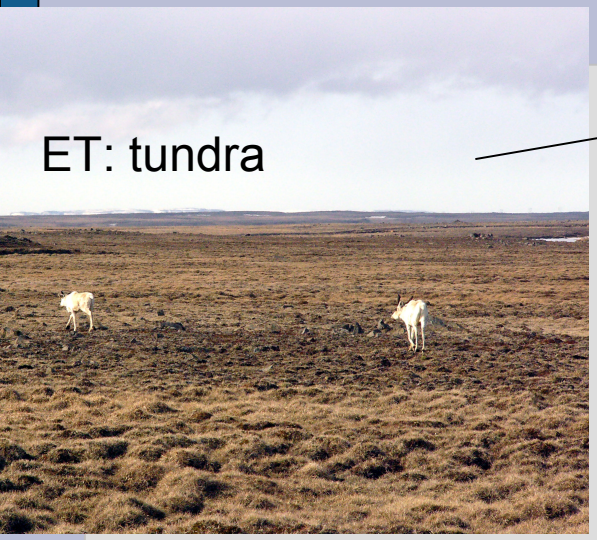
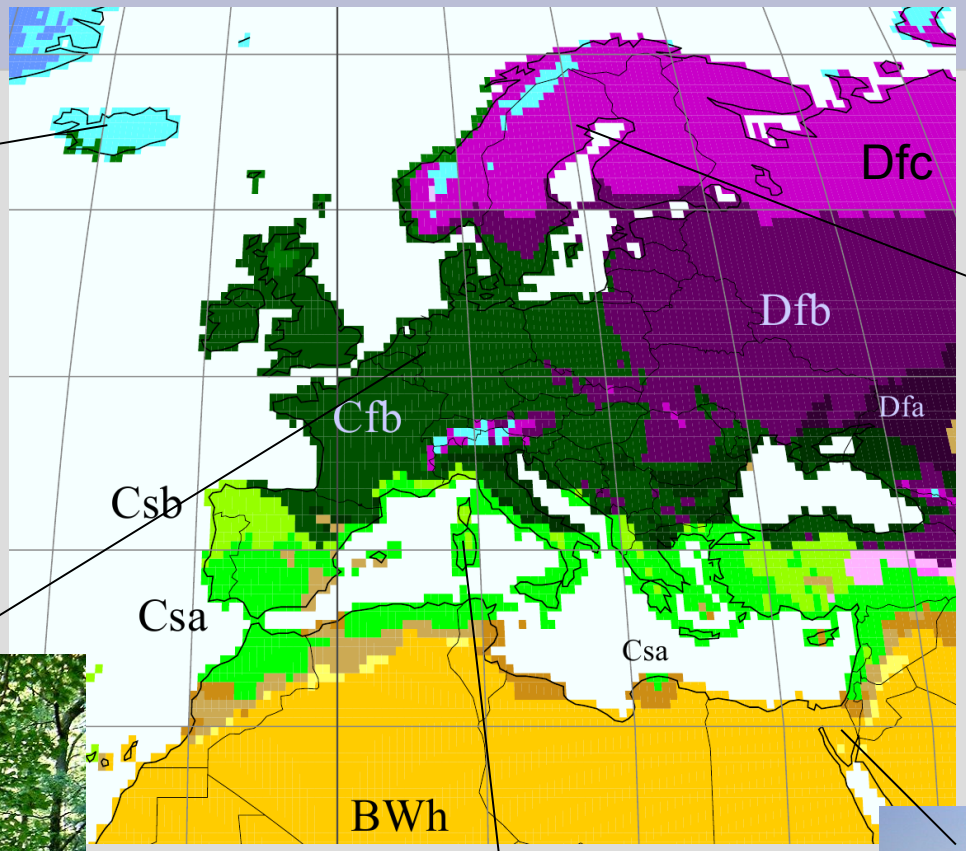
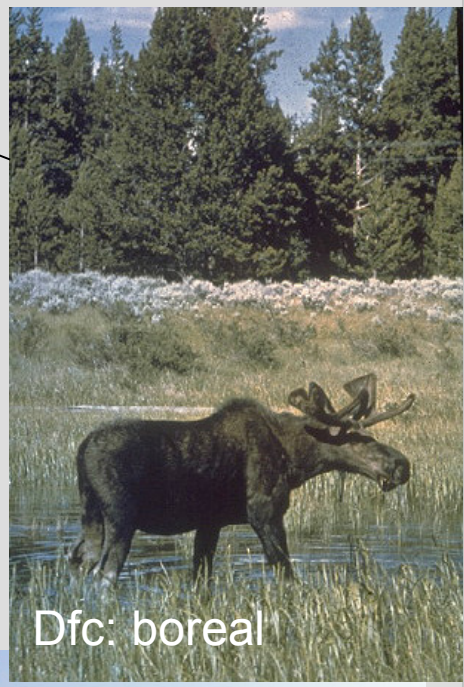
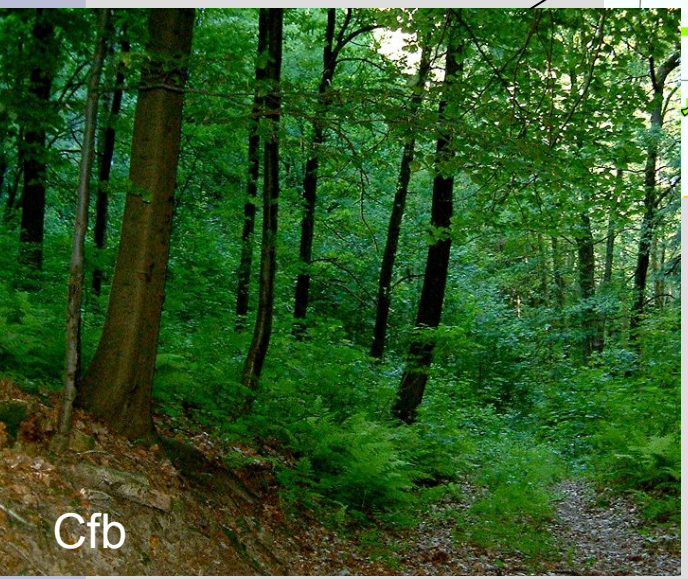
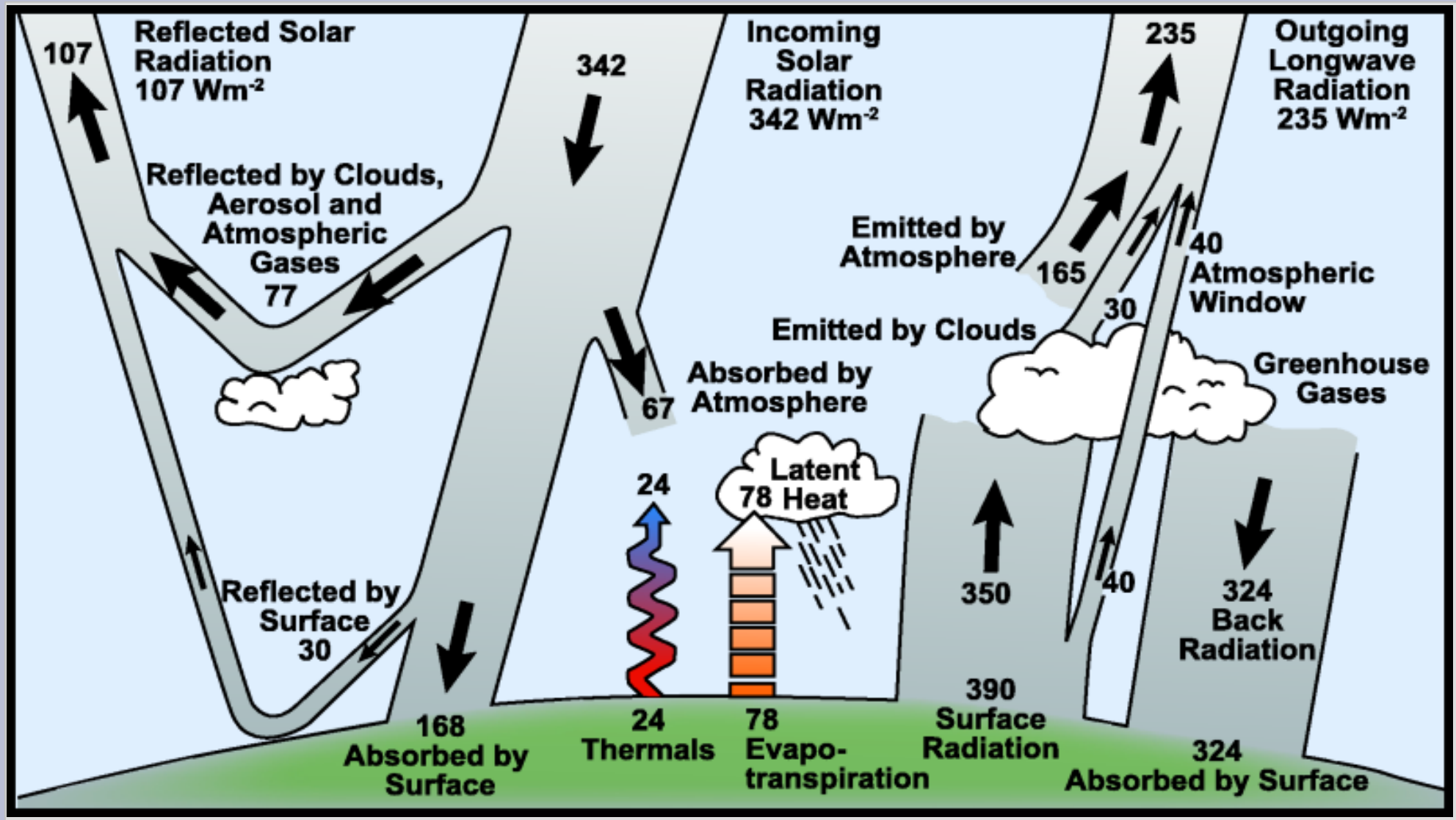






