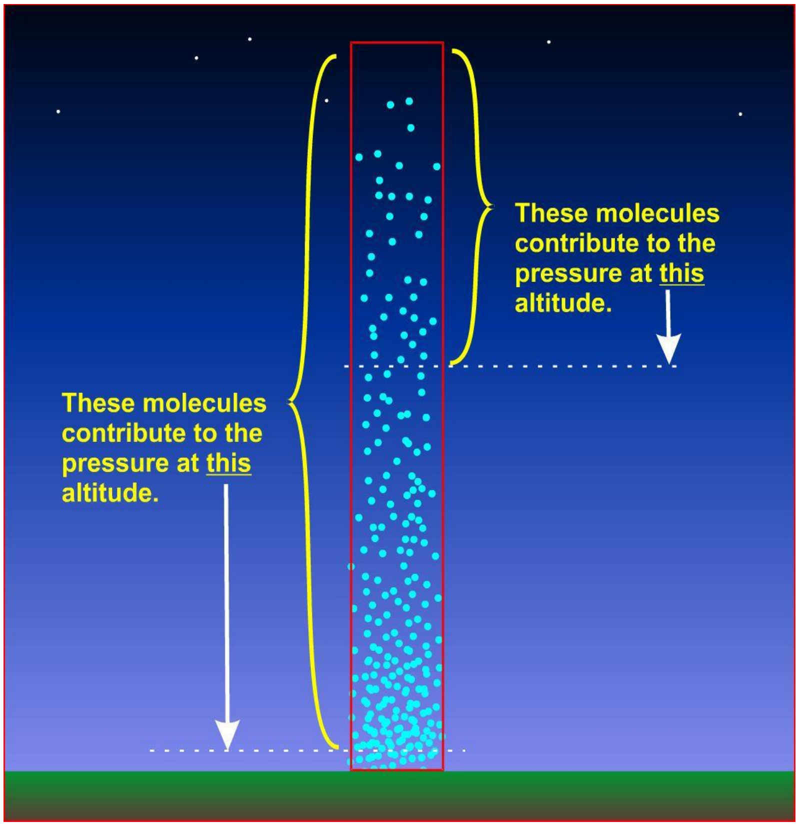
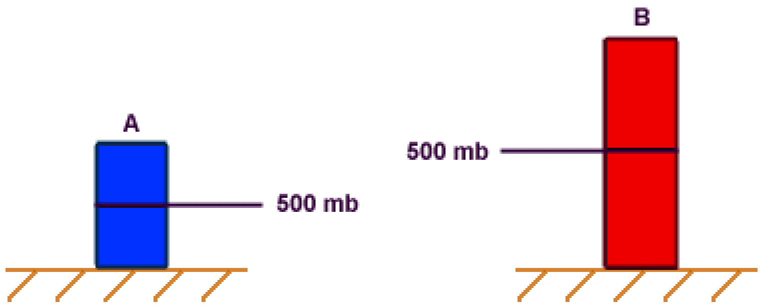
## V. SEA and LAND BREEZES:

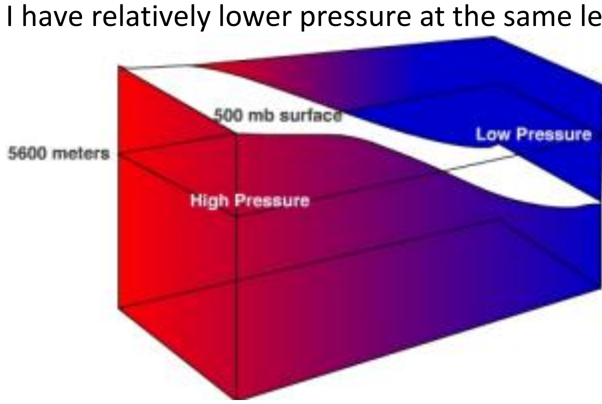
A. Pressure largely reflects the weight of overlying air, owing to gravity, and is proportional to mass. Therefore pressure decreases with height.




