POSSIBLE DROUGHT DEVELOPMENT IN CENTRAL EUROPE

CLIMATE CHANGE - CHANGES IN EVAPOTRANSPIRATION AND INTENSE RAINS

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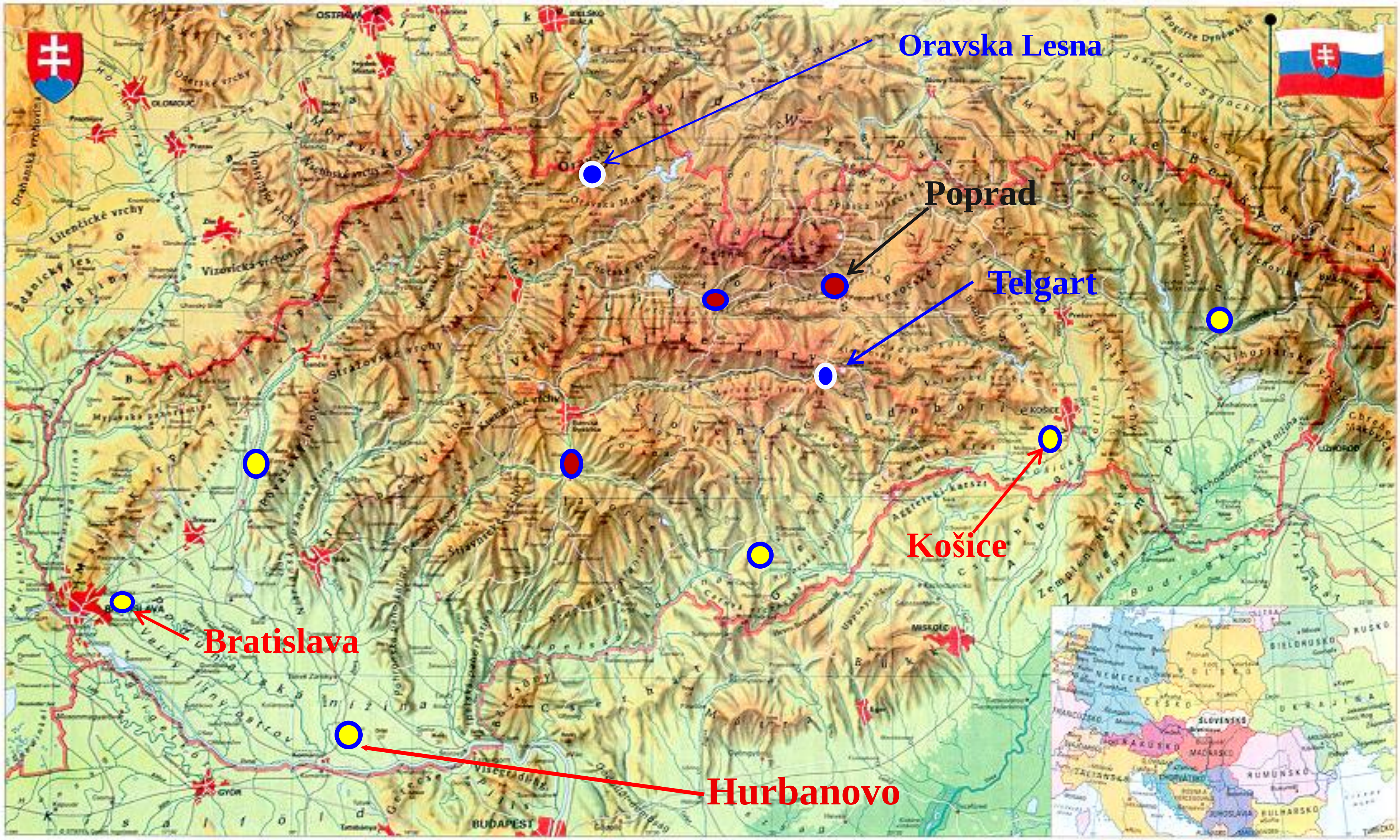
ABSTRACT 1

- **Potential (E_o) and actual (E) evapotranspiration are impossible to be measured correctly, we can calculate it with some accuracy and use it at soil moisture and hydrological balance evaluation and forecast**
- **Division of droughts: physiologic (plants), hydrologic (runoff, soil, ground water), meteorologic and climatologic (evapotranspiration - precipitation), socio-economic (damages, losses)**
- **At any humidity/moisture analysis it is needed the evaluation of precipitation regime in relation with evapotranspiration needs**
- At present we will apply only climatologic analysis - calculation of water balance using relations of E_o, E and precipitation totals (R) for standard surface (short natural and horizontal lawn)
- E_o is sum of maximum possible evaporation + plants transpiration at given unchanged meteorological conditions in case of unlimited water supply
- Because of drought development analysis, we will evaluate first the past situation in 1951-2018 based on evapotranspiration calculation using Budyko-Tomlain Complex Method, further development will be assessed by scenarios of saturation deficit and E_o up to 2100 – Zubenok Method

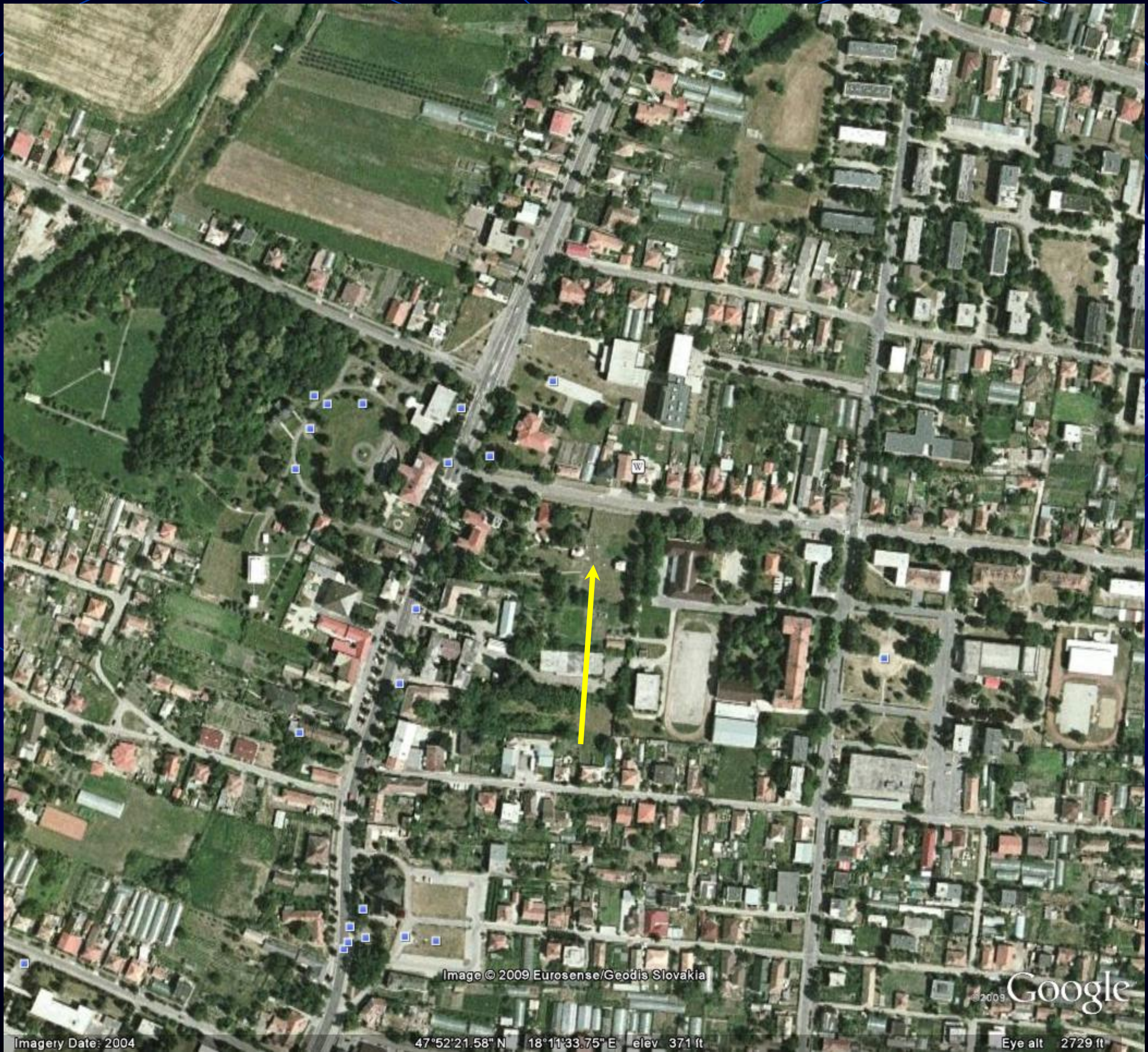
MAP OF EUROPE – CETRAL EUROPE (BLUE)?

SLOVAK REPUBLIC – 49 036 sq. km, 440 m mean elevation, 5.4 mil. inhabitants, 747 mm mean precipitation, 7.5 °C mean temp.

50% agricultural land, 41% forest land, 2% water area, 3% built-up areas, 5.4% above 1000 m
About 100 climatic stations and about 700 precipitation gauges are in operation since 1951



Meteo-Station Hurbanovo, 115 m a.s.l., since 1871



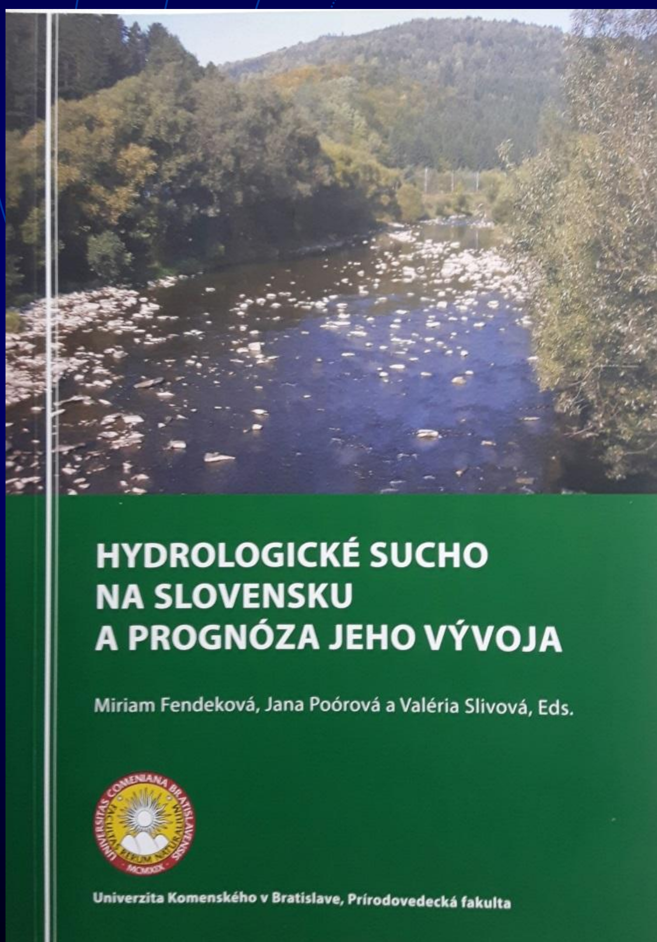
2017: Hydrological Drought in Slovakia and its Forecast, 300 pp

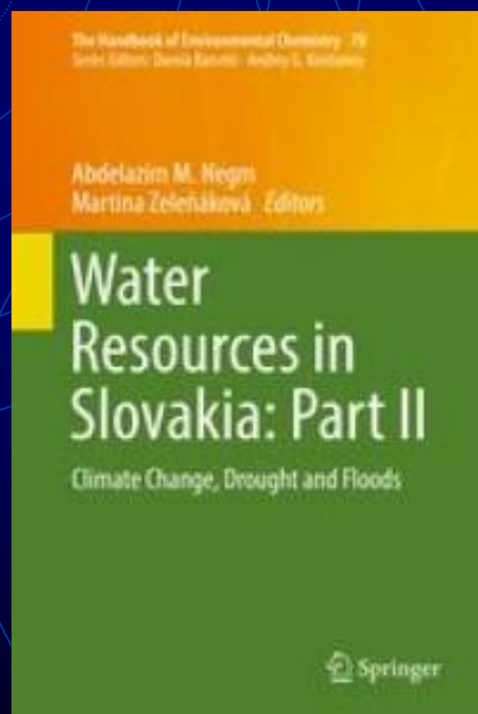
http://www.shmu.sk/File/Hydrologia/Publikacna_cinnost/2018/monografia_sucho_12042018_chranene.pdf

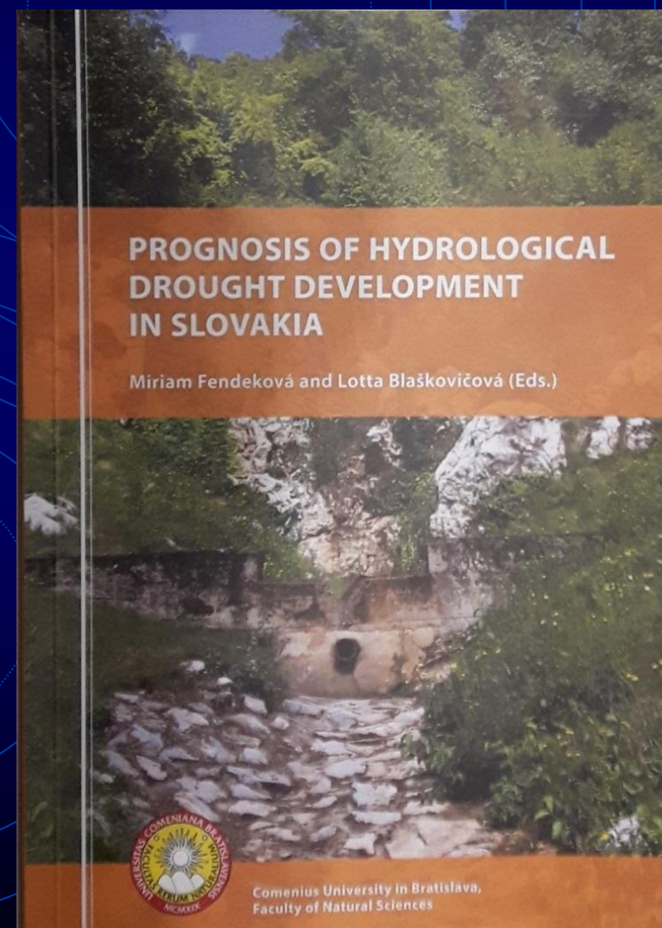
2018: Water Resources in Slovakia: Part II, 342 pp

https://www.springer.com/la/book/9783319928647

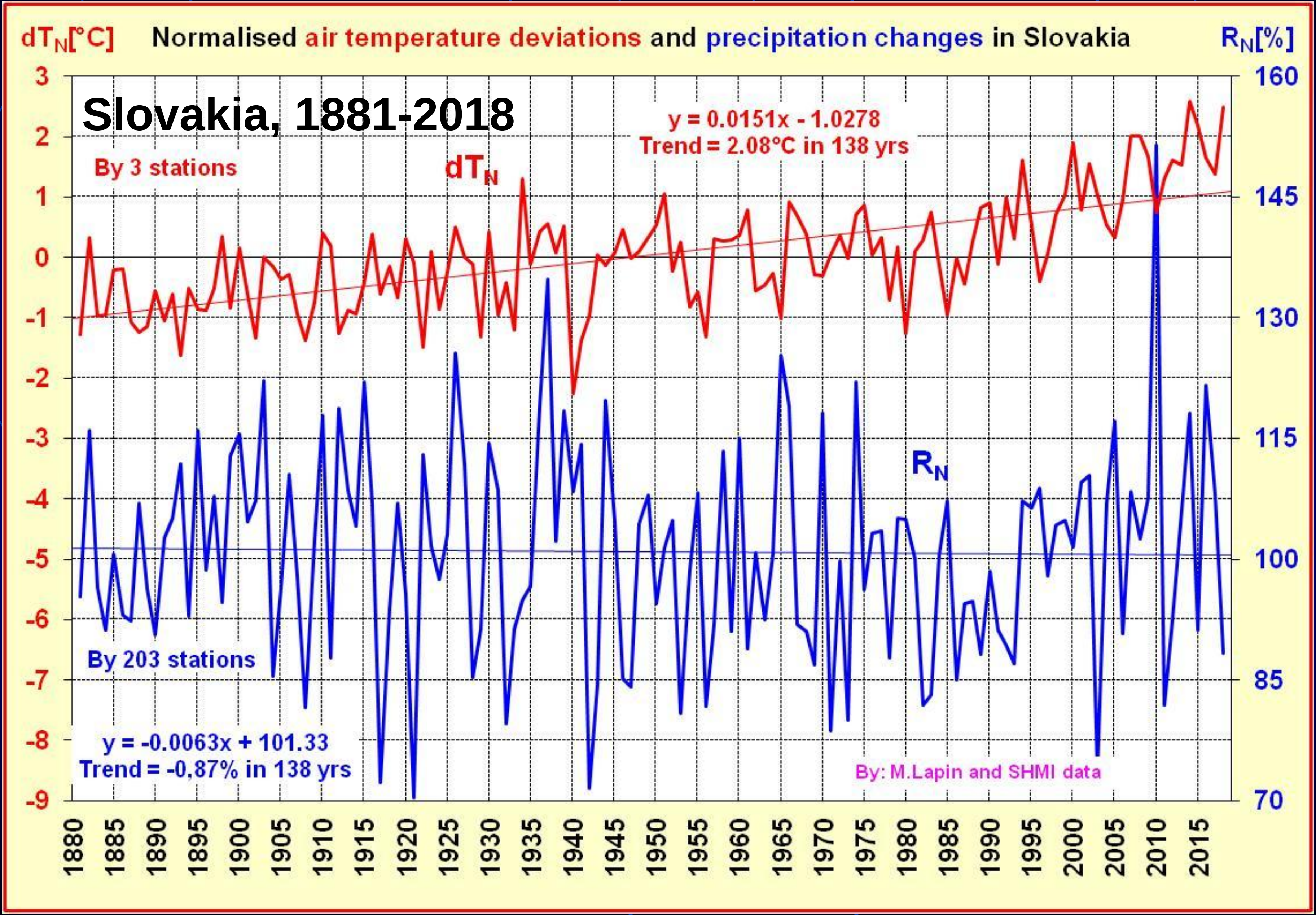
2018: Prognosis of Hydrological Drought Development in Slovakia, 182 pp



