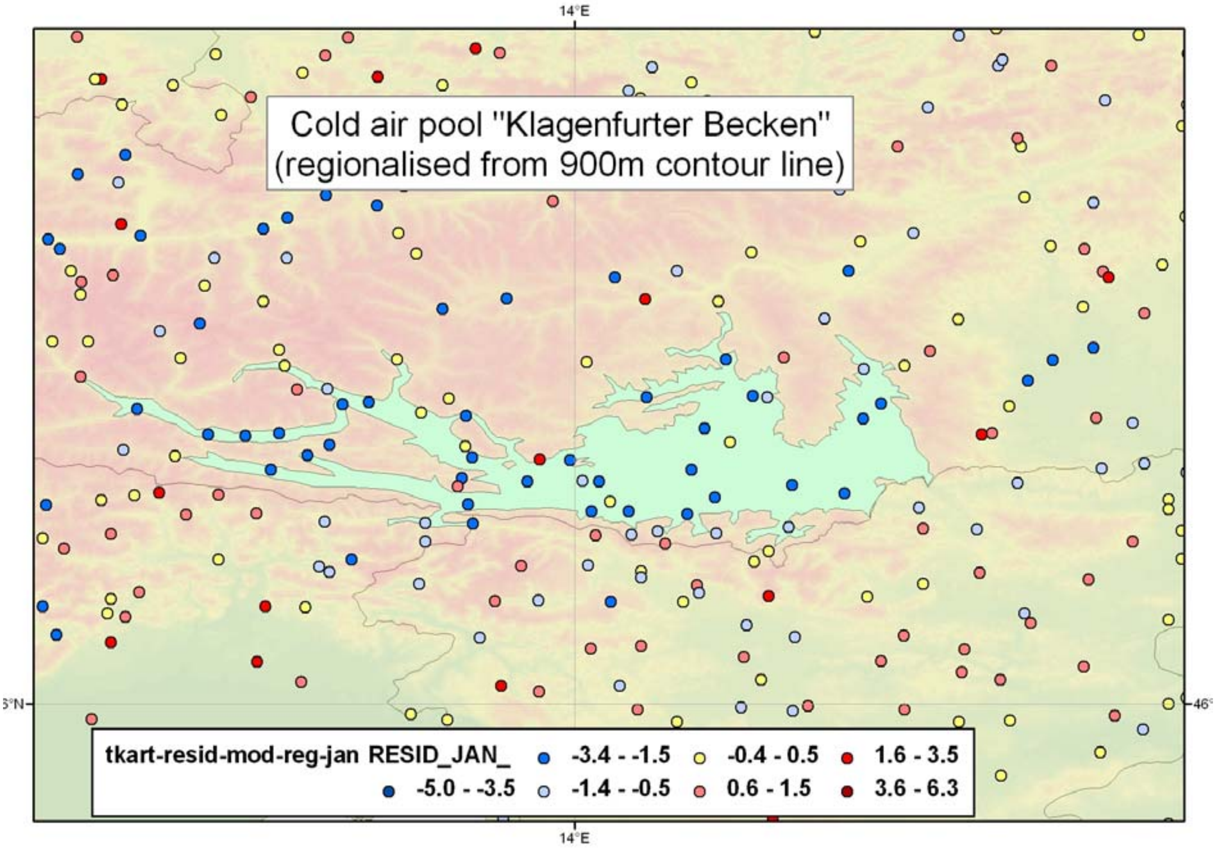
ECSN – HRT/GAR

High Resolution Temperature Climatology in Complex Terrain – demonstrated in the test area Greater Alpine Region GAR

Annex 2 to Final Report

GEOGRAPHICAL SPECIFICS OF AIR TEMPERATURE AND THE CONCEPT OF ECSN/HRT-GAR



Vienna, June 2008

GEOGRAPHICAL SPECIFICS OF AIR TEMPERATURE AND THE CONCEPT OF ECSN / HRT-GAR

1. Concept to reach the goal of ECSN-HRT / GAR

To reach the goal of ECSN-HRT/GAR a number of considerations have to be taken into account. On from the beginning it was clear to use the power of GIS tools for spatial modelling. In connection with our concept was defined as the following:

- Allow for a final standard error because climate station data always have final measurement uncertainties and describe local climate effects
- Apply only statistical modelling with a physical meaning (consequently this means that we did not apply residual interpolation by e.g. Kriging)
- Model only temperature effects inherent in the HRT-GAR climate station network
- Validate the spatial temperature model only on station data and not on gridded data because of large differences in DEM elevations to station elevations (errors and difference point to grid cell)

2. Geographical effects to be considered

Concerning the geographical effects to be considered we decide between larger and smaller scale effects.

