Project No. 037005

CECILIA

Central and Eastern Europe Climate Change Impact and Vulnerability Assessment

Specific targeted research project

1.1.6.3.I.3.2: Climate change impacts in central-eastern Europe m

D4.1: Measures and indices to be validated, which observational data sets to be used for the validation of extremes, plan of the analyses to be performed under D4.2, D4.3, D4.4, D4.5, and D4.6

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

CECILIA WP4 DELIVERABLE D4.1

Lead partner for deliverable: ETH

Contributing partners: DMI, CUNI, NMA, CHMI, ELU, IAP, OMSZ, ICTP, AUTH, NIMH

December 1, 2006

1. Introduction

The purpose of this deliverable is to provide a concerted research plan between the WP4 partners. In particular, this report entails following information:

- Definition of which measures and indices are to be validated within WP4 (based on indices of extremes as defined by the WMO and the STARDEX project)
- Identification of the observational datasets to be used for the validation of extremes.
- Detailed implementation plan concerning the analyses to be performed under D4.2, D4.3, D4.4, and D4.5.

2. List of indices to be analyzed within CECILIA WP4

This section presents a first-stage list of 131 indices chosen by the WP4 partners for the analysis of extremes in WP4. This list is primarily based on STARDEX and WMO indices, but also includes additional indices considered useful for the analyses to be conducted within WP4. The final list of indices will be defined at the CECILIA January 2007 meeting in Semmering. A software will be developed by CHMI based on the existing software by Štěpánek (2006) for computing the final list of indices from daily data as part of D4.2. This software will be available to all WP4 partners. This will guarantee that the indices are computed in a consistent way for all considered observational (and modeling) datasets. From the total list of 131 indices, 41 "core indices" are highlighted in bold face. The list of core indices is based on the ECA&D indices and inputs from WP4 partners.

Whenever possible, the indices will be computed for annual, seasonal (MAM, JJA, SON, DJF) **and** monthly time frames. This will allow us to identify changes in the seasonality of extreme events, which can also better be linked with responsible physical processes. In order to identify trends in extreme indices, these will be computed as climatological estimates over the following time periods: 1961-1990, 1961-1970, 1966-1975, 1971-1980, 1976-1985, 1981-1990, 1986-1995, 1991-2000, 1996-2005. **The core indices will be provided as yearly output (indicated in bold in Tables 1-3).**

2.a. Reference time period

The period 1961-1990 will be used as base period for the computation of the reference percentiles whenever required.

2.b. Temperature indices

The first-stage list of temperature indices is given in Tables 1 (indices over all time frames) and 2 (annual indices). For each index, the tables indicate whether the given index has been used in previous projects and softwares. The letters A-E correspond respectively to:

A: index from STARDEX 57-indices list *(http://www.cru.uea.ac.uk/projects/stardex/deis/Diagnostic_tool.pdf)*
B: index from STARDEX core 10 indices list *(http://www.cru.uea.ac.uk/projects/stardex/deis/Core_Indices.pdf)*
C: index from ClimDex list *(http://cccma.seos.uvic.ca/ETCCDMI/software.html; http://cccma.seos.uvic.ca/ETCCDMI/list_27_indices.html)*
D: index from RClimDex list *(http://cccma.seos.uvic.ca/ETCCDMI/software.html; http://cccma.seos.uvic.ca/ETCCDMI/ClimDex/climdex-v1-3-users-guide.pdf)*
E: index from ECA&D list *(http://eca.knmi.nl/indicesextremes/indicesdictionary.php)*

If a modified version of the proposed index has been used in these previous projects or softwares, the corresponding cross is set between parentheses (“ (x) “).

Comments on content of Tables 1&2

NB: “time frame” refers to annual, seasonal, and monthly time frames

in blue: this index is computed from the total number of available days over all years (i.e. for a monthly time frame and a 10-year time period, from 300 values)

in green: this index is computed separately for each year and averaged over all years (i.e. for a monthly time frame and a 10-year time period, mean of 10 values, each one of which is computed from 30 values)

in gray: indices with special definition

The indices denoted in bold face will be provided as yearly output for the observational datasets analyzed in WP4 (“core indices”)

Table 1: Temperature indices to be computed over all time frames

	Index	A	B	C	D	E	definition
1	**Mean Tmax**	**x**				**x**	**daily max T° averaged over time frame**
2	**Mean Tmin**	**x**				**x**	**daily min T° averaged over time frame**
3	**Mean Tmean**	**x**				**x**	**daily mean T° averaged over time frame**
4	**Mean diurnal temperature range**	**x**			**(x)**	**x**	**daily values of (Tmax-Tmin) averaged over time frame**

	Index	A	B	C	D	E	definition
5	10th percentile diurnal temperature range	x					10th percentile of daily values of (Tmax-Tmin) within given time frame
6	90th percentile diurnal temperature range	x					90th percentile of daily values of (Tmax-Tmin) within given time frame
7	Tmax 1st percentile						1st percentile of daily values of Tmax within given time frame
8	Tmax 5th percentile						5th percentile of daily values of Tmax within given time frame
9	Tmax 10th percentile	x					10th percentile of daily values of Tmax within given time frame
10	Tmax 20th percentile						20th percentile of daily values of Tmax within given time frame
11	Tmax 30th percentile						30th percentile of daily values of Tmax within given time frame
12	Tmax 40th percentile						40th percentile of daily values of Tmax within given time frame
13	Tmax 50th percentile						50th percentile of daily values of Tmax within given time frame
14	Tmax 60th percentile						60th percentile of daily values of Tmax within given time frame
15	Tmax 70th percentile						70th percentile of daily values of Tmax within given time frame
16	Tmax 80th percentile						80th percentile of daily values of Tmax within given time frame
17	Tmax 90th percentile	x	x				90th percentile of daily values of Tmax within given time frame
18	Tmax 95th percentile						95th percentile of daily values of Tmax within given time frame
19	Tmax 99th percentile						99th percentile of daily values of Tmax within given time frame
20	Tmean 1st percentile						1st percentile of daily values of Tmean within given time frame
21	Tmean 5th percentile						5th percentile of daily values of Tmean within given time frame
22	Tmean 10th percentile						10th percentile of daily values of Tmean within given time frame
23	Tmean 20th percentile						20th percentile of daily values of Tmean within given time frame
24	Tmean 30th percentile						30th percentile of daily values of Tmean within given time frame
25	Tmean 40th percentile						40th percentile of daily values of Tmean within given time frame
26	Tmean 50th percentile						50th percentile of daily values of Tmean within given time frame
27	Tmean 60th percentile						60th percentile of daily values of Tmean within given time frame
28	Tmean 70th percentile						70th percentile of daily values of Tmean within given time frame
29	Tmean 80th percentile						80th percentile of daily values of Tmean within given time frame
30	Tmean 90th percentile						90th percentile of daily values of Tmean within given time frame
31	Tmean 95th percentile						95th percentile of daily values of Tmean within given time frame
32	Tmean 99th percentile						99th percentile of daily values of Tmean within given time frame
33	Tmin 1st percentile						1st percentile of daily values of Tmin within given time frame

