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*****.**

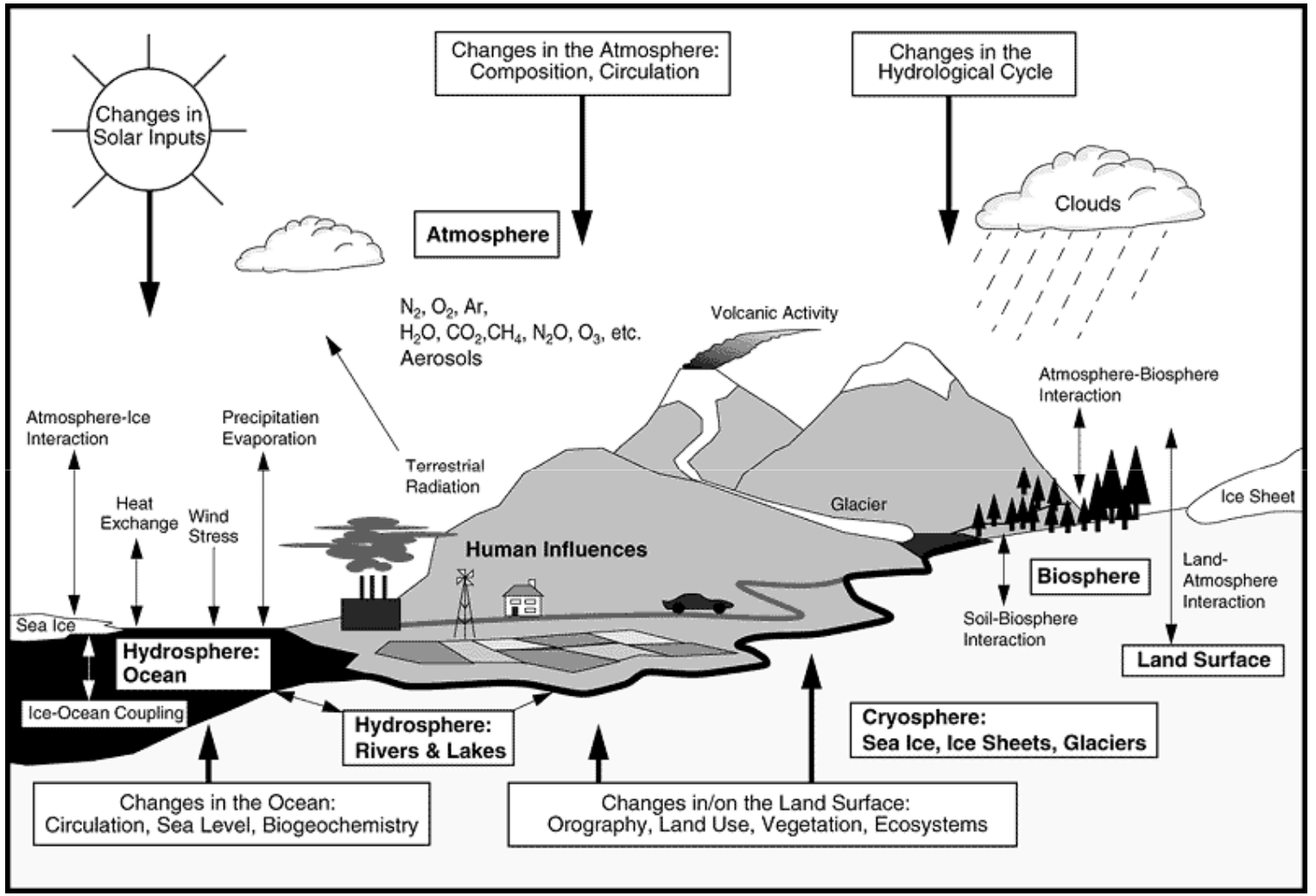
clima ***stato medio del sistema e sue variazioni nel tempo*****.**

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
Clouds
Atmosphere
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
Soil-Biosphere Interaction
Hydrosphere: Ocean
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;

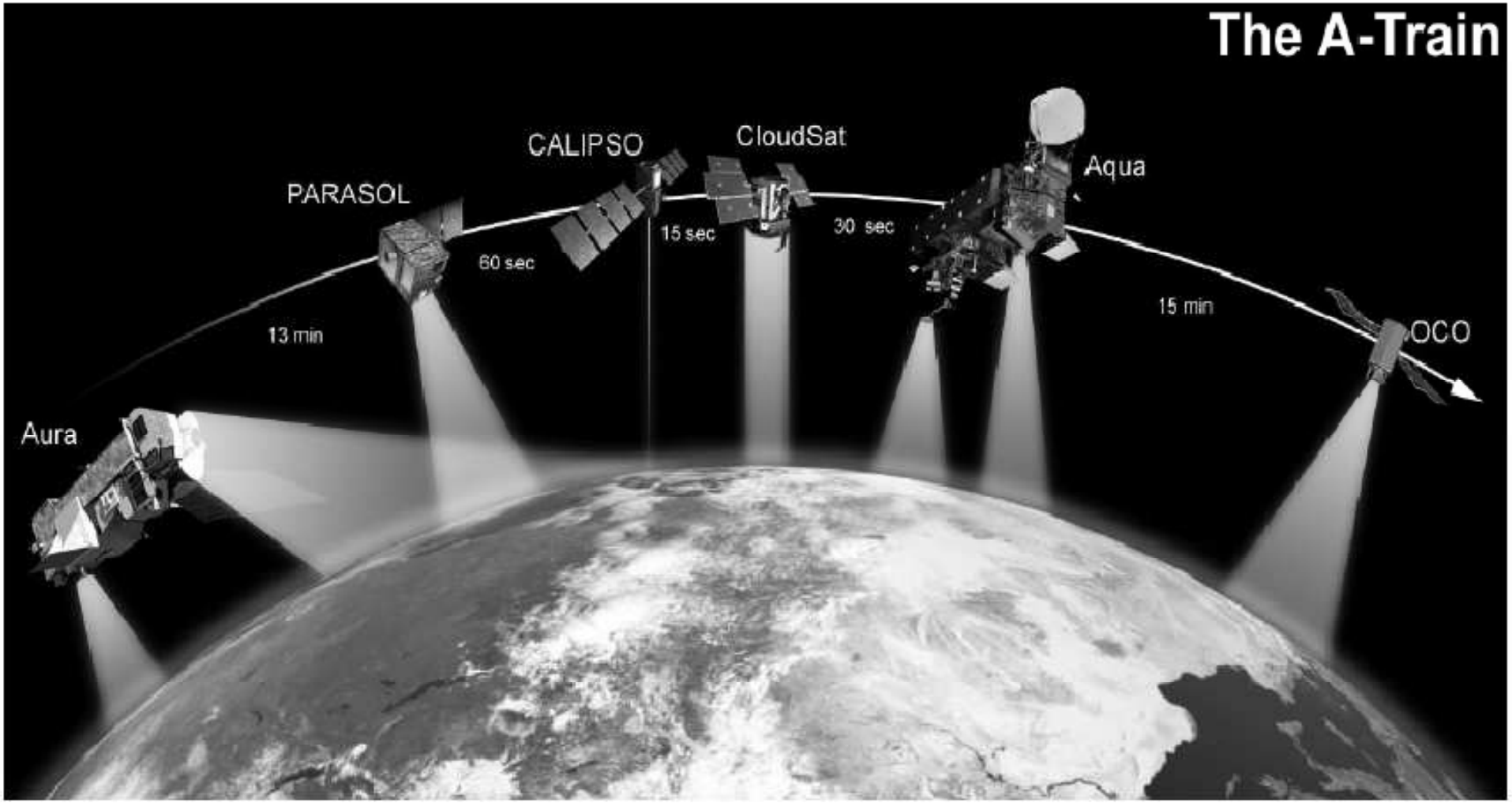
4) sistema caotico.

*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
CALIPSO
CloudSat
PARASOL
Aqua
60 sec
15 sec
30 sec
13 min
15 min
OCO
Aura

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, ….

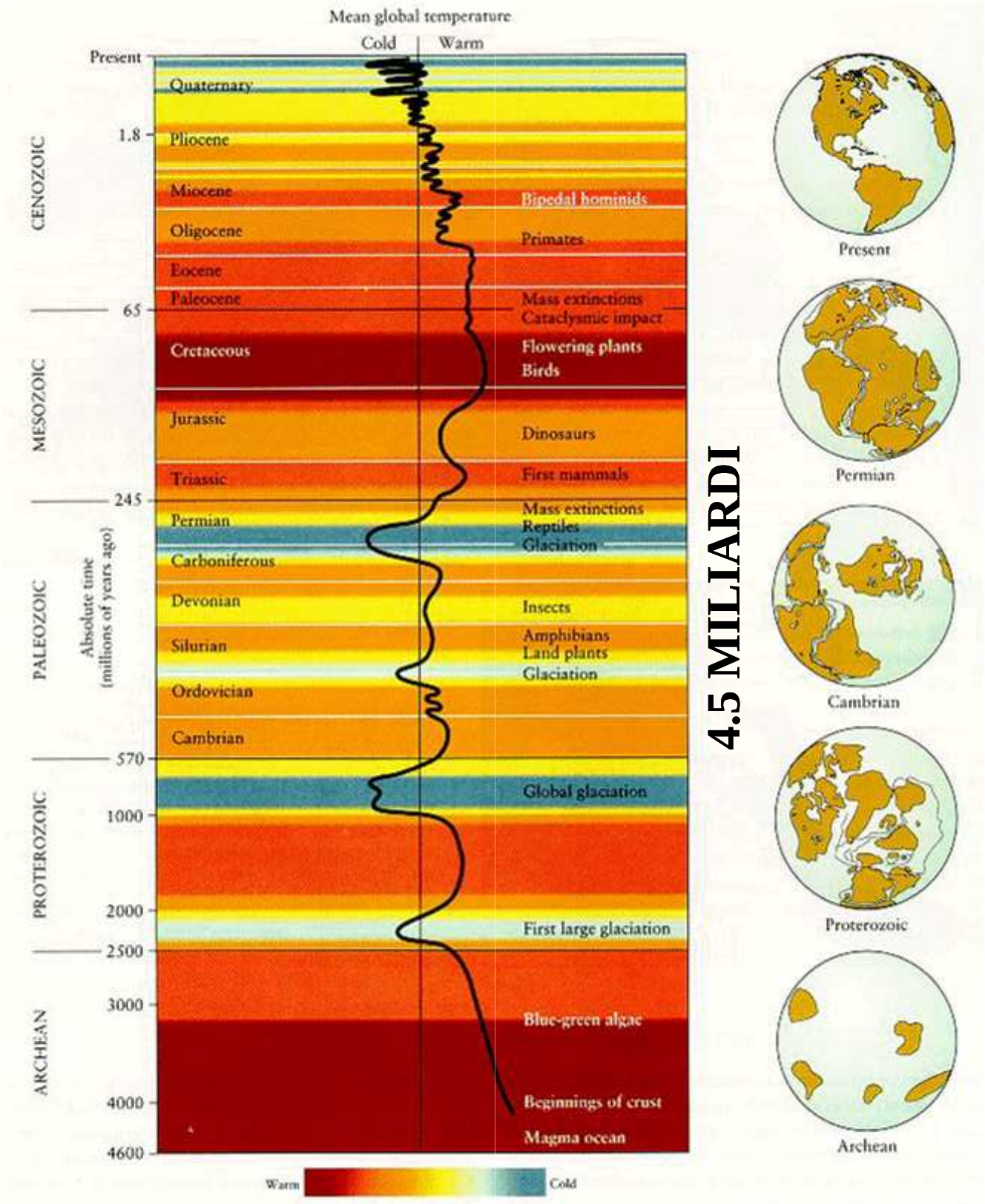
<u>temperatura dell'aria</u> ***(h=2 m)***

termometri (tempi recenti < 200 anni):

- termometri a mercurio
- termometri a stato solido (termistori)

