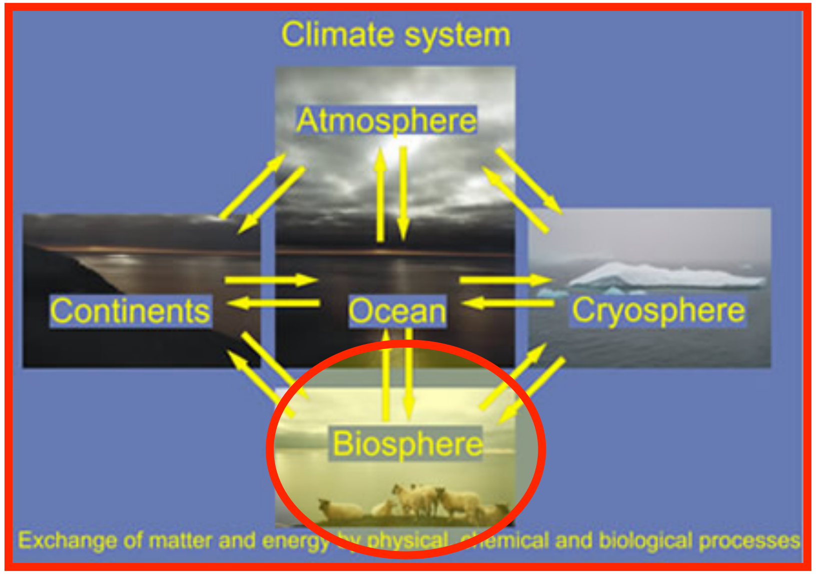
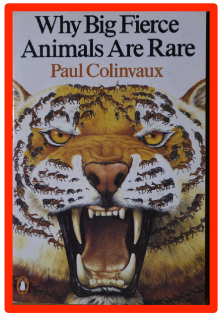
# Alma Mater Studiorum Università di Bologna
# sede di Ravenna
# Laurea Triennale in Scienze Ambientali
# Corso: Climatologia

Marco.Zavatarelli@unibo.it

# Biosfera




# Riferimenti



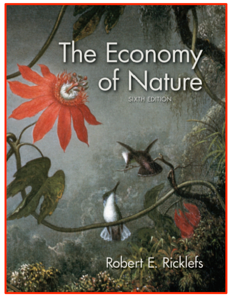

P. Colinvaux
Why big fierce animals are rare.
Penguins book
Capitolo 5 the nation states of trees

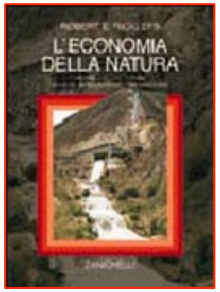
**James Lovelock**

www.jameslovelock.org/key2.html

The Encyclopedia OF EARTH

Pidwirny, M. (2011) http://www.eoearth.org/view/article/162312



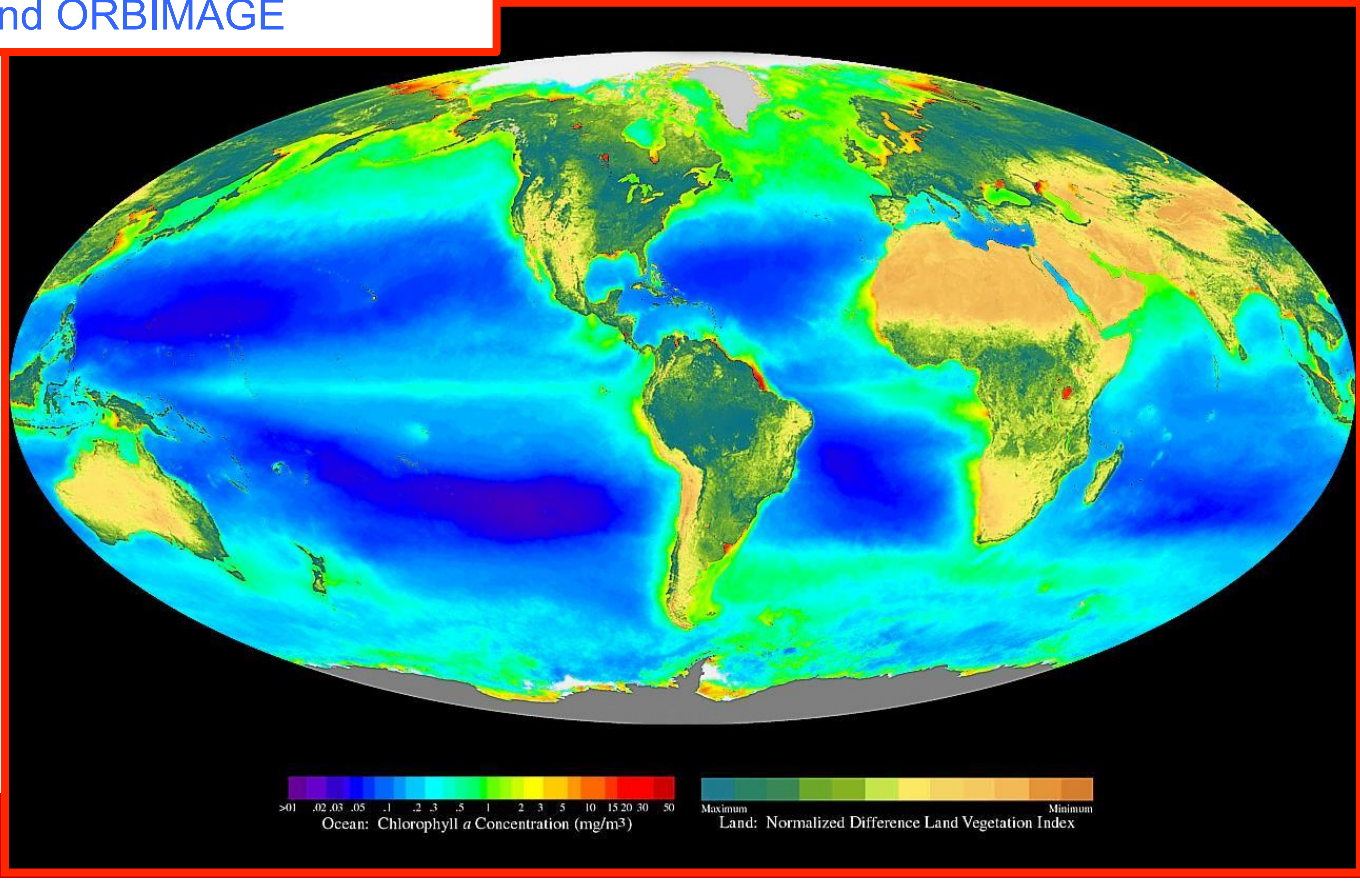

R.E. Ricklefs. The economy of nature. Freeman & C.
(L'economia della natura, Zanichelli)

https://en.wikipedia.org/wiki/Gaia_hypothesis (copia del testo nel materiale Scaricabile da AMS campus)

# La Biosfera


false-color composite of global oceanic and terrestrial photoautotroph abundance, from September 1997 to August 2000. Provided by the SeaWiFs Project, NASA/Goddard Space Flight Center and ORBIMAGE

**Biosphere (terrestrial and marine)**
The part of the Earth system comprising all →ecosystems and living organisms, in the atmosphere, on land (terrestrial biosphere) or in the oceans (marine biosphere), including derived dead organic matter, such as litter, soil organic matter and oceanic detritus.



# La Biosfera

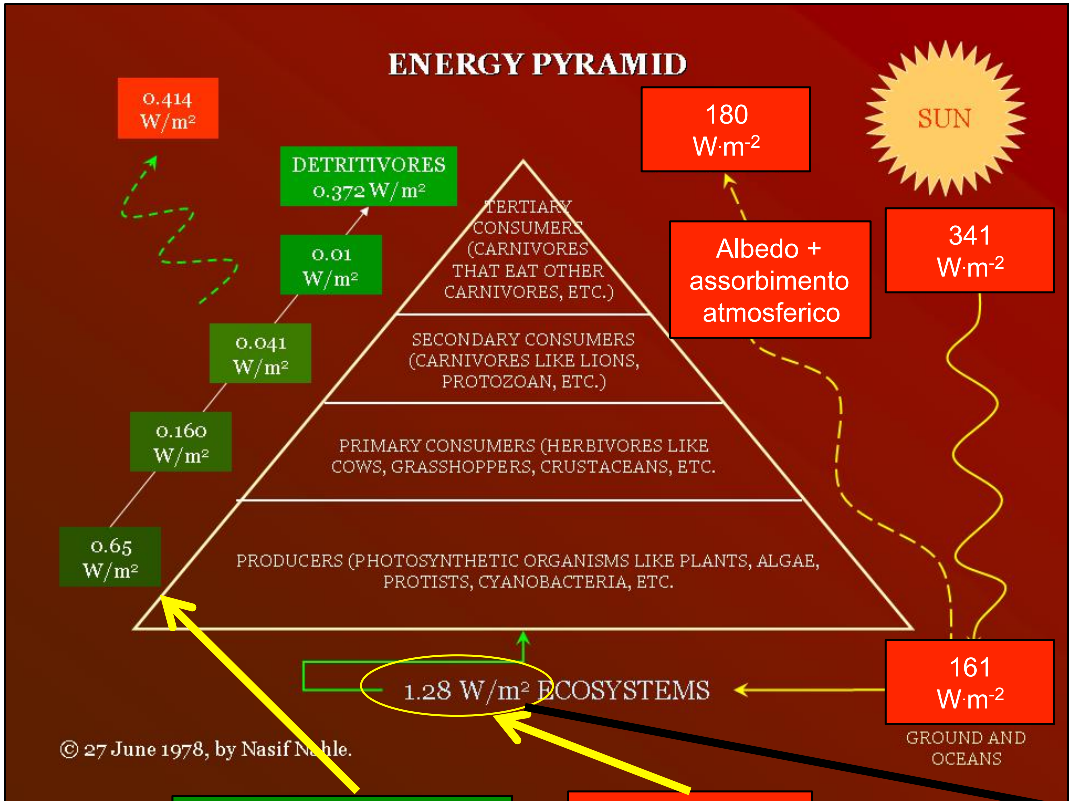
Vernadsky identified the boundaries of the biosphere as well as its composition, energetics, and dynamics. He included in the biosphere the upper part of the lithosphere to a depth of 2-3 km, which contains living bacteria, the hydrosphere, and the lower part of the atmosphere. Within the biosphere he distinguished two component types of matter: minerals, which he termed "inert," and living matter. The morphology of inert matter (its chemical composition and physical state) is preserved unchanged in the course of geological time, while living matter, both in totality and in its individual forms, undergoes continual change in the process of the biosphere's evolution as an integrated system. Vernadsky considered living matter,

**Vladimir Ivanovich Vernadsky**
Russian, Ukrainian and Soviet mineralogist and geochemist who is considered one of the founders of geochemistry, biogeochemistry, and of radiogeology, **In his 1926 book *The Biosphere* he hypothesized that life is the geological force that shapes the earth.**

*Living matter gives the biosphere an extraordinary character, unique in the universe... Cosmic energy determines the pressure of life that can be regarded as the transmission of solar energy to the Earth's surface...*
*Activated by radiation, the matter of the biosphere collects and redistributes solar energy, and converts it ultimately into free energy capable of doing work on Earth...*
*A new character is imparted to the planet by this powerful cosmic force.*
*The radiations that pour upon the Earth cause the biosphere to take on properties unknown to lifeless planetary surfaces, and thus transform the face of the Earth...*
*In its life, its death, and its decomposition an organism circulates its atoms through the biosphere over and over again.*

Vladimir Vernadsky, *Biosfera*, 1926

# *Biosfera e bilancio energetico del pianeta*

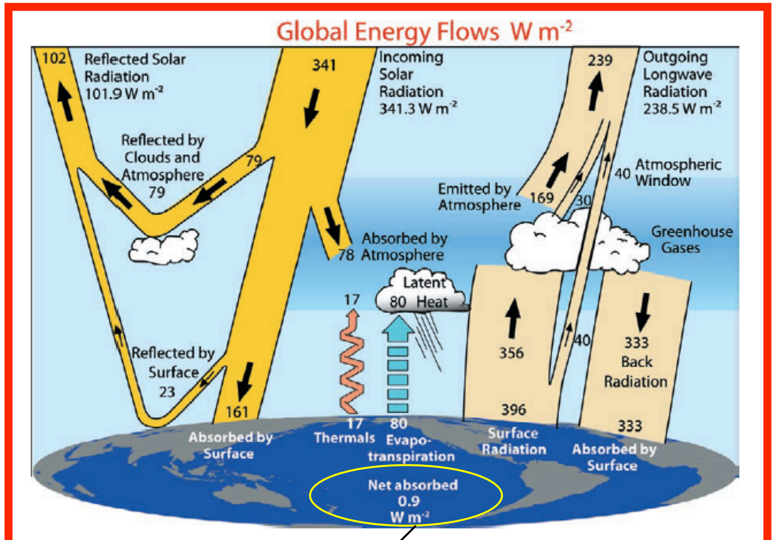



180 W·m$^{-2}$

Albedo + assorbimento atmosferico

341 W·m$^{-2}$

161 W·m$^{-2}$



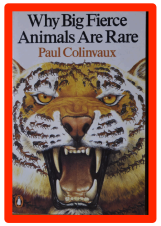

Energia corrispondente a Produzione Primaria netta

Energia utilizzata Per Produzione Primaria lorda

STIME..soggette ad incertezza ed errore

Una MINIMA quantità della radiazione solare che raggiunge il pianeta “Rifornisce la biosfera

# Vegetazione e clima




A partire dal 18° secolo

The travelling naturalists of the eighteenth and nineteenth centuries brought back to their European universities the astonishing news that the plants of the earth were organised by continents and geography into something like nation states. Over enormous blocks of territory there spread formations of plants whose members were all of the same shape. This was, on the face of it, an uncalled-for thing. Naturalists knew, of course, that plants had a number of clearly recognisable shapes, that there were conical trees and round-topped trees, straggling herbs and bunched-up herbs, but that these should be organised, as it were, into nation states of plants was a new idea. It gave rise to some intriguing thoughts about the qualities of life on earth, the echoes of which are with us still.

Domande:

- Perchè la vegetazione nelle diverse parti Del mondo è drasticamente differente?
- Perchè vaste aree del pianeta hanno Vegetazione (formazioni) relativamente uniforme?
- Perchè la transizione da una formazione all'altra è piuttosto netta/

# Vegetazione e clima

De Candolle nel 1855 diede una risposta ecologica (climatologica) a queste domande  individuando nel regime termico prevalente e,il fattore determinante le formazioni vegetali e la loro Transizione dall’una all’altra.

