Meteorology with Dr. Marshall Shepherd
Ologies Podcast
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Oh hi, it's that vitamin stuck in your throat, I'm so sorry, Alie Ward. How do I even start this? Okay. We're going to chitchat about the weather in a way that is anything but small talk. As it turns out, the stuff that is all around us is just raging, and swirling, and heavy with emotion. And likewise, I don't even know how to preface this ologist's experience. His bio is the longest list of accreditations, and awards, and bonkers important jobs I have ever seen. I do not know how someone achieves so much high level and deeply important work in one lifetime and I'm shocked he said yes to do this. So, several folks told me to find him and beg him to be friends, which I did, and this one has been in the works for a couple years.

So, he got his bachelor's, his MS, and his PhD in physical meteorology from Florida State University. He's been a NASA researcher, the President of the American Meteorological Society, where he now holds a rare distinction of being a fellow. He was awarded the Presidential Early Career Award for weather and climate research by the White House. And in 2021 he received the American Geological Institute's Award for Outstanding Contributions to the Public Understanding of the Geosciences. He's advised the US Senate, the Department of Defense, and Congress on climate and extreme weather. He's currently a distinguished professor of geography and atmospheric sciences at the University of Georgia, and this past year he was selected as Professor of the Year. He also co-hosts The Weather Channel's excellent podcast, *Weather Geeks*, he writes for *Forbes*, he's authored several books including a kids' book called, *Dr. Fred's Weather Watch*. Frankly, I was lucky to weasel my way onto his schedule. So, we hopped on our respective mics, and I asked him all kinds of questions that were way below his paygrade.

But before we get there, just a quick thanks to everyone who supports the show at Patreon.com/Ologies. A dollar or more a month gets you in the club and you can submit questions ahead of time. *Ologies* merch is available at OlogiesMerch.com, and thank you to everyone who just supports by telling a friend or by rating, or subscribing, or by leaving reviews; I literally do read them all. And as proof, thank you Zachary Daiquiri, who wrote this review this week:

> *Alie Ward is the best thing to listen to while driving a garbage truck. Best binge-worthy podcast out there, I will even stop my truck to charge my headphones to keep listening for my entire shift.*

Drive safely Zachary Daiquiri, thank you for the work you do! Everyone listen to Discard Anthropology if you haven't, it's such a good one. So, thanks for the work you do. I hope someone brings cookies to your garage, and if anyone left a review, know I have read it.

Okay, let's get into meteorology. Legend has it, the field was named by Aristotle who wrote a tome about weather and named it, *Meteorologica*, from a root word, 'meteor' for lofty, so stuff above us. So, let's get to what is over our heads, let's get it in our domes, and get ready for tornadoes, typhoons, wind, rain, forecasting, newscasting, wet-bulb globes, windchill, humidity, polar vortices, atmospheric rivers, bomb cyclones, storm chasing, climate delaying, pop cultural weather phenomena, and more with the distinguished icon of atmospheric sciences, professor, and lifelong meteorologist and weather geek, Dr. Marshall Shepherd.

Dr. Shepherd: Dr. Marshall Shepherd, I guess I'm he but... What else did you ask?

Alie: That's it, that's all. Yeah, so I've been wanting to talk to you for literally years. [*Dr. Shepherd laughs*] This is pretty exciting. You are one of the most celebrated meteorologists in the country. And I'm sure you have to explain this a lot to people, but the difference between being a meteorologist and being a weather person... There's a difference, yes?

Dr. Shepherd: Yeah, so you know, I get called a weatherman a lot, or the weather guy, and then the really derogatory term that I hear from some of my female colleagues is when they call them weather girls. These are celebrated scientists with degrees, they're women, they're not weather girls. But yeah, you're really onto a point because the term meteorologist is synonymous with weatherman for most of the public.

But there are different types of meteorologists in the same way that there are different types of engineers. In fact, only a small percentage of our field are TV meteorologists, or what we call broadcast meteorologists or weathercasters. And even within that group, there's a range. There are actually some people that have meteorology degrees, and you'll see the AMS seal by their name typically, or some other seal. There are some people that have more journalism backgrounds but report the weather and so forth, although there's less of that and more degreed meteorologists. So yeah, I'm a meteorologist that doesn't do forecasting and I'm not on TV unless I'm a special guest on The Weather Channel. [*"He joins us now from Gwinnett County, Georgia. Dr. Shepherd, thank you so much for being here today."*]

Alie: When it comes to meteorology, how do you think that people choose their field? I do think so many people think meteorology is just forecasting, but how did you pick what you do and what are some of the options?

Dr. Shepherd: Yeah, it's a great question. I got interested in this in 6th grade, as most meteorologists do. I did a science project: Can a 6th Grader Predict the Weather? That started because I got stung by a bee. I wanted to be an entomologist, but I got stung by a bee and found out I was highly allergic to bee stings and said, "Well, I need a Plan B, pun intended." [*Alie laughs*] And so I did my science project on weather. So, at that point I was bitten by the weather bug, second pun intended. [*Alie laughs*]

And so, from that point on, I knew I didn't want to be on TV pointing at a screen with cold fronts, and I knew I didn't want to be a forecaster. I was more interested in the hows and why of weather. Why does that hurricane get stronger than others? Why do certain storms spin out tornadoes and some storms don't? So, that's when I started investigating schools and Florida State University… I'm from Georgia, and Florida State was the closest meteorology program, and the rest is history. I went on to graduate school, ultimately got a master's and a PhD, worked at NASA for a while developing large space missions to study weather and climate.

Aside: So, Dr. Shepherd spent a mere 12 years as a research meteorologist at NASA Goddard Space Flight Center and was the Deputy Project Scientist for the Global Precipitation Measurement Mission, just casually one of the best meteorologists in the world.

Dr. Shepherd: And now still do high-level research, teach, and do a lot of other things as well.

But to really answer the second part of your question, what are some of the other options? Again, I think about 9 to 10% of our field work as TV meteorologists. Others go into more private sector for airlines or other commodities companies, power companies, energy companies, and so forth. There are quite a few meteorologists that work in federal agencies like the National Weather Service, or NASA, or NOAA.

Aside: So, NOAA is not a guy or a biblical rising oceans flood reference, but it just stands for the National Oceanic and Atmospheric Administration, air and sea.

Dr. Shepherd: EPA state agencies have meteorologists, and then a lot of private companies are now developing interest in weather, whether it be IBM or formerly, before that Panasonic, and even smaller companies as well. So weather, there's quite a few places atmospheric scientists, which is the broader term including meteorologists and climate scientists, can work.

Alie: Is it such a good meteorology program at Florida State because there's so much weather there? Would that program suck in LA?

Dr. Shepherd: No, I mean UCLA has a really good meteorology program actually.

Alie: Oh, that's good to know.

Dr. Shepherd: It's one of the best, so no, I don't think it has anything to do with the geography. Although it does have a reputation for being pretty good at tropical meteorology expertise there, so obviously being close to Florida, even as we're recording this podcast today, Tallahassee, Florida, which is where Florida State is, is probably experiencing tropical storm Nicole, as we speak.

Aside: And just FYI, so Nicole ended up being a category 1 hurricane; about 75 miles an hour is what it made landfall at, and it caused 11 deaths and $520 million in damages.

Now, if a tropical storm develops in the north Atlantic, or the north Pacific, in the east, off the coast of the US and Canada, and has sustained winds of 74 miles per hour or faster, we call it a hurricane. But if they form over the south Pacific and the Indian Ocean, they would like to go by cyclones, please. Well then, what are typhoons? This is a great question, I'm glad you asked. Those are the same thing but they're over the northwest Pacific, off the coast of Asia. So, we could do a whole episode on intra-planetary meteorology terminology, trust me.

Alie: And what about learning about the weather on planet Earth versus working for NASA?

Dr. Shepherd: We didn't study other planets' weather; [*laughs*] we were studying Earth's weather.