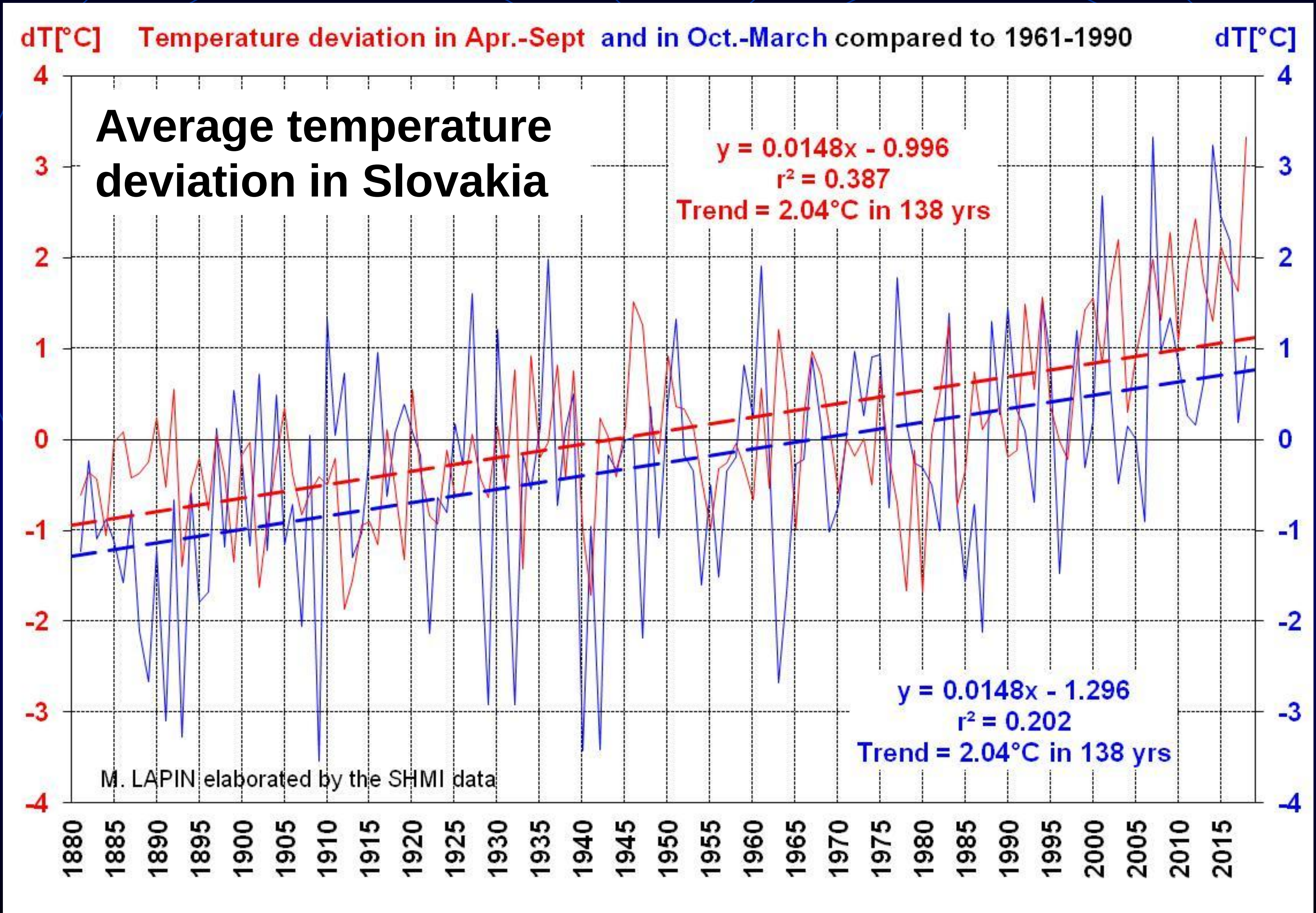




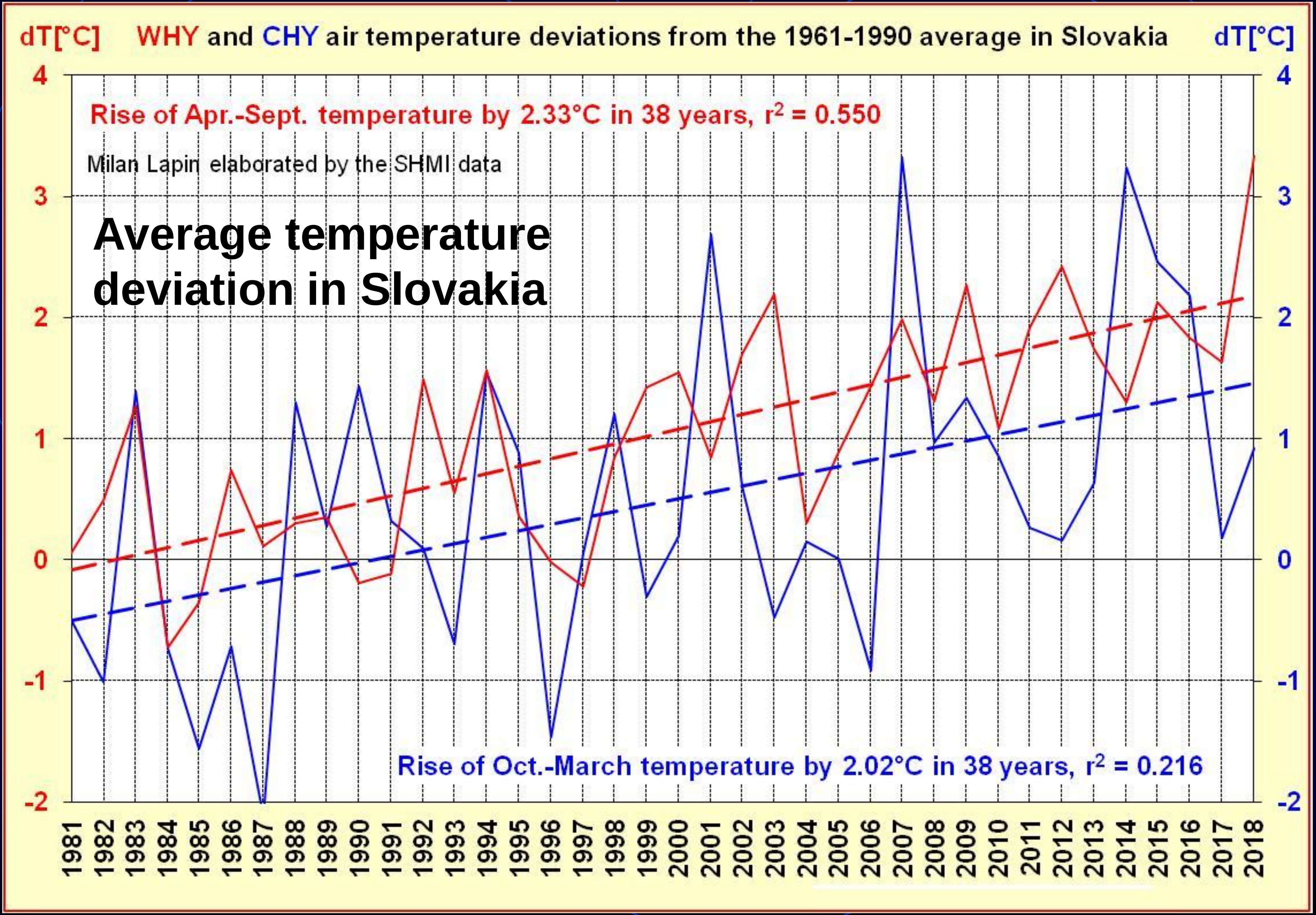
TRENDS OF TEMPERATURE AND PRECIPITATION



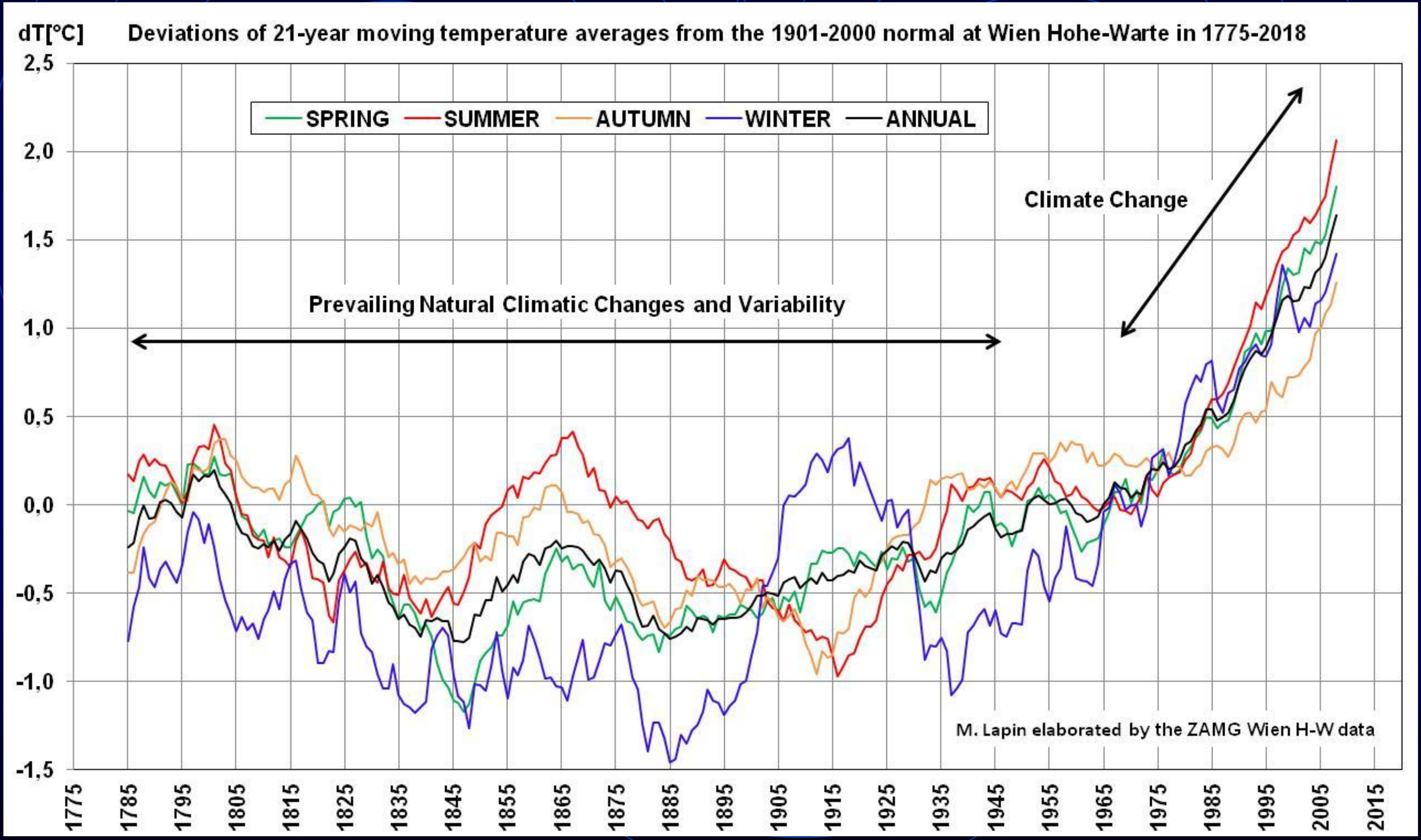
TRENDS OF TEMPERATURE IN IV-IX AND X-III



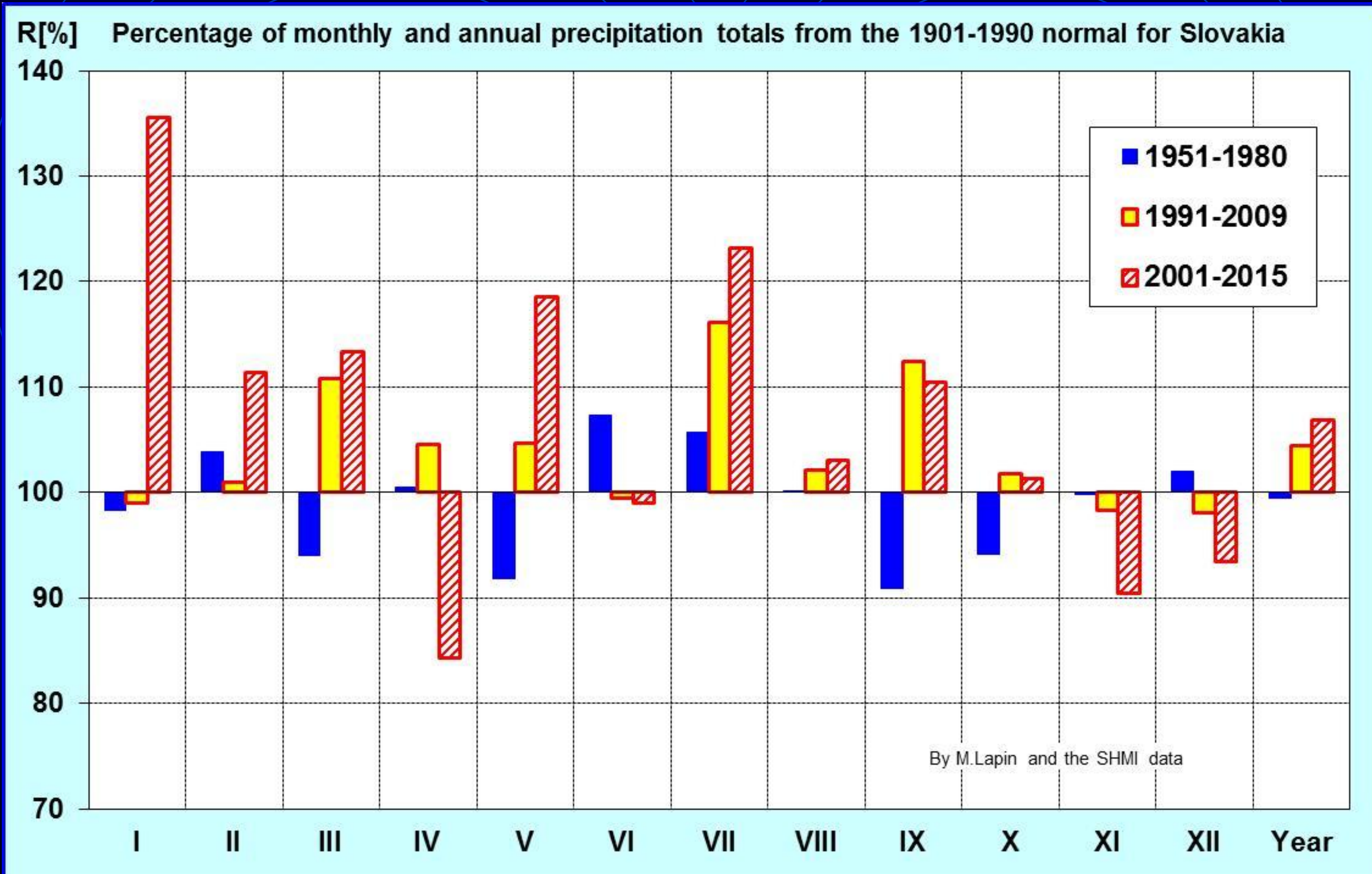
TRENDS OF TEMPERATURE IN IV-IX AND X-III



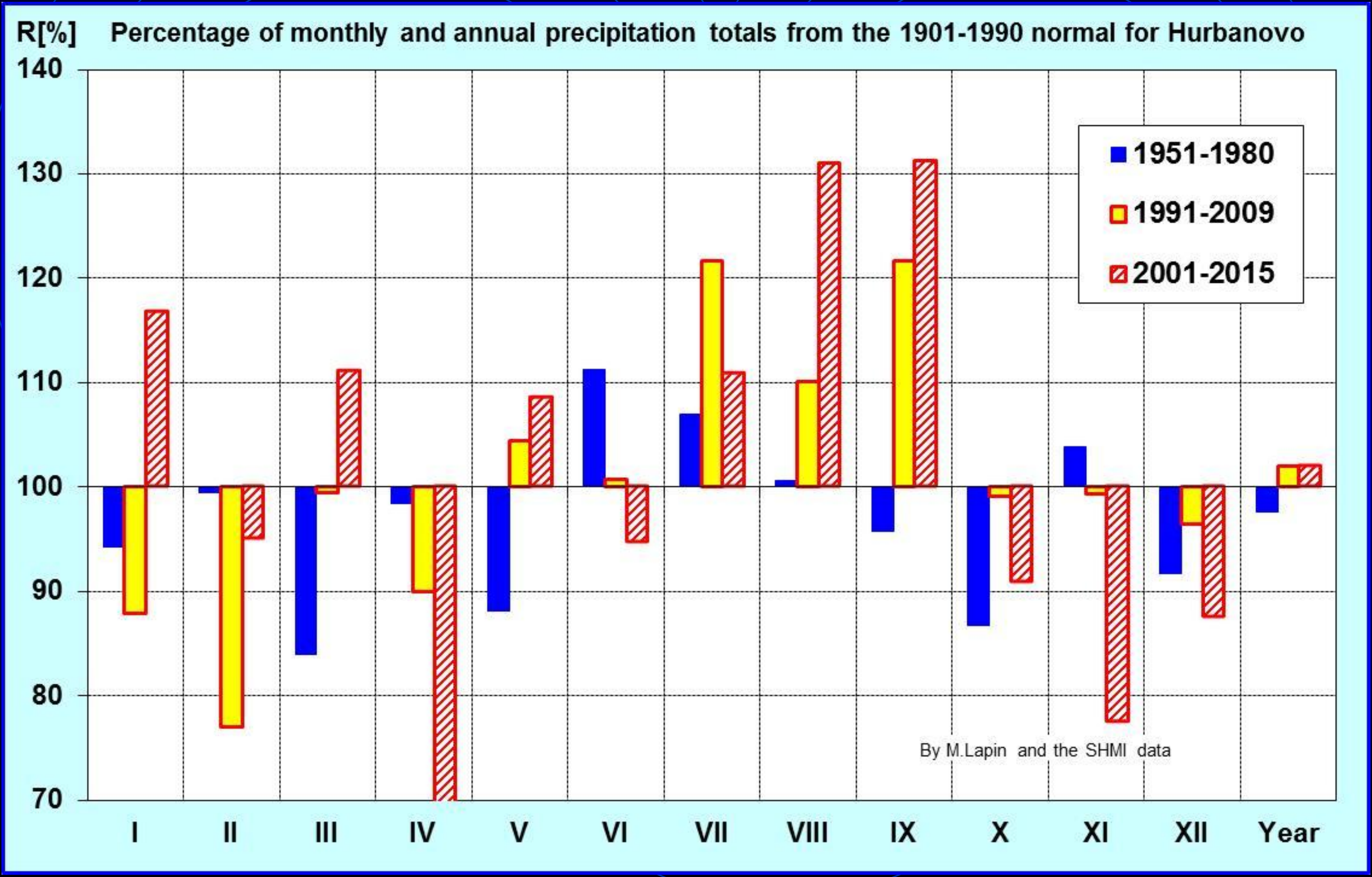
TRENDS OF TEMPERATURE WIEM H-W, 1775-2018
21-year moving averages of seasonal temperatures



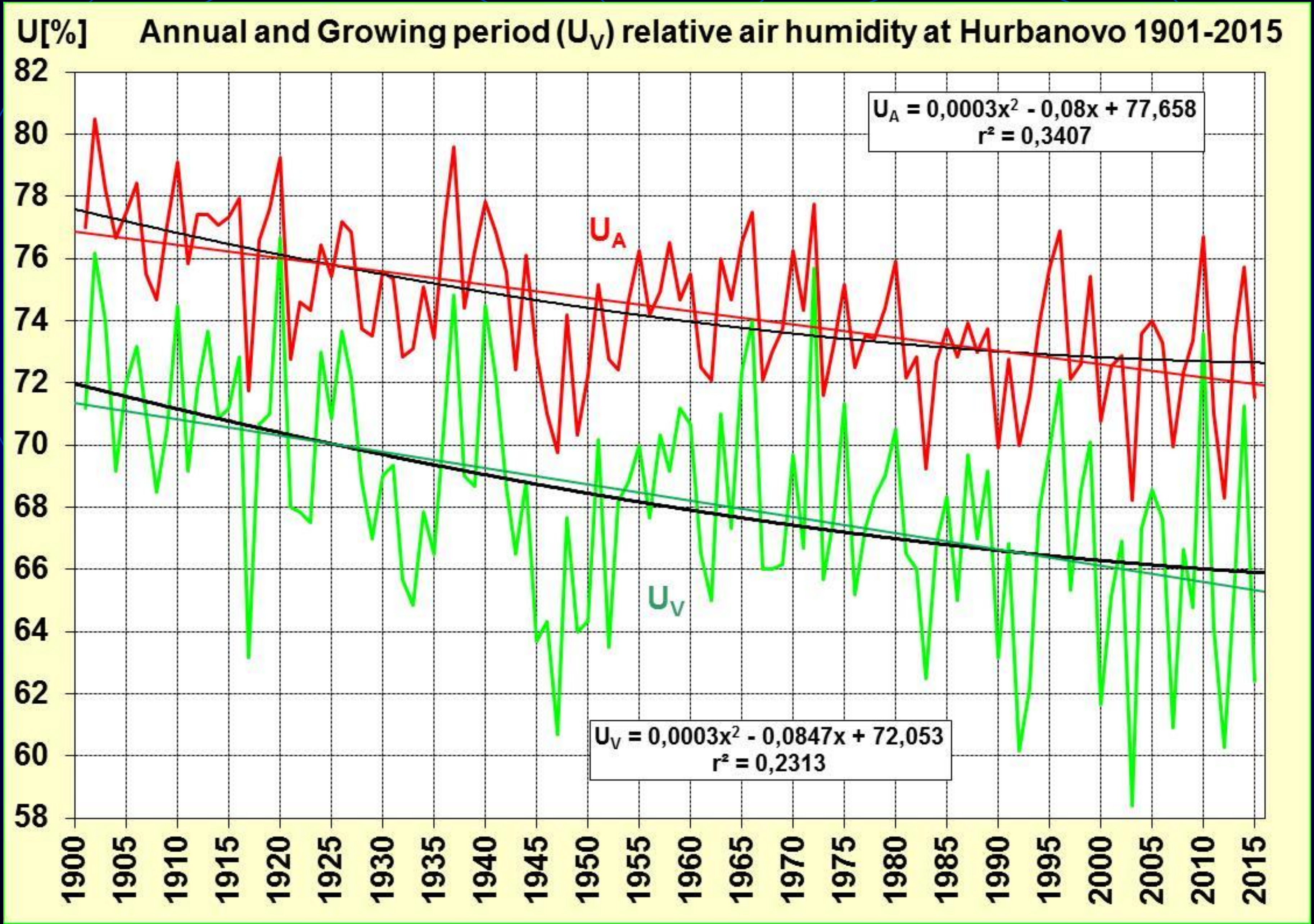
PRECIPITATION CHANGES IN SLOVAKIA (in % of 1901-1990 average)



PRECIPITATION CHANGES AT HURBANOVO (in % of 1901-1990 average)



AIR HUMIDITY TRENDS AT HURBANOVO, 1901-2015



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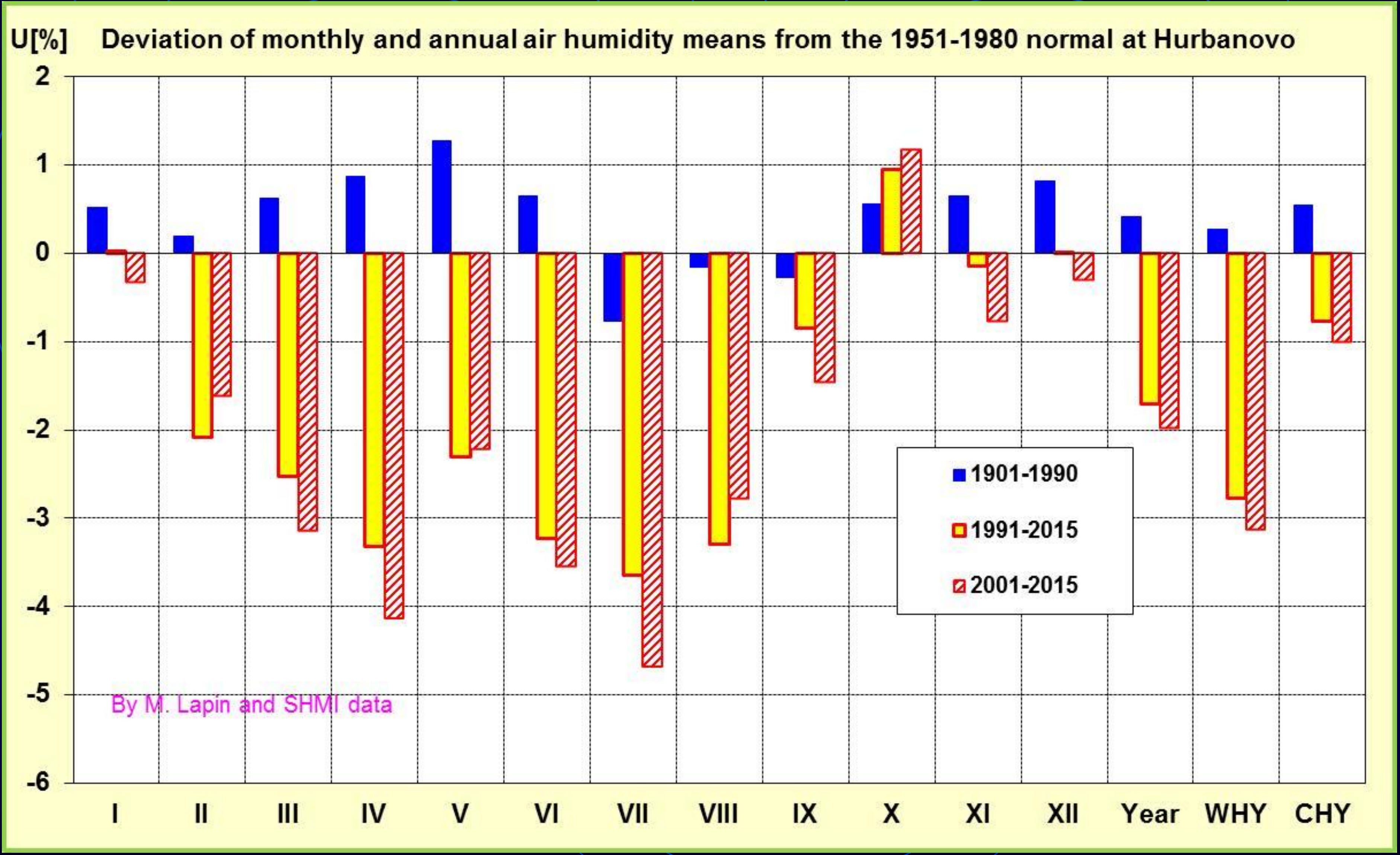
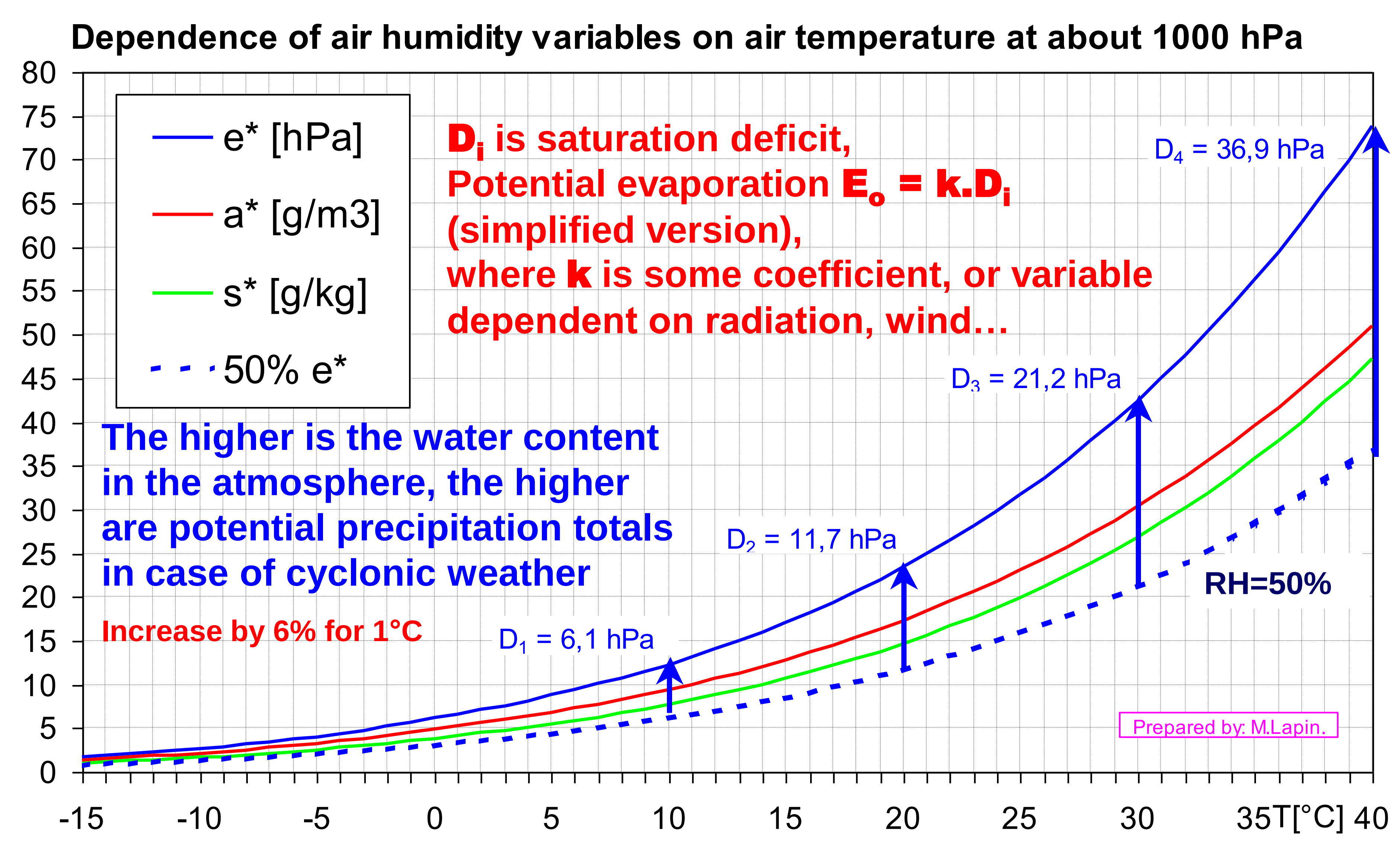
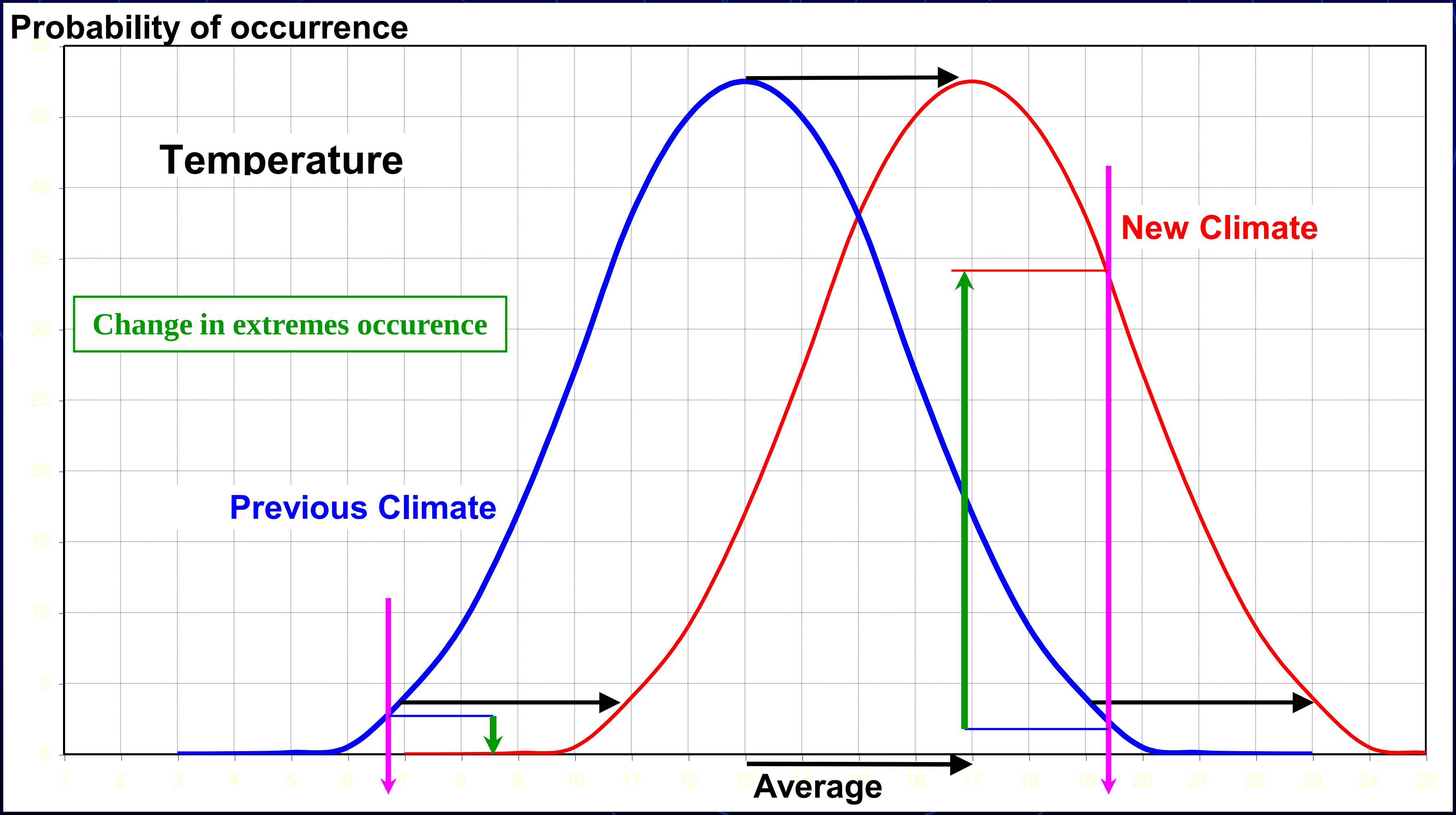


