Oxygen Isotope Evidence for Paleoclimate Change during the Vandal Minimum Climate Episode from *Ariopsis felis* Otoliths and *Mercenaria campechiensis* Shells, Southwest Florida

Ting Wang

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Approved by:

Advisor: Dr. Donna M. Surge

Reader: Dr. Joseph G. Carter

Reader: Dr. Stephen R. Meyers

ABSTRACT

TING WANG: Oxygen Isotope Evidence for Paleoclimate Change during the Vandal Minimum Climate Episode from *Ariopsis felis* Otoliths and *Mercenaria campechiensis* Shells, Southwest Florida
(Under the direction of Donna M. Surge)

The Vandal Minimum climate episode (500-800 AD) was first documented in European proxy records as cold and dry with increased frequency of severe weather. Archaeological evidence from coastal southwest Florida suggests this region and its local inhabitants, the Calusa, were affected by the Vandal Minimum climate. Drought and cooling may have been responsible for the Calusa people's abandonment of coastal southwest Florida by 750 AD. To provide a paleoclimate context during this time, we reconstructed the Vandal Minimum climate using high-resolution oxygen isotope records from otoliths (ear bones) of the hardhead catfish, *Ariopsis felis*, and shells from the southern hard clam, *Mercenaria campechiensis*. Four otoliths and eight shells from Calusa archaeological deposits dating between 450 and 750 AD were selected and microsampled for isotopic analysis. Climate reconstruction based on the isotopic ratios of archaeological otoliths and shells is in good agreement with archaeological evidence and climate conditions documented in Europe.

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LIST OF ABBREVIATIONS AND SYMBOLS

α	oxygen isotope fractionation factor
AD	Anno Domini
A. felis	*Ariopsis felis*
AMS	accelerator mass spectrometry
CALIB	calibration program for radiocarbon age
^{13}C	carbon isotope 13
^{14}C	radiocarbon isotope 14
Cal. IIA	cultural period of Caloosahatchee IIA
CIIA-A	Caloosahatchee IIA-*Ariopsis felis*
CIIA-M	Caloosahatchee IIA-*Mercenaria campechiensis*.
cm	centimeter
^{o}C	degrees Celsius
$25^{o}N$-$27^{o}N$	25 degrees North to 27 degrees North
$\Delta^{13}C$	carbon isotope 13 fractionation factor
$\delta^{13}C$	carbon isotope ratio
$\delta^{18}O$	oxygen isotope ratio
$\delta^{18}O_w$	oxygen isotope ratio of water
DIC	dissolved inorganic carbon
et al.	and others
FLMNH	Florida Museum of Natural History
HCO_3^-	bicarbonate

i.e.,	that is
M. camphechiensis	*Mercenaria campechiensis*
M. Mercenaria	*Mercenaria Mercenaria*
μg	microgram, 10^{-6} gram
mm	millimeter
NBS	National Bureau of Standard
n.d.	no date
NOSAMS	National Ocean Sciences Accelerator Mass Spectrometry
1σ	one sigma range
^{18}O	oxygen isotope 18
‰	per mil or parts per thousand
±	plus or minus
psu	practical salinity units
RC	Radiocarbon
SST	sea surface temperature
T	temperature
VPDB	Vienna Pee Dee Belemnite
VSMOW	Vienna Standard Mean Ocean Water

PREFACE

Understanding preindustrial climate change plays an important role in advancement of our knowledge of present global warming and the effects of human activities on climate change. Archaeological sites of coastal southwest Florida preserves abundant animal remains, providing an opportunity to study climate change in the preindustrial late Holocene and human response to these rapid environmental change events.

Previous archaeological investigation revealed a cold and dry climate with low sea level during 500-800 AD in southwest Florida (Walker, 2000). Both the timing and characteristics of this rapid climate change agree with the Vandal Minimum climate records in Europe. However, there are few climate proxy records for the Vandal Minimum in low latitude areas such as southwest Florida. Nonetheless, based on the work of Walker and Surge (2006), we can utilize high-resolution oxygen isotope proxies from the multi-taxa pair of archaeological *Ariopsis felis* otoliths (fish "ear bones") and *Mercenaria campechiensis* shells to reconstruct the climate change in southwest Florida to fill this gap in our knowledge.

The next chapter estimates seasonal temperature and precipitation change during the Vandal Minimum from oxygen isotope ratios of four archaeological otolith-shell pairs, and four individual archaeological shells. [This manuscript will be submitted to *The Holocene* and therefore follows the formatting of that journal.]

CHAPTER 1

OXYGEN ISOTOPE EVIDENCE FOR PALEOCLIMATE CHANGE DURING THE VANDAL MINIMUM CLIMATE EPISODE FROM *ARIOPSIS FELIS* OTOLITHS AND *MERCENARIA CAMPECHIENSIS* SHELLS, SOUTHWEST FLORIDA

Ting Wang

Department of Geological Sciences, University of North Carolina at Chapel Hill, Mitchell Hall, Campus Box # 3315, Chapel Hill, NC 27599, Email: twang@email.unc.edu

Donna M. Surge

Department of Geological Sciences, University of North Carolina at Chapel Hill, Mitchell Hall, Campus Box # 3315, Chapel Hill, NC 27599, Email: donna64@unc.edu

Karen J. Walker

Florida Museum of Natural History, University of Florida, PO Box 117800, Gainesville, FL 32611-7800, Email: kwalker@flmnh.ufl.edu

Abstract

Archaeological evidence from coastal southwest Florida suggests this region and its local inhabitants (the Calusa) were affected by drought and cooling during the Vandal Minimum climate episode (500-800 AD). To test this hypothesis, we reconstructed seasonal-scale climate conditions using the oxygen and carbon isotope ratios ($\delta^{18}O$ and $\delta^{13}C$) preserved in *Ariopsis felis* otoliths (fish "ear bones") and *Mercenaria campechiensis* shells.

Comparing $\delta^{18}O$ records from both species distinguish between cool versus warm and wet versus dry conditions. The $\delta^{18}O$ time series from four otoliths and eight shells indicate the winters in the beginning of the Vandal Minimum were about 5°C warmer than modern winters. Cooling of winter temperatures occurred in the early Vandal Minimum (500-600 AD) and late half of the middle Vandal minimum (650-700 AD). In addition, persistent dry summers were detected in the early Vandal Minimum (500-600 AD) and the late Vandal Minimum (700-750 AD). Our climate reconstructions based on isotopic data are in good agreement with archaeological observations and with the cool and dry conditions documented in Europe. Carbon isotope ratios from the archaeological otoliths and shells are approximately 2-4‰ more positive relative to the modern specimens. The difference in $\delta^{13}C$ values between the modern and archaeological specimens reflects the Suess effect due to postindustrial burning of fossil fuels and change of vegetation structure.

Keywords: oxygen and carbon isotopes, *Ariopsis felis*, *Mercenaria campechiensis*, Vandal Minimum, Calusa, southwest Florida, Suess effect

Introduction

With the present trend of global warming, understanding rapid climate change in the recent decades and the role of human activities in climate change is critically important (Bradley and Jones, 1993; Mann et al., 1995; 1998; Free and Robock, 1999; Crowley, 2000; Crowley and Lowery, 2000; Bauer et al., 2003; Osborn and Briffa, 2006). Abrupt climate change during the Holocene, and especially the late Holocene (i.e., the past 3000 years), has been targeted for investigation because of important events in human history that may further our understanding of human-climate interactions. Several rapid climate change events during the late Holocene have been identified, such as the Roman Warm Period (0-500 AD), the Vandal Minimum (also known as the Dark Age Cold Period) (500-800 AD), the Medieval Warm Period (800-1200 AD), and the Little Ice Age (1200-1550 AD) (Keigwin, 1996; Woodhouse and Overpeck, 1998; McDermott et al., 2001; Willard et al., 2001; Cronin et al., 2003; Carbotte et al., 2004). Among these events, the Little Ice Age, Medieval Warm Period and Roman Warm Period have received much attention; however, the Vandal Minimum has not been well studied due to the low resolution of proxy records in the previous studies and also relatively small change in climate compared with the climate change in the Medieval Warm Period and the Little Ice Age. To fill this knowledge gap, we deciphered high-resolution climate information preserved in archaeological otoliths (fish “ear bones”) and shells that were deposited during the Vandal Minimum by the local inhabitants of southwest Florida (the Calusa people).

We chose southwest Florida as our study area because this low-lying, estuarine region is sensitive to climate change and contains abundant biogenic carbonate remains. Furthermore, the ancient Calusa people inhabited this area from 0-1750 AD with periodic episodes of abandonment; therefore, this location has important archaeological value for studying human-climate relationships. The archaeological evidence suggests that the climate transition from the Roman Warm Period to the Vandal Minimum lowered the sea level, brought the drought in the interior South Florida and caused the seaward reoccupation of the Calusa people at coastal southwest Florida around A.D. 500; however, the cooling and persistent drought during the Vandal Minimum might have forced the Calusa people to abandon this area around A.D. 750 (Walker, 2000). Oxygen and carbon isotope ratios ($\delta^{18}O$ and $\delta^{13}C$) of fish otoliths and mollusc shells have been widely used in paleoclimate, paleoecological, and paleoproductivity studies (Krantz et al., 1987; Jones et al., 1989, 1990, 1996; Ivany et al., 2000; Wurster and Patterson, 2001; Surge and Walker, 2005, 2006; Fenger et al., 2007; Goewert and Surge, 2008). Archaeological shells and otoliths are particularly interesting because they preserve not only environmental and climate proxy data, but they also contain evidence of human behavior. Therefore, we deciphered climate proxy data from otoliths of the hardhead catfish *Ariopsis felis* and shells of the hard clam *Mercenaria campechiensis* to answer these questions: how long did cooling/drought last in the Vandal Minimum, how severe were these conditions, and how do the paleoclimate records compare with the archaeological evidence? To answer these questions, we compared isotopic records between modern and archaeological otoliths/shells from the Vandal Minimum, and also compared the reconstructed temperatures from archaeological otoliths/shells with the instrumental climate records.

Ecology of *Ariopsis felis* and *Mercenaria campechiensis*

The fish *Ariopsis felis* inhabits tropical to subtropical estuaries and coastal lagoons. It has a wide geographical range from Cape Cod, Massachusetts, to the Yucatan Peninsula (Muncy and Wingo, 1983). The adults prefer water temperature between 25°C and 36°C. When the water temperature exceeds 37°C or falls below 6°C, they will move away. Therefore, in winter and early spring, adult *A. felis* (~2 years old) live offshore to avoid the cold estuarine water, and in spring they migrate back to inshore estuaries to spawn (Jones et al., 1978). Otoliths form by the accretionary deposition of aragonite secreted by the endolymph in the inner ear. Because of its accretionary growth pattern, otoliths contain growth increments separated by prominent growth lines, which represent the cessation of aragonitic deposition during intervals of slow growth (Wurster and Patterson, 2001). We can estimate the seasonal range of growth temperature and productivity information from the isotope records preserved in otoliths. In the subtropical waters of southwest Florida, *A. felis* lives in normal marine salinity water at depths no deeper than 20m during winter months (Muncy and Wingo, 1983). This depth range is above the thermocline; therefore, $\delta^{18}O_{otolith}$ values record seasonal temperature variability rather than depth-related temperature changes.

Mercenaria campechiensis inhabits sandy or muddy sand sediment in the intertidal to subtidal zone, and is especially abundant in bays and estuaries (Kraeuter and Castagna, 2001). This species occurs in the warm- to cold-temperate biogeographic provinces from south Florida to southern New Jersey along the Atlantic coast of the United States and along the Gulf of Mexico coast (Merril and Ropes, 1967; Arnold et al., 1998; MacKenzie et al.,

2002). Optimal water temperature and salinity for growth ranges from 15-25°C and 20-30 psu (practical salinity units), respectively, and growth rate slows below 9°C and above 31°C or below 17 psu (Ansell, 1968; Kraeuter and Castagna, 2001). *M. campechiensis* shells are equivalved and ovoidly shaped. Each valve contains three aragonitic layers, one of which is formed by the concentric accretion of shell material along the valve margins, and two of which are formed on the shell's interior. This accretionary growth pattern is readily visible in cross-section. In addition to environmental conditions, ontogeny (i.e., age) can affect shell growth rate and the resultant growth patterns (Kraeuter and Castagna, 2001). Dark, translucent growth increments form during intervals of slowed growth; whereas light, opaque growth increments reflect intervals of fast growth (dark and light increments are observed under reflected light, whereas translucent and opaque increments are observed under transmitted light; see Jones and Quitmyer, 1996 for a detailed discussion of increment nomenclature). Arnold, et al. (1991) reported that *M. campechiensis* shells from the Indian River in Florida form dark increments (slow growth) from May to October when the water temperature is above 25°C, and light increments (fast growth) during the remainder of the year. They also observed that growth rate slows with ontogeny after five to six years of age.

Study Area

Coastal southwest Florida (25°N-27°N) (Figure 1) has a subtropical climate, a low-lying landscape and shallow, micro-tidal, inshore estuaries (Widmer, 1988; Surge and Walker, 2005). Therefore, the estuarine ecosystems and low-lying landscape are hypersensitive to climate change, sea level fluctuation, and storm frequency (Surge and Walker, 2005).

Impacts of these changes include shifts in salinity gradients that in turn effect the distribution of animals and biodiversity. Local archaeological deposits potentially capture these changes and resultant impacts. By collecting local estuarine animals and discarding their remains in revealing spatial and temporal patterns, these ancient human residents unknowingly recorded a rich archive of environmental change in this dynamic setting.

Today, this area is characterized by a wet and dry season as shown by the instrumental records of monthly average air temperature (from 1891-2007) and precipitation (from 1931-2007) at Fort Myers (www.ncdc.noaa.gov) (Figure 2). The coldest average monthly temperature is 17.4±1.7^{o}C, whereas the warmest average monthly temperature is 28.1±0.6^{o}C (Figure 2a). These data indicate that the winter temperatures have higher inter-annual variability than the summer temperatures. Surge and Walker (2005) documented that water temperature has similar seasonal variability as air temperature. Monthly accumulation of rainfall during the wet season (May-October) averages 181 mm/month, whereas the dry season (November-April) averages 50 mm/month (Figure 2b). Pine Island Sound receives limited freshwater from Pine Island (the focus of this study). Rainfall and runoff from Cape Coral provides most of the freshwater that enters Pine Island Sound (Rudolph, 2000). There may be some contribution of groundwater from shallow aquifer sources, although the water budget from this source is poorly understood. Regardless, we assume that seasonal rainfall largely controls the evaporation/precipitation budget in Pine Island Sound based on seasonal fluctuations in salinity (Surge and Walker, 2006).

Archaeological Context

Our study focuses on the Caloosahatchee area, where the socio-politically complex Calusa people inhabited the areas surrounding Pine Island Sound and Charlotte Harbor from approximately 0 AD to 1750 AD (Widmer, 1988; Marquardt and Walker, 2001). The Calusa were nonagricultural, and their diet consisted mainly of fish and shellfish supplemented by some land animals and plants. Therefore, the rich aquatic resources formed the basis of Calusa subsistence strategy, quite different from the typical adaptation associated with agriculture (Widmer, 1988).

According to the zooarchaeological evidence, the Calusa residents collected fish and shellfish along the shallow-water shoreline close to home (Wang and Raney, 1971; Walker, 1992). After consuming these organisms, the skeletal remains of the estuarine animals accumulated to form middens and mounds often in stratigraphic succession. In the absence of subsidence or tectonic uplift, these stratigraphic shell middens and mounds have the potential to accurately reflect the paleoenvrionmental and paleoecological changes during the late Holocene through the spatial change of the habitation and the temporal variation of animal diversity and abundance (Walker, 1992; Marquardt and Walker, 2001; Walker and Surge, 2006). Our specific study area is located at the Pineland site complex (see Walker, 1992; Marquardt and Walker, 2001 for a detailed description). Five cultural periods are preserved at this site (Table 1): Caloosahatchee late I (0-500AD); Caloosahatchee IIA (500-800 AD); Caloosahatchee IIB (800-1200 AD); Caloosahatchee III/IV (1200-1500 AD) and Caloosahatchee V (1500-1750 AD) (Walker and Surge, 2006). We investigated the zooarchaeological remains of

Caloosahatchee IIA, which more or less coincides with the cold climate episode documented in Europe, the Vandal Minimum (500-800 AD).

Methods

Dating of Archaeological Specimens

Following the approach of Walker and Surge (2006), our aim is to select otolith-shell pairs from the Caloosahatchee IIA (AD 500-800) cultural context housed in the zooarchaeological collections at the Florida Museum of Natural History (FLMNH) for isotopic analysis. To achieve the best spatial and temporal representation possible for the Vandal Minimum, a composite section representing Pineland's Caloosahatchee IIA chronostratigraphy was set up based on conventional radiocarbon and pottery dates (Walker and Marquardt, n.d.). From the composite section, we identified four otolith-shell pairs (otolith-shell identification numbers: CIIA-A2/CIIA-M2, CIIA-A7/CIIA-M7, CIIA-A8/CIIA-M8, and CIIA-A9/CIIA-M9; see Table 2 for corresponding FLMNH catalogue numbers) and analyzed an additional four shells (shell identification numbers: CIIA-M1, CIIA-M4, CIIA-M5, and CIIA-M6; Table 2). Shells were dated using AMS (accelerator mass spectrometry) at the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) Facility, Woods Hole Oceanographic Institute. Measured AMS ^{14}C ages of the archaeological shells were then calibrated in the program MARINE04 of CALIB 5.0.2 and corrected for global ocean reservoir effect (408 years), local reservoir effect (−5±20 years), and ^{13}C fractionation (Hughen et al., 2004; Stuiver et al., 2005). Finally, combining the stratigraphic order of archaeological proveniences and the conventional radiocarbon dates

with the calibrated AMS ^{14}C dates, the 50-year archaeological AD time ranges of the specimens were estimated (Table 2).

Microsampling and Isotopic Analysis

Besides the archaeological otoliths and shells from the FLMNH, we also analyzed one modern otolith (otolith identification number: MOD2002 collected on May 8, 2002) and two modern shells (shell identification numbers: 05PI05 and 05PI17, collected on June 8, 2005) from Pine Island Sound to compare the Vandal Minimum climate relative to present conditions.

A. felis otolith is small in size (~1cm in length) and was set in an epoxy resin cube to facilitate cutting and polishing. To get high-resolution samples, each otolith in this study was cut along the transverse plane (Figure 3a), and each shell was cut along the axis of maximum growth (Figure 3b). Cross-sections of otoliths and shells were then polished until the internal growth lines and increments were clearly visible. Before microsampling, the microstructure of all archaeological otoliths and shells was screened under a stereomicroscope to evaluate preservation of original aragonite. If original aragonite was present, we assumed the specimen was not diagenetically altered.

Otoliths were microsampled at 15-20 samples per year across the second to sixth years of growth to achieve submonthly resolution. Visible growth increments guided our sampling strategy. For *Mercenaria* shells, we microsampled the first 5 years of growth because growth rate slows down after 5-6 years of age (Jones and Quitmyer, 1996). Shells were

microsampled at 24-26 samples per year to achieve fortnightly resolution. The sampling resolution of shells was higher than that of the otoliths because the shells were larger with faster growth rates. Microsampling was performed on a Merchentek micromill fitted with a 0.3 mm dental burr. Each digitized drilling path produced approximately 20-40 μg of carbonate powder for isotopic analysis. Oxygen and carbon isotope ratios of carbonate powdered samples were measured using an automated carbonate preparation device (Kiel-III) coupled to a gas-ratio mass spectrometer (Finnigan MAT 252) housed at the University of Arizona. Powdered samples were reacted with dehydrated phosphoric acid under vacuum at 70°C for one hour. The isotope ratio measurement was calibrated based on repeated measurements of NBS-19 (National Bureau of Standard) and NBS-18. The precision of the measurements was ±0.1 ‰ for $\delta^{18}O$ (1σ) and ±0.06‰ for $\delta^{13}C$ (1σ). The results were reported in per mil units (‰) relative to the VPDB (Vienna Pee Dee Belemnite) standard.

Estimated Temperature

To reconstruct climate change during the Vandal Minimum, we use two approaches: (1) comparison of $\delta^{18}O$ and $\delta^{13}C$ values and estimated temperature between modern and archaeological shells and otoliths; and (2) comparison of estimated temperature based on $\delta^{18}O$ values of archaeological specimens to modern instrumental records. Estimated temperature was calculated using the procedures outlined by Surge and Walker (2005 and 2006). Following these previous studies, we used the equilibrium fractionation equation reported by Patterson et al. (1993) to calculate temperature from $\delta^{18}O_{otolith}$ values:

$$10^3 \ln\alpha = 18.56(10^3 T^{-1}) - 33.49$$

We used the equilibrium fractionation equation reported by Dettman, et al. (1999) as modified from Grossman and Ku (1986) to calculate temperature from $\delta^{18}O_{shell}$ values:

$$10^3 \ln\alpha = 2.559(10^6 T^{-2}) + 0.715$$

In both equations, α is the fractionation factor and T is temperature in Kelvin. The relationship between α and δ is:

$$\alpha = (\delta^{18}O_{arag}+10^3) / (\delta^{18}O_w+10^3)$$

where $\delta^{18}O_{arag}$ is the oxygen isotope ratio of aragonite and $\delta^{18}O_w$ is the oxygen isotope ratio of water, which are both reported relative to VSMOW (Vienna Standard Mean Ocean Water). Therefore, before employing the above equations, the measured $\delta^{18}O_{arag}$ (VPDB) must be converted to VSMOW scale using the equation reported by Gonfiantini, et al. (1995):

$$\delta^{18}O_{VSMOW} = 1.03091*\delta^{18}O_{VPDB} + 30.91$$

As discussed previously, southwest Florida has seasonal changes in temperature and precipitation (wet/dry seasons). Therefore, deconvoluting these two parameters using oxygen isotope ratios preserved in carbonate hard parts is challenging. However, Surge and Walker (2006) overcame this challenge by using a multi-taxa approach. Because of its seasonal

migration behavior, *A. felis* can provide winter temperature information because we can constrain $\delta^{18}O_w$ to marine seawater values (see ecology section). The $\delta^{18}O_w$ value of seawater in this region is approximately +1‰ (VSMOW) (Surge and Lohmann, 2002). During summer months, adult *A. felis* migrate into estuarine water having an average $\delta^{18}O_w$ value of approximately −1‰ (VSMOW) (Surge and Lohmann, 2002). *M. campechiensis* are sessile and inhabit estuarine-marine environments where, in this region, modern $\delta^{18}O_w$ varies between −1‰ and +1‰ (VSMOW) during the wet and dry seasons, respectively. We simplified the temperature estimates by assuming $\delta^{18}O_w$ is +1‰ (VSMOW) so that the estimated winter temperatures should be close to the actual temperature, whereas the estimated summer temperatures should be overestimated more or less, depending on the input of freshwater due to variations in precipitation resulting in more negative $\delta^{18}O_w$ values (Surge and Walker, 2005). This approach is justified because winter temperature varies from year to year (standard deviation = 1.7°C), whereas summer temperature does not vary much interannually (standard deviation = 0.6°C) (Figure 2a).

Results

Each archaeological otolith (CIIA-A9, CIIA-A8, CIIA-A7, CIIA-A2) has a temporal variation of $\delta^{18}O$ values following a sinusoidal trend, ranging from −2.3‰ to 0‰ (CIIA-A9), −3.1‰ to +1.4‰ (CIIA-A7),−2.3‰ to +0.7‰ (CIIA-A8), and −1.4‰ to +1.0‰ (CIIA-A2) (Figure 4). The variation of $\delta^{18}O$ values in the modern otolith (MOD2002) range from −3.0‰ to +0.6‰, consistent with the $\delta^{18}O$ range (−3.6‰ to +0.3‰) of the modern otolith reported by Surge and Walker (2005). The temporal variation of $\delta^{13}C$ values recorded in the

archaeological otoliths also follows a more or less sinusoidal pattern; however, the pattern is not in phase with $\delta^{18}O$ values (Figure 4). $\delta^{13}C$ values of the four archaeological otoliths range from −4.4‰ to +1.6‰ (CIIA-A9), −6.7‰ to −0.7‰ (CIIA-A7), −2.8‰ to +2.9‰ (CIIA-A8), −3.2‰ to +5.6‰ (CIIA-A2) (Figure 4). Those of the modern otolith range from −6.8‰ to −2.1‰ (Figure 4).

Oxygen isotope ratios of the archaeological shells range from −2.0‰ to +0.8‰ (CIIA-M9), −2.1‰ to +0.7‰ (CIIA-M7), −2.1‰ to +1.2‰ (CIIA-M6), −3.4‰ to +0.7‰ (CIIA-M4), −3.0‰ to +0.5‰ (CIIA-M8), −1.9‰ to +1.8‰ (CIIA-M1), −2.4‰ to +0.5‰ (CIIA-M2), −1.8‰ to +1.1‰ (CIIA-M5) (Figure 5). $\delta^{18}O$ values for the two modern shells range from −2.6‰ to +1.0‰ (05PI05) and from −2.7‰ to +0.7‰ (05PI17) (Figure 5). $\delta^{13}C$ values of the archaeological shells range from −0.2‰ to +1.0‰ (CIIA-M9), −1.3‰ to +1.1‰ (CIIA-M7), −1.3‰ to +0.8‰ (CIIA-M6), −1.4‰ to +1.4‰ (CIIA-M4),−1.0‰ to +0.8‰ (CIIA-M8), −1.0‰ to +1.1‰ (CIIA-M1), −0.7‰ to +1.0‰ (CIIA-M2), −0.6‰ to +1.4‰ (CIIA-M5) (Figure 5). $\delta^{13}C$ values of the two modern shells range from −0.9‰ to −3.5‰ (05PI05) and from −1.4‰ to −4.1‰ (05PI17) (Figure 5).

To reconstruct climate, we estimated the coldest and warmest temperature recorded in each archaeological otolith and shell (Figure 6 and 7). The archaeological otoliths record the following lowest winter temperatures: 21.9°C (CIIA-A9), 15.1°C (CIIA-A7), 18.4°C (CIIA-A8) and 17.0°C (CIIA-A2); and the following warmest temperatures: 32.8°C (CIIA-A9), 37.2°C (CIIA-A7), 33.1°C (CIIA-A8) and 28.4°C (CIIA-A2) (Figure 6). The archaeological shells record the following lowest winter temperatures: 18.1°C (CIIA-M9), 18.5°C (CIIA-

M7), 16.1°C (CIIA-M6), 18.4°C (CIIA-M4), 19.4°C (CIIA-M8), 13.7°C (CIIA-M1), 19.3°C (CIIA-M2) and 16.8°C (CIIA-M5); and the following warmest summer temperatures: 31.6°C (CIIA-M9), 32.1°C (CIIA-M7), 31.8°C (CIIA-M6), 38.6°C (CIIA-M4), 36.6°C (CIIA-M8), 31.0°C (CIIA-M1), 33.3°C (CIIA-M2) and 30.6°C (CIIA-M5) (Figure 7).

Discussion

Isotopic geochemistry of otoliths

Previous studies have shown that otolith carbonate precipitates in oxygen isotope equilibrium with ambient water (Kalish, 1991; Iacumin et al., 1992; Patterson et al., 1993; Thorrold et al., 1997). Kalish (1991) and Iacumin et al. (1992) reported that the $\delta^{18}O$ values of otolith carbonate are close to equilibrium with the ambient water because the incorporation of oxygen isotopes during otolith precipitation is not affected by kinetic/hydration-hydroxylation processes. Consequently, the oxygen isotope ratios of otoliths can serve as a proxy for estimating temperature (±<1°C), provided the $\delta^{18}O_w$ of the surrounding environment is known (Patterson et al., 1993; Thorrold et al., 1997). Surge and Walker (2005) evaluated the $\delta^{18}O$ values of modern *A. felis* otoliths and determined that the fractionation equation by Patterson et al. (1993) is best suited for this species.

In our study, modern and archaeological otoliths record seasonal variation in $\delta^{18}O$ values (Figure 4). The most positive $\delta^{18}O$ values represent cold winter temperature, whereas the most negative $\delta^{18}O$ values represent warm summer temperature. Compared with the average winter temperature in the past century (Figure 6), the winter temperature reconstructed from

modern otolith MOD2002 is warmer than the average winter temperature. The winter temperatures estimated from archaeological otoliths are also no colder than the average winter temperature, except the first winter of CIIA-A7. This observation implies that *A. felis* otolith has the potential of not being able to record the coldest winter temperature and should be treated with caution when applied in winter temperature reconstruction.

In addition to seasonal fluctuation, variation in $\delta^{18}O_{otolith}$ values provide ontogenetic information. In the $\delta^{18}O_{otolith}$ profiles with well-defined seasons, there are more $\delta^{18}O_{otolith}$ values recorded in warm intervals than in cold intervals, suggesting that growth rate of otolith is high in summer and slows significantly in winter. The winter growth cessation due to slow growth rate increases the time averaging of winter cold temperatures and explains the potential of otoliths not recording coldest winter temperatures. Patterson et al. (1993) encountered the same problem when they used freshwater otoliths to reconstruct cold temperature in winter. However, this seasonal growth pattern is not obvious in the final two years of MOD2002 and the last year of CIIA-A2, which reflects that growth rate of otolith is not only determined by temperature but also affected by biological factors such as food resources.

Unlike the equilibrium isotope effects between temperature and the oxygen isotope of otolith aragonite, the equilibrium fractionation of carbon isotopes in biogenic carbonate is easily interrupted by biological growth or activities resulting in vital effects. In fact, carbon isotope disequilibrium is a very common phenomenon and occurs in most biogenic carbonates to varying degrees. McConnaughey (1989) classified the isotopic disequilibria

into two primary patterns: kinetic disequilibrium and metabolic disequilibrium. Kinetic disequilibrium is caused by the isotopic discrimination against heavy isotopes such as ^{18}O and ^{13}C during the process of formation and diffusion of HCO_3^-. As a result, the biogenic carbonates are depleted in ^{18}O and ^{13}C simultaneously (Turner, 1982; McConnaughey, 1989; Kalish, 1991; Thorrold et al., 1997). Metabolic disequilibrium results from the incorporation of carbon produced by metabolic activities such as respiration or photosynthesis. Therefore, it is strongly associated with biological activities and tends to affect principally carbon isotope fractionation without affecting oxygen isotope equilibrium (McConnaughey, 1989; Kalish, 1991; Thorrold et al., 1997).

