Computation of PET on daily scale to estimate the surface energy budget components in the region of the PannEx RHP

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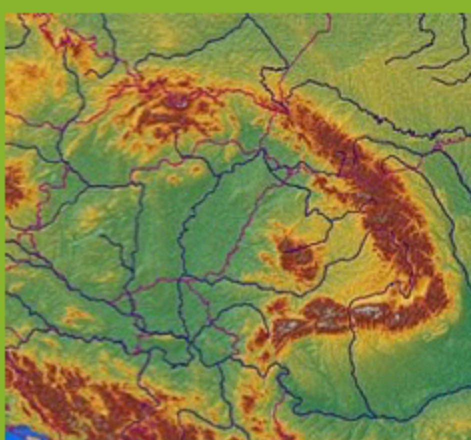
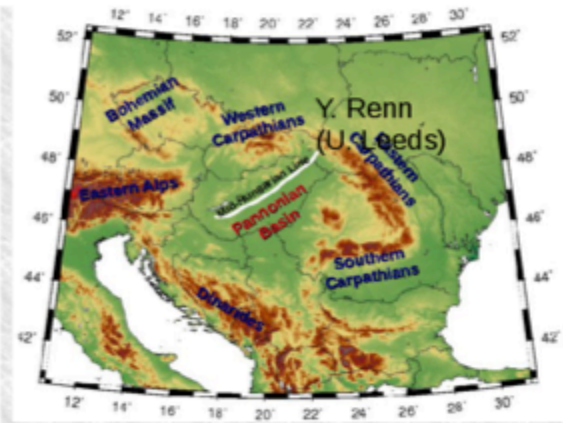
Outline

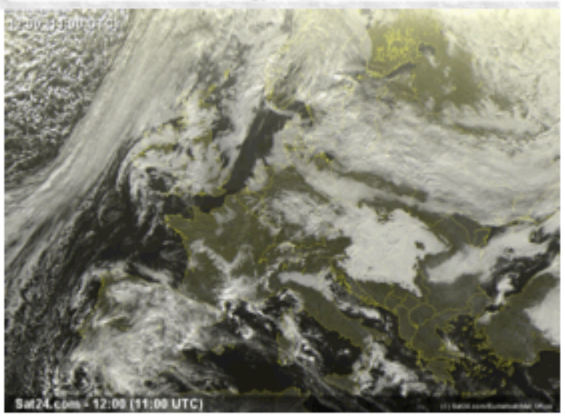
- PannEx: Pannonian Basin Experiment - Initiating RHP status
- FQs and Cross Cuts within PannEx
- CarpatClim Gridded dataset: freely avalable gridded in-situ surface observations for the region
- Daily PET estimation for the CarpatClim grid
- Case study: Modelling evapotranspiration (WRF) and comparison with PET values for a five day long period

Pannonian (Carpathian) basin



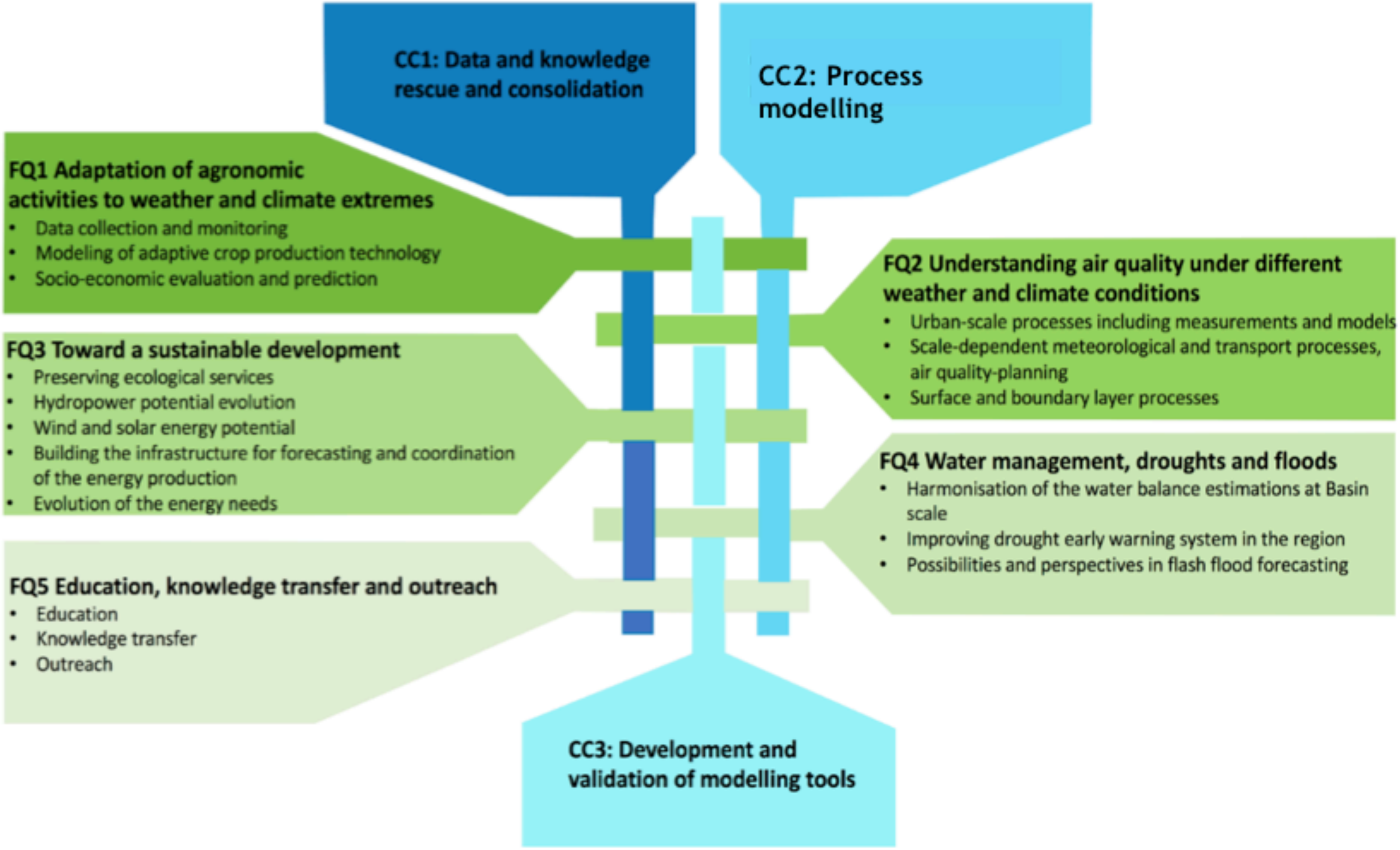
PannEx: Pannonian Basin Experiment - Initiating RHP status





