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A palaeorainfall record from Central Pacific over the last millennia from speleothems: preliminary results

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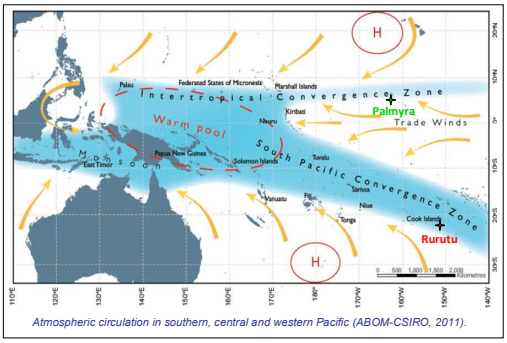


Atmospheric circulation in southern, central and western Pacific (ABOM-CSIRO, 2011).

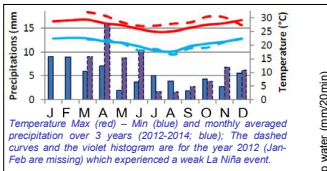
Rurutu island and cave locations

INTRODUCTION

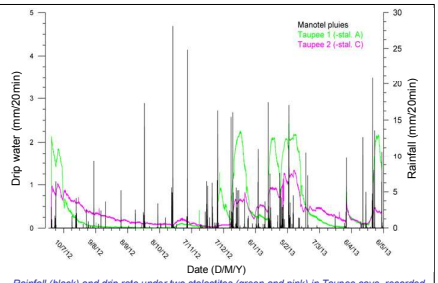
The South Pacific Convergence Zone (SPCZ) is a major feature of the South Pacific basin. Its position and activity fluctuate seasonally and at interannual and decadal timescales under the influence of ENSO and the IPO, driving changes in temperature and precipitation in the region. Zonal SPCZ events have also been shown to be associated to cyclogenesis in the Central Pacific, inducing serious hazards for the islands and populations of French Polynesia[1].

The reconstruction of past SPCZ position and intensity for pre-industrial periods could help to understand its dynamics and improve models aimed at predicting its evolution in a context of global change but long-term, highly resolved and chronologically well-constrained archives of palaeoclimate from the tropical South and Central Pacific are scarce.

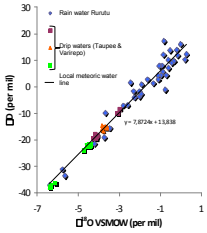
To address this issue, we collected speleothems from caves located on the uplifted atoll of Rurutu, in the Australes archipelago at the eastern part of the SPCZ. We present preliminary speleothem proxy data of regional palaeohydrology covering the last few millennia.



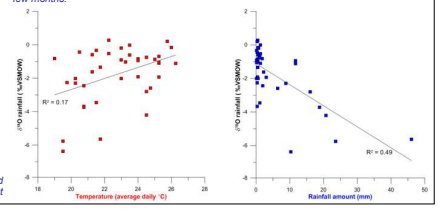
Temperature Max (red) – Min (blue) and monthly averaged precipitation over 3 years (2012-2014; blue); The dashed curves and the violet histogram are for the year 2012 (Jan-Feb are missing) which experienced a weak La Niña event.



Rainfall (black) and drip rate under two stalactites (green and pink) in Taupee cave, recorded every 20 min. This monitoring indicates storage and mixing of the order of several weeks to a few months.



δ18O and δD of rainwater and dripwaters in both studied caves.



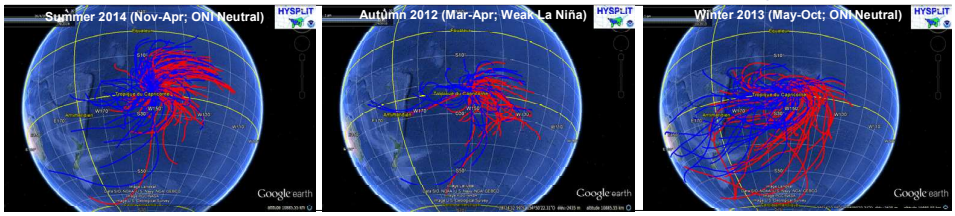
δ18O of the rainfall vs.Temperature and δ18O of the rainfall vs. Rainfall amount

SITE and METHODS

The island of Rurutu is a makatea, an uplifted atoll, located in the eastern part of the South Pacific Convergence Zone (SPCZ). Activity and position of the SPCZ are essentially controlled by ENSO on an annual scale, and by the IPO (Interdecadal Pacific Oscillation) on longer scales[2]. Maximal cyclone occurrence is during El Niño periods[3]. Rurutu has been hit every 7 to 10 years over the period 1970-2009[4].

In order to evaluate the capacity of the sampled speleothems to register palaeorainfall fluctuations, we screened the samples according to their petrography, internal structure, growth interval, and we studied the response of the hydrological system to meteorological variations.

- Monitoring:
  - meteo station: Pluvimate + min-max thermometer + cumulative rain gauge
  - $\delta^{18}O$ and δD of daily rain water and monthly drip water
  - ibuttons for cave temperature and Stalagmate for drip counting (20 min interval)
  - modern calcite for $\delta^{18}O$ and $\delta^{13}C$ comparison with drip water and cave temperature
- Speleothem analyses:
  - $\delta^{18}O$ and $\delta^{13}C$ variations (increment 100 mm or 1mm; Univ. of Innsbruck & Univ. de Savoie)
  - dating by $^{230}Th/^{234}U$ (MC-ICP-MS Univ. of Melbourne) and ^{14}C (AMS ANSTO).