To evaluate the controls on the carbon isotope ratios of otolith aragonite, Thorrold et al. (1997) raised juvenile *Micropogonias undulatus* in temperature-controlled tanks. They found a statistically significant correlation between temperature and $\Delta^{13}C$, where $\Delta^{13}C$ represented the correction of the otolith $\delta^{13}C$ data for variations in the $\delta^{13}C$ of dissolved inorganic carbon (DIC) in the individual tanks ($\Delta^{13}C = \delta^{13}C_{otolith} - \delta^{13}C_{DIC}$). However, they observed that the $\delta^{13}C_{otolith}$ values were depleted by 5‰ relative to predicted values at 25ºC due to a vital effect. They evaluated whether kinetic or metabolic processes controlled this vital effect, and their findings suggested that metabolic, rather than kinetic, isotope effects produced the carbon isotope disequilibrium.

We did not observe evidence of a kinetic isotope effect as described by McConnaughey (1989), which is consistent with the findings of Thorrold et al. (1997). The carbon isotope ratios of *A. felis* otoliths likely result from the combination of $\delta^{13}C_{DIC}$ variation and metabolic

isotope effects. The combination of these factors may explain the absence of a seasonal trend in the $\delta^{13}C_{otolith}$ values. Nonetheless, comparison of $\delta^{13}C$ values within and among modern and archaeological otoliths provide informative trends related to ontogenetic change and possibly to the effects of industrialization (i.e., the Suess effect discussed later in this paper). We observed overall increases in the general trend of $\delta^{13}C_{otolith}$ values from juvenile to adult stages in four of the otoliths (specimens MOD2002, CIIA-A2, CIIA-A8, and CIIA-9) likely related to ontogenetic change and metabolic isotope effects. This finding is in agreement with the observation by Kalish (1991) that juvenile fish have high metabolic rates and incorporate more light carbon isotopes by consuming food items from lower trophic levels than adult fish. This conclusion cannot explain the decreasing trend observed in specimen CIIA-A7. We hypothesize that the $\delta^{13}C_{DIC}$ of the estuarine water decreased largely in the third growth year, which caused the significant decrease in $\delta^{13}C$ values, counteracting the increase of $\delta^{13}C$ produced by metabolic isotope effects.

Isotope Geochemistry of Shells

Earlier studies reported that oxygen isotope ratios in *Mercenaria mercenaria* and *M. campechiensis* can be used to reconstruct ambient environmental conditions (Elliot et al., 2003; Surge and Walker, 2006; Surge et al., 2008). However, $\delta^{18}O_w$ of estuarine water where *M. campechiensis* lives is difficult to constrain, and we simplified the temperature estimates by assuming $\delta^{18}O_w$ is +1‰ (VSMOW) as previously stated. The estimated temperatures from modern shells (05PI05 and 05PI17) have the winter temperatures close or equal to the average winter temperature in the past century except the first winter of 05PI05 (Figure 7), indicating that the approximation of winter $\delta^{18}O_w$ in our study area is acceptable. The

average winter temperature of 05PI05 (19.6^{o}C) and the average winter temperature of 05PI17 (19.1^{o}C) are both in the range of average winter temperature in the past century, which suggests that error from the approximation can be reduced by averaging winter temperatures of successive years. The summer temperature of modern shells estimated from $\delta^{18}O_{shell}$ and $\delta^{18}O_{w}$ (+1‰) is overestimated 3-7°C compared with the average summer temperature in the past century (Figure 7), indicating that $\delta^{18}O_{w}$ is 0.8-1.8‰ lighter than the assumed $\delta^{18}O_{w}$ (+1‰) because a 0.25‰ change in $\delta^{18}O_{w}$ can cause a 1.1^{o}C difference (Gillikin et al., 2005). Therefore, the large range of summer $\delta^{18}O_{w}$ makes accurate estimation of summer temperatures impossible. Nonetheless, based on the comparison of estimated summer temperature between modern shells and archaeological shells, we can predict how the precipitation of the Vandal Minimum is different from today.

Combining oxygen isotope ratios with incremental growth increment analysis (sclerochronology) provides information on seasonal changes between slow and fast shell growth rates. Previous studies reported that *Mercenaria* shells from subtropical latitudes form dark growth increments during the summer reflecting summer growth cessation (Jones and Quitmyer, 1996; Quitmyer et al., 1997; Arnold et al., 1998; Elliot et al., 2003; Surge and Walker, 2006; Surge et al., 2008). In this study, modern shells and most growth years of the archaeological specimens form dark growth increments that coincide with the most negative oxygen isotope ratios (Figure 7). This pattern represents summer growth cessation and is consistent with previous studies. However, dark disturbance increments observed in CIIA-M2 and CIIA-M1 do not coincide with warm summer temperatures (Figure 7), and were likely produced by other biological factors, like food availability, predation or reproduction.

Unlike the equilibrium precipitation of $\delta^{18}O_{shell}$ values, carbon isotope ratios of bivalve shells are determined by $\delta^{13}C_{DIC}$ values of the ambient water and metabolic isotope effects. Kinetic effects can be ignored in *M. campechiensis* shells because kinetic effects influence oxygen isotope equilibrium and carbon isotope equilibrium at the same time. As *M. campechiensis* precipitates its shell in oxygen isotope equilibrium with surrounding water, the kinetic effect should be minimal (Gillikin et al., 2007). Understanding the controls on the variation of the carbon isotope time series remains challenging given that 5-35% of the carbon can be metabolically derived (Gillikin, et al. 2007). Surge and Walker (2006) also observed that variation of $\delta^{13}C_{shell}$ lacked reproducibility among modern *M. campechiensis* individuals growing during the same time and at the same location near our study area. Due to these complexities in interpreting $\delta^{13}C_{shell}$ of *M. campechiensis*, we cannot explain the temporal change of $\delta^{13}C_{shell}$ observed in the modern shells and archaeological shells. Nonetheless, a negative offset of modern shells relative to the archaeological is observed which may be explained by Suess effect and will be discussed in detail below.

Reconstructed Temperature and Precipitation

In order to decipher the isotopic records to reconstruct climate change during the Vandal Minimum, we used two approaches. First, we compared the estimated winter temperatures with the average winter temperature from modern instrumental records measured over the last century (i.e., 17.4±1.7^{o}C). This approach is justified based on the observations reported by Walker and Surge (2006). Walker and Surge (2006) estimated winter temperatures from modern shells and otoliths agree with instrumental measurements. Second, we compared the

estimated summer temperatures from modern shells and otoliths with the estimated summer temperatures from archaeological shells and otoliths and with the modern instrument records (average temperature over the last century 28.1±0.6^{o}C) to predict the summer precipitation change in the Vandal Minimum. We justified this approach based on the observations of Surge and Walker (2006) that overestimated summer temperatures (i.e., temperatures that are unrealistically high) reflect a decrease in $\delta^{18}O_w$.

We observed warming and cooling trends during winter in the archaeological otoliths (Figure 6). The earliest otolith (CIIA-A9; 450-500 AD) records average winter temperature of 22.5±0.4^{o}C, which is as much as 5°C warmer than the instrument records. A subsequent cooling that falls within modern values is recorded in otolith CIIA-A7 (500-550 AD; average winter temperature of 18.2±1.6^{o}C). Otolith CIIA-A8 (600-650 AD) records a slight warming above modern values with an average winter temperature of 20.3±1.0^{o}C. Another relative cooling is recorded in otolith CIIA-A2 (650-700 AD), having an average winter temperature of 17.8±0.3^{o}C which also falls within modern values.

Most of the archaeological shells fall within or are slightly warmer than modern instrument records. Only one shell (CIIA-M1; 650-700 AD) records extremely cold average winter temperature of 15.0±0.6^{o}C, which is ~2°C colder than the lower limit of the modern recorded average winter temperature (Figure 7; Table 3). In comparison with the otolith pairs, only one shell (CIIA-M8) is in agreement with its otolith pair (CIIA-A8). One possible explanation for the lack of agreement is that otolith-shell pairs do not grow during exactly the same years. Alternatively, because *Mercenaria* are sessile, they may be influenced by slight

changes in $\delta^{18}O_w$ within the estuary. Gillikin et al. (2005) reported that a small change in $\delta^{18}O_w$ by 0.25‰ can result in a 1.1ºC error in temperature estimation based on the $\delta^{18}O_{shell}$ of the estuarine bivalve shells, *Saxidomus giganteus*. Nonetheless, our data show that most of the Vandal Minimum during winter months was not very different than today.

To reconstruct environmental conditions during the summer wet season, we calculated temperature assuming $\delta^{18}O_w$ of +1‰ and compared estimated temperature between archaeological and modern specimens and with the modern instrument records (Figure 6). The modern otolith (MOD2002) records an average mean summer temperature of 29.0±1.5^{o}C, which is warmer than the instrument record because estuarine water is more negative during the summer wet season. This finding is consistent with summer temperature estimates from a modern otolith reported by Surge and Walker (2005). We expect this overestimation of temperature because *A. felis* spends its summer reproductive season in estuarine water that is more negative than the assumed $\delta^{18}O_w$ of +1‰. Therefore, we can use the relationship between estimated temperature from modern otoliths and the summer temperature from the instrument records to interpret data from the archaeological otoliths. Calculated temperatures during the first summer recorded in otoliths CIIA-A9 (32.8^{o}C) and CIIA-A8 (33.1^{o}C) are overestimated by several degrees relative to the modern otoliths. Therefore, they represent summer conditions wetter than today. The remaining summers recorded in otoliths CIIA-A9 and CIIA-A8 are similar to those from the modern otoliths and represented summers similar to today. Summer temperatures calculated from otoliths CIIA-A7 are highly variable from summer to summer. Estimated temperature for the first summer is 24.5^{o}C, which is ~4ºC colder than modern values. We interpreted this result as extremely

dry conditions (i.e., elevated $\delta^{18}O_w$ due to evaporation). The second summer records temperatures similar to modern conditions (28.7°C); however, estimated temperature for the third summer is very high (37.2°C) representing extremely wet conditions. The average summer temperature of CIIA-A2 is 27.0±0.5°C, indicating slightly dry summers.

We compared average summer temperature between modern and archaeological shells. As with the otoliths, we assumed a $\delta^{18}O_w$ of +1‰ which resulted in overestimated summer temperatures in the modern shells (specimens 05PI05: 33.3±1.4 and 05PI17: 33.9±1.1) as predicted (Figure 7). Seven of the archaeological shells (specimens CIIA-M9, CIIA-M7, CIIA-M6, CIIA-M8, CIIA-M1, CIIA-M2, and CIIA-M5) record colder summer temperatures than the modern shells, representing drier summers than today (Table 3). Shell CIIA-M1 records the driest summers. Only the third and the fourth summer from shell CIIA-M4 and the first summer from shell CIIA-M8 are wetter than modern (i.e., warmer estimated temperatures). In comparing the shell and otolith data, estimated summer conditions are consistent within otolith-shell pair CIIA-A2/CIIA-M2 and CIIA-A8/CIIA-M8. However, estimated summer conditions are inconsistent within otolith-shell pairs CIIA-A9/CIIA-M9 and CIIA-A7/CIIA-M7. The inconsistency between these two otolith-shell pairs can be explained by the same reasons outlined above for estimated winter temperatures.

We summarized our findings by plotting estimated winter and summer temperatures in chronological order (Figure 8). Based on the above observations, we conclude that the winter temperature of the Vandal Minimum was not significantly different from today. We detect persistent drought conditions during summer months that are observed in most

archaeological otoliths and shells. The fluctuations of winter temperature and summer precipitation generally agree with the archaeological evidence (Appendix A; Walker and Marquardt, n.d.). According to Walker and Marquardt (n.d.), the transition between the end of Roman Warm Period and the beginning of the Vandal Minimum (the time of otolith-shell pair CIIA-M9/CIIA-A9) was the warmest and wettest time with high sea level and therefore high-elevation human habitation. The average winter temperature of otolith CIIA-A9 is indeed the warmest in the Vandal Minimum. However, neither shell CIIA-M9 nor otolith CIIA-A9 suggests that this interval was the wettest part of the Vandal Minimum. The early Vandal Minimum (500-600AD), the time of CIIA-M7/CIIA-A7, CIIA-M6, and CIIA-M4, is thought to be the first cold episode of the Vandal Minimum when many ducks such as the lesser scaup (*Aythya affinis*) migrated far to the south (in normal winters, many migratory ducks fly to Maryland and the Mississippi Delta region) (Walker, 2000). The decreasing winter temperatures recorded in otolith CIIA-A7 relative to CIIA-A9 and in shell CIIA-M6 compared to CIIA-M7 are consistent with the archaeological evidence. Moreover, during the time intervals represented by otolith-shell pair CIIA-A7/CIIA-M7 and shell CIIA-M6, summers were dry with low-elevation human habitation. This observation is supported by the dry summers recorded in shells CIIA-M7 and CIIA-M6. Between 600-650 AD, the time of CIIA-M8/CIIA-A8, the environment was warm (few migratory ducks) and wet (high abundance of estuarine ribbed mussels, *Geukensia demissa*). Between 650-700AD, the time of CIIA-M1 and CIIA-M2/CIIA-A2, a second cooling interval occurred identified by migratory duck remains and supported by the decreasing winter temperatures from shells CIIA-M8 to CIIA-M1. During 700-750 AD, dry conditions were characterized by a change in the fuel wood used by the Calusa people from mangrove to pine. Our data from shells

CIIA-M2 to CIIA-M5 support this interpretation. Based on our results and the archaeological evidence, we suggest that climate conditions during the Vandal Minimum in southwest Florida is characterized by cooling during 500-600 AD and 650-700 AD and dry summer conditions during 500-600 AD and 700-750 AD. We also infer that the dry summers resulted in a persistent drought coincident with low sea level (Walker et al., 1994). These conditions may have forced the Calusa people to abandon their residence in southwest Florida around 750 AD.

Suess Effect

Carbon isotope ratios of otoliths and shells show an overall negative shift from the Vandal Minimum to today. The carbon isotope records of the archaeological otoliths range from −4.4‰ to +5.6‰ (except CIIA-A7 ranged from −6.7‰ to −0.7‰), whereas the modern otolith (MOD2002) range from −6.8‰ to −2.1‰ (Figure 9). The carbon isotope records of the archaeological shells range from −1.4‰ to +1.1‰ whereas the modern shells (05PI05, 05PI17) range from −4.1‰ to −0.9‰ (Figure 10). There is a 1.4-3.8‰ difference in average $\delta^{13}C_{otolith}$ values between the archaeological otoliths and the modern otolith, and a 2.0-3.0‰ difference in average $\delta^{13}C_{shell}$ between the archaeological shells and the modern shells (Table 3). Under the assumption that the metabolic effect of shells and otoliths did not change from the Vandal Minimum to present, this negative shift between the archaeological specimens and the modern specimens is mainly contributed by the negative shift of $\delta^{13}C_{DIC}$. Both offsets are close to that observed by Surge et al. (2003) based on $\delta^{13}C$ values recorded in pre-industrial subfossil oyster shells relative modern oyster shells from the Ten Thousand Islands

region of southwest Florida. They concluded that the negative shift was derived from the change of freshwater input, the anthropogenic carbon sources (Suess effect), and vegetation types C_4 to C_3 plants (Surge et al., 2003). In our study, changes in freshwater input are not likely to be the cause, otherwise a similar negative offset in $\delta^{18}O$ values would have been observed between the archaeological and modern specimens. The anthropogenic activities of burning fossil fuels have depleted the $\delta^{13}C$ in the reservoirs of atmosphere and ocean due to the uptake of light carbon isotope from CO_2 produced by fossil fuels (Bacastow et al., 1996). The above process of ^{13}C depletion is called the Suess effect which has been detected in sponges, corals, oysters and other biologic carbonate skeletons (Nozaki et al., 1978; Druffel and Benavides, 1986; Bohm et al., 2002; Surge et al., 2003; Butler et al., 2009). However, the Suess effect can only explain at most a 1-1.5‰ negative shift. A change in vegetation type from terrestrial C_4 plants to C_3 plants may have contributed to the rest of the offset.

Conclusions

Although reconstructing the temperature change from the hard part remains of estuarine molluscs and fish is difficult because of seasonal fluctuation of $\delta^{18}O_w$ in coastal southwest Florida, a multi-taxa approach has provided an effective way to interpret the $\delta^{18}O$ results (Walker and Surge, 2006). Our study derived temporal shifts in temperature and precipitation during the Vandal Minimum in southwest Florida from the four otolith-shell pairs (CIIA-A/M 9,7,8,2) and another four shells (CIIA-M 6,4,1,5). The reconstructed climate information from the oxygen isotope values confirmed the existence of cooling and persistent

drought during the Vandal Minimum, and provided insights into the impact of climate change on the Calusa people.

The fluctuation between the warm, wet climate and the cool, dry climate during the Vandal Minimum may have been influenced by ENSO (El Niño Southern Oscillation) conditions. Longer and more successive $\delta^{18}O$ records will allow us to better evaluate this mechanism influencing climate patterns of the past.

Our study also detected the Suess effect by comparing the $\delta^{13}C$ results between modern and archaeological specimens, confirming the effect of industrialization on the environment. However, to more fully evaluate the significance of the Suess effect in the $\delta^{13}C_{DIC}$ change in the study area, the ecological history of local vegetation structure is needed.

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Table 1 Time scale for the archaeological periods of the Calusa society (Tanner, 1991; Walker et al., 1994; Walker and Surge, 2006).

	Archaeological Periods	Climate & Culture Changes	
AD 1500-1750	Caloosahatchee V	1750 AD	demise of Calusa due to the warfare, disease and slavery;
		~ 1710 AD	abandonment;
		1500-1600 AD	stable climate, Calusa society broadened their control over the south Florida;
AD 1200-1500	Caloosahatchee III/IV	1200-1500 AD	Little Ice Age, low sea level/water salinity, Calusa community developed rapidly, forming the major Calusa center.
AD 800-1200	Caloosahatchee IIB	800-1200 AD	Medieval Warm Period, high sea level/storms;
		950 AD	resettlement;
AD 500-800	Caloosahatchee IIA	750 AD	abandonment;
		500-800 AD	Vandal Minimum, low sea level/drought;
		500-550 AD	resettlement;
AD 0-500	Caloosahatchee I-late	400 AD	abandonment;
		350-400 AD	Roman Optimum, high sea level/storms;
		100-350 AD	occupation intensified;
		~ 0 AD	first occupied;

Table 2 Time range of the archaeological shells (Walker and Marquardt, n.d.)

Specimen No.	FLMNH-ANT Catalog No.	NOSA MS No.	Uncorrected AMS ^{14}C Age (years BP)	$\delta^{13}C$ (‰)	AMS Date (AD, 1-sigma range)	Chrono-stratigraphic Range (AD)
CIIA-M5	*CIIA-M5:* 90-3-27	OS-54179	1750±35	0.59	610-680	700-750
CIIA-M2	*CIIA-M2*: 90-3-53-1/4b	OS-54155	1850±40	0.65	490-610	650-700
CIIA-M1	*CIIA-M1:* 90-3-54-1/1	N/A	N/A	N/A	N/A	650-700
CIIA-M8	*CIIA-M8*: 90-3-57-1/1	OS-54182	1740±35	0.61	620-690	600-650
CIIA-M4	*CIIA-M4:* 95-3-6	OS-54178	1870±30	1.02	480-580	550-600
CIIA-M6	*CIIA-M6*: 92-24-2	OS-54180	1930±40	0.83	420-540	500-550
CIIA-M7	*CIIA-M7:* 95-3-31/5	OS-54181	1970±35	0.67	350-470	500-550
CIIA-M9	*CIIA-M9*: 2003-38-8/2/5	OS-54183	1890±30	0.93	460-560	450-500

Table 3 Average temperatures and carbon isotope ratios of modern and archaeological shells and otoliths.

Specimen No.	Average temperatures with standard errors (winter; summer) (°C)	$\delta^{13}C_{shell}$ (‰)	Specimen No.	Average temperatures with standard errors (winter; summer) (°C)	$\delta^{13}C_{otolith}$ (‰)
05PI05	19.6±2.2; 33.3±1.4	−2.1±0.7	MOD2002	20.5±0.5; 29.0±1.5	−4.2±0.9
05PI17	19.1±0.7; 33.9±1.1	−2.5±0.7			
CIIA-M5	18.2±0.6; 29.1±0.7	0.3±0.4			
CIIA-M2	20.2±0.4; 31.6±0.8	0.2±0.4	CIIA-A2	17.8±0.3; 27.0±0.5	−0.4±2.2
CIIA-M1	15.0±0.6; 27.7±0.8	0.1±0.5			
CIIA-M8	20.0±0.2; 31.7±1.7	−0.1±0.4	CIIA-A8	20.3±1.0; 30.3±1.4	−0.4±1.6
CIIA-M4	20.6±1.5; 34.2±1.3	0.5±0.5			
CIIA-M6	19.0±1.3; 29.6±0.9	−0.1±0.4			
CIIA-M7	20.6±1.1; 30.7±0.8	0.1±0.4	CIIA-A7	18.2±1.6; 30.2±3.7	−2.8±1.5
CIIA-M9	18.4±0.3; 29.6±0.8	0.5±0.3	CIIA-A9	22.5±0.4; 29.7±1.1	−0.7±1.6

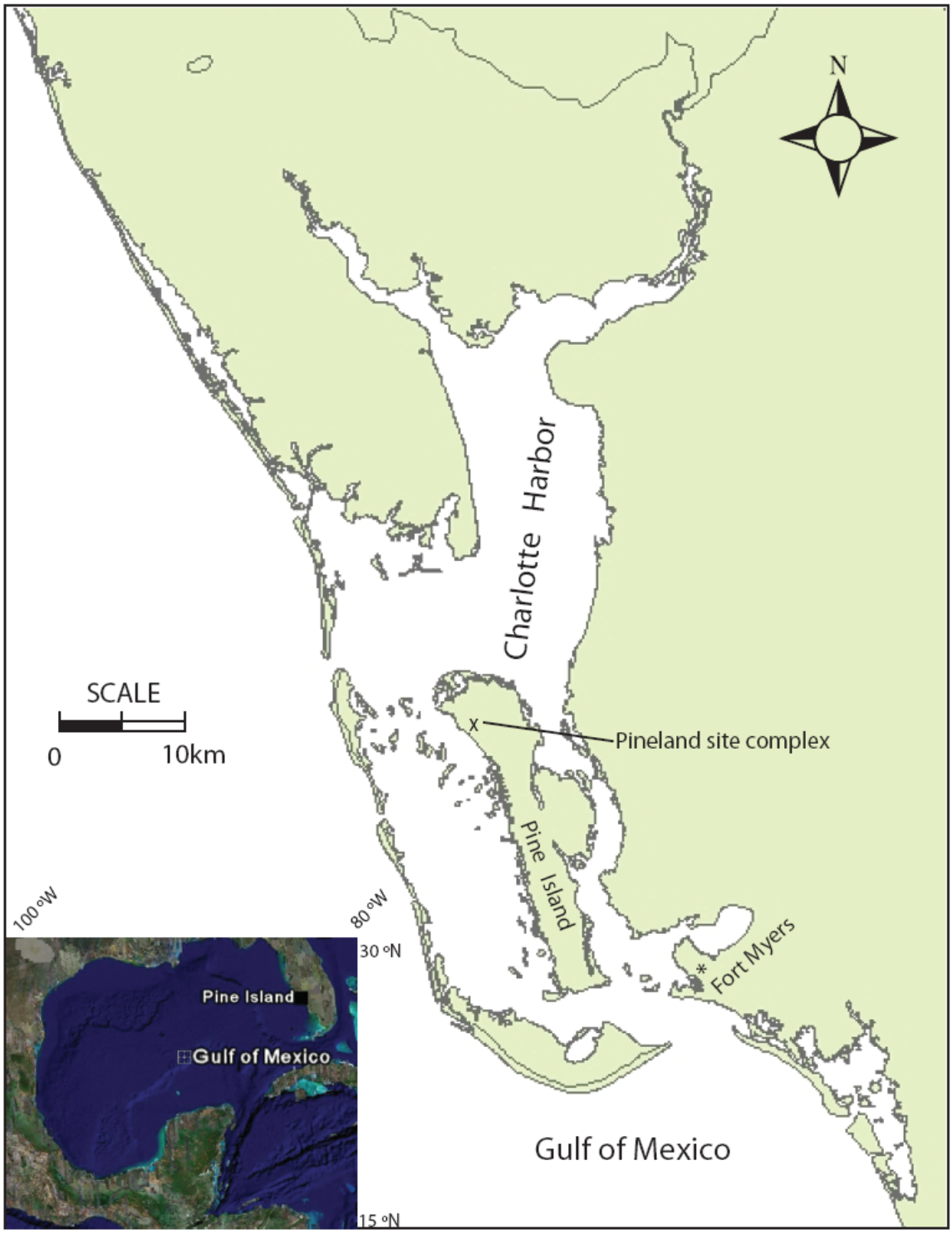

Figure 1 Map of the study area in southwest Florida, United States. An "x" identifies the major archaeological site "Pineland site complex", which is located on the northwestern shore of Pine Island. A "*" refers to the location of Fort Myers.

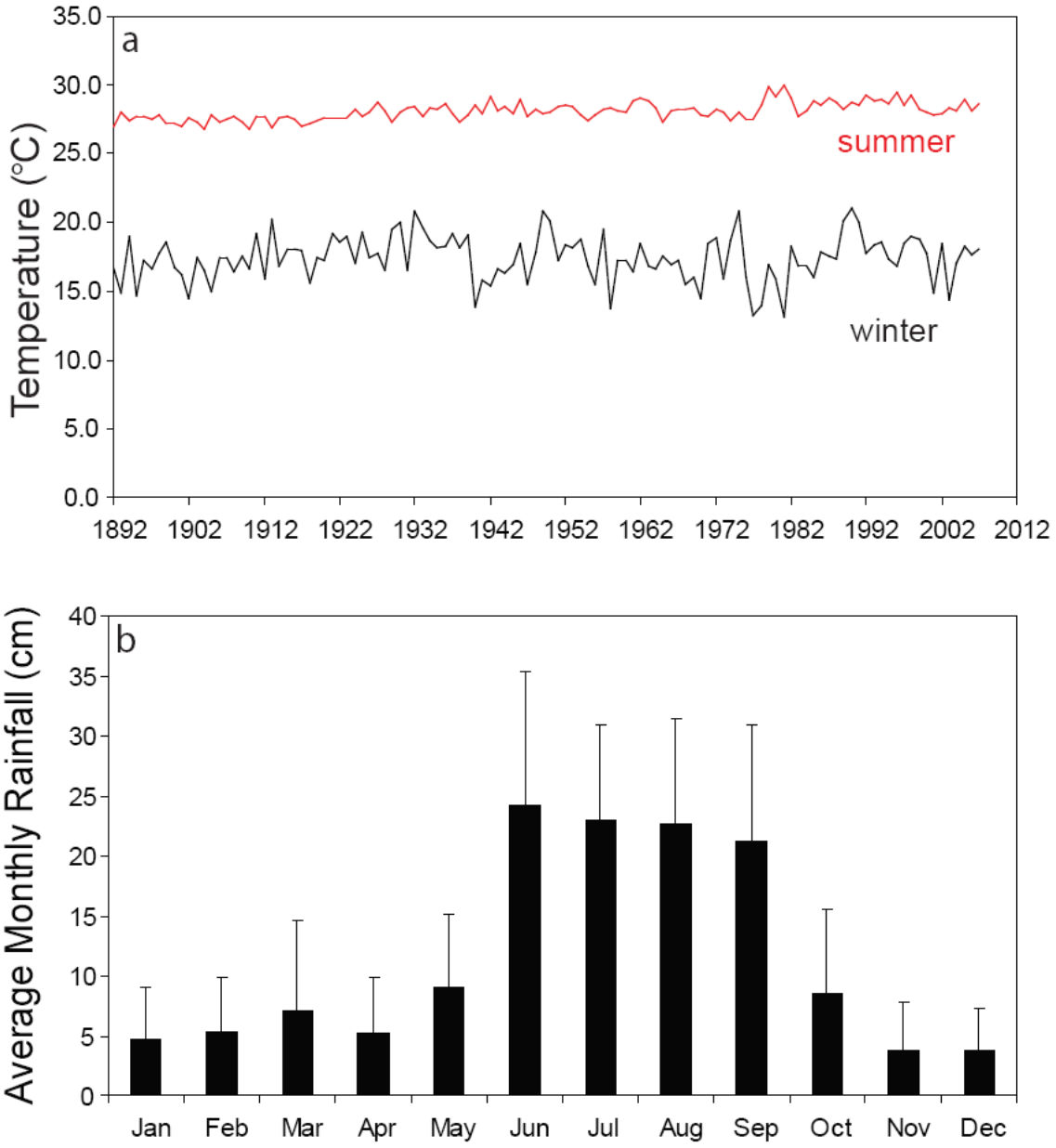

Figure 2 Modern climate records in southwest Florida. (a) Average monthly air temperature for the warmest month (red line) and coldest month (black line) of the year for the period 1891 to 2007 measured at Fort Myers, Florida. (b) Monthly rainfall amounts averaged over the period 1931 to 2007 measured at Fort Myers, Florida. The lines above the vertical bars represent standard deviations. Data provided by the National Climate Data Center (www.ncdc.noaa.gov).

