Chapter Three

Energy Balance and Temperature

The Fate of Solar Radiation

- We owe it all to the sun…
- 3 things can happen to solar (and all) radiation:
    1) Absorption
    2) Scattering and Reflection
    3) Transmission

Absorption

- **Absorption** – the full energy transfer from radiation to a substance
- Atmospheric absorption varies by substance:

    UV – absorbed by O3 (stratosphere)

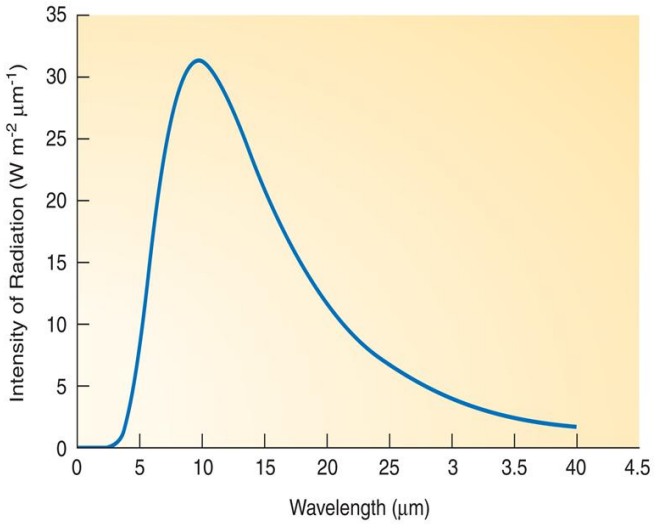
    Visible – hardly absorbed (lucky for us)

    Infrared – partially absorbed by water

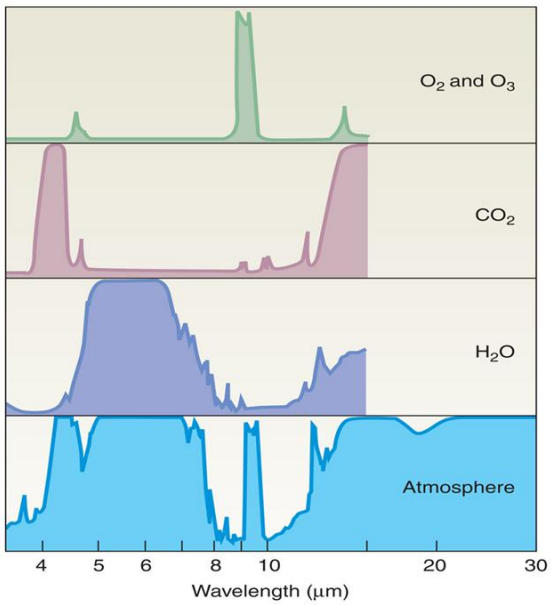
    vapor, CO2 (less cooling in high humidity..)

The Atmospheric Window

- The atmospheric window is a band (8-12 μm) of very little absorption



Earth's surface emission



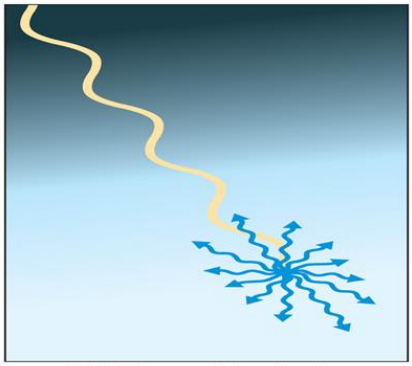
Atmospheric absorption

- Liquid water (i.e. clouds), however, are good absorbers of all longwave radiation
- Are cloudy or clear nights warmer???

Scattering and Reflection

Scattering – the deflection of radiation by a substance
Diffuse scattering – radiation deflected in many directions, becomes diffuse radiation

Reflection – a type of scattering, radiation is deflected back with equal intensity (mirror)
Albedo – the fraction of light reflected (earth's albedo is ~0.3)

