Physical Geography

GEOGRAPHY 1710

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Chapter 4
Atmosphere & Surface Energy Balances
Energy Pathways

- Reflection to space
- Shortwave radiation
- Diffuse radiation
- Direct radiation
- Atmospheric heat flow
- Longwave radiation
- Surface heat flow
- Energy gained and lost by Earth's surface

Earth
Energy Pathways

- **Transmission**
  - Passage of energy through atmosphere or water

- **Scattering**
  - Changing direction of light’s movement, without altering its wavelengths

- **Refraction**
  - Change in speed and direction of light
Refraction

What is happening in the photograph?

- Sun’s image
- Sun’s actual position
- Refraction by the atmosphere
- Observer
- Earth
Energy Principles

Insolation input

On a sunny day 75% of insolation may reach the earth’s surface; on an overcast day only 15%. On average 51% of insolation is absorbed by the surface as thermal energy — 29% as direct radiation and 22% as diffused radiation; i.e. scattered by atmospheric dust, water vapor and air molecules.

Albedo

About 4% of the radiation reaching the surface is directly reflected, at the same wavelength, from the surface back into space.

Absorption

Altogether some 70% of insolation is absorbed at the earth’s surface and in the upper atmosphere but eventually all this absorbed radiation is re-radiated back into space.
Albedo

Is the **reflectivity** of a surface.
Clouds and Albedo

(a) Shortwave radiation

(b) Longwave radiation
Heat Transfer

- **Conduction**
  - Molecule to molecule transfer

- **Convection**
  - Energy transferred by movement

- **Radiation**
  - Energy traveling through air or space
The Greenhouse Effect and Atmospheric Warming

- Atmosphere absorbs heat energy
- A real greenhouse *traps* heat inside
- Atmosphere *delays* transfer of heat from Earth into space
Clouds and Earth’s “Greenhouse”

(a) High clouds: net *greenhouse* forcing and atmospheric warming

(b) Low clouds: net *albedo* forcing and atmospheric cooling
Earth–Atmosphere Energy Budget

Solar energy input $+100$

Longwave portion of the budget
- Energy radiated to space $-69$
  - Radiated by ozone layer to space $-3$
  - $-66$ (21 + 23 + 14 + 8 = 66)

Shortwave portion of the budget
- Earth's albedo $-31$
- Diffuse reflection and scattering $-7$
- Absorbed by clouds $+3$
- Reflected by clouds $-21$
- Stratospheric absorption by ozone $+3$
- Absorbed by atmospheric gases and dust $+18$

Surface heat input
- Direct and diffuse radiation absorbed by Earth's surface $+25$
- Direct $+45$

Latent heat transfer (evaporation) $+19$
Convective (turbulent) transfer $+4$
Infrared radiation and reradiation $+110$
Greenhouse effect $+96$
Direct heat loss to space $-8$

Energy gained and lost by Earth's surface
- $-19$
- $-4$
- $-110$
- $+96$
- $-8$
Energy Balance at Earth’s Surface

- Daily Radiation Patterns
- Simplified Surface Energy Balance
- The Urban Environment
Daily Radiation Patterns

- **Radiant energy flow**
- **Air temperature**

- Coolest time of day
- Local noon
- Lag
- Warmest time of day
- Surplus
- Absorbed insolation

- Midnight
- Sunrise
- Noon
- 3 P.M.
- Sunset
- Midnight

- Absorbed insolation
- Air temperature
Urban Heat Islands - The consistently higher temperature found in cities as compared to rural areas

- The air in an urban area can be as much as 20°F (11°C) higher than rural areas surrounding the city.

- Urban surfaces of metal, glass, asphalt, concrete, and stone conduct up to three times more energy than wet sandy soil and are termed urban heat islands.
The image spans Salt Lake City on the western (l) edge of the image to the foothills of the Wasatch Mountains on the eastern (r) edge.
• The hard, dark surfaces like pavement store heat during the day, heat that is then released at night, keeping the city hotter for longer periods of time.

• A growing percentage of Earth’s population live in urban areas.

• Each person then experiences a unique set of altered microclimate effects:
  * Increased conduction
  * Lower albedos
  * Higher NET R values
  * Increased run-off

  * Complex radiation
  * Complex reflection
  * Anthropogenic heating
  * Pollution
Aerial thermal photograph of Sacramento showing cool areas and hot spots.
What is Albedo?

- Reflectivity + Emissivity = Albedo
- Reflectivity: the percentage of incident light or electromagnetic radiation that is reflected.
- Emissivity: the rate at which absorbed energy is radiated from an object.
What can be done to reduce the Heat Island Effect?

- Plant more canopy type trees
- Use lighter colored materials for roads and parking lots
- Use high Albedo materials