

EPISODE FORTY-THREE OF "ARMED WITH SCIENCE: RESEARCH APPLICATIONS FOR THE MODERN MILITARY," A DEPARTMENT OF DEFENSE WEBCAST HOST: JOHN OHAB GUEST: LIEUTENANT COMMANDER JEREMY CALLAHAN, OPERATIONS OFFICER, JOINT TYPHOON WARNING CENTER (JTWS) DATE: TUESDAY, NOVEMBER 10, 2009

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ANNOUNCER: Armed with Science Research and Applications for the Modern Military is a weekly webcast that discusses cutting-edge science and technology and how they apply to military operations. Each week we will interview scientists, administrators and operators to educate and inform our listeners about the importance of science and technology to the modern military.

DR. OHAB: Good afternoon and welcome. You are listening to Episode Number 43 of Armed with Science, Research and Applications for the Modern Military on Tuesday, November 10, 2009. I am your host, Dr. John Ohab at the office of the Assistant Secretary of Defense for Public Affairs.

Today we are joined by Lieutenant Commander Jeremy Callahan, Operations Officer at the Joint Typhoon Warning Center. He'll give us a primer on the field of tropical meteorology and explain how the Joint Typhoon Warning Center relies on the latest satellite technology, improvements in computer modeling, and partnerships with other federal agencies to accomplish its mission.

Lieutenant Commander Callahan, thank you so much for taking the time to be here today. I know it's early, but you're in Hawaii, so I don't feel quite so bad.

LT. CMDR. CALLAHAN: Good morning, John.

DR. OHAB: Quick note to our listeners. If you have any questions on matters typhoon, weather technology or otherwise, please tweet them to [atarmedwscience](https://twitter.com/atarmedwscience), and I will make sure to get those to Lieutenant Commander Callahan by the end of the show.

Now this is a science show, but in light of the Joint Typhoon Warning Center's 50th anniversary this year, we're going to start today with a bit of a history lesson. Can you tell us how the Center got its start and what kind of role you play today?

LT. CMDR. CALLAHAN: Well, the Joint Typhoon Warning Center was established by the United States Pacific Command in 1959. As you mentioned, 50th anniversary. It actually formed out of consolidation of several smaller tropical forecast centers that were scattered throughout the Pacific Region, and those were actually created in the wake of what's known as Halsey's Typhoon or Typhoon Cobra, which happened in 1944, right near the end of World War II.

It was actually the worst disaster in U.S. Naval history. Something like 790 lives were lost and ships were sunk and aircraft were lost. And Russia got hit by a couple of typhoons in 1945. Consolidated those centers in 1959 to create the JTWC, which was originally out in Guam and then with the BRAC closures it eventually got moved out here to Pearl Harbor.

Our responsibility is basically the tropical cyclone reconnaissance and forecasting in the Pacific Command and United States Central Command areas of responsibility, so that's basically the West Coast of the Americas out to the East Coast of Africa. We actually only do the forecasting west of the dateline. The Central Pacific Hurricane Center and National Hurricane Center, we use their forecasts east of the dateline in the Pacific Ocean and apply those to the Department of Defense uses, but our area includes both the northern and southern hemispheres. So right now, where the northern hemisphere is starting to wind down, it's early November. We're starting to see the number of tropical cyclones fall off.

We're just starting to gear up for the southern hemisphere, so it's a year-round job here and with both hemispheres in the Pacific and Indian Ocean, we actually cover about 89 percent of the world's tropical cyclones within our AOR. And then our customers are predominantly the Department of Defense, but we also support U.S. government assets, so we have U.S. bases in that AOR. The ships that operate throughout the area are our responsibility, U.S. embassies that are west of the date line and U.S. territories, so for instance, Guam is a U.S. territory. It's west of the date line so the National Weather Service office there uses the JTWC forecast to produce its local forecast if they're being threatened by a tropical cyclone.

