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Homogenisation and interpolation of Slovenian temperature series in period 1950–2020

11th Seminar for Homogenization and Quality Control in Climatological Databases and 6th Interpolation Conference jointly organized with the 14th EUMETNET Data Management Workshop

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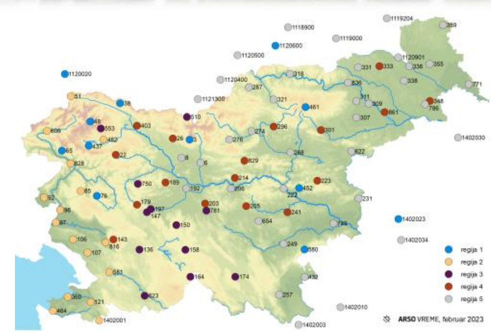

Budapest, 9 May 2023

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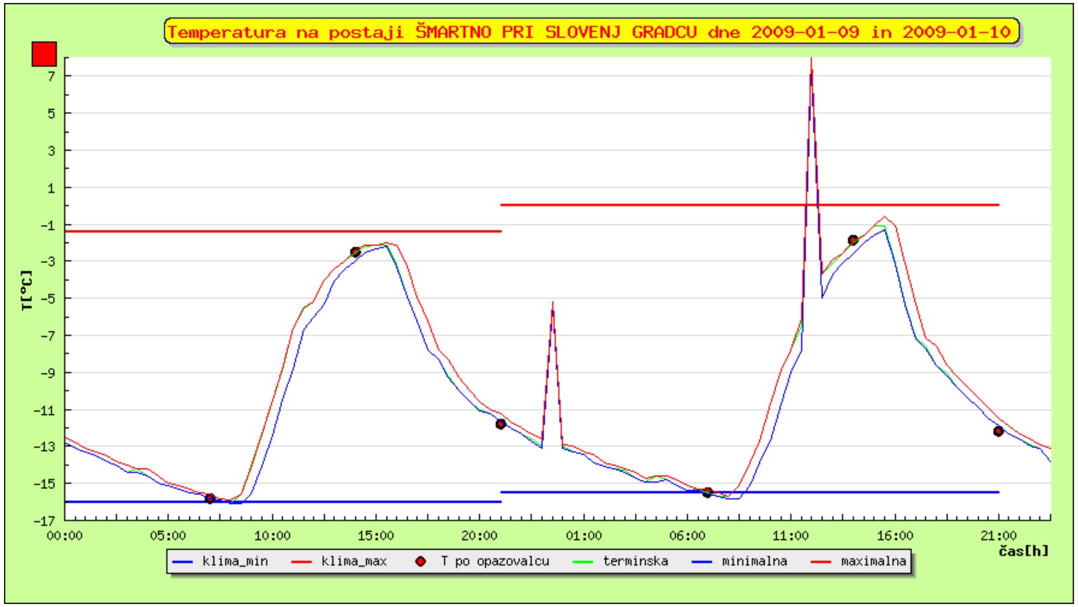
Introduction

- First comprehensive analysis of climate change in Slovenia (PSS, 1961–2011) at ARSO in 2008–2014
- Huge expansion of automatic weather stations AWS in period 2014–2017
- Renewed homogenisation & climate change analysis (project HDS):
  - more data sources (AWS)
  - longer period (1950–2020 vs 1961–2011)
  - homogenisation with HOMER v2.6 as in PSS
  - preparation of new climate normals (1991–2020)
  - more focus on daily data
  - interpolation of daily data for short series → climate normals

Quality control

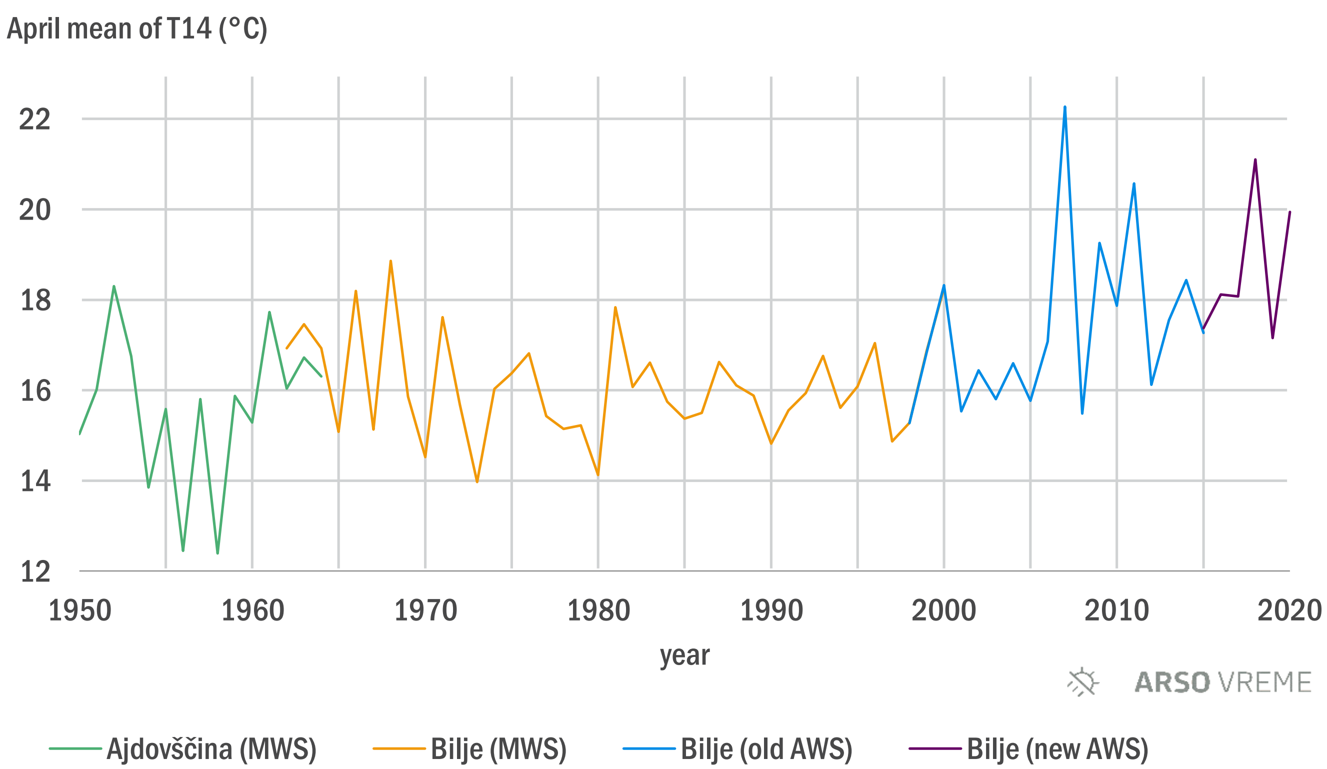
- Operative QC (daily, monthly) and project oriented (latest and comprehensive methods on older data):
  - consistency & time series checks (extreme vs hourly values, variability, duplicate records)
  - spatial QC via interpolated values
  - manual vs automatic weather stations
  - monthly means QC by HOMER software (outliers)

Manual climate station vs automatic station temperature data at Šmartno pri Slovenj Gradcu on January 9 and 10, 2009



