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CLIMATE RESEARCH AND APPLICATIONS NEEDS IN SUPPORT OF CLIMATE SERVICES

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> "*If we are not careful we will end up where we are going*."

The year 2007 was a record breaking season: Salt Lake City and Las Vegas experienced their hottest June through August temperatures; Phoenix had 32 days of temperatures above 110 degrees; Utah had their largest fire in history with 618,679 acres burned during the fire season; record high and maximum low temperatures were recorded in Missoula, Montana, and the Southeast experienced their worst drought in 100 years. Los Angeles received 3.21 inches of rain from July 1, 2006 to June 30, 2007. This is nearly one foot or 11.93 inches below normal during the same period, or just 21 percent of normal. This was the driest since records began some 130 years ago in 1877. It was a rough year.

Climate services of the National Oceanic and Atmospheric Administration provide "The timely production and delivery of useful climate data, information, and knowledge to decision makers." More specifically, we ask what should we do with our lessons? We have a network of activities that maintains well-structured paths from observations, modeling, and research to usable information.

Why do we need a National Climate Service? There is a growing awareness within research and resources management communities that climate variability and climate change are affecting natural and socioeconomic systems. These impacts vary from region to region given variations in climate patterns and natural/socioeconomic systems. There is a recognized need (and demand) for spatially relevant research on climate and climate impacts and a need for reliable and responsive technical support for the resource management community (if we are going to get a broader use of forecasts) for climate-ecosystem impacts, trends, and changes.

We need to get local data down to where it is needed and to help in having the data understandable. Currently, there are a couple of bipartisan bills that address this need: the Global Change Research Improvement Act, which directs NOAA—only as the lead agency, not the only one—to develop a National Climate Service. NOAA is not doing this on its own; there are folks telling us what we ought to be doing. The Udall-Inglis bill is another bipartisan bill, the Global Climate Change Research, Data, and Management Act. All these bills direct us to ask what we should be doing to adapt to climate change. I am taking a position that the climate is changing, and we need to figure out what are we going to do about it.

There are other things being asked of us. I love the National Academy and have sat on several of their panels. They are great at coming to you and telling you what you ought to do. Recommendations from academia are useful but what they are really telling us is that they have been trying to evaluate what we have been doing regarding global change science for the last 20 years, and even where regular scientific progress is being made, the use of knowledge to support decision making is proceeding too slowly. The Government Accountability Office released a report, Climate Change 2007, The Physical Science Basis, basically saying, “Good. We are good at the science, but so what?” It is not getting us to where we can actually use the science.

I wanted to make a couple of comments concerning the Intergovernmental Panel on Climate Change (IPCC) and to make a clear distinction of which few people are aware. For international agreements like Kyoto and others, climate change is defined only as human activity produced. For the ICPP, climate change refers to both natural variability and whatever might be attributed to human activity. So keep in mind when you hear about the IPCC that we are considering both of these factors, not just the human-induced piece. The question is what you do about it.

Warming is here. We have the data, folks. We can’t avoid this. It is not just some model imagined into the future telling us what is happening. This is actually what is going on. What do we see? In the West, we have seen one to four weeks earlier peak streamflow due to earlier warming-driven snowmelt. A portion of precipitation falling as snow is declining. The duration and extent of snow cover is declining over most of North America. Water temperature of lakes is going up (0.1 to 1.5 degrees C) over most of North America. Annual precipitation is decreasing over the central Rockies and southwestern U.S. Dry days and timing between rainfall events are increasing over most of North America. The mountain snow water equivalent is falling over western North America, and periods of drought are increasing over the Western U.S. and southern Canada. These things are happening. Those are the trends. We see this in the data, it is not guesswork. Remember the old saying, “If you want to make God laugh, you tell him your plans for the future.” But this is really what is happening.