Larger scale effects

- Dependency of air temperature on elevation including inversions during winter
- Large scale continentality effect (dependency on longitude)
- Global radiation effect from inclination of sunbeam (dependency on latitude)
- Regional scale dependency of air temperature on distance to the sea (considering advection of air masses)

Smaller scale effects

- Local scale dependency of air temperature on distance to the sea (land-sea brise circulation effect)
- Lake effect
- Urban effect
- Cold air pools effect
- Slope effect

First of all we have to study how well our DEM GTOPO30 represents the existing station network (Figure 1). A straight line would be a perfect reproduction of the true orography, but as one can see sometimes relatively big differences are occurring and above 2500 m all high alpine stations are represented in pixels to low. GTOPO30 is a global digital elevation model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer). It has been made freely available by the United States Geological Survey, shortly USGS. On http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html more information has been made available.

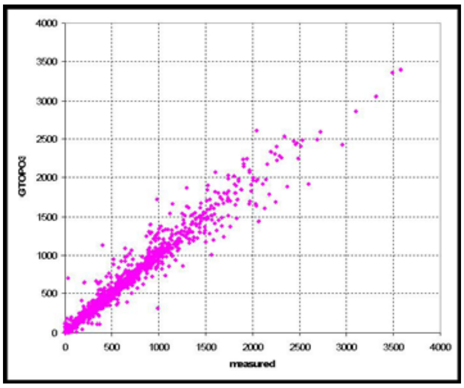


Figure 1: Comparison of station elevation and station elevation represented by DHM pixels of GTOPO30.

3. Distance-from-the-sea effect

Beside the most relevant effect played by geographical location (mostly latitude and, to a lower extent, longitude) and elevation, also the distance from the sea can affect environmental temperature.
The sea is characterized by higher heat capacity than the air, in fact the land warms up and cools down more quickly than the sea. So, places located near the sea experience cooler temperatures than nearby inland places in summer and warmer temperatures in winter.
This effect has been studied and quantified on the basis of the temperature climate normals of three coastal regions of the GAR: Po Plain Adriatic coast, Dalmatian Adriatic coast, and Tyrrhenian coast.

The sea effect on coastal stations has been studied by analysing the multiple regression residuals obtained by using elevation and latitude as predictors. Figure 2 shows the scatter plot of the January temperature residuals versus the distance from the sea (expressed in degrees) for the Po Plain Adriatic coast. The positive relative anomaly of the stations close to the sea compared to those farther from the coast is evident. On the contrary, in summer the behaviour is opposite, with the coastal stations proving cooler than the inland ones. In both cases the sea effect is (obviously) maximum close to the sea and it fades approximately linearly to zero at a threshold distance from the sea that is dependent on the season, such distance being maximum in summer and minimum in winter (in spring and autumn the sea effect in more or less negligible).

The linear fits shown in Figure 2 represent the signal to be subtracted from the residuals in order to take the sea effect into account or, better, the additive predictor to be added to the model in order to obtain white-noise residuals.

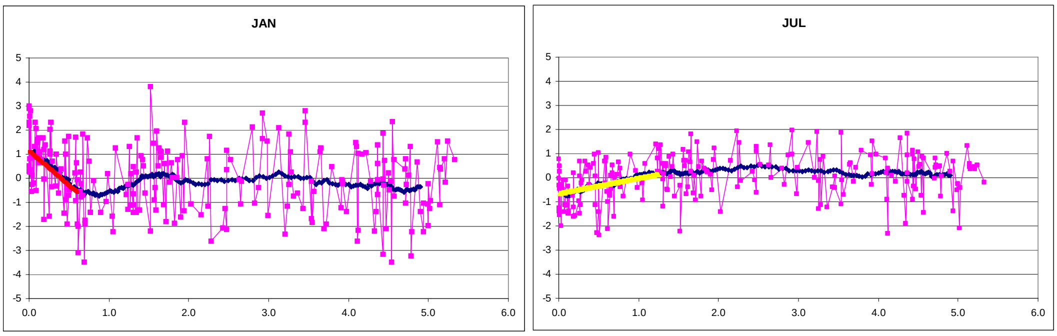


Figure 2: Scatter plot of the January (left) and July (right) temperature residuals versus the distance from the sea (expressed in degrees) for the Po Plain Adriatic coast; y-axis display the mean temperature in °C, x-axis the distance to sea in deg.

The sea effect turned out to be not the same when estimated for the other coastal regions, showing a remarkable dependence on the geography and morphology of the coast and its inland.

