Ask A Biologist Vol 087 (Guest Joellen Russell)

Ocean Winds and Climate

Did you know the westerly winds in the Southern Ocean have been helping to keep our planet livable? Yes, they have been responsible for soaking up half of the human-made carbon dioxide (CO_2) along with a whole lot of excess heat. Dr. Biology has the opportunity to talk with geoscientist **Joellen Russell** about the research she and a group of scientists have been doing in the southern hemisphere that tells us how important these winds and the oceans are for regulating the temperature of the planet.

Transcript

[Wind blowing the background]

Dr. Biology: This is "Ask A Biologist," a program about the living world. I'm Dr. Biology. The winds of change are here. We could say the winds are changing the world. In this case, we're talking about the westerly winds in the ocean and the southern hemisphere.

How these two play an important role in our climate is the topic of today's show. My guest is professor Joellen Russell, a geoscientist at the University of Arizona, Department of Geosciences.

While it might seem odd to have a scientist studying the winds in the ocean of the southern hemisphere, based in the desert southwest in the US, we will soon learn that technology makes it possible to study parts of our planet from almost anywhere, including your classroom or home.

Welcome to the show, Joellen Russell and thank you for taking time to talk about your work.

Joellen Russell: Happy to be here. Thank you.

Dr. Biology: To get us started today, how about we talk about climate change, because there are some misconceptions about what we mean by climate and what we mean by weather.

Joellen: Sure. We know that every year, because of the tilt in the planet and the way that it spins, that we have seasons. We have a summer and we have a winter, and that every summer it's going to get hot, and we have some monsoon rain.

Every winter, it's going to get cold and we may have some winter westerly rain coming off the Pacific. That's off California. We know that this happens every year because the planet rotates around the sun, and we have a little tilt. That means sometimes we're leaning towards the sun and sometimes we're leaning away from the sun.

Every year we do this, and every year we have a few storms. Now, the storm part, we can expect. The climate that we expect, usually is three to five storms every winter.

What we see is that over time, with this big change of the amount of carbon dioxide -- which is one of these what we call greenhouse gases which tends to trap some of the sun that comes into the earth's atmosphere -- which would normally go back out to space. Instead, a fraction of that stays within the earth's atmosphere.

Because it's just like your down sleeping bag. If you go camping and you have one of those really thin sleeping bags, if it's cold outside, you're going to be really cold. But if your bag is one of those nice, thick, puffy bags with lots and lots of loft in it, you're going to stay nice and toasty. That's like the earth and its atmosphere.

The atmosphere keeps us nice and toasty. The more CO2 and water vapor in the atmosphere, the more you're likely to stay nice and warm. What we see is that over time, we're still going to have seasons exactly like we always do, and we're going to have storms associated with these. That are the weather that we expect.

But you're also going to see -- because it's getting warmer and warmer, that CO2 is trapping more and more of this heat -- essentially that numbers of record warm temperatures broken every year is going to go up a little bit.

That is not significantly going to affect how many storms we get unless we see a little bit of reorganization of the plumbing of the atmosphere where maybe the storms don't dip as far south to us anymore. But generally, over many years, over tens and tens of years that we expect there to be fewer days of snow and more days of rain.

Dr. Biology: Whether you're talking about if you're in Arizona. But as you look around the planet, the seasons are a little bit different.

Joellen: Absolutely.

Dr. Biology: Instead of having a summer, winter, spring, and fall. If you live around the equator for example. You might have a wet and dry season.

Joellen: That's right.

Dr. Biology: But still impacted by the slight tilt of the earth.

Joellen: Right.

Dr. Biology: The other analogy we've used is the climate where you live will determine if you own an umbrella.

Joellen: Yeah. [laughs] That's a great way to put it.

Dr. Biology: The weather on the other hand, determines if you're going to take your umbrella with you on a particular day.

Joellen: That's a very good way to put it. I hadn't thought of it like that.

Dr. Biology: Let's get back to weather and wind and the ocean.

Joellen: Absolutely.

Dr. Biology: Your work is with the wind and the ocean.

Joellen: It is.

Dr. Biology: And not just any wind, your work is in the southern hemisphere of the ocean.

Joellen: Yeah.

Dr. Biology: Down by the Antarctic.

Joellen: Absolutely.

Dr. Biology: And you have a very interesting story to tell.

