FINAL REPORT

ECORD Grant for research proposal:

Contribution of TEX_{86}-based temperatures to the climatic variations of the equatorial Pacific during the last 10 Myrs

Gabrielle Rousselle
Institut des Sciences de la Terre de Paris (ISTeP) - Université Pierre et Marie Curie

1. Scientific objectives

As the world's largest ocean, the Pacific is closely linked to major changes in the global climate system. Throughout the Cenozoic, Pacific plate motion has had a northward motion. Thus, the Pacific is unique in that the thick sediment bulge of biogenic-rich deposits from the narrow equatorial upwelling zone is slowly moving from the Equator. The Equatorial Pacific shows an East-West asymmetry of sea surface temperatures (SST) and depth of the thermocline. This configuration is set up during the Miocene-Pliocene, as the Antarctic and Arctic ice sheet grow and the Indonesian seaway and Central American seaway close. Given the modern configuration, a large part of paleoceanographic changes can be inferred from the evolution of the thermocline depth during the last 10 Myrs, currently high in the East and deep in the West. Then, this evolution was explored at IODP site 1338 using $\delta^{18}O$ gradient between surface and subsurface waters, based on isotopical measurements of several species of calcareous nannofossils (*Noelaerhabdaceae*) and planctonic foraminifera (*G. sacculifer, G. menardii*). In parallel, we were able to reconstruct variations of sea-surface temperatures, based on the alkenone unsaturation ratio $U^{k'}_{37}$. To go further in the climatic comprehension of these water masses, the ECORD Project funded here aimed to used an other absolute palaeothermometer biomarker-based (TEX_{86}), to confirm trends of past temperatures. These measurements were then performed in collaboration with the Netherlands Institute for Sea Research (NIOZ), in Texel.

2. Methodology

The total organic matter have been extracted from the samples (100 samples) in the laboratory "Biominéralisations et Paléoenvironnements" in Paris.
The organic matter has been separated at NIOZ, in polar and apolar fractions, depending on polarity of molecules. The polar fraction containing GDGTs is then flitered and analyzed in Liquid Chromatography. Measurements were performed at NIOZ, and we had times to process 40 samples. Temperatures are then inferred from TEX_{86} values using the calibration of Kim *et al*. (2010).

3. Results

Results of temperatures based on TEX_{86} are shown on the figure 1, and compared to the SST based on alkenones.

The temperature record based on TEX_{86} is relatively parallel to the SST record based on $U^{k'}_{37}$ (figure 1). However the temperatures based on TEX_{86} (T_{TEX}) are slightly cooler than the one based on the $U^{k'}_{37}$ (SST_{Uk}), and the figure 1 show a progressive shift of 1 to 2°C between the both records. Indeed, the amplitude variations of T_{TEX} between 9 Ma and 0.06 Ma ($\Delta T \approx 5°C$) is more important than the one recorded by SST_{Uk} ($\Delta T \approx 3°C$).

