Climate change and agriculture

Luigi Mariani

Università degli Studi di Milano

Dipartimento di Produzione Vegetale

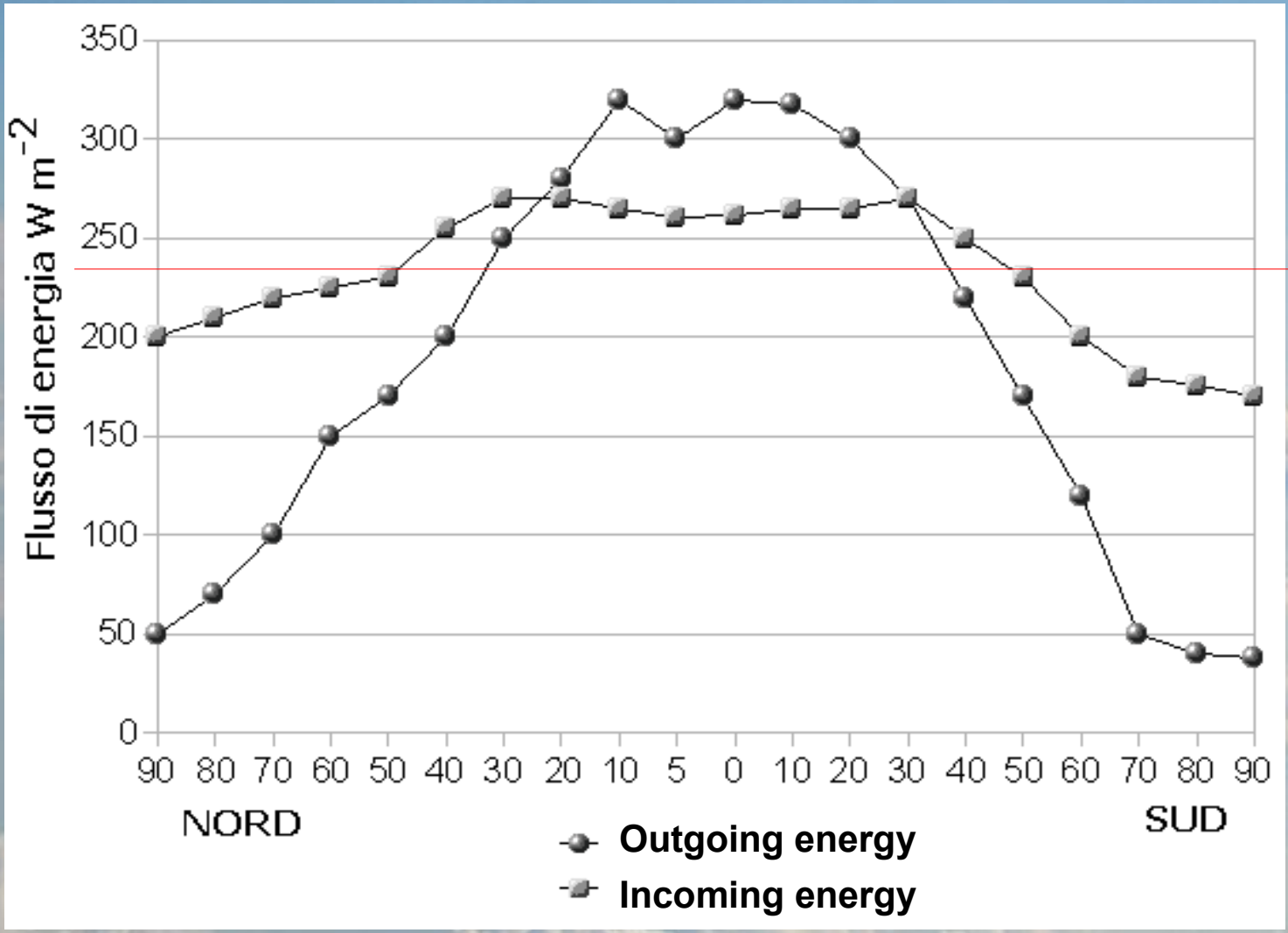
CNR Imati, 24-25 february 2011

Climate change

climate change is any systematic change in the long-term statistics of climate elements (such as temperature, pressure, or winds) sustained over several decades or longer (source: AMS glossary).

Climate variability is one of the main features of the climate system

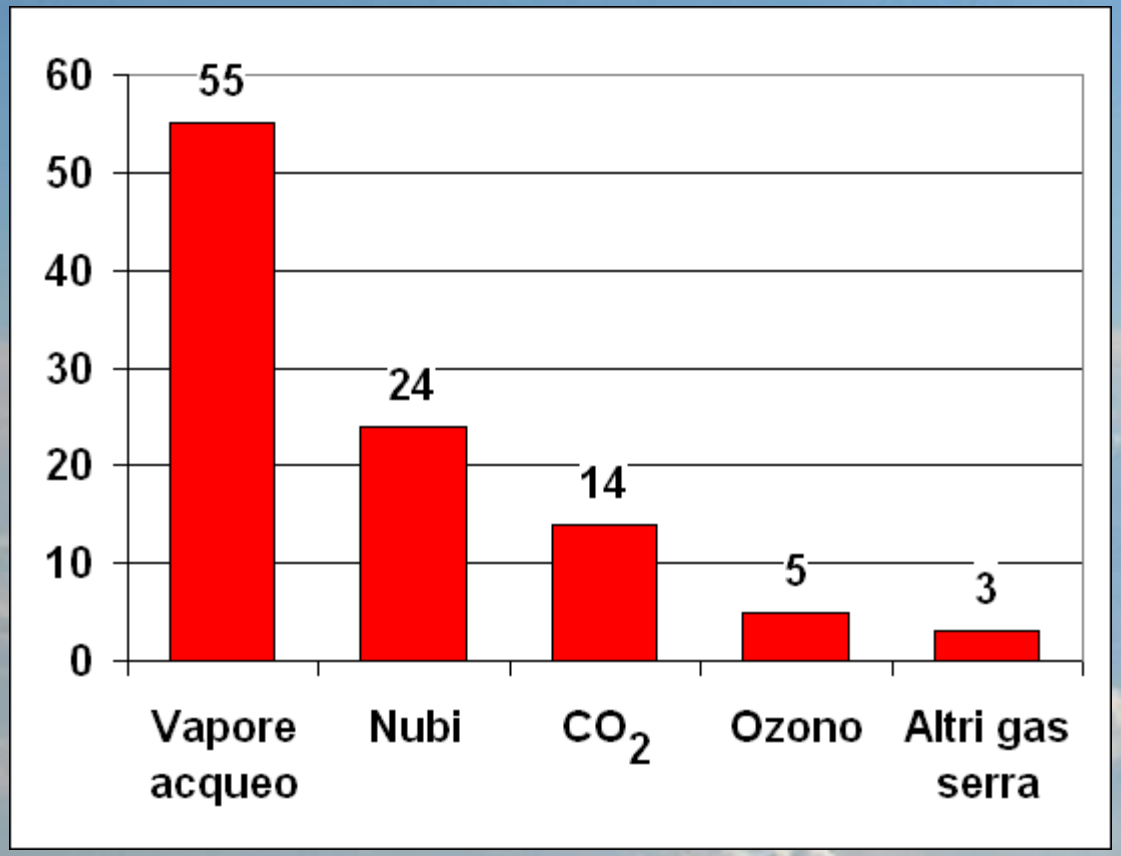
Energetic synthesis of the climate system (compact and effective)



235 W m^{-2}

Mean value of income and outgoing energy (1th principle of th.dyn.)

Greenhouse effect

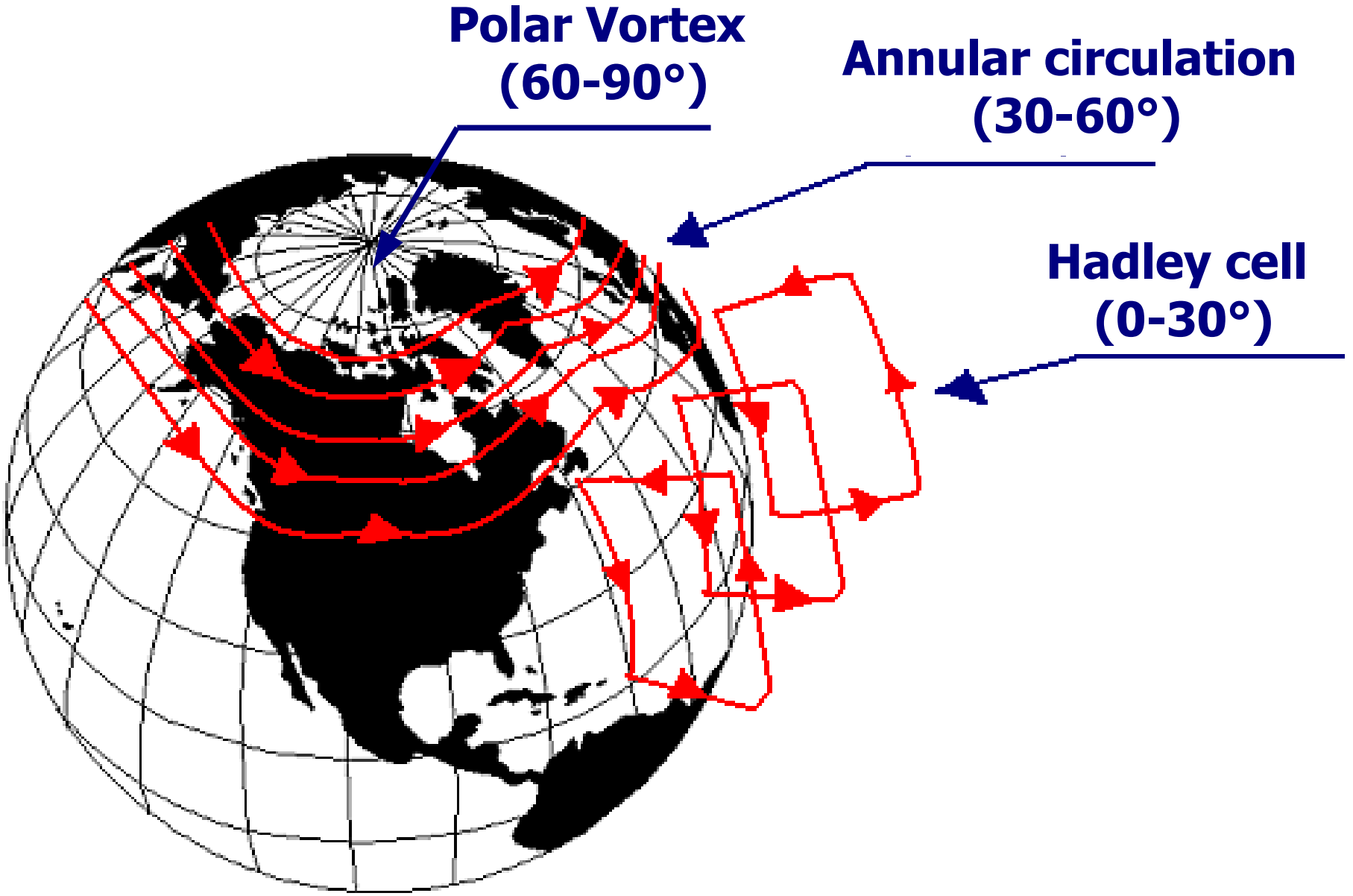


% of longwave radiation intercepted by atmospheric components

Sources

Schmidt G., 2005. Water vapour: feedback or forcing?-http://www.realclimate.org/index.php?p=142
Ramanathan, V., and J. A. Coakley, 1978: Climate modeling trough radiative-convective models. Rev. Geophys. Space Phys., 16, 465-489.