Alie: Okay, wasn't sure.

Dr. Shepherd: NASA has a very robust Earth science program. So yeah, that's another misconception that I often get, in the same way that people would ask me if I was a weatherman. Most people that hear NASA think space, looking at Mars and places, but a large part of what NASA does and still does is to develop missions to study Earth's weather, climate, oceans, volcanic eruptions, changes in the cryosphere which is Greenland, and arctic ice sheets, and Antarctic. That's one of the things that I'm glad you asked me because NASA studies planet... I argue it studies the most important planet of all, Earth, because that's where we live and we're not going to be going anywhere for some time. So, thankfully NASA devotes quite a bit of its resources and expertise to studying this planet using the vantage point of space.

Alie: Climate versus weather. How many times a day do you have to explain the difference?

Dr. Shepherd: Yeah, you're hitting all the common misconceptions that I deal with in my field. [*Alie laughs*] So, we're going to like, take a number here.

So, it's getting to be the cold season, we'll start seeing snow and colder weather and inevitably I'll have someone tweet me, "Hey Dr. Shepherd, I've got 20 inches of global warming in my yard. It's snowing out here in Boston in January, why do you guys keep talking about this climate change stuff?" And so, after I kind of fix my face and sort of, roll my eyes a little bit, I say "Well you know, it's winter in Boston, you're supposed to get snow, first of all. But then secondly, weather is your mood and climate is your personality," something I like to say and you may have heard me say it. The weather today doesn't say anything about climate any more

than your mood tells me about your personality. So, it's a really ill-posed premise to suggest that because it's snowing in Boston on Tuesday in January that that somehow refutes climate change and global warming.

Aside: Okay, so in a bit, we're going to cover why a warming climate would make digging your car out of the snow a more giant pain in the ass. Trust me, nerds.

Alie: Your podcast is called *Weather Geeks*; do you feel like you are kind of geeky about this? Does it get you really excited?

Dr. Shepherd: Absolutely, totally. Yeah, no The Weather Channel, when they came to me about hosting the *Weather Geeks*, we did it as a TV show for 4 or 5 years on The Weather Channel, came on on Sunday afternoon, and then we just realized the changing landscape of how people consume information so we switched it to a podcast. [*"Nice move, kid."*] And we embrace the term "weather geek" because people call us weather geeks anyway, or weather weenies, or weather nerds. But we wanted to empower the term weather geek because some people often use the term in a more derogatory or spiteful or slight of... I guess the word, insulting manner. But we wanted to flip it, we wanted to own it. So, that's why we call our podcast *Weather Geeks*.

Alie: I love that it's something that you have so much knowledge, you're so authoritative about, but that you still love so much. Weather gets such a bad rap in conversation, people talking about weather, but what could be more exciting than storms, whether or not you're going to have to wear a jacket, or if your crops are going to grow.

Dr. Shepherd: Yeah, all of those. You even touched on another misconception that's out there because you're right, weather is often a conversation point and it makes it a struggle for those of us that are scientists in this field because everyone experiences the weather, and so because of that everyone thinks they know as much about it as people with degrees in it. [*laughs*] So, I'll often have people come up and challenge me on the forecast or about climate change and they're totally wrong, but you know, it's an opportunity to share and educate.

So, for example, people often say, "Meteorologists and forecasts are wrong most of the time." Well actually, they're right almost all of the time, about 95% of the time within 3 to 5 days. It's just that it's human nature for people to remember the bad ones. There are few bad ones but those are the ones they remember, if their cookout was rained on, or their child's soccer game got rained on.

But you know, I'll use a football analogy; a field goal kicker kicks a field goal, and they make every single field goal all year long, that's a really good kicker. But if they miss one field goal in a Super Bowl that could have won the game, people are going to be remembering and talking about that kick and, "Wow, that kicker, he stinks," and, "Oh my gosh, fire him." But in fact, he's a really good kicker, he just missed that one. So, people don't tend to remember all the days that we're right in terms of the forecast, so they anchor on those, sort of, more isolated and fewer bad forecasts.

Aside: So, don't blame the messenger for the nature of statistics, folks, just keep an umbrella in your bag and a smile on your face. You're alive and there are crickets, and birds, and sunsets, and electricity, and indoor plumbing.

Alie: And how much has weather science changed since you've been studying it and even since the Industrial Revolution?

Dr. Shepherd: It's really... quite a few changes. Just the ability to observe the aspects of the weather with different types of satellites and radar systems and so forth has changed. The speed of computers means that our weather models have gotten so much better.

Aside: And this part was absolutely news to me.

Dr. Shepherd: You know, weather forecasting is done by solving these very complex fluid dynamics equations, that's why people that want to be a meteorologist have to take so much calculus, and dynamics, and thermodynamics, and physics. As a director of a major program, I have students come to me all the time, "Oh, I love clouds, I love hurricanes, I love storm chasing. I want to be a meteorologist, I want to be in your program." I'm like, "That's fine, but how's your calculus, and how's your physics, and how are your partial differential equations? Because that's what's mostly going to be in the classes you'll be taking." And so, it's really an interesting sort of shock to the system for many of these students.

But the observations, the computing capacity and capabilities, one thing that's really big right now is social sciences. There are a lot of psychologists, and sociologists, and communications experts working at the intersection of weather right now because they're trying to understand how people perceive information about forecast. Do they make decisions based on a red warning box or do they hear certain things a certain way? And so forth. So, that's kind of an emerging area, as is artificial intelligence. That's why companies like IBM and various others that come to mind, Tomorrow.io, and others are really using, sort of, advanced data technologies to mine all of this data, to make precision information forecasts, weather intelligence, if you will, for agriculture, for business, industries, energy companies, infrastructure. So, that's the main thing on the weather front.

Now, on the climate front, it's obviously the increase in CO2. I mean, look, I wrote an article in *Forbes*, I'm a contributor to *Forbes* magazine, I said, what's your CO2 number? In other words, everyone has a birthday but go look at that birthday, that year, and see what the parts per million CO2 in the atmosphere was when you were born and compare it to today. And some of us that are older will be really scared when you see it because we're around 420 parts per million right now. Our atmosphere is responding to that, our seas are responding to that, our ecosystems, our ice sheets. So, our climate has changed in response to human activities, and the burning of fossil fuels, and greenhouse gas emissions.

Aside: And I'll link Dr. Shepherd's *Forbes* article on my site, but you can also go to Nature.org and calculate the CO2 levels in your birth year; it's kind of like astrology but sadder. And today I learned that carbon dioxide has increased by 25% in the scant time that I've been dickin' around on this planet and this fact can be a real vibe changer, so to speak.

Alie: How is that personality affecting our mood? I feel like in the last few years we've heard more about bomb cyclones, and names for blizzards, and storms, and hurricanes that I'd never heard of growing up. But how is that climate affecting the weather?

Dr. Shepherd: Well, you know, that's just the media actually. I mean, bomb cyclones and derechos, these terms have been around forever in meteorology, they've just been used more in the popular media. I wouldn't use those as anchors of something different about the climate because bombogenesis and polar vortex, these are very common weather terms that have been around in meteorology, if you've studied meteorology, for decades. So, there's nothing new about those terms.

Aside: Let's do a lightning rundown of some of the ones you probably thought were just meteorologists yanking your chain. So, bombogenesis happens when a cold air mass collides

with a warm one and the barometric pressure drops fast in a low-pressure system. So, some of the other fun things that you can call a bombogenesis include explosive cyclogenesis, a weather bomb, a meteorological bomb, or a bomb cyclone. And at one point someone was like, "Shouldn't we stop calling this a bomb? It's very scary to the people." And a meteorologist was like, "You call them cold and warm fronts like it's a war, so shut your rain hole, you coward." And a bomb cyclone it was.