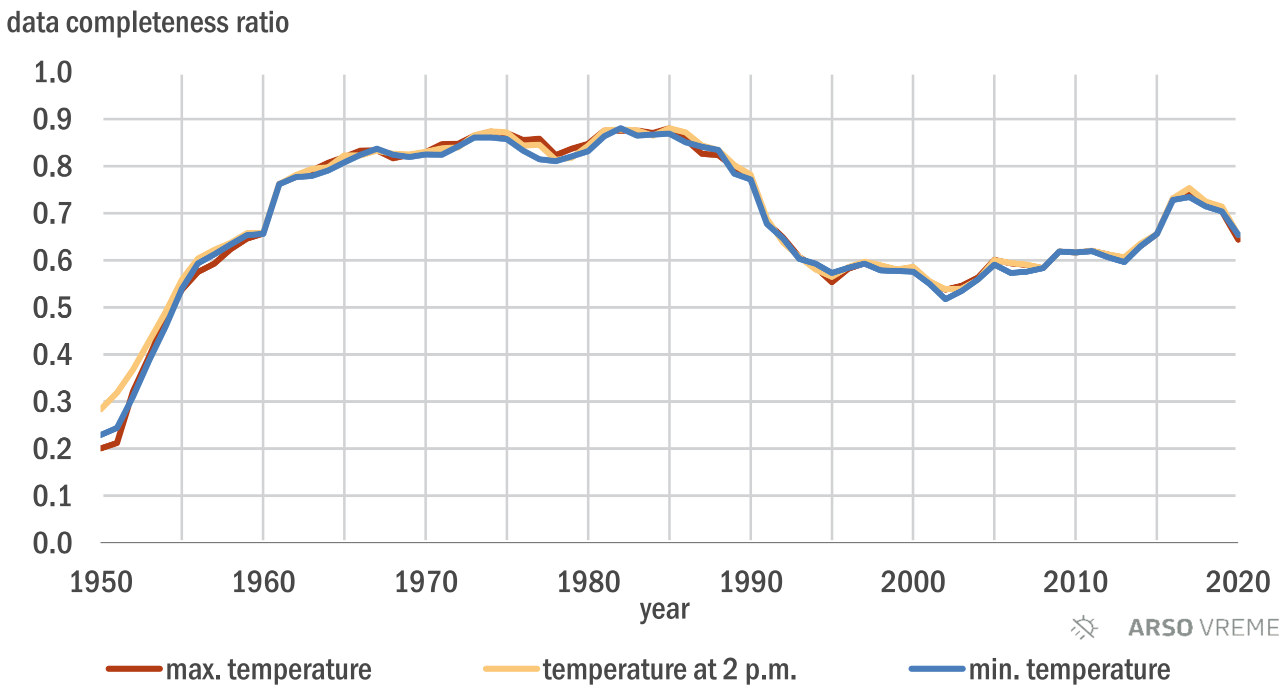
Time series selection

- Adequate quality and quantity of data
- Merging similar time series to get longer series (~ 40 years and more)
- Homogenisation with parallel series when possible (overlap 1–3 years)



How much temperature data did we have for homogenisation?

- 82 Slovenian + 16 foreign stations time series, ~49 years long



- Data completeness ratio increases rapidly in the fifties, plateuas till eighties, quickly lowers and stays at the same level till last years (AWS network upgrade)
- In the first few years some stations without extreme thermometers, only measuring current temperature

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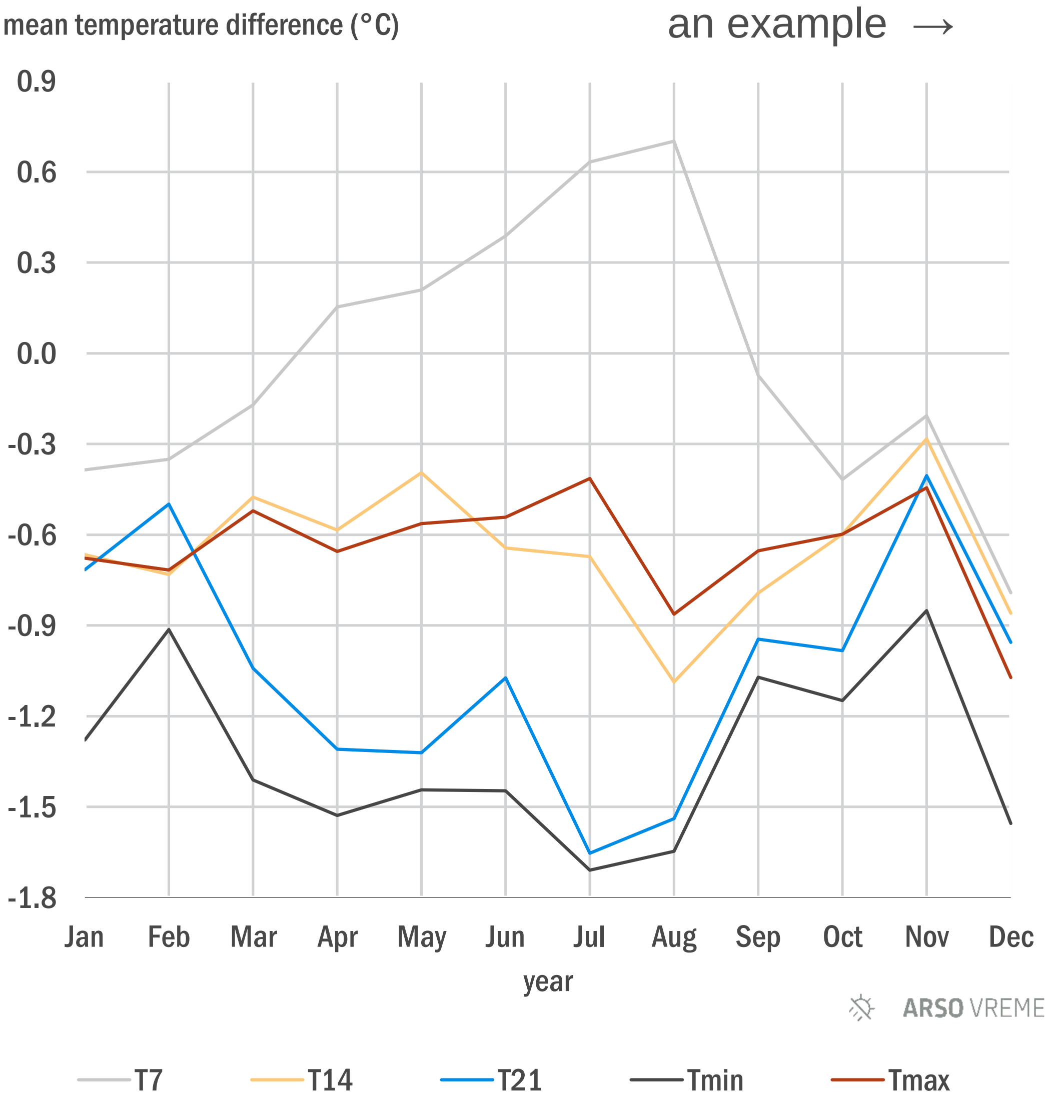
Merging series issues?

