**EP\_3\_atmosphericrivers**

[00:00:00] **Intro:** [00:00:00] Welcome to come rain or shine podcast of the USDA Southwest Climate Hub and the department of interior Southwest Climate Adaptation Science Center, or Southwest CASC. I'm Sarah LeRoy science communications coordinator for the Southwest CASC. And I'm Emily Elias, Director of the USDA Southwest Climate Hub.

Here, we highlight stories to share the most recent advances in climate science. Weather and climate adaptation and innovative practices to support resilient landscapes and communities. We believe that sharing some of the most forward thinking and creative climate science and adaptation will strengthen our collective ability to respond to even the most challenging impacts of climate change in one of the hottest and driest regions of the world.

[00:01:00] **Sarah LeRoy:** [00:01:06] In February, 2017 an atmospheric river damaged spillways of California's Oroville dam. Spurring the emergency evacuation of 180,000 people, and almost bringing down the dam, atmospheric rivers also known as ARs are narrow streams of moisture in the atmosphere that transport water vapor from the tropics to other regions.

In the US they mostly impact the West coast accounting for much of the region’s moisture. And they have been identified as the primary source of hydrologic flooding in the Western United States. Some ARS transport vast amounts of moisture further inland, as far as Utah and Arizona, where they have triggered floods and related impacts.

We'll be talking with three atmospheric river researchers from the Climate Atmospheric Science and Physical Oceanography Department at Scripps Institution of Oceanography at [00:02:00] University of California, San Diego. Their extensive research provides insights on the causes, impacts, and projected changes to ARS.

Alexander or Sasha Gershunovand Dan Cayan, our research meteorologists and Tom Corringham is a postdoctoral research economist, and they are all affiliated with the Center for Western Weather and Water Extremes or CW3E, devoted to the study of atmospheric rivers. Sasha and Dan are also principal investigators with the Southwest CASC.

Thank you all for taking the time to participate in this podcast and share with us your research, especially during these unprecedented and challenging times. I want to start by asking why you believe it is important to learn about atmospheric rivers. What makes them a noteworthy phenomenon to study?

**Dan Cayan:** [00:02:52] You want to lead off?

**Sasha Gershunov:** [00:02:54] All right then I, I reckon I'll say that, um, [00:03:00] atmospheric rivers, even though they're less frequent than other storms provide the lion's share of the water resources in this region. Especially the coastal region, but, uh, also inland and particularly in Arizona, atmospheric rivers, get in sort of these, uh, sort of conduit when they make landfall in Baja, California, can produce, um, extreme precipitation events and actually the largest proportion of our extreme precipitation events, uh, is associated with atmospheric rivers, you know, an average atmospheric river transports as much water instantaneously as something like 20 Mississippis I think it was, or three Amazon rivers. So they, they're very important for generating water [00:04:00] resources for the region, as well as flood risks.

**Dan Cayan:** [00:04:04] So this is Dan Cayan, and I would, only, uh, add that, um, they are really the major conveyance of moisture from low latitudes to high latitudes, which of course in planetary terms is extremely important in driving, not only the water cycle, but climate.

**Sasha Gershunov:** [00:04:34] Yeah, for sure.

**Dan Cayan:** [00:04:37] In the West and particularly in, in the Southwest, we have a great deal of variability in the delivery of precipitation from year to year.

And when we've, um, sort of taken that, that variability [00:05:00] apart by looking at its daily, uh, sort of ingredients. What we find is that, as Sasha said, even though atmospheric rivers occur relatively rarely, uh, it turns out that the atmospheric rivers either their presence or their absence, that drives a considerable part of the year to year, uh, fluctuations in our water supply.

So years in which we get, um, a large handful of atmospheric rivers in the wintertime in California, tend to be wet years. Years in which we are deprived of atmospheric rivers. And for example, this year [00:06:00] 2020, we've had relatively few atmospheric rivers that have struck the central and Northern part, of California.

Uh, we ended up being, uh, generally on the dry side. So our, uh, disposition in terms of our water supply is, uh, very centrally dictated by the position, strength, uh, presence, absence of ARs. Uh, Sasha mentioned the fact that ARs are not only a benefit, but they're also a danger. And, um, our colleague, Tom Corringham has led the charge, uh, in actually evaluating the, uh, the influence of ARs along [00:07:00] the West coast. So, Tom, that's a segue.

