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Rockies Snowmelt: A Tale of Climate Change

by Ker Than

Layers of snow, or snowpack, in the Rocky Mountains have been declining at an unprecedented rate for the last 30 years, according to a study that appeared in *Science* in June 2011. The declines could lead to water shortages in the western United States in the coming decades, the researchers warned. They found that the Rocky Mountain snowpack shrank more during the late 20th and early 21st centuries than during any other period in the past 800 years. This is anything but trivial, given that more than 70 million people depend on water from the Columbia, Colorado and Missouri Rivers, which are fed by meltwater from the snowpacks.

Greg Pederson/USGS

Layers of snow, or snowpack, in the Rocky Mountains have been declining at an unprecedented rate for the last 30 years. The declines could lead to water shortages in the western United States in the coming decades.

Prior to the new study, scientists had only limited amounts of snowpack data in the West because good measurements are only available for the past century or so. "Fifty to 100 years of record is, in many cases, compared to the rest of the Earth's history, a pretty short time interval," study leader Gregory Pederson, a paleoclimatologist with the U.S. Geological Survey (USGS), told National Public Radio (NPR). He added, "We were curious how, over the past 500 to 1,000 years, snowpack may have changed."

Recording Growth

With direct snowfall records lacking, the researchers had to find other records that would allow them to determine historical levels of snowfall. They decided to study tree rings. Tree rings, also called growth rings, are the concentric circles that you see if you look at the cross sections of trees. The patterns can be used to determine how much wood a tree produced during a growing season. In the new study, Pederson and his colleagues reasoned that since trees rely on water to grow, tree rings for years when there was less water should be thinner than for years when water was plentiful. "We built a system to observe our changing environment during the period it's been changing rapidly," Pederson told the *New York Times*. [See Tree Rings Write Europe's Past, February 2011].

Matt Cardy/Getty Images

Tree rings are the concentric circles that you see if you look at the cross sections of trees. The patterns can be used to determine how much wood a tree produced during a growing season. ABOVE: The clearly defined growth rings on the stump of a subalpine larch tree.

The team gathered 66 tree ring records from the Columbia, Colorado and Missouri River regions. They used records from ponderosa pine and Douglas fir trees, which thrive at lower elevations and in years with heavy snowfalls. To track snowfall at higher elevations, they examined rings from subalpine larch, mountain hemlock and subalpine fir trees — species that grow more slowly during periods of snowfall.

