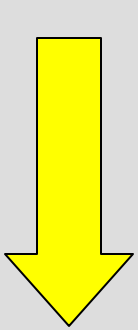
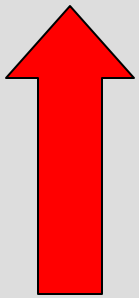
NATS 101
Section 13: Lecture 8

Temperature Variations

Concept of a surface energy budget



ENERGY IN



ENERGY OUT

GROUND

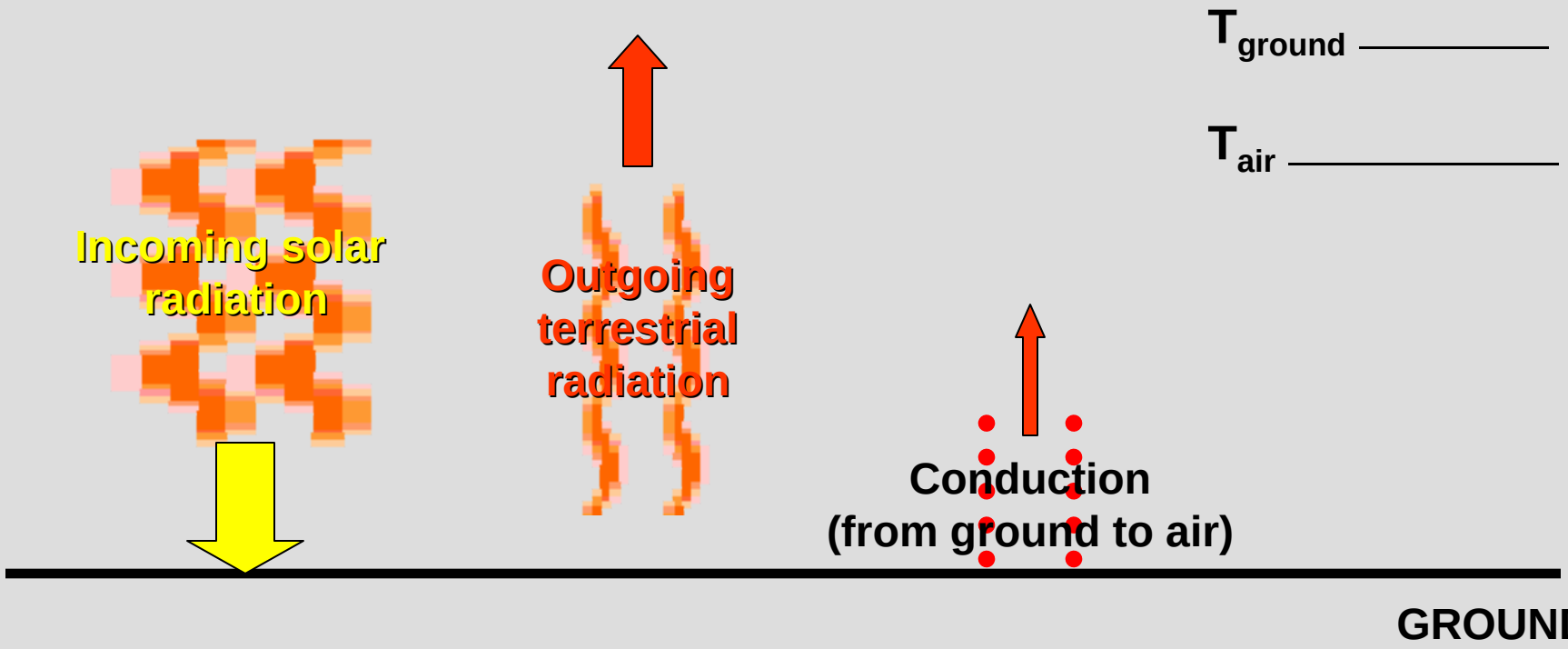
ENERGY IN = ENERGY OUT → Temperature _____

ENERGY IN > ENERGY OUT → Temperature _____

ENERGY IN < ENERGY OUT → Temperature _____

ENERGY TRANSPORT = CONVECTION, CONDUCTION, RADIATION

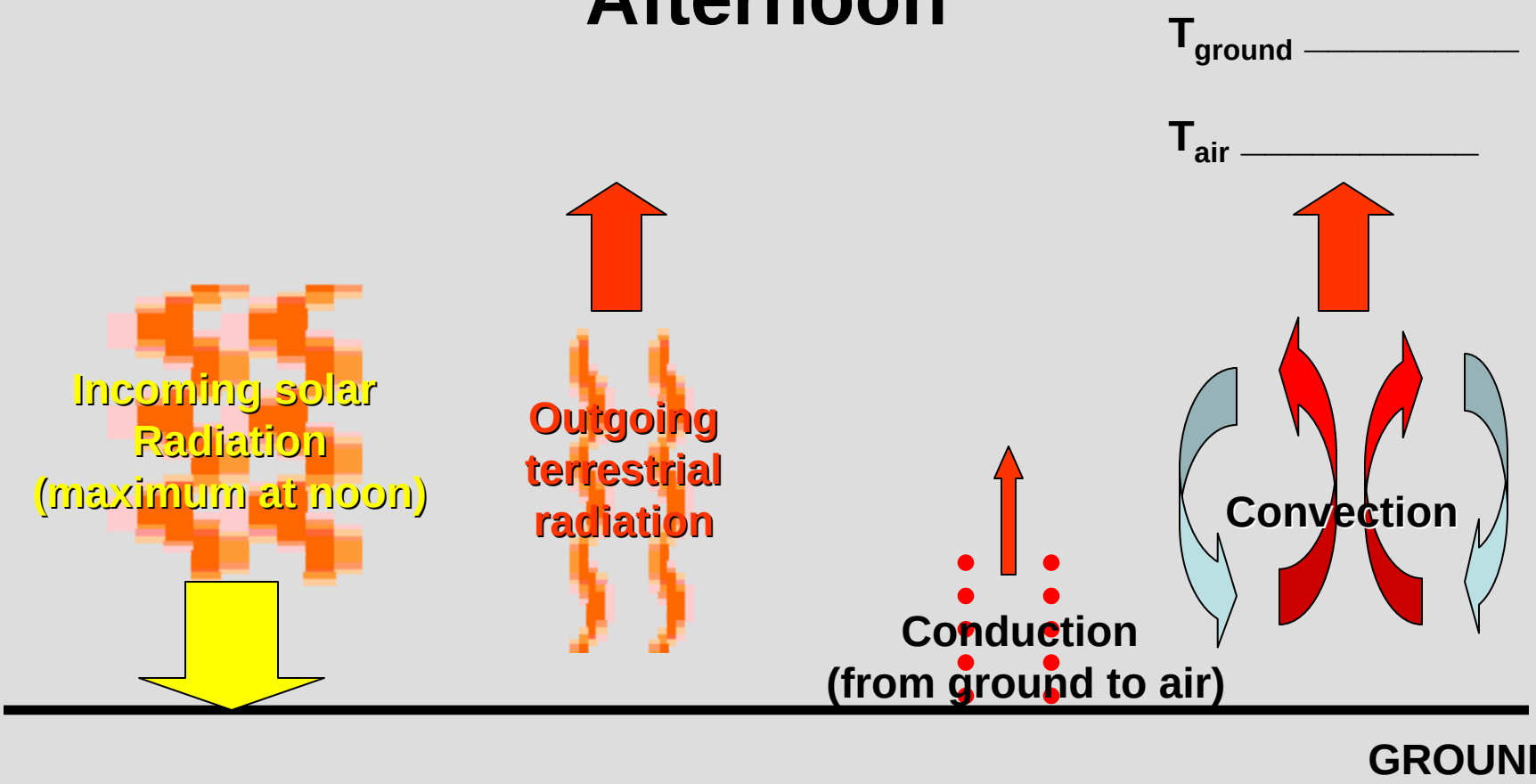
Daytime Energy Budget: Morning



Incoming solar radiation exceeds outgoing terrestrial radiation. The temperature of the ground warms.

Conduction heats the air, but because air is a poor conductor, this only happens in the few centimeters above the ground.

