Intro (00:01):

Welcome to Earthly, a Clemson University podcast discussing issues of agriculture, horticulture, nature, and design, impacting the world nation, state of South Carolina and even your home. Here's your host, Jonathan Vet,

Jonathan (00:17):

Clemson University faculty member Ley Mets is not just an academic, but also a licensed commercial pilot. One day while piloting skydivers to their jump altitude, met could see this aha and dust plume over the upstate and had a research epiphany to see what genetic matter was flying around in the sky. In this episode of Earthly, I talked to Metris about her work, monitoring the skies for genetic matter, how she designed and constructed her own instrumentation and what she found. She'll also talk about next steps for her research. Kimberly, thanks for joining me on Earthly To start, there aren't a lot of university researchers who are both pilots and scientists. So what came first for you? Was it the flight or was it the science?

Kimberly (01:01):

Well, thanks for having me. So technically the science brought me to flight after my undergrad in biology. In 2007, I moved to Africa and I pursued a Master's of Science in Zoology. And so I worked at National Parks and other wild spaces conducting research, monitoring tuberculosis and parasites and African buffalo. And so I was in helicopters and light aircraft to immobilize the wildlife and to get to remote places. And, you know, it was just inspiring to me and I wanted to do that. I wanted to be a part of that. I came back to the states to pursue my PhD and in so doing, I also started earning all of my flying certificates up through certified Flight instructor.

Jonathan (01:52):

So according to a recent news article about you, you had a sort of epiphany about combining research in flight. Why don't you tell us about that?

Kimberly (02:00):

So I've worked as a pilot and I've worked as a scientist separately, but they're both who I am, you know, as a person. So really being able to leverage my passions, my unique experiences, my talents to make scientific discoveries, to push the application of those forward and to give aircraft, some of which were, you know, manufactured in the 1940s and used for aerial surveys. Essentially a new meaningful mission is, it's what I wanna do.

Jonathan (02:35):

You had to design and build your own device in order to collect these genetic samples. Tell us about that.

Kimberly (02:42):

So I had this glorious goal of using airplanes to collect samples, and I needed a way to capture them so I could be sure I was getting reliable samples so that I wouldn't lose the sample and that it wouldn't be contaminated. I designed this sterilizable probe that has an isolation chamber to protect the sample and no inlet lines to be contaminated, and it can be mounted outside of an aircraft away from contaminants as well.

Jonathan ([03:11](#)):

What part of the aircraft do you mount it on for these flights?

Kimberly ([03:14](#)):

I mounted on the wing strutt, so the, it's in front of the wings leading edge so that it's, again, away from contaminants.

Jonathan ([03:25](#)):

Tell us about the aircraft you've been using.

Kimberly ([03:27](#)):

The type of aircraft that we use this instrumentation are, are light aircraft that our single engine, they fly at relatively slow air speeds. You're not getting anywhere fast necessarily, you know, maybe 80 to a hundred miles per hour is, is our cruise air speed. Sometimes the cars on the highways are passing us if we've got a strong headwind. So, you know, it's, it's sort of a low and slow type aircraft, so it works well for, for survey type missions.

Jonathan ([04:04](#)):

Does the slow speed of the plane give you some type of advantage in collecting the genetic matter?

Kimberly ([04:09](#)):

Well, there's different techniques to collect the genetic matter. So, you know, if you're flying a, a high speed, high velocity jet, you've got other factors to contend with, and that's going to impact the type of sampling system you'd use. So it's not necessarily that it's an advantage for collecting the material that we fly at a slow air speed, but what the advantage is to our instrumentation is that we, it's directly quantifiable. We know exactly how much air we're sampling for a given flight time, and so that's really essentially one of the, uh, crucial factors for what we're doing.

Jonathan ([04:50](#)):

Well okay, let's get into the details of the experiments.

