Climate System

Lecture during
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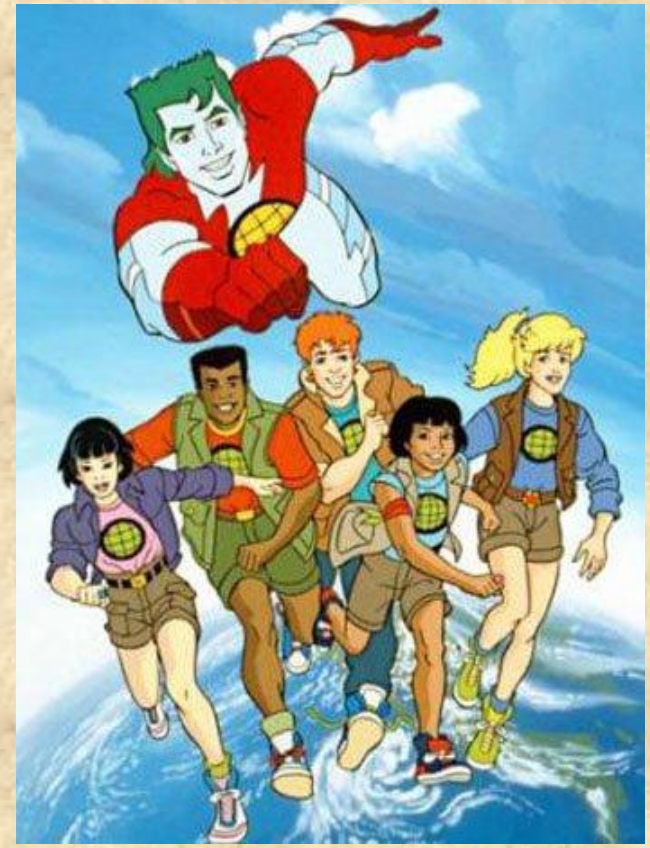
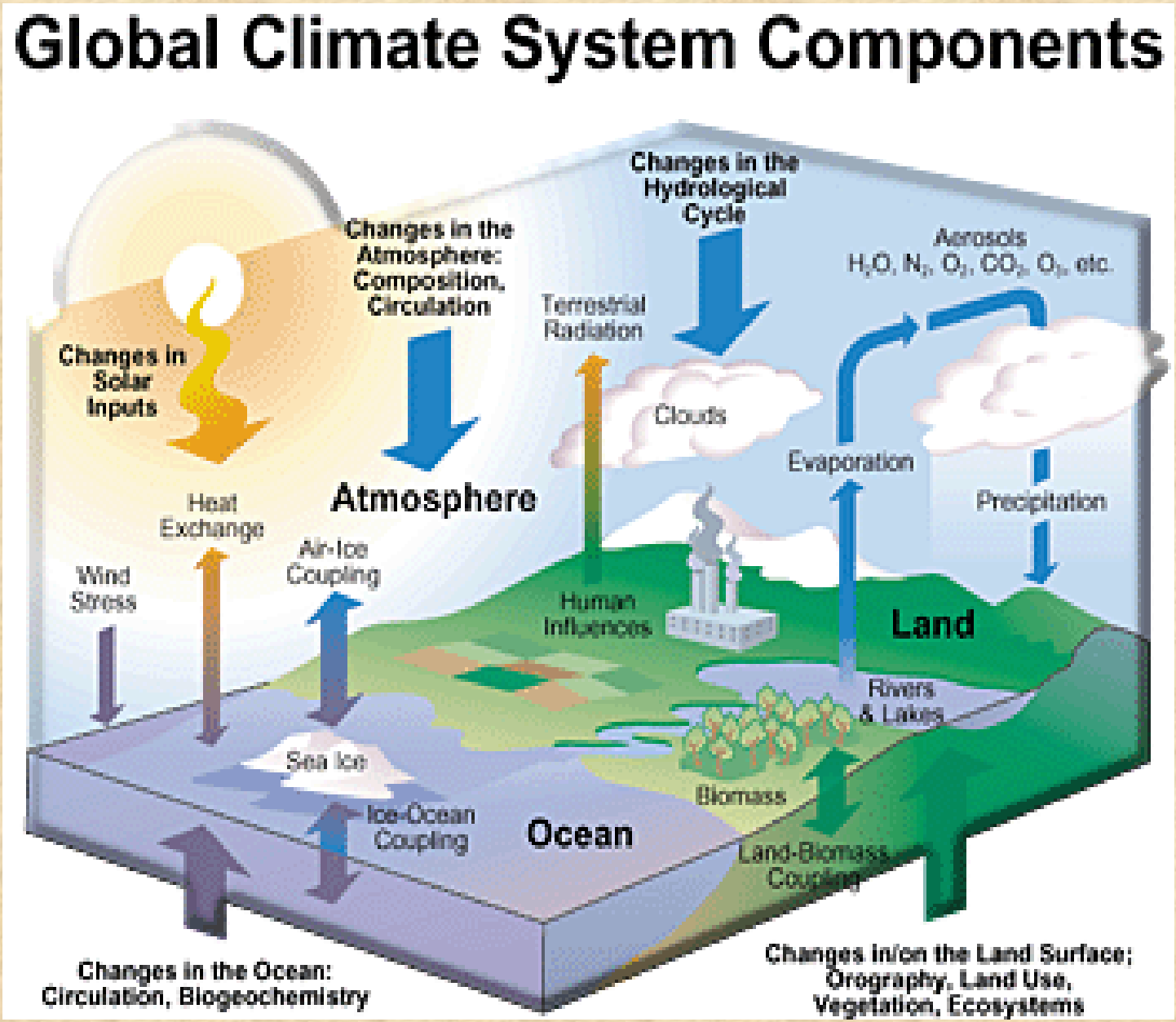


Global Climate System Components



"Climate System" is a definition which appeared in the mid-20th century in relation to the evolution of the definition of climate.

Many definitions of climate exist in the literature and still it is based on the intuitive understanding about the difference between weather and climate.

How do you understand the difference between weather and climate?

The origin of the word – in the Ancient Greek "klima" means an inclination, and respectively, climatology is the science which studies the effect of the inclination.

Which inclination is this?

“Weather” is the actual state of the atmosphere characterized by state variables – temperature, humidity, wind, clouds, precipitation etc.

According to the most widely accepted definitions:

“climate” refers to the averaged weather in terms of the mean and its variability over certain area and certain period of time.

IPCC Glossary gives this:

Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

What is bothering in these definitions?

-only atmosphere important?

-what about the extremes?

Another definition which pretends to cover all aspects of the intuitive understanding of the climate is: "Climate" is the statistical ensemble average of the climate system over a period of 30 years.

The introduction of the climate system reflects the realization that it is not only atmosphere but also other planet components to impact the climate. And from the thermodynamics point of view, the statistical ensemble means the probability distribution for a given state of the system. Thus also the extreme events are taken into account with their probability to occur.

Climate System:

- *Atmosphere*
- *Hydrosphere*

- *Cryosphere*

- *Lithosphere*

- *Biosphere*

- *???Homosphere*

Climate System:

