

Weather and Climate
Jim Keller & Paul Belanger

Classroom assistant: Fritz Ihrig

Week 2: January 22nd , 2019

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Announcements

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The Great Courses®

Lecture Chapters About the Professor

Meteorology: An Introduction to the Wonders of the...

LECTURE 1 Nature Abhors Extremes

LECTURE 2 Temperature, Pressure, and Density

LECTURE 3 Atmosphere—Composition and Origin

LECTURE 4 Radiation and the Greenhouse Effect

LECTURE 5 Sphericity, Conduction, and Convection

LECTURE 6 Sea Breezes and Santa Anas

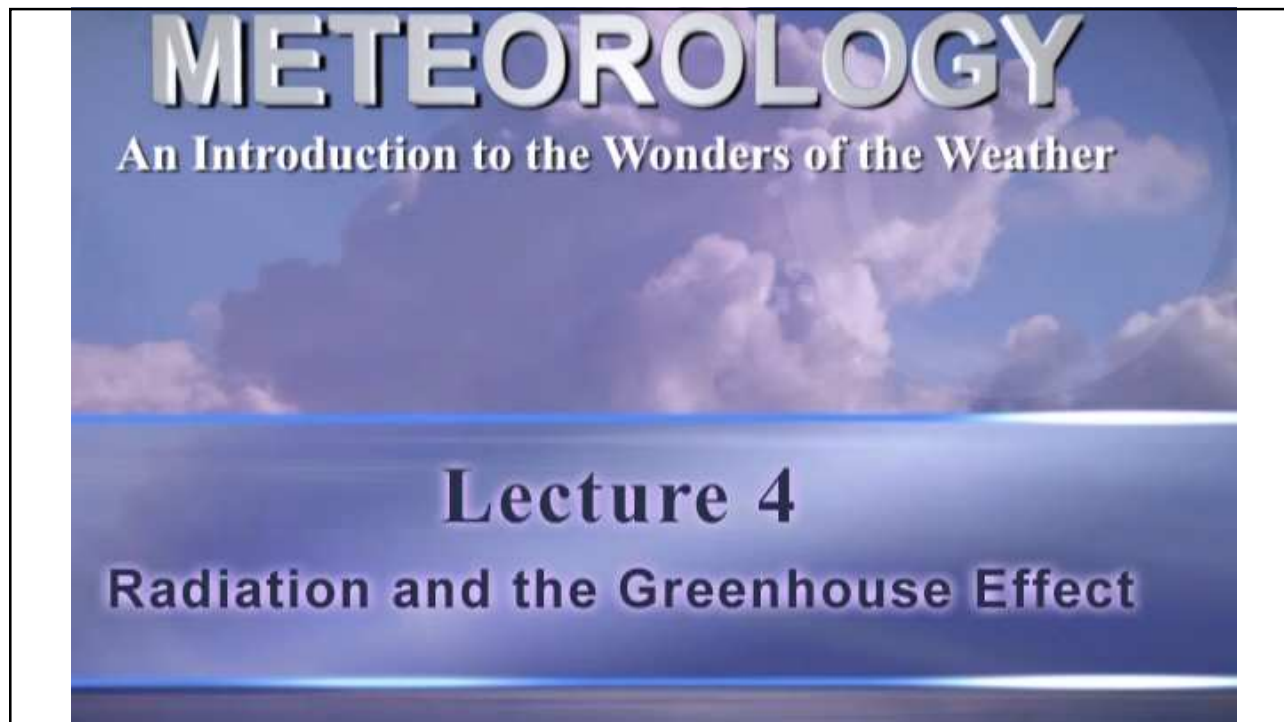
WEEK 2

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2nd Session links/references

- Links: Disk 4 References: <https://www.space.com/17683-earth-atmosphere.html>
- https://en.wikipedia.org/wiki/Electromagnetic_spectrum ;
https://en.wikipedia.org/wiki/Thermal_radiation;
<https://www.acs.org/content/acs/en/climatescience/greenhousegases/properties.html>
- Links: Disk 5 References: <http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/heatra.html>
- Link Disk 6: References:
https://en.wikipedia.org/wiki/Santa_Ana_winds ;
https://en.wikipedia.org/wiki/Chinook_wind

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Radiation:
https://en.wikipedia.org/wiki/Electromagnetic_spectrum

All objects emit radiation.

- Solar radiation
- Earth radiation

High Energy
High Frequency ←

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Radiation

- All objects emit radiation.
- The total amount of energy emitted is a very strong function of temperature.
- All objects radiate energy at all wavelengths of the electromagnetic spectrum.
- Objects radiate much more energy at some wavelengths than others.

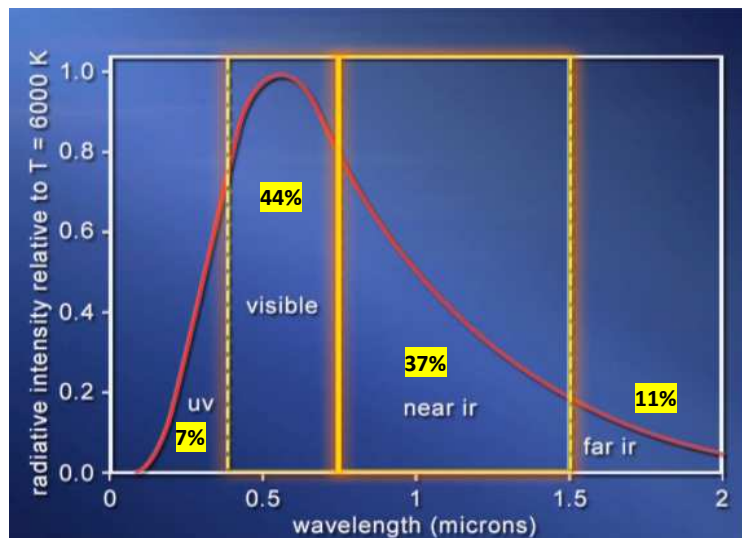
$E \propto T^4$
Stefan-Boltzmann law

warm ground 300 K
surface of sun 6000 K

160,000 times hotter!

