SPARTACUS: A km-scale daily dataset of the surface climate in Austria – overview and new developments

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11th Seminar for Homogenization and Quality Control in Climatological Databases and 6th Interpolation Conference jointly organized with the 14th EUMETNET Data Management Workshop
11 May 2023

Who is GeoSphere Austria?

National weather service of Austria

ZAMG
Zentralanstalt für Meteorologie und Geodynamik

GeoSphere Austria

Until 2022

Since 2023

Agenda

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- SPARTACUS: general information
- In brief: Data preparation
- Interpolation method for air temperature
- Interpolation method for precipitation amount
- Interpolation method for sunshine duration
- New development: Interpolation method for air humidity
- Challenges

SPARTACUS: general information

- Operational climate-monitoring dataset produced by GeoSphere Austria
- Spatial analysis of daily station observations applying geostatistical interpolation methods
- Parameters:
  - Minimum and maximum temperature
  - Precipitation amount
  - Sunshine duration
  - In development: Air humidity (dew-point depression)
- Temporal resolution: 1 day (temporal aggregates – month, season, year – are generated as well)
- Data since: 1 January 1961
- Spatial resolution: 1 km x 1 km
- Spatial coverage: Territory of Austria (including some river catchments at the boarder)
- Spatial reference system: ETRS89 / Austria Lambert
- Data availability: available for the public as netCDF via Datahub of GeoSphere Austria (https://data.hub.zamg.ac.at/)

In brief: Data preparation

… for temperature, precipitation and sunshine duration

- Data from Austria and its neighbouring countries is used
- Different number of stations – depending on parameters
  - Temperature: 172 (GeoSphere: 120, Others: 52)
  - Precipitation: 593 (GeoSphere: 114, Hydrological Service Austria: 410, Others: 69)
  - Sunshine duration: 73 (GeoSphere: 48, Others: 25)
- Data checks (e.g. value ranges) and conversion (absolute to relative sunshine duration)
- Filling data gaps using method from Schneider (2001) – transformation of data for precipitation and sunshine duration

=> Complete time series for each station for interpolation

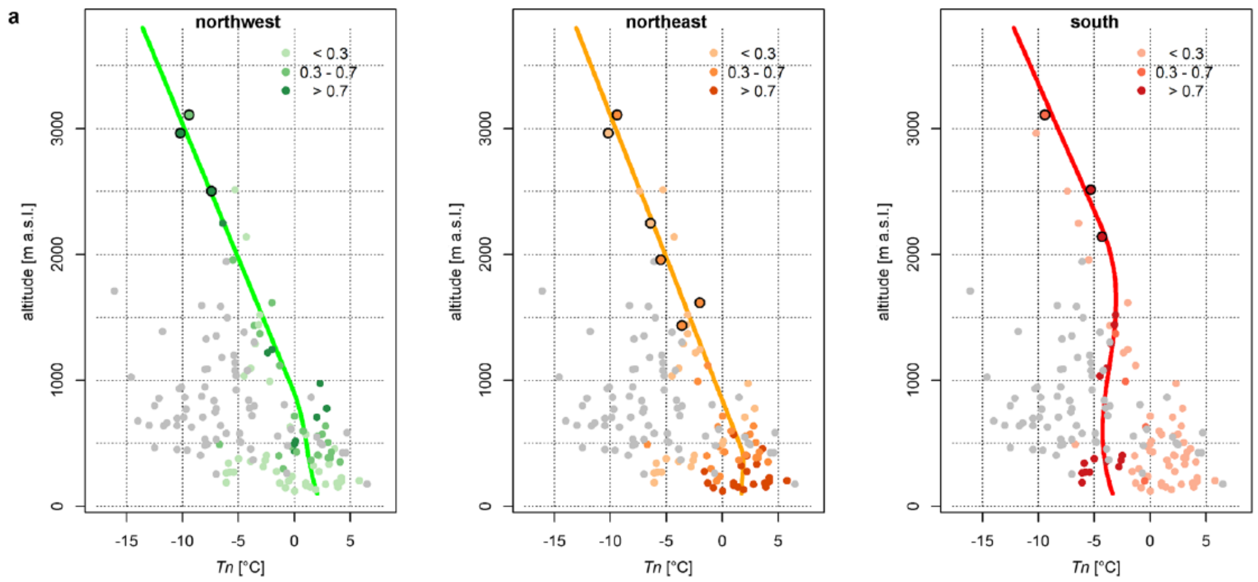
- **Challenge**: stable station network over long time

Schneider, T. Analysis of incomplete climate data: Estimation of mean values and covariance matrices and imputing of missing values. *J. Climate* **14**, 853-871 (2001).

Interpolation – two steps

1) Background field (macro-climatic field)

- Large-scale nonlinear vertical temperature profiles in three subregions
- Subregional weighting of stations
- Cold-pool (valley) stations are omitted, summit stations are defined
- Temperature profile is described by a nonlinear parametric function with two linear sections (upper and lower level) and an intermediate section
- Profile estimated by minimising squared differences