At first no, but in the analysis of climate change … an example →

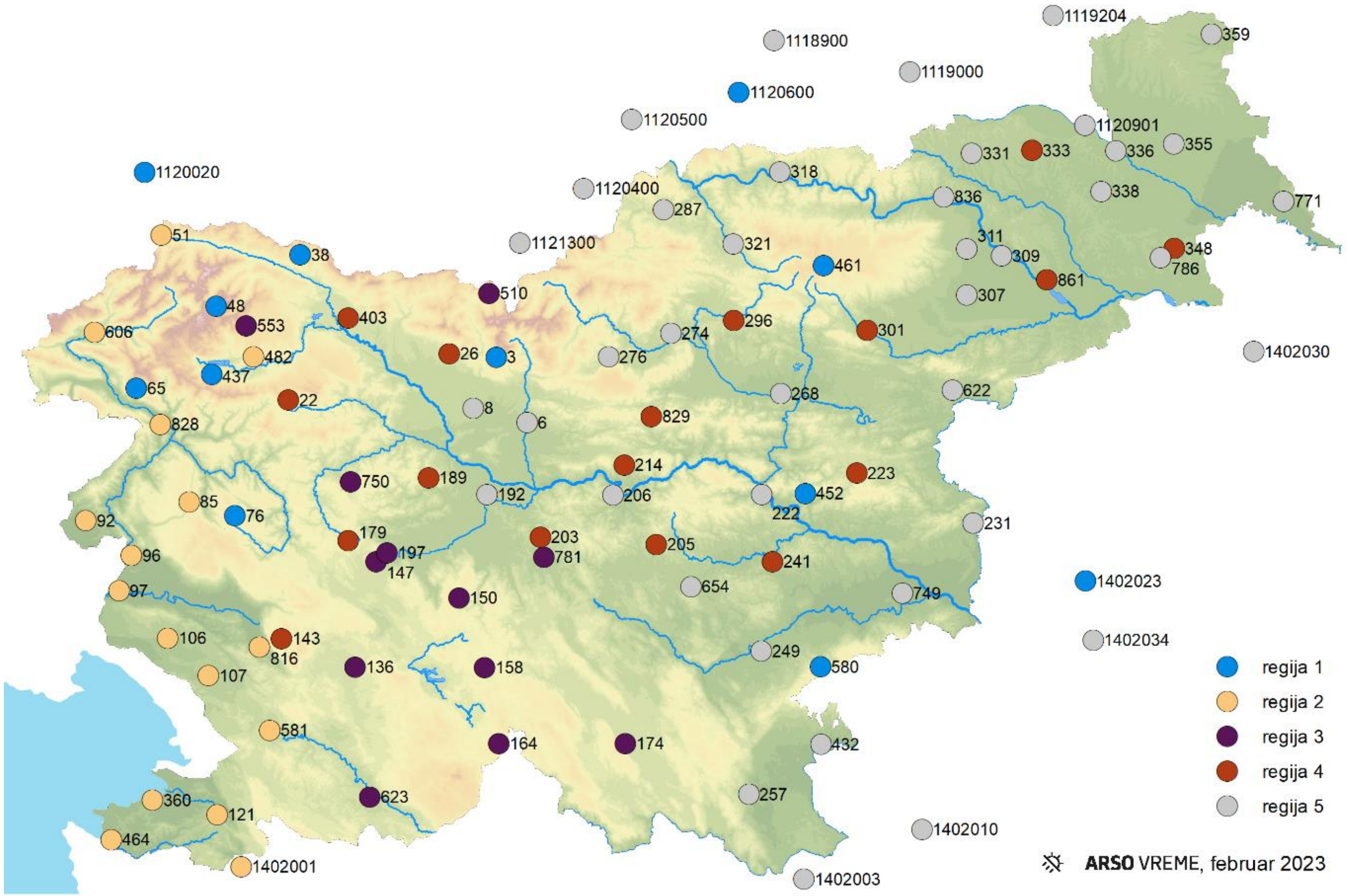


Nova vas on the Bloke plateau (400 meters AWS to MWS): frequent **strong nocturnal temperature inversion, different obstacles and difference between thermometer screens**

Regionalisation of station network

- Temporally & climatically diverse network leads to some issues with HOMER software:
  - fixed maximum distance in geographic mode → too low or too high number of comparison stations in some cases
  - correlation coefficient between marginally overlapping time series may be spuriosly high, affecting both detection and correction process
  - all stations mode time consuming and leading to spatiall „oversmoothing“

- Our solution → five climate regions:
  - five core stations, representing certain climate
  - selection based on correlation between difference series



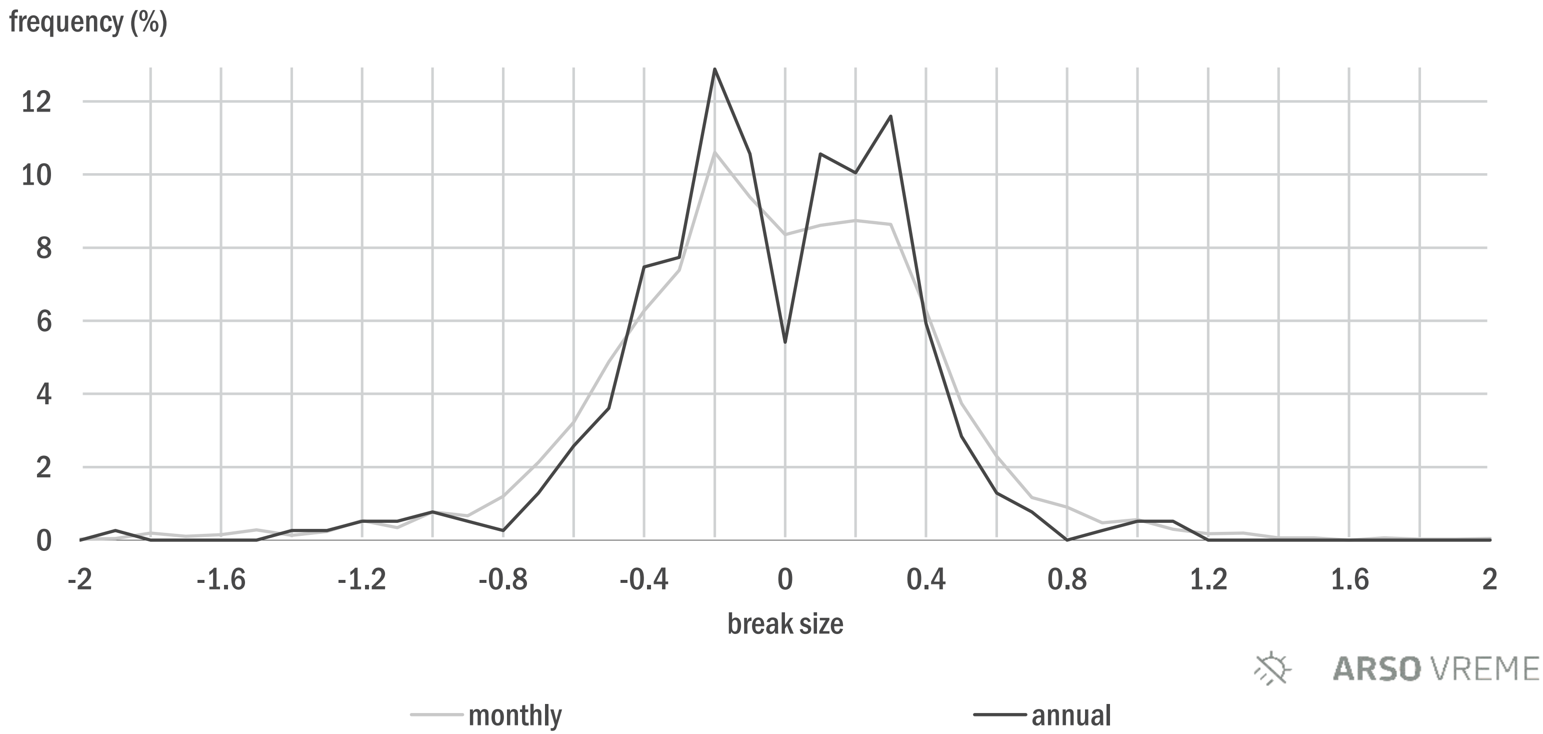
Homogenisation of monthly data

- Monthly data of five temperature variables and five regions homogenised separetely
- Regional stations + „buffer stations“ → overlapping homogenisation subnetworks
- Iterative & interactive homogenisation using metadata:
  - 10 trends, none confirmed by metadata
  - 1867 breaks, 66 % (63−70 % by variables) confirmed by metadata
- Final homogenised series as weighted sum of series (if station‘s time series in more than one subnetwork)

variable	region 1	region 2	region 3	region 4	region 5
T7	6.4	7.7	6.7	7.4	9.6
T14	6.6	7.8	6.7	8.6	7.7
T21	6.4	7.5	7.6	7.3	8.4
Tmin	6.6	7.8	6.3	8.2	8.1
Tmax	7.7	8.6	6.3	8.8	8.4

Break points per 100 years of Homer input data for every temperature variable & region (only primary stations)