Figure 3 Cross-sections of archaeological otolith and shell. (a) Photomicrograph of the cross-section of *A. felis* otolith CIIA-A8 (lapilli) cut along the transverse plane; Bar=1mm. (b) Photograph of the polished *M. campechiensis* shell cross-section of CIIA-M8 cut along the plane of maximum growth from umbo (left) to commissure (right); Bar=1cm.

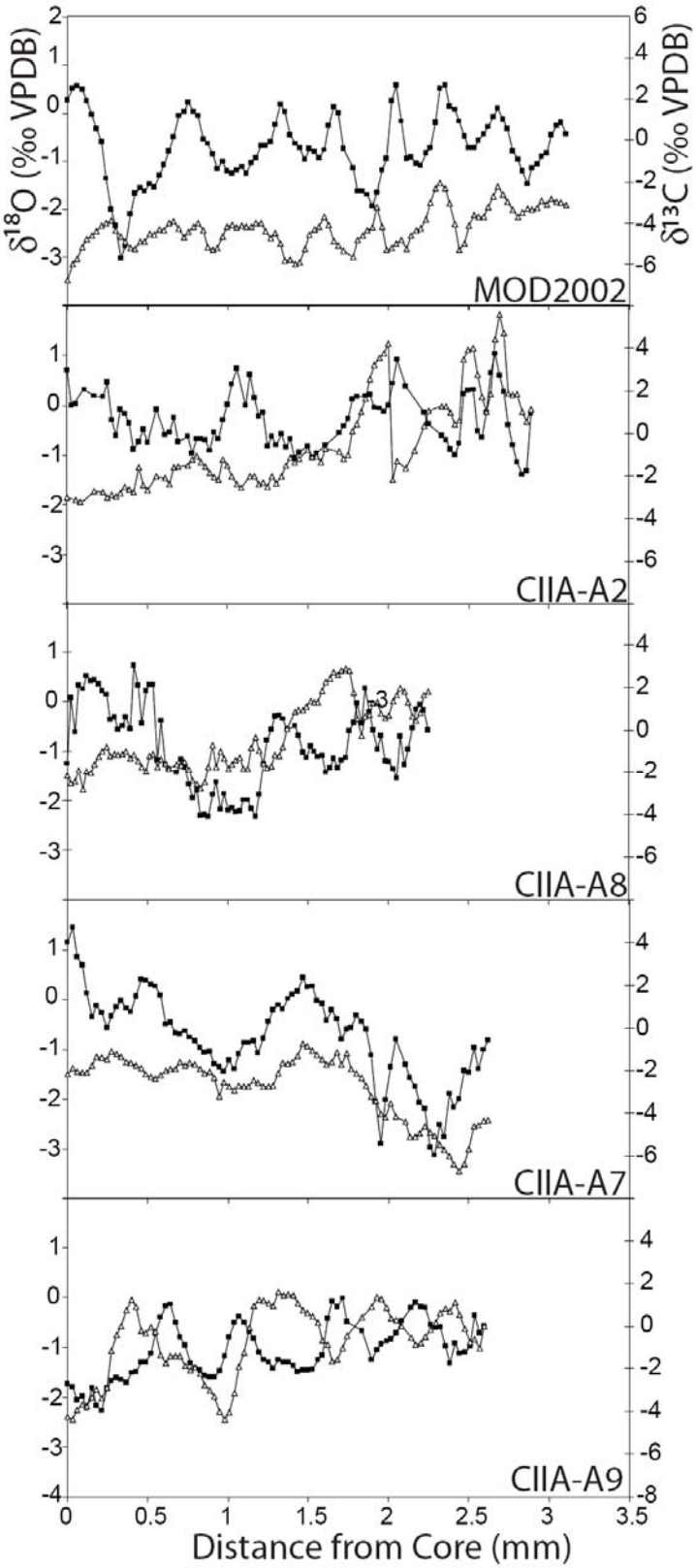

Figure 4 Variation of $\delta^{18}O$ and $\delta^{13}C$ values of archaeological and modern otoliths versus distance from the core toward the growth margin (i.e., growth direction is from left to right). Filled squares represent $\delta^{18}O$ values and open triangles represent $\delta^{13}C$ values.

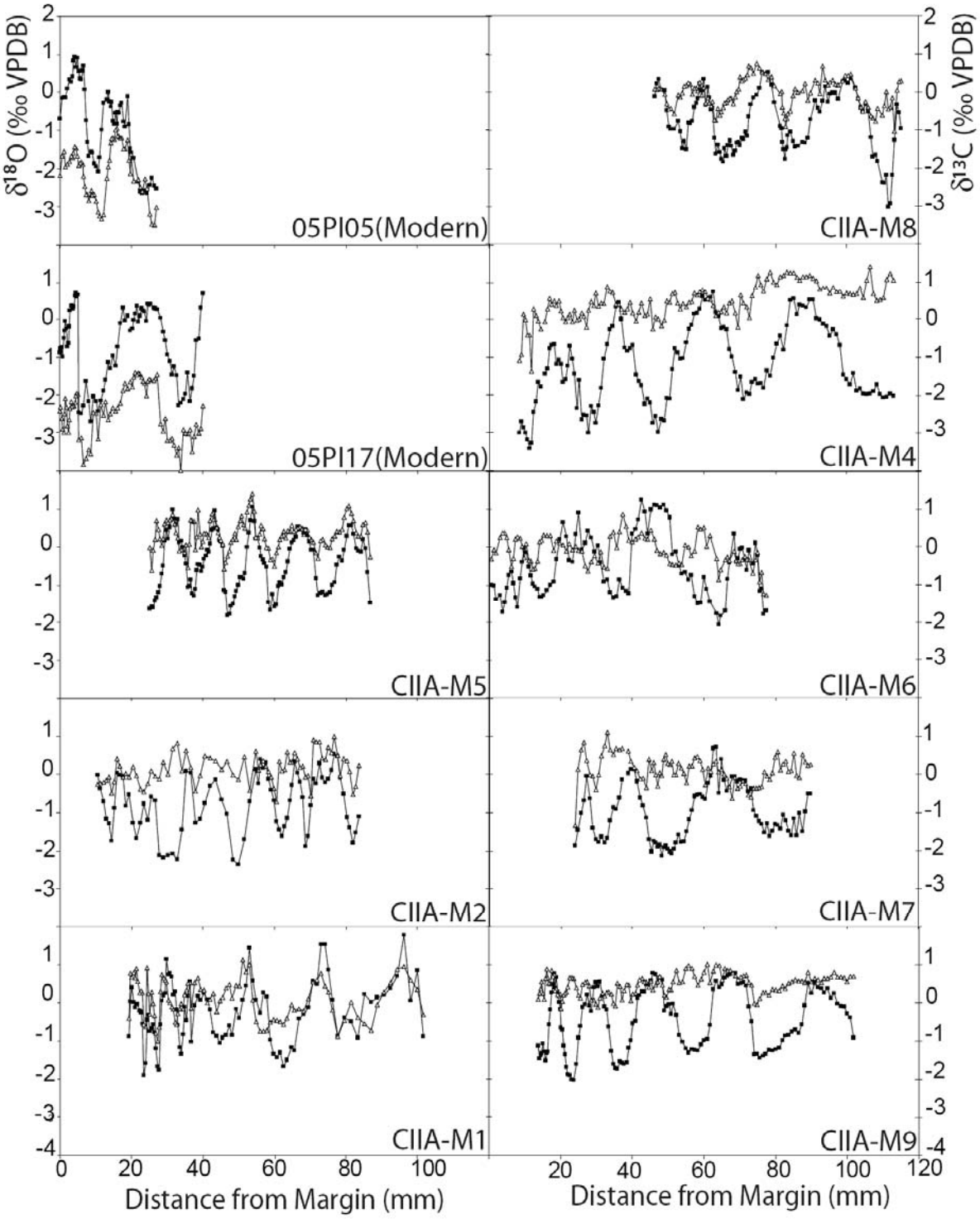

Figure 5 Variation of $\delta^{18}O$ and $\delta^{13}C$ values of archaeological and modern shells versus distance from growth margin (i.e., growth direction is from right to left). Filled squares represent $\delta^{18}O$ values and open triangles represent $\delta^{13}C$ values.

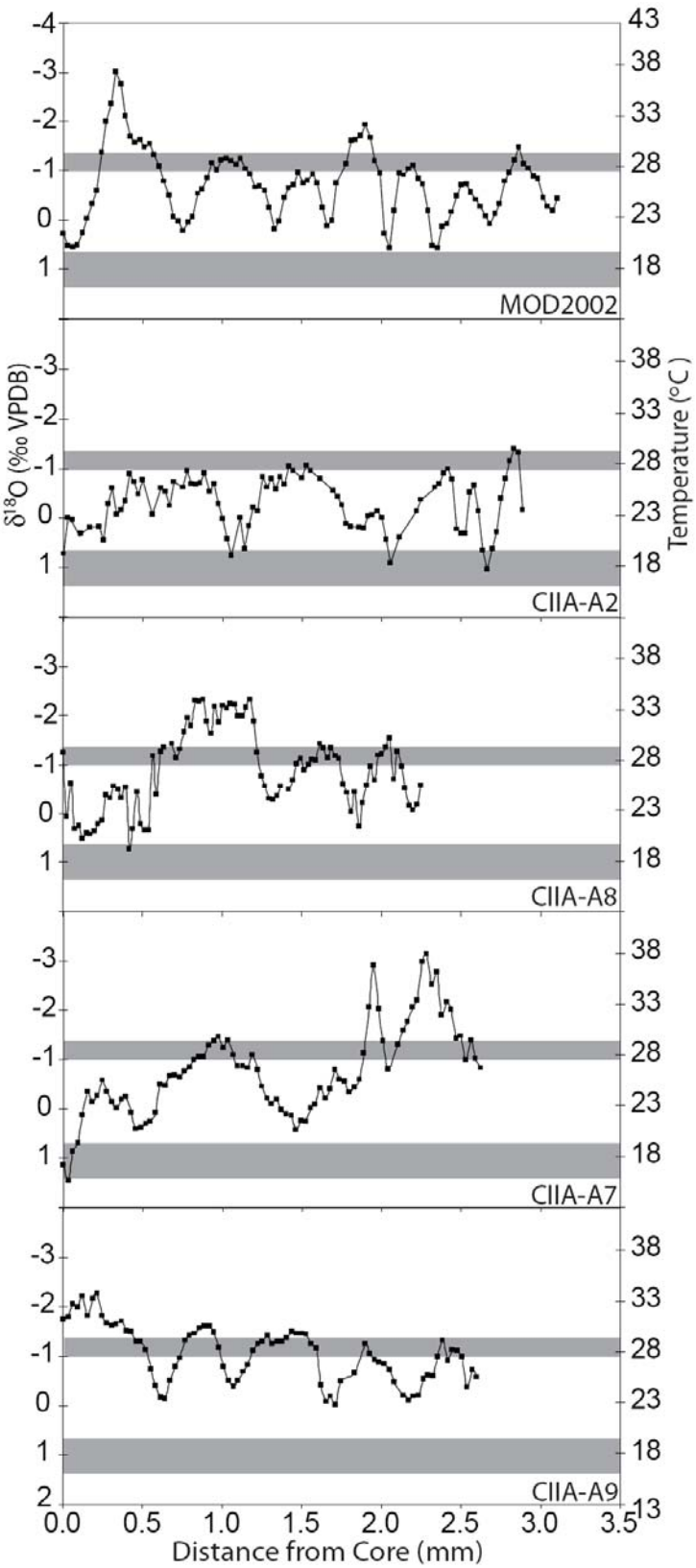

Figure 6 $\delta^{18}O$ values and estimated temperatures of archaeological and modern otoliths versus distance from the core toward the growth margin. The narrow grey bar represents the average summer temperature (28.1±0.6°C) observed at Ft. Myers over the past century; the wide grey bar represents the average winter temperature (17.4±1.7°C) for the past century. The ordinate of $\delta^{18}O$ is decreasing upward to coincide with the temperature scale.

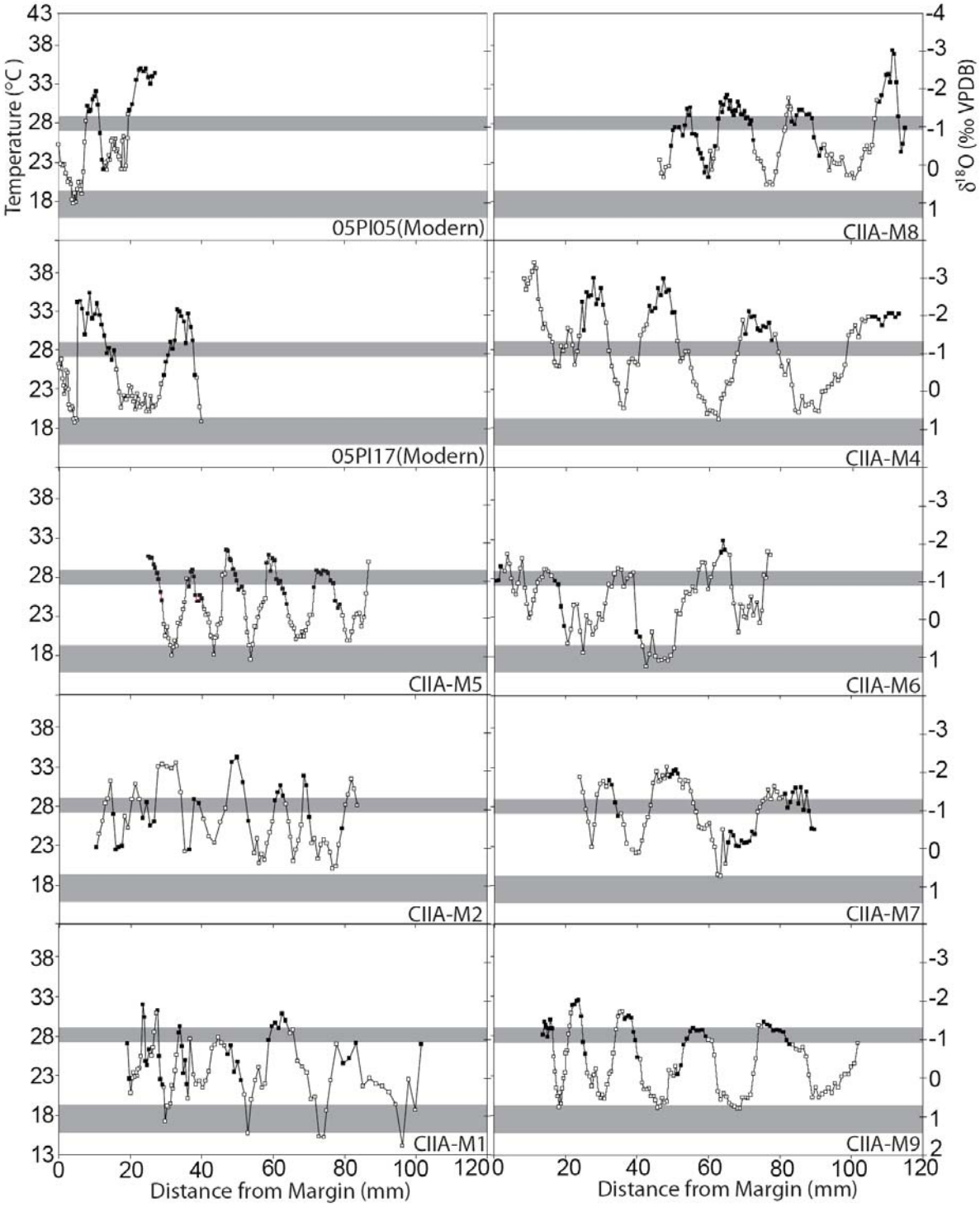

Figure 7 $\delta^{18}O$ values and estimated temperatures of archaeological and modern shells versus distance from growth margin. The narrow gray bar represents the average summer temperature (28.1±0.6°C) observed at Ft. Myers over the past century; the wide gray bar represents the average winter temperature (17.4±1.7°C) for the past century. The ordinate of $\delta^{18}O$ is decreasing upward to coincide with temperature scale.

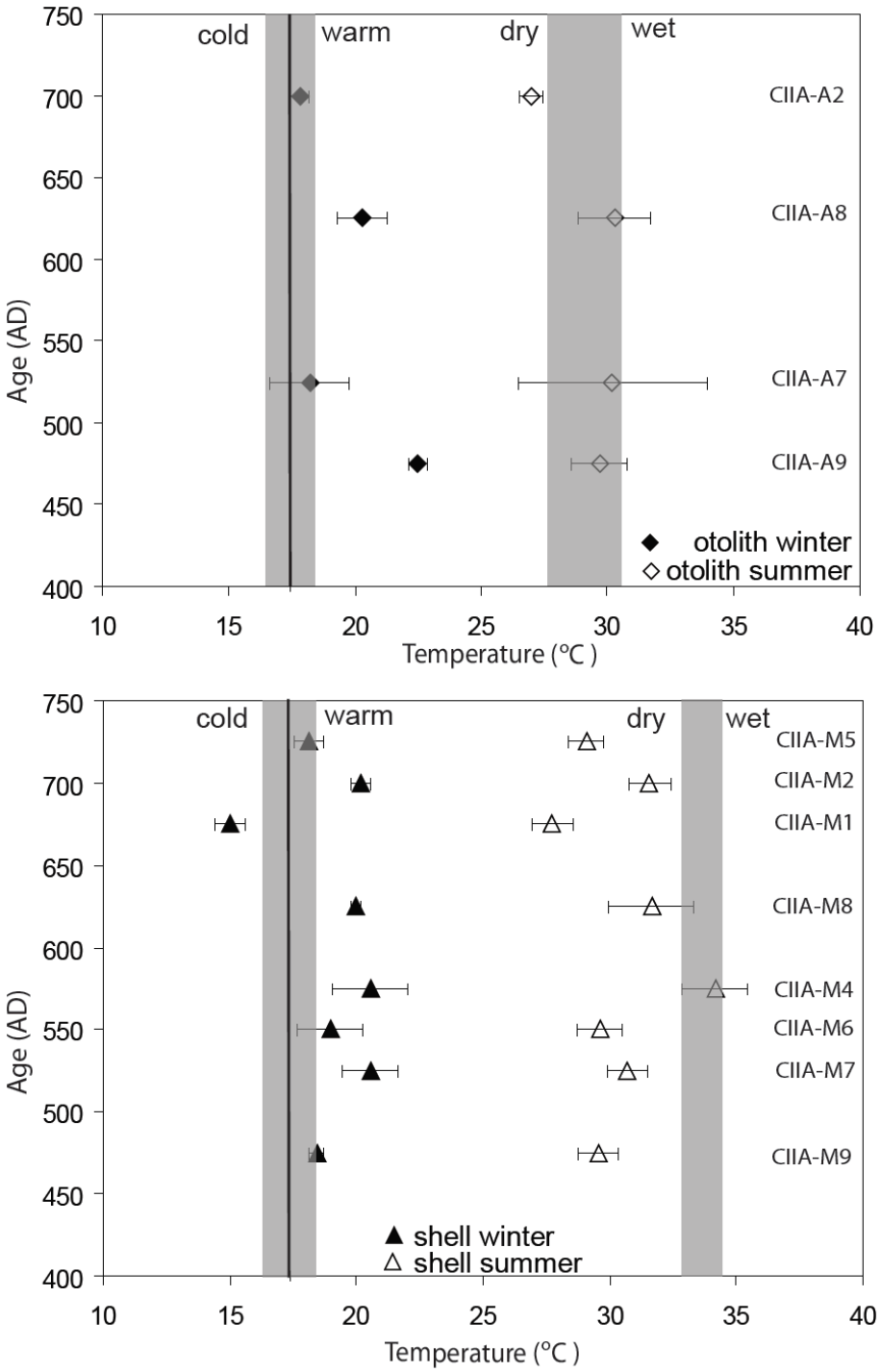

Figure 8 Reconstructed winter and summer temperatures from otoliths and shells during the Vandal Minimum (500-750 AD). The diamonds represent the temperatures estimated from otoliths with standard errors, while the triangles represent the temperatures estimated from shells with standard errors. The left gray bar in each figure is the average winter temperature (17.4±1.0°C) at the level of moving 4-year average based on the modern instrumental records, with the dark line indicating the average winter temperature at the level of individual year. The right gray bar is the average summer temperature of modern otolith (29.0±1.5°C) and the average summer temperature of modern shells 05PI05 and 05PI17 (33.6±0.8°C), respectively.

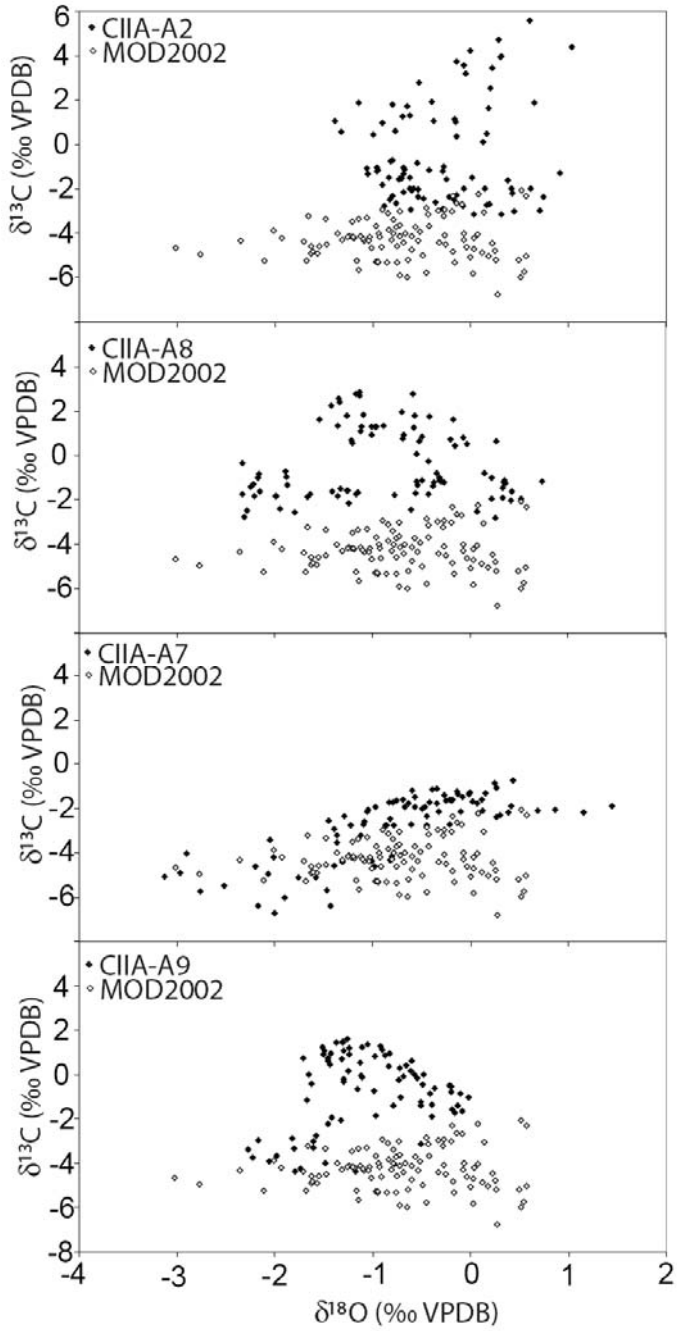

Figure 9 Covariation of $\delta^{13}C$ and $\delta^{18}O$ values of archaeological and modern otoliths. Filled diamonds represent the archaeological otoliths and open diamonds represent the modern otolith.

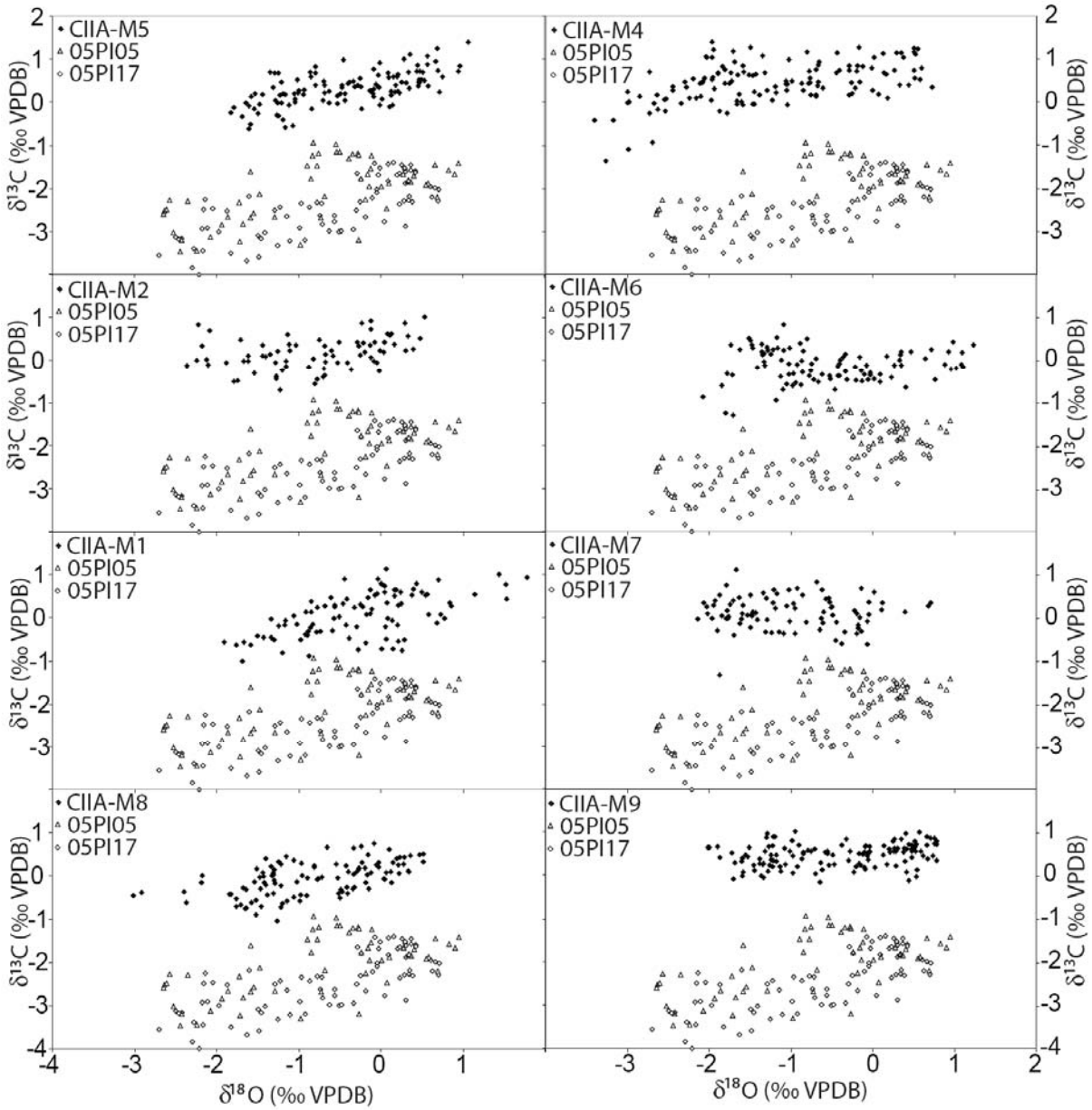

Figure 10 Covariation of $\delta^{13}C$ and $\delta^{18}O$ values of archaeological and modern shells. Filled diamonds represent the archaeological shells and open diamonds represent the modern shells.

APPENDIX A: Archaeological Vandal Minimum shells and otoliths from Pineland and Useppa, southwest Florida.

Specimen No.	Pineland/Useppa Cultural Subperiod	FLMNH-ANT Catalog No.	RC Date (AD, 1-sigma range)	AMS Date (AD, 1-sigma range)	Approximate AD Time Range	Archaeological Provenience	Environmental and Cultural Change
CIIA-M5 CIIA-A5*	Cal. IIA (middle-c)	*CIIA-M5:* 90-3-27 *CIIA-A5:* 90-3-30-1	680-780 (B72991)	610-680 (OS-54179)	700-750	Pineland BC (8LL33); CIIA-M5: C-3-17[73] CIIA-A5: C-5-19[75]-1	Partial rebound transgression. Shift from blk-mangrove to pine for fuel wood. High abundance of crown conchs. Near absence of fish. No migratory ducks.
CIIA-M2 CIIA-A2	Cal. IIA (middle-b)	*CIIA-M2:* 90-3-53-1/4b *CIIA-A2:* 90-3-44-2	630-670 (B41300)	490-610 (OS-54155)	650-700	Pineland BC (8LL33); CIIA-M1: C-5-33[89]-1/4b CIIA-A1: C-5-32[88]-2	Cooling. Abrupt regression (Lower). Mod. Abundance migratory ducks.
CIIA-M1 CIIA-A1*	Cal. IIA (middle-b)	*CIIA-M1:* 90-3-54-1/1 *CIIA-A1:* 90-3-54-1	630-670 (B41300)	N/A	650-700	Pineland BC (8LL33); CIIA-M1: C-5N-34[90]-1 CIIA-A1: C-5N-34[90]-1	Cooling. Abrupt regression (Lower). Mod. Abundance migratory ducks.
CIIA-M8 CIIA-A8	Cal. IIA (middle-a)	*CIIA-M8:* 90-3-57-1/1 *CIIA-A8:* 90-3-57	590-680 (B41301)	620-690 (OS-54182)	600-650	Pineland BC (8LL33); CIIA-M8: C-5N-37-1/1 CIIA-A8: C-5-37[93]	Warming. Slight rebound transgression. High abundance ribbed mussels (= blk-mangrove wetland). Few migratory ducks.
CIIA-M4 CIIA-A4*	Cal. IIA (early-c)	*CIIA-M4:* 95-3-6 *CIIA-A4:*	N/A	480-580 (OS-54178)	550-600	Pineland Old Mound (8LL37); CIIA-M4:C-1-77	Continued cooling. Abrupt regression (low). High

		95-3-6				CIIA-A4: C-1-77	abundance migratory ducks.
CIIA-M6 CIIA-A6*	Cal. IIA (early-b)	*CIIA-M6:* 92-24-2 *CIIA-A6:* 474-0629	530-630 (B52551)	420-540 (OS-54180)	500-550	Pineland Old Mound (8LL37); CIIA-M6: A-8-90 CIIA-A6: A-16-92	AD 536 cooling event. Slowed transgression. Low-elevation (shoreline) habitation. High abundance of crown conchs. High abundance of migratory ducks.
CIIA-M7 CIIA-A7	Cal. IIA (early-b)	*CIIA-M7:* 95-3-31/5 *CIIA-A7:* 95-3-19	530-630 (B52551)	350-470 (OS-54181)	500-550	Pineland Old Mound (8LL37); CIIA-M7: C-1-90 S.Prof.#5 CIIA-A7: C-1-90	AD 536 cooling event. Slowed transgression. Low-elevation (shoreline) habitation. High abundance of crown conchs. High abundance of migratory ducks.
CIIA-M9 CIIA-A9	Cal. IIA (early-a)	*CIIA-M9:* 2003-38-8-2/5 *CIIA-A9:* 2003-57-22-1	420-580 (B88251) & 450-580 (B78803)	460-560 (OS-54183)	450-500	Pineland Surf Clam Ridge (8LL33); CIIAM-9: L-5-86.5-2/5 Z2 CIIAA9: L-9SW-85-1 Z1	Last warming of the Roman Warm Period. Abrupt transgression. High-elevation (sand ridge) habitation. No migratory ducks.

