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## Abstract

Sea Surface Temperature (SST) estimates for the deep sea sediment core GC007 on the South Tasman Rise, were calculated using  $U_{37}^K$  for the last full glacial cycle (~100,000 yrs).  $U_{37}^K$  is an organic geochemical technique based on long chain ( $C_{37}$ ) alkenones that estimate late spring temperatures; the season of growth for the organisms that make the alkenones. South of Tasmania, the Holocene and last interglacial were ~18°C. For the Last Glacial Maximum (LGM) SST was ~13°C a ~5°C cooling. Alkenone based temperatures were compared to SST estimates based on foraminiferal assemblages (Modern Analog Technique, MAT) for the last glacial to present. Foraminiferal SST estimates were ~3-4°C cooler during the Holocene than alkenone SST and maintained this offset during the LGM and Holocene with faunal SST estimates of ~13.5°C and LGM estimates ~10°C. The temperature offset present during the different climate regimes is interpreted as a difference in growth seasonality between the organisms on which the SST estimates are based. However, in the deglaciation both alkenone and foraminiferal SSTs match more closely indicating that the difference in temperatures of the two-organism growth season might have diminished during the transition from glacial to interglacial climates.

## Introduction

The idea of oceanic cooling during the last glaciation is universally accepted with the amount of oceanic cooling known to differ from area to area. Conditions in the Southern Ocean are considered to be important in controlling global climate because of the ocean's influence on deep-water mass formation, and ocean circulation. Past SST is estimated by analyzing proxies for SST from deep-sea cores and the record of paleo-SST from many locations has given us an understanding of conditions in the Southern Ocean during the last glaciation. Previous work has indicated that the Southern Ocean underwent glacial cooling. The magnitude of the estimate of the temperature drop ranging depending on the technique used. Estimates of cooling from this region of the Southern Ocean vary from ~4 to 8°C (Connell and Sikes 1997; Howard 1992; Sikes et al. 2002; Climap, 1981).

Research in this study focuses on the South Tasman Rise (STR) south of Tasmania in the Southern Ocean. The South Tasman Rise is the approximate location of the Subtropical Convergence Zone (STZ) South of Australia. The STZ is a frontal zone where subtropical waters meet subantarctic waters to form the northern boundary of the Southern Ocean. (Figure 1.2). A number of cores appropriate for this work were collected by the RV *Rig Seismic* in 1995 in the study area (Figure 1.1).



Fig 1.1 Field map Area with analyzed cores in red taken from (Samson, 1998)

Fig 1.2 The Subtropical Convergence/Subtropical Front in the Southern Ocean off Australia and Tasmania

## Alkenones

Alkenones are organic molecules produced by the phytoplankton *Emiliania huxleyi*. The number of di- to tri- double bonds (or unsaturation) in the compounds in *E. huxleyi* have been shown to change with temperature. (Brassell et al., 1986).



Figure 2 Photo of *E. huxleyi* (<http://www.soes.soton.ac.uk/sta/ff/w/>)

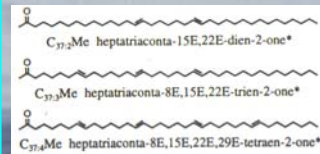


Figure 3. Chemical structure of the 2, 3, and 4 double bonded 37 carbon straight chained alkenones

## What is the $U_{37}^K$ number?

$$U_{37}^K = \frac{[C_{37:2}]}{[C_{37:2}] + [C_{37:3}]}$$

A mathematical method used to estimate paleo-SST by examining the ratio of 2-3 double bond, in straight chained 37 carbon length alkenones. The ratio of double bonds has been shown to vary linearly with temperature. (Prah and Wakeham 1987).

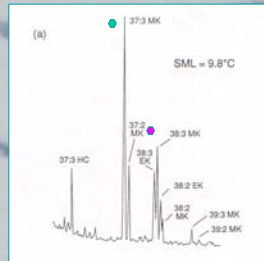


Figure 4. Chromatogram showing the ratio between 2 (in pink) and 3 double bonded alkenones (in green) in water from the South Tasman Rise (Sikes and Volkman 1993)

To convert  $U_{37}^K$  values to SST, we use the calibration established by Sikes and Volkman (1993) for Southern Ocean waters:  $T = 0.9414T - 0.156$  ( $r = 0.979$ ,  $r^2 = 0.958$ ,  $n = 48$ )

