BASIC FACTS ON CLIMATE CHANGE, POSSIBLE IMPACTS, ADAPTING AND MITIGATION OPTIONS

Milan LAPIN

Faculty of Mathematics, Physics and Informatics,
Comenius University, Bratislava, SLOVAKIA

lapin@fmph.uniba.sk , www.milanlapin.estranky.sk , www.ipcc.ch

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Basic facts (1)
Definitions

- **Meteorology –** Science on the Earth's atmosphere, its composition, attributes, and on the processes taken place in it (simply on the weather, or actual state of the atmosphere, and on weather forecast up to 16 days)
- **Climatology –** Science on the Earth's climates, on the connections and reasons of the certain climatic conditions origination and changes, on impacts of climate on human activities and vice versa (simply on the long-term weather regime (≥ 30 years) in the relationship with geographic conditions, ecosystems and socio-economic sphere)
- **Hydrology –** Science on the temporal and areal patterns of water circulation on the Earth, as well as on its physical, chemical and biological regime (relations among Meteorological, Climatic and Hydrologic regimes are also important). All 3 branches are solved in SR in the SHMI.

Basic facts (2) - study

- Objects of meteorology, climatology and hydrology, their relation with other socio-economic branches and environment
- Historical development of these branches as scientific and applied activities in Slovakia and abroad (1593 thermoscope)
- World Meteorological Organization (WMO), WMO Commission for meteorol., climatol., and hydrol., World Climate Program (WCP) – contribution to the World Climate System (WCS) protection, and environment or natural systems protection
- Definition of climate system (atmosphere, hydrosphere, cryosphere, litosphere, biosphere, noosphere), climate forming factors (atronomic, terrestrial, circulation, anthropogene) and climate forming proceses – physical, chemical, biological...
- Regional and global extent of climate system and subsystems
- Statistical, physical, geographic and philosophical view on climate, climatology and hydrologic cycle
- Temporal and areal climate and hydrologic cycle variation

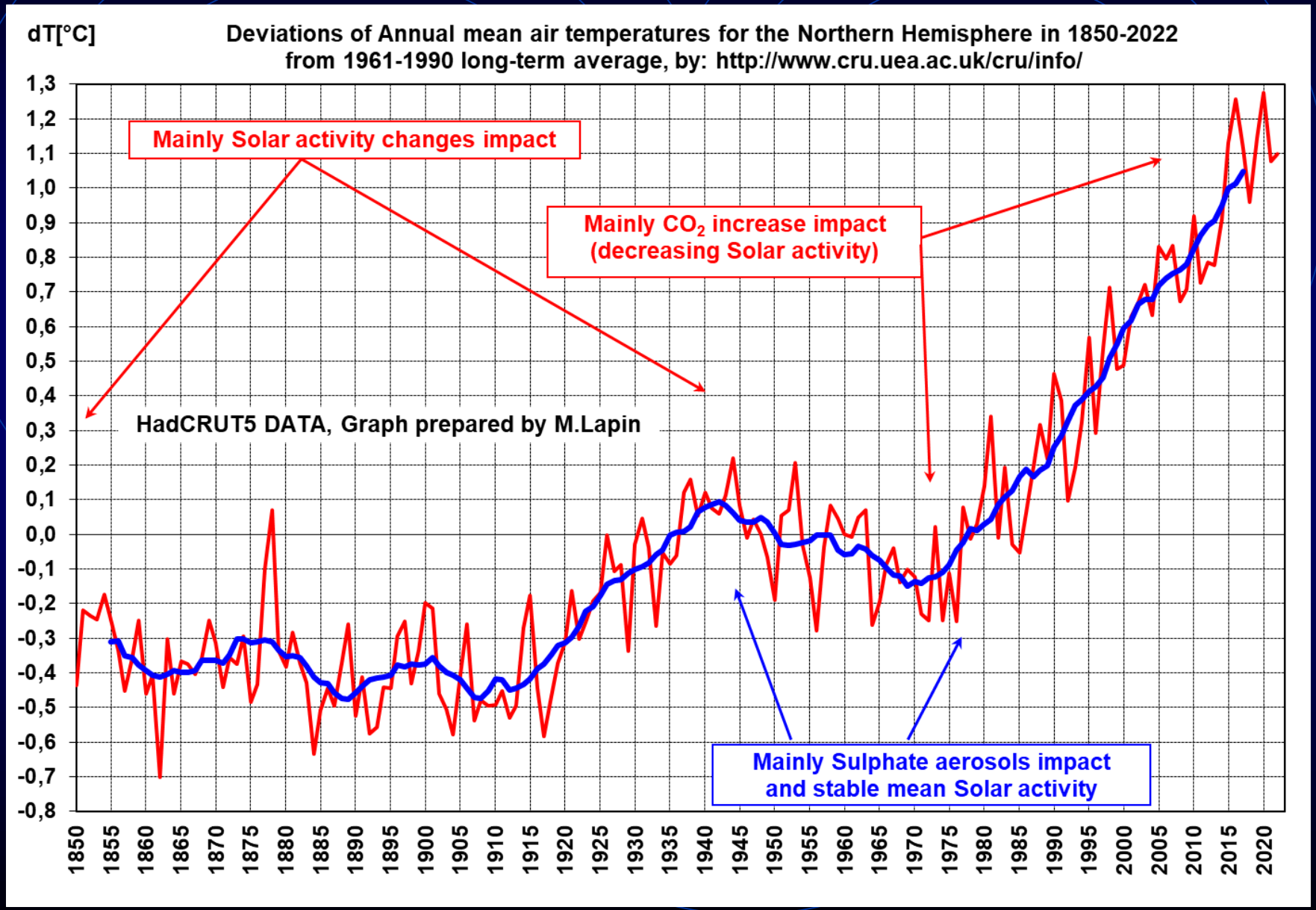
ABSTRACT 1

- „Climate change“ due to anthropogenic enhancement of greenhouse effect (besides of several other „climatic changes“ caused naturally)
- Up to 1945 the natural causes (Solar radiation changes, volcanoes, oceanic and air circulation oscillations…) are considered as principal
- In 1945-1985 the human interference (CO_2, sulfates, land use change…) was probably comparable with the natural ones
- Since 1985 the greenhouse gases (GHGs) emission by human activities (fossil fuels use, industry, transport, agriculture, land use…) surely exceeded the natural causes in greenhouse effect rise and climatic changes
- The period 1991-2022 – significant in exceptional weather events occurrence (heat waves, flash floods, drought, desertification, Arctic seaice decrease …)

ABSTRACT 2

- **Reliable time series of daily meteorological, hydrologic and other data are used at assessments of climate change vulnerability and impacts (in Slovakia since 1900)**
- **In Slovakia: Twelve GCMs outputs from 7 World Modeling Centers applied – CGCM2/3 (Canada) and GISS 1998 (USA) the most frequently used before 2010, 15 other tested, the newest ones used in Slovakia now are: GCMs CGCM3.1 and ECHAM5, and RCMs KNMI and MPI, all also with daily data and extremes. At present new RCMs outputs and new RCP emission scenarios are applied.**
- **Water cycle, water resources, water management, agriculture, field ecosystems, forestry, forest ecosystems – vulnerability and impacts studied**
- **Mitigation measures and their co-ordination with adaptation options in the Slovak National Reports on Climate Change (1995, 1997, 2001, 2005, 2009, 2014, 2017): https://www.minzp.sk/files/oblasti/politika-zmeny-klimy/7nc_svk.pdf in English**

VARIABILITY OF ANNUAL TEMPERATURE DEVIATIONS FROM THE 1961-1990 AVERAGE IN THE NORTHERN HEMISPHERE IN 1850-2022 (Air Temperatures, HADLEY-CRU UK DATA)



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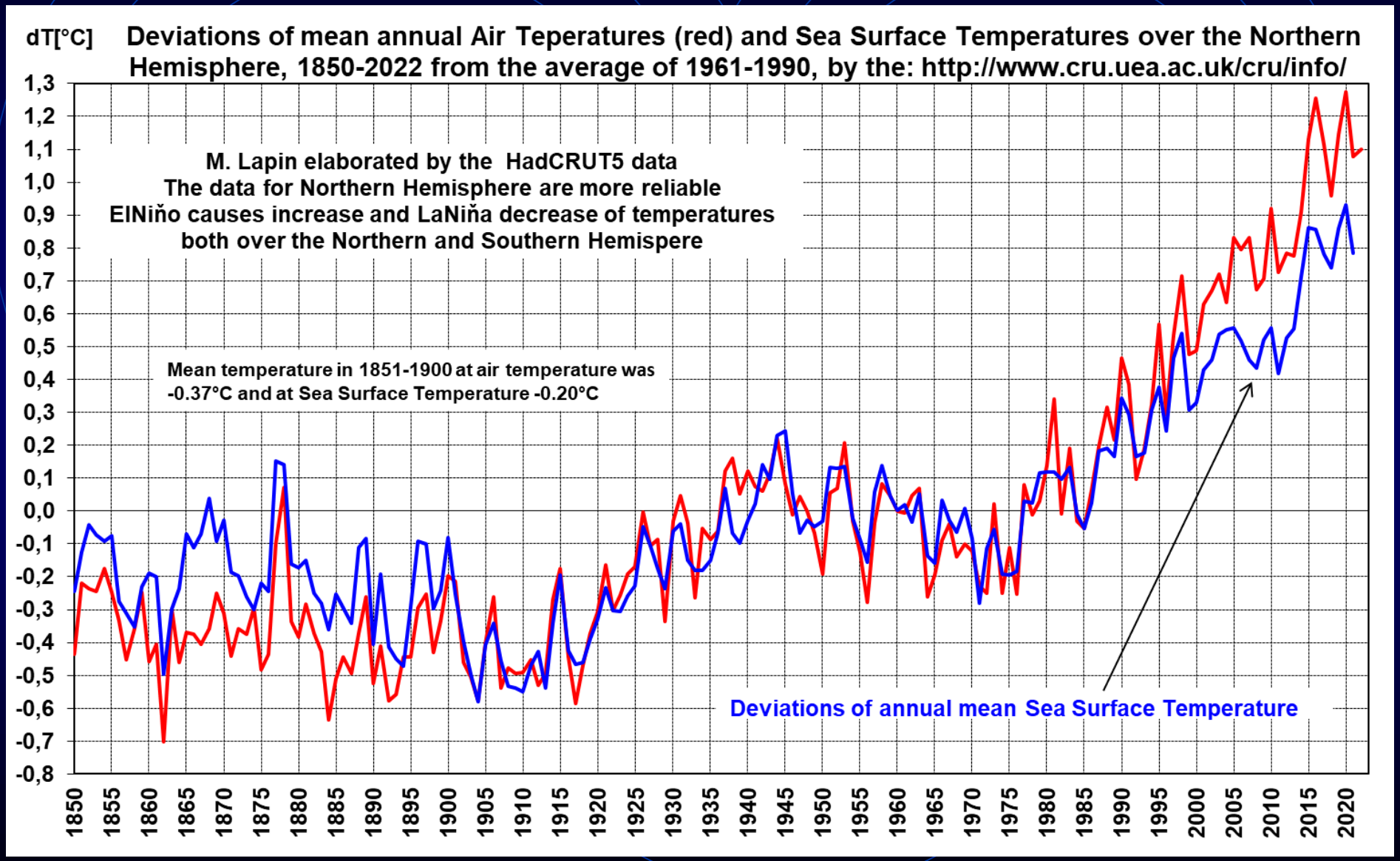
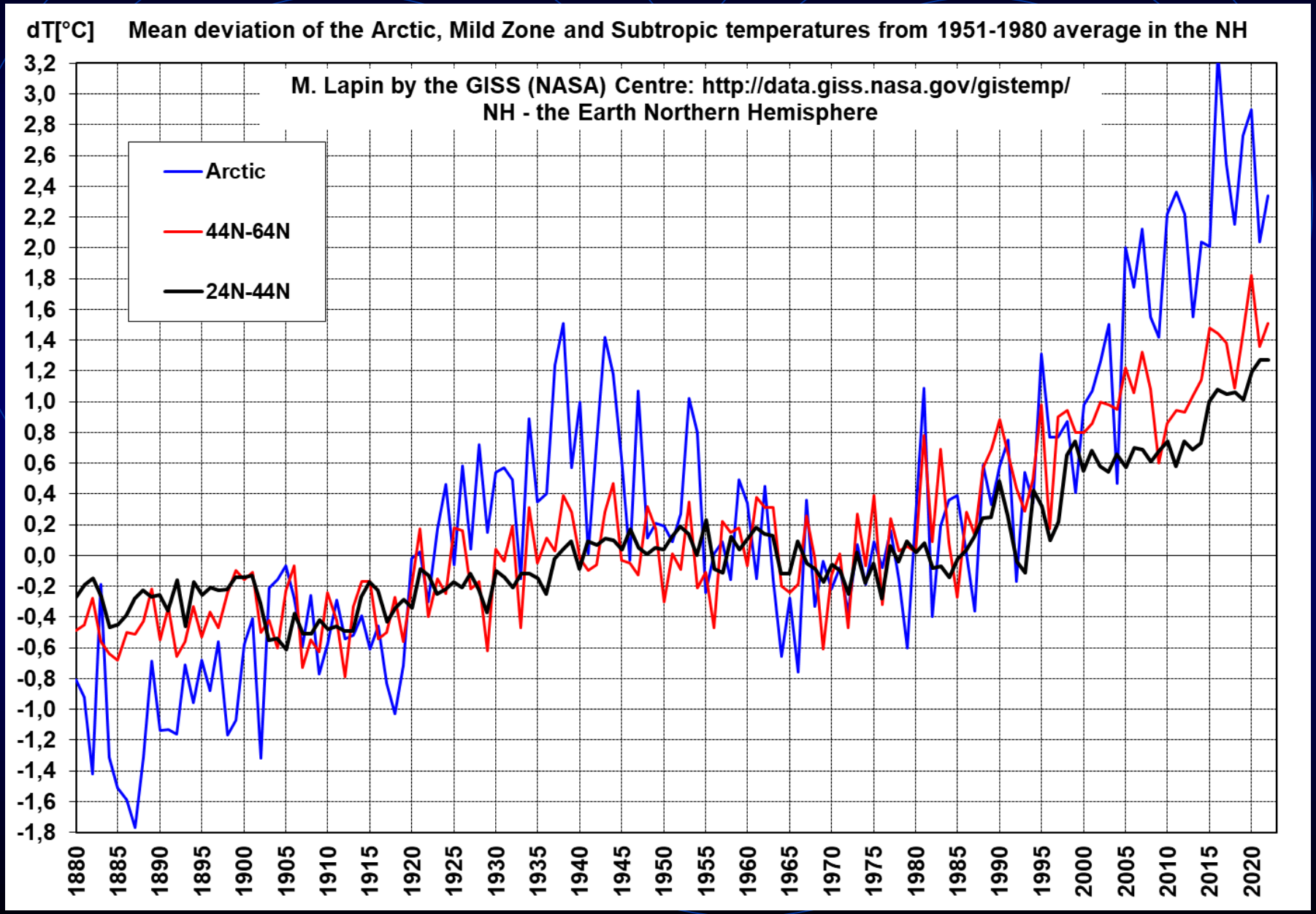
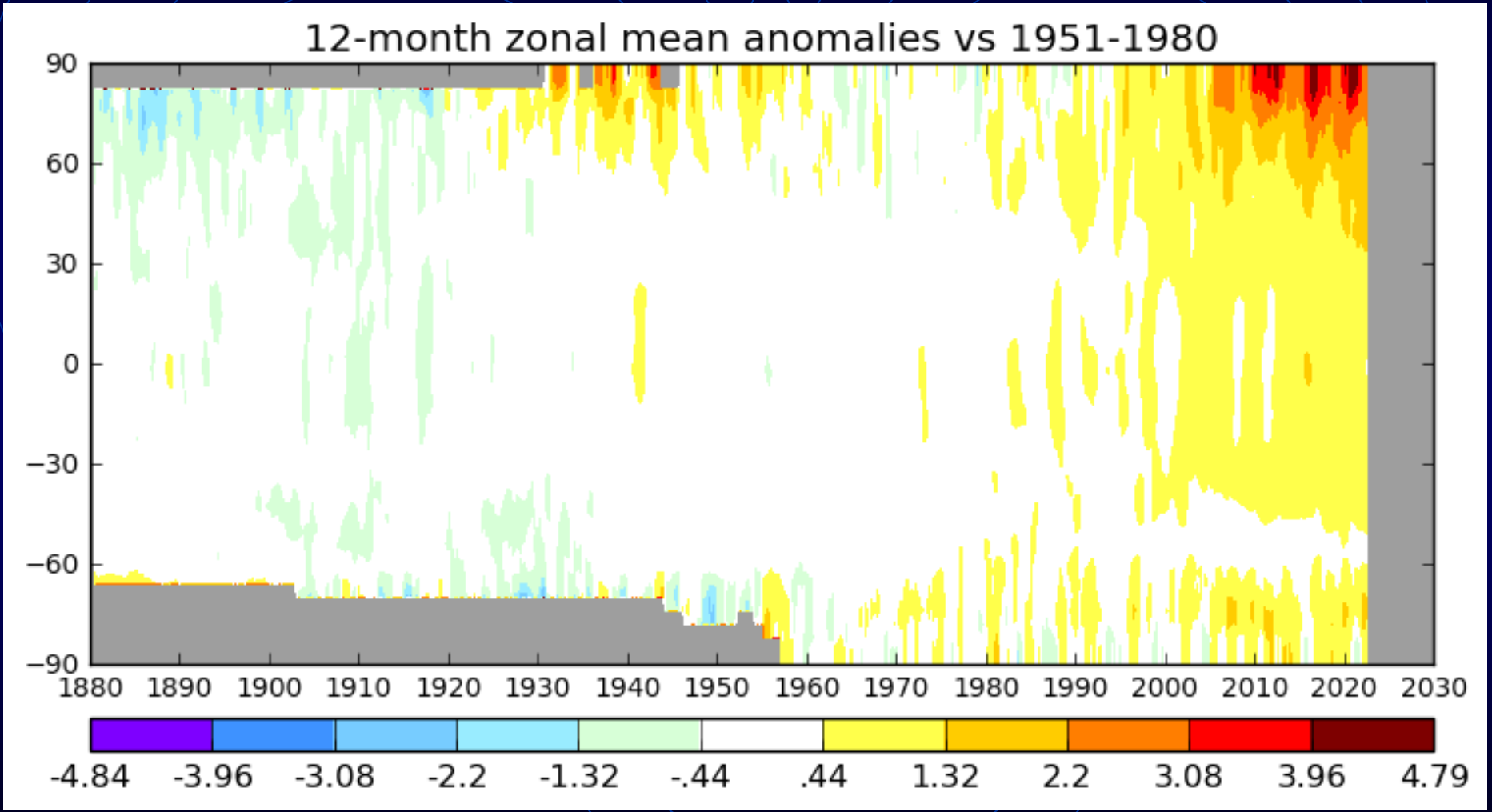


TRENDS OF TEMPERATURE SINCE 1880 NH L+O

Subtropics, Mild zone and the Arctic of the Northern Hemisphere



Deviations of mean zonal air temperatures from normal in 1880-2022 (by NASA, GISS)

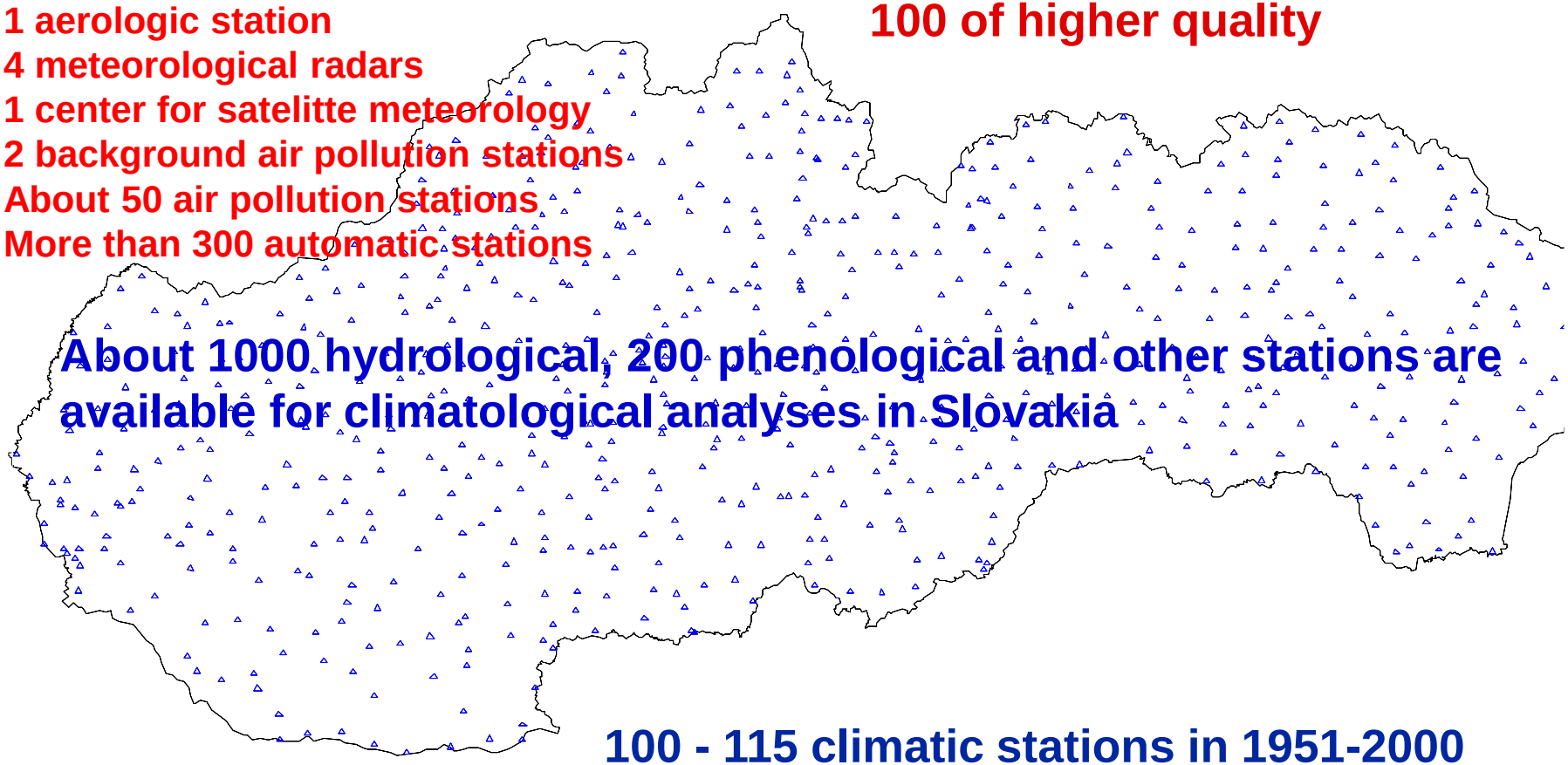


PRECIPITATION STATIONS NETWORK IN SLOVAKIA

Figure 3 - National Observing System
Part D of the Surface Sub-system

607 stations in 1951-2000,
557 of higher quality
203 in 1901-2000,
100 of higher quality

