CLIMATE SCIENCE

Tree rings and storm tracks

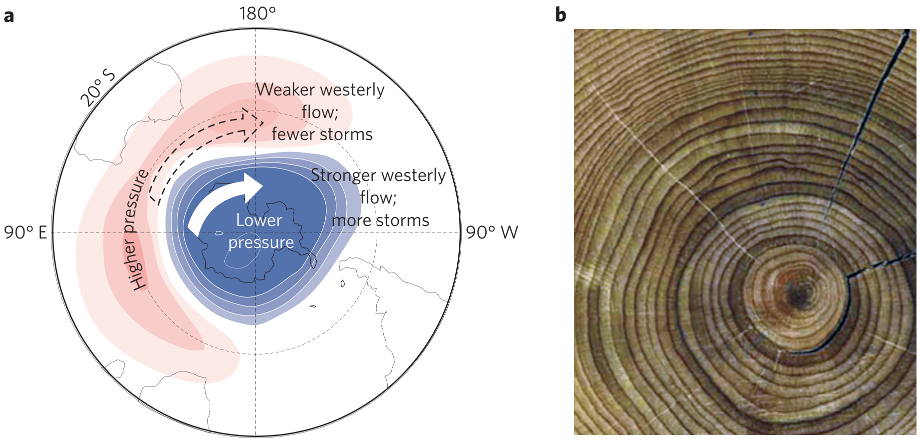
Reconstructing past climate in the Southern Hemisphere is a challenge. An analysis of tree-ring records suggests that recent changes in the southern storm track in summer are unprecedented in the past 600 years.

Julie Jones

The influence of the Antarctic ozone hole on surface levels of ultraviolet radiation is well known, particularly to sunbathers in the Southern Hemisphere. Less well known is its role in moving the southern storm track towards the South Pole in summer[1,2]. This large-scale movement of air flow and weather systems has altered surface temperature, precipitation and winds at both mid and high latitudes[3]. As such, it is important to understand how the recovery of Antarctic ozone levels will influence the storm track, and thus surface climate[3]. It is expected that the recovery of the ozone hole and increasing greenhouse gas concentrations will exert strong and opposing influences in the coming decades, with ozone recovery shifting the track towards the Equator, and rising greenhouse gas concentrations shifting it towards the South Pole[3]. Writing in *Nature Geoscience*, Villalba and colleagues[4] show that changes in the Southern Hemisphere storm track in the latter half of the twentieth century significantly modified tree growth, with consequences for climate reconstruction in the region.

Differences in atmospheric pressure between the mid and high latitudes of the Southern Hemisphere are captured by a mode of climate variability known as the Southern Annular Mode (SAM). In the past four decades or so, atmospheric pressure has declined over the South Pole and risen over the mid-latitudes. As a result, the circumpolar westerly winds and the storm track have strengthened. These changes — collectively known as the positive phase of the SAM — have led, for example, to cooling in East Antarctica, and strong warming in parts of the Antarctic Peninsula[3,5]. The latter is thought to have contributed to the collapse of the Larsen B ice shelf in 2002[5].

Records of past changes in the SAM are needed to validate the climate and chemistry-climate models used to project future changes in this mode of climate variability. To date, however, observation-based assessments of SAM behaviour have been restricted to the period of time since 1957, when regular measurements in Antarctica began. These records show a trend towards the positive phase of the SAM since the mid-1960s[5]. Extended reconstructions of the SAM are needed to provide a longer-term perspective.



RICARDO VILLALBA

Figure 1 | Positive phase of the Southern Annular Mode. **a**, Differences in atmospheric pressure between the mid and high latitudes of the Southern Hemisphere are captured by a mode of climate variability known as the Southern Annular Mode. The positive phase of this mode, documented here, is characterized by an increase in atmospheric pressure over the mid-latitudes (pink) and a decline in pressure at high latitudes (blue). This pressure difference leads to a strengthening of the circumpolar westerly winds (white arrow) and a southward movement of the Southern Hemisphere storm track. **b**, Villalba and colleagues[4] use tree-ring records to reconstruct changes in the Southern Annual Mode over the past six centuries, and show that it was more positive at the end of the twentieth century than at any other point over this 600-year period.

