A comparison of E-OBS and CARPATCLIM gridded datasets of minimum temperatures, maximum temperatures and precipitation by Analysis of Variance (ANOVA)

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Alapítva: 1870

Motivation

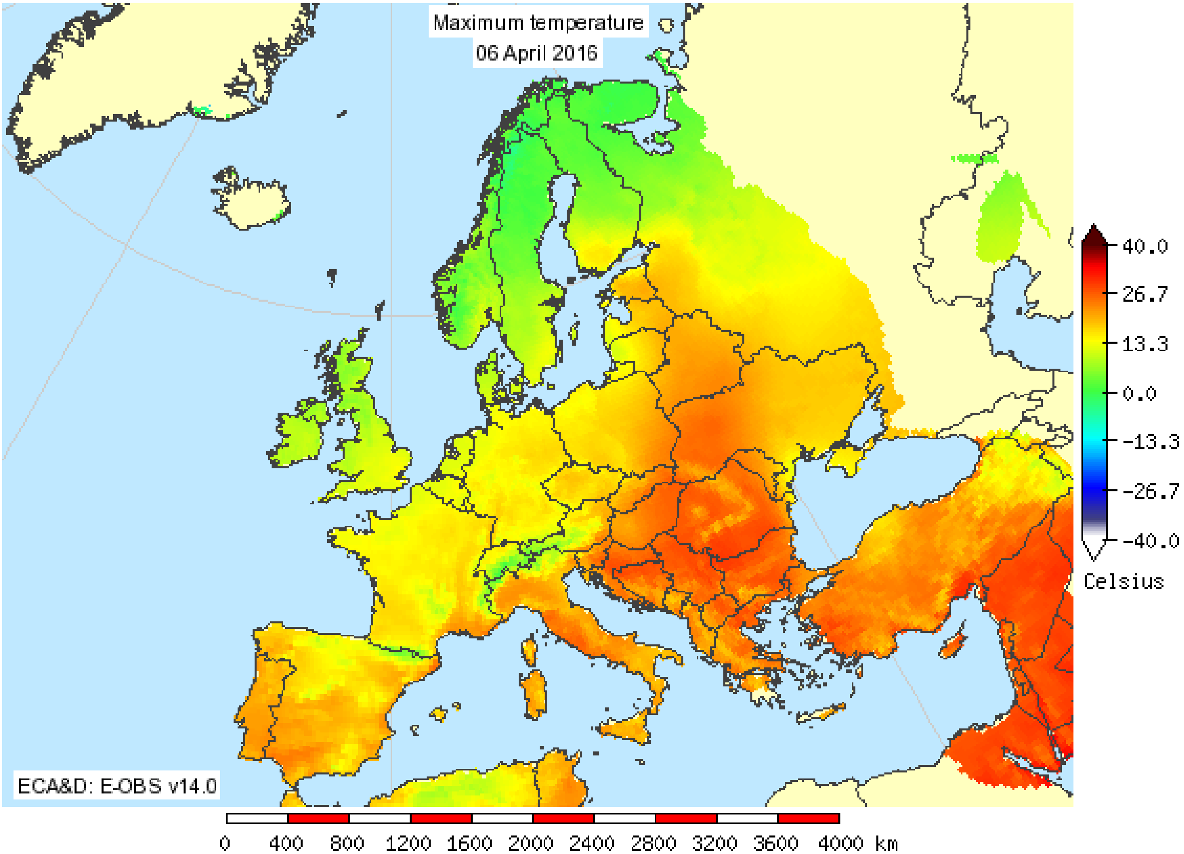
- Usage of gridded climate products
- Copernicus C3S Surf project: Climate monitoring products for Europe based on **Surf**ace *in-situ* Observations
- building upon ECA&D and E-OBS
- Subregional datasets covering Alps and Fennoscandia will be produced, CarpatClim (static)
- C3S Surf WP4, Task 2: Product comparisons
- comparison of E-OBS v14.0 and CarpatClim by applying ANOVA

E-OBS v14.0,
"Haylock, et al, 2008)
0.25 deg. regular grid

tx, tn, rr

1961-2010 for Carpathian Region

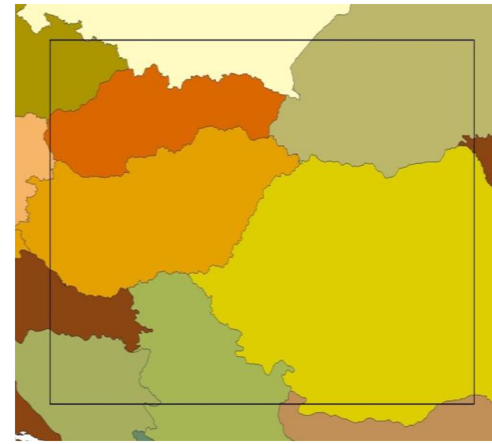
Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones and M. New. 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), **113**, D20119, doi:10.1029/2008JD10201



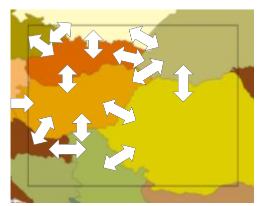
thanks to Peter Szabo for preparation of E-OBS data

CarpatClim

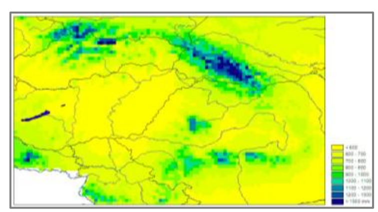
- JRC support, duration 2010-2013
- Commonly used methods: MASH-MISH
- Consortium leader: OMSZ, 9 countries
- Results: 13 basic meteorological variables, and 37 climate indicators, daily, 0.1 degree resolution, 1961-2010, publically available



- **MASHv3.03**: bilateral data exchange before and after homogenization guaranteed the harmonization



- **MISHv1.03**: the gridded daily time series were generated automatically in one step for the 50 years long period.



Variable	Description	units
Ta	2 m mean daily air temperature	°C
Tmin	Minimum air temperature	°C
Tmax	Maximum air temperature	°C
p	Accumulated total precipitation	mm
DD	10 m wind direction, Degrees	0-360
VV	10 m horizontal wind speed	m/s
Sunshine	Sunshine duration	hours
cc	Cloud cover	tenths
Rglobal	Global radiation	J/cm^2
RH	Relative humidity	%
pvapour	Surface vapour pressure	hPa
pair	Surface air pressure	hPa
Snow depth	Snow depth (ZAMG model)	cm

www.carpatclim-eu.org/

Interpolation Formulas

MISH

Predictand: $Z(\mathbf{s}_0)$ Predictors: $Z(\mathbf{s}_i)$ $(i=1,..,M)$

Optimum Interpolation Formula depends on the probability distribution.

Additive (Linear) Formula (normal, temperature)

$$\hat{Z}(\mathbf{s}_0)=\lambda_0+\sum_{i=1}^{M}\lambda_i\cdot Z(\mathbf{s}_i)\ , \quad \text{where} \sum_{i=1}^{M}\lambda_i=1\ .$$

where $\sum_{i=1}^{M}\lambda_i=1$ and $\lambda_i\geq 0$ $(i=1,...,M)$, are the interpolation parameters.

Multiplicative Formula of MISH (lognormal, precipitation)

$$\hat{Z}(\mathbf{s}_0)=\vartheta\cdot\left(\prod_{q_i\cdot Z(\mathbf{s}_i)\geq\vartheta}\left(\frac{q_i\cdot Z(\mathbf{s}_i)}{\vartheta}\right)^{\lambda_i}\right)\cdot\left(\sum_{q_i\cdot Z(\mathbf{s}_i)\geq\vartheta}\lambda_i+\sum_{q_i\cdot Z(\mathbf{s}_i)<\vartheta}\lambda_i\cdot\left(\frac{q_i\cdot Z(\mathbf{s}_i)}{\vartheta}\right)\right)$$

where $\vartheta>0$, $q_i>0$, $\sum_{i=1}^{M}\lambda_i=1$ and $\lambda_i\geq 0$ $(i=1,...,M)$,

are the interpolation parameters.

The optimum interpolation parameters are uniquely determined by certain climate statistical parameters.

ANOVA (Analysis Of Variance) examination in MISH

MISH

Partitioning of Total Variance of station data series

$$\hat{V} = \frac{1}{M}\sum_{i=1}^{M}\left(\hat{E}(\mathbf{s}_i) - \hat{E}\right)^2 + \frac{1}{M}\sum_{i=1}^{M}\hat{D}^2(\mathbf{s}_i) = \hat{S}^2_{space} + \hat{D}^2_{time} \quad ,$$

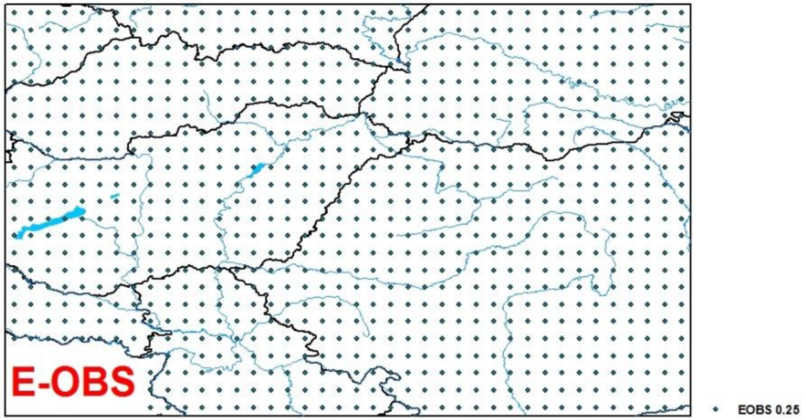
$\hat{S}^2_{space}$ is the variance of spatial trend, $\hat{D}^2_{time}$ is the mean temporal variance.

CARPATCLIM ANOVA results for months in Hungary

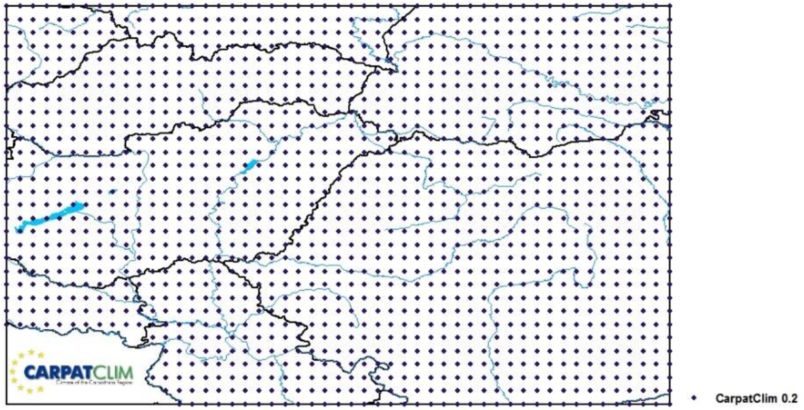
	1	2	3	4	5	6	7	8	9	10	11	12
Tx												
D_t:	2.67	3.24	2.69	1.87	1.96	1.64	1.71	1.98	1.96	1.83	2.43	2.11
S_s:	1.00	1.23	1.33	1.21	1.31	1.34	1.37	1.39	1.43	1.34	1.21	1.02
Tn												
D_t:	2.76	2.88	1.86	1.35	1.20	1.12	1.21	1.18	1.29	1.67	1.97	2.12
S_s:	0.85	0.85	0.83	0.88	0.91	0.87	0.90	0.88	0.82	0.77	0.70	0.80
R												
D_t:	22.5	22.9	21.3	25.6	36.2	39.0	39.3	40.7	36.5	35.7	33.3	27.9
S_s:	7.1	5.9	6.9	7.8	7.8	8.9	9.3	10.5	10.2	8.3	10.8	8.6