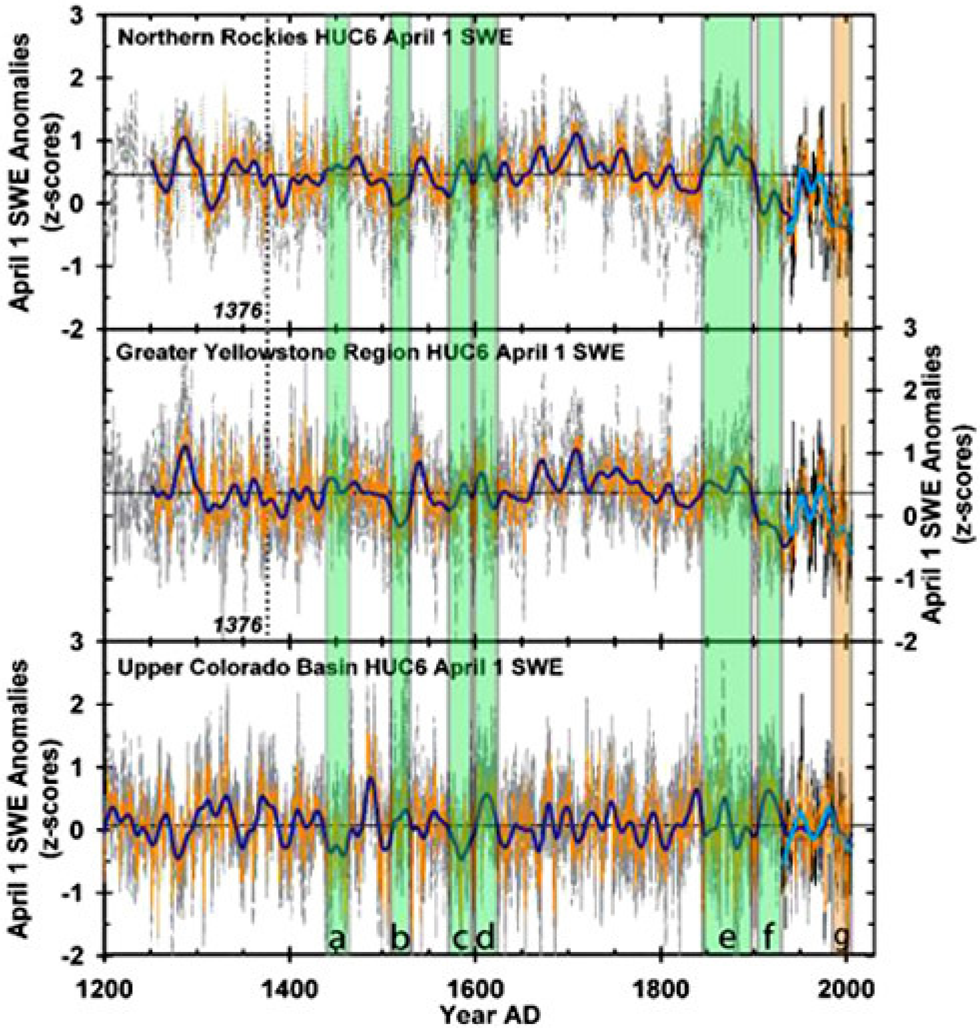
Left: Mary Clay/Taxi/Getty Images; Right: Rob Casey/Brand X Pictures/Getty Images

The research team gathered 66 tree ring records from the Columbia, Colorado and Missouri River regions. Among the trees for which they gathered records were ponderosa pine (left) and Douglas fir (right).

To ensure that the tree ring records were accurate, Pederson and his team compared the snowpack results derived from them to actual measurements taken as far back as the 1950s. The two sets of snowpack data (tree ring records and the historical measurements) not only matched, but looked like "photocopies" of one another, Pederson said. This gave the researchers confidence that the tree ring records were an accurate indicator of snowpack melt in the Rockies.

A Seesaw Effect

The data indicates that from A.D. 1200 to the 1980s, when snowpack was low in the Northern Rockies, it was high in the Southern Rockies, and vice versa. But since the 1980s, this seesaw effect has ceased, and average springtime snowpack in both regions has shrunk drastically. The team speculates that warmer springs — caused by a combination of rising greenhouse gas levels in the atmosphere and natural climate variations — are responsible for the leveling-out effect. Higher temperatures means that less snow and more rain will fall on the mountain range. Rain can't form into snowpacks, which can stick around for long periods of time and help to sustain the rivers that depend on water from the Rockies even in warm dry months.



The data indicates that from 1200 to the 1980s, when snowpack was low in the Northern Rockies, it was high in the Southern Rockies, and vice versa. But since the 1980s, this seesaw effect has ceased, and average springtime snowpack in both regions has shrunk drastically. ABOVE: Graphs of the individual watershed reconstructions (gray) by region and latitude, and regional averages calculated from each individual reconstruction (orange and dark blue). The 20th-century records are plotted for each region (black and cyan) and the shaded columns show mapped intervals: (a) 1440-70, (b) 1511-30, (c) 1565-1600, (d) 1601-20, (e) 1845-95, (f) 1902-32, (g) 1980-2006.

Higher temperatures also means that when snow does fall in the Rockies, it doesn't stick around as long. "After we get the delivery of snow, we're oftentimes seeing warmer air masses coming in afterward," Pederson told NPR. "So even if it's dropped as snow, everything's warmer, so it tends to melt faster once the snow is delivered."

