

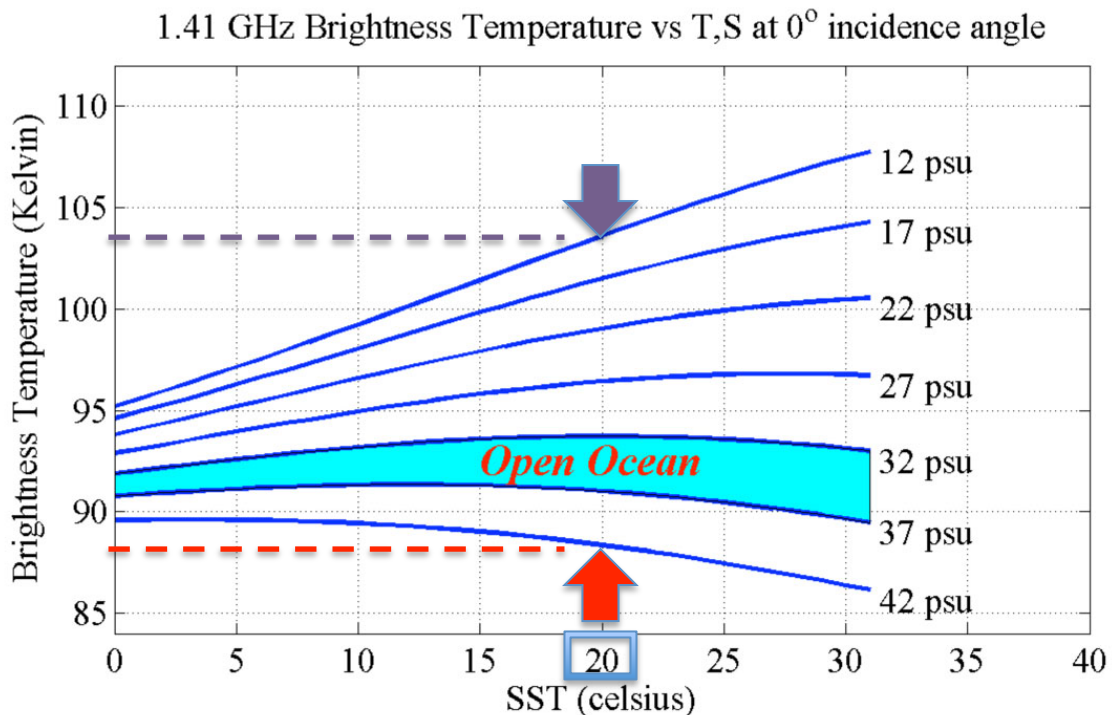
Can you explain “brightness temperature”? [Note that Gary and David covered this during the webinar and a participant wanted more clarification.]

Gary: David did a good job with that.

David: What we’re measuring is natural radiation from the ocean surface. Everything has energy because it’s not at absolute zero temperature and thus gives off radiation. An example of that is night vision. The military is able to see people at night not because they look at light but because they look at infrared radiation. The people are giving off energy at lots of frequencies. One of those (frequencies) is slightly below the optical and is called “infrared” and we use night vision to see that.

Another example of natural radiation is the heating of your electric stove. You turn on the burner, it warms up, and it glows red because it has gotten more energy and the added energy changes its frequency distribution. Now because it’s so hot, it actually gives off more energy in the optical frequencies that our eyes are sensitive to. But it is also putting off radiation at all frequencies. So if we looked at it with night vision, then it would be overwhelmingly bright. And if you looked at it in the microwave frequency range (e.g., 1.41 GigaHertz, GHz like the Aquarius instrument measures), it would also look very bright. So it’s giving off energy.

We talk about that energy as an equivalent temperature. So you can say that if the temperature is higher, there is more energy and if the temperature is lower, then is less energy. The scale isn’t so important because it depends on the frequency (e.g., the same temperature scale wouldn’t work for the night vision scale at the infrared frequencies). But we have a scale called “Brightness Temperature” that is measuring the amount of energy that’s being given off by the ocean surface at a fixed temperature.



So in the graph above, go along the horizontal axis and stop at a sea surface temperature (SST) equal to 20 degrees Celsius (see blue box). If you go up to the blue line labeled “12 psu” (practical salinity units, psu), you’ll see a purple arrow. If you read across to the vertical axis (i.e., follow the purple dashed line to the left), you see that **lower salinity** water gives off **higher energy** because the Brightness Temperature is about 104. At that same SST of 20 degrees Celsius, **higher salinity** water (see red arrow at 42 psu), gives off relatively **lower energy** (i.e., follow the red dashed line to Brightness Temperature on the vertical axis at about 88).

