BRITISH GEOLOGICAL SURVEY
BGS TECHNICAL REPORT WB/00/04C

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BGS TECHNICAL REPORT WB/00/04C

Temperature Measurements collected during the BGS 1998 & 1999 Drilling Operations

By
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Geographical index
Rockall and Hatton Banks, UK NW Frontier Area, West of Shetland, Faroe-Shetland Channel, West of Ireland - Rockall to Porcupine Bank

Subject index
Marine Geological Surveys, Offshore Stratigraphic Coring, Wireline Coring

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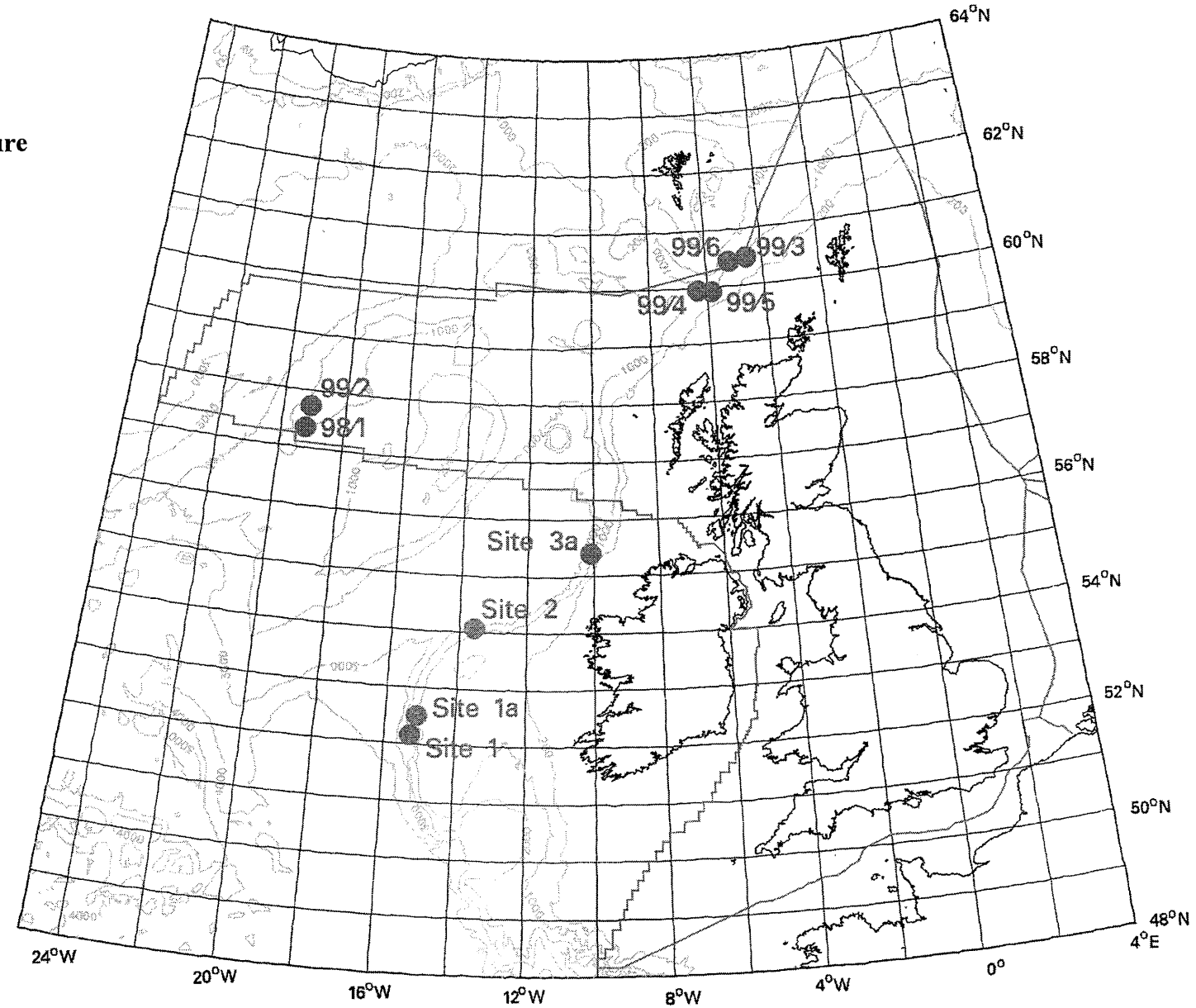

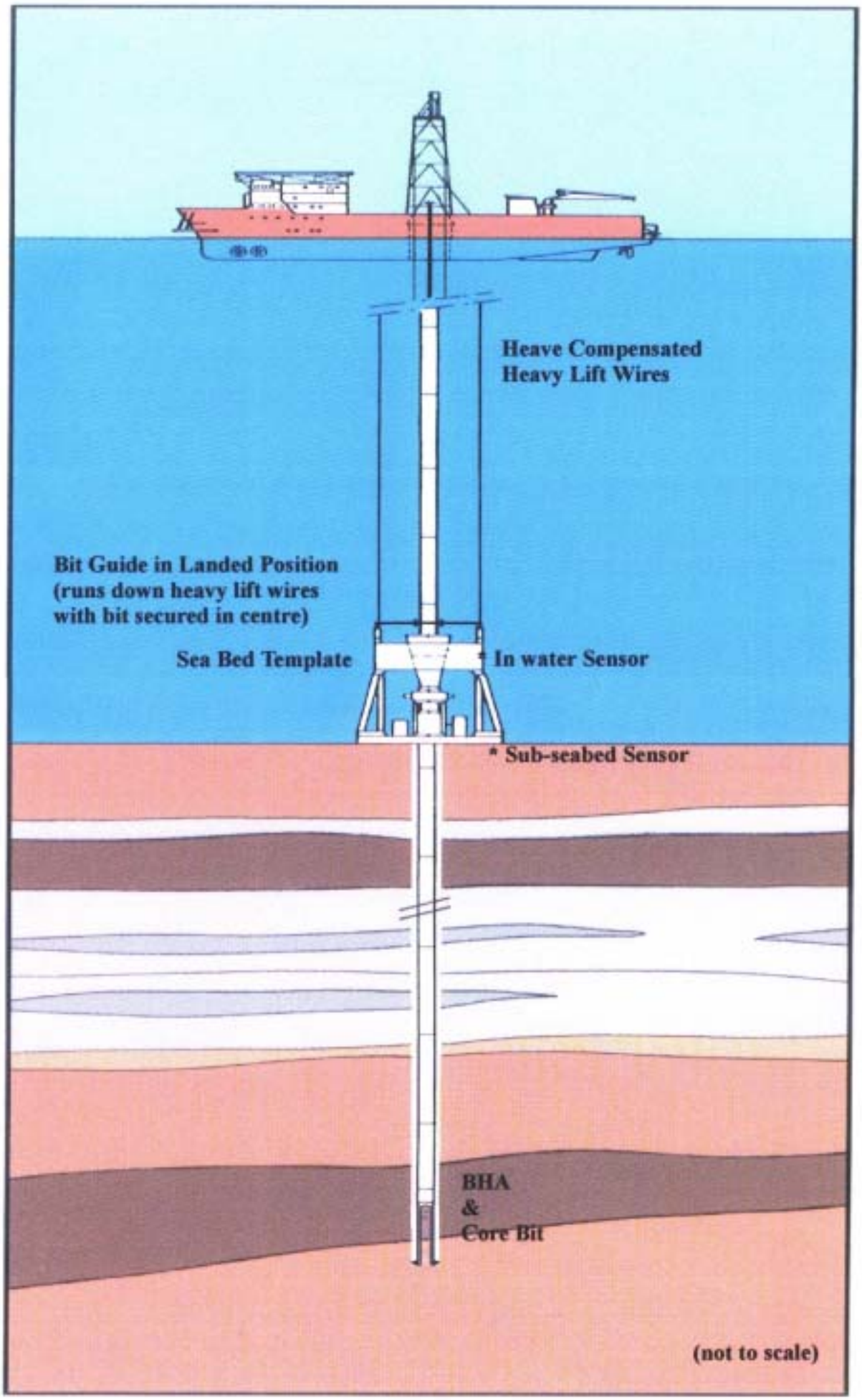

Fig. 2 - Location of Temperature Sensors on Template

1. Introduction

In 1998 the Western Frontier Association (WFA) funded the design and development of temperature sensor equipment suitable for measuring the in-situ temperature of the seawater and seabed sediments in water depths to 2000m.

