Fluctuations of selected meteorological elements in mountainous regions of the Czech and Slovak republic according to RCM ALADIN-Climate/CZ outputs in the periods 2021-2050 and 2071-2100

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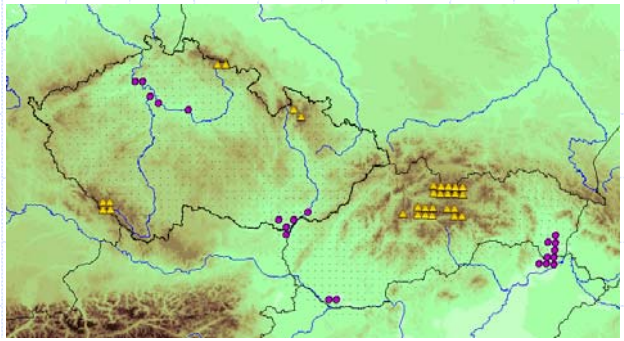
Outline

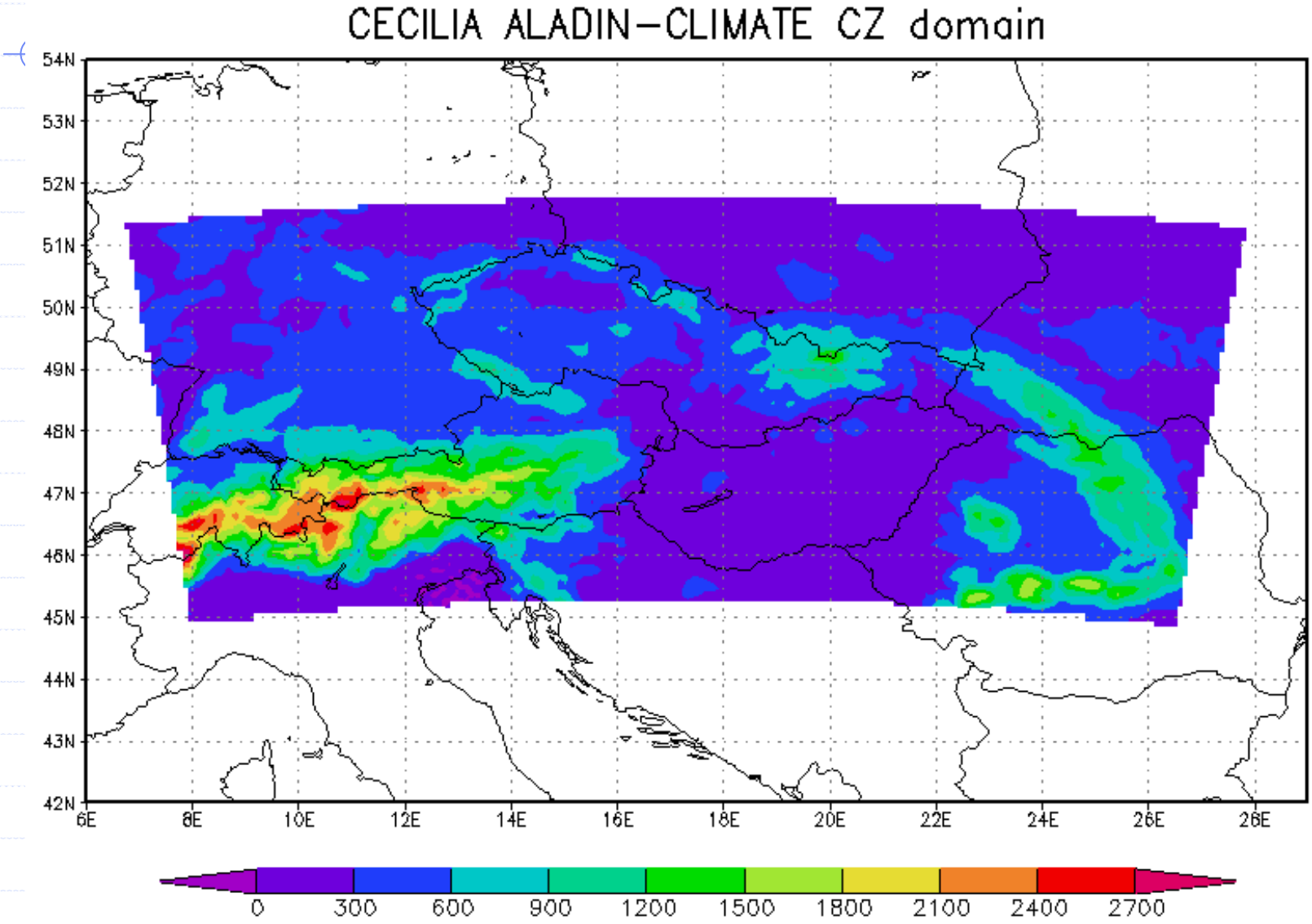
- **Description of model and experiments**
- Validation and correction of RCM outputs
- Future climate projection (A1B) with focus on comparison between highlands and lowlands regions



CECILIA

- ALADIN configuration:
  - 10 km spatial step
  - 450 seconds time step
  - 43 atmosphere levels
  - one month integration ~20.000 s. at NEC computer in Prague
  - 164 x 90 points (LON x LAT, C+I), 148 x 74 points (C)
- Experiment definitions:
  - ERA40 simulation 1960 – 2000
  - Present time slice 1960 – 2000 (ARPEGE-CLIMATE)
  - Near future time slice 2020 – 2050 (ARPEGE-CLIMATE, **A1B**)
  - Distant future time slice 2070 – 2100 (ARPEGE-CLIMATE, **A1B**)

CECILIA Experiments



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- Description of model and experiments
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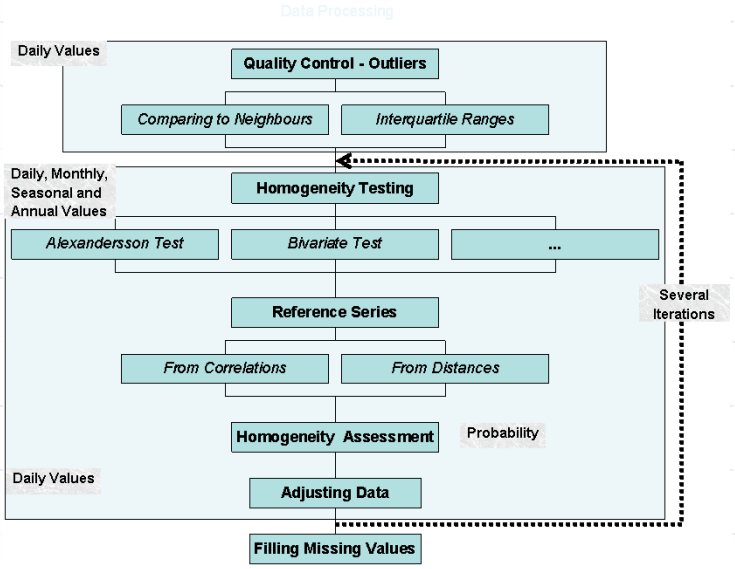
Station time series processing

- **Quality control, homogenization**
- **Completing gaps in series**
- **Calculation of new series in a given location**
  - **technical “station” series (QC, homogenized, filled missing periods)**
  - **grid point series (for RCM outputs validations, correction)**



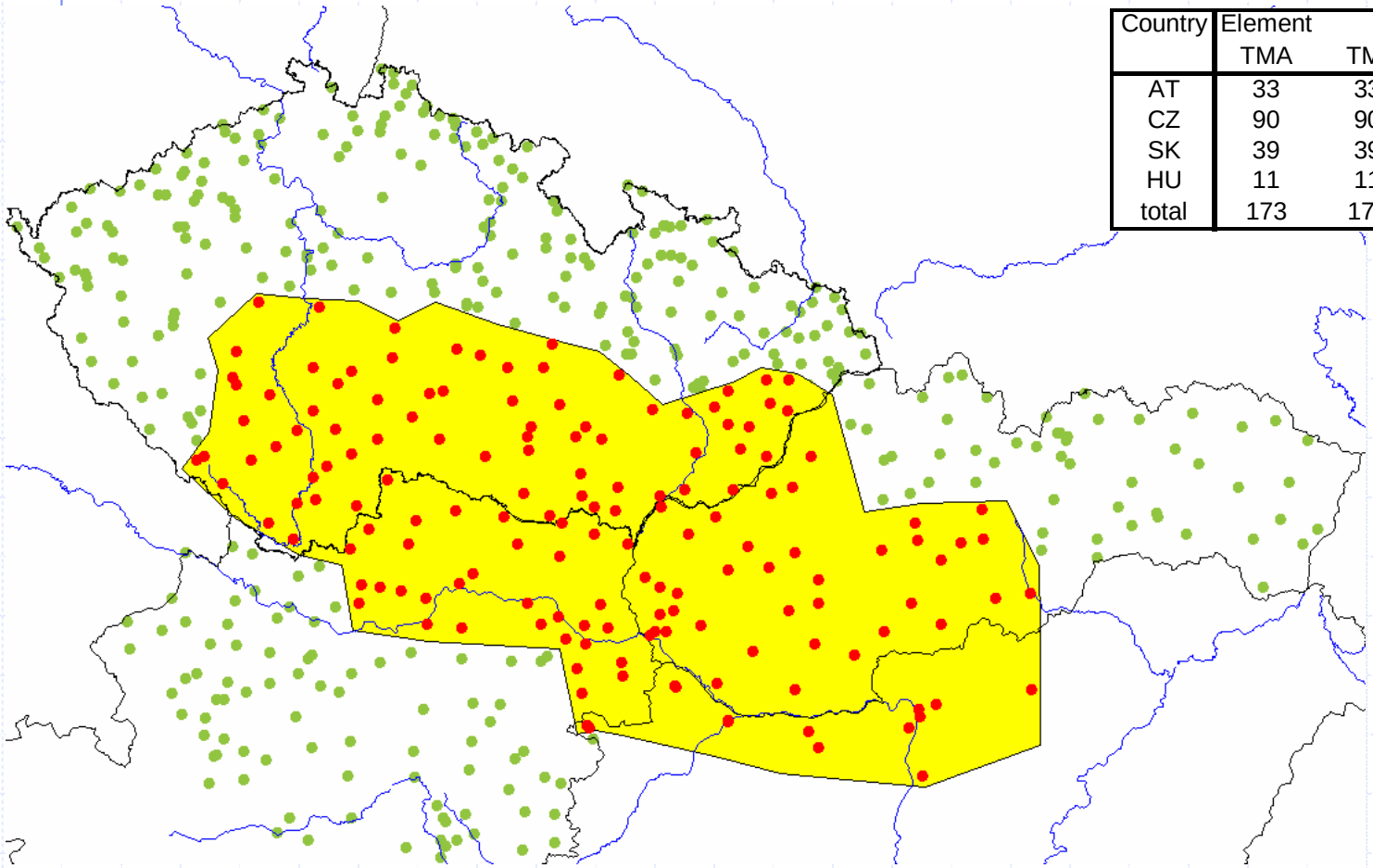
Technical series calculation

Output:

- Station technical series
- Grid points series (regular network)

- Daily scale
- 1961-2000 / 2008 (adding new years)
- Various elements (T,TMA,TMI,SRA,SSV,E,F)
- Various regions:
  - whole CZ, various spatial resolution (10, 25km)
  - whole SK (10 km)
  - CECILIA region (10 km)

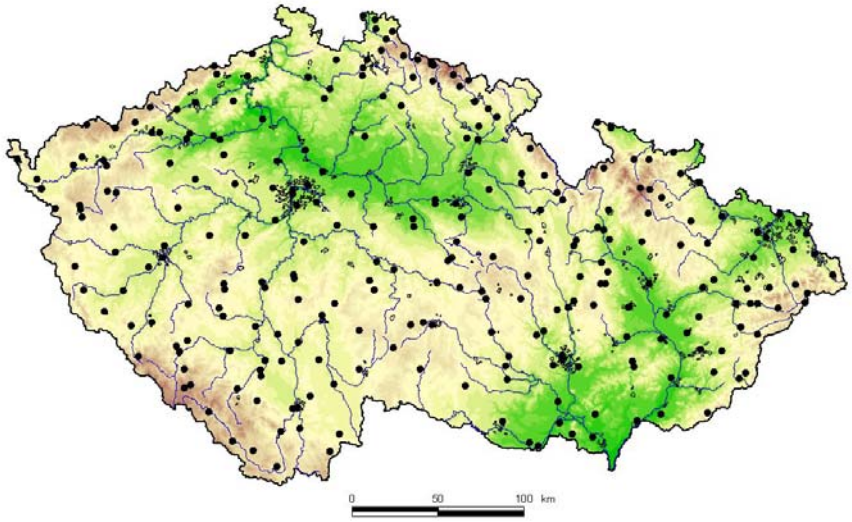
Stations with calculated technical series, climatological stations, CECILIA central European domain, 1961-2000