- A closed basin with only one main outflow, the Iron Gates
- A large low central plain (100 m asl) surrounded by mountains with elevations nearing 2000 m asl
- A very good test area for many geophysical processes (natural or human-induced)
- The Pannonian basin is a transition area between mediterranean, atlantic and continental climates
- The area is fragmented between many different countries
- Research institutions and universities, performing networking activities
- Good potential for international funding.
- Between the HyMeX and Baltic Earth
- It is one of the selected Food Baskets by GEWEX

FQs and Cross Cuts within PannEx



An innovative idea: the Task Teams

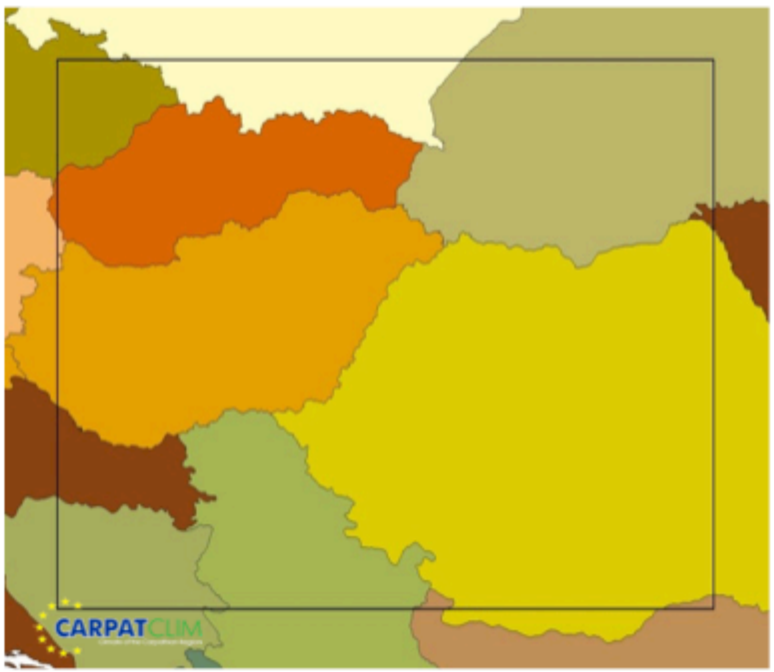
They are intended to be the basic units of organization within PannEx, they are currently being setup

1. Agroclimatological and Biological Systems
2. Micrometeorology and Agronomical Process Modelling
3. Urban Studies
4. Energy Production
5. Ecological Services
6. Water Balance at the Basin Scale
7. Modelling from Climate to Flash Floods
8. Outreach and Education
9. Special Observations and Data Analysis

Estimation of PET using the available in-situ observations in the region of the PannEx RHP

CarpatClim: the publically available in-situ surface observations for the region

CARPATCLIM GRIDDED DATASET



DAILY, 10X10 KM RESOLUTION, PERIOD: 1961-2010

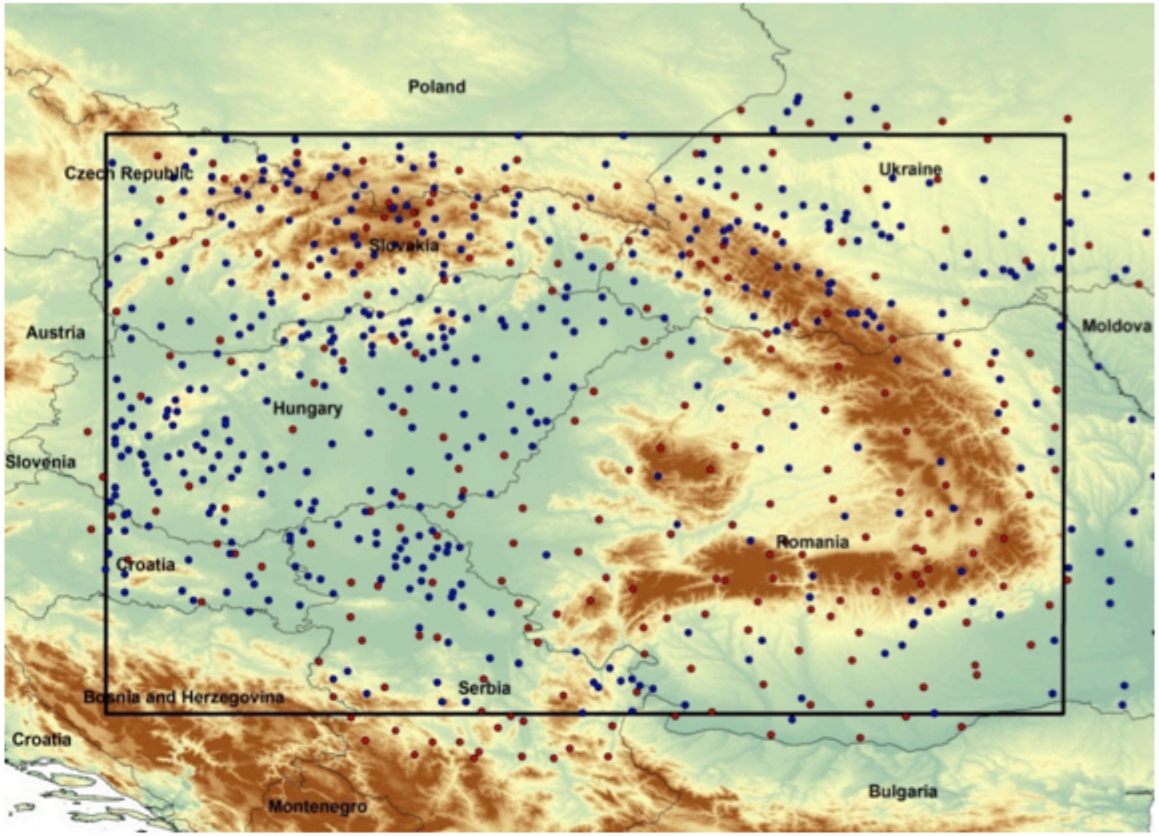
- CarpatClim project: 9 countries, leader Hungarian Meteorological Service
- Partly covers: Czech Republic, Slovakia, Poland, Ukraine, Hungary, Romaina, Serbia, Croatia
- ~500 000 sqkm
- Commonly used methods for homogenization and interpolation: MASH-MISH (developed at OMSZ)
- 13 basic meteorological variables and
- 37 climate indicators were gridded
- publically available

