VEÐURSTOFA ÍSLANDS

Report
03006

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Spatial interpolation of Icelandic monthly mean temperature data

VÍ-ÚR06
Reykjavík
February 2003

1 Introduction

This report contains results from spatial analysis of the temperature field in Iceland using data from both manual and automatic weather stations. The analysis project can be logically separated into several different components or phases, and each of these will now be briefly described

1. The generation of 30 year (1961 - 1990) series of monthly temperature anomaly maps using manual weather stations stations in Iceland.

2. The construction of "best-guess" 1961-1990 monthly temperature means for the automatic stations. These thirty year temperature averages are referred to as *standard normals*, as defined by the World Meteorological Organization (WMO).

3. The generation of a map of the mean diurnal cycle in Iceland in June.

4. The construction of a "temperature model" for Iceland, i.e. a set of 13 maps each showing the mean temperature in Iceland, for a particular month as well as the annual mean temperature.

Below, the station network, the data and the methodology will be briefly described. Following this a discussion and a presentation of the results for each of the project components. A discussion section and appendices follow.

2 Data and methodology

2.1 The data

The data used comes from the observation network maintained by the Icelandic Meteorological Office. The location of the stations used in this project is shown in figure 1. The reference period is 1961 - 1990, although we also use from 1990 to 2000 for certain comparisons. Data from two types of stations are used in the study, from 84 manual stations and 31 automatic stations. The former yield fairly continuous time series of monthly mean temperatures throughout the reference period. The number of manual stations in operation at any one month was 62 at the start of the reference period, slowly increased to 78 stations towards 1990, but was sharply reduced in the 1990s. The manual stations tend to be close to the coast with few stations in the highlands. The latter data, from the automatic stations, are of much shorter duration, mostly from the late 1990s, but with several stations in the highlands.

2.2 Methodology

This section only discusses the methodology briefly and in general terms. For each project component further details on the methodology will be given in the appropriate section.

The project makes heavy use of the *kriging* interpolation method. The kriging method is a statistical interpolation method that uses all available data to evaluate

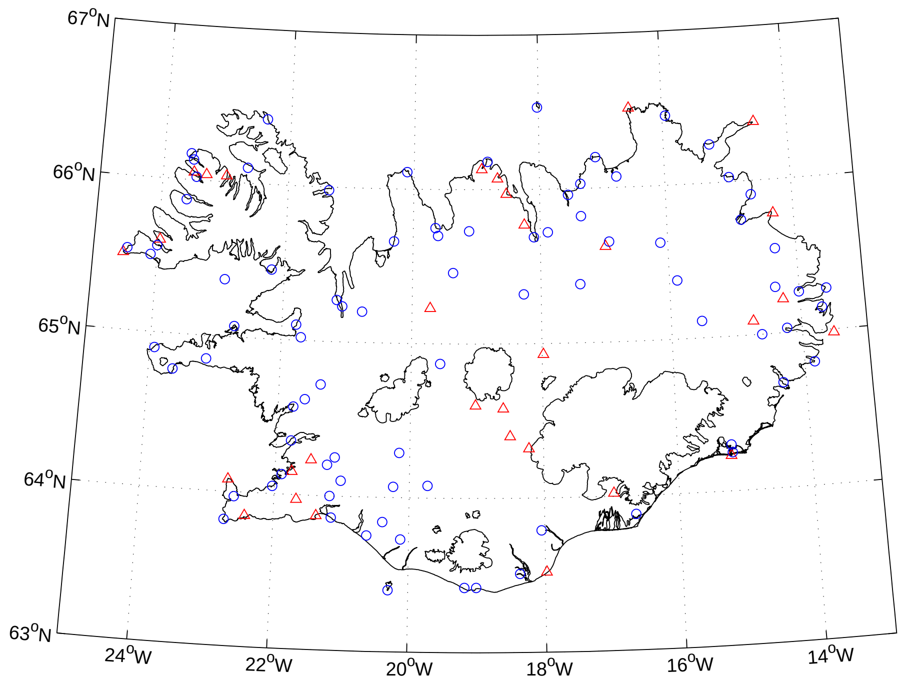


Figure 1: The station network used in this study. The manual stations (blue circles) have been operated throughout the 1961-1990 reference period, whereas the automatic stations (red triangles) have been in operation for less than a decade.

the interpolated value at a chosen point, weighing it according to the distance from the point of interpolation. The weights are calculated using the semivariogram of the data. Since the influence of points located far away from the interpolation point is small, we choose to use kriging *with moving neighborhood*. In that method a chosen number of points nearest to the interpolation point are used in the interpolation. This reduces the number of calculations and therefore the processing time. However, note that the weights are found from the semivariogram which is calculated using all the data. Kriging is exact in that the interpolation produces the observed value at each station. This method is used during phase 1 (the construction of mean temperature anomaly maps) of the project. Using the 1961-90 standard normals the mean monthly temperature anomalies are calculated for each station and the results subsequently interpolated to a grid using the kriging method. These are then used to provide a best guess for the standard normals of the automatic stations resulting in standard normals for each calendar month of 84 manned stations and 31 automatic stations. This data set provides the basis for the construction of a temperature model for Iceland.

The construction of the temperature model was done as follows : for each calendar month the mean temperatures are interpolated to a grid using a two step method consisting of *detrending* and the kriging of residuals. The detrending step is performed by fitting a linear model to the temperatures with the predictands of the model consisting of the station latitude, longitude and altitude. Furthermore, the fourth predictand used is an indicator of maritime influence. Two such indicators are tested, first the stations distance to coast (DTC model), and second the stations diurnal variability (DV model). In either case the residuals (the difference between the actual temperature and the linear model estimation) are calculated and these interpolated to a grid of resolution 1×1 km^2 using the kriging method. The temperature model is then obtained by using the linear model to produce a map of temperature estimations and adding to that the interpolated residual map. This is performed for each month of the year as well as the annual mean temperature, and for both DTC and DV methods.

To construct the DV model, the mean diurnal variability is first calculated for each station and then interpolated onto a grid using the kriging method. Finally, the time series of monthly temperatures are obtained by adding the anomaly maps found in the first phase to the temperature model.

3 Temperature anomalies at manual stations

Monthly temperature anomaly maps are useful for examining if a particular month was unusual at some specific location. The IMO publication Veðráttan has published hand drawn temperature anomaly maps since January 1981, and these can be used to check the quality of the automatically generated maps produced herein (see figure 4).

3.1 Methodology

Using monthly means of temperature and standard normals from all available manned stations, at each station the monthly temperature anomaly is calculated viz.,

$$a_{\mathrm{month}} = T_{\mathrm{month}} - \overline{T}_{\mathrm{std.n}},$$

where a_{month} is the anomaly for a given month with mean temperature T_{month} and standard normal $\overline{T}_{\mathrm{std.n}}$ for the corresponding month.

For each of the $30 \times 12 = 360$ months the data from the stations is then interpolated to a grid using kriging. A climatological semivariogram was calculated for each calendar month, using temperature data from 1961-90. It turned out that the semivariograms differed very little between months, so a mean climatological semivariogram was found, and used for all months. An exponential model was fitted to the raw data, resulting in

$$\gamma(h) = 0.9881 \left(1 - e^{-\left|\frac{h}{0.0132}\right|}\right),$$

where h is the separation distance (see figure 2).

Cross-validation of the results is performed by dropping a station out of the network, redoing the analysis and comparing the value from the interpolation (the estimated anomaly) to the value at the station that is dropped out (the actual anomaly). The difference between these two is a measure of the error associated with the method at the station location. Performing this for all the stations gives the error distribution inherent in the method. Furthermore, the hand drawn maps from Veðráttan for specific months can be used for additional comparison.

3.2 Results

The climatological semivariogram is shown in figure 2. The deviation from the mean 1961-90 temperature of three chosen months is shown in figures 3 - 5. For January 1992 we also show the hand drawn map for comparison. Most of the error values lie between -0.5 and 0.5 and the error is close to normally distributed. Comparison with hand drawn maps gives a measure of confidence in the method.

