Integrated Scenarios of the Future Northwest Environment

Ashley Fortune: Good afternoon from the U.S. Fish and Wildlife Service's National Conservation Training Center in Shephardstown, West Virginia.

My name is Ashley Fortune, and I would like to welcome you to our webinar series, held in partnership with the U.S. Geological Survey's National Climate Change and Wildlife Science Center in Reston, Virginia.

The NCCWSC Climate Change, Science, and Management webinar series highlights their sponsored science projects related to climate change impacts and adaptation, and aims to increase awareness and inform participants like you, about potential and predicted climate change impacts on fish and wildlife.

I'd like to welcome Shawn Carter, senior scientist at the NCCWSC, to introduce our speaker. Shawn?

Shawn Carter: Thanks, Ashley. Today, I'm happy to have Dr. Phil Mote present on some of the work that he's been doing with our Northwest Climate Science Center.

Phil is a professor in the College of Earth's Ocean and Atmospheric Sciences, at Oregon State University. He's also the director for OCCRI, the Oregon Climate Change Research Institute. He also is director of Oregon Climate Services, which is the state climate office for Oregon.

Phil's current research interests include scenario development, regional climate change, regional climate modeling, and adaptation to climate change.

Phil is also part of the leadership team at the Northwest Climate Science Center, and has been involved with the IPCC National Climate Assessment, and also the National Research Council.

Without further ado, I'd like to turn it over to Phil.

Phil Mote: Thank you Shawn, Ashley, and Holly, for setting this up. Thanks to all of you for tuning in. I look forward to your questions at the end. On the first slide here you see the cast of folks involved in this work.

My colleague, Dave Rupp, here at Oregon State University, John Abatzoglou and Katherine Hegewisch of University of Idaho.

Dennis Lettenmaier, who leads the hydrology group at University of Washington, along with Julie Vano, Homero Flores, and Matt Stumbaugh, Dominique Bachelet and John Kim, who've done the vegetation modeling, I should also add Dave Turner from Oregon State University.

This is the culmination of a project funded by the Northwest Climate Science Center, with support also from the NOAA regional entity here, the Climate Impacts Research Consortium.

John Abatzoglou and I also had some funding from the USDA-funded project, Regional Approaches to Climate Change and Pacific Northwest Agriculture.

I particularly want to thank Gus Bisbal, Director of the Northwest Climate Science Center for supporting this vision of providing these scenarios to the Northwest region, which also led to a lot of conversations with CSCs around the country.

This project is wrapping up, but we don't have all the results in yet. You'll see our, in some cases, preliminary results.

We have a workshop coming up in Portland, Oregon, two weeks from today. We'll spend a whole day on this topic. We'll have our final report due to the Northwest CSC three months after the completion of the project.

The motivation for this work was a recognition that natural resource managers were paying attention to climate change science, but at a bit of a loss for how to apply it.

If someone told them, "Your habitat conservation plan or this species management plan is no good, because you haven't considered climate change," even if they fully bought the science of climate change, they wouldn't really know where to turn, or how to apply that to such an activity.

This is the space that Climate Science Centers intend to occupy, providing such guidance. It was natural that the CSC would play a lead role in this.

What we were hearing was a need for a complete and scientific description of what the future would look like in the Northwest Region.

Water availability, soil moisture and stream flow, snow cover, flood risk. How will the drivers of climate impact the change in temperature and participation? How will vegetation change?

The objectives of this project are to use the best available science to describe the future climate, hydrology, and vegetation. There are fully-coupled regional models that have vegetation and hydrology.

But, with just a single model as we've learned and as you'll see, a single model is only able to produce a modest spread of results, which may not accurately represent the true range of possibilities, because of how models are constructed and choices that are made.

We wanted to be able to characterize the uncertainties of the system. That meant using a different approach than just one single, wonderful model. We want to use a range of climate inputs, and at least two impact models.

We have two hydrology models, one of which is nearly done with a set of simulations from 20 climate model scenarios, and a second one that will follow shortly.

And then we also have two vegetation models in play. We're fortunate to have a new generation of global climate models that were released in the last few years, and what we've done is coordinate the climate model outputs with the inputs to both the hydrologic and vegetation modeling. And we have a spectrum of audiences ranging from, “I want a simple quality of description, may be a number here and there”, to researchers who want the full visible data and the resolution of the model outputs for some additional scientific analysis or modeling.

The climate scenarios that we're using as inputs come from the Coupled Model Intercomparison Project stage five, CMIP5. This is a coordinated global modeling effort that uses 41 models that have been contributed to date for the 20th century.

About 25 or 30 that have done simulations for the 21st century. These started to be available in the year 2011 and they're still being uploaded to various archives.

We wanted to evaluate these models on the regional scale, and we've done this now both for the Northwest and to a lesser extent the Southwest, but also for the Southeast, and then recommend some models that are top tier.