**Tom:** [00:07:05] Sure. Thanks, Dan. Thanks Sarah for having us, I guess I would say the reason I'm interested in atmospheric rivers they affect every aspect of our landscape in Southern California and in the Western United States.

They govern our hydrology. And I think we're becoming increasingly aware as a society that weather and climate have real impacts in terms of our economy. At CW3E at all different ways in which atmospheric rivers and extreme West coast weather and hydrology impact the economy. Some of our work has been focused on evaluating the costs of flooding associated with atmospheric rivers.

[00:08:00] Mmm. We found that 84% of the flood damages in Western 11 States over the last 40 years have been caused by atmospheric rivers, which works out to be about a billion dollars a year on average. Although those damages are distributed pretty unevenly across the years, you can have several years with very low damages, and then a few storms will create extreme damages, but so atmospheric rivers are also beneficial to our economy in the sense that they provide water. They replenish our water supplies, which we use for agriculture, and municipal water use, and industrial use. We use them to manage our wetlands and our scenic rivers. So they're critical in many ways to the economy of the West.

**Sarah LeRoy:** [00:08:56] Excellent. Thank you. So you spoke a little bit about the [00:09:00] impacts to water resources and stream flows, and as well as, um, the economic impacts, could you speak a little bit about impacts to coastal systems and ecosystems from ARs?

**Sasha Gershunov:** [00:09:15] I might like to say that, um, you know, for anybody who has seen the map of precipitation distribution in the West, uh, we realized that it's governed by the presence of mountains.

Uh, And atmospheric rivers produce orographic precipitation, meaning that when they deliver Mmm, a lot of moisture. So it's basically wind and moisture is an atmospheric river. And when all that moisture hits the mountain range [00:10:00] it gets squeezed out of the river as orographic precipitation. And so atmospheric river has really contributed a lot to that picture of the precipitation distribution in the West.

Um, basically making the Windward sides of mountains, both coastal ranges in the Sierra, Nevada, and further inland. Uh, wet, uh, and, uh, and also producing a rain shadow on the Leeward side. Um, so, um, you know, obviously that goes a long way to determining the, the spatial distribution of our ecosystems. Um, and, um, certainly atmospheric rivers are also warmer storms than, than other winter storms. So the snow levels are higher associated with atmospheric rivers. There's more runoff. [00:11:00] Um, and, uh, that, uh, all ends up,if the reservoirs can't capture that most of that ends up in the coast. Uh, and a lot of that, uh, actually a lot of that runoff carries toxic, um, material, with it that's been collecting on the surface in between storms that has impacts on coastal ecosystems, uh, as well as, uh, public health for people that, that go in the water after these events.

You know, the same places that, that get wet from atmospheric rivers are typically susceptible to wildfires and, um, weather, um, you know, so the presence or absence of atmospheric rivers can determine [00:12:00] or impact a wildfire risk as well. I think Dan can talk more about that because he's been leading some really interesting research into that question.

**Dan Cayan:** [00:12:13] Yeah. Okay. I guess I'll, I'll jump in, in our Mediterranean climate system here in California we have, we have long dry seasons starting usually in June and persisting into sometimes, uh, September, sometimes October. Sometimes we don't get meaningful rainfall until December. And it turns out that the onset of, um, relatively bountiful, uh, sort of ground wetting precipitation varies from year to year [00:13:00] on average by about a month.

So one year it can be relatively early and the next year it could be two months later, uh, on average, um, the, the first really good wetting storm in Southern California is, um, occurs about on November one. And now we've looked at a record that goes back to world war two, um, and catalog these autumn precip onsets.

And, um, interestingly, so we've, we've identified these first events of the, uh, essentially that punctuates, that ends very dry, uh, summer and early autumn season. [00:14:00] And in hindsight, what we find is that atmospheric rivers um, are more often than not the driver of that first wetting rainfall. So they're extremely important to ecosystems, they're extremely important to our society and essentially the cost of wildfires and so on.

If we have a, if we have a season in which this first wetting rainfall is delayed, we tend to get more wildfires. We have more opportunities for Santa Ana winds and that kind of risk. If on the other hand, we wet the, uh, the soil and the vegetation, then even if we have those kinds of events, they're not as risky because the system [00:15:00] is moisture.

I also want to turn back to the coastal part of this and just, um, mention that, um, a lot of the damage that's inflicted by atmospheric rivers happens in coastal regions. And maybe again, Tom might want to take off on that one because he's looked at this in great detail along the West coast.

