Aquarius Version 5 Salinity Product Tutorial

Aquarius Sea Surface Density and Spiciness

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Hello, my name is Maria Jacob. I work for the Argentinian space agency, the name is, La Comisión Nacional de Actividades Espaciales or CONAE. For three years, I have been at the Central Florida Remote Sensing Laboratory in Orlando, which is part of the University of Central Florida.

This video tutorial provides an overview of the Aquarius Rain Impact Model, known as "RIM"
This is one in a series of improvements we are making towards a version 5 release.

If you want to learn more about the mission, go to aquarius.nasa.gov. Aquarius data are available from the Physical Oceanography Distributed Active Archive Center (podaac.jpl.nasa.gov).

My colleagues and I were motivated by the belief that careful interpretation of Aquarius data is needed during and near rain events. This is due to the dilution of salinity with the addition of freshwater at the ocean surface.

The RIM Model has been developed and is available to science users to promote the understanding of the relationship between precipitation and the corresponding Aquarius sea surface salinity measurement.

I will describe the RIM model itself and also comparisons between RIM and Aquarius Level-2 swath data for a number of rain events along the Pacific Intertropical Convergence Zone , or ITCZ.

Results will demonstrate the high correlation between RIM and Aquarius salinity for moderate to strong rain events that occurred within a few hours of the Aquarius observation time.

For the rain, we use the NOAA CMORPH product with coverages between 60° North to 60° South in latitude.

A key thing to understand about RIM is how we apply weighted averages based on the beam efficiency signal retrieved by Aquarius.

The red circle represents the footprint for one of the three Aquarius beams. We subdivided the footprint, or IFOV, into 13 boxes as we can see in the figure. Boxes near the center of the beam have higher signal efficiency than those on the periphery.

So, the weighted average for the box in the middle will be higher than the boxes with 2, than the boxes with 3, than the boxes with 4.

Aquarius measures the top centimeter of the ocean. For this, we took an average of that top centimeter and produced a product at 0.5 cm depth as you can see in the figure. This represents the middle of the layer that is measured by Aquarius.

In addition to modeling salinity based on RIM, we also provide ancillary parameters.

Which are the Rain Beam Fill Fraction, or BF, and the Probability of Salinity Stratification, or PS. Since it doesn't rain equally in each of the RIM boxes, we need to estimate how much it rains in each of the boxes. So, BF represents area weighted percentage of the beam that exceeds a set Instantaneous Rain Rate (IRR) threshold of 0.25 mm per hour.

It is also important to flag where rain might reduce salinity enough to cause stratification at the ocean. So, PS is normalized delta-sea surface salinity per orbit between RIM at 10 m depth and RIM at 0.05 m depth.

If you measure salinity over depth and over time you will see it change after a rain event. The blue curve shows the initial salinity, T_0, after a rain event. At that point salinity is low at the surface and increases with depth as we can see in the figure. Over curves show how the salinity profile changes over time after the rain event. Until finally, at some point, it is just a straight line. At that point, the salinity is uniform with depth.

This curve shows the big reduction in salinity after the rain event. Then the salinity will start increasing until it is close to the original value, but not quite the same.

The NOAA CMORPH data, gives us the rain rate every half hour. We take the time that is closest to the Aquarius observation time and use this for T_0. We then go back 24 hours and calculate the rain every half hour before T_0. This gives us 48 other data points to consider since they would potentially contribute to the salinity seen at T_0.

These equations are the base equations that we use for our model. The equation on the top shows how the salinity behaves with depth and time, where S0 is salinity and S0 is the parameter we measure with in situ data.

We use this equation for our model. Where we have RIM, it's modeled by the salinity we are using from HYCOM which is an ocean salinity model. And then we have two main equations. One for the 48 previous rain [measurements], and one for the instantaneous rain. Why do we do this separation? Because the instantaneous rain has higher weight than the previous rain. So the S, R2 and R1i are the input functions that represent the rain every half an hour, z is the depth - for us it will be half a centimeter – Kz is the vertical diffusivity that represents the wind, and in this case it's constant, and t is the time.

Here are the results of the RIM model for three dates in early 2012. Blue values are Aquarius sea surface salinity measurements. Red are outputs of the RIM_{SSS} model, Black dots are HYCOM model data. For all plots, the X-axis is the latitude and the Y-axis is the salinity. Overall, there is very good agreement between RIM and Aquarius.

Let's look more closely at how the Aquarius and RIM values are influenced by Instantaneous Rain and Rain Accumulation during the previous 24 hours. This is the case for January 10^{th}, 2012, Orbit 5, beam one. The first plot is salinity vs. latitude, the second plot is Instantaneous Rain Rate vs. latitude.