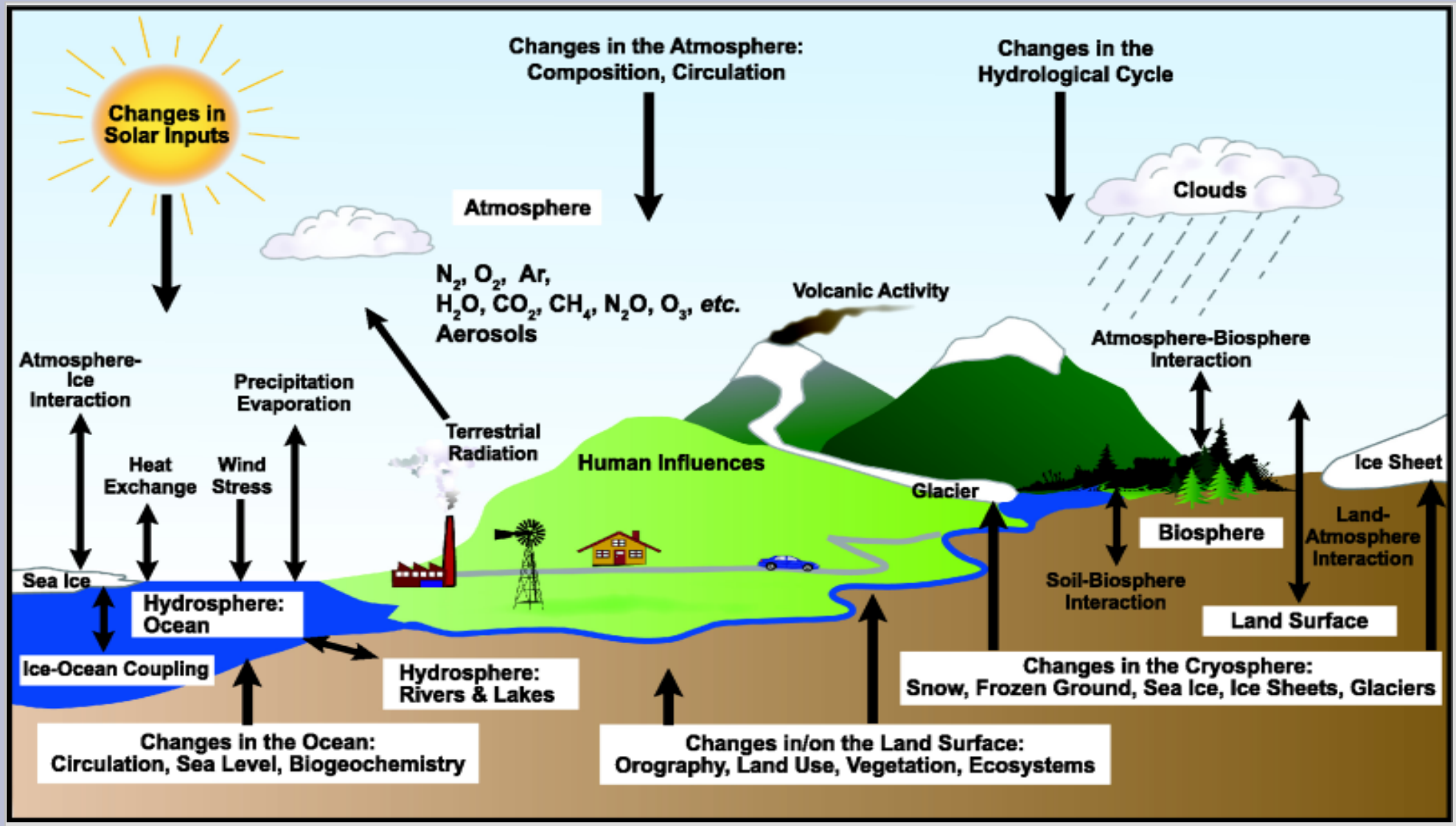


Energy Balance in the Atmosphere



IPCC (2007), p 96.

Factors affecting climate



IPCC (2007), p 104.

Methods for Climate Reconstruction

- Can you think of a method to reconstruct the climate of the past?
- What is the temporal range? How far back in time does this method work?
- What are assumptions and uncertainties?