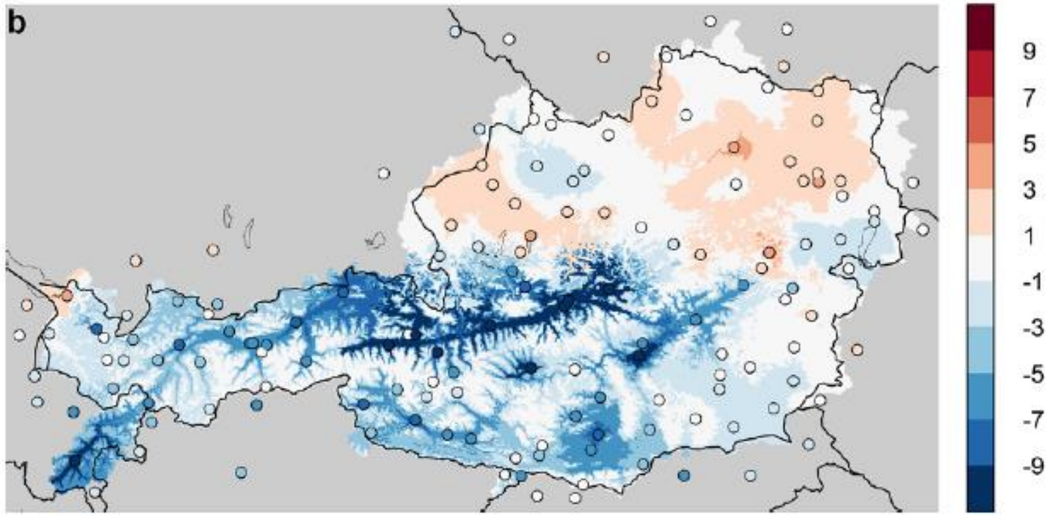


Vertical profiles (Tmin on a winter day)

Interpolation – two steps

2) Residual field (meso-climatic field)

- Weighting station residuals from the background field
- Weighting scheme: Non-Euclidean
  - Use of predefined generalised distance fields accounting for the topographic obstruction on the horizontal exchange of air masses
  - Use of λ to determine the relative weighting of horizontal and vertical distance increments along the paths
- Generalized distance fields are only calculated once



Residuals from the vertical profile (Tmin on a winter day)

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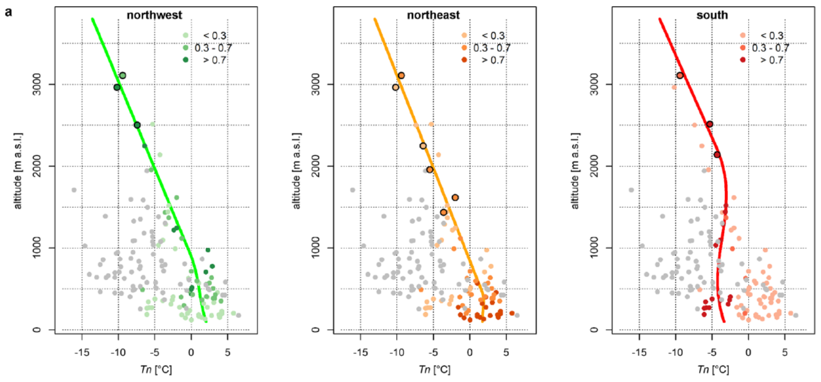
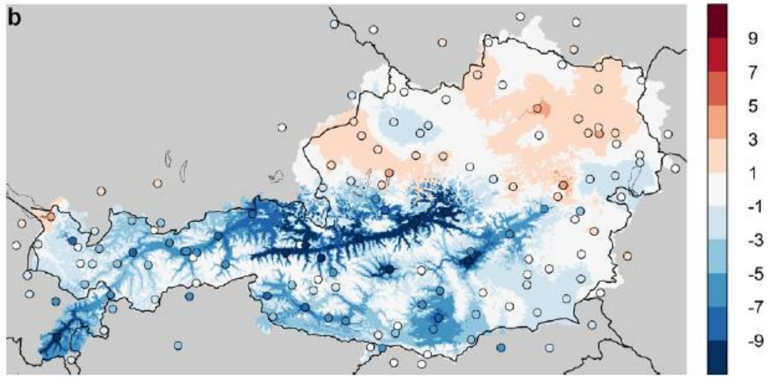
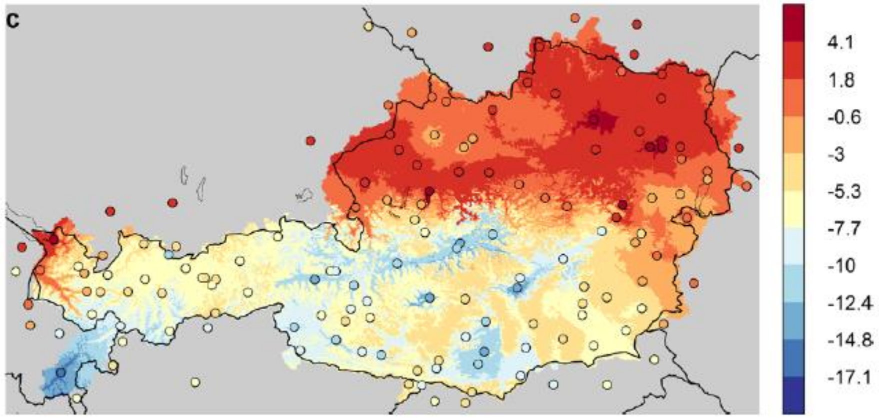
Interpolation – two steps

3) Combination of background field and residual field







Evaluation

- Result of systematic cross-validation
- No systematic under- or overestimation
- Errors larger for Tmin than for Tmax
- Errors larger for the interior of the Alps than for the flatland
- Errors larger for winter than for summer

