ENVIRONMENTAL MANAGEMENT I

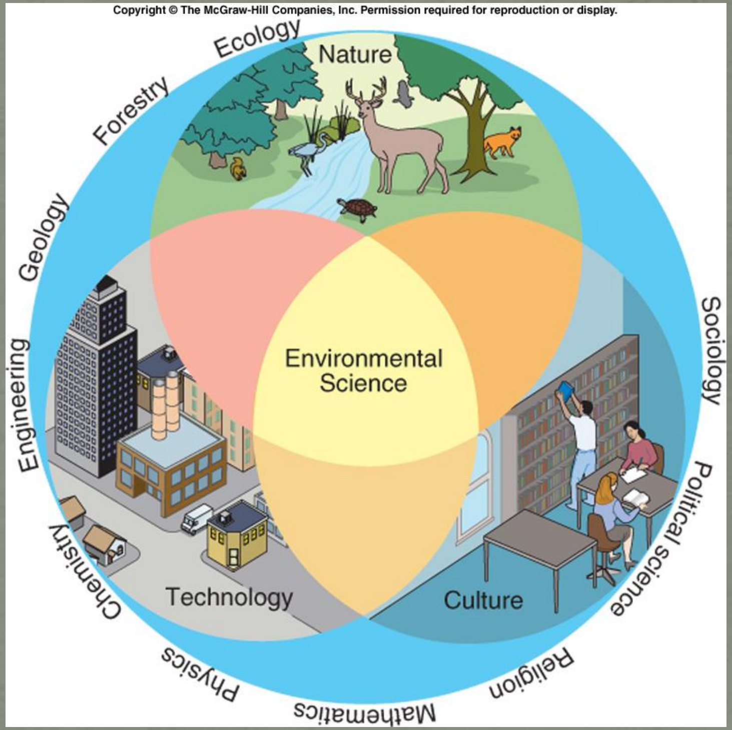
Environmental Science

- **Environmental science** is the study of the interaction of humans with the natural environment.
- The environment includes all conditions that surround living organisms:
  - Climate
  - Air and water quality
  - Soil and landforms
  - Presence of other living organisms
  - Vegetation
  - Ocean

Environmental Science Cont'd

Environmental science and the issues that it studies are complex and interdisciplinary.

- Includes concepts and ideas from multiple fields of study.
- Decisions have impacts in all these fields of study.
- It thus deals with multi-systems with elements constantly interacting with one another.



Source: Principles of Environmental Science, Cunningham, 2005.

Definitions

- environmentalism
  - social movement for protecting earth’s life support systems for us and other species.
    - Sometimes it is not driven by Science but certain belief systems
    - Some can be formed around key environmental issue – e.g., pollution and hazardous waste.

More definitions

- ecology
  - study of the interactions between organisms and between organisms and their environment
- ecosystem
  - includes all organisms living in an area and the physical environment with which these organisms interact.

What is environment?

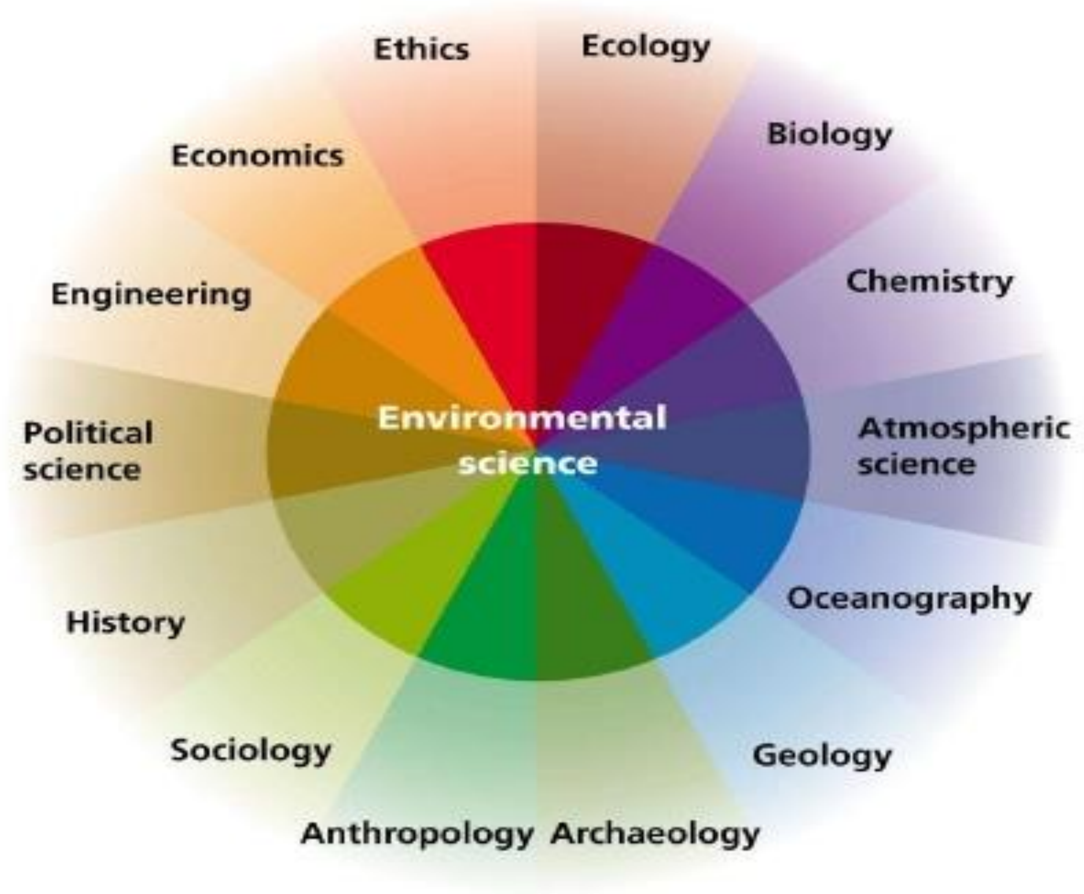
- Environment is everything that affects a living organism.
- Environment can include both living (biotic) and non-living (abiotic) components.
- What makes up a forest environment?
- What makes up a marine environment?
- What makes up your personal environment?

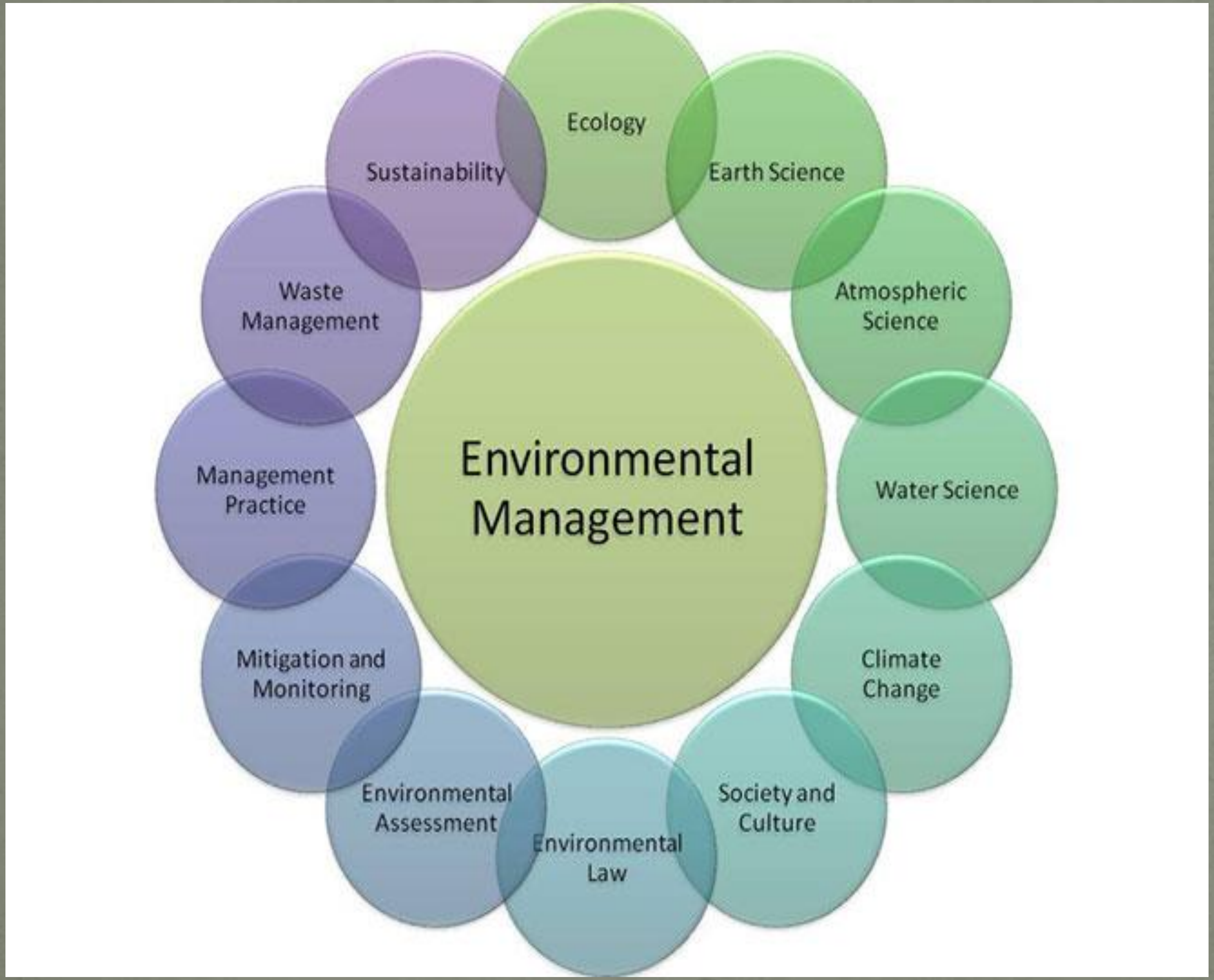
ENVIRONMENTAL SCIENCE SCENARIO

- A community decides to use coal for electricity, as it is the cheapest source available. **(Economics)**
- The coal must be mined from under the soil. ***(Geology)***
- The coal must be transported to the population center by road or rail. **(Engineering)**
- When it is burned at a power plant, air pollution is released. Some of that pollution is converted to acid in the atmosphere. **(Chemistry)**
- This falls as acid rain somewhere downwind. **(Meteorology)**
- The acid stresses plants by affecting their nutrient absorption. **(Ecology)**
- Laws are passed requiring the plant to install pollution scrubbers. **(Politics)**

Environmental science

… is an **interdisciplinary** field, drawing on many diverse disciplines.





- Environmental management essentially is about the application of a specific management approach to address environmental problems

CLIMATE, WEATHER SYSTEMS and Diversity

INTRODUCTION

State weather the phrasing of each of the following is technically (scientifically) correct or incorrect :

1. The climate of Cape Town changes several times in a day.
2. The weather of Cape Town is characterised by strong winds and wet winters.
3. The climate on the plane's route from Cape Town to Durban was not favourable for the flight.
4. The leafing pattern of savanna plants each year is guided by the climate.
5. The climate of the Namib desert is characteristically dry.

INTRODUCTION

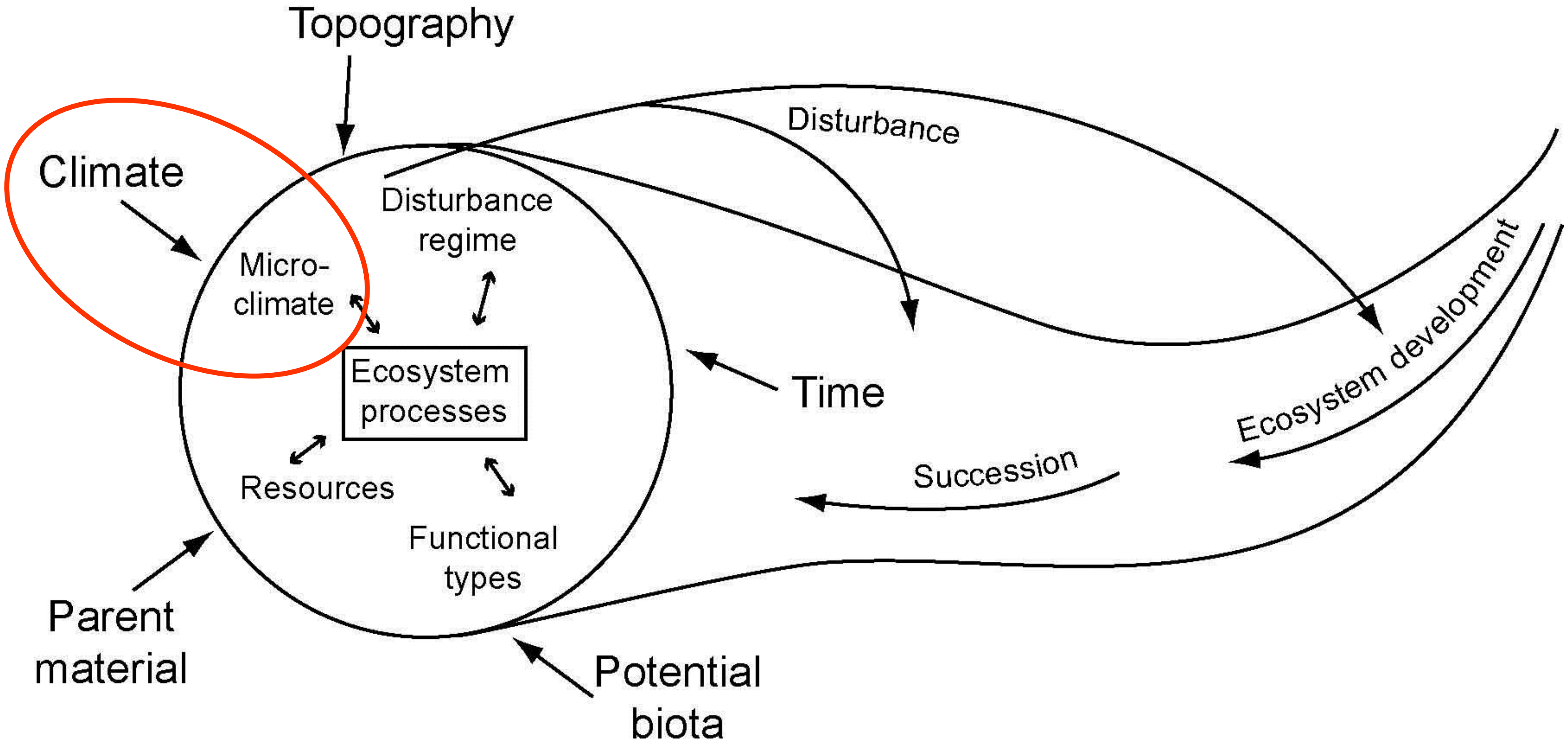
- WEATHER:

  = the state of the atmosphere, particularly with respect to its effect on human activities and in terms of its **short-term** variability.

