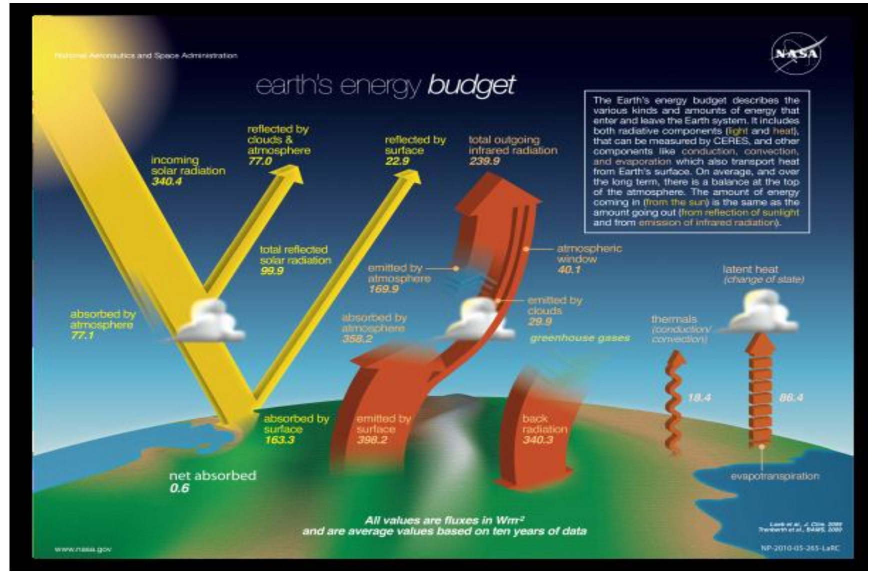
MY picks on KEY concepts Chap 1-2:



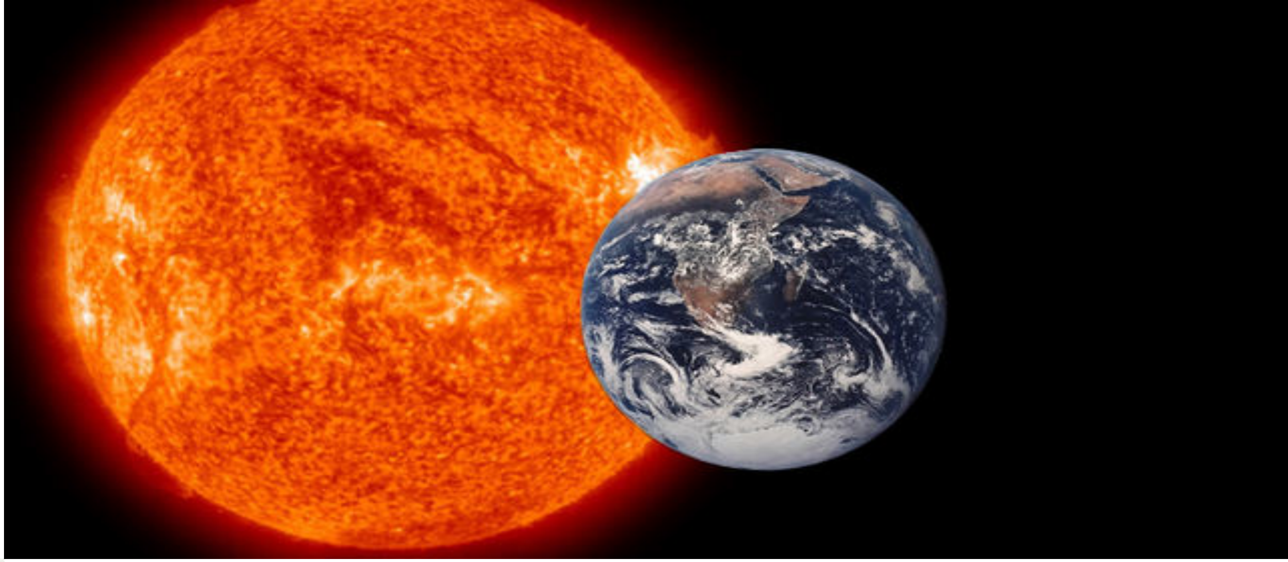
Earth Energy balance

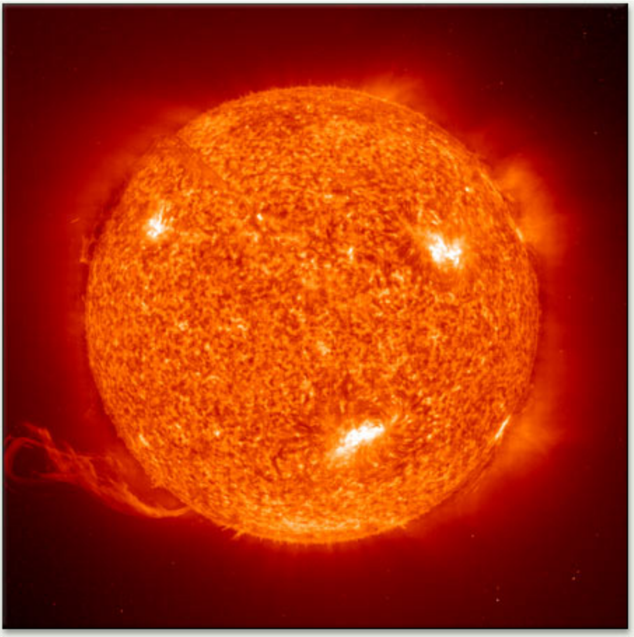
- Black body radiation
- Infrared emission
- Equilibrium Calculations of Earth’s radiation energy balance

⬇

Earth Temperature

- Assumption that Earth emits at the same temperature everywhere
- Neglected geothermal energy
- Assumed steady state





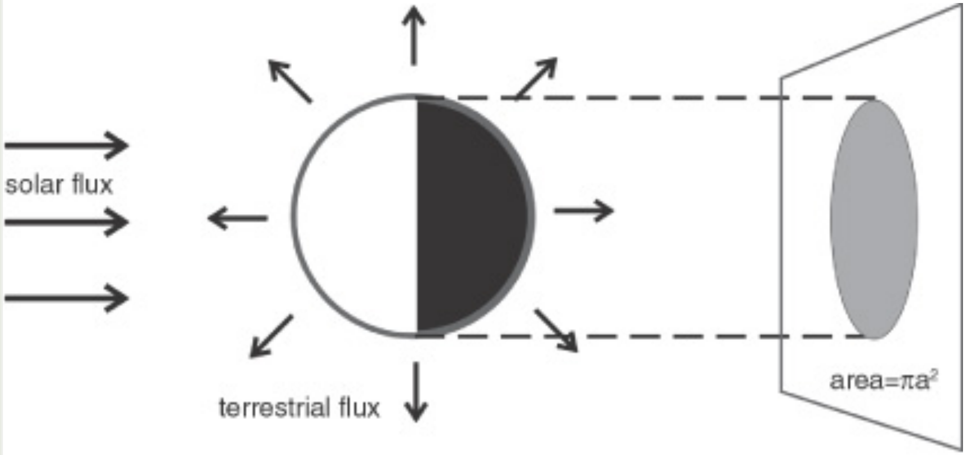


Figure 2.4: The spinning Earth is imagined to intercept solar energy over a disk of radius a and radiate terrestrial energy away isotropically from the sphere.

(Modified from Hartmann, 1994.)

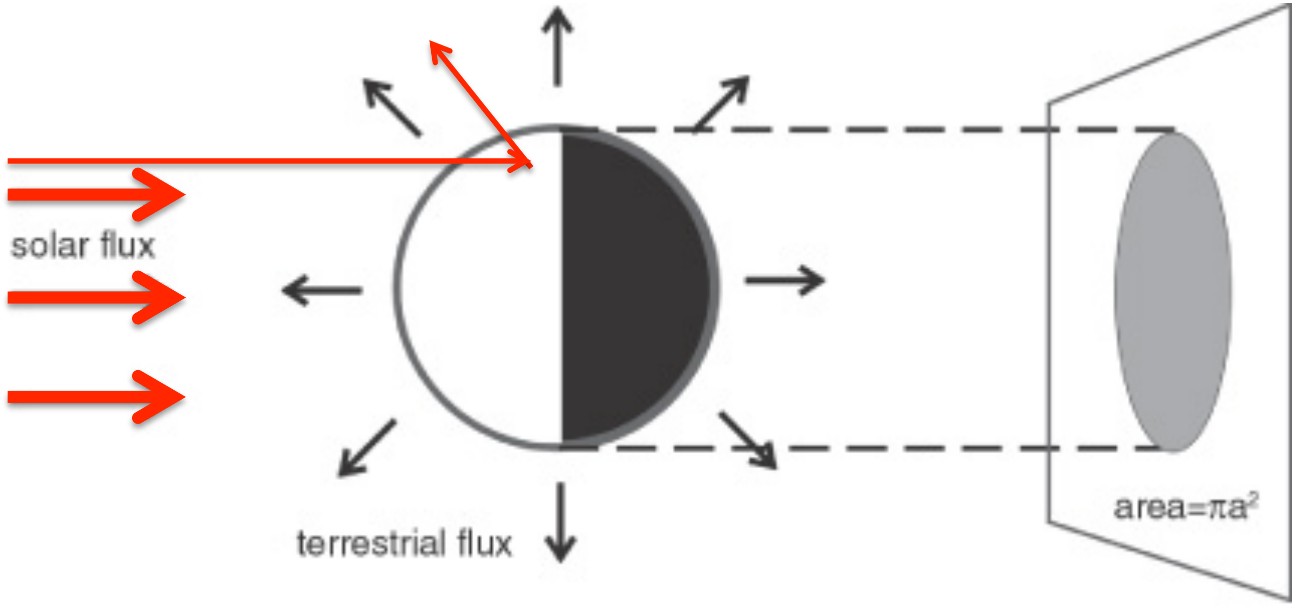


Figure 2.4: The spinning Earth is imagined to intercept solar energy over a disk of radius a and radiate terrestrial energy away isotropically from the sphere.