Kimberly ([04:53](#)):

Yeah, so we flew over Northeast Georgia at three altitudes on the same day, uh, about a month apart. We, we flew there because it was close to our home airport for efficiency, uh, and it was an uncongested area, limited obstructions safe altitude. I was familiar with the area, I conduct flight lessons there frequently, and, um, it was over major aerosolization sources. So those structures on the ground that could potentially be responsible for bio aerosol emissions.

Jonathan ([05:35](#)):

What were some of those aerosolization sources?

Kimberly ([05:38](#)):

So if you were in the aircraft with me looking down, you would see so many poultry facilities and agricultural fields, farmers plowing and planting their fields. There were wastewater treatment facilities, more urban areas, although the majority was rural, agricultural and uncongested. There were some urban areas with construction activity, um, clinics, things of that nature. But by and large, a lot of agricultural facilities for sure.

Jonathan (06:17):

Did you fly in a specific pattern?

Kimberly (06:19):

We did. So we actually designed a flight grid that had me flying in all four cardinal directions so that I could minimize the impact of essentially wind direction on the sampling and focus instead on on height above the surface. And the grid was essentially, uh, designed to be 10 nautical miles in, in every direction.

Jonathan (06:46):

How do you fly in a grid when you're in an airplane? It sounds like that would be quite a challenge. <laugh>,

Kimberly (06:52):

When, when we're flying aerial surveys, we as pilots will call it mowing the lawn. So <laugh>, so essentially, you know, we've got a GPS, it's not, you know, the most high tech GPS, but it does the trick and essentially our aircraft is, it's looking outside and you pick a point and you fly to it. And so we had it mapped on, we've got an aviation flight app, uh, for flight. Most pilots are extremely familiar with it. We, we picked our grid and we planned it out and essentially doing your homework allows you to fly it well when you're actually up there because you have winds to contend with traffic, to contend with all of those things. So we flew the grid, all four cardinal directions, essentially crisscrossing each other and for it ended up being a 75 minute flight. So, so we would time it that way and try to keep those lines straight as best we could. Um, <laugh>,

Jonathan (07:56):

So when you're flying in this grid, do you need to tell air traffic control that you're gonna be doing it? I would think it'd be disconcerting for people to look up into the sky and see a plane flying back and forth and back and forth.

Kimberly (08:09):

<laugh>, well, the grid was so much larger. If we passed by somebody, they would, they would've no idea we're in the next city essentially by the time we're turning back around. Um, and so we flew about a thousand feet above the ground at our lowest altitude. Up to 8,500 feet above sea level at our highest. So that's very, um, comparably pretty high for a general aviation type light aircraft. Um, we were not in any controlled airspace, so there are no requirements to, to talk to anybody. Of course we monitor ATC and just listen for, for what's going on in the area. We're aware of traffic and we follow them on that same app that we have our survey planned out on. Um, we can see traffic, we can hear it. There were a few times we had to essentially take a little detour, deviate or do a 360 holding pattern, essentially just to let traffic pass by. But it was, it's a pretty quiet area over the, over the agricultural area there. <laugh>,

Jonathan (09:23):

What altitude increments did you fly at? It sounds like 1000 feet was the lowest and 8,500 feet was the highest. What altitudes were in between those two?

Kimberly (09:34):

So essentially we threw, we flew at 300 meters, 1200 meters and 2,500 meters, which would be about a thousand feet and then about forty five hundred and eighty five hundred feet.

Jonathan (09:49):

How did you come up with the design for the device you used. You're a pilot, you're a geneticist. Are you an engineer too?

Kimberly (09:58):

Right, so, you know, I had the idea of, hey, I wanna collect this genetic material from the air. Okay, I need a tool. How am I going to do that? I can fly the airplane, but now I need to get at the genetic material that's hanging out up there and being transported in the atmosphere. And so I had the best consultant that I could ever imagine. My husband who has an engineering background, I told him what I needed and what I wanted and we brainstormed, uh, together, we came up with a few different options and essentially, uh, we picked what was the simplest version of what we could do that was the most straightforward, to have fewer points of essentially failure problems and to be safe, right? So also looking at regulations and that sort of thing. And, um, we did a lot of homework and just thinking about it so that by the time we put it together and made it happen, it, it worked beautifully. It worked like a charm.