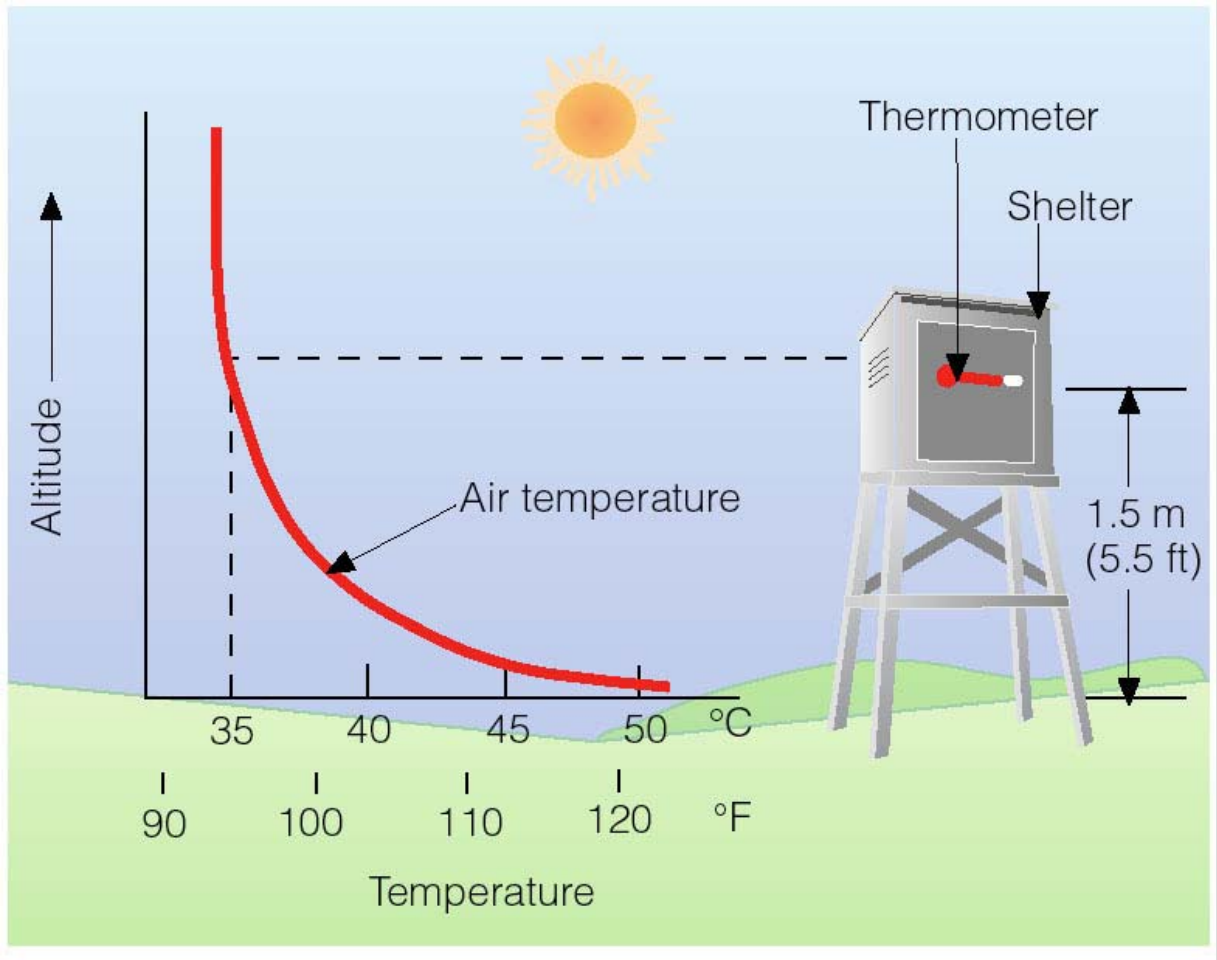
Daytime Energy Budget: Midday and Afternoon



Convection begins near the surface, in the form of thermals, and helps to redistribute the heat upward.

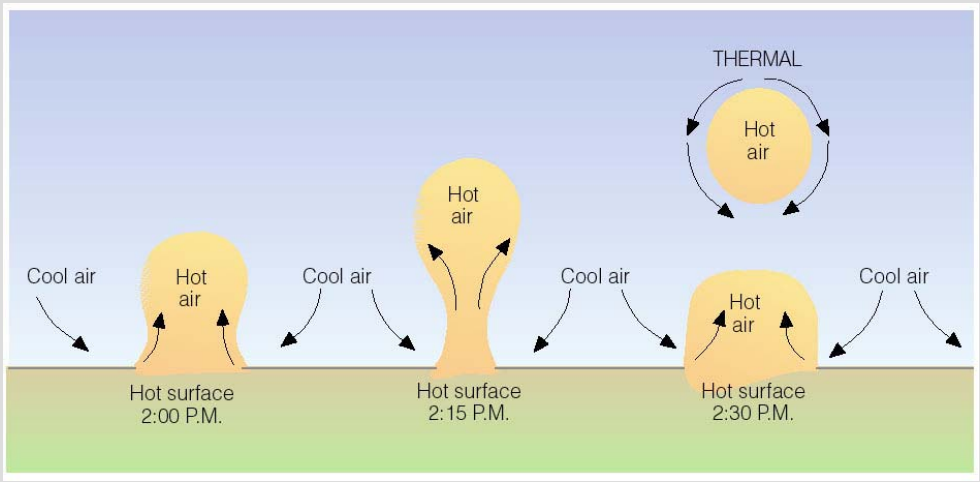
As long as the incoming solar radiation exceeds the sum of the outgoing terrestrial radiation, conduction, and convection, the air temperature continues to increase.

Typical Temperature Profile on a Calm, Clear Summer Day in Arizona



COTTON REGION SHELTER

Convective Thermals

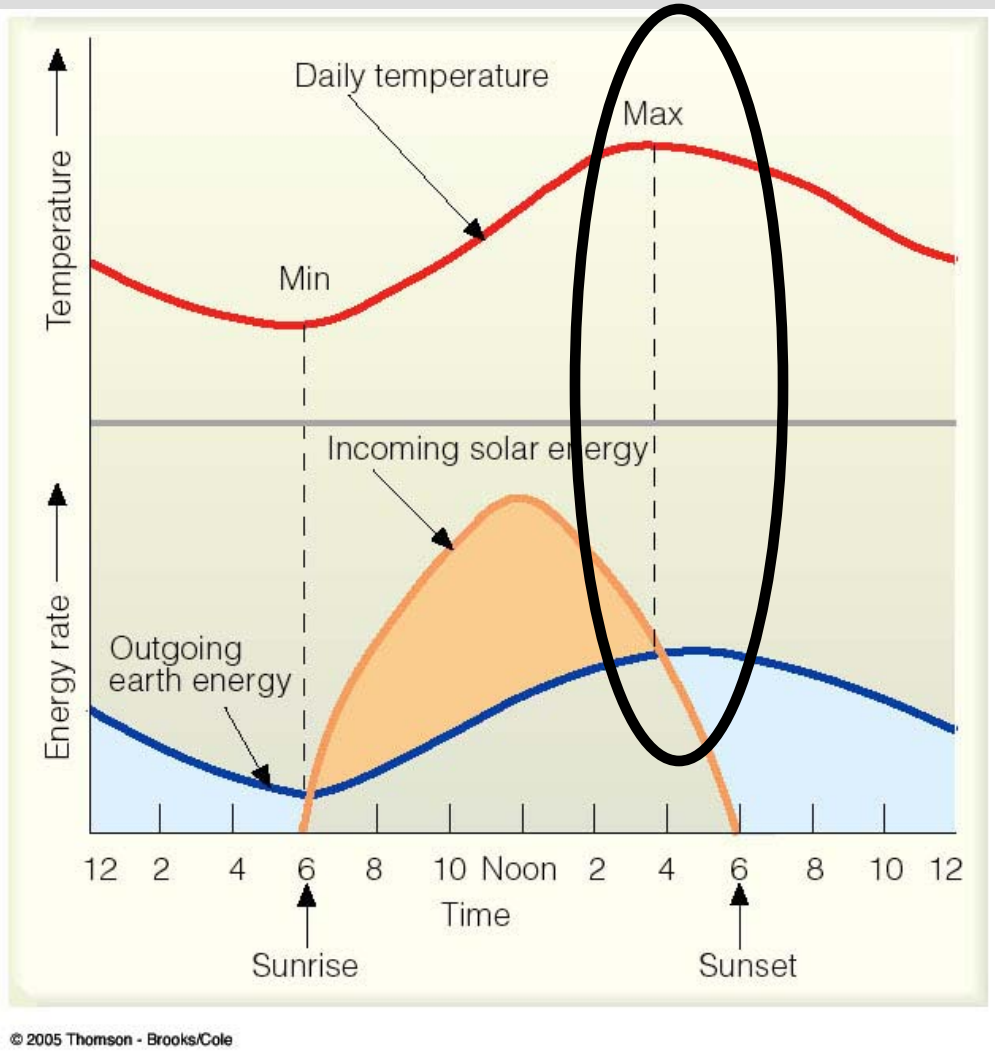


On really warm days, the convective thermals can cause dust devils. This is a common occurrence in Arizona during the summer.

We'll talk about how these occur later in the semester.