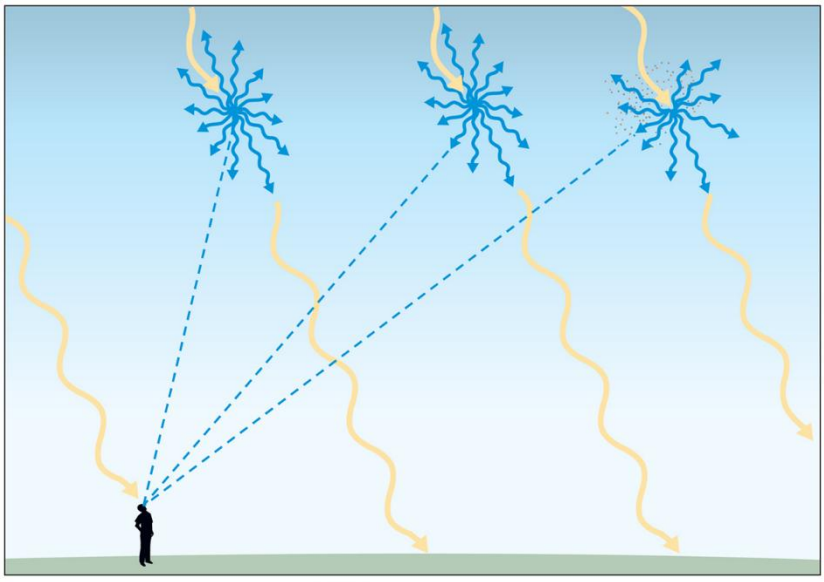


- Scattering affects many things:
  - Shaded areas still receive solar radiation (better buy more sunscreen!)
  - The sky is blue and sunsets are red (**Rayleigh scattering**)
  - Hazy or polluted days make the sky white or gray **(Mie scattering**)
  - Clouds are white (**nonselective scattering**)

Rayleigh Scattering

- Occurs when substance is small compared to wavelength of radiation (such as atmospheric gases)
- Scatters smaller wavelengths (blue) more than longer wavelengths (red)
- Makes the sky appear blue, sunsets red

Rayleigh Scattering



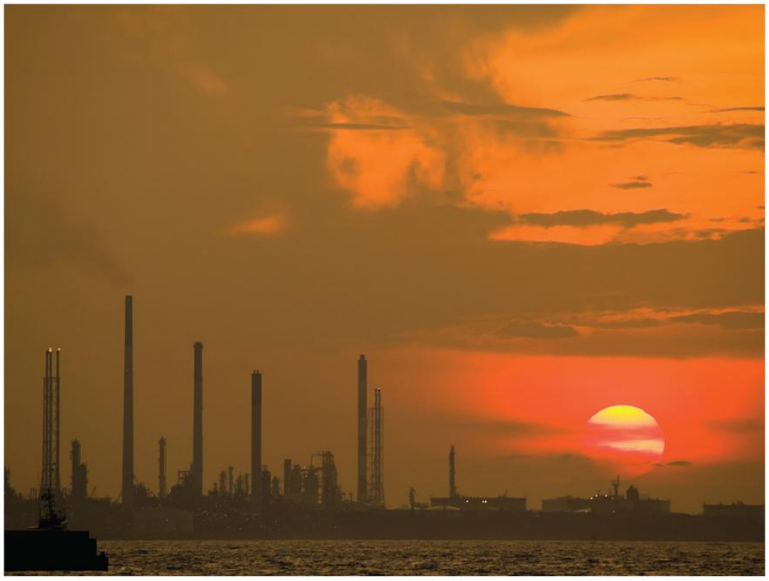
(a)

(b)

(c)

Mie Scattering

- Occurs when substance is of comparable size to wavelength of radiation (such as aerosols)
- Unlike Rayleigh scattering, scatters all wavelengths more efficiently
- Makes hazy and polluted skies look white or gray, enhances sunsets



Nonselective Scattering

- Scattering by relatively large particles such as cloud droplets
- Scatters all wavelengths comparably
- Makes clouds white or gray