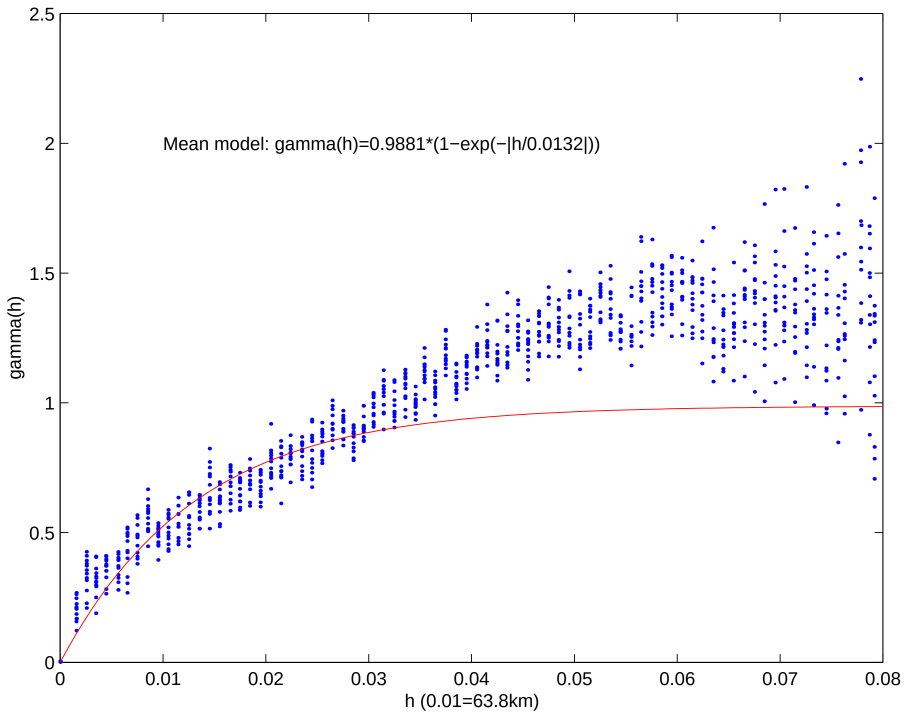


Figure 2: The climatological semivariogram. Blue dots: semivariogram values, red line: fitted exponential model.

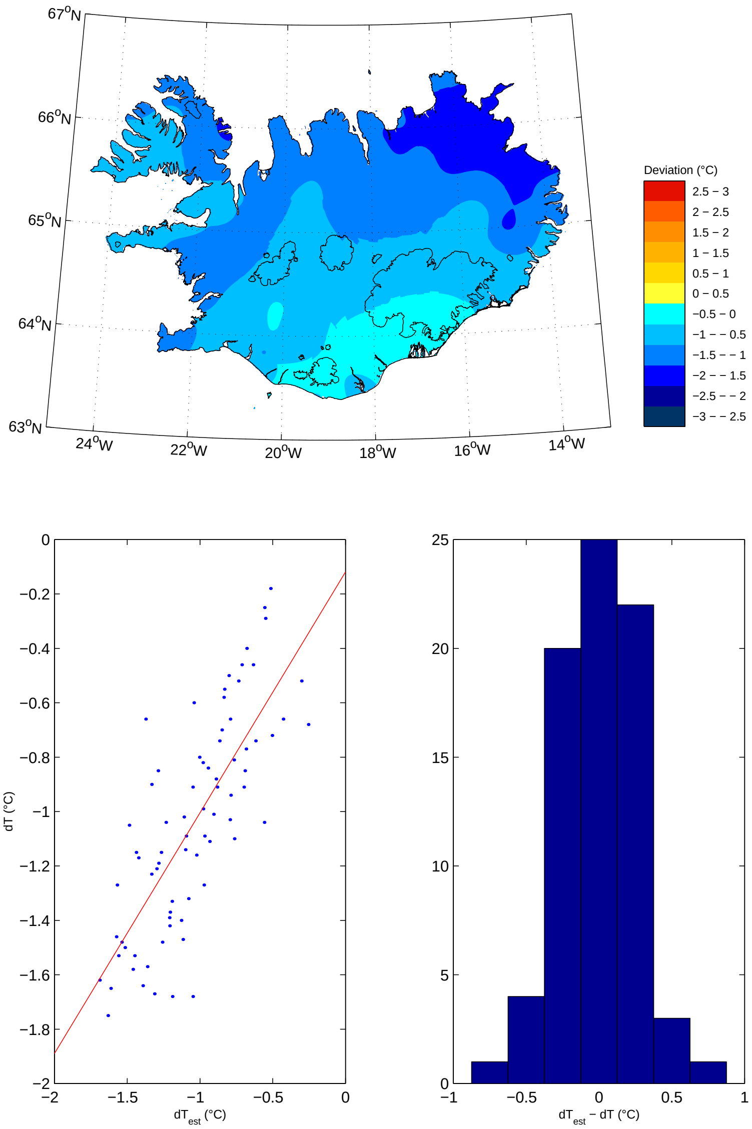


Figure 3: Deviation from mean April temperature 1961-90 in April 1979. Upper: deviation map. Lower: error distribution. The straight line is the $y = x$ case.

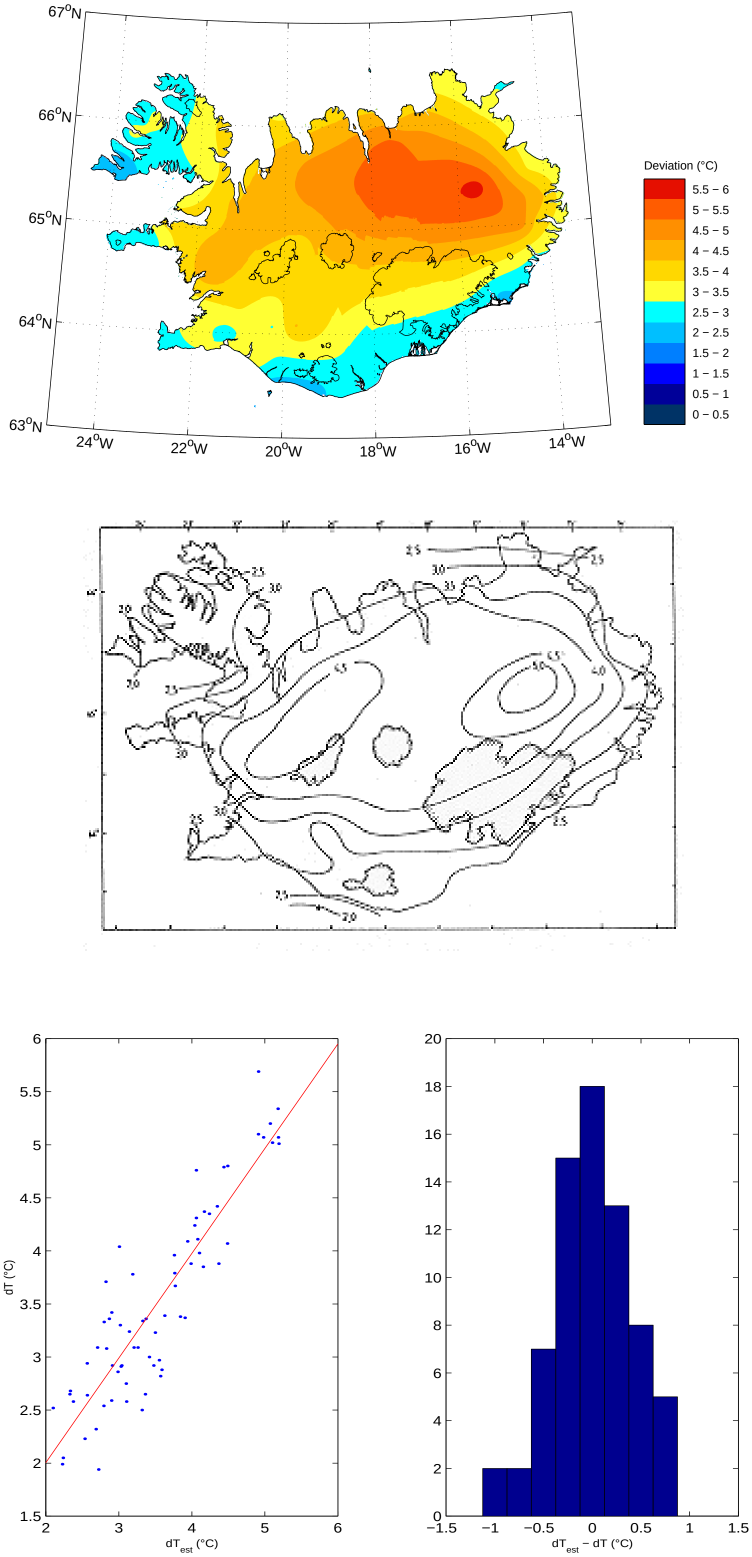


Figure 4: Deviation from mean January temperature 1961-90 in January 1992. Top: deviation map. Middle: hand drawn map. Bottom: error distribution.