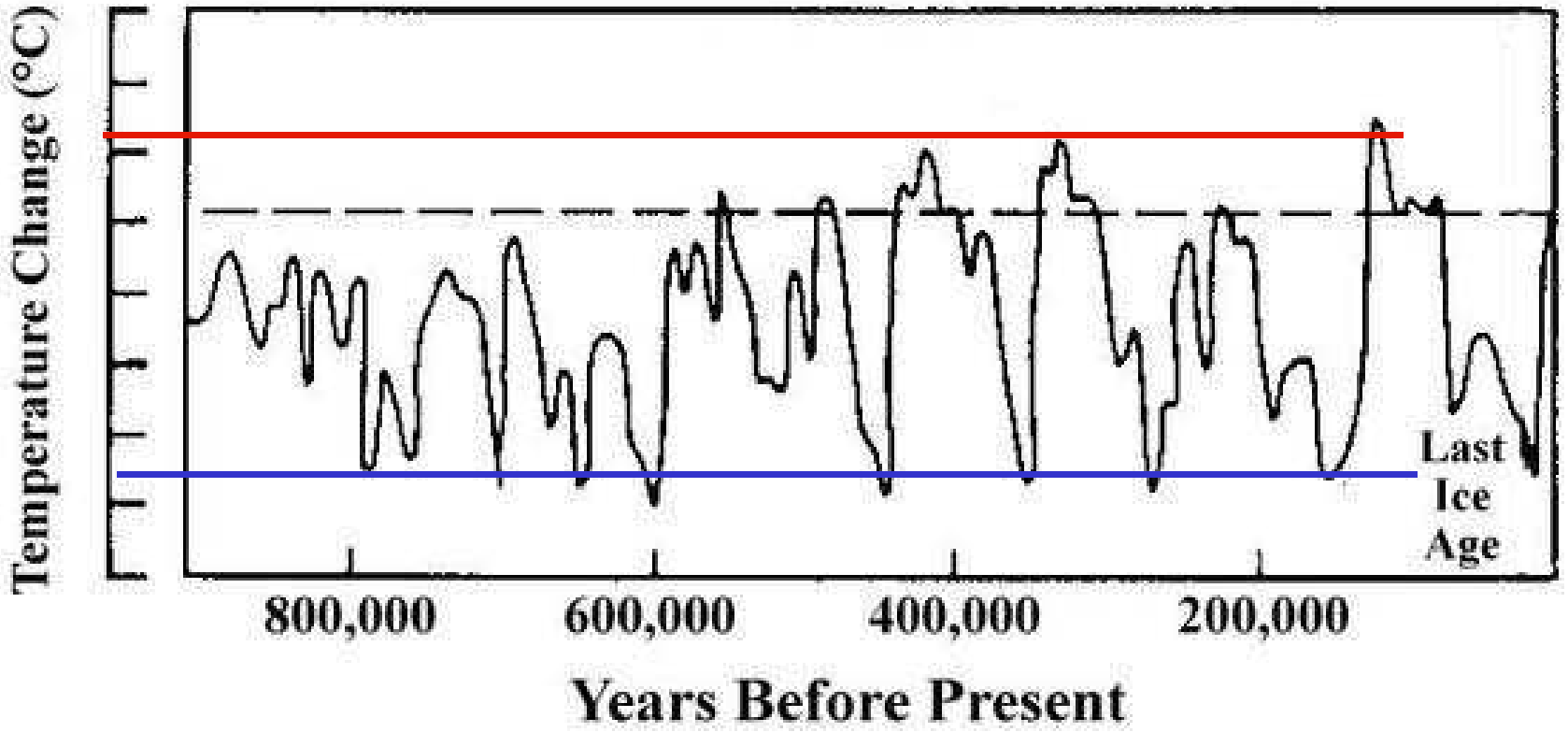
proxy data (paleoclima):

- anelli di accrescimento degli alberi
- O^{16}/O^{18}
- carotaggi
- coralli
- cronache storiche

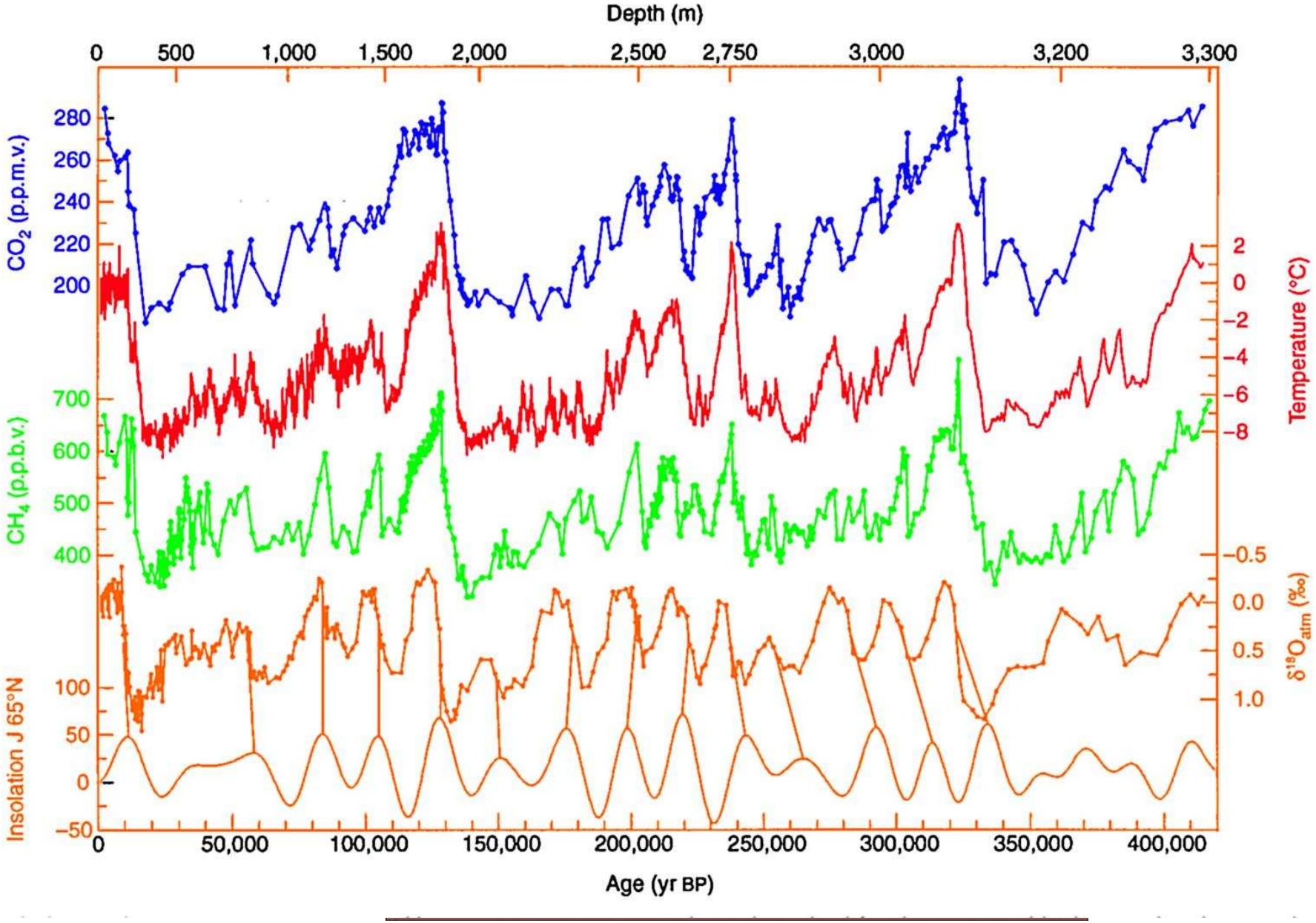

Mean global temperature
Cold
Warm
Present
1.8
65
245
570
1000
2000
2500
3000
4000
4600
CENOZOIC
MESOZOIC
PALEOZOIC
PROTEROZOIC
ARCHEAN
Absolute time (millions of years ago)
Quaternary
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Devonian
Silurian
Ordovician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