Villalba and colleagues[4] investigate the influence of ozone-hole-induced changes in the SAM on tree growth over the past few centuries, using tree-ring width data from more than 3,000 trees from Patagonia, New Zealand and Tasmania. They detect a significant shift in tree growth patterns since the 1950s, relative to the previous 250 years, and create regional tree growth records to assess the climatic factors responsible for this shift. According to this approach, the reduction in tree growth in northwestern Patagonia is related to a reduction in summer runoff, and the rise in growth in New Zealand is related to regional warming. These climatic changes, in turn, can be explained by a shift to a more positive phase of the SAM: the higher pressures and weaker westerly winds in the mid-latitudes that accompany the positive phase of the SAM bring fewer moist Pacific air masses, and thus less precipitation, to northwestern Patagonia, and more warm air masses to much of New Zealand[3].

Further exploration of the relationship between tree growth and the SAM, using regression techniques, suggests that variations in SAM behaviour can explain up to 33% and 48% of the variation in tree growth in New Zealand and South America, respectively. On the basis of this relationship, Villalba *et al.* use these tree-ring records to reconstruct changes in the SAM. Their reconstruction extends over the past 600 years, and represents the longest proxy-based record of SAM variability with annual temporal resolution to date. Even when errors are taken into account, the reconstruction suggests that the SAM was more positive at the end of the twentieth century than at any other time over this 600-year period.

This tree-ring-based reconstruction of the SAM supports the results of model simulations and shorter measurement-based records, which also suggest that current values are outside the range of natural variability[6]. Furthermore, Villalba and colleagues demonstrate significant agreement between their reconstructions during the twentieth century and existing ones, giving confidence in their estimates.

Key strengths of their reconstruction of the SAM include the reliance on a large and up-to-date network of trees, the careful analysis of the relationship between tree growth and regional climate, and the production of sound error estimates. The scarcity of tree records extending back to AD 1400 does mean that the earliest parts of the record are based on fewer trees. And as with all reconstructions that rely on relationships between large-scale circulation, local climate and proxies, the assumption is made that these relationships do not change with time. This is difficult to test — if the long time series were available, we would not need reconstructions in the first place. However, it has been suggested that links between SAM and local climate can change through time in some regions[7,8]. This is a particular issue for the Antarctic Peninsula region[7], where the tropical Pacific Ocean modulates the SAM–climate signal, with implications for reconstructions of the SAM reliant on ice-core isotope data from the region.

Villalba and colleagues[4] utilize tree growth signals to show that changes in the summer SAM in the latter half of the twentieth century are unprecedented in the past 600 years. The vast areas of ocean and the inhospitality of Antarctica make reconstructing climate in the Southern Hemisphere a challenging yet fascinating task. Climate reconstructions using new proxy data sources, such as those presented in this study, will help to address this challenge[9]. ❑

Julie Jones is in the Department of Geography, University of Sheffield, Sheffield, S10 2TN, UK.
e-mail: julie.jones@sheffield.ac.uk

References

1. Gillett, N. P. & Thompson, D. W. J. *Science* **302,** 273–275 (2003).
2. Polvani, L. M., Waugh, D. W., Correa, C. J. P. & Son, S. W. *J. Clim.* **24,** 795–812 (2011).
3. Thompson, D. W. J. *et al. Nature Geosci.* **4,** 741–749 (2011).
4. Villalba, R. *et al. Nature Geosci.* http://dx.doi.org/10.1038/ngeo1613 (2012).
5. Marshall, G. J., Orr, A., van Lipzig, N. P. M. & King, J. C. *J. Clim.* **19,** 5388–5404 (2006).
6. Fogt, R. L. *et al. J. Clim.* **22,** 5346–5365 (2009).
7. Marshall, G. J., Di Battista, S., Naik, S. S. & Thamban, M. *Clim. Dynam.* **36,** 277–287 (2011).
8. Silvestri, G. & Vera, C. *J. Clim.* **22,** 6142–6148 (2009).
9. Neukom, R. & Gergis, J. *Holocene* **22,** 501–524 (2012).