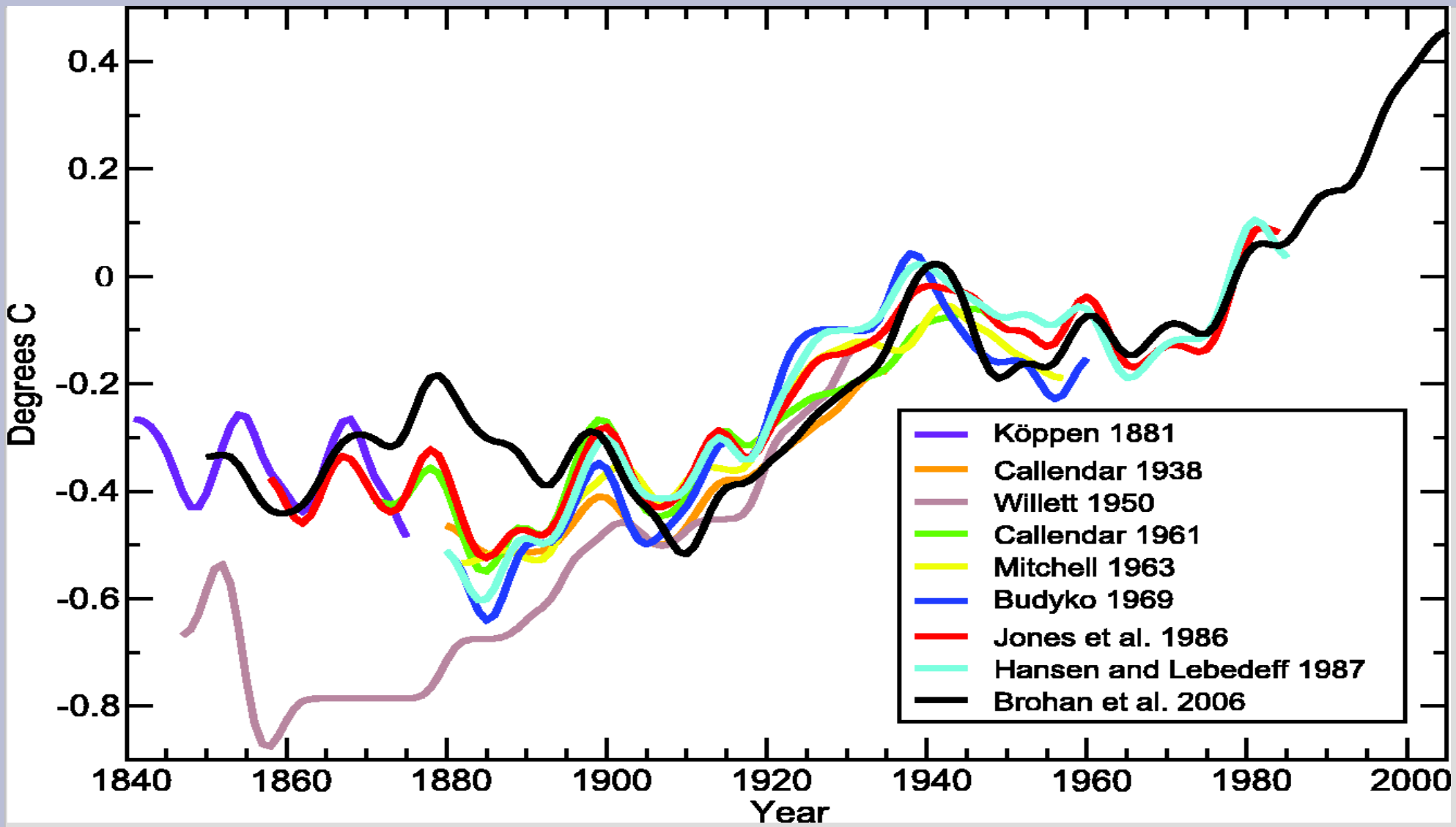
Methods for Climate Reconstruction I

- Instrumental Records
  - Weather stations
  - Ship logs
- Historical Records
- Geomorphological and lithological evidence
  - glacial landforms
  - lake sediments
- Borehole temperature

Methods for Climate Reconstruction II

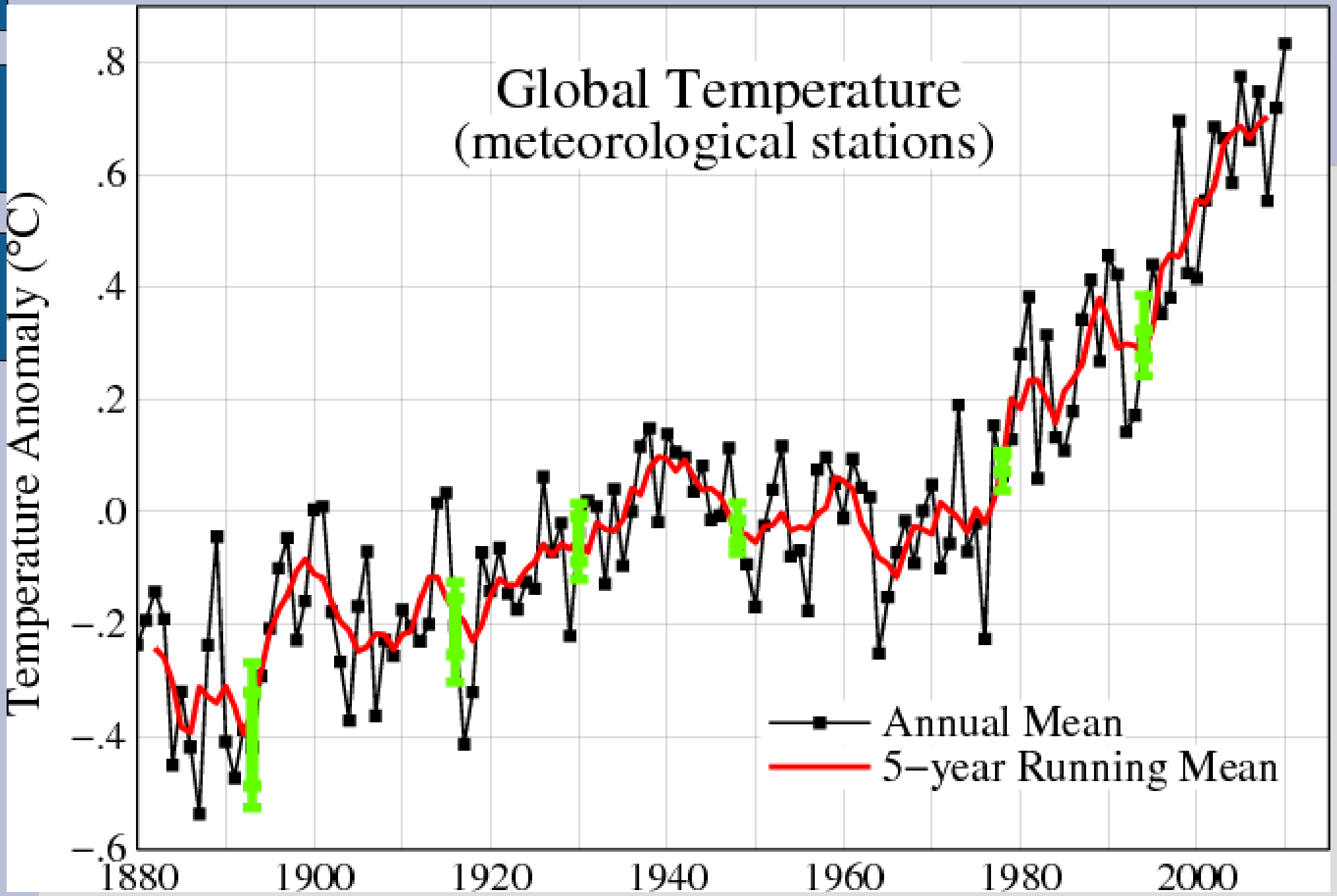
- Biological evidence
  - Tree rings
  - Pollen
  - Macrofossils (also rodents)
  - Insects (particularly in lake sediments)
  - Marine Plancton assemblages (diatoms, foraminifera)
- Geochemistry
  - Isotope methods (oxygen isotope)
  - from ice cores and (marine) sediment cores

Instrumental Records



IPCC (2007), p 101.

Instrumental Records



GISSTEMP (http://data.giss.nasa.gov/gistemp/graphs_v3/, downloaded 19 Jan 2012)

Glaciers

80°N Franz Josef Land

78°N Svalbard

69°N Northern Scandinavia

60°N Southern Scandinavia

68°N Brooks Range

49°N-52°N Canadian Cordillera

46°N Alps

28-38°N Himalaya & Karakorum

0.6°S Mt. Kenya

45°S New Zealand

12 11 10 9 8 7 6 5 4 3 2 1 0

Time (ka)