* Otoliths CIIA-A5, CIIA-A1, CIIA-A4 and CIIA-A6 were not analyzed.

APPENDIX B: Oxygen and Carbon Isotope Ratios of *Ariopsis felis* Otoliths

MOD2002 (measured in 1/15/2008-1/17/2008)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from core (mm)	Estimated temperature (^{o}C)	Comments
MODERN2002-1/SURGE/	-6.78	0.28	0.061	0.053	0.00	20.48	
MODERN2002-2/SURGE/	-5.99	0.52	0.050	0.051	0.03	19.38	
MODERN2002-3/SURGE/	-5.73	0.55	0.029	0.010	0.06	19.23	
MODERN2002-4/SURGE/	-5.20	0.50	0.054	0.073	0.09	19.47	
MODERN2002-5/SURGE/	-4.77	0.25	0.016	0.014	0.12	20.59	
MODERN2002-6/SURGE/	-4.62	-0.04	0.037	0.011	0.15	21.94	
MODERN2002-7/SURGE/K236	-4.42	-0.32	0.058	0.096	0.18	23.30	
MODERN2002-8/SURGE/	-4.14	-0.60	0.012	0.054	0.21	24.61	
MODERN2002-9/SURGE/	-4.00	-1.36	0.071	0.026	0.24	28.30	
MODERN2002-10/SURGE/	-3.88	-2.01	0.038	0.030	0.27	31.53	
MODERN2002-11/SURGE/	-4.34	-2.36	0.014	0.086	0.30	33.25	
MODERN2002-12/SURGE/	-4.67	-3.02	0.036	0.081	0.33	36.65	
MODERN2002-13/SURGE/	-4.94	-2.77	0.016	0.107	0.36	35.36	
MODERN2002-14/SURGE/	-5.23	-2.11	0.027	0.005	0.39	32.02	
MODERN2002-15/SURGE/	-5.26	-1.68	0.025	0.014	0.42	29.88	
MODERN2002-16/SURGE/	-4.92	-1.57	0.070	0.053	0.45	29.32	
MODERN2002-17/SURGE/	-4.91	-1.63	0.026	0.013	0.48	29.61	
MODERN2002-18/SURGE/	-4.52	-1.47	0.042	0.051	0.51	28.85	
MODERN2002-19/SURGE/	-4.58	-1.55	0.038	0.012	0.54	29.23	
MODERN2002-20/SURGE/	-4.31	-1.31	0.034	0.043	0.57	28.06	
MODERN2002-21/SURGE/	-4.35	-1.09	0.021	0.034	0.60	26.95	
MODERN2002-22/SURGE/	-3.99	-0.78	0.010	0.019	0.63	25.50	
MODERN2002-23/SURGE/	-3.94	-0.51	0.031	0.030	0.66	24.20	
MODERN2002-24/SURGE/	-4.29	-0.07	0.036	0.077	0.69	22.10	

MODERN2002-25/SURGE/	-4.70	0.03	0.011	0.092	0.72	21.63	
MODERN2002-26/SURGE/	-4.46	0.23	0.068	0.052	0.75	20.72	
MODERN2002-27/SURGE/	-4.20	0.03	0.028	0.037	0.78	21.61	
MODERN2002-28/SURGE/	-4.00	-0.07	0.036	0.091	0.81	22.09	
MODERN2002-29/SURGE/	-4.35	-0.54	0.049	0.094	0.84	24.31	
MODERN2002-30/SURGE/	-5.20	-0.64	0.018	0.021	0.87	24.78	
MODERN2002-31/SURGE/	-5.33	-0.86	0.041	0.103	0.90	25.84	
MODERN2002-32/SURGE/	-5.24	-1.17	0.024	0.053	0.93	27.34	
MODERN2002-33/SURGE/	-4.68	-1.01	0.031	0.034	0.96	26.59	
MODERN2002-34/SURGE/	-4.19	-1.21	0.018	0.080	0.99	27.57	
MODERN2002-35/SURGE/	-4.12	-1.24	0.031	0.102	1.03	27.71	
MODERN2002-36/SURGE/	-4.23	-1.19	0.020	0.069	1.06	27.45	
MODERN2002-37/SURGE/	-4.15	-1.12	0.040	0.049	1.09	27.13	
MODERN2002-38/SURGE/	-4.17	-1.25	0.013	0.019	1.12	27.77	
MODERN2002-39/SURGE/	-4.19	-1.03	0.049	0.036	1.15	26.69	
MODERN2002-40/SURGE/	-3.99	-0.93	0.045	0.024	1.18	26.22	
MODERN2002-41/SURGE/	-3.99	-0.67	0.074	0.062	1.21	24.93	
MODERN2002-42/SURGE/	-4.41	-0.68	0.047	0.067	1.24	25.01	
MODERN2002-43/SURGE/	-4.75	-0.60	0.063	0.056	1.27	24.61	
MODERN2002-44/SURGE/	-4.48	-0.25	0.024	0.059	1.30	22.95	
MODERN2002-45/SURGE/	-5.02	0.18	0.025	0.079	1.33	20.93	
MODERN2002-46/SURGE/	-5.82	0.03	0.191	0.143	1.36	21.65	high stdev
MODERN2002-47/SURGE/	-5.77	-0.45	0.030	0.100	1.39	23.90	
MODERN2002-48/SURGE/	-5.99	-0.65	0.019	0.085	1.42	24.83	
MODERN2002-49/SURGE/	-5.91	-0.72	0.020	0.021	1.45	25.20	
MODERN2002-50/SURGE/	-5.28	-0.97	0.062	0.109	1.48	26.38	high stdev
MODERN2002-51/SURGE/	-4.60	-0.75	0.013	0.029	1.51	25.34	

MODERN2002-52/SURGE/	-4.30	-0.81	0.035	0.063	1.54	25.60	
MODERN2002-53/SURGE/	-4.19	-0.93	0.037	0.044	1.57	26.18	
MODERN2002-54/SURGE/	-3.73	-0.76	0.027	0.097	1.60	25.37	
MODERN2002-55/SURGE/	-4.08	-0.27	0.034	0.035	1.63	23.03	
MODERN2002-56/SURGE/	-4.88	0.12	0.031	0.052	1.66	21.21	
MODERN2002-57/SURGE/	-5.08	0.00	0.044	0.086	1.69	21.76	
MODERN2002-58/SURGE/	-5.34	-0.76	0.038	0.085	1.72	25.36	
MODERN2002-60/SURGE/	-5.66	-1.14	0.046	0.018	1.78	27.22	
MODERN2002-61/SURGE/	-4.85	-1.61	0.024	0.059	1.81	29.53	
MODERN2002-62/SURGE/	-4.60	-1.63	0.010	0.034	1.84	29.61	
MODERN2002-63/SURGE/	-4.37	-1.71	0.037	0.038	1.87	29.99	
MODERN2002-64/SURGE/	-4.22	-1.93	0.032	0.046	1.90	31.12	
MODERN2002-65/SURGE/	-3.22	-1.66	0.004	0.015	1.93	29.79	
MODERN2002-66/SURGE/	-4.17	-1.20	0.027	0.082	1.96	27.51	
MODERN2002-67/SURGE/	-5.31	-0.95	0.018	0.015	1.99	26.27	
MODERN2002-68/SURGE/	-5.21	0.26	0.037	0.025	2.02	20.54	
MODERN2002-69/SURGE/	-5.03	0.57	0.053	0.049	2.05	19.13	
MODERN2002-70/SURGE/	-4.82	-0.18	0.023	0.093	2.08	22.62	
MODERN2002-71/SURGE/	-5.28	-0.95	0.044	0.012	2.11	26.30	
MODERN2002-72/SURGE/	-4.60	-0.91	0.024	0.031	2.14	26.11	
MODERN2002-73/SURGE/	-4.35	-1.04	0.007	0.056	2.17	26.72	
MODERN2002-74/SURGE/	-4.27	-1.10	0.020	0.022	2.20	27.03	
MODERN2002-75/SURGE/	-3.83	-0.84	0.045	0.039	2.23	25.75	
MODERN2002-76/SURGE/	-3.03	-0.73	0.024	0.092	2.26	25.22	
MODERN2002-77/SURGE/	-2.33	-0.19	0.034	0.016	2.29	22.64	
MODERN2002-78/SURGE/	-2.07	0.52	0.033	0.021	2.32	19.37	
MODERN2002-79/SURGE/	-2.31	0.57	0.021	0.007	2.35	19.11	

MODERN2002-80/SURGE/	-3.05	0.14	0.029	0.032	2.38	21.13	
MODERN2002-81/SURGE/	-4.05	0.07	0.054	0.080	2.41	21.43	
MODERN2002-82/SURGE/	-5.33	-0.17	0.011	0.013	2.44	22.55	
MODERN2002-83/SURGE/	-5.01	-0.49	0.025	0.037	2.47	24.10	
MODERN2002-84/SURGE/	-4.13	-0.72	0.024	0.032	2.50	25.20	
MODERN2002-85/SURGE/	-3.62	-0.73	0.034	0.051	2.53	25.22	
MODERN2002-86/SURGE/	-3.72	-0.57	0.064	0.104	2.56	24.45	
MODERN2002-87/SURGE/	-3.69	-0.43	0.002	0.058	2.59	23.78	
MODERN2002-88/SURGE/	-3.23	-0.28	0.025	0.067	2.62	23.08	
MODERN2002-89/SURGE/	-2.71	-0.09	0.011	0.051	2.65	22.19	
MODERN2002-90/SURGE/	-2.23	0.08	0.020	0.030	2.68	21.40	
MODERN2002-91/SURGE/	-2.65	-0.14	0.074	0.014	2.71	22.44	
MODERN2002-92/SURGE/	-2.96	-0.33	0.005	0.008	2.74	23.32	
MODERN2002-93/SURGE/	-3.37	-0.79	0.008	0.075	2.77	25.53	
MODERN2002-94/SURGE/	-3.69	-0.97	0.055	0.100	2.80	26.37	
MODERN2002-95/SURGE/	-3.49	-1.21	0.016	0.038	2.83	27.55	
MODERN2002-96/SURGE/	-3.34	-1.48	0.057	0.013	2.86	28.87	
MODERN2002-97/SURGE/	-3.37	-1.15	0.032	0.076	2.89	27.25	
MODERN2002-98/SURGE/	-3.29	-1.06	0.011	0.032	2.92	26.81	
MODERN2002-99/SURGE/	-2.95	-0.90	0.010	0.096	2.95	26.05	
MODERN2002-100/SURGE/	-3.11	-0.84	0.064	0.022	2.98	25.78	
MODERN2002-101/SURGE/	-2.84	-0.45	0.034	0.039	3.02	23.88	
MODERN2002-102/SURGE/	-2.95	-0.27	0.037	0.080	3.05	23.04	
MODERN2002-103/SURGE/	-3.03	-0.19	0.047	0.032	3.08	22.68	
MODERN2002-104/SURGE/	-3.15	-0.43	0.022	0.040	3.11	23.81	

CIIAA2 (measured in 12/15/2007-12/18/2007)

SAMPLE ID	$\delta^{13}C$	$\delta^{18}O$	C std	O std	Distance	Estimated	

	VPDB (‰)	VPDB (‰)	dev (‰)	dev (‰)	from core (mm)	temperature (^{o}C)	Comments
CIIAA2-1/SURGE/	-2.99	0.71	0.050	0.034	0.00	18.48	
CIIAA2-3/SURGE/	-3.13	0.04	0.063	0.042	0.06	21.60	
CIIAA2-5/SURGE/	-3.12	0.32	0.054	0.039	0.11	20.30	
CIIAA2-7/SURGE/	-2.71	0.19	0.064	0.087	0.17	20.86	
CIIAA2-9/SURGE/	-2.73	0.17	0.071	0.086	0.22	20.98	
CIIAA2-10/SURGE/	-3.01	-0.19	0.060	0.082	0.25	19.68	low voltage
CIIAA2-11/SURGE/	-2.87	-0.29	0.019	0.097	0.28	23.12	
CIIAA2-12/SURGE/	-2.94	-0.61	0.066	0.050	0.31	24.65	
CIIAA2-13/SURGE/	-2.77	-0.08	0.044	0.047	0.33	22.14	
CIIAA2-14/SURGE/	-2.48	-0.17	0.029	0.081	0.36	22.56	
CIIAA2-15/SURGE/	-2.61	-0.36	0.052	0.059	0.39	23.45	
CIIAA2-16/SURGE/	-2.75	-0.89	0.023	0.036	0.42	25.98	
CIIAA2-17/SURGE/	-1.58	-0.73	0.014	0.048	0.44	25.23	
CIIAA2-18/SURGE/	-2.42	-0.48	0.031	0.036	0.47	24.05	
CIIAA2-19/SURGE/	-2.65	-0.91	0.113	0.227	0.50	25.38	low voltage
CIIAA2-21/SURGE/	-1.99	-1.19	0.026	0.063	0.56	22.10	low voltage
CIIAA2-23/SURGE/	-2.07	-0.60	0.040	0.014	0.61	24.61	
CIIAA2-24/SURGE/	-2.38	-0.54	0.044	0.020	0.64	24.31	
CIIAA2-25/SURGE/	-1.57	-0.25	0.012	0.034	0.67	22.94	
CIIAA2-26/SURGE/	-1.55	-0.73	0.018	0.046	0.69	25.21	
CIIAA2-28/SURGE/	-1.51	-0.62	0.033	0.103	0.75	24.70	
CIIAA2-29/SURGE/	-1.22	-0.96	0.087	0.053	0.78	26.34	
CIIAA2-30/SURGE/	-1.03	-0.69	0.043	0.031	0.81	25.03	
CIIAA2-31/SURGE/	-1.31	-0.68	0.018	0.071	0.83	25.00	
CIIAA2-32/SURGE/	-1.54	-0.70	0.009	0.020	0.86	25.11	
CIIAA2-33/SURGE/	-1.82	-0.90	0.015	0.056	0.89	26.07	
CIIAA2-34/SURGE/	-2.04	-0.54	0.024	0.089	0.92	24.31	
CIIAA2-35/SURGE/	-2.16	-0.69	0.062	0.096	0.94	25.03	
CIIAA2-36/SURGE/	-1.20	-0.28	0.006	0.056	0.97	23.10	
CIIAA2-37/SURGE/	-1.48	0.01	0.011	0.042	1.00	21.72	
CIIAA2-38/SURGE/	-2.00	0.42	0.033	0.035	1.03	19.83	
CIIAA2-39/SURGE/	-2.38	0.74	0.019	0.040	1.06	18.33	
CIIAA2-42/SURGE/	-2.01	0.62	0.037	0.059	1.14	18.90	leak
CIIAA2-43/SURGE/	-1.99	0.15	0.007	0.081	1.17	21.07	
CIIAA2-44/SURGE/	-2.35	-0.21	0.039	0.085	1.19	22.77	leak
CIIAA2-45/SURGE/	-2.28	-0.14	0.070	0.035	1.22	22.43	
CIIAA2-46/SURGE/	-2.48	-0.82	0.024	0.066	1.25	25.69	leak
CIIAA2-47/SURGE/	-2.00	-0.62	0.020	0.084	1.28	24.72	
CIIAA2-48/SURGE/	-2.32	-0.80	0.049	0.009	1.31	25.55	leak
CIIAA2-49/SURGE/	-1.99	-0.58	0.045	0.024	1.33	24.52	
CIIAA2-50/SURGE/	-1.49	-0.84	0.056	0.027	1.36	25.76	leak
CIIAA2-51/SURGE/	-1.12	-0.68	0.022	0.075	1.39	24.98	
CIIAA2-52/SURGE/	-1.35	-1.05	0.025	0.047	1.42	26.76	leak
CIIAA2-53/SURGE/	-1.16	-0.95	0.075	0.080	1.44	26.28	
CIIAA2-55/SURGE/	-0.77	-0.82	0.033	0.012	1.50	25.65	
CIIAA2-56/SURGE/	-1.09	-1.06	0.004	0.036	1.53	26.83	leak

CIIAA2-57/SURGE/	-1.05	-0.96	0.045	0.027	1.56	26.33	
CIIAA2-59/SURGE/	-0.73	-0.80	0.021	0.049	1.61	25.58	
CIIAA2-62/SURGE/	-0.82	-0.55	0.050	0.075	1.69	24.36	
CIIAA2-63/SURGE/	-1.16	-0.42	0.023	0.019	1.72	23.75	
CIIAA2-64/SURGE/	-0.99	-0.28	0.010	0.013	1.75	23.07	leak
CIIAA2-65/SURGE/	0.10	0.13	0.078	0.062	1.78	21.18	
CIIAA2-66/SURGE/	0.46	0.17	0.015	0.088	1.81	21.00	leak
CIIAA2-68/SURGE/	1.64	0.19	0.021	0.034	1.86	20.89	leak
CIIAA2-69/SURGE/	2.56	0.20	0.043	0.069	1.89	20.82	
CIIAA2-70/SURGE/	3.21	-0.05	0.038	0.041	1.92	21.99	
CIIAA2-71/SURGE/	3.58	-0.06	0.038	0.019	1.94	22.07	
CIIAA2-72/SURGE/	3.74	-0.14	0.048	0.029	1.97	22.42	
CIIAA2-73/SURGE/	4.24	0.00	0.073	0.123	2.00	21.77	
CIIAA2-74/SURGE/	-2.18	0.43	0.005	0.015	2.03	19.76	
CIIAA2-75/SURGE/	-1.30	-0.62	0.011	0.144	2.05	17.57	low voltage
CIIAA2-77/SURGE/	-1.63	-0.35	0.012	0.018	2.11	20.00	low voltage
CIIAA2-81/SURGE/	0.35	-0.15	0.100	0.072	2.22	22.46	
CIIAA2-82/SURGE/	1.07	-0.37	0.055	0.072	2.25	23.54	
CIIAA2-85/SURGE/	1.29	-0.62	0.020	0.098	2.33	24.69	
CIIAA2-86/SURGE/	1.26	-0.70	0.052	0.011	2.36	25.09	
CIIAA2-87/SURGE/	0.98	-0.90	0.088	0.029	2.39	26.04	
CIIAA2-88/SURGE/	0.44	-1.00	0.040	0.056	2.42	26.53	
CIIAA2-89/SURGE/	0.60	-0.77	0.041	0.030	2.44	25.44	
CIIAA2-90/SURGE/	3.45	0.22	0.043	0.038	2.47	20.74	
CIIAA2-91/SURGE/	3.93	0.30	0.034	0.075	2.50	20.36	
CIIAA2-92/SURGE/	4.00	0.32	0.014	0.003	2.53	20.29	
CIIAA2-93/SURGE/	2.78	-0.52	0.017	0.050	2.55	24.25	
CIIAA2-94/SURGE/	1.72	-0.65	0.079	0.030	2.58	24.85	
CIIAA2-95/SURGE/	1.01	-0.15	0.078	0.035	2.61	22.48	
CIIAA2-96/SURGE/	1.87	0.65	0.013	0.039	2.64	18.75	
CIIAA2-97/SURGE/	4.41	1.04	0.017	0.092	2.67	16.98	
CIIAA2-98/SURGE/	5.60	0.61	0.014	0.102	2.69	18.96	
CIIAA2-99/SURGE/	4.72	0.28	0.035	0.055	2.72	20.44	
CIIAA2-100/SURGE/	1.92	-0.40	0.013	0.046	2.75	23.64	
CIIAA2-101/SURGE/	1.81	-0.80	0.029	0.074	2.78	25.58	
CIIAA2-102/SURGE/	1.87	-1.15	0.024	0.071	2.80	27.25	
CIIAA2-103/SURGE/	1.04	-1.39	0.037	0.098	2.83	28.43	
CIIAA2-104/SURGE/	0.58	-1.32	0.016	0.020	2.86	28.10	
CIIAA2-105/SURGE/	1.14	-0.17	0.029	0.048	2.89	22.55	

CIIA-A8 (measured in 1/23/2008-1/25/2008)

SAMPLE ID	$\delta^{13}C$ VPDB	$\delta^{18}O$ VPDB	C std dev	O std dev	Distance from core	Estimated temperature	Comments

	(‰)	(‰)	(‰)	(‰)	(mm)	(^{o}C)	
CIIAA8-1/SURGE/	-2.17	-1.24	0.031	0.079	0.00	27.72	
CIIAA8-2/SURGE/	-3.12	-1.39	0.053	0.031	0.02	21.44	low voltage
CIIAA8-3/SURGE/	-2.44	-0.61	0.067	0.062	0.05	24.66	
CIIAA8-4/SURGE/	-2.28	-0.56	0.020	0.035	0.07	20.23	low voltage
CIIAA8-5/SURGE/	-2.24	0.20	0.020	0.137	0.10	20.56	low voltage
CIIAA8-6/SURGE/	-2.00	0.43	0.052	0.069	0.12	19.35	low voltage
CIIAA8-7/SURGE/	-2.05	0.41	0.109	0.046	0.15	19.84	
CIIAA8-8/SURGE/	-1.60	0.42	0.018	0.088	0.17	19.81	
CIIAA8-9/SURGE/	-1.41	0.07	0.023	0.070	0.20	20.09	low voltage
CIIAA8-10/SURGE/	-1.09	0.07	0.009	0.115	0.22	20.74	low voltage
CIIAA8-11/SURGE/	-0.90	-0.03	0.025	0.089	0.24	21.12	low voltage
CIIAA8-12/SURGE/	-1.20	-0.37	0.024	0.064	0.27	23.51	
CIIAA8-13/SURGE/	-1.14	-0.32	0.027	0.071	0.29	23.26	
CIIAA8-14/SURGE/	-1.18	-0.55	0.041	0.024	0.32	24.38	
CIIAA8-15/SURGE/	-1.21	-0.56	0.045	0.207	0.34	24.08	low voltage
CIIAA8-16/SURGE/	-0.99	-0.31	0.088	0.073	0.37	23.25	
CIIAA8-17/SURGE/	-1.35	-0.54	0.032	0.132	0.39	24.33	
CIIAA8-18/SURGE/	-1.67	-0.46	0.013	0.118	0.42	18.39	low voltage
CIIAA8-19/SURGE/	-2.10	-1.24	0.071	0.156	0.44	20.23	low voltage
CIIAA8-20/SURGE/	-1.89	-0.69	0.049	0.038	0.46	23.80	low voltage
CIIAA8-21/SURGE/	-2.45	-0.93	0.070	0.060	0.49	20.74	low voltage
CIIAA8-22/SURGE/	-1.62	-0.63	0.043	0.024	0.51	20.19	low voltage
CIIAA8-23/SURGE/	-1.57	-0.65	0.029	0.130	0.54	20.14	low voltage
CIIAA8-24/SURGE/	-1.75	-1.17	0.028	0.015	0.56	27.35	
CIIAA8-25/SURGE/	-1.81	-1.36	0.039	0.061	0.59	23.56	low voltage
CIIAA8-26/SURGE/	-1.59	-1.27	0.017	0.029	0.61	27.82	
CIIAA8-27/SURGE/	-1.84	-1.35	0.014	0.013	0.64	28.26	
CIIAA8-29/SURGE/	-1.61	-1.42	0.044	0.067	0.68	28.56	
CIIAA8-30/SURGE/	-1.93	-1.67	0.056	0.100	0.71	27.26	low voltage
CIIAA8-31/SURGE/	-1.50	-1.32	0.028	0.096	0.73	28.11	
CIIAA8-32/SURGE/	-1.85	-1.67	0.026	0.065	0.76	29.79	
CIIAA8-33/SURGE/	-2.38	-1.95	0.093	0.055	0.78	31.21	
CIIAA8-34/SURGE/	-2.58	-1.80	0.006	0.075	0.81	30.45	
CIIAA8-35/SURGE/	-2.78	-2.31	0.021	0.107	0.83	33.02	
CIIAA8-36/SURGE/	-2.47	-2.28	0.047	0.020	0.86	32.89	
CIIAA8-37/SURGE/	-1.75	-2.33	0.030	0.005	0.88	33.10	
CIIAA8-38/SURGE/	-0.80	-2.01	0.061	0.052	0.90	30.91	low voltage
CIIAA8-39/SURGE/	-1.72	-1.63	0.066	0.058	0.93	29.64	
CIIAA8-40/SURGE/	-1.01	-2.17	0.016	0.070	0.95	32.34	
CIIAA8-41/SURGE/	-1.42	-2.01	0.075	0.052	0.98	30.81	low voltage
CIIAA8-42/SURGE/	-1.83	-2.21	0.023	0.058	1.00	32.51	
CIIAA8-43/SURGE/	-1.62	-2.15	0.088	0.015	1.03	32.21	
CIIAA8-44/SURGE/	-1.42	-2.24	0.023	0.100	1.05	32.68	
CIIAA8-45/SURGE/	-1.29	-2.22	0.042	0.069	1.08	32.58	
CIIAA8-46/SURGE/	-1.81	-1.99	0.081	0.023	1.10	31.39	
CIIAA8-47/SURGE/	-1.81	-1.99	0.044	0.051	1.12	31.41	
CIIAA8-48/SURGE/	-0.83	-2.17	0.028	0.019	1.15	32.30	

CIIAA8-49/SURGE/	-0.35	-2.33	0.016	0.021	1.17	33.13	
CIIAA8-50/SURGE/	-0.96	-1.88	0.048	0.042	1.20	30.85	
CIIAA8-51/SURGE/	-1.57	-1.25	0.062	0.070	1.22	27.74	
CIIAA8-52/SURGE/	-1.77	-0.78	0.012	0.100	1.25	25.46	
CIIAA8-53/SURGE/	-1.69	-0.56	0.022	0.016	1.27	24.43	
CIIAA8-54/SURGE/	-1.18	-0.30	0.040	0.053	1.30	23.17	
CIIAA8-55/SURGE/	-1.22	-0.27	0.044	0.058	1.32	23.04	
CIIAA8-56/SURGE/	-0.80	-0.35	0.021	0.062	1.34	23.41	
CIIAA8-57 and 58 combined	0.06	-0.55	0.013	0.016	1.37	24.39	
CIIAA8-59/SURGE/	0.87	-0.49	0.064	0.022	1.42	24.09	
CIIAA8-60/SURGE/	0.95	-0.69	0.012	0.084	1.44	25.02	
CIIAA8-61/SURGE/	0.94	-1.01	0.041	0.096	1.47	26.58	
CIIAA8-62/SURGE/	1.11	-1.12	0.059	0.091	1.49	27.13	
CIIAA8-63/SURGE/	1.36	-0.89	0.047	0.042	1.52	26.01	
CIIAA8-64/SURGE/	1.31	-1.01	0.012	0.064	1.54	26.56	
CIIAA8-65/SURGE/	1.31	-1.11	0.012	0.051	1.56	27.06	
CIIAA8-66/SURGE/	1.84	-1.10	0.020	0.091	1.59	27.00	
CIIAA8-67/SURGE/	2.26	-1.42	0.021	0.053	1.61	28.60	
CIIAA8-68/SURGE/	2.43	-1.34	0.043	0.076	1.64	28.18	
CIIAA8-69/SURGE/	2.69	-1.13	0.046	0.027	1.66	27.18	
CIIAA8-70/SURGE/	2.60	-1.34	0.055	0.020	1.69	28.21	
CIIAA8-71/SURGE/	2.77	-1.17	0.025	0.042	1.71	27.37	
CIIAA8-72/SURGE/	2.86	-1.13	0.019	0.100	1.74	27.17	
CIIAA8-73/SURGE/	2.78	-0.59	0.040	0.025	1.76	24.56	
CIIAA8-74/SURGE/	1.74	-0.42	0.036	0.016	1.78	23.75	
CIIAA8-75/SURGE/	0.53	-0.03	0.017	0.084	1.81	21.93	
CIIAA8-76/SURGE/	-0.24	-0.43	0.033	0.026	1.83	23.79	
CIIAA8-77/SURGE/	0.35	-0.37	0.007	0.027	1.86	20.51	low voltage
CIIAA8-78/SURGE/	0.45	-0.77	0.037	0.144	1.88	22.71	low voltage
CIIAA8-79/SURGE/	1.27	-0.58	0.031	0.077	1.91	24.51	
CIIAA8-80/SURGE/	1.33	-0.96	0.034	0.014	1.93	26.33	
CIIAA8-81/SURGE/	0.66	-0.89	0.085	0.082	1.96	25.04	low voltage
CIIAA8-82/SURGE/	0.58	-1.20	0.044	0.019	1.98	27.52	
CIIAA8-83/SURGE/	0.67	-1.21	0.018	0.073	2.00	27.58	
CIIAA8-84/SURGE/	1.14	-1.71	0.061	0.041	2.03	28.29	low voltage
CIIAA8-85/SURGE/	1.57	-1.63	0.054	0.064	2.05	29.17	low voltage
CIIAA8-86/SURGE/	1.52	-1.69	0.042	0.172	2.08	25.09	low voltage
CIIAA8-87/SURGE/	1.80	-1.26	0.027	0.053	2.10	27.82	
CIIAA8-88/SURGE/	1.29	-0.97	0.027	0.057	2.13	26.39	
CIIAA8-89/SURGE/	0.67	-0.52	0.014	0.023	2.15	24.25	
CIIAA8-90/SURGE/	0.43	-0.15	0.015	0.080	2.18	22.49	
CIIAA8-91/SURGE/	0.82	-0.07	0.039	0.008	2.20	22.10	
CIIAA8-92/SURGE/	1.63	-0.17	0.059	0.055	2.22	22.59	
CIIAA8-93/SURGE/	1.81	-0.57	0.021	0.047	2.25	24.47	