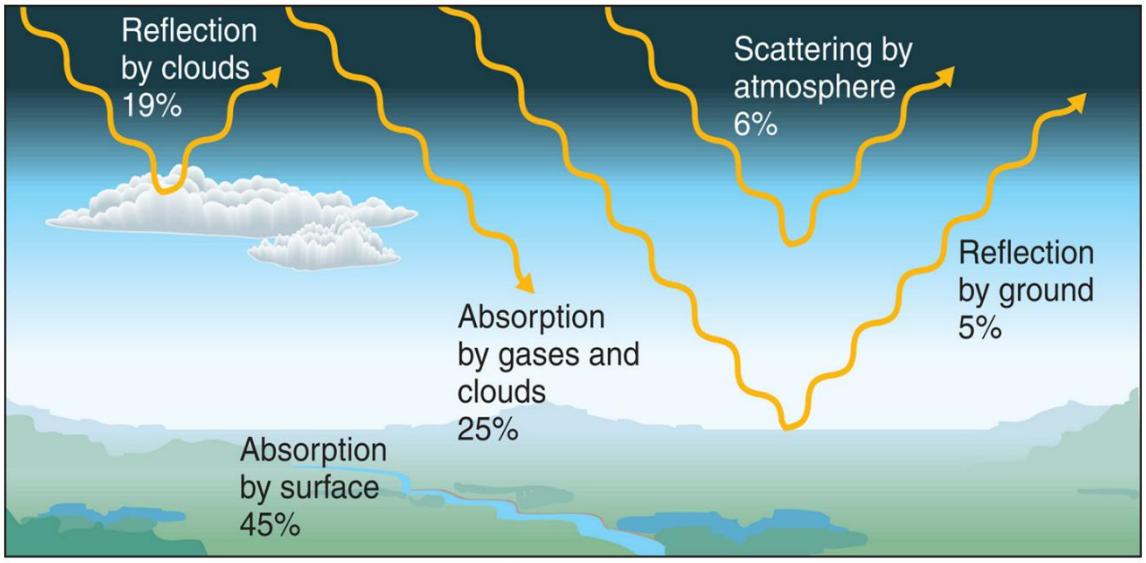
Transmission

- **Transmission** – radiation passes through a substance without being absorbed or scattered

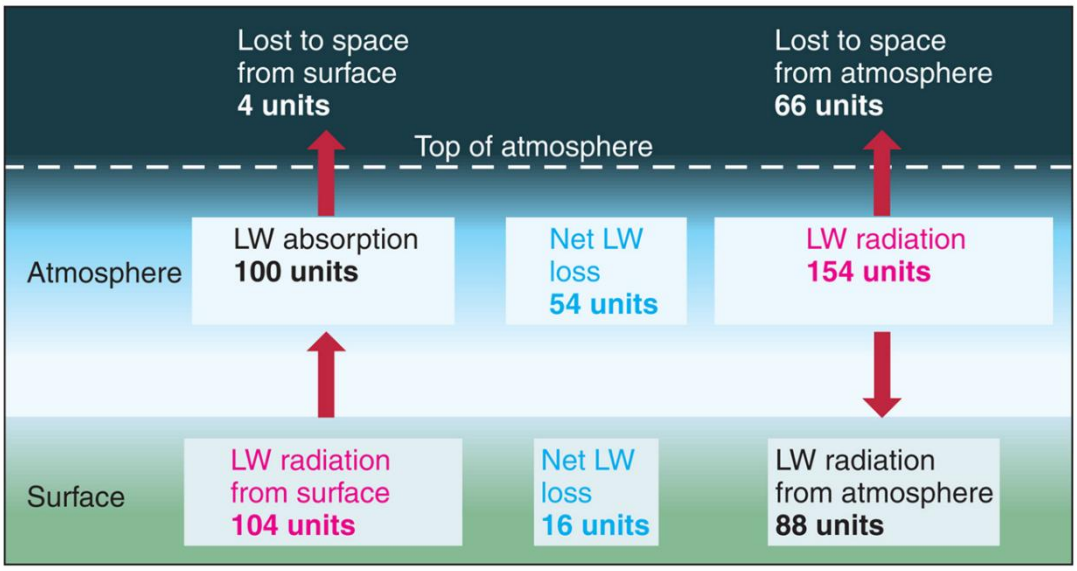
The Energy Balance of Earth

- Earth is generally neither warming or cooling (global climate change aside) – it is in steady-state, or equilibrium (just like a skydiver at terminal velocity…)
- This means the gain from solar radiation must be balanced by the loss from terrestrial radiation

The story begins with a net gain of solar radiation



The story ends with a loss of longwave radiation from earth and the atmosphere



But the story isn't really over….

- Why don't they?

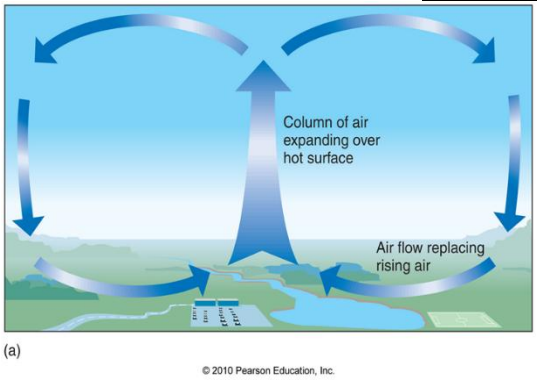
- Conduction and convection!!!