	Index	A	B	C	D	E	Definition
34	Tmin 5th percentile						5th percentile of daily values of Tmin within given time frame
35	Tmin 10th percentile	x	x				10th percentile of daily values of Tmin within given time frame
36	Tmin 20th percentile						20th percentile of daily values of Tmin within given time frame
37	Tmin 30th percentile						30th percentile of daily values of Tmin within given time frame
38	Tmin 40th percentile						40th percentile of daily values of Tmin within given time frame
39	Tmin 50th percentile						50th percentile of daily values of Tmin within given time frame
40	Tmin 60th percentile						60th percentile of daily values of Tmin within given time frame
41	Tmin 70th percentile						70th percentile of daily values of Tmin within given time frame
42	Tmin 80th percentile						80th percentile of daily values of Tmin within given time frame
43	Tmin 90th percentile	x					90th percentile of daily values of Tmin within given time frame
44	Tmin 95th percentile						95th percentile of daily values of Tmin within given time frame
45	Tmin 99th percentile						99th percentile of daily values of Tmin within given time frame
46	**Percentage of frost days**	**(x)**	**(x)**	**(x)**	**(x)**	**(x)**	**%age of days within time frame with Tmin < 0C (ECA&D Number of frost days)**
47	**Percentage of days without defrost (ice days)**	**(x)**			**(x)**	**(x)**	**%age of days within time frame with Tmax < 0C (ECA&D: Number of ice days)**
48	**Consecutive frost days**					**x**	**Max. nb of consecutive frost days with Tmin < 0C**
49	**Growing degree days (def1)**	**x**				**x**	**Sum of (Tmean-4C) for all days with Tmean>4C within time frame (ECA definition)**
50	Growing degree days (def2)						Sum of (((Tmax+Tmin)/2)-10C) for all days with Tmax>10C within time frame using the following rules: if Tmin<10C, then use 10C for Tmin; if Tmax>30C then use 30C for Tmax
51	**Extreme temperature range within time frame**	**(x)**		**(x)**		**(x)**	**Range between max. Tmax and min. Tmin within time frame (for annual time frame equivalent to intra-annual extreme temperature range)**
52	**Mean heat wave duration**	**x**		**x**		**x**	**Let Tx_{ij} be the daily maximum temperature at day i of period j and let Tx_{inorm} be the calendar day mean calculated for a 5 day window centred on each calendar day during a specified period. Then counted is the number of days per period where, in intervals of at least 6 consecutive days: $Tx_{ij} > Tx_{inorm} + 5$ (STARDEX definition)**

	Index	A	B	C	D	E	definition
53	90th percentile-based heat wave duration	x	x				Let Tx_{ij} be the daily maximum temperature at day i of period j and let $Txq90_{inorm}$ be the calendar day 90th percentile calculated for a 5 day window centred on each calendar day during a specified period. Then counted is the maximum number of consecutive days per period where: $T_{ij} > Txq90_{inorm}$ (STARDEX definition)
54	Heating degree days					x	Sum of 17C-Tmean for days with Tmean<17C
55	Mean cold wave duration	x				x	Let Tn_{ij} be the daily minimum temperature at day i of period j and let Tn_{inorm} be the calendar day mean calculated for a 5 day window centred on each calendar day during a specified period. Then counted is the number of days per period where, in intervals of at least 6 consecutive days: $Tn_{ij} < Tn_{inorm} - 5$ (STARDEX definition)
56	10th percentile-based cold wave duration	x					Let Tn_{ij} be the daily minimum temperature at day i of period j and let $Tnq10_{inorm}$ be the calendar day 10th percentile calculated for a 5 day window centred on each calendar day during a specified period. Then counted is the maximum number of consecutive days per period where: $Tn_{ij} < Tnq10_{inorm}$ (STARDEX def.)
57	Frost season length	(x)					Mean duration within time frame of time spans of minimum 5 consecutive days where Tmin<0 (adapted from STARDEX definition)
58	Percentage of "summer days"				(x)	(x)	%age of days where Tmax > 25C
59	Percentage of "tropical nights"				(x)	(x)	%age of days where Tmin > 20C
60	Percentage of days with Tmax < 10th percentile	x		x	x	x	%age of days with Tmax < 10th percentile, where 10th percentile is taken from all values for 5-day window around calendar day within base period (ECA&D def.)
61	Percentage of days with Tmax > 90th percentile	x		x	x	x	%age of days with Tmax > 90th percentile, where 90th percentile is taken from all values for 5-day window around calendar day within base period (ECA&D def.)
62	Percentage of days with Tmean < 10th percentile					x	%age of days with Tmean < 10th percentile, where 10th percentile is taken from all values for 5-day window around calendar day within base period (ECA&D def)