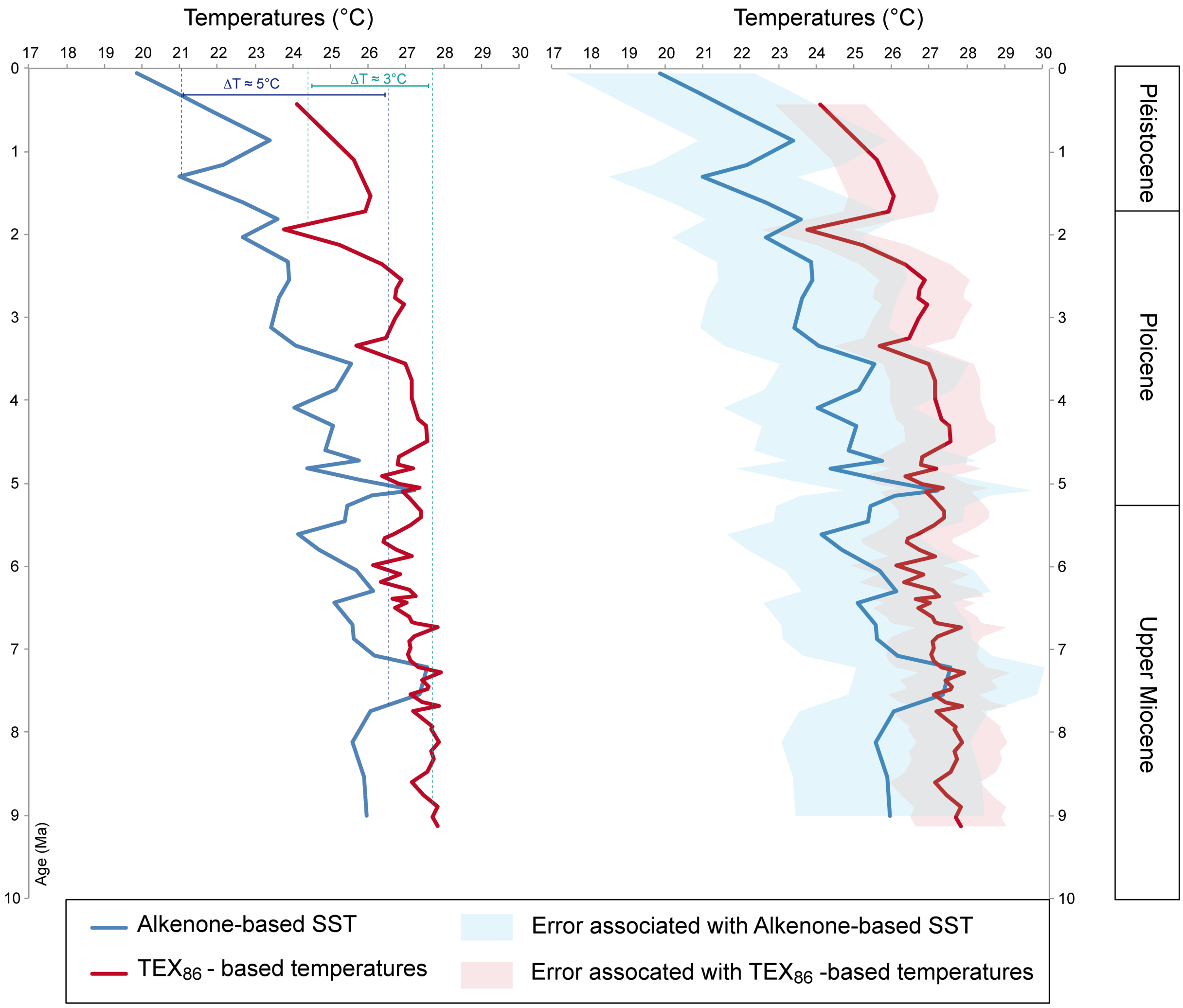

Figure 1: Variations and comparisons of temperatures based on alkenone unsaturation ratio ($U^{k'}_{37}$) and TEX_{86} at site 1338 (Eastern equatorial Pacific) during the last 10 Myrs.

4. Discussion and preliminary conclusions

It seems that temperatures based on the TEX_{86} don't record the same absolute temperatures than SST_{Uk}. The observed offset can be explained by three reasons:
- The error associated with the temperature calculations.
- The seasonnality of the GDGTs production.
- A difference between the production depth of alkenones and GDGTs.

Temperatures calculations based on $U^{k'}_{37}$ and TEX_{86} imply an uncertainty of 1.2°C and 2.5°C, respectively (figure 1). If T_{TEX} are interpreted as sea urface temperature, we need to assume that T_{TEX} are under-estimated, or that SST_{Uk} are over-estimated. However we see from 5 Ma, a complete decoupling between the both records (figure 1), where T_{TEX} seems to cool faster than SST_{Uk}. Moreover, studies highlights a shift between this to temperatures records (Huguet *et al*., 2007 ; Lee *et al*., 2008 ; Leider *et al*., 2010 ; Lopes dos Santos *et al*., 2010 ; Rommerskirchen *et al*., 2011). Then it appears that this observation is general, and not a located phenomenon in the Eastern equatorial Pacific.
The production of GDGTs show a strong seasonality, with a more intense production in winter, and at the beginning of spring, which can explain cooler temperatures recorded by T_{TEX}. However, the seasonality at low latitudes (under 10°) is very week, and do not seems to have a big impact on the production near the equator.
The last hypothesis regards the depth production of alkenones *vs* GDGTs. Indeed, GDGTs are present in the entire water column, with a maximum between 100 m and 200 m water depth. Then, it seems that the *Crenarchaeota* (GDGTs producers) grow preferentially in subsurface waters, compared to alkenone producers who live in the photic zone and surface waters. Here, T_{TEX} are then assumed to reflect temperatures of subsurface waters, than the surface, and both temperatures records allow us to infer variations between these two water masses.

