Osservazioni di stato e tendenza del sistema climatico terrestre

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La scienza è fatta di dati come una casa di pietre.
Ma un ammasso di dati non è scienza più di quanto un mucchio di pietre sia una casa.

-Henri Poincaré-

- definizioni e impostazione del problema;
- evidenze della tendenza climatica;
- osservazioni;

CLIMA E TEMPO METEOROLOGICO

diversa scala temporale

diversità di metodo, dati e formulazioni teoriche

tempo meteorologico ***stato del sistema (in particolare dell'atmosfera) ad un preciso istante*****.**

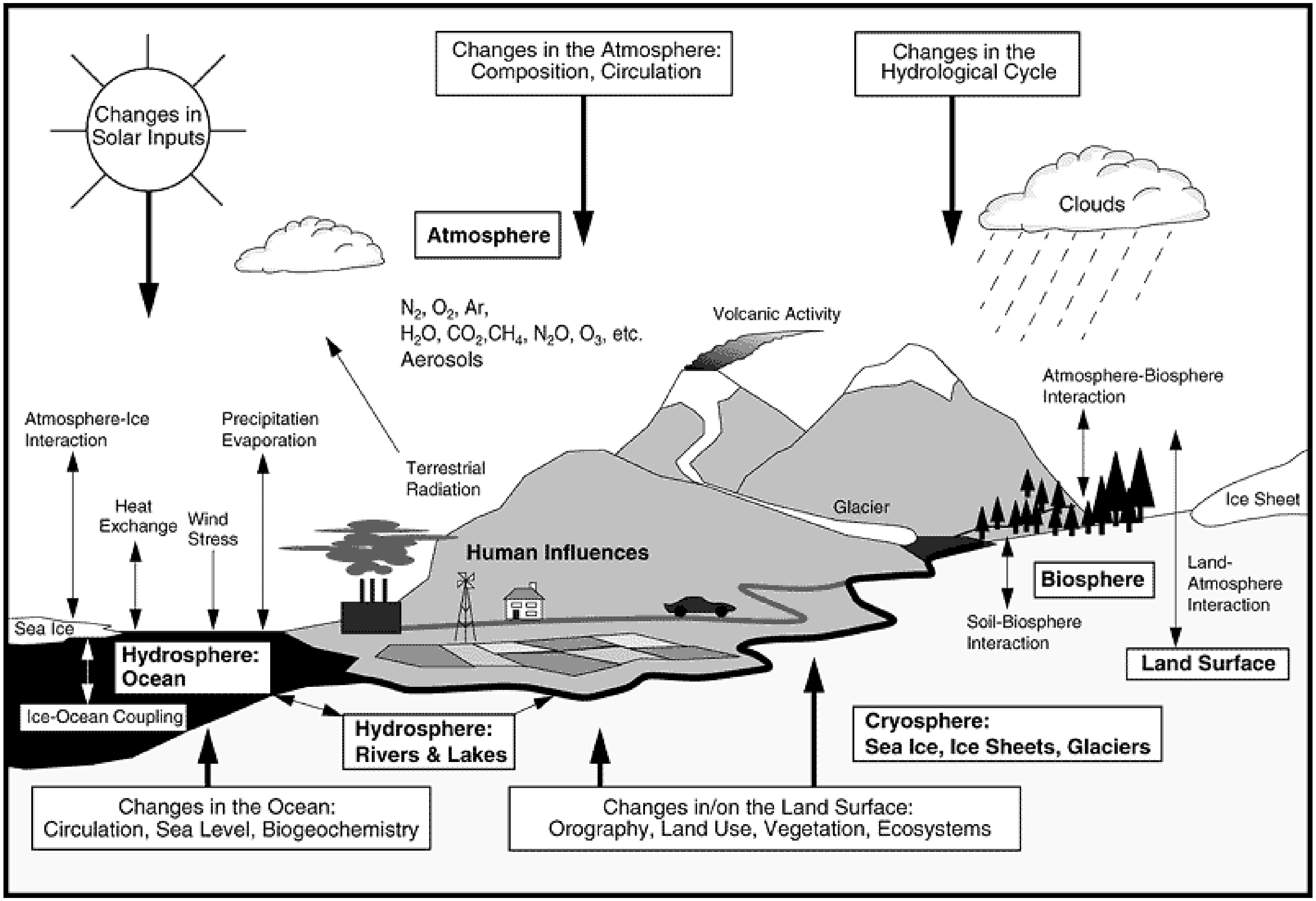
clima ***stato medio del sistema e sue variazioni nel tempo*****.**

definizione dello stato e delle sue variazioni

monitoraggio **indicatori**

previsioni sull’evoluzione del sistema

modelli **parametrizzazioni**


Changes in Solar Inputs
Changes in the Atmosphere: Composition, Circulation
Changes in the Hydrological Cycle
Atmosphere
Clouds
N_2, O_2, Ar,
H_2O, CO_2, CH_4, N_2O, O_3, etc.
Aerosols
Volcanic Activity
Atmosphere-Biosphere Interaction
Atmosphere-Ice Interaction
Precipitatien Evaporation
Terrestrial Radiation
Heat Exchange
Wind Stress
Glacier
Ice Sheet
Human Influences
Biosphere
Land-Atmosphere Interaction
Sea Ice
Hydrosphere: Ocean
Soil-Biosphere Interaction
Land Surface
Ice-Ocean Coupling
Hydrosphere: Rivers & Lakes
Cryosphere: Sea Ice, Ice Sheets, Glaciers
Changes in the Ocean: Circulation, Sea Level, Biogeochemistry
Changes in/on the Land Surface: Orography, Land Use, Vegetation, Ecosystems

caratteristiche del sistema climatico:

1) diversi sottosistemi con:
   - diversi scale spazio-temporali,
   - diverse metodologie di studio,
   - diversi livelli di conoscenza;

2) interazioni tra sottosistemi:
   - difficilmente osservabili,
   - poco studiate,

3) necessità di tempi “sperimentali” lunghi;

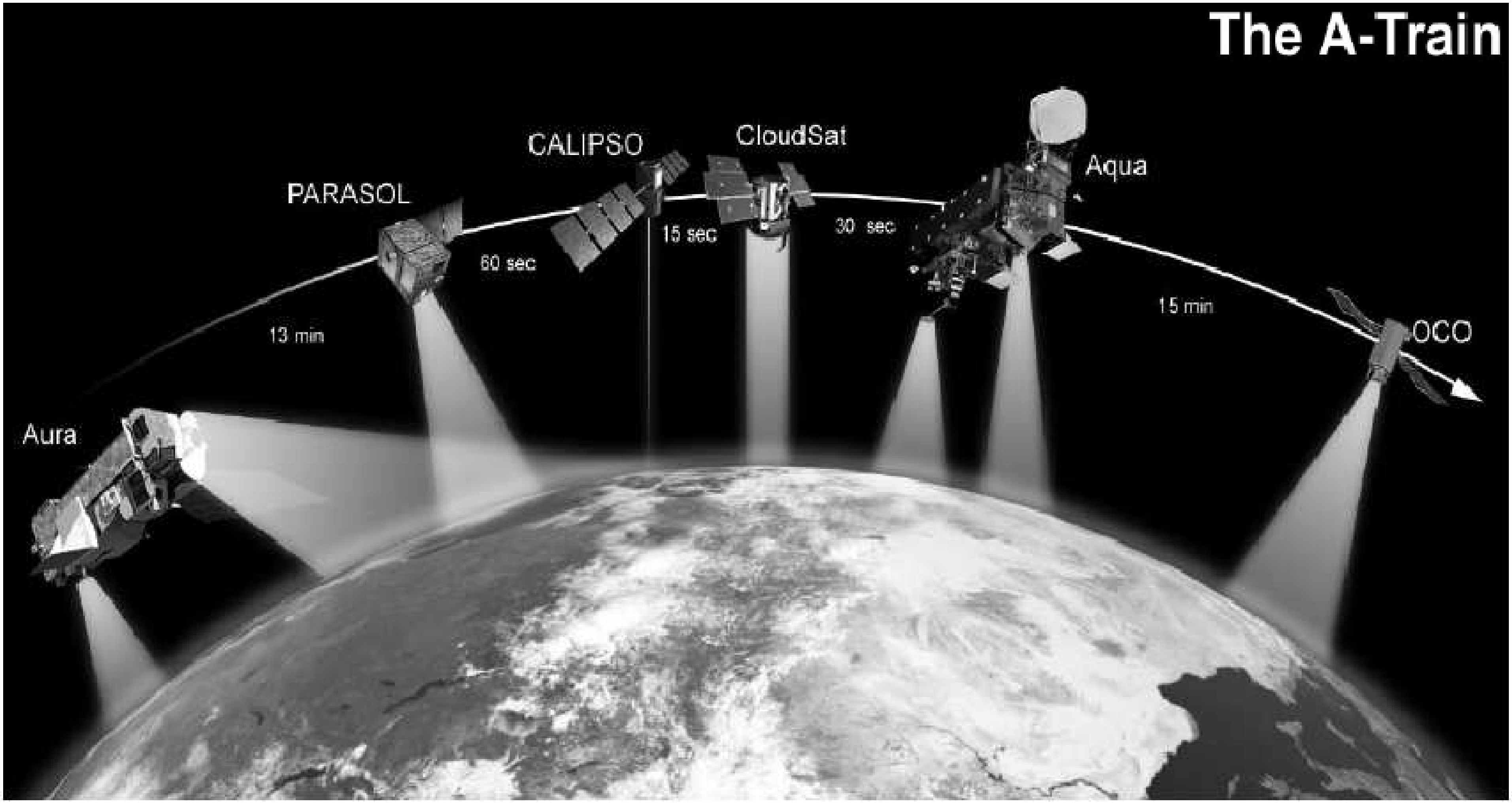
4) sistema caotico.

The key to gaining a better understanding of the ***global environment*** *is exploring how the Earth's systems of air, land, water, and life interact with each other,* ***blending together*** *fields like meteorology, oceanography, biology, and atmospheric sciences*

1991: Earth Science Enterprise

1999: Earth Observing System

EOS will observe the key physical variables needed to advance understanding of the entire Earth system and develop a ***deeper comprehension*** *of the* ***components*** *of that system and the* ***interactions*** *among the components*


The A-Train
Aura
PARASOL
CALIPSO
CloudSat
Aqua
OCO
13 min
60 sec
15 sec
30 sec
15 min

24 EOS Measurements

ATMOSPHERE	**Cloud Properties** *(amount, optical properties, height)*	**MODIS, GLAS, AMSR-E, *MISR, AIRS, ASTER,*** SAGE III
	Radiative Energy Fluxes *(top of atmosphere, surface)*	**CERES, ACRIM III, MODIS, AMSR-E, *GLAS, MISR, AIRS,*** ASTER, SAGE III
	Precipitation	**AMSR-E**
	Tropospheric Chemistry *(ozone, precursor gases)*	**TES, MOPITT,** SAGE III, MLS, HIRDLS, LIS
	Stratospheric Chemistry *(ozone, ClO, BrO, OH, trace gases)*	**MLS, HIRDLS, SAGE III, OMI, *TES***
	Aerosol Properties *(stratospheric, tropospheric)*	**SAGE III, *HIRDLS*** **MODIS, MISR, *OMI, GLAS***
	Atmospheric Temperature	**AIRS/AMSU-A, MLS, *HIRDLS,*** TES, MODIS
	Atmospheric Humidity	**AIRS/AMSU-A/HSB, *MLS, SAGE III, HIRDLS,*** Poseidon 2/JMR/DORIS, MODIS, TES
	Lightning *(events, area, flash structure)*	**LIS**
SOLAR RADIATION	**Total Solar Irradiance**	**ACRIM III, TIM**
	Solar Spectral Irradiance	**SIM, SOLSTICE**

24 EOS Measurements

LAND	**Land Cover & Land Use Change**	**ETM+, MODIS, *ASTER*, *MISR***
	Vegetation Dynamics	**MODIS, MISR, ETM+, *ASTER***
	Surface Temperature	**ASTER, MODIS, *AIRS*, *AMSR-E*,** ETM+
	Fire Occurrence ***(extent, thermal anomalies)***	**MODIS, ASTER, *ETM+***
	Volcanic Effects ***(frequency of occurrence, thermal anomalies, impact)***	**MODIS, ASTER, ETM+, *MISR***
	Surface Wetness	**AMSR-E**
OCEAN	**Surface Temperature**	**MODIS, AIRS, *AMSR-E***
	Phytoplankton & Dissolved Organic Matter	**MODIS**
	Surface Wind Fields	**SeaWinds, *AMSR-E*,** Poseidon 2/JMR/DORIS
	Ocean Surface Topography ***(height, waves, sea level)***	**Poseidon 2/JMR/DORIS**

24 EOS Measurements

CRYOSPHERE	**Land Ice** ***(ice sheet topography, ice sheet volume change, glacier change)***	**GLAS, ASTER, ETM+**
	Sea Ice ***(extent, concentration, motion, temperature)***	**AMSR-E, *Poseidon 2/JMR/DORIS,*** MODIS, ETM+, ASTER
	Snow Cover ***(extent, water equivalent)***	**MODIS, AMSR-E, *ASTER, ETM+***

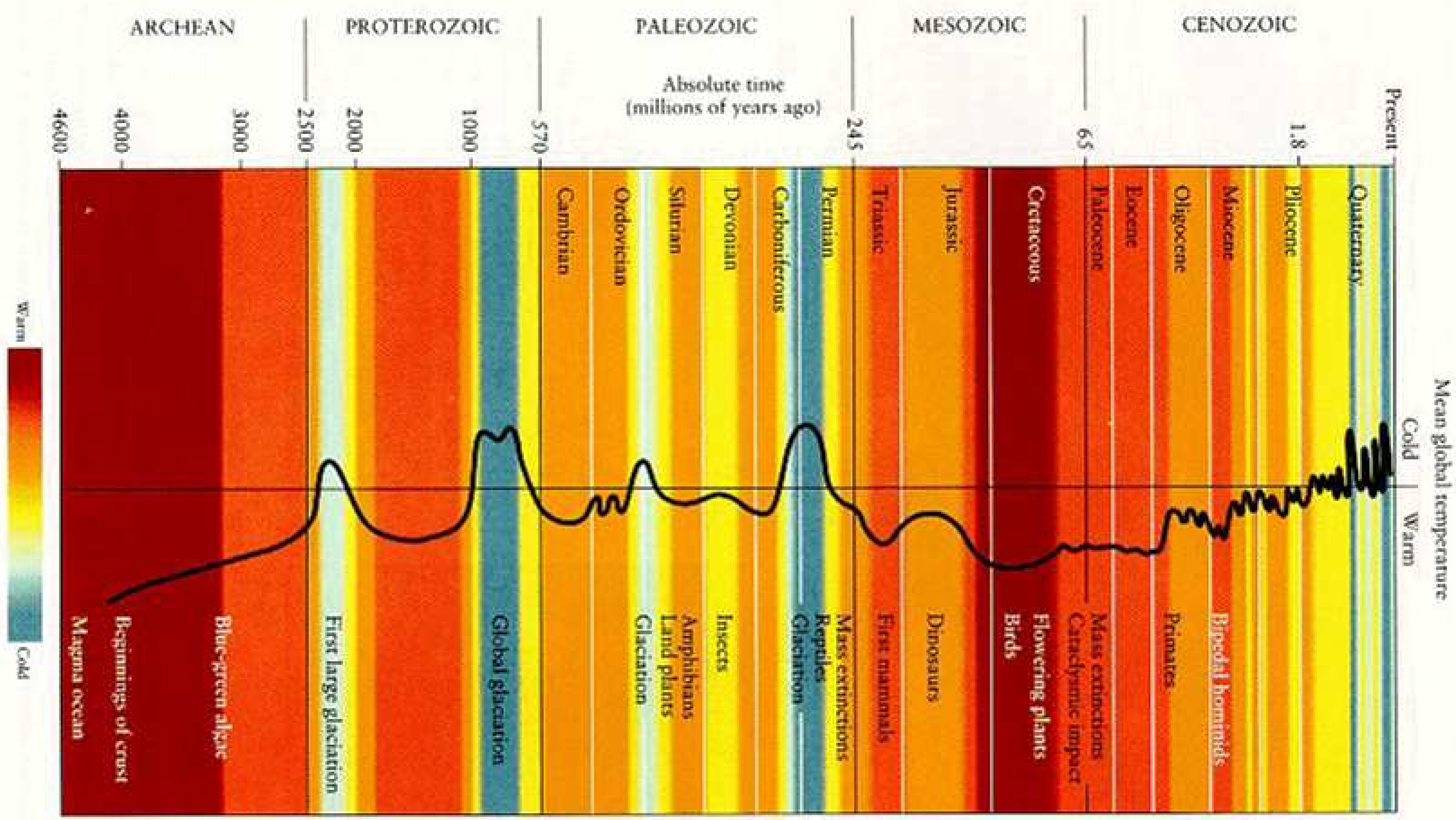
misure della tendenza

temperatura dell’aria

altezza del mare

precipitazione, vegetazione, insolazione, estensione dei ghiacci, ….

