ECORD Research Grant Final Report

Reconstruction of environmental and sea ice variations in Adélie Land, East Antarctica, over the last 2,000 years, based on diatom assemblages, diatom specific biomarkers and modelisation

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1. Aim of the mission in the framework of our study

The core IODP U1357B (66.4°S, 140.4°E) taken in the Dumont D'Urville Trough (DDUT), East Antarctica (fig.1), in the framework of the Expedition 318 (C. Escutia lead proponent and co-chief) recovered ~180 meters of Holocene sediment in the DDUT (Escutia et al., 2010). The upper 40m long sequence I am studying covers the last 2000 years, a period that has never been studied in the marine realm off East Antarctica because of the lack of adequate sediment cores. For the first time, our archive enables reconstruction of past sea ice and environmental conditions off East Antarctica, over the Late Holocene, and at an unprecedented resolution of ~4 years for biomarkers analyses (HBI) and ~10 years for diatom census counts.

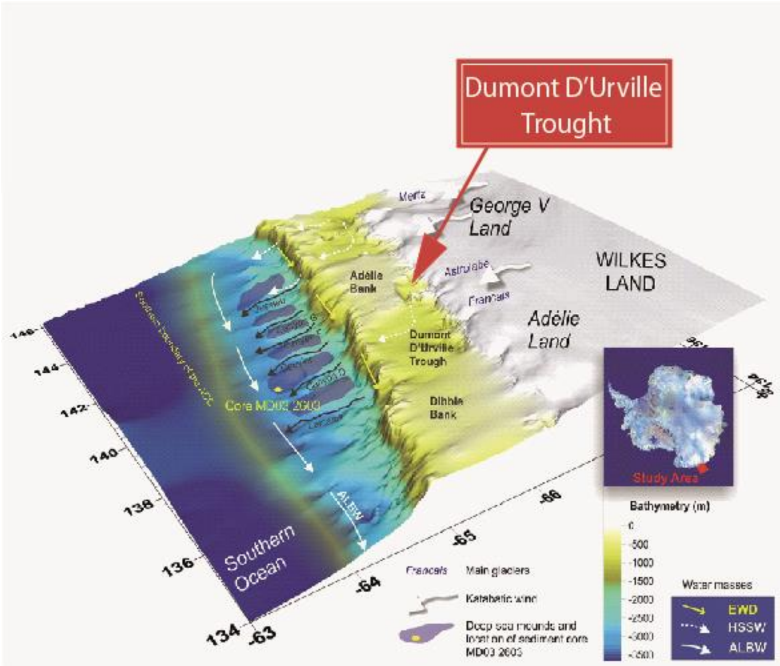

Figure.1

Map of the Adélie Land area, with positions of core site at the Dumont D'Urville Trough.

Within the framework of this Ecord project, we have focused on comparison between IODP U1357B Late Holocene sea ice record and (1) sea ice records estimated by different models (LOVECLIM, MPI_ESM_P and CCSM4) and (2) air temperature records in Antarctic ice core. The Ecord Grant was therefore central to replace the IODP U1357B core at both temporal and spatial scales, which is a great opportunity to detect the forcing that control sea ice variations at different timescales (oceanic, solar activity, climate modes), and to study the apparent anti-correlation between our sea ice record and global climate periods during the last 2000 years (warm “Dark Ages”, cold “Warm Roman Period” and warm “Little Ice Age” off Adélie Land).