The equipment was then to be operationally tested using opportunistic offshore programmes in order to gain more information on the seabed temperatures occurring in and around the WFA area of interest.

In 1998 the equipment was taken to sea on the geotechnical vessel 'Norskald' with a view to conducting above seabed, immediately below seabed and down borehole measurements. Due to various operational problems with the vessel the planned programme of work was suspended and only two measurements, at one site, were made.

In 1999 the equipment was again deployed, this time from the geotechnical vessel 'Bucentaur'. Despite bad weather which introduced operational constraints and caused damage to equipment (at times there was 3-5m heave conditions when trying to place equipment on the seabed) sub-seabed and 3m above seabed temperatures were recorded at four sites in UK designated waters and one site in Faroese designated waters. At three sites in Irish waters the temperature 3m above seabed was measured, the lower sensor having been broken off from the base of the seabed template and lost during the drilling programme. One downhole temperature probe was prepared but could not be deployed due to an unstable borehole. Another was prepared and deployed but, upon recovery of the drillstring was found to have snagged at the drillpipe/drillcollar crossover sub and therefore although it had recorded it was not correctly positioned to give meaningful results.

2. Summary of Data Collection

In July 1998 information at the seabed and 3m above it were concurrently recorded at one site on Hatton Bank from the vessel 'Norskald'. In June and July 1999 a further four deployments were made at the same depth intervals on Hatton Bank and in the Faroe - Shetland Channel together with three sea bottom measurements in Irish waters between Rockall and Porcupine.

Details of the locations and duration of measurement are shown in **Table 1** and **Appendix 1** respectively. The graphs in Appendix 1 have been annotated with pertinent drilling information which shows the effects of drilling and associated activities but which do not detract from other environmental patterns of temperature change. Other data regarding these cruises are available with BGS should any questions on the data or its interpretation arise outwith this report.

The data are correlated and discussed in Section 4. **Tables 2 – 13** show the results obtained at each Location and compare them with bottom water temperature data researched from the literature in the vicinity of the Locations discussed in this report. Good correlations have been obtained and some data has been added in other areas.

The equipment has proved to be robust although some further modifications have to be made. Two avenues for further data collection have become apparent – a simple probe assembly should be possible for incorporation on the vibrocorer and a further measurement technique can be developed to take deck measurements immediately cores are retrieved.

3. Confidentiality of Data

All data pertinent to the operation are confidential to the Western Frontier Association, the BGS Rockall Consortium and the PIPCo RSG, Irish Rockall Studies Group as co-sponsors of this data gathering venture.

4. Method of Data Collection and Presentation

Figure 1 shows the location of each of the measurement sites and **Figure 2** the positions of the sensors on the seabed frame which is 3m square and 2.5m high. The sensors were positioned one above each other on the outside of the frame so were at least one metre away from the drilling point. Both were set to record continuously so the top sensor could record air temperature in the 'splash zone' of the moonpool when the template was raised to normal steaming position whereas the lower sensor stayed under water under the same circumstances.

The data has been translated from the sensor files into excell spreadsheet graphs as shown in **Appendix 1** for ease of presentation. All data present in the files may not be shown on the accompanying graphs attached for reasons of clarity.

During drilling the template stays on the seabed but, if the weather dictates, the ship's heading may have to be changed. If this is done by more than a few degrees then the template has to be raised off the seabed some 3-5m then allowed to rotate and stabilize before being re-set to allow drilling to recommence. Such changes are noticeable in the temperature graphs and are recorded. **Table 1**, below, summarises the site details.

Location	Lat.	Long.	Water Depth	Remarks
98/1	57 12'N	19 12'W	954m	Various technical problems on site. Long periods with no drilling activity
99/2	57 49'N	19 12'W	965m	2.5 days on site, template on seabed all the time
99/3	60 25'N	4 39'W	983m	3.75 days on site, template lifted to change heading
99/4	59 59'N	6 24'W	486m	1 day on site, template on seabed all the time
99/5	59 53'N	6 00'W	700m	1.5 days on site, template lifted to change heading
99/6	60 23'N	5 19'W	1183m	2.4 days on site, template on seabed all the time
Site 1	52 15'N	15 18'W	1568m	4.75days on site, template lifted to deck once
Site 1a	52 27'N	15 07'W	1045m	3.1 days on site, template on seabed all the time
Site 2	54 02'N	13 31'W	1462m	3.8 days on site, template on seabed all the time
Site 3a	55 25'N	10 1'W	1092m	1.9 days on site, template lowered and raised a few times before landing on seabed and staying there

Table 1 - Locations at which Temperature Measurements were made

5. Data Interpretation and Comparison with other Available Data

Several of the sites where seabed sediment and bottom water temperature measurements were made are close to localities where measurements had been made previously and the data was held by BGS as a result of other studies for the Western Frontiers Association (Long 1996; Long, in press). As water depth is a major control on bottom water temperatures measurements at sites of similar water depth within 25km of the site have been compared. This pre-existing data on bottom water temperatures is derived from CTD casts and current meter deployments,

which frequently have continuous temperature recording.

Location 98/1A

Latitude	Longitude	Water Depth	Sensor	Meter Depth	Average Temp.	Standard Deviation	Min. Value	Max. Value
Deg. Min.	Deg. Min.	m		m	°C	°C	°C	°C
57 12'N	19 12'W	954	Bottom water	951	6.66	0.11	6.5	6.8
57 12'N	19 12'W	954	Seabed sediment	954	6.79	0.15	6.3	7.0
Values derived from data collected whilst seabed template on the bottom 12/07/98 23:34 to 15/07/98 01:34								

Table 2 – Data at Location 98/1

Location 99/2

Latitude	Longitude	Water Depth	Sensor	Meter Depth	Average Temp.	Standard Deviation	Min. Value	Max. Value
Deg. Min.	Deg. Min.	m		m	°C	°C	°C	°C
57 49'N	19 12'W	965	Bottom water	962	6.17	0.19	5.9	6.5
57 49'N	19 12'W	965	Seabed sediment	965	6.30	0.25	6.0	6.7
Values derived from data collected whilst seabed template on the bottom 16/06/99 12:00 to 19/06/99 23:59								

Table 3 – Data at Location 99/2

No data held by BGS was available from other sources for comparisons at these two sites. However both sites are close by each other and show similar temperature properties. The main observation is the absence of a cold arctic water influence.

Location 99/3

Latitude	Longitude	Water Depth	Sensor	Meter Depth	Average Temp.	Standard Deviation	Min. Value	Max. Value
Deg. Min.	Deg. Min.	m		m	°C	°C	°C	°C
60 25'N	4 39'W	983	Bottom water	980	-0.81	0.04	-0.9	-0.7
60 25'N	4 39'W	983	Seabed sediment	983	0.05	0.32	-0.8	0.9
Values derived from data collected whilst seabed template on the bottom 20/06/99 22:05 to 24/06/99 22:10								

Table 4 – Data at Location 99/3

Latitude	Longitude	Water Depth	Depth of Cast	Temperature	Original Number	Reference
Deg. Min.	Deg. Min.	m	m	°C		
60 25.91N	4 54.25W	993	960	-0.80	472-1	Suess et 1994
60 28.3N	4 27.3W	991	939	-0.85	43	Saunders & Gould 1988
60 34N	4 44.5W	1074	1037	-0.83	44	Saunders & Gould 1988

Table 5 - CTD casts in the vicinity of Location 99/3

Latitude	Longitude	Water Depth	Meter Depth	Average Temp.	Standard Deviation	Min. Value	Max. value	Reference Identifier	Data Source
Deg. Min.	Deg. Min.	m	m	°C	°C	°C	°C		
60 29.7N	4 58.6W	1005	990	-0.87	0.07	-0.98	-0.50	R314/M4, MA3727	BODC supplied data collected by IOS Deacon Laboratory

Table 6 - Temperature record, current meter deployment in the vicinity of Location 99/3

Discussion of the Data at or near Location 99/3

There are strong similarities in the bottom water temperature measured at 99/3 with that reported at nearby sites. It varies only slightly and is within the range reported at the current meter site. The temperature measured by the sediment probe matches the bottom water temperature until drilling activity begins. As well as rising immediately on drilling the temperature continues to rise increasing most rapidly as the weather deteriorated imposing stress on the seabed template. During the period of drilling there is an apparent difference between bottom water and sediment temperature of approximately 0.8°C indicating that they are not in equilibrium. This suggests that the seabed sensor is being influenced by the drilling activity. The most obvious explanation is that drilling fluids, principally seawater, is extending to the edge of the seabed template and circulating around the probe 30cms below the seabed. The seawater used for drilling is derived from surface waters that are typically 9 to 10°C.