- *Atmosphere – the air*
- *Hydrosphere*

oceans, rivers, lakes

- *Cryosphere*

sea ice, ice sheets, glaciers, permafrost

- *Lithosphere*

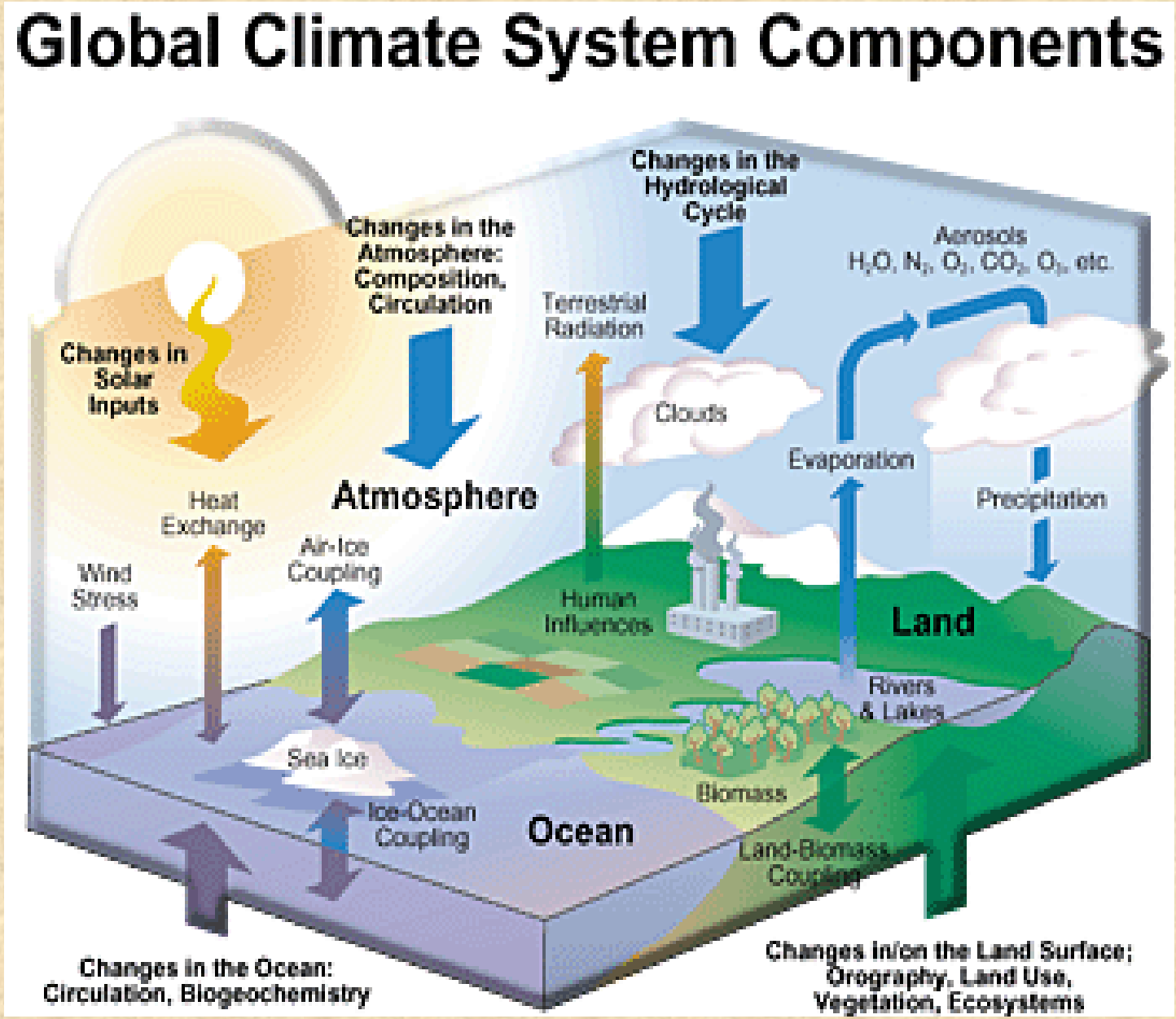
land

- *Biosphere*

biomass

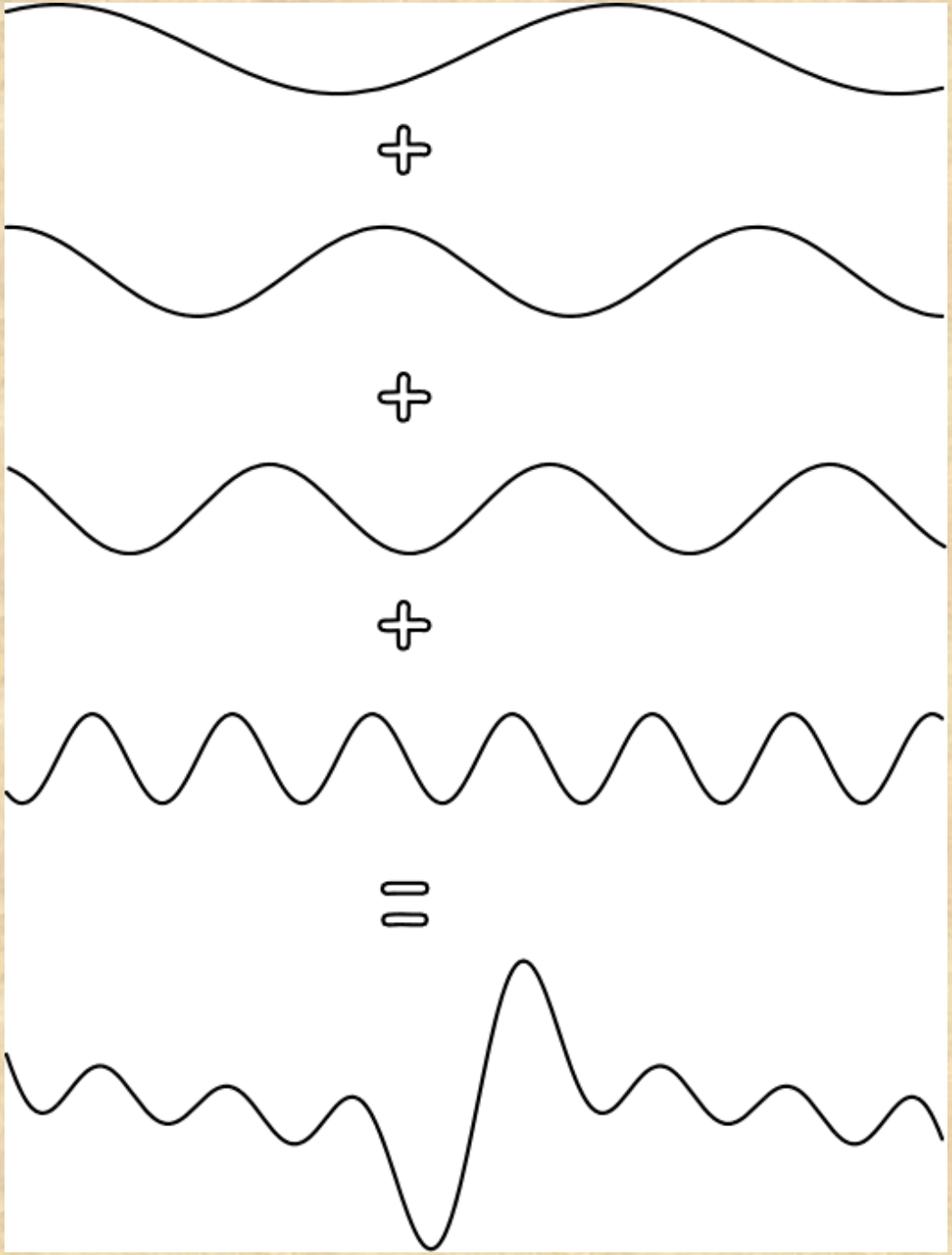
- *???Homosphere*

human influence

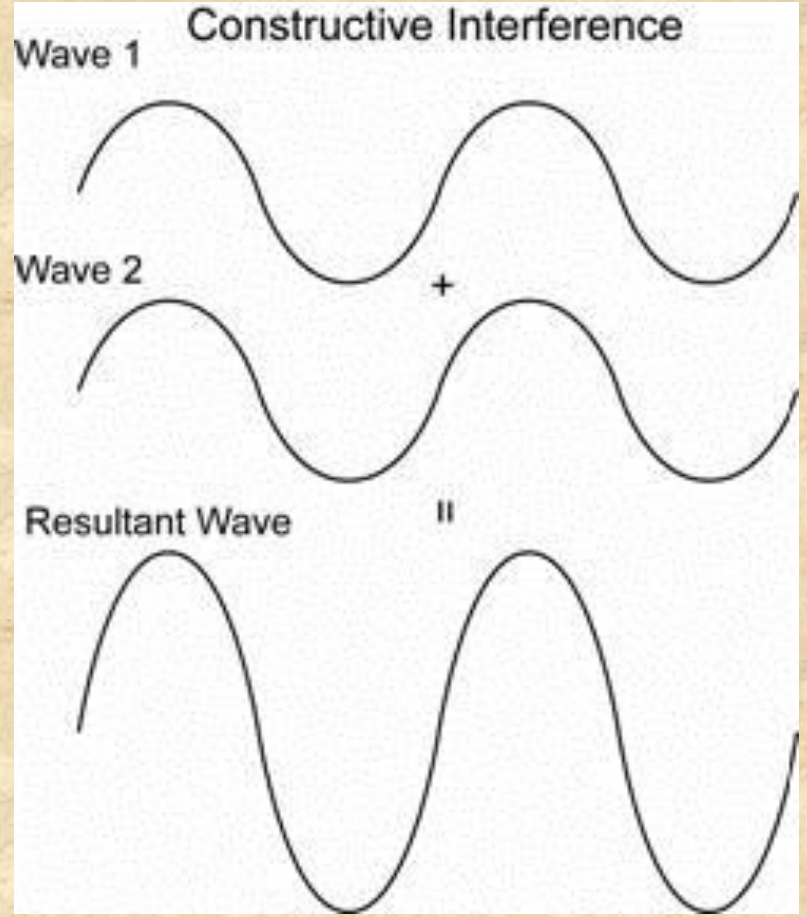


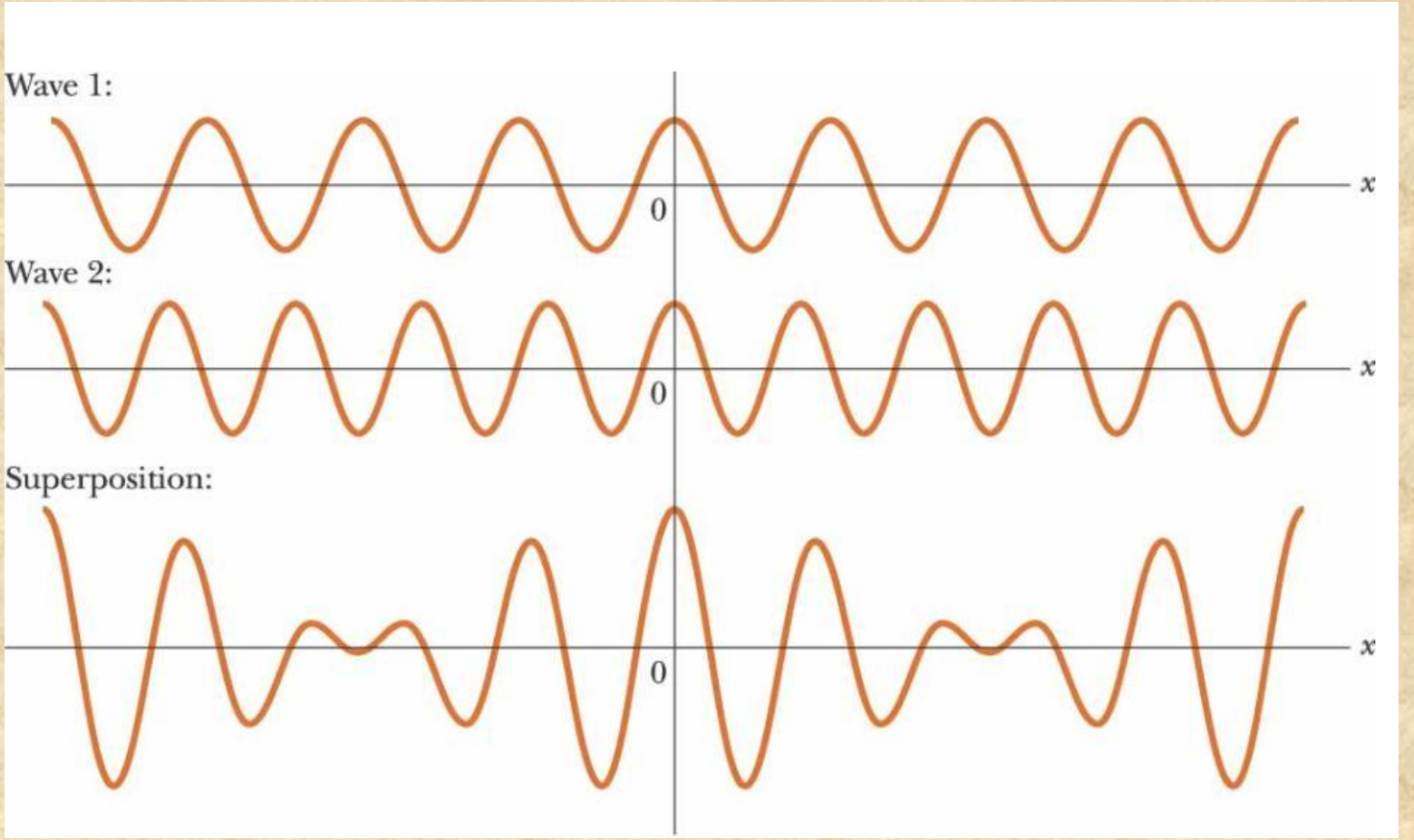
What is the main characteristic of the climate system: very complex behavior due to the exchange between all the components of matter, energy and gases with different time-scales.

Let us remember the principle of the superposition of waves:



Even if the waves are of same frequency:





The difference between “climate variability” and “climate change”: related to the period of 30 years, chosen to determine the climate:

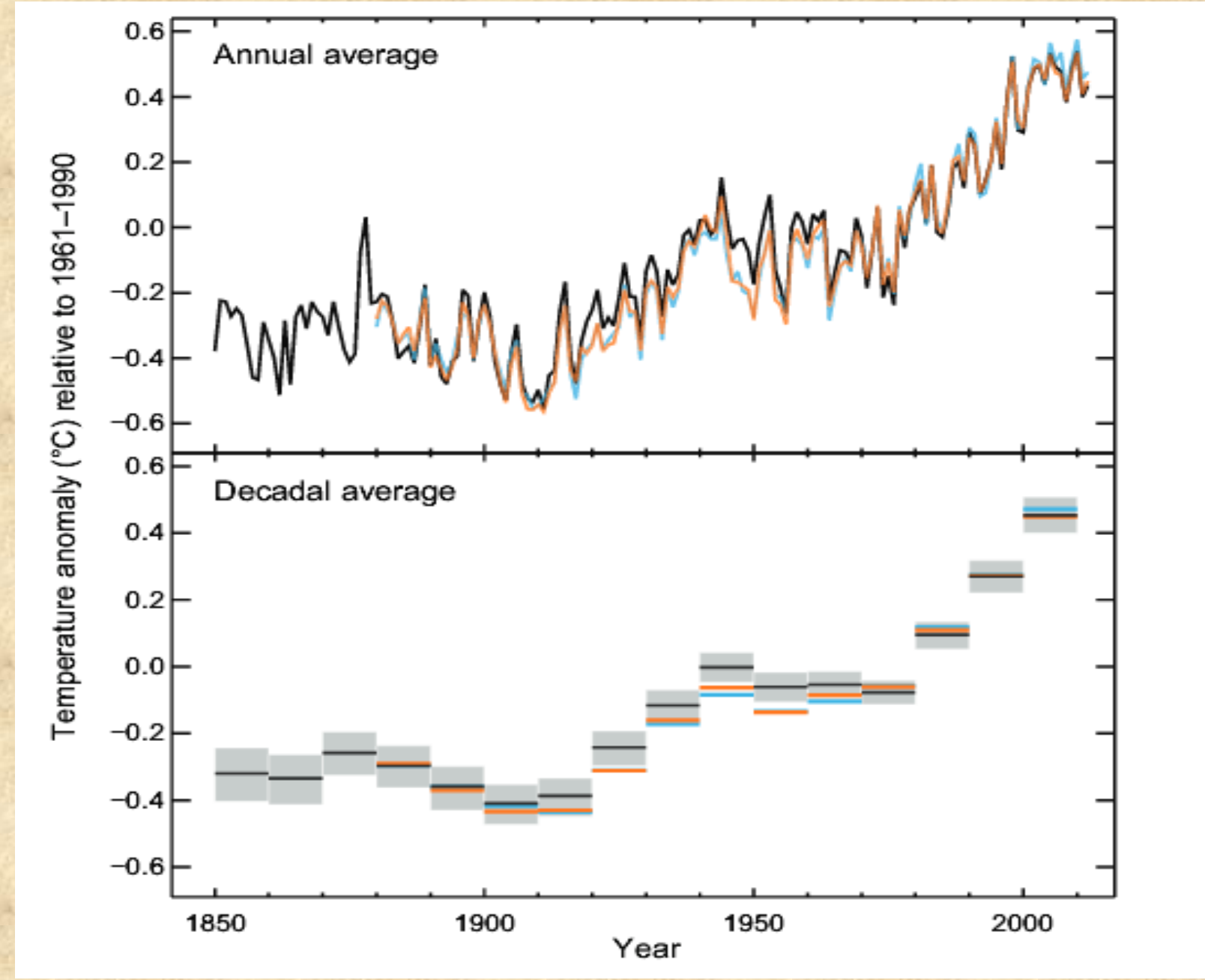
- Variation with period < 30 years – variability
- Variation with period > 30 years – change

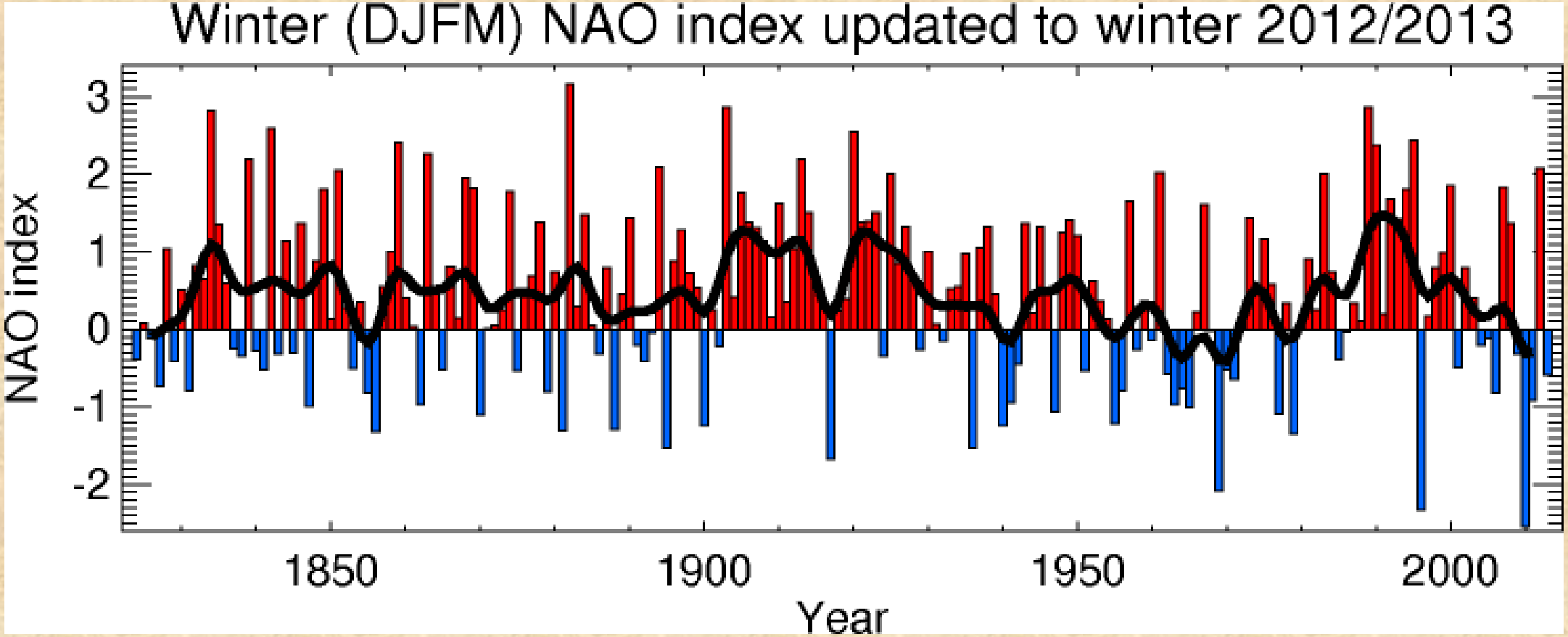
Variability is mainly due to interactions between climate system components and feedback mechanisms

- Positive feedbacks – *example?*
- Negative Feedbacks – *example?*

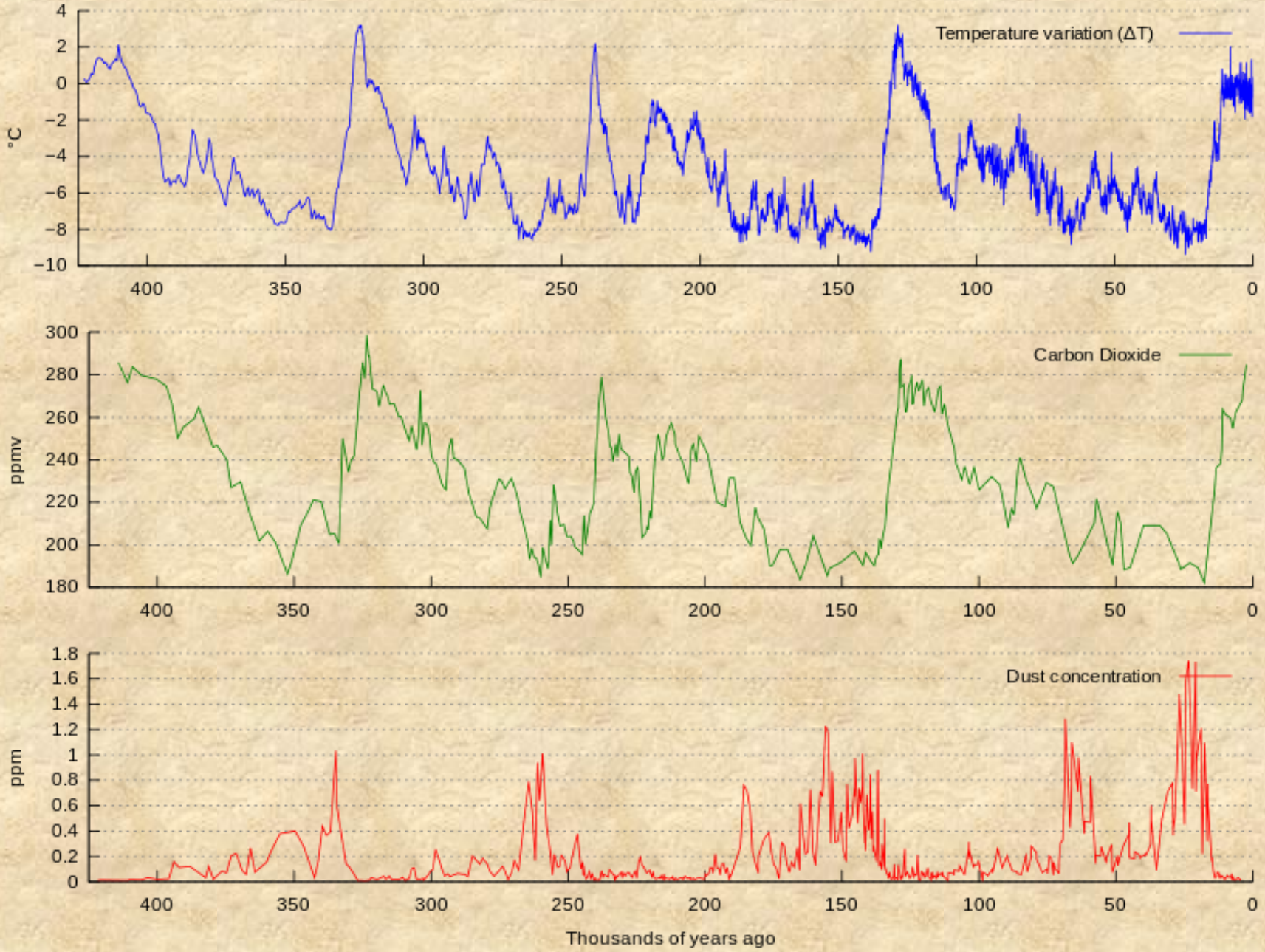
To balance the climate system what feedbacks do we need?

