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# Comparison between in situ temperature measurements and NOAA/AVHRR based SSTs from SAF O&SI

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OCEANOGRAFISK TJENESTE

## Introduction

This report summarizes the results from the work performed under the Work Package 3 in the BOOS SST group. Participants in the SST group were: Claus Sølvesteen (RDANH, project coordinator), Adam Krężel (University of Gdansk, Poland) and Peter Löwe (BSH, Germany). The primary contents of the report is a comparison between calculated “subskin” SST values from Ocean & Sea Ice Satellite Application Facility and in situ temperature measurements.

The original goal of WP3 was to examine existing cloud-detection and SST algorithms in order to find the ones which were best suited for the Baltic region.

However, during the work of WP3, we became aware that another group had already done some work in this area for about 5 years, and we decided to examine the SST product from this group instead of trying to develop our own algorithms. Therefore, in November 2002 we decided to become beta testers on the Ocean & Sea Ice Satellite Application Facility (O&SI SAF) SST product.

The O&SI SAF was started in 1997 as cooperation between Eumetsat, Ifremer and the national meteorological services in Denmark, Norway, Sweden, the Netherlands and France. The O&SI SAF SST product covers several regions, including the Baltic area. This latter area is included in the so-called MNOR region. In the MNOR region daily SST images are produced on a 2 km resolution. Currently, SST data in this region are only produced from NOAA/AVHRR images. The production of SST images started on the 24<sup>th</sup> of June 2001. Until the 5<sup>th</sup> of November 2001, both NOAA 14 and NOAA 16 were used. Due to the failure of NOAA 14, only NOAA 16 was used during the period 05-11-2001 till 03-02-2003,. Since the 3<sup>rd</sup> of February 2003, both NOAA 16 and NOAA 17 have been used. For each satellite there are two daily products (morning and afternoon passes). Each SST image may be a composite of three NOAA/AVHRR images. More information about the SAF and its SST product can be found on several websites, for instance:

<http://www.osi-saf.org/index.php>

[http://www.meteorologie.eu.org/safo/gb\\_html\\_sst/sst\\_reg.html](http://www.meteorologie.eu.org/safo/gb_html_sst/sst_reg.html)

[http://www.meteorologie.eu.org/safo/gb\\_html\\_sst/regional/regsst\\_manual.pdf](http://www.meteorologie.eu.org/safo/gb_html_sst/regional/regsst_manual.pdf)

The purpose of the beta tester project was to compare in situ measured sea surface temperatures with satellite calculated SSTs. If the O&SI SAF product turned out to be convincing, the BOOS SST group might decide to base its daily Internet presented SST maps on the SAFOSI calculations.

The SST data may be downloaded freely from the ftp site:

<ftp://ftp.ifremer.fr/pub/ifremer/cersat/SAFOSI/Products/NARSST/>

The products of interest are file names that include the letters “mnor”.

The images are in hdf 4.0 format (actually, hdf-eos grid format), implying that some effort must be done in order to read and interpret data. However, some high level languages like IDL and MATLAB have routines to read this format.

## Dataset

In order to do the comparison, all the institutions involved in the BOOS SST working group were asked to collect and deliver in situ measurements from their respective countries from the period summer 2001 till end of 2002. Since the first version of this report (from May 2003), several new measurements have been delivered, implying that the results of this report are based on a significantly higher amount of data. Apart from Latvia and Estonia, all BOOS members have contributed with data, some of which are from 2003.

Though NOAA 14 was used for SST products during the first months of the O&SI SAF product, we have omitted to perform an analysis of these data since NOAA 14 has now been cancelled. Furthermore, NOAA 17 data (starting February 3<sup>rd</sup>, 2003) and covering only a short period of data have been excluded. So only NOAA 16 based SST products have been analysed.

The nominal acquisition times of the NOAA 16 based SST products are 2 UTC (night scenes) and 12 UTC (day scenes). However, since three satellite scenes may be included in each product, the SST grid points may have time stamps that deviate significantly from these times.

In order to compare in situ temperatures with the SST product we have chosen the following time window: in situ data measured between 22 UTC (the previous day) and 6 UTC can be compared with night scene SSTs, and data measured between 10 UTC and 14 UTC can be compared with day scene SSTs. The reason for the difference in time windows for day and night is that surface temperatures are more constant during the night than during the day.

For the analysis 373131 in situ measurements have been collected for the period June 24<sup>th</sup> 2001 till August 2<sup>nd</sup> 2003.<sup>1</sup> In the previous version of this report we omitted data without indication of depth. However, since the data analysis concluded that the difference between in situ temperatures and SST measurements were approximately the same for depths between 0 and 4 meters, we have decided to include “depth-less” measurements in this report. “Depth-less” data comprise data marked with “gts”, “dbs” and “tsg” and are all delivered via BSH in Germany. Peter Löwe from BSH describes them as “SST-measurements”, so we assume that the measurements are taken “near the surface”. 135146 (i.e. 36.2 %) of the total number of measurements are without indication of depth.

72199 of the 373131 observations lie within the day time window, and 131621 of the observations lie within the night time window. 14657 of the day time observations and 27038 of the night time observations are related to grid points which have valid satellite based SST data. Finally, the 14657 day time observations and the 27038 night time observations may be further reduced if we only consider the in situ measurements from a given grid point which are closest in time to the SST measurement. Performing such a reduction, we end up with 5262 day time observations and 6696 night time observations. Accordingly, the original 373131 observations have been reduced by 96.8 % to 11958 observations. 4361 (36.5 %) of these observations are without indication of depth. These figures indicate the necessity to have a large amount of in situ observations in order just to obtain a useful set of observations to compare with SST data.

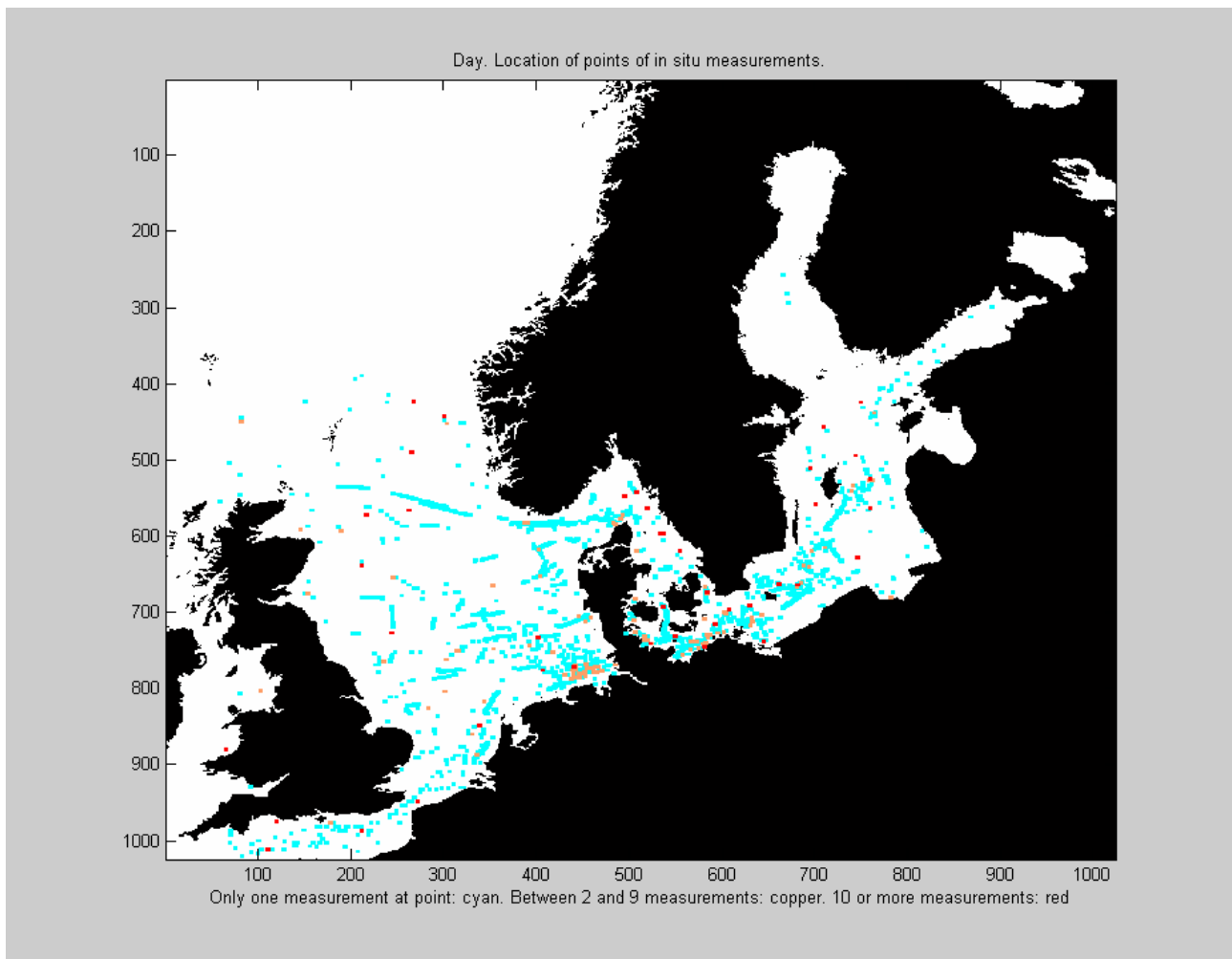
To sum up, each of the 11958 observations fulfils the criteria:

- It lies within the day time or the night time window (i.e. it is observed either between 10 and 14 UTC or between 22 and 6 UTC).
- The SST grid point which is closest to the in situ measurement contains a valid SST measurement for the relevant time.
- In case, for a grid point with a valid SST value, several in situ measurements have been obtained within the time window (i.e. the measurements are part of a time series), then only the measurement which is closest in time to the time of the SST grid point has been included in the analysis.

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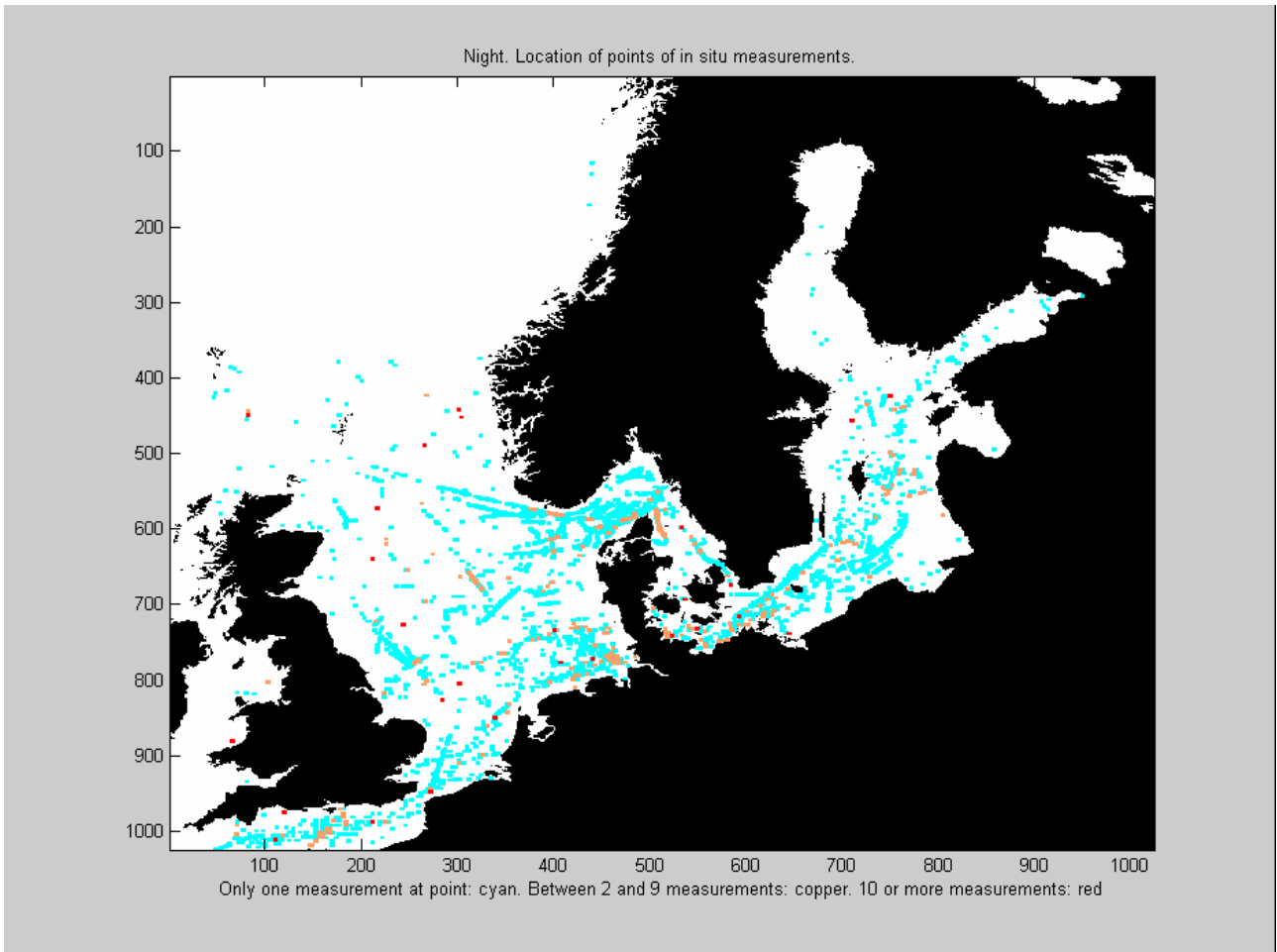
<sup>1</sup> If, for a given location and time, several measurements have been made at different depths, we have chosen that valid measurement which is closest to the surface.

The location of the 5262 day time and 6696 night time observations can be seen at the following figures:



**Figure 1a.** Location of daytime in situ measurements.

Colour code: Only one measurement at the location: cyan. Between 2 and 9 measurements: copper. 10 or more measurements: red. The red dots represent among others the 7 stations from the Marnet dataset.



**Figure 1b.** Location of nighttime in situ measurements.  
Colour code: As figure 1a.

## Data Analysis

During the initial analysis it turned out that a few in situ measurements were significantly different from the corresponding satellite SSTs. In order to avoid a misleading influence of erroneous measurements, we have chosen to eliminate in situ measurements that deviated more than 4K from the SST values. This elimination implies that the number of used in situ measurements reduces from 5262 to 4826 (day), and from 6696 to 6609 (night).

For different depths we have compared the calculated satellite based SST values with the corresponding in situ measurements and the following table can be made for the 4826 daytime data:

Depth (m)	Mean value of 'in situ – SST' (K)	Std. of 'in situ – SST' (K)	Number of observations
0	-0.07	0.74	612
1	0.08	0.70	134
2	0.14	0.86	293
3	-0.05	0.69	304
4	-0.09	0.76	1025
5	-0.37	0.93	60
6	-0.13	0.92	177
7	-1.25	1.08	17
8	-0.46	0.95	67
> 8 m	-0.53	1.57	417
Unknown	0.12	0.81	1720
<b>Total</b>	<b>-0.06</b>	<b>0.91</b>	<b>4826</b>

**Table 1:** Daytime data.

And a similar table for the 6609 nighttime data:

Depth (m)	Mean value of 'in situ – SST' (K)	Std. of 'in situ – SST' (K)	Number of observations
0	0.26	0.81	832
1	0.18	0.36	120
2	0.17	0.57	329
3	0.20	0.47	329
4	0.18	0.53	1900
5	0.06	0.27	28
6	0.19	0.65	189
7	-0.41	0.76	16
8	0.05	0.68	72
> 8 m	-0.17	1.22	218
Unknown	0.29	0.69	2576
<b>Total</b>	<b>0.22</b>	<b>0.68</b>	<b>6609</b>

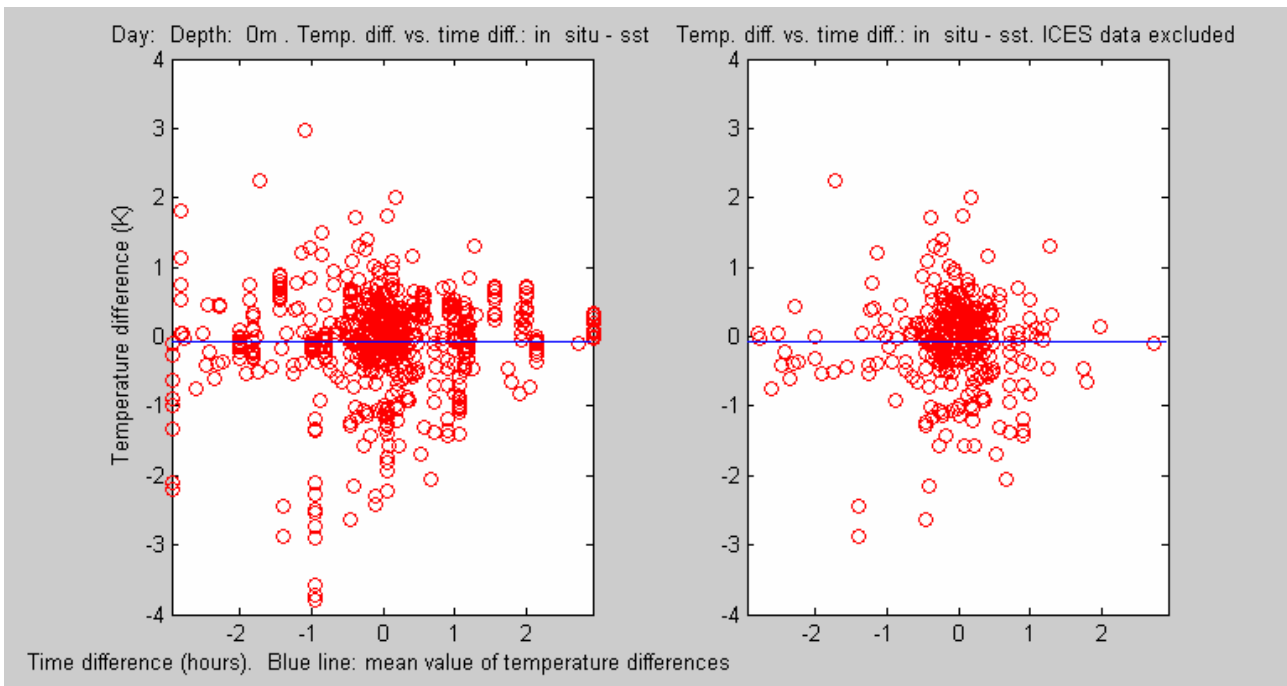
**Table 2:** Nighttime data.

From these tables several conclusions may be drawn:

- If a “success criterion” for the SST product is that in situ measurements are close to the calculated (“subskin”) SSTs, then the absolute value of the mean value of the difference ‘in situ – SST’ as well as the corresponding standard deviation should be as small as possible. It is seen that for the upper five-six meters, acceptable mean values and standard deviations are obtained. It seems a bit surprising that the best results are obtained from in situ measurements from a depth of 3 meters (for daytime images) and from 5 meters (for nighttime images) - and not from 0 meters depth.
- In spite of the fact that the diurnal warming effect is much smaller for night time images than for daytime images, the mean values for nighttime differences are slightly higher than the mean values for daytime differences. The standard deviation is slightly lower for daytime images at 0 meters depths compared to nighttime images, while for depths between 1 and 6 meters the daytime std.s are higher than the nighttime std.s.
- It might be assumed that the reason for the poor nighttime result compared to the daytime result is that the time window is larger for nighttime data. However, if we look at the behaviour of mean values as a function of time distance from in situ measurements to SST measurements, then there is no indication that the mean values should become worse when the time distance increases.

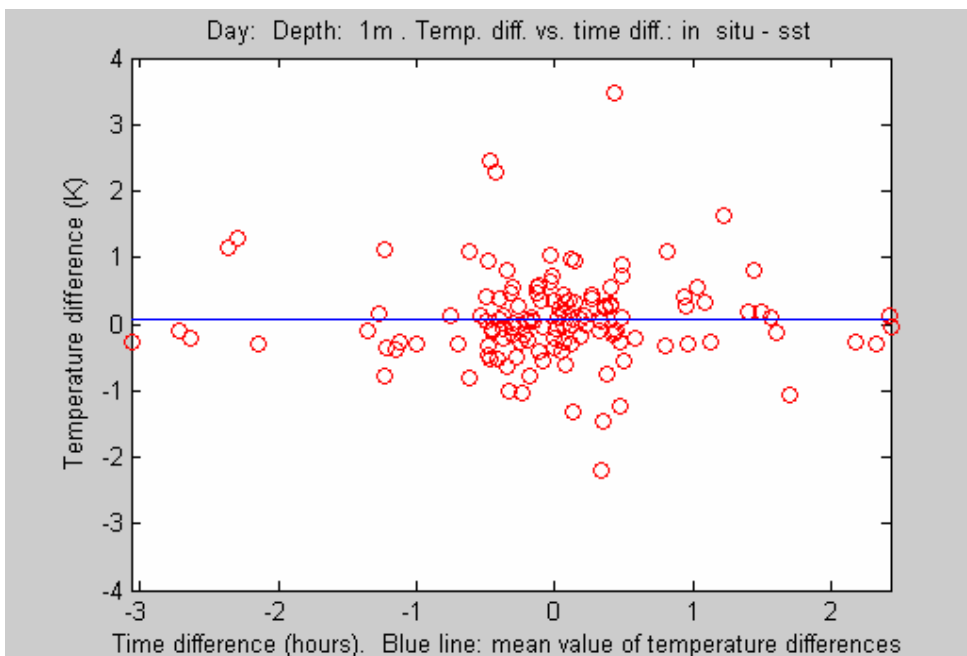
The following figures show for different depths the distribution of temperature differences (in situ – SST) as a function of time differences (in situ measurement time – SST time). The blue lines show the mean value of the temperature differences (identical to the ones found in tables 1 and 2).

At the Riga meeting it was suggested to exclude ICES data from the observations, since they are often of a poor quality. 305 of the 4826 daytime observations come from the ICES dataset, and 291 of these are obtained at 0 meters depth. 589 of the 6609 nighttime observations come from the ICES dataset, and 568 of these are obtained at 0 meters depth. We have therefore displayed the situation at 0 meters depth with and without ICES data.

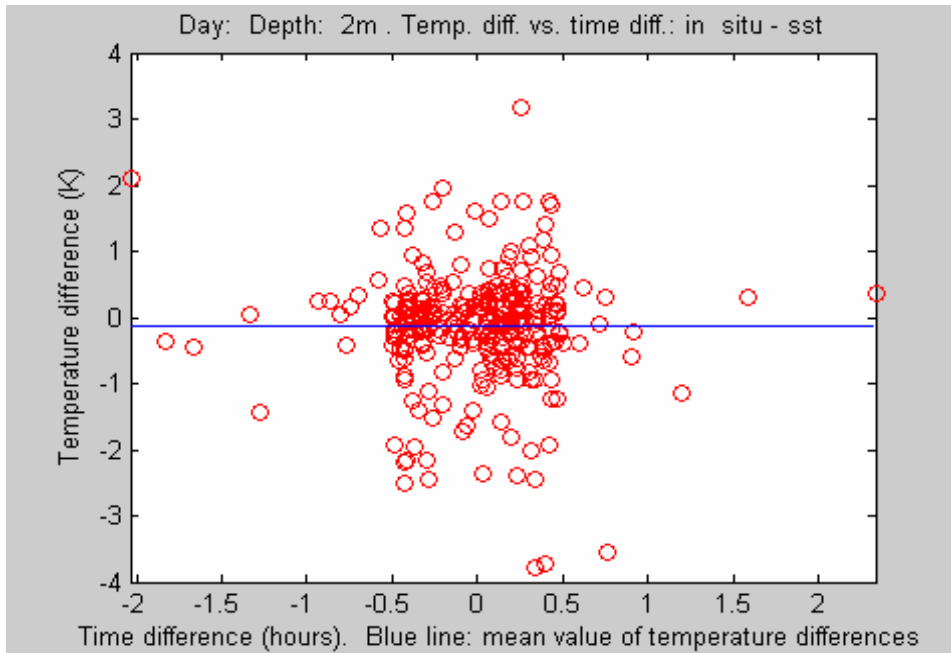


**Figure 2a.**

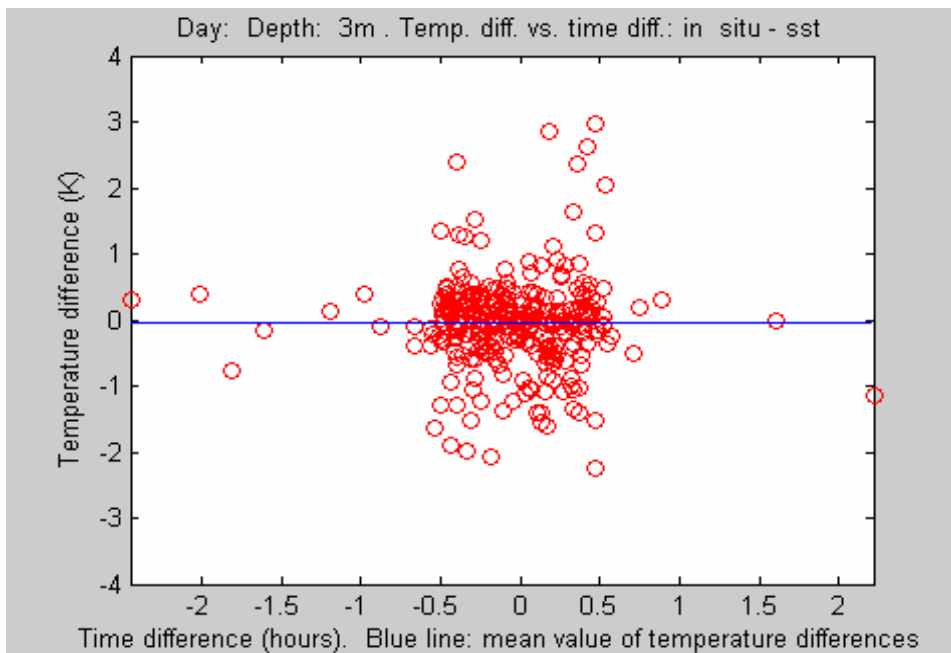
Left: All data with depth 0 meters (612 observations). Right: Data with depth 0 meters, without ICES data (321 observations). (Mean, std) changes from (-0.07 K, 0.74 K) to (-0.06 K, 0.65 K) with exclusion of ICES data. (Mean, std) of the ICES data is (-0.09 K, 0.83 K).



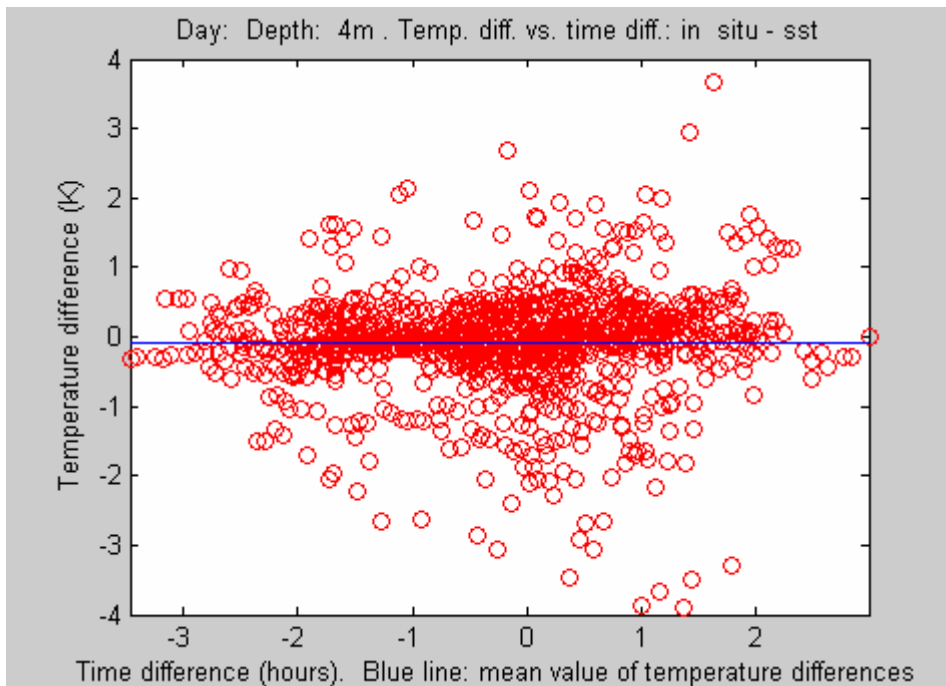
**Figure 2b.** All data with depth 1 meter (134 observations – 5 are ICES observations). (Mean, std) = (0.08 K, 0.70 K).



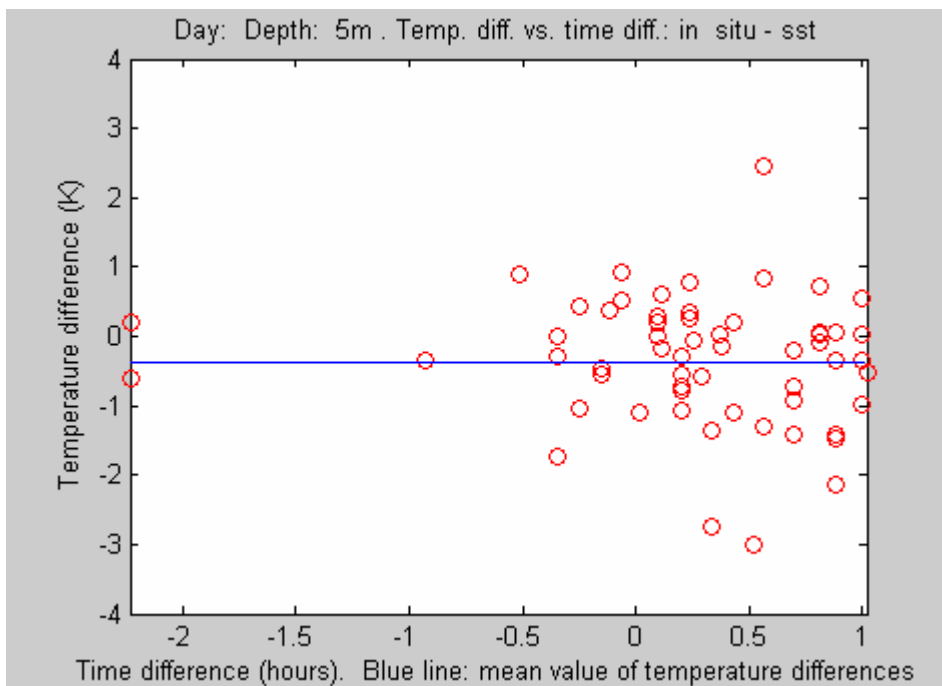
**Figure 2c.** All data with depth 2 meters ( 293 observations – 4 are ICES observations). (Mean, std) = (-0.14 K, 0.86 K).