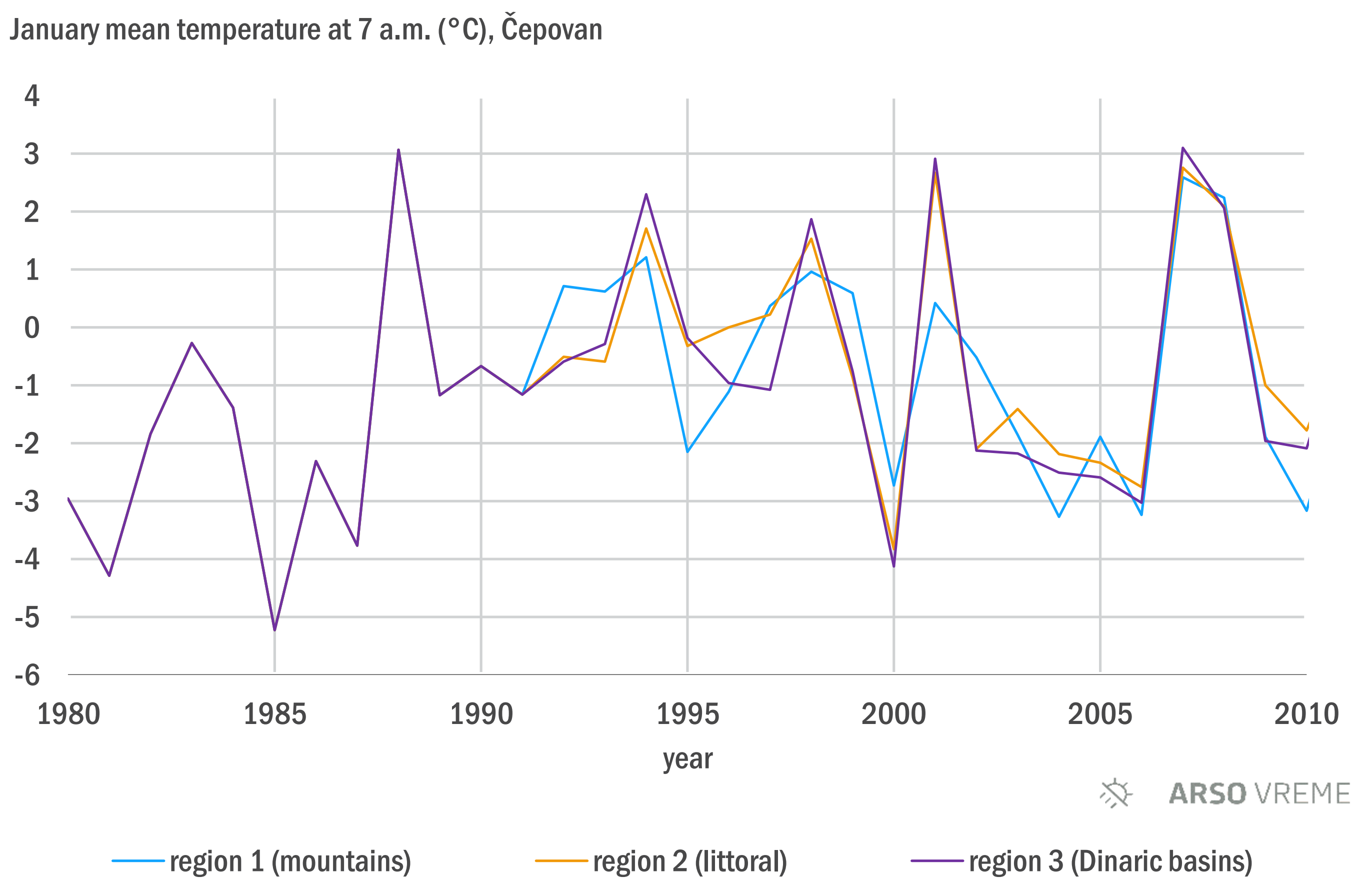
Break size distribution for maximum temperature and all regions together



variable	monthly	annual
t7	0.32	0.26
t14	0.33	0.30
t21	0.43	0.38
tmin	0.39	0.35
tmax	0.36	0.32

Mean absolute size of breaks by variable, all regions together

Choice of reference stations is **crucial** for interpolation …



HOMER homogenisation results for station Čepovan, T7 in January, three regions. Lower time series variability in region 1, some years differ by more than 1 °C (eg. 1995, 2001)

Interpolation of daily data

- Monthly corrections (hom-QC) for full-data months applied to daily values, **no weather adjusted**
- Database of homogenised daily time series with a lot of data gaps
- Advanced spatial interpolation, **based on weather (spatio-temporal temperature field)**
- Regresion values are variance-corrected for each station pair
- Final values are linear combinations of regression values (weights according to regression error)

Results

- Corrections on input (QC) data are not symmetrical and are variable dependent: mean & linear trend ≠ 0
- Homogenised & interpolated temperature time series exhibit statistically significant linear trend, ~ 0.2–0.4 °C/decade → **warming of ~ 2 °C in 71 years**
- Spatially coherent trends with more warming in eastern, less in western Slovenia
- Important difference between some variables (day / night)
- Trends in extreme daily values (e.g. annual Tmin) less homogenous!

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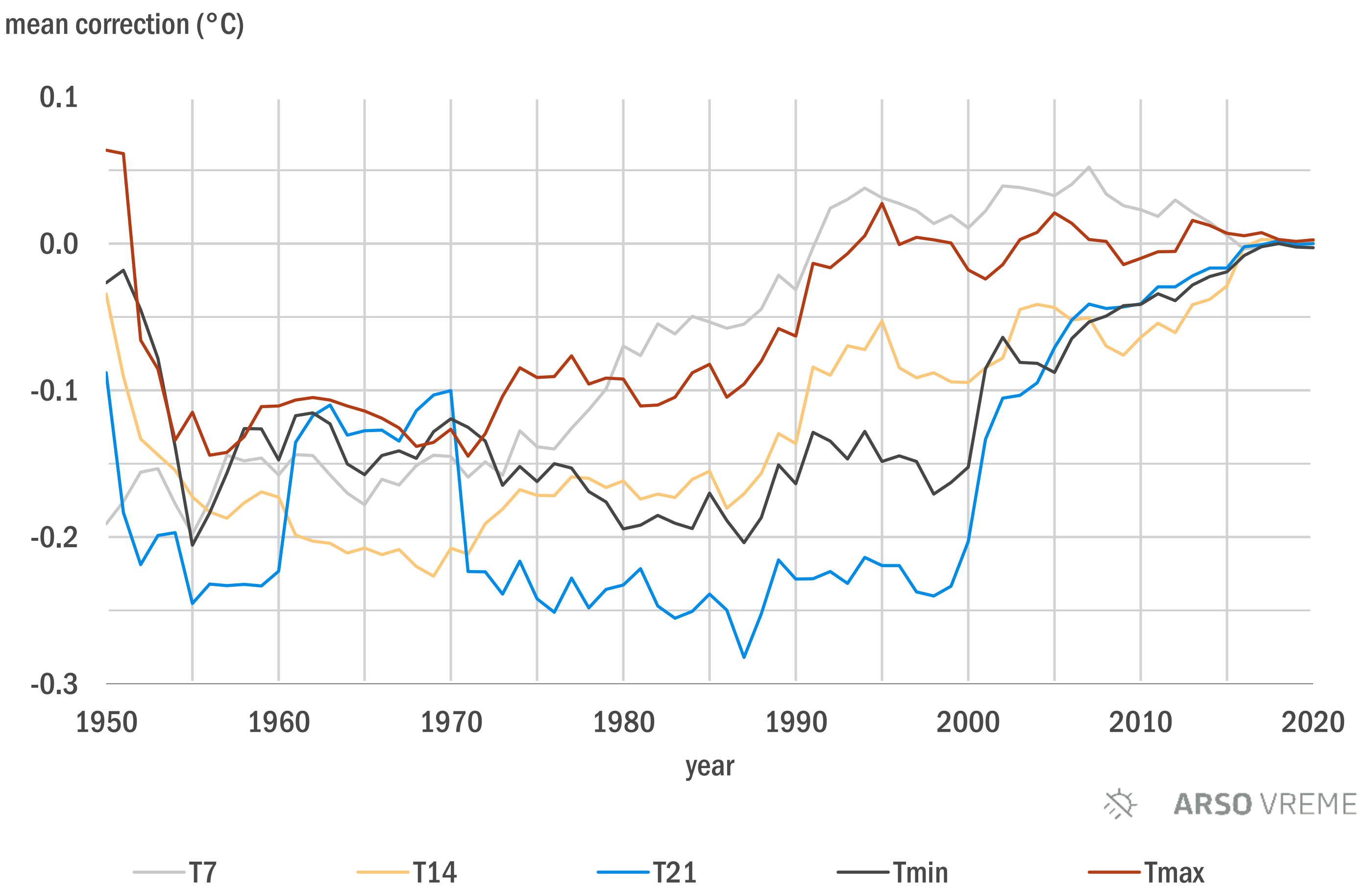
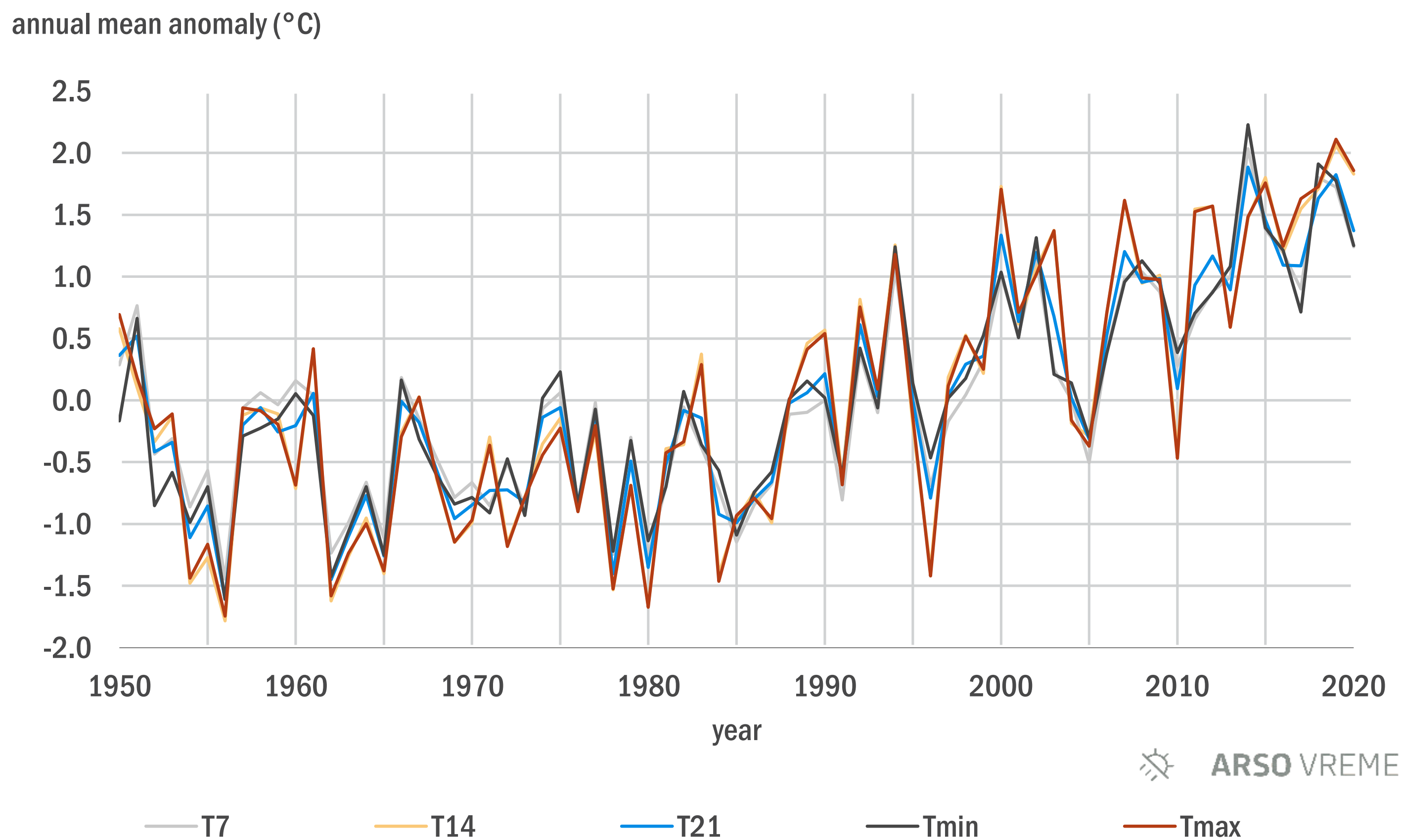