Jonathan (11:07):

Is the device you designed adaptable to other vehicles?

Kimberly (11:10):

So our instrumentation is actually designed, uh, not only to be mountable on an aircraft, but also ground-based vehicles, um, stationary ground and flight regimes, um, potentially even UAVs if there's a UAV that can take that payload.

Jonathan (11:31):

Alright, Kimberly, let's get down to brass tacks. What happened next and what did you find floating around up in the sky above northeast Georgia?

Kimberly (11:39):

Right, so we keep the sample safe in that isolation chamber in the instrument until I'm in the laboratory and I can open it essentially under controlled conditions, right? So we then I extract the genetic material, so in this case DNA and then sequence simultaneously all of the things that I was interested in. So essentially sequencing the plants, the bacteria, any animals that are captured on that filter. When we filtered the air through the instrumentation, essentially we found plants. So we detected crops, weeds, grasses, many of which are aeroallergens. So the things that cause us to get sick in different seasons, we found over 50 different types of bacteria. Some of them pathogenic, many of them known to be in extreme environments in the atmosphere, pollen and bacteria can serve as ice or cloud condensation nuclei. So they hang out in the atmosphere and then essentially clouds and precept builds up around 'em. So it's an important finding of course. And then also animal DNA as well, we found it at all altitudes flown all the way up to high altitude of the 8,500 feet..

Jonathan (13:10):

So you found animal d n A at 8,500 feet. Did you also find human DNA at that height?

Kimberly (13:16):

Mm-hmm. <affirmative>? Yes. So human DNA all the way up to 8,500, the highest altitude we flew for the, for that initial survey. So yeah, it really does reveal a connection between what's on the ground and, and what's in the air.

Jonathan (13:32):

How do we explain that? How do we explain that human DNA and animal DNA are being found that high up in the sky,

Kimberly (13:41):

Aerosolization efficacy, essentially wastewater treatment or agricultural impacts, we've got lifting action. And so atmospheric processes, lifting action, convection buoyancy in general for different types of bio aerosols, lifting action is important and it's really effective at what it does. And so, you know, this matter's being picked up from the surface and then taken up, transported, carried, both short and likely long, long range transport. So it's pretty impressive what what our ecosystem is, is capable of. And that cycling, that connection,

Jonathan (14:31):

The lifting action we're describing, are we talking about thermals for example, where raptors and vultures circle the air?

Kimberly (14:40):

Sort of, so essentially the lifting action is more like, have you ever watched a thunderstorm build and see how it starts to get taller and taller and taller and then it'll spread out and you know, as it's growing it looks like it's mushrooming up and just, just really expanding the force. And then so you've got the updrafts that lifting, and then as it goes through the thunderstorm goes through its stages, you've got the dissipation and the deposition. And so you not only have updrafts but also downdrafts and they're very powerful forces. So we might think of convection or just lift and buoyancy, but these are very, very powerful and even, um, inversion. So, you know, going from day to night, you might have lifting when solar radiation is creating heat and warm air is rising, but then as it cools, you may have deposition of whatever's in the atmosphere back to the ground. So it's cycling, but essentially these processes like lift, it's, it's generates a lot of force.

Jonathan (15:59):

We have Sahara dust storms affecting our air quality. We have Canadian wildfires affecting our air quality. How does that relate to what we're talking about?

