Ocean Bights Interview with Yi Chao, Aquarius Project Scientist, Jet Propulsion Laboratory
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CMS: How did the Aquarius mission begin? Yi: The mission officially started about ten years ago. The P.I. (Principal Investigator) has been working on Aquarius for about twenty years. I got involved in the late nineties. A lot of us have been working on Aquarius for a long time. Officially, the mission started in 2002. The aircraft program (to develop the instruments) began well before the satellite program in the late '90s.

CMS: How did you become involved with the mission? Yi: I received my Bachelor's degree from China in atmospheric physics and came to the United States for graduate school in 1985. I went to Princeton to study atmosphere/ocean sciences. After two years, having received my master's degree, I became more and more interested in the ocean, so I switched from atmospheric science to ocean science, which is very similar. They're both in the Earth/science, geo/science category. I got my Ph.D. in Oceanography, and then I came to UCLA as a post-doc, and began to interact with the people at JPL. I became fascinated with remote sensing techniques from aircraft and space, and after three years, I moved to JPL. I started my first job here in '93.

My main interest is studying ocean processes and phenomena. I try to ask the question why does the ocean do this, how does ocean health affect the ecosystem, atmospheric processes and climate? JPL is working with a lot of engineers who try to think about future ways of measuring the ocean from space. It evolved from sea-level measurements in the nineties, wind-level measurements in the late nineties, and then ocean salinity being the natural course of study.

Salt controls the weight of the water. More importantly, the temperature and the salinity determine the weight of the seawater, the density. The weight of the water determines how the ocean flows, how it overturns. So, heavy water sinks. It's like the atmosphere where light air rises and that drives the convection. The vertical motion of the atmosphere affects the rainfall, the circulation. It's the same thing for the ocean. It's the heavier water that's important. That weight, with heat convection, drives the three-dimensional flow. By knowing the surface salinity you can condition this kind of flow. Without knowing the salinity information, you only have partial information.

Scientists have been dreaming about remote salinity sensing for decades. The first paper on it came out in the seventies exploring a theory on how we might use microwaves to measure salinity. So the theoretical work was done thirty years ago. Because the signal is very small, it's very challenging and took about twenty years for the community to sort out how to make all those little corrections and extract a small fraction of the signal being measured. The frequency we use is 1.413 gigahertz in the microwave band. We chose that frequency because it gives us the biggest response to salinity. So, in other words, we found that this is the frequency where a slight change of salinity corresponds to the biggest changes in the microwave signal the Aquarius radiometers can detect.

CMS: In the on-line graphic representing Aquarius, it depicts the three radiometers as red, green and blue, looking something like an early video projector. How did that come to be? Yi: (laughter) Each radiometer is identical. We don't have to fly three. We can fly one. It would just take three times as long to cover the globe. So, think about it. We line up the three footprints, first one, then the second, then the third in a nice configuration. They line up horizontally. So rather than cover a hundred kilometers, now we can cover three hundred, and within a week, we can cover the whole globe. If we were to fly only one, it would take three weeks to cover the whole globe. Three is a nice configuration.

We could fly more, but mechanically, it's difficult to arrange. How do you fly five? With three, you optimize the coverage while giving the mechanical engineer less of a headache to configure. The original concept was to rotate the dish. Rather than have a mechanical dish with three radiometers, we would have had one radiometer in constant rotation. That option proved not to be very practical. It would have cost a lot of money, and would have presented a lot of risk. Eventually, we decided to take a more conservative course, utilizing three radiometers for the configuration. That was optimal. These studies took a few years before we were ready to begin the project.

CMS: Can you say more about the spacecraft's orbit tracking just inside the nightline of our planet as it spins on its axis? Yi: We fly a so-called "terminator" orbit. Basically, we follow the sun by flying the boundary between day and night. This way, the spacecraft can collect solar energy while the instrument looks at the dark side of the planet, allowing us to minimize the "noise" caused by sunlight reflecting off the water. On the night side, the only thing reflecting off the water is the light from stars and galaxies, making it much easier to work with.