Arizona Dept. of Transportation photo

Time of Maximum Temperature



The maximum temperature occurs when the incoming solar energy is equal to the outgoing earth energy

"Outgoing earth energy" is the sum of:

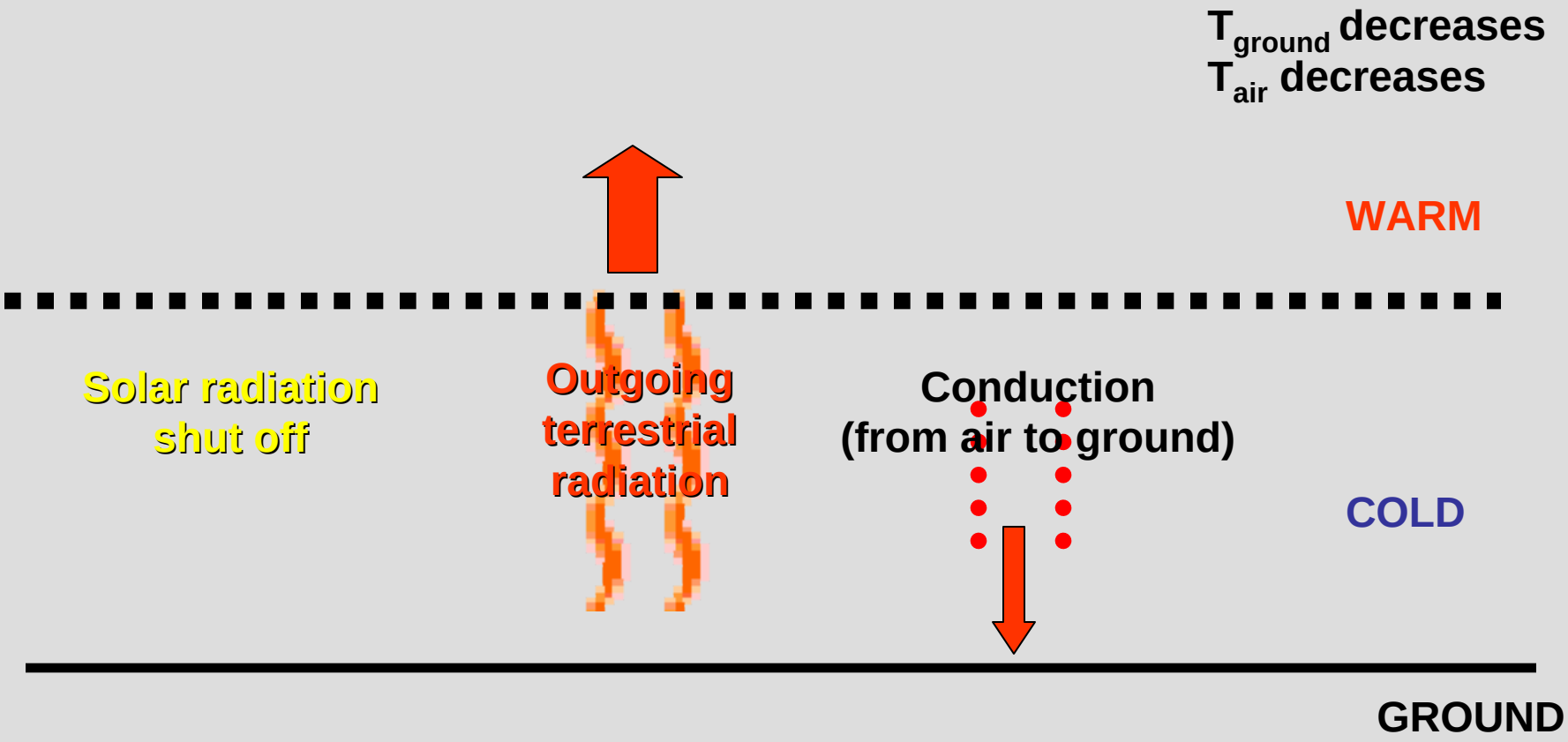
1._____

2._____

3._____

Maximum temperature typically occurs in mid-afternoon, several hours after the maximum in incoming solar energy.

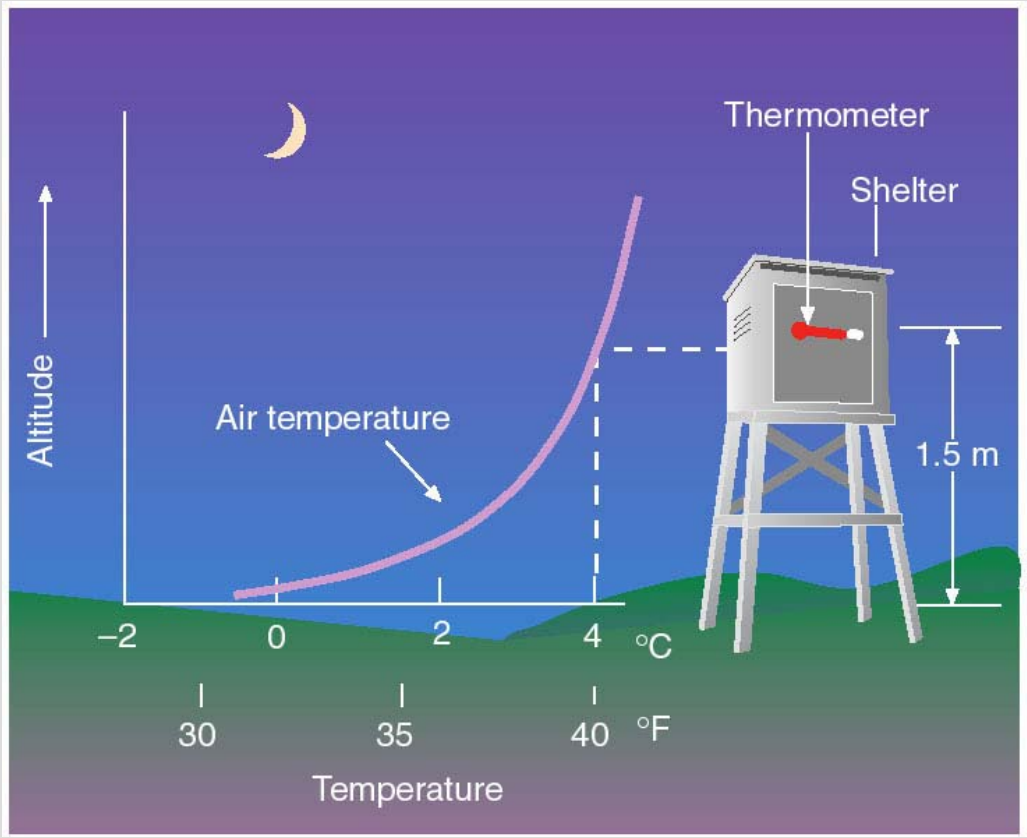
Nighttime Energy Budget



Solar radiation is shut off and the air and ground begins to cool by radiating terrestrial radiation. This process is called radiational cooling. Because the ground radiates more effectively then air, it cools faster.

The air just above the ground transfers additional energy to ground by conduction.

Typical Nighttime Temperature Profile

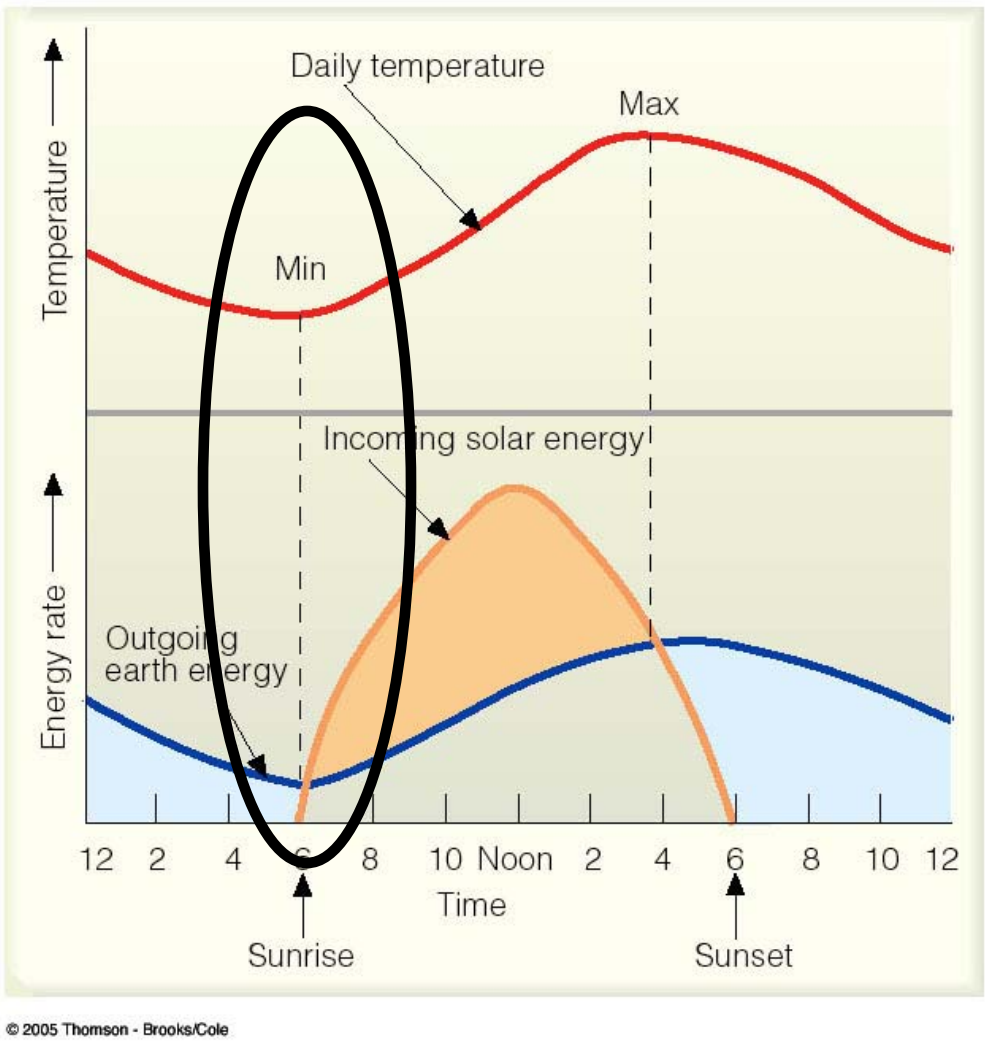


Radiational cooling of the surface causes the air near the ground to be colder than the air above.