	Index	A	B	C	D	E	definition
63	**Percentage of days with Tmean > 90th percentile**					**x**	**%age of days with Tmean > 90th percentile, where 90th percentile is taken from all values for 5-day window around calendar day within base period (ECA&D def.)**
64	**Percentage of days with Tmin < 10th percentile**	**x**		**x**	**x**	**x**	**%age of days with Tmin < 10th percentile, where 10th percentile is taken from all values for 5-day window around calendar day within base period (ECA&D def.)**
65	**Percentage of days with Tmin > 90th percentile**	**x**		**x**	**x**	**x**	**%age of days with Tmin > 90th percentile, where 90th percentile is taken from all values for 5-day window around calendar day within base period (ECA&D def.)**
66	**Percentage of hot days**						**%age of days with Tmax ≥ 30C (adapted from ELU definition)**
67	Percentage of extremely hot days						%age of days with Tmax ≥ 35C (adapted from ELU definition)
68	Percentage of severe cold days						%age of days with Tmin < -10C (adapted from ELU definition)
69	Interannual variability of Tmean						Standard deviation of mean yearly values of Tmean averaged over given time frame (e.g. month)
70	Interannual variability of Tmax						Standard deviation of mean yearly values of Tmax averaged over given time frame (e.g. month)
71	Interannual variability of Tmin						Standard deviation of mean yearly values of Tmin averaged over given time frame (e.g. month)
72	Intra-annual variability of Tmean						Mean over whole time period (e.g. 10-yr period) of yearly standard deviation of Tmean within given time frame
73	Intra-annual variability of Tmax						Mean over whole time period (e.g. 10-yr period) of yearly standard deviation of Tmean within given time frame
74	Intra-annual variability of Tmin						Mean over whole time period (e.g. 10-yr period) of yearly standard deviation of Tmean within given time frame

Table 2: Temperature indices to be computed only over annual time frames

	Index	A	B	C	D	E	definition
75	**Growing season length**	**x**		**x**	**x**	**x**	**Annual count between first span of at least 6 days with daily mean temperature Tmean>5C and first span after July 1st of 6 days with Tmean<5C (RClimDex definition)**

2.c. Precipitation indices

The first-stage list of precipitation indices is given in Table 3 (indices over all time frames). For each index, the table indicates whether the given index has been used in previous projects and softwares (see corresponding comments under 2.b. for temperature indices).

For precipitation indices, "wet days" and "dry days" are distinguished, where the wet-day precipitation ≥ 1 mm/d, and the dry-day precipitation is < 1 mm/d.

Comments on content of Table 3

NB: "time frame" refers to annual, seasonal, and monthly time frames

in blue: this index is computed from the total number of available days over all years (i.e. for a monthly time frame and a 10-year time period, from 300 values)

in green: this index is computed separately for each year and averaged over all years (i.e. for a monthly time frame and a 10-year time period, mean of 10 values, each one of which is computed from 30 values)

in gray: indices with special definition

The indices denoted in bold face will be provided as yearly output for the observational datasets analyzed in WP4 ("core indices")

Table 3: Precipitation indices to be computed over all time frames

	Index	A	B	C	D	E	definition
76	**Mean climatological precipitation**	**x**				**x**	**Mean precipitation (including both wet and dry days)**
77	**Mean wet-day precipitation**	**x**	**x**	**x**	**x**	**x**	**Mean wet-day precipitation (equivalent to "simple daily intensity")**
78	**Percentage of wet days**					**x**	**Nb wet days/ total nb of days [%]**
79	10^{th} percentile of wet-day amounts						10^{th} percentile of wet-day amounts [mm/d]
80	20^{th} percentile of wet-day amounts	x					20^{th} percentile of wet-day amounts [mm/d]
81	30^{th} percentile of wet-day amounts						30^{th} percentile of wet-day amounts [mm/d]
82	40^{th} percentile of wet-day amounts	x					40^{th} percentile of wet-day amounts [mm/d]
83	50^{th} percentile of wet-day amounts	x					50^{th} percentile of wet-day amounts [mm/d]
84	60^{th} percentile of wet-day amounts	x					60^{th} percentile of wet-day amounts [mm/d]
85	70^{th} percentile of wet-day amounts						70^{th} percentile of wet-day amounts [mm/d]
86	80^{th} percentile of wet-day amounts	x					80^{th} percentile of wet-day amounts [mm/d]
87	90^{th} percentile of wet-day amounts	x	x				90^{th} percentile of wet-day amounts [mm/d]

	Index	A	B	C	D	E	Definition
88	95th percentile of wet-day amounts	x					95th percentile of wet-day amounts [mm/d]
89	99th percentile of wet-day amounts						99th percentile of wet-day amounts [mm/d]
90	Fraction of total precipitation above annual 10th percentile						Fraction of total precipitation above annual 10th percentile
91	Fraction of total precipitation above annual 20th percentile	x					Fraction of total precipitation above annual 20th percentile
92	Fraction of total precipitation above annual 30th percentile						Fraction of total precipitation above annual 30th percentile
93	Fraction of total precipitation above annual 40th percentile	x					Fraction of total precipitation above annual 40th percentile
94	Fraction of total precipitation above annual 50th percentile	x					Fraction of total precipitation above annual 50th percentile
95	Fraction of total precipitation above annual 60th percentile	x					Fraction of total precipitation above annual 60th percentile
96	Fraction of total precipitation above annual 70th percentile						Fraction of total precipitation above annual 70th percentile
97	Fraction of total precipitation above annual 80th percentile	x					Fraction of total precipitation above annual 80th percentile
98	**Fraction of total precipitation above annual 90th percentile**	**x**					**Fraction of total precipitation above annual 90th percentile**
99	**Fraction of total precipitation above annual 95th percentile**	**x**					**Fraction of total precipitation above annual 95th percentile**
100	**Fraction of total precipitation above annual 99th percentile**						**Fraction of total precipitation above annual 99th percentile**
101	**Percentage of wet days above 10 mm/d**	**(x)**		**(x)**	**(x)**	**(x)**	**%age of wet days above 10 mm/d (ECA&D: number of days)**
102	**Percentage of wet days above 20 mm/d**				**(x)**	**(x)**	**%age of wet days above 20 mm/d (ECA&D: number of days)**
103	**Max. nb of consecutive dry days**	**x**	**x**	**x**	**x**	**x**	**Max. nb of consecutive dry days**
104	**Max. nb of consecutive wet days**	**x**			**x**	**x**	**Max. nb of consecutive wet days**
105	Mean wet-day persistence	x					Total number of consecutive wet days/Total number of wet days (STARDEX definition)
106	Mean dry-day persistence	x					Total number of consecutive dry days/Total number of dry days
107	**Mean wet spell length (days)**	**x**					**Mean wet spell length (days)**
108	Median wet spell length (days)	x					Median wet spell length (days)
109	Standard deviation of wet spell length (days)	x					Standard deviation of wet spell length (days)
110	**Mean dry spell length (days)**	**x**					**Mean dry spell length (days)**