Origin: IPCC Fifth assessment report





Origin: http://www.cru.uea.ac.uk/~timo/datapages/naoi.htm

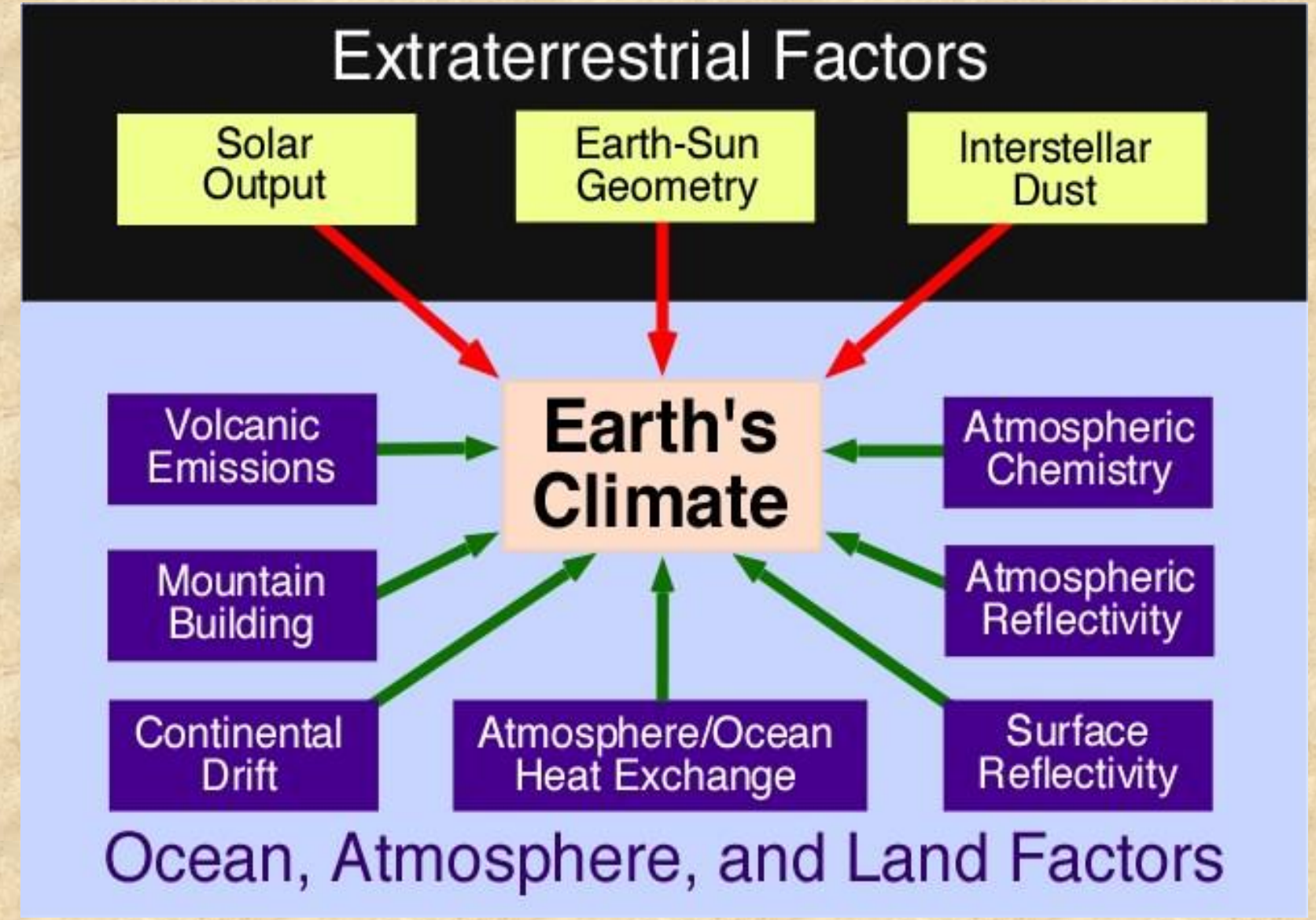

Temperature variation (ΔT)
°C
4
2
0
−2
−4
−6
−8
−10
400
350
300
250
200
150
100
50
0
Carbon Dioxide
ppmv
300
280
260
240
220
200
180
Dust concentration
ppm
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Thousands of years ago

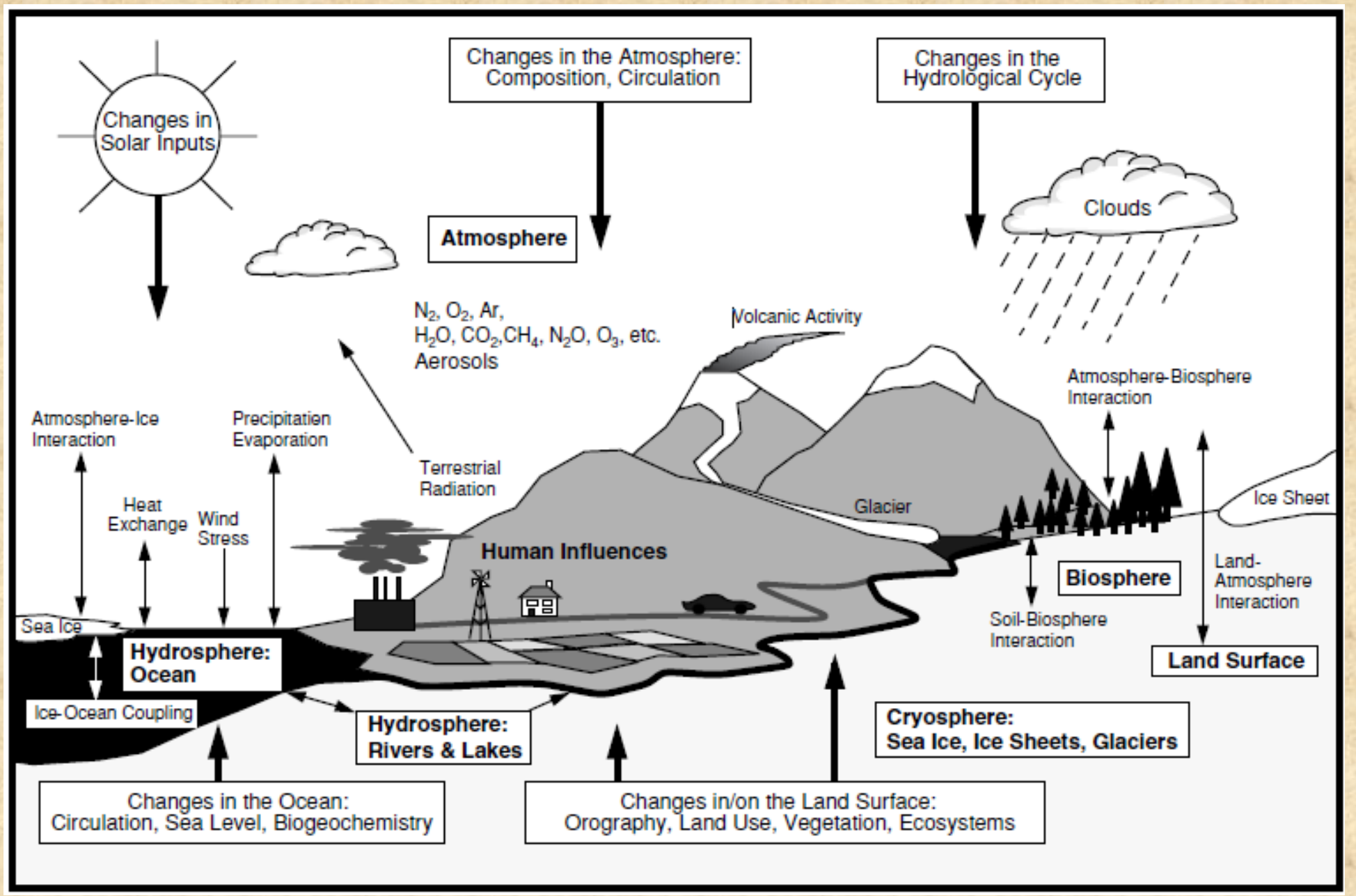
Thus what causes change in the climate system could be separated in two big groups:

- External factors
- Internal factors

Then we also have two groups of variations:

- Natural variations
- Human-induced variation





Origin: IPCC Third assessment report

The solar input: a source of energy for the Earth

A physics law (Kirchoff) states that if a body absorbs energy it has to emit the same amount of energy. It is valid for the climate system as well.

Some simple calculations:

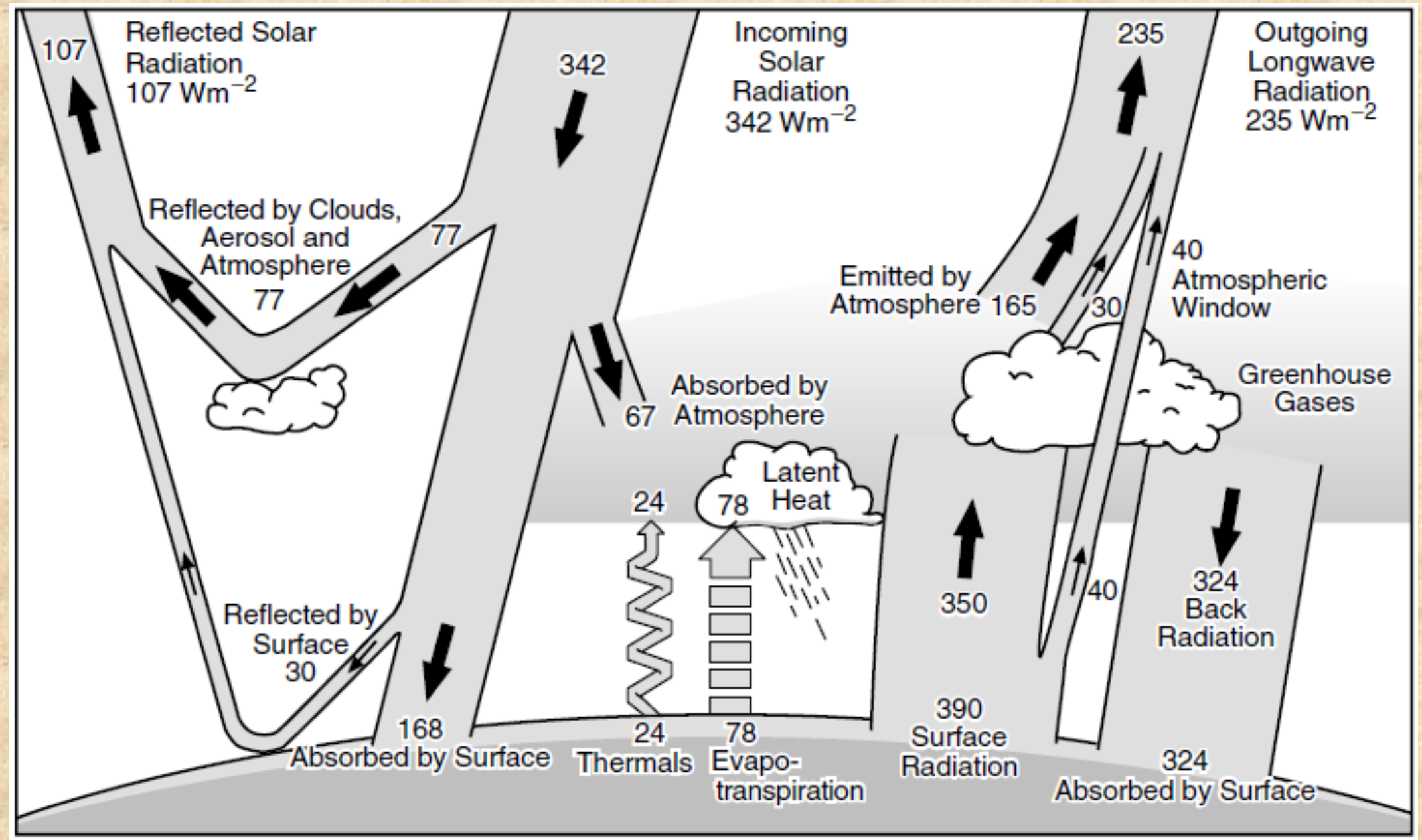
Solar radiation on the TOA: 342 W/m^2

Planet albedo 31%

=>235 W/m^2 should be absorbed and emitted by the climate system.

According to Stephan-Boltzman law the effective temperature of a body which emits 235 W/m^2 is -19ºC

The average surface temperature of Earth is about 14ºC and -19ºC is reached at about 5 km height. The reason: natural green-house effect.


107
Reflected Solar Radiation 107 Wm^{-2}
342
Incoming Solar Radiation 342 Wm^{-2}
235
Outgoing Longwave Radiation 235 Wm^{-2}
Reflected by Clouds, Aerosol and Atmosphere
77
77
Emitted by Atmosphere
165
30
40 Atmospheric Window
Greenhouse Gases
67
Absorbed by Atmosphere
Latent Heat
24
78
Reflected by Surface
30
350
40
324 Back Radiation
168
Absorbed by Surface
24
Thermals
78
Evapo-transpiration
390 Surface Radiation
324
Absorbed by Surface

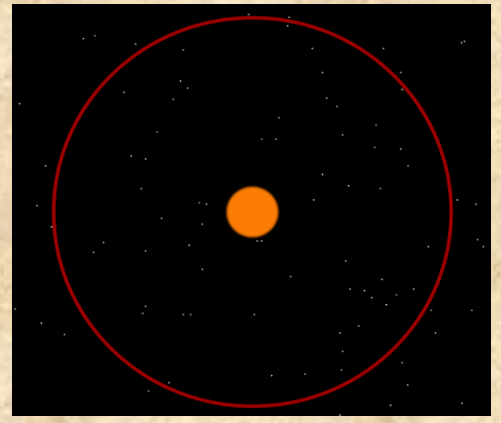
In equilibrium climate state at TOA absorbed = emitted radiation.

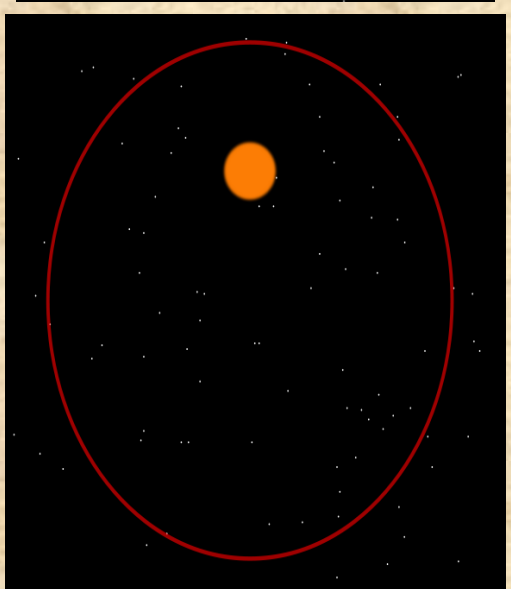
An imbalance of this state is referred as “radiative forcing”.