CIIAA7 (measured in 1/09/2008-1/13/2008)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from core (mm)	Estimated temperature (^{o}C)	Comments
CIIAA7-1/SURGE/	-2.17	1.16	0.035	0.058	0.00	16.45	
CIIAA7-2/SURGE/	-2.31	0.49	0.007	0.046	0.03	15.13	low voltage
CIIAA7-3/SURGE/	-2.24	0.50	0.049	0.033	0.06	17.75	low voltage
CIIAA7-4/SURGE/	-2.24	0.42	0.042	0.014	0.09	18.57	low voltage
CIIAA7-5/SURGE/	-2.09	0.13	0.040	0.072	0.12	21.16	
CIIAA7-6/SURGE/	-1.78	-0.35	0.057	0.061	0.15	23.41	
CIIAA7-7/SURGE/	-1.35	-0.13	0.024	0.072	0.18	22.38	
CIIAA7-8/SURGE/	-1.39	-0.26	0.014	0.047	0.21	23.01	
CIIAA7-9/SURGE/	-1.48	-0.57	0.041	0.109	0.24	24.48	
CIIAA7-10/SURGE/	-1.10	-0.34	0.057	0.077	0.27	23.39	
CIIAA7-11/SURGE/	-1.23	-0.14	0.010	0.084	0.30	22.44	
CIIAA7-12/SURGE/	-1.35	-0.02	0.057	0.045	0.34	21.86	
CIIAA7-13/SURGE/	-1.62	-0.18	0.008	0.011	0.37	22.62	
CIIAA7-14/SURGE/	-1.63	-0.25	0.057	0.094	0.40	22.93	
CIIAA7-15/SURGE/	-1.75	0.07	0.065	0.055	0.43	21.45	
CIIAA7-16/SURGE/	-1.87	0.42	0.025	0.026	0.46	19.83	
CIIAA7-17/SURGE/	-2.17	0.39	0.017	0.010	0.49	19.96	
CIIAA7-18/SURGE/	-2.28	0.30	0.049	0.107	0.52	20.36	
CIIAA7-19/SURGE/	-2.37	0.27	0.011	0.074	0.55	20.53	
CIIAA7-20/SURGE/	-2.20	0.08	0.039	0.043	0.58	21.39	
CIIAA7-21/SURGE/	-2.03	-0.49	0.065	0.129	0.61	24.10	
CIIAA7-22/SURGE/	-1.93	-0.46	0.030	0.029	0.64	23.95	
CIIAA7-23/SURGE/	-1.93	-0.67	0.094	0.103	0.67	24.95	
CIIAA7-24/SURGE/	-1.62	-0.69	0.051	0.037	0.70	25.04	
CIIAA7-25/SURGE/	-1.77	-0.63	0.030	0.010	0.73	24.77	
CIIAA7-26/SURGE/	-1.65	-0.76	0.021	0.036	0.76	25.37	
CIIAA7-27/SURGE/	-1.73	-0.83	0.036	0.054	0.79	25.74	
CIIAA7-28/SURGE/	-1.92	-0.98	0.014	0.078	0.82	26.41	
CIIAA7-29/SURGE/	-2.14	-1.06	0.046	0.041	0.85	26.80	
CIIAA7-30/SURGE/	-2.06	-1.05	0.018	0.057	0.88	26.75	
CIIAA7-31/SURGE/	-2.35	-1.29	0.040	0.007	0.91	27.93	
CIIAA7-32/SURGE/	-3.30	-1.52	0.073	0.111	0.95	28.34	low voltage
CIIAA7-33/SURGE/	-2.54	-1.45	0.011	0.075	0.98	28.74	
CIIAA7-34/SURGE/	-2.76	-1.22	0.061	0.074	1.01	27.62	
CIIAA7-35/SURGE/	-2.93	-1.40	0.055	0.067	1.04	28.47	
CIIAA7-36/SURGE/	-2.73	-1.10	0.010	0.068	1.07	27.00	
CIIAA7-37/SURGE/	-2.75	-0.86	0.040	0.096	1.10	25.88	
CIIAA7-38/SURGE/	-2.75	-0.86	0.074	0.018	1.13	25.86	
CIIAA7-39/SURGE/	-2.45	-0.82	0.008	0.020	1.16	25.69	
CIIAA7-40/SURGE/	-2.60	-1.09	0.017	0.073	1.19	26.96	
CIIAA7-41/SURGE/	-2.77	-0.79	0.053	0.064	1.22	25.50	
CIIAA7-42/SURGE/	-2.75	-0.45	0.057	0.059	1.25	23.89	
CIIAA7-43/SURGE/	-2.70	-0.21	0.026	0.012	1.28	22.75	
CIIAA7-44/SURGE/	-2.14	-0.10	0.022	0.040	1.31	22.23	
CIIAA7-45/SURGE/	-1.66	-0.19	0.025	0.035	1.34	22.68	
CIIAA7-46/SURGE/	-1.70	0.02	0.021	0.042	1.37	21.66	

CIIAA7-47/SURGE/	-1.58	0.11	0.045	0.051	1.40	21.23	
CIIAA7-48/SURGE/	-1.30	0.15	0.012	0.025	1.43	21.06	
CIIAA7-49/SURGE/	-0.74	0.43	0.037	0.103	1.46	19.75	
CIIAA7-50/SURGE/	-0.87	0.25	0.034	0.027	1.49	20.60	
CIIAA7-51/SURGE/	-1.07	0.27	0.018	0.074	1.52	20.52	
CIIAA7-52/SURGE/	-1.28	-0.01	0.060	0.039	1.55	21.82	
CIIAA7-53/SURGE/	-1.47	-0.08	0.058	0.098	1.59	22.15	
CIIAA7-54/SURGE/	-1.73	-0.42	0.025	0.016	1.62	23.74	
CIIAA7-55/SURGE/	-1.60	-0.21	0.030	0.100	1.65	22.76	
CIIAA7-56/SURGE/	-1.14	-0.40	0.027	0.041	1.68	23.63	
CIIAA7-57/SURGE/	-1.73	-0.80	0.027	0.020	1.71	25.55	
CIIAA7-58/SURGE/	-1.19	-0.60	0.032	0.067	1.74	24.61	
CIIAA7-59/SURGE/	-1.92	-0.57	0.036	0.038	1.77	24.45	
CIIAA7-60/SURGE/	-2.12	-0.33	0.037	0.102	1.80	23.30	
CIIAA7-61/SURGE/	-2.35	-0.44	0.022	0.078	1.83	23.86	
CIIAA7-62/SURGE/	-2.72	-0.60	0.017	0.043	1.86	24.62	
CIIAA7-63/SURGE/	-3.22	-1.12	0.020	0.070	1.89	27.11	
CIIAA7-64/SURGE/	-3.40	-2.05	0.021	0.056	1.92	31.72	
CIIAA7-65/SURGE/	-4.01	-2.90	0.010	0.033	1.95	36.06	
CIIAA7-66/SURGE/	-4.18	-2.02	0.027	0.014	1.98	31.54	
CIIAA7-67/SURGE/	-3.54	-1.37	0.013	0.057	2.01	28.33	
CIIAA7-68/SURGE/	-4.14	-0.80	0.033	0.037	2.04	25.58	
CIIAA7-70/SURGE/	-4.39	-1.31	0.022	0.009	2.10	28.03	
CIIAA7-71/SURGE/	-5.10	-1.58	0.017	0.025	2.13	29.36	
CIIAA7-72/SURGE/	-5.09	-1.76	0.040	0.067	2.16	30.26	
CIIAA7-73/SURGE/	-4.96	-2.07	0.042	0.018	2.20	31.80	
CIIAA7-74/SURGE/	-4.60	-2.20	0.062	0.033	2.23	32.47	
CIIAA7-75/SURGE/	-4.88	-2.97	0.019	0.086	2.26	36.41	
CIIAA7-76/SURGE/	-5.25	-3.44	0.041	0.048	2.29	37.23	low voltage
CIIAA7-77/SURGE/	-5.47	-2.52	0.005	0.061	2.32	34.08	
CIIAA7-78/SURGE/	-5.73	-2.77	0.017	0.108	2.35	35.34	
CIIAA7-79/SURGE/	-6.00	-1.90	0.007	0.029	2.38	30.95	
CIIAA7-80/SURGE/	-6.39	-2.17	0.012	0.023	2.41	32.30	
CIIAA7-81/SURGE/	-6.82	-2.08	0.018	0.094	2.44	31.46	low voltage
CIIAA7-82/SURGE/	-7.03	-2.99	0.038	0.202	2.47	28.63	low voltage
CIIAA7-83/SURGE/	-5.77	-1.55	0.048	0.023	2.50	28.83	low voltage
CIIAA7-84/SURGE/	-4.60	-0.98	0.026	0.092	2.53	26.44	
CIIAA7-85/SURGE/	-4.57	-1.39	0.017	0.106	2.56	28.44	
CIIAA7-86/SURGE/	-4.38	-1.01	0.022	0.058	2.59	26.58	
CIIAA7-87/SURGE/	-4.46	-1.05	0.060	0.043	2.62	25.66	low voltage

CIIAA9 (measured in 1/11/2008-1/15/2008)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from core (mm)	Estimated temperature (^{o}C)	Comments
CIIAA9-1/SURGE/	-4.25	-1.74	0.011	0.054	0.00	30.14	
CIIAA9-2/SURGE/	-4.39	-1.79	0.020	0.065	0.03	30.42	
CIIAA9-3/SURGE/	-3.91	-2.05	0.031	0.098	0.06	31.73	

CIIAA9-4/SURGE/	-3.67	-1.99	0.014	0.036	0.09	31.39	
CIIAA9-5/SURGE/	-3.74	-2.22	0.024	0.016	0.12	32.59	
CIIAA9-6/SURGE/	-3.33	-1.80	0.013	0.101	0.15	30.48	
CIIAA9-7/SURGE/	-2.97	-2.17	0.055	0.024	0.18	32.32	
CIIAA9-8/SURGE/	-3.38	-2.27	0.031	0.027	0.21	32.81	
CIIAA9-9/SURGE/	-2.88	-1.82	0.019	0.014	0.24	30.56	
CIIAA9-10/SURGE/	-1.18	-1.67	0.014	0.032	0.28	29.82	
CIIAA9-11/SURGE/	-0.44	-1.62	0.051	0.068	0.31	29.58	
CIIAA9-12/SURGE/	-0.01	-1.65	0.012	0.034	0.34	29.74	
CIIAA9-13/SURGE/	0.73	-1.71	0.050	0.083	0.37	30.01	
CIIAA9-14/SURGE/	1.22	-1.51	0.044	0.102	0.40	29.05	
CIIAA9-15/SURGE/	0.89	-1.50	0.027	0.015	0.43	28.97	
CIIAA9-16/SURGE/	-0.22	-1.29	0.023	0.045	0.46	27.96	
CIIAA9-17/SURGE/	-0.36	-1.30	0.016	0.068	0.49	27.99	
CIIAA9-18/SURGE/	-0.05	-1.12	0.054	0.043	0.52	27.11	
CIIAA9-19/SURGE/	-0.26	-0.74	0.033	0.067	0.55	25.26	
CIIAA9-20/SURGE/	-1.37	-0.39	0.011	0.066	0.58	23.63	
CIIAA9-21/SURGE/	-1.72	-0.16	0.039	0.033	0.61	22.54	
CIIAA9-22/SURGE/	-1.42	-0.13	0.017	0.030	0.64	22.38	
CIIAA9-23/SURGE/	-1.40	-0.51	0.013	0.027	0.67	24.18	
CIIAA9-24/SURGE/	-1.40	-0.79	0.018	0.018	0.70	25.51	
CIIAA9-25/SURGE/	-1.85	-0.96	0.030	0.082	0.73	26.36	
CIIAA9-26/SURGE/	-2.08	-1.33	0.041	0.062	0.76	28.12	
CIIAA9-27/SURGE/	-1.93	-1.42	0.035	0.086	0.79	28.57	
CIIAA9-28/SURGE/	-2.25	-1.46	0.020	0.014	0.83	28.78	
CIIAA9-29/SURGE/	-2.77	-1.57	0.027	0.048	0.86	29.34	
CIIAA9-30/SURGE/	-3.03	-1.60	0.019	0.049	0.89	29.49	
CIIAA9-31/SURGE/	-3.29	-1.61	0.019	0.037	0.92	29.51	
CIIAA9-32/SURGE/	-4.00	-1.48	0.024	0.056	0.95	28.88	
CIIAA9-33/SURGE/	-4.36	-1.18	0.004	0.047	0.98	27.39	
CIIAA9-34/SURGE/	-4.04	-0.78	0.017	0.059	1.01	25.47	
CIIAA9-35/SURGE/	-3.13	-0.51	0.116	0.045	1.04	24.16	
CIIAA9-36/SURGE/	-1.92	-0.39	0.050	0.029	1.07	23.61	
CIIAA9-37/SURGE/	-1.24	-0.51	0.056	0.090	1.10	24.17	
CIIAA9-38/SURGE/	-0.07	-0.68	0.023	0.044	1.13	25.02	
CIIAA9-39/SURGE/	0.95	-0.83	0.012	0.034	1.16	25.69	
CIIAA9-40/SURGE/	1.23	-1.11	0.027	0.018	1.19	27.08	
CIIAA9-41/SURGE/	1.19	-1.24	0.063	0.082	1.22	27.70	
CIIAA9-42/SURGE/	1.08	-1.30	0.023	0.046	1.25	27.98	
CIIAA9-43/SURGE/	0.92	-1.42	0.012	0.024	1.28	28.60	
CIIAA9-44/SURGE/	1.60	-1.25	0.038	0.084	1.31	27.77	
CIIAA9-45/SURGE/	1.45	-1.30	0.030	0.028	1.35	28.00	
CIIAA9-46/SURGE/	1.46	-1.30	0.064	0.026	1.38	28.00	
CIIAA9-47/SURGE/	1.42	-1.37	0.042	0.058	1.41	28.35	
CIIAA9-48/SURGE/	1.06	-1.49	0.025	0.013	1.44	28.92	
CIIAA9-49/SURGE/	0.72	-1.45	0.014	0.061	1.47	28.75	
CIIAA9-50/SURGE/	0.59	-1.45	0.044	0.028	1.50	28.74	
CIIAA9-51/SURGE/	0.42	-1.43	0.011	0.026	1.53	28.64	

CIIAA9-52/SURGE/	0.16	-1.25	0.026	0.067	1.56	27.74	
CIIAA9-53/SURGE/	-0.67	-1.16	0.069	0.030	1.59	27.30	
CIIAA9-54/SURGE/	-0.96	-0.53	0.011	0.069	1.62	23.70	low voltage
CIIAA9-55/SURGE/	-1.67	-0.09	0.011	0.021	1.65	22.17	
CIIAA9-56/SURGE/	-1.57	-0.19	0.027	0.002	1.68	22.65	
CIIAA9-57/SURGE/	-1.29	-0.53	0.021	0.032	1.71	21.86	low voltage
CIIAA9-58/SURGE/	-0.46	-0.48	0.040	0.046	1.74	24.06	
CIIAA9-61/SURGE/	0.34	-0.73	0.041	0.074	1.83	24.90	low voltage
CIIAA9-63/SURGE/	0.88	-1.24	0.033	0.030	1.90	27.70	
CIIAA9-64/SURGE/	1.35	-1.06	0.047	0.054	1.93	26.80	
CIIAA9-65/SURGE/	1.28	-0.92	0.032	0.010	1.96	26.16	
CIIAA9-66/SURGE/	0.84	-0.88	0.036	0.008	1.99	25.94	
CIIAA9-67/SURGE/	0.35	-0.84	0.008	0.021	2.02	25.75	
CIIAA9-68/SURGE/	0.29	-0.73	0.023	0.041	2.05	25.21	
CIIAA9-69/SURGE/	0.00	-0.48	0.038	0.059	2.08	24.02	
CIIAA9-71/SURGE/	-0.57	-0.20	0.053	0.063	2.14	22.71	
CIIAA9-72/SURGE/	-0.89	-0.10	0.017	0.007	2.17	22.24	
CIIAA9-73/SURGE/	-0.81	-0.19	0.026	0.014	2.20	22.68	
CIIAA9-74/SURGE/	-0.49	-0.21	0.013	0.068	2.23	22.78	
CIIAA9-75/SURGE/	-0.16	-0.54	0.014	0.080	2.26	24.33	
CIIAA9-76/SURGE/	0.15	-0.61	0.054	0.017	2.29	24.67	
CIIAA9-77/SURGE/	0.62	-0.60	0.024	0.090	2.32	24.59	
CIIAA9-78/SURGE/	0.83	-0.98	0.043	0.089	2.35	26.44	
CIIAA9-79/SURGE/	0.68	-1.31	0.065	0.098	2.38	28.06	
CIIAA9-80/SURGE/	1.10	-0.91	0.027	0.102	2.42	26.08	
CIIAA9-81/SURGE/	0.50	-1.13	0.050	0.093	2.45	27.14	
CIIAA9-82/SURGE/	-0.13	-1.10	0.004	0.017	2.48	27.04	
CIIAA9-83/SURGE/	-0.91	-1.29	0.034	0.087	2.51	26.49	low voltage
CIIAA9-84/SURGE/	-0.99	-1.20	0.053	0.123	2.54	23.51	low voltage
CIIAA9-85/SURGE/	-1.03	-0.71	0.020	0.073	2.57	25.16	
CIIAA9-86/SURGE/	0.00	-0.57	0.019	0.073	2.60	24.46	

APPENDIX C: Oxygen and Carbon Isotope Ratios of *Mercenaria campechiensis* Shells

05PI05 (measured in 5/15/2007-5/27/2007)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from margin (mm)	Estimated temperature (^{o}C)	Comments
05PI05-1/SURGE/	-3.02	-2.53	0.03	0.02	27.01	34.12	Near umbo, band
05PI05-2/SURGE/	-3.47	-2.44	0.03	0.02	26.37	33.67	Band
05PI05-3/SURGE/	-3.45	-2.24			25.72	32.69	Band
05PI05-4/SURGE/	-3.19	-2.43			25.08	33.61	Band
05PI05-5/SURGE/	-2.52	-2.64	0.02	0.02	24.44	34.68	Band
05PI05-6/SURGE/	-2.27	-2.57			23.79	34.34	Band
05PI05-7/SURGE/	-2.59	-2.64	0.02	0.01	23.15	34.71	Band
05PI05-8/SURGE/	-2.48	-2.61			22.51	34.55	Band
05PI05-9/SURGE/	-2.29	-2.35			21.87	33.20	Band
05PI05-11/SURGE/	-2.33	-1.73	0.03	0.07	20.58	30.10	Band
05PI05-12/SURGE/	-1.62	-1.58	0.02	0.06	19.94	29.38	Band
05PI05-13/SURGE/	-2.13	-1.48	0.03	0.03	19.60	28.86	
05PI05-14/SURGE/	-1.78	-0.84	0.01	0.01	19.26	25.78	
05PI05-15/SURGE/	-1.24	-0.11	0.04	0.03	18.92	22.27	
05PI05-17/SURGE/	-1.48	-0.90	0.01	0.02	18.24	26.03	
05PI05-18/SURGE/	-1.48	-0.77	0.04	0.02	17.90	25.45	
05PI05-20/SURGE/	-1.19	-0.27	0.02	0.02	17.23	23.05	
05PI05-21/SURGE/	-1.20	-0.35	0.01	0.03	16.89	23.40	
05PI05-22/SURGE/	-1.15	-0.53	0.02	0.02	16.55	24.29	
05PI05-23/SURGE/	-1.14	-0.50	0.03	0.04	16.21	24.12	
05PI05-24/SURGE/	-0.94	-0.82	0.02	0.03	15.87	25.68	
05PI05-25/SURGE/	-0.98	-0.54	0.01	0.04	15.53	24.35	
05PI05-26/SURGE/	-1.24	-0.83	0.06	0.09	15.19	25.70	
05PI05-27/SURGE/	-1.19	-0.76	0.02	0.02	14.85	25.38	
05PI05-28/SURGE/	-1.22	-0.26	0.02	0.02	14.51	23.01	
05PI05-29/SURGE/	-1.31	-0.39	0.02	0.06	14.18	23.60	
05PI05-30/SURGE/	-1.78	-0.24	0.02	0.03	13.84	22.91	
05PI05-31/SURGE/	-1.95	0.01	0.01	0.03	13.50	21.71	
05PI05-32/SURGE/	-2.25	-0.18	0.02	0.03	13.16	22.63	
05PI05-34/SURGE/	-3.20	-0.27			12.14	23.04	Band
05PI05-35/SURGE/	-3.31	-0.97	0.01	0.04	11.63	26.41	Band
05PI05-36/SURGE/	-3.24	-1.71	0.02	0.01	11.12	30.02	Band
05PI05-37/SURGE/	-3.13	-2.07	0.02	0.01	10.61	31.82	Band
05PI05-38/SURGE/	-2.85	-1.94	0.03	0.01	10.10	31.15	Band
05PI05-39/SURGE/	-2.67	-1.86	0.01	0.01	9.59	30.78	Band
05PI05-40/SURGE/	-2.69	-1.59	0.02	0.02	9.08	29.40	Band
05PI05-41/SURGE/	-2.57	-1.55	0.02	0.05	8.73	29.23	Band
05PI05-42/SURGE/	-2.83	-1.68	0.01	0.02	8.03	29.86	Band
05PI05-43/SURGE/	-2.67	-1.29	0.02	0.03	7.68	27.96	
05PI05-44/SURGE/	-2.68	-0.73	0.02	0.03	7.33	25.23	
05PI05-45/SURGE/	-2.47	0.07	0.01	0.02	6.98	21.44	

05PI05-46/SURGE/	-2.20	0.69	0.02	0.03	6.64	18.58	
05PI05-47/SURGE/	-1.88	0.58	0.03	0.04	6.29	19.09	
05PI05-48/SURGE/	-1.84	0.34	0.02	0.03	5.94	20.20	
05PI05-49/SURGE/	-1.84	0.37	0.02	0.02	5.59	20.06	
05PI05-50/SURGE/	-1.91	0.56	0.01	0.02	5.24	19.19	
05PI05-51/SURGE/	-1.67	0.90	0.01	0.02	4.89	17.62	
05PI05-52/SURGE/	-1.45	0.66	0.02	0.03	4.54	18.70	
05PI05-53/SURGE/	-1.42	0.95	0.01	0.03	4.19	17.39	
05PI05-54/SURGE/	-1.59	0.83	0.01	0.02	3.84	17.93	
05PI05-55/SURGE/	-1.70	0.40	0.02	0.03	3.49	19.89	
05PI05-56/SURGE/	-1.67	0.28	0.01	0.02	3.14	20.47	
05PI05-57/SURGE/	-1.82	0.34	0.01	0.02	2.62	20.20	
05PI05-58/SURGE/	-1.87	0.10	0.02	0.04	2.09	21.31	
05PI05-59/SURGE/	-1.96	-0.14	0.02	0.01	1.57	22.41	
05PI05-60/SURGE/	-1.54	-0.12	0.01	0.03	1.05	22.33	
05PI05-61/SURGE/	-1.67	-0.15	0.01	0.03	0.52	22.49	
05PI05-62/SURGE/	-2.19	-0.68	0.01	0.03	0.00	25.00	

05PI17 (measured in 5/22/2007-5/27/2007)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from margin (mm)	Estimated temperature (^{o}C)	Comments
05PI17-1/SURGE/	-2.30	0.70	0.03	0.02	40.02	18.54	
05PI17-2/SURGE/	-2.88	0.30	0.04	0.05	39.40	20.37	
05PI17-3/SURGE/	-3.01	-0.50	0.04	0.04	38.78	24.15	
05PI17-4/SURGE/	-2.78	-0.56	0.03	0.05	38.15	24.44	Band
05PI17-5/SURGE/	-3.09	-1.49	0.02	0.03	37.53	28.93	Band
05PI17-6/SURGE/	-3.50	-1.82	0.02	0.02	36.91	30.58	Band
05PI17-7/SURGE/	-2.93	-2.17	0.02	0.02	36.29	32.32	Band
05PI17-8/SURGE/	-3.03	-1.41	0.01	0.03	35.66	28.55	Band
05PI17-9/SURGE/	-3.00	-1.97	0.02	0.03	35.04	31.32	Band
05PI17-10/SURGE/	-2.92	-2.11	0.01	0.02	34.42	32.01	Band
05PI17-11/SURGE/	-4.00	-2.21	0.03	0.03	33.80	32.53	Band
05PI17-12/SURGE/	-3.39	-2.27	0.02	0.04	33.17	32.83	Band
05PI17-13/SURGE/	-3.59	-1.48	0.01	0.02	32.55	28.89	Band
05PI17-14/SURGE/	-3.32	-1.26	0.02	0.02	31.93	27.78	Band
05PI17-15/SURGE/	-3.16	-1.45	0.03	0.03	31.30	28.75	Band
05PI17-16/SURGE/	-3.21	-1.11	0.02	0.03	30.68	27.04	Band
05PI17-17/SURGE/	-3.20	-0.93	0.03	0.04	30.06	26.17	Band
05PI17-18/SURGE/	-2.63	-0.56	0.01	0.05	29.44	24.44	Band
05PI17-19/SURGE/	-2.95	-0.34	0.02	0.02	28.81	23.35	
05PI17-20/SURGE/	-2.77	0.04	0.01	0.01	28.19	21.56	
05PI17-21/SURGE/	-1.45	0.26	0.02	0.04	27.10	20.55	
05PI17-22/SURGE/	-1.57	0.30	0.02	0.04	26.67	20.38	
05PI17-23/SURGE/	-1.61	0.30	0.02	0.03	26.24	20.37	
05PI17-25/SURGE/	-1.60	0.42	0.01	0.02	25.38	19.81	
05PI17-26/SURGE/	-1.58	0.37	0.02	0.02	24.95	20.05	
05PI17-27/SURGE/	-1.64	0.42	0.02	0.03	24.51	19.82	

05PI17-28/SURGE/	-2.02	-0.05	0.05	0.11	24.17	21.99	
05PI17-29/SURGE/	-1.69	0.21	0.01	0.03	23.65	20.81	
05PI17-30/SURGE/	-1.64	0.23	0.01	0.02	23.22	20.69	
05PI17-31/SURGE/	-1.53	0.30	0.02	0.01	22.79	20.38	
05PI17-32/SURGE/	-1.43	0.09	0.02	0.03	22.36	21.33	
05PI17-33/SURGE/	-1.42	-0.07	0.02	0.04	21.93	22.11	
05PI17-34/SURGE/	-1.45	0.36	0.05	0.06	21.50	20.07	
05PI17-35/SURGE/	-1.41	0.15	0.03	0.04	21.07	21.05	
05PI17-36/SURGE/	-1.53	-0.01	0.02	0.03	20.63	21.80	
05PI17-37/SURGE/	-1.80	-0.24	0.03	0.03	20.20	22.89	
05PI17-38/SURGE/	-1.65	-0.29	0.03	0.04	19.77	23.13	
05PI17-40/SURGE/	-1.83	0.09	0.01	0.06	18.91	21.34	
05PI17-41/SURGE/	-1.68	-0.03	0.03	0.04	18.23	21.89	
05PI17-42/SURGE/	-1.87	0.30	0.02	0.03	17.55	20.35	
05PI17-43/SURGE/	-2.23	-0.10	0.02	0.01	16.87	22.25	
05PI17-44/SURGE/	-2.34	-0.72	0.03	0.02	16.18	25.18	
05PI17-45/SURGE/	-2.44	-1.23	0.03	0.02	15.50	27.64	Band
05PI17-46/SURGE/	-2.35	-0.97	0.03	0.04	14.82	26.38	Band
05PI17-47/SURGE/	-2.50	-1.29	0.02	0.05	14.14	27.96	Band
05PI17-48/SURGE/	-2.65	-1.15	0.01	0.03	13.46	27.24	Band
05PI17-49/SURGE/	-2.18	-1.61	0.02	0.03	12.78	29.50	Band
05PI17-50/SURGE/	-2.53	-1.88	0.03	0.03	12.10	30.84	Band
05PI17-51/SURGE/	-2.26	-2.14	0.02	0.04	11.41	32.16	Band
05PI17-52/SURGE/	-3.16	-2.42	0.02	0.02	10.73	33.58	Band
05PI17-53/SURGE/	-2.48	-2.16	0.03	0.03	10.05	32.26	Band
05PI17-54/SURGE/	-2.47	-2.04	0.04	0.06	9.37	31.68	Band
05PI17-55/SURGE/	-3.55	-2.70	0.02	0.03	8.69	35.03	Band
05PI17-56/SURGE/	-3.45	-2.17	0.05	0.03	8.01	32.30	Band
05PI17-57/SURGE/	-3.69	-1.63	0.05	0.07	7.33	29.63	Band
05PI17-58/SURGE/	-3.83	-2.29	0.04	0.05	6.64	32.93	Band
05PI17-59/SURGE/	-3.13	-2.50	0.03	0.09	5.96	33.99	Band
05PI17-60/SURGE/	-3.18	-2.47	0.03	0.02	5.28	33.81	Band
05PI17-61/SURGE/	-1.99	0.67	0.01	0.02	5.02	18.68	
05PI17-62/SURGE/	-1.95	0.61	0.01	0.01	4.75	18.96	
05PI17-63/SURGE/	-2.02	0.71	0.01	0.03	4.49	18.47	
05PI17-64/SURGE/	-2.20	0.63	0.01	0.05	4.22	18.85	
05PI17-65/SURGE/	-2.28	0.34	0.01	0.03	3.96	20.19	
05PI17-66/SURGE/	-2.29	0.29	0.01	0.03	3.70	20.42	
05PI17-67/SURGE/	-2.31	0.38	0.02	0.03	3.43	19.98	
05PI17-68/SURGE/	-2.18	0.35	0.02	0.02	3.17	20.13	
05PI17-69/SURGE/	-2.36	0.23	0.01	0.03	2.90	20.69	
05PI17-70/SURGE/	-2.66	-0.18	0.01	0.02	2.64	22.64	
05PI17-71/SURGE/	-2.99	-0.63	0.02	0.05	2.38	24.75	
05PI17-72/SURGE/	-2.82	-0.71	0.05	0.13	2.11	25.15	
05PI17-73/SURGE/	-2.32	-0.25	0.02	0.02	1.85	22.93	
05PI17-74/SURGE/	-2.10	-0.05	0.04	0.03	1.58	22.01	
05PI17-75/SURGE/	-2.50	-0.30	0.01	0.02	1.32	23.17	
05PI17-76/SURGE/	-2.99	-0.48	0.01	0.02	1.06	24.04	