DR. OHAB: Now is the Joint Typhoon Warning Center the only organization forecasting for tropical cyclones in that region of the world?

LT. CMDR. CALLAHAN: No, actually, every region has a world meteorological organization designated center that supports the general public. A world meteorological organization is a department of the United Nations and they have assigned these centers to protect the civilian populace and so, for instance, the National Hurricane Center is the world meteorological organization designated center for North America, so they're the official forecaster for the U.S., Canada, Cuba and the Caribbean.

Out in the western Pacific, where we do most of our business, Japan is the official forecasting agency and then India and the northern

Indian Ocean and Australia and there's a couple other bases, and they provide the official forecast for civilian populace and they're also responsible for the naming of storms, so if you look at our products, we'll combine both our numbering designation and the official name to alleviate any confusion, but we don't actually produce the name that you'll see listed with our products.

DR. OHAB: Well, earlier in the year we interviewed the National Ice Center and they talked about naming the icebergs, so we got the naming of the icebergs and the storms down. Now I know I've heard a number of different terms over the years -- hurricanes, tropical cyclones, typhoons. Can you help us get a handle on some of this terminology and what actually constitutes a tropical cyclone?

LT. CMDR. CALLAHAN: Well, a tropical cyclone is the generic name for these systems and they're warm core cyclonic systems in the tropics. To break that down, a warm core system is different than what we normally see happening through North America, which is a cold core system associated with a cold front and a warm front, but a warm core system, which is down in the tropics, is being fueled by -- I'm going to get a little sciencey here -- the release of latent heat, so as warm, moist air starts to move up in the atmosphere, up to higher elevations.

It expands and it releases the moisture because the expanding edges can't keep as much water as solution and that condensation of the water releases latent heat and that latent heat then warms the area even more and becomes more buoyant and it becomes almost a heat engine, a big circulation in the vertical extent. And that's its cyclonic turn; that's in the northern hemisphere systems that are turning counter-clockwise and in the southern hemisphere the systems are turning clockwise and down in the tropics. These systems, in order to create themselves and to live, they need five factors, really, that we like to track. They need warm water in order to produce the warm, moist air, they need low vertical wind shear.

Vertical wind shear is a description of how the wind is different throughout the column of air, so the systems kind of need wind to be pretty much the same throughout the vertical extent; otherwise, it disrupts that vertical flow of the air as it starts to expand and release the latent heat.

It needs the coriolis effect, the tendency of a parcel of air to turn to the right in the northern hemisphere as it moves along a trajectory. That's actually what causes these systems to start to spin. The coriolis effect is everywhere, but it's much, much less, actually, at the equator and it increases as you get towards the poles, but obviously as it increases toward the poles, the water temperature starts to go down, so it actually defines a pretty narrow band that the tropical cyclones can form.

Then the outflow, all this rising air, needs to go somewhere, and if the wind is converging above this area it will cap off the rising air and it won't be able to sustain itself and then, generally, it needs a preexisting disturbance because the tropical air is actually pretty

stable, but once it gets perturbed and a little bit of disturbance happens, then it can start to release this latent heat and then it becomes self-sustaining.

Now you mentioned several different terminology and, as I said, they're all tropical cyclones, but hurricanes are what we're most familiar with in North America but those define systems that are over 64 knots in the northeast Pacific Ocean and the north Atlantic Ocean and the same intensity for a typhoon defines that same, about 64 knot, system in the northwest Pacific Ocean.

Tropical storms are 35 to 64 knots; the tropical depressions are 25 to 34 knots, and, as I said, all of them are tropical cyclones.

So, for instance in the Indian Ocean, I had mentioned that's outside of where hurricanes and typhoons are, we just call -- even if they're above 64 knots, they're still just a tropical cyclone.