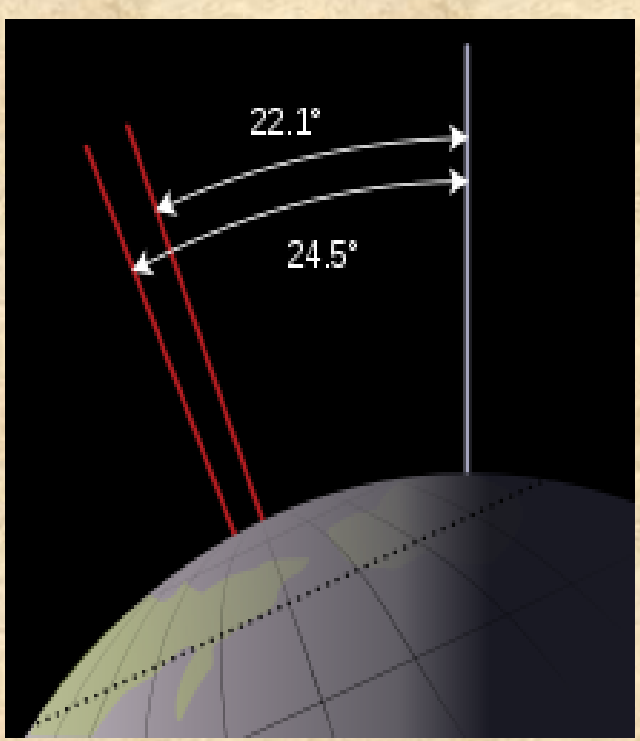
As radiative forcing could be considered:

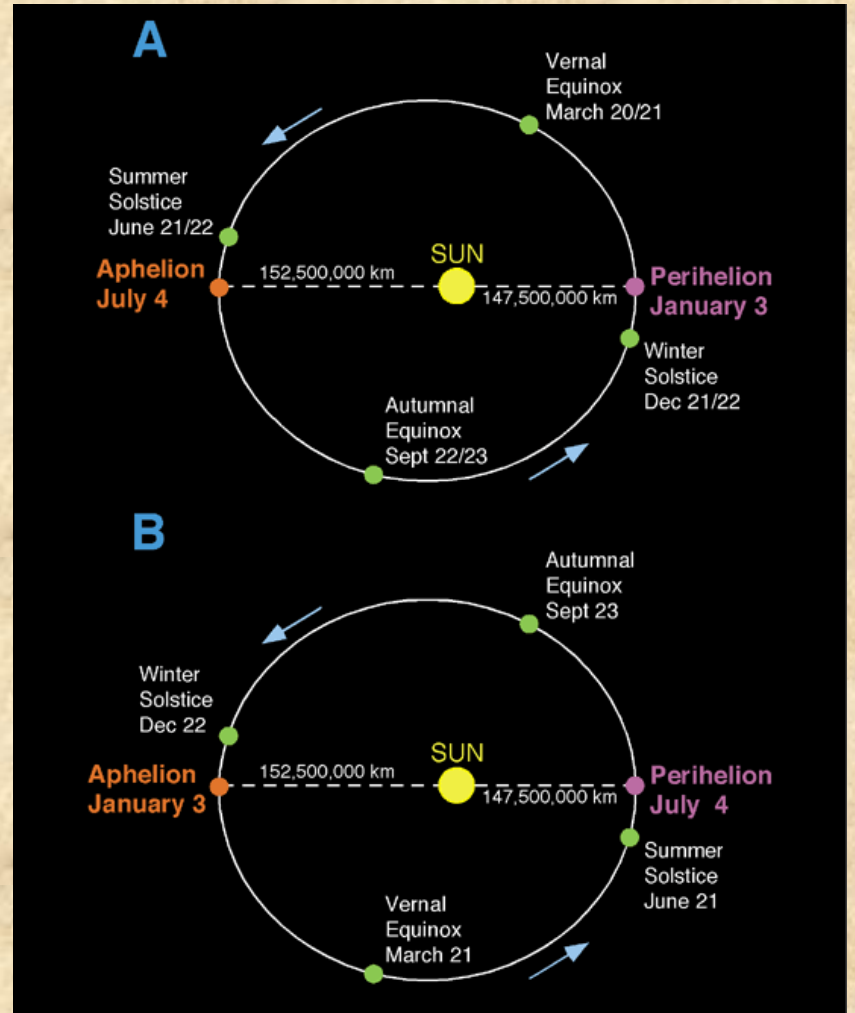
- Changes in the solar input energy
- Changes in the content of aerosols in the atmosphere
- Changes of green-house gasses concentration

An example of natural climate variability of the solar input is the Theory of Milankovich. It links the changes in climate to the change of 3 parameters of the Earth orbit rotating around the Sun: eccentricity (100 000 years), axes inclinations (40 000) and precesion of the equinox (23 000).





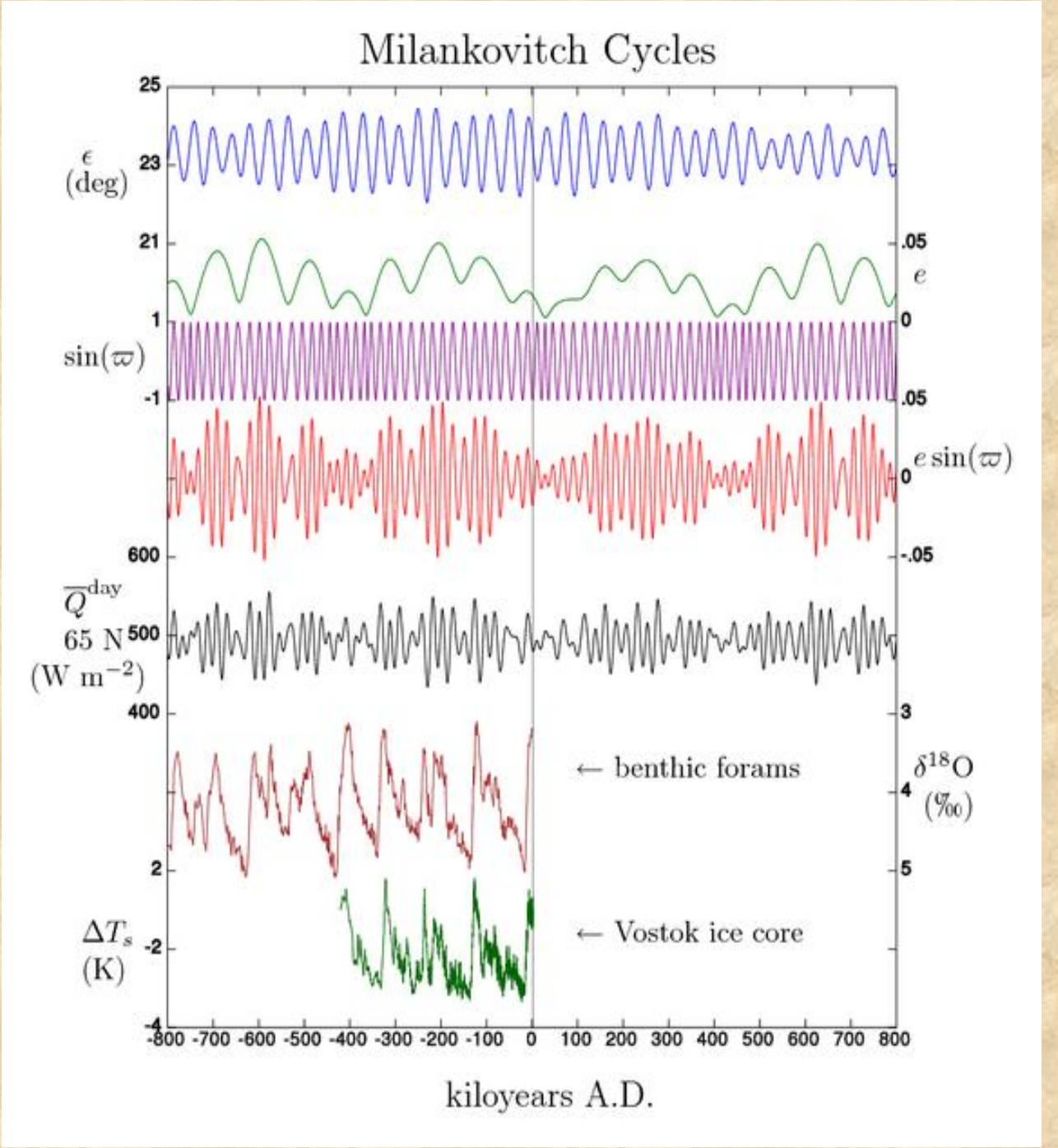




Milankovich cycles explain well the alternation of glacial and interglacial periods in the quaternary (the last ~1 My).

But they can not explain the rapid change between “warm” and “cold” regimes of the Earth (transitions to ice age).

However the changes in the solar radiation cause also natural internal climate variability.



Basic characteristics of the climate system components:

- Atmosphere: the most unstable and rapidly changing component; the time- scale of response/adjustment is ranging from 1s to 1 month; the concentration of the green-house gasses is crucial for the energy budget; water vapor is the strongest green-house gas and because of this peculiarity and the transition between various phases absorb and release much energy, water vapor is central to the climate and its variability or change.

- Hydrosphere - all liquid surface and subterranean water, both fresh and saline water. The ocean store and transport a large amount of energy and dissolve and store great quantities of carbon dioxide; large thermal inertia so they damp vast changes and regulate Earth's climate; response time months to decades (thermohaline circulation much longer)

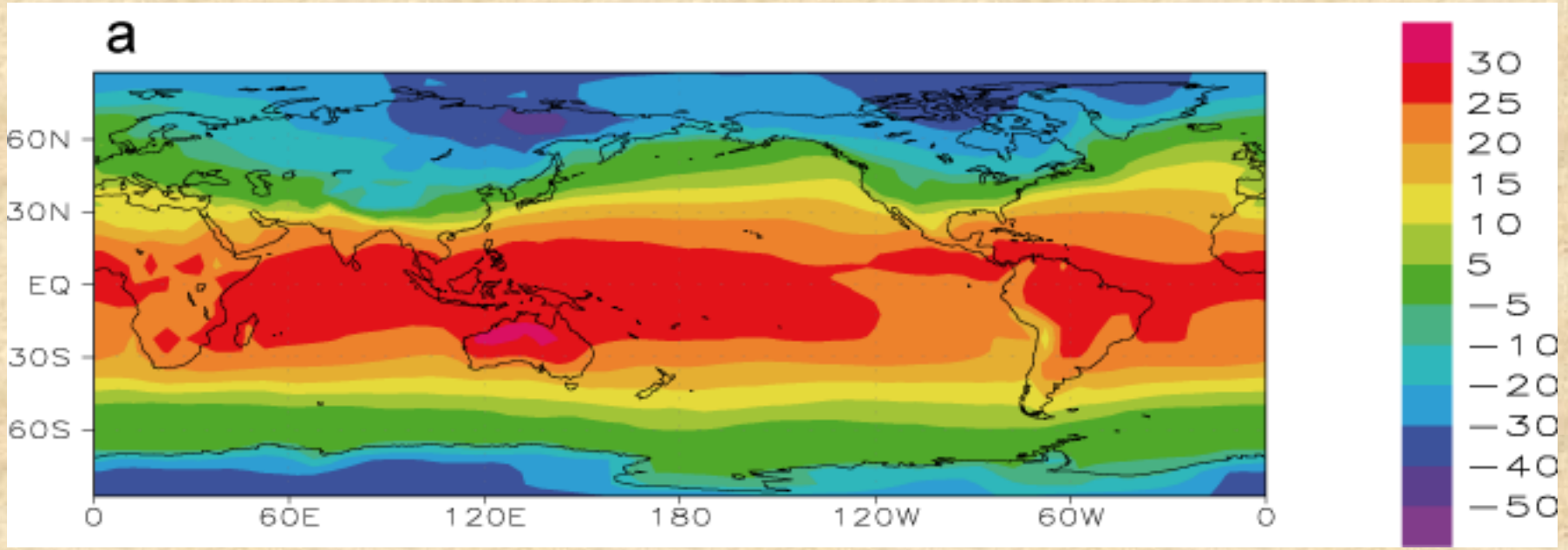
Basic characteristics of the climate system components:

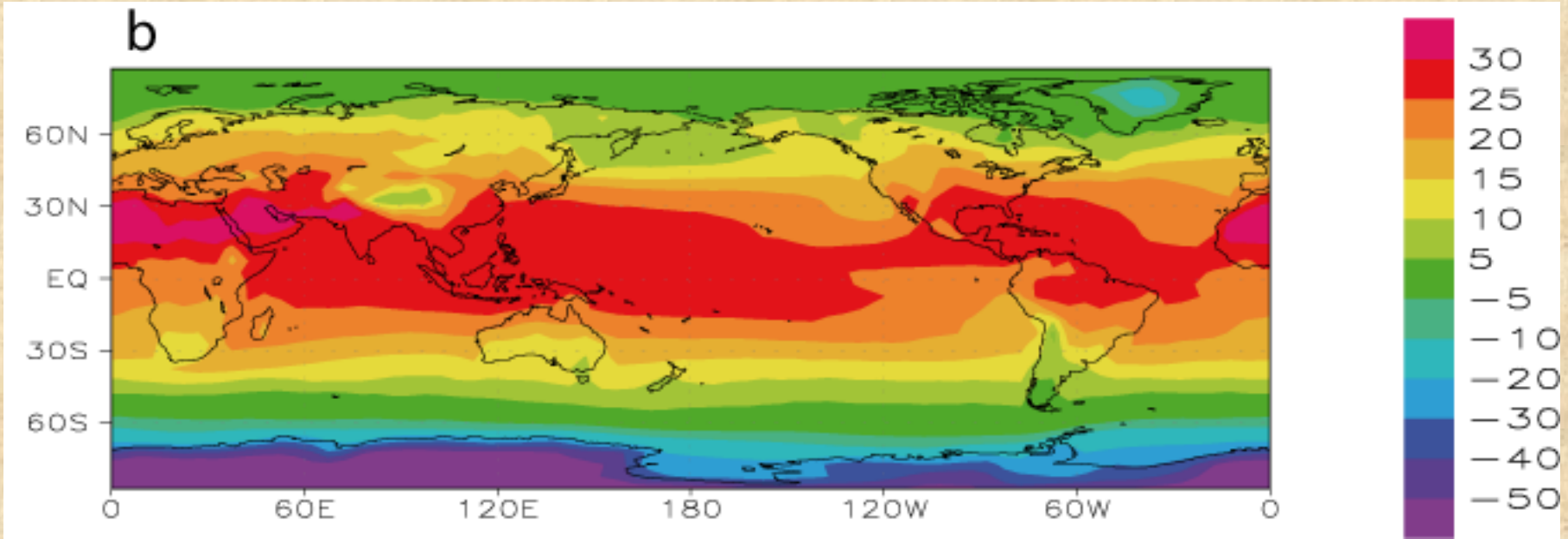
- Cryosphere – sea ice, ice sheets, glaciers, permafrost: the most important for the climate is the high albedo value; it is a store of water, thus influences the sea level; store of latent heat; time response from decades to millennium.

- Lithosphere – land surface: vegetation and soil type impact the albedo, evaporation; time response –millennium (continental drift, orogenesis, erosion).

- Biosphere – marine and terrestrial vegetation: affect the atmosphere composition; time response ranges from short to very long-term.