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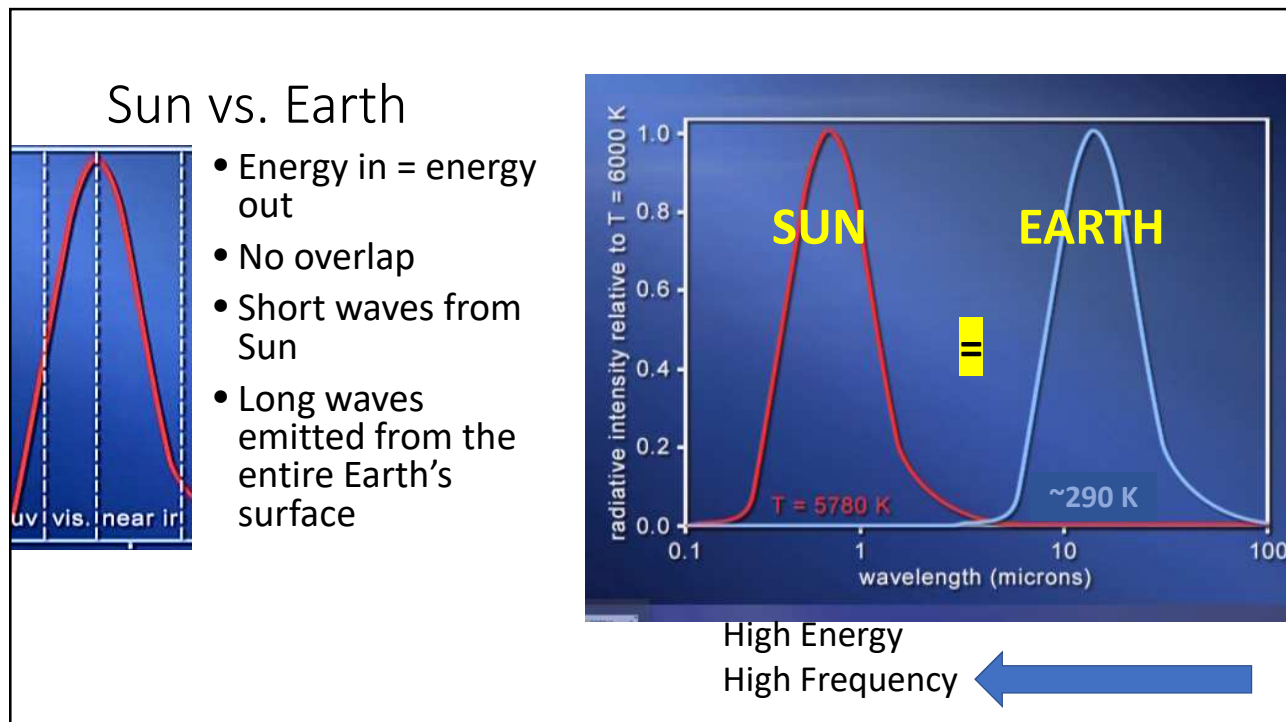
Where the energy of the sun is distributed



High Energy
High Frequency



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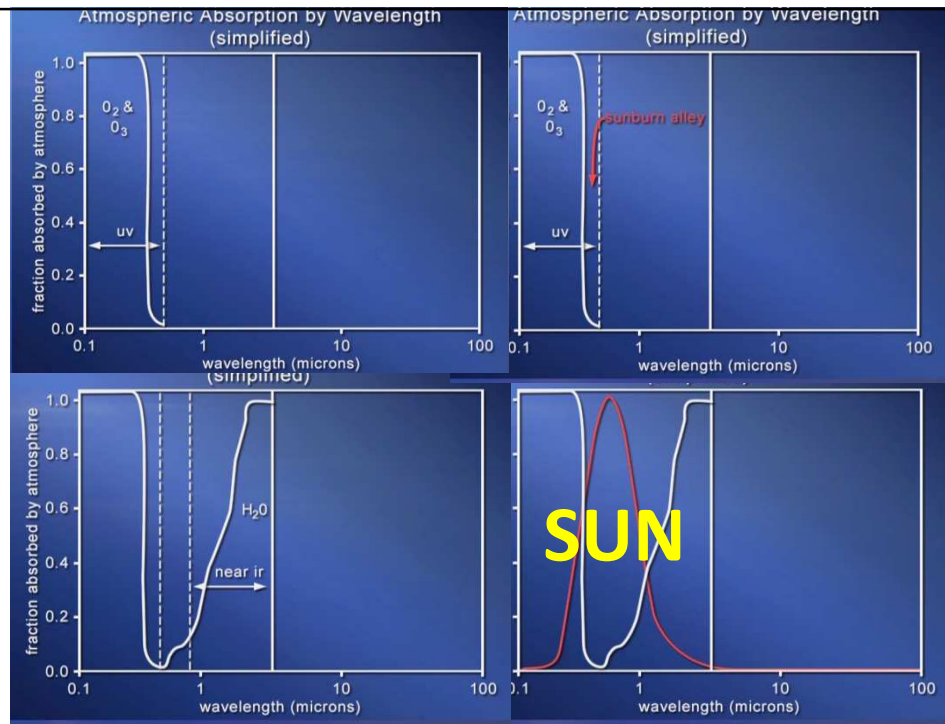
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Reflection & Absorption

- A color of something indicates the color that is NOT absorbed
- Which gases absorb Infrared: carbon dioxide (CO_2), water (H_2O), Nitrous Oxide (N_2O), methane (CH_4), etc.
- Absorption vs. emission – video talks about:
 - Black body absorption, plus specific affinity for infrared due to greenhouse gases' molecular vibrations:
<https://www.acs.org/content/acs/en/climatescience/greenhousegases/properties.html>
 - Black body emission depends on temperature of emitter:
https://en.wikipedia.org/wiki/Thermal_radiation
 - But greenhouse Gases also emit infrared at specific frequencies

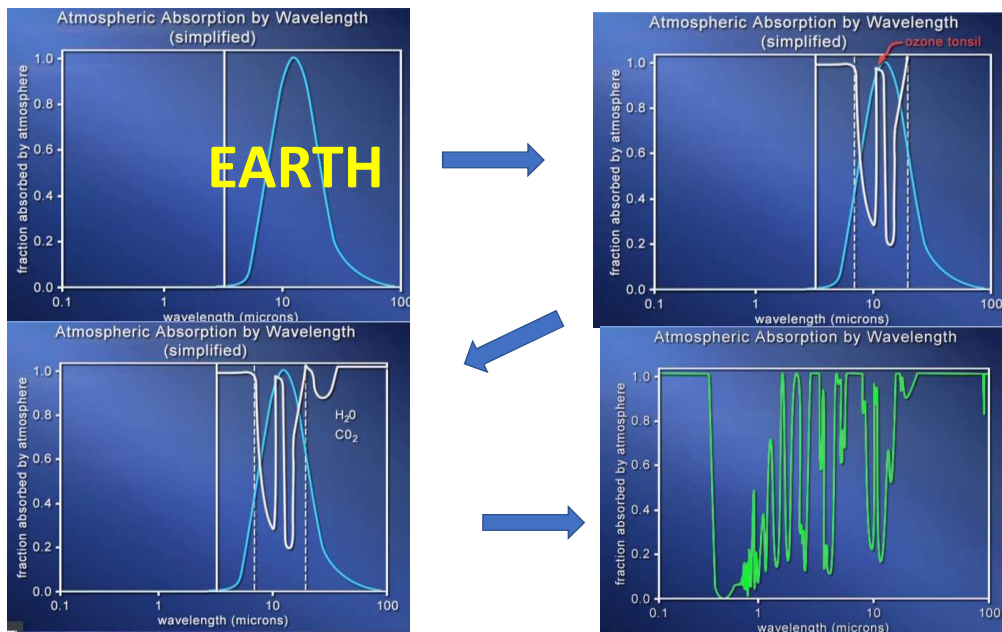
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The Atmosphere absorbs BEST what the Sun makes the LEAST of