There are enough models that we can get a pretty good spread of results using the ones that performed well in the 20th century.

Now I would note that there is a supposition here that the performance of a model in the 20th century is an indication of how well it will do in the 21st century. We don't know whether that's true, but it seems reasonable and we use model performance to shape our choices for models in the future.

Then, John Abatzoglou at the University of Idaho who had developed this MACA, Multivariant Adaptive Constructed Analogue approach to downscaling, has downscaled 20 GCMs for the whole continental U.S.

We were initially intending to just do the Northwest, but it turned out not to be that much work to do the whole continental U.S. Then we also have a comparison, which I won't talk much about. A comparison with the previous generation of models, CMIP3, which was released around the year 2005.

The drivers for these global models are what are called Representative Concentration Pathways, or RCPs. You'll see this in a number of slides, it's worth taking a few minutes to explain.

Socioeconomic modeling has postulated a wide variety of futures for the world depending on both market and non market forces, on policy choices, on availability of fossil fuels and a wide range of other considerations, and also global population.

I draw your attention to the orange curve, the RCP8.5. This is a world in which development is fairly unfettered and in which coal is widely available and remains cheap, and the developing countries are able to rapidly follow the developed world into a much more prosperous and consumptive future.

RCP6 is a more modest version of that, in which the carbon dioxide amounts by the end of the century don't quite reach 700, versus over 900 for RCP8.5. RCP4.5 is more of a gentle, sustainable future where carbon dioxide amounts level off by around 2070 at 540 parts per million.

Climate continues to change a little bit after that, but it's a rather different future. And then finally RCP3PD, which is also known as RCP2.6, is intended to reflect the postulated success of policies which would reduce greenhouse gas emissions so substantially as to limit the global temperature change to two degrees Celsius, which is a stated goal of many governments.

It's all a very totally Pollyanna view of the world, dialing back emissions so dramatically would be politically and economically a very heavy load.

For this work we're going to focus on the gentle, sustainable, RCP4.5, the green curve and RCP8.5. Those are shown here in comparison with the earlier generation, the CMIP3 model input and that's the dashed curve.

The RCPs also extend beyond the year 2100, that's an important distinction. You see there the RCP2.6, which initially is fairly similar to the others, to about 2025, and then departs rather dramatically. The Y-axis here is Radiative Forcing.

This is essentially how much extra energy is added in watts to each square meter over the earth. The amounts are initially a little over one watt per square meter, and they rise from anywhere from 2.6 by the year 2100, all the way up to 8.5, and that's what the numbers for the RCP correspond to.

These are the 20 models that we're using in this study, listed in alphabetical order by country. And you can see there a number of entries from several different countries.

This is, again, a subset of the total ones available, and the next several slides will show that the climate variables for the northwest, including a spread across the models to show the uncertainty.

They're smoothed for easier reading. Later you'll see some un-smoothed curves that indicate why we want to smooth them. This is a result of a model ranking approach that David Rupp came up with and was published last year.

Which he's also now applied a dimension to the southeastern U.S. for the Southeast CSC. It's a fairly complicated approach, as explained in the paper. It includes a variety of metrics of spatiotemporal variability, of temperature and precipitation.

We use this to guide our selection of models, tending to recommend we use the ones on the left hand of this figure.

We'll start on the climate model results with the slightly complicated figure. The only one of these I'm going to show, but I have a reason for showing it. What this figure shows is the change in temperature and precipitation, the Y and X axes respectively, for this set of models currently available.

The number is the model rank, one is the best and 30-something is the lowest. Not all models are included because as I noted before, some models that had 20th century runs which led to the ranking did not have 21st century runs, and those are gradually being filled in.

But generally the numbers in the 20's and 30's models works on the 20th century. The plus symbol is the mean of all of the model simulations for that RCP. The dark numbers have MACA data available and the light are not available.

The gray shading around both the X and Y axes are the percentiles of inter-annual variability during the 20th century.

It helps us see, for instance, looking at just the X axis variability, that most of the models say that the future, late 21st century precipitation, annual mean precipitation will be within the range of variability experienced in the past.

If you look at those plus symbols, they're shifting by only five percent or eight percent. Some of the models, in the upper right hand corner, you see 11's and 29's, indicate large increases in precipitation. No models indicate large decreases in precipitation.

I circled the number 15 because for some of the results you'll see we're going to focus on that model, the MIROC5 model, because it's in the middle of the pack and it's a reasonably good performer.

This is the first of several slides like this that I will show, where the 20th century simulations are shown in gray, with the all model average shown as the heavy black line.

And then going into the future where RCP4.5 is shown in yellow with one heavy curve ending at about six degrees Fahrenheit warming, and the other heavy curve for RCP8.5. You notice the RCP4.5 and 8.5 worlds start to diverge somewhere around 2030 or 2040.