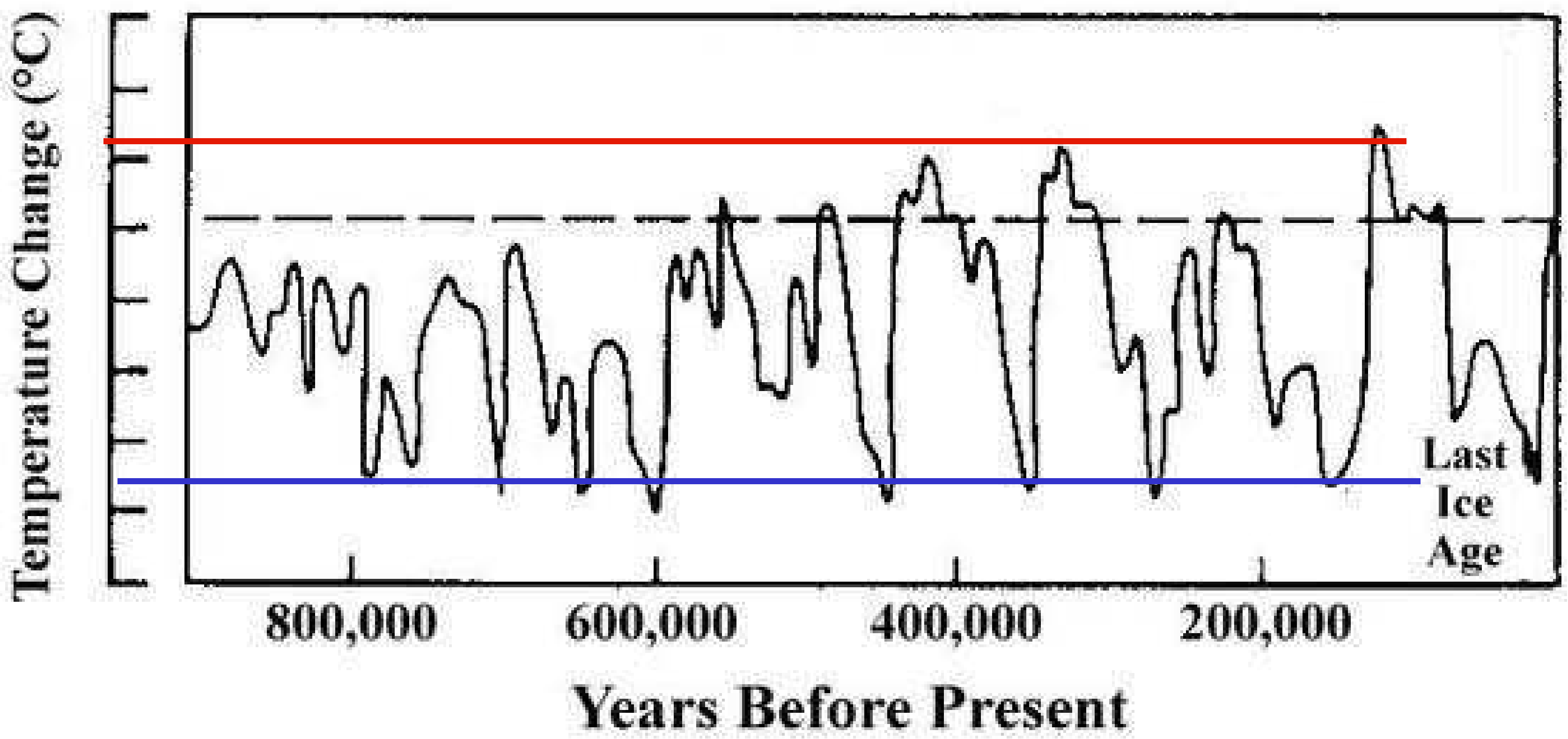
temperatura dell'aria


ARCHEAN
PROTEROZOIC
PALEOZOIC
MESOZOIC
CENOZOIC
Absolute time (millions of years ago)
4600
4000
3000
2500
2000
1000
570
245
65
1.8
Present
Cambrian
Ordovician
Silurian
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous
Paleocene
Eocene
Oligocene
Miocene
Pliocene
Quaternary
Warm
Cold
Mean global temperature
Cold
Warm
Magma ocean
Beginnings of crust
Blue-green algae
First large glaciation
Global glaciation
Glaciation
Land plants
Amphibians
Insects
Glaciation
Reptiles
Mass extinctions
First mammals
Dinosaurs
Birds
Flowering plants
Cataclysmic impact
Mass extinctions
Primates
Bipedal hominids

