Teresa (00:14):

Cynthia Garcia-Eidell is the fourth year PhD student on earth and environmental sciences at the University of Illinois, Chicago. She was trained on satellite data processing and geospatial analysis at the Goddard Goddard Space Flight Center, where she was previously appointed as a visiting scientist under the guidance of Dr. Joey Comiso. At Goddard, she led and contributed to publications on remote sensing of oceanic salinity. She has recently expanded her research into a broader set of topics, including understanding how land and ocean ecosystems are coupled along the coastal margins.

Teresa (00:53):

Through her work, she hopes to characterize broad scale coastal couplings and how land and ocean carbon sinks may act in tandem with one another to mitigate the buildup of anthropogenic CO2. She focuses on analyzing set coupled responses in all of the major river basins of the planet. Cynthia is currently an ACM SIG HPC/Intel computational and data science fellow. Today, Cynthia Garcia=Eidell's topic is Please Don't Pass The Salt.

Cynthia Garcia-Eidell (01:32):

Hi, everyone. I hope you're all healthy and safe, and I'm very happy to have all of you this evening for my talk entitled, Please Don't Pass the Salt: Progress on Ocean Salinity Monitoring. So for many of you, salinity is probably an obscure quantity, right? But it is of critical importance in studying a lot of the major components and processes in our earth's system. And in recent years, through the advent of observing technologies like this one, this is the global graded salinity data from Aquarius satellite, as well as NC2 measurements, salinity research has gained much attention now leading to growing new insights.

Cynthia Garcia-Eidell (02:16):

So before I start with my talk, let me first introduce myself. My name is Cynthia Garcia-Eidell. I just started with my fourth year as a PhD student with the Department of Earth and Environmental Sciences at UIC. I'm part of the atmosphere, climate and ecosystems lab led by our amazing advisor Professor Max Berkelhammer. I've always been fascinated about how our climate works and the connection for example, systems like the frozen Arctic here, connections to the tropics where I lived. I grew up in the Philippines, right?

Cynthia Garcia-Eidell (02:49):

So I'm also fascinated about the amazing ways that we study the earth. And that for me is the of remote sensing and satellite imaging. And so to further hone my skills on that, I joined Dr. Joey Comiso's group at the NASA Goddard Space Flight Center, where I helped analyze sea surface salinity data in polar oceans, where we're helping to track how the hydrologic cycle is changing as it responds to warming. Right? I recently expanded my research for my PhD, like what Teresa said on land ocean coupling along the coastal margins in the Arctic, as well as in the different river basins of the world.

Cynthia Garcia-Eidell (03:32):

Apart from analyzing big data sets in front of the computer, I'm also trying to develop more skills as a field scientist. For example, here is a field work that we did in the Arctic where we went to the Canadian Arctic aboard the icebreaker Oden. This was in the summer of 2019 when we were still able to go on fieldwork. So hopefully soon we can do that again. But this is me on top of a CTD. We're preparing this

CTD rosette for casting along the Lancaster Sound. So apart from all these, I'm also interested in the use of remote sensing and satellite imaging for education purposes, which we're actually applying in some of the classes that we teach at UIC.

Cynthia Garcia-Eidell (04:21):

So acknowledgements here, my studies that I included in this presentation won't be possible without the support of my lab, my advisor, my funding source ACM SIGHPC Computational Data and Science Fellow. That's a mouth. As well as my collaborators, Dr. Joey Comiso, which I noticed is in the participants right now. Larry Stock, Rob Gersten, as well as Manu and Ludovic Brucker.

Cynthia Garcia-Eidell (04:47):

All right, let's get started. So here's a quick outline of the talk today. So basically, hopefully at the end of the talk, we're able to answer these questions. First is, why do we study ocean salinity? Second is I'm going to share a brief history of the study of salinity, and then we're going to go to, how do we measure salinity and what are we learning from the now decade measurement of salinity from space. And then we're going to try to summarize everything in one slide as the main takeaways.

Cynthia Garcia-Eidell (05:20):

All right. So now, let's go to the why we study ocean salinity. So since roughly 80% of the Earth's surface fresh water fluxes occur over the ocean, like precipitation is about 78% occurring over the ocean, evaporation 86% occurring over the ocean, salinity is a really good indicator of the changes in the global water cycle wherein it will decrease when you have more precipitation, more river runoff and more ice melt. On the other hand, it will increase when you have more evaporation and also more sea ice formation through the brine rejection process when ice forms.

