Global Focus on Knowledge Lecture Series (Nov.12, 2007)

The Earth as a Water Planet

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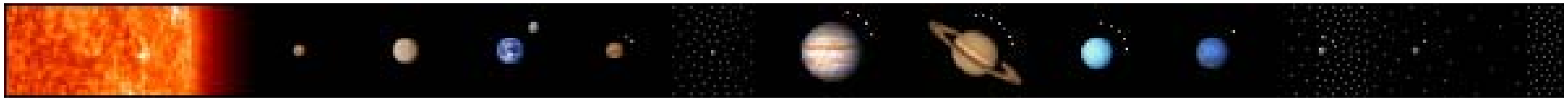
Earth: The Small, Blue Water Planet

Wikipedia

Planets in the Solar System



Wikipedia

Terrestrial Planets and Gas-Giant Planets

Terrestrial Planets (Inner Planets) And Gas-Giant Planets (Outer Planets)

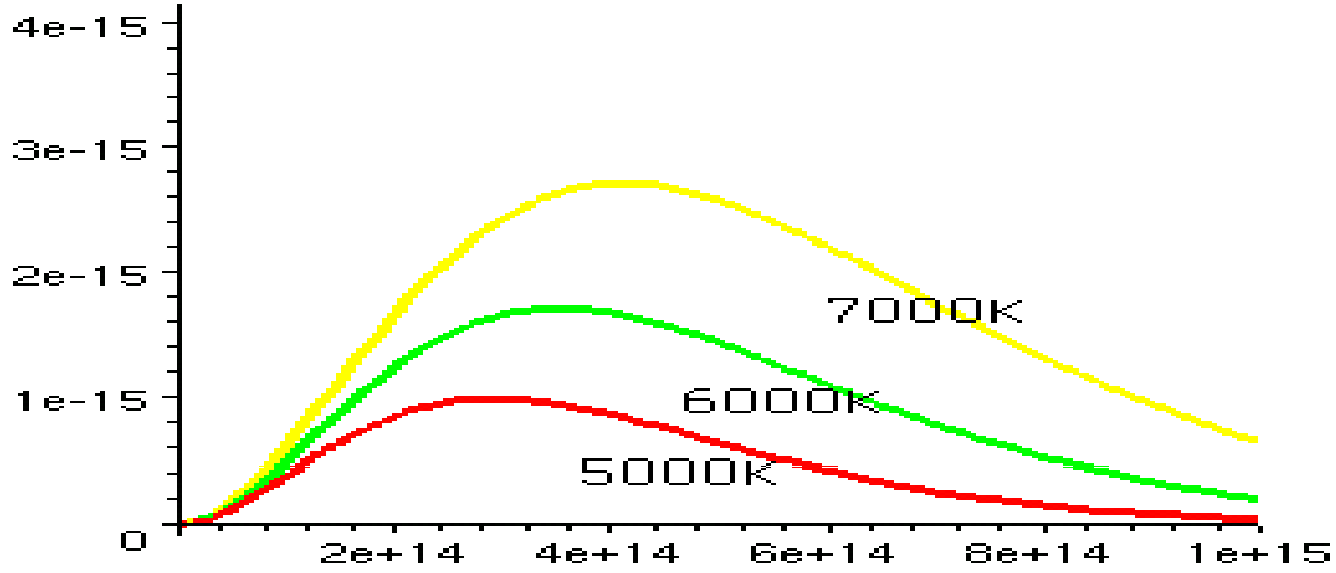
	Distance from the Sun	Mass
Mercury	0.4	5.4
Venus	0.7	5.2
Earth	1	5.5
Mars	1.5	3.9
Jupiter	5.2	1.3
Saturn	9.5	0.7
Uranus	19	1.2
Neptune	30	1.7

Energy Resources of the Earth

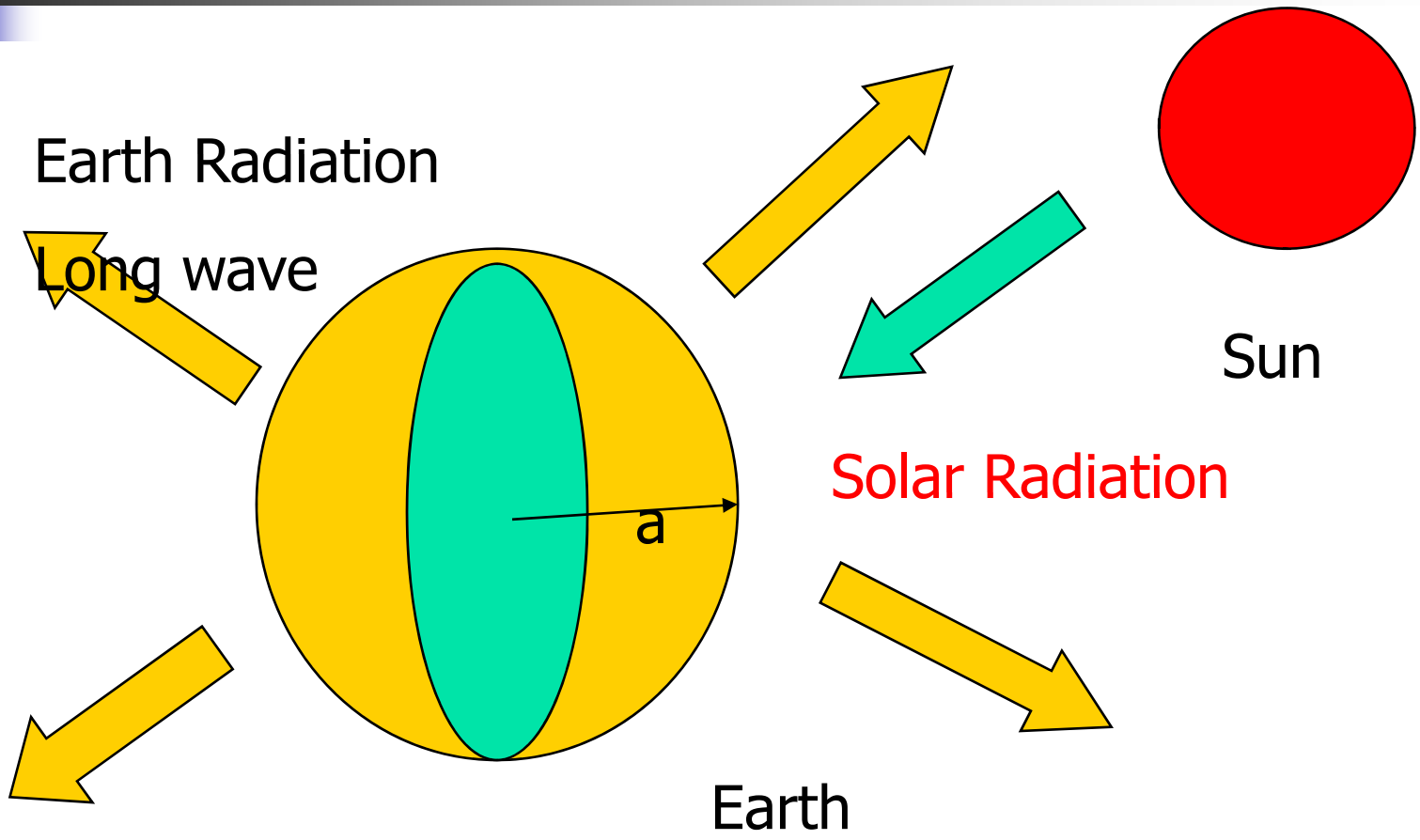
- Radiation Energy from the Sun
  - Heat radiation（Every substance radiates electro-magnetic wave corresponding to its temperature, Stefan-Boltzman Law）
- Radiation collapse energy of minerals
- Magma（gravity energy in the past）