(Modified from Hartmann, 1994.)

incoming solar energy flux
$S_0 = 1367\ \mathrm{Wm^{-2}}$

solar power incident on the Earth =

$$S_0 \pi a^2 = 1.74 \times 10^{17}\ \mathrm{W},$$

Solar radiation absorbed by the Earth =

$$(1 - \alpha_p) S_0 \pi a^2 = 1.22 \times 10^{17}\ \mathrm{W}. \quad (2\text{-}1)$$

TABLE 2.1. Properties of some of the planets. S_0 is the solar constant at a distance r from the Sun, α_p is the planetary albedo, T_e is the emission temperature computed from Eq. 2 4, T_m is the measured emission temperature, and T_s is the global mean surface temperature. The rotation period, τ, is given in Earth days.

	r 10^9 m	S_0 W m^{-2}	α_p	T_e K	T_m K	T_s K	τ Earth days
Venus	108	2632	0.77	227	230	760	243
Earth	150	1367	0.30	255	250	288	1.00
Mars	228	589	0.24	211	220	230	1.03
Jupiter	780	51	0.51	103	130	134	0.41

TABLE 2.1. Properties of some of the planets. S_0 is the solar constant at a distance r from the Sun, α_p is the planetary albedo, T_e is the emission temperature computed from Eq. 2-4, T_m is the measured emission temperature, and T_s is the global mean surface temperature. The rotation period, τ, is given in Earth days.

Incoming solar energy flux = S_0

S_0 depends on Sun diameter, Sun Temperature (see Bolzamann Law) and distance from a planet

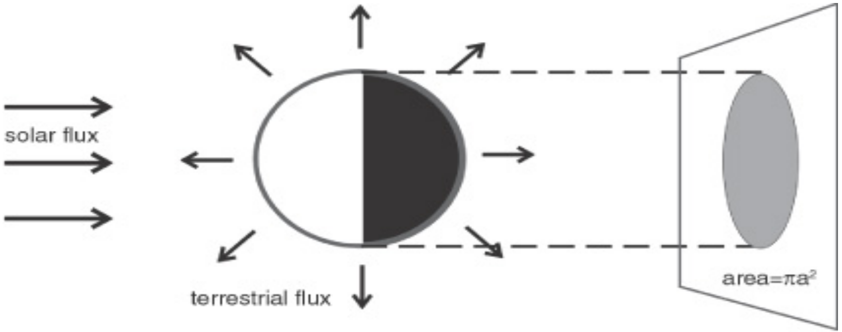


Figure 2.4: The spinning Earth is imagined to intercept solar energy over a disk of radius a and radiate terrestrial energy away isotropically from the sphere.

(Modified from Hartmann, 1994.)

$$\lambda_m T = 2897.9[\mu m K]$$

Stefan-Boltzmann law gives:

$$\text{Emitted radiation per unit area} = \sigma T_e^4 \quad (2\text{-}2)$$

where $\sigma = 5.67 \times 10^{-8} \mathrm{W\,m^{-2}\,K^{-4}}$ is the Stefan-Boltzmann constant. So

$$\text{Emitted terrestrial radiation} = 4\pi a^2 \sigma T_e^4. \quad (2\text{-}3)$$

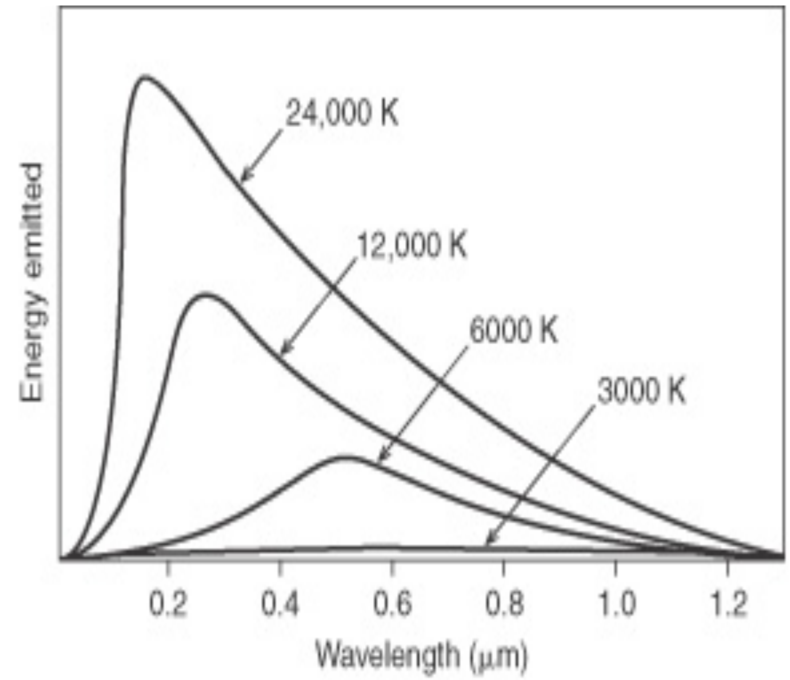


Figure 2.3: The energy emitted at different wavelengths for blackbodies at several temperatures. The function $B_\lambda (T)$, Eq. A-1, is plotted.

Hp: All the sphere emits equally

Steady state
Assumption no atmosphere

- Absorbed Earth radiation = emitted Earth radiation (2.1 + 2.3)

with the assumption that a fraction α_p = 0.30 of the incoming solar radiation at the Earth is reflected back to space

Equating Eq. 2-1 with Eq. 2-3 gives

$$T_e = \left[\frac{S_0(1-\alpha_p)}{4\sigma}\right]^{1/4}. \qquad (2\text{-}4)$$

T_e = 255 K = - 18 °C

Pretty low .. What is missing?

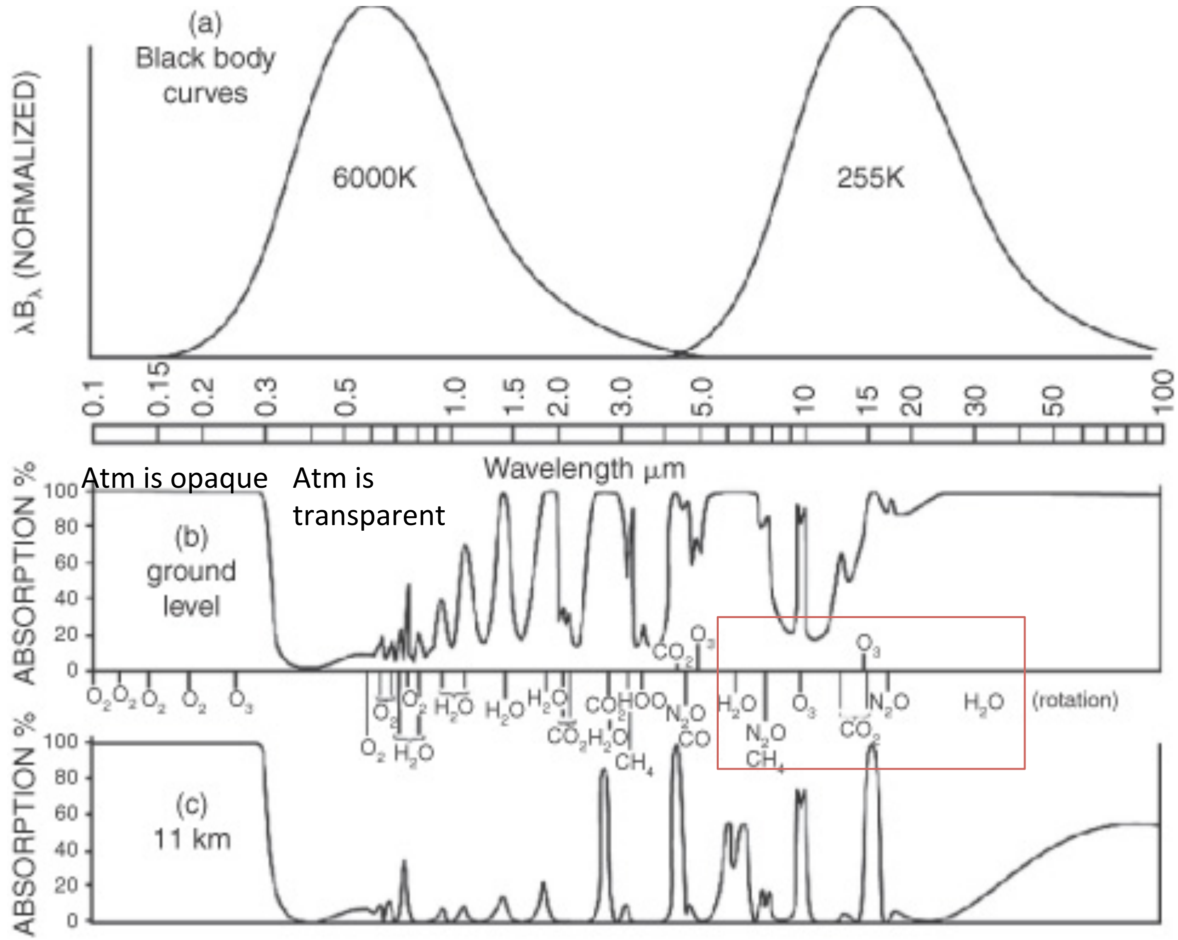


Figure 2.6: (a) The normalized blackbody emission spectra, $T\text{-}4\lambda\ B_{\lambda}$, for the Sun ($T = 6000$ K) and Earth ($T = 255$ K) as a function of ln λ (top), where $B\ \lambda$ is the blackbody function (see Eq. A-2) and λ is the wavelength (see Appendix A.1.1 for further discussion). (b) The fraction of radiation absorbed while passing from the ground to the top of the atmosphere as a function of wavelength. (c) The fraction of radiation absorbed from the tropopause (typically at a height of 11 km) to the top of the atmosphere as a function of wavelength. The atmospheric molecules contributing the important absorption features at each frequency are also indicated. After Goody and Yung (1989).