Now, a polar vortex is a bunch of cold air near the poles of the Earth, and it's called a vortex because it's spinning, spinning, spinning, and in the winter, it gets bigger and parts of it kind of get caught up in the jet stream and then they blast your whole face with colder arctic air.

Now, a pineapple express is another, "that's got to be fictional" weather term, but it's true, and it's like a hundred years old, in terms of terms. But it's when colder, low-pressure air from the Gulf of Alaska, meets up with some high pressure, west coast winds, plus a little bit of Hawaiian, AKA pineapple moisture, and it forms this thing called an atmospheric river, which is a long, thin thread of wet weather than can carry sometimes as much moving water as the Amazon River, apparently. And you can call an atmospheric river a tropical plume or a water vapor surge, or cloud band. But just keep a rain slicker handy.

Dr. Shepherd: But having said that, we know that climate change is impacting our weather today. We have more intense rainstorms, our heatwaves have more intensity and are happening with more frequency, rapid intensification and the intensity of hurricanes is likely responding to climate change. There's a higher sea level amount, so when the storms push inland, they are actually pushing more water, so you see more storm surge damage. And even without the storms, just the higher sea level itself causes problems. We see changes in drought, which ultimately ends up affecting the cost of things we buy at the market or the grocery stores. There are mosquitoes that carry diseases that used to live in the tropical regions of the planet but now they can live in the United States and carry those diseases.

Aside: What diseases, you ask? You want a little sampler platter of them? Okay. Well, I asked a 2021 paper published in *The Lancet* called, "Projecting the risk of mosquito-borne diseases in a warmer and more populated world," which said that in the next 30 years, nearly half a billion more people on the planet could be at risk for contracting mosquito-borne diseases such as yellow fever, Zika, dengue, and Chikungunya, which I'm sorry, sounds delicious, but it's a disease. Also, things like heat islands in densely populated cities may up the risks of malaria and dengue arriving right on your doorstep. Ding-dong, hi, here to kill ya.

Dr. Shepherd: There are a host of ways– I often like to talk about climate change in terms of what I call the kitchen table issues, the 'so what'. For too long we've talked about climate change in terms of polar bears in the year 2100. Climate change is now. We've got to stop using future tense, we're living it right now and it's likely going to accelerate in the same way we saw with the COVID pandemic. It started and accelerated rapidly, that's what we worry about as scientists right now.

But the good news, in terms of your question is, I don't like to even harbor on just the bad that's happening because we know that, that is what it is. But we know what needs to be done! That's the good news, if anyone is listening to me and saying, "What's the optimism?" The optimism is, this is not a problem we're scratching our heads like, what do we need to do? We know what we need to do, we need to reduce carbon emissions. [*"It's on my to-do list."*] And we have technologies and processes to do that.

And in some cases, we also have to adapt. Things are already past the point of non-change; it's going to change so we have to develop adaptation strategies. I'll give you an example. Out West, I know you're talking to me from out West, up in the Pacific Northwest in 2021, there was a tremendous heat wave, people just aren't used to that type of heat in parts of the Pacific Northwest, many homes don't have air conditioning and there were many deaths because of that heat.

Aside: And just a side note, so this heatwave in June and July 2021 reached 120°F in *Canada*, folks. It was a once-in-a-thousand-year weather event, they said, and it was 150 times more likely to occur because of climate change. What was the cost? Nearly 9 billion dollars financially, but 1,400 lives lost to heat-related deaths. So, global warming is not a future issue, it's now. So, what can we do immediately?

Dr. Shepherd: So, an adaptation strategy might be to retrofit many of those homes with air conditioning now that don't have it because they may not have expected that type of heat in Portland. And the same in London this year, it got to 104°; 85% of homes in London do not have air conditioning because they never expected those types of temperatures. So, we know what we need to do, we just have to act and move beyond what I call climate delayism.

Alie: Climate delayism, I've never heard that, but I mean, that's a great term for it.

Aside: So yes, a little urgency is needed because we know the cause and the effects are already underway.

Alie: What about these weather systems where we've got droughts in some areas, we've got flooding in others, we know that glaciers, not doing so well. Where is the water going and what is moving it around?

Dr. Shepherd: Well, water is conserved on the planet. The amount of water in the Earth's system is a finite amount. We live on a very small percentage of the freshwater that's available to us, you know. We all learned about the water cycle somewhere along the way. But most of the water is in the ocean, or it's locked away frozen in the ice caps, and glaciers, and so forth. So, we live on a very small percentage of water that's evaporating and condensing to form rainfall and falling back into our reservoirs, and rivers, and streams, or snowpack that melts.

Aside: Okay, so I looked this up because I needed numbers and apparently there are 326 quintillion gallons of water on Earth. What does that mean to you? Nothing? I get it. It means it's 326 million cubic miles of water on Earth, and 99.7% of that is in the oceans, it's in the soil, it's all wrapped up, busy in the ice caps, for now at least. It's also in the atmosphere. So, that just leaves a slim little 0.3% of water that's usable by our weird little species of human and we definitely need water to exist.

So, if you are me and you're dehydrated and you're filled with taquitos and gingerbread cookies and you're sitting there thirsty but you're refusing to hydrate yourself, please drink some water and say thank you to the water. Say, "I would literally die without you, water." You would die so fast.

Dr. Shepherd: So, one of the things we've always known about climate change is that places that are dry will probably become drier and places that are wetter will become wetter. That's how you maintain conservation or balance, because the wet places becoming wetter, while the drier places on average are becoming drier.

But what is really of more concern to us as climate scientists is not necessarily the amount that falls on an annualized basis or the amount, it's the rate of change. So, what I mean by that is

here in Atlanta, where I am, the rainstorms now, there's just greater intensity in the rain. So, when it rains really hard, it's much harder than it would have been on average in 1960 or 1970. [*"Boy, when it rains it pours."*] So, because of these higher intensity rain rates, it overwhelms the engineered system and that's why we see so much flooding on roadways and cities and so forth. With Hurricane Ida last year, it made landfall in the New Orleans, Louisiana area, a little bit south of there, and then it moved into New York and caused tremendous flooding, flooded the subways and so forth because the engineered system that we currently live in was designed for the rainstorms of 1960, not 2022.

Aside: So, if you're good at SimCity and you have been looking for a calling in life, consider the urban planning field of climate change mitigation, it's a real thing. And according to one article I just read, urban designer Elizabeth Plater-Zyberk cited things like more walkable communities that could lower carbon emissions, smaller and attached housing structures, and also architecture that requires less of a strain on your HVAC system, also tree planting. Those are a few ways to go in urban planning for the future. But let's look back in time for a second.

Alie: Was your grandfather's walk to school uphill both ways in the snow, worse than your current situation?

Dr. Shepherd: You know, it's counterintuitive to people but I can actually make an argument to people that the snowstorms and blizzards are worse because of climate warming. See, that's counterintuitive because I just said warming, and snow is cold. But we know that the hurricanes, rainstorms, snowstorms, they all sort of get started from water vapor, the gaseous phase of water in our atmosphere, and there's a basic physics principle called the Clausius-Clapeyron equation, let's break that down for all the listeners out there. It's a really fancy-sounding term, Clausius-Clapeyron, but all it really means is as our atmosphere warms, there's more water vapor available to it. So, as we have a net warmer atmosphere, there's more water vapor available to it which means there's more water vapor available to snowstorms, hurricanes, and even rainstorms.

Aside: So, that's huge. A warmer planet means more water in the atmosphere. But how much? How much water we talking? So, per degree Fahrenheit, about a 4% increase in water vapor, or that's 7% for all the places that are not the US and use Celsius.

So, let's take the northeast United States though. About a century ago, the winters averaged 22°F, but they have risen 4° to 26°F. Some years are topping 30°F, which would be a 32% increase in water vapor, while still being below the freezing temperature of 32°. So, if your weird uncle is hitting the vape pen and declares global warming to be horse shit because his picnic table is under five feet of powder, just feel free to kindly educate him, just get some numbers up in there. Any other flimflam to address?