DR. OHAB: Now, you mentioned a couple of primary functions of the center. One was forecasting for these tropical systems. The other was cyclone reconnaissance. We're going to get to both of those, but first can you tell us about tropical forecasting. LT. CMDR. CALLAHAN: Well, the Joint Typhoon Warning Center, or JTWC, forecasts -- our main products are the storm track, the horizontal extent of the winds and the intensity of the systems, so that's what we're actually forecasting for. The actual local effects, like local wind and storm surge and precipitation, is done by the cognizant local entity, but to do that forecast is very complex, so we use very large complex computer models run on super computers. We actually have a large suite of these computer models with specially designed tropical cyclone trackers within the model.

They're created by numerical computer models that describe how the atmosphere behaves by taking an initial set of conditions, mainly developed by observations taken around the world, and create a numerical description of the atmosphere that's then set into motion using the laws of physics and the mathematical equation that describe those laws of physics. And these computer models generally can depict out for several weeks what the atmosphere is going to do, but they tend to start to lose the ability to do tropical cyclones after about five days. And these models are what we predominantly use to do our tropical forecasting.

DR. OHAB: Now are these weather models run there at the Joint Typhoon Warning Center?

LT. CMDR. CALLAHAN: Actually, some are run here at Joint Typhoon Warning Center, but most are run elsewhere. For instance, the Navy has some models that are being run at the Fleet Numerical Meteorological and Oceanography Center, also known as CIMOC. The National Center for Environmental Prediction, which is the NOES computing center, run some of these models. Air Force Weather Agency runs a model for us. And then in addition to the U.S. agencies, we actually are getting models that are run by foreign meteorological agencies, such as

Japan, the European Center Meteorology, the United Kingdom Met Office. Australia contributes a model that we use.

And these models are, actually, there are a mix of these models that run at these different agencies that can depict, they're both global models that depict the whole planet's atmosphere and some regional models that just do a small base center, such as just the western Pacific Ocean or just the Gulf of Mexico. The larger ones do a good job on the overall flow and the overall track.

One of the big things that we're always trying to do is get a good analysis of the subtropical ridge, which is a delta of high pressure just north and south of the tropics that circles the entire earth, and the analysis of that is the key to good track forecasting and this is handled very well by the global models, but we also need the small, regional models because the global models don't have the resolution, just because of the scale of doing the whole earth, they can't do small resolution forecasting, so we need the smaller regional models to be able to do the structure of the cyclone and what the winds are and then how the system is actually behaving with the local environment. And the way we use all these models is actually what we call consensus-based forecasting, which takes currently our eight best models and it's a straight average of where those eight best models are taken, the track, and we evaluate models for several years before they actually go into this because if someone claims they have the latest and greatest model, we could just throw it in, but we could learn that it brings down our average so we evaluate them for several years and see if it actually brings up our average and then we take this consensus and that's the basis for our forecast.

And actually we've learned over the years that we can't beat the consensus. It statistically actually has a better error rate than the official forecasts, but we base our forecast on the consensus and we go from there.

DR. OHAB: Talking with Lt. Commander Jeremy Callahan. He's the Operations Officer at the Joint Typhoon Warning Center. At the core, you are a meteorologist. Can you tell us about your background and how you came to be at the center?

LT. CMDR. CALLAHAN: My background is, I've been a naval meteorologist for a little over 11 years. The Navy has a pipeline for their meteorology officers. We go to a basic meteorology school that only lasts for a couple months to give you an idea of how meteorology is used in the military and an idea of what kind of products and support the military gives. Then following that we generally go to what's kind of a hands-on training tour, where we work under the mentorship of more experienced forecasters and actually support the operators.

And so I went through that and then, following that tour, pretty much all of the meteorologists in the Navy will then go through the Naval Postgraduate School and get their masters degree in meteorology. And then, following that, I've gone through a couple other tours where I've done meteorology in the Navy and, following my sea tour, where I was

supporting operations on one of the large deck amphibious assault ships, I came here to become the Operations Officer. I'm starting to move out of the actual direct forecasting and starting to move into the leadership role where I'm supporting the forecasters that are putting out the products.