The area in focus

E-OBS, 1961-2010



CarpatClim01 --> 02



Comparison of different statistics of CarpatClim 0.1° and 0.2°, 1961-2010

- Tx CarpatClim**01**

Tx CC01
Total mean: 13.83
Total variance: 6.90

Spatial st. deviation of temporal means: 2.48
Root spatial mean of temporal variances: 0.88
Spatial mean of temporal st. deviations: 0.88
Temporal st. deviation of spatial means: 0.83
Root temporal mean of spatial variances: 2.49
Temporal mean of spatial st. deviations: 2.49

- Tx CarpatClim**02**

Tx CC02Total mean: 13.82
Total variance: 6.97

Spatial st. deviation of temporal means: 2.49
Root spatial mean of temporal variances: 0.88
Spatial mean of temporal st. deviations: 0.88
Temporal st. deviation of spatial means: 0.83
Root temporal mean of spatial variances: 2.50
Temporal mean of spatial st. deviations: 2.50

Comparison of different statistics of CarpatClim 0.1° and 0.2°

- Prec CarpatClim01

Pr CC01
Total mean: 701.21
Total variance: 40565.66

Spatial st. deviation of temporal means: 156.75
Root spatial mean of temporal variances: 126.47
Spatial mean of temporal st. deviations: 124.51
Temporal st. deviation of spatial means: 91.07
Root temporal mean of spatial variances: 179.64
Temporal mean of spatial st. deviations: 178.17

- Prec CarpatClim02

PrCC02
Total mean: 700.32
Total variance: 41227.35

Spatial st. deviation of temporal means: 159.01
Root spatial mean of temporal variances: 126.27
Spatial mean of temporal st. deviations: 124.28
Temporal st. deviation of spatial means: 90.57
Root temporal mean of spatial variances: 181.72
Temporal mean of spatial st. deviations: 180.22

ANOVA method / notations

$Z(\mathbf{s}_j, t)\ (j = 1,.., N;\ t = 1,..., n)$ – data series $(\mathbf{s}_j$: location; t : time$)$

$\hat{E}(\mathbf{s}_j) = \frac{1}{n}\sum_{t=1}^{n} Z(\mathbf{s}_j, t) \quad (j = 1,.., N)$ – temporal mean at location $\mathbf{s}_j$

$\hat{D}^2(\mathbf{s}_j) = \frac{1}{n}\sum_{t=1}^{n} \left(Z(\mathbf{s}_j, t) - \hat{E}(\mathbf{s}_j)\right)^2 \quad (j = 1,.., N)$ – temporal variance at location $\mathbf{s}_j$

$\hat{E}(t) = \frac{1}{N}\sum_{j=1}^{N} Z(\mathbf{s}_j, t) \quad (t = 1,.., n)$ – spatial mean at moment t

$\hat{D}^2(t) = \frac{1}{N}\sum_{j=1}^{N} \left(Z(\mathbf{s}_j, t) - \hat{E}(t)\right)^2 \quad (t = 1,.., n)$ – spatial variance at moment t

$\hat{E} = \frac{1}{N \cdot n}\sum_{j=1}^{N}\sum_{t=1}^{n} Z(\mathbf{s}_j, t) = \frac{1}{N}\sum_{j=1}^{N} \hat{E}(\mathbf{s}_j) = \frac{1}{n}\sum_{t=1}^{n} \hat{E}(t)$ – total mean

$\hat{D}^2 = \frac{1}{N \cdot n}\sum_{j=1}^{N}\sum_{t=1}^{n} \left(Z(\mathbf{s}_j, t) - \hat{E}\right)^2$ – total variance

Partitioning of Total Variance (Theorem)

$$\hat{D}^2 = \frac{1}{N}\sum_{j=1}^{N}\left(\hat{E}(\mathbf{s}_j) - \hat{E}\right)^2 + \frac{1}{N}\sum_{j=1}^{N}\hat{D}^2(\mathbf{s}_j) = \frac{1}{n}\sum_{t=1}^{n}\left(\hat{E}(t) - \hat{E}\right)^2 + \frac{1}{n}\sum_{t=1}^{n}\hat{D}^2(t)$$

spatial variance of temporal means

spatial mean of temporal variances

temporal variance of spatial means

temporal mean of spatial variances

Tx 50 years

	$\hat{E}$	$\hat{D}^2$	$\frac{1}{N}\sum_{j=1}^{N}\left(\hat{E}(s_j)-\hat{E}\right)^2$	$\frac{1}{N}\sum_{j=1}^{N}\hat{D}^2(s_j)$	$\frac{1}{n}\sum_{t=1}^{n}\left(\hat{E}(t)-\hat{E}\right)^2$	$\frac{1}{n}\sum_{t=1}^{n}\hat{D}^2(t)$	$\sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(\hat{E}(s_j)-\hat{E}\right)^2}$	$\sqrt{\frac{1}{N}\sum_{j=1}^{N}\hat{D}^2(s_j)}$	$\sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(\hat{E}(t)-\hat{E}\right)^2}$	$\sqrt{\frac{1}{n}\sum_{t=1}^{n}\hat{D}^2(t)}$
winC02Tx	2.07	6.33	3.69	2.64	2.24	4.09	1.92	1.63	1.50	2.02
winEOTx	1.97	6.07	3.49	2.58	2.20	3.87	1.87	1.61	1.48	1.97
spC02Tx	14.46	9.83	7.76	2.07	1.87	7.96	2.79	1.44	1.37	2.82
spEOTx	14.57	7.65	5.61	2.04	1.80	5.85	2.37	1.43	1.34	2.42
suC02Tx	24.40	10.26	8.72	1.55	1.32	8.95	2.95	1.24	1.15	2.99
suEOTx	24.49	7.89	6.36	1.52	1.26	6.63	2.52	1.23	1.12	2.58
auC02Tx	14.36	7.73	6.16	1.57	1.32	6.41	2.48	1.25	1.15	2.53
auEOTx	14.38	6.56	4.91	1.65	1.39	5.17	2.22	1.29	1.18	2.27

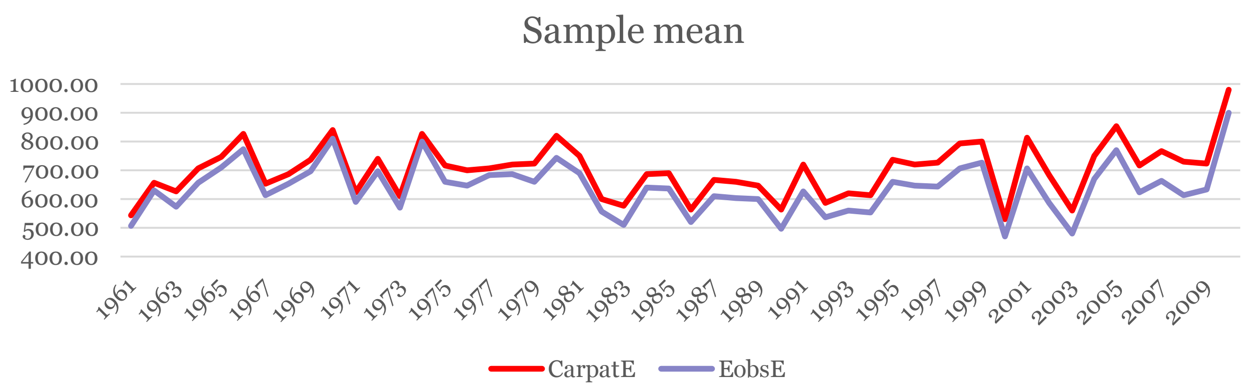
Tn 50 years

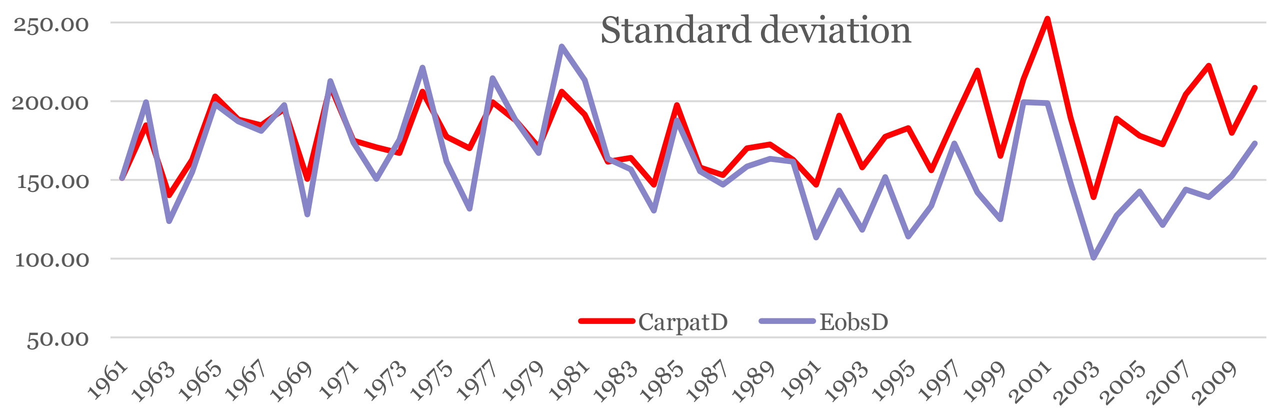
	$\hat{E}$	$\hat{D}^2$	$\frac{1}{N}\sum_{j=1}^{N}\left(\hat{E}(s_j)-\hat{E}\right)^2$	$\frac{1}{N}\sum_{j=1}^{N}\hat{D}^2(s_j)$	$\frac{1}{n}\sum_{t=1}^{n}\left(\hat{E}(t)-\hat{E}\right)^2$	$\frac{1}{n}\sum_{t=1}^{n}\hat{D}^2(t)$	$\sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(\hat{E}(s_j)-\hat{E}\right)^2}$	$\sqrt{\frac{1}{N}\sum_{j=1}^{N}\hat{D}^2(s_j)}$	$\sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(\hat{E}(t)-\hat{E}\right)^2}$	$\sqrt{\frac{1}{n}\sum_{t=1}^{n}\hat{D}^2(t)}$
winC02Tn	-4.75	6.53	3.62	2.91	2.40	4.13	1.90	1.71	1.55	2.03
winEOTn	-4.77	6.70	3.84	2.86	2.37	4.34	1.96	1.69	1.54	2.08
spC02Tn	3.94	4.84	4.00	0.85	0.74	4.11	2.00	0.92	0.86	2.03
spEOTn	4.03	4.75	3.89	0.86	0.71	4.04	1.97	0.93	0.84	2.01
suC02Tn	12.74	4.82	4.07	0.75	0.68	4.14	2.02	0.87	0.83	2.03
suEOTn	12.81	4.83	4.07	0.76	0.62	4.21	2.02	0.87	0.79	2.05
auC02Tn	4.83	3.94	2.99	0.95	0.80	3.14	1.73	0.98	0.89	1.77
auEOTn	4.84	4.15	3.17	0.98	0.80	3.36	1.78	0.99	0.89	1.83