Joellen: I do. I think we're seeing and we have two ways of doing it. We have observations where we go down in ships and I used to do a lot of this and I've shifted towards more big computer models. But I used to go out to sea and actually make lots of measurements and I thought I knew what wind felt like. I thought I knew because I'd been in some blizzards before in the northern hemisphere.

But the westerly winds are much stronger in the southern hemisphere about 30 percent stronger. They are enormous winds that blow constantly and have big storms riding along with them. Intensification and then in between the storms you think it'll get all calm. But it doesn't. It just a little bit less roar and what this does is because they roar round and around and around these big winds around Antarctica.

They push the water away from Antarctica. Because there's a little bit of tendency for the water to move away from Antarctica when you're pushing along with these really big winds in the Coriolis force. I'm not going to explain the full Coriolis force but it's related to the rotation of the planet and so pulls the water at the surface away from Antarctica. Because you can't have a hole in the ocean, it upwells.

It doesn't just upwell from the very surface layer, it upwells from the deepest, deepest black abyss from 2,000 meters deep which is roughly 20 football fields down into the ocean. Because you've push the surface away and essentially when you push it away it fills in from this water below. When it comes up, that water has never seen our atmosphere.

The atmosphere that we've put all these fossil fuel emissions into, that has all this carbon dioxide and all this extra heat. It's never seen this atmosphere before. Because it might have gone back down, 200, 300 even 1,000 years before.

When it comes up to the surface, it's very cold and it's full of CO2. But it's got much capacity to even have more because of this excess in the atmosphere that we put in from burning coal and lots of fossil fuels.

It comes up to the surface and it absorbs CO2 and it absorbs heat and then it sinks. Because even though it's absorbed a little heat, it's still very dense, very cold water and it sinks back down carrying the heat and the carbon with it. When it carries that heat and carbon down, it's essentially storing it away from the atmosphere.

If we had all the heat that we have added to the ocean over the last 50 years, if we put it all in the atmosphere, we would be 100 degrees hotter. It's not a little bit of heat. It's a lot of heat. Basically more than 90 percent -- more in the 9 out of 10 of the total amount of heat that we've grown in our atmosphere -- is in the ocean.

Only a small fraction like three percent, three pennies out of a buck are actually in the atmosphere.

Dr. Biology: So it's kind of a heat sink.

Joellen: It is. It's a huge heat sink and carbon dioxide sink as well. It doesn't just take up the heat, it takes up some of the things that helps trap the heat the CO2, which means that although we're going to continue to warm, we don't warm as much as we would have. I like to give this public outreach talk called, "How the Antarctic helps Arizona keep its cool" which is actually true.

It turns out that one of the things that is most important to understanding how much warmer it might be in Tucson or in Phoenix in the next 20 years, 30 years, is how much heat the ocean continues to take up. Because remember, let's go back to the first part, how does that water upwell? It upwells because the wind is pushing the water away from Antarctica.

We think that the winds have actually intensified gotten stronger and moved towards Antarctica because -- and you're not going to believe this -- the ozone hole. I know, everybody talks about global warming as just being the main driver of the changing in the plumbing of the atmosphere in the ocean. But fact in this case it's the ozone hole.

The ozone hole over Antarctica as really big. Everybody knows this, and we know that it's manmade. Because we made all these refrigerant molecules called Freon's or chlorofluorocarbons that helped us keep our refrigerators and air conditioners running. They had to be these gases that were very long lived. So that they would last a long time in our AC's and our refrigerators.

They leaked and they escaped and they went into the stratosphere basically and created an ozone hole, because the chlorine left from the chlorofluorocarbons. That destroyed the ozone. When the ozone was destroyed, it made the upper atmosphere very, very cold. Because it turns out that the same way that the ozone saved us from skin cancer -- a photon from the sun would hit a molecule of ozone.

The ozone would break apart saving us from that UV that would have given us skin cancer -- ultraviolet radiation that would have given a skin cancer. Hit the ozone molecule, broke apart. When it reforms, it actually releases heat. It's an exothermic reaction, which is amazing. That's how the ozone used to keep our stratosphere warm.

Without the ozone anymore, the stratosphere started to cool. It's now seven degrees colder over Antarctica up high in the atmosphere than it was 30 years ago.

Dr. Biology: You were talking about how oceans work as a heat sink. Do they have an unlimited capacity?