Location 99/4

Latitude	Longitude	Water Depth	Sensor	Meter Depth	Average Temp.	Standard Deviation	Min. Value	Max. Value
Deg. Min.	Deg. Min	m		m	°C	°C	°C	°C
59 59'N	6 24'W	486	Bottom water	483	8.79	0.80	7	9.5
59 59'N	6 24'W	486	Seabed sediment	486	9.32	0.15	9	9.5
Values derived from data collected whilst seabed template on the bottom 25/06/99 07:20 to 26/06/99 06:20								

Table 7 – Data at Location 99/4

Latitude	Longitude	Water Depth	Depth of Cast	Temperature	Original Number	Reference
Deg. Min.	Deg. Min.	m	M	°C		
59 51.0N	6 15.0W	435	425	8.91	355458	BODC supplied data collected by University College of North Wales
59 54.0N	6 24.0W	405	390	9.21	355483	BODC supplied data collected by University College of North Wales

Table 8 - CTD casts in the vicinity of Location 99/4

Latitude	Longitude	Water Depth	Meter Depth	Average Temp.	Standard Deviation	Min. Value	Max. Value	Original Reference	Data Source
Deg. Min.	Deg. Min.	m	m	°C	°C	°C	°C		
59 59.0N	6 47.5W	450	447	8.70	0.22	7.08	9.43	N2002,M1 916	BODC supplied data collected by Scottish Office, Agriculture and Fisheries Dept

Table 9 - Temperature record, current meter deployment in the vicinity of Location 99/4

Discussion of the Data at or near Location 99/4

The bottom water values collected are similar to, but slightly higher than, that previously reported for the area but within the range noted at the current meter site. This area is affected by current – derived "slugs" of cooler water which cause cooling of the near seabed sediment. As can be seen in the graphs in Appendix 1 the bottom water temperature drops 2°C virtually instantly. The sediment temperature 1m below seabed falls 0.3°C in 7.5hrs.

Location 99/5

Latitude	Longitude	Water Depth	Sensor	Meter Depth	Average Temp.	Standard Deviation	Min. Value	Max. Value
Deg. Min.	Deg. Min.	m		m	°C	°C	°C	°C
59 53'N	6 00'W	700	Bottom water	697	-0.34	0.31	-0.6	0.8
59 53'N	6 00'W	700	Seabed sediment	700	0.25	1.08	-0.5	5.1
Values derived from data collected whilst seabed template on the bottom 26/06/99 10:10 to 27/06/99 20:55								

Table 10 – Data at Location 99/5

Latitude	Longitude	Water Depth	Depth of Cast	Temperature	Original Number	Reference
Deg. Min.	Deg. Min.	m	M	°C		
59 53.0N	6 12.0W	880	845	-0.83	355471	BODC supplied data collected by University College of North Wales
59 50.0N	5 50.0W	750	745	-0.52	355422	BODC supplied data collected by University College of North Wales
59 54. 0N	6 03.0W	865	840	-0.83	355631	BODC supplied data collected by University College of North Wales

Table 11 - CTD casts in the vicinity of Location 99/5

Discussion of the Data at or near Location 99/5

There is not a good correlation with data available for comparison at this location. This can probably be explained by topography and water depth differences, over a short distance, causing differing water flow patterns. The CTD casts, although taken nearby are in water depths 50m to 180m deeper than site 99/5.

Location 99/6

Latitude	Longitude	Water Depth	Sensor	Meter Depth	Average Temp	Standard Deviation	Min. Value	Max. Value
Deg. Min.	Deg. Min.	m		m	°C	°C	°C	°C
60 23'N	5 19'W	1183	Bottom water	1180	-0.70	0.05	-0.8	-0.5
60 23'N	5 19'W	1183	Seabed sediment	1183	-0.20	0.34	-0.7	0.8
Values derived from data collected whilst seabed template on the bottom 29/06/99 16:05 to 2/07/99 1:15								

Table 12 – Data at Location 99/6

Latitude	Longitude	Water Depth	Depth of Cast	Temperature	Original Number	Reference
Deg. Min.	Deg. Min.	m	m	°C		
60 29.49N	5 8.54W	1021	1011	-0.80	470-2	Suess et 1994

Table 13 - CTD casts in the vicinity of Location 99/6

Latitude	Longitude	Water Depth	Meter Depth	Average Temp.	Standard Deviation	Min. Value	Max. Value	Original Reference	Data Source
Deg. Min.	Deg. Min.	m	m	°C	°C	°C	°C		
60 29.7N	4 58.6W	1005	15	-0.87	0.07	-0.98	-0.50	R314/M4,M A3727	BODC supplied data collected by IOS Deacon Laboratory

Table 14 - Temperature record, current meter deployment in the vicinity of Location 99/6

Discussion of the Data at or near Location 99/6

There is a reasonable agreement between this data and comparative data from CTD casts and Current Meter recordings. Such differences as do exist are probably accounted for by the slightly different water depths.

PIPCo RSG Sites

Site	3a	2	1a	1	1
Data Collected in Period	07/07/99 01:00 to 08/07/99 15:30	09/07/99 17:10 to 14/07/99 10:20	15/07/99 09:15 to 18/07/99 23:55	19/07/99 12:40 to 20/07/99 19:35	21/07/99 13:25 to 24/07/99 20:20
Av. Temp. °C	6.60	4.45	7.39	4.11	4.08
St deviation	0.33	0.27	0.24	0.15	0.04
Max. Temp. °C	7.3	5.0	8.1	4.6	4.2
Min. Temp. °C	6.0	3.9	7.0	3.9	4.0

Table 15 – Data from PIP Sites

No data was available from other sources for comparisons at this site. Note however the marked cyclicity in the data at site 2. (See Appendix 1).

6. Conclusions

6.1 Data Interpretation and Comparisons.

Comparison with historical data shows that there is broad general agreement where results can be directly compared. This serves to indicate the validity of making long term measurement and repeating measurements. It also highlights that topography, water depth and water mass and flow all affect the temperatures recorded. Thus it is important to make as many measurements in as many different environments as possible in order to build up a coherent picture of seabed temperature. If sub-seabed and water temperatures can also be added to this then temperature profiles and limited geothermal gradient can be calculated. Presently no comparative data could be obtained for the seabed results and, in part at least, the graphs show that the data recorded are

affected by the rotary drilling process. As drilling provides a good opportunity for obtaining a long time temperature profile some though will have to be given to a method of deployment of the probes away from the influence of the drilling.

6.2 Operational Aspects

Despite a few operational problems encountered the equipment appeared to work very well, even in adverse weather conditions and suffered no pressure or 'G-Force' problems.
It was not the intention to run the probes for extended periods of time between checking and downloading but the weather throughout was such that the standing orders did not allow moonpool operations. Therefore unless the seabed template was lifted to deck for inspection or repairs the probes remained installed and unexamined during all drilling operations and steaming between sites. Although this practice would not be considered the norm it again serves to indicate that a robust design has been produced.
Consideration will now be given to identifying a different strength non-conducting connector for seabed entry and also more centralisation on the downhole dart. With both of these improvements it is expected that the tool will be both robust and reliable.
Report CR/00/78 gives details of the proposed improvements. A method to record temperatures in the seabed with the vibrocoring tool and another to record core temperatures immediately after they are collected are also discussed in that report.

7. Acknowledgments

The WFA funded the design and fabrication of the equipment while the BGS Rockall Consortiun and the Rockall Studies Group of Ireland granted permission to deploy the temperature sensors while carrying out drilling work. thanks are due to all of them for allowing the concept to reach a successful working tool which has further potential for future data gathering.

8. References

Long, D. 1996. Hydrates and their potential existence in the Faroe – Shetland Channel. **BGS Technical Report WB/96/34C**.

