MAGIC

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A newsletter for non-scientists (and scientists) interested in MAGIC

One of the core atmospheric measurements, along with temperature, is pressure. We all remember from grade school that atmospheric pressure is 14.7 pounds per square inch (psi), and we fill our automobile tires to 32 psi, but what really is pressure (and why do we care)? The units, pounds per square inch, provide some clue as to what pressure is. A pound is a weight, which is really a force (our weight is the force with which gravity is pulling on us), and a square inch is a unit of area. Thus, pressure is a force per unit area. But what causes this force?

Pressure is actually nothing more than the weight of the air above us. Although we generally don't notice it in our everyday lives, air has weight. One cubic foot of air weighs a bit over an ounce, and the weight of air in a normal size room is about 100 lbs. Thus an inflated tire on your car weighs more than an uninflated one (although not by much). A given volume of air will weigh about 1/800 as the same volume of water (i.e., the density of air is about 1/800 of the density of water). Although air doesn't weight much, because there is a large amount of air above us, its weight adds up. The total weight of air in a column above an area one inch by one inch is about 14.7 pounds (at sea level). This weight decreases as elevation increases, as there is less air above. This is why the air pressure in Denver, the "mile-high city," is about 80% of the air pressure at sea level: only about 80% of the atmosphere is more than a mile high. Conversely, only about 20% of the atmosphere is in the lowest mile.

There are a variety of units in which pressure can be given, and a number of these are still in use in different fields. This can become quite confusing. Years ago, to deal with this situation, I wrote a program that converts the value of pressure in any one set of units to the pressure in any of eight other units. The actual definition of one atmosphere (1 atm) of pressure was set by an international committee in 1927 as 101,325 Pascals (exactly). A Pascal, named after the French mathematician and philosopher Blaise Pascal (1623-1662), is the unit of pressure in the so-called metric system (the official name is the SI system). As an aside, the U.S. is the only industrialized nation (and possibly the only nation) in the world that doesn't use this system as its official system of measurement. Until recently, Burma and Liberia also fell into this category, although it has been reported that these countries have recently or will soon adopt the SI system. I'll let you draw your own conclusions on this.

To given an example of the different pressure units that are still commonly used, the value of one atmosphere of pressure is given below in a variety of different units (I won't go into what all of these mean, but you see how moving from one unit to another can be a bit confusing):

1 atm	101,325 Pa	101.325 kPa
1.01325 bar	1013.25 mbar	760 torr
14.69595 psi	29.9213 in Hg	1,013,250 dynes per cm^2

Several of these are exact, and some are approximate and depend on choices such as the value of the acceleration due to gravity, the density of water and/or mercury, and thus the temperature. As the need for higher accuracy becomes more important, smaller and smaller effects have to be taken into account. For instance, formerly pressure was measured by the height of a column of mercury, but the density of mercury varies (although very slightly) with temperature, and the mercury at the bottom of a column gets compressed by the weight of the mercury above, and so forth.

Air pressure is easily measured, and accurate sensors are readily and cheaply available. I was in a lab once and my friend Rick said "Watch this" and moved an air pressure sensor from his waist to his head, about three feet. The pressure display changed; not a lot, but noticeably. I thought the sensor was broken and that was why he was showing me, but the effect was very repeatable. He explained what was occurring, and I did a calculation to confirm it: by moving the sensor up and down and taking the difference in the pressure reading, he was essentially weighing the amount of air in the column between his waist and head. The difference in pressure in a distance of three vertical feet is approximately 0.01% of the total atmospheric pressure, or, in other words, the weight of a column of air three feet high is 0.01% of the weight of all the air in the column from the ground on up, a small but measureable amount.