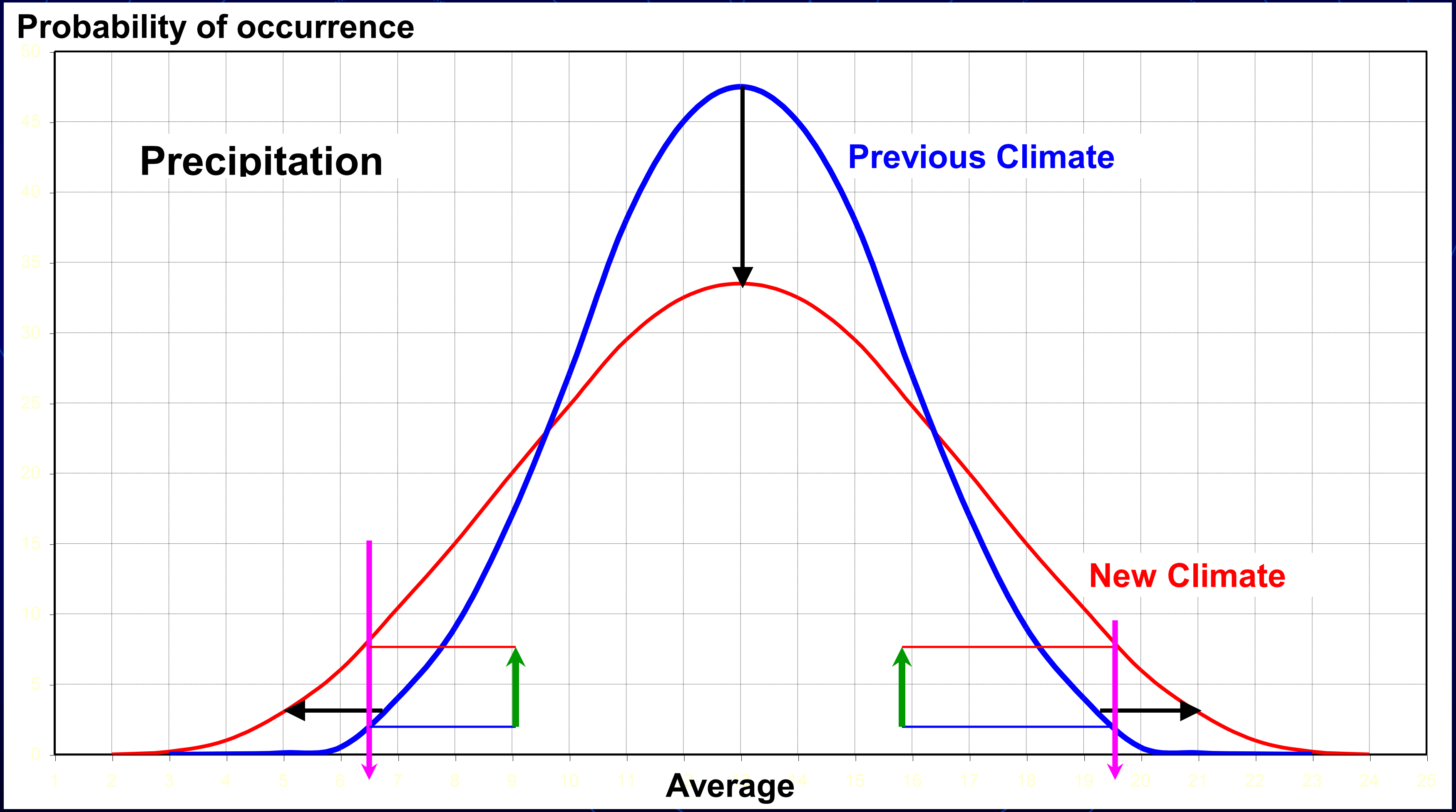
AIR HUMIDITY AND AIR TEMPERATURE



CLIMATE CHANGE POSSIBILITIES
(Temperature, based on the IPCC, 2001)
The lowest and highest 2% of occurrence



CLIMATE CHANGE POSSIBILITIES
(Precipitation, based on the IPCC, 2001)



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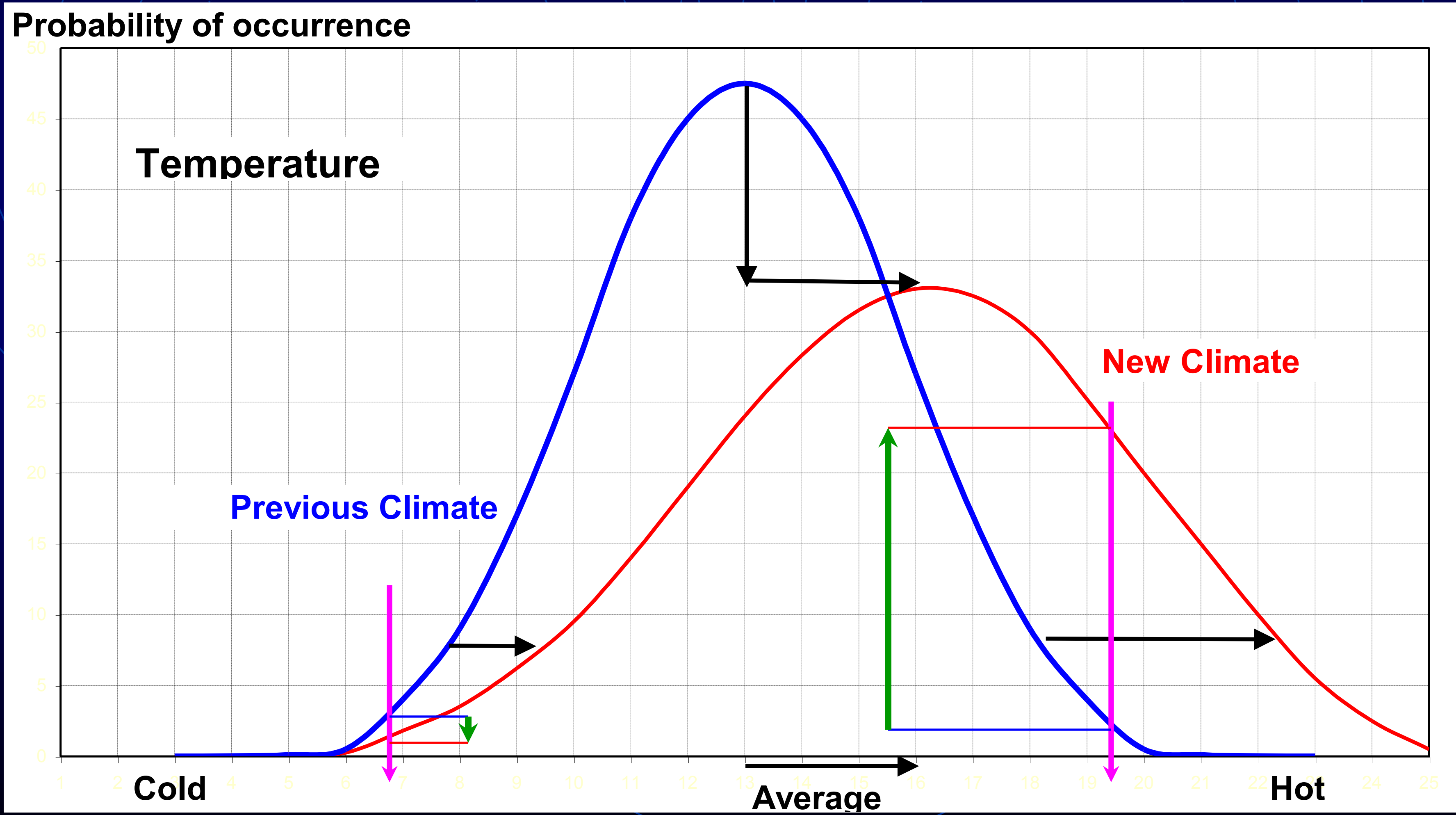
(Temperature, based on the IPCC, 2001)



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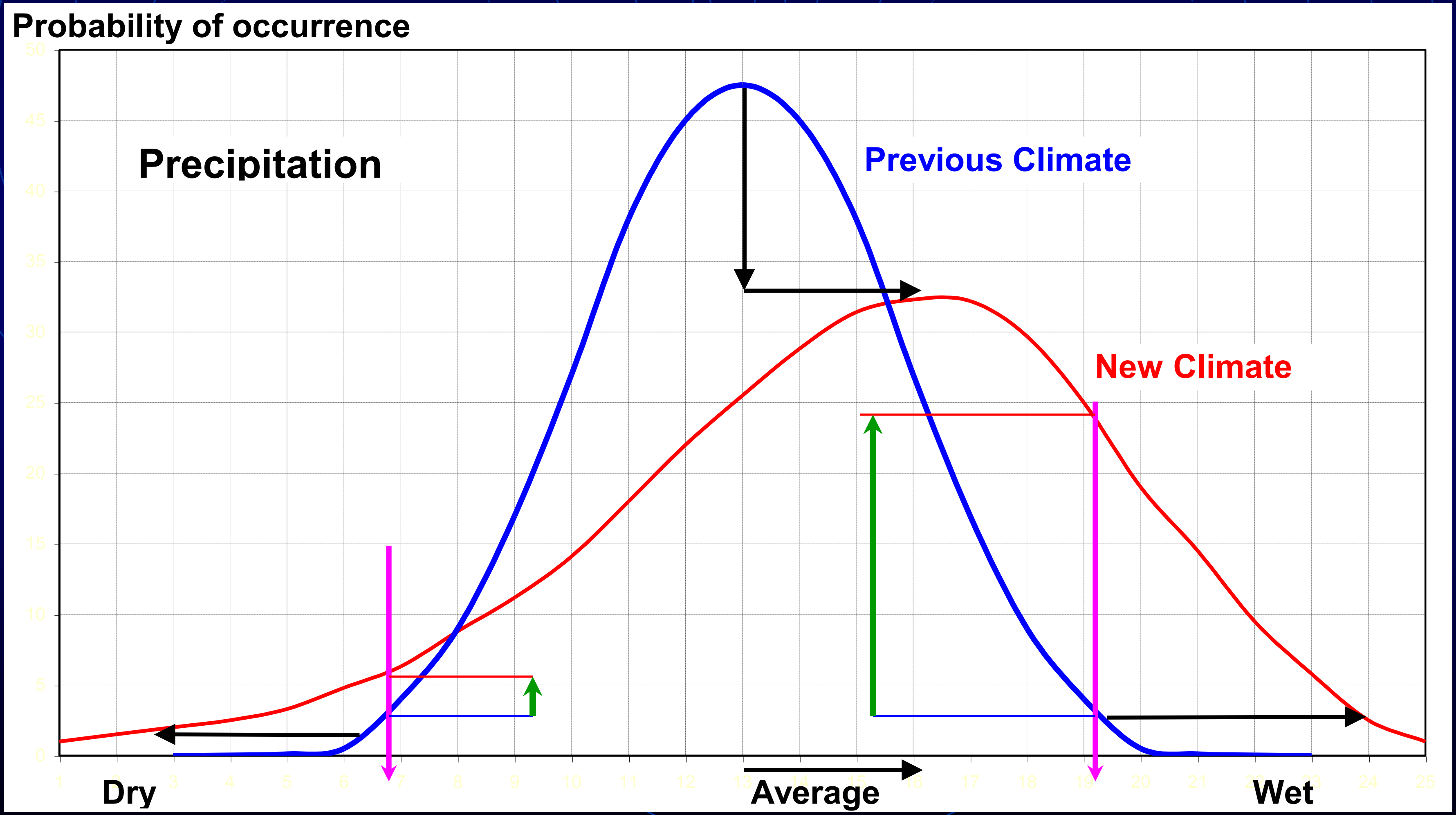


Potential (E_o) and actual (E) evapotranspiration in Slovakia, calculated for abou 30 stations in 1951-2018

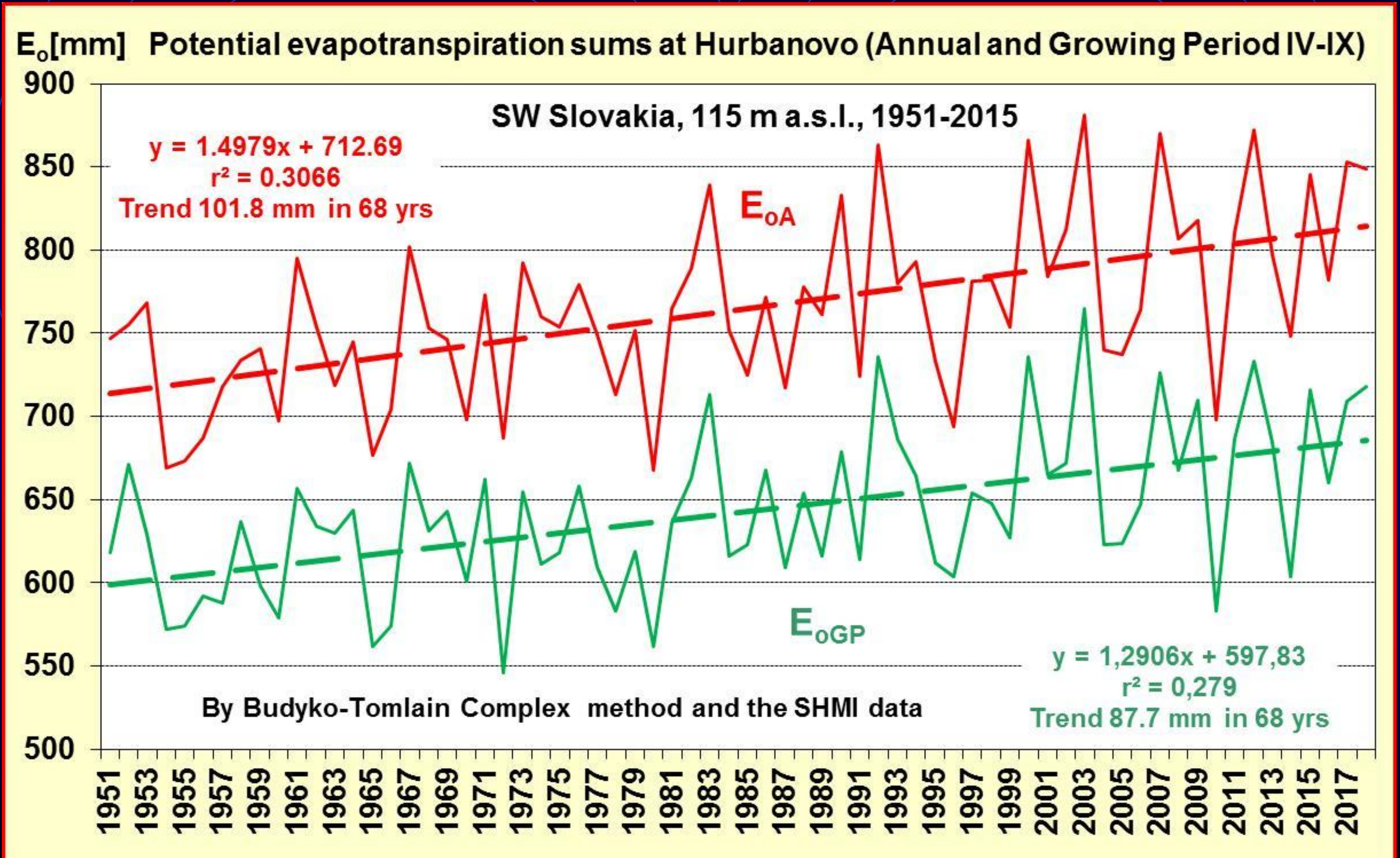
Budyko complex method modified for Slovakia by J. Tomlain has been applied.

1. Budyko MI (1974) Climate and life. Gidrometeorizdat. Leningrad. (in Russian)
2. Hrvoľ J, Lapin M, Tomlain J (2001) Changes and variability in solar radiation and evapotranspiration in Slovakia in 1951-2000. In: Acta Meteorologica Universitatis Comenianae, Vol. 30. Bratislava: Comenius University, 31-58. ISBN 80-223-1692-X
3. Tomlain J (1980) Evaporation from soil and its distribution over the Czechoslovak territory. Vodohospodársky časopis, Vol. XXVIII, No. 2. (in Slovak)
4. Zubenok L I (1976) Evaporation on Continents, Gidrometeoizdat. Leningrad, 264 pp. (in Russian)

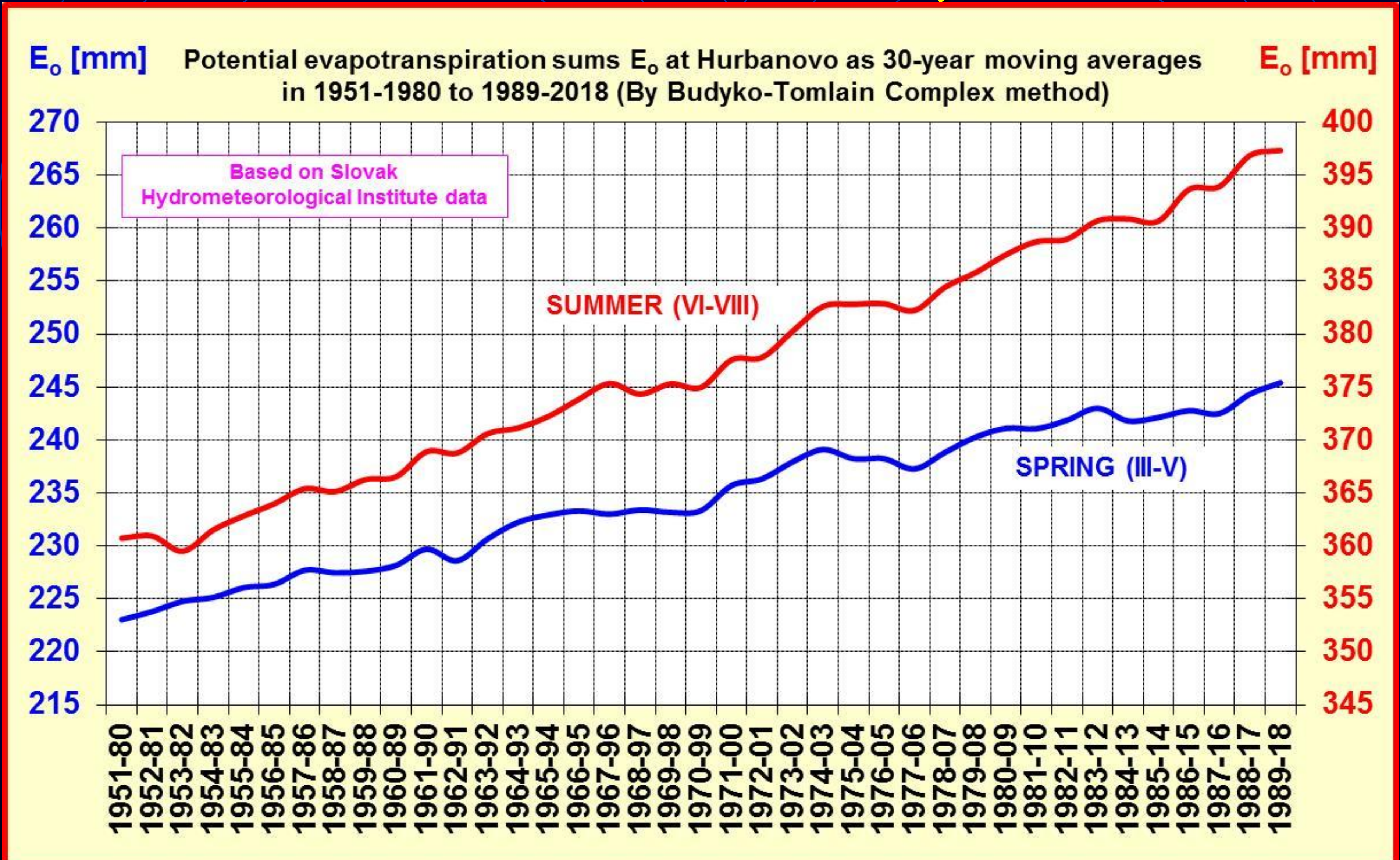
Basic philosophy of method is based on calculation of E_o and measurement or caclulation od soil moisture W at consideration of sasonal critical soil moisture W_o

$$\text{If } \overline{W} \geq W_o, \text{ then } E = E_0 \text{ and if } \overline{W} < W_o, \text{ then } E = E_0 \frac{\overline{W}}{W_0}$$