Precipitation 50 years

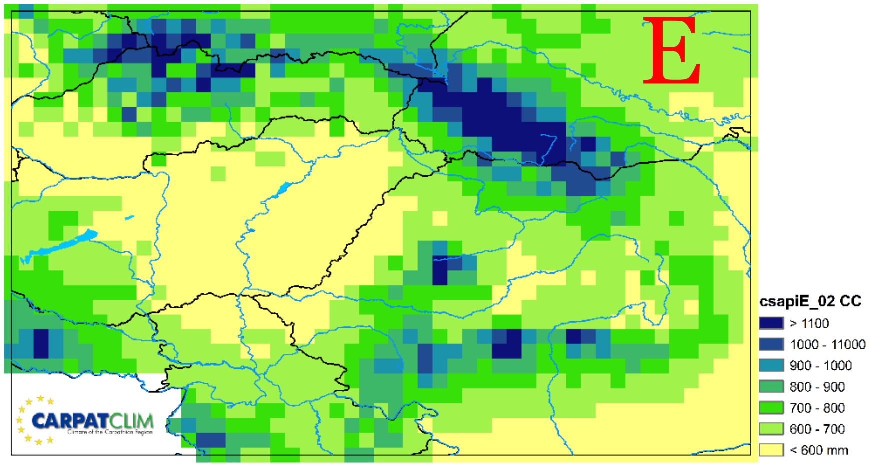
	$\hat{E}$	$\hat{D}^2$	$\frac{1}{N}\sum_{j=1}^{N}\left(\hat{E}(s_j)-\hat{E}\right)^2$	$\frac{1}{N}\sum_{j=1}^{N}\hat{D}^2(s_j)$	$\frac{1}{n}\sum_{t=1}^{n}\left(\hat{E}(t)-\hat{E}\right)^2$	$\frac{1}{n}\sum_{t=1}^{n}\hat{D}^2(t)$	$\sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(\hat{E}(s_j)-\hat{E}\right)^2}$	$\sqrt{\frac{1}{N}\sum_{j=1}^{N}\hat{D}^2(s_j)}$	$\sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(\hat{E}(t)-\hat{E}\right)^2}$	$\sqrt{\frac{1}{n}\sum_{t=1}^{n}\hat{D}^2(t)}$
winC02R	126.06	3638.55	1469.51	2169.04	1108.65	2529.90	38.33	46.57	33.30	50.30
winEOR	114.03	2946.99	935.48	2011.50	1024.24	1922.72	30.59	44.85	32.00	43.85
spC02R	169.49	4135.46	1534.45	2601.01	1033.17	3102.26	39.17	51.00	32.14	55.70
spEOR	154.75	3438.57	968.89	2469.68	1066.01	2372.55	31.13	49.70	32.65	48.71
suC02R	249.57	9446.81	3870.71	5576.09	2661.01	6785.72	62.22	74.67	51.59	82.38
suEOR	227.67	8403.98	3062.14	5341.84	2507.50	5896.50	55.34	73.09	50.07	76.79
auC02R	155.19	4866.06	1396.40	3469.66	1846.69	3019.40	37.37	58.90	42.97	54.95
auEOR	143.25	4283.28	1017.43	3265.85	1660.77	2622.50	31.90	57.15	40.75	51.21