When temperature increases with height, this is called an inversion.

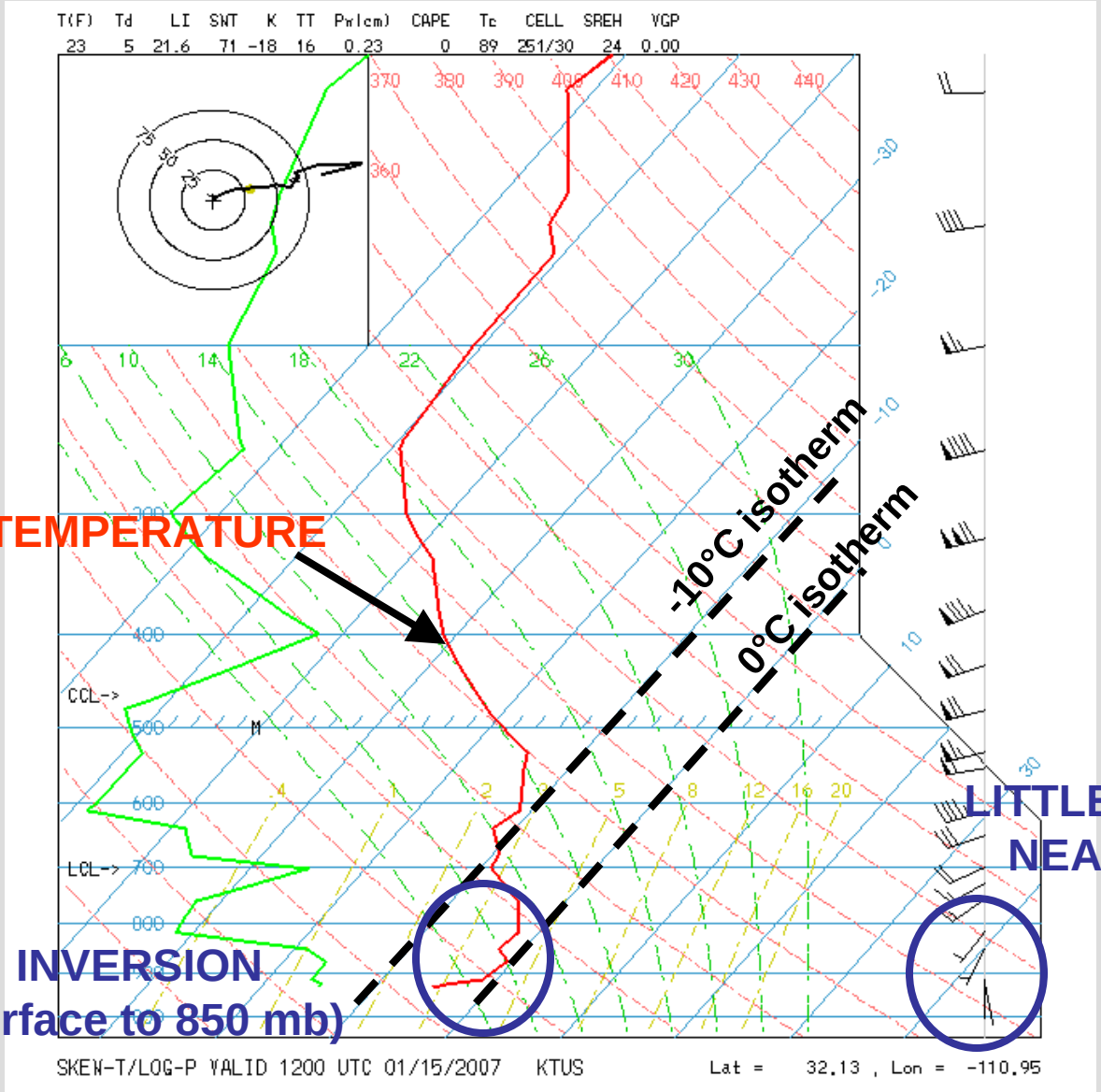
We'll see next time that a certain type of fog may occur in the inversion.

Time of Minimum Temperature



The minimum temperature occurs right around sunrise, after the Earth's surface has radiationally cooled during the entire night.

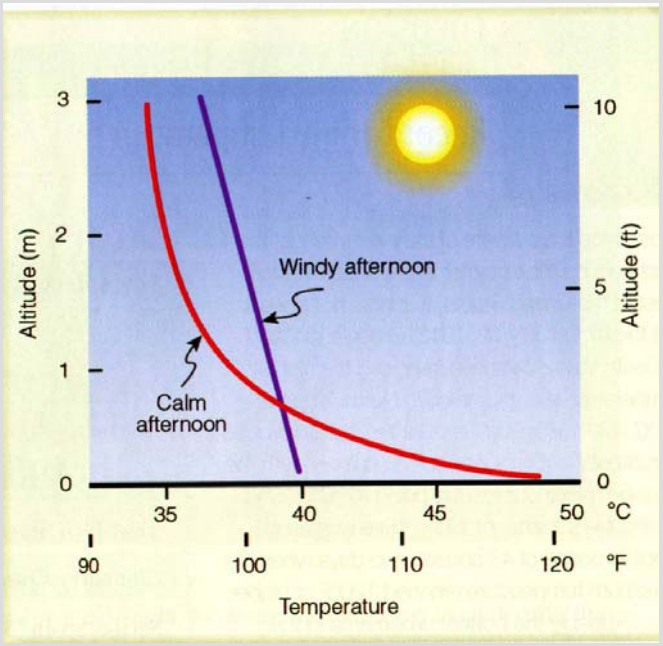
Tucson Morning Sounding for 1-15-07

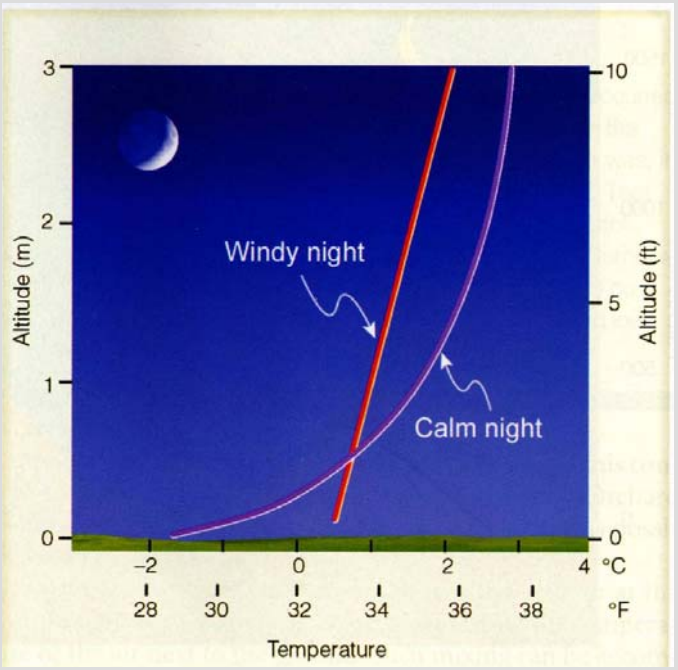


So far we've considered the diurnal evolution of temperature for the idealized case of clear and calm conditions.

What are some factors that would make conditions less than ideal?

Wind: Mixes the air by forced convection



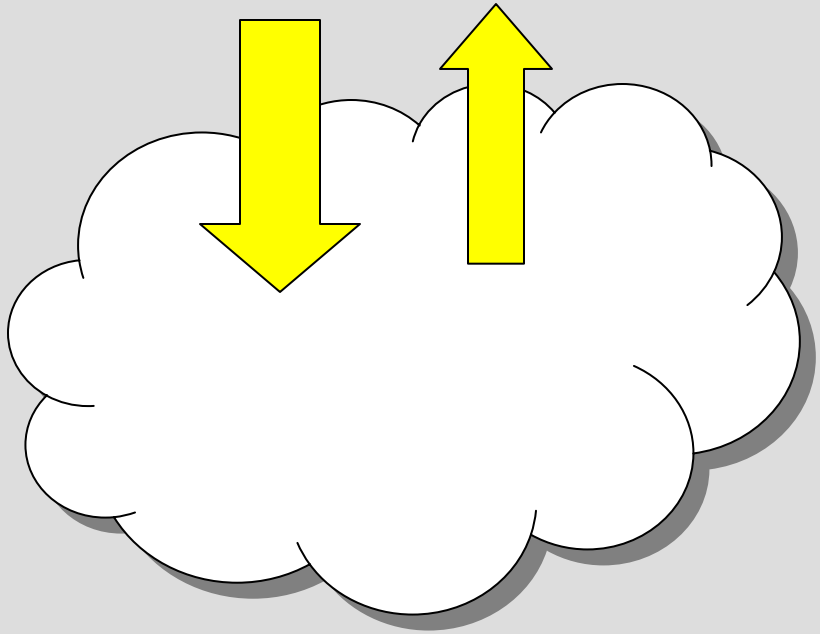


Wind provides a mechanical mixing mechanism to transfer heat away from the surface during the day and to the surface at night.