Cynthia Garcia-Eidell (06:00):

Aside from this, salinity also affects ocean circulation since salinity and temperature both dictates the density of the water. So because of this effect on density, it controls the water column stability, right? And so it's able to move water masses. And because of this movement of water masses, it's able to redistribute fresh water, nutrients, carbon, and most especially heat. And because of this movement of heat, we're able to regulate the climate. And this is a diagram of the thermohaline circulation of our planet from one basin to another.

Cynthia Garcia-Eidell (06:39):

And lastly, salinity is also important as an ecological factor for marine species. Profound effects in the marine ecosystems has been observed to be related with salinity variations. For example, in polar regions, surface water stratification due to accumulation of ice melt is now being observed to affect phytoplankton bloom, which is actually the topic of our recently submitted article to the Journal of Climate.

Cynthia Garcia-Eidell (07:07):

And so because of all these relative importance of in the said fields, salinity has been recognized as an essential climate variable or an ECV in the global climate observing system.

Cynthia Garcia-Eidell (07:22):

All right. So now let's go to a brief history on how we study salinity. So through the years, efforts have been made to substantially improve our understanding of salinity from the ancient concepts here, where Aristotle said that the sea owes its saltiness to the mixture of earth with similar properties, that the sea is the sweat of the earth and important observations by Pliny the Elder like salt content should be greater at the surface due to loss of water. However, we're also seeing fresh water in the surface. And why is that? And so it led to a lot of expeditions.

Cynthia Garcia-Eidell (08:00):

And one of the leading expeditions on salinity is the HMS Challenger in the 1800s where Buchanan and Dittmar collected a lot of samples and patched together all of these measurements. And Marcet and Forchhammer actually led to this discovery that ratio of salts in samples of seawater from various locations is constant leading to this principle of constant proportions that is now what we use in able to measure salinity. And since then, we developed a lot of ways to measure salinity, salinometers and recommended the use of the practical salinity unit or practical salinity scale that we use for computation reporting of ocean salinity data.

Cynthia Garcia-Eidell (08:48):

How do we measure salinity? So basically, salinity is the amount of salt dissolved in seawater, and we use 1,000 grams of seawater. So our denominator is 1,000. So the unit is parts per thousand or we just use the dimensionless PSU, practical salinity unit. The way we measure it in the global ocean is through a lot of different in-situ systems. A few of this that are popular are the thermosalinographs in the ships. So this is an example of a thermosalinograph. It's typically attached in the bow or the hull of the ship. It measures temperature, salinity among others through a flow through system and it measures salinity in all those parameters at that fairly high resolution.

Cynthia Garcia-Eidell (09:35):

Another is a CTD sensor, which I showed earlier I'm helping prepare during our Arctic expedition. CTD stands for conductivity, temperature and depth. So the sensor is typically attached on top or at the bottom of this rosette of Niskin bottles. So this Niskin bottles, you typically trip this and then aside from measuring salinity and temperature, you're also capturing samples of water at every depth that you want to observe in later on for analysis in your lab or in the ship.

Cynthia Garcia-Eidell (10:07):

Another is moored buoys. This is popular in the tropics. And lastly, ARGO profiling floats. These floats were launched in 2000. And now, I think we have more than 4,000 ARGO profiling floats all over the world. What I'm showing here in this figure is a sampling distribution of all of the historical salinity measurements. And what I'm showing here is the spatial limitation of NC2 measurements, wherein the blue dots are areas where we have one sample. For example, ARGO is only capturing one measurement by three degree. That means it's 330 kilometers by 330 kilometers, we have one measurement, right? So because of that, we can't really resolve short period features as well as spatial gradients of salinity. And then obviously ship based data are only available along the transect, right? And expeditions are fairly expensive.

Cynthia Garcia-Eidell (11:09):

And so because of that, the amazing engineers and scientists developed sensors that are sensitive enough to be able to measure salinity. And that started with the European space agency's satellite, the

SMOS satellite. It's the soil moisture ocean salinity. This was launched in November 2009, and it's still in operation. Spatial resolution SMOS is 35 kilometers with a temporal resolution of three days. Now, all three satellites are in the 1.4 gigahertz L-band, right? This was followed by Aquarius/SAC-D, which is satellite in collaboration between, well, NASA and the Argentinian space agency CONAE. It was launched in June 2011, and it ended its life cycle in June 2015. It has three radiometers in push-broom configuration. It has a spatial resolution of 150 kilometers, and a revisit time of one week.