4.5 MILIARDI

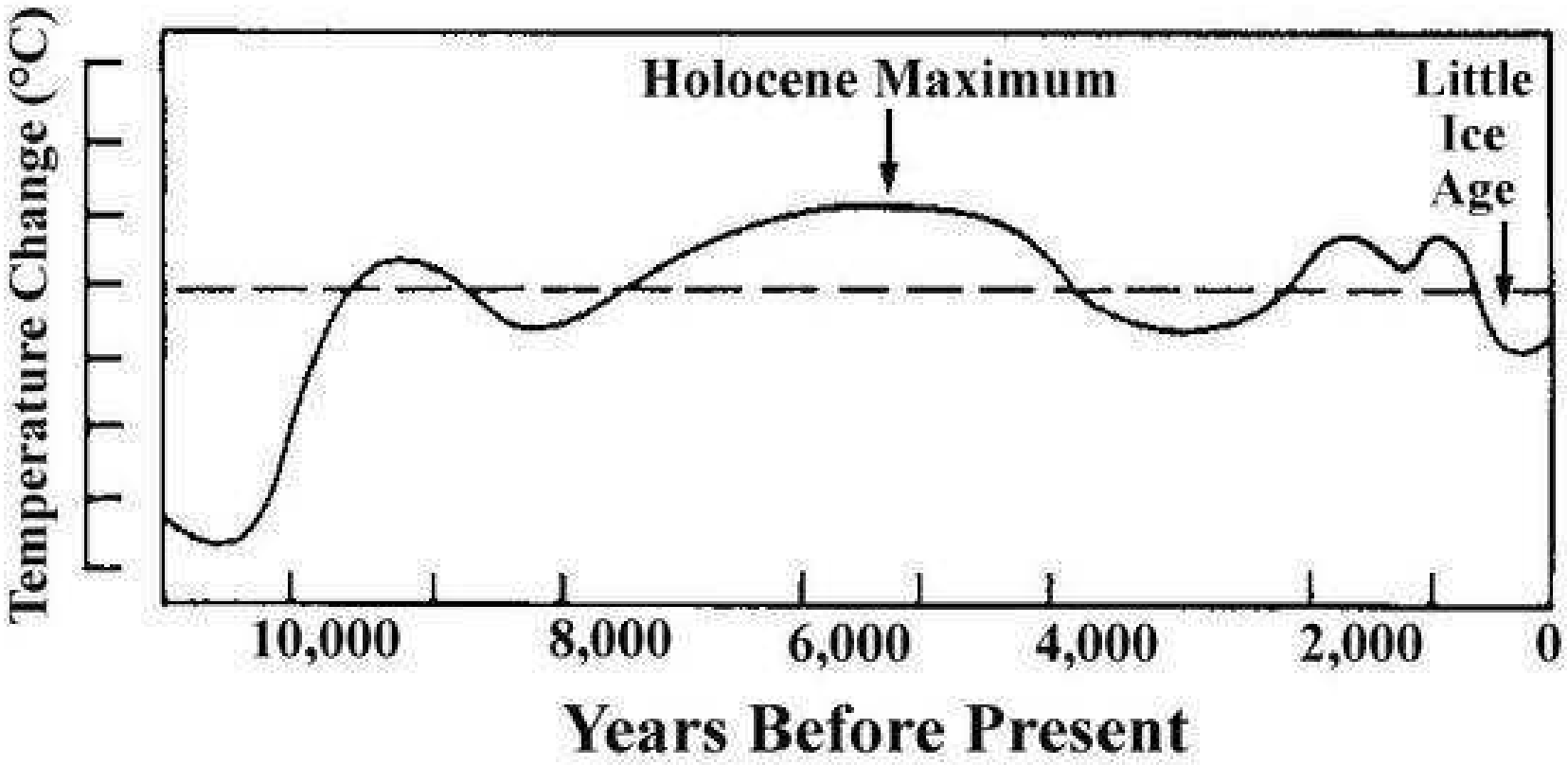
1 MILIONE DI ANNI



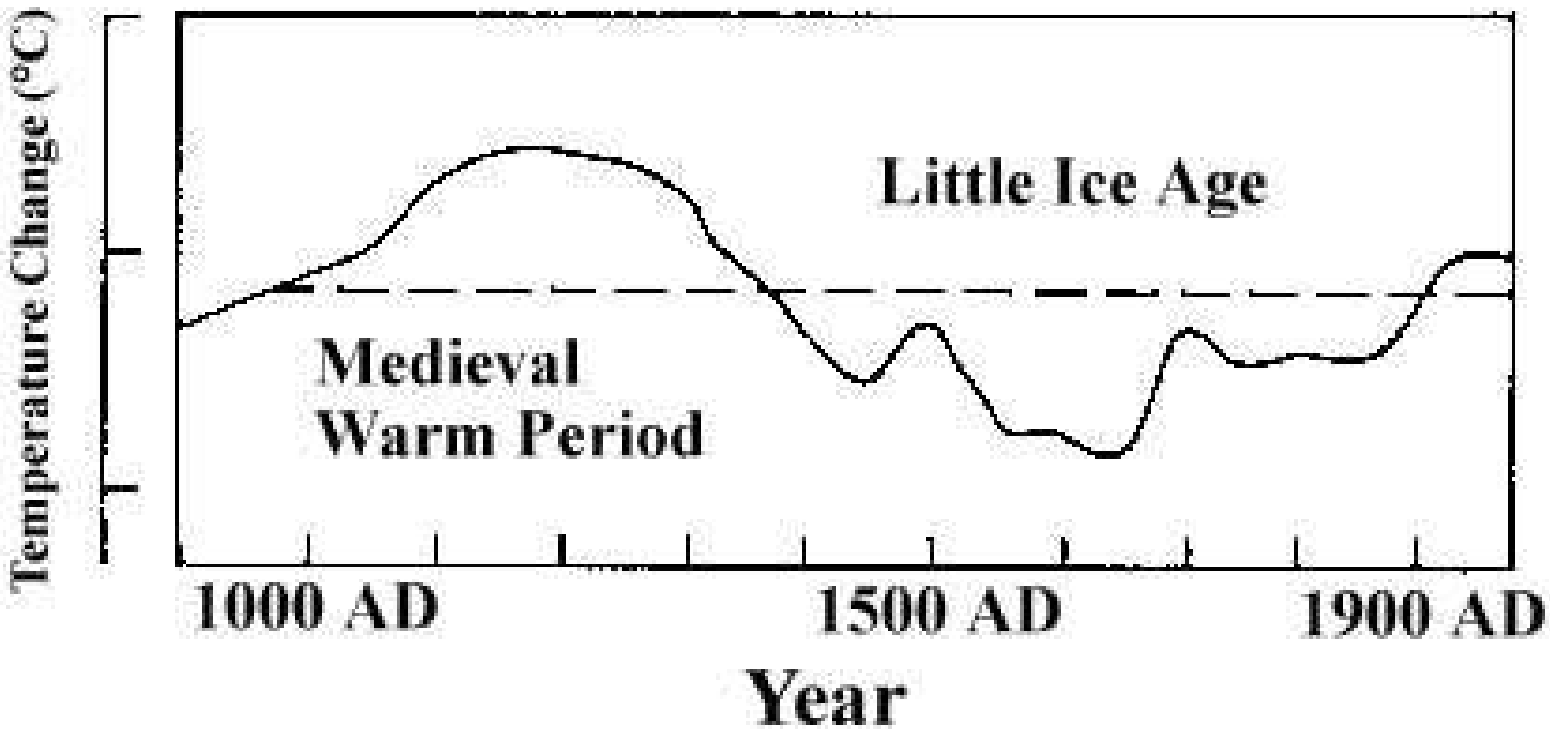
420.000 ANNI – Vostok Ice Core



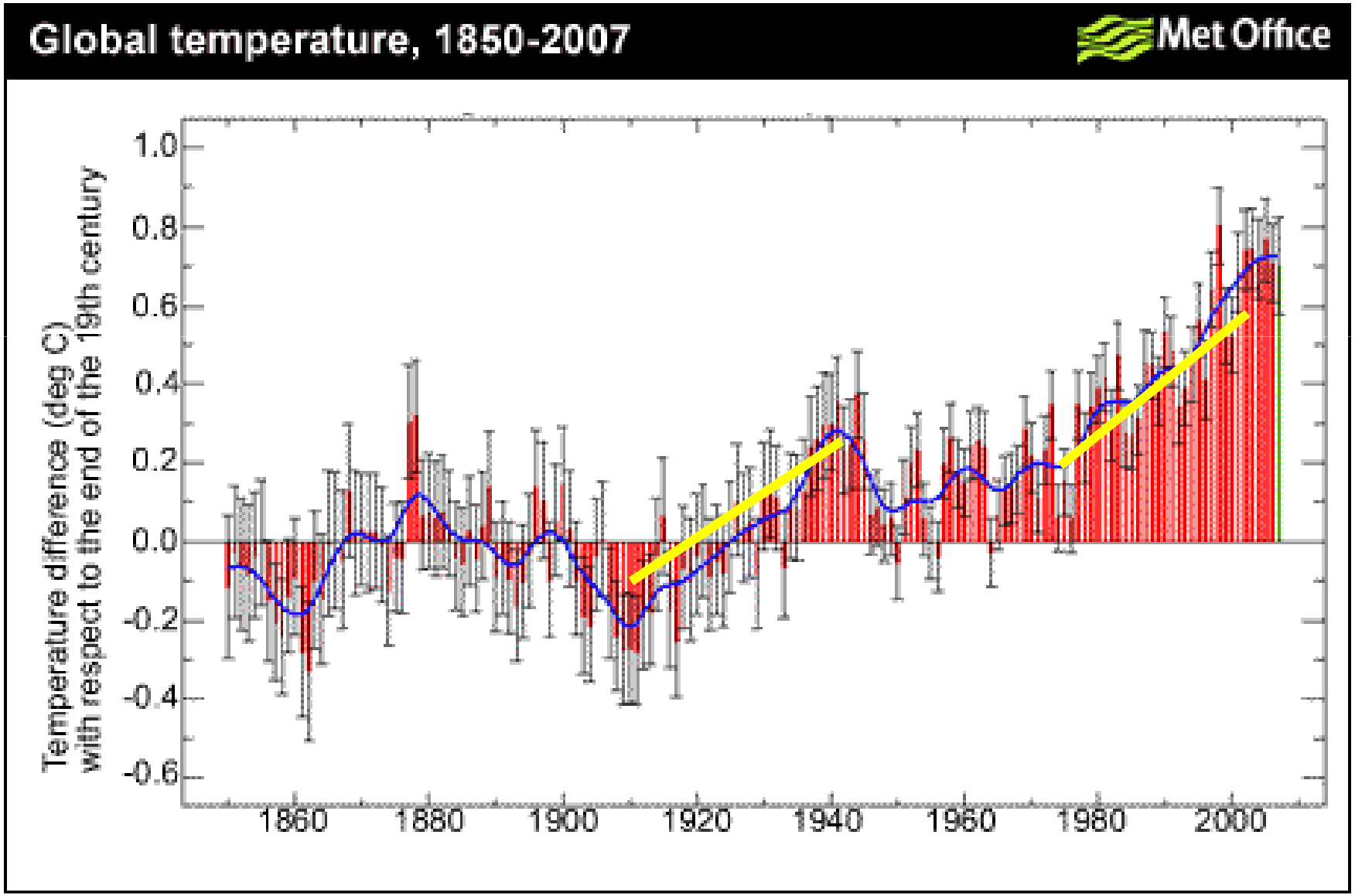
10.000 ANNI


Temperature Change (°C)
Holocene Maximum
Little
Ice
Age
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

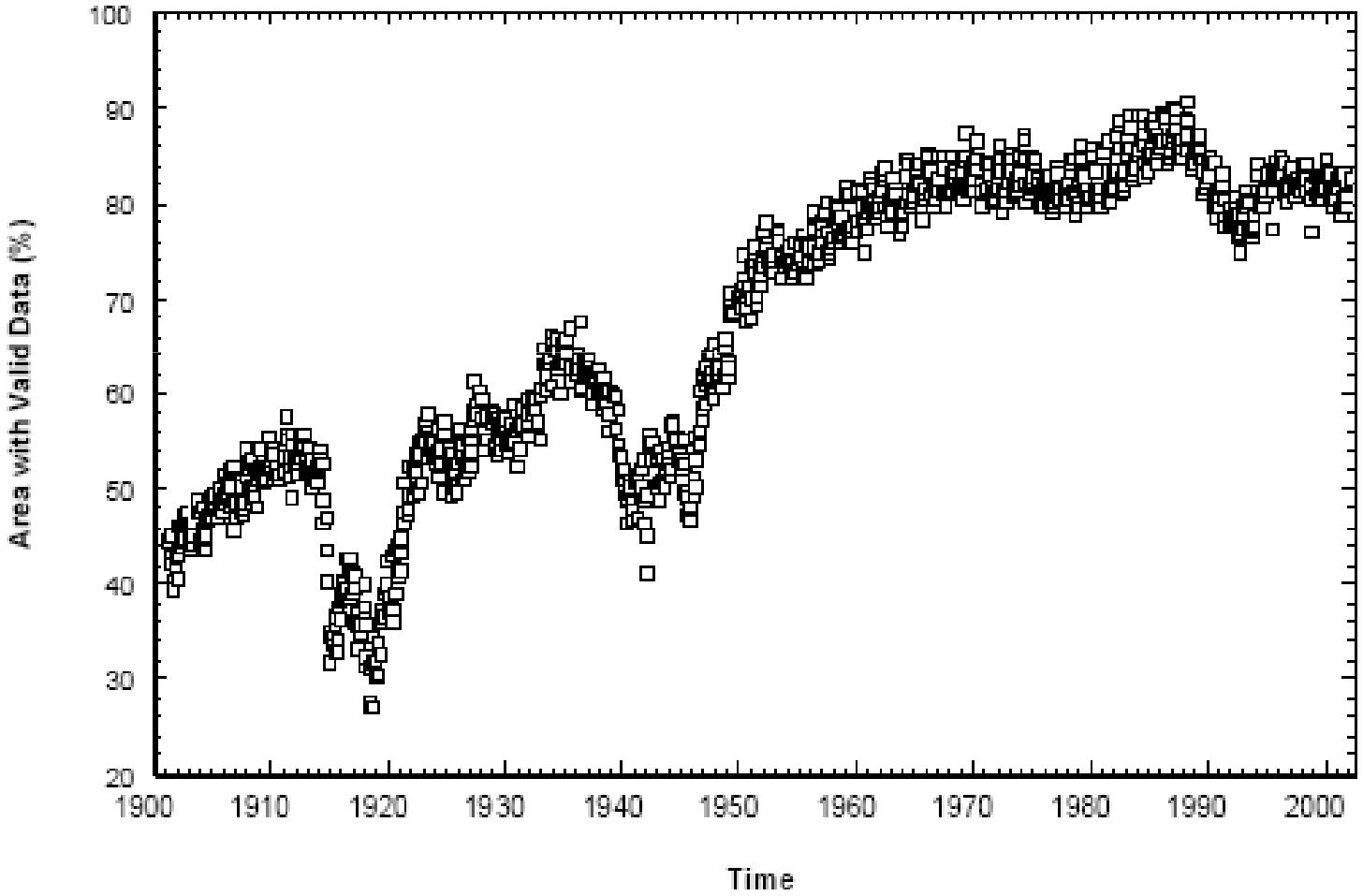
100 ANNI


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

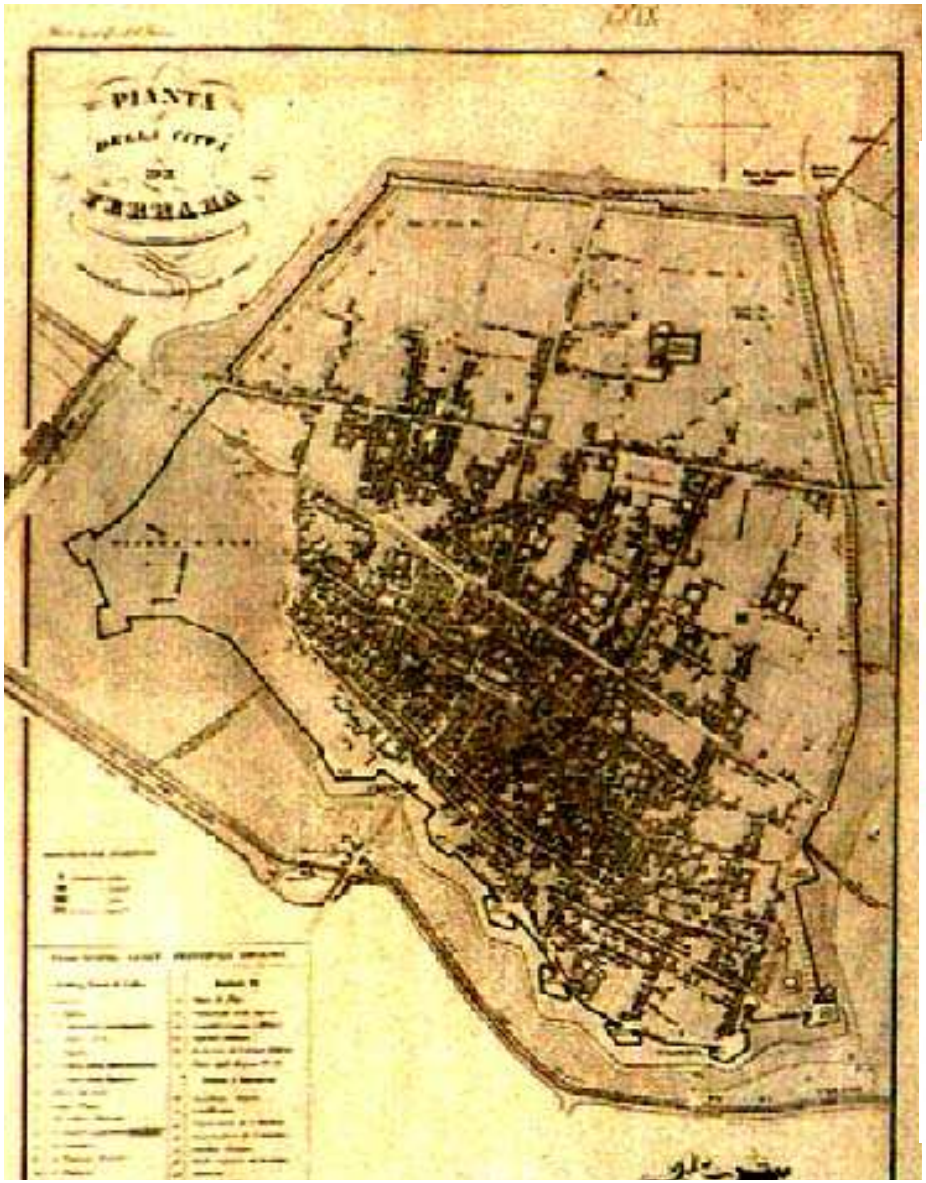
la frazione di superficie globale monitorata varia