24 professional meteorological stations
1 meteorological mast (203 m)
1 aerologic station
4 meteorological radars
1 center for satelitte meteorology
2 background air pollution stations
About 50 air pollution stations
More than 300 automatic stations



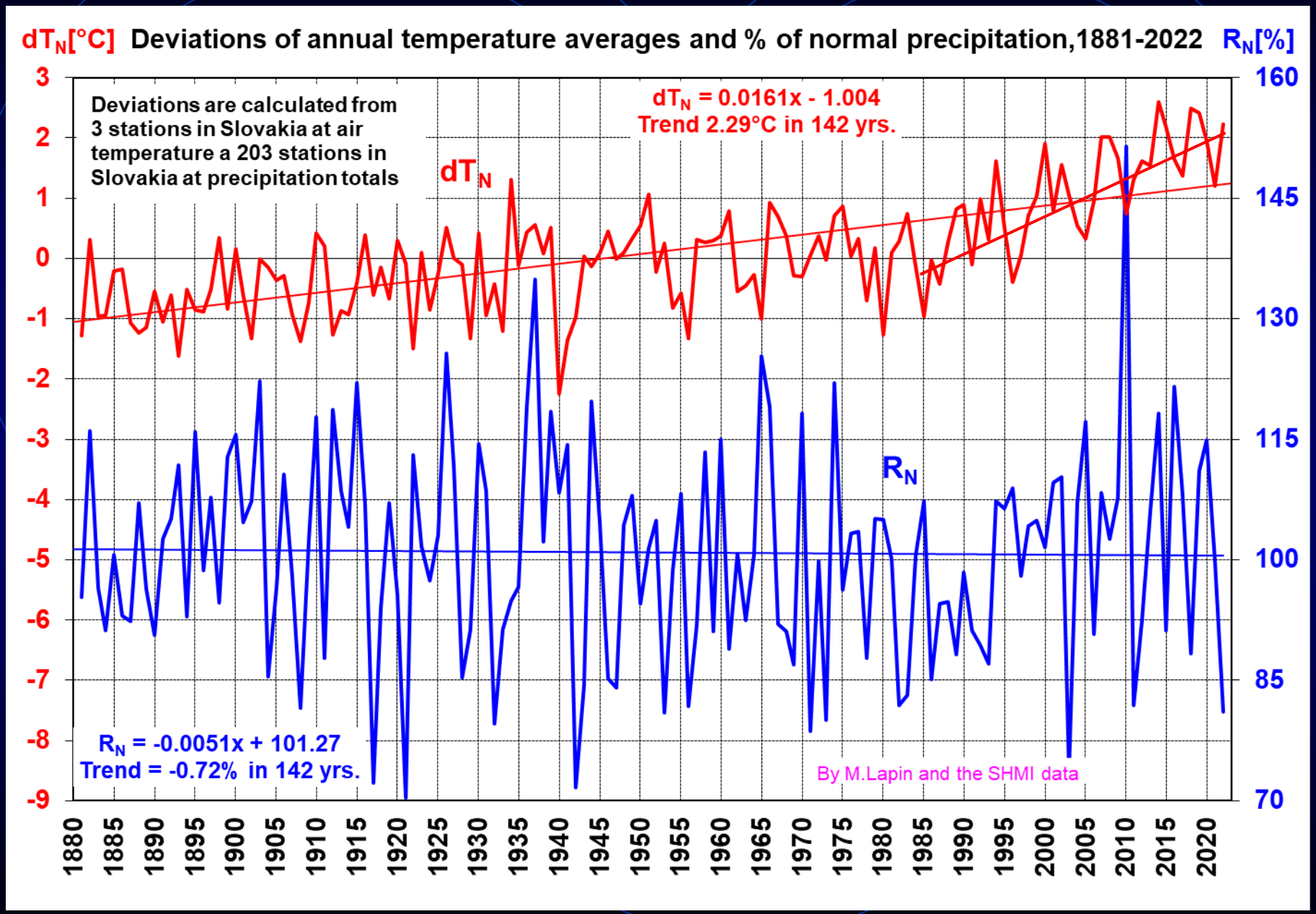
About 1000 hydrological, 200 phenological and other stations are available for climatological analyses in Slovakia

100 - 115 climatic stations in 1951-2000
35 complete stations in 1961-2000
3 complete in 1881-2000

Slovak Hydrometeorological Institute

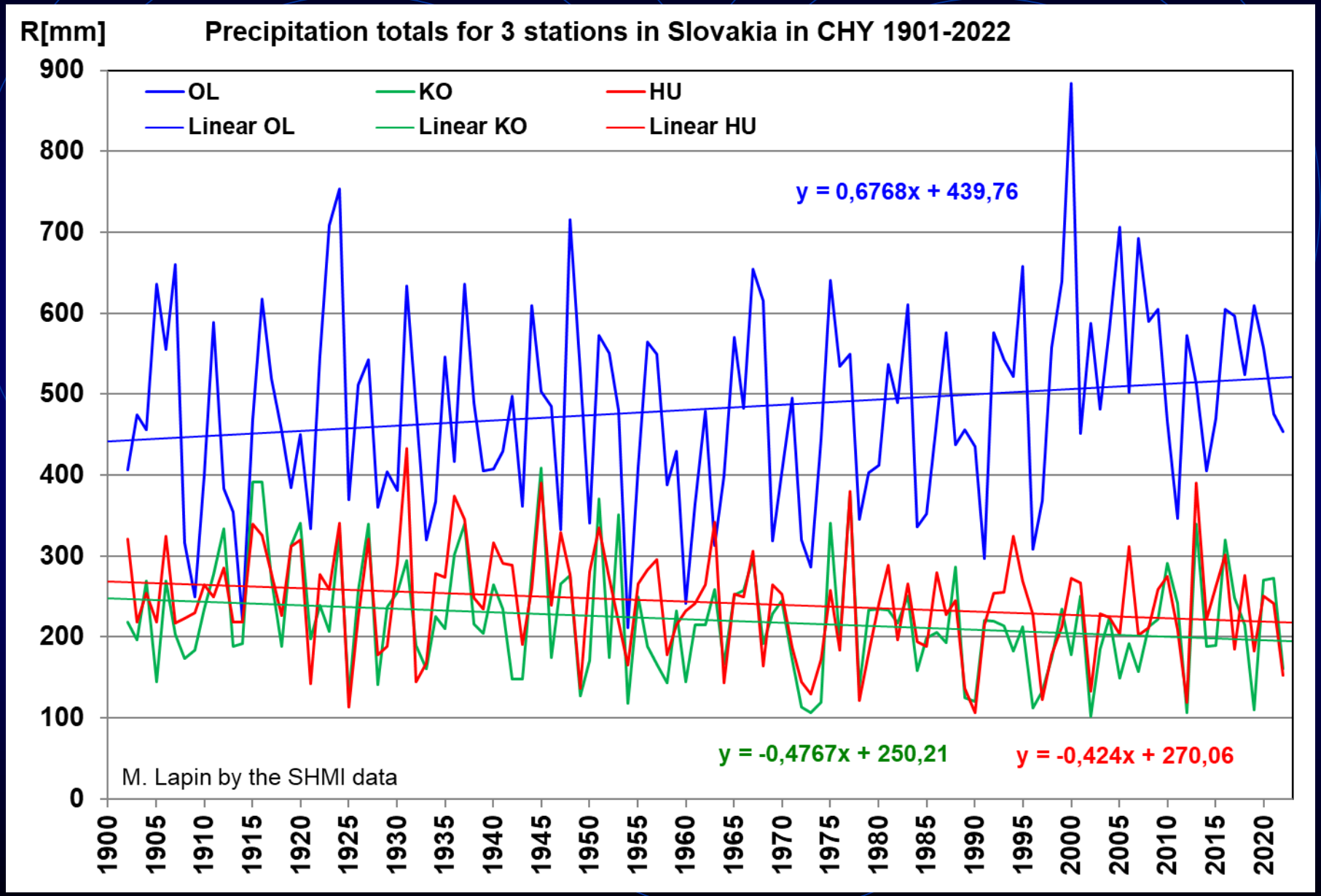
D: Partial Observing System for Climatology - only stations with the Rainfall Programme (655)

TRENDS OF TEMPERATURE AND PRECIPITATION - SLOVAKIA



TRENDS OF COLD/WARM HALF-YEAR PRECIPITATION – SLOVAKIA

Hurbanovo, 115 m SW, Košice 230 m SE, O. Lesná 780 m NW



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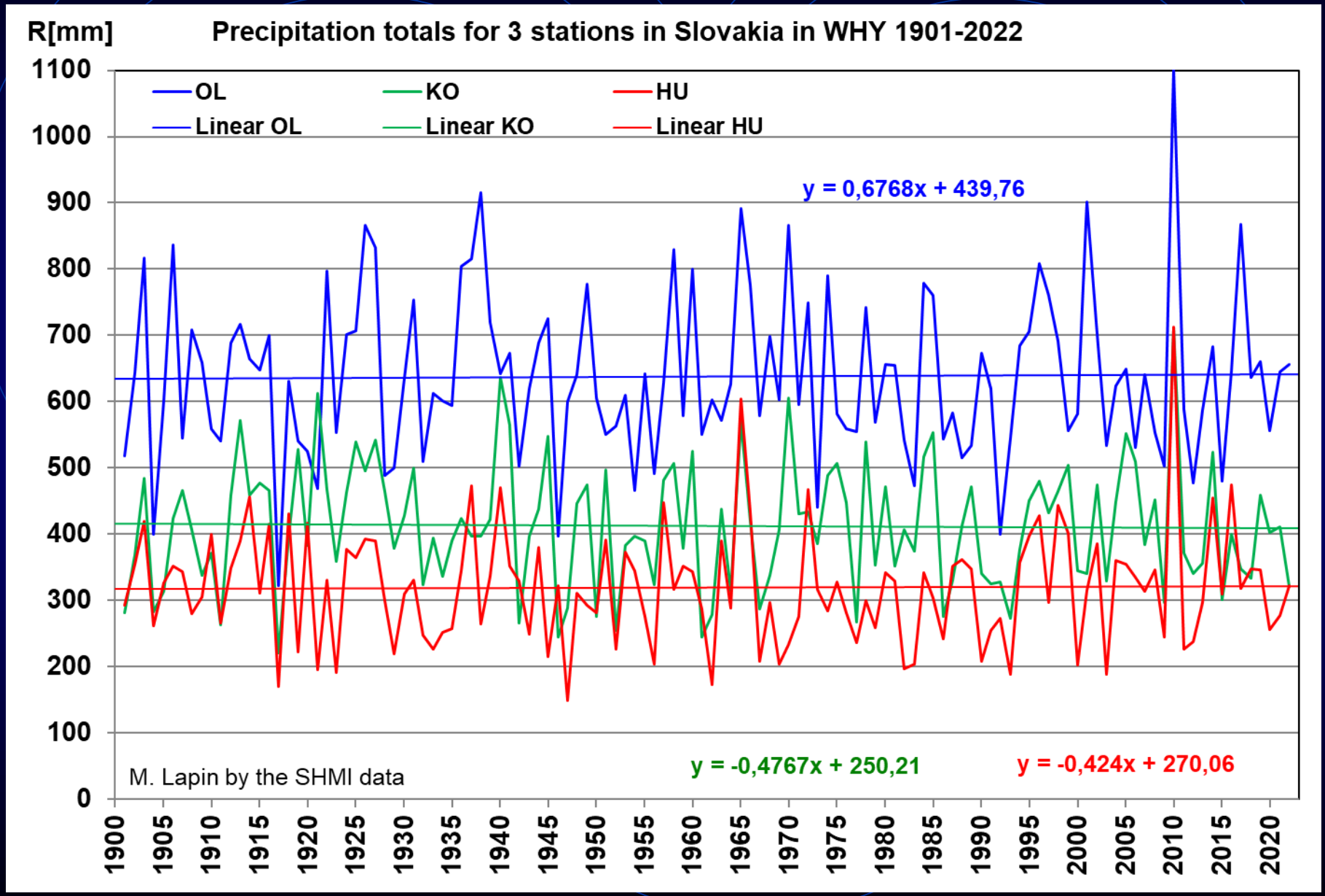
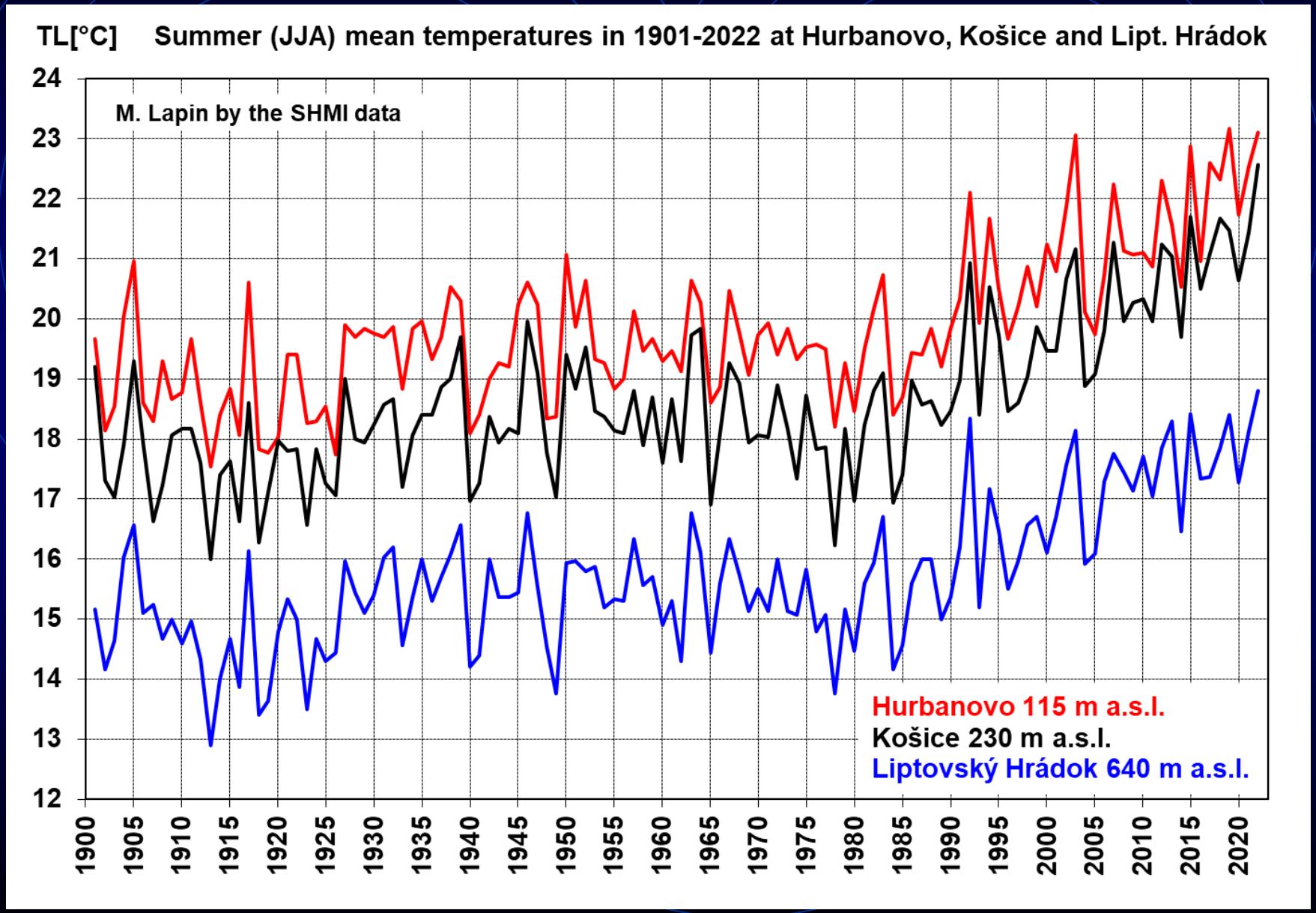


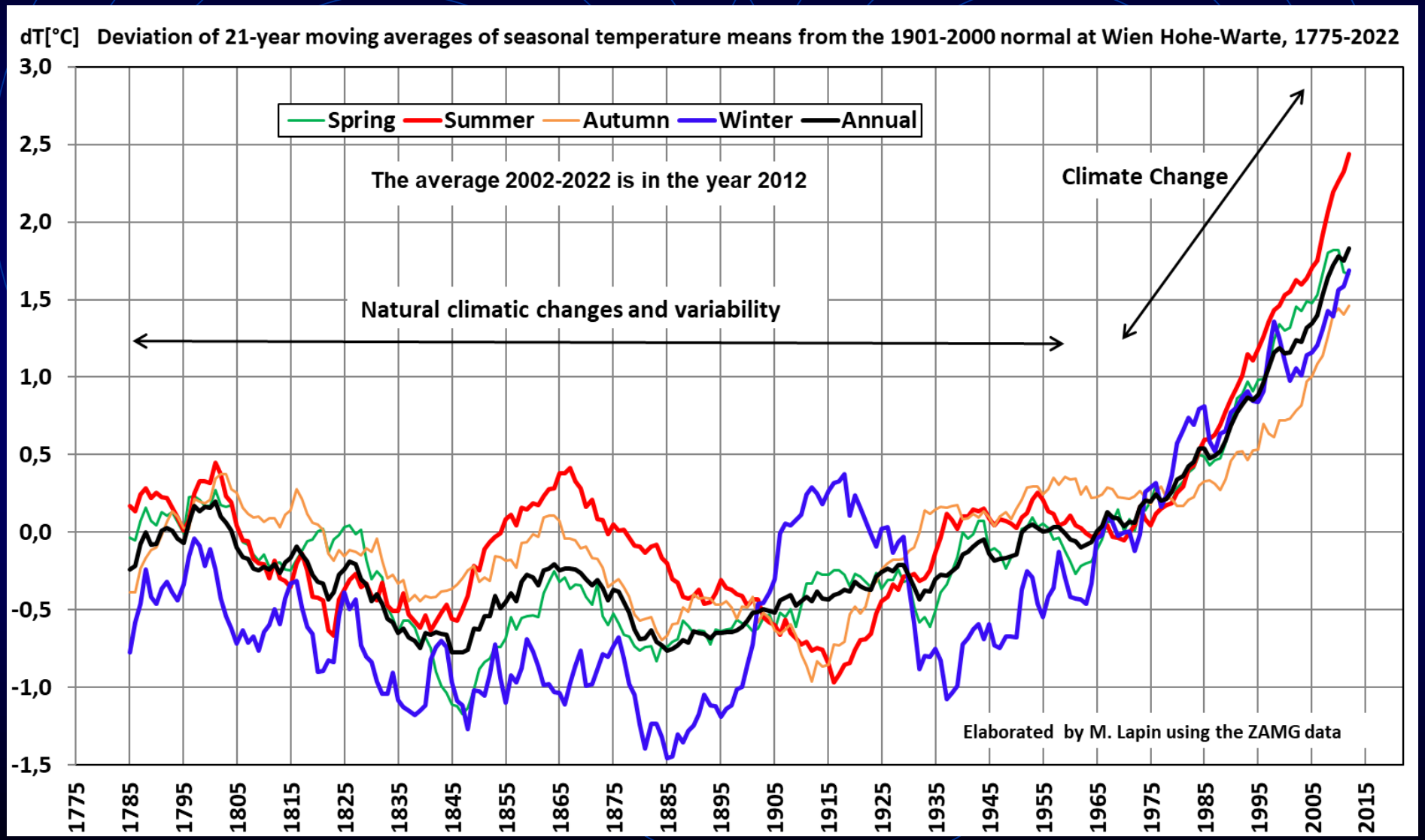
TRENDS OF SUMMER TEMPERATURE – SLOVAKIA

Increase of Spring and Summer temperature and no change in precipitation totals – small increase in the North and small decrease in the South SR

