Daily reconstruction of water temperature from oxygen isotopic ratios of a modern *Tridacna* shell using freezing microtome sampling technique

T. Watanabe and T. Oba

Graduate School of Environmental Earth Science, Hokkaido University, Nishi 5, Kita 10, Kita-ku, Sapporo 060-0810 Japan

Daily (1-2 day interval) reconstruction of sea water temperature is calculated via a freezing microtome sampling technique for oxygen isotope analysis and by counting the daily growth lines in a modern *Tridacna* (*Hippopus hippopus,* LINNE, 1758) shell collected from Ishigaki island, Japan. This method enables the first direct comparison between shell oxygen isotopic values and daily meteorological data. The *H. hippopus* shell calcifies mainly under isotopic equilibrium with surrounding sea water. The high resolution profile of $\delta^{18}O$ of the *H. hippopus* shell recorded monthly to seasonal sea surface temperature variations of the local coral reef environment.

INTRODUCTION

Recent attempts to reconstruct paleoenvironments using carbonate skeletons, such as corals or molluscs, have focused on high resolution and high precision. (e.g., [*Gagan et al.*, 1994; *Alibert and McCulloch*, 1997]). Carbonate precipitation in each kind of organism has its own advantage and disadvantage for high resolution studies of paleoenvironments. For example, corals have yearly bands and record the environmental changes for up to several hundreds years. However, it is difficult to obtain samples without contamination, because of the porous shell structure of coral. On the other hand, most molluscan shells have demurely compacted and fine-layered shell structure, which enable us to take successive samples for high resolution analysis, but their life spans are generally short, e.g., up to several years. However, the giant mollusca, *Tridacnids*, have hard aragonite shells which sometimes grow over 1 m in length, and have life spans of several decades to a few centuries. Furthermore, as *Tridacna* shells have daily growth lines in the inner layer [*Aharon and Chappell*, 1986; *Hirunuma and*

Nakamori, 1995], this allows investigation of daily paleoenvironmental change when an appropriate sampling technique is developed. Thus *Tridacna* shells provide an ideal material for high resolution paleotemperature reconstruction on decadal to century time scales.

Several paleoenvironmental studies have used the oxygen isotopic composition ($\delta^{18}O$) of *Tridacna* shells. *Aharon et al.* [1980] and *Aharon* [1983] showed that the $\delta^{18}O$ of their *Tridacna* shells (*Tridacna gigas* LINNE, 1758) indicate temperature-controlled isotopic equilibrium with surrounding sea water. The relationship between temperature and the isotopic ratios of giant-clam aragonite and water was described by a linear equation [*Aharon* , 1983] as follows :

$$T = 21.30 - 4.42\ (\delta_C - \delta_W)$$

Here δ_C is the $\delta^{18}O$ value of the shell (vs. V-PDB) and δ_W is the $\delta^{18}O$ of the sea water (vs. V- SMOW) adding a -0.20 ‰ correction between PDB and SMOW scales [*Craig*, 1965].

Jones et al. (1986) revealed the existence of two growth phases related to sexual maturity of *Tridacna maxima* RÖDING, 1798. The changeover from the first to the second growth phase at an age of approximately 10 years was accompanied by a decrease in the rate of calcification under isotopic disequilibrium. They suggested, with the onset of sexual maturity, a reordering of energy priorities between biomineralization and reproduction causing isotopic disequilibrium in the $\delta^{18}O$ value of the shell during summer. The annual cycles of the $\delta^{18}O$ decrease in amplitude because of slower growth rate. *Romanek and Grossman* (1989) showed only juvenile portions of the *T. maxima* accurately record seasonal water temperature fluctuations.

Påtzold et al. (1991) showed that the inner shell layer which deposited below the pallial line revealed undisturbed shell accretion with high growth rates. They also mentioned that the inner layer is especially suitable for high resolution analysis, because it is here that daily growth lines are observed under scanning electron microscopy (SEM) and the oxygen isotope signal is more sensitive than in outer layer. The inner shell of *T. Gigas* displays the maximum seasonal oxygen isotopic range and the highest resolution in light attenuation changes (light attenuation meaning the light transmission properties of the shell, such that light transmission is greater when light attenuation is reduced). Lighter oxygen isotopic values (high water temperature) correspond to a layer of low light attenuation values, whereas heavier values (low water temperature) correspond to a layer of high light attenuation values. *Påtzold et al.* (1991) explained the light attenuation changes with varying sizes of skeletal crystallites and varying amounts of organic carbon. During phase of higher summer temperature, the crystallites in the daily growth increments are larger and tightly packed with less organic matter deposited in the shell. On the other hands, during winter growth shows thinner daily increments with smaller crystallites and higher organic content.

Aharon (1991) reported extreme seasonal $\delta^{18}O$ amplitudes of up to 2.2‰, which exceeded the equivalent seasonal temperature contrast in reef environments. This was attributed to the combined effect of rainfall and evaporation during the monsoon wet and dry seasons, respectively. However, the sample resolution of their shells was less than 5 to 12 samples per year and their carbonate samples weighed as much as 0.5 mg.

Watanabe and Oba (1995) measured $\delta^{18}O$ values of inner shell of a *Tridacni*a, *Hippopus hippopus,* with two sampling intervals; low (12 samples per year) and high (123 samples per 5 months) resolutions. They confirmed that the shell precipitated under isotopic equilibrium with surrounding sea water and its $\delta^{18}O$ was mostly determined by the water temperature, although they did not directly compare with daily meteorological data.

In the present study freezing microtome sampling technique is adopted for high resolution analysis of the same *Tridacna* specimen previously used in the *Watanabe* *and Oba* (1995) study. The oxygen isotopic values of the shell are compared with daily meteorological data by counting the daily growth lines of the shell.