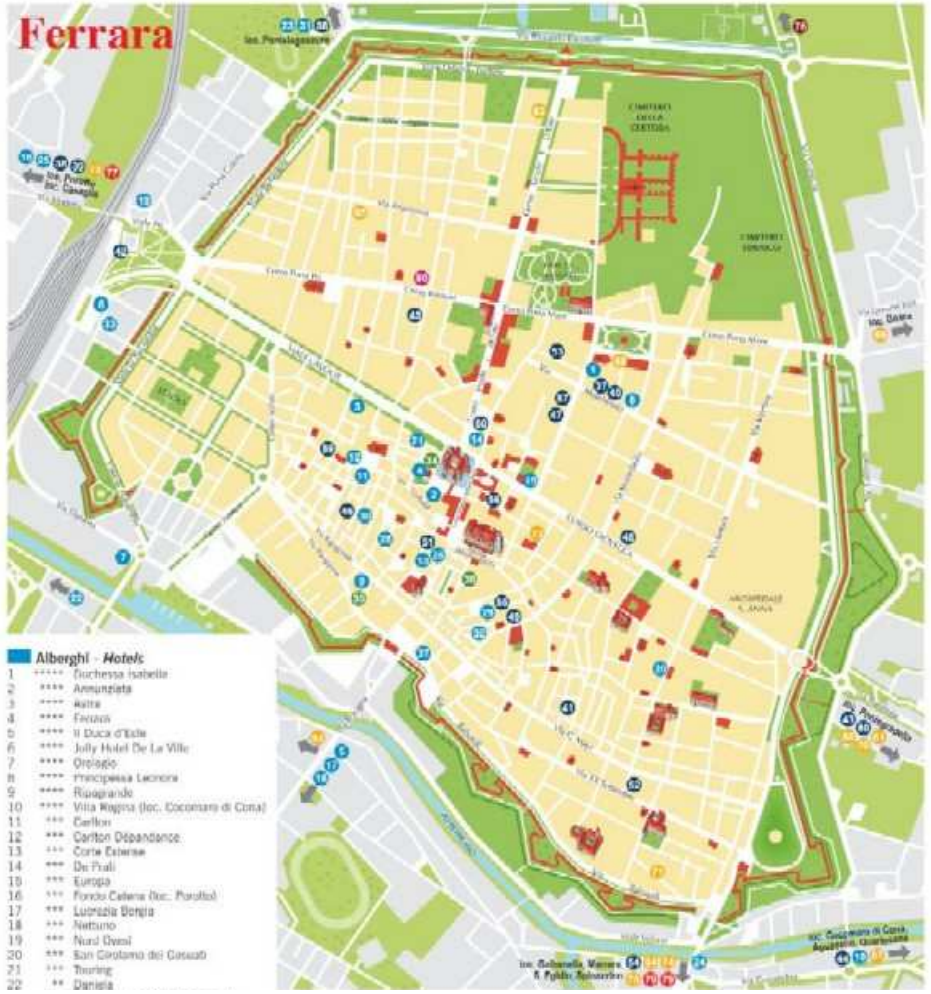
5°×5° ~ 550×400 km²



Problema II: effetti urbani

da meta’ ottocento la struttura urbana e’ mutata





Problema III: manutenzione delle stazioni
non controllabile, variabile, importante

capannine “bianche”

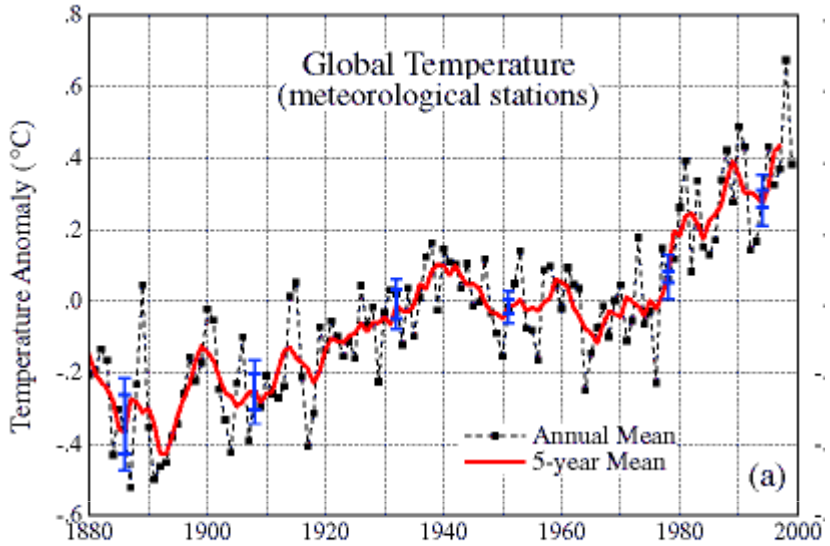
areate

modalita’ di lettura

tipo di strumento

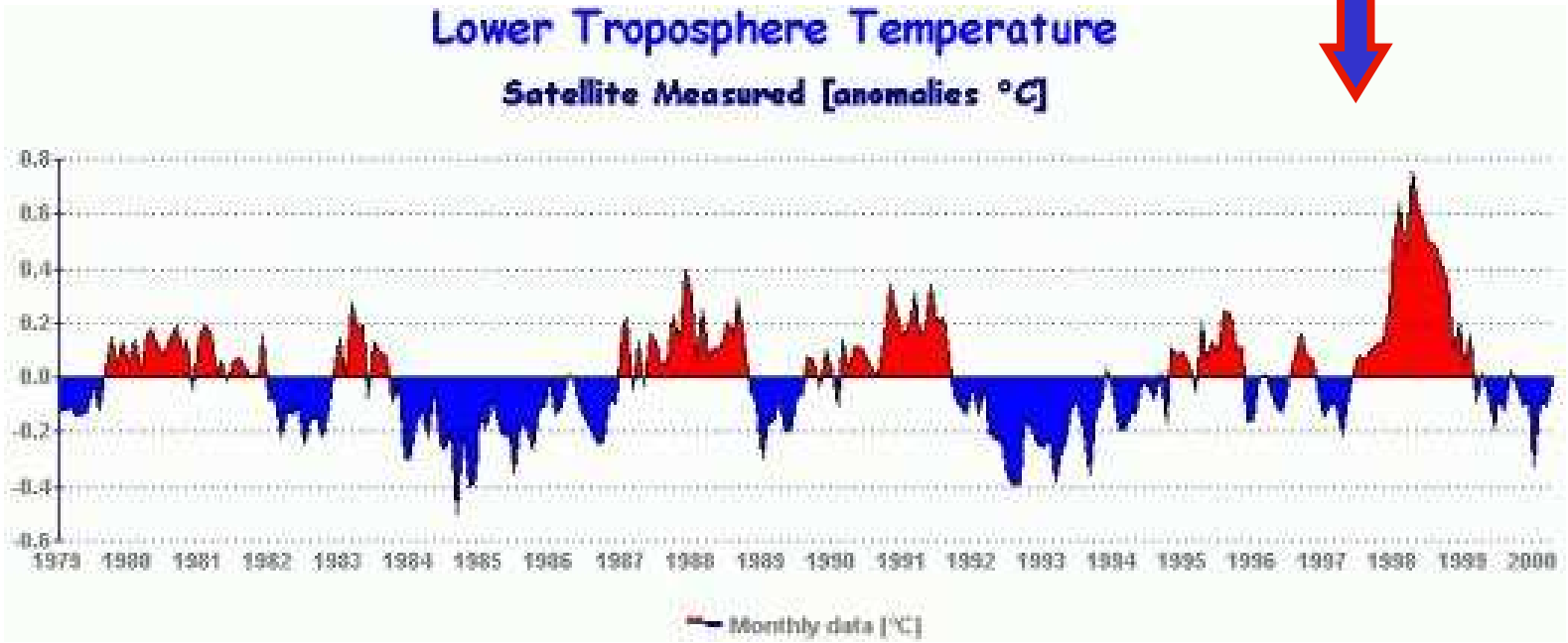
operatori

Problema IV: confronti con dati da satellite



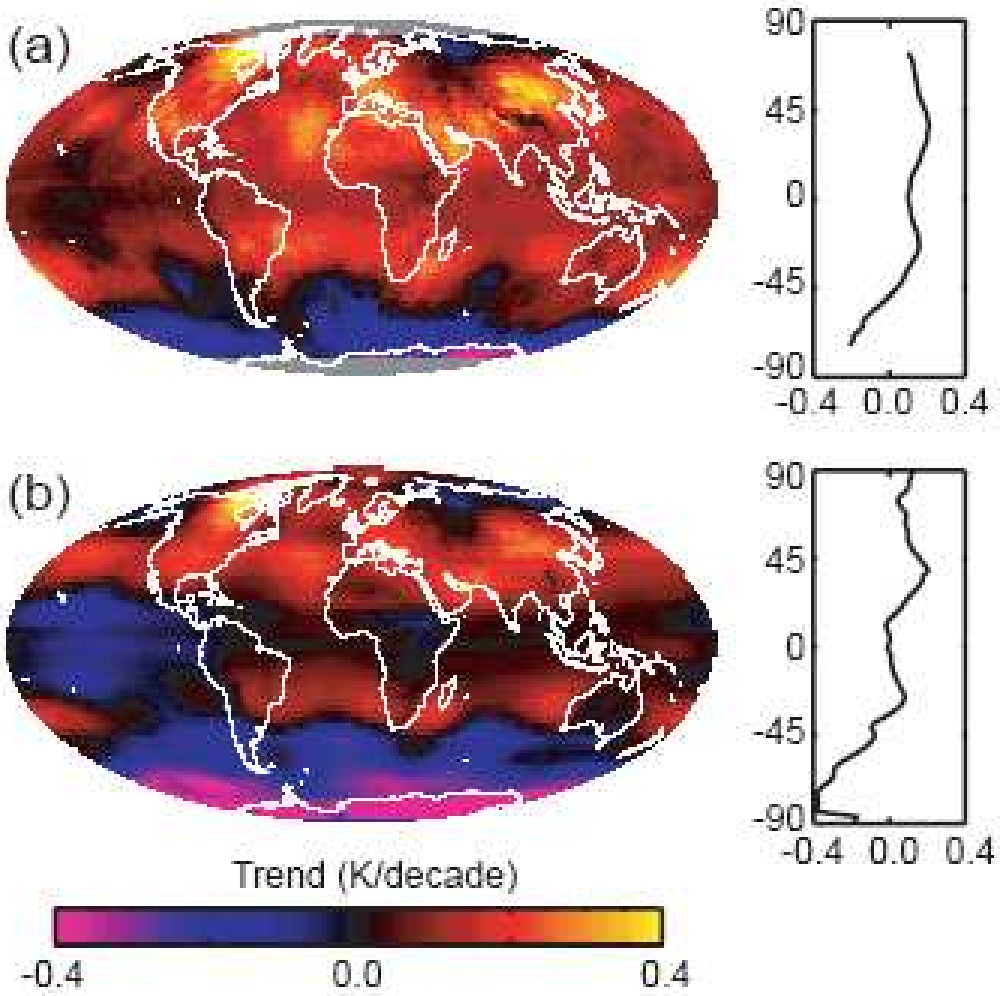
0,2 K/decade

0,09 K/decade



Problema IV: confronti con dati da satellite

Microwave Sounding Unit (MSU)



VARIAZIONE DEL LIVELLO DEL MARE

LIVELLO DEI MARI

cause:

1) dilatazione termica ~ 0.5 m / K

2) scioglimento del ghiaccio:

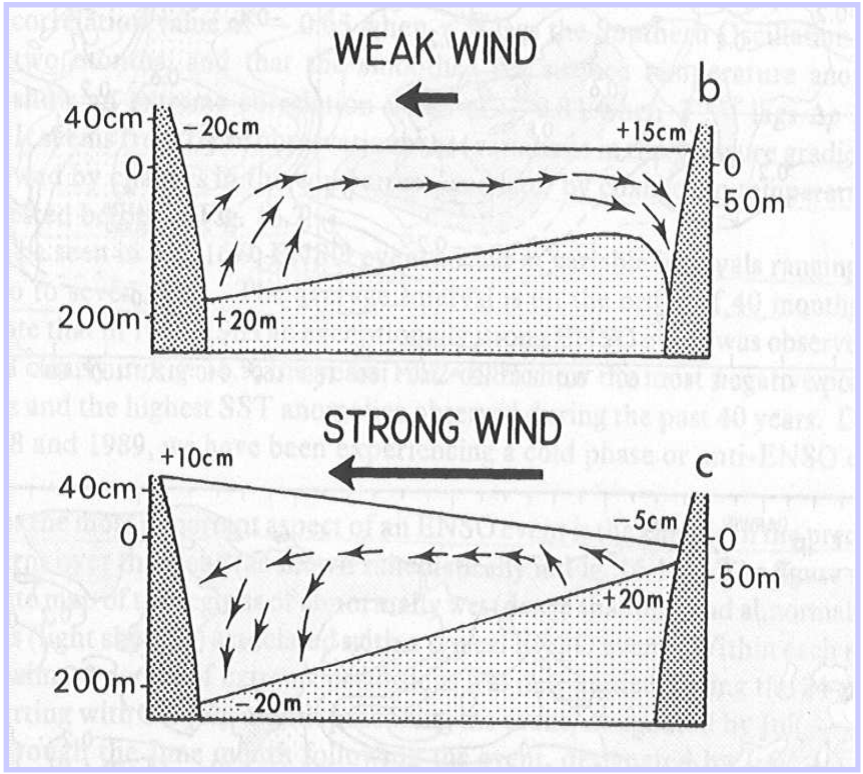
a) ghiacciai	**+ 0.5 m**
b) Antartide e Groenlandia	**+ 68.8 m**
c) ghiaccio marino	**~ 0.1 m**