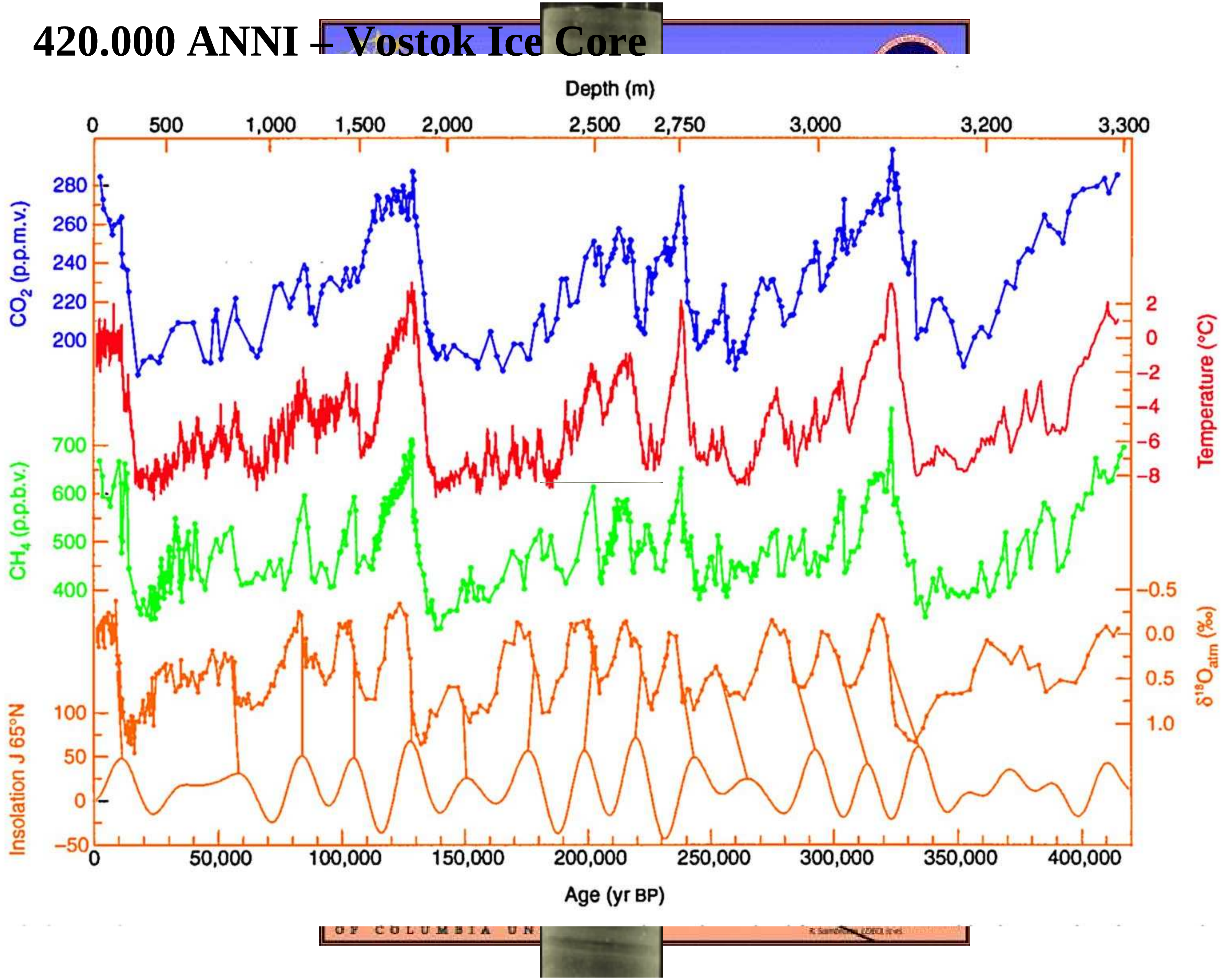
4.5 MILIARDI


Archean
Proterozoic
Cambrian
Permian
Present

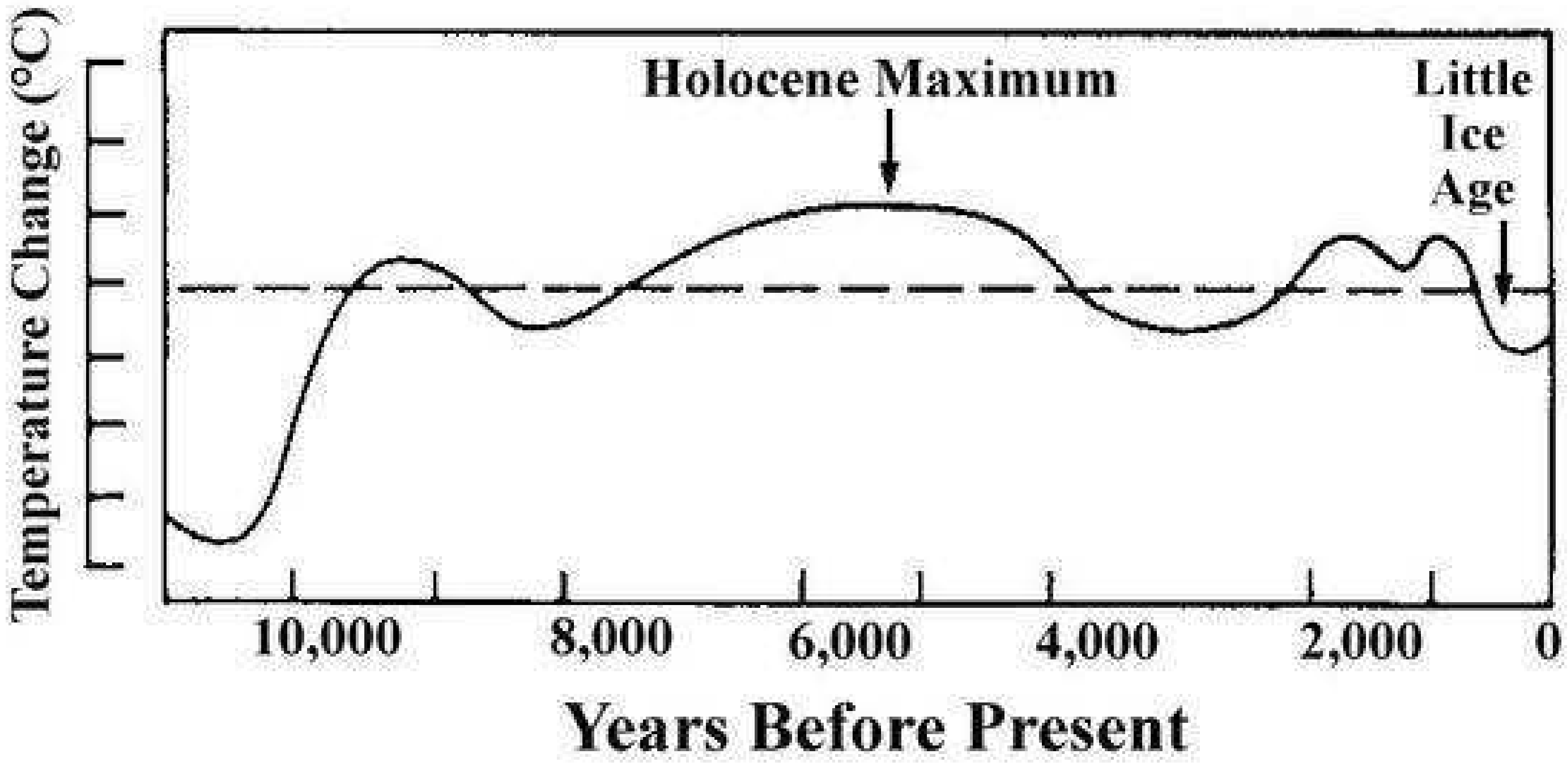
1 MILIONE DI ANNI



420.000 ANNI – Vostok Ice Core

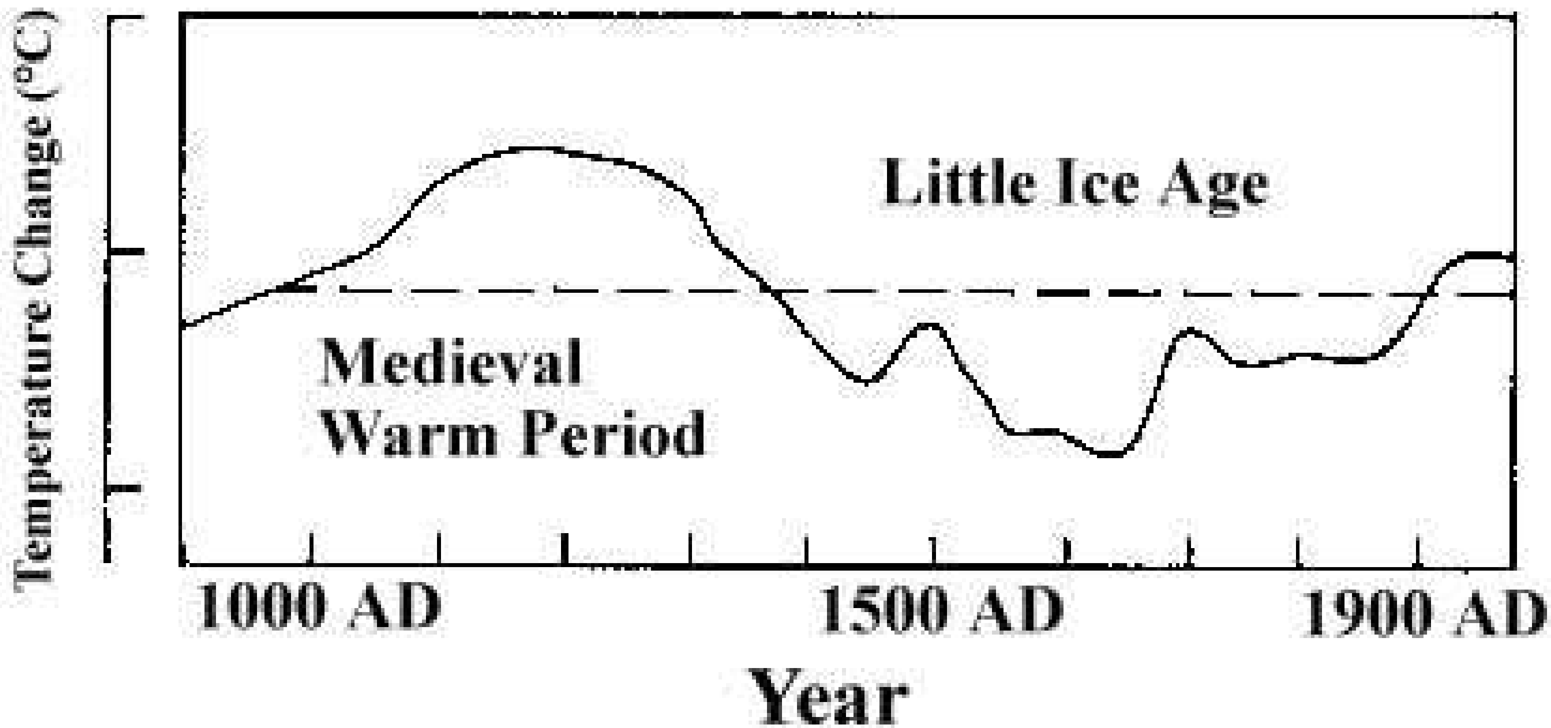


10.000 ANNI



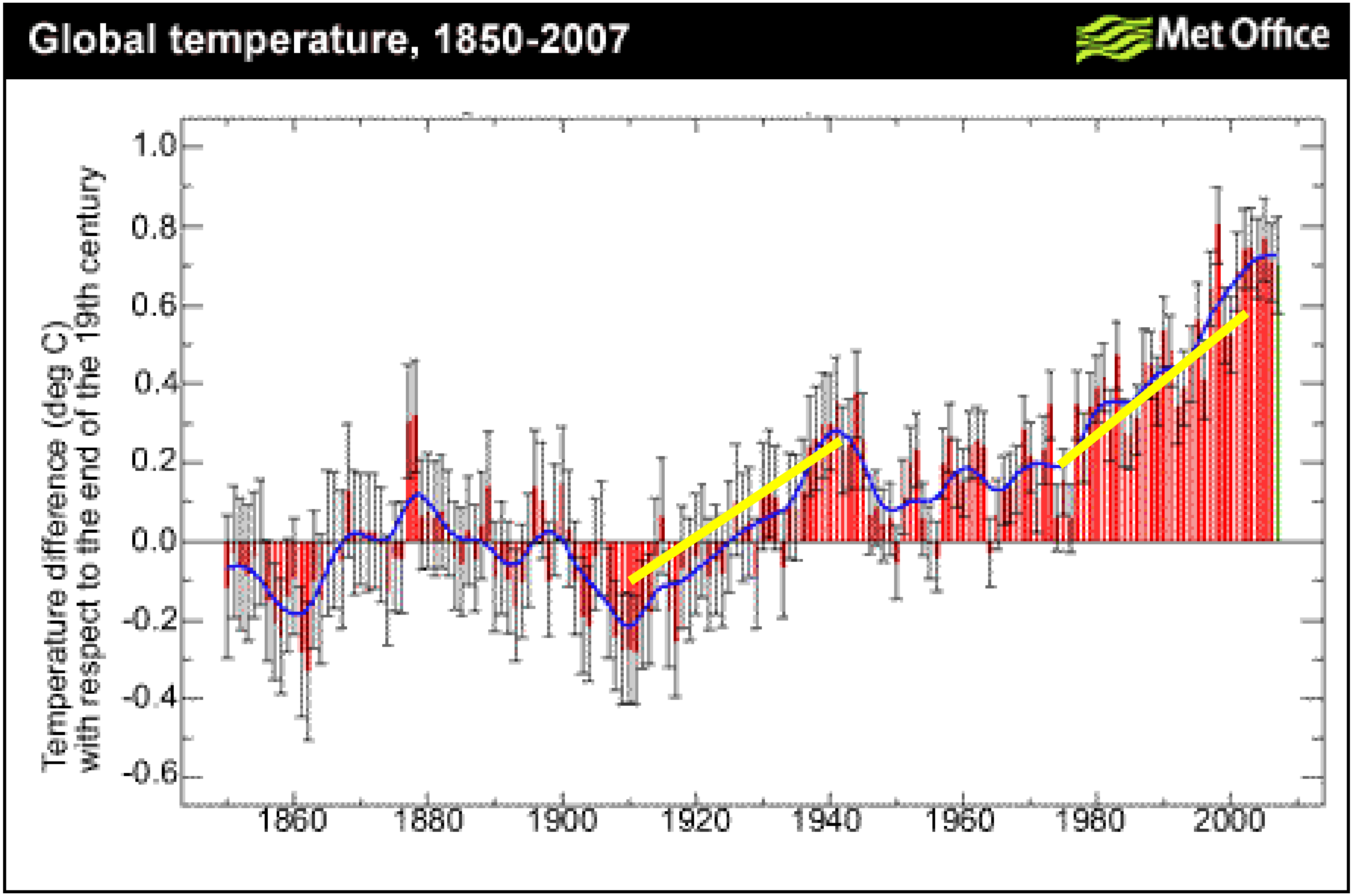
Holocene Maximum
Little Ice Age
Temperature Change (°C)
10,000
8,000
6,000
4,000
2,000
0
Years Before Present

1.000 ANNI



Temperature Change (°C)
Little Ice Age
Medieval
Warm Period
1000 AD
1500 AD
1900 AD
Year

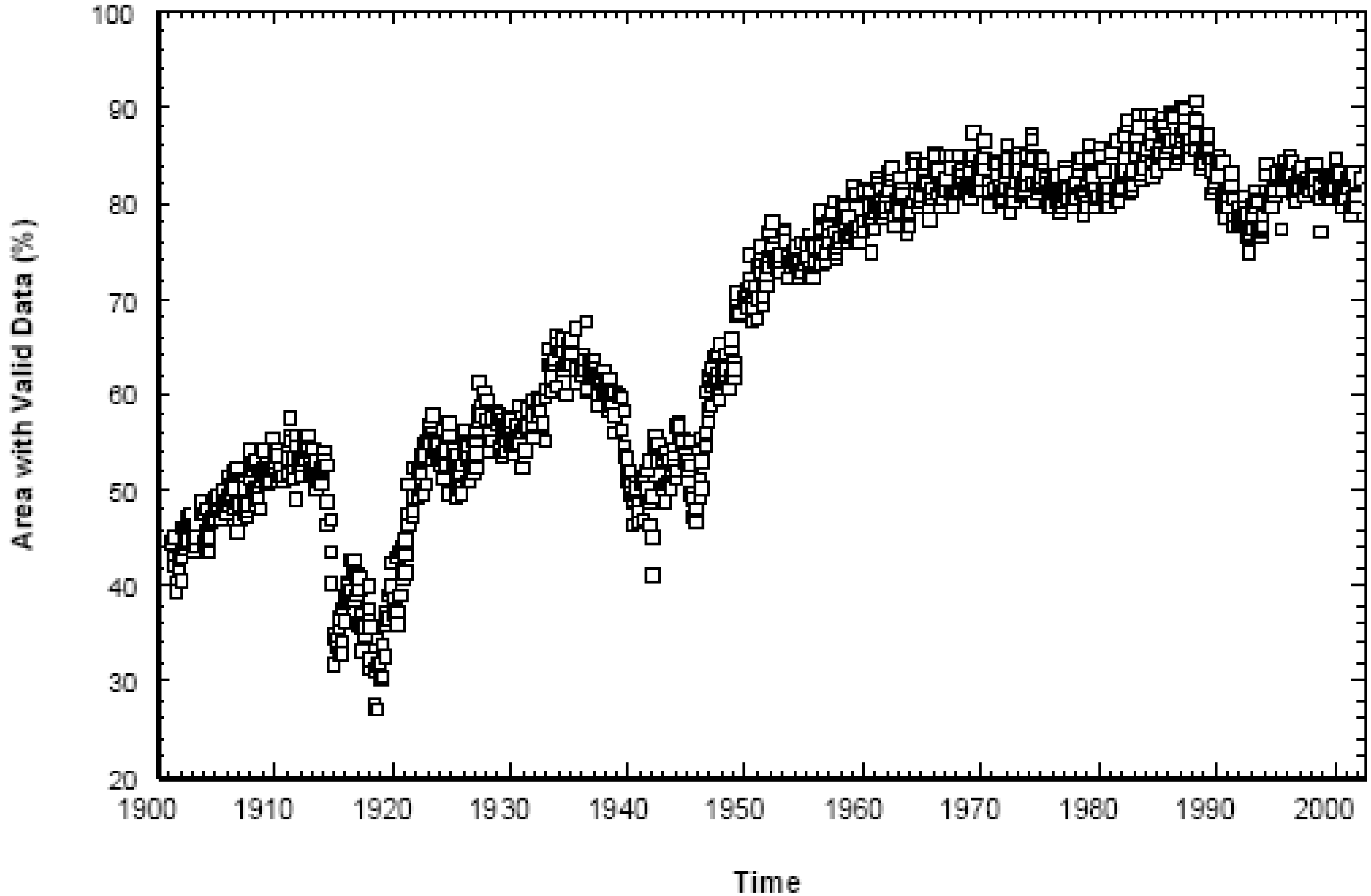
100 ANNI


Global temperature, 1850-2007
Met Office
Temperature difference (deg C) with respect to the end of the 19th century
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1860
1880
1900
1920
1940
1960
1980
2000

Problema I: copertura dei sensori

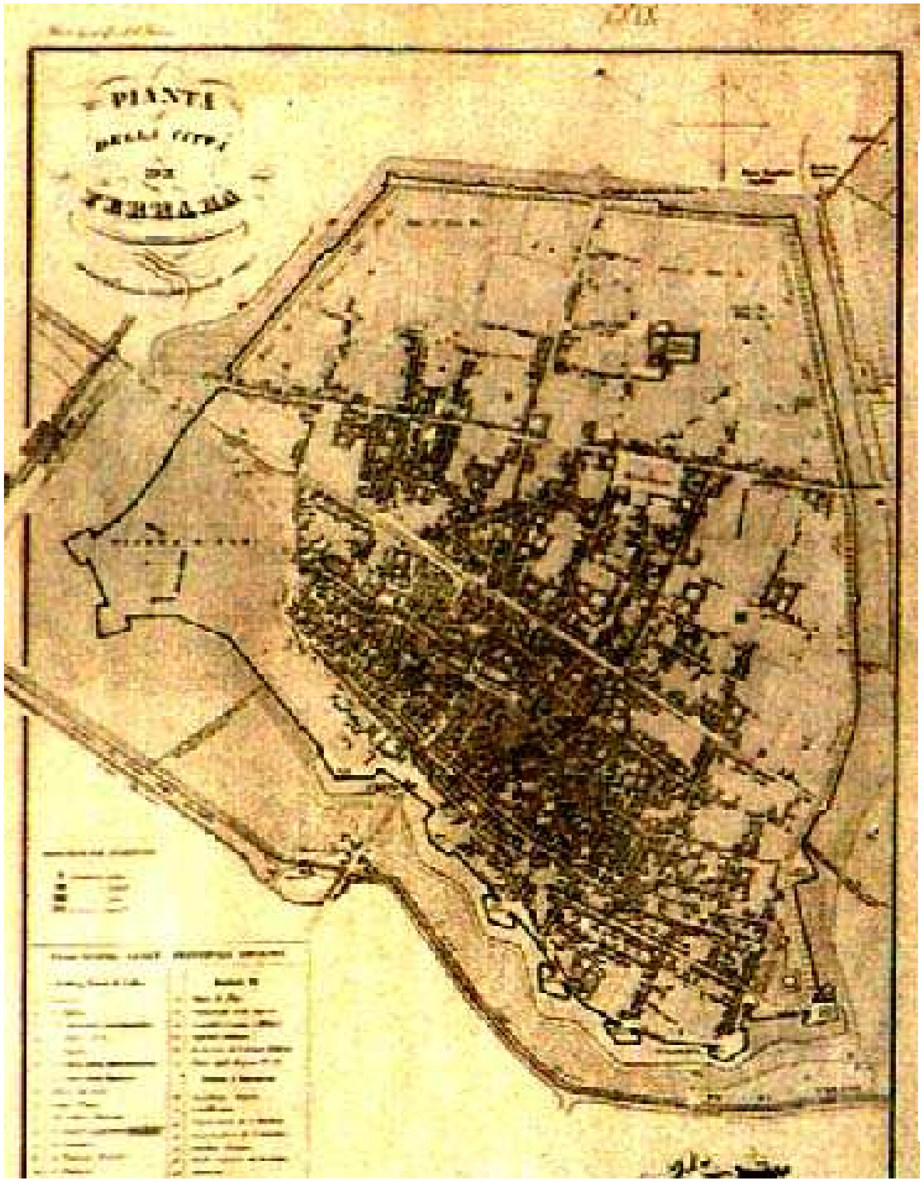
la frazione di superficie globale monitorata varia

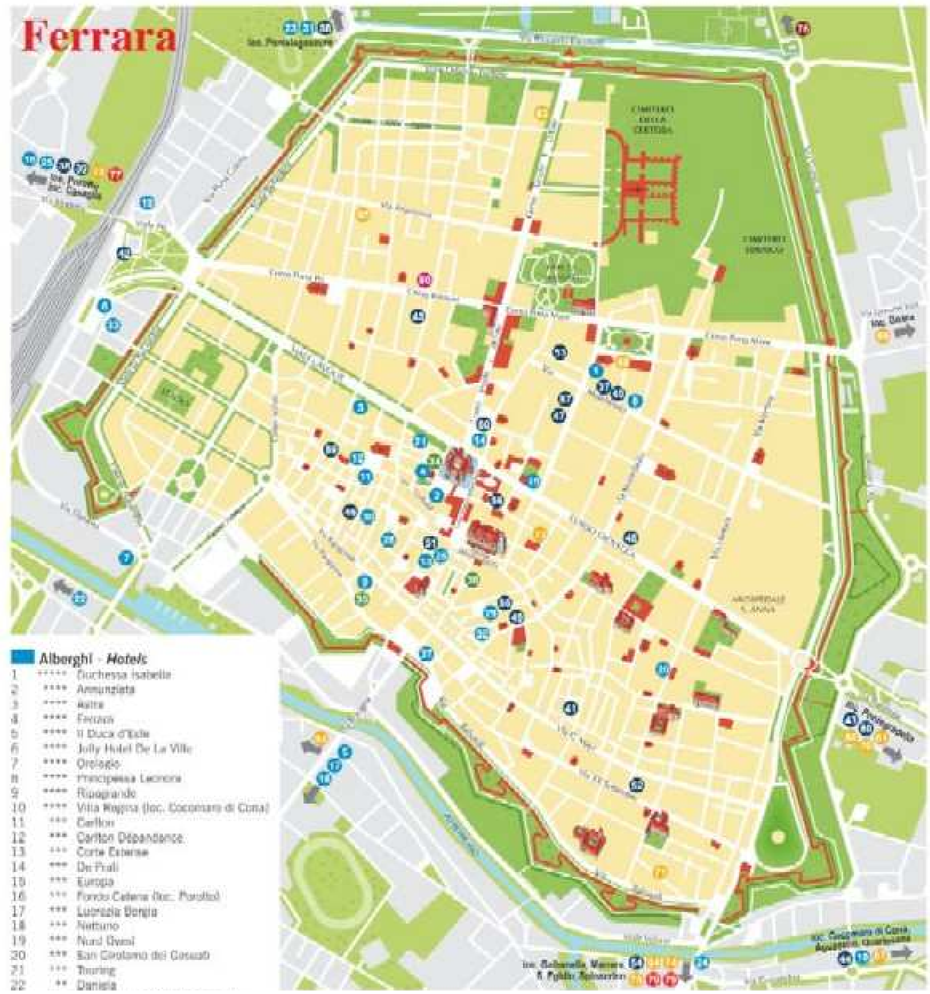
$5° \times 5° \sim 550 \times 400\ km^2$



Problema II: effetti urbani

da meta' ottocento la struttura urbana e' mutata





Problema III: manutenzione delle stazioni

non controllabile, variabile, importante

capannine “bianche”