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Skinner, A.C. and Derrick, J.F., 1998. Construction and field Testing of a Temperature Probe string for Sea bed and Borehole Applications. **BGS Technical Report WB/98/33C.**

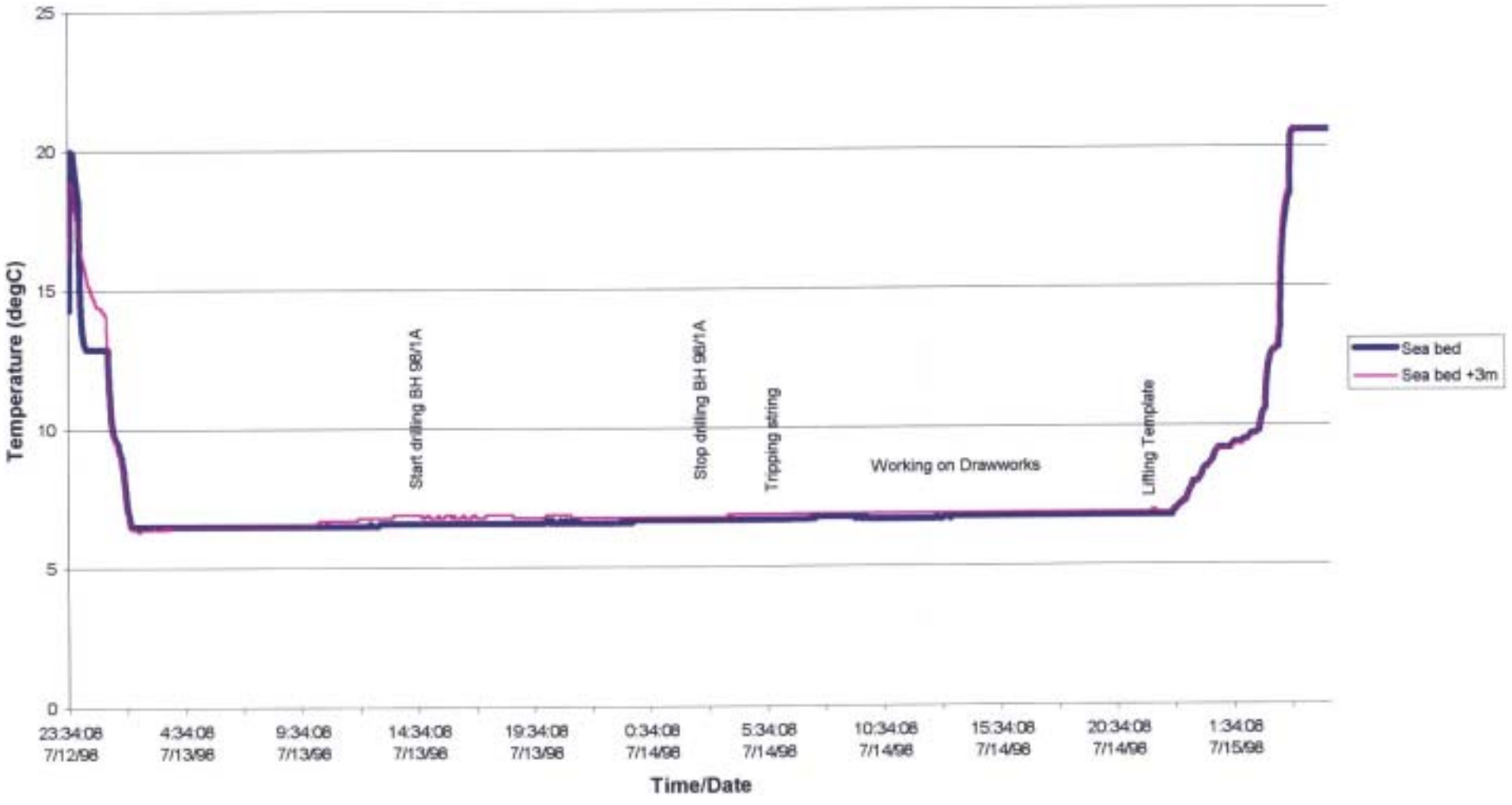
Skinner, A.C. 2000. Further considerations for Enhancement of Environmental Temperature Recording while Conducting Offshore Coring and Immediate Onboard Core Inspection. **BGS Technical Report CR/00/78C.**

Suess, E., Kremling, K. & Mienert,J. 1994. NORDATLANTIK 1993, Cruise No 26, 24 August – November 1993. METEOR-Berichte, Universitat Hamburg, 94-4, 256pp.