Kimberly (16:12):

Right, so, you know, when we've got the Sahara dust storms coming by, essentially we've got atmospheric rivers. So you know, these forces just think about the jet stream, you know, they're, this is global. It's not just air circulating over an area, over a region, over a country for that matter. This is cross continental. Not only do you have short range transport, but also longer range transport. When I was flying skydivers and there was the Sahara dust plume there, you know, you could at that point you could visually see at least the sediment that was the visual indicator. There can be a lot carried in the air. And at that point it was something that I could see. But you know, what is in the air that we can't see? How do we get at it? You know, that's, that's the whole focus of, of where my line of research is.

Kimberly (17:06):

But even the, the wildfires, you know, when I'm flying, we're flying in the southeast. If there are fires out west in California or in Canada, we can smell that. And so we can see it, it might take a couple days, but we're going to see the impacts of that. And so that's the atmosphere. It's all connected. That's essentially the message is that everything's connected, the atmosphere, the hydrosphere, the you know, the land. And recently in, up in the Upstate we had, we've had days where the visibility is extremely low due to fires in, you know, in other countries.

Jonathan (17:48):

Did you, you find any genetic matter that you can identify as having traveled from far, far away?

Kimberly (17:54):

So the majority of what I found is selective of the area I overflew. So, you know, most of it was either what I could visually see as far as the agricultural and human mediated impacts going on at the, at the surface there were the composition of the bacteria is very similar to what we see out west in the atmosphere. There are some differences just based on local prevalence and occurrence of, of specific species, but there was nothing that was only indicative of long range transport. If anything it was more localized, um, with a few differences. And then of course extremophiles that prefer harsher environments or at least can survive there as opposed to more comfortable environments at the surface.

Jonathan (18:59):

Kimberly, what's next for your research?

Kimberly (19:02):

I wanna keep, I want to keep collecting EDNA, environmental DNA, and making discoveries to keep learning about what's in the air that we breathe that we can't see. So, you know, we share the air, we breathe with plants, bacteria, fungi, animals, you know, we share the air together. And so really discovering and learning about what's in the air, what's in the atmosphere, how is it carried and its role or impact on plant, animal, and human health. And a myriad of other things is, it's a crucial block for environmental impacts, assessments and, and biomonitoring for sure.

Jonathan (19:48):

Covid really brought our attention to what's floating around in the air to the aerosolization of genetic matter. Do you think there's a future medical application for this type of research?

Kimberly (20:01):

I do. I think that initially we need to establish a long-term baseline of genetic materials and bio aerosols and over seasons over time so that we know what normal looks like and then, and capture that temporal variation so that we can then detect changes or emergent pathogens with our sensors. More flights are needed to, to interrogate this, we need to be flying more <laugh>.

Jonathan (20:32):

Do you have more flights planned?

Kimberly (20:34):

We do. Um, so, so with the last studies that we did, surprisingly the, the high altitude samples captured similar biodiversity as the ones closer to the surface, but we do see some heterogeneity in that everything is not everywhere all the time. So we, we now have flight campaigns to keep that sustained sampling and that, and make that baseline map of what, what is this area? What does a given region look like over time baseline. And then if there's a deviation, we will be, um, more, um, prone or poised to, to detect that early and also focus on applying these discoveries, right? So applications as we discussed previously to plant animal human health, um, and really putting the science to work, right? Right. It's not just about research, it's, it's about applying those discoveries and what we're gleaning from the atmosphere and the air that we breathe. We care about water quality. We also are now we're having a greater appreciation or at least a renewed public appreciation for air quality as well with, with what we're observing going on at home and further away. So gaining more information to be able to accurately conduct those assessments and apply, um, apply this research because it, it really matters when it's applied and put to use.

Jonathan (22:10):

You mentioned that the variety of genetic material didn't vary according to altitude, but did the density or the amount of genetic material vary?