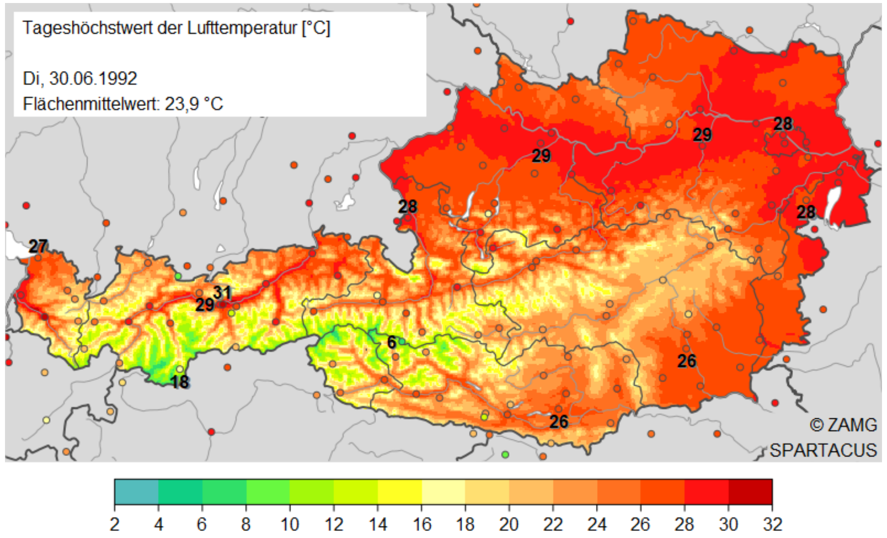
Table 1 Mean error metrics [°C] from cross-validation over the period 2003–2012. Results are based on within-Austria stations only

	Tn			Tx		
	Year	DJF	JJA	Year	DJF	JJA
ME	0.02	0.00	0.02	0.04	0.07	0.02
MAE	1.14	1.25	0.97	0.98	1.17	0.86
RMSE	1.51	1.64	1.25	1.31	1.58	1.10

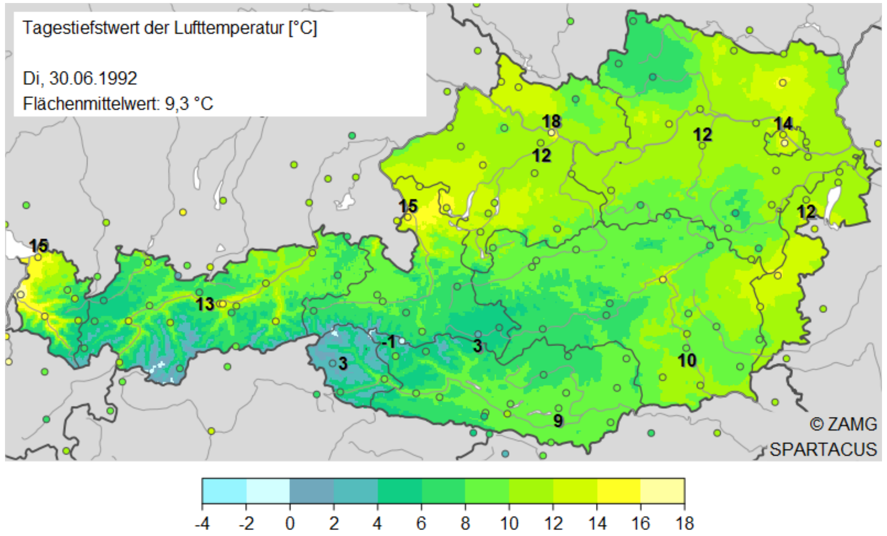
More details: Hiebl, J., Frei, C. Daily temperature grids for Austria since 1961—concept, creation and applicability. *Theor Appl Climatol* **124**, 161–178 (2016).