**Augustin-Pyramus De Candolle**
(1778-1841)

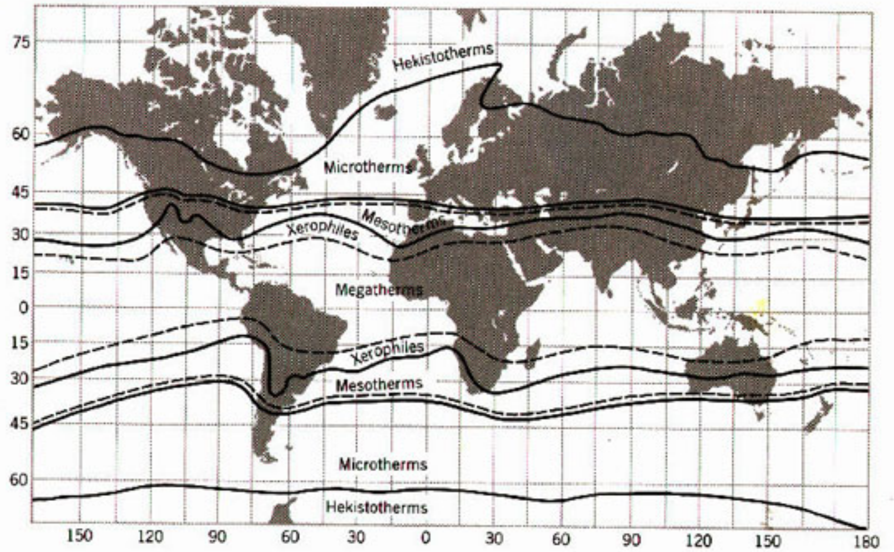
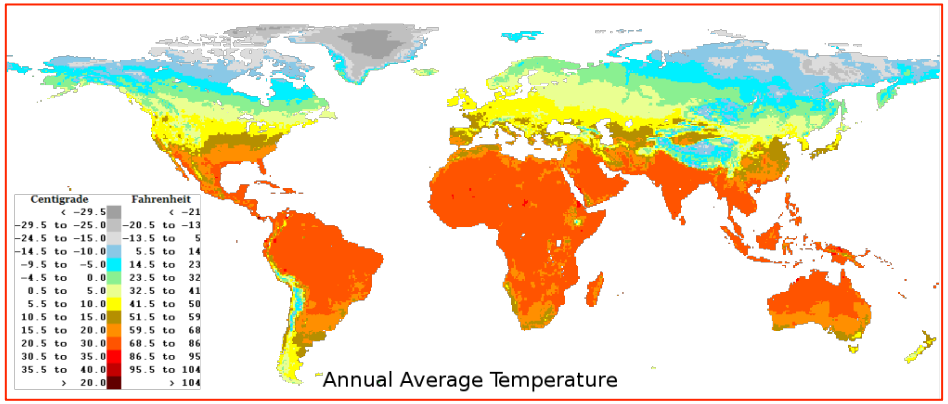
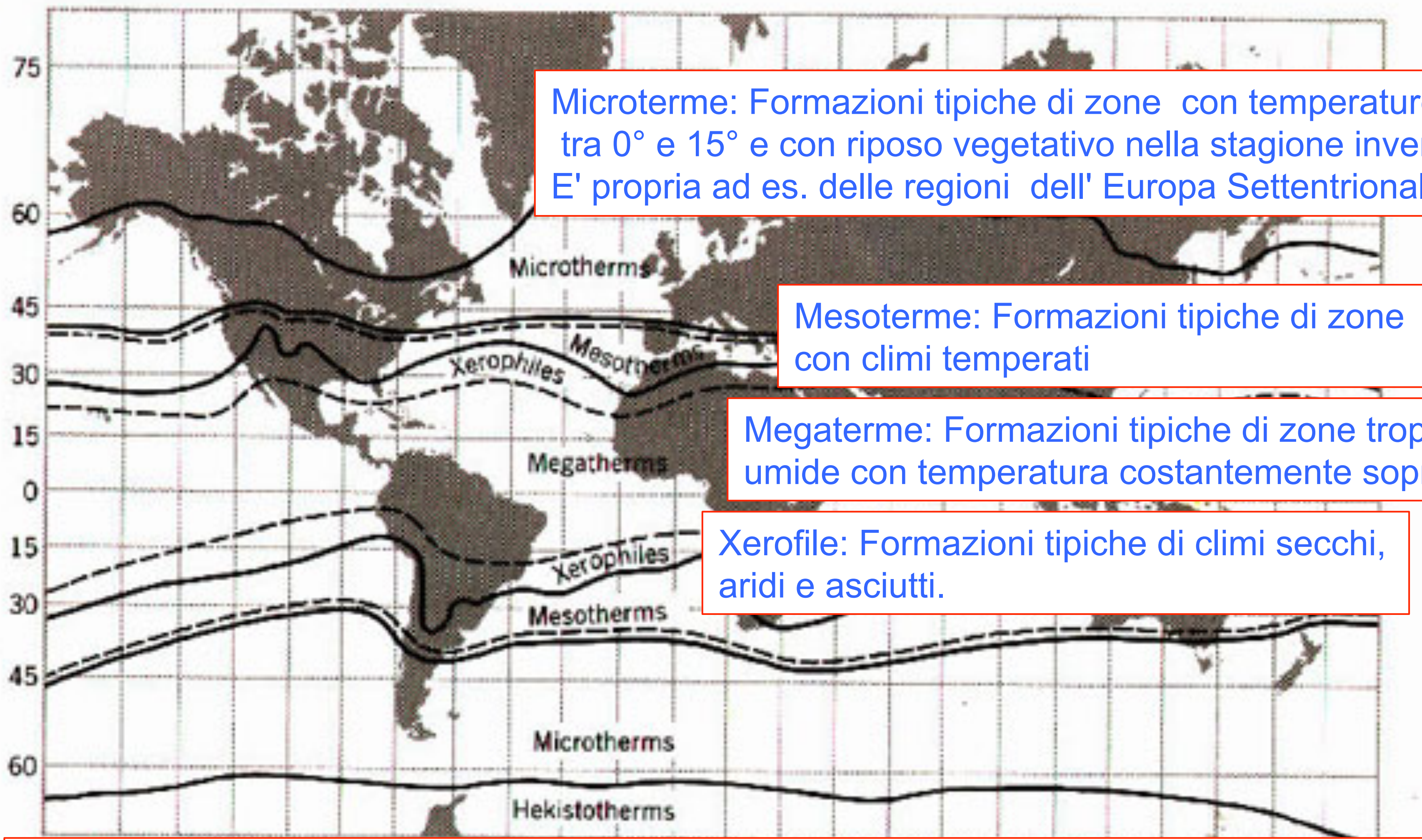



**Figure 2.8** De Candolle’s division of the earth according to the properties of plants. The broad extent of formations was thought to be set by temperature, except that shortage of water set the limits of plants of hot deserts (the xerophiles). De Candolle’s ideas forshadowed the attempts of ecological biogeographers like Allen to show that the forms of life on earth were distributed in latitudinal bands. The hypothesis that formation boundaries could be correlated with temperature and water led to the use of vegetation maps as the basis for climatic maps. The isotherms shown here are those suggested by De Candolle but are plotted from modern meteorological data.



# *Vegetazione e clima*




Microterme: Formazioni tipiche di zone con temperature tra 0° e 15° e con riposo vegetativo nella stagione invernale. E' propria ad es. delle regioni dell' Europa Settentrionale.

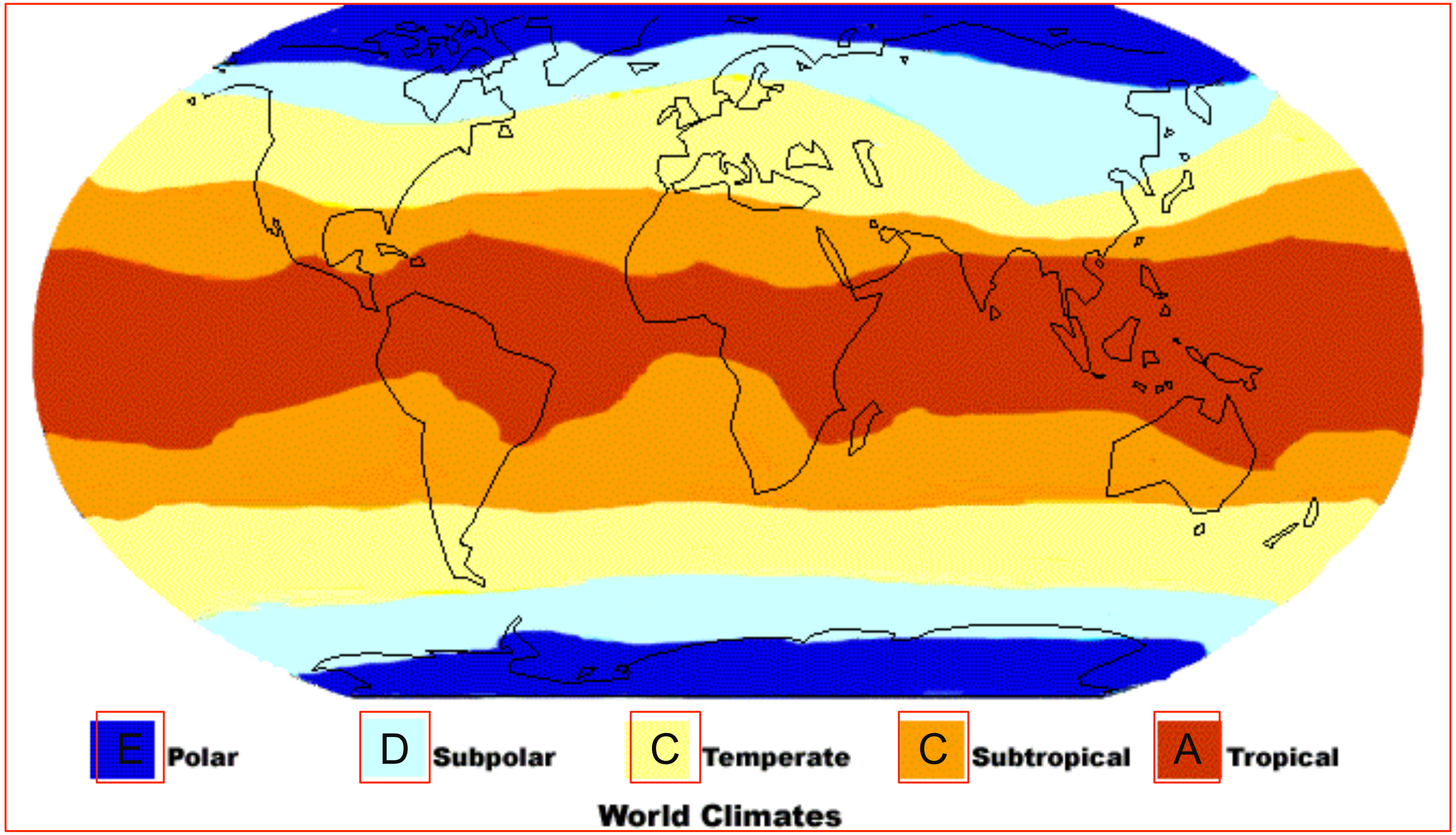
Mesoterme: Formazioni tipiche di zone con climi temperati

Megaterme: Formazioni tipiche di zone tropicali umide con temperatura costantemente sopra i 20°

Xerofile: Formazioni tipiche di climi secchi, aridi e asciutti.

Echistoterme: Formazioni tipiche di zone dove la temperatura annua media è inferiore a 0° e la stagione vegetativa è limitata a 2 o 3 mesi. (Erbe di alta montagna, piante delle tundre)

# Vegetazione e clima




Una prima classificazione dei climi del pianeta Basata sulla distribuzione delle formazioni vegetali Che (In assenza di satelliti o sistemi osservativi meteorologici) rispecchiavano I principali regimi di temperatura.

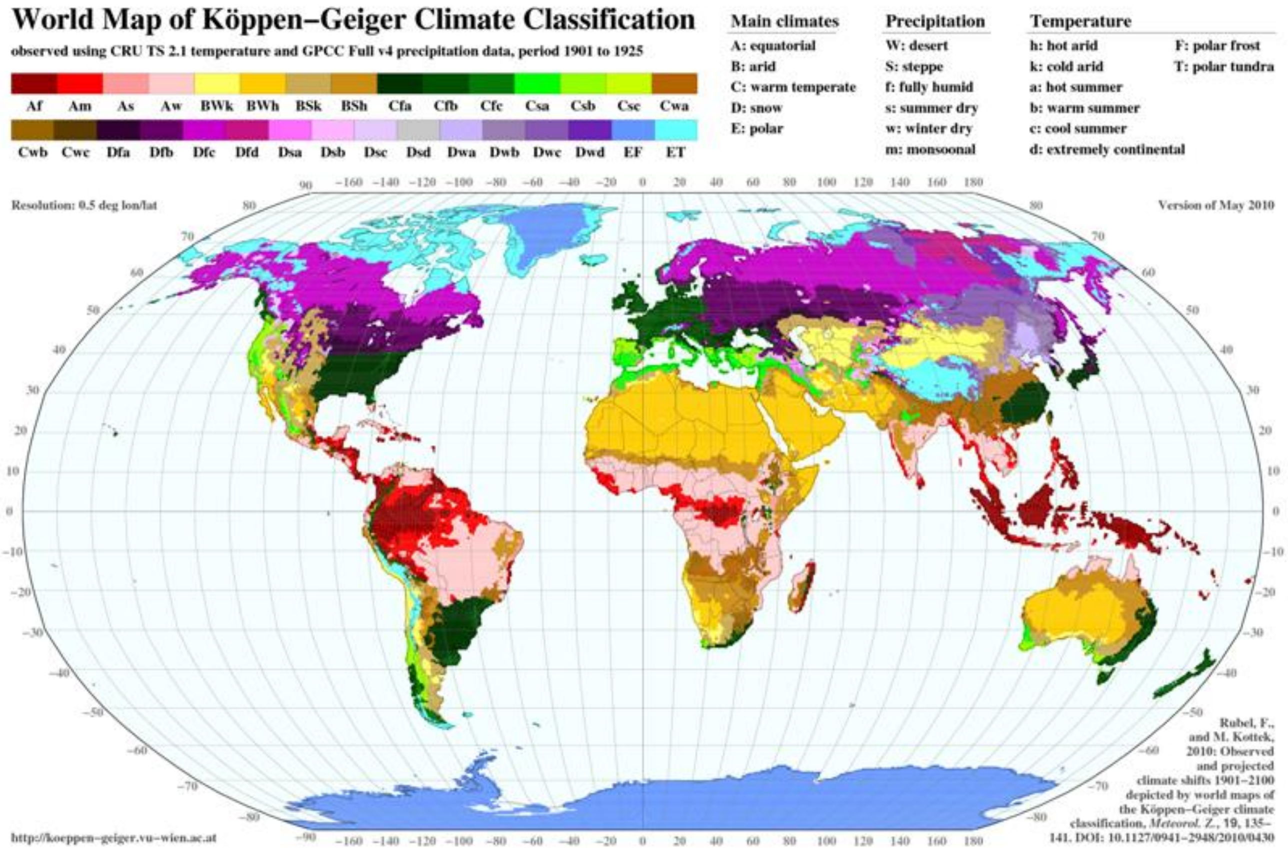
# Vegetazione e clima


Il sistema di classificazione climatico di Vladimir Koppen.

Basato originalmente sulla ipotesi che la distribuzione delle formazioni vegetali fosse
Essenzialmente definita dalle caratteristiche climatiche (temperatura e diponibilità di acqua)
Le prime mappe climatiche erano essenzialmente mappe della vegetazione

# La classificazione climatica di Koppen-Geiger

The Encyclopedia OF EARTH




A: Clima tropicale Umido
B: Clima Arido
C: Clima Umido Temperato
D: Clima Umico freddo
E: Clima Polare

Il sistema di classificazione climatico di Vladimir Koppen.
Attualmente basato su valori di temperatura e precipitazione.
5 Tipi climatici Principali

# La classificazione climatica di Koppen-Geiger

The Encyclopedia OF EARTH

## World Map of Köppen–Geiger Climate Classification

observed using CRU TS 2.1 temperature and GPCC Full v4 precipitation data, period 1901 to 1925


Sottotipi climatici
Basati sulle specifiche caratteristiche di:

Precipitazione

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

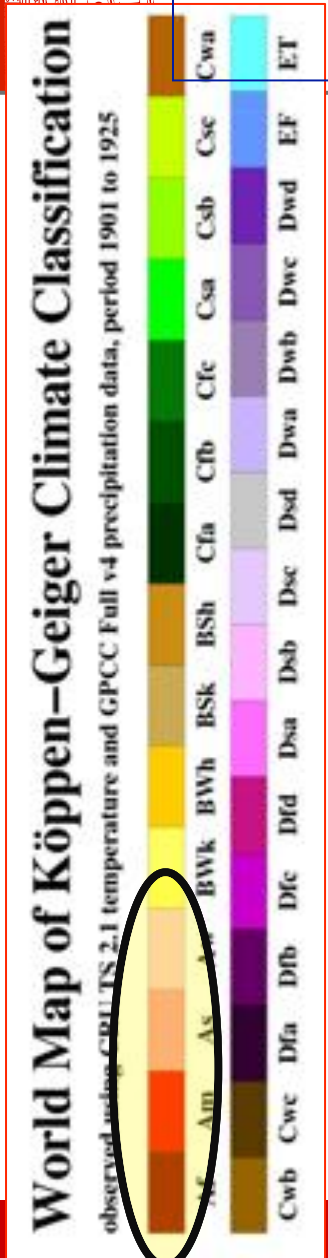
Temperatura

**Temperature**
h: hot arid
k: cold arid
a: hot summer
b: warm summer
c: cool summer
d: extremely continental

Più 2 sottotipi polari specifici

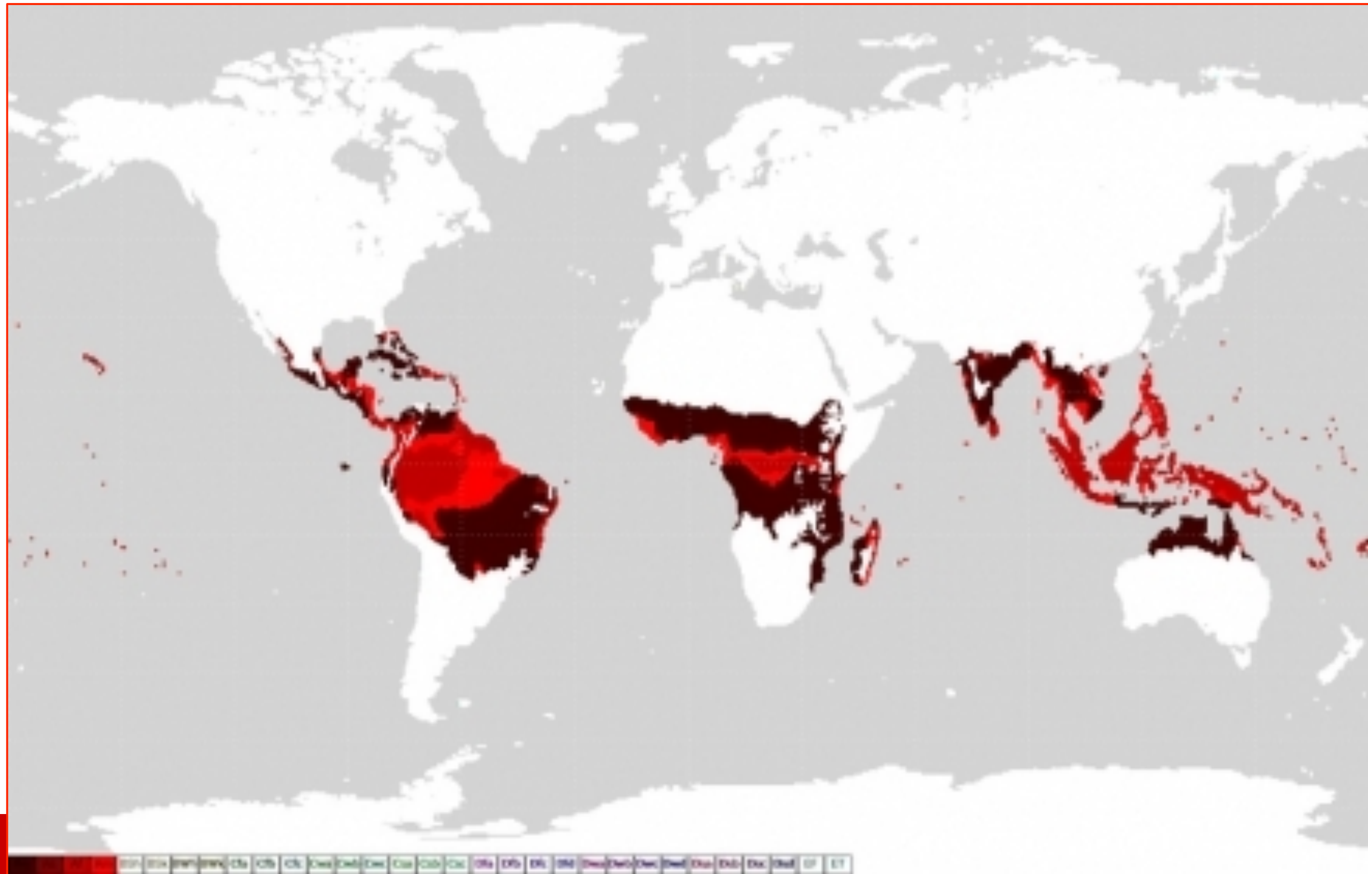
F: polar frost
T: polar tundra

# La classificazione climatica di Koppen-Geiger

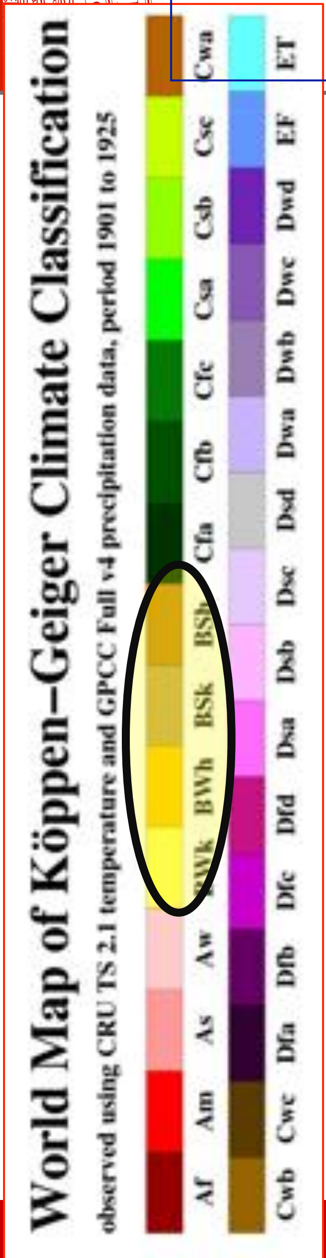



The Encyclopedia OF EARTH

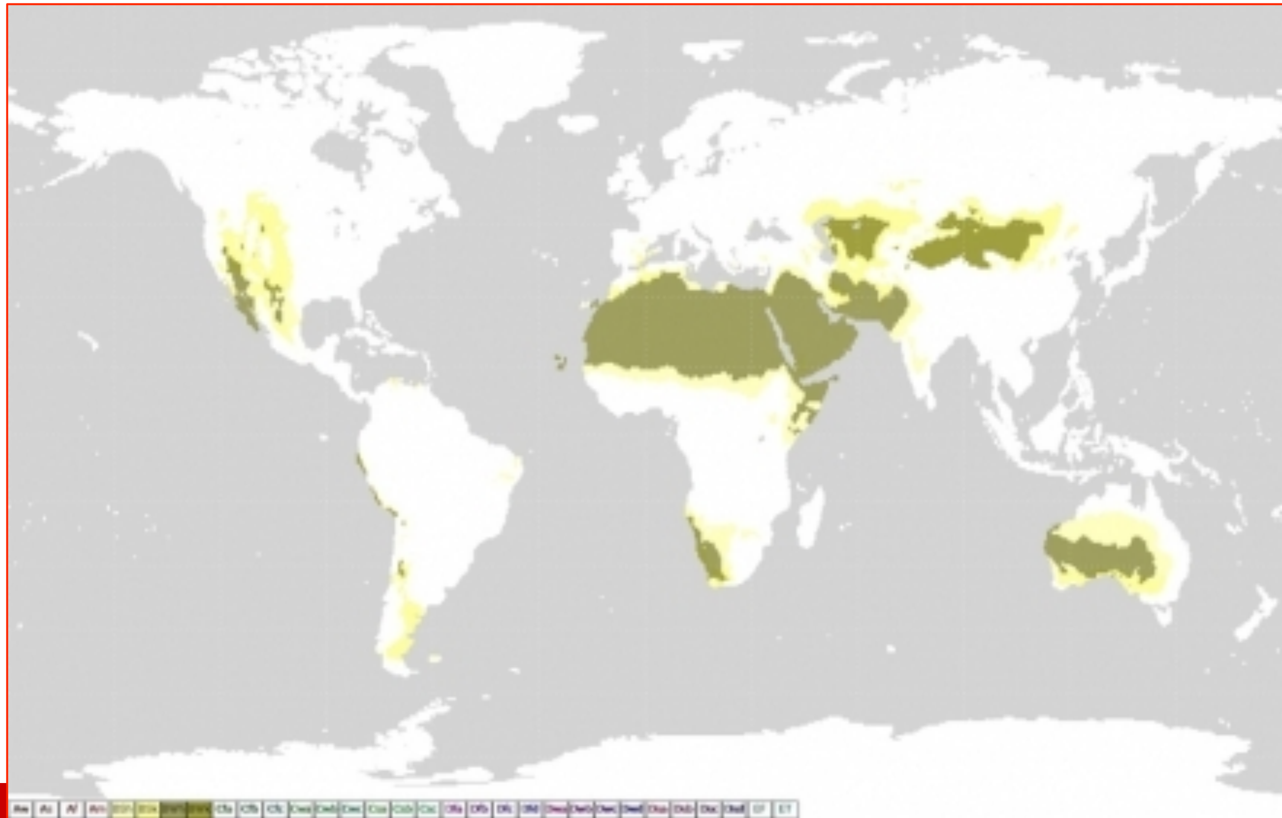
**Tropical moist**:Very warm climates (tropics) with high precipitation. All months have average temperatures above 18°C



# La classificazione climatica di Koppen-Geiger

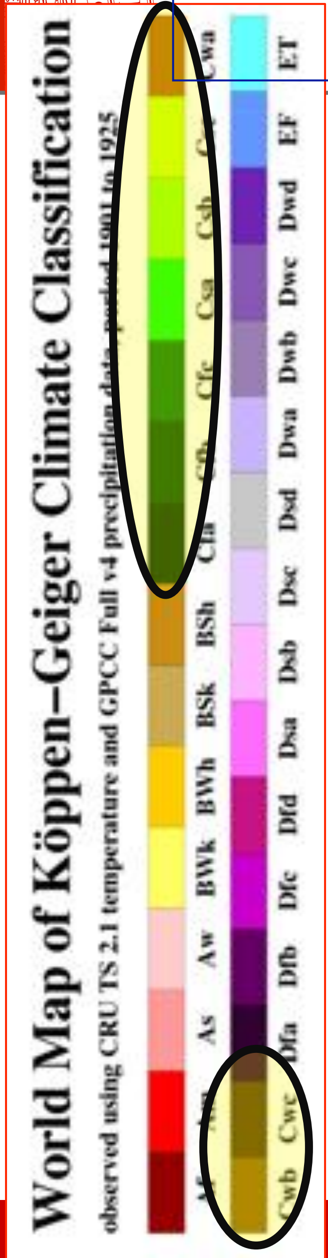



**Dry**: climate with little precipitation during most of the year. Losses of water from evaporation and transpiration greatly exceed atmospheric input.

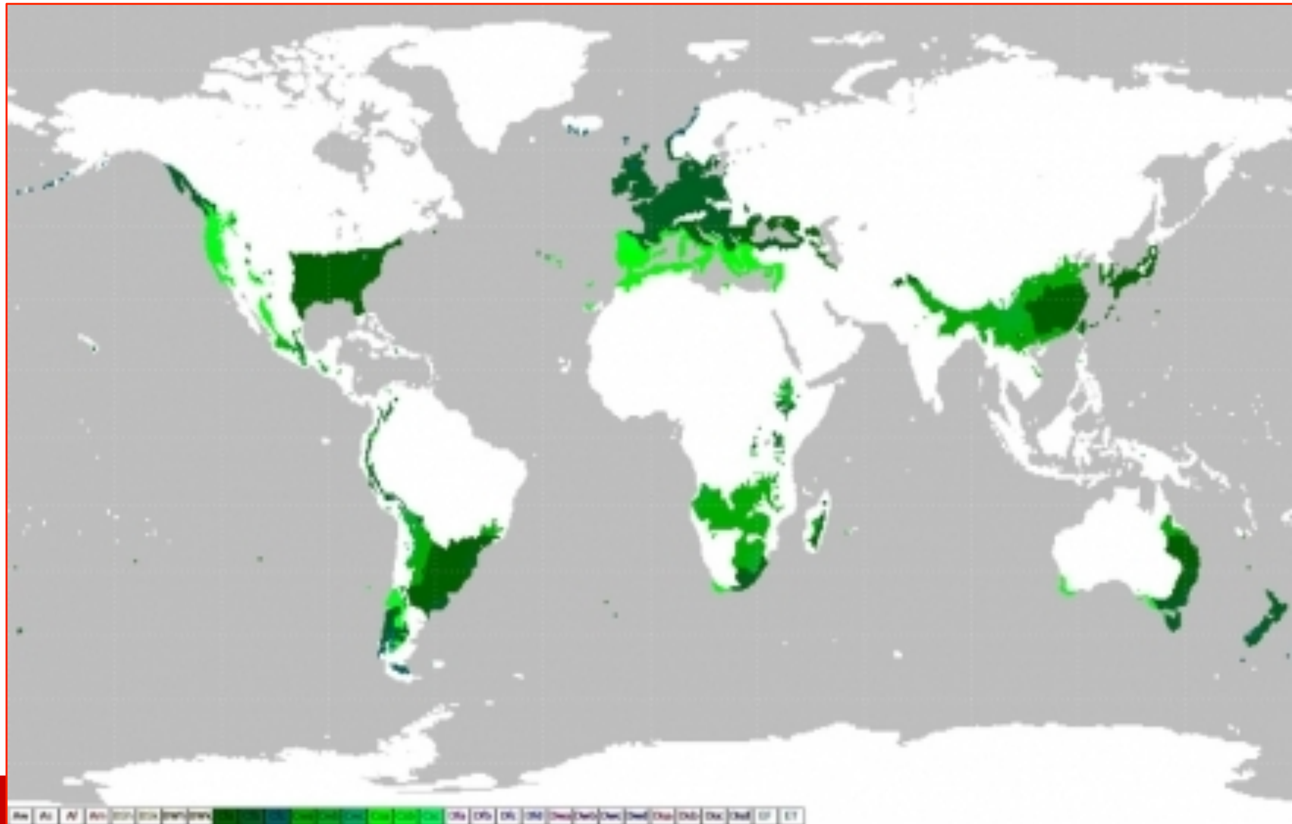


# La classificazione climatica di Koppen-Geiger

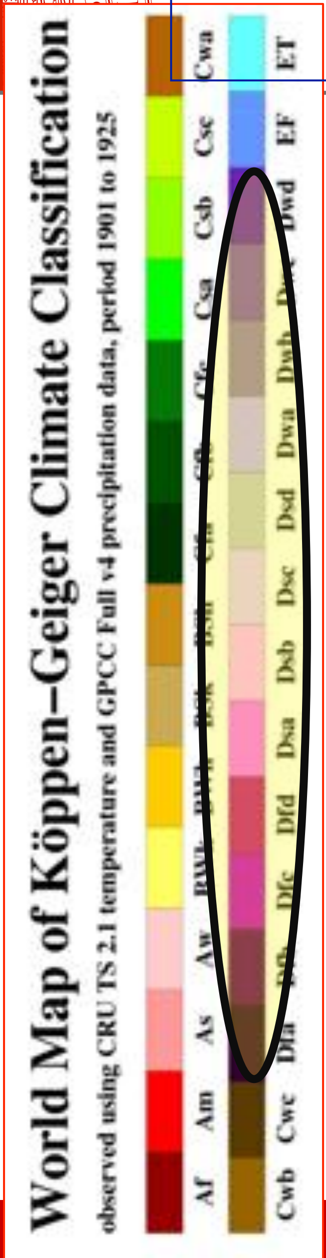
The Encyclopedia OF EARTH

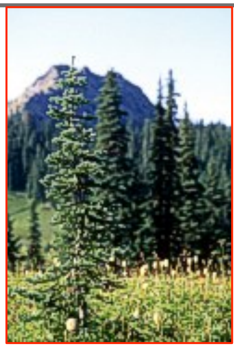



**Moist mid latitude climate with mild winter**:
Summer temperatures are warm to hot and winters are mild. The primary distinguishing characteristic of these climates is the coldest month has an average temperature between 18° and -3°C.