Back trajectories of the precipitation over 4 days, at altitudes 1500 m asl (850hPa; red) and 3015 m (700 hPa; blue), plotted with HYSPLIT

MONITORING DATA

- Cave temperature is quite stable over the year (maximal amplitude ~1°C in Taupee / 2,5°C in Varirepo).
- Isotopic analyses of modern calcite and drip water provide calculated temperatures consistent with the measured one.
- Dripping can get low but never stops, even during the dry season; rhythms indicate water storage and mixing of the order of several weeks to a few months => high frequency variability can be recorded.
- Drip water isotopic composition falls on the local meteoric water line => it still reflects rainwater composition after its transit to the cave.
- After 3 years of monitoring, it seems that summer rainfall (wet season) is primarily sourced from the NE of the island while winter rainfall (drier season), is rather coming from the South-West of the island.
- However, in 2012, which was a **weak La Niña** episode, it seems that rainfall sources shifted to East or SE. The amount of precipitation that year was larger and the temperature slightly warmer.
- $\delta^{18}O$ of the rainfall shows no correlation with the temperature but a significant negative correlation with the rainfall amount.

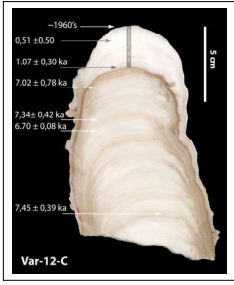
⇒ From these observations, we suggest that the $\delta^{18}O$ signal in Rurutu speleothems is a proxy for rainfall amount.

⇒ During La Niña episode, it seems that Rurutu weather gets warmer and wetter.

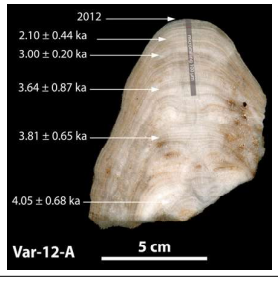
⇒ This observation could be linked to a southward shift of the SPCZ, becoming more centered over Rurutu island[5].

Although more monitoring data is needed, at this early stage we interpret the $\delta^{18}O$ from Rurutu speleothems as follows:

If $\delta^{18}O_{sp}$ ↓ ⇔ rainfall amount ↑ ⇔ SPCZ shifts South ⇔ La Niña-like episode.

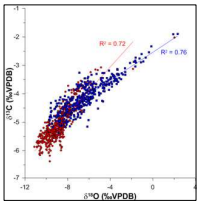


Detail of Var12-C

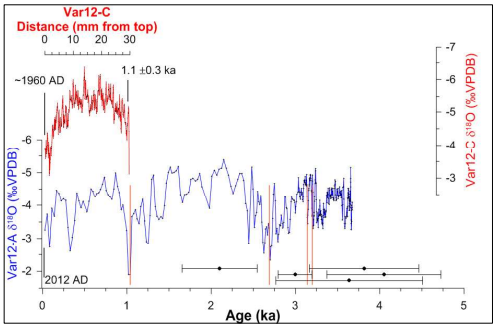


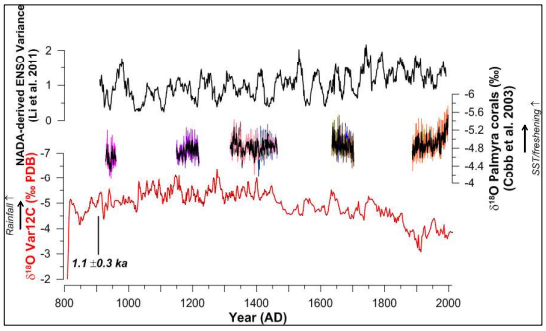
Speleothems under focus in this study. The position of the dating samples is indicated in white, with the corrected ages and 2σ uncertainties; the top ages have been confirmed by ^{14}C measurements. The stable isotope profiles have been obtained from the shaded area, on the stalagmite growth axis, by micromilling at 100 µm resolution.

Detail of Var12-A



δ13C vs δ18O for both stalagmites,. The strong correlation suggests that kinetic fractionation during calcite precipitation can not be discounted. However, in this case, it will amplify the isotopic expression of the rainfall changes.





- $\delta^{18}O$ profiles from both speleothems show some similarities, in trend, in variability, and in absolute values, within the uncertainties of the current Age-Depth models.
- Var12-C shows the highest resolution; when compared with ENSO variance[7], it seems that its multidecadal fluctuations vary with a similar frequency; the long-term trends of both records are comparable.

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- Comparison of Var12-C record with Palmyra $\delta^{18}O$: in the light of the context discussed above, we expect that during periods of higher $\delta^{18}O$ / lower SST in Palmyra, the SPCZ is shifted southward and it rains more on Rurutu, and vice-versa, the two proxy-series should thus vary in anti-phase. It seems to be the case during the XXth century but not during the previous millemium, on long term scale; our proxy-series lacks of chronological controls at this stage to allow any refined comparison.

PERSPECTIVES: The age models require further dates (^{14}C for the last centuries then U-series). The lamina are too faint for layer counting so trace element analysis (LA-ICP-MS) will be used to resolve annual layers. These and older speleothems spanning most of the Holocene will be studied to develop a longer-term reconstruction of hydrological variability in the Central Pacific.

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