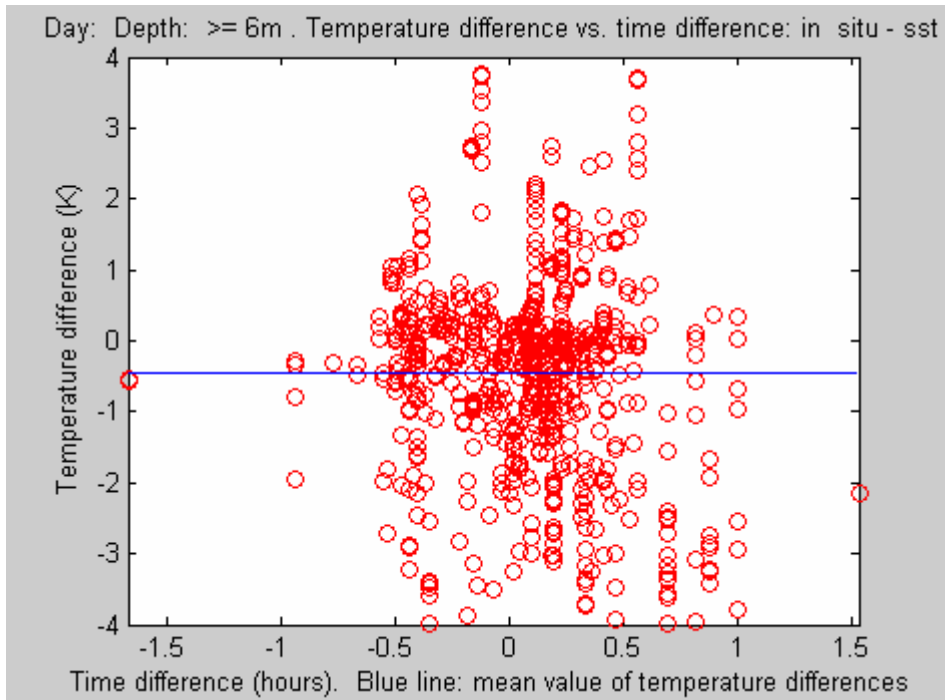
**Figure 2d.** All data with depth 3 meters ( 304 observations – 2 are ICES observations). (Mean, std) = (-0.05 K, 0.69 K).



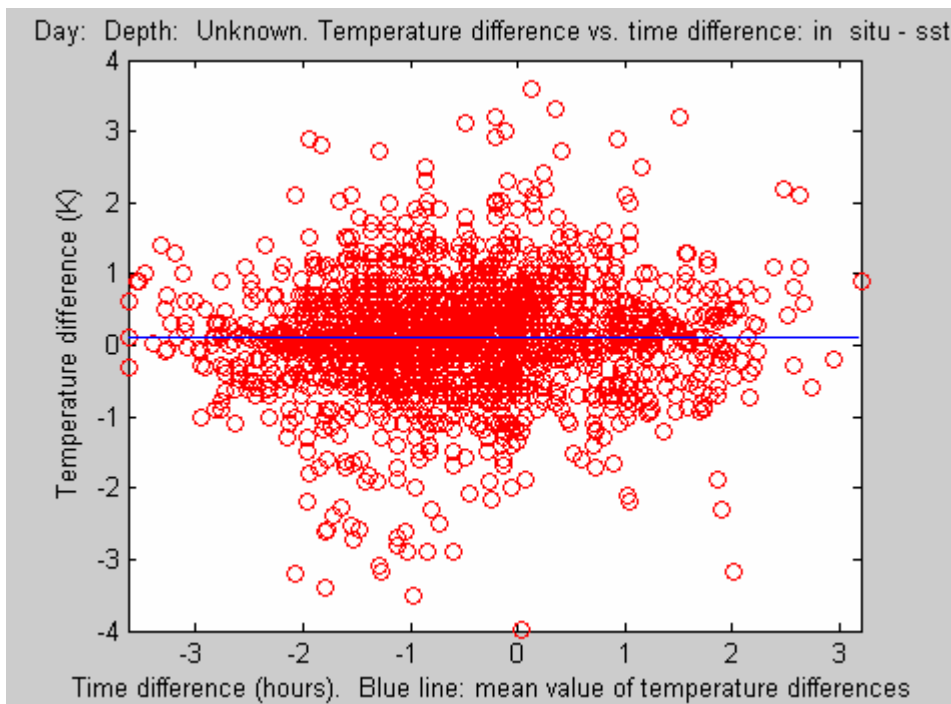
**Figure 2e.** All data with depth 4 meters ( 1025 observations – 2 are ICES observations). (Mean, std) = (-0.09 K, 0.76 K).



**Figure 2f.** All data with depth 5 meters ( 60 observations – 1 is an ICES observation). (Mean, std) = (-0.37 K, 0.93 K).

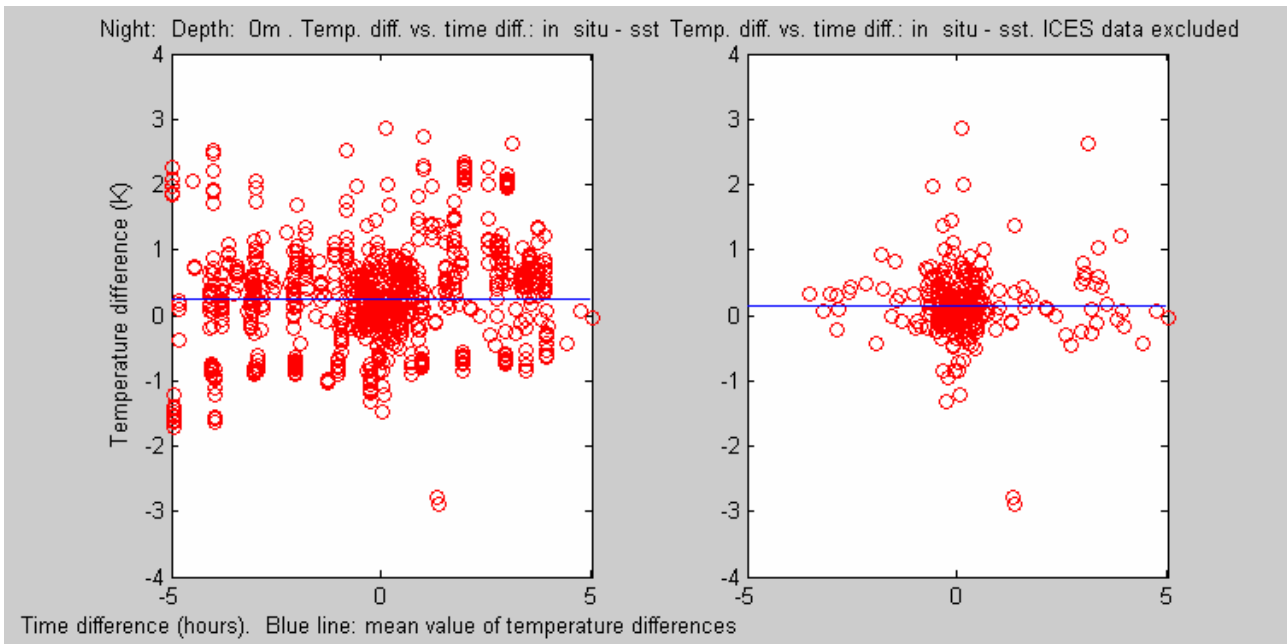


**Figure 2g.** All data with depth more than 5 meters ( 678 observations – 0 are ICES observations).  
 (Mean, std) = (-0.44 K, 1.38 K).



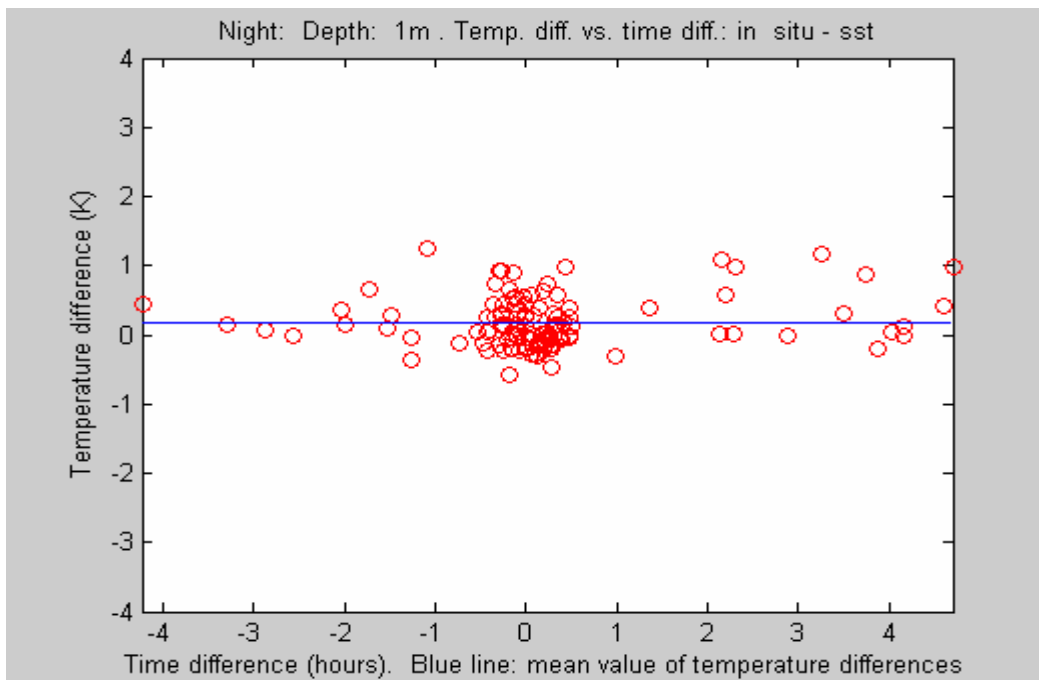
**Figure 2h.** All data with unknown depth ( 1720 observations – 0 are ICES observations).  
 (Mean, std) = (0.12 K, 0.81K).

Similar figures can be made for the night time images:

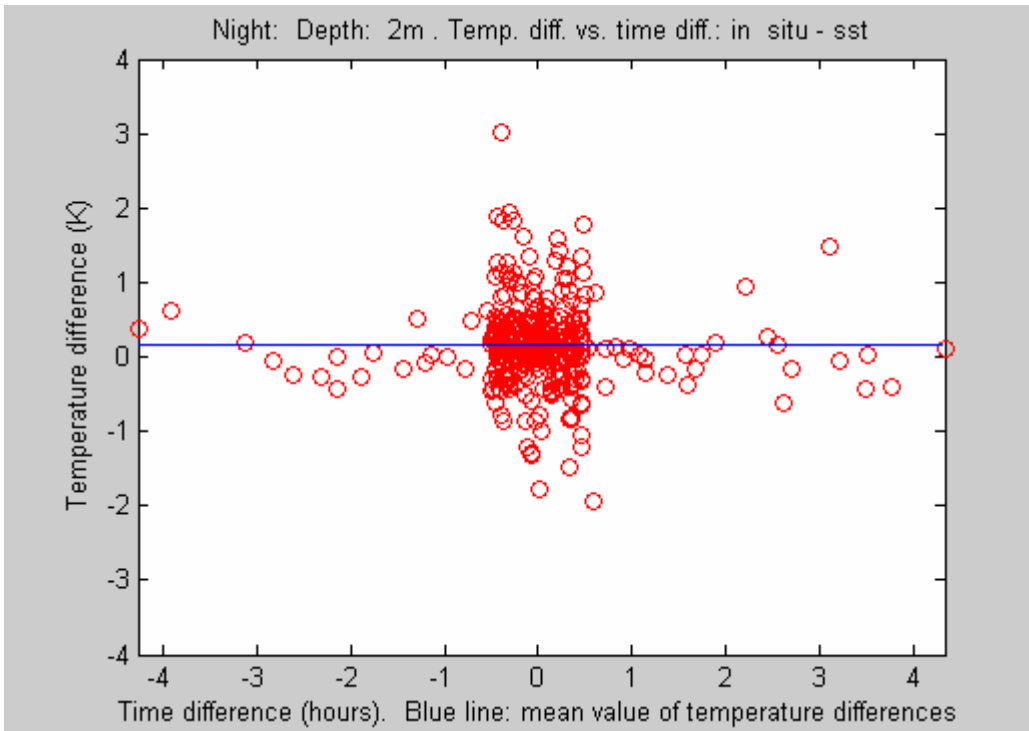


**Figure 3a**

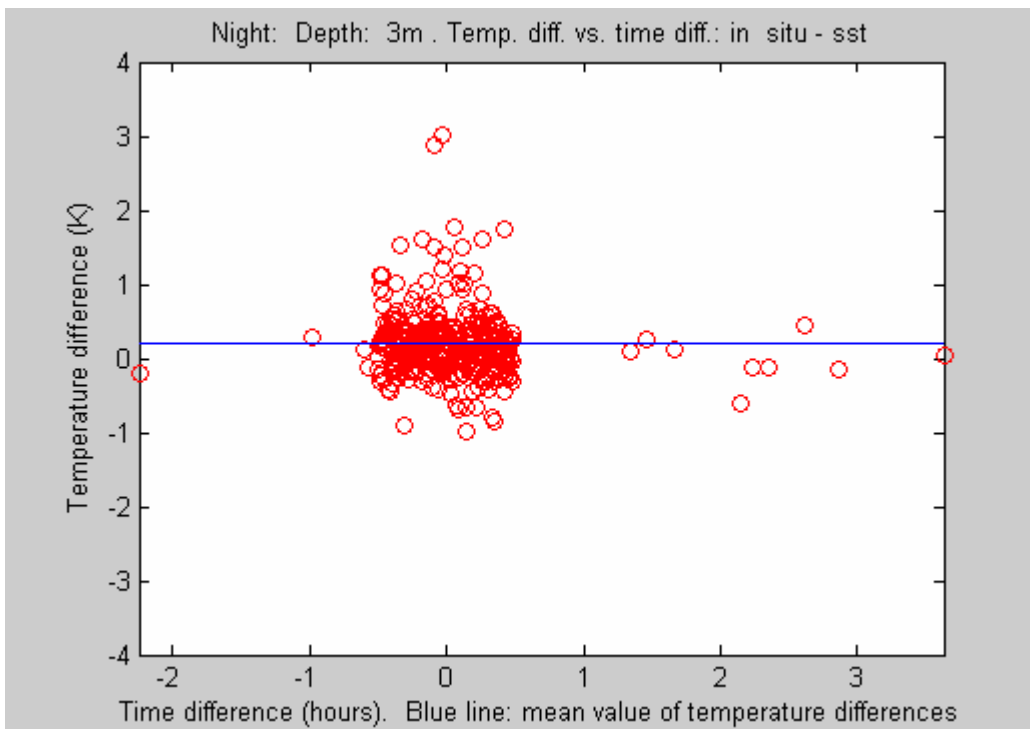
Left: All data with depth 0 meters (832 observations). Right: Data with depth 0 meters, without ICES data (264 observations). (Mean, std) changes from (0.26 K, 0.81 K) to (0.15 K, 0.55 K) with exclusion of ICES data. (Mean, std) of the ICES data is (0.31 K, 0.90 K).



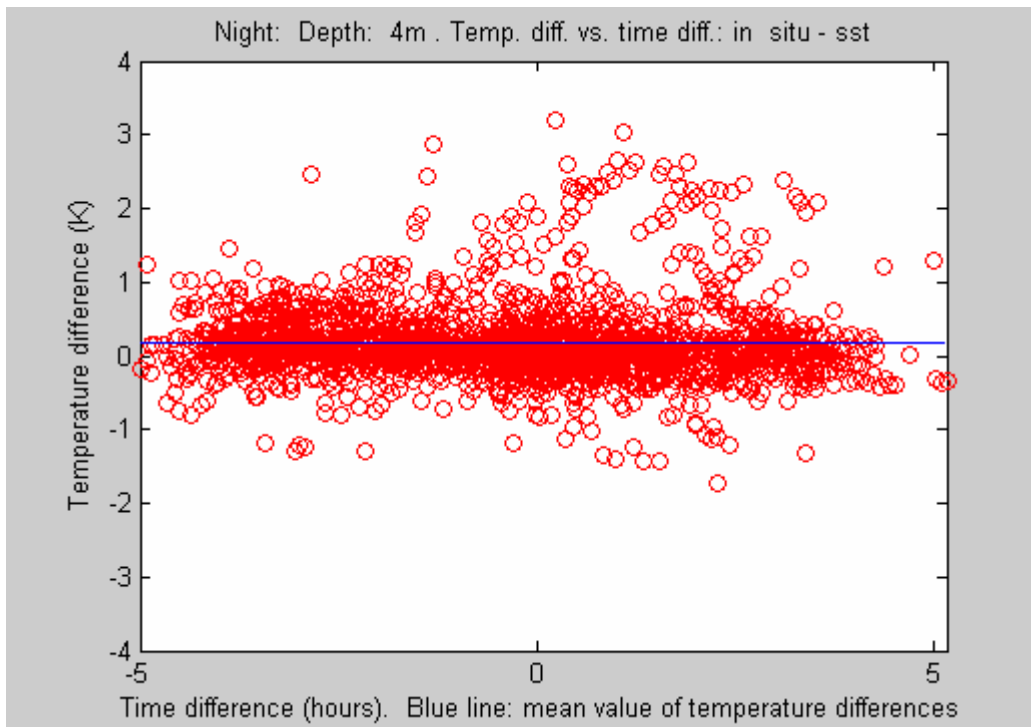
**Figure 3b.** All data with depth 1 meter (120 observations – 6 are ICES observations). (Mean, std) = (0.18 K, 0.36 K).



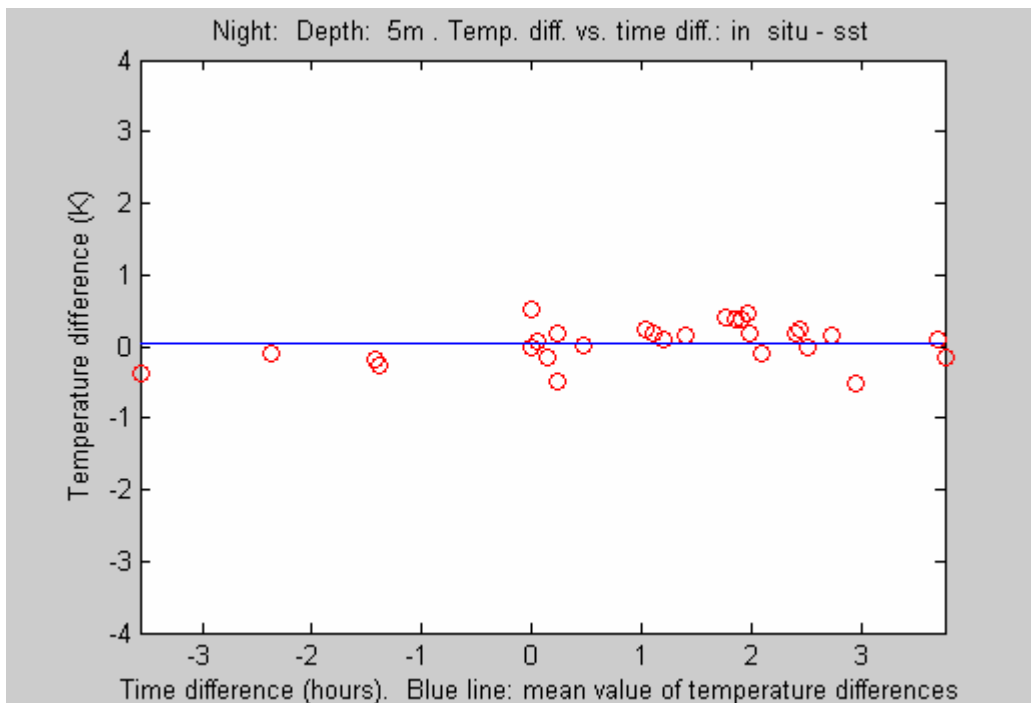
**Figure 3c.** All data with depth 2 meters ( 329 observations – 5 are ICES observations). (Mean, std) = (0.17 K, 0.57 K).



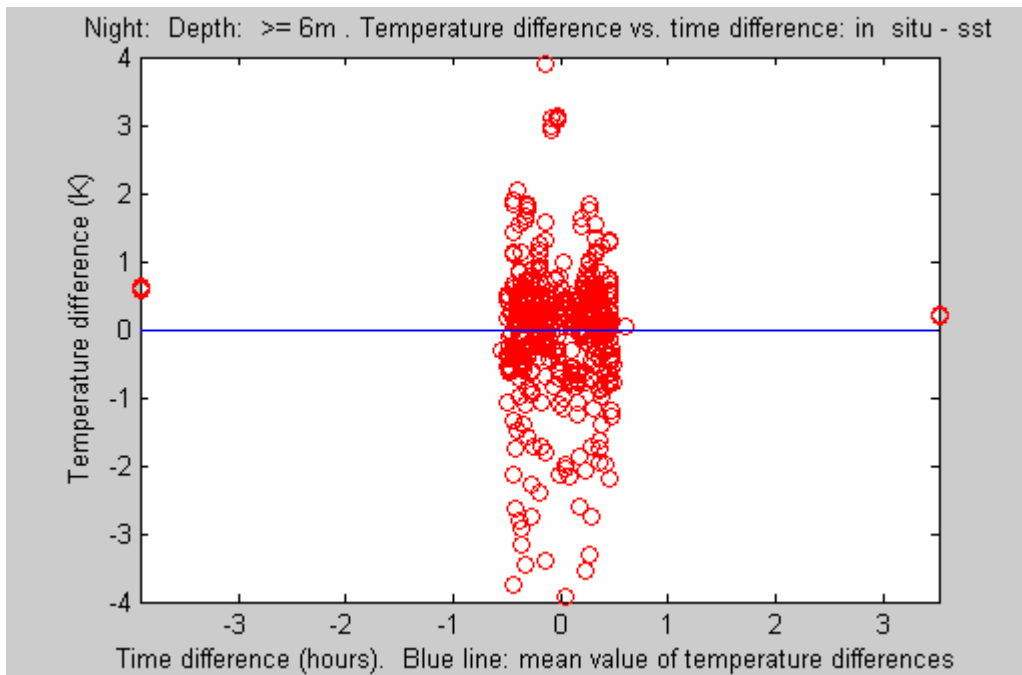
**Figure 3d.** All data with depth 3 meters ( 329 observations – 2 are ICES observations). (Mean, std) = (0.20 K, 0.47 K).



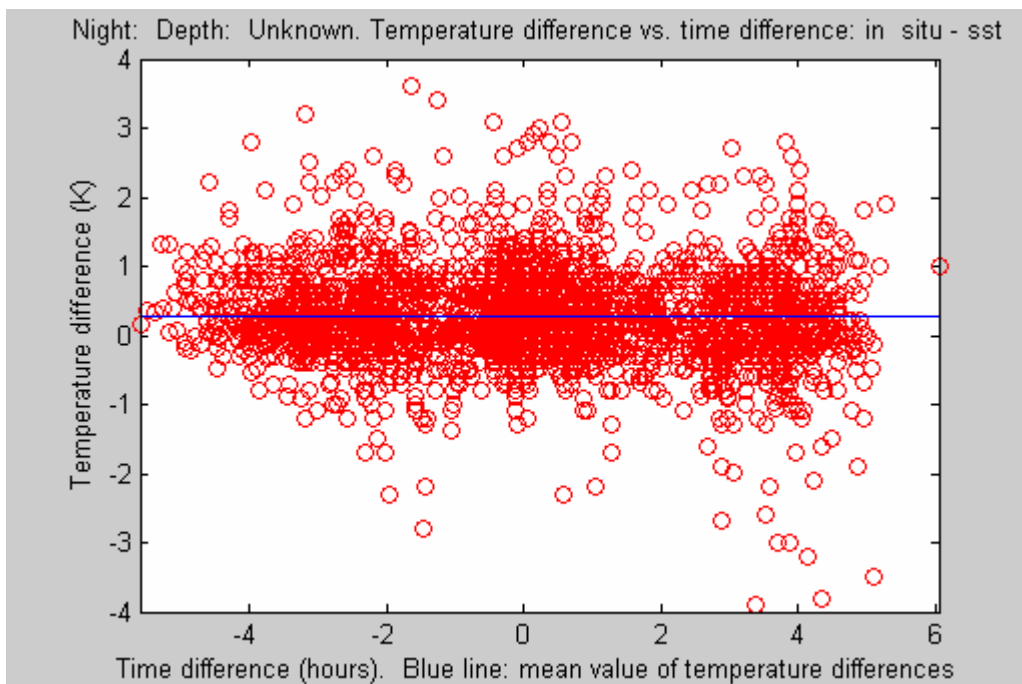
**Figure 3e.** All data with depth 4 meters ( 1900 observations – 8 are ICES observations).  
 (Mean, std) = (0.18 K, 0.53 K).



**Figure 3f.** All data with depth 5 meters ( 28 observations – 0 are ICES observations).  
 (Mean, std) = (0.06 K, 0.27K).



**Figure 3g.** All data with depth more than 5 meters ( 495 observations – 0 are ICES observations). (Mean, std) = (-0.01 K, 0.97 K).



**Figure 3h.** All data with unknown depth ( 2576 observations – 0 are ICES observations). (Mean, std) = (0.29 K, 0.69K).

It is clear from figures 2 and 3 that there is no correlation between time differences and temperature differences. This fact indicates that the time windows are reasonable (or at least not too large).

Furthermore, in situ measurements from depths 0 to 5 meters are slightly closer to the SST values than measurements taken at a higher depth and measurements with unknown depth. Results from “unknown depth data”, however, tend to give similar results as “0 meters depth data”.

Exclusion of ICES data for 0 meters depth seems to improve the results. This result, however, has not been found for other depths (on the contrary, exclusion of ICES data increases the absolute value of the mean value). This implies that the ICES data are not generally wrong, but that there may be a small problem with the ICES dataset called “26NA”. However, this problem does not seem to be significantly worse than for other stations (see tables 3 and 4 below), and at least for the daytime “26NA” data the mean value is actually close to 0K. Consequently, there is no argument to exclude ICES data from the analysis.

In order to further examine whether some stations are more reliable than others the following two tables are produced (for day and night, respectively). The tables give information about points with at least three measurements with known depth or with at least 40 measurements with unknown depth. The tables below show mean values and standard deviations of temperature differences for depths between 0 and 7 meters and for unknown depths (-99 m).

Station name	Depth (m)	Mean of in situ –sst (K)	Std of in situ – sst (K)	Number of observations
Marnet Kiel Lighthouse	0	0.238	0.699	87
Danish SKA15	0	-0.316	0.873	17
Danish SKA16	0	-0.049	0.765	14
Finnish Pohj	0	0.239	0.419	101
ICES 26NA	0	-0.081	0.838	284
Danish FLYV	0	0.035	0.226	6
Polish IOPAN	0	0.013	0.092	8
Danish DMU data	0	0.063	0.797	19
Polish PAP	0	-0.410	0.261	10
Swedish P2	0	0.027	0.604	6
Swedish By20	0	-0.423	0.707	4
Danish Anholt	0	-0.567	0.730	4
Swedish Fladen	0	-0.428	0.929	4
Swedish By10	0	-0.444	0.613	5
Swedish By32	0	0.272	0.454	4
Swedish Aa13	0	0.117	0.334	4
Swedish Aa17	0	0.017	0.315	3
Swedish By2	0	-0.180	0.985	3
Swedish Bcsiii10	0	-0.093	0.742	3
Swedish By5	0	-0.777	0.760	3
Marnet Fehmarn Belt Buoy	1	0.124	0.695	87
ICES 34ARENQ629G	1	-0.390	0.582	3
Danish DMU data	1	0.342	0.683	9
Danish O-1	1	0.025	0.846	10
Polish IOPAN	1	0.057	0.137	4
Polish IOPAS	1	0.093	0.510	4
tsp data Ei	1	-0.518	0.414	5
Swedish Huvudskaersbojen	2	-0.057	0.863	70
Swedish Laesoe Buoy	2	-0.307	0.790	65
ICES 74SCENQ716k	2	0.127	0.435	3
Delphin 3701001	2	-0.347	0.116	3
Marnet Darss Sill	2	0.053	0.827	84
Polish IOPAS	2	0.847	2.153	4
Danish Drogden	2	-0.401	0.850	57
Marnet Ems Lightship	3	0.084	0.621	73
Marnet Dbucht Lightship	3	-0.078	0.596	95
Marnet Fehmarn Belt Buoy	3	-0.314	0.595	18
Marnet Oder Bank Buoy	3	0.006	0.507	20
Danish W26	3	-0.058	0.886	88
Danish DANA	4	-0.066	0.747	935
Marnet North Sea Buoy	4	0.187	0.576	16
Danish Drogden	4	-0.380	0.936	67
Swedish P2	5	-0.132	1.403	6
Swedish By20	5	-0.558	0.833	4
Danish Anholt	5	-0.583	0.752	4
Swedish Fladen	5	-0.774	1.384	5
Swedish By10	5	-0.456	0.617	5

Swedish By32	5	0.252	0.440	4
Swedish Aa13	5	-0.266	1.576	5
Swedish By2	5	-0.193	0.973	3
Swedish Bcsiii10	5	-0.083	0.746	3
Swedish By5	5	-0.807	0.779	3
Marnet Dbucht Lightship	6	0.153	0.434	10
Marnet Ems Lightship	6	0.482	0.389	12
Danish W26	6	-0.047	0.931	88
Danish Drogden	6	-0.384	0.955	67
Marnet Darss Sill	7	-1.250	1.076	17
gts data DBBC	-99	-0.027	0.720	46
gts data 62101	-99	-0.057	0.925	45
gts data 62305	-99	-0.031	0.642	53
gts data 62103	-99	0.206	0.429	40
dbs data Y3CW	-99	0.200	0.857	66
gts data DBFO	-99	0.577	0.536	63
dbs data DBBA	-99	0.402	0.969	52
gts data 62301	-99	0.420	0.642	43
gts data 62304	-99	0.143	0.799	40
gts data DBJM	-99	0.116	0.761	45
gts data DBFR	-99	0.001	0.668	42
tsg data	-99	-0.265	0.642	325

**Table 3.** Day time data with information about each station/point with at least three measurements (or at least 40 measurements, if the depth is unknown). An unknown depth is put to -99. Depths known to be larger than 7 meters are not included. Data marked Marnet, tsp, gts, dbs, tsg and Delphin are delivered from BSH in Germany, but may also comprise data from other countries.

