3.4 Temperature at the sediment surface – mini heat probe versus CTD

J. Simstich, B. Shmelkov, V. Stanovoy

Abstract

The water temperature directly at the sediment surface was measured with a mini heat probe. The obtained data were compared to the water temperature in the deepest depth levels, reached by CTD measurements, which usually is some meters above ground. The data show that the temperature between the two investigated depth levels differs no more than 0.01 K, which is neglegible for geological questions like the oxygen isotope ratios in calcareous shells of benthic living organisms. However, in very shallow water (<20 m), where the pycnocline is close to the bottom, the measured temperatures may differ considerably.

Purpose

A well-established tool for the reconstruction of past marine environments is the ratio between the oxygen isotopes ^{18}O and ^{16}O ($\delta^{18}O$) in calcareous shells of benthic living animals like foraminifera, ostracods, or mussels (Emiliani 1955). One factor determining this ratio is the water temperature during the precipitation of the carbonate shells, because the calcifying organisms fractionate with a temperature-dependent factor (Urey et al. 1951). Therefore the actual bottom water temperature directly on the sediment surface, which is the habitat for most of the animals, is of special interest. Before the expedition no information was available on the actual bottom water temperature in the Kara Sea, because for safety reasons the CTD (conductivity-temperature-depth) measuring devices normally stop some meters above the sea floor. In this work we present results of measurements of the bottom water temperature and compare them with the water temperature in the deepest reached CTD level.

The mini heat probe

To measure the temperature at the sediment surface we used a mini heat probe, which originally was constructed for in-sediment temperature measurements by Norbert Kaul and Bernd Heesemann of the Department for Earth Sciences, University of Bremen. The mini heat probe delivers one value every 2 seconds via 7 channels. These channels are connected to 7 temperature sensors, which are fixed equally spaced within a 50 cm long, sediment penetrating steel spine, thus enabling to measure the temperature in 7 different sediment depths (Fig. 3.24). A metal plate prohibits the complete penetration of the probe and keeps the uppermost sensor (channel 7) out of the mud and approx. 0.5 to 1 centimeter above the sea floor (Fig. 3.24). An additional sensor, connected to channel 8, measures the angle of the probe all the time during the measuring and shows, whether the probe is staying upright or has fallen down. The data can be achieved "real time" via a data cable from water depths of max. 50 m. In deeper water an offline operation mode with data storage in an internal memory is possible. The construction allows the deployment by hand, even from ice flows.

The water depth at most stations of the expedition "Kara Sea 2001" on board of RV "AKADEMIK BORIS PETROV" required the deployment of the mini heat probe in the offline mode over a winch. This was done several times, until, after a small accident, the plugs on top of the heat probe were damaged and caused failors of the internal data storage due to short interruptions of the power supply.

For the initial calibration of the sensors the mini heat probe and the ship's CTD device were deployed for 15 minutes in the same water depth, simultaneously. The obtained values were compared (Fig. 3.25), and correction factors were calculated as differences between the temperature data from the mini heat probe and the CTD device for each channel separately. These calculated correction factors were applied to the regular measurements. During the actual measuring the heat sensors had approx. 5 min for adaption after penetration into the sediment. The values of the following 2-6 min. were averaged and are given in table 1 as the bottom water temperature.

Table 3.3: Results of the temperature measurements at the bottom (T_{bot}) and the deepest CTD level (T_{CTD}).

Station	Water depth (m)	Depth of T_{CTD} (m)	T_{bot} (°C)	T_{CTD} (°C)	$T_{CTD-bot}$ (K)
BP01-26	33	30.6	-1.28	-1.28	0.00
BP01-28	51	50.6	-1.12	-1.12	0.00
BP01-30	47		No vertical penetration		
BP01-34	92	90.7	-1.41	-1.41	-0.01
BP01-35	160	150.1	-1.38	-1.39	-0.01
BP01-40	46	43.6	-1.35	-1.34	0.01
BP01-41	38	35.0	-1.14	-1.14	0.00
BP01-45	77		No vertical penetration		
BP01-46	295		No vertical penetration		

Results and discussion

For unknown reasons the mini heat probe did not stay vertically during the measurements at three stations (Tab. 3.3). The values on channel 8, which measures the angle of the device, show that the probe was fallen down. Most probably the spine with the sensors did not penetrate vertically or even did not penetrate at all into the sediment. In these cases the temperature data in the internal memory were rejected, because it is not clear from which water depth above the sediment surface the measured temperature values actually are.