Examples and application

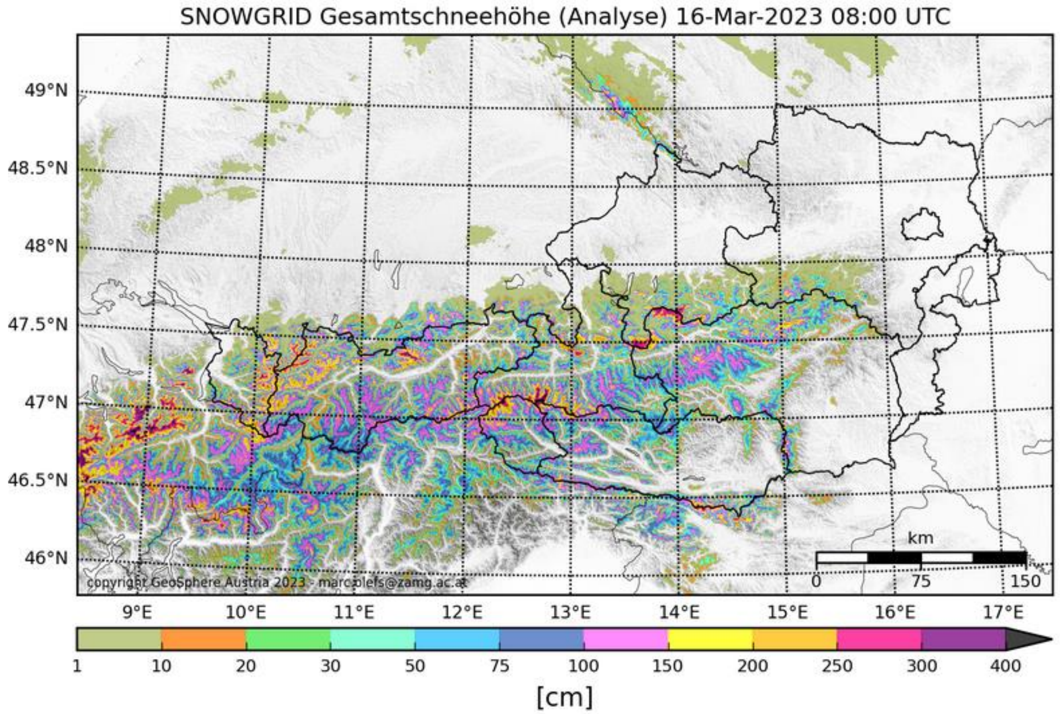
Tmax



Tmin

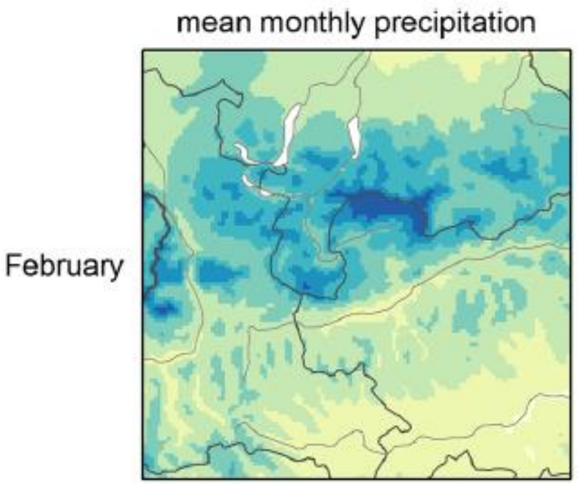


Application: SNOWGRID – snow monitoring

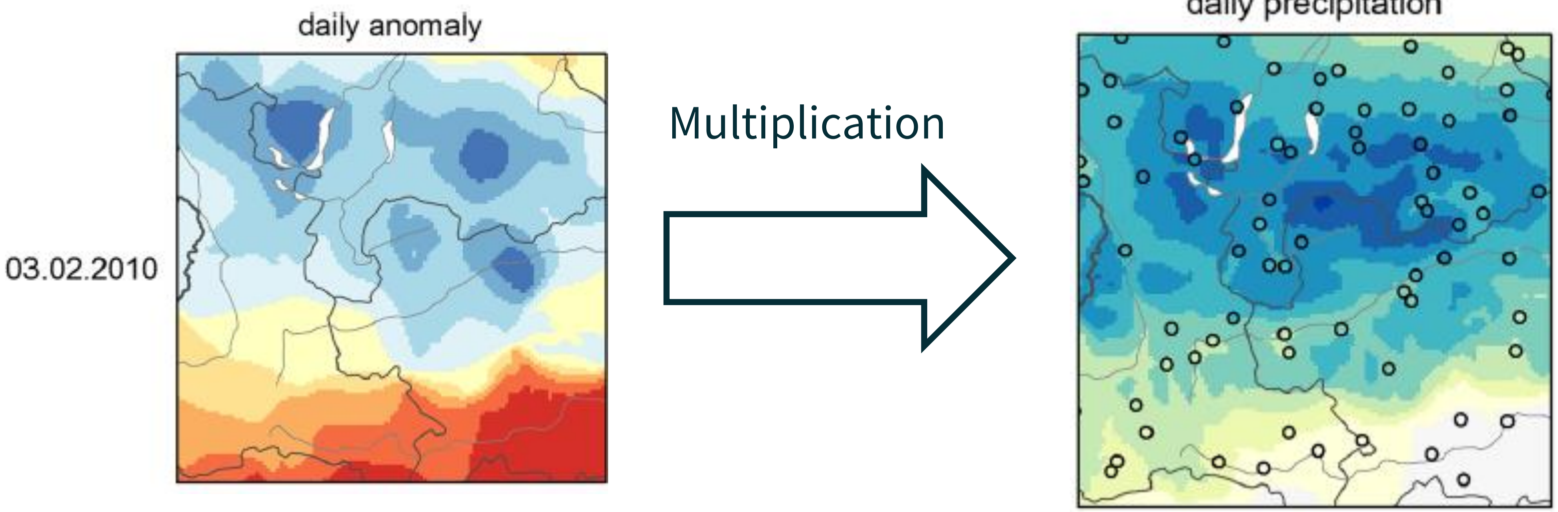


Interpolation – two steps

1) Mean monthly background fields



2) Daily anomaly fields



- One-time preparatory calculation
- Climatological background considers > 2000 stations
- Based on KED (kriging with external drift) using topographic predictors and modelling spatial covariance

- Daily calculation
- Spatial interpolation of relative anomalies of station observations from monthly background field
- Using adapted version of angular distance weighting algorithm SYMAP

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Evaluation

- Accuracy of dataset depends on interpretation
- Grid point value = point value => considerable systematic and random errors
- Grid point value = area mean value => errors are reduced compared to point-value view
- Example: Bias of cross-validation shows slight underestimation

Table 4 Cross-validation statistics for the daily precipitation grid dataset

Altitude band	*n*	B				
		DJF	MAM	JJA	SON	Year
<500 m	215	0.98	0.99	0.99	0.99	0.99
500–1000 m	207	0.97	0.98	0.99	0.99	0.98
1000–1500 m	88	0.98	0.97	0.99	0.98	0.98
>1500 m	13	0.98	1.00	1.01	1.03	1.01
All	523	0.98	0.98	0.99	0.99	0.99

More details: Hiebl, J., Frei, C. Daily precipitation grids for Austria since 1961—development and evaluation of a spatial dataset for hydroclimatic monitoring and modelling. *Theor Appl Climatol* **132**, 327–345 (2018).