Station name	Depth (m)	Mean of in situ –sst (K)	Std of in situ – sst (K)	Number of observations
Marnet Kiel Lighthouse	0	0.110	0.529	86
Danish SKA15	0	0.604	0.199	7
Finnish Pohj	0	0.172	0.406	109
ICES 26NA	0	0.309	0.904	567
Danish FLYV	0	0.294	0.542	16
Polish IOPAN	0	0.179	0.262	26
Russian Centaurus	0	0.720	1.084	6
Russian Sibirjakov	0	-0.772	1.293	5
Marnet Fehmarn Belt Buoy	1	0.152	0.349	90
ICES 4ARENQ629G	1	0.300	0.485	3
ICES 74SCENQ716k	1	-0.117	0.235	3
Polish IOPAN	1	0.081	0.133	8
Polish IOPAS	1	0.520	0.603	3
Swedish Huvudskaersbojen	2	0.188	0.444	63
Swedish Laesoe Buoy	2	0.218	0.530	70
ICES 06WHENQ710j	2	0.197	0.673	3
Delphin 3702504	2	0.093	0.064	3
Marnet Darss Sill	2	0.234	0.710	95
Polish IOPAN	2	-0.189	0.196	31
Danish Drogden	2	0.167	0.618	60
Marnet Ems Lightship	3	0.218	0.450	70
Marnet Dbucht Lightship	3	0.211	0.366	106
Marnet Fehmarn Belt Buoy	3	0.231	0.528	15
Polish IOPAN	3	-0.245	0.194	6
Marnet Oder Bank Buoy	3	0.277	0.500	25
Danish W26	3	0.173	0.574	97
Danish DANA	4	0.182	0.529	1799
Marnet North Sea Buoy	4	0.443	0.735	9
ICES 74CZENQ512u	4	0.137	0.301	7
Danish Drogden	4	0.140	0.586	71
Delphin 370506	5	0.073	0.095	3
Delphin 370508	5	0.170	0.075	3
Delphin 370510	5	0.410	0.044	3
Delphin 3702902	5	0.103	0.178	3
Delphin 3702903	5	-0.123	0.347	3
Marnet Dbucht Lightship	6	0.088	0.270	5
Marnet Ems Lightship	6	0.302	0.274	15
Danish Drogden	6	0.140	0.637	71
Danish W26	6	0.217	0.724	97
Marnet Darss Sill	7	-0.414	0.758	16
gts data 62305	-99	0.169	0.649	50
gts data 62103	-99	0.191	0.389	53
gts data OVUN6	-99	0.160	0.485	47
dfs data Y3CW	-99	0.271	0.581	109
gts data DBFO	-99	0.644	0.483	88
gts data DBFM	-99	-0.107	0.404	42

gts data DBJM	-99	0.251	0.635	75
gts data DGNB	-99	0.850	0.372	40
dbs data SHIP	-99	0.401	0.767	54
gts data 62304	-99	0.167	0.461	40
dbs data DBJM	-99	0.260	0.577	46
gts data DBFR	-99	0.174	0.356	53
tsg data	-99	0.110	0.328	451

**Table 4.** Night time data with information about each station/point with at least three measurements (or at least 40 measurements, if the depth is unknown). An unknown depth is put to -99.

From tables 3 and 4 it can be seen that some measurements are “worse” than others, but it is difficult to identify a station/group of observations which 1) gives obviously wrong results, and 2) consists of a significant amount of data. Furthermore there is no clear evidence that ship measurements acquired at 0 meters depth should give poorer results (higher absolute mean values and/or higher standard deviations) than fixed stations.

Based on the considerations made so far, we will not exclude measurements from specific stations/observation sets, but we will exclude measurements with depths higher than 5 meters. Measurements with unknown depth will, however, be included since the results from those data look like the results from “0 meters data”.

For the rest of this report we shall therefore confine ourselves to in situ measurements either obtained at depths between 0 and 5 meters or being without indication of depth. This reduces the number of observations to 4148 (day) and 6114 (night). In this reduced set of observations, the mean value of temperature differences become 0.00 K (day) and 0.24 K (night), while the standard deviations become 0.79 K (day) and 0.64 K (night).

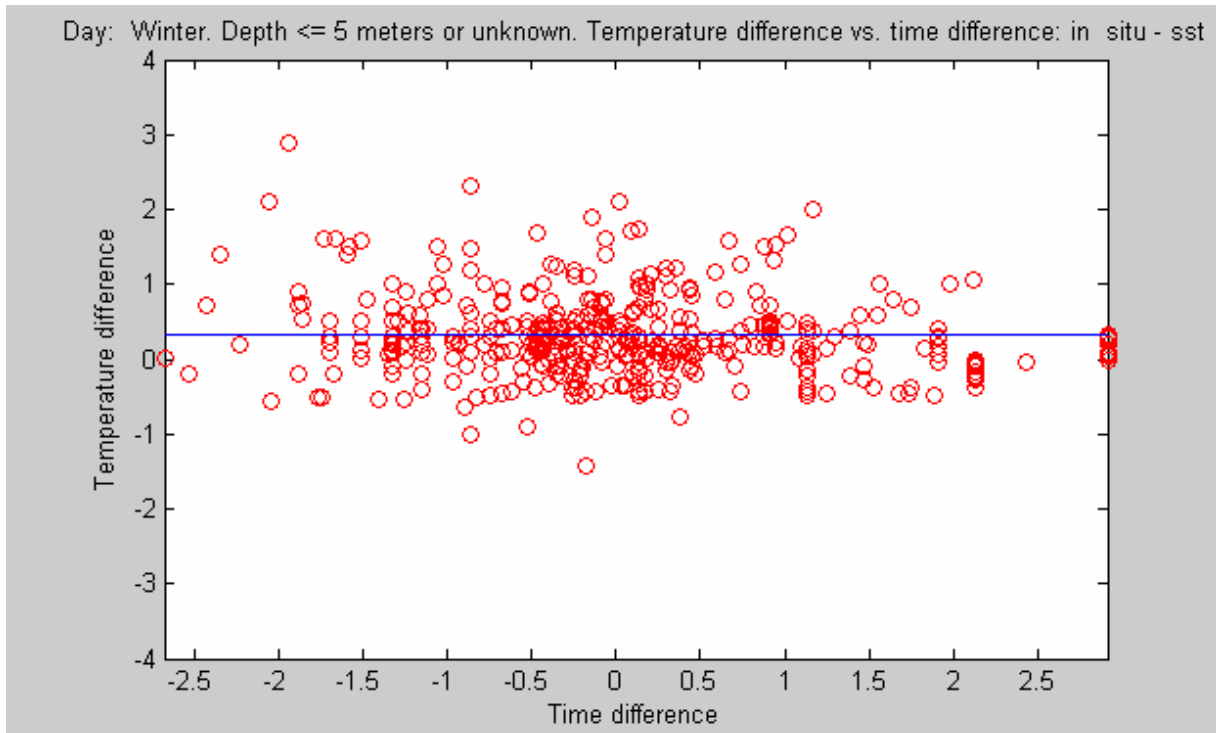
The O&SI SAF goals for mean values and standard deviations for the SST product is formulated in [http://www.meteorologie.eu.org/safo/gb\\_html\\_sst/regional/regsst\\_manual.pdf](http://www.meteorologie.eu.org/safo/gb_html_sst/regional/regsst_manual.pdf) ). Comparing our results with these goals it can be seen that 1) for the daytime data the standard deviation is a bit higher than the goal of 0.7 K, while there is no precisely formulated mean value goal for daytime data due to the diurnal warming problems, and 2) for nighttime data our results are slightly below the values set by O&SI SAF (mean values within +/- 0.4 K and standard deviations below 0.7 K. So generally the goals of O&SI SAF seem to be reached for the MNOR region.

## Seasonal variations

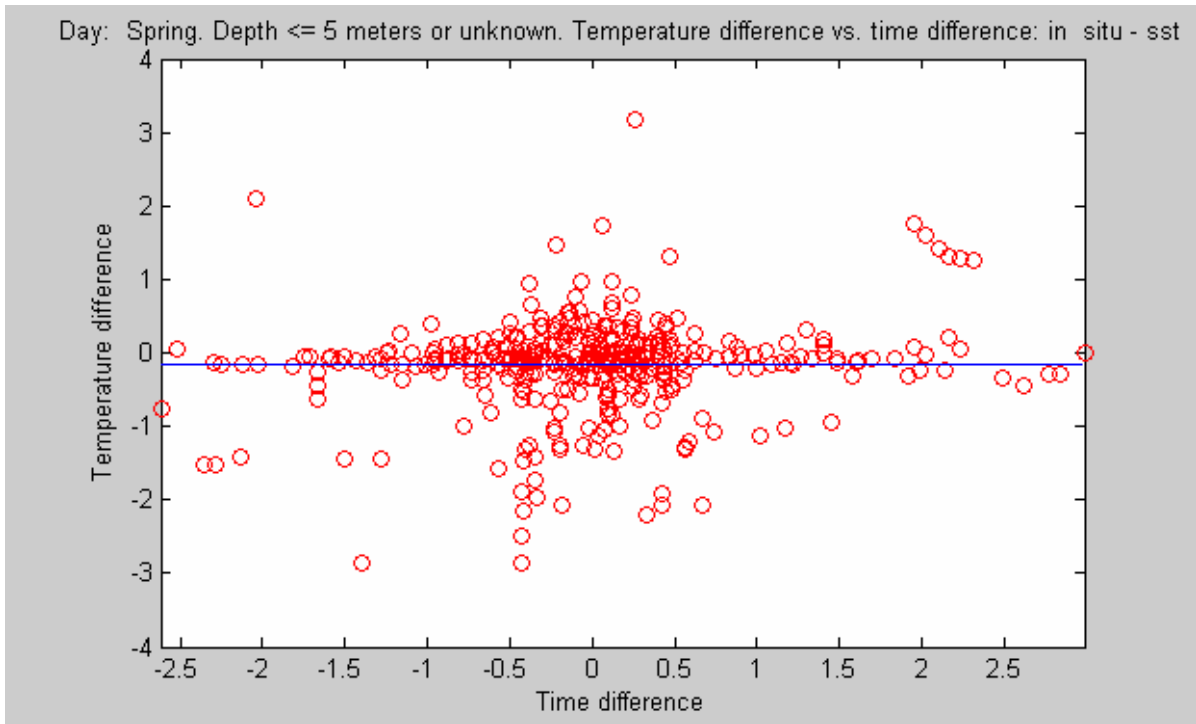
The next step will be to examine whether there are different results depending on the month or season of acquisition.

First we have separated the dataset into seasons: winter (December, January, February), spring (March, April, May), summer (June, July, August), and autumn (September, October, November).

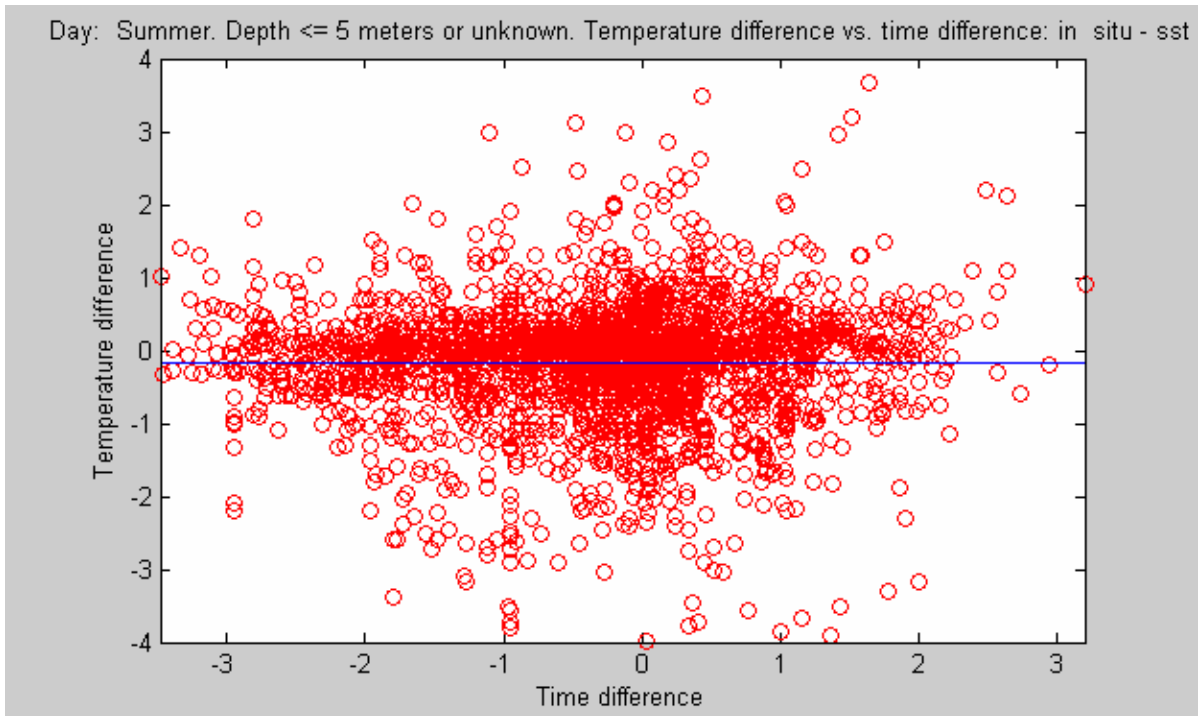
The horizontal blue lines in figures 4-7 represent the mean value for all measurements for the given season and time of day.



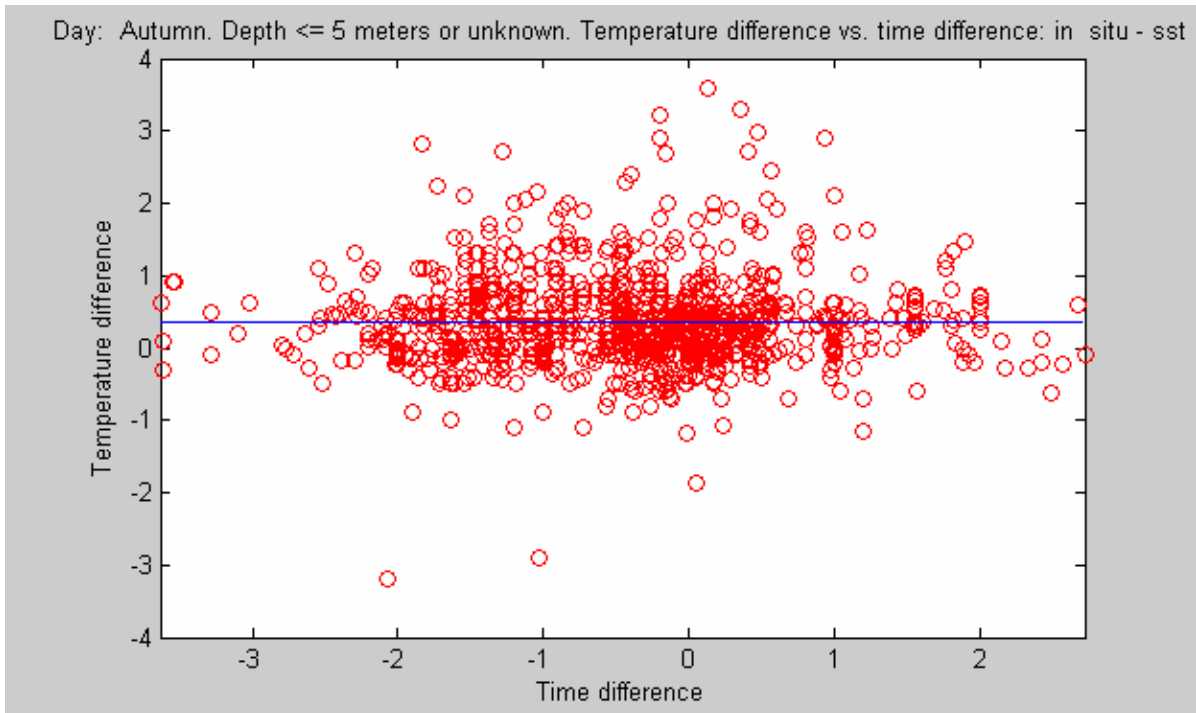
**Figure 4a.** Day. Winter. 422 observations. Mean value of 'in situ - SST': 0.32 K. Std. = 0.54 K.



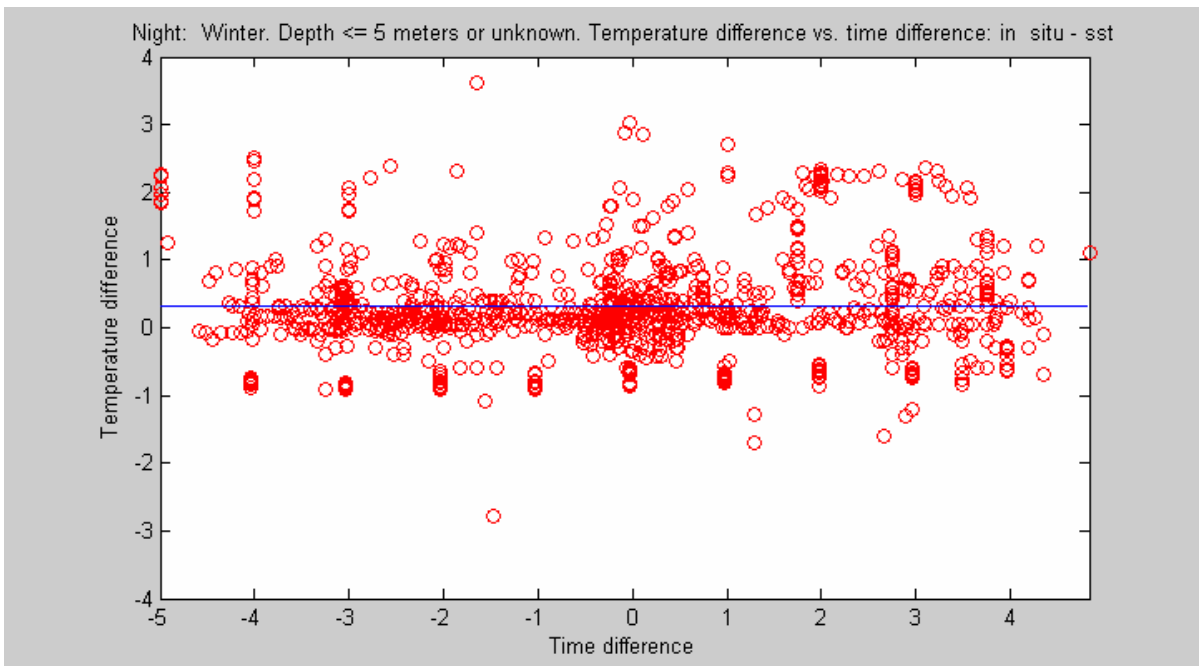
**Figure 4b.** Day. Spring. 367 observations. Mean value of 'in situ – SST': -0.16 K. Std. = 0.66 K.



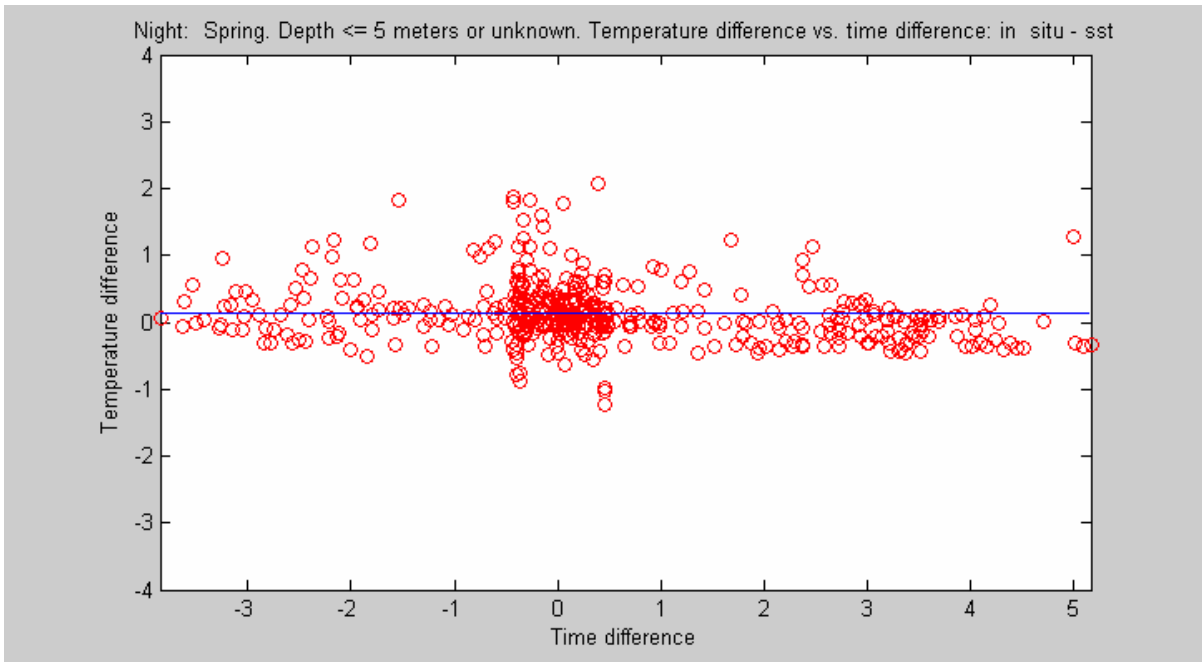
**Figure 4c.** Day. Summer. 2395 observations. Mean value of 'in situ – SST': -0.18 K. Std. = 0.84 K.



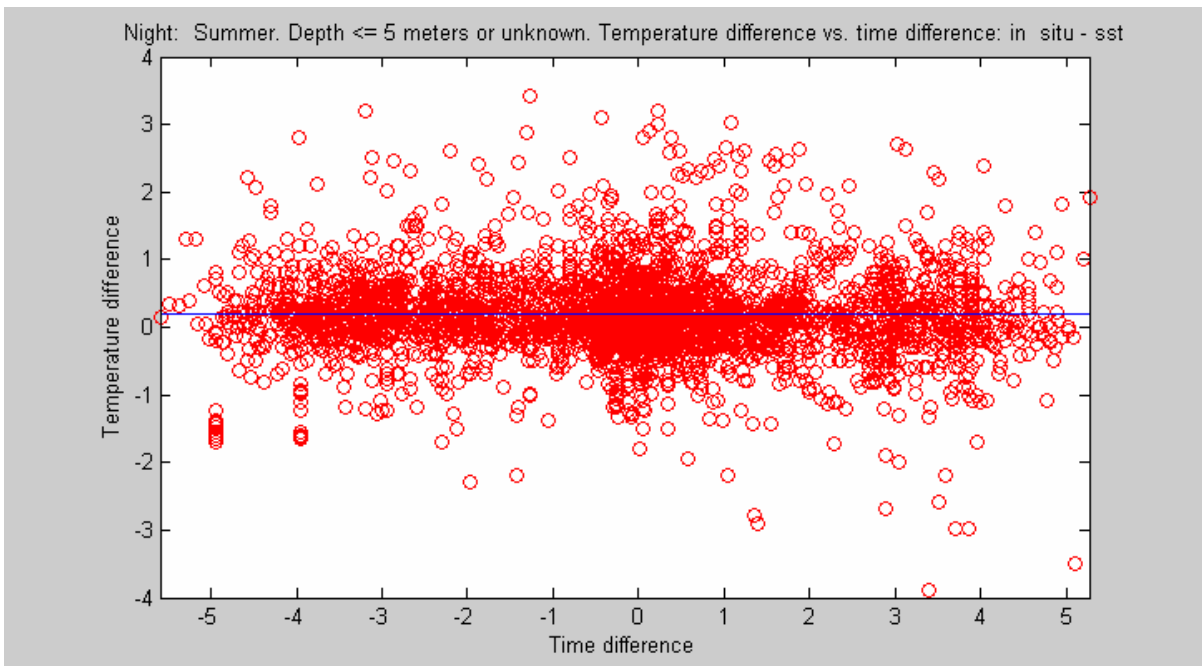
**Figure 4d.** Day. Autumn. 964 observations. Mean value of ‘in situ – SST’: 0.37 K. Std. = 0.63 K.



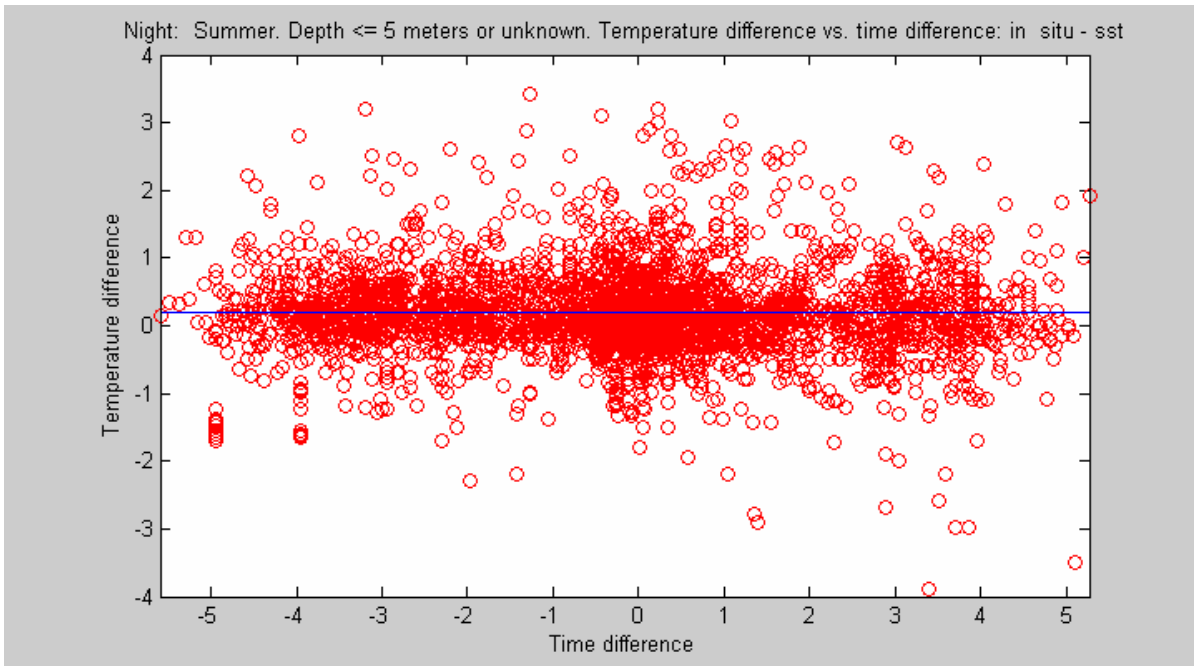
**Figure 5a.** Night. Winter. 1010 observations. Mean value of ‘in situ – SST’: 0.32 K. Std. = 0.74 K.



**Figure 5b.** Night. Spring. 430 observations. Mean value of ‘in situ – SST’: 0.13 K. Std. = 0.45 K.



**Figure 5c.** Night. Summer. 3304 observations. Mean value of ‘in situ – SST’: 0.18 K. Std. = 0.65 K.



**Figure 5d.** Night. Autumn. 1370 observations. Mean value of ‘in situ – SST’: 0.33 K. Std. = 0.59 K.

From figures 4 and 5 the following remarks can be made:

First of all it is seen that for day and night and for all the four seasons there is still no correlation between time and temperature differences.

Secondly there are some differences between the seasons. Generally there are higher absolute mean values at winter/autumn than at spring/summer. For daytime observations the mean values are positive at winter/autumn and negative at spring/summer. Positive mean values indicate that the in situ measurements are higher than the SST values, while negative mean values are due to high SST values compared with the in situ measurements. The seasonal variations will be examined further below for different in situ measurement sources.

One might assume that the reason for the variations does not lie in the SST calculations, but in the in situ measurements. In order to examine this assumption we will look at some of the fixed stations which contribute the most to the dataset. These stations are all part of the Marnet dataset from BSH, Germany.

The stations are:

Kiel Lighthouse:	latitude = 54.5000 N, longitude = 10.2667 E
Darss Sill:	latitude = 54.7000 N, longitude = 12.7000 E
Dbucht Lightship:	latitude = 54.1667 N, longitude = 7.4500 E
Ems Lightship:	latitude = 54.1667 N, longitude = 6.3500 E
Fehmarn Belt Buoy:	latitude = 54.6000 N, longitude = 11.1500 E

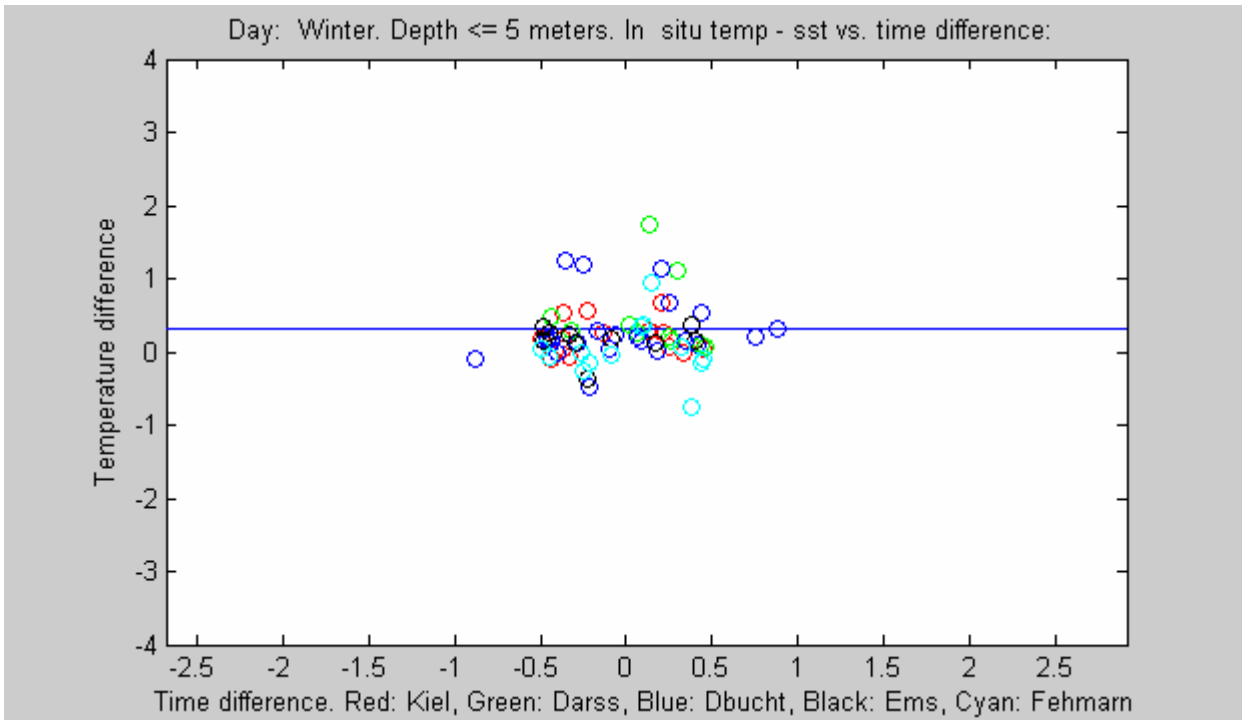
The number of observations between 0 and 5 meters depth is, for each station and for day and night, respectively:

Kiel Lighthouse:	87 observations (day), 86 observations (night)
Darss Sill:	86 observations (day), 95 observations (night)
Dbucht Lightship:	95 observations (day), 106 observations (night)
Ems Lightship:	73 observations (day), 70 observations (night)
Fehmarn Belt Buoy:	105 observations (day), 105 observations (night)

We shall also examine the influence of the ICES measurements. The number of ICES observations between 0 and 5 meters depth are: 305 observations (day), 589 observations (night).

