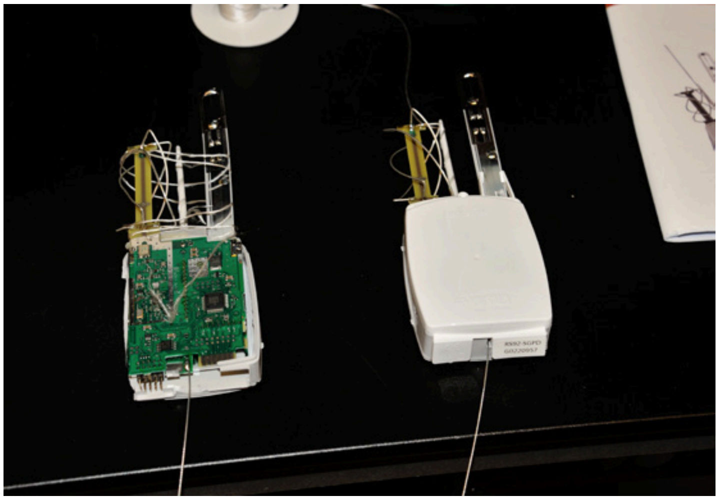
MAGIC

2013-04-24

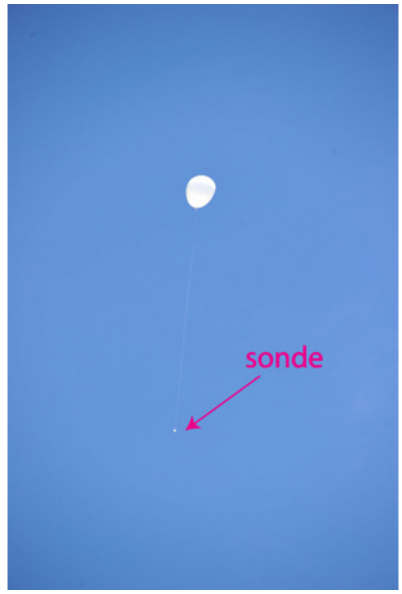
A newsletter for non-scientists (and scientists) interested in MAGIC

I received several comments on the last update. One person wrote that the pressure I stated for automobile tires, 32 psi, was too low and suggested that 44 psi would be a better estimate. However, 32 psi is what is written on the door of my car. It turns out that recommended tire pressures for his jeep are much higher than those for my Honda. I hadn't realized that these recommendations varied so much. Another person took me to task, and rightly so, for stating that "pressure is actually nothing more than the weight of the air above us," which it is not. In most circumstances the value of the pressure is approximately *equal* to the weight of the air in a column above, divided by the area of that column. However, pressure is not weight but a different thing entirely. The pressure of a gas (such as air) is the force that the gas exerts on an area, divided by that area, and it exerts this same force in all directions. The weight of the air in a column above a given area is the gravitational force of Earth on that air, and this force is downward. These forces may generally balance, but the concepts of pressure and weight are entirely different ones. As always I appreciate the comments and want to make sure that I don't disperse any information that is not correct. Fortunately, readers of the updates help me in this regard.

This update is about radiosondes (or just "sondes") and how the data obtained from them provides information on atmospheric structure. I've discussed sonde launches several times previously, and I am still amazed at how well the techs manage to get successful balloon launches under challenging conditions. A sonde is a small unit that contains sensors that measure temperature, pressure, and relative humidity. It also has a sensor to receive signals from GPS satellites and a small transmitter. The sonde is attached with a string to a weather balloon that is filled with helium. During ascent the sonde measures the above quantities and transmits the information back to a receiver on the ship. From the GPS signal, we can determine the sonde's location and how far it moved in a given time, and thus obtain horizontal wind speed and direction. The pressure, temperature, and relative humidity allow us to calculate the elevation, and thus we can determine the temperature and relative humidity at each elevation. This information allows us to determine the amount of water vapor in the column of air above us, for instance, and atmospheric properties such as stability and CAPE, which was discussed in the 2013-03-28 update. There are around 200 sonde launches every day in the US (and well over 1000 around the world), and the data they provide are extremely valuable for weather forecasts.