METHODS

A living Tridacna, *H. hippopus*, was collected from Kabira coral reef at Ishigaki Island in the southwestern part of Ryukyu Archipelago, southern Japan, on September 5th in 1993 (Figure 1, A). Kabira reef is a well-developed fringing coral with a distinct topographical zonation from land to ocean including; moat, inner reef flat, reef crest, outer reef flat, and reef edge. The southeast side of Kabira reef is connected by the narrow and deep Kabira channel to the open ocean. The *H. hippopus* specimen (Figure 1, B) was collected at 1.5 m water depth in the inner reef flat 500 m away from the shore. The height of the shell is 17 cm, and the length is 31 cm. The age of this specimen was 3 years according to the rough (1 mm interval) oxygen isotope measurements of the inner shell [*Watanabe and Oba* , 1995]. The center of one side of the shell was cut from its umbo to ventral edge (Figure 1, C) and a radial section measuring 12.4 mm long, 1.0 mm wide, and 2.0 mm deep was obtained using a dental cutting machine along the inner surface of the shell. The portion of sampled section represents the second to third growth season. After freezing the 12.4 mm section in water, 50 μm thick samples were shaved off using a microtome, which is usually used for making very thin slices of biological samples. The sampling was done in a thermal-constant room maintained at -20℃. The frozen samples (about 250 μg) were then freeze-dried. Samples were reacted in 100% phosphoric acid at 60.0℃, and the oxygen isotopic composition of the extracted CO_2 was determined with a Finnigan MAT 251 mass spectrometer. Isotopic values are expressed relative to the isotopic ratio of the carbon dioxide gas derived from the Pee Dee Belemnite (PDB) in conventional delta notation through NBS-20 standard. The $\delta^{18}O$ standard deviation for fifteen duplicate measurements of a powdered carbonate samples were 0.08‰.

By using a microtome, the distance of each sample from the inner surface can be measured. In the inner layer of this *H. hippopus* shell, there were about 360 daily growth lines in a year, as inferred from the $\delta^{18}O$ curve measured at 1 mm intervals [*Watanabe and Oba*, 1995]. These daily lines were counted by observing the cut surface of the shell using an optical microscope at 100x magnification (Figure 1, D). Then we can determine the date of each sample both by measuring the distance from the inner surface and by counting the daily lines from the inner surface. In this way, the exact date of the formation of each sample was determined and its oxygen isotopic value was compared to meteorological data (Japan Sea Association and Japan Meteorological Agency, personal communication) collected from Urazoko bay and Ishigaki port (Figure 1, A). Water temperature and salinity data were recorded at 10 a.m. everyday from Urazoko Bay which is about 8 km east of Kabira coral reef. Water temperature was measured at 1 m and depth and salinity at 12 m depth. The precipitation and solar radiation data were recorded at Ishigaki port, about 13 km south from Kabira coral reef (Figure 1, A).

RESULTS

Table 1 shows the time series of $\delta^{18}O$ measurements at 50 μm intervals in the complete 12.4 mm section from the inner surface of the *H. hippopus* shell. Each value of $\delta^{18}O$ has a corresponding date spanning from October 4, 1992 to September 5, 1993, when the *H. hippopus* was collected. The $\delta^{18}O$ values are lower in summer than those in winter and give a similar curve to the corresponding the sea surface temperature

(SST) at Urazoka bay and Ishigaki Port (Figure 2). The correlation coefficient between the $\delta^{18}O$ values of the shell and SST at Urazoko bay and Ishigaki Port are 0.88 and 0.89, respectively. A total amplitude of 2.75‰ is observed between the minimum of -2.37‰ in summer and the maximum of 0.38‰ in winter season. If the inner shell was formed under isotopic equilibrium with the surrounding sea water, the $\delta^{18}O$ curve includes both seasonal changes of the oxygen isotope of the sea water and the water temperature. Since the oxygen isotope of the sea water has the following linear relationship with salinity of the surface waters from the East China sea to the Kuroshio Current region [*Oba*, 1988]: $\delta^{18}O$‰ = 0.203 S - 6.76 (S = Salinity, ‰), we can estimate the oxygen isotopic values of the sea water by substituting the salinity values reported from Urazoko bay.

The seasonal change of the salinity in 12 m water depths at Urazoko bay is 33.8 - 34.8 except for a short period during October 29 - November 2 1992 (Figure 2). This 1.0 ‰ change in salinity should cause a 0.20‰ variation in $\delta^{18}O$ of the sea water, which corresponds to only about 7% of the total range (2.75‰). If the seasonal change of the salinity recorded in Urazoko bay can be applied to the site in the Kabira coral reef, we can assume that the shell's $\delta^{18}O$ curve (Figure 2) is mostly determined by the seasonal change of the water temperature. Subsequently, we can compare the value of ($\delta^{18}O_c$ - $\delta^{18}O_w$) with the corresponding SST at Urazoko bay, in which the salinity effect is eliminated (Figure 3). The regression line yields the following equation,

$$T\,(°C) = 22.4 - 3.91\,(\delta_C - \delta_W)$$

The standard deviation of the residuals of the regression is ± 1.4 °C (Figure 3, B). Although the data show some scatter (Figure 3), the slope of the regression line is only slightly different from that of derived from Aharon's (1983) *Tridacna* shell and other aragonitic molluscs [*Grossman and Ku*, 1986] and is parallel to the slope of inorganic calcite [*O'Neil et al.*, 1969] and close to the inorganic aragonite point at 25°C [*Tarutani et al.*, 1969]. These results suggest that the *H. hippopus* precipitated its inner shell under isotopic equilibrium with the surrounding sea water, confirming the conclusion of earlier studies [*Aharon*, 1983; *Aharon and Chappell*, 1986; *Jones et al*, 1986; *Romanek et al.,* 1987; *Romanek and Grossman*, 1989; *Pätzold et al.*, 1991; *Aharon,* 1991; *Watanabe and Oba*, 1995].