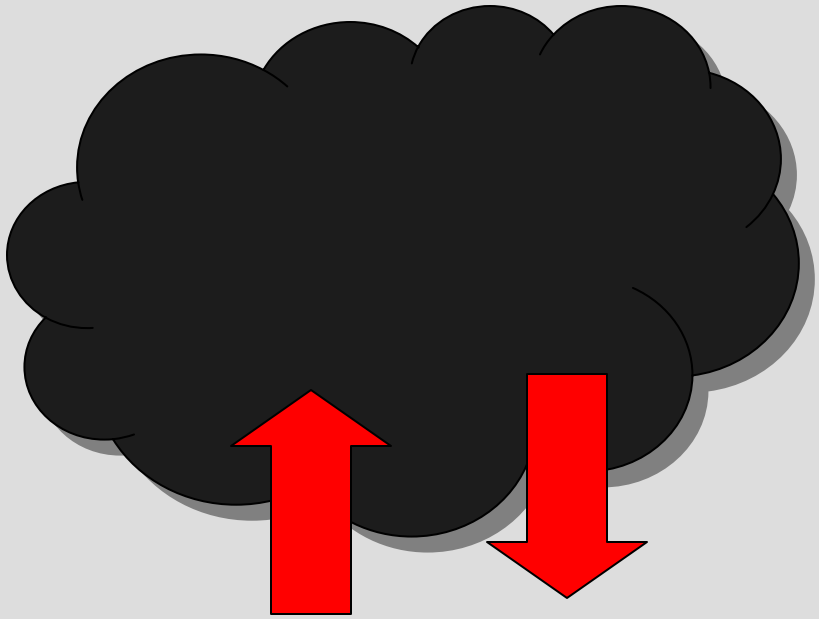
Temperature variation with height is more uniform.

