FRANKENSTORM

AND THE ISOTOPES

Lessons from Hurricane Sandy and how that teaches us about past climate

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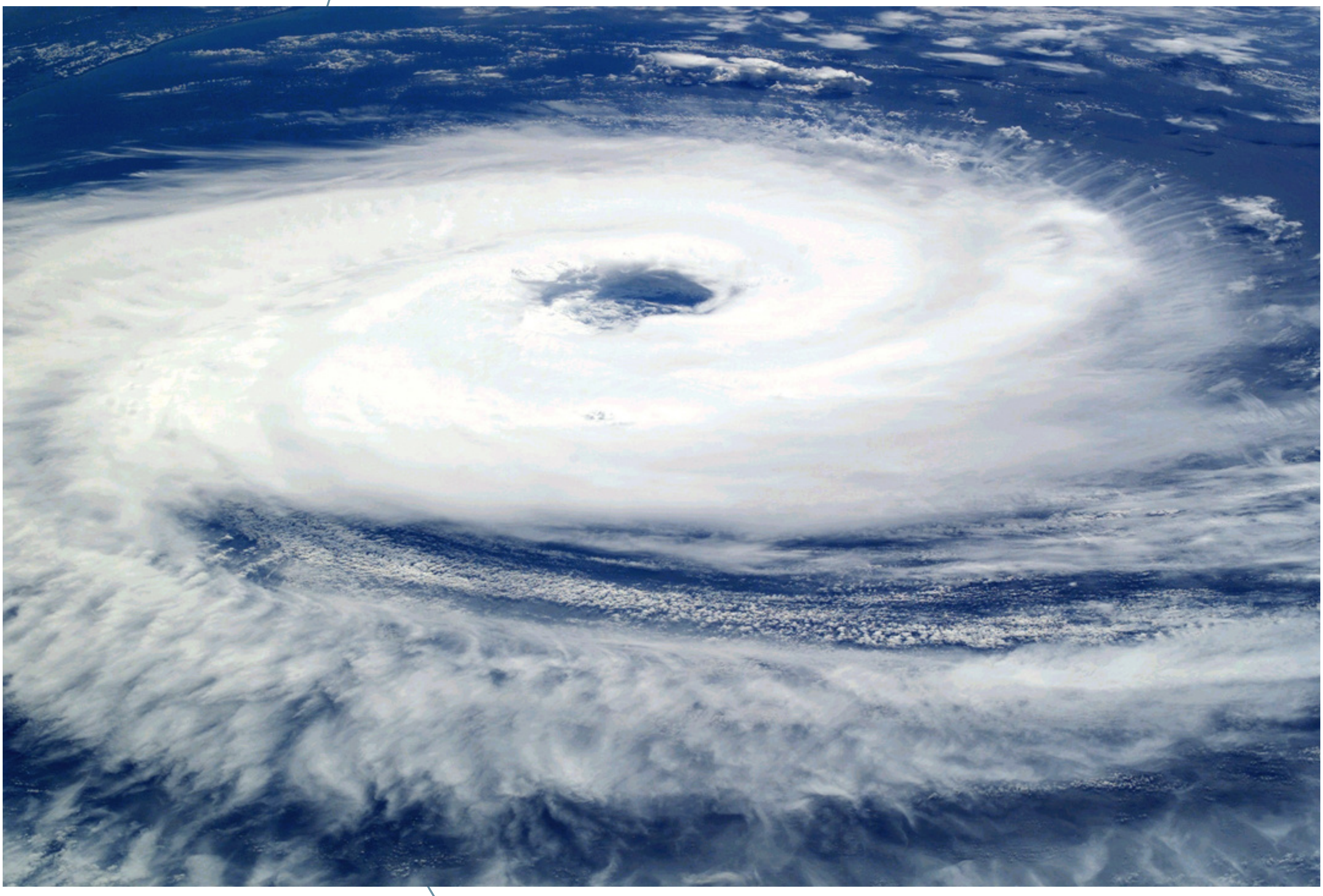

The story behind the

FRANKEN STORM

Hurricane Sandy made landfall on top of New York City on October 29, 2012. Because it struck near Halloween plus its coincidental collision with another major weather system, it was called "Frankenstorm."

Frankenstorm and the Isotopes

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Earlier this week, Hurricane Sandy (an anomalous late-season hurricane) made landfall in the United States near Atlantic City, NJ (also anomalously far North). Because of the timing of Sandy (near Halloween), and it's coincidence with another strong system moving across North America from the West, the weather event was given the moniker "Frankenstorm".

This storm was a big deal, and my heart goes out to everyone adversely affected by its aftermath. My own heart broke with each image the popped up on my Twitter-feed that night. Yet there were some heartwarming stories, and certainly some good will come from this unfortunate event.