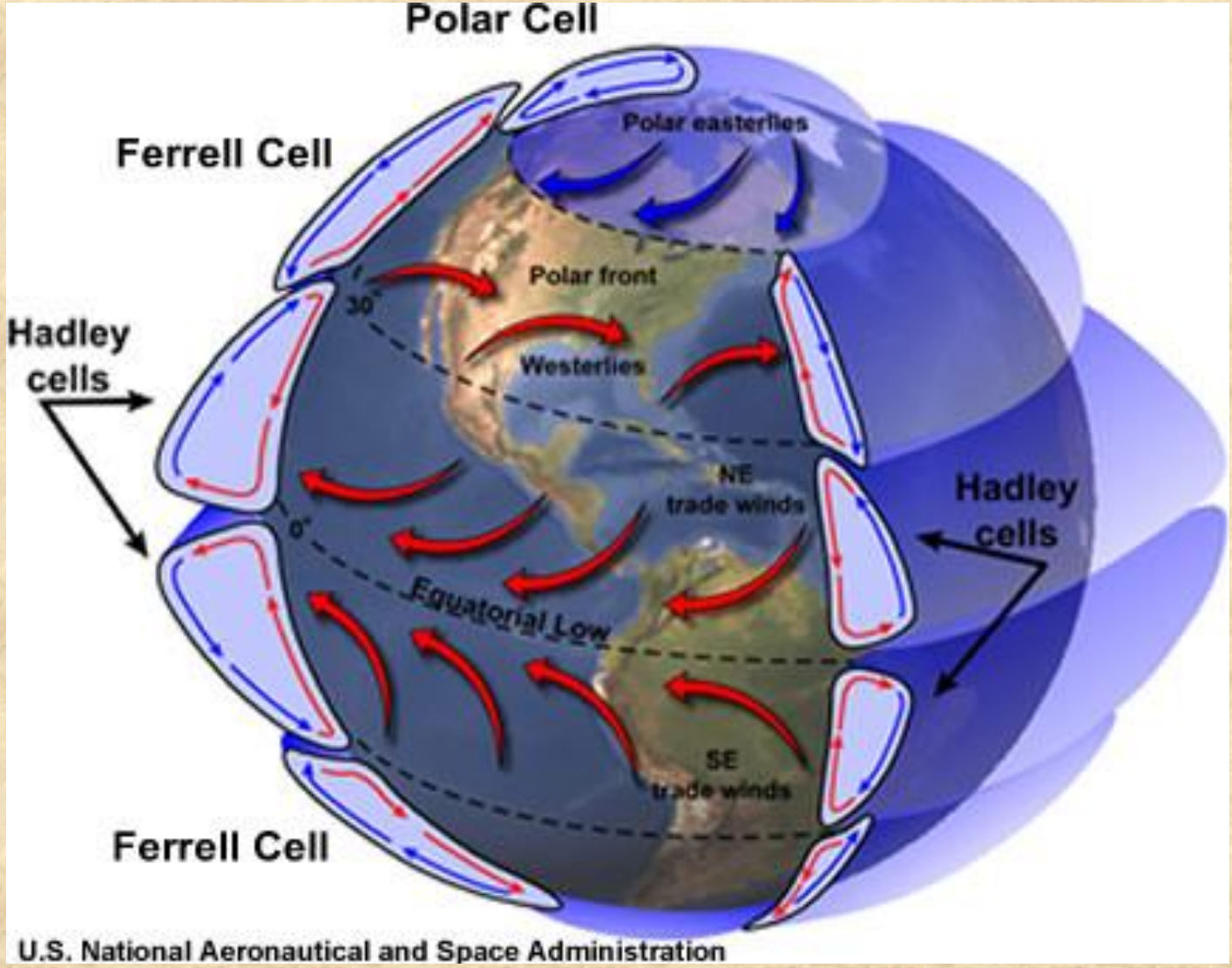
Mean state of the climate system components: Temperature



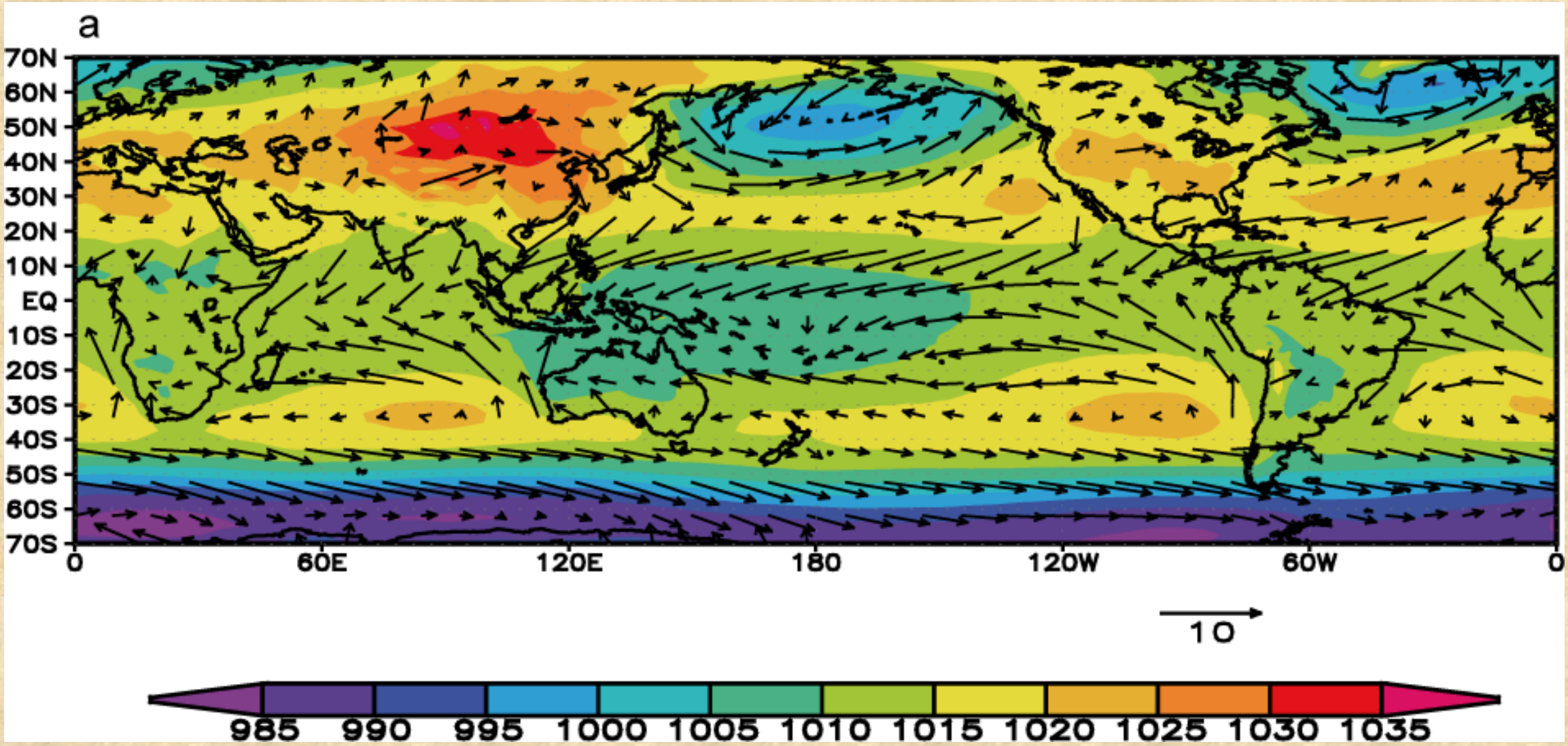


Mean state of the climate system components:

Global circulation



Mean state of the climate system components:
MSLP and winds (winter)



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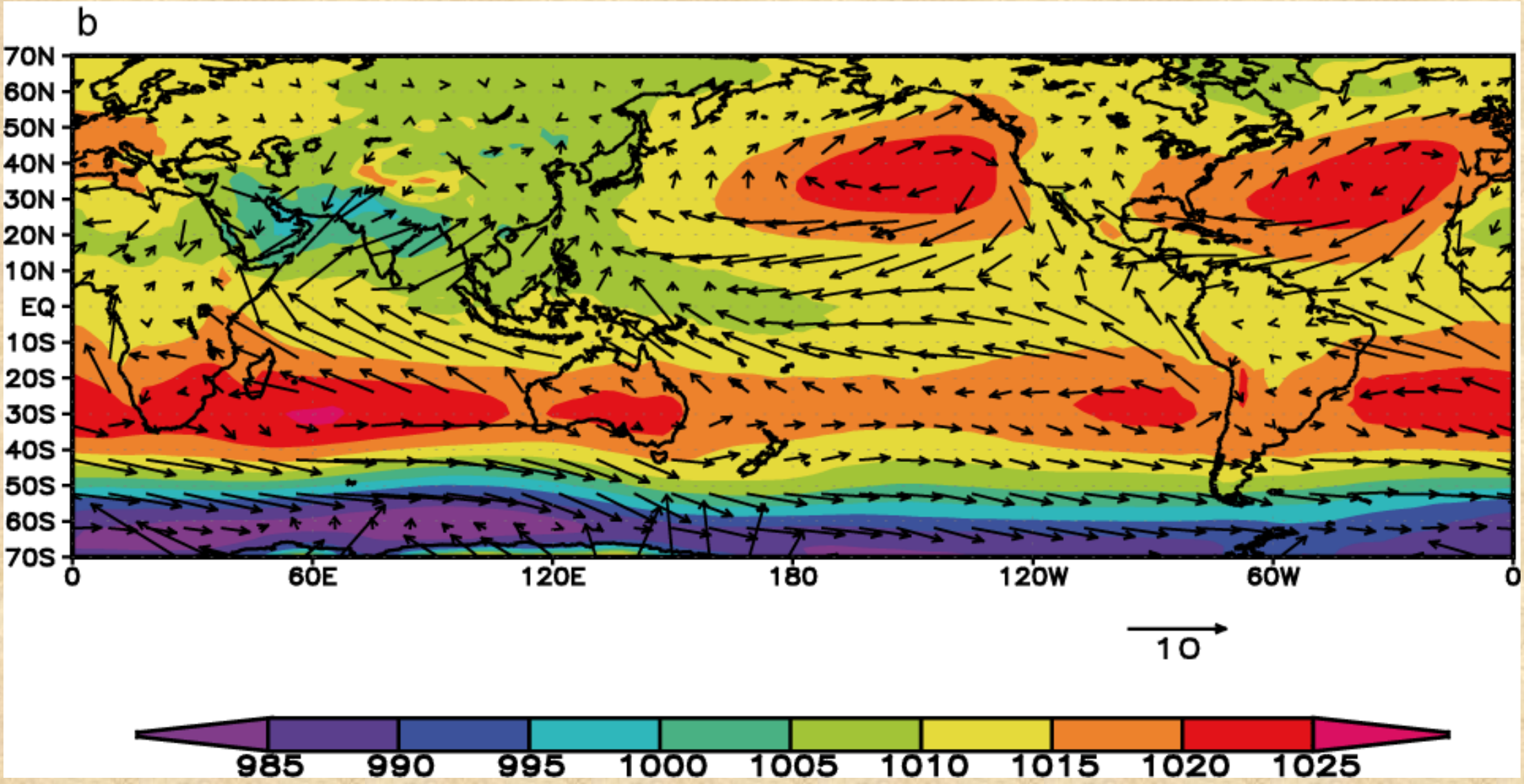
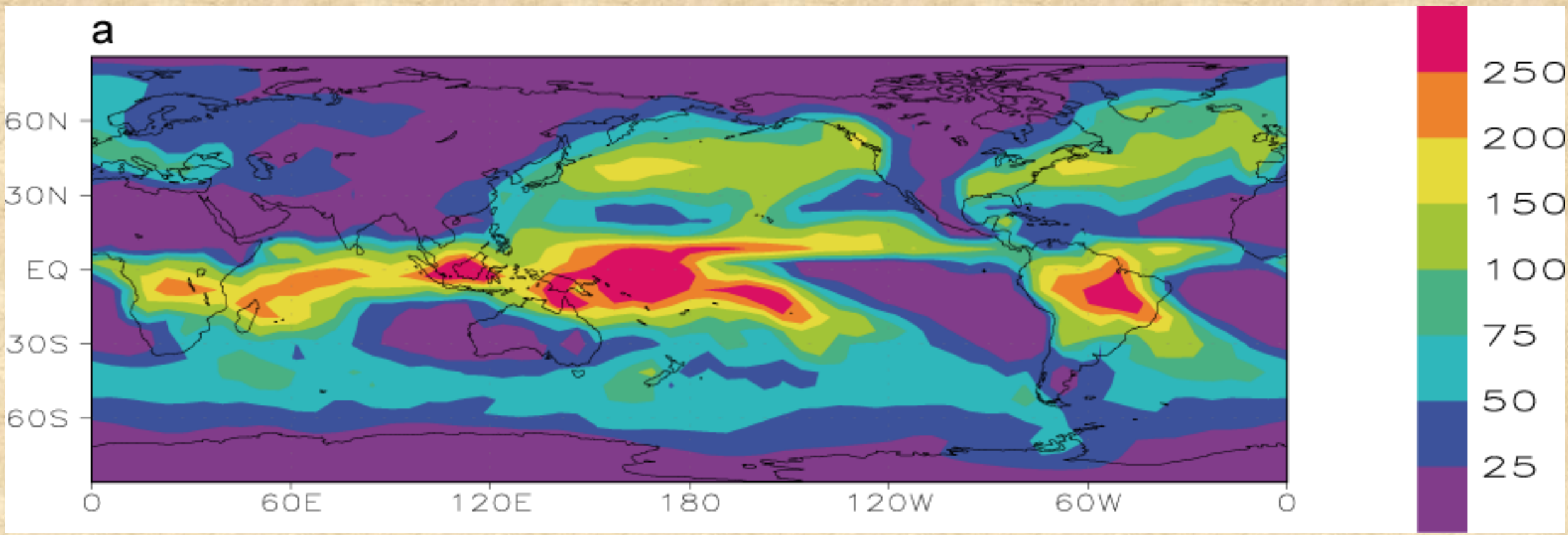


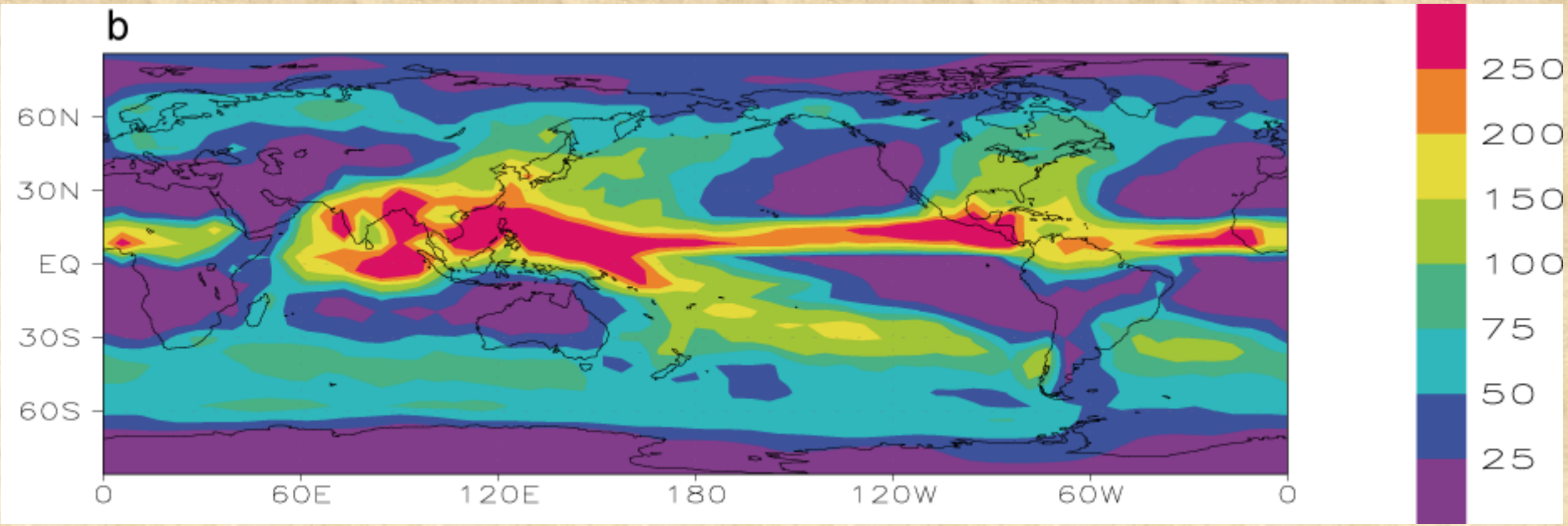
Mean state of the climate system components:

Precipitation (winter)



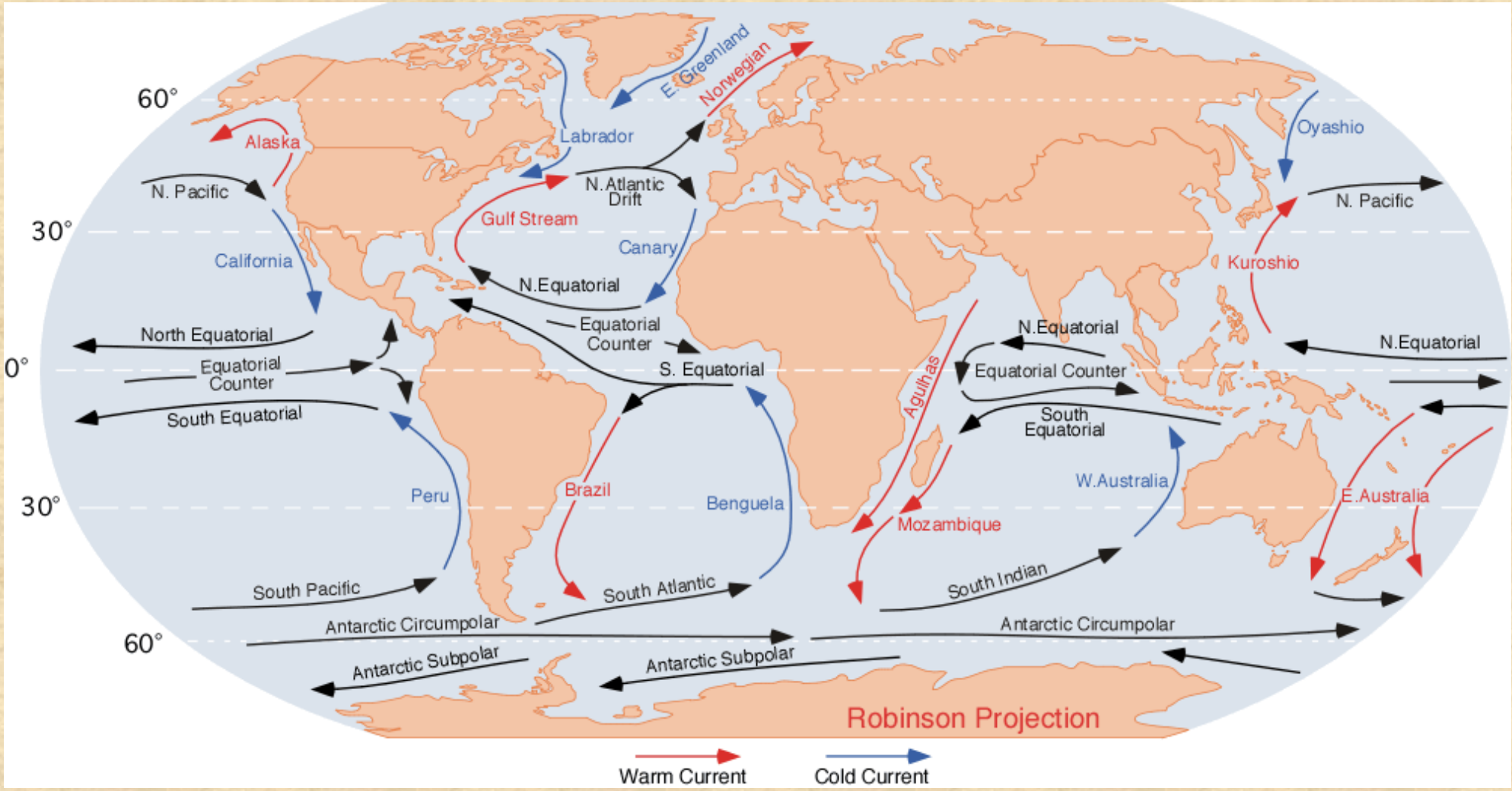
Mean state of the climate system components:

Precipitation (summer)

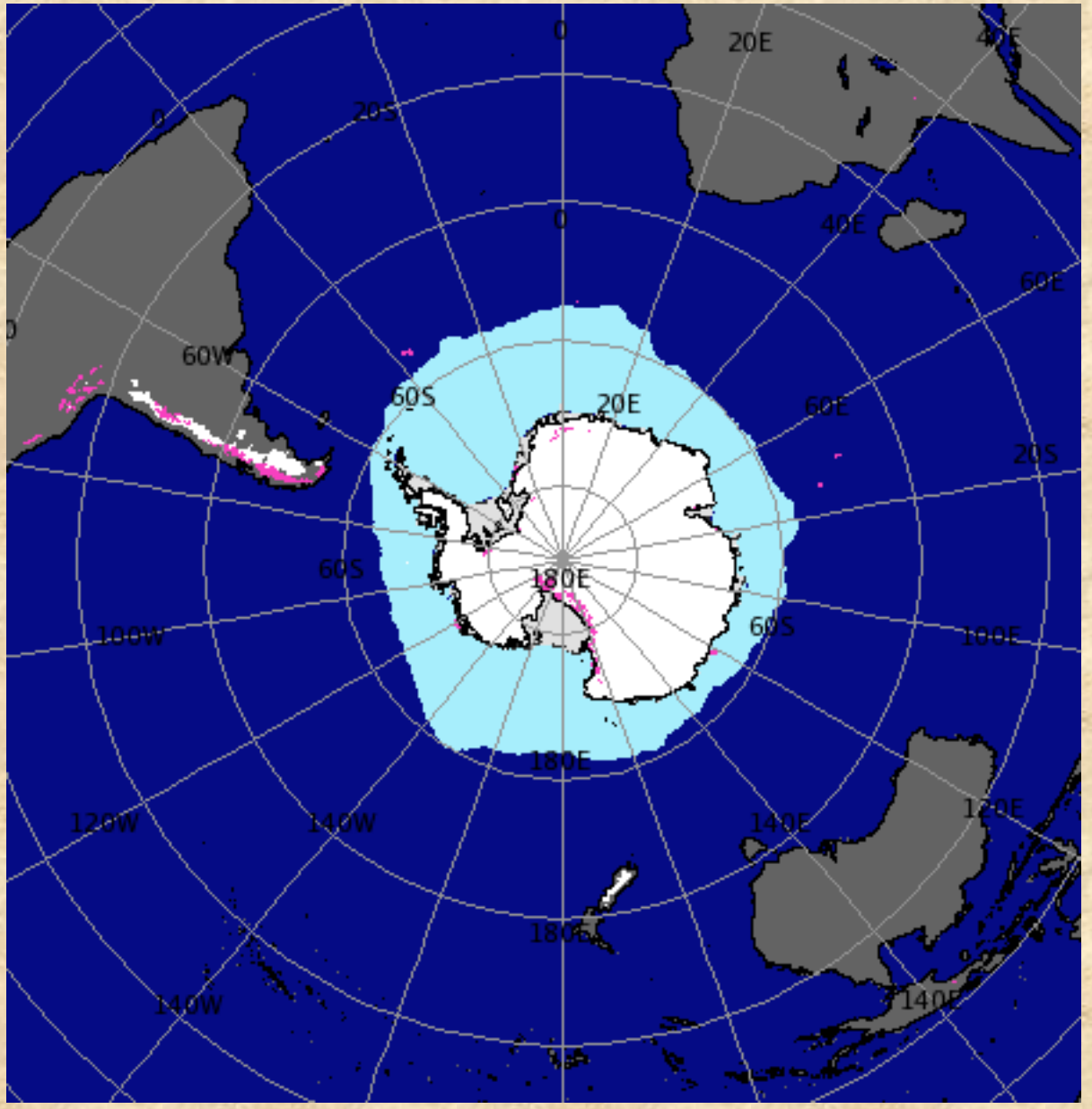


Mean state of the climate system components:

Ocean currents



Mean state of the climate system components:



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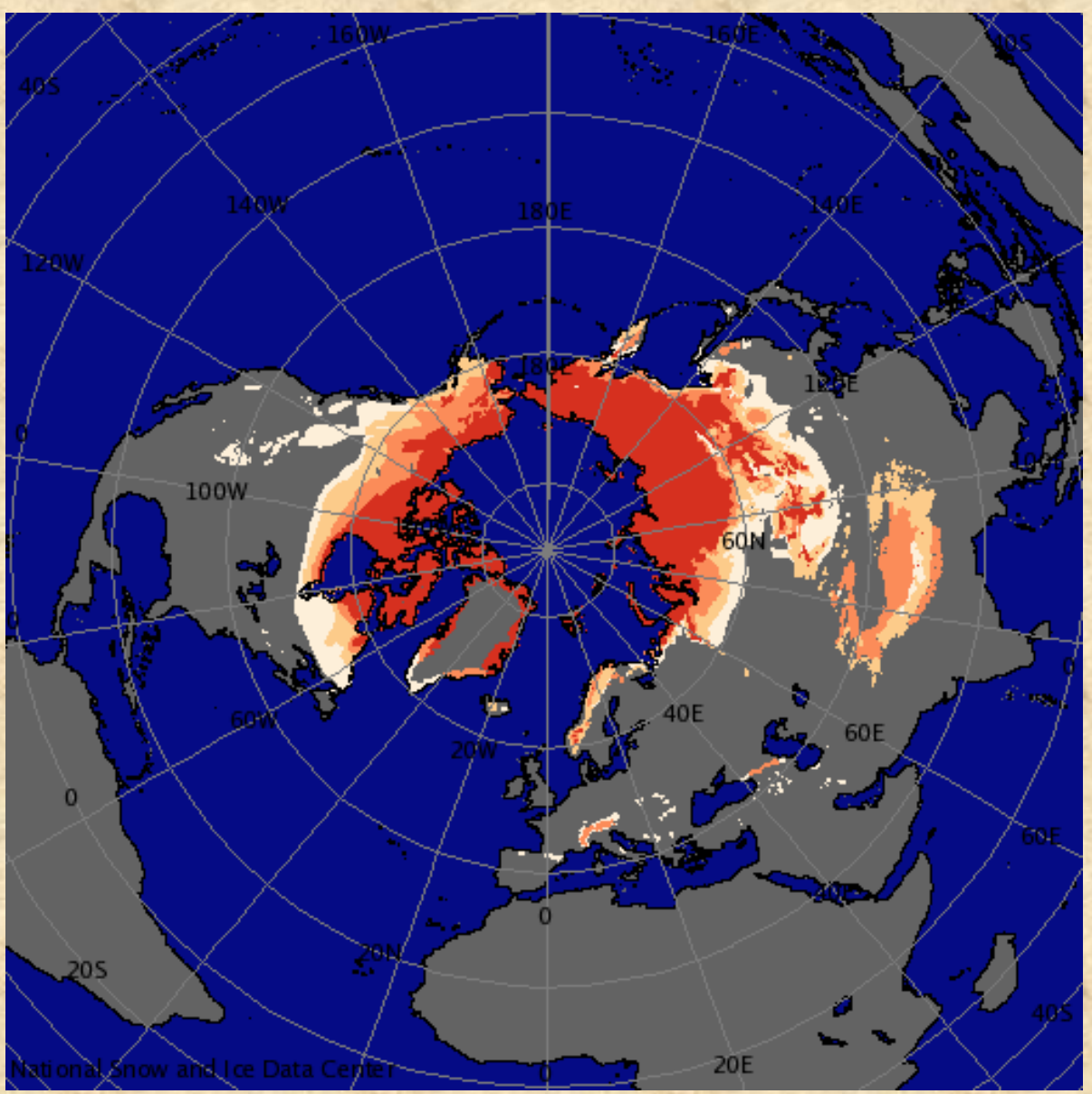
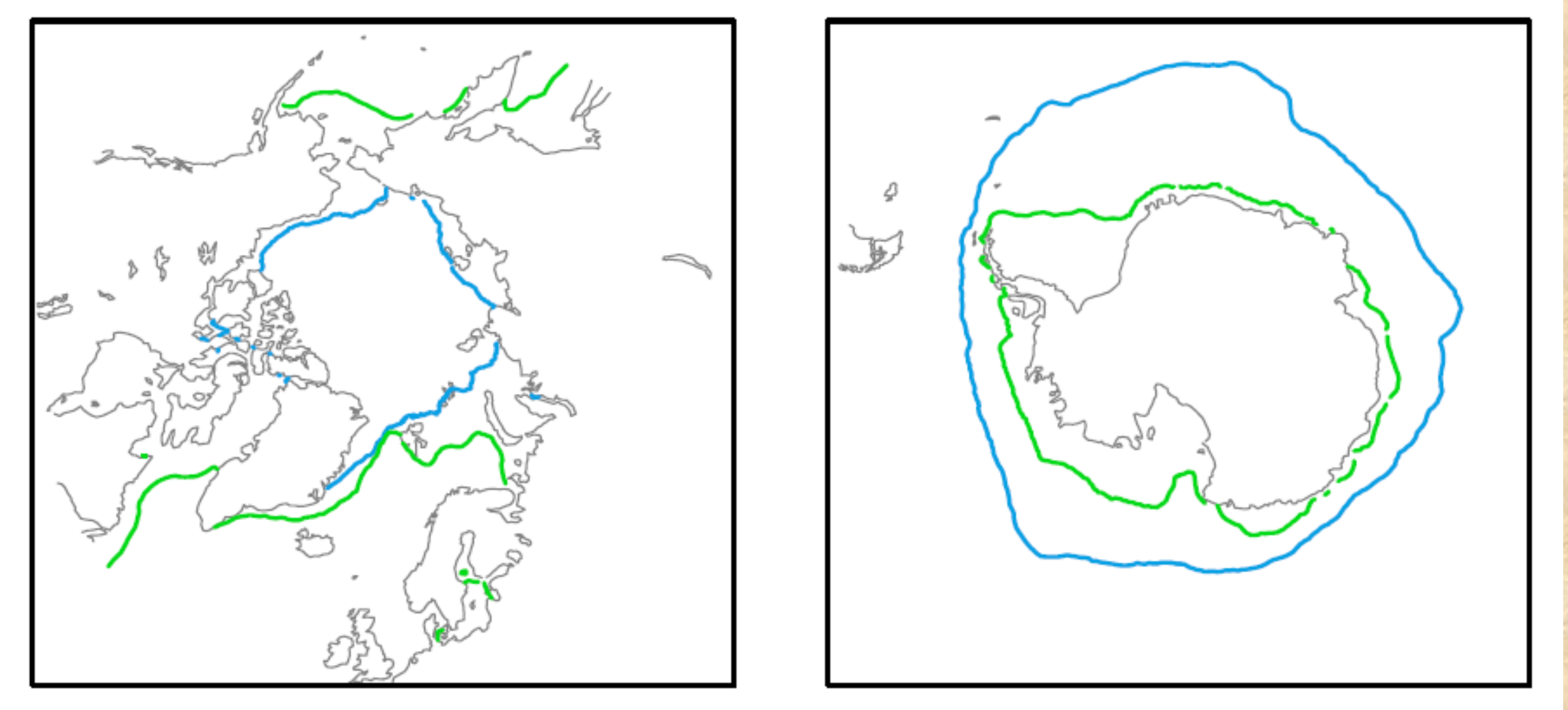


continuous permafrost (90-100%)
discontinuous permafrost (50-90%)
sporadic permafrost (10-50%)
isolated permafrost (0-10%)
land