Clouds: Affect solar and terrestrial radiation

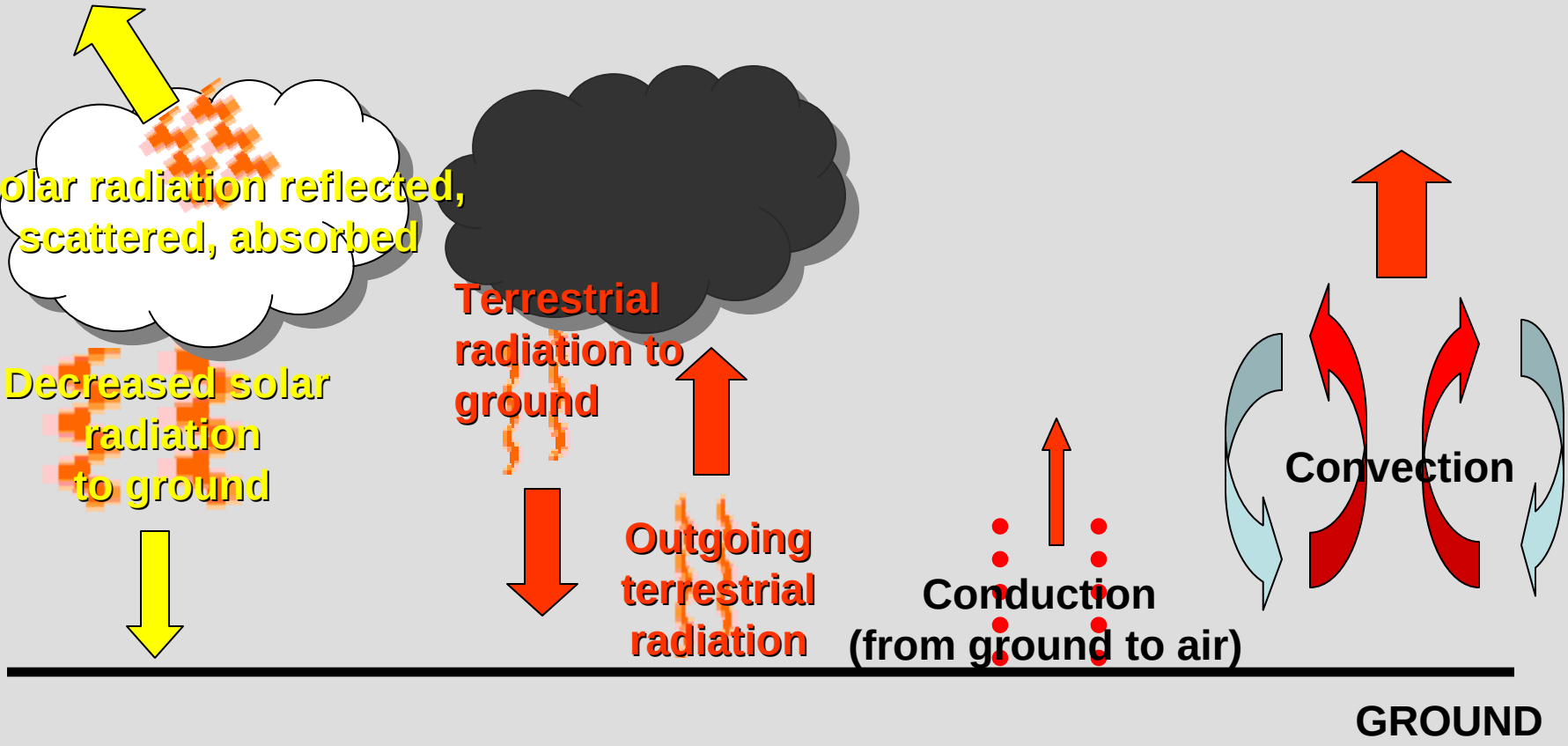
ABSORPTION, SCATTERING AND REFLECTION OF SOLAR RADIATION



VERY EFFECTIVE ABSORBERS AND EMITTERS OF TERRESTRIAL RADIATION

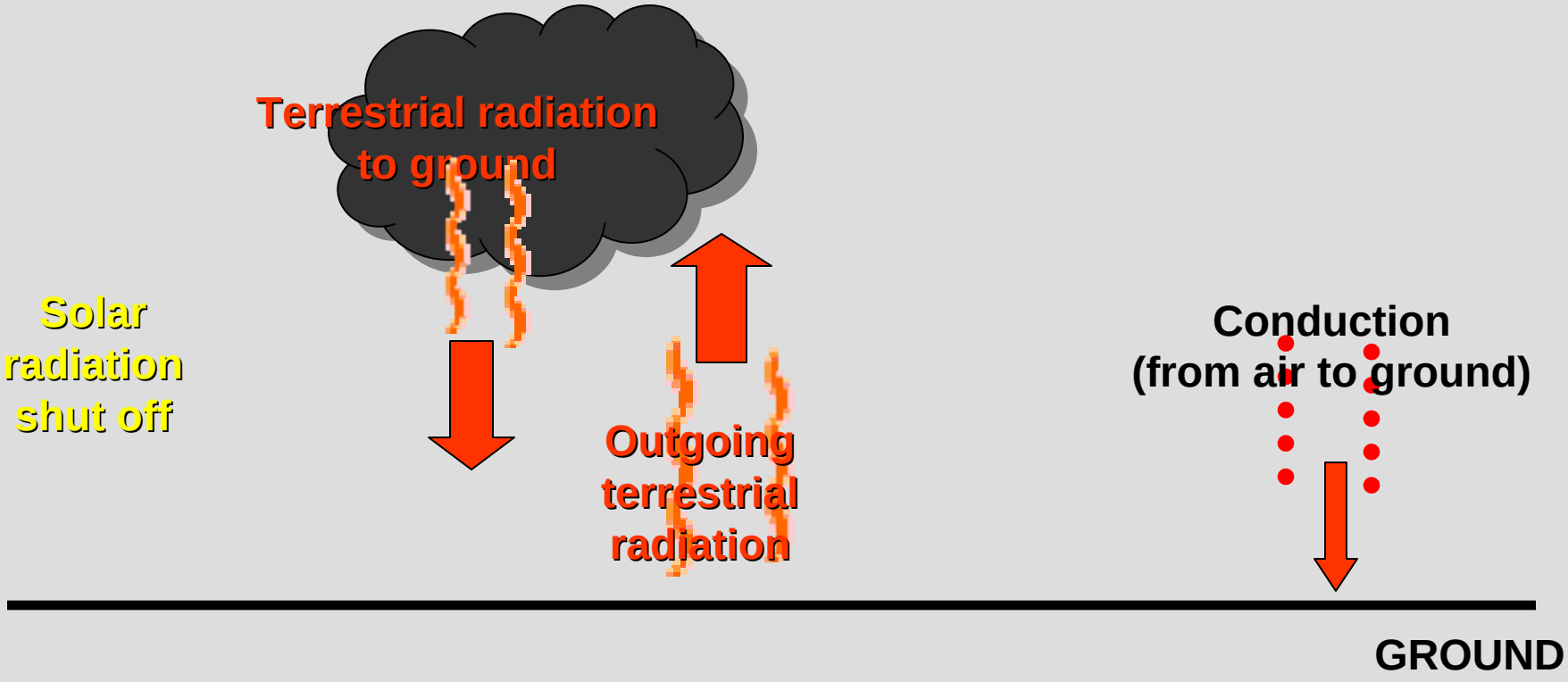


Daytime Energy Budget: With Clouds



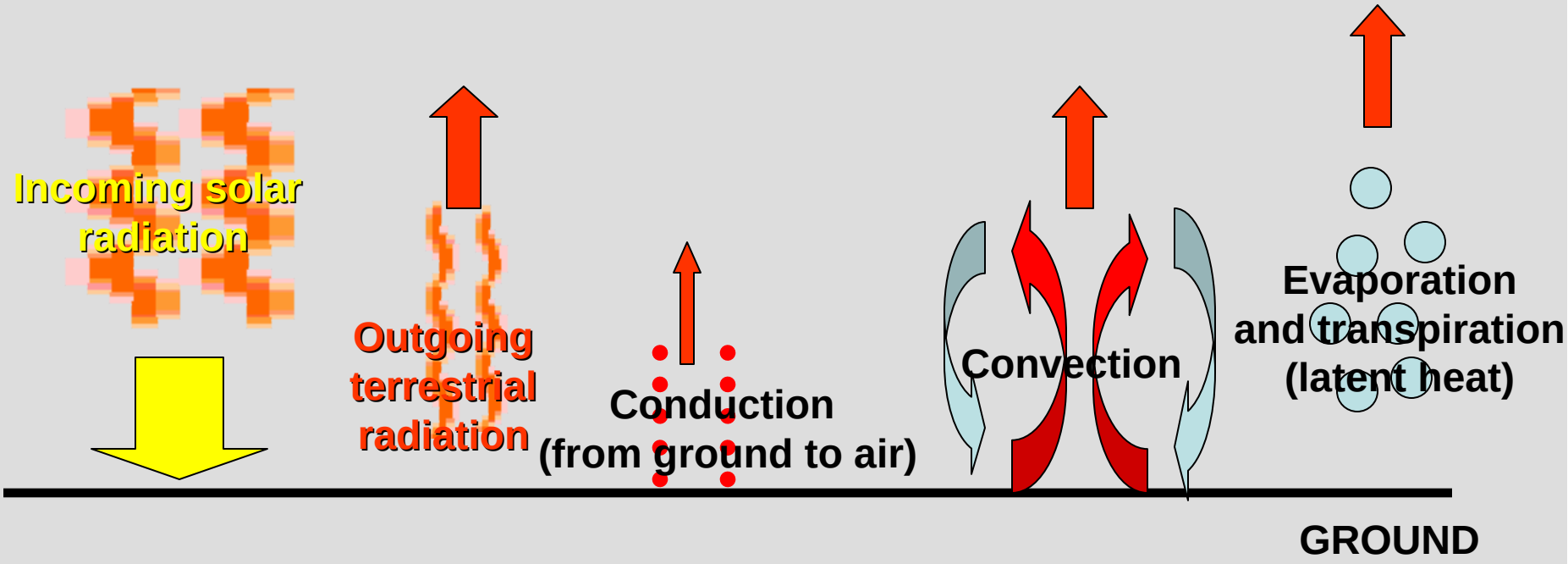
The effect of reflection of solar radiation is most dominant, so the presence of clouds typically results in cooler surface temperatures during the day.

Nighttime Energy Budget: With Clouds



Because of their emission of terrestrial radiation, the presences of clouds results in warmer surface temperatures at night.

Effect of Surface Moisture: Latent Heating



The presence of water, causes some of the surface energy to be partitioned to evaporation and transpiration of moisture—or latent heating.

This effect decreases the surface temperature during the day.

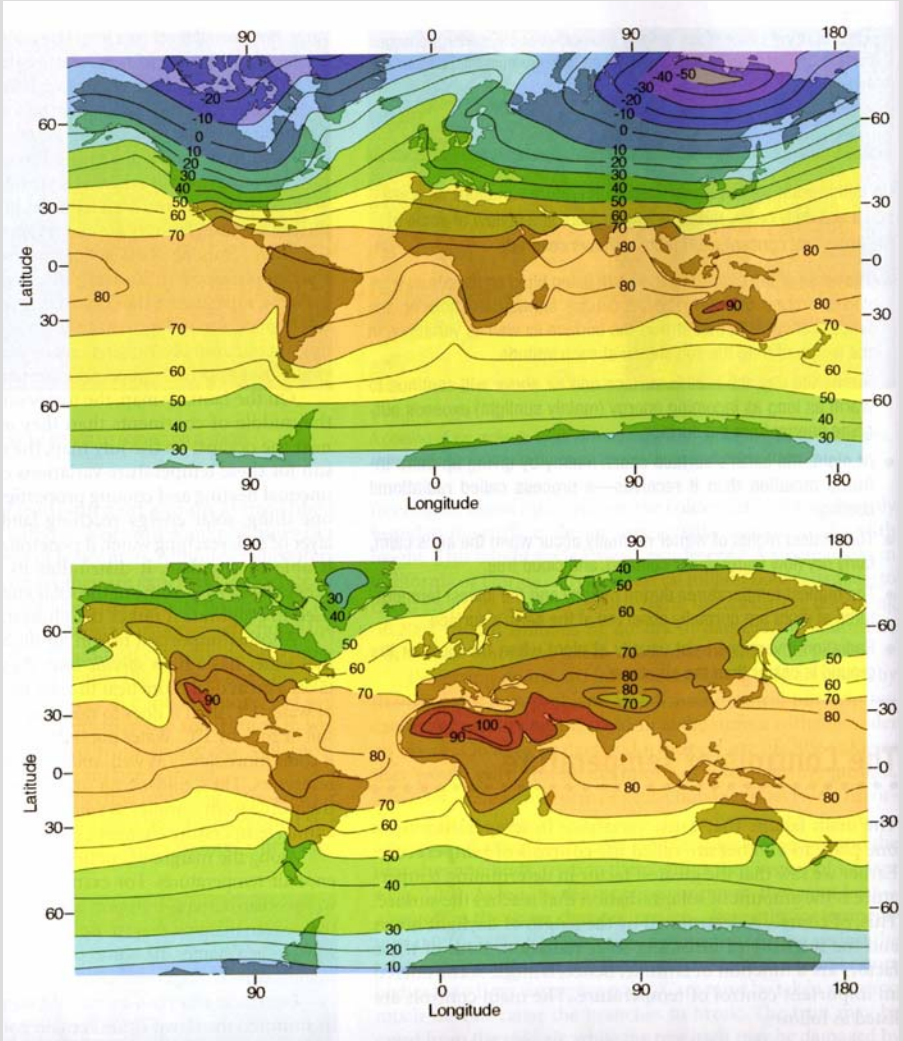
What controls temperature variations from place to place?

Latitude
Land and water distribution
Ocean currents
Elevation

Global Surface Temperature Variability: Latitude

January

July



Maximum Temperature

<u>Effect of latitude</u>:

Temperatures decrease with increasing latitude. Effect is more pronounced in wintertime.

Largest annual changes occur at higher latitudes.

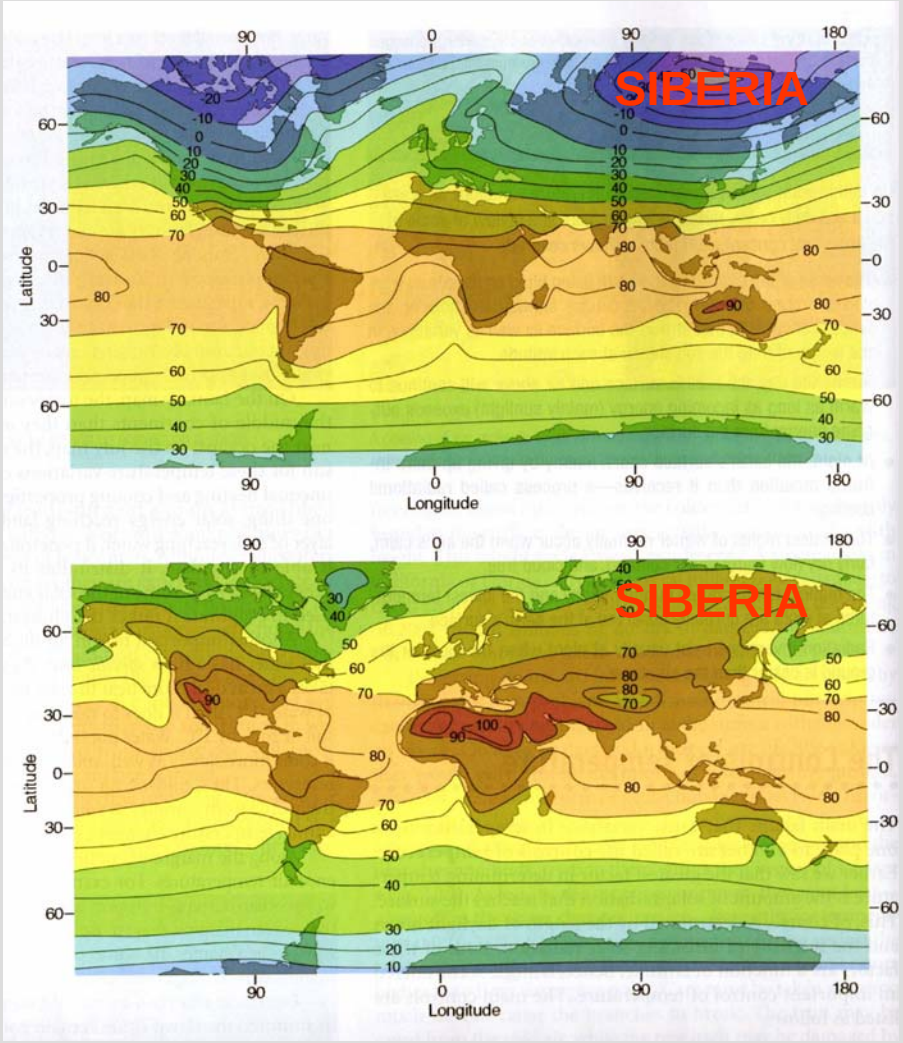
Temperature does not change much in the low-latitude tropics

