Bell Ringer

1. What is the layer of the Earth farthest from the surface?
2. Where does most of Earth's weather occur?
3. True/False – Earth is the only planet in the solar system that has an atmosphere
4. How did Earth's atmosphere form?

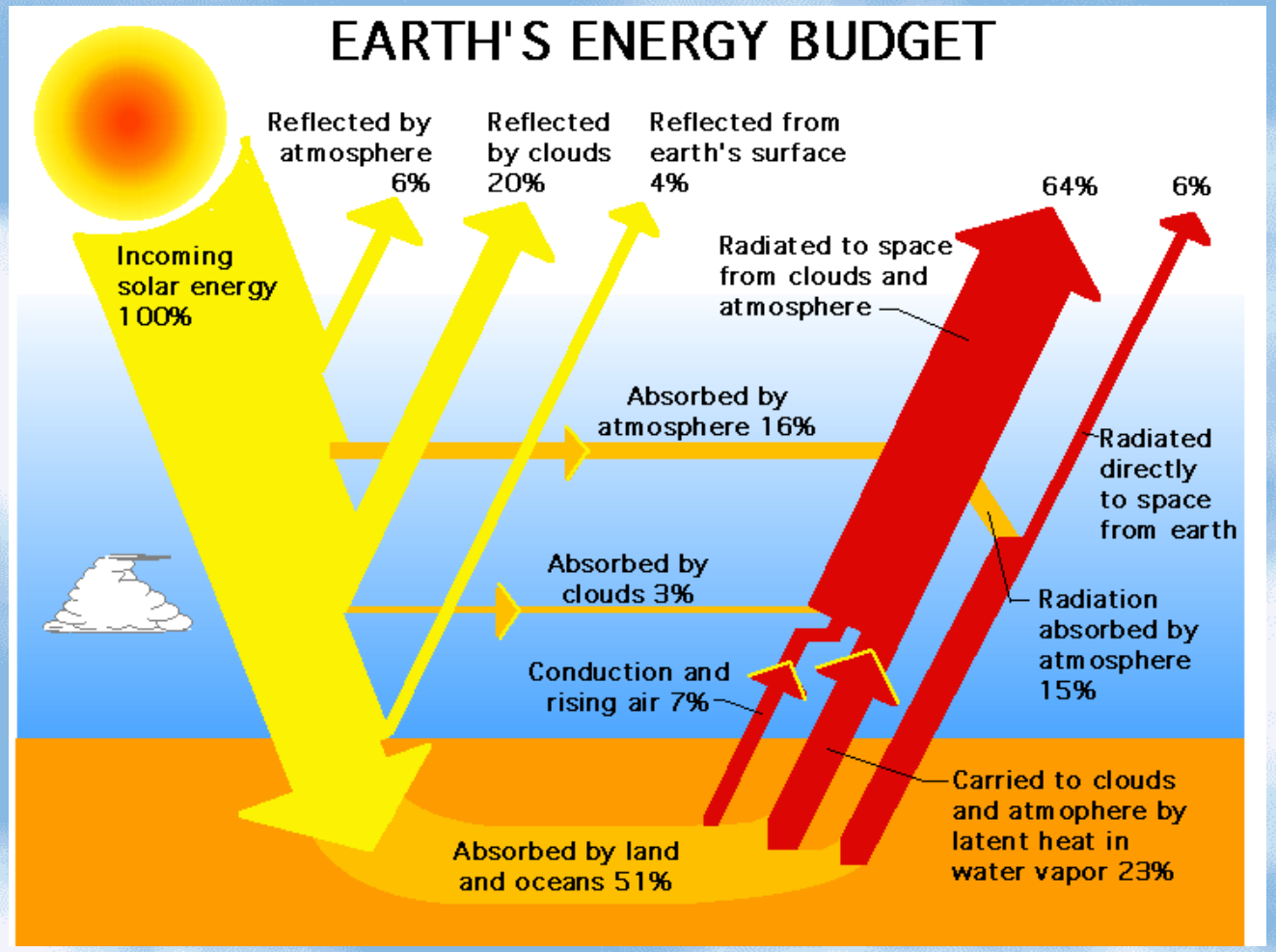
The Earth’s Energy Budget

Objectives

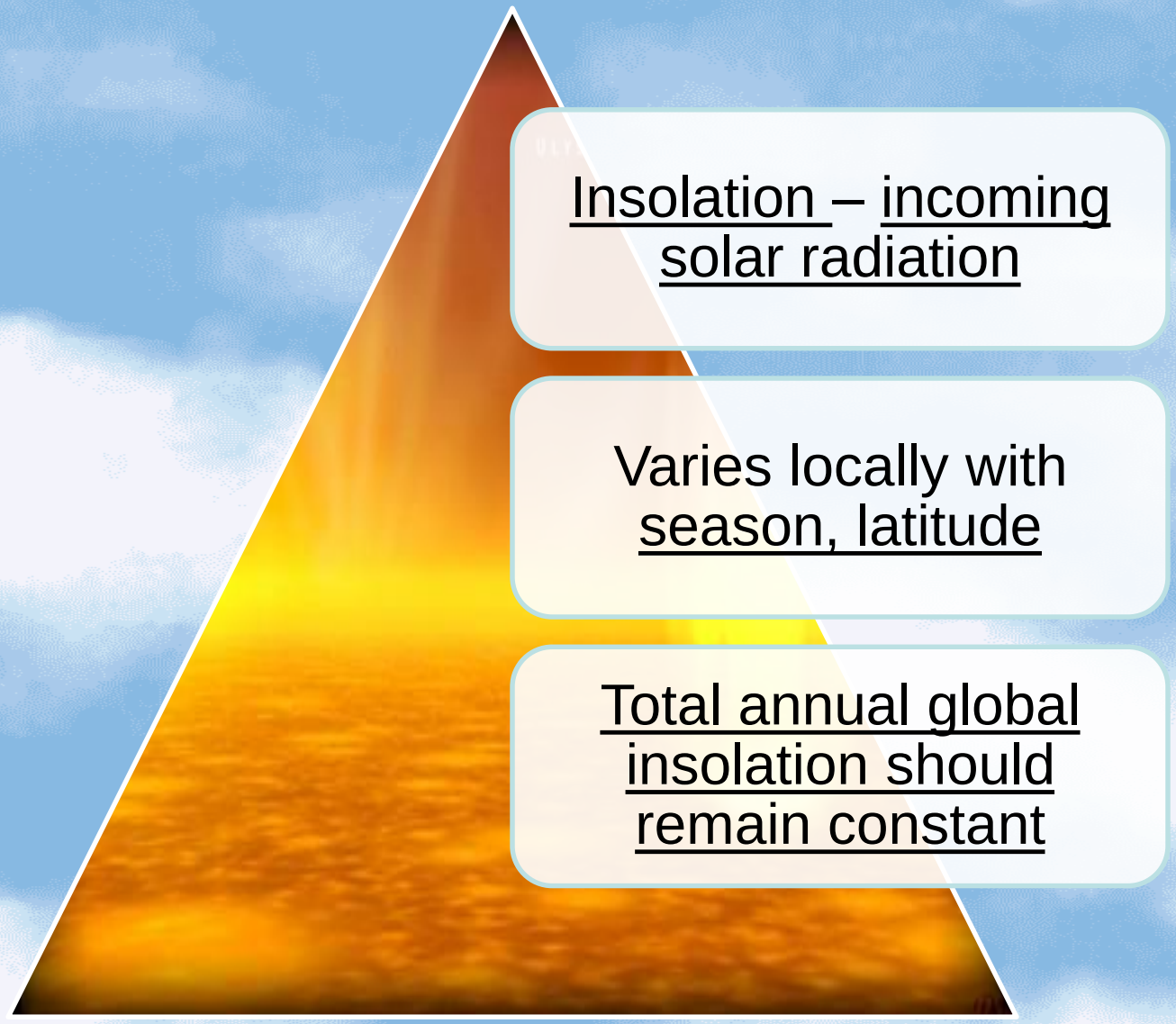
Trace the flow of energy through the atmosphere