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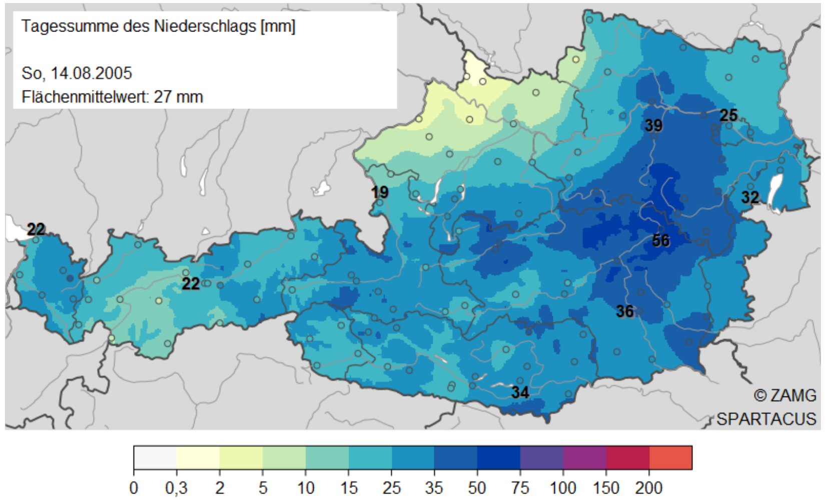
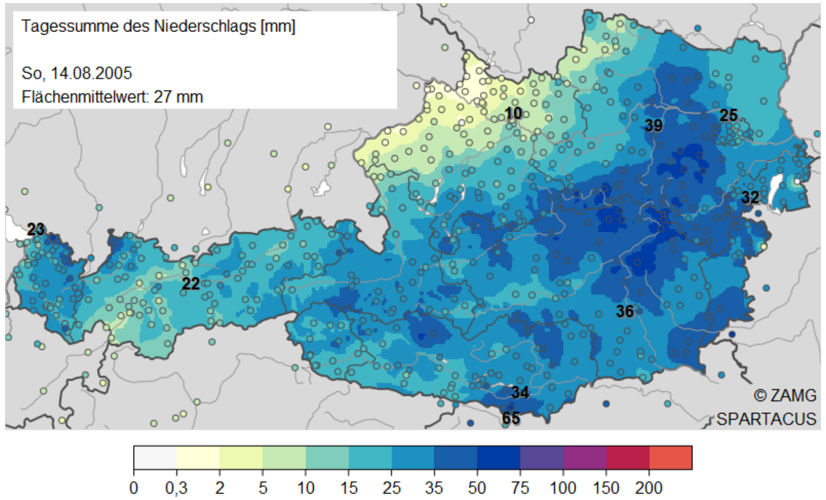
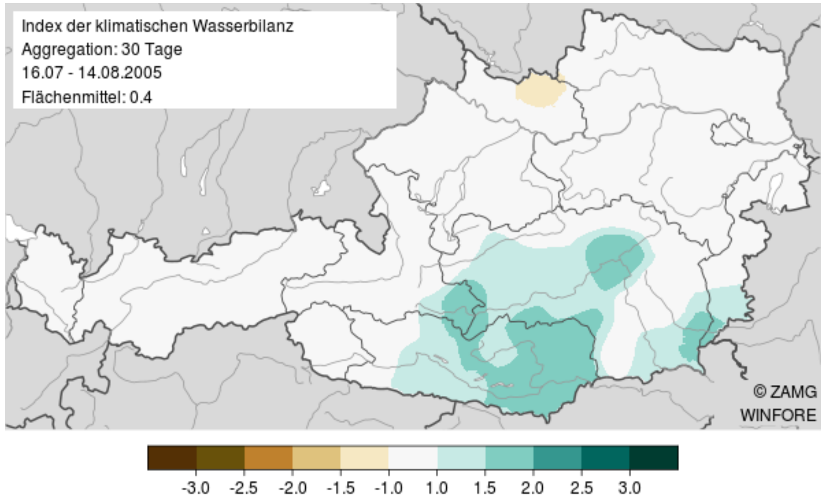
Examples and applications

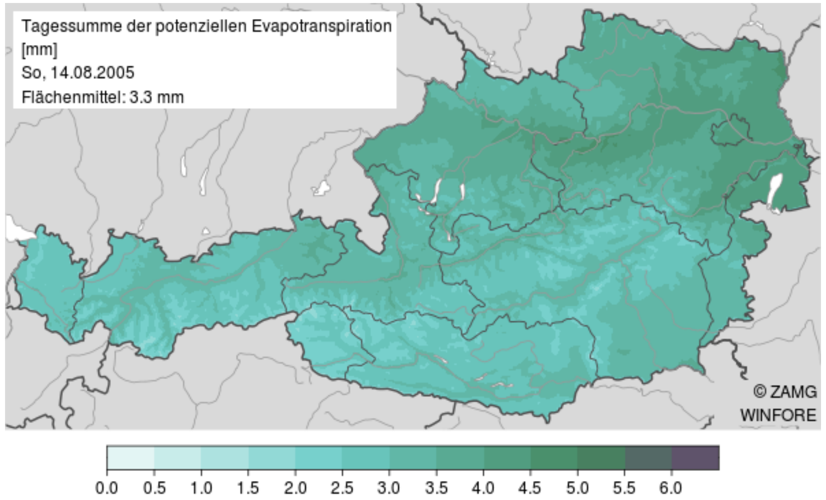




Application: WINFORE – Drought monitoring



Standardised Precipitation-Evaporation Index (SPEI)



Reference Evaporation (ET0)

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Interpolation

One-time preparatory calculation → Daily calculation

One-time preparatory calculation

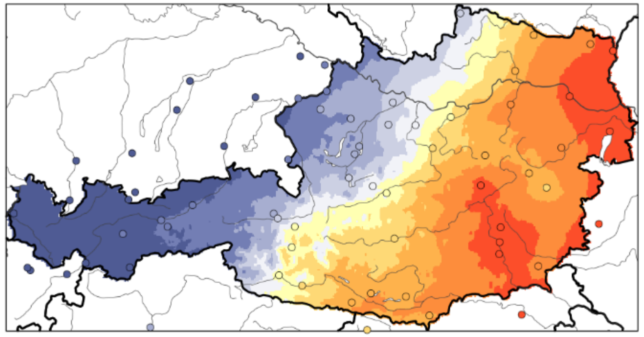
- PCA of clear-sky index to get time-invariant anomaly fields which describe small-scale cloud patterns that are not resolved by the station network
- Certain number of PC loadings for each month selected