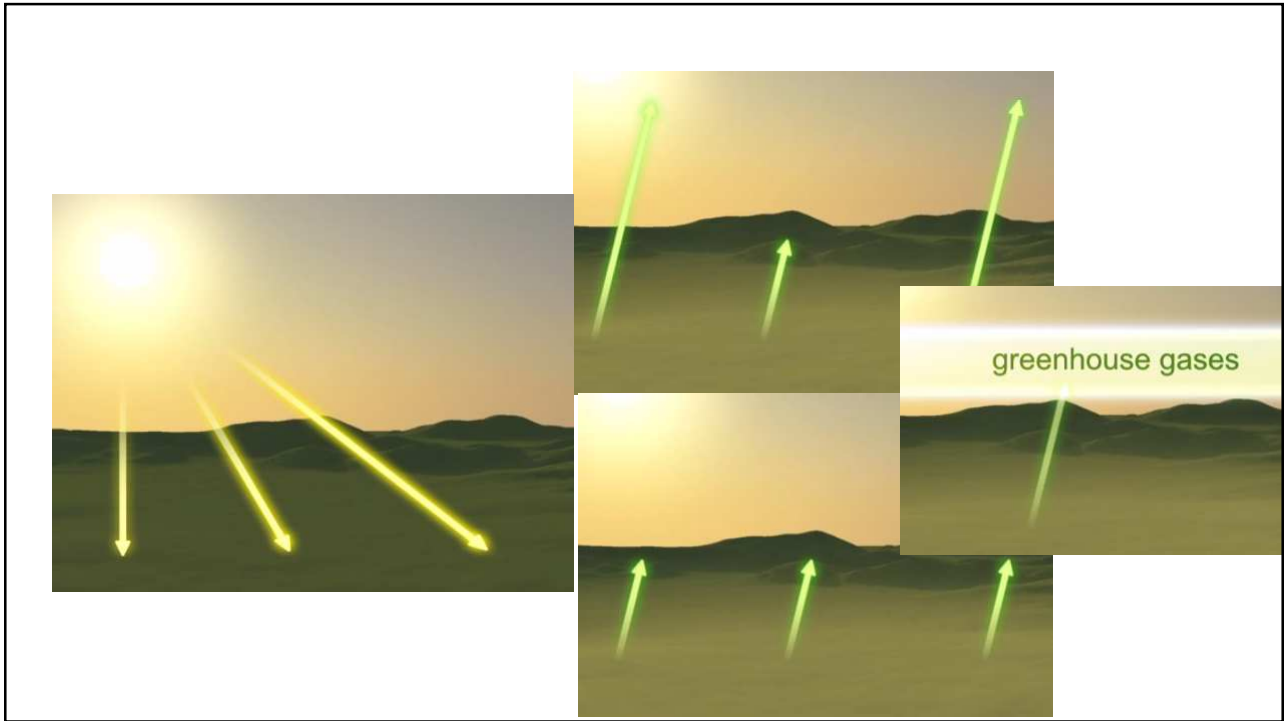


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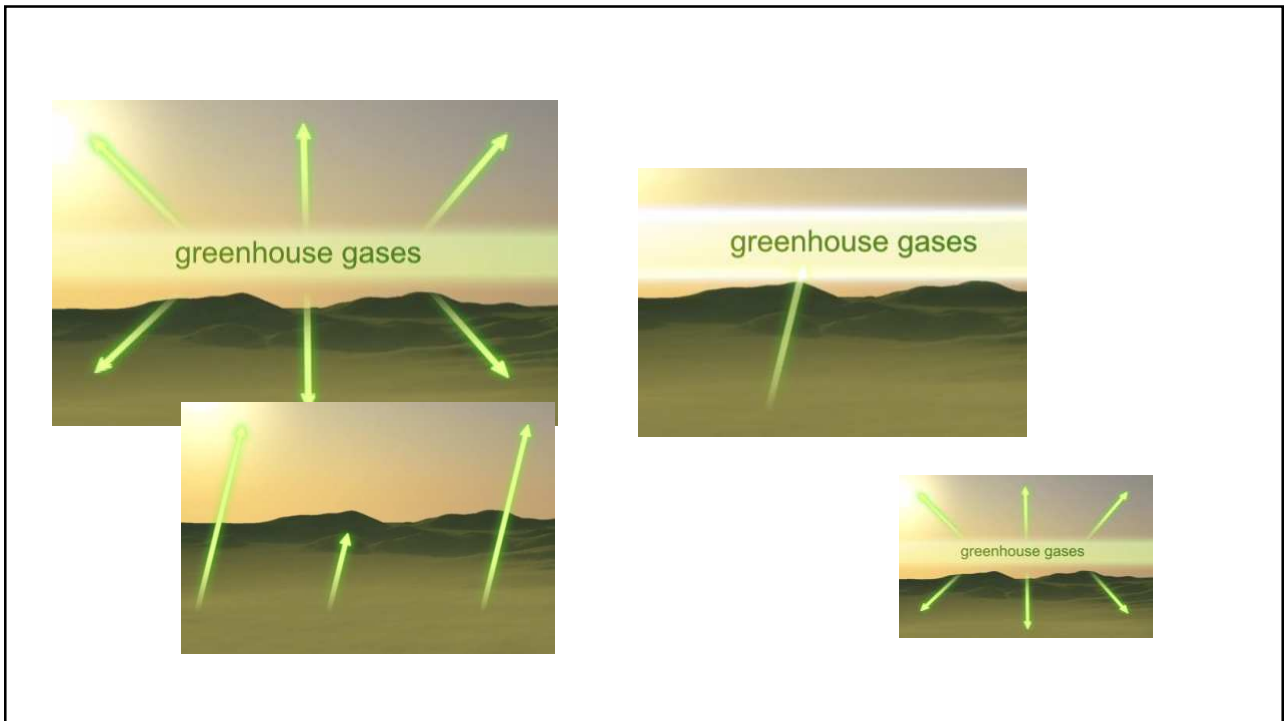
A progression of captures from video



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How GHGs Blanket the Earth

Blanket Earth:

- **NASA –Global Climate Change Cause:**

<http://climate.nasa.gov/causes/>

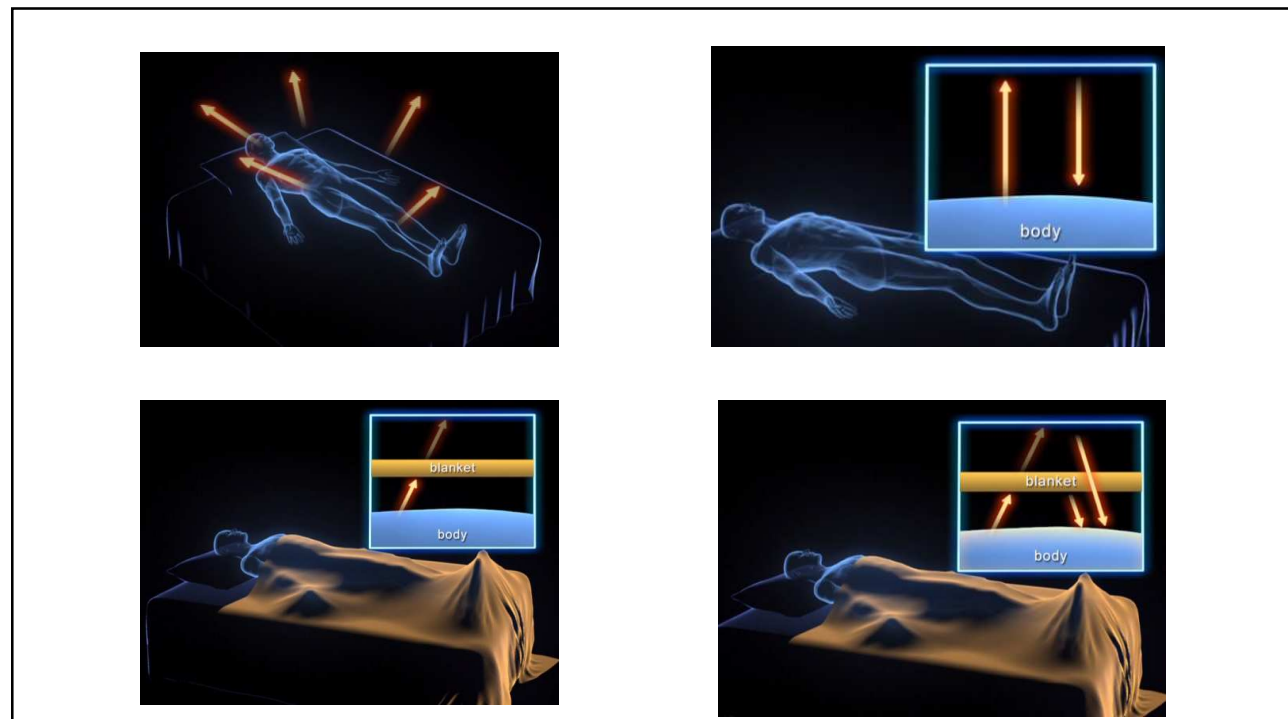
Denial 101x – Video: Global warming:

- https://www.youtube.com/watch?v=aqkGoCgIp_U&feature=youtu.be

Denial 101x – Video: Increasing Greenhouse Effect:

- <https://www.youtube.com/watch?v=we8VXwa83FQ>

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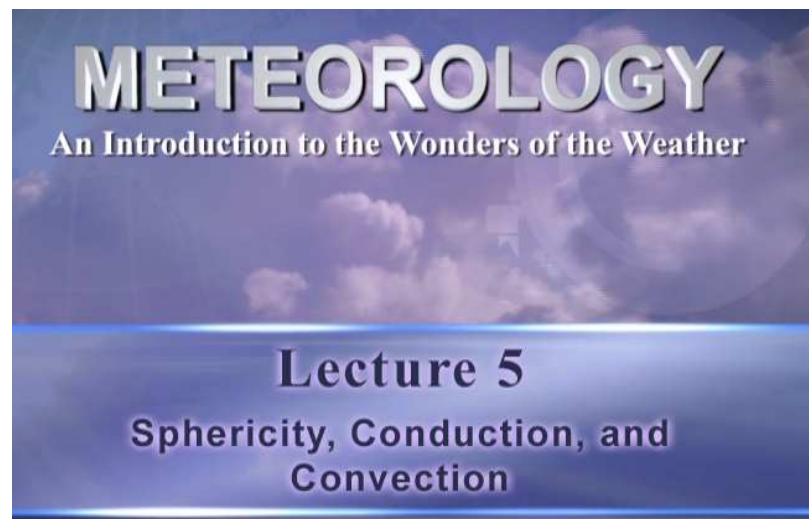
Greenhouse Warming

The presence of greenhouse gases have made the Earth much warmer than it would have otherwise been.

Earth's average temperature is 60° F. Without the greenhouse effect Earth's temperature would be 0°F.

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Lecture 5: Conduction vs. convection



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- What causes the seasons?
- Why does a metal spoon feel cooler than a drinking glass when both have the same temperature?
- When we touch it with our hand, why do we tend to dramatically underestimate the temperature of the sea?



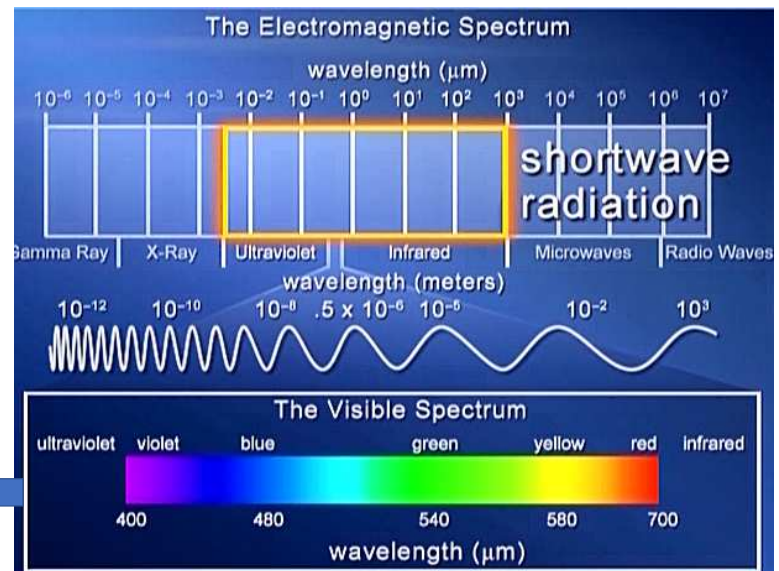
- Why does beach sand get so hot on a sunny summer day?
- Why is that same sand so cold just before sunrise?

Temperature differences make pressure differences; pressure differences cause winds.

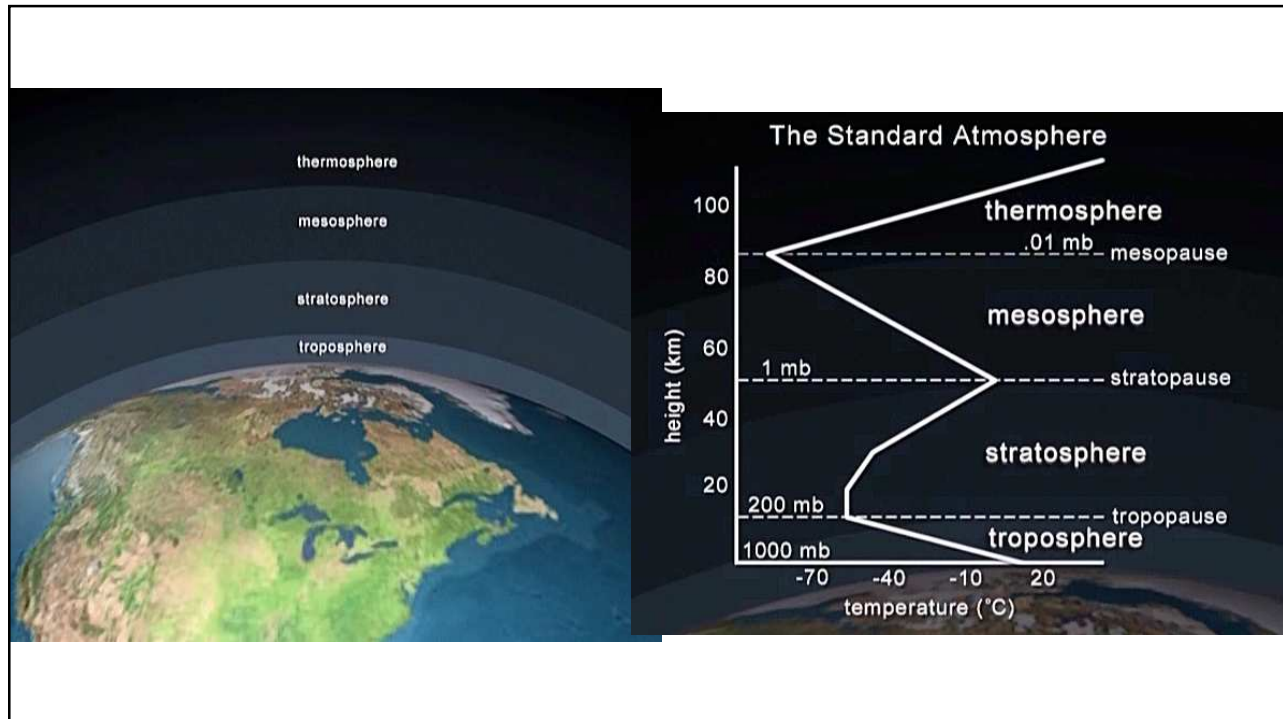
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The Sun

