Dr. John Nielsen-Gammon

Interviewed by Dr. Jen Brown
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Interview conducted via Zoom

Transcribed by Kenya Zarate and Alyssa Lucas

**[Dr. Jen Brown]:** Okay. It is February 11, 2022, and I'm Jen Brown and I am talking to Dr. John Nielsen-Gammon via Zoom, and this is an oral history to talk about his life and work with Texas weather and climate and in regards to Texas water issues and freshwater inflow. So, for the record, do I have your permission to record?

**[Dr. John Nielsen-Gammon]:** Sure.

**[Brown]:** Okay, great. Well, we're just going to jump into it here. Since this is an oral history, I'd like to capture some of the kind of life history of you. So, could you start by telling me a little bit about your background and early life?

**[Nielsen-Gammon]:** Sure. I grew up in Northern California, where weather is a function of location rather than a time. We lived in a place we called Hurricane Hill, which was along the gap and the hills between the Pacific Ocean and the Central Valley of California, so the wind blew all the time in the summer months. I went to school in Massachusetts at MIT for ten years, finished that up in 1990, did a postdoc in Albany, New York for about a year, and came to [Texas] A&M [University] in 1991. My specialization was in weather and weather forecasting. Nonetheless, I became the Texas State Climatologist in 2000, and have been focusing more on climate related issues ever since.

**[Brown]:** Okay, and—okay, first off, I have to say that's one of the coolest titles, job titles (both laugh) anyone has, and we'll come back to that. But going back to growing up, what drew you to weather?

**[Nielsen-Gammon]:** I don't know. Around about the fourth, fifth, sixth grade, kicking around for at least hypothetical career choice, and I'd get interested in something and then it'd be boring after a while, and then I'd get interested in something else. And I decided weather, it was a possibility, and to determine whether it was actually something I'd stay with for a long time, I convinced my parents to buy me a weather station, which we mounted on our chimney, and I took daily weather measurements, and I figured if I could—if I kept that up for a year, and it was still interesting, it was probably always going to be interesting, and so, it proved.

**[Brown]:** What sort of experiments and weather observations did you make?

**[Nielsen-Gammon]:** Well, we recorded temperature and precipitation, and wind, and I think humidity, and then I would also take the daily weather map that was published in our newspaper and analyze it. Make it quite a bit more comfortable—colorful before the days of *USA Today*.

**[Brown]:** Oh, about how old did you start—when you started?

**[Nielsen-Gammon]:** About age ten or eleven.

**[Brown]:** Okay, wow. Not too many ten or eleven-year-olds interested in studying weather, I don't think.

**[Nielsen-Gammon]:** Well, when I teach our incoming freshmen class, I always asked them what got them interested in weather, and more often than not, it was either going to be an experience with severe weather like a tornado or a hurricane while they were growing up or they have a parent or grandparent that was fascinated by the weather and dragged them into a similar interest.

**[Brown]:** (laughs) Nice. So, when you got to college, you knew you were going to study weather. And tell me how—what you learned. Tell me kind of what questions interested you at that time, that sort of thing.

**[Nielsen-Gammon]:** Well, let's see. At undergraduate level I was able to get involved in a weather study called the New England winter storms experiment where we would launch weather balloons in the middle of winter and hand operate a tracking dish to monitor the information that's sent back and also monitor weather radar. So that was a unique opportunity, I think, as an undergraduate to be involved in that, and some of the results from that ended up being a part of my master's thesis, and then my PhD was based on another field program that was a bit bigger that was focused on winter storms that develop off the Carolina coast, and that involved spending a couple weeks down there at the field program headquarters, where I was one of the six lead forecasters for the—for the project deciding when and where to carry out operations. So, those were the main things I was involved with. I did manage to submit a paper on climate, basically looking at a synthesis of studies of global temperatures over the past ten thousand years and was encouraged. It was a term project, I was encouraged to submit it to a journal by my professor, and basically, the reviews came back and said, "Hey, that was a that was a good term project, but it's not a good paper" (laughs).

**[Brown]:** And so, from there, what drew you to Texas?

**[Nielsen-Gammon]:** Ah, Texas A&M [University] offered me a job when I was looking for one as a faculty member. It was one of three choices. The other, another offer I had, which was the largest value offer, was from MIT, which was flattering, however, the position I'd be occupying would be the position they'd basically denied tenure to my PhD advisor from. So I'd be replacing him and if I didn't think I was sufficiently smarter than him, there was not much point in me taking that job. So, I turned that down, wanting something where more likely I could survive and thrive. So, it was between here and the University of Wisconsin at Madison, which also has an excellent atmospheric sciences program, except they interviewed me in the middle of January.