Annual mean of **temperature data correction** in homogenisation on network level, 1950–2020



Annual anomaly of all homogenised temperature variables. Reference period 1950–2020, arithmetic mean of all time series. Excellent agreement of Tmax & T14 series, medium of (T7, Tmin) & (T14, Tmax) series.

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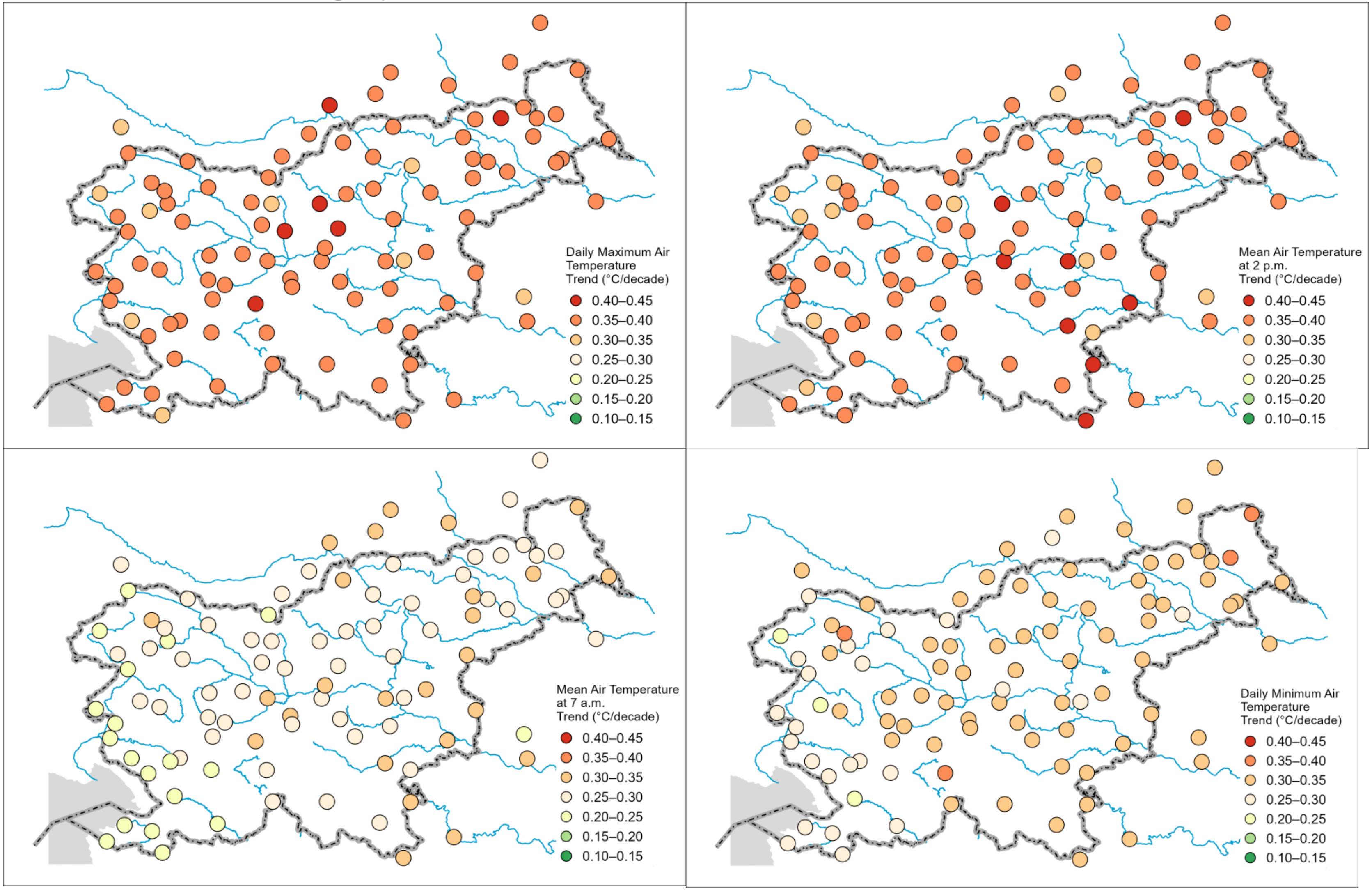

Linear trends (Theil-Sen) of **homogenised temperature series, for all variables & stations** for period 1950–2020. All trends are statistically significant (p = 0.05, Mann-Whitney test).