4. Lakeside effects

For seven larger lakes in the GAR a few lakeside and some more comparative sites in the surroundings could be identified and used for the comparison. As for All temperature means have been altitude adjusted before using. The three larges water bodies of the GAR are included in the analysis (Lago di Garda, Lac Léman, Bodensee / Lake Konstanz), the steppe-like shallow Balaton (more frequently freezing in winter than all the other analysed lakes) is included as well as the group of three medium size northern Italian Fjord-like lakes of Como, Lugano and Maggiore. The results from northern Italy are physically understandable and show cooler lakesides in the warm and warmer ones in the cold season. This meets the expectations based on the physics of the effect and the evidence already existing within ZAMG from some smaller Austrian lakes (gained some years ago during the work at the digital climatology of Austria). Not really expected, but clear to see in the data, are the systematically warmer lakesides of the two large western-and northern pre-alpine lakes (Bodensee and Lac Léman). They have to be used anyway, although the physical reason for the summer-heat excess of the lakeside sites is not clear. But the comparisons seem to be all right, altitude effects can be excluded, and for Bodensee we could use 9 lakeside and 13 remote sites, for Lac Léman 5 lakeside and 7 remote sites. The only really questionable case is the one of Balaton. Here the comparison produced colder lakesides in February and slightly warmer ones the rest of the year. This may be due to the possibility of freezing in later winter here, but the comparison could be based on from lakeside sites only and 7 rather remote comparative sites. Due to a special climatic situation of one of the two lakeside sites we have not applied any additional lakeside modifications on the temperature fields round lake Balaton. This makes sense also if the very shallow depth of this lake is taken into account. The same conclusion has been drawn for the similarly formed shallow lake Neusiedl at the Austro-Hungarian border.

Table 1: Deviations of mean monthly temperature at lakeside sites from remote sites in the surroundings, shown are the mean differences lakeside minus remote for 1961-1990, altitudes adjusted to lake-level

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Balaton	0.08	-0.22	-0.02	0.22	0.26	0.52	0.66	0.49	0.58	0.57	0.34	0.13	°C
Bodensee	0.70	0.48	0.34	0.39	0.34	0.41	0.47	0.48	0.59	0.56	0.71	0.63	°C
Garda	1.67	0.57	-0.08	-0.16	-0.38	-0.48	-0.12	-0.13	0.08	0.50	1.06	1.73	°C
Léman	1.61	1.31	0.86	0.76	0.58	0.70	1.11	1.17	1.19	1.36	1.52	1.90	°C
Maggiore, Como, Lugano	0.57	0.61	0.42	0.14	-0.24	-0.59	-0.43	-0.31	-0.06	0.20	0.31	0.47	°C

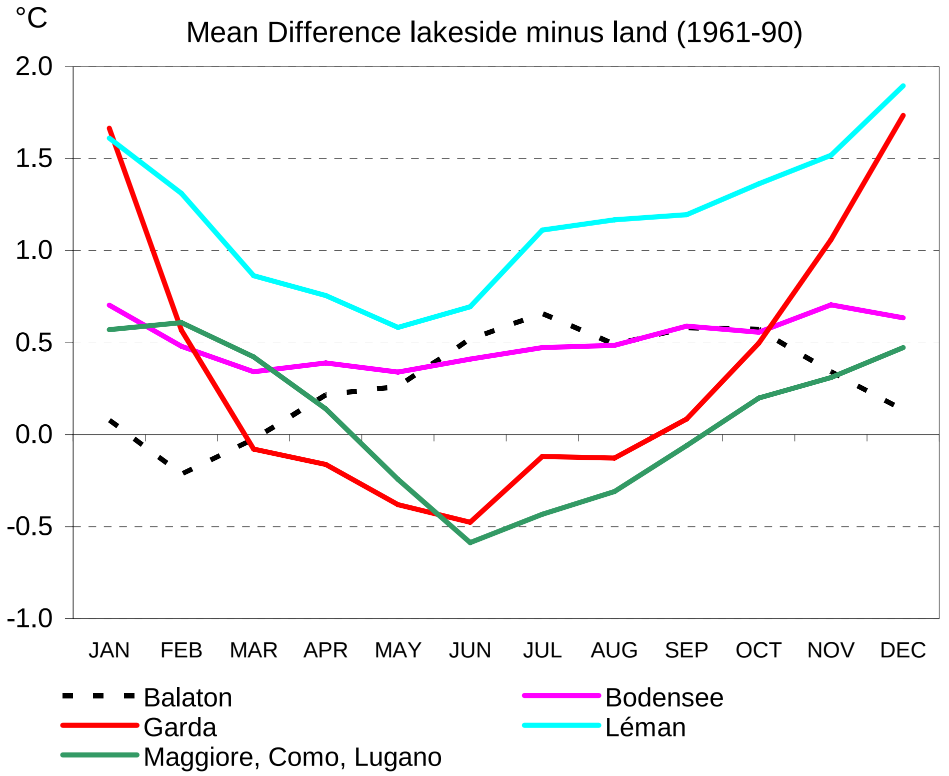


Figure 3: deviations of mean monthly temperature at lakeside sites from remote sites in the surroundings. Shown are the mean differences lakeside minus remote for 1961-1990, altitudes adjusted to lake-level

