Warming Temperatures and California Snowpack Press Briefing

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February 28, 2018

While the biggest snowfall of the season this coming weekend should boost snowpack totals in the Sierra Nevada, the long-term outlook remains grim. After months of snow drought, snowpack totals will still sit well below average and the end of the season looms.

Snowpack hand measurements as of March 1 show the snowpack sits at 24 percent of average. Near record-warm temperatures have been a driving factor in this year's snow drought, causing a greater proportion of overall precipitation to fall as rain instead of snow. Average temperatures in the Sierras over the last 60 days ran 6-8 degrees F above normal over much of the mountain range. Likewise, overnight low temperatures, a key threshold for maintaining snowpack, ran 4-8 degrees F above normal.

Climate Nexus hosted a press call with panelists discussing the current snow drought, the potential for this storm to bring the state out of drought, and snow drought impacts on water and food supplies. The briefing was held in advance of closely watched March snowpack measurements that were pushed back by the snowstorm to Monday, March 5.

The full transcript is below. Highlights can be found here and full audio is available here.

Speakers

- Daniel Swain, NatureNet Postdoctoral Fellow at UCLA, expert on global warming and climate extremes
- Ellen Hanak, Director and Senior Fellow of the PPIC Water Policy Center, expert on water policy
- Renata Brillinger, Executive Director of CalCAN, expert on agriculture