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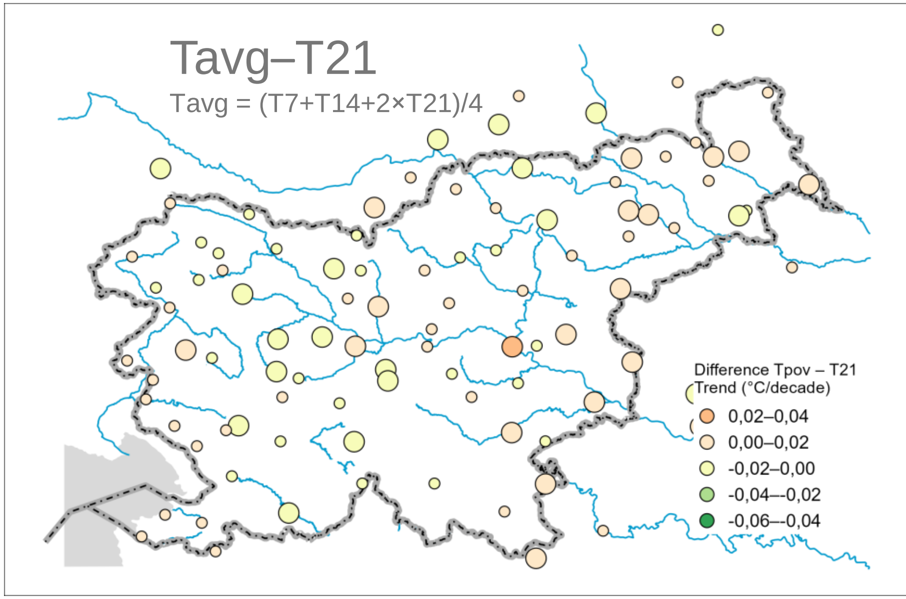

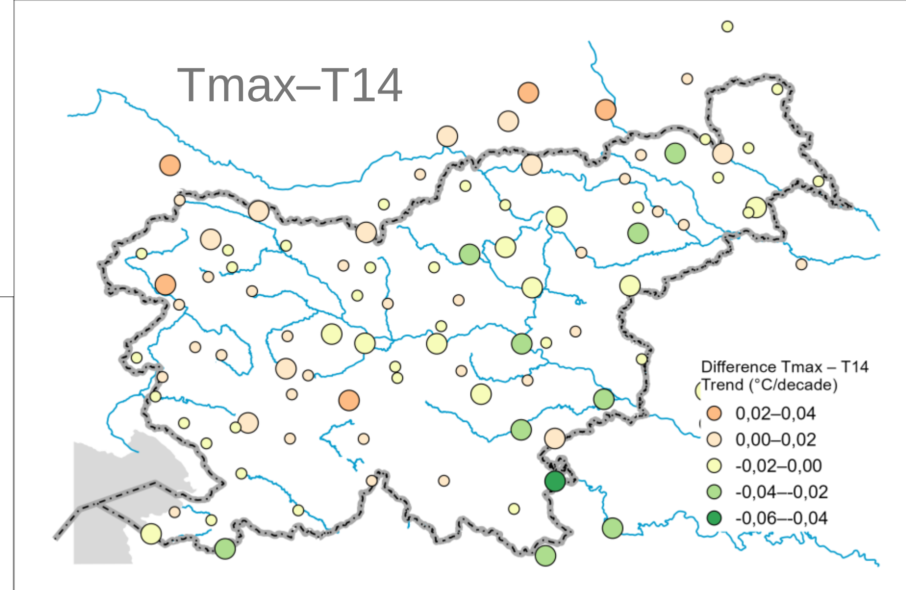

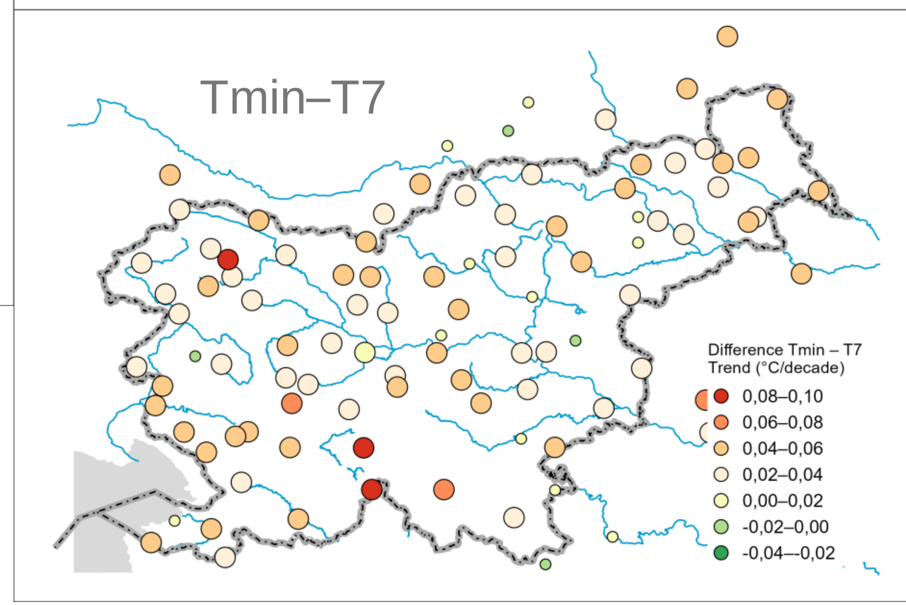

Linear trends (Theil-Sen) of the **difference of homogenised temperature series** for period 1950–2020. Statistically significant values are marked by larger circles (p = 0.05, Mann-Whitney test)

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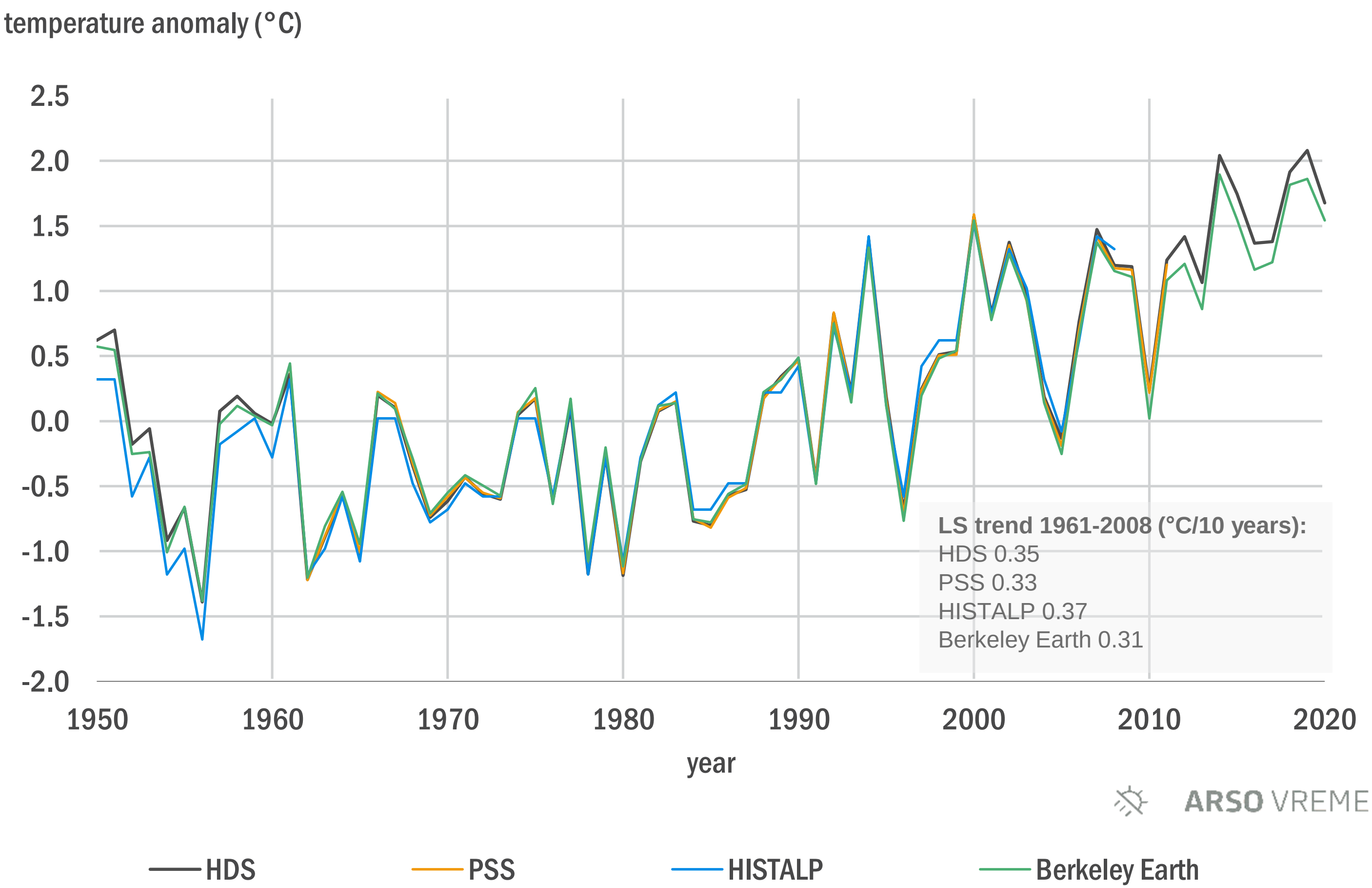

Annual mean temperature anomaly in Slovenia for **four datasets**. Reference periode 1961-2008. Arithmetic mean of Slovenian stations in HDS and PSS projects, grid cell values in HISTALP (46 °N, 15 °E), and areal mean in Berkeley Earth. Colder start in HISTALP, colder end in Berkeley Earth.