Much of the discussion of Sandy revolved around how unusual it was and how it might be related to global warming. I even got a call from a local journalist wondering if I would be willing to comment on that. (I said no, because it's really outside of my realm of expertise, but hopefully might be contacted later regarding ancient episodes of global warming which really are my specialty.) There are plenty of web resources on the topic, which cover that question better than I can. This is one of my favorites:

How global warming helped transform Sandy from a hurricane into a Frankenstorm

http://qz.com/21156/how-global-warming-helped-transform-sandy-from-a-hurricane-into-a-frankenstorm/

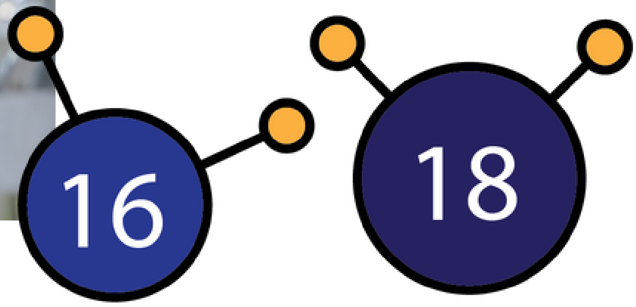
HURRICANE SANDY PROVIDED A GREAT ISOTOPIC EXPERIMENT

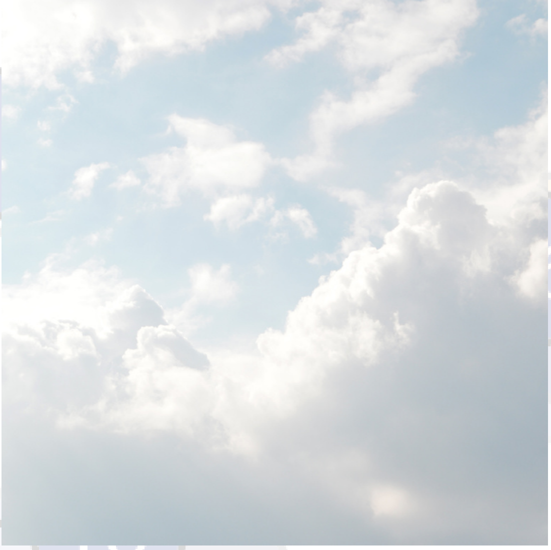
This is all interesting, but is not why I was kind of excited about Sandy (in the way only a geochemist can be). For me, Sandy provides an opportunity to verify what we think we can learn about ancient weather patterns using chemical tracers in rocks. That is, Sandy is a natural isotopic experiment. I'm not the only person who thought this. Gabriel Bowen of the University of Utah thought of it first. I'll explain below.

Before you get upset about the term 'isotope,' remember that all atoms are isotopes and that not all isotopes are radioactive. Most atoms are 'stable' meaning that they don't undergo radioactive decay. It's just that the term 'isotope' makes people think of nuclear reactors and meltdowns (and somehow Homer Simpson).

So then, what do I mean by an isotopic experiment? I'll save the details of how isotopes work for a later blog post, and just start with a simpler story of just water. Different isotopes have different masses, or weights. Most oxygen atoms have a weight of 16 atomic mass units. When you add two hydrogen atoms, this results in most water molecules having a mass of 18. Some water molecules have a mass of 19, where one of the hydrogen atoms is 'heavy' (but stable) and some molecules have a mass of 20, where the oxygen atom is 'heavy' (but also stable).

When the mass of the molecule is heavier than most the molecule is, well, heavy! That means that if water evaporates, the lighter molecules evaporate first, because they're lighter, leaving the heavier water behind in the puddle. This seems very common-sense, and it is. Vapor that evaporates from puddle is lighter than the water that remains in the puddle and, in fact, the remaining water gets heavier. This process is called fractionation.





RAYLEIGH DISTILLATION IS ONE OF THE BASIC CONCEPTS IN ISOTOPE GEOCHEMISTRY

Now, if we have a bunch of water vapor, like a cloud for example, and the vapor condenses, the heavier water condenses first and falls as rain (because it's heavier). The rain is heavier than the vapor in the cloud and the cloud's water gets lighter and lighter as it rains more. Again, this is fractionation.

When we're talking about isotopes, we use this crazy delta notation. If we want to say something about the oxygen isotopes in water we use δ18O. For hydrogen, we use δD or δ2H. The number we report is really a ratio, but we tack on the permil symbol (‰) to make the numbers easy to talk about (again, this is something to talk about later). What's important is that if the delta value is more positive, that means that the water is heavier. If the delta value is more negative, the water is lighter. Everything is measured relative to ocean water which has been assigned a delta value of zero for both hydrogen and oxygen. δ18O = 0‰ and δD = 0‰ for ocean water.

A hurricane, like Sandy, gets all its water from the evaporation of the ocean – so the clouds forming over the ocean will have delta values more negative than zero. As long as the storm is over the ocean rain from the hurricane and falls back on the ocean and new water evaporates keeping the isotopic value of the clouds stable. But once the storm moves over land, the addition of new water vapor from the ocean stops, but lots of water is lost as rain.