A budget

Income = Outgo



Energy Income



Insolation – incoming solar radiation

Varies locally with season, latitude

Total annual global insolation should remain constant

When energy enters the atmosphere it can be ….

- Absorbed
- Reflected
- Scattered
- Transmitted

Absorbed

Energy is absorbed by gasses, particulates, droplets

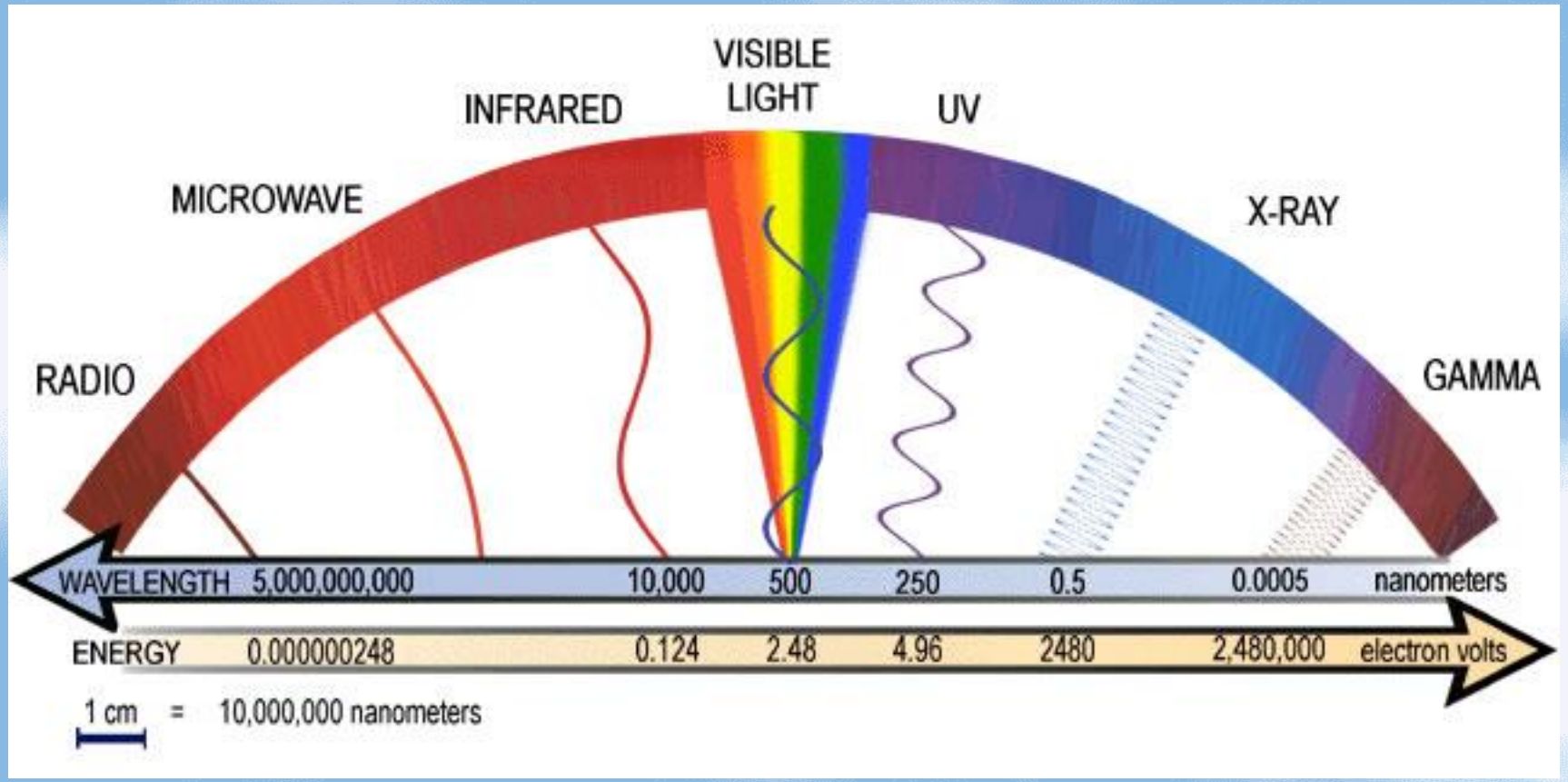
Different wavelengths are absorbed differently.

Ex.

