Discussion 2: Earth's Energy Balance

Composition of the Atmosphere

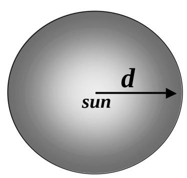
Solar Flux Emitted From The Sun

- Solar Luminosity (***L***)
  the constant flux of energy put out by the sun

  $L = 3.9 \times 10^{26}$ **W**

- Solar Flux Density (***S$_d$***)
  the amount of solar energy per unit area on a sphere centered at the Sun with a distance ***d***

  $S_d = L / (4 \pi d^2)$ **W/m^2**

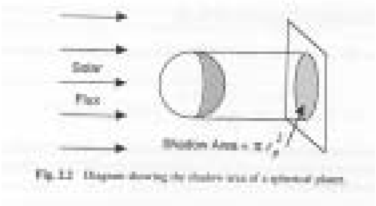


Solar Flux Density Reaching Earth

- Solar Constant (***S***)
  The solar energy density at the mean distance of Earth from the sun (1.5×10^{11} m)

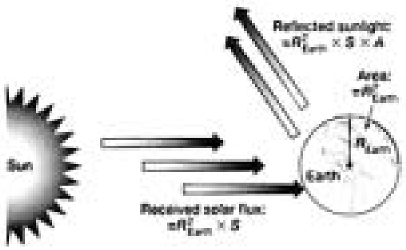
$$S = L / (4 \pi d^2)$$
$$= (3.9 \times 10^{26} \text{ W}) / [4 \times 3.14 \times (1.5 \times 10^{11} \text{ m})^2]$$
$$= 1370 \text{ W/m}^2$$

Solar Energy Incident On the Earth



- ❑ Solar energy incident on the Earth
  - = total amount of solar energy **can be** absorbed by Earth
  - = (Solar constant) x (Shadow Area)
  - = $\boldsymbol{S \times \pi R^2_{Earth}}$

Albedo = [Reflected] / [Incoming] Sunlight



Albedo is the percentage of the sunlight that is reflected back to the space by the planet.

Solar Energy Absorbed by Earth

(from *The Earth System*)

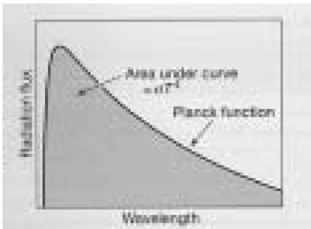
- **Solar Constant (S)**
  - = solar flux density reaching the Earth
  - = 1370 W/m^2
- **Solar energy incident on the Earth**
  - = S x the "flat" area of the Earth
  - = $S \times \pi R^2_{Earth}$
- **Solar energy absorbed by the Earth**
  - = (received solar flux) – (reflected solar flux)
  - = $S \pi R^2_{Earth} - S \pi R^2_{Earth} \times A$
  - **=** $\boldsymbol{S \pi R^2_{Earth} \times (1-A)}$

A is the *planetary albedo* of the Earth, which is about 0.3.

What Happens After the Earth Absorbs Solar Energy?

- ❑ The Earth warms up and has to emit radiative energy back to the space to reach a equilibrium condition.
- ❑ The radiation emitted by the Earth is called "terrestrial radiation" which is assumed to be like blackbody radiation.

Energy Emitted from Earth



(from *The Earth System*)

- **The Stefan-Boltzmann Law**

  The energy flux emitted by a blackbody is related to the fourth power of the body's absolute temperature

  $F = \sigma T^4$ where σ is 5.67×10^{-8} W/m²/K

- **Energy emitted from the Earth**
  = (blackbody emission) x (total area of Earth)
  = (σT_e^4) x $(4\pi R^2_{Earth})$

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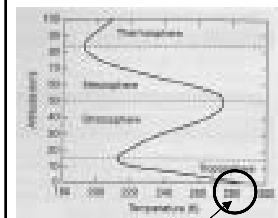
Planetary Energy Balance



(from *Global Physical Climatology*)

- **Energy emitted by Earth = Energy absorbed by Earth**

σT_e^4 x $(4\pi R^2_{Earth})$ = $S \pi R^2_{Earth}$ x $(1-A)$

σT_e^4 = S/4 * (1-A)

= 1370/4 W/m² * (1-A)

= 342.5 W/m² * (1-A)

= 240 W/m²

- **Earth's *blackbody* temperature**
  T_e = 255 K (-18C)

Earth's *surface* temperature
T_S = 288 K (15C)

greenhouse effect (33C) !!