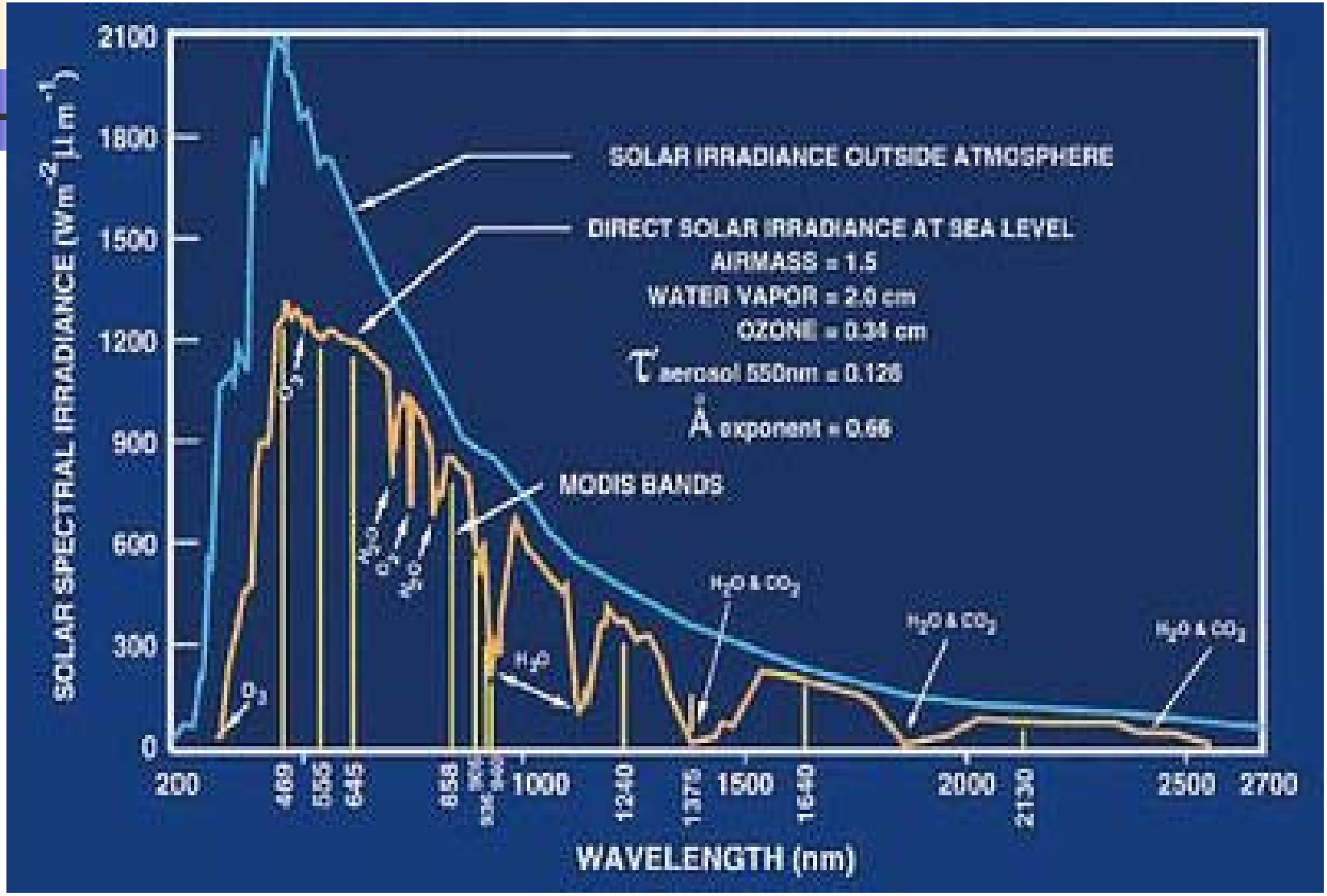
Stefan-Boltzman Law

$E=\sigma T^4$



Radiation Balance on the Earth




SOLAR SPECTRAL IRRADIANCE (Wm^{-2}(μm)$^{-1}$)
2100
1800
1500
1200
900
600
300
0
SOLAR IRRADIANCE OUTSIDE ATMOSPHERE
DIRECT SOLAR IRRADIANCE AT SEA LEVEL
AIRMASS = 1.5
WATER VAPOR = 2.0 cm
OZONE = 0.34 cm
τ aerosol 550nm = 0.128
Å exponent = 0.66
MODIS BANDS
O_3
H_2O
H_2O & CO_2
200
469
555
645
858
1000
1240
1500
1640
2130
2500
2700
WAVELENGTH (nm)