Cynthia Garcia-Eidell (12:16):

Before Aquarius died, it was followed by the launch of SMAP or the soil moisture active passive, probably it's popular for those studying soil moisture right now. It was launched in January 2015. Just like Aquarius it was supposed to be an active passive, however, the active component, the scatterometer malfunctioned a few months after the launch. It is a conical scanning beam radar, unlike Aquarius in a push-broom, spatial resolution is higher. It's 40 kilometer and the revisit time of SMAP is eight days, right? So these are the three satellites or sensors now that are available specifically for salinity.

Cynthia Garcia-Eidell (12:59):

The main objectives of those sensors are basically what I mentioned earlier as to why we study salinity. And that is to monitor global salinity or fresh water changes. For example, here, plumes from Congo river or the plume of the Amazon river, or the fresh water transport to the north Atlantic, which is important in thermohaline circulation and deep water formation, as well as the tropical rain band here in the Pacific and the relatively fresh water in the Pacific. Also, you will see here, some of the really fresh areas of the Bay of Bengal and mouths of other rivers.

Cynthia Garcia-Eidell (13:37):

Great. And another important in understanding or measuring salinity from space is validation of those satellites compared with NC2 measurements. And this is precisely what we did in this project in 2017, where we compared four products of salinity in the Arctic. I used three salinity products from Aquarius. One is from NSIDC and JPL uses the NASA JPL algorithm. And then AqGSFC uses the Goddard Space Flight Center algorithm. The SMOS product that we use is produced by the Barcelona Expert Center. And I would just go with you here on how we produced the AqGSFC polar-gridded product.

Cynthia Garcia-Eidell (14:27):

So basically we started with orbital swath of the salinity and orbital swath looks like this. So that's the swath of Aquarius. The swath width of Aquarius is about 350 kilometers. And the color here is salinity off the surface. So from the orbital swath, we did some data quality control there eliminating data that are potentially contaminated by land. So we remove pixels where we're seeing land fraction greater than 1%. We remove pixels or discarded data where wind speed is high or greater than 20 meters per second, surface temperatures that are freezing, sea water freezing temperature for sea water, or salinity that has greater than 50 or less than 20, as well as the use of other quality flags like for radio frequency interference, as well as instances for pointing anomaly.

Cynthia Garcia-Eidell (15:21):

We then applied a median filter along track. Remember Aquarius has three beams, right? So these are the three beams of Aquarius. And we applied a median filter with a window of nine to get rid of the short wavelength noise, if you observe here. After that, this is an important step. We masked out salinity measurements that are potentially contaminated by sea ice, which is again important in the Arctic. And for this, we used the higher resolution sea ice concentration SB2 data by Joey Comiso. Sea ice concentration with greater than 10% were removed in the processing.

Cynthia Garcia-Eidell (15:59):

To deal with missing data, we applied a linear interpolation for pixels with missing data. However, when there's more than 16 adjoining pixels that are missing, we just applied a NaN or not a number. We gridded everything in a polar stereographic grid. This is an example of polar stereographic grid at 12.5 kilometer resolution on a running weekly average. And this product, the AqGSFC is available in the NASA website here. And this is the link, if you're interested to explore that and use it for your studies.

Cynthia Garcia-Eidell (16:34):

So we used all four, and we compared the four satellite measurements with NC2 measurements from ship based data. What I'm showing here are the track of polar strength, the icebreaker Polarstern. The color here is showing the salinity as measured by the ship thermosalinograph. I also included here the sea ice edge. So you can see that the Polarstern really broke ice like went through the ice, right?

Cynthia Garcia-Eidell (17:01):

Aside from thermosalinograph, we also got data from the ARGO floats, like what I mentioned earlier, as well as CTD data from the Coriolis database for the time period of our study. And we see here that there are limitations in terms of measurements from ARGO and others in the higher latitudes. And when compared with NC2 data, we observed that AqGSFC outperformed other available SSS products.

Cynthia Garcia-Eidell (17:31):

We also observed that when we track it with seasonality of sea ice concentration, that all four were able to track the change of sea ice wherein during the sea ice minima in September, we see the ... By the way, sea ice is the dash line here, the gray dash line. We see that salinity also drops. So that's when we see fresh waters. And during sea ice formation and in winter, we see that salinity increases mostly because of brine rejection. And after we published this paper in 2017, we were fortunate enough to be featured in the AGU Eos research spotlight for that month.

Cynthia Garcia-Eidell (18:18):

And then after that, so that's for the Arctic. We followed it with our study in the Southern ocean. So basically did the same thing. And the salinity measurements that we got basically, we observed that the changes that we saw are associated with sea ice precipitation and polar fronts, which were expected, and that we can use this salinity products to look at the changes in the potentially other parts of that system, such as the phytoplankton blooms near the ice edge, which is precisely what we did with our journal climate paper that's currently in review.