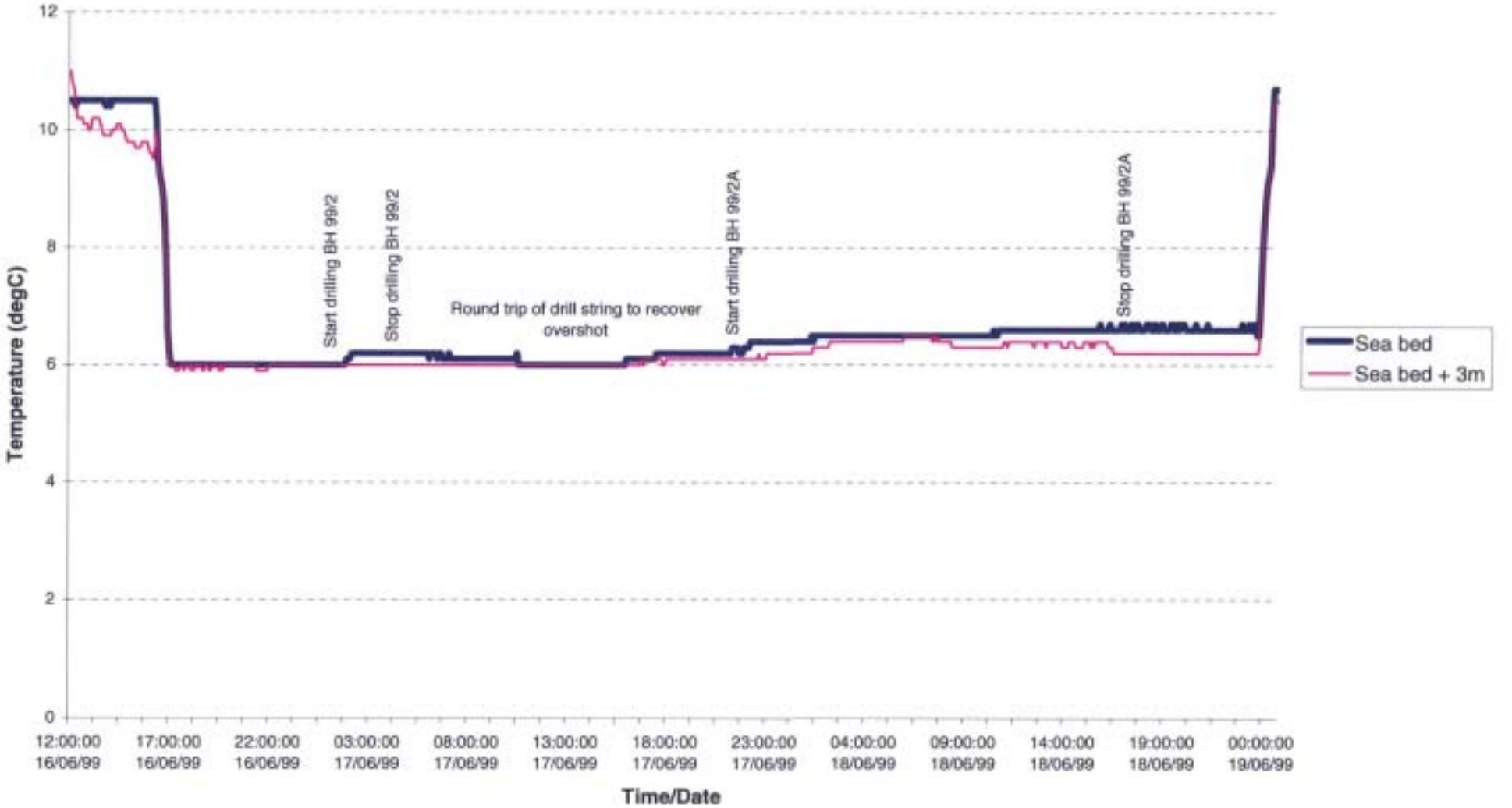
Appendix 1

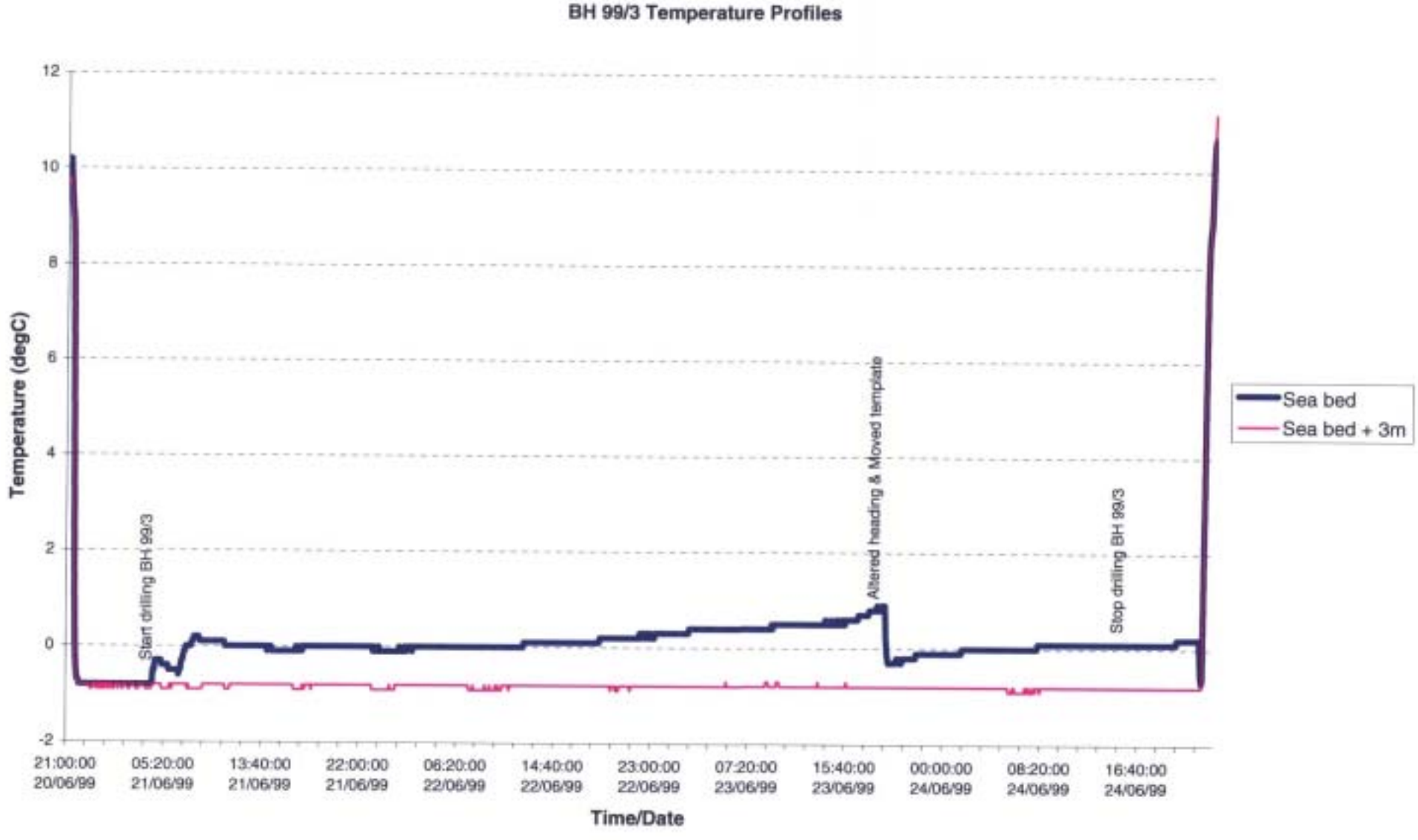
Seabed Temperature Graphs

BH 98/01A Temperature Profiles



BH 99/2 Temperature Profiles




BH 99/3 Temperature Profiles
Temperature (degC)
12
10
8
6
4
2
0
-2
Start drilling BH 99/3
Altered heading & Moved template
Stop drilling BH 99/3
21:00:00 20/06/99
05:20:00 21/06/99
13:40:00 21/06/99
22:00:00 21/06/99
06:20:00 22/06/99
14:40:00 22/06/99
23:00:00 22/06/99
07:20:00 23/06/99
15:40:00 23/06/99
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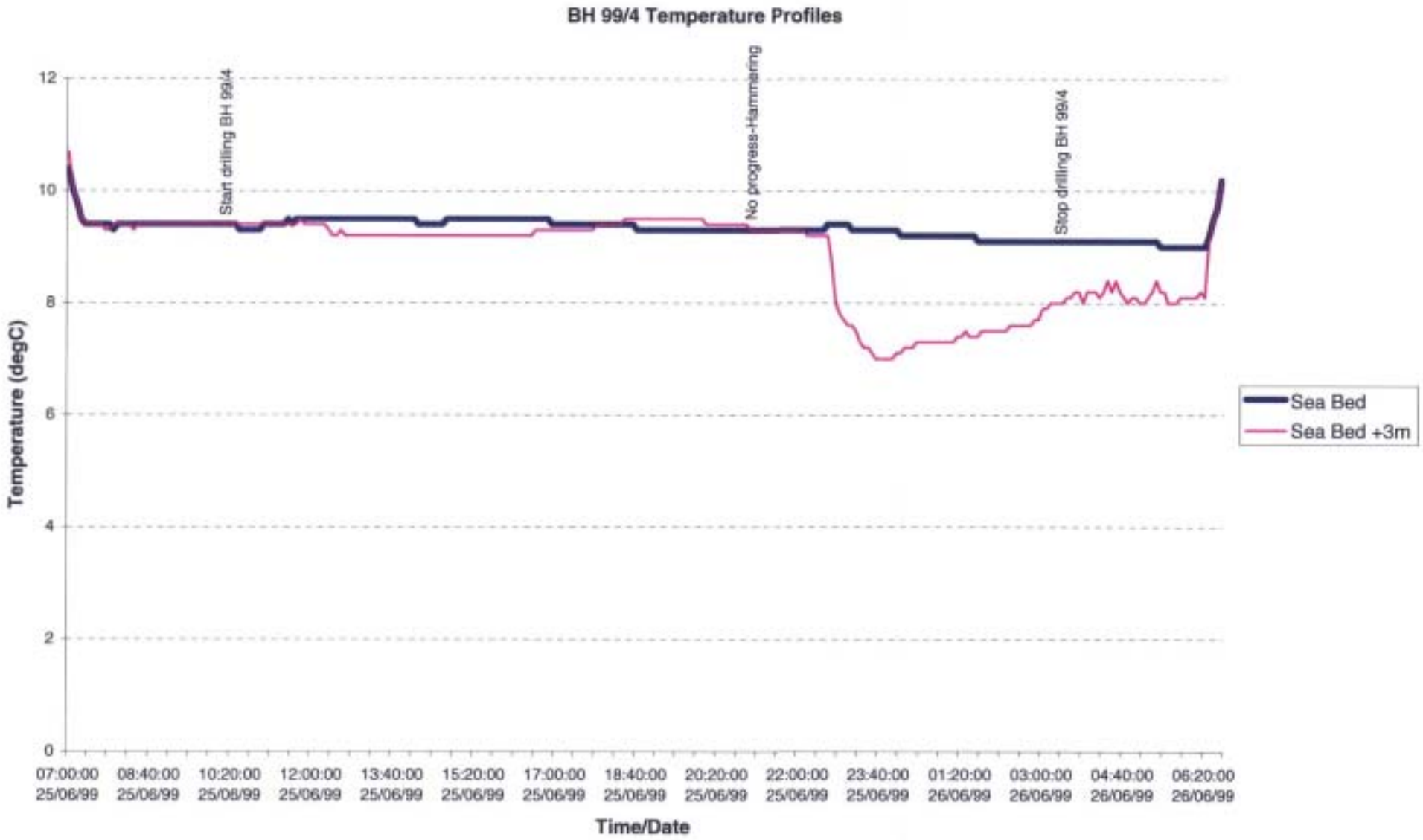
16:40:00 24/06/99
Time/Date
Sea bed
Sea bed + 3m


