MAGIC

2015-02-24 update

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

MAGIC was a field program funded and operated by the Atmospheric Radiation Measurement (ARM) Climate Research Facility of the U.S. Department of Energy. The ARM MAGIC webpage is http://www.arm.gov/sites/amf/mag. Information on MAGIC and all previous updates can be found at http://www.bnl.gov/envsci/ARM/MAGIC/.

In the last update I included a picture to illustrate how thin the atmosphere is. As the picture did not come through with the email on the copy I sent to my home email address, I sent an update to the update with a link to the picture. However, this also didn't work, as (unbeknownst to me) my computer made the period at the end of the sentence part of the link, rendering it invalid. The correct link to the picture is http://spaceflight.nasa.gov/gallery/images/station/crew-21/html/iss021e031766.html. Several people wrote that their update contained the picture, so perhaps it was just me and my email at home.

The point of me telling all this is that it provides a great illustration of how science should work. I make mistakes, and scientists make mistakes, but despite this it is necessary to continue to strive to get things correct. I receive quite a few comments on these updates, especially when I state something incorrectly, but I welcome them–I want to know when I did something wrong so I can correct it and notify everyone of my mistake. I am extremely fortunate that I work with a lot of people, both here at the lab at which I am employed, and elsewhere, who feel the same. A colleague recently asked me to read an article he is writing for that very reason–to receive comments from someone (me) who hadn’t been working on this topic and thus could read it with a fresh set of eyes. I made quite a few comments, and he welcomed them, as they would allow him to improve his article.

I have had several students, both high school and college level, who work under my supervision for a semester (I wrote about some of them in previous updates: Michelle in the 2013-07-02 update, Danielle in the 2013-08-15 update, Sarah in the 2014-02-18 update, and Anastasia in the 2014-03-18 update), and each of them received the same message from the first day: please let me know when I make a mistake. Notice the "when I make a mistake" rather than “if I make a mistake," because I know I will make them (and they quickly learn that too). I also told them that I hope that they make mistakes too, because the only way to ***not*** make any mistakes is to never try anything. Making mistakes is ok, as it means you're trying, but once a mistake is discovered, corrections should be made, models should be changed, and data should be re-evaluated in light of this new understanding. I try to explain to my students that I should know more than they do about atmospheric science, after all, I’ve been working at it for nearly 20 years, and have 20+ years of science experience before that. However, that doesn’t mean that I’m smarter than they are, just that I know more. I need every mind working, especially theirs. Thus I insist that they question and challenge me; this is important for their understanding as well as for mine.

Science should have no blind appeal to authority. The motto of the Royal Society of London, founded in 1660 by Christopher Wren (who built St. Paul’s Cathedral in London), Robert Boyle, and others (Isaac Newton was a president), is “*Nullius in verba*,” which roughly translates to “take nobody’s word for it.” This was an expression of the determination of the members to verify all statements by checking them experimentally rather than take someone’s word for it, or be dictated by authority.

Naturally, one can’t check every fact for oneself, and one must believe somebody, but the principle is very important. In science, the ultimate decision is made by experiment and observation. We observe, measure, and try to understand, which means we try to develop equations that explain what we observe, and put these equations into models (i.e., computer programs that solve these equations), and hopefully the results of these models look like what we observe in nature. If not, we refine and try again. If so, then we as scientists feel that we understand how this aspect of nature works, and we proceed and try to see how we can extend the model, and how we can validate (or not) its predictions. For instance, a model might say, “If such a thing happens, then the result will be such-and-such,” and this can be tested.

There will, of course, be mistakes during this process. Some of the measurements might have errors; this is why a large amount of time is spent calibrating instruments, to ensure that the measurements that they give are the best possible. If the measurements are good, there might be errors in how these measurements are interpreted–the equations that were derived to explain the measurements might be faulty. This is often quickly checked, by a process called “peer review,” which means that your results are judged by other scientists. When a scientific paper is submitted to a journal for publication, the journal’s editor sends the paper out to (typically) three reviewers, who read the manuscript and evaluate it. They decide whether it is worthy of publication (Are the results correct? Are they new? Are they sufficiently interesting to warrant publication?), and if so, the reviewers make comments on how the manuscript can be improved. The identity of the reviewers is not revealed to the authors of the submitted manuscript. This process continues, sometimes through several iterations, until the paper is either accepted or rejected. By this process, papers that are published are (hopefully) correct and meaningful.

Does this process work perfectly? Of course not, but it would be unreasonable to expect that any system involving humans (whether it be in medicine, government, or anything else) always will, but nonetheless, there is a process in place with the goal of reaching an accurate understanding of nature, and it works surprisingly well.

I recently came across a 1975 article by Samuel Gorovitz and Alasdair Macintyre entitled "Toward a theory of medical fallibility," which discusses "distinguishing culpability from necessary error." This article contained some thoughts that resonated with me, and which I think describe science well:

> "Indeed, should everything be known about a given area of science, all scientific activity in that area would cease, even though work might continue on the practical applications of that knowledge. Therefore, where there is scientific activity, there is partial ignorance–the ignorance that exists as a precondition for scientific progress. And since ignorance is a precondition of progress, where there is the possibility of progress there is the possibility of error. This ignorance of what is not yet known is the permanent state of all science and a source of error even when all the internal norms of science have been fully respected."