2. Preliminary results and discussion

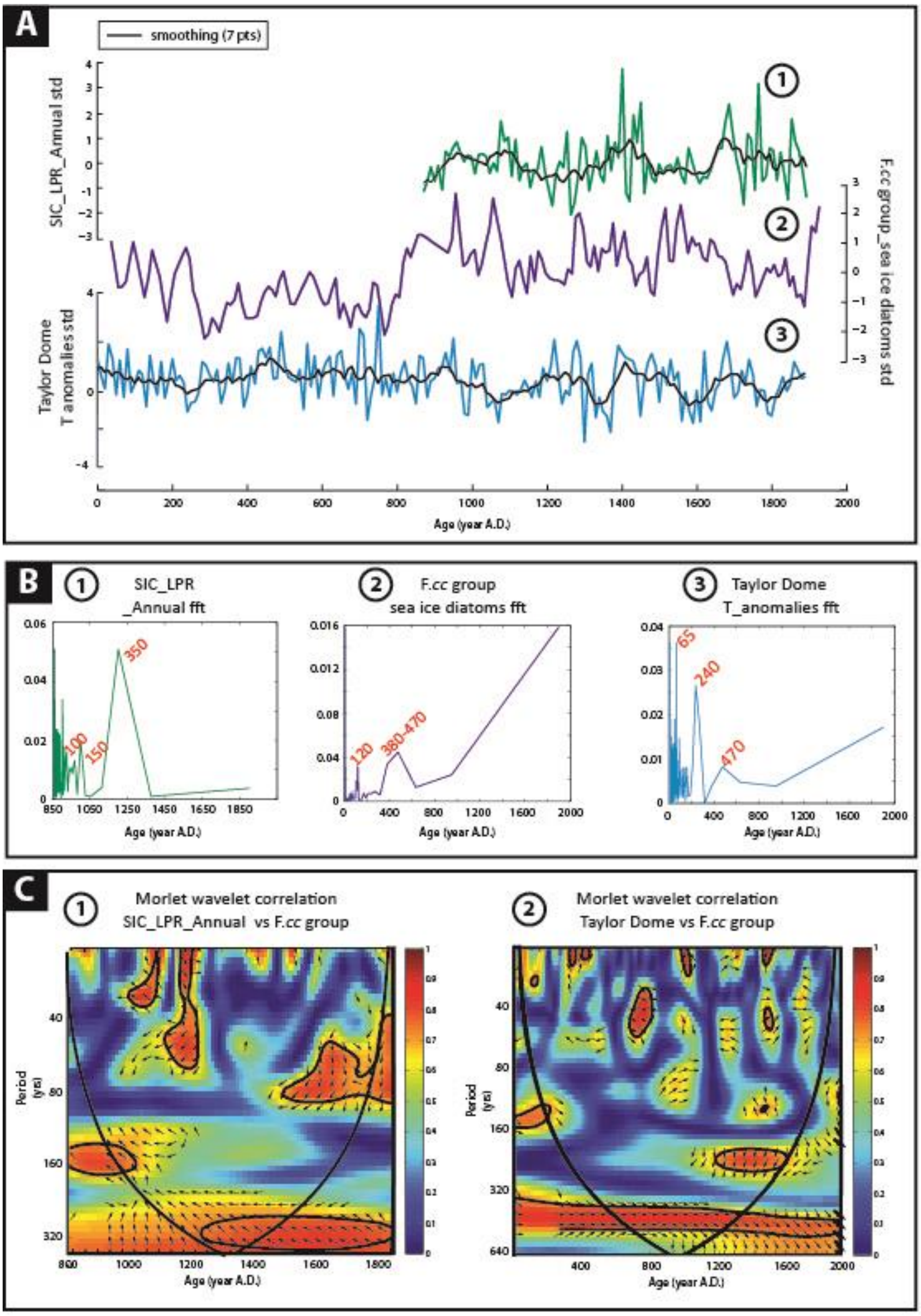

Figure.2

A) Normalized signals over age (years A.D.), 10 years scaling: 1) SIC_LPR, LOVECLIM simulation with data assimilation, based on annual mean values from monthly modeled sea ice concentration-SIC; 2) F*cc* group, sea ice diatoms from relative percent of Fragilariopsis *curta* + F.*cylindrus*; 3) Taylor Dome temperature anomalies from $\delta^{18}O$ ice core, taking as reference the mean value between 0.5- 1.5 ka BP.

B) Fourier Transform over age (years A.D.): 1) SIC_LPR; 2) F*cc* group, sea ice diatoms; 3) Taylor Dome temperature anomalies.

C) Morelet Wavelet Correlation-WTC analyses over age (years A.D.) for 2 signals: 1) SIC_LPR versus sea ice diatoms; 2) Taylor Dome temperature anomalies versus sea ice diatoms.