Cynthia Garcia-Eidell (18:57):

Another opportunity that was presented to us with this paper in 2019 is that the SMAP dataset was publicly available already then. However, the SMAP dataset then was just a version one, we're now at version four. So the version one, there were challenges in terms of capturing the seasonality and annual variability of salinity. So that's salinity when we compare SMAP and Aquarius.

Cynthia Garcia-Eidell (19:26):

All right. So now, let's go to the other major findings here. I'm highlighting some of the major findings on salinity from NC2 as well as from satellites. So in terms of relationship with hydrologic cycle, climate prediction, marine ecosystems, and bio geochemistry. So if I were to summarize the mean patterns that we're seeing from salinity from NC2 and satellites it's this, that salty gets saltier and fresh gets fresher. From studies by Curry and others in 2003, Boyer and others in 2005, basically through transects from ships, they're seeing a general freshening of the global ocean, as well as a general decrease in salinity along the poles and increasing salinity in lower latitudes, probably in high evaporation regions like the centers of subtropical gyres, and freshening in high latitudes in the tropics, in the tropical rain band.

Cynthia Garcia-Eidell (20:30):

In terms of the relationship of salinity with climate change, so studies like that of Durack and others and Vinogradova and Ponte and others using ECCO for example, this is estimating circulation and climate of the ocean data sets. We're observing that for warming, for example, for Durack, half a degree Celsius of surface warming, they inferred a water flux amplification of 8% per degree Celsius, which is close to the Clausius-Clapeyron rate of 7% per degree Celsius. Similar, again, Vinogradova and Ponte performed the same experiment and they observed a 7.6% per degree warming of the lower troposphere.

Cynthia Garcia-Eidell (21:17):

More and more we're also seeing studies on polar and subpolar freshening using satellite data sets, including this study by Alexander and Haumann in 2016, where they observed a freshening rate of 0.2 PSU per decade in Antarctica, mostly observed along the Ross Sea and the Bellingshausen-Amundsen Seas, which is well known now as a warming spot. Maybe you will note that 0.2 PSU is not a lot, but remember, salinity has a very low dynamic range, right? And so that could mean a lot in our climate.

Cynthia Garcia-Eidell (21:55):

It's also now being used to improve our predictions of the El Niño-Southern Oscillation. Because it provides us with a really good estimate of the mixed layer dynamics, and also surprisingly salinity is now a meaningful predictor of summer precipitation as well as monsoonal precipitation in the African Sahel. So Li and others in 2016 used sea surface salinity from satellites along with other 10 climate variables. And they saw that salinity ranked as the most important predictor for land precipitation.

Cynthia Garcia-Eidell (22:31):

For this also, lastly, salinity can also be used as for space based assessment of ocean acidification, which is typically assessed using NC2 measurements, right? Because of the linear relationship of salinity and total alkalinity, Fine and others in 2017 took advantage of that relationship with salinity as the first guess for space based assessment of ocean acidification.

Cynthia Garcia-Eidell (22:59):

And just early this year, we used the AqGSFC SSS to polar-gridded salinity to analyze the changes that are happening in the Antarctic marginal ice zone. And to visualize that, the red line here every time step here is a weekly change in the marginal ice zone area. So we gathered data from that marginal ice zone, and we saw a robust connection of spring and summer chlorophyll blooms within the low salinity surface layers. So if you can imagine that here, when you have fresh waters that are melting from the ice sheet and the sea ice carrying with it nutrients and is also buoyant, right? So this fresh water lens is an ideal platform for photosynthesis having the free floating phytoplankton in the euphotic zone. And this is only made possible because this large scale analysis is only made possible because of the concurrent availability of salinity sea ice temperature and chlorophyll A concentration that we now have.

Cynthia Garcia-Eidell (24:00):

And lastly, salinity can also be used now to trace the origin and fate of freshwater signal to help improve our understanding of the LOL, the land ocean linkages, right? Examples are understanding the watershed influence on the marine components, so marine region of influence. And here, I'm showing the plumes or the salinity trends from SMAP next to the river mouth, the Mississippi river mouth, the Congo river mouth, and the Amazon river mouth. And we can use the cell trend as the spatial extent of the marine region of influence of different watersheds, thereby helping us study this coupling between land and ocean.

