# Climate cycles and change

**Dr. David Sauchyn**

Dr. Sauchyn is the Senior Research Scientist at the Prairie Adaptation Research Collaborative (PARC). His main research interest is in the climate of the past millennium in Canada's western interior and what past climate can tell us about the climate to expect in the near future.

The Reno Welch family ranches at the southern end of the Porcupine Hills. It's a typical scenic southwestern Alberta ranch; rolling hills of fescue prairie with Douglas Fir forest at the higher elevations. In September 2012 I asked Reno for his permission to collect some small samples of old Douglas Fir for a study of climate variability. He responded in the same way as all the farmers and ranchers we ask; he was happy to help and invited us up to the house for coffee and conversation, mostly about weather and climate. Reno told us that we probably wouldn't find very old trees, because he once had a sawmill. Then he said:

*"I found looking at the tree-ring growth, that there's an approximate 60-year weather cycle in this country, but 60 years isn't definite, it could be 70 years and it could be even less, with weather there's nothing written in stone."*

Over the past 25 years, my students and I have collected about 8000 samples of old wood from nearly 200 locations in Alberta and Saskatchewan, and the nearby regions of Manitoba, Montana, North Dakota, and the NWT. We've sanded and polished each piece of wood to highlight the annual rings. Below is an image of a cross section from an old Douglas fir (it was dead; from the living trees, we take a small

Cross section from an old Douglas fir.

*Photo courtesy of David Sauchyn*

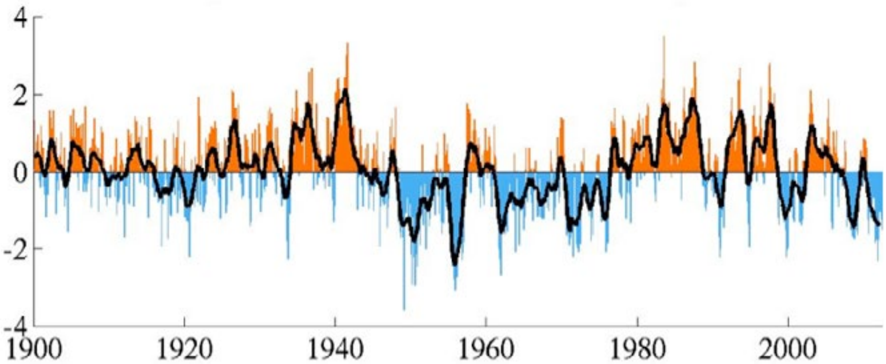


Figure 1 – Annual index of the Pacific Decadal Oscillation

diameter core, less than the size of a pencil). Using image-analysis software, we measure the width of each tree ring to within 0.001 mm.

From the statistical analysis of the ring-width data from thousands of wood samples, spanning the past 1000 years, we found the same 60-year cycle that Reno observed. However, as scientists we can't stop with an observation; we have to explain it – that's how we earn our keep. To understand these long cycles you have to look to the west, where our weather comes from, and to the Pacific Ocean, the source of nearly all of our water. The ocean currents and sea surface temperatures have a strong influence on our weather and climate.

The best example of this strong ocean influence is the circulation of the surface waters and overlying air in the tropical Pacific Ocean, the so-called El Niño Southern Oscillation. ENSO has two extreme phases, known as El Niño and La Niña, when the water off the coast of South America is unusually warm and cold, respectively. The balmy winter we just had was mostly the result of a strong El Niño. The excessive moisture and flooding of 2010-11 occurred during a La Niña. This link, or so called teleconnection, between sea surface temperatures near the equator and the climate of western Canada, explains much of the year-to-year variation in our weather; but what explains the longer cycle? As is turns out, it's also the circulation of the Pacific Ocean.

In the mid 1990s, scientists from the University of Washington noticed a long-term fluctuation in Pacific Ocean salmon stocks. When they compared data on fish populations to sea surface temperatures measured over the 20th century, they found a strong correlation. In a paper published in 1997, Nathan Manuta described a cycle in surface water temperature in the northern part of the Pacific Ocean. He called it the Pacific Decadal Oscillation or PDO. Hundreds of studies since then have documented the strong teleconnections between the PDO and the weather of western North America (and South America as well). Figure 1 is a graph of the annual index of the PDO since 1900. Notice how it tends to remain either positive or negative for about 25-30 years, so that a full cycle consisting of the two phases is about 50-60 years.

In the 1920s to early 1940s, the PDO was mostly positive and dry conditions dominated prairie weather. The PDO flipped in the late 1940s and was mostly negative until the mid the 1970s. If you lived through these decades, you might remember many more wet years than dry. The droughts of the 80s occurred in a phase of negative PDO and then, with another phase shift about 8 years ago, we've had much more excess water then deficits.