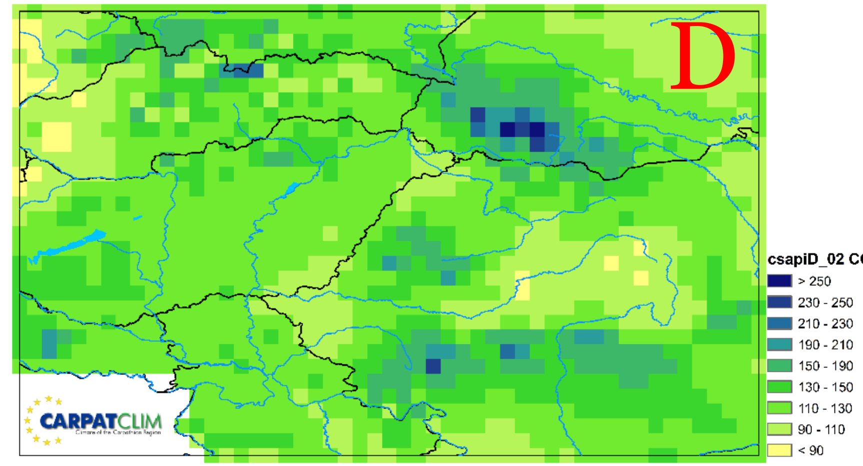
Precipitation/ year

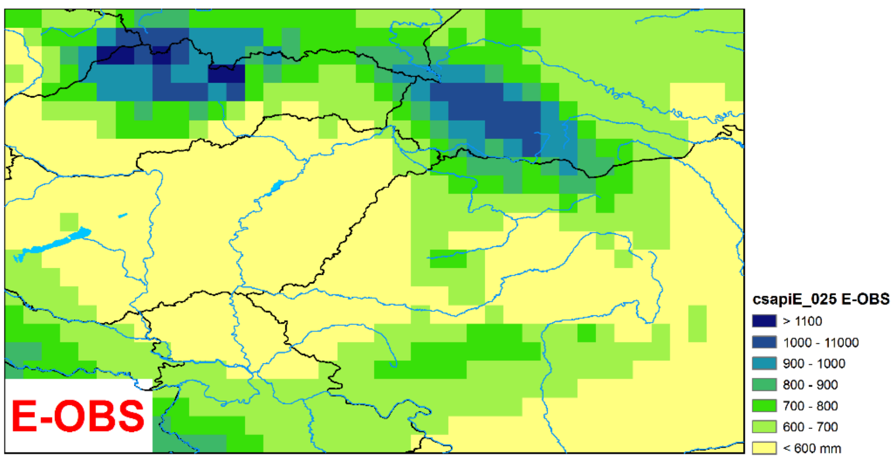


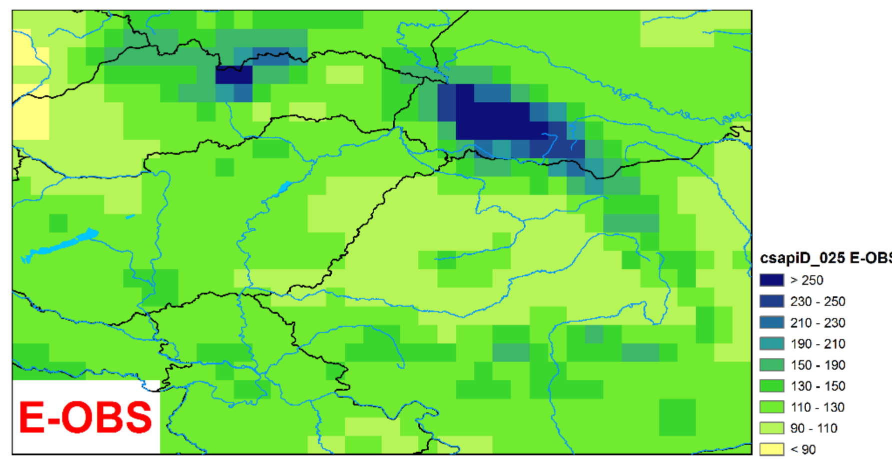


Precipitation 50 years

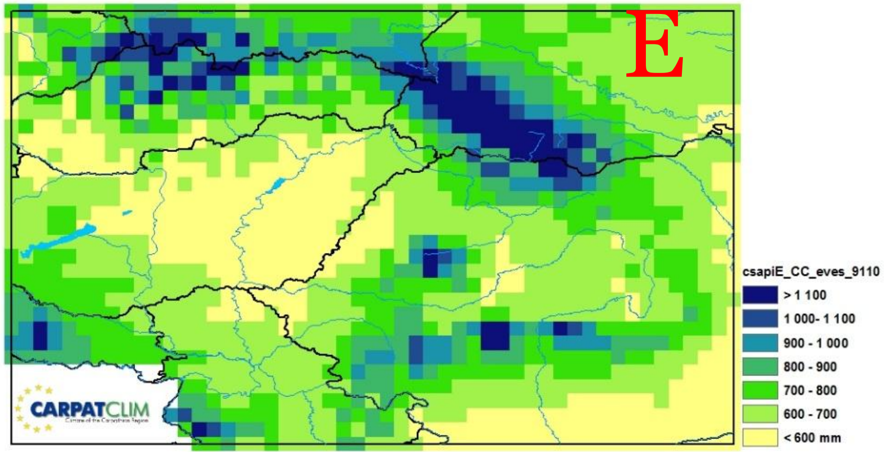


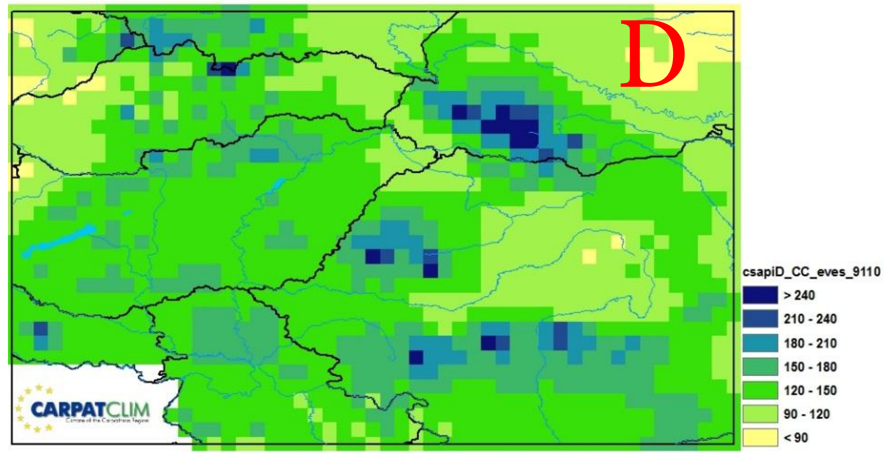


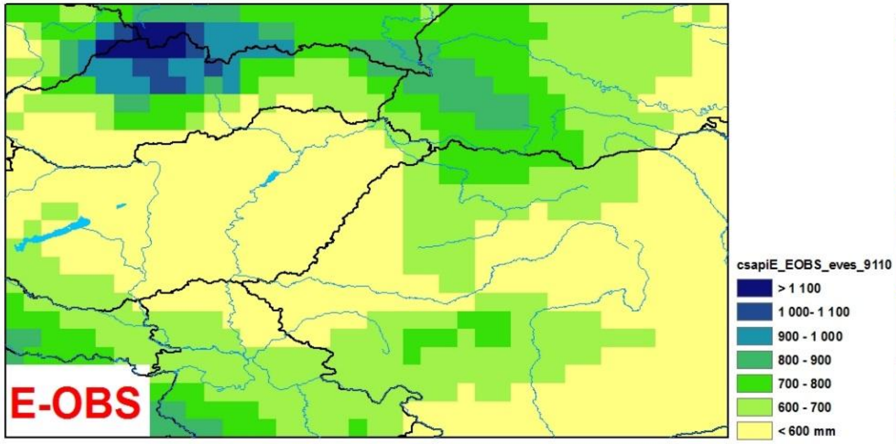


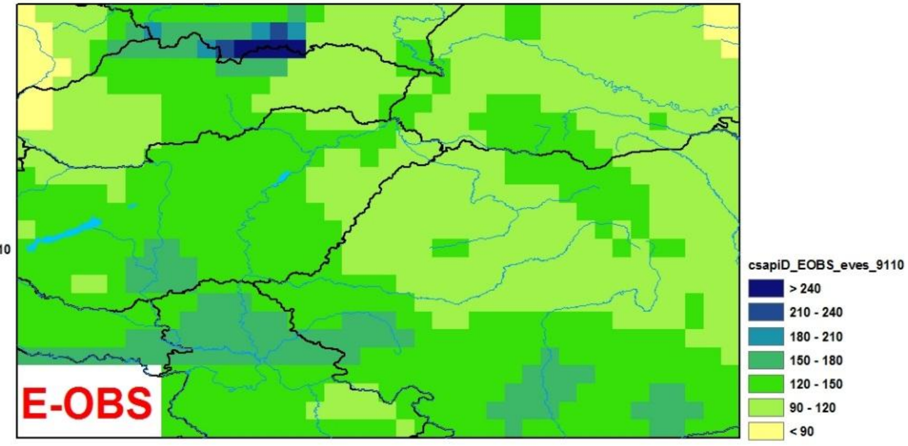


Precipitation, 1981-2010



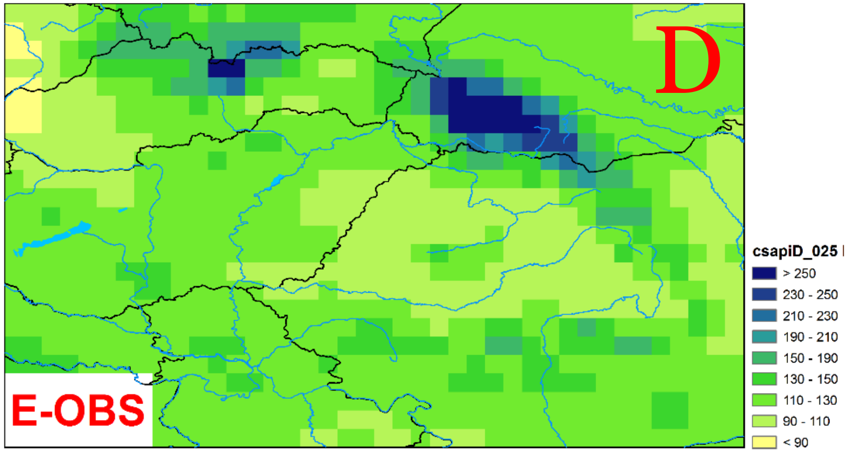




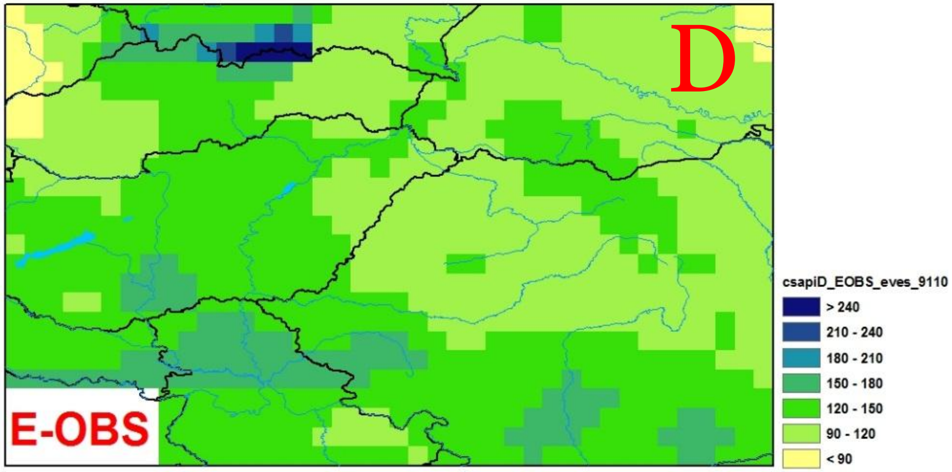


Precipitation

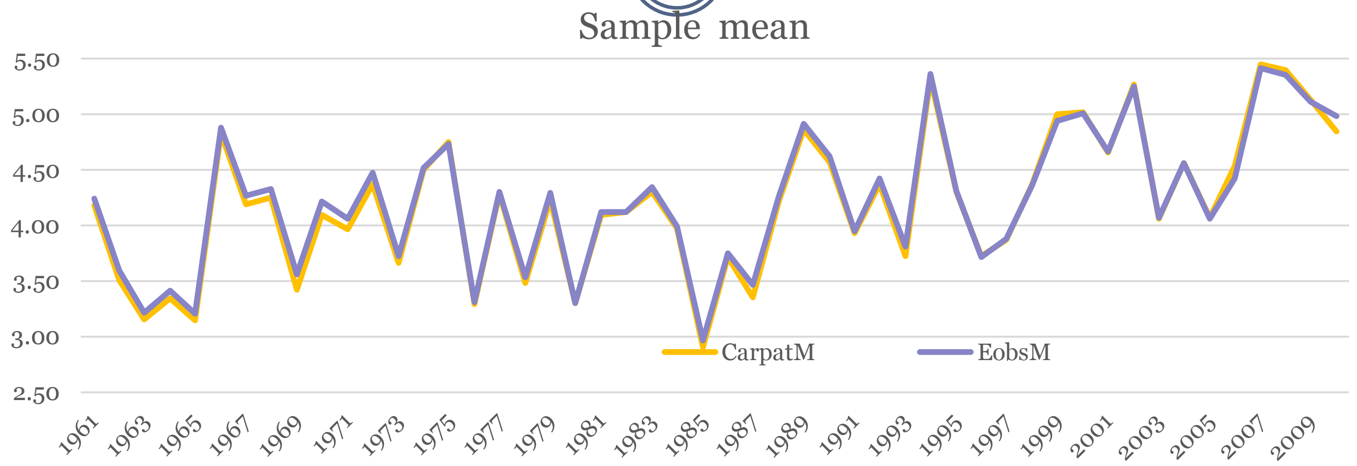
1961-2010



1981-2010



Tn year


Sample mean
5.50
5.00
4.50
4.00
3.50
3.00
2.50
CarpatM
EobsM
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
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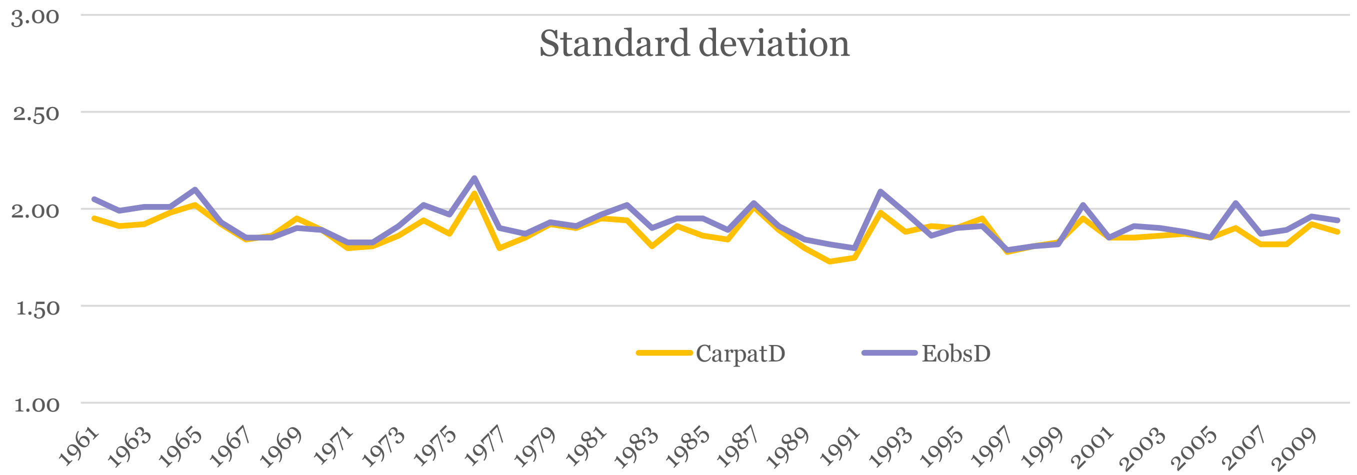
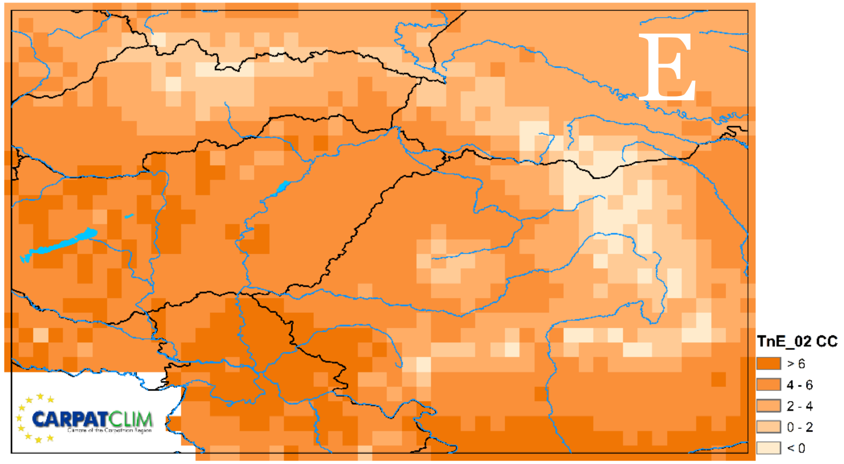
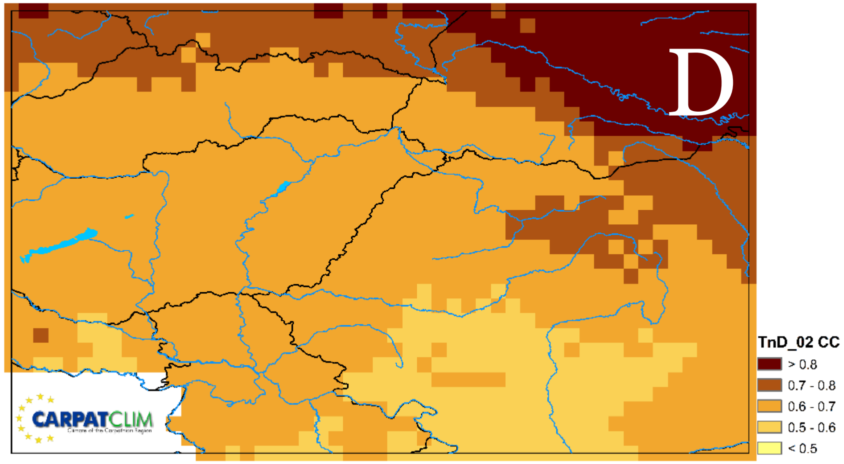
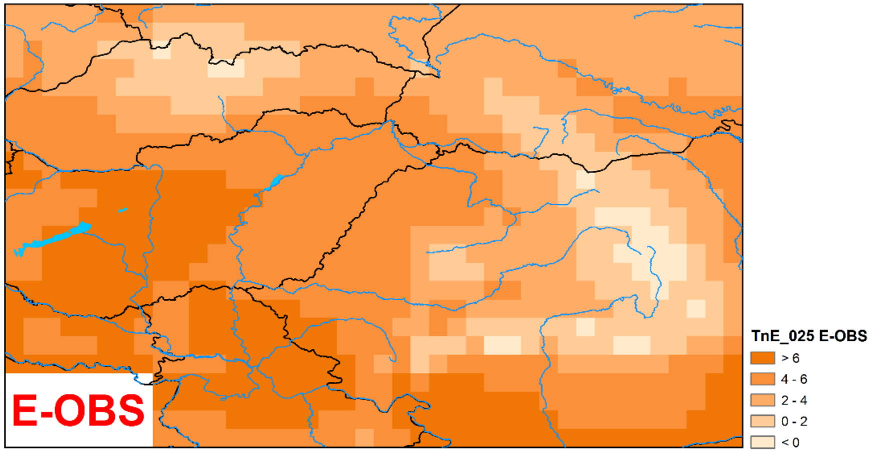
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009

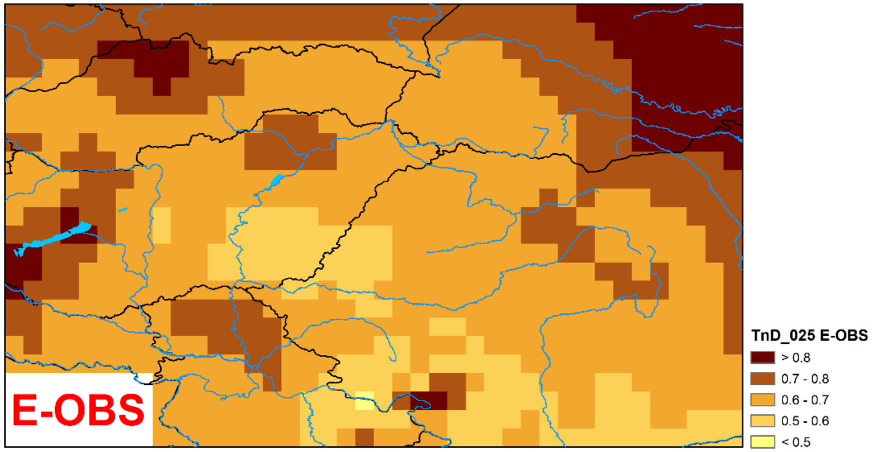

Standard deviation
3.00
2.50
2.00
1.50
1.00
CarpatD
EobsD
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009