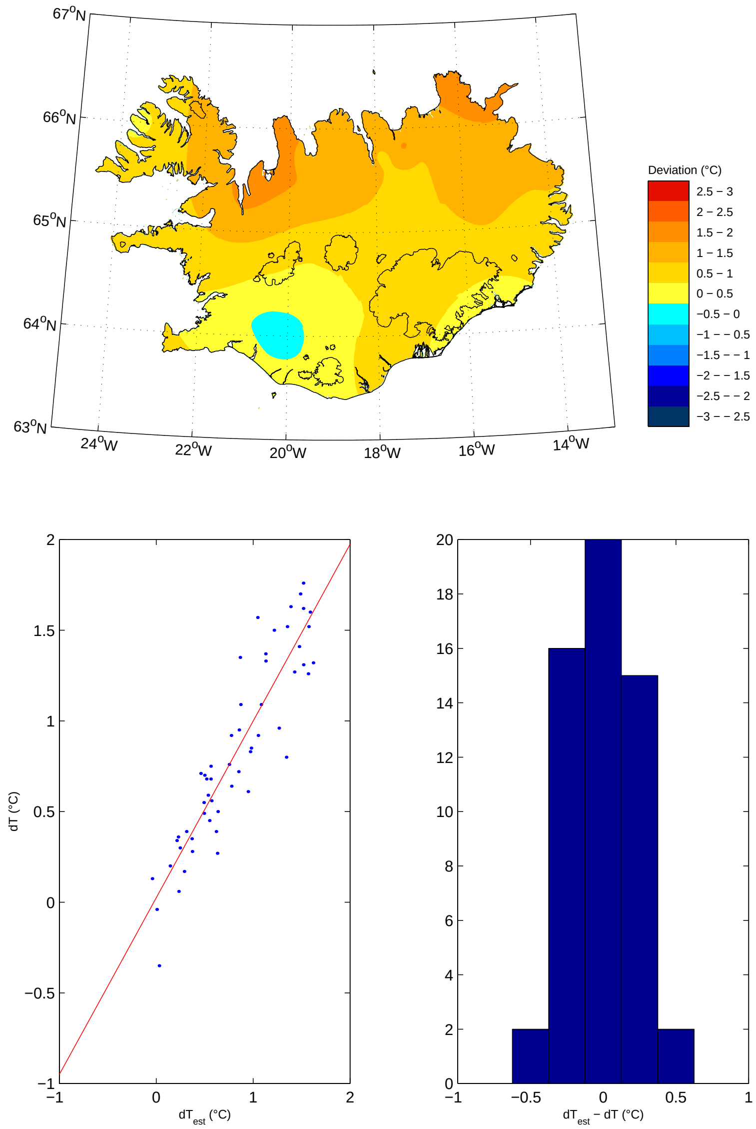


Figure 5: Deviation from mean July temperature 1961-90 in July 1996. Upper: deviation map. Lower: error distribution.

4 Estimates of standard normals for automatic stations

4.1 Methodology

The automatic stations selected are shown in figure 1 (red triangles). For a selected automatic station and a given month in the 5 year interval 1996-2001 the mean monthly temperature is calculated. Next the method from the previous phase is used to find how much the monthly temperature for this month and at this station deviated from the standard normal. Adding this deviation to the monthly mean (just calculated) gives an estimate of the 1961-90 temperature mean for this particular month at the station location. Performing this analysis for all months in the above 5 year interval yields 4-5 estimates of the standard normal for each calendar month (4 estimates for stations with shorter measurement periods). The mean of those estimates is then used as a best guess for the standard normal for this calendar month. This adds 31 automatic stations to the network.

4.2 Results

Figure 6 shows the distribution of monthly temperatures and estimated standard normals for the station in Grindavík (#1362). It is shown for January and July 1996-2001. The results are convincing for January but less so for July.

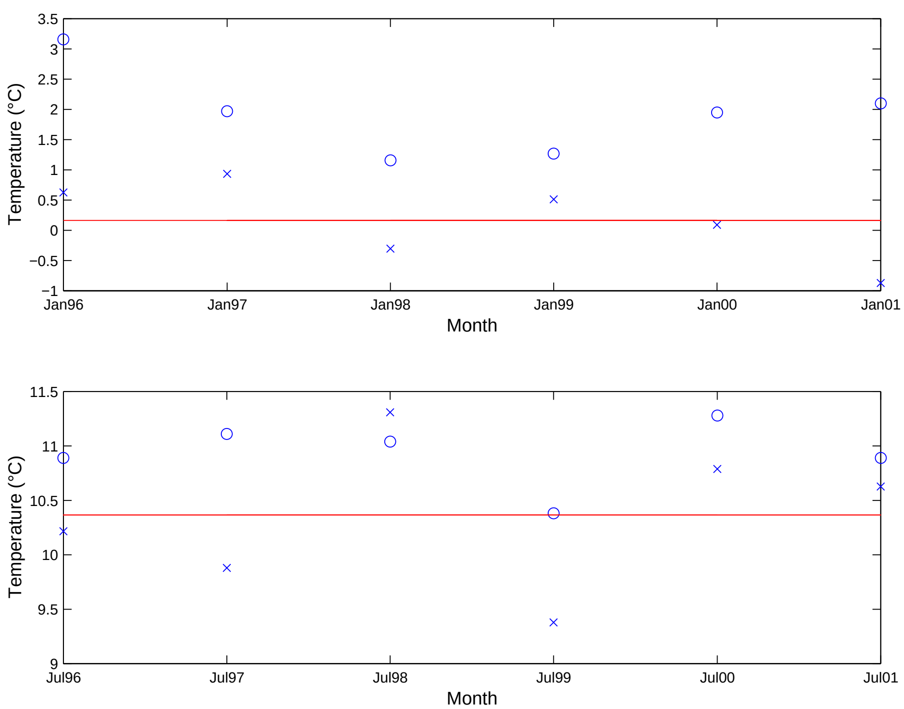


Figure 6: Standard normal estimation for automatic station in Grindavík (1362). Circles: mean monthly temperature. Crosses: estimated standard normal. Red line: mean estimated standard normal.

5 Diurnal variability map

5.1 Methodology

The structure of the diurnal variability field in of interest for two reasons. First, it may be important for various meteorological and agricultural studies and second for later use (the DV model) we need to calculate the diurnal variability in June. It is calculated for each station in the network. For each month the diurnal variability is defined as the difference between the maximum and minimum hourly temperature mean. This is calculated for the automatic stations and the mean diurnal variability found as the average over the measurement interval. Since measurements at manual stations are not done at every hour (generally every 3 hours) this method is not applicable. However, at these stations the daily maximum and minimum temperature is measured. The difference of these is generally around 2 °C higher than the diurnal variability defined above and we can use the automatic stations to find a linear fit

$$\overline{T^{\text{hr}}_{\text{max}} - T^{\text{hr}}_{\text{min}}} = b_0 + b_1 \left(\overline{T_{\text{x}} - T_{\text{n}}} \right)$$

where $T^{\text{hr}}_{\text{max/min}}$ is the mean maximum and minimum temperature calculated using hourly measurements, and $T_{\text{x/n}}$ is the mean maximum and minimum temperature calculated as an average over each day of the month. The fit (figure 7) is then used to estimate the mean diurnal variability at manual stations. For mapping purposes the mean June diurnal variability is interpolated onto a grid using 18 point kriging with moving neighborhood (figure 8).

5.2 Results

Figure 7 shows the results of the linear fit. The map of the mean June diurnal variability is shown in figure 8.

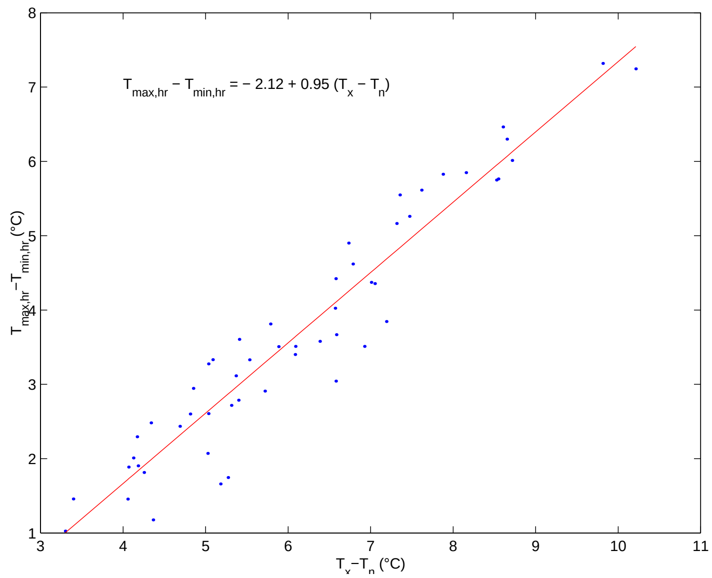


Figure 7: Linear fit of mean hourly measurements and mean daily temperatures. Blue points: actual values, red line: linear fit.