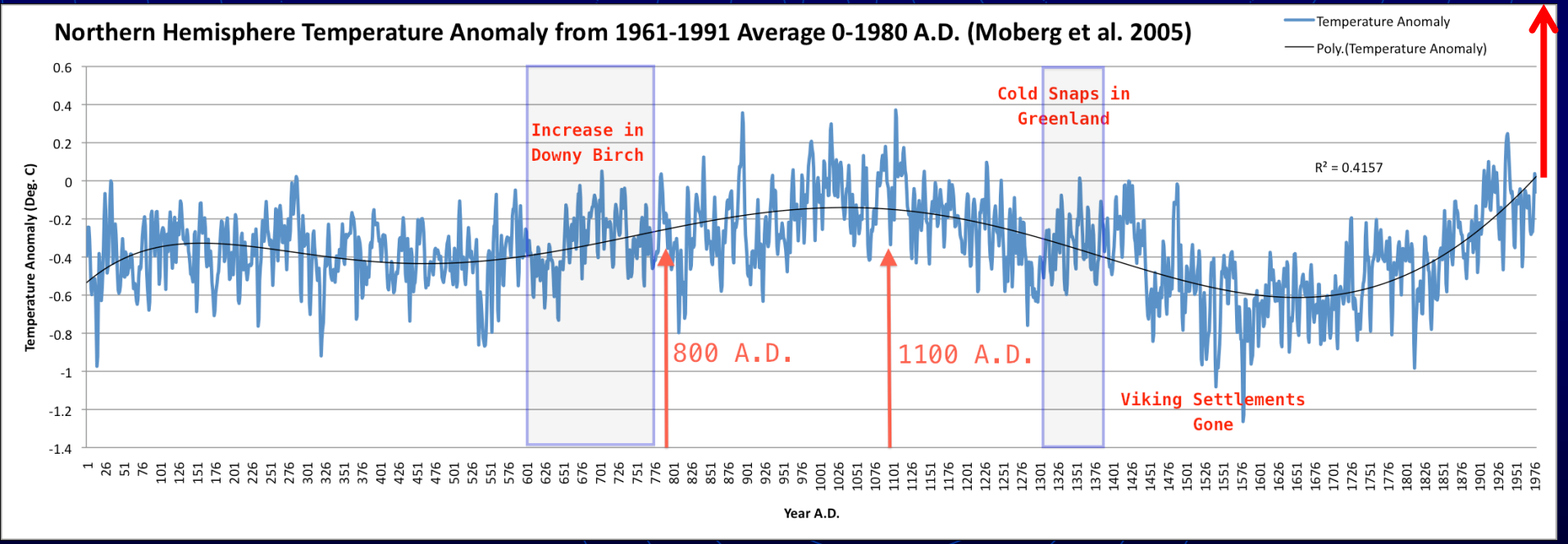


TRENDS OF TEMPERATURE SINCE 1775 IN VIENNA

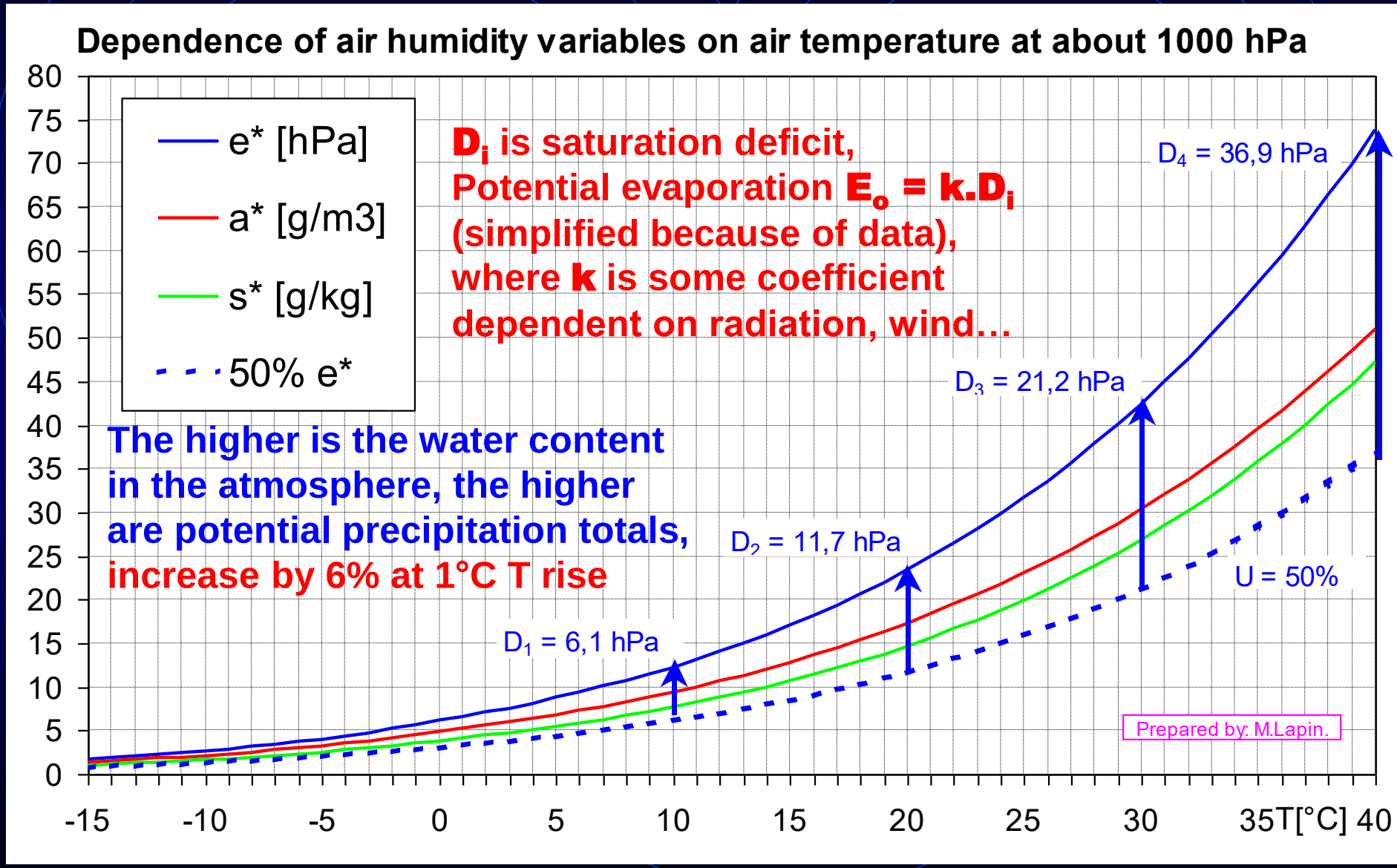
In 1775-1965 mostly natural reasons of climatic changes – different changes in seasons Spring, Summer, Autumn and Winter



NORTHERN HEMISPHERE AIR TEMPERATURE DEVIATIONS IN 0-1980 YEAR FROM 1961-1990 NORMAL (by Moberg, 2005, rise until 2022)



AIR HUMIDITY AND AIR TEMPERATURE

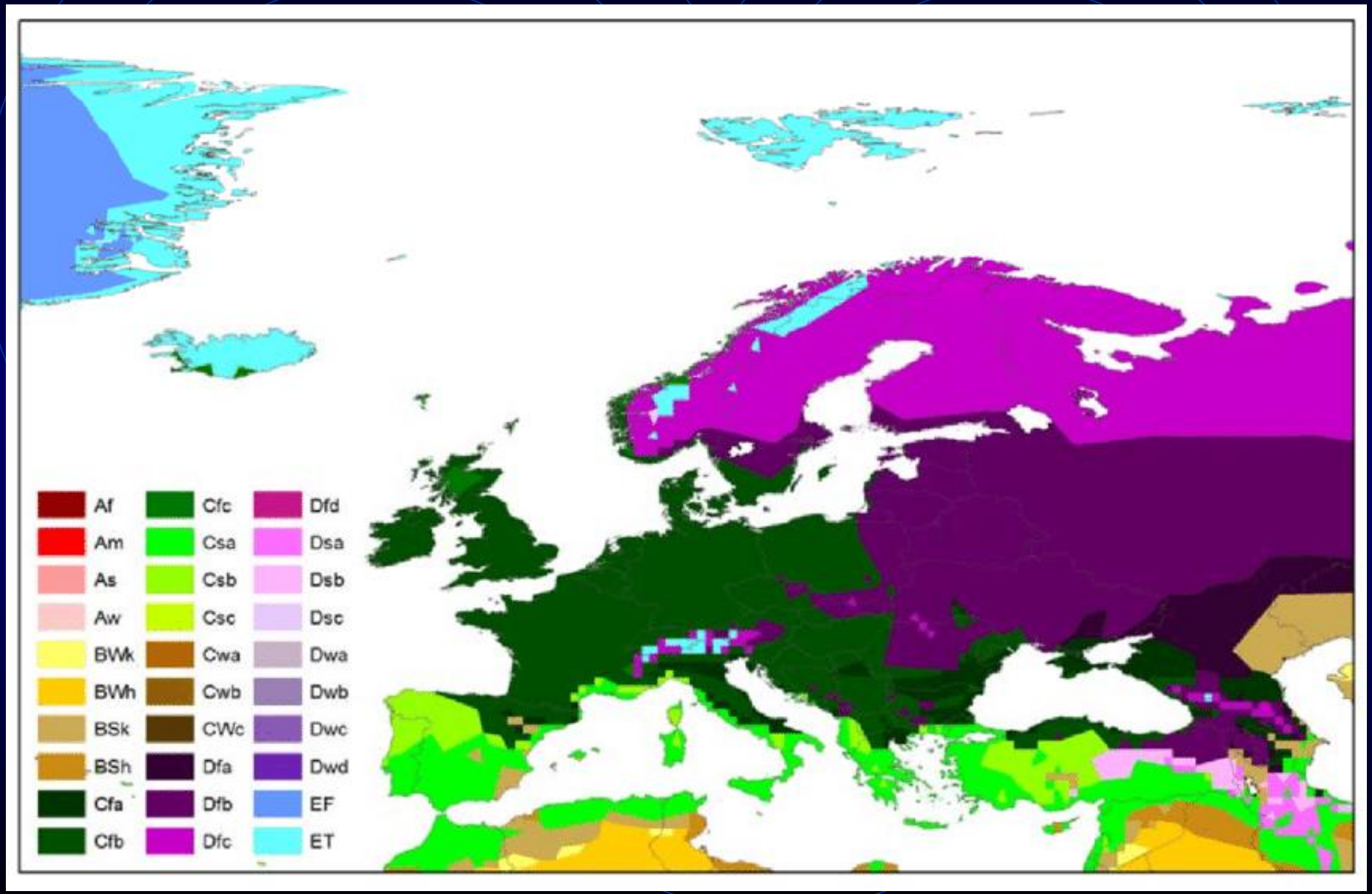


ABSTRACT 3

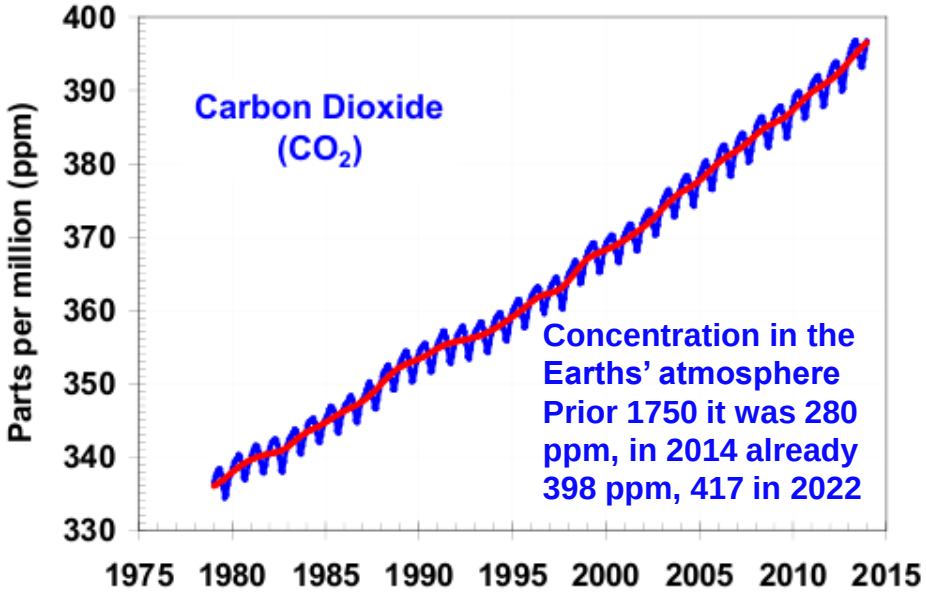
- **Water balance is the most important quantity for the classification of local and regional climatic condition. The highest is mean air temperature the greater are water demands for evaporation. Very important is also temporal distributon of precipitation and soil moisture during seasons**
- **Water balance equation: R = E + q + ΔW; Slovakia: E = 0.65 R and q = 0.35 R in 1931-1980, but in 1991-2020 E = 0.70 R and q = 0.3 R; it seems that due to increase of mean temperature and decrease of relative humidity the mean E will increase well above 0.70 R and q will decrease below 0.30 R**
- **Other attributes of climatic classification are mean annual temperature, mean temperature of the warmest and coldest month during the year and annual regime of precipitation**
- **From the hydrological and water economy point of view also the regime of heavy/intense rains, drought periods and snow cover episodes are important. I will not present any details on these topics during this lecture.**

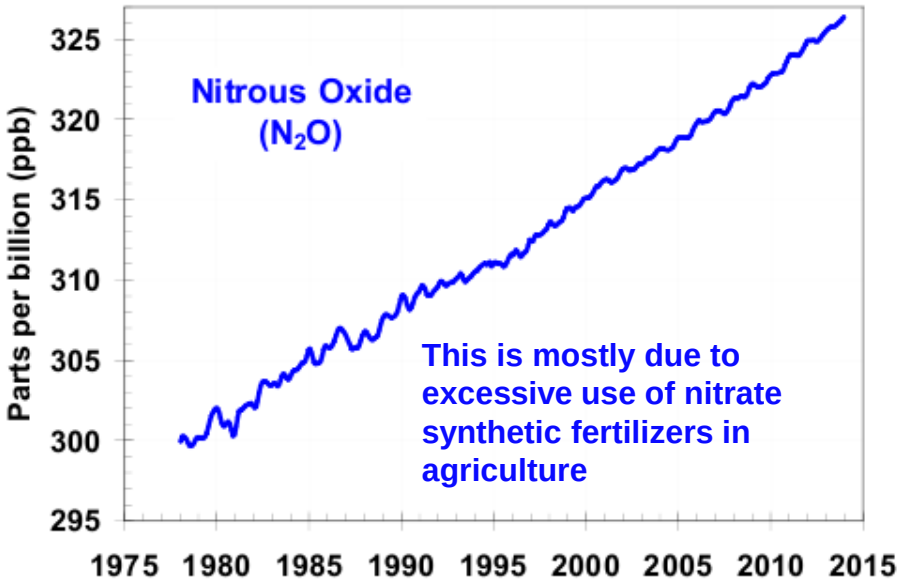
KOPPEN – GEIGER CLIMATIC CLASSIFICATION – EUROPE

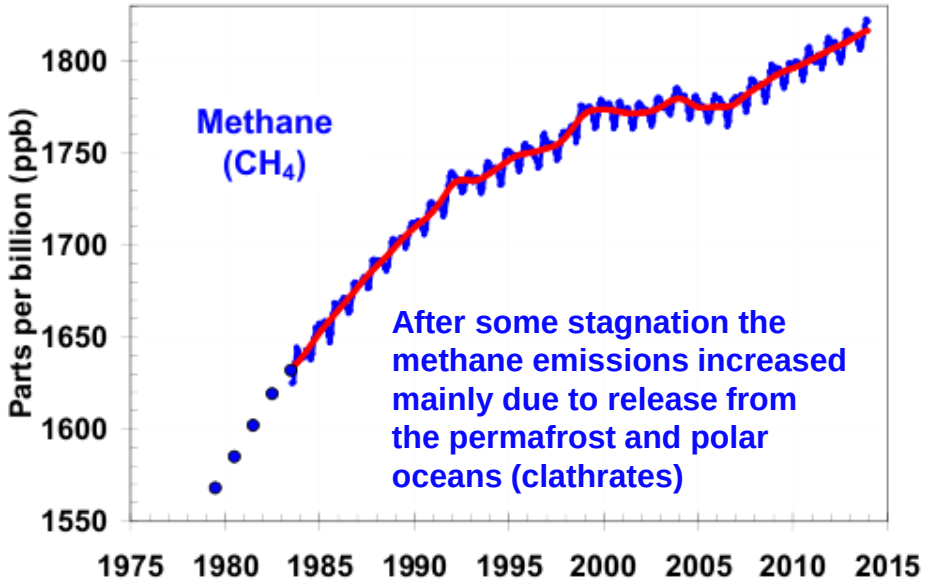
A – tropical climate, B – dry climate, C – mild climate, D – boreal climate, E – cold climate