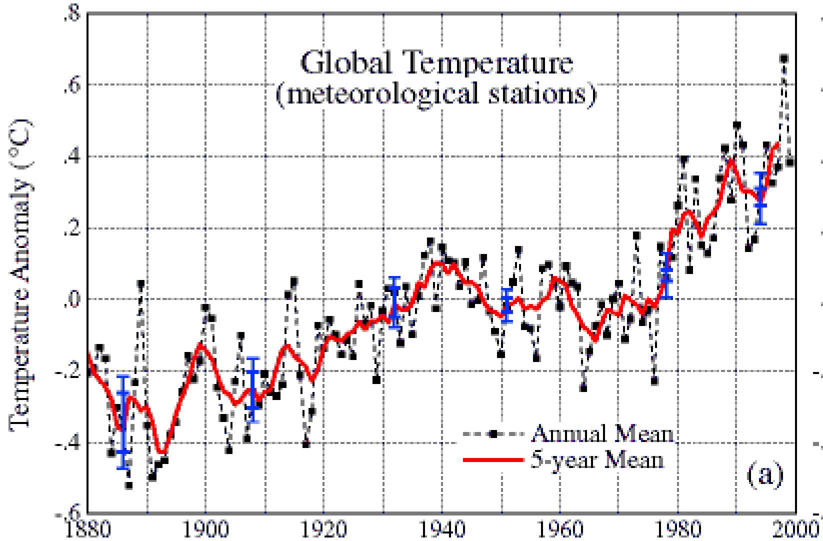
areate

modalita’ di lettura

tipo di strumento

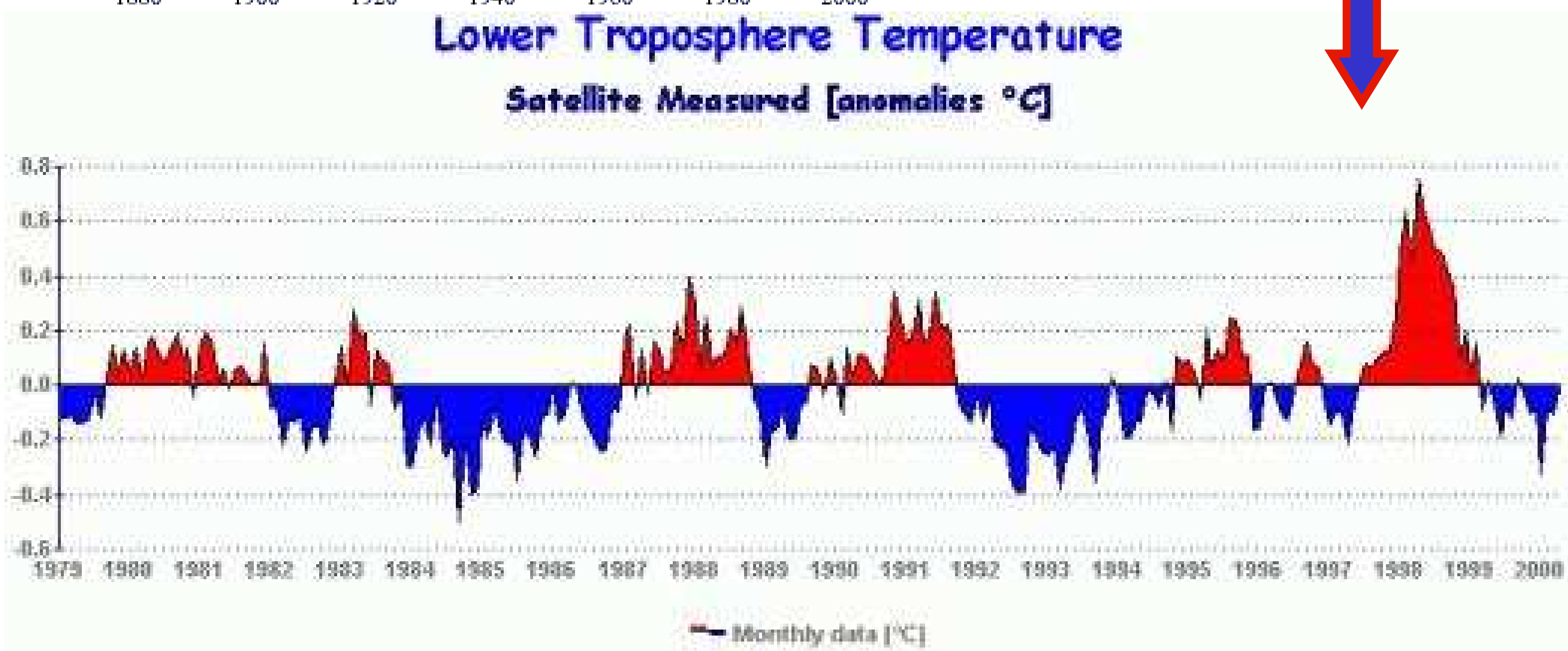
operatori

Problema IV: confronti con dati da satellite



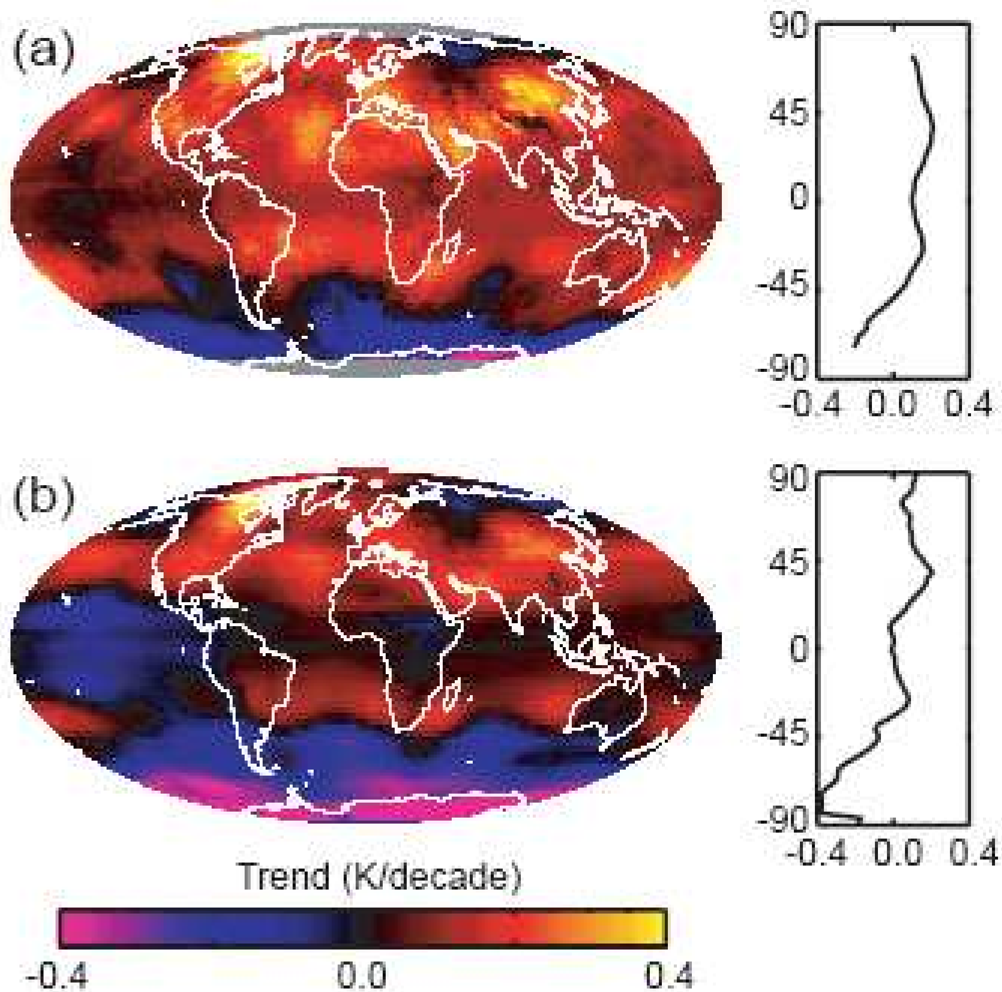
0,2 K/decade

0,09 K/decade

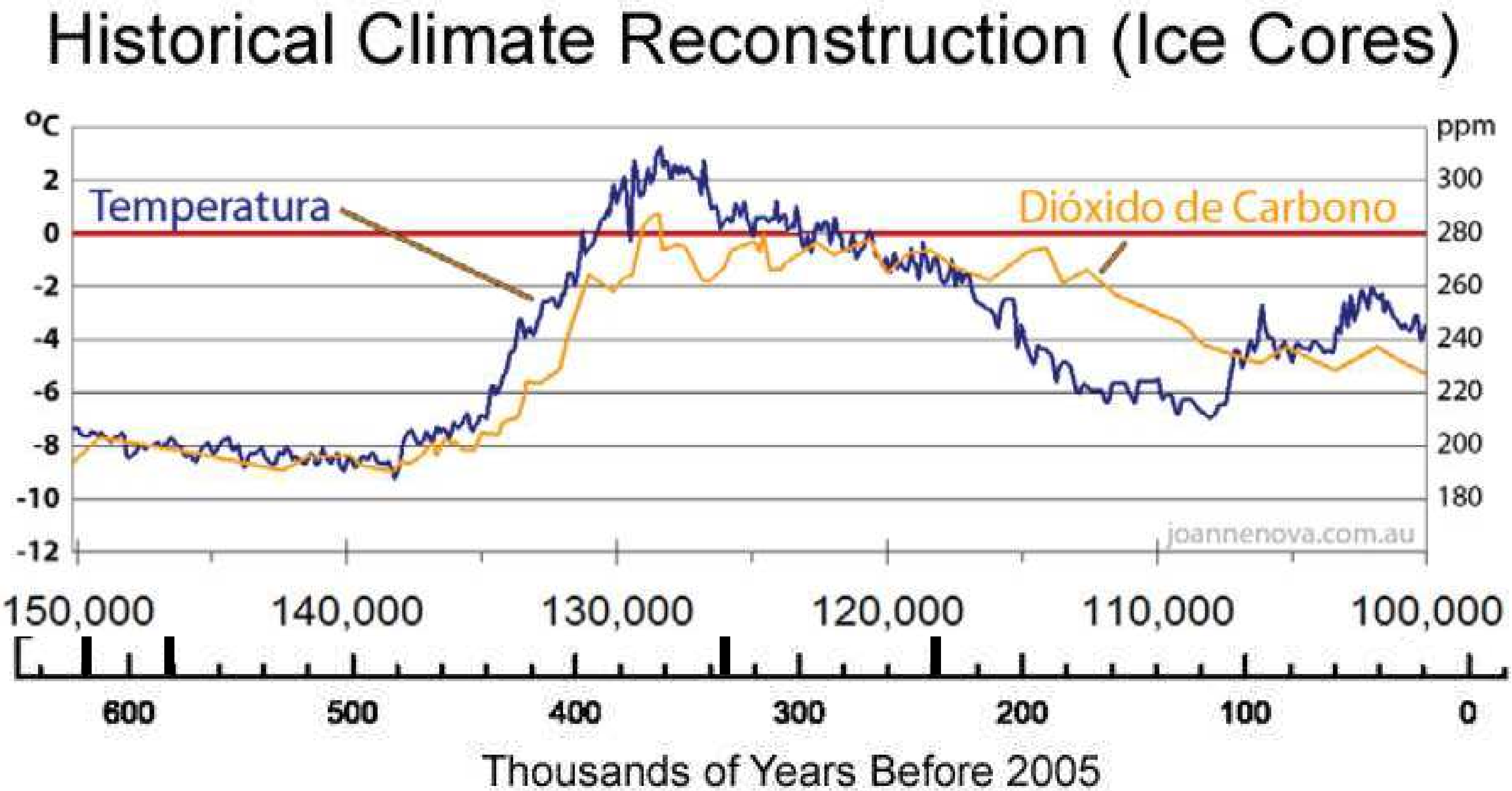


Problema IV: confronti con dati da satellite

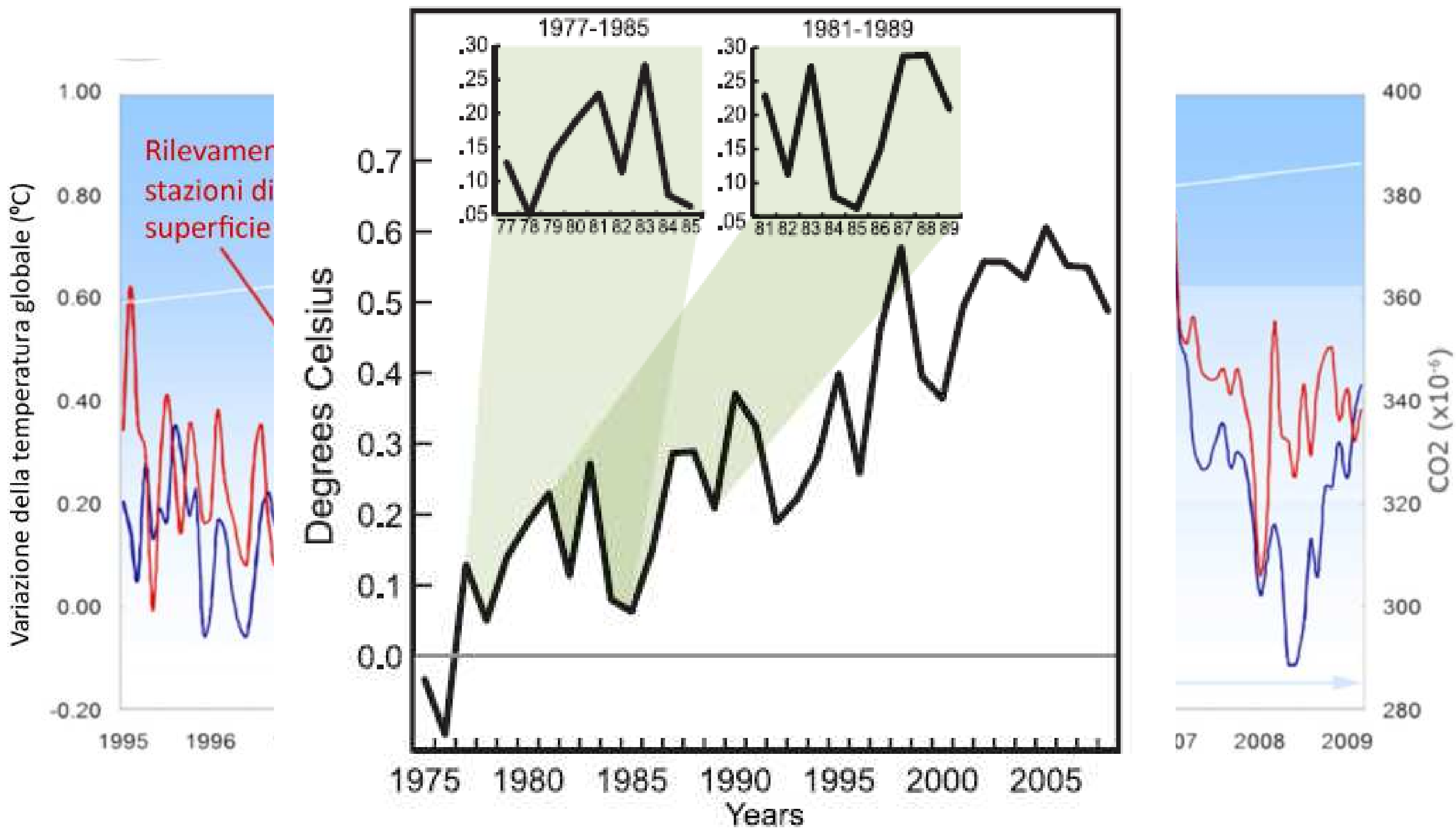
Microwave Sounding Unit (MSU)