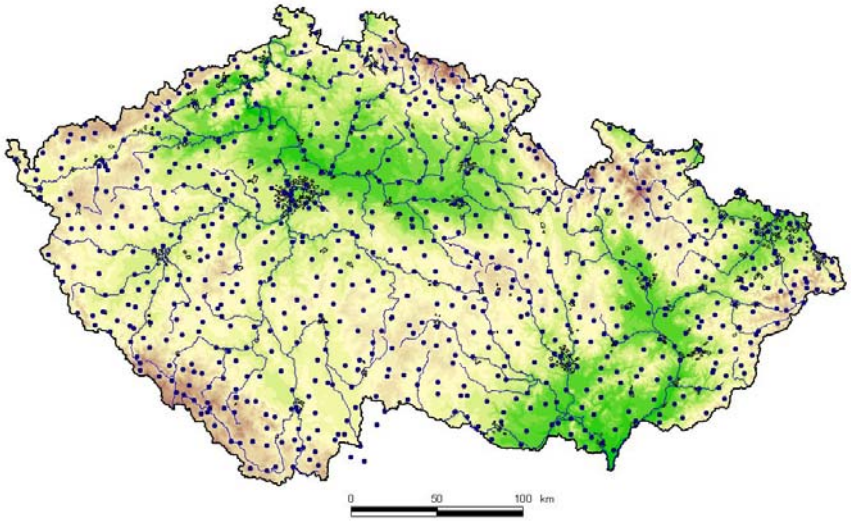
Country	Element				
	TMA	TMI	SRA	SSV	H
AT	33	33	35	11	30
CZ	90	90	90	68	91
SK	39	39	39	39	40
HU	11	11	11	6	11
total	173	173	175	124	172

Stations with technical series, for grid points of ALADIN-Climate/CZ, CECILIA central European domain, 1961-2000

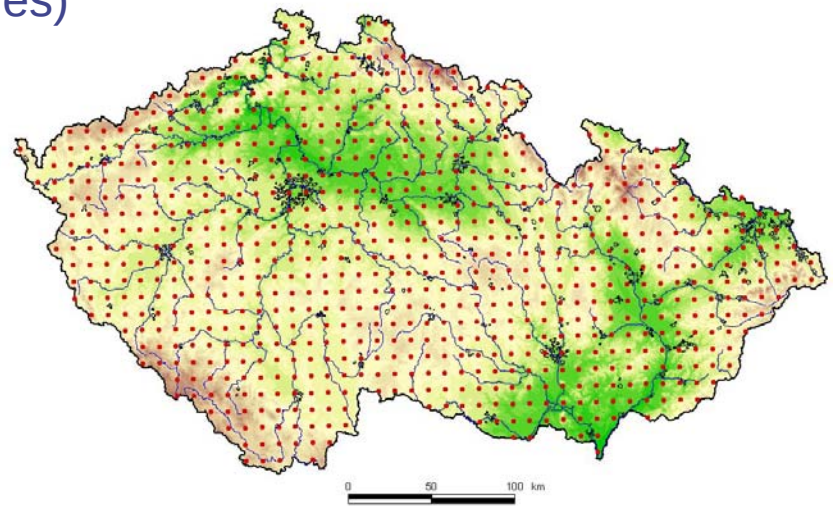
Stations (268) with calculated technical series, climatological stations



Stations with technical series, precipitation stations



Stations with technical series, for grid points of ALADIN-Climate/CZ (1961-2008, 7 met. variables)

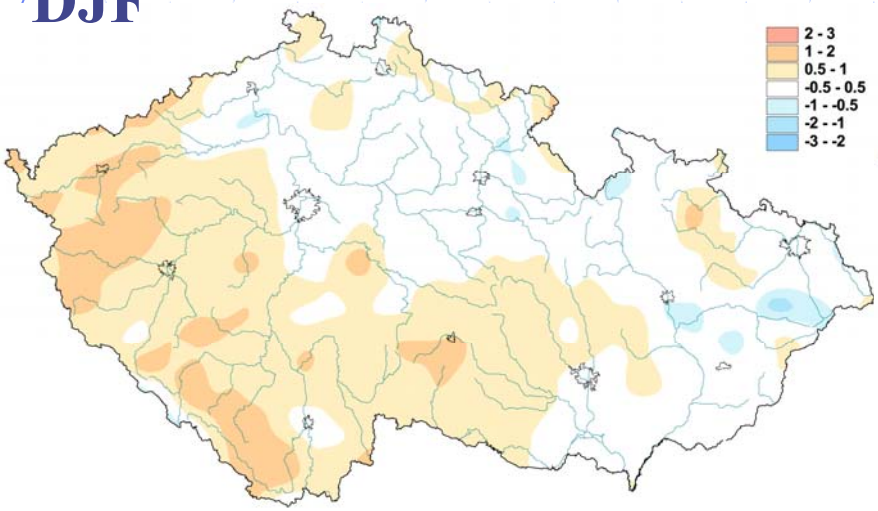


Validation and correction of RCM outputs

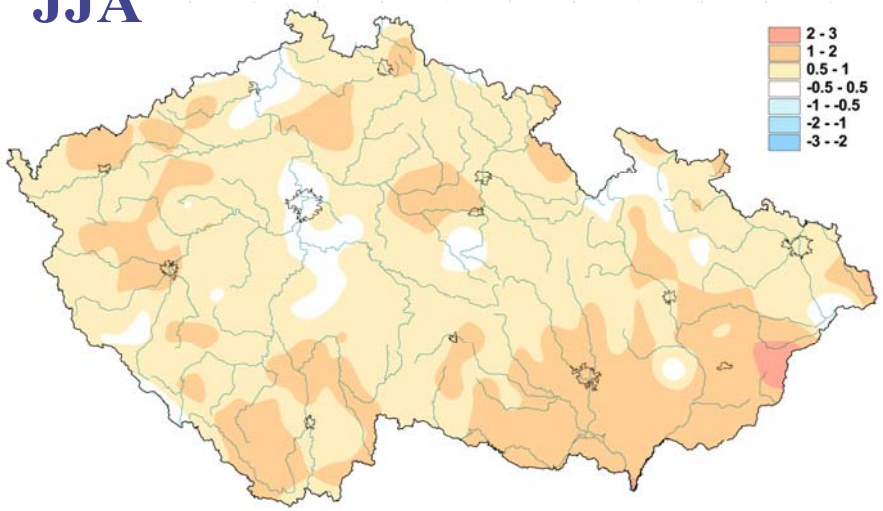
- **Station vs. RCM output comparison for each grid point (validation), various statistics calculated …**
- **Correction of RCM outputs based upon validation results**