Glaciers shorter than at the end of 20th century

Glaciers longer than at the end of 20th century

Continuous records

Discontinuous records

Unknown extent of retreated glaciers

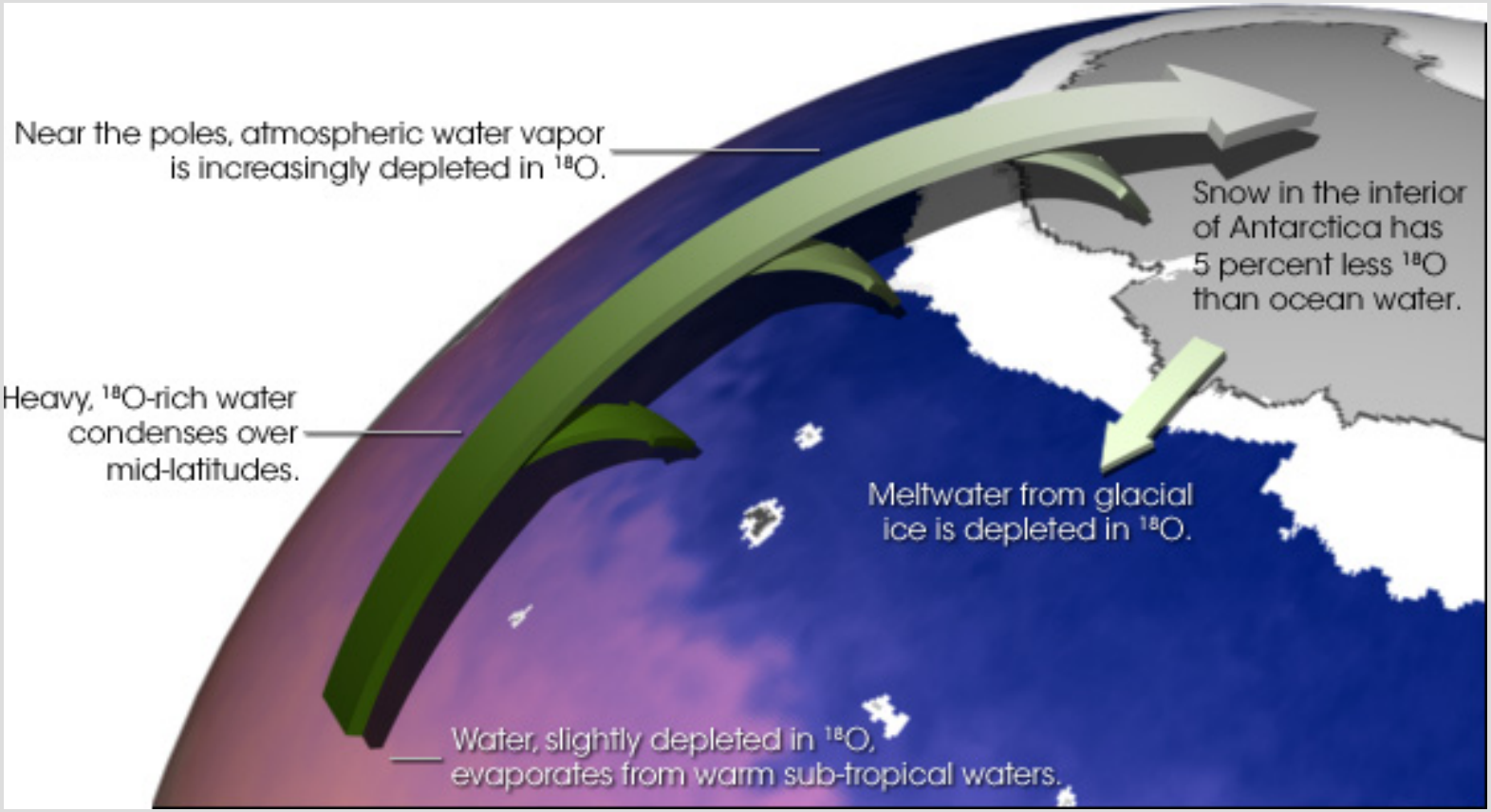
Retreated glaciers:

Direct evidence (organic material buried under glacier)

Indirect evidence (wood upper the modern tree limit, buried soils etc.)

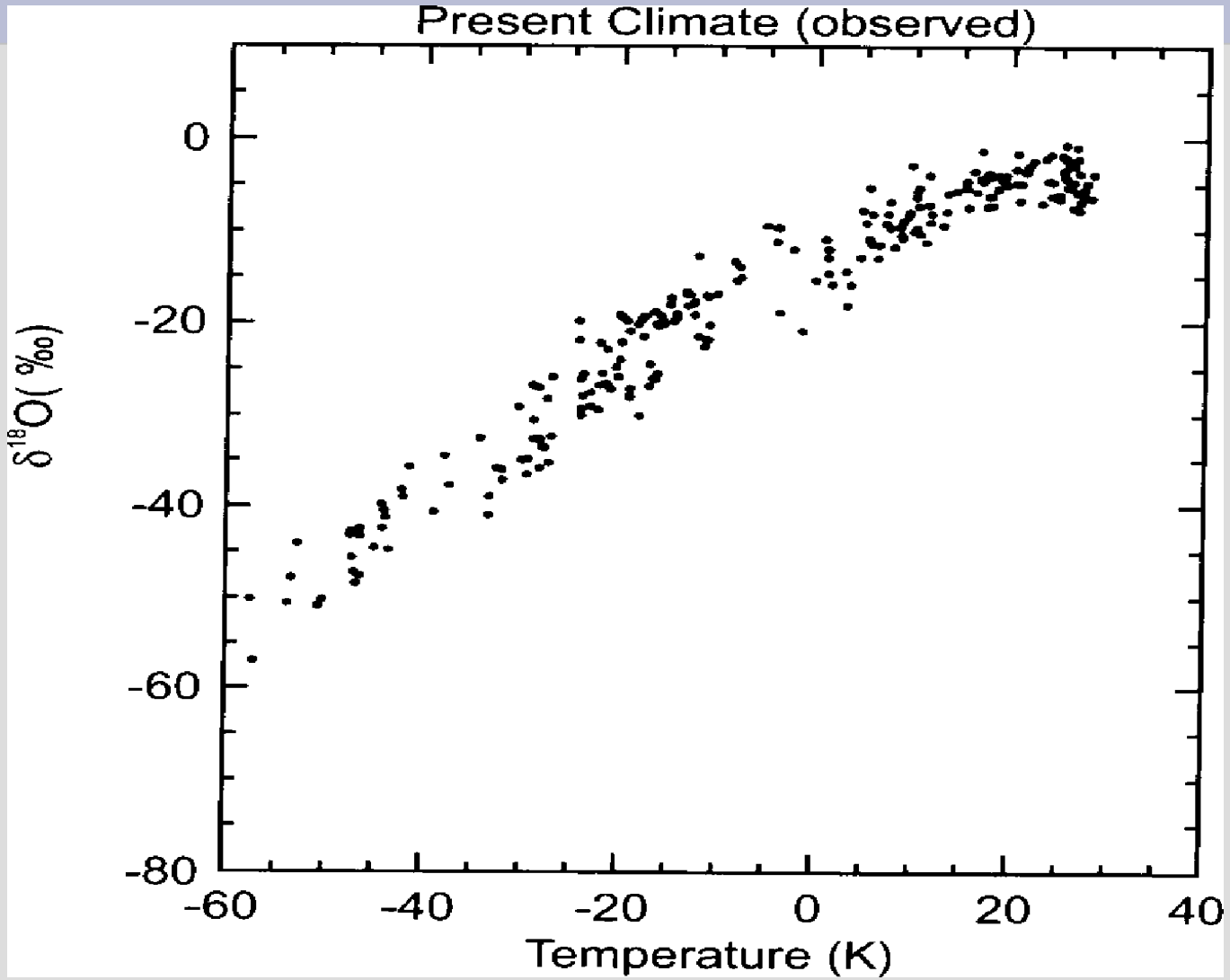
Oxygen isotope method

- Fractionation (temperature dependent:
  more fractionation at lower temperatures)
- Isotopes bound in ice sheets change global distribution