Overall scheme of general circulation



General circulation using clouds as tracers

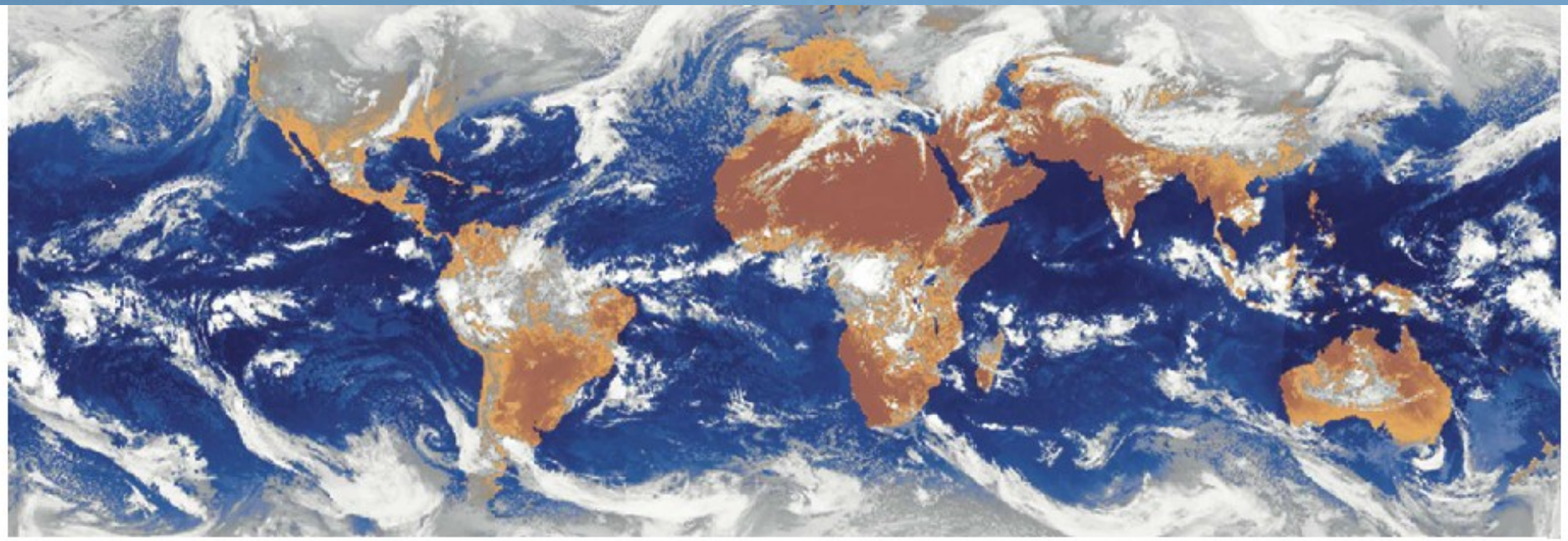
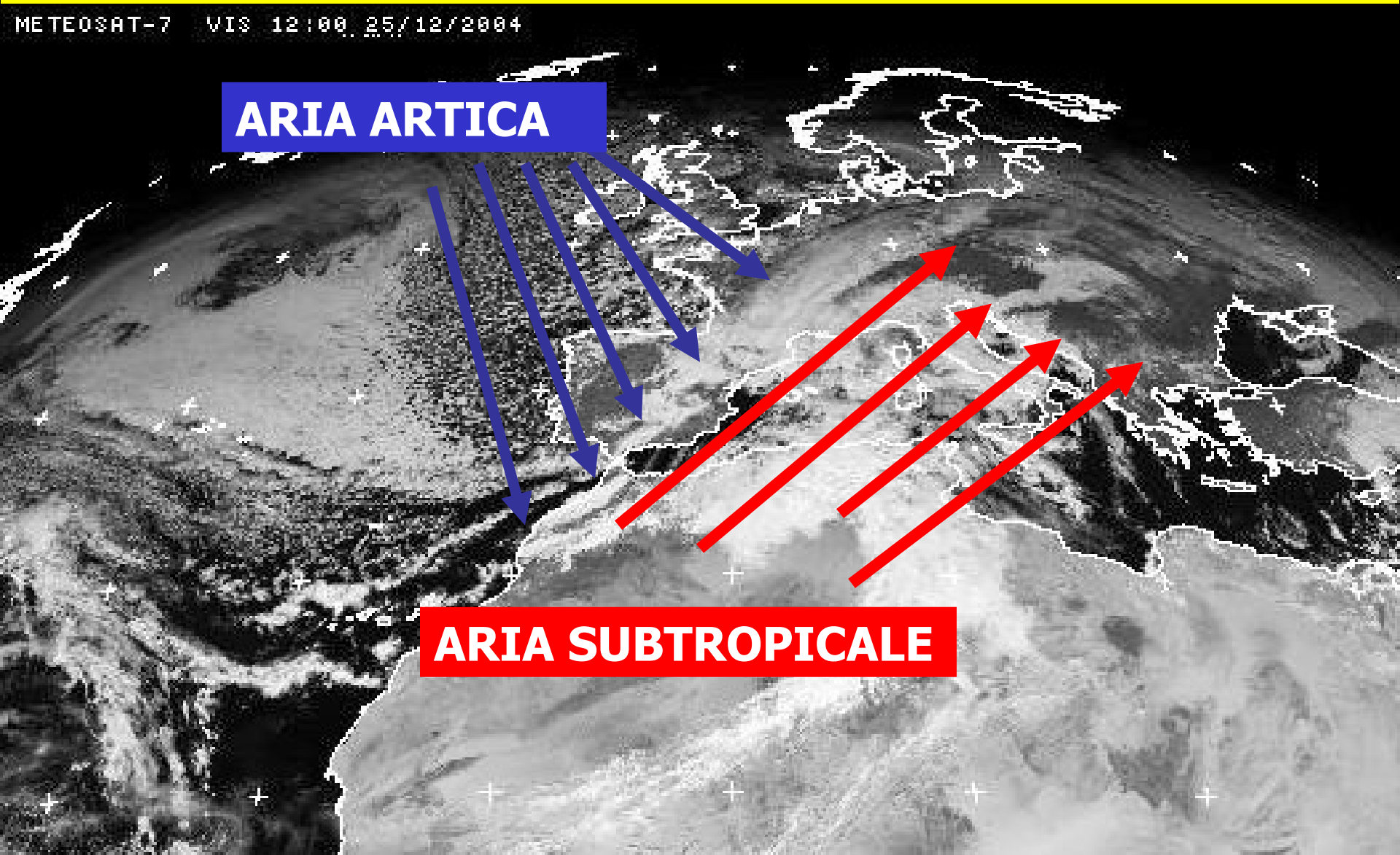


FIG. 2. Composite of instantaneous infrared imagery from geostationary satellites (at 1200 UTC 29 Mar 2004) showing the contrast between the large-scale organization of the atmosphere and of the cloudiness in the Tropics and in the extratropics. [From SATMOS (©METEO-FRANCE and Japan Meteorological Agency).]

Tropical area: a very active convective zone near the equator
Mid latitudes: frontal systems with a West-East field of motion (annular circulation alias westerlies)

Annular circulation and energy exchange between low and high latitudes

Meteosat visibile 25 dicembre 2004 h 12 UTC



Mean state of annular circulation and blocking

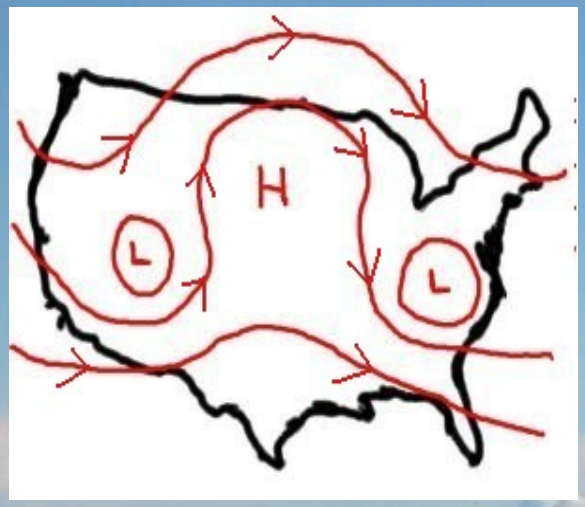
The mean state of mid latitudes annular circulation is **zonal** (from west to east - slowly ondulated)

Blocking = deviations from this dominant regime due to cyclonic or anticyclonic areas that block the westerly flow,

Blokings can persist for days / weeks /months.

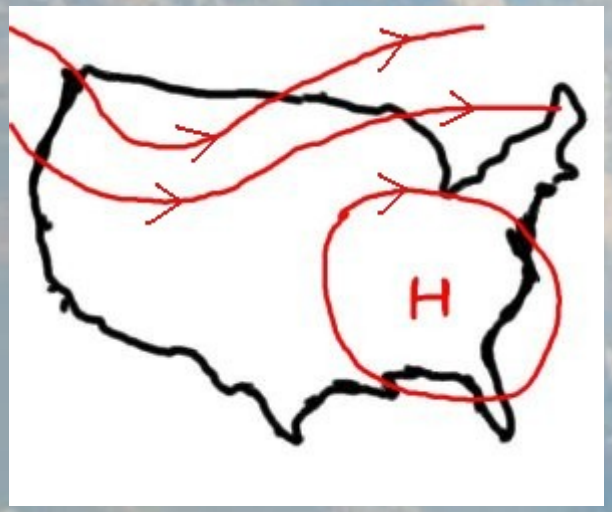
Blocking weather patterns

Zonal (mean) regime



Omega block

Inverse S shaped
(Rex block)



Cutoff High

Cutoff low

Split flow

Source: Jeff Haby - http://www.theweatherprediction.com/blocking/

blockings climatology and extreme events

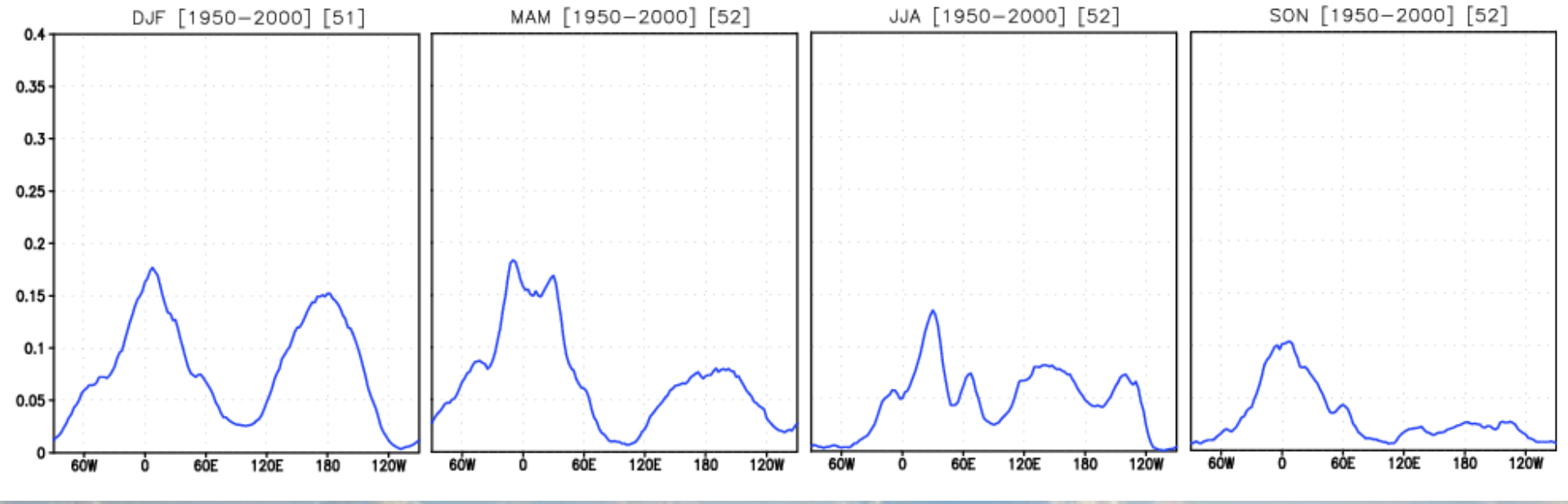
Blockings climatology (frequency and persistence) is strictly related to severe weather anomalies like:

- hot outbreaks (e.g.: European hot wave of 2003)
- cold outbreaks (e.g.: European cold winters 1929,1956,1985)
- persistent rainfalls (e.g.: Florence flloding of 1966)
- droughts (eg: dust bowl of '30 years in Usa)

Dust bowl in USA (1935)

Summer floods in UK (2008)

Boreal hemisphere: frequency of blockings

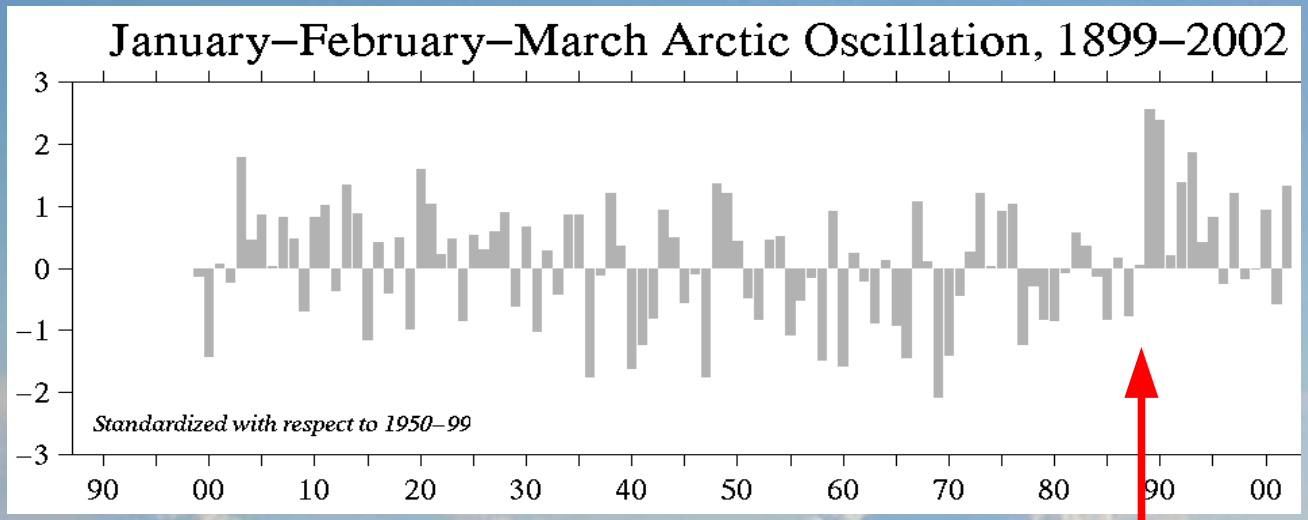


Using the blocking index of Tibaldi and Molteni (1990) we can consider the frequency of "blocked days" for each of the four traditional seasons (DJF, MAM, JJA, SON) for the northern hemisphere for the period 1950 to 2000.