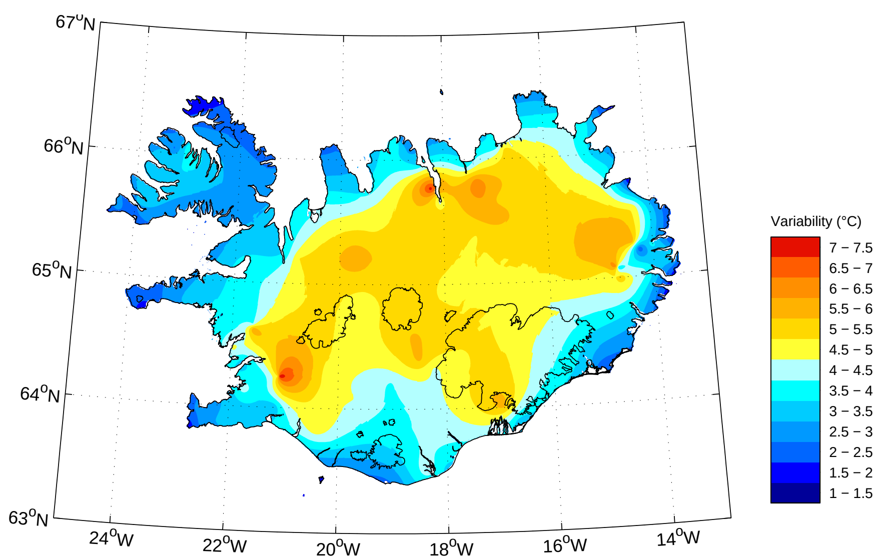


Figure 8: Mean June diurnal variability map.

6 A temperature model for Iceland

6.1 Methodology

The construction of the temperature model is a two step process. First, the temperature data is "detrended". Trend components of the temperature field are found using multiple linear regression on chosen predictands believed to be the most influential on temperature. This linear model does not capture local variability features which will be dominant in the residual field, i.e. the field that describes the difference between the actual temperature and the linear model estimations. This field is found by interpolating the residuals at the stations to a grid using the kriging method. The temperature model is then the sum of the linear component and the interpolated residual field.

We examine two models of temperature, both including longitude, latitude and altitude. The two models differ in the fourth variable, which for one is the distance to coast (DTC model)

$$T = a_0 + a_1 \cdot L_x + a_2 \cdot L_y + a_3 \cdot H + a_4 \cdot D_c$$

where L_x is the longitude, L_y latitude, H altitude and D_c the distance to coast. The other model uses the June diurnal variability, D_v, as an index of continentality (DV model)

$$T = c_0 + c_1 \cdot L_x + c_2 \cdot L_y + c_3 \cdot H + c_4 \cdot D_v.$$

When linear regression is performed it is often the case that the predictands need to be normalized. This is done in order to ensure proper balancing of matrices that need to be inverted during the course of the method. Here, it was found that normalizing the predictands was not needed.

6.2 Results

We show maps of mean 1961-90 temperatures for January and July, as well as the mean annual temperature (figures 9 - 11). Both models are shown, and the model difference. Maps were drawn for all months and they can be seen at

`http://www.vedur.is/vedurfar/vedurfarsmyndir`

Table results are presented in Appendix A, giving the model parameters, their significance and partial coefficient of determination.

In general, the absolute difference between the two models is on the order of 0.5 °C. The DTC model is slightly warmer in the winter but colder in the summer. Cross-validation of the results will be discussed in the next section.

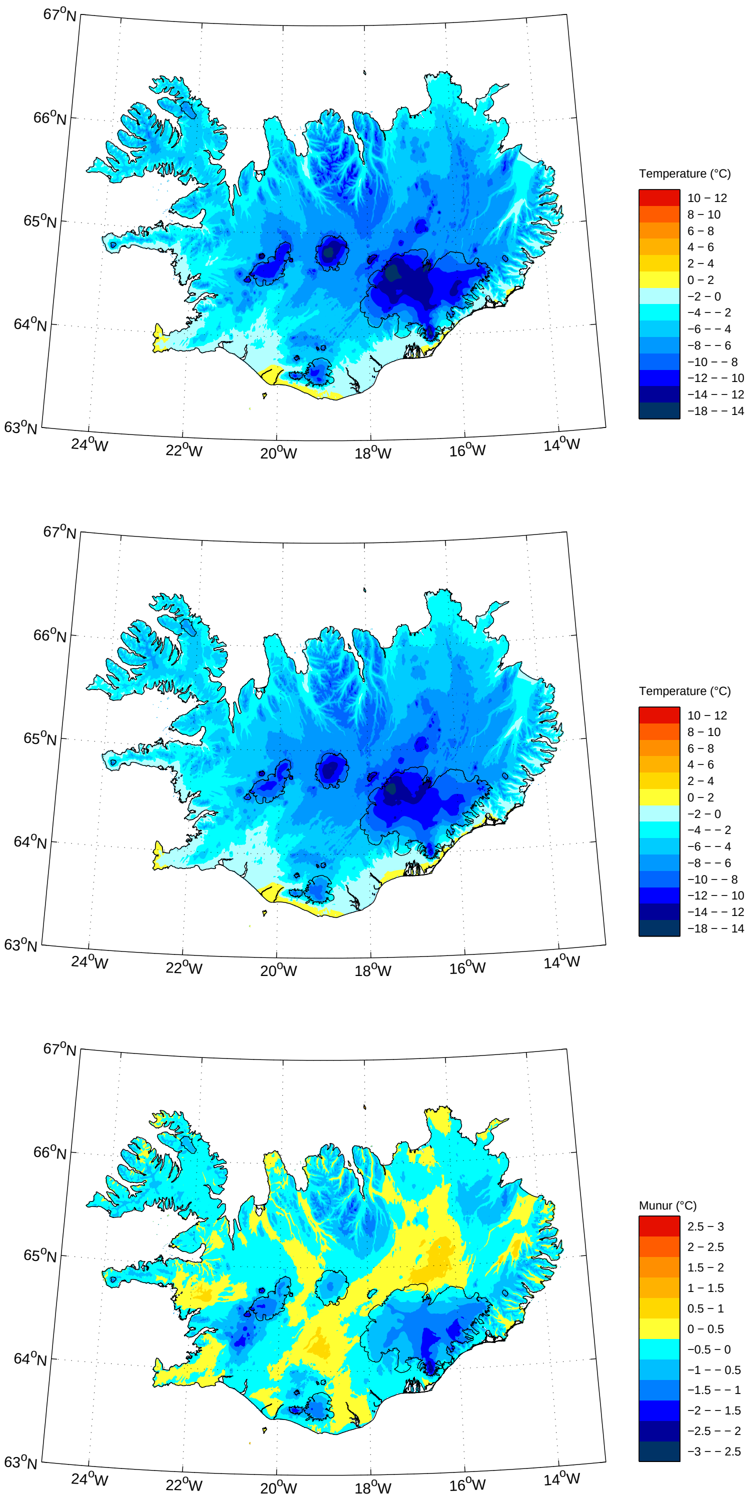


Figure 9: Model results for January. Top: DV model, middle: DTC model, bottom: model difference.