1) Conduction causes heat transfer to air in contact with ground
2) Convection causes this air near the surface to rise like a helium balloon, mixing heat throughout the atmosphere

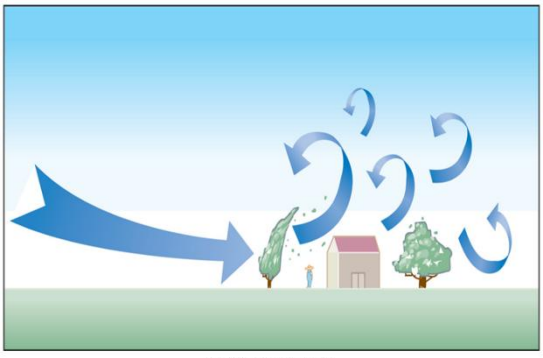
→ **Sensible heat flux**

- Conduction and convection!!!

2 types of convection

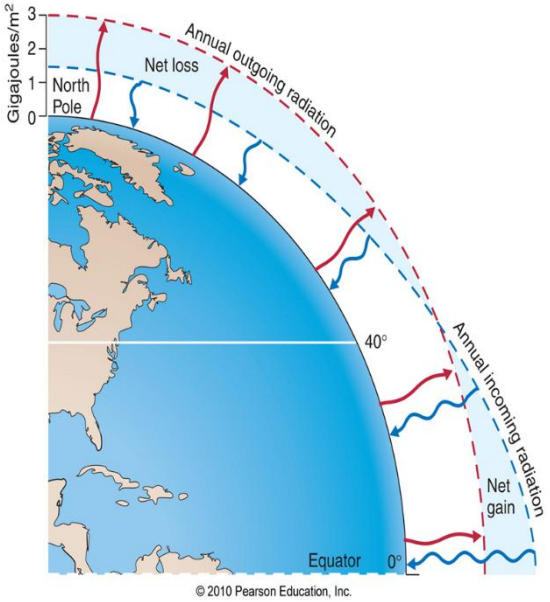


Free convection



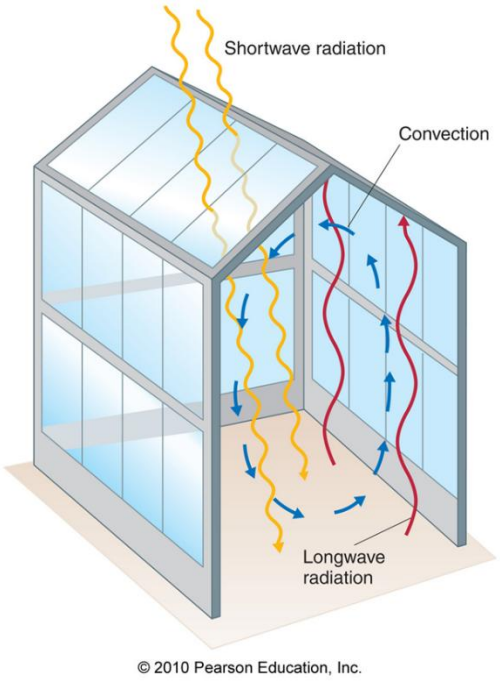
Forced convection

- Let's get specific – latitudinal variations also exist in the radiation budget
- But these are opposed by advection of heat through wind and ocean currents

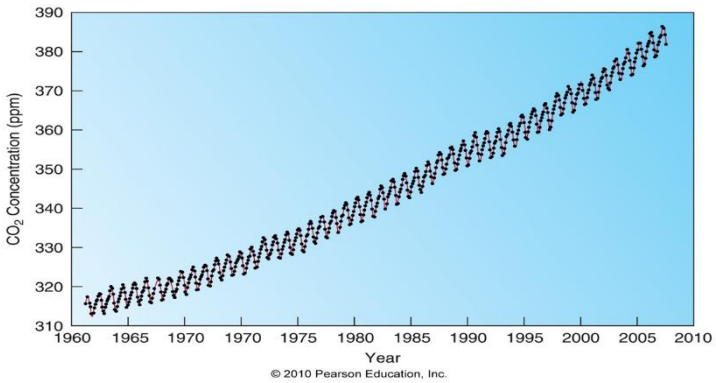


The Greenhouse Effect

- The atmosphere is kind of like a greenhouse, and kind of not
- Earth stays warm by atmospheric absorption/re-emission
- Without greenhouse gases, earth's equilibrium temperature would be much cooler (-17° C instead of 15° C