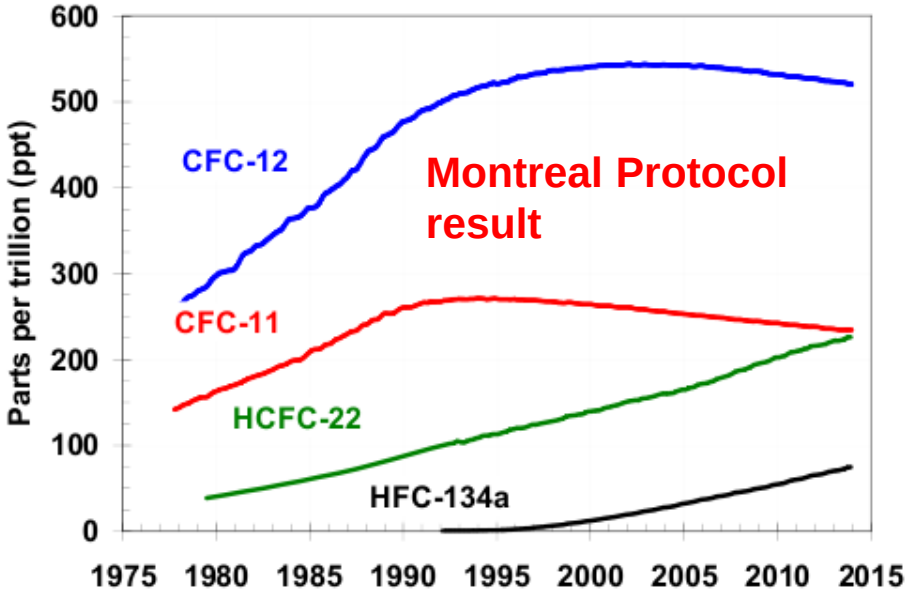


TREND OF MAIN GREENHOUSE GASES

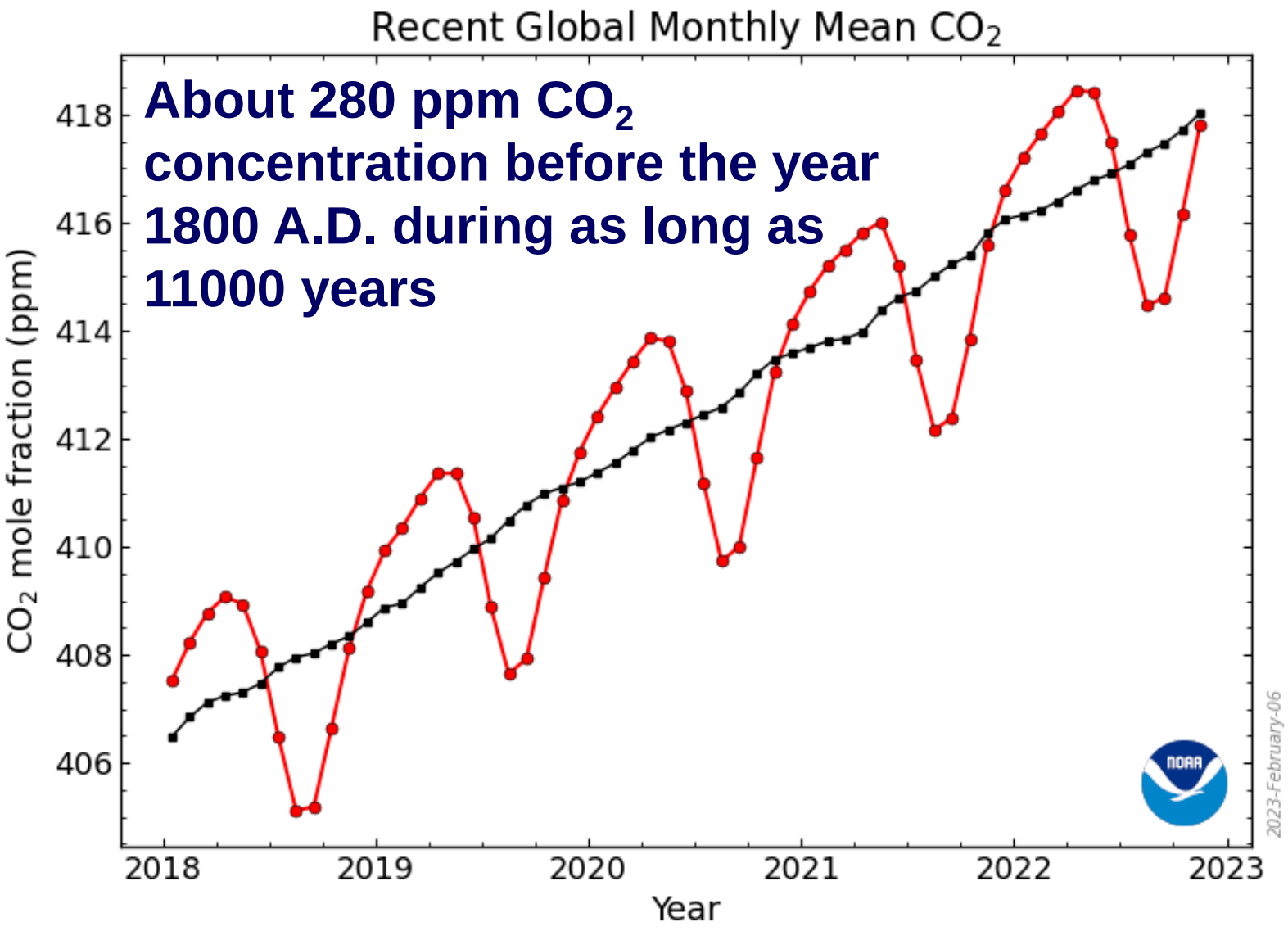




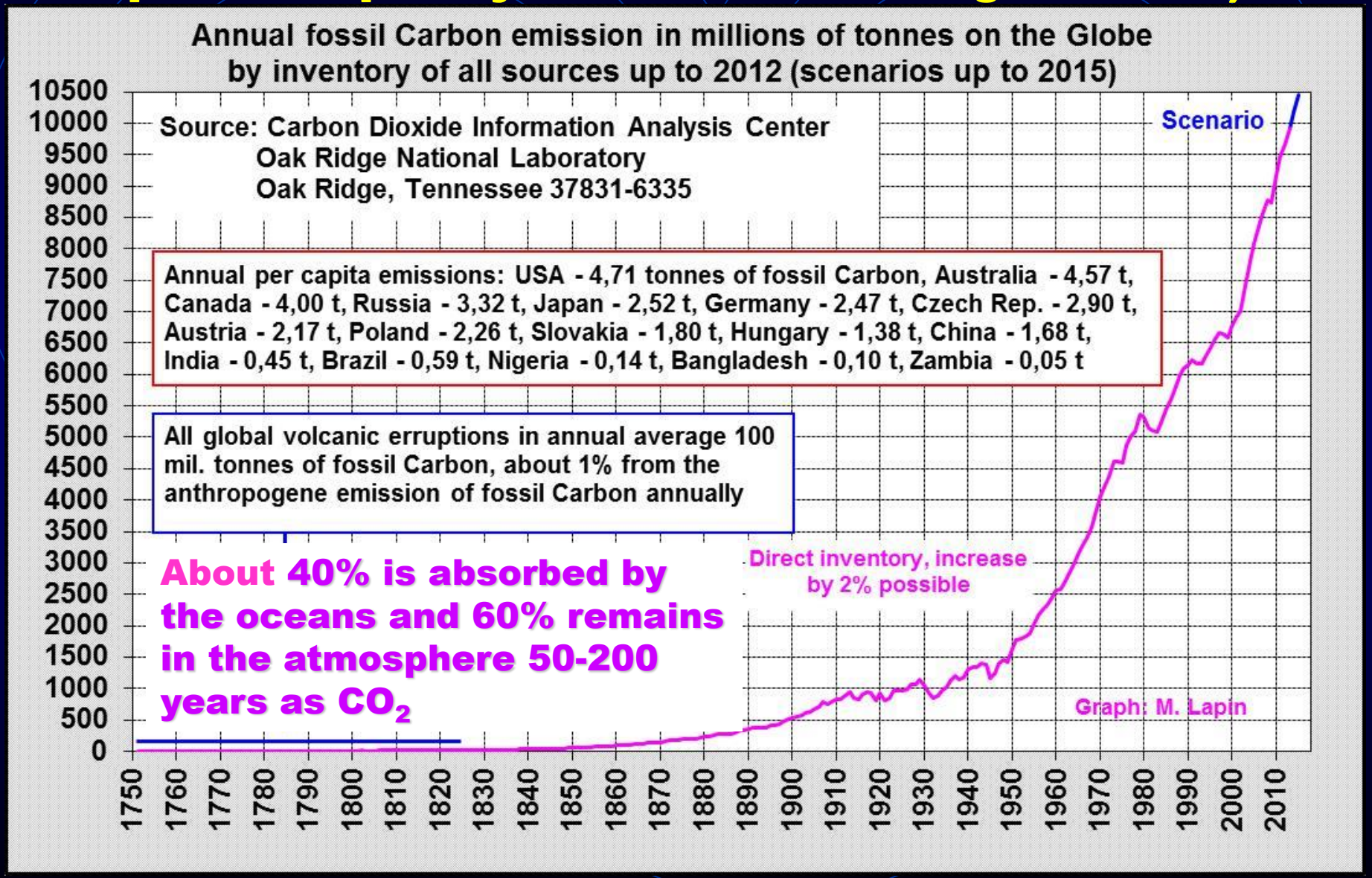


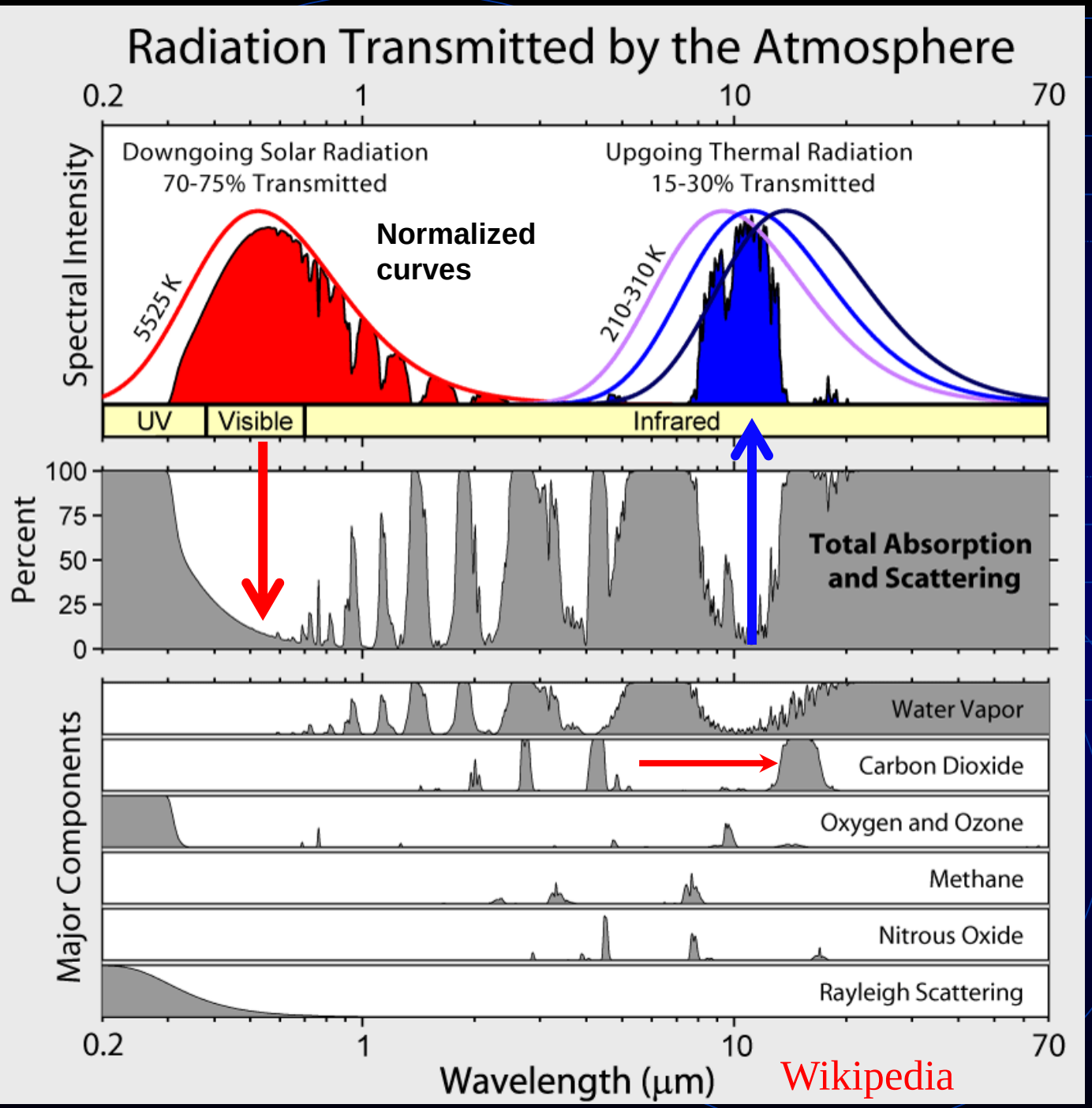


TREND OF CARBON DIOXIDE – GLOBAL



GLOBAL EMISSION OF FOSSIL CARBON MILLION TONNES IN 1751-2015 (inventory up to 2012, assessment up to 2015, possible uplift by 2% + land use change addition)





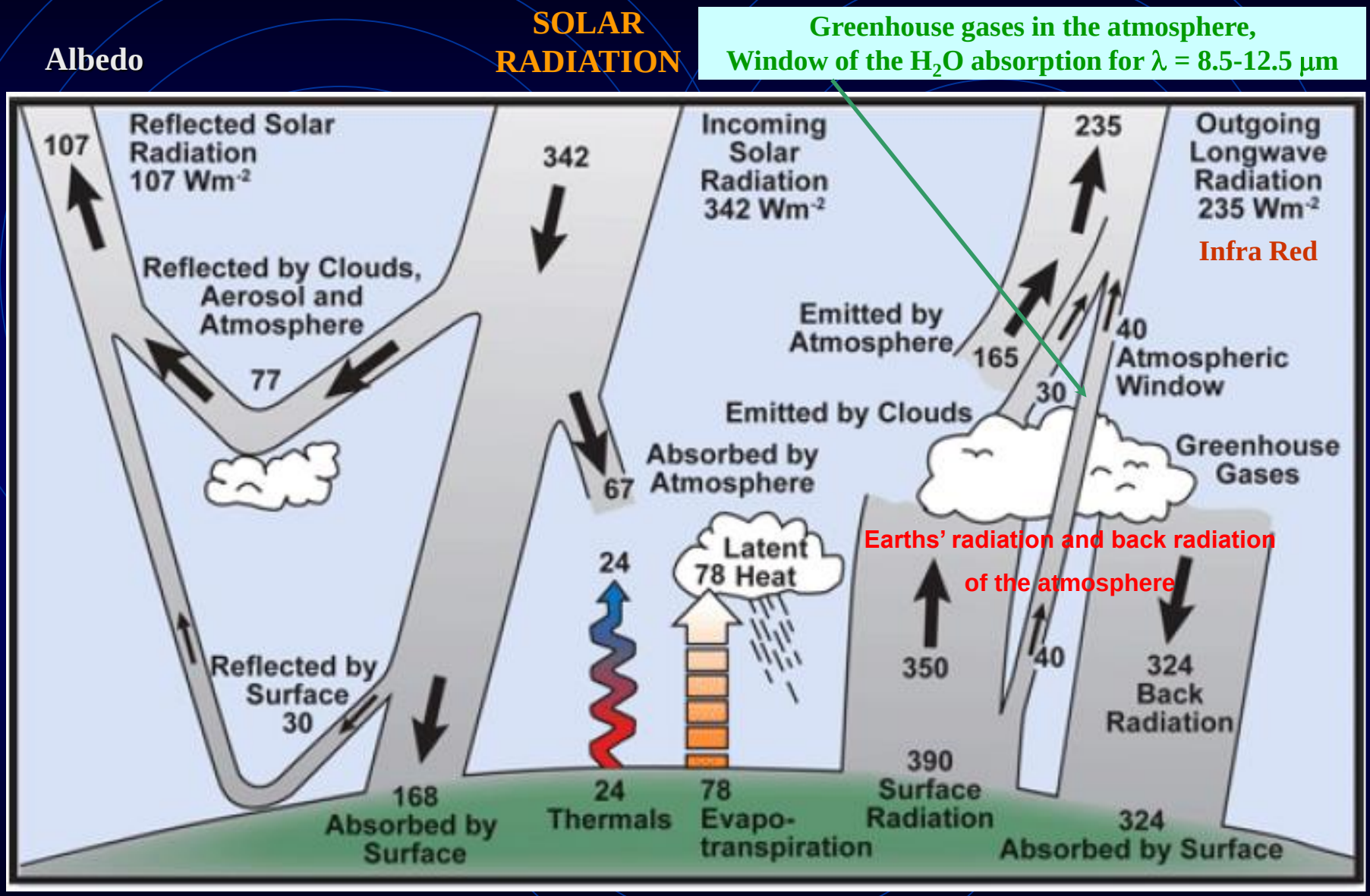
Wikipedia

It is important, that total IR radiation can be absorbed in lower layer of the atmosphere, if some GHG increases its concentration.

The atmosphere produce IR radiation as well, and the absorption process continues up to the top of the atmosphere.

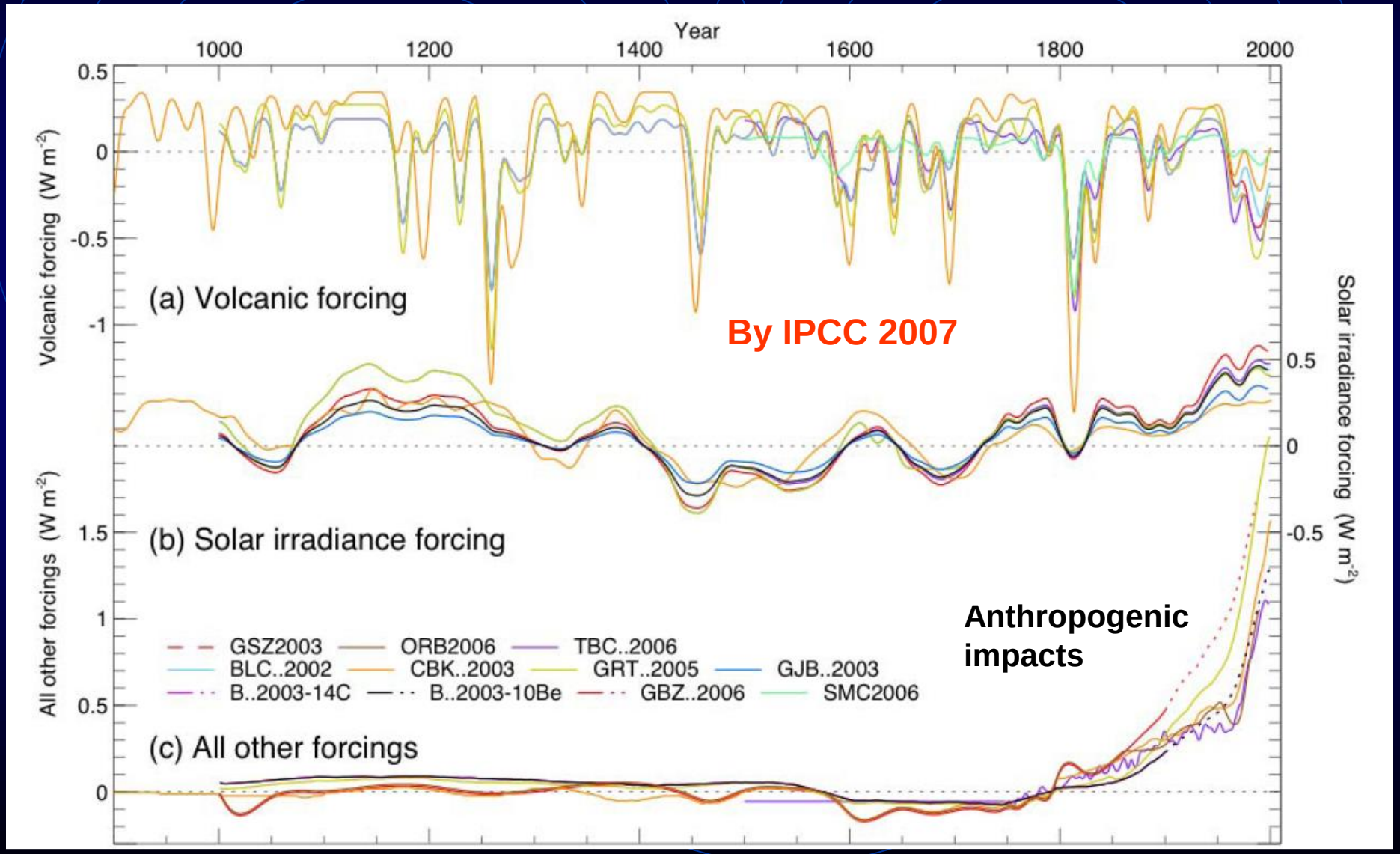
The higher is GHGs concentration in the atmosphere, the greater is increase of surface atmosphere temperature.

Annual means of the Earths' radiation and heat balance



By IPCC 2007

MAIN CLIMATE FORMING FACTORS SINCE 900 – VOLCANIC ACTIVITY, SOLAR ACTIVITY AND ANTHROPOGENIC ENHANCEMENT

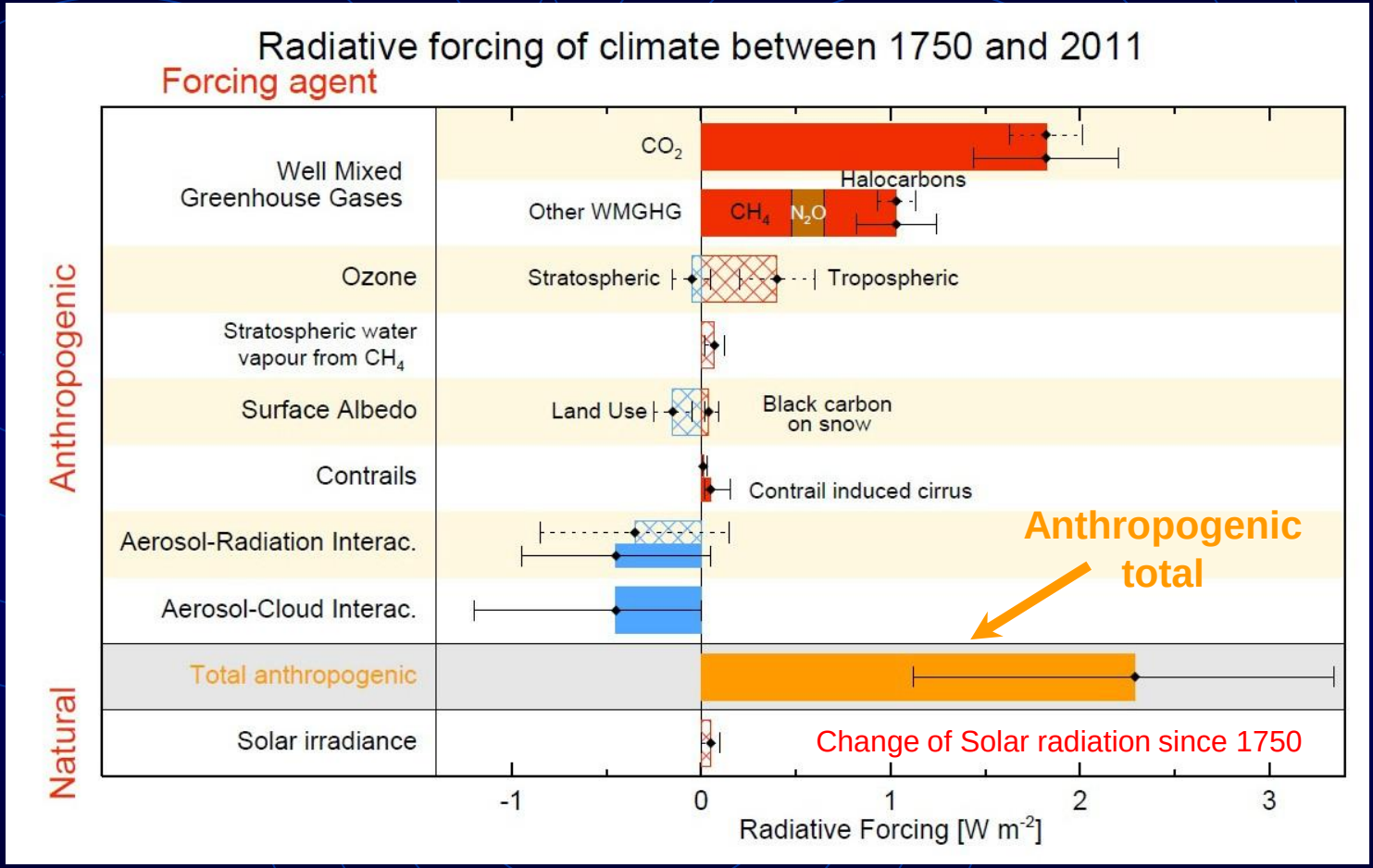


SHARE OF ALL ANTHROPOGENIC FORCINGS ON CLIMATE CHANGE SINCE 1750 (IPCC 2013)

Greenhouse gases with positive forcing on climate change

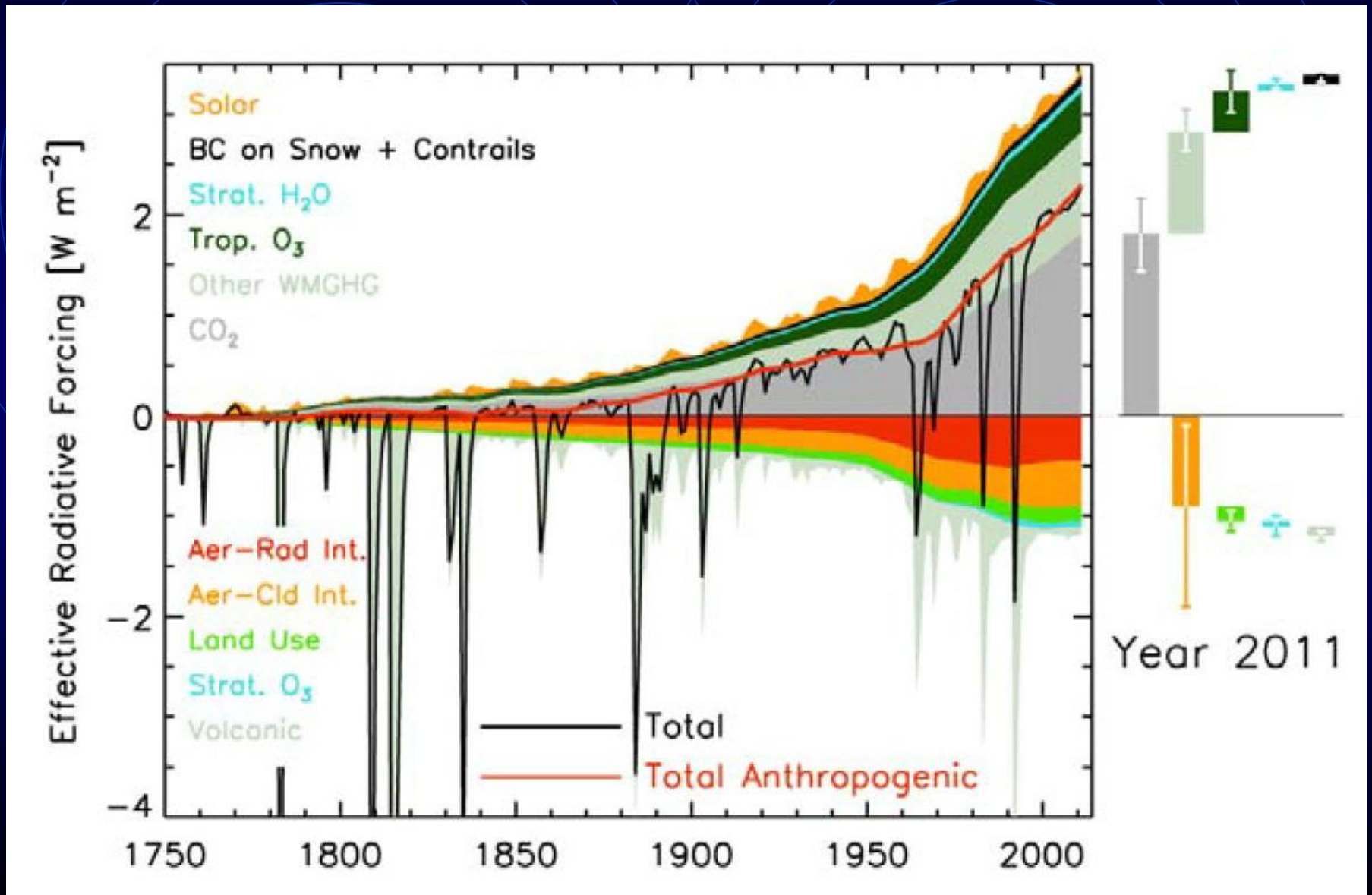
Aerosols and change in land use with negative forcing on climate change