Moderator

- Markeya Thomas, Media Manager at Climate Nexus

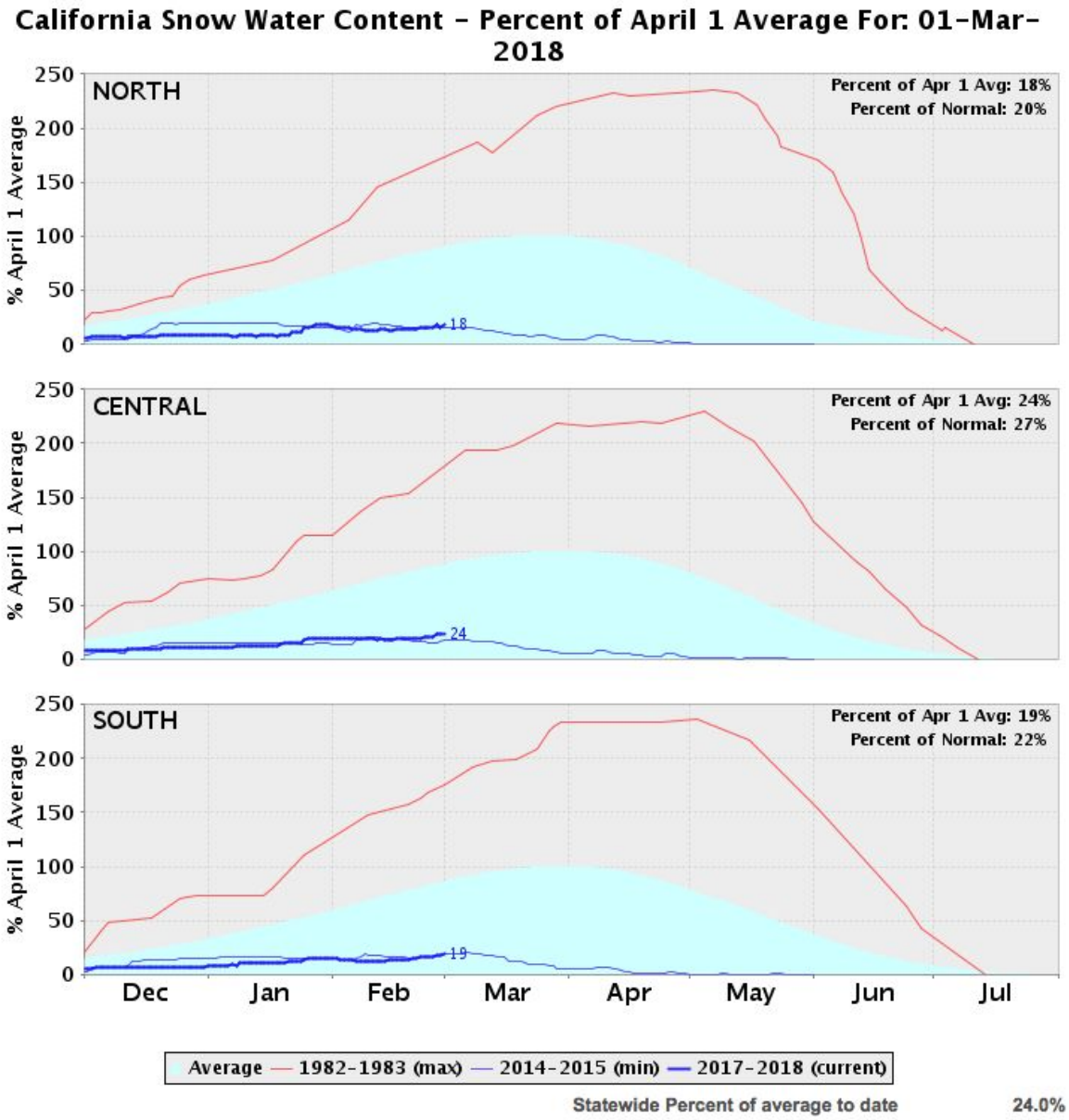

Image: California Department of Water Resources, California Data Exchange Center

Briefing

Markeya:

Good afternoon from here on the east coast, and good morning to those out west. Welcome to the briefing on the Sierra Nevada Snowpack. My name is Markeya Thomas, and I'll be moderating the call today. As of February 27th the snowpack measured at about 23% of average to date, but the state is set to get rain and snow throughout the weekend. Near record-warm temperatures have been driving the snow drought, and today we're talking about what this means and how it impacts water and food supply and policy. This call is being recorded, and an audio file will be available upon request.

Today we'll just jump right into it. We'll hear from Daniel Swain at UCLA, Ellen Hanak at PPIC, and Renata Brillinger at CalCAN. There will be time for Q&A after the speaking lineup has concluded. If you've joined online you can ask a question by clicking the Ask a Question button which should be at the top of your screen. We'll put you in cue, and I will read your question aloud to the panel.

If you've joined by phone, you'll need to email me your question. My email address is listed on the advisory for this briefing, and I'll re-prompt the question at the end of the speaking order. Now, let's hear from our panel. We'll start with Daniel Swain.

Daniel:

Hello everyone, and thanks for the invitation to put together the call today. I'll just run through a couple of key points that I think were already touched upon, and then I guess we can go from there. The first is that we really have seen this cluster of very slow snow years, also known as snow droughts, for the past decade in California, and that, as was mentioned, that these very low snow years are primarily being caused by very warm temperatures relative to what is historically expected in California during the winter, and also, secondarily, low precipitation.

Not all the years in which we've seen low snow in the mountains have seen extremely low precipitation, but this is one of those years. The second point is that there has been, already, a strong warming trend in the Sierra Nevada in recent decades, and that has resulted in a pretty substantial increase in the fraction of precipitation falling as rain rather than snow, and also an increase in the mean elevation in which that rain-snow line is occurring. And that regional warming trend is partially the product of greenhouse gases emissions, so it can be traced to human activities.

And snow losses are expected to accelerate in the future as that warming trend continues. And the final point relates to what's going on right now this week. Snowpack as of this morning, as was mentioned, is in the low 20's percent of average, which is actually still at a record, or very close to the record-low level. It's sort of very close to what was occurring during 2014-15, or '76-'77, and sort of tracking between those two very low years. But there is a really big storm upcoming in the Sierra Nevada over the next 48 to 72 hours.
It will bring impressively heavy snowfall to most of California's mountains. And that single storm is probably going to bring several feet of snow, so a much needed boost, but in itself won't constitute a March miracle. For that to happen we would need an essentially unprecedented amount of cold and snow over the next month, because we're further behind than we were during even that miracle March in 1991. So I would estimate right now that this year, even after this big, multi-foot snow event coming up, we'll probably still be in the top five of record-low snow years after this weekend.