Daily calculation

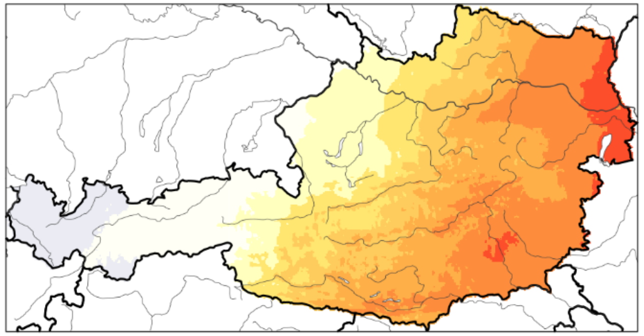
- Kriging with external drift
- External drift variables: PCA loadings and other topo-geographic fields (longitude, latitude and height)
- Spatial covariance structure modelled with isotropic exponential variogram and a nugget effect

Evaluation

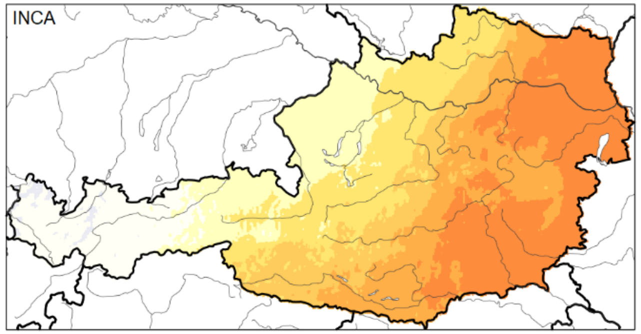
SPARTACUS relative sunshine duration [%]



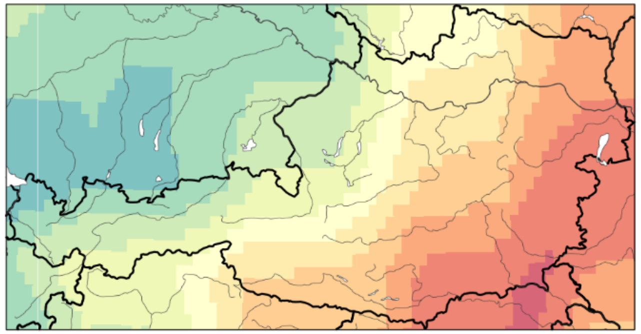
SPARTACUS absolute sunshine duration [h]



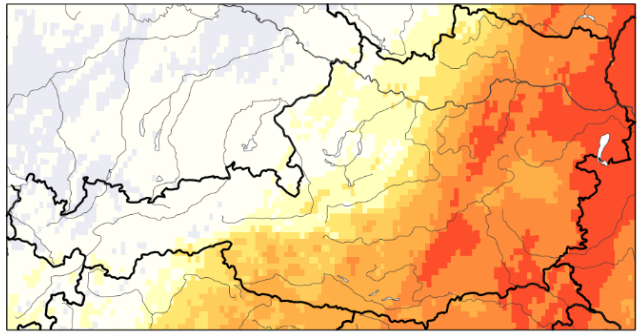
INCA/APOLIS absolute sunshine duration [h]



E-OBS global radiation [Wm^{-2}]



CM SAF absolute sunshine duration [h]



Publication in preparation; method based on Frei, C., Willi, M., Stöckli, R., Dürr, B.: Spatial analysis of sunshine duration in complex terrain by non-contemporaneous combination of station and satellite Data, *Int. J. Climatol* **35**, 4771-4790 (2015)

New development: Humidity

Goal: development of method for spatial interpolation of an atmospheric humidity parameter

Parameter selection

- Possible parameters: Relative humidity, vapour pressure, vapour pressure deficit, dew point temperature, dew-point depression
- Considering user needs, suitability for spatial analysis , accurate calculation of daily means and accurate conversion for selection
- Interpolation of dew-point depression

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Challenge in calculation of daily mean of relative humidity (and air temperature)

Reason: shift in observation time in 1971 in Austria

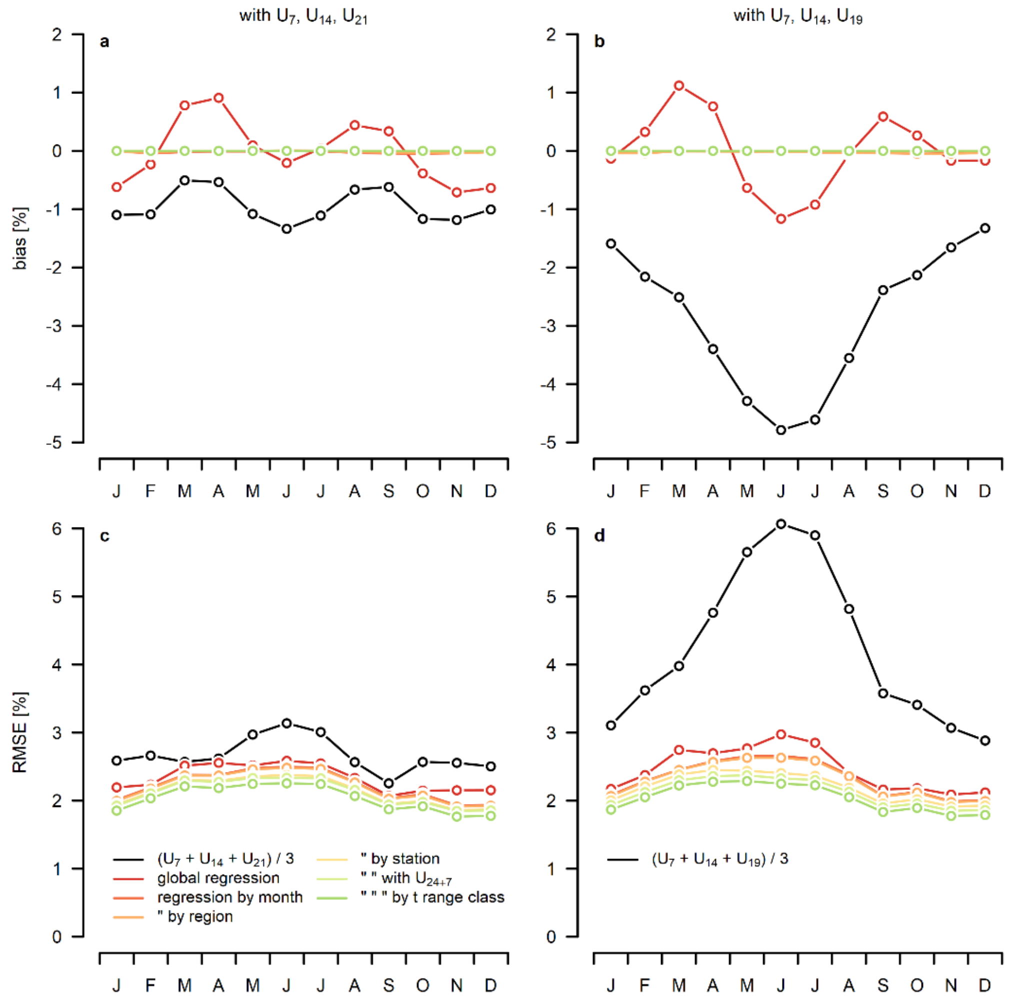
Relative humidity until 1970: $\overline{U} \approx (U_7 + U_{14} + U_{21})/3$