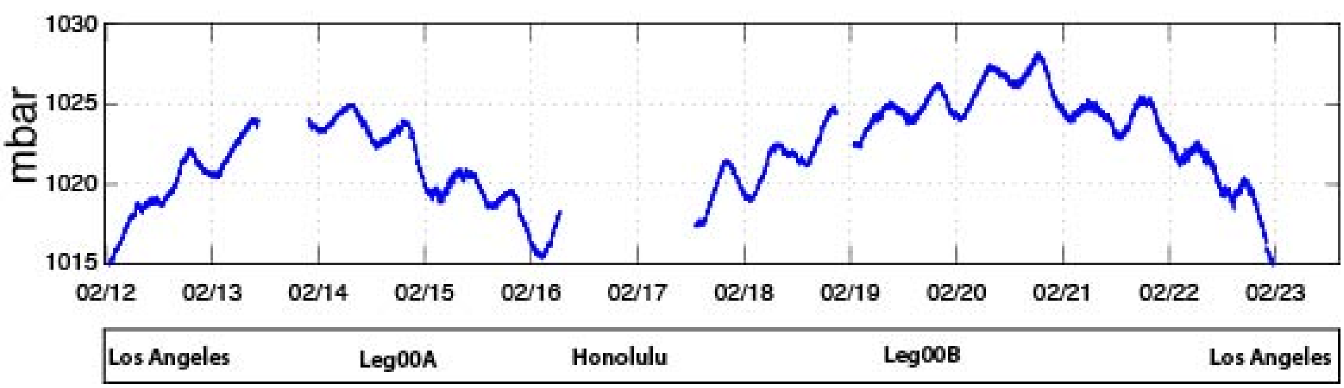
I almost wrote "from the ground to the top of the atmosphere," but there really isn't any "top" to the atmosphere; the air just gets less dense as the elevation increases, as there is less weight above to compress the air (we know air is compressible, as we can continue to put air in a tire or a basketball, neither of which increases in volume; the more air we put in, the greater the pressure). Although there isn't a true "height" of the atmosphere, we can talk about some "effective height," which is the height the atmosphere would be if we stacked up all the air, and it didn't get less dense with increasing elevation but rather remained the same density as near the surface. This effective height is about 5 miles (by contrast, the average depth of the oceans is about half of this value). This is consistent with what I said above, as three feet (the height the pressure sensor moved) is about 0.01% of five miles.

Anyone who has been scuba diving knows that the pressure increases by one atmosphere for every 33 feet in depth that one dives. In other words, the weight of a column of water 33 feet high is the same as the weight of the atmosphere in the column above it. In contrast, the amount of heat it takes to raise the entire atmosphere one degree is the same as that it takes to raise the top 8 feet of water one degree! Remember, the average depth of the oceans is 2.5 miles. This means that the ability of oceans to store heat and regulate Earth's climate is **immense** compared to that of the atmosphere, and hence that it is important to study the oceans and to have accurate measurements of the ocean temperature. There are two instruments in the MAGIC suite that measure sea surface temperature: an infrared thermometer (IRT) and an Infrared Sea Surface Temperature Autonomous Radiometer (ISAR). Both of these work by measuring the infrared radiation (i.e., light with wavelengths longer than our eyes can see) that is emitted from the sea surface, in the same way that your doctor takes your temperature by pointing the thermometer at you and reading your temperature from a distance (although we use rather more sophisticated instruments).


Mike Reynolds with ISAR in Port of Los Angeles

A common unit of air pressure is the height of a column of mercury that weighs the same as the atmosphere in the column above it (which is the same as the weight of a column of water 33 feet high). Mercury is that shiny metal that's a liquid at room temperature, and used to be in all thermometers, although most thermometers now are either electronic or contain alcohol that is dyed red, as it is less toxic than mercury. The felt used in hats used to be treated with mercury, and after a career of making hats, many hatters were afflicted by chronic mercury poisoning and suffered neurological damage, which gave rise to the term "mad hatter." Mercury is about thirteen times as dense as water (i.e., a given volume of mercury weighs thirteen times as much as the same volume of water), thus standard atmospheric pressure is 1/13 of 33 feet, or about 30 inches of mercury–this is the number that they give on the weather report.

The reason pressure is important is that differences in pressure cause winds. A pressure difference means that there is a force on part of the atmosphere, and this causes the air to move. Exactly how the air moves with respect to a pressure difference is a bit complicated, as wind doesn't blow directly from high pressure to low pressure as one might think. The explanation of why not involves the Coriolis effect and the rotation of the Earth, and is a bit involved (try walking in a straight line on a rotating merry-go-round). Differences in air pressure are generally rather small, and the pressure at a given location typically doesn't vary by more than a few percent. Even during a hurricane the pressure isn't much different from normal: the lowest pressure measured during Hurricane Sandy last fall was only 8% lower than one atmosphere. The graph below of pressure during Leg00 of MAGIC in February, 2012 shows that over a nearly two-week period the pressure ranged between 1015 to 1030 mbar (mbar, or milli bar [1/1000 of a bar], is a unit of pressure); this range is only 1.5% of the average value.



Besides changes in the pressure that occur over several days, smaller variations can be seen that occur twice per day. The amplitudes of these are roughly 0.2% of the total–a very small amount. These smaller variations are atmospheric tides, which are similar to oceanic tides except that they are caused by solar heating; thus they occur on a solar cycle, roughly every twelve hours, instead of on a lunar cycle, which would be once every thirteen hours.

The next update will discuss atmospheric structure and the layers of the atmosphere.

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Please address any questions or comments to elewis@bnl.gov.
All updates and other MAGIC information can be found at http://www.bnl.gov/envsci/ARM/MAGIC/.