Markeya:

Thank you Daniel. And now we'll hear from Ellen Hanak.

Ellen:

Good morning everyone, and thank you for joining this call. I'm going to just give a few thoughts on what this means for water policy and water management. I guess on the bright side of things you could say that California already has a very variable climate. So a lot of the responses that we have to take on as a state and at the local level are basically strengthening the kinds of tools that we already have to manage the fact that we have a dry summer every summer, so we have to store water for that. And we also have a history of patterns of wet years and dry years, so we have to also be able to manage for that, both in terms of water supply and in terms of flood management.

What the changing climate is doing is basically heating things up, so it's reducing the share of free storage that we get in the winter in our snowpack, and it's also seeming, already, to be increasing the variability, and kind of increasing the peaks of the dry and of the wet, and that's something that climate models are projecting is going to be more and more in our future. There is less certainty about whether we're facing a future that's going to be dryer on average, but even with knowing that it's going to be warmer and more variable, there are some steps that we know we have to take, and those include thinking about managing our storage systems in a more comprehensive way.

And that really means thinking about connecting our surface reservoir storage system with our groundwater basins, and getting more of the water that we save up for dry years into the ground so that we make more room in our reservoirs for floodwaters, and for the fact that we have less snow and more rain coming in. The other piece of it is managing demand, and this really means thinking about how we can go on a diet wherever we can do that in ways that are not harmful to the economy, and to society, and to the environment.

And that means both reducing water use where we can, but also having more flexibility to trade it so that water can go to places and uses that are most critical when it is dry. I'll stop there for now.

Markeya:

Thanks, Ellen. And now we'll hear from Renata Brillinger.

Renata:

Hi, folks, it’s Renata here. I work with California Climate and Agriculture Network, and we are a coalition of sustainable and organic farming organizations. We represent them in the state climate policy arena. And of course, doing that work we rely a lot on members and advisors who are farmers and ranchers, and I get to talk with many of them through my days. And one of my first questions I always ask them, especially in years like this, is, "How's the water situation where you are?"

It's integral, obviously, to the business of producing food and fiber. And those folks really understand intimately the challenges that we're going to be facing with climate change to their businesses and to their communities. And I think by and large we're fortunate to be working with many who want to provide solutions.

There's a number of ways that water scarcity is impacting agriculture already. It always has. Farmers are among the most adaptable and resilient professionals that I know because they're constantly dealing with natural resources constraints. But what's happening now is somewhat unprecedented, and I think it's especially challenging for new farmers coming into the business, because even their elders don't really have much to offer by way of trends and precedents.

It's increasingly more extreme and more unpredictable. At the risk of oversimplifying I just want to say clearly that there are two sources of irrigation water for agriculture. There's surface water, and there's ground water, and both are affected by snow droughts, and by decreased

annual precipitation. And different farms in different regions really have relied differently on those sources, some just one, some the other, and some both. It's a constant balancing act.

When the state's water infrastructure surface water delivery declines, as it has in the five-year drought that just temporarily ended last year, producers basically have two options. Number one, they can let their fields fallow, go unplanted. There was a 2016 report out of the UC Davis Center for Watershed Sciences that found that there were, in 2015, half a million acres fallowed. That has tremendous impacts economically and on jobs. The other choice they have is, they can turn to groundwater.

And as Ellen mentioned, there's a relationship there between surface water and groundwater. And in many areas in California where we have overdraft and water basins, that's not really a great option anymore, or it's an expensive option that's pricing out a lot of the smaller farmers who can't afford to drill deeper wells to tap into those receding water tables. The warmer temperatures in earlier springs that people have mentioned already, like what we're having this year, create longer growing seasons, and that increases water requirements.