Analysis carried out on NCEP Ncar reanalysis

source: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/blocking/seasonal_nh/seasonal_nh.shtml

Long time evolution of zonal regime the abrupt change of '80

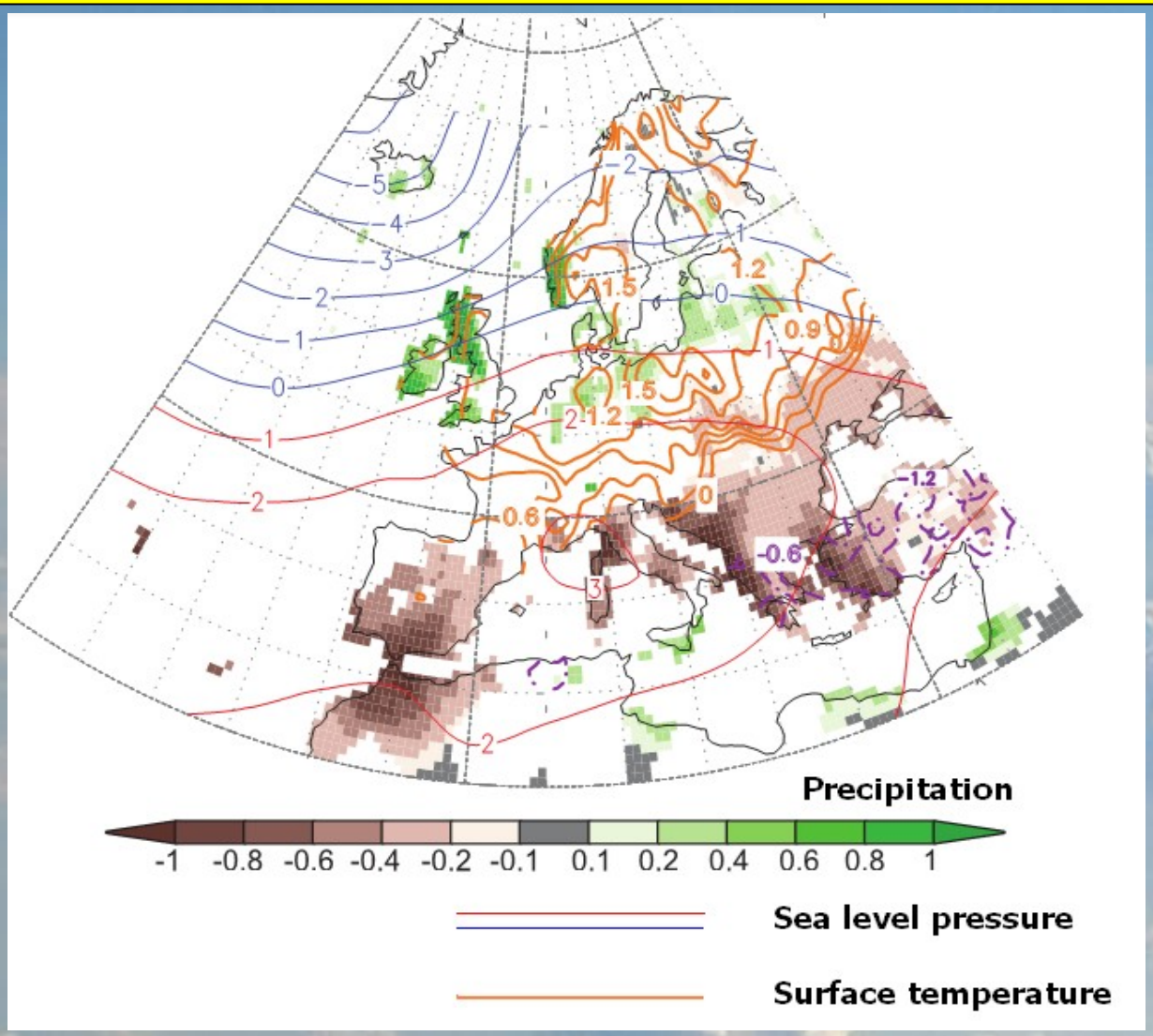


http://www.jisao.washington.edu/ao/

Long time behaviour of annular circulation can be described by indexes bases on atmospheric pressure distributions.

AO and Nao: circulation indexes adopted to describe behaviour of zonal circulation in the North hemisphere.
An abrupt AO (and Nao) change of phase was observed at the end of the '80 with strengthening of zonal regime.

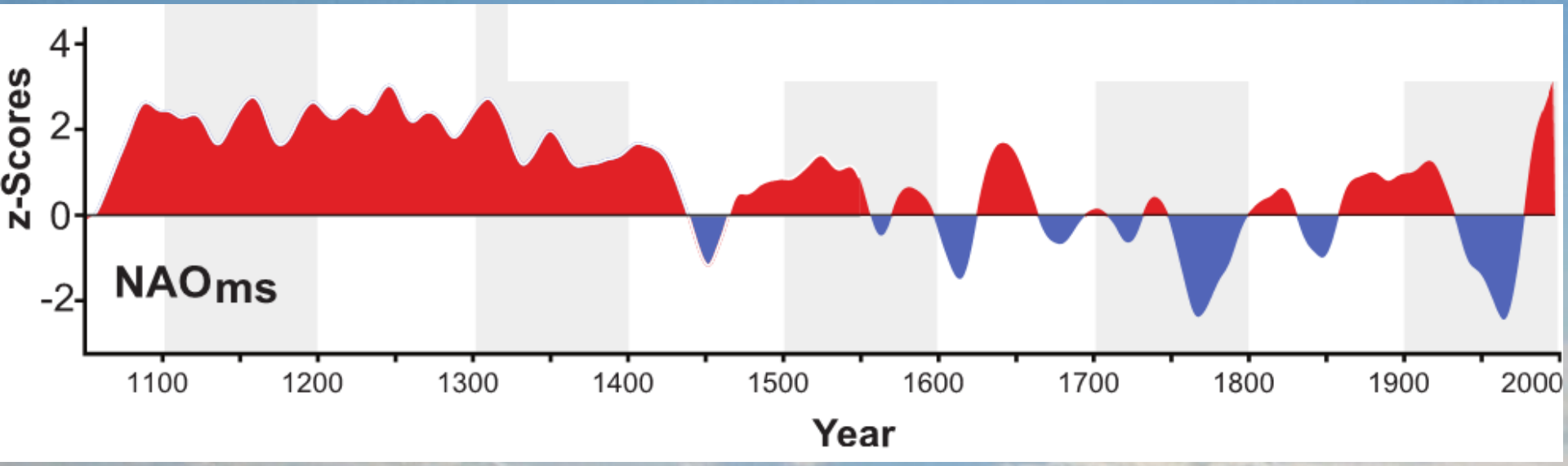
NAO positive phases
Effects on the Euro-Mediterranean area



Anomalies in SLP, temperarure and precipitation obtained from proxies and instrumental data referred to 1659-1995 period

Source - Trouet et al., 2009. Persistent Positive North Atlantic Oscillation Mode Dominated the Medieval Climate Anomaly, Science, 3 april 2009, Vol 324

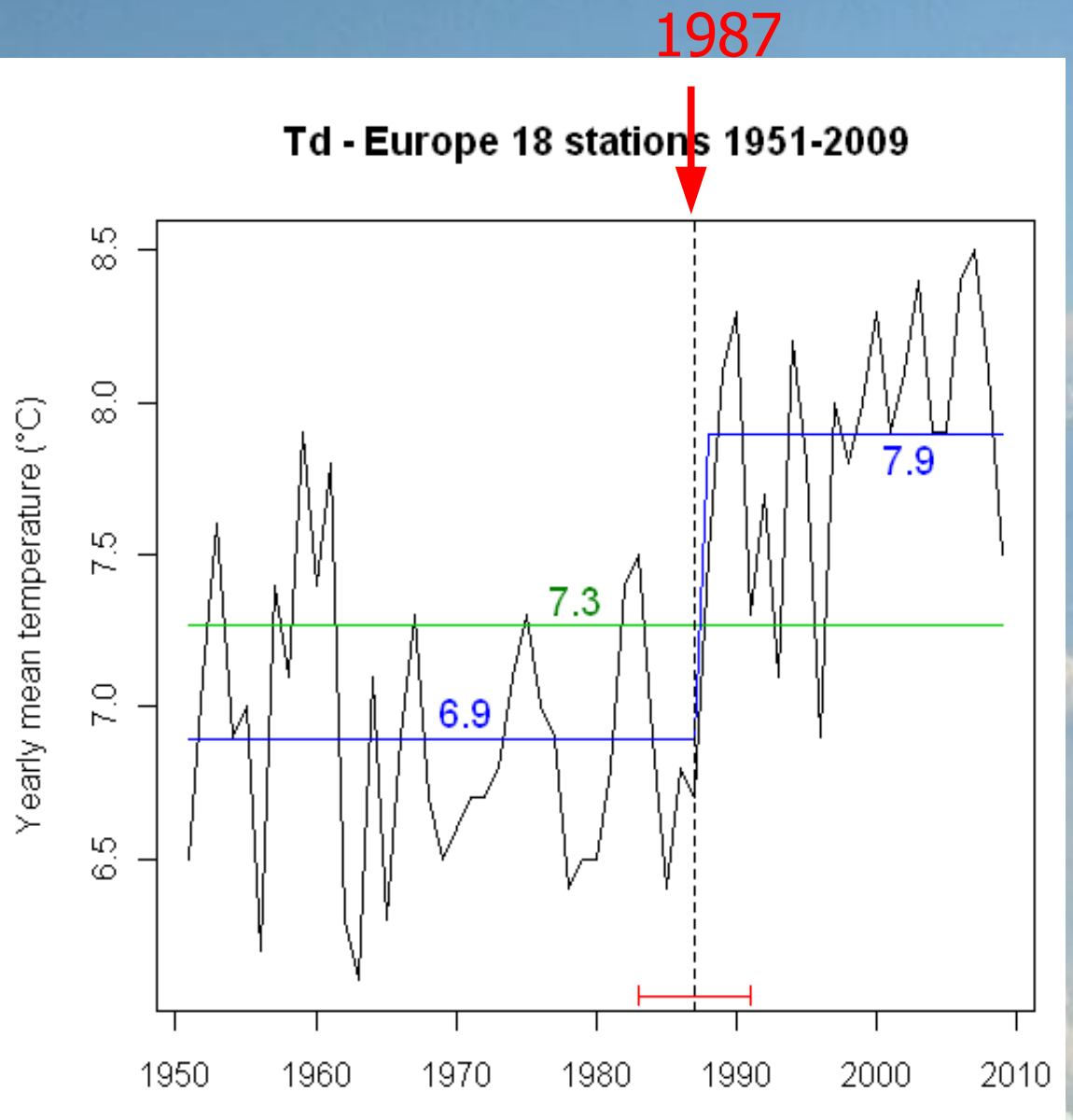
Historical precedents

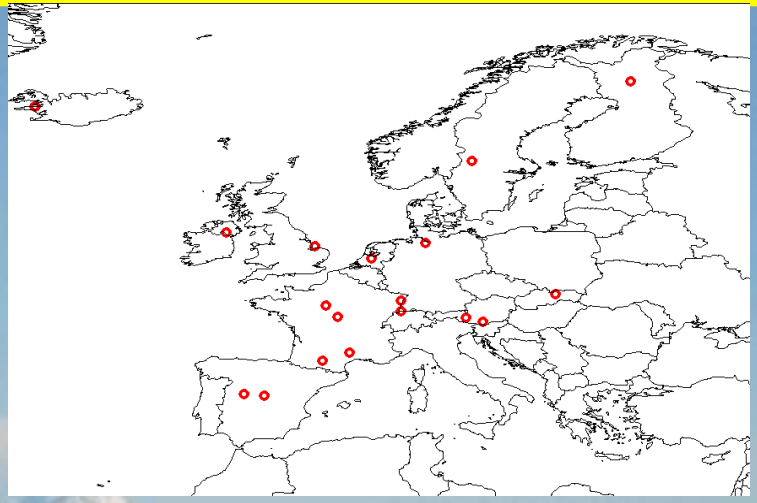


NAO recostruction from proxy data from Marocco, Alps and Scotland).

Trouet et al., 2009. Persistent Positive North Atlantic Oscillation Mode Dominated the Medieval Climate Anomaly, Science, 3 april 2009, Vol 324

Mean yearly temperature of 18 European stations (1951-2009) (available data: 93%)

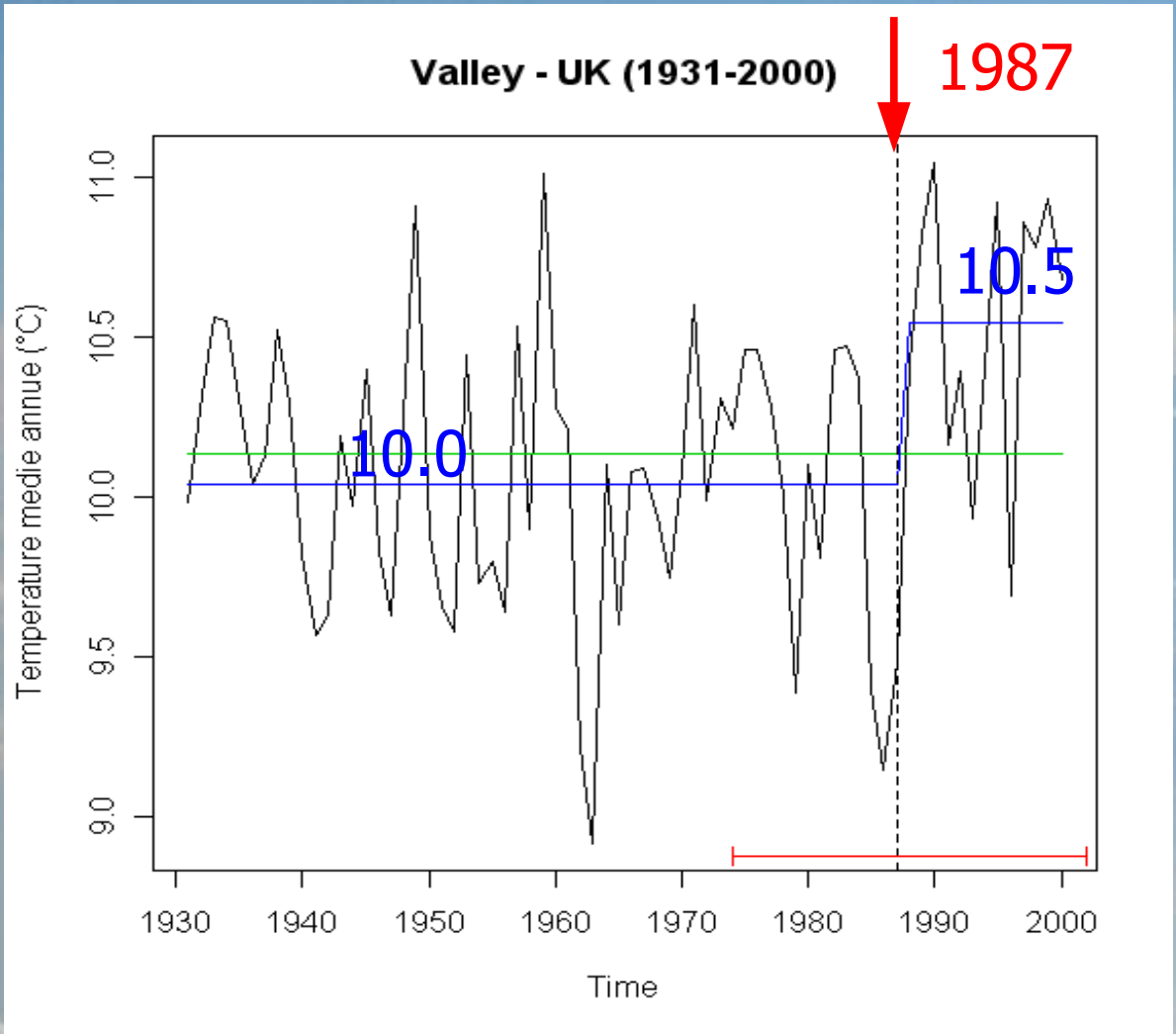




With the 99% of confidence the breakpoint drops between 1983 and 1991. Most probable year=1987 (mean 1951-1987=6.9; mean 1988-2009=7.9)