Most UV is absorbed by ozone, but most visible light is not absorbed

CO_2 and H_2O are better at absorbing IR than N_2 or O_2

EM Spectrum


VISIBLE
LIGHT
INFRARED
UV
MICROWAVE
X-RAY
RADIO
GAMMA
WAVELENGTH 5,000,000,000 10,000 500 250 0.5 0.0005 nanometers
ENERGY 0.000000248 0.124 2.48 4.96 2480 2,480,000 electron volts
1 cm = 10,000,000 nanometers

Absorbed

Result

Absorber warms

Amount of solar energy reaching the surface is reduced

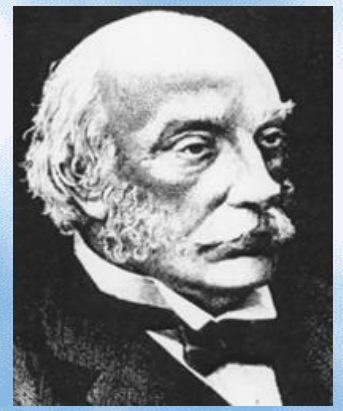
Reflected

Specular reflection – a beam is reflected with equal intensity

Diffuse radiation – a beam is split into many smaller, less intense beams = scattering

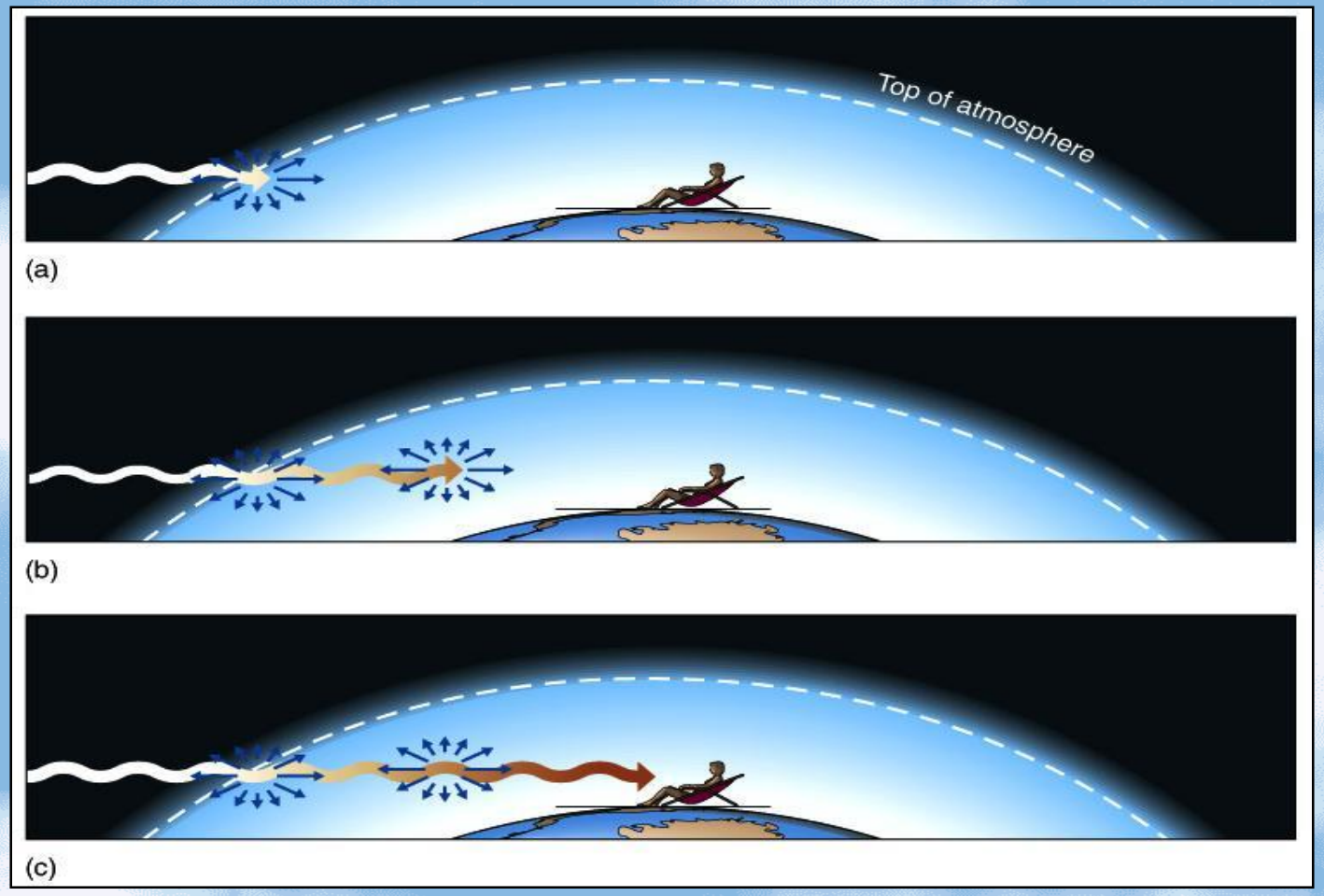
Rayleigh scattering

- Caused by individual gas molecules
- Scatters shorter wavelengths (blue) more than longer wavelengths
- Redirects the scattered waves in every direction (and thus toward any direction), therefore, the sky looks blue