Reduced runoff during peak planting season also increases the demand for irrigation and heightens the competition that we hear a lot about between urban, agricultural, and environmental uses. And then something that doesn't always get talked about is that as we see our storage resources declining, that puts pressure on our electrical resources, our hydroelectricity, at the same time as we're requiring more energy generation to deal with the increased heat and increased irrigation demands.

Farmers are really trying to respond, I'd say to varying degrees, to all of these challenges in creative ways. They worked hard to improve irrigation efficiency. They're developing catchment systems. There are groundwater recharging and water banking schemes going on. Some cases people are shifting crops. And there's an increasingly strong awareness of the connection between improving soil health and increasing water holding capacity, which effectively creates a reservoir in the soil for storing water, and that's something I think that we need to put more attention on.

There's also a role for the state, though, in all of this, because the magnitude of the changes is so significant. There are two ways I just briefly want to mention that California has responded. In 2016 California became the last state in the arid west that began grappling with monitoring and regulating groundwater use. They passed a bill called The Sustainable Groundwater Management Act, but it's years away from full implementation. They're just in the early stages of setting up local authorities to implement solutions at the local level.

Then in 2015 Governor Brown launched a new program called The State Water Efficiency and Enhancement Program, or SWEEP for short. It's funded by the Cap and Trade Revenue. And it's made 600 grants to farmers in 33 counties to date, with a total of $67 million. However, it was not funded in the current budget year, and in the coming budget year the governor has proposed only $18 million. There's a lot more that needs to be done to support farmers as they continue as individuals to deal with this.

I think there's certainly a role for more systemic support, and more resources, more monitoring, more incentives, and more research. I think it's not something that is appropriate to just put on the shoulders of individual farmers alone, given the unprecedented nature of what we're facing.

Markeya:

Thank you, Renata. Now I'd like to open the floor to questions. Again, just click the Ask a Question button if you've joined online, and it'll put you in a cue. If you are on the phone you can email me your question. My email address is spelled M-T-H-O-M-A-S at climatenexus.org. I want to remind our panelists to introduce yourselves again before you answer a question so listeners know who is speaking.

Okay, first question. Last spring a major snow/rainfall filled reservoirs and helped shore up the snowpack, and it led elected leaders to declare an end to the drought. As California prepares for a big snowfall, is there any advice you would like to offer policy makers about water management?

Ellen:

This is Ellen Hanak. Maybe I'll start with that, and probably Daniel and Renata can jump in too. There are a lot of questions now that are going to be coming up in the press about whether or not the governor should've ended the drought last year, because now it looks like it's going to be dry again. I think that the answer is that it was the right call to make last year to say that the drought emergency was over, because we were facing one of the wettest years on record.

Now, going into this year, as Daniel said, even if we get a whopping storm in the next few days, we're still going to be pretty far behind. We're very likely to be entering a dry year as our big water demands go up in the summer with irrigation and landscaping uses. But we're not going to be in the midst of a major drought emergency statewide yet because we've had so much water carried over from . . . [inaudible 00:15:41] of the increasingly variable climate that we live

in, and that it's important to be making conservation a way of life as we go forward, whether or not it's a severe dry year or not, and also that it's important for us to be preparing in every way we can to manage this more variable climate. And Renata mentioned the Sustainable Groundwater Management Act, which was a historic law that was enacted back during the drought.

It's amazing to see the energy that's going into implementing this law at the local level, and farmers are really weeding away on this. And a lot of the hope, I think, for California in terms of our ability to manage increased variability really lies with the ability of local folks, local water users, to put in place sustainable groundwater management plans that can really help us to cope with this variability by socking away as much water as possible in the wet times in our groundwater basins, and then managing that resource sustainably so that it's available in the dry times and the droughts.