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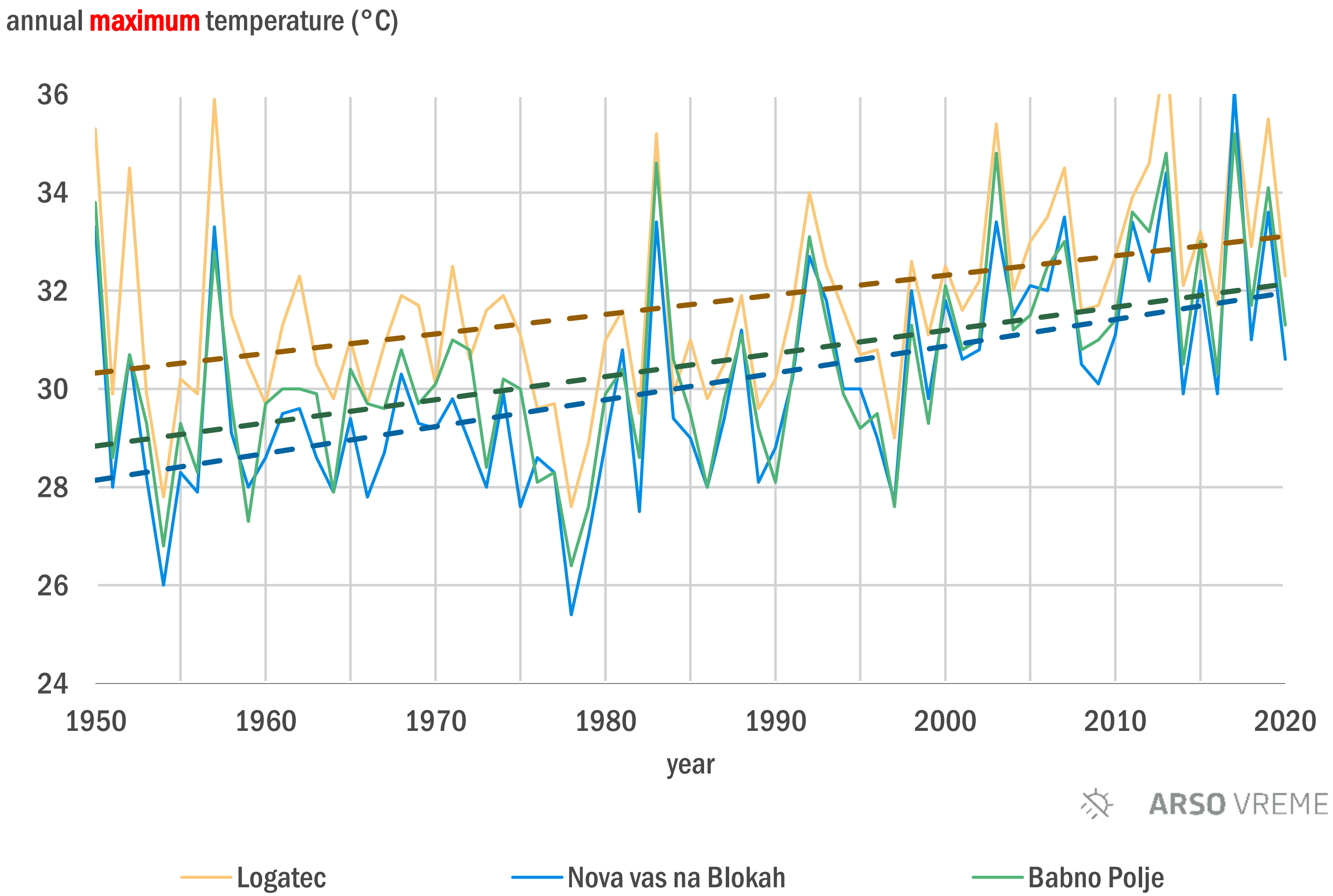

Annual maximum temperature in homogenised and interpolated time series of three „frost-hollow“ stations. Linear trend is shown with dashed line. Temperature trend is quite similar for all the stations.