http://www.carpatclim-eu.org

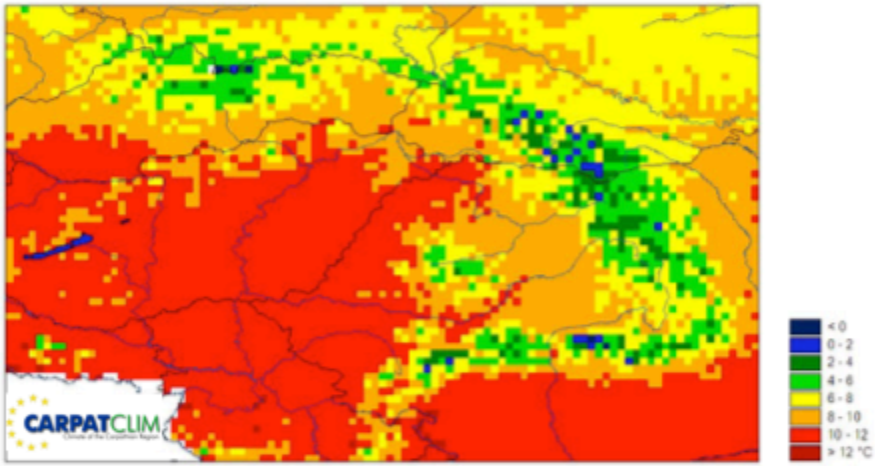
Data sources of CarpatClim

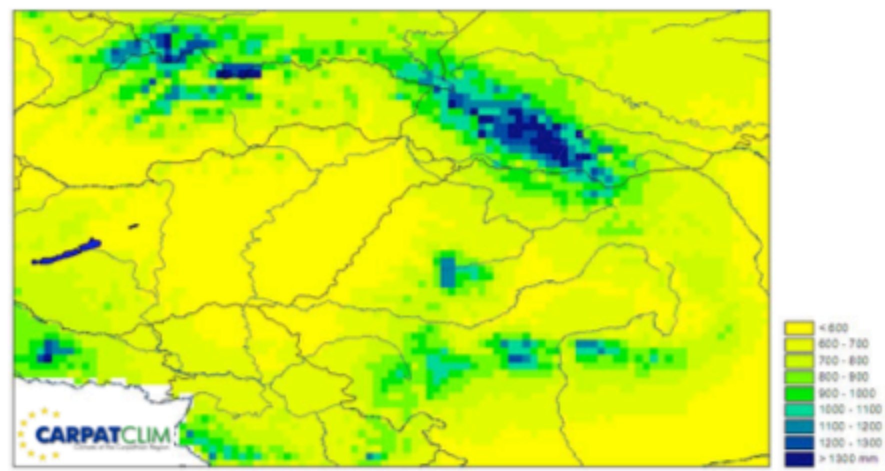
NMHSs in the region

415 climate stations and 904 precipitation stations were used



Annual mean T and prec, 1961-2010





Available parameters and indicators

Table 1. List of parameters/indicators

No.	Indicator	Description	Units	Frequency
1.	TA_M	Average mean air temperature	°C	Monthly
2.	TA_Y	Average mean air temperature	°C	Yearly
3.	TMIN_M	Average minimum air temperature	°C	Monthly
4.	TMIN_Y	Average minimum air temperature	°C	Yearly
5.	TMAX_M	Average maximum air temperature	°C	Monthly
6.	TMAX_Y	Average maximum air temperature	°C	Yearly
7.	PREC_M	Accumulated total precipitation	mm	Monthly
8.	PREC_Y	Accumulated total precipitation	mm	Yearly
9.	WS10_M	Average 10m horizontal wind speed	m/s	Monthly
10.	WS2_M	Average 2m horizontal wind speed	m/s	Monthly
11.	SUN_M	Sunshine duration	hours	Monthly
12.	SUN_Y	Sunshine duration	hours	Yearly
13.	CC_M	Average cloud cover	tenths	Monthly
14.	RG_M	Global radiation	J/cm^2	Monthly
15.	RH_M	Average relative humidity	%	Monthly
16.	PV_M	Mean vapour pressure	hPa	Monthly
17.	PA_M	Mean surface air pressure	hPa	Monthly
18.	SNOW_M	Snow depth	cm	Monthly
19.	SWE_M	Snow water equivalent	mm	Monthly
20.	FD_M	Number of frost days (Tmin < 0°C)	days	Monthly
21.	PFD_M	Percentage of frost days (Tmin < 0°C)	%	Monthly
22.	FD_Y	Number of frost days (Tmin < 0°C)	days	Yearly
23.	PFD_Y	Percentage of frost days (Tmin < 0°C)	%	Yearly
24.	SD_M	Number of summer days (Tmax > 25°C)	days	Monthly
25.	PSD_M	Percentage of summer days (Tmax > 25°C)	%	Monthly
26.	SD_Y	Number of summer days (Tmax > 25°C)	days	Yearly
27.	PSD_Y	Percentage of summer days (Tmax > 25°C)	%	Yearly
28.	HD_M	Number of hot days (Tmax > 30°C)	days	Monthly
29.	PHD_M	Percentage of hot days (Tmax > 30°C)	%	Monthly
30.	HD_Y	Number of hot days (Tmax > 30°C)	days	Yearly
31.	PHD_Y	Percentage of hot days (Tmax > 30°C)	%	Yearly
32.	PAI	Palfai Drought Index	-	Yearly
33.	SPI-3	Standardized Precipitation Index – 3-months	-	Monthly
34.	SPI-6	Standardized Precipitation Index – 6-months	-	Monthly
35.	SPI-12	Standardized Precipitation Index – 12-months	-	Monthly
36.	SPEI-3	Stand. Prec. Evapotranspiration Index – 3-months	-	Monthly
37.	SPEI-6	Stand. Prec. Evapotranspiration Index – 6-months	-	Monthly
38.	SPEI-12	Stand. Prec. Evapotranspiration Index – 12-months	-	Monthly
39.	RDI-3	Reconnaissance Drought Index (3-months)	-	Monthly
40.	RDI-6	Reconnaissance Drought Index (6-months)	-	Monthly
41.	RDI-12	Reconnaissance Drought Index (12-months)	-	Monthly
42.	PDSI	Palmer Drought Severity Index	-	Monthly
43.	ID_M	Number of ice days (Tmax < 0°C)	days	Monthly
44.	PID_M	Percentage of ice days (Tmax < 0°C)	%	Monthly
45.	ID_Y	Number of ice days (Tmax < 0°C)	days	Yearly
46.	PID_Y	Percentage of ice days (Tmax < 0°C)	%	Yearly