Tn 50 years

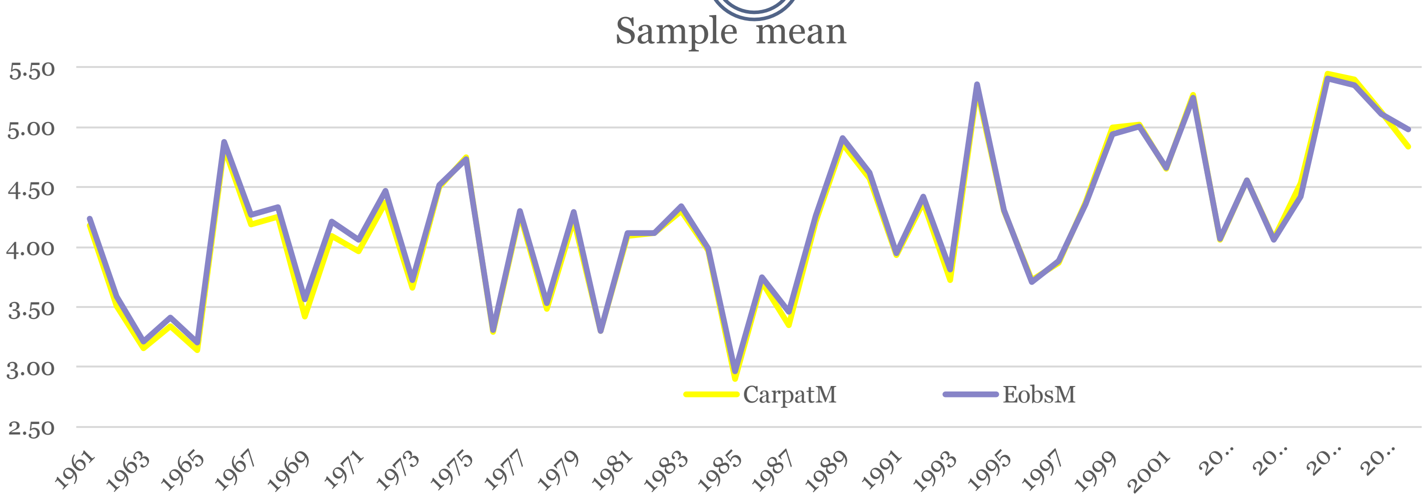

E
CARPATCLIM
TnE_02 CC
> 6
4 - 6
2 - 4
0 - 2
< 0


D
CARPATCLIM
TnD_02 CC
> 0.8
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
< 0.5


E-OBS
TnE_025 E-OBS
> 6
4 - 6
2 - 4
0 - 2
< 0


E-OBS
TnD_025 E-OBS
> 0.8
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
< 0.5

Tx year


Sample mean
5.50
5.00
4.50
4.00
3.50
3.00
2.50
CarpatM
EobsM
1961
1963
1965
1967
1969
1971
1973
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1981
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2001
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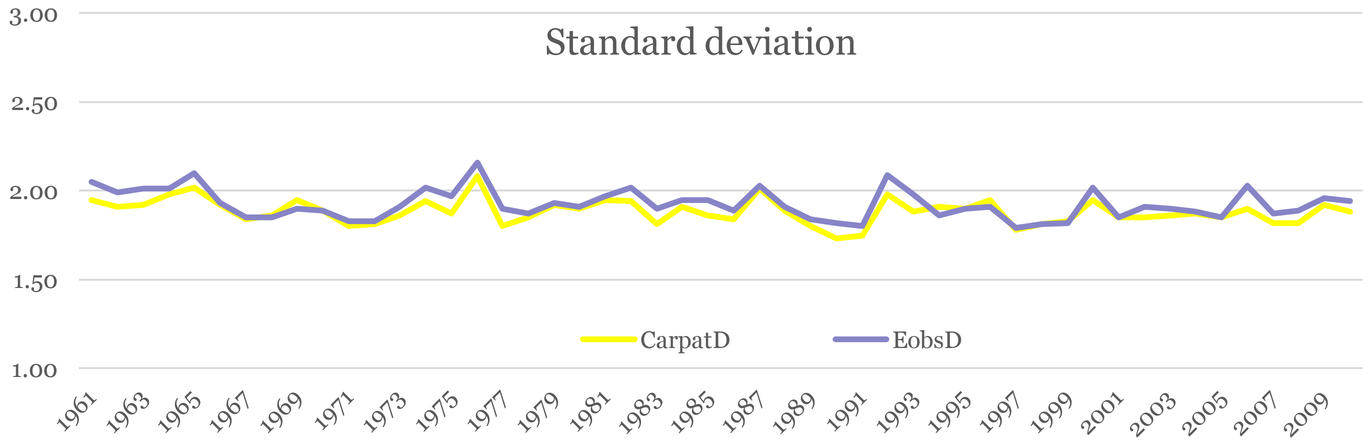
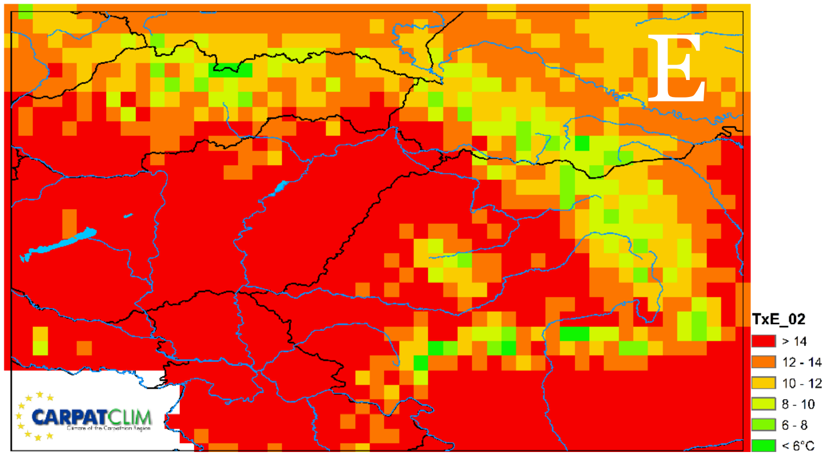
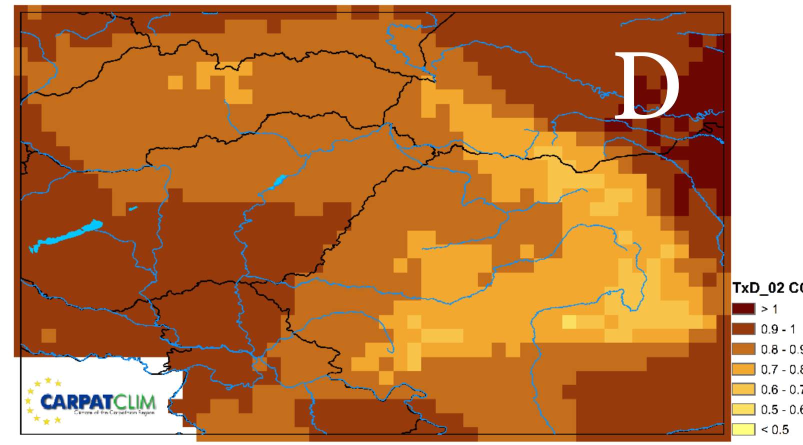
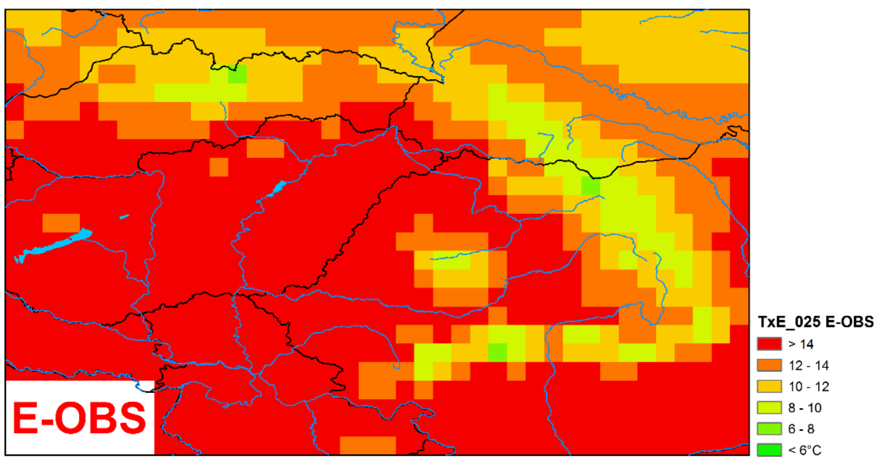
20..
20..
20..