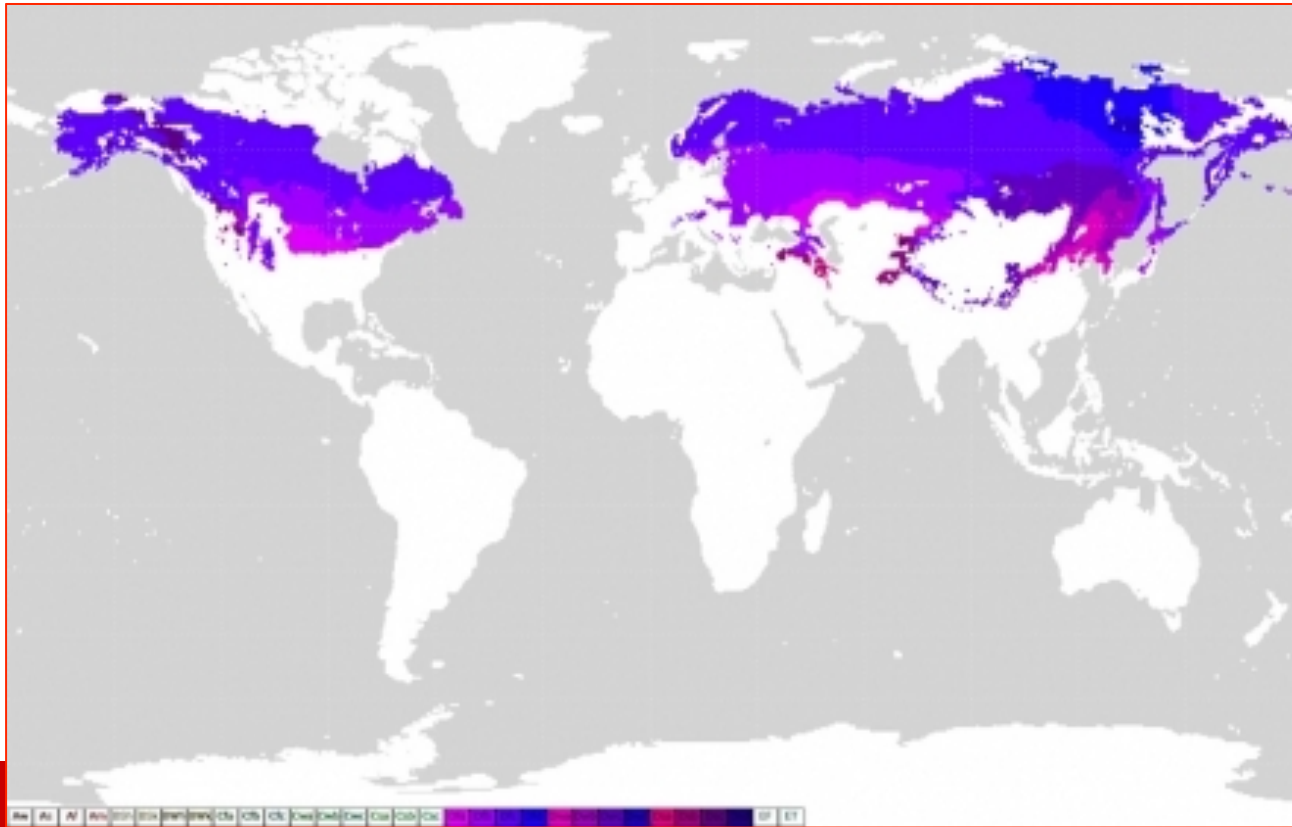


# La classificazione climatica di Koppen-Geiger

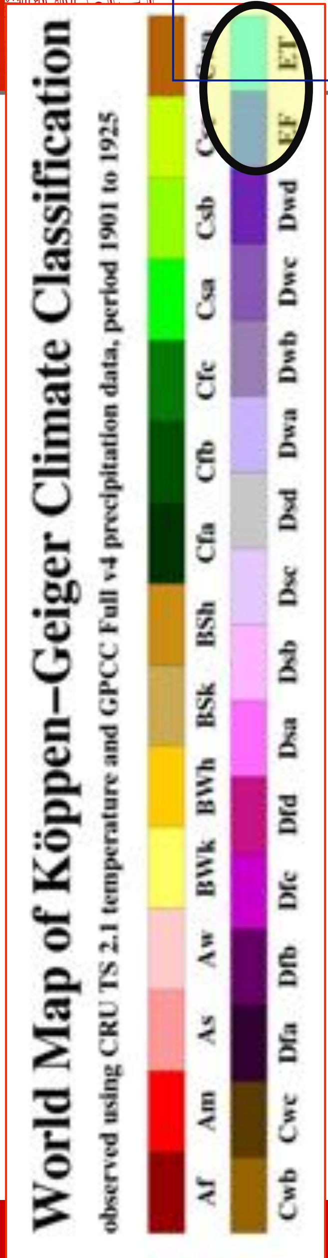


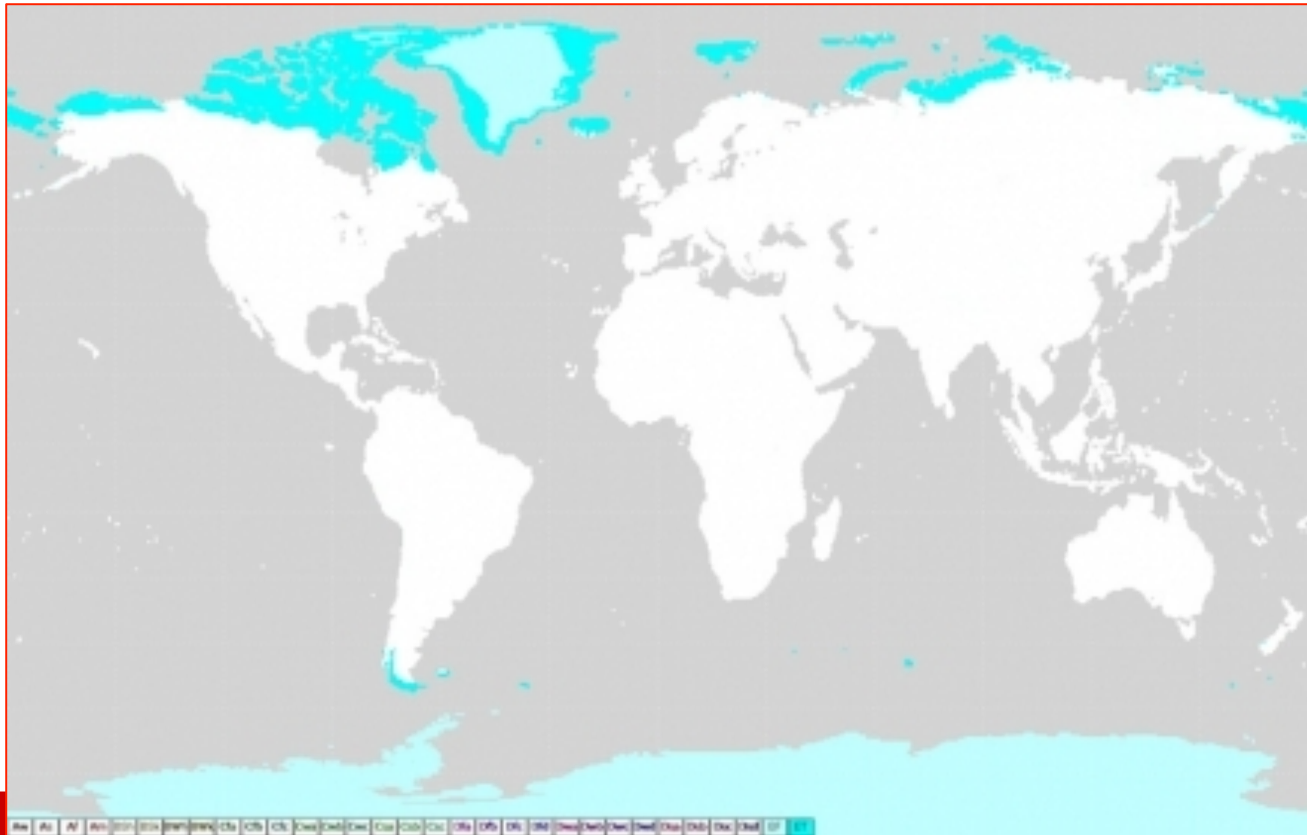
**Moist mid latitude climate with cold winter**:
Summer temperatures are warm and winters are cold. The primary distinguishing characteristic of these climates is the average temperature of warmest month exceeds 10°C, and average temperature of coldest is below -3°C .



# La classificazione climatica di Koppen-Geiger




**Polar**: Very cold winters and summers, with no real summer season. The primary distinguishing characteristic of these climates is the warmest month has an average temperature below 10°C.



# Vegetazione e clima

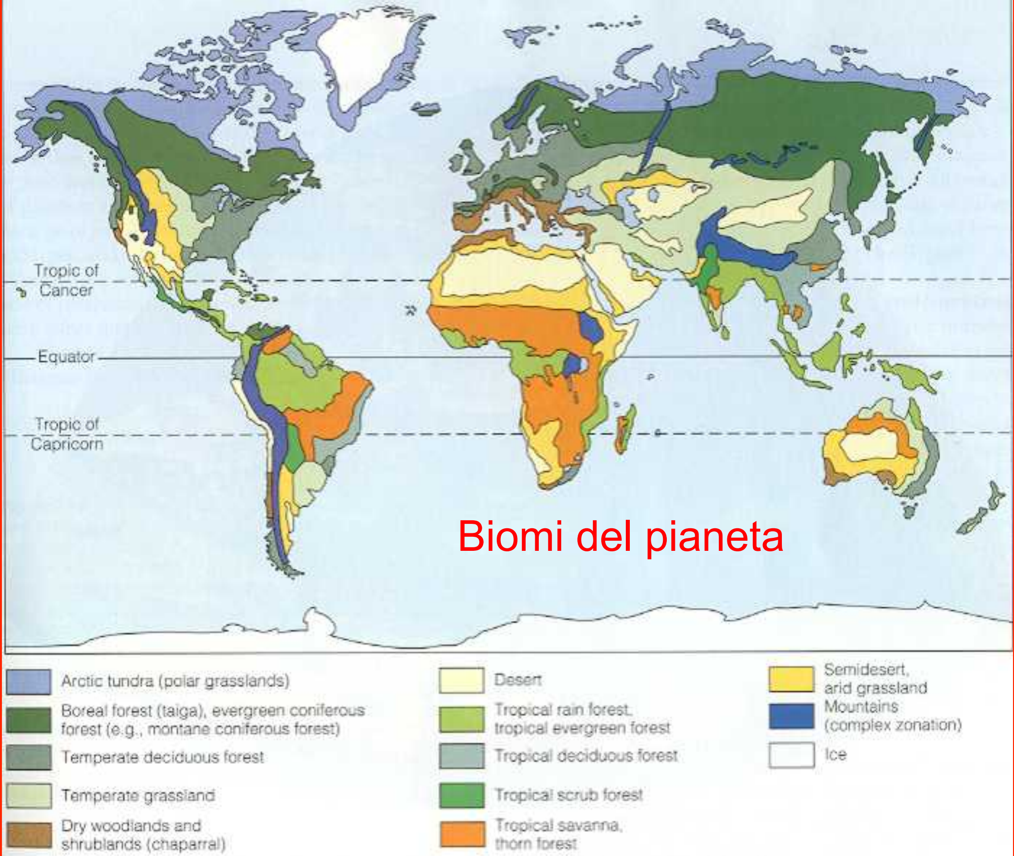
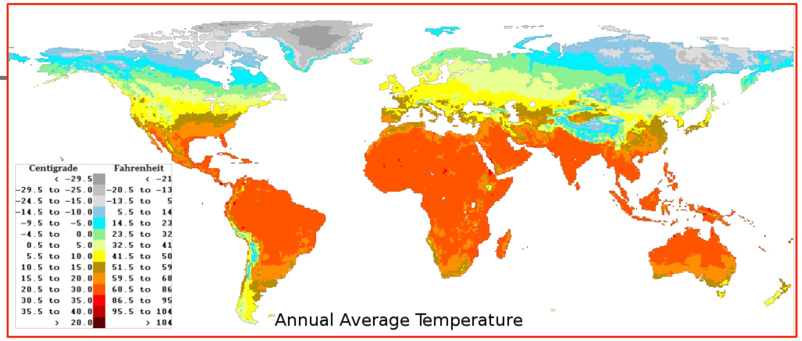
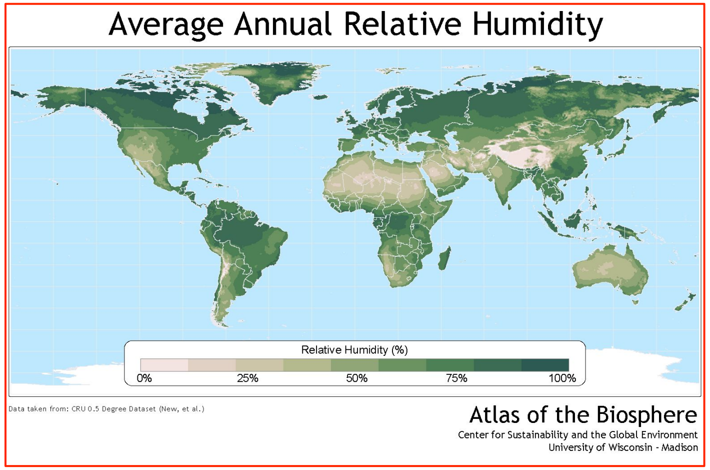
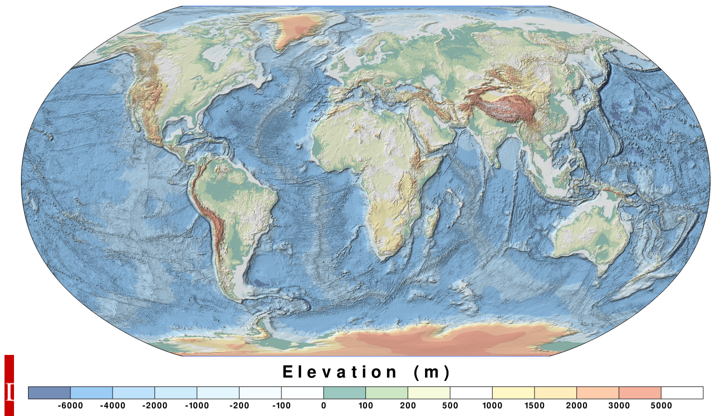



**Figure 7-11** The earth's major biomes—the main types of natural vegetation in different undisturbed land areas—result primarily from differences in climate. Each biome contains many ecosystems whose communities have adapted to differences in climate, soil, and other environmental factors within the biome. In reality, people have removed or altered much of this natural vegetation for farming, livestock grazing, harvesting lumber and fuelwood, mining, and constructing villages and cities, thereby altering the biomes (Figure 1-20).

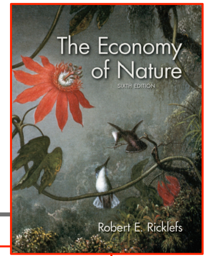


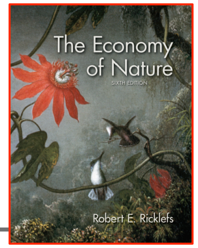




Biomi del pianeta
Identificati principalmente da variazioni delle caratteristiche Ambientali (temperatura, umidità, precipitazioni) e geografici (altitudine)

# Vegetazione e clima




| Biome name | Climate zone | | | Vegetation |
|---|---|---|---|---|
| Tropical rain forest | I | Equatorial: | Always moist and lacking temperature seasonality | Evergreen tropical rain forest |
| Tropical seasonal forest/ savanna | II | Tropical: | Summer rainy season and "winter" dry season | Seasonal forest, scrub, or savanna |
| Subtropical desert | III | Subtropical (hot deserts): | Highly seasonal, arid climate | Desert vegetation with considerable exposed surface |
| Woodland/shrubland | IV | Mediterranean: | Winter rainy season and summer drought | Sclerophyllous (drought-adapted), frost-sensitive shrublands and woodlands |
| Temperate rain forest | V | Warm temperate: | Occasional frost, often with summer rainfall maximum | Temperate evergreen forest, somewhat frost-sensitive |
| Temperate seasonal forest | VI | Nemoral: | Moderate climate with winter freezing | Frost-resistant, decidous, temperate forest |
| Temperate grassland/ desert | VII | Continental (cold deserts): | Arid, with warm or hot summers and cold winters | Grasslands and temperate deserts |
| Boreal forest | VIII | Boreal: | Cold temperate with cool summers and long winters | Evergreen, frost-hardy needle-leaved forest (taiga) |
| Tundra | IX | Polar: | Very short, cool summers and long, very cold winters | Low, evergreen vegetation, without trees, growing over permanently frozen soils |




# Vegetazione e clima

**FIGURE 5.5 Whittaker's biomes are delineated according to average temperature and precipitation.** Whittaker plotted the boundaries of observed vegetation types with respect to average temperature and precipitation. In climates intermediate between those of forest and desert biomes, climatic seasonality, fire, and soils determine whether woodland, grassland, or shrubland develops. *Inset:* Average annual temperature and precipitation for a sample of localities more or less evenly distributed over the land area of the earth. Most of the points fall within a triangular region that includes almost the full range of climates. Only the climates of high mountains do not fall within the triangle. From R. H. Whittaker, *Communities and Ecosystems*, 2nd ed., Macmillan, New York (1975).