Rayleigh scattering

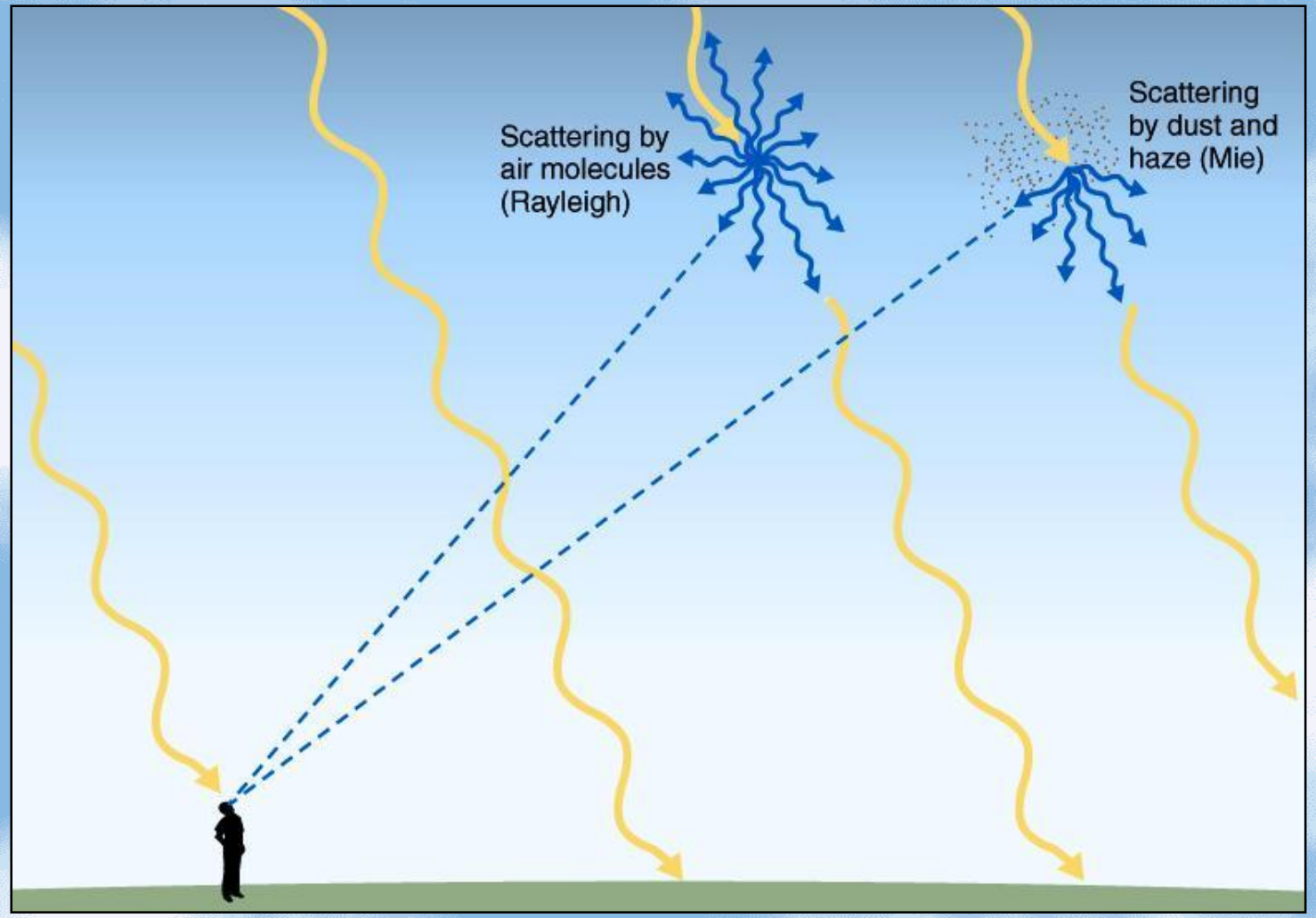
Responsible for red sunsets



Mie scattering

- Caused by aerosols – dust / particulates
- Tend to scatter all wavelengths
- Tends to scatter energy forward (toward the surface of the earth)
- E.g. Pollution causes the sky to look gray

Rayleigh and Mie scattering



Nonselective scattering

Water droplets act like little lenses – create rainbows

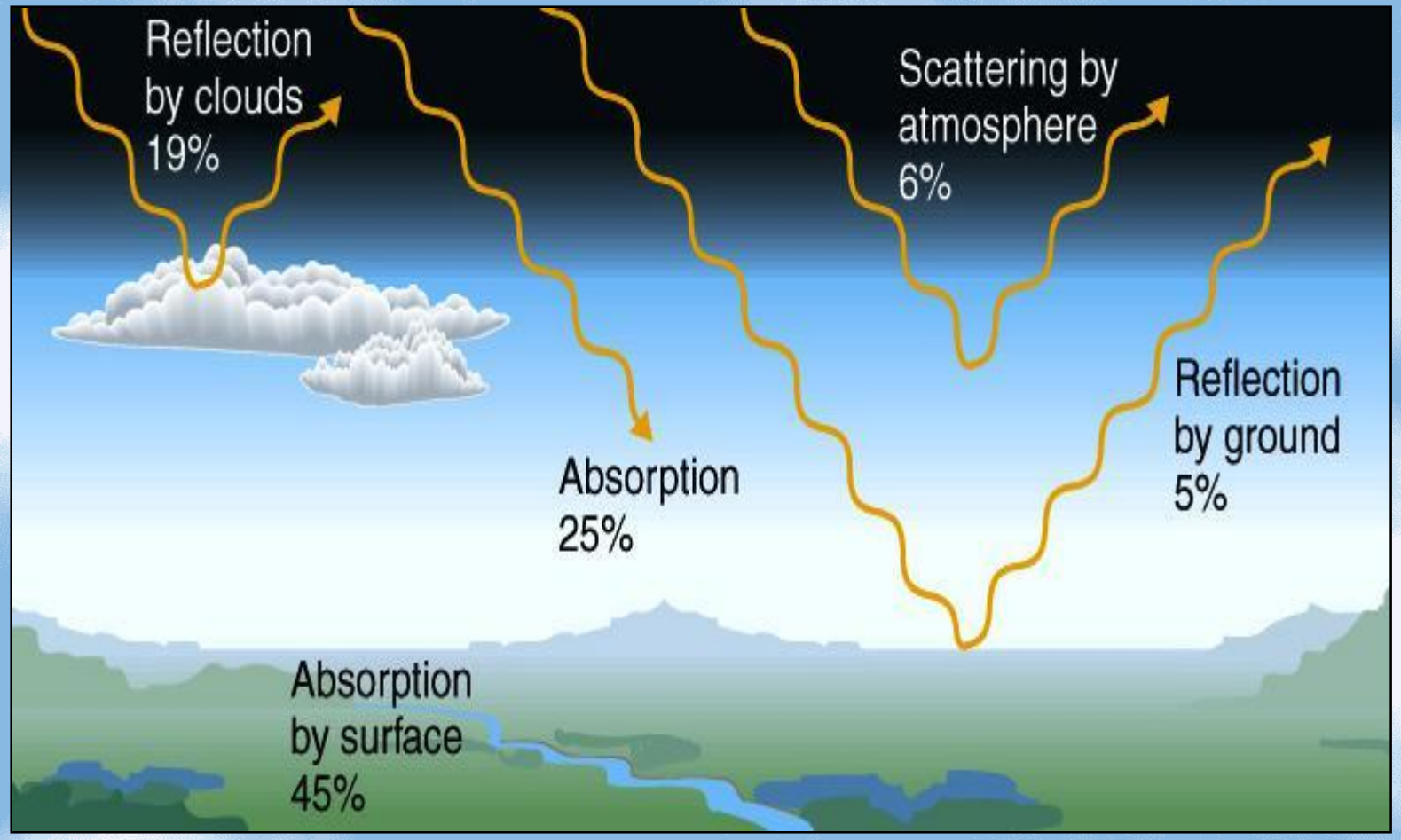
Masses of water droplets (clouds) reflect all wavelengths equally, thus they appear white or gray