- CLIMATE:

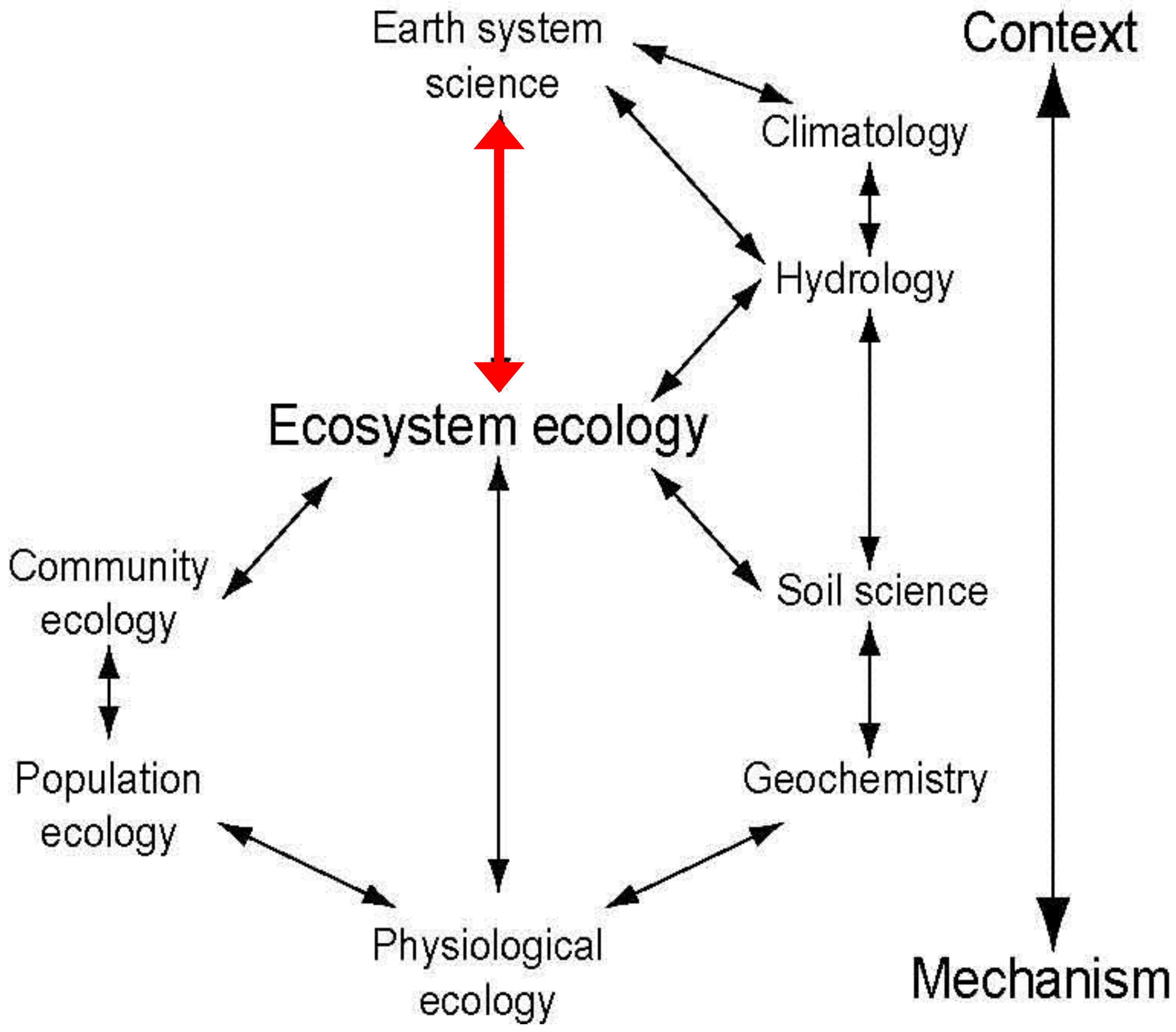
  = the totality of weather **over long periods** in a region, usually summarised by averages and statistical measures of variability

Climate is the state factor that most strongly governs the global pattern of ecosystem structure and processes



1.3

Climate is a key mechanism by which ecosystems interact with the total Earth System

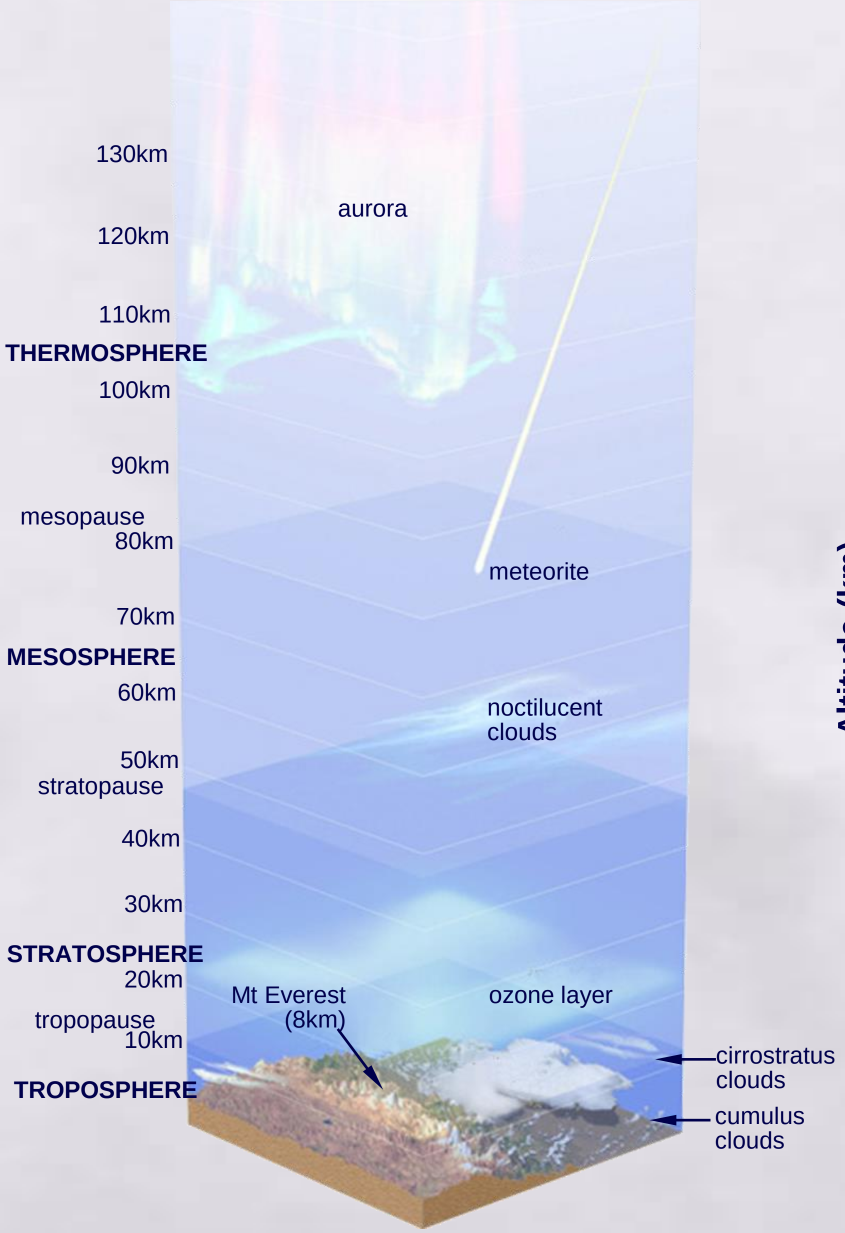


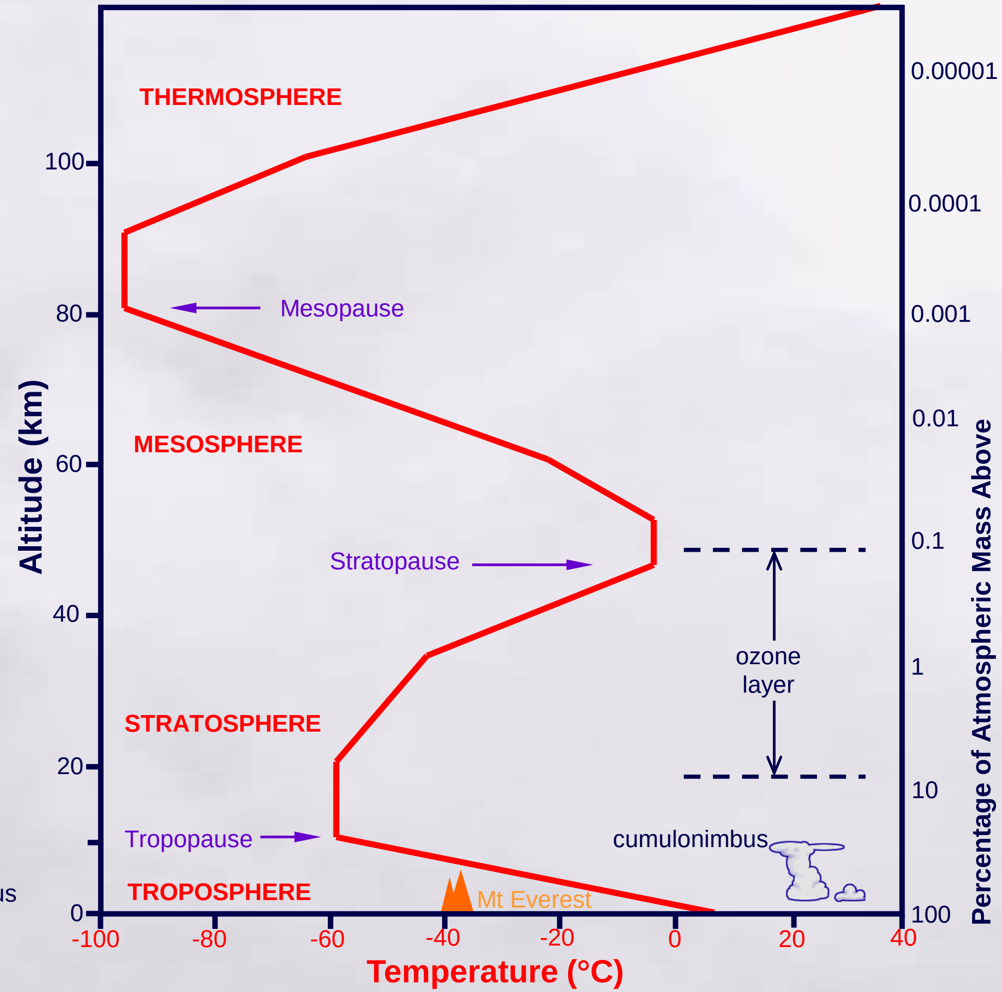
1.2

INTRODUCTION

- Elements of weather:
  - Temperature
  - Humidity
  - Rainfall
  - Wind
  - Cloud cover
  - Sunshine
  - Pressure
- Elements of climate? = as for weather.

Vertical Structure: Temperature





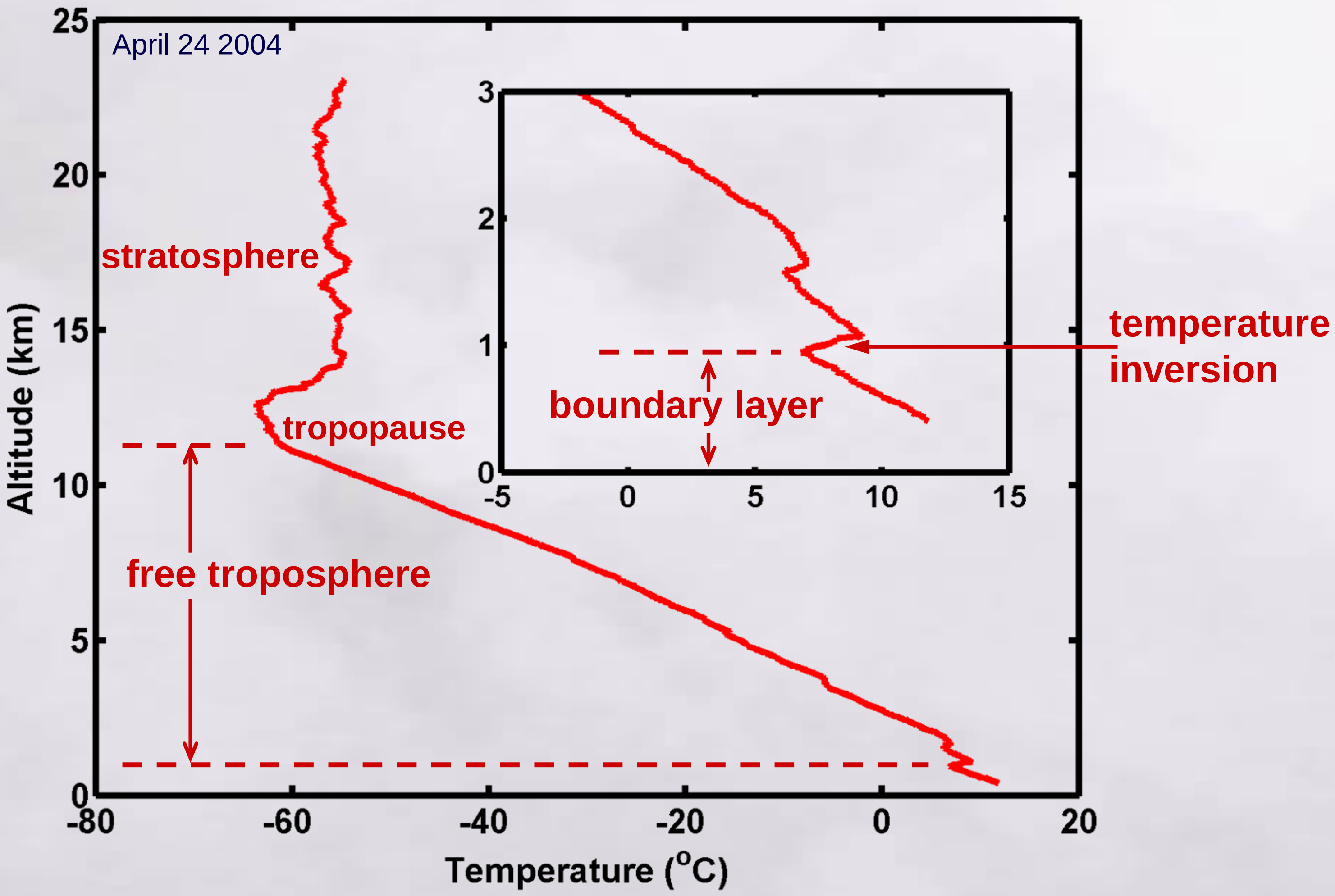
Vertical Structure

- **TROPOSPHERE**
  - Lowest layer of atmosphere
  - ~8km deep at poles, ~16km deep at equator. Depth varies both spatially & with time.
  - Region where virtually all ‘weather’ occurs. Most of the water vapour in the atmosphere is concentrated in the lower troposphere.
  - Temperature generally decreases with altitude (though with significant variability)
  - Capped by a region of increasing temperature (a temperature inversion) or isothermal layer, the ***Tropopause.***
  - The tropopause acts as a lid, preventing the exchange of air between troposphere and stratosphere.

Structure of the Atmosphere

- **The Boundary Layer**
  - A sublayer of the troposphere
  - In contact with the surface – experiences direct effect of friction at surface
  - Dominated by turbulence and surface exchange processes: heat, moisture, momentum
  - Exhibits large diurnal changes in many properties: depth, temperature,…
  - Depth varies from a few 10s of metres (in very stable conditions), to ~2km over tropical oceans. A few 100 m to ~1 km is typical.
  - Temperature decreases with altitude.
  - Usually capped by a temperature inversion that inhibits mixing with the air in the *free troposphere* above.
  - N.B. A well defined boundary layer is not always present

Temperature Profile



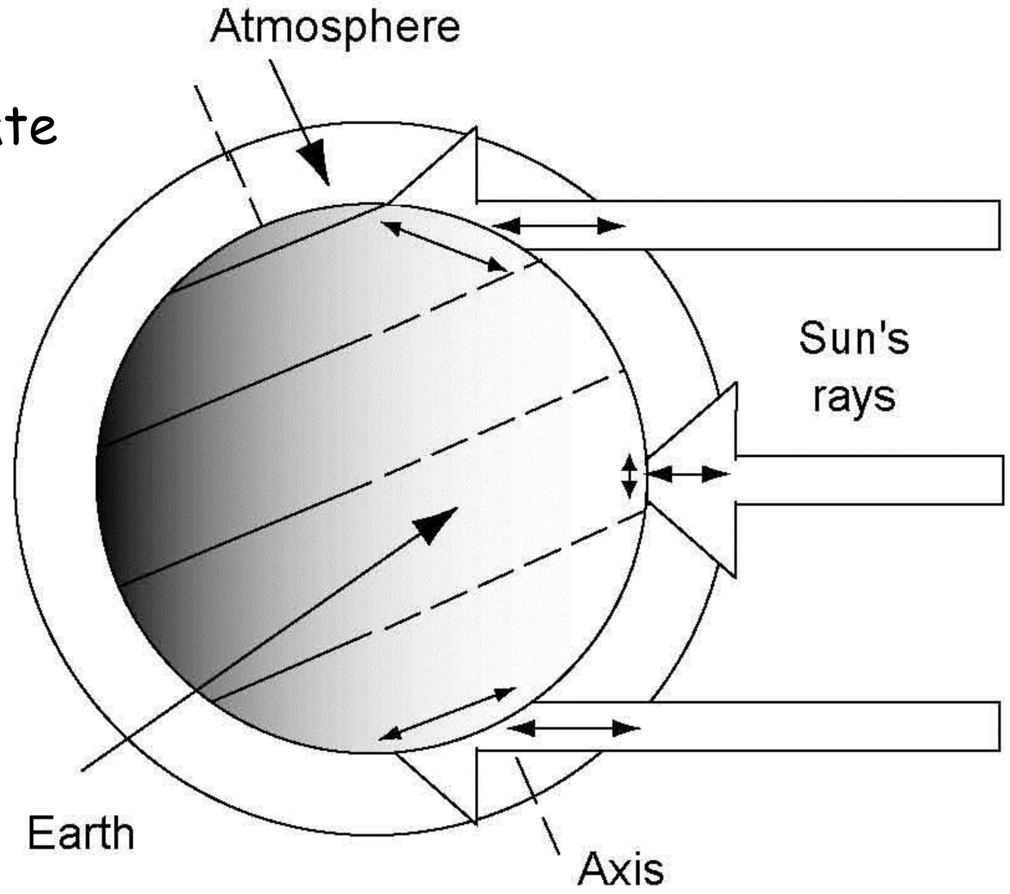
Chemical composition of the atmosphere

Table 1–2 Principal gases of dry air

Constituent	Percent by Volume	Concentration in Parts Per Million (PPM)
Nitrogen (N_2)	78.084	780,840.0
Oxygen (O_2)	20.946	209,460.0
Argon (Ar)	0.934	9,340.0
Carbon dioxide (CO_2)	0.036	360.0
Neon (Ne)	0.00182	18.2
Helium (He)	0.000524	5.24
Methane (CH_4)	0.00015	1.5
Krypton (Kr)	0.000114	1.14
Hydrogen (H_2)	0.00005	0.5