Comparison of anthropogeni-cally based forcing and naturally based forcing since 1750



Mean radiation balance on the Earth was 104 W/m^2 in 1931-1960. Present radiative forcing is about 2.7 W/m^2

COMPARISON OF MAIN FORCINGS ON CLIMATE CHANGE IN 1750-2011 (Black line represents the final result of all radiative forcings, at present (2016) it is about 2,5 W.m^{-2}, rapid variations by volcanoes)



IMPACTS IN SOCIO-ECONOMIC SECTORS & ENVIRONMENT

- Climate (monitoring, analysis, scenarios…)
- Hydrological Cycle (runoff, evaporation, ground water…)
- Water Economy (management of water supply…)
- Water Resources (drinking water, irrigation…)
- Agricultural Economy (management, plant production)
- Agricultural Ecosystems (pest, diseases, weeds…)
- Forestry (management, uniformity…)
- Forest Ecosystems (instability, pest, diseases…)
- Biodiversity (instability, new species…)

Important Sectors – seldom participating in analyses in Slovakia

- Recreation and Tourism
- Health and Hygiene
- Economy, Civil engineering and Energy supply
- Transport and Telecommunications

COMMENT: Sea level rise; Coastal regions; Fisheries; Glaciers; Permafrost; Tropical cyclones and some others – not solved in Slovakia

SCIENTIFIC THEORY OF CLIMATE CHANGE

- "**Climate Change**" – anthropogenic influence
- Physics, chemistry and biology of climate change and natural climate changes
- Socio-economic cross-correlation and impacts
- Natural ecosystems and climate change
- Positive and negative feedbacks and forcings

- **CLIMATE CHANGE MONITORING IS THE FIRST AND THE MOST IMPORTANT STEP IN SOLVING OF THE ISSUE !**

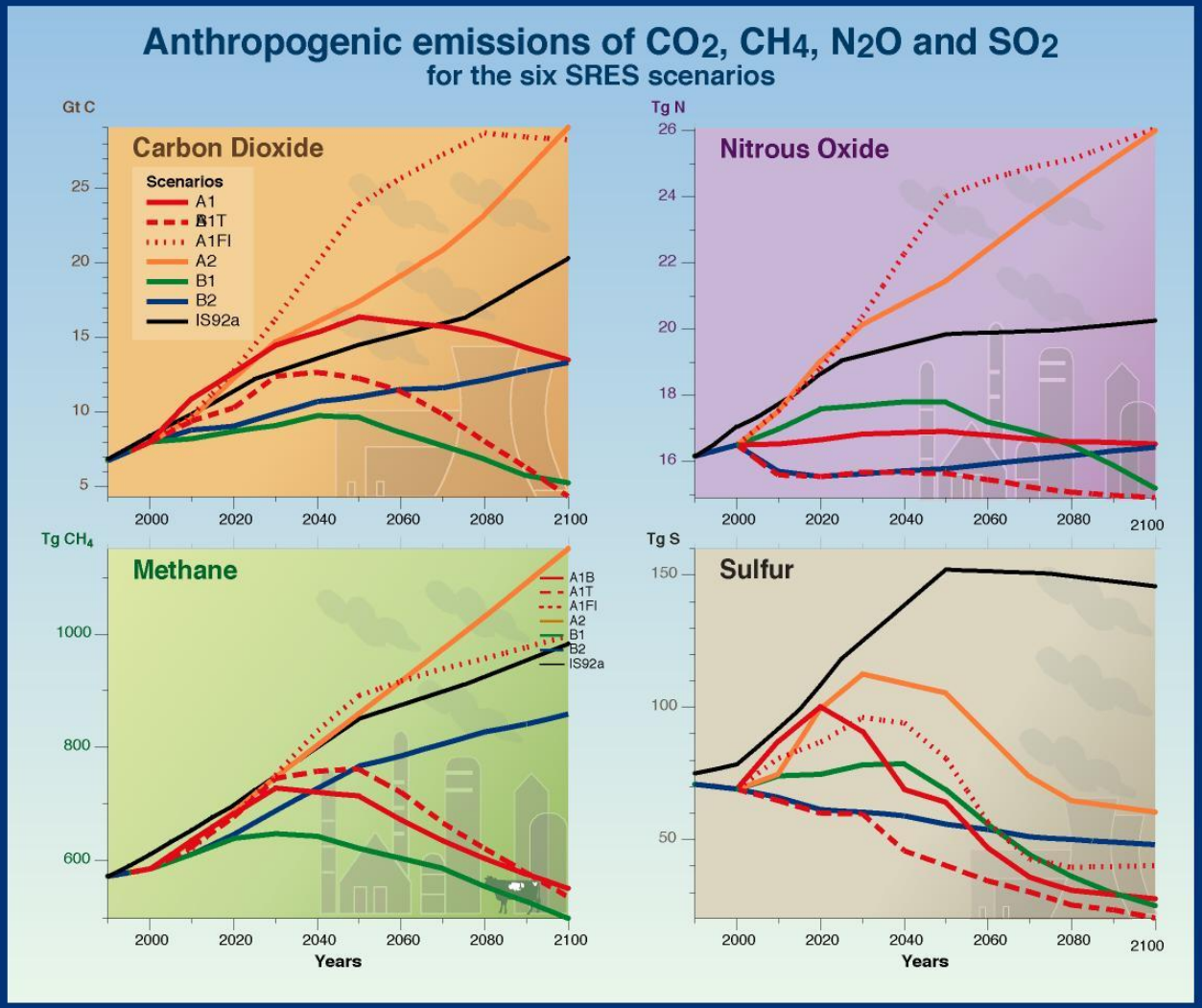
CLIMATE CHANGE SCENARIOS SUMMARY

- Scenarios based on the Atmosphere General Circulation Models - GCMs (Atmosphere-Ocean Models and Regional Models at present – also 10x10 km resolution)
- 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, events, extremes...
- The first series of scenarios in 1995, the second in 1997, then in 2000, 2010 and 2014 (comparison with 2010 frame – good success)

IPCC SRES SCENARIOS

- Outputs of the CGCM3.1 and ECHAM5 models contain results by SRES A2 and SRES B1 emission scenarios assessments
- The first one represent pessimistic supposition of mankind behavior up to 2100 and the second the optimistic one (IPCC 2000)
- Emission of **fossil Carbon** is supposed as 28.9 Gt by SRES A2 (cumulative 1773 Gt) and 5.2 Gt by SRES B1 (cumulative 989 Gt) in 2100.
- **A1B** – central scenarios family - balanced emphasis on all energy sources
- This difference is much more expressed in air temperature scenarios after 2040
- **New RCP series of emission scenarios in the IPCC AR5**

Emission scenarios
A1, B1T, A1F1, A2, B1, B2 and older IS92a represent different ways of Climate Change mitigation



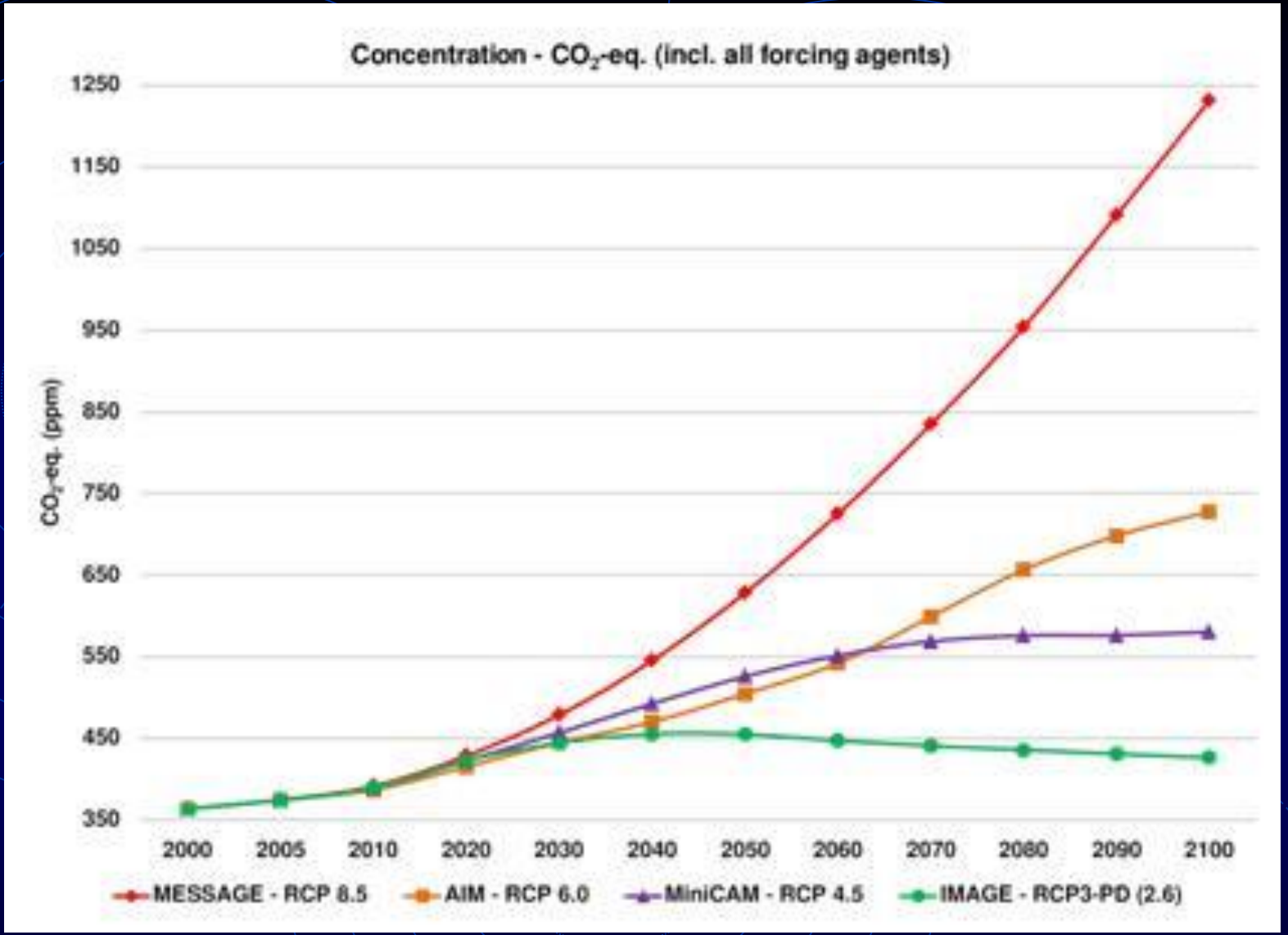
Alternative scenarios prepared by 6 different centers

Emission scenarios RCP 8.5, RCP 6.0, RCP 4.5, RCP 2.6

Older

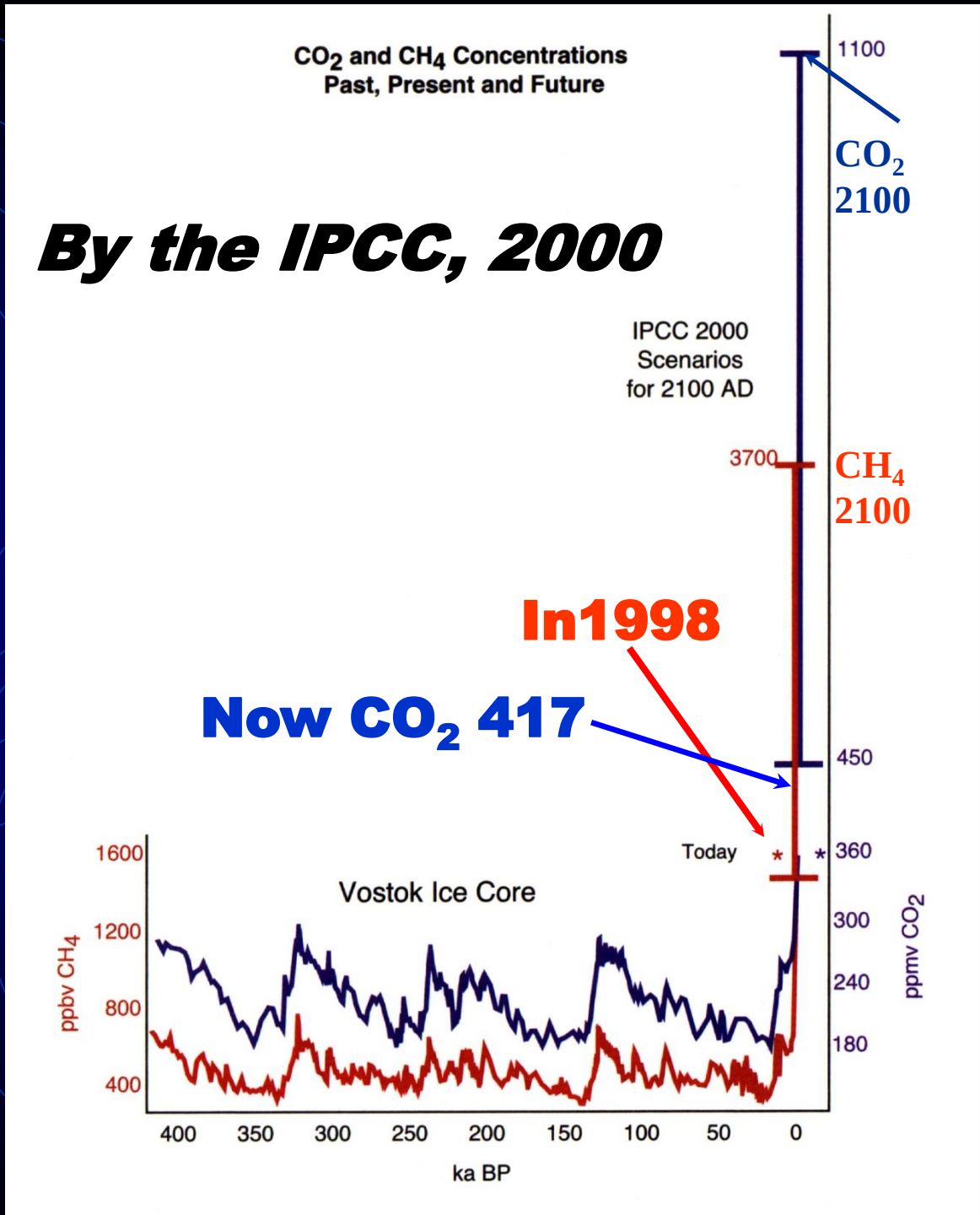
A1, B1T, A1F1, A1B, A2, B1, B2

and more older IS92a, IS92b, IS92c represent different ways of Climate Change mitigation

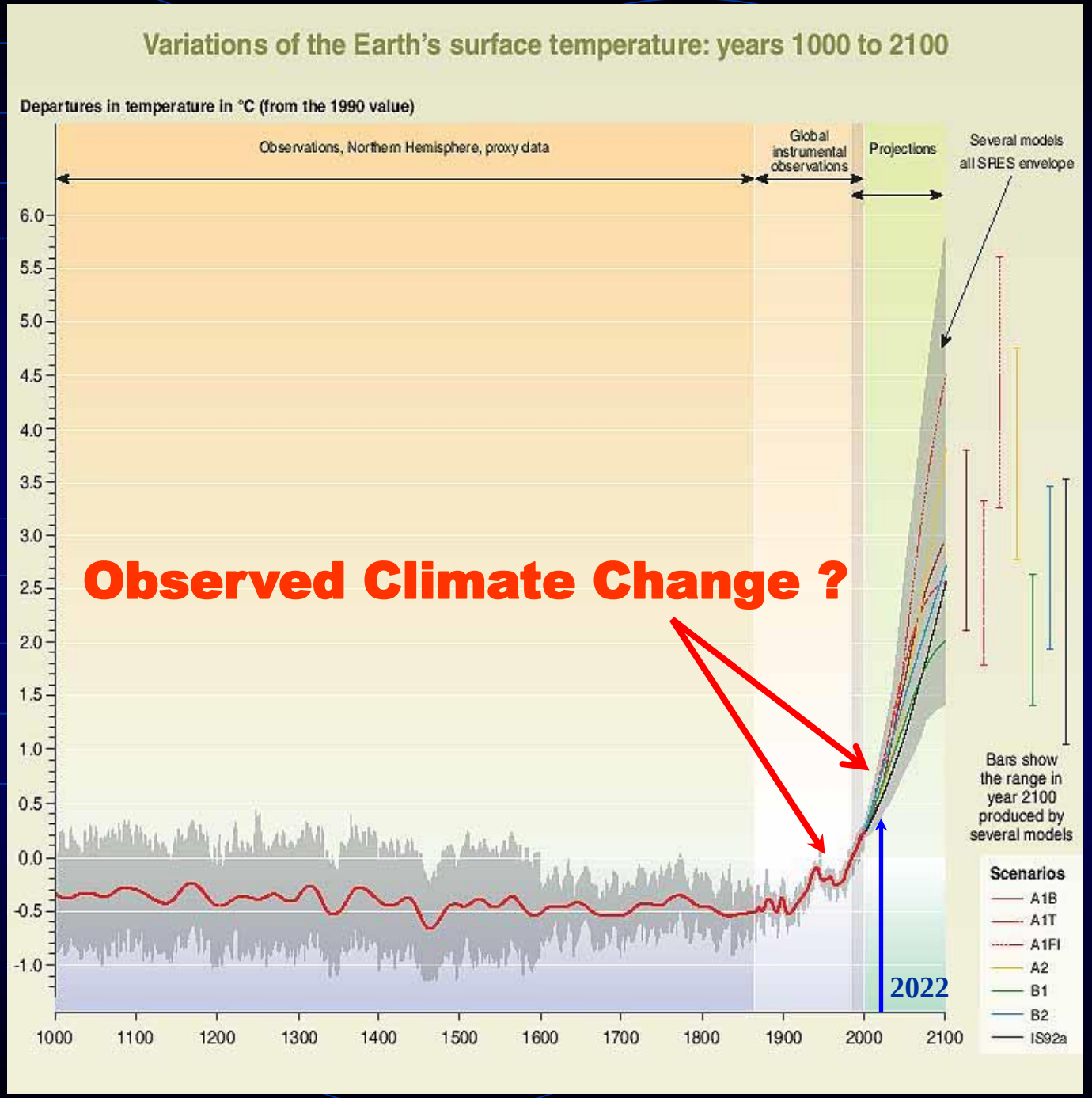


Alternative scenarios prepared by different centers and published in IPCC AR 5

Atmospheric CO_2 and CH_4 concen- tration in the last 400 thousand yrs. Based on Vostok (Antarctic) data Possible scenarios up to the year 2100

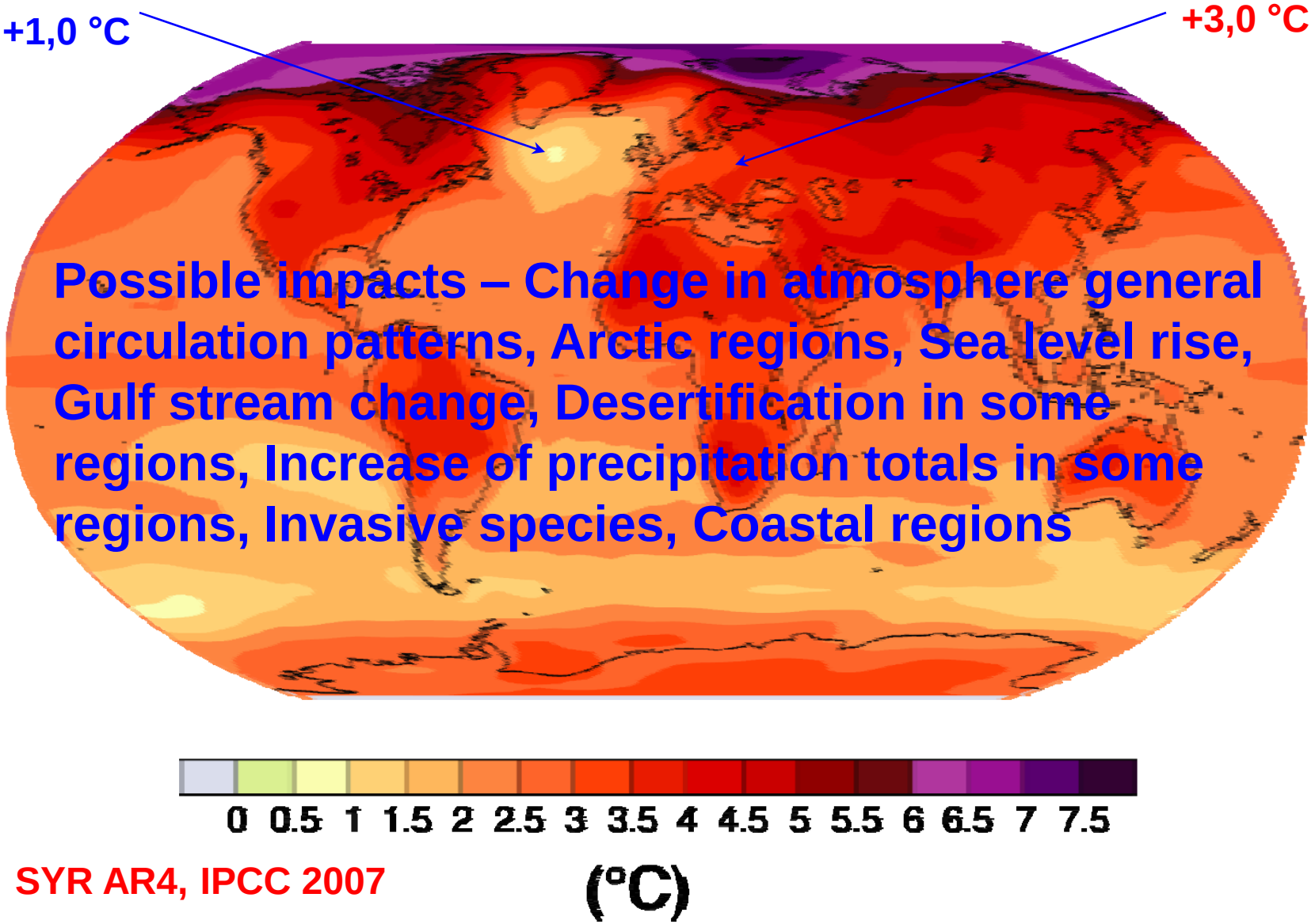


From year 1000 to year 1850 variations in average surface temperature of the Northern Hemisphere are shown (corresponding data from the Southern Hemisphere not available) reconstructed from proxy data (tree rings, corals, ice cores, and historical records). The line shows the 50-year average, the grey region the 95% confidence limit in the annual data. 1850-2000 measured data, 2001-2100 are scenarios (by: IPCC).