Discussion

The results presented in Figure 3 were obtained by comparing the isotopic values of ($\delta^{18}O_c$ - $\delta^{18}O_w$) of the *Tridacna* shell with the corresponding SST data recorded at Urazoko bay, 8 km apart from the Kabira coral reef. Nevertheless, the data display a lot of scatter along the regression line. Some reasons for this are considered: 1) Geographical and bathmetrical differences between Kabira coral reef and Urazoko bay. 2) Physiological effects as mentioned by *Jones et al.* [1986]. 3) Kinetic effects related to growth rate as suggested by *MacConnaughey* [1989] in his coral study. To investigate these possibilities, we compared the shell's $\delta^{18}O$ fluctuations about the seasonal trend with similarly treated SST at Urazoko bay and at Ishigaki port (Figure 4, A). Since the $\delta^{18}O$ and SST have a strong seasonal component, these seasonal trends were removed by a sine curve to reveal monthly, weekly, and daily variations. As a result, the $\delta^{18}O$ variation of the shell partly corresponds to the weekly to monthly trend of the SST at Urazoko bay. In particular, during middle October - December in 1992 the shell $\delta^{18}O$ and SST (Urazoko bay 1 m) have similar monthly to weekly trend (r = 0.70), if we disregard extreme peaks for both the shell $\delta^{18}O$ and SST. However, there is no complete agreement between the detrended $\delta^{18}O$ and SST. The SST records from Urazoko bay and Ishigaki port are partly different each other (Figure 2, B-C, 4, A), especially high temperature peaks are observed at Urazoko bay during summer when the surface water was stratified. The correlation coefficient between the SST at Urazoko bay and at Ishigaki Port is 0.70, and 0.16 during summer. The average difference between them is 1.04°C and 0.87°C during summer. This suggests that while the SST varies slightly among different in localities around the island the $\delta^{18}O$ record of the shell still basically reflects the local SST. Kabira coral reef sometimes become closed from open sea water because of the reef crest morphology. As the *H. hippopus* lived at 1.5 m water depth in the inner reef flat, the water temperature might be more strongly affected by the air temperature and sea level change than in other places in Urazoko bay. During the low sea level period from February to April in 1993, the profiles of the residuals from the regrresion and the defference between air temperature and SST have similar weekly to monthly trend (r = 0.66) (Figure. 4, B and C). Then this kind of high frequency shell $\delta^{18}O$ signal may indicate that the $\delta^{18}O$ record of the shell shows the weekly to monthly SST signal.

On the other hand, the salinity effect does not seem to affect on the $\delta^{18}O$ of the shell. For example, no $\delta^{18}O$ depletions correspond to the salinity drop in early November 1992 (Figure 2) nor just after several heavy precipitation events (Figure 4, E). This is probably due to active circulation of offshore water, which enters over the Kabira coral reef crest and exits through the channel, removing the fresh water, rather than relatively stagnant waters at Urazoko bay and Ishigaki port.

Jones et al. [1986], *Romanek et al.* [1987], and *Aharon* [1991] claimed that an alternative factor affected Tridacna's $\delta^{18}O$ composition. In adult shells it changes with the onset of sexual maturity showing isotopic disequilibirum in summer with the start of gametogenesis. The age of sexual maturity of *H. hippopus* is not known, but similar sized *T. maxima*, reach the onset of sexual maturity at 14 - 15 years [*McMichael*, 1974, *Romanek et al.,* 1987]. In contrast our specimen is only 3 years old [*Watanabe and Oba*, 1995]. According to *Romanek et al.* [1987] the growth rate during summer becomes slower after onset of sexual maturity. However, our shell recorded high growth rates (60±10 μm/day) in summer near the inner surface of the shell [*Hirunuma and Nakamori*, 1995] (Figure 4, G). Therefore, the *H. hippopus* in this study was likely in the juvenile stage. Althoght there are the extreme $\delta^{18}O$ values during summer (Figure 4 A and B), the possibility of physiological effects on the shell $\delta^{18}O$ in the juvenile stag can not neglect in this study because of the lack of physiological data.

MacConnaughey [1989] discussed kinetic $\delta^{18}O$ disequilibrium occurring in rapidly growing parts of photosynthetic corals. The *H. hippopus* which we used has symbiont algae in the shell and the growth rates (Figure. 4, F) are similar to those of solar radiation (Figure 4, G). The growth rates of the *H. hippopus* are larger from middle April to August in 1993 than these from October in 1992 to early April in 1993 (Figure 4, F). However, any specific relationship did not detected between the growth rate variation and the detrended $\delta^{18}O$ record (Figure. 4, A and F) ($r = 0.19$) and the residuals from the regression (Figure. 4, B and F) ($r = 0.18$).

As discussed above, the $\delta^{18}O$ curve of the *H. hippopus* shows very similar pattern to the SST at Urazoko bay. However, is not perfect. The main reason likely is due to the hydrographical differences between the shell's habitat and the SST monitoring location, although the effects of physiological and kinetic factor on the extreme $\delta^{18}O$ values can not completely neglect at this moment of this study.

CONCLUSION

By adopting the microtome sampling technique for a modern *Tridacna*, (*Hippopus hippopus*), a high resolution time-series of shell $\delta^{18}O$ was obtained along with the following:

1. The date of all analyzed samples were determined by shaving the shell section with a microtome at constant (50 μm, corresponding one or two days) intervals from the inner surface of the shell and by counting the daily growth lines of the shell.

2. The $\delta^{18}O$ curve of the *H. hippopus* shows very similar pattern of the nearby SST and the monthly to seasonal SST changes are recorded in the oxygen isotopic ratio.

3. The *H. hippopus* shell calcifies under isotopic equilibrium with the surrounding sea water. The temperature scale for this *H.hippopus* is expressed as follows,

$$T\ (°C) = 22.4 - 3.91\ (\delta_C - \delta_W)$$

This suggests that temperature and water mass $\delta^{18}O$ properties are primary controls on $\delta^{18}O$ composition of the *H. hippopus* shell.

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Figure Captions

Fig. 1

A: Location of Kabira coral reef at Ishigaki Island in the Kuroshio Current region.