**[Brown]:** (laughs) So College Station it was. Okay. Well, can you talk a little bit about when you first started off? Obviously, you were teaching as well, but what sort of questions were you asking, and topics were you studying in terms of weather and climate?

**[Nielsen-Gammon]:** I was originally looking at extreme weather events around Texas. So, we did—we looked at a small study on severe weather. We also looked at sort of larger scale stuff like what determines how storm systems form, how they interact with the jet stream, and how things get triggered in that regard, and I also, eventually also got involved in looking at air pollution, and how weather affects air pollution, so that we can predict air pollution better and understand the circumstances that lead to high, heavily polluted days, and also started looking at heavy rainfall, which seemed to happen with fairly regular frequency within Texas. And last little bit of stuff was on what we call data assimilation, which is figuring out how to take observations of the weather and best use them most effectively in simulations, or unimodal predictions of future weather.

**[Brown]:** Okay, well, that seems like a lot (laughs), in terms of different topics. So, I guess we could just—somewhere along the line, you got the title Texas State Climatologist. Can you tell me more about that?

**[Nielsen-Gammon]:** Well, in the late 1990s, we were working with what's now the Texas Commission on Environmental Quality to try to get a statewide Mesonet in place. Mesonet being an automated network of weather stations. Oklahoma had one which was very useful and very successful. So, we were trying to convince this legislation to fund something similar down here, and ultimately, we came very close to getting it passed. Twenty years later, it is actually happening through the Texas Water Development Board, but in the meantime, around that time, our previous state climatologist retired, Professor John Griffiths, and the Mesonet in Oklahoma was operated by the Oklahoma Climate Survey. And so, it made sense if I was trying to operate a Mesonet in Texas, I would also be the Texas State Climatologist taking weather and climate observations and overseeing quality of those. So, I volunteered for that, and after a highly competitive process, which involved the department head trying to find someone else who wanted it, the university put my name forward and then the governor's office scratched their heads about what the heck is a state climatologist, and they finally decided I probably couldn't do much damage, so I got the appointment.

**[Brown]:** (laughs) Okay. Um, now can you maybe tell me a little bit more about, you know, just the big picture on Texas climate and weather and maybe how that's changed over time?

**[Nielsen-Gammon]:** Well, Texas is sort of in a bad spot, geographically speaking. We're at the southern end of tornado alley, so we get a lot of severe weather, mainly in the springtime. We are also on the Gulf Coast, so we get a lot of, we're susceptible to hurricanes, so we get a lot of them. Most years, we go by without a hurricane, but about one in three a hurricane will make landfall along the Texas coast. And there's also a big difference in rainfall from western Texas to eastern Texas, and that can cause big problems when weather patterns shift slightly so that if you have a year like 2011, where East Texas gets the amount of rainfall West Texas normally gets, you have very big problems. So, we are vulnerable to all sorts of different types of extreme weather. That's predominately how we're vulnerable to climate change as well, because climate change has its impacts, not through what happens during a normal day, but what happens during the more extreme days, and climate change is not especially rapid in Texas. It's about, maybe about twenty five percent faster than the global average according to climate model projections, but we essentially go along for the ride with the extreme weather that's affected by it as well. Primary connections are with temperatures, so the extreme heat is becoming more extreme and extreme cold is becoming less extreme, and with rainfall, where the predominant change is with rainfall intensity, we're getting more heavy rain than we used to, and that's true all across most of the United States. And of course, when we get heavy rain, we can get really heavy rain. Hurricane Harvey was like the biggest rain event in the United States history as far as we can tell.

**[Brown]:** Um-hm, and droughts as well. Can you talk a little bit about that? I was just reading your drought article, so (laughs).

**[Nielsen-Gammon]:** All right. Yeah, the drought is a complicated thing. So, drought, a drought year is basically a year that has relatively low precipitation such that normal amounts of water related activities or uses of water by the environment can't take place, they've become limited. So that, that's what determines whether we have a drought on one year or not another year is mainly change in rainfall, but long-term trends in rainfall are not too clear. Climate models say maybe it'll go up a little bit, probably go down a little bit, but certainly not unanimous, so that's where all the other factors that affect drought come in. One of them I mentioned, two of them I mentioned already, higher temperatures, that affects drought because water evaporates from the ground more rapidly and evaporates from lakes more rapidly. So, you get less water in the environment where it can be utilized by plants and by water supplies, and also in changing rainfall intensity changes the partitioning between rainfall soaking into the ground and rainfall running off. So, climate change will probably lead to greater amounts of runoff than before and so possibly greater freshwater inflows on average, but at the same time, when you have a drought, things dry up faster and so the low inflow events might also become more common and last longer.