Hottest places are in the sub-tropics, where most deserts are

Global Surface Temperature Variability: Land and water distribution

January

July



Maximum Temperature

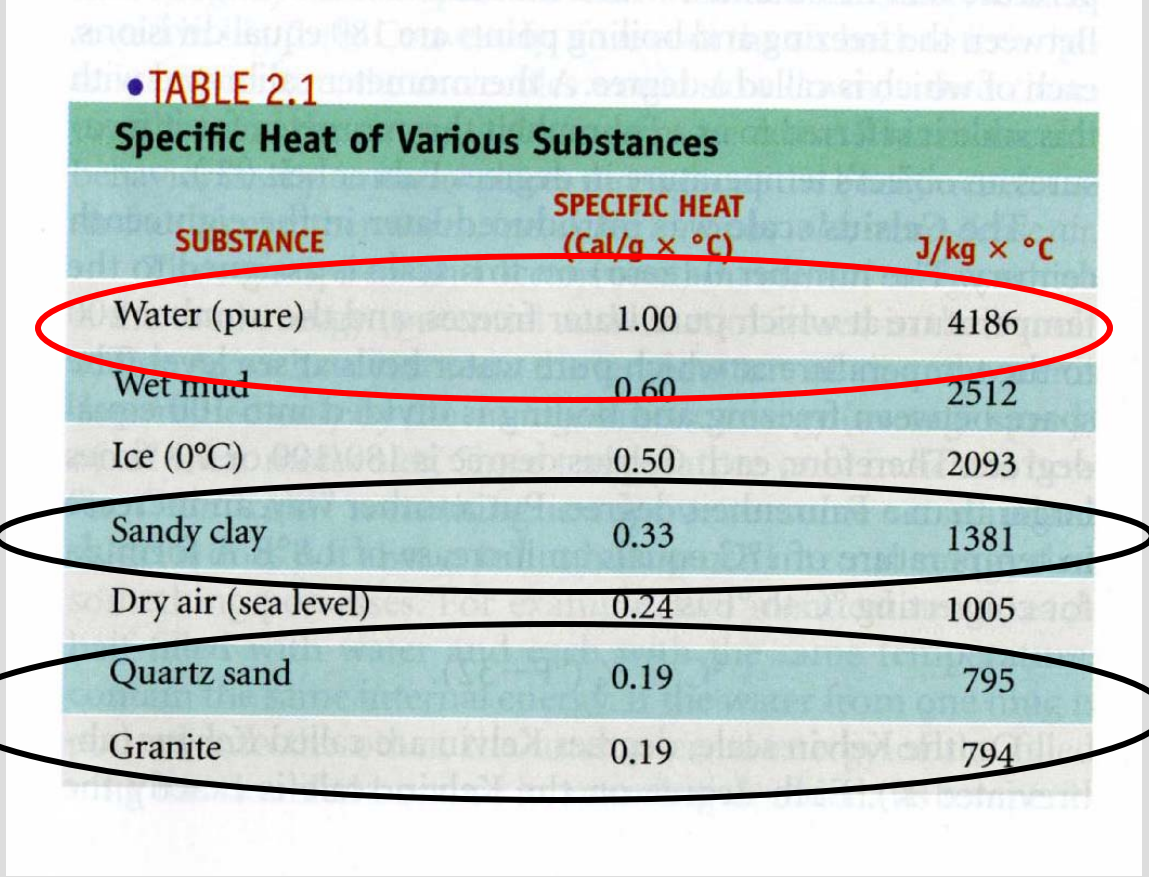
<u>Effect of oceans and continents</u>:

Greatest temperature swings are in the interior of continents.

Siberia:
60° F summer
-50° F winter

<u>Reason</u>:

Flashback:
High Heat Capacity of Water



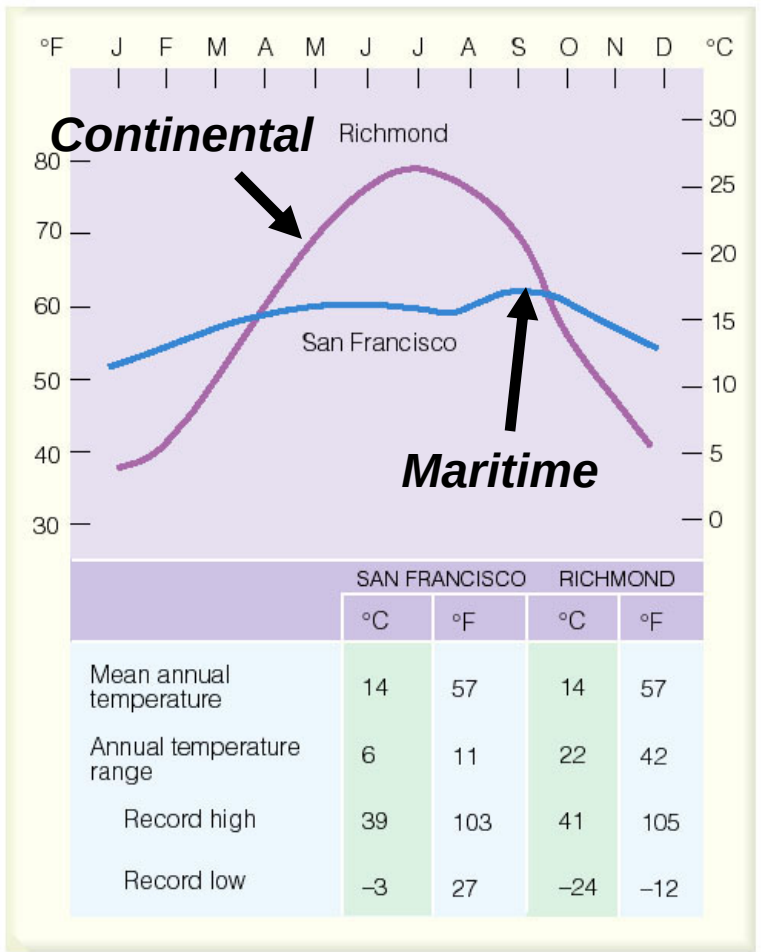
• TABLE 2.1

Specific Heat of Various Substances

SUBSTANCE	SPECIFIC HEAT (Cal/g × °C)	J/kg × °C
Water (pure)	1.00	4186
Wet mud	0.60	2512
Ice (0°C)	0.50	2093
Sandy clay	0.33	1381
Dry air (sea level)	0.24	1005
Quartz sand	0.19	795
Granite	0.19	794

Heat capacity of water is 4 to 5 times greater than rock or soil!

Continental vs. Maritime Climate



	SAN FRANCISCO		RICHMOND	
	°C	°F	°C	°F
Mean annual temperature	14	57	14	57
Annual temperature range	6	11	22	42
Record high	39	103	41	105
Record low	–3	27	–24	–12

<u>Two things to notice here</u>:

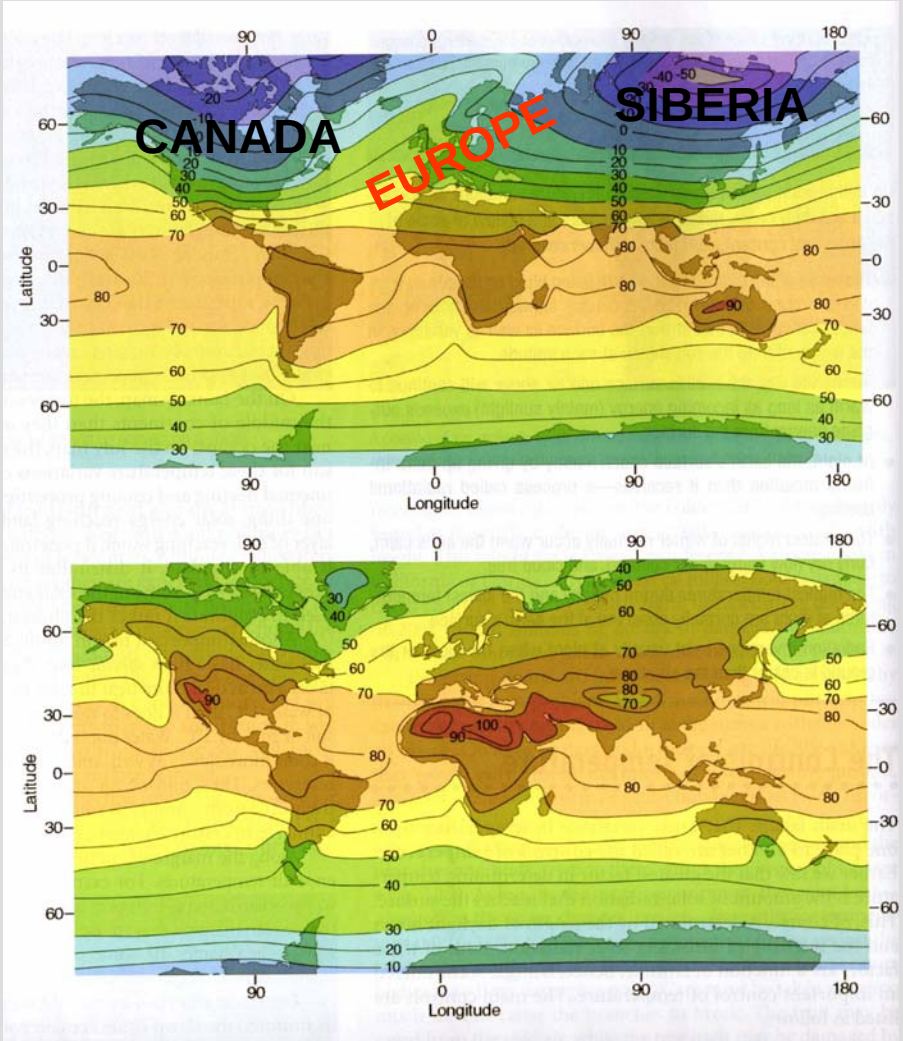
1. For both places, the hottest and coldest month DO NOT occur at the time of the winter and summer solstices.