The result is that as a storm moves across the landscape, the isotopic value of the cloud gets lighter and lighter over time. The precipitation coming from the cloud also gets lighter and lighter over time, though it's always heavier than the cloud it came from.

This is called Rayleigh Distillation, and is one of the basic concepts in isotope geochemistry.

SNOWZILLA

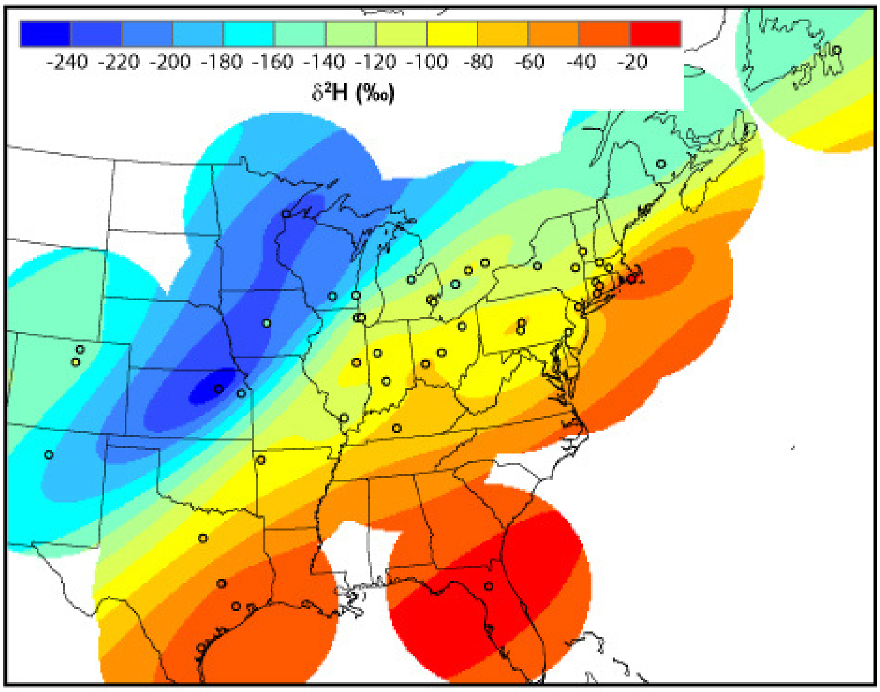
Rayleigh Distillation seems pretty straight forward and reasonable, and has been used as the basis of isotopic interpretation for many years. But it's been difficult to test… Until now. With electronic messaging and, more importantly, social media, it is now possible to recruit a fleet of people of a broad geographic area with only a few hours notice to collect rain samples that can then be measured for their isotopic values. We can finally ground-truth this important hypothesis!

This was tried for the first time with a storm called "Snowzilla" (now less creatively called the 'Groundhog Day Storm') that happened in 2011. Snow fractionates from clouds just like rain does, so would be expected to show a similar isotopic pattern as rain water. When this huge storm that hit much of the eastern United States, and Gabriel Bowen, then at Purdue University, put out a call for people to collect snow samples and send them to him. The results are detailed here [broken link].

Looking at the figure below, we see that the isotopic values shift from more positive in the southeast to more negative in the northwest. From this, it's easy to see that the vapor moved in from the Gulf of Mexico and Atlantic Ocean.

What might we expect to see from Sandy? Well, this time when the call went out, Dr. Bowen asked participants to collect samples over specified time intervals and to record those times, meaning that it will be possible to make an isotope movie and perhaps watch Sandy move across the continent.

So… Why does this matter? Oxygen isotopes from rain can be preserved in rocks. As rain water is exposed to carbon dioxide and percolates through the soil, it forms carbonate (CO_3^{2-}) which is then bound into carbonate minerals like calcite. This calcite can form little nodules in the soil or a calcrete layer. The oxygen in the carbonate records the oxygen in the water (with a little more fractionation).



The pattern of hydrogen isotopes from the Groundhog Day Storm in 2011. Warmer colors represent isotopically heavier water.

Later – as in millions of years later – geoscientists like me can analyze the oxygen from the carbonate and get back to the original distribution of oxygen isotopes in the rain water. From there, we can then figure out ancient air-flow patterns around the world.

With this knowledge, we can start answering other questions. How does the uplift of high mountains (like the Himalayas) affect global air flow? What happens to air circulation when climate changes rapidly, whether it be warming or cooling? We can address these questions and more, which might help us understand what the future might bring if projections of warming bear out.

In the meantime, I'm a participant in the project myself and am still collecting waters. Sandy's not quite dead, though her destructiveness is well past. We'll see what the data tell when all is said and done!

UPDATE

Here they are: the sample set from my house. I'm done sampling, so the analyses can begin!