Alie: What about red sky at night, sailor's delight? Any truth in that?

Dr. Shepherd: Yeah, there are certainly these little sorts of sayings, they have some truth in that they tend to be related to, sort of, cloud systems that are moving in as it interacts with the sun as the sun is setting, you get longer pathways of that light through and there's red. But that can change depending on the types of clouds that are in the sky, so that tends to indicate certain types of weather systems that are on the horizon and so forth. So, anecdotally, there are some truths.

Now, what are not true is that rodents like groundhogs or almanacs can predict the weather. [*Alie laughs*] I often get that question, I'll have someone that says, "Well, I don't believe all this climate science stuff but hey, what do you think of the groundhog forecast today?" [*Alie laughs*] I'm like, "I think it's a rodent, that's what I think." So, we have to kind of, there are the anecdotal

things that people have grown up on and they just believe that they're true. Like here in the South, people ask me all the time, "Is that heat lightning? Is heat lightning a thing?" And I say, "No, it's not. But people have grown up hearing about heat lightning all their life, the sky lights up with lightning but you don't hear any thunder and that's just because the storm is too far away to hear the thunder, but people think it's the heat of the day causing the sky to light up.

Aside: So, for more, so much more, on lightning and clouds, we have whole ass episodes, Fulminology and Nephology episodes. I will link them in the show notes, you will be swimming in storm facts.

Alie: And not-smart question, but when it comes to cyclones, and tornadoes, and hurricanes, why so twisty? Why do things go in big circles?

Dr. Shepherd: Yeah, seems like a lot of things in weather do do that don't they? Like tornadoes, and low-pressure systems, and hurricanes. Well, you know, it really gets into a very complex dynamics lesson that we probably would lose half your listening audience from, if we really go down too deep in that road. [*"Try me."*] But it's really an interplay between some fancy things called pressure gradient forces and Coriolis force, because remember, we're on a rotating planet, we are not on a stagnant planet. We are on a rotating planet with this fluid, the atmosphere, flowing around. So, if you think about a river, that's a fluid, and that river flows in a certain way. But now think about if you put that river on a rotating platform, within a rotating platform, you're going to get all kinds of eddies and whorls and so forth. And so, these rotating systems are really very much related to the complexity of having fluid on a rotating Earth that also is differentially heated. It's colder at the poles and warmer at the equator, so because of that you get some really interesting dynamics.

Aside: If you're wondering what a pressure gradient force is all about, let's tell you, let's back up a second. Okay so, high-pressure areas are going to naturally flow into low-pressure areas, and the pressure gradient force is the difference in pressure between the two areas and the greater the difference, the faster the air is going to rush from the high-pressure area into the low and boom, you get wind. You get gentle breezes, you get gale forces, it's all fluid dynamics, spinning around on a spinning rock. And the Coriolis effect is all about which way that spin seems to deflect a flow.

In the northern hemisphere, low-pressure weather systems circle counterclockwise, or to the right, but below the equator, they take a clockwise or a left turn. And yes, this is affecting giant storms and cyclones, but also how the water drains out of your bathtub; southern hemisphere, to the left, to the left, northern, right, and near the equator, your bathtub spin will be much less twisty. Isn't that weird?

Alie: And really basic terms, but things like low-pressure system, high-pressure system, cold front... What exactly do those mean for people who watch the weather or read about it and say, "I kind of don't get it"?

Dr. Shepherd: Fronts are sort of boundaries of air masses, and so cold fronts tend to be frontal systems where you have a cold, dense air mass moving in to lift and replace warmer air because warmer air tends to be less dense, so it rises. And so, you get really violent storms oftentimes at cold fronts. Low pressure is just what it says, it's lower atmospheric pressure whereas high pressure is higher atmospheric pressure. Lower pressure tends to be associated with more stormy, cloudy type weather because the air rises associated with low pressure. Whereas with high pressure, air tends to sink; when air sinks it compresses and warms and so that's why, typically, when

you see high pressure, you're going to be dealing with really clear, perhaps dry even drought-like weather that can lead to things like wildfires and so forth.

Aside: So, fronts are big patches of air and cold patches are more dense and they lift the warmer, less dense air up and that's called a low-pressure system, which is stormier, while high-pressure systems tend to be hotter and drier. I have never understood weather before, so this is thrilling.

Dr. Shepherd: I like to use this very simple analogy. I used to use the analogy of a waterbed but now people under, like, 30 look at me like, "What is a waterbed?"

Alie: My parents had a waterbed!

Dr. Shepherd: Yeah, I was going to say, your parents probably had a waterbed. So, you push down on one part of the waterbed, it goes down, but another part goes up. Well, something that younger listeners may know about is the bounce houses, the inflatable bounce houses, same concept. You push down on one part; another part goes up. Well, our atmosphere has these, sort of, low-pressure troughs and high-pressure ridges and it's sort of this undulating fluid and has areas of highs and lows as well.

Aside: That banging noise was Dr. Shepherd's arm undulating as a visual aid.

Dr. Shepherd: It's hard for many people to envision that the atmosphere is a three-dimensional fluid from the surface all the way up to the top of the atmosphere, and there are various wave patterns within it.

Aside: Speaking of visuals...

Alie: What's your favorite movie about weather?

Dr. Shepherd: We just did a podcast episode on that, so check out the *Weather Geeks* podcast by The Weather Channel. We had myself, and Jen Carfagno, and Alex Wallace from The Weather Channel, two on-camera meteorologists, we talked about what their favorite weather movies are and what some of the *Weather Geeks'* listeners' favorite movies are.

Aside: So, that's the *Weather Geeks* podcast episode called, Lights... Camera... Climate!... which is linked on my website. So, he had an answer all teed up for this, bless him.

Dr. Shepherd: So, the one that came to mind for me was not one that probably many people would even think about. It's a movie by Spike Lee called *Do the Right Thing*. The star of the movie, really, even though you might not think about it was the massive heat wave that was going on at the time, and it was just almost every scene of that movie, the heat was playing some role. [*"I have today's forecast for you... Hot!!"*]

A lot of people will say *Twister*, and I like *Twister* too, tornado movie. And one that's really more climate-focused is *The Day After Tomorrow*. Dennis Quaid, Jake Gyllenhaal and others were in that movie. It's a movie about the climate going wacky here on planet Earth and it caused some very strange weather. [*"The storm is just going to get worse." "What should we do?" "I will come for you, do you understand me?"*] Really good movie, it was very unrealistic from a scientific standpoint, [*Alie laughs*] but it was very entertaining.

Alie: Do you get asked to consult on movies?

Dr. Shepherd: I've had a couple of that, yes. I was involved a little bit in the most recent movie *Don't Look Up*, which is a climate movie. They reached out to me to comment on aspects of the movie after the fact and also, one of the really nice things I liked about that movie, they created an online community of people. Because that whole movie, *Don't Look Up*, even though it was about a

comet approaching and destroying Earth, it was really a large metaphor for climate change. [*"There's a 100% chance, that we're all going TO DIE!" "Well, the handsome astronomer can come back anytime but the yelling lady, not so much."*] And so, they created an entire online community with things that people can go do to learn more about climate change and what they can do, and I'm one of the science advisors for their website there too.

Aside: This website is DontLookUp.CountUsIn.com, I'll link this on my website. But no, the producers did not call him and just have him scream into the void with frustration.

Alie: But it was so wonderfully done with that kind of allegory about climate science, but I thought one thing it did so well and all the people I talked to who were involved with climate science are like, "Yes, we're upset and it's upsetting that no one will listen."

Dr. Shepherd: Well, I think we're kind of past that though. I think more people are listening. I think there are still pockets of people that aren't listening but it's not the majority of people. Although they tend to be the loudest, they tend to be the ones that are on Twitter the most and at your Thanksgiving table saying, "Well, I saw on YouTube this," and I was like, "Well, was it a peer-reviewed vetted study or was it a YouTube study?" [*both chuckle*] So, you know, we still deal with a little of that, but for the most part, I think we're kind of over that hump of having to convince most people.