And by the end of the century not only are they five degrees Fahrenheit difference in the multi model average, but notice the slope as well. The RCP4.5 world has climate starting to stabilize, and the RCP8.5 world is continuing to change at a pretty rapid clip.

There's an overlap between the two that's indicated in orange, and you can see the range of variability is a couple of degrees Celsius, or several degrees Fahrenheit.

The coolest model down at the very bottom of the yellow area would give a warming of only a couple degrees Fahrenheit by the end of the century in the RCP4.5 scenario, whereas the hottest model in the RCP8.5 would have us warming by about 15 degrees Fahrenheit.

Many of the results that I'll show later are either from my level five, or from the all model average.

This is the same kind of plot for precipitation, and you'll notice that there was very little change during the 20th century.

Even during the 21st century only a few percent change for the all model average. Now you remember from the complicated scatter diagram there were a few models that indicated large increases in precipitation.

But the robust message is that there doesn't appear to be a solid indication that precipitation would change dramatically in the annual mean.

We'll come to the seasonal differences shortly. The MACA data, which are summarized here for the Pacific northwest region, includes other variables like wind speed. This is the plot of change in the average wind speed over the northwest.

A decrease of roughly five percent for the all model average for the RCP4.5, but slightly more for RCP8.5. This appears to be because several models tend to have the Pacific storm track shifting farther north we get fewer windy winter storms.

The diurnal temperature range is important for many ecological applications, and here we start to see some interesting seasonal variations. Winter diurnal temperature range decreases, and the summer diurnal temperature range increases. Notice the Y axes are somewhat different here, the decreases and increases are fairly comparable in magnitude, roughly one degree Celsius. And this is mostly having to do with changes in cloudiness, as indicated by this figure.

Now, we don't yet have full results for RCP4.5, so all that's shown here is RCP8.5. But the winter, shortwave radiation goes down indicating an increase in cloudiness, which is also connected with the decrease in diurnal temperature range.

Then in summer, the reverse is true and a decrease in cloudiness leads to an increase in incoming shortwave radiation and an increase in diurnal temperature range.

The maximum temperature in June, July, August is shown here, along with the MIROC5 results. And again, all results have been smoothed so that you're not seeing thousands of individual symbols indicating each model's annual output.

But the results here broadly align with what's been observed, an increase in the summer daily maximum temperature of a couple of degrees. And then going out into the future, pretty substantial increases in summer temperature, especially in the RCP8.5 scenario.

Much more modest in the RCP4.5. Seasonal precipitation in general, the seasons include models that say it will get wetter and models that say it will get drier.

So these broad shaded areas you see for winter, almost all of them go up, but some of them don't go up much, and in the individual models, there are some that go down for winter.

Likewise for summer, the average precipitation averaging across all the models goes down somewhat. For some, it goes down dramatically, and for some it goes up. A lot more ambiguity about changes in precipitation, even on the seasonal time scale, than about changes in temperature.

All of these data are available from the MACA website, and I'll repeat this URL on the last slide so you don't need to scramble to write it down.

This is a screen shot of the MACA website, and if you do intend to use this, I strongly suggest that under analysis tools, you read the FAQ and guidelines on applying scenarios so that you can avoid common pitfalls.

On the right you see the variables, many of which I just showed you. You can do time slices, 2040 to 2069 or 2070 to 2099. You can also do some time series on other things. I selected the maps option here to give you a sense of exploring some of the possibilities.

The reason that we do the MACA downscaling is that the raw model output looks something like this. This is the change in temperature at roughly the spatial resolution of a typical global climate model. And you can see that the pixels are roughly one to two degrees longitude by latitude.

This figure shows the same map, but from the MACA downscaling. And you see much finer features. The way MACA works is essentially to use large-scale global model outputs in connection with fine scale observations to do a statistical connection between the two.

It still can't see mountains, so as I'll show shortly, we're also using regional modeling. But this gives you a sense of what MACA is about. This is the same kind of map, but for winter diurnal temperature range.

And you can see those reductions we were seeing earlier are not ubiquitous in the Northwest region, but they're really concentrated over the Rocky Mountains.

This is a sample of the results from some regional models. This is what we call a super ensemble where we use volunteer's personal computers to complete tens of thousands of one year simulations. We've got 1960 to 2009, we have 130,000 simulations over that period, and then 2029 to 2049.

And this shows the difference in temperature in the spring from these modeling results, and if you know anything about the geography of the Western U.S., you'll recognize that the mountain ranges tend to warm more than the lower elevation areas around them.

You see the Cascades in Washington and Oregon warming more than the areas to the east and west of them. And then down into California, the Sierras and Trinity Mountains warming more than their surrounding areas.