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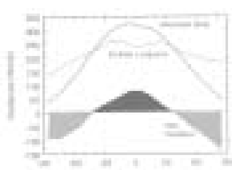
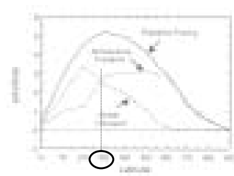
Polarward Energy Transport

Annual-Mean Radiative Energy



Polarward Heat Flux



Polarward heat flux is needed to transport radiative energy from the tropics to higher latitudes

The atmosphere dominates the polarward heat transport at middle and high latitudes. The ocean dominates the transport at lower latitudes.

(1 petaWatts = 10^{15} W)

(figures from *Global Physical Climatology*)

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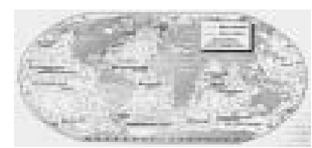
How Do Atmosphere and Ocean Transport Heat?

Atmospheric Circulation

(from USA Today)

Ocean Circulation



(top from *The Earth System*)
(bottom from USGCRP)

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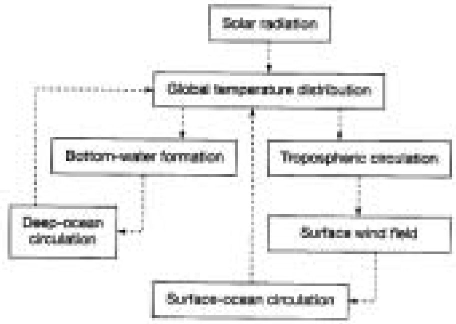
How Surface and Deep Ocean Circulation Are Driven?



(from *The Earth System*)

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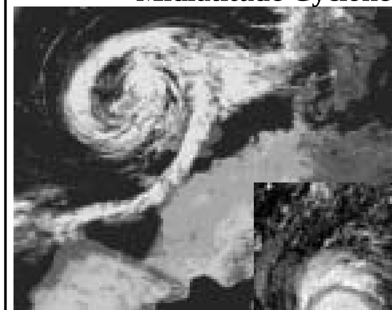
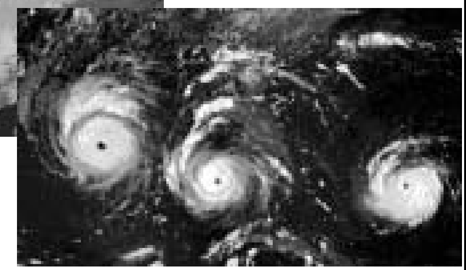
Midlatitude Cyclone



(from *Weather & Climate*)



Tropical Hurricane

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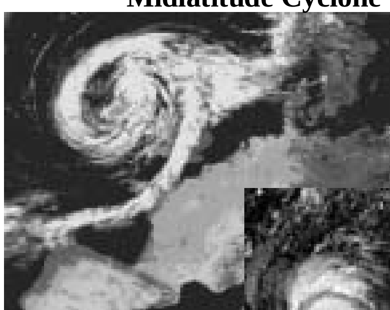
Midlatitude Cyclone



(from *Weather & Climate*)

Tropical Hurricane

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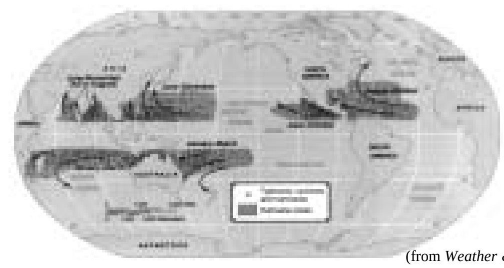
They Are the Same Things…



(from *Weather & Climate*)

- ***Hurricanes:*** extreme tropical storms over Atlantic and eastern Pacific Oceans.
- ***Typhoons:*** extreme tropical storms over western Pacific Ocean.
- ***Cyclones:*** extreme tropical storms over Indian Ocean and Australia.

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