**[Brown]:** Can you walk me through how you construct these climate models?

**[Nielsen-Gammon]:** Well, I didn't, I don't build them. I just use them.

**[Brown]:** Okay (both speaking at once).

**[Nielsen-Gammon]:** What they consist of basically is the basic equations that govern how things work, things like force equals mass times acceleration and that sort of thing. I get applied to different parts of the atmosphere, and different parts interact with other parts because one of the driving forces is air pressure. So, higher pressure in one place, lower pressure on another means there's going to be wind being driven from one place to another, and there's rotation modifies that direction somewhat and so, all of that's in there. So, climate models are basically directly simulating what happens on the large scale in the atmosphere, in the ocean as well, similar principles apply to the ocean. And the more advanced climate models these days are also simulating what happens on land with not just moisture, but also what happens to vegetation, and how all that is interacting with the climate system. The challenges in climate modeling come in, because first off, you're limited by how powerful your computers are as to what level of detail you can simulate, and that means that a lot of what happens on the small scale has to be essentially estimated statistically, given what's happening on the large scale. So, if you have, if you have strong winds on a particular day, then, you know from physical principles, that means there's going to be a lot of turbulence near the ground and a lot of exchange of heat and momentum, and so forth. And so, you're basically writing equations that would say, oh, given this amount of wind, there should be this amount of turbulence, rather than actually simulating the motion of the air and the turbulence directly, you're estimating its effects on the large scale. The biggest challenge with all that is with clouds, which are typically fairly small, and they consist of tiny droplets of water that are less than a millionth of an inch in diameter. But yet, those are important in determining how much sunlight gets absorbed, and how much energy gets emitted back out to space, and those are the sorts of things that make the climate models challenging to get it exactly right.

**[Brown]:** And how do you deal with in the modeling competing scenarios for the future?

**[Nielsen-Gammon]:** Well, the model is basically taking as input what we call, well I don't even remember what we call it, taking input say emissions of greenhouse gases, or aerosol particles, or changes in sunlight, that sort of thing, and simulating the physical consequences of that. So, where scenarios come in is trying to figure out well, what should we say the future emission rate of carbon dioxide will be, or the future emission rate of methane, or the amount of burning in coal, and so forth. So, there are a variety of, let's call them socioeconomic pathways. Is the world going to become more unified? Is it going to become more fractured? Is technology going to advance dramatically? How's all that going to play out? And then given those possibilities, just take one of them and say, well, what would happen if we didn't do anything to fight climate change? What would happen if we tried to do a lot to fight it, and so forth. And so, you end up with a whole range of possibilities. There's a few standard possibilities that the climate modelers have agreed to simulate so we get a range of possible climate responses to those possibilities, and those used to be called RCPs [Representative Concentration Pathways]. They're now SSPs [Shared Socioeconomic Pathways], but it basically amounts to the same thing. And some of them, a couple of them are assuming no further action in the climate. Others involve more intensive action, and some of them are basically to see well, what happens if we try to put in such strong restrictions that we're able to keep global temperatures from going above one and a half Celsius or two degrees Celsius above what they used to be, and that gives the range of possibilities for the future.

**[Brown]:** Uh-hm. And what does it—I mean in terms of Texas, what do those models tell us about the future? You touched on that a little bit, but can you go into a little more depth?