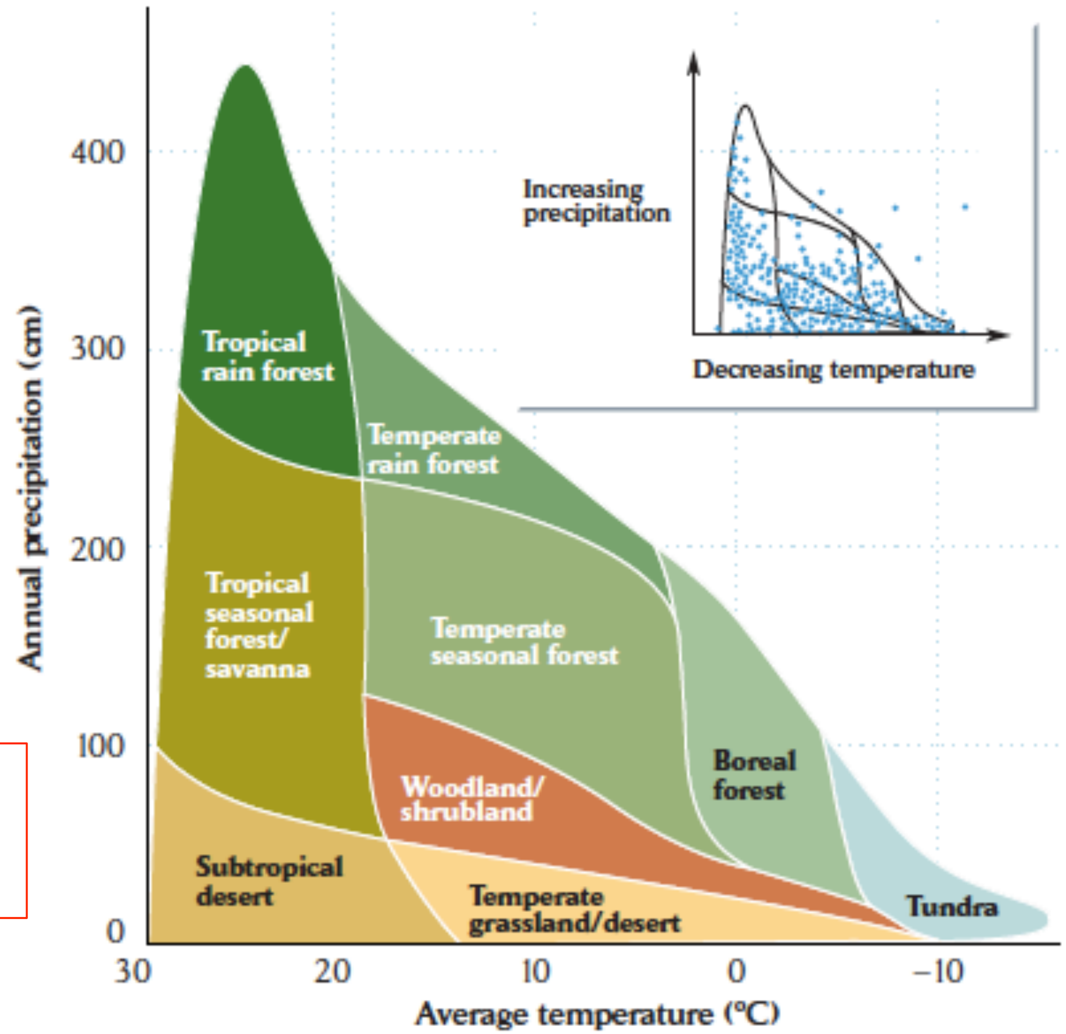
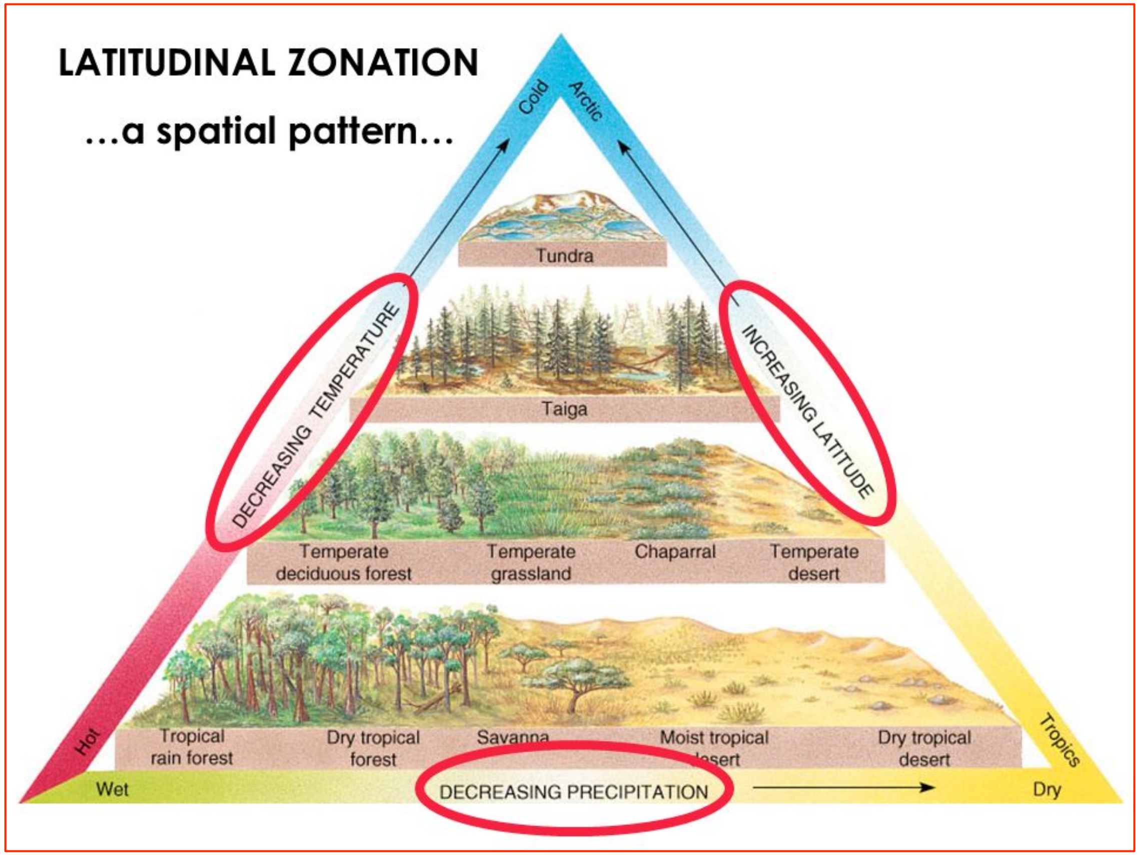



Diagramma di Whittaker
Biomi classificati in base a temperatura e precipitazioni

# Vegetazione e clima




Corrispondenza diretta (In generale)
Fra proprietà climatiche e Biomi

Variazione osservabile in funzione
Della latitudine…..............

# Vegetazione e clima

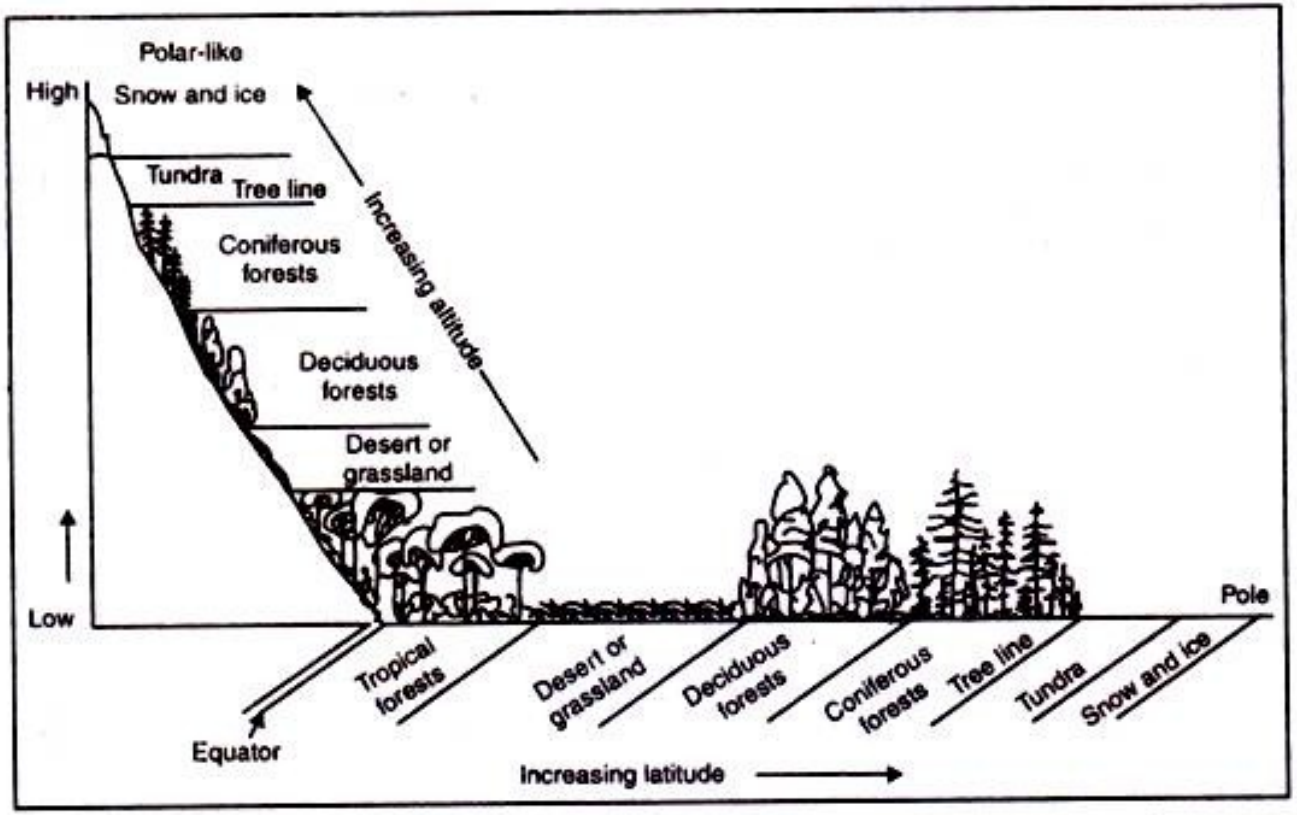



**Fig. 4.20.** The parallel between the horizontal and vertical distribution of life zones.

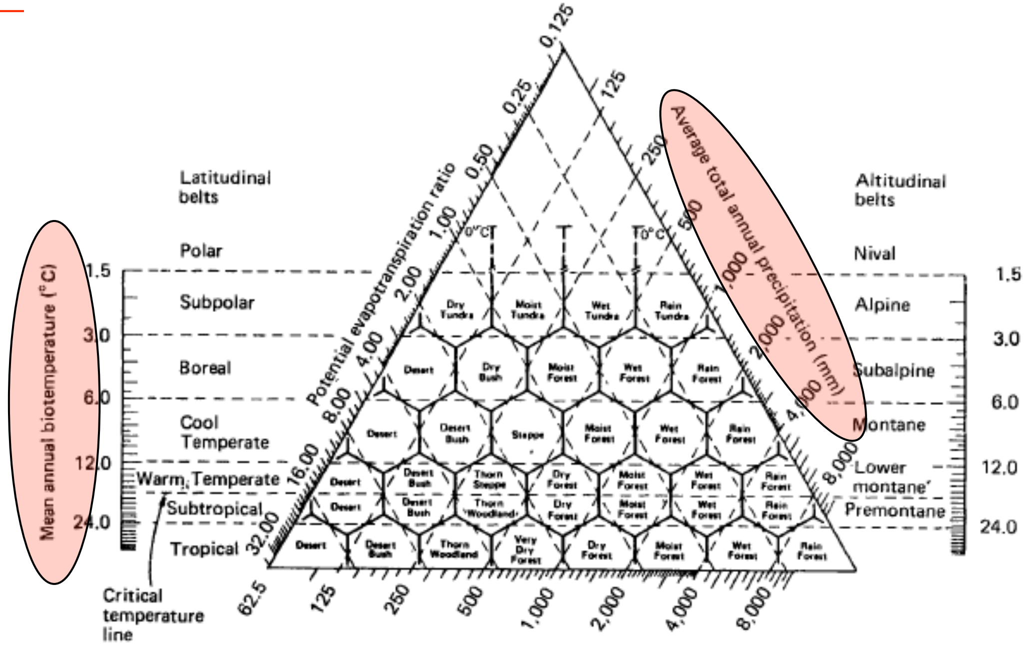
…….o della elevazione

# Vegetazione e clima

CLIMATIC CHANGE AND THE BROAD-SCALE DISTRIBUTION OF TERRESTRIAL ECOSYSTEM COMPLEXES*

WILLIAM R. EMANUEL, HERMAN H. SHUGART, and MARY P. STEVENSON**
*Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, U.S.A.*

In sintesi: Holdridge's life zones. Definizione dei biomi sulla base di  variazionidi temperatura e precipitazione.



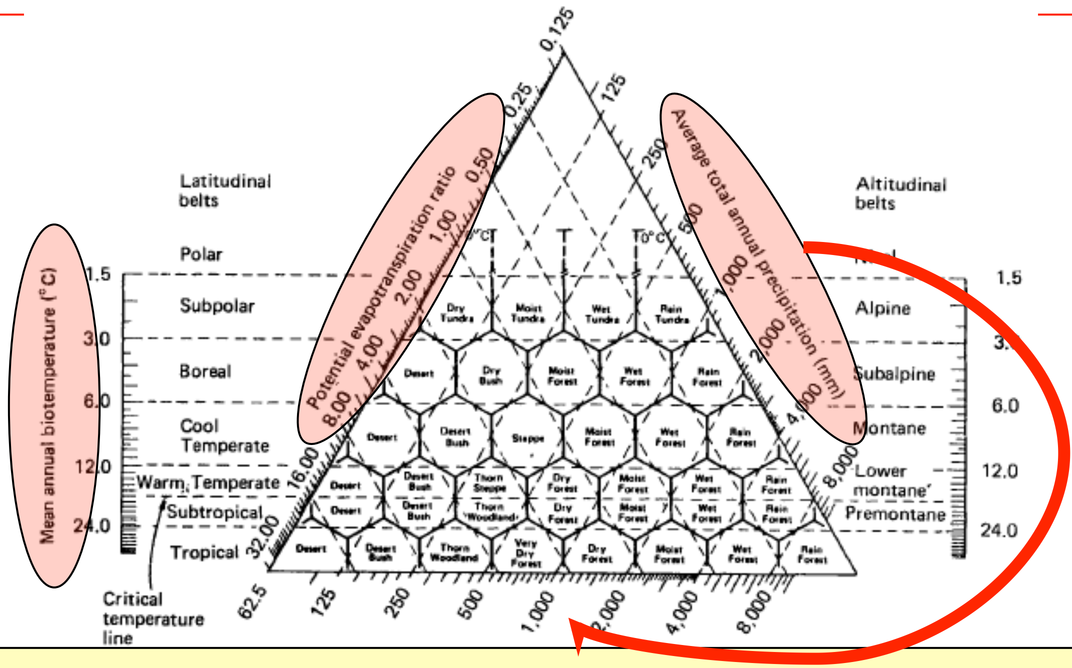

The Holdridge Life-Zone Classification System is a scheme for relating the character of natural vegetation associations to climate indices. The features of the Holdridge Classification are summarized in Figure 1, in which life zones are depicted by a series of hexagons formed by intersecting intervals of climate variables on logarithmic axes in a triangular coordinate system. Two variables, average biotemperature and average annual precipitation, uniquely determine a classification. Average biotemperature is the average temperature over a year with the unit temperature values (i.e. daily, weekly, or monthly temperatures) that are used in computing the average set to 0 °C if they are less than or equal to 0 °C.

# Vegetazione e clima

CLIMATIC CHANGE AND THE BROAD-SCALE DISTRIBUTION OF TERRESTRIAL ECOSYSTEM COMPLEXES*

WILLIAM R. EMANUEL, HERMAN H. SHUGART, and MARY P. STEVENSON**
*Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, U.S.A.*

In sintesi: Holdridge's life zones. Definizione dei biomi sulla base di variazionidi temperatura e precipitazione.