47.	EHD_M	Number of extremely hot days (Tmax ≥ 35°C)	days	Monthly
48.	PEHD_M	Percentage of extremely hot days (Tmax ≥ 35°C)	%	Monthly
49.	EHD_Y	Number of extremely hot days (Tmax ≥ 35°C)	days	Yearly
50.	PEHD_Y	Percentage of extremely hot days (Tmax ≥ 35°C)	%	Yearly
51.	ECD_M	Number of severe cold days (Tmin < -10°C)	days	Monthly
52.	PECD_M	Percentage of severe cold days (Tmin < -10°C)	%	Monthly
53.	ECD_Y	Number of severe cold days (Tmin < -10°C)	days	Yearly
54.	PECD_Y	Percentage of severe cold days (Tmin < -10°C)	%	Yearly
55.	GSL_Y	Growing season length	days	Yearly
56.	WD_M	Number of wet days (RR ≥ 1 mm/day)	days	Monthly
57.	PWD_M	Percentage of wet days (RR ≥ 1 mm/day)	%	Monthly
58.	WD_Y	Number of wet days (RR ≥ 1 mm/day)	days	Yearly
59.	PWD_Y	Percentage of wet days (RR ≥ 1 mm/day)	%	Yearly
60.	EWD_M	Number of wet days with (RR > 20 mm/day)	days	Monthly
61.	PEWD_M	Percentage of wet days with (RR > 20 mm/day)	%	Monthly
62.	EWD_Y	Number of wet days with (RR > 20 mm/day)	days	Yearly
63.	PEWD_Y	Percentage of wet days with (RR > 20 mm/day)	%	Yearly
64.	M1DTOT_M	Maximum 1-day total rainfall	mm	Monthly
65.	M1DTOT_Y	Maximum 1-day total rainfall	mm	Yearly
66.	M5DTOT_M	Maximum 5-day total rainfall	mm	Monthly
67.	M5DTOT_Y	Maximum 5-day total rainfall	mm	Yearly
68.	ARI	Aridity index	-	Monthly
69.	MI	Moisture index	-	Monthly
70.	EI	Ellenberg index	C/mm	Yearly
71.	CDD6	Cooling degree days (summer)	°C	Yearly
72.	HDD6	Heating degree days (winter)	°C	Yearly
73.	GDD8	Growing degree days (extended summer)	°C	Yearly
74.	PET	Potential evapotranspiration	-	Monthly

in this work we prepared daily PET for the region by applying Penman-Monteith method

Monthly PET in CarpatClim

3.36 Potential evapotranspiration

Inputs: Mean temperature (T_M, in °C, for all 12 months), Latitude (ϕ in radians)

PET [mm] $$\mathrm{PET}^* = \begin{cases} 0 & T_M < 0°C \\ 16\left(10\frac{T_M}{I}\right)^a & 0°C \le T_M < 26.5°C \\ -416.85 + 32.24(T_M) - 0.43(T_M)^2 & T_M \ge 26.5°C \end{cases}$$

Exponential a coefficient $$a = 6.75(10^{-7})I^3 - 7.71(10^{-5})I^2 + 0.49239$$

Annual Heat Index [°C] $$I = \sum_{j=1}^{12} i_j$$

Monthly Heat Index [°C] $$i_j = \left(\frac{T_{M_j}}{5}\right)^{1.514}$$

Adjusted PET [mm] $$\mathrm{PET} = \left(\frac{\vartheta h}{360}\right)\mathrm{PET}^*$$ ϑ = days (in that month)

Daylight [hours] $$h = \frac{2\omega_{ss}}{15}$$

Sunset hour angle [degrees] $$\omega_{ss} = arccos\big(-tan(\phi)tan(\delta)\big)$$

Solar Declination [radians] $$\delta = \left(\frac{\pi}{180}\right)(23.45)sin\left(\frac{2\pi(284+d_n)}{365}\right)$$

Julian day (15th) $$d_n = 1(01\ Jan), \ldots, 365(31\ Dec)$$ (Use the 15th of each month)

Outputs: monthly PET (Carpathians 1961–2010)

Daily PET: Penman-Monteith Reference Evapotranspiration method

17 steps for calculations from standard meteorological data (CarpatClim grid)