And then the same thing over in Utah with the Wasatch Mountains, and then to some extent the Rockies in Idaho. We've done a little bit of analysis, and this seems to be linked both to changes in solar radiation, (i.e. cloudiness), and also snow pack.

These are interesting and important results, but we have not fed them into the vegetation and hydrologic modeling, the results I'm about to show are from the MACA data.

A summary for the climate, all of the scenarios show warming in every season. However, there's a very wide range, we can't say with confidence what the amount of warming will be, only that it will warm.

And our forthcoming publications include tables with estimates of the 25th and 75th percentiles and a lot of other statistics. The omissions scenario starts to matter a lot after about 2030 in the total amount of warming that you get in any given period.

The models with the least warming in the 21st century, I forgot to point this out on the scatter diagram.

Down in the bottom of the scatter diagram, the models with the least amount of warming tended to have numbers in the upper 20's and 30's.

Meaning that they didn't do very well with 20th century climate. This suggests that a quality weighting on the models leads to a slight increase in the estimate of the lower bound of warming.

Seasonal differences: summer appears to be somewhat warmer and drier and sunnier than other seasons. It trends in that direction, not just the baseline. And winter is somewhat wetter and cloudier.

In other words, an accentuation of the existing seasonal cycle with enhanced warming in summer, less precipitation in summer, more in winter. And then the regional modeling strongly suggests the mountains, especially in spring, will warm more.

And for the hydrology modeling, we used a couple of different approaches. We started with a sensitivity approach, which is to compute the response in flow at 200 plus points in the Northwest. The small changes in temperature and precipitation, using one of these hyrdologic models.

This is all based on some work that Julie Bano did, which was the cover article in the most recent issue of the Bulletin in the American Meteorological Society.

She initially did this work, and that’s what was just published in the Colorado River basin, and now she's done it for the Northwest. This is a useful way to explore uncertainty, and I’ll show an example of it next.

The second approach we use is to do full, distributed hydrologic modeling using the Variable Infiltration Capacity, VIC model developed at the University of Washington over 20 years ago and continuously updated since then.

It's really the workhorse for climate impact studies in the U.S. and around the world. Dennis Lettenmaier, the head of the hydrology group at UW has recently developed a Unified Land Model which is a merger of two other models. Those simulations have not yet been completed, but they're on the way.

And again, the objective is to use available tools to characterize and quantify the range of possibilities, or the uncertainty. This is a brief additional detail. The Unified Land Model is the merger of the Noah and Sacramento hydrologic models.

On the right are the equations that describe the sensitivity approach. The elasticity of precipitation is a flow response where Q stands for flow to a one percent increase in precipitation and the temperature sensitivity is the flow response to a tenth degree increase in temperature.

And we've done that on a monthly time scale, seasonal and annual time scale to fully understand what's going on. This is an example of the sensitivity approach applied to the Willamette River basin.

The VIC model was run with the baseline historical climate, and then increasing the temperature and separately increasing the precipitation. We've done this for temperature increases one, two, three and four degrees Celsius, which is why the curves here are nonlinear. I'll explain the curves in a minute.

This is the same kind of scatter plot that you saw earlier, with the listed models indicated as numbers, and the precipitation change on the X axis and the temperature change on the Y axis.

We're now taking the precipitation season of January through June that makes the most difference for June, July, August stream flow. And likewise, the temperature change October through June which makes the most difference.

The curving lines are the outputs of the sensitivity approach and they indicate a constant, or the same amount of change, in the summer flow.

If you start down at the bottom at 0, 0, there is a zero percent curve which tracks up into the right. You'll see that a one degree Celsius increase in temperature can be offset roughly by a ten percent increase in precipitation in that season.

As the warming gets more and more, it takes less and less precipitation increase to offset the temperature increase. The curves end up at the top of the diagram going almost vertical.

Now you can see there's only two models that suggest an increase in summer flow, model number 15 and model number 21.

The big plus symbols indicating the averages for RCP4.5 and 8.5 are in the 20 to 25 percent decrease range, if you see the contoured labels down at the lower left part of the diagram.

And the most extreme scenarios are those from model number seven, the HodGEM2 model, which has been a solid performer in the Northwest. That leads to decreases of, according to our linear estimates here, over 50 percent in the summer as well.

This is the quick way to get a sense of what the probability distribution is of changes in flow, given in this case over 100 scenarios from different climate models.

Now for some early results from the VIC modeling, again from MIROC5. This is for the Columbia basin at Dalles, the cold part of the Northwest. 1950 to 2005 shown as solid curves, and 2006 to 2100 shown as dashed curves.

Even with some increases in precipitation in this MIROC simulation the shift in the flow is quite pronounced starting in March future flows are quite a bit more than past flows, and starting in June the future flows are quite a bit lower than past flows.

Which as we've seen in earlier studies is indicative of a reduced role of snow melt, and we'll show the snow melt shortly. August soil moisture, this is what is called an exceedance probability curve.