## Methods

The gravity core used in this project was collected in 1995 during a scientific cruise on the RV *Rig Seismic* which spanned the area over the South Tasman Rise off the coast of Tasmania. (Connell and Sikes 1997 Figure 1.1). The cores were sampled on board ship, sediments were kept frozen until extraction and extracts were kept frozen until analysis. After extraction, the samples were concentrated in order to obtain sufficient alkenones samples to detect. Alkenone levels were determined using capillary gas chromatography (GC) on a Shimadzu GC-17A, fitted with an on-column injector, a flame ionization detector, and a DB-5 fused silica column, and following the methods of Sikes et al. (2002). The temperature program was: 50-150°C at 30°/min and 150-325°C at 3°/min and isothermal at 325° for 18 mins and the carrier gas hydrogen. Alkenone levels are calculated from the area of the peaks of the 2 and 3 double bonded straight chained  $C_{37}$  alkenones.  $U_{37}^K$  is calculated using the formula of Prah and Wakeham (1987) and temperatures are calculated from using the calibration of Sikes and Volkman (1993)

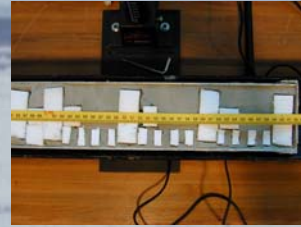


Figure 5 The core GC007 after sampling for alkenones,  $\delta^{18}O$  and faunal analysis were conducted.

Core GC7 as chosen because prior  $^{18}O$  stratigraphy,  $^{14}C$  dating were conducted on the core (unpublished Thesis, Samson 1998). In addition faunal SST analyses provided an alternate SST record comparison with the alkenone data. Alkenone sample resolution is more widely spaced but covers an entire glacial cycle.

## Stratigraphy

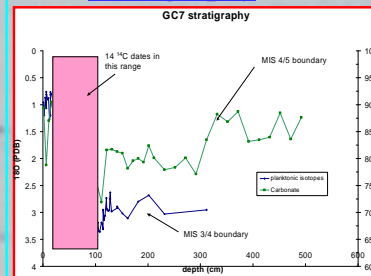


Figure 6 GC & Stratigraphy created with  $C^{14}$  and Marine Isotope Stages (MIS)

GC7 core stratigraphy and age model was based on  $^{14}C$  (Samson, 1998) and tuning of  $^{18}O$  and  $CaCO_3$  Marine Isotope Stages (Shakleton 2000) in order to convert core depths to age.

## Results & Discussion

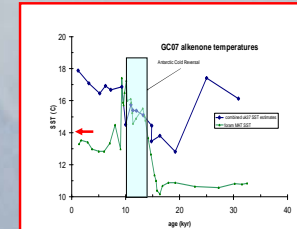


Figure 7 Alkenone vs. Foram (MAT) SST. Actual spring/summer SST indicated by red arrow. In comparing Alkenone and Foram SST estimation in Fig 7 while Foram MAT SST estimates show a clear Antarctic Reversal, Alkenone response is minimal to nonexistent. The absence of the Antarctic reversal could be caused by to wide a distance in sampling down core.

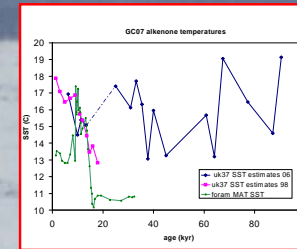


Figure 9 two alkenone data sets vs. foram SST estimates. Alkenone results previously run in 1998 in pink, results from this study in blue, foraminiferal data in green. Note the dashed line represents a gap in alkenone SST estimation.

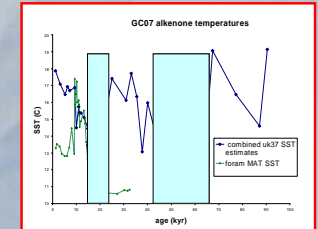


Figure 8 Combined Alkenone vs. Foram MAT SST

During the late Holocene, alkenone SST estimates are ~18°C which is ~4° higher than the actual temperature of about 14°C (See Figs 7,8,9). Late Holocene foraminiferal SST reconstructions are close to modern, and about ~4° cooler than  $U_{37}^K$ . During the LGM the difference of ~4°C between foram and alkenone SST is maintained (Fig 6). However, during the transition between the LGM interglaciation the two temperature proxies match closely (Figure 9 and 10). The 4°C difference between proxies is interpreted as different in growing seasonality between alkenones and forams (Sikes et al., 2002).

During transitional deglaciation, environmental controls may have changed. Variations in nutrient availability, thermocline depth, and seasonality might have varied more widely which could account lesser difference between temperature estimations.

## Summary

- Alkenones show a late Holocene SST of 18°C and a LGM SST of ~13°C.
- Actual late Holocene SST is 14°C indicating that the Alkenone response is 4 °C to warm.
- Foram (MAT) estimates are 4°C cooler than alkenone estimates, but match actual modern temperatures more closely.
- Differences in Foram (MAT) SST and Alkenone SST estimates could be due to changes in growth seasonality.

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