T2m seasonal mean 61-90, Arpege

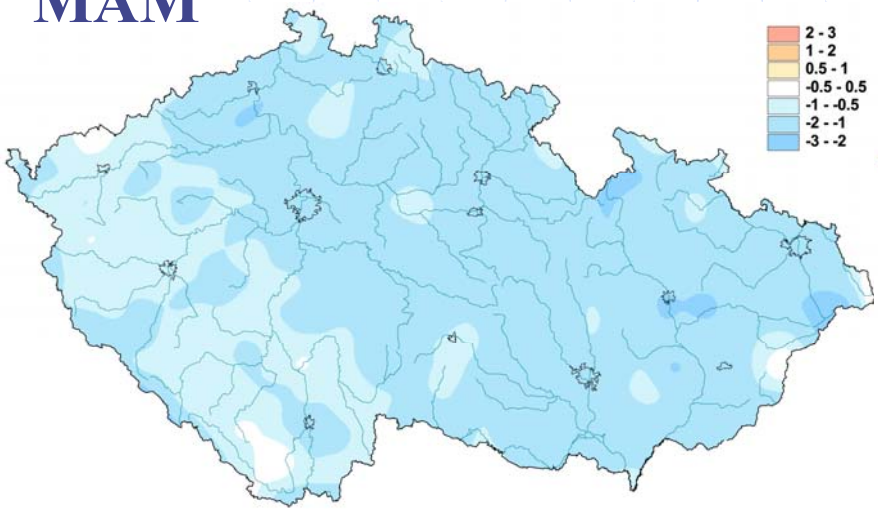
DJF



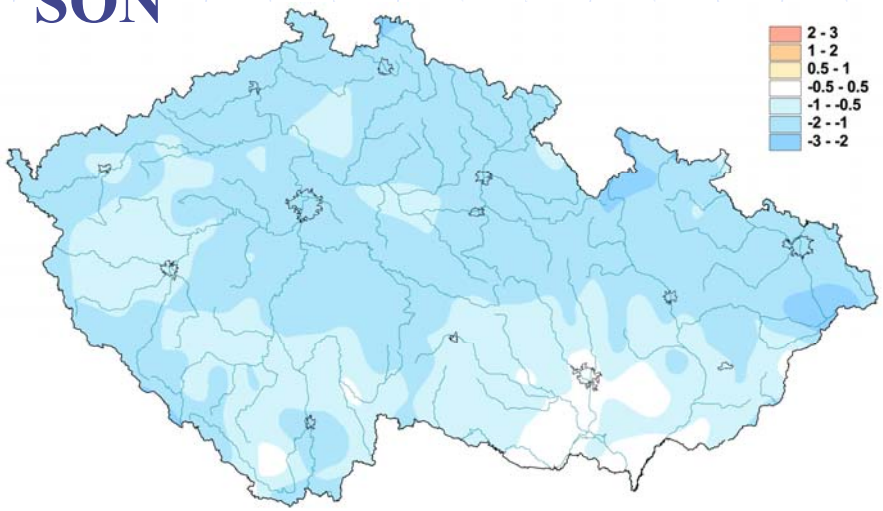
JJA



MAM

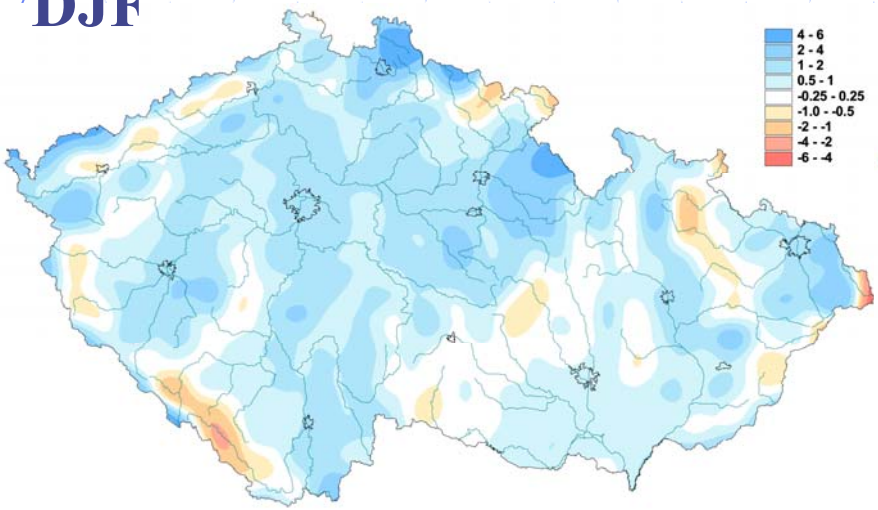


SON

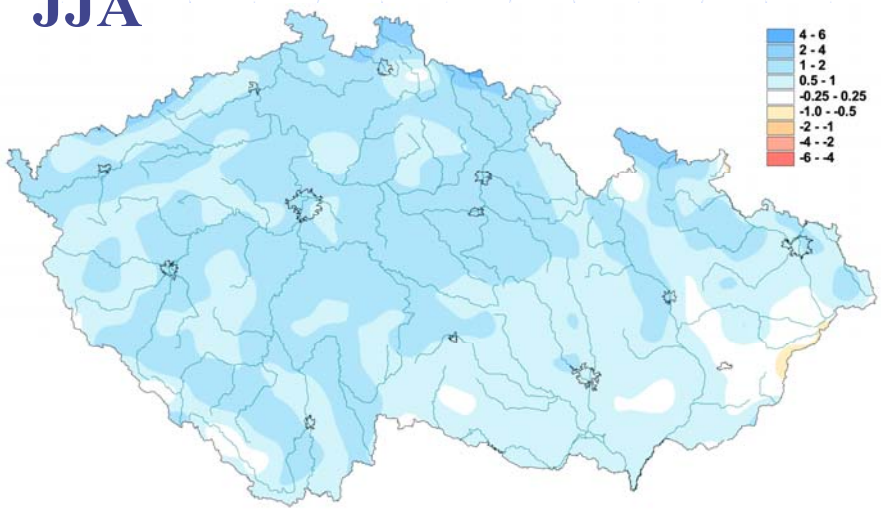


Prec: seasonal mean 61-90, Arpege

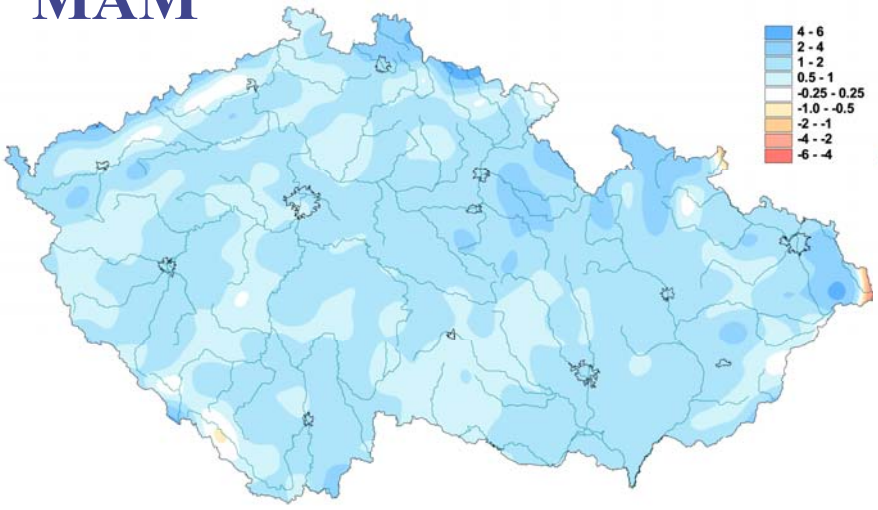
DJF



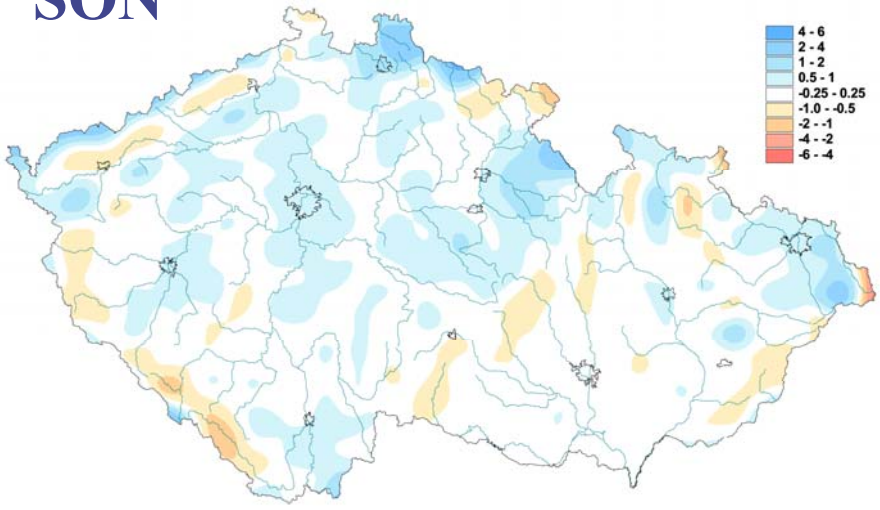
JJA



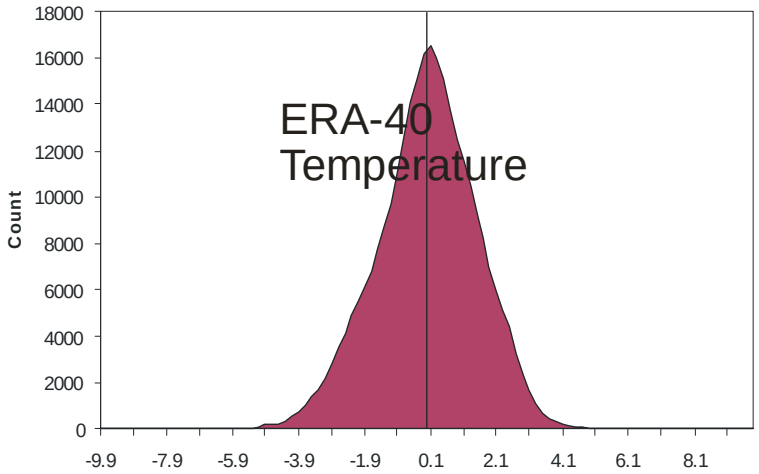
MAM

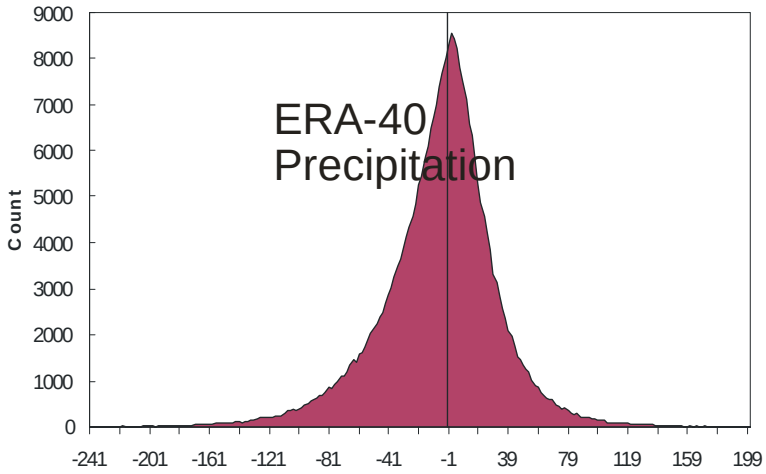


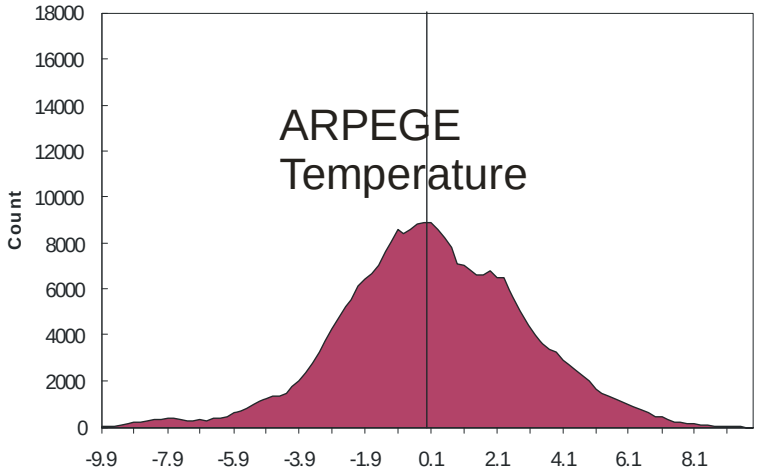
SON

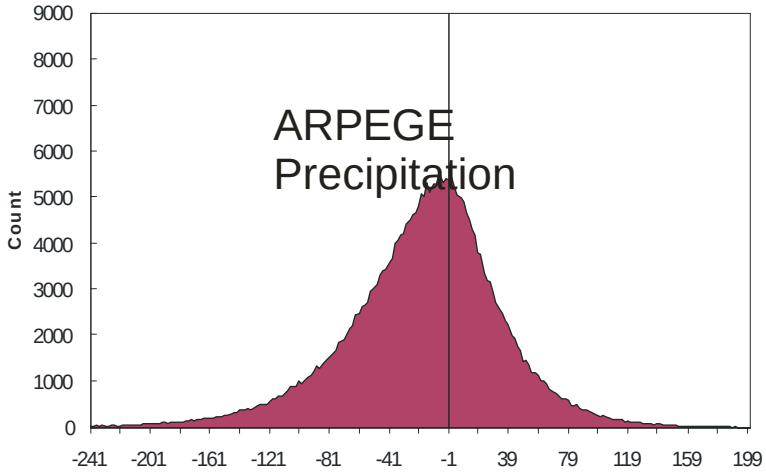


Histogram of anomalies

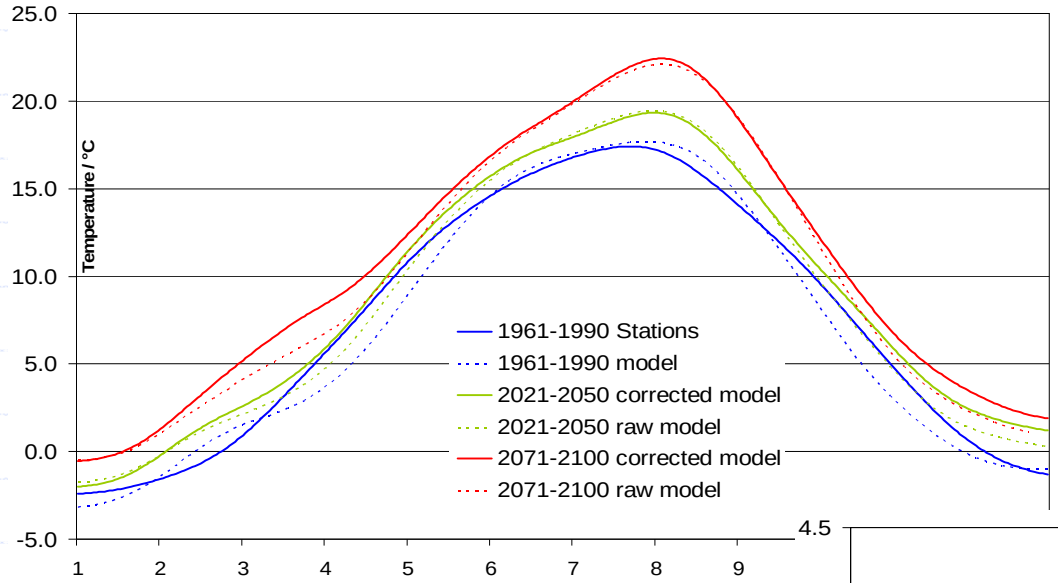


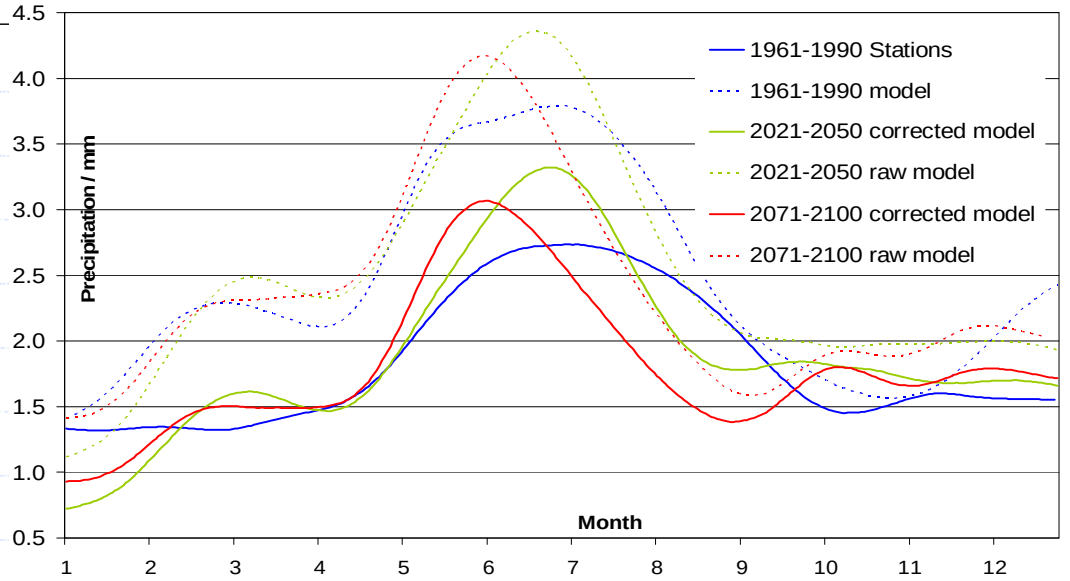






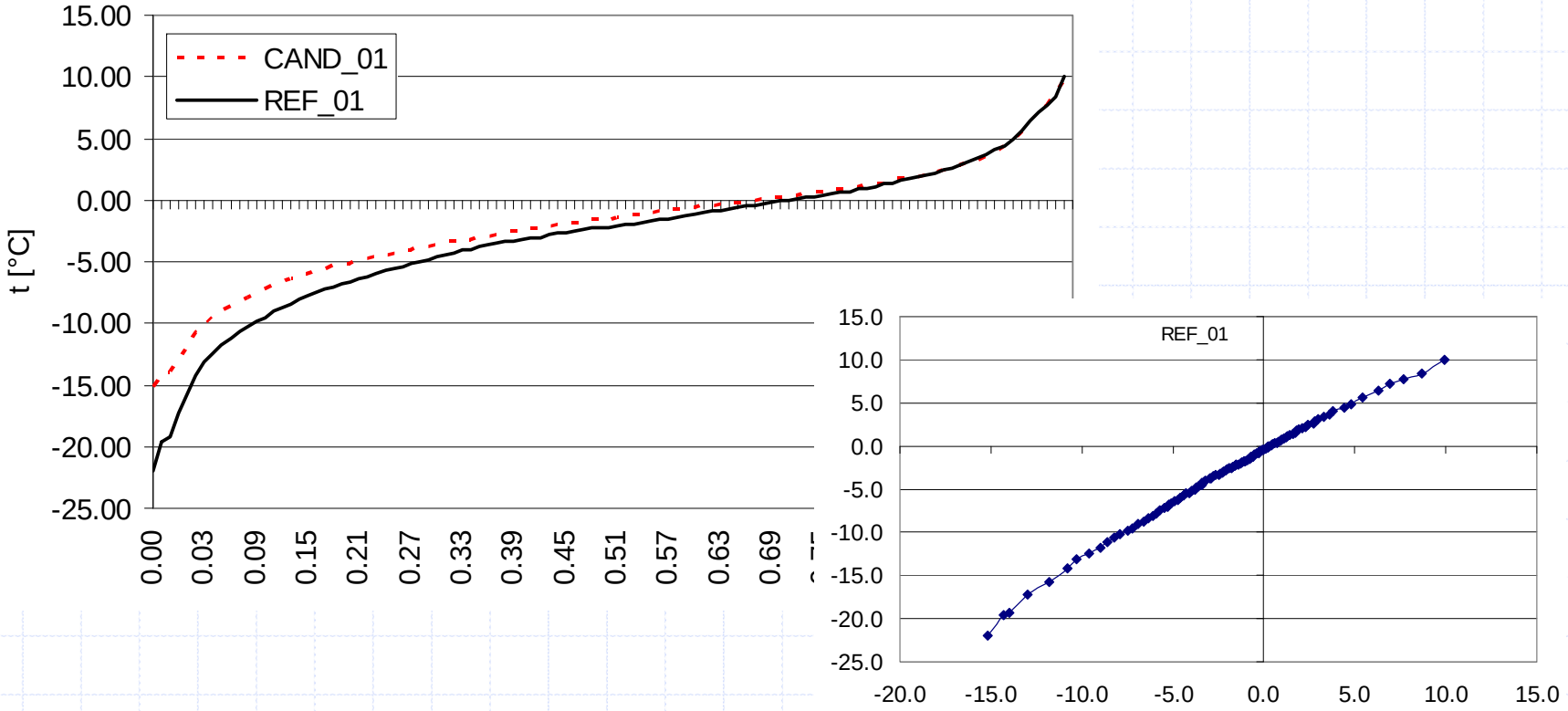