This Time It's Different

Using the tree ring data, Pederson and his colleagues also found evidence that a similar leveling-out effect occurred during the 14th and 15th centuries. However, in those cases, the warmer temperatures were followed by periods of cooling. "Now, alas, we don't expect to return to a cooler period," Pederson told the *New York Times*.

Philip Mote, an atmospheric scientist at Oregon State University who was not involved in the study, agreed. "The recent changes in snowpack are unusual both in duration and in geographic extent, and they are outside the envelope of what can be considered natural changes," Mote told *ScienceNow*.

The ramifications of the disappearing snowpack could extend far beyond disappearing ski slopes. Scientists estimate that between 60 and 80 percent of the water that 70 million Americans in the western United States depend on comes from snowmelt in the Rockies.

ScienceNation/NSF

Tree-ring dating, or dendrochronology, provides a snapshot of climate change over time. Trees encode fires, droughts and floods into their growth rings. Like fingerprints, tree rings offer a window into the past.

"We're going to have to start looking at how we're going to get through potentially warmer and drier summers of the future, without that free bank account of snowpack," Pederson told NPR.

Gregory Pederson: Planning Healthy Ecosystems

Gregory Pederson is an ecologist at the U.S. Geological Survey's Northern Rocky Mountain Science Center (Norock) in Bozeman, Montana. Shortly before joining Norock in 2004, Pederson received his master's degree in environmental science from Montana State University. Four years earlier, he had earned his undergraduate degree from Michigan State University. In 2010, Pederson completed his Ph.D. in watershed management and ecohydrology from the University of Arizona.

Pederson's scientific expertise covers paleoclimatology, dendroclimatology, dendroglaciology and dentrogeomorphology. His research focuses on "understanding ecosystems and predicting ecosystem change." This includes "climate variability and its role in driving biological and physical components of mountainous ecosystems of western North America." In particular, he "uses instrumental and tree-ring based records of climate to assess the time intervals and spatial scales over which these processes operate." His recent research has "addressed the susceptibility of natural resources within national parks and protected areas to climate variability and change."

Below are Pederson's June 30, 2011 responses to questions posed to him by Today's Science.

Courtesy of Gregory Pederson

"With global population expected to hit 9 billion by 2050, we have to start planning now for how society will maintain water and food for so many, while maintaining healthy ecosystems and a large diversity of species."

Q. When did you realize you wanted to become a scientist?

A. I've always enjoyed science, especially the physical and biological sciences. My interest was piqued throughout my youth by my grandfather, uncle and father, who were all scientists, and by my mother, who was a teacher. My grandfather was an entomologist, my uncle is a biologist, and my dad is a retired biochemist. Through their life experiences, and my time in the outdoors with all of them, I learned a great deal about each of their scientific fields and slowly developed my own interests. But, for a number of reasons, I didn't actually realize I was interested in becoming a scientist until after my second year in college. First, for most of my life, various educators and guidance counselors would often agree with me that the sciences are interesting, but usually follow that statement with information about how hard it was to get a job in the field, and that one shouldn't pin their hopes on having a career in the sciences. Second, at that stage of my life I was also more interested in hiking, biking, and kayaking, so admittedly my focus on school was not what it needed to be to pursue a career in the sciences. So, at that point, having quit worrying about whether or not I would have a job in the sciences, I decided to focus on studying something I was truly interested in and declared a major in the sciences. Then I started applying and volunteering for all the field and laboratory jobs I could find. Since I wasn't sure of my interests, I spent time working in chemistry labs, in field ecology positions (agricultural experiments, and Oak Savannah ecology), and in evolutionary biology (evolutionary consequences of pollinator selection preferences on two hybridizing alpine plant species). To find what you're interested in, experiencing many different fields is critical.

Q. How did you choose your field?

A. I see it more as my field of study having chosen me. I ended up working in the area of snow, ice, water, climate, and biological interactions because I had enough prior experience within other fields to know that I wasn't interested in continuing to do them. It's hard to say which is more important, but in some respects I've always felt knowing what I didn't want to do was perhaps more important than ever really knowing what I wanted to do. So, I've always remained open-minded, have always kept my options open, and have always been willing to move and travel to gain new experiences.