**[Nielsen-Gammon]:** Well, as far as temperature goes, Texas is basically along for the ride. Temperatures will go up about as quickly or a little bit more quickly than the global average. That's generally true of land surfaces versus ocean, the land that responds more quickly. Rainfall is sort of, literally and figuratively, up in the air. Probably, there's so many big swings in rainfall just naturally in Texas, we probably wouldn't be able to notice much in the way of future long-term trends, but rainfall actually has increased in Central and Eastern Texas by more than ten percent over the past century or so. We expect to see and have been seeing more intense rainfall. We expect to see less frequent snow. Hurricanes are, there's a lot of different aspects of hurricanes that could change, like we expect that the most intense storms, the upper limit of intensity will actually be going up, but the total number of storms may go down. Storms will probably be producing more intense rainfall when they do happen. They, there's some evidence they might slow down on a on a global basis. There's some evidence they might speed up in the neighborhood of Texas. All sorts of different possibilities with varying levels of confidence associated with them. Basically, the way we, the way we can tell which things very likely and which ones are hard to tell is by looking at the three different types of evidence we have. We can look at the historical data, if there's good data with where we can pin down a trend, that's useful. If climate model projections have a clear signal, that's useful. And if there's a clear physical relationship between global warming and a particular consequence, that's useful. All three of those line up great for temperature, for example. They don't line up at all for say tornadoes, climate models can't simulate them. The tornado record is all over the map because we weren't chasing tornadoes until recently, and they're such small scale, there's not an obvious direct connection with global temperatures. So, each extreme really has a different level of competence and a different likelihood of changing and some of them get better. Probably most of them will get worse, as it turns out.

**[Brown]:** In terms of, you know, thinking about those future models, the sky's the limit in terms of the imagination of the modeler, right, but in terms of historical data and what exists, I mean, how far does that go back?

**[Nielsen-Gammon]:** Well, we have historical data, fairly comprehensively in Texas, back to the 1890s, and you can get observations, a few locations, mainly old Army forts, going back to the mid-nineteenth century. Before that, there's indirect evidence of climate like the growth of stalactites and stalagmites in caves. You can look at the composition of the water and how that, you can tell somewhat how that's influenced by temperatures. You can look at the pollen that's deposited in ponds, and so forth. You can look at tree rings and their rates of growth over time. And if it's a tree that's near a water source, then it might be sensitive to the amount of rainfall that takes place, and you can potentially look even farther back using other techniques. Of course, the farther back you go, the less direct the connection is to climate, less clear the picture is, but we do use that long term information to, basically, as a sanity check on climate models, and we're just now getting the point I think where observations, both past observations and present observations are able to pin some thing's down in terms of trends even better than climate models can.

**[Brown]:** So, when did—I'm not sure how to phrase this. When was it noticeable? When was climate change noticeable in Texas? I mean, that's—

**[Nielsen-Gammon]:** Yeah. (both speaking at once)

**[Brown]:** —That's worded poorly. But, um—

**[Nielsen-Gammon]:** Well, we had the temperature trend in Texas, it's gone up maybe about two degrees Fahrenheit over the past 125 years. Three degrees of that is over the past forty years or so, and that's because the 1970s and 1980s were actually the coolest decades of the past century, and so, it wasn't until, like after the year 2000 that the temperatures started being clearly on the warm side, and it's not until the past decade that it's, at least been clear, from a statistical point of view that you're, you're starting to get outside of the normal envelope of historical conditions. So actually, the emergence of climate change signals is a bit late in Texas compared to other places, and back in the early part of this century, I would sometimes get asked by a TV film crew, "Where can we go this to show people the evidence of climate change?" I wouldn't have any place to show that because things hadn't changed enough to be noticeable. Probably the first place you could actually go take a camera and film the impact of climate change is with the Bastrop Fire in 2011. We did a study on the 2011 drought and there hasn't been, like I mentioned, there hasn't been a downward trend in rainfall, but temperatures have gone up, and that means that things dried out faster, that means that the trees were dryer than they used to be. So, you can say pretty commonly the fire wouldn't have been as large without climate change, and so, on the edge, some homes burned because of when—if there hadn't been climate change, they would not have burned. So, that's really the first time you could actually go see climate change, I think. Hurricane Harvey sort of woke people up to climate change, but what we saw from Harvey is basically an event that is going to be really rare, even with climate change, but the odds of it have increased by a factor of three compared to a hundred years ago, and the odds of something like it repeating will be increasing as well in the future.

**[Brown]:** In terms of climate change, how do climatologists deal with causation?

**[Nielsen-Gammon]:** Well, with a climate model, it's pretty easy because you've got this simulation of a planet very much like our own and you can do experiments on it, you can change something and see what the effect is of it. So, that's our main tool for dealing with causation. If you're just working with observations, you can often get at causation by looking at the time sequence of events. If something, uh, if two things are correlated with them, but one thing tends to happen before the other than it seems it's likely that the one is causing the other or that there's something else that's causing both of them, but the causation is not working in the opposite direction. So that's—our main tool is with climate models, but there's some ways of doing it that don't involve the climate models also.