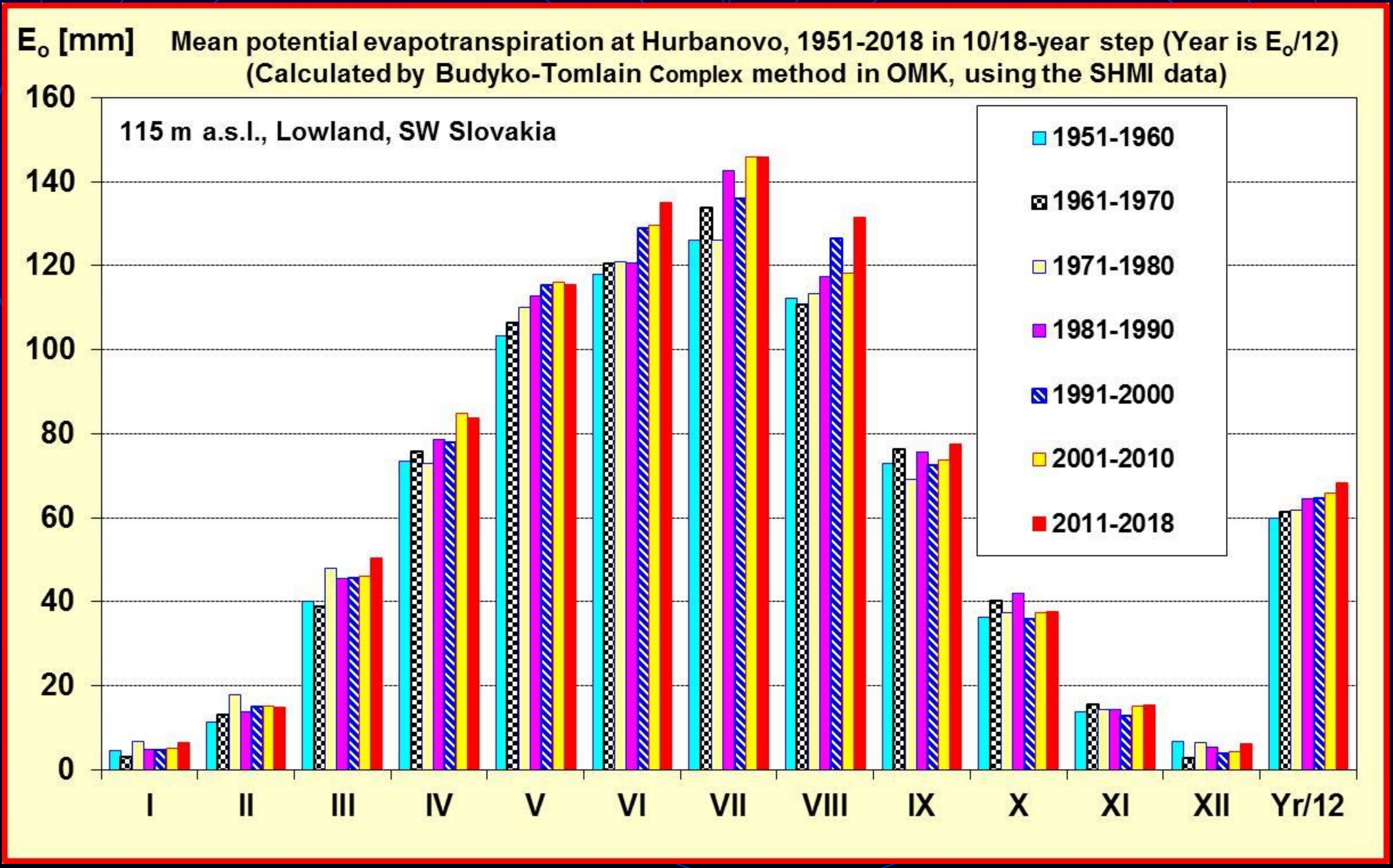
POTENTIAL EVAPOTRANSPIRATION TRENDS AT HURBANOVO, 1951-2018



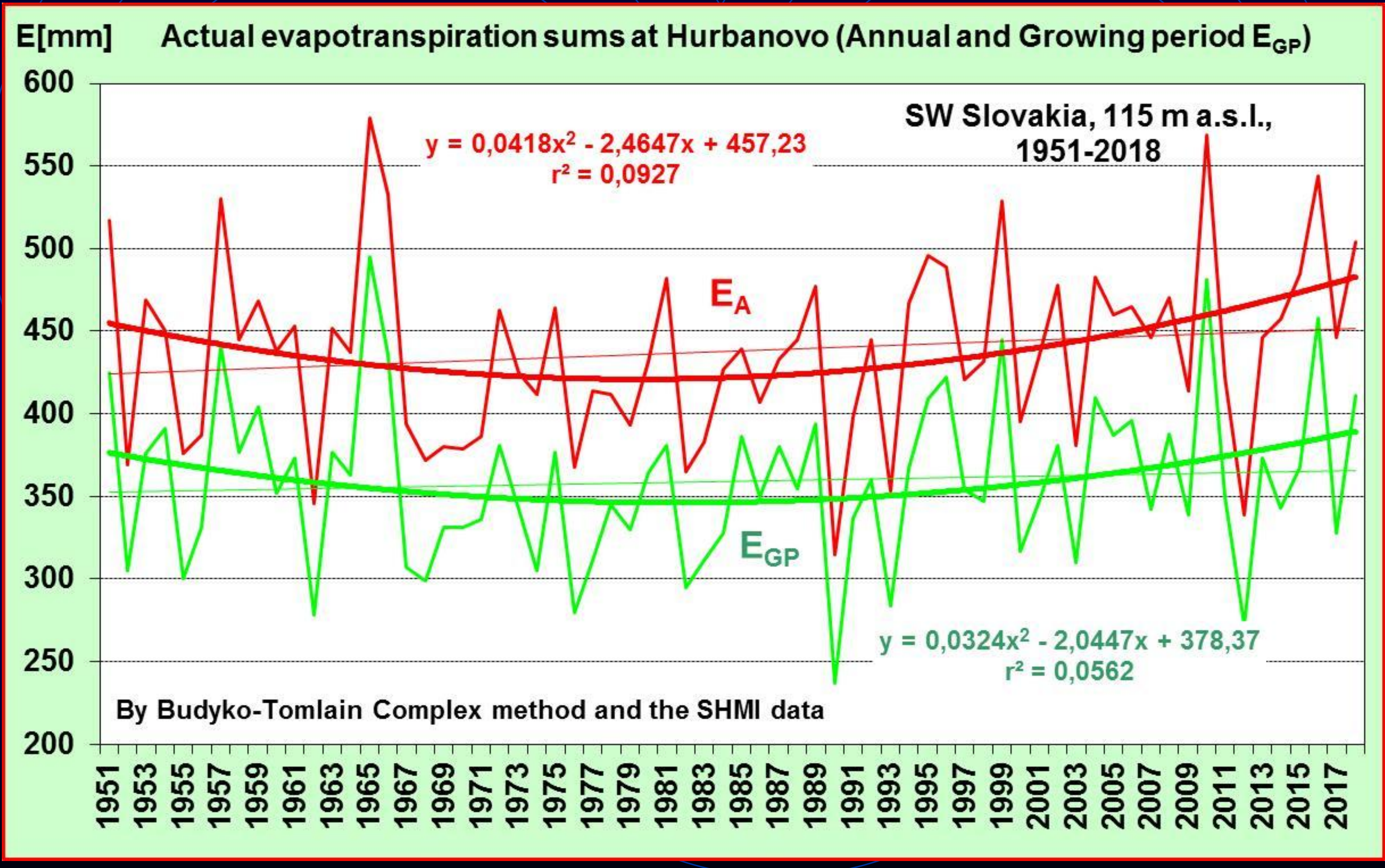
POTENTIAL EVAPOTRANSPIRATION TRENDS AT HURBANOVO, 1951-2018



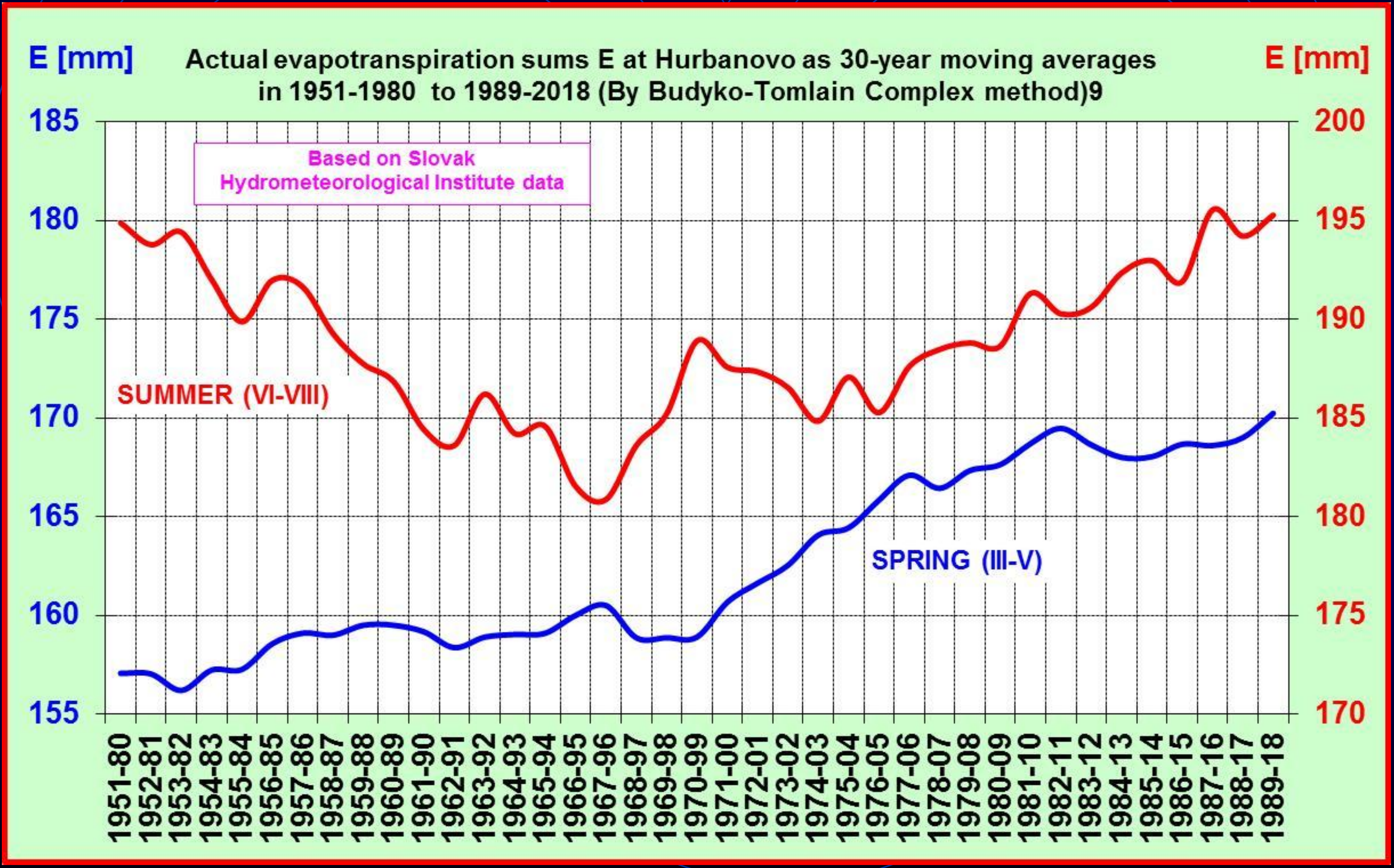
POTENTIAL EVAPOTRANSPIRATION TRENDS AT HURBANOVO, 1951-2018



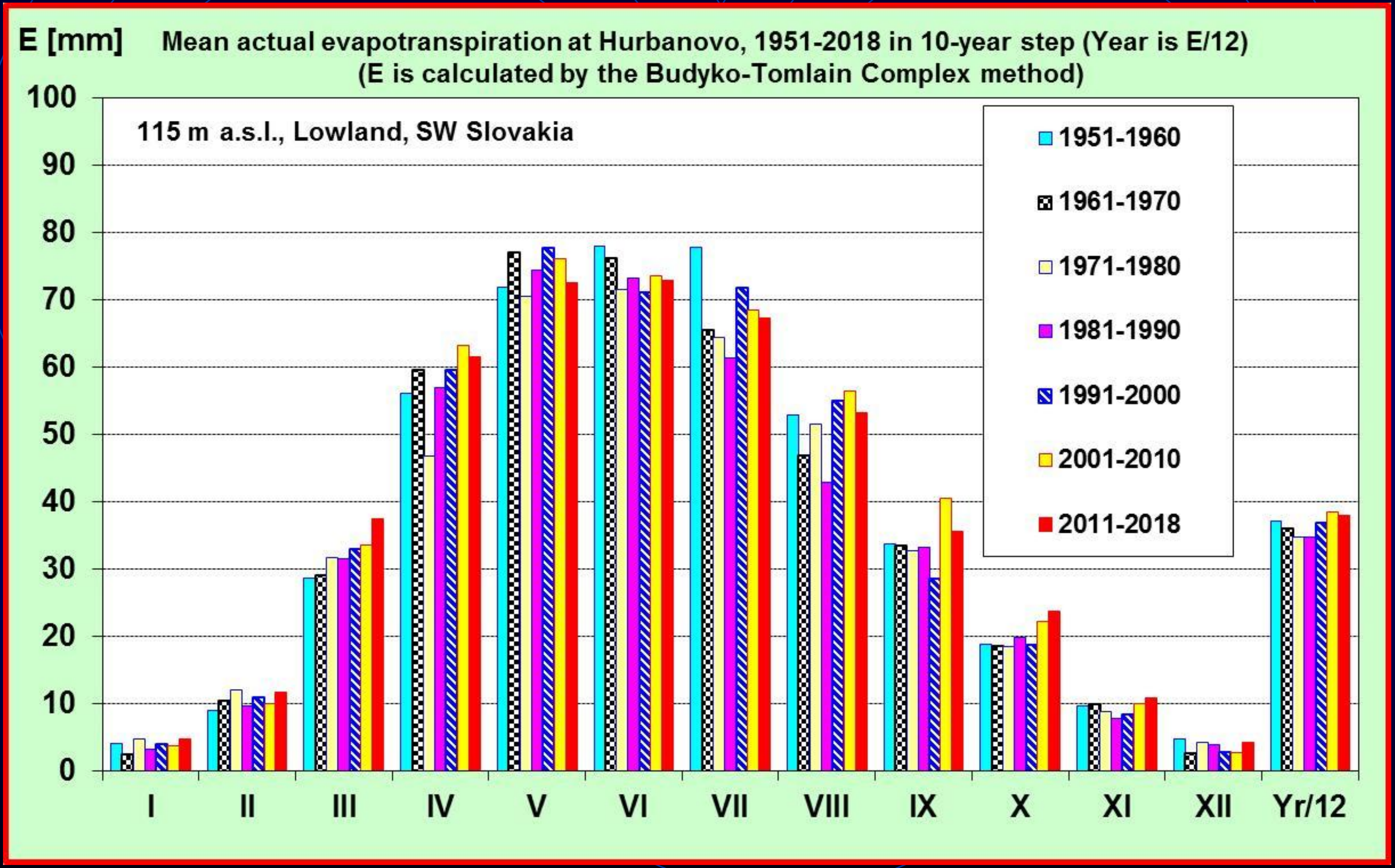
ACTUAL EVAPOTRANSPIRATION TRENDS AT HURBANOVO, 1951-2018



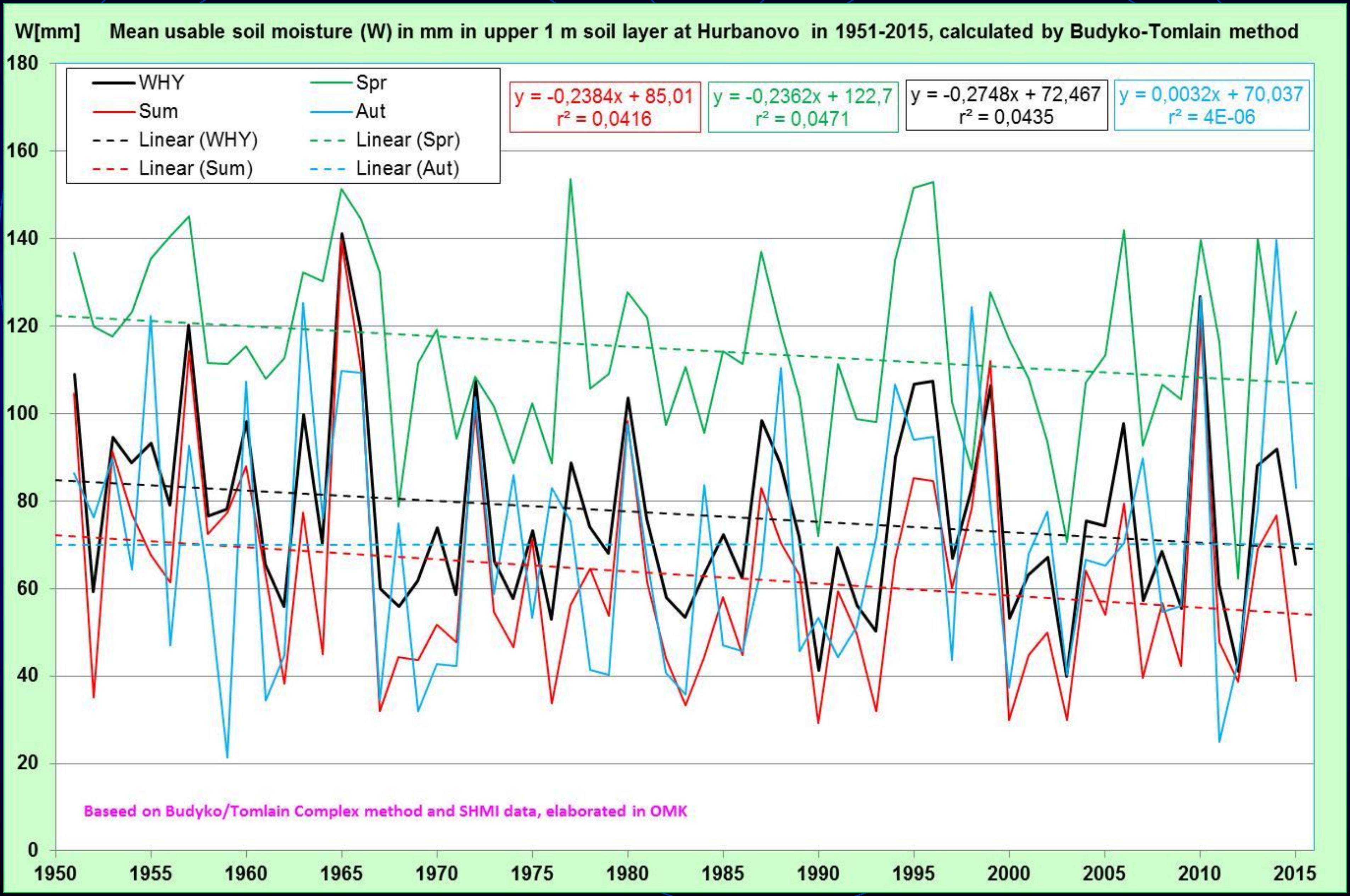
ACTUAL EVAPOTRANSPIRATION TRENDS AT HURBANOVO, 1951-2018

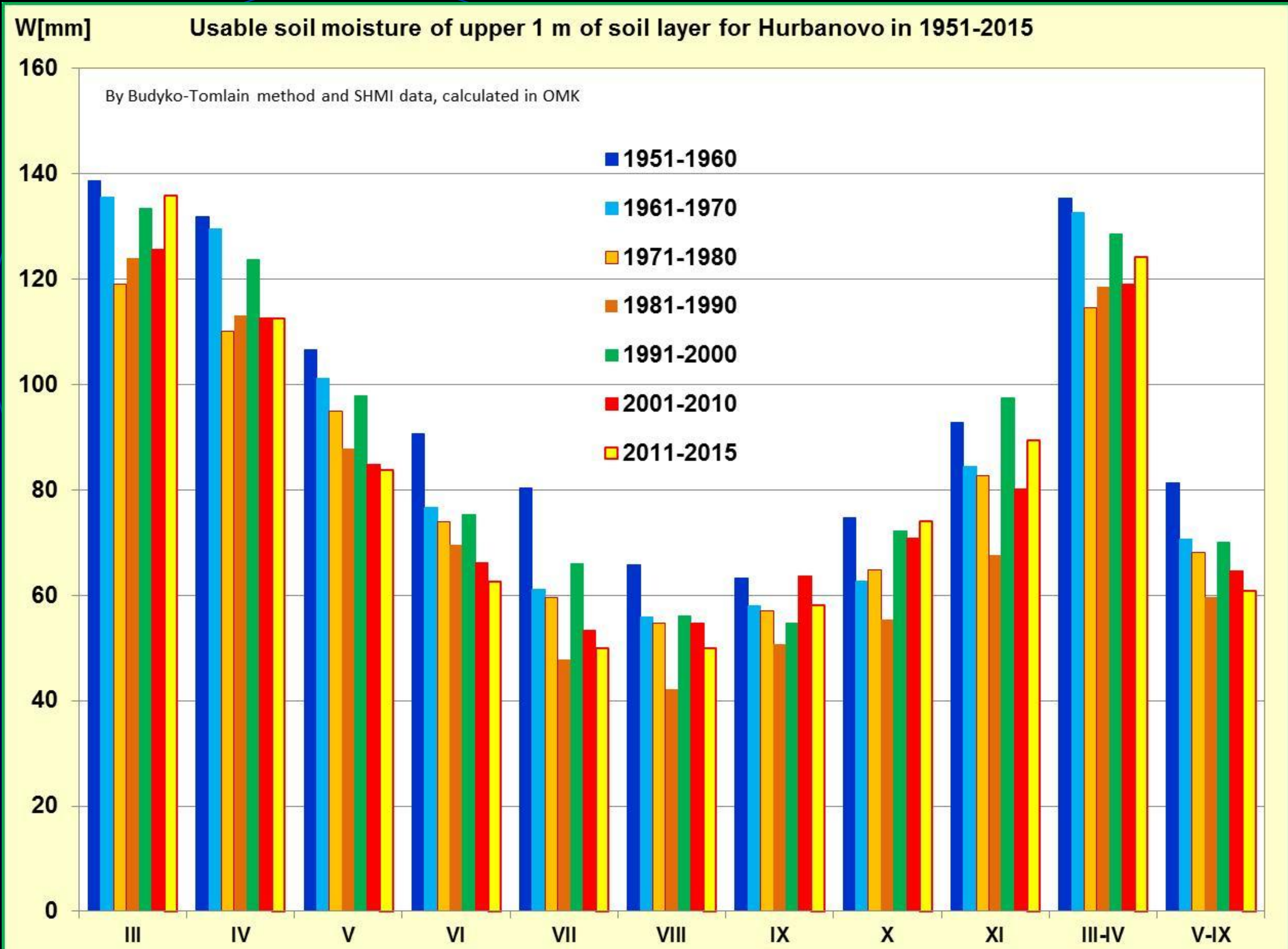


ACTUAL EVAPOTRANSPIRATION TRENDS AT HURBANOVO, 1951-2018

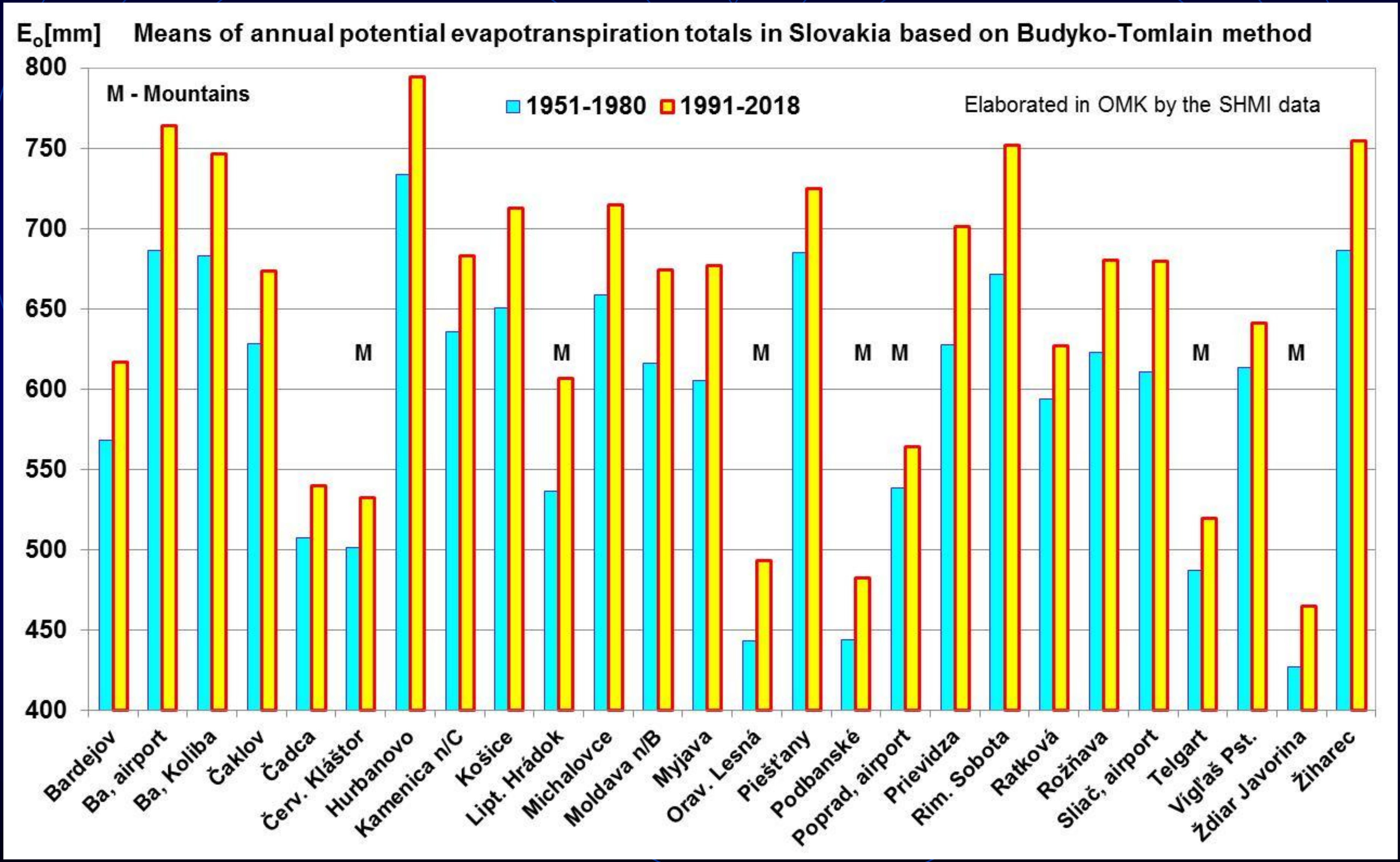


USABLE SOIL MOISTURE AT HURBANOVO

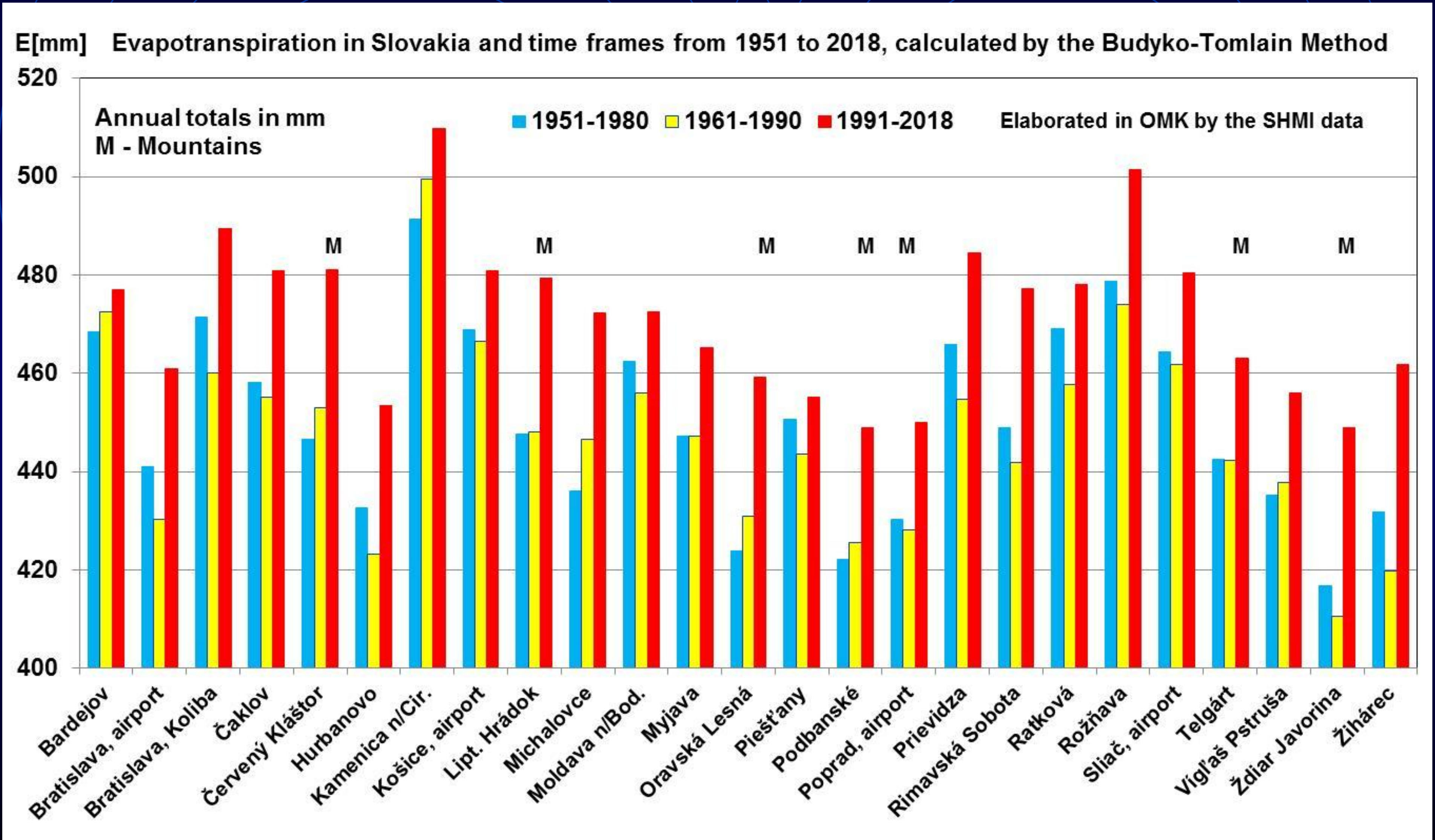



W[mm]
Usable soil moisture of upper 1 m of soil layer for Hurbanovo in 1951-2015
By Budyko-Tomlain method and SHMI data, calculated in OMK
1951-1960
1961-1970
1971-1980
1981-1990
1991-2000
2001-2010
2011-2015
0
20
40
60
80
100
120
140
160
III
IV
V
VI
VII
VIII
IX
X
XI
III-IV
V-IX

