Inflow variability in the Murray & Murrumbidgee rivers

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- Analysis of dust from core samples of peat bogs in the Snowy Mountains has revealed series of wet-dry cycles over the past 6,500 years.
- The wet-dry cycles can be related to a climate influencing phenomena called the Pacific Decadal Oscillation which has strong influences on the magnitude of El Niño and La Niña, giving a clearer understanding of the potential for medium-term weather forecasts.
- Further study, associating the chemistry of lake sediment with particular types of weather events, may provide data for longer-term forecasting.

Detailed records of river flows in Australia did not commence until well after European settlement of the continent. As a result, these records rarely span more than 100 years, and seldom contain evidence of medium- to long-term climate variability. This presents significant challenges for the management of water resources.

The capacity to forecast likely future inflows into major rivers and storages with reasonable certainty is severely limited by our lack of knowledge and understanding of what the "normal" range of conditions is over the longer term.

Over the past four years, Snowy Hydro Limited scientists and researchers from The University of Queensland have been investigating the underlying relationships between atmospheric and ocean conditions and the droughts that have impacted the Murray and Murrumbidgee river systems.

The objectives of the research were to improve understanding of the causes of extreme drought sequences, such as those that occurred in the 1930s when the Snowy Mountains Hydro-electric Scheme was designed, and the more recent millennium drought which severely impacted south eastern Australia for almost a decade (2000–2008).

Developing a drought record

Severe drought in Australia is not random – it is heavily influenced by cyclic climate patterns.

The El Niño-Southern Oscillation (ENSO) pattern has attracted the most attention in recent years. ENSO has been shown to explain up to 40% of seasonal rainfall variability, and under El Niño conditions the mean rainfall over the headwaters of the Murray River occurs in the 30–40% of the driest years.

El Niño conditions typically occur every 3 to 7 years. Impacts are often relatively short lived, generally spanning several months to slightly more than one year before a return to more normal conditions. These events can usually be forecast 9 to 12 months in advance with reasonable confidence, and water supply infrastructure can usually be designed and managed appropriately to satisfy demands during single events. However, low inflows during prolonged drought or drought sequences that span several years to more than a decade, present a greater challenge to water resource managers, and are influenced by factors other than ENSO.

These longer-term extreme drought events are under-represented in historical rainfall and streamflow records. As a result, very little research has been conducted into their causes and reoccurrence, and reliable prediction of these types of events is currently not possible.

In other countries, researchers have been able to reconstruct longer-term climate records using surrogates for rainfall or streamflow such as tree rings, cactus spikes or other indicators of climate. These indicators are called proxies, and can be used to determine climate in the distant past, well before records were kept.

Unfortunately, drought events in south eastern Australia are not well recorded in natural archives such as tree rings. While pollen collected from peat or sediment cores may record changes in vegetation communities due to rainfall variability, these records can only be resolved at timescales of hundreds or thousands of years with reasonable confidence, and are of little use in reconstructing a meaningful drought history.

Detailed information about the El Niño-Southern Oscillation can be found at the Bureau of Meteorology website.

Go to: **www.bom.gov.au**

Or type into your browser:

www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.shtml?bookmark=enso

Windblown history

Dust deposits, however, offer a proxy for drought in Australia because our landscape responds quickly to rainfall variability. Drought in the Murray-Darling Basin is synonymous with blowing dust and dust storms. Dust from the Basin is transported in an easterly direction, and some is deposited in peat swamps in the headwater catchments of the Murray and Murrumbidgee rivers.

This dust can be extracted by taking core samples from the peat swamps. The research team has developed special geochemical fingerprinting techniques to identify the source of the dust, and the information recovered from this archive has been used to construct a 6,500-year drought history for the Murray-Darling Basin. This research identified a number of multi-decadal wet-dry cycles over this period, with a 30- to 40-year cycle found to be the most dominant.

An examination of the much shorter inflow records for the Snowy Mountains Hydro-electric Scheme was found to show a similar cycle.

Linking drought to climate patterns

As described earlier, the 3–7 year ENSO cycles have an important short-term influence on climate, but there are other important atmospheric and ocean cycles which have a significant impact. The Pacific Decadal Oscillation (PDO) is one of these climate phenomena. The PDO has positive and negative phases at timescales of 30–40 years, and has been found to intensify or suppress the effects of ENSO, depending on the phase of each of the phenomena involved.