BH 99/4 Temperature Profiles
Start drilling BH 99/4
No progress-Hammering
Stop drilling BH 99/4
Temperature (degC)
0
2
4
6
8
10
12
07:00:00 25/06/99
08:40:00 25/06/99
10:20:00 25/06/99
12:00:00 25/06/99
13:40:00 25/06/99
15:20:00 25/06/99
17:00:00 25/06/99
18:40:00 25/06/99
20:20:00 25/06/99
22:00:00 25/06/99
23:40:00 25/06/99
01:20:00 26/06/99
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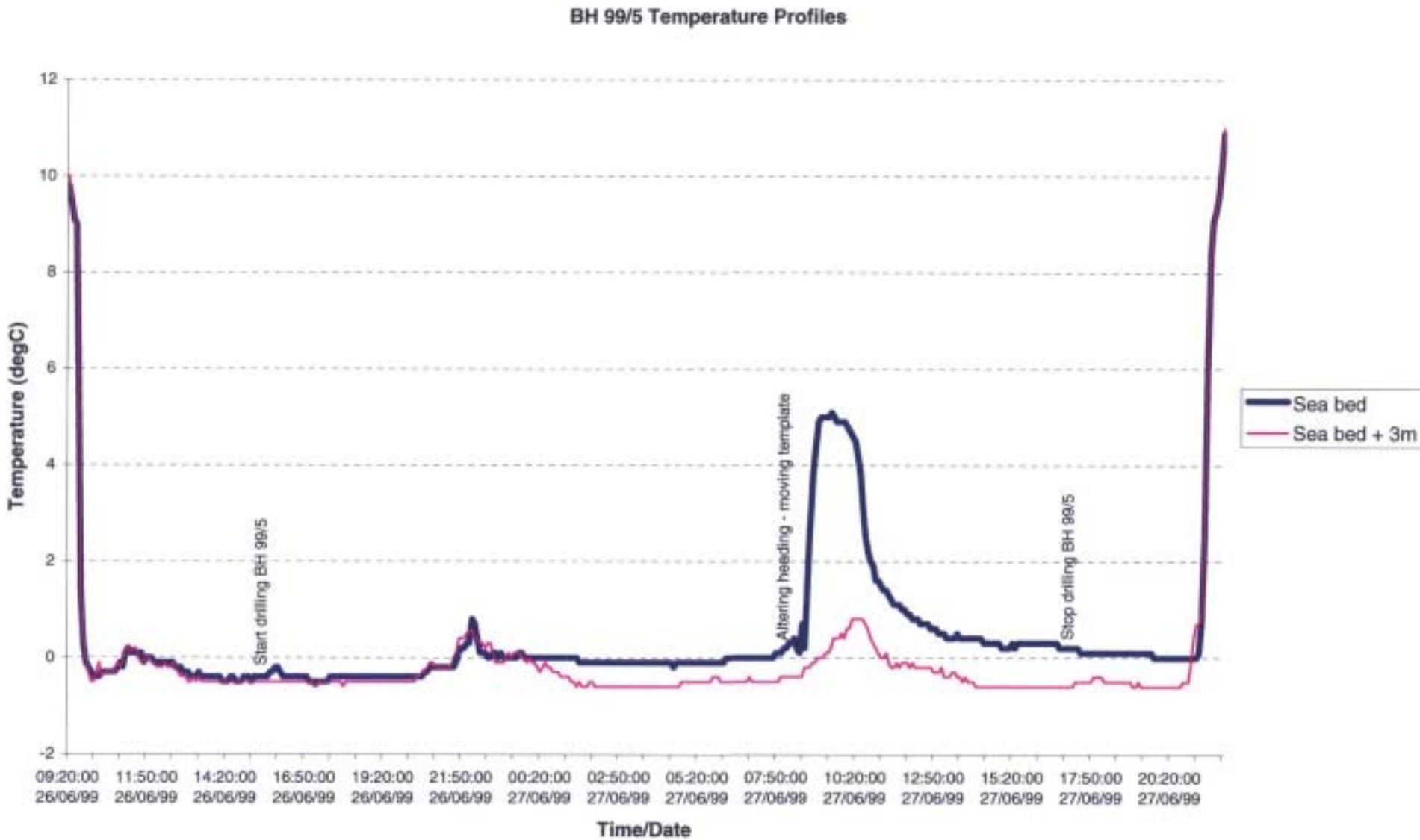
06:20:00 26/06/99
Time/Date
Sea Bed
Sea Bed +3m