**[Brown]:** And what do you tell people when they ask, you know, how much of it is human cause?

**[Nielsen-Gammon]:** Well, it's a—it's a weird question, because most people think of it in terms of you got this like, pie diagram, you got a hundred percent of the change and some fraction of it is this some fractions that. Actually, we're doing a bunch of things to the climate system. Greenhouse gases are warming the system, and if nothing else were happening, the climate would probably be even warmer than it is, but we're also producing more particles in the atmosphere than there were a hundred years ago, and that increases cloud cover, and makes the temperatures cooler than they would be without that. So, that has reduced the magnitude of climate change. Natural factors are probably really, over the past hundred years haven't been a very significant effect, especially like the sun has not intensified since the 1950s. Volcanic eruptions come and go, but there's not a strong trend in decrease of those. So, it's pretty easy to point to humanity as the cause of the recent rise because there's nothing natural that could possibly account for it.

**[Brown]:** Um-hm.

**[Nielsen-Gammon]:** And, of course, that's relatively weak evidence from a scientific point of view that we haven't thought of anything that could account for it but conversely, when you do the math and see how big an effect greenhouse gases should have had, it's similar to what we've actually seen.

**[Brown]:** Okay, well do you ever deal with in your office like climate deniers?

**[Nielsen-Gammon]:** Um, they don't often actually show up in my office.

**[Brown]:** Oh (laughs).

**[Nielsen-Gammon]:** I do talk to them a lot. I was involved in a mailing list of let's say, calm, open-minded climate deniers for some time. And, you know, presumably when I go out and talk to a group of farmers or ranchers, I expect that most of them are seriously skeptical, skeptical about human caused climate change. Now, they're not skeptical about climate change, per se, because they're so attuned to what's happening on their landscape they can, they can see the temperatures are going up and rainfall patterns are changing. They're just not totally sure what the causes are for that.

**[Brown]:** Um-hm. Well, can you tell me more about your work on Hurricane Harvey?

**[Nielsen-Gammon]:** Well, when Harvey happened, we got a rapid grant from the National Science Foundation that's, by the way, that's the official name of the program, the Rapid

Program, to collect as much rainfall data as we could, after the fact. We didn't go out with a bunch of rain gauges. There wasn't time to tell that that was going on, but we collected data from official rainfall networks, and unofficial rainfall networks, and we even set up a webpage where people could input the observations they made in their backyard that didn't otherwise get distributed to anything like Weather Underground, or Earth Networks or something like that, and we got, we collected more than fifty observations that way. All in all, somewhere we ended up with thousands of observations and that allowed us to really map out the distribution of rainfall fairly accurately, and unfortunately, turns out that the sixty-inch rainfall totals that were reported at the time were probably incorrect amounts, and probably the greatest amount was close to fifty-four or fifty-five inches, which is still a big deal. Then we also looked at how big a deal that is compared to other parts of the country, other storms, and so we've got this catalogue of the biggest storms in history. Harvey is the top of the list, whether you look at the rainfall over a small area or a large area, or just a couple of days or a week, so, really impressive. We looked at how much heavy rainfall has been changing across the state of Texas and across all the southern United States, and it is indeed going up. And we did one what if scenario, which wasn't climate change related, but related to the fact that when Harvey was making landfall, some of the official forecasts had it really even slower than it did. So, we did a what if and said, well, what if it had been slow? What if the rainfall pattern hadn't moved along as quickly as it did? And we estimated that we would have seen in some places eighty inches of rainfall, and the total amount of water flowing into Addicks and Barker Reservoir in West Houston, where people actually lived, would have been about thirty percent higher, it could have been thirty percent higher than it was otherwise. That's again without climate change just from a slightly different, but entirely possible at the time, tweak to the forecast track.

**[Brown]:** That's really interesting. Now, I think that I can't remember where I was reading this, but you'd also kind of mentioned that some of the flooding issues aren't dealing necessarily with the amount of rainfall per se, but the infrastructure.

**[Nielsen-Gammon]:** Well, you know, Houston has had a problem with subsidence. A lot of the water supply, up until recently was coming from shallow aquifers, coastal aquifers, and that means that the land has fallen by several feet in places. So, that basically means that they're—water doesn't run off as fast as it used to, in some places it will collect where it didn't use to, and that by itself has led to an increase of flood-prone locations in Texas, and in Houston specifically. And on top of that, as far as building Houston means that you reduce the amount of water that can soak into the soil because a lot of the ground is paved over. That probably didn't have much effect on Harvey because if we got—the ground can typically absorb maybe a couple inches of rain. We had thirty inches so that's not a really big deal for the really big events, but it can increase flooding for the for the smaller events.