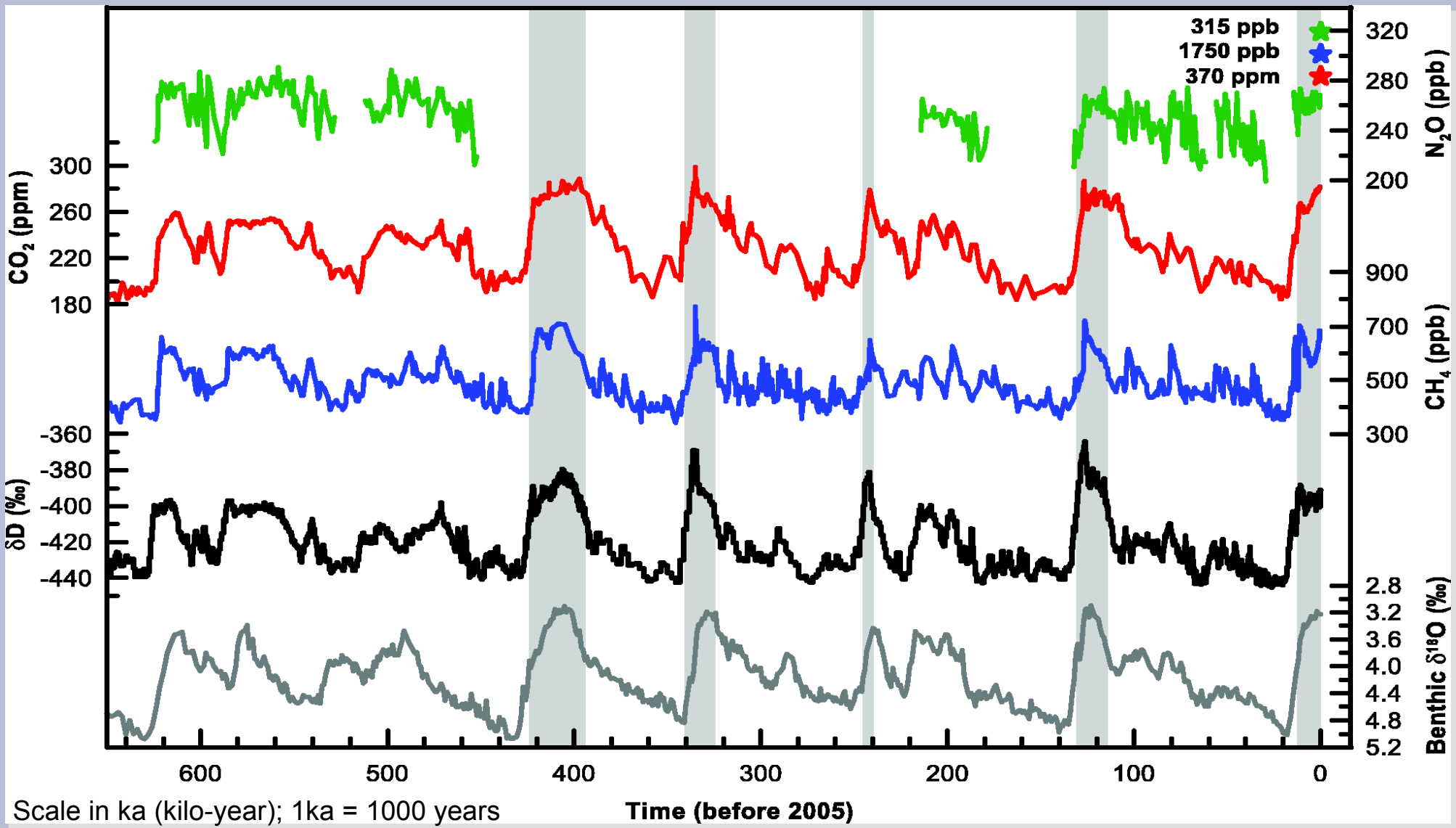
http://earthobservatory.nasa.gov/Features/Paleoclimatology_OxygenBalance/

Oxygen isotope method



Relation between oxygen isotope ratio in snow and mean annual temperature at the same site (from Bradley 1999, p. 134)

Ice Cores

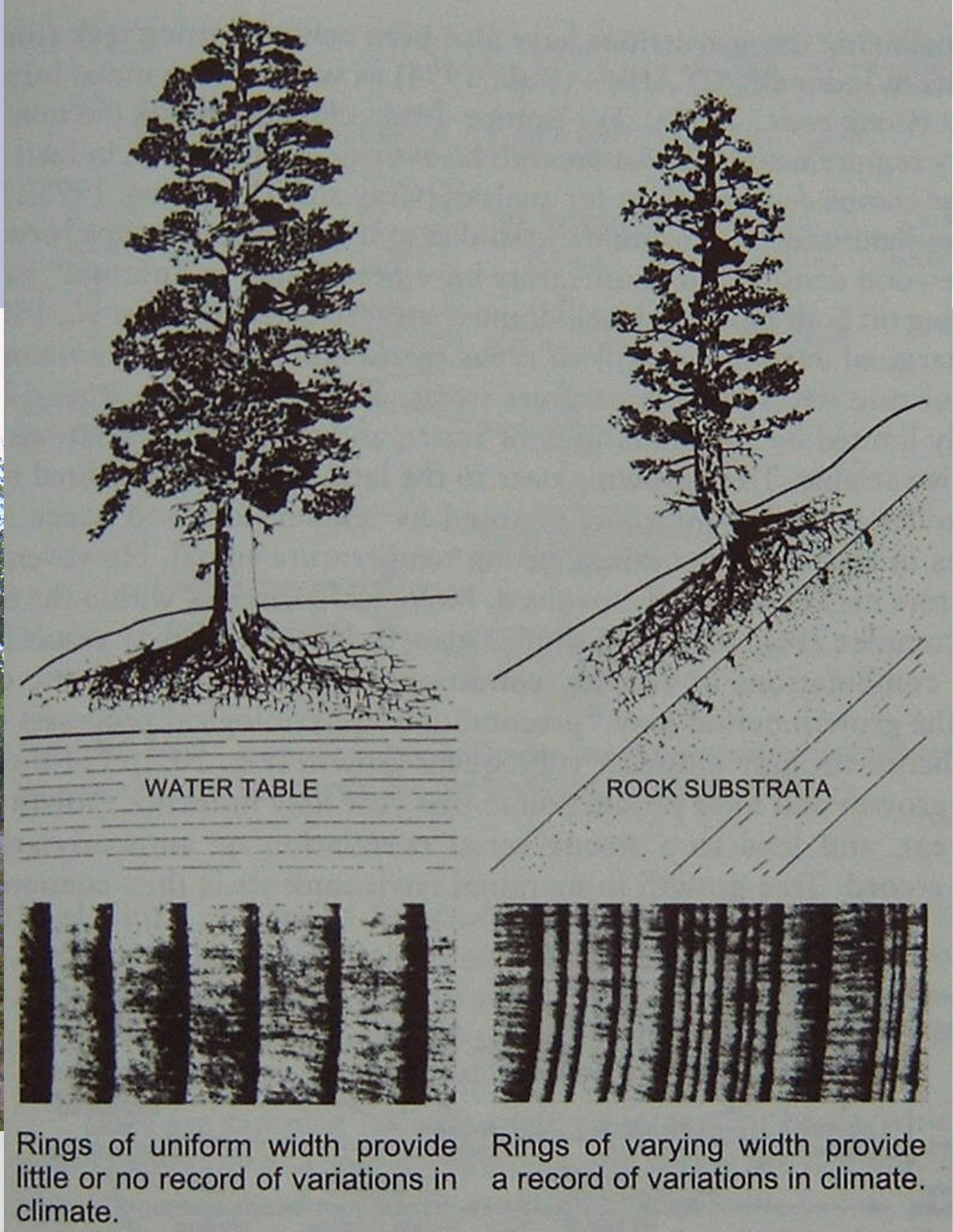


Scale in ka (kilo-year); 1ka = 1000 years

IPCC (2007), p 444.

Tree ring (Dendro-climatology)

Bradley (1999): Paleoclimatology, p. 401



Rings of uniform width provide little or no record of variations in climate.

Rings of varying width provide a record of variations in climate.