If you haven't seen these before it may be a little bit confusing, but at the left edge are the largest amounts, that is the amounts that are never exceeded, they have an exceedance probability of zero. On the right are the lowest amounts, they have an exceedance probability of 100 percent.

The future distribution across the board shifts by about 10 or 15 percent: so the lowest soil moistures in the future drop from 255 millimeters soil depth to 230.

Now I'm going to step quickly through the MIROC results for snow. So this is an historical simulation. So notice the very bright white amounts, very high amounts on the east slopes of the Cascade Mountains on the left edge of the map, and also in the Rocky Mountains on the right edge of the colored part of the diagram.

This is the same thing now on the left but for 2021 to 2040, and the right panel shows the percentage change. So at lower elevations the percent change is quite dramatic, 60 to 100 percent. You can even see that happening in the river valleys as well up in British Columbia, for example.

Notice there are some places, the higher elevations, that see increases in April snow water equivalent. I'm now going to step forward to 2040, and you'll see more blue, less white on the left diagram and more red on the right diagram 2060 to 2080, and then 2081 to 2100.

To summarize the hydrology, note these are preliminary results. The sensitivity approach is a promising way to get a large number of simulations and estimate what the effects would be of a wide range of climates.

What we find is for the current generation of models the Willamette flow would decrease by about 25 percent with a range from 0 to a little over 50 percent.

Snow greatly decreases over the 21st century as we saw in the MIROC5 maps, and late summer soil moisture also decreases and lots more simulations to follow. These are preliminary results.

Now for vegetation, a quick word about the two vegetation models we're using. These are constructed differently. They have different approaches entirely. Whereas our two hydrologic models are both disturbed models that use water and energy balance, these use quite different approaches.

The MC2 is a dynamic general vegetation model. The intent is to simulate the bio-geography, that is essentially what grows where, keying into key seasons for climate variables. It also simulates bio-geochemistry and wildfire interactions.

Plant types in the model are distinguished by whether they're evergreen or deciduous and by leaf shape. The main climate drivers are the temperature in the coldest months and the precipitation during the growing season.

Those determine the dominance of the life forms: grass, shrubs and trees. The simulation domain that we're using here is Western US.

The 3PG model is the forest physiology model. It has a light-use-efficiency based photosynthesis algorithm. It simulates net primary production, which MC2 does as well, but with a somewhat different approach. It also simulates wood production and forest succession.

Model outputs like the soil water and the vapor pressure deficit predicts species presence and absence. Nicholas Coops who is the primary author on the 3PG model, published this study in 2011 showing that this species presence/absence accuracy was 82 percent for 20th century climate and the domain here is Western US as well.

For some purposes the results will be aggregated by ecoregions as shown here. For these purposes for simplicity I'm going to show Northwest average results and also Willamette Valley, which is ecoregion number three over near the left edge of the diagram.

This is for the northwestern part of the domain, north of 42 degrees and west of 111 degrees longitude. This is curious.

You can see at the bottom the model simulations that went into the MC2 model shown here. The RCP8.5 scenario has the vegetation carbon initially decreasing to about mid-century and then starting to increase again.

Essentially what happens is the wildfires over the first half of the century, which are indicated here, gradually increase, and there's a reduction in certain types of trees and then a transformation to other types of trees.

And as the wildfires decrease towards the end of the century, the vegetation carbon increases again.

This is more dramatic if we look just at the Willamette Valley. This is now ecosystem carbon, which is a little different from vegetation carbon, and the initial carbon storage drops by about 20 percent from the beginning of the runs to about 2070, and then it starts to increase again.

Again, this has a lot to do with wildfire. It's more dramatic here. The spikes are unfiltered time series for individual models, and you can see each of the models at some point has a big fire in the first half of the century and then things quiet down.

What can burn has burned, and we're left with a new configuration of vegetation. This is a fairly dramatic example of this transformation.

These results are available from a website. The URL will follow shortly, but, again, there's some mapping tools where you can select an ecoregion, select some variables.

You can output both the climate data, which are the inputs, and then also these diagrams on the lower right, which indicate the fraction of domain that's in forest, shrub, grass, or desert.

These in some cases show pretty interesting and dramatic transformations from one type of vegetation to another. This is an example. This is for...this is not for the Northwest, but it shows the kinds of plots that we'll be making available shortly.

For a particular model, the CanESM2, over this domain the forest increases at the expense of grassland and especially desert.

This is one preliminary slide results from the 3PG model. The upper left is, again, our favorite MIROC model, the net primary productivity in the 1990's on the right, the same thing for the 2090's.

At first glance they look quite similar, but if you look, for example, in the Willamette Valley or the northern Sacramento Valley of California you'll see some pretty big reductions, and the bottom left panel shows the reduction amounts.