B: Schematic illustration of *Hippopus hippopus*. The shell has 17 cm height, 31 cm length, and 4.3 cm shell thickness.

C: Transmitted light photograph of the vertical cutting section of the half valve. Two sampling lines from the inner surface of the shell are shown on the section; solid line : 50 μ m intervals, dash line : 1 mm intervals (Watanabe and Oba, 1995)

D: Daily growth lines of this *Hippopus hippopus* (optical microscope image).

Fig. 2

The time series of $\delta^{18}O$ records of *Hippopus hippopus* (A), sea surface temperatures (SST) at Urazoko bay (B) and at Ishigaki Port (C), and salinity change at Urazoko bay (D).

Fig. 3

A: Relationship between $\delta^{18}O_C$ - $\delta^{18}O_W$ and temperature (Urazoko Bay 1 m) for *H. hippopus* . Also shown is published data; inorganic calcite [*O'Neil et al*. 1969], biogenitic aragonite Tridacna and molluscs [*Aharon*, 1983; *Grossman and Ku*, 1986], inorganic aragonite [*Tarutani et al*., 1969].

B: Residual SST is calculated by subtracting estimated SST from measured SST. Dashed lines denote the standard deviation of the residuals.

Fig. 4

Comparison of the shell $\delta^{18}O$ with meteorological and growth rate. A: the seasonally detrended shell $\delta^{18}O$ and SST, B: Residual SST, C: Air temperature -SST, D: Sealev-el, E: Precipitation, F : growth line thickness, and G: solar radiation

The growth line thickness of this *Hippopus hippopus* is cited from *Hirunuma and Nakamori* [1995]

Table captions

Table 1

Oxygen isotope of the *H. Hippopus* , SST (Urazoko Bay 1 m).