Transmitted

Some amount of solar energy passes unobstructed to the surface of the earth

Amount depends on atmospheric conditions

Overall annual amounts



When solar energy reaches the surface of the earth it can be…

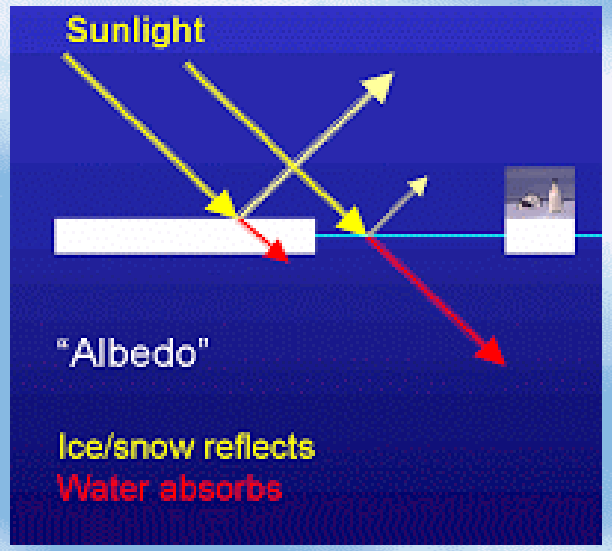
- Reflected
- Absorbed

Reflected

Albedo – reflectivity. Percent of energy reflected by a material.

Snow has a higher albedo than dirt

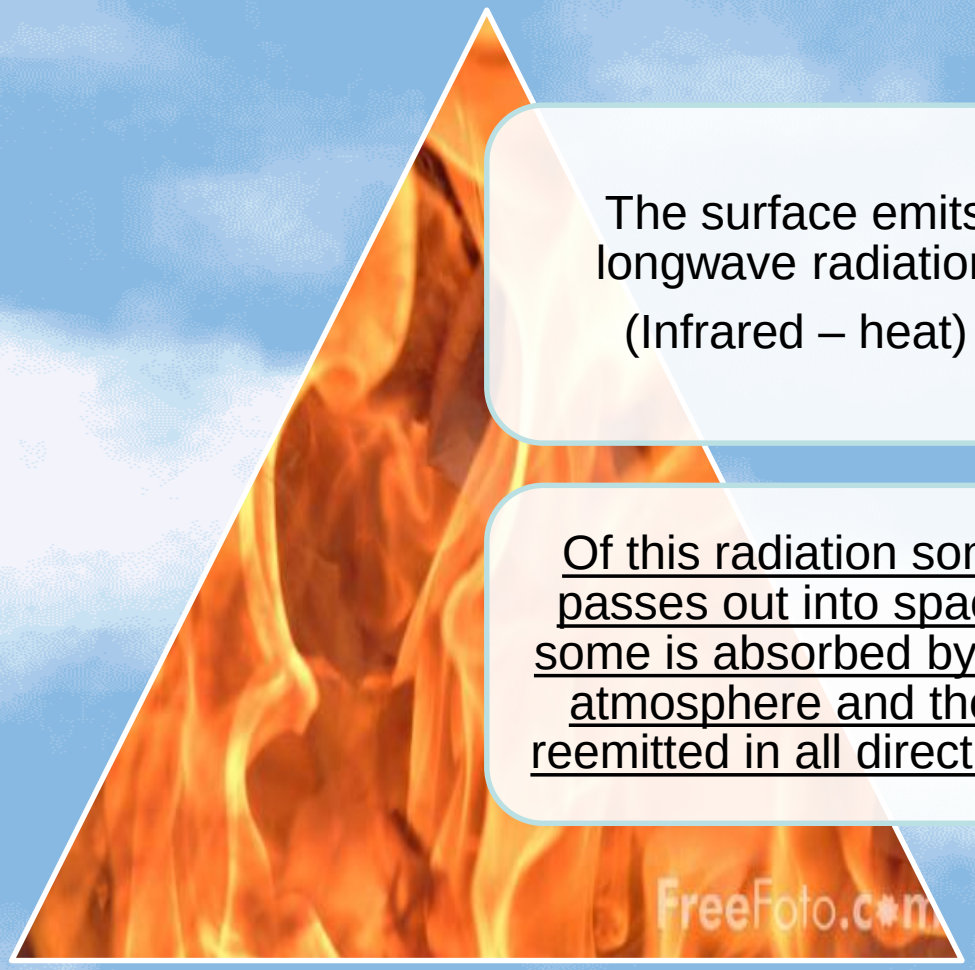
Overall the albedo of the earth is about 30%



If solar energy is absorbed by the surface it will eventually be removed by …

- Radiation
- Conduction
- Convection

Radiation



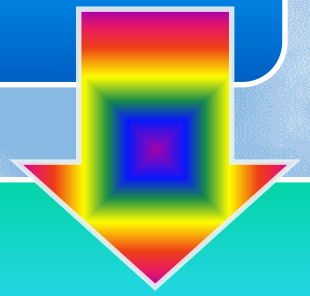
The surface emits longwave radiation

(Infrared – heat)

Of this radiation some passes out into space, some is absorbed by the atmosphere and then reemitted in all directions