The next plots are the Rain Accumulation vs. latitude, but the difference is that the third plot is the rain accumulation from 0-6 hours previous to the Aquarius observation time. Then we have the Rain Accumulation between 6 and 12 hours previous to the Aquarius observation time. The fifth plot is Rain

Accumulation between 12-18 hours previous to the Aquarius observation time. And, finally, the last plot is for rain between 18-24 hours prior to the Aquarius observation time.

We see in the first panel, in blue, is the Aquarius sea surface salinity, in red we see our model (RIM) and in black we see HYCOM. As you can see here, there is a big difference between HYCOM and Aquarius. This is because the HYCOM model does not compare any rain. As we see here, where salinity has dropped, it is coincident with the rain that is occurring instantaneously. We have seen that even if the instantaneous rain rate is the one that shows up more in the salinity, other previous rain also affects the salinity.

Here's another example but this one has wind speed in the bottom panel. So, as I was saying earlier, salinity vs. latitude, instantaneous rain rate, the next four are the rain accumulation, and the final one is wind speed vs. latitude.

Even if our model has good correlation to the Aquarius measurements, we see there are some differences, like here.

We are working, for this, on a new model that also includes wind speed from Aquarius' scatterometer. This is because higher winds can help to mix the ocean surface.

We're hoping that the new model will do an even better job of matching Aquarius and RIM sea surface salinity.

In this plot we can see salinity vs. time. These are eight cases concatenated. In blue we see Aquarius sea surface salinity, and in red we see RIM. And we see that we have some differences between the two. These concatenated data show that there is good agreement between Aquarius and RIM but there is also room for improvement. We are hoping that adding wind speed will address these differences.

The plot on the right is RIM sea surface salinity vs. Aquairus, and we can see there is a very good agreement but we think we can do better when we include wind.

At top is another example showing salinity from Aquarius, RIM, and HYCOM versus latitude. These data are from April 9, 2012. The bottom plot shows the Probability of Stratification (PS), which is a RIM ancillary product that we mentioned earlier. As we can see here highest probability of stratification occurs where you have the most dilution.

PS is calculated from the salinity at two depths: 10 meters and 5 centimeters. In-water profilers such as Argo typically measure salinity up to 10 meters depth.

As we have shown, the salinity is time dependent and depends on the rainfall accumulation. The analysis of Aquarius sea surface salinity measurements in the presence of rain, requires careful interpretation to account for near-surface salinity stratification.

All the work that has been done Aquarius is now being applied to the salinity retrieved from the SMAP satellite. The results for SMAP look very promising. The next slides will show how RIM is being incorporated into the Aquarius V5 product.

The first bullet shows a paper that explains in detail, our model, and shows more examples. The variables, as we mentioned earlier, that we are going to include. RIM which is sea surface salinity estimated based on our model and our equation; PS is the Probability of Stratification; QF is the Quality Flag for RIM. Other parameters are Instantaneous Rain, the Rain Accumulation for the previous 24 hrs, and BF which is the Rain Beam Fill Fraction. Then there is a status flag of Rain Accumulation for the last 24 hours. Those are all the parameters that are going to be included in the RIM product and the Aquarius Version 5.

This plot is a flow chart that explains the general process of how the RIM data is produced. For this, we need to look first at pre-processing. We have CMORPH data, coming from NOAA, that has a 30-minute resolution and 8 kilometer resolution, and the Aquarius files that are L2 data. For this we do a gridding for both products on a resolution of .25 degrees. Then we obtain one file per day with the 48 records for the rain. Remember that the gridding will be 60 N to 60 S in latitude. From the Aquarius files, we get one file per orbit, around 15 orbits per day. From this data we extract only lat and longitude indexes, HYCOM data and the time.

With this, we can now have the inputs for our model, which are: CMORPH data for the previous day to the Aquarius observation time; CMORPH data for the current date (the Aquarius observation time); and, from the Aquarius product, the Aquarius latitude and longitude indexes at .25 degrees resolution, the HYCOM data and the Aquarius observation time.

This is input in the main process, which we'll explain in the next figure. So as we say, we have the inputs, then we have our main process.

So, for each Aquarius sample, we use the rain history which constitutes the instantaneous rain rate averaged over the Aquarius footprint using the 13 boxes we were explaining earlier, and the 48 samples from the previous observation time from Aquarius.

From this we obtain the beam fraction and this information from instantaneous rain and rain accumulation goes into the RIM calculation (using the formula we showed previously). We calculate RIM at half a centimeter and RIM at 10 meters. With this information, we produce a probability of stratification, and then we have our output file.

This will be included in Aquarius as auxiliary info where we have the flags, the rain information, the beam fill fraction information, probability of stratification, the RIM product and also the rain information – the instantaneous rain and the rain accumulation.

We hope that this video has helped you to better understand how RIM is being incorporated into Aquarius V5 processing.

Thank you and enjoy the data!