Wikipedia

Radiative Equilibrium

- Input from the Sum
- $\pi a^2 S_0 (1-\alpha) = 4\pi a^2 \ \sigma T^4$

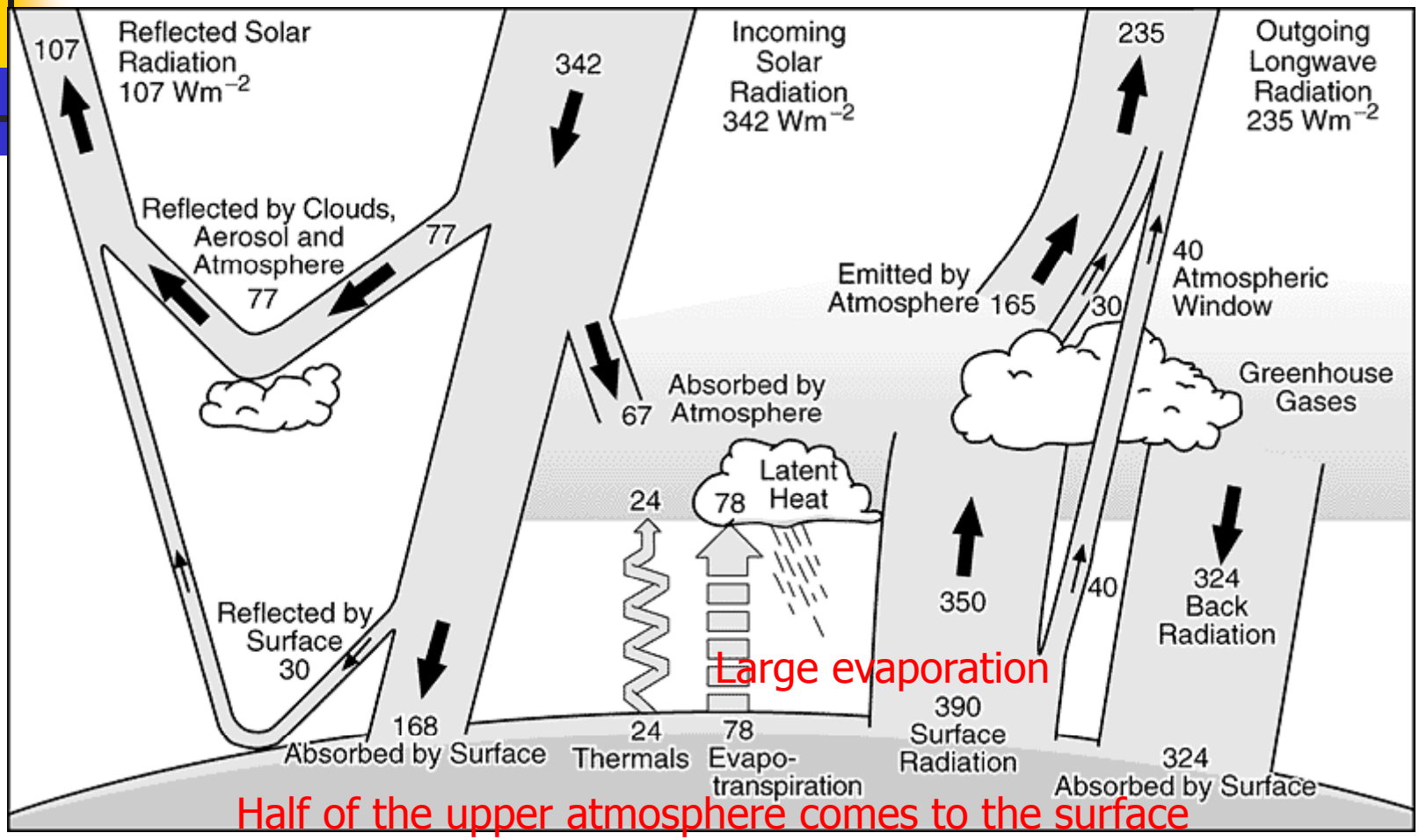
a=radius of the Earth

σ=Stefan Boltzman constant

α=Planetary Albedo

S_0 **=Solar Constant**

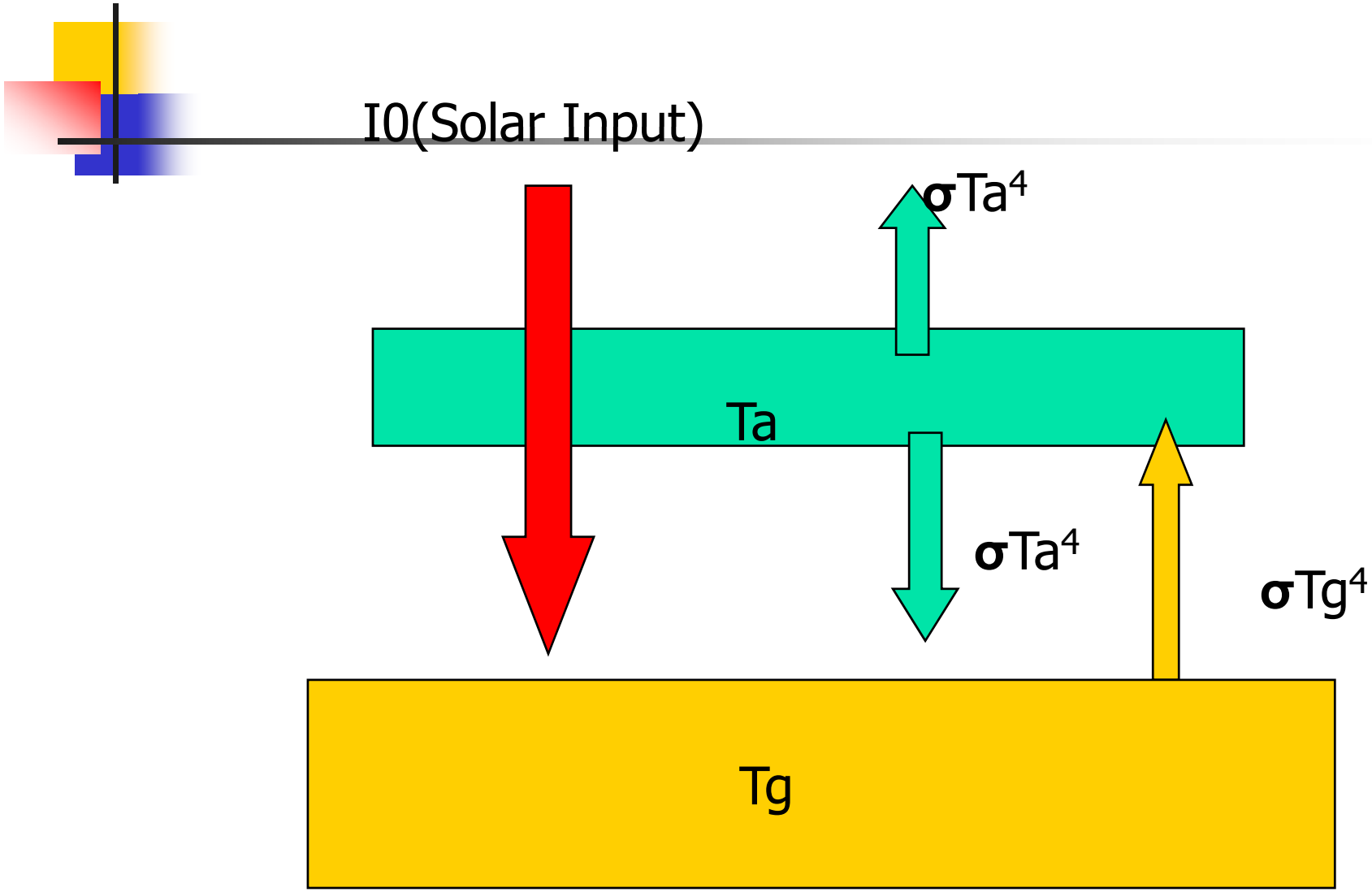
Radiation Balance(Energy Flow)



Energy flow is important.

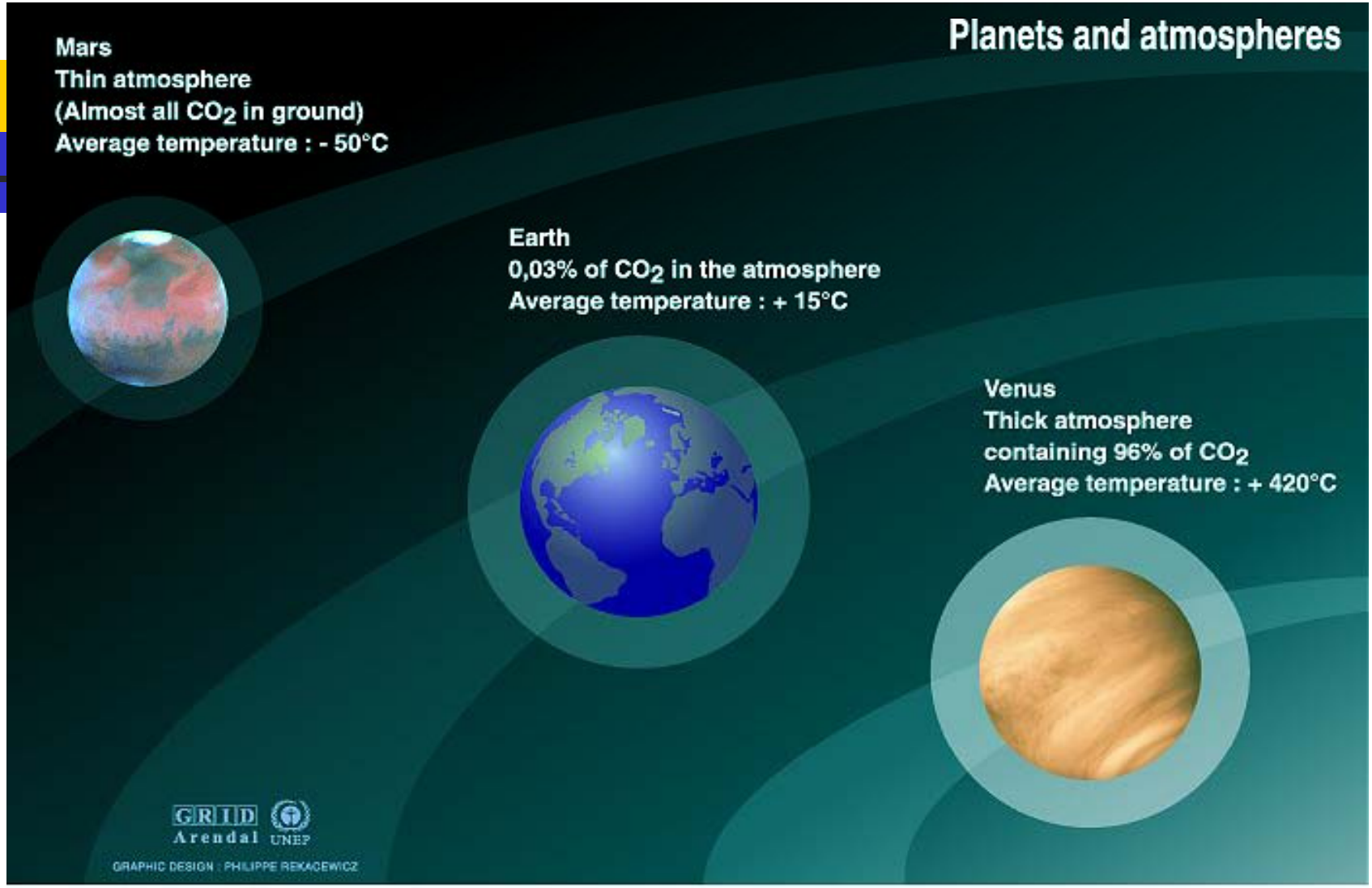
Reflectance of the Earth（planetary albedo）
＝0．3