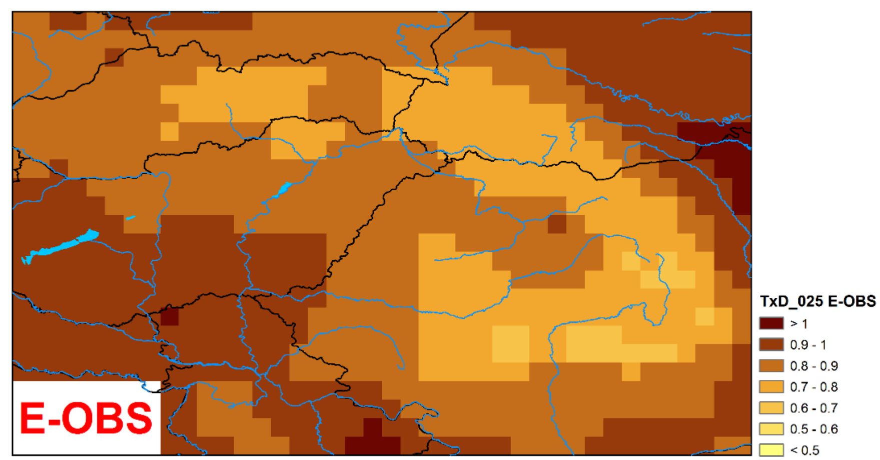

3.00
Standard deviation
2.50
2.00
1.50
CarpatD
EobsD
1.00
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009

Tx 50 years

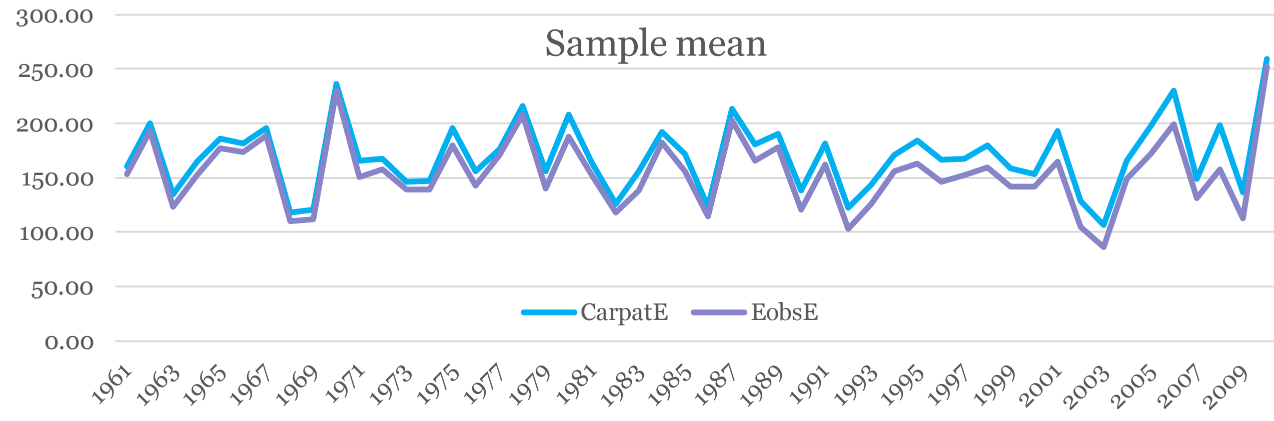

E
CARPATCLIM
TxE_02
> 14
12 - 14
10 - 12
8 - 10
6 - 8
< 6°C

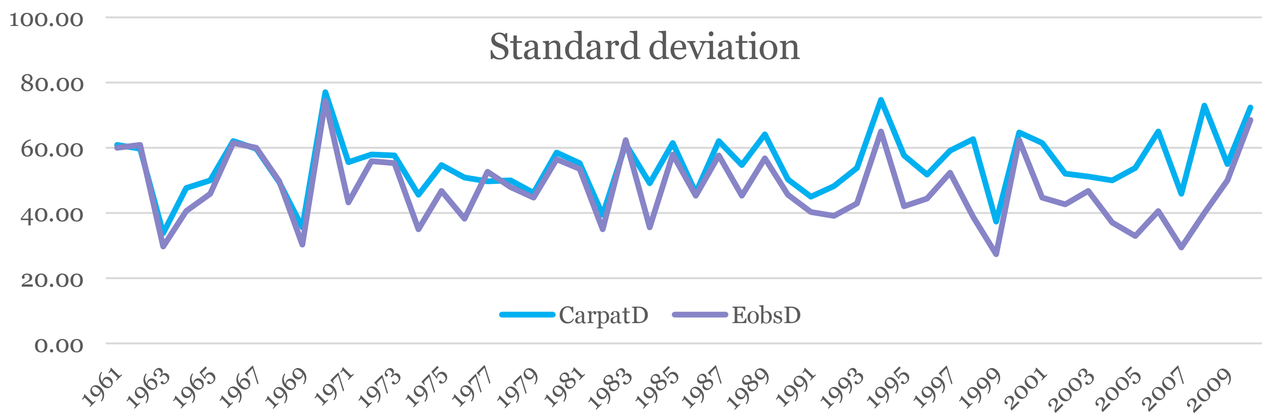

D
CARPATCLIM
TxD_02 CC
> 1
0.9 - 1
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
< 0.5


E-OBS
TxE_025 E-OBS
> 14
12 - 14
10 - 12
8 - 10
6 - 8
< 6°C

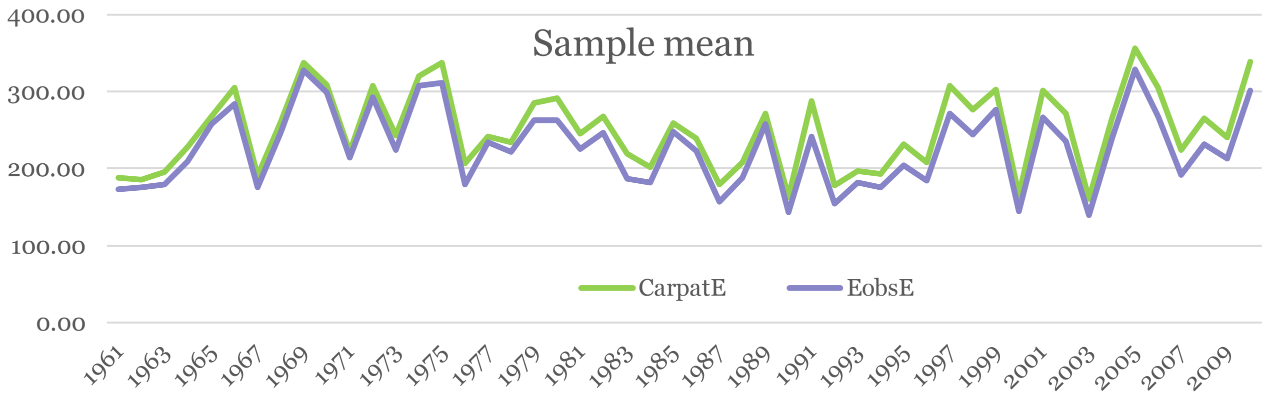

E-OBS
TxD_025 E-OBS
> 1
0.9 - 1
0.8 - 0.9
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
< 0.5

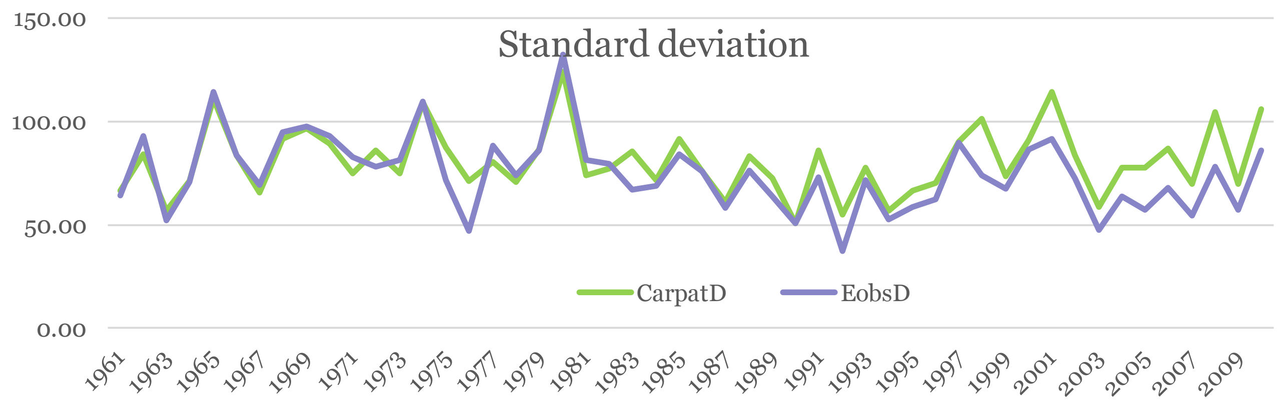
Spring R


Sample mean
300.00
250.00
200.00
150.00
100.00
50.00
0.00
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
CarpatE
EobsE

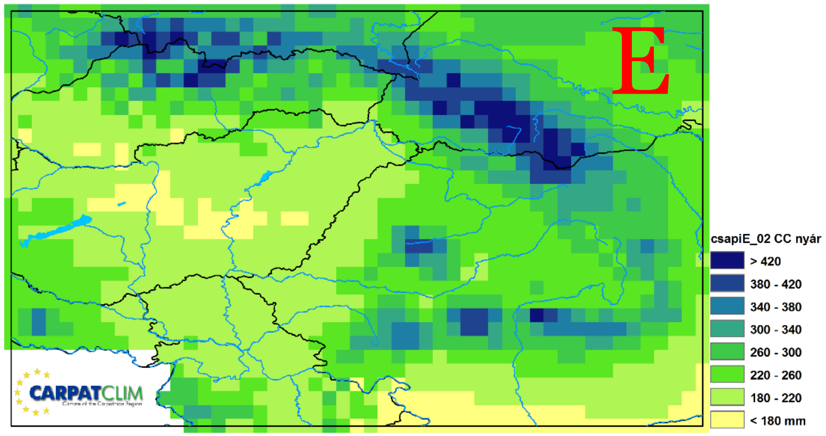

Standard deviation
100.00
80.00
60.00
40.00
20.00
0.00
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
CarpatD
EobsD