Cynthia Garcia-Eidell (24:46):

So main takeaways here. So traditional ways in determining salinity were challenging and time consuming. Some of them trying to titrate samples in the ship. Imagine it in a really bad weather, but now with satellite salinity, we are learning the connection between ocean and the hydrologic cycle with a mean pattern of salinity, salty becoming saltier, and fresh becoming fresher. We are learning more about water mass formation, oceanic features such as eddies and important ocean dynamics. Improvement of prediction of climate indices, models, land processes, and carbon fluxes, as well as understanding critical areas in climate change, like the polar regions, as well as land ocean interactions.

Cynthia Garcia-Eidell (25:33):

So looking ahead, ocean and carbon models need to account salinity effects in order to represent the ocean state more. We need more of satellite SSS coverage to continue the robustness of data through longer records. And lastly, in terms of me, for my research application of salinity on identifying spatial extent of the marine region of influence of major river basins in the world. And that's it for me. Thank you very much, everyone, for listening. And I'm excited for the discussions.

Teresa (26:05):

Thank you so much, Cynthia Garcia-Eidell. If anyone has questions, you should be able to unmute yourself now.

Cynthia Garcia-Eidell (26:14):

Oh, by the way, I'd also want to advertise this documentary Frozen Obsession. This is documentary about our research expedition through the Northwest passage. It'll be available in the PBS station, WTTW. I'm not sure what channel that is, the channel. I'm not sure channel 11. It'll be shown in April 18 and April 22 on these times.

Speaker 3 (26:42):

Cynthia, will you tell us how you got into doing the Arctic researching and how you applied for that and how that actually got you started? So just a little background for the students to know how you found such a great opportunity.

Cynthia Garcia-Eidell (26:58):

Sure. So Dr. Joey Comiso ... So what I said earlier, I grew up in the Philippines. I studied in the Philippines, and Dr. Joey Comiso is a NASA scientist, and he's also a Filipino, and he's actually in the participants right now. He gives climate change talks in the Philippines. And I basically introduced myself and I said, "I'm interested in this. And I just finished my masters in environmental engineering, and I have these abilities to code and process data, et cetera." And there, so I basically got in touch with him and we exchanged emails. And then before I knew it, I was part of the project. So very thankful to Dr. Joey Comiso for that opportunity and for the training.

Speaker 3 (27:44):

So basically for students that are listening, they should not be afraid to reach out to people if they're interested in the person's research to make that connection.

Cynthia Garcia-Eidell (27:53):

Exactly. I think that's a very important thing to not be afraid to ask questions, not be afraid to email, reach out. Yeah.

Courtney (28:01):

Hi, I have a question. My name is Courtney. I attend North Illinois University. I just had a question about like, if the salinity of the water, if it doesn't change, how do you think this is going to affect how ... I know there's different predictions of how much time you think we would have to make these changes or to discover a way to reverse the effects that we've put the climate through.

Cynthia Garcia-Eidell (28:36):

How much time do you think we have now in terms of climate change?

Courtney (28:41):

Yeah. Like more negatively effect of the climate. I know it's already causing melting of ice and stuff like that, but what else could be expected possibly?

Cynthia Garcia-Eidell (29:01):

Yeah. That's a great question. So for the use of salinity, we can definitely track those changes, right? Because salinity is a signal of the hydrologic cycle and whether the hydrologic cycle is amplified, right? Whether that is more fresh water flux coming from the polar regions, which would have potentially adverse effect on the thermohaline circulation. I mentioned earlier that that is the circulation of the cold and warm waters in our planet that modulates our climate. So we can use salinity to identify that. And actually, some of the studies that are coming out now is characterizing the conveyor belt of the ocean as slowing down. In terms of the rate, modeling is we're still improving that, but hopefully with the information of salinity, we can help in really representing the ocean state because salinity is fairly new. It's only been available in the last decade, unlike salt temperature that has been available in a couple of decades now. Yeah. That's our goal really understand it more using salinity.

Teresa (30:17):

We do have another question in the chat. Basically, someone would like to know since you've been developing your field work, what has been the most interesting adventure that you've been on while you're doing that?

Cynthia Garcia-Eidell (30:30):

Yeah. So being in the Arctic was really ... it's out of this world. It's literally in figuratively being on top of the world. Right? But for me, the experience of riding the helicopter out of the icebreaker and then landing on an ice flow and then coring that ice flow while that ice flow is slowly drifting along barrel straight. So that experience was definitely surreal, but really, it gave me another perspective in terms of viewing that data because not a lot of people can go there and get that sample. So I value the data more because of the difficulty, the challenges that we went through just to get that sample. So, yeah, and it's important for us to study large scale changes from the pixels from satellites, but also it's important for us to identify whether those signals are really nature. And that's why we go to the field work and validate those measurements from space.