Kimberly (22:22):

The amount of genetic material did not necessarily differ depending on which altitude I flew at, essentially. You can almost think of it as if you're up in the air flying and you fly through a plume, maybe someone's burning something on the ground, you fly through that plume and you get whatever is being aerosolized by that plume. But if you were to not fly through it and just fly past it, you might not detect that. And so we see that depending on the day you fly with different conditions, you may pick up species that you didn't detect the previous day or even a previous flight depending on where you're flying and the meteorological, uh, the physical conditions at the moment. So nope, the altitude did not necessarily impact what we captured or the amount of what we captured. It's still bioaerosols are not necessarily, you know, it's not a high level of material. Our instrument is designed to, to take a lot sample, a lot of air to get the little bit of genetic material that's there. But we're still surprised how many different taxo we were able to detect on one filter.

Jonathan (23:45):

What was the variety of genetic material you were able to capture?

Kimberly (23:49):

Simultaneously from one 47 millimeter filter, we're able to sequence over 50 different types of bacteria in the atmosphere. Many different crop plant and weeded species as well as animal d n A as well. So the amount of different types of genetic material is, is massive. It, it's mind blowing.

Jonathan ([24:19](24:19)):

Have you learned anything about weather and atmospheric conditions and how that might affect the variety or the amount of genetic material in the air?

Kimberly ([24:28](24:28)):

What we found with regard to the, um, meteorological conditions and things of that nature is that even though the conditions didn't vary as far as uh, temperature, humidity, wind, wind speed, because remember we minimize the effects of wind direction. So that's not one factor we were looking at. But as far as wind speed, um, not a lot of effect because again, you need the lifting action. So it's more about, you know, taking into account, uh, indices of lift and air mass characteristics. So not only that, but okay, so the air mass that we flew through, where did it originate from? So air mass transport history. And so in some cases the air masses that I flew through and sampled came from the, the arctic up north and came down into South Carolina and Georgia. In other cases, they cut, came more from like the Gulf of Mexico and we're talking the same day. So at one altitude there's an air mass that has a history of having come down from the north and then one from the Gulf. So you might imagine that they're bringing different particulate matter, uh, to this area. So that can also account for, for variants and the heterogeneity that we might see in the atmosphere. But you know, that that was, this is an initial study, so that's why we have the sustained flight campaigns ongoing to really get at, okay, what conditions are preferable for sampling? How long do we have to sample the that nature?

Jonathan ([26:13](26:13)):

Was there any wildlife DNA floating around up in the sky?

Kimberly ([26:16](26:16)):

There was no wild animal DNAthat we detected. And that can be due to the, the, the genetic approaches that we took. So if you, you can have, it's possible for one type of, or one prevalent type of d n a to sort of swamp out or overwhelm in some cases or preferentially amplify one template that might be in the, the mix. And so we can't definitively say that we didn't capture any other animals, but what is there, uh, for sure are it's poultry avian species chicken. Um, and that was actually the, the first hypothesis that I had from all of my flights up there is I'm going to see chicken. I need to see chicken, DNA.

Jonathan ([27:15](27:15)):

Well, Kimberly, I know this is an ongoing program, um, and you have plans for the future. Are you looking for other scientists to collaborate with also?

Kimberly ([27:24](27:24)):

Yeah, so you know, we, we love to fly and these data can serve many applications from health and air quality monitoring. So anyone who might have interest in the data, in collecting data from a region of interest to them, we are open and happy to collaborate and, and share data.

Jonathan ([27:53](27:53)):

What else do we need to know about what you found when you were flying around up in the sky?

Kimberly (27:57):

What's in the air genetically and bioaerosol-wise is not only like a threat, right? There are emerging studies that show that the composition of what's in the atmosphere, what's in the air. We may be dependent on a certain makeup to essentially sustain or maintain our health and that of the plants and animals that sustain us as well.

Jonathan (28:29):

Kimberly, this has been a lot of fun. It's not every day that you get to talk to somebody who has the opportunity to combine two of their passions. In this case, your passion for flight and your passion for research. Uh, thank you so much for coming on Earthly.

Kimberly (28:43):

Thank you for having me.

Outro (28:50):

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