Joellen: They're always going to take heat as long as the atmosphere is warming. If we stopped emitting so much CO2, it started to come down the total concentration, then eventually the oceans would actually be releasing heat rather than taking it up. Because the atmosphere would cool and it would release a little bit as it goes.

But as long as we increase our CO2 in the atmosphere, we're going to increase their capacity -- the ocean will continue to warm.

Dr. Biology: Will the oceans keep slowing the rate of global warming?

Joellen: There are two thresholds that I worry about. The first one isn't actually not the Southern Ocean. The first one is the North Atlantic. Where if we put enough warm water into the North Atlantic and the winds are not strong enough to remove enough freshwater and enough heat to make it cold and salty and sink then we would significantly reduce the amount of CO2 and heat that would go in the North Atlantic.

I would expect that to happen first. The second thing that will happen if we continue to accelerate our warming with accelerated CO2. What I'd expect is that in the Southern Ocean at some point the thick layer of warm water that forms in the summer -- when the winds are weaker and the warming is most intense.

I would expect, if that layer got thick enough that the total wind energy that we have to expose it to, to mix it away and mix it down. If it's not enough when energy anymore, we will cap the southern ocean deep sink. That would mean that, it basically just sit on it like a lid. All that warm water and if the winds aren't strong enough to break through and that could happen in the future. Probably not soon, but say 30, 40, 50 years.

At that point, we would see abrupt warming in the atmosphere. Both cases but particularly in the southern hemisphere case where so much of the heat is going.

The sink in the northern hemisphere is big but it's not like the Southern Ocean. The Southern Ocean is more than two-thirds of the total sink. It's more than 68 percent of all of the ocean heat uptake is in the Southern Ocean.

If that ever happens, we will see the rate of warming in the atmosphere increase significantly. Because then it won't be able to reach all that deep ocean cold water -- be like making the capacity of the ocean much smaller.

Dr. Biology: As part of this program we talk about certain topics, like say climate change. We know there are skeptics. But before you come to any conclusion, you need to investigate the research and look at quality data.

Joellen: Absolutely.

Dr. Biology: This is something that scientists live by.

Joellen: We test our hypotheses with real observations.

Dr. Biology: Yes, and there is a possibility that we could change our predictions based on our observations.

Joellen: We revise our hypotheses if they're shown to be wrong.

Dr. Biology: Right, so for example the models -- by the way we're not talking about fashion runway models. These models, which were done on computers, predicted a much faster rate of air temperature warming than we've seen. But it appears that it was because they didn't account for the impact of the oceans.

Joellen: That is very likely to be true. Partly because we weren't getting our winds quite in the right places, over the Antarctic in the Southern Ocean there, partly because the oceans weren't mixing properly -- when you did stir them with this extra wind energy -- and partly because we didn't know. I'll just say this, in 1998, we still thought that it was the difference in the temperature between the equator -- the tropics -- and the poles.

We thought it was that difference that mattered to how strong the winds were. The bigger the difference the bigger the winds. That as we were near the poles, it would actually relax and the winds would weaken and that would mean we wouldn't stir our oceans as much.

But it turns out that because of the ozone hole and that cold, cold temperatures way, way up in the atmosphere, associated with this big hole in the ozone, that in fact the winds have increased. They are stirring the ocean much more strongly than we anticipated. This effect wasn't in some of our early models because they didn't have stratospheres, the upper atmosphere.

They thought they only needed to resolve the big thick weather atmosphere that we live in and not the atmosphere above it, way up high, where the planes fly when they're trying to avoid the weather. That's the stratosphere and that's where the ozone layer is. In fact it turns out that that cooling, way up high, it's also another way to talk to skeptics.

Because many of them believe that it might be due to something, some change in the sun and not to human made influences. But in fact, that's not true at all. Because if it were the sun, then the upper atmosphere and the lower atmosphere would be warming all together. In fact what we see is that the lower atmosphere, where we live, the air temperature is increasing everywhere globally.

In fact, 2015 was the hottest year on record ever on planet Earth that we observed in the last say, at least 100 years.

But in addition to that, the stratosphere is colder than we've ever observed it to be, ever. You know how we make those measurements of crisis with these wonderful weather balloons, right? The weather service in Tucson where I'm at the University of Arizona, they released two balloons a day. They will release one at 4:00 PM and one at 4:00 AM.

This is part of a network globally of these balloons that we released to actually look at the profile of the temperature from the surface all the way up into the stratosphere.

