Amazon isotope discovery should sharpen climate predictions

While studying the cycle of water in the Amazon Basin, Professor Ann Henderson-Sellers, of the Australian Nuclear Science and Technology Organisation (ANSTO), and Dr Kendal McGuffie, of the University of Technology Sydney, have developed crucial new insight into deforestation's link to water and climatic cycles, and global warming. Their findings could provide the first independent test of current Global Climate Models (GCMs).

Canoeing a tributary of the Amazon, part of the world's largest river basin. Scientists have found that its waters recycle locally and incredibly rapidly. istockphoto

The key to the research was a 'treasure trove' of baseline rainfall and water isotope measurements, fortuitously recorded around the world including in far-flung regions, such as the Amazon and the Andes mountains, as part of a United Nations program initiated to measure radioactive fallout from atomic tests during the 1950s and 1960s.

Water molecules come in three forms (or isotopes), two of which – HDO (with a deuterium atom) and $H_2{}^{18}O$ (with a different version of the oxygen atom) – occur naturally at frequencies of only about one in 500 and one in 6500 respectively, and are heavier than the normal, common H_2O isotope.

With an understanding that it is only vegetation that releases these heavier water isotopes into the atmosphere (through transpiration), while normal evaporation doesn't, the researchers were able to compare isotope readings in the earlier nuclear monitoring programme data with isotope recordings in rainfall made during 2000 and 2003 in the Amazon and Andes. This was the link. They saw that the levels of the heavy isotopes falling from the atmosphere in rain over the Andes and Amazon basin had changed significantly, and were then able to relate it to the dramatic reduction of vegetation in the Amazon Basin.

'We are very excited by the results as they not only support previous studies but this time we went further and used the isotopic signals to "fingerprint" plant transpiration, giving us extra information about the effects of land use changes' said Professor Henderson-Sellers.

'We've found that these rare isotopes provide a new and independent way of evaluating GCMs. By tracking these isotopes of water, we can diagnose the pathways and history of evaporation, of transpiration by plants and of condensation. For the first time we can distinguish between water that has been transpired by plants and that which has passed through the rest of the water cycle.'

Henderson-Sellers explains that the different heavy isotopes of water behave quite differently in the water cycle. For example, the rare isotopes of water are less likely to evaporate and are quicker to condense. The mix of isotopes will vary according to whether water has been transpired by plants or evaporated from a lake, river or ocean. This is because plants transpire heavy water through leaf pores at the same rate as everyday water while, during evaporation, the heftier isotopes of water tend to be left behind, which means the ratio or mix of isotopes changes – they fractionate.

So by looking at the ratios of the isotopes in water collected over time and space, scientists can glean information about where water comes from, for example from a lake or forest, how climate has changed, and even how deforestation affects water behaviour, weather and climate change. As the researchers told the *Bulletin*, water isotopes can be used to measure and predict groundwater recharge; monitor evapo-transpiration from plants or other elements of landscapes; gauge evaporation from open water; and determine the extent and age of groundwater flow into river systems.

Previous applications of this knowledge in the Amazon Basin revealed that the Basin actually recycles about half its water, in just five-and-a half days. Using isotope signatures as a validation tool for GCMs, the Australian team discovered that these models were not properly taking into account evaporation from open water in the Amazon river system, and not correctly simulating transpiration by the rainforest as compared to normal evaporation from rivers, ponds and other settled water. Given that, at times, 20 per cent of the Amazon Basin is flooded, this is a considerable source of uncertainty in climate predictions.

'Our long-term goal is to use water isotopes to separate the impacts on climate and global water cycling of natural habitat as against human changes, such as deforestation,' says Henderson-Sellers. 'So far we have found that in the Amazon system, widespread deforestation has caused depletion of heavy isotopes in the upper basin. In other words, removal of forests has reduced water recycling in the Amazon – fewer transpiring trees means less heavy isotopes being re-introduced back into the atmosphere. However, reading of the isotopes suggests that this effect is

Water from the Amazon Basin cycles to the Andes where it falls as rain and snow. Retrieved data from water samples collected in the mountains during the 1950s and 1960s are proving a crucial resource for scientists modelling climate change. istockphoto

masked by the impact of global warming on the hydrology. We still need to tease out the two.'

The close analysis of isotopes collected in precipitation high in the Andes, over 25 years, shows that deforestation in the central Amazon can affect climate many thousands of kilometres upstream. 'This is an important validation of predictions made by numerous GCMs over the last 20 years,' says Henderson-Sellers. 'In fact,' she adds, 'it's the first validation of these GCM predictions and this is why it is so significant.'

GCMs suggest that tropical deforestation can affect the large planetary (Rossby) waves in the atmosphere that disturb jet stream and ocean currents at mid- and high-latitudes, far from the tropics. Knowing whether such predictions are valid is clearly important. Isotope studies, therefore, provide hope for further validations of GCMs and hence of predictions for global warming, changing circulation and regional rainfall, temperatures and other weather patterns.

'The bottom line is that, using stable water isotopes as a fully independent tool we will be able, bit by bit, to reduce the uncertainty in predictions for climate change – uncertainty that is often used by sceptics as an excuse to put-off action to counter global warming,' concludes Henderson-Sellers.

● **Steve Davidson**

More information:

McGuffie, K. and Henderson-Sellers. A. (2004) Stable water isotope characterization of human and natural impacts on land-atmosphere exchanges in the Amazon Basin. *Journal of Geophysical Research*, 109, D17104, doi:10.1029/2003JD004388.