You see that for the inland west the brown color, which indicates small reductions between 0 and negative 3 of these units - which I've forgotten what MGDM stands for - that color is pretty prevalent in the western U.S.

The lighter brown color is prevalent in the coastal parts of Washington, Oregon, and California, larger decreases in NPP, and, again, this model also indicates changes in NPP possibly related to fire and other things.

Again, some preliminary results, the summary for the vegetation. West-wide increases in stored carbon and net primary productivity for RCP8.5.

The burned area increases initially and then decreases, especially in the Willamette Valley, fairly large transition in vegetation, which we're still working on for the Willamette Valley, and some shift in vegetation to shrub and forest across the West.

The MC2 results are at this website, which, again, I'll repeat this URL at the very end of the talk.

A summary of the whole talk, climate models indicate robustly that the region will warm in the 21st century as it has in the 20th century, but more dramatically.

We're still catching up to the carbon levels emitted over the last few decades so there's a time lag between emissions of carbon and warming. So we're locked into some additional warming, but also the emissions are increasing rapidly.

Precipitation changes are uncertain. There's a general tendency for winters to be wetter and summers to be drier. There are profound shifts in some basins in snowmelt driven hydrology with summer flows decreasing even in fairly rain dominant basins like the Willamette.

In some places there will be wholesale changes in vegetation types and in fire risks. That seems to be more of an issue west of the Cascade and Sierra Nevada Mountains than east.

That is the extent of my talk. For more information as I mentioned there is a full day version of this in two weeks. It will also be webcast.

You can sign up for the web cast or for the workshop at our website occri.net. You can get the climate data from this URL or vegetation data from that URL. Now I'd be happy to open it up to questions.

Hi, David. Thanks for tuning in. Always enjoy interacting with you. That's a very good question. The question is why would anyone choose MACA over the BCSD monthly ARRM or other products?

Have you done an inner comparison that shows the advantages and disadvantages or a comparison to regional climate modeling outputs?

Yea, so there are, as you note, a wide range of downscaling products available. Previously BCSD, which was sort of the workhorse was primarily monthly, and the reason for that is that it relied on the outputs of the climate models. The CMIP3 models only made available monthly outputs with a few exceptions.

This time around at CMIP5 we do have daily outputs and BCSD has been repeated with all the CMIP5, or a great many of the CMIP5 model simulations, and that's available as well.

Part of the reason that we were interested in using MACA was that it has a lot more variables available as I noted, not just max and min temperature and precipitation, which are available through BCSD, but also wind speed, solar radiation, relative humidity, which as it turns out are the variables that a large number of impact models want to use.

John initially developed MACA for input to fire modeling, but it's also useful for the MC2 vegetation modeling and for the hydrologic modeling.

In fact, we had a separate project to see how including the full suite of MACA inputs changed the simulation of stream flow with VIC, and we do see some improvements, particularly in drier climates with the treatment of solar radiation.

It's not a panacea. There may be a better approach that comes down the road, and we would love to use regional modeling outputs. The problem is that aside from the NARCCAP there are not - which is a whole separate conversation that I don't want to get into here - it's difficult to find a good range of regional models except with our super ensemble, and we're pretty excited about that.

We're going to do some new runs that include full daily outputs so that we can start using those for inputs, and we can play around with model parameters to get a bigger spread in temperature and precipitation projections.

You asked if we compared MACA with regional modeling outputs. If you think back to the slide I showed of the temperature change from the regional model, no statistical downscaling approach is going to be able to mimic that terrain-induced change in climate where there's something going on in the regional model.

It's an interplay between clouds and snow in the mountains that leads to more warming. Statistical approaches can only key off what the global model does, and if the global model doesn't know there's a mountain range there it's not going to be able to have that cloud and snow interaction.

Ashley: Thank you. We have another question from Laura. It says, "How reliable are the fire predictions from the vegetation models?"

Phil: We won't know until we get there, right? Yes, that's a good question. The fire modules in MC2 have been tested to some extent against observations. The problem is you never know when a fire would occur or how big it will be given fire conditions.

In some ways it's pretty difficult to compare a past simulation of fire with observations. That said, we know that warmer, drier summers, especially in the Northwest, lead to greatly increased average area burn, and mechanisms like that are in the fire module.

But, yes, we won't know how well those perform with future climates, because we're going to...until we get there, because the hot, dry...the heat and dryness of future summers will very likely exceed anything we've experienced, and we won't know exactly how these systems will react.

Another thing to note about these vegetation-modeling efforts. The system as simulated is a bit more responsive to climate changes than the actual system. What I mean by that is, although there's a bit of history built in, part of what's being simulated is the potential vegetation.

Particularly when we talk about vegetation distribution, which I left those results out, but they influence the net primary productivity and the fire, when the vegetation changes in the model it changes more rapidly than in the observations.