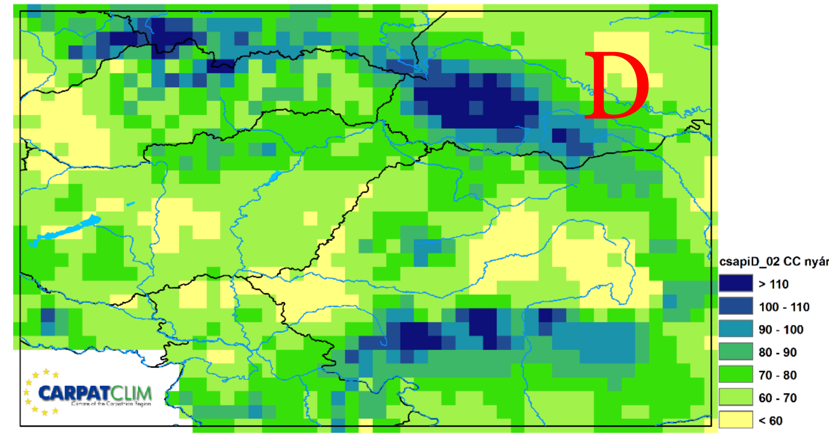
Summer precipitation

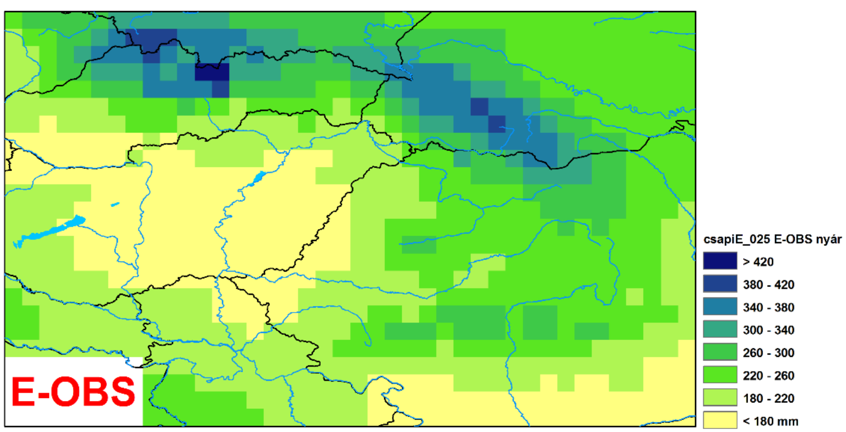


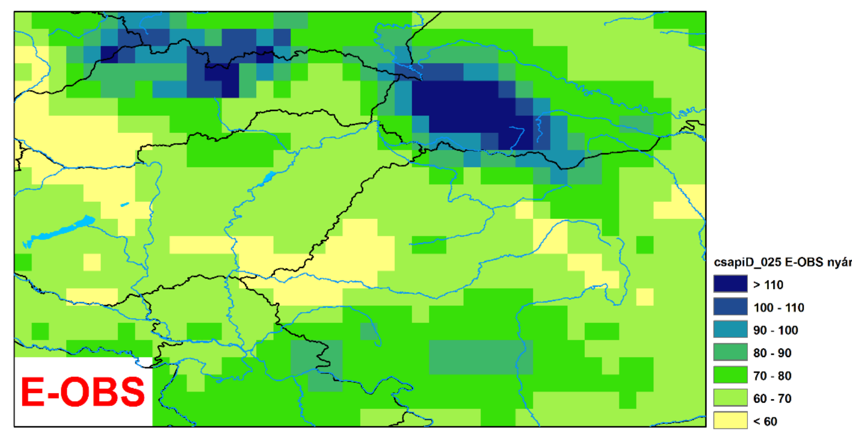


Precipitation / Summer, 50 years

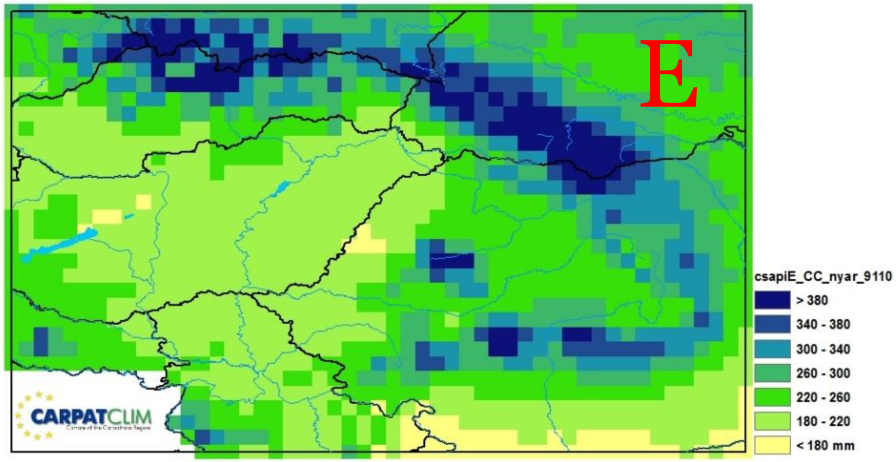


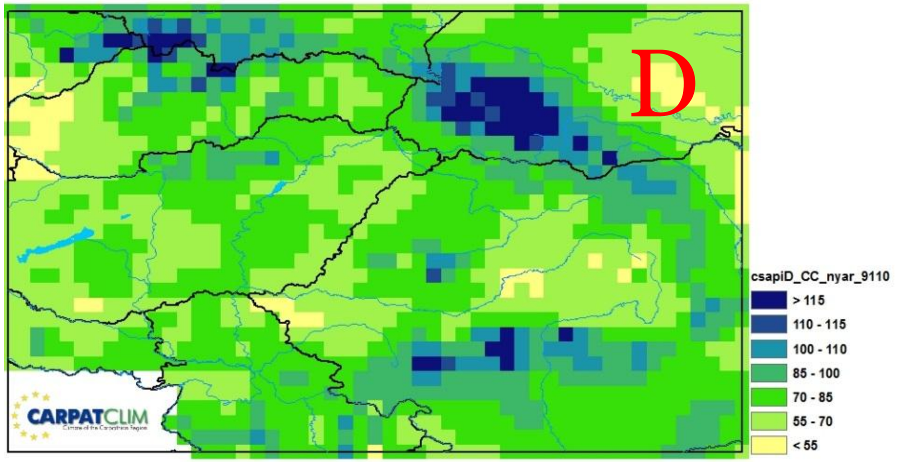


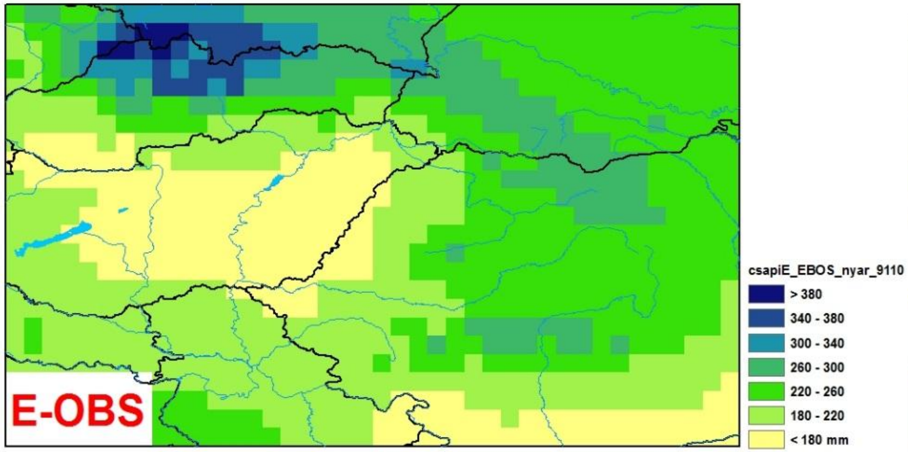


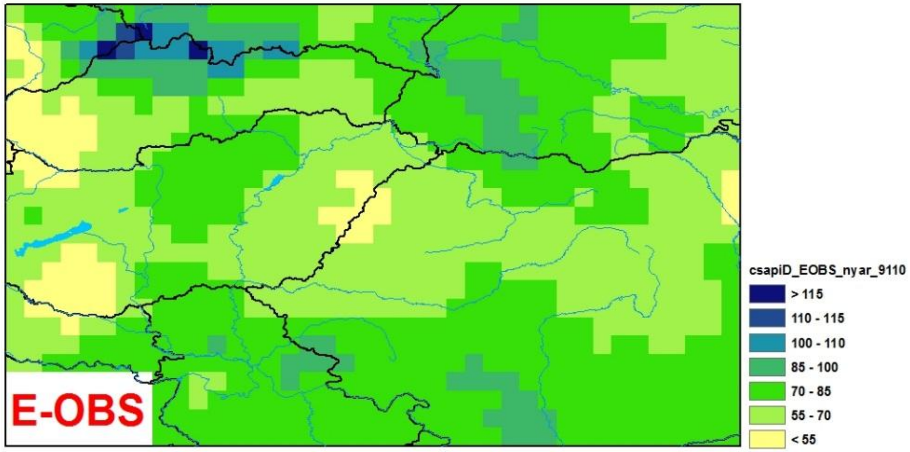


Precipitation/ Summer 1981-2010



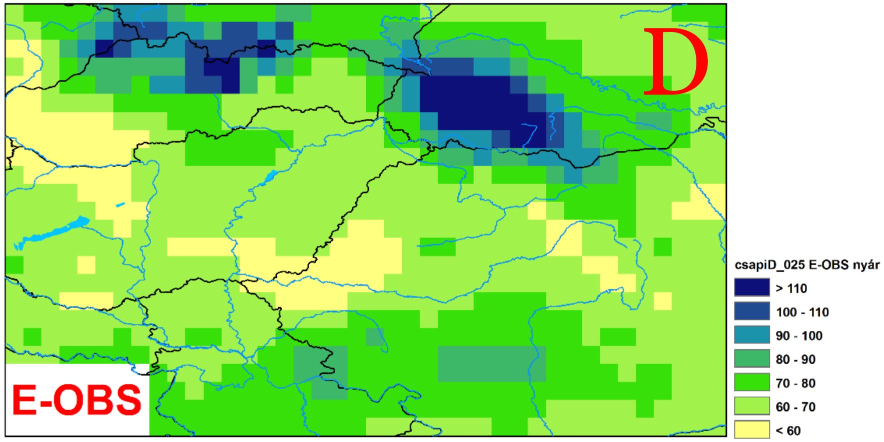


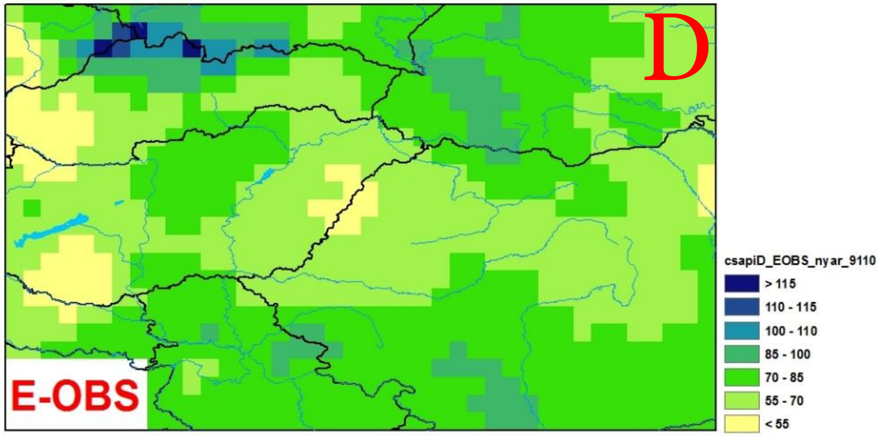




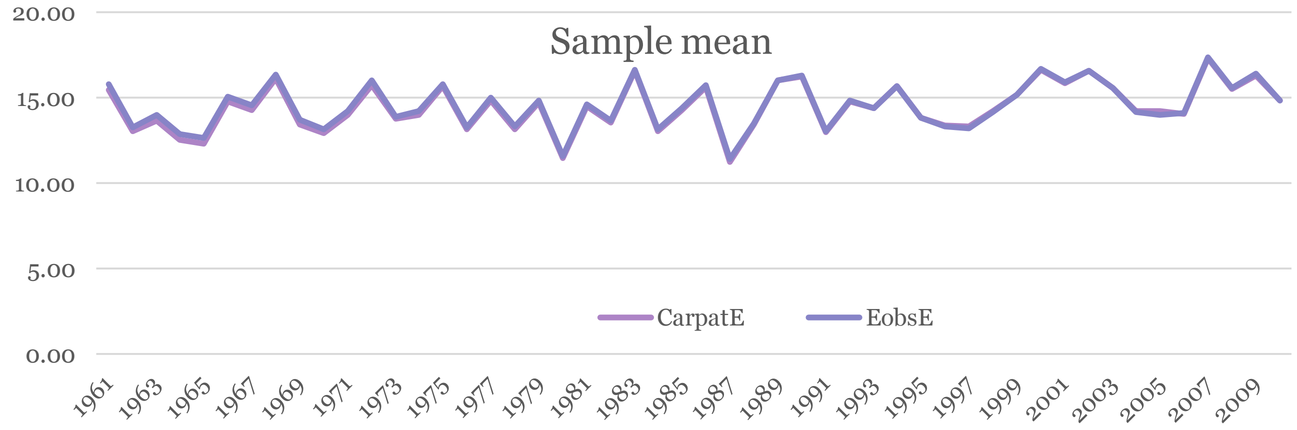
Precipitation Summer

1961-2010	1981-2010

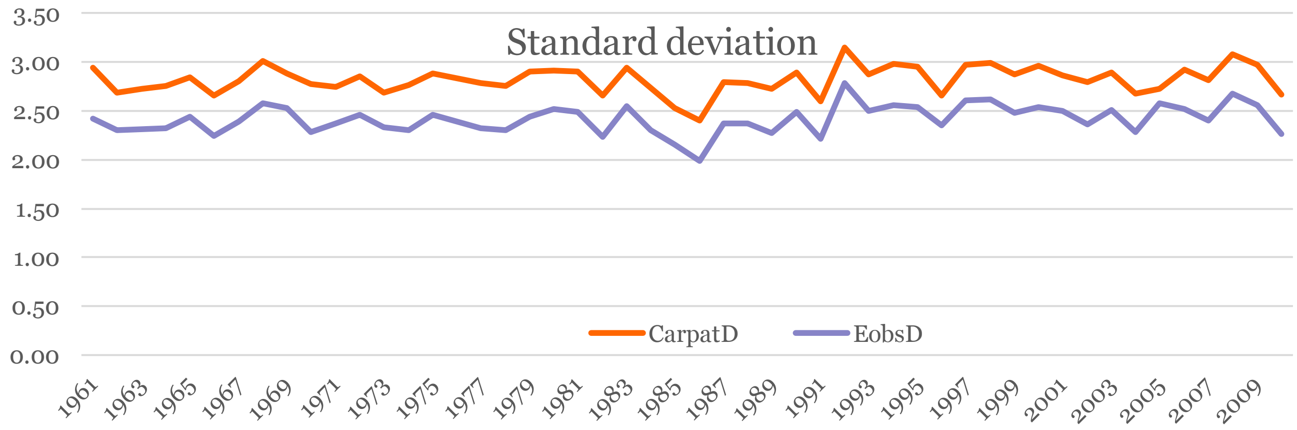




Spring Tx

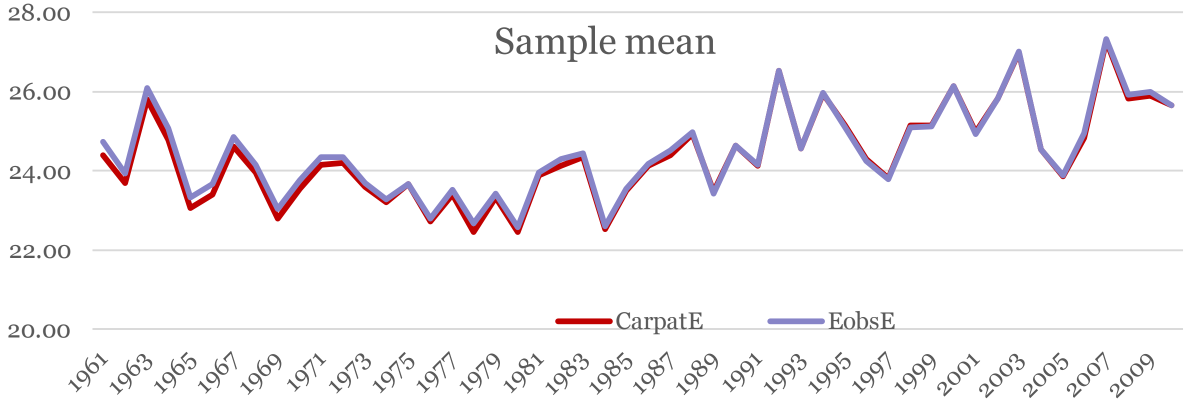


Sample mean
20.00
15.00
10.00
5.00
0.00
CarpatE
EobsE
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009