- Altering greenhouse gas (i.e. CO2) concentrations in the atmosphere will alter earth's equilibrium temperature



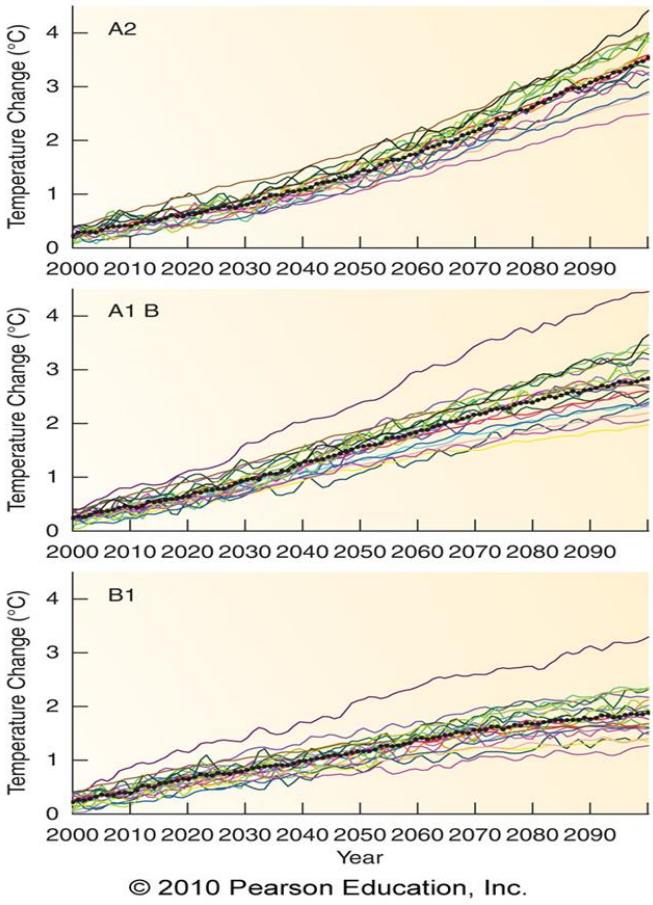
Global Climate Change

The Intergovernmental Panel on Climate Change (IPCC) stated in 2007 that:

1) Average global temperature is increasing (1.33oF in the last 100 years)
2) Temperatures are increasing faster now than they did earlier last century
3) Extreme warm events are increasing, extreme cold events are decreasing
4) Global snow cover is decreasing
5) All of the above is very likely due to anthropogenic greenhouse gas emissions

Predicted Global Temperature 2000-2100

Greenhouse gas emissions



High

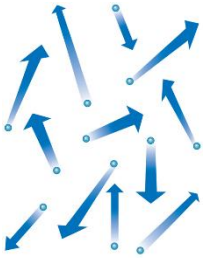
Medium

Low

- Uncertainties still exist for global warming predictions (effect of aerosols, cloud cover, greenhouse gas emission)
- Local climate change is a very important aspect of current research

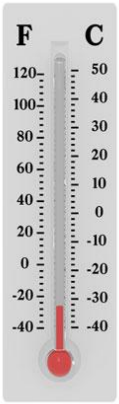
Temperature

- **Temperature** is a measure of the average kinetic energy of a substance

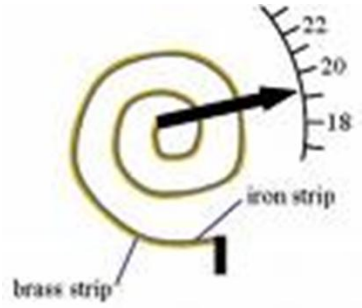


Measuring Temperature

- Mercury (or other fluid) **thermometer** – measures temperature by fluid expansion/contraction



- **Bimetallic strip** – measures temperature by different contraction/expansion of metal strips



- **Thermistor** – measure temperature based on resistance to electrical current (fast response)

- Instrument shelters used for surface observations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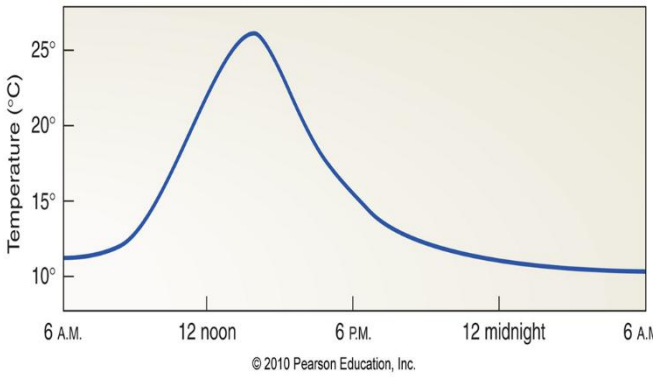
More Tidbits on Temperature…