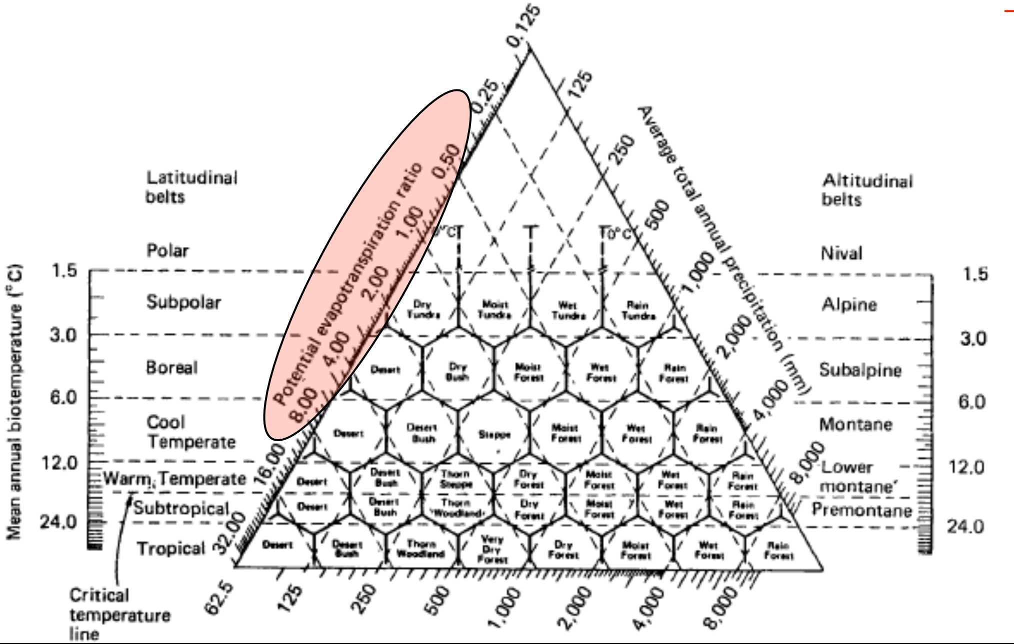

In the Holdridge Diagram (Figure 1), identical axes for average annual precipitation form two sides of an equilateral triangle. A logarithmic axis for the potential evapotranspiration (*PET*) ratio (effective humidity) forms the third side, and an axis for mean annual biotemperature is oriented perpendicular to its base. By striking equal intervals on these logarithmic axes, hexagons are formed that designate the Holdridge Life Zones. Each life zone is named to indicate a vegetation association.

# Vegetazione e clima

CLIMATIC CHANGE AND THE BROAD-SCALE DISTRIBUTION OF TERRESTRIAL ECOSYSTEM COMPLEXES*

WILLIAM R. EMANUEL, HERMAN H. SHUGART, and MARY P. STEVENSON**
*Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, U.S.A.*

In sintesi: Holdridge's life zones. Definizione dei biomi sulla base di  variazion idi temperatura e precipitazione.



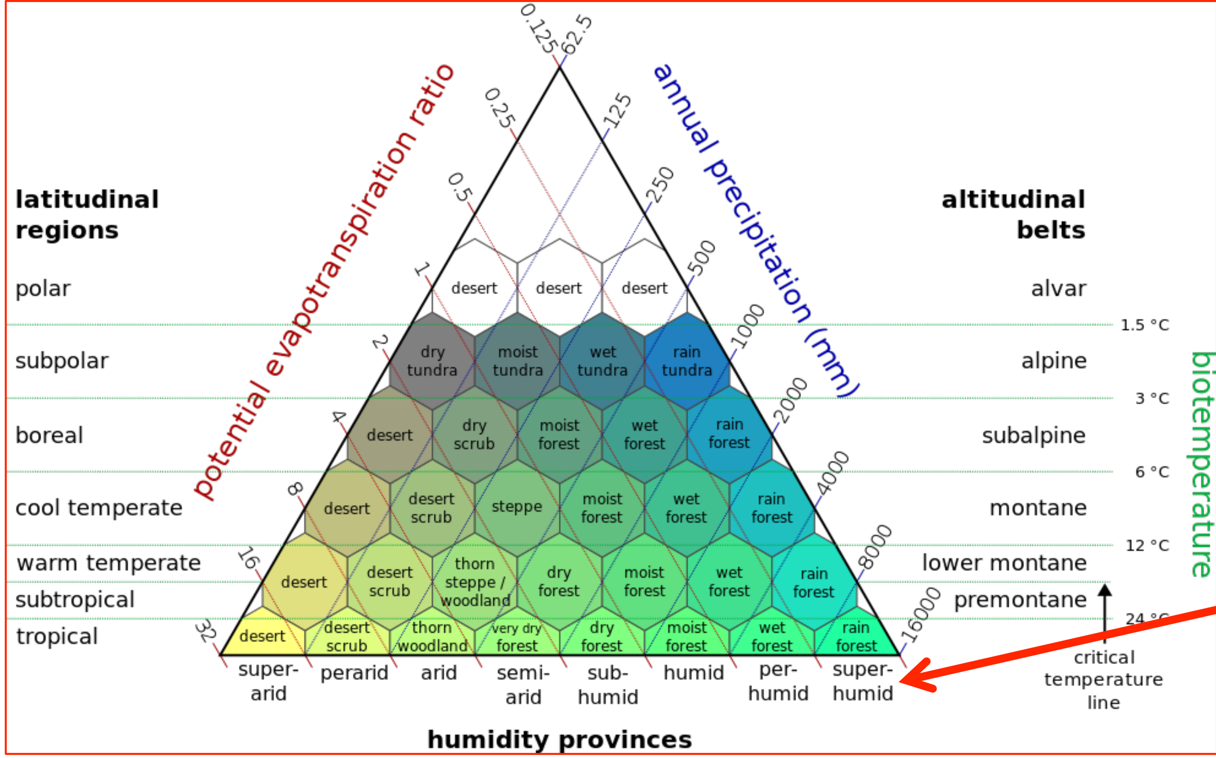

The potential evapotranspiration is the amount of water that would be released to the atmosphere under natural conditions with sufficient but not excessive water available throughout the growing season. The potential evapotranspiration ratio is the quotient of *PET* and average annual precipitation. Holdridge (1964) assumes, on the basis of studies of several ecosystems, that *PET* is proportional to biotemperature (constant of proportionality, 58.93). The *PET* ratio in the Holdridge Diagram is therefore dependent on the two primary variables, annual precipitation and biotemperature.

# Vegetazione e clima

CLIMATIC CHANGE AND THE BROAD-SCALE DISTRIBUTION OF TERRESTRIAL ECOSYSTEM COMPLEXES*

WILLIAM R. EMANUEL, HERMAN H. SHUGART, and MARY P. STEVENSON**
*Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, U.S.A.*

In sintesi: Holdridge's life zones. Definizione dei biomi sulla base di variazioni di latitudine, altitudine, e valori di temperatura, umidità e evapotraspirazione.




Potential evapotranspiration (PET): Amount of water that would be evaporated and transpired if there were sufficient water available.
High temperatures result in Higher PET. Evapotranspiration (ET) is the sum of evaporation and plant transpiration from the Earth's land surface to atmosphere. The ratio, precipitation/PET, is the **aridity index (AI)**

Coldest regions have not much evapotranspiration nor precipitation, hence polar deserts. In the warmer regions, there are deserts with maximum PET but low rainfall that make the soil even drier, and rain forests with low PET and maximum rainfall causing river systems to drain excess water into oceans.

# Vegetazione e clima

CLIMATIC CHANGE AND THE BROAD-SCALE DISTRIBUTION OF TERRESTRIAL ECOSYSTEM COMPLEXES*

WILLIAM R. EMANUEL, HERMAN H. SHUGART, and MARY P. STEVENSON**
*Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, U.S.A.*

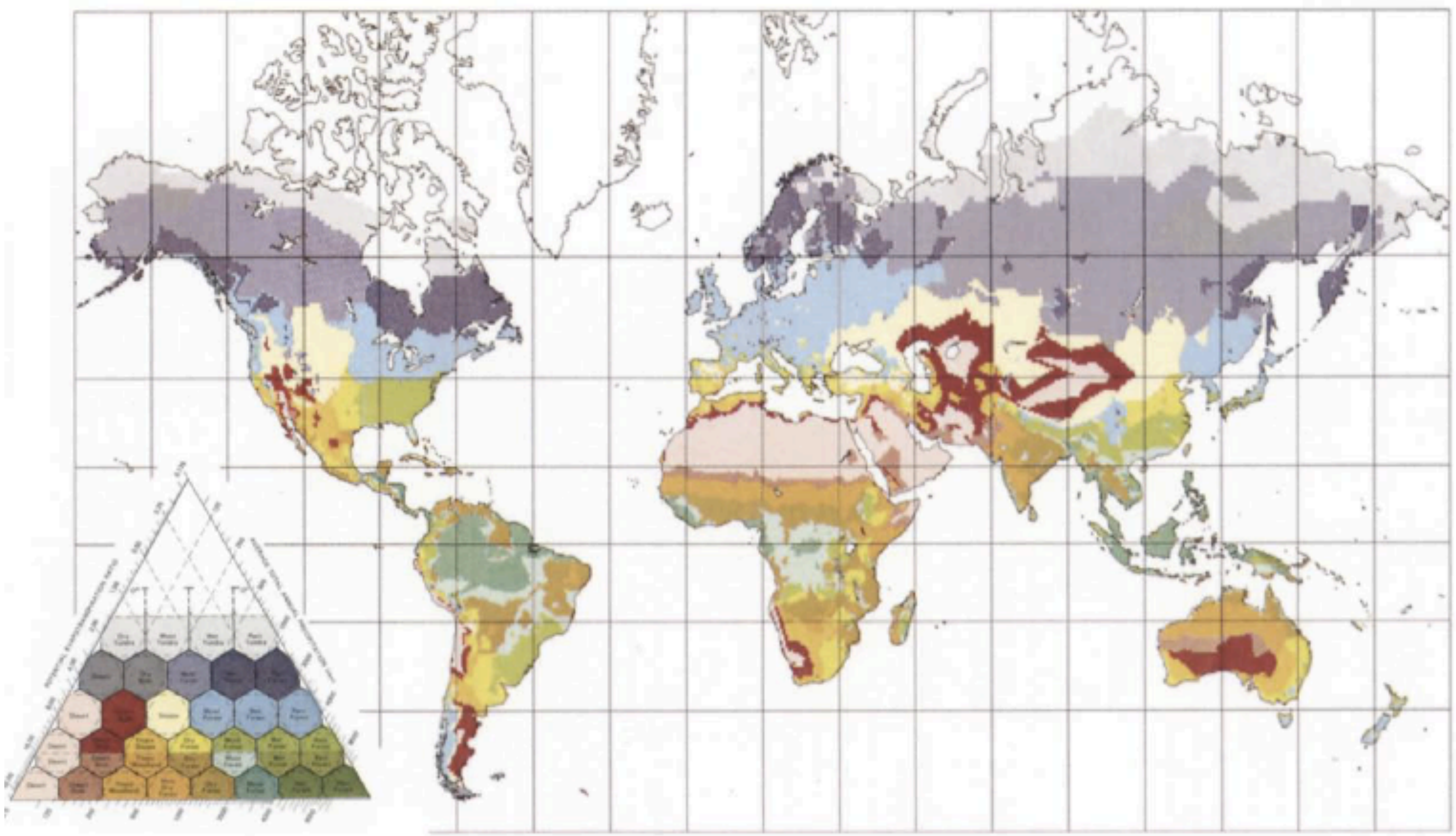
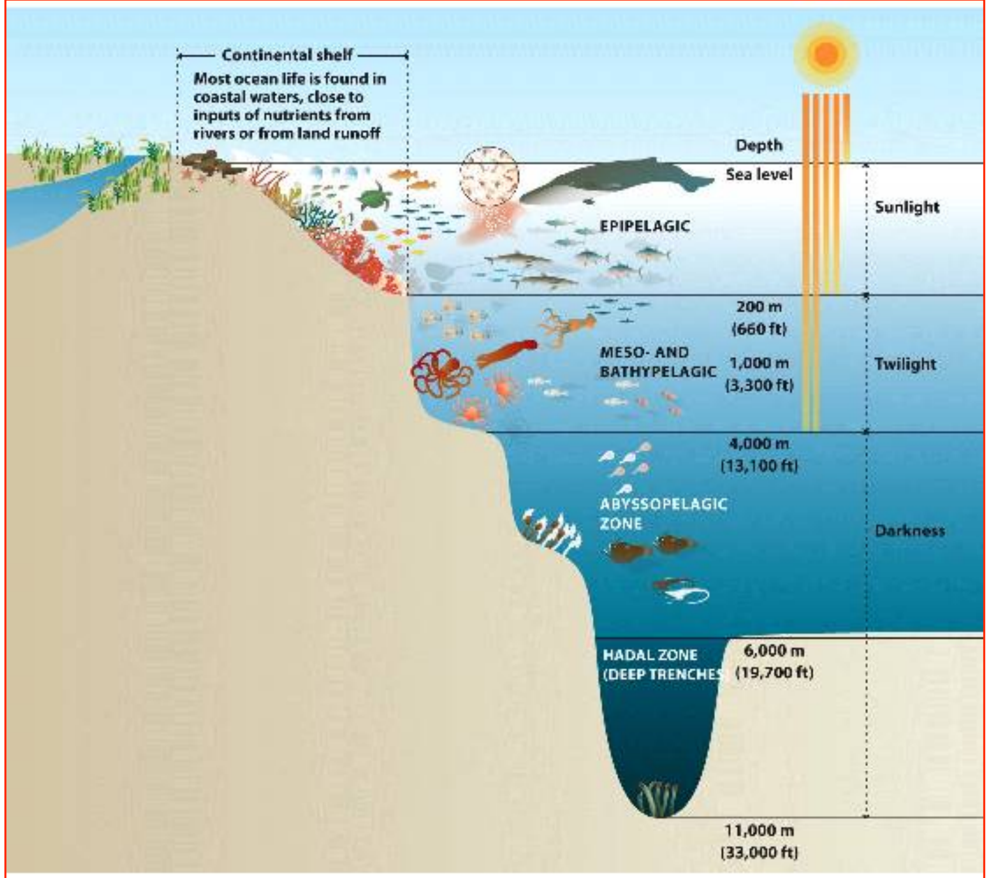


Fig. 2. World map of the Holdridge Classification (base case). The resolution is 0.5° latitude × 0.5° longitude and the extent is from 80° N to 60° S – Greenland is not classified (Aitof's Equal Area Projection). The key is

# Biomi marini




Da "epipelagico" a "adale".
Biomi sotanzialmente definiti sulla base
Della penetrazione della radiazione
Solare nella colonna d'acqua (e sul
valore di temperatura)

## James Lovelock

Quindi…...
Le caratteristiche fisiche del sistema climatico determinano e governano le caratteristiche della biosfera. (gli elementi biologici del sistema climatico sono governati da quelli fisici).
È pensabile una interazione diretta (non passiva) della biosfera sull'intero sistema climatico?
Una possibilità (estrema) di questo tipo è formulata nella cosiddetta "ipotesi Gaia" formulata nel 1972 da Lovelock e Margulis.

### Atmospheric homeostasis by and for the biosphere: the gaia hypothesis

By JAMES E. LOVELOCK, *Bowerchalke, Nr. Salisbury, Wilts. England* and LYNN MARGULIS, *Department of Biology, Boston University, 2, Cummington Street, Boston, Mass. USA*

(Manuscript received May 8; revised version August 20, 1973)

ABSTRACT

During the time, $3.2 \times 10^9$ years, that life has been present on Earth, the physical and chemical conditions of most of the planetary surface have never varied from those most favourable for life. The geological record reads that liquid water was always present and that the pH was never far from neutral. During this same period, however, the Earth's radiation environment underwent large changes. As the sun moved along the course set by the main sequence of stars its output will have increased at least 30 % and possibly 100 %. It may also have fluctuated in brightness over periods of a few million years. At the same time hydrogen was escaping to space from the Earth and so causing progressive changes in the chemical environment. This in turn through atmospheric compositional changes could have affected the Earth's radiation balance. It may have been that these physical and chemical changes always by blind chance followed the path whose bounds are the conditions favouring the continued existence of life. This paper offers an alternative explanation that, early after life began it acquired control of the planetary environment and that this homeostasis by and for the biosphere has persisted ever since. Historic and contemporary evidence and arguments for this hypothesis will be presented.

# Ipotesi "Gaia"

## Gaia hypothesis

The **Gaia hypothesis**, also known as **Gaia theory** or **Gaia principle**, proposes that all organisms and their inorganic surroundings on Earth are closely integrated to form a single and self-regulating complex system, maintaining the conditions for life on the planet.

The study of planetary habitability is partly based upon extrapolation from knowledge of the Earth's conditions, as the Earth is the only planet currently known to harbour life.