**Tom:** [00:15:27] Sure, yeah, in terms of coastal systems. Uh, Dan is right. A lot of the flooding is coastal flooding. Um, in the West, obviously there are a lot of different forms of the flooding, there's river flooding, um, areas like the Russian river, uh, have been very significant. Um, we see, um, Mudslides, um, and debris flows in more hilly terrain, especially after wildfires.

So there's an interesting [00:16:00] interaction there between wildfires, and atmospheric rivers, um, and then in coastal areas, Um, we see flooding associated with atmospheric rivers, and we expect this to get worse, uh, in the coming century for two reasons. First we expect, uh, atmospheric rivers, uh, to become more intense.

And I think we'll probably talk a little bit more about that. Um, But we also expect sea level rise associated with human caused climate change. Those two combined are likely to produce significant increases in coastal damages. And it's not just houses that are at risk, but we have our infrastructure, coastal infrastructure, um, energy supply, transportation networks.

Uh, so that's something we need to be thinking about as a society is how to respond [00:17:00] to the giant threat of sea level rise and increased intensity in atmospheric rivers. Um, in terms of ecosystems more generally, obviously atmospheric rivers have impacts on the drought cycle, which modulates all of the ecosystems of the West and, um, have significant economic impacts through agriculture, but also through impacts on endangered species, so endangered salmonids, salmon, steelhead in rivers in the West. So these are, um, these are all impacts of atmospheric rivers that we are working to understand and better manage.

**Sasha Gershunov:** [00:17:46] Yeah. If I can just jump in and sorta, uh, join some of the things that Dan and Tom just said with one recent example. Uh, thinking [00:18:00] specifically of the Thomas fire, that was the biggest wildfire in California.

Uh, and the time it occurred, the unusual thing about that wildfire was, um, how late in the season it was. It started, uh, it basically burned through most of December and into January because there hadn't been any um, sizable precipitation of the type that Dan was talking about, uh, until early January, um, and, uh, uh, December is actually the peak month for Santa Ana winds, which are the down slope, dry, gusty winds, that fan most of our most catastrophic wildfires in Southern California. Uh, if they occur before, uh, before significant rains, [00:19:00] then a catastrophic wildfires are possible. And if the rains are, if the rains are late and don't occur, uh, until, uh, you know, into December, we're getting to the peak of the Santa Ana wind season when you're likely to get back to back Santa Ana winds.

And that's what happened. Uh, in the case of the Thomas fire that ended up burning through most of December, um, fanned by back to back Santa Ana wind events, it became the largest wildfire in Southern California history by now. And it was finally put out. I think on January 9th, by an atmospheric river, which put out the smoldering remains of the Thomas fire and caused the debris flows that added insult to injury and killed more people.

**Dan Cayan:** [00:19:59] That was a great [00:20:00] example, Sash of, uh, of how this sort of fits together.

**Sasha Gershunov:** [00:20:06] It's also an example of what we expect, um, more in the future, because one of the things that, um, um, that we're expecting with climate change, for example, is a later start to the wet season.

**Sarah LeRoy:** [00:20:26] So that's a perfect segue, Sasha and Tom touched a little bit on this too, but could you elaborate more on the kinds of changes that we expect to see in the future with climate change in regards to the behavior of atmospheric rivers?

**Sasha Gerchinov:** [00:20:44] There is a very specific regime change that we expect in terms of precipitation to occur in the Southwest. Um, and, um, specifically, uh, in the Mediterranean Southwest. [00:21:00] So, um, that’s mostly California, and basically that's where as Dan said earlier, um, we have a winter time wet season and a, and a dry summer season.

These Mediterranean climate regions basically sit on the boundaries of the subtropics and the mid-latitudes. And so they have a subtropical dryness in the summertime and, uh, and mid-latitude storms producing pretty much all the precipitation in the winter time. Well, with polar amplified climate change, uh, the subtropics are basically expanding and that's evident from observations and, uh, climate projections as well.

Uh, and as the subtropics expand, the dry season basically gets longer. And, uh, those [00:22:00] mid-latitude storms that, that bring us the precipitation get pushed into a narrower winter season, focused more on December, January and February. Um, basically what we see is that there's a decrease in precipitation frequency projected for the future, which is mostly driven by decreased storm activity in the fall and spring, but the really extreme, impactful, um, precipitation events, which are mostly atmospheric rivers are becoming more extreme in a warmer climate.