1. Remember, surface pressure is approximately 1000 millibars, and 50% of the mass resides between the levels where the pressure is 1000 and the pressure is 500 millibars.
   a. Picture a vertical cross-section.
   b. Also visualize 2 isobars, ("iso" meaning equal and "bar" from the barometer).
   c. Here are the 1000 and 500-millibar isobars, and we know that half of the atmospheric mass is in between. The 500-millibar level is only 5.5 kilometers, or 3.5 miles, above our heads, on average, so that the 1000 to 500-millibar layer is only 5.5 kilometers, or 3.5 miles, thick. (Note: We have a layer of air, the 1000 to 500-millibar layer. It contains a certain amount of mass).
   d. What if I warm up that air? It wants to expand, right? We've now realized that the temperature affects thickness.
   e. When it's relatively warmer, the 1000 and 500-millibar isobars are farther apart. The 1000 to 500-millibar layer is thicker.
   f. By the same token, when the temperature is relatively colder, the 1000 to 500-millibar thickness is thinner.
   g. This demonstrates that, although pressure decreases with height, pressure decreases with height faster in colder air.

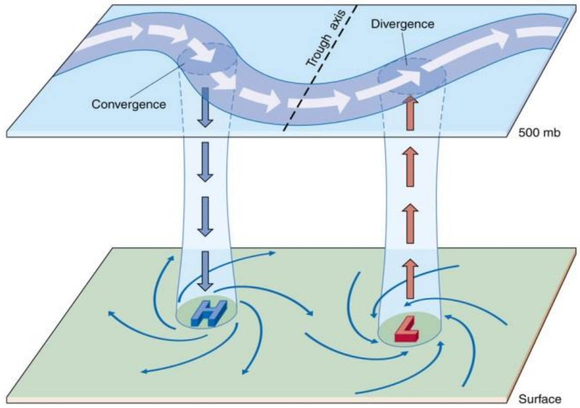



2. Let's start again with visualizing a cross-section of atmosphere with the same thickness everywhere. This implies the temperature is the same, but let's introduce a temperature difference. Let's make it warmer to the right.
   a. Now the 500-millibar isobar is relatively higher above the ground because the 1000-500-millibar thickness is thicker because the temperature is warmer.
   b. Do you see a horizontal pressure difference here?
   c. Let's pick a point along the 500-millibar level, and let's look towards the colder and the warmer air at the same height.
      i) If we look towards the colder air, we see that the 1000-millibar isobar is beneath us, and the 500-millbar isobar is beneath us as well.
      ii) But now let's look towards the warmer air. The 500-millibar level has risen and the 1000-millibar level is below me. The 500-millibar level is above me.
   d. So what I see from this is the pressure is higher than 500-millibars here.
      i) I have relatively higher pressure at the same level in the warmer column.
      ii) I have relatively lower pressure at the same level in the colder column.




   e. Now I have a pressure difference. Nature wants to move the mass from high to low pressure.
   f. Where does the blowing out of the warm column come from? It's rising up within the warm column, and air is diverging out of that column.
      i) Mass is leaving this relatively warmer column.
      ii) Since there's less mass in this column now, the surface pressure is dropping.
   g. Now, where has that air gone? The air is moving toward the colder column.
      i) It's converging into the colder column, adding mass to that column, and that causes the surface pressure there to rise.

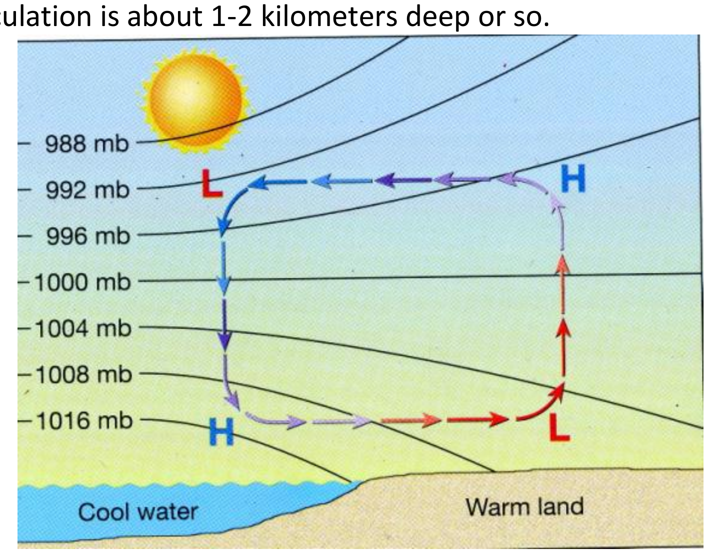
h. So now the 1000-millibar isobar is tilted as well, and we have relatively higher pressure where it's colder near the surface, and relatively lower pressure where it's warmer near the surface, and we've made a circulation.