It's amazing how much warmer it's gotten in the lower atmosphere and how much colder in the upper atmosphere, which is absolutely counter to the idea that it could be the sun. Even if the earth's radiation budget experiment with IRB, my favorite set of satellites, which does this really neat experiment where it looks out at the sun.

It's up in the upper atmosphere, in orbit, and it looks out at the sun and in at the top of the atmosphere. It looks at the energy imbalance between what's going in and what's coming out. What IRB tells us is that every single year, the imbalance is bigger. That's because there's more carbon dioxide in the atmosphere every year. Therefore more is trapped every year. We are warmer in the lower atmosphere and we are colder in the upper atmosphere.

All of these different kinds of ways of looking at the atmosphere, at the ocean, at the sun, at the ice and we use all of these different measurements and we test our hypotheses and we test and test and test. We push it as hard as we can. Because each one of us would like to be the scientist who has the breakthrough that shows that everybody was wrong and we were the only one who figured it out.

In fact what we find is that although the nuance we..."I did mine a little better than he did. I found out about this great effect of the winds in the oceans stirring." These are great things but they don't change the main story which is more carbon dioxide in the atmosphere is leading to warmer atmosphere temperatures. We're bracing for the change as we increase our CO2.

Dr. Biology: We talked about the winds in the ocean in the southern hemisphere. But what happens in the tropics?

Joellen: Yeah. The westerlies are what we call subtropical to polar phenomenon. They work for about 30 degrees north to 30 degrees south. By the way Tucson is down at 32 degrees north. So you know right about where the boundary is. Between that 30 degrees south of Tucson all the way to the other side of the equator at about 30, what is happening there?

Because this is not the domain of the westerlies anymore. This is the domain of the tropics and the tropics have a really interesting phenomenon. Because of course this is where it's hottest. It's because the sun is coming in most directly from right along the equator. Even with seasonal shifts, we see this very warm water.

Because although we have some continents. We have Africa, we've got pieces of Papua New Guinea, and we've got parts of South America and the Brazilian rain forests. We've got all of these things but most of it's water. What happens -- and this is amazing, is called the Hadley cell.

The very warm water at the surface, it lifts and you get convection, which is where you're actually getting big clouds. They boil up, boil up, boil up. I'm sure you've all seen this happen during a big thunderstorm or in a summer monsoon. They boil up, boil up and they rain as they go, losing some of that water vapor. Losing, losing it, losing it.

When they finally get up to the top of the atmosphere where they've lost all their water and they have no more energy left and they can't get any higher, they flatten out and they form these anvil clouds. The trick is there's lots of hot water and lots of up, lots of convection. The problem is what goes up must come down and where it comes down it is very, very dry.

Because of course it was cooling as it went up and then when it comes down, it warms as it comes closer and closer to the surface. But of course it's already dropped all its water. As it warms, it gets even drier. Low, low humidity, the kind that makes your nose crack and bleed. Guess where it comes down? It comes down right here in the Sonoran Desert.

Not just the Sonoran desert, it comes down in the Atacama desert, it comes down the Gobi desert, it comes down in the Sahara desert, it comes down in the Simpson desert in Australia. At 30 North and 30 South are what we call the downwelling arms of the Hadley cell and it's where we always find our deserts.

Dr. Biology: I'm so glad you talked about the Hadley cell because we have a great set of stories on biomes on the Ask A Biologist website. That biomes, rain forest and desert are great to go to because they discuss the Hadley cell. They also include an illustration of how the Hadley cell works.

Joellen: That's actually the plumbing of our atmosphere. You have the Hadley cell that creates the tropical wet rain belt. The two dry zones where we find our deserts in the northern hemisphere in the deserts in the southern hemisphere. Then just North and South of that, we find our westerly wind rain belts where we see the subtropical rain. The big winds with the big storms and we're talking Seattle, etc.

Dr. Biology: Let's transition. Since you talked about IRB, and we're talking about satellites and sensors...

Joellen: Sure, love sensors.

Dr. Biology: Because your research lab is in the middle of the desert.

Joellen: Absolutely.

Dr. Biology: Because we also have an oceanographer who has her lab in the desert, Susanne Neuer.

Joellen: Terrific oceanographer.

Dr. Biology: I have two oceanographers in the middle of the desert, studying the ocean. How can this be?