Day of the year, latitude, longitude, T_{min}, T_{max},

wind speed,

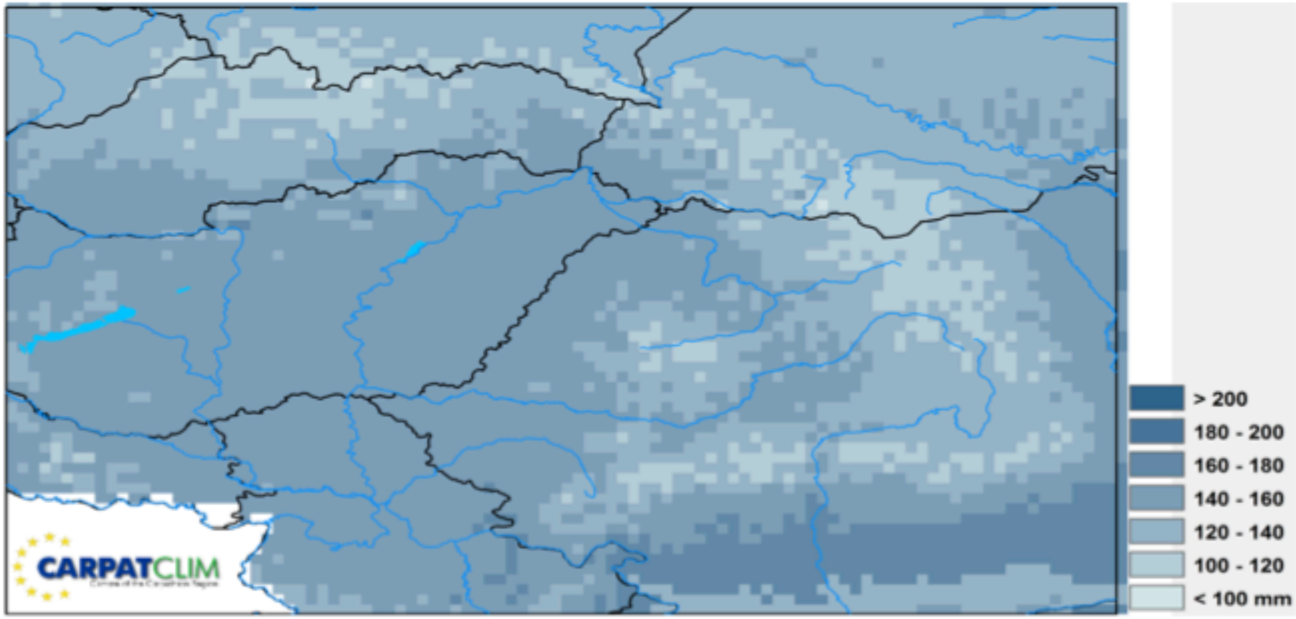
relative humidity

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

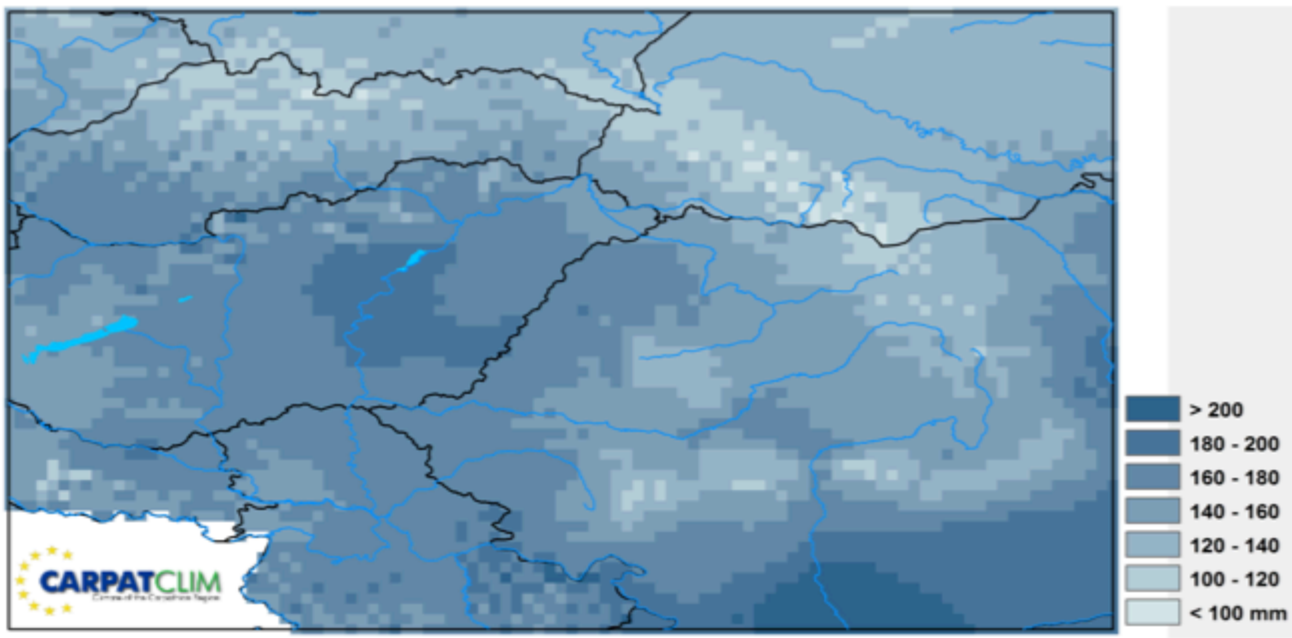
ET_o = reference evapotranspiration, mm day^{-1};
R_n = net radiation at the crop surface, MJ m^{-2} d^{-1};
G = soil heat flux density, MJ m^{-2} d^{-1};
T = mean daily air temperature at 2 m height, °C;
u_2 = wind speed at 2 m height, m s^{-1};
$e_s - e_a$ = saturation vapor pressure deficit, kPa;
Δ = slope of the vapor pressure curve, kPa °C^{-1};
γ = psychrometric constant, kPa °C^{-1}.