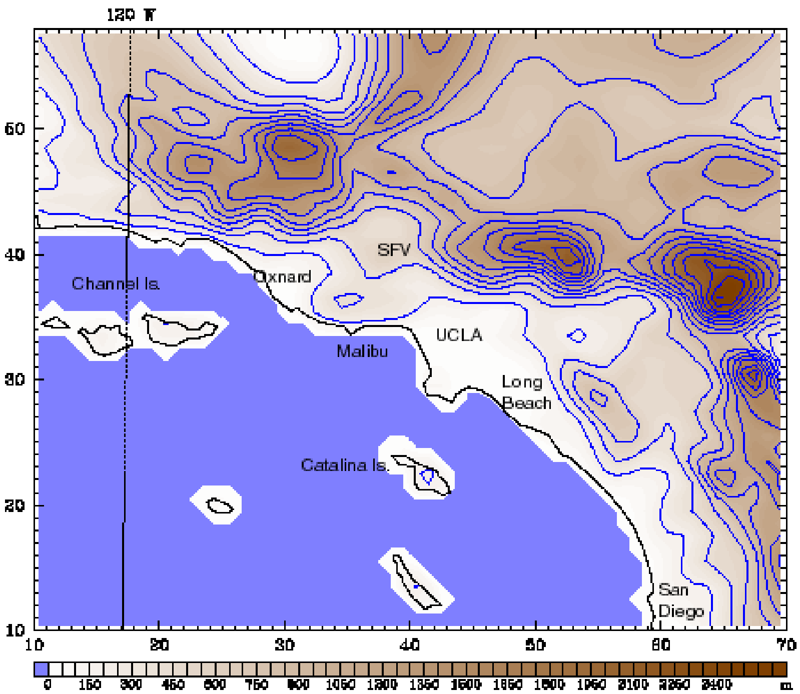

i. Note that, at least at the surface, the wind is blowing form the colder to the warmer place.

B. The Sea Breeze.

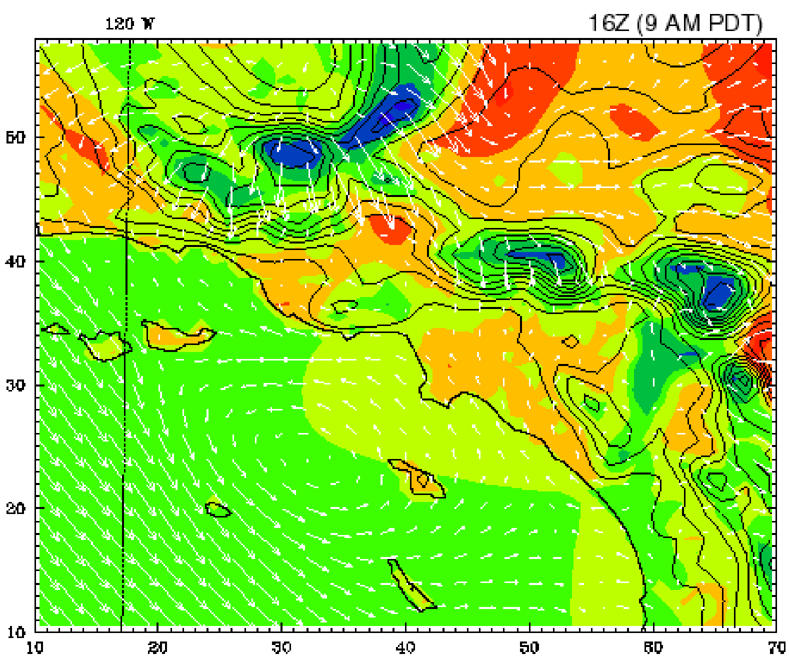
1. We start with the Ocean and Land. Which surface absorbs more solar radiation during the day? The Ocean does.
   a) The ocean absorbs more solar radiation during the day because it's darker. The relatively light color of the sand actually reflects away a fairly large fraction of the sunlight.
   b) Why isn't the ocean hotter than the land, since it is absorbing more solar radiation.
      i) Ocean water has an internal circulation. It's moving the warmed water around. With the sand, the very top is heated.
      ii) Liquid water has a huge thermal inertia. It resists temperature change, up or down.
2. The Sea Breeze circulation:
   a) We have warm air rising over the heated land, cool air sinking over the cooler ocean.
   b) The surface sea breeze is blowing inland from the cooler sea to the warmer land.
   c) The entire circulation is about 1-2 kilometers deep or so.



