Atmospheric Radiation Measurement
Climate Research Facility
U.S. Department of Energy

Climate Education Update

NEWS AND INFORMATION ABOUT CLIMATE CHANGE FOR TEACHERS AND STUDENTS

INVERSIONS

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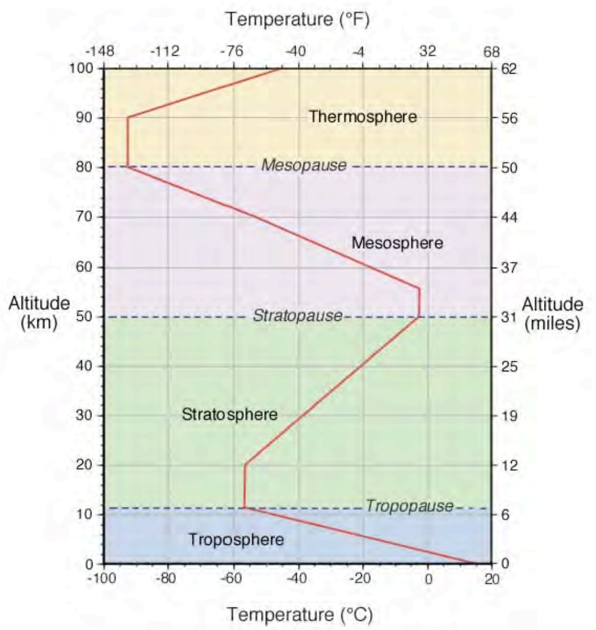
In the August 2008 issue of *Climate Education Update,* we looked at the concept of inversions, situations in which the temperature increases with increasing altitude. This is the opposite of what one would expect in the **troposphere,** the lowest shell of the atmosphere that is in contact with the Earth. Inversions are always present when fog is present.



Permission of Dr. Michael Pidwirny, University of British Columbia.

The most commonly observed inversion is the one found near the ground overnight and in the early morning. This inversion develops as the Earth radiates energy into space and cools down overnight. The air near the ground cools by conduction or contact. These inversions may be associated with morning ground fog but not always.

The second most common inversion is the one at the **tropopause,** which is between the troposphere and the strato-sphere. Here the atmosphere transitions from the up-and-down air currents, known as **convection,** and develops into the **stratosphere** in which motions are mostly horizontal.

The tropopause is higher and colder in the tropics and lower and warmer nearer the poles. In middle latitudes, the tropopause height is variable as low- and high-pressure regions (troughs and ridges) pass by. Check out the soundings for Barrow, AK, Norman, OK, and Guam in the attached activity.

Inversions also occur when air at high altitudes sinks toward Earth. Coming under higher pressure, the sinking air warms and often becomes warmer than air at lower levels. These inversions are often associated with heat waves in middle latitudes.

SOUNDING OUT INVERSIONS

Inversions also occur elsewhere in the atmosphere. We can find them through **radiosonde** or weather balloon soundings, which involve tracking a helium-filled balloon with a radiosonde attached instrument package and radio transmitter.

Temperature, moisture, and pressure data are measured directly; wind speed and direction, based on the balloon's geographical position.

A technician releases a white balloon-borne sounding system at the Southern Great Plains site. Courtesy: U.S. Department of Energy's Atmospheric Radiation Measurement Program.

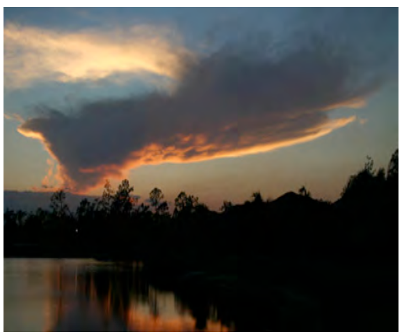
Such soundings are part of the suite of weather observations taken at ACRF research sites. Soundings are taken at about 1500 sites globally; most sites launch radiosondes twice daily. You can access soundings from ACRF and around the world at http://weather.uwyo.edu/upperair/sounding.html

Weather satellites can also estimate sounding information in cloud-free areas. The soundings provide useful information about atmospheric temperature and humidity profiles in between radiosonde sites and at hourly time periods throughout the day. http://www.star.nesdis.noaa.gov/smcd/opdb/goes/soundings/skewt/html/skewtus.html

SEEING AN INVERSION

It is easy to see inversions visually, if you know what to look for. Fog is a given; see last month's newsletter at http://education.arm.gov/outreach/publications/aug08.pdf.

Keying on this "layered look," let's look to the top of a cumulonimbus, or thunderstorm, cloud. Notice that its top is mostly flat, signifying that rising air has reached a **stable** layer. Then the excess cloud material spreads out based on upper level winds and the interaction of the upper winds with the rising air currents in the thunderstorm.



It's easy to see where the rising air source was for this dissipating thunderstorm. But the storm's cloud top (called an anvil) has spread out horizontally over a much larger area. The cloud top marks the approximate inversion layer. Photo by H. Michael Mogil

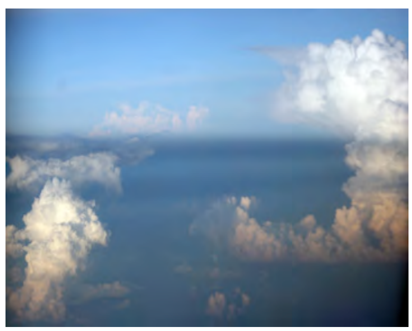
You don't need a cumulonimbus cloud to see this flattening. Even cumulus or small towering cumulus clouds may reach an inversion layer and spread out horizontally.