Again, there's a study out there called the *Six Americas* study that Yale does every year, and they survey the American public. And that crowd that we call the dismissive crowd, they're coming in at about 7 or 8% now, the folks that are just dismissive and you're not going to be able to move the needle with them no matter what you say. So, my approach is on Twitter, I don't bother, I don't try to engage with them or play Twitter tennis going back and forth.

Aside: And that survey by the way measures six different responses to climate science ranging from, here are some flavors: Alarmed, Concerned, Cautious, Disengaged, Doubtful, and Dismissive. Now, Alarmed, thankfully, largest group, clocking in this past year at 33% of those surveyed, they're like, "I'm alarmed! This shit's scary." Dismissive, on the other end of that spectrum, which is like, "No, not real," that's at 9%. But the smallest group of them all is apathetic, with just 5% of Americans identifying as Disengaged. So, I'm going to link this short four-question Yale survey on my website, it's called the *Six Americas Survey*, aka SASSY, which is a fantastic reason to take it already, in addition to helping climate researchers learn stuff. But what about information that *you* are gathering?

Alie: What are some things that you wish people knew about weather? What are some facts to have in your pocket that you're like, "How do more people not know this?"

Dr. Shepherd: Well, I wish most people knew that we make weather predictions based on computer models that solve equations that try to predict how that fluid that I've been talking about changes in one day, or three days, or five days. I wish people knew what 30% chance of rain means because most people don't. When I ask people, they generally get it wrong, and because of that, they often misinterpret that we got the forecast wrong, when in fact, they didn't know what 30% chance of rain means, which really is trying to capture this notion that there's a 30% chance with certain confidence for a given area of the forecast.

I wish people understood what the hurricane cone really means. We saw that recently with Hurricane Ian in Florida, which devastated parts of Florida this year in 2022. And there were people that evacuated from one part of the hurricane cone to another part of the hurricane cone, when in fact, you shouldn't evacuate anywhere in the hurricane cone. But most people interpret that cone as meaning, "Oh, the storm is going to go down the center of the cone and if

it doesn't, I'm good." But in fact, what that cone means is there's a 67% chance that the center of that storm can be *anywhere* in the hurricane cone.

There are just... One of the things that I've learned over the years as a professor at the University of Georgia, and a scientist at NASA, and a communicator with The Weather Channel and *Forbes*, the American public generally struggles with probabilities, anything related to uncertainty, anything that has more than two processes happening at the same time, or anything that they can't simplify to their level. One thing that I've noticed as a scientist, people will tend to sort of simplify things to the level of their understanding at the expense of getting it wrong sometimes.

Alie: That makes plenty of sense and there's a reason why there are people like you who are very good at this, and then there are people like me who forget to bring a jacket...

Dr. Shepherd: No, you're fine.

Alie: ... everywhere I go, which is why it's amazing to interview you.

Can I ask you some questions from our listeners?

Dr. Shepherd: Sure, happy to do it. And shoutout, I hear there's a special question coming from someone that maybe had me in class or something?

Alie: Yes! Not even a question. Jessica Ventre says: I'm too excited to formulate a question but Dr. Shepherd taught my weather and climate class at UGA!! He was a fabulous professor. I taught high school science for a decade and always recommended his class to my students. And Jessica says that they still have notes from your class.

Dr. Shepherd: That's so cool. And you know, if she taught high school that long, then that means she took me probably over a decade ago at the University of Georgia so shoutout to Jessica, thanks for taking what I bet was, Intro to Weather and Climate 11/12.

Aside: But before we do, we like to shower a cause of the ologist's choosing with some monetary thank yous. And this week, Dr. Marshall Shepherd selected the international nonprofit, Institute for Sustainable Communities, which supports communities by creating, and implementing, and scaling equitable climate change mitigation and resilient solutions for those most profoundly impacted by the global climate crisis. They also ensure solutions emerge from within the community. And Marshall is a board member and you can learn all about them at Sustain.org. That is linked in the show notes and that donation was made possible by sponsors of the show.

[*Ad Break*]

Okay, great questions about to rain down on you from patrons of the show via Patreon.com/Ologies. Now, this first one was also asked by patrons Miranda Panda, Slayer, Derrick Allen, and Brittany Kaufman.

Alie: We had some great questions. A bunch of listeners wanted to know: Sleet, hail and graupel, what's the difference? Suzen Baxter is a first-time question-asker and said: Can you tell us about graupel? What exactly is it?

Dr. Shepherd: So yeah, graupel, you know, in clouds, oftentimes precipitation is formed by ice crystals. The rain that falls in most places in the United States actually started out as a snowflake, it just melts and becomes rain when it gets down below the freezing level. But there are often times in clouds where these ice crystals, they bump into some of the liquid water in the clouds and it freezes, and it becomes this little seedling of ice and we call that graupel. But in thunderstorms,

that graupel can continue to take trips up and down in that big thunderstorm or cumulonimbus cloud, and they can grow and take on layers like an onion if you sliced it, and it falls out of the thunderstorm as hail.

Sleet is actually ice crystals; they fall, they may melt, and they refreeze as they fall down to the ground and that's what we get as sleet. And then there's another one that I'll add to her question, freezing rain. Freezing rain, the ice crystal starts out as a snowflake in the cloud, it melts when it falls down to the ground, when it falls to the ground the temperature is below freezing and then it freezes on surfaces, and that's called freezing rain. The thing that I would note about this question, hail only happens in thunderstorms.

Alie: Oh!

Dr. Shepherd: So, if you see bouncing pieces of ice falling during the winter, it's probably sleet because I often hear people say, "Oh, it's hailing outside." And no, no that's sleet. [*Alie grunts in surprise*] Because hail only happens in thunderstorms.

Aside: So yes, sleet is snow that melted and then refroze before hitting the ground. Hail happens in thunderstorms, graupel is snow coated in ice, and freezing rain turns slick upon hitting a surface. There's so much, also more about snowfall in the Snow Hydrology episode, which I'm going to link in the show notes, and I hope you listen to it with a warm mug of something because my digits are frigid just thinking about it.

Alie: I had no idea! Okay, what about humidity? Tyler Nelson and Stephanie Coombes want to know, Tyler says: Is a fall 40° actually colder than a spring 40° because of differences in moisture? And Stephanie Coombes wants to know: Is there really a difference in wet versus dry cold or is it all in our heads?

Aside: Lauren Mascibroda and Kristi Hager also desperately needed answers on this.

Dr. Shepherd: Yes, I'll flip that a little bit because you often hear people talk about, "Hey, I'm going to Vegas, it's 110° but it's a dry heat so it's not that bad." Yeah, but 110° is still hot, whether it's dry or not. But I think the point there is that 110° with more humidity would be oppressive. Here in Georgia, we can get to 90° but our humidity may be quite high, so it feels like it's 110° because of that extra humidity. So yeah, there is something to the fact that humidity does add to the comfort level in terms of temperature. We often use something called the heat index to sort of talk about what the temperature really feels like when you add in the humidity as well.

But a better metric these days is something called the wet-bulb globe temperature, [*chuckles*] yeah that's a big fancy one. It tries to capture the temperature and humidity but also some ways that our body is exchanging heat with the surrounding atmosphere. So, it's just a better metric to determine whether our bodies are going to be sensitive to heat and humidity.

Aside: And that is called the wet-bulb globe temperature, which according to Weather.gov is a measure of the heat stress in direct sunlight, which is just a dirty little combination of temperature, humidity, wind speed, and the sun angle, plus cloud cover. And some wet-bulb globe thermometers need to be covered in a moistened cloth to get good ratings. Also, why does wet-bulb globe sound so horny? It doesn't help that the weather reporting service AccuWeather has trademarked the term, RealFeel, for this measurement. Meteorology, making wet-bulb globes hotter than expected.