Aquarius has a very precise instrument that tells us how much energy is coming off the ocean surface and we express that as a “Brightness temperature.” If the brightness temperature is higher, then the seawater is fresher (i.e., less salty; see purple arrow / dashed line above). If the brightness temperature is lower, then the seawater has more salt (i.e., red arrow / dashed line). The graph shown above was published in 1977. So an important new area of research is to develop a set of curves that are very carefully calibrated so we know exactly what energy corresponds to what salinity. And the instrument we use is very precise and makes these measurements accurately and consistently.

### **Why are salt levels in the oceans and lakes so different?**

Gary: The sea is salty and lakes pretty much contain only fresh water and very little salt. The reason for that is, over geologic time, as rivers erode the land and carry minerals to the sea, some of those minerals accumulate in the seawater and build up over time. These minerals make up what is called “sea salt.” There is a more complicated chemical balance between what is dissolved in seawater and what gets absorbed by the ocean sediments but, over time, it has reached an equilibrium and the saltiness of the oceans has remained relatively constant for hundreds of millions of years. So if you were to go back in time to the earliest days of the dinosaurs and you took saltwater samples, it would be pretty much the same salinity as we observe today. So it is a very complicated chemical balance that maintains the ocean salinity the way it is. But the water in lakes doesn’t accumulate minerals to the same degree because, first of all, they haven’t existed as long (as the ocean basins) and the chemistry of lakes is different.

### **So does that mean freshwater lakes have not been in contact with the substrate (underlying rocks) for as long as the ocean?**

Gary: That could be part of the answer but because the oceans are so vast that there’s a much bigger chemical process going on than in a lake. And there are also some lakes that are extremely salty, for example the Great Salt Lake. For various reasons because of the nature of the minerals that feed into the lake, the amount of evaporation that goes on in the lake and because the Great Salt Lake is in the desert, water flows in and then evaporates away and leaves the residue behind.

Whereas in lakes like the Great Lakes there is more of a turnover in fresh water: the water flows in and goes back out again so there is a flushing. The water eventually makes its way to the Saint Lawrence River and to the ocean. So the Great Lakes get flushed through and the salt doesn’t accumulate. In the Great Salt Lake there’s no outflow (i.e., the water flows in from a river and then evaporates into the atmosphere and leaves the salt behind). This is the same reason why the Dead Sea is very salty.

## **In terms of exploration of other planetary systems, can Aquarius's technology be applied to looking for salt elsewhere in the solar system?**

Gary: It could. At this point there are not any instruments on any interplanetary satellites that are making this kind of measurement but they could. We don't really have any other ocean-covered planet in the solar system that we're aware of... but these measurements are also useful over land but they're more useful for detecting the moisture content of the soil than they are for measuring the salt content (of soil). I don't think we could actually measure the salt content of soil with this kind of instrument but we can measure the moisture content.

David: There have been some thoughts and proposals, nothing has been put into action, but it has been proposed to use the same frequency (as Aquarius; 1.41 GHz) to look for water in inter-planetary space because the difference between water and non-water at this frequency is very, very strong.

## **How long did it take to build Aquarius?**

Gary: It kind of depends on where you start but the design work began back in 2001 with some conceptual designs that David and I worked on with a number of other scientists and engineers. We put together this basic concept of a passive/active system: that means a (passive) radiometer and an (active) radar together with three "horns" bundled together in such a way that we could create a wide enough swath to make the global measurements that we wanted. That led to a proposal that we made to NASA and, after two rounds of reviews, we were selected as a mission to be built. So then we went into much more detailed design. We didn't start the process of building the actual instrument that's now being flown in space until 2006 or 2007. We built of number prototype components before, called "engineering models," to test out the design and so on. I guess you would have to say, from beginning to end including the development of the satellite and everything else, it took us about six or seven years to build the space hardware that's now operating. There was quite a bit of time devoted to design work and engineering model development before that.

David: It also rests on the research that was done before. So you see in the concept map is the chronology that takes you back to when the idea began. What's not really shown in this map so much is the engineering that went into instrument design; so there was also progress being made in the 1970s, 1980s and 1990s on the type of instrument that actually makes measurement of the brightness temperature (i.e., the Aquarius radiometer).

Gary: Without the heritage that we described (in the concept map) -- going all the way back to the 1970s -- we wouldn't have been able to do this. There was really a long, slow build up of knowledge that led us to where we are.

## **Why does freshwater give off more energy than saltwater?**

David: It's a little bit complicated in engineering terms but I'll see if I can make point this clear: conductivity is what makes currents flow. So something that has good conductivity, like the wires in your house, conduct electricity very well. If something has poor conductivity, like a glass window, it doesn't conduct electricity well at all. It turns out that the saltiness of seawater increases its conductivity. That conductivity suppresses the energy that's emitted from the ocean surface. Actually, what happens is that (the energy) bounces off the surface and back into the ocean; so the more conductivity, the more energy is retained (i.e., bounced back into the ocean).