CMS: How does the scatterometer work? Yi: The radiometer is a passive instrument collecting radiation emitted from the planet's surface. The scatterometer, on the other hand, is an active radar that measures the "roughness" of the water caused by waves and swells. It sends a pulse to the ocean's surface to measure the reflectance. If it's a perfect mirror, you get a perfect reflection. The spacecraft uses the same dish antenna for both instruments, combining the two separate signals from the radiometer and the scatterometer to produce an accurate measurement.

CMS: Can you tell us about the instrument-calibration process once the craft reached its designated orbit? Yi: Once you start turning on the instruments, there are a number of different calibration processes to complete. There are the orbital parameters and the pointing of the instrument. You want to make sure you're pointing in the right direction, and to calibrate the antenna patterns and the antenna temperatures. All of this is first tested on the ground and in the lab. Then, in space, we have to make sure everything functions the way it was designed to. So, calibrating the stability of the radiometer is still ongoing at this point with less than a month of the data sets in. The first of the data sets began to come in almost a month into flight, around 21 July 2011. Now, we want to take a little more time and better understand how the instrument works.

Once we finish the calibration, then we start the validation. We have many independent surface measurement sources to verify calibration. Salinity readings taken by ships, buoys, robotic vehicles, and drifting vehicles in the ocean are vital to the process. With their conductivity sensors, they measure salinity at the surface, and then we compare the two. One is touching the water and one is four hundred miles in space. We are still in this calibration phase and working out some issues. Yesterday was our "first light" (Aquarius completed its first global mapping on Sept. 23, 2011). There are still some issues we need to work out. We need to understand the scatterometer data better. In first light, we only used the information from the radiometer. We're still working to calibrate the scatterometer so we can better utilize all the information. There's a variety of information you can feed into the retrieval program. So right now, we call it quick-look processing.

CMS: How high is the bird flying? Yi: The Aquarius satellite is flying at 657 kilometers, or 408 miles.

CMS: Touching on the practical implications of the mission, how will the information from this and related projects help us to understand the effects of global climate change in both our ocean and atmosphere? Yi: If you go to the NASA Website, you will see 15 or 16 satellites already flying which measure different aspects of the Earth's systems: atmospheric, land processes, ice, snow and the ocean. Aquarius is one of the many, yet we are providing this very important piece of information, this missing piece of the puzzle. I couldn't say this is going to be the silver bullet that's going to change everything, right? But this is certainly one of the key pieces of missing information to be added to our database of all known knowledge and to monitor the global changes. The capability of the satellites is global coverage. You don't have to send a thousand ships and all their technicians to the ocean, because every week, the satellite will cover every part of the planet.

Salinity is affected by precipitation, evaporation, river runoff, ice melting; so anything related to salt and freshwater will give you a signature in salinity. This is part of the water cycle. In other words, if you are melting more of the snow pack in California, where does the snow go? You can't store it in your backyard; it eventually has to go back to the ocean. When the water goes back to the ocean, you will see the salinity becomes fresher. If the ice is melting, you're going to see salinity changes. Salinity is really an indicator of many of these processes. Aquarius will provide information about the global water cycle, and more importantly, will quantify the change. You can use the salinity changes to infer how much the source is changing. In that way, it's a very powerful data set to be added to the so-called knowledge database.

CMS: Do you think this data will influence industrial behavior? Yi: I wouldn't expect immediate changes. All of these climate data sets need a long record. You can't use something changing from today to next year, or even two years from now, to infer something magically is evolving, right? I hope Aquarius' data sets eventually will have a strong impact on policy. An example would be the famous Keeling Curve where we've seen how atmospheric CO2 is changing in Hawaii over a period of fifty years. When started in the ‘50's, the scientist from San Diego (David Keeling of the Scripps Institution of Oceanography) never thought "that's a powerful curve," that it would be named after him, and the enormous impact it would have on policy. It may take a decade or more to accumulate enough accurate data, then to understand the trend and eventually influence the policy makers.