Diurnal range – the range of temperatures over the night/day cycle at a given location



Highest temperature ever recorded on earth:

58°C in Libya

Lowest temperature ever recorded on earth:

-90°C in Antarctica

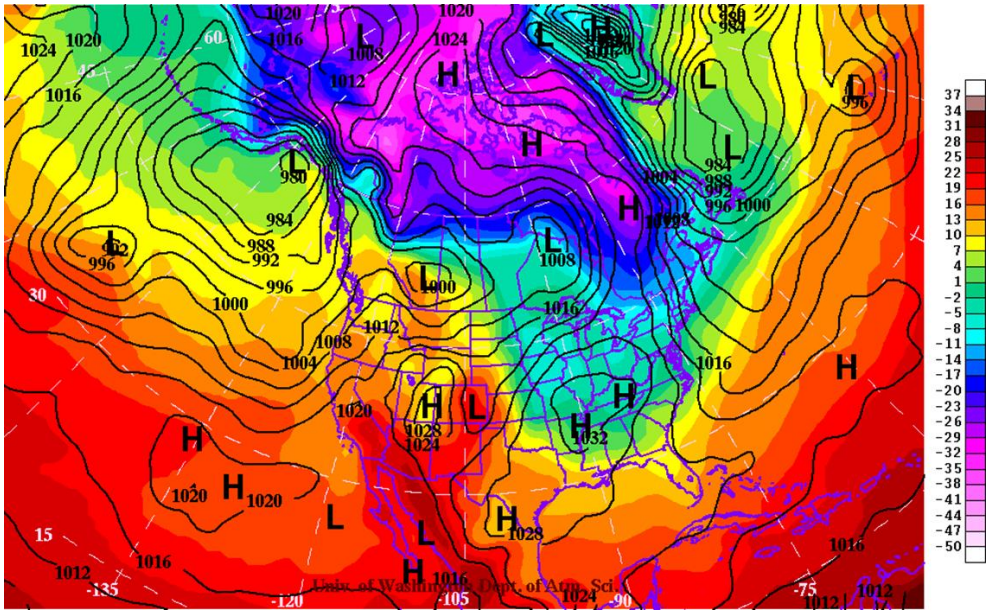
- Wind chill index – provides an estimate of the perceived temperature based on actual temperature and wind

Wind (mph) \ Temperature (°F)	Calm	40	35	30	25	20	15	10	5	0	–5	–10	–15	–20	–25	–30	–35	–40	–45
5		36	31	25	19	13	7	1	–5	–11	–16	–22	–28	–34	–40	–46	–52	–57	–63
10		34	27	21	15	9	3	–4	–10	–16	–22	–28	–35	–41	–47	–53	–59	–66	–72
15		32	25	19	13	6	0	–7	–13	–19	–26	–32	–39	–45	–51	–58	–64	–71	–77
20		30	24	17	11	4	–2	–9	–15	–22	–29	–35	–42	–48	–55	–61	–68	–74	–81
25		29	23	16	9	3	–4	–11	–17	–24	–31	–37	–44	–51	–58	–64	–71	–78	–84
30		28	22	15	8	1	–2	–12	–19	–26	–33	–39	–46	–53	–60	–67	–73	–80	–87
35		28	21	14	7	0	–7	–14	–21	–27	–34	–41	–48	–55	–62	–69	–76	–82	–89
40		27	20	13	6	–1	–8	–15	–22	–29	–36	–43	–50	–57	–64	–71	–78	–84	–91
45		26	19	12	5	–2	–9	–16	–23	–30	–37	–44	–51	–58	–65	–72	–79	–86	–93
50		26	19	12	4	–3	–10	–17	–24	–31	–38	–45	–52	–60	–67	–74	–81	–88	–95
55		25	18	11	4	–3	–11	–18	–25	–32	–39	–46	–54	–61	–68	–75	–82	–89	–97
60		25	17	10	3	–4	–11	–19	–26	–33	–40	–48	–55	–62	–69	–76	–84	–91	–98

Frostbite Times: 30 minutes; 10 minutes; 5 minutes

How Meteorologists Analyze Temperature

- In the horizontal…



- In the vertical...