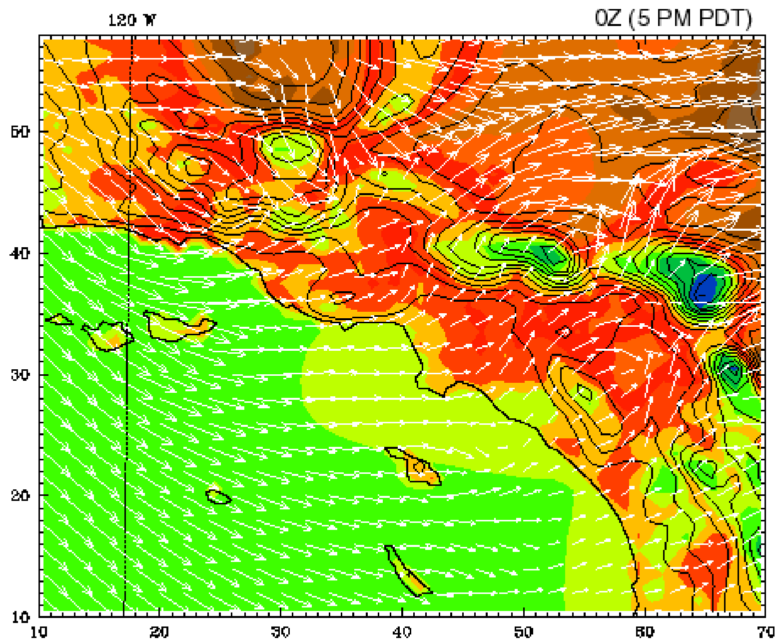
3. A typical sea breeze case is Los Angeles, California.
   a) Below is a topographic map, where brown indicates relatively higher elevation.




   b) Note 2 places on the above map, where you see L.A. Campuses between the ocean and downtown, a few miles from the coast, and the San Fernando Valley, SFV, which is tucked around and behind the Santa Monica Mountains.

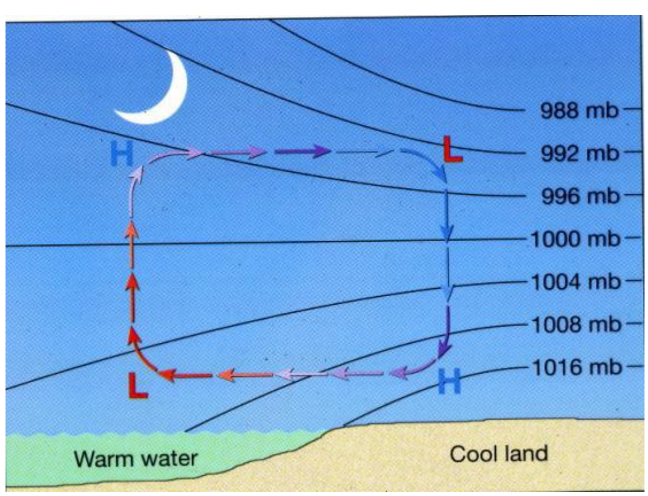



   c) The colored field is surface temperature. Green colors indicate cool temperatures, and when we see red, they'll be very hot. I'm also showing the surface winds. This plot above is for 9 A.M. Pacific Daylight time. At this time, it's cool everywhere, and we see the winds are pretty weak.




d) By 5 P.M. the next day in Los Angeles, the land has warmed up a lot. There's been relatively little temperature rise over the sea, a consequence of seawater's very large thermal inertia. The winds have started blowing from sea to land.
   i) The lengths of these wind vectors indicate the wind speed, and you can see how the winds are much stronger. They're headed inland.
   ii) It's very hot inland, particularly in the SFV. Meanwhile, at UCLA, we're a lot cooler because the sea air is helping to keep it cool.
   iii) Notice that it is still hot at SFV in the morning because the sea breeze reaches there last, and is the weakest by the time it gets there.

C. If at night the land surface becomes colder, we will develop a **land breeze**. The circulation will reverse.
   1) The land breeze blows from land to sea, just as the sea breeze blew from sea to land.



2) Temperature differences make pressure differences, and pressure differences drive winds. We have warm air rising over the relatively warmer place, and sinking over the relatively cooler place.
3) We call this “thermally direct”, the better, more natural way for circulation to develop in response to temperature difference.