DR. OHAB: Now, I imagine there is a lot of research being done at the Joint Typhoon Warning Center, investigating both models which you've talked a little bit about, and the effects of the tropical cyclones. Can you tell us about that a little bit.

LT. CMDR. CALLAHAN: We actually do very little of our own research here at the Joint Typhoon Warning Center. Surprisingly, we're only comprised of 19 people right now. What research that we do here is primarily the evaluation of the new techniques and research done by other agencies and see how they can support the JTWC operations. As I mentioned, most of the research and development is done at other locations. Primarily we use the Naval Research Lab, Marine Meteorology Division in Monterey, California, but in addition to them, we also have, as I mentioned, the Fleet Numerical Meteorology and Oceanography Center that run some of our models, does some model development and some other computer development for us. In addition to that, there's the Naval Postgraduate School that I mentioned that I went to get my masters degree.

We have a lot of naval and air force students that go through and do a lot of research.

All three of those centers are all located in Monterey, California, both by design and coincidence, so there's a very close relationship between those three entities and they do a lot of support, both in model development and techniques development and statistical analysis, over the years that we use and we leverage to do our own improvement in our forecasting.

And outside of the federal agencies, we also get support -- actually, outside of the Navy, we also get support from the Colorado State University and the University of Wisconsin. They both do a lot of tropical cyclone research and they actually produce some products that we use operationally in our forecasts, so we have very close relationships with those two agencies. And in addition to those, we also get a lot of the research that's done at the NOE labs that support the National Hurricane Center, specifically the Geophysical Fluid Dynamics Lab produces a lot of new computer model development that we have been able to use in our development.

For instance, one of the models that's being produced by the Geophysical Fluid Dynamics Lab that we just put into use is their model that, they used to use a model, 1-D ocean coupling and now we're using our new model they just developed as a 3-D ocean coupling. A quick synopsis of that is that I mentioned that tropical cyclones rely a lot on the latent heat release to fuel them and that latent heat is being picked up from the ocean.

The 1-D coupled model would just pretty much model the heat that was being released by the ocean through the normal mixing of the waves and the wind, but the new 3-D coupling can now determine if there's deep, warm water below the system that some systems are able to tap into through a process called up-welling. And if they can do that, they're known to go undergo rapid intensification.

We saw that with Hurricane Katrina in 2005. It went over the loop current in the Gulf of Mexico when it went up to a Category 5 hurricane, and this model shows a lot of promise in being able to start modeling that, identifying that before it happens. You can see why we'd be excited about that. We also are getting excited about the Navy's global model called No Gaps, starting to do a new four-dimensional data assimilation, so instead of just taking a snapshot of the data that they do the initialization off of, it's able to do it over the six hours before the model runs, so it's able to get, instead of just the static picture, it's able to get trends in the data and, hopefully, get a better initialization off before the model starts to run.

We also just implemented the Navy's regional model, COAMPS. They have a specialized tropical cyclone tracker that we're currently under evaluation of and then the Air Force weather agencies is running a regional model called HWARF that also is starting to implement a TC tracker, so there's a lot of good model development right now and some other research that we're starting to get excited about.

DR. OHAB: One thing you mentioned was that Katrina was a Category 5 hurricane. Could you talk about how the category relates to the storm intensity?

LT. CMDR. CALLAHAN: Actually, out here in the Joint Typhoon Warning Center AOR, since we only do the typhoons, tropical cyclone designation, we don't use the Saffir-Simpson scale of categories and so the only cutoff point that we use is in the Western Pacific; we have the typhoons which are above 64 knots, but then we also have the super typhoon category at 130 knots, which actually, I think falls in between a Category 4 and a Category 5, but outside of that, we don't do that a lot. But the categories for Saffir-Simpson, it's one through five and it's the minor and major hurricane intensities that go up above 140 knots, so Katrina got up to the highest category, the Category 5, based on that sudden ability to get a whole bunch of heat out of that loop current in the Gulf of Mexico.

