CNRC intern Elizabeth Panner conducted this interview with Dr. Jon Derek Loftis, Assistant Research Scientist at the Virginia Institute of Marine Science (VIMS) on September 18, 2020. Dr. Loftis installed tidal watershed monitoring equipment at the CNRC in summer 2020 that feeds data into a regional network of StormSense water sensors for the sake of predicting storm surge. (This interview has been condensed due to its original long length.)

1. In the description of your project, you mentioned that the water sensors are "Internet-of-Things"-enabled. How does that special feature impact your ability to utilize and collect the data?

   Internet-of-Things (IoT) allows the water sensors to send information in real time to the StormSense network. Whereas it used to be that sensors would record data that could only be collected manually a few months after the fact, now most sensors - those maintained by the government and VIMS - send data every few minutes. The government sensors, for instance, those maintained by National Oceanic and Atmospheric Administration (NOAA) and US Geological Survey, use satellite to transmit data. This approach is very expensive, however. By contrast, IoT uses cell service to do the same thing, since many places have 3G or 4G. If the cell service cuts out, the sensors will continue to collect data and store it to be collected manually. If the cell service is working, the information is sent to a network maintained by StormSense and it can then be used to report flooding and make predictions in real time.

2. What are the different data that the equipment collects?

   Most of the water sensors maintained by StormSense only collect water-level data. Most of the sensors are placed directly above the water so that they have a downward view of water levels. The data is used to make flooding predictions. Some cities or locations that have issues with road conditions – like icy roads or bridges - opt also to measure water-temperature or salinity, but these additional data collection points add cost to the monitoring equipment. The sensor at the CNRC is a simple design that only monitors water level.

3. Why is the water monitoring system designed the way that it is? How does it collect data? Which elements allow it to withstand different conditions and continue to function? Are solar panels always able to provide enough energy and why was this the method you chose to power the sensors?

   The IoT sensors, in addition to their data-transmitting capabilities, are low-cost and use a relatively small amount of energy. This means they are able to be run entirely on solar panels. Of course, many of the times when these sensors are most valuable, during storms, there is limited to no sunlight available. So, each sensor is equipped with a solar controller which maintains the battery level and helps recharge it using the panel. The panel is 1-2 times as big as it needs to be to last through rainy days. In terms of the water sensors, they aren't actually in the water, like another common type that measures water level using the amount of pressure above it. This latter approach tends to pose problems, since algae and other things will grow on it over time making it less accurate, or people tend to run over them with boats, unaware of what they are. Instead, the sensor at CNRC uses something called an ultrasonic sensor. These are non-contact—meaning the measuring device never actually has to touch the water, which is helpful to avoid issues with algae and other things that may be in the water. These sensors emit a pulse of sound—too high to hear—and then measure how long it takes for that sound to reflect back from the water. They then use the speed of sound to calculate how far away the water is. Sometimes, near military installations where there are lots of sounds of different frequencies that may interrupt things, radar sensors are used, which operate similarly, only with radio waves.

4. Why did you place the sensors where you did?

   The sensors are placed in areas that have issues with frequent flooding. The cities of Hampton Roads, Virginia Beach, Newport News, and Norfolk were the first cities to be a part of StormSense, though others have joined since. Cities will become a part of the network and thereby provide their citizens information on what's happening in the area. Marlborough Point was one area where sensors were lacking, and so one was placed at CNRC.

5. What are some examples of the different types of organizations that use the VIMS Tidewatch Network? Why do they utilize it?

   Cities use the StormSense network to provide information to their citizens so that they can then make their own plans based on the predictions. This service to their citizens then qualifies for the Community Rating System, a program of the National Flood Insurance Program which is part of FEMA. This program gives cities that take action against flooding, beyond the minimal requirements, reduced flooding insurance premium rates. There are a variety of ways that the city puts out this information. One way is that elevation of roads is tied into the data collected by the sensors. That way, once the water-level gets to a certain point, alerts can be automatically sent out that the roads are starting to flood. Another way the flood data are being used is to collaborate with navigation services like Google Maps, Apple Maps, and Waze. Right now, those apps don't know when it's flooding, and will actually direct people into inundated roads. They are programmed to take users where there is the least amount of traffic, and so, of course, when roads are flooded the route is fairly traffic-free. This lack of coordinated information poses a big problem, particularly in Hampton Roads and Virginia Beach, since there are lots of military families who don't realize how bad the flooding really is and will end up losing their cars after driving through an inundated road. The information also will be available through Amazon Web Services, so you could ask Alexa what the water level is. Cities sometimes have their own apps to put out alerts; Newport News has NN alerts to tell people when there's flooding, and the City of Virginia Beach has an app covering all of Virginia's sensors.

6. It seems like the data collected by the monitors both inform predictions and allow for the fine-tuning of the modeling that makes these predictions. How accurate is the modeling now and how much more accuracy can you expect to achieve? What will it take to make these adjustments?