POTENTIAL EVAPOTRANSPIRATION TRENDS IN SLOVAKIA BY THE DMC AND SHMI DATA, 1951-2018



ACTUAL EVAPOTRANSPIRATION TRENDS IN SLOVAKIA BY THE OMK AND SHMI DATA, 1951-2018



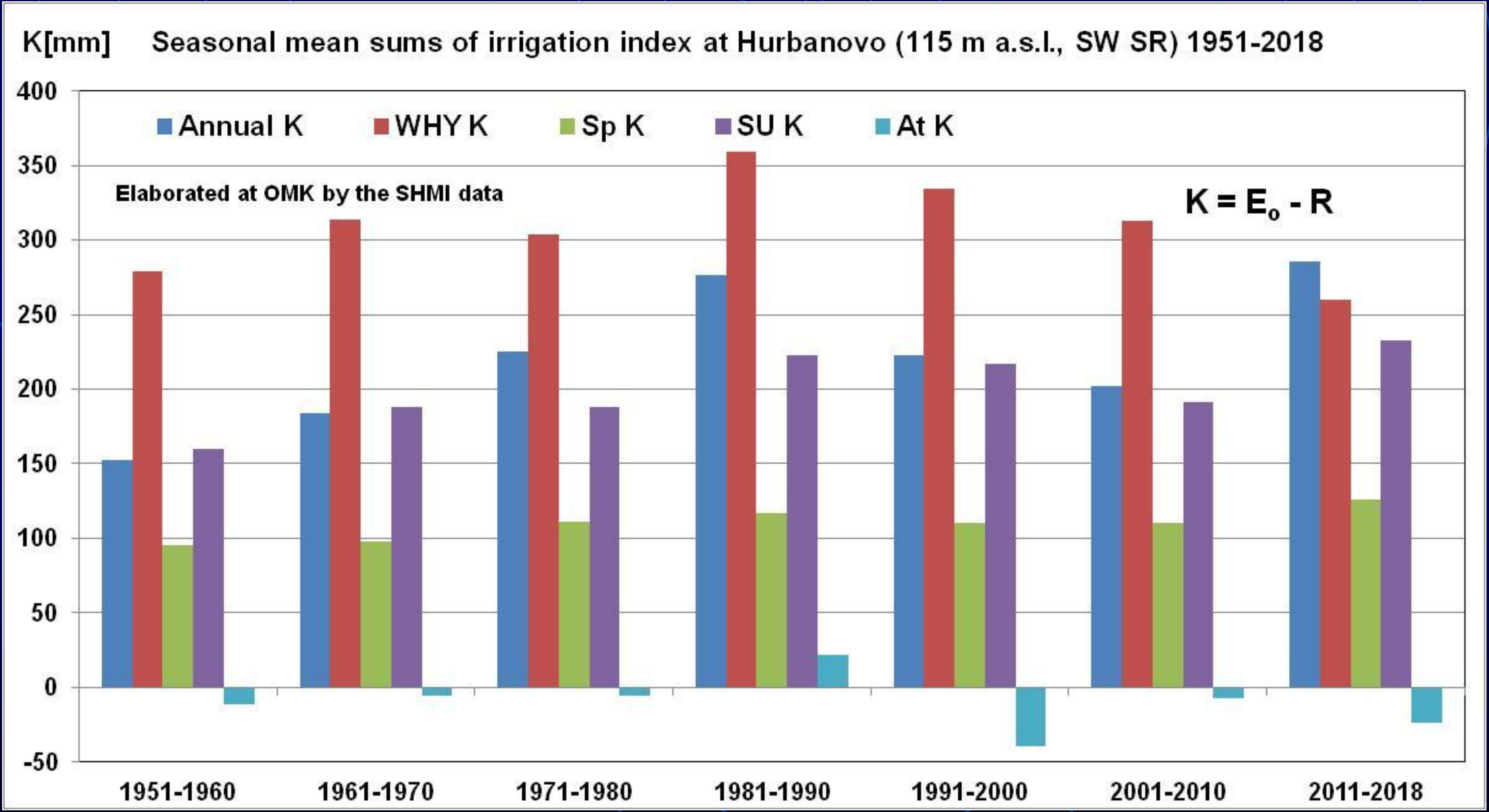
Comparison of different irrigation coefficients at Hurbanovo in 10-year periods, in whole period 1951-2010 and in 5-year period 2011-2015. The year 2010 was unusually wet and warm extreme, so it is evaluated separately (WHY – April-September, Spring, Summer and Autumn, E_o – potential evapotranspiration sum, E – actual evapotranspiration sum, R – precipitation total)

K – index of irrigation, better $K = E_o – (1-\phi)R$, $\phi = q/R$, q – runoff, dE – evapotranspiration deficit, Er – relative evapotranspiration

Coefficient	$K = E_o – R$ [mm]				$dE = E_o – E$ [mm]				$E_r = E/E_o$ [%]			
Period/Season	**WHY**	**Spr**	**Sum**	**Aut**	**WHY**	**Spr**	**Sum**	**Aut**	**WHY**	**Spr**	**Sum**	**Aut**
1951-1960	283.6	93.4	166.3	-8.6	236.6	58.9	147.4	63.8	61.4	73.2	59.1	49.4
1961-1970	300.3	101.9	175.1	-13.2	261.5	57.9	173.6	65.7	58.6	74.5	53.3	51.5
1971-1980	318.2	110.6	198.8	9.6	282.4	80.3	179.9	64.6	54.5	65.4	50.8	48.4
1981-1990	334.2	106.4	203.7	14.6	281.6	67.8	185.6	68.4	56.1	71.0	50.7	48.8
1991-2000	327.9	113.9	216.6	-45.9	296.2	75.2	192.7	63.6	55.1	69.3	51.1	48.5
2001-2010	379.5	134.7	218.9	5.7	321.8	77.4	218.3	61.6	53.5	69.9	46.1	53.2
2010	*-130*	*-101*	*36*	*-100*	*102*	*34*	*71*	*19*	*82.5*	*83.5*	*80.7*	*82.4*
2011-2015	*272.6*	*88.3*	*193.0*	*-26.6*	*294.2*	*79.4*	*190.4*	*61.2*	*56.4*	*68.5*	*52.5*	*54.4*
1951-2015	**320.6**	**108.7**	**196.8**	**-7.8**	**281.8**	**70.5**	**184.1**	**64.4**	**56.4**	**70.3**	**51.8**	**50.3**

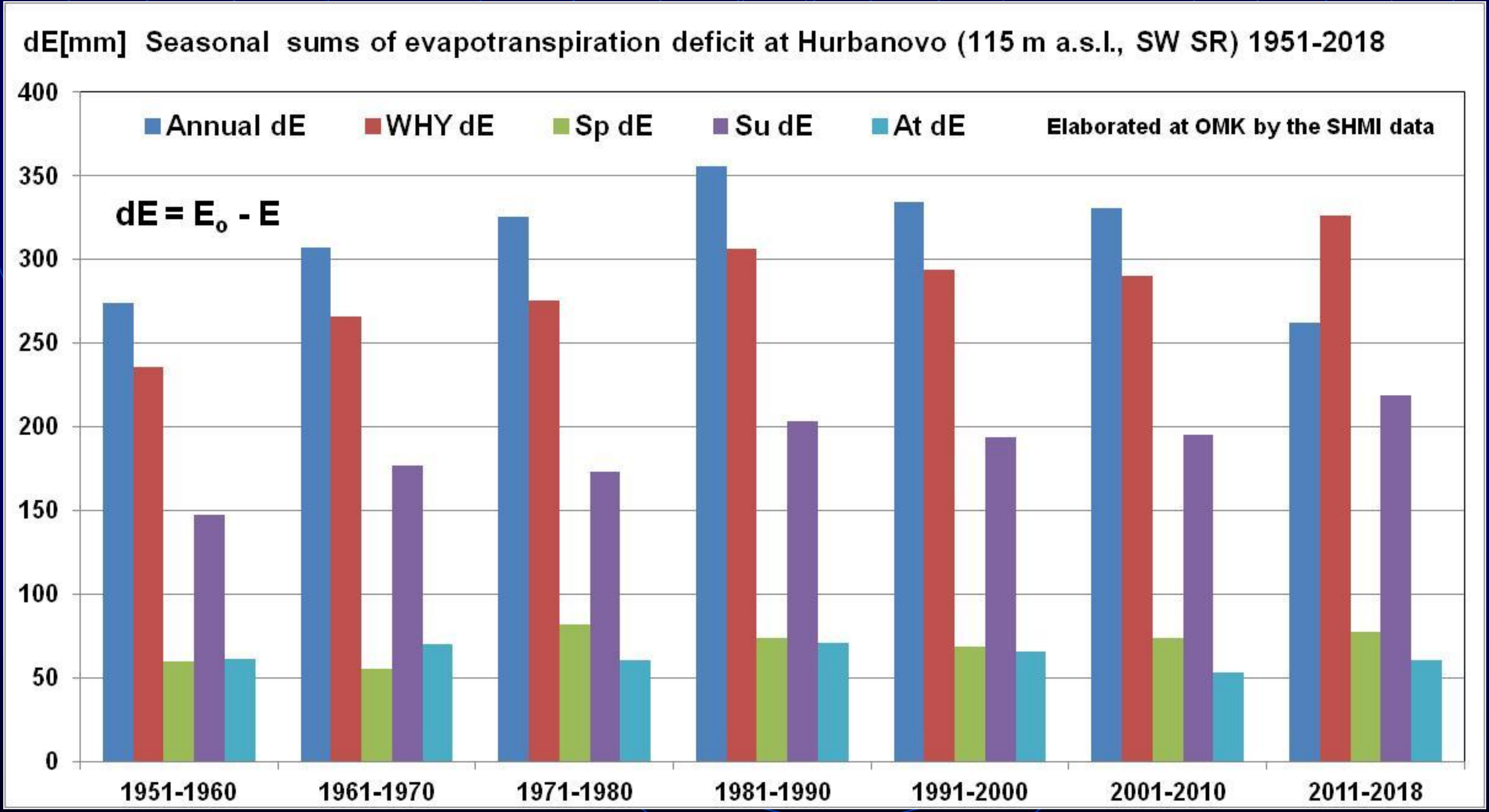
EVAPOTRANSPIRATION COEFFICIENTS TRENDS AT HURBANOVO, 1951-2018

Irrigation index $K = E_o - R$



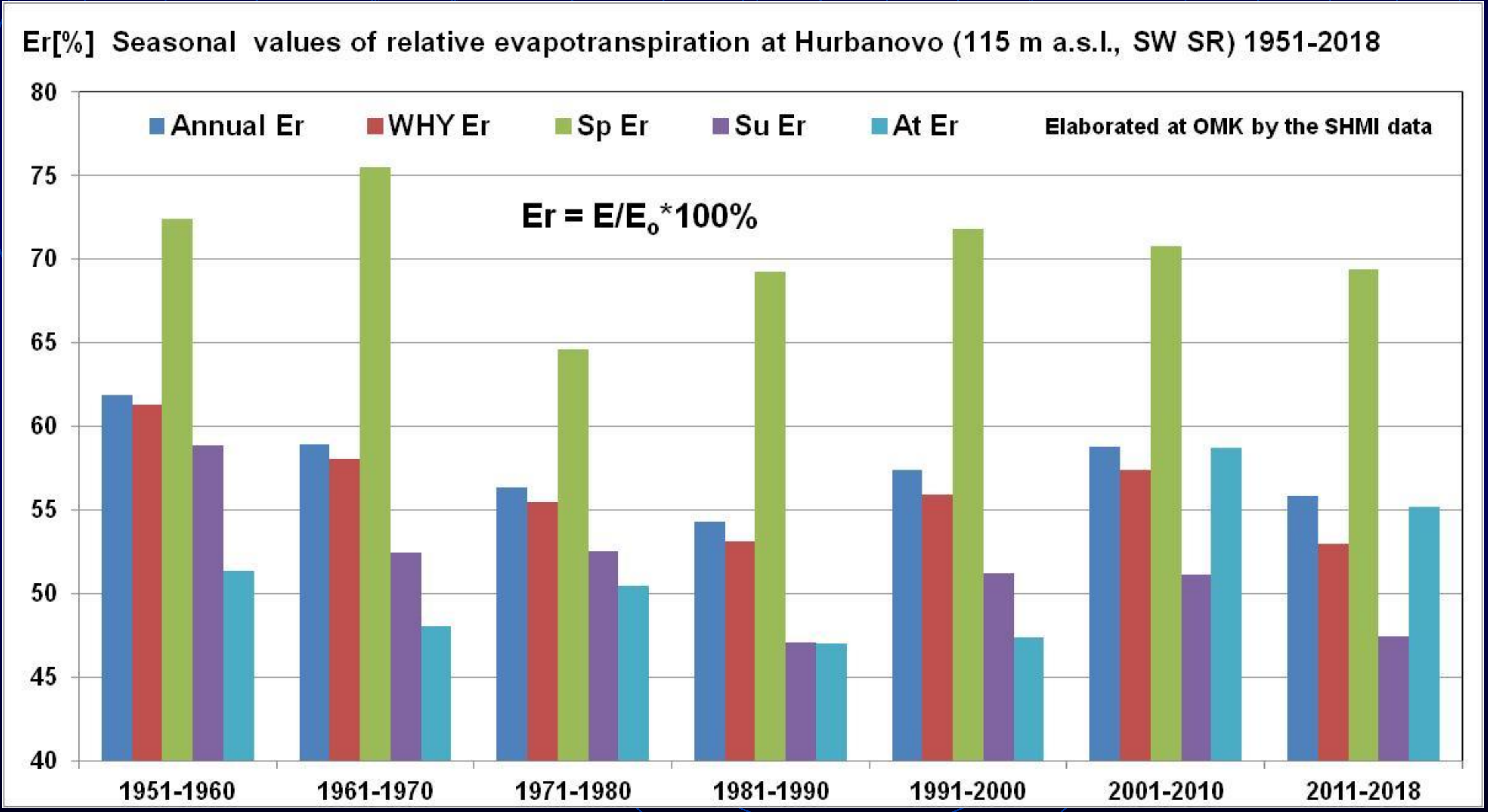
EVAPOTRANSPIRATION COEFFICIENTS TRENDS AT HURBANOVO, 1951-2018

Evapotranspiration deficit $dE = E_o - E$



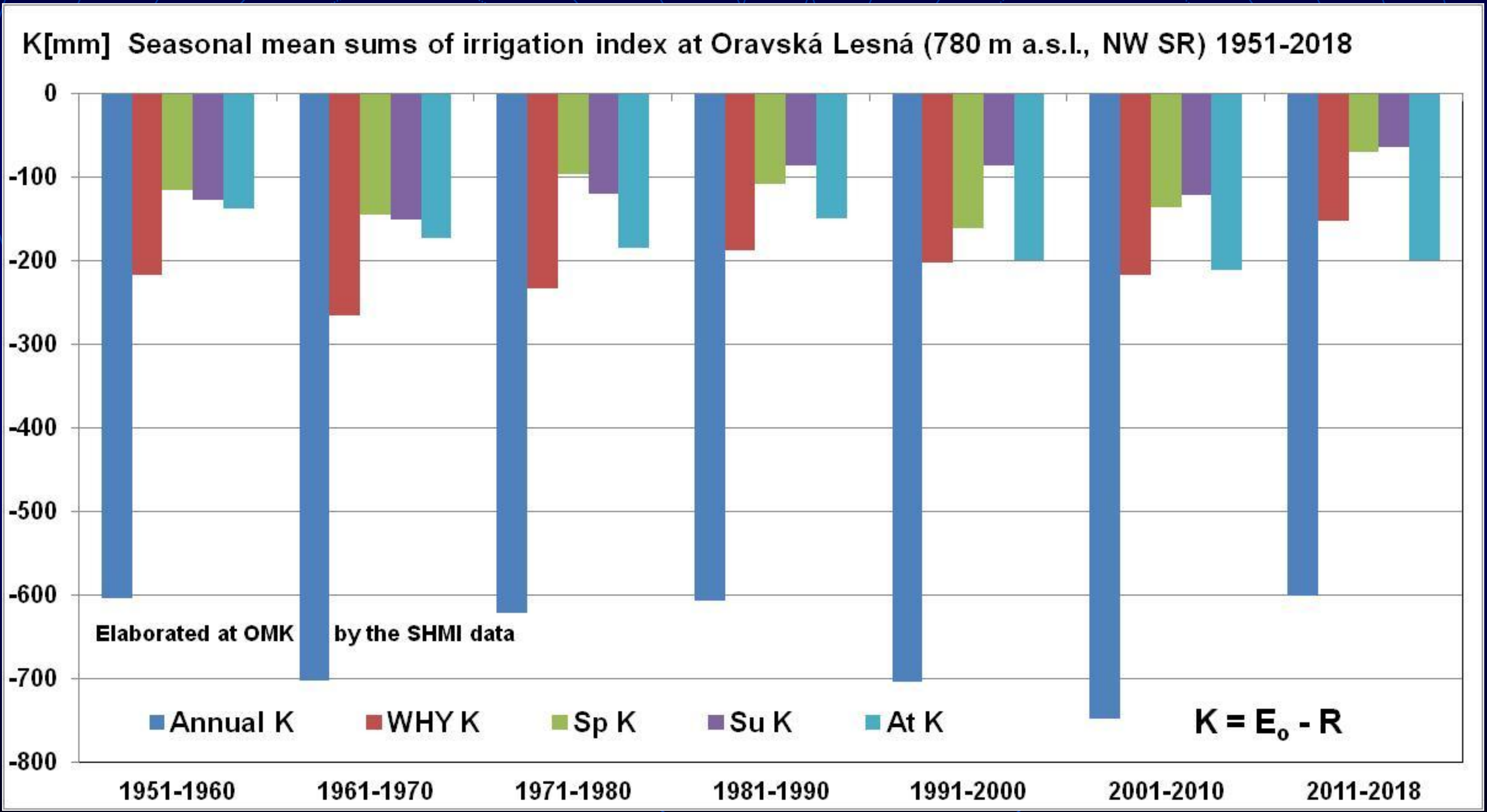
EVAPOTRANSPIRATION COEFFICIENTS TRENDS AT HURBANOVO, 1951-2018

Relative evapotranspiration $Er = E/E_o*100\%$



EVAPOTRANSPIRATION COEFFICIENTS TRENDS AT ORAV. LESNÁ, 1951-2018

Irrigation index $K = E_o - R$



EVAPOTRANSPIRATION COEFFICIENTS TRENDS AT ORAV. LESNÁ, 1951-2018

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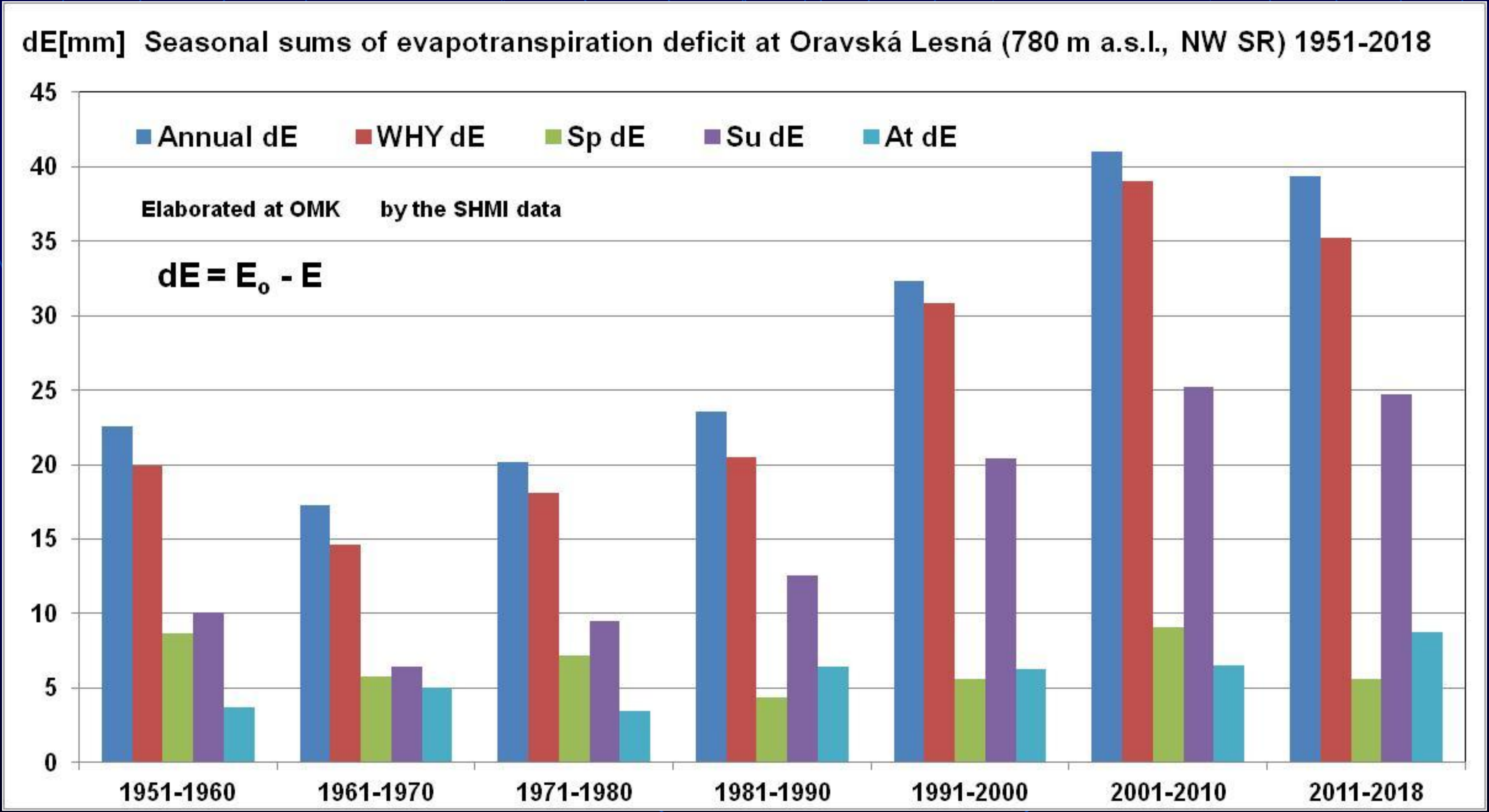

EVAPOTRANSPIRATION COEFFICIENTS TRENDS AT ORAV. LESNÁ, 1951-2018

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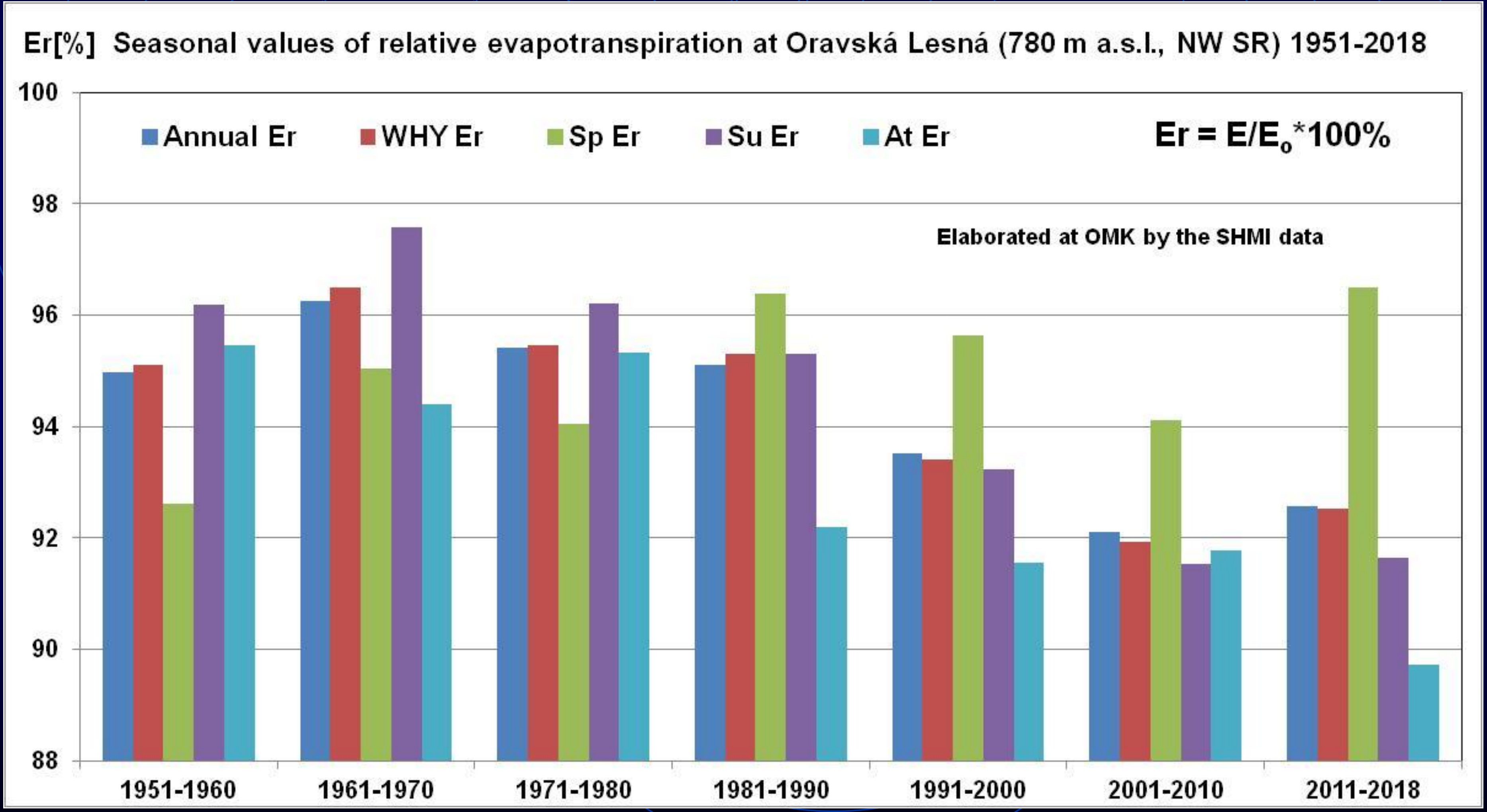