5. Urban effects

For the **urban regions** we decided to choose the following proceeding:
Firstly exclude urban infected stations from the dataset, then produce typical urban excess temperatures for the mean months 1961-90 and finally overlay those on the “rural” temperature fields. 12 cities could be used, for which a sufficient number of urban and rural sites in the surrounding exists. Those single city-subsets were each adjusted to constant altitude (using the draft regional t(z) models already analysed during the project). To keep any altitude biases small, only comparative rural sites were used which had altitude differences of less than 200m to the urban site(s). Figure 4 shows the result, mean monthly urban excess temperatures for 12 cities in the GAR. Three of the urban regions produced questionable results. The Torino case with more than 2° mean urban temperature excess seems large for a Mediterranean city, where theory expects less pronounced heat islands, particularly in summer (less evapotranspiration in the surroundings, stronger urban cooling through shading). The Milano-Bergamo case

can be considered more typical and reliable for the Mediterranean part of the GAR. Praha and the combination of medium size southern German cities are supposed to be too low and not realistic. For those cities further investigations should be done, but the project dataset does not contain the necessary data. The other analysed cities show reliable results, not in contradiction with the respective literature on urban heat islands.

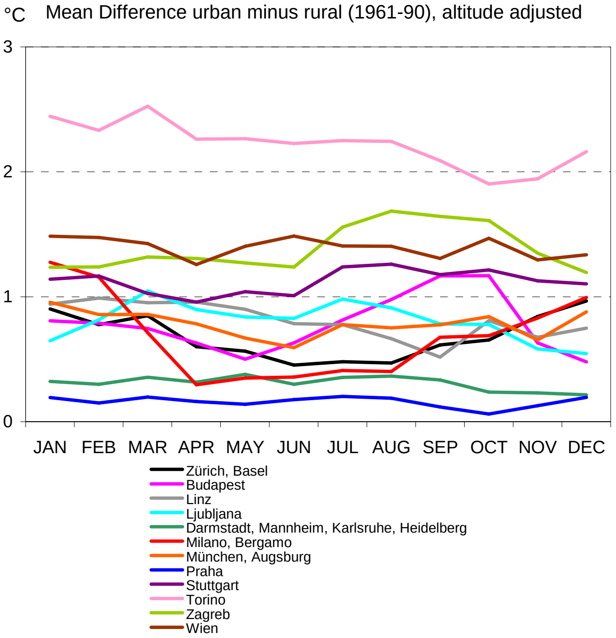


Figure 4: Mean monthly altitude adjusted urban excess temperatures for 12 urban subregions in the GAR. Sample: 28 urban and 109 comparative rural sites for 12 cities or urban regions of several cities

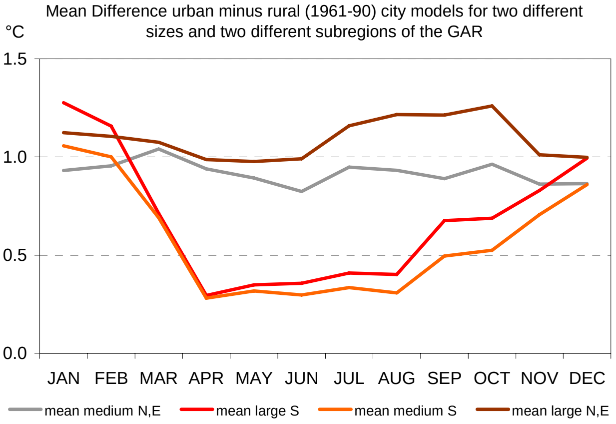


Figure 5: Same as Fig.1 but for four generalized model cities (respective values in Table 2)

Finally our conclusion was to produce two city models (depending on city size) for two sub-regions, one for the NW-N-E and one for the Mediterranean part of the GAR. Table 2 and Figure 5 show those models which have been applied on the final monthly fields based on rural sites only.

