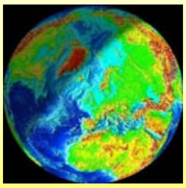
Seasonal & Daily Temperatures

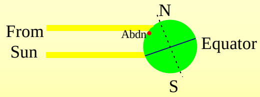

Photo MER



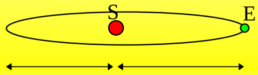
- Variations in energy input control seasonal and daily temperature fluctuations

Cause of the Seasons

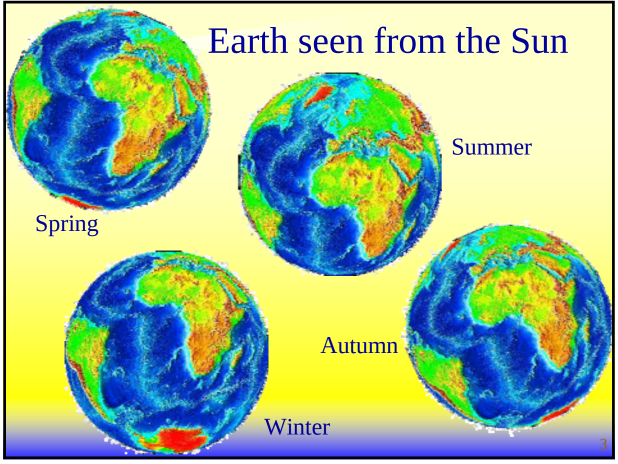
- The tilt of the Earth's axis relative to the plane of its orbit around the Sun
  - in mid-summer, the N Hemisphere is tilted towards the Sun [fig. 3.3]
  - in mid-winter, the N Hemisphere is tilted away from the Sun



- The elliptical path of the Earth brings it closer to the Sun in mid winter

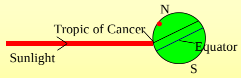


Earth seen from the Sun

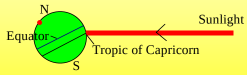


The Tropics

- At mid-summer, the Sun is overhead at the **Tropic of Cancer**

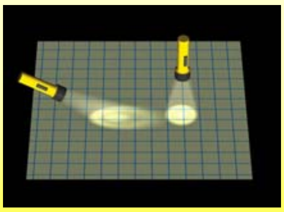


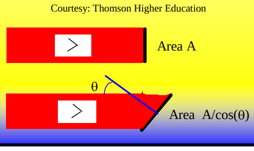
- At mid-winter, the Sun is overhead at the **Tropic of Capricorn**



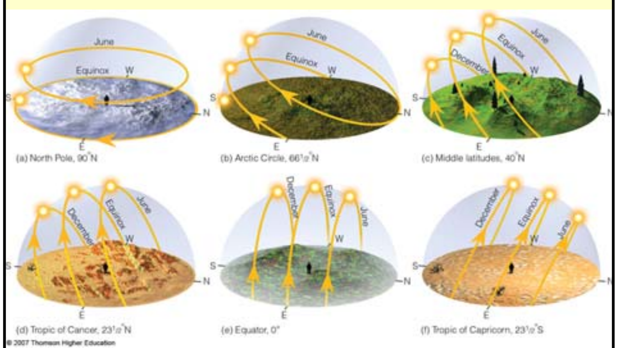
Energy depends on angle of illumination

- Sunlight falling at an angle spreads over a larger area
  - [page 55/56/56]
- Area increases as 1/cosθ
  - see diagram for definition of angle θ


Courtesy: Thomson Higher Education



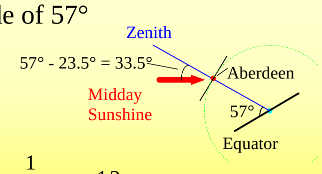
Sun tracks at different latitudes



Courtesy: Thomson Higher Education

Aberdeen's Position on the Globe

- Aberdeen is at a latitude of 57°
- Maximum angle of summer Sun from zenith is 33.5°
  - spreading factor is: $\frac{1}{\cos(33.5°)} = 1.2$



- Maximum angle of winter Sun is 57° + 23.5° = 80.5°
  - spreading factor is: $\frac{1}{\cos(80.5°)} = 6.1$