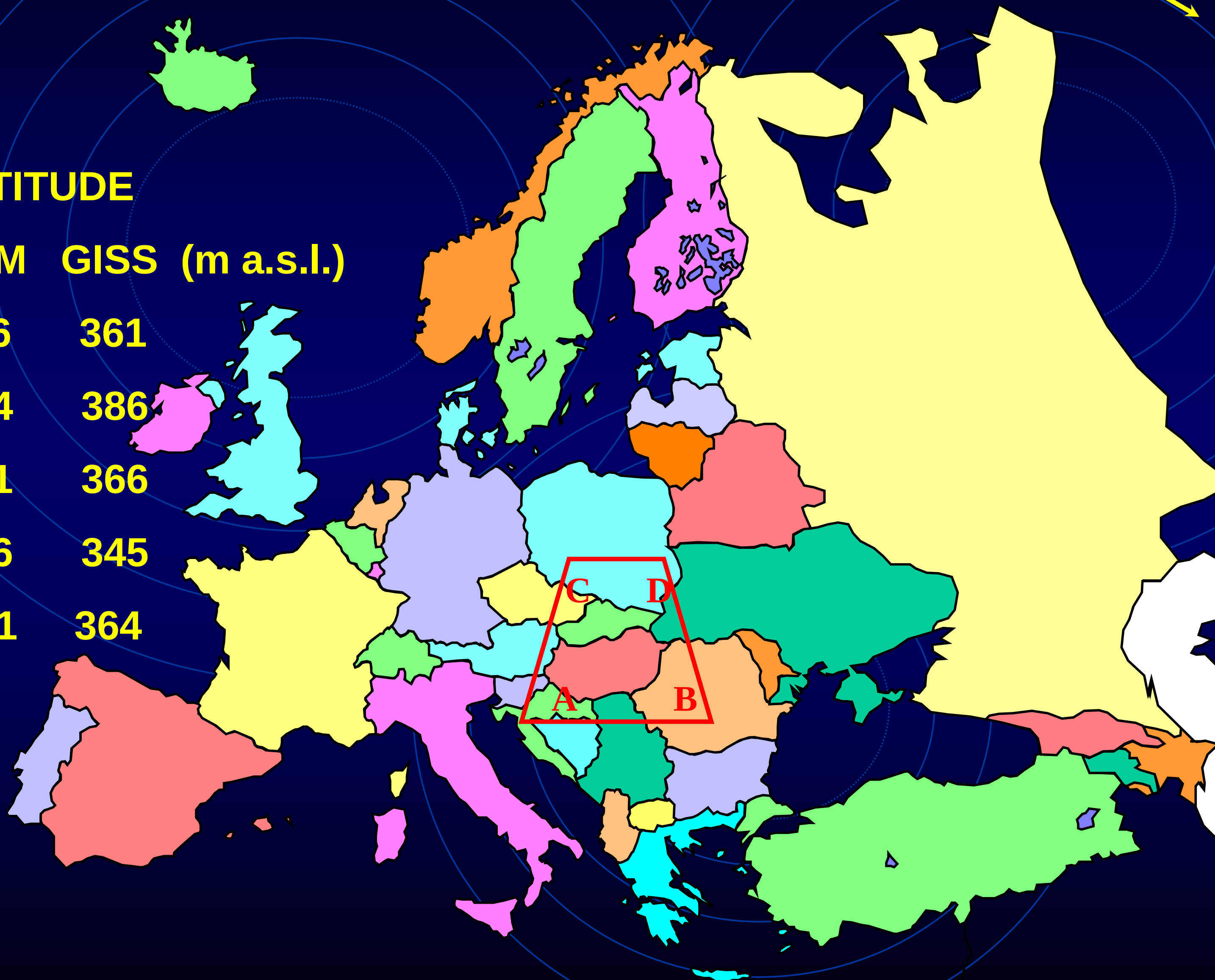
CLIMATE CHANGE SCENARIOS SUMMARY

- Scenarios based on the Atmosphere General Circulation Models - GCMs (Atmosphere-Ocean Models and Regional Models at present)
- Scenarios based on historical analogues
- Incremental scenarios – acceptable for impact models testing only
- Stochastic weather generator based time series as scenarios
- Combined scenarios – 1. Step: selection of reliable T (temperature), R (precipitation) and s (specific humidity) GCMs scenarios and
  2. Step: calculation of analogs for other climatic/hydrologic elements using correlation/regression and simple modeling – scenarios for whole distribution range – **Priority in Slovakia**
- Scenarios for time frames, time series, extremes...
- The first series of scenarios in 1995, the second in 1997, then in 2000, 2010 and 2014 (comparison for 2010 time frame in the Graph)

4 CCCM2000 & GISS98 AND 9 CGCM3.1 GRID POINTS ROUND SLOVAKIA USED

ALTITUDE

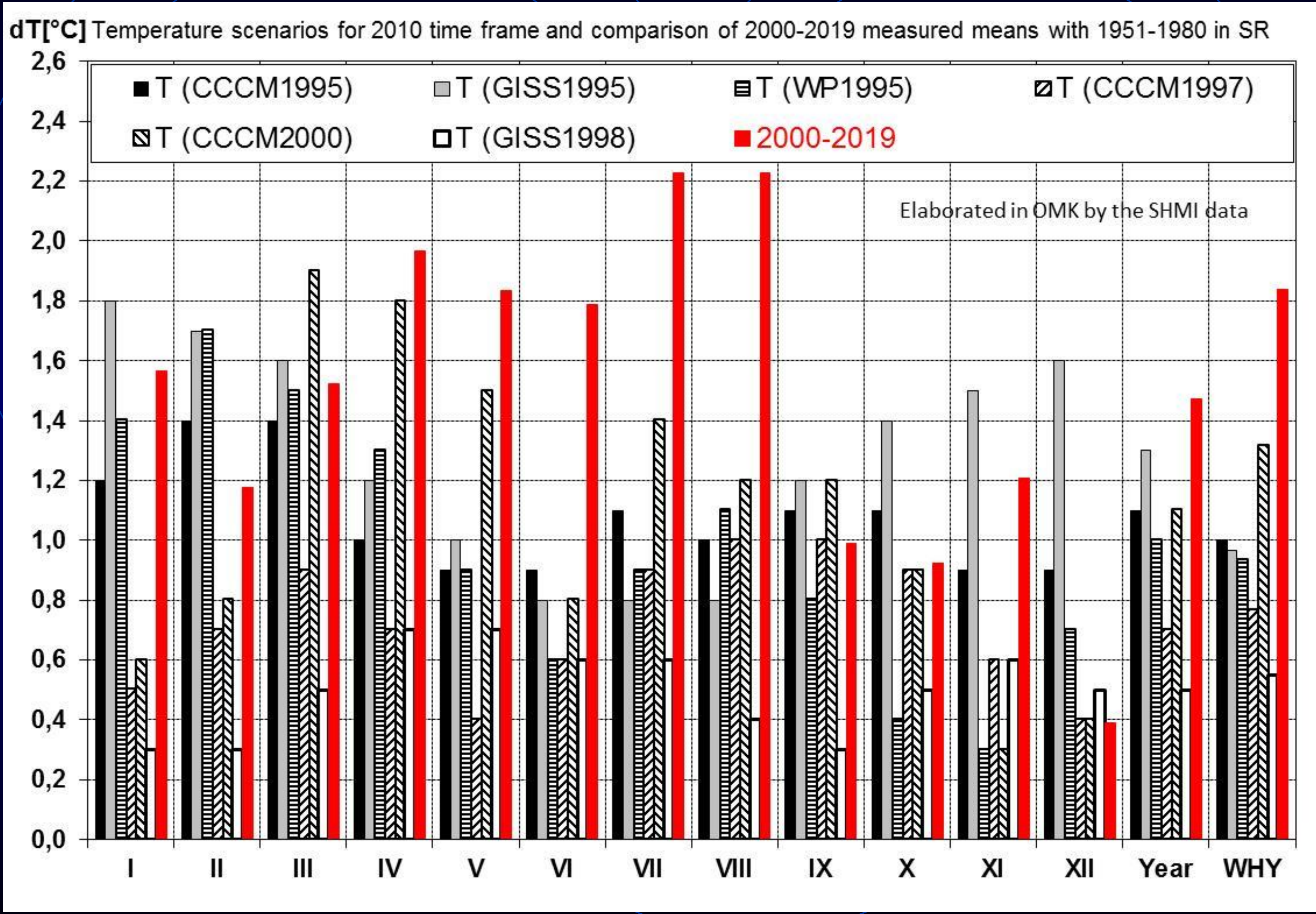
	CCCM	GISS (m a.s.l.)
A	616	361
B	554	386
C	531	366
D	566	345
	561	364



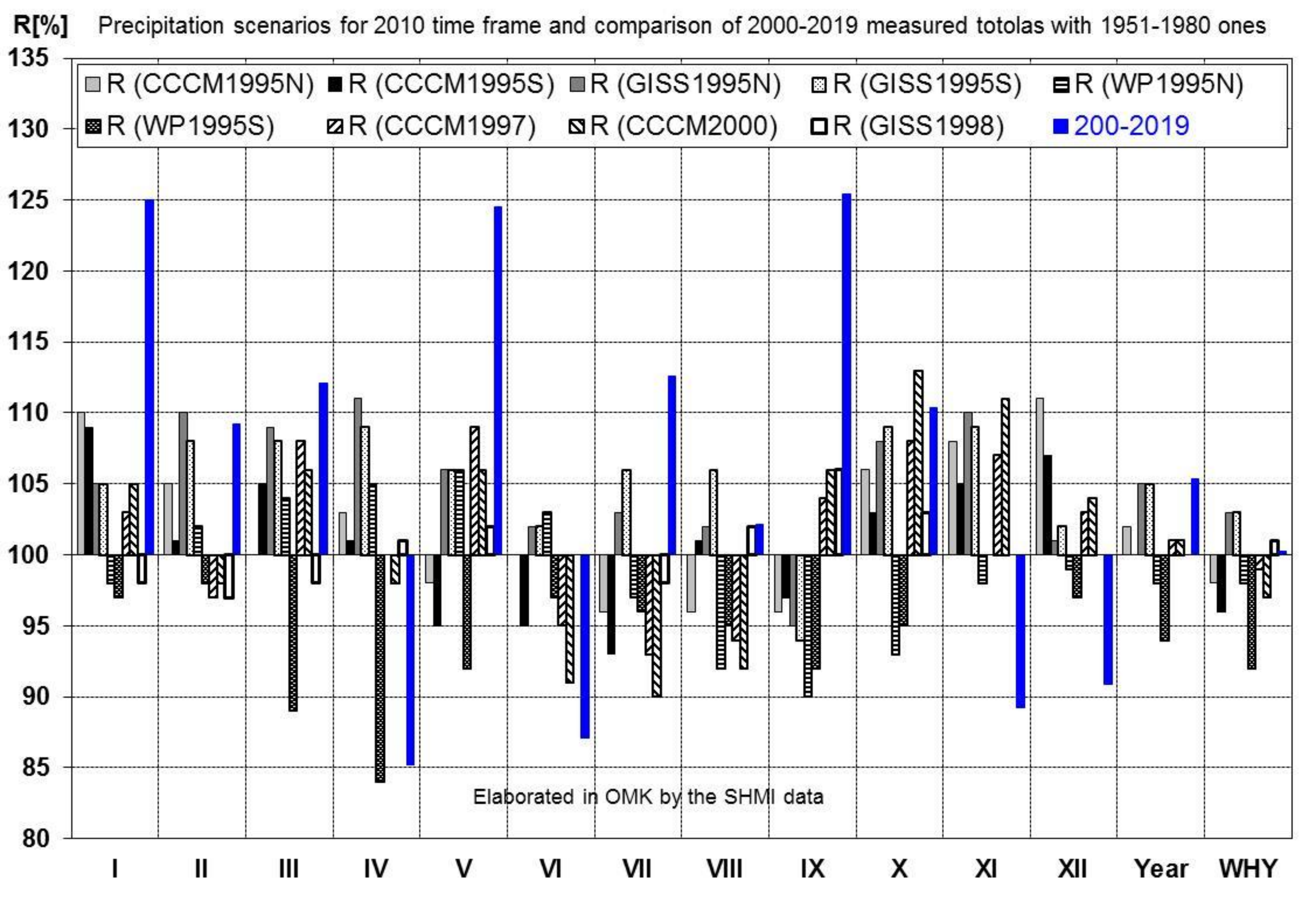
m a.s.l.

1	306 m
2	239 m
3	483 m
4	474 m
5	337 m
6	463 m
7	193 m
8	200 m
9	216 m

CLIMATE CHANGE SCENARIOS

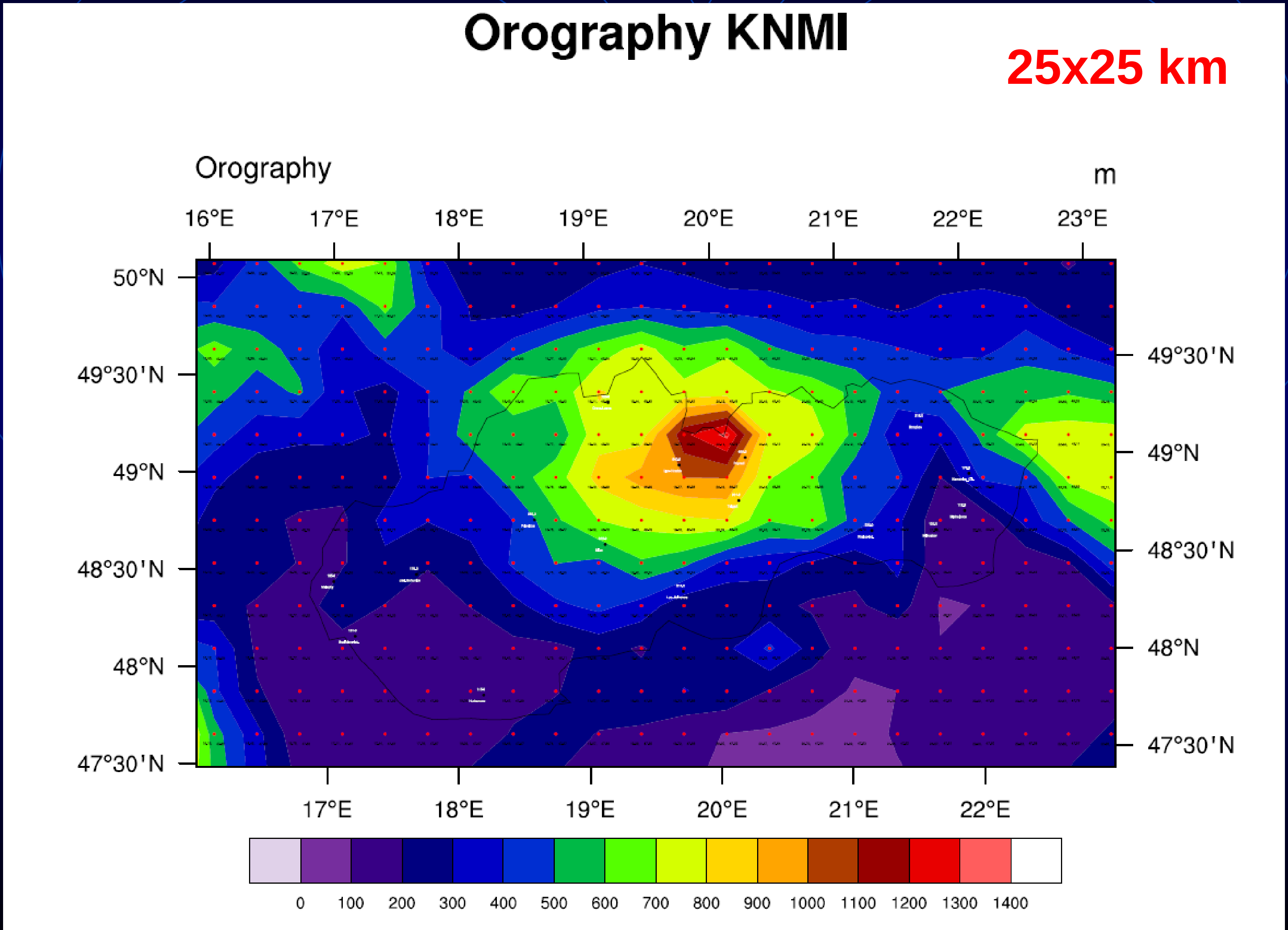


CLIMATE CHANGE SCENARIOS

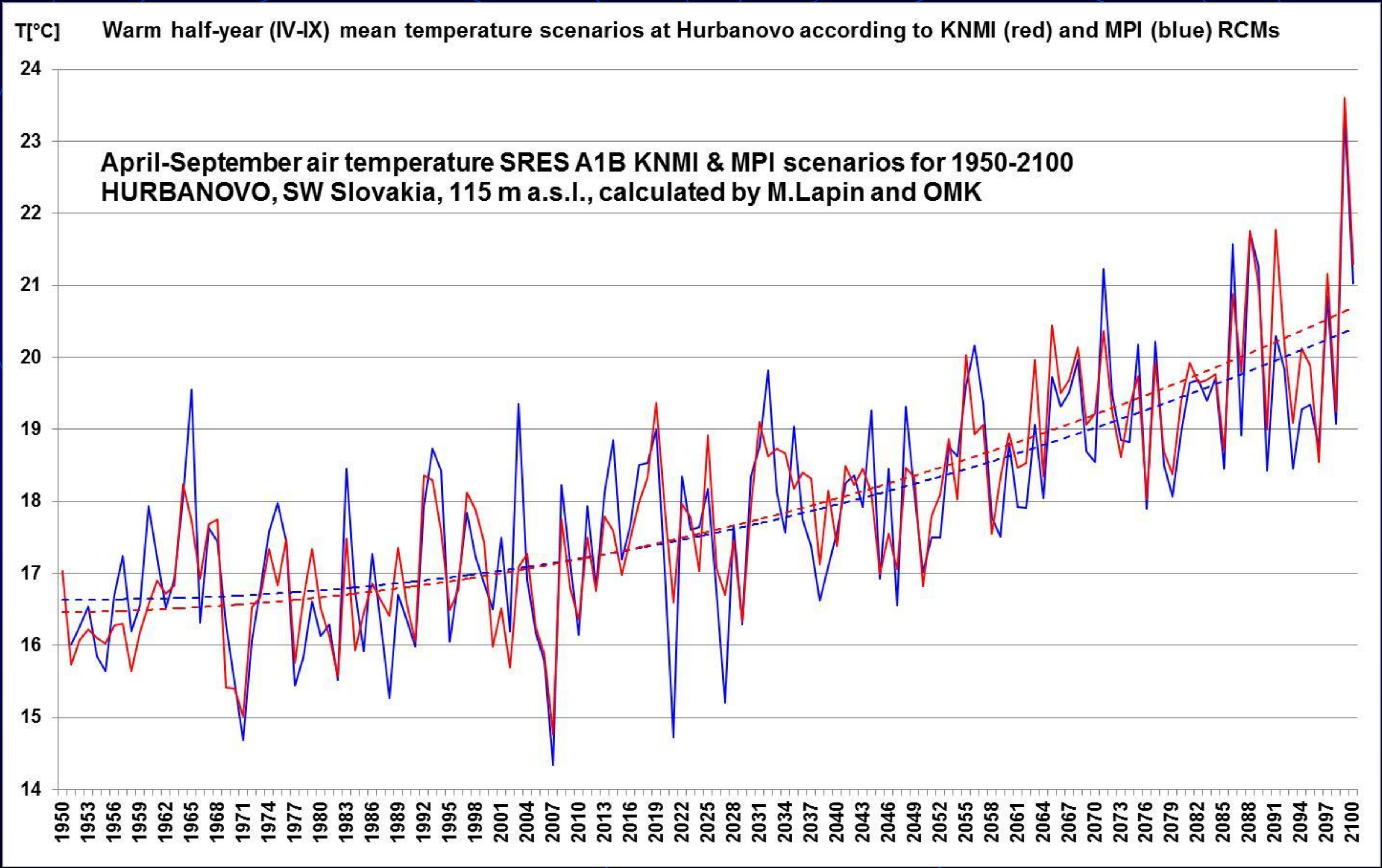


NEW REGIONAL CLIMATIC MODELS

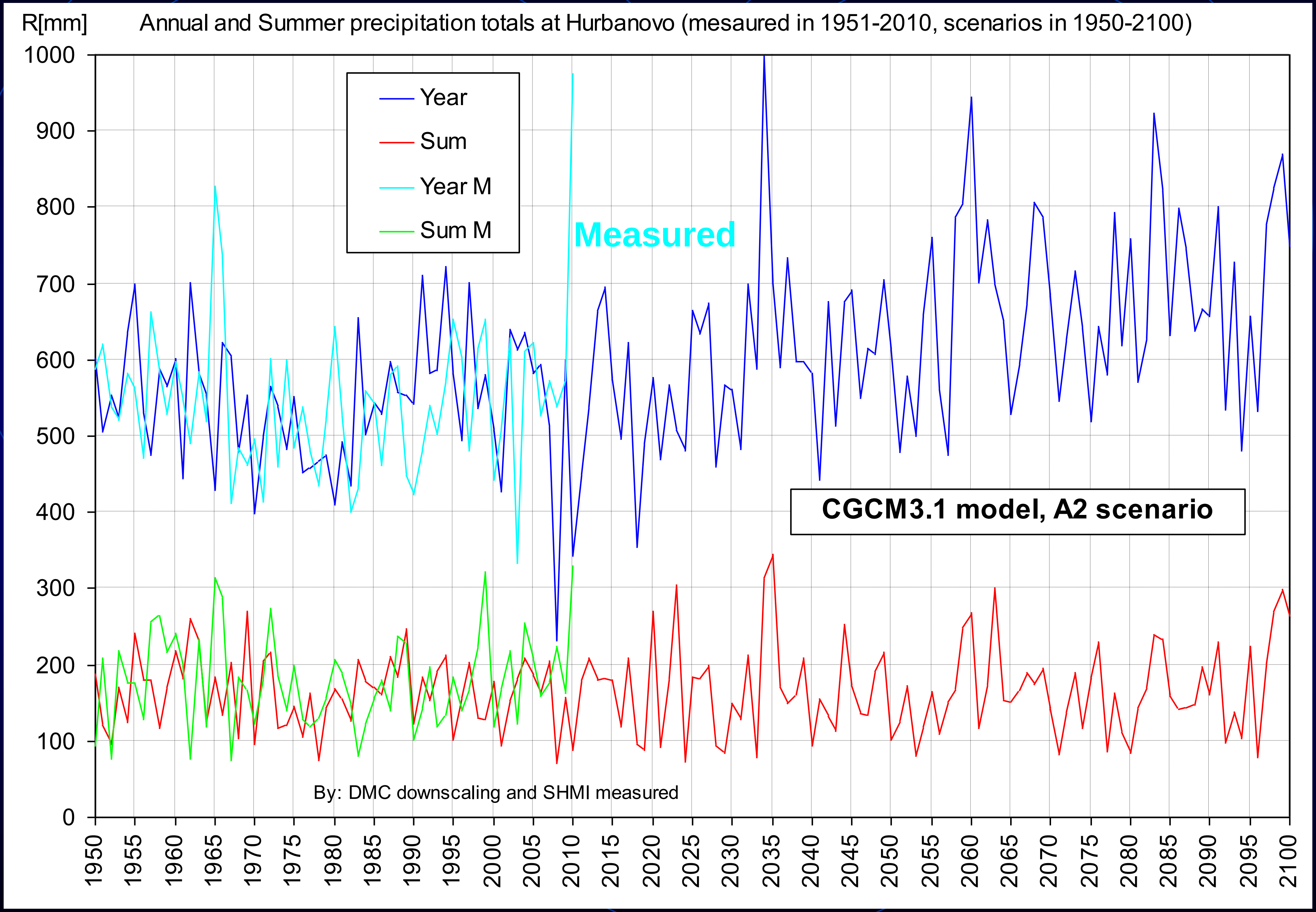
Dutch KNMI and German MPI based on Global model ECHAM5, 2012