The scientific investigation of the Gaia hypothesis focuses on observing how the biosphere and the evolution of life forms contribute to the stability of global temperature, ocean salinity, oxygen in the atmosphere and other factors of habitability in a preferred homeostasis. The Gaia hypothesis was formulated by the chemist James Lovelock and co-developed by the microbiologist Lynn Margulis in the 1970s. Initially received with hostility by the scientific community, it is now studied in the disciplines of geophysiology and Earth system science, and some of its principles have been adopted in fields like biogeochemistry and systems ecology. This ecological hypothesis has also inspired analogies and various interpretations in social sciences, politics, and religion under a vague philosophy and movement.

# Ipotesi "Gaia"

The existence of a planetary homeostasis influenced by living forms had been observed previously in the field of biogeochemistry, and it is being investigated also in other fields like Earth system science. The originality of the Gaia theory relies on the assessment that such homeostatic balance is actively pursued with the goal of keeping the optimal conditions for life, even when terrestrial or external events menace them.[3]

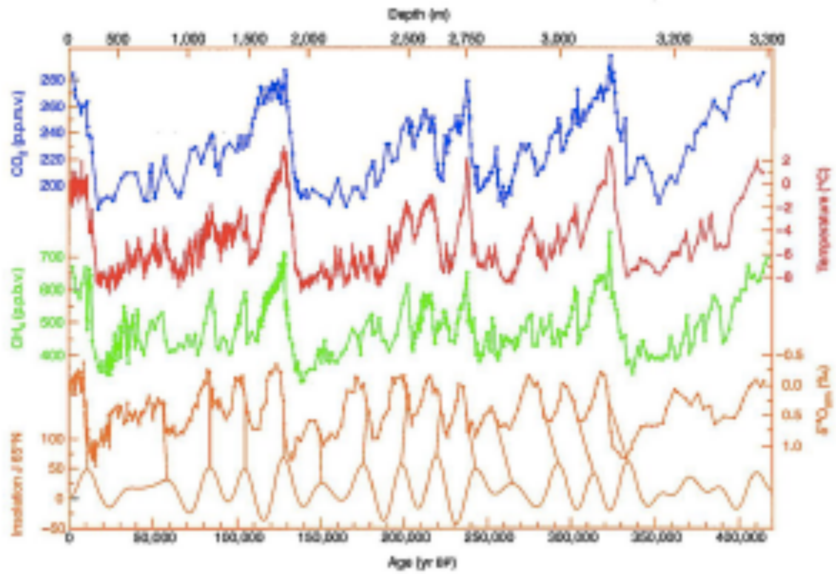
Concetto maggiormente criticato

# Ipotesi “Gaia”

## Regolazione dell’Ossigeno atmosferico

The atmospheric composition remains fairly constant providing the ideal conditions for contemporary life. All the atmospheric gases other than noble gases present in the atmosphere are either made by organisms or processed by them. The Gaia theory states that the Earth's atmospheric composition is kept at a dynamically steady state by the presence of life.[6]

The stability of the atmosphere in Earth is not a consequence of chemical equilibrium like in planets without life. Oxygen is the second most reactive element after fluorine, and should combine with gases and minerals of the Earth's atmosphere and crust.




Levels of gases in the atmosphere in 420,000 years of ice core data from Vostok, Antarctica research station. Current period is at the left.

# Ipotesi “Gaia”

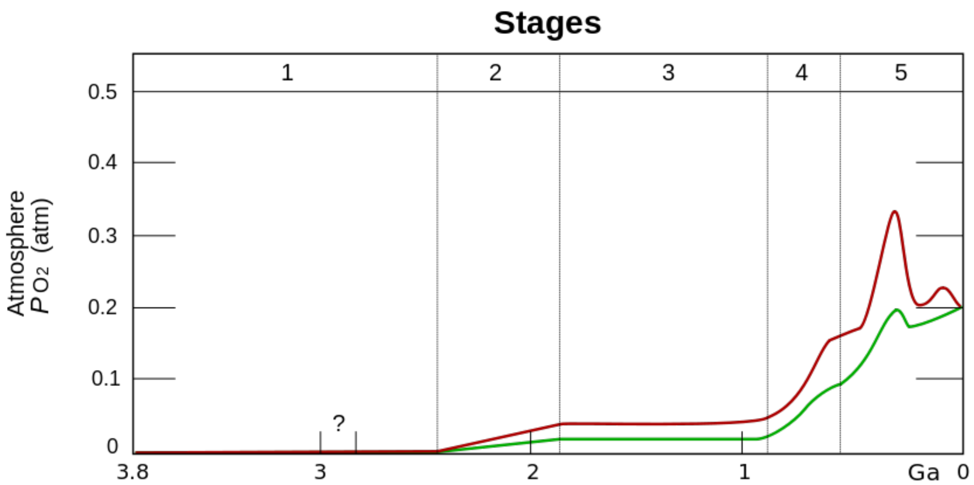
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B
Phil. Trans. R. Soc. B (2006) 361, 903–915
doi:10.1098/rstb.2006.1838
Published online 19 May 2006

**The oxygenation of the atmosphere and oceans**

Heinrich D. Holland*
Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, USA

## Regolazione dell’Ossigeno atmosferico

Before photosynthesis evolved, Earth's atmosphere had no free oxygen Photosynthetic prokaryotic organisms that produced $O_2$ as a waste product lived long before the first build-up of free oxygen in the atmosphere perhaps as early as 3.5 billion years ago. The oxygen they produced would have been rapidly removed from the atmosphere by weathering of reducing minerals, most notably iron. This 'mass rusting' led to the deposition of iron oxide on the ocean floor, forming banded iron formations. Oxygen only began to persist in the atmosphere in small quantities about 50 million years before the start of the Great Oxygenation Event[
This mass oxygenation of the atmosphere resulted in rapid buildup of free oxygen.



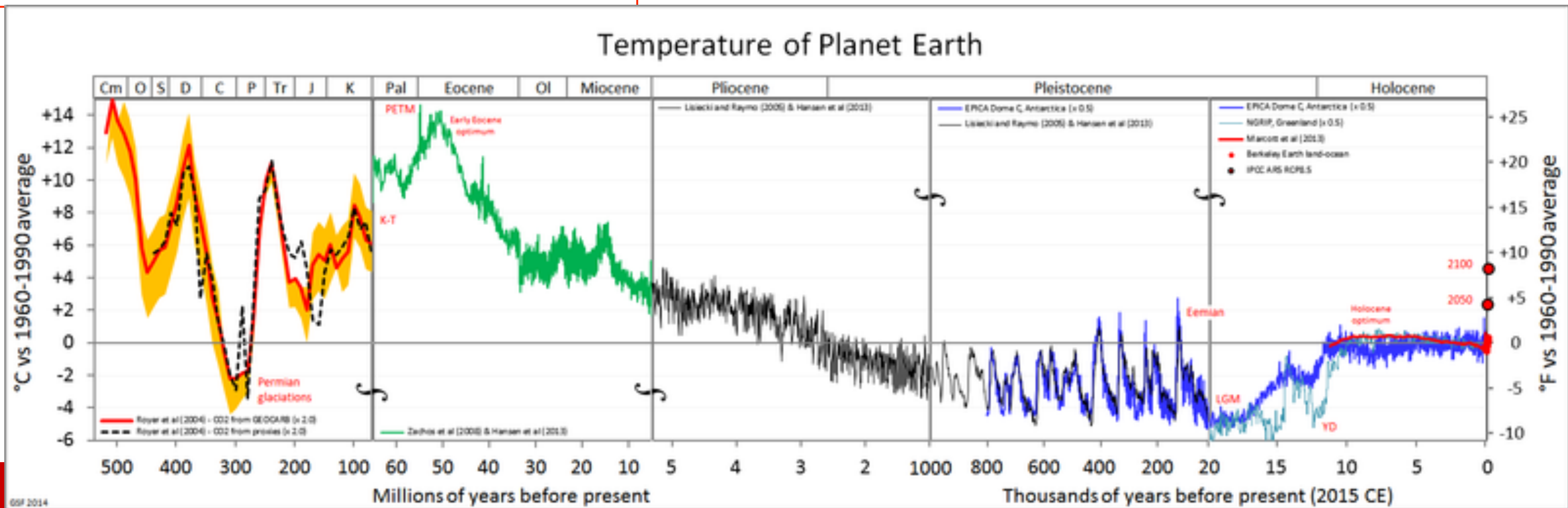

$O_2$ build-up in the Earth's atmosphere. Red and green lines represent the range of the estimates while time is measured in billions of years ago (Ga).
Stage 1 (3.85–2.45 Ga): Practically no $O_2$ in the atmosphere.
Stage 2 (2.45–1.85 Ga): $O_2$ produced, but absorbed in oceans & seabed rock.
Stage 3 (1.85–0.85 Ga): $O_2$ starts to gas out of the oceans, but is absorbed by land surfaces and formation of ozone layer.
Stages 4 & 5 (0.85 Ga–present): $O_2$ sinks filled, the gas accumulates.[1]

# *Ipotesi "Gaia"*

## Regolazione della temperatura planetaria

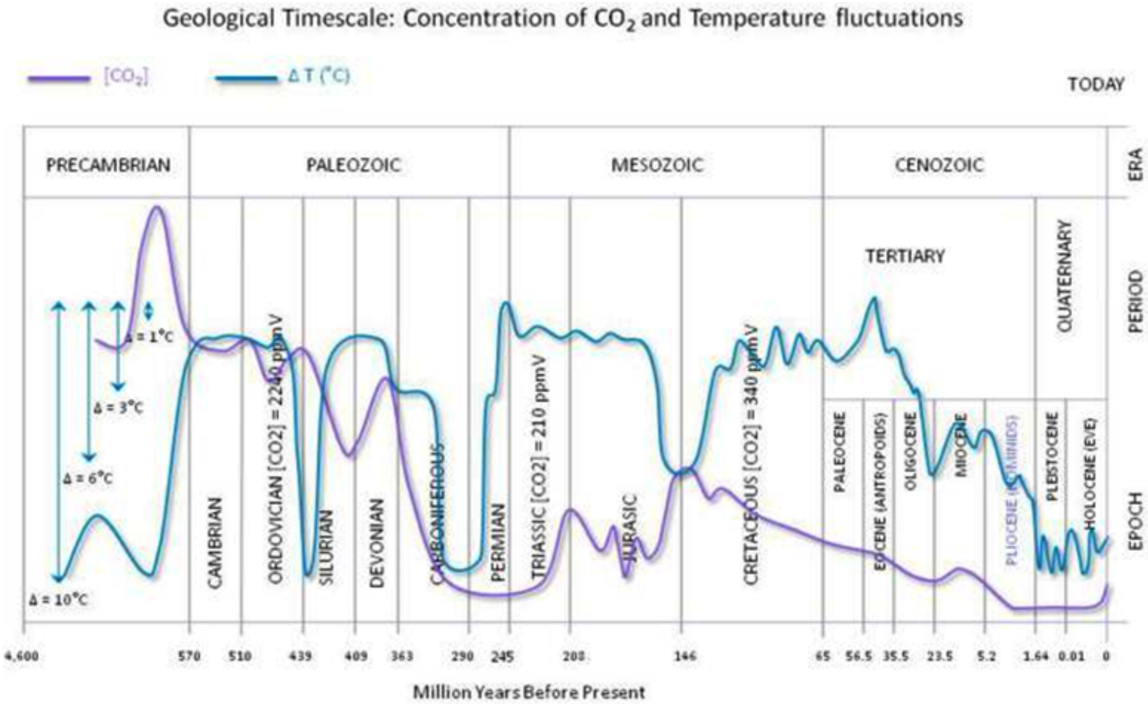
Since life started on Earth, the energy provided by the Sun has increased by 25% to 30%;[8] however, the surface temperature of the planet has remained within the levels of habitability, reaching quite regular low and high margins.

| Time ($10^9$ yr BP) | $S$ (W $m^{-2}$) | $T_s$ (K) |
|---|---|---|
| 4.25 | 1,039 | 310 |
| 3.5 | 1,096 | 296 |
| 3.0 | 1,133 | 293 |
| 2.5 | 1,171 | 292 |
| 2.0 | 1,209 | 290 |
| 1.5 | 1,247 | 288 |
| 1.0 | 1,284 | 286 |
| 0.5 | 1,322 | 287 |
| 0 | 1,360 | 290 |



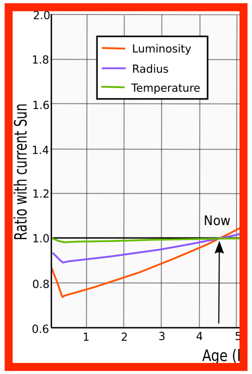
# Ipotesi "Gaia"

## Regolazione della temperatura planetaria




1- *Analysis of the Temperature Oscillations in Geological Eras* by Dr. C. R. Scotese © 2002. 2- Ruddiman, W. F. 2001. *Earth's Climate: past and future*. W. H. Freeman & Sons. New York, NY. 3- Mark Pagani *et all. Marked Decline in Atmospheric Carbon Dioxide Concentrations During the Paleocene*. Science; Vol. 309, No. 5734; pp. 600-603. 22 July 2005.
*Corrected on 07 July 2008 (CO2: Ordovician Period).*

Relativa costanza della
Temperatura terrestre a fronte
Di una diminuita concentrazione
Di CO2 (riduzione effetto serra)
E di un aumento della radiazione
Solare'…....




...che presuppone un meccanismo
Omeostatico di regolazione

# Ipotesi “Gaia”

NATURE VOL. 326 16 APRIL 1987 REVIEW ARTICLE 655

**Oceanic phytoplankton, atmospheric sulphur, cloud albedo and climate**

Robert J. Charlson*, James E. Lovelock†, Meinrat O. Andreae‡ & Stephen G. Warren*

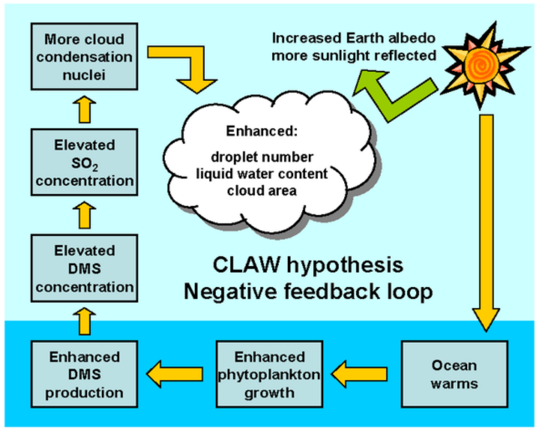
* Department of Atmospheric Sciences AK-40, University of Washington, Seattle, Washington 98195, USA
† Coombe Mill Experimental Station. Launceston, Cornwall PL15 9RY, UK
‡ Department of Oceanography, Florida State University, Tallahassee, Florida 32306, USA

## Regolazione della temperatura planetaria

Un possibile meccanismo di regolazione “The CLAW (Charlson,Lovelock, Andreae, Warren) Hypothesis

*The major source of cloud-condensation nuclei (CCN) over the oceans appears to be dimethylsulphide, which is produced by planktonic algae in sea water and oxidizes in the atmosphere to form a sulphate aerosol. Because the reflectance (albedo) of clouds (and thus the Earth's radiation budget) is sensitive to CCN density, biological regulation of the climate is possible through the effects of temperature and sunlight on phytoplankton population and dimethylsulphide production. To counteract the warming due to doubling of atmospheric $CO_2$, an approximate doubling of CCN would be needed.*

The CLAW hypothesis, proposes a feedback loop that operates between ocean ecosystems and the Earth's climate.It proposes that phytoplankton that produce dimethyl sulfide are r responsive to variations in climate forcing, and that these responses lead to a negative feedback loop that acts to stabilise the temperature of the Earth's atmosphere.