And finally, we shall examine the influence of measurements with unknown depth. The numbers of such observations are: 1720 observations (day), 2576 observations (night).

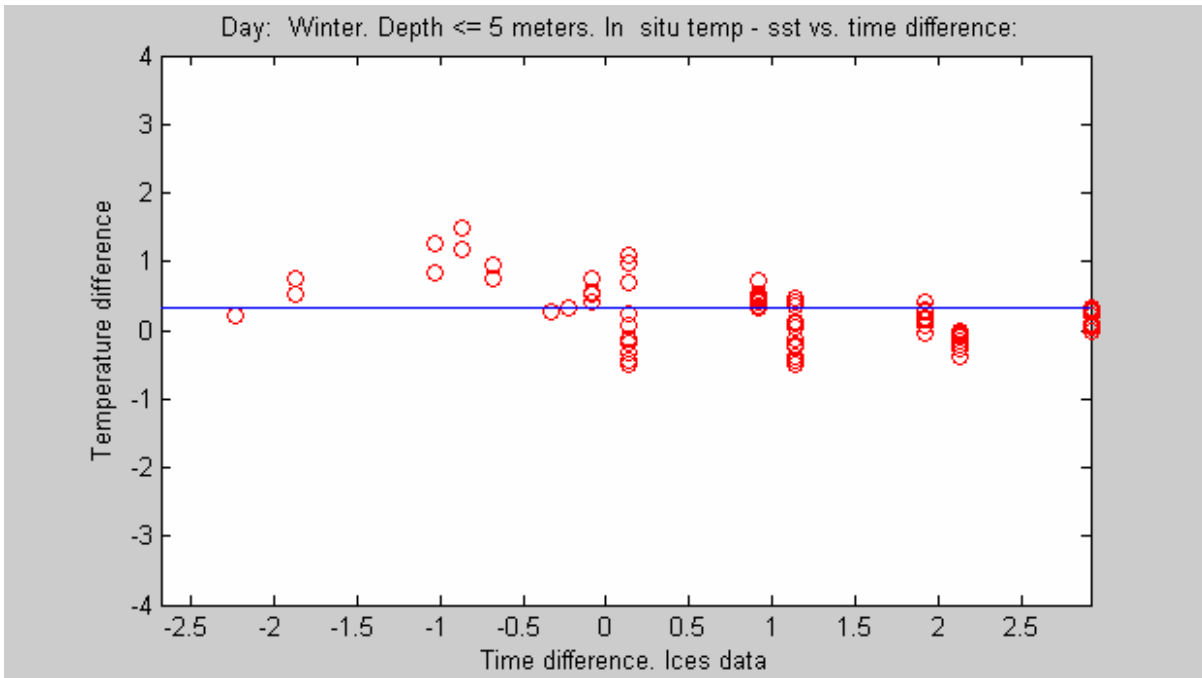
Figures 6 and 7 below show similar observations as figures 4 and 5, but only for the five German stations, the ICES data, and the data with unknown depth, respectively.



**Figure 6a.** Day. Winter. Distribution of five German stations with fixed location. Colour codes are: Kiel Lighthouse: red. Darss Sill: green. Dbucht Lightship: blue. Ems Lightship: black. Fehmarn Belt Buoy: cyan.

Mean and std. values and number of observations are:

All data:	0.31 K, 0.55 K,	422
Kiel:	0.21 K, 0.24 K,	14
Darss:	0.47 K, 0.54 K,	10
Dbucht:	0.29 K, 0.42 K,	23
Ems:	0.15 K, 0.21 K,	10
Fehmarn:	0.02 K, 0.39 K,	13

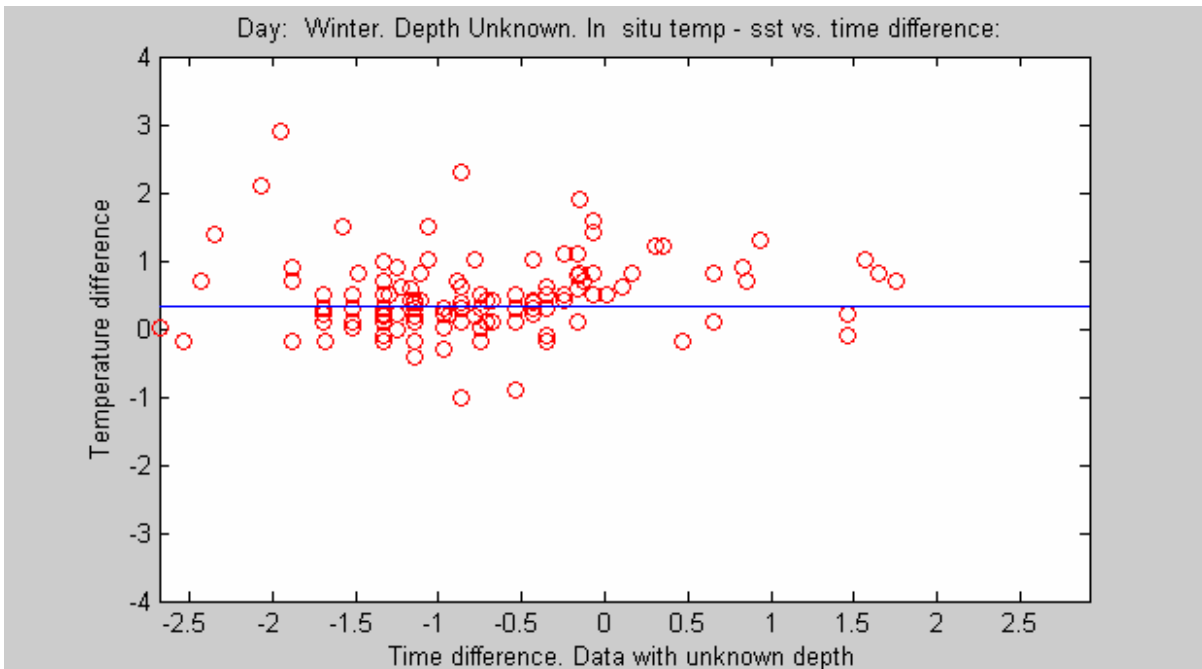


**Figure 6b.** Day. Winter. Distribution of Ices data.

Mean and std. values and number of observations are:

All data: 0.31 K, 0.55 K, 422

Ices: 0.25 K, 0.41 K, 88 (85 from the „26NA“ dataset)

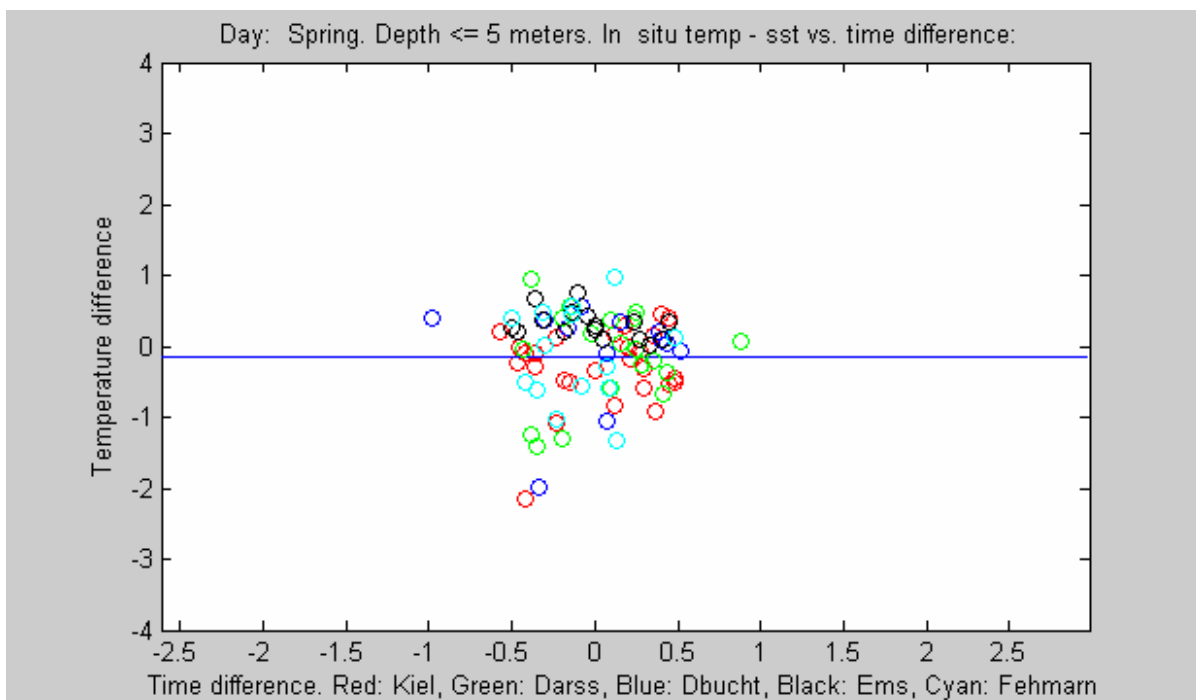


**Figure 6c.** Day. Winter. Distribution of data with unknown depth.

Mean and std. values and number of observations are:

All data: 0.31 K, 0.55 K, 393

Data with unknown depth: 0.48 K, 0.56 K, 125

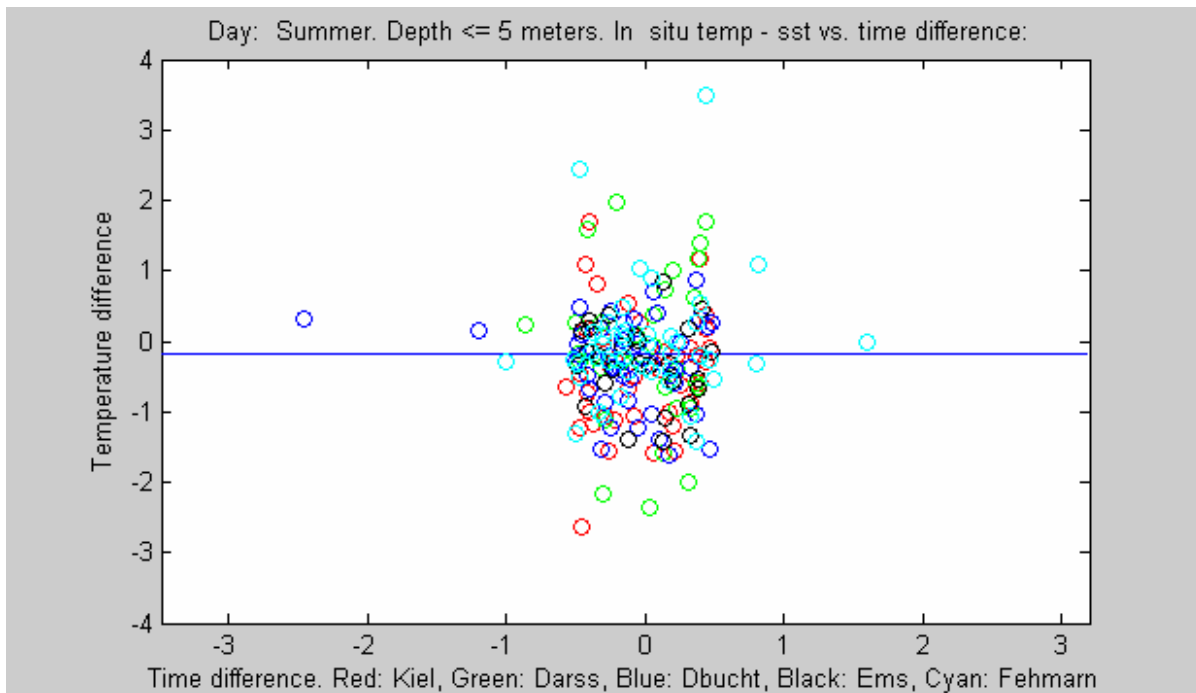


**Figure 6d.** Day. Spring. Distribution of five German stations with fixed location. Colour codes as figure 7a.

Mean and std. values and number of observations are:

All data:	-0.16 K,	0.66 K,	367
Kiel:	-0.29 K,	0.54 K,	27
Darss:	-0.14 K,	0.66 K,	19
Dbucht:	-0.08 K,	0.73 K,	12
Ems:	0.30 K,	0.20 K,	16
Fehmarn:	-0.14 K,	0.67 K,	14

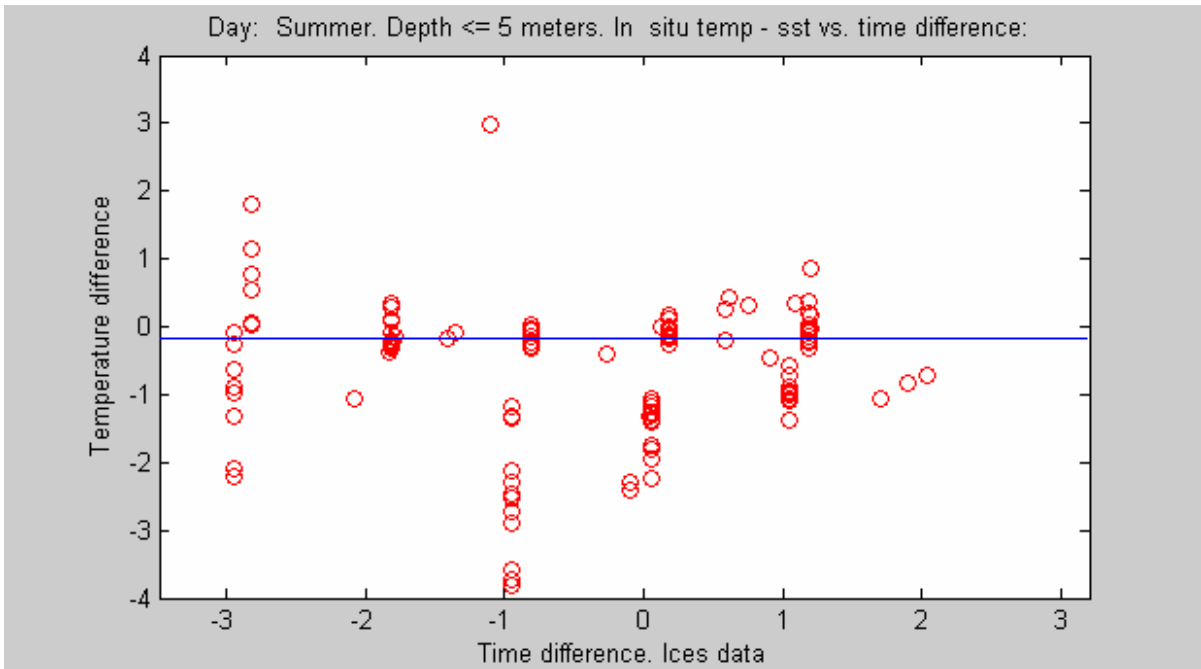
There are no ICES data and no unknown-depth data for the Spring period.



**Figure 6e.** Day. Summer. Distribution of five German stations with fixed location. Colour codes as figure 7a.

Mean and std. values and number of observations are:

All data:	-0.18 K, 0.84 K,	2395
Kiel:	-0.44 K, 0.84 K,	40
Darss:	-0.13 K, 1.10 K,	31
Dbucht:	-0.29 K, 0.61 K,	47
Ems:	-0.33 K, 0.57 K,	28
Fehmarn:	-0.04K, 0.85 K,	45

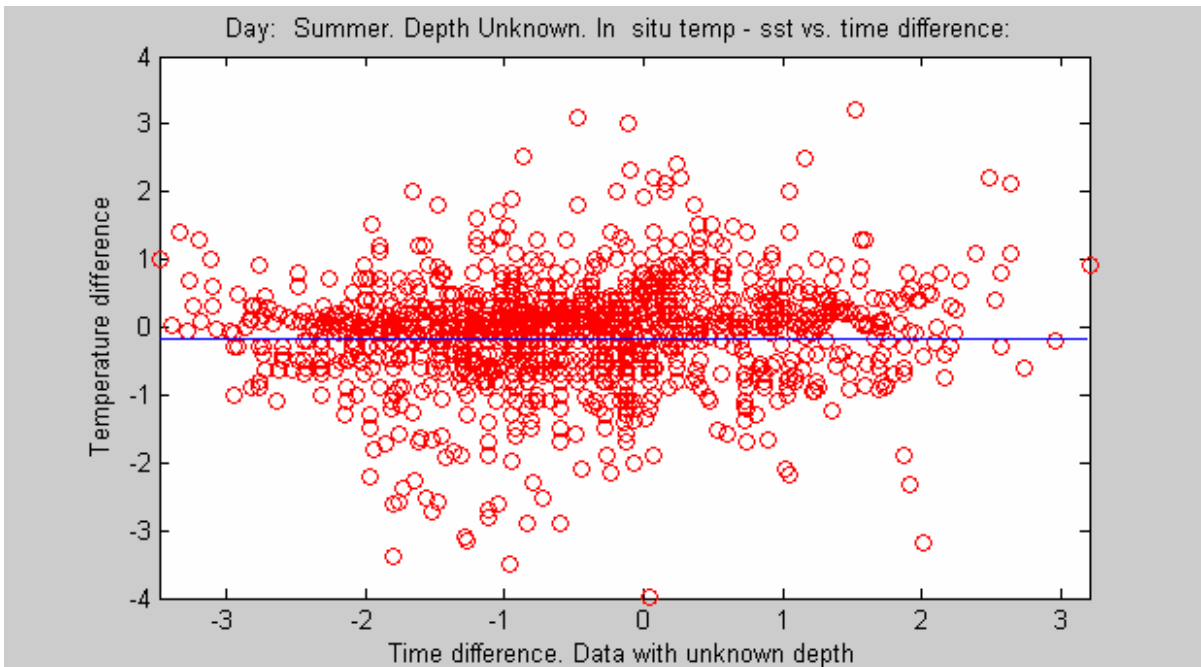


**Figure 6f.** Day. Summer. Distribution of Ices data.

Mean and std. values and number of observations are:

All data: -0.18 K, 0.84 K, 2395

Ices: -0.61 K, 1.04 K, 118 (103 from the „26NA“ dataset)

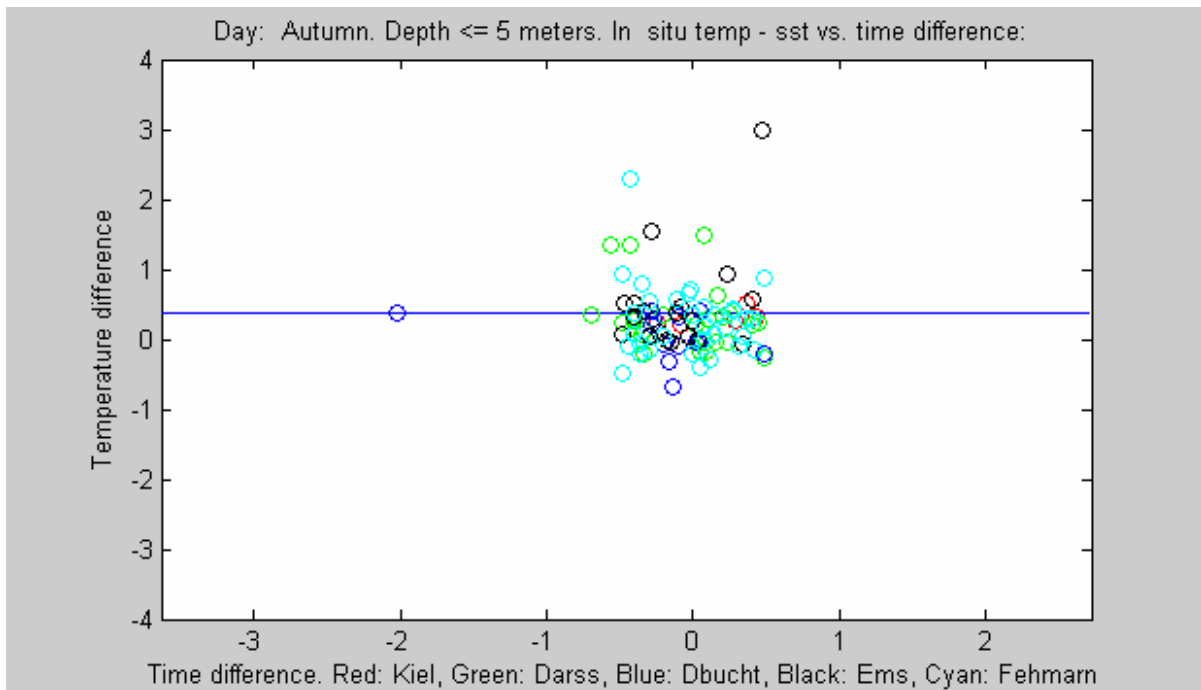


**Figure 6g** Day. Summer. Distribution of data with unknown depth.

Mean and std. values and number of observations are:

All data: -0.18 K, 0.84 K, 2395

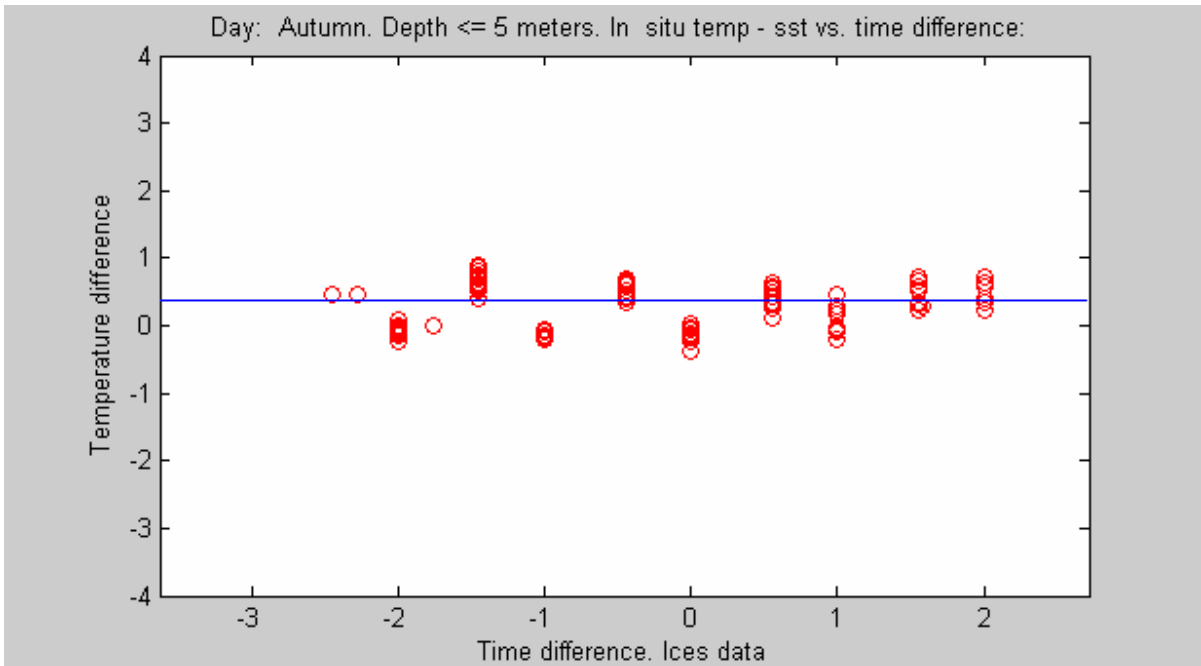
Data with unknown depth: -0.08 K, 0.82 K, 1109



**Figure 6h.** Day. Autumn. Distribution of five German stations with fixed location. Colour codes as figure 7a.

Mean and std. values and number of observations are:

All data:	0.37 K, 0.63 K,	964
Kiel:	0.31 K, 0.11 K,	6
Darss:	0.26 K, 0.47 K,	26
Dbucht:	0.04 K, 0.33 K,	13
Ems:	0.47 K, 0.72 K,	19
Fehmarn:	0.26 K, 0.52 K,	33

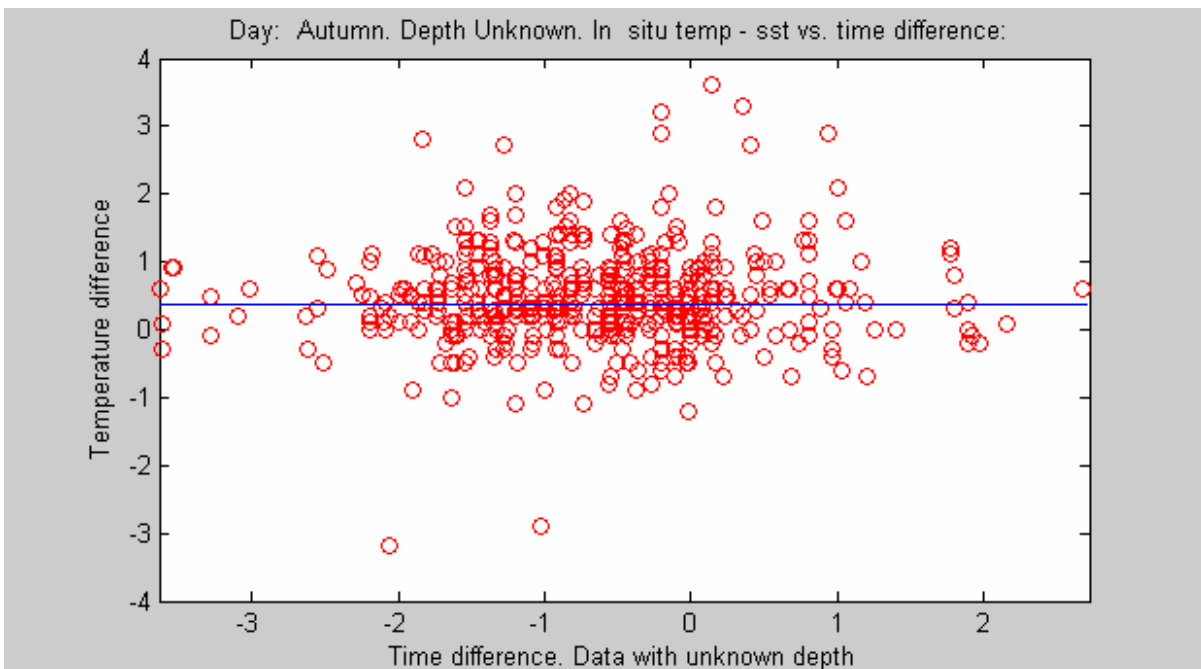


**Figure 6i.** Day. Autumn. Distribution of Ices data.

Mean and std. values and number of observations are:

All data: 0.37 K, 0.63 K, 964

Ices: 0.24 K, 0.34 K, 99 (96 from the „26NA“ dataset)

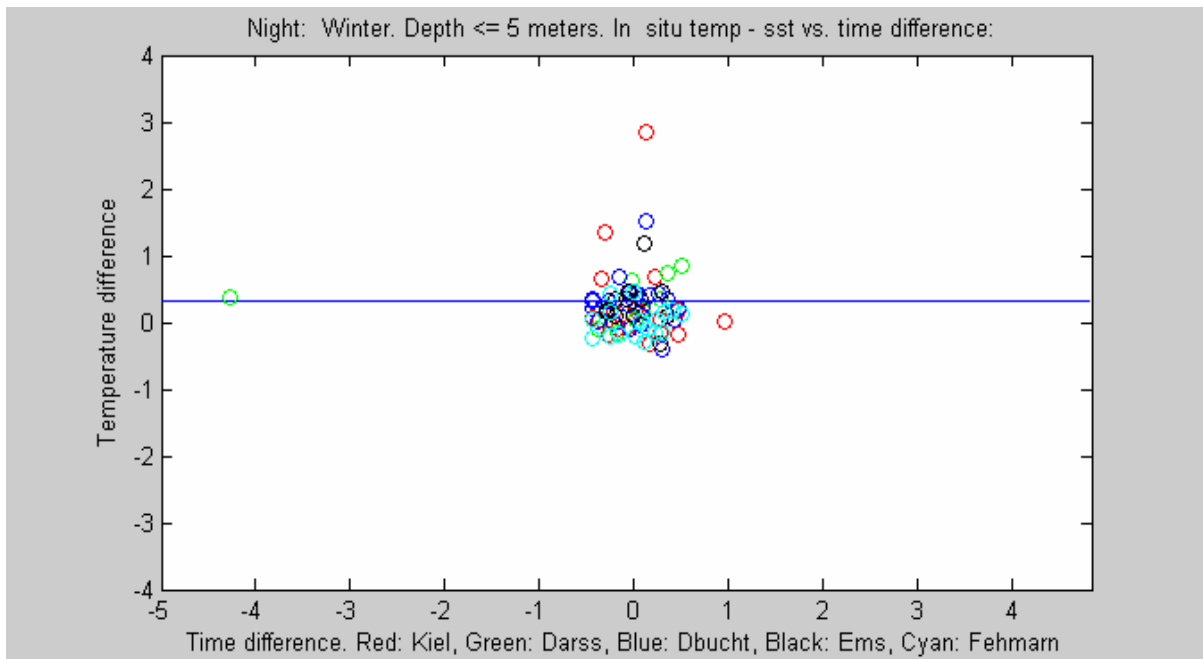


**Figure 6j.** Day. Autumn. Distribution of data with unknown depth.

Mean and std. values and number of observations are:

All data: 0.37 K, 0.63 K, 964

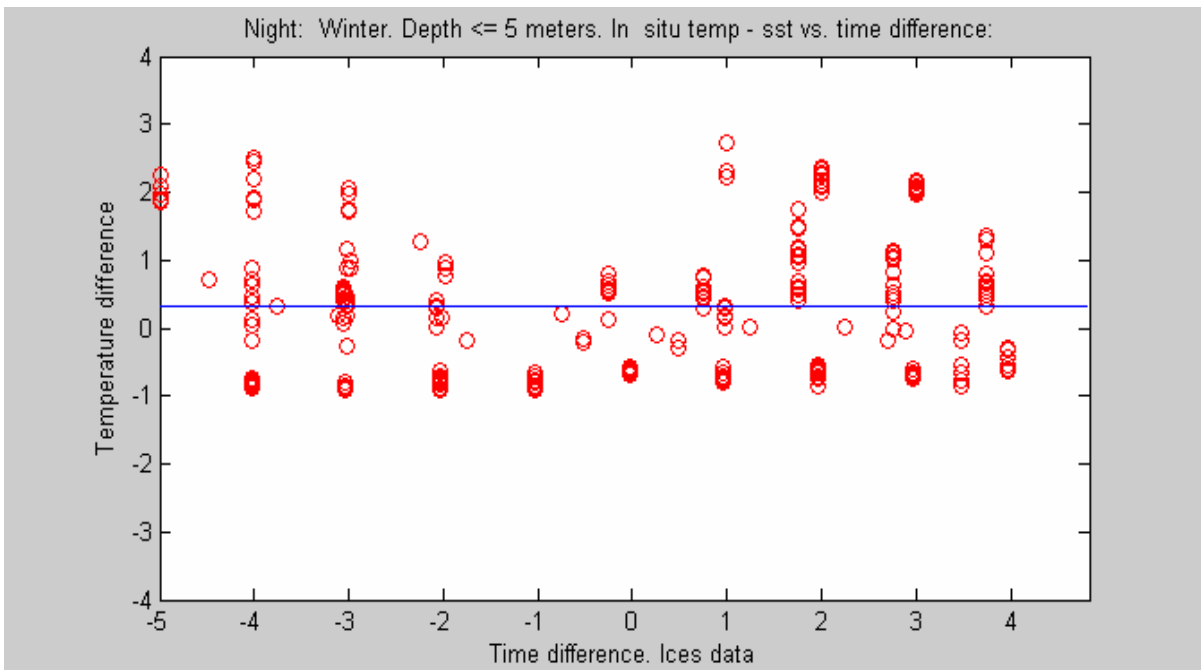
Data with unknown depth: 0.48 K, 0.70 K, 486



**Figure 7a.** Night. Winter. Distribution of five German stations with fixed location. Colour codes are: Kiel Lighthouse: red. Darss Sill: green. Dbucht Lightship: blue. Ems Lightship: black. Fehmarn Belt Buoy: cyan.