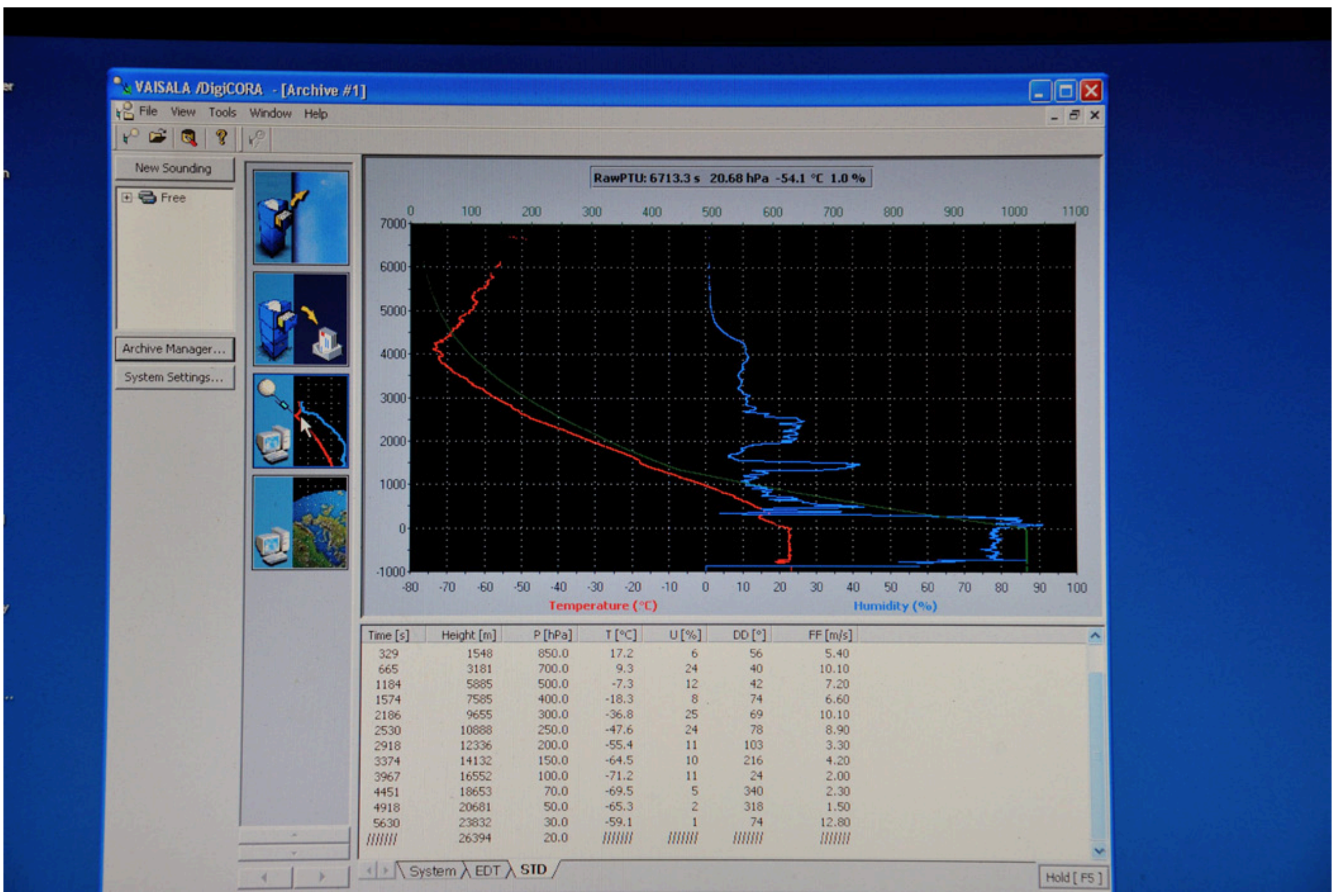


Radiosondes: the one on left shows what they look like after hitting a container; the one on right is still functional.



This is what we like to see!. The sonde is barely visible below the balloon.

The picture below was taken of the computer screen displaying the data from one of the sonde launches during Leg03 of MAGIC. The left axis is the time (in seconds) after launching, and the bottom axis is the temperature for the red curve, and relative humidity for the blue curve.