LOVECLIM model (coupled model of intermediate complexity) has been developed in Louvain La Neuve University by Hugues Gosse (Goosse et al., 2004) and has been previously successfully used in Antarctic climate reconstructions (Goosse et al., 2013). The LOVECLIM_PR (LR) simulation with data assimilation processes was ran annually by averaging monthly values of modeled sea ice concentration (SIC) from 850 until 1890 AD. Multi centennial and decadal variability is well expressed in the LR signal (fig.2,A-1) but the decadal variability is dampened because of the rescaling (10 yrs). LR tends to a slight warming over the last millennium. The Fourier's Transform (fft) equation on LR reveals cyclicity around 80, 130 and 300 yrs (fig.2,B-1), and confirms our preliminary observations about centennial and decadal variability. Additionally, some peaks occur under 80 yrs, and might be considered as noise (rescaling step).

Two additional models, MPI_ESM_P and CCSM4, have been tested and overestimate the multi decadal variability as well. Moreover, they show a warm trend over the last millennium, according to LR. Nevertheless, a cool trend prevails in other Loveclim's simulations that have been run without data assimilation.

Record of the diatom sea ice group F. *curta* and F. *cylindrus* experiences an obvious multi centennial variability indicating five distinct climatic periods and changes in sea ice cover associated (fig.2,A-2): 0-200 AD, ~200-750 AD, ~750-1550 AD, ~1550-1850 AD and 1850-1890 AD. Particularly, the step around 750-800 AD is well marked, as we have observed in LOVECLIM simulations covering the last 2,000 yrs, and could indicate a sharp climatic transition. Diatom records also evidence a less marked decadal variability, probably in relation to the sampling resolution of the core IODP U1357 B (~10 yrs). Fft analyses (fig.2,B-2) allow the distinction of two cycles at around 120 yrs and 380-470 yrs.

Air temperature at Taylor Dome was reconstructed through the classical approach, based on the spatial δ^{18}O/T (or δD/T) slope using a value of 0.8‰ /°C (or 6.34‰ /°C for δD) (Stenni & Braida, pers. comm.). As LR, temperature anomalies experience an important multi decadal variability (fig.2,A-3) and centennial variability. Fft analyses confirm these observations and shows a ~65, 240 and 470 yrs cycles (fig.2,B-3).

Both fft and wavelet analyses agree for each signal and reveal significant cyclicities at different timescales that may highlight cyclic climate changes at decadal-to-centennial scales in coincidence to known solar cycles (Crosta et al., 2007); e.g. diatom and model signals exhibit cycles of ~80-130 yrs in agreement with the Gleissberg cycle. Solar activity might influence diatom productivity in our area by impacting sea surface conditions (e.g. sea ice cover; Crosta et al., 2007).
Wavelet cross-correlations between the diatom sea ice group and 1) LR simulation (fig.2,C-1) and 2) Taylor Dome temperature anomalies (fig.2,C-2) show positive or negative phases at the multi centennial timescale for the three parameters over the entire 2,000 yrs. Positive or negative phases are also evident at the decadal timescale but only in some parts of the record.
More signal treatment analyses are required, especially on the model and ice core data set, in order to study and quantify the decadal variability part in respect to the centennial one. Such work is currently ongoing on the whole dataset in close collaboration with Hugues Goose (UCL, Belgium) and Barbara Stenni (Univ. Trieste, Italy). We intent to integrate the IODP core in a temporal climate reconstruction and if possible to initiate the study at the spatial scale using ice core dataset.

3. Budget

Originally, I had applied to the ECORD Grant for two missions: 1) in Granada to work with Drs Carlota Escutia and Fransisco Jiménez at the Instituto Andaluz de Ciencias de la Tierra in Granada (Spain), and 2) in Louvain-La-Neuve (LLN) to work with Dr Hugues Goose at the Université Catholique de Louvain (Belgium). After a first meeting in Granada between the Spanish team and my supervisors by the end of June 2012, we decided to focus on the modelling approach and my visit at LLN. Thus, the ECORD grant of 1760 € was used to support travel fees, housing and daily expenses of my mission in LLN (see fig.3 and attached invoice).

Louvain La Neuve mission	
BUDGET PLAN	COSTS
Plane	156.06 €
Transports (train, taxi)	130.4 €
Housing	1089.6 €
Daily expenses	266.75 €
TOTAL	**1642.81 €**

Figure.3

Budget plan for travel fees.

Cited references

Crosta X., Debret M., Denis D., Courty M.A., Ther O. (2007) Holocene long- and short-term climate changes off Adélie Land, East Antarctica, *Geochemistry, Geophysics, Geosystems*, 8 (11), Q11009, doi: 10.1029/2007GC001718.

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