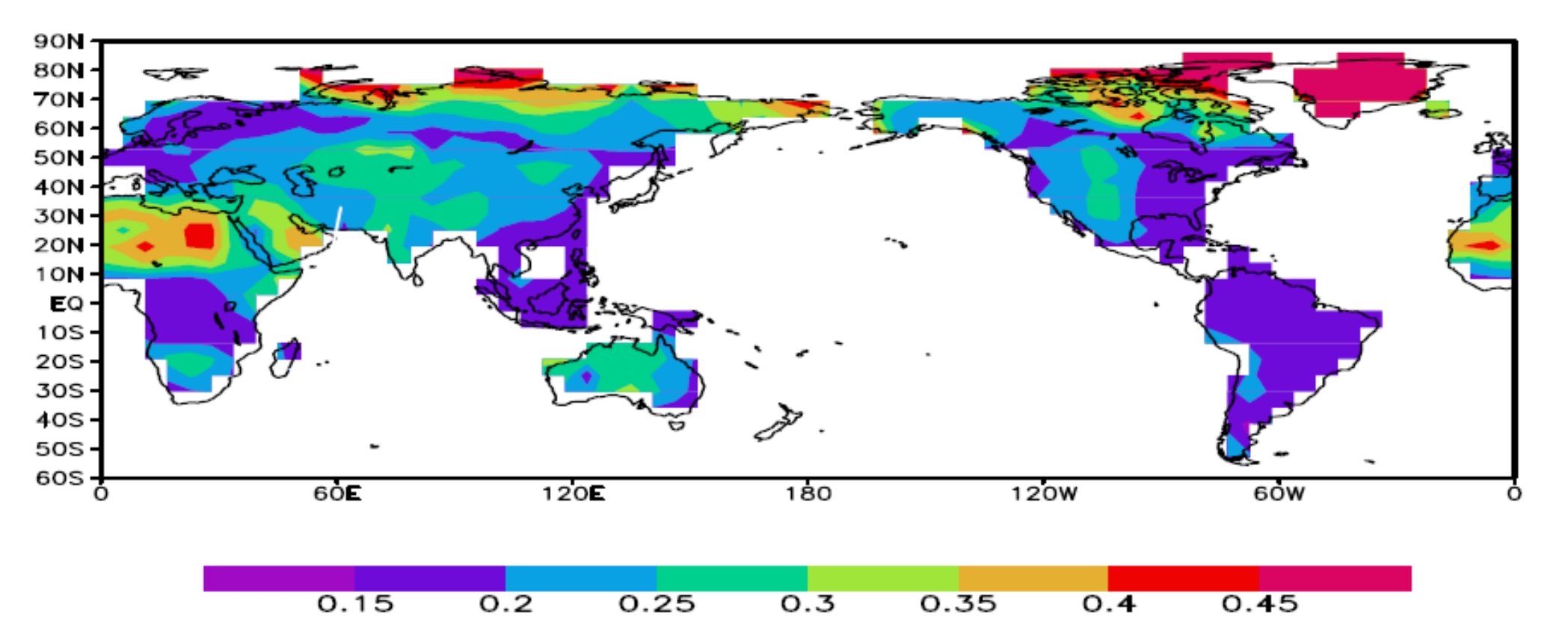
Mean state of the climate system components:

Ice edges:



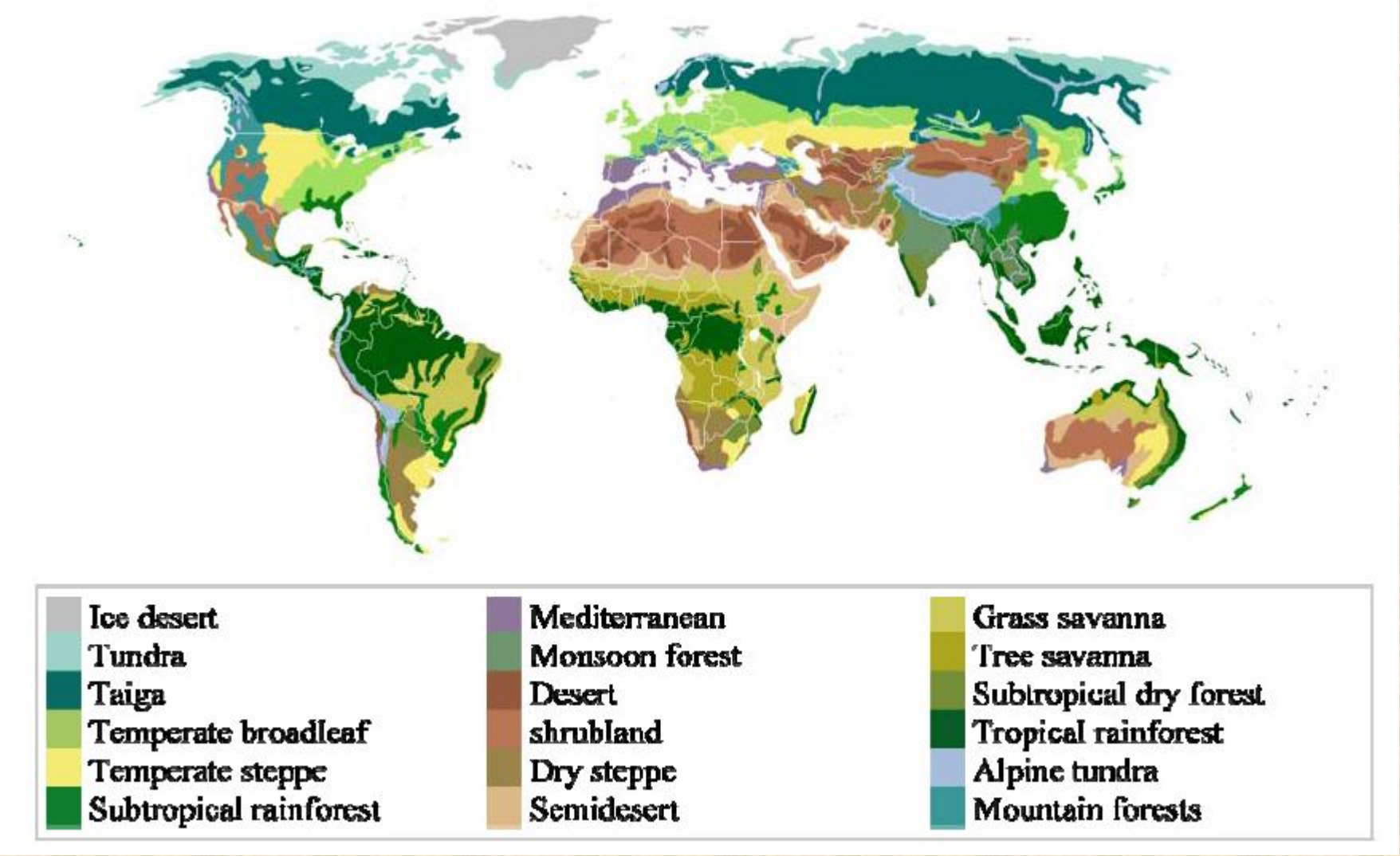
Mean state of the climate system components:

Land surface albedo:



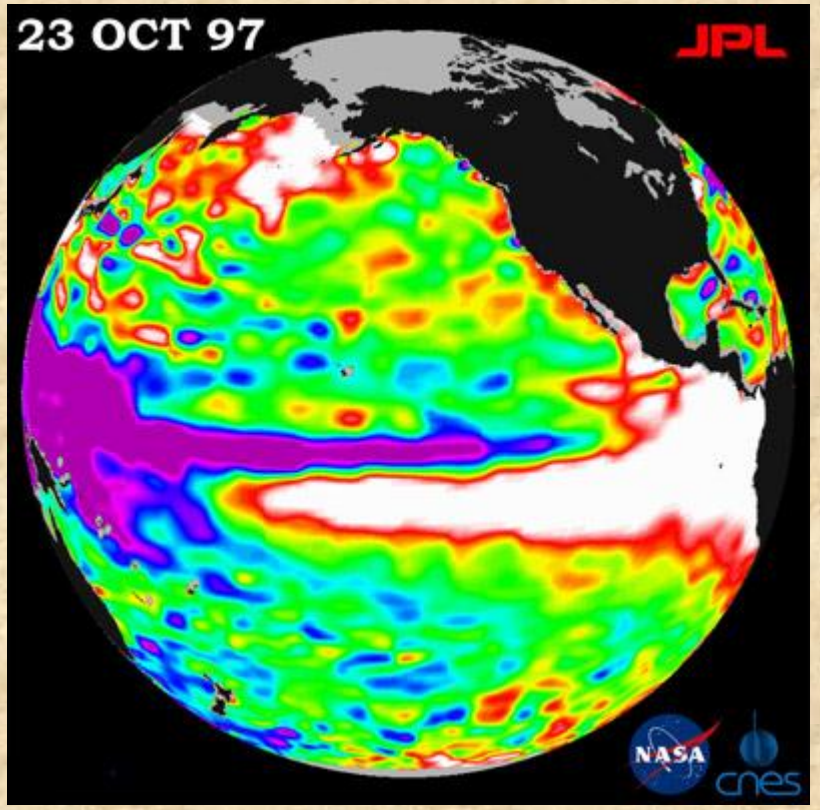
Mean state of the climate system components:

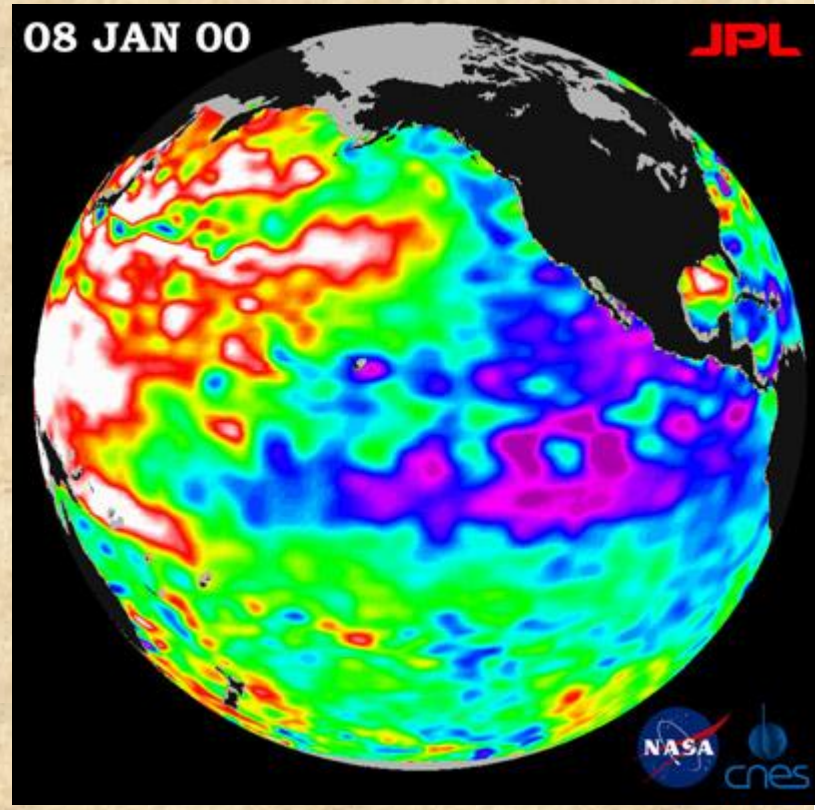
Global vegetation

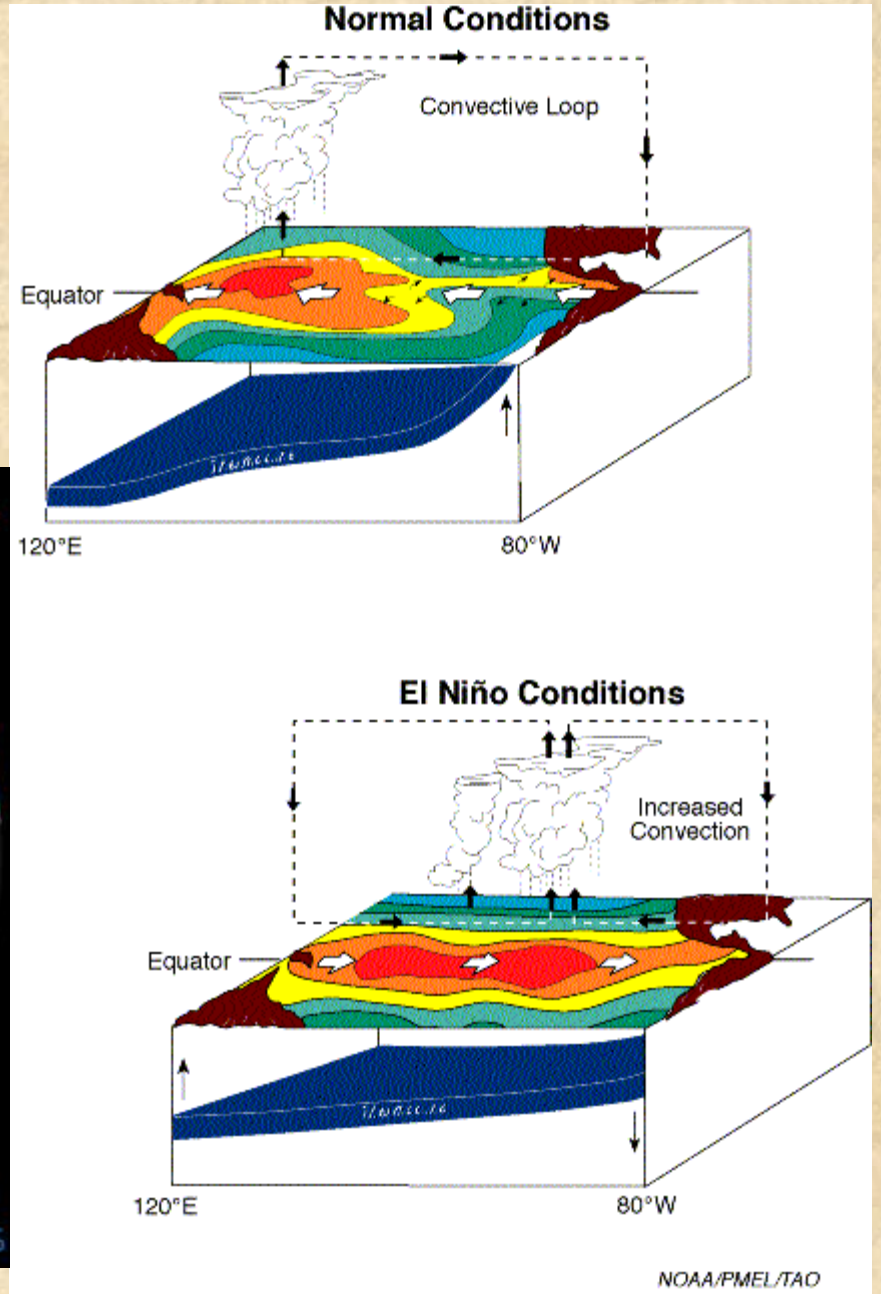


Examples for natural climate variability:

El Nino Southern Oscillation







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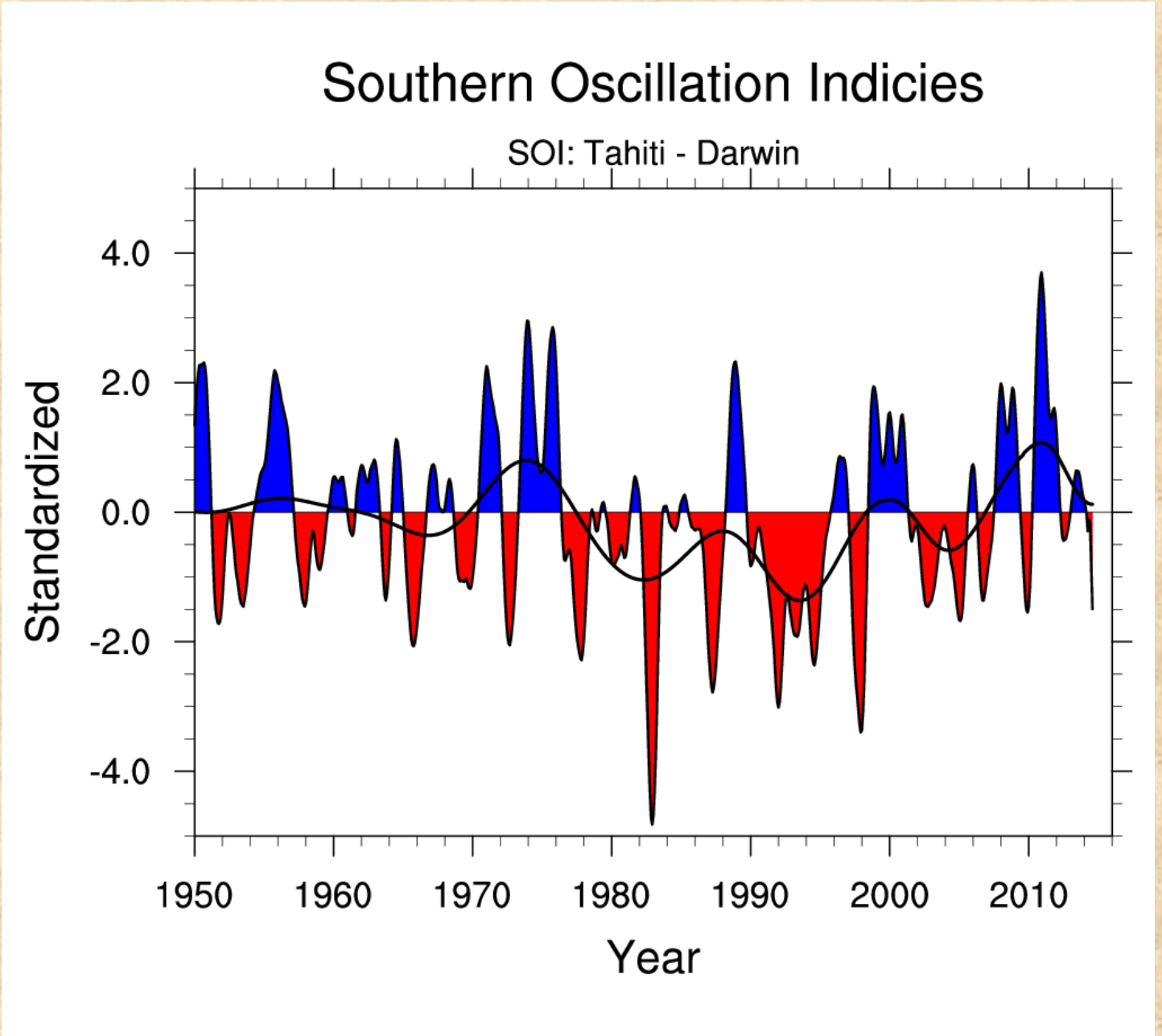
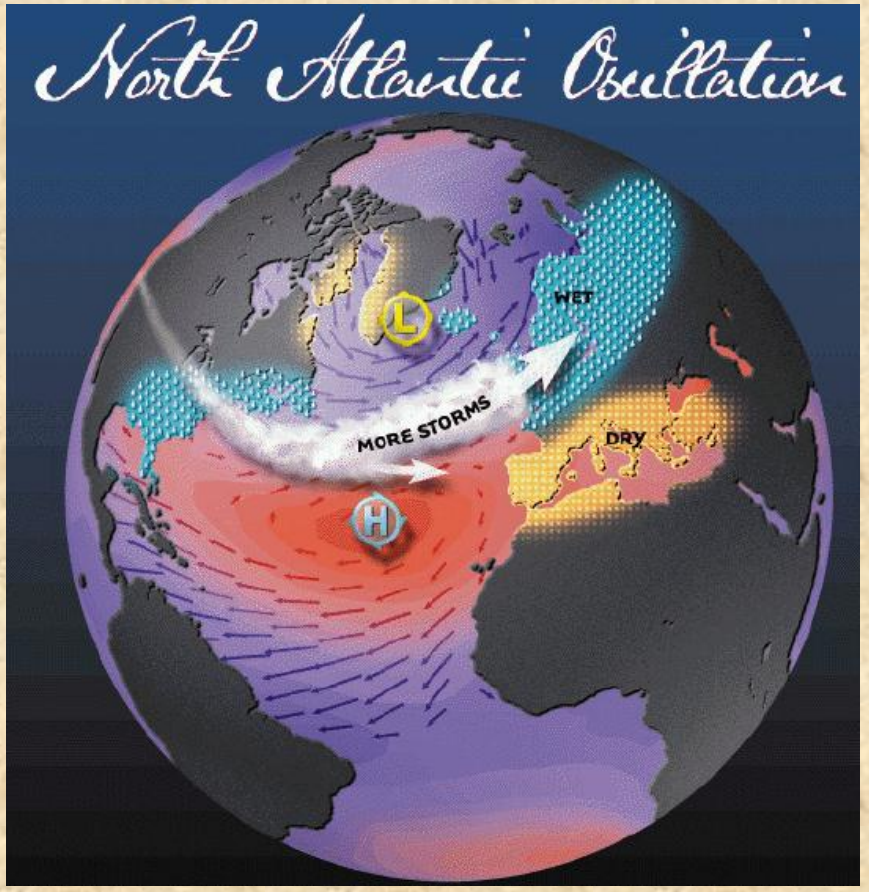
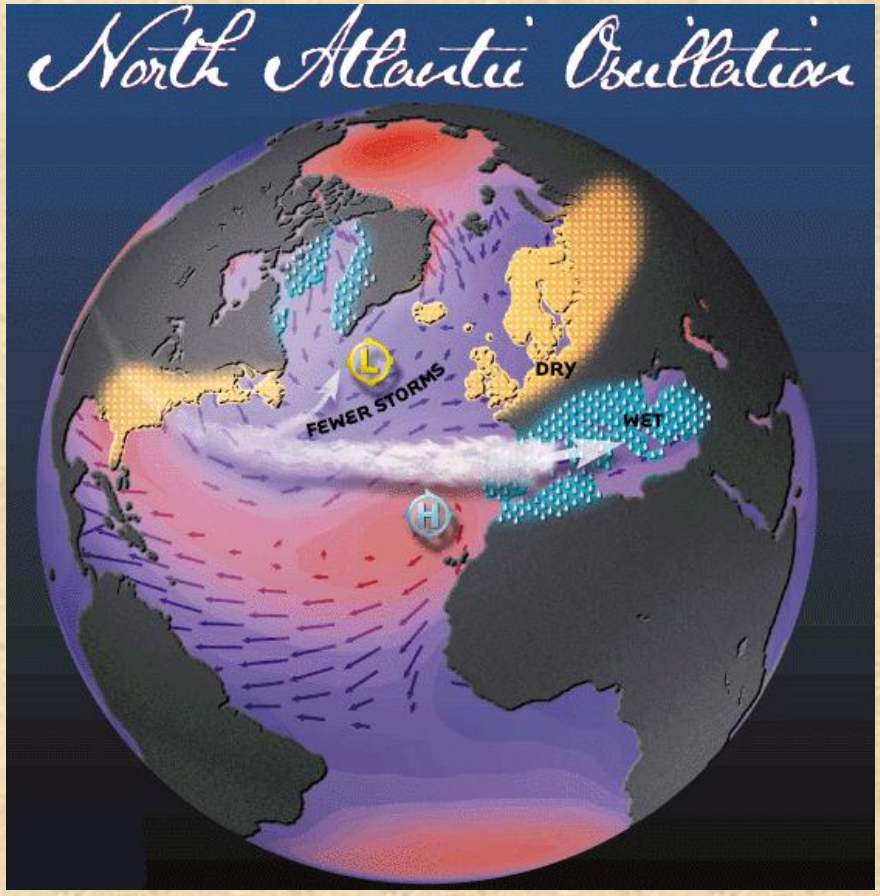
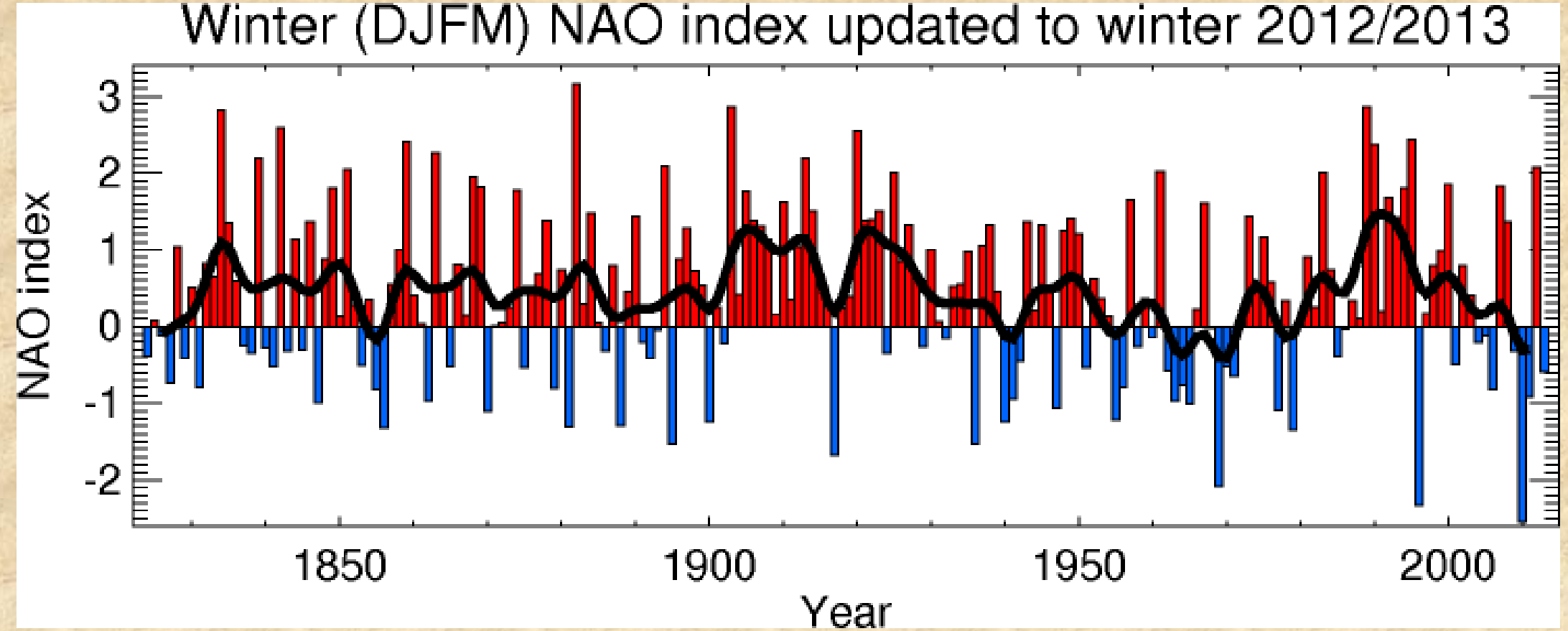


Examples for natural climate variability:

NAO- variations of the gradient between Azores high and Iceland low pressure system

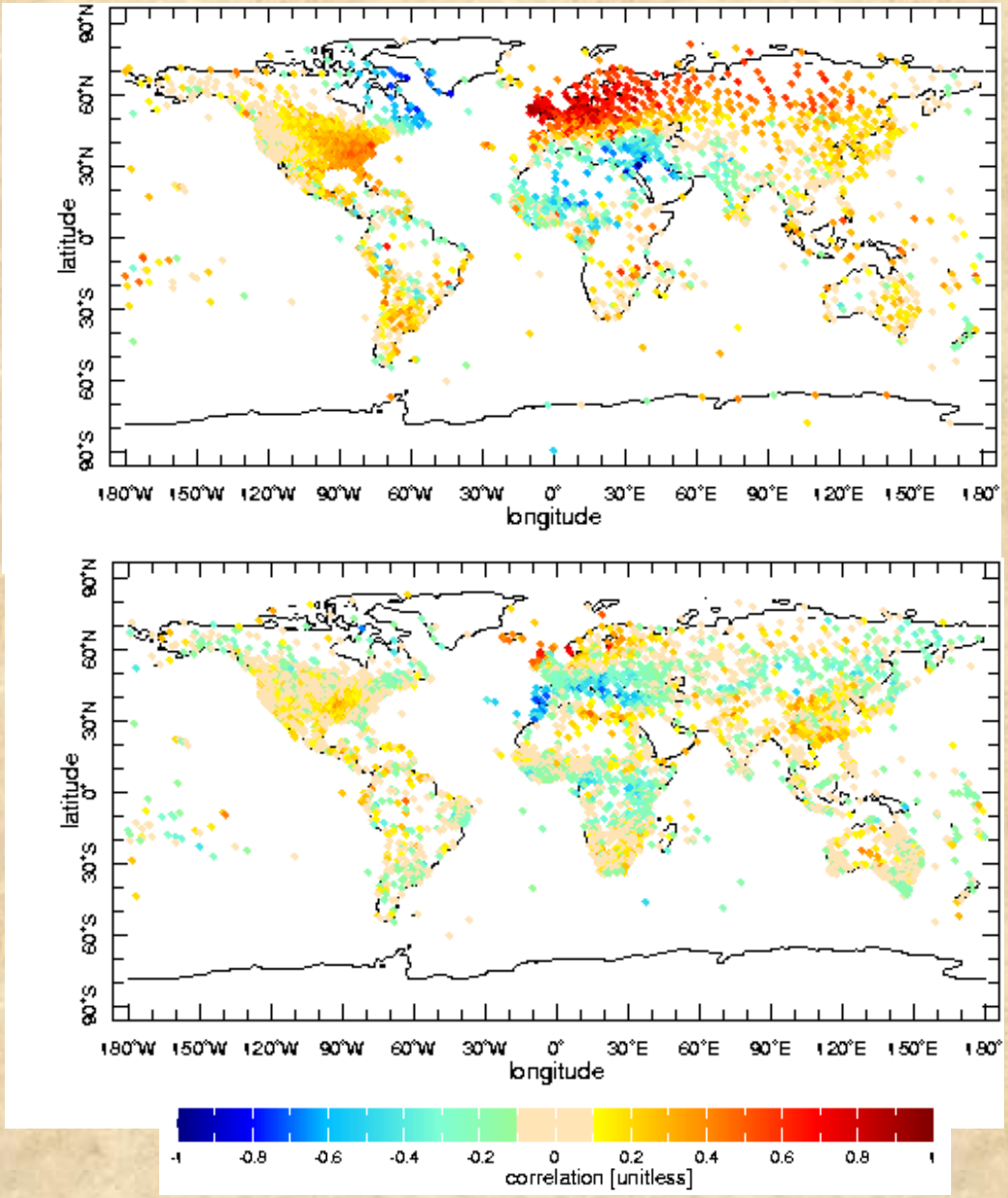






Origin: http://www.cru.uea.ac.uk/~timo/datapages/naoi.htm

Correlation between NAO index and temperature and precipitation on the globe



I hope to be able to answer your questions. Thank you!