Renata:

This is Renata. I'll just jump in. I think Ellen said a lot of what I would've said as well, so just to underscore a couple things, I think declarations of drought, or ending of drought should definitely be scientifically accurate. In other words, they shouldn't be political calculations, and so they will naturally come and go, to reflect the scientific conditions. I wouldn't fault Governor Brown for declaring the drought over. Scientifically speaking it was, but as Ellen made clear, we can't switch on and off our attitude about the longer term trends, and the longer term investments that are necessary.

And Governor Brown has also said, famously remarked that conservation should be a way of life in California, and that's 100% true. What needs to follow that statement, though, is a consistent, reliable, attention paid to making that possible in all sectors. And speaking about agriculture specifically, what's difficult for farms is, if the resources and the incentives turn on and off, they can't plan. We can't build momentum in terms of letting people know what the resources are.

Farmers sometimes need some seasons to change their practices, to invest in new capital equipment. The reliability of the research flow, the monitoring, the feedback loops, and the incentives is what really needs to be consistent.

Daniel:

Daniel here. Just, I'll add a couple quick points, partly to echo what's already been said in response to this, the first of which is that how we define drought, and how we think about

drought, and how different people and different institutions define drought is actually not as cut and dry as you might imagine. And in the case of a state-level drought emergency declaration it does deviate somewhat from what the scientific definitions of drought are, as it should, probably, because really the purpose of that sort of declaration is to mitigate, or alleviate, or respond to impacts on different sectors economically, agriculturally, socioeconomically, to drought as it is perceived on the ground by people.

One of the tricky parts, though, is that if you think about drought from the perspective of groundwater, for example, in the Central Valley, or from the perspective of Sierra Nevada forests, our multi-year drought never really ended, but if you think about it from the perspective of the state level water projects, these large reservoirs that can capture a lot of water during a single wet year like it did last year, then it certainly did end. And from the perspective of supplying San Francisco, and Los Angeles, and much of the agricultural regions in California with water, it's the water in those reservoirs right now that matters.

From that perspective, ending a formal drought regulation does make sense, but there's all these other sorts of impacts, and ways to define drought that maybe deviate a bit from that state-level declaration. And the second point I would make is also that, as others have noted, California is no stranger to these wide swings between drought and flood, and precipitation extremes and temperature extremes, but in terms of temperature we're definitely drifting in a certain direction right now, and towards warmer, which does increase drought stresses whenever precipitation is low, but even during wet years.

We even saw last year, we got a lot of snow last year in the mountains, but that snow actually lagged the rainfall much more than would have been the case had that same wet year occurred 30 or 40 years ago. And so, when we think about drought I keep pointing this out, we probably shouldn't be thinking about it as this continuous period of extremely low precipitation, because right now there is very little indication, actually, that that's what the future holds in California, a permanently dryer period with lower rain years.

We probably will see more low rain years, and more severe, and more prolonged droughts, but in between we are also likely to see significantly wetter years, years more like last year or even wetter than that. And these swings back and forth, as has been mentioned, probably are going to pose some significant challenges, not just from people on the ground, for example, farmers in agriculture who have to deal with these wide swings, but also from a water management and state infrastructure perspective, where these systems that we have in place right now were designed for a particular climate that no longer exists, and will be even further from the climate we're likely to have just a couple of decades from now.

Markeya:

Great. This next question is from Lisa with The Mercury News, and it's for Daniel. She asks, "Can you specify the previous clusters of low snow years?"

Daniel:

The previous clusters, I actually don't have that data off the top of my head. This year, right now, we are tracking very close to 2014-15, and '76-'77. We are sort of right smack in the middle there. These three years are essentially indistinguishable from one another to date. I imagine we'll pull ahead, in a good way, a little bit this year, which is really to say to fall behind those two years a little bit with this big upcoming storm, but I don't actually have the other years off the top of my head. But those are the top three.

In general though, in this past decade there's been a really sustained trend towards seeing the snowline creep up the mountain. There was a study that came out a few months ago pointing to the fact that the snow line near Tahoe, Lake Tahoe, for example, over the past 10 to 15 years has been rising up the mountain at a rate of almost 300 feet per year vertically. And that's a big deal, because cumulatively over 10 or 15 years, that's a substantial chunk of the mountainside.