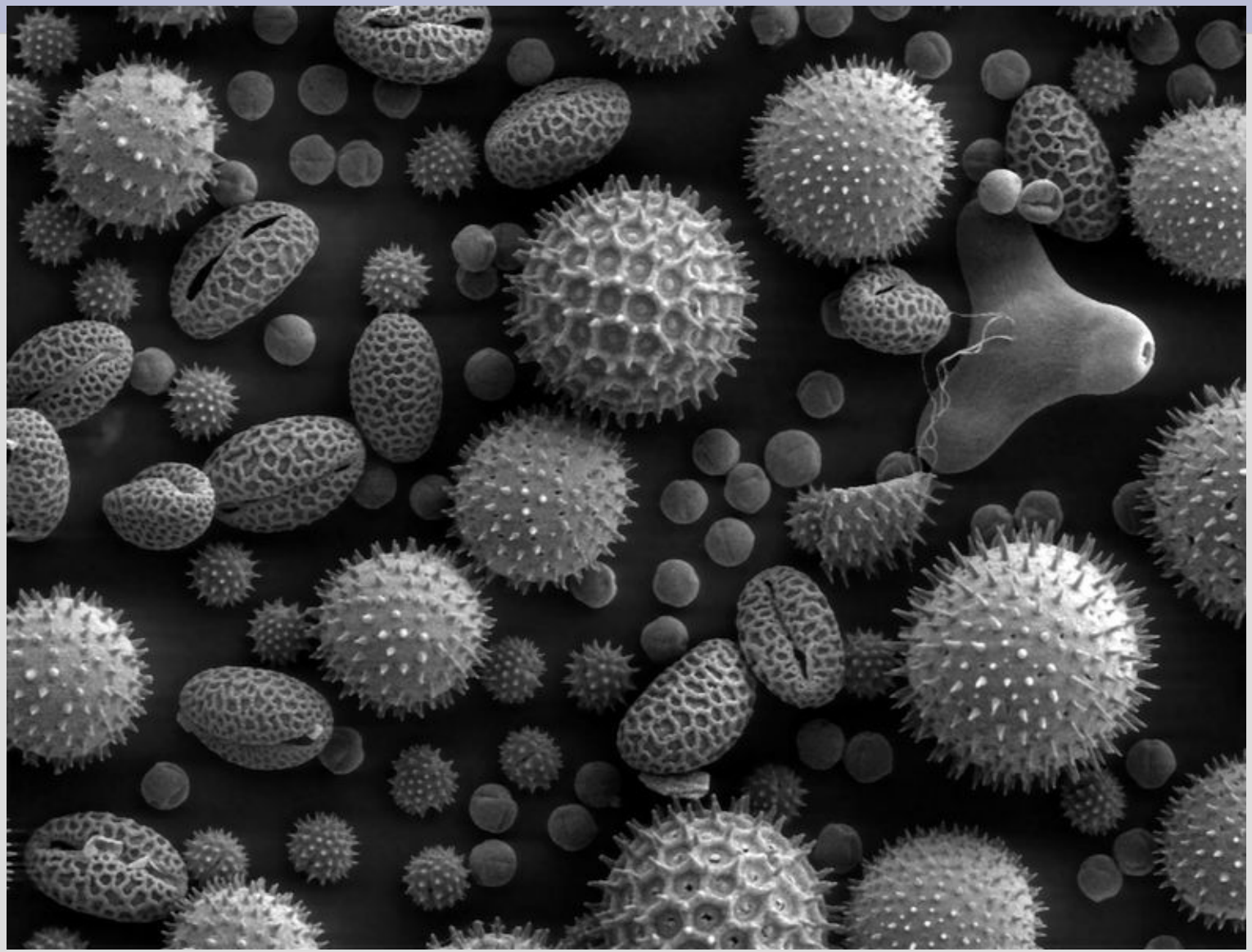
Tree ring data (Dendroclimatology)

Confounding factors:

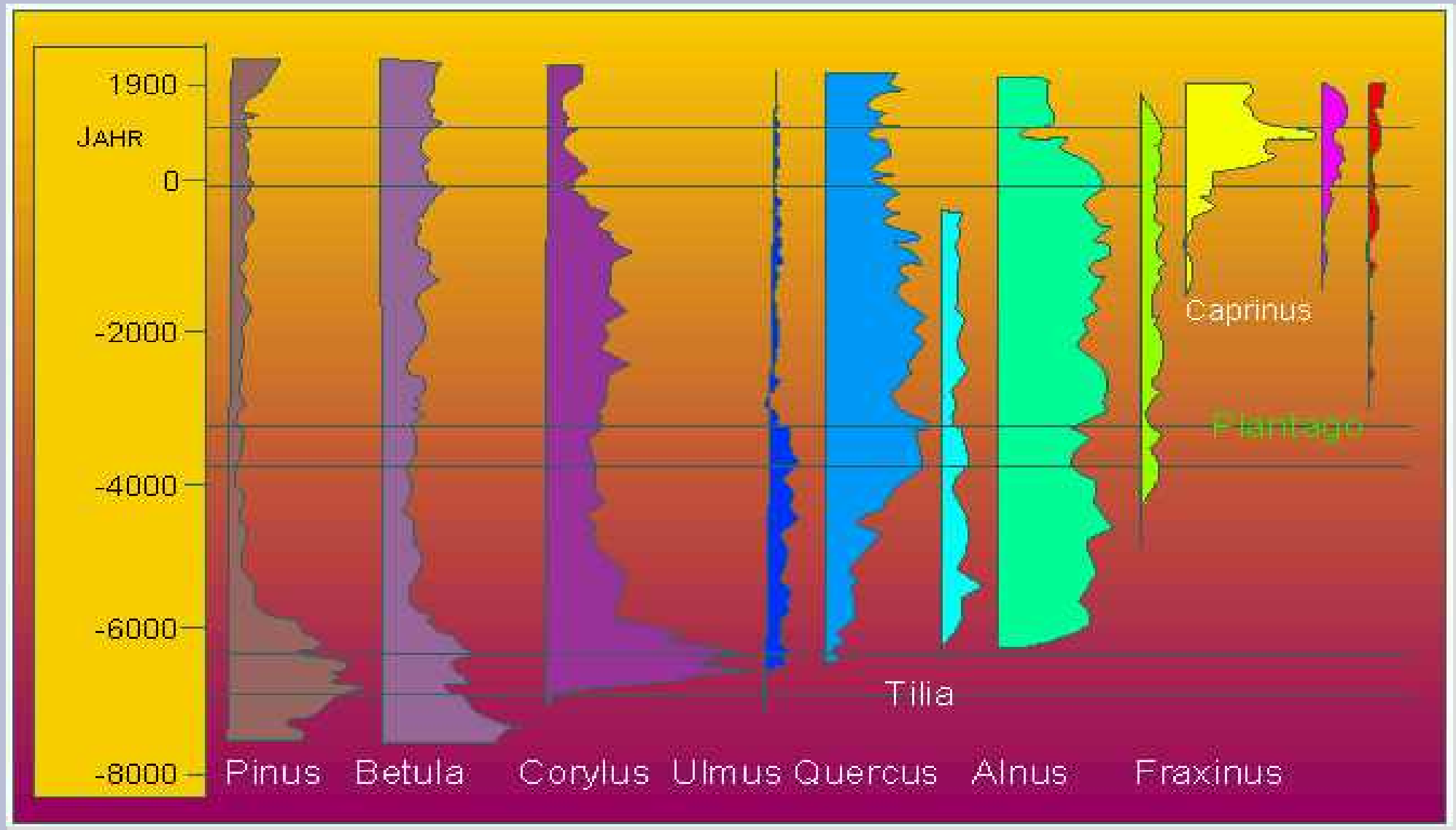
- Climate factors
  - Temperature
  - Precipitation
  - Sunlight
  - Wind
- Soil
- Tree age
- Disease, Disturbances, herbivore impact

Bradley: Paleoclimatology, p. 7.

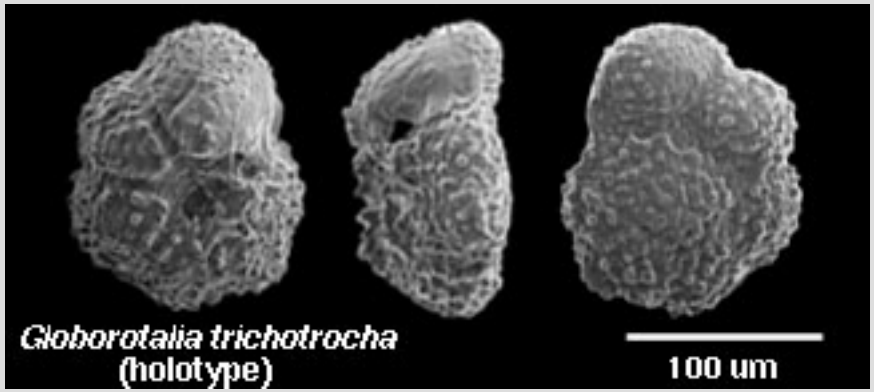
Palynology (pollen analysis)