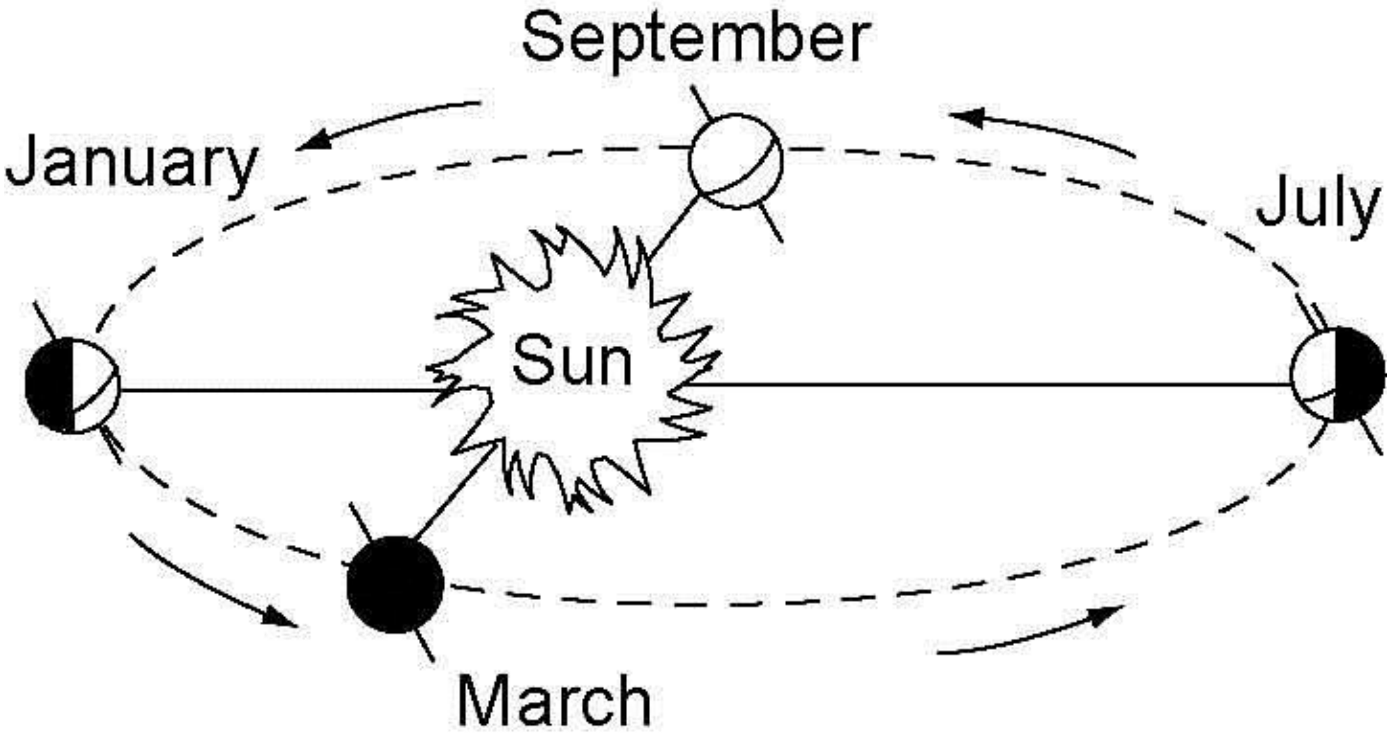
Uneven heating of Earth's surface causes predictable latitudinal variation in climate.

1. Greater heating at equator than poles
2. Why?
   a. sun's rays hit more directly
   b. less atmosphere to penetrate



B. Seasonality
What causes seasons?

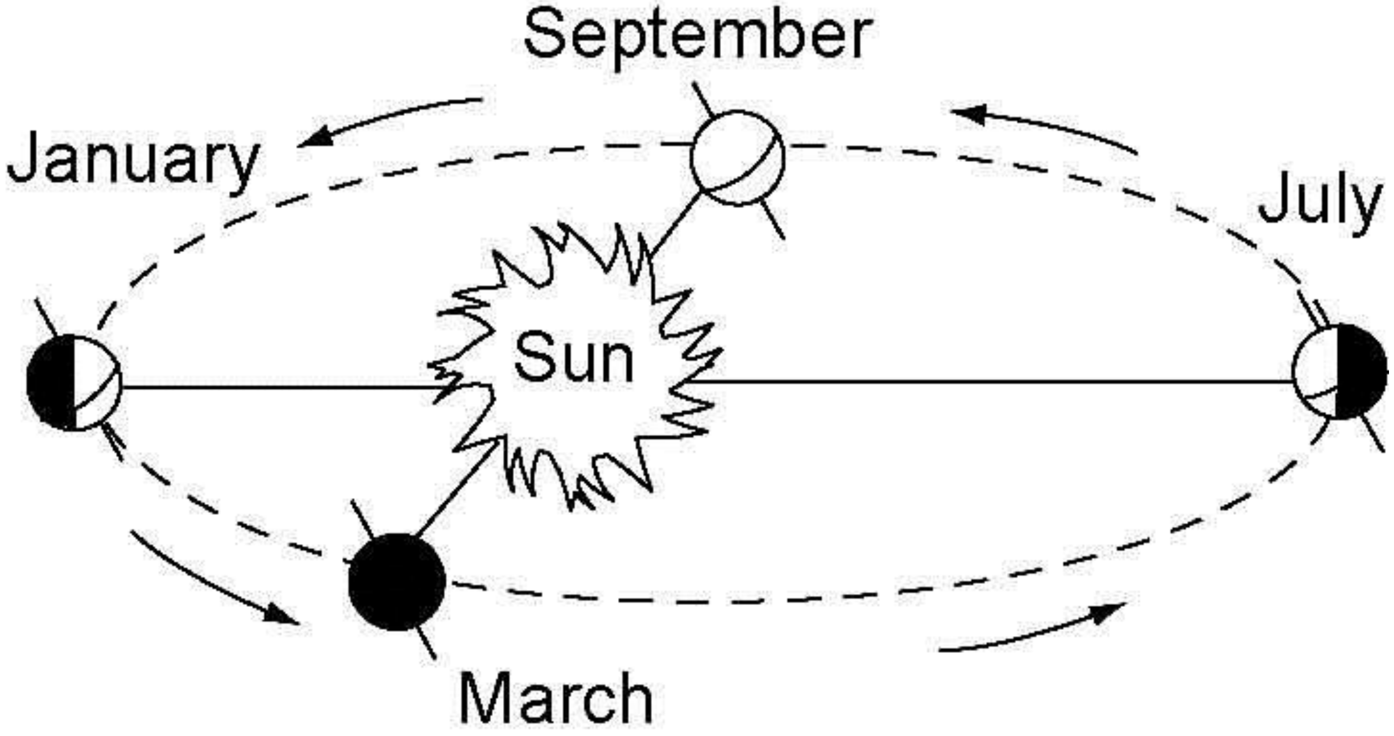
~~Earth's distance from the sun varies throughout the year~~



2.20

Tilt!

Because of the tilt of Earth's axis, the amount of radiation received by Northern and Southern Hemispheres varies through the year
- angle of incidence and day length



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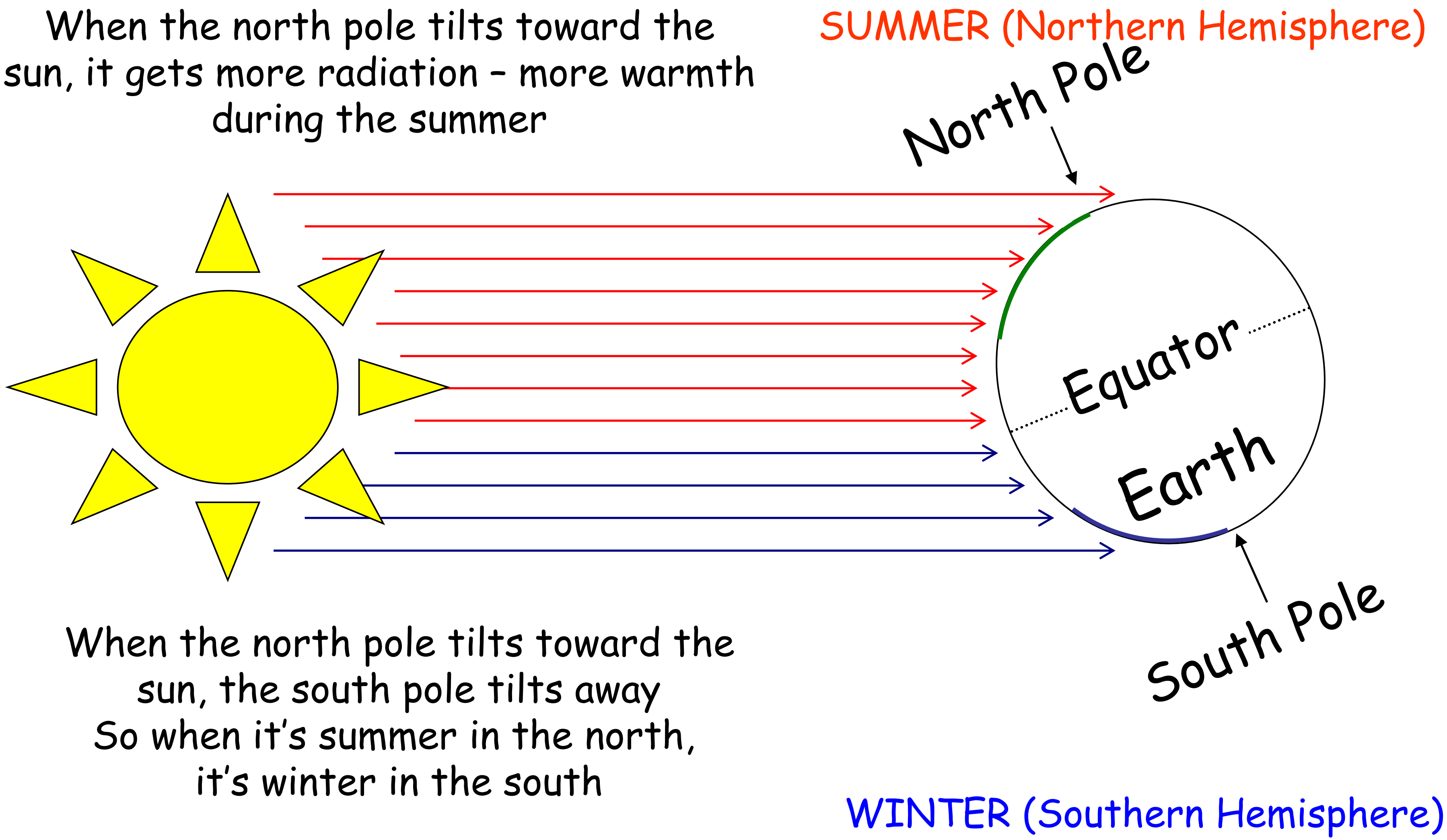
Earth’s Seasons

Tilt of the Earth’s axis towards or away from the sun creates the seasons

When the north pole tilts toward the sun, it gets more radiation – more warmth during the summer



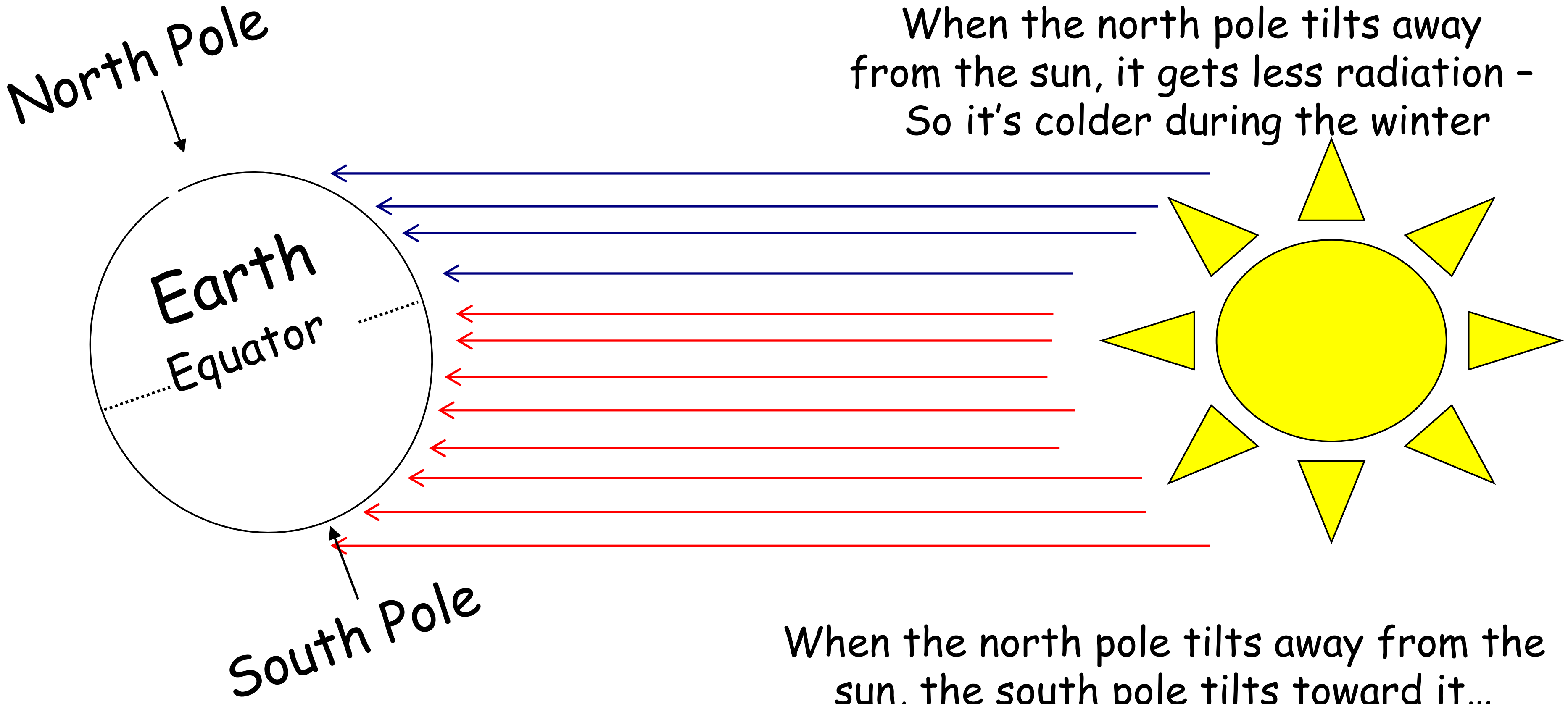
When the north pole tilts toward the sun, the south pole tilts away
So when it’s summer in the north, it’s winter in the south

Earth's Seasons

Tilt of the Earth's axis towards or away from the sun creates the seasons

WINTER (Northern Hemisphere)