**[Brown]:** Uh-hm. Let's see, I also wanted to ask you about your work on the air pollution events in Texas cities.

**Nielsen-Gammon]:** Yeah, we looked—we're mainly involved in Houston, but we've also helped out with studies in Dallas and elsewhere, and my focus was on the weather patterns, because most places that get a lot of pollution like Los Angeles and San Jose, California, you can easily tell why they would be polluted, not just the fact that you got emissions, but also the fact they're surrounded by mountains and so air gets trapped there, but there's nothing obvious to trap pollution in Houston. So even though they have some pretty significant sources of pollution from oil refineries, and so forth, that doesn't imply the pollution should be as bad as it often was. So, what we found is that, essentially, Houston is at a particular latitude, that allows the lens to sort of get locked into place so that air would flow inland during the day, flow offshore at night, and come back in the next day, and that sounds a lot like the sea breeze, which it is, except it's—it's much stronger effect in Houston than it is in most other places. And there are rare days when you actually get the same air coming back the following day, but more likely, what happens is you've got some weak winds, which mean that the air moves inland a large amount, then for a few hours, it's moving offshore, and then moving inland again, so you get the same air that was there a few hours ago. And the slower the air is moving, the greater the buildup of pollution into that air because it's sitting over the same sources for an extended period of time, but if you get just enough wind that it never stagnates like that, and there's almost no chance of a pollution problem on that particular day. So basically, what we found explains why the worst days are all when the winds are less than a few miles per hour, and it doesn't really matter how much less they are, if they fall into that category, you're going to have some stagnation, you're going to have some significant pollution buildup.

**[Brown]:** Uh-hm. When you were doing that study, I'm kind of curious because it's pretty interesting like, did you expect that—I mean, did you kind of have a sense of what was going on or how did you come to those conclusions?

**[Nielsen-Gammon]:** Well, we were in charge of forecasting for a field program looking at air pollution in Houston back in 2000. And so, we knew what to expect, and what we saw was not what we expected. We expected it to be like a normal sea breeze where the wind would be blowing strongly onshore in the afternoon, but it turned out that if you looked at say at the wind at the top of a skyscraper in downtown Houston, the strongest flow inland would be like nine or ten at night, way later than a typical sea breeze. So, it's like immediately had to go back to the drawing board and see what's actually going on here? What are they—what's the data telling us and so we finally figured out that it was basically Houston is a special place which some people know already, but I didn't realize how much it affected the sea breeze.

**[Brown]:** (laughs) Yeah, neat. Well, let's go back to that idea of freshwater inflow. So why—what is going on in Texas that's leading you to believe there's going to be more rainfall in East and Central Texas in the future?

**[Nielsen-Gammon]:** Well, there has been more rainfall. It's gone up by about ten to fifteen percent since 1900. I don't know whether it's going to keep going up. Climate models don't indicate that it will, but it has so far. And so, we got the historical trend and climate models opposing each other, and there's no real physical expectation, that rainfall ought to go up or down with warming temperatures, because it's controlled by weather patterns and just by temperature itself. So, we don't know what's going to happen to the rainfall really, but if rainfall doesn't increase, we'll still be getting more intense rainfall when it does rain, and that means more runoff when it rains also. Now, that water then has to make it to the coast. Fortunately, most of the inflows don't come from West Texas, they come from fairly close to the coast anyway. So, temperatures causing more evaporation of water within streams is probably not going to be big enough to overcome the greater intensity, particularly because when it floods, it's oftentimes still raining and there's not a lot of sunlight anyhow.

**[Brown]:** So, thinking about kind of future planning for freshwater inflow, what do you think is needed?

**[Nielsen-Gammon]:** Well, at least from a from a climate context, we can talk about what climate model trends are for streamflow and rainfall and so forth, and it'd be easy to say you should take that into account, but that doesn't get you there really because most of the runoff ends up getting used for other purposes, drinking water, cooling, and so forth. So, and our society is also going to be experiencing climate change at the same time that the streams are, and they're going to be responding to climate change in different ways. For example, if temperatures go up, there could be a greater demand for water, and so that can affect inflows to bays and estuaries. We've got environmental flow requirements, but the time when those really matter, which is when you're in a drought, is also the time when society really needs all the water it can get, and it's not clear how that conflict will play out in the future. So, we actually, I think, need to try to at least develop scenarios for how society might respond to climate change and changes in water demand, at the same time that the characteristics of rainfall and streamflow are changing also, so that we can see the overall impact on inflows. So, that's a challenging thing to do, but I think ignoring it is pretty dangerous.