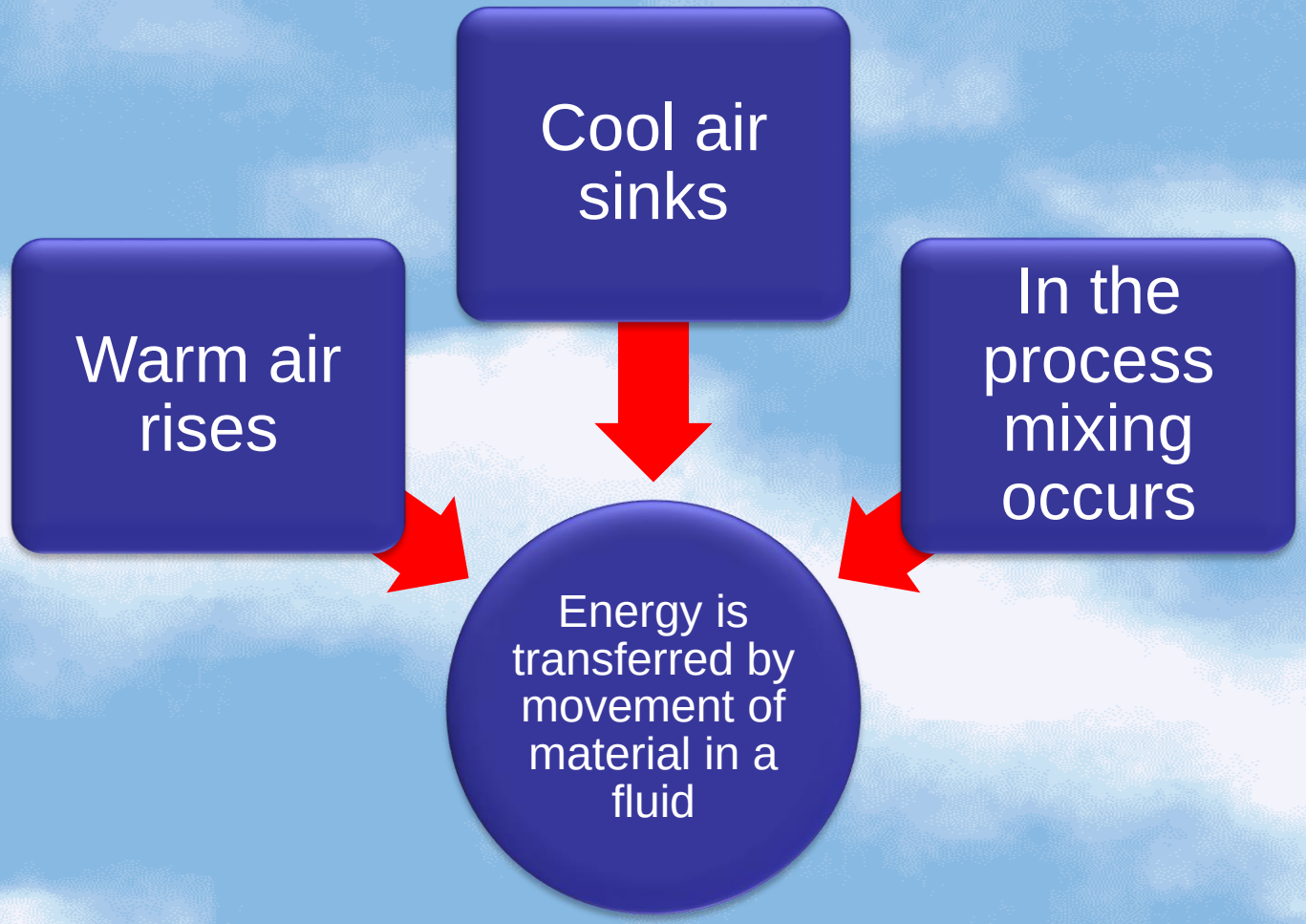
Conduction

Can warm the earth below

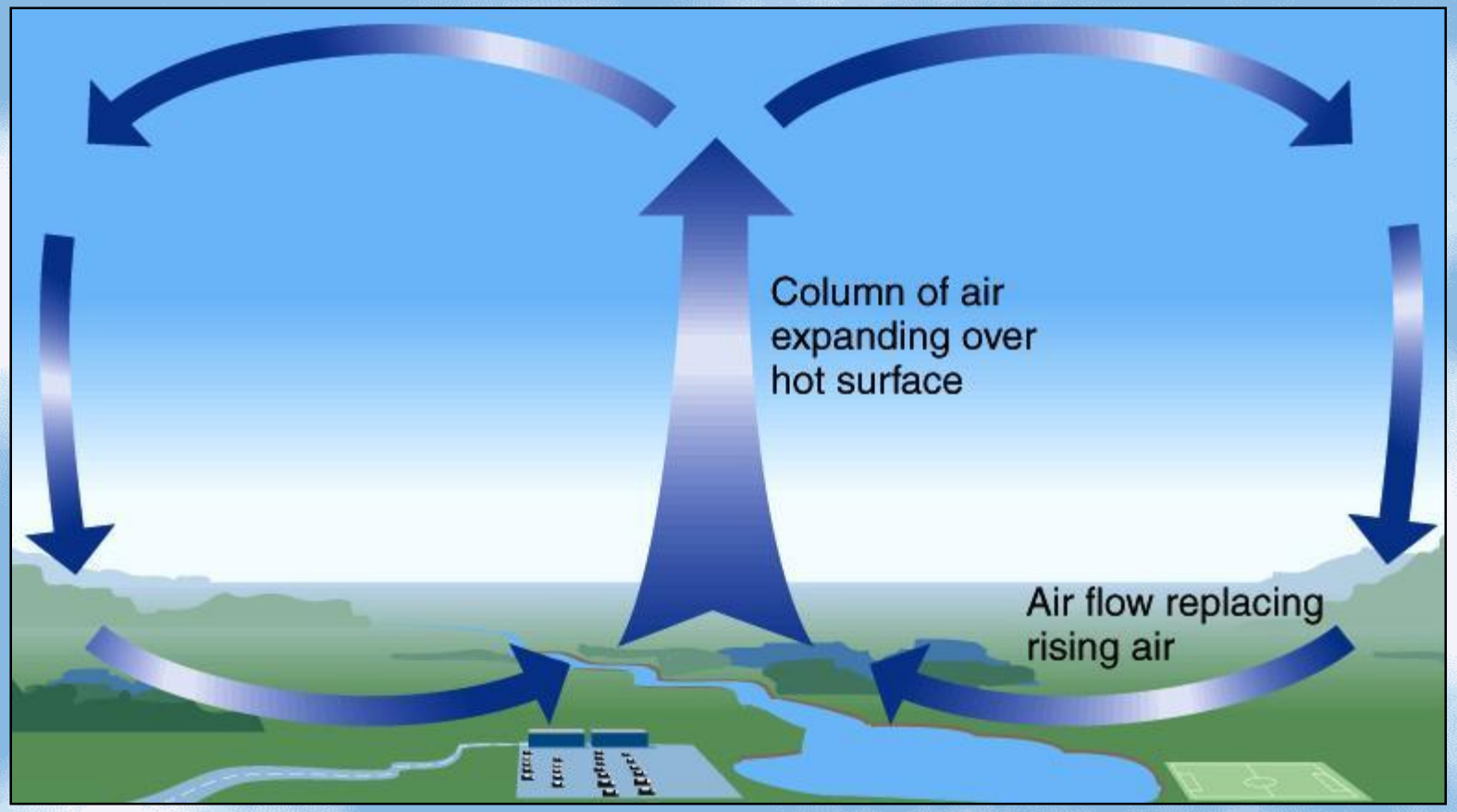


Can warm the laminar boundary layer (very thin layer of air in contact with the surface)