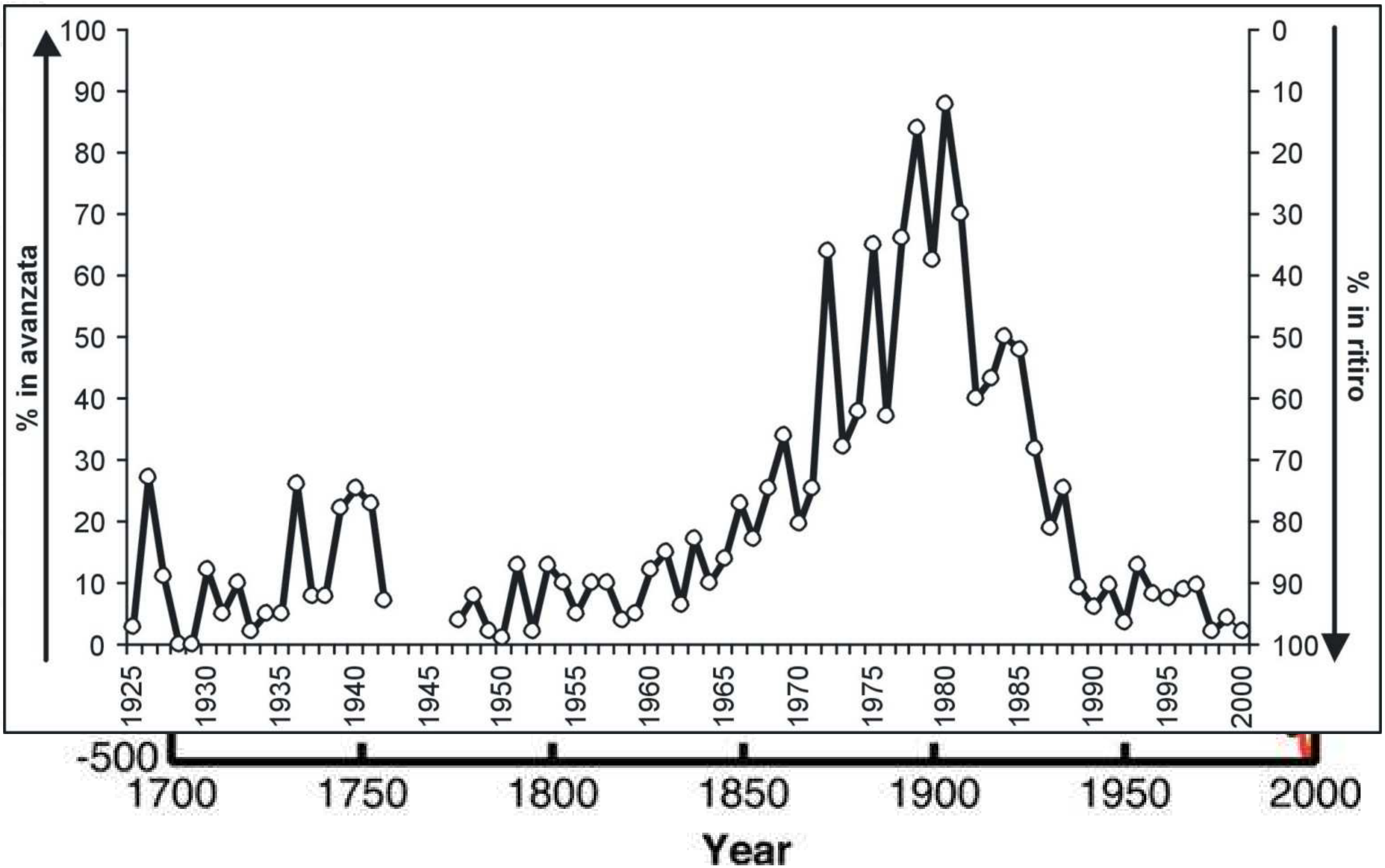
Problema V: l'aumento di concetrazione di CO2 causa riscaldamento o viceversa ?



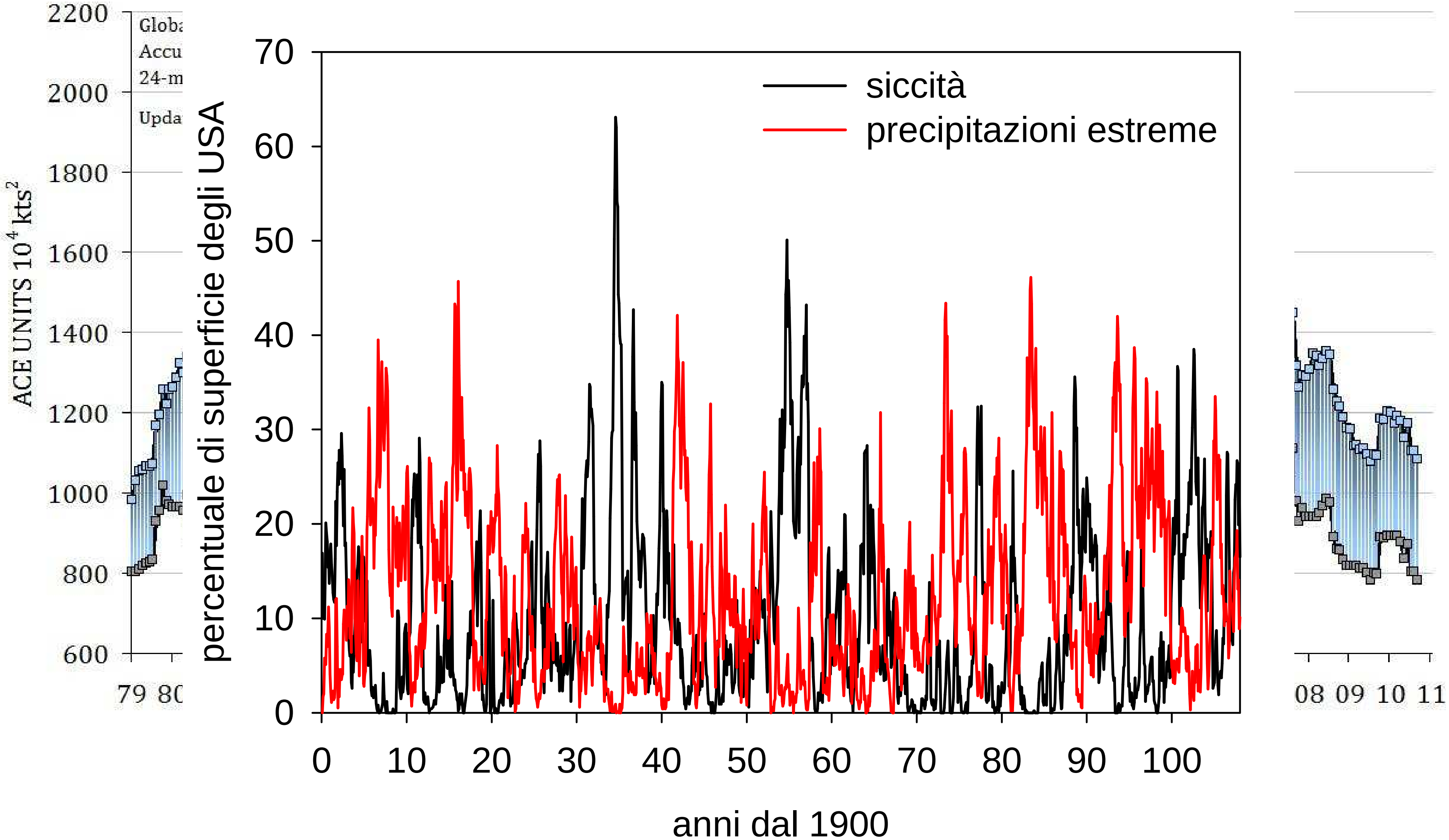
Problema VI: ultimi 10 anni di non riscaldamento



Problema VII: ritiro dei ghiacciai



Problema VIII: segnali minimi sugli eventi estremi



VARIAZIONE DEL LIVELLO DEL MARE

LIVELLO DEI MARI

<u>**cause:**</u>

1) dilatazione termica ~ 0.5 m / K

2) scioglimento del ghiaccio:

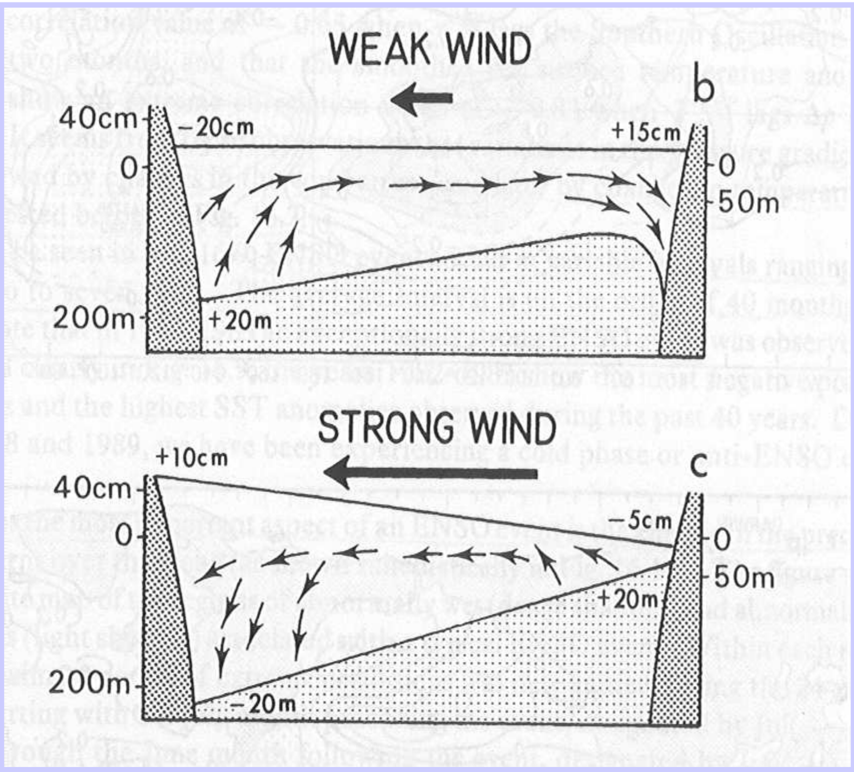
a) ghiacciai	**+**	**0.5 m**
b) Antartide e Groenlandia	**+**	**68.8 m**
c) ghiaccio marino	**~**	**0.1 m**

3) innalzamento (Scandinavia ~ + 1m / 100 anni)

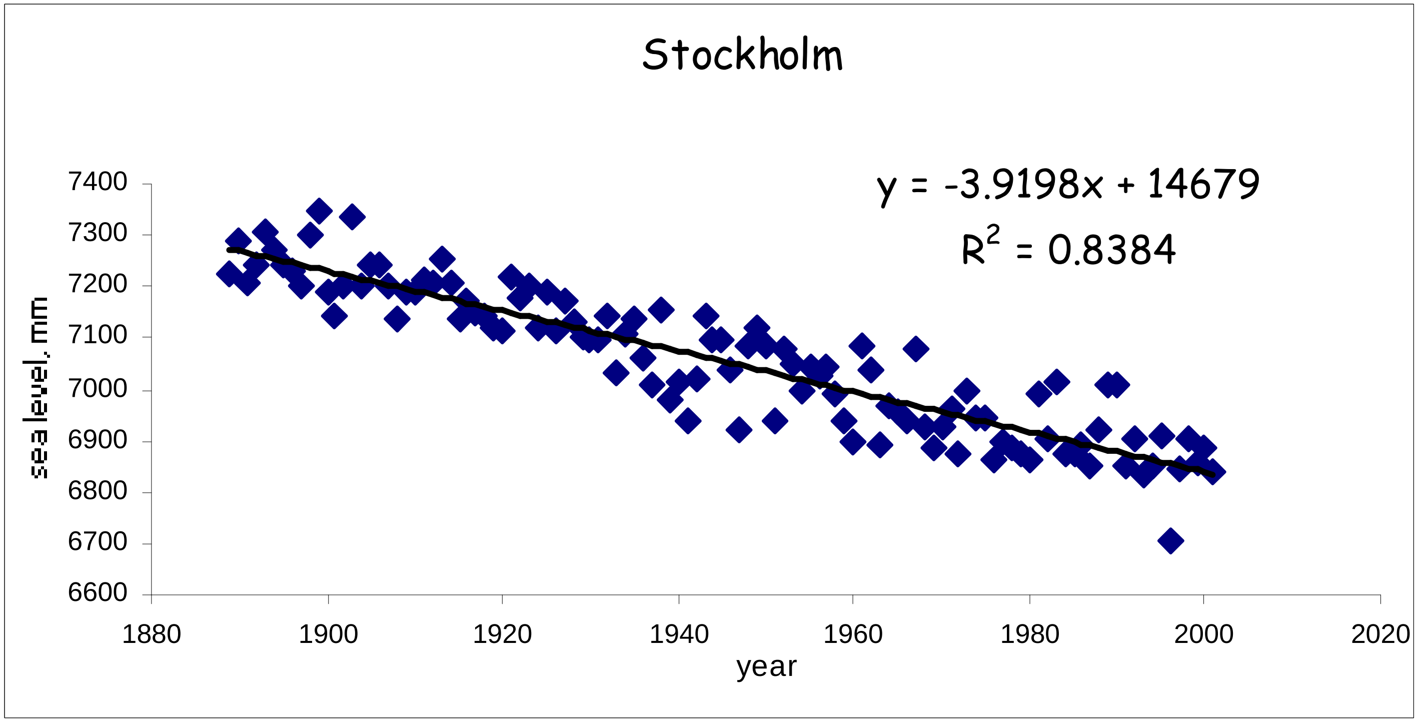
4) subsidenza (Thailandia ~ - 1 m / 30 anni)

il livello del mare varia localmente per forzature dinamiche (vento, correnti)

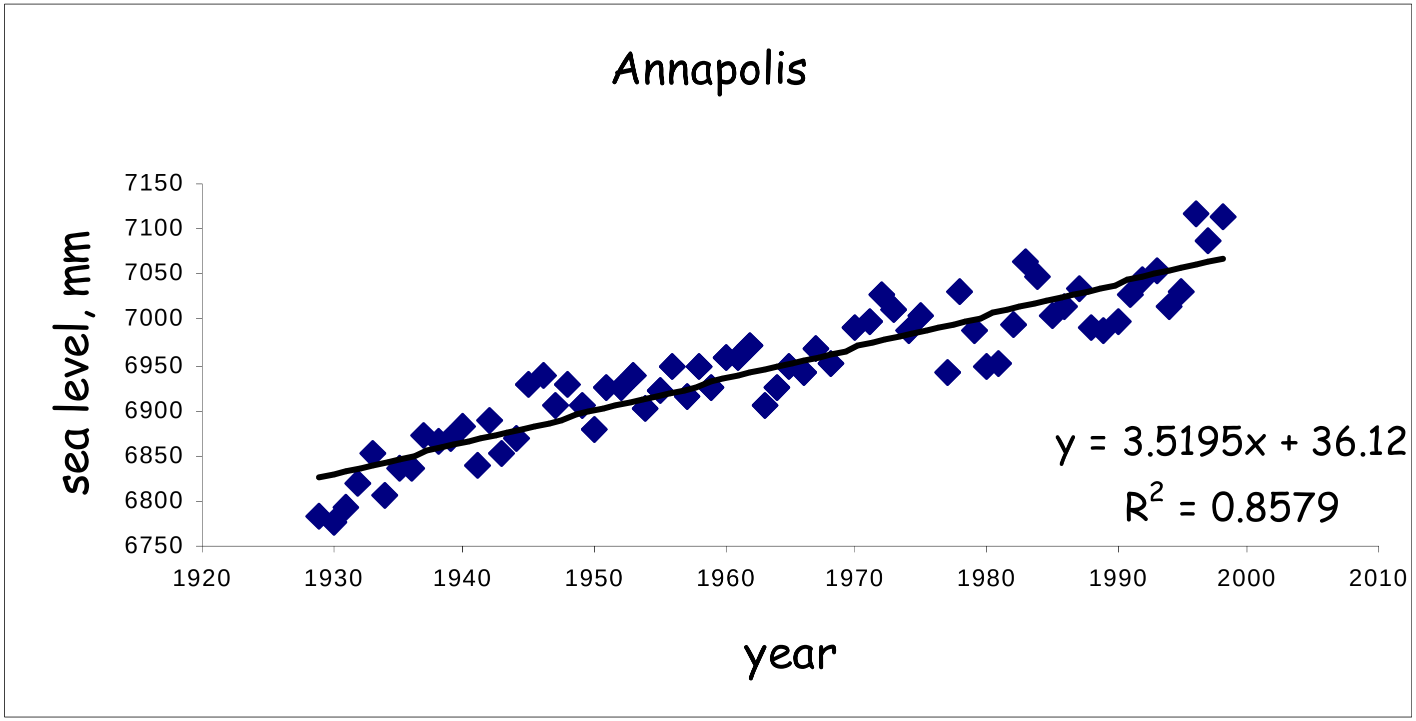
Pacifico equatoriale influenzato da El niño