We have basically studied both parts of this, both the decreased precipitation frequency as well as the increased intensity. Well the increased [00:23:00] intensity is almost entirely driven by wetter, longer, fatter, uh, and more impactful atmospheric rivers. So, uh, what Dan said earlier about the very volatile precipitation regime and water resources in this region where so much of the precipitation depends on that one, two, three big storms per year.

That volatility is only going to get exacerbated with future warming.

**Dan Cayan:** [00:23:33] Tom has done some interesting recent work on, um, the prospects of, um, of flooding and damages in the future. Largely driven by atmospheric rivers.

**Tom:** [00:23:50] Yeah, we've taken some work that was developed initially by Sasha and Tamara Shulgina and colleagues at [00:24:00] CW3E building on 16 global climate models that project through to the end of the century. And we found that our preliminary results suggest that, um, the damages associated with flooding due to atmospheric rivers could double by the end of the century, relative to the end of the last century. Uh, what seems to be driving that is this increasing intensity of the really strong atmospheric rivers.

So, um, last year at CW3E, Marty Ralph, and, um, several colleagues developed a scale to categorize the intensity of atmospheric rivers from one to five, similar to the way that hurricanes are classified or tornadoes. And, um, our preliminary results suggest that using these models, it looks like, uh, the AR one and [00:25:00] AR two storms, which are, uh, weak and mild storms, uh, typically, um, more beneficial than harmful, hey just replenish the water supply, but they don't do much in the way damage. Those will probably remain fairly constant in frequency. But AR three, AR four, AR five storms, which are increasing intensity, uh, will become more frequent, um, as the climate changes and in some work that we published in December, we found that, um, the damages associated with atmospheric rivers increased exponentially with category.

So AR one storms typically cost on the order of a few hundred thousand dollars in damages. Um, three is in the millions, AR four in the tens of millions, and AR fives in the hundreds of millions of dollars in terms of medium damages. So this shift to, um, more intense atmospheric rivers could have a [00:26:00] really significant impact on total damages associated with atmospheric rivers.

**Dan Cayan:** [00:26:04] I might just, uh, comment that the, the warming planet, which is involved in, uh, making atmospheric rivers richer, um, more moist and, uh, and more impactful, the sort of phenomena that Sasha mentioned, uh, that we see in climate models projected over the 21st century. But this warming is, is a two edged sword. Uh, as, as Sasha mentioned in taking stock of climate models in future decades, we see the decline of the, the number of days with precipitation.

Uh, [00:27:00] so, uh, the future Mediterranean system actually has more dry days and because of inter-annual climate variability, there's going to be some years where the, um, the orientation and, uh, the impact of atmospheric rivers in California is likely to be absent. You know, we get a big ridge instead of a trough along the West coast.

And it's it's those years, of course, that are, that are traditionally our dry years. But now when they occur in the future, they're occurring during a period when, uh, temperatures are even warmer. So, um, a couple of things there, one is that, uh, with fewer opportunities [00:28:00] for precipitation, uh, we, we actually see in climate models, the incidents of more dry years, occasionally very wet years because of this richer atmospheric moisture ingredient to ARs. The more dry years means that more dry years could gang up so that we're actually concerned. Um, not only from the aspect of atmospheric rivers becoming more powerful. But also the fact that in certain years, they're just, they're just not a presence. And in those years we have warm droughts and potentially longer warm droughts.

So this is a really interesting picture that's unfolding. And of course, we're looking at it through [00:29:00] the pages of climate model, uh, catalogs. And, and of course we'll continue to do that in the, in the future, but right now, um, it looks as if our variable and volatile, uh, climate in the Southwest may get even moreso.

**Sarah LeRoy:** [00:29:22] And with that, do you anticipate any changes, so right now, ARS can propagate inland right, and reach Utah, Arizona and affect precipitation there. Is that expected to change at all in the future?

**Dan Cayan:** [00:29:40] Oh, that's a, that's a great question. Um, the, um, I think the, the forms of, um, synoptic weather patterns that drives those penetrations, uh, is, is going to continue to exist.

Um, Sasha had [00:30:00] mentioned earlier that a lot of that is, um, is dictated by topographic features where streams of moisture can penetrate, um, through gaps in coastal mountains and so on. So, uh, I would anticipate that atmospheric rivers are still going to be a presence in the future. And on average, globally, the atmosphere is moister under a warmer climate.