Q. Are there particular scientists, whether you know them in person or not, that you find inspiring?

A. Yes, I find many scientists from a variety of fields very inspiring. From solar physicists to geologists, one of the fun things about working in the sciences is tracking developments in other fields, and then meeting and interacting with such a broad array of incredibly intelligent people. It's not only inspiring, it's very humbling, and I feel quite fortunate to be able to discuss the issues of the day with so many accomplished people who have a diversity of skill sets and perspectives on the world.

Q. What do you think is the biggest misconception about your profession

A. Is this a trick question? At present there are so many misconceptions about my profession among the general public that I'm not sure which I could label the biggest. So, I find it most important to just keep doing the best research one can do and ignore the misconceptions. Societal perspectives always lag behind the sciences, so misconceptions are par for the course.

Q. If the total precipitation remains constant, but more of it comes in the form of rain than snow, that presumably would affect snowpack levels, but would it also have implications for water availability for people in the regions of the Columbia, Colorado and Missouri Rivers?

A. In short, yes. The form of precipitation is important because snow acts as free water storage. Snow holds a large amount of water high in the mountains, and it generally slowly releases it to streams, rivers and lakes as we enter the warm dry summers — which are normal for the Western U.S. So, as snow melts out earlier, that leaves water managers with a longer span of time to provide water for agricultural irrigation, hydroelectric generation, fisheries and aquatic ecosystems, and growing urban areas.

Q. Are low snowpack levels correlated with droughts?

A. Yes, they often are, but what happens with spring and summer precipitation can make a large difference by either ameliorating or exacerbating potential drought conditions set up by a low winter snowpack.

Q. Are there any other methods besides tree rings people have used to try to reconstruct snowpack levels for eras before records were kept?

A. Yes, lake sediment records have been used in several cases. Specifically, the delta O18 isotope stored in accumulated calcium carbonate contains information on the form of precipitation (rain or snow). But no other single study has looked at such a broad area with as much proxy data as we have in our research article

Q. Are there features of the Rockies that would make their snowpack level changes different from those of other mountain ranges, or do you suspect that there has been a similar decline in snowpack levels for other mountains around the world over the past 30 years?

Jeremy Littell/University of Washington

"One of the largest differences between mountain ranges is their latitude, and the average elevation at which most of the snowmass exists."

A. There are features of the Rockies that make them different from other mountain ranges. One of the largest differences between mountain ranges is their latitude, and the average elevation at which most of the snowmass exists. How close the snowpack resides to the 0 degree Celsius melt point during the critical snow accumulation months makes the snowpack more or less sensitive to seemingly small changes in temperature. So, in general, I'm sure this is happening in many other mountain ranges, but not necessarily all of them.

Q. Besides national or international initiatives to control global warming, are there any regional or state-level *steps that could be taken to try to address the issue of declining snowpacks and their presumed impact on water supplies?*

A. Sure, there are many ways in which water supplies can be augmented. Some options include rainwater capture and storage, utilization of graywater [wastewater generated from domestic activities such as laundry, dishwashing and bathing which can be recycled on-site], construction of new dams, more efficient agricultural irrigation, etc.

Q. Where do you spend most of your workday?

A. Well, recently I've spent most of my workdays in the office analyzing data and writing more articles on the results. In a typical year, though, I spend roughly 30% of my time working in the field collecting data, and traveling to conferences to exchange ideas with other scientists. I find this to be a very nice balance between being stuck in an office thinking and writing, and being out in the field thinking and collecting data.

Q. Who are the people you work with?

A. I work with a wonderfully diverse group of people. See our website for more information: www.nrmsc.usgs.gov/.

Q.What do you find most rewarding about your job?