Acqua alta nella laguna di Venezia

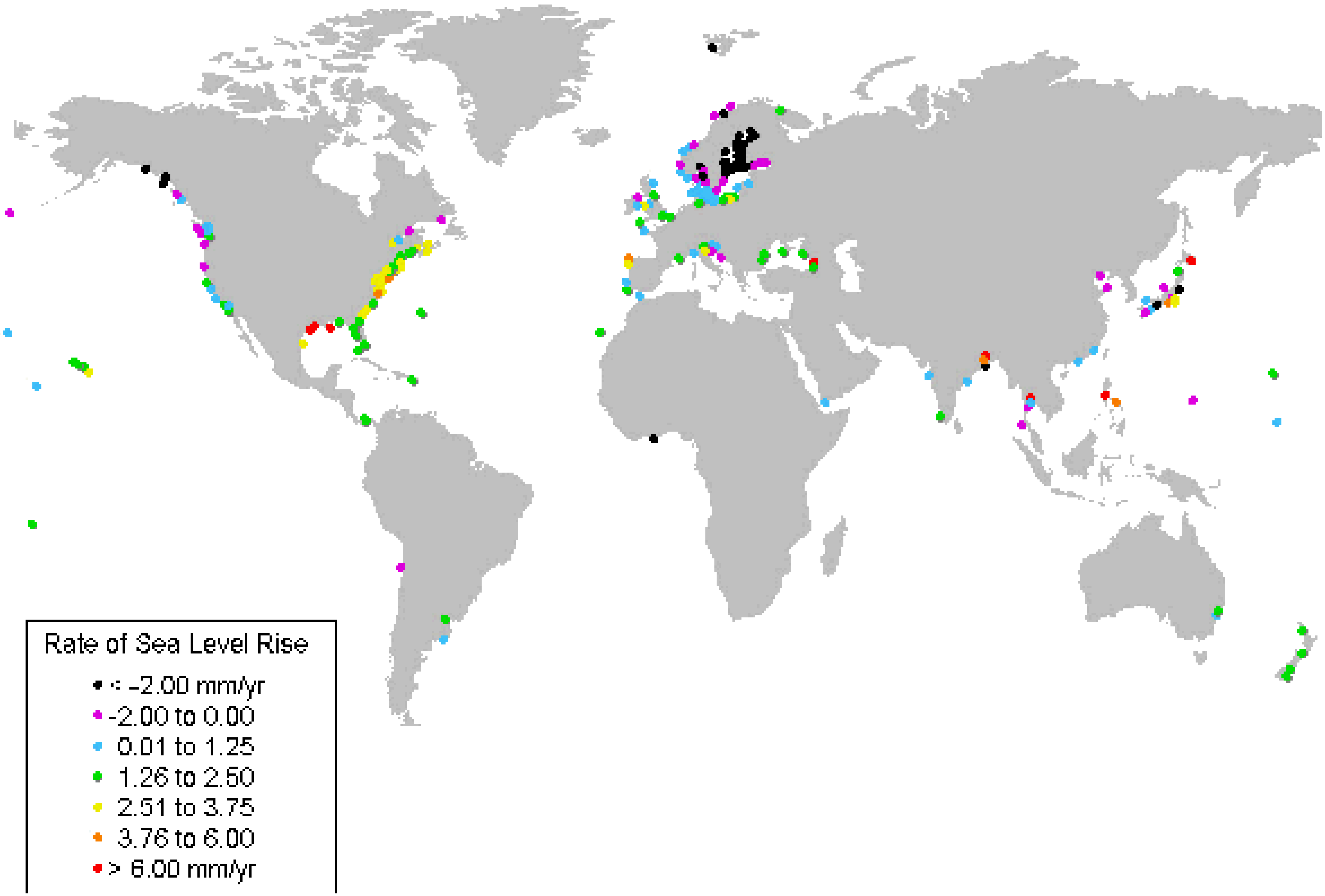


Stockholm
y = -3.9198x + 14679
R^2 = 0.8384
sea level, mm
7400
7300
7200
7100
7000
6900
6800
6700
6600
1880
1900
1920
1940
1960
1980
2000
2020
year

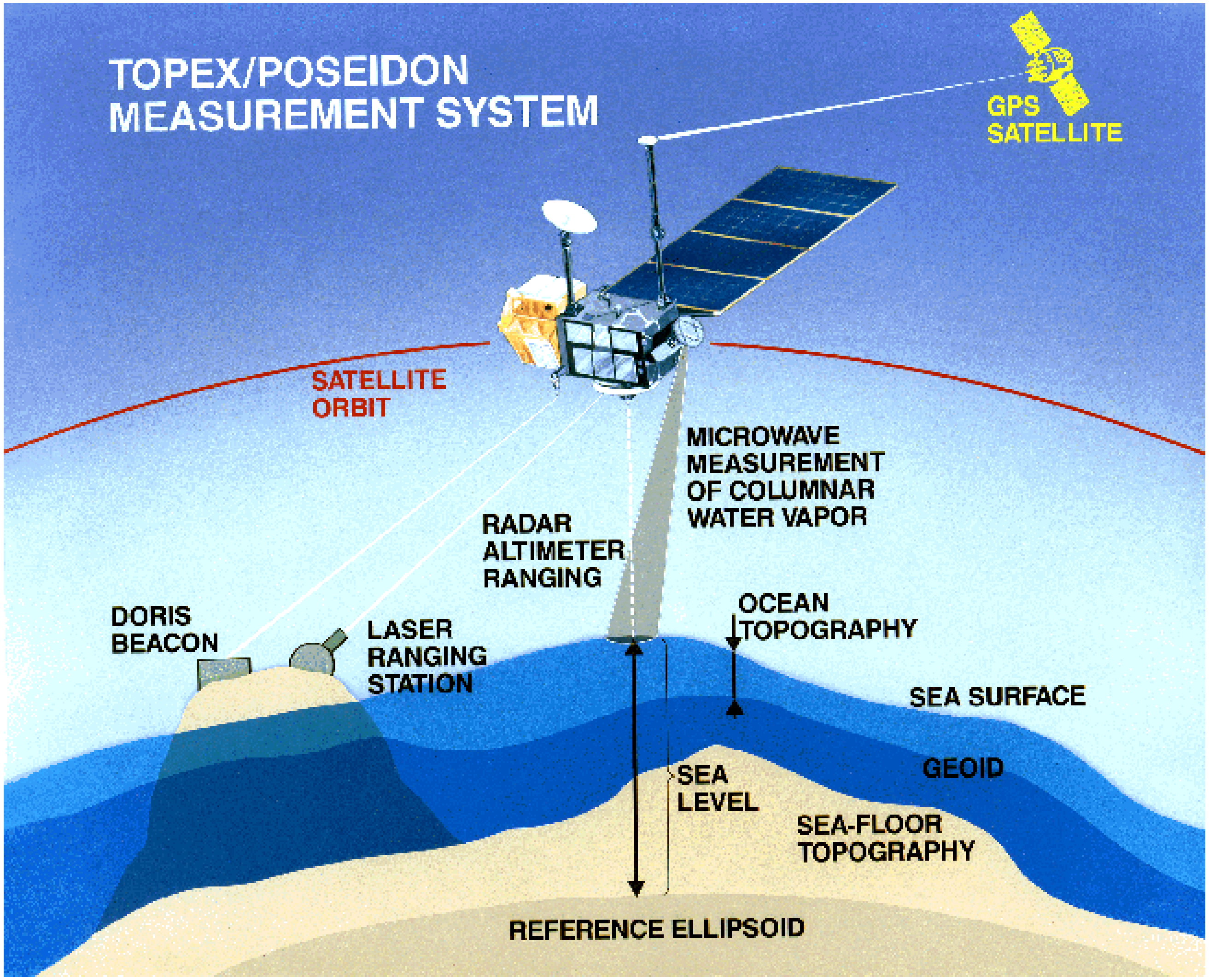


Annapolis
sea level, mm
7150
7100
7050
7000
6950
6900
6850
6800
6750
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
y = 3.5195x + 36.12
R^2 = 0.8579
year

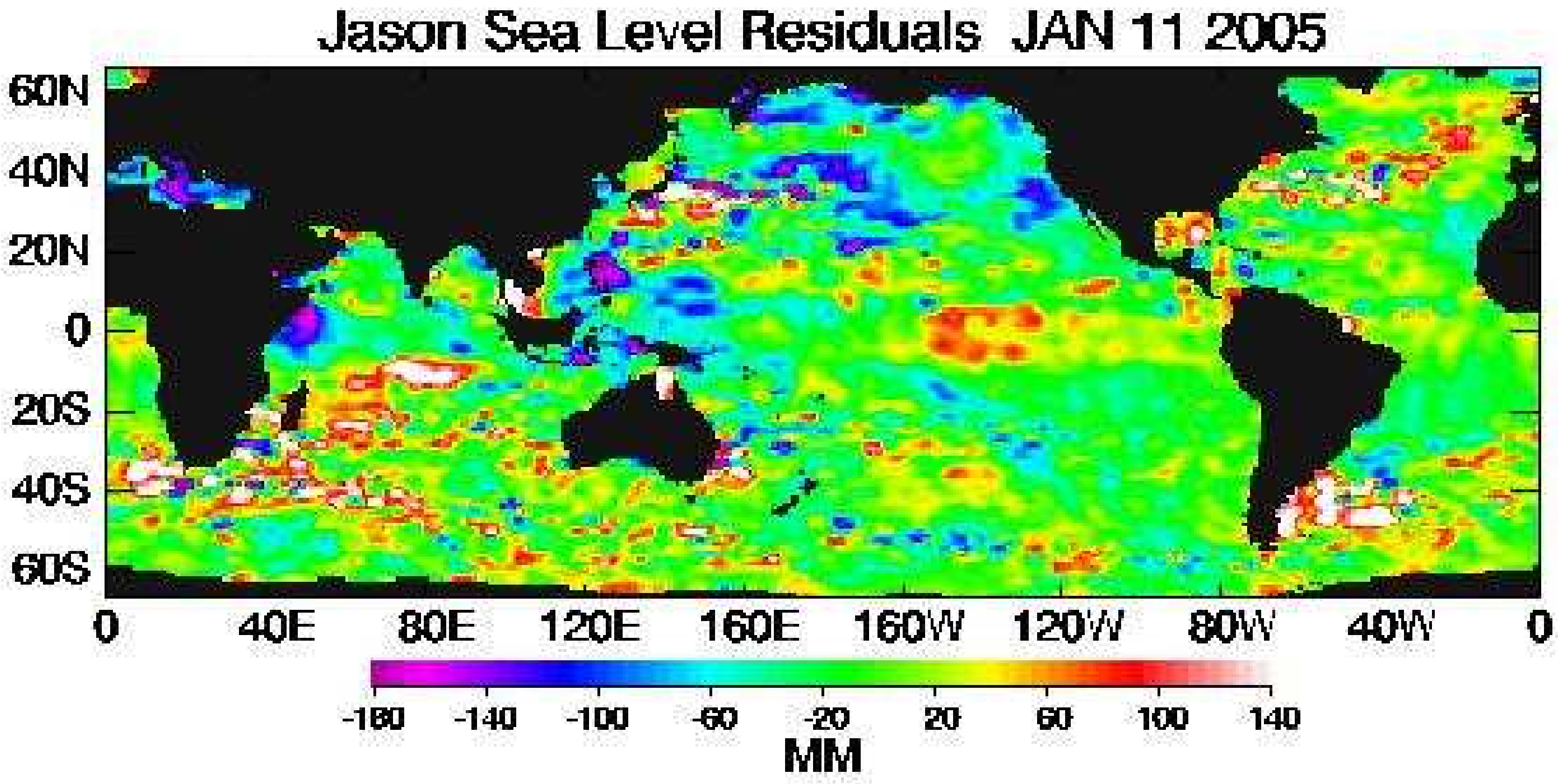
LIVELLO DEI MARI



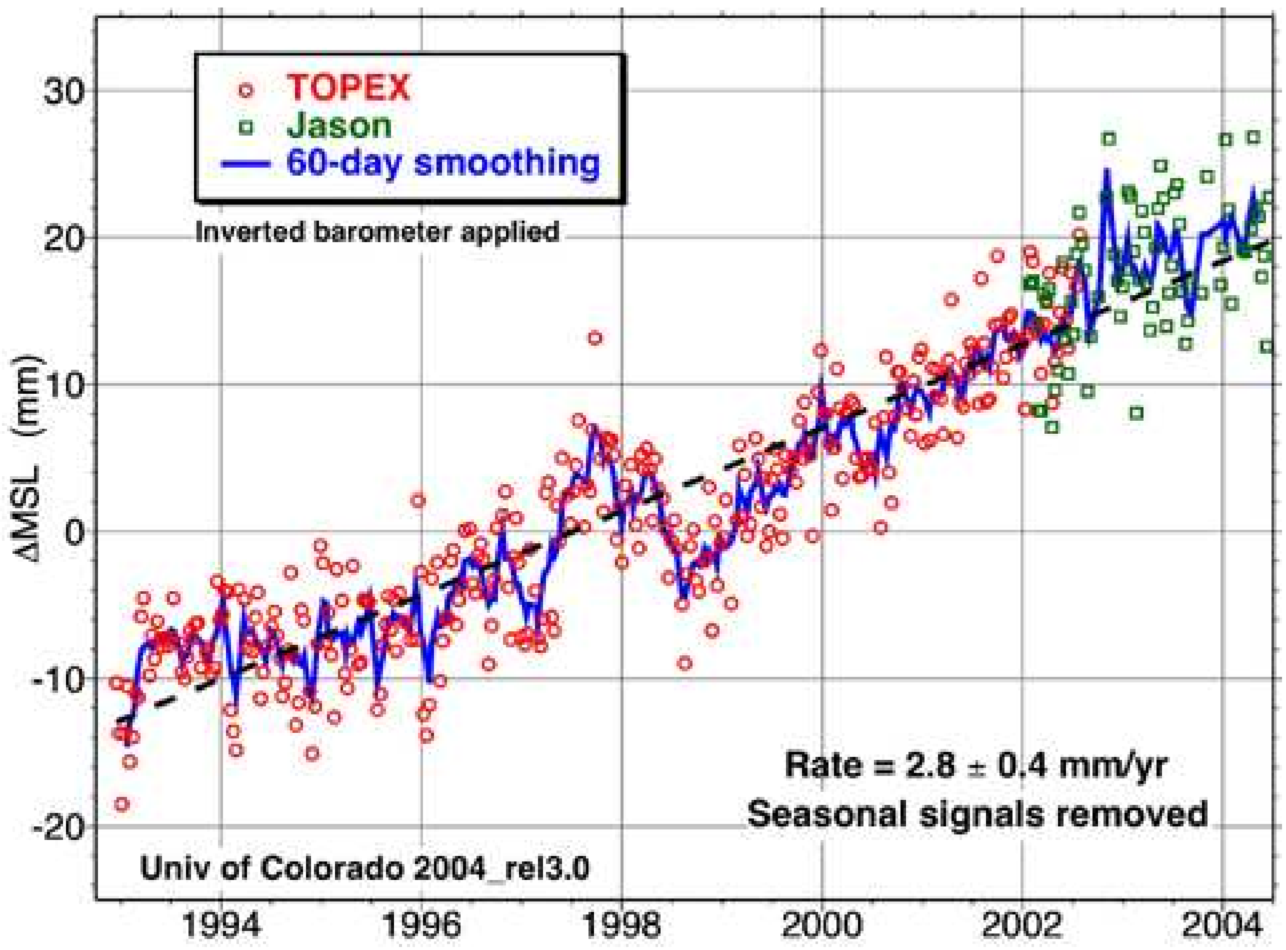
LIVELLO DEI MARI



LIVELLO DEI MARI



LIVELLO DEI MARI



con le boe:

1-2 mm/y

<u>osservazioni dallo spazio</u>

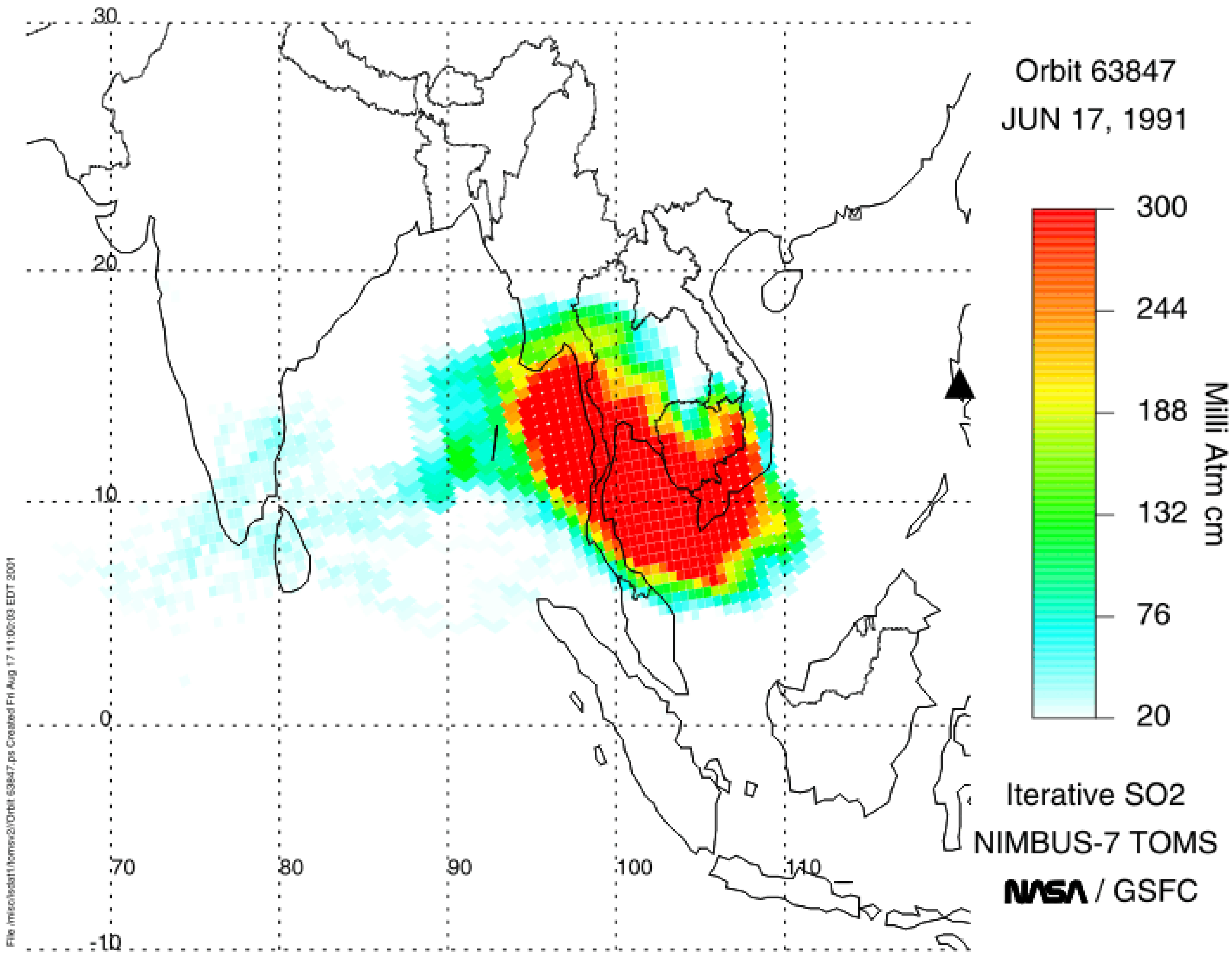
vulcani,

vegetazione,

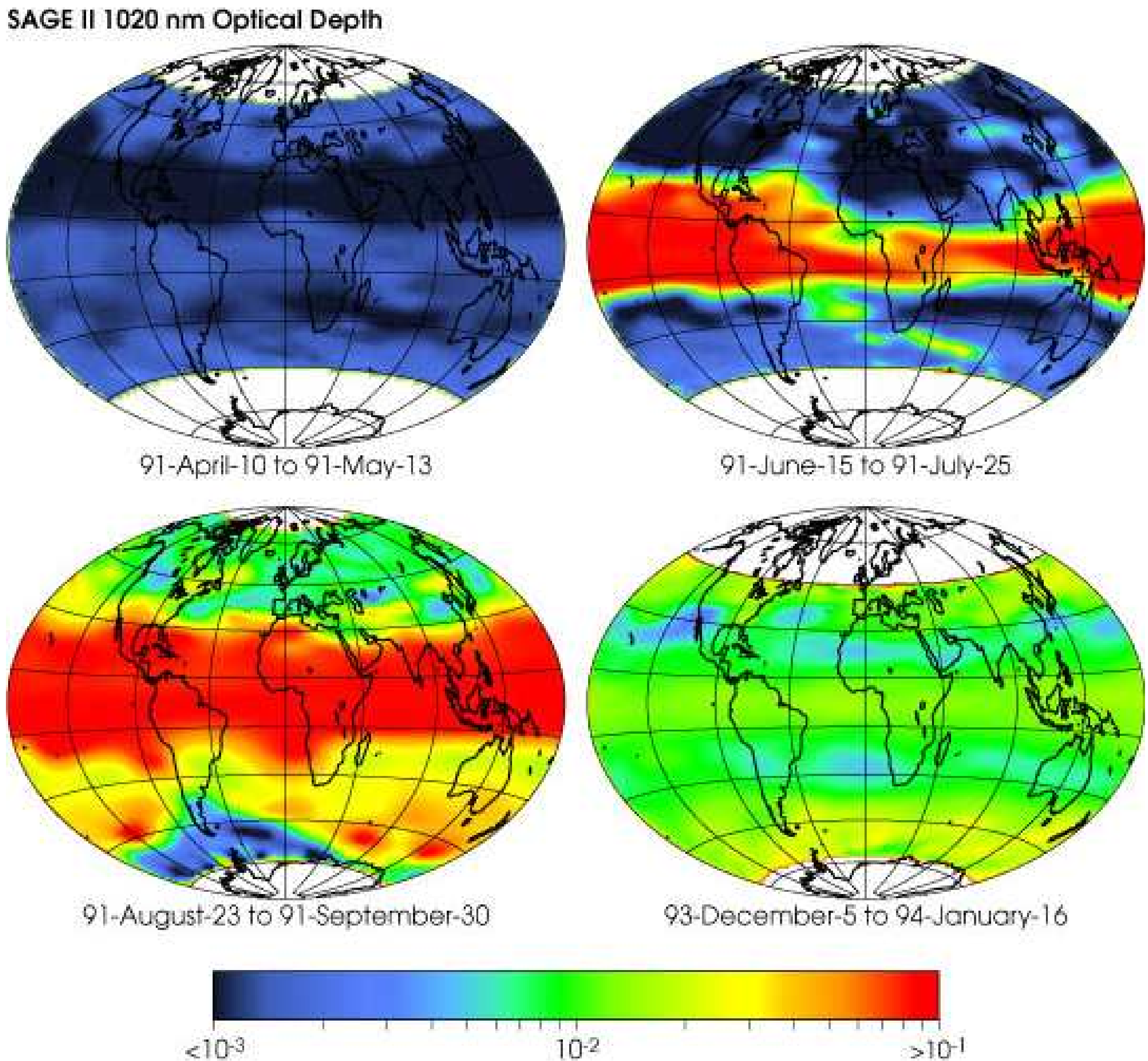
el nino.

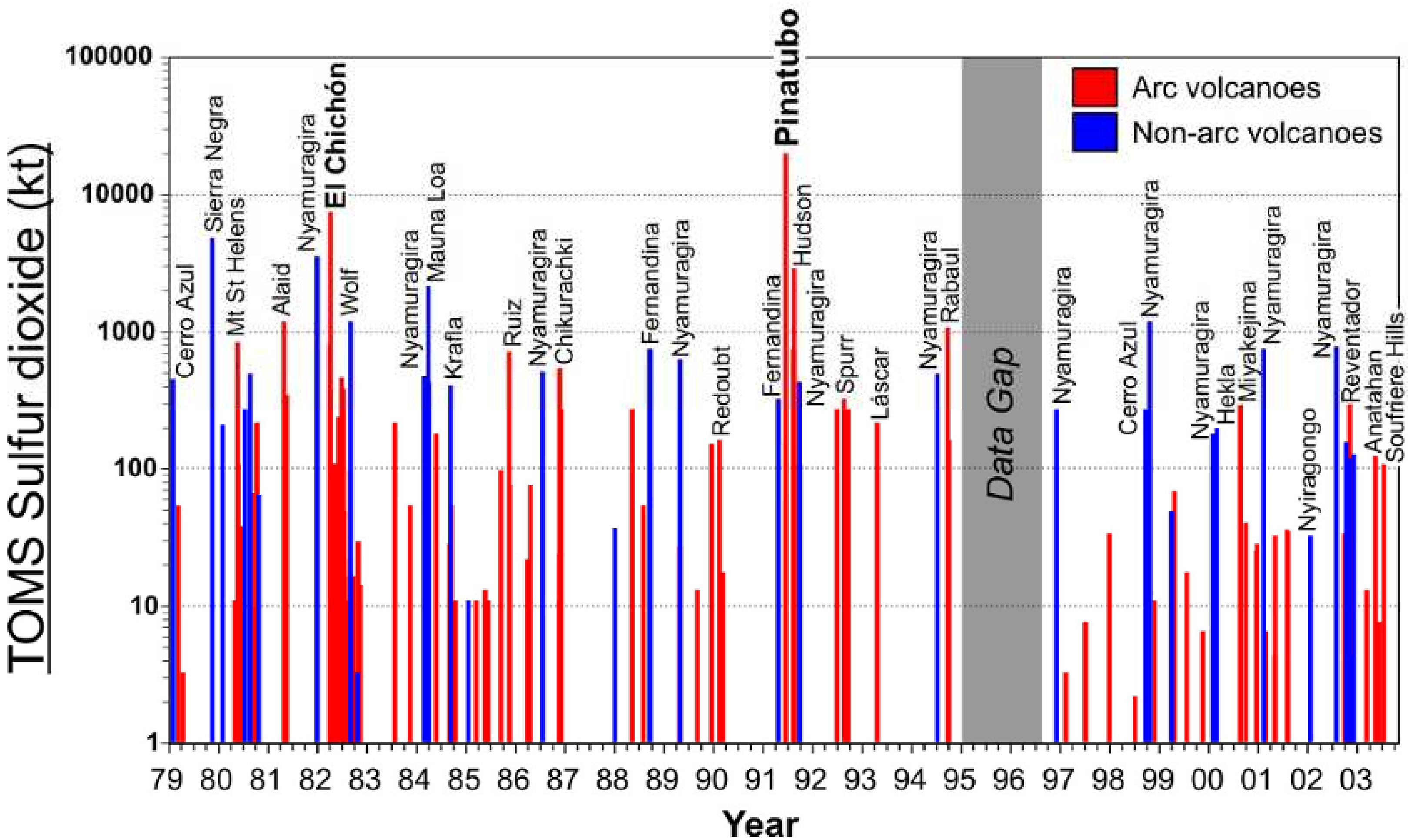
eruzione del monte Pinatubo (12-16/06/91)