	Index	A	B	C	D	E	Definition
111	Median dry spell length (days)	x					Median dry spell length (days)
112	Standard deviation of dry spell length (days)	x					Standard deviation of dry spell length (days)
113	**Greatest 1-day total rainfall**					**x**	**Greatest 1-day total rainfall (ECA&D: max. daily precipitation)**
114	Greatest 3-day total rainfall	x					Greatest 3-day total rainfall
115	**Greatest 5-day total rainfall**	**x**	**x**	**x**		**x**	**Greatest 5-day total rainfall**
116	Greatest 10-day total rainfall	x					Greatest 10-day total rainfall
117	Percentage of rainfall from events > base-period 90th percentile	x	x				%age of rainfall from events > base-period 90th percentile (for given time frame)
118	Percentage of rainfall from events > base-period 95th percentile			(x)	(x)		%age of rainfall from events > base-period 95th percentile (for given time frame)
119	Percentage of rainfall from events > base-period 99th percentile						%age of rainfall from events > base-period 99th percentile (for given time frame)
120	Percentage of wet days > base-period 75th percentile					x	(Nb of wet days > base-period 75th percentile)/Nb of wet days [%]
121	**Percentage of wet days > base-period 90th percentile**	**(x)**	**(x)**				**(Nb of wet days > base-period 90th percentile)/Nb of wet days [%]**
122	**Percentage of wet days > base-period 95th percentile**					**x**	**(Nb of wet days > base-period 95th percentile)/Nb of wet days [%]**
123	**Percentage of wet days > base-period 99th percentile**					**x**	**(Nb of wet days > base-period 99th percentile)/Nb of wet days [%]**
124	Percentage of wet days > 20mm						(Nb of wet days > 20mm)/Nb of wet days [%]
125	Percentage of wet days > 10mm						(Nb of wet days > 10mm)/Nb of wet days [%]
126	Percentage of wet days > 5mm						(Nb of wet days > 5mm)/Nb of wet days [%]
127	Interannual variability of mean precipitation						Standard deviation of mean yearly values of precipitation averaged over given time frame (e.g. month)
128	Interannual variability of wet-day precipitation						Standard deviation of mean yearly values of wet-day precipitation averaged over given time frame (e.g. month)
129	Intra-annual variability of mean precipitation						Mean over whole time period (e.g. 10-yr period) of yearly standard deviation of mean precipitation within given time frame
130	Intra-annual variability of wet-day precipitation						Mean over whole time period (e.g. 10-yr period) of yearly standard deviation of wet-day precipitation within given time frame
131	Correlation of (Tmean, Pmean)						Correlation over whole time period (e.g. 10-yr period) between mean temperature and mean precipitation within given time frame

3. Available datasets

3.a. ECA&D dataset

The European Climate Assessment & Dataset (ECA&D) project (http://eca.knmi.nl/) provides datasets of climate extremes and daily data from 42 countries. Altogether, the ECA&D database contains presently 1864 stations, of which 1100 stations with free downloadable series of temperature and precipitation (ECSN 2006). The available stations as of 2002 are presented in Fig 1. The extreme indices provided by ECA&D (see also http://eca.knmi.nl/indicesextremes/indicesdictionary.php for full definition) are indicated in column "E" of Tables 1-3.

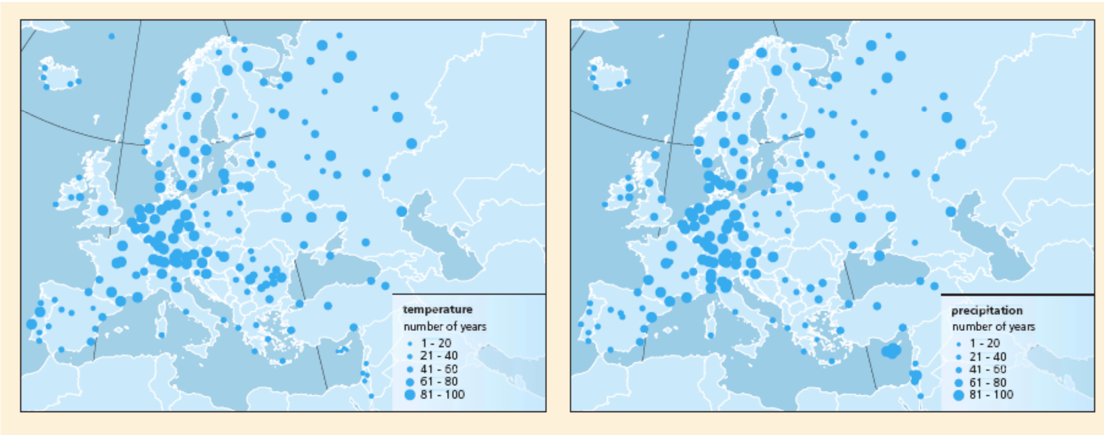


Fig. 1: Stations with daily temperature and daily precipitation timeseries in the ECA dataset (from Klein Tank et al. 2002)