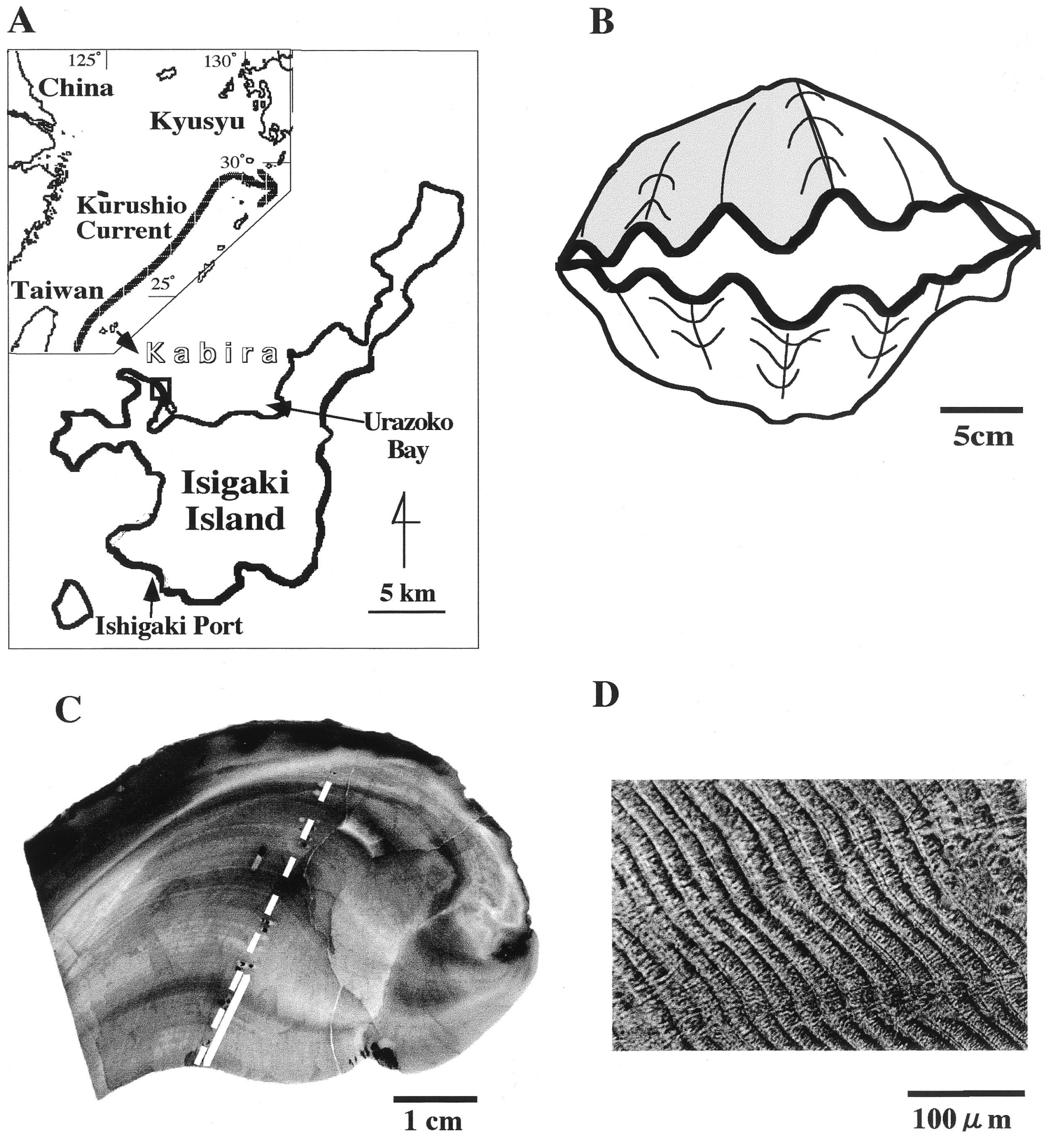
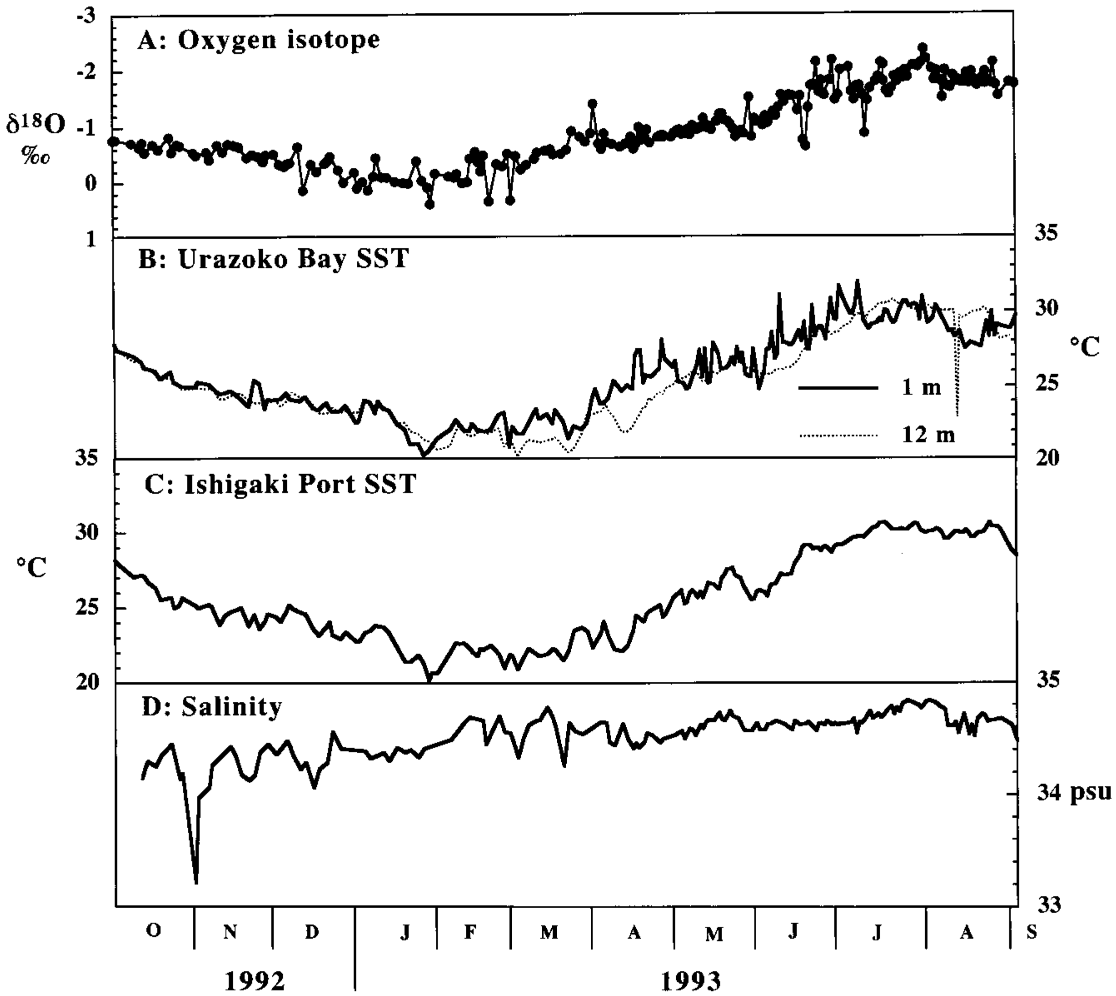
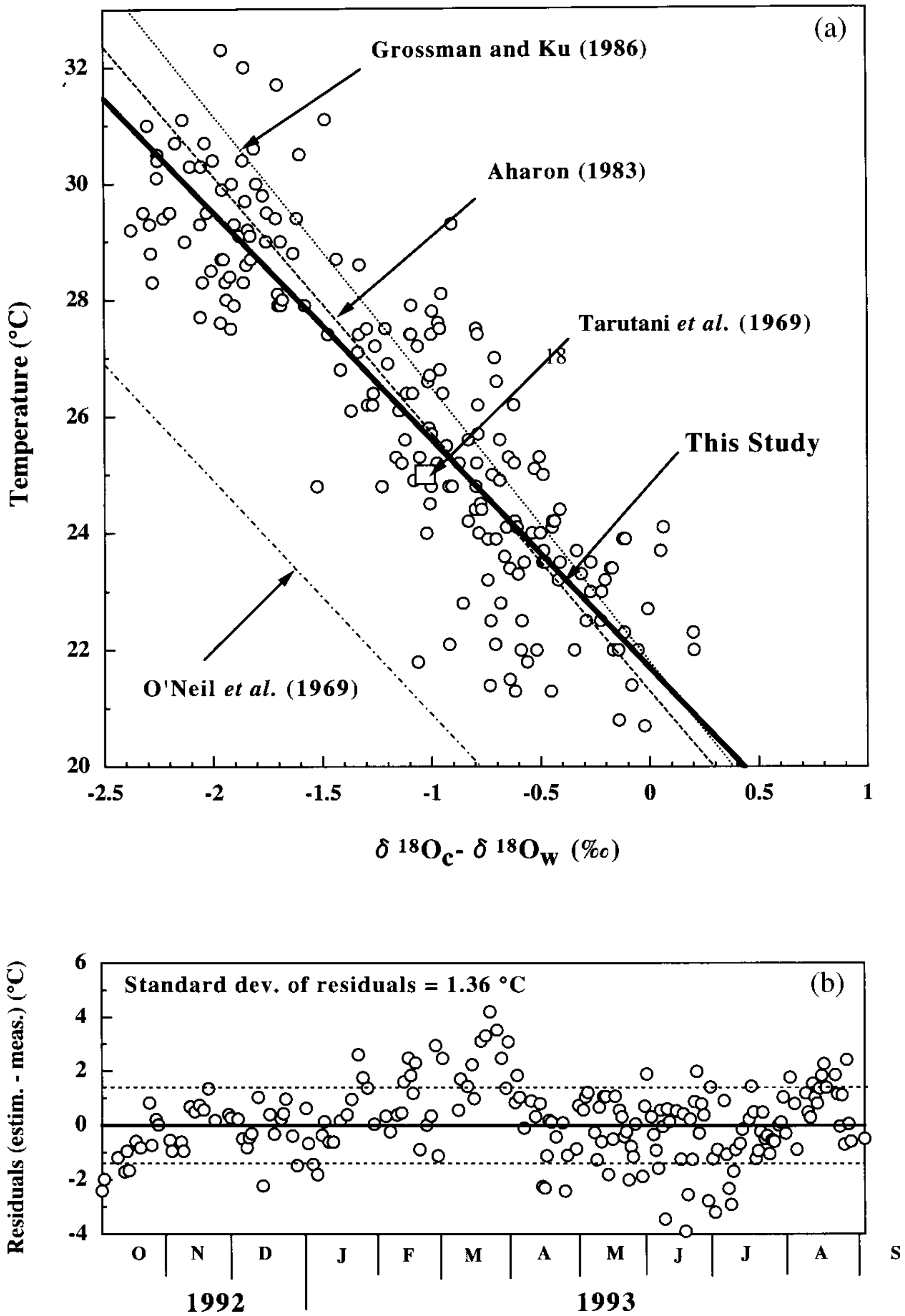