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

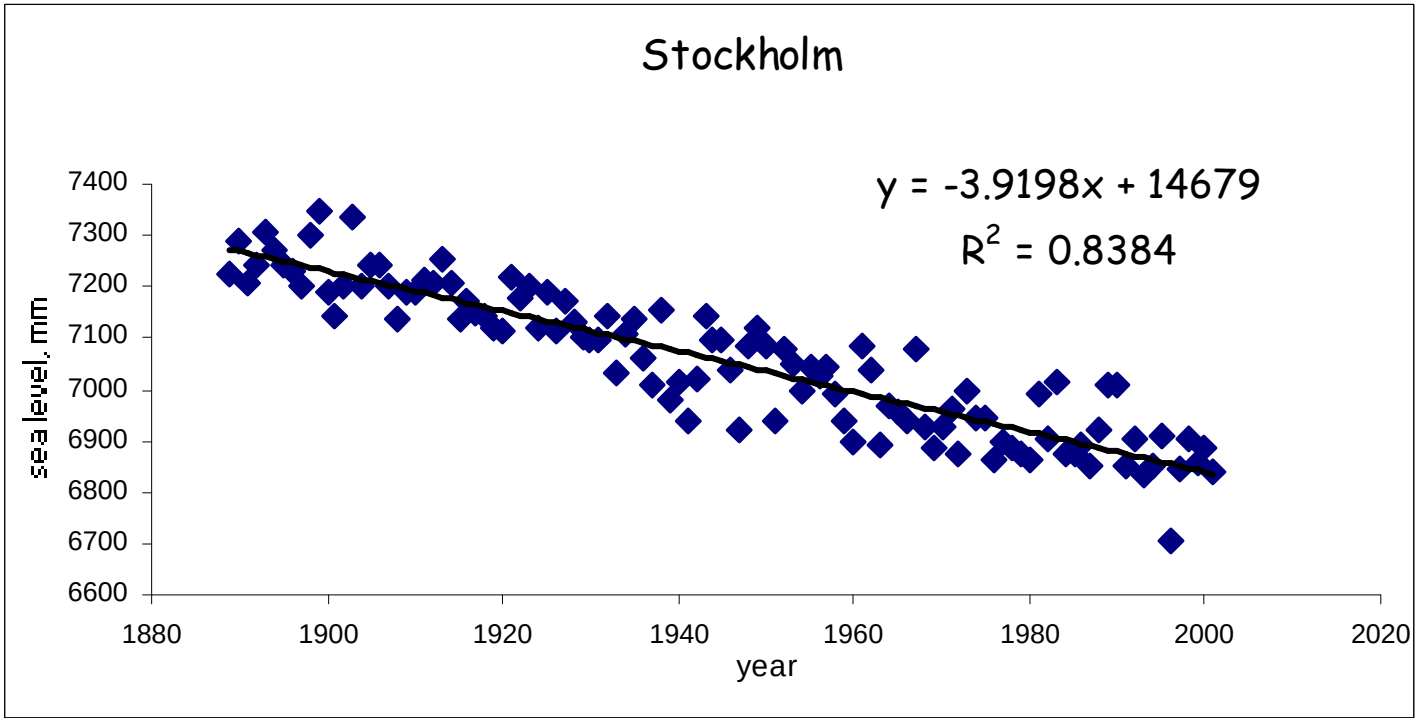
4) subsidenza (Thailandia ~ - 1 m / 30 anni)

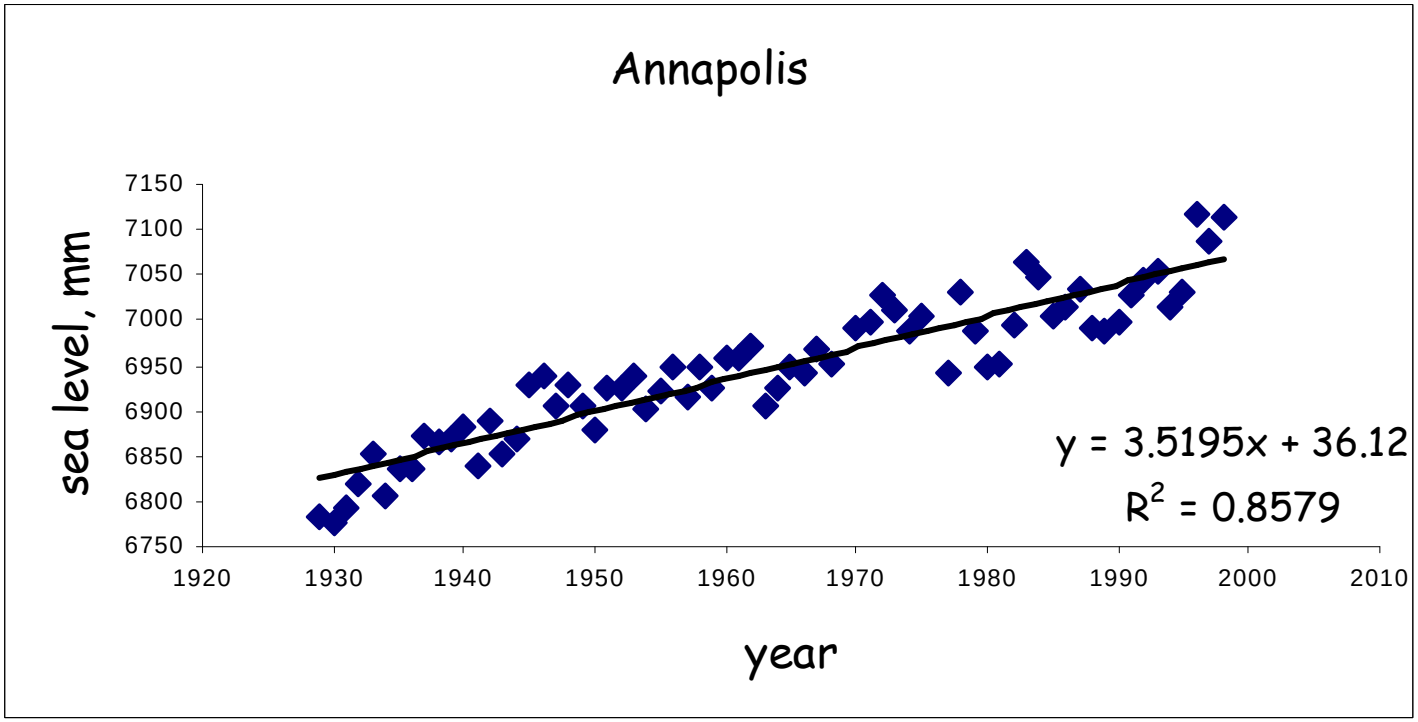
il livello del mare varia localmente per forzature dinamiche (vento, correnti)

Pacifico equatoriale influenzato da El niño

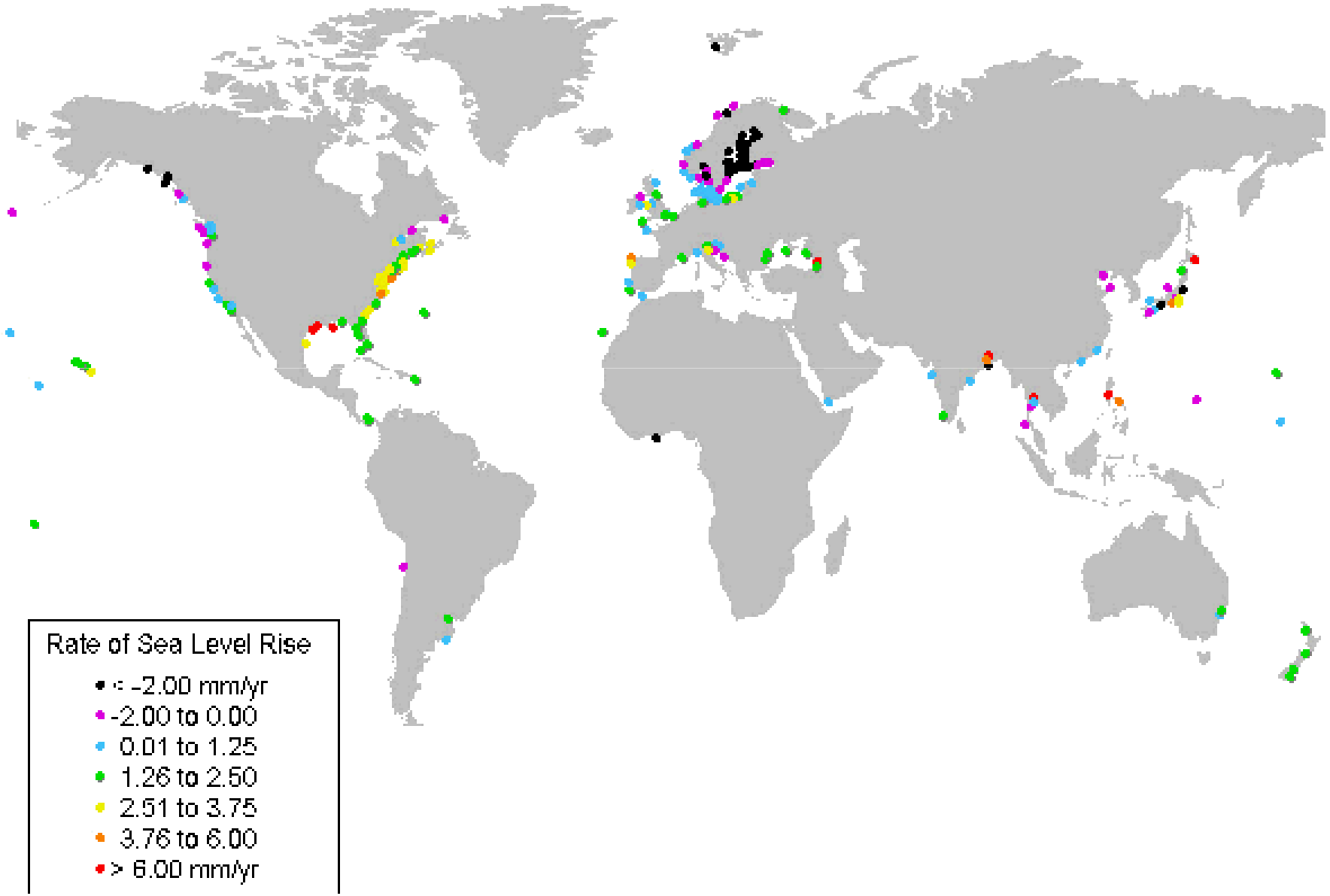


Acqua alta nella laguna di Venezia

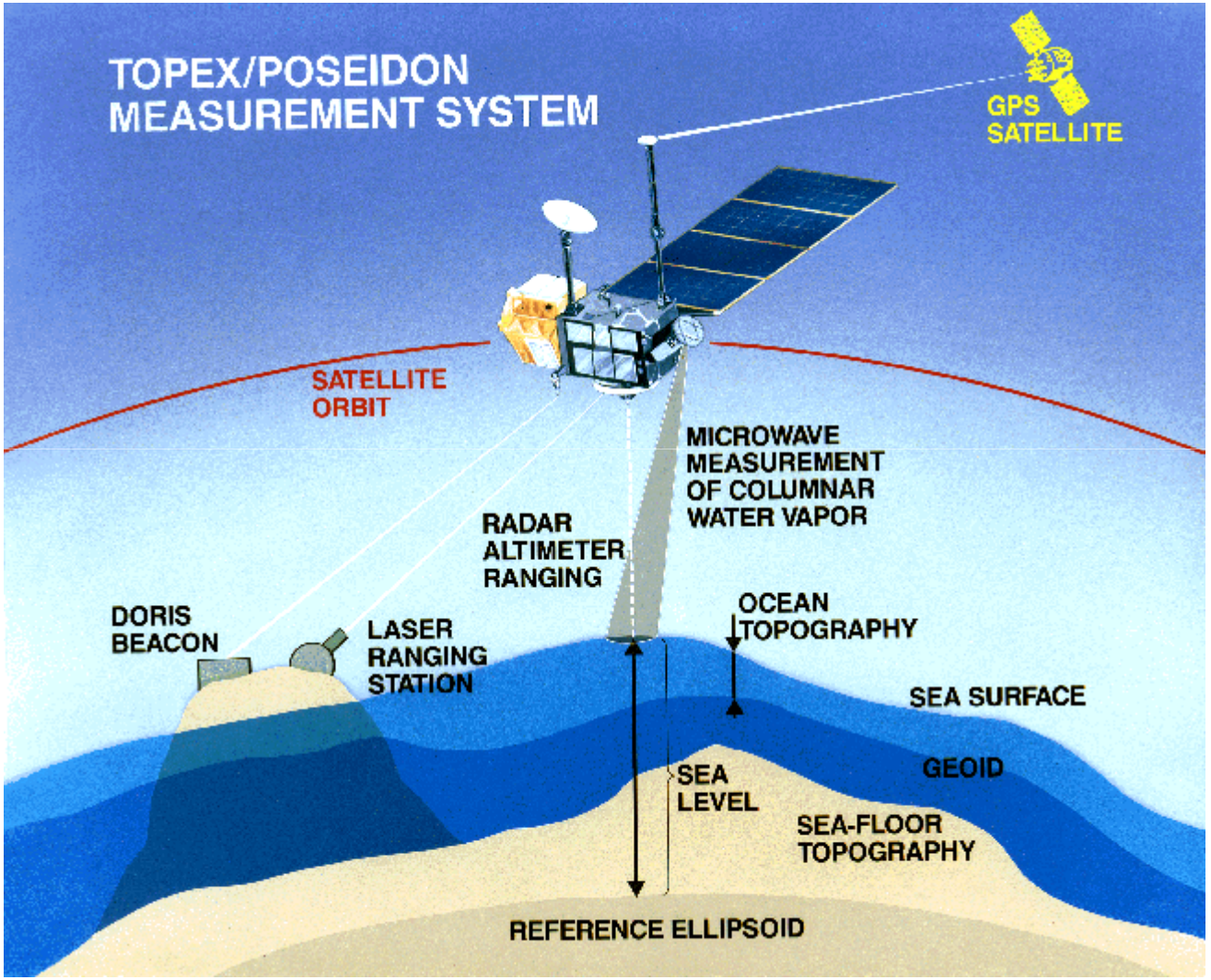

Stockholm
y = -3.9198x + 14679
R2 = 0.8384
sea level, mm
7400
7300
7200
7100
7000
6900
6800
6700
6600
1880
1900
1920
1940
1960
1980
2000
2020
year