Mean and std. values and number of observations are:

All data:	0.32 K, 0.74 K,	1010
Kiel:	0.30 K, 0.75 K,	18
Darss:	0.32 K, 0.34 K,	10
Dbucht:	0.27 K, 0.35 K,	23
Ems:	0.29 K, 0.35 K,	12
Fehmarn:	0.00 K, 0.22 K,	17

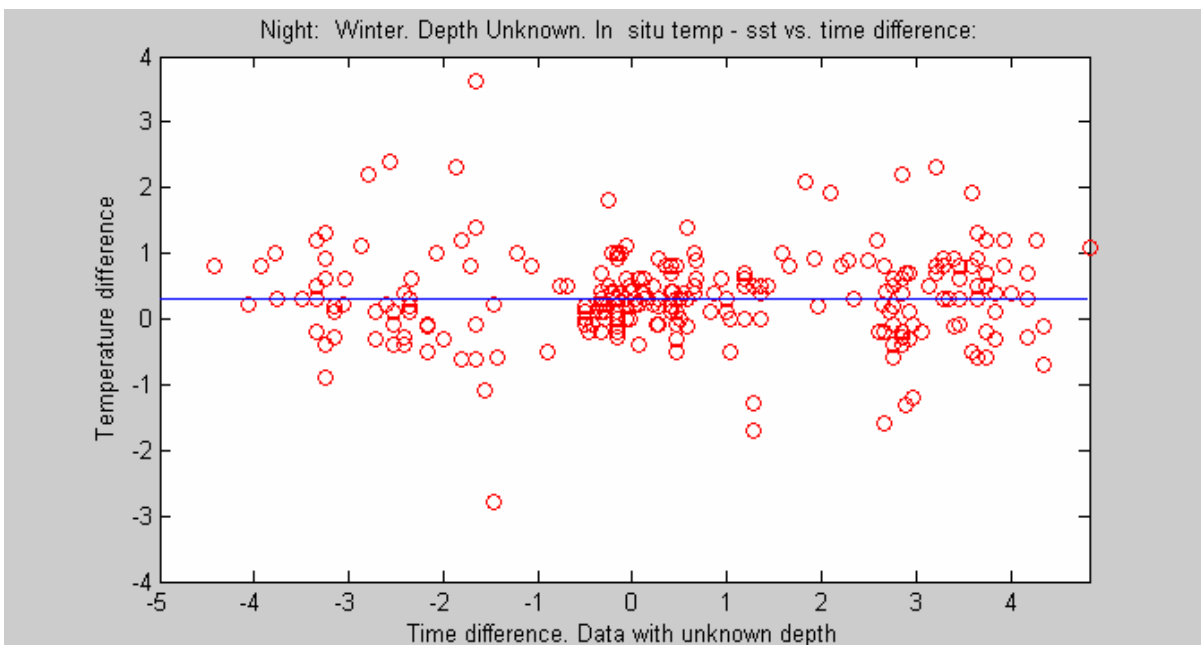


**Figure 7b.** Night. Winter. Distribution of Ices data.

Mean and std. values and number of observations are:

All data: 0.32 K, 0.74 K, 1010

Ices: 0.28 K, 1.01 K, 277 (266 from the „26NA“ dataset)

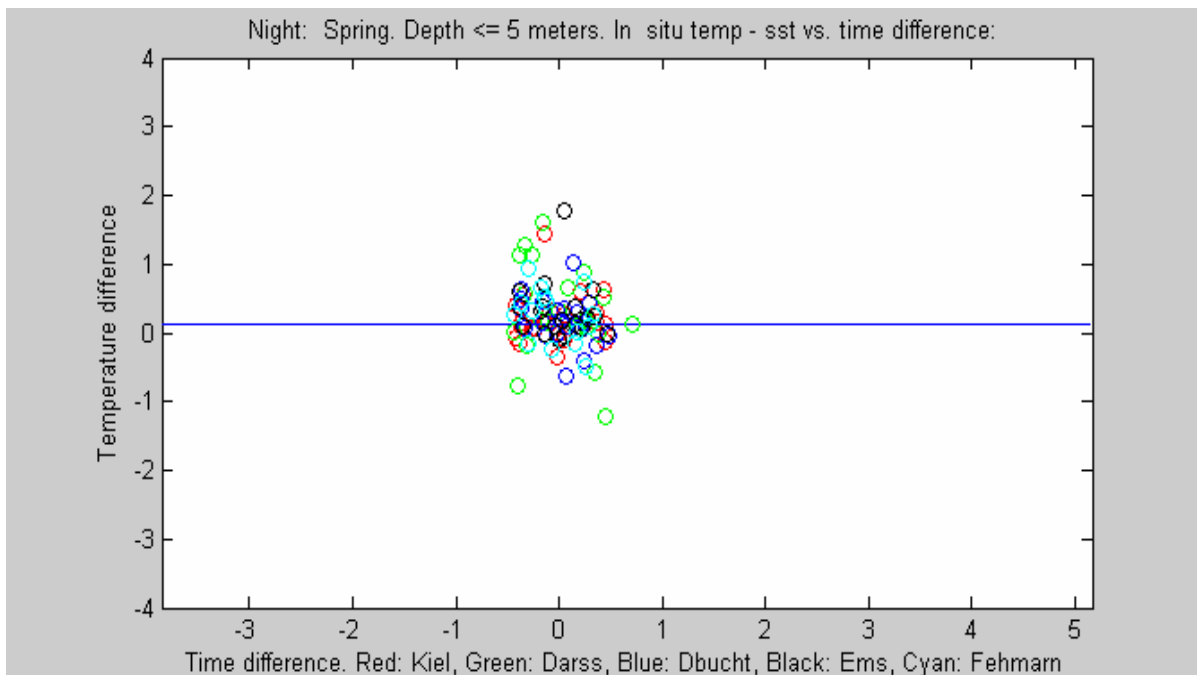


**Figure 7c.** Night. Winter. Distribution of data with unknown depth.

Mean and std. values and number of observations are:

All data: 0.32 K, 0.74 K, 1010

Data with unknown depth: 0.34 K, 0.69 K, 249

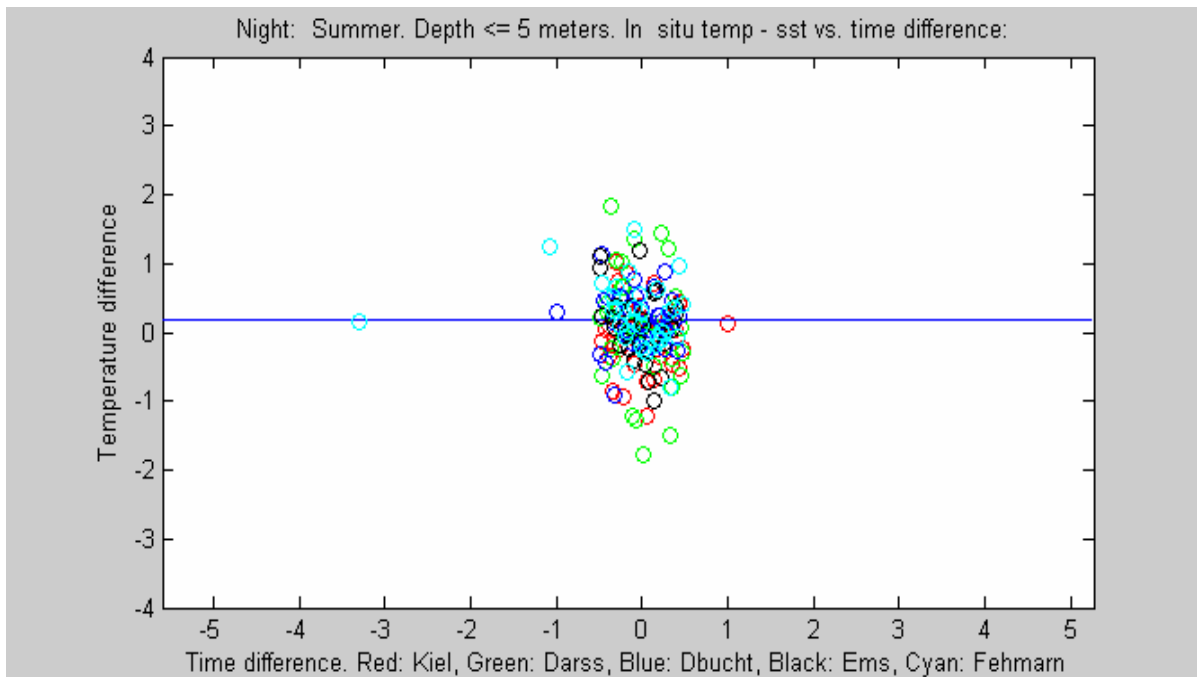


**Figure 7d.** Night. Spring. Distribution of five German stations with fixed location. Same colour codes as figure 6a.

Mean and std. values and number of observations are:

All data:	0.13 K,	0.45 K,	430
Kiel:	0.21 K,	0.38 K,	21
Darss:	0.29 K,	0.67 K,	22
Dbucht:	0.18 K,	0.34 K,	23
Ems:	0.32 K,	0.42 K,	19
Fehmarn:	0.25 K,	0.39 K,	15

There are no ICES data and no unknown-depth data for the Spring period.

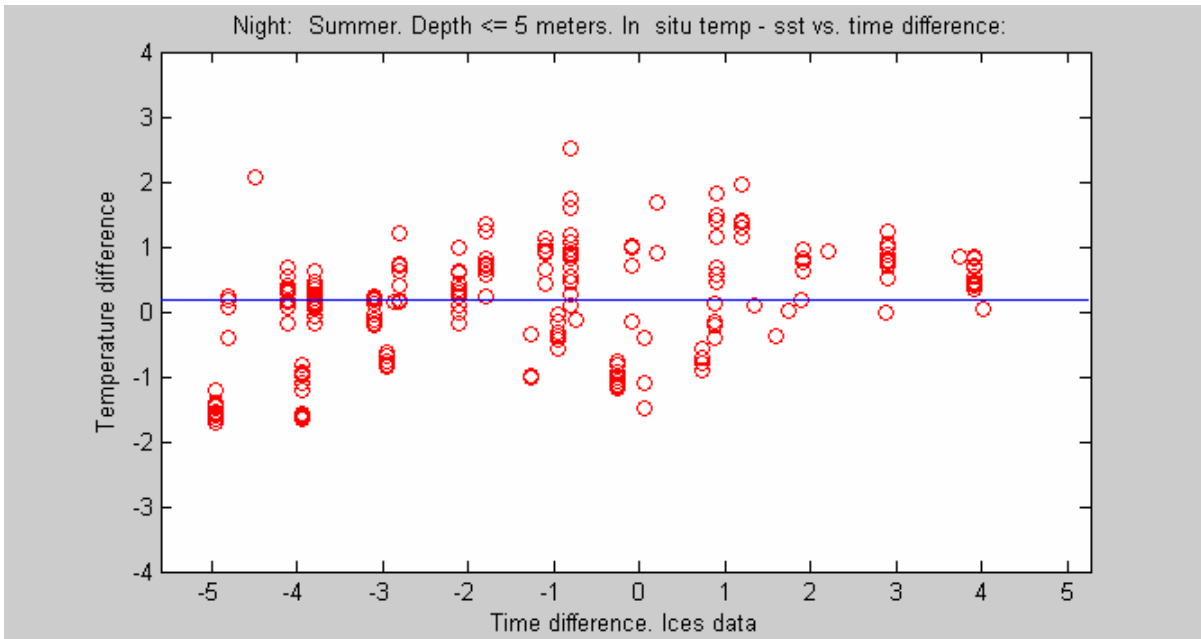


**Figure 7e:** Night. Summer. Distribution of five German stations with fixed location.

Same colour codes as figure 6a.

Mean and std. values and number of observations are:

All data:	0.18 K, 0.65 K, 3304
Kiel:	-0.05 K, 0.47 K, 42
Darss:	0.04 K, 0.86 K, 32
Dbucht:	0.17 K, 0.38 K, 40
Ems:	0.10 K, 0.51 K, 28
Fehmarn:	0.19 K, 0.45 K, 42

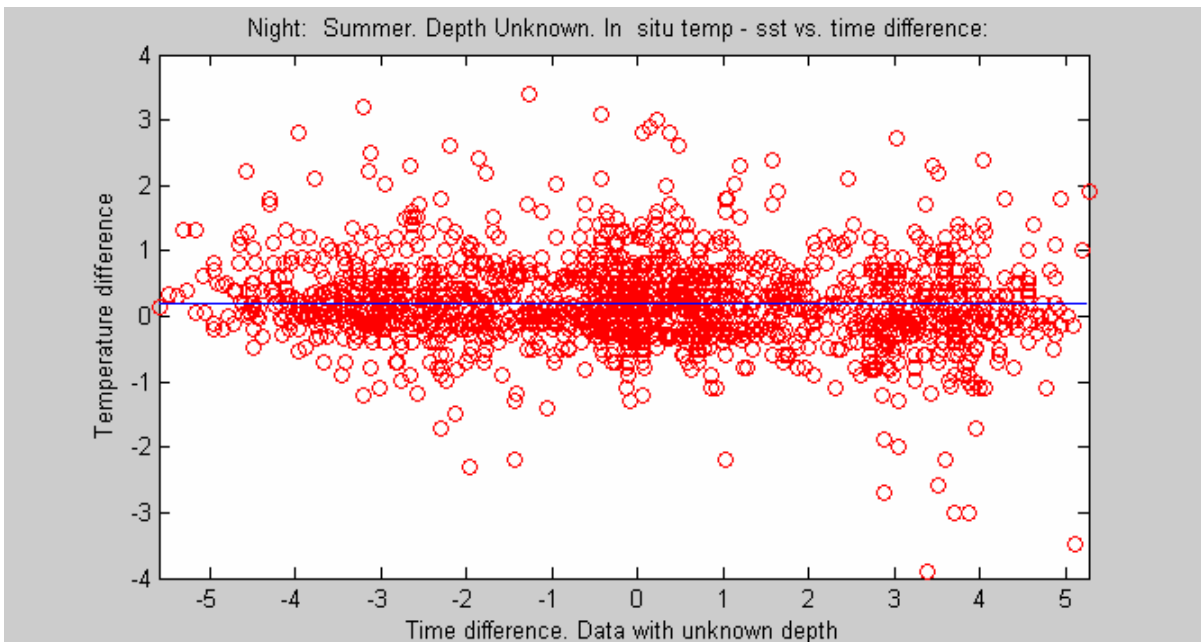


**Figure 7f.** Night. Summer. Distribution of Ices data.

Mean and std. values and number of observations are:

All data: 0.18 K, 0.65 K, 3304

Ices: 0.14 K, 0.84 K, 213 (202 from the „26NA“ dataset)

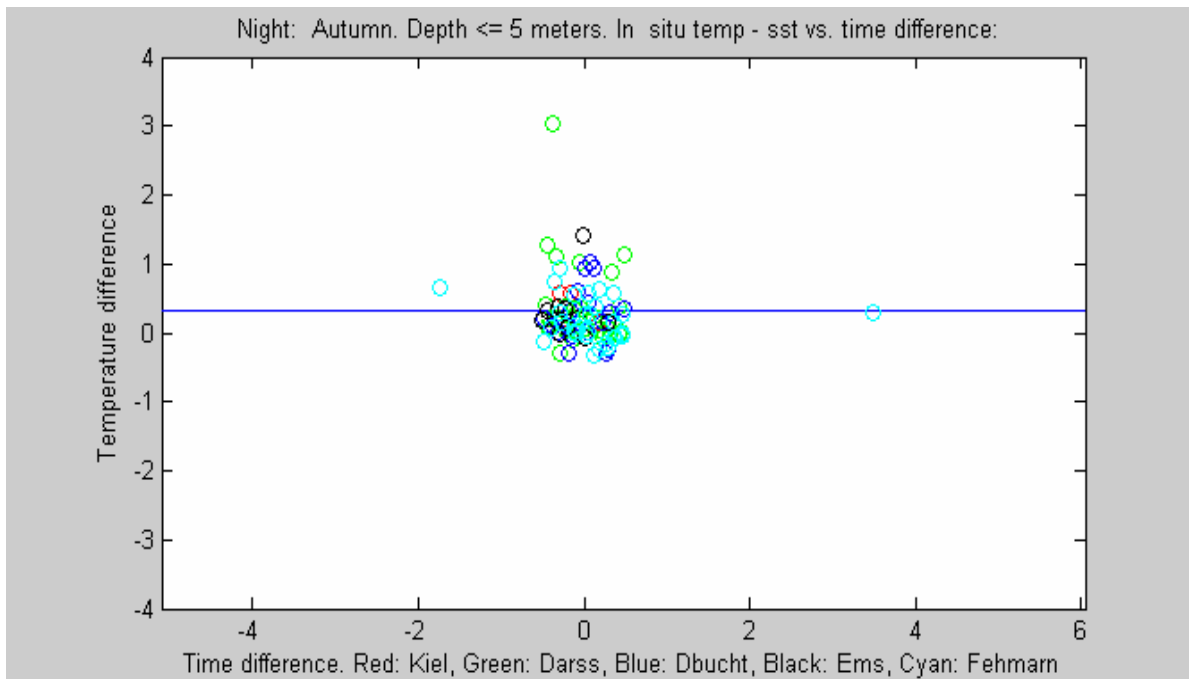


**Figure 7g.** Night. Summer. Distribution of data with unknown depth.

Mean and std. values and number of observations are:

All data: 0.18 K, 0.65 K, 3304

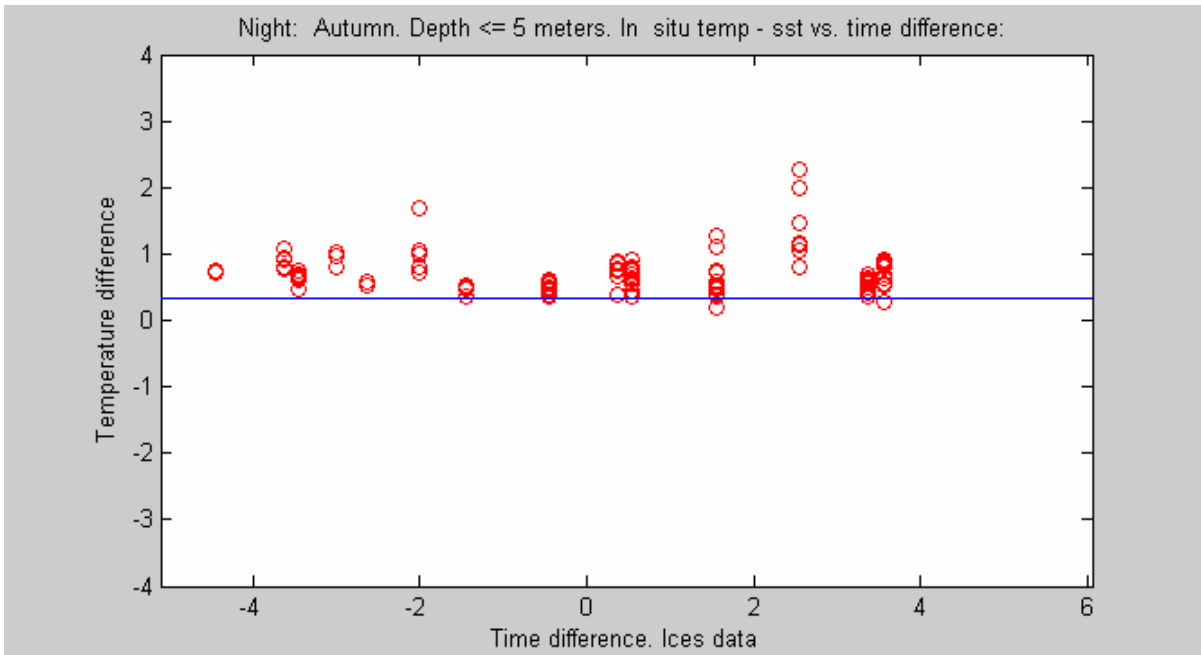
Data with unknown depth: 0.22 K, 0.68 K, 1618



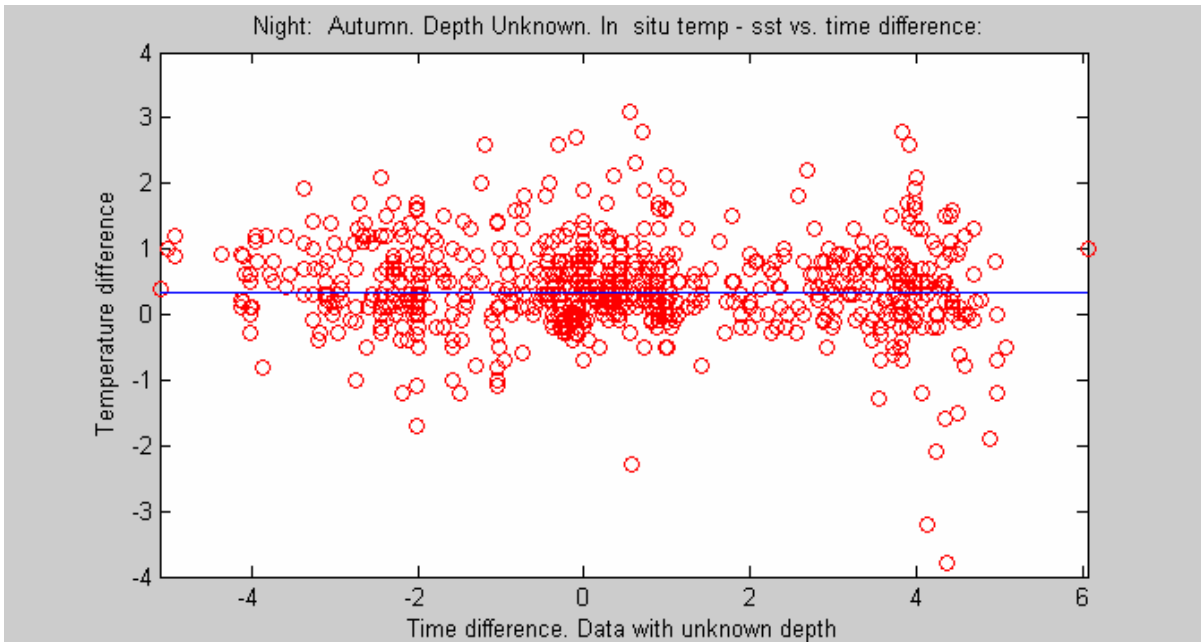
**Figure 7h.** Night. Autumn. Distribution of five German stations with fixed location. Same colour codes as figure 6a.

Mean and std. values and number of observations are:

All data:	0.33 K,	0.59 K,	1370
Kiel:	0.36 K,	0.21 K,	5
Darss:	0.37 K,	0.63 K,	31
Dbucht:	0.27 K,	0.39 K,	20
Ems:	0.28 K,	0.40 K,	11
Fehmarn:	0.18 K,	0.32 K,	31



**Figure 7i.** Night. Autumn. Distribution of Ices data.  
 Mean and std. values and number of observations are:  
 All data: 0.33 K, 0.59 K, 1370  
 Ices: 0.70 K, 0.33 K, 99 (99 from the „26NA“ dataset)

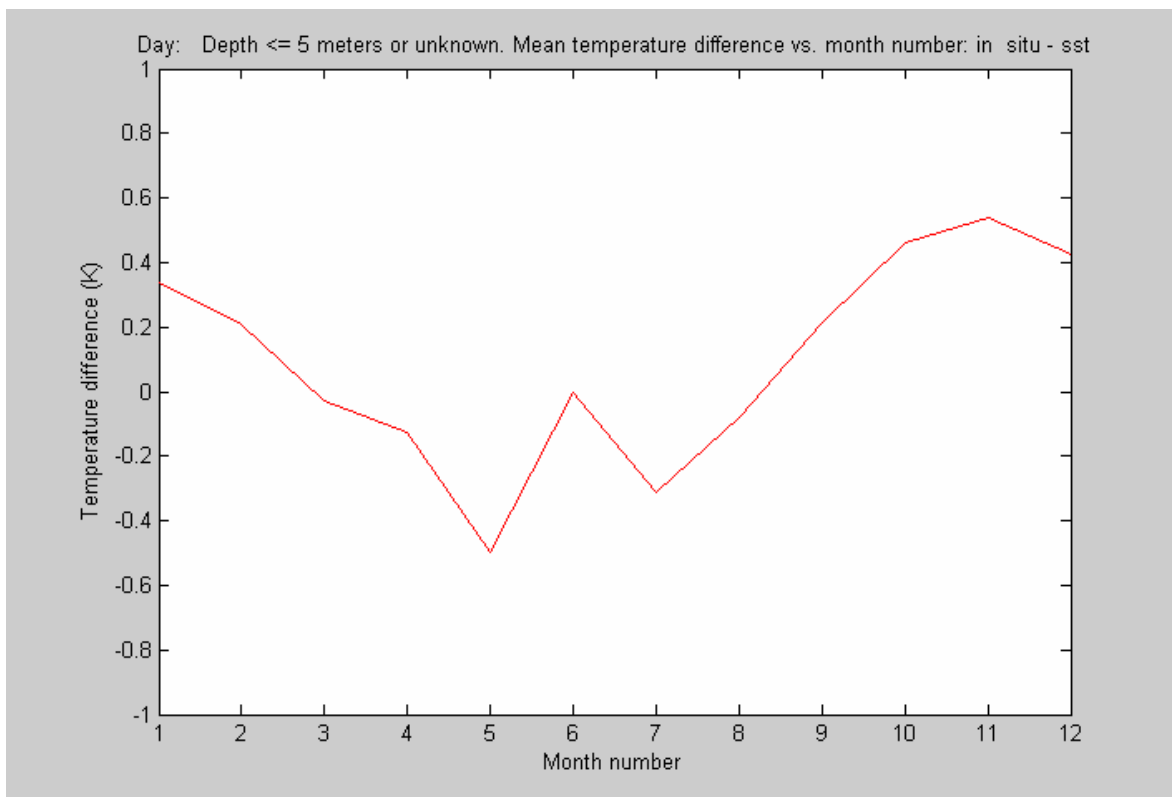


**Figure 7j.** Night. Autumn. Distribution of data with unknown depth.  
 Mean and std. values and number of observations are:  
 All data: 0.33 K, 0.59 K, 1370  
 Data with unknown depth: 0.43 K, 0.69 K, 709

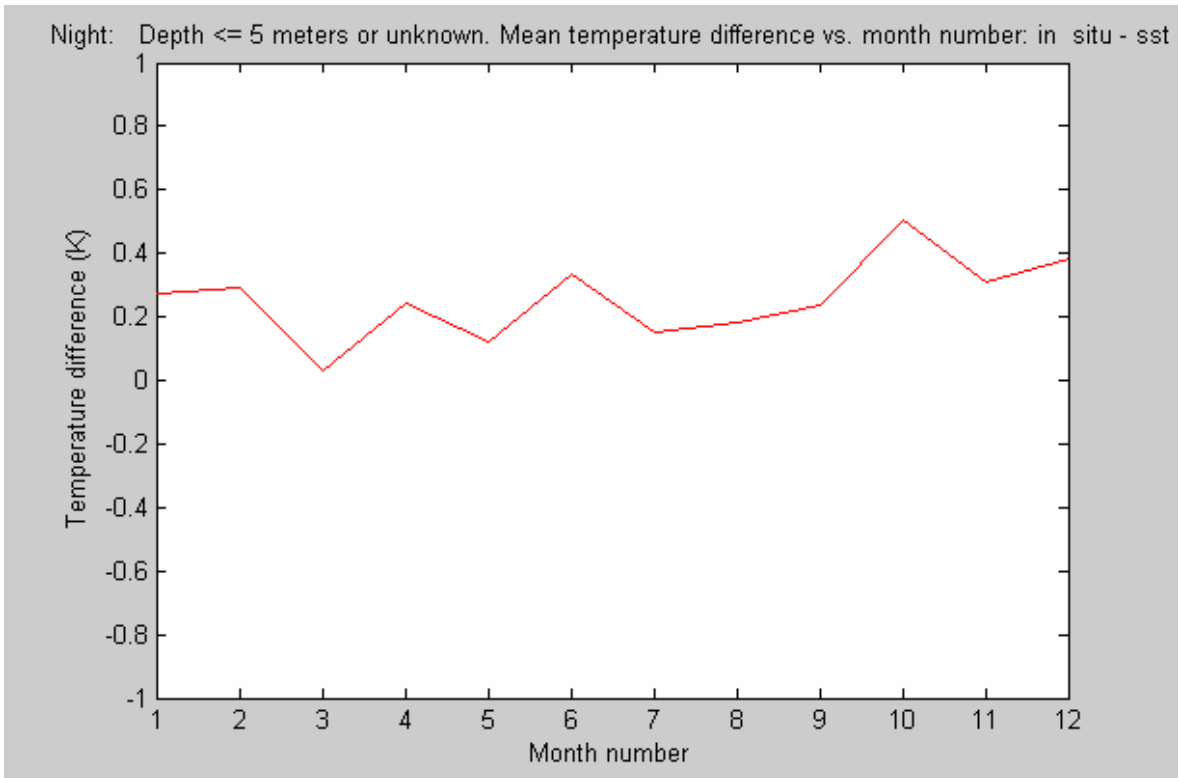
Figures 6 and 7 show that the temperature differences from the five Marnet stations are distributed approximately the same way and with mean differences that resemble the mean values of the whole dataset. Also the behaviour of the Ices dataset resemble the behaviour of the whole dataset, apart from the (Day, Summer) and (Night, Autumn) observations. The behaviour of data with unknown depth is similar to the behaviour of the whole dataset.