IR wavelengths Absorbed by atm compounds (greenhouse gases)

Not 100% abs

A leaky greenhouse

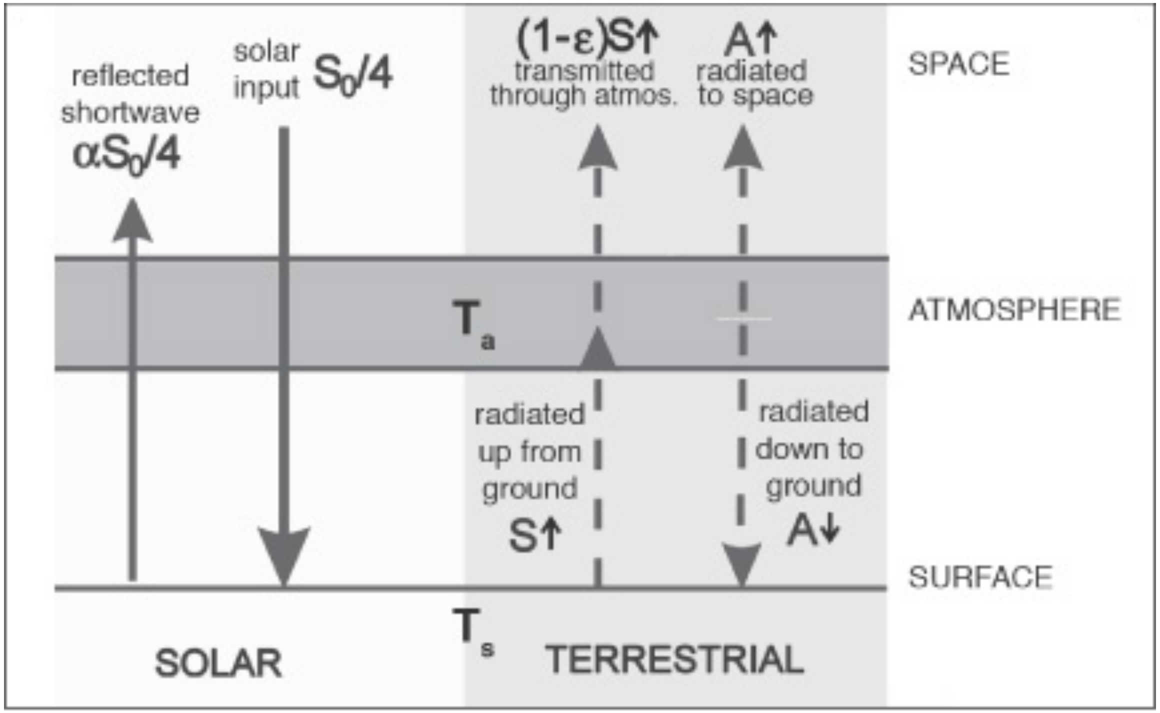


Figure 2.8: A leaky greenhouse. In contrast to Fig. 2.7, the atmosphere now absorbs only a fraction, ε, of the terrestrial radiation upwelling from the ground.

A leaky greenhouse

$$T_s = \left(\frac{2}{2-\varepsilon}\right)^{\frac{1}{4}} T_e$$

Limit cases $\varepsilon \longrightarrow 1$ (opaque) $\qquad T_s = 2^{1/4} T_e$

$\varepsilon \longrightarrow 0$ (transparent) $\qquad T_s = T_e$ — the 'no atmosphere' case.

In general $0 < \varepsilon < 1$

$$\underbrace{T_e}_{255} < T_s < \underbrace{2^{\frac{1}{4}} T_e}_{303}$$

For ε=0.78,

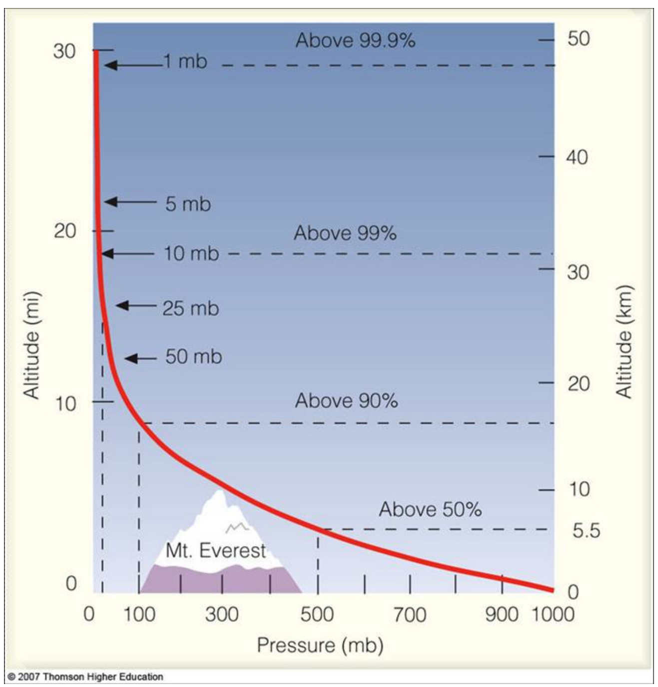
$T_s = 288.3\ \mathrm{K}$ Close to measurements!

My picks KEY concepts Chap 3

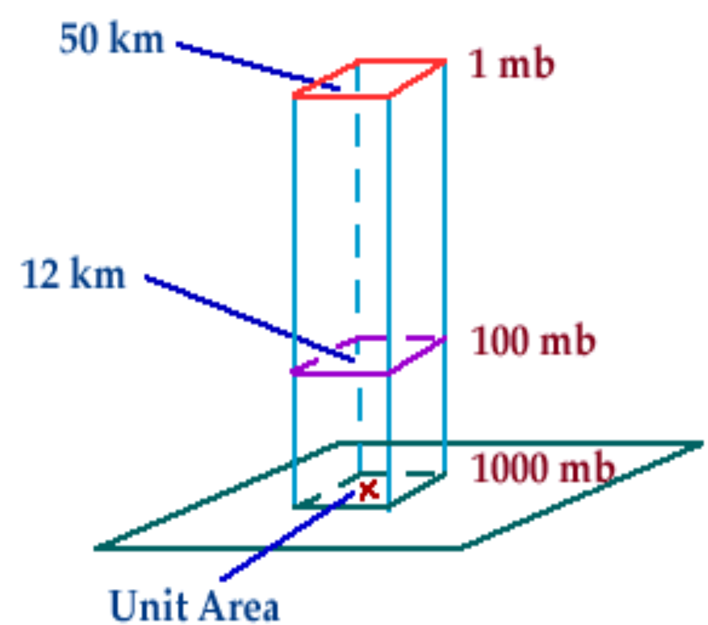
hydrostatic equation

Pascal discovers that the pressure at each level has to push up to support the weight of the air above!

https://climate.ncsu.edu/edu/k12/.AtmStructure



http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/prs/hght.rxml

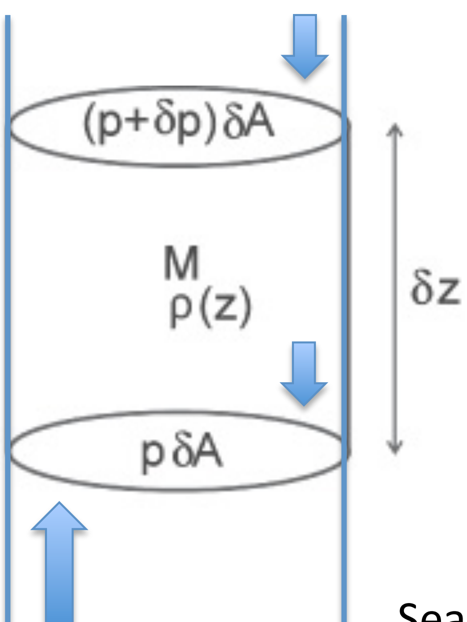


Air has weight

- Hydrostatic balance/static system: (applied to fluid – no vertical acceleration). At rest, or when the flow velocity at each point is constant over time

Column of air

Above the atm



Sea level

$$P_{bottom} - P_{top} = \rho g \Delta z$$

i) gravitational force $F_g = -gM = -g\rho\delta A\delta z$,

ii) pressure force acting at the top face, $F_T = -(p + \delta p)\,\delta A$, and

iii) pressure force acting at the bottom face, $F_B = p\delta A$.