When the north pole tilts away
from the sun, it gets less radiation –
So it's colder during the winter

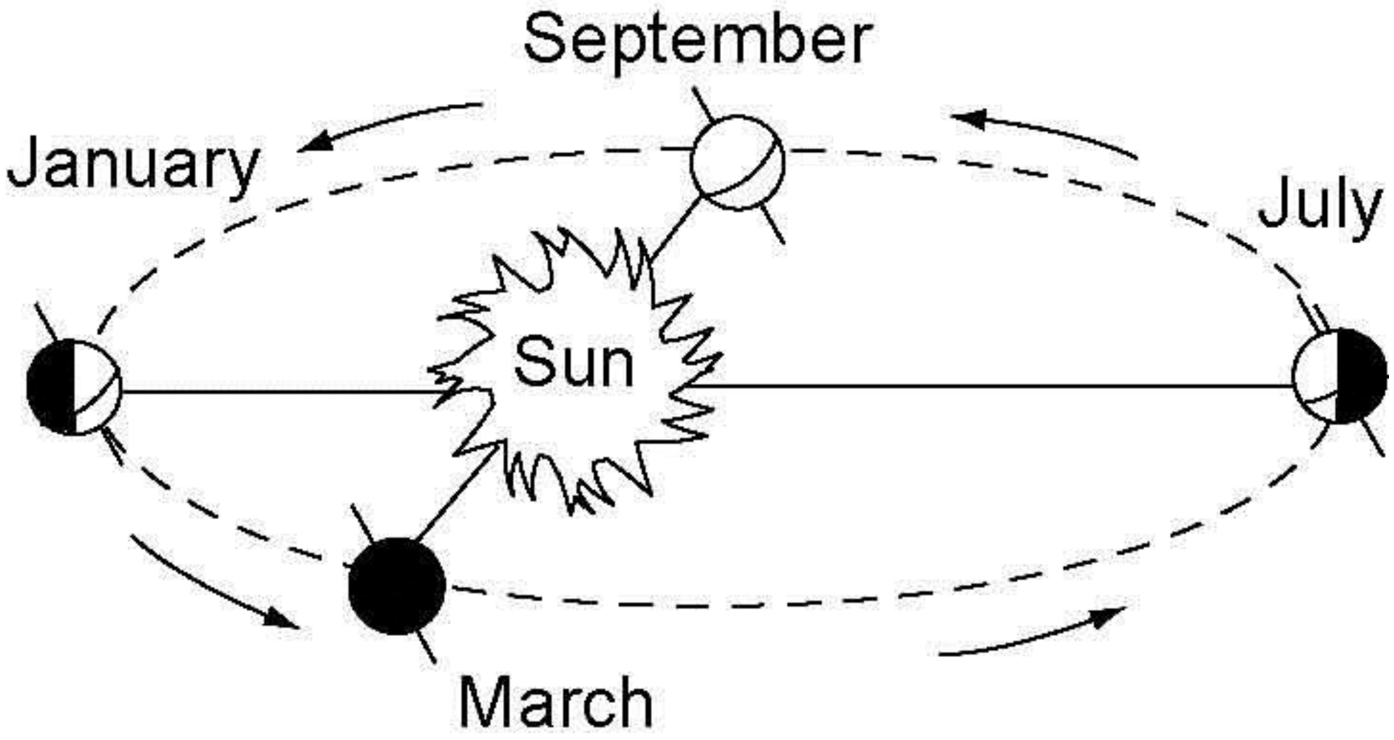


SUMMER (Southern Hemisphere)

When the north pole tilts away from the
sun, the south pole tilts toward it…
When it's winter in the north,
it's summer in the south

Common geographic boundaries relate directly to Earth's tilt

Tropics: Capricorn (S) & Cancer(N)
Arctic, Antarctic circles



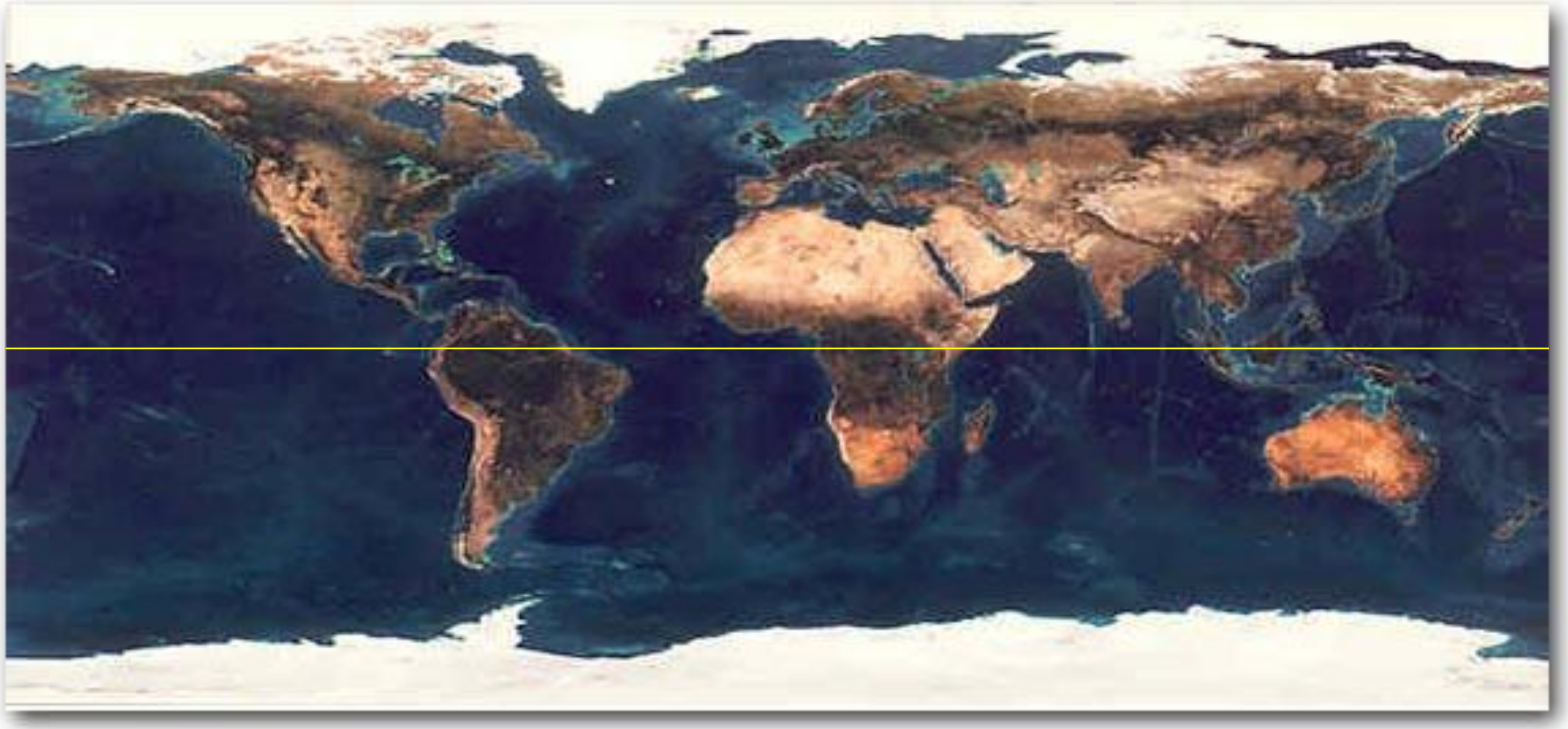
2.20

C. Atmospheric circulation

Questions

1. Why are there rainforests in the tropics and deserts at ~30°N and S?

2. What drives the major wind patterns? (e.g., Doldrums, Tradewinds, Westerlies)



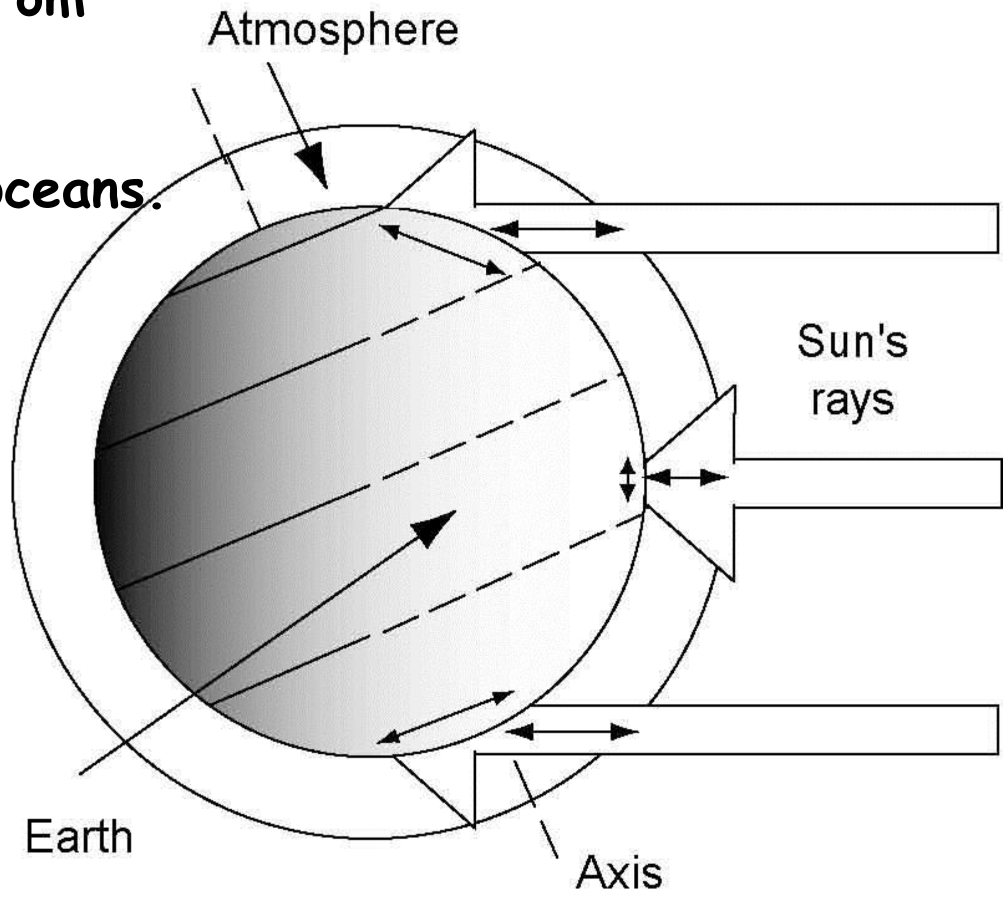
C. Atmospheric circulation - Uneven heating of Earth's surface causes atmospheric circulation