So, uh, it would be. It would be surprising if atmospheric rivers don't continue to affect the interior Western States, but I know Sasha's anxious to offer his thoughts on this. So I'll let him go ahead.

**Sasha Gershunov:** [00:30:50] Well, I just wanted to say that, uh, Sarah's question is actually, you know, a research project that, [00:31:00] uh, uh, that, uh, we need to look at. It's on our agenda. Um, you know, so far the changes that we've described are mostly driven by thermodynamics. You know, like Dan just mentioned the warmer atmosphere basically can hold more water and the atmospheric rivers are near saturated windy conditions, basically, they, will certainly get wetter.

Um, and, uh, Uh, the way that precipitation is produced from atmospheric rivers, like I mentioned before is, orographic uplift. It's when all that moisture hits the mountain range, which in this region our mountain ranges are perfectly aligned to squeeze, uh, moisture out of atmospheric rivers, well those mountain ranges are not going anywhere on these timescales that we're talking about. And so atmospheric rivers will [00:32:00] certainly result in more precipitation. Um, and, um, So, um, you know, that's thermodynamics, uh, but, uh, the dynamical changes in the circulation that may occur are not nearly as clear from what we've looked at so far.

Um, a lot of those, you know, it can be different from model to model and so on, but we're developing some tools to assess those dynamical changes in a more robust way. Um, but I think what I would like to add, you know, in terms of climate change is that atmospheric rivers are becoming more impactful and bigger contributors to water resources in the region.

But at the same time, Uh, they're already warmer storms, uh, and, uh, they're, they're becoming wetter because [00:33:00] they're getting warmer. And so that means that there's going to be less snow and more rain associated with them. Uh, and, uh, that means a lot of runoff. And as Dan said, Um, we're also expecting, you know, more dry years.

And then the wet years is when we generate the water resource. Well, those water resources tend to come in these big spurts that are the atmospheric rivers. And basically that means that we have to learn um, how to derive water resources from flood water as our colleague Mike Dettinger would say, uh, so that's, that's really a big challenge for the Southwest, I think.

**Sarah LeRoy:** [00:33:56] So last question. Um, I know all of you are [00:34:00] doing very exciting research. Um, what are some new and exciting, what's some new and exciting research that's being done to learn more about atmospheric rivers and especially, you know, what's going to happen in the future. Are there some specific areas that are, you know, Sasha mentioned the penetration inland is one area that that's an active area of research.

What are some other areas?

**Sasha Gershunov:** [00:34:25] I can list a couple, I suppose, you know, one topic that we're working on now is, is looking at, um, uh, snow lines associated with different types of storms in the historical record, as well as in climate projections. Uh, and we're certainly looking at atmospheric rivers, as a specific type of storm, as well as the orientation of atmospheric river, that is very important in terms of producing extreme precipitation on [00:35:00] specific slopes, you know, oriented in a different direction, um, and, um, uh, We need to understand how snowpack accumulates from, from these different storms as atmospheric rivers become bigger contributors to the hydro-climate of the region. We need to understand how those impact snowpack and run off specifically. Um, that's one thing that we're looking at and we can clearly see, uh, snow lines increasing in the historical record over the last seven decades, basically. Um, and, uh, another, another research topic that we've just embarked on is learning how to assess the contribution of climate change, to atmospheric rivers, [00:36:00] to rainfall precipitation from atmospheric specific atmospheric rivers storms, and, and basically, Mmm. Get to the point where we could even assess recent events and what the contribution of climate change was to precipitation from those specific events.

So for example, if the same storm occurred, Mmm let's say the same storm that, um, um, that, uh, uh, caused havoc, uh, in, uh, around Oroville dam. Uh, if that had occurred 50 years ago or 50 years from now how different would that have been, for example.

So these are the [00:37:00] kinds of things that we are working on now. And there are many other avenues of research as well that I'm sure my colleagues could expand on.

**Tom:** [00:37:10] One of the things that we're looking at on the economic side is the impacts of atmospheric rivers, on transportation networks. Um, so ARS can penetrate inland and can cause avalanches and road closures in mountain passes and we're interested in seeing what the impact is there. We're also looking at the end, the economic impact of atmosheric rivers on water supply, uh, on agricultural productivity in particular. Um, so I mentioned that, uh, flooding related to atmospheric rivers causes damages on the order of a billion dollars a year, um, in the Western US over the last 40 years or so. Um, and the potential I should add, I guess the [00:38:00] potential is much higher.