Setting the net force $F_g + F_T + F_B$ to zero gives $\delta p + g\rho\delta z = 0$, and using Eq. 3-2 we obtain

$$\frac{\partial p}{\partial z} + g\rho = 0. \qquad (3\text{-}3)$$

$$p(z) = g\int_z^\infty \rho\, dz. \qquad (3\text{-}4)$$

Perfect gas law $\quad p = \rho RT$

Hydrostatic equation $\quad \dfrac{\partial p}{\partial z} = -\dfrac{gp}{RT}$

What is total atmospheric mass?

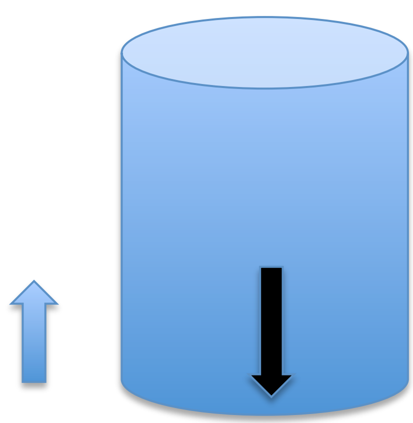
Hydrostatic balance:
Weight of air column = pressure force on a surface

$$Mg = pA$$

$$M / A = p / g$$

where
M=total atmospheric mass
g=acceleration const.=9.8 m/s
P=Pressure at the surface=101300 Pa
A=surface area of Earth =4pir^2

In one square meter 10tons of air!
Total mass=54*10^{17}



MY picks on KEY concepts on Chap 4

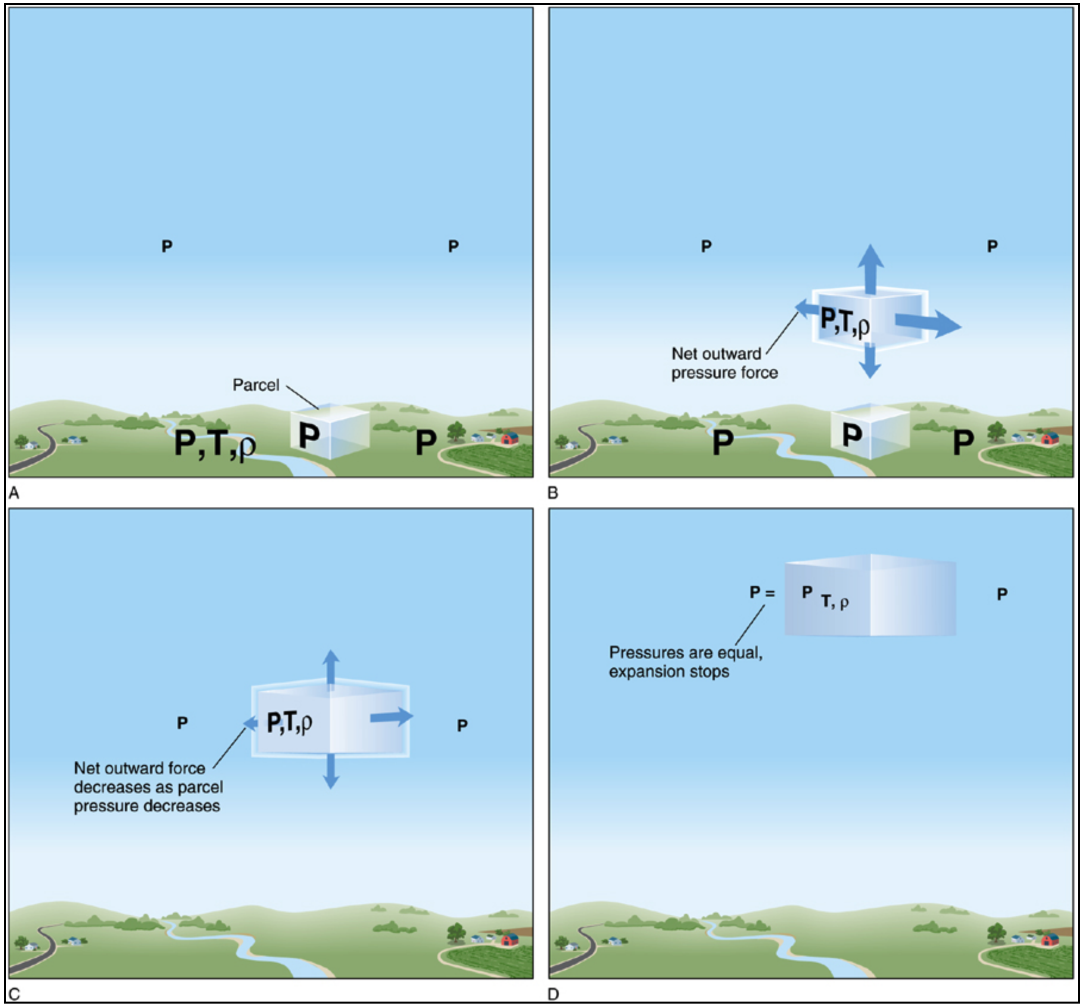
a. air parcel theory, adiabatic processes
b. how do we define/determine atmospheric stability?

UPWARD MOTION AS A COOLING MECHANISM

Important Terms:

air parcel = small portion of air characterized by its T, p and ρ

adiabatic process = no exchange of heat energy between air parcel and surrounding environment

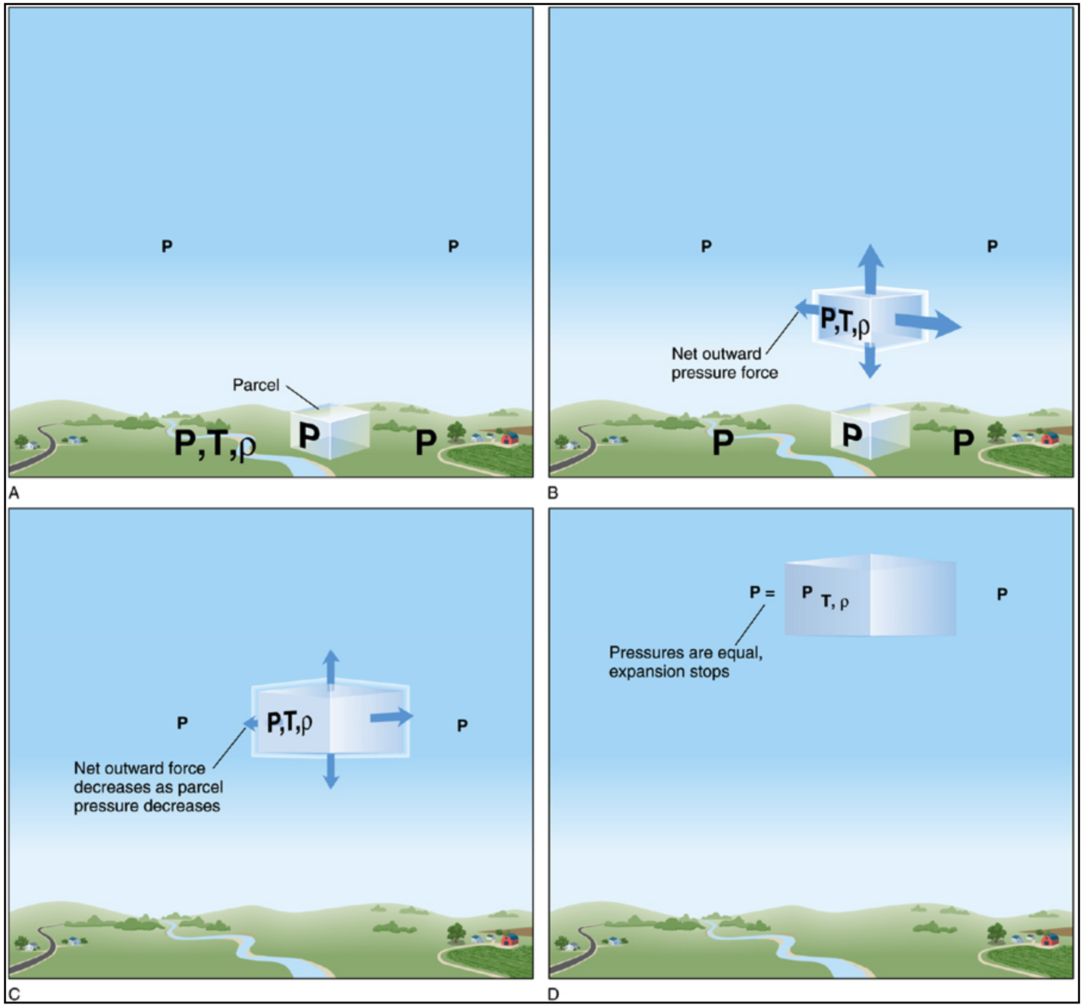


DLA Fig. 5.4

UPWARD MOTION AS A COOLING MECHANISM

1. Same characteristics as surrounding air
2. Parcel expands, density decreases
3. Thermal energy is used to expand the volume of the air parcel ➔ T decreases
4. Expansion stops once air parcel pressure is equal to surrounding air and expansion ceases

dry adiabatic lapse rate = 9.8 °C / km



DLA Fig. 5.4

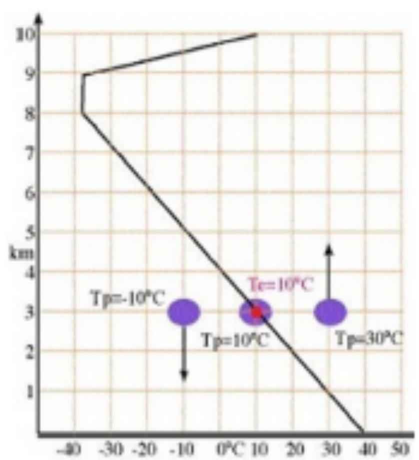
Parcel Buoyancy

$$b' = g\frac{\rho_{env} - \rho_{parcel}}{\rho_{parcel}} = g\frac{T_{parcel} - T_{env}}{T_{env}}$$