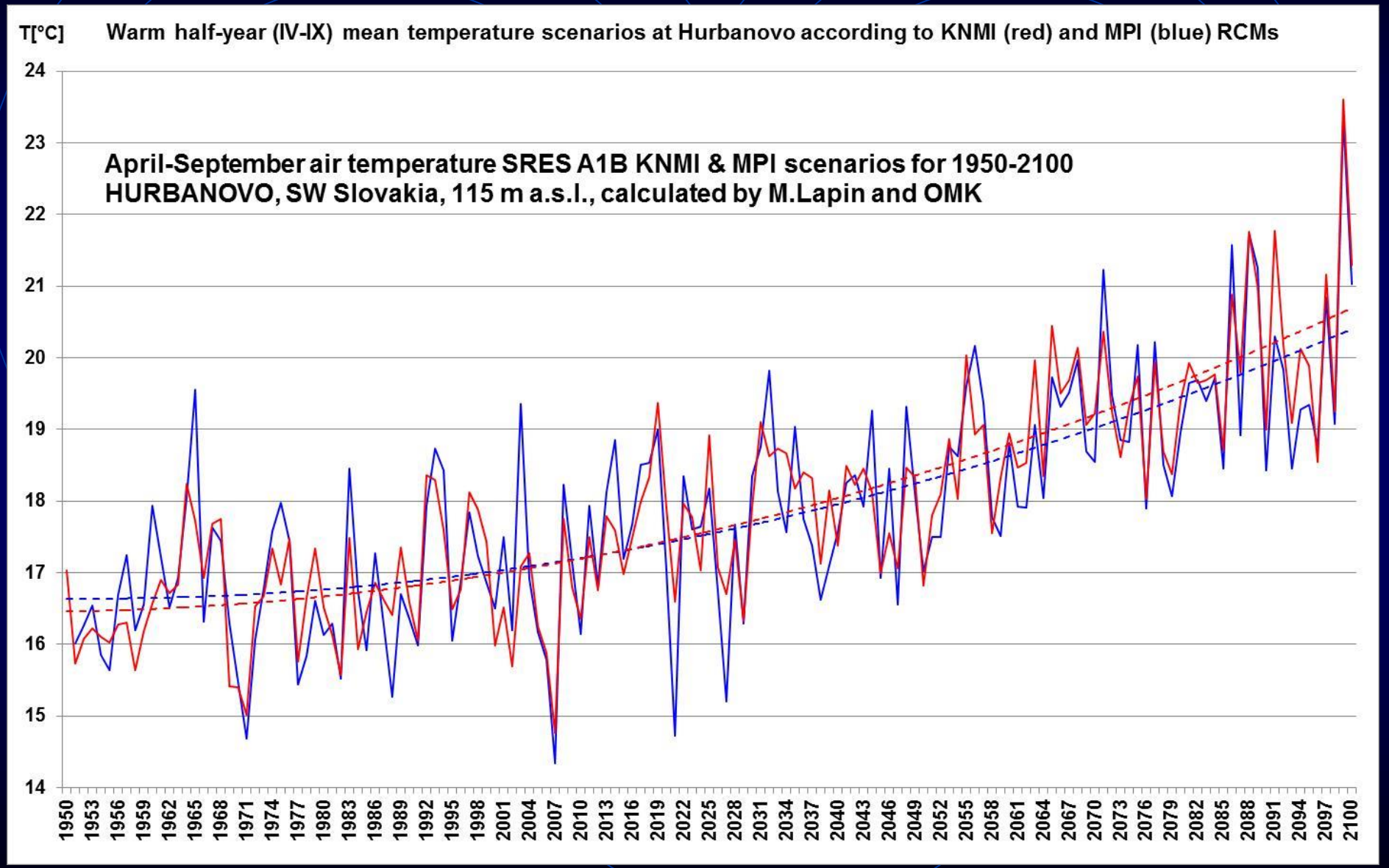
10-year mean warming in 2090-2099 compared to 1980-1999, A1B SRES

Geographical pattern of surface warming



SYR AR4, IPCC 2007

AIR TEMPERATURE SCENARIOS FOR HURBANOVO (115 m)



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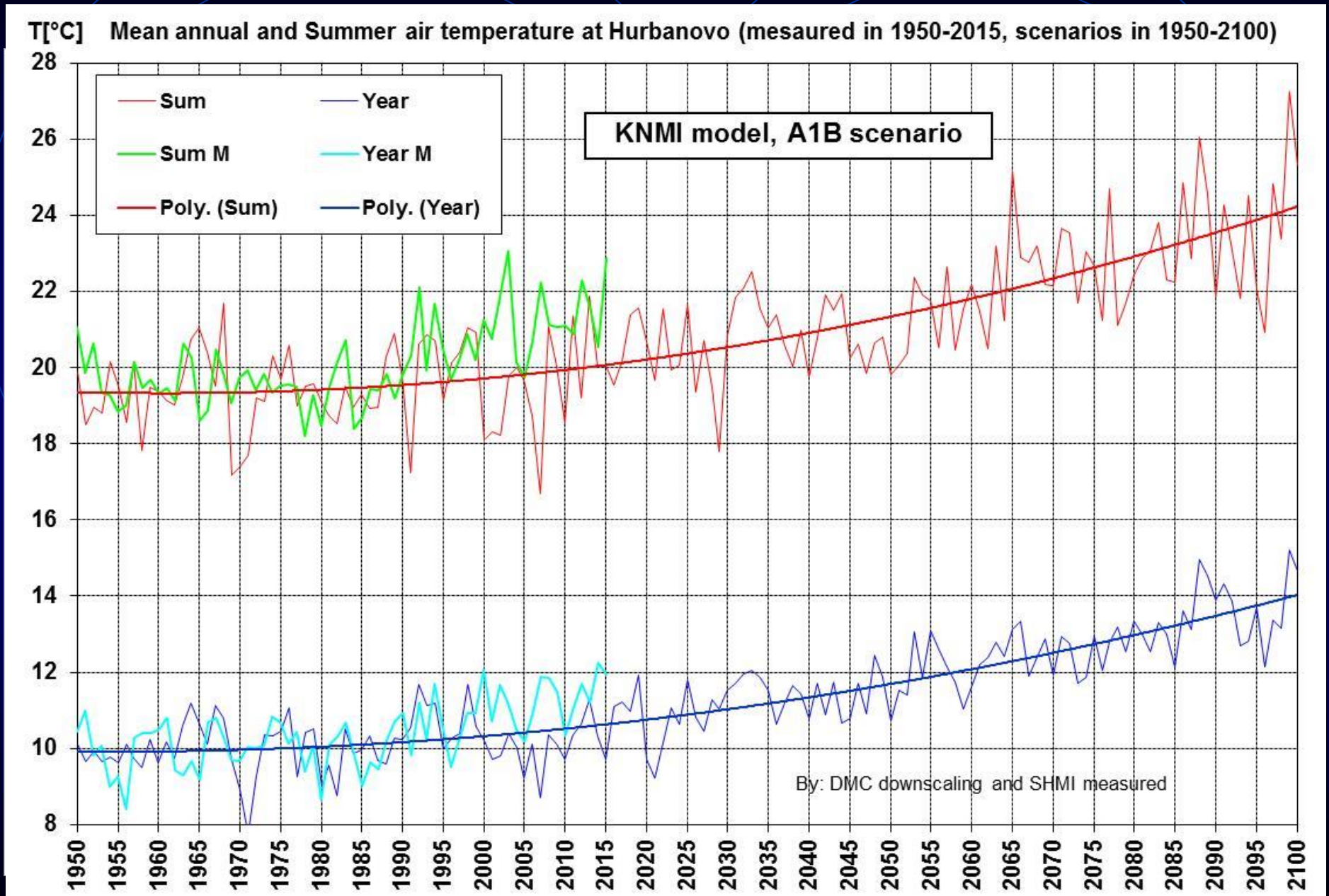

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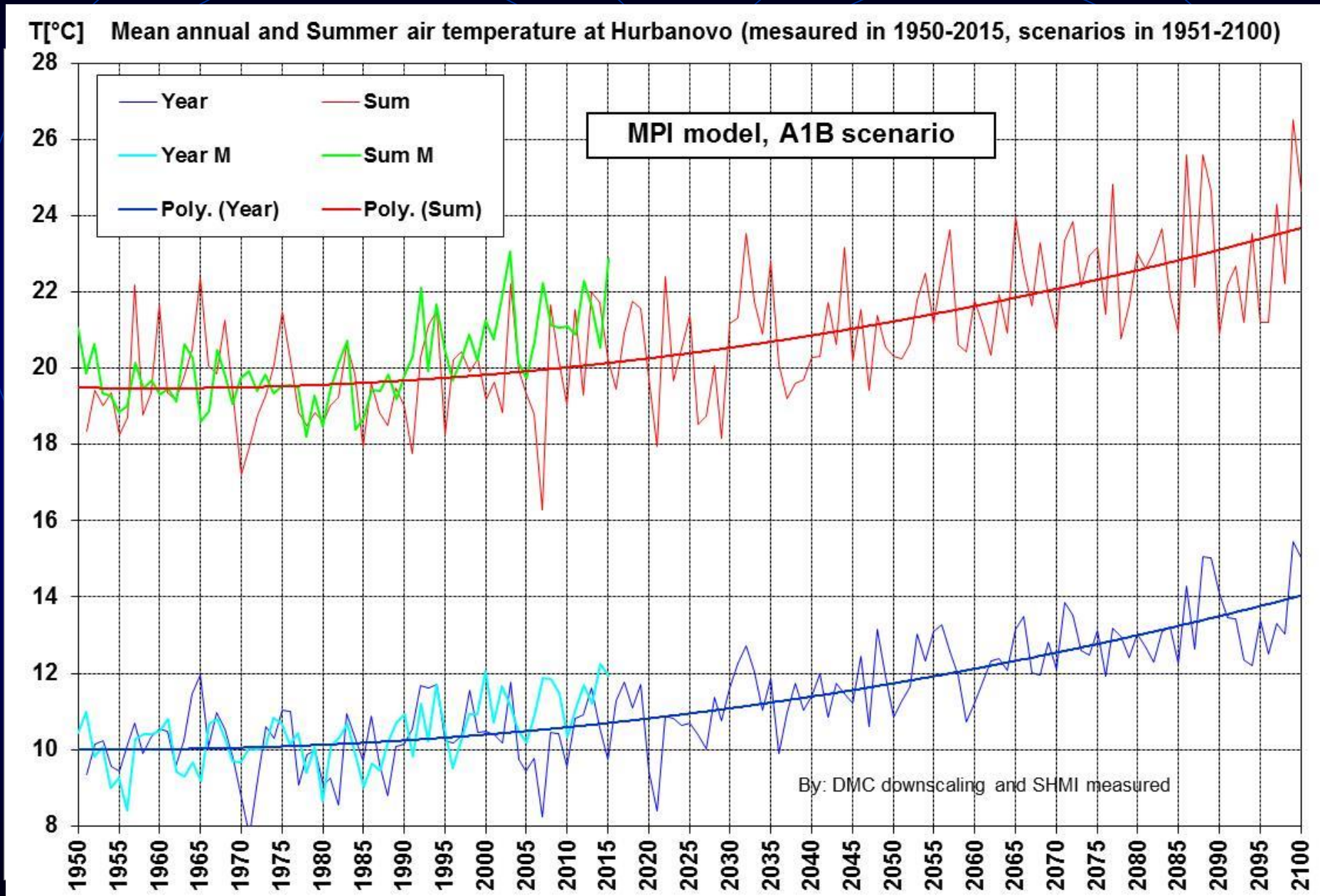
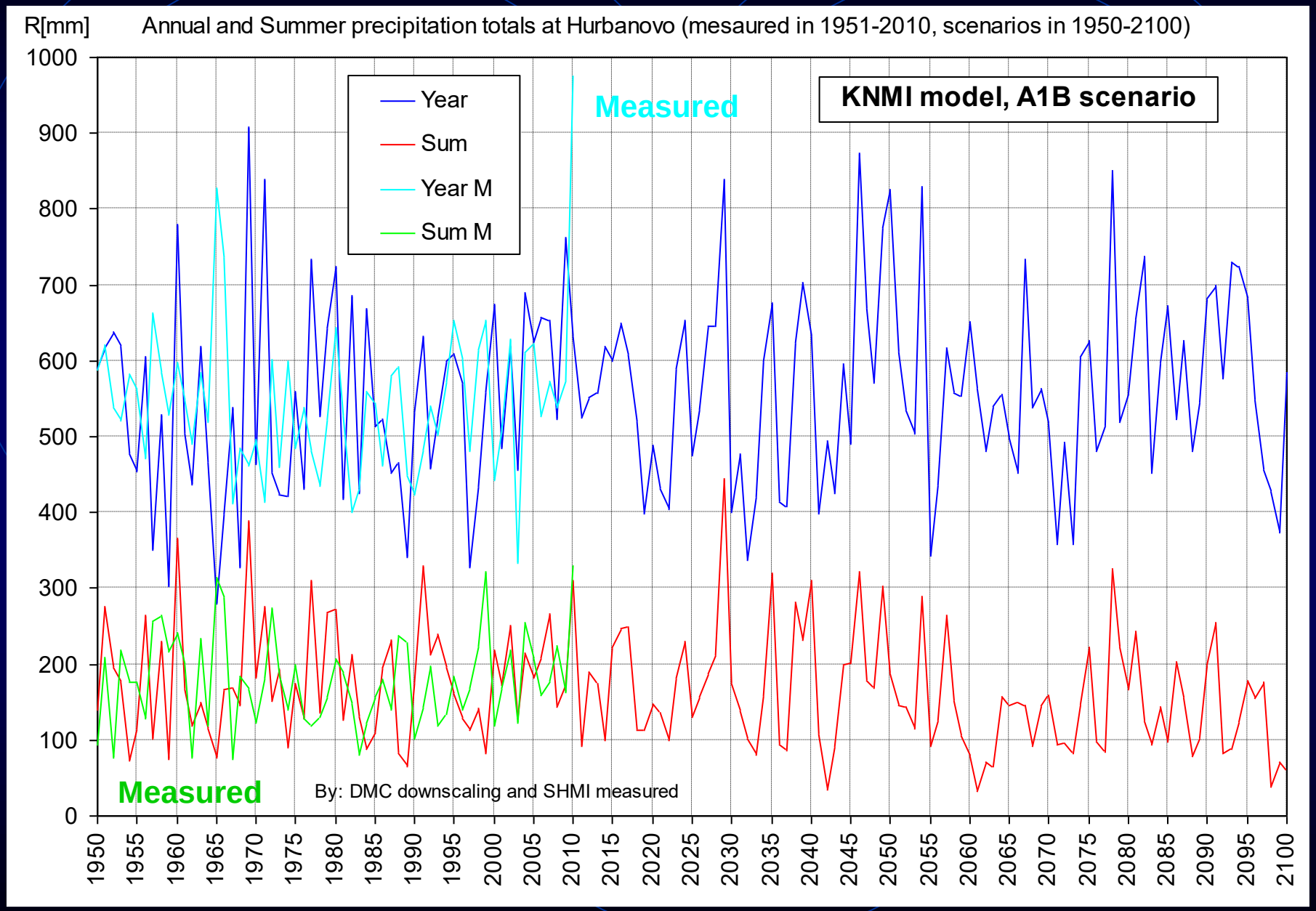


PRECIPITATION SCENARIOS FOR HURBANOVO, ANNUAL AND SUMMER



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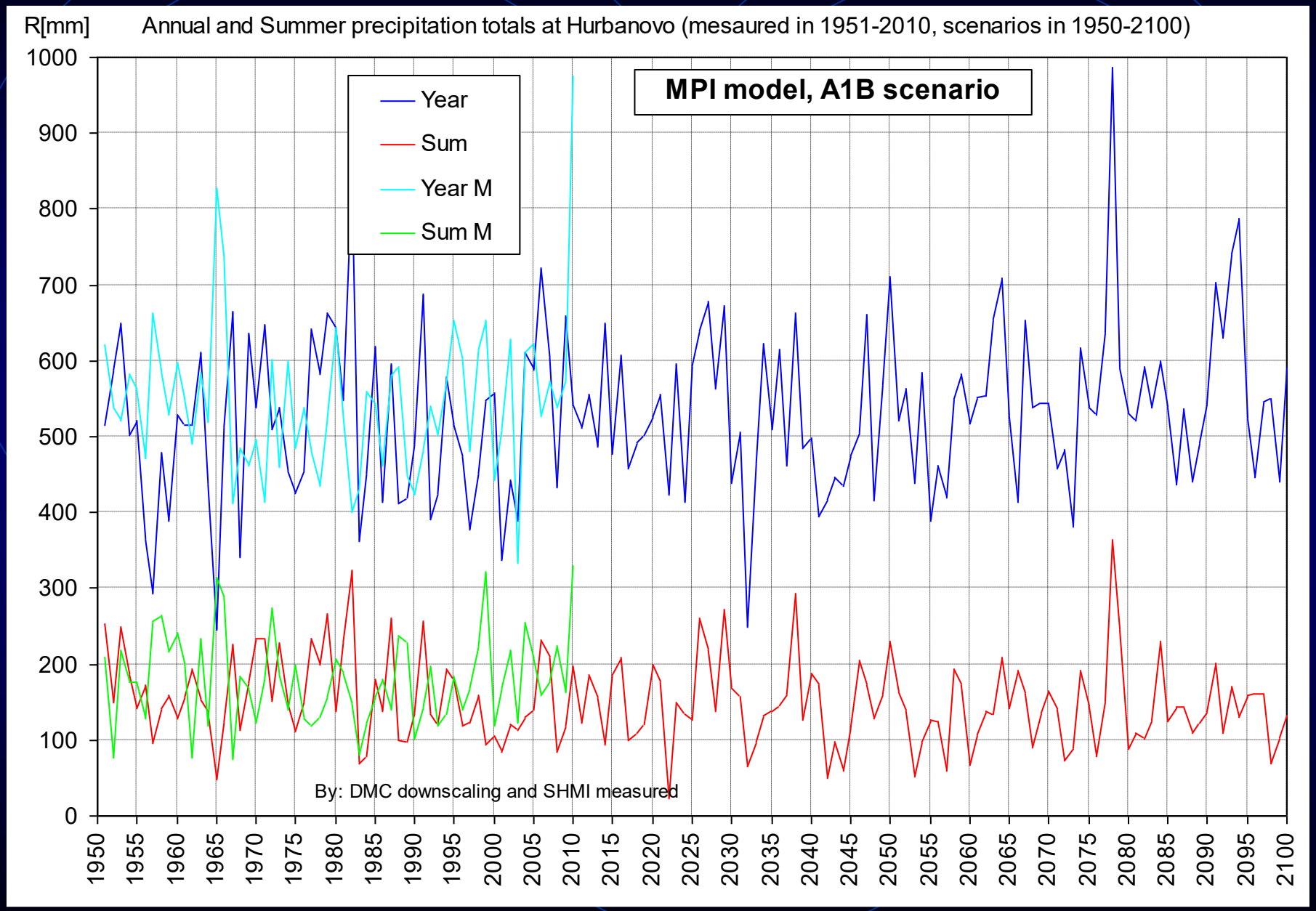