BH 99/5 Temperature Profiles
Temperature (degC)
12
10
8
6
4
2
0
-2
Start drilling BH 99/5
Altering heading - moving template
Stop drilling BH 99/5
Sea bed
Sea bed + 3m
09:20:00 26/06/99
11:50:00 26/06/99
14:20:00 26/06/99
16:50:00 26/06/99
19:20:00 26/06/99
21:50:00 26/06/99
00:20:00 27/06/99
02:50:00 27/06/99
05:20:00 27/06/99
07:50:00 27/06/99
10:20:00 27/06/99
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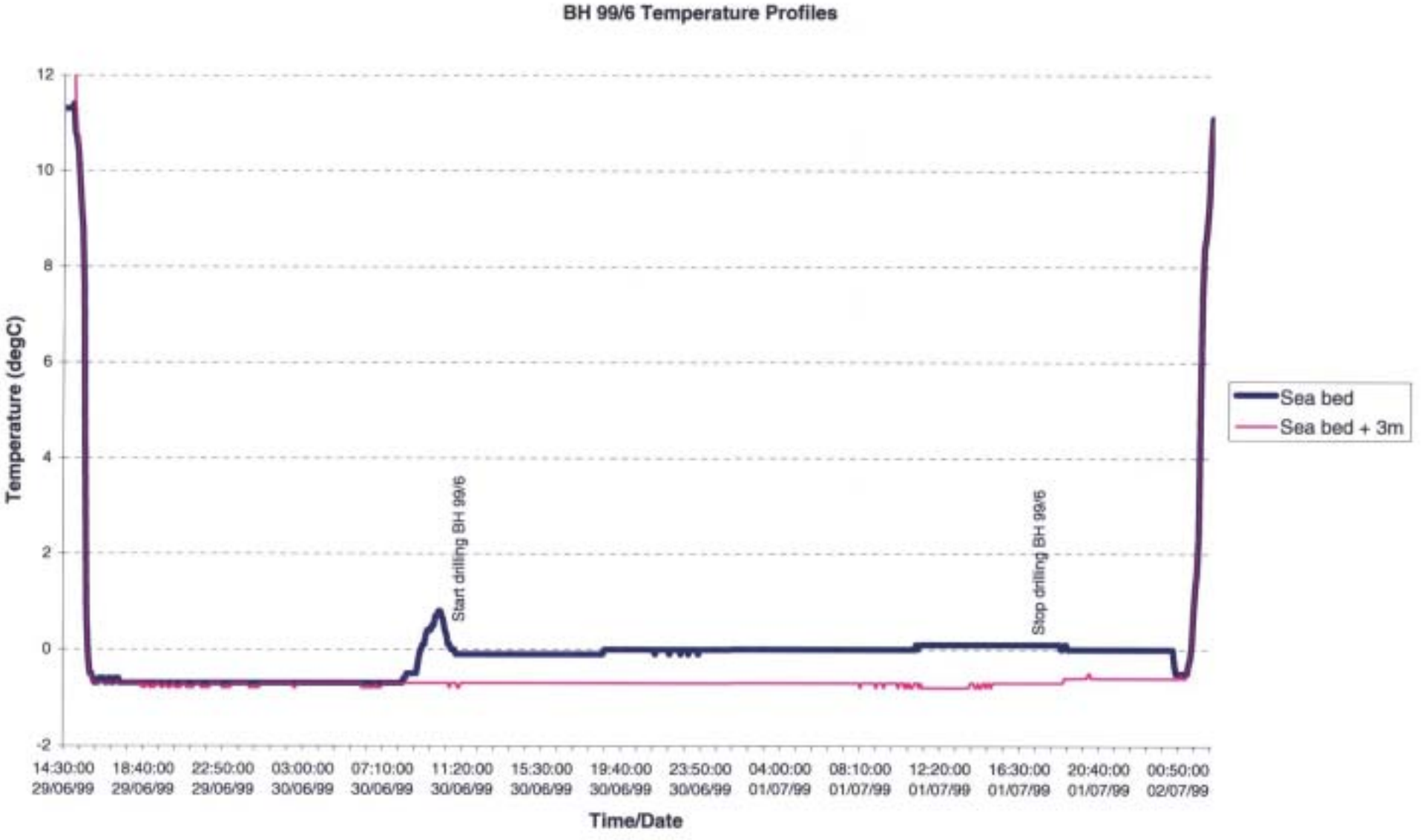
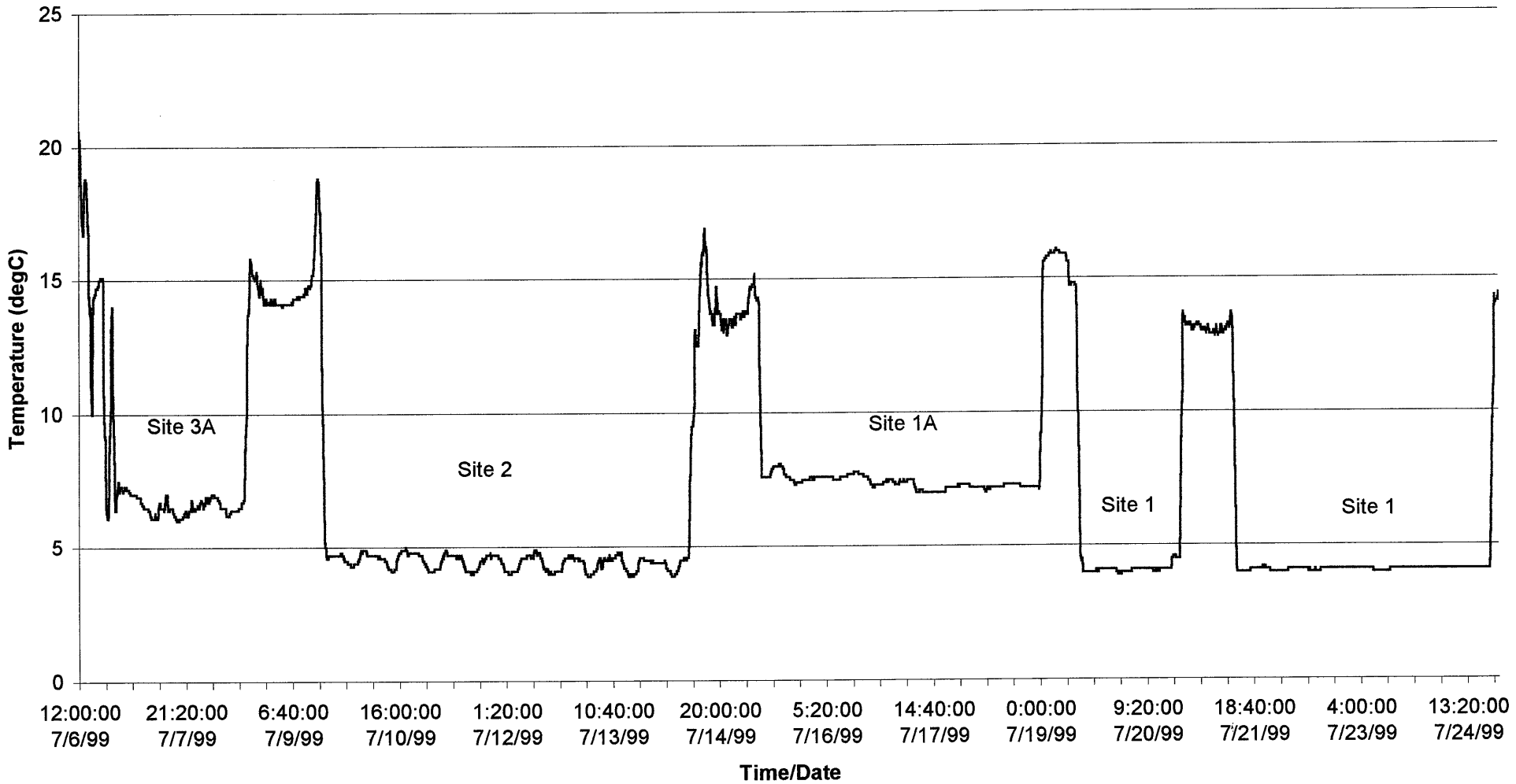
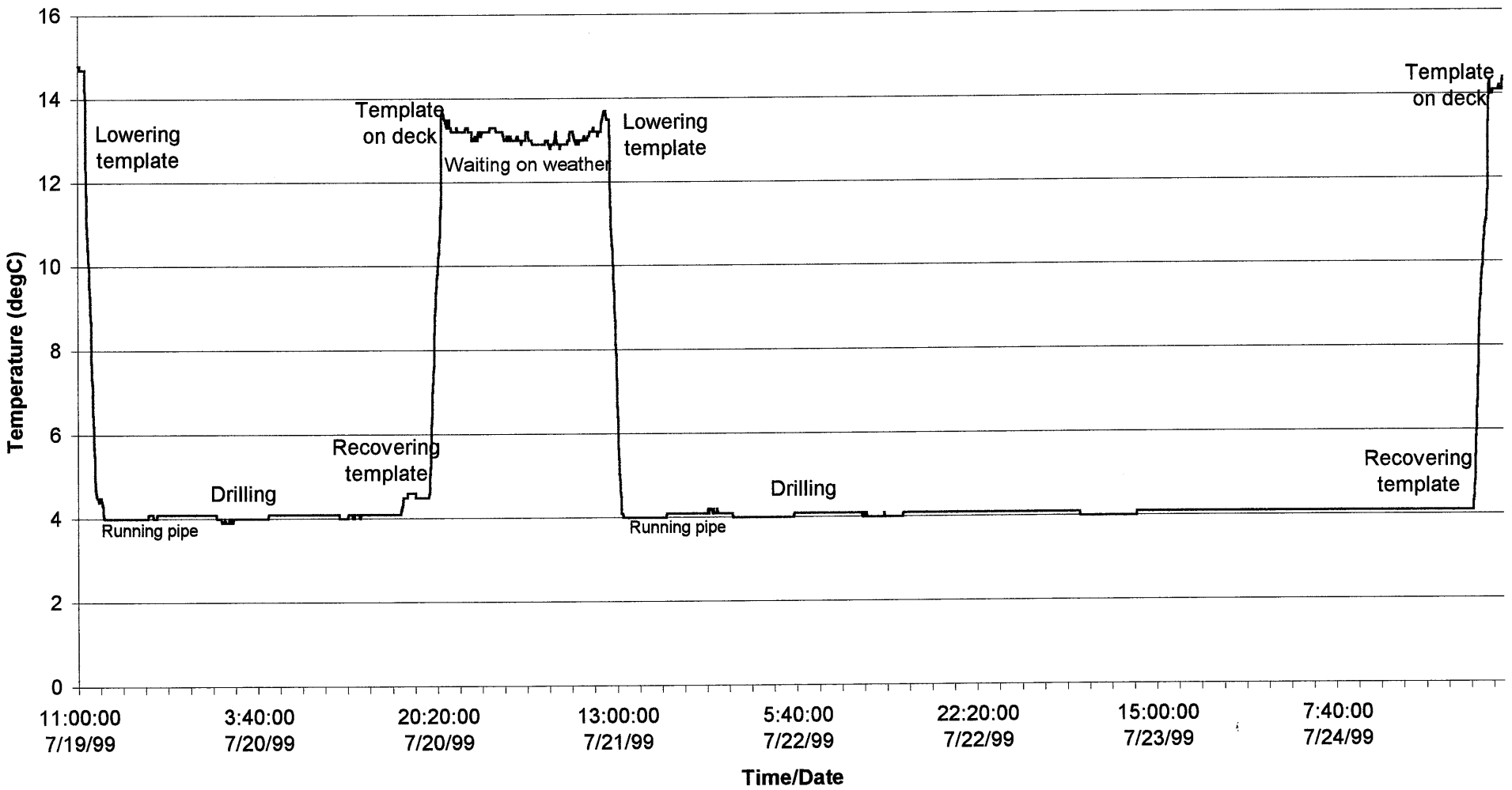
17:50:00 27/06/99
20:20:00 27/06/99
Time/Date


BH 99/6 Temperature Profiles
Temperature (degC)
12
10
8
6
4
2
0
-2
Start drilling BH 99/6
Stop drilling BH 99/6
Sea bed
Sea bed + 3m
14:30:00 29/06/99
18:40:00 29/06/99
22:50:00 29/06/99
03:00:00 30/06/99
07:10:00 30/06/99
11:20:00 30/06/99
15:30:00 30/06/99
19:40:00 30/06/99
23:50:00 30/06/99
04:00:00 01/07/99
08:10:00 01/07/99
12:20:00 01/07/99
16:30:00 01/07/99
20:40:00 01/07/99
00:50:00 02/07/99
Time/Date