Table 4: Number of ECA&D stations with daily timeseries and extreme indices in Central and Eastern European countries. Focus regions of CECILIA are highlighted in blue

Country	*Number of stations with daily timeseries*	*Number of stations with extreme indices*
Austria	6	16
Belarus	48	50
Bosnia and Herzegovina	2	2
Bulgaria	0	3
Croatia	1	3
Czech Republic	1	11
France	58	70
Germany	50	97
Greece	8	24
Hungary	0	7
Italy	9	30
Poland	2	9
Republic of Macedonia	1	1
Republic of Moldova	17	17
Romania	10	11
Serbia and Montenegro	2	2
Slovakia	2	2
Slovenia	1	1
Switzerland	5	31
Ukraine	190	194

As can be seen from Fig. 1, the density of stations is generally low in Eastern-European countries. Moreover, many stations only provide extreme indices and no daily timeseries (Table 4). Some stations are found in the CECILIA focus regions (highlighted in blue in Table 4), however the total number of stations providing either daily timeseries or extreme indices for these regions is often very low.

ETH will be responsible for computing the common list of extreme indices chosen within WP4 for the available ECA&D daily timeseries. It will apply this analysis to the whole Central and Eastern European region (i.e. including Central-European countries with a good density of stations).

3.b. CHMI

CHMI has access to data from 661 long-term (at least 20 years) measuring stations within the Czech Republic for the time period 1961 to present (out of a total of currently 847 stations). All 661 stations have daily precipitation measurements, and 166 stations also have further meteorological/climatological variables: temperature, relative humidity, sunshine duration, wind speed, in addition to precipitation. Moreover, CHMI also has 15-mn data for a period of up to 5 years. Some of the data are freely available (http://www.chmi.cz/meteo/ok/infklim.html) as monthly output. As part of CECILIA WP4, CHMI will perform an analysis of all the long-term measuring stations and will provide extreme indices of stations with homogeneized and quality-controlled data for selected 75 climatological stations measuring during the whole period 1961-2005 (i.e. with less than 6 missing months during the period).

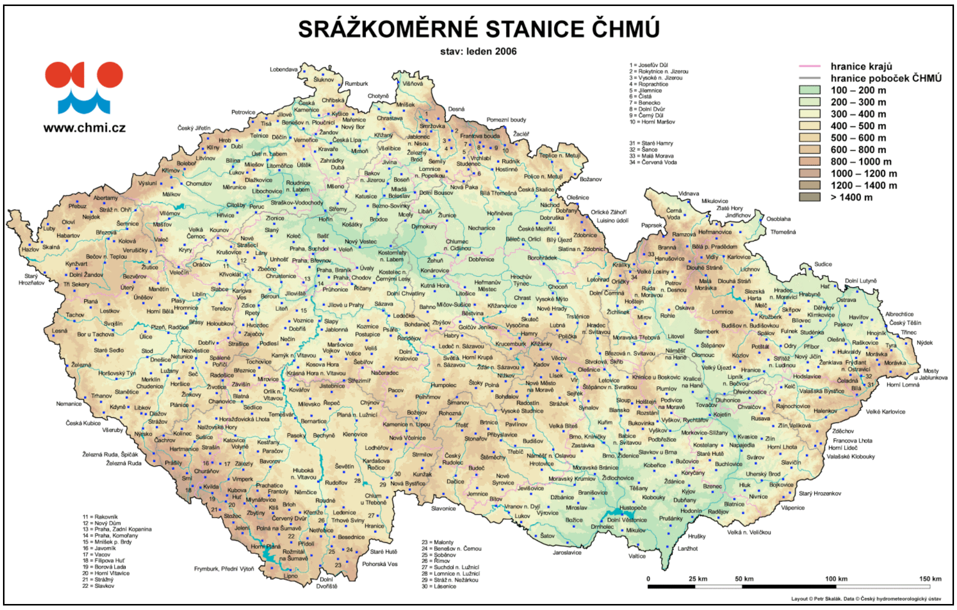


Fig. 2: Precipitation stations (847) from CHMI.