Greater heating at equator than poles

Therefore

1. Net transfer of energy from Equator to poles.
2. Transfer occurs through circulation of atmosphere and oceans.

Here's how it works…



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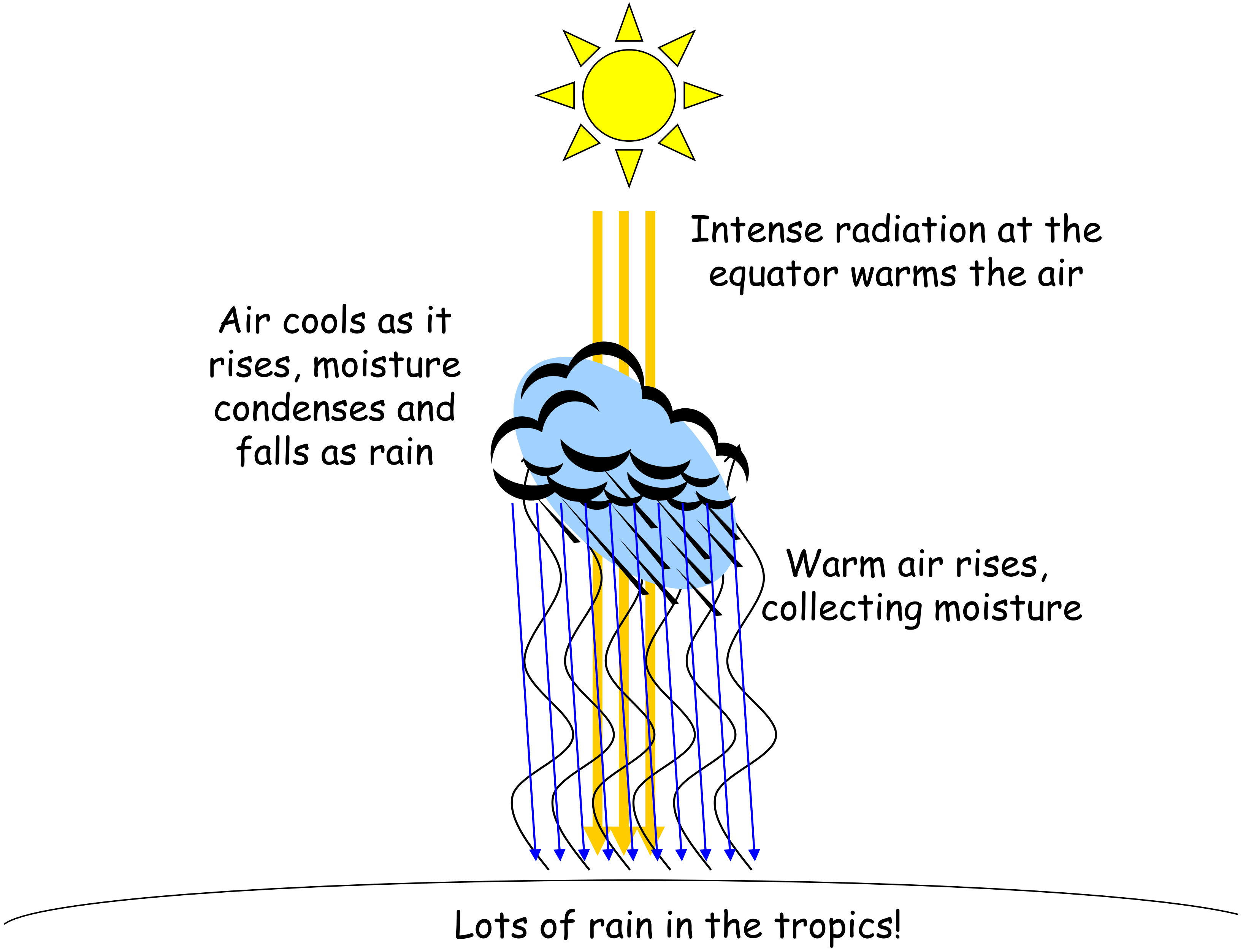
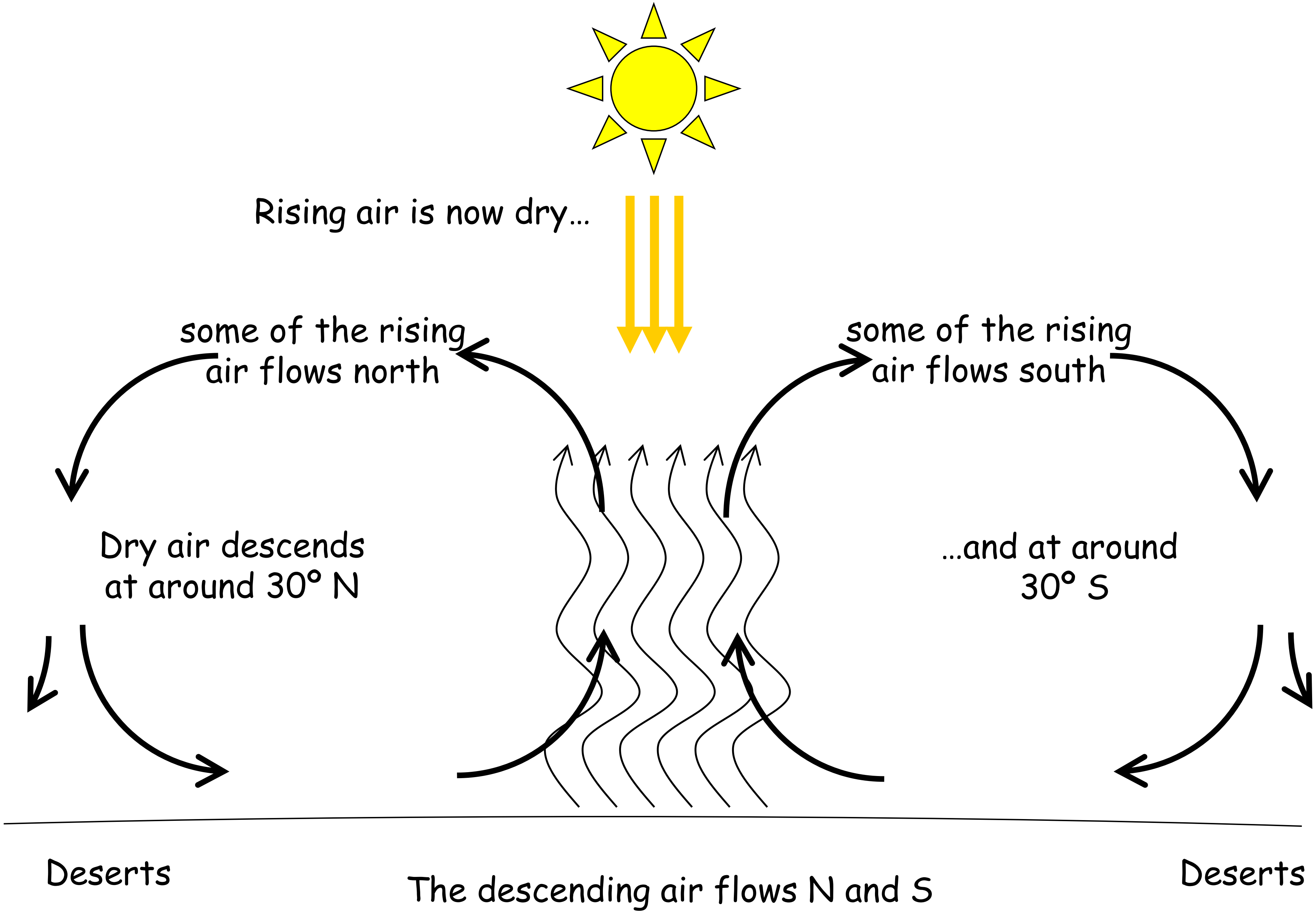
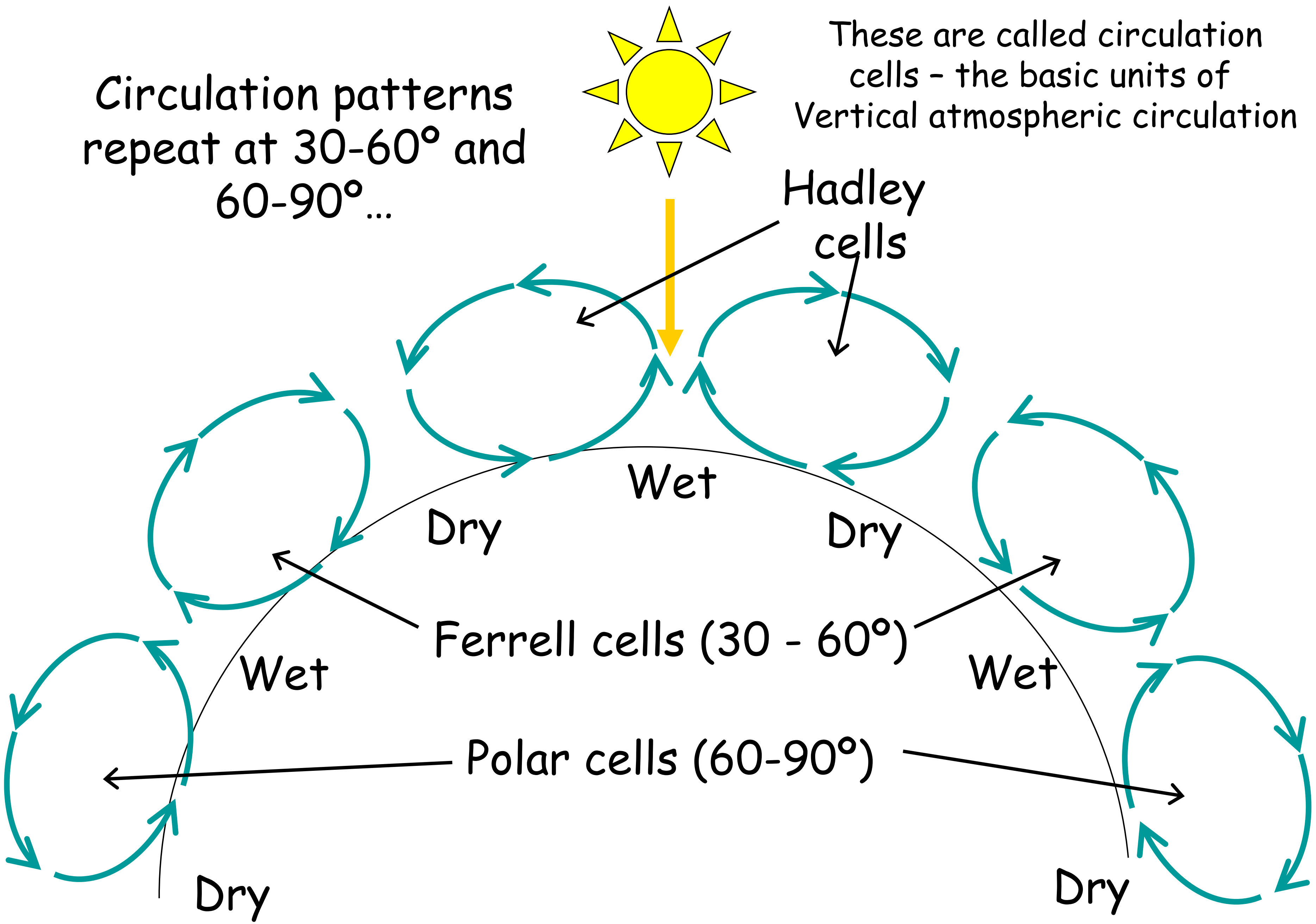

Intense radiation at the equator warms the air
Air cools as it rises, moisture condenses and falls as rain
Warm air rises, collecting moisture
Lots of rain in the tropics!


Rising air is now dry...
some of the rising air flows north
some of the rising air flows south
Dry air descends at around 30° N
...and at around 30° S
Deserts
The descending air flows N and S
Deserts

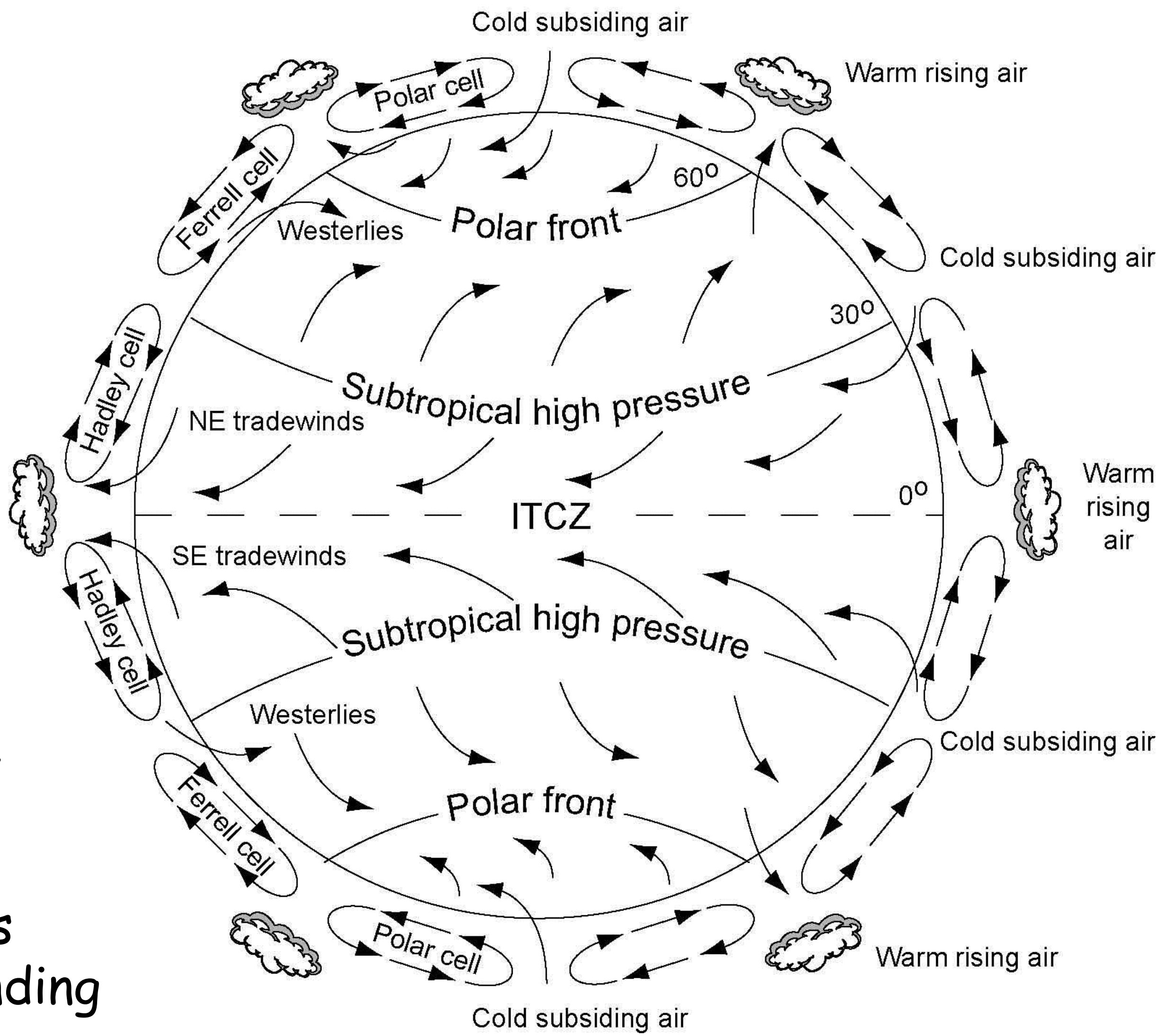

Circulation patterns repeat at 30-60° and 60-90°…
These are called circulation cells – the basic units of Vertical atmospheric circulation
Hadley cells
Wet
Dry
Dry
Ferrell cells (30 - 60°)
Wet
Wet
Polar cells (60-90°)
Dry
Dry

Air rises and falls
in Hadley, Ferrel, and
Polar cells
(vertical circulation)

Circulation cells
explain global
distribution of
rainfall

Earth's rotation
determines
wind direction
(horizontal circulation,
Coriolis force)

ITCZ and cell locations
shift seasonally depending
on location of maximal
heating of Earth's surface



These general circulation patterns are modified by the distribution of oceans and continents.

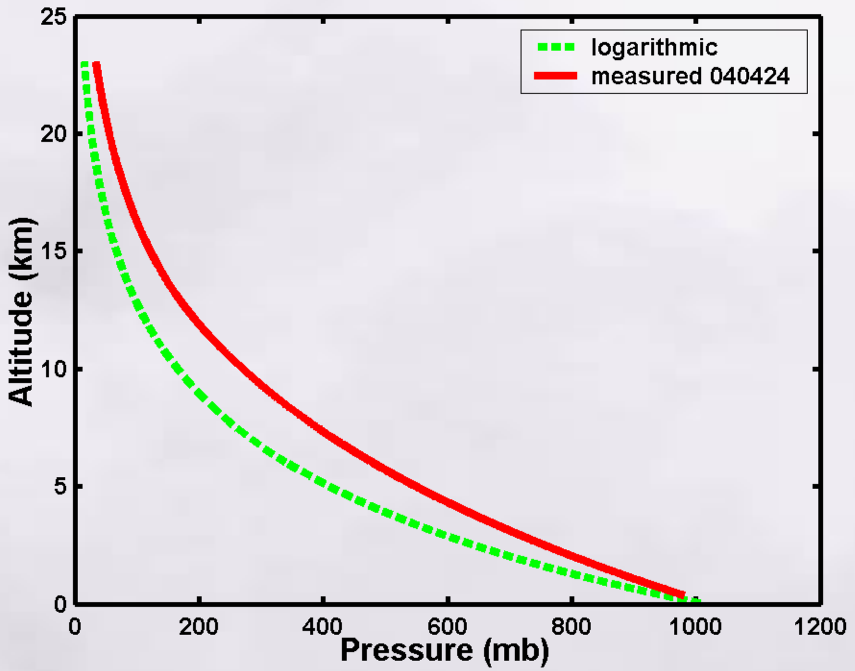
High heat capacity of water and ocean currents buffer ocean temperatures

Land temperatures fluctuate more, especially in higher latitudes

These differences in surface energy balance influence air movements, and create prevailing winds

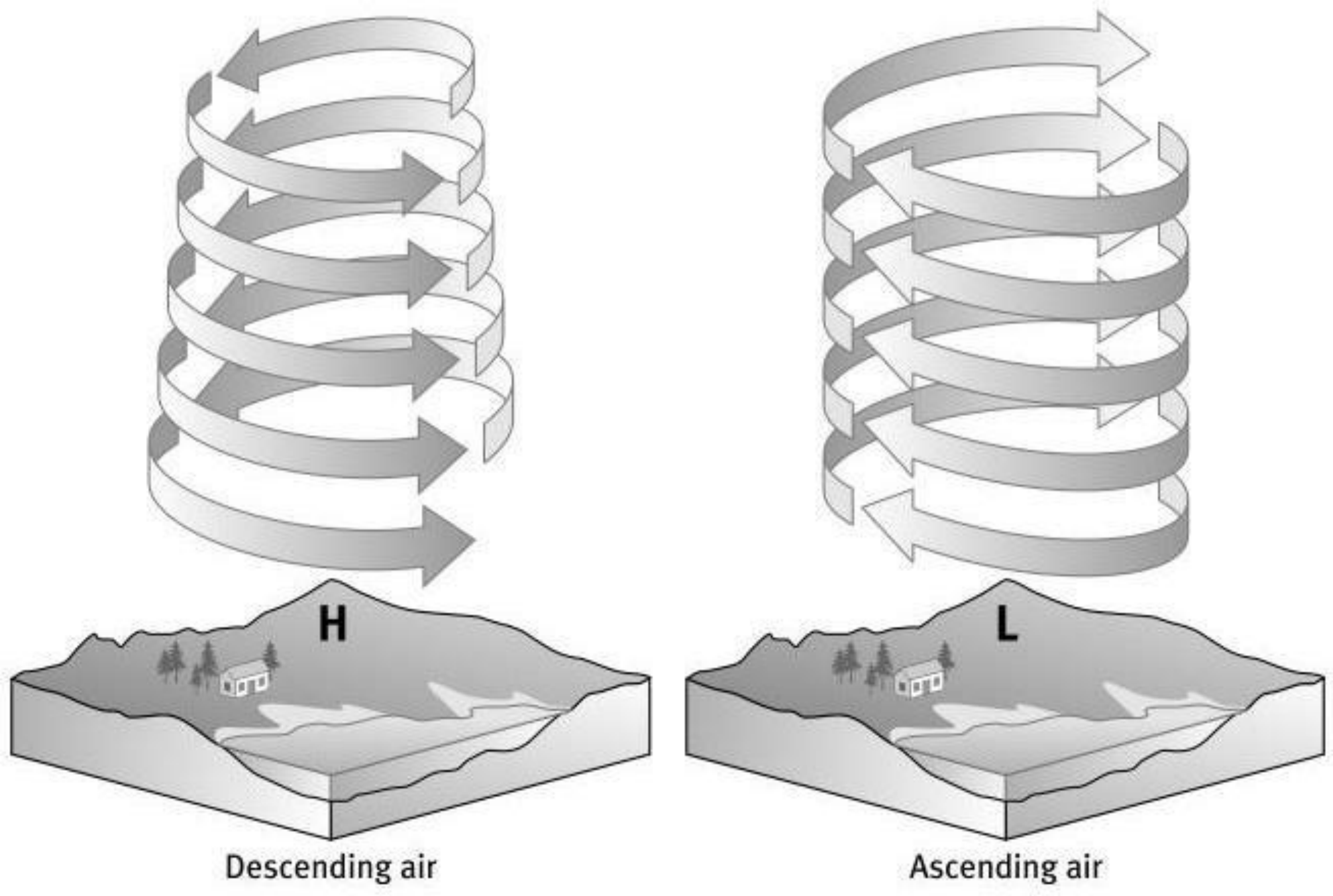
Vertical Structure: Pressure

- The pressure at any point is the result of the weight of all the air in the column above it.
- Upwards force of pressure exactly balances downward force of weight of air above
- Decreases approximately logarithmically with altitude
  - Departures from logarithmic profile are due to changes in air density resulting from changes in temperature & moisture content.