Table 2: Urban temperature excess, but for four generalized model cities in the GAR

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
mean large N,E	1.12	1.10	1.07	0.99	0.98	0.99	1.16	1.22	1.21	1.26	1.01	1.00
mean large S	1.28	1.16	0.71	0.30	0.35	0.36	0.41	0.40	0.68	0.69	0.83	0.99
mean medium N,E	0.93	0.96	1.04	0.94	0.89	0.83	0.95	0.93	0.89	0.96	0.86	0.86
mean medium S	1.06	1.00	0.69	0.28	0.32	0.30	0.33	0.31	0.50	0.53	0.71	0.86

6. Shape effects

Table 3: deviations of mean monthly temperature at sites in specific shape-surroundings from the mean over all sites (sample: 100 Austrian sites 1961-1990, shape parameters taken from station descriptions)

	Group means of specific mesoscale sourroundings																
	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	spr	sum	aut	win	year
PLAIN																	
mean	0.006	0.079	0.158	0.21	0.19	0.182	0.243	0.227	0.236	0.134	0.065	-0.02	0.186	0.217	0.145	0.02	0.142
standard dev.	0.391	0.385	0.444	0.428	0.379	0.372	0.457	0.482	0.492	0.468	0.391	0.371	0.402	0.427	0.426	0.349	0.367
n	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
m+sd	0.397	0.464	0.602	0.638	0.57	0.555	0.699	0.709	0.728	0.602	0.456	0.346	0.588	0.645	0.571	0.369	0.509
m-sd	-0.38	-0.31	-0.29	-0.22	-0.19	-0.19	-0.21	-0.26	-0.26	-0.33	-0.33	-0.4	-0.22	-0.21	-0.28	-0.33	-0.22
BASIN																	
mean	-0.7	-0.41	-0.3	-0.13	-0.09	-0.09	-0.18	-0.22	-0.26	-0.45	-0.4	-0.61	-0.18	-0.17	-0.37	-0.57	-0.32
standard dev.	0.472	0.42	0.315	0.254	0.237	0.256	0.29	0.278	0.233	0.493	0.325	0.389	0.255	0.261	0.226	0.395	0.203
n	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
m+sd	-0.23	0.007	0.014	0.12	0.145	0.164	0.105	0.054	-0.03	0.042	-0.07	-0.22	0.079	0.095	-0.15	-0.18	-0.12
m-sd	-1.17	-0.83	-0.62	-0.39	-0.33	-0.35	-0.47	-0.5	-0.5	-0.94	-0.72	-1	-0.43	-0.43	-0.6	-0.97	-0.53
HILL																	
mean	0.242	0.074	0.183	0.259	0.306	0.345	0.403	0.453	0.407	0.325	0.235	0.5	0.249	0.4	0.322	0.272	0.311
standard dev.	0.297	0.423	0.4	0.539	0.36	0.361	0.431	0.561	0.592	0.557	0.255	0.333	0.42	0.436	0.438	0.298	0.372
n	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
m+sd	0.539	0.497	0.583	0.798	0.667	0.706	0.834	1.014	0.999	0.882	0.49	0.833	0.67	0.836	0.76	0.57	0.683
m-sd	-0.06	-0.35	-0.22	-0.28	-0.05	-0.02	-0.03	-0.11	-0.18	-0.23	-0.02	0.167	-0.17	-0.04	-0.12	-0.03	-0.06
SUMMIT																	
mean	0.039	-0.02	-0.07	-0.02	0.005	-0.01	-0.09	0.031	-0.02	0.037	0.086	0.099	-0.03	-0.02	0.034	0.038	0.006
standard dev.	0.58	0.349	0.262	0.34	0.396	0.401	0.392	0.292	0.252	0.34	0.306	0.635	0.305	0.351	0.266	0.518	0.268
n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
m+sd	0.619	0.325	0.197	0.323	0.401	0.389	0.303	0.323	0.231	0.376	0.392	0.734	0.279	0.328	0.3	0.556	0.274
m-sd	-0.54	-0.37	-0.33	-0.36	-0.39	-0.41	-0.48	-0.26	-0.27	-0.3	-0.22	-0.54	-0.33	-0.37	-0.23	-0.48	-0.26
VALLEY																	
mean	-0.13	-0.13	-0.11	-0.12	-0.05	-0.09	-0.1	-0.12	-0.13	-0.15	-0.17	-0.18	-0.1	-0.1	-0.15	-0.15	-0.12
standard dev.	0.715	0.673	0.535	0.552	0.496	0.5	0.564	0.537	0.569	0.565	0.598	0.823	0.503	0.525	0.53	0.702	0.462
n	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
m+sd	0.588	0.543	0.425	0.432	0.441	0.41	0.464	0.415	0.443	0.412	0.423	0.642	0.408	0.422	0.379	0.556	0.338
m-sd	-0.84	-0.8	-0.65	-0.67	-0.55	-0.59	-0.66	-0.66	-0.69	-0.72	-0.77	-1	-0.6	-0.63	-0.68	-0.85	-0.59
N-SLOPE																	
mean	0.326	0.245	0.199	0.225	0.312	0.305	0.263	0.262	0.202	0.151	0.189	0.328	0.246	0.277	0.181	0.3	0.251
standard dev.	0.529	0.5	0.658	0.738	0.649	0.671	0.689	0.586	0.555	0.388	0.378	0.558	0.668	0.642	0.388	0.467	0.444
n	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
m+sd	0.855	0.744	0.858	0.963	0.962	0.976	0.952	0.849	0.757	0.54	0.567	0.886	0.914	0.918	0.569	0.767	0.695
m-sd	-0.2	-0.26	-0.46	-0.51	-0.34	-0.37	-0.43	-0.32	-0.35	-0.24	-0.19	-0.23	-0.42	-0.37	-0.21	-0.17	-0.19
S-SLOPE																	
mean	0.872	0.56	0.336	0.232	0.237	0.232	0.212	0.254	0.338	0.517	0.605	0.97	0.268	0.232	0.487	0.801	0.447
standard dev.	0.611	0.318	0.394	0.591	0.431	0.342	0.333	0.347	0.304	0.344	0.356	0.584	0.448	0.335	0.29	0.484	0.3
n	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
m+sd	1.483	0.878	0.73	0.823	0.668	0.574	0.544	0.601	0.641	0.861	0.961	1.553	0.716	0.568	0.777	1.284	0.747
m-sd	0.261	0.242	-0.06	-0.36	-0.19	-0.11	-0.12	-0.09	0.034	0.173	0.249	0.386	-0.18	-0.1	0.196	0.317	0.147