‡ **Source: IPCC AR3**


I0(Solar Input)
σTa4
Ta
σTa4
σTg4
Tg

Energy Balance in Each Layer

- $\sigma T_a^4 = S_0$ at the top of atmosphere
- $\sigma T_g^4 = 2\sigma T_a^4$ for the atmosphere
- $S0 + \sigma T_a^4 = \sigma T_g^4$ for the surface
- $\sigma T_g^4 = 2S_0$
- Without atmosphere, $\sigma T_g^4 = S_0$
- This increase of Tg is due to the greenhouse effect of the atmosphere



Sources: Calvin J. Hamilton, Views of the solar system, www.planetscapes.com; Bill Arnett , The nine planets, a multimedia tour of the solar system, www.seds.org/billa/tnp/nineplanets.html

‡ **Source: UNEP**

The Earth is a Water Planet

- Distance from the Sun.
- 3 states of water（solid, liquid, gas）

Wikipedia

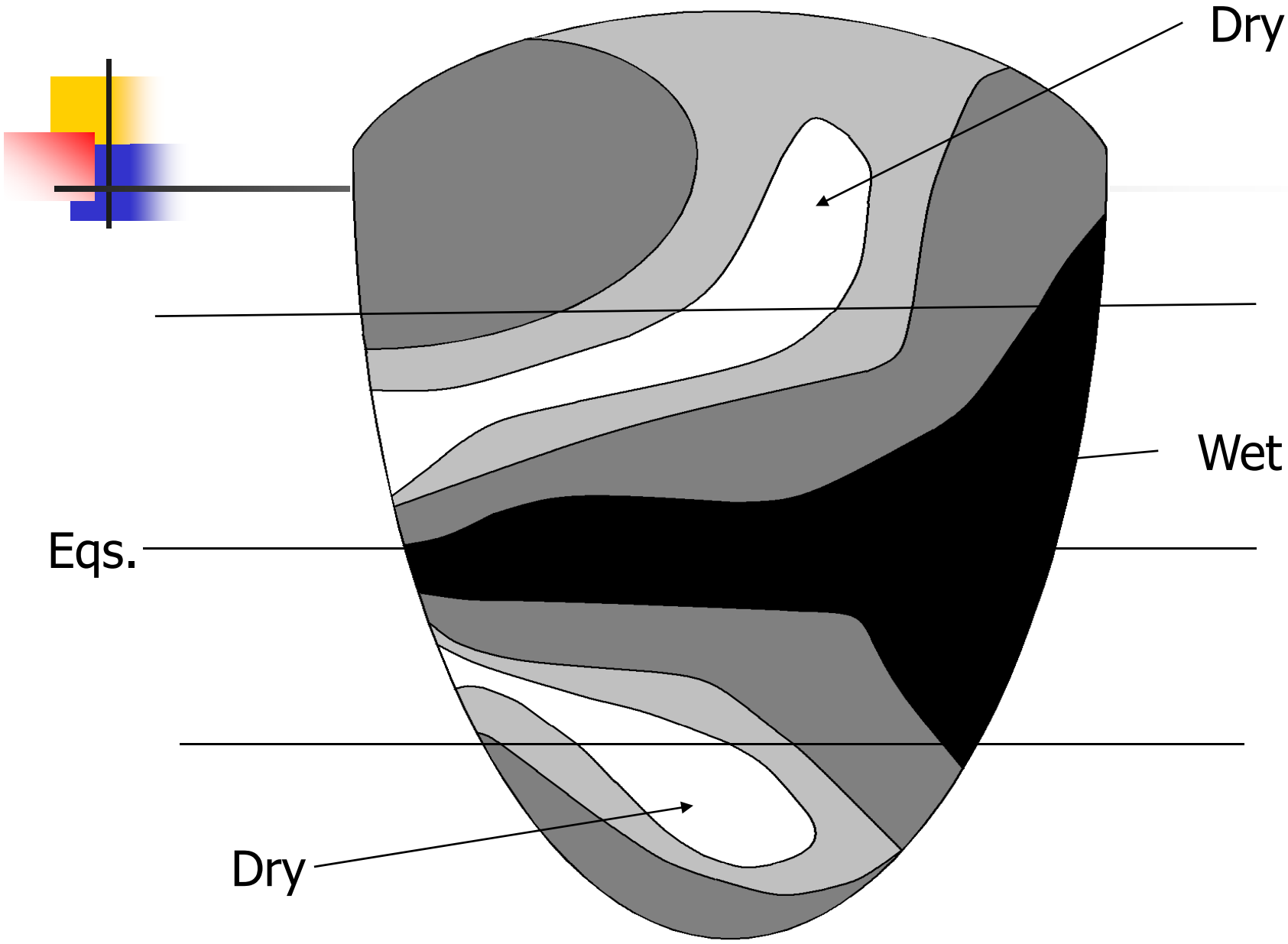
Humans seized the power of God!

The Logic of Climate Formation

- Time average of conditions of atmosphere and ocean in a certain period
- Changes in the long history of Earth

The Logic of Climate Formation

- External factors
  - Sphere, rotation, gravity, distribution in the sea and on land, solar activity
- Internal factors
  - Specific changes, ENSO, PDO, glacial stage-mid glacial stage cycle