Dr. Shepherd: So yes, some of your listeners may not be familiar with the term but it's going to become more broadly used in the future.

Now, the other side of that is something called windchill. When it's cold and windy, it makes it feel colder to us, so you have to factor in that wind to determine what it actually feels like to our skin.

One other thing that might be another interesting tidbit to go along with this question, when it's very humid outside, in fact when the atmosphere is almost near saturation, which means it can't hold any more water vapor, oftentimes, that's when we feel very uncomfortable because our bodies produce sweat or perspiration. And the function of that perspiration or sweat is to evaporate because when it evaporates, it cools the layer of skin. But if the atmosphere is saturated, the evaporation of sweat doesn't happen because that water vapor from the sweat has nowhere to go, the air is full. So, it can't evaporate, so it just stays there as sticky, sticky sweat on your body, and it doesn't evaporate. Because when evaporation happens, it cools things.

Alie: When they're forecasting what a windchill, or trying to figure out what exactly windchill is, I always picture them having like a mannequin with a bunch of sensors out in the wind, trying to figure out how cold the mannequin would be. But with the windchill, is that all just done numerically or how do they figure it out?

Dr. Shepherd: Yeah, it's done with the forecast. I mean there are laboratory studies I'm sure and other things that have been conducted on sort of, bodies and how they respond to different windchills, or heat indices, or wet-bulb globe temperatures. But once that is established, our weather models predict the temperatures and the winds, and then you can determine the windchill based on your expected wind and/or temperature.

Alie: Ah! Okay. See, I'm learning so much already. A ton of people want to know about tornadoes.

Aside: Looking at you, patrons Frances Hurst Brubaker, Elijah, Kelsy Simpson, Leah Anderson, Rebekah Rodarte, Jonathan Merry, Richard, Rebecca Ann Frey, on behalf of their 2nd grader, Aldo Frey, one-time Kansas-dweller Mary Franks and...

Alie: Sarah Montgomery, first-time question-asker, says their understanding is that hurricanes can only rotate in one direction, but tornadoes can rotate in either direction. And also, what causes a tornado alley? Why do some places get tornadoes, and some places don't?

Dr. Shepherd: Yes. So, hurricanes in the northern hemisphere rotate counterclockwise and they're much larger storms than the tornadoes, which are much smaller scale storms that tend to also have counterclockwise rotation as well, but there may be some that spin out in the opposite direction.

I would highly recommend, and it's not because I'm in this series, but I am in this series, [*Alie laughs*] Netflix just dropped a new series called *Earthstorm*, and there's *Earthstorm: Hurricane*, *Earthstorm: Tornado*. I'm in the hurricane episode but in that *Earthstorm: Tornado* episode, does a really good job of explaining why, for example, the United States gets quite a few tornadoes. It's because of our juxtaposition, particularly the great plains of the cold Canadian land mass, the Rockies to the west, and the Gulf of Mexico, those three geographic features are very important in setting up the environment that's conducive for the formation of tornadoes. [*"It's a twister, it's a twister!"*]

Alie: I should ask though; you did mention *Twister*. What's the closest you've ever been to a tornado? Have you ever tornado chased?

Dr. Shepherd: Not very close at all. I run away from them, not *to* them. [*laughs*] I say that because there are certainly... We're in this era of storm chasers now, and some storm chasing is very important

because you want to get data for science and so forth. But there are some people that go out there for the thrill, or to get pictures to sell to the media, and so forth. More power to them but I am a person that wants to be as far away from a tornado as possible.

Alie: Okay, good. So, have you ever been in peril from your work?

Dr. Shepherd: Not directly. I've certainly been in some pretty bad hurricane situations, particularly Opal is one that comes to mind. I don't put myself– that's not the kind of research or work that I do to go put myself in front of a landfalling hurricane or tornado.

Aside: Patrons Mark Hewlette and Alia Myers asked if he had to storm chase and I hope they sleep better tonight.

Dr. Shepherd: I was, I had a chance to fly, we were doing a mission for NASA when I was a scientist at NASA and the plane was going to fly into the hurricane to take some data and I think I had an opportunity to do that, but I passed. I'm very risk averse.

Alie: Good. Yeah, we need you here. [*both laugh*]

Dr. Shepherd: But there are certainly people that do it though.

Alie: I have a theory that they have to put people, like on CNN, have to be out in a windbreaker in a storm because you won't know how bad the storm is until you see a windbreaker flapping around.

Dr. Shepherd: Yeah. I think you've got that right, actually. There are a lot of people that criticize reporters like my colleague Jim Cantore at The Weather Channel. Some people are like, "Why don't you just go inside." Look, if he's willing to take the risk... It *is* providing a service because I don't think people have a good sense of how strong winds are and what a storm surge looks like. Mike Seidel, my colleague at The Weather Channel, was reporting recently from Florida during Hurricane Ian and he was in a protected place, but you could really get a sense of the storm surge and how dangerous it was. Without that journalism, I don't think people would really have a sense of that and they might be inclined to stay in a dangerous situation in the future, but maybe by seeing that, maybe it'll make them make a better decision down the road.

Alie: Yeah, it always helps me to realize, "Oh, I know what wind feels like and I've never felt wind like that." So, that's helpful for me at least.

Dr. Shepherd: Yeah, when I watch coverage of like, out your way, earthquakes… I mean we don't experience really bad earthquakes here in Georgia, we do have them, or wildfires in the way that you have them out there, you know. But seeing them or experiencing them from the lens of the camera gives me an idea that if I did ever live in that area, I'd sort of have a feel of what to do and what not to do.

Alie: Yeah, I mean, 1989 World Series, anyone? [*"And he fails to get Dave Parker at second base, so the Oakland A's take–" loud, crashing, thrashing, static sounds*] I don't know if you watched the Giants and the A's but we had a giant earthquake in San Francisco as the World Series was playing out in the Bay Area, and it was live so a lot of people got to see you know, Candlestick Park shaking and they're like, "Oh yeah, that sucks. That's big."

Dr. Shepherd: Yeah, I've seen those images for sure.

Alie: Wheuff. A ton of Floridians wrote in, of course. I feel like people of Florida see meteorology and they're like, "I have questions!" But Katie Collins wants to know: Floridian here. Why are hurricanes so hard to track? And also a few people, Mykenzie King, wanted to know: Is hurricane season maybe going to go longer in the year?

Dr. Shepherd: So yeah, some good questions. Actually, hurricanes aren't that hard to track within about 5 days, they tend to be a little less easy to track when they're beyond 5 days out, in the 10-day range. Where we've had progress over the years is actually our forecast track has been improved steadily over the last several decades.

We're never going to be perfect. That's another thing I wanted to mention so I'm glad you asked this question. There is this expectation by the public that we can get it exactly right. We'll *never* be able to do that, whether it's a hurricane track, a tornadic storm. That's why we give you the forecast as a cone or as a probability because we can't and we won't ever have the ability to give you a precise answer to, "Is it going to rain in the backyard near my tomato plant next to the dog bowl?" We will never be able to give you that precision of a forecast, the atmosphere doesn't behave that way; it's a nonlinear system that we're trying to predict with equations. We will never have that level of accuracy with weather forecasting because we're dealing with a fluid on a rotating planet that we're trying to predict with equations.

But we've reduced the error in track forecast significantly in the 3-day, 4-day, 2-day, 1-day out. So, 50-100 nautical miles of error, from my vantage point is actually pretty good. So, in other words, we can tell you within 50 to 100 miles where the hurricane is making landfall. That's about as good as the science allows us to get right now.

Aside: So, the track or location of a hurricane/typhoon/cyclone is easier to predict than the intensity of it. And the intensity follows the Saffir-Simpson Hurricane Wind Scale, SSHWS, from a... ready? Starts at tropical depression to a tropical storm, to a category 1, if it reaches 74-mile-an-hour sustained winds, all the way up to a category 5, which has over 157-mile-per-hour winds.