DR. OHAB: Now earlier you said the Joint Typhoon Warning Center was also responsible for cyclone reconnaissance. Does that mean that you actually direct aircraft like the hurricane hunters to fly into the storms?

LT. CMDR. CALLAHAN: Actually, they used to do the hurricane reconnaissance or the typhoon reconnaissance out in the Western Pacific, but that ended in 1987. But we now use a suite of remote sensing technologies set on geostationary and polar orbiting satellites, along with shore and ship observations, to do that reconnaissance. Geostationary satellite is one that's at a high orbit and does not move

in relation to the earth's surface, so it stays over a single location the whole time the earth rotates and the polar orbiters rotate from the south to the north and then back from the north to the south and cross the poles as the earth literally spins underneath them and, over the course of 12 hours, can cover most of the planet.

And then we're also able to leverage some observations from other agencies that are doing some reconnaissance. Specifically, Taiwan has a DOTSTAR aircraft that doesn't actually fly into the typhoons, but goes around the periphery and we're able to get the horizontal extent of the winds and pressure observations from those aircraft. DR. OHAB: Could you talk a little bit more about the role of satellite observations? Exactly what kind of data can you get through satellites?

LT. CMDR. CALLAHAN: Certainly. Actually, a surprising amount of data is coming out of these satellites these days. The number one tool we use is called the scatterometer and that's able to give us ocean surface vector winds, which is to say it can give us a direction and wind speed on winds at the surface over the ocean. It does this through the polarization of microwave energy reflected off the little tiny capillary waves, the little, small one and two millimeter waves that are being caused by the wind as it goes over the surface of the ocean. It actually measures the radiation coming off these waves and the polarization of them to tell which way the wave is going.

It runs through an algorithm, compares it to computer models and gives us wind direction and speed out in the middle of the ocean. It's a great tool for the weaker systems, for identifying small disturbances and weaker tropical depressions and storms. The data tends to get not as good when it starts to have precipitation that disrupts the capillary waves and at a certain point the wind speed can get too high, that it's unable to measure it, but it is definitely a wonderful tool for early-on reconnaissance.

We also have microwave imagers that are microwave sensors that are active and passive sensors that are on the polar orbiting satellites that provide imagery in the microwave band, so oftentimes the systems will start to get under a very dense cloud shield or cirrus clouds will form under or over it and we're unable to see, you know, the shape of the eye, the shape of the spiral banding because of this overcast that's over the system. And these microwave imagers are able to actually see through those cloud shields that are over the system, and we can analyze the eye wall and the banding at several different layers within the system.

We also have microwave sounders that can actually give us a vertical profile of temperature and moisture. We're able to measure, as I mentioned, warm core. We're able to measure the extent of the warm core, how strong it is and see how much moisture is entrained in the system to see how much potential energy it still has.

We also have the traditional weather satellites that most people think of, the geostationary ones that give you -- because they don't move in relation to the earth's surface, they give movies of the clouds moving over the whole footprint of the satellite and, from those, we have the

visible images which are basically black and white digital photos, so those are only good when the sun is out.

We have infrared images that measure the temperature of the clouds, so the clouds could be cooler than the earth so we see those as white and the higher the clouds, the whiter they are, so we get those 24 hours a day because those can work at night. We also have water vapor imagery, which measures the radiation emitted from the very high upper levels. I mentioned earlier that we're looking for a good upper level outflow on these systems and if the water vapor band happens up around 300 millibars, which is a measurement of the pressure. It's way up in the upper atmosphere and we can see how the clouds and the winds are moving and those levels.