[breakpoint analysis carried out with Struchange library – R cran]

Yearly mean temperature at Valley – UK (1931-2000)
(source: dataset ECAD)

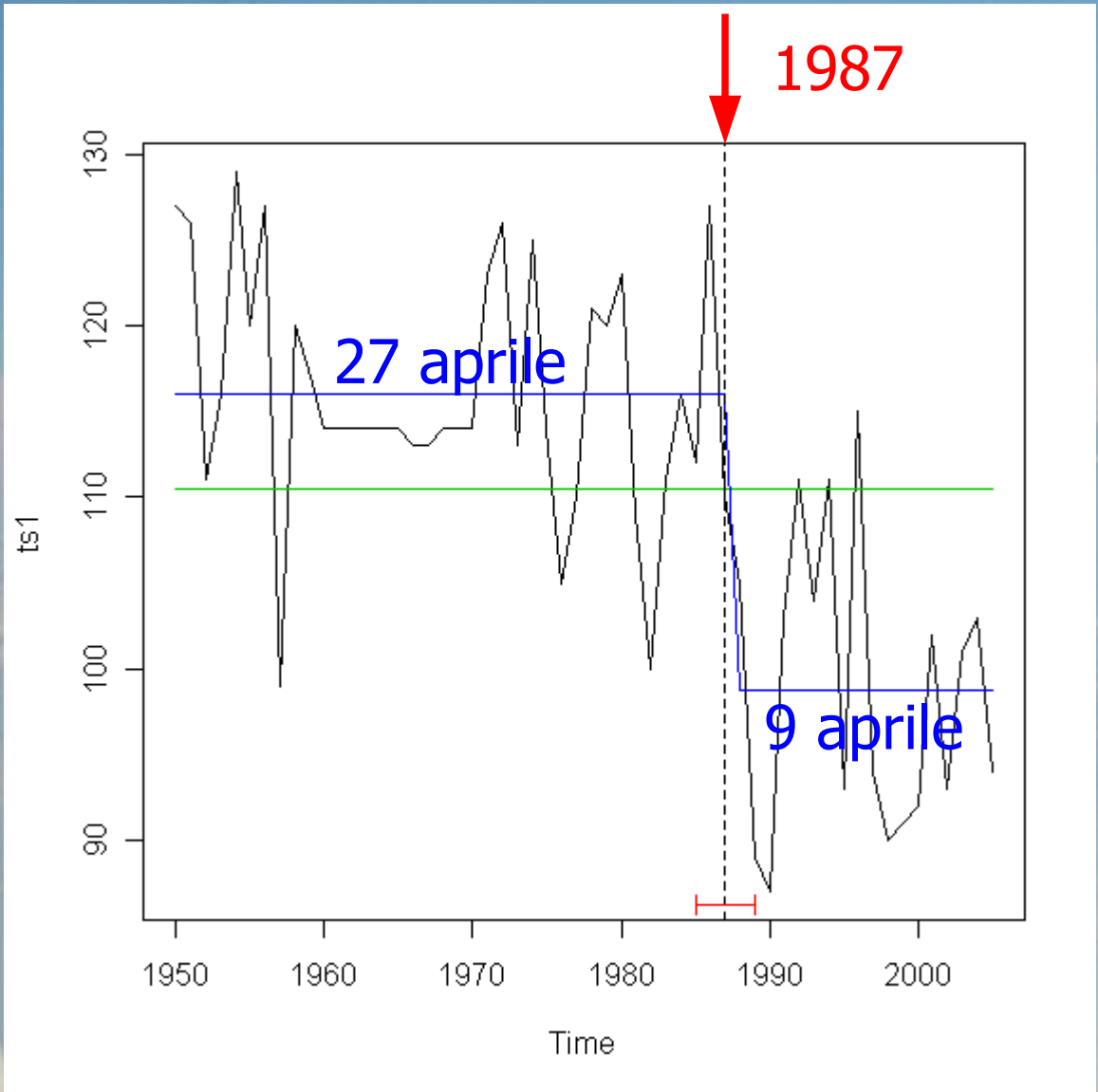


Con il 99% di probabilità la discontinuità ricade fra 1974 e 2000. Anno più probabile di discontinuità= 1987 (media 1931-1987=10.0; media 1988-2000=10.5)

[analisi di discontinuità eseguita con la libreria statistica Struchange]

Oak budding in UK (1950-2005)

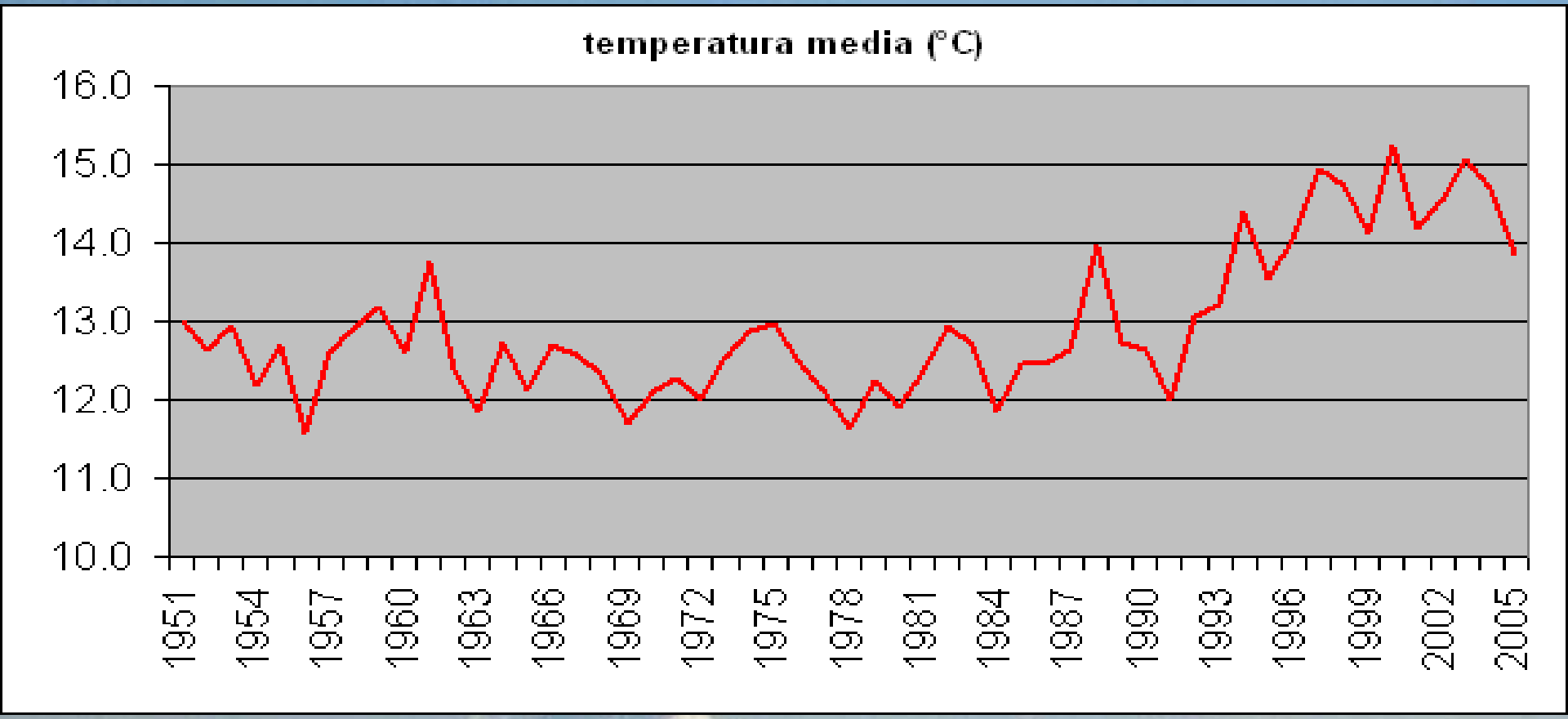
(source: Maracchi, Baldi, 2006)



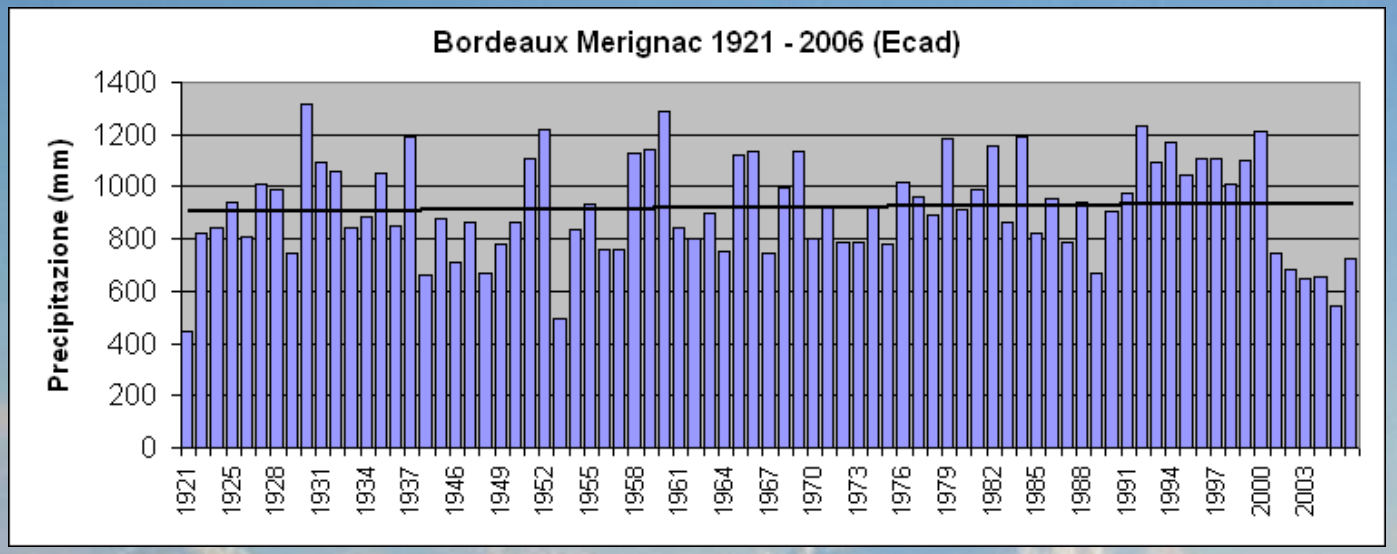
Con il 90% di probabilità la discontinuità ricade fra 1985 e 1989. Anno più probabile di discontinuità= 1987 (media 1950 -1986=117; media 1989-1997=99)

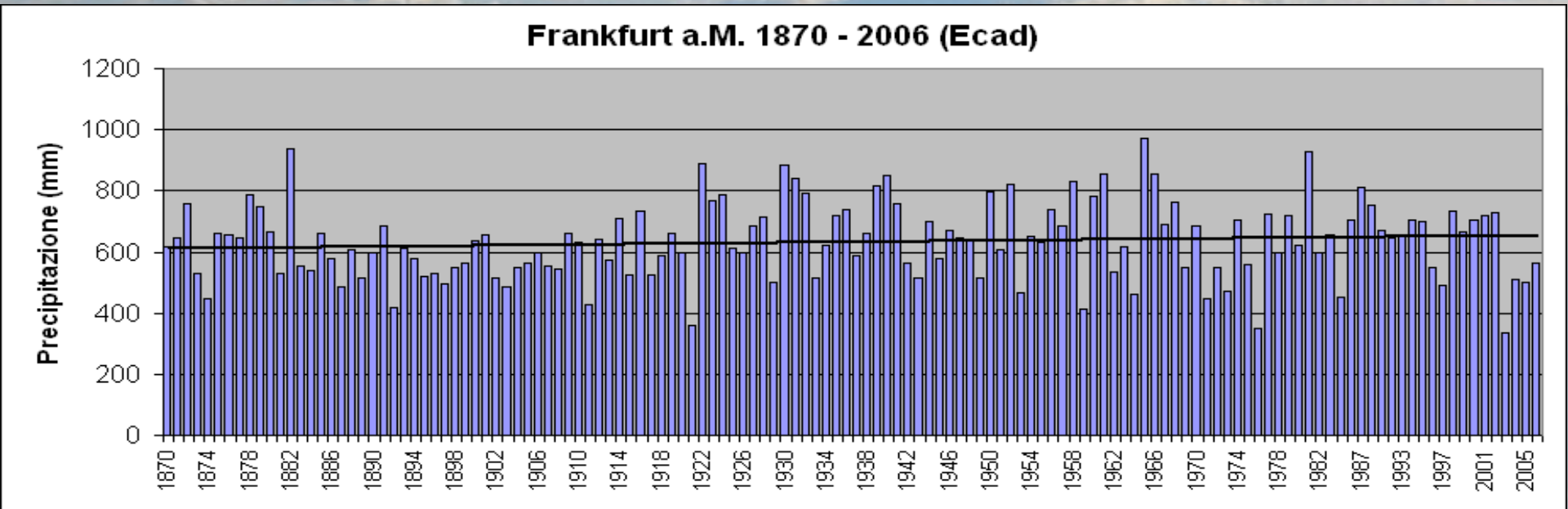
[analisi di discontinuità eseguita con la libreria statistica Struchange]