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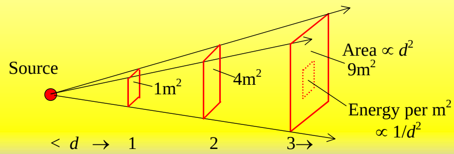
Inverse Square Law of Radiation

- At increasing distance *d* from a source of radiation, the energy passing through 1 m^2 decreases as $1/d^2$ [page 36/38/38]
  - this is essentially a statement of the law of conservation of radiant energy

From 2nd slide $(152/147)^2$ =1.07



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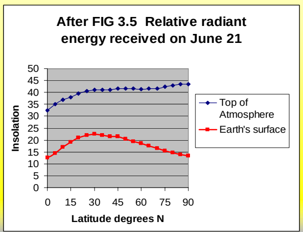
Irradiation in Summer


Photo JSR

- Compared with tropical regions, do the extra hours of sunshine in Aberdeen make up for the fact that the Sun is never overhead?
  - 'yes', in the upper atmosphere, but 'no' at ground level, due to the extra distance through the atmosphere travelled by slanting rays of the Sun [fig. 3.5]



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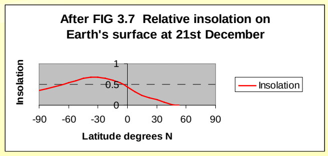
Irradiation in Winter



- Is the solar energy received in Britain at the end of the year really very little?
  - 'yes' [Fig. 3.7/-]


Photo JSR

- Average temperatures tend to be a month behind average sunshine
  - highest temperatures come in late July or August
  - lowest temperatures come at end of January or into February

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Energy Balance over the Globe

- Is there a balance between incoming solar energy and outgoing energy at all latitudes?
  - 'no'. In Scotland, we loose more radiation than we receive


Near Lismore: photo JSR

- Energy is transported from tropical regions to the higher latitudes by:
  - pattern of circulating ocean currents
  - mid-latitude cyclones and anti-cyclones
  - transfer of evaporated water from tropical regions

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Global Climate

- Global climate is driven by the Sun
- Every feature of the Earth's orbit influences climate: its extent, its eccentricity, the tilt and direction of the Earth's axis
- Global climate is influenced by everything that influences energy balance
- There is no such thing as 'the law of averages' [e.g. p 509/522/442 for long-term temperature changes]

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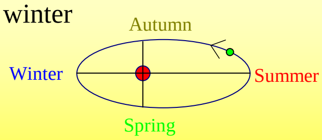
Earth Receives the Same Solar Radiation in Each Season

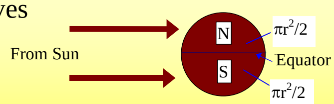
- Because the Earth's orbit is an ellipse, with the Sun off-centre, winter and summer are at present unequal in length



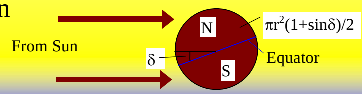
- **However**, when the Earth is father from the Sun it travels more slowly and the extra time it takes just makes up for the weaker sunlight
  - **hence**, the surprising conclusion above

N & S Hemispheres don't share their Radiant Energy much

- With the Sun overhead at the equator, each hemisphere receives half the Sun's radiation



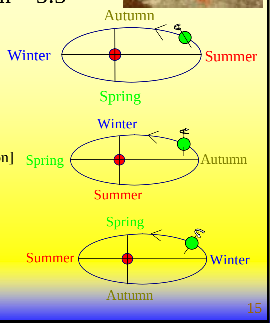
- With the Earth's axis tilted, one hemisphere receives more than half the radiation



Changes Past and Future

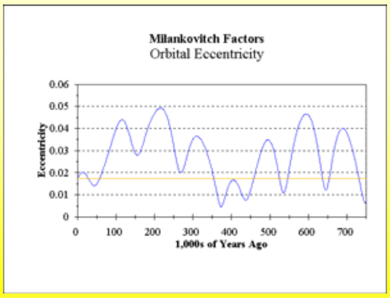
Examining dinosaur footprints: photo JSR