Unless there's just been a fire then something new can grow in.

Ashley: Thank you. We have a question from James Rourke. “This is outside the scope for the current talk, but is there any plans to address climate change effects on coastal ecosystems?”

Phil: True, that's outside the scope of this talk. We're really trying to describe the broad scale changes.

There are coastal ecoregions in the vegetation models, and they unsurprisingly change less, because the ocean moderates the climate change somewhat less than the Willamette Valley and other inland locations.

But as for more broad scale types of impacts that's...we leave that to others to work out.

Ashley: Amy Daniels asks that you go back to the model-ranking graph, and if you could explain that in a little bit more detail. She wants to confirm that it was for native resolution of GCM simulations.

Phil: OK. I should be able to see the figure now. These were...I believe David first interpolated these to a common grid for comparing with observations, and the observations were coarsened in a similar way so that we could have a fair comparison.

I don't remember the second part of Amy's question.

Ashley: The second part is...sorry, pulling it right back up. It says, "Was that for native resolution GCM simulations?"

Phil: Yes. OK, so just one question.

Ashley: Yes.

Phil: OK.

Ashley: Amy, does that answer your question? Was that enough detail for you? While she's getting back to it we'll take another question. It's from Kavita. It says, "The two vegetation models are still at relatively coarse ecoregional scale.

To be a great use to natural resource managers at small scales, are there any efforts to develop finer vegetative models for the Northwest?"

Phil: Yes, thank you, Kavita. I was not clear in describing the details of these models. The MACA outputs are at quite fine scale, and both the hydrology and the vegetation models were also run at quite fine scales. I believe four to six kilometers in both cases.

That level of detail is available. I didn't highlight the fineness of the resolution in the results that I presented.

I'm going to steal back the camera here and put the hydrologic model up. This is roughly the same spatial resolution in the hydrologic model that's also used in the vegetation model.

You can see some pretty fine details there. For instance in the Washington Cascades you can see the low snow area in the Yakima Valley, which slices east to west, roughly at the latitude of Puget Sound.

And up in the Canadian part of the basin you can see, the Colombia River Valley roughly paralleling the Continental Divide as a very low snow area

Then, up towards the north end of it, you can see it's one pixel wide and the mountains around it are quite a bit higher and snowier. It's the same kind of thing for the vegetation.

Here's the native resolution of the vegetation model, the 3PG model. Again, you can see the actual details are at a few kilometers resolution.

Phil: We had another question that came in by text, too.

Ashley: Yes, Amy asked "What went into the principal component analysis, if she's understanding that correctly?"

Phil: Yeah, fair question. The point of principal components analysis was basically to cluster types of metrics that were similar.

For instance, if you think about various temperature metrics, the area average temperature, if a model is too warm in the annual mean, is it also too warm in the winter and the summer? Those might be related. Is the summer minus winter difference, say, in temperature or precipitation related?

There were about 20 different metrics that went into this. The point of the principal components analysis was to reduce them to meaningfully different ones that ended up, some covering spatial values and others temporal variability.

For details, see the paper. It would take a while to explain the next level of complexity, but that's the upshot.

Ashley: We have one from Robert. It says, "Can you explain further the projected wintertime trends of the modest precipitation increase? More cloudiness and less wind speed. Less wind speed because the storm track is farther north, and then more precipitation because warmer air can hold more moisture. What about the cloudiness?"

Phil: Yeah, that's a good question. We haven't dug into those results in that level of detail.

The shifts in the storm track are probably modest. The average across all models...

This isn't our work, but it was in the report of the Intergovernmental Panel on Climate Change. It's only a couple of degrees latitude shift by the end of the century.

The storms do carry more moisture. You're quite right about that. We may get fewer of them. As to why we get fewer storms but more clouds, again, that's something that we haven't looked into.

Ashley: Thank you.

Phil: Good question, though.

Ashley: Then we'll have to bring up the link again for the integrated scenarios calculator. People would like to write those down.

Phil: OK.

Ashley: A question from Paul. It says, "How detailed is the vegetation information. For example, does it define tree species that are changing?"

Phil: No, not quite. There are vegetation classes. MC2 and 3PG handle them differently. There are a variety of tree species collected into one type.

I showed the example of the wholesale shift from one type of vegetation to another. Those are large vegetation classes.

There are also much smaller groupings that are the native outputs of the models. You can learn more on the website here, "Conservation Biology."

Ashley: Then, again from Paul, it says, "When you say that there is uncertainly in the precipitation trend what level is the uncertainty, especially in regards to the winter precipitation?"

Phil: Yeah, great question. Here is that same kind of scatter diagram that I showed before.

This is the diagram for winter. On the right you can see the tables that summarize range and the twenty-fifth and seventy-fifth percentile.

The table there in the middle that says, "Change in precipitation." For the RCP8.5, there's one model that has a 29 percent increase.