Simply put:

- Positive phases of the PDO have a strong tendency to exacerbate the impacts of El Niño (i.e. conditions tend to be drier), and suppress the effects of the La Niña. The risk of severe drought is significantly higher toward the end of the positive PDO phase (as were the conditions during the recent millennium drought of 2000–2008).
- Negative phases of the PDO tend to suppress the impacts of El Niño, and increase the effects of La Niña (i.e. conditions tend to be wetter). The PDO commenced moving to the negative phase in 2008, and is currently enhancing the effects of La Niña in south eastern Australia, with apparent effects of significant rain since November 2010.

Using the relationship found between wet and dry climate cycles found in the peat cores and the cycles of the PDO, the research team modeled inflows (10-year running averages) to the headwater catchments of the Murray River back to 1474 AD, using a historical record of the PDO from eastern China (a region also significantly affected by the PDO cycle). To verify the performance of the model (in other words, how reliable are these predictions?), the modeled inflows were compared with the actual inflows for the period 1904 to 1994. The predictions for this period were found to be accurate to within approximately 5%.

The inverse relationship between the PDO and modeled inflows can be seen in Figure 1. From this we see when the PDO phase is negative Scheme inflows tend to be greater. When the PDO phase is positive, inflows tend to be lower. We note however that this relationship deteriorated around the turn of this century (not shown on the graph), when Scheme inflows of 684 GL in 2006 were the lowest in the previous 526 years. This highlights the severity of the millennium drought, suggesting it was at least a 1:500 year drought sequence. The cause of the breakdown is currently unknown; however the relationship between the PDO and Scheme inflows now appears to have re-established, with the change in the PDO to a negative phase in 2008 being associated with an increase in Scheme inflows.