Reference:
Zotarelli, L., Dukes, M. D., Romero, C. C., Migliaccio, K. W., , and Morgan, K. T., 2010: Step by Step Calculation of the Penman-Monteith Evapotranspiration (FAO-56 Method), IFAS Extension, University of Florida, http://edis.ifas.ufl.edu

July 2007 Monthly PET



CarpatClim monthly PET



derived from daily (Penman-Monteith) PET values

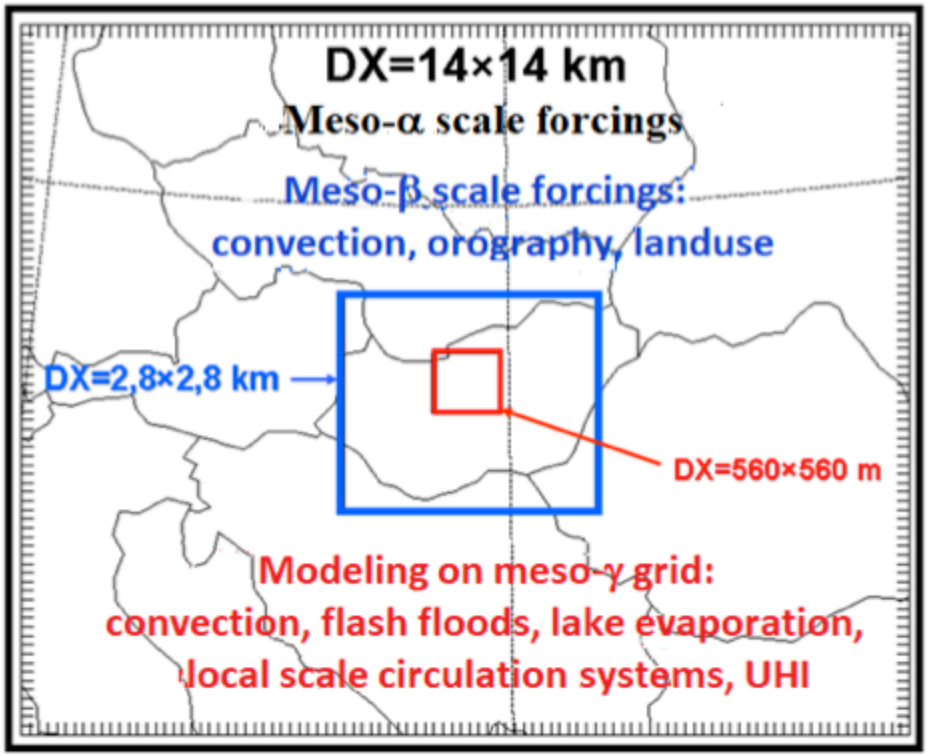
Modelling evapotranspiration and comparison with PET values

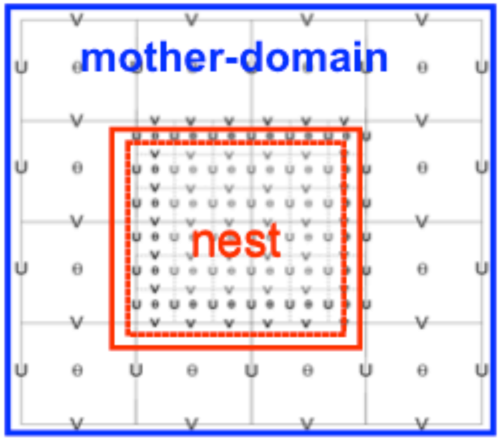
CASE STUDY FOR 18.07.2007-22.07.2007
VERY HOT PERIOD IN THE CARPATHIAN
(PANNONIAN BASIN)

EVAPOTRANSPIRATION – WRF model implementation

Initial and boundary conditions

48 hours forecasts, ECMWF model results in every 3 hours with 0.25° x 0.25° space resolution





Boundary conditions:
relaxation schemes are applied

References:
Horváth, Á., Nagy, A., Simon, A., Németh, P., 2015: MEANDER: The objective nowcasting system of the Hungarian Meteorological Service. IDŐJÁRÁS Quarterly Journal of the Hungarian Meteorological Service, 119(2), 197-213.
The Weather Research and Forecasting (WRF) Model, https://www.mmm.ucar.edu/weather-research-and-forecasting-model

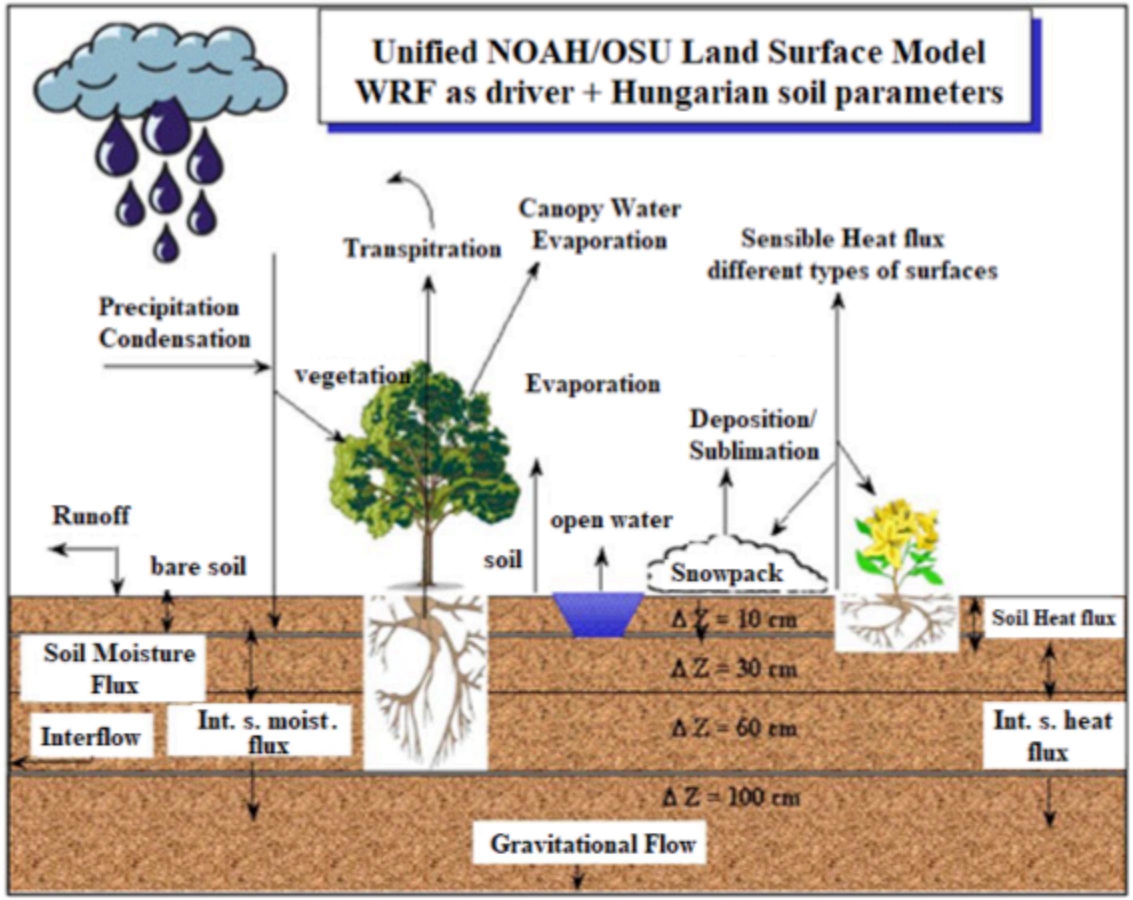
WRF-NOAH coupled model system

Effect of soil moisture is critical on the model output

Next slide - sensitivity study

Important to estimate the component of the surface energy budget components in the region PannEx region