I would note that if you look on the diagram and you look closely, you would say, "Wait a minute, I see an 11. That's not that 35 percent."

The reason the 35 percent isn't shown is that there are number of 11's. Those are all different stimulation's from the same model, and those have been averaged together before inclusion in the table on the right.

All of model number 11 averaged together gives about a 29 percent increase in winter precipitation. The 75th percentile is 11.5.

We're going to have to get to the bottom of this. I'm not understanding why the mean of the twenty-fifth percentile go up. The minimum is 7.5 percent decrease.

Ashley: We have a couple more questions as we're running out of time. Steve Klein, you can ask your question now. Please remember to press *6.

Steve Klein: Phil, my question is in regard to the vegetation models and whether in fact it's possible to leverage this modeling work and use the drivers of moisture and temperature to look at the effect of plant associations.

In other words, is there a level of refinement that can build upon what's been done in these two models?

Phil: Yeah, I'll have to talk to the vegetation-modeling folks and get back to you on that, Steve. It's a good question.

Steve: One comment, if the host could send those links out to the data sources and where the webinar would be posted, that would be helpful to the participants.

Ashley: Yes, Holly will be sending the information out. It takes about one to two weeks to edit the recorded version of the webinar and get it closed-captioned. She will send that all out.

Currently the link is there in the chat box, when we go back to that screen. That's going to be where this webinar, as well as all the previous webinars, are held.

Steve: Thank you.

Ashley: All right, a question from Nancy Green. She says, "Excellent webinar. You mentioned some applications are available for the Southwest and Southeast. How can we get that information?"

Phil: The MACA data are available for the whole continental U.S. That's from the website shown here.

The hydrology and vegetation modeling is available west of, I think, 105 degrees longitude. I need to check. Those have not been done for the Southeastern US.

What I specifically mentioned had been done for the Southeast is the same model evaluation approach that we published in JGR last fall. Those were done for the Southeast CSC in a project that's taking place this spring. We haven't yet handed off the results.

We're still in process with that. But you can check back with us or with the Southeast CSC in a month or two. That's, again, only the model evaluation part for the climate models.

Ashley: Thank you. And our last question will be from Paul, which says "The trend from the desert to the forest is surprising. A trend from Douglas fir to the pine, or the pine to the scrub would be more expected. What is driving those predictions?"

Phil: I'm not even sure the domain that that covered, that was for a different project. The graphics for the Northwest are still being developed, and we're not prepared to show this yet.

And without knowing what domain that covered, I can't comment intelligently. I included that as an example of what's about to be available. But presumably, increases in precipitation, which show up in some areas to drive that kind of change.

Ashley: Excellent, thank you. And I do not see any more questions. Holly or Shawn, did you have any closing remarks?

Shawn: No closing remarks, I guess, other than we will be, in addition to posting the material on the web, people would like some additional materials related to data sources and information, we'll be making those available as well. They'll be on our website.

Phil: There was one other question in the chat box from Jon Butcher.

Ashley: OK, go ahead.

Phil: Yeah, good question Jon. He asks "Does hydrologic modeling include the effects of increased atmospheric CO2 on plants in the model conducted inside ET?" No, it does not. The hydrologic modeling with VIC that we've done assumes static vegetation.

That is an area where a coupled model would do better in the hydrologic part, and the vegetation part would talk to each other, more than they have in these modeling frameworks. That's an ambition for somewhere down the road, that we could have better coupling between those two types of models.

But at this point, they're a static vegetation. There have been experiments with the VIC model using changing vegetation, but we haven't attempted to do that here.

Ashley: Excellent, thank you. All right. For everybody who has been asking, that website again is in the chat box. If you have any problems getting that down, please let me know.

We had one more pop in from Dan Isaak, and it says "There's some recent research published in Science, Missing Mountain Water, suggesting total precipitation is decreasing. Do new runs address this?"

Phil: Yeah, the paper that Dan is referring to was published, Charlie Luce was the lead author, John Abatzoglou, who's on this project, was a co-author. The point that they made was that, if you look over the past, I forget what the period of record in that paper was, 50 years or so.

It looks as if weakening westerly winds across the Cascade Mountains have led to a reduced rain shadow effect, and the ornographic enhancement as the wind is forced up and over the mountain range has gotten weaker.

That effect would not show up explicitly in the MACA results, but it would show up in the regional modeling, and it's not something that we've seen very robustly in the regional model.

The decreases in wind speed that I noted out of the GCM's are important, but it's hard to gauge how much effect, how well that effect will play out in the future. It would tend to shift the distribution of precipitation a little bit from the west to the east, ironically.

A strong rain shadow effect squeezes out more of the moisture before it crosses the mountains, and therefore a weaker rain shadow effect leaves more moisture in to be dumped on the other side of the mountain.

Ashley: Thank you.

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