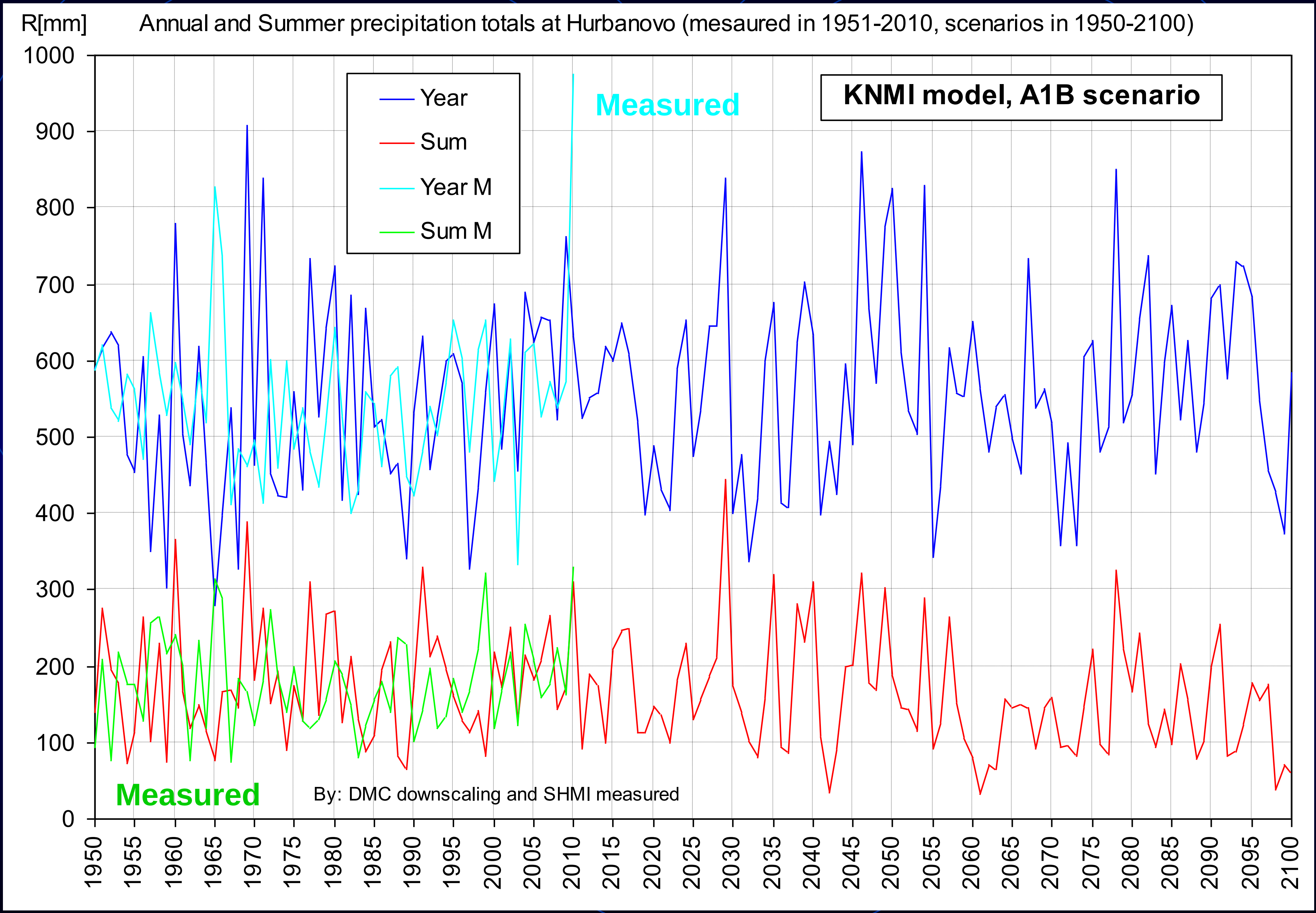
AIR TEMPERATURE SCENARIOS FOR HURBANOVO



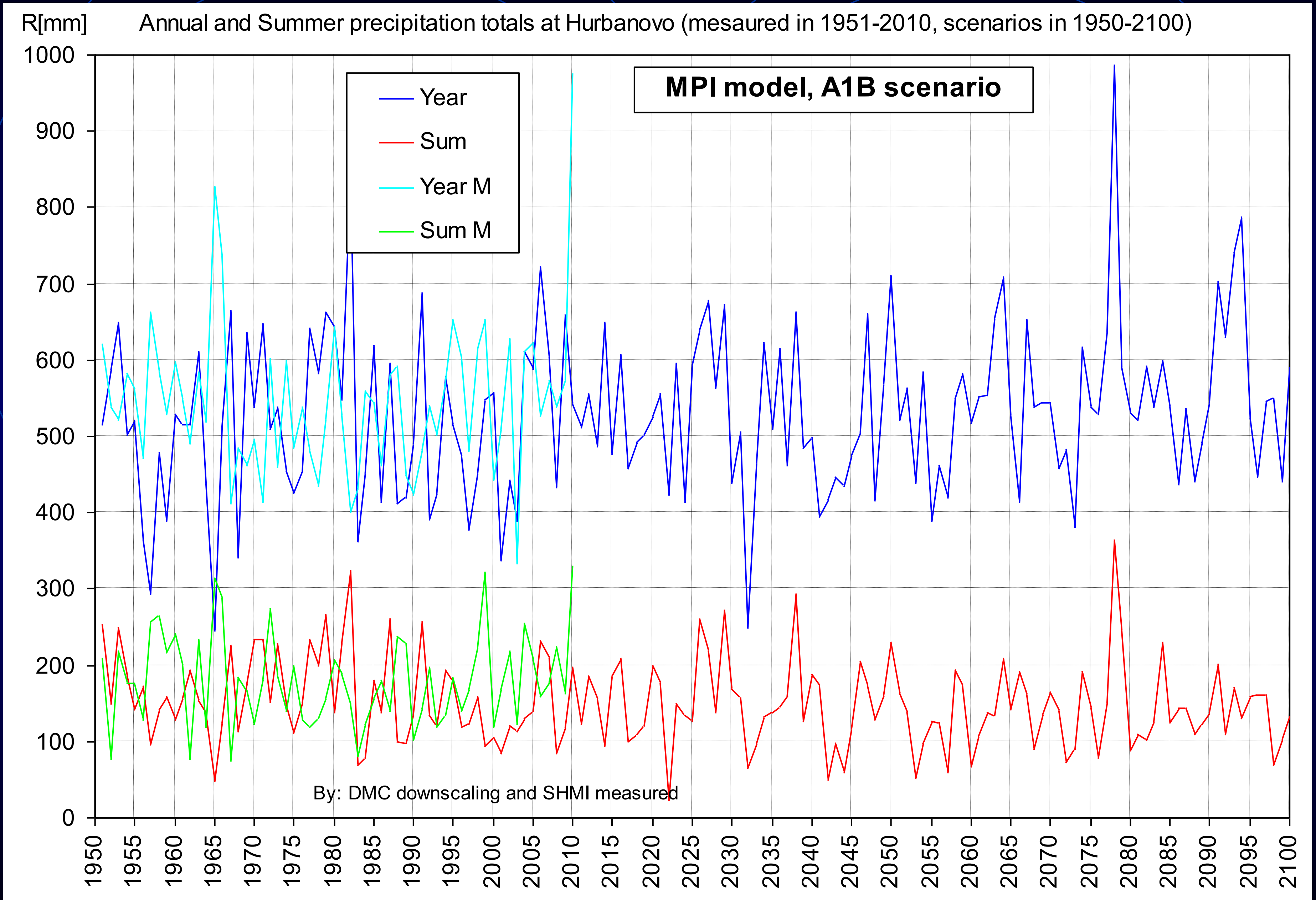
PRECIPITATION SCENARIOS FOR HURBANOVO, ANNUAL AND SUMMER



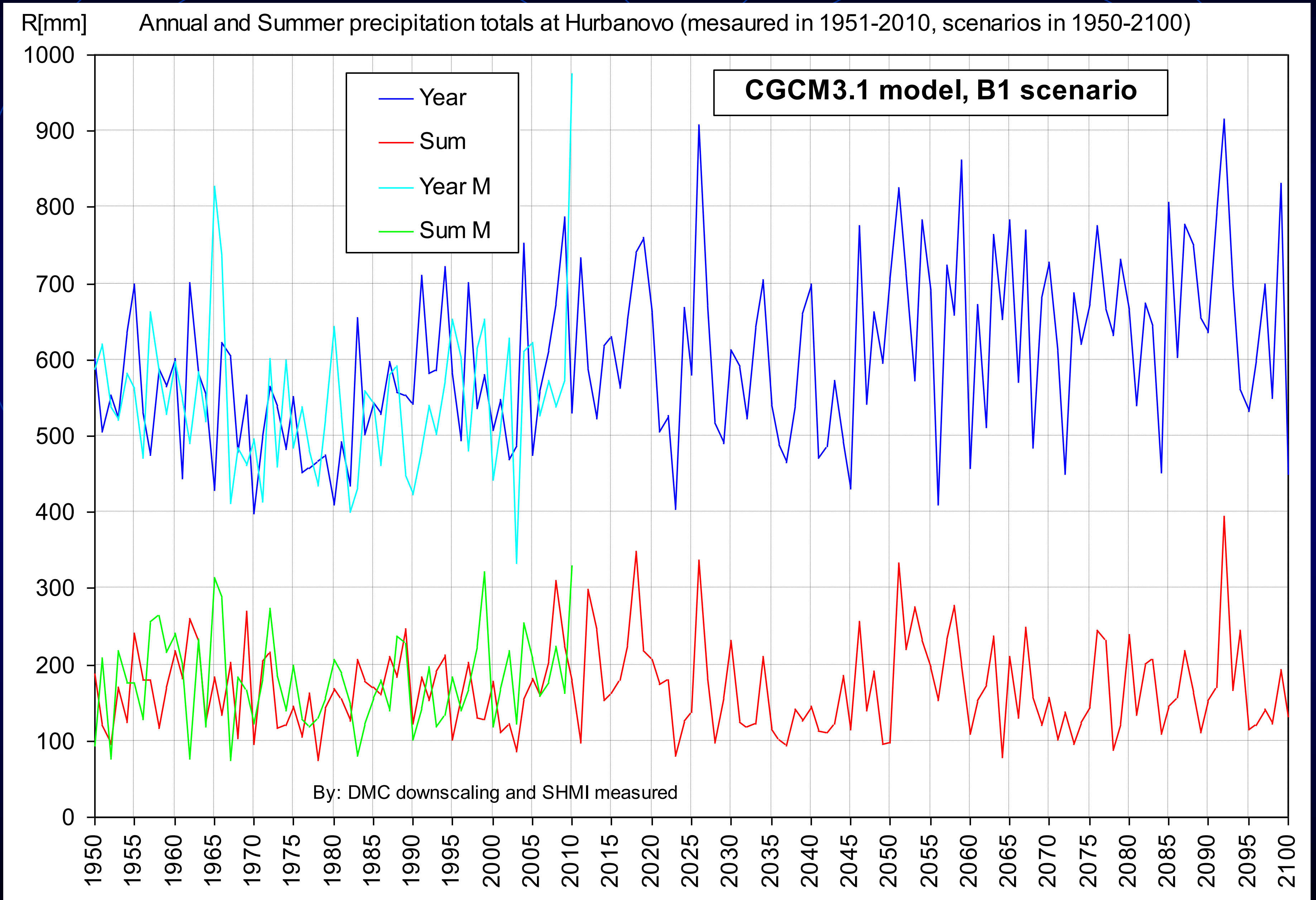
PRECIPITATION SCENARIOS FOR HURBANOVO, ANNUAL AND SUMMER



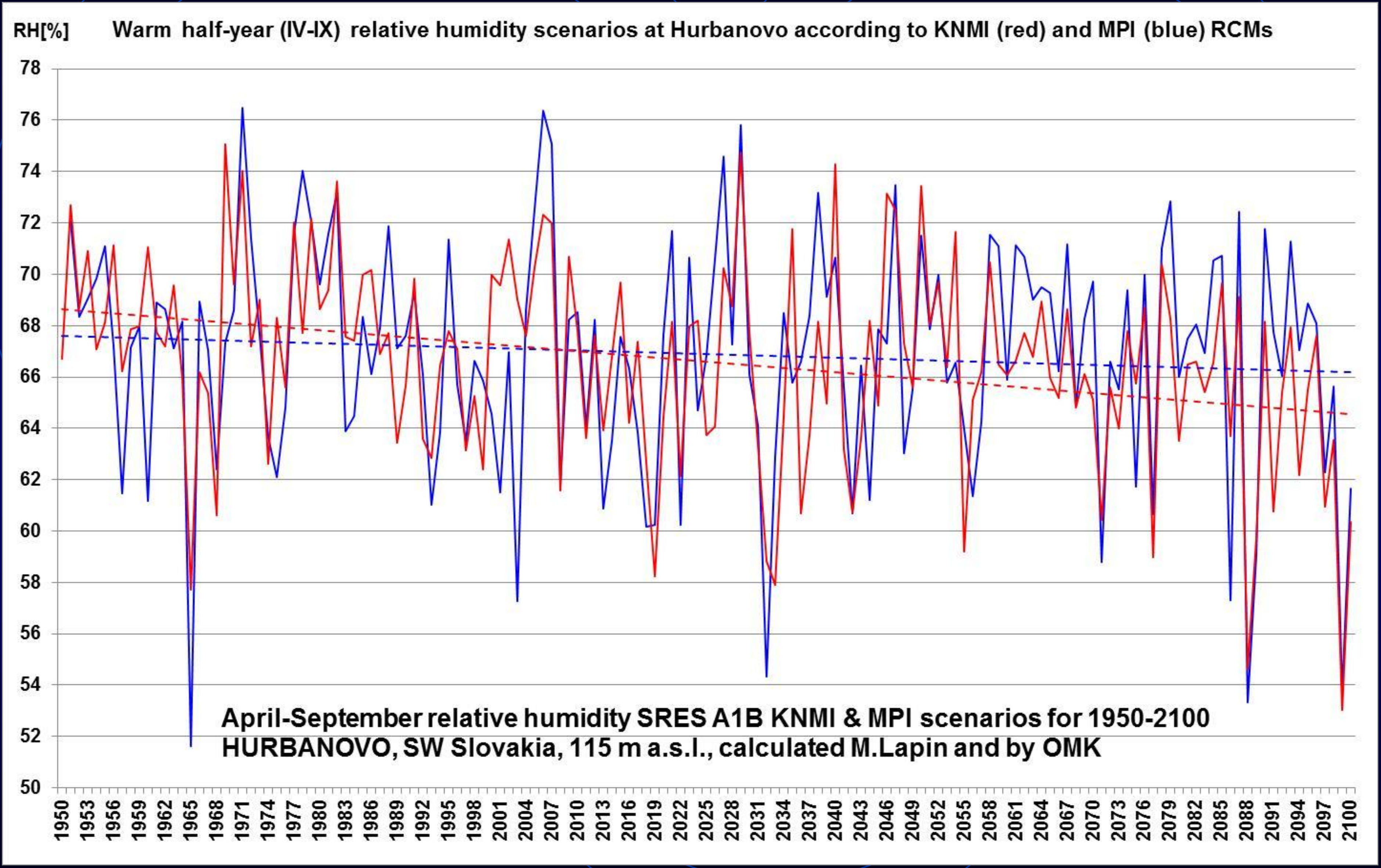
PRECIPITATION SCENARIOS FOR HURBANOVO, ANNUAL AND SUMMER



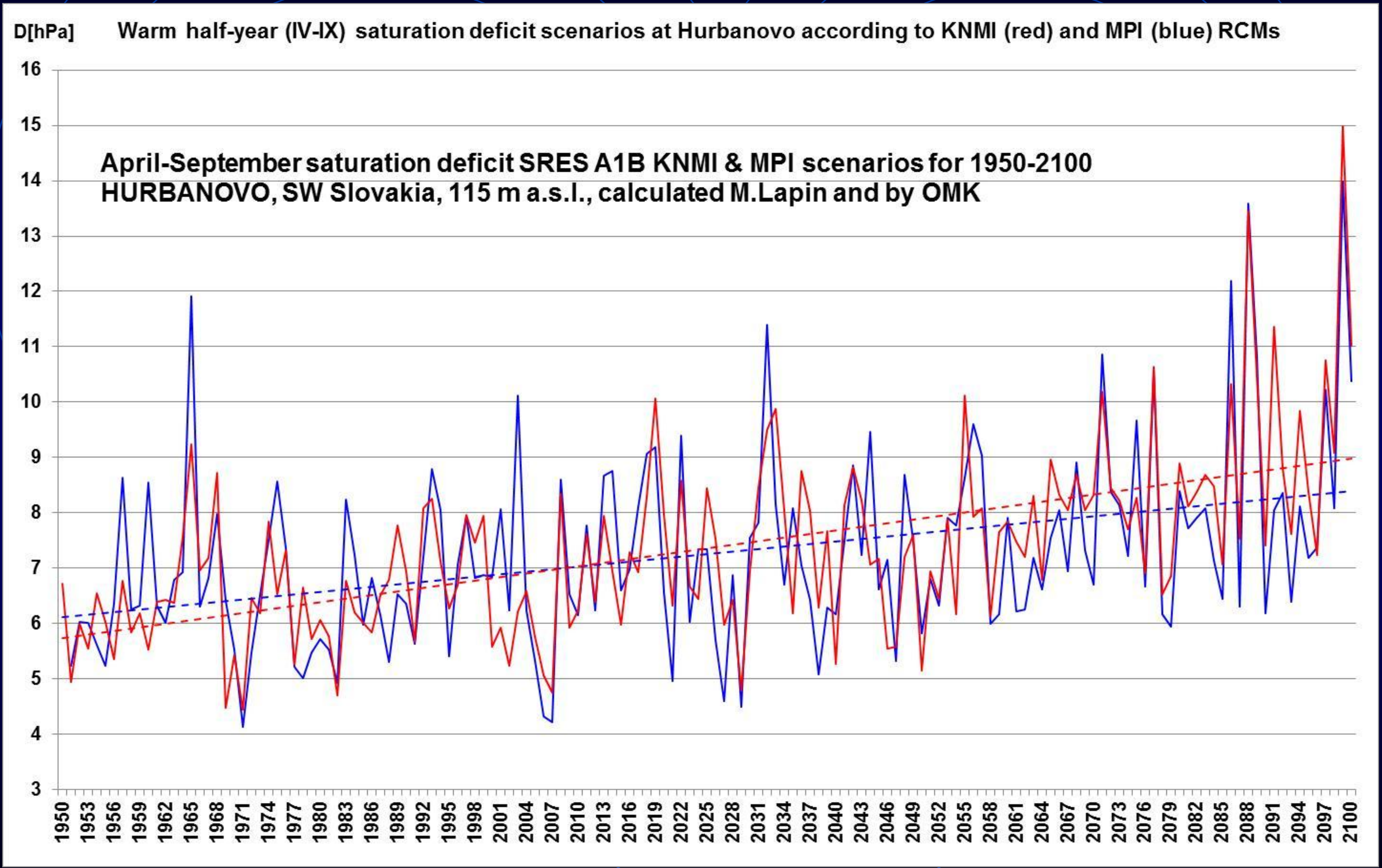
PRECIPITATION SCENARIOS FOR HURBANOVO, ANNUAL AND SUMMER



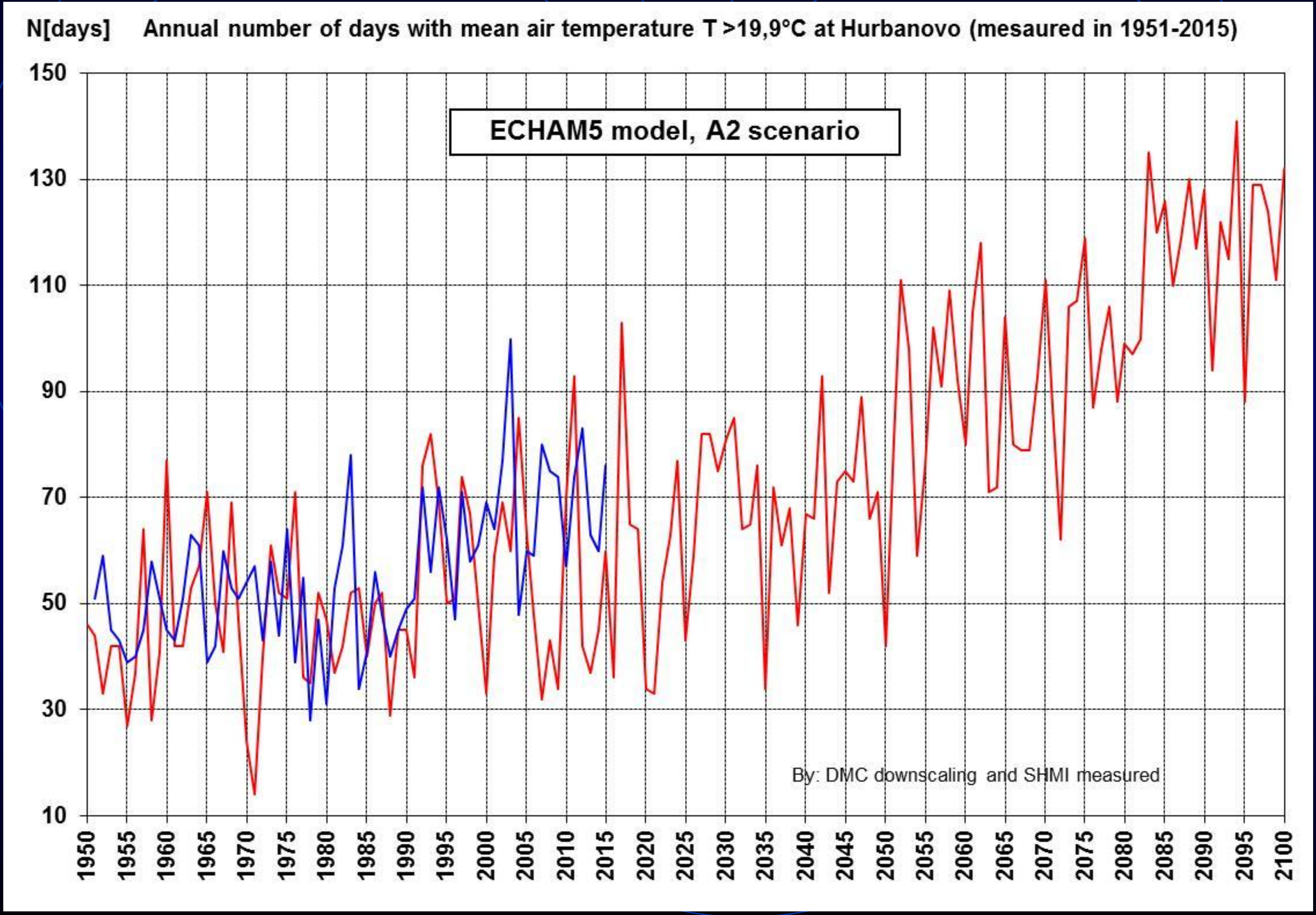
RELATIVE HUMIDITY SCENARIOS FOR HURBANOVO



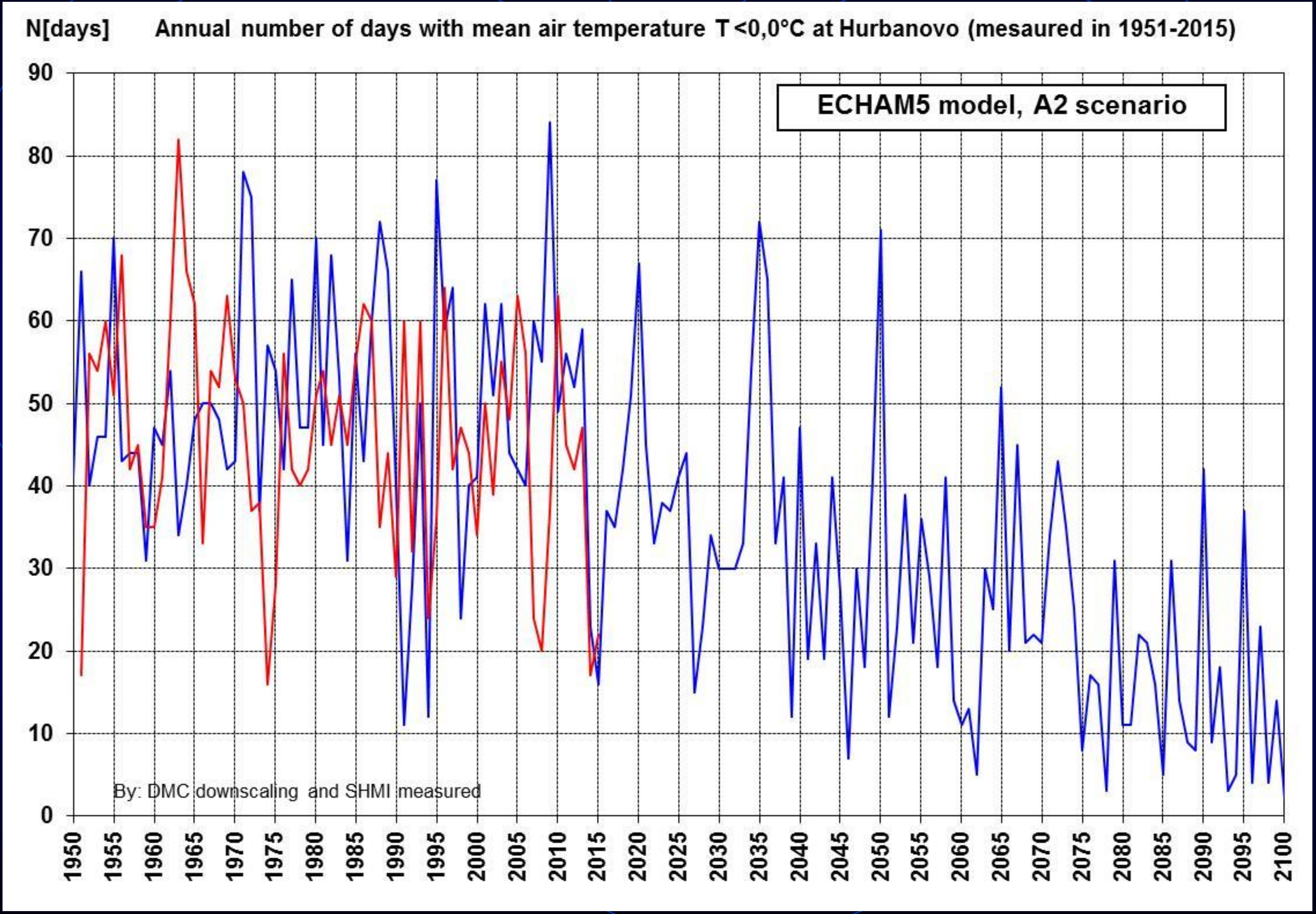
SATURATION DEFICIT SCENARIOS FOR HURBANOVO



TEMPERATURE SCENARIOS FOR HURBANOVO

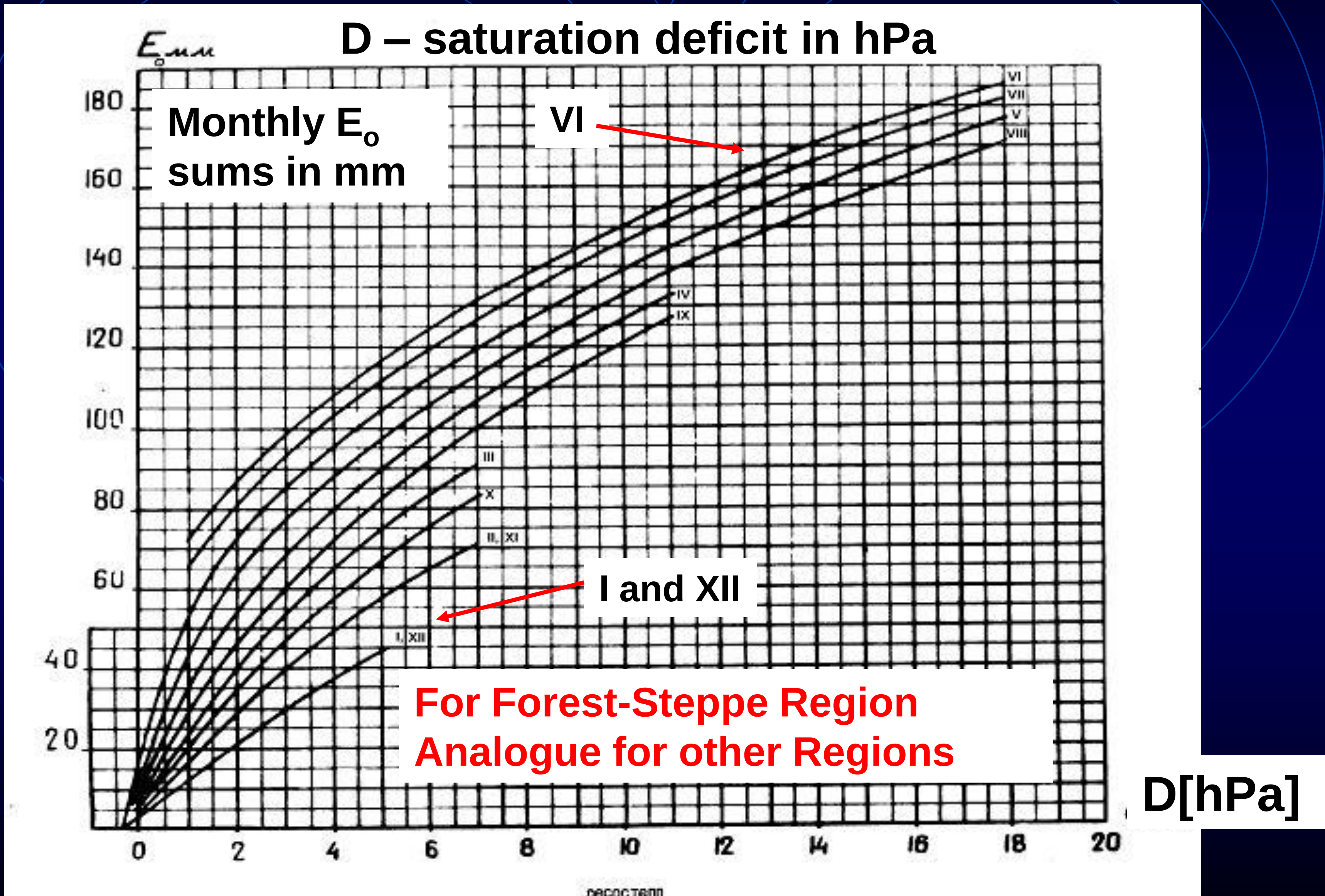


TEMPERATURE SCENARIOS FOR HURBANOVO

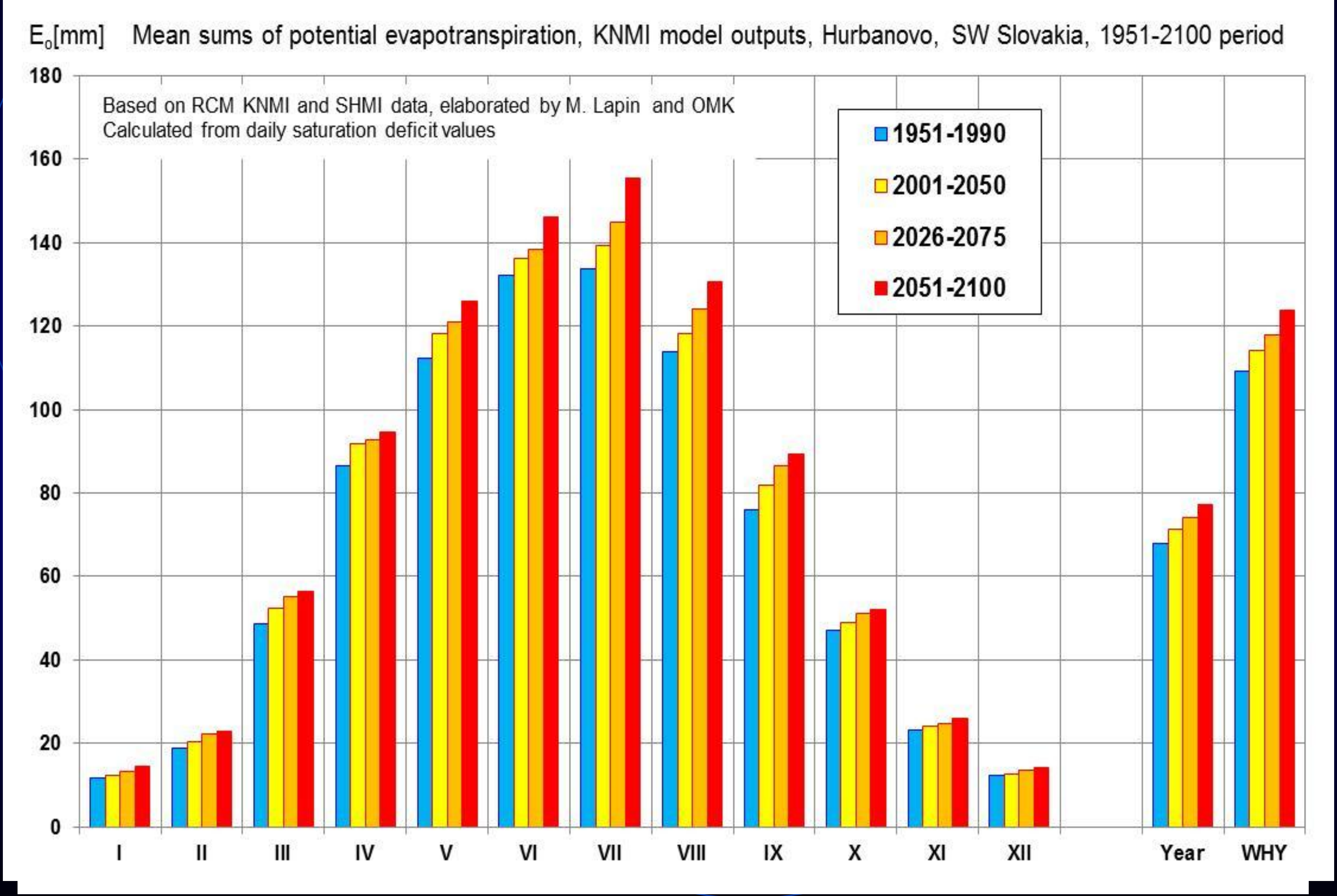


SIMPLE METHOD OF E_o CALCULATION

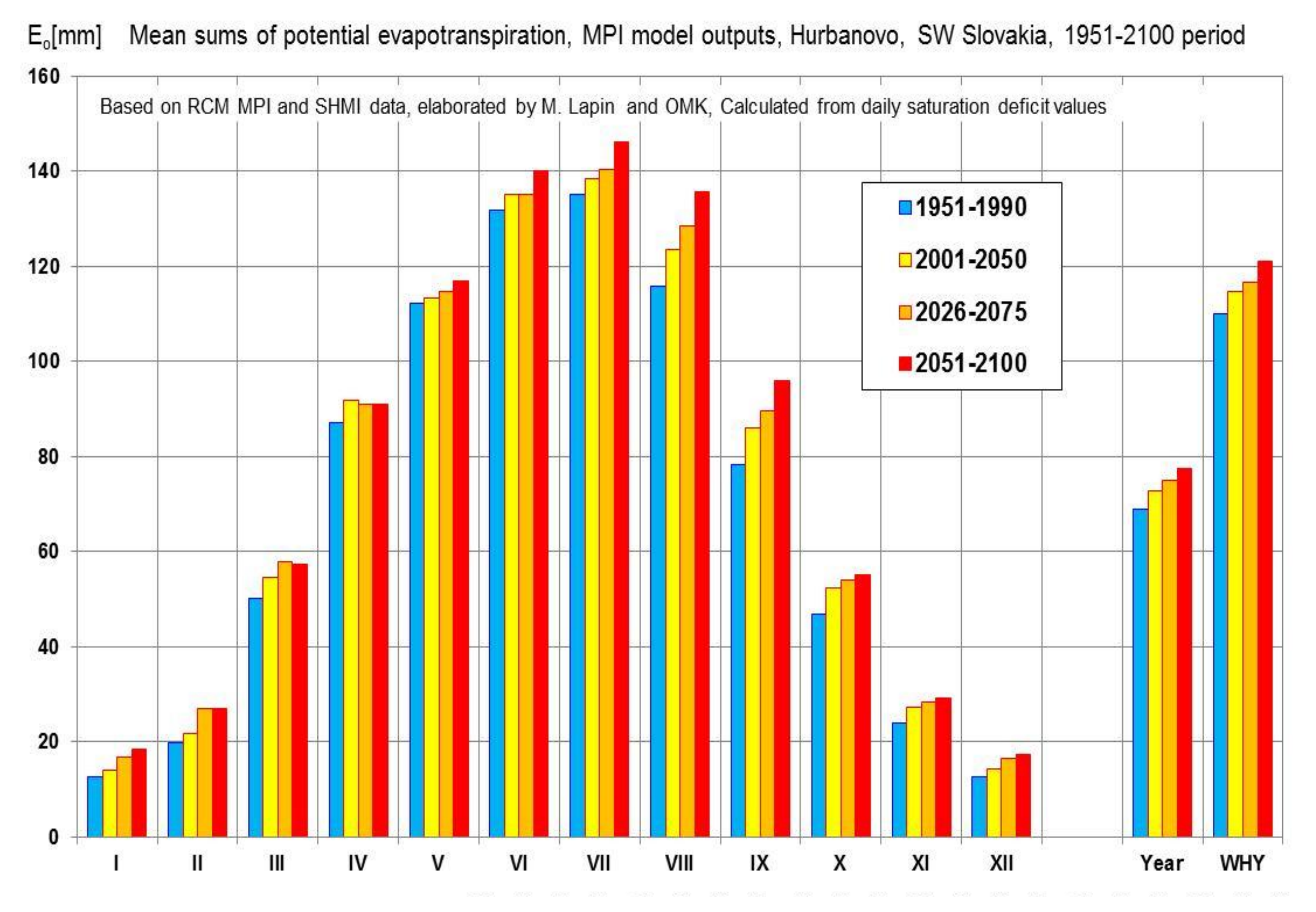
By Zubenok, L.I., agreed in Russia as official since 1976



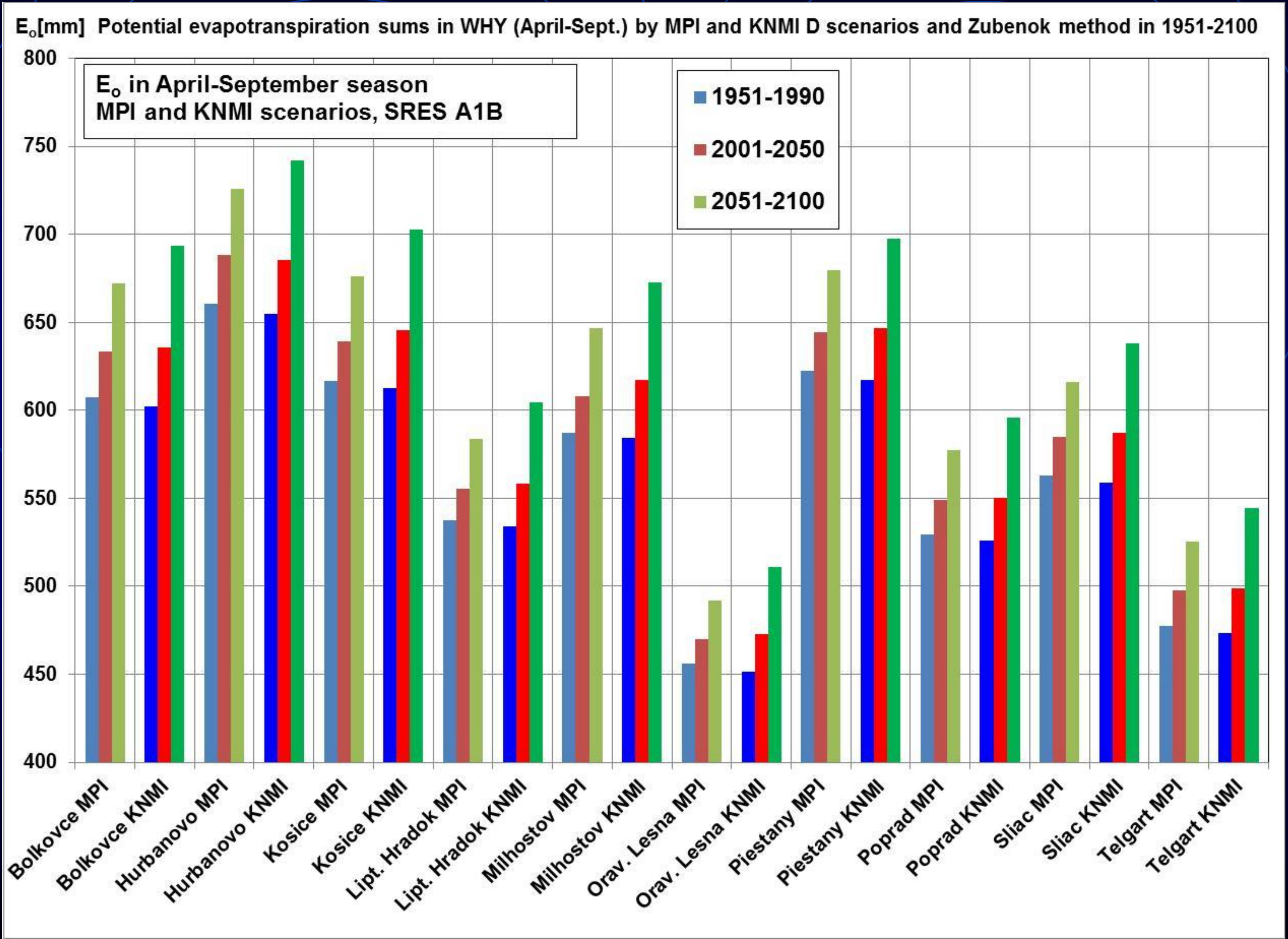
POTENTIAL EVAPOTRANSPIRATION SCENARIOS FOR HURBANOVO BY KNMI RCM, SRES A1B



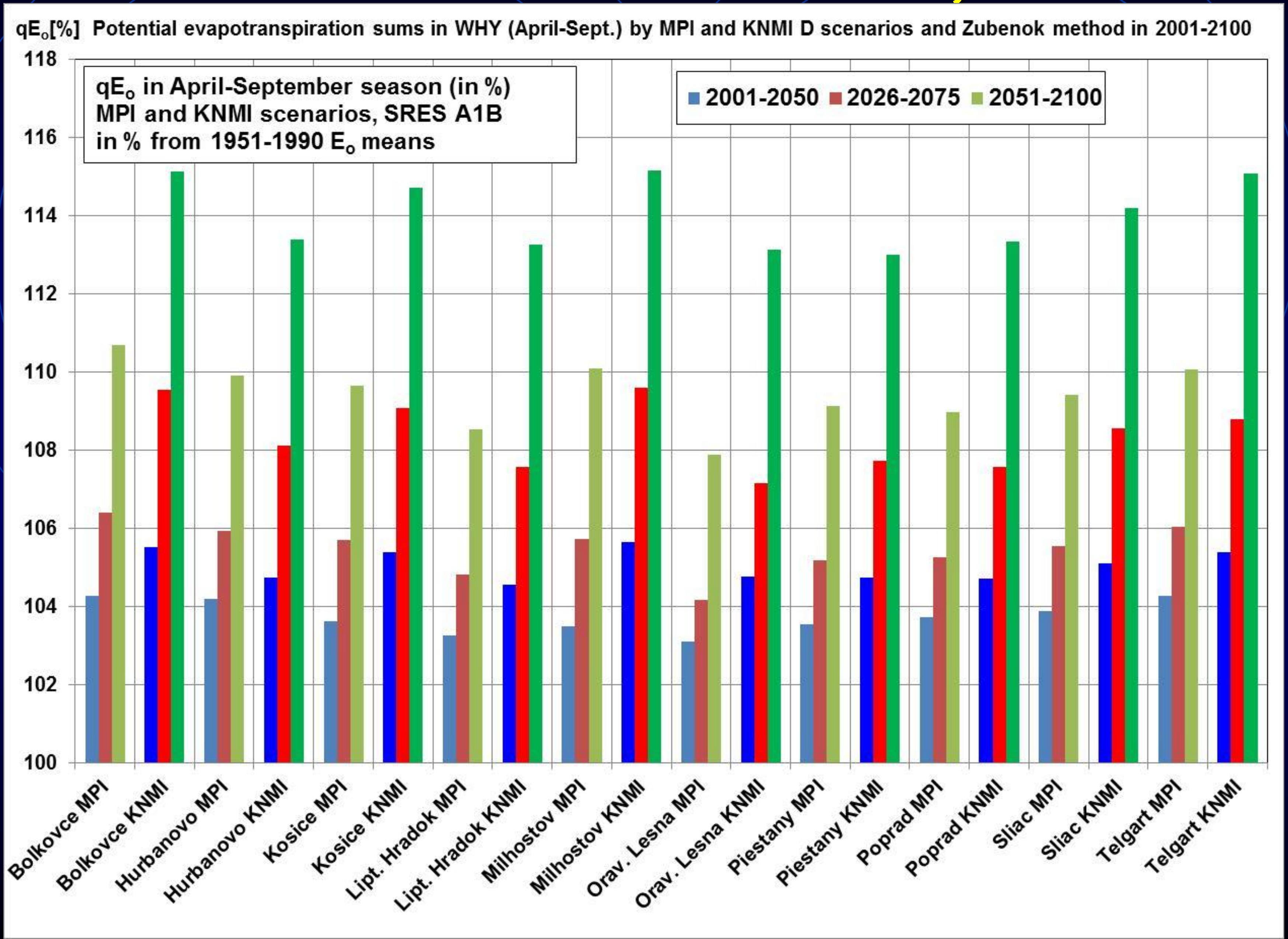
POTENTIAL EVAPOTRANSPIRATION SCENARIOS FOR HURBANOVO BY MPI RCM, SRES A1B



POTENTIAL EVAPOTRANSPIRATION SCENARIOS FOR 10 STATIONS BY MPI & KNMI RCMs, SRES A1B



POTENTIAL EVAPOTRANSPIRATION SCENARIOS FOR 10 STATIONS BY MPI & KNMI RCMs, SRES A1B



ABSTRACT 2

- The summer type of heavy rains possibly causing flash floods in Slovakia occurred in the 1950-2010/2018 period has been analyzed.
- Totally 557 precipitation stations have uninterrupted series in 1950-2018. Mean annual precipitation totals vary between about 550 mm in the lowlands and 2200 mm in the High Tatras.
- Absolute summer maximum in daily totals was 232 mm at Salka on July 17, 1957. The 1-day total with 100 years return period is above 150 mm in some regions, but only about 80 mm in several lowland areas, at 5-day totals it is above 320 mm in the Little Carpathians, above 200 mm in the most of mountainous areas, only below 100 mm in central part of the Danubian lowland in SW Slovakia
- Simplified equation for calculation of short-term precipitation totals at changing air temperature (T), specific air humidity (q) and vertical velocity (w) was developed. These short-term precipitation scenarios follow the T and q outputs of the GCMs and RCMs models by presumption that the w at condensation process will slightly increase with rising T and q, mainly in the summer months. Projected increase in precipitation totals for extreme precipitation events (causing flash floods) is 20-40% at short-term (stormy) totals and 15-30% at 3- to 5-day totals by the 2075 time frame