High Energy
High Frequency

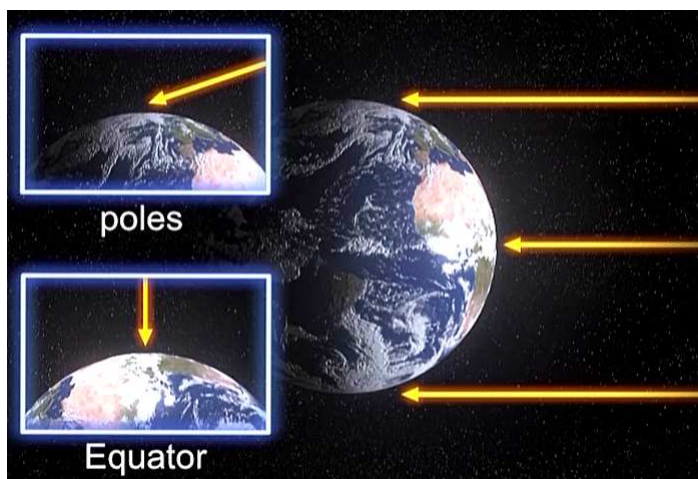


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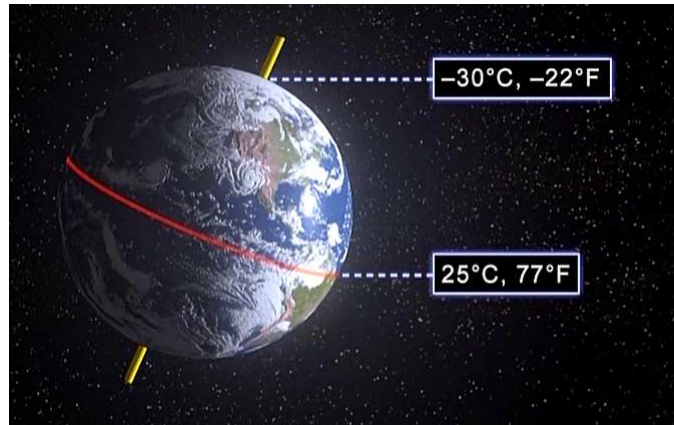
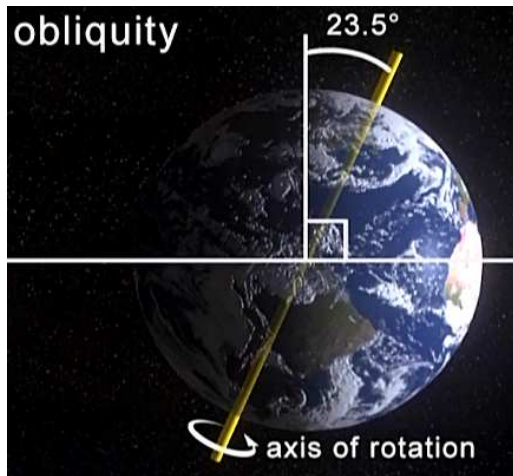
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Unequal heating: Sun's energy is spread out towards poles



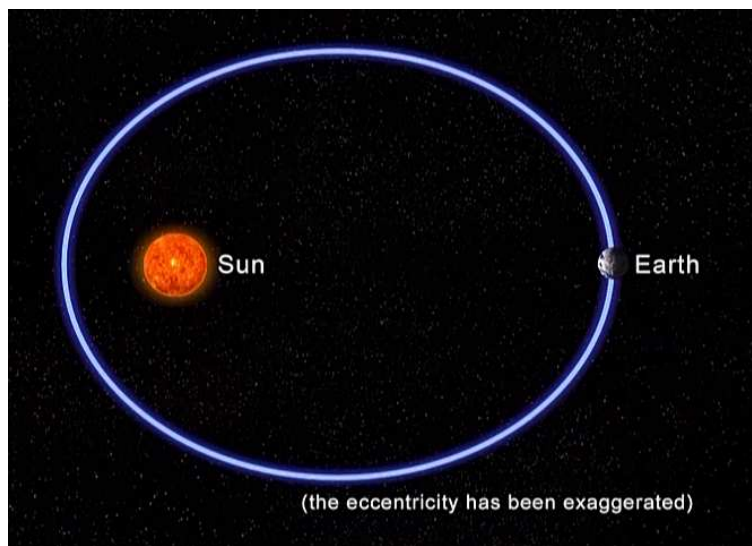
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Obliquity – 41,000 year



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The Earth's Elliptical Orbit – CHANGES EVERY 100,000 YEARS



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Radiation, conduction, convection

- Radiation does not need mass to transfer energy
- Conduction needs mass – solid or fluid (gas or liquid)
- Convection needs mass and it needs to be a fluid (gas or liquid)

- What is heat? = a property (internal energy – heat transfer – temperature is the means to measure ; something that's hot -flow of energy)
- Heat transfer =
- Heat capacity of substances

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Conduction

- conduction: heat transfer by direct atomic contact
- operates in one direction – warm to cold
- T is a measure of microscopic kinetic energy of atoms & molecules
 - vibration
 - translation
 - and rotation

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Transfer of Energy

- **Warm to cold**
- Objects differ in conductive properties
- Air – poor conductor - poor in transfer of heat
- Water conducts 26x better
- 650 times worse than copper
- Air = good insulation

• when warmer (more vibrant) molecules come into contact with cooler (less vibrant ones)
– Some microscopic kinetic energy transferred from warmer object to cooler one

“Cook with metal, and serve with glass.”