To modify the temperature fields according to special effects caused by the shape of the altitude model, for the time being only a study on the basis of a set of about 100 Austrian sites with good metadata about the shape of station surroundings could be used and points at the size of the expected effects. Similar studies for non Austrian sites are not available.

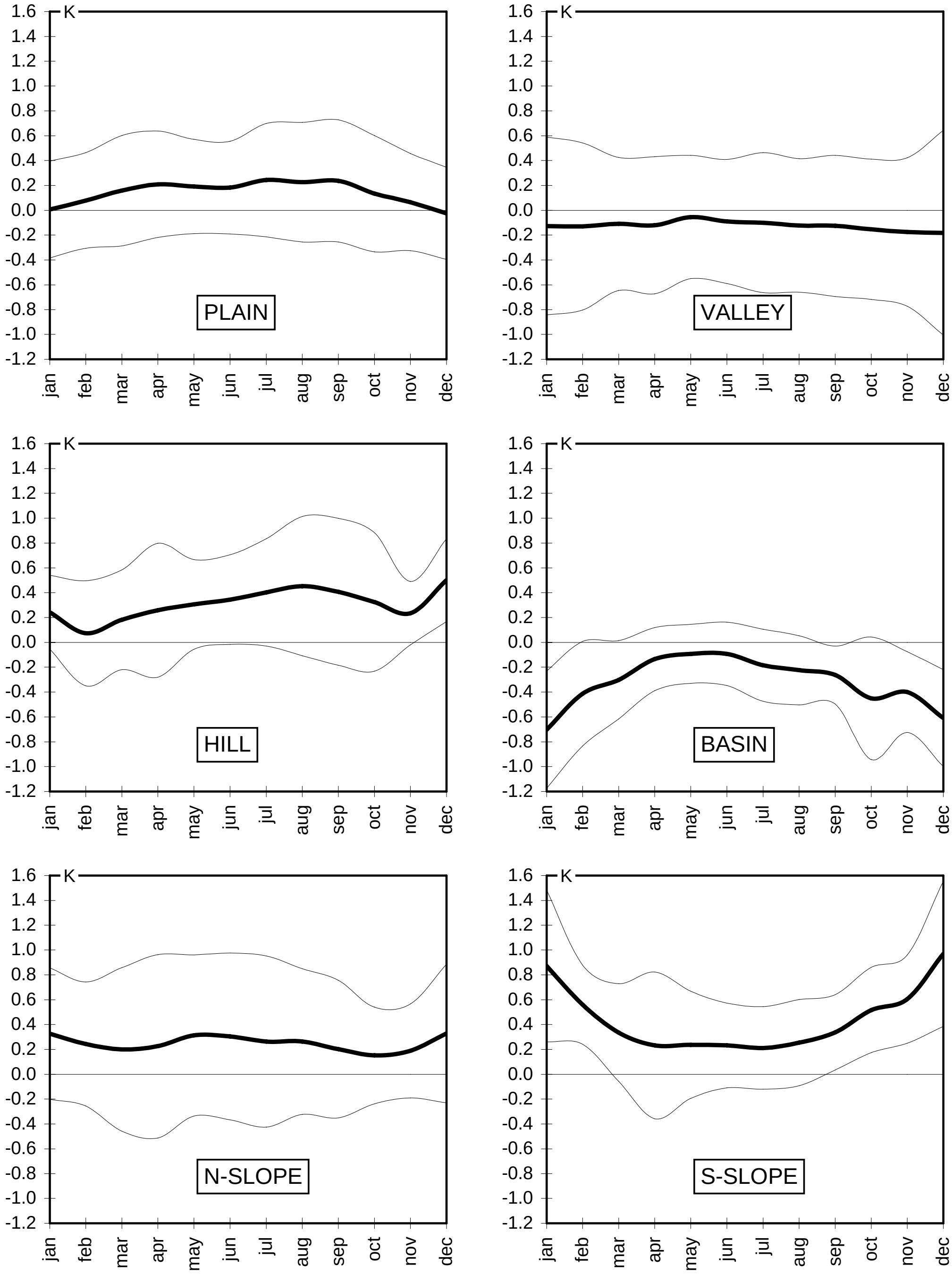


Figure 6: Mean monthly deviations of sites located in special landscape-shape from a neutral (flat) meso-scale surrounding from the mean over all stations. Bold: mean deviations, thin: ±1stdev.range (sample: 100 sites 1961-1990 of the Austrian climate network)