# Ipotesi “Gaia”

NATURE VOL. 326 16 APRIL 1987 REVIEW ARTICLE 655

**Oceanic phytoplankton, atmospheric sulphur, cloud albedo and climate**

Robert J. Charlson*, James E. Lovelock†, Meinrat O. Andreae‡ & Stephen G. Warren*

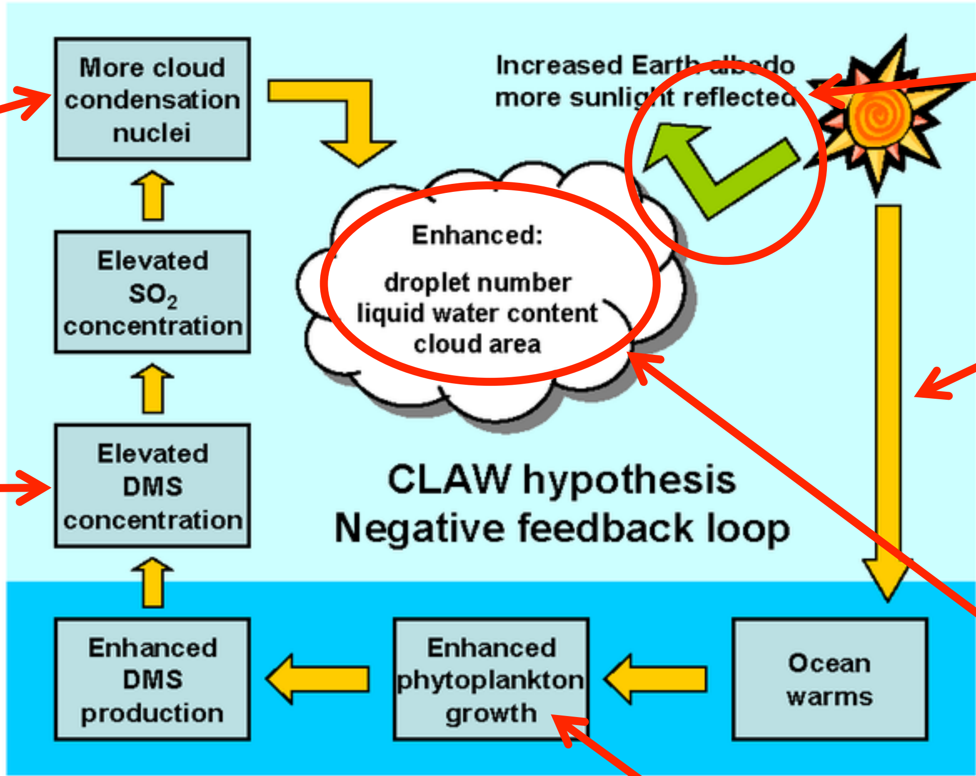
* Department of Atmospheric Sciences AK-40, University of Washington, Seattle, Washington 98195, USA
† Coombe Mill Experimental Station, Launceston, Cornwall PL15 9RY, UK
‡ Department of Oceanography, Florida State University, Tallahassee, Florida 32306, USA

## Regolazione della temperatura planetaria

Un possibile meccanismo di regolazione “The CLAW (Charlson,Lovelock, Andreae, Warren) Hypothesis

4.
+ Nuclei di condensazione

3. Aumento
Conc. Atm. DMS




6.Aumento
Albedo

1. Global Warming (Anthropogenic Greenhouse)

5.Aumento
Copertura nuvolosa

2. Aumento produzione
Primaria Oceanica

# Ipotesi “Gaia”

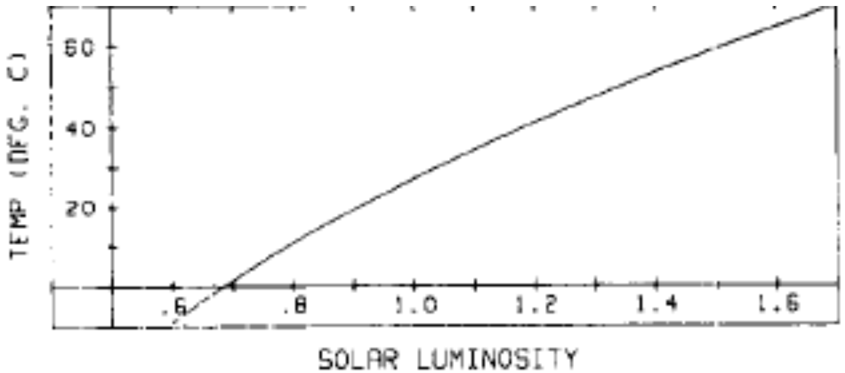
**Biological homeostasis of the global environment: the parable of Daisyworld**

By ANDREW J. WATSON, *Marine Biological Association, The Laboratory, Citadel Hill, Plymouth PL1 2PB, England* and JAMES E. LOVELOCK, *Coombe Mill, St. Giles on the Heath, Launceston, Cornwall PL15 9RY, England*

## “Daisyworld” (Mondo Margherita)

James Lovelock and Andrew Watson developed the mathematical model Daisyworld, that shows how temperature regulation can arise from organisms interacting with their environment. The purpose of the model is to demonstrate that feedback mechanisms can evolve from the actions or activities of self-interested organisms, rather than through classic group selection mechanisms.[13]

Daisyworld examines the energy budget of a planet populated by two different types of plants, black daisies and white daisies. The colour of the daisies influences the albedo of the planet such that black daisies absorb light and warm the planet, while white daisies reflect light and cool the planet. Competition between the daisies (based on temperature-effects on growth rates) leads to a balance of populations that tends to favour a planetary temperature close to the optimum for daisy growth.

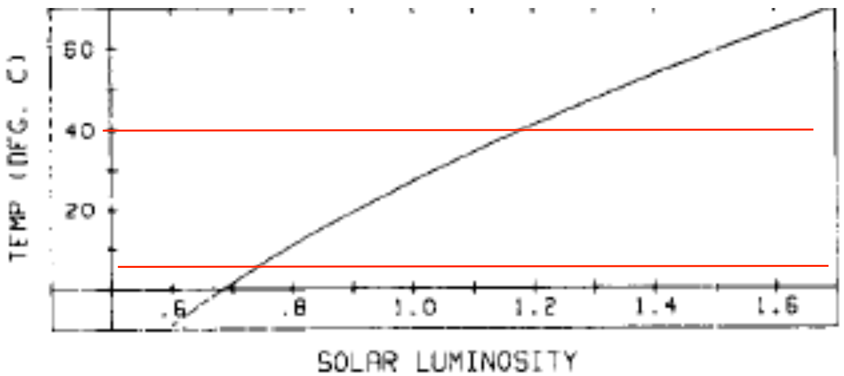


# Ipotesi “Gaia”

**Biological homeostasis of the global environment: the parable of Daisyworld**

by ANDREW J. WATSON, *Marine Biological Association, The Laboratory, Citadel Hill, Plymouth PL1 2PB, England* and JAMES E. LOVELOCK, *Coombe Mill, St. Giles on the Heath, Launceston, Cornwall PL15 9RY, England*

## “Daisyworld”




Variazione della temperatura planetaria in Funzione della Luminosità solare
In ASSENZA di Margherite

Il tasso di $\beta$ crescita delle daisies é zero per $T<5°C$ e per $T>40°C$

Per $5.0<T<22.5$ °C $\quad 0<\beta<1$

Per $22.5<T<40.9$ °C $\quad 1<\beta<0$

# Ipotesi “Gaia”

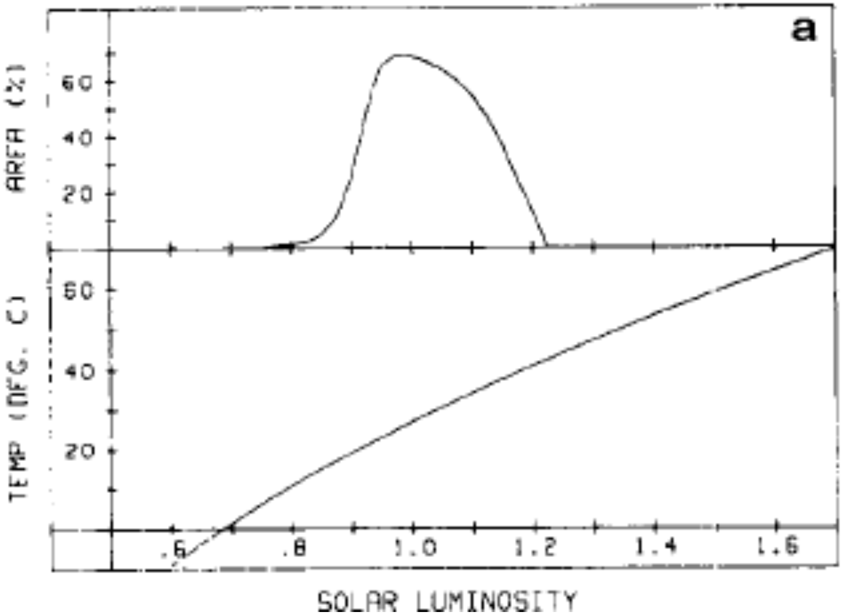
**Biological homeostasis of the global environment: the parable of Daisyworld**

By ANDREW J. WATSON, *Marine Biological Association, The Laboratory, Citadel Hill, Plymouth PL1 2PB, England* and JAMES E. LOVELOCK, *Coombe Mill, St. Giles on the Heath, Launceston, Cornwall PL15 9RY, England*

**“Daisyworld” 1**

Daisies (margherite) con valore di albedo identico a quello del suolo

Superficie del pianeta (%)
Ricoperta dalle margherite




Margherite “Neutrali”
Nessuna crescita al di sopra e al di sotto delle Temperature che limitano la crescita.
Crescita nel range:

$$5.0 < T < 22.5\ °C$$

Con valori massimi per la temperatura ottimale

$$T = 22.5\ °C$$

Nessuna variazione nell’evoluzione della temperatura rispetto ad un pianeta senza margherite

# Ipotesi "Gaia"

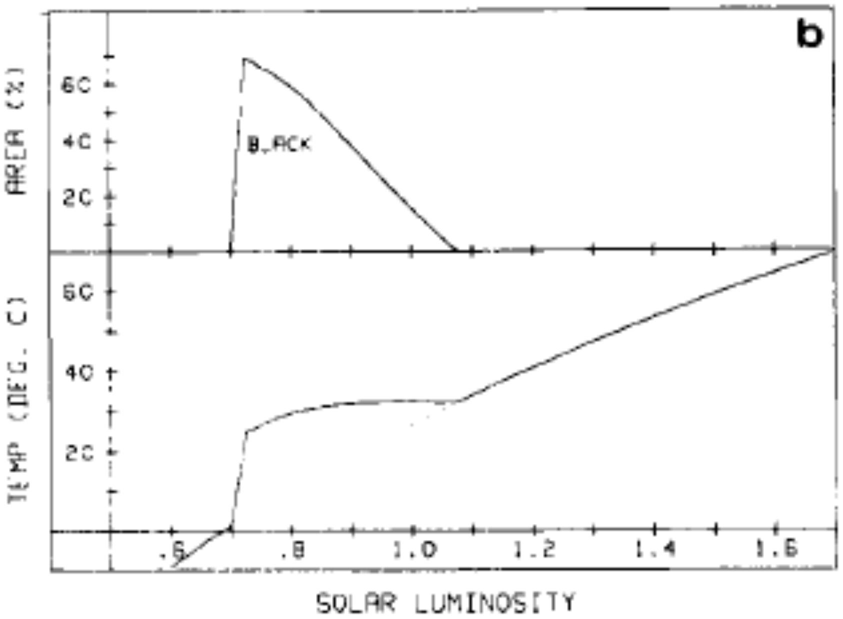
**Biological homeostasis of the global environment: the parable of Daisyworld**

By ANDREW J. WATSON, *Marine Biological Association, The Laboratory, Citadel Hill, Plymouth PL1 2PB, England and* JAMES E. LOVELOCK, *Coombe Mill, St. Giles on the Heath, Launceston, Cornwall PL15 9RY, England*

**"Daisyworld" 2**

Daisies (margherite) solo **nere** con valore di albedo minore di quello del suolo (maggior assorbimento)

Superficie del pianeta (%) Ricoperta dalle margherite




Le margherite "nere" assorbono maggiormente La radiazione solare e portano più rapidamente la temperatura planetaria al valori prossimi a quello ottimale, mantenedola costante per un certo periodo nonostante l'aumento della luminosità solare.

# Ipotesi "Gaia"

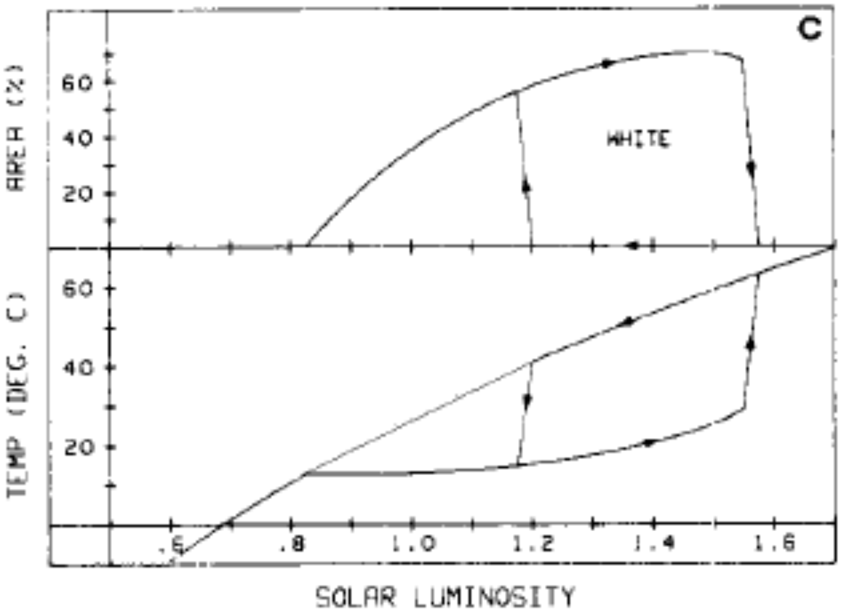
**Biological homeostasis of the global environment: the parable of Daisyworld**

By ANDREW J. WATSON, *Marine Biological Association, The Laboratory, Citadel Hill, Plymouth PL1 2PB, England and* JAMES E. LOVELOCK, *Coombe Mill, St. Giles on the Heath, Launceston, Cornwall PL15 9RY, England*

**"Daisyworld" 3**

Daisies (margherite) solo **bianche** con valore di albedo maggiore di quello del suolo (minor assorbimento assorbimento)

Superficie del pianeta (%)
Ricoperta dalle margherite




Le margherite "bianche" riflettono maggiormente
La radiazione solare.
Una volta raggiunta la temperatura ottimale, questa viene mantenuta più o meno costante nonostante l'aumento della luminosità solare.

N.B. La figura Mostra anche il processo di diminuzione della luminositàsolare

# Ipotesi “Gaia”

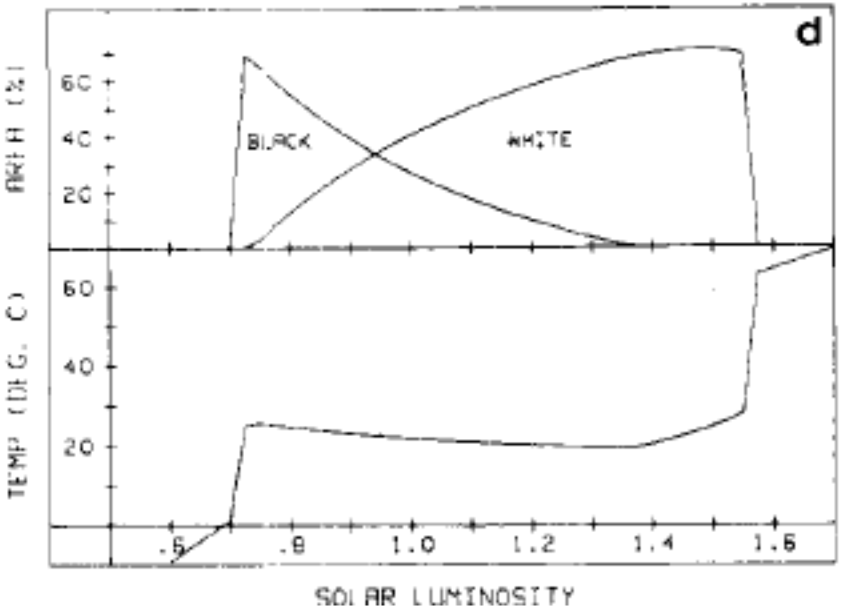
Biological homeostasis of the global environment: the parable of Daisyworld

by ANDREW J. WATSON, *Marine Biological Association, The Laboratory, Citadel Hill, Plymouth PL1 2PB, England* and JAMES E. LOVELOCK, *Coombe Mill, St. Giles on the Heath, Launceston, Cornwall PL15 9RY, England*

**“Daisyworld” 4**

Daisies (margherite) solo **bianche** e **nere**

Superficie del pianeta (%) Ricoperta dalle margherite




Lo sviluppo iniziale di una sola specie (nera), la coesistenza di entrambe (bianche e nere) le specie ed il prevalere della seconda (bianche). Permette il massimo mantenimento della temperatura ottimale, ottimizzando quindi il processo di omeostasi.