05PI17-77/SURGE/	-2.91	-0.99	0.01	0.01	0.79	26.47	
05PI17-78/SURGE/	-2.63	-0.74	0.01	0.03	0.53	25.28	
05PI17-79/SURGE/	-2.33	-0.77	0.03	0.03	0.26	25.45	
05PI17-80/SURGE/	-2.43	-0.87	0.02	0.03	0.00	25.90	

CIIA-M5 (measured in 11/06/2007-11/28/2007)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from margin (mm)	Estimated temperature (^{o}C)	Comments
CIIAM5-1/SURGE/	-0.27	-1.50	0.006	0.063	86.8	28.95	
CIIAM5-2/SURGE/	0.39	-0.68	0.040	0.070	86.14	24.99	
CIIAM5-3/SURGE/	0.63	-0.03	0.007	0.023	85.48	21.91	
CIIAM5-4/SURGE/	0.59	0.20	0.043	0.065	84.81	20.83	
CIIAM5-5/SURGE/	0.28	-0.12	0.032	0.074	84.15	22.36	
CIIAM5-6/SURGE/	0.27	-0.11	0.019	0.022	83.49	22.27	
CIIAM5-7/SURGE/	0.37	-0.03	0.027	0.034	82.82	21.91	
CIIAM5-8/SURGE/	0.70	0.34	0.003	0.056	82.16	20.17	
CIIAM5-9/SURGE/	0.89	0.57	0.056	0.023	81.5	19.10	
CIIAM5-10/SURGE/	1.08	0.57	0.052	0.059	80.84	19.12	
CIIAM5-11/SURGE/	1.00	0.29	0.022	0.020	80.17	20.42	
CIIAM5-12/SURGE/	0.77	-0.08	0.015	0.086	79.51	22.14	
CIIAM5-13/SURGE/	0.47	-0.38	0.046	0.075	78.85	23.54	Band
CIIAM5-14/SURGE/	0.40	-0.27	0.020	0.057	78.18	23.05	Band
CIIAM5-15/SURGE/	0.41	-0.47	0.047	0.085	77.52	24.01	Band
CIIAM5-16/SURGE/	0.29	-0.93	0.011	0.022	76.86	26.21	Band
CIIAM5-17/SURGE/	0.22	-1.00	0.012	0.034	76.2	26.54	Band
CIIAM5-18/SURGE/	-0.01	-1.21	0.005	0.037	75.53	27.55	Band
CIIAM5-19/SURGE/	-0.01	-1.26	0.019	0.040	74.87	27.77	Band
CIIAM5-20/SURGE/	0.05	-1.28	0.036	0.069	74.21	27.90	Band
CIIAM5-21/SURGE/	0.20	-1.19	0.027	0.023	73.54	27.44	Band
CIIAM5-22/SURGE/	0.16	-1.22	0.020	0.034	72.88	27.62	Band
CIIAM5-23/SURGE/	-0.30	-1.27	0.011	0.020	72.22	27.83	Band
CIIAM5-24/SURGE/	-0.16	-0.84	0.006	0.067	71.55	25.74	Band
CIIAM5-25/SURGE/	0.12	-0.09	0.014	0.069	70.89	22.18	
CIIAM5-26/SURGE/	0.20	-0.09	0.014	0.064	70.34	22.20	
CIIAM5-27/SURGE/	0.25	0.13	0.029	0.021	69.8	21.17	
CIIAM5-28/SURGE/	0.44	0.31	0.018	0.028	69.25	20.33	
CIIAM5-29/SURGE/	0.45	0.47	0.024	0.018	68.7	19.60	
CIIAM5-30/SURGE/	0.32	0.35	0.016	0.041	68.16	20.13	
CIIAM5-31/SURGE/	0.47	0.47	0.030	0.054	67.61	19.58	
CIIAM5-32/SURGE/	0.53	0.47	0.060	0.025	67.06	19.60	
CIIAM5-33/SURGE/	0.50	0.53	0.026	0.023	66.52	19.30	
CIIAM5-34/SURGE/	0.46	0.26	0.013	0.085	65.97	20.55	
CIIAM5-35/SURGE/	0.40	0.18	0.017	0.029	65.42	20.92	
CIIAM5-36/SURGE/	0.57	0.10	0.004	0.007	64.87	21.30	
CIIAM5-37/SURGE/	0.41	-0.06	0.044	0.043	64.33	22.03	
CIIAM5-38/SURGE/	0.43	-0.40	0.045	0.054	63.78	23.65	Band
CIIAM5-39/SURGE/	0.22	-0.68	0.011	0.049	63.23	24.99	Band

CIIAM5-40/SURGE/	0.40	-0.80	0.016	0.064	62.69	25.55	Band
CIIAM5-41/SURGE/	0.28	-1.00	0.011	0.029	62.14	26.52	Band
CIIAM5-42/SURGE/	0.19	-0.94	0.001	0.019	61.59	26.22	Band
CIIAM5-43/SURGE/	0.00	-1.04	0.044	0.028	61.04	26.74	Band
CIIAM5-44/SURGE/	-0.16	-1.54	0.034	0.032	60.5	29.17	Band
CIIAM5-45/SURGE/	-0.51	-1.59	0.016	0.032	59.95	29.41	Band
CIIAM5-46/SURGE/	-0.32	-1.25	0.017	0.013	59.4	27.74	Band
CIIAM5-47/SURGE/	-0.33	-1.68	0.060	0.045	58.86	29.88	Band
CIIAM5-48/SURGE/	-0.04	-1.47	0.013	0.062	58.31	28.84	Band
CIIAM5-49/SURGE/	-0.02	-0.53	0.045	0.089	57.76	24.26	
CIIAM5-50/SURGE/	0.20	-0.43	0.045	0.090	57.27	23.81	
CIIAM5-51/SURGE/	0.48	-0.33	0.052	0.062	56.78	23.32	
CIIAM5-52/SURGE/	0.56	-0.25	0.083	0.051	56.28	22.96	
CIIAM5-53/SURGE/	0.34	-0.02	0.037	0.057	55.79	21.84	
CIIAM5-54/SURGE/	0.22	0.23	0.024	0.100	55.29	20.70	
CIIAM5-55/SURGE/	0.25	0.21	0.057	0.085	54.8	20.78	
CIIAM5-56/SURGE/	0.95	0.67	0.035	0.048	54.3	18.64	
CIIAM5-57/SURGE/	1.39	1.07	0.052	0.048	53.81	16.84	
CIIAM5-58/SURGE/	1.25	0.69	0.010	0.033	53.32	18.56	
CIIAM5-59/SURGE/	1.10	0.36	0.011	0.037	52.82	20.08	
CIIAM5-60/SURGE/	0.92	-0.01	0.011	0.106	52.33	21.79	
CIIAM5-61/SURGE/	0.49	-0.69	0.013	0.024	51.84	25.06	
CIIAM5-62/SURGE/	0.59	-0.85	0.017	0.056	51.34	25.79	Band
CIIAM5-63/SURGE/	0.82	-0.80	0.051	0.041	50.85	25.55	Band
CIIAM5-64/SURGE/	0.69	-0.79	0.045	0.115	50.35	25.51	Band
CIIAM5-65/SURGE/	0.53	-1.01	0.022	0.030	49.86	26.60	Band
CIIAM5-66/SURGE/	0.19	-1.16	0.051	0.026	49.36	27.33	Band
CIIAM5-67/SURGE/	0.35	-1.31	0.074	0.047	48.87	28.02	Band
CIIAM5-68/SURGE/	0.20	-1.53	0.010	0.078	48.38	29.12	Band
CIIAM5-69/SURGE/	0.12	-1.58	0.023	0.059	47.88	29.37	Band
CIIAM5-70/SURGE/	-0.11	-1.79	0.074	0.059	47.39	30.42	Band
CIIAM5-71/SURGE/	-0.25	-1.83	0.009	0.066	46.9	30.59	Band
CIIAM5-72/SURGE/	-0.40	-1.19	0.046	0.065	46.4	27.46	Band
CIIAM5-73/SURGE/	-0.58	-1.16	0.033	0.084	45.91	27.30	
CIIAM5-74/SURGE/	0.08	0.02	0.010	0.010	45.48	21.69	
CIIAM5-75/SURGE/	0.17	0.13	0.065	0.058	45.06	21.18	
CIIAM5-76/SURGE/	0.24	0.17	0.023	0.088	44.64	20.96	
CIIAM5-77/SURGE/	0.38	0.46	0.006	0.016	44.21	19.62	
CIIAM5-78/SURGE/	0.52	0.50	0.023	0.095	43.79	19.44	
CIIAM5-79/SURGE/	0.72	0.95	0.012	0.023	43.36	17.38	
CIIAM5-80/SURGE/	0.72	0.48	0.008	0.073	42.94	19.53	
CIIAM5-81/SURGE/	0.86	0.45	0.106	0.117	42.52	19.67	
CIIAM5-82/SURGE/	0.69	0.10	0.015	0.057	42.09	21.32	
CIIAM5-83/SURGE/	0.26	-0.12	0.008	0.050	41.67	22.33	
CIIAM5-84/SURGE/	0.31	-0.09	0.026	0.048	41.24	22.18	
CIIAM5-85/SURGE/	0.35	-0.24	0.086	0.100	40.82	22.89	
CIIAM5-86/SURGE/	0.36	-0.31	0.037	0.025	40.4	23.23	
CIIAM5-87/SURGE/	0.15	-0.53	0.039	0.068	39.97	24.27	Band

CIIAM5-88/SURGE/	-0.01	-0.63	0.032	0.075	39.55	24.75	Band
CIIAM5-89/SURGE/	0.34	-0.47	0.068	0.043	39.12	23.99	Band
CIIAM5-90/SURGE/	0.98	-0.45	0.015	0.103	38.7	23.91	Band
CIIAM5-91/SURGE/	0.26	-0.62	0.037	0.098	38.28	24.73	Band
CIIAM5-92/SURGE/	-0.07	-1.11	0.022	0.036	37.85	27.07	Band
CIIAM5-93/SURGE/	0.68	-1.29	0.026	0.028	37.43	27.97	Band
CIIAM5-94/SURGE/	0.69	-1.25	0.088	0.081	37	27.73	Band
CIIAM5-95/SURGE/	0.71	-0.86	0.056	0.075	36.58	25.85	Band
CIIAM5-96/SURGE/	0.07	-1.04	0.011	0.008	36.16	26.73	Band
CIIAM5-97/SURGE/	-0.55	-1.07	0.022	0.017	35.73	26.85	
CIIAM5-98/SURGE/	0.05	-0.44	0.031	0.016	35.27	23.82	
CIIAM5-99/SURGE/	-0.15	-0.23	0.027	0.082	34.8	22.85	
CIIAM5-100/SURGE/	-0.07	-0.01	0.025	0.042	34.34	21.80	
CIIAM5-101/SURGE/	-0.07	0.15	0.039	0.009	33.88	21.07	
CIIAM5-102/SURGE/	-0.10	0.11	0.028	0.014	33.41	21.24	
CIIAM5-103/SURGE/	0.24	0.72	0.002	0.065	32.95	18.43	
CIIAM5-104/SURGE/	0.37	0.58	0.010	0.016	32.48	19.08	
CIIAM5-105/SURGE/	0.60	0.75	0.081	0.095	32.02	18.29	
CIIAM5-106/SURGE/	0.84	0.97	0.007	0.048	31.56	17.30	
CIIAM5-107/SURGE/	0.74	0.70	0.015	0.015	31.19	18.53	
CIIAM5-108/SURGE/	0.71	0.52	0.041	0.051	30.73	19.36	
CIIAM5-109/SURGE/	0.64	0.22	0.020	0.017	30.26	20.76	
CIIAM5-110/SURGE/	0.71	0.44	0.030	0.028	29.8	19.70	
CIIAM5-111/SURGE/	0.60	0.15	0.017	0.025	29.34	21.06	
CIIAM5-112/SURGE/	0.20	-0.49	0.022	0.023	28.87	24.09	Band
CIIAM5-113/SURGE/	0.04	-0.70	0.042	0.057	28.41	25.09	Band
CIIAM5-114/SURGE/	0.20	-1.05	0.047	0.058	27.94	26.77	Band
CIIAM5-115/SURGE/	0.47	-1.20	0.018	0.028	27.48	27.52	Band
CIIAM5-116/SURGE/	0.70	-1.35	0.077	0.060	27.02	28.23	Band
CIIAM5-117/SURGE/	0.19	-1.44	0.041	0.081	26.55	28.67	Band
CIIAM5-118/SURGE/	-0.09	-1.61	0.037	0.027	26.09	29.51	Band
CIIAM5-119/SURGE/	-0.62	-1.60	0.016	0.071	25.62	29.47	Band
CIIAM5-120/SURGE/	-0.01	-1.64	0.020	0.097	25.1	29.66	Band

CIIAM2 (measured in 10/06/2002-10/16/2002)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from margin (mm)	Estimated temperature (^{o}C)	Comments
CIIAM2-1/SURGE/	0.23	-1.10	0.02	0.03	83.64	27.03	Umbo
CIIAM2-2/SURGE/	-0.32	-1.54	0.01	0.03	82.77	29.16	
CIIAM2-3/SURGE/	-0.52	-1.79	0.02	0.04	81.90	30.39	
CIIAM2-4/SURGE/	0.08	-1.40	0.01	0.01	81.03	28.47	
CIIAM2-5/SURGE/	0.36	-1.12	0.03	0.02	80.16	27.10	
CIIAM2-6/SURGE/	0.42	-0.51	0.03	0.05	79.29	24.18	Band
CIIAM2-7/SURGE/	-0.02	-0.08	0.01	0.02	78.45	22.14	
CIIAM2-8/SURGE/	0.51	0.48	0.01	0.01	77.60	19.55	
CIIAM2-9/SURGE/	1.00	0.54	0.01	0.01	76.76	19.28	
CIIAM2-10/SURGE/	0.57	0.11	0.01	0.02	75.92	21.24	

CIIAM2-11/SURGE/	0.72	-0.12	0.01	0.02	75.07	22.35	
CIIAM2-12/SURGE/	0.39	-0.21	0.01	0.04	74.23	22.75	
CIIAM2-13/SURGE/	0.42	-0.07	0.03	0.02	73.38	22.12	
CIIAM2-14/SURGE/	0.86	0.29	0.02	0.03	72.54	20.39	
CIIAM2-15/SURGE/	0.86	-0.23	0.02	0.03	71.69	22.87	
CIIAM2-16/SURGE/	0.91	-0.12	0.01	0.01	70.85	22.31	
CIIAM2-17/SURGE/	-0.57	-0.80	0.00	0.03	70.12	25.58	Band
CIIAM2-18/SURGE/	-0.03	-1.61	0.02	0.02	69.38	29.54	Band
CIIAM2-19/SURGE/	-0.06	-1.88	0.00	0.01	68.64	30.88	Band
CIIAM2-20/SURGE/	0.22	-0.60	0.01	0.02	67.91	24.59	
CIIAM2-21/SURGE/	0.18	-0.20	0.04	0.05	67.17	22.69	
CIIAM2-22/SURGE/	0.41	0.04	0.02	0.02	66.44	21.57	
CIIAM2-23/SURGE/	0.56	0.33	0.01	0.03	65.70	20.21	
CIIAM2-24/SURGE/	0.32	-0.27	0.01	0.01	64.97	23.03	
CIIAM2-25/SURGE/	0.33	-0.68	0.01	0.05	64.23	24.99	
CIIAM2-26/SURGE/	0.59	-1.14	0.00	0.03	63.50	27.20	
CIIAM2-27/SURGE/	0.13	-1.35	0.02	0.02	62.76	28.22	Band
CIIAM2-28/SURGE/	0.10	-1.62	0.02	0.02	62.03	29.55	Band
CIIAM2-29/SURGE/	0.35	-1.44	0.02	0.01	61.29	28.66	Band
CIIAM2-30/SURGE/	-0.71	-1.23	0.00	0.02	60.56	27.63	Band
CIIAM2-31/SURGE/	-0.37	-0.68	0.01	0.01	59.82	24.99	
CIIAM2-32/SURGE/	-0.07	-0.41	0.01	0.03	59.09	23.69	
CIIAM2-33/SURGE/	0.07	-0.12	0.01	0.01	58.35	22.34	
CIIAM2-34/SURGE/	0.22	0.30	0.02	0.02	57.62	20.37	
CIIAM2-35/SURGE/	0.35	0.17	0.02	0.02	56.88	20.99	
CIIAM2-36/SURGE/	0.25	0.40	0.02	0.02	56.15	19.92	
CIIAM2-37/SURGE/	0.12	-0.25	0.01	0.03	55.41	22.94	
CIIAM2-38/SURGE/	0.60	0.13	0.03	0.04	54.67	21.18	
CIIAM2-39/SURGE/	-0.41	-0.70	0.03	0.03	53.09	25.11	Band
CIIAM2-40/SURGE/	0.47	-1.70	0.01	0.04	51.51	29.98	Band
CIIAM2-41/SURGE/	-0.13	-2.36	0.01	0.03	49.92	33.27	Band
CIIAM2-42/SURGE/	-0.02	-2.24	0.02	0.04	48.34	32.64	Band
CIIAM2-43/SURGE/	0.35	-1.03	0.02	0.04	46.76	26.69	
CIIAM2-44/SURGE/	0.13	-0.67	0.03	0.06	45.17	24.94	
CIIAM2-45/SURGE/	0.35	-0.13	0.01	0.03	43.59	22.36	
CIIAM2-46/SURGE/	0.42	-0.29	0.01	0.03	42.00	23.13	
CIIAM2-47/SURGE/	0.48	-0.75	0.01	0.01	40.42	25.32	
CIIAM2-48/SURGE/	-0.02	-1.15	0.02	0.04	39.14	27.27	Band
CIIAM2-49/SURGE/	-0.43	-1.27	0.01	0.02	37.87	27.86	Band
CIIAM2-50/SURGE/	0.19	0.04	0.01	0.02	36.59	21.61	Band
CIIAM2-51/SURGE/	0.62	0.09	0.01	0.02	35.32	21.37	
CIIAM2-52/SURGE/	0.10	-1.44	0.01	0.03	34.04	28.69	
CIIAM2-53/SURGE/	0.82	-2.22	0.01	0.01	32.77	32.59	
CIIAM2-54/SURGE/	0.68	-2.08	0.02	0.02	31.49	31.86	
CIIAM2-55/SURGE/	0.01	-2.12	0.02	0.02	30.21	32.05	
CIIAM2-56/SURGE/	0.33	-2.18	0.02	0.01	28.94	32.35	
CIIAM2-57/SURGE/	-0.12	-2.10	0.02	0.07	27.66	31.98	
CIIAM2-58/SURGE/	-0.05	-0.68	0.02	0.02	26.63	24.97	Band

CIIAM2-59/SURGE/	0.09	-0.58	0.02	0.02	25.59	24.53	Band
CIIAM2-60/SURGE/	-0.24	-1.20	0.01	0.04	24.55	27.48	Band
CIIAM2-61/SURGE/	-0.45	-0.78	0.01	0.02	23.52	25.46	Band
CIIAM2-62/SURGE/	-0.38	-1.27	0.02	0.05	22.48	27.86	
CIIAM2-63/SURGE/	-0.03	-1.66	0.02	0.04	21.44	29.79	
CIIAM2-64/SURGE/	0.20	-1.26	0.01	0.02	20.40	27.78	
CIIAM2-65/SURGE/	-0.06	-0.52	0.01	0.01	19.37	24.24	
CIIAM2-66/SURGE/	0.02	-0.82	0.02	0.01	18.33	25.66	
CIIAM2-67/SURGE/	-0.06	-0.05	0.02	0.02	17.55	22.00	Band
CIIAM2-68/SURGE/	0.21	0.00	0.01	0.01	16.77	21.79	Band
CIIAM2-69/SURGE/	0.42	0.04	0.02	0.03	15.99	21.57	Band
CIIAM2-70/SURGE/	-0.18	-0.88	0.03	0.02	15.21	25.95	Band
CIIAM2-71/SURGE/	-0.49	-1.75	0.02	0.04	14.44	30.19	
CIIAM2-72/SURGE/	-0.06	-1.29	0.02	0.01	13.66	27.92	
CIIAM2-73/SURGE/	-0.15	-1.15	0.02	0.03	12.88	27.28	
CIIAM2-74/SURGE/	-0.20	-0.69	0.01	0.03	12.10	25.05	
CIIAM2-75/SURGE/	-0.22	-0.36	0.01	0.03	11.32	23.45	
CIIAM2-76/SURGE/	-0.26	-0.02	0.02	0.05	10.54	21.86	Band

CIIA-M1 (measured in 12/2001 and 12/2002)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from margin (mm)	Estimated temperature (°C)	Comments
CIIAM1-1/SURGE/	-0.32	-0.88	0.02	0.05	101.57	25.97	End of band 1 - Umbo
CIIAM1-2/SURGE/	0.35	0.84	0.02	0.03	99.92	17.91	
CIIAM1-3/SURGE/	0.59	0.05	0.01	0.01	98.02	21.56	
CIIAM1-4/SURGE/	0.94	1.78	0.02	0.02	96.18	13.68	
CIIAM1-5/SURGE/	0.88	0.70	0.04	0.04	94.34	18.52	
CIIAM1-6/SURGE/	0.52	0.37	0.01	0.01	92.50	20.03	
CIIAM1-7/SURGE/	0.28	0.21	0.01	0.05	90.66	20.79	
CIIAM1-8/SURGE/	-0.06	0.14	0.02	0.01	88.82	21.10	
CIIAM1-9/SURGE/	-0.73	0.01	0.02	0.03	86.98	21.71	
CIIAM1-10/SURGE/	-0.55	0.21	0.05	0.03	85.14	20.77	
CIIAM1-11/SURGE/	-0.39	-0.92	0.02	0.03	83.30	26.15	Band
CIIAM1-12/SURGE/	0.02	-0.51	0.02	0.04	81.46	24.16	Band
CIIAM1-13/SURGE/	-0.47	-0.39	0.01	0.03	79.62	23.60	Band
CIIAM1-14/SURGE/	-0.89	-0.87	0.01	0.06	77.78	25.91	
CIIAM1-15/SURGE/	-0.20	0.06	0.01	0.02	76.19	21.50	
CIIAM1-16/SURGE/	0.28	0.86	0.04	0.05	75.06	17.80	
CIIAM1-17/SURGE/	0.43	1.53	0.01	0.03	74.15	14.76	
CIIAM1-18/SURGE/	0.77	1.52	0.02	0.03	72.92	14.83	
CIIAM1-19/SURGE/	0.59	0.50	0.03	0.05	71.82	19.47	
CIIAM1-20/SURGE/	0.53	0.56	0.02	0.05	70.72	19.17	
CIIAM1-21/SURGE/	0.10	-0.13	0.01	0.03	69.42	22.38	
CIIAM1-22/SURGE/	-0.22	-0.30	0.02	0.03	68.12	23.17	
CIIAM1-23/SURGE/	-0.17	-0.43	0.02	0.02	66.82	23.78	
CIIAM1-24/SURGE/	-0.19	-1.25	0.02	0.02	65.52	27.74	

CIIAM1-25/SURGE/	-0.06	-1.16	0.02	0.03	64.72	27.31	
CIIAM1-26/SURGE/	-0.42	-1.50	0.01	0.04	63.40	28.98	Band
CIIAM1-27/SURGE/	-0.56	-1.67	0.01	0.03	62.60	29.81	Band
CIIAM1-28/SURGE/	-0.50	-1.30	0.03	0.16	61.64	28.00	Band
CIIAM1-29/SURGE/	-0.46	-1.43	0.02	0.04	60.68	28.62	Band
CIIAM1-30/SURGE/	-0.45	-1.34	0.01	0.02	59.72	28.19	Band
CIIAM1-31/SURGE/	-0.51	-0.98	0.02	0.02	58.76	26.41	Band
CIIAM1-32/SURGE/	-0.72	0.15	0.02	0.03	57.80	21.09	
CIIAM1-33/SURGE/	-0.75	0.26	0.02	0.03	56.84	20.58	
CIIAM1-34/SURGE/	-0.75	-0.28	0.02	0.02	55.88	23.07	
CIIAM1-35/SURGE/	-0.50	0.07	0.02	0.05	54.92	21.46	
CIIAM1-36/SURGE/	0.07	0.58	0.02	0.04	53.96	19.09	
CIIAM1-37/SURGE/	1.01	1.44	0.01	0.02	53.00	15.18	
CIIAM1-38/SURGE/	0.80	0.44	0.01	0.03	52.04	19.75	
CIIAM1-39/SURGE/	1.12	0.06	0.03	0.02	51.08	21.48	Band
CIIAM1-40/SURGE/	0.43	-0.41	0.02	0.05	50.12	23.72	Band
CIIAM1-41/SURGE/	0.46	-0.16	0.03	0.05	49.16	22.50	Band
CIIAM1-42/SURGE/	0.13	-0.85	0.02	0.01	48.20	25.79	Band
CIIAM1-43/SURGE/	0.47	-0.61	0.04	0.04	47.32	24.67	Band
CIIAM1-44/SURGE/	0.38	-0.85	0.02	0.03	46.44	25.80	
CIIAM1-45/SURGE/	0.14	-0.92	0.02	0.05	45.55	26.13	
CIIAM1-46/SURGE/	0.05	-1.06	0.01	0.02	44.67	26.82	
CIIAM1-47/SURGE/	-0.23	-0.86	0.02	0.05	43.78	25.86	
CIIAM1-48/SURGE/	0.23	-0.77			42.90	25.44	
CIIAM1-49/SURGE/	0.08	-0.18	0.01	0.01	42.01	22.61	
CIIAM1-50/SURGE/	-0.01	0.08	0.03	0.03	41.13	21.38	
CIIAM1-51/SURGE/	0.33	0.25	0.02	0.02	40.25	20.61	
CIIAM1-52/SURGE/	0.34	0.07	0.01	0.04	39.36	21.44	
CIIAM1-53/SURGE/	0.64	0.17	0.02	0.02	38.48	20.99	
CIIAM1-54/SURGE/	0.52	-0.08	0.02	0.03	37.59	22.13	
CIIAM1-55/SURGE/	-0.15	-1.02			36.71	26.63	
CIIAM1-56/SURGE/	0.52	0.54	0.01	0.03	36.25	19.25	
CIIAM1-57/SURGE/	0.51	0.16	0.03	0.04	35.79	21.00	Band
CIIAM1-58/SURGE/	0.33	-0.46	0.01	0.03	35.33	23.93	Band
CIIAM1-59/SURGE/	0.20	-0.11	0.01	0.01	34.87	22.30	Band
CIIAM1-60/SURGE/	-0.16	-0.83	0.03	0.02	34.41	25.70	Band
CIIAM1-61/SURGE/	-0.02	-1.34	0.01	0.02	33.95	28.18	Band
CIIAM1-62/SURGE/	-0.17	-1.17	0.01	0.01	33.49	27.35	Band
CIIAM1-63/SURGE/	-0.29	-0.59	0.02	0.04	33.03	24.55	
CIIAM1-64/SURGE/	-0.58	-0.18	0.01	0.04	32.57	22.63	
CIIAM1-65/SURGE/	-0.51	0.29	0.02	0.03	32.11	20.42	
CIIAM1-66/SURGE/	-0.17	0.21	0.01	0.04	31.65	20.80	
CIIAM1-67/SURGE/	-0.11	0.68	0.01	0.04	31.19	18.60	
CIIAM1-68/SURGE/	-0.01	0.77	0.03	0.02	30.73	18.20	
CIIAM1-69/SURGE/	0.07	0.72	0.01	0.04	30.27	18.41	
CIIAM1-70/SURGE/	0.54	1.14	0.01	0.02	29.81	16.52	
CIIAM1-71/SURGE/	0.59	0.24	0.02	0.03	29.35	20.66	
CIIAM1-72/SURGE/	0.64	0.18	0.02	0.01	28.93	20.92	Band