Annual cycle of air temperature and precipitation



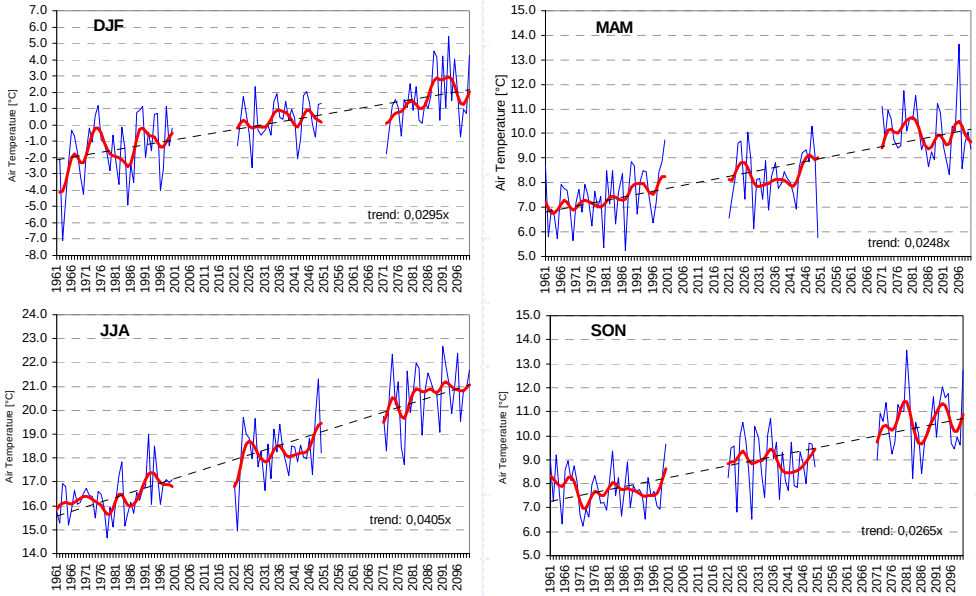


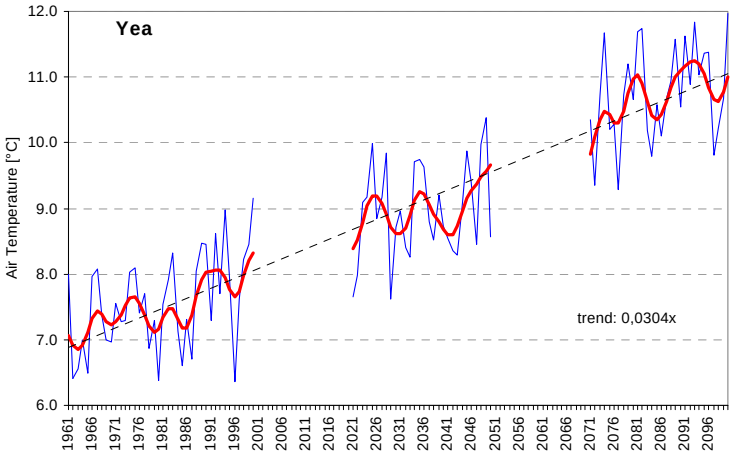
Model output correction

- an approach of Michel Déqué (2007) based on variable correction using individual percentiles
  - for each grid point and month individually

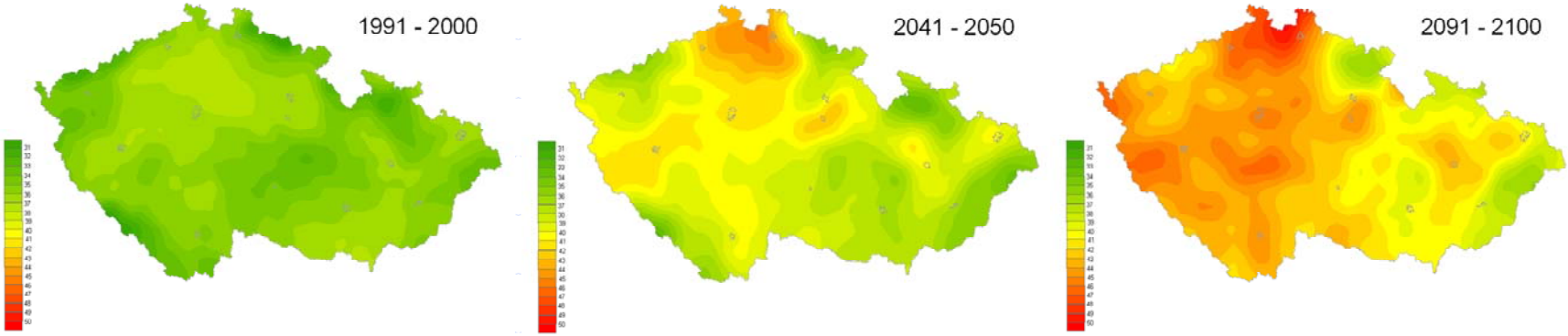


Corrected RCM outputs analysis





- Absolute maximum temperature [°C] for decade 1991-2000, 2041-2050 and 2091-2100



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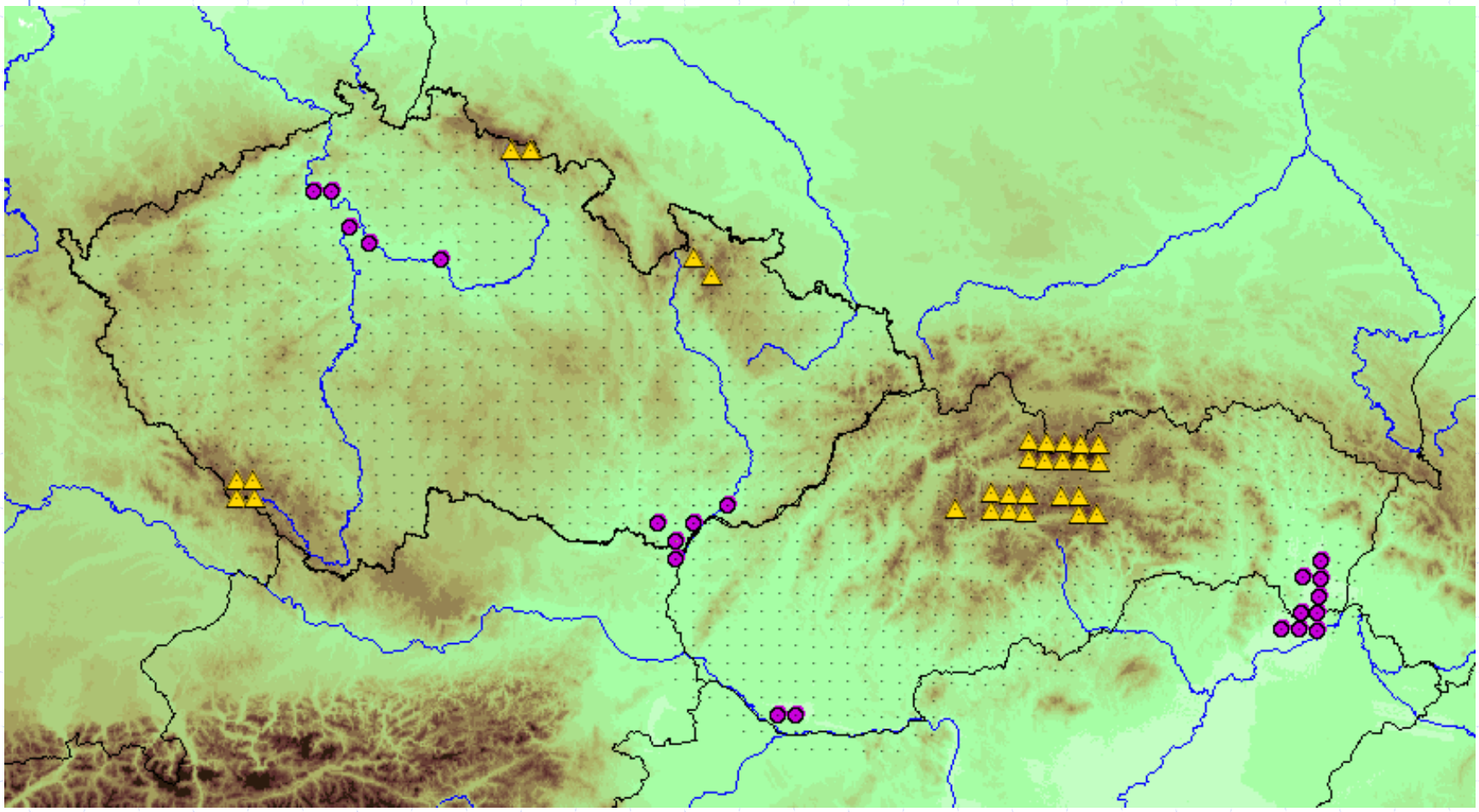
Studied area and selected grid points for the analysis. Yellow triangles mark mountainous regions, purple circles mark lowland regions.