   One of the reasons the StormSense network was first developed was to validate the hydrodynamic modeling that VIMS had developed. Before installing and using sensors throughout Virginia, there was no real way for them to know that their assumptions were true. NOAA had sensors, and soon they became cheap enough that VIMS could install their own. The model was quite accurate, but it's a continuous work in progress since the elements keeps changing. Every twelve hours, the National Weather Service wind and pressure information is updated to predict where inundation will happen. Elevation also plays a big part. The model needs to know how much space there is for the water to go—which means how deep rivers and creeks are as well as new land features like culverts and ditches. Another feature that can affect accuracy is friction between the water and the land it flows over. This relationship helps determine how strong the flow of water will be farther downstream. Flow rate changes depending on whether it's flowing over mud or grass—and grass can even soak up some of the water. This land composition will change as sea-levels rise and certain areas become more drowned. The data that the sensors collect constantly check the assumptions of the model to find if there are errors in elevation or surfaces. In this way the model is always being updated to ensure it makes accurate predictions.

7. It seems like many of the outcomes you hope to get from the monitoring equipment have to do with understanding wetlands and how they are affected by environmental change. What are the data that will allow you to understand this piece better?

   A lot of the data collected by the water monitors can be fed into a model to find what will happen overtime as things like sea-level rise occur. The model tracks what will happen to some animals and plants as waters become saltier or areas become drowned and less vegetated. One thing happening near Marlborough Point right now is that there has been a lot of rainfall in the past year, meaning lots of fresh water. Most plant-life is not saltwater tolerant and will be vulnerable due to salt-burn later as the saltwater inevitably comes during big storms that push rising tidal water farther inland. Changes like these affect the animals that depend on those plants for food or shelter as well. Using water-level data, VIMS can plot what will happen to trees, woody species, and shrubs in wetlands and the intertidal areas that are frequently flooded.

8. How will this data allow you to protect wetlands better?

   The information the sensor provides will be able to tell what's happening every six minutes, and then predict inundation up to 36 hours in advance. This gives time for mitigating efforts so that things or people can be moved or move to higher ground, if needed. At CNRC, the frequency of flooding above a certain point is one of the main data points that we'll assess as well as tracking what's going on in the wetlands over time. The water levels are different than in Washington, DC or Dahlgren nearby, so this data may provide additional insight.

9. I saw that the "Catch the King Tide" project won a Guinness world record because of the amount of data collected by so many citizen scientists. What do you think made this project so compelling to all of these people?

   The Catch the King Tide event happens at the highest astronomical tide of the year, which occurs on October 18 in 2020. This year there are fewer volunteers, since people are wary of being outside with the coronavirus pandemic, and so while some zoom-classes have been given to new participants, it is mostly former data collectors who will be participating. These volunteers use a sea-level rise app to mark where the high-water line is wherever they can see it. Virginia Beach, Chesapeake, and Hampton Roads are the main participants, with some in Williamsburg, Newport News, and places farther up like Alexandria. One important piece is that there be good cell-service, since that affects the accuracy of the GPS. For this reason, there isn't a lot of recruiting along the eastern shore or parts of northern Virginia near CNRC where cell service isn't so reliable. There have been so many volunteers, though, because flooding is such a pervasive issue in these communities. They want to be able to use the StormSense network to make decisions before flood events, and so they want to help improve its accuracy. There can be issues due to incorrect elevations in areas that can't be seen like under bridges or new culverts. Citizens who are familiar with areas and know that the model has been incorrect help to fix those errors. In the model those new creeks or ditches or culverts—whatever it may be—can be added.

10. Some of the data seems to have to do with water quality – algal blooms, contagions, hypoxia. Can any of these problems or conditions be predicted using the water level sensors? How do these factors affect people who use the local waterways for recreation or commercial reasons? What are some ways that this data will inform the actions taken to address these issues?

    It's mostly water quality sensors that will tell us that information. However, the water level data can tell you something based on why they are high. If it's due to rainfall during the summer or fall, then there may be algal blooms due to high amounts of fertilizer from farmlands. The nitrogen and phosphorus get into the water and algal species consume those nutrients and their population goes up. Algal blooms can be very harmful. Some types of algae produce toxins dangerous to both humans and animals and make swimming in the water hazardous. In addition, when the algae die, decomposing them requires large amounts of oxygen. Then there isn't enough oxygen left in the water to support aquatic life including young fish, crabs, and shellfish. These issues pose threats to commercial fishing and also to other economic areas like real estate values, which go down because of the odor and sight of algal blooms, as well as raising the cost of drinking water with increased filtration required

11. Are there some longer-term research projects that VIMS contributes to with its modeling?

VIMS keeps track of all of the major flooding events they have recorded, including hurricane Dorian, Isabel, Irene, and Matthew among others. The data includes both predictions VIMS made and the actual flooding that occurred. We can use that data to find what a big storm in the past would be like in 2040, based on increased water-levels. We also can help predict loss of wetlands. Diminished wetlands negatively impact ecosystem services those wetlands otherwise would provide, so adjustments may need to be made to wastewater treatment plants at a county or state level. The model can see how wetlands might migrate farther inland. But you know how we love our waterfront property! A lot of people try to slow or prevent rising waters from making their way further inland. Marshland plants start to populate peoples' backyards. These plants help anchor the land, but people may cut or mow them down in favor of lawn and grass. Waterfront property poses its own risk to that as those marshland plants are mowed or removed. So, there you have the gist of all the different research applications that the VIMS tidal monitors have at the Crow's Nest Research Center.