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Thermal Inertia (Heat Capacity)

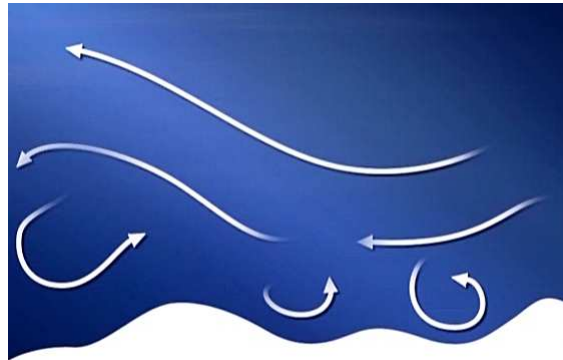
Heat conductivity, convection & thermal inertia

- Heat Transfer (Q) = $C_p (T_2 - T_1)$
- C_p = heat capacity
- **Water has high heat capacity**
- **solids typically have much lower heat capacity**

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Convection

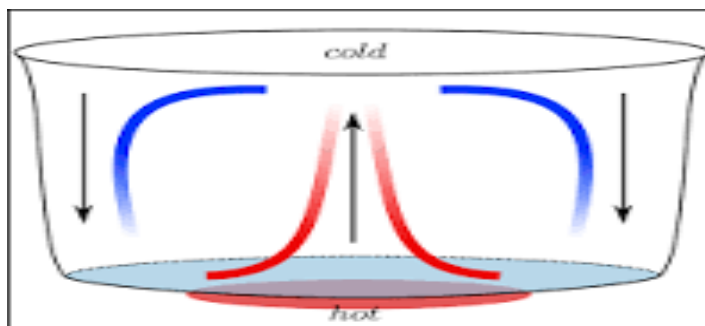
- Wind as the means



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Convection of Fluids

- Hot fluid becomes less dense and rises; cold fluid descends to replace it and is heated in turn.



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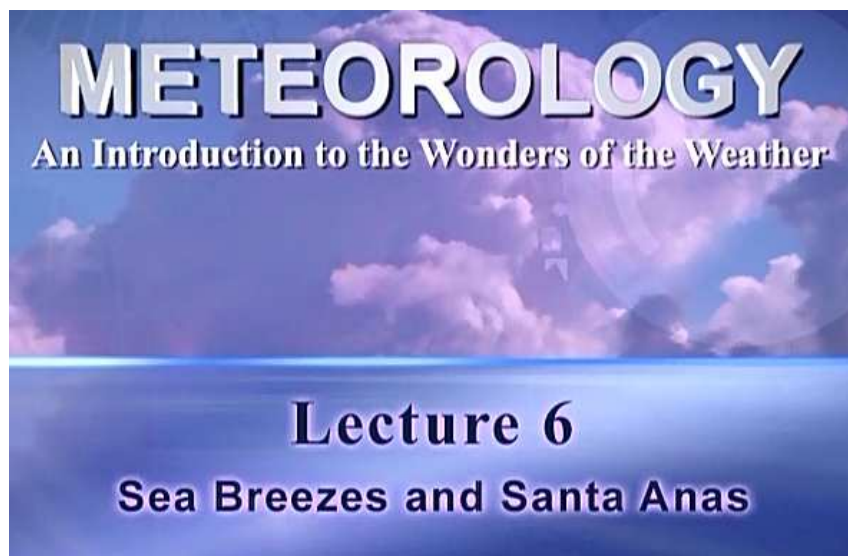
FROST

Under what conditions are we most likely to get frost (subfreezing) conditions at the ground?

- when the air is relatively dry
- when the sky is clear
- when the surface has a low thermal inertia
- when the winds are calm

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Lecture 6: Sea Breezes and Santa Anas In Colorado – Chinook winds



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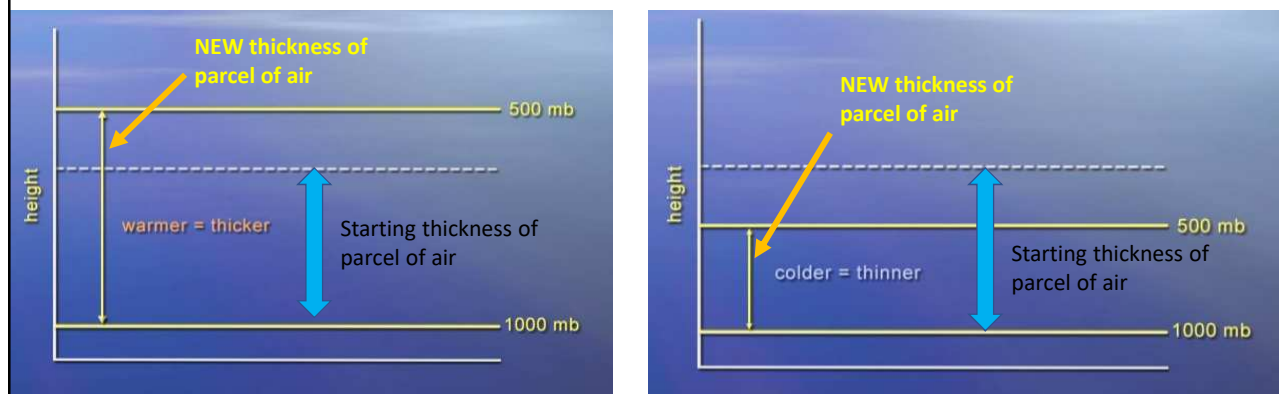
Temperature differences

- Varying locations
- Varying amounts of sun (due to clouds, latitude (incident angle), time of year, time of day)
- Surface color: albedo, heat capacity/thermal inertia (water vs. land)
- Radiation, conduction, convection
- Winds – to equalize
- **Hot to cold** – vs cold to warm expressions

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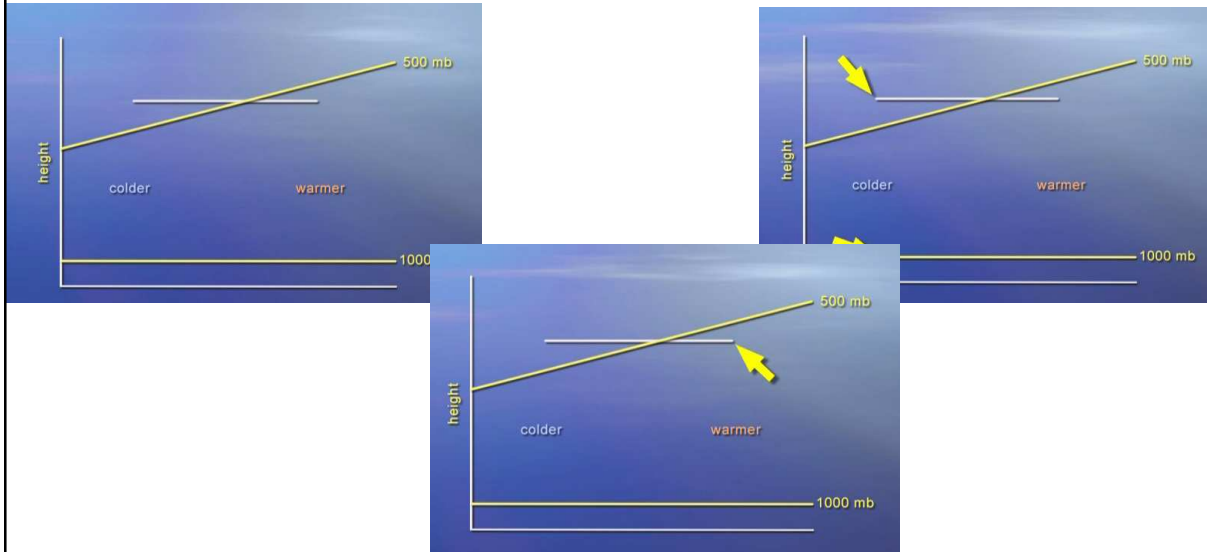
Pressure