One of the key things we use off of this kind of imagery, specifically the infrared, is the Dvorak technique, which is a technique that was developed to determine intensity using a set of metrics by measuring the wrap of clouds and the shape of a system and the trends on the infrared imagery of a tropical cyclone. It was developed when we still had airplane reconnaissance of the Western Pacific and using airplane reconnaissance in the Atlantic Ocean, which is ongoing, and so they were able to compare certain kind of patterns with certain intensities, and we're now able to use that, years after airplane reconnaissance has gone away, to try to estimate the intensity of these systems. So we're able to get that from infrared imagery.

We also have cloud track winds using infrared imagery. A computer will find a target in the infrared picture and then look in the next picture an hour later and see what direction it moved and measure that vector. And then, by looking at the brightness temperature, it can tell what altitude that cloud was, so we can get winds at different altitudes using that method.

We have radar altimeters which can measure just incremental little differences in the mean ocean level, just one or two millimeter changes. They can filter out the change from the tidal fluctuations, and these little changes tell us how much density changes in the ocean, so we can measure how much warm water is below just the surface. That's one of the things that we use to be able to model the ocean to find the deep, warm water that I mentioned earlier that can cause the typhoons to rapidly intensify.

We can measure total precipital water using a microwave sensor and that measures how much moisture that can be precipitated out. It's in the mid-level, so we can see how much water is going into the tropical cyclones to fuel them or sometimes dry air will go into them and cut them off.

And that's just from the satellites. And we're also, on top of that, able to get ship observations, shore observations. We have partnerships with some of the other countries, so we are able to get the feed from their radar stations on the coastlines, the winds and pressures from the different airports throughout the country, so even though

we've lost that airplane reconnaissance, we actually get a very large suite of data from all these different sensors throughout the world.

DR. OHAB: I think if there's one take home message it's that forecasters have absolutely no trouble staying busy. Can you walk us through a typical day on the forecasting floor?

LT. CMDR. CALLAHAN: Certainly. We do 12-hour watches and we do 24-hour manning because, as we all know, weather happens all the time. We have four different watch sections so we'll have 12 hours on, 12 hours off and then generally it's two days on, two days off with some changes around the weekends. And the regular manning, day-to-day manning, it's just one forecaster and one satellite analyst. The forecaster does the tracking and the analyst does a lot of the reconnaissance work.

They start their day off with their hand-done streamline analysis, so we have a program that consolidates a lot of this wind data that we have and we look at both the surface and a mean of the upper levels, and we hand draw the direction that the wind flow is and that gives us a good starting point on what the surface winds are doing and what the upper level winds are doing. And we compare the two to see how the environment is favorable or unfavorable for both existing and still forming tropical cyclones.

And then, after that, we do a significant tropical weather advisory bulletin, which is basically a summary of all the disturbances that are not yet a tropical depression, so areas of interest that we do poor, fair, good probabilities for development within the next 24 hours, and all those will be on our significant tropical weather advisory bulletin.

And then by the time they finish those two products, they're already getting ready for the first warning because we warn on our systems every six hours, so in one 12-hour watch, they'll do two warning cycles and each of those last about three hours long, so getting ready for that warning cycle, they'll review the past track, make sure our positions are still good because we constantly get new data in that we can compare our previous positions for.

And the question comes up, why are we so concerned about the previous positions? Well, a lot of the models use past motion to extrapolate out future motion to see how that system has been behaving in the current environment or else they won't be able to tell what actually is affecting the system, so we do our past track analysis, get into the warning cycle. We use the reconnaissance from the satellite analysis, ingest our computer models.

We develop the classic warning graphic that everyone's used to with a code of uncertainty and the actual forecast track in the center and the wind radii. We do a text write-up describing what is actually going on with the system and what's affecting the system. And then we also produce a bunch of associated other products - the stuff that's used in some of the GIS programs throughout the Department of Defense, wind probabilities, and we also produce a couple of products that are used by

research entities to be able to implement into their studies, and then following that we immediately do an updated position, especially if a storm is starting to threaten a U.S. asset, so instead of having the positions every six hours, we also get the intermediate between the warnings every three hours.