Knowledge of this decadal cycle in our weather is useful for several reasons. Students in science and engineering are taught that dry and wet weather events are 'independently and identically' distributed. Translated to plain English, this means that we assume that every event has the same likelihood of occurring and thus the frequency of droughts and flood remains more or less constant. This 'iid' assumption very much simplifies

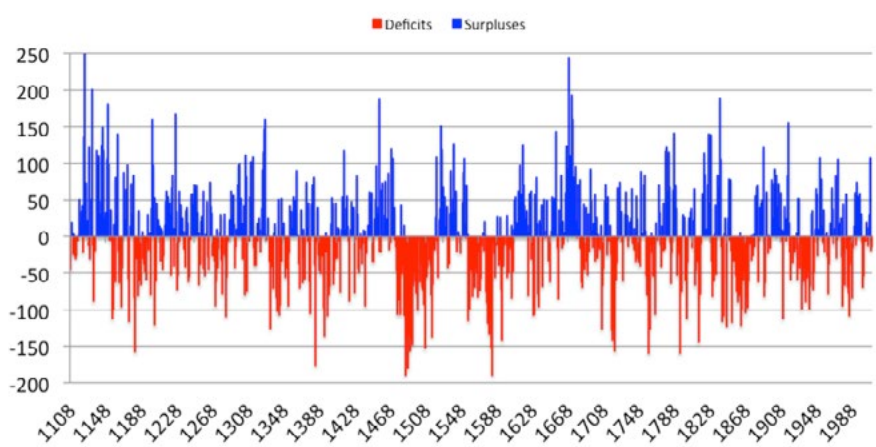


Figure 2 – 900-year record of water levels in the South Saskatchewan River Basin

the analysis of weather and water data, but we now know that it's not valid – excess water is much more likely during a La Niña and negative PDO, and drought is much more likely in an El Niño year and with a positive PDO. The prominent and provocative Canadian hydrologist Vit Klemes anticipated this violation of the 'iid' assumption back in the 1980s. He said

*"Despite preaching about the importance of long records, hydrologists are in fact more comfortable with short ones."*

Dr. Klemes was referring to long water level records, which by the 1980s were beginning to exceed 60 years. These records, from gauges installed in the 1910s, are now longer than 100 years and show the effects of a full PDO cycle. To get an even longer view of climatic variability, in our Tree-Ring Lab at the University of Regina, we've produced the a 900-year record of water levels in the South Saskatchewan River Basin (figure 2).



Note how surpluses and deficits of water tend to last for decades. There are periods of consistently low water levels that lasted more than 30 years – a reoccurrence of one of these 'megadroughts' would be catastrophic, especially in our warming climate. The interaction of natural cycles and global warming is a hot topic of scientific research. There is much debate about the recent hiatus in global warming, a slowing of the rise in global air temperatures over the past 10-15 years. Scientists have various hypothesis, but the strong consensus is that the natural causes of climate variability, and especially the circulation of the oceans, can speed up or slow down the rise in global air temperature, depending on the phase of the ENSO, PDO and other ocean-atmosphere oscillations. As a result, there are times, like the 1990s, when the rate of global warming was faster than we would expect based just on emissions of greenhouse gases (the major human cause of climate change), and there are times like the 2000s when global warming was offset but the cooling affect of natural processes. We can expect that the current 'hiatus' will be followed by a future episode of accelerated global warming. In fact, it may have just begun; 2015, and the first nine months of 2016, have had the highest global average temperatures ever recorded by weather instruments.

So here's the take home message – anthropogenic global warming has been superimposed on the natural variability of the earth's climate system. To anticipate weather trends and extreme events like floods and drought, and adapt to minimize the adverse consequences, we have to understand the natural cycles and how they interact with our human interventions in the global climate system. But as greenhouse gas concentrations continue to rise well beyond pre-industrial levels, trapping heat and fertilizing plants, at some point the distinction between natural and human causes will be hard to make. Consider that 1) the variation in our weather can be explained largely in terms of surface water temperatures in the Pacific Ocean, and 2) the oceans are rapidly warming, because water has a large capacity to store heat and ¾ of the earth is ocean. Most of the global warming of the past several decades has been of the oceans, not the atmosphere. If our weather is tied strongly to the state of the Pacific Ocean and we are heating it up, then at what point are El Niño, La Niña and the PDO no longer natural drivers of weather and climate? This might seem like an academic question, but think of it this way – the impacts of global warming in western Canada will depend largely on the future of El Niño, La Niña and the PDO, and we have begun to alter these determinants of our weather and climate. FFT