What are the gaps? Where should we be paying attention? We need to look at regional climate models that have variability. Most of the models that we have right now only include temperature. They need to incorporate variability, like El Niño events, for example. We need to fill gaps in hydrological monitoring with gridded data sets. We need to look at water budgets and the impacts climate change has on groundwater. We need monitoring sites especially for soil and moisture content, which are very little understood in the West. What piece of this is anthropogenic? What piece isn’t? What are the climate-related management triggers? How do we use them to design criteria? Where are the limits and thresholds in ecosystems? Some really good work is being done out here on the pinyon trees. We need to know the cost of these impacts, whether they are third party costs or water transfer costs.

How do you develop a collaborative framework for research and management? We have seen the template for research, development, prototyping, and services that includes identifying user requirements, conducting research, developing applications, integrating knowledge and products, delivering products, disseminating information, and controlling data quality. We’ve been talking about this process and what we need for over the last 50 years. The question is why we haven’t done anything about it. Well, we have done some things. The issue is why we don’t have a better collaborative framework for research and management. That is the essence of the Climate Service. If it is so easy, why is it so hard? Why do we still have this problem? I always like talking to people in other agencies and states. They tell me, "We're doing everything." So then, you don't have problems with drought and everything? And they say, "Well, yeah." Okay, something is missing between what we are doing and the resulting outcomes. Everyone asks us to be proactive. I say, "You first." What are the incentives for strategic and long-term thinking? Do we actually need it? Can we just adapt and adjust our way through this?

The challenge is to link research, development, the experiments we have, and the services. I am going to talk about why it is important to delivering products. Most of you in this room are familiar with the map in Figure 1. Note the dark blue areas that represent where our water comes from. Those areas are a small percent of the entire U.S., and minor changes in these areas affect the entire country dramatically. What we have are basically small areas that supply water for all of us. Small changes in temperature and in wind impact these areas a great deal. Why does this matter? If we look at the Colorado River and talk about climate impacts we have to talk about the short-term, year-to-year, and decade-to-century periods. Each of these periods has different decision timeframes on the Colorado River. In the short-term we consider power and irrigation. On a year-to-year timeframe, we are concerned with balancing Lake Mead and Lake Powell, deliveries to Mexico, and lower basin requirements. Each of these areas requires different kinds of information. Each of these has different degrees of uncertainty. When we talk about climate change, it is not just about 2050 or 2100. We need to know how to get from one period to another over time.

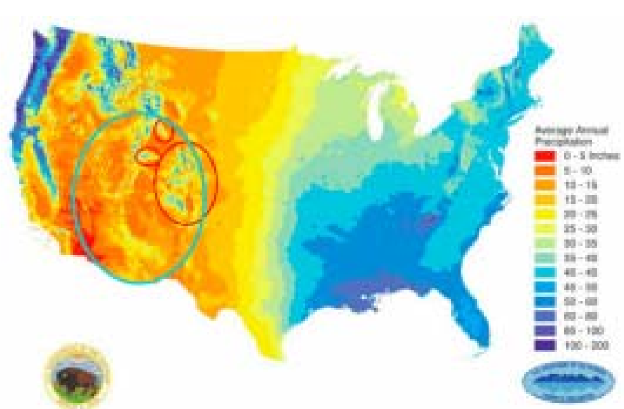

Figure 1. Average Inches of Annual Precipitation in the United States 1961-1990

Figure 2 shows Lower Colorado Basin mean annual temperature from 1895 to 2006. As some of you know, it has been much warmer during the more recent droughts than it was during earlier droughts at the beginning of the century. Where is that warming signal in the U.S. that we are seeing?