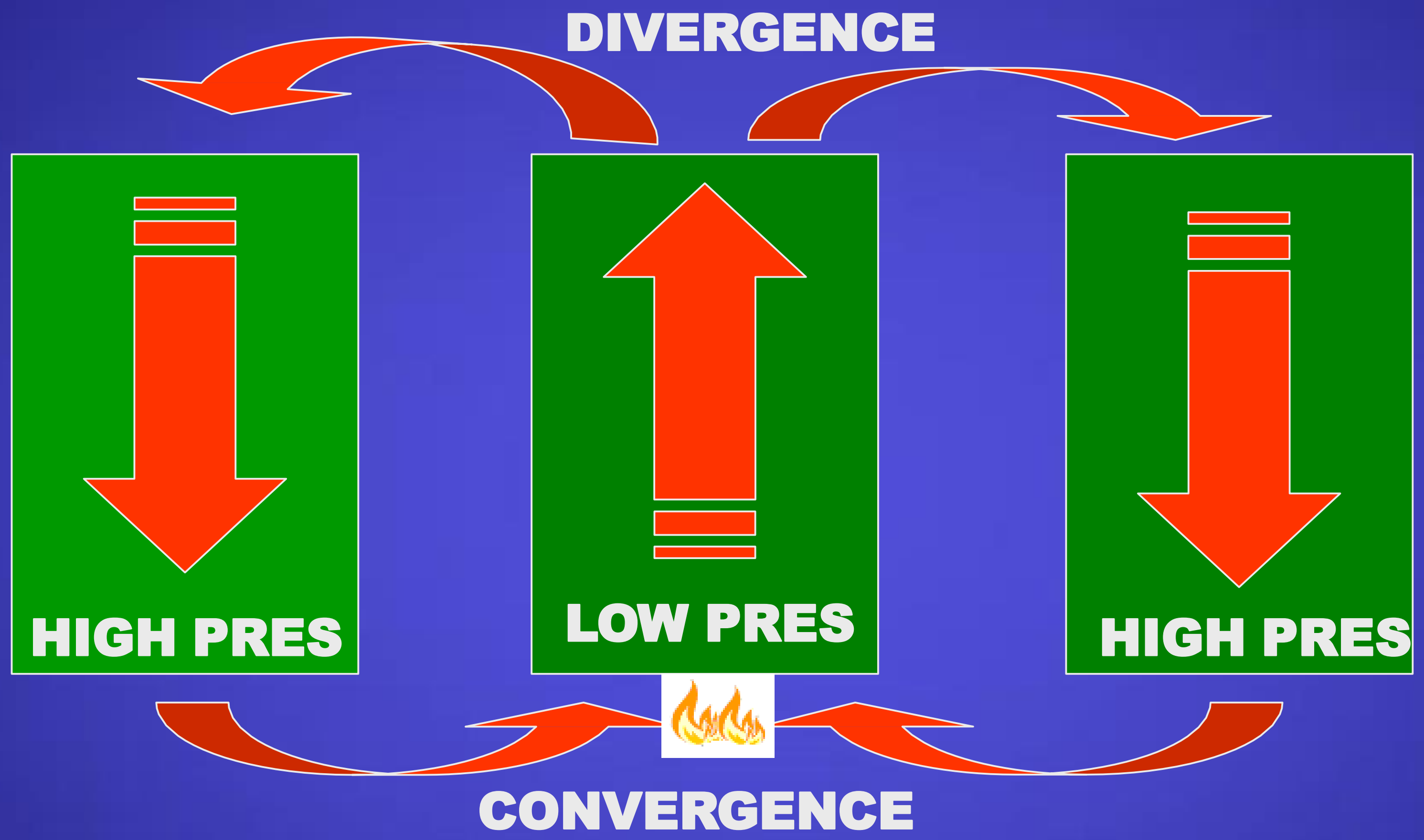


Near the surface a 1mb change in pressure is equivalent to $\approx$7m change in altitude.

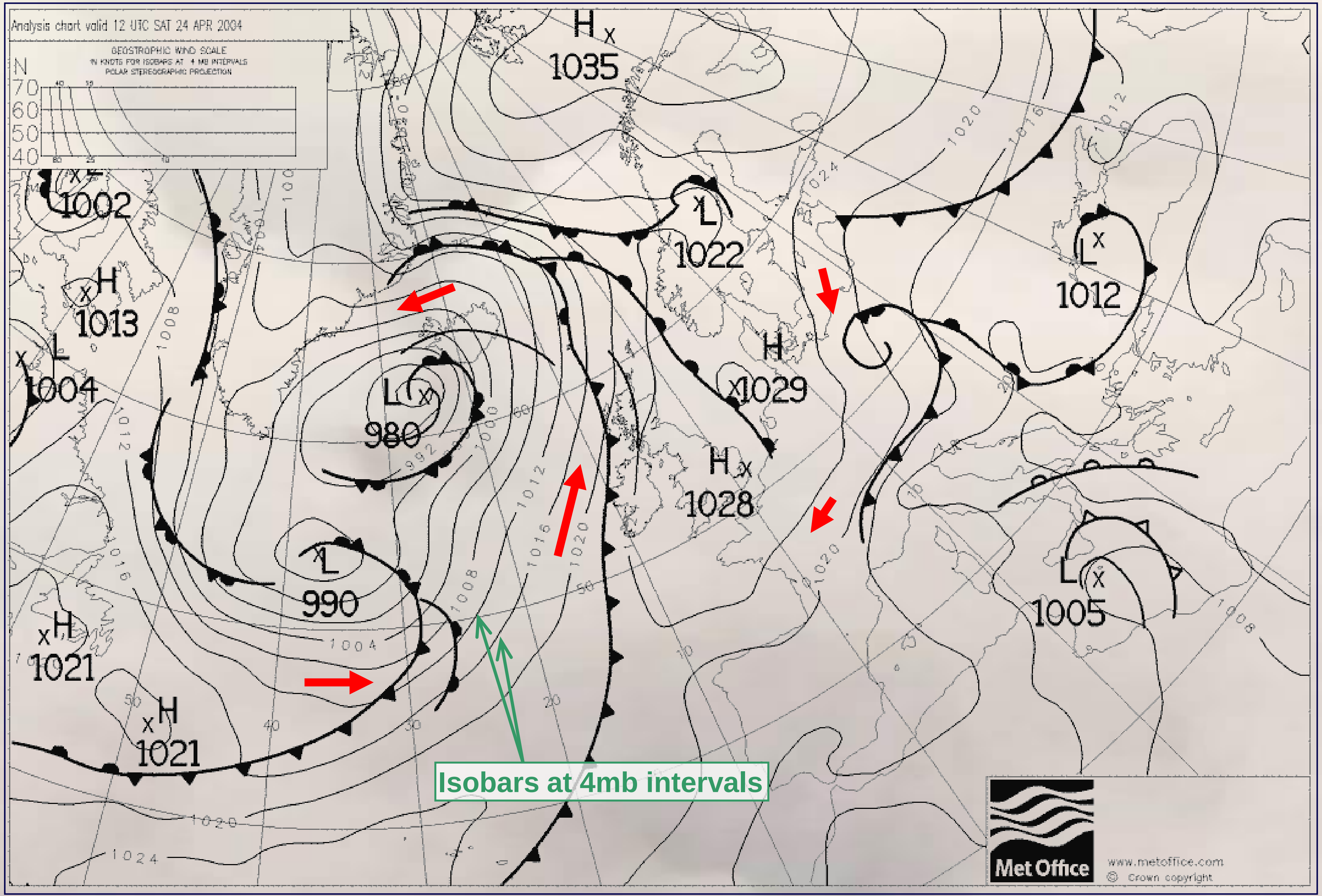
HIGH AND LOW PRESSURES



RELATIONSHIP BETWEEN AIR PRESSURE AND WIND



Wind always blows from a HIGH PRES to a LOW PRES


Analysis chart valid 12 UTC SAT 24 APR 2004
GEOSTROPHIC WIND SCALE
IN KNOTS FOR ISOBARS AT 4 MB INTERVALS
POLAR STEREOGRAPHIC PROJECTION
H 1035
L 1002
H 1013
L 1004
L 980
L 990
H 1021
H 1021
L 1022
H 1029
H 1028
L 1012
L 1005
Isobars at 4mb intervals
Met Office
www.metoffice.com
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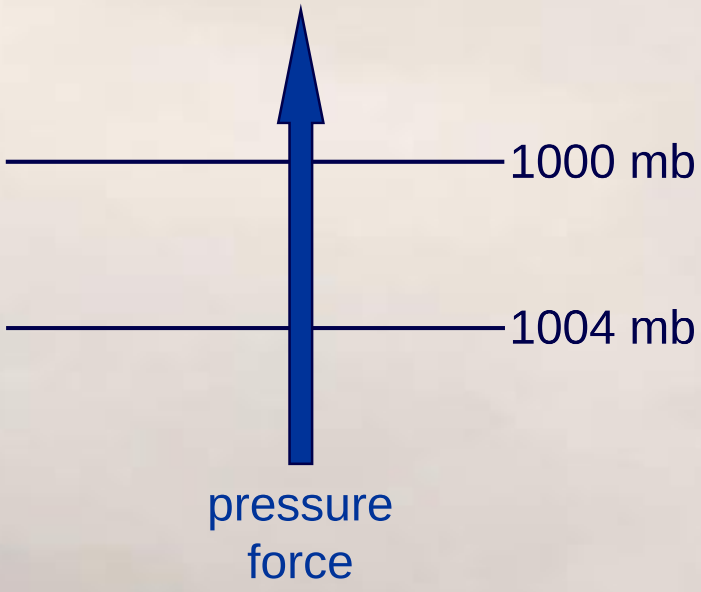
The PressureGradient Force

Horizontal pressure gradients are the main driving force for winds.

$$\text{Pressure gradient force} = -\frac{1}{\rho}\frac{dP}{dx}$$

where P is pressure, ρ is air density, and x is distance. The force is thus inversely proportional to the spacing of isobars (closer spacing $\Rightarrow$ stronger force), and is directed perpendicular to them, from **high** pressure to **low**.

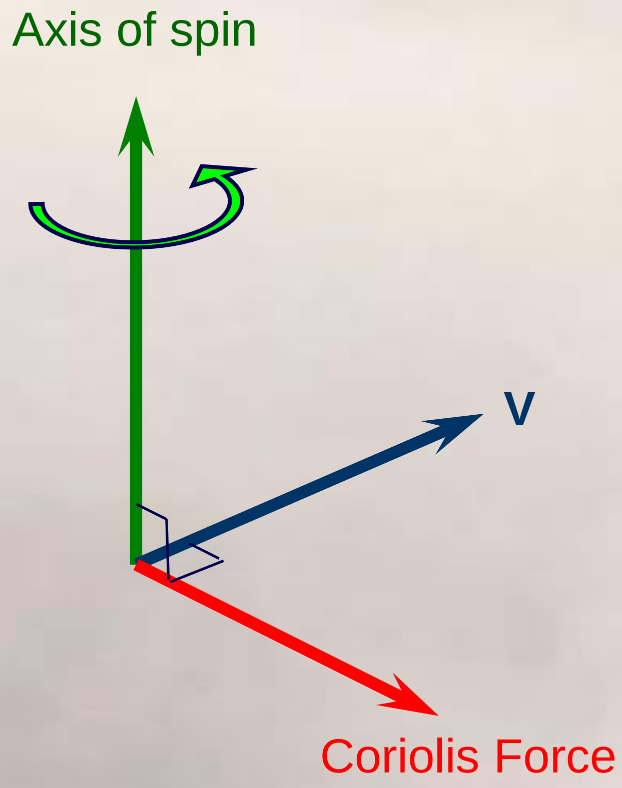
The pressure force acts to accelerate the air towards the low pressure.