eruzione del monte Pinatubo

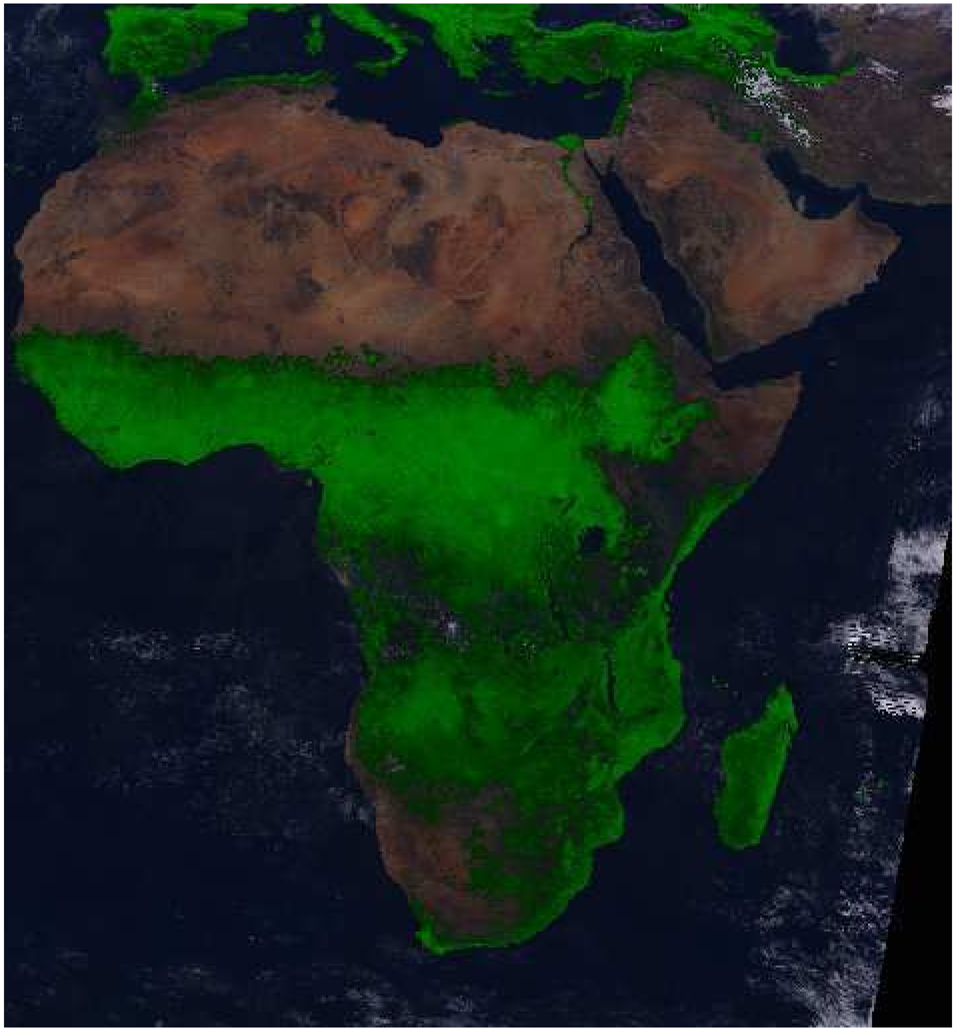


eruzione del monte Pinatubo

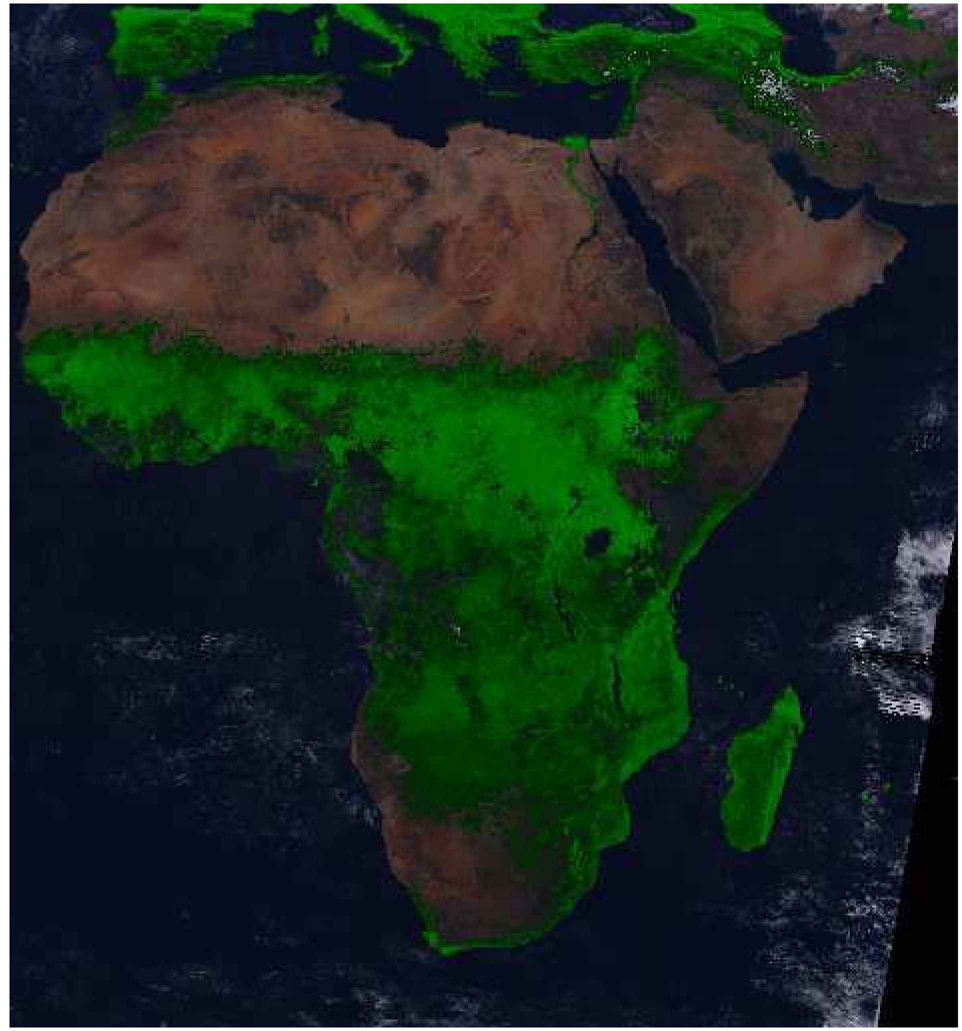


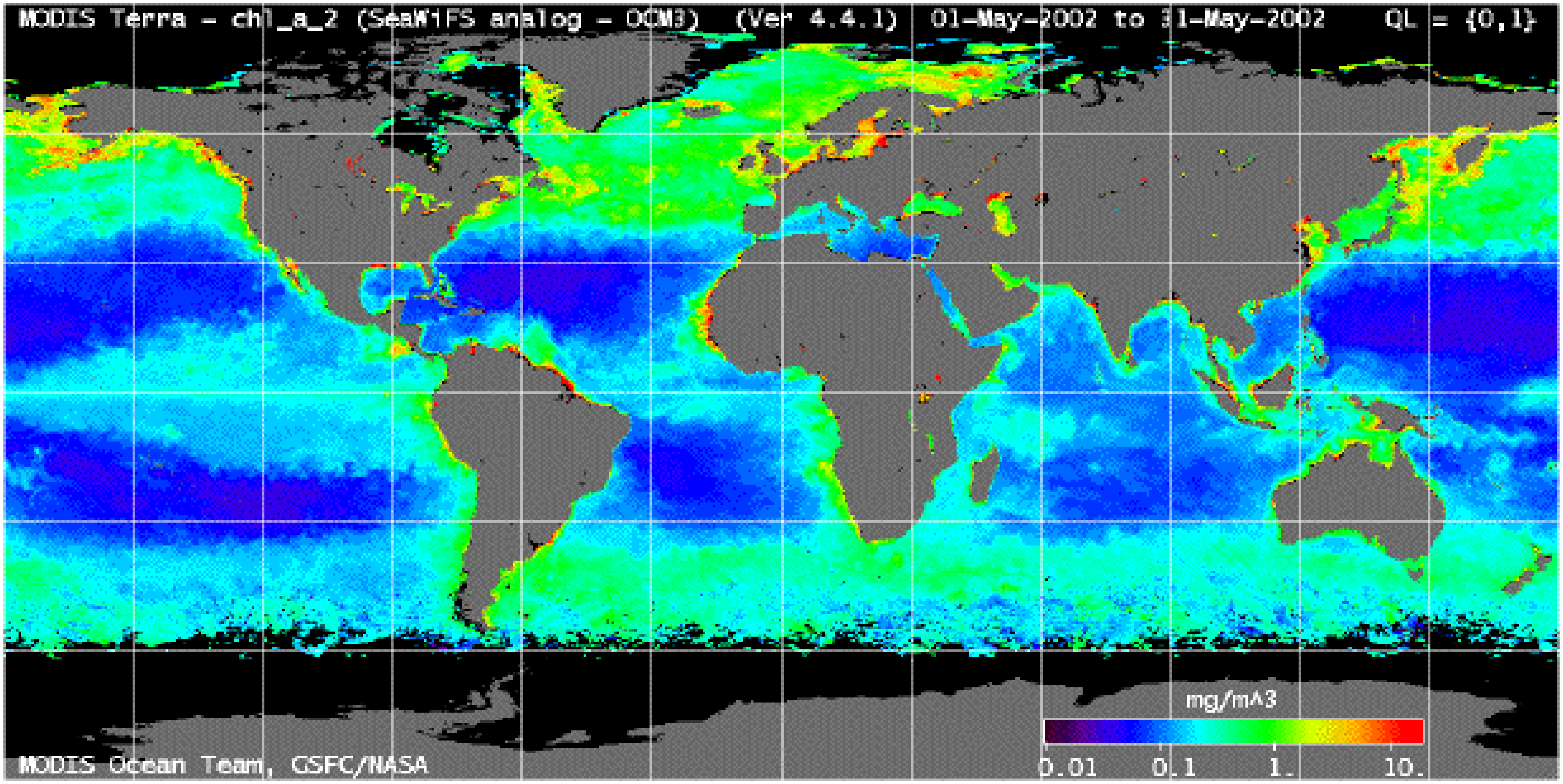

TOMS Sulfur dioxide (kt)
Year
Arc volcanoes
Non-arc volcanoes
Data Gap
Cerro Azul
Sierra Negra
Mt St Helens
Alaid
Nyamuragira
El Chichón
Wolf
Nyamuragira
Mauna Loa
Krafla
Ruiz
Nyamuragira
Chikurachki
Fernandina
Nyamuragira
Redoubt
Fernandina
Pinatubo
Hudson
Nyamuragira
Spurr
Láscar
Nyamuragira
Rabaul
Nyamuragira
Cerro Azul
Nyamuragira
Nyamuragira
Hekla
Miyakejima
Nyamuragira
Nyiragongo
Nyamuragira
Reventador
Anatahan
Soufriere Hills
100000
10000
1000
100
10
1
79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03

1984

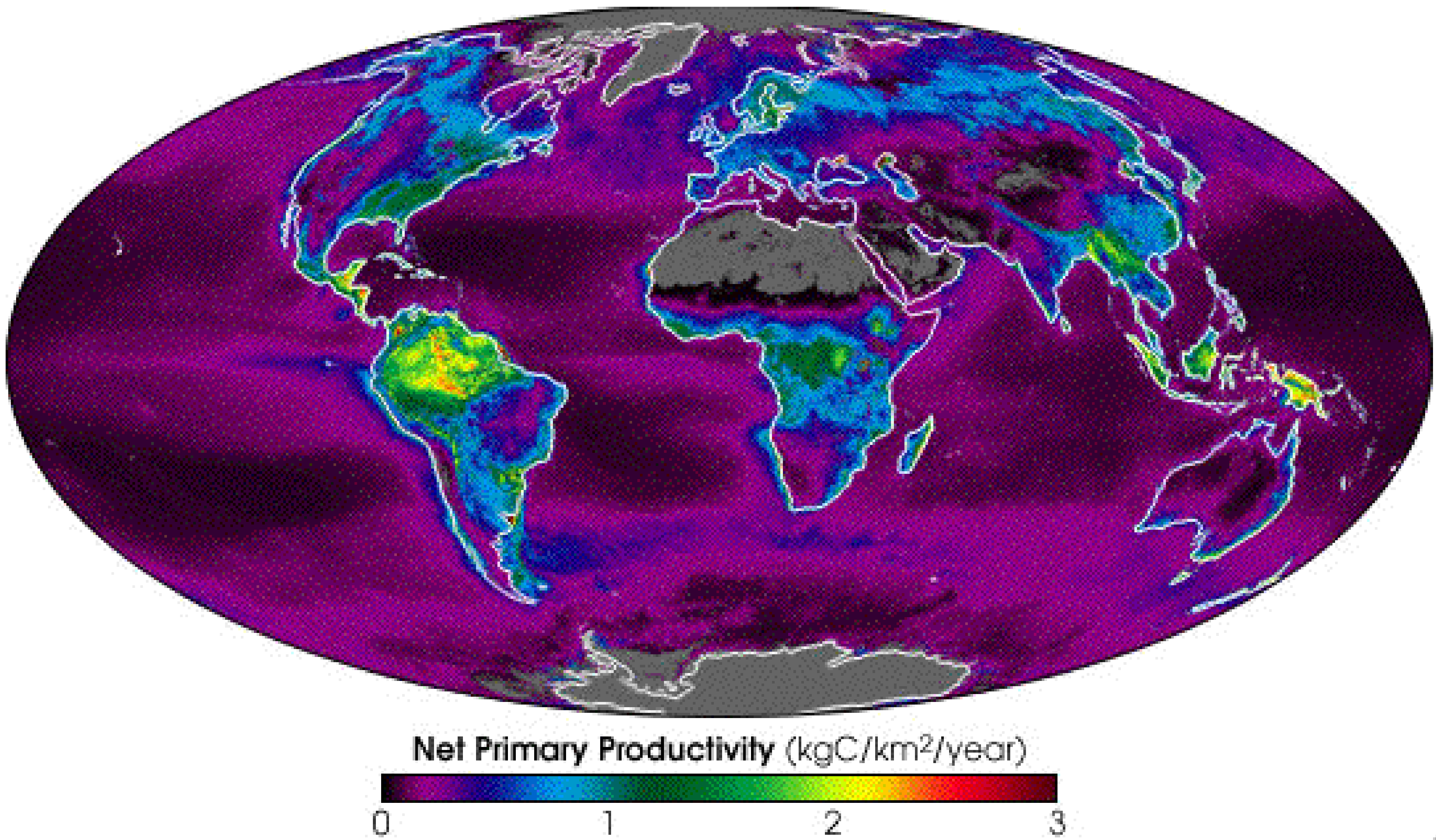


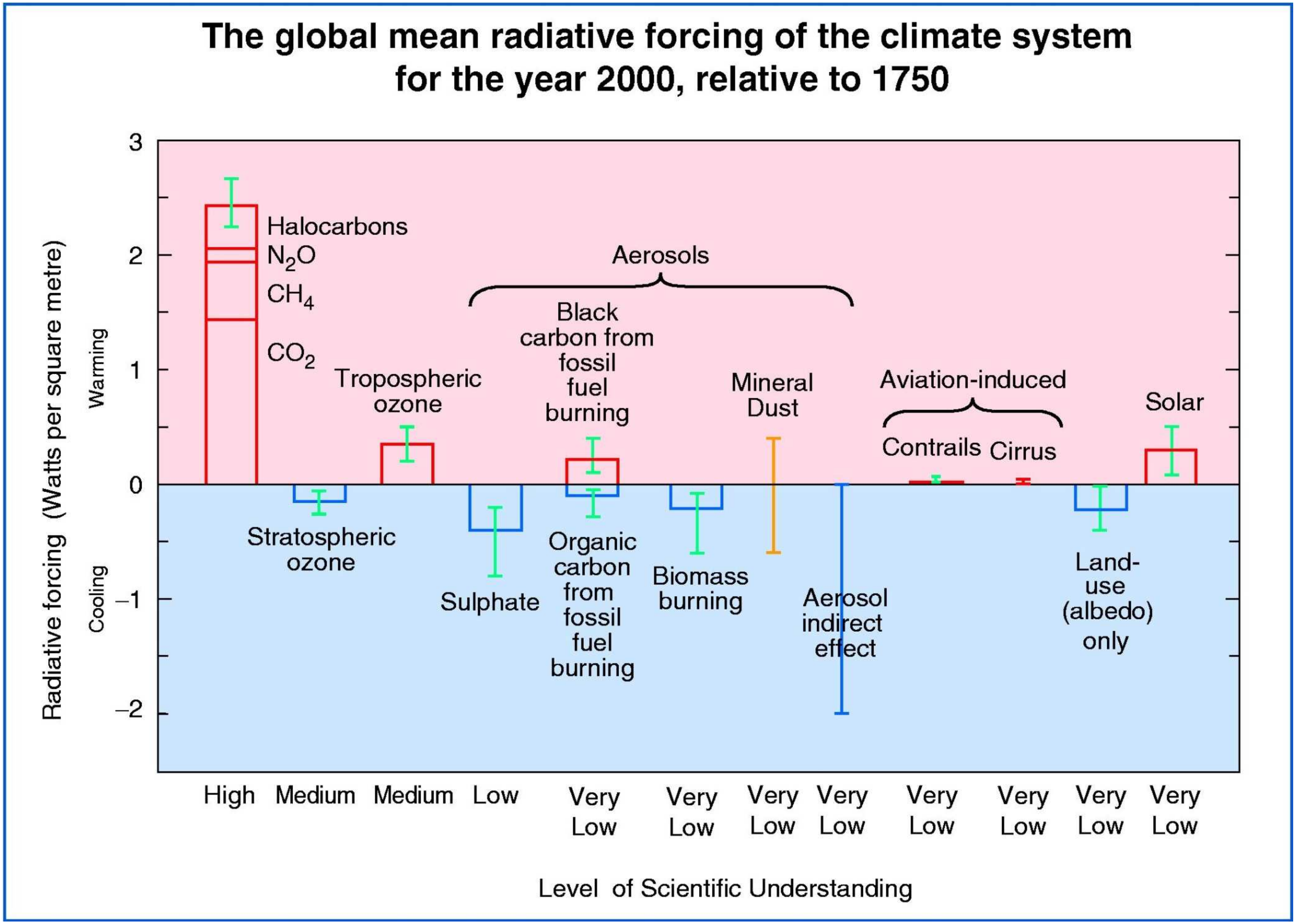
1994




MODIS Terra - chl_a_2 (SeaWiFS analog - OCM3) (Ver 4.4.1) 01-May-2002 to 31-May-2002 QL = {0,1}
mg/m^3
0.01
0.1
1.
10.
MODIS Ocean Team, GSFC/NASA

flusso annuo di Carbonio verso la superficie (vegetazione)





The global mean radiative forcing of the climate system
for the year 2000, relative to 1750
Radiative forcing (Watts per square metre)
Warming
Cooling
3
2
1
0
–1
–2
Halocarbons
N_2O
CH_4
CO_2
Tropospheric ozone
Stratospheric ozone
Aerosols
Black carbon from fossil fuel burning
Mineral Dust
Aviation-induced
Contrails
Cirrus
Solar
Sulphate
Organic carbon from fossil fuel burning
Biomass burning
Aerosol indirect effect
Land-use (albedo) only
High
Medium
Medium
Low
Very Low
Very Low
Very Low
Very Low
Very Low
Very Low
Very Low
Very Low
Level of Scientific Understanding