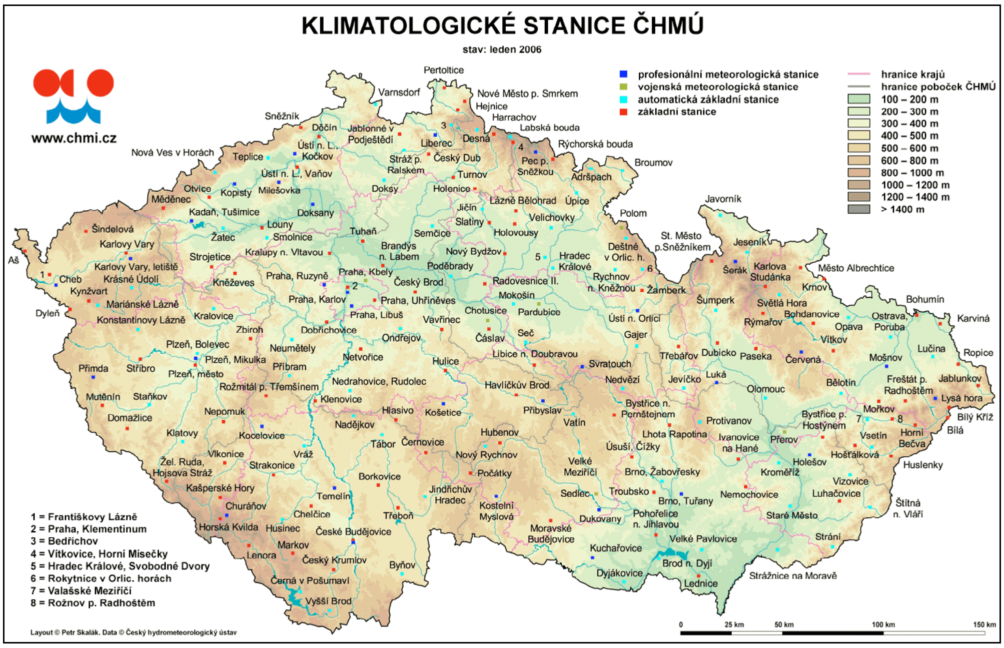


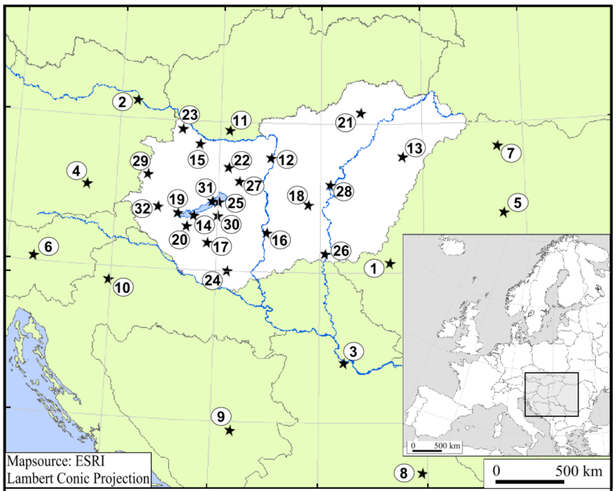
Fig. 3: Climatological stations (166) from CHRMI measuring air temperature (2m, min, max), precipitation + snow cover (liquid, height of new snow, height of snow cover, water equivalent of snow), relative humidity, wind speed and direction, water vapour, cloud cover, sunshine duration, and in some cases the soil temperature (at 5,10,20,50,100 cm depth).

3.c. OMSZ

OMSZ has access to gridded daily data for precipitation, and maximum and minimum temperature over the period 1960-1990. This is a gridded dataset covering Hungary with a resolution of 0.1° x 0.1° (~10 km x 10 km). Extreme indices computed based on this dataset will be provided as part of CECILIA WP4.

3.d. ELU

ELU has annual timeseries of 27 extreme indices computed for Hungary and surrounding regions within the Carpathian basin using in total 32 stations: Data of 11 stations are from the ECA&D dataset (outside Hungary), and the other 21 (within Hungary) from the Hungarian Met. Service. The location of the stations is displayed in Fig. 2. The temperature indices are available for 13 stations for the time period 1961-2001. The precipitation indices are available for 31 stations for the time period 1946-2001 (and in some cases 1901-2001; 13 stations). The following indices of Tables 1-3 are available from this analysis: 46, 47, 51, 52, 58-61, 64-68, 77, 78, 103, 113, 115, 118, 120, 122, 124-126. ELU is planning to compute additionally seasonal and monthly extreme indices, which could be provided as part of CECILIA WP4.



Station	N.lat.	E.long.	m	Station	N.lat.	E.long.	m
Stations in neighbouring countries				16 Kalocsa	46°31'	18°59'	92
1 Arad	46°08'	21°21'	117	17 Kaposvár	46°22'	17°50'	152
2 Vienna	48°14'	16°21'	199	18 Kecskemét	46°54'	19°46'	114
3 Beograd	44°48'	20°28'	132	19 Keszthely	46°45'	17°15'	115
4 Graz	47°05'	15°27'	366	20 Marcali	46°35'	17°25'	128
5 Cluj Napoca	46°47'	23°34'	410	21 Miskolc	48°08'	20°48'	118
6 Ljubljana	46°04'	14°31'	299	22 Mór	47°23'	18°12'	203
7 Baia Mare	47°40'	23°30'	216	23 Mosonmagyaróvár	47°53'	17°16'	121
8 Nis	43°20'	21°54'	202	24 Pécs	46°00'	18°14'	202
9 Sarajevo	52°30'	22°30'	211	25 Siófok	46°55'	18°02'	108
10 Zagreb	45°49'	15°59'	157	26 Szeged	46°15'	20°06'	82
11 Hurbanovo	47°53'	18°12'	115	27 Székesfehérvár	47°12'	18°25'	111
Hungarian stations				28 Szolnok	47°10'	20°12'	90
12 Budapest	47°31'	19°02'	118	29 Szombathely	47°15'	16°38'	218
13 Debrecen	47°33'	21°37'	123	30 Tab	46°44'	18°01'	177
14 Fonyód	46°44'	17°33'	166	31 Tihany	46°55'	17°54'	150
15 Győr	47°41'	17°38'	119	32 Zalaegerszeg	46°50'	16°51'	162

Fig. 4: Geographical locations of meteorological stations used in the ELU extreme climate index analysis for the Carpathian Basin. The following 13 stations are used for the extreme temperature indices: 1, 3, 5, 7, 8, 9, 10, 11, 12, 13, 21, 26, 29. The following 31 stations are used for the extreme precipitation indices: 1-10, 12-32. The 13 stations with precipitation data from 1901-2001 are: 1, 2, 4, 9, 10, 12, 13, 16, 18, 19, 23, 24, 26.

3.d. NMA

NMA partners have access to the national Romanian meteorological/climatological datasets at a daily temporal resolution. The datasets include the following measurements: temperature, precipitation, relative humidity, precipitation, pressure, as well as other climatological variables. In total 162 stations are available, most of them for the time period 1961 to present. Out of these 162 stations, 23 stations could be provided to the whole CECILIA community as raw data following the data policy used with other partners also having access to these data. Extreme indices for all stations passing quality check from the total 162 stations available to NMA could be provided as part of CECILIA WP4.

3.e. NIMH

NIMH has a meteorological database with daily values of precipitation, as well as maximum, minimum, and mean temperature for the time period 1961-2005. The stations are divided in synoptic, climatic and rain-gauge stations (Fig. 5). The datasets from the synoptic weather stations (more than 30 in total) will be used in the CECILIA project. Extreme indices computed for these stations will be provided as part of CECILIA WP4.