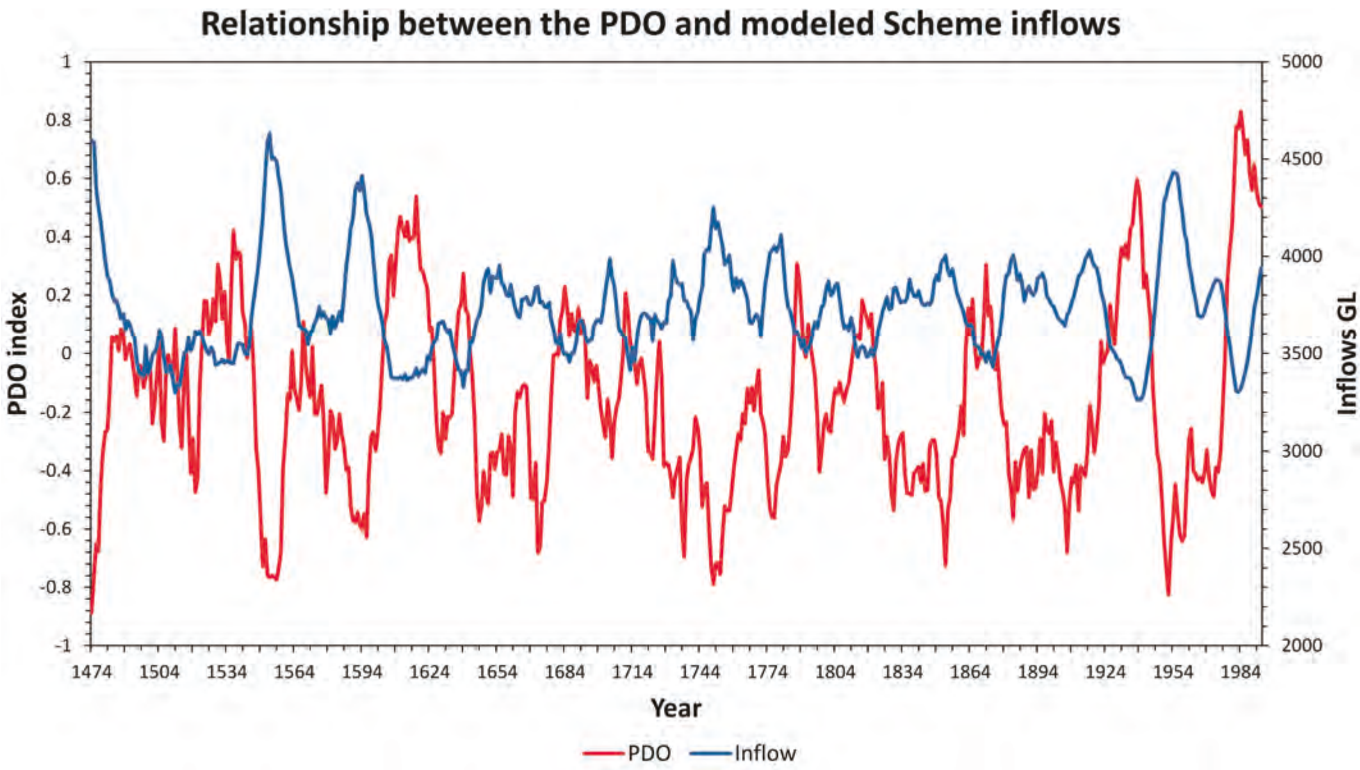

Figure 1. Modelled inflows to the Snowy Mountains Hydro-Electric Scheme and the PDO index (10-year running mean values). Note how the inflow record is almost the mirror of the PDO record, so when the PDO is negative inflows increase and vice versa.

Based on the findings of this research, it is likely that the climate regime of southern and eastern Australia will experience less severe drought events over the next two to three decades as a result of La Niña events being enhanced, and El Niño events being suppressed by the current negative phase of the PDO. Recent climate modeling studies tend to support this assessment however it is not possible to completely discount future breakdown of this relationship due to global warning and/or other climate variability.

Although this research study did not explicitly investigate the potential impacts of human activity on climate, the considerable advances in understanding medium-term climate variability in the headwater catchments of the Scheme have laid the foundations necessary for future research.

Inflow forecasting

The research team will now attempt to develop an inflow forecasting capability at shorter timeframes.

This will require the reconstruction of historical weather patterns associated with various phases of key climate cycles such as ENSO and the Pacific Decadal Oscillation over several thousand years. This presents a significant research challenge, as the period of climate record required predates any national or international weather observation records.

Initially, the focus will be on the development of a hydroclimate record using a technique called *isotopic inflow partitioning.*

To explain further, rain or snow which falls to the Snowy Mountains and headwaters of the Murray and Murrumbidgee rivers carries with it an isotopic signature (unique chemistry that can be traced in biological systems) that is specific to the meteorological history of the rain or snow bearing weather system.

Preliminary sampling of specific types of weather systems that caused snow and rainfall during 2010 confirmed that the oxygen isotope ratios were characteristically different for these different types of weather systems.

Using these characteristics, methods will be developed to enable precipitation and run-off over the mountains to be attributed to particular types of events, for example a cold front from a northwest cloud band.

The isotopic signature of the precipitation is initially preserved in the snowpack until the snow melts. Melt water carries this signature into the streams and lakes of the Scheme, where microscopic fauna known as diatoms incorporate the isotopic signature into their shells. Diatoms are short-lived creatures, and thus the shells of diatoms gradually accumulate in the sediments of the alpine lakes. Over time this has created an extensive archive of the weather systems that caused precipitation in the catchment.

To recover information from this archive, the research team will extract sediment cores from these lakes. The cores will be then be dated, and the diatoms extracted from the sediments. Oxygen isotope analysis of diatom shells will then allow the team to determine the dominant weather patterns, and their variability over the period of the record in response to different climate cycles.

Longer records for decision making

Research efforts will then be directed to the development of a model to predict precipitation trends of rain and snowfall for the catchments of the Scheme, and the impacts on the related hydrology.

Essentially, we are seeking to answer the question *"are the climate related changes in inflows to the Murray River system due to anthropogenic global warming or natural cyclical climate variability, or a combination of both, and if so how significant is each one?"*

The recent release of the *Guide to the proposed Murray–Darling Basin Plan* highlights the current shortfalls in balancing socio-economic drivers and environmental needs of the system. If droughts and periods of above-average rainfall can be predicted with higher confidence, early and informed decisions can be made in a more open and transparent manner. The reform of water allocation in the Murray-Darling Basin would also benefit from a longer hydro-climate context on which to base decisions.

Further information

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Collecting a peat core from an alpine bog site in the upper Snowy River catchment. Dust extracted from the cores is analysed to determine wet-dry cycles over time. Inset: Close-up of a core sample.

Prof. Hamish McGowan and Dr. Nikolaus Callow collecting snow samples for oxygen isotope analysis