Annapolis
sea level, mm
7150
7100
7050
7000
6950
6900
6850
6800
6750
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
year
y = 3.5195x + 36.12
R2 = 0.8579

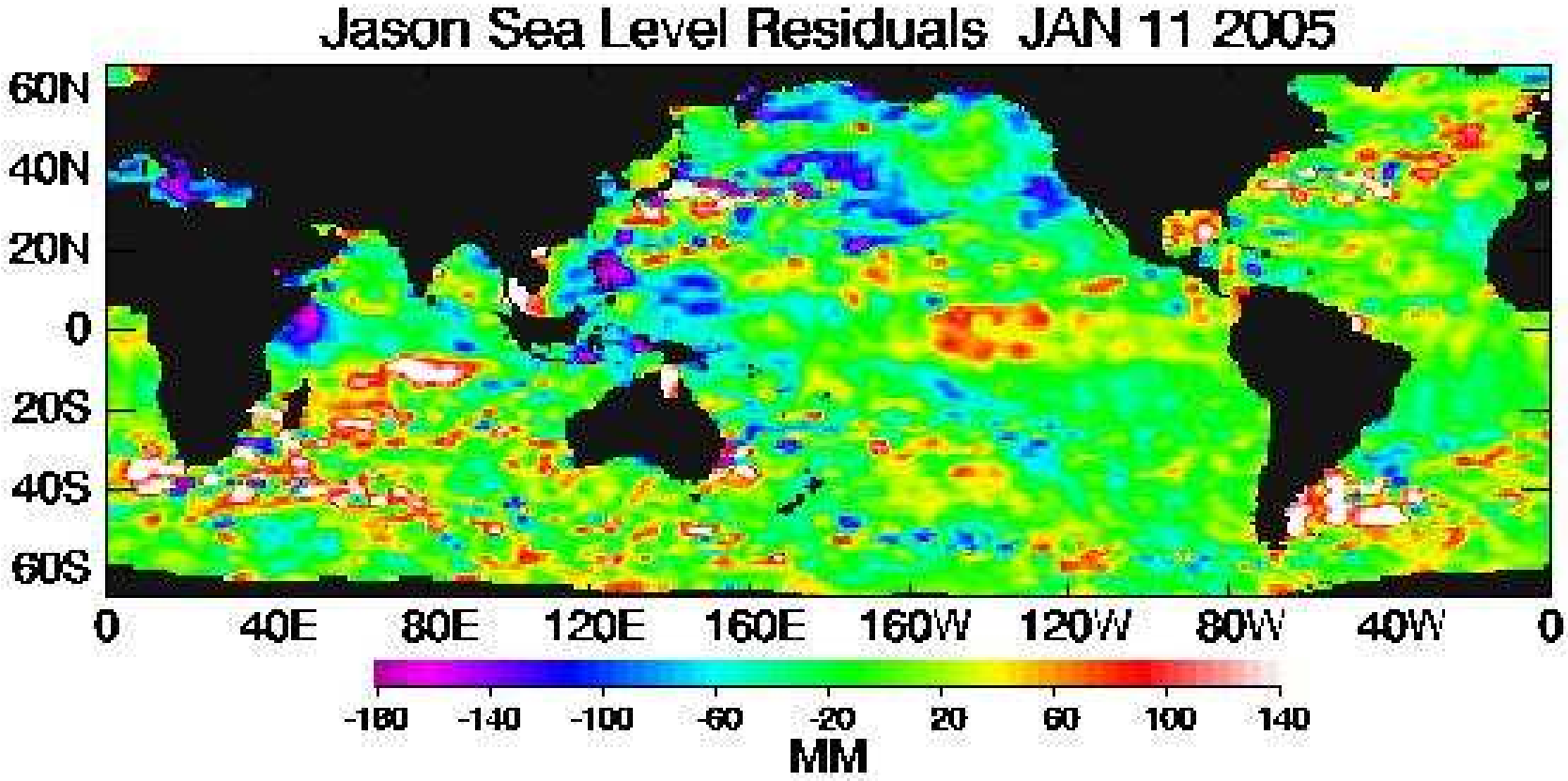
LIVELLO DEI MARI



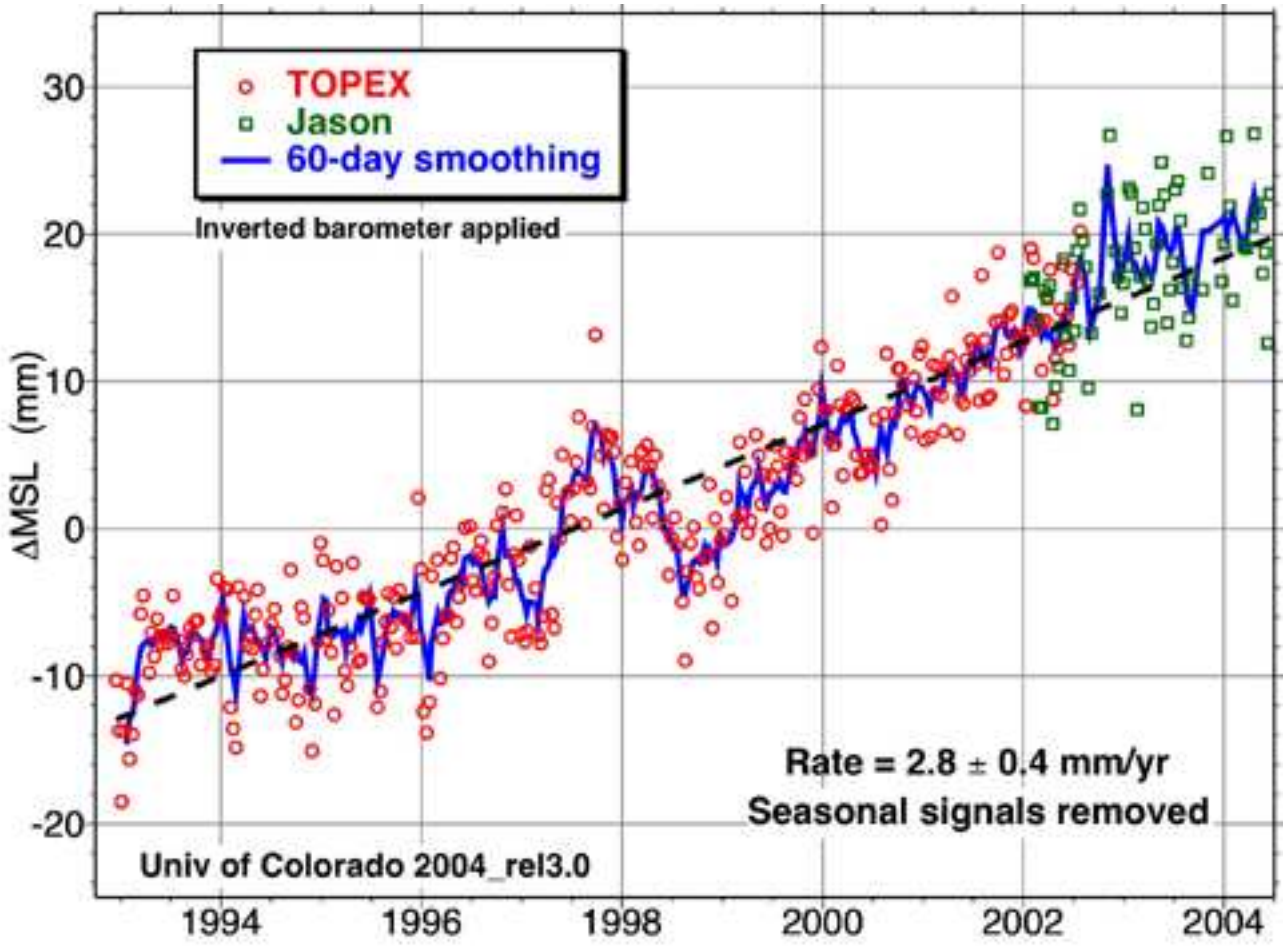
LIVELLO DEI MARI



LIVELLO DEI MARI



LIVELLO DEI MARI



con le boe:

1-2 mm/y

<u>osservazioni dallo spazio</u>

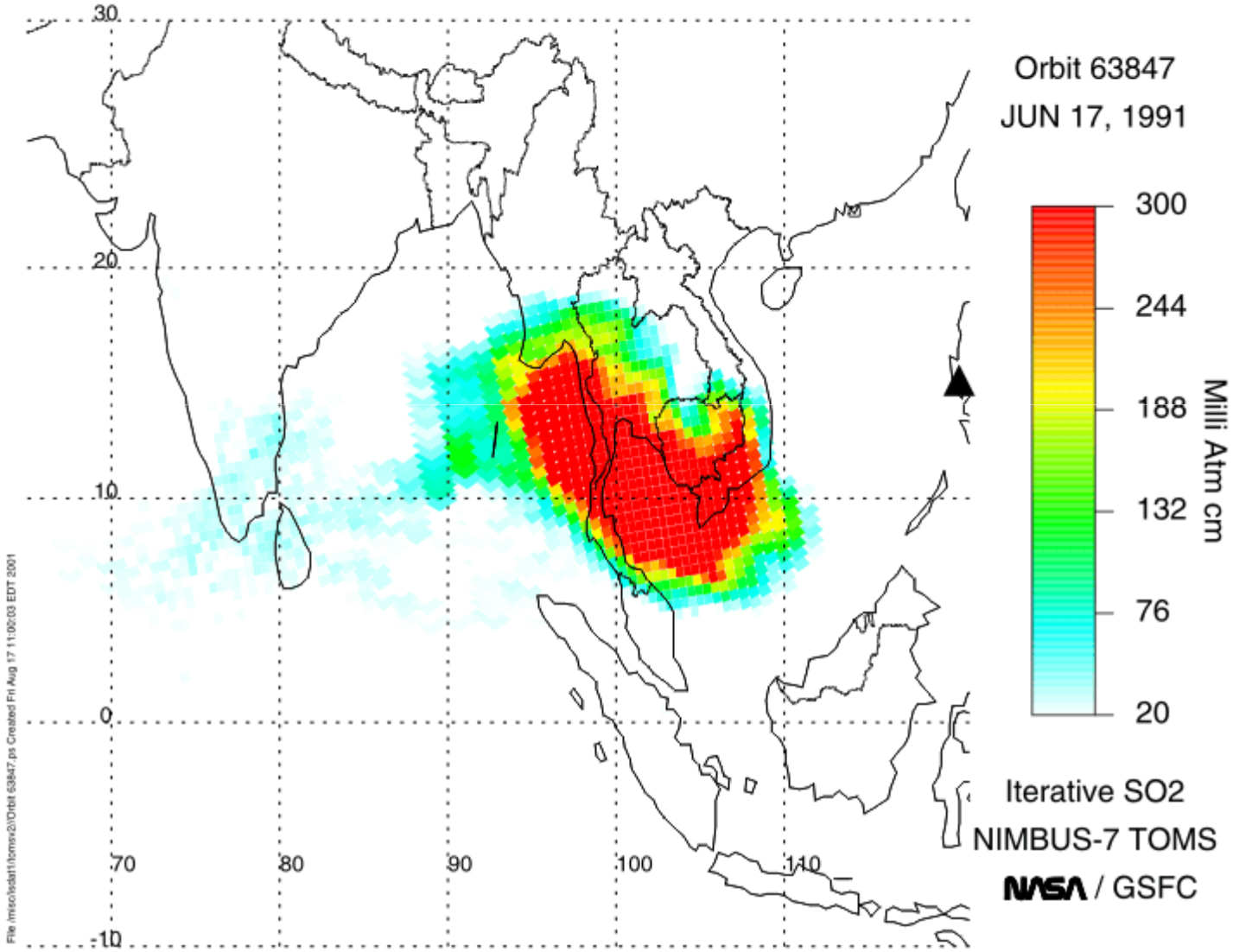
vulcani,

vegetazione,

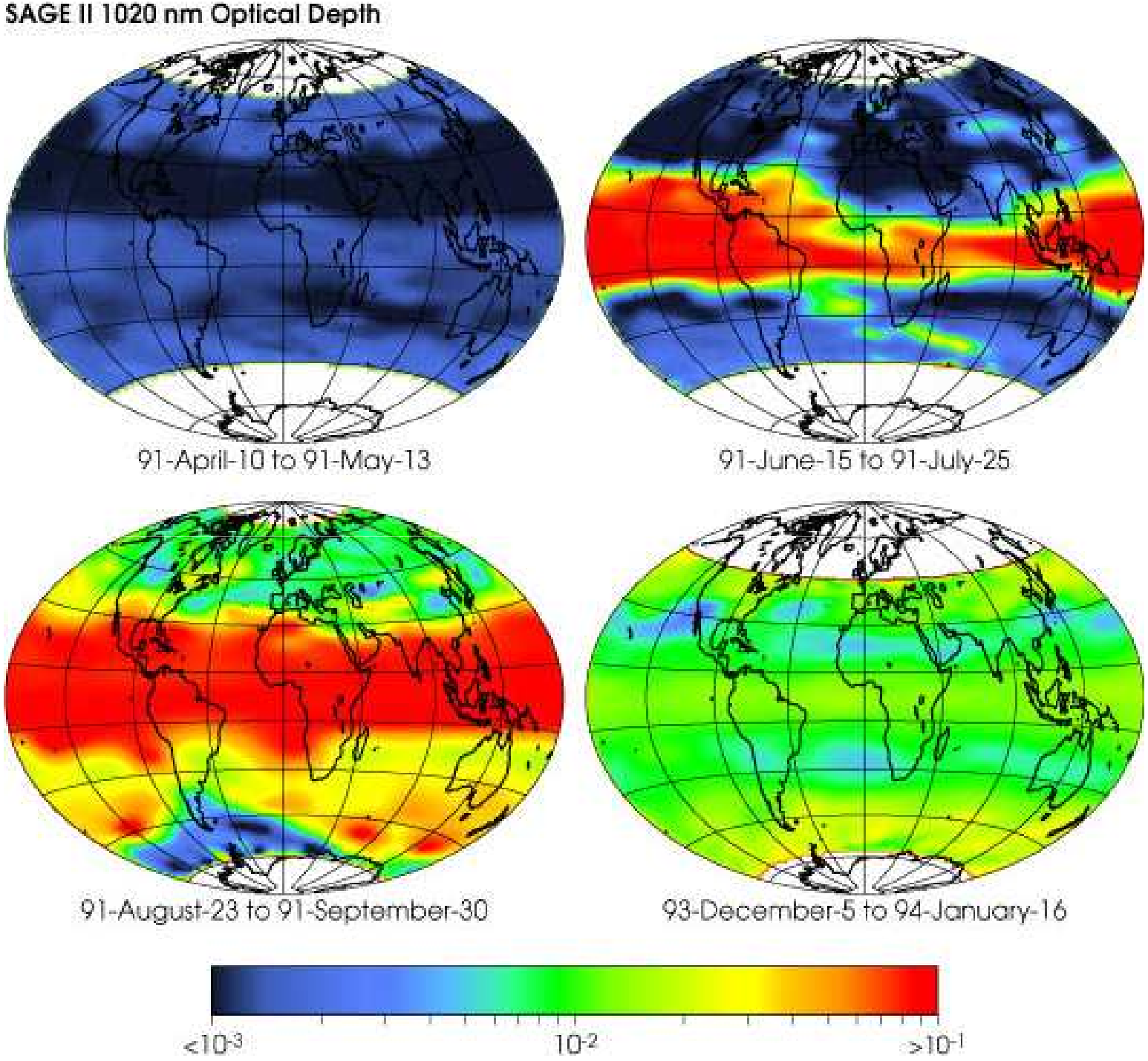
el nino.

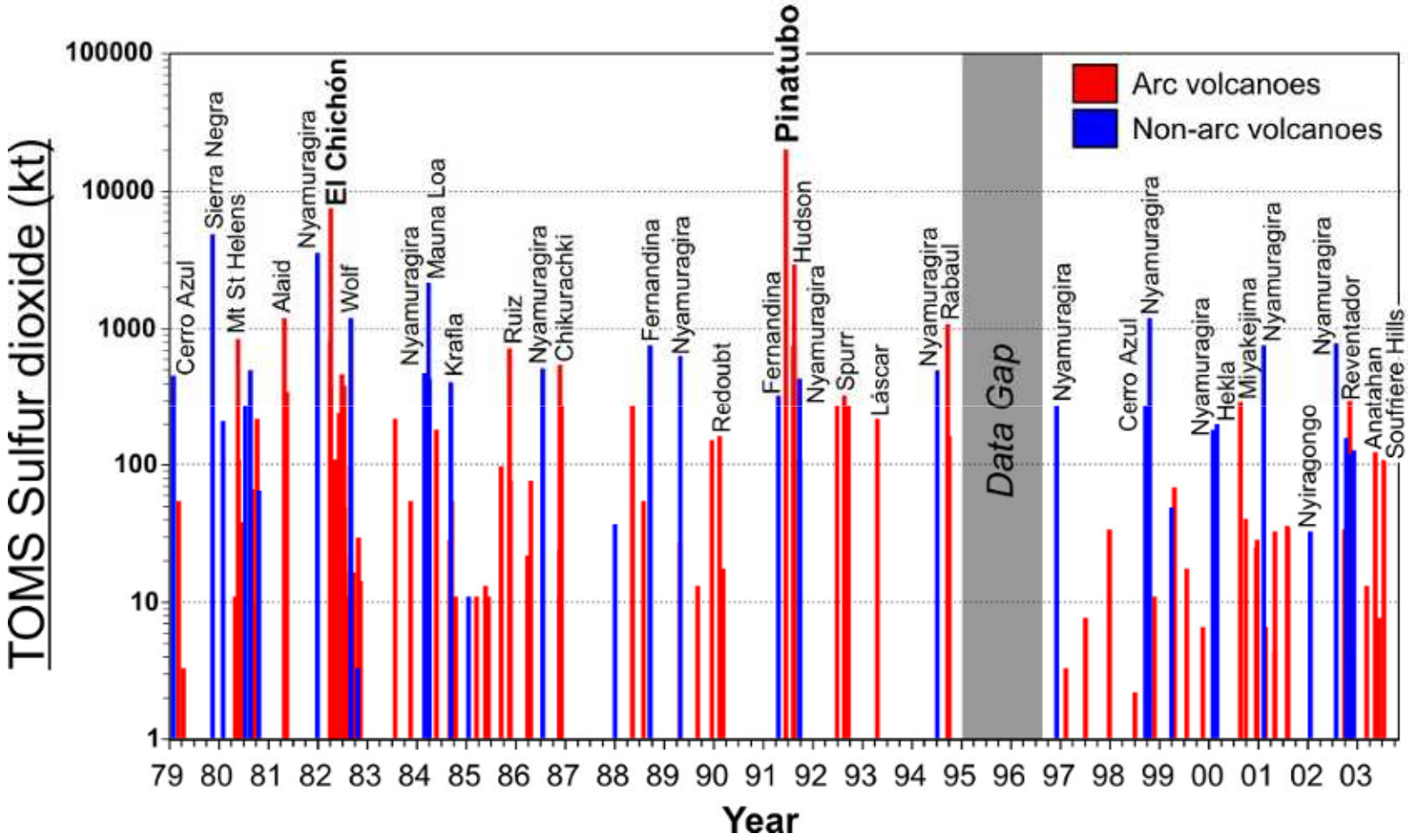
eruzione del monte Pinatubo (12-16/06/91)

eruzione del monte Pinatubo

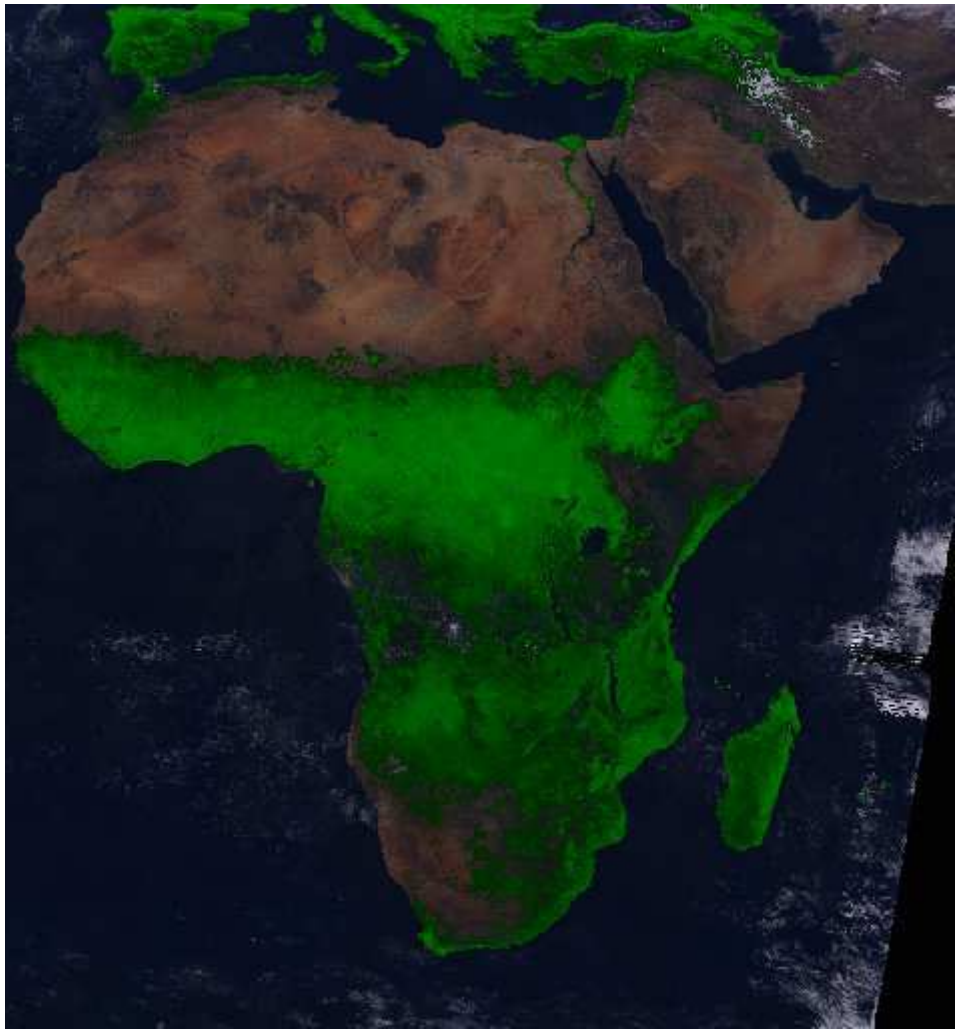


eruzione del monte Pinatubo

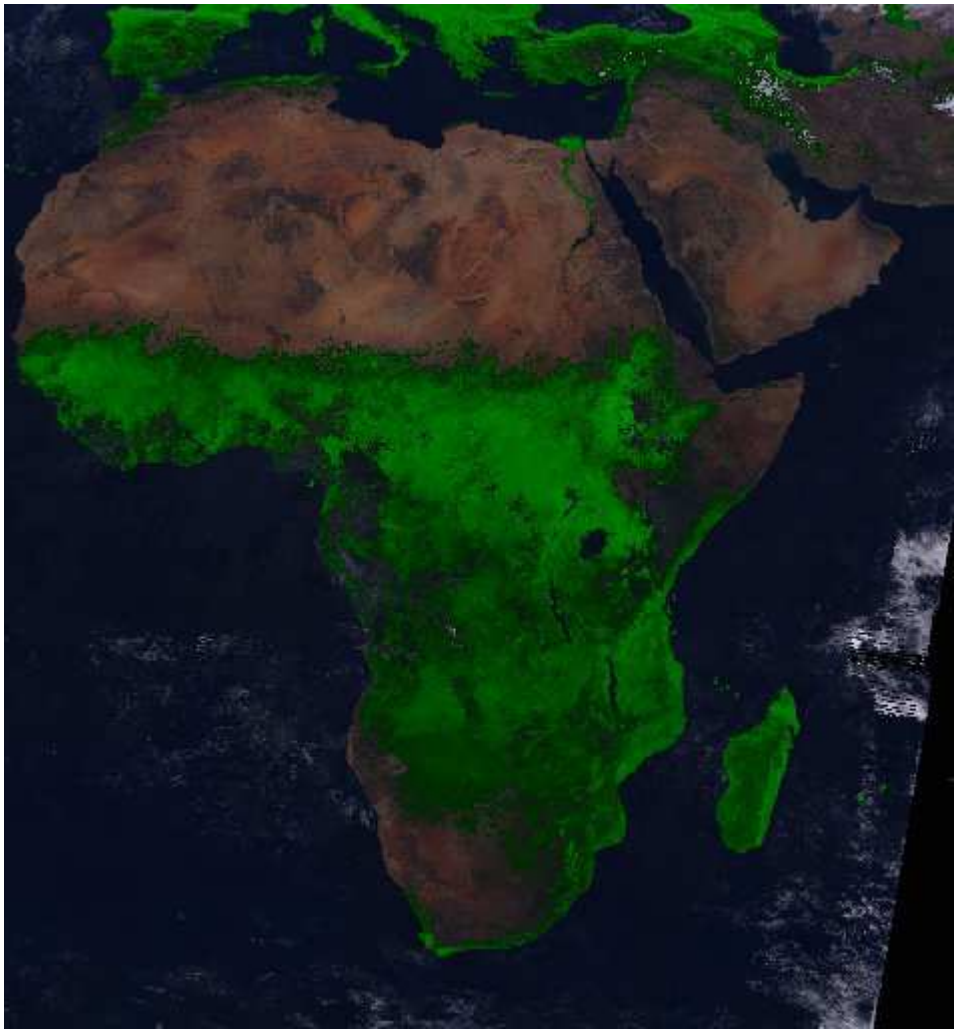



TOMS Sulfur dioxide (kt)
100000
10000
1000
100
10
1
Year
79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Arc volcanoes
Non-arc volcanoes
Data Gap
Cerro Azul
Sierra Negra
Mt St Helens
Alaid
Nyamuragira
El Chichón
Wolf
Nyamuragira
Mauna Loa
Krafla
Ruiz
Nyamuragira
Chikurachki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