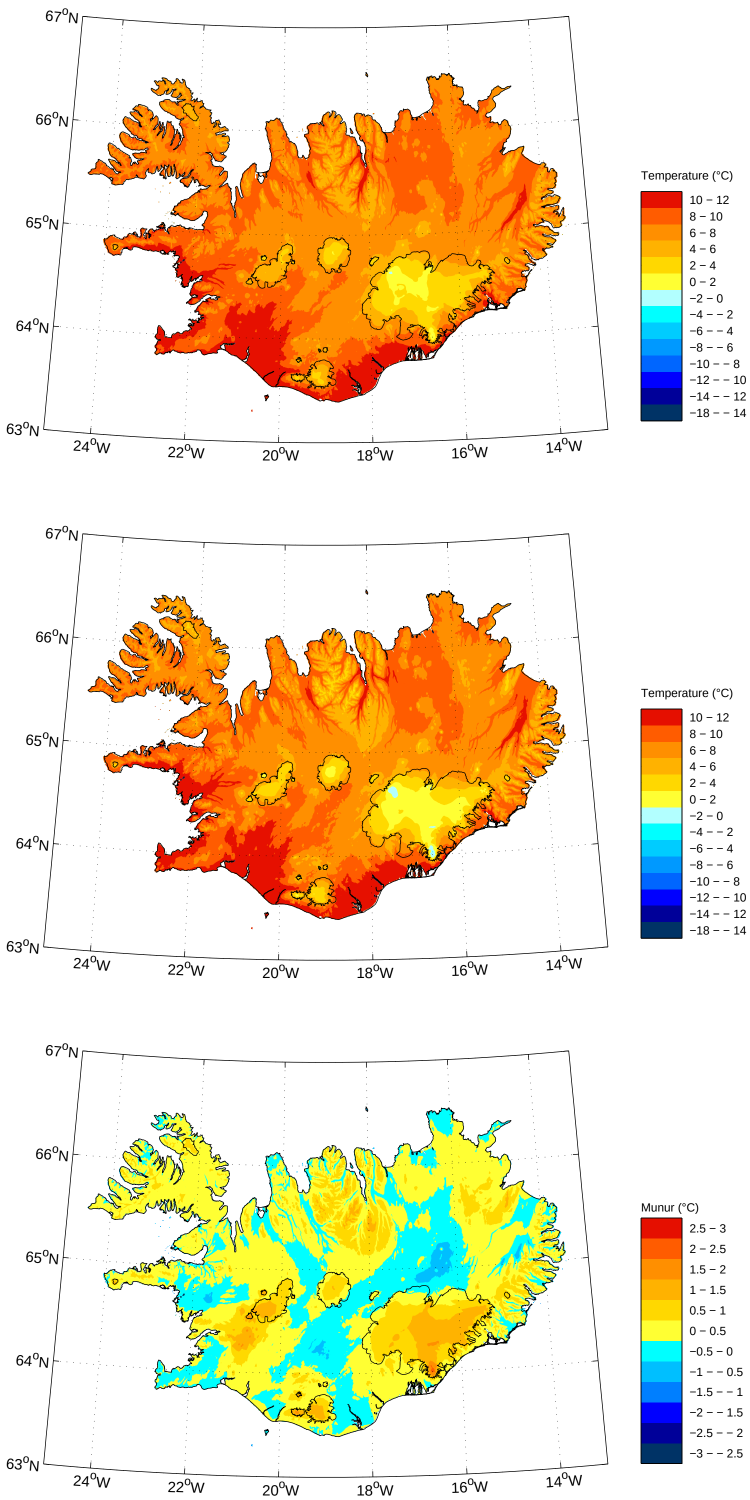


Figure 10: Model results for July. Top: DV model, middle: DTC model, bottom: model difference.

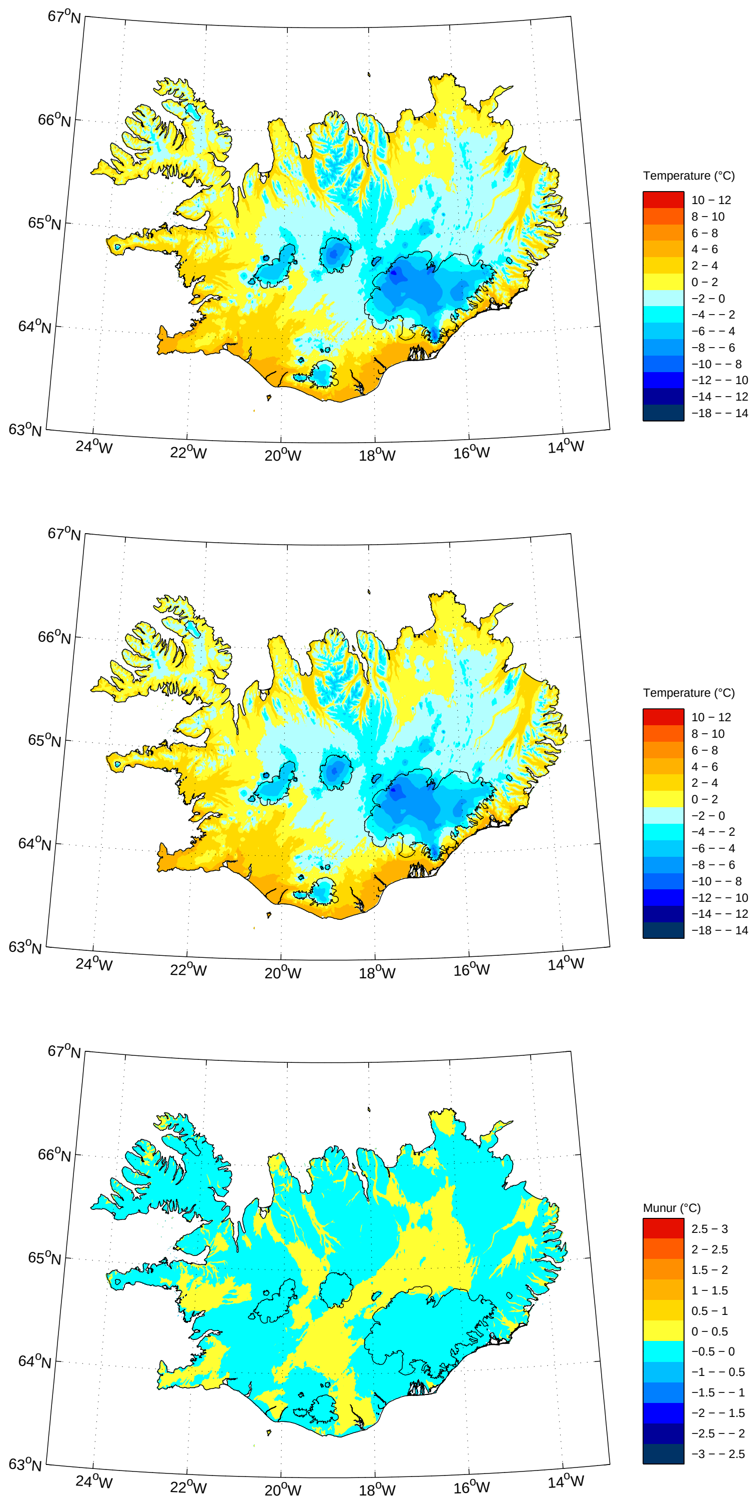


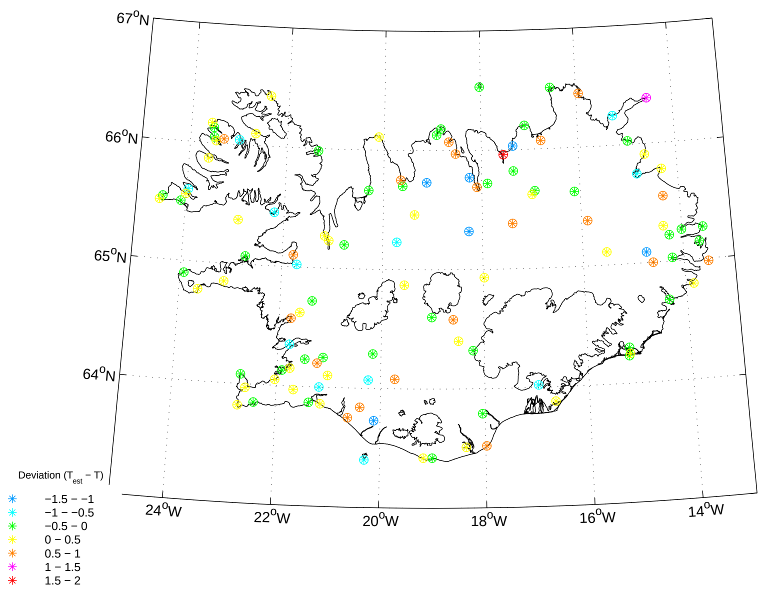
Figure 11: Model results for the mean annual temperature. Top: DV model, middle: DTC model, bottom: model difference.

6.3 Cross-validation

For each month statistical methods are used to examine the significance of the linear fit, and individual parameters (see tables in Appendix A). However, the real test of the method comes through a cross-validation procedure similar to that described in section 3.1 We leave one station out, and find a temperature model for Iceland with that station absent. We then examine the temperature that the model (linear + interpolated residual) estimates at the station location. The difference between this and the station data gives a measure of the error associated with the method at the station location. Performing this for all the stations gives the error distribution inherent in the method.

6.4 Results

Results of the cross-validation for selected months are shown in figures 12 - 15. In general, the error distribution is close to gaussian with most of the errors in the range of -1 to 1 °C. The spatial distribution of the errors is shown on maps, and there does not appear to be any bias with certain regions systematically yielding worse results than the others.