- Ratio summer Sun: winter Sun = 5:3
- Now summer exceeds winter by about 7 days
- 5,500 yrs time: equal winters and summers
  [see page 485/514/442 for a longer discussion]
- 11,000 years time: long winters, glacial epoch?
  (the equinoxes are precessing in reverse around the Earth's orbit)



Changes in Earth's eccentricity

- Eccentricity changes of the Earth's orbit may have been one of the main drivers of ice-ages



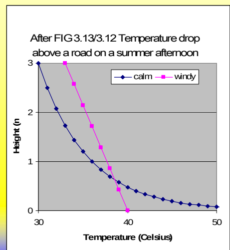
Courtesy: http://www.museum.state.il.us/exhibits/ice_ages/eccentricity_graph.html

Daily Temperature Changes

- Daily variation in temperature is controlled by the Earth's rotation
  - general level of temperature is determined by air mass passing over
- Air continues to heat as long as influx of radiation exceeds radiation loss [fig. 3.14/3.13]
- Warmest time of day is typically mid afternoon
  - coldest, near sunrise

Temperature Changes with Height

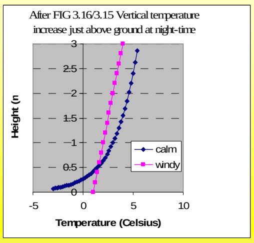
- On calm days, temperature decreases quickly for a few metres above ground
  - on windy days, it decreases more slowly



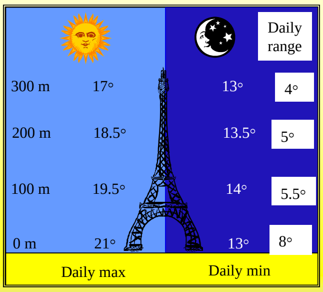
Gulf coast: photo JSR

Temperature Changes at Night

- On calm nights, you will particularly notice a **temperature inversion**
  - temperature begins to rise with height
  - the difference is less on windy days



Daily Temperature Variation Decreases with Height



- Temperatures decrease faster with height by day than by night
  - this gives a smaller daily temperature range for higher places

After fig. 3.23/3.22

It’s Warmer Under the Ice

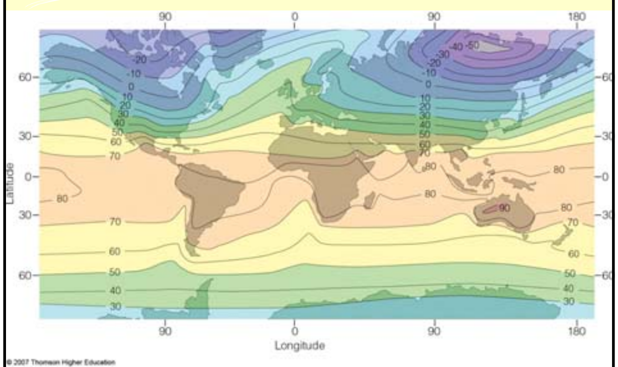
- Snow and ice insulate us against very cold ground temperatures
  - snow is a poor thermal conductor; a poor IR radiator; a good IR reflector; it has a large specific heat capacity
  - Here frozen fruit trees at -7°C have been sprayed with water

Sea-level Isotherms

- **Isotherms** are lines of **constant temperature**
- Making an allowance for change in temperature with height, sea-level isotherms show the influence of land and sea on average temperatures across the Earth. Figs. - see next two slides

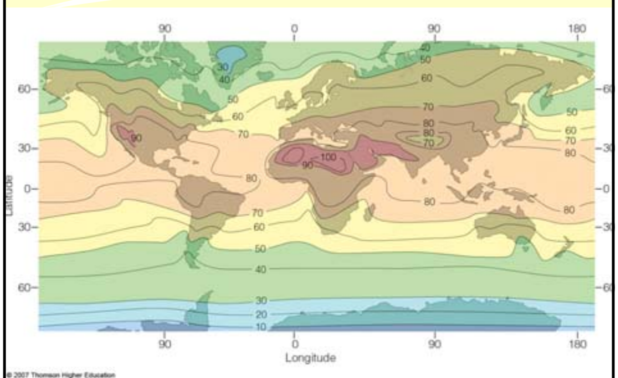
Aberdeen in January: photo JSR

January Isotherms (°F)