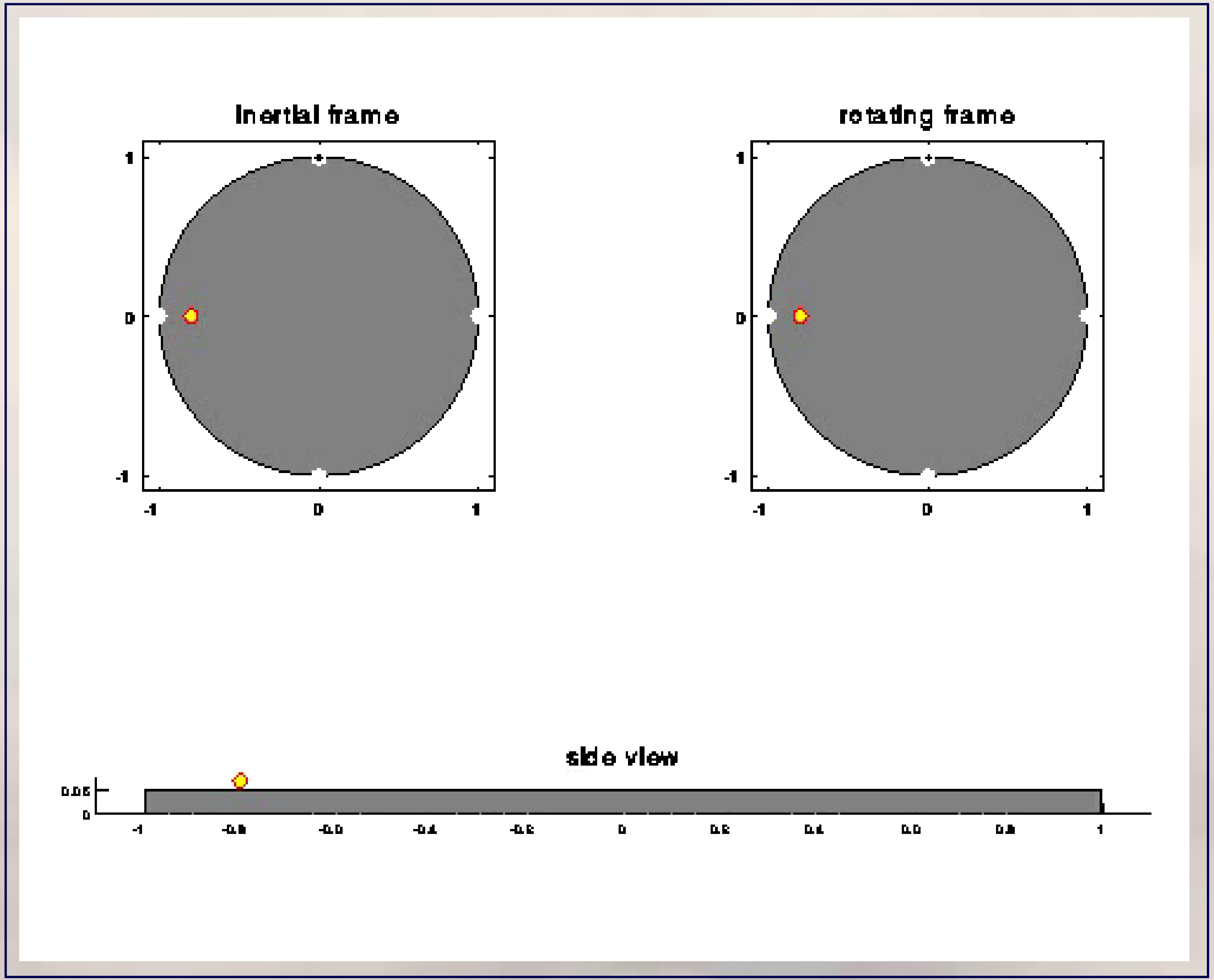


The Coriolis Force

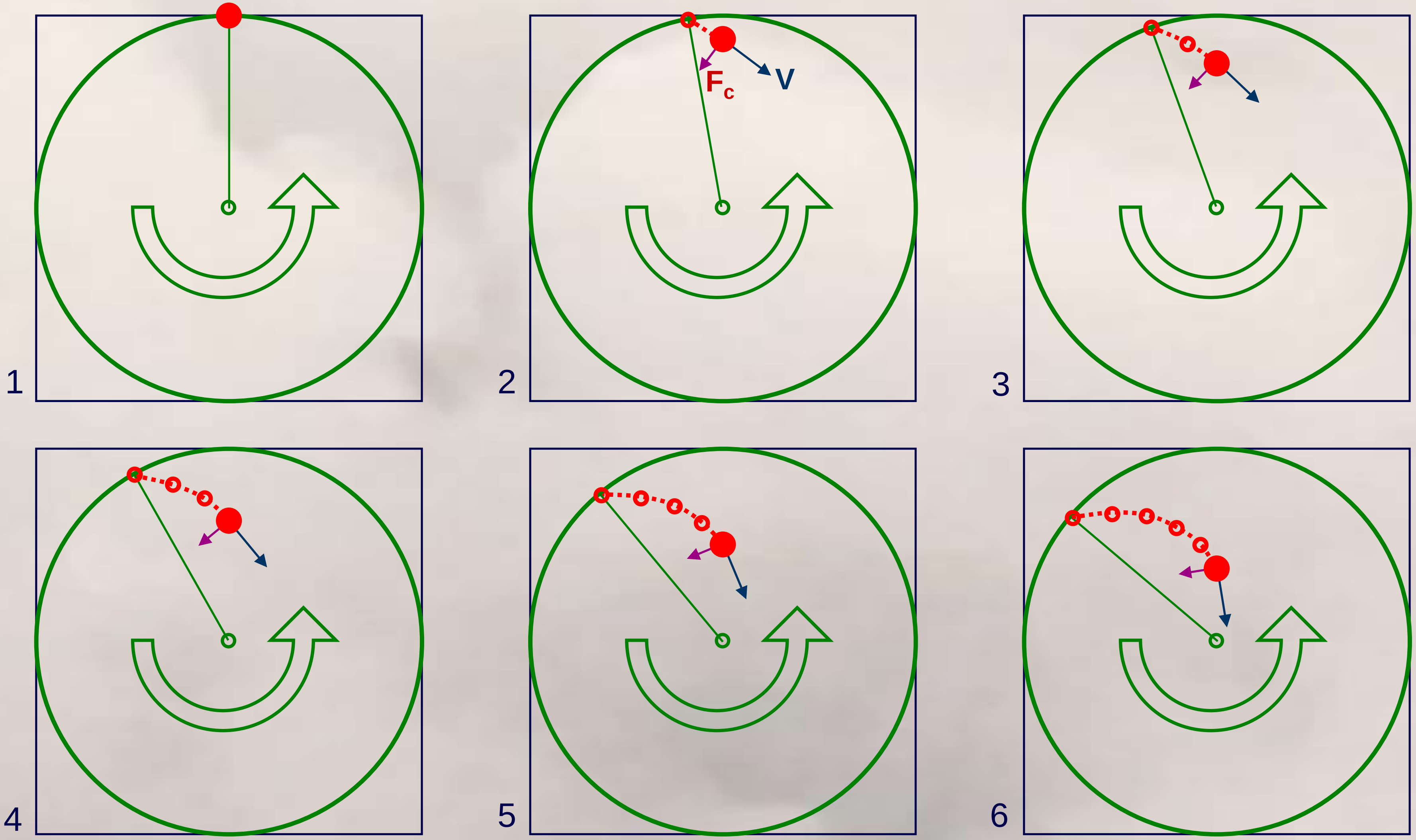
The coriolis force is an **apparent** force, introduced to account for the **apparent** deflection of a moving object observed from within a rotating frame of reference – such as the Earth.

The coriolis force acts at right angles to both the direction of motion and the spin axis of the rotating reference frame.

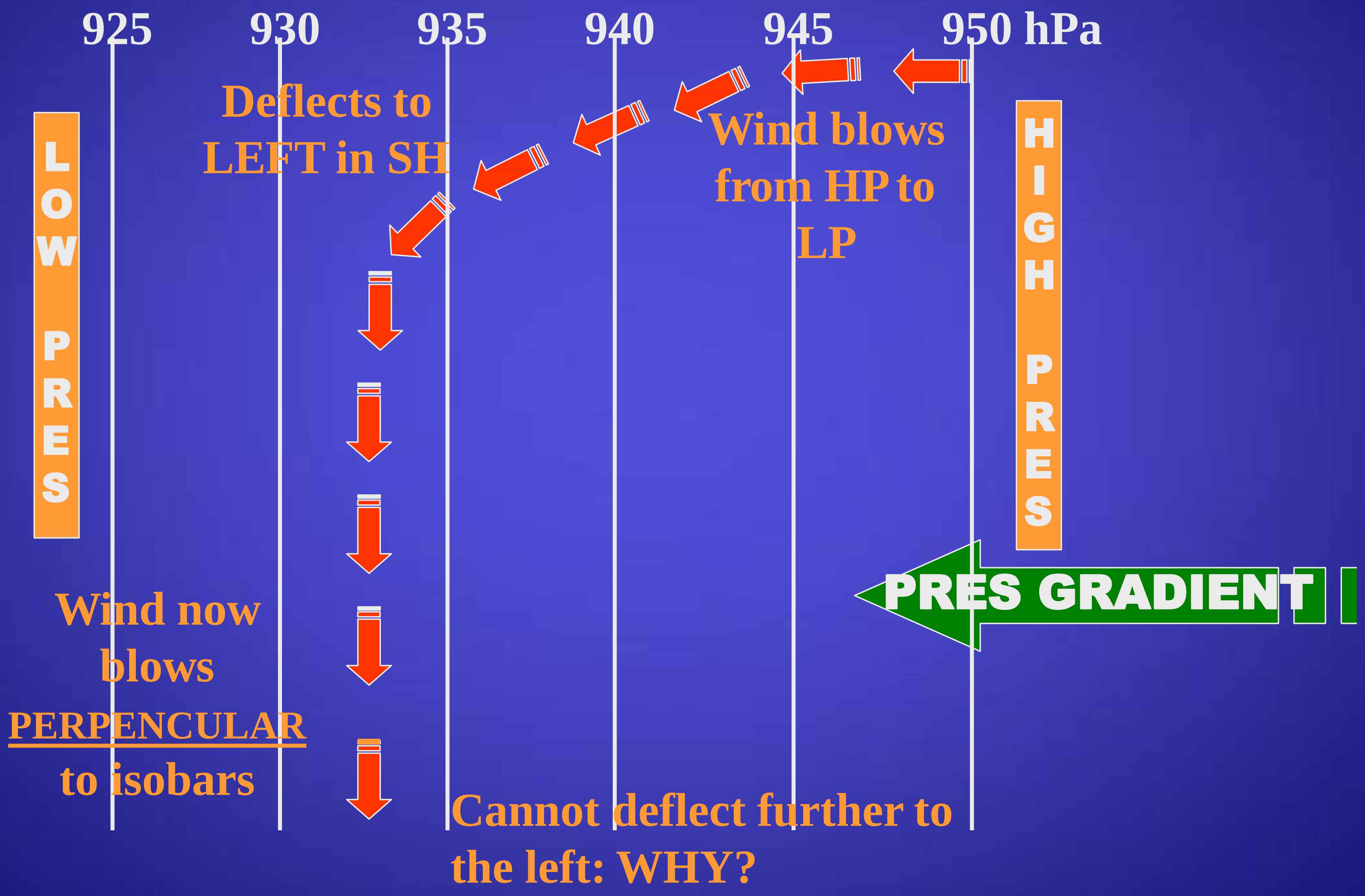



inertial frame
rotating frame
side view
1
0
-1
-1
0
1

Coriolis Force on a Flat Disk



GEOSTROPHIC WIND (SH)



Atmospheric motion

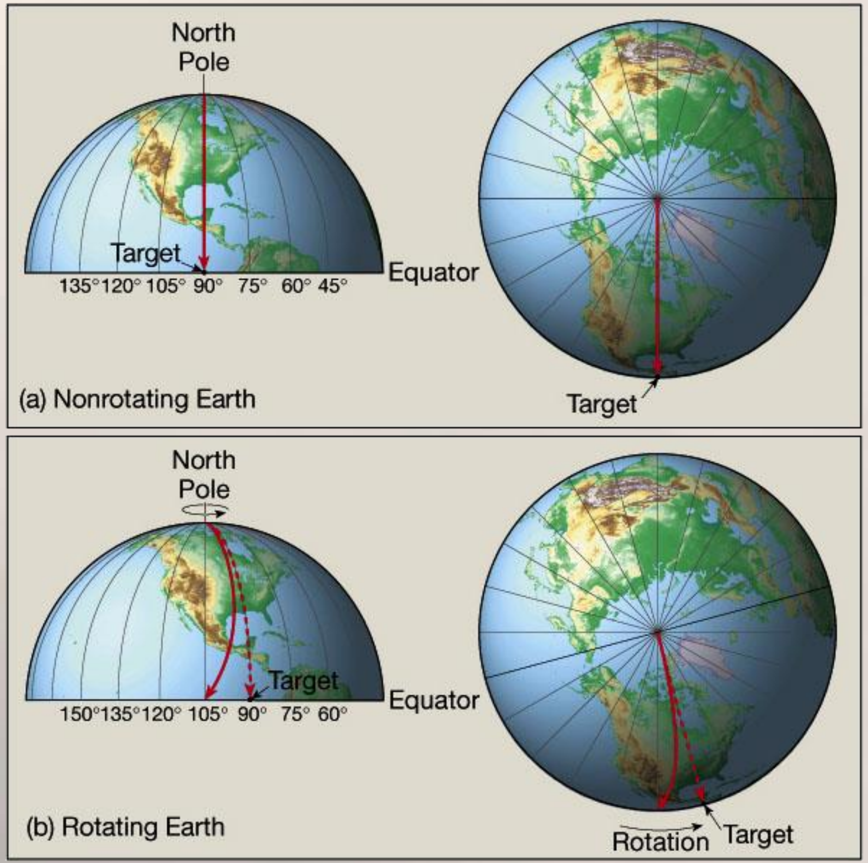
Earth is a sphere – more complex than disk: horizontal and vertical components to the coriolis force.

In the atmosphere, we are concerned only with the **horizontal** component of the coriolis force. It has a magnitude (per unit mass) of:

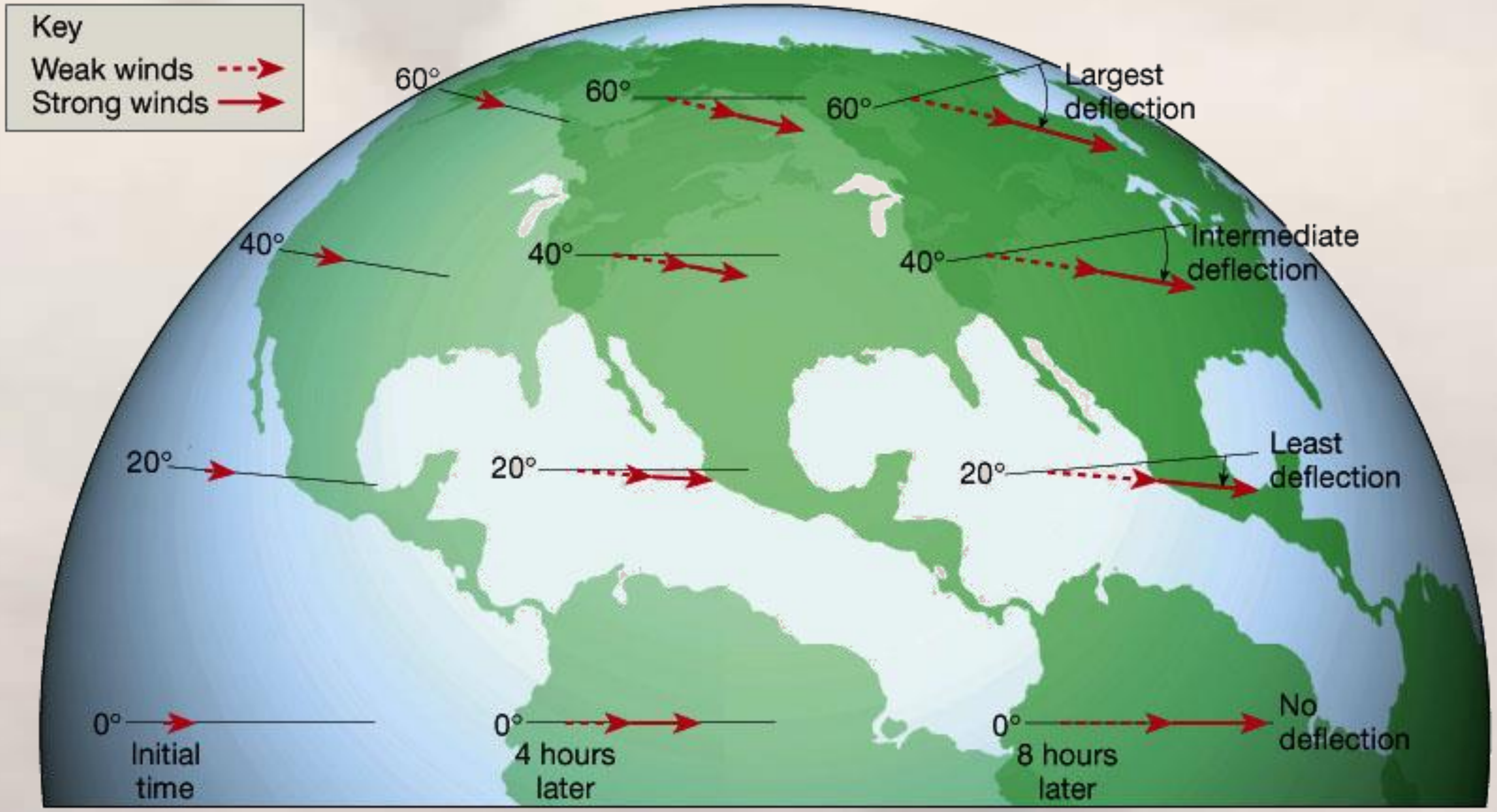
$$2\omega V \sin\phi$$

- ω = angular velocity of the earth
- V = wind speed
- ϕ = latitude

This is a maximum at the poles and zero at the equator, and results in a deflection to the right in the northern hemisphere, and to the left in the southern hemisphere.



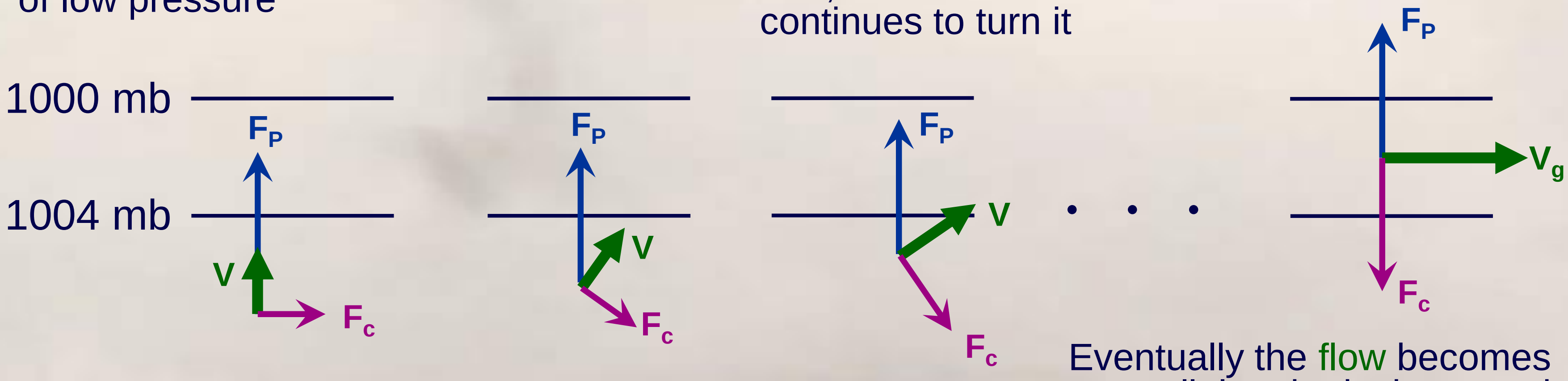
Wind Motion


Key
Weak winds
Strong winds
60°
60°
60°
Largest deflection
40°
40°
40°
Intermediate deflection
20°
20°
20°
Least deflection
0°
0°
0°
No deflection
Initial time
4 hours later
8 hours later

Geostrophic Balance

A pressure gradient imposed on a stationary air mass will start to accelerate it towards the region of low pressure

The pressure force continues to accelerate the flow, and the coriolis force continues to turn it



The coriolis force acts to turn the flow to the right (in the northern hemisphere)

Eventually the flow becomes parallel to the isobars, and the pressure and coriolis forces balance. This is termed **geostrophic** balance, and $\mathbf{V_g}$ the geostrophic wind speed.