Holton Eq. 9.46

$b' > 0$

- parcel air is **less** dense than environment air
- parcel is **warmer** than environmental air
- positively buoyant ➔ parcel will **rise**



$b' < 0$

- parcel air is **more** dense than environment air
- Parcel is **colder** than environmental air
- negatively buoyant ➔ parcel will **sink**

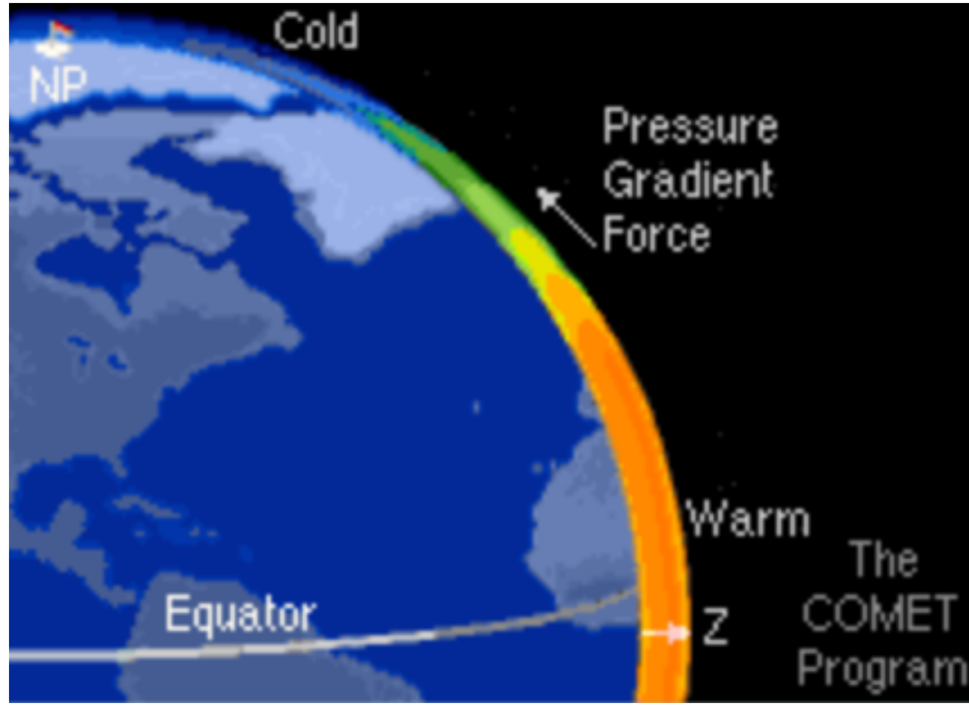
MY picks on KEY concepts on Chap 5.

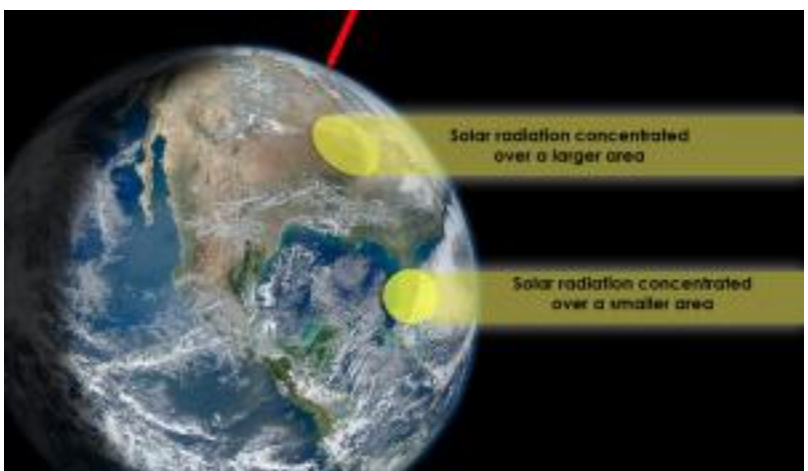
Understand the concept of radiation balance between intake and loss of energy by the earth and atmosphere

- **Observed climatology of atmospheric temperature, pressure, humidity, ad wind.**

Energy density min at NP

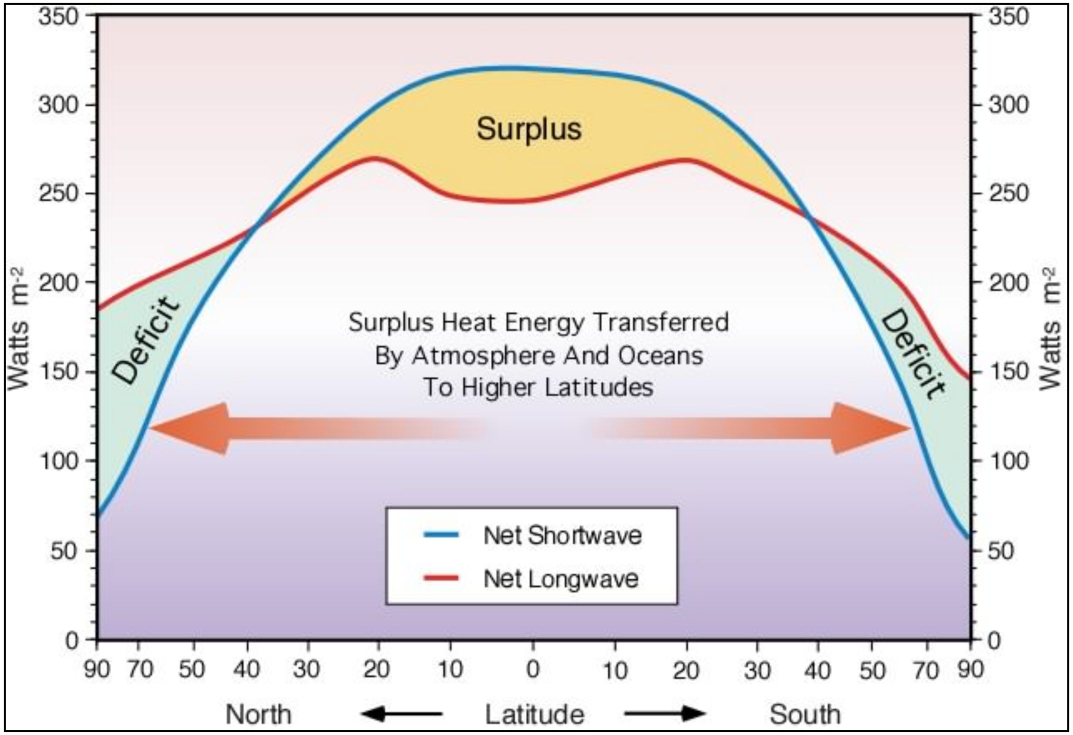
Energy density max at EQ

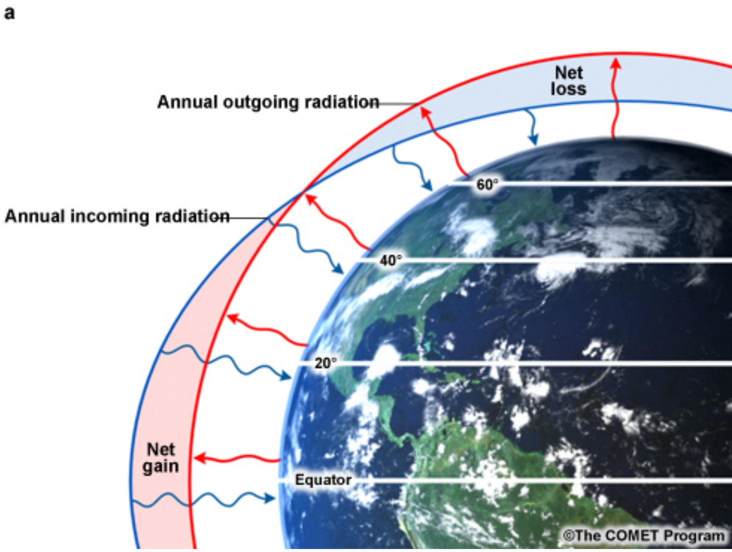




http://www.ces.fau.edu/nasa/module-3/why-does-temperature-vary/angle-of-the-sun.php