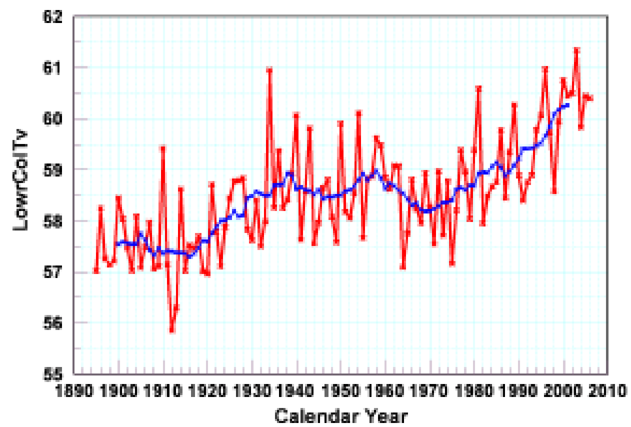

Figure 2. Lower Colorado Basin Mean Annual Temperature 1895-2006

What is the current thinking on projections? The models used by the IPCC and a bunch of other folks with whom we are working show that we are moving toward increasing aridity, not just drought, but increasing aridity. A more recent study by Seager and others (2007) shows virtually the same thing for our region. Even worse, the same study indicated that evapotranspiration rates in the Colorado Basin increased by 3 to 4 inches in the last 50 years.

What makes this so difficult is that we are trying to make decisions about our future based on what the models are telling us—and the models are beginning to agree—but we are not sure that this is actually going to happen. So how do you make a decision that incorporates what the models are telling us with the possibility that maybe this won't happen?

What are the estimated effects of climate change on Colorado River streamflow? Christensen and Lettenmaier (2007) think it will be a small decrease (0-8 percent by mid-century); Hoerling and Eischeid (2007) think we will see a large decrease (up to 40 percent); and Seager and others (2007) think we'll see a moderate decrease (in between). None of the studies show the streamflow increase. Any decrease is a source of concern, and it is a big concern. Ten percent is a major change. We must resolve these differences. The paleo-record says our average flow on the Colorado

River is 13.2 million acre-feet. We use more than that already.

You may be familiar with the vanishing snowpacks recorded in 2004 in Arizona, Colorado, Montana, and New Mexico (Figure 3). Let's take New Mexico. It had an 80 percent state-wide average the first of March 2004, and it went down to a 37 percent state-wide average on the first of April; this is strictly temperature related, not precipitation related. During 2005, we received 105 percent of the snowpack we needed in Colorado. We lost 25 percent of that, though strictly because of soil moisture and warmer January to June temperatures, not because precipitation declined. We can experience big changes simply because of temperature changes.

to kill outbreaks and that will affect forest hydrology and wildfires. Since 1986, the fire season has been extended by 78 days in parts of the West. Dust storms threaten snowpacks with snowmelt occurring up to three weeks earlier if there is significant dust. What do you do with this information?

One of the things we have to remember is that the anthropogenic piece, plus the decadal, plus the ENSO, plus the regional and local variability add up to one thing: surprise. The drought of 2002 was not projected in any climate model. It was a complete surprise. It was outside the realm of everything we were projecting including climate change. There are surprises in the system that we have to try to account for. That is the problem with creating a service that has a high degree

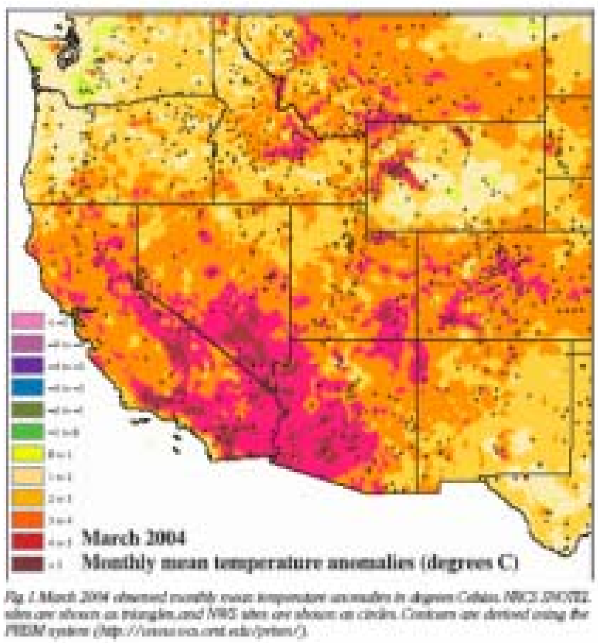

Table 1. Summary of Mountain Snowpack (Snow Water Equivalent) Changes Between 1 March and 1 April 2004.

