Lecture 3—Where is all the world's water?

We know fresh water is indispensable to life on this planet. That said, where does the world's water reside? Where does it come from?

Origin of the world's water

We know, from dating of chondritic meteorites, that the solar system is about 4.6 billion years old. We also know of water-laid sedimentary rocks on the earth's surface that are 3.9 billion years old. This suggests that at least some of the water on the earth's surface has been around for a long time, and got here relatively early in earth's history.

There are three hypotheses for the origin of the world's water. Two are probably partly correct. One theory is that the water is outgassed from the earth's interior during volcanic eruptions, geysers, and the like. Another is that the water comes from "late-accreting" water-rich meteorites, similar to carbonaceous chrondrites. Last is that the water was supplied to the earth by comet bombardment during a period of earth's history about 3.9 billion years ago called the Heavy Bombardment Period.

First, the meteor hypothesis. The problem here is that all meteors contain excess xenon, and we don't have it here. So, on with the show…

In favor of the outgassing hypothesis, some volcanic, geyser, and fluid inclusion water is "juvenile"; that is, it has never seen the atmosphere before. This is known because of the large amount of helium 3 contained in the water. Helium 3 is a daughter product of tritium decay, but because it's a noble gas, ^{3}He leaves the water and enters the atmosphere if the water is able to equilibrate.

In favor of the comet hypothesis is evidence that the deuterium ratio in the world's oceans is approximately equal to that of comet water, though this is currently under debate. Evidence from comets like Hale-Bopp is that the deuterium ratio of comet water is too enriched in deuterium to be the source of the earth's water, BUT new evidence from LINEAR suggests that at least some comets contain the right ratio.

Ok, so that's where water comes from. It's some combination of outgassing from hydrous minerals in the earth's interior and comet impact, but the relative importance of each is a matter of heated debate.

Where is all the water?

Well, take a look at the handout. Sure enough, most of the world’s water is in the ocean. Duh. It’s also too salty for us to drink. Do’h! Turns out most of the world’s *fresh* water is held as polar ice and groundwater. So, yeah. Turns out I’m teaching a class in *water* and I’m not talking about like 98% of the water. Get used to it—that’s science, baby. Besides the groundwater part, most of the world lives on the rivers and lakes part of this, which is to say on not much of the cycle. To make matters worse, we’re trying to grab it on its way from hither to yon—that is to say, in the brief period of time between the time it arrives on land and the time it goes back into the ocean. For *groundwater* this time period is quite long. Let me give you an example:

mean residence time=total reservoir/flux out

so for groundwater it’s 10,530,000 / 2,200 = 4786 years

In short, then, when water gets into the ground, it’s there for a while. Note that this calculation only takes into consideration natural drainage and not our pumping activities.

On the opposite end of the spectrum, how long does water stay in the atmosphere?

(answer will be 8.2 days)

The net result of computations like this is the concept of a series of reservoirs that store water (list them—oceans, ice, groundwater, rivers, lakes) and a series of processes that connect these reservoirs (evaporation and precipitation, runoff and infiltration). We’ll spend the rest of the time here trying to understand how to go from a blithely qualitative diagram like the one I gave you to one that can answer more important questions like “will there be enough water this year?”, which is ultimately a life-or-death question, and one over which wars are fought.