Dry
Wet
Eqs.
Dry

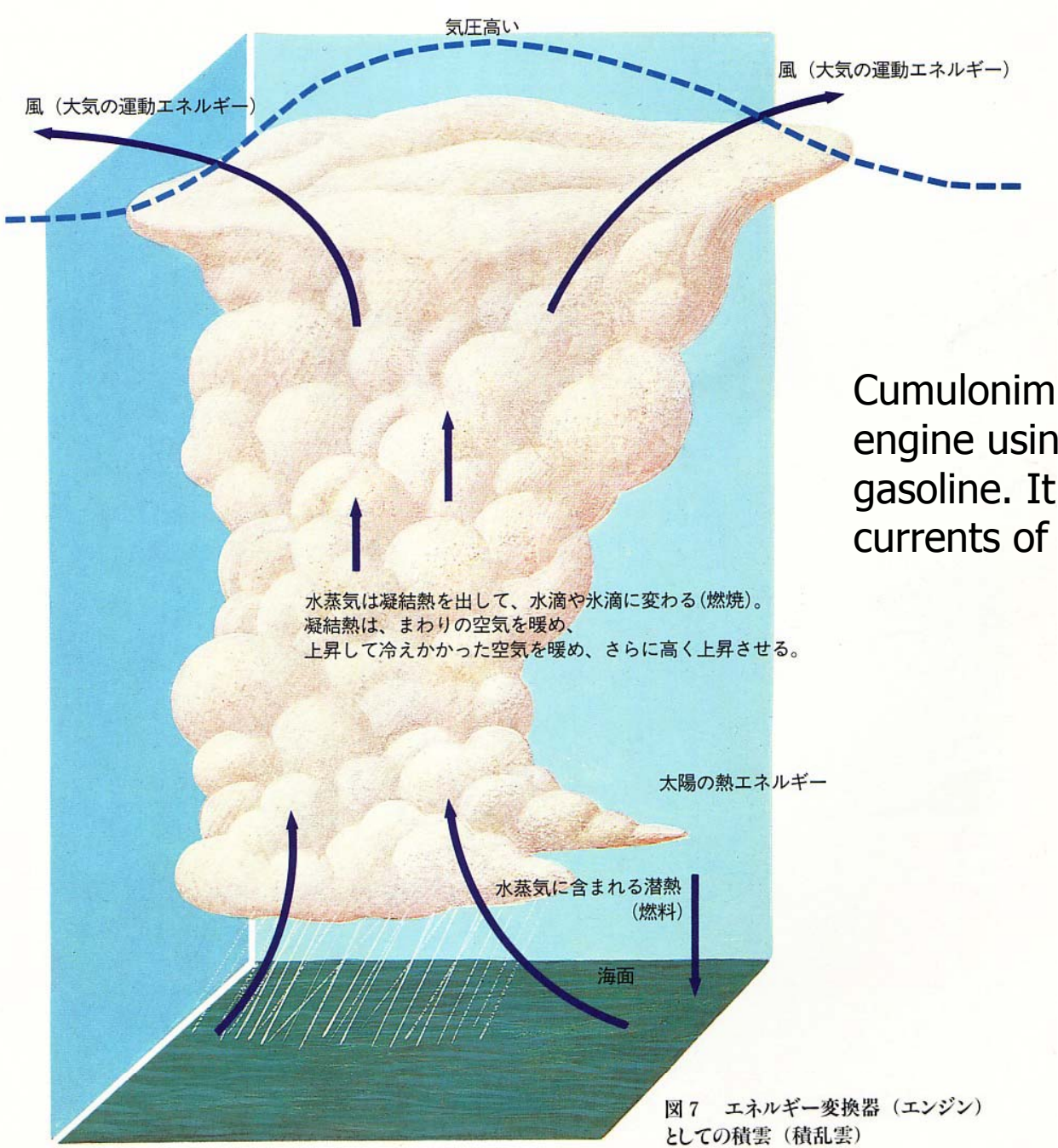
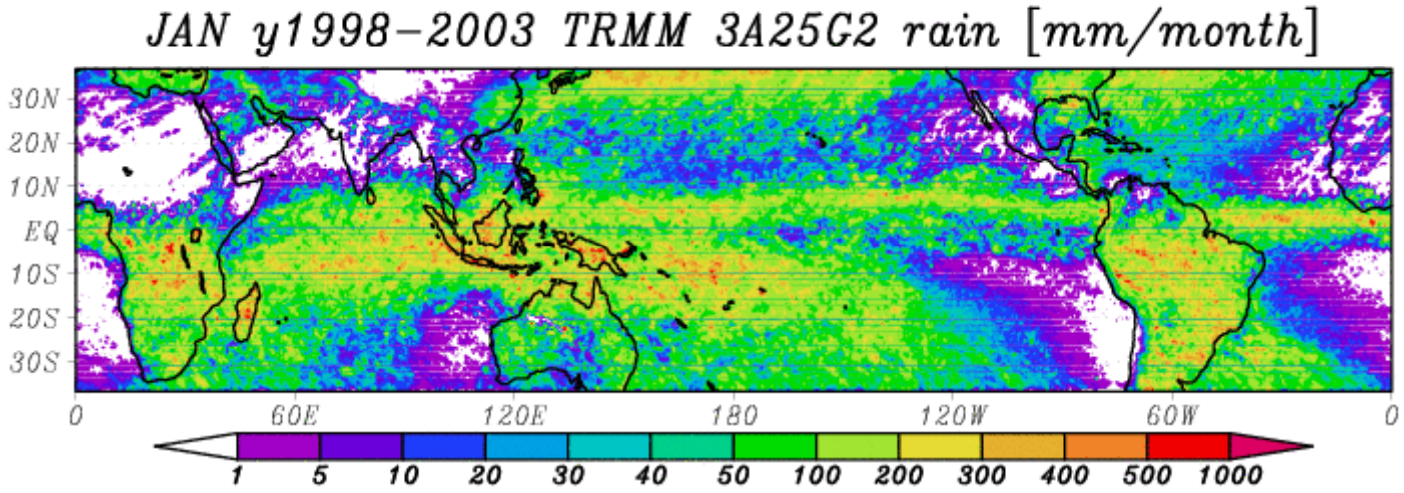


図7　エネルギー変換器（エンジン）としての積雲（積乱雲）

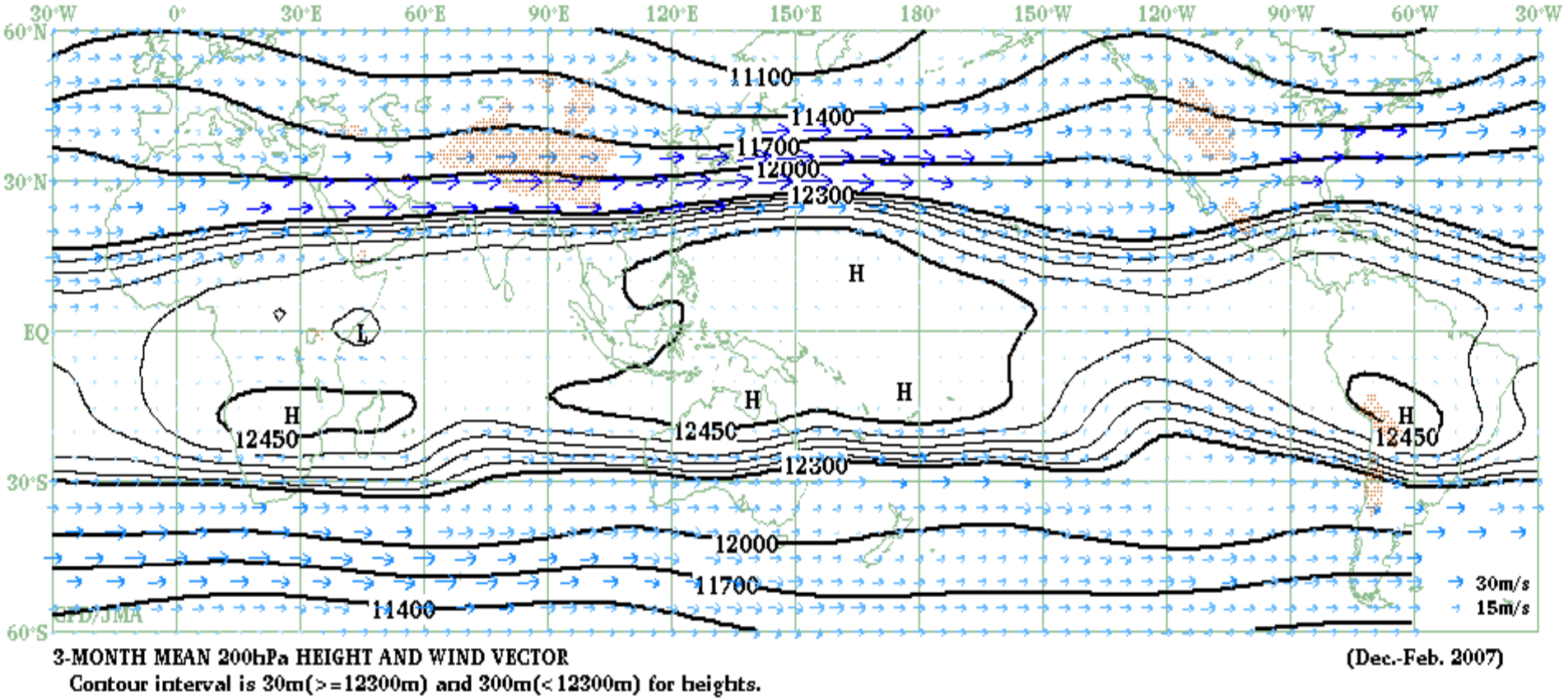
Cumulonimbus is an engine using vapor as gasoline. It forms currents of air.



Distribution of precipitation is also distribution of energy source (heat source).

These heat sources make currents of atmosphere.