And at the same time, the amount of snow, or the ratio of rain to snow at these middle- and upper-elevation parts of the state has been also increasing to the point where places that used to be snow-dominated during the winter, they have recently flipped over to being rain-dominated, and that is essentially a temperature effect. We're getting less snow even during those years that we're getting plenty of precipitation falling from the sky, we could say.

Markeya:

Great. Thank you. Next question, "Can anyone speak about the increased flood risk if the reservoirs are full?

Ellen:

This is Ellen. I'll give a little stab at that. When you think about what our reservoirs do now, our above ground reservoirs, they store water for the irrigation season. They have seasonal storage for the dry times, the dry months in California, which are about half of the year every year. They store some water for next year in case it's dry next year. That's called carryover storage. And then, during the periods where there's a lot of runoff coming in from upstream, they have to have space available for those floodwaters, that flood space.

And what is happening with these changes in the mix between snow and rain is that we're putting stress on that piece of the equation. And what will have to happen over time is, we're going to have to be adjusting how we make room for flood water, and where we can put it. One piece of that is competition with the space and reservoirs for saving water for use in the summer, and in next year, so what's called the conservation part of it. That's the water saved for use.

Another option is to find ways to release more of those flood waters downstream and make room in the floodplains. This is something that's kind of an exciting trend in looking at flood management, of thinking about how to allow flood waters in some years to spread more out on the land in places where that is safe to do. You can get a lot of flood protection benefits, but you're also looking at a lot of other benefits from a habitat perspective, and a wetlands, and ecosystem perspective. Some places you can also help to reach our groundwater basins that way.

There's a new Central Valley flood plan that was just finalized very recently that very much focuses on looking for opportunities to do this kind of really modern flood management. And interestingly, we have some very good models right around the Sacramento area with the Yolo Bypass and the Sutter Bypass. You drive up to Sacramento from the Bay Area on Highway 80 you see that big floodplain there that sometimes has a lot of water in it. Sometimes it has a lot of water birds, and sometimes it has [inaudible 00:27:07]. That is the kind of thing that folks are really looking to be able to do more of, in ways that compensate the landowners, obviously, who would participate in those things. And that's where you're seeing, also, some very exciting ways in which farmers are working with others to look for those opportunities.

Daniel:

Daniel here. I just really wanted to echo some of what Ellen just said, and amplify it from a climate perspective. As was mentioned, California already has significant tension between these competing water storage during dry times imperative, and then the flood control mandates, which I think we sometimes forget about during drought because we don't need to think about them as much. But during wet years, and during big storm events, those are critically important really for public safety in California.

I mean, there are a lot of rivers, and people who live in floodplains, places that naturally used to flood most winters, before we built a lot of California's flood control infrastructure. Those levies and those dams, for example. One of the challenges is that, in the future, we actually have more confidence that the biggest storms are going to become more intense, and warmer, and

result in not just incrementally more runoff, but in some cases dramatically more runoff than the biggest storms we're used to historically.

And as we know, the biggest storms historically have tested the system already in pretty serious ways. It has largely held up most of the time historically, but I think that those tests are going to be more severe in the not-too-distant future. And there's this notion that climate change is bringing a new normal, but the reality is there's no new equilibrium state. The climate is continuing to evolve, and it's going to continue to evolve in that direction as we move forward.

That risk of increasingly big storms, and wet years, and warm storms bringing less snow and more rain, for example, really will test the flood control part of the system. But at the same time, as we have warmer years, and less snowpack, that also means that the storage role of this infrastructure becomes more important as well. And in some cases there's that direct competition between needing to keep as much water as possible in the reservoirs so we have that carryover during dry and warm periods, but also making sure that if we have a really big storm come along, and need all the space we can get for flood protection, that we haven't underestimated the amount of runoff that might have entered the system.