A. The most rewarding thing about my job is the time it gives me to think about physical and biological problems and processes, spend time in the field investigating those questions, and then (most important of all) coming up with new insights into the world when analyzing all the data.

Q.What do you find most challenging about your job?

A. All of the administrative paperwork it entails, and the increasing difficulty in obtaining resources to continue research projects. I imagine scientists have been complaining about this since the dawn of science.

Q. What has been the most exciting development in your field in the last 20 years? What do you think will be the most exciting development in your field in the next 20 years?

A. There have been so many it's hard to pinpoint just one. I'd say, in both my field and many others, the increasing ability to instrument large areas with environmental sensors, and then analyze immense amount of data rapidly on computers; this has led to so many new and exciting discoveries. It's hard to say where my field will be in the next 20 years. If developments are as rapid as they've been over the last 20 years, we will certainly reach an entirely different level of understanding, and much of what we think we know now may look silly. That of course depends on more motivated and intelligent young people getting interested in and pursuing careers in the sciences.

Q. How does the research in your field affect our daily lives?

A. Well, hopefully, people gain a better understanding of how the climate and natural resources around them have changed over time, and what the expectations for change are for the future. With global population expected to hit 9 billion by 2050, we have to start planning now for how society will maintain water and food for so many, while maintaining healthy ecosystems and a large diversity of species.

Q. For young people interested in pursuing a career in science, what are some helpful things to do in school? What are some helpful things to do outside of school?

A. While in school, take as many math, chemistry, physics, and biology classes as possible. Learn how to think critically about issues, and most importantly learn how to write well. Developing understanding across those fields provides the tools needed to understand so many of today's societal challenges, no matter which specific field of science you decide to specialize in. Math and statistics give you the ability to work with and analyze data (a critical aspect of science, and what separates it from all other forms of information), whereas developing good writing skills will help you communicate your findings. I'd say the most difficult thing I face every day in my job is how to write something so the majority of people (including those in other scientific disciplines, and, more importantly, nonscientists) will understand our major findings. This is critical, and it's important to remember, there's no such thing as good writing, just good rewriting. The article featured here went through so many drafts, revisions and reworkings that I lost count. Major input from my coauthors and advice taken from five different reviewers made the article even better, though.

Outside of school, I can't stress enough that you explore the world around you, volunteer for different work experiences, and remain open-minded about work/research/travel opportunities as they present themselves. Also, if you want to try something, be persistent and willing to volunteer or start at a lower level than you had hoped for. This will provide experience and insight into what it's like to work in different professions.

Remember, it's probably more important for you to learn what you're interested in and what you're not, rather than knowing exactly what you want to do in the future. Life has a funny way of unfolding, and that has derailed many of the best-laid plans. If you're watching carefully enough, often better plans than you could have imagined eventually present themselves. I'm still watching for and working on what I want to do NEXT . . .

Discussion Questions

What other methods might be used to reconstruct past snowpacks? Do you think the method used here would distinguish between years with heavy snowfall and years with heavy precipitation that was not necessarily snowfall? Are there possible alternative explanations — besides global warming — that might explain reduced snowpacks in the Rockies in recent decades? How would you explore this question?

Journal Abstracts and Articles

"The Unusual Nature of Recent Snowpack Declines in the North American Cordillera." www.sciencemag.org/ content/ early/ 2011/ 06/ 08/ science.1201570.

Bibliography

Pederson, G.T., et al. "The Unusual Nature of Recent Snowpack Declines in the North American Cordillera." *Science* (June 9, 2011) [accessed June 26, 2011]: www.sciencemag.org/ content/ early/ 2011/ 06/ 08/ science.1201570.

Perkins, Sid. "Drying Rockies Could Bring More Water Woes to Western U.S." *Science* (June 9, 2011) [accessed June 26, 2011]: news.sciencemag.org/sciencenow/ 2011/ 06/ drying - rockies - could - bring - more -.html.

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Rocky Mountains, tree rings, drought, water shortage, snowmelt, snow, rain, global warming, climate change, Gregory Pederson