A
125°
130°
China
Kyusyu
30°
Kurushio
Current
Taiwan
25°
Kabira
Urazoko
Bay
Isigaki
Island
5 km
Ishigaki Port
B
5cm
C
1 cm
D
100 μm

Figure 1.



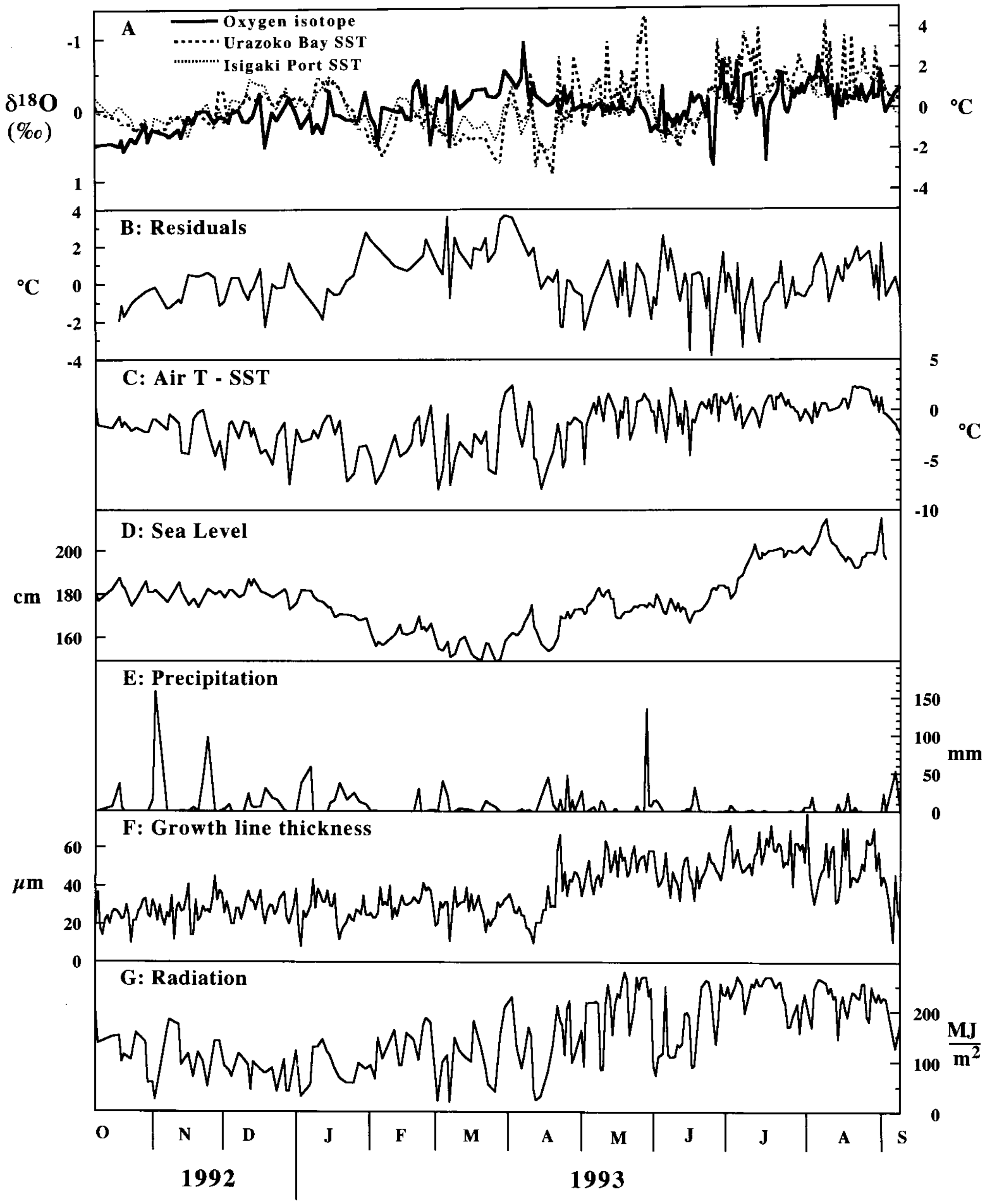
A: Oxygen isotope
δ18O ‰
-3
-2
-1
0
1
B: Urazoko Bay SST
1 m
12 m
35
30
25
20
°C
C: Ishigaki Port SST
°C
35
30
25
20
D: Salinity
35
34 psu
33
O
N
D
J
F
M
A
M
J
J
A
S
1992
1993

Figure 2.