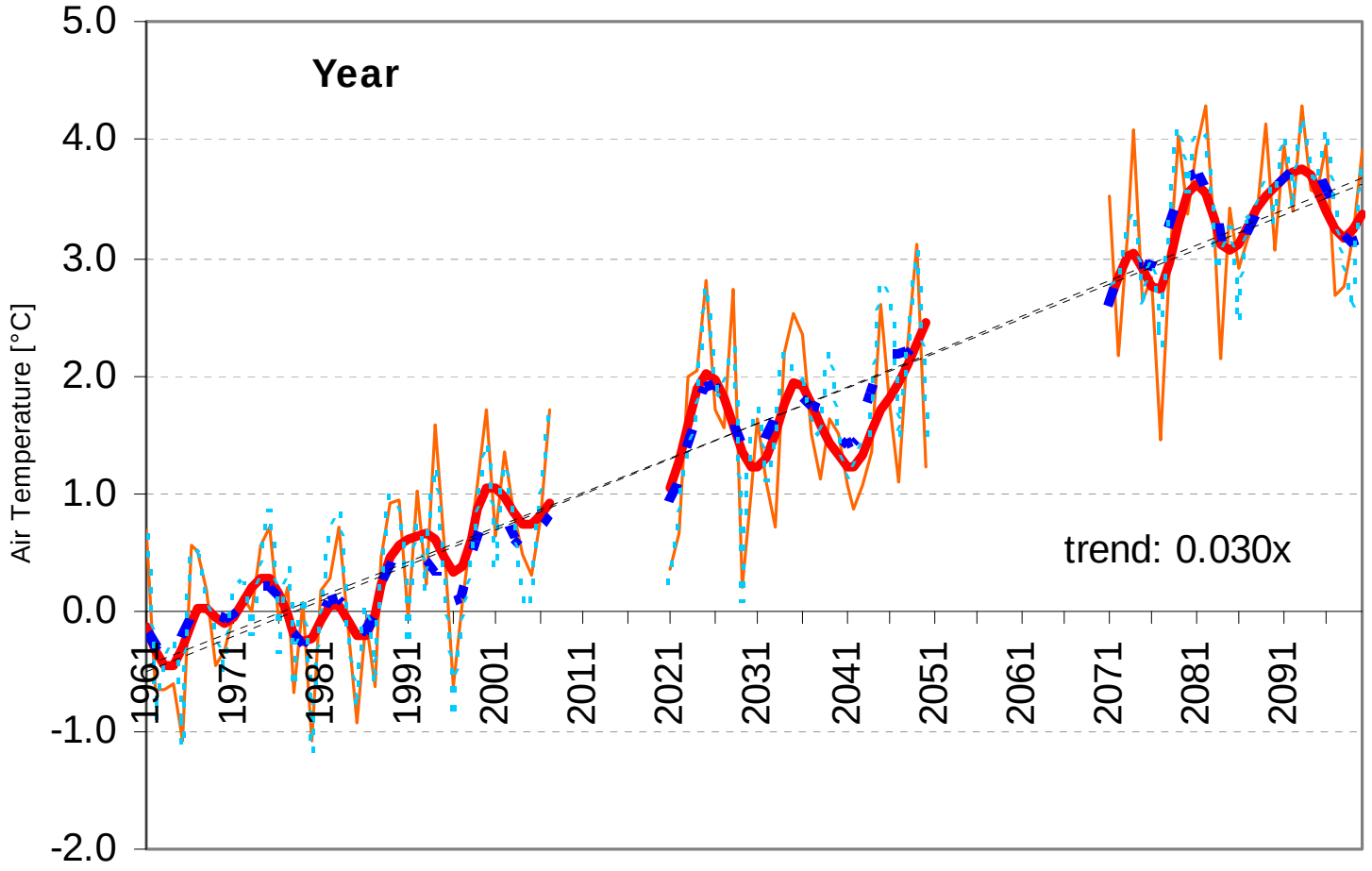
Air temperature deviations (°C) from 1961-1990 period for individual regions (average for lowlands and mountains grid points) for year and individual seasons. The bold font represents statistically significant values at α = 0.01 (two sample t-test).

Region	Period		YEAR	DJF	MAM	JJA	SON
Lowlands	2021	2050	**1.6**	**1.9**	**1.2**	**2.1**	**1.3**
Lowlands	2071	2100	**3.3**	**3.3**	**3.0**	**4.1**	**2.8**
Mountains	2021	2050	**1.7**	**2.0**	0.9	**2.6**	**1.1**
Mountains	2071	2100	**3.3**	**3.1**	**2.7**	**4.9**	**2.6**

Change in precipitation (%) compared to 1961-1990 period for individual regions (average for lowlands and mountains grid points) for year and individual seasons. The bold font represents statistically significant values at α = 0.05.

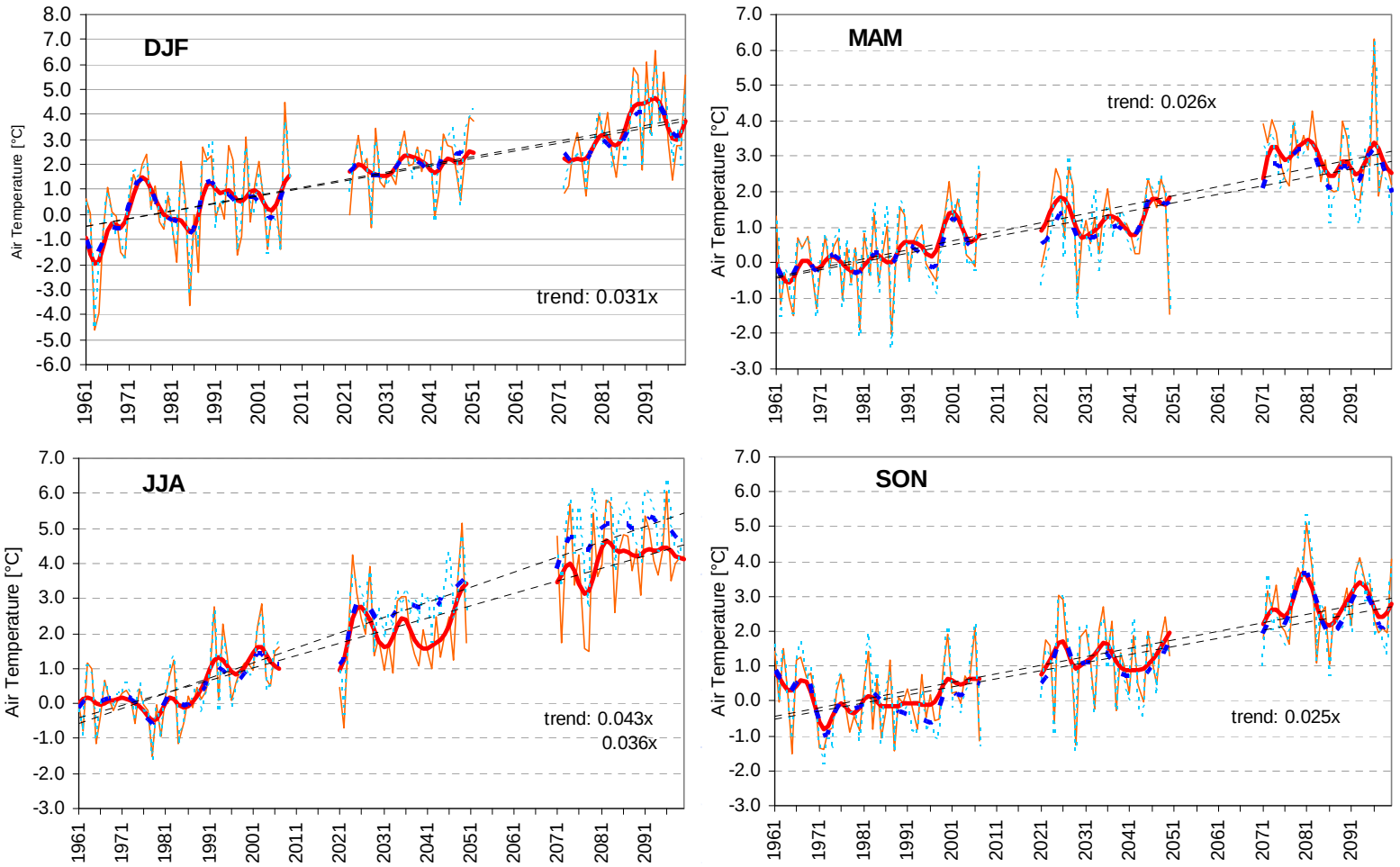
Region	Period		YEAR	DJF	MAM	JJA	SON
Lowlands	2021	2050	103	94	111	97	112
Lowlands	2071	2100	96	108	110	**79**	102
Mountains	2021	2050	103	92	114	101	107
Mountains	2071	2100	96	100	116	**83**	95

Air Temperature anomalies (°C) compared to 1961-1990 reference period) expressed for lowlands (solid lines) and mountains (dashed lines). Smoothed with Gaussian low-pass filter for 10 years.

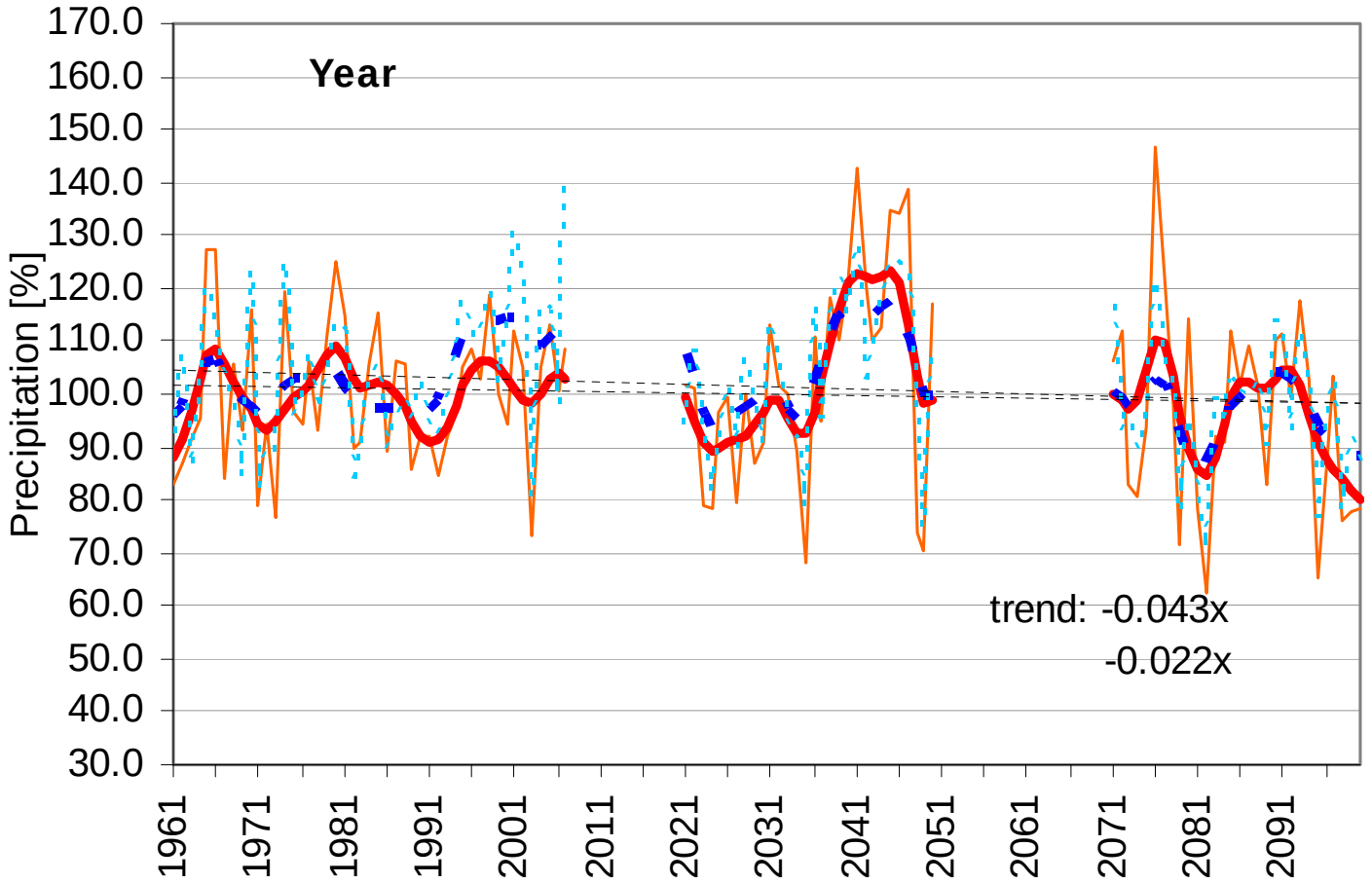


Trends statistically sign. for 0.01

Air Temperature anomalies (°C) compared to 1961-1990 reference period) expressed for lowlands (solid lines) and mountains (dashed lines). Smoothed with Gaussian low-pass filter for 10 years.