Joellen: Because almost all oceanographers aren't based in the middle of the ocean. We're based on land. We have to fly to get on our ship, and then, "Chug, chug, chug" out to the middle of the ocean. In addition to that, I'm working on a big project called the "Southern Ocean Carbon and Climate Observations and Modeling," which is doing a combined modeling and observational experiment to look at how much heat and carbon the Southern Ocean is taking up and helping us out here in Arizona.

The big thing is that we're not just using ships, we're using ships to deploy robot floats. These autonomous sensors -- and that means that we're not controlling them we don't drive them around -- they float, they drift with the currents, they sit down at about 10 football fields down -- about a thousand meters down.

Every 5 to 10 days, they drop down to 2,000 meters -- 20 football fields -- then they do a full profile, taking measurements all the way up to the surface. They beam all that data back by Iridium satellite and we put it up on the Web within two hours of when it reports back to us.

All of these floats are doing profile, after profile, after profile, all by themselves out in the ocean and reporting all this wonderful data back so that I can be an armchair oceanographer in the middle of Arizona.

Dr. Biology: Can students get to this?

Joellen: Absolutely. Welcome, welcome. We have a website called www.soccom, S-O-C-C-O-M, .princeton P-R-I-N-C-E-T-O-N, .edu. The reason it's at Princeton is because this program is led by Jorge Sarmiento who's a professor at SOCCOM, a dear friend and collaborator of mine.

I'm leading the modeling component and my friend Lynne Talley who's a professor at the Scripps Institution of Oceanography in San Diego is leading the observational component. You can check us out and see the data, access the models, access the new observations from the floats. Come on in, the water's fine. We'd love for you all to take a look.

Just, by the way, some classrooms have adopted some of our floats. We even put little stickers on and we'll sign them for you and send you a video of it being deployed. You can follow it around if you'd really like to, because there's a fantastic science fair science that can be done, classroom science that can be done. Come see the world change in real time.

Dr. Biology: So you're sharing data in real time and students can come and get it? They can do their own research?

Joellen: Absolutely. Please come on in. We love this. The more, the merrier.

Dr. Biology: You mention models again. And already, I said this is not a fashion runway model.

Joellen: [laughs] No, this is what I tell my kids. I'd say, "Look, momma works with math and super computers and I can see the future. Whooo!" [laughs]

Dr. Biology: Do they believe you?

Joellen: Actually, it's almost exactly true. That what we do is we use these basic equations of thermodynamics and motion to describe what the water would do if we did a numerical model of how it mixes. We've coupled these ocean models that have the topography and the amount of water and the energy from the winds and all the rest of it.

We've coupled them to atmospheric models of the weather and climate. Not just that, we've now coupled it to the ocean biology chemistry and the land hydrology and dynamic vegetation. We've fully closed the carbon budget and these are now called our system models. We're looking at the fuller system breathing and moving.

If you want to come in, seriously check us out at soccom.princeton.edu. because, you can see how we diagnose our models, how we validate these models, how we test them repeatedly. To make sure that we're getting it right. That in fact it looks like the real world so that we can trust these projections.

Dr. Biology: When you're testing your models, do you go back in time and run the model to see if it matches what really happened?

Joellen: Absolutely. In fact, a lot of our runs start at 1860 when we just started. But it's even before the Industrial Revolution as we're ramping up all the extra carbon from coal burning -- actually whale oil and all kinds of stuff, all the way through the present day. Then we make projections of what we think the carbon change will be in the future.

The reason we do this is we assume that we're all going to do aggressive reductions of emissions and we see what the climate would be like if we did that. We tried at the very highest if we pumped it all out, we burn it all, what would that look like. We use an envelope basically to see what the difference in climate might be the low end, the middle and the high end.

All the code is available online. It would probably take a supercomputer but you're welcome to all of it. You can see our diagnostic tools as well. We actually have a Southern Ocean model atlas, you're welcome to see the pictures of what we do. We've actually embedded underneath it all of the code for the analysis as well so welcome, welcome.

You can do all the same work I do. Come on in, the water's fine.

Dr. Biology: Let's move into a part of the show where I ask all my scientists three questions.

Joellen: Hit me.

Dr. Biology: Here we go. When did you first know you wanted to be a scientist?

Joellen: At leased by 12 because that's when I decided I didn't want to be an astronaut. I definitely wanted to be an oceanographer. But probably before that.