CMS: How will the (Aquarius) information be released? Yi: Once we are through the calibration/validation phase, the data will be released and made available to the public. JPL's data center, known as PODAAC (Physical Oceanography Distributed Active Archive Center), is responsible for gathering the data and publishing it on the website. The digital data, the images, the graphs, everything is public access. It's open to everybody on the globe without restriction.

Before releasing the data to public domain, the science team makes sure the instrument is working properly and the information is accurate. That's the calibration/validation phase. Our goal is to release accurate data within a year of the launch. Coming up in the next few months, in early 2012, there'll be a major meeting with all of the science team members presenting their findings. Hopefully, we'll conclude that the data are accurate, then, release it so that everybody can do their own research. Then, the public can then go to the website and access ocean salinity information in their region of interest.

CMS: Part of the Aquarius project calls for a 2012 deep water project in the Atlantic using ships, smaller craft, buoys and submersibles. Yi: There's a dedicated website describing this as well called SPURS (Salinity Processes in the Upper Ocean Regional Study). That experiment will have two goals. One is to provide more in situ data to help us to compare with Aquarius and more importantly, to collect three-dimensional information at various depths. We have five cruises planned. Each cruise will be thirty days long and will take place in the North Atlantic about 28 degrees north, away from the coast, where maximum salinity in the Atlantic is present. We'll deploy a number of different vehicles, including robotic vehicles, to measure saline concentration in the three-dimensional water column, and then try to understand what controls the change at the surface. Aquarius measures only surface salinity. By knowing the surface changes, we hope to use this field campaign to understand the processes that take place within the water column. So, if we see some changes at the surface, we can anticipate what may be happening at depth.

CMS: What depths will the study gather information from? Yi: Some of the robotic vehicles go down to two thousand meters; some of them go down to a few hundred meters.

CMS: Will this research be conducted only in the North Atlantic? Yi: Yes, for the first series. There will be five cruises at the same spot at different seasons. Each cruise is thirty days long.

The first cruise will take place in the fall of 2012, with the first series concluding in the summer of 2013. All will take place in the same North Atlantic location. We call it sub-tropical: 28 degrees north, 38 degrees west. You can go to the website for a detailed description. Each cruise will occupy an area a few hundred kilometers by a few hundred kilometers, so we'll have a view of Aquarius' footprint. A lot of information will be collected in that footprint. And even within this designated portion of Aquarius' path, a lot of changes occur such as microclimates and even micro-oceans. We chose that area because it's very salty, around 38 PSUs (practical salinity units). We want to understand what maintains the salty water. That's a simple question.

CMS: In the global water cycle, is salty good? Yi: There's no such thing as absolute good or bad right? In certain areas, you want to monitor the change, that's really the key. You want to see whether the area's freshwater gets fresher, you know, and if the salty water gets saltier. That represents the speeding up or slowing down of the water cycle. So you ask the questions: do we have more evaporation as we change the climate? Do we have more freshwater melting? All these questions are related.

CMS: Speaking of climate, I've read that ocean events known as El Niño and La Niña actually begin in the region of Indonesia during monsoon season. Yi: El Niño begins in the western Pacific where major rainfall changes occur. That, presumably, will have a salinity signal. One of our science questions is to quantify this. We anticipate that Aquarius will be able to see El Niño/La Niña signals, but we'll need several years time to compare our data.

CMS: How long will Aquarius' mission run? Yi: The nominal, or baseline mission, is like the warranty on your car. The engineer can't promise the longevity of the craft beyond a certain period. So, as for reliability, they say the baseline is three years. The team is very confident that most, if not all of the parts, are going to work for at least three years in space. But, nobody is going to throw away a car when the warranty is up. Some NASA satellites last ten, twelve years or more.

CMS: Yi, thank you very much for meeting with us. Yi: Sure! Thanks for your interest!