7. Cold air pools effect

Cold air pools are a ground-based layer of air confined by topography colder than the air above. They usually form in winter when solar radiation input is too weak to remove the cold air layer. Regionally analysed temperature fields confirmed that alpine air pools are frequent and prominent to be seen even in mean monthly temperature fields.

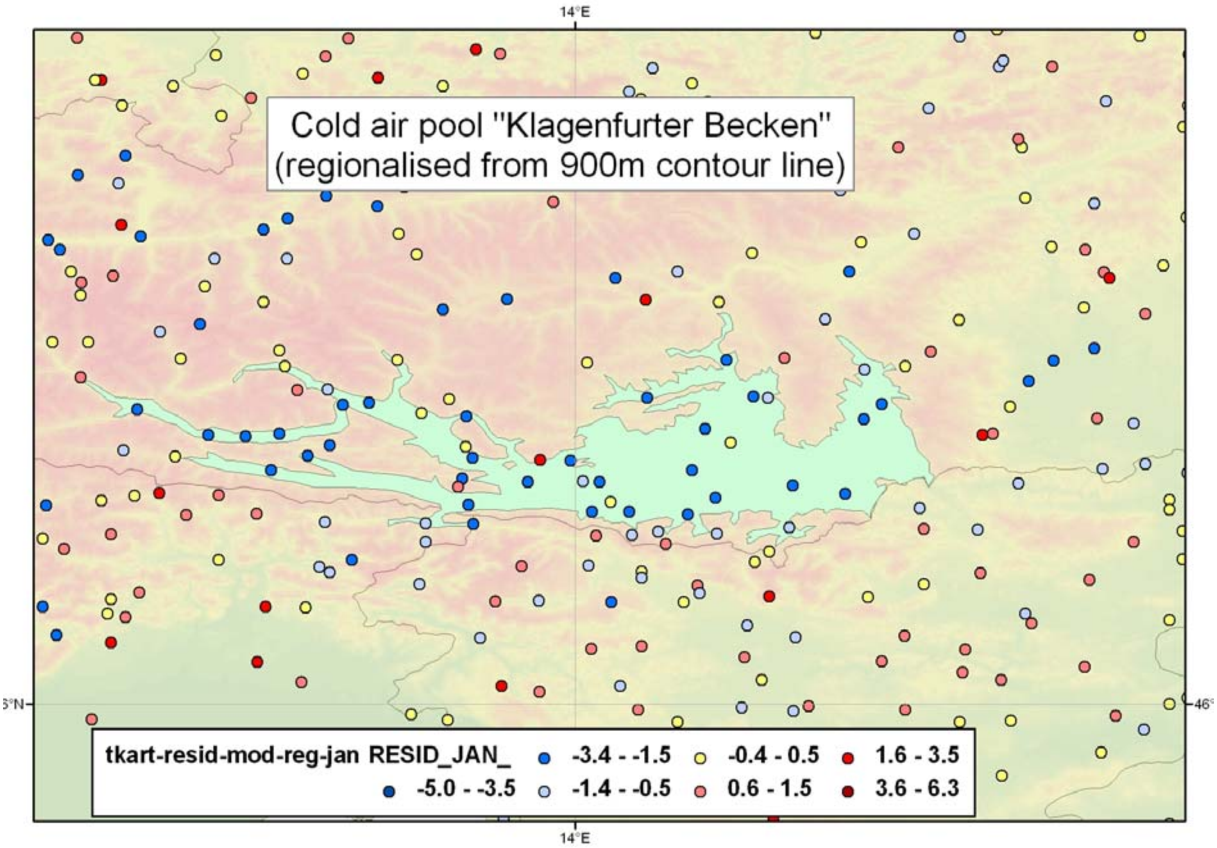


Figure 7: mean monthly temperature in Carinthia (south of Austria) displaying the cold air pool of Klagenfurter Becken with negative temperature deviations up to -5°C.