To me, this is very accurate, and very different from the popular perception of how science works. As scientists, we live in a world of uncertainty. We try explaining this to our students, whose experience before they arrive is generally limited to doing homework problems, checking if they have the correct answer, and then taking a test to see if they can remember it. We don't *know* the correct answer–that's what we're trying to find out! As a colleague of mine describes it, we bang our head against the wall every day trying to solve a problem, and then once we figure it out, we find a different problem so we can again bang our head against the wall trying to figure that one out. There will always be some disagreement among scientists while in the process of trying to figure things out, but once the correct answer is determined, the topic becomes part of our body of knowledge and we move on to others.

Back to the original topic in the first sentence of the update–the thinness of the atmosphere. My friend Mike (whom I've discussed in these updates several times) sent me another picture that illustrates how little atmosphere there really is above us (in case the picture doesn't come through, the link is http://www.sciencephoto.com/media/159214/view). The entire atmosphere, at pressure equal to that at Earth's surface, would be the size of the sphere shown on the right. To make our atmosphere, this would have to be spread out over the entire globe. Amazingly thin! Thanks for sending Mike!

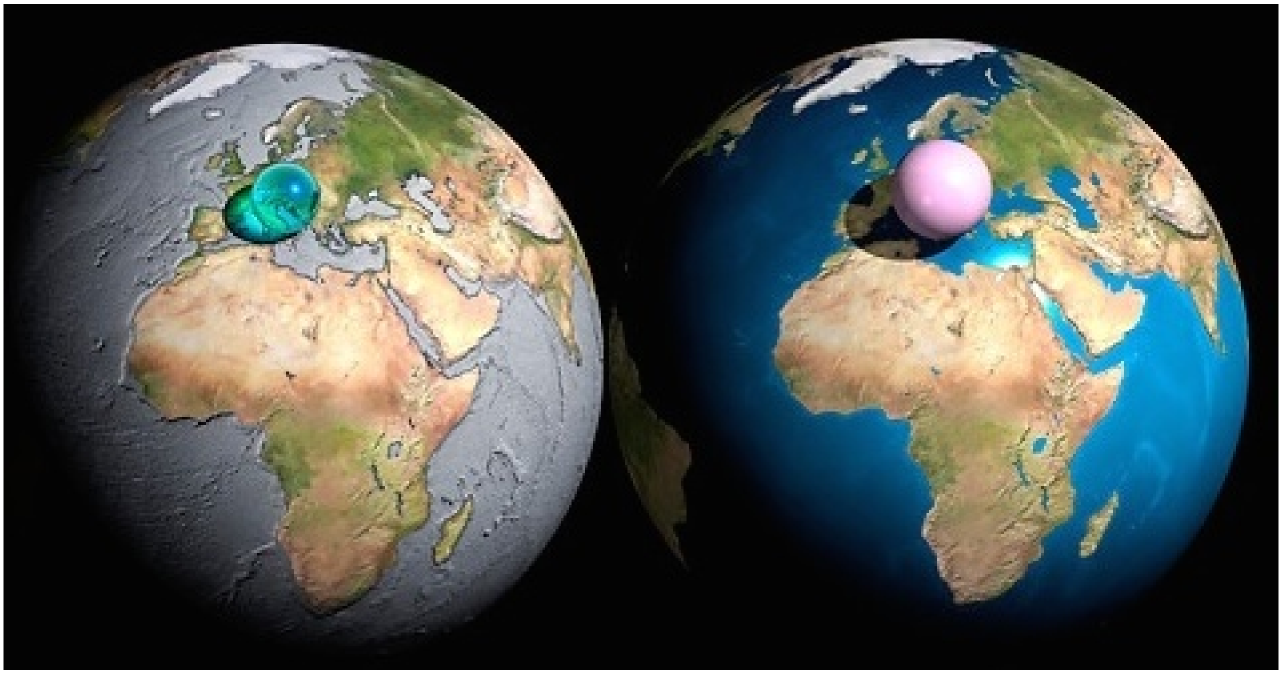

Image by Adam Neiman. Original caption: Global water and air volume. Conceptual computer artwork of the total volume of water on Earth (left) and of air in the Earth's atmosphere (right) shown as spheres (blue and pink). The spheres show how finite water and air supplies are. The water sphere measures 1390 kilometres across and has a volume of 1.4 billion cubic kilometres. This includes all the water in the oceans, seas, ice caps, lakes and rivers as well as ground water, and that in the atmosphere. The air sphere measures 1999 kilometres across and weighs 5140 trillion tonnes. As the atmosphere extends from Earth it becomes less dense. Half of the air lies within the first 5 kilometres of the atmosphere.

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