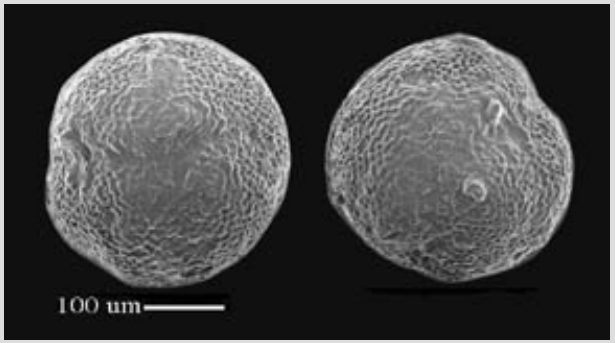


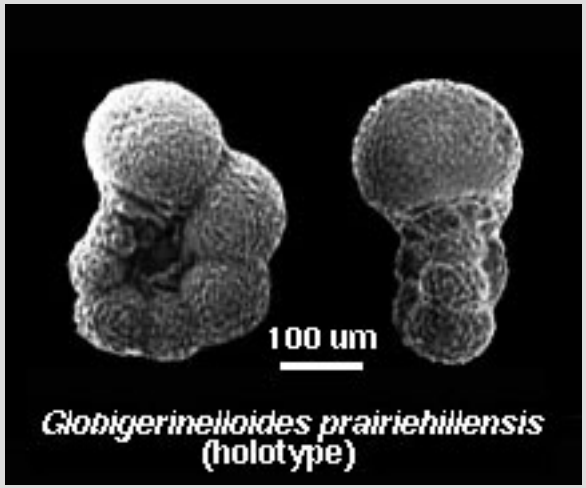
Palynology (pollen analysis)