Milano Linate

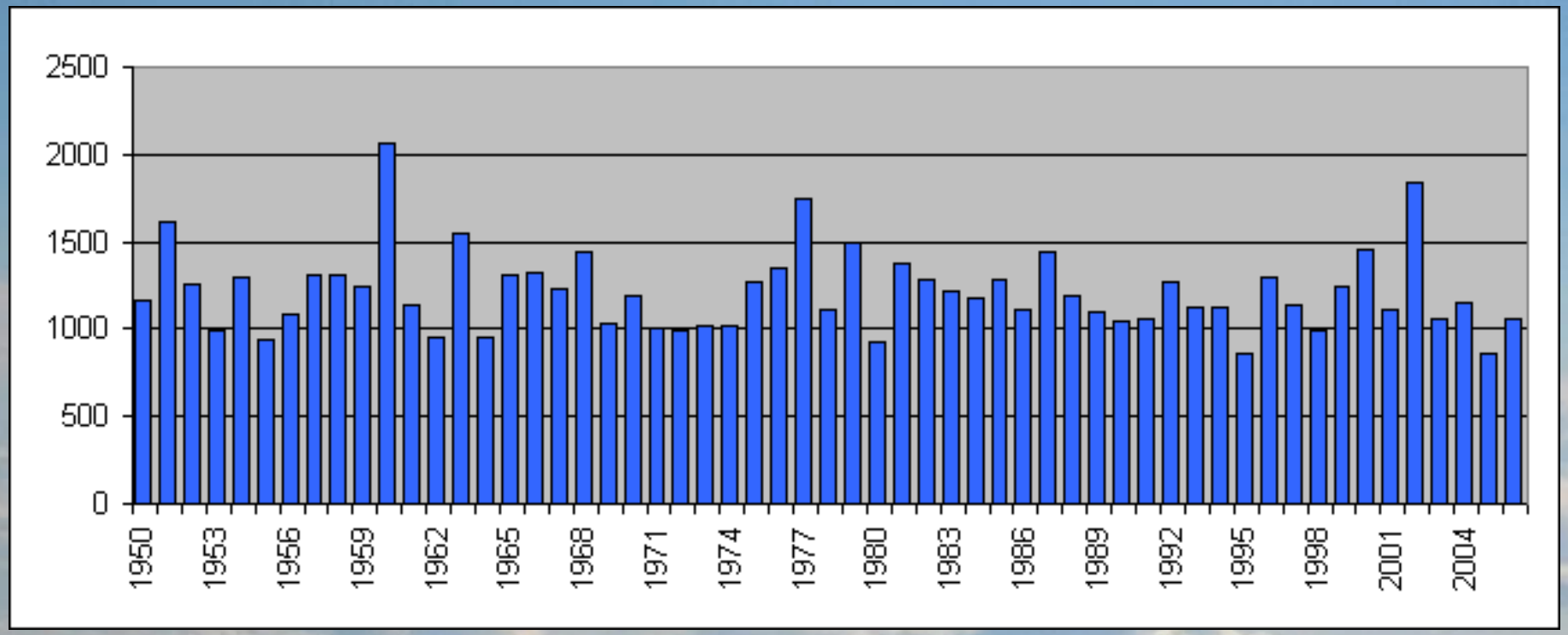


Precipitazioni 1921-2006 – Bordeaux e Francoforte (fonte: Ecad)





Precipitazione media annua 1950-2006 - 18 stazioni della provincia di Sondrio (Dati progetto RICLIC WARM)

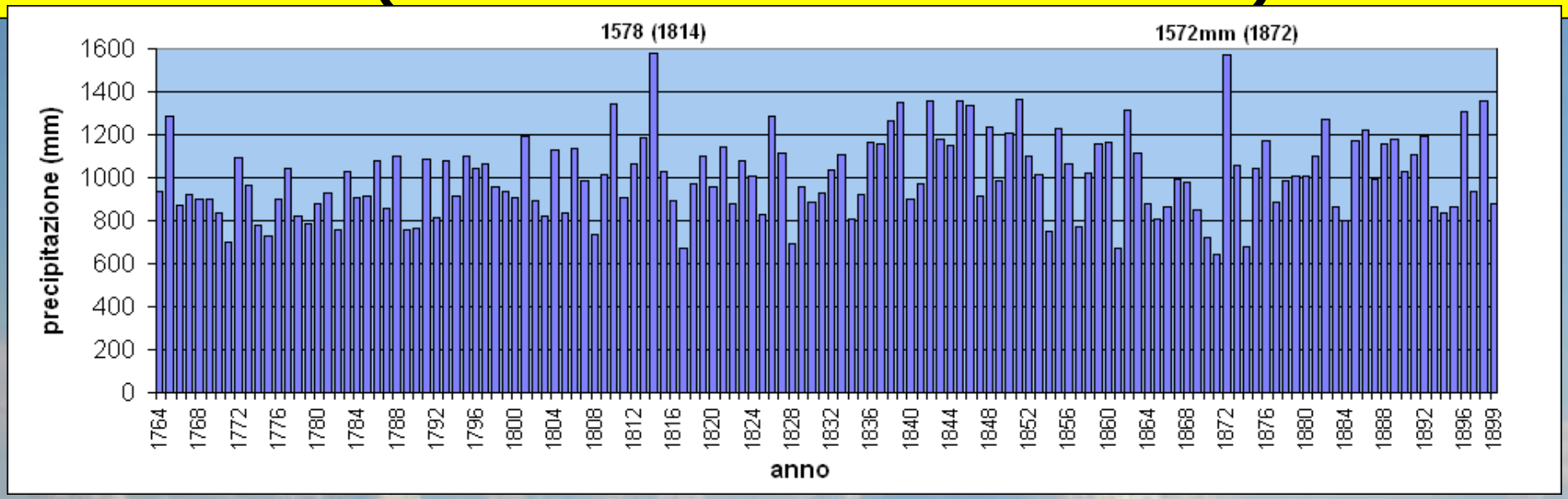


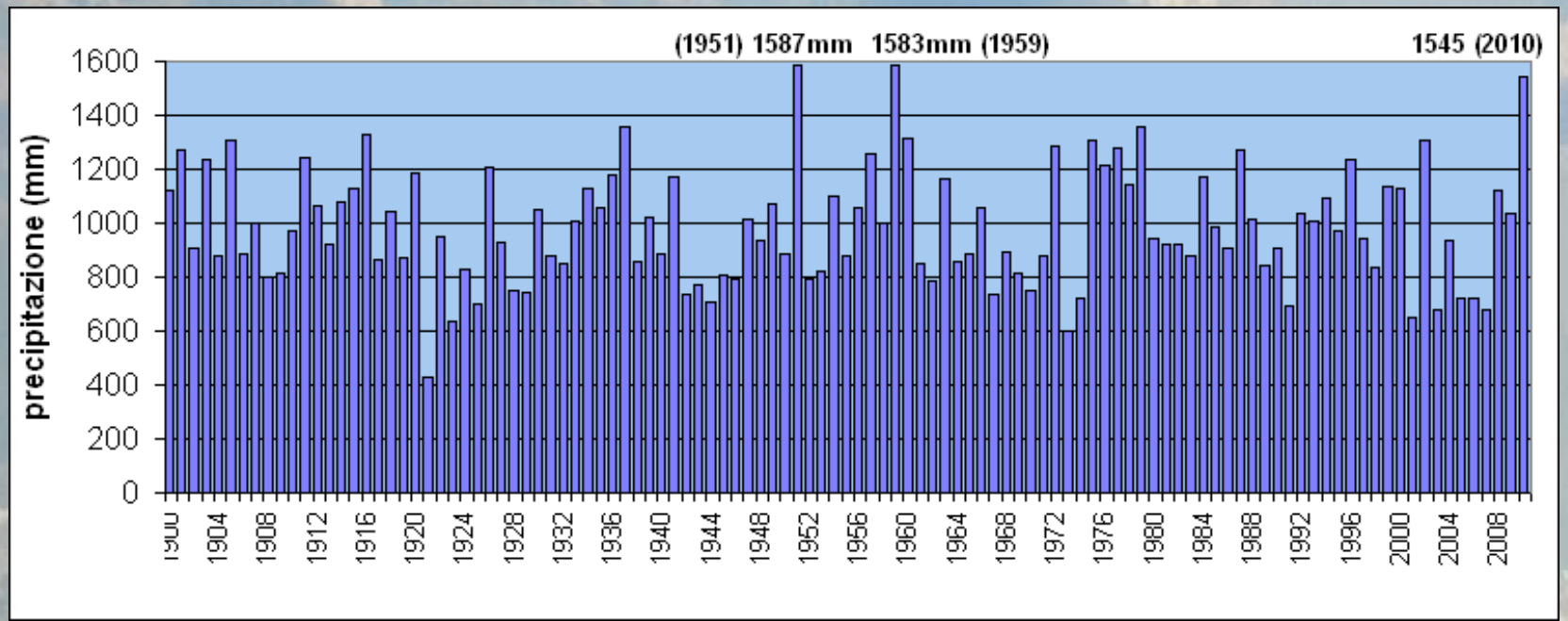
Media 1950-1989 1238 mm/anno

media 1990-2006 1157 mm/anno

Milano Brera - Precipitazione annua 1764-2010

(in evidenza i 5 massimi assoluti)





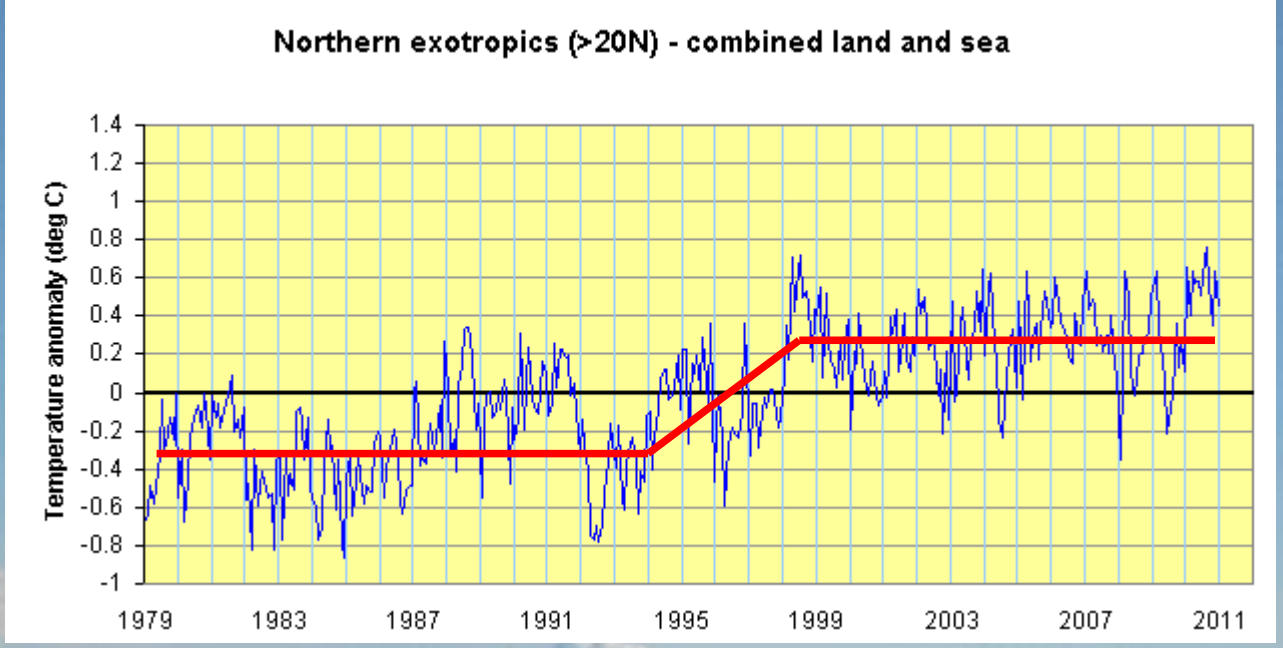
Milano Brera - Precipitazione annua 1764-2010

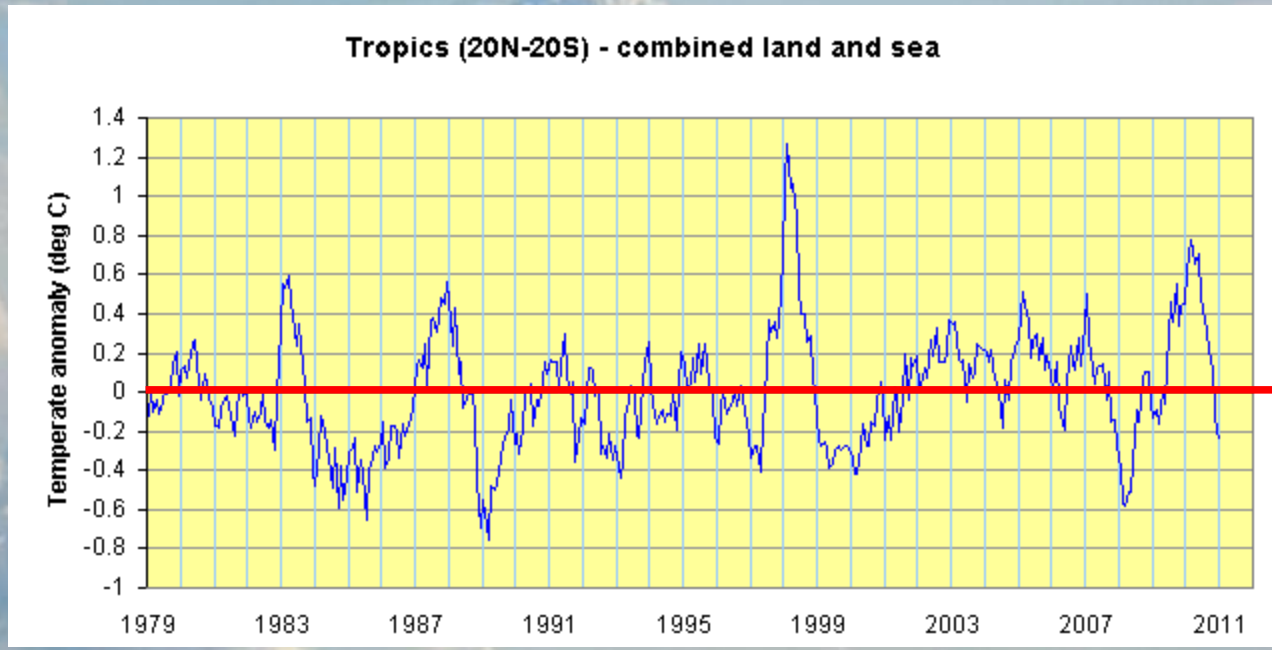
Valori medi (mm/anno)