**[Brown]:** Yeah, definitely. Well, in terms of reservoirs and drought, how does temperature and kind of water storage play into that?

**[Nielsen-Gammon]:** The higher the temperature, the greater the capacity of air to hold water vapor, and so that means that the, you know, the reservoir you can think about, it's at full capacity—it's all liquid water, but the air above it doesn't have all the water vapor that it could and so the atmosphere is always sucking water out of the reservoir. And if there's a greater capacity for water vapor in the atmosphere, then it's going to suck water out more rapidly. So, higher temperatures will lead to greater evaporation rates unless the total humidity in the air increases rapidly enough to cancel out that effect, and as best we can tell from both physical principles and climate models, that's not going to happen. Maybe relative humidity will stay about the same, but that means that the gap, that unfilled capacity in the air will keep increasing with higher temperatures, and so that's the reason that we expect reservoir loss rates to increase. Another thing that could happen is it gets cloudier which reduces sunlight, but there's no good reason to expect clouds to change in any particular manner. People tend to point to clouds and say, "Gee, the clouds just change this much, then they'll have a big effect," but clouds are there because air is rising and sinking, and you can't have more air rising without having more air sinking, and so you really can't change the amount of cloud cover very easily as the climate changes.

**[Brown]:** Now, we've talked about Hurricane Harvey as a historic rainfall event, but can you tell me more about some historic drought events?

**[Nielsen-Gammon]:** Well, 2011 is the most recent one that would fit the historic category, and it was pretty dry, at least for hydrologic purposes until 2015 when we had an extremely wet year. We can go back. We'd had droughts that were intense in different parts of the state all the way since the mid-1990s, but that was the strongest one and then also the longest lasting one in recent history. The worst drought, generally speaking, was in the 1950s. Most parts of the state would say it was like from 1950 to 1956, when it was dry, and '56, in particular, was the driest of those years. So, it was a—the droughts just kept getting worse and worse and reached its peak in 1956. Whereas the more recent 2011 drought, it dried out quickly and then just sort of stayed there for a while, and didn't really recover for a long time. The Dust Bowl people sort of imagined must have been a pretty bad drought, but that was really—there was a dry year in there but mainly the Dust Bowl affected the panhandle of Texas and not most of the rest of the state, but if you keep going back, 1917 to 1918 were pretty darn dry as well, and for a while there, you can say hey, we got a drought in the 1910s, and you had drought in the 1930s, we got a drought in the 1950s, we know it's going to happen the 1970s. Well, it didn't happen in the 1970s. As soon as you think you see a cycle, it goes away.

**[Brown]:** Um, also, your article talked about megadroughts. Can you explain that a little bit?

**[Nielsen-Gammon]:** Well, a megadrought is a drought that extends over several decades. We haven't had one of those in Texas in recorded history, but there's evidence from tree rings and so forth, that we have had them in the past millennium. Back in the sixteenth century, the twelfth or the thirteenth century, that sort of thing. And you know, our paper, we didn't say that a megadrought is—another new megadrought is coming because that would be misleading because droughts and megadroughts sort of by definition, they're temporary. What's actually apparently going on, at least for soil moisture in the state of Texas, is what we call aridification, you know, arid means dry, and we're talking about a trend toward dry conditions in general. So, droughts will be drier, wet periods will be drier, average conditions be drier, and it won't be a megadrought, but it'll be as dry as it was during the past megadroughts, potentially. That's based on the most extreme climate change scenarios. So, it's within the realm of possibility we won't necessarily get that bad, but it's something to be concerned about.

**[Brown]:** Uh-hm. Well, what do you say when people ask you if there could be another Dust Bowl or another drought of the 1950s?

**[Nielsen-Gammon]:** Well, it has happened. There are things that have happened that I would say that's not going to happen until it did, like Hurricane Harvey. So, the fact that we've seen a drought of the 1950s is certainly means they're going to happen again. It'll be different than it was before because if we have a similar lack of rainfall, it will happen while temperatures are warmer. So, we'll see somewhat different consequences of such a drought, and the fifties drought is perhaps like the third worst drought of the past five hundred years, according to the tree rings. So, we have seen, or Texas has seen or pre-Texas has seen drought worse than the 1950s drought, and there's really no physical limit to how bad a drought can be. There's nothing that guarantees that if you have eleven dry months in a row, the twelfth month's got to be wet. So just hopefully it doesn't happen anytime soon, because it would be challenging to deal with if it does.