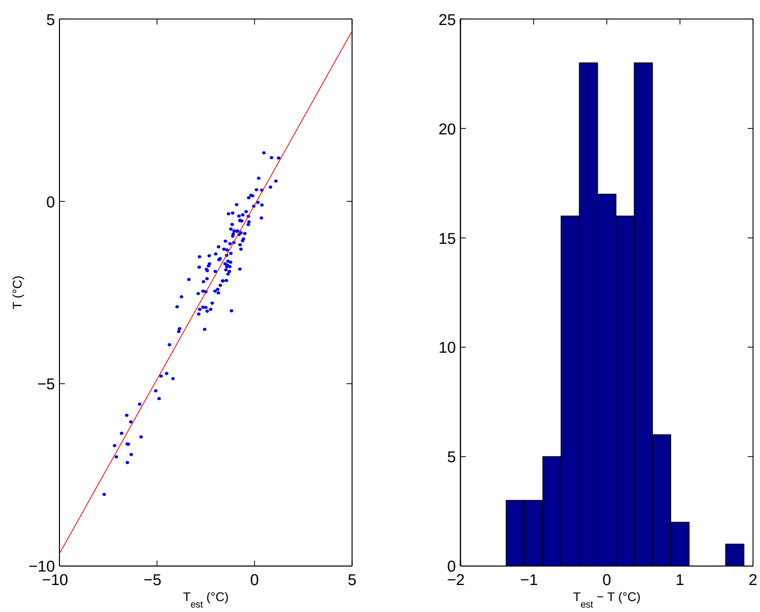


Figure 12: Cross-validation results for the DV model in January. Upper: map of the deviation. Lower: error distribution.

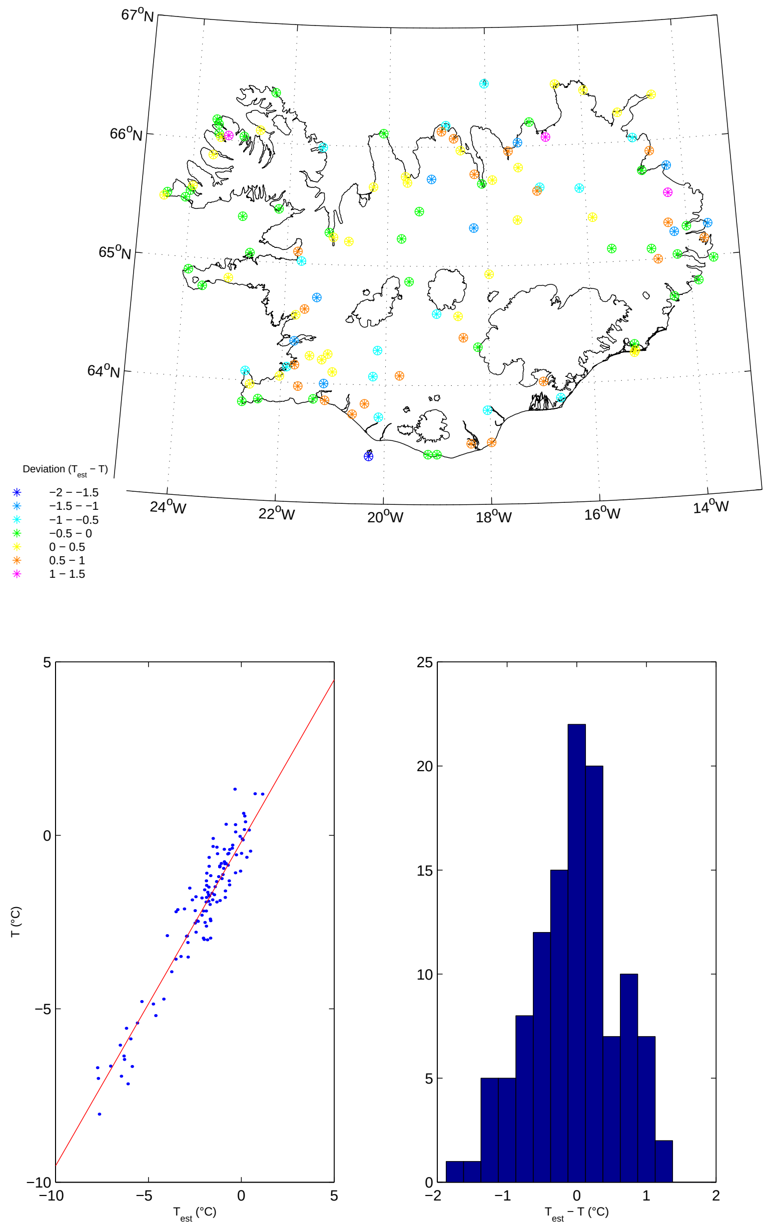


Figure 13: Cross-validation results for the DTC model in January. Upper: map of the deviation. Lower: error distribution.

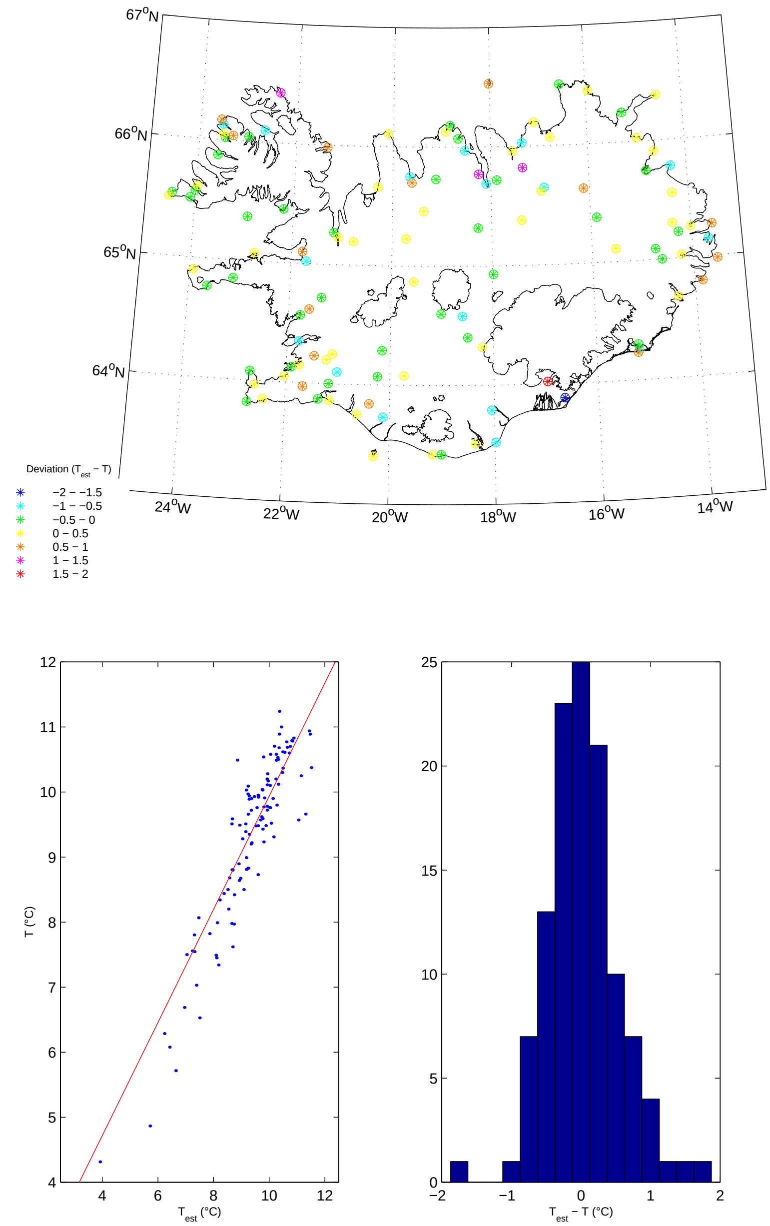


Figure 14: Cross-validation results for the DV model in July. Upper: map of the deviation. Lower: error distribution.