- Media 1764-1800=928
- Media 1801-1850=1053
- Media 1851-1900= 1023
- Media 1901-1950= 963
- Media 1951-2000= 1016
- Media 2001-2010= 938

→ Media 1764-2010=998

Temperatures (1979-2009)





Source: University of 'Alabama – Huntsville (satellite data MSU-UAH) numerical data available at: http://vortex.nsstc.uah.edu /public/msu/t2lt/uahncdc.lt

VARIAZIONI DELLE TEMPERATURE ANNUALI NEL PERIODO 1979-1997 SULLO STRATO ATMOSFERICO FRA 1000 E 500 HPA

(Dati analisi modello NCEP e sensore da satellite Microwave Sounding Unit (MSU). (da T.N. Chase, R.A. Pielke, J.A.Knaff, T.G.F. Kittel e J.L. Eastman, *A comparison of regional trends in 1979-1997 dept-averaged tropospheric temperatures*, Int. Journal of Climatology, Vol 20 n.5, aprile 2000, 503-518)

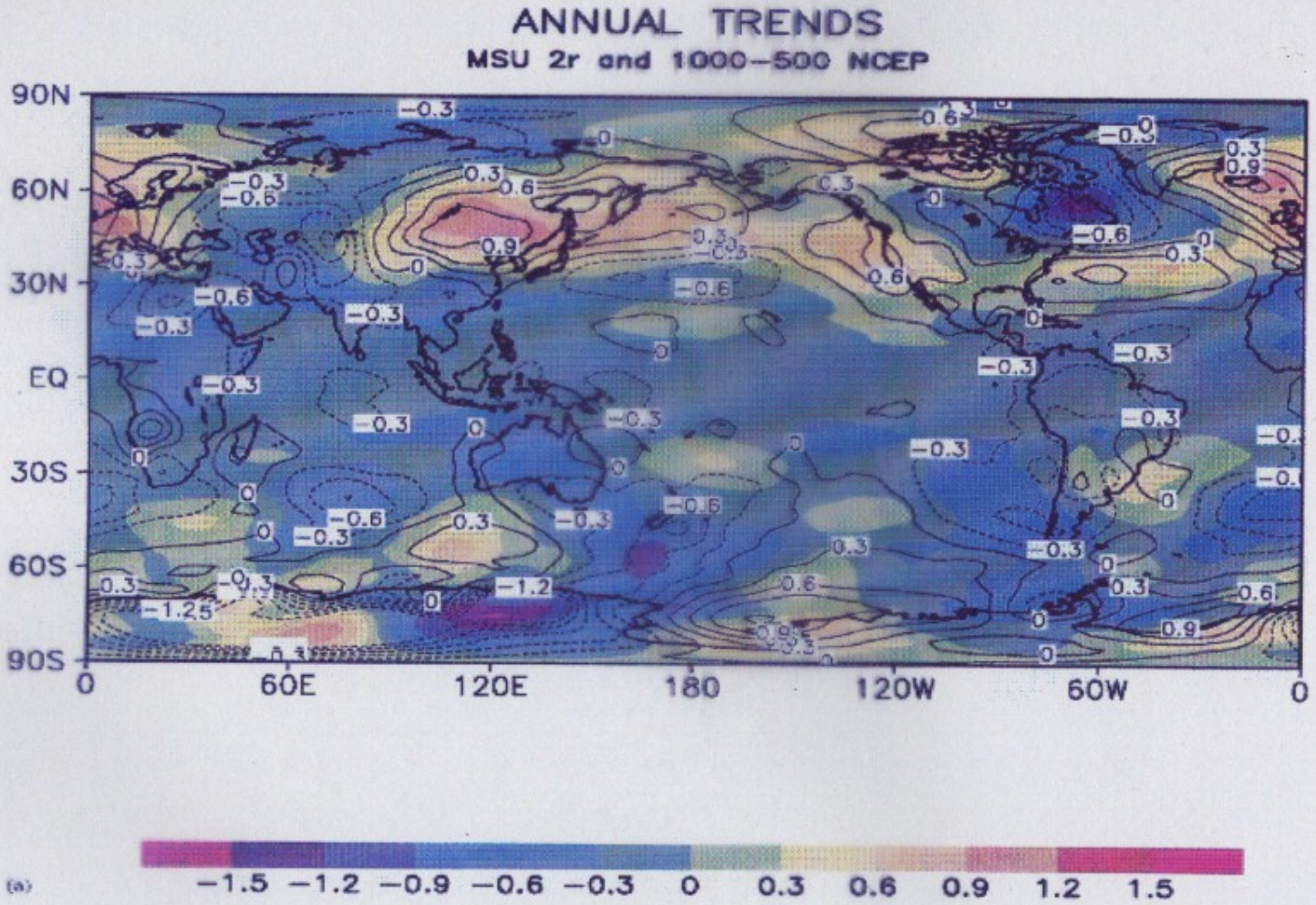
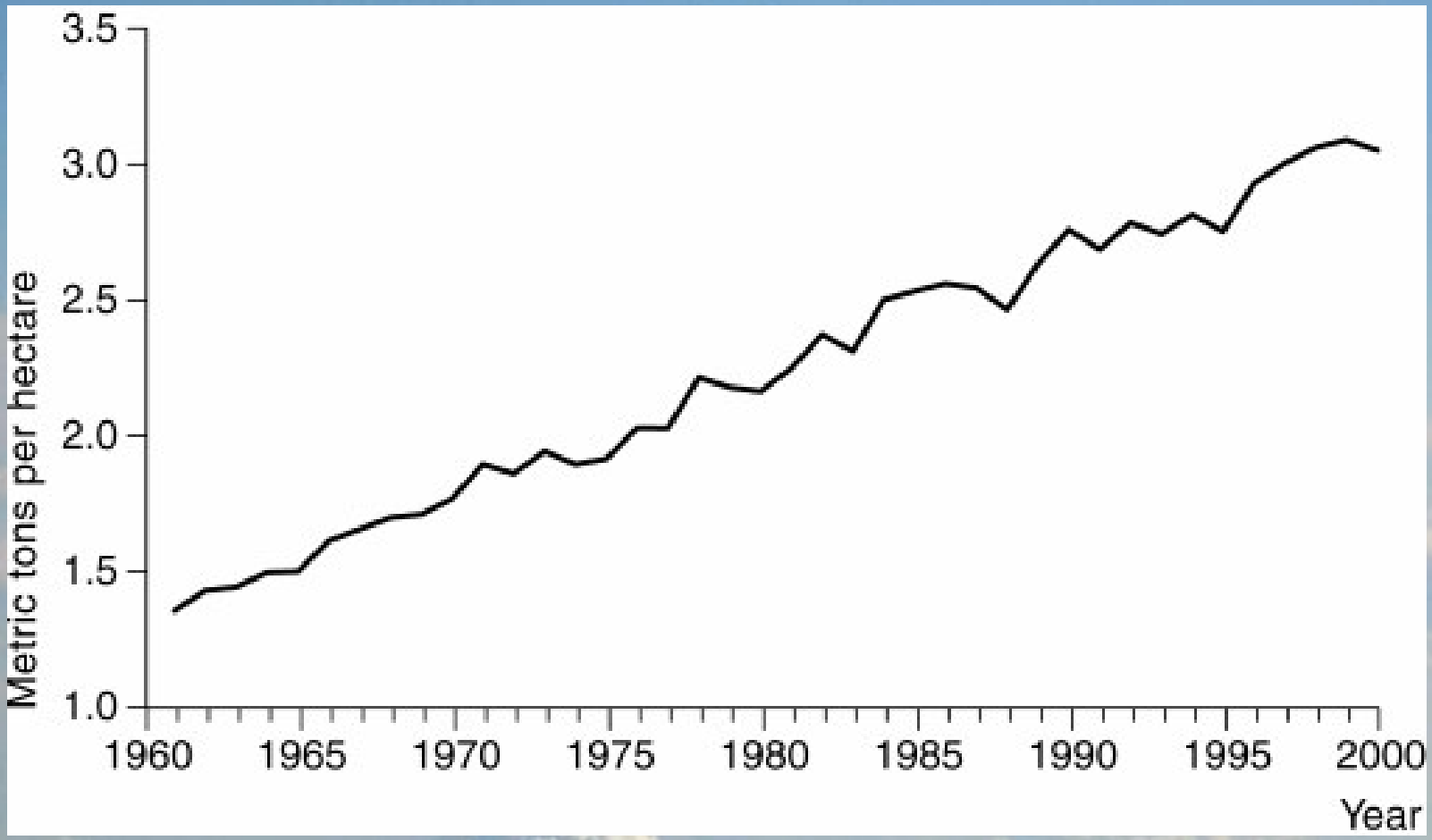


Plate 1 MSU (coloured) and NCEP 1000–500 mb (contoured) trends in °C/19 years for (a) annual average, (b) DJF average and (c) JJA average

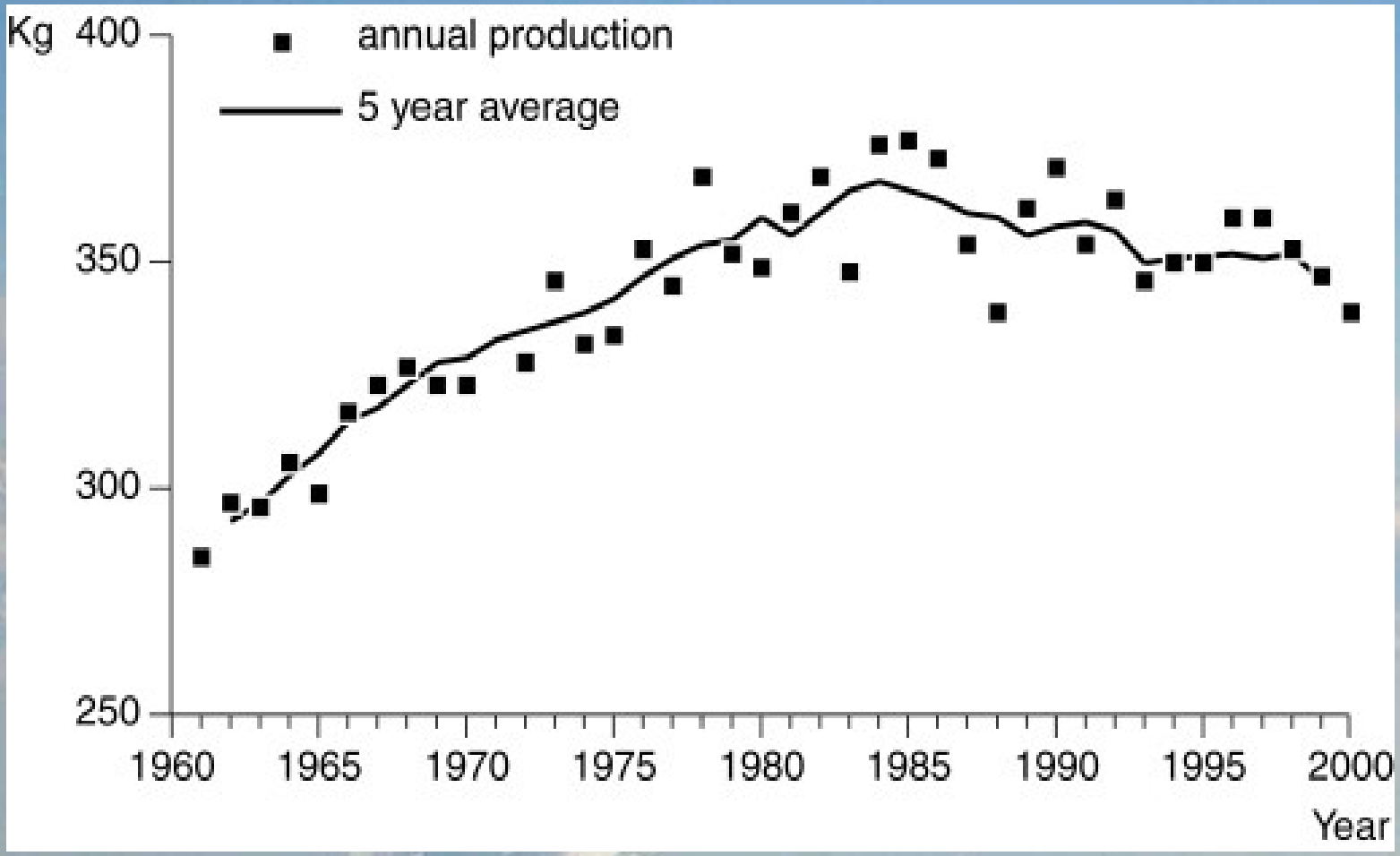
Effects on agriculture

Mean global cereal unitary production (1961-2000)