Average height field in winter of 2007（Dec~ Feb）(200hPa)



‡ **Source: Japan Meteorological Agency**

Response to Heat Source

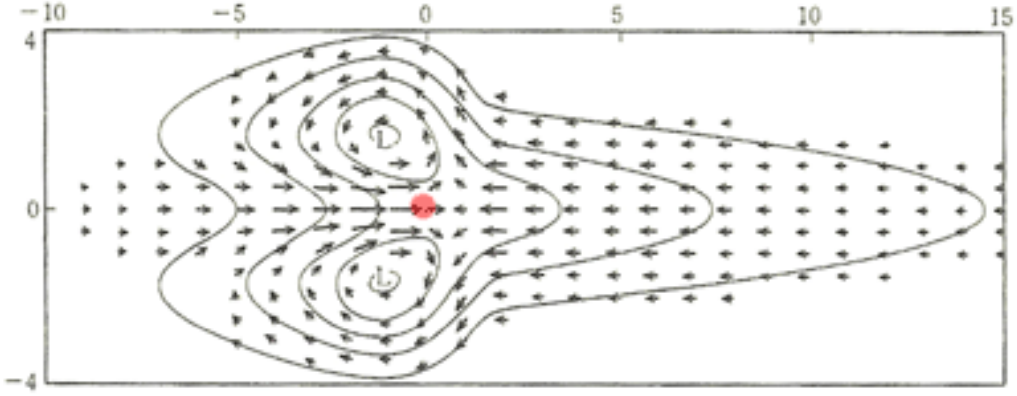


図 1 松野–ギルパターン
● 原点のところに熱源をおいたときにつくられる大気下層の風系.

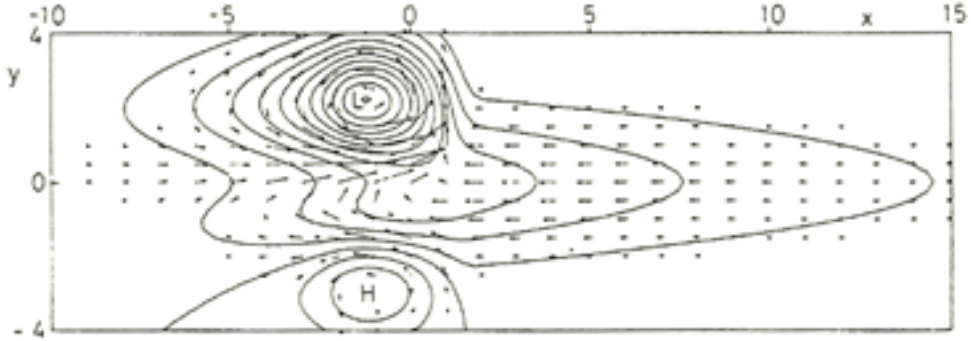
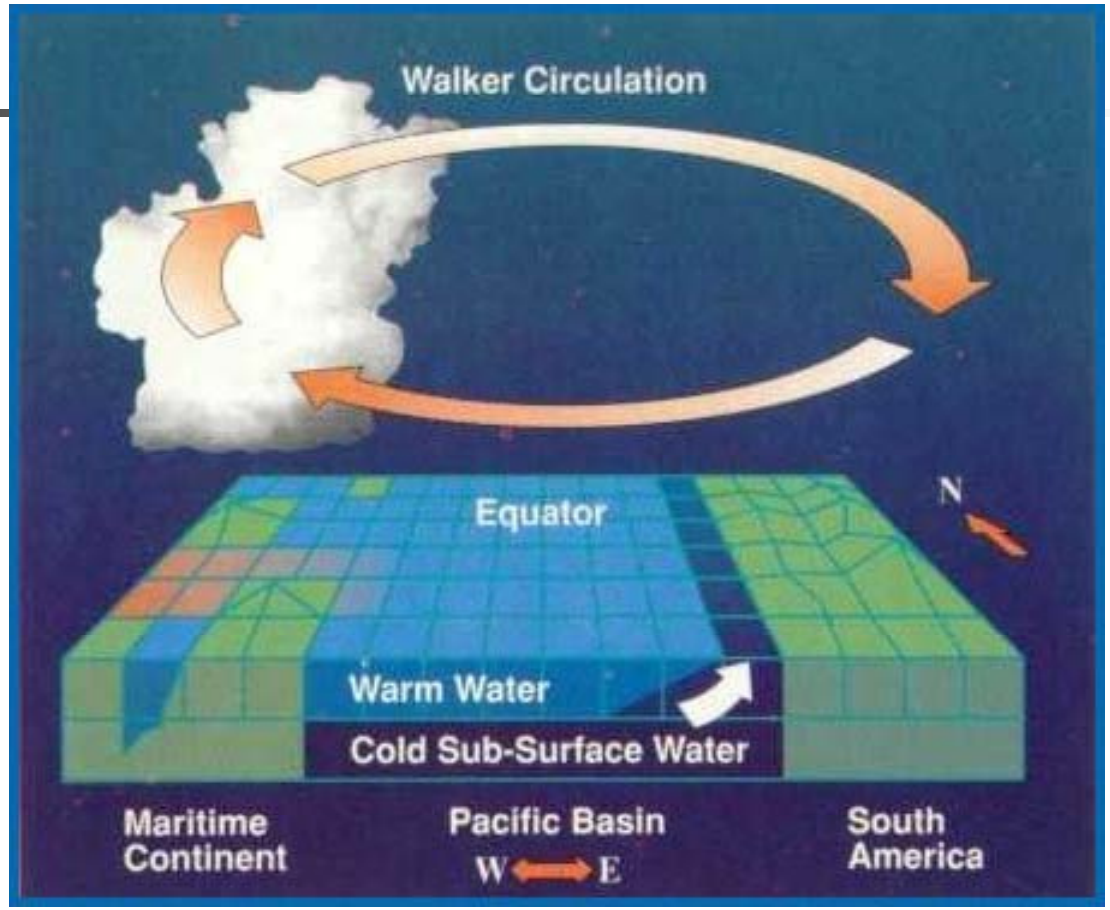


図 2 北半球熱帯域に熱源を与えたときに線形モデルから得られた大気下層の気圧と風のパターン（Gill, 1980）
横軸：経度，縦軸：緯度，縦軸の 0：赤道.

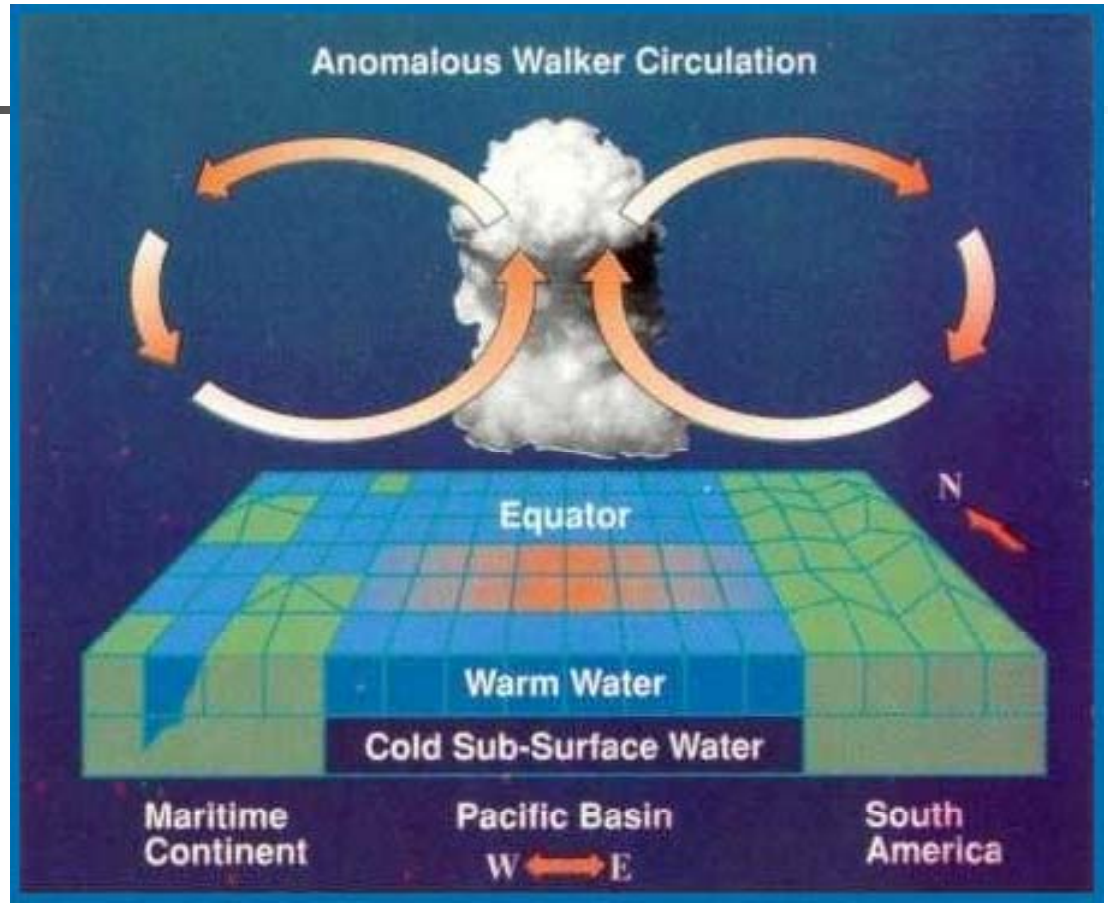
‡ Source: Iwanami Lecture
11 Theory of Changing in Weather