Cold air pools have been defined from too cold residuals and topography.

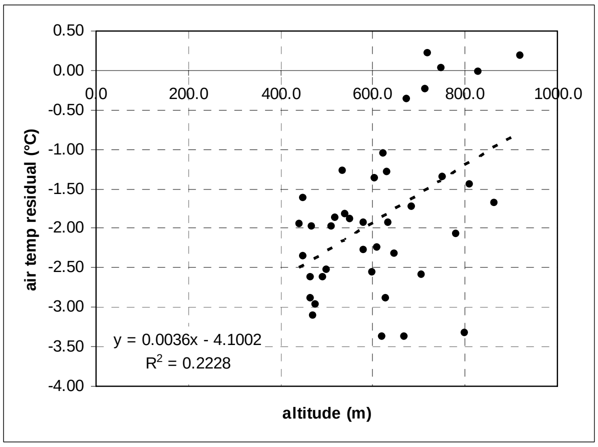


Figure 8: scatter plot of air temperature residuals and altitude in the Klagenfurter Becken.

8. Effects not to be included in the analyses

A number of additional effects modifying the alpine temperature fields are well known existing however could not be treated within the project. On the hand the network did not allow for such special analyses (like those for sea-shores) and also from literature we could not find specifications which would allow for being included in an overall analysis.

8.1 Effects of forests on the temperature field

Forests are covering large parts of the alpine landscape and are expected to modify the temperature field in the forests themselves, but also in their nearer surroundings. We could not find enough references which would have been allowed to include this effect in our analyses.

8.2. Effects from glaciers and snow fields

Air above glaciers is expected to be considerably cooler in the warm season, when snow cover has vanished from the high Alpine non glaciated surroundings. This is due to two reasons. The one is based on the different heat balance of ice compared to solid surface with or without vegetation; the second is caused by advective heat transport from higher parts of a glacier via the “Gletscherwind”. Measurements published by Greull, 2006 showed that using a constant lapse-rate could introduce some more problems.

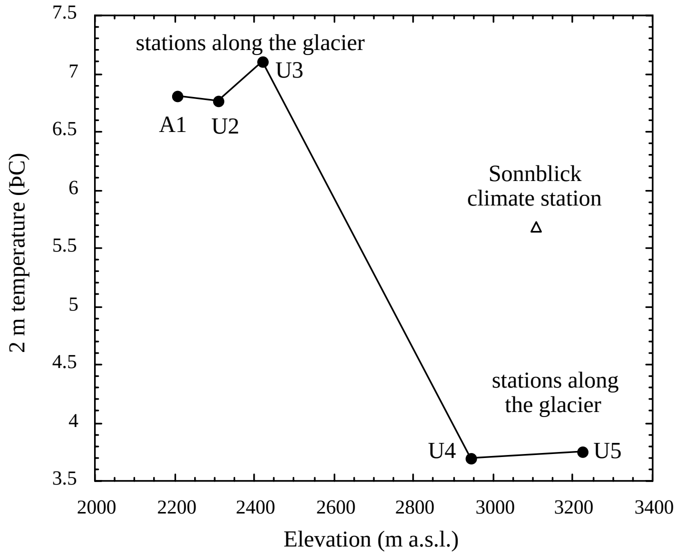


Figure 9: averaged temperature field over Pasterze (20 km^2, Austria) during 48 days of the ablation season (Greull, 2006)

8.3 others

there are effects which could not be included into the ECSN/HRT-GAR considerations, like sink holes (e.g. dolines in karst regions), or rice-fields covering large areas of the Po plain.

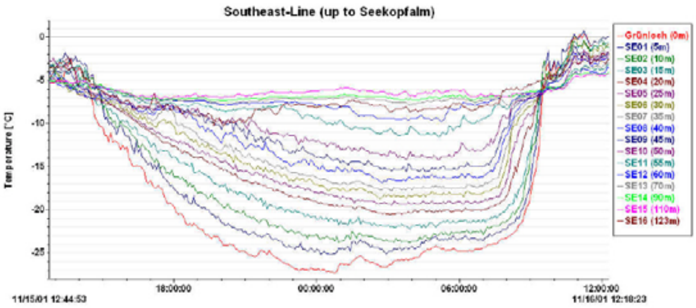


Figure 10: Doline temperature profile at Grünloch, Herzkogelplateau, Austria. source: Bernhard Pospichal: Struktur und Auflösung von Temperaturinversionen in Dolinen am Beispiel Grünloch, Diplomarbeit zur Erlangung des akademischen Grades Mag. rer. nat.