State/Area	*Statewide % of Average, 1 March 2004*	*Statewide % of Average, 1 April 2004*	*Statewide % of Average, Change*
Arizona	74	22	-51
Sierra/Tahoe	113	70	-35
Colorado	90	64	-26
Idaho	105	81	-25
Montana	93	78	-16
Nevada	118	64	-54
New Mexico	80	37	-43
Oregon	126	96	-30
Utah	109	70	-39
Washington	93	86	-7
Wyoming	91	71	-19

Figure 3. 2004 Snowpack Vanishing Act (Pagano, Pasteris, Redmond, Dettinger, EOS)

So what do you do with this information? Is the current Southwest drought a once-or- twice-a-century drought like those of the past 500 years? In other words, will we come out of it? Is it more important now because we are here? Or is the drought a harbinger of things to come, a new type of drought that we haven't observed before? Is the jet stream actually moving north a little bit more permanently? That is part of the question.

And what do we do about this? There are wildcards like the pine beetles. We haven't had enough cold nights

of uncertainty. Uncertainty doesn't mean that we don't know anything. As a famous philosopher by the name of Satchel Paige once said, "Uncertainty is not what you don't know. It is what you know that isn't so." If anybody tells you, "Oh no. It is not going to change," then they are being as certain as the person who tells you it will change. We have to ask the question of what is in between that. If so, so what? How do you develop a system and a service that incorporates this information?

Well, that is why we collaborate and we have a history of working together. The environment is up there saying basically, "I don't know if we are exceeding the design specs." But you know, we are all in the room and we're talking.

We have multiple competing values and multiple competing objectives. We have a social and economic context that is changing. For example, the population is changing on the Colorado front range. Population is increasing, but we have ways of managing water use at the same time. It is not necessarily the case that population increases always lead to an increase in water use.

There are paradoxes in our planning. We want decentralization, but we are also asking for better coordination. We are reducing smaller floods and droughts, but is that increasing our vulnerability to larger events? What do I mean by that? Everything that we put in place in New Orleans reduced the risk from flooding for a long time, but what we did of course was to induce people to live in places of higher risk. We have to ask why the city of Phoenix is where it is – it's because of planning. We only plan after a crisis or focusing event. Lessons are available on particular events but not on gradual changes or abrupt regime shifts. I have looked at the details of the drought plans post-1977. They look exactly like the ones we have now. Why is that the case? We must ask how better to use those lessons, not just say, "Oh. Here's my latest study, and it says we should all coordinate and work together." We've been saying that for a long time, and some of it is working. We have to ask how to draw on those lessons.

Another paradox has to do with Integrated River Basin Management. We want that, but we have national, state, and borderland priorities. We ask to develop procedural and participatory mechanisms, but as all of you know—those who have worked at this scale—you have individuals even at the local level. You do not want to go back to the time when the sheriff and the mayor were brothers-in-law. We want to figure out how to work together to have maximum participation and to learn what is needed at this scale. There are paradoxes in our system—while we may ask for one thing, we need to balance unintended consequences. It is not as simple as choosing one or the other. We are asking to reduce these risks, but we may be increasing our vulnerability. How do we deal with these questions?

Planning depends on a stable climate and baselines. As I pointed out, small mountainous areas drive runoff. We see some change going on in the system already. Given our observed values, regardless if whether we stop producing CO_2 today, we are still going to experience change to some extent, and you must add variability on top of that. Most climate studies suggest that in the near future, droughts may be more common in the Colorado Basin even if precipitation stays the same. We need a full investigation of the potential yield from increased storage. Is increased storage actually going to help us in a drier environment? We must figure out how much increased storage will help us.