Dr. Biology: So even at the age of 12. You knew you wanted to be an oceanographer.

Joellen: Yes. I'd always wanted to be an explorer. I grew up in an Eskimo fishing village 31 miles above the Arctic Circle called Kotzebue. It's actually north of the Bering Straits. My dad worked for the Indian Health Service and he worked at the hospital there. I lived there with my brother, my mom, and my dad and it was wonderful. Great way to grow up.

It meant I wanted to be an explorer and I was certain that people had been everywhere on the land. I had two choices, the ocean or space, and I picked the ocean.

Dr. Biology: Actually we studied space more than we've studied the ocean.

Joellen: Yes, that's absolutely true. There really are only about 6,000 PhD level oceanographers in the world out of the seven billion people that live here. That means that those 6,000 people have responsibility to study observe, monitor and predict what happens to 70 percent of the planet's surface, 93 percent of all the human made heat.

Half of all the carbon uptake and something like 30 percent of all the protein consumed by people in the developing world who rely on marine sources for their protein. It's an amazing thing that only 6,000 people out of seven million have such a responsibility. I'm so glad I picked this field and any of you listening should definitely consider it.

Dr. Biology: Now I'm going to take it all away from you. You can't be a scientist and since you're at a university, I'm going to take away your teaching. This is an exercise that makes you stretch. If you could do anything, or be anyone, what would you do and what would you be?

Joellen: You're not going to want to hear the answer to this. [laughs] You're going to think I'm nuts but I would probably be a lawyer. When I was young, I thought if they ever threw me out or didn't give me tenure whatever I would become a lawyer because I want to fight. I want to fight for the people and I think that science in the public interest is a vital national importance.

I think that sometimes the EPA doesn't do their job. I think sometimes the federal agencies aren't held to account, forced to do more to protect us. We should be pushing our politicians and pushing our legal system to hold companies, hold the public, hold us all to account to live by the rules that will help make the world a better place for our children and our grandchildren.

It's not right that we will leave it in worse shape than when we entered and I'm going to spend the rest of my life trying hard to leave it in better shape than I found it.

Dr. Biology: The last question. What advice would you have for a young budding scientist or oceanographer? Perhaps there's a lawyer out there that wants to be an oceanographer?

Joellen: There are so many opportunities. Many people just don't realize that science fairs have prizes. Science fairs have scholarships. You know there is SARSEF. We're about to have the International Science Fair right here at Arizona State. You can participate in a science fair in kindergarten. Your teachers support you. They can do it as a class, they can do as individuals.

If you're bigger and you want to do career switching, I bet you didn't know that you can go to graduate school. They will give you a fellowship. We'll pay you a stipend and pay your tuition. If you go into STEM, if you go into science, technology, engineering, or math.

In some ways, I know it's a big pay cut. You wouldn't be making much. It's just in a stipend, it's not a real salary. But this is an amazing life and discovery every day as part of your job. It just is irresistible to many people and I'd invite you to start young, do it often, enjoy exploring the world around you and test those hypotheses.

You never know what you could discover. The US is full of tinkerers and dreamers and innovators and I just feel like we should be open to all these things.

Dr. Biology: What about that lawyer that wants to switch to oceanography?

Joellen: I don't know. Do lawyers know how to do math? [laughs] Yes. I would say that in many ways advocacy is also -- and that's what lawyers are advocates. There might be many, many great places they could work. I think of our great A National Resources Defense Fund. There's all kinds of fantastic places that they could put their lawyerly talents to work.

Dr. Biology: On that note, Joellen Russell, thank you very much for visiting with me today.

Joellen: I'm delighted. Thank you for having me and I apologize to all the lawyers.

Dr. Biology: You've been listening to Ask A Biologist and my guest has been, Joellen Russell. A geoscientist at the University of Arizona Department of Geosciences. In case you missed the address earlier in the show, don't forget to visit the Southern Ocean Carbon and Climate Observations and Modeling website.

That's a mouthful but you want to go there so you can learn how the Southern Ocean impacts our climate. The address is S-O-C-C-O-M dot P-R-I-N-C-E-T-O-N dot E-D-U. That's soccom.princeton.edu.

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Remember, even though our program is not broadcast live. You can still send us your questions about biology using our companion website. The address is askabiologist.asu.edu. Or you can just Google the words, Ask A Biologist.

I'm Dr. Biology.

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