A series of studies done in the last decade called the ARkStorm scenario, where they looked at a one in 1000 years, series of atmospheric river events, estimated potential costs of such, uh, a storm, um, to be on the order or $750 billion. Um, so this will be a storm similar to the, um, the great flood, uh, in California of 1861, 1862, if it were to happen today.

And so, um, A lot of our research now is looking at how to strengthen flood protection, to deal with potential storms of that magnitude. I would add that we're also looking at, um, using forecasts of atmospheric rivers to better manage our water supply. Through an [00:39:00] initiative called the Forecast Informed Reservoir Operations Program at CW3E or FIRO and preliminary results there suggests that by using predictions of atmospheric rivers in particular, uh, precipitation more generally we can revise the water control manuals for our large reservoirs in the West and potentially store more water leading into the dry season. Um, the way it works is in advance of a big storm with a good forecast we are able to pre-release water from the reservoir, and that allows us to store higher levels in the winter without necessarily increasing flood risk, but with an increase in water supply.

And, uh, our pilot study in Lake Mendocino in Northern California indicates that [00:40:00] using our best forecast of atmospheric rivers, we may be able to increase water supply by up to 20%, which could have significant economic impacts. And another research program we have running at CW3E is the AR reconnaissance program where we fly weather aircrafts that drop radiosondes into the path of atmospheric rivers in the Pacific. And these are being used to improve these forecasts, which could, which feed into this forecast and reservoir operations and all kinds of improvements in water managements in the future. So there's a lot of exciting research that's being done on atmospheric rivers.

**Sasha Gershunov:** [00:40:51] I might just add that improved predictions [00:41:00] is something that's, that's a big goal for CW3E and determines directions of our research as well. Not just on climate change timescales, but, but also on extended range, weather prediction, timescales. So, you know, two to five weeks out, as well as seasonal climate prediction, um, which is predicting, statistics of precipitation, atmospheric river activity over a three month season say, um, several months ahead.

**Dan Cayan:** [00:41:42] So maybe I'll, uh, I'll turn this back to the Southwest CASC. Um, In my, in my view the interactions with ecologists and so forth, which comes with [00:42:00] land management kinds of perspectives is a really important ingredient in the West. And the Southwest CASC is one of our primary avenues to that discipline. A project that, um, we are involved with, with, um, CASC members from the Desert Research Institute that would be Tamara Wall and Tim Brown, and also, um, exterior, uh, collaborators with CASC in this case, John Keeley from Sequoia Kings National Park and Alex Sifford, um, who has now a private industry affiliation as well as with a conservation group. [00:43:00] Um, John and Alex in particular are wildfire ecologists. And the project that we're working on is aimed at, um, sort of better understanding the fingerprint of weather and climate on wildfires, large wildfires, uh, such as the Thomas fire, which was one that Sasha mentioned.

At its time, the largest wildfire in California history. But, um, sorta conversely, uh, we're not only interested in conditions that breed and spread wildfires, but also conditions that, um, that quell and, uh, And reduce [00:44:00] wildfire activity. And of course, atmospheric rivers play into that. Um, they're critical elements in our economies and ecosystems and, um, they're a lot of fun to think about and study.

So that's gonna, I think, occupy us in the coming years as we untangle, uh, these influences not only from short term, but from longer term changes, we talked about the fact that there may be this regime change, where the shoulder seasons in particular are going to become somewhat leaner in terms of their precipitation delivery.

And of course, there's going to be lots of ups and downs on top of that, but [00:45:00] it's going to be interesting to see how that plays out in the next decade of observations and also a climate model projections.

**Sarah LeRoy:** [00:45:16] Thanks, Dan. I think that's a perfect point to end on. Um, so thank you all so much for your time today.

**Dan Cayan:** [00:45:25] Thank you, Sarah.

**Outro:** [00:45:29] Thanks for listening to Come Rain or Shine podcast of the USDA Southwest climate hub. And the DOI Southwest Climate Adaptation Science Center. If you liked this podcast, don't forget to subscribe like or follow for more great episodes. If you want more information, have any questions for the speakers or would like to offer feedback, please visit climatehubs.usda.gov.

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