Convection


Cool air sinks
Warm air rises
In the process mixing occurs
Energy is transferred by movement of material in a fluid

Free convection



Convection

- Sensible heat – heat that you can sense (feel)

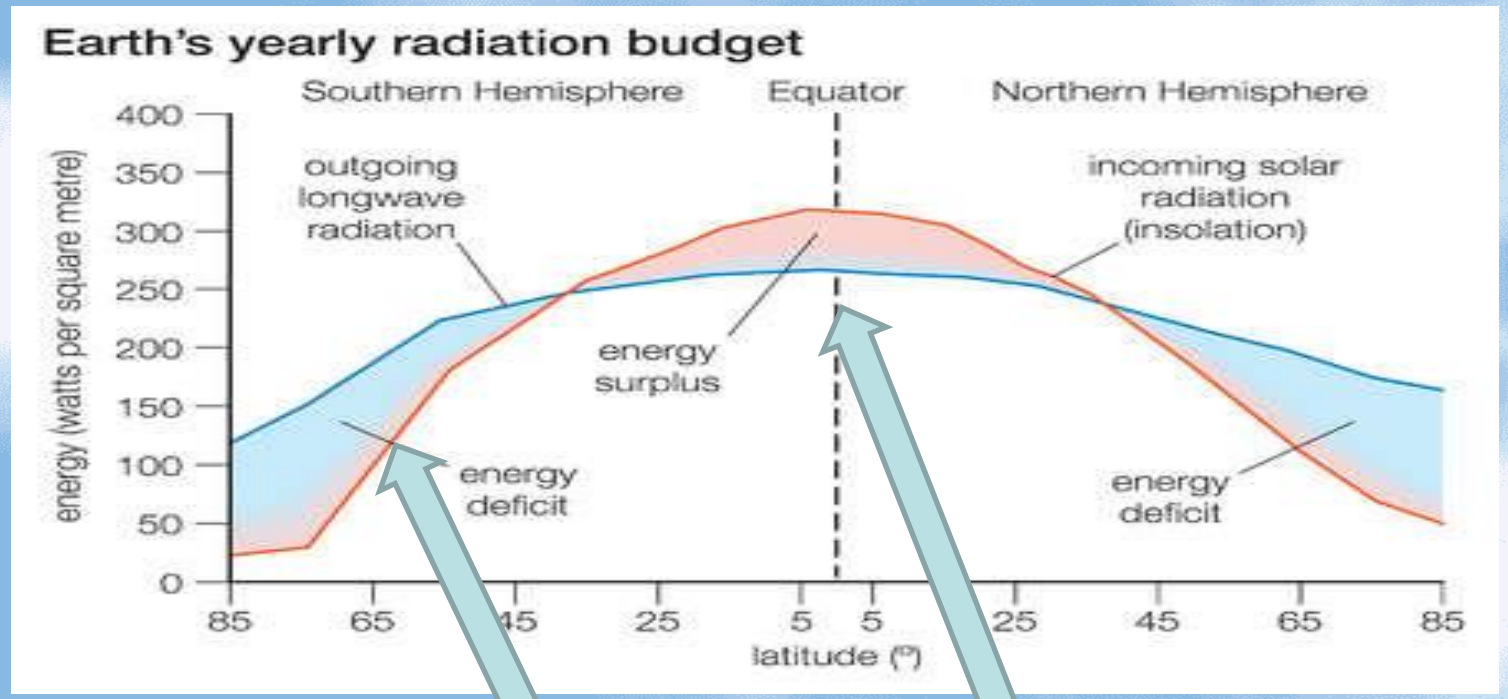
i.e. warm air

- Latent heat – energy used to change the phase of water

Latent heat of fusion – heat required to melt ice

Latent heat of evaporation

Even though the energy budget of the atmosphere remains balanced there are latitudinal variations.