The General Circulation

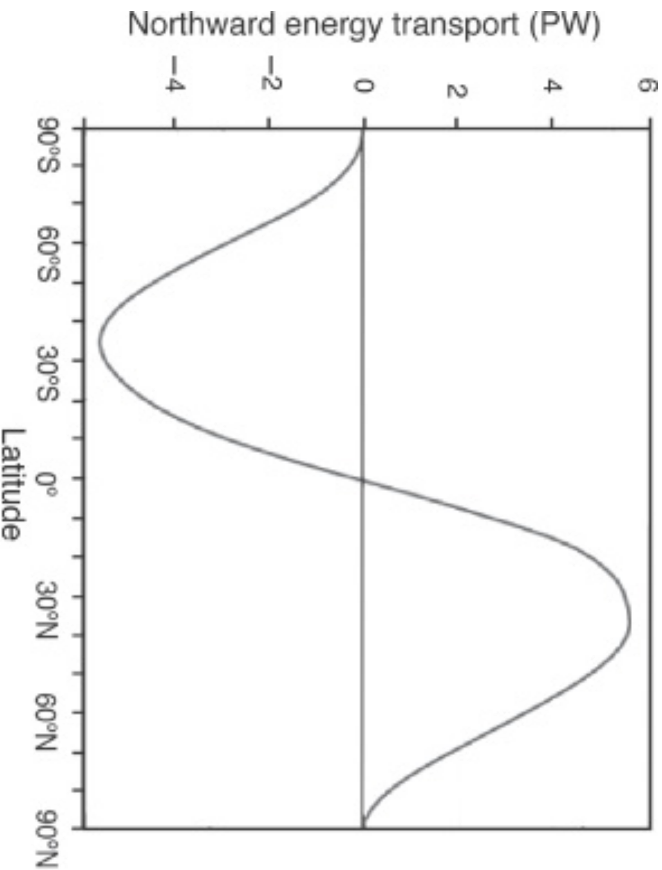


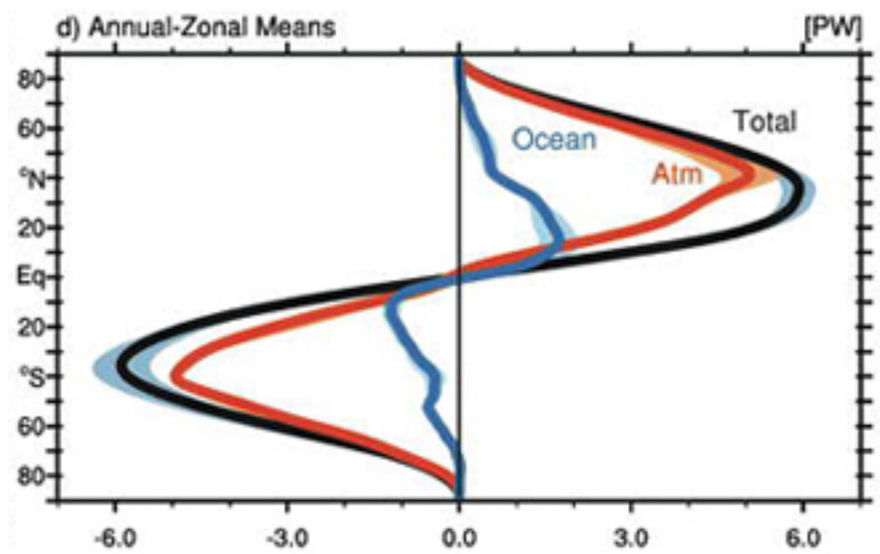


The role of the general circulation is to redistribute energy from the tropics (surplus) to the poles (deficit)

Meridional transport -> local energy balance -> transport of energy

Annual Mean Meridional Energy Transport

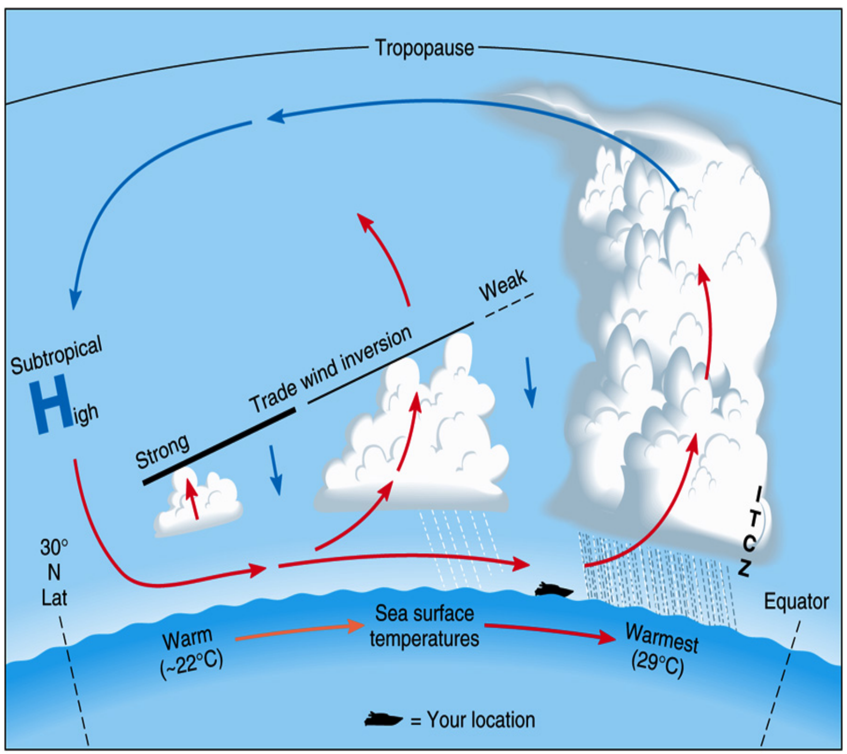




Fasullo and Trenberth 2008

The General Circulation - Tropics

The Hadley circulation describes a large (almost half the surface of the Earth) thermal circulation



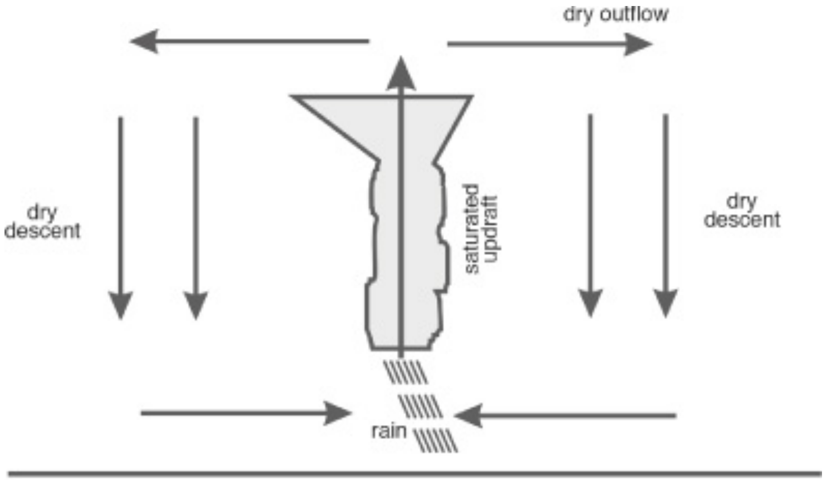


Figure 5.18: Drying due to convection. Within the updraft, air becomes saturated and excess water is rained out. The descending air is very dry. Because the region of ascent is rather narrow and the descent broad, convection acts as a drying agent for the atmosphere as a whole.

- With updraft air became saturated -> producing precipitation
- Top cloud -> lower T than ground -> lost most its water