(a)
Grossman and Ku (1986)
Aharon (1983)
Tarutani et al. (1969)
This Study
O'Neil et al. (1969)
Temperature (°C)
δ 18Oc- δ 18Ow (‰)
(b)
Standard dev. of residuals = 1.36 °C
Residuals (estim. - meas.) (°C)
O N D J F M A M J J A S
1992
1993

Figure 3.



A
Oxygen isotope
Urazoko Bay SST
Isigaki Port SST
δ18O (‰)
-1
0
1
4
2
0
-2
-4
°C
B: Residuals
°C
4
2
0
-2
-4
C: Air T - SST
5
0
-5
-10
°C
D: Sea Level
cm
200
180
160
E: Precipitation
150
100
50
0
mm
F: Growth line thickness
μm
60
40
20
0
G: Radiation
200
100
0
MJ/m2
O
N
D
J
F
M
A
M
J
J
A
S
1992
1993

Figure 4.

Interval (ǂm)	Date 1992	δ (_)	ア (_)	SST (。C)	Interval (ǂm)	Date 1993	δ (_)	ア (_)	SST (。C)	Interval (ǂm)	Date 1993	δ (_)	ア (_)	SST (。C)
50	10/4	-0.77	0.01	27.8	4300	3/10	-0.43	0.01	23.5	8200	6/17	-1.54	0.02	28.0
100	10/5	-0.77	0.02	27.4	4350	3/11	-0.54	0.03	22.8	8250	6/18	-0.77	0.05	29.3
150	10/11	-0.72	0.02	26.4	4400	3/14	-0.57	0.01	23.2	8300	6/19	-0.65	0.04	27.5
200	10/14	-0.64	0.01	26.6	4450	3/16	-0.60	0.07	22.5	8350	6/20	-1.34	0.04	27.4
250	10/15	-0.73	0.03	26.2	4500	3/17	-0.51	0.05	23.4	8400	6/21	-1.73	0.04	30.4
300	10/16	-0.55	0.01	26.2	4550	3/20	-0.51	0.07	21.3	8450	6/22	-1.73	0.01	28.3
350	10/19	-0.69	0.02	25.7	4600	3/22	-0.59	0.21	21.4	8500	6/23	-2.14	0.05	28.8
400	10/21	-0.61	0.01	25.6	4650	3/24	-0.92	0.06	21.8	8550	6/24	-1.61	0.06	29.0
450	10/25	-0.82	0.02	24.8	4700	3/27	-0.82	0.03	22.1	8600	6/25	-1.81	0.06	28.7
500	10/26	-0.55	0.03	25.3	4750	3/29	-0.73	0.05	22.8	8650	6/26	-1.56	0.01	28.1
550	10/28	-0.69	0.01	24.9	4800	3/31	-0.88	0.11	24.5	8700	6/28	-1.82	0.04	32.3
600	10/29	-0.67	0.01	25.0	4850	4/1	-1.40	0.07	24.8	8750	6/29	-2.18	0.08	29.5
650	11/3	-0.55	0.01	25.1	4900	4/3	-0.70	0.09	23.8	8800	6/30	-1.48	0.04	29.4
700	11/4	-0.50	0.02	25.3	4950	4/4	-0.60	0.02	23.9	8850	7/1	-1.56	0.04	31.7
750	11/8	-0.56	0.01	25.2	5000	4/5	-0.88	0.03	24.0	8950	7/2	-2.00	0.01	31.1
800	11/9	-0.42	0.03	25.0	5050	4/6	-0.72	0.02	24.2	9050	7/5	-2.05	0.01	29.5
850	11/12	-0.68	0.01	24.4	5100	4/8	-0.69	0.02	25.2	9150	7/6	-1.62	0.01	29.8
900	11/14	-0.56	0.01	24.1	5150	4/11	-0.64	0.01	24.0	9200	7/7	-1.48	0.01	30.5
950	11/16	-0.70	0.02	24.4	5200	4/13	-0.69	0.02	24.8	9300	7/8	-1.71	0.02	32.0
1050	11/18	-0.68	0.02	24.5	5250	4/15	-0.82	0.01	24.8	9350	7/9	-1.67	0.02	30.6
1150	11/20	-0.65	0.01	23.6	5300	4/16	-0.60	0.02	27.0	9450	7/9	-1.72	0.02	30.6
1250	11/23	-0.45	0.01	24.0	5350	4/17	-0.69	0.04	27.4	9500	7/10	-1.56	0.01	29.4
1350	11/25	-0.51	0.02	25.4	5450	4/18	-0.99	0.02	27.4	9550	7/11	-0.88	0.02	
1400	11/27	-0.48	0.02	25.2	5550	4/19	-0.77	0.01	25.2	9600	7/12	-1.47	0.02	28.8
1450	11/29	-0.38	0.01	23.5	5600	4/20	-0.88	0.02	25.7	9650	7/13	-1.68	0.01	29.1
1500	11/30	-0.50	0.02	24.1	5650	4/21	-0.95	0.01		9750	7/15	-1.80	0.01	29.2
1550	12/3	-0.52	0.01	24.2	5700	4/22	-0.71	0.01	25.6	9850	7/16	-1.88	0.01	29.5
1600	12/5	-0.33	0.01	24.2	5800	4/25	-0.81	0.01	25.5	9900	7/17	-2.13	0.02	29.3
1650	12/7	-0.30	0.04	24.4	5850	4/26	-0.84	0.02	28.1	10000	7/18	-2.10	0.02	30.1
1700	12/8	-0.34	0.01	24.2	5900	4/27	-0.82	0.02		10100	7/18	-1.81	0.02	30.1
1750	12/9	-0.36	0.01	24.1	5950	4/27	-0.84	0.01	26.8	10150	7/19	-1.63	0.02	30.0
1800	12/12	-0.65	0.01	23.9	6000	4/30	-0.82	0.01		10200	7/20	-1.58	0.02	29.5