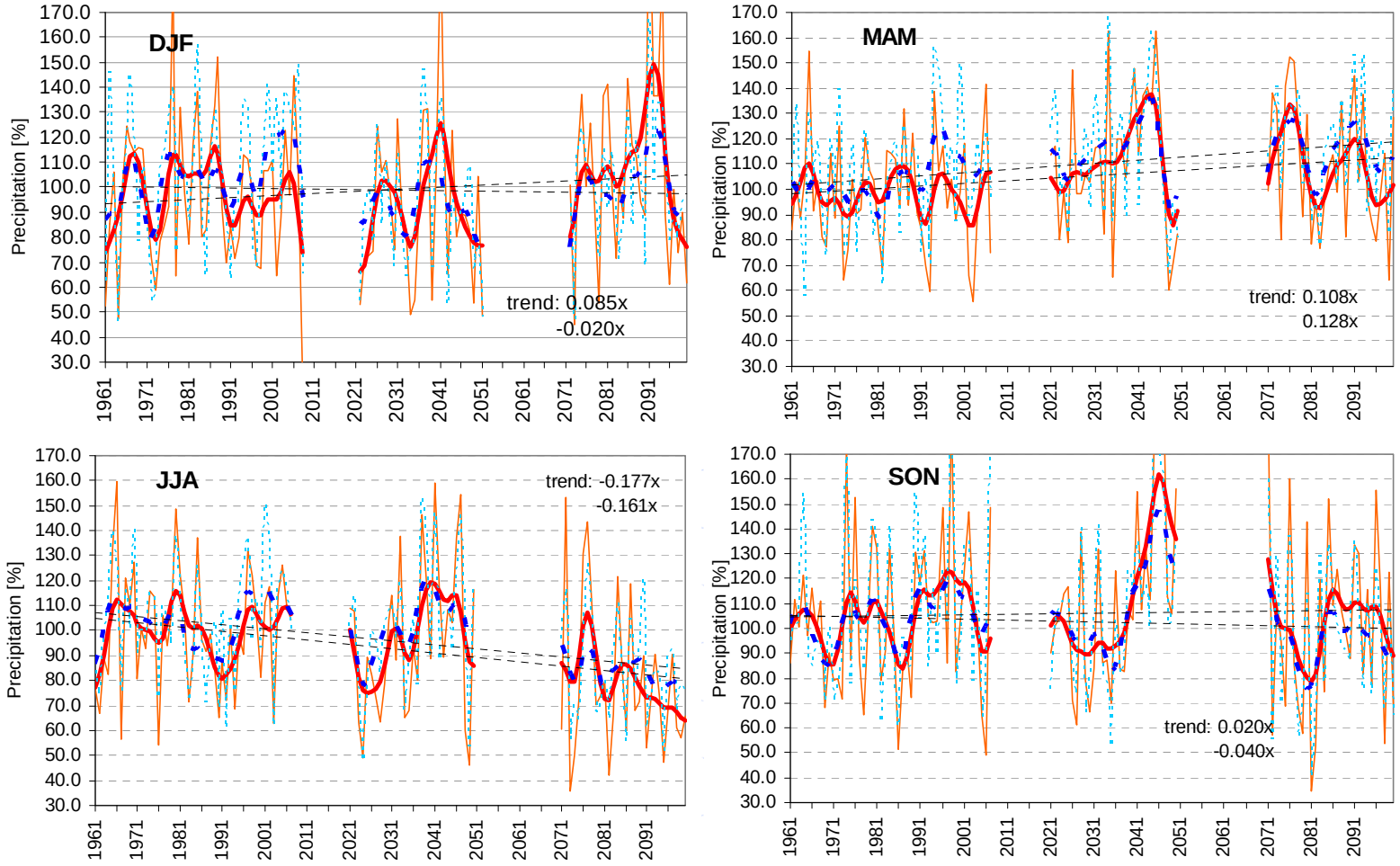


Change in Precipitation (%) compared to 1961-1990 reference period) expressed for lowlands (solid lines) and mountains (dashed lines). Smoothed with Gaussian low-pass filter for 10 years.



statistically significant (0.05) only for JJA

Change in Precipitation (%) compared to 1961-1990 reference period) expressed for lowlands (solid lines) and mountains (dashed lines). Smoothed with Gaussian low-pass filter for 10 years.



CECILIA WP4 Temperature and precipitation indices (selection out of 131)

- Temperature indices
- Index 001 (daily maximum temperature)
- Index 002 (daily minimum temperature)
- Index 003 (daily mean temperature)
- Index 004 (diurnal temperature range)
- Index 052 (mean heat wave occurrence)
- Index 058 (percentage of summer days)
- Index 067 (percentage of extremely hot days)
- Index 068 (percentage of severe cold days)
- Precipitation indices
- Index 076 (mean climatological precipitation)
- Index 077 (mean wet-day precipitation)
- Index 078 (percentage of wet days)
- Index 103 (maximum number of consecutive dry days)
- Index 104 (maximum number of consecutive wet days)
- Index 113 (greatest 1-day total rainfall)
- Index 115 (greatest 5-day total rainfall)

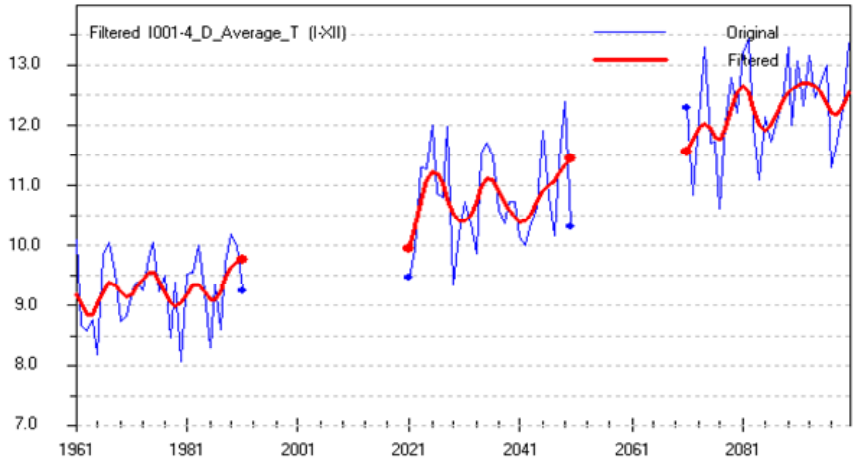
Trends for indices, medians from grid points

D – lowlands, M – mountains, T – air temperature, TMA – maximum temperature, TMI – minimum temperature, SRA - precipitation

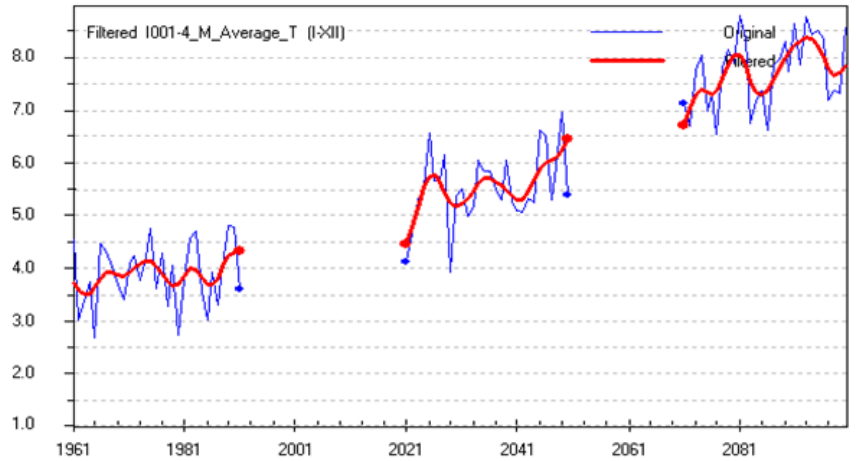
ID_1	ID_2	BEGIN	END	YEAR	DJF	MAM	JJA	SON	
I001-4_D_Average_T	LinTrend (b1)	1961	2100	**0.029**	**0.033**	**0.020**	**0.032**	**0.023**	
I001-4_M_Average_T	LinTrend (b1)	1961	2100	**0.035**	**0.039**	**0.028**	**0.046**	**0.026**	
I001-4_D_Average_DTA	LinTrend (b1)	1961	2100	**0.003**	0.000	0.001	**0.006**	0.003	
I001-4_M_Average_DTA	LinTrend (b1)	1961	2100	**0.004**	0.002	0.000	**0.005**	**0.005**	
I001-4_D_Average_TMA	LinTrend (b1)	1961	2100	**0.032**	**0.031**	**0.027**	**0.038**	**0.027**	
I001-4_M_Average_TMA	LinTrend (b1)	1961	2100	**0.032**	**0.030**	**0.025**	**0.043**	**0.026**	
I001-4_D_Average_TMI	LinTrend (b1)	1961	2100	**0.029**	**0.031**	**0.026**	**0.031**	**0.024**	
I001-4_M_Average_TMI	LinTrend (b1)	1961	2100	**0.028**	**0.030**	**0.024**	**0.037**	**0.022**	
I052F_D__TMA	LinTrend (b1)	1961	2100	0.000	0.001	-0.007	-0.001	-0.001	mean heat wave occu
I052F_M__TMA	LinTrend (b1)	1961	2100	-0.003	-0.003	-0.005	-0.003	-0.003	
I076_D_Average_SRA	LinTrend (b1)	1961	2100	-0.001	0.000	0.001	**-0.004**	0.001	
I076_M_Average_SRA	LinTrend (b1)	1961	2100	-0.001	0.000	**0.003**	**-0.006**	-0.001	
I077_D_Average_SRA	LinTrend (b1)	1961	2100	**0.004**	0.002	0.004	0.003	**0.009**	
I077_M_Average_SRA	LinTrend (b1)	1961	2100	0.001	**0.003**	**0.006**	**-0.005**	**0.006**	
I078_D__SRA	LinTrend (b1)	1961	2100	**-0.021**	-0.006	0.011	**-0.063**	-0.020	percentage of wet day
I078_M__SRA	LinTrend (b1)	1961	2100	**-0.019**	-0.009	0.020	**-0.044**	**-0.039**	
I103F_D_Maximal value_SRA	LinTrend (b1)	1961	2100	**0.056**	0.025	-0.005	**0.060**	0.031	maximum number of c
I103F_M_Maximal value_SRA	LinTrend (b1)	1961	2100	0.019	0.002	-0.009	**0.025**	0.013	
I104F_D_Maximal value_SRA	LinTrend (b1)	1961	2100	0.001	0.000	0.003	0.000	-0.003	
I104F_M_Maximal value_SRA	LinTrend (b1)	1961	2100	-0.001	**-0.008**	0.003	0.000	-0.006	
I113_D_Maximal value_SRA	LinTrend (b1)	1961	2100	**-0.060**	**-0.028**	**-0.038**	**-0.078**	**-0.039**	
I113_M_Maximal value_SRA	LinTrend (b1)	1961	2100	**-0.185**	**-0.084**	**-0.068**	**-0.153**	**-0.106**	
I115_D_Maximal value_SRA	LinTrend (b1)	1961	2100	**0.064**	0.027	**0.050**	0.016	0.026	greatest 5-day total rai
I115_M_Maximal value_SRA	LinTrend (b1)	1961	2100	0.002	0.003	**0.086**	-0.038	-0.011	

ID_1	ID_2	BEGIN	END	YEAR	DJF	MAM	JJA	SON
I001-4_D_Average_T	LinTrend (b1)	1961	2100	**0.029**	**0.033**	**0.020**	**0.032**	**0.023**
I001-4_M_Average_T	LinTrend (b1)	1961	2100	**0.035**	**0.039**	**0.028**	**0.046**	**0.026**
I001-4_D_Average_DTA	LinTrend (b1)	1961	2100	**0.003**	0.000	0.001	**0.006**	0.003
I001-4_M_Average_DTA	LinTrend (b1)	1961	2100	**0.004**	0.002	0.000	**0.005**	**0.005**