What if Heat Source Moves？

- When heat source, i.e. cumulonimbus moves, the current of the atmosphere changes.
- When the distribution of the water surface temperature changes, the distribution of cumulonimbus also changes.



‡ National Oceanic Atmospheric Administration



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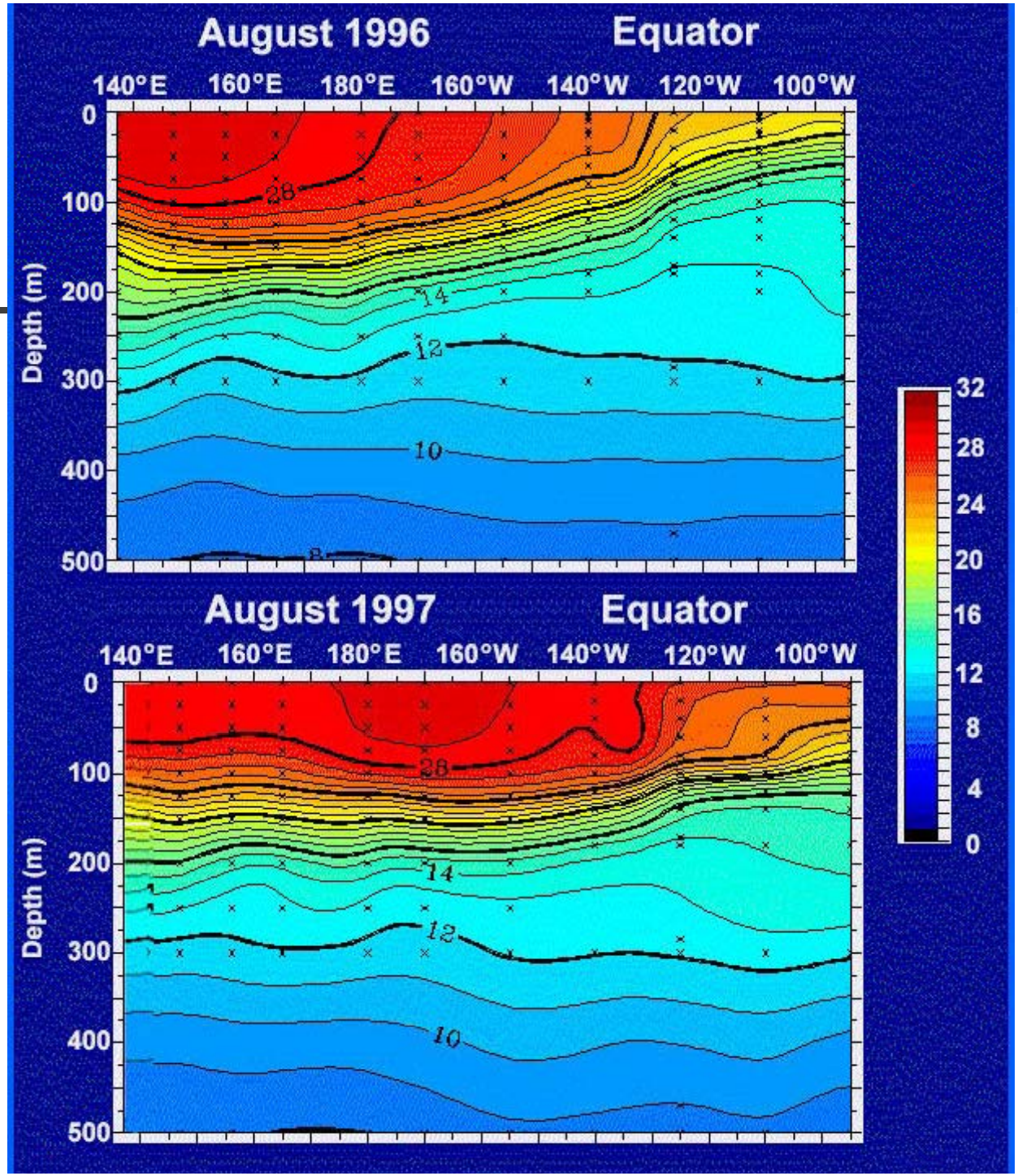

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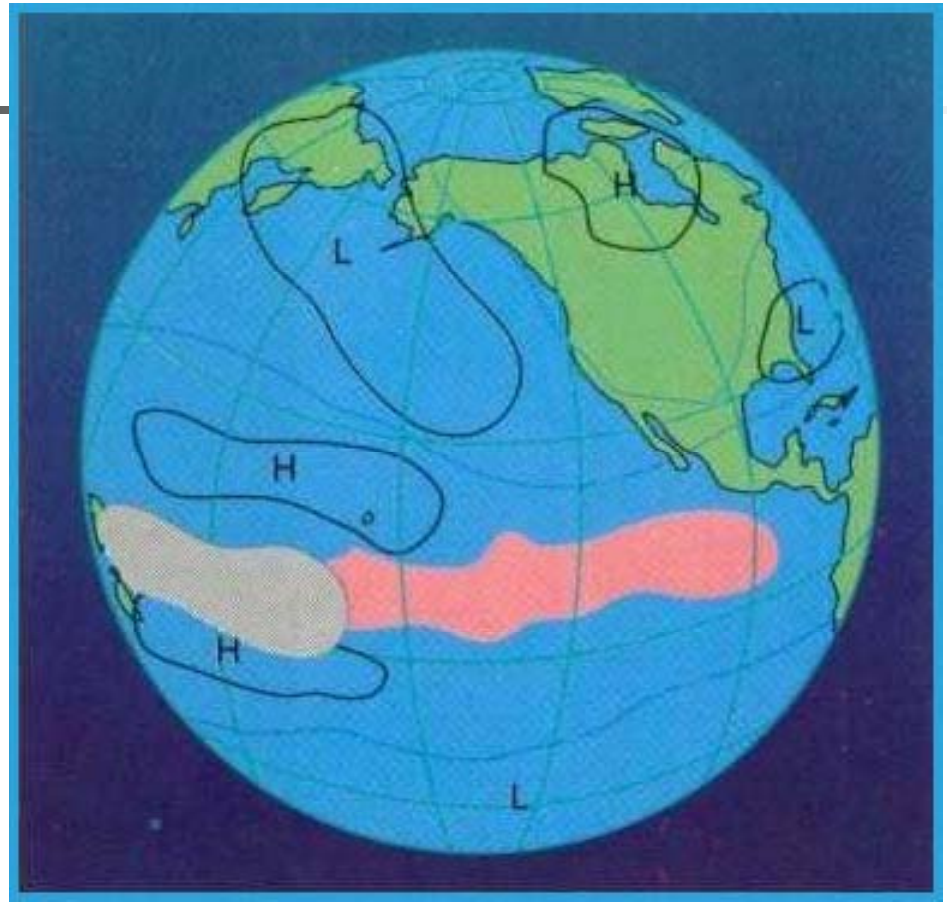