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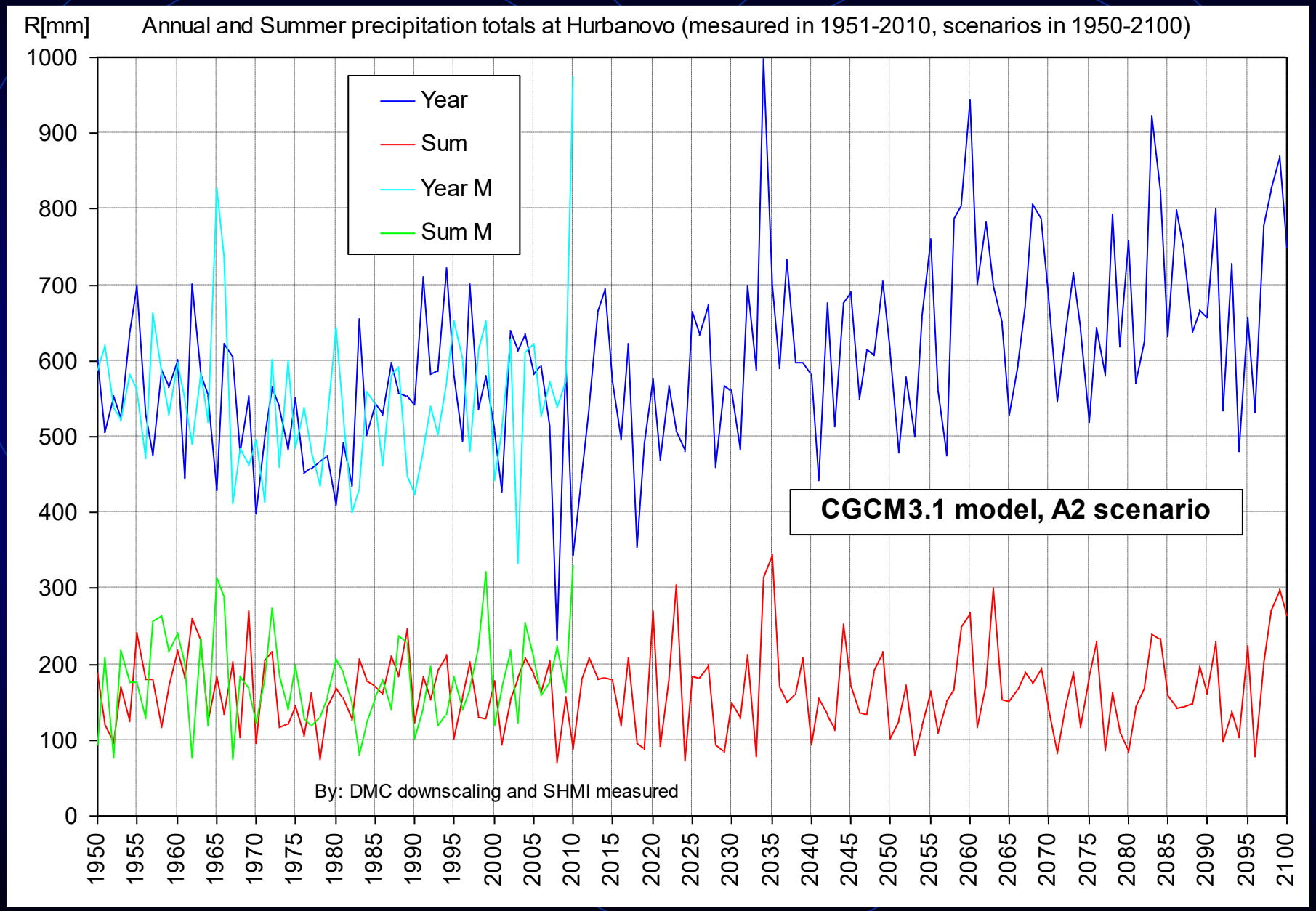

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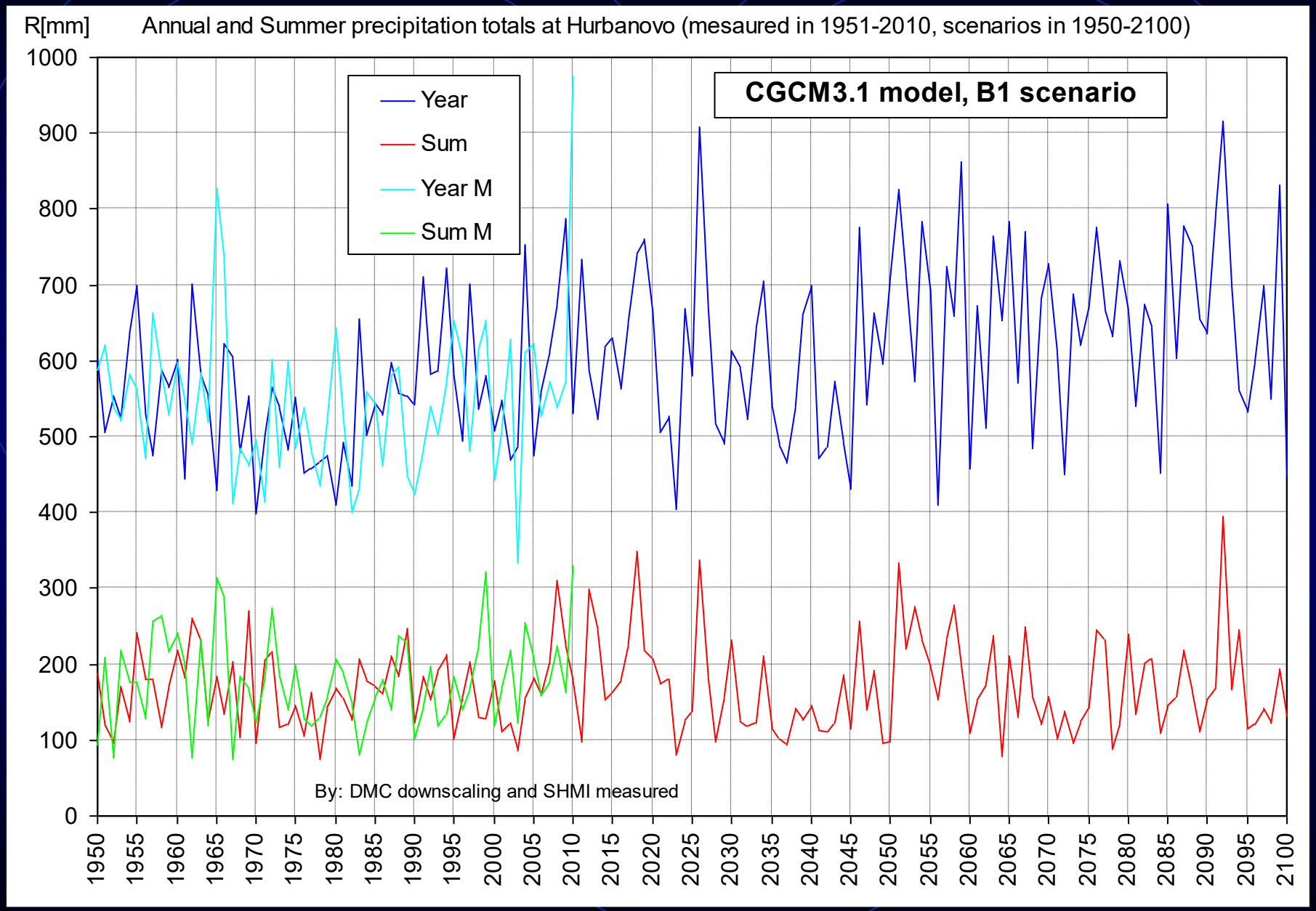
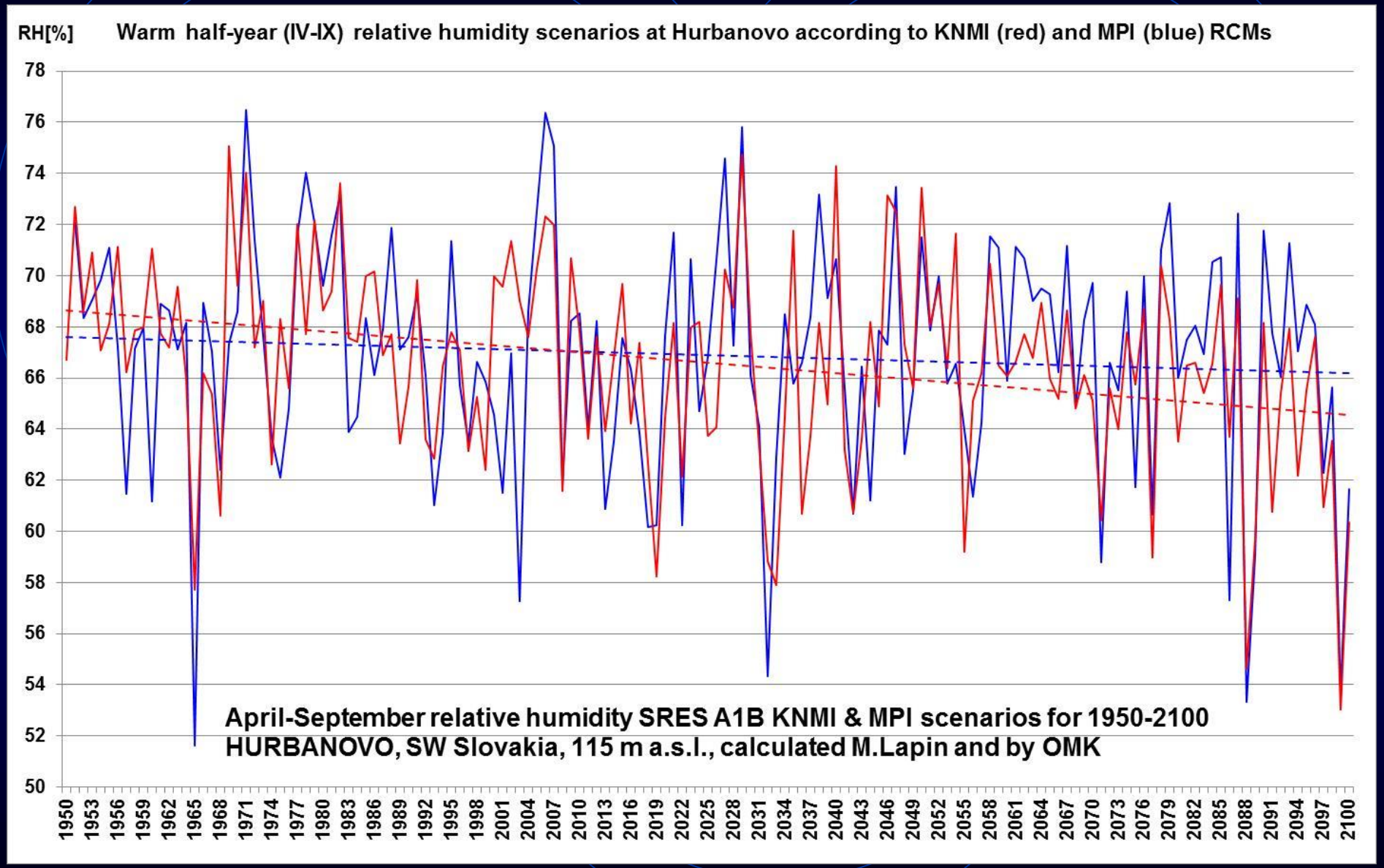
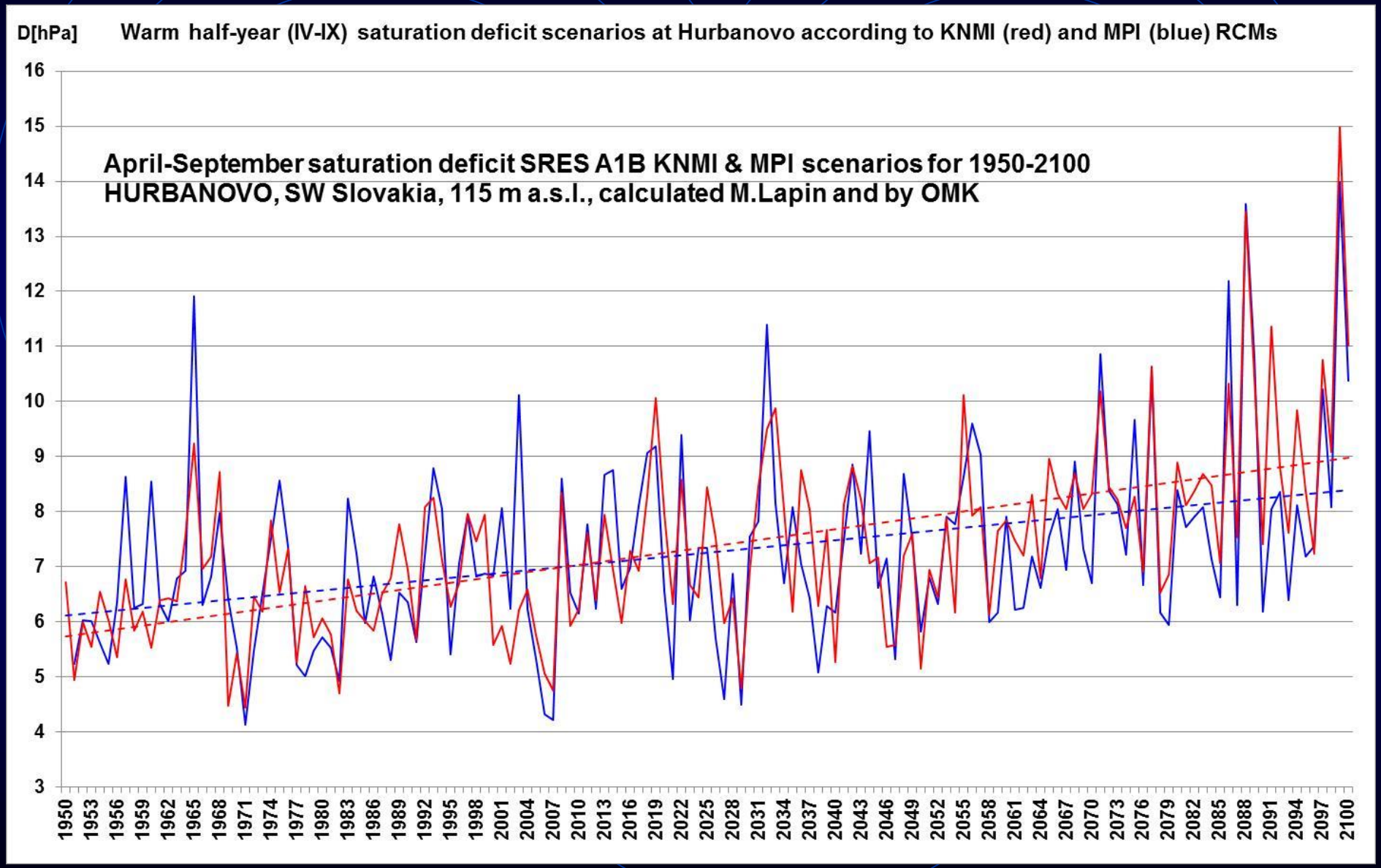


