

Patagonian glacier yields clues for improved understanding of global climate change

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Although ice cores obtained from Antarctica have now provided more than 800 000 years' worth of climate records, analysis of them alone is insufficient for understanding the history of climatic interactions between the diverse regions of the world. Boreholes drilled during the 1990s on six glaciers in the tropical zone of the Andean Cordillera gave rise to a substantial collection of data on the changes and developments of the tropical climate of the Southern Hemisphere.

However, no investigation of this type had hitherto been performed at mid latitudes, leaving a large gap in documentation on climate. An expedition in 2005 by an IRD team and its partners¹ on the San Valentin glacier in the Chilean part of Patagonia demonstrated the potential of that site for exploring climatic variations of the past. The analyses gave the first evidence of influences from Antarctica and the Pacific on the Southern climate of the American continent, thus indicating the complexity of the climate system in this ecologically fragile region. A follow-up to this test study, a borehole made in 2007 on the whole thickness of the glacier, should provide the element that was still missing from the glacier records on the Southern Hemisphere's climate.

A better understanding of climate variations at planetary scale is one of climate scientists' crucial concerns. Stable water isotope analysis, the chemistry of ice cores taken from the Arctic and Antarctic polar ice caps and of air bubbles trapped in them now allow a chronology to be drawn up of the climate changes that took place over the past 800 000 years. However, those data, collected at extreme latitudes, are not enough for

understanding climatic interactions operating at the scale of the whole Earth or of the most densely populated regions. Similar investigations are needed on glaciers located at lower latitudes. Scientists have therefore since the 1990s been undertaking borehole surveys in the Andean glaciers. The Andes are particularly suited for sampling climate data concerning the whole of the Southern Hemisphere owing to their high altitudes and N-S orientation. Boreholes on six glaciers of the Andean Cordillera at tropical latitudes have already yielded information on South America's past climate variability (up to 25 000 years). However, no study of this type had yet been conducted in Patagonia, at mid-latitudes of the Southern Hemisphere. During a 2005 expedition by an IRD team and its Chilean partners on the San Valentin glacier (Patagonia, 47°S, 4032 m), a 16 m shallow firn core was extracted in order to evaluate this site's potential as a record of our climate. A borehole at this latitude should provide the element still missing from ice field documentation on the Southern Hemisphere's climate. Geographically, it is at the interface between the tropics and the South Pole and should contain clues as to how tropical and polar atmospheric circulation influence this region's climate.

Preliminary ice core analysis revealed that the isotopic and chemical tracers are remarkably well preserved owing to a sufficiently cold ice temperature (-11°C). Dating combining determination of radioactive element levels (tritium, cesium, americium, lead 210) and the number of seasonal cycles of chemical species gave an estimated annual snow accumulation of about 35 cm. With just 16 m of ice the hope was to obtain a climate record for a period of at best a few years, but dating showed that the record in fact went back to the early 1960s. Combination of oxygen isotope ratio determinations with those of hydrogen was then used to estimate the precipitations that feed the San Valentin glacier.

The difference between the isotopic ratios - the deuterium excess - is

linked essentially to the temperature of the oceanic source of the precipitation, making it possible to differentiate the air masses coming from the pole, formed above a cold ocean, from those arising over a more temperate ocean like the Pacific. Similarly, a high marine salt concentration in ice means that the precipitation that feeds the glacier arrives with marine air masses, formed over the Pacific. Conversely, a low sodium concentration characterizes continental air masses, which have travelled for a longer time. Patagonia was hitherto thought to be subjected mainly to westerly winds off the Pacific, but this dual ice core analysis yielded the first evidence that this region also comes under the influence of meteorological regimes that arise further south, in the Antarctic (see Figure).

A second drilling expedition conducted on San Valentin in 2007 gave the team the opportunity to drill through the entire 122 m thickness of the glacier. The first investigations on this second ice core suggest that it contains a climate record of several thousand years. By cross-referring the information contained in this unique core with those already obtained for the glaciers lying further North on the Cordillera, it could therefore be possible to trace the climate changes in all the whole of the Southern Hemisphere during the past few thousand years and thus better anticipate its reactions to global climate variations.

Citation: Vimeux, F., M. de Angelis, P. Ginot, O. Magand, G. Casassa, B. Pouyaud, S. Falourd, and S. Johnsen (2008), A promising location in Patagonia for paleoclimate and paleoenvironmental reconstructions revealed by a shallow firn core from Monte San Valentín (Northern Patagonia Icefield, Chile), *Journal Geophysical Research*, in press.
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