‡ National Oceanic Atmospheric Administration

Argo Project

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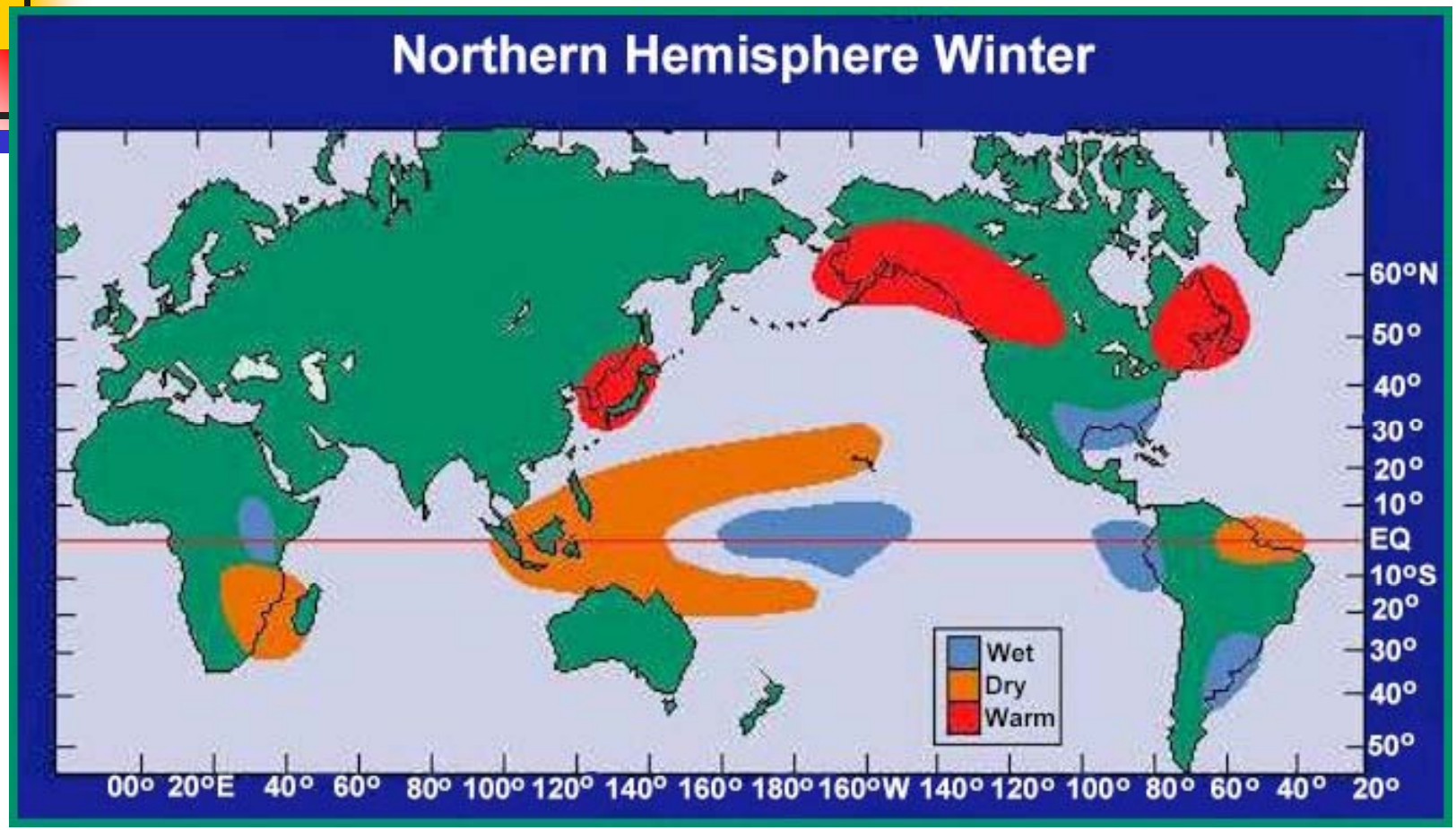

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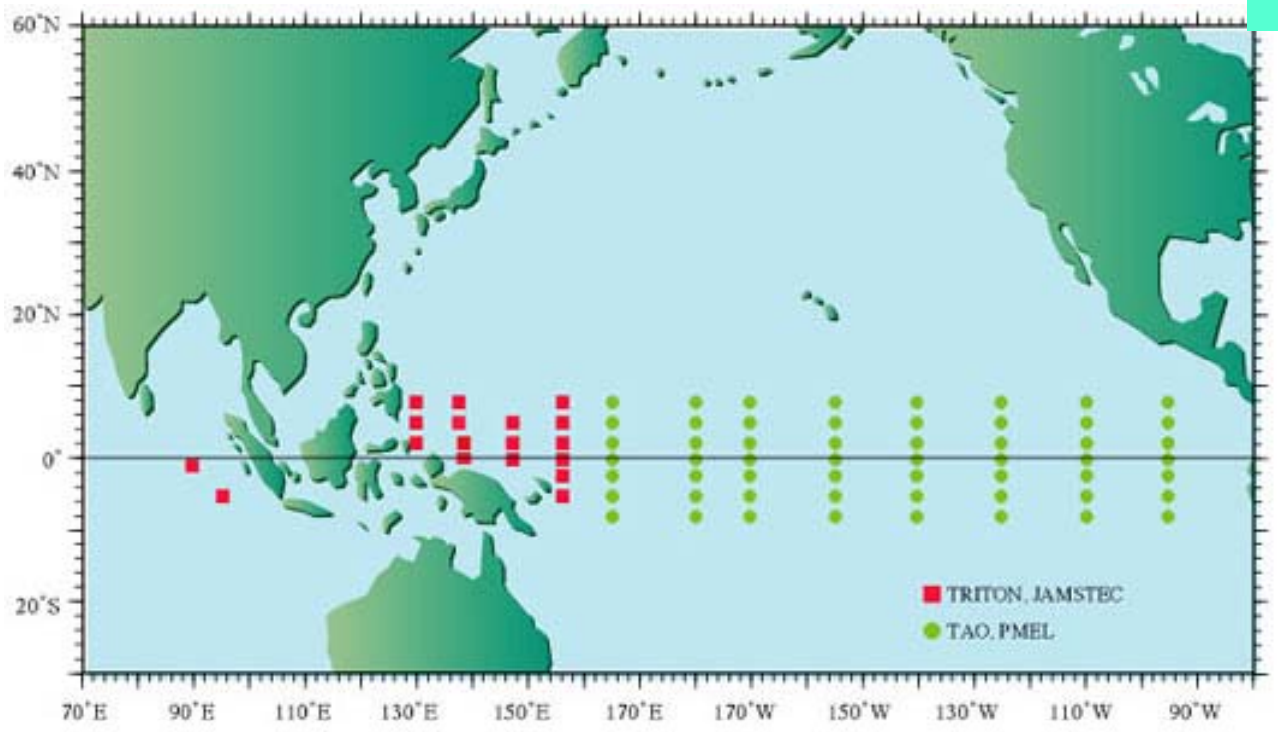

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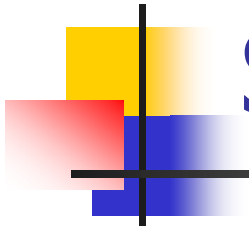

Summary

- The climate of the Earth is determined by its radiation balance.
- The greenhouse effect is important.
- When considering the Earth as a water planet, cumulus convection plays an important role.
- There are external and internal factors in climate formation.
- Changes specific to systems such as ENSO
- The climate system: coupled systems.