Moist air

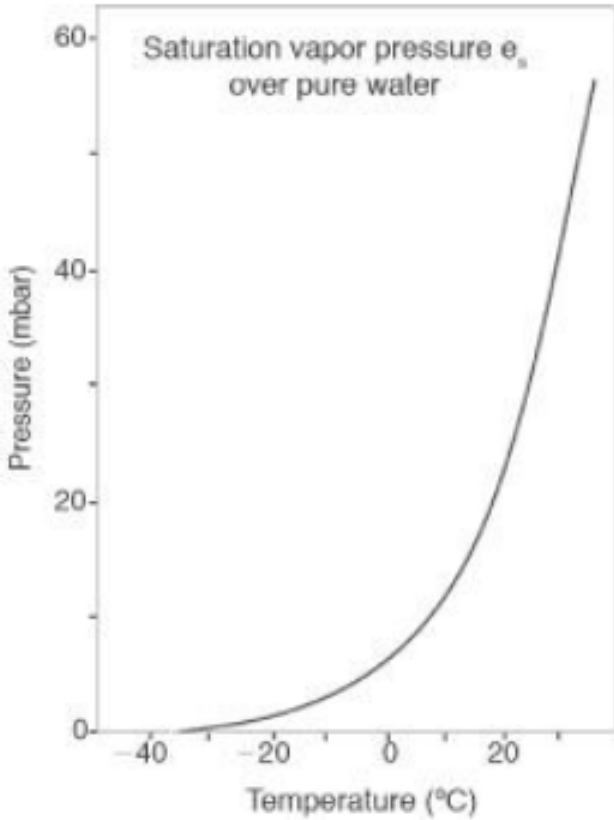
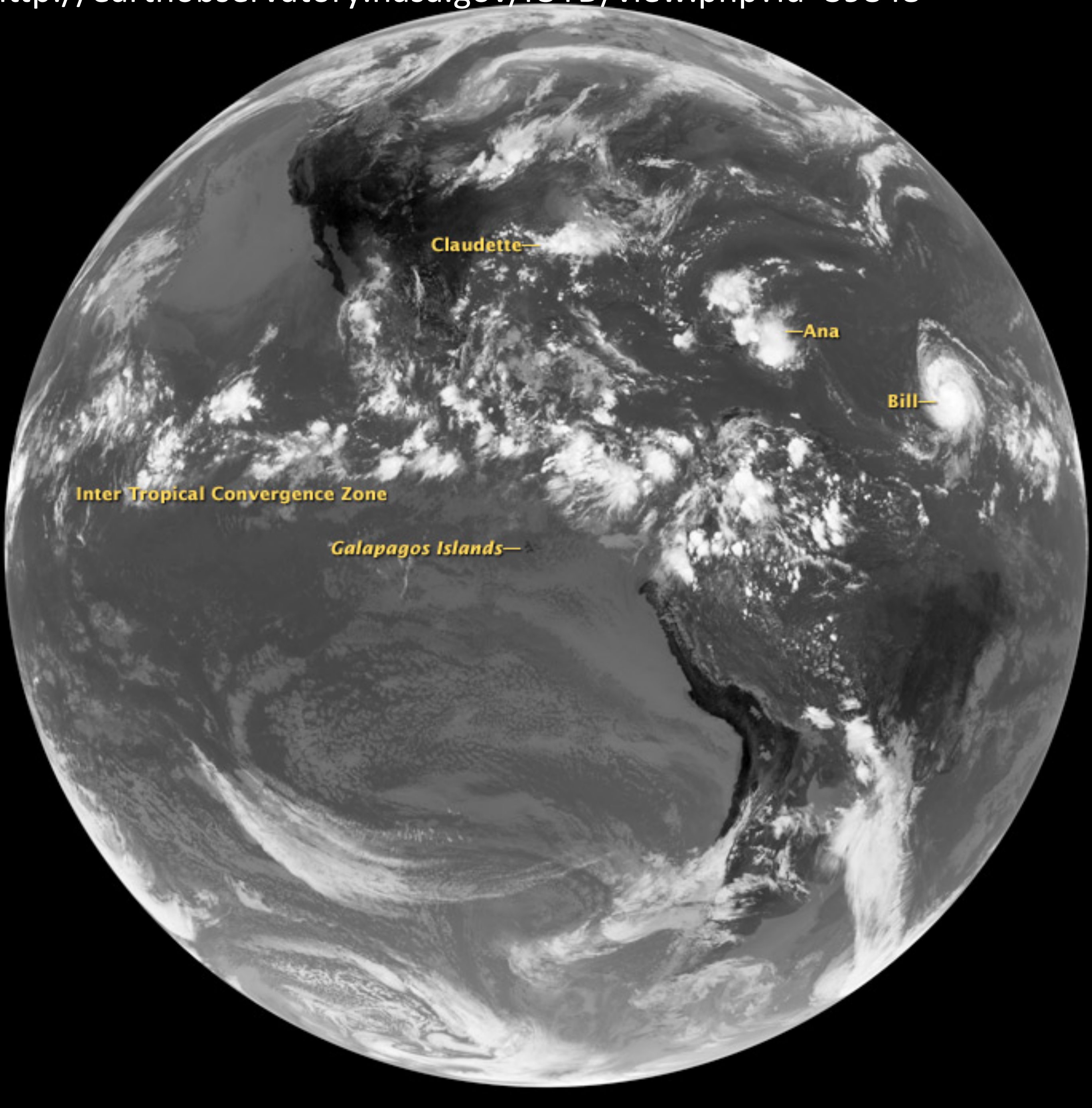


Figure 1.5: Saturation vapor pressure e_s (in mbar) as a function of T in °C (solid curve).

(From Wallace & Hobbs, (2006).)

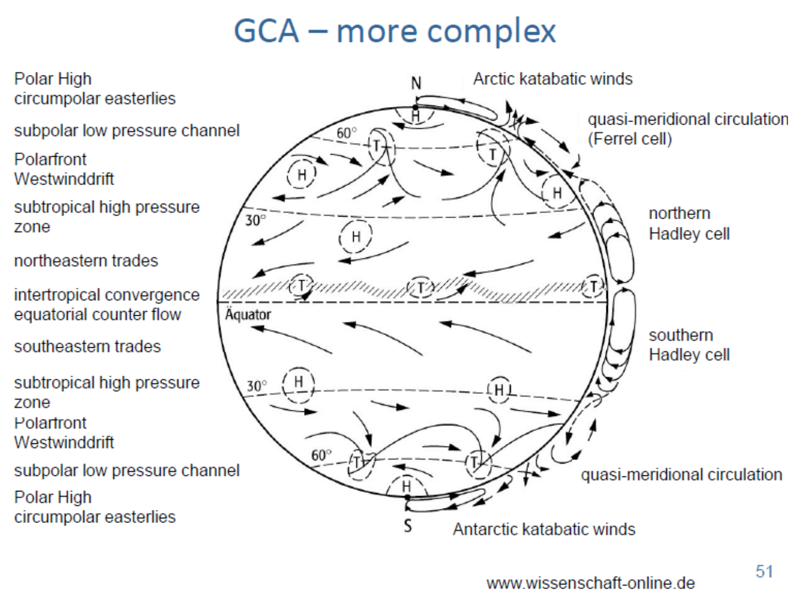
- Moisture content decays rapidly with height
- The tropics more moist than polar regions
- Clouds form and precipitation occurs when moist air is cooled
  - Rising air (clouds)
  - Radiative cooling (fog)

http://earthobservatory.nasa.gov/IOTD/view.php?id=39848



MY picks on KEY concepts first part of Chap 12

- El Niño Southern Oscillation (ENSO)
- North Atlantic Oscillation (NAO)
- How do they affect climate?



NORMAL CONDITIONS

Normally a warm pool of ocean water builds up in the western equatorial Pacific Ocean, kept at bay from the trade winds, blowing east to west

The easterly trade winds are driven by surface pressure pattern of lower pressure in the western Pacific and higher pressure in the eastern pacific.

Normal Conditions

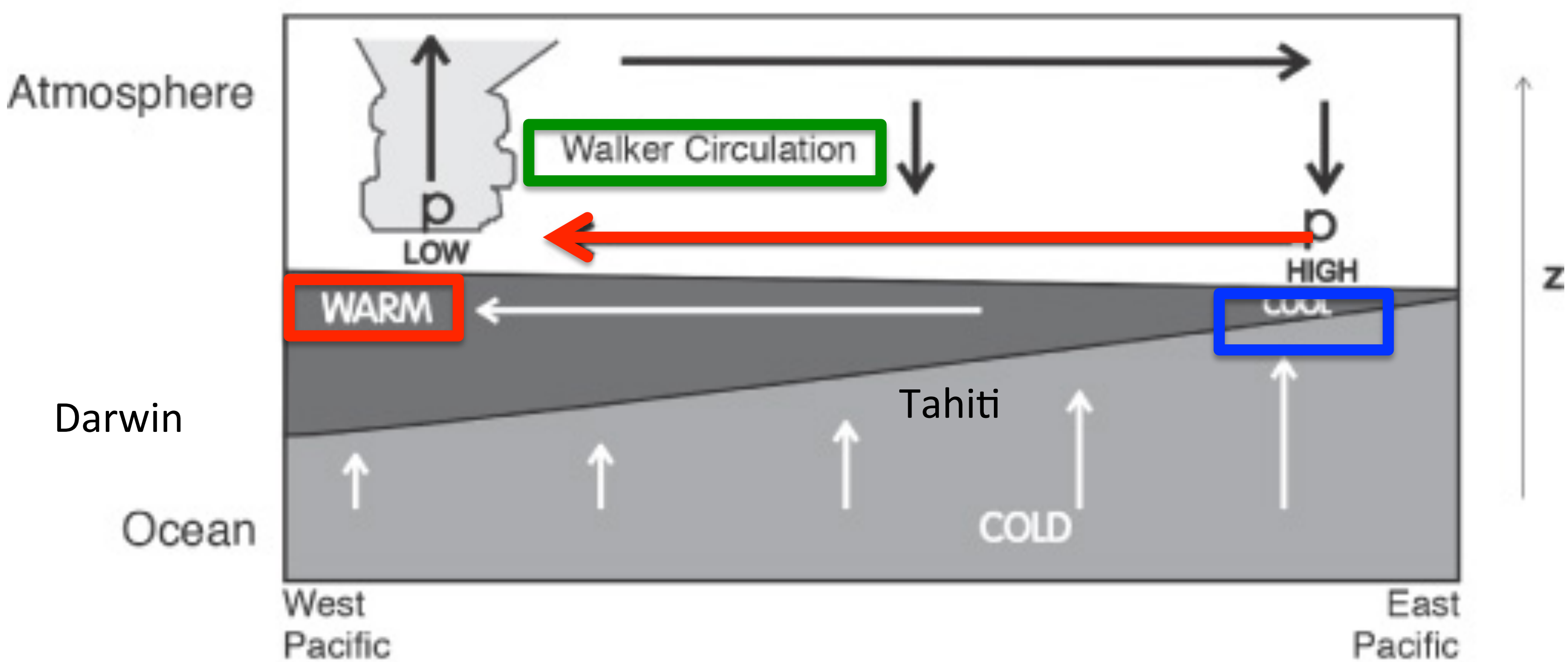
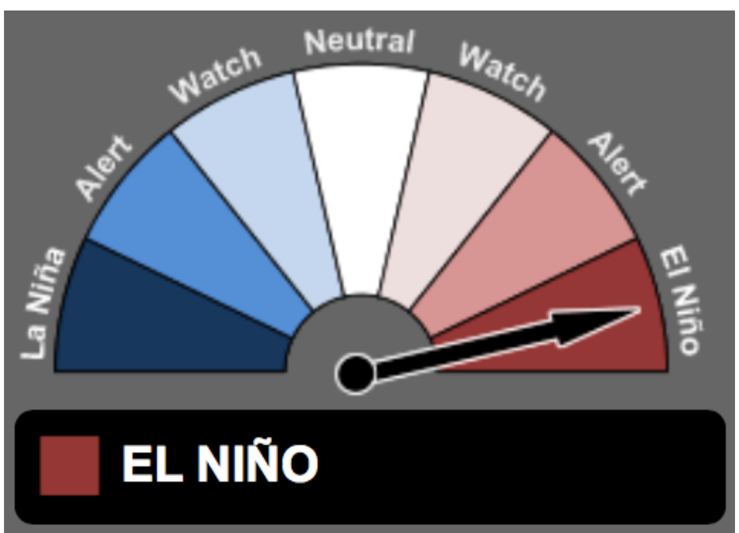