CIIAM1-73/SURGE/	0.74	0.04	0.01	0.03	28.51	21.56	Band
CIIAM1-74/SURGE/	0.29	-0.57	0.01	0.03	28.09	24.45	Band
CIIAM1-75/SURGE/	-0.64	-1.76	0.01	0.02	27.67	30.28	Band
CIIAM1-76/SURGE/	-1.00	-1.68	0.01	0.05	27.25	29.89	
CIIAM1-77/SURGE/	-0.81	-1.20	0.02	0.02	26.83	27.48	
CIIAM1-78/SURGE/	-0.34	-0.78	0.02	0.04	26.41	25.48	
CIIAM1-79/SURGE/	-0.02	-0.58	0.03	0.05	25.99	24.49	
CIIAM1-80/SURGE/	0.27	-0.68	0.02	0.03	25.57	24.99	
CIIAM1-81/SURGE/	-0.31	-0.74	0.01	0.00	25.15	25.26	Band
CIIAM1-82/SURGE/	0.23	-0.33	0.02	0.04	24.73	23.30	Band
CIIAM1-83/SURGE/	0.90	-0.44	0.01	0.02	24.31	23.84	Band
CIIAM1-84/SURGE/	-0.63	-1.59	0.01	0.04	23.89	29.40	Band
CIIAM1-85/SURGE/	-0.56	-1.90	0.01	0.02	23.47	30.98	Band
CIIAM1-86/SURGE/	0.26	-0.56	0.02	0.02	23.05	24.41	
CIIAM1-87/SURGE/	0.31	-0.25	0.02	0.03	22.63	22.95	
CIIAM1-88/SURGE/	0.26	-0.23	0.01	0.02	22.21	22.83	
CIIAM1-89/SURGE/	0.56	-0.05	0.02	0.04	21.79	22.00	
CIIAM1-90/SURGE/	0.89	-0.04	0.02	0.04	21.37	21.94	
CIIAM1-91/SURGE/	0.64	-0.13	0.03	0.04	20.95	22.37	
CIIAM1-92/SURGE/	0.79	0.00	0.02	0.04	20.53	21.75	
CIIAM1-93/SURGE/	0.66	0.40	0.02	0.03	20.11	19.91	
CIIAM1-94/SURGE/	0.77	0.02	0.04	0.07	19.69	21.67	Band
CIIAM1-95/SURGE/	-0.41	-0.89	0.02	0.02	19.27	26.00	Band

CIIA-M8 (measured in 6/08/2007-8/29/2007)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from margin (mm)	Estimated temperature (^{o}C)	Comments
CIIAM8-1/SURGE/	0.29	-0.96	0.029	0.049	115.10	26.36	Umbo, band
CIIAM8-2/SURGE/	0.27	-0.55	0.018	0.115	114.51	24.36	Band
CIIAM8-3/SURGE/	0.04	-0.34	0.010	0.068	113.92	23.35	Band
CIIAM8-4/SURGE/	-1.04	-1.27	0.028	0.050	113.34	27.83	Band
CIIAM8-5/SURGE/	-0.16	-2.18	0.033	0.045	112.75	32.37	Band
CIIAM8-6/SURGE/	-0.39	-2.92	0.027	0.028	112.16	36.12	Band
CIIAM8-7/SURGE/	-0.45	-3.02	0.041	0.067	111.57	36.65	Band
CIIAM8-8/SURGE/	0.01	-2.18	0.024	0.064	110.98	32.35	Band
CIIAM8-9/SURGE/	-0.37	-2.39	0.130	0.086	110.40	33.45	Band
CIIAM8-10/SURGE/	-0.61	-2.37	0.010	0.044	109.81	33.33	Band
CIIAM8-12/SURGE/	-0.43	-1.83	0.021	0.039	108.63	30.59	Band
CIIAM8-13/SURGE/	-0.77	-1.65	0.017	0.025	108.04	29.71	Band
CIIAM8-14/SURGE/	-0.68	-1.71	0.028	0.029	107.34	29.99	
CIIAM8-15/SURGE/	-0.63	-1.20	0.030	0.029	106.63	27.52	
CIIAM8-16/SURGE/	-0.40	-0.52	0.029	0.070	105.93	24.21	
CIIAM8-17/SURGE/	-0.26	-0.32	0.028	0.021	105.22	23.28	
CIIAM8-18/SURGE/	-0.50	-0.50	0.011	0.022	104.51	24.12	
CIIAM8-19/SURGE/	-0.41	-0.40	0.049	0.036	103.81	23.67	
CIIAM8-20/SURGE/	-0.16	-0.18	0.045	0.047	103.10	22.62	
CIIAM8-21/SURGE/	0.09	0.12	0.037	0.050	102.40	21.22	

CIIAM8-23/SURGE/	0.47	0.36	0.035	0.042	100.98	20.08	
CIIAM8-24/SURGE/	0.44	0.23	0.035	0.044	100.28	20.70	
CIIAM8-25/SURGE/	0.42	0.29	0.016	0.059	99.57	20.43	
CIIAM8-26/SURGE/	0.28	0.28	0.011	0.033	98.87	20.48	
CIIAM8-28/SURGE/	0.19	-0.19	0.033	0.033	97.45	22.68	
CIIAM8-29/SURGE/	0.20	-0.02	0.024	0.029	96.75	21.88	
CIIAM8-30/SURGE/	0.31	-0.02	0.021	0.074	96.04	21.88	
CIIAM8-31/SURGE/	0.26	-0.05	0.022	0.043	95.34	22.02	
CIIAM8-32/SURGE/	0.18	-0.27	0.026	0.015	94.63	23.03	
CIIAM8-33/SURGE/	0.30	0.15	0.019	0.045	93.92	21.07	
CIIAM8-34/SURGE/	0.68	-0.24	0.016	0.041	93.22	22.90	
CIIAM8-35/SURGE/	-0.05	-0.53	0.027	0.106	92.51	24.26	
CIIAM8-36/SURGE/	0.23	-0.42	0.114	0.093	91.82	23.76	Band
CIIAM8-37/SURGE/	0.30	-0.23	0.015	0.022	91.12	22.85	Band
CIIAM8-39/SURGE/	-0.03	-0.72	0.019	0.050	89.73	25.18	Band
CIIAM8-40/SURGE/	-0.23	-1.22	0.054	0.114	89.04	27.60	Band
CIIAM8-41/SURGE/	0.22	-1.34	0.035	0.038	88.34	28.19	Band
CIIAM8-42/SURGE/	0.03	-1.31	0.027	0.020	87.65	28.04	Band
CIIAM8-44/SURGE/	-0.02	-1.43	0.032	0.056	86.26	28.63	Band
CIIAM8-45/SURGE/	0.08	-1.44	0.026	0.088	85.56	28.68	Band
CIIAM8-46/SURGE/	-0.10	-1.30	0.026	0.057	84.87	27.99	Band
CIIAM8-47/SURGE/	-0.50	-1.06	0.033	0.026	84.17	26.82	Band
CIIAM8-48/SURGE/	-0.58	-1.14	0.010	0.031	83.48	27.21	Band
CIIAM8-49/SURGE/	-0.70	-1.46	0.028	0.008	83.18	28.78	
CIIAM8-50/SURGE/	-0.91	-1.52	0.014	0.021	82.89	29.07	
CIIAM8-51/SURGE/	-0.70	-1.76	0.024	0.089	82.60	30.26	
CIIAM8-52/SURGE/	-0.56	-1.52	0.018	0.044	82.30	29.07	
CIIAM8-53/SURGE/	-0.40	-1.31	0.013	0.023	82.01	28.04	
CIIAM8-54/SURGE/	0.01	-0.96	0.031	0.060	81.71	26.34	
CIIAM8-55/SURGE/	-0.04	-0.89	0.025	0.061	81.42	26.00	
CIIAM8-57/SURGE/	0.16	-0.27	0.040	0.063	79.75	23.04	
CIIAM8-58/SURGE/	0.39	0.19	0.042	0.049	78.91	20.88	
CIIAM8-59/SURGE/	0.32	0.52	0.010	0.047	78.08	19.35	
CIIAM8-60/SURGE/	0.49	0.47	0.023	0.019	77.24	19.58	
CIIAM8-61/SURGE/	0.51	0.52	0.019	0.016	76.40	19.35	
CIIAM8-62/SURGE/	0.62	0.10	0.037	0.083	75.57	21.30	
CIIAM8-63/SURGE/	0.75	-0.08	0.068	0.023	74.73	22.14	
CIIAM8-64/SURGE/	0.48	-0.16	0.010	0.029	73.90	22.52	
CIIAM8-65/SURGE/	0.64	-0.33	0.030	0.029	73.06	23.32	
CIIAM8-66/SURGE/	0.67	-0.65	0.013	0.032	72.58	24.85	Band
CIIAM8-67/SURGE/	0.45	-1.15	0.019	0.060	72.10	27.26	Band
CIIAM8-68/SURGE/	0.36	-1.06	0.028	0.053	71.62	26.82	Band
CIIAM8-69/SURGE/	0.33	-1.24	0.030	0.050	71.14	27.70	Band
CIIAM8-70/SURGE/	0.28	-1.22	0.010	0.021	70.66	27.60	Band
CIIAM8-71/SURGE/	0.40	-1.40	0.024	0.055	70.18	28.48	Band
CIIAM8-72/SURGE/	0.07	-1.31	0.019	0.031	69.70	28.04	Band
CIIAM8-73/SURGE/	0.00	-1.33	0.009	0.021	69.22	28.14	Band
CIIAM8-74/SURGE/	-0.14	-1.54	0.079	0.068	68.74	29.17	Band

CIIAM8-75/SURGE/	-0.32	-1.64	0.020	0.039	68.26	29.69	Band
CIIAM8-76/SURGE/	-0.16	-1.42	0.085	0.084	67.78	28.58	Band
CIIAM8-77/SURGE/	-0.17	-1.29	0.020	0.034	67.30	27.95	Band
CIIAM8-78/SURGE/	-0.20	-1.40	0.025	0.032	66.82	28.48	Band
CIIAM8-79/SURGE/	-0.28	-1.68	0.025	0.070	66.34	29.87	Band
CIIAM8-80/SURGE/	-0.30	-1.47	0.026	0.018	65.86	28.83	Band
CIIAM8-81/SURGE/	-0.42	-1.84	0.021	0.029	65.38	30.68	Band
CIIAM8-82/SURGE/	-0.52	-1.76	0.030	0.031	64.90	30.25	Band
CIIAM8-83/SURGE/	-0.62	-1.57	0.039	0.035	64.42	29.34	Band
CIIAM8-84/SURGE/	-0.44	-1.39	0.121	0.071	63.94	28.41	Band
CIIAM8-85/SURGE/	-0.75	-1.64	0.013	0.033	63.46	29.67	Band
CIIAM8-86/SURGE/	-0.73	-1.22	0.021	0.100	62.98	27.59	Band
CIIAM8-87/SURGE/	-0.26	-0.42	0.024	0.033	62.50	23.73	Band
CIIAM8-88/SURGE/	-0.37	-0.47	0.039	0.023	62.02	24.00	Band
CIIAM8-89/SURGE/	-0.30	-0.15	0.042	0.026	61.54	22.47	
CIIAM8-90/SURGE/	-0.15	0.13	0.060	0.077	61.06	21.15	
CIIAM8-91/SURGE/	-0.30	-0.34	0.021	0.036	60.58	23.39	
CIIAM8-92/SURGE/	0.11	0.33	0.078	0.065	60.03	20.22	Band
CIIAM8-93/SURGE/	-0.08	0.05	0.042	0.017	59.49	21.55	Band
CIIAM8-94/SURGE/	0.26	0.21	0.097	0.117	58.94	20.79	Band
CIIAM8-95/SURGE/	0.02	-0.16	0.057	0.023	58.40	22.54	Band
CIIAM8-96/SURGE/	0.09	-0.29	0.083	0.067	57.85	23.15	Band
CIIAM8-97/SURGE/	0.10	-0.40	0.082	0.107	57.30	23.64	Band
CIIAM8-98/SURGE/	-0.06	-0.77	0.039	0.073	56.76	25.41	Band
CIIAM8-99/SURGE/	0.21	-0.82	0.028	0.069	56.21	25.64	Band
CIIAM8-100/SURGE/	0.23	-0.81	0.086	0.116	55.67	25.64	Band
CIIAM8-101/SURGE/	0.16	-1.51	0.030	0.013	55.12	29.04	Band
CIIAM8-102/SURGE/	0.14	-1.30	0.120	0.165	54.57	27.98	Band
CIIAM8-103/SURGE/	-0.03	-1.47	0.031	0.040	54.03	28.85	Band
CIIAM8-104/SURGE/	-0.14	-1.03	0.085	0.072	53.48	26.66	Band
CIIAM8-105/SURGE/	-0.09	-0.78	0.174	0.072	52.94	25.46	Band
CIIAM8-106/SURGE/	-0.58	-0.99	0.036	0.059	51.84	26.47	Band
CIIAM8-108/SURGE/	-0.44	-0.98	0.044	0.039	50.75	26.44	Band
CIIAM8-110/SURGE/	-0.46	-0.91	0.093	0.108	50.21	26.08	Band
CIIAM8-111/SURGE/	-0.31	-0.49	0.020	0.058	49.66	24.09	Band
CIIAM8-112/SURGE/	-0.06	0.03	0.116	0.077	49.11	21.61	
CIIAM8-115/SURGE/	0.08	0.06	0.027	0.037	48.02	21.47	
CIIAM8-116/SURGE/	0.09	0.34	0.062	0.022	47.48	20.18	
CIIAM8-117/SURGE/	0.06	0.22	0.084	0.119	46.93	20.74	
CIIAM8-118/SURGE/	0.08	-0.12	0.047	0.114	46.38	22.33	

CIIAM4 (measured in 7/20/2004-8/11/2004)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from margin (mm)	Estimated temperature (^{o}C)	Comments
CIIAM4-1/SURGE/	1.04	-2.03	0.01	0.02	112.97	31.61	Umbo-Band
CIIAM4-2/SURGE/	1.21	-1.94	0.01	0.03	112.04	31.18	Band
CIIAM4-3/SURGE/	1.06	-2.04	0.01	0.02	111.11	31.66	Band

CIIAM4-4/SURGE/	0.57	-2.05	0.01	0.02	110.18	31.73	Band
CIIAM4-5/SURGE/	0.52	-1.97	0.00	0.02	109.25	31.30	Band
CIIAM4-6/SURGE/	0.49	-1.72	0.01	0.03	108.32	30.08	Band
CIIAM4-7/SURGE/	0.67	-1.89	0.01	0.03	107.39	30.93	Band
CIIAM4-8/SURGE/	1.39	-1.96	0.02	0.03	106.45	31.25	Band
CIIAM4-9/SURGE/	1.04	-1.97	0.02	0.04	105.52	31.29	Band
CIIAM4-10/SURGE/	0.58	-1.96	0.02	0.03	104.59	31.24	
CIIAM4-11/SURGE/	0.83	-1.83	0.02	0.04	103.66	30.62	
CIIAM4-12/SURGE/	0.68	-1.89	0.02	0.02	102.73	30.92	
CIIAM4-13/SURGE/	0.65	-1.43	0.02	0.04	101.80	28.63	
CIIAM4-14/SURGE/	0.67	-1.73	0.03	0.03	100.87	30.12	
CIIAM4-15/SURGE/	0.70	-1.57	0.01	0.02	99.94	29.35	
CIIAM4-16/SURGE/	0.60	-1.47	0.02	0.02	99.01	28.81	
CIIAM4-17/SURGE/	0.75	-0.69	0.02	0.01	98.07	25.03	
CIIAM4-18/SURGE/	0.74	-0.40	0.01	0.02	97.14	23.67	
CIIAM4-19/SURGE/	0.85	-0.28	0.03	0.03	96.21	23.11	
CIIAM4-20/SURGE/	0.69	-0.44	0.01	0.05	95.28	23.85	
CIIAM4-21/SURGE/	0.84	-0.19	0.01	0.01	94.35	22.65	
CIIAM4-22/SURGE/	0.83	-0.12	0.03	0.03	93.42	22.31	
CIIAM4-23/SURGE/	0.79	-0.01	0.01	0.03	92.49	21.83	
CIIAM4-24/SURGE/	1.04	0.02	0.01	0.01	91.56	21.67	
CIIAM4-25/SURGE/	1.11	0.52	0.02	0.01	90.63	19.34	
CIIAM4-26/SURGE/	1.17	0.51	0.01	0.01	89.70	19.40	
CIIAM4-27/SURGE/	1.14	0.30	0.01	0.02	88.76	20.37	
CIIAM4-28/SURGE/	1.14	0.35	0.02	0.01	87.83	20.12	
CIIAM4-29/SURGE/	1.04	0.38	0.04	0.06	86.90	20.01	
CIIAM4-30/SURGE/	1.12	0.13	0.01	0.02	85.97	21.17	
CIIAM4-31/SURGE/	1.23	0.55	0.01	0.01	85.04	19.20	
CIIAM4-32/SURGE/	1.24	0.51	0.01	0.03	84.11	19.42	
CIIAM4-33/SURGE/	1.27	-0.17	0.00	0.03	83.18	22.57	
CIIAM4-34/SURGE/	1.16	-0.80	0.03	0.03	82.25	25.57	
CIIAM4-35/SURGE/	1.14	-0.43	0.02	0.01	81.32	23.80	
CIIAM4-36/SURGE/	0.92	-0.65	0.01	0.02	80.38	24.86	
CIIAM4-37/SURGE/	0.99	-1.03	0.03	0.05	79.45	26.66	
CIIAM4-38/SURGE/	1.26	-1.49	0.01	0.03	78.52	28.95	
CIIAM4-39/SURGE/	1.08	-1.35	0.01	0.04	77.59	28.24	Band
CIIAM4-40/SURGE/	0.75	-1.80	0.01	0.01	76.78	30.48	Band
CIIAM4-41/SURGE/	0.93	-1.69	0.02	0.06	75.97	29.89	Band
CIIAM4-42/SURGE/	1.18	-1.71	0.00	0.03	75.16	30.00	Band
CIIAM4-43/SURGE/	0.85	-1.58	0.02	0.04	74.35	29.38	Band
CIIAM4-44/SURGE/	0.63	-1.65	0.02	0.02	73.54	29.70	Band
CIIAM4-45/SURGE/	0.05	-1.97	0.03	0.07	72.73	31.31	Band
CIIAM4-46/SURGE/	0.32	-1.93	0.02	0.04	71.91	31.13	Band
CIIAM4-47/SURGE/	0.42	-2.11	0.03	0.03	71.10	32.00	Band
CIIAM4-48/SURGE/	0.63	-1.51	0.02	0.04	70.29	29.02	Band
CIIAM4-49/SURGE/	-0.20	-1.87	0.01	0.03	69.48	30.80	
CIIAM4-50/SURGE/	0.17	-1.38	0.02	0.04	68.72	28.40	
CIIAM4-51/SURGE/	0.49	-0.99	0.01	0.01	67.96	26.47	

CIIAM4-52/SURGE/	0.43	-0.78	0.02	0.05	67.20	25.49	
CIIAM4-53/SURGE/	0.17	-0.28	0.02	0.05	66.44	23.10	
CIIAM4-54/SURGE/	0.32	-0.21	0.03	0.04	65.68	22.75	
CIIAM4-55/SURGE/	0.20	-0.25	0.03	0.06	64.92	22.93	
CIIAM4-56/SURGE/	0.19	0.08	0.02	0.04	64.16	21.41	
CIIAM4-57/SURGE/	0.10	0.18	0.02	0.05	63.40	20.93	
CIIAM4-58/SURGE/	0.35	0.73	0.01	0.03	62.64	18.38	
CIIAM4-59/SURGE/	0.51	0.58	0.02	0.03	61.88	19.07	
CIIAM4-60/SURGE/	0.55	0.52	0.02	0.06	61.12	19.36	
CIIAM4-61/SURGE/	0.73	0.51	0.04	0.10	60.36	19.41	
CIIAM4-62/SURGE/	0.79	0.60	0.02	0.02	59.60	19.00	
CIIAM4-63/SURGE/	0.74	0.27	0.02	0.05	58.84	20.51	
CIIAM4-64/SURGE/	0.65	0.17	0.02	0.02	58.08	20.99	
CIIAM4-65/SURGE/	0.69	0.14	0.02	0.04	57.32	21.11	
CIIAM4-66/SURGE/	0.47	-0.16	0.02	0.01	56.55	22.52	
CIIAM4-67/SURGE/	0.45	-0.26	0.05	0.05	55.79	22.99	
CIIAM4-68/SURGE/	0.33	-0.61	0.01	0.02	55.03	24.64	
CIIAM4-69/SURGE/	0.41	-1.04	0.01	0.03	54.27	26.74	
CIIAM4-70/SURGE/	0.27	-1.05	0.02	0.03	53.51	26.76	
CIIAM4-71/SURGE/	0.44	-0.87	0.04	0.08	52.75	25.90	
CIIAM4-72/SURGE/	0.72	-0.78	0.00	0.02	51.99	25.46	
CIIAM4-73/SURGE/	0.68	-1.32	0.01	0.04	51.23	28.08	
CIIAM4-74/SURGE/	0.44	-2.09	0.02	0.02	50.47	31.89	Band
CIIAM4-75/SURGE/	0.48	-2.07	0.01	0.06	49.69	31.82	Band
CIIAM4-76/SURGE/	-0.04	-2.67	0.01	0.02	48.91	34.88	Band
CIIAM4-77/SURGE/	-0.16	-2.62	0.03	0.03	48.12	34.62	Band
CIIAM4-78/SURGE/	0.00	-2.97	0.01	0.02	47.34	36.42	Band
CIIAM4-79/SURGE/	0.07	-2.54	0.03	0.08	46.56	34.21	Band
CIIAM4-80/SURGE/	-0.26	-2.73	0.03	0.02	45.77	35.15	Band
CIIAM4-81/SURGE/	0.53	-2.19	0.00	0.03	44.99	32.43	Band
CIIAM4-82/SURGE/	0.14	-2.10	0.02	0.08	44.21	31.95	Band
CIIAM4-83/SURGE/	0.09	-2.24	0.00	0.00	43.42	32.65	Band
CIIAM4-84/SURGE/	0.43	-1.75	0.05	0.06	42.64	30.21	
CIIAM4-85/SURGE/	0.19	-1.63	0.01	0.05	41.83	29.62	
CIIAM4-86/SURGE/	-0.05	-1.46	0.03	0.02	41.02	28.80	
CIIAM4-87/SURGE/	0.16	-0.69	0.01	0.05	40.21	25.04	
CIIAM4-88/SURGE/	0.45	-0.77	0.04	0.05	39.40	25.41	
CIIAM4-89/SURGE/	0.27	-0.85	0.02	0.03	38.59	25.79	
CIIAM4-90/SURGE/	0.17	-0.76	0.01	0.03	37.78	25.37	
CIIAM4-91/SURGE/	0.27	0.00	0.02	0.03	36.97	21.77	
CIIAM4-92/SURGE/	0.40	0.44	0.03	0.02	36.16	19.70	
CIIAM4-93/SURGE/	0.39	0.33	0.01	0.02	35.35	20.22	
CIIAM4-94/SURGE/	0.71	-0.19	0.02	0.03	34.54	22.68	
CIIAM4-95/SURGE/	0.74	-0.28	0.02	0.02	33.73	23.09	
CIIAM4-96/SURGE/	0.87	-0.66	0.02	0.02	32.92	24.90	
CIIAM4-97/SURGE/	0.41	-1.06	0.06	0.03	32.11	26.80	
CIIAM4-98/SURGE/	0.44	-1.81	0.03	0.03	31.30	30.51	
CIIAM4-99/SURGE/	0.34	-2.27	0.02	0.03	30.49	32.84	Band

CIIAM4-100/SURGE/	0.69	-2.73	0.02	0.02	29.83	35.14	Band
CIIAM4-101/SURGE/	0.35	-2.44	0.02	0.05	29.16	33.68	Band
CIIAM4-102/SURGE/	0.47	-2.30	0.01	0.05	28.50	32.95	Band
CIIAM4-103/SURGE/	0.24	-2.99	0.01	0.04	27.84	36.53	Band
CIIAM4-104/SURGE/	-0.21	-2.54	0.01	0.03	27.17	34.18	Band
CIIAM4-105/SURGE/	0.08	-2.52	0.03	0.05	26.51	34.11	Band
CIIAM4-106/SURGE/	0.17	-2.63	0.02	0.03	25.84	34.67	Band
CIIAM4-108/SURGE/	0.01	-1.60	0.02	0.04	25.18	29.49	Band
CIIAM4-110/SURGE/	-0.03	-2.34	0.03	0.01	24.52	33.19	Band
CIIAM4-112/SURGE/	0.23	-1.45	0.02	0.05	23.85	28.73	
CIIAM4-114/SURGE/	-0.06	-1.04	0.03	0.06	23.22	26.75	
CIIAM4-115/SURGE/	0.12	-0.69	0.01	0.03	22.59	25.05	
CIIAM4-117/SURGE/	0.04	-1.22	0.02	0.04	21.95	27.63	
CIIAM4-119/SURGE/	-0.07	-1.59	0.04	0.03	21.32	29.40	
CIIAM4-121/SURGE/	0.03	-1.66	0.02	0.03	20.69	29.77	
CIIAM4-122/SURGE/	0.22	-1.18	0.01	0.02	20.05	27.41	
CIIAM4-124/SURGE/	0.48	-1.06	0.04	0.02	19.42	26.84	
CIIAM4-126/SURGE/	0.36	-1.19	0.02	0.07	18.79	27.43	
CIIAM4-128/SURGE/	0.48	-0.66	0.01	0.04	18.15	24.92	
CIIAM4-130/SURGE/	0.39	-0.68	0.03	0.02	17.52	24.98	
CIIAM4-132/SURGE/	0.56	-0.76	0.01	0.02	16.89	25.40	
CIIAM4-133/SURGE/	0.28	-1.29	0.02	0.05	16.26	27.96	
CIIAM4-134/SURGE/	-0.06	-1.44	0.02	0.03	15.62	28.70	
CIIAM4-136/SURGE/	-0.25	-1.78	0.01	0.04	14.36	30.37	
CIIAM4-137/SURGE/	-0.05	-1.66	0.05	0.04	13.72	29.76	
CIIAM4-138/SURGE/	0.10	-2.16	0.02	0.07	13.09	32.27	
CIIAM4-139/SURGE/	0.27	-2.44	0.03	0.02	12.46	33.68	
CIIAM4-140/SURGE/	-1.37	-3.26	0.04	0.06	11.82	37.91	
CIIAM4-141/SURGE/	-0.41	-3.40	0.01	0.01	11.19	38.64	Band
CIIAM4-142/SURGE/	-0.41	-3.17	0.04	0.06	10.64	37.44	Band
CIIAM4-143/SURGE/	-0.01	-2.99	0.02	0.04	10.10	36.52	Band
CIIAM4-144/SURGE/	0.13	-2.85	0.03	0.04	9.55	35.78	Band
CIIAM4-145/SURGE/	-0.93	-2.69	0.02	0.03	9.00	34.96	Band
CIIAM4-146/SURGE/	-1.09	-2.99	0.03	0.05	8.45	36.48	Band

CIIAM6 (measured in 3/08/2007-5/12/2007)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from margin (mm)	Estimated temperature (^{o}C)	Comments
CIIAM6-1/SURGE/	-1.29	-1.70	0.03	0.03	77.36	29.97	near umbo
CIIAM6-2/SURGE/	-1.25	-1.80	0.02	0.02	76.76	30.47	
CIIAM6-3/SURGE/	-0.69	-1.10	0.04	0.03	76.16	27.01	
CIIAM6-4/SURGE/	-0.93	-1.18	0.03	0.02	75.56	27.43	
CIIAM6-5/SURGE/	-0.16	-0.22	0.04	0.03	74.96	22.78	
CIIAM6-6/SURGE/	-0.34	0.09	0.03	0.03	74.36	21.34	
CIIAM6-7/SURGE/	-0.70	-0.46	0.05	0.02	73.76	23.93	
CIIAM6-9/SURGE/	-0.34	-0.11	0.02	0.03	72.56	22.27	
CIIAM6-10/SURGE/	-0.32	-0.62	0.02	0.02	71.96	24.70	