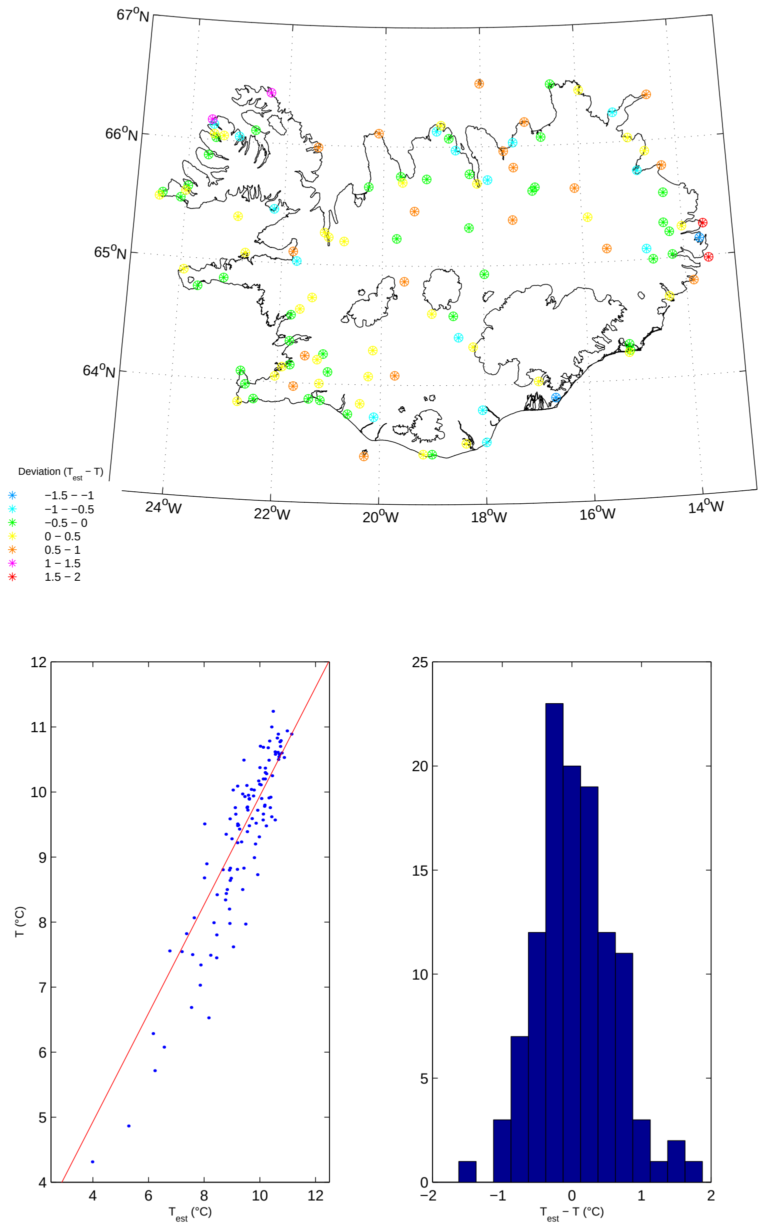


Figure 15: Cross-validation results for the DTC model in July. Upper: map of the deviation. Lower: error distribution.

A Model results

Below we present the results of linear model estimation. In the tables Coeff are the coefficients of the models

$$T = a_0 + a_1 \cdot L_x + a_2 \cdot L_y + a_3 \cdot H + a_4 \cdot D_c$$

and

$$T = c_0 + c_1 \cdot L_x + c_2 \cdot L_y + c_3 \cdot H + c_4 \cdot D_v.$$

(see section 6.1). Also shown in the tables are the standard deviation of the model parameters, StDev, the value of the student-t distribution and associated probability. The coefficients with p>0.05 are not significant at the 95% level. Finally, in the last column R_p^2 is the partial coefficient of determination, viz.,

$$R_p^2 = \frac{R^2 - R_{red}^2}{1 - R_{red}^2}$$

where R^2 is the model coefficient of determination and R_{red}^2 is the model coefficient of determination when the predictand in question is dropped out. For each table the lower part gives the multiple coefficient of determination, the value of the F distribution obtained for the model, the observed significance level for the test, p_F, and the standard error of the model.

For some months the t probability exceeds 0.05, in most cases for the longitude. This means that for those particular months the longitude does not contribute to the estimate of the temperature and could therefore be excluded from the model. However, we are constructing a physical model of temperature and thus choose to use the same parameters for all months of the year.

DV						**DTC**					
	Coeff	StDev	t	p	R_p^2		Coeff	StDev	t	p	R_p^2
a_0	47.5230	4.0915	11.6	0.000		c_0	49.1530	5.793	8.49	0.000	
a_1	0.0546	0.0173	3.2	0.002	0.08	c_1	0.0269	0.024	1.13	0.262	0.01
a_2	-0.7002	0.0618	-11.3	0.000	0.54	c_2	-0.7621	0.088	-8.70	0.000	0.41
a_3	-0.0076	0.0003	-28.9	0.000	0.88	c_3	-0.0064	0.001	-12.50	0.000	0.59
a_4	-0.5694	0.0431	-13.2	0.000	0.61	c_4	-0.0272	0.005	-5.97	0.000	0.24
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.93		347.63	0.00	0.56		0.86		164.71	0.00	0.78	

Table 1: Model results for mean January temperature 1961-90.

DV						DTC					
	Coeff	StDev	t	p	R^2_p		Coeff	StDev	t	p	R^2_p
a_0	57.9203	3.8047	15.2	0.000		c_0	59.1293	5.229	11.31	0.000	
a_1	0.0427	0.0161	2.6	0.009	0.06	c_1	0.0184	0.022	0.85	0.395	0.01
a_2	-0.8582	0.0574	-14.9	0.000	0.67	c_2	-0.9085	0.079	-11.49	0.000	0.55
a_3	-0.0081	0.0002	-33.0	0.000	0.91	c_3	-0.0071	0.000	-15.38	0.000	0.68
a_4	-0.4866	0.0401	-12.1	0.000	0.57	c_4	-0.0224	0.004	-5.46	0.000	0.21
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.94		428.26	0.00	0.52		0.89		220.31	0.00	0.71	

Table 2: Model results for mean February temperature 1961-90.

DV						DTC					
	Coeff	StDev	t	p	R^2_p		Coeff	StDev	t	p	R^2_p
a_0	72.8568	3.3439	21.8	0.000		c_0	74.3584	3.948	18.83	0.000	
a_1	0.0553	0.0142	3.9	0.000	0.12	c_1	0.0413	0.016	2.54	0.013	0.06
a_2	-1.0930	0.0505	-21.6	0.000	0.81	c_2	-1.1365	0.060	-19.04	0.000	0.77
a_3	-0.0083	0.0002	-38.5	0.000	0.93	c_3	-0.0074	0.000	-21.27	0.000	0.80
a_4	-0.3244	0.0353	-9.2	0.000	0.43	c_4	-0.0179	0.003	-5.78	0.000	0.23
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.95		554.29	0.00	0.46		0.94		401.09	0.00	0.53	

Table 3: Model results for mean March temperature 1961-90.

DV						DTC					
	Coeff	StDev	t	p	R^2_p		Coeff	StDev	t	p	R^2_p
a_0	76.2613	3.6495	20.9	0.000		c_0	77.4379	3.634	21.31	0.000	
a_1	-0.0201	0.0155	-1.3	0.196	0.02	c_1	-0.0184	0.015	-1.23	0.223	0.01
a_2	-1.1479	0.0551	-20.8	0.000	0.80	c_2	-1.1669	0.055	-21.24	0.000	0.80
a_3	-0.0082	0.0002	-34.8	0.000	0.92	c_3	-0.0077	0.000	-24.11	0.000	0.84
a_4	-0.0332	0.0385	-0.9	0.390	0.01	c_4	-0.0062	0.003	-2.17	0.032	0.04
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.94		417.52	0.00	0.50		0.94		433.52	0.00	0.49	

Table 4: Model results for mean April temperature 1961-90.

DV						DTC					
	Coeff	StDev	t	p	R^2_p		Coeff	StDev	t	p	R^2_p
a_0	66.5435	4.1506	16.0	0.000		c_0	66.3602	4.814	13.78	0.000	
a_1	-0.0790	0.0176	-4.5	0.000	0.16	c_1	-0.0626	0.020	-3.15	0.002	0.08
a_2	-0.9831	0.0627	-15.7	0.000	0.69	c_2	-0.9603	0.073	-13.20	0.000	0.61
a_3	-0.0076	0.0003	-28.6	0.000	0.88	c_3	-0.0081	0.000	-18.99	0.000	0.77
a_4	0.2960	0.0438	6.8	0.000	0.29	c_4	0.0113	0.004	2.98	0.004	0.07
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.90		261.73	0.00	0.57		0.88		193.31	0.00	0.65	

Table 5: Model results for mean May temperature 1961-90.

	DV					DTC					
	Coeff	StDev	t	p	R^2_p		Coeff	StDev	t	p	R^2_p
a_0	52.5951	4.3456	12.1	0.000		c_0	51.6663	5.848	8.83	0.000	
a_1	-0.0958	0.0184	-5.2	0.000	0.20	c_1	-0.0692	0.024	-2.87	0.005	0.07
a_2	-0.7386	0.0656	-11.3	0.000	0.54	c_2	-0.6905	0.088	-7.81	0.000	0.36
a_3	-0.0060	0.0003	-21.3	0.000	0.80	c_3	-0.0069	0.001	-13.35	0.000	0.62
a_4	0.5121	0.0458	11.2	0.000	0.53	c_4	0.0221	0.005	4.81	0.000	0.17
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.85		153.50	0.00	0.59		0.73		75.14	0.00	0.79	

Table 6: Model results for mean June temperature 1961-90.