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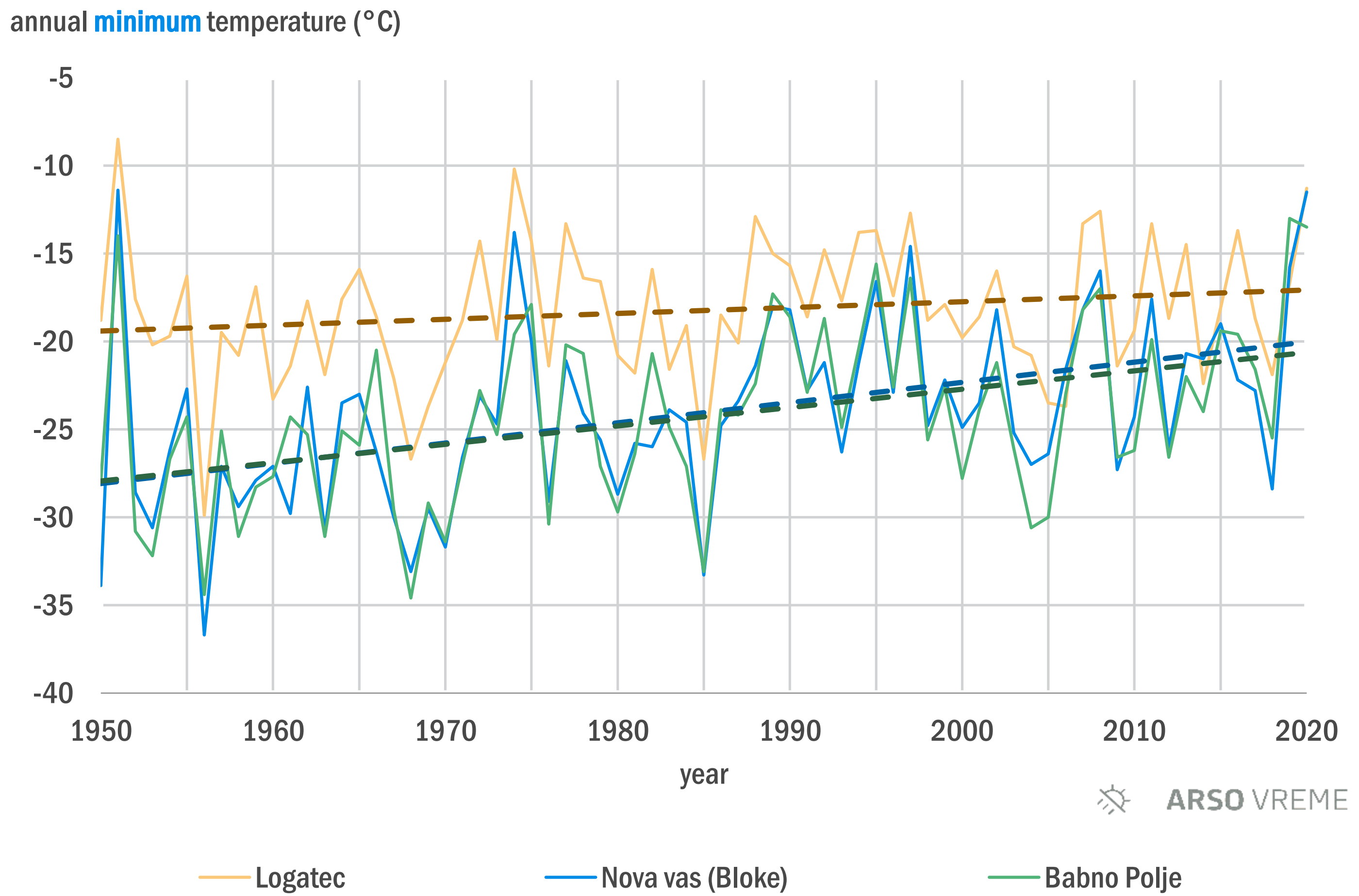
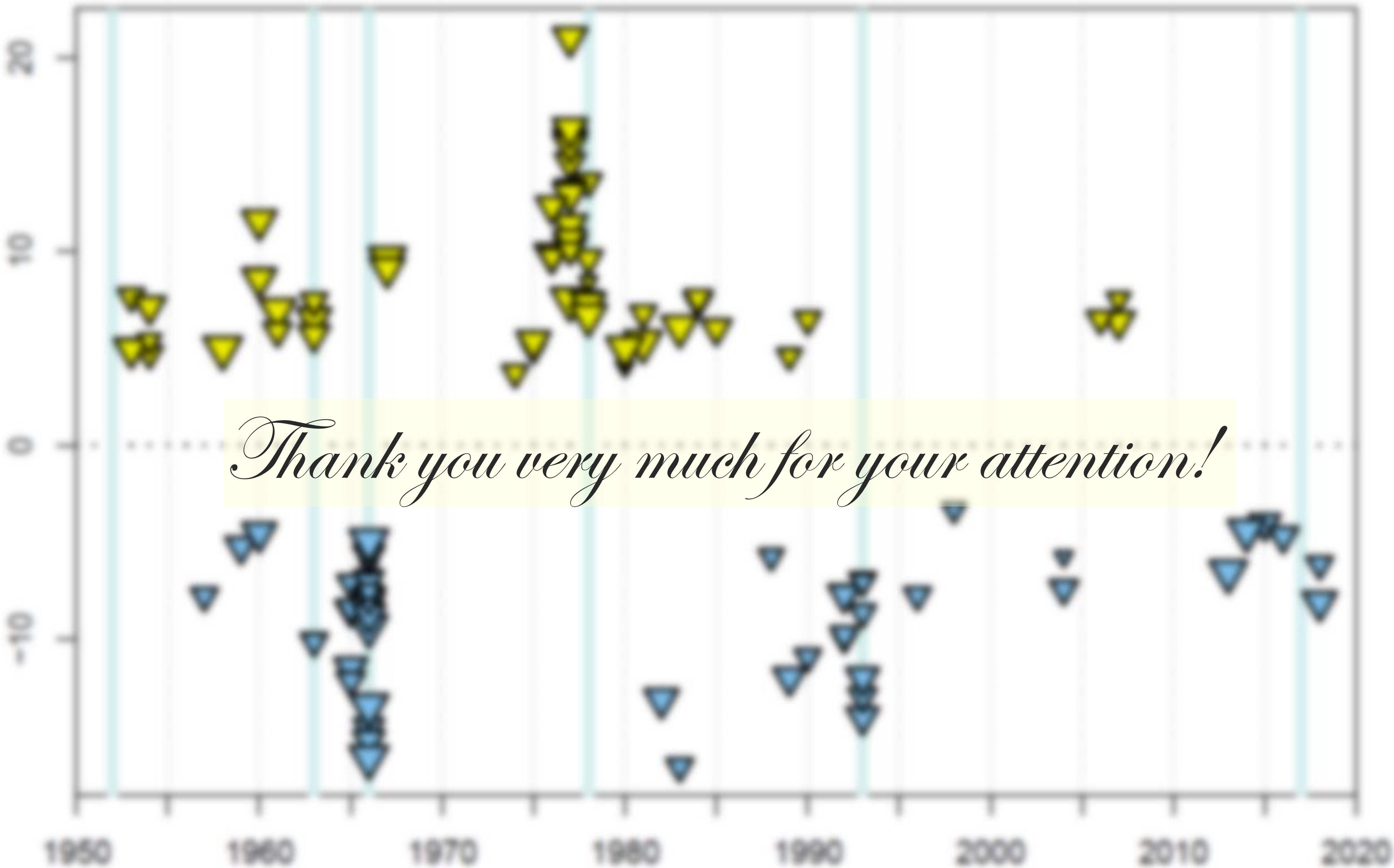


Annual minimum temperature in homogenised and interpolated time series of three „frost-hollow“ stations. Linear trend is shown with dashed line. Temperature trend for Logatec is much smaller than for the other stations as due to remaining inhomogeniety in tails of distribution (relocation from less to more variable site).

Conclusions

- Very time-consuming process from QC to climate change analysis
- Regionalisation of time series as solution to statistical issues with HOMER
- Complete database of daily values for period 1950–2020 to study weather & climate variability, climate change
- Homogenisation & interpolation also done for precipitation, snow depth and bright sunshine duration

- Adding current AWS measurements to the database enables „real-time“ climatological assesment of weather and climate conditions (daily & monthly anomalies, return periods etc.)
- Inhomogenieties in day-to-day variability could significantly affect extreme value analysis (minimum temperature!)
- Future plans:
  - digitisation of old data (ongoing project)
  - extending QC and homogenised series backwards (1925, 1896?)
  - using existing or developing new methods to deal with inhomogenieties in variability



Thank you very much for your attention!

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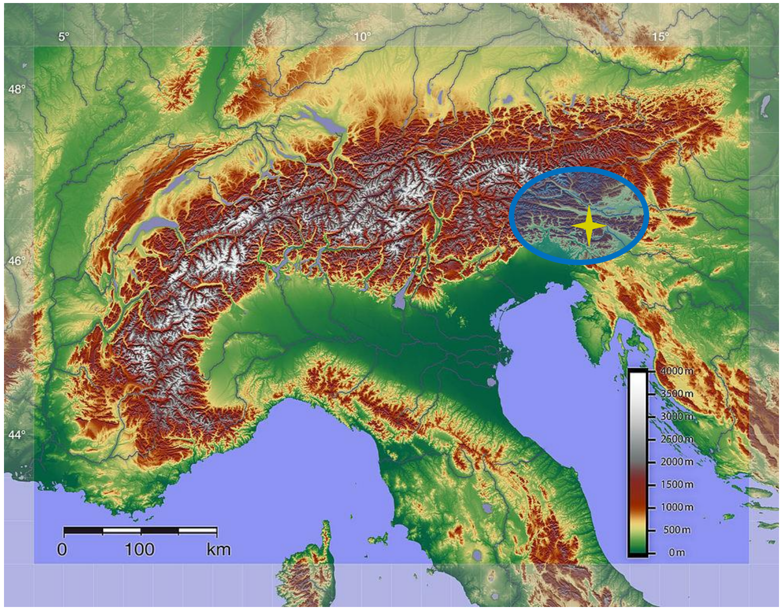
An example of comparison between HOMER and our daily interpolation



Alpine terrain map. Source: https://en.wikipedia.org/wiki/List_of_prominent_mountains_of_the_Alps_above_3000_m#/media/File:Alpenrelief_01.jpg

Comparison of **monthly temperature anomaly (T21/Tmean)** for several Alpine sites (courtesy of ARSO and Geosphere Austria), interpolated values at Kredarica (two methods) and reanalysis products (https://psl.noaa.gov/cgi-bin/data/testdap/timeseries.pl). Reference period is 1951–1980. Colors corresponds to anomaly values (**blue negative, red positive**).

								850 hPa pressure level (~ 1500 m)		700 hPa pressure level (~ 3000 m)	
Month	**Rateče (valley, 864 m)**	**Planina pod Golico (slope, 1050 m)**	**Dom na Komni (plateau edge, 1522 m)**	**Villacher Alpe (peak, 2140 m)**	**Kredarica HOMER (2513 m, peak)**	**Kredarica Daily INT (2513 m, peak)**	**Sonnblick (Tmean, peak, 3106 m)**	**20th CR V3**	**NCEP NCAR R1**	**20th CR V3**	**NCEP NCAR R1**
Oct. 53	3,4	2,5	1,7	1,1	**2,5**	**0,7**	1,0	1,6	2,4	0,8	1,4
Nov. 53	–1,0	–0,2	0,8	3,0	**–0,1**	**2,6**	3,5	1,2	1,4	2,3	2,8
Feb. 54	–2,4	–4,0	–3,4	–2,2	**–3,5**	**–0,9**	–0,7	–2,6	–2,8	–0,7	–1,2