What has worked in the West in the past, and how do we take advantage of that for developing a Climate Service? We have found that the following elements make a difference: a strong focusing event that concentrates public and private interests like a drought, close federal/state/tribal and local partnerships, personal attention of key leaders, and strong support for collaboration between research and management. Every local, state, or federal partnership that we have identified to have been successful has had these four elements in them. That has been our experience.

One of our initiatives is the National Integrated Drought Information System (NIDIS), the regional implementation of an early drought warning system. The first experiment is going to be on the Colorado River Basin. You can find out more about this effort on www.drought.gov. This initiative is an example of how we are trying to use some of our systems. We need this to be a coordinated effort. We know states need to have drought plans, but we need to talk about what pieces of those plans need to go on this scale of the watershed. We have research on monitoring and predictions, and we've done some work on applications, but they are very idealized applications, using, for example, ideal farmers and a cost/benefit analysis that we don't know how to use in practice. We will be working on integrated tools for planning, mitigation, and adaptation.

Let's get back to why we need a National Climate Service? What regional functions should it perform? Who are the regional and local partners, and how should they be engaged (public, private, and tribal)? What information services should it provide? How can a framework for research and management be adopted and supported? How do we know that it is working? How should it be designed? We are now working with the states to put into place a regional assessment program to improve our monitoring.

So if the products we have today are good but still not helping local decision makers on most of their local scale items with drought, then what is needed above what we have today? What we need is to continue our understanding of climate issues and to understand what causes changes in the climate. Although we are quite good at forecasting weather on a day-to-day basis, we need to be able to do the same with climate over longer periods of time. We also need a more integrated national and regional approach that can provide localized information in the real time. NIDIS is NOAA moving toward what we need tomorrow and over the long-term.

Where are we now? We have all of these elements being put together: research, development, prototyping, and services. We need to find out from groups such as yours how to work better with the professional associations and groups on delivering the services. That is the plea I make today. Thank you very much.

Question: This is something that I brought up yesterday, and I keep bringing it up. I may be the only one in the world who ever talks about it, but I don't care. There always has to be a component of growth management and those related things thrown into any talk like this. It has to be with carrying capacity—population and area—in mind. The answer yesterday was that it takes local public will. My experience has been that local politicians don't seem to have the clout. The president can make a decision on the national level. Local politicians often make decisions based on not wanting to step on their friends' toes. That is the social aspect, in my view, of all this science.

Pulwarty: I want to point out that half of my talk was on the social aspects of this issue. One of the things that we need to address is the issue of growth. It was off the table in Georgia and Alabama. There is no legal requirement to restrict growth in a lot of instances. The issue, to me, is a state issue. Now that is not passing the buck. The other thing to remember before we get away from the carrying capacity idea is that carrying capacity works really well with ecosystems and organisms that don't modify their environment on the scale that we do. I don't know that there is a limit to how much we can put into one place. Look at places like Phoenix and so on. If carrying capacity were a limitation, Phoenix shouldn't be there. We move water from one place to the next pretty easily. But if the place that you are moving water from is also tending toward dryness, you have a problem. If the adaptation strategies that we have used in the past, such as interbasin transfer, are themselves vulnerable, then you have a problem. As Pat Mulroy from the city of Las Vegas, Nevada, keeps telling me, growth will happen. The question is how we manage it. How do you want growth to happen? I think our role is to provide better climate products and information services, including how to use them, for people making decisions about growth. I don't want to pass the buck here, but it really is a state issue. Political will should come from the people that vote. Remember I talked about a focusing event. If enough of your population doesn't think that growth is a problem, then we don't make changes. Remember the four things we talked about that led us to change our minds? That is the nature of the beast. It is how we make agreements.