Chapter 2: Solar Energy, Seasons, and the Atmosphere
Milky Way Galaxy

Figure 2.1

(a) Top view

Our Solar System is in the Orion Spur of the Sagittarius Arm

Sun and Solar System

(b) Side view

Our Solar System

100,000 light-years
Planetesimal Hypothesis
Solar Energy: From Sun to Earth

- Solar Wind
- Electromagnetic Spectrum of Radiant Energy
- Energy at the Top of the Atmosphere
The Solar Wind and Earth's Magnetosphere
Auroral Displays

Flares and Coronal Mass Ejections: trigger the Aurora borealis and Aurora australis as charged particles from the Sun are drawn to the magnetic north and south poles.
Auroral displays can be monochrome or polychrome: can extend to Lower 48 [Wisconsin]
Images from the Solar Heliospheric Observatory [SOHO] sensor suite.
Solar fusion releases an incredible amount of energy with minimal loss of solar “gas mass” or fuel… potentially, could be a virtually inexhaustible power source here on Earth due to abundant fuels such as Deuterium...

Fusion power on Earth is not *science fiction*… early stages of production underway
Contemporary nuclear energy by fission: about 1/6 of world’s electricity

In the not-so-distant future, fusion reactors may supply virtually all electricity, since the fuel for fusion reactions is the various isotopes of hydrogen...
Tokamak: hypothetical design for fusion reactors

[Russian, from to(roidal'naya) kam(era s) ak(sial'nym magnitnym polem), toroidal chamber with axial magnetic field.]
The Electromagnetic Spectrum
Solar Energy:
intense shortwave spectra

Terrestrial Energy:
less intense longwave spectra
Earth’s Energy Budget

Overall, there is a balance between the amount of incoming solar radiation and outgoing terrestrial radiation, even though they are different spectra of radiation.

Figure 2.6
Surface area receiving insolation

- More diffuse, larger area covered
- Annually 2.5 times more energy than poles
- More concentrated, smaller area covered
- Direct
- Oblique
- Sun’s rays arrive parallel to Earth
Angle of Incidence
**Solar Constant**

- The amount of energy received at the *thermopause* when Earth is at an average distance from the Sun

- 1372 watts per square meter *input* to Earth’s systems from the Sun

- Net radiation values indicate *gains* of energy in some locations, and *losses* of energy in other locations around the planet
Global Net Radiation at the Thermopause

Figure 2.8

Net radiation at top of atmosphere, in Watts/m²
The Seasons

Seasonality:
- Altitude: angle between Sun and horizon
- Declination: latitude of direct insolation
- Daylength: duration of sunlight

Factors That Influence Seasonal Change

Annual March of the Seasons
Revolution and Rotation

Revolution: one solar year

Rotation: one solar day
Axial Tilt and Parallelism

Figure 2.11
Annual March of the Seasons

Geosystems 2: pp. 46-47
Older Figure 2.13
Seasons occur as the Sun migrates in the sky from Tropic to Tropic, casting varying insolation across the globe.
Camera facing due north during Northern Hemisphere summer

In winter, the Sun may never rise above the horizon…
Pressure decreases as altitude increases, simply because there is less atmosphere at altitude... gravity pulls most of the molecules down towards the surface.
Normal Lapse Rate

This is the condition we expect, wherein temperature decreases as altitude above the Earth’s surface increases: a ‘normal lapse rate’

Figure 2.14
Profile of Atmosphere

Heterosphere: layered gases
Homosphere: mixed gases
Thermosphere: inverted lapse rate; lots of molecular motion, little ‘heat’
Mesosphere: normal lapse rate
Stratosphere: inverted lapse rate; this is due to ozone creation and destruction
Troposphere: normal lapse rate
Ionosphere: absorbs many harmful wavelengths of insolation
Ozonosphere: absorbs UV rays

Figure 2.14
Composition of the Homosphere

Layer in the atmosphere that typically contains a mixture of these gases

Also, this ‘layer’ encompasses the stratosphere and troposphere, where most forms of weather occur.

Figure 2.19 (old textbook figure)
Protective Properties of the Atmosphere

Figure 2.15
Ultraviolet light hits a chlorofluorocarbon (CFC) molecule, breaking off a chlorine atom.

Once free, the chlorine atom is off to attack another ozone molecule.

A free oxygen atom pulls the oxygen atom off the chlorine monoxide molecule.

The chlorine atom and the oxygen atom join to form a chlorine monoxide molecule.

The chlorine atom attacks an ozone molecule, pulling an oxygen atom off it.

This is why many CFC refrigerants are restricted for use in many countries...
Ozone & UV Rays

- UV radiation is involved in both the creation and destruction of ozone (O$_3$)

- Release heat energy = higher molecular activity = higher temperatures

- Antarctic Ozone Hole: occurs at transition from winter to spring, as returning sunlight activates chemical reactions within Polar Stratospheric Clouds
Southern Ozone Hole

Sep 18 1979

Sep 21 1988

Sep 10 2000

Sep 24 2002
Forecast from 22 Mar 2004 00h00

ENVISAT / MIPAS

BASCOE

4D-VAR chemical data assimilation

http://bascoe.oma.be  BIRA-IASB / ESA  Forecast v3b04

O₃

Total column [D.U.]

150 300 400 500

24 Mar 2004 12h00

25 Mar 2004 12h00

26 Mar 2004 12h00

27 Mar 2004 12h00

28 Mar 2004 12h00

29 Mar 2004 12h00

30 Mar 2004 12h00

31 Mar 2004 12h00

ENVISAT: Ozone Forecast for Northern Hemisphere
Most harmful radiation is filtered out by the atmosphere above the Tropopause
Variable Atmospheric Components (Pollutants)

- Natural Sources
- Natural Factors That Affect Air Pollution
- Anthropogenic Pollution
Volcanics

Vatnajökull eruption in Iceland... sulfur oxides and particulate matter source

ics
Atmospheric pollution from Alaskan wildfires on August 4, 2002

Source of:
- Carbon dioxide
- Carbon monoxide
- Nitrogen oxides
- Particulates
Decaying organic matter in marshes as a source of:

Methane gas
Hydrogen sulfide
Natural Factors That Affect Air Pollution

- Winds
- Local and regional landscapes
- Temperature inversion
Formation of the infamous "Asian Brown Cloud", composed of natural and human created air pollutants: desert dust, power plant emissions, industrial soot, etc. Put in motion by local, regional, and global wind patterns.
Puget Sound

Topographic influences: the greater Seattle metropolitan area's air quality can suffer as the Olympics to the west and the Cascades to the east form a natural 'bowl' in which the atmosphere can become trapped and stagnant under the appropriate weather conditions.
Normal conditions, with air temperature decreasing as altitude increases… resulting in vertical movement upward from the surface.

(a) A normal temperature profile.
Temperature Inversion 2

Descending air creates warm inversion layer

(b) A temperature inversion in the lower atmosphere prevents the cooler air below the inversion layer from mixing with air above. Pollution is trapped near the ground.
Examples from Helena, Montana
Anthropogenic Pollution

- Carbon monoxide
- Photochemical smog
- Industrial smog
- Sulfur oxides
- Particulate matter
- and *et cetera*...
Map of CO during the first week of August, 2003: derived from MOPITT imagery

High concentrations of the gas due to various forest and prairie fires in Washington, Idaho, Montana, British Columbia, and Alberta
Alpine Topography

MODIS: satellite view of trapped particulates (and gases) over Italy
Smog trapped in the Central Valley of California