And the good news as well, Ellen was emphasizing, is that the solution to this is actually kind of appealing, where we engage in this floodplain management, because there are going to be events in the future where our existing infrastructure cannot contain all the water. But what we can do is, in advance, decide where we want that excess water to go. And if we can redirect in ways that are largely not destructive, and in fact, in many cases essentially constructive, if you can flood areas that will recharge groundwater, for example, wide open agricultural regions where you make these agreements ahead of times with farmers, they provide temporary habitats as was mentioned.

And that Yolo Bypass west of Sacramento on the Sacramento River really has been a great example of this. And last year, for example, the bypass was very full during these storm events that we saw, during this near record-wet winter in California, and it did manage to prevent any major flooding in the Central Valley near Sacramento, for example. If that bypass wasn't available, I don't think you would have avoided that major flooding. That's a good example of the kind of interventions that we probably will have to engage in on a bigger scale to adapt to future climate.

Markeya:

Thank you. Next question, "How are snow droughts and wildfires connected or related, and what does this mean for the water supply and agriculture?"

Daniel:

Well, it's Daniel again. I can jump in briefly on this. I'm not a wildfire expert, per se. I mean, I'm a climate scientist, so I can sort of push this from the climate side of things, and at first acknowledge that the response of wildfire to drought is complex. It's not always as obvious as it sounds at the outset. Generally speaking, if things are drier, vegetation is drier, it burns more easily and more intensely, and you get larger and more intense fires. That's sort of the first order response.

But then the complicating factor is that, in some cases where you have what might be called a fuel-limited regime, so an area where there's sometimes not even really enough vegetation for the fire to really get going, if you have really dry conditions you can actually decrease fire risk, because it means there's almost no vegetation to burn. That's something that might be true in really sparse scrublands, or chaparral regimes, which do exist throughout significant portions of California, especially in Southern California.

In those cases, sometimes you have this competition between the fact that vegetation that does exist is dryer and more flammable during a drought, but also maybe more sparse, so there's less fuel to burn. In the other kind of fire regime we have in California, in the dense, coniferous forest for example, in the Sierra Nevada, the response of wildfire to snow drought, and drought in general is a little more straightforward.

If you have these large trees in the forest, and there's a low snow winter, which means there's a warmer spring, because that snow feedback isn't keeping things cool and moist through the spring, it means that by the time summer rolls around, there's very little moisture in the soil for the tree to take advantage of. What ends up happening is those trees, in the summer time, and in the early autumn when this fire risk peaks, are drastically dryer than they would be, and they're more flammable, and they're more drought stressed, and they tend to burn more easily and more intensely.

It gets more complicated, again, if we talk about tree mortality. We know that hundreds of millions of trees, now, in the Sierra Nevada, have succumbed to the combination of drought stresses and bark beetle infestations, which are sort of intertwined. There's been a lot of work recently on whether these big stands of dead trees actually contribute to increased fire risk or not, and there are differences of opinion among fire experts about whether that's the case.

It seems to be the case that, at least initially, it does contribute to increased fire risk, but in the longer run that actually might have the opposite effect. There are some complicating factors,

but generally speaking snow droughts result in higher fire risk in the forested areas, and droughts in general result in more intense fires in places that are not fuel-limited.

Renata:

This is Renata. I'll just jump in with a couple of different points as pertain to agriculture. I think generally, I think what we're experiencing here with climate change is it's really revealing so many of the interconnections, in our ecosystem certainly, and in how humans interact with them and depend on them. That's just a general and very obvious thing to say, but where it gets interesting is in specifics.

For example, as Daniel just said with the tree mortality in the Sierra, we're seeing a lot of standing dead trees, and the governor has ordered that their removal and incineration for bioenergy be prioritized to deal with that crisis. And the effect it's having on agriculture was, I think, unintended, which is that with the state's limited ability to incinerate biomass, it's redirecting resources away from a need in agriculture for dealing with tree removal, and prunings, other agricultural waste that otherwise, some of which, would have have otherwise have gone to those facilities.