Courtesy: Thomson Higher Education

July Isotherms (°F)



Courtesy: Thomson Higher Education

Daily, Monthly & Yearly Temperatures

- Nearby water is the most important factor in decreasing the range of temperatures experienced [page 71/73/72]
  - large lakes and seas are a huge reservoir of heat in winter, warming air above them
  - in summer they cool air and provide atmospheric moisture
  - humidity absorbs IR at night and re-radiates it toward the ground
  - haze and cloud reduce the solar radiation reaching the ground by day

Muchalls: photo JSR

Two Measures of Heat

- **Specific heat capacity** is the amount of heat energy (in calories) needed to raise the temperature of 1 g of material by 1 C° [p. 28/30/29]
  - water has a specific heat capacity of 1 cal g^{-1} °C^{-1}
  - rock, typically 0.2 cal g^{-1} °C^{-1}
- **Latent heat** is the amount of heat energy needed to evaporate 1 g of material or, more generally, to change its state at constant temp
  - 600 cal g^{-1} is needed to evaporate water
  - 80 cal g^{-1} is needed to melt ice

Wind Chill

- Nearly still air around us generally keeps our skin temperature warmer than the ambient air
- Wind sweeps away this insulating blanket, chilling our skin
- Wind encourages evaporation, which carries away 600 cal g^{-1} of evaporated water
- Table 3.4/3.3 gives wind chill figures (see next slide)

Summer in the West coast: photo JSR

Wind Chill in °C

•TABLE 3.4

Wind-Chill Equivalent Temperature (°C)*

WIND SPEED (KM/HR)	AIR TEMPERATURE (°C)												
Calm	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40	−45	−50
10	8.6	2.7	−3.3	−9.3	−15.3	−21.1	−27.2	−33.2	−39.2	−45.1	−51.1	−57.1	−63.0
15	7.9	1.7	−4.4	−10.6	−16.7	−22.9	−29.1	−35.2	−41.4	−47.6	−51.6	−59.9	−66.1
20	7.4	1.1	−5.2	−11.6	−17.9	−24.2	−30.5	−36.8	−43.1	−49.4	−55.7	−62.0	−68.3
25	6.9	0.5	−5.9	−12.3	−18.8	−25.2	−31.6	−38.0	−44.5	−50.9	−57.3	−63.7	−70.2
30	6.6	0.1	−6.5	−13.0	−19.5	−26.0	−32.6	−39.1	−45.6	−52.1	−58.7	−65.2	−71.7
35	6.3	−0.4	−7.0	−13.6	−20.2	−26.8	−33.4	−40.0	−46.6	−53.2	−59.8	−66.4	−73.1
40	6.0	−0.7	−7.4	−14.1	−20.8	−27.4	−34.1	−40.8	−47.5	−54.2	−60.9	−67.6	−74.2
45	5.7	−1.0	−7.8	−14.5	−21.3	−28.0	−34.8	−41.5	−48.3	−55.1	−61.8	−68.6	−75.3
50	5.5	−1.3	−8.1	−15.0	−21.8	−28.6	−35.4	−42.2	−49.0	−55.8	−62.7	−69.5	−76.3
55	5.3	−1.6	−8.5	−15.3	−22.2	−29.1	−36.0	−42.8	−49.7	−56.6	−63.4	−70.3	−77.2
60	5.1	−1.8	−8.8	−15.7	−22.6	−29.5	−36.5	−43.4	−50.3	−57.2	−64.2	−71.1	−78.0

*Dark blue shaded areas represent conditions where frostbite occurs in 30 minutes or less.

Courtesy: Thomson Higher Education

Measuring Temperatures

- Liquid-in-glass **thermometers**
  - maximum 
  - minimum 
- Ubiquitous digital thermometers
- Platinum resistance thermometers are the standard at normal temperatures. Their resistance is directly related to the implementation of the ITS-90 temperature scale

Physics platinum resistance thermometer on Fraser Noble building: photo JSR

Measuring Enclosures

- Meteorological thermometers, hygrometers, and barometers must be protected from direct sunlight and from rain
  - usual housing is a **Stevenson screen**
  - variant designs in other countries

Fraser Noble building Stevenson screen, before painting: photo JSR