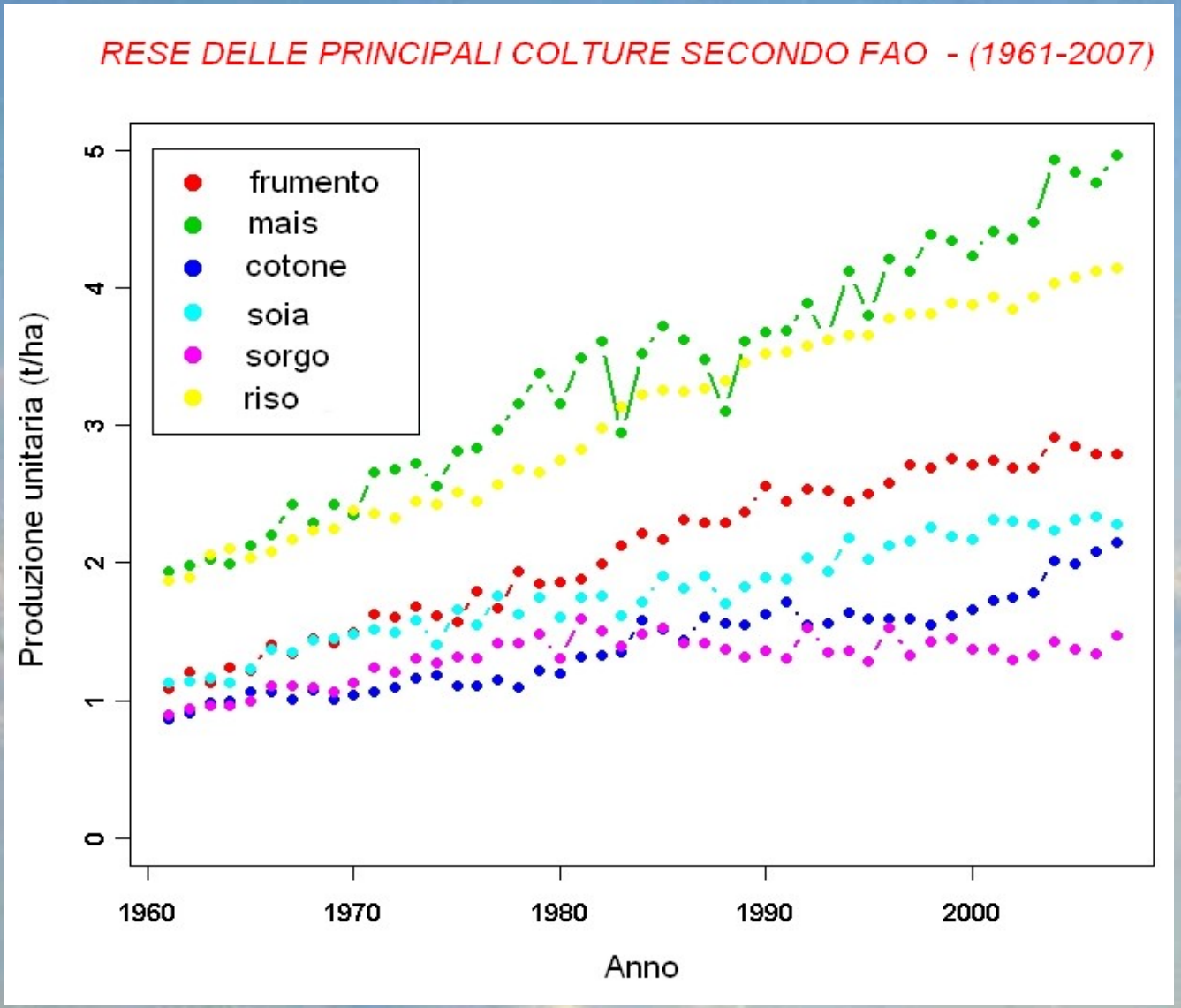
Tim Dyson, 2001, World Food Trends: A Neo-Malthusian Prospect?, PROCEEDINGS OF THE AMERICAN PHILOSOPHICAL SOCIETY VOL. 145, NO. 4, DECEMBER 2001

Per capita cereal production 1961-2000



Tim Dyson, 2001, World Food Trends: A Neo-Malthusian Prospect?, PROCEEDINGS OF THE AMERICAN PHILOSOPHICAL SOCIETY VOL. 145, NO. 4, DECEMBER 2001

Produzione media mondiale per unità di superficie e per le maggiori colture



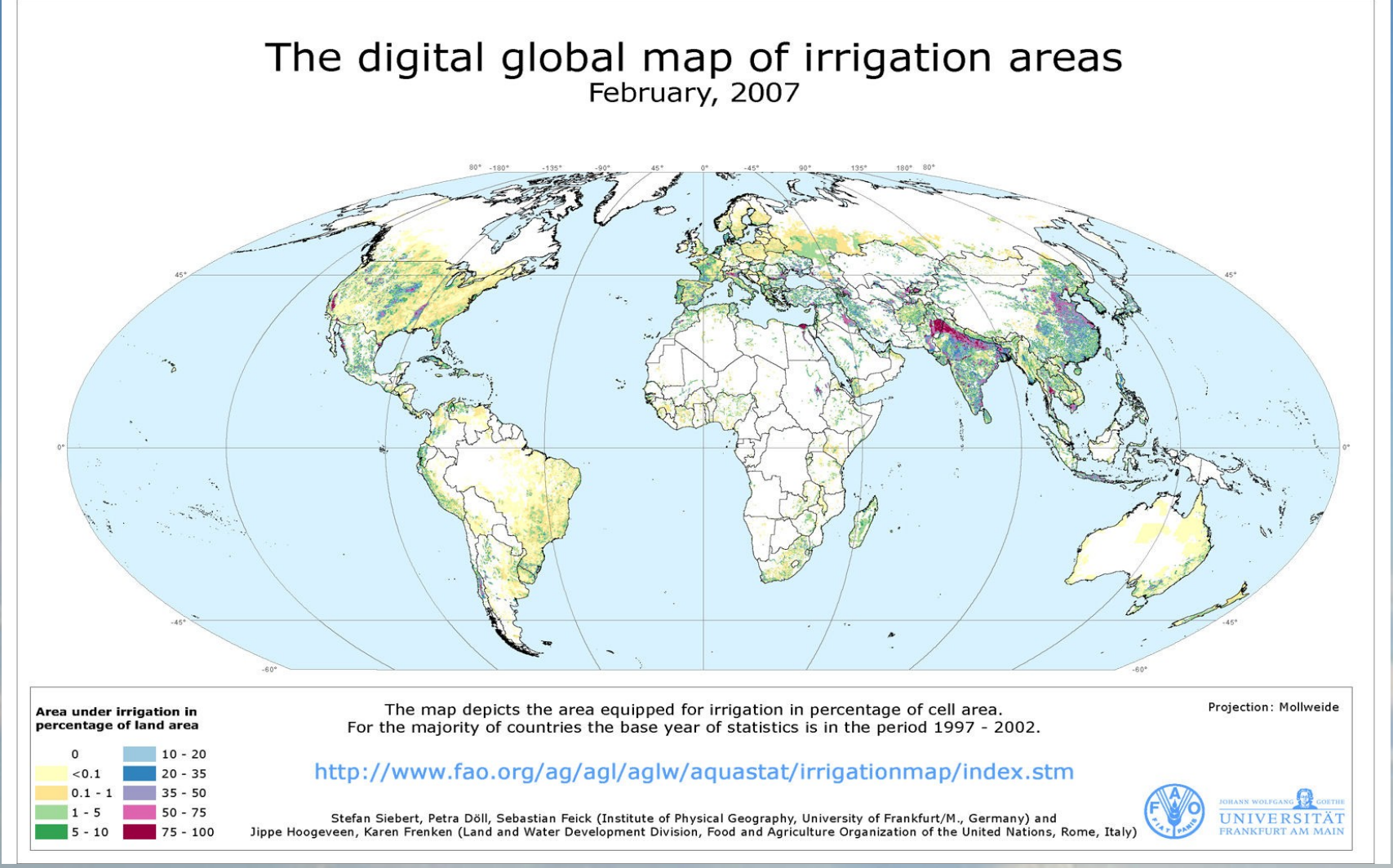
Fonte: dati FAO- database, faostat (http://faostat.fao.org/site/567/default.aspx#ancor)

How to interpret these data

In the last 50 years there is an apparent insensitivity of global crop production to climate variability.

Possible reasons:

1. global distribution of weather anomalies (each year show some anomalies which compensate on a global scale giving a nearly constant global impact)
2. effectiveness of adaptation strategies of farmers (choices in genetics and agro-techniques)
3. increasing presence of irrigation (a powerful stabilizer of agricultural production)
4. the observed temperature increase is not harmful for crops on a global scale



Some statistics

Global arable land: 1.5 Billions of ha

Irrigated land: 16%

Food produced by irrigated lands: 36%

(http://12.000.scripts.mit.edu/mission2014/solutions/modernized-irrigation)

Results coherent with the lesson of the past

The civilization can be considered as the system built by the humankind to counteract the dictatorship of the climate (Leroy Ladurie, 2004).

The worst climatic periods for crop production:
- cold phases (e.g.: LIA; France, 1740)
- rainy periods (e.g. Ireland, 1846)
- warm phases with drought (e.g.: 11th century bC - end of Ittite and Micenean civilization)

Warm phases with good water availability are optimal for agriculture and this explain the name of optimum given to such periods (Great Postglacial opt. GPo, micenean opt., ronan opt, medieval opt.). (e.g.: During GPO agricultural technology colonized Europe)

Results coherent with the lesson of the recent past

During the XXth century:
- world population increased 4 times (from 1.5 to 6 billions)
- agricultural production increased 5-6 times (green revolution)

The green revolution was founded on the intensification of cropping systems carried out by means of strong enhancements genetics (new optimized varieties) and agro-techniques (soil works, weeds, pesticides, fertilizers, food conservation, etc.)

Triticum aestivum L. (1910)

Height = 1,70 m

Triticum aestivum L. (2000)

Height = 0.8 m (effects of genetic improvement)

http://cropandsoil.oregonstate.edu/wheat/pics.htm

Intensive agriculture and biodiversity

A paradox that should be analyzed:

Intensive agriculture (strong density of a single specie on a limited territory) is the contrary of biodiversity.

Intensive agriculture preserve biodiversity in natural environments

Forest surface in Italy in 2000 (+70%)

Source: Conti G, Fagarazzi L., 2005. Avanzamento del bosco in ecosistemi montani: "sogno degli ambientalisti o incubo per la società"?

The case of Cencenighe (BL)

1900

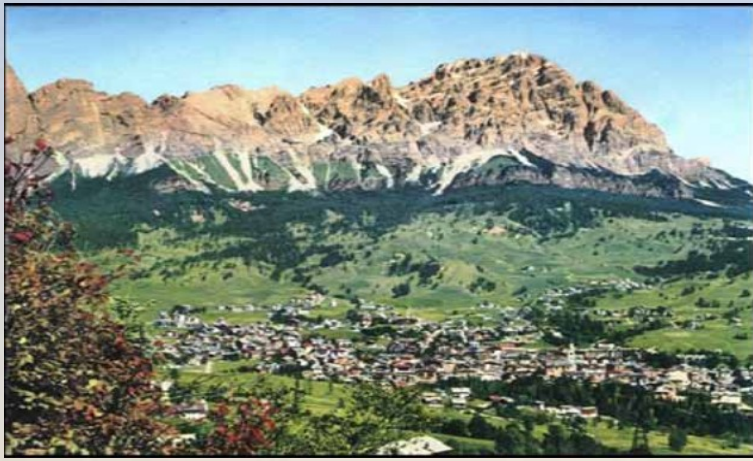
Fonte: Conti G, Fagarazzi L., 2005. Avanzamento del bosco in ecosistemi montani: "sogno degli ambientalisti o incubo per la società"?

2004

The case of Cortina d'Ampezzo

1903

1958



Fonte: Conti G, Fagarazzi L., 2005. Avanzamento del bosco in ecosistemi montani: "sogno degli ambientalisti o incubo per la società"?

2004

These kinds of mechanisms are in place in other areas too?

(trend NDVI 1982-2003 in areas prone to desertification risk)

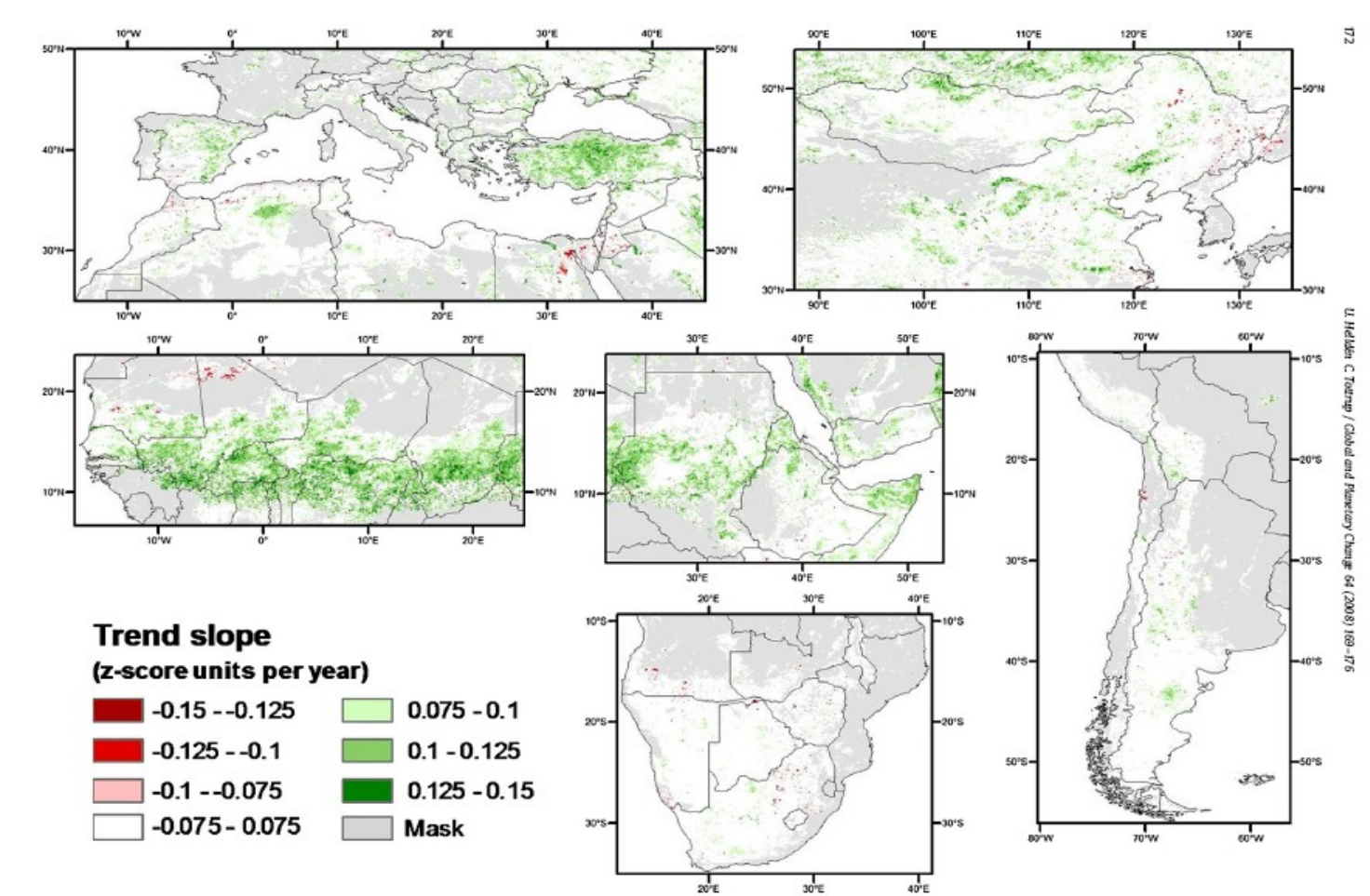


Fig. 2. 1982–2003 trends in standardized z-scores. Due to the standardization these maps can be compared across regions. The strongest greening is in the Sahel (West to East), hereafter comes the Mediterranean and East Asia while the greening in both South Africa and South America is rather insignificant. But perhaps more importantly for all cases is the absence of significant negative trends.

source: Ulf Helldén e Christian Tottrup, 2008. Regional desertification: A global synthesis. Global and Planetary Change 64 (2008) 169–176

The future - until 2050

2050: world population will reach 9.5 billions.