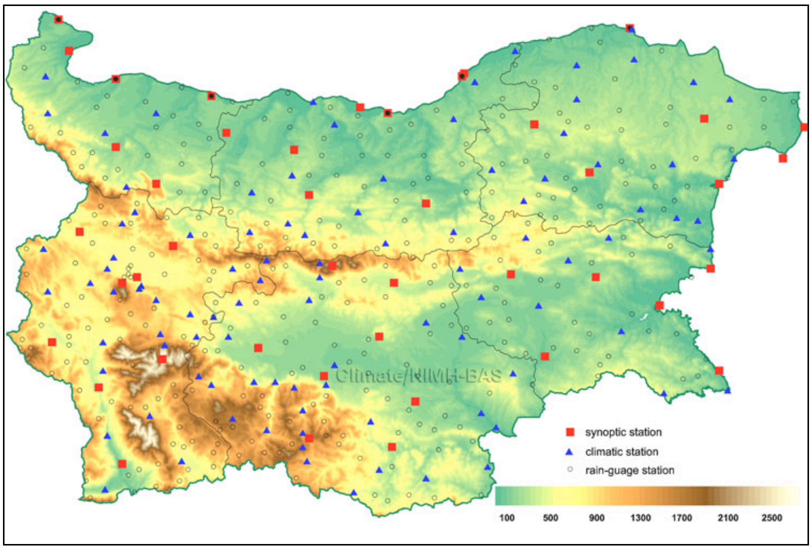


Fig. 5. NIMH weather stations in Bulgaria

4. Detailed implementation plan for deliverables D4.2, D.4.3, D4.4, and D4.5

D4.2 (Month 18)

This deliverable will focus on the analysis of available observational datasets (described under 3.) and a selection of pre-existing RCM/GCM datasets (PRUDENCE, ENSEMBLES). Extreme indices from the local observational datasets will be computed by local partners and provided to the CECILIA partners through WP4. The relevant indices for the simulations (NetCDF format) and observations (ASCII format) will be provided to the project participants as datasets obtainable via the internet. Several analyses will be performed with the data.

The involved partners will contribute to the D4.2 activities in the following way:

DMI (5PMs) will lead this deliverable and be responsible for the reporting of the results achieved. It will set up a central database to archive computed indices based on observational and modeling data. It will also coordinate the definition of the data output format with all involved partners. DMI will be responsible for the computation and analysis of the common WP4 indices for PRUDENCE and ENSEMBLES model data in collaboration with ETH. The computed indices will be provided to all CECILIA WP4 partners.

CHMI (4PMs) will produce a software to compute the list of indices chosen within WP4. This software will be shared among CECILIA WP4 partners to ensure that all indices are computed in a consistent way. Moreover, CHMI will be responsible for the computation of extreme indices for the CHMI dataset.

ETH (5PMs) will compute the relevant WP4 extreme indices for the daily timeseries from the ECA&D dataset available in Central and Eastern Europe. It will assist CHMI in testing the software provided to WP4 partners for the computation of extreme indices. Moreover, it will be responsible for the computation and analysis of the common WP4 indices for PRUDENCE and ENSEMBLES model data in collaboration with DMI. Based on the available data, ETH will perform process-based analyses investigating the physical processes responsible for the occurrence of extreme events in present and future climate in Central and Eastern Europe, with a special focus on land-atmosphere coupling.

NMA (4PMs) will calculate the common WP4 extreme indices for the daily station data in Romania. Moreover, it will conduct analyses in order to investigate the link between regional-scale (Romania) extreme events (heavy precipitation, heat waves, etc) and the large-scale circulation patterns using observational and pre-existing model data.

ELU (4PMs) will perform an analysis of extremes from observational datasets and PRUDENCE output for the Carpathian Basin. Monthly, seasonal and annual scale analysis and comparison are planned. Moreover it will provide its station-based extreme indices to other WP4 partners.

CUNI (2PMs) will perform an analysis of extremes from observational datasets and comparisons with pre-existing model output. It will focus on return frequencies of extreme precipitation, changes in the distribution of extreme temperature, and heat and cold waves analyses.

IAP (1PM) will shift an additional 1 PM from D4.3 to D4.2. It will perform the following activities as part of D4.2:

- Development of extreme value models in observed datasets (Czech Republic).
- Comparison of the ‘peaks-over-threshold’ (POT) and ‘block maxima’ analysis of extreme high daily temperatures/heavy precipitation amounts; evaluation of various setting of the POT analysis
- Application of the extreme-value models to pre-existing RCM output, evaluation of the ability of the RCMs to reproduce observed distributions (e.g. the shape parameters) and their quantiles (return values). Uncertainty (confidence intervals) will be estimated using a parametric bootstrap.

AUTH (2PMs) plans to investigate NAO and blocking frequency from the observations and the numerical experiments under consideration, with an emphasis on the link with precipitation and temperature extremes in Central and Eastern Europe.

OMSZ (0PM) will shift 3PMs from D4.4 to D4.2. As part of D4.2 OMSZ will compute the common indices chosen within WP4 for the OMSZ gridded dataset.

NIMH (1PM) will compute the common WP4 extreme indices based on daily data in Bulgaria. A trend analysis will be applied. Relationships between NAO and extreme events in Bulgaria will be investigated.

D4.3 (Month 24)

This deliverable will focus on the analysis of the CECILIA driving-model simulations and will be performed in coordination with D4.2. This will allow the assessment of the quality of the CECILIA driving-model simulations with regard to features relevant for extreme events in comparison with pre-existing RCM data (PRUDENCE, ENSEMBLES).

The involved partners will contribute to the D4.3 activities in the following way:

ETH (6PMs) will lead this deliverable and be responsible for the reporting of the results achieved. It will perform a detailed comparison of the representation of processes responsible for the occurrence of extremes between the CECILIA driving-model simulations and previous RCM data (PRUDENCE, ENSEMBLES), in coordination with DMI. This analysis will be performed in parallel with the ETH D4.2 model analyses and will be used for an assessment of the quality of the CECILIA driving-model simulations in comparison with pre-existing model data.