Figure 12.6: Schematic E-W cross section of "normal" conditions in the atmosphere and ocean of the equatorial Pacific basin. The east-west overturning circulation in the atmosphere is called the Walker Circulation.

El Niño – Southern Oscillation (ENSO)

- The warmer water causes the thermocline to sink.
- without the upwelling of nutrient rich bottom water the fish population is greatly reduced.



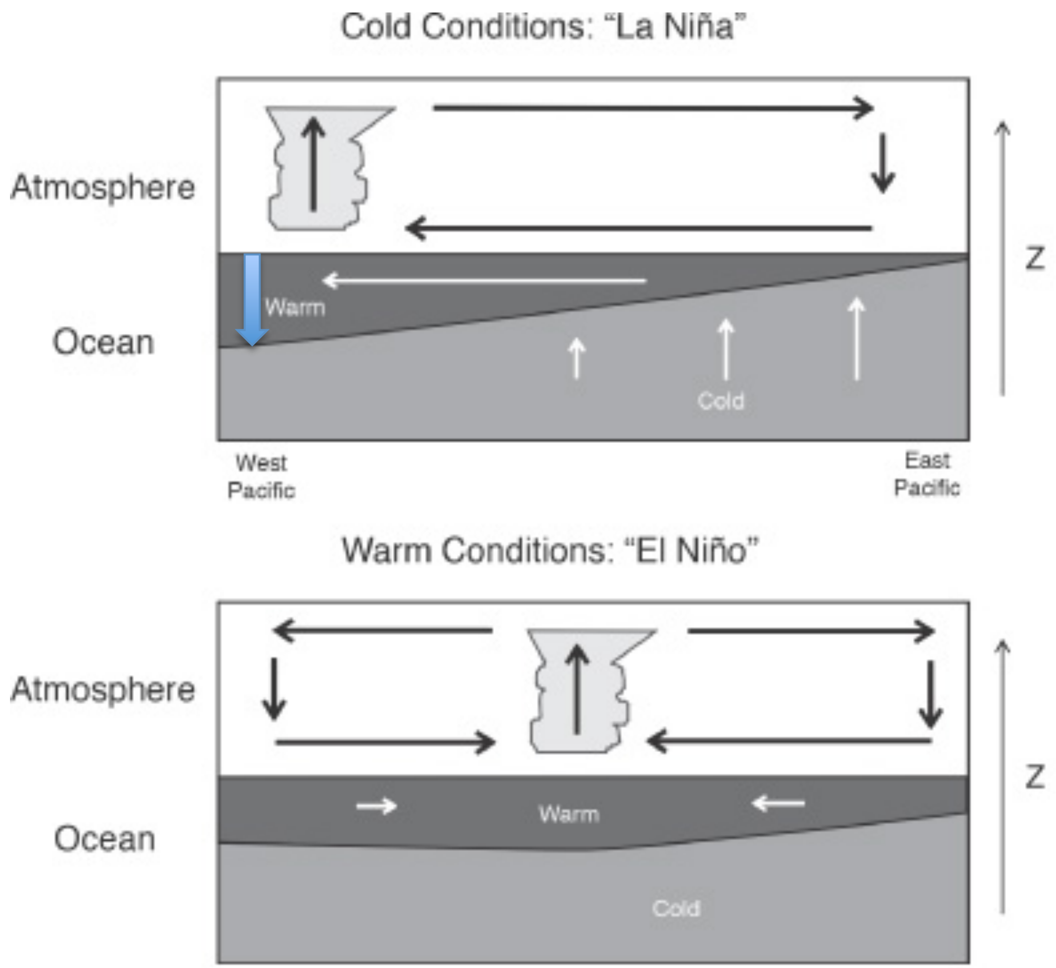
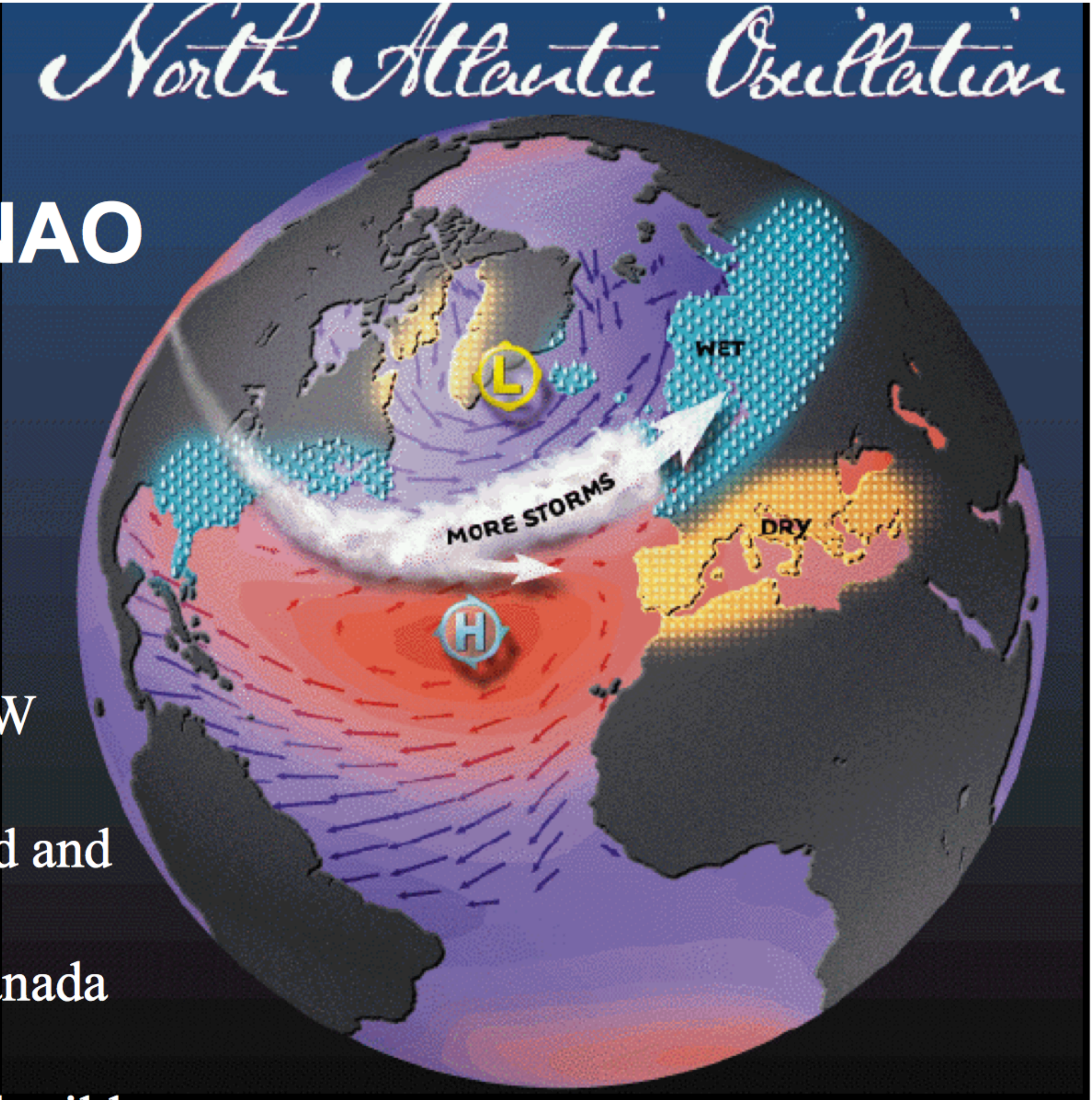


Figure 12.11: Schematic of the Pacific Ocean-Atmosphere system during (top) cold La Niña and (bottom) warm El Niño conditions.

The positive NAO index phase

- Azores High strong
- Icelandic Low deep
- westerlies strong
- wind and rain
- mild conditions in NW Europe
- dry conditions in Med and N Africa
- Dry and cold in N Canada and Greenland
- Eastern USA wet and mild



The negative NAO index phase

- Azores high weak
- Icelandic Low shallow
- westerlies weak
- NW Europe cold and dry
- wet conditions in Med and N Africa
- US east coast cold outbreaks and snow
- Greenland mild conditions