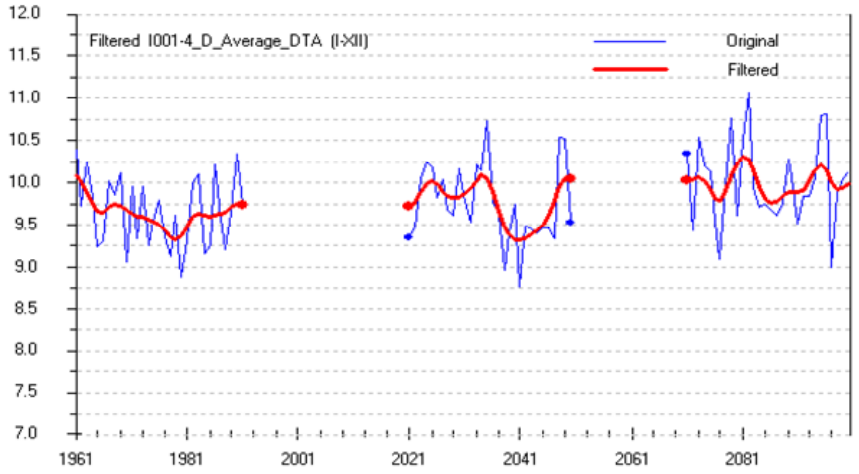
T D

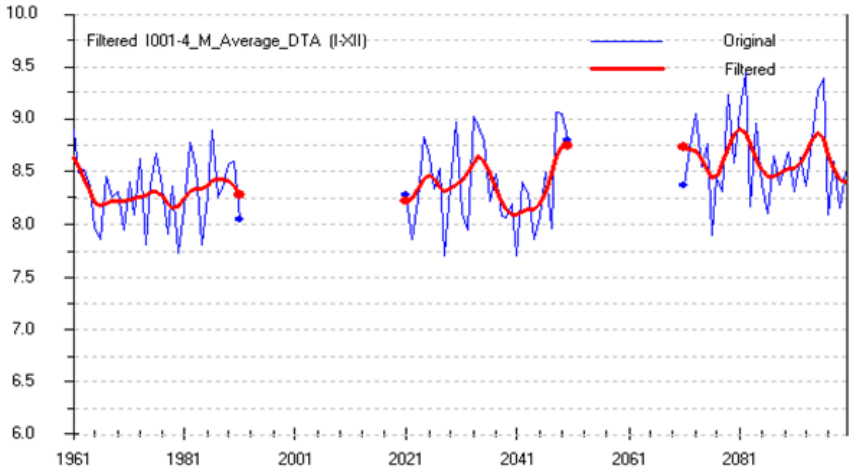


M



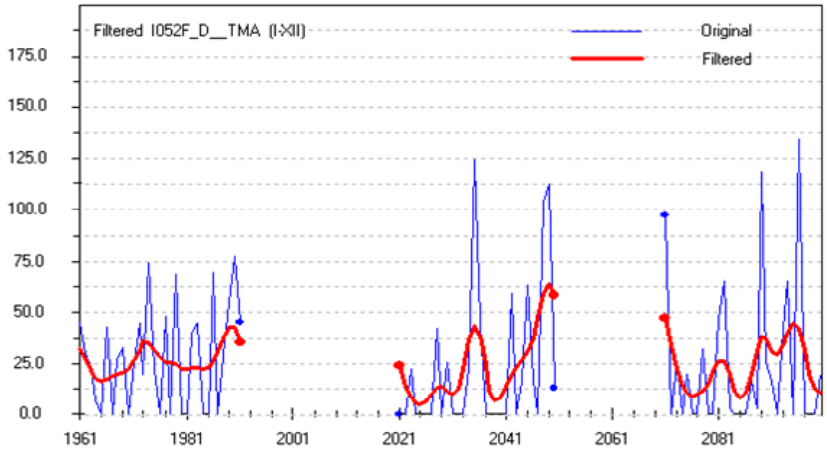
DTA

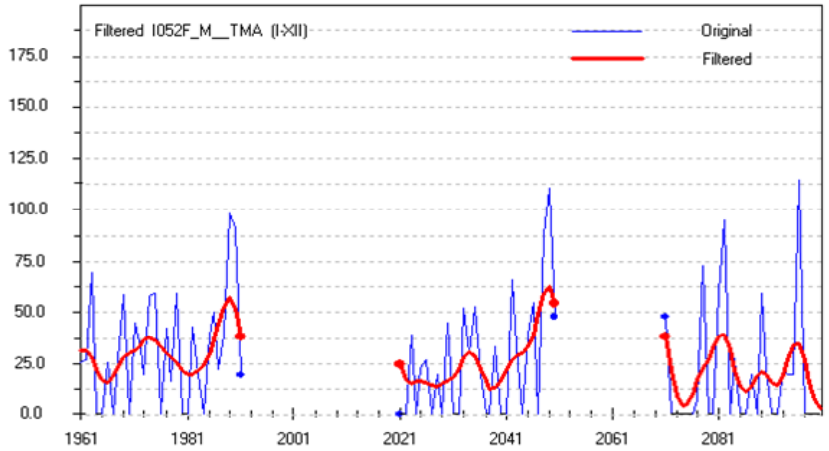




ID_1	ID_2	BEGIN	END	YEAR	DJF	MAM	JJA	SON
I052F_D__TMA	LinTrend (b1)	1961	2100	0.000	0.001	-0.007	-0.001	-0.001
I052F_M__TMA	LinTrend (b1)	1961	2100	-0.003	-0.003	-0.005	-0.003	-0.003

mean heat wave occurrence percentage of days per period where, in intervals of at least 6 consecutive days: Txij > Txinorm + 5

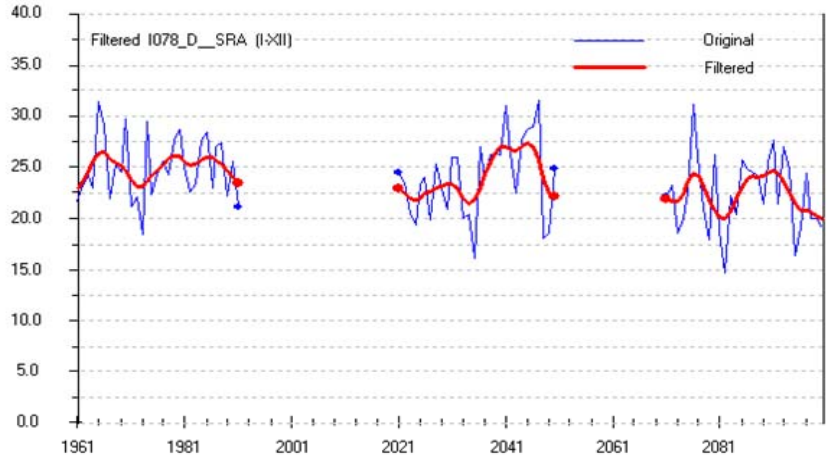


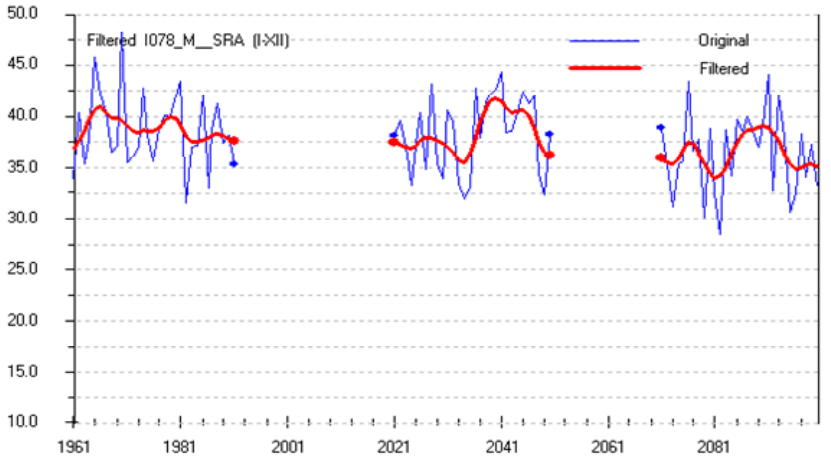


ID_1	ID_2	BEGIN	END	YEAR	DJF	MAM	JJA	SON
I078_D__SRA	LinTrend (b1)	1961	2100	**-0.021**	-0.006	0.011	**-0.063**	-0.020
I078_M__SRA	LinTrend (b1)	1961	2100	**-0.019**	-0.009	0.020	**-0.044**	**-0.039**

percentage of wet days

Nb wet days/ total nb of days [%]

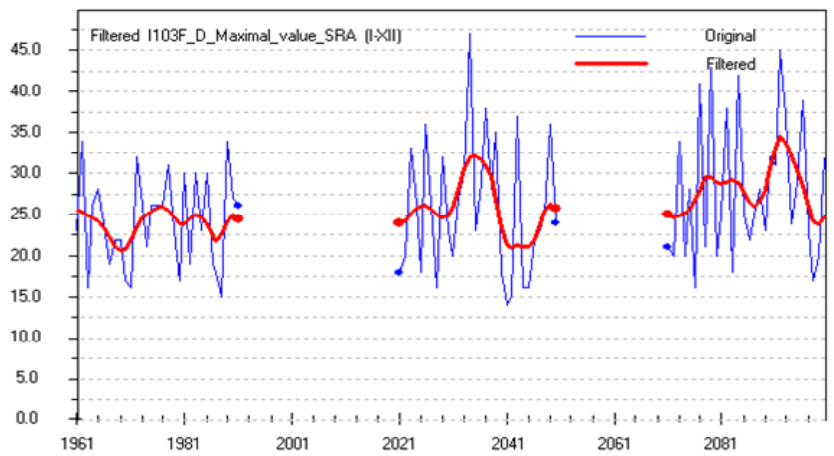


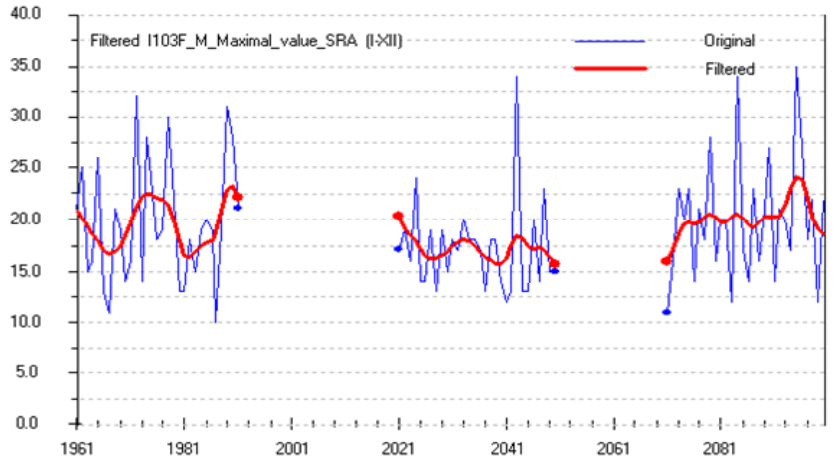


ID_1	ID_2	BEGIN	END	YEAR	DJF	MAM	JJA	SON
I103F_D_Maximal value_SRA	LinTrend (b1)	1961	2100	**0.056**	0.025	-0.005	**0.060**	0.031
I103F_M_Maximal value_SRA	LinTrend (b1)	1961	2100	0.019	0.002	-0.009	**0.025**	0.013

maximum number of consecutive dry days

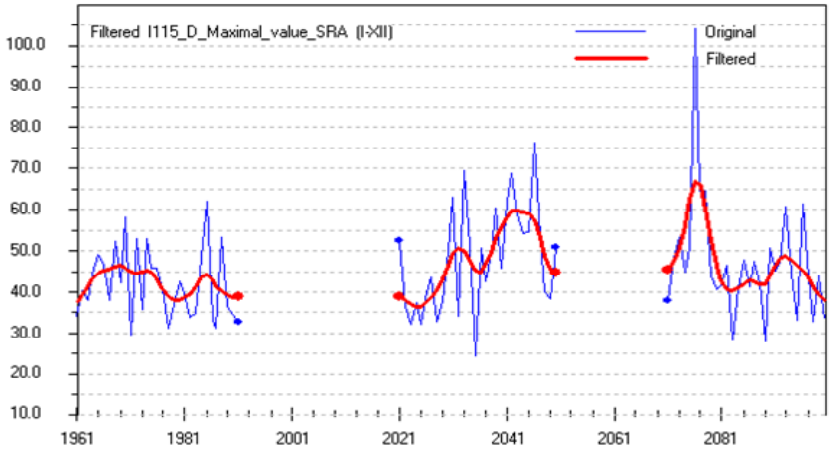
Max. nb of consecutive dry days. Full length considered