	DV					DTC					
	Coeff	StDev	t	p	R^2_p		Coeff	StDev	t	p	R^2_p
a_0	48.1287	4.0919	11.8	0.000		c_0	46.6150	5.346	8.72	0.000	
a_1	-0.0931	0.0173	-5.4	0.000	0.21	c_1	-0.0700	0.022	-3.17	0.002	0.08
a_2	-0.6422	0.0618	-10.4	0.000	0.50	c_2	-0.5878	0.081	-7.27	0.000	0.32
a_3	-0.0052	0.0003	-19.6	0.000	0.78	c_3	-0.0063	0.000	-13.28	0.000	0.62
a_4	0.4830	0.0432	11.2	0.000	0.53	c_4	0.0236	0.004	5.62	0.000	0.22
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.83		134.39	0.00	0.56		0.72		69.90	0.00	0.72	

Table 7: Model results for mean July temperature 1961-90.

	DV					DTC					
	Coeff	StDev	t	p	R^2_p		Coeff	StDev	t	p	R^2_p
a_0	45.8105	3.3733	13.6	0.000		c_0	44.5146	3.757	11.85	0.000	
a_1	-0.0698	0.0143	-4.9	0.000	0.18	c_1	-0.0589	0.016	-3.80	0.000	0.12
a_2	-0.5919	0.0509	-11.6	0.000	0.55	c_2	-0.5559	0.057	-9.79	0.000	0.47
a_3	-0.0054	0.0002	-24.7	0.000	0.85	c_3	-0.0061	0.000	-18.47	0.000	0.76
a_4	0.2587	0.0356	7.3	0.000	0.32	c_4	0.0147	0.003	4.98	0.000	0.18
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.87		187.01	0.00	0.46		0.85		150.06	0.00	0.51	

Table 8: Model results for mean August temperature 1961-90.

	DV					DTC					
	Coeff	StDev	t	p	R^2_p		Coeff	StDev	t	p	R^2_p
a_0	50.5458	2.6064	19.4	0.000		c_0	49.8563	2.684	18.57	0.000	
a_1	-0.0211	0.0110	-1.9	0.058	0.03	c_1	-0.0263	0.011	-2.38	0.019	0.05
a_2	-0.6777	0.0394	-17.2	0.000	0.73	c_2	-0.6716	0.041	-16.55	0.000	0.71
a_3	-0.0065	0.0002	-38.6	0.000	0.93	c_3	-0.0066	0.000	-28.12	0.000	0.88
a_4	-0.0538	0.0275	-2.0	0.053	0.03	c_4	0.0010	0.002	0.49	0.623	0.00
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.95		473.51	0.00	0.36		0.94		457.71	0.00	0.36	

Table 9: Model results for mean September temperature 1961-90.

DV						DTC					
	Coeff	StDev	t	p	R_p^2		Coeff	StDev	t	p	R_p^2
a_0	53.1290	3.1760	16.7	0.000		c_0	53.1136	4.178	12.71	0.000	
a_1	0.0259	0.0134	1.9	0.057	0.03	c_1	0.0070	0.017	0.40	0.687	0.00
a_2	-0.7316	0.0480	-15.3	0.000	0.68	c_2	-0.7538	0.063	-11.94	0.000	0.56
a_3	-0.0070	0.0002	-34.1	0.000	0.91	c_3	-0.0066	0.000	-17.89	0.000	0.74
a_4	-0.3287	0.0335	-9.8	0.000	0.47	c_4	-0.0116	0.003	-3.53	0.001	0.10
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.94		427.54	0.00	0.43		0.90		242.62	0.00	0.56	

Table 10: Model results for mean October temperature 1961-90.

DV						DTC					
	Coeff	StDev	t	p	R_p^2		Coeff	StDev	t	p	R_p^2
a_0	40.5520	3.6026	11.3	0.000		c_0	41.3621	5.635	7.34	0.000	
a_1	0.0147	0.0153	1.0	0.337	0.01	c_1	-0.0150	0.023	-0.65	0.519	0.00
a_2	-0.5780	0.0544	-10.6	0.000	0.51	c_2	-0.6278	0.085	-7.37	0.000	0.33
a_3	-0.0074	0.0002	-31.8	0.000	0.90	c_3	-0.0064	0.000	-12.98	0.000	0.60
a_4	-0.5614	0.0380	-14.8	0.000	0.66	c_4	-0.0234	0.004	-5.28	0.000	0.20
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.94		425.06	0.00	0.49		0.86		162.50	0.00	0.76	

Table 11: Model results for mean November temperature 1961-90.

DV						DTC					
	Coeff	StDev	t	p	R_p^2		Coeff	StDev	t	p	R_p^2
a_0	44.7520	3.6844	12.1	0.000		c_0	46.2941	5.487	8.44	0.000	
a_1	0.0187	0.0156	1.2	0.232	0.01	c_1	-0.0088	0.023	-0.39	0.699	0.00
a_2	-0.6645	0.0556	-11.9	0.000	0.56	c_2	-0.7247	0.083	-8.74	0.000	0.41
a_3	-0.0076	0.0002	-31.9	0.000	0.90	c_3	-0.0064	0.000	-13.21	0.000	0.61
a_4	-0.5620	0.0389	-14.5	0.000	0.66	c_4	-0.0265	0.004	-6.15	0.000	0.26
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.94		427.60	0.00	0.50		0.87		183.28	0.00	0.74	

Table 12: Model results for mean December temperature 1961-90.

DV						DTC					
	Coeff	StDev	t	p	R_p^2		Coeff	StDev	t	p	R_p^2
a_0	54.7182	2.8202	19.4	0.000		c_0	54.9884	2.977	18.47	0.000	
a_1	-0.0139	0.0119	-1.2	0.247	0.01	c_1	-0.0196	0.012	-1.60	0.113	0.02
a_2	-0.7839	0.0426	-18.4	0.000	0.75	c_2	-0.7955	0.045	-17.68	0.000	0.74
a_3	-0.0071	0.0002	-38.9	0.000	0.93	c_3	-0.0068	0.000	-26.03	0.000	0.86
a_4	-0.1141	0.0297	-3.8	0.000	0.12	c_4	-0.0052	0.002	-2.22	0.028	0.04
R^2		F	p_F	S.E.		R^2		F	p_F	S.E.	
0.95		499.76	0.00	0.39		0.94		458.39	0.00	0.40	

Table 13: Model results for mean annual temperature 1961-90.

B Matlab scripts

The Matlab scripts used in this project are listed in alphabetical order below. They are stored on IMO's computer `skuggi`, in folder

`/disk3/urs/ursv1/siggasif/tempmaps/matlab/`

and some use Matlab scripts stored in

`/disk3/urs/ursv1/siggasif/interp2D/matlab/.`

A description of the function of each script as well as dependencies is included in the files and can be retrieved by writing `help <name of script file>` in Matlab's command window.

`distll.m`	Calculates the distance between points given in longitude-latitude coordinates.
`draw_annrange`	Draws a map of the annual temperature range.
`draw_diff`	Draws a map of the month to month temperature difference.
`draw_dv`	Draws a map of the June diurnal variability.
`draw_map`	Draws a map of the mean 1961-90 temperature.
`draw_model_diff`	Draws a map of the model difference.
`draw_region`	Draws a regional map of the temperature field.
`draw_resid`	Draws a map of the residual field.
`estim_resid`	Estimates the residual at a particular station by cross-validation.
`estim_temp`	Estimates the temperature at a particular station by cross-validation.
`KrigDistll`	Calculates the distances between points in two arrays, with coordinates given in longitude-latitude.
`krigll`	Interpolation using the kriging method, with coordinates given in longitude-latitude.
`map_dev`	Maps the deviations found in the cross-validation process.
`MDVgrid`	Interpolates the stations diurnal variability onto a regular grid.
`mean_temp`	Calculates the deviation from mean 1961-90 temperature at

weather stations and interpolates onto a grid of resolution 1×1 km^2.

`mean_year` Calculates the mean 1961-90 annual temperature.

`model_stats` Finds the model parameters and statistical test values of both DV and DTC models and writes the results as a LaTeX table in output file.

`nlreg_e` Uses nonlinear regression to find an exponential model of the semivariogram.

`s_model_stats` Finds the model parameters when using one predictand at a time for both. DV and DTC models. Writes the results as a LaTeX table in output file.

`semivarll` Calculates the smoothed semivariogram of input data.

`temp_grid_all` Finds the mean 1961-90 temperature model for all calendar months as well as the mean annual temperature. Also does cross-validation.

`TempInit` Loads the data files needed in `temp_grid_all`.