But what about their names? Why are we calling them names that we would name our nieces or nephews? Well, in order to not confuse storm systems during World War II, military meteorologists named hurricanes after their partners, and love interests, and wives, and girlfriends until this wonderful person, named Roxcy Bolton, in the '70s, an ardent and accomplished feminist icon and activist, suggested maybe they should alternate those with male names. Although Roxcy initially suggested that the devastating storms should be named after Senators.

But the baby name convention stuck and NOAA keeps these prewritten lists that rotate every six years until there's a hurricane that's so devastating that they just retire its jersey for good. Like, there will never be another Hurricane Katrina. And yes, there has been an oft-cited study that came out in 2014 titled, "Female hurricanes are deadlier than male hurricanes," and it found that because of gender bias, folks do not heed warnings when it comes to a hurricane named after a woman as much as they do one named after a man. Although some people contested this saying that the data set included hurricanes from 1950 to 1978 when they only used female names, so some people contest it. What's my point? My point is, if a hurricane is coming, please don't fuck around, thank you.

So, if you want to win some easy money though, you can bet someone that the first hurricane of 2023 will be named... Arlene, and hope that they don't look at the link that I'm posting on my website to NOAA.gov that has all the hurricane names for the next six years and hopefully they don't listen to that before hurricane season which starts in June and it lasts longer than Thanksgiving leftovers.

Dr. Shepherd: But there is some evidence, because the waters stay warmer longer or perhaps get warmer earlier in the season that the hurricane season might start to be extended beyond June 1st to

November 30th. I remember in 2006 we had hurricanes and tropical systems into December. A few years ago, we had tropical storm Alex and that was in January, so it's all related to when those waters start to warm enough to support a hurricane. You typically want about an 80°F temperature or so, but because of the climate warming of the ocean, we're starting to see warmer oceans that can feed these storms.

Alie: A lot of folks spoke to one of the flimflams that you were kind of busting earlier. Maisie Lopez, Jenn 'Squirrel' Alvarez, Joe Savina, Benjamin N DuBow, James Hales, Olivia French, Andrea Cade, Rebecca Davis, Justine Doll, Cat Kessler's husband, and Freddy B all wanted to know: What does a percent chance really mean? And how do you quantify the chance of precipitation?

Dr. Shepherd: It's related to the data that comes out of our models, so we look at how much confidence do we have that a certain amount of rain is going to fall at that location within a given area. So, it's a probabilistic forecast.

So, I'll give you a little anecdotal example. I was up in the North Georgia Mountains, doing some river tubing with my son one day, and it started raining, and this woman starts complaining about the meteorology. She says, "There was only a 20% chance of rain today! See, the meteorologists are always wrong." Obviously, she didn't know I was a meteorologist, and I was floating right down next to her, so I'm thinking to myself, "It wasn't a 0% chance of rain." [*Alie laughs*] In fact, we were probably in the 20% region that day. So, that forecast wasn't wrong at all. There wasn't a 0% chance that that particular area would receive rain, there was a 20% chance. So, it rained. Likely in a statistical sense, 80% of the area didn't get rain but we were in the 20% that did, nothing was wrong with that forecast at all.

Aside: So, that percentage can mean that 20% of the area will definitely see rain. But other meteorologists might use a slightly different formula to determine the POP, or the Probability of Precipitation, which works out to be the confidence of rain times the area. So, if there is a 60% confidence that rain will occur over 60% of a given geography then the POP for that day would be 36% chance of rain. You know what, as long as we're getting formulaic and jargony, these next ones are for the real weather geeks.

Alie: One last listener question, I'm going to pick one that I feel like you will appreciate because we don't know what it means. Kass C wants to know: How do we get the precision of in-situ measurements with the coverage of remote sensing to improve model accuracy? And Trevor Durning wants to know: ENSO is highly predictable, how far would you say we are from being able to predict AMO at similar resolution? I don't know what any of those mean.

Dr. Shepherd: Yeah, well ENSO is just the El Niño Southern Oscillation cycle and AMO is the Atlantic Multidecadal Oscillation. So, ENSO is the El Niño, La Niña phase so there is some level of some predictability of the ENSO cycle. Right now, for example, we're still in a La Niña phase, which means the ocean waters in the equatorial Pacific are cooler than normal and that tends to affect weather patterns. Whereas a warmer than normal equatorial Pacific is the El Niño. And so the Climate Prediction Center, or the European Center, they actually can predict the sort of ENSO phase, whether we're El Niño or La Niña, not as precisely as we can day-to-day weather but we can have a sense of whether we're going to be in a La Niña or El Niño pattern. And that, in turn, leads to some understanding of what type of weather we'll see in certain parts of the US.

Aside: So, El Niño is warmer Pacific Ocean waters and yes, La Niña is cooler, and per Trevor's question, more predictable. So, scientists are still figuring out the AMO, which is the Atlantic Ocean's pattern of warming and cooling that tends to switch about every 70 or so years, perhaps due to the regular ocean conveyor belt currents, but scientists think it may also be

affected lately through climate change. And Trevor Durning wanted to know: How far away would you say we are from being able to predict the AMO at similar resolution?

Dr. Shepherd: The AMO is the larger, long, varying cycle in the atmosphere that has been linked to hurricane activity in the Atlantic for example, and whether we're in an active phase versus a nonactive phase. I think our predictability of that is less clear right now. I think one question you mentioned was about QG theory and something about a Skew-T chart. [*laughs*]

Aside: So, that was patron Dana Warheit's question, which read: Ooh, please ask about QT theory and how the Skew-T is the ultimate atmospheric gauge for what is happening in the atmosphere at the moment.

Dr. Shepherd: Which is a plot that we use to plot soundings, which is when we send weather balloons up, they take information about temperature, and moisture, and wind, and we plot those on a Skew-T chart. And Quasi-geostrophic Theory or QG Theory, which was mentioned, that's just one of the governing synoptic dynamic theories in atmospheric sciences that explains many of the motions. Again, it's way too complex to talk about on a podcast. So, I would recommend a dynamics class in a meteorology program to get in QG Theory because if I start talking about it your head is going to explode and your headphones or ear pods are going to fly out of your ear.

Aside: Hi, I went to the American Meteorological Society's glossary terms, and I brought this back in my little basket for us. So, a Quasi-geostrophic theory is a theory of atmospheric dynamics that involves the quasi-geostrophic approximation and the derivation of the quasi-geostrophic equations. What's a quasi-geostrophic approximation? You're dying to know. I'll tell you. It's:

> *A form of the primitive equations in which an approximation to the actual winds is selectively used in the momentum and thermodynamic equations. Specifically horizontal winds are replaced they their geostrophic values in the horizontal acceleration terms of the momentum equations and horizontal advection in the thermodynamic equation is approximated by geostrophic advection...*

It continues but I blacked out trying to read it so just please respect your weather people, never comment on their outfits on TV, they deserve so much better.

Dr. Shepherd: Oh, it's some good geeky stuff that we certainly talk about on *Weather Geeks* though. [*laughs*]

Alie: Is there an issue with weather balloons because of a helium shortage?

Dr. Shepherd: There was. Periodically, we have had some issues with the National Weather Service. Now, I think one thing that really helps us out is we can get some of the same kind of information from satellites these days that we can get from weather balloons, and in some ways the satellites are better because we can get coverage more consistently and over many other places. With a weather balloon, we only have it where we have it and when we launch it, and that's sometimes just twice a day. But the satellites don't have the same level of resolution, satellites are much coarser resolution.