Interpreted as variations in the stratification of the upper water column, temperatures records allow us to define some different intervals, where the surface water mass is deep (7-7.8 Ma and 5.3-4,8 Ma) (figure 2). Conversely, we can observe some periods when the two water masses are decoupling, with a thin water surface mass (e.g. before 8 Ma, and especially after 5 Ma).
These intervals can be interpreted as periods where the thermocline (linked to subsurface) is deep or shallow, and infer a progressive shoaling of the thermocline from 5 Ma. In order to confirm these results, we can compare these temperatures records with results of $\delta^{18}O$ on *G. menardii*, which is a thermocline dweller planktonic foraminifera (figure 2). This record shows a similar trend to T_{TEX}, which confirms that both parameters are recording subsurface (thermocline) conditions. Moreover, the variations of $\delta^{18}O$ gradients between surface and subsurface waters have been interpreted by a progressive shoaling of the thermocline from 5 Ma, indicating the progressive installation of the modern configuration of the equatorial Pacific.

In conclusion, the T_{TEX}, compared to SST_{Uk} allow us to infer variations of suface and thermocline water masses, and infer a progressive shoaling of the thermocline from 5 Ma. These results are confirmed by other analyses ($\delta^{18}O$ gradients), and will be published soon, included in a global study of the climatic variations of the equatorial Pacific during the Miocene-Pliocene. Moreover, some of these results have been presented at the EGU in April 2013.