CIIAM6-11/SURGE/	-0.25	-0.33	0.02	0.04	71.36	23.33	
CIIAM6-12/SURGE/	-0.35	-0.03	0.02	0.02	70.76	21.89	
CIIAM6-13/SURGE/	-0.45	-0.06	0.04	0.01	70.16	22.04	
CIIAM6-14/SURGE/	-0.45	-0.32	0.01	0.03	69.56	23.25	
CIIAM6-15/SURGE/	-0.37	-0.41	0.03	0.02	68.96	23.69	
CIIAM6-17/SURGE/	-0.12	0.35	0.05	0.02	68.36	20.16	
CIIAM6-18/SURGE/	-0.37	-0.43	0.04	0.01	67.16	23.78	
CIIAM6-19/SURGE/	-0.27	-0.85	0.02	0.04	66.56	25.83	
CIIAM6-20/SURGE/	-0.36	-1.71	0.03	0.02	65.91	30.03	
CIIAM6-22/SURGE/	-0.60	-1.85	0.01	0.04	64.71	30.69	Band
CIIAM6-23/SURGE/	-0.87	-2.07	0.02	0.03	64.11	31.83	Band
CIIAM6-24/SURGE/	-0.32	-1.78	0.02	0.01	63.51	30.36	Band
CIIAM6-27/SURGE/	0.29	-1.46	0.01	0.03	61.71	28.78	
CIIAM6-28/SURGE/	0.00	-1.12	0.02	0.02	60.84	27.10	
CIIAM6-29/SURGE/	0.50	-0.80	0.05	0.04	59.97	25.57	
CIIAM6-30/SURGE/	0.47	-1.50	0.01	0.02	59.1	28.96	
CIIAM6-31/SURGE/	0.52	-1.51	0.02	0.06	58.23	29.02	
CIIAM6-32/SURGE/	-0.11	-1.32	0.03	0.07	57.36	28.08	
CIIAM6-33/SURGE/	-0.25	-0.76	0.01	0.05	56.49	25.38	
CIIAM6-34/SURGE/	-0.01	-0.87	0.02	0.03	55.62	25.90	
CIIAM6-35/SURGE/	0.04	-0.69	0.03	0.04	54.75	25.03	
CIIAM6-36/SURGE/	-0.46	-0.72	0.01	0.02	53.88	25.18	
CIIAM6-37/SURGE/	-0.43	-0.51	0.02	0.02	53.01	24.20	
CIIAM6-38/SURGE/	-0.49	-0.13	0.02	0.05	52.14	22.39	
CIIAM6-39/SURGE/	-0.48	-0.20	0.02	0.04	51.27	22.73	
CIIAM6-40/SURGE/	-0.45	0.77	0.05	0.03	50.4	18.22	
CIIAM6-41/SURGE/	-0.22	0.96	0.01	0.02	49.53	17.34	
CIIAM6-42/SURGE/	-0.15	1.11	0.03	0.02	48.66	16.68	
CIIAM6-43/SURGE/	-0.19	1.03	0.01	0.02	47.79	17.04	
CIIAM6-44/SURGE/	-0.10	1.08	0.02	0.04	46.92	16.78	
CIIAM6-45/SURGE/	0.19	1.10	0.01	0.02	46.05	16.70	
CIIAM6-46/SURGE/	0.44	0.98	0.04	0.03	45.18	17.23	
CIIAM6-47/SURGE/	0.20	0.35	0.03	0.01	44.31	20.15	
CIIAM6-48/SURGE/	0.21	0.93	0.01	0.02	43.44	17.47	
CIIAM6-49/SURGE/	0.36	1.24	0.02	0.02	42.57	16.09	
CIIAM6-50/SURGE/	0.25	0.72	0.03	0.06	41.7	18.45	
CIIAM6-51/SURGE/	0.20	0.47	0.03	0.03	40.83	19.57	Band
CIIAM6-52/SURGE/	0.13	0.35	0.01	0.02	39.96	20.16	Band
CIIAM6-53/SURGE/	0.16	-1.24	0.02	0.03	39.09	27.70	
CIIAM6-54/SURGE/	0.54	-1.17	0.02	0.04	38.21	27.36	
CIIAM6-55/SURGE/	0.85	-1.09	0.02	0.02	37.33	26.97	
CIIAM6-56/SURGE/	0.40	-0.88	0.02	0.05	36.45	25.96	
CIIAM6-57/SURGE/	-0.03	-1.33	0.08	0.02	35.57	28.12	
CIIAM6-58/SURGE/	0.37	-1.36	0.02	0.09	34.69	28.28	
CIIAM6-59/SURGE/	0.26	-1.21	0.08	0.02	33.81	27.58	
CIIAM6-60/SURGE/	-0.58	-0.87	0.03	0.03	32.93	25.92	
CIIAM6-61/SURGE/	-0.53	-0.94	0.03	0.02	32.05	26.23	
CIIAM6-62/SURGE/	-0.13	-0.42	0.02	0.06	31.17	23.75	

CIIAM6-63/SURGE/	-0.44	0.01	0.02	0.02	30.29	21.70	
CIIAM6-64/SURGE/	-0.24	-0.14	0.03	0.06	29.41	22.43	
CIIAM6-65/SURGE/	-0.40	0.23	0.03	0.04	28.53	20.68	
CIIAM6-66/SURGE/	-0.64	0.41	0.02	0.03	27.65	19.87	
CIIAM6-67/SURGE/	-0.50	0.09	0.01	0.02	26.77	21.35	
CIIAM6-68/SURGE/	-0.12	-0.07	0.02	0.01	25.89	22.12	
CIIAM6-69/SURGE/	-0.11	0.88	0.01	0.03	25.01	17.70	
CIIAM6-70/SURGE/	0.00	0.33	0.03	0.01	24.13	20.23	
CIIAM6-71/SURGE/	-0.09	-0.40	0.03	0.04	23.25	23.68	
CIIAM6-72/SURGE/	0.08	-0.36	0.04	0.04	22.37	23.49	
CIIAM6-73/SURGE/	-0.11	0.27	0.03	0.01	21.48	20.53	
CIIAM6-74/SURGE/	0.05	0.64	0.02	0.03	20.59	18.78	
CIIAM6-75/SURGE/	0.09	0.18	0.02	0.03	19.7	20.95	Band
CIIAM6-76/SURGE/	0.15	-0.33	0.02	0.04	18.81	23.34	Band
CIIAM6-77/SURGE/	-0.10	-0.92	0.03	0.07	17.92	26.16	Band
CIIAM6-78/SURGE/	0.29	-1.01	0.03	0.04	17.03	26.58	Band
CIIAM6-79/SURGE/	0.29	-1.16	0.02	0.03	16.14	27.31	
CIIAM6-80/SURGE/	0.31	-1.29	0.07	0.02	15.25	27.93	
CIIAM6-81/SURGE/	0.17	-1.33	0.02	0.02	14.64	28.13	
CIIAM6-82/SURGE/	0.13	-1.34	0.03	0.03	14.03	28.20	
CIIAM6-83/SURGE/	-0.38	-1.13	0.02	0.02	13.42	27.16	
CIIAM6-84/SURGE/	-0.57	-1.05	0.02	0.04	12.81	26.76	
CIIAM6-85/SURGE/	-0.60	-0.97	0.03	0.01	12.2	26.41	
CIIAM6-86/SURGE/	-0.37	-0.78	0.04	0.02	11.59	25.47	
CIIAM6-87/SURGE/	-0.36	-0.53	0.03	0.03	10.98	24.27	
CIIAM6-88/SURGE/	0.07	-0.15	0.02	0.04	10.37	22.50	
CIIAM6-89/SURGE/	-0.30	-0.03	0.04	0.04	9.76	21.89	
CIIAM6-90/SURGE/	0.01	-0.40	0.03	0.03	9.15	23.66	
CIIAM6-91/SURGE/	0.22	-0.84	0.02	0.01	8.54	25.78	
CIIAM6-92/SURGE/	0.26	-1.62	0.02	0.03	7.93	29.58	
CIIAM6-93/SURGE/	0.20	-1.35	0.02	0.02	7.32	28.25	
CIIAM6-94/SURGE/	-0.31	-0.97	0.03	0.02	6.71	26.40	
CIIAM6-95/SURGE/	-0.51	-0.66	0.02	0.04	6.1	24.91	
CIIAM6-96/SURGE/	-0.09	-0.75	0.03	0.03	5.49	25.33	
CIIAM6-97/SURGE/	0.24	-1.09	0.03	0.02	4.88	26.97	
CIIAM6-98/SURGE/	0.36	-1.48	0.01	0.03	4.27	28.86	
CIIAM6-99/SURGE/	0.35	-1.73	0.03	0.01	3.66	30.13	
CIIAM6-100/SURGE/	0.24	-1.28	0.02	0.05	3.05	27.90	
CIIAM6-102/SURGE/	-0.17	-1.41	0.02	0.04	1.83	28.54	Band
CIIAM6-103/SURGE/	-0.09	-1.03	0.02	0.03	1.22	26.67	Band
CIIAM6-105/SURGE/	-0.33	-1.02	0.02	0.01	0.61	26.64	Band

CIIAM7 (measured in 3/07/2007-5/15/2007)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from margin (mm)	Estimated temperature (^{o}C)	Comments
CIIAM7-1/SURGE/	0.25	-0.50	0.05	0.01	89.75	24.14	Umbo,band
CIIAM7-2/SURGE/	0.24	-0.51	0.01	0.01	88.99	24.17	Band

CIIAM7-3/SURGE/	0.32	-0.97	0.01	0.03	88.23	26.39	Band
CIIAM7-4/SURGE/	0.52	-1.49	0.03	0.03	87.47	28.92	Band
CIIAM7-5/SURGE/	-0.08	-1.02	0.03	0.02	86.71	26.61	Band
CIIAM7-6/SURGE/	-0.03	-1.60	0.03	0.03	85.95	29.48	Band
CIIAM7-7/SURGE/	0.55	-1.17	0.03	0.05	85.19	27.34	Band
CIIAM7-8/SURGE/	0.10	-1.60	0.02	0.02	84.43	29.45	Band
CIIAM7-9/SURGE/	0.08	-1.47	0.04	0.01	83.67	28.84	Band
CIIAM7-10/SURGE/	0.34	-1.21	0.02	0.01	82.91	27.57	Band
CIIAM7-11/SURGE/	0.27	-1.05	0.04	0.02	82.15	26.79	Band
CIIAM7-12/SURGE/	0.11	-1.43	0.04	0.01	81.39	28.64	Band
CIIAM7-13/SURGE/	0.58	-1.34	0.02	0.03	80.63	28.19	
CIIAM7-14/SURGE/	0.45	-1.30	0.01	0.01	79.87	27.99	
CIIAM7-15/SURGE/	0.03	-1.48	0.02	0.06	79.11	28.86	
CIIAM7-16/SURGE/	-0.13	-1.62	0.02	0.03	78.35	29.57	
CIIAM7-17/SURGE/	-0.04	-1.29	0.02	0.01	77.59	27.93	
CIIAM7-18/SURGE/	0.05	-1.53	0.02	0.01	76.83	29.12	
CIIAM7-19/SURGE/	-0.33	-1.30	0.04	0.01	76.07	28.02	
CIIAM7-20/SURGE/	-0.34	-1.24	0.02	0.02	75.31	27.69	
CIIAM7-21/SURGE/	-0.36	-1.08	0.03	0.05	74.56	26.94	
CIIAM7-22/SURGE/	-0.37	-0.95	0.03	0.01	73.81	26.28	
CIIAM7-23/SURGE/	-0.60	-0.38	0.01	0.02	73.06	23.57	Band
CIIAM7-24/SURGE/	-0.54	-0.45	0.03	0.02	72.31	23.89	Band
CIIAM7-25/SURGE/	-0.25	-0.17	0.03	0.03	71.56	22.59	Band
CIIAM7-26/SURGE/	-0.17	-0.17	0.02	0.01	70.81	22.58	Band
CIIAM7-27/SURGE/	-0.32	-0.14	0.02	0.04	70.06	22.42	Band
CIIAM7-28/SURGE/	-0.37	-0.20	0.02	0.02	69.31	22.69	Band
CIIAM7-29/SURGE/	-0.08	-0.06	0.02	0.08	68.56	22.06	Band
CIIAM7-30/SURGE/	-0.62	-0.07	0.02	0.02	67.81	22.09	Band
CIIAM7-31/SURGE/	-0.33	-0.34	0.03	0.02	67.06	23.36	Band
CIIAM7-32/SURGE/	-0.10	-0.44	0.01	0.02	66.31	23.85	Band
CIIAM7-33/SURGE/	0.01	-0.16	0.02	0.04	65.56	22.50	Band
CIIAM7-34/SURGE/	0.13	0.39	0.02	0.00	64.81	19.94	
CIIAM7-35/SURGE/	0.06	-0.49	0.05	0.06	64.06	24.09	
CIIAM7-36/SURGE/	0.34	0.71	0.03	0.02	63.31	18.48	
CIIAM7-37/SURGE/	0.27	0.68	0.04	0.06	62.56	18.60	
CIIAM7-38/SURGE/	0.08	-0.04	0.01	0.02	61.81	21.98	
CIIAM7-39/SURGE/	0.17	-0.22	0.03	0.06	61.06	22.81	
CIIAM7-40/SURGE/	-0.28	-0.65	0.03	0.02	60.31	24.84	
CIIAM7-41/SURGE/	0.14	-0.60	0.02	0.04	59.56	24.59	
CIIAM7-42/SURGE/	0.37	-0.52	0.02	0.01	58.81	24.24	
CIIAM7-43/SURGE/	0.46	-0.54	0.02	0.04	58.06	24.31	
CIIAM7-43SPLIT	0.43	-0.57	0.01	0.03	57.31	24.46	
CIIAM7-44/SURGE/	0.21	-0.95	0.02	0.03	56.56	26.30	
CIIAM7-45/SURGE/	0.21	-1.18	0.02	0.03	55.81	27.43	
CIIAM7-46/SURGE/	-0.22	-1.50	0.03	0.02	55.06	28.96	
CIIAM7-47/SURGE/	0.03	-1.76	0.05	0.09	54.31	30.26	
CIIAM7-48/SURGE/	0.16	-1.78	0.04	0.02	53.56	30.37	
CIIAM7-49/SURGE/	0.29	-1.59	0.04	0.04	52.81	29.40	

CIIAM7-50/SURGE/	-0.01	-1.79	0.04	0.01	52.06	30.40	
CIIAM7-51/SURGE/	-0.02	-1.96	0.03	0.09	51.51	31.26	Band
CIIAM7-52/SURGE/	0.35	-2.07	0.02	0.03	50.96	31.80	Band
CIIAM7-53/SURGE/	0.26	-2.03	0.05	0.06	50.41	31.60	Band
CIIAM7-54/SURGE/	0.29	-1.95	0.02	0.03	49.86	31.20	Band
CIIAM7-55/SURGE/	0.52	-1.87	0.03	0.02	49.31	30.80	Band
CIIAM7-56/SURGE/	0.40	-1.93	0.02	0.02	48.76	31.09	
CIIAM7-57/SURGE/	-0.04	-2.13	0.09	0.02	48.21	32.14	
CIIAM7-58/SURGE/	0.05	-1.84	0.01	0.01	47.66	30.67	
CIIAM7-59/SURGE/	-0.30	-1.90	0.07	0.02	47.11	30.95	
CIIAM7-60/SURGE/	-0.02	-1.79	0.05	0.04	46.56	30.42	
CIIAM7-61/SURGE/	0.31	-1.74	0.03	0.04	46.01	30.18	
CIIAM7-62/SURGE/	0.09	-2.02	0.03	0.01	45.46	31.55	
CIIAM7-63/SURGE/	0.40	-1.71	0.02	0.02	44.63	29.99	
CIIAM7-64/SURGE/	-0.34	-1.14	0.04	0.01	43.8	27.21	
CIIAM7-65/SURGE/	-0.10	-0.81	0.01	0.05	42.97	25.64	
CIIAM7-66/SURGE/	-0.12	-0.60	0.01	0.02	42.14	24.63	
CIIAM7-67/SURGE/	0.10	-0.19	0.02	0.02	41.31	22.67	
CIIAM7-68/SURGE/	0.18	0.11	0.01	0.02	40.48	21.27	
CIIAM7-69/SURGE/	0.35	0.12	0.07	0.02	39.65	21.20	
CIIAM7-70/SURGE/	0.60	0.02	0.01	0.02	38.82	21.67	
CIIAM7-72/SURGE/	0.68	-0.14	0.03	0.02	37.16	22.41	
CIIAM7-73/SURGE/	0.65	-0.62	0.05	0.06	36.33	24.70	
CIIAM7-74/SURGE/	0.67	-0.92	0.05	0.02	35.5	26.14	
CIIAM7-75/SURGE/	0.52	-0.86	0.01	0.03	34.67	25.84	Band
CIIAM7-76/SURGE/	0.64	-1.20	0.04	0.02	33.84	27.53	Band
CIIAM7-77/SURGE/	1.10	-1.67	0.03	0.01	33.02	29.80	Band
CIIAM7-78/SURGE/	0.76	-1.79	0.03	0.05	32.2	30.40	Band
CIIAM7-79/SURGE/	0.47	-1.63	0.02	0.04	31.38	29.63	
CIIAM7-80/SURGE/	-0.01	-1.77	0.02	0.03	30.56	30.31	
CIIAM7-81/SURGE/	-0.40	-1.70	0.04	0.04	29.74	29.95	
CIIAM7-82/SURGE/	-0.04	-1.41	0.01	0.03	28.92	28.54	
CIIAM7-83/SURGE/	0.00	-0.63	0.04	0.02	28.1	24.74	
CIIAM7-84/SURGE/	0.36	-0.05	0.02	0.02	27.28	21.99	
CIIAM7-85/SURGE/	0.83	-0.68	0.02	0.03	26.46	25.01	
CIIAM7-86/SURGE/	0.64	-1.02	0.01	0.00	25.64	26.63	
CIIAM7-87/SURGE/	0.13	-1.46	0.05	0.01	24.82	28.80	
CIIAM7-88/SURGE/	-1.33	-1.87	0.03	0.02	24	30.81	

CIIAM9 (measured in 10/29/2007-11/06/2007)

SAMPLE ID	$\delta^{13}C$ VPDB (‰)	$\delta^{18}O$ VPDB (‰)	C std dev (‰)	O std dev (‰)	Distance from margin (mm)	Estimated temperature (^{o}C)	Comments
CIIAM9-1/SURGE/	0.70	-0.91	0.048	0.027	101.85	26.09	
CIIAM9-2/SURGE/	0.69	-0.38	0.030	0.062	100.94	23.55	
CIIAM9-3/SURGE/	0.55	-0.28	0.011	0.067	100.03	23.07	
CIIAM9-4/SURGE/	0.67	-0.09	0.018	0.052	99.12	22.20	
CIIAM9-5/SURGE/	0.68	-0.08	0.035	0.064	98.21	22.15	

CIIAM9-6/SURGE/	0.67	-0.03	0.014	0.048	97.30	21.92	
CIIAM9-7/SURGE/	0.80	0.25	0.005	0.015	96.39	20.62	
CIIAM9-8/SURGE/	0.67	0.14	0.005	0.070	95.48	21.14	
CIIAM9-9/SURGE/	0.64	0.38	0.012	0.011	94.56	19.98	
CIIAM9-10/SURGE/	0.63	0.27	0.033	0.017	93.65	20.53	
CIIAM9-11/SURGE/	0.53	0.38	0.021	0.043	92.74	20.01	
CIIAM9-12/SURGE/	0.61	0.42	0.059	0.077	91.83	19.83	
CIIAM9-13/SURGE/	0.64	0.51	0.039	0.089	90.92	19.39	
CIIAM9-14/SURGE/	0.56	0.26	0.015	0.046	90.01	20.57	
CIIAM9-15/SURGE/	0.80	0.51	0.185	0.180	89.10	19.38	
CIIAM9-16/SURGE/	0.53	-0.07	0.025	0.049	88.19	22.09	
CIIAM9-17/SURGE/	0.56	-0.56	0.023	0.060	87.28	24.40	
CIIAM9-18/SURGE/	0.57	-0.80	0.007	0.046	86.38	25.55	
CIIAM9-19/SURGE/	0.60	-0.71	0.023	0.060	85.47	25.12	
CIIAM9-20/SURGE/	0.56	-0.75	0.028	0.013	84.57	25.34	
CIIAM9-21/SURGE/	0.51	-0.85	0.005	0.034	83.66	25.79	
CIIAM9-22/SURGE/	0.37	-0.86	0.027	0.036	82.76	25.88	Band
CIIAM9-23/SURGE/	0.45	-0.98	0.017	0.067	81.85	26.43	Band
CIIAM9-24/SURGE/	0.32	-1.18	0.001	0.018	80.95	27.41	Band
CIIAM9-25/SURGE/	0.35	-1.22	0.019	0.060	80.04	27.59	Band
CIIAM9-26/SURGE/	0.36	-1.25	0.029	0.079	79.14	27.73	Band
CIIAM9-27/SURGE/	0.21	-1.22	0.030	0.030	78.23	27.63	Band
CIIAM9-28/SURGE/	0.27	-1.34	0.010	0.062	77.33	28.19	Band
CIIAM9-29/SURGE/	0.26	-1.38	0.038	0.013	76.42	28.40	Band
CIIAM9-30/SURGE/	0.11	-1.45	0.024	0.071	75.52	28.72	Band
CIIAM9-31/SURGE/	-0.04	-1.34	0.023	0.065	74.77	28.17	
CIIAM9-32/SURGE/	-0.01	-1.36	0.019	0.053	74.03	28.29	
CIIAM9-33/SURGE/	0.46	-0.49	0.025	0.008	73.28	24.08	
CIIAM9-34/SURGE/	0.54	-0.10	0.034	0.027	72.53	22.26	
CIIAM9-35/SURGE/	0.72	0.44	0.045	0.092	71.79	19.70	
CIIAM9-36/SURGE/	0.72	0.54	0.068	0.046	71.04	19.27	
CIIAM9-37/SURGE/	0.68	0.52	0.038	0.047	70.30	19.36	
CIIAM9-38/SURGE/	0.60	0.50	0.021	0.050	69.55	19.42	
CIIAM9-39/SURGE/	0.72	0.79	0.030	0.046	68.80	18.12	
CIIAM9-40/SURGE/	0.78	0.79	0.007	0.033	68.06	18.13	
CIIAM9-41/SURGE/	0.86	0.75	0.031	0.078	67.31	18.29	
CIIAM9-42/SURGE/	0.86	0.71	0.011	0.053	66.57	18.50	
CIIAM9-43/SURGE/	0.90	0.66	0.066	0.063	65.82	18.70	
CIIAM9-44/SURGE/	0.61	0.48	0.013	0.066	65.07	19.54	
CIIAM9-45/SURGE/	0.97	0.40	0.027	0.046	64.33	19.89	
CIIAM9-46/SURGE/	1.00	0.57	0.022	0.030	63.47	19.12	
CIIAM9-47/SURGE/	0.84	0.35	0.026	0.101	62.61	20.13	
CIIAM9-48/SURGE/	0.54	-0.58	0.038	0.060	61.75	24.53	
CIIAM9-49/SURGE/	1.02	-0.95	0.002	0.068	60.89	26.30	
CIIAM9-50/SURGE/	0.80	-0.98	0.013	0.056	60.03	26.46	
CIIAM9-51/SURGE/	0.63	-1.08	0.026	0.065	59.17	26.92	Band
CIIAM9-52/SURGE/	0.47	-1.25	0.042	0.011	58.31	27.73	Band
CIIAM9-53/SURGE/	0.69	-1.22	0.037	0.011	57.45	27.61	Band

CIIAM9-54/SURGE/	0.90	-1.22	0.049	0.031	56.59	27.59	Band
CIIAM9-55/SURGE/	0.97	-1.29	0.050	0.014	55.73	27.97	Band
CIIAM9-56/SURGE/	0.90	-1.20	0.036	0.043	54.87	27.50	Band
CIIAM9-57/SURGE/	0.55	-1.01	0.022	0.015	54.01	26.60	Band
CIIAM9-58/SURGE/	0.54	-0.84	0.032	0.089	53.15	25.78	Band
CIIAM9-59/SURGE/	0.85	-0.33	0.014	0.044	52.29	23.30	Band
CIIAM9-60/SURGE/	0.55	-0.04	0.009	0.044	51.43	21.93	Band
CIIAM9-61/SURGE/	0.34	-0.29	0.025	0.064	50.81	23.15	
CIIAM9-62/SURGE/	0.36	-0.05	0.037	0.027	50.18	22.03	
CIIAM9-63/SURGE/	0.15	-0.09	0.064	0.029	49.56	22.18	
CIIAM9-64/SURGE/	0.20	-0.20	0.012	0.044	48.94	22.71	
CIIAM9-65/SURGE/	0.46	0.61	0.016	0.055	48.31	18.92	
CIIAM9-66/SURGE/	0.70	0.66	0.019	0.023	47.69	18.71	
CIIAM9-67/SURGE/	0.56	0.53	0.042	0.042	47.07	19.33	
CIIAM9-68/SURGE/	0.46	0.74	0.022	0.026	46.44	18.35	
CIIAM9-69/SURGE/	0.35	0.78	0.020	0.085	45.82	18.15	
CIIAM9-70/SURGE/	0.56	0.59	0.012	0.092	45.20	19.03	
CIIAM9-71/SURGE/	0.42	0.48	0.039	0.056	44.58	19.53	
CIIAM9-72/SURGE/	0.55	0.48	0.034	0.033	43.95	19.53	
CIIAM9-73/SURGE/	0.55	0.28	0.052	0.019	43.33	20.44	
CIIAM9-74/SURGE/	0.63	0.30	0.017	0.058	42.71	20.35	
CIIAM9-75/SURGE/	0.61	0.20	0.033	0.094	42.08	20.82	
CIIAM9-76/SURGE/	0.47	0.13	0.046	0.051	41.46	21.16	
CIIAM9-77/SURGE/	0.25	-0.47	0.023	0.049	40.84	23.99	
CIIAM9-78/SURGE/	0.24	-0.53	0.014	0.042	40.21	24.29	Band
CIIAM9-79/SURGE/	0.05	-0.98	0.041	0.057	39.59	26.42	Band
CIIAM9-80/SURGE/	0.46	-1.18	0.020	0.065	38.97	27.42	Band
CIIAM9-81/SURGE/	0.47	-1.56	0.047	0.056	38.35	29.26	Band
CIIAM9-82/SURGE/	0.32	-1.61	0.030	0.075	37.72	29.51	Band
CIIAM9-83/SURGE/	0.07	-1.58	0.011	0.014	37.10	29.39	Band
CIIAM9-84/SURGE/	0.43	-1.53	0.028	0.079	36.48	29.11	Band
CIIAM9-85/SURGE/	0.52	-1.72	0.040	0.030	35.87	30.08	
CIIAM9-86/SURGE/	-0.08	-1.71	0.030	0.067	35.26	30.00	
CIIAM9-87/SURGE/	0.00	-1.59	0.029	0.024	34.65	29.43	
CIIAM9-88/SURGE/	0.23	-1.26	0.037	0.071	34.04	27.82	
CIIAM9-89/SURGE/	0.29	-0.63	0.058	0.103	33.43	24.77	
CIIAM9-90/SURGE/	0.27	-0.16	0.053	0.079	32.82	22.53	
CIIAM9-91/SURGE/	0.18	-0.11	0.023	0.087	32.21	22.27	
CIIAM9-92/SURGE/	0.26	0.18	0.031	0.018	31.60	20.93	
CIIAM9-93/SURGE/	0.13	0.55	0.019	0.010	31.00	19.23	
CIIAM9-94/SURGE/	-0.11	0.44	0.037	0.030	30.39	19.73	
CIIAM9-95/SURGE/	-0.03	0.54	0.032	0.081	29.78	19.27	
CIIAM9-96/SURGE/	0.07	0.42	0.049	0.070	29.17	19.83	
CIIAM9-97/SURGE/	0.08	-0.23	0.021	0.066	28.56	22.85	
CIIAM9-98/SURGE/	0.46	-0.07	0.037	0.015	27.95	22.08	
CIIAM9-99/SURGE/	0.55	0.21	0.062	0.031	27.34	20.79	
CIIAM9-100/SURGE/	0.54	-0.04	0.028	0.061	26.73	21.96	
CIIAM9-101/SURGE/	0.49	-0.12	0.029	0.004	26.12	22.35	

CIIAM9-102/SURGE/	0.13	-0.61	0.008	0.050	25.51	24.68	Band
CIIAM9-103/SURGE/	0.20	-0.92	0.030	0.101	24.91	26.14	Band
CIIAM9-104/SURGE/	0.40	-1.60	0.017	0.039	24.30	29.46	Band
CIIAM9-105/SURGE/	0.64	-2.02	0.045	0.043	23.69	31.57	Band
CIIAM9-106/SURGE/	0.65	-2.00	0.022	0.036	23.08	31.45	Band
CIIAM9-107/SURGE/	0.66	-1.89	0.028	0.048	22.47	30.93	Band
CIIAM9-108/SURGE/	0.41	-1.87	0.052	0.062	21.86	30.83	Band
CIIAM9-109/SURGE/	0.28	-1.68	0.044	0.049	21.52	29.88	
CIIAM9-110/SURGE/	0.25	-1.35	0.037	0.091	21.18	28.23	
CIIAM9-111/SURGE/	0.21	-1.13	0.005	0.020	20.84	27.17	
CIIAM9-112/SURGE/	0.04	-0.70	0.053	0.064	20.50	25.10	
CIIAM9-113/SURGE/	-0.15	-0.64	0.053	0.027	20.16	24.81	
CIIAM9-114/SURGE/	0.23	-0.14	0.053	0.036	19.81	22.45	
CIIAM9-115/SURGE/	0.18	0.03	0.013	0.030	19.47	21.65	
CIIAM9-116/SURGE/	0.23	0.28	0.010	0.020	19.13	20.45	
CIIAM9-117/SURGE/	0.38	0.67	0.012	0.037	18.79	18.65	
CIIAM9-118/SURGE/	0.32	0.40	0.028	0.039	18.45	19.92	
CIIAM9-119/SURGE/	0.74	0.76	0.030	0.041	18.11	18.27	
CIIAM9-120/SURGE/	0.69	0.48	0.013	0.019	17.77	19.54	
CIIAM9-121/SURGE/	0.85	0.27	0.029	0.035	17.43	20.51	
CIIAM9-122/SURGE/	0.50	-0.16	0.026	0.035	17.09	22.53	
CIIAM9-123/SURGE/	0.51	-0.55	0.017	0.023	16.75	24.38	
CIIAM9-124/SURGE/	0.67	-1.27	0.027	0.038	16.40	27.87	
CIIAM9-125/SURGE/	0.89	-1.30	0.031	0.031	16.06	27.97	Band
CIIAM9-126/SURGE/	0.64	-1.51	0.020	0.066	15.72	29.03	Band
CIIAM9-127/SURGE/	0.10	-1.28	0.009	0.013	15.38	27.90	Band
CIIAM9-128/SURGE/	0.26	-1.07	0.053	0.083	15.04	26.86	Band
CIIAM9-129/SURGE/	0.55	-1.31	0.024	0.044	14.7	28.06	Band
CIIAM9-130/SURGE/	0.37	-1.38	0.054	0.034	14.36	28.38	Band
CIIAM9-131/SURGE/	0.24	-1.46	0.007	0.055	14.02	28.76	Band
CIIAM9-132/SURGE/	0.09	-1.12	0.027	0.093	13.68	27.13	Band

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