Surface evaporation and energy budget components from WRF-NOAH coupled model system



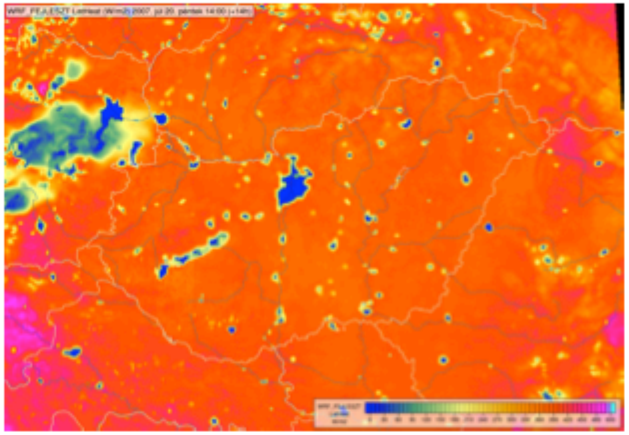
References:

Ács, F., Gyöngyösi, A. Z., Breuer, H., Horváth, Á., Mona, T., Rajkai, K.., 2014 Sensitivity of WRF-simulated planetary boundary layer height to land cover and soil changes. Meteorologische Zeitschrift ,Vol. 23, No. 3, 279-293

WRF Noah Noah-MP Modeling System https://ral.ucar.edu/solutions/products/wrf-noah-noah-mp-modeling-system

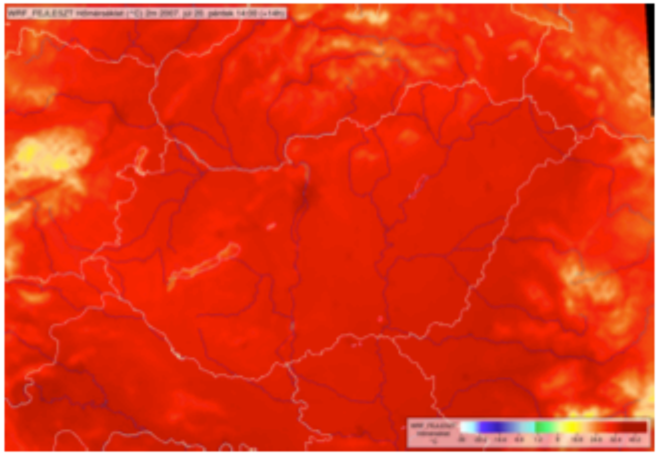
Case study/WRF run for 18.07.2007-22.07.2007 very hot period