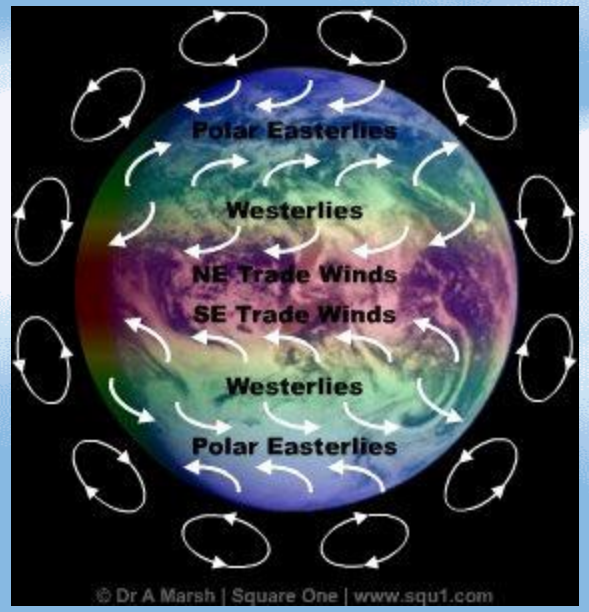


40^0 to 90^0 net deficit

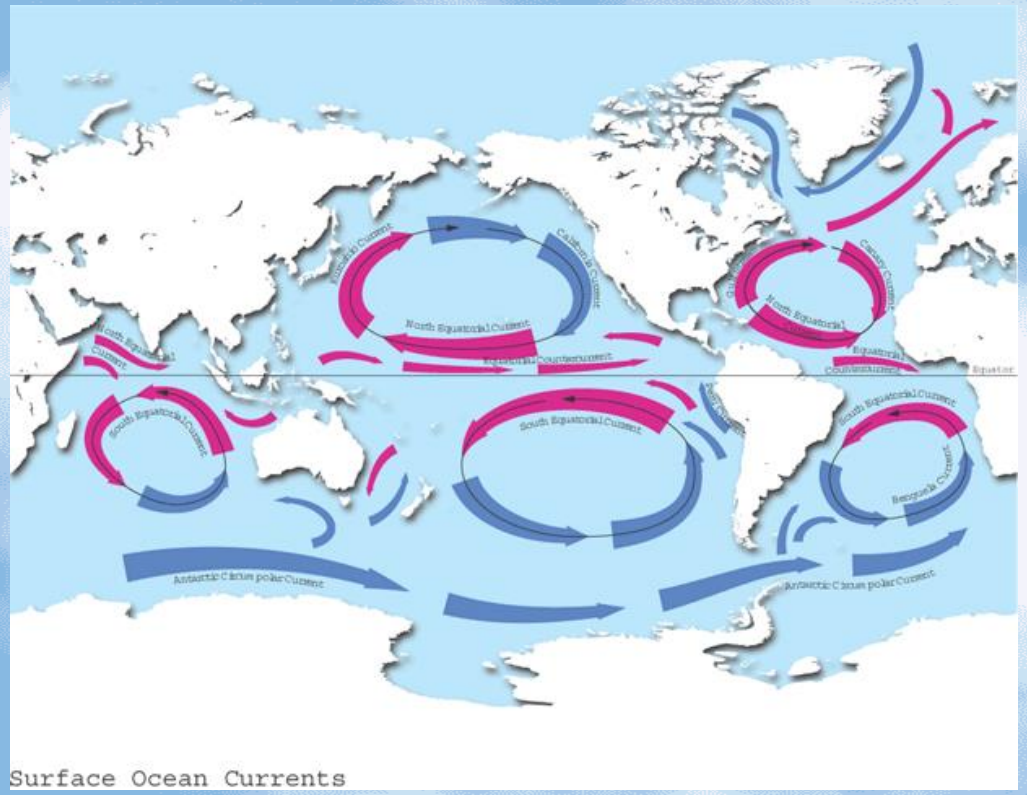
0^0 to 40^0 net surplus

Budget is balanced by advection – horizontal movements of energy

Global wind currents



Ocean currents

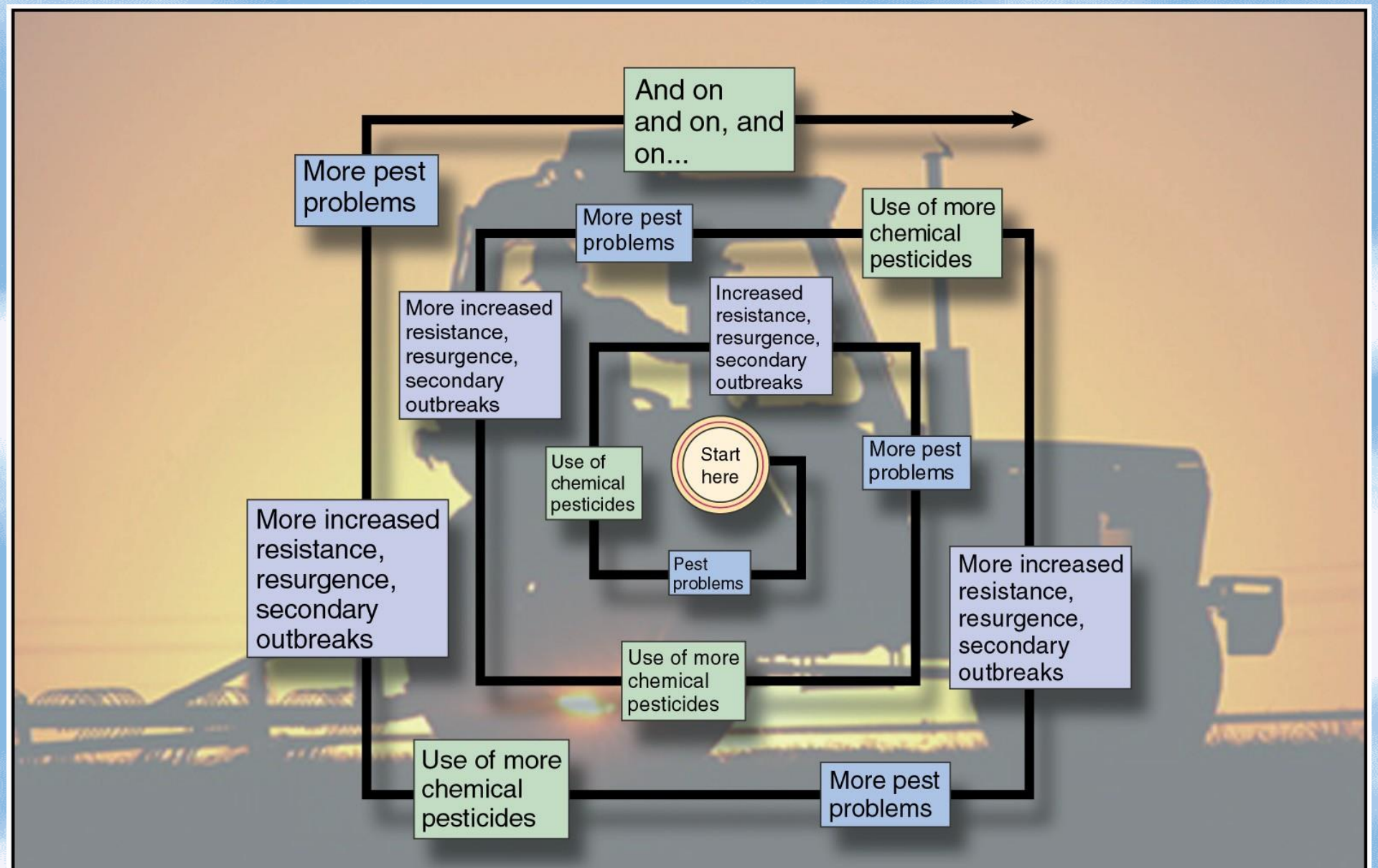


Earth’s energy budget WS

Earth’s feedback loops

- Earth has lots of feedback loops that either build on each other or balance each other out, depending on their effects.

Example - Pesticide



Positive and Negative Feedback

- Positive feedback – Makes the original change even more extreme. E.g. – the pesticide example.
- Enhance or amplify changes; this tends to move a system away from its equilibrium state and make it more unstable.

- Negative feedback – Pushes a system back to its original position.
- E.g. – You get cold, you shiver and put on a jacket, you get warm again.
- Tend to dampen or buffer changes; this tends to hold a system to some equilibrium state making it more stable.

Feedback loops WS