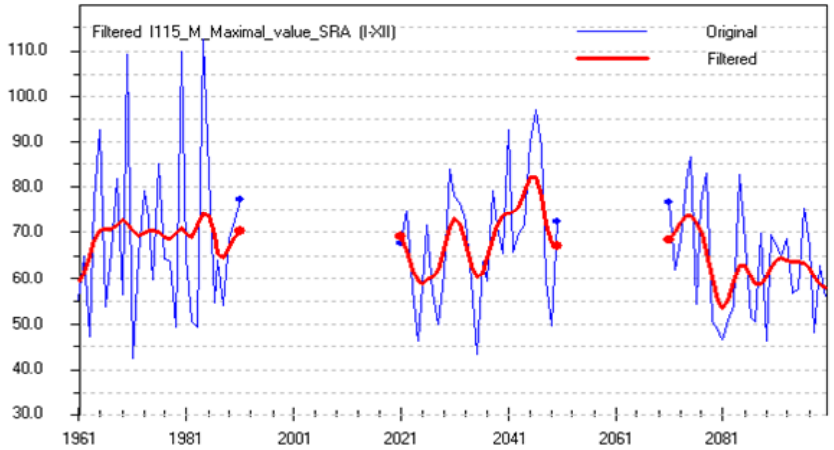




ID_1	ID_2	BEGIN	END	YEAR	DJF	MAM	JJA	SON
I113_D_Maximal value_SRA	LinTrend (b1)	1961	2100	**-0.060**	**-0.028**	**-0.038**	**-0.078**	**-0.039**
I113_M_Maximal value_SRA	LinTrend (b1)	1961	2100	**-0.185**	**-0.084**	**-0.068**	**-0.153**	**-0.106**
I115_D_Maximal value_SRA	LinTrend (b1)	1961	2100	**0.064**	0.027	**0.050**	0.016	0.026
I115_M_Maximal value_SRA	LinTrend (b1)	1961	2100	0.002	0.003	**0.086**	-0.038	-0.011

greatest 5-day total rainfall





4. Conclusions & outlooks

- ALADIN-Climate/CZ is well capable to provide a realistic picture of the climate in the Central Europe
- Corrected RCM outputs used to improve analysis of future climate
- No significant changes between the lowlands and highlands were found neither for near (2051-2070) nor far future (2071-2100)
- Comparisons with other RCMs

Software Package for Processing Climatological Data

- Application for downloading data from central database (e.g. Oracle)
- ProClimDB software for processing whole dataset (finding outliers, combining series, creating reference series, preparing data for homogeneity testing, analysis ...)
- AnClim software for homogeneity testing

http://www.climahom.eu

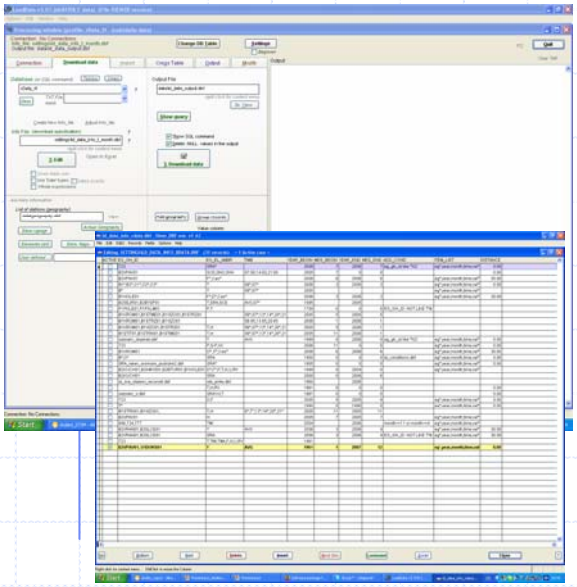
Software package

- Originally created for homogeneity testing and time series analysis (trends, cycles, correlation analysis)
- Recently added functions for extreme values analysis (GEV, GPD), RCM outputs validation and correction, multivariate analysis (connection with R software)

http://www.climahom.eu

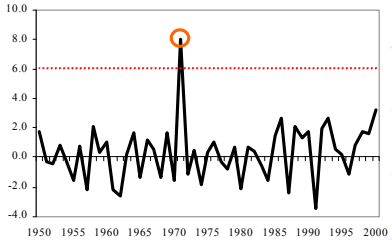
Download data from database (e.g. Oracle)

(LoadData)



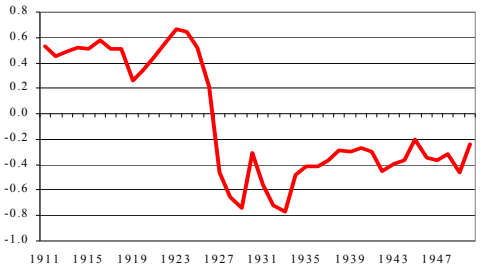
Quality control

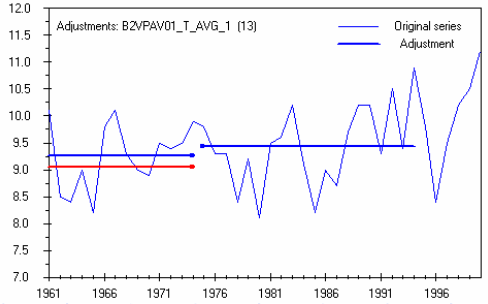
(ProClimDB)



Homogenization

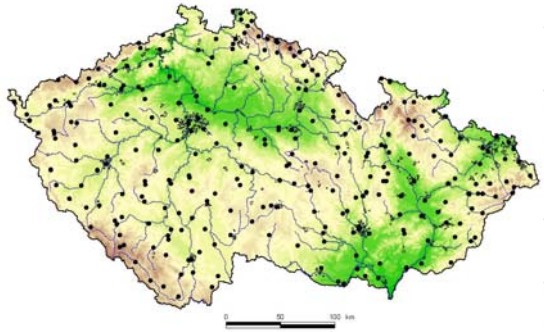
(ProClimDB/AnClim)

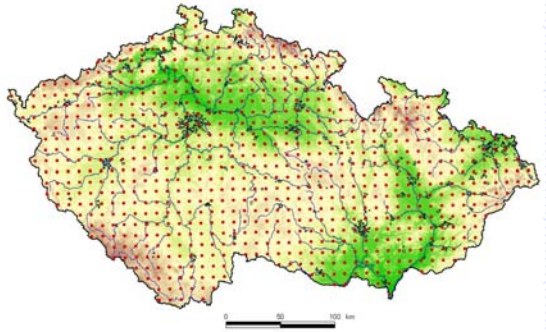




„Technical“ series and grid points calculation

(ProClimDB)





Statistical analysis

...

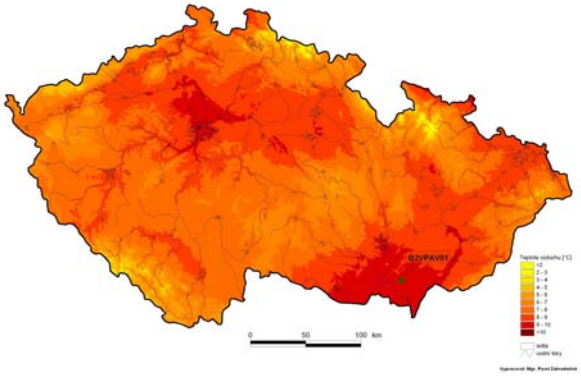
Validation of RCM outputs

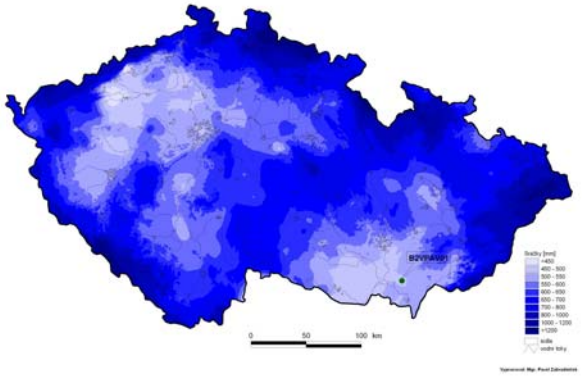
Extreme value analysis

Correction of RCM outputs

Spatial analysis

(connection ProClimDB - ArcView)

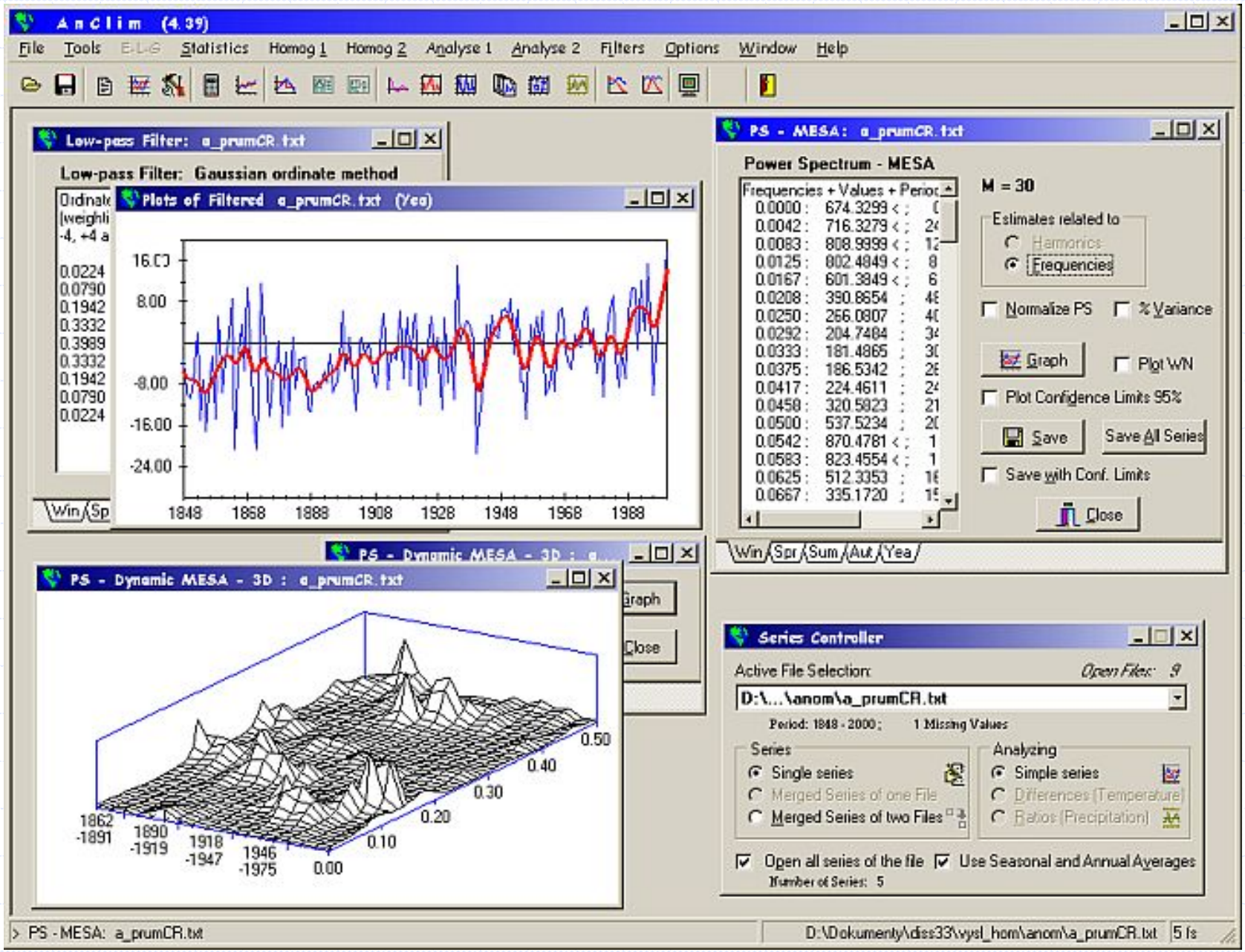




Further tools:

(connection ProClimDB - R)

AnClim software



ProClimDB software