Then we do a conference call right after all that and discuss what's going on and it allows all interested parties to discuss at one time and ask all their questions and it frees the forecaster up from having to answer the same question over and over and enables other people to listen to questions that are already asked that they may not have considered. And about the time they're done with all that they go right back into the next warning cycle and they do the whole thing again.

And they generally finish the second warning cycle right at the end of 12 hours, oftentimes going a little bit longer than the 12-hour watch. So, yes, it's a very busy day just to forecast for the typhoons and the tropical cyclones.

DR. OHAB: Just a couple of quick questions before we finish today's program. You had mentioned earlier a little bit about your training, but what does it take to become a forecaster in general at the Joint Typhoon Warning Center?

LT. CMDR. CALLAHAN: Well, our forecasters typically require a masters degree in meteorology. There's been a rare exception to that and so when they have a masters degree in meteorology they generally tend to be a little bit more senior, tend to fall around the O3 rank for the military forecasters. That would be a lieutenant in the Navy or a captain in the Air Force. I mentioned, it is a joint command, so we do have Air Force personnel working side by side with Navy personnel and then the actual training process just for a three-year tour here, it's actually four to six months of training just to get up to the qualification, so they spend about a sixth of their time just getting qualified before they can actually become a qualified forecaster.

And, actually, several of our positions have been civilianized which is a great move because it lends the corporate knowledge and consistency to our team. If you have people rotating out every three years, strange things that happened in previous years and certain situations won't be recognized by the new forecasters, but we now have a couple civilians that are in the mix and they're able to lend that experience and help our new forecasters become even better than they were able to in the past.

And then, after the qualification, there's just constant ongoing training. We have a monthly training session where we have people do past storm reviews. We get guest speakers that come in and give some training. We do in-house training. We do review of the in-house research and then, on top of the ongoing training on the monthly meetings, we all have a reading list that we have to complete of Scientific Journal reviews and articles that have been published that are relevant to what we do here.

DR. OHAB: Now is there a website where the public can go to see some of your products and get more information?

LT. CMDR. CALLAHAN: Yes, even though our predominant customers are the Department of Defense, we do have a public facing web page and they can be seen at www.usno.navy.mil/JTWC. In addition to that, we also have other sites on the NIPR(NET) and SIPRNet for our DOD customers, but on that page you will be able to see our regular tropical cyclone warnings, both the text and graphical products. We put out satellite imagery, the close-up of our current systems, and we also have the significant weather bulletins that have all the disturbances on that web page.

However, I'm going to put out my little reminder here that our viewers should consult the National Meteorological Agency or the appropriate world meteorological organization, regional specialized meteorological center for products pertinent to their country, region or locality. They should still make their planning on their local forecast agency, but it is okay to review our products in addition to that.

DR. OHAB: Well, this has been a really interesting and informative discussion. Is there anything else that you'd like to add or any final thoughts?

LT. CMDR. CALLAHAN: None here. I think we covered quite a lot, and I think there's just a lot of data out there for people to learn about.

DR. OHAB: Our guest today is Lieutenant Commander Jeremy Callahan. He's the Operations Officer at the Joint Typhoon Warning Center. Thank you for taking the time out of your schedule. Best of luck.

LT. CMDR. CALLAHAN: Thank you.

DR. OHAB: Please tune in next Wednesday, November 18th, when we are joined by Dr. Robert Heinsen, Acting Director of the Division of Services and Intervention Research at the National Institute of Mental Health. He'll discuss the largest study of suicide and mental health among military personnel ever undertaken, the Army study to assess risk and resilience in service members. The U.S. Army has invested \$50 million to help researchers identify not only potentially relevant risk factors but potential protective factors as well. The study investigators will move quickly to provide information that the Army can use immediately in its suicide prevention efforts. Thank you again for listening. Have a wonderful and safe Veterans Day. I am Dr. John Ohab, and you have been scienced.

END.