MAGIC

2013-02-19

The Horizon *Spirit* is on its way to China for its previously scheduled maintenance and the AMF2, which is the suite of instruments used on MAGIC, is currently sitting in a warehouse in Los Angeles, but rest assured that much MAGIC activity is still occurring. The techs are at the warehouse this week tuning up instruments, calibrating, performing maintenance, etc. There is a conference in mid-March for the Atmospheric Science Research Program of the U.S. Department of Energy, which funds scientists that use MAGIC data to better understand clouds, aerosols, precipitation, etc. – and ultimately climate, and I am lining up speakers to present some early results from the data collected during the first few months of MAGIC. Several investigators have expressed interest in providing additional instruments that can be installed when MAGIC resumes operations around May 1, and we have been discussing measurement needs and writing proposals for these.

I was talking with a friend the other day, a former physics instructor, and he said "I like the updates, but I want some *science*. I want to see something about latent heat!" I thought about this for a while and came up with the topic for this update (thanks Drew!): energy fluxes. In a previous update I stated that many of the MAGIC measurements revolved around water, but the main topic of interest for climate is ultimately energy: how much energy is coming *toward* Earth, and how much energy is going *away* from Earth. These quantities are known as fluxes. Although there are various scientific definitions of "flux," we can think of a flux as a continuous transfer, or flow, of something; for instance, when it is raining there is a flux of water to Earth's surface.

Energy comes in several forms, and one of the basic principles of physics is that energy is neither created nor destroyed, but merely transformed from one form to another. By far the largest source of energy we have on Earth is that from the sun, which is in the form of infrared, visible, and ultraviolet light. These are collectively referred to as shortwave, or SW, radiation (recall that the word "radiation" in this sense does NOT refer to radioactivity). Clouds scatter some of this radiation back to space, they absorb some of it (converting it to heat energy), and they scatter the rest downward to Earth's surface. The surface scatters some of this energy back to space (we know this because we have seen photographs of Earth that are taken by satellites and during space missions), it absorbs most of the rest, and a small amount is transferred to the underlying soil, or to the ocean layers below the surface. The absorbed energy is converted to heat energy, and from there the story gets interesting, especially if the surface is the ocean, as it is for MAGIC.

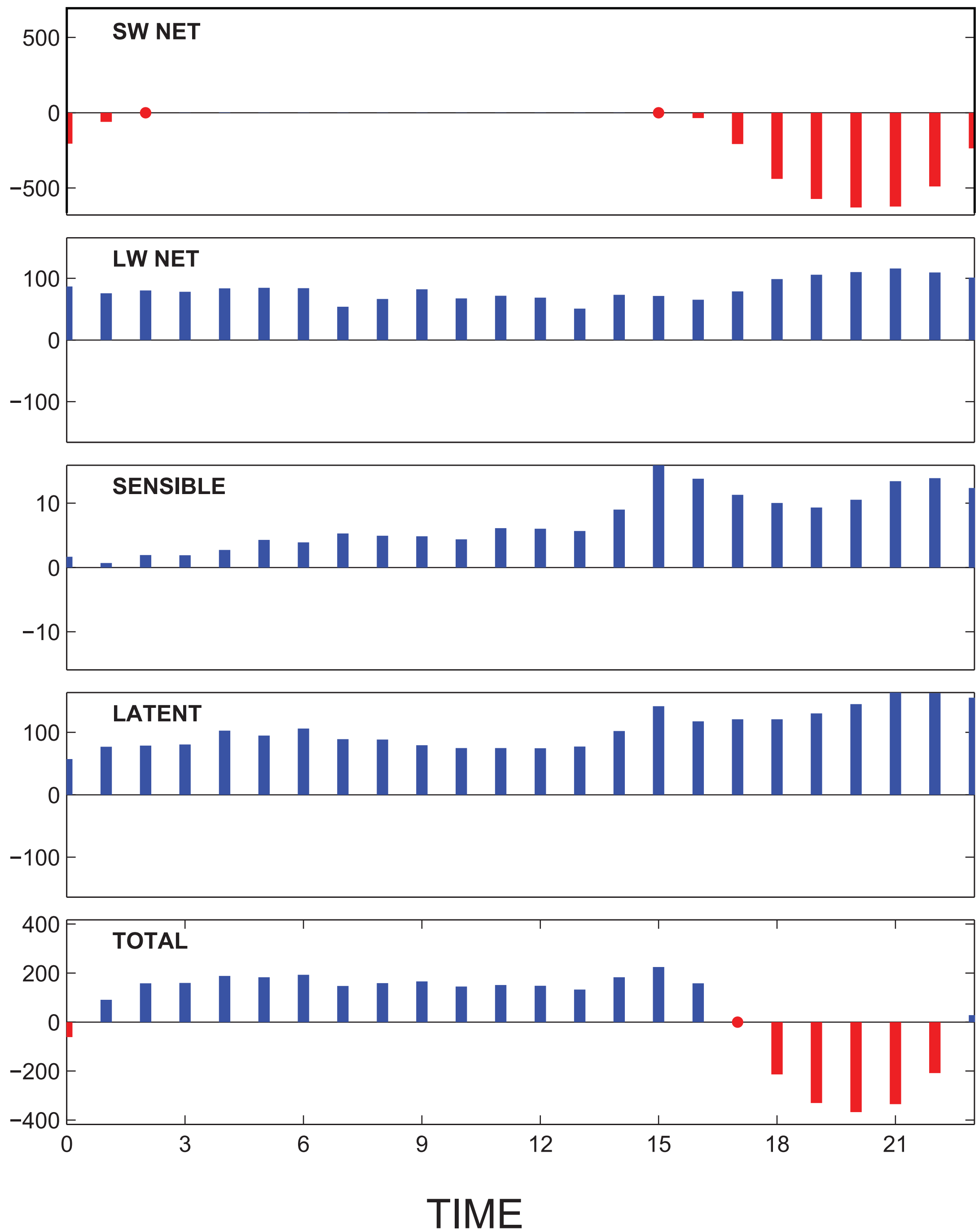
As the ocean can absorb much more heat than the atmosphere above (it takes roughly the same amount of energy to raise the upper one meter of the ocean by one degree as it does to raise the entire column of air above it by one degree!), the temperature of the atmospheric over the ocean closely follows, and is generally driven by, the ocean surface temperature. Some of the energy absorbed by the ocean surface, known as sensible heat, is transferred to the overlying atmosphere, and some of it, known as latent heat, goes into evaporating water.