- Decreases with height
- Isobars = pressure
- Temperature differences make pressure differences



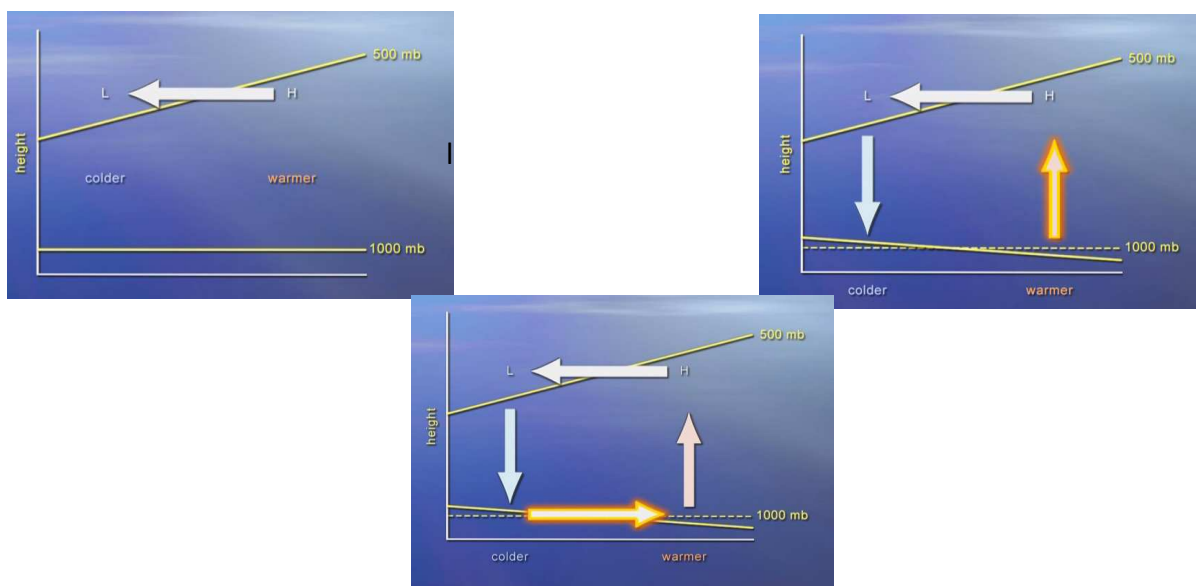
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- From a certain height: when I look toward colder area, both 500 and 1000 mb below; but when I look toward warmer 1000 mb still below but 500 mb above. Cold dense air lowers 500 mb level.



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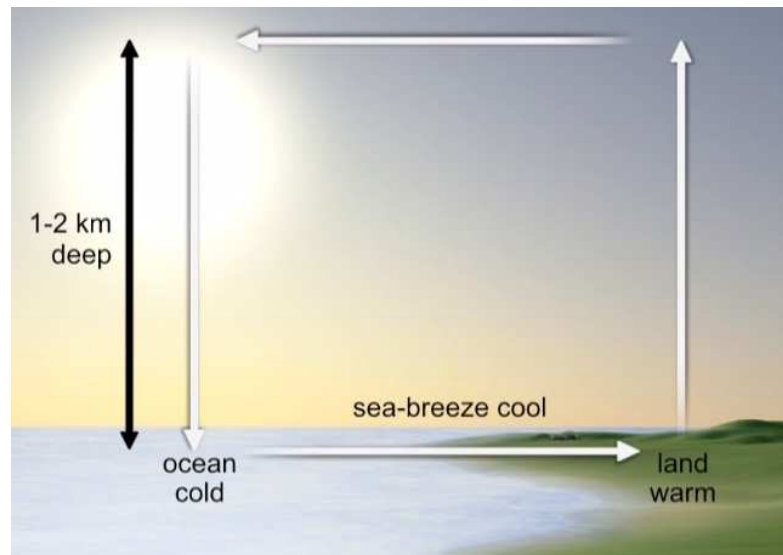
This makes wind From high to low – adds mass and then creates a circulation



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Sea Breezes

- Ocean absorbs more heat than land
- But land heats faster (lower thermal inertia /heat capacity) so less dense air rises, moves out over ocean, cools and descends; cool air from ocean moves to land replacing rising hot air and is heated in turn