1850	12/14	0.13	0.02	24.1	6050	5/1	-0.88	0.02	26.7	10300	7/21	-1.68	0.03	29.2
1900	12/17	-0.33	0.03	23.3	6100	5/2	-0.93	0.02	25.3	10350	7/22	-1.89	0.02	29.3
1950	12/19	-0.20	0.02	23.5	6150	5/3	-0.95	0.02		10400	7/23	-1.79	0.01	29.9
2050	12/22	-0.34	0.01	23.5	6200	5/4	-0.86	0.01	25.2	10450	7/24	-1.93	0.02	30.3
2100	12/23	-0.39	0.02	23.5	6250	5/5	-0.88	0.01	24.8	10500	7/25	-1.86	0.01	30.7
2150	12/24	-0.48	0.03	23.3	6300	5/6	-0.95	0.02	24.9	10550	7/26	-1.99	0.01	30.7
2200	12/27	-0.23	0.01	23.7	6350	5/7	-0.86	0.02		10600	7/27	-1.87	0.03	30.3
2250	12/29	-0.01	0.01	23.9	6400	5/8	-1.02	0.02		10650	7/29	-2.08	0.01	30.5
2300	1/2/93	-0.19	0.02	22.5	6450	5/9	-0.96	0.01	26.4	10700	7/30	-2.08	0.01	30.4
2350	1/3	0.09	0.01	22.7	6500	5/10	-0.96	0.02	27.4	10750	7/31	-2.06	0.01	29.4
2400	1/5	-0.02	0.01	23.9	6550	5/11	-0.99	0.02	25.6	10800	8/1	-2.12	0.01	31.0
2450	1/7	0.13	0.01	23.7	6600	5/12	-1.15	0.01	27.5	10850	8/2	-2.37	0.01	
2500	1/9	-0.11	0.02	23.2	6650	5/13	-0.99	0.03	25.2	10900	8/3	-2.19	0.02	29.2
2550	1/10	-0.44	0.02	24.0	6700	5/14	-1.01	0.02	25.3	10950	8/5	-2.02	0.02	29.5
2600	1/12	-0.10	0.01	23.4	6750	5/15	-0.95	0.02	27.9	11000	8/6	-1.82	0.02	30.4
2650	1/14	-0.10	0.02	23.4	6800	5/17	-1.10	0.02	27.2	11050	8/7	-1.98	0.01	
2700	1/17	-0.02	0.02	22.3	6850	5/18	-1.22	0.02	26.1	11100	8/8	-1.82	0.01	
2850	1/20	0.00	0.01	22.0	6900	5/19	-1.23	0.01		11150	8/9	-1.51	0.02	
2900	1/22	0.01	0.02	21.4	6950	5/20	-1.12	0.03	26.2	11200	8/10	-1.99	0.01	29.0
2950	1/25	-0.39	0.01	21.3	7050	5/21	-1.10	0.02	26.4	11250	8/11	-1.71	0.02	28.6
3000	1/27	-0.04	0.01	20.8	7100	5/22	-1.05	0.02	26.9	11300	8/12	-1.69	0.01	28.7
3050	1/29	0.08	0.02	20.7	7150	5/23	-0.96	0.02	26.4	11350	8/13	-1.90	0.01	28.3
3100	1/30	0.38	0.01		7200	5/24	-0.82	0.02	27.6	11400	8/14	-1.80	0.01	28.4
3150	2/1	-0.16	0.02	23.0	7250	5/25	-0.87	0.01	26.6	11450	8/15	-1.82	0.01	28.7
3200	2/6	-0.11	0.02	22.5	7300	5/26	-0.93	0.03	27.2	11500	8/16	-1.78	0.02	28.0
3250	2/8	-0.09	0.01	23.0	7350	5/27	-0.88	0.01	25.8	11550	8/17	-1.78	0.01	27.5
3300	2/9	-0.16	0.01		7400	5/29	-1.52	0.02		11600	8/18	-1.94	0.02	27.7
3450	2/11	0.00	0.01	22.0	7450	5/30	-0.83	0.01	27.5	11650	8/19	-1.76	0.02	27.9
3500	2/13	-0.02	0.01	22.0	7500	5/31	-1.15	0.02	26.2	11700	8/20	-1.96	0.01	
3550	2/14	-0.44	0.02	22.5	7550	6/1	-1.10	0.01	24.8	11750	8/21	-1.81	0.01	
3600	2/16	-0.56	0.02	22.1	7600	6/3	-1.03	0.02	26.1	11800	8/22	-1.72	0.02	
3650	2/17	-0.37	0.02	22.0	7650	6/4	-1.19	0.02	27.4	11850	8/23	-1.81	0.01	27.6
3700	2/18	-0.20	0.02	22.0	7700	6/5	-1.07	0.01	27.5	11900	8/24	-1.85	0.02	28.5
3750	2/19	-0.49	0.01	22.0	7750	6/6	-1.18	0.02	28.6	11950	8/25	-1.96	0.01	28.5
3800	2/21	0.33	0.01	22.0	7800	6/7	-1.27	0.02	26.8	12000	8/25	-1.76	0.03	29.3
3850	2/24	-0.33	0.01	23.7	7850	6/8	-1.19	0.01	27.1	12050	8/26	-1.80	0.02	28.3
3950	2/26	-0.29	0.01	23.2	7900	6/9	-1.34	0.02	31.1	12100	8/27	-1.77	0.01	30.0
4000	2/28	-0.52	0.02	21.5	7950	6/10	-1.56	0.02	27.9	12150	8/28	-2.13	0.01	28.3
4050	3/1	0.31	0.01	22.3	8000	6/11	-1.44	0.01	27.9	12200	8/29	-1.73	0.03	29.1
4150	3/3	-0.48	0.02	21.8	8050	6/13	-1.55	0.02		12250	8/30	-1.54	0.01	29.0
4200	3/5	-0.24	0.02	21.8	8100	6/14	-1.54	0.02	27.9	12300	9/3	-1.78	0.01	28.8
4250	3/7	-0.32	0.02		8150	6/16	-1.29	0.06	28.7	12350	9/5	-1.75	0.02	29.7

Table. 1