There is one final energy flux that is important for our energy balance. Every substance radiates energy at wavelengths that depend on its temperature. As the sun is hot (about 6000 degrees Celcius), it radiates energy predominantly as SW radiation, as discussed above. Earth’s surface is much cooler than the sun, so the wavelengths at which it predominantly radiates are much longer, in the far-infrared. This energy, known as long-wave (LW) radiation, is what is radiated back to space from Earth. We all know that it is generally colder on a clear night than on a cloudy night when some of the LW radiation from Earth’s surface is absorbed and reradiated back downward by clouds.

Now that we have dealt with all the energy fluxes to Earth’s surface that are important (incoming SW, outgoing LW, sensible heat, and latent heat), we need to consider energy balance: is the incoming energy flux greater than, less than, or equal to the outgoing energy flux? In other words, is the net, or total, energy flux positive or negative? The answer, of course, depends on the time and on the time period over which we average. We expect a large incoming SW energy flux toward Earth’s surface during the day when the sun is shining. We expect the largest outgoing LW energy flux during that time as well, as it depends on the temperature, and the warmer surface during the day will result in a larger outgoing flux. We also expect larger outgoing fluxes of sensible and latent heat during the day when the sun is shining and the ocean surface temperature is greatest.

Among the various measurements made during MAGIC are radiation measurements, which determine the upward and downward SW and LW energy fluxes, and measurements of ocean and atmospheric temperature and of atmospheric wind speed and relative humidity, which determine the fluxes of sensible and latent heat. Once we have all of these, we add them up (we ARE scientists, and mathematics is the language of science, so naturally we need mathematics- addition and other more advanced topics) and see if there is a net flux toward, or away from, the ocean surface.

The graph below was made by Mike Reynolds (thanks Mike!), our radiation and flux specialist, whom I have mentioned before in these updates. The time period is November 19, 2012, from midnight to midnight UTC. "UTC" refers to Universal Time Coordinated (formerly known as GMT), and is the unique time base in which all measurements are recorded. November 19 was during Leg06A and the *Spirit* was approximately 1/3 the way from Los Angeles to Honolulu. At this location and date (i.e., after Daylight Savings Time ended), local time was approximately 9 hours behind UTC, so 00:00 UTC on Nov. 19 corresponds to 3 pm local on the previous day (Nov. 18).



This graph shows net fluxes of SW, LW, sensible heat, and latent heat, and the total flux. Negative values mean that the energy flux is *toward* the surface, and positive values mean that the energy flux is *away* from the surface. The bottom axis is the time (UTC) during the day, in hours. The left axes are the energy fluxes (the units, for you nerds who care, are watts per meter squared, or W m^{-2}, but I will leave these off for the following discussion). Note that the different graphs have different ranges on the left axes; the fluxes of sensible heat are considerably smaller than the other ones, for example.

Let's see if our expectations are correct. Look first at the SW flux. It is essentially zero from around 3 to around 16, which corresponds to 6 pm to 7 am local. This makes sense – the sun isn't shining during that time. For the remaining time, the values are negative, which means that energy is coming *toward* the surface (the sun IS shining during that time). The magnitude of this flux is larger than the others, also as expected, as SW is our dominant source of energy. Looking at the LW flux, we see that it is always positive. The ocean temperature is warmer than outer space, so this flux is *away* from the surface, as expected. There are some indications of a diurnal cycle, but this can be affected by cloud cover, and further investigation would involve looking at other data streams such as cloud coverage, etc. Sensible heat is rather small in magnitude (the scale is -10 to +10, as opposed to -500 to +500 for the SW net), but is always positive, meaning that the ocean warms the air above. There appears to be a diurnal cycle, with more heat transfer occurring during the daytime. The latent heat flux is always positive, meaning that evaporation is occurring at the ocean surface (rather than condensation of moisture occurring on the surface), as expected. Looking at the total, we see that it is positive during the night (there is a net energy flux *away* from the surface), and negative during the day (a net energy flux *toward* the surface), as expected. Which one wins overall?

When the numbers for the day are summed up, the average net fluxes are -146 for the SW, +82 for the LW, +7 for sensible heat, and +105 for latent heat, for an average net total of +46 (these don't add up because of a small correction that I didn't discuss). Thus, this day saw a net **loss** of energy from the ocean surface in the region that we measured. By doing this same calculation for each day, we can begin to study energy flow in a region of Earth's surface where it has been difficult to make measurements up to now, and thus obtain better understanding of Earth's climate.

Ernie Lewis
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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/.