Starting at the bottom of the red curve, notice that there is initially a slight jump to the right (i.e., an increase in temperature). This probably occurred when the sonde was moved from inside the air-conditioned container (where we logged it into the computer) to outside on deck, near where we were filling the balloon. The curve is then a straight vertical line for a bit, which means that the temperature remained constant. This makes sense, as the sonde remained stationary as we were filling the balloon. Zero on the left axis denotes when the balloon was launched, and the sonde then increased in height at a nearly constant rate. The red curve moves to the left, meaning that temperature was decreasing. There is a slight irregularity when the blue curve intersects this, which corresponds to the balloon leaving the marine boundary layer and entering the free troposphere; these are levels of the atmosphere that will be discussed in a future update. As time continues (i.e., we move farther up the graph), the red curve continues to move to the left (meaning the temperature was decreasing) until about 4000 seconds (a bit over an hour) when the temperature reached -75°C (about -100°F). The balloon had already reached the height at which aircraft fly at around 2500 seconds (about 40 minutes), when the temperature was near -50° C (near -60°F).

Although in the U.S. temperature is commonly reported in degrees Farenheit (°F), scientists, and most other countries in the world (including even England and other countries that still use miles, feet, and inches) report temperature in degrees Celcius (°C), formerly knows as degrees Centigrade. The Farenheit temperature scale was named after Daniel Farenheit, a German-Polish physicist, who invented this temperature scale in the early 1700s. He also invented the mercury thermometer. The Celcius temperature scale was named after Anders Celcius, a Swedish astronomer, who invented what he called the centigrade temperature scale, also in the 1700s. On his original scale, the freezing point of water was 100° and the boiling point at 0°; this has since been reversed so that on the Celcius temperature scale water freezes near 0°C and boils near 100°C (these values aren't exact and depend ever so slightly on pressure and other factors). Most of us are familiar with the formulae to convert between the Farenheit and Celcius temperature scales: $F = \frac{9}{5}C + 32$ and $C = \frac{5}{9}(F - 32)$, where F is the temperature in degrees Farenheit and C is the temperature in degrees Celcius. The value -40° is the same on both scales.

Continuing with the red curve on the graph, after attaining its leftmost value (i.e., when the temperature was a minimum), it reverses and moves to the right, meaning that the temperature was increasing. This seems puzzling–as the balloon rose higher in the atmosphere, it was recording higher temperatures, meaning the air was getting warmer (relatively speaking, of course, as the temperature was still far below zero). This trend continued until about 6000 seconds (one hour and forty minutes) until the temperature reached -55°C (-67°F) when the red curve ends.

What explains these behaviors–the increase in temperature and the curve ending? The latter phenomenon is easily explained: the red curve ends because the balloon popped. The computer is programmed to stop recording data when the pressure increases, which means that the elevation is decreasing; i.e., the balloon is falling back to the surface. This launch ended when the balloon reached a height of around 25,000 meters, or nearly 16 miles. The air pressure at that elevation was only about 2% of that at the surface. Because the helium inside the balloon continued to exert pressure, it became very large. It also became stretched very thin and eventually popped, the same thing that happens when you blow up a balloon too much. I have been told that when they pop the balloons are about 30 feet in diameter. Why did the red curve turn around and go back to the right? What we really want to ask is: Why does the temperature increase with height above a certain level? This behavior indicates that the sonde entered the stratosphere, which is the region of the atmosphere above the troposphere. One of its properties is that temperature increases with height. More on the stratosphere in a later update.

In February of last year I was on Leg00 and in the middle of the Pacific over Valentine's Day. At that time we were trying to see if we could even successfully launch balloons, so for payload we wanted something that was comparable in weight to a sonde but was cheap and biodegradable. We decided on potatoes and other vegetables (which I think was rather creative). I emailed my wife and said that she should feel special, because she was probably the only woman in the world who received a Valentine's Day greeting from someone who had launched a potato into the stratosphere. She wasn't impressed.

Acorn squash with rolled-up balloon.

Mike Reynolds with parsnip.

I thought this was a pretty good story, and I told it to Donna, who is in charge of the sonde systems for ARM, when I met her at Argonne National Laboratory near Chicago last summer. She said she had a better one than that, and I have to agree (Donna was worried that people might think she was odd, and I said, "Of COURSE people are going to think you're odd, but I happen to think odd is good!" She said I could use the story anyway – thanks Donna!). One of her undergraduate professors, who was a meteorologist, had recently passed away and was cremated. Because of his profession his family wanted his ashes to be launched in a weather balloon, with Donna and two other of his favorite students chosen to perform the ceremonies. I must say, launching a professor trumps launching a potato any day. I just can't imagine the pressure (no pun intended) of filling and launching the balloon with the family looking on, hoping it doesn't burst on the ground or blow into a tree or something. The launch occurred successfully last fall.

The next update will follow the blue curve and will discuss layers of the atmosphere.

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2013-04-24
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/.