CLIMATE CHANGE SCENARIOS OF EXTREME 5-DAYS PRECIPITATION

- **Simplified equation for calculation of short-term precipitation totals at changing air temperature (T):**

$$R = g^{-1} \int_{to}^{t} \int_{pc}^{0} \omega \frac{ds}{dp} . dp . dt$$

- **g** ≈ 9.8 m.s^{-2}, ω = **dp/dt = -ρ.g.*w*** – e.g. generalized vertical velocity, ***w*** – vertical component of wind velocity vector, ***s*** – specific air humidity above the condensation level **p$_c$**, **p** – air pressure, **t** – time, ρ - air density

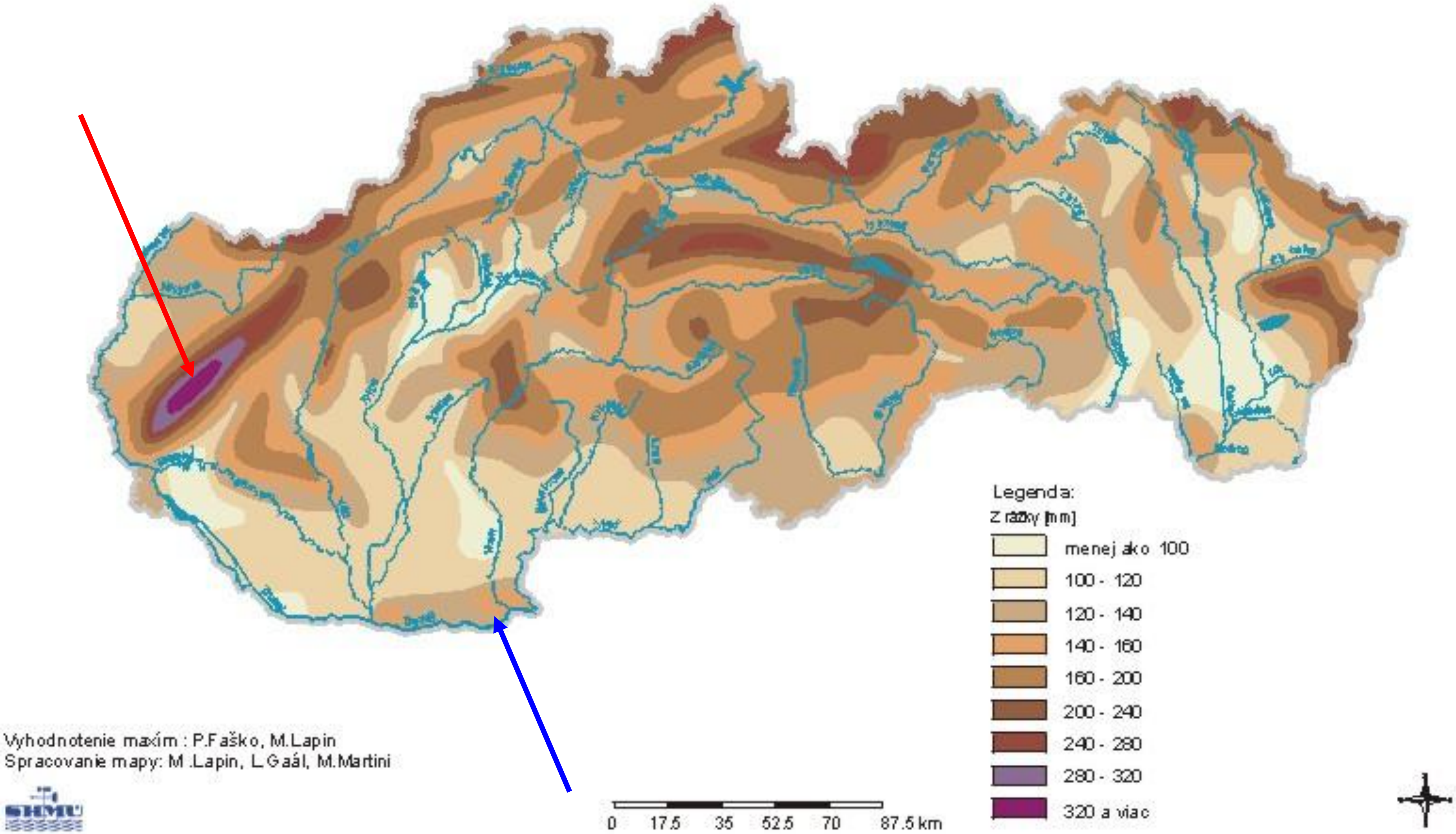
CLIMATE CHANGE SCENARIOS OF EXTREME 5-DAYS PRECIPITATION, 2001

Model	Horizon	IV	V	VI	VII	VIII	IX	X	XI
CCCM1997	2010	1.07	1.05	1.10	1.13	1.12	1.10	1.10	1.11
	2030	1.11	1.10	1.16	1.20	1.17	1.15	1.13	1.12
	2075	1.25	1.29	1.41	1.47	1.42	1.36	1.28	1.24
CCCM2000	2010	1.18	1.19	1.11	1.15	1.12	1.10	1.09	1.07
	2030	1.25	1.25	1.17	1.24	1.18	1.14	1.12	1.11
	2075	1.38	1.41	1.38	1.47	1.37	1.31	1.28	1.25
GISS1998	2010	1.07	1.08	1.08	1.08	1.06	1.05	1.05	1.05
	2030	1.09	1.11	1.11	1.11	1.08	1.07	1.08	1.10
	2075	1.26	1.25	1.25	1.28	1.28	1.23	1.21	1.25

Scenarios of 5-day heavy precipitation qR are combined from R increase due to rise of s* at warming dT, some rise of w and rise of turbulence in warmer air

Slovakia - Annual maximum in 5-day precipitation totals with 100-year return period

In case of 2 – 4 °C warming these values can increase by 20 – 40%



CONCLUSIONS

- According to reliability evaluation the temperature scenarios are the best, precipitation scenarios are partly uncertain with clear tendency – increase in winter (mainly in the North), small changes in Summer
- Scenarios of hydrological balance elements, drought and soil moisture is a serious problem – basic tendency is also clear – increase of E_o, longer and more dangerous drought spells
- Regional Circulation Models offer better results – more realistic topography, more reliable fields of climatic and hydrologic data
- This impacts also the reliability of scenarios for air humidity, precipitation, evapotranspiration and soil moisture regime
- Several different GCMs/RCMs and Emission scenarios are needed
- Statistical downscaling of outputs from 25x25 km grids enables quite detail assessment also in saturation deficit development
- This is inevitable step prior to E_o, E and soil moisture scenarios calculation for the selected sites in Slovak regions / river basins
- Further development of these methods will be directed to the analyses of temporal and areal variability of hydrologic balance

THANK YOU FOR THE ATTENTION

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