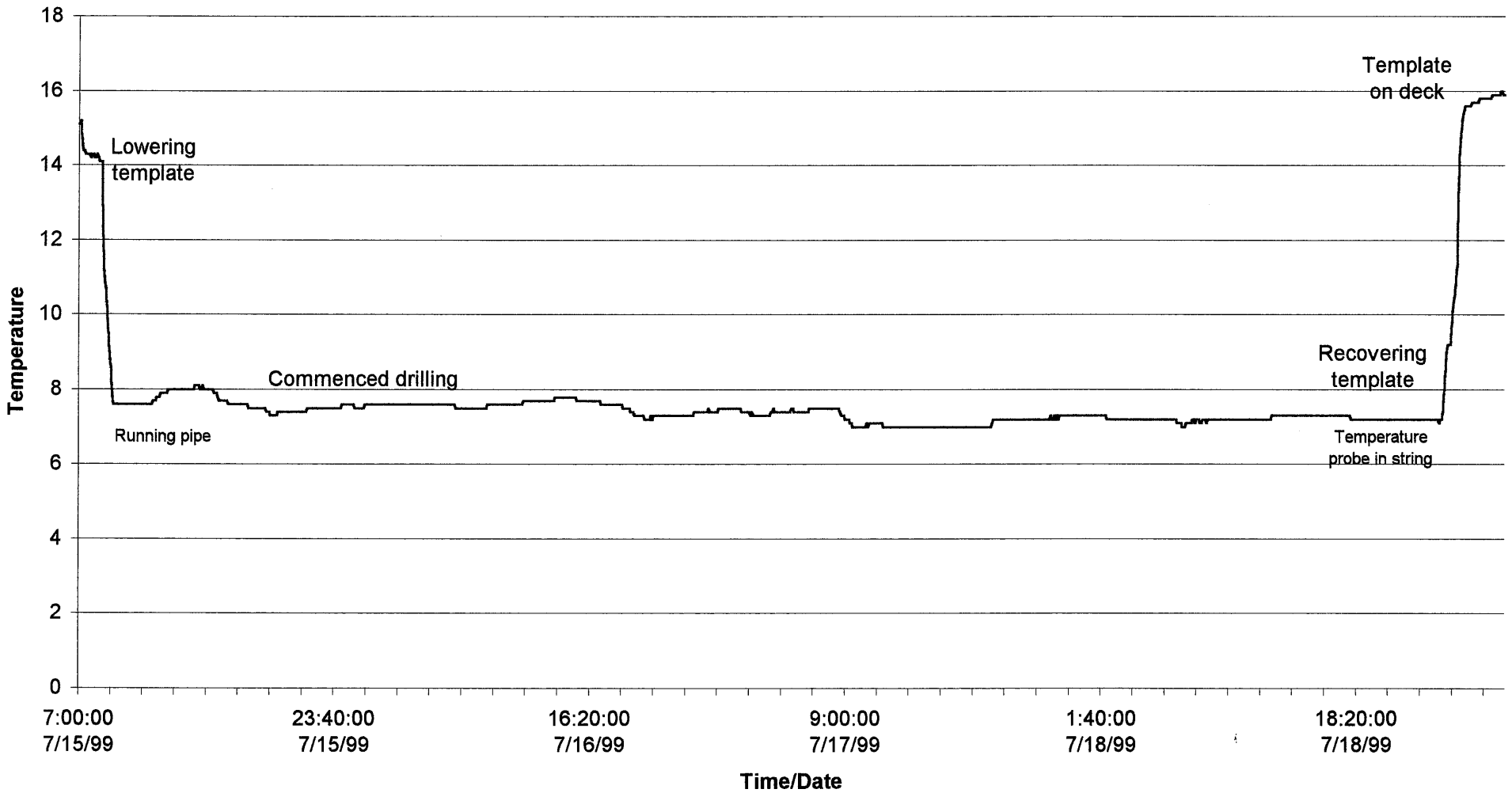
Combined Temperature Graph - 3m above Seabed



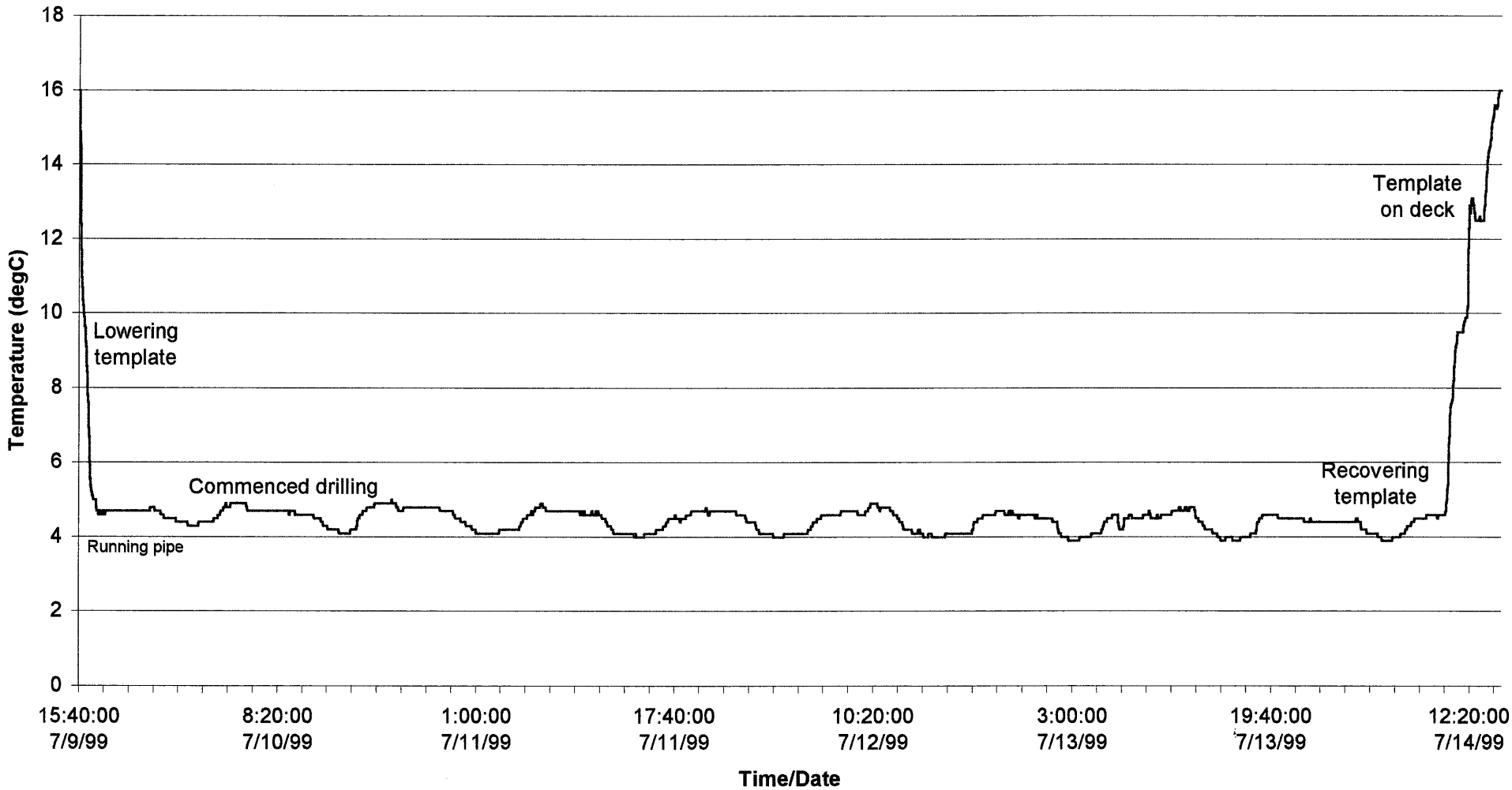
Temperature at Site 1 - 3m above Seabed



Temperature at Site 1A - 3m above Seabed



Temperature at Site 2 - 3m above Seabed



Temperature at Site 3A - 3m above Seabed