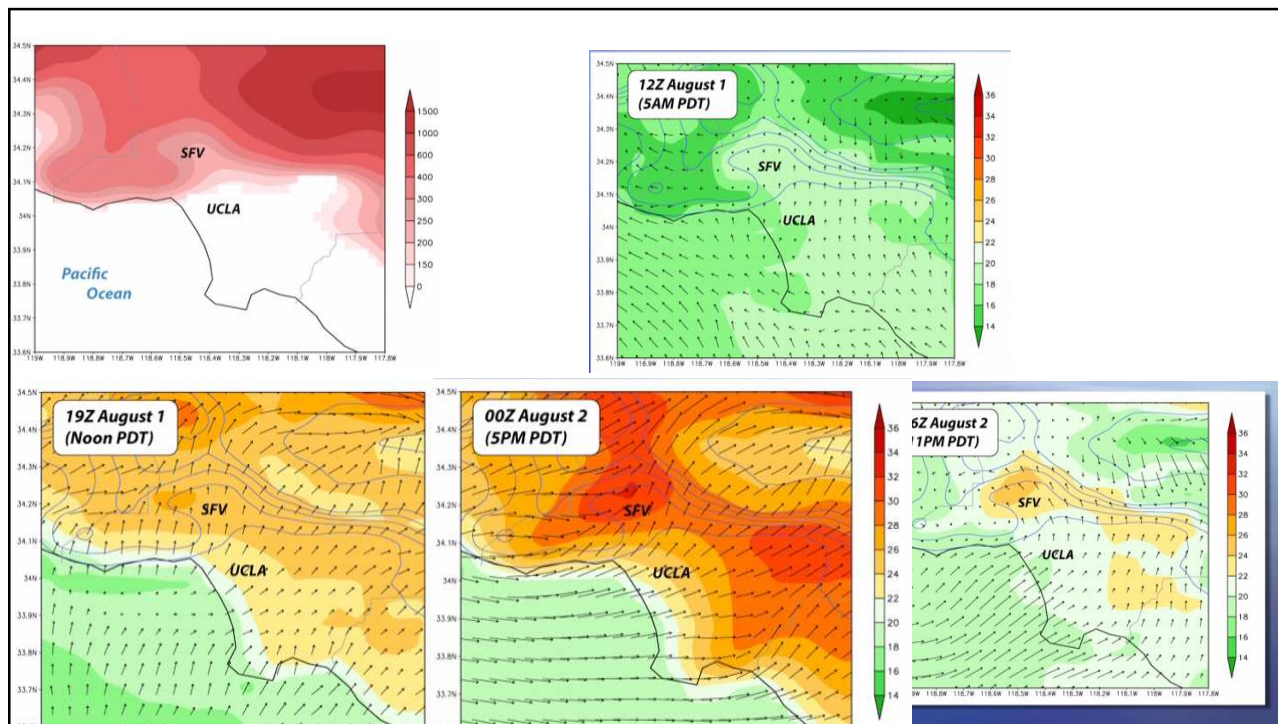


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Typical weather stations

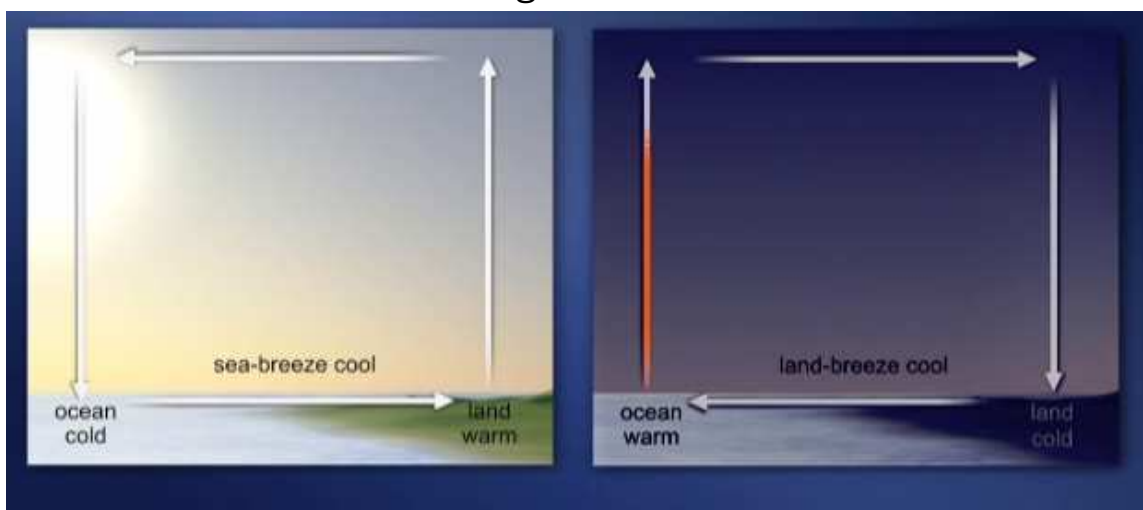
- Temperature measured at 2.5 m above surface
- Wind at 10 m above surface
- And free of buildings

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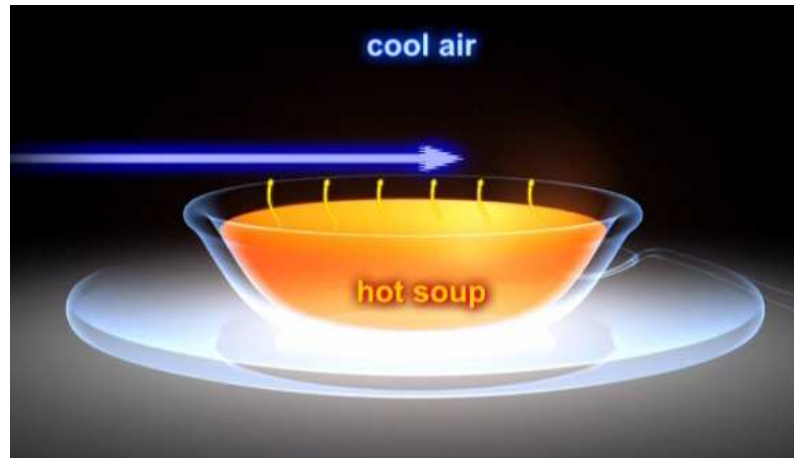
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The breeze reverses at night when the land cools faster



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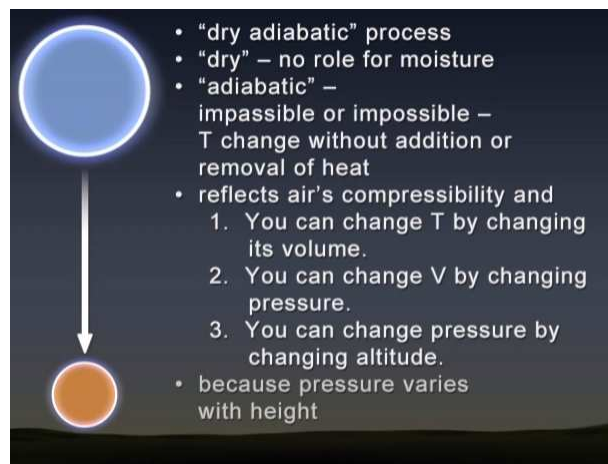
Wind chill



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How to change air temperature

- Mix, but parcels of air of different densities don't easily mix.
- Thermally direct: Change pressure – i.e. change parcel's elevation (in absence of heat input)
 - Chinook & Santa Ana winds compress and heat up when losing altitude
- Thermally indirect – forcing air to descend over warm ground
 - Or forcing cold air to rise over cold air



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Katabatic winds

- C_p = heat capacity
- https://en.wikipedia.org/wiki/Katabatic_wind
- https://en.wikipedia.org/wiki/Anabatic_wind

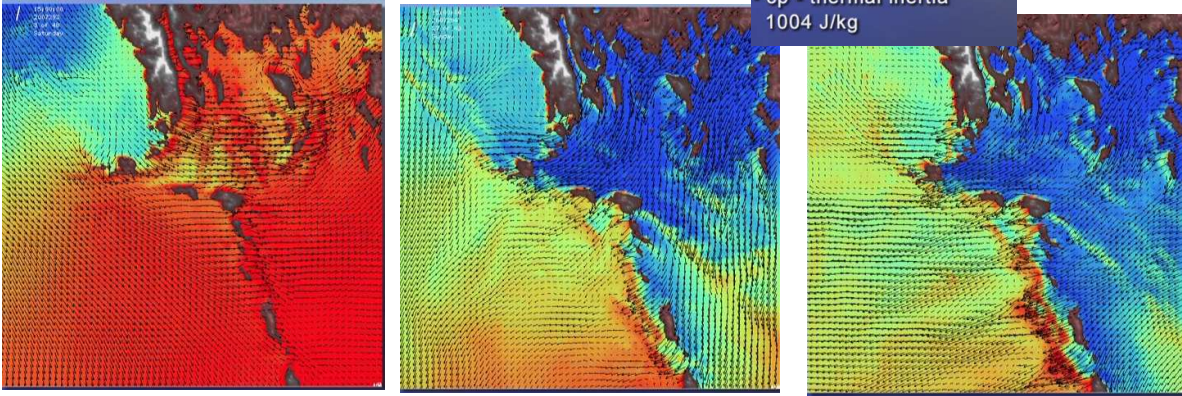
- descending air warms

- ascending air cools

- $30^\circ\text{F}/\text{mi}$ $10^\circ\text{C}/\text{km}$

- g - acceleration of gravity
 $32 \text{ ft}/\text{s}^2$ $10 \text{ m}/\text{s}^2$

- c_p - thermal inertia
 $1004 \text{ J}/\text{kg}$



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- End of week 2 – lessons 4, 5 6

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