Earth's Energy Balance

• 100 units of solar radiation hits the top of the atmosphere
• Surface absorbs 51 solar units (49 reflected & absorbed)
• Surface absorbs another 96 units from the warm sky!
• Atmosphere emits 96 units down (warm) but 64 up (cold)
• Surface has to get rid of 147 units: 117 by radiation, 23 by evaporated water, only 7 by rising hot air

The Job of the Atmosphere

• "Piles up" in tropics
• "Escapes" near poles and aloft

The movement of the air (and oceans) allows energy to be transported to its "escape zones!"

Energy In

• North-south contrast
• Land-sea contrast
• Ice and snow
• Deserts vs forests
**Energy Out**

- Given by $\varepsilon \sigma T^4$ (which $T$?)
- Combined surface and atmosphere effects
- Decreases with latitude
- Maxima over subtropical highs (clear air neither absorbs or emits much)
- Minima over tropical continents (cold high clouds)
- Very strong maxima over deserts (hot surface, clear atmosphere)

**Energy In minus Energy Out**

- Incoming solar minus outgoing longwave
- Must be balanced by horizontal transport of energy by atmosphere and oceans!

**Earth's Energy Balance**

Earth's annual energy balance between solar insolation and terrestrial infrared radiation is global but not local.

The global balance is maintained by transferring excess heat from the equatorial region toward the poles.

**It Takes a Lot of Energy to Evaporate Water!**

- Heat energy taken from environment
- Melting 335 kJ/kg
- Freezing
- Liquid Water
- Condensation
- Water Vapor
- Heat energy released to environment
Energy Balance of Earth’s Surface

Energy from the Surface to the Air
- Energy absorbed at the surface warms the air
- Some of this energy is transferred in rising warm “thermals”
- But more of it is “hidden” in water vapor

Seasons & Solar Intensity
- At solstice, one pole is light & one is dark (24/7)
- At equinox, tilt provides exactly 12 hours of night and 12 hours of day everywhere

A sunlight beam that strikes at an angle is spread across a greater surface area, and is a less intense heat source than a beam impinging directly.
Midnight Sun

The region north of the Arctic Circle experiences a period of 24 hour sunlight in summer, where the Earth's surface does not rotate out of solar exposure.

Daily Solar at Top of Atmosphere

- 75° N in June gets more sun than the Equator!
- Compare N-S changes by seasons
- Very little tropical seasonality

Regional Seasonal Cycles

Regional differences in temperature, from annual or daily, are influenced by geography, such as latitude, altitude, and nearby water or ocean currents, as well as heat generated in urban areas.

San Francisco is downwind of the Pacific Ocean.

Richmond, VA is downwind of North America!
Local Solar Changes

Northern hemisphere sunrises are in the southeast during winter, but in the northeast in summer.

Summer noon time sun is also higher above the horizon than the winter sun.

Landscape Solar Response

South facing slopes receive greater insolation, providing energy to melt snow sooner and evaporate more soil moisture.

North and south slope terrain exposure often lead to differences in plant types and abundance.

Temperature Lags Radiation

Earth's surface temperature is a balance between incoming solar radiation and outgoing terrestrial radiation.

Peak temperature lags after peak insolation because surface continues to warm until infrared radiation exceeds insolation.