They're now struggling to deal with this biomass in a lot of the orchards in the Central Valley especially, and that's now having the unintended consequence of increasing numbers of exemptions or exceptions to the ban on openly burning that waste. And that's creating, exacerbating the air quality issues in the Valley, and frankly just burning up an otherwise quite valuable resource in the form of that biomass.

It's the chain reaction of dealing with these very extreme and difficult challenges with some solutions that then have some unintended consequences. The other point I want to make that's completely unrelated is, I live up in Sonoma County. We just went through, in October, our very, very severe wildfire. But of course, it wasn't just a wildfire. It was also an urban fire. And looking at it and the experiences down in the Santa Barbara, Ventura County area, it's very illustrative.

Up here what we saw, I'm much more familiar with the impacts up here, what we saw here is that agricultural land on the edges of urban areas actually served as a kind of buffer in a lot of cases. There's a lot of range land in the mountainous sort of foothills of the mountains here. And that ... I don't know if I would say it slowed the fire down necessarily. I think there's still a lot of understanding that has to be unpacked here but it does seem that those landscapes are adapted to burn.

The species in them are recovered from burn. Some of them benefit from being burned. And compared to the huge fuel load in both heavily wooded areas and in urban areas, the range lands seemed to serve as a buffer. And there wasn't the erosion problems we saw further down south, and there are a bunch of reasons for that and we can go into that if there's interest. But I think just the point being that looking at agricultural land as an asset, and as a feature of the landscape, maximizing its benefits with an eye to dealing with increasing wildfire threat region by region would be an advisable thing to do.

Markeya:

Thank you. And last question. When we think of global warming we often think of record-high temperatures, but can anyone discuss the trend that we're seeing of rising average low temperatures, which is key to maintaining snowpack?

Daniel:

Yeah, I can talk about this a little bit. Daniel again. It's actually one of the signatures of global warming is that temperatures are generally increasing everywhere at all times of year, but that the rate of increase is very different from place to place, from time to time, and also, depending on the kind of temperature statistic you're looking at. If we think about daily temperatures, for example, versus annual temperatures, or if we think of overnight low temperatures versus daytime high temperatures, the reason for this, there's a lot of interesting scientific reasons for this that I won't go into right now, but the main idea is that in most places overnight temperatures are warming faster than daytime temperatures, even though they're both increasing.

And as is mentioned, that can have a disproportionate impact really on two major things: One is whether ice or snow stays frozen or not, and the other is sort of impacts on human health, because if the temperatures, especially when it's very hot, if they fail to drop below a particular threshold, then there is a greatly increased physiological burden during heat waves. And actually I would add a third thing that we might hear a little bit more about in a minute. Agriculturally speaking, and ecologically, there are a lot of plant species that require, especially a lot of high value crops in California actually, that require a certain number of what are known as chill hours, so temperatures below a certain temperature threshold.

And those almost always are occurring at night in California. And we've seen recently a big trend toward fewer of those chill hours in the Central Valley, for example, and fewer sub-freezing nights in the Sierra Nevada. Part of the problem earlier this winter with

maintaining snowpack is not just that it was warm when it was precipitating, so it was falling as rain, but even when it did fall as snow, we had several weeks in January up in the mountains where the overnight temperatures weren't even getting down to freezing at all.

At no point during the 24-hour cycle were temperatures falling below freezing. Obviously that's not an environment in which snow can persist, even if it's falling in the first place. That differential rate of change of temperature, where the overnight lows are warming faster than the daytime temperatures in a lot of the cases, in some places, where places higher up in the mountains, during the winter, are in some cases warming faster than the Valley. A lot of these non-linearities tend to amplify the impact of warming as compared to if it were totally uniform across time and space.

Markeya:

Thank you. Seeing as there are no more questions at this time I'd like to let people know that if you have any follow up questions you can email me. A recording of this briefing will be available upon request. I'd like to thank our panelists for their time, expertise, and leadership, and thanks to our listeners for joining. This concludes the call. Have a great day, everyone.