What I mean by resolution if... Most of you probably have an iPhone, I'm team Android, I have a Samsung, but on our cameras on our phones, the number of megapixels tells us how good the photos are on those phones, so the more megapixels the better the picture. So, the finer the resolution is of the model or of the observation, the more fine-scale weather we can actually measure. So, right now, when you've got a weather balloon or you've got a temperature measurement from a thermometer or pressure measurement from a barometer where you're sitting Alie, that's pretty good resolution. A satellite might only be able to give you a resolution

over the square mile of where you're sitting so it would be a much more blurred, coarser measurement.

Aside: I just wanted to tell you that in 1982, a truck driver named Larry Walters filled 45 weather balloons with helium and then he tied them to a lawn chair and flew 16,000 feet over Long Beach for about 45 minutes, just cruising in a lawn chair covered in balloons. And then he took a pellet gun, he thought about this ahead of time, and he shot the balloons until he dropped the gun on accident, he didn't think about that. But he floated back down to Earth, he got tangled in some powerlines, but he climbed down to safety, and then he was on some talk shows. But ultimately his life got really sad, and he died by his own hand, we won't go into it. Also, I know you don't care, but I just figured out that to lift me off the ground, it would take 557 party balloons, which would be scary and a waste of helium, so I'm good just sobbing to *Up*.

Alie: Last two questions I always ask, hardest thing about meteorology? It can be annoying, it can be difficult, it can be whatever. Hardest thing about your job?

Dr. Shepherd: I just think the hardest thing about meteorology is that it's fluid dynamics but it's accessible to many of the public, so they think it's much more simple than that. [*both laugh*] It really is. The discipline from a science standpoint is just fluid dynamics, a bunch of physics, and a bunch of calculus, but to the public all they see is cold fronts on the map or something. But a lot went in to getting to that point and so that, the challenge of explaining that complexity to me is very difficult.

Alie: Mm-hm. What about your favorite thing? Your favorite thing about weather, about meteorology?

Dr. Shepherd: Oh, it's fascinating. I can't help but when there's a storm coming, if I'm looking at the radar, I'm out on my deck or in the front yard as long as I can, trying to see what's going on before I have to get to safety. But no, I'm still legitimately fascinated by weather. I don't feel like I work, what I do– Look, I was a former president of the American Meteorological Society, I've worked for NASA, I get to do big science projects for a living now as a scientist and a professor at the University of Georgia. I mean, I'm still a kid in a candy store, I don't dread going to work.

Alie: This is why I wanted to talk to you. You're honestly the most qualified meteorologist I've ever seen. Your list of awards is bonkers! How celebrated you are, and clearly, you are very into this and passionate about it because I mean, it shows in the work you do and the outreach you do. I follow you on Twitter and you're a joy to follow on Twitter, but anything else you want to shout out? I know we mentioned *Weather Geeks*...

Dr. Shepherd: Yeah, I would definitely get... If you like anything you hear, we geek out every week with various weather, climate, and science experts on the *Weather Geeks* podcast by The Weather Channel. Check out my *Forbes* articles, follow me on Twitter @DrShepherd2013. I'm on Instagram @Marsh4FSU, I'm on TikTok @DrShepherdKnows. That's just a new… I forayed into TikTok very recently so still feeling my way around that format but yeah, I'm out there. I'm not your typical scientist or professor, I really like to engage.

Alie: Thank you so much for doing this, this is a joy. It's been an honor, honestly.

Dr. Shepherd: Thank you so much for having me, Alie.

So, there you have it, you can ask brilliant, distinguished professors sometimes dorky questions because they're just a deluge of facts, and learning stuff makes the planet healthier for all of us. So,

there are links to Dr. Marshall Shepherd's social media and website, and to Sustain.org, and so many things that we discussed up at my website at AlieWard.com/Ologies/Meteorology, that's linked in the show notes.

We're @Ologies on Twitter and Instagram, I'm @AlieWard on both. I'm at @Alie_Ologies on TikTok, say hi. *Smologies* episodes are right in the feed and they're safe for all ages, you can find them at AlieWard.com/Ologies. Thank you, Mercedes Maitland, Jarrett Sleeper, and Zeke Rodrigues Thomas for editing those. *Ologies* merch is available at OlogiesMerch.com. Thank you Susan Hale for managing that plus doing so much more. Thank you, Noel Dilworth, for all the scheduling. Emily White of The Wordary makes our professional transcripts and Caleb Patton bleeps them. Those are up for free at AlieWard.com/Ologies-Extras. Erin Talbert admins the *Ologies* Podcast Facebook group, with assists from Boni Dutch and Shannon Feltus. Kelly R. Dwyer stays on top of our website and can design one for you. Nick Thorburn made the theme music.

And lead editor for this episode was the wonderful Mercedes Maitland of Maitland Audio Productions, which is linked in the show notes at MaitlandAudio.com. Huge thanks to her for the tremendous job she's doing and giving Mr. Jarrett Sleeper some time to explore his other passions, I'm so excited for him for that.

If you stick around to the end of the show, you know I tell you a secret, and this week's secret is that I watched Guillermo del Toro's *Pinocchio* on Netflix and the entire time I was watching it, they have a Jiminy Cricket character and he's got kind of a rotund little belly, and I just kept thinking, "Man, I wonder if he's got a horsehair worm in there..." Because if you've ever seen a horsehair worm crawl out of a cricket or a praying mantis' butt, wow, it puts pimple videos to shame, just google it. They put its little butt in water and then the horsehair worm is like, "I'm outta here," and it is like a mile of worm. But no, *Pinocchio* didn't touch on horsehair worms, I wish it did. It did make me cry, a lot... I cried so much.

Also, Guillermo del Toro, at one point on Twitter said he would appear on *Ologies* on an episode about creatures and monsters so, he's been a little busy since he tweeted that two years ago but don't think that it's not on my wish list! [*deep sigh*] All right, that's enough out of me. Go dance around in the rain, it's great. Okay, berbye.

Transcribed by Aveline Malek at TheWordary.com

Links to things we discussed:

Follow Dr. Shepherd on Twitter, Instagram or TikTok

Visit his website

Listen to his podcast Weather Geeks

A donation went to the Institute for Sustainable Communities

Dr. Marshall Shepherd's kids weather book, "Dr. Fred's Weather Watch"

Do You Know Your Carbon Dioxide Birth Number?

Determining your carbon number via Nature.org

Projecting the risk of mosquito-borne diseases in a warmer and more populated world: a multi-model, multi-scenario intercomparison modelling study

Etymology of Climate Delayism

What is the Polar Vortex?

Coriolis Effect | National Geographic

The Coriolis Effect and Draining Water: Tested with one container on 3 continents.

Female hurricanes are deadlier than male hurricanes

"Female hurricanes are deadlier than male hurricanes" disputed via Snopes

Future hurricane names

Video: 1989 Live World Series Quake coverage

Video: 7.1 Earthquake hits during Dodgers/Padres game 7/5/19

Weather term glossary

2021 Western Heat Wave

Where exactly is the Earth's water?

Lights... Camera... Climate! Weather Geeks episode about movies

Clausius–Clapeyron relation

Red Sky At Night … Any Truth To It?

National Oceanic and Atmospheric Administration

Hurricanes, Cyclones, and Typhoons Explained

Rough map of hurricane/typhoon/cyclone terminology

Why snowstorms are even worse with global warming

Atlantic Multidecadal Oscillation Modulates the Relation of ENSO With the Precipitation in the Central-Western Indian Ocean

What is the Atlantic Multidecadal Oscillation (AMO)?

Don't Look Up's climate action website

Climate adaptation, mitigation, and urban design

Global Warming's Six Americas, September 2021 results via Yale

Take The Six Americas Survey (SASSY), a short, four-question online quiz about climate concern

How much water is on Earth?

Wet-bulb Globe Temperature

More on wet-bulb globe temperature measurements from Weather.gov

Earth Storm on Netflix (see his Hurricane episode)

1989 World Series Quake Broadcast with Al Michaels

Quasigeostrophic approximation

Larry Walter's balloon flight

How many balloons to float what?

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