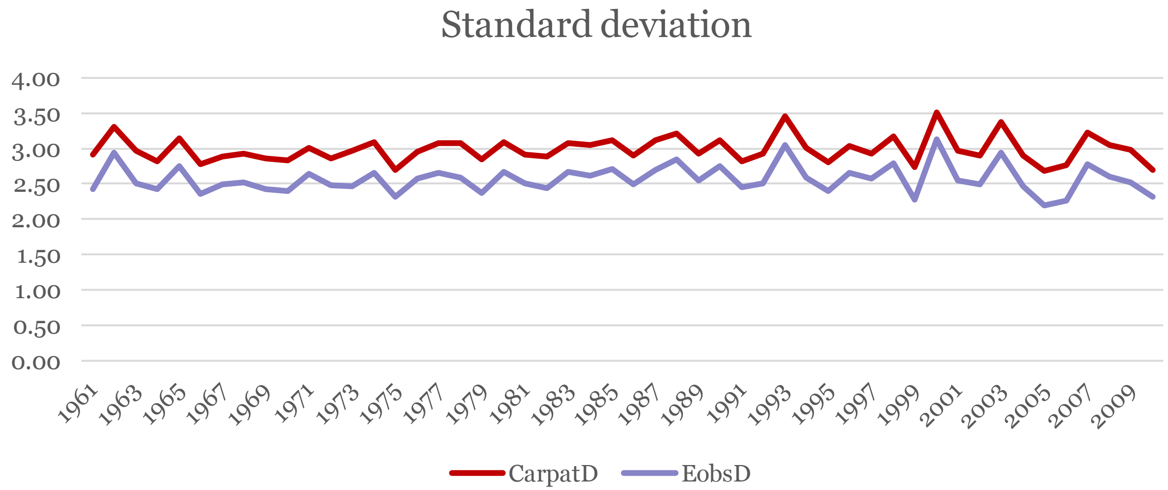


Standard deviation
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
CarpatD
EobsD
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009

Summer Tx

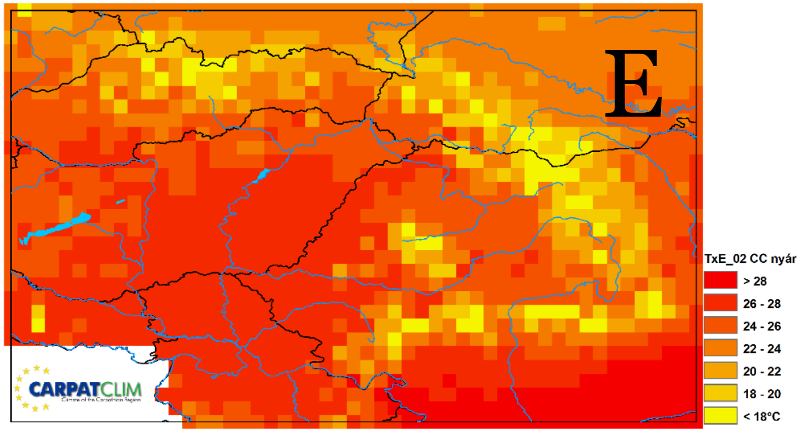


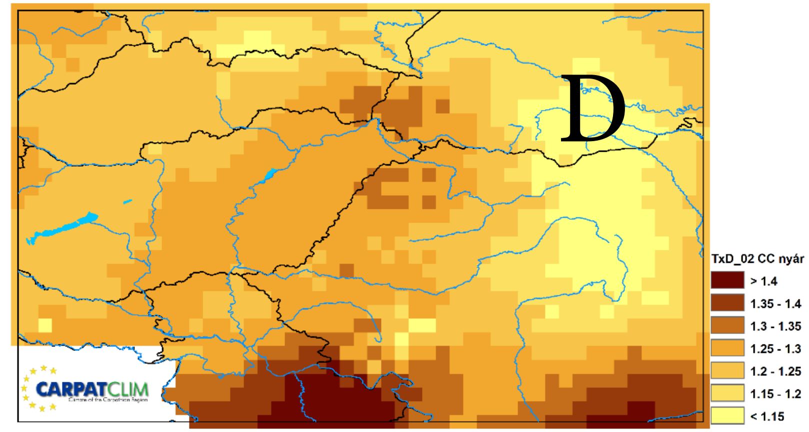
Sample mean
28.00
26.00
24.00
22.00
20.00
CarpatE
EobsE
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009

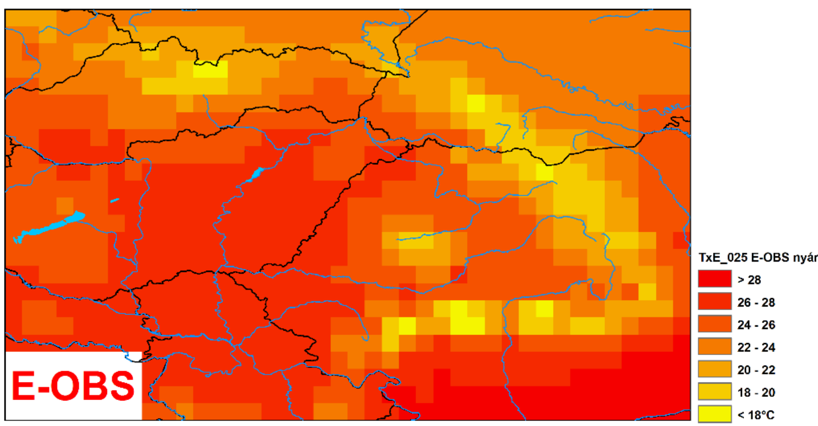


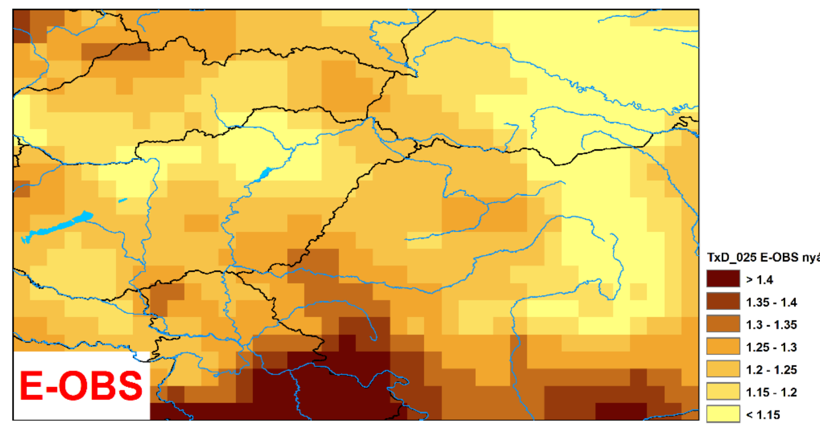
Standard deviation
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
CarpatD
EobsD

Tx summer 50 years

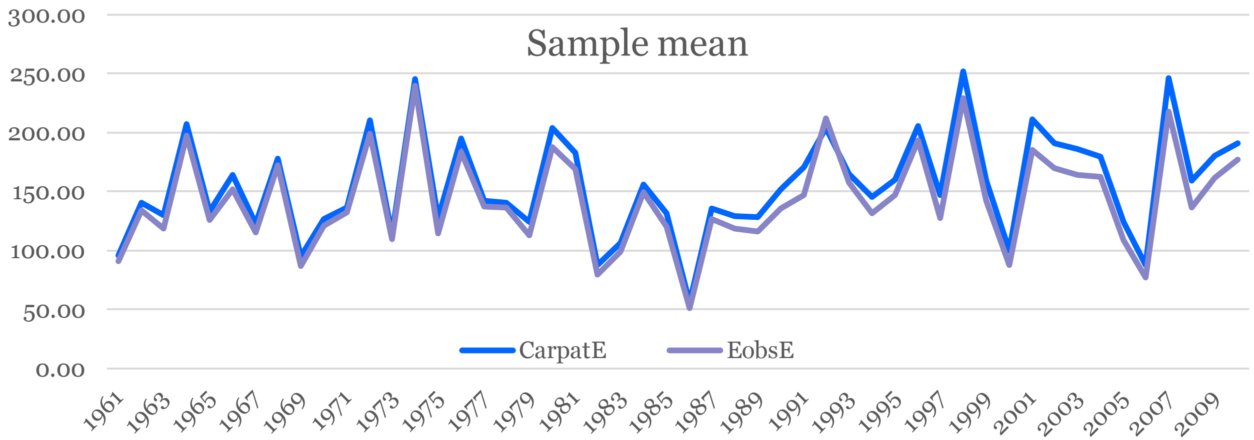


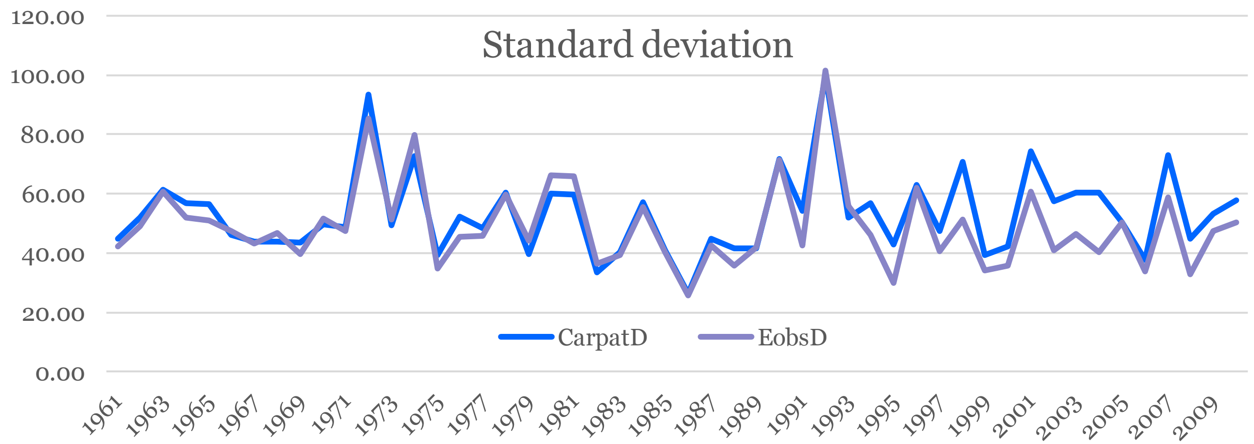






Autumn precipitation





Conclusion

- ANOVA is an adequate tool for comparison of gridded datasets for a region as a whole
- Same statistical properties of CarpatClim01 and CarpatClim02
- Precipitation: less in E-OBS, diverge from 1981
- Spatial variance is lower in E-OBS in Tx seasonal

Thank you for your kind attention!

Alapítva: 1870