2. The place located on the ocean has less of an annual temperature range and its hottest month occurs about a month or two after the more continental location.

Global Surface Temperature Variability: Ocean currents

January

July

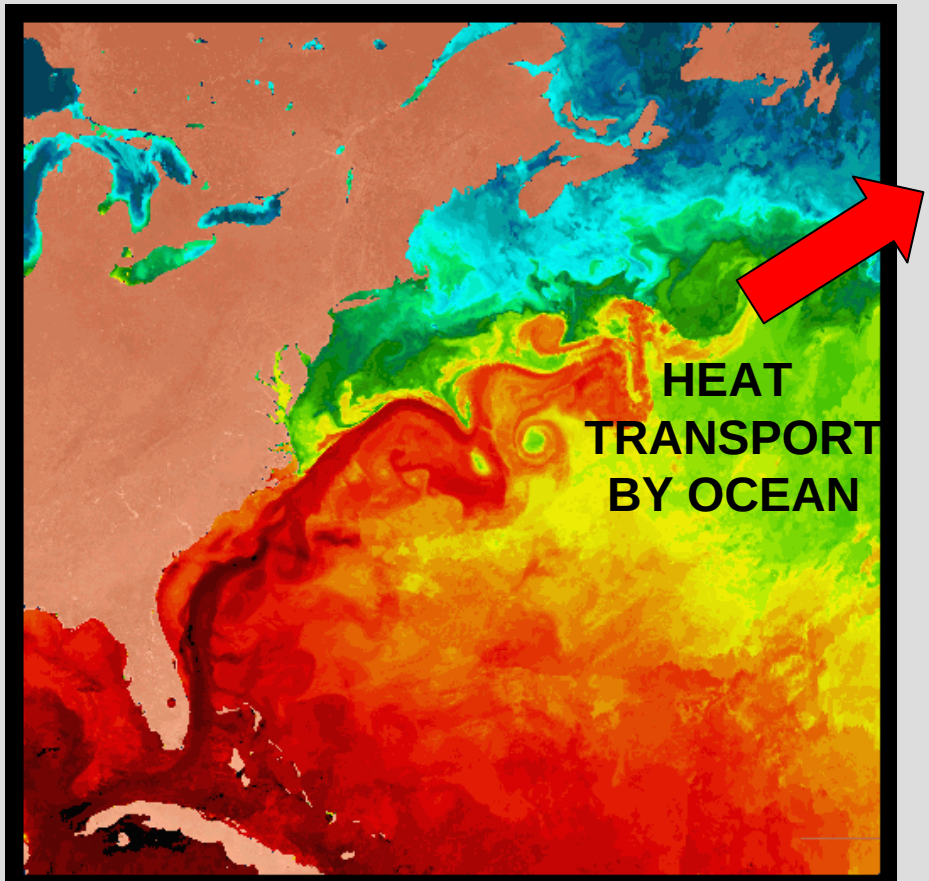


Maximum Temperature

Some areas at high latitudes are quite warm relative to other places at the same latitude, especially in winter.

Most of northern Europe, including England, Germany, France, and Scandanavia is at the same latitude as Siberia or Canada!

European Climate and the Influence of the Gulf Stream



Gulf-Stream and mesuscale eddies pictured on a color-enhanced NOAA/AVHRR image (downloaded from http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/eastcoast.gif).

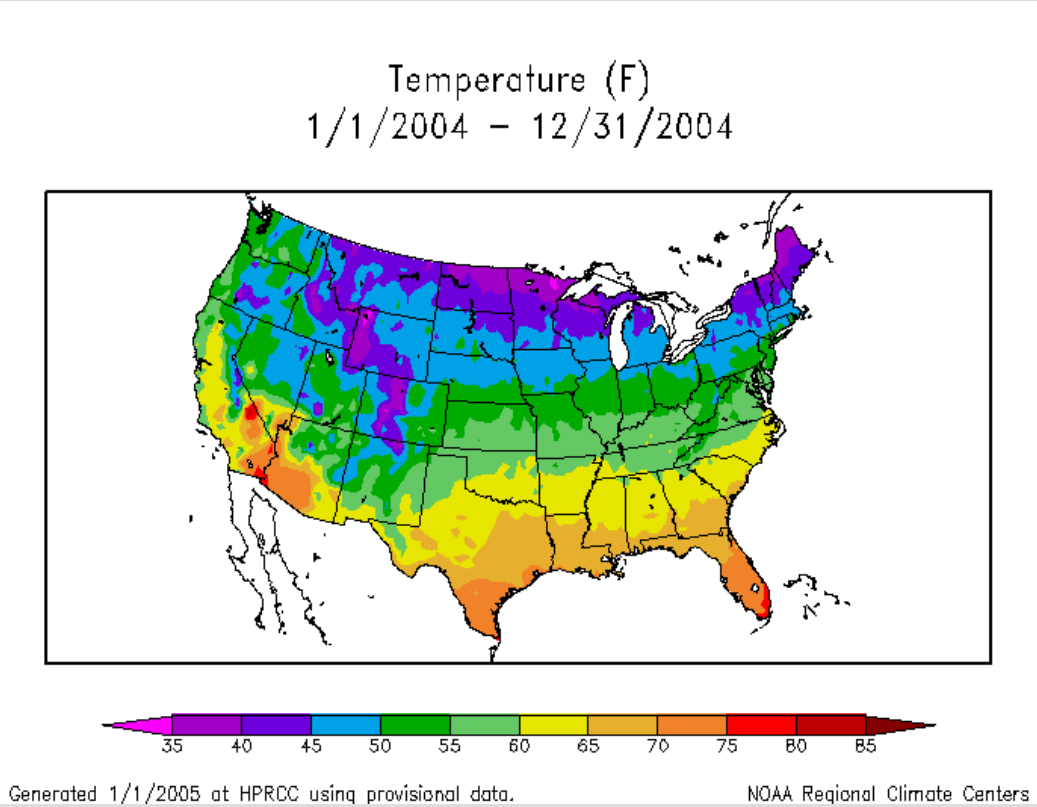
Figure 1.3.1

The Gulf Stream current in the North Atlantic transports warm water from the tropics toward Europe.

As a result, Europe is much warmer than it otherwise would be.

We'll discuss this topic in more detail later in the course.

Elevation and Temperature



Temperatures decrease as elevation increases.

Lapse rate = 6.5°C per km

Note the uniform decrease in temperature with latitude in the eastern U.S.

Temperature pattern in the western U.S. reflects the topography.

Surface Temperature
Tucson vs. Humphrey's Peak

Humphrey's Peak:
Elevation 3850 m
Highest Point in AZ
About 20°C cooler than Tucson, on average!

Tucson:
Elevation 728 m

Summary of Lecture 8

We looked at how daytime and nighttime temperatures are affected by the three modes of heat transfer.

During a clear, calm day the ground warms because the incoming solar radiation exceeds the outgoing terrestrial radiation and conduction from ground to air, and convection. The time of maximum temperature occurs in mid-afternoon, several hours after the maximum in incoming solar energy.

During a clear, calm night, the ground cools because of outgoing terrestrial radiation and conduction from air to ground. An inversion forms when the temperature near the surface is colder than above. Minimum temperature occurs around sunrise after the surface has cooled the entire night.

Winds, clouds, and evaporation and transpiration are three factors that would change how temperature evolves during the day.

Temperature variations over space are controlled by latitude, land and water distribution, ocean currents, and elevation. Oceans in particular moderate climate because of the high heat capacity of water and heat transported by currents (like the Gulf Stream).

Reading Assignment and Review Questions

All of Chapter 4
Appendix D

<u>Chapter 3 questions</u>:

Questions for Review: 7,8,9,10,11,12,13,16,17,18,19,20,25,26,27

Questions for Thought: 6,7,9,11,12,13