**[Brown]:** Let's see. Just checking out my list here. So, in terms of the state water plan, and those kind of five-year cycles of the state water plan, how does climatology go into those plans?

**[Nielsen-Gammon]:** Well, the planning is really focused around the drought of record, which is the worst conditions that have been experienced and monitored, and there's value in doing that, because you can test your models of streamflow and water use and so forth and make sure they're working properly if you tie everything to that. Um, and there's some hope that the drought of record is actually, you know, a reasonably rare event. It's been rare historically so, you know, hopefully that'll apply in the future, but it doesn't really apply if droughts are becoming more intense. So, there's not a standard framework for dealing with changing droughts within the state water plan. The Water Development Board has proposed having the guidance for the next round of planning, say explicitly that planners can plan for something worse than the historical data record if they want to, so it will still be optional. It'd be nice if they actually had a specific sort of framework target to say, it'd be realistic to plan for something twenty percent worse or something along those lines, but at least there's the capacity to plan for it if not the requirement.

**[Brown]:** Yeah, that's interesting. So, in terms of your chapter contribution on Texas climate and weather, is there anything we haven't covered?

**[Nielsen-Gammon]:** I don't know for sure, because we haven't written the chapter yet, but we have covered the main issues I've been worrying about.

**[Brown]:** Yeah. Well, what's your favorite part about being a climatologist?

**[Nielsen-Gammon]:** Well, I like working with numbers and working with statistics. So, climate is a lot of that. Then I like understanding issues and particularly contradictory points of view on different issues, and climate has become a lot of that also. And lastly, I like being able to learn things that are going to be useful for society in general, and climate has become a lot of that too. So, it's—my brain is well suited to it, and it's serving a useful purpose for society.

**[Brown]:** Uh-hm. Do you have any memorable events of the last thirty years that you'd like to talk about? In terms of your own career, and you know, maybe some of the weather or other aspects.

**[Nielsen-Gammon]:** I'm trying to think of anything memorable. Obviously, if I can't think of one, it wasn't memorable (laughs). I've been on a few storm chases, nothing recently, though. I'm a little too busy for that. I do like going outside to catch the first really strong cold front, and the watch the insects go by and watch the birds go by and they're trying to feed on the insects that are moving south and feel the cold air and detect the different smell of the air. You know, seasons on the calendar change gradually but it's nice to be there during the half hour when it actually happens.

**[Brown]:** (laughs) One of the things that you had touched on is communicating climate to the public, and how do you go about this?

**[Nielsen-Gammon]:** Well, there are lots of types of climate communication. There is, for example, people who are very concerned about climate change and trying to convince everybody else that it's a serious problem and we need to do this and that about it. And there's people who are worried about people doing things about climate change that would be a waste of money, and they're trying to convince people to do this and that about it. As a Texas state climatologist, I figured my role is to essentially explain what's actually happening and what is expected to happen and not go into the policy controversies because, well, for one thing, no matter what your point of view, there are people arguing that position. So, we don't need, necessarily need someone else arguing that position. What we do it is somebody who is providing unbiased, nonpartisan information about climate and so, I'm trying to fill that role as best I can.

**[Brown]:** Uh-hm. Well, I think I covered everything I wanted to. Is there anything you wanted to add or include for the historical record?

**[Nielsen-Gammon]:** Well, I'll mention my most memorable coastal location. It's a place probably most people haven't heard of Indianola, Texas. It's memorable because it doesn't really exist anymore. We had—they had a, it was one of the biggest ports in Texas during the nineteenth century and then it got nearly wiped out by a hurricane in 1875, and they rebuilt, and then it got seriously wiped out by a hurricane in 1886, and people said, this is stupid, we're not going to rebuild again. In 1900, Galveston got nearly wiped out by a hurricane and they rebuilt and reinforced, and the next hurricane that came along didn't do nearly as much damage. So, somewhere between the Indianola hurricane of 1886 and the Galveston hurricane in 1900, Texas changed from dealing with the climate, as they found it, to fighting back against the climate. We've been fighting climate ever since.

**[Brown]:** (laughs) Nice. Um, okay, well, I guess that's it. Thank you so much for talking to me today. I'm going to turn off the recorder here.

**[Nielsen-Gammon]:** Okay.

(end of recording)