The results of the successful bottom temperature (T_{bot}) measurements and the temperature in the deepest reached CTD levels (T_{CTD}) can be seen in table 3.3. At all stations the difference between bottom and CTD temperature is very small and does not exceed 0.01 K (Tab. 3.3). The bottom temperature is a continuation of the vertical temperature trend in the water column. This means that the temperature at the bottom is colder/warmer than at the deepest CTD level, when the temperature in the deeper water column becomes likewise colder/warmer with depth.

The temperature difference between T_{bot} and T_{CTD} is too small to affect the oxygen isotopic composition ($\delta^{18}O$) in calcitic shells of foraminifera by more than 0.003‰ (O'Neil et al. 1969; Shackleton 1974), or 0.002‰ in aragonitic shells of mussels

(Grossman and Ku 1986). These values are far below the measuring accuracy, which is 0.08‰ $\delta^{18}O$ (Erlenkeuser et al. 1999). As the main result we conclude that for studies of $\delta^{18}O$ of benthic organisms in the Kara Sea the temperature at the sediment surface can be approximated by the temperature in the deepest reached CTD level, without making a significant error.

However, this approximation is not applicable in areas where a temperature gradient in the deep water causes a significant temperature difference between the deepest CTD level and the sea floor. Such situations probably exist in the shallow and estuarine areas of the Kara Sea where the pycnocline is situated close to the ground. For example, in areas where the water depth is below 20 m the salinity at the sediment surface deviates considerably from the salinity in the deepest CTD level (Simstich 2001). This might also be the case for temperature, because in the southern Kara Sea the depth of the thermocline is closely connected to the depth of the halocline, as can be seen in the CTD profiles (Shmelkov et al., this volume).

Conclusions

From the comparison of the water temperature directly above the sediment surface with the temperature in the deepest reached CTD level we conclude that the temperature difference between these two depth levels is too small to significantly affect oxygen isotope ratios in calcareous shells of benthic organisms. Presumably, this does not apply to shallow areas where the pycnocline is situated close to the ground.

Acknowledgements

We thank the crew of RV "AKADEMIK BORIS PETROV", especially Viktor Chorschev, Alexander Latko, and Vladimir Markovskiy for helping in many ways during the cruise. We are obliged to Norbert Kaul and Bernd Heesemann, University of Bremen, for carefully training the first author in the handling of the mini heat probe.

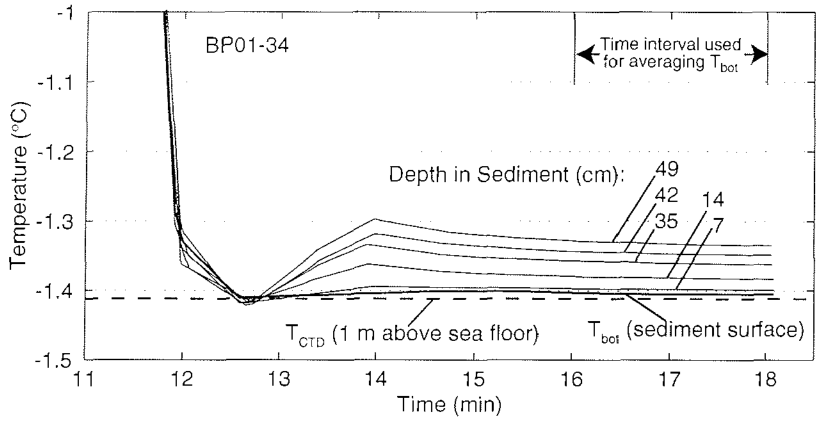

Fig. 3.24: Temperature in different depths at station BP01-34. The correction factors (see text and Fig. 3.25) are applied.

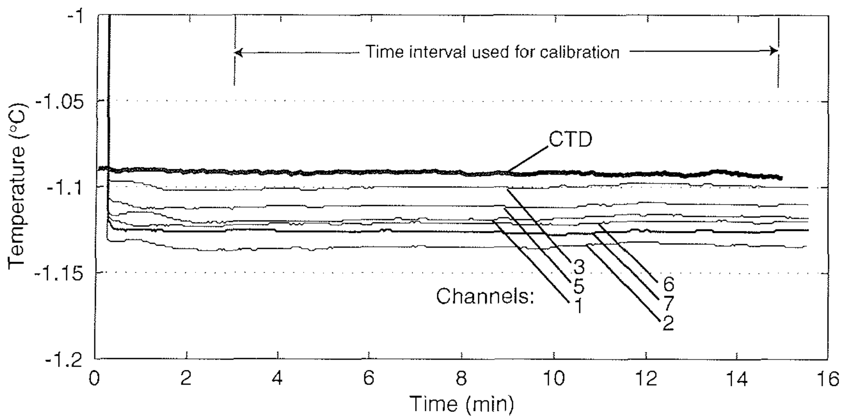

Fig. 3.25: Calibration data.