Pressure Gradient Force=CF

Since the coriolis force balances the pressure force we have:

Pressure gradient force = coriolis force

$$\frac{1}{\rho}\frac{dP}{dx} = 2\omega V_g \sin\phi$$

Geostrophic wind speed is directly proportional to the pressure gradient, and inversely dependent on latitude.

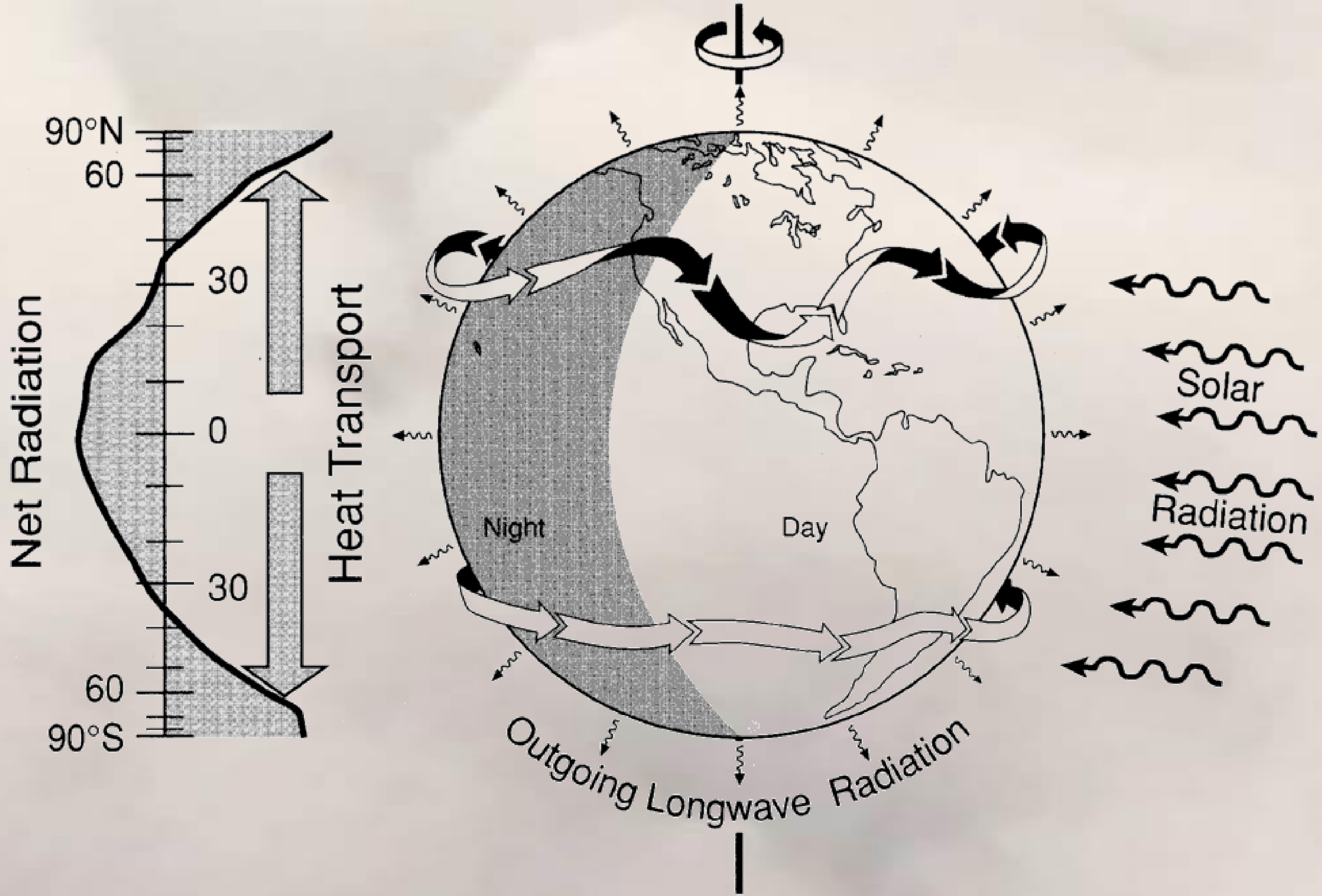
⇒ For a fixed pressure gradient, the geostrophic wind speed decreases towards the poles.

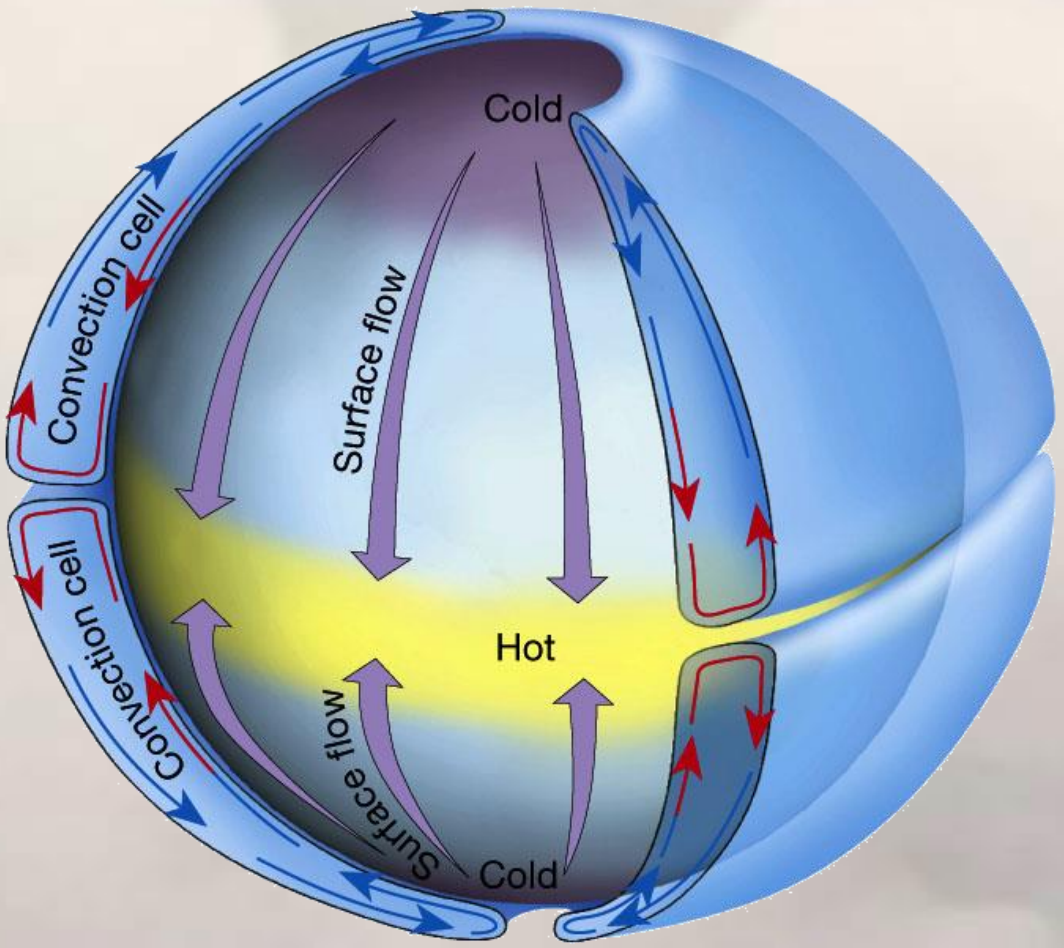
N.B. air density ρ changes very little at a fixed altitude, and is usually assumed constant, but decreases significantly with increasing altitude

⇒ pressure gradient force for a given pressure gradient increases with altitude

⇒ geostrophic wind speed increases with altitude.

Global Circulation



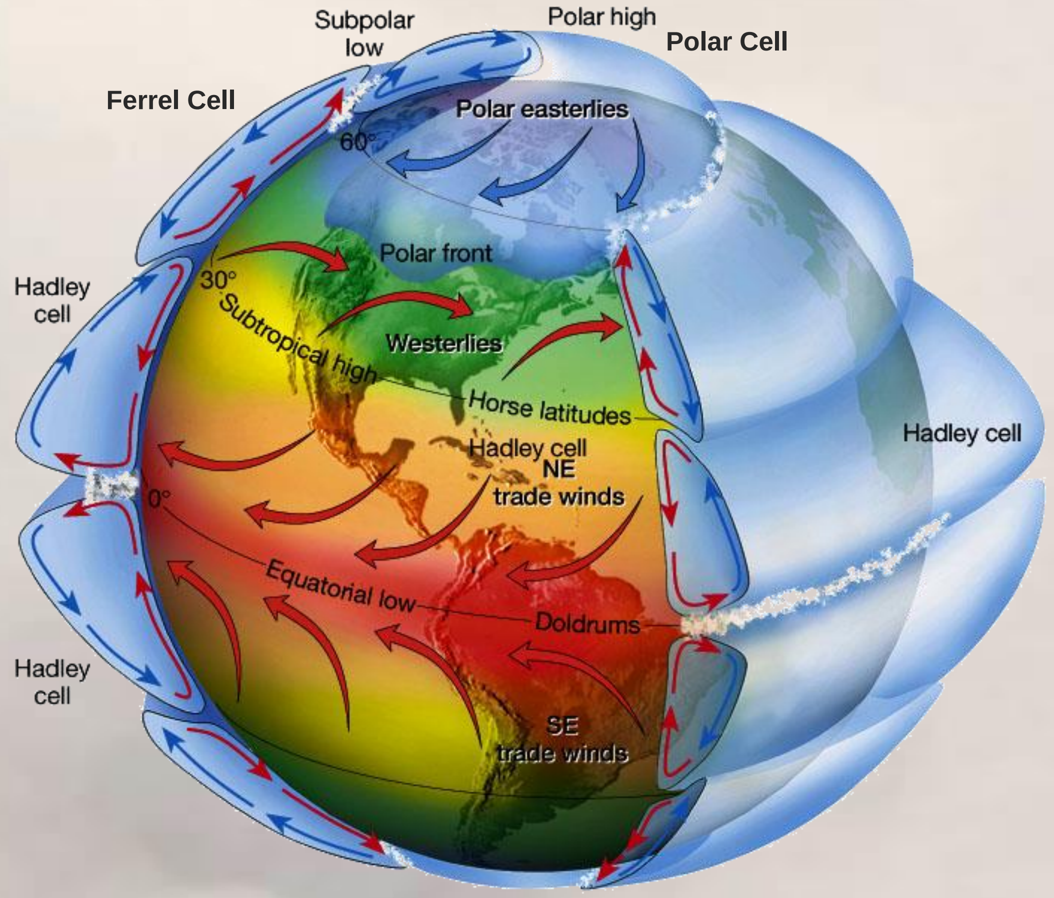


For a non-rotating Earth, convection could form simple symmetric cells in each hemisphere.

Coriolis force turns the air flow. Stable mean circulation has 6 counter-rotating cells – 3 in each hemisphere.

Within each cell, coriolis forces turn winds to east or west. Exact boundaries between cells varies with season.

N.B. This is a simplified model, circulations are not continuous in space or time.



Summarise

- Balance of pressure and coriolis forces results in geostrophic flow parallel to isobars
- Curvature of isobars around centres of high and low pressure requires centripetal acceleration to turn flow, resulting gradient wind is:
  - supergeostrophic around **HIGH**
  - subgeostrophic around **LOW**
- Friction reduces wind speed near surface
- Lower wind speed $\Rightarrow$ reduced coriolis turning, wind vector describes an Ekman Spiral between surface and level of geostrophic flow
- Surface wind lies 10-35° to left of geostrophic wind, crossing isobars from high to low pressure.

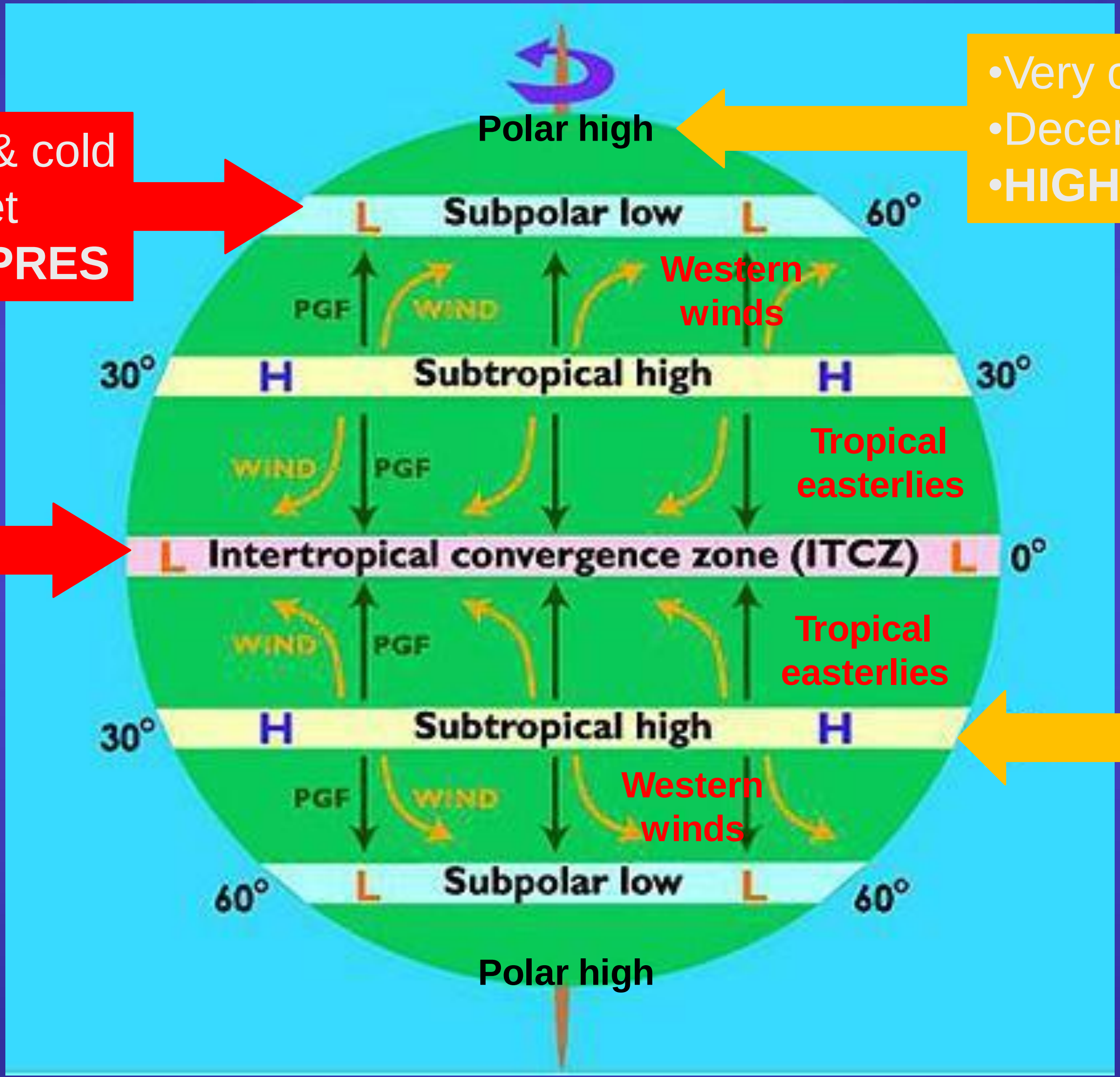
SECONDARY CIRCULATION

•Warm & cold air meet
•**HIGH PRES**

•Very cold
•Decending air
•**HIGH PRES**

•Very hot
•Ascending air
•**LOW PRES**

•Air from Equator sinks
•**HIGH PRES**



Winds deflect to the RIGHT in NH and to the LEFT in SH

REVIEW QUESTIONS

1. Explain how intense solar heating can cause low pressure at the surface of the earth.

2. What is the relationship between atmospheric pressure and wind?

3. Suppose two places on the surface of the earth have pressure differences as follows:

Place A		Place B	
710 mb	1150 mb	2050 mb	850 mb

   At which place will the wind be stronger?

4. In the following sketch of the earth, illustrate the likely path of a surface wind blowing from zone A to B, and the one from C to D.