These figures stress that none of the larger observation sets can be detected as erroneous, and consequently none of these sets should be excluded from analysis.

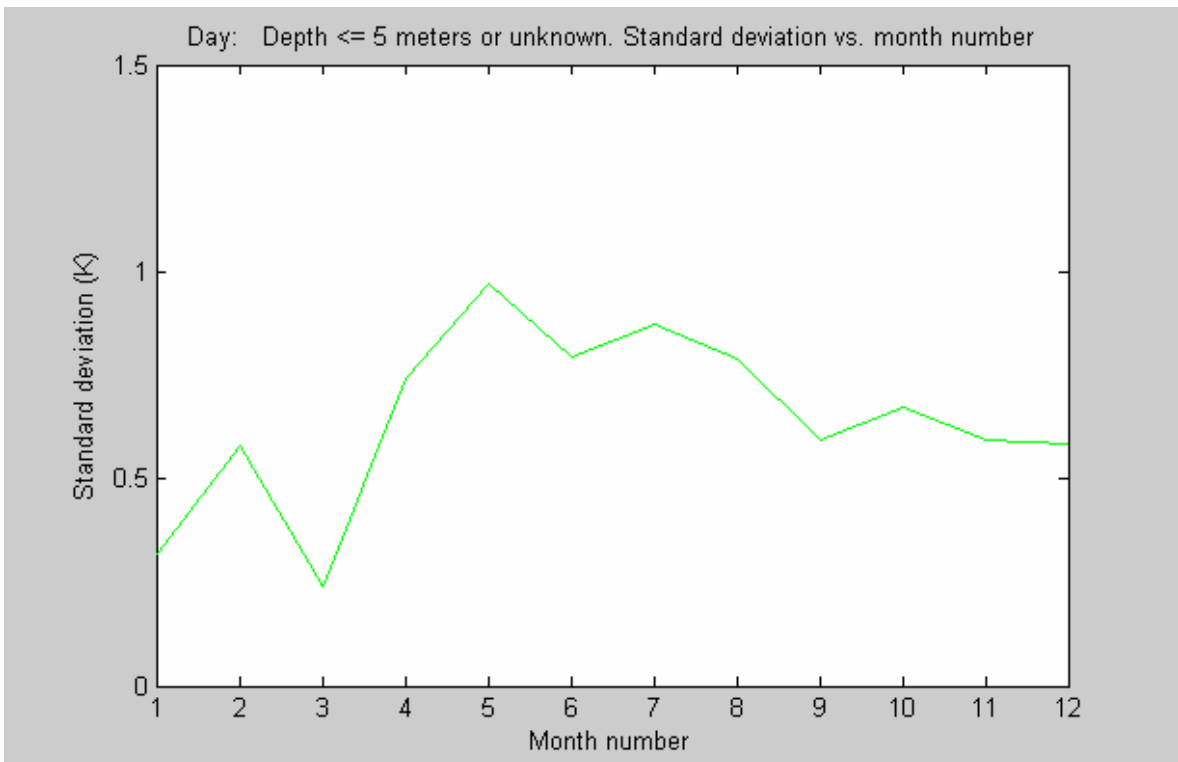
In order to further examine the seasonal variations, we have plotted the monthly mean temperature differences vs. month number:



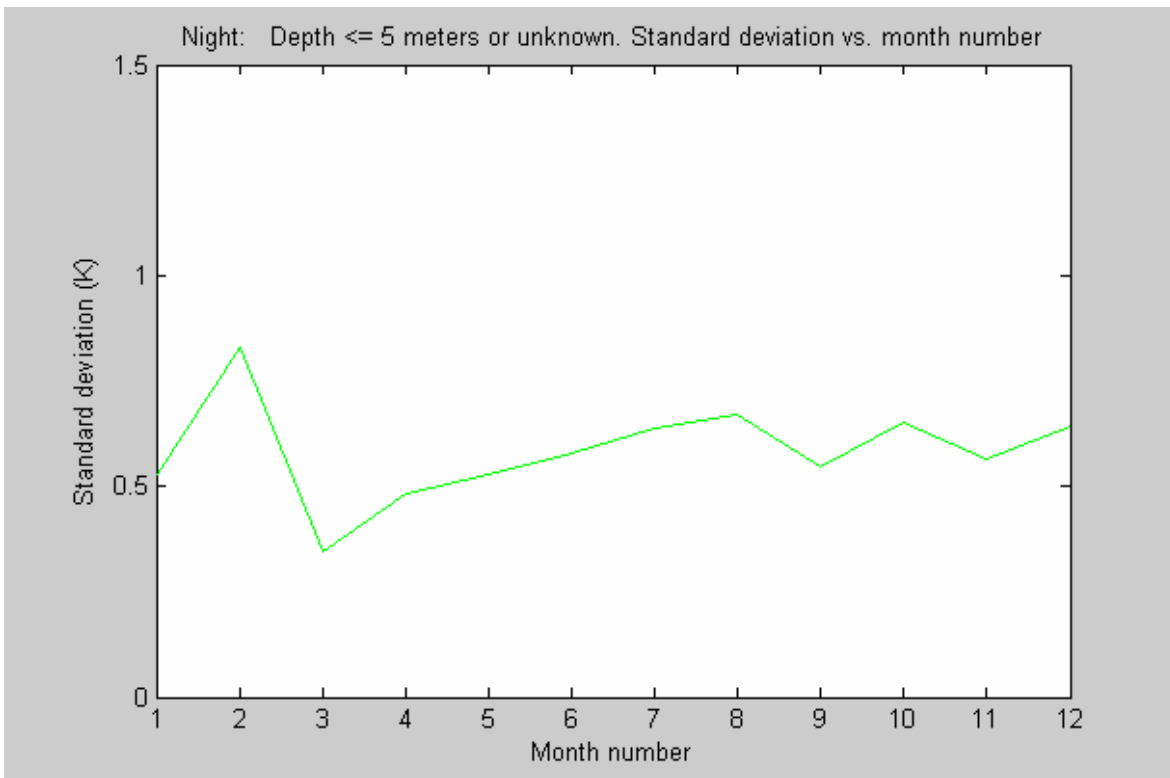
**Figure 8a:** Day. Mean monthly temperature differences vs. month number



**Figure 8b.** Night. Mean monthly temperature differences vs. month number.



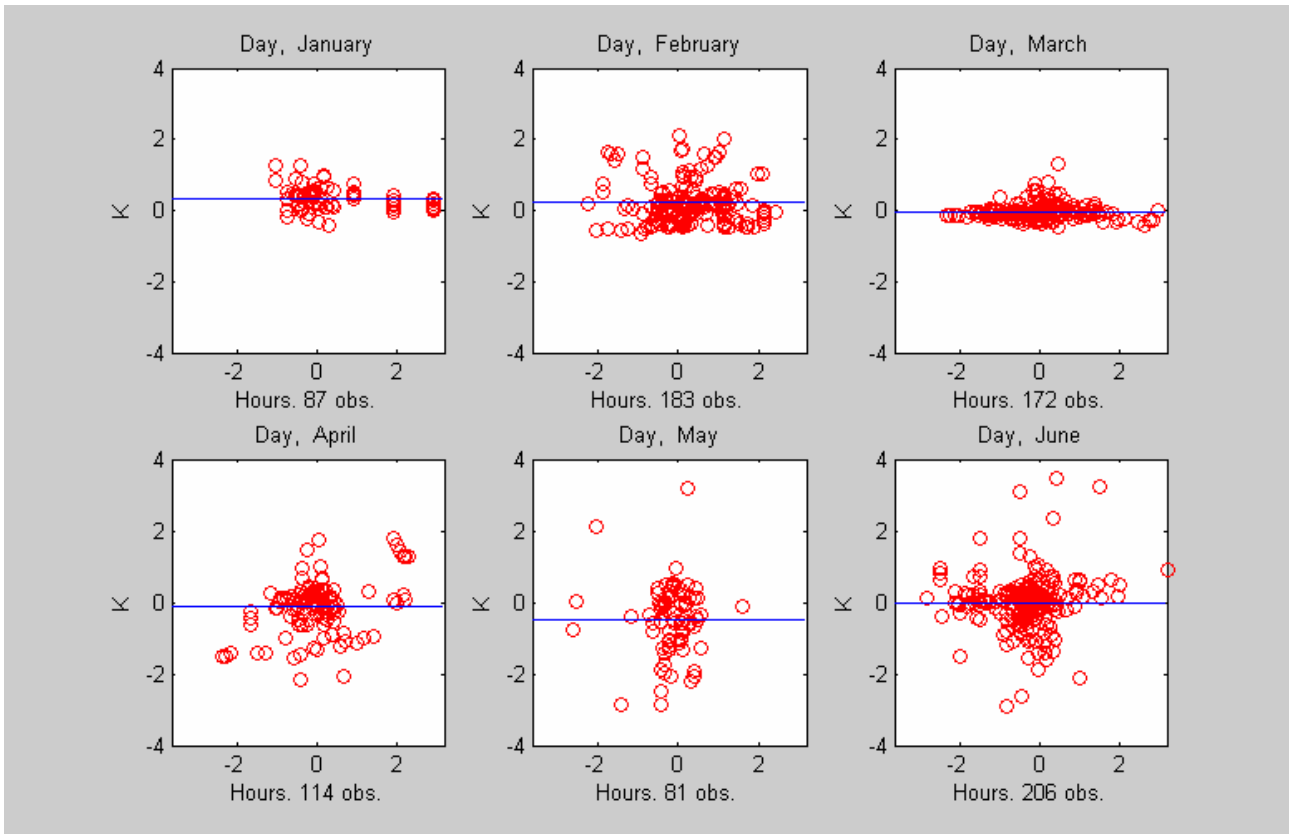
**Figure 8c.** Day. Standard deviation of temperature differences vs. month number.



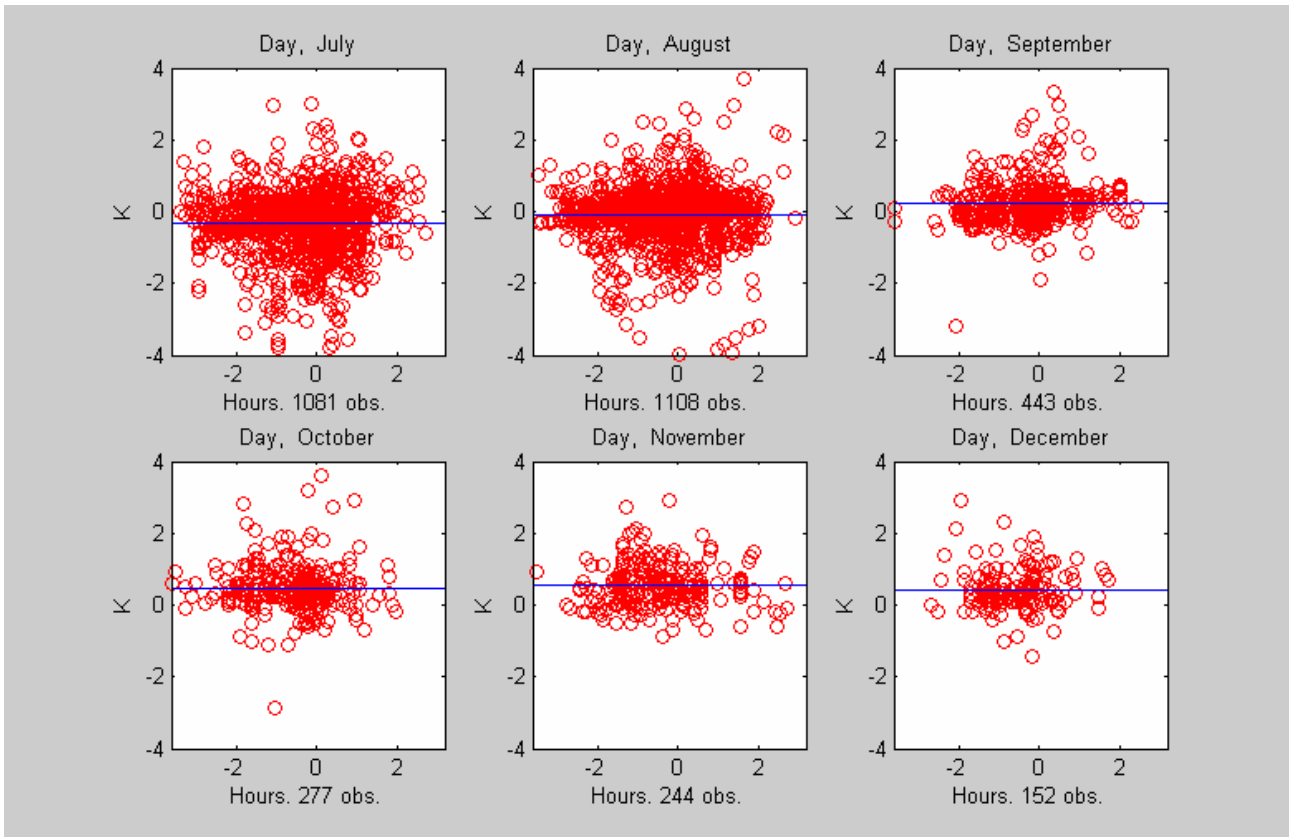
**Figure 8d.** Night. Standard deviation of temperature differences vs. month number.

From figures 8a and 8b it can be seen that there is no significant season dependence of temperature differences for the nighttime data, while for the daytime data it seems as if the calculated SSTs are too low during the winter and autumn periods and too high during the spring and summer periods. Similarly, the standard deviations (figures 8c and 8d) are season-independent for nighttime data, but season-dependent for daytime data, where the std. values are highest during the summer period. So the daytime data have a seasonal variation, while the nighttime data do not.

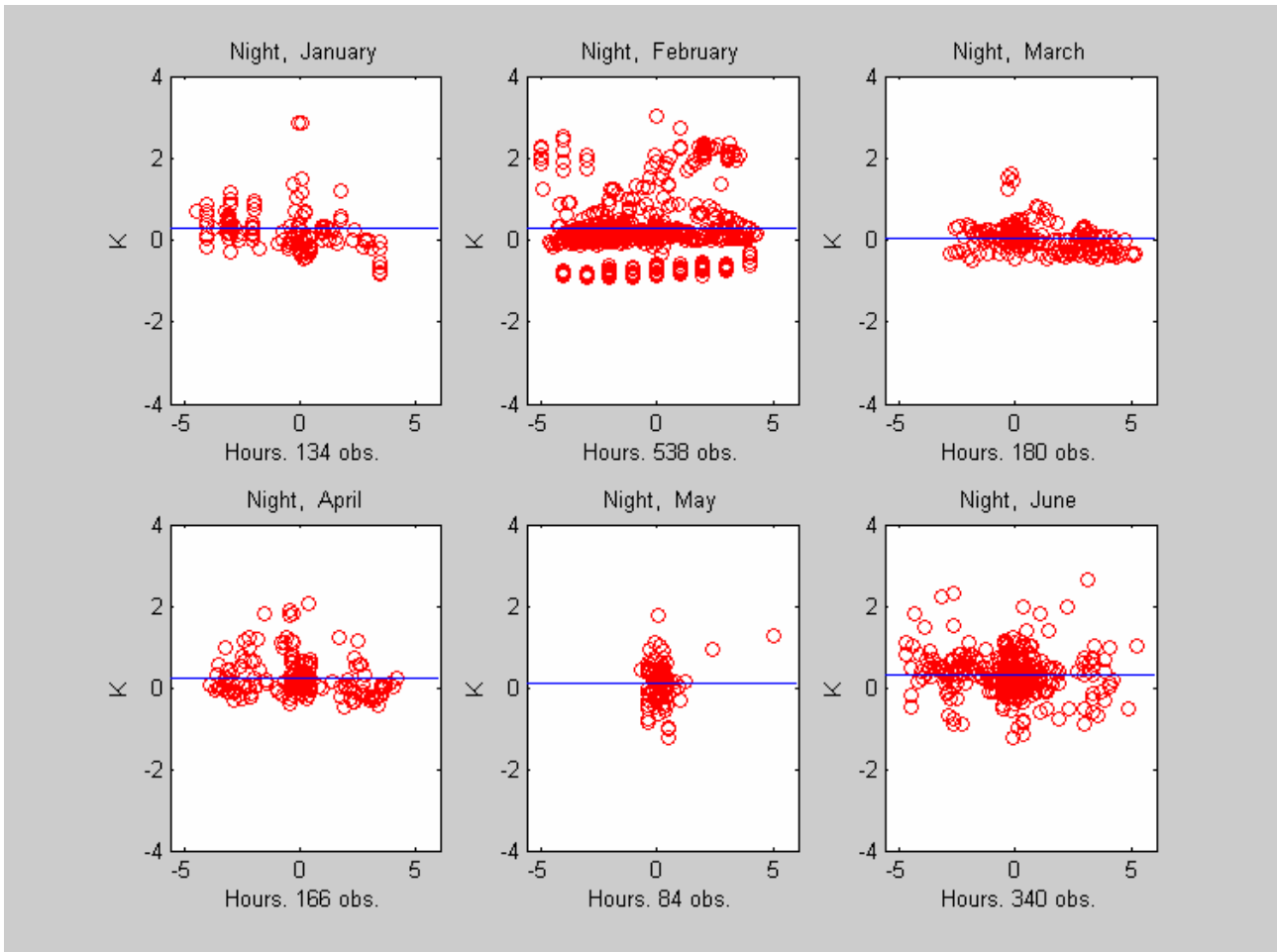
Below, we shall take a closer look at each month.



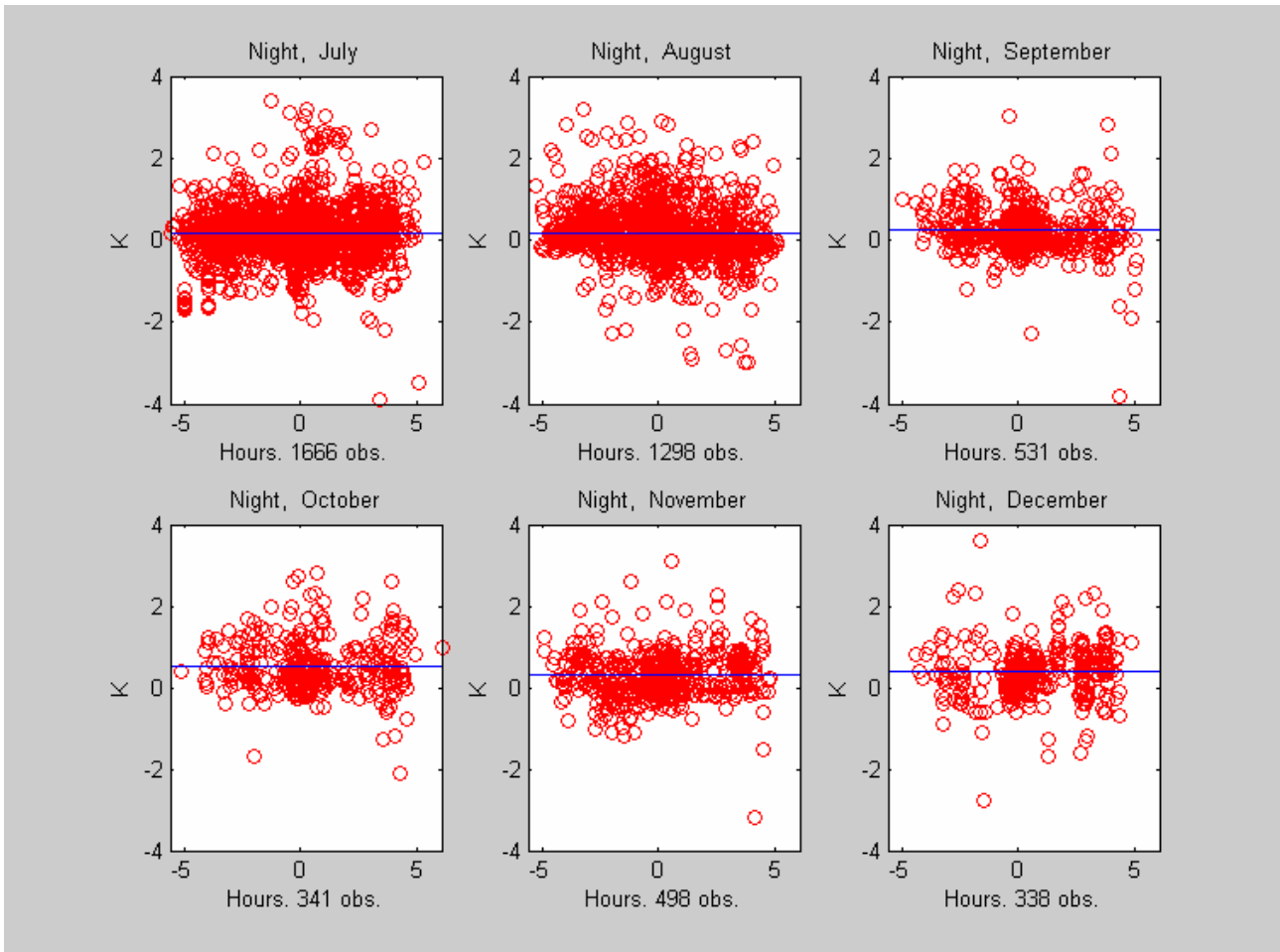
**Figure 9a.** Similar to figure 4 and 5, but with temperature differences for each month instead of each season. Daytime data. January to June. Blue lines are mean temperature differences of the months (cf. figures 8a and 8b).



**Figure 9b.** As figure 9a. Daytime data. July to December.



**Figure 9c.** As figure 9a. Night time data. January to June. The many observations in February are due to a long series of vessel based temperature measurements (from the ICES data archive), where measurement times for some reason is given in integer hours; this remark also applies for some of the January data.



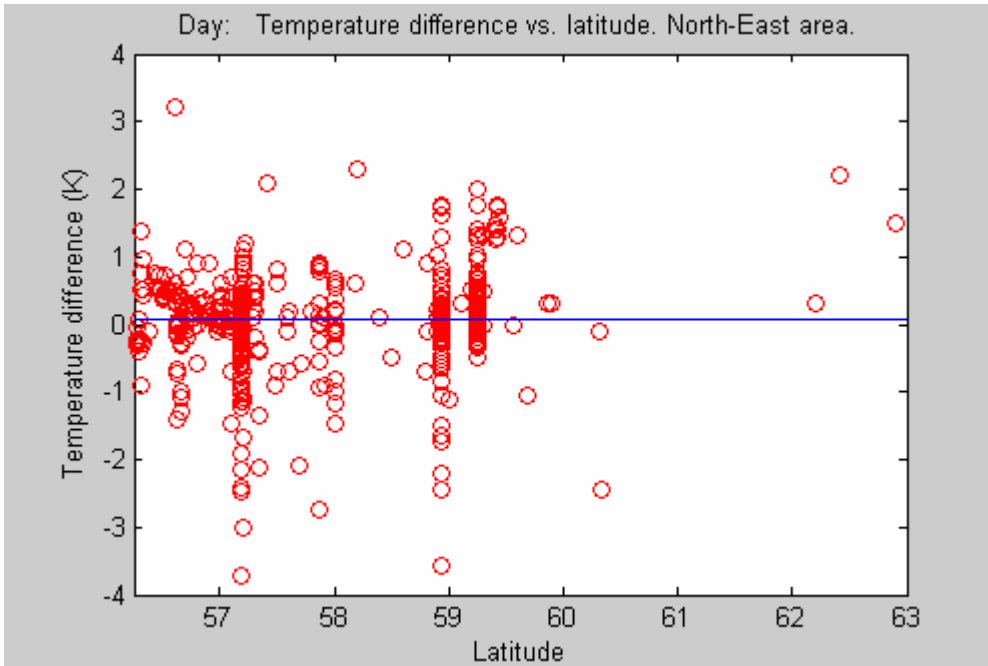
**Figure 9d.** As figure 9a. Night time data. July to December.

In figures 9 the detailed behaviour of the temperature differences can be observed. The conclusions to these are similar to the conclusions of figures 8. The high standard deviations for daytime data in July and August may be due to significant diurnal warming effects during these months.

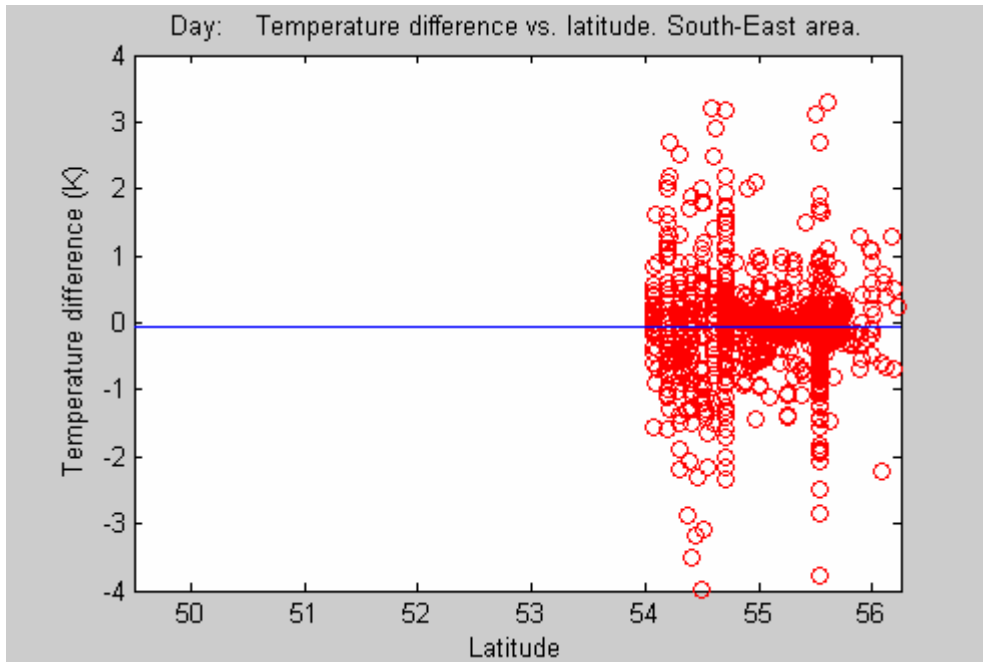
## Geographical variations

Apart from the seasonal variations, another interesting topic would be to examine whether there is any geographical bias in the variations.