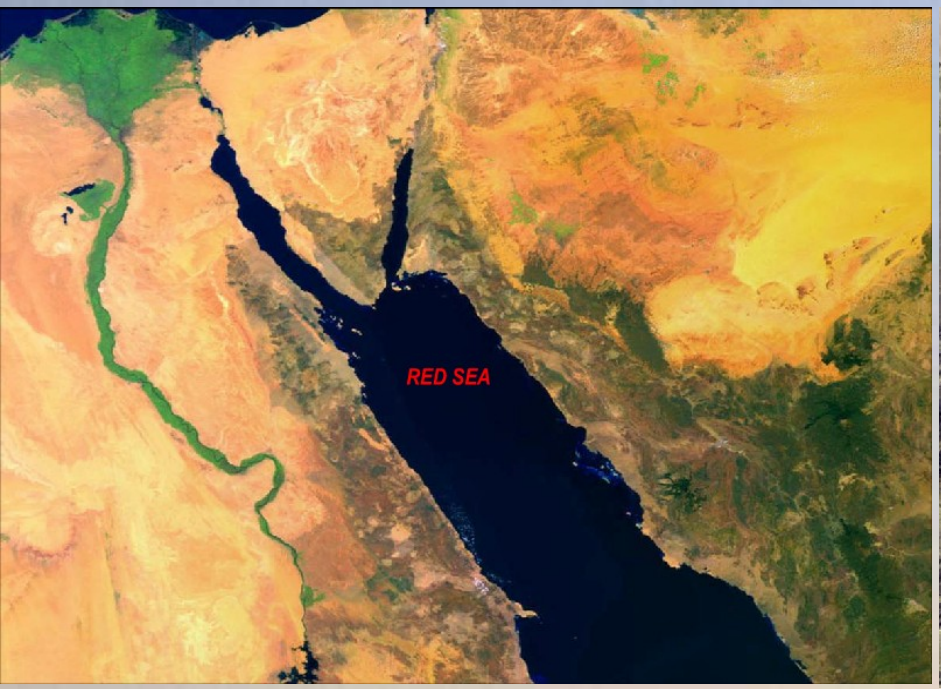
How to produce: further intensification (genetics and agro-techniques).

Where to produce: production will be mainly carried out on suitable lands (1.4 billions of ha of arable lands maily at mid latitudes; 3.2 billions of ha of pastures)

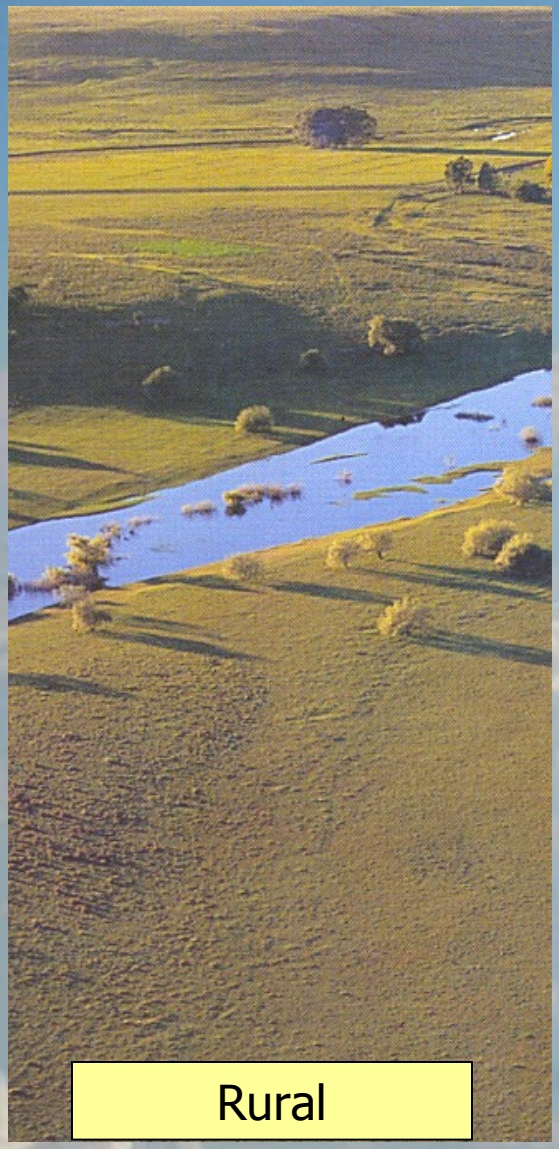
Why to produce: for food, for consumables, for durable goods

CO2 could be seen as a fundamental resource for crop production!

Water policy



Land policy



Rural

Fonte: Uruguay - Min. del Turismo

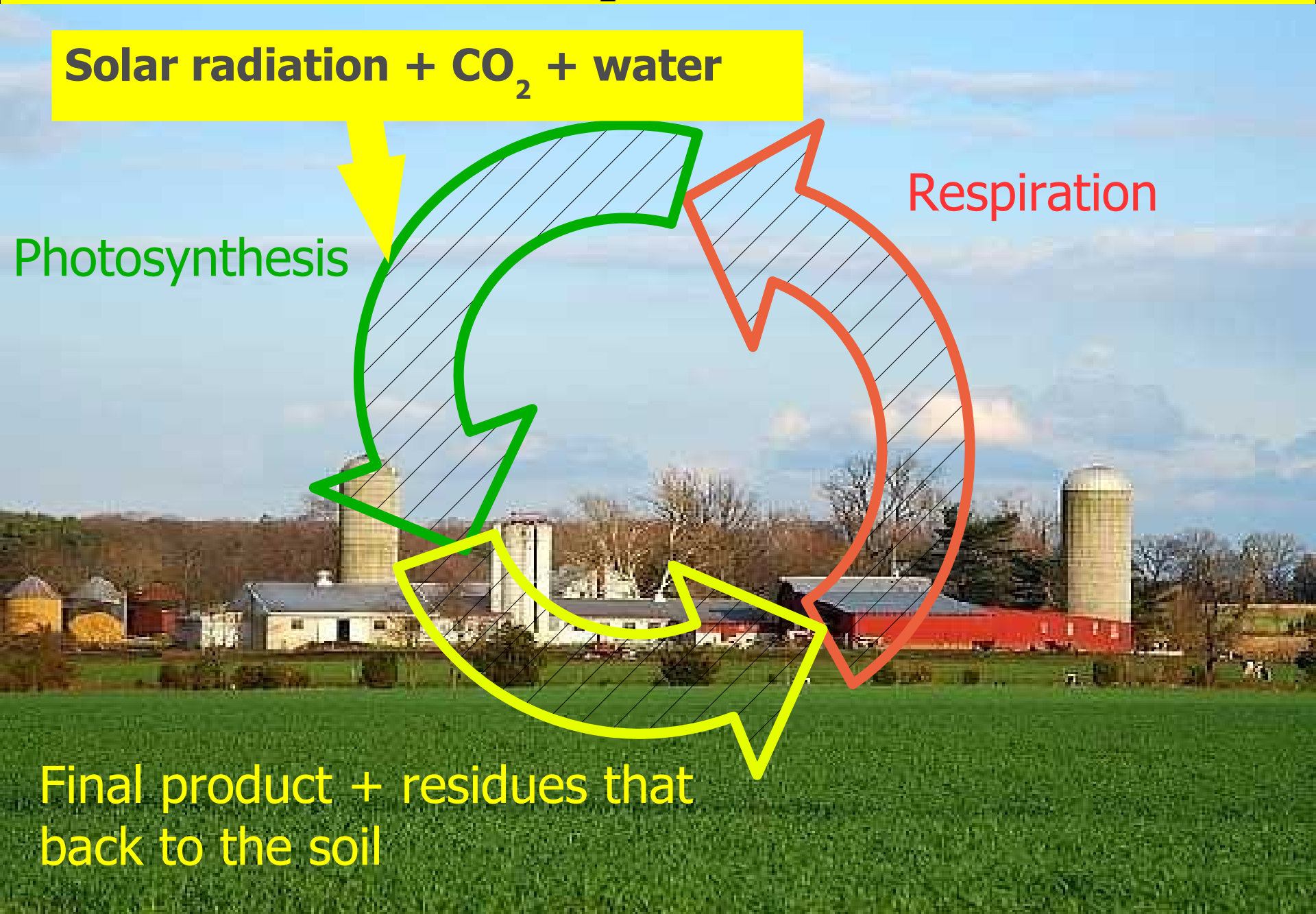
Sub-urban

Urban

Fonte: Agenzia Milanese Mobilità e Ambiente, rapporto sulla qualità dell'aria 2001

Policy against soil degradation (erosion, salinization, etc.)

CO_2, policy


Solar radiation + CO_2 + water
Photosynthesis
Respiration
Final product + residues that
back to the soil

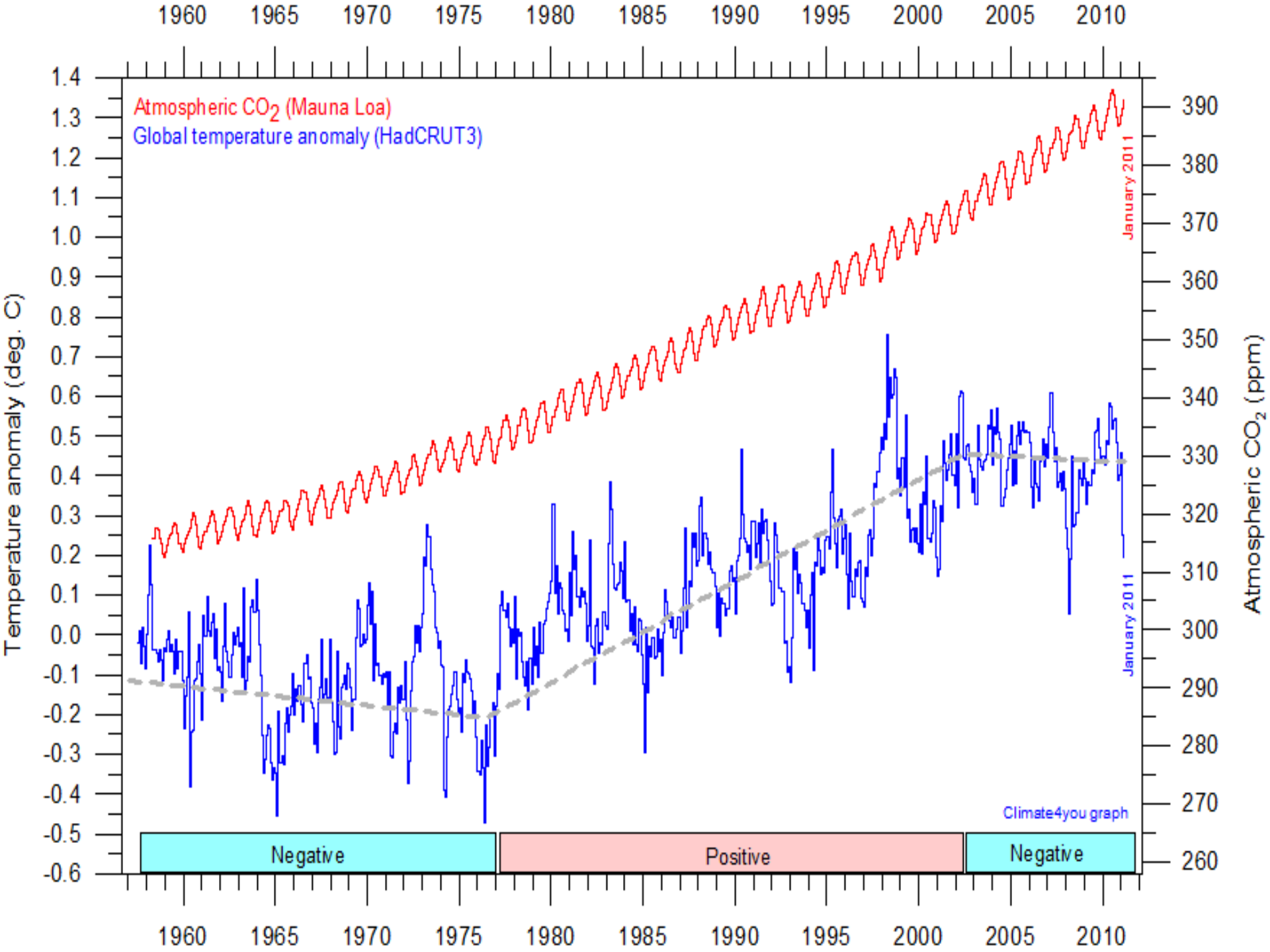
CO2 policy

Agriculture can be seen as the govern of the carbon cycle (both in the terrestrial and the atmospheric segment) by the mankind

Some data (t/ha)

Crop	Grain yield (t/ha)	CO2 absorption (t/ha)	
		gross	net
Winter wheat	8	23.5	17.8
Maize cl 500	13	38.1	29.5

vaso in steatite con corteo di mietitori, (palazzo di Hagia Triada, Tardo minoico, 1500 aC)


Atmospheric CO2 (Mauna Loa)
Global temperature anomaly (HadCRUT3)
Temperature anomaly (deg. C)
Atmospheric CO2 (ppm)
January 2011
January 2011
Climate4you graph
Negative
Positive
Negative
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
390
380
370
360
350
340
330
320
310
300
290
280
270
260