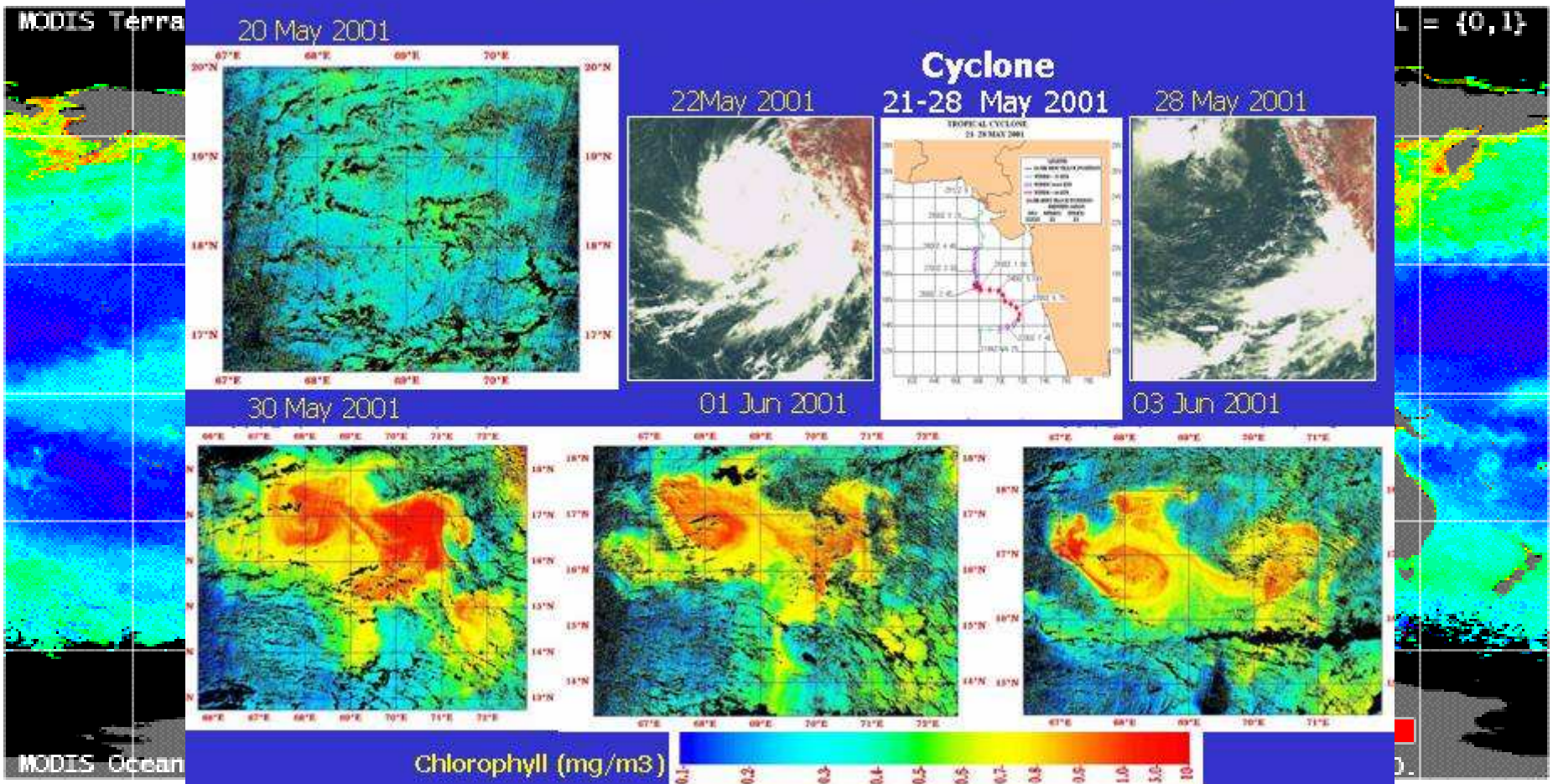
1984



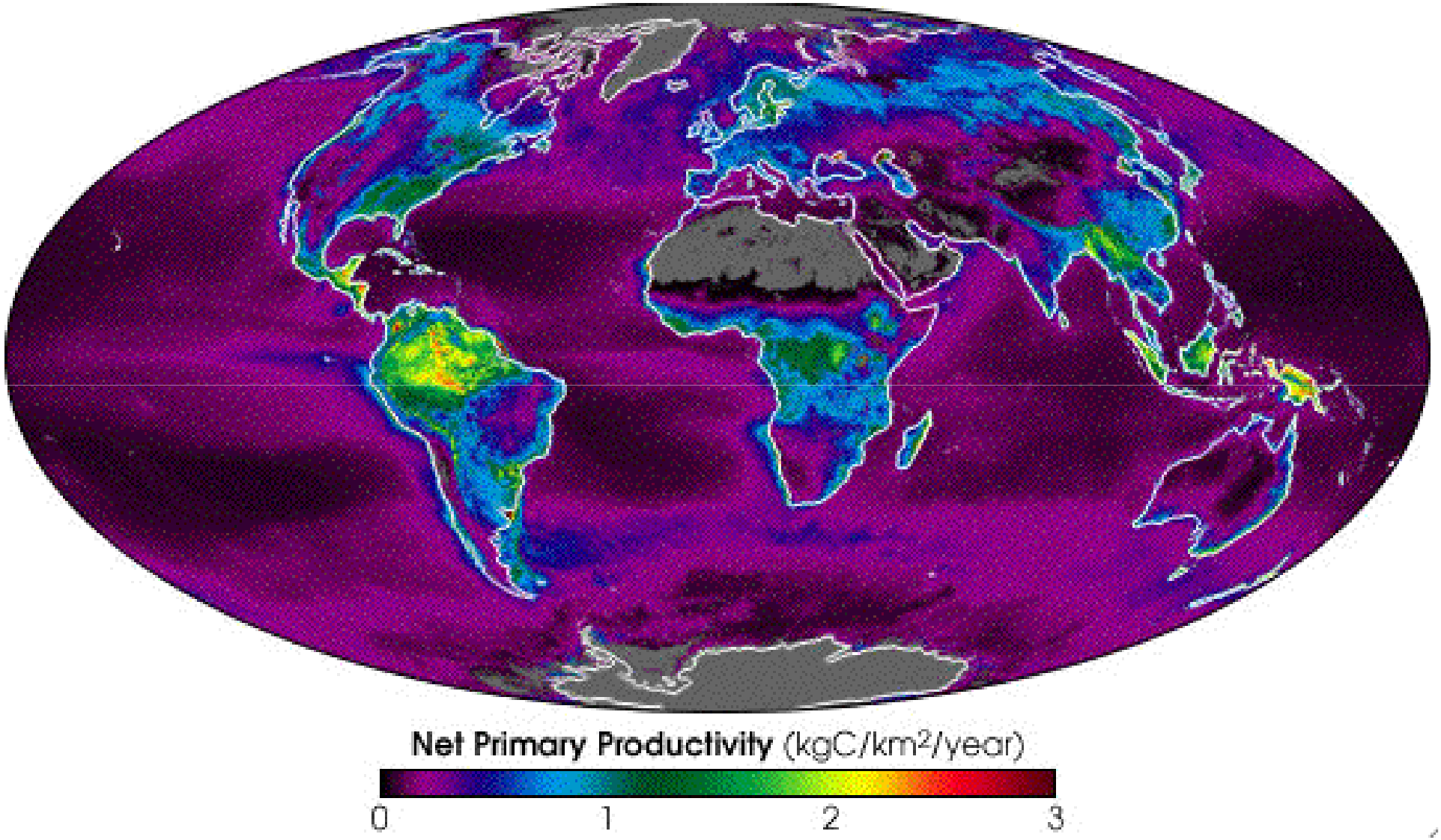
1994

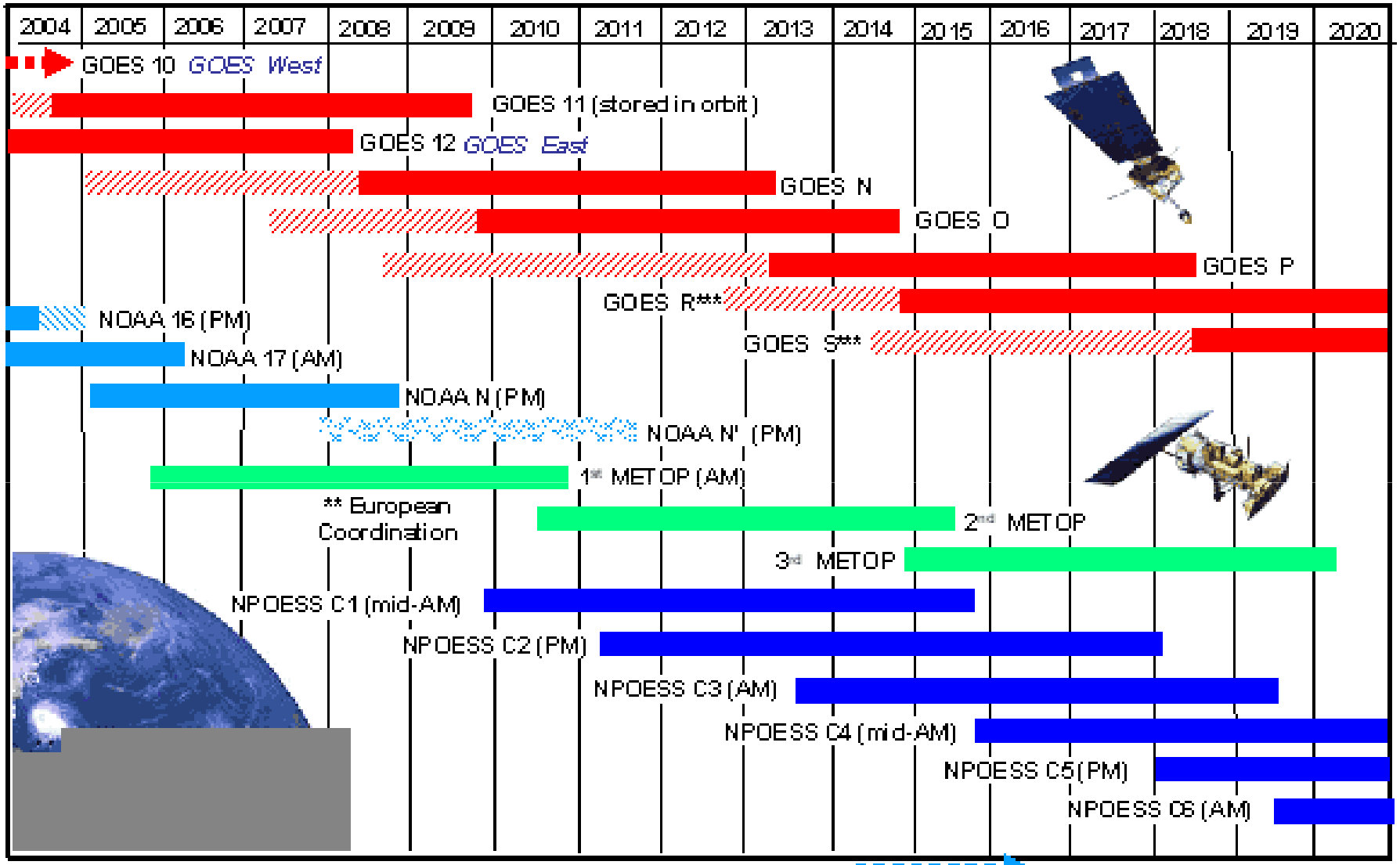


Enhanced chlorophyll for the tropical cyclone 21-28 may, 2001



flusso annuo di Carbonio verso la superficie (vegetazione)




2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
GOES 10 GOES West
GOES 11 (stored in orbit)
GOES 12 GOES East
GOES N
GOES O
GOES P
GOES R***
GOES S***
NOAA 16 (PM)
NOAA 17 (AM)
NOAA N (PM)
NOAA N' (PM)
1st METOP (AM)
** European Coordination
2nd METOP
3rd METOP
NPOESS C1 (mid-AM)
NPOESS C2 (PM)
NPOESS C3 (AM)
NPOESS C4 (mid-AM)
NPOESS C5 (PM)
NPOESS C6 (AM)
* Actual launch dates are determined by the failure of on-orbit assets
** Assumes METOP will provide the morning orbit and NOAA-N' will provide afternoon orbit instruments
*** GOES R-Series may be single or suite of satellites (distributed constellation)
Satellite is operational beyond design life
On-orbit GOES storage
Extended operation

The global mean radiative forcing of the climate system for the year 2000, relative to 1750