DMI (4PMs) will perform a detailed comparison of the representation of processes responsible for the occurrence of extremes between the CECILIA driving-model simulations and previous RCM data (PRUDENCE, ENSEMBLES), in coordination with ETH. This analysis will be performed in parallel with the DMI D4.2 model analyses and will be used for an assessment of the quality of the CECILIA driving-model simulations in comparison with pre-existing model data.

IAP (1PM): 1PM will be shifted to D4.2. Consequently, IAP has no activities as part of D4.3.

NMA (2PMs) will perform a similar analysis as for the pre-existing model data under D4.2 but for the CECILIA driving-model simulations (link between regional-scale extreme events in Romania and large-scale circulation pattern). This will be used for an assessment of the quality of the CECILIA driving-model simulations in comparison with pre-existing model data.

AUTH (2PMs) will perform a similar analysis as for the pre-existing model data under D4.2 but for the CECILIA driving-model simulations (links between NAO and blocking frequency and the occurrence of extremes in the region). This will be used for an assessment of the quality of the CECILIA driving-model simulations in comparison with pre-existing model data.

D4.4 (Month 34)

This deliverable will focus on the analysis of extremes in the CECILIA high-resolution simulations. The observational data analysis performed under D4.2 will be used for the validation of the experiments. The comparison with coarser-scale model data (pre-existing data from PRUDENCE and ENSEMBLES, and the CECILIA driving-model simulations) will allow to assess the impact of model resolution for the simulation of extremes.

The involved partners will contribute to the D4.4. activities in the following way:

NMA (7PMs) will lead this deliverable and be responsible for the reporting of the results achieved. Moreover, NMA will perform similar model analyses as in D4.2 and D4.3, but for the high-resolution control and scenario runs. The following aspects will be investigated (for **Romania**):

- Future changes in extreme events
- Emphasis on resolution impact on extreme events
- Investigation of added value of high resolution

OMSZ (6PMs; 3PMs will be moved to D4.2) will apply an analysis of extremes (linear trend estimation, significance tests) to the four 30-year-long high-resolution climate simulations carried out by OMSZ for the **Carpathian basin**. The analysis of extremes for the simulations of the 1960-1990 period will be compared to a similar analysis based on a local gridded observational dataset (see also OMSZ activities under D4.2). Work for the Carpathian basin will be coordinated between ELU and OMSZ.

ELU (4PMs) will conduct analyses of extremes on the CECILIA high-resolution simulations for the **Carpathian basin**. Since ELU is planning to run the RegCM model with 10 km resolution, the outputs for the 3 time slices (1961-90, 2021-50, 2071-2100) will be analysed using the extreme climate indices. Work for the Carpathian basin will be coordinated between ELU and OMSZ.

CHMI (5PMs) will apply an analysis of extremes to the high-resolution climate simulations carried out by CHMI. It will also evaluate the CECILIA experiments with respect to observational data of the **Czech Republic** and compare the added value with respect to ENSEMBLES experiments, both for the temperature and precipitation extremes (indices and data sets defined in D4.1). Work for the Czech Republic will be coordinated between CHMI, CUNI, and IAP.

CUNI (5PMs) will perform an analysis of extremes for the high-resolution climate simulations carried out by CUNI. It will analyze return frequencies of extreme precipitation, changes in the distribution of extreme temperature, and modifications in the occurrence of heat and cold waves, with a focus on the **Czech Republic**. Work for the Czech Republic will be coordinated between CHMI, CUNI, and IAP

IAP (2PMs) will apply extreme-value models to the CECILIA high-resolution simulations. It will evaluate the impact of model resolution on the simulated changes in temperature/precipitation extremes (return values). Scenarios of changes in parameters of extreme value distributions and return values will be investigated. The analysis will focus on the added value of the 10 km simulations in specific regions of the **Czech Republic**. Work for the Czech Republic will be coordinated between CHMI, CUNI, and IAP.

NIMH (5PMs) will provide an analysis of the high-resolution 10-km CECILIA simulations over **Bulgaria**, with a special focus on extremes. The following aspects will be considered for the country: analysis of expected changes in extreme events, relative to the current climate; analysis on model resolution impact on extreme events

ETH (7PMs) and DMI (4PMs) will provide a synthesis of the results for the **whole Central and Eastern European region** and an intercomparison of the high-resolution simulations with pre-existing RCM (PRUDENCE, ENSEMBLES) simulations and other datasets analyzed in D4.2. The impact of high resolution for the simulation of extremes will be investigated.

D4.5 (Month 34)

In this deliverable, sensitivity experiments will be conducted and analyzed in order to investigate specific feedback processes (land-atmosphere coupling) and other physical interactions relevant for the simulation of extremes.

ICTP (4PMs) will lead this deliverable and be responsible for the reporting of the results achieved. It will conduct 25km-simulations with the RegCM model investigating the role of land-atmosphere coupling for present and future climate in Central and Eastern Europe, in coordination with ETH, CUNI, and NMA.

ETH (4PMs) will conduct the analysis of the sensitivity experiments investigating the role of land-atmosphere coupling for present and future climate in Central and Eastern Europe, in collaboration with ICTP, CUNI, and NMA. It will perform shorter test experiments investigating aspects of land surface processes and land cover changes relevant for extremes.

CUNI (3PMs) will perform 10km sensitivity experiments investigating the role of land-atmosphere coupling for present and future climate in Central and Eastern Europe, in coordination with ETH, ICTP, and NMA.

NMA (1PM) will perform 10km sensitivity experiments investigating the role of land-atmosphere coupling for present and future climate in Central and Eastern Europe, in coordination with ETH, ICTP, and CUNI. It will also investigate the role of Mediterranean and Black Sea cyclogenesis for extreme events in the region.

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