Relative humidity since 1971: $\overline{U} \approx (U_7 + U_{14} + U_{19})/3$

Since start of automatic measurements:

Relative humidity: $\overline{U} = \frac{1}{24}\sum_{i=1}^{24} U_i$

Solution: Multi-linear regression to calculate quasi-24-hour mean value of relative humidity and air temperature in period before automatic measurements

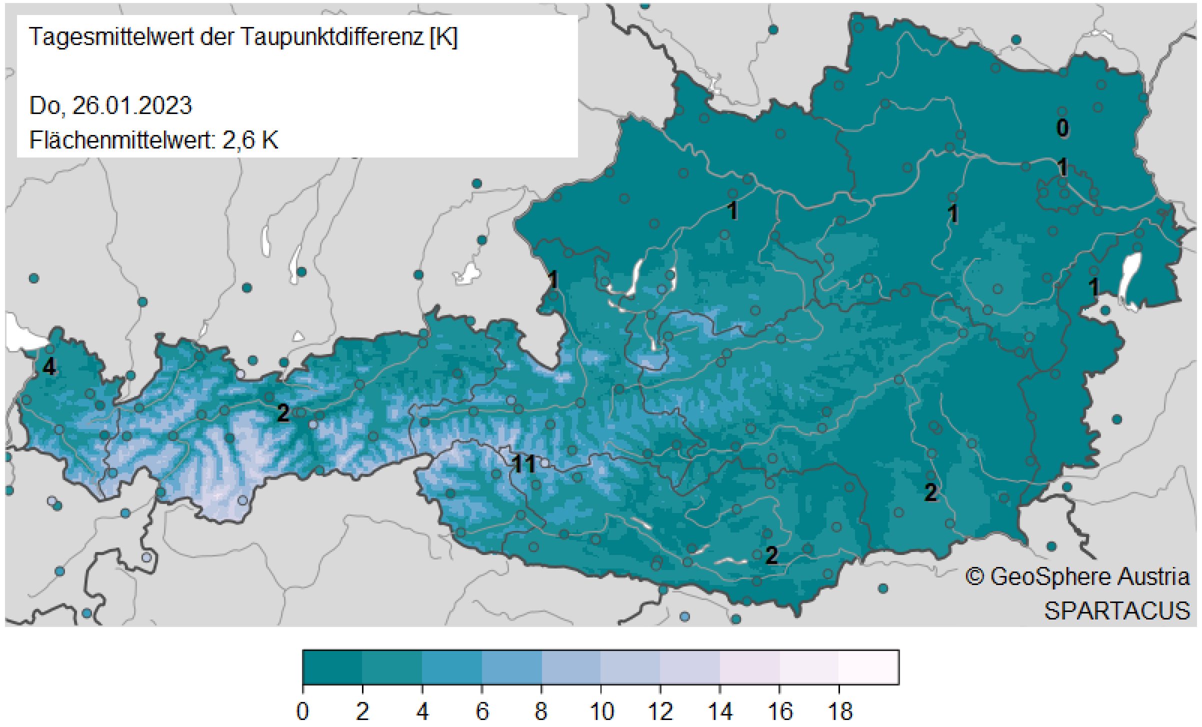


Interpolation

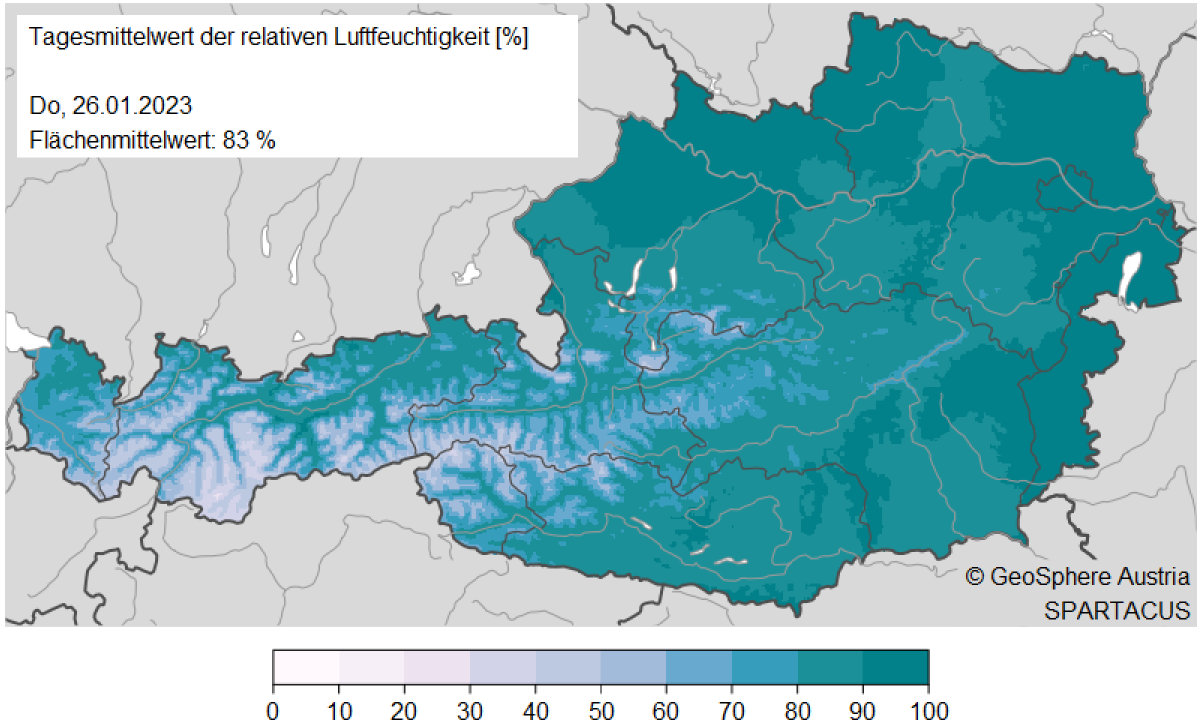
Method to interpolate dew-point depression is similar to the interpolation of air temperature

- Step 1: Estimating nonlinear vertical profiles of dew-point depression in four different sub regions (NW, NO, SO, SW)
- Step 2: Interpolation of difference between vertical profile and station value using non-euclidean distance
- Step 3: Combination of field 1 and field 2 to receive final result

Examples



Dew-point depression



Converted into relative humidity

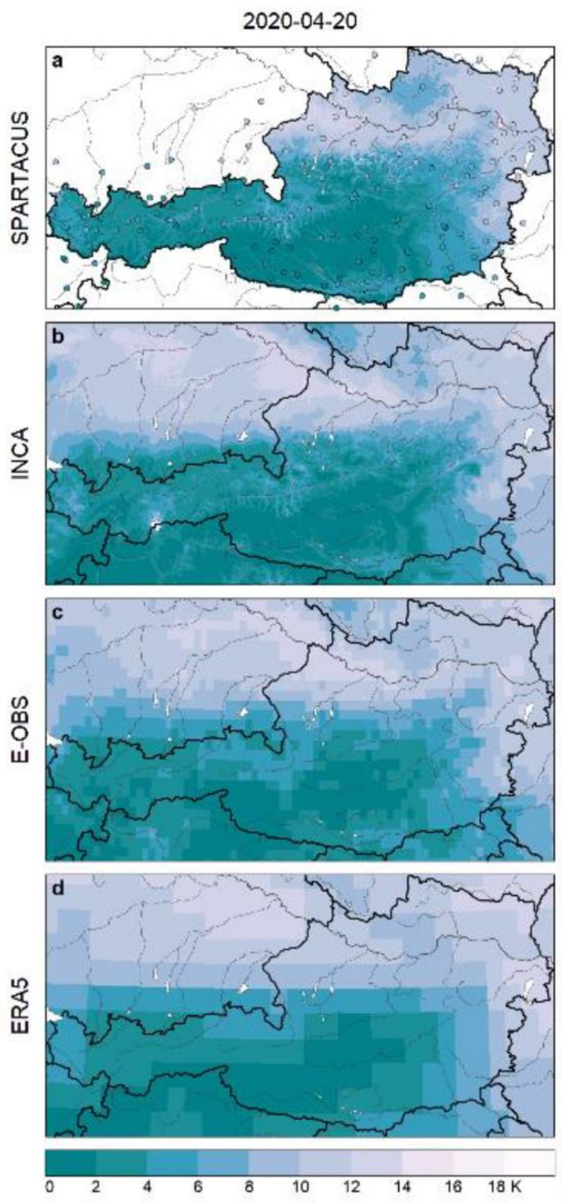
Evaluation

Preliminary results

- Good agreement with other gridded datasets

- Low temporal consistency of error due to change of data quality (increased with time) => consequence: gridded dataset is not suited for trend analysis!

Publication in preparation



… in interpretation of grid point values of station-based gridded data