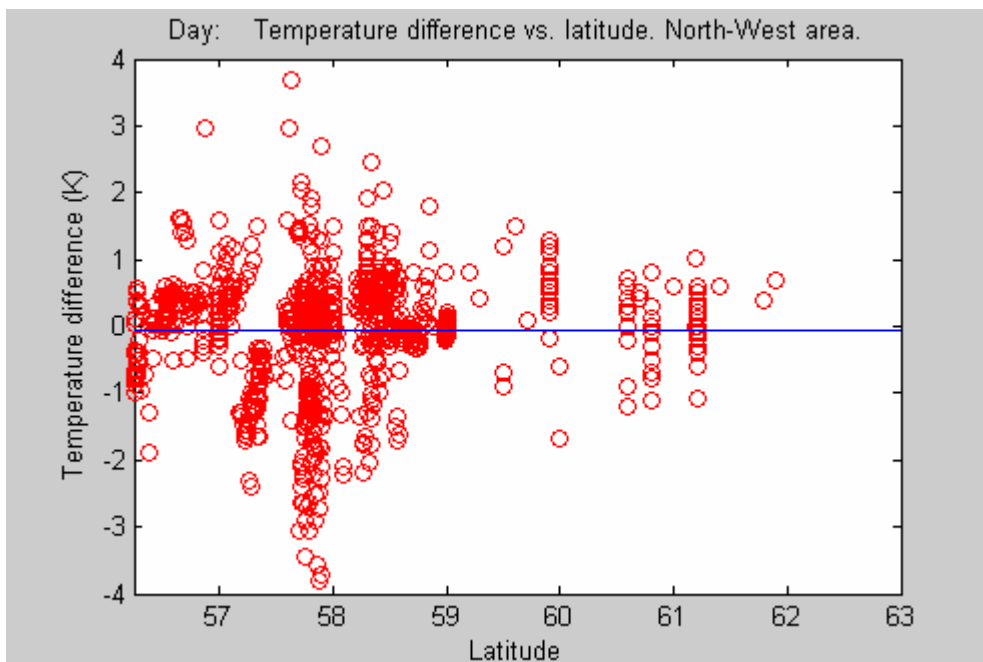
If we divide the examined area into four regions (North-East, South-East, North-West and South-West), and examine these areas separately, we obtain the following figures:



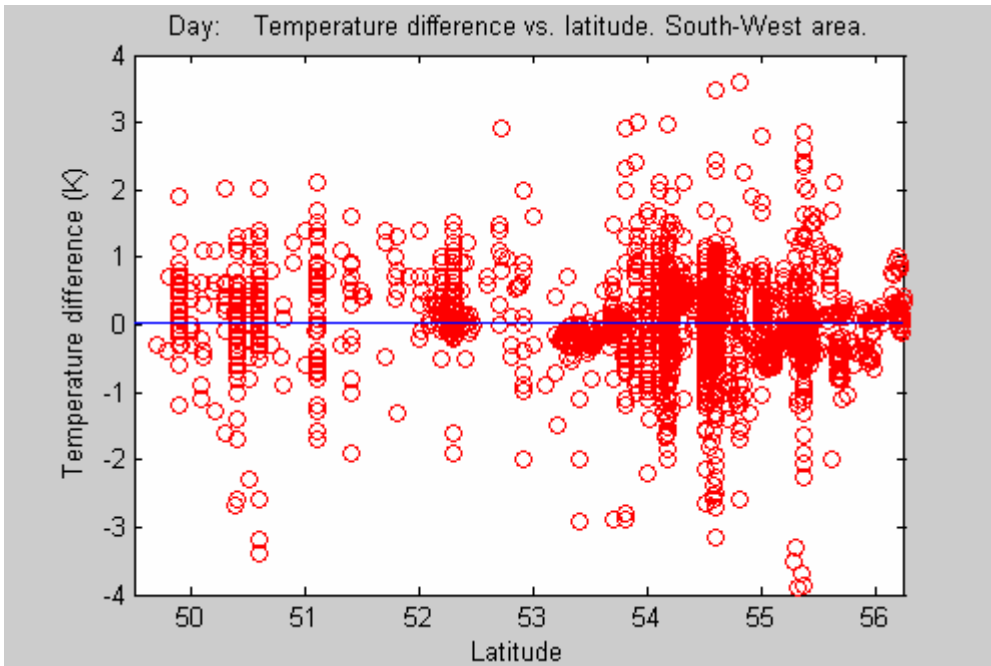
**Figure 10a.** Daytime data. Variations of temperature differences in the North-East area: Lower left corner: (56.27 N, 11.28 E). Upper right corner: (62.91 N, 28.02 E). Mean value: 0.07 K. Standard deviation: 0.76 K. Number of observations: 470.



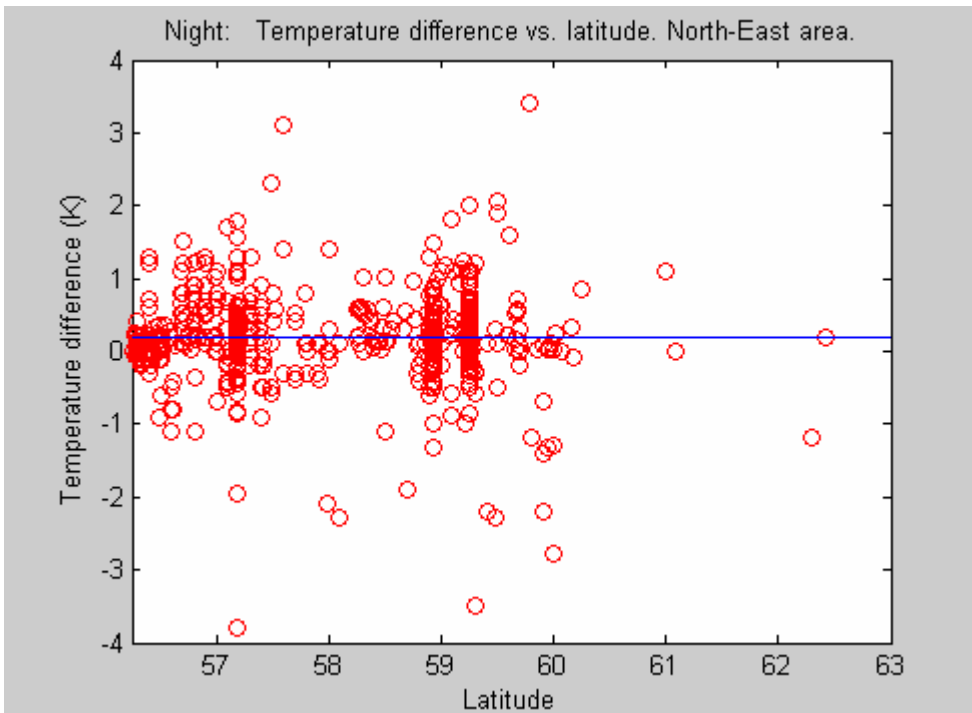
**Figure 10b.** Daytime data. Variations of temperature differences in the South-East area: Lower left corner: (54.07 N, 11.25 E). Upper right corner: (56.22 N, 21.04 E). Mean value: -0.06 K. Standard deviation: 0.79 K. Number of observations: 903.



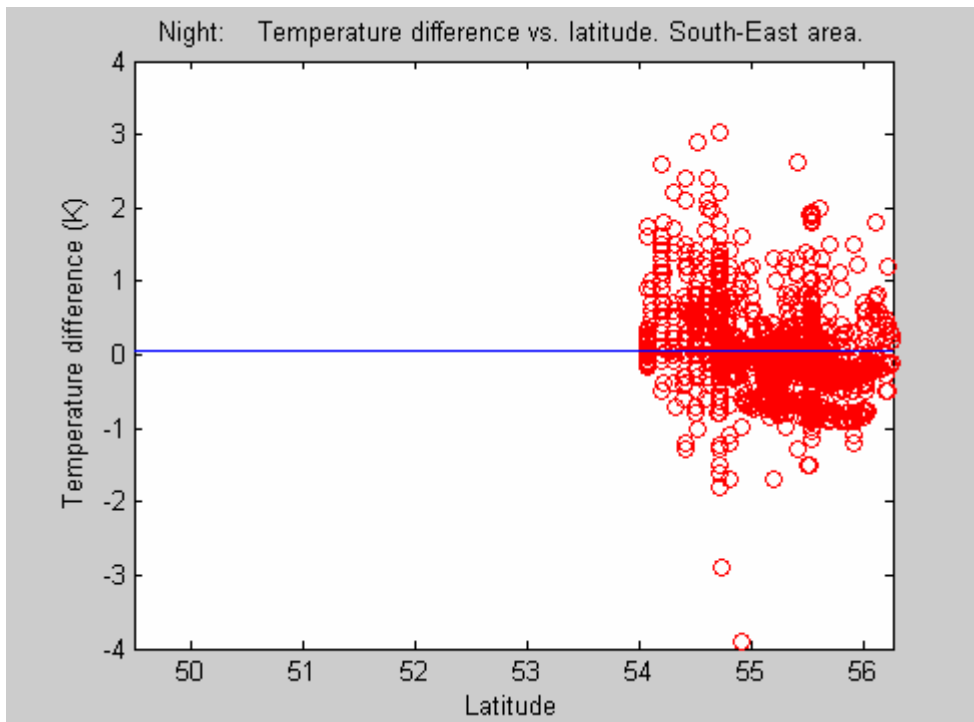
**Figure 10c.** Daytime data. Variations of temperature differences in the North-West area: Lower left corner: (56.25 N, -5.70 E). Upper right corner: (61.90 N, 11.24 E). Mean value: -0.05 K. Standard deviation: 0.89 K. Number of observations: 861.



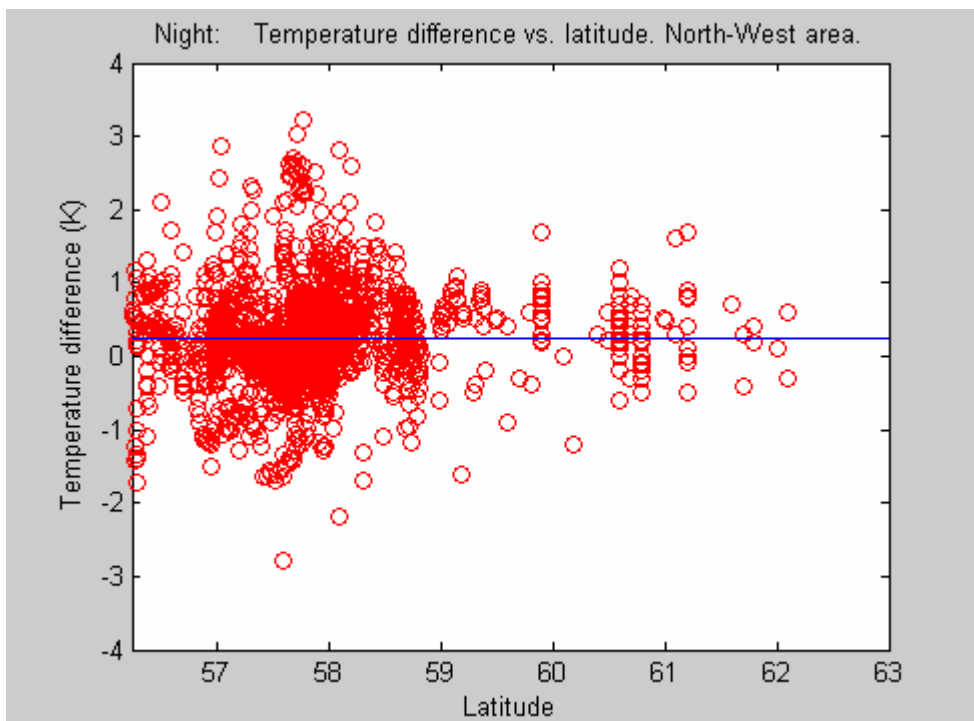
**Figure 10d.** Daytime data. Variations of temperature differences in the South-West area: Lower left corner: (49.70 N, -4.49 E). Upper right corner: (56.25 N, 11.23 E). Mean value: 0.04 K. Standard deviation: 0.75 K. Number of observations: 1914.



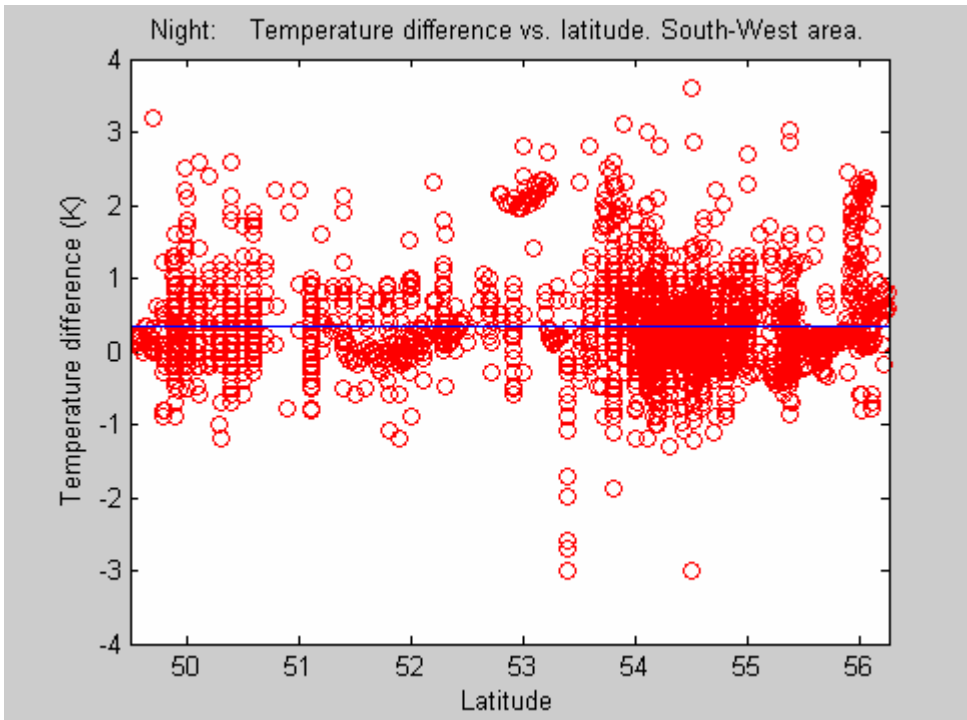
**Figure 11a.** Night time data. Variations of temperature differences in the North-East area: Lower left corner: (56.26 N, 11.27 E). Upper right corner: (66.90 N, 30.20 E). Mean value: 0.18 K. Standard deviation: 0.67 K. Number of observations: 589.



**Figure 11b.** Night time data. Variations of temperature differences in the South-East area: Lower left corner: (54.07 N, 11.30 E). Upper right corner: (56.25 N, 20.95 E). Mean value: 0.06 K. Standard deviation: 0.63 K. Number of observations: 1201



**Figure 11c.** Night time data. Variations of temperature differences in the North-West area: Lower left corner: (56.26 N, -6.70 E). Upper right corner: (65.81 N, 11.24 E). Mean value: 0.24 K. Standard deviation: 0.63 K. Number of observations: 1814



**Figure 11d:** Night time data. Variations of temperature differences in the South-West area: Lower left corner: (49.58 N, -4.68 E). Upper right corner: (56.24 N, 11.21 E). Mean value: 0.33 K. Standard deviation: 0.64 K. Number of observations: 2510

The following table extracts information from figures 10 and 11:

Region	Mean temp. diff.		Std. of temp. diff.		Number of obs.	
	Day	Night	Day	Night	Day	Night
NE	0.07 K	0.18 K	0.76 K	0.67 K	470	589
SE	-0.06 K	0.06 K	0.79 K	0.63 K	903	1201
NW	-0.05 K	0.24 K	0.89 K	0.63 K	861	1814
SW	0.04 K	0.33 K	0.75 K	0.64 K	1914	2510
Total	0.02 K	0.24 K	0.78 K	0.63 K	4148	6114

**Table 5.** Distribution on geographical regions.

Figure 10 does not give any reason to assume that there are regional dependencies in the temperature differences for daytime SSTs, while figure 11 indicates that the Western part of the region is worse determined than the Eastern part (especially the South-Eastern part) in the nighttime case. The standard deviations are slightly higher for daytime data than for nighttime data.

## Analyses that involve quality stamps of SST data

Finally, we shall examine whether the temperature differences depend on the quality stamp of the SST measurements. The SST product assigns a quality stamp between 0 and 5 to each grid point in the SST grid. Stamp values between 2 and 5 represent valid SST data. The meaning of the quality stamps is:

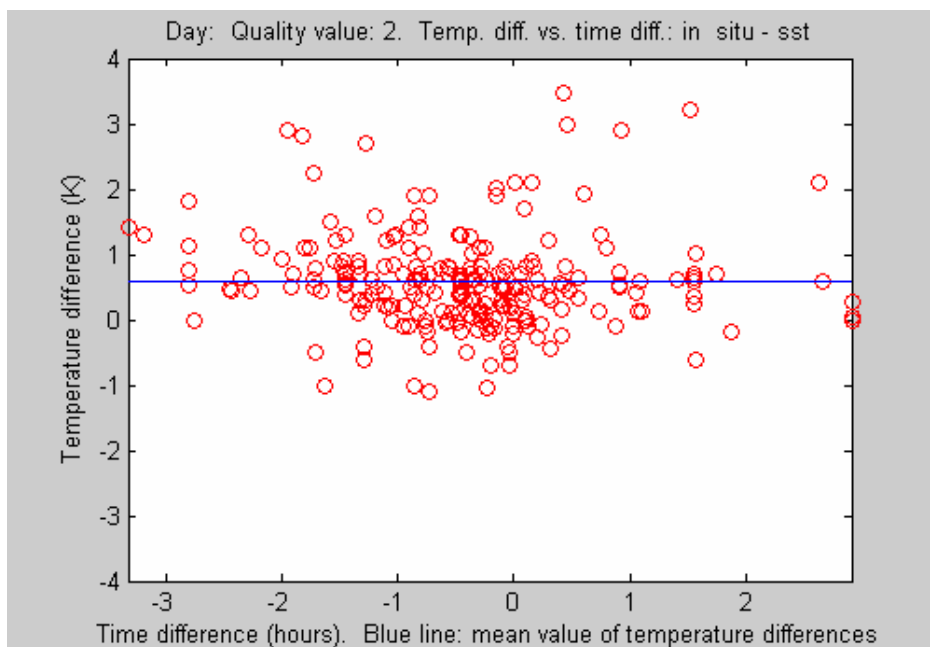
- 5: “Excellent” → No problem
- 4: “Good” → Close to the minimum climatologic value
- 3: “Acceptable” → Close to a cloudy pixel
- 2: “Bad” → Close to the minimum climatologic value and close to a cloud
- 1: “Erroneous” → No cloud classification or failure in SSI calculations
- 0: “Unprocessed” → Out of area, land, no satellite data

The climatologic values mentioned above are derived from a climatologic atlas based on 7 years of satellite derived SST measurements. Obviously, 7 years of measurements is not an overwhelming dataset to constitute a climatologic atlas. However, the fact that a calculated SST value is close to a sort of “minimum expected SST value” indicates that the calculated value may be too low.

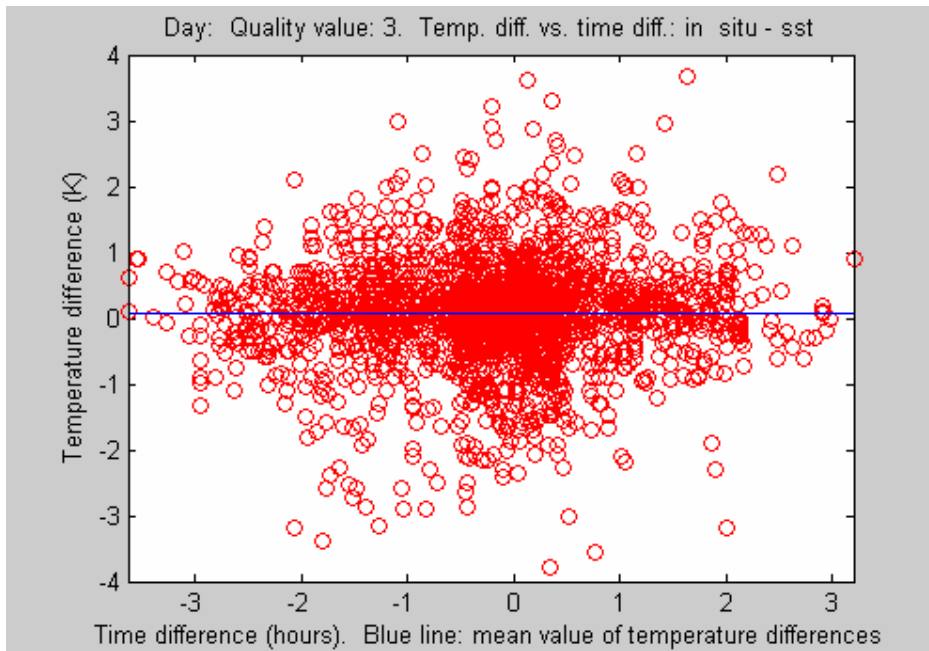
Quality stamps 2 and 4 involve “Close to the minimum climatologic value”, while quality stamps 2 and 3 involve “Close to cloud”. Consequently, SSTs classified as quality 2 and 4 data are by definition suspected to be too low, while quality 3 data are suspicious only because of their geographical location near a cloud.

Consequently, one may expect that the SST values are too low for quality 2, 3 and 4 data (compared to the in situ measurements), but that quality 3 SSTs fit better to in situ measurements than quality 2 and 4 SSTs. Quality 2 SSTs are expected to be worse than the others (compared to the in situ measurements).

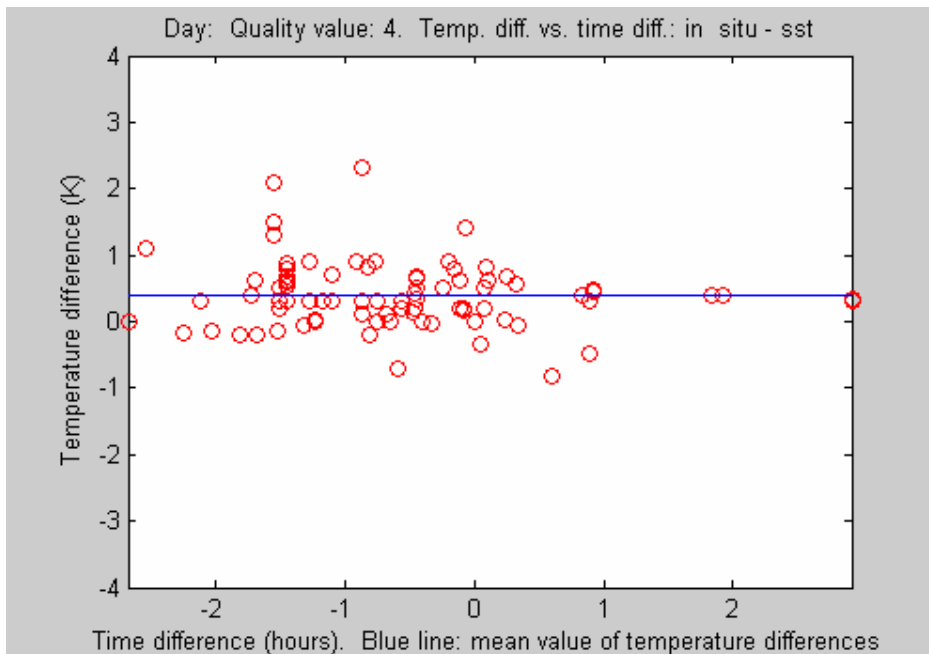
In order to examine these hypotheses, we have separated the temperature differences into four datasets depending on the quality value:



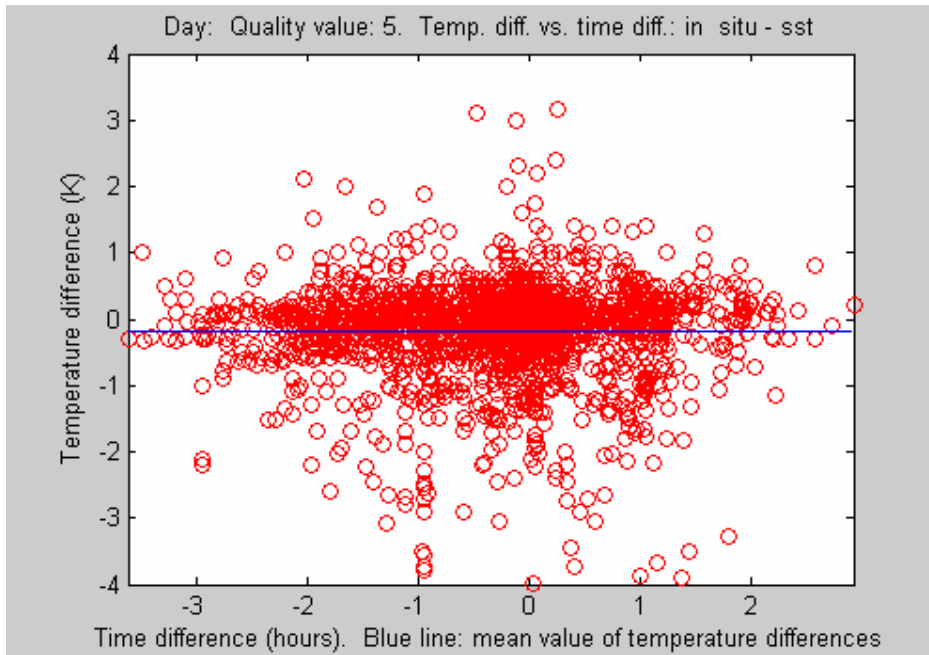
**Figure 12a.** Daytime data. Temperature differences vs. time differences for quality value 2. Mean value: 0.58 K. Standard deviation: 0.73 K. Number of observations: 233. Percentage of total number of obs.: 5.6 %.



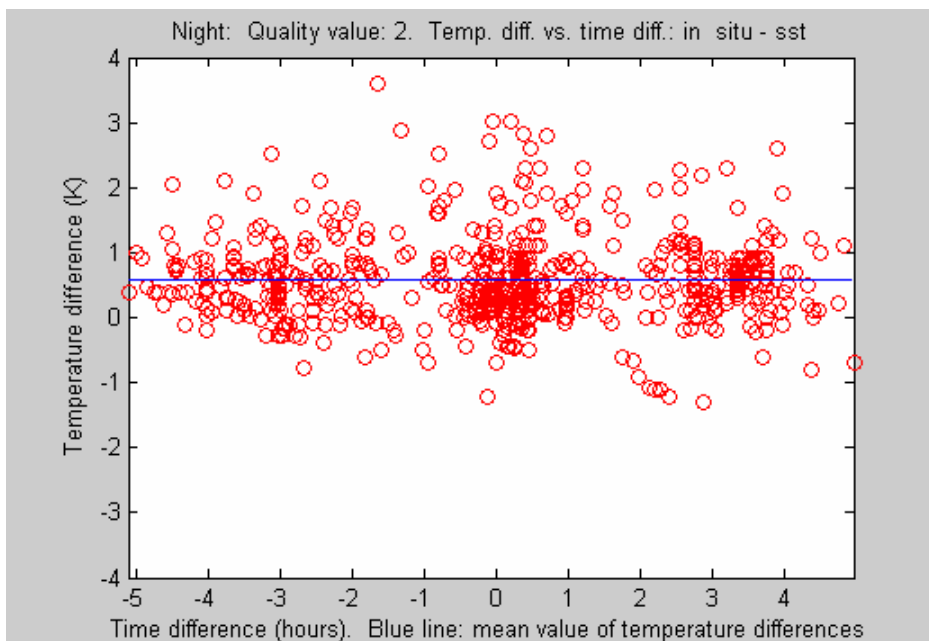
**Figure 12b.** Daytime data. Temperature differences vs. time differences for quality value 3. Mean value: 0.08 K. Standard deviation: 0.81 K. Number of observations: 2035. Percentage of total number of obs.: 49.1 %.



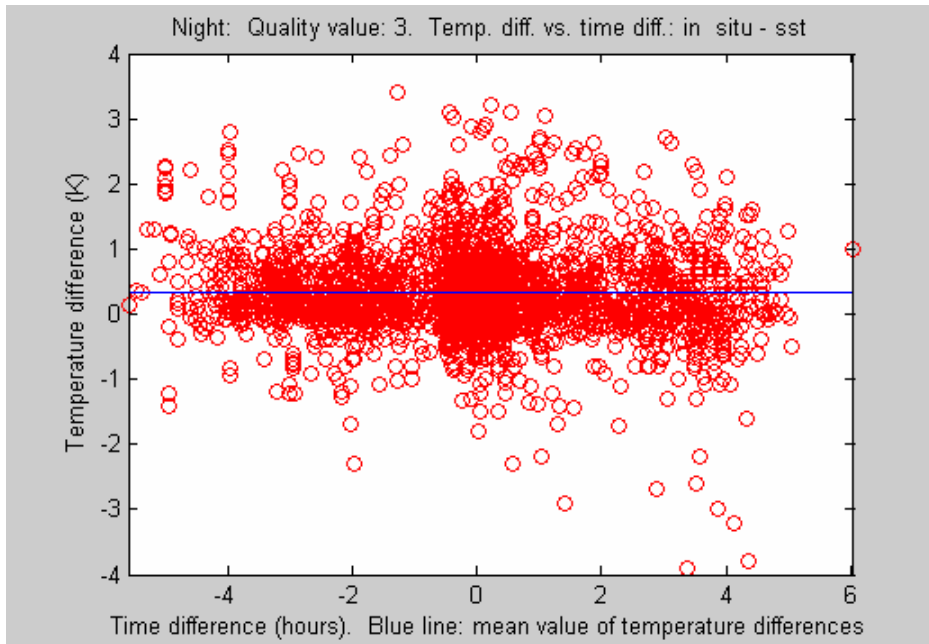
**Figure 12c.** Daytime data. Temperature differences vs. time differences for quality value 4. Mean value: 0.40 K. Standard deviation: 0.51 K. Number of observations: 83. Percentage of total number of obs.: 2.0 %.



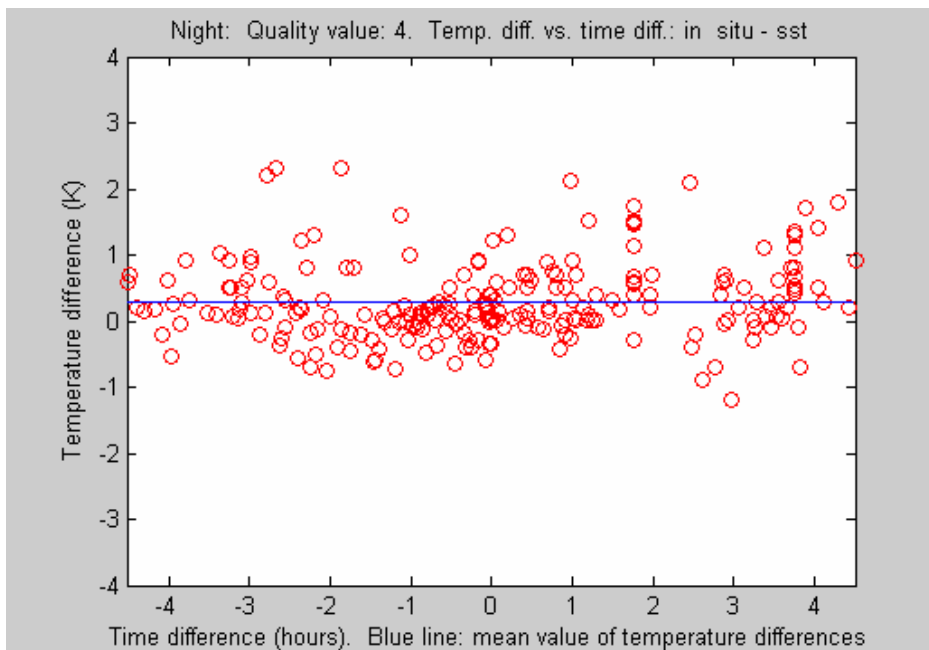
**Figure 12d.** Daytime data. Temperature differences vs. time differences for quality value 5. Mean value: -0.19 K. Standard deviation: 0.73 K. Number of observations: 1797. Percentage of total number of obs.: 43.3 %.