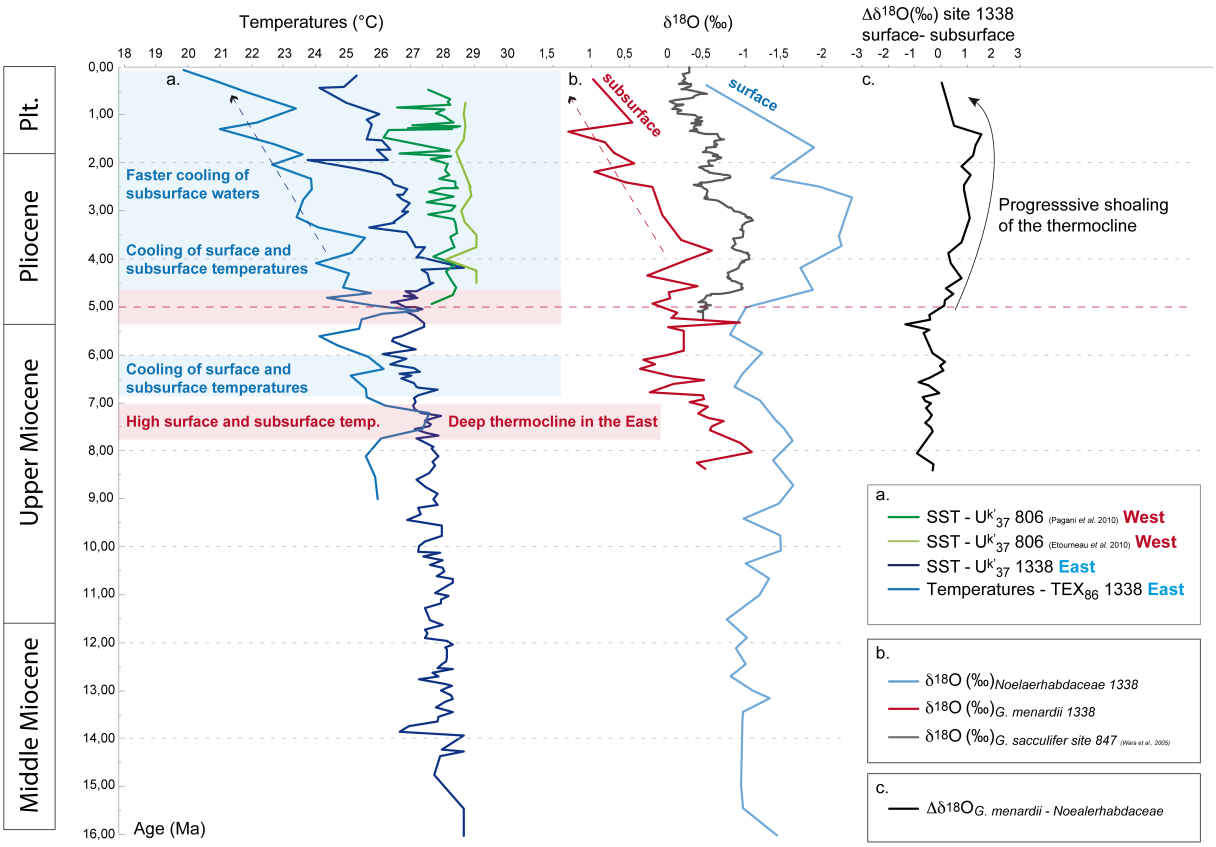

Figure 2: Comparison between different proxies. a. Records of alkenone-based SST at site 1338 (eastern equatorial Pacific) and 806 (eastern equatorial Pacific). TEX_{86}-based temperatures at site 1338. b. $\delta^{18}O$ records in the eastern equatorial Pacific, on *Noelaerhabdaceae* (site 1338) (Rousselle *et al.*, 2013), *G. sacculifer* (site 847, Wara *et al.*, 2005) and *G. menardii* (site 1338). c. $\Delta\delta^{18}O$ between surface waters (*Noealerhabdaceae*) and subsurface (*G. menardii*) at site 1338.

5. Budgets

The ECORD grant was requested for funding costs of laboratory analyses (406,06 **€** for consumables, glassware and solvents), accommodation (790 **€**) and travel (567,37 **€**) (total of 1763,83 **€**). A part of this funding has been use to finance travel and accommodation to the stay at NIOZ, and a part of participation to the EGU where results were presented. The provided funding of 1760 **€** was used to cover all the expenses.

6. References

Huguet C., Schimmelmann A., Thunell R., Lourens L.J., Sinninghe Damsté J., Schouten S. (2007) A study of the TEX_{86} paleothermometer in the water column and sediments of the Santa Barbara Basin, California, *Paleoceanography 22*, 9 p.

Kim J.-H., van der Meer J., Schouten S., Helmke P., Willmott V., Sangiorgi F., Koç N., Hopmans E.C., Sinninghe Damsté J.S. (2010) New indices and calibrations derived from the distribution of crenarchaeal isoprenoid tetraether lipids: implications for past sea surface temperature reconstructions, *Geochimica et Cosmochimica Acta 74*, pp. 4639–4654.

Lee K.E., Kim J.H., Wilke I., Helmke P., Schouten S. (2008) A study of the alkenone, TEX_{86}, and planktonic foraminifera in the Benguela Upwelling System : Implications for past sea surface temperatures estimates, *Geochemistry, Geophysics, Geosystems 9(10)*, 19 p.

Leider A., Hinrichs K.U., Mollenhauer G., Versteegh G.J.M. (2010) Core-top calibration of the lipid-based $U^{k'}_{37}$ and TEX_{86} temperature proxies on the southern Italian shelf (SW Adriatic Sea, Gulf of Taranto), *Earth and Planetary Science Letters 300(1-2)*, pp. 112 - 124.

Lopes dos Santos R.A., Prange M., Castañeda I.S., Schefuß E., Mulitza S., Schulz M., Niedermeyer E.M., Sinninghe Damsté J.S., Schouten S. (2010) Glacial-interglacial variability in Atlantic meridional overturning circulation and thermocline adjustments in the tropical North Atlantic, *Earth and Planetary Science Letters 300*, pp. 407 - 414.

Rommerskirchen F., Condon T., Mollenhauer G., Dupont L., Schefuss E. (2011) Miocene to Pliocene development of surface and subsurface temperatures in the Benguela Current system, *Paleoceanography 26*, 15 p.

Rousselle G., Beltran C., Sicre M.-A., Raffi I., De Rafélis M. (2013) Sea-surface condition changes in the Equatorial pacific during the Mio-Pliocene as inferred from coccolithe geochemistry, *Earth and Planetary Science Letters 361*, pp. 412 - 421.

Wara M.W., Ravelo A.C., DeLaney M.L. (2005) Permanent El Niño-Like Conditions During the Pliocene Warm Period, *Science 309*, pp. 758 - 761.

Communication thanks to the ECORD Grant

Rousselle G., Beltran C., Sicre M.-A., Raffi I., De Rafélis M., Changes in sea-surface conditions in the Equatorial Pacific during the middle Miocene-Pliocene (IODP Site 1338), Talk EGU, Vienne, April 2013.