Document of DWD, MeteoSwiss and GeoSphere Austria about uncertainties and interpretation of grid point values of station-based gridded data

Sources of uncertainty and their consequences

- Measurement uncertainty
- Conditional bias
- Effective resolution

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

ZAMG

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

DACH-Empfehlungen zu Unsicherheiten und Interpretation der Gitterpunktwerte von stationsbasierten Gitterdaten

Basierend auf Analysen und Überlegungen durch Christoph Frei (MeteoSchweiz) anlässlich des DACH - Workshops vom 25. August 2021

https://www.zamg.ac.at/cms/de/dokumente/klima/dok_projekte/grids/Limitierungen_Gitterdaten_DACH.pdf?anonymous=true

In a nutshell …

	Temperature	Precipitation	Sunshine duration	Humidity
Parameters	Tmin, Tmax (Tmean)	Daily rain amount	Daily (relative) sunshine duration	Dew point spread
Data	172 stations	114 / 593 stations	73 stations	~ 175 stations
Interpolation method	Combination of background (vertical) and residual field	Monthly background field (KED) and daily anomaly field (SYMAP)	PCA of satellite data, KED using PCA loadings and other fields	Combination of background (vertical) and residual field
Publication	https://doi.org/10.1007/s00704-015-1411-4	https://doi.org/10.1007/s00704-017-2093-x	In preparation	In preparation

THANK YOU!

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