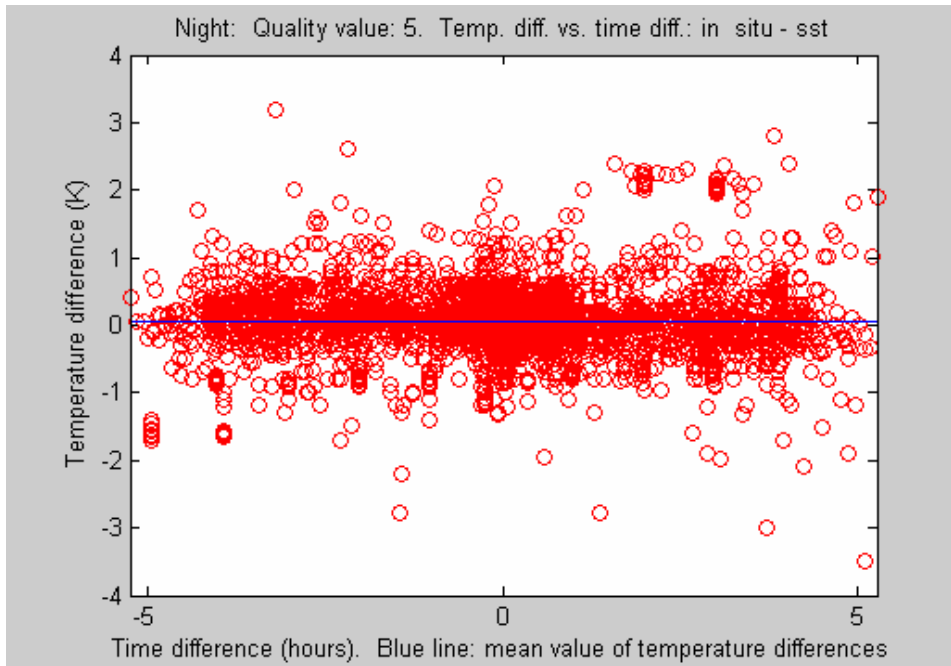
**Figure 13a.** Night time data. Temperature differences vs. time differences for quality value 2. Mean value: 0.58 K. Standard deviation: 0.66 K. Number of observations: 595. Percentage of total number of obs.: 9.7 %.



**Figure 13b.** Night time data. Temperature differences vs. time differences for quality value 3. Mean value: 0.32 K. Standard deviation: 0.67 K. Number of observations: 2662. Percentage of total number of obs.: 43.5 %.



**Figure 13c.** Night time data. Temperature differences vs. time differences for quality value 4. Mean value: 0.29 K. Standard deviation: 0.59 K. Number of observations: 233. Percentage of total number of obs.: 3.8 %.



**Figure 13d.** Night time data. Temperature differences vs. time differences for quality value 5. Mean value: 0.06 K. Standard deviation: 0.56 K. Number of observations: 2624. Percentage of total number of obs.: 42.9 %.

The following table extracts information from figures 12 and 13:

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.58 K	0.58 K	0.73 K	0.66 K	233	595	5.6 %	9.7 %
3	0.08 K	0.32 K	0.81 K	0.67 K	2035	2662	49.1 %	43.5 %
4	0.40 K	0.29 K	0.51 K	0.59 K	83	233	2.0 %	3.8 %
5	-0.19 K	0.06 K	0.73 K	0.56 K	1797	2624	43.3 %	42.9 %
Total	0.00 K	0.24 K	0.79 K	0.65 K	4148	6114	100.0 %	100.1 %

**Table 6.** Data analysis distributed on quality values.

It can be seen that quality values 3 and 5 are much more frequent than values 2 and (especially) 4, implying that the climatological atlas has a minor role in the quality classification. Furthermore, classification as quality 2 or 4 seems to be more frequent for nighttime images than for daytime images.

For nighttime data the mean temperature differences decrease significantly and the standard deviations decrease slightly with increasing quality value.

For daytime images the picture is more complex. The mean temperature difference is significantly higher for quality 4 data than for quality 3 data, but on the other hand the standard deviation is much smaller for quality 4 than for quality 3. The number of quality 4 data is, however, relatively small.

As expected the SST values are lower than the in situ measurements for quality values 2, 3 and 4. For both day and night, quality 2 mean temperature differences are – as expected - remarkably higher than for SSTs with other quality flags.

For daytime data, the quality 4 mean temperature difference is higher than for quality 3 data, but the standard deviation is remarkably lower. For nighttime data, quality 4 mean temperature difference as well as the standard deviation are slightly lower than for quality 3 data. Since also the number of daytime quality 4 SSTs

is relatively small, it is difficult to make any firm conclusions about the reliability of quality 3 SSTs compared to that of quality 4 SSTs.

For the nighttime situation, data with quality stamp 5 are best (if “best” is interpreted like “the mean value of the differences is closest to 0” or, equivalently, “the SST values are closest to the in situ temperatures”). Quality 4 data are second best.

For the daytime situation, data with quality stamp 3 are best, while quality 5 data are only second best. A possible explanation for this could be that while the daytime diurnal warming effect may cause the calculated SST to be too high (especially during the summer period), the presence of clouds may pull in the opposite direction. Therefore, the cloud effect and the diurnal warming effect may “cancel out” in quality 3 data, while only the diurnal warming effect is present in quality 5 data. This suspicion is supported by the observation that the very low temperature differences in figure 12d are exactly those found in the July and August data in figure 9b. See also table 7 below.

A consequence of the last two observations is that for the nighttime case, an exclusive use of quality 5 SSTs would give better results (i.e. mean values closer to 0.0 K) than the use of all SSTs. For the daytime case, an exclusive use of quality 5 SSTs would worsen the results. However, an exclusive use of quality 5 SSTs will of course reduce the number of valid observations significantly.

### Combined analysis of quality values with seasonal and geographical variations

The analyses from figures 8-9 and 12-13 may be combined into an analysis of temperature means for different months and quality flags. Due to a small number of observations with quality flags 2 and 4, it is necessary to perform the analysis based on seasons instead of individual months. Table 7 below summarises this analysis.

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.61 K	0.46 K	0.65 K	0.61 K	53	144	12.6 %	14.3 %
3	0.38 K	0.46 K	0.56 K	0.73 K	200	343	47.4 %	34.0 %
4	0.39 K	0.46 K	0.52 K	0.63 K	26	68	6.2 %	6.7 %
5	0.10 K	0.15 K	0.40 K	0.76 K	143	455	33.9 %	45.1 %
Total	0.32 K	0.32 K	0.54 K	0.74 K	422	1010	100.1 %	100.1 %

**Table 7a.** Data analysis distributed on quality values. Winter observations (Dec., Jan., Feb.)

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	-0.25 K	0.39 K	0.32 K	0.51 K	8	30	2.2 %	7.0 %
3	-0.13 K	0.23 K	0.68K	0.50 K	210	215	57.2 %	50.0 %
4	-0.11 K	0.19 K	0.08 K	0.08 K	6	6	1.6 %	1.4 %
5	-0.21 K	-0.03 K	0.66 K	0.31 K	143	179	39.0 %	41.6 %
Total	-0.16 K	0.13 K	0.66 K	0.45 K	367	430	100.0 %	100.0 %

**Table 7b.** Data analysis distributed on quality values. Spring observations (Mar., Apr., May)

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.61 K	0.56 K	0.96 K	0.79 K	41	179	1.7 %	5.4 %
3	-0.08 K	0.30 K	0.87 K	0.70 K	1087	1460	45.4 %	44.2 %
4	0.08 K	0.35 K	0.51 K	0.63 K	14	62	0.6 %	1.9 %
5	-0.29 K	0.03 K	0.78 K	0.54 K	1253	1603	52.3 %	48.5 %
Total	-0.18 K	0.18 K	0.84 K	0.65 K	2395	3304	100.0 %	100.0 %

**Table 7c.** Data analysis distributed on quality values. Summer observations (Jun., Jul., Aug.)

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.62 K	0.69 K	0.67 K	0.59 K	131	242	13.6 %	17.7 %
3	0.39 K	0.34 K	0.68 K	0.60 K	538	644	55.8 %	47.0 %
4	0.61 K	0.14 K	0.43 K	0.52 K	37	97	3.8 %	7.1 %
5	0.15 K	0.13 K	0.44 K	0.47 K	258	387	26.8 %	28.2 %
Total	0.37 K	0.33 K	0.63 K	0.59 K	964	1370	100.0 %	100.0 %

**Table 7d.** Data analysis distributed on quality values. Autumn observations (Sep., Oct., Nov)

From tables 7a-7d several conclusions can be drawn:

- For both day and night observations, the overall mean values are higher at winter and autumn than at spring and summer.
- For all seasons and for both day and night, quality 5 observations have a lower mean value than the whole dataset for the given season.
- During autumn and winter, in most cases there are nearly identical day and night biases for each quality flag.
- The quality 5 bias for winter and autumn is 0.10 – 0.15 K. This may be considered as a bias when diurnal and seasonal effects are eliminated.
- Apart from night observations at winter, quality 2 observations always behave worse than the other quality flags.
- Apart from night observations at spring and autumn, there is no indication that quality 4 observations give better results (i.e. lower absolute mean values) than quality 3 observations. However, quality 4 observations have always lower standard deviation than quality 3 observations.
- For both day and night observations there are relatively more quality 2 and 4 observations at winter and autumn than at spring and summer.
- For all seasons there are relatively more quality 2 observations and fewer quality 3 observations at night than at day.

The analyses of figures 10-11 and 12-13 may be combined into an analysis of temperature means for different geographical areas and quality flags. Table 8 below summarises this analysis.

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.31 K	0.50 K	0.31 K	0.82 K	11	14	2.3 %	2.4 %
3	0.25 K	0.31 K	0.81 K	0.71 K	208	259	44.3 %	44.0 %
4	0.23 K	0.03 K	0.31 K	0.30 K	7	17	1.5 %	2.9 %
5	-0.10 K	0.06 K	0.71 K	0.61 K	244	299	51.9 %	50.8 %
Total	0.07 K	0.18 K	0.76 K	0.67 K	470	589	100.0 %	100.1 %

**Table 8a.** Data analysis distributed on quality values. North-East region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.60K	0.44 K	0.91 K	0.50 K	33	81	3.7 %	6.7 %
3	-0.06 K	0.21 K	0.84 K	0.70 K	527	533	58.4 %	44.4 %
4	-0.11 K	-0.12 K	0.08 K	0.31 K	6	63	0.7 %	5.2 %
5	-0.13 K	-0.14 K	0.67 K	0.52 K	337	524	37.3 %	43.6 %
Total	-0.06 K	0.06 K	0.79 K	0.63 K	903	1201	100.1 %	99.9 %

**Table 8b.** Data analysis distributed on quality values. South-East region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.59 K	0.59 K	0.58 K	0.66 K	81	214	9.4 %	11.8 %
3	0.25 K	0.36 K	0.81 K	0.69 K	317	708	36.8 %	39.0 %
4	0.39 K	0.65 K	0.44 K	0.50 K	30	45	3.5 %	2.5 %
5	-0.41 K	0.03 K	0.86 K	0.48 K	433	847	50.3 %	46.7 %
Total	-0.05 K	0.24 K	0.89 K	0.63 K	861	1814	100.0 %	100.0 %

**Table 8c.** Data analysis distributed on quality values. North-West region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.60 K	0.62 K	0.80 K	0.70 K	108	286	5.6 %	11.4 %
3	0.07 K	0.36 K	0.78 K	0.62 K	983	1162	51.4 %	46.3 %
4	0.52 K	0.42 K	0.58 K	0.64 K	40	108	2.1 %	4.3 %
5	-0.11 K	0.21 K	0.65 K	0.60 K	783	954	40.9 %	38.0 %
Total	0.04 K	0.33 K	0.75 K	0.64 K	1914	2510	100.0 %	100.0 %

**Table 8d.** Data analysis distributed on quality values. South-West region

From tables 8a-8d several conclusions can be drawn:

- For the daytime case the absolute values of the quality 5 mean values are higher than for the whole set of observations in all regions except the North-Eastern region, and for the nighttime case this also applies to the South-Eastern region. In the other cases quality 5 data are better than the whole dataset. Consequently, for nighttime SSTs there is generally an improvement when only quality 5 data are used, while the opposite seems to be the case for daytime observations. See also discussion on tables 6 and 7 above.
- For both day and night observations quality 4 observations are worse (i.e. have higher absolute mean values) than quality 3 observations in the Western regions. This also applies to daytime observations in the South-Eastern region.
- For both day and night observations quality 4 observations are better (i.e. have lower absolute mean values) than quality 3 observations in the North-Eastern region. This also applies to nighttime observations in the South-Eastern region.

- In the Western regions there is a large difference between quality 4 and 5 SSTs. This also applies to daytime observations in the North-Eastern region.
- For both day and night observations there are relatively more quality 2 observations in the Western regions than in the Eastern regions (especially the North-Eastern region). For quality 4 data no obvious regional variations are seen.
- Consequently, some East-West differences may be seen with respect to the results for different quality values. Whether these differences are of importance or not, is a question for further investigation.

The analyses from tables 7 (comparison of quality values and seasons) and tables 8 (comparison of quality values and regions) will now be combined into an analysis of quality values as function of as well seasons and regions:

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.35 K	0.12 K	0.32 K	0.71 K	8	6	17.0 %	14.6 %
3	0.39 K	0.26 K	0.32 K	0.48 K	13	20	27.7 %	48.8 %
4	0.27 K	-0.16 K	0.31 K	0.30 K	6	8	12.8 %	19.5 %
5	0.23 K	0.11 K	0.19 K	0.52 K	20	7	42.6 %	17.1 %
Total	0.30 K	0.13 K	0.27 K	0.50 K	47	41	100.1 %	100.0 %

**Table 9a.** Data analysis distributed on quality values. Winter observations in the North-East region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.38 K	0.08 K	0.00 K	0.17 K	1	4	2.0 %	2.9 %
3	0.46 K	0.11 K	0.57 K	0.40 K	22	35	44.9 %	25.2 %
4	-	-0.28 K	-	0.44 K	0	2	0.0 %	1.4 %
5	-0.03 K	-0.70 K	0.39 K	0.23 K	26	98	53.1 %	70.5 %
Total	0.20 K	-0.46 K	0.53 K	0.52 K	49	139	100.0 %	100.0 %

**Table 9b.** Data analysis distributed on quality values. Winter observations in the South-East region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.51 K	0.37 K	0.62 K	0.46 K	10	67	23.8 %	41.1 %
3	0.47 K	0.05 K	0.65 K	0.66 K	26	35	61.9 %	21.5 %
4	0.31 K	0.74 K	0.00 K	0.54 K	1	24	2.4 %	14.7 %
5	0.01 K	0.12 K	0.16 K	0.77 K	5	37	11.9 %	22.7 %
Total	0.42 K	0.30 K	0.61 K	0.64 K	42	163	100.0 %	100.0 %

**Table 9c.** Data analysis distributed on quality values. Winter observations in the North-West region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.71 K	0.61 K	0.71 K	0.72 K	34	67	12.0 %	10.0 %
3	0.35 K	0.58 K	0.56 K	0.74 K	139	253	48.9 %	37.9 %
4	0.43 K	0.44 K	0.59 K	0.63 K	19	34	6.7 %	5.1 %
5	0.11 K	0.42 K	0.43 K	0.67 K	92	313	32.4 %	46.9 %
Total	0.32 K	0.50 K	0.57 K	0.70 K	284	667	100.0 %	99.9 %

**Table 9d.** Data analysis distributed on quality values. Winter observations in the South-West region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	-	2.07 K	-	0.00 K	0	1	0.0 %	1.0 %
3	0.86 K	0.56 K	0.58 K	0.44 K	19	36	42.2 %	35.0 %
4	-	0.18 K	-	0.07 K	0	5	0.0 %	4.9 %
5	-0.01 K	0.13 K	0.45 K	0.31 K	26	61	57.8 %	59.2 %
Total	0.36 K	0.30 K	0.67 K	0.44 K	45	103	100.0 %	100.1 %

**Table 9e.** Data analysis distributed on quality values. Spring observations in the North-East region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	-0.14 K	0.34 K	0.07 K	0.26 K	7	24	3.4 %	12.8 %
3	-0.26 K	0.12 K	0.62K	0.55 K	111	98	53.4 %	52.4 %
4	-0.11 K	0.27 K	0.08 K	0.00 K	6	1	2.9 %	0.5 %
5	-0.11 K	-0.17 K	0.59 K	0.29 K	84	64	40.4 %	34.2 %
Total	-0.19 K	0.05 K	0.59 K	0.48 K	208	187	100.0 %	99.9 %

**Table 9f.** Data analysis distributed on quality values. Spring observations in the South-East region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	-	-	-	-	0	0	0.0 %	0.0 %
3	-0.14 K	-	0.21 K	-	2	0	10.5 %	0.0 %
4	-	-	-	-	0	0	0.0 %	0.0 %
5	-1.21 K	-0.21 K	0.39 K	0.12 K	17	30	89.5 %	100.0 %
Total	-1.10 K	-0.21 K	0.50 K	0.12 K	19	30	100.0 %	100.0 %

**Table 9g.** Data analysis distributed on quality values. Spring observations in the North-West region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	-1.03 K	0.29 K	0.00 K	0.88 K	1	5	1.1 %	4.5 %
3	-0.17 K	0.20 K	0.61 K	0.38 K	78	81	82.1 %	73.6 %
4	-	-	-	-	0	0	0.0 %	0.0 %
5	-0.01 K	0.14 K	0.64 K	0.21 K	16	24	16.8 %	21.8 %
Total	-0.16 K	0.19 K	0.62 K	0.38 K	95	110	100.0 %	99.9 %

**Table 9h.** Data analysis distributed on quality values. Spring observations in the South-West region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	-	1.00 K	-	1.12 K	0	2	0.0 %	0.6 %
3	0.09 K	0.33 K	0.84 K	0.70 K	133	129	44.0 %	40.6 %
4	-0.04 K	-	0.00 K	-	1	0	0.3 %	0.0 %
5	-0.19 K	0.05 K	0.79 K	0.63 K	168	187	55.6 %	58.8 %
Total	-0.06 K	0.17 K	0.82 K	0.68 K	302	318	99.9 %	100.0 %

**Table 9i.** Data analysis distributed on quality values. Summer observations in the North-East region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	1.35 K	0.58 K	1.28 K	1.18 K	5	7	1.1 %	1.5 %
3	-0.28 K	0.15 K	0.88K	0.75 K	255	223	55.3 %	47.3 %
4	-	-	-	-	0	0	0.0 %	0.0 %
5	-0.17 K	0.02 K	0.76 K	0.54 K	201	241	43.6 %	51.2 %
Total	-0.21 K	0.09K	0.85 K	0.66 K	461	471	100.0 %	100.0 %

**Table 9j.** Data analysis distributed on quality values. Summer observations in the South-East region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.42 K	0.62 K	0.71 K	0.90 K	21	65	3.8 %	4.9 %
3	0.12 K	0.36 K	0.86 K	0.72 K	213	564	38.9 %	42.7 %
4	-0.03 K	0.42 K	0.66 K	0.48 K	7	10	1.3 %	0.8 %
5	-0.57 K	0.01 K	0.90 K	0.48 K	307	681	56.0 %	51.6 %
Total	-0.26 K	0.19 K	0.94 K	0.65 K	548	1320	100.0 %	100.0 %

**Table 9k.** Data analysis distributed on quality values. Summer observations in the North-West region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.61 K	0.51 K	1.09 K	0.69 K	15	105	1.4 %	8.8 %
3	-0.12 K	0.29 K	0.85 K	0.64 K	486	544	44.8 %	45.5 %
4	0.24 K	0.34 K	0.30 K	0.66 K	6	52	0.6 %	4.4 %
5	-0.21 K	0.07 K	0.67 K	0.57 K	577	494	53.2 %	41.3 %
Total	-0.15 K	0.22 K	0.77 K	0.63 K	1084	1195	100.0 %	100.0 %

**Table 9l.** Data analysis distributed on quality values. Summer observations in the South-West region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.21 K	0.44 K	0.34 K	0.53 K	3	5	3.9 %	3.9 %
3	0.46 K	0.17 K	0.72 K	0.85 K	43	74	56.6 %	58.3 %
4	-	0.21 K	-	0.28 K	0	4	0.0 %	3.1 %
5	0.07 K	0.01 K	0.50 K	0.79 K	30	44	39.5 %	34.6 %
Total	0.30 K	0.13 K	0.65 K	0.81 K	76	127	100.0 %	99.9 %

**Table 9m.** Data analysis distributed on quality values. Autumn observations in the North-East region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.69 K	0.50 K	0.84 K	0.44 K	20	46	10.8 %	11.4 %
3	0.40 K	0.36 K	0.75	0.69 K	139	177	75.1 %	43.8 %
4	-	-0.13 K	-	0.31 K	0	60	0.0 %	14.9 %
5	0.03K	0.00 K	0.32 K	0.43 K	26	121	14.1 %	30.0 %
Total	0.38 K	0.19K	0.73 K	0.59 K	185	404	100.0 %	100.1 %

**Table 9n.** Data analysis distributed on quality values. Autumn observations in the South-East region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.67 K	0.75 K	0.50 K	0.51 K	50	82	19.8 %	27.2 %
3	0.56 K	0.48 K	0.62 K	0.50 K	76	109	30.2 %	36.2 %
4	0.53 K	0.65 K	0.25 K	0.41 K	22	11	8.7 %	3.7 %
5	0.15 K	0.19 K	0.40 K	0.32 K	104	99	41.3 %	32.9 %
Total	0.41 K	0.47 K	0.53 K	0.50 K	252	301	100.0 %	100.0 %

**Table 9o.** Data analysis distributed on quality values. Autumn observations in the North-West region

Quality stamp	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
2	0.56 K	0.74 K	0.75 K	0.68 K	58	109	12.9 %	20.3 %
3	0.33 K	0.33 K	0.65 K	0.47 K	280	284	62.1 %	52.8 %
4	0.74 K	0.58 K	0.60 K	0.58 K	15	22	3.3 %	4.1 %
5	0.22 K	0.25 K	0.47 K	0.42 K	98	123	21.7 %	22.9 %
Total	0.35 K	0.41 K	0.64 K	0.54 K	451	538	100.0 %	100.1 %

**Table 9p.** Data analysis distributed on quality values. Autumn observations in the South-West region

The next two tables show quality 5 observations only. First each season is displayed by area, and then each area is displayed by season.

Area	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
N-E	0.23 K	0.11 K	0.19 K	0.52 K	20	7	14.0 %	1.5 %
S-E	-0.03 K	-0.70 K	0.39 K	0.23 K	26	98	18.2 %	21.5 %
N-W	0.01 K	0.12 K	0.16 K	0.77 K	5	37	3.5 %	8.1 %
S-W	0.11 K	0.42 K	0.43 K	0.67 K	92	313	64.3 %	68.8 %
Total	0.10 K	0.15 K	0.40 K	0.76 K	143	455	100.0 %	99.9 %

**Table 10a.** Data analysis distributed on areas. Quality 5 Winter observations

Area	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
N-E	-0.01 K	0.13 K	0.45 K	0.31 K	26	61	18.2 %	34.1 %
S-E	-0.11 K	-0.17 K	0.59 K	0.29 K	84	64	58.7 %	35.8 %
N-W	-1.21 K	-0.21 K	0.39 K	0.12 K	17	30	11.9 %	16.8 %
S-W	-0.01 K	0.14 K	0.64 K	0.21 K	16	24	11.2 %	13.4 %
Total	-0.21 K	-0.03 K	0.66 K	0.31 K	143	179	100.0 %	99.9 %

**Table 10b.** Data analysis distributed on areas. Quality 5 Spring observations

Area	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
N-E	-0.19 K	0.05 K	0.79 K	0.63 K	168	187	13.4 %	11.7 %
S-E	-0.17 K	0.02 K	0.76 K	0.54 K	201	241	16.0 %	15.0 %
N-W	-0.57 K	0.01 K	0.90 K	0.48 K	307	681	24.5 %	42.5 %
S-W	-0.21 K	0.07 K	0.67 K	0.57 K	577	494	46.0 %	30.8 %
Total	-0.29 K	0.03 K	0.78 K	0.54 K	1253	1603	99.9 %	100.0 %

**Table 10c.** Data analysis distributed on areas. Quality 5 Summer observations

Area	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
N-E	0.07 K	0.01 K	0.50 K	0.79 K	30	44	11.6 %	11.4 %
S-E	0.03 K	0.00 K	0.32 K	0.43 K	26	121	10.1 %	31.3 %
N-W	0.15 K	0.19 K	0.40 K	0.32 K	104	99	40.3 %	25.6 %
S-W	0.22 K	0.25 K	0.47 K	0.42 K	98	123	38.0 %	31.8 %
Total	0.15 K	0.13 K	0.44 K	0.47 K	258	387	100.0 %	100.1 %

**Table 10d.** Data analysis distributed on areas. Quality 5 Autumn observations

Area	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
Winter	0.23 K	0.11 K	0.19 K	0.52 K	20	7	8.2 %	2.3 %
Spring	-0.01 K	0.13 K	0.45 K	0.31 K	26	61	10.7 %	20.4 %
Summer	-0.19K	0.05 K	0.79 K	0.63 K	168	187	68.9 %	62.5 %
Autumn	0.07 K	0.01 K	0.50 K	0.79 K	30	44	12.3 %	14.7 %
Total	-0.10 K	0.06 K	0.71 K	0.61 K	244	299	100.1 %	99.9 %

**Table 11a.** Data analysis distributed on seasons. Quality 5 North-East observations

Area	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
Winter	-0.03 K	-0.70 K	0.39 K	0.23 K	26	98	7.7 %	18.7 %
Spring	-0.11 K	-0.17 K	0.59 K	0.29 K	84	64	24.9 %	12.2 %
Summer	-0.17 K	0.02 K	0.76 K	0.54 K	201	241	59.6 %	46.0 %
Autumn	0.03 K	0.00 K	0.32 K	0.43 K	26	121	7.7 %	23.1 %
Total	-0.13 K	-0.14 K	0.67 K	0.52 K	337	524	99.9 %	100.0 %

**Table 11b.** Data analysis distributed on seasons. Quality 5 South-East observations

Area	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
Winter	0.01 K	0.12 K	0.16 K	0.77 K	5	37	1.2 %	4.4 %
Spring	-1.21 K	-0.21 K	0.39 K	0.12 K	17	30	3.9 %	3.5 %
Summer	-0.57 K	0.01 K	0.90 K	0.48 K	307	681	70.9 %	80.4 %
Autumn	0.15 K	0.19 K	0.40 K	0.32 K	104	99	24.0 %	11.7 %
Total	-0.41 K	0.03 K	0.86 K	0.48 K	433	847	100.0 %	100.0%

**Table 11c.** Data analysis distributed on seasons. Quality 5 North-West observations

Area	Mean temp. diff.		Std. of temp. diff.		Number of obs.		Percentage of obs.	
	Day	Night	Day	Night	Day	Night	Day	Night
Winter	0.11 K	0.42 K	0.43 K	0.67 K	92	313	11.7 %	32.8 %
Spring	-0.01 K	0.14 K	0.64 K	0.21 K	16	24	2.0 %	2.5 %
Summer	-0.21 K	0.07 K	0.67 K	0.57 K	577	494	73.7 %	51.8 %
Autumn	0.22 K	0.25 K	0.47 K	0.42 K	98	123	12.5 %	12.9 %
Total	-0.11K	0.21 K	0.65 K	0.60 K	783	954	99.9 %	100.0%

**Table 11d.** Data analysis distributed on seasons. Quality 5 South-West observations

## Conclusions

3873 day time observations and 5926 night time observations (SSTs and corresponding in situ temperatures) have been compared. The observations are located within the MNOR area.

In situ measurements from depths between 0 and 5 meters and observations with unknown depth fit equally well to the corresponding SSTs, so most of the analysis has been concentrated on these measurements. This reduces the number of observations to 3832 (day) and 5886 (night).

For this set of observations the overall mean temperature differences between in situ temperature and SST are -0.02 K (day) and 0.24 K (night), and the corresponding standard deviations are 0.78 K (day) and 0.65 K (night). For nighttime data these numbers are slightly below the goals of O&SI SAF (mean values within +/- 0.4 K and standard deviations below 0.7 K). For the daytime data the standard deviation is a bit higher than the goal of 0.7 K. There is no precisely formulated mean value goals for daytime data, due to the diurnal warming problems. So generally the goals of O&SI SAF seem to be reached for the MNOR region.

The analyses lead to the following conclusions:

1. Time windows of 2 UTC +/- 4 hours (night time) and 12 UTC +/- 2 hours (day time) have been chosen. There is no indication that these time windows are too large.
2. There is no indication that any of the involved fixed stations (from the Marnet dataset), the ICES dataset or the data with unknown depths contribute with more erroneous data than others.
3. There is no indication that in situ measurements obtained at 0 meters depth are closer to the SST values than measurements obtained at 1-5 meters depth. Actually, for the nighttime case data from 1-5 meters depth are closer to the corresponding SSTs than data from 0 meters depth.
4. There seems to be a seasonal variation in the mean values of temperature differences for the daytime case, but not for the nighttime case. For daytime observations the SSTs are generally too high during the spring and (especially) summer periods and too low during the winter and autumn periods. Similarly, the daytime standard deviations are higher during the (spring and) summer time than for the rest of the year.
5. There is no indication that the temperature differences depend on the geographical region for the daytime case. For the nighttime case there may be a tendency for Western data to have higher mean values than Eastern data.
6. In the O&SI SAF product, each valid SST value is assigned a quality stamp between 2 and 5, where 5 is assumed to be best. For night time observations, SST data with quality 5 are best (mean temperature difference is 0.07 K), while quality 4 is second best (mean temp. diff. is 0.29 K). For daytime observations quality 3 SSTs are best with a mean value of 0.13 K, where quality 5 SSTs have a mean value of -0.18 K. For daytime data, quality 4 SSTs behave significantly worse than quality 3 and 5 SSTs. Quality 2 SSTs are worst in both the daytime and the nighttime case. Consequently, there is no firm indication that quality 4 data are generally better than quality 3 data.
7. There are some differences in the behaviour of quality flags in different geographical regions. However, in order to find out whether these differences are artefacts or not, it is necessary to look further into the SST processing routines.

**Based on these remarks we recommend the following:**

- 1. The seasonal variation of daytime temperature differences should be examined.**
- 2. Eventual geographical variations in SST calculations and quality stamps should be examined.**
- 3. It should be examined whether quality 4 SSTs are actually of a higher quality than quality 3 SSTs.**
- 4. It could be considered to perform a bias correction for the nighttime data.**