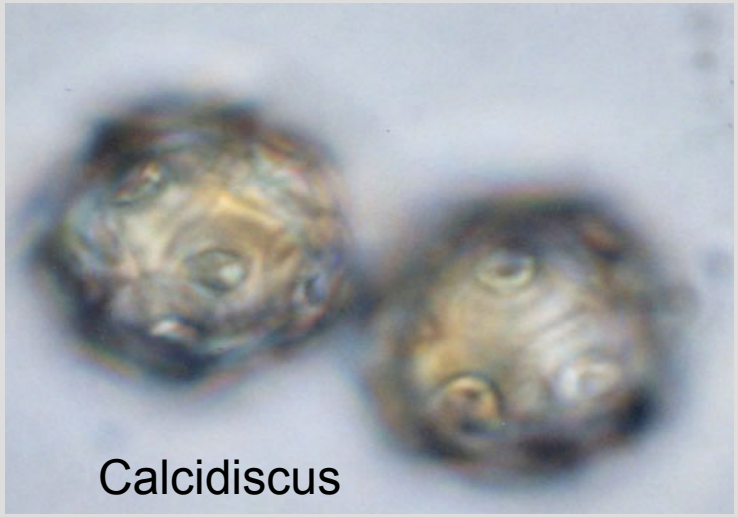


Plancton faunal assemblages

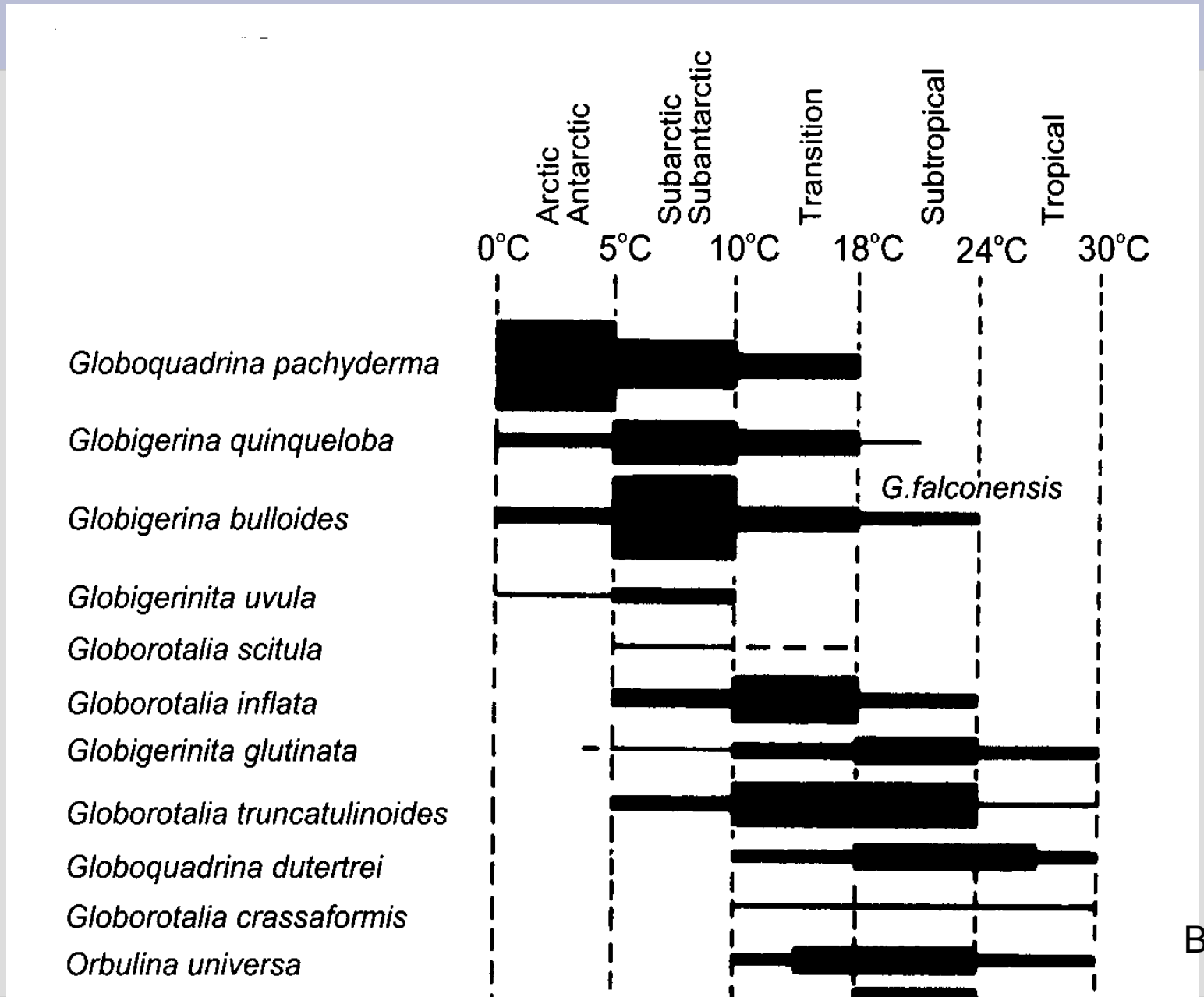








Plancton assemblages



Bradley, p 198

Ocean drilling

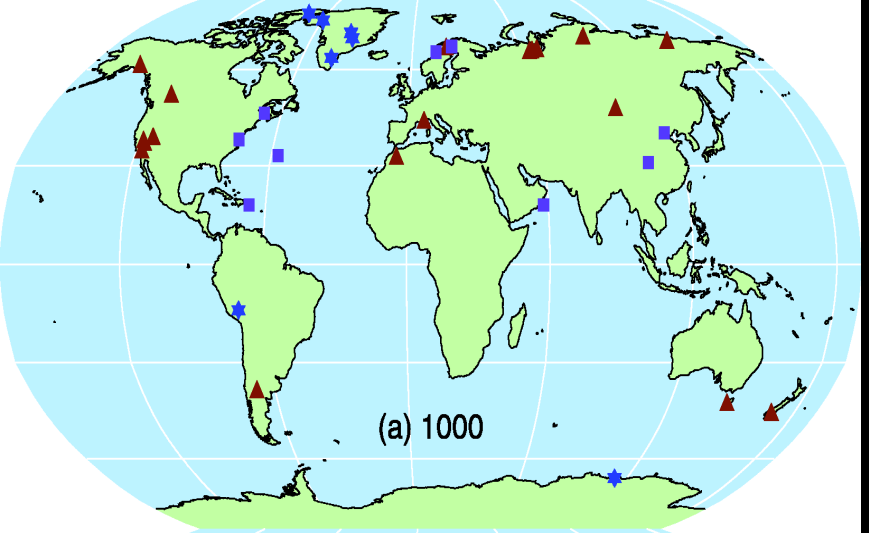
Drilling for sediment cores

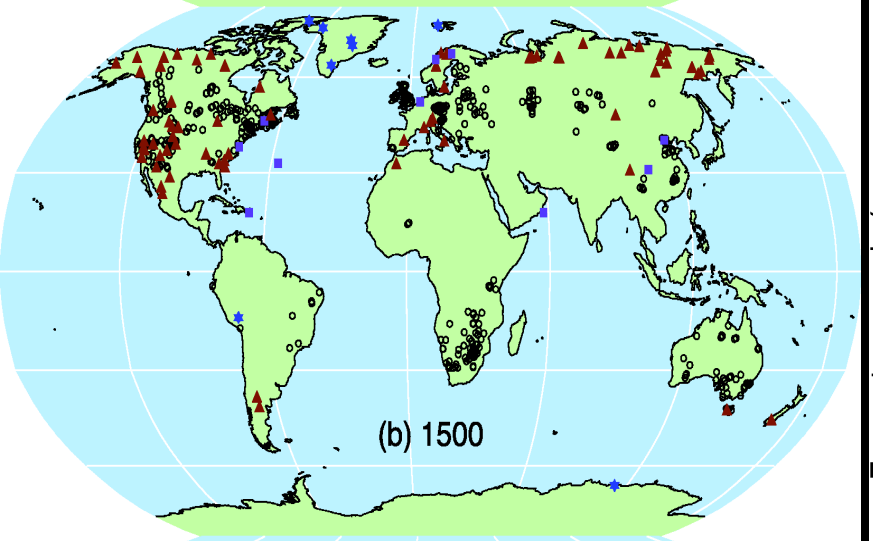
Sediment cores

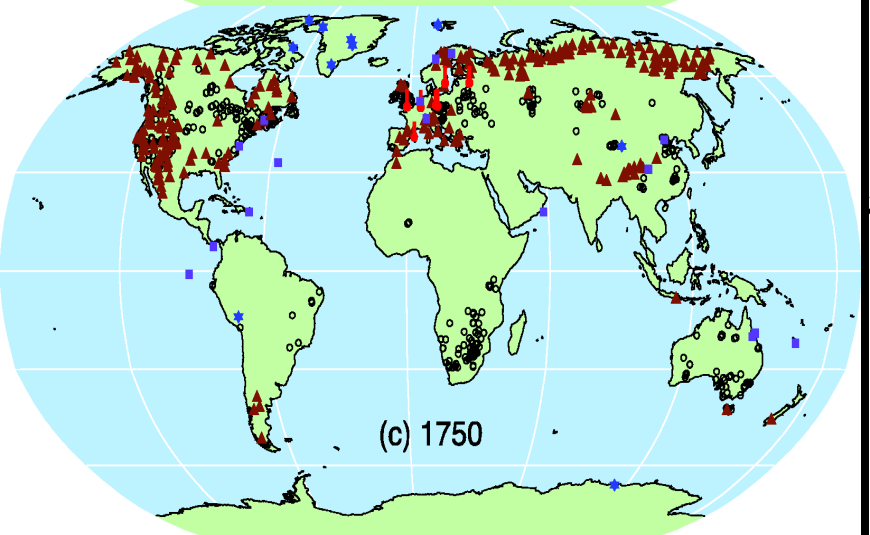
Analysing the sediment core

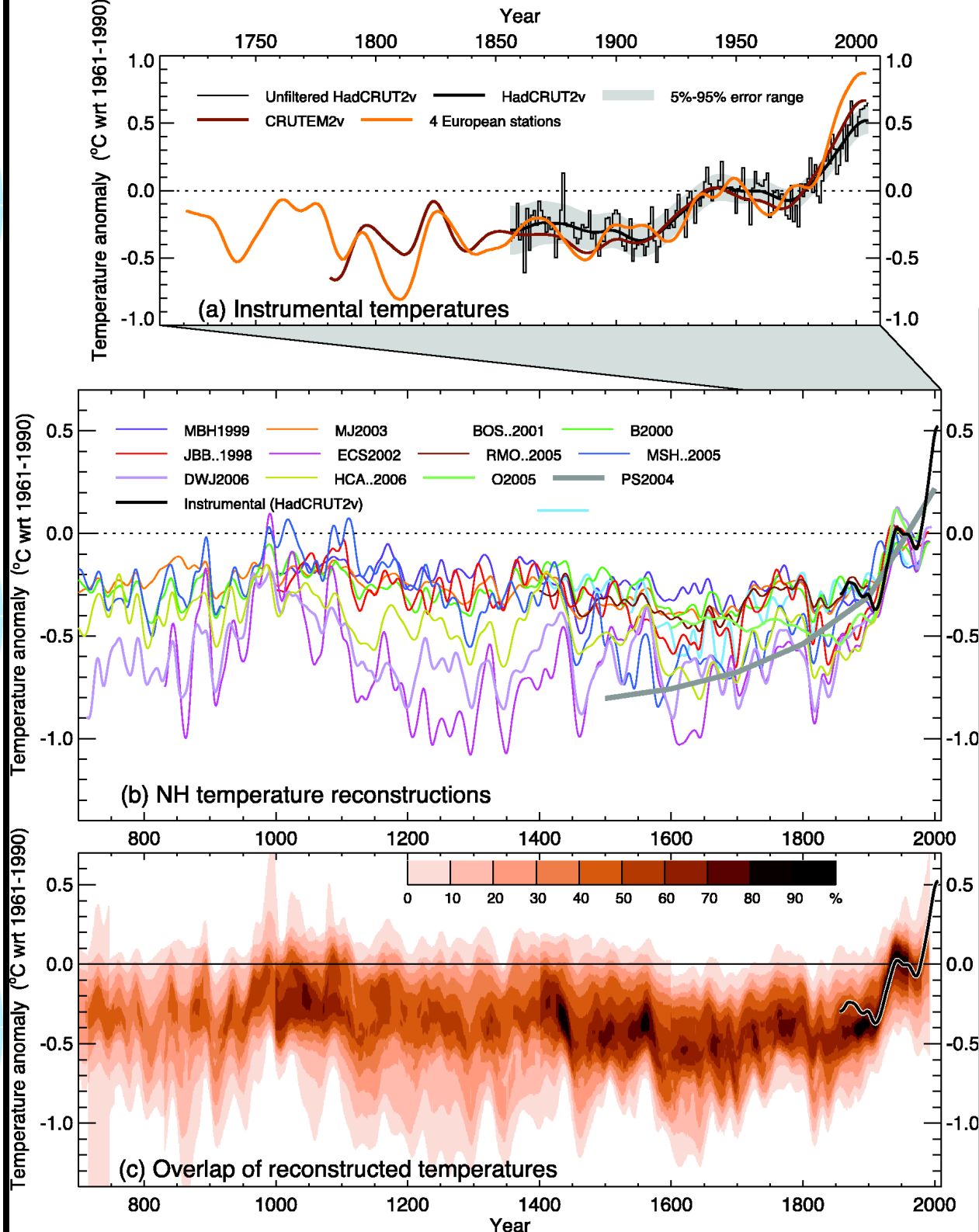
Climate Reconstruction

- 1000 years
- Multi-proxy:
  - Instrumental (red)
  - Tree rings (brown triangles)
  - Ice cores (blue stars)
  - Boreholes (black circles)
  - Other (purple squares)


(a) 1000


(b) 1500


(c) 1750


Year
1750
1800
1850
1900
1950
2000
Temperature anomaly (°C wrt 1961-1990)
Unfiltered HadCRUT2v
HadCRUT2v
5%-95% error range
CRUTEM2v
4 European stations
(a) Instrumental temperatures
MBH1999
MJ2003
BOS..2001
B2000
JBB..1998
ECS2002
RMO..2005
MSH..2005
DWJ2006
HCA..2006
O2005
PS2004
Instrumental (HadCRUT2v)
(b) NH temperature reconstructions
0
10
20
30
40
50
60
70
80
90
%
(c) Overlap of reconstructed temperatures
800
1000
1200
1400
1600
1800
2000
Year

Literature

- IPCC (2007): Fourth Assessment Report. (available at http://www.ipcc.ch/)
- Bradley (1999): Paleoclimatology. Academic Press.
- Lowe, Walker (1997): Reconstructing Quaternary Environments. Longman.
- General reading on weather and climate: Eyewitness companion “Weather”, Dorling-Kindersley, 2008.