D. How do these breezes decrease or increase temperature differences?
   1) Wind chill is accelerated heat exchange, owing to wind.
      a) The wind chill effect depends on air being a poor conductor and a good insulator.
      b) In the case of the sea breeze, the cool sea air helps hasten the heat loss form the hot land as it blow across.
   2) Mixing of land and sea air will moderate the temperatures of both, and reducing the temperature difference from land to sea.
   3) Recall that air is very compressible and that compressed air gets warmer. Also recall, that pressure decreases upwards, and increases downwards.
      a) If I take air and force it to descend, it is encountering higher pressure. This is mechanically compressing the air. As a result, descending air warms.
      b) Descending air warms at a very rapid rate, 10°C per kilometer, almost 30°F per mile.
      c) This is temperature change due to volume change alone. There has been no heat transfer.
      d) We call this the “dry adiabatic” process. This is temperature change without addition or removal of heat.
      e) This reflects air’s compressibility and 3 things:
         i) You can change the temperature of air by changing it’s volume.
         ii) You can change volume by changing pressure.
         iii) You can change pressure by changing altitude because pressure varies with height.
      f) Just as descending air warms because increasing pressure causes it’s volume to contract, so too does ascending air cool at the same rapid dry adiabatic rate of 30°F per mile, 10°C per kilometer.
      g) In the absence of a heat source or sink, rising air cools and sinking air warms up.
      h) Therefore, air sinking over the sea is warmed by compression. The rising air over the warm land is cooled by expansion.
      i) This is why we call the circulation “thermally direct”.
      j) Vertical air motions are contributing to reducing the temperature differences.
   4) The sea breeze and land breeze are both cool winds, but the winds don’t always stay cool.

E. The Katabatic wind
   1) The Santa Ana winds are hot, dry winds that blow from the desert, but they blow when the desert is cool, so how do they get hot?
      a) Most Santa Ana events start with cold, dense air, spilling down across the Great Basin of Nevada and Utah. This cold air is trapped on the west by the Sierra Nevada Mountains, which are a tall and formidable obstacle.

b) The southward progress towards Los Angeles is partially stopped by a ring of mountains surrounding the Los Angeles basin.
c) Some is sneaking through the passes and canyons, making the winds fast.
d) The situation is a lot of the air is actually a passing over the mountain, and then diving down into the L.A. basin. The air has gone downslope. It has experienced compression and it has warmed 30°F per mile of descent, 10°C per kilometer.
e) So Santa Ana winds start off cool, but then it gets hot while flowing down-hill.
f) This type of wind is called the "katabatic wind".
g) It flows down, owing to its initially larger density, initially greater weight.

F. Summary:
1) Temperature differences make pressure differences, and pressure differences drive winds.
2) The driving force, pressure, is gravity force per unit area, reflecting the fact that air has weight.
3) Air pressure decreases with height because there's less air to push down as we ascend. Pressure increases downward towards the ground for the same reason. There's more air above us, pressing down.
4) The not-fully-realized goal of winds is to remove the temperature imbalances that created the pressure differences to begin with.
a) Where unequal heating led to a circulation, the sea breeze, owing to the relationship between temperature and pressure.
b) Layers of air became thicker upon being heated. This created horizontal pressure differences that started the air in motion.
c) The sea breeze and it's nighttime counterpart, the land breeze, are examples of where the surface winds blow from cold towards warm, but it's part of a circulation where, in other places the winds are blowing in the opposite direction.
d) In some places, air is rising, and in other places, air is sinking.
e) But even winds that start out cold may not stay that way because air is very compressible.
f) Forcing air to descend makes its temperature rise, since the air pressure pushing on the air is increased.
g) This is why the Santa Ana winds can be so hot after they are impelled downslope. Those are hot dry winds that blow from the desert, but they do so when the desert is cold.

G. Questions:

1) What is the definition of the atmospheric pressure?

2) What is the surface pressure in millibars?
3) What is the pressure when only 50% of the atmosphere is above you?
4) Is the layer of air between 2 isobars thicker or thinner when the temperature is colder? Explain.

5) At a particular elevation in the atmosphere, is the pressure higher or lower in a colder region? Explain.

6) Does air within a relatively warm region rise or fall? Explain

7) Does air within a relatively warm region diverge or converge? Explain

8) Does the mass greater in a warmer or colder region? Explain.

9) Make a sketch of a Lake Breeze circulation in Layton, Utah. (Indicate the time of day)

10) Make a sketch of a Land Breeze circulation in Layton, Utah and the Great Salt Lake.

11) We’ve always heard that heat flows form warm to cold, but we’ve experienced cold winds as well, so is that statement, in fact, always true? Explain

12) Which would better eliminate temperature differences if you could only accomplish one, to blow warm air to the cold place, or to blow cold air to the warm place? Explain.

13) Is the dry adiabatic lapse rate also 10°C per kilometer (30°F per mile on Venus, Mars, or Jupiter?  Why or why not?

14) How would the Santa Ana winds be different if you flattened the topography of the western United States? Explain.