Nature Park Kopački rit, 177 km^2 in Eastern Croatia, moorland



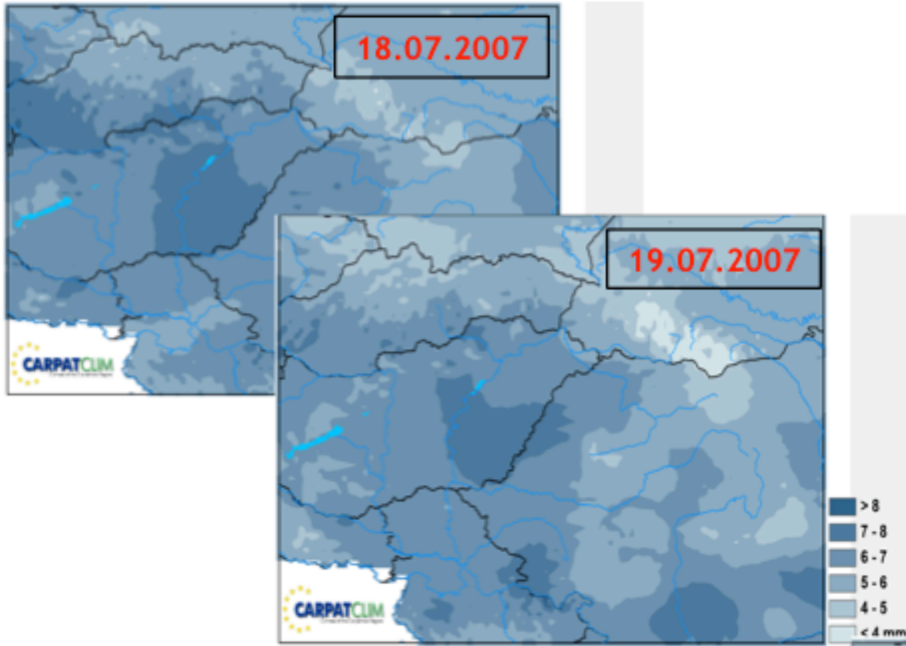
LE

20 July
14 UTC

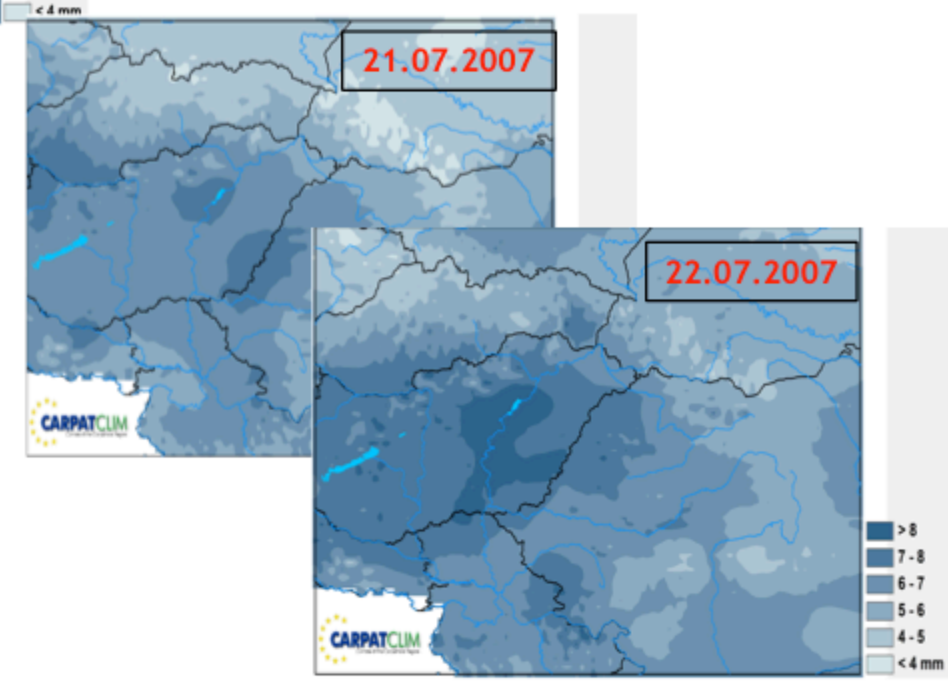


T(2m)

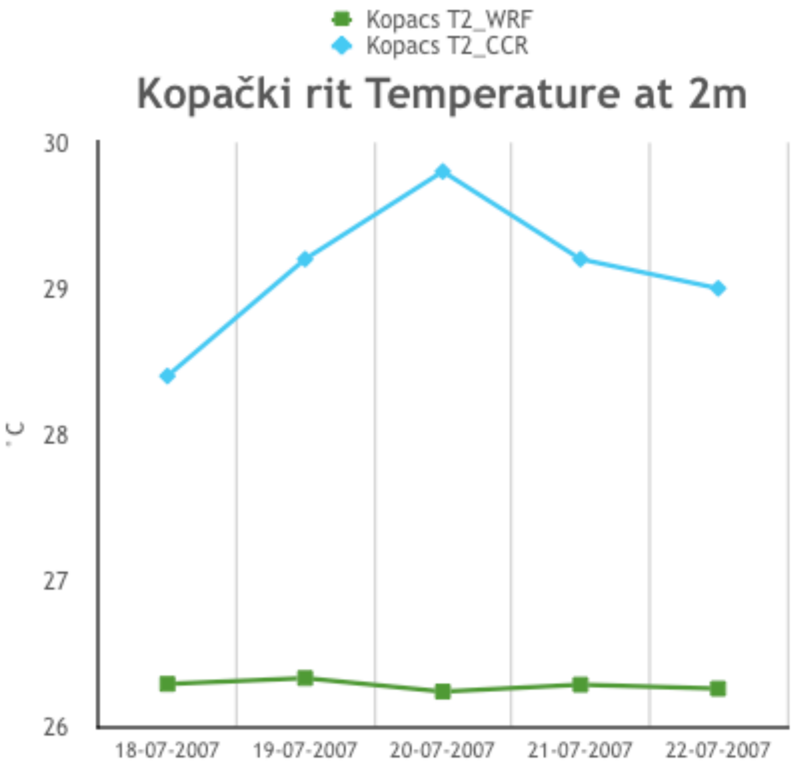
Daily PET in the PannEx region

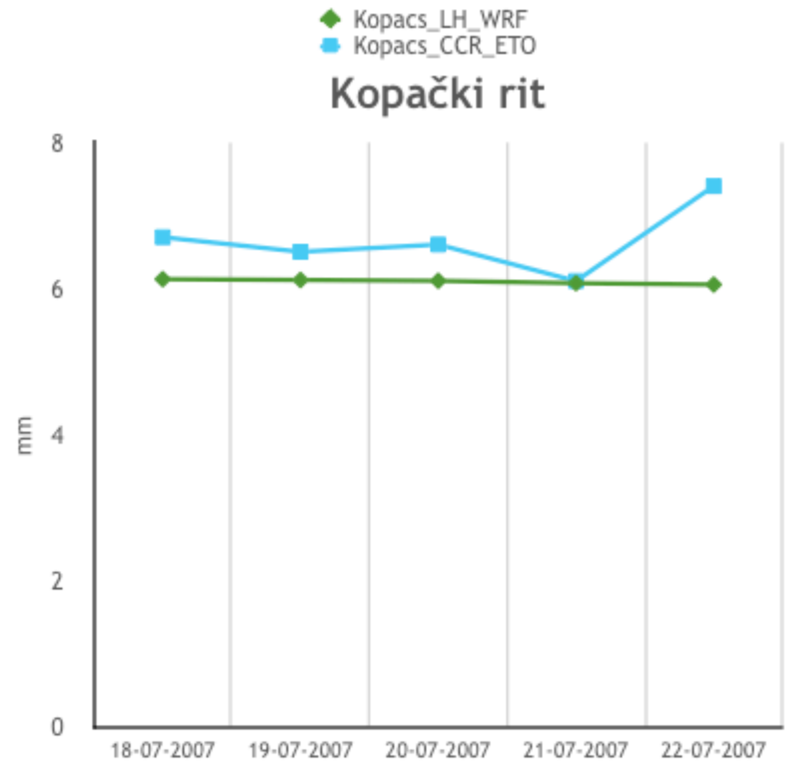


20.07.2007



Comparison of the regional average of the modelled (WRF) and measured (CCR: CarpatClim) values for the Kopački rit





Conclusion and future plans

- The CarpatClim dataset is an appropriate dataset for studying the radiation and energy budget components in daily scale in the PannEx region
- In this study the CarpatClim is extended with daily PET values for other applications
- Analysis of climatology of surface energy budget components based on the WRF-NOAH coupled model system
- Further extension of the CarpatClim dataset with land-use, albedo and soil moisture data to support the PannEx activities
- Estimation of daily PET with using actual land-cover CarpatClim database