Layers of high-based stratocumulus clouds in Australia. Although the clouds are somewhat puffy, the layering (linked to an inversion) is more dramatic. Photo by H. Michael Mogil

Smoke or cloud plumes from factories, forest fires, or even the stacks of cruise ships will often reach an inversion layer.

The phenomenon of increasing wind with increasing height (known as ***wind shear*** *and shown by arrows) controls the path of this man-made cloud. Once the cloud reaches the inversion layer, it spreads out horizontally.* Photo by H. Michael Mogil

Haze layers, which show pollutants, dust, and/or ground-level ozone, are often evident from the window of an airplane.



A thick haze layer from 30,000 feet. Although some thunderstorms have punctured the layer, many weaker cumulus clouds are trapped beneath it. Photo by H. Michael Mogil

CONCLUSION

Inversions are an integral part of the troposphere and are the mainstay of the stratosphere. To understand our weather, it is important to understand these upside-down temperature profiles. You now have three tools to do this:

- visually
- radiosondes
- satellite-derived soundings.

Weather balloons help ACRF collect essential atmospheric data, which are then evaluated and made available to scientists, educators, and others.

Why are radiosonde balloons white or light colored?

The balloons are weighed before launch to ensure a pre-determined rate of rise. Dark-colored balloons absorb sunlight and become more buoyant, affecting the rate of rise and data collected.

DEFINITIONS

convection: up and down motion of air.

radiation: transfer of energy via electromagnetic waves.

stable: condition of a fluid in which vertical motions are limited.

stratosphere: stratified atmospheric layer lying just above the troposphere.

tropopause: separation region between the troposphere and stratosphere.

troposphere: atmospheric layer closest to the Earth.

wind shear: increasing wind with increasing height.

For more information:

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More About Inversions

Background

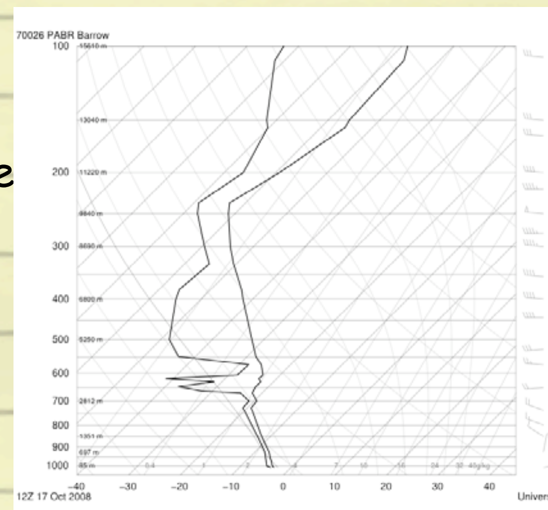
Inversions occur in fluids when a more dense fluid lies beneath a less dense fluid. In the atmosphere, the density is linked to temperature variations with warmer air lying atop colder air.

Sounding Analysis - Inversions (Activity)

Objective
To evaluate radiosonde soundings for inversions.

Materials
- ❑ Soundings for the same date and synoptic time (provided or obtained online)

Important Points to Understand
The soundings here appear on a Stuve diagram. Because the temperature scale (degrees Celsius) runs horizontally (increasing from left to right) and has vertical lines, it is easy to see temperature inversions. The Skew-T diagram has slanted temperature lines and should not be used for this activity.



Sounding data for Barrow, Alaska. Use the following link to see other data. http://weather.uwyo.edu/upperair/sounding.html

The vertical scale is atmospheric pressure (millibars*) that decreases with increasing altitude (shown along the left margin in meters). The right-most plotted line is temperature; the left-most plot is dew point temperature.

Procedure
1. Print out the radiosonde soundings.
2. Examine the soundings and find inversions.
List the inversions, noting the pressure value at the bottom and top of the inversion.
3. Compare the inversions found for the three locations.

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*average global sea level pressure is 1013.25 millibars or 29.92" of mercury

Questions

Where is the tropopause highest, i.e., at lowest pressure?
NOTE: If no tropopause inversion is evident, then the tropopause is located at a pressure less than 100 millibars.
2. Which location has the most intense inversion near the ground? Why do you think this is so?
3. Which site has the thickest inversion?
4. Which location has the greatest temperature change through the inversion layer?

Extension Activity

1. If you have Internet access, repeat the activity using soundings for a week or so. Are findings repeated or different?
2. Compare soundings for the three locations (or other similar locations) for a date in each of the 4 classical astronomical seasons. You can select dates at random or use a specific date.

Observing Inversions (Activity)

Objective

To look for inversions in the atmosphere.

Materials

- ❑ camera
- ❑ drawing paper
- ❑ crayons, pens, pencils and/or paint

Important Points to Understand

Clouds, smoke, and other things in the sky tell us about inversions.

Procedure

1. Observe the sky at a specific time each day or when you can.
2. If you see layered clouds, thunderstorm clouds with flat tops, smoke or pollution layers, or anything that indicates an inversion, document your findings. Cameras provide the easiest approach but drawing or sketching the scene works too.
3. Post pictures with date and time and discuss as a class.
4. If you can't do steps 1 to 3, use the images provided with this CEU to discuss visual clues to inversions.

Questions

1. Was the inversion layer easy to see?
2. Did it last for a while or did it break apart quickly?
3. How often do you see similar inversions?