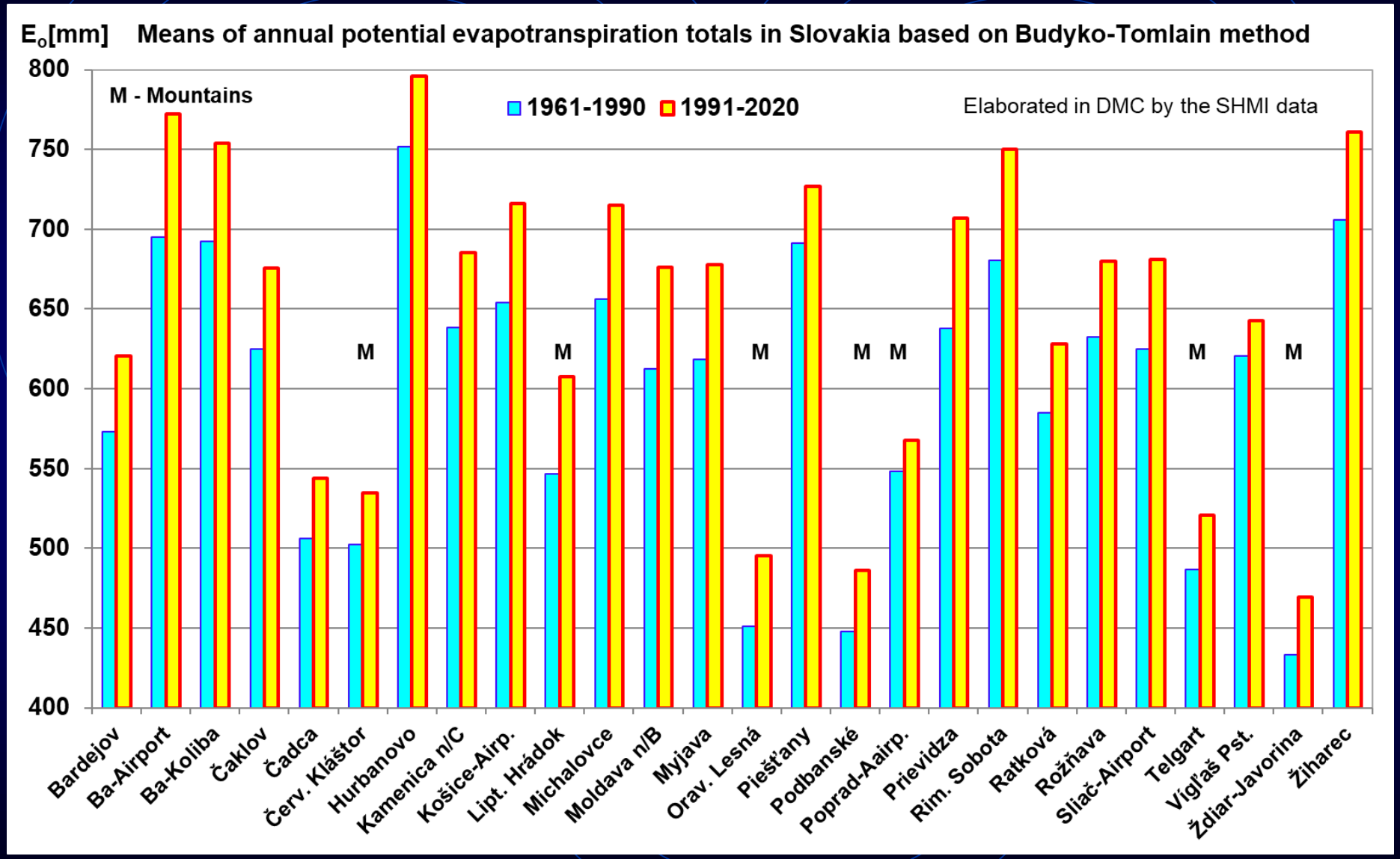
RELATIVE HUMIDITY SCENARIOS FOR HURBANOVO



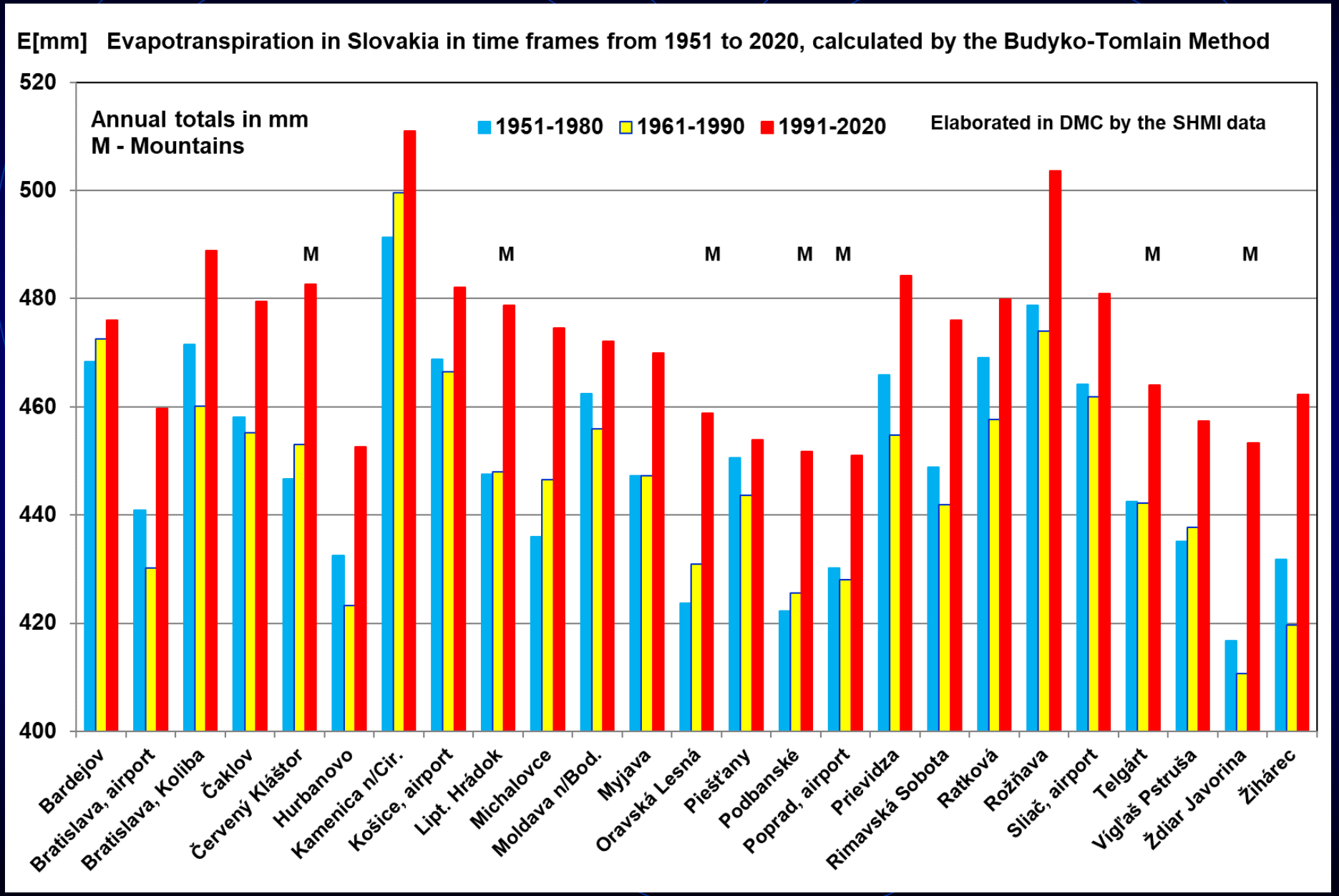
SATURATION DEFICIT SCENARIOS FOR HURBANOVO



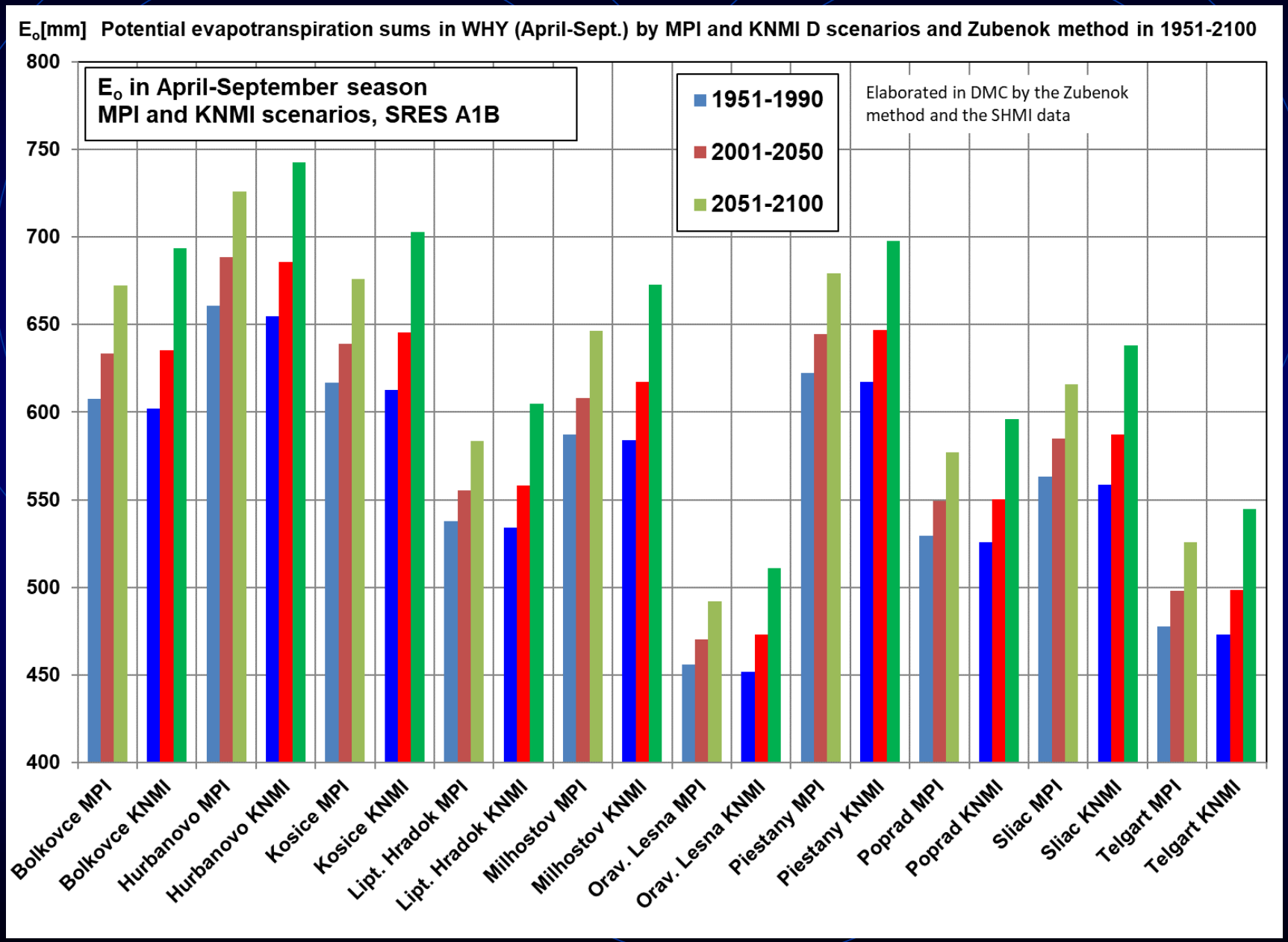
POTENTIAL EVAPOTRANSPIRATION IN SLOVAKIA



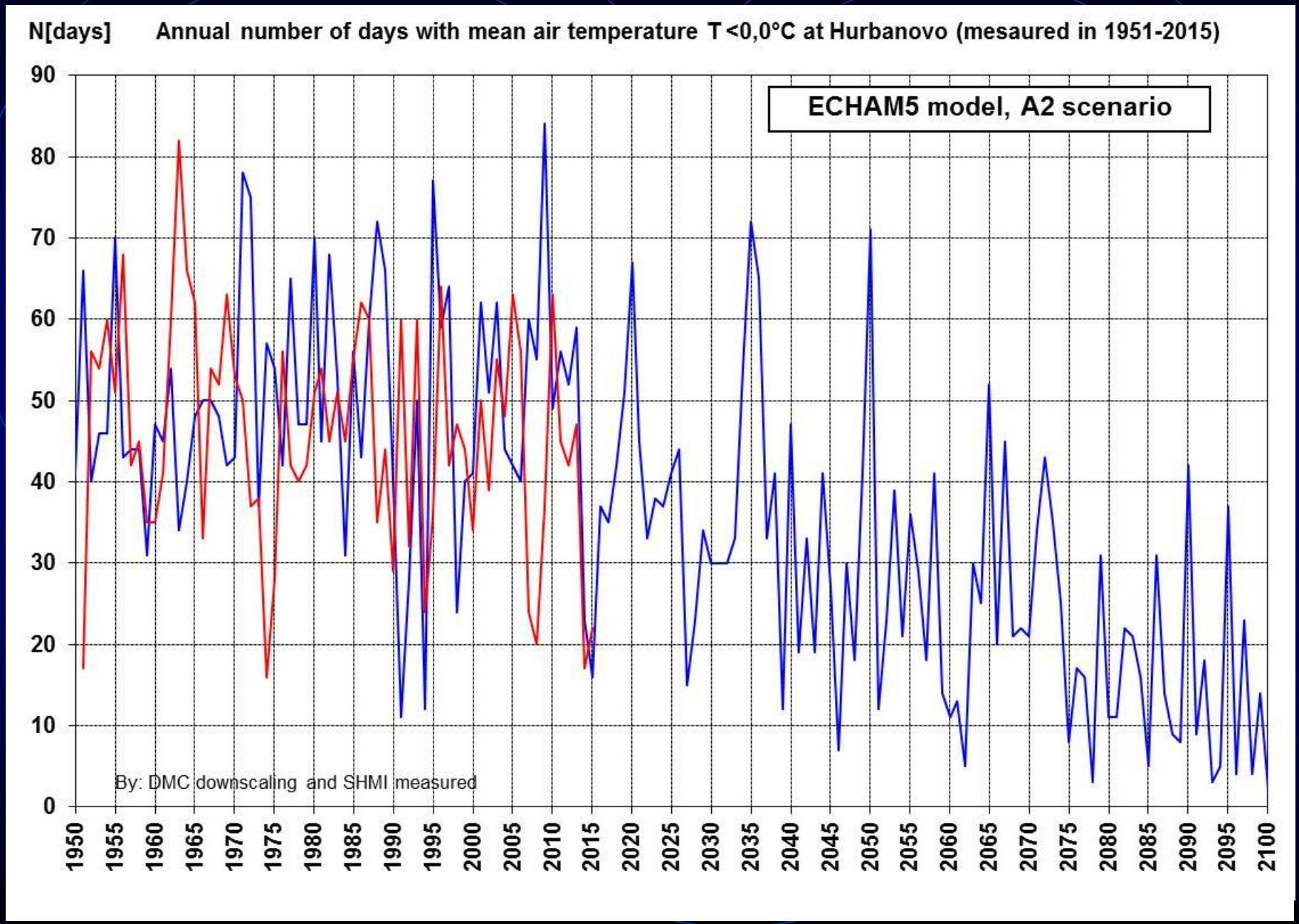
ACTUAL EVAPOTRANSPIRATION IN SLOVAKIA



POTENTIAL EVAPOTRANSPIRATION SCENARIOS

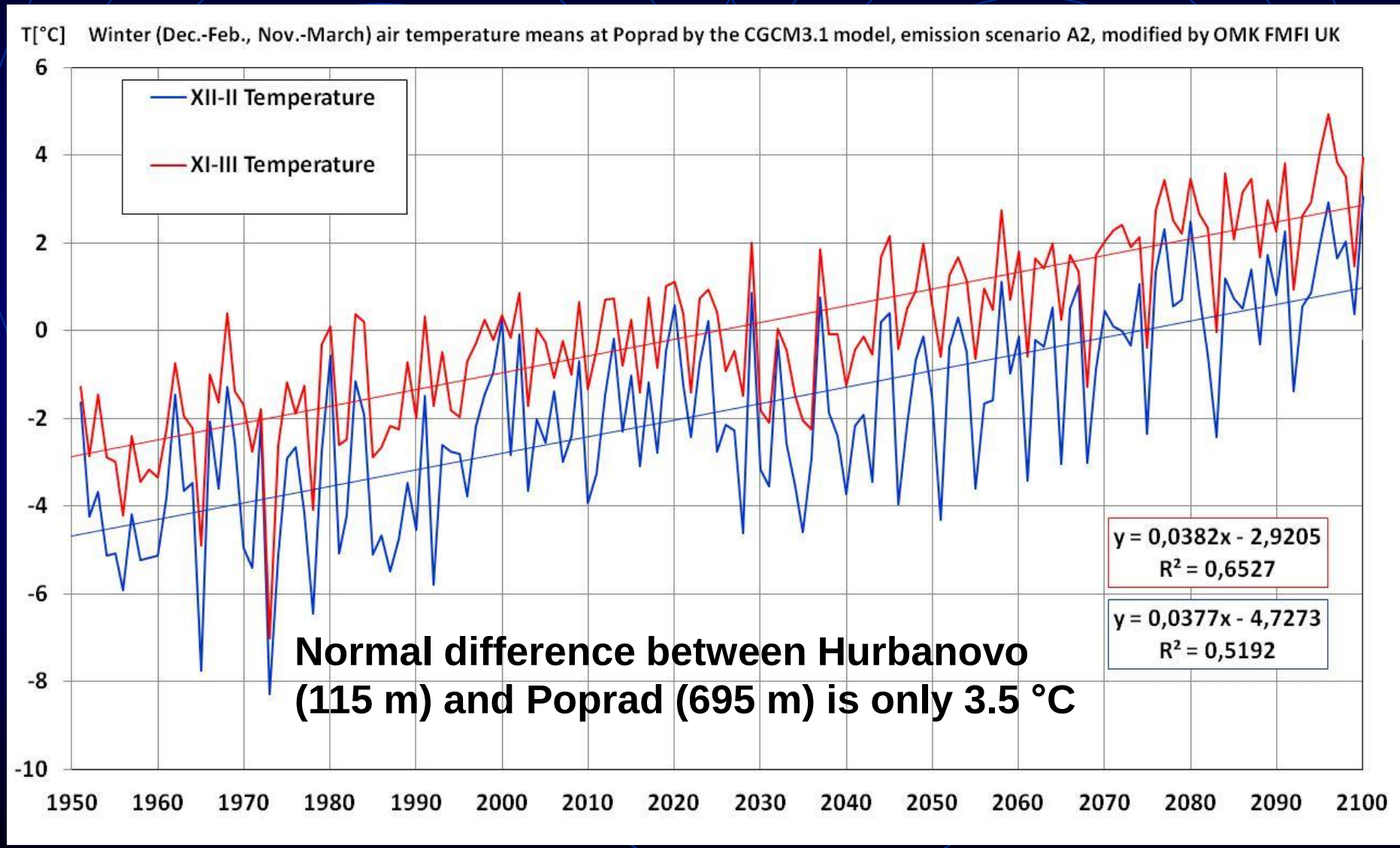


TEMPERATURE SCENARIOS FOR HURBANOVO (115 m)



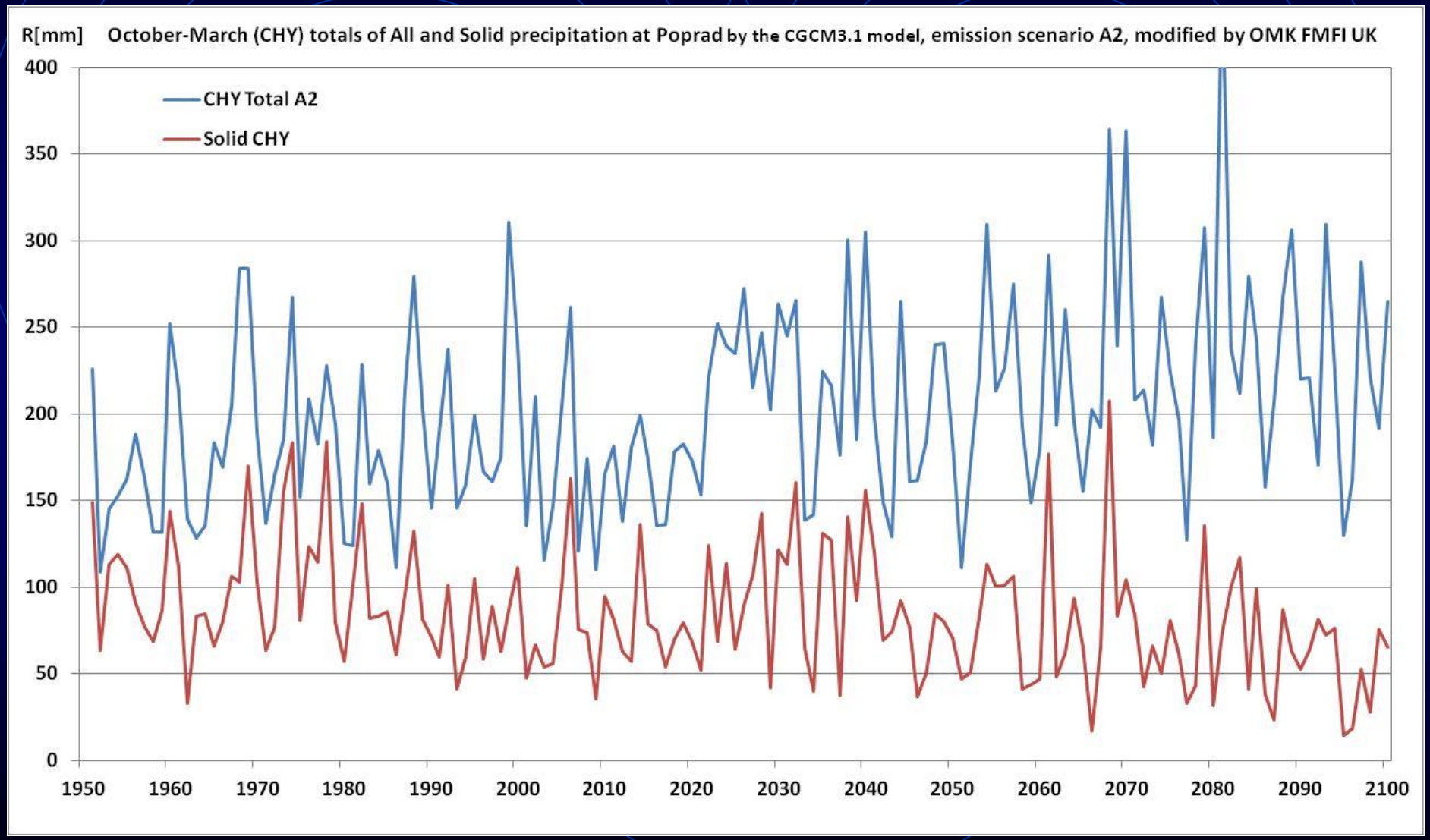
TEMPERATURE SCENARIOS FOR POPRAD (695 m)

Up to present by about 2°C increase, another increase by about 2.5°C is possible by the end of the 21st century



PRECIPITATION SCENARIOS FOR POPRAD (695 m)

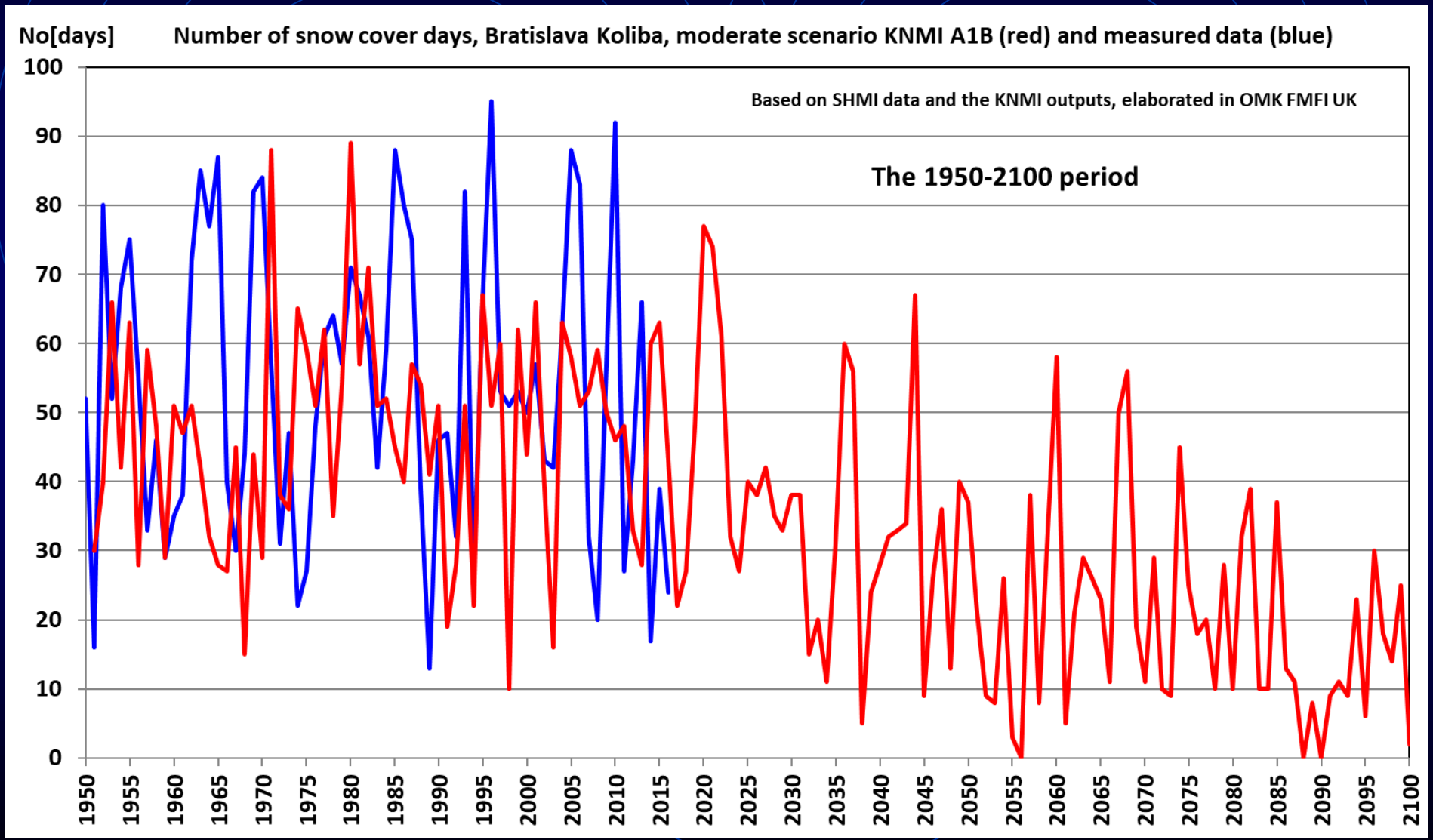
The share of solid precipitation (snow) is decreasing in the Cold half-year, a decrease from 70% to 20% is possible by the end of the 21st century



SNOW COVER DAYS SCENARIO FOR BRATISLAVA KOLIBA (285 m a.s.l.)

Number of snow cover days represent 1 cm and more snow cover at 6.00 h UTC measured at the meteorological station, moderate KNMI scenario

Measured data (blue), modelled data as scenario (red)



WE EXPECT CONTINUATION OF CLIMATE CHANGE, WHAT IMPACTS CAN OCCUR?

- **It is sure that the GHGs emission will continue and therefore also the warming of the atmosphere remains (at least lower 5 km of it):**
  - Natural climatic changes can partly modify this effect
  - Climate change and warming will be the fastest in the Arctic
  - This will cause decrease of the Arctic sea ice extent and change of the mild zone general atmospheric circulation
  - On the other hand this will cause increase of water vapor content in the atmosphere (6%/1°C), mainly up to 5 km
  - The characteristics of tropical and extratropical cyclones will change significantly (strong wind, rains, storms, new snow…)

WHAT CAN WE DO?

- Basically there are 3 possibilities how to manage the Climate Change impacts (in fact the anthropogenic + natural climatic changes ones) – no examples are listed here!
- **1) Not to take into account any anthropogenic climate change** and our actions determine only on the basis of natural climatic changes – as stable state as before (skeptical expertises basic attributes)
- **2) To prepare adapting options according to accepted scenarios** – in case of less important activities the average scenarios, at very important ones the highest (pessimistic) assessments
- **3) To prepare also measures how to slow down the ongoing climate change (MITIGATION OPTIONS)** – reduction of greenhouse gases (GHGs) emission into the atmosphere, manage our negative impacts in land use change, increase of biospheric sinks of atmospheric GHGs, slow down of GHGs emission from the natural and artificial sources (reservoirs)

Comment: While the adapting measures can do everybody independently (state, city, firm, person…) without taking into account the rest of Globe, the mitigation options need to be **co-ordinated on all over the World (UNO)**, it is important that the social and historical equity must be taken into the account also among the regions

QUESTIONS?

- Is the greenhouse effect increase caused by human activities ?
- Can we separate the natural and anthropogenic impacts ?
- Is climate warming positive or not ?
- Can we mitigate Climate Change by GHGs emission reduction?
- Can we calculate the cost/benefit in case of mitigation ?
- How long in advance we need to prepare adapting measures ?
- Can we calculate the cost/benefit in case of adaptation ?
- Is there any possibility to assess Climate Change impacts on socio/economic sectors, sustainable development, natural ecosystems and on vanishing of biological species ?
- Is the economic effectiveness more important than the natural biodiversity or the healthy humans and ecosystems ?

- **Other questions ?**
- Can Climate Change cause great number of refugees ?
- Can the mitigation options slow down economic development ?

REAL OPTIONS ?

- Energy consumption / GDP unit is much higher compared to EU15 !
- New technologies and equipments can save > 20% energy !
- No significant investments are needed in household to save energy (heating, hot water use, air condition, equipments) !
- New transport devices can save > 20% energy !
- Renewable energy sources can save > 20% of fossil fuels !
- Recycling can save energy, raw materials and decrease CO_2 and other GHGs emission !
- Goods with long guarantee period can save energy and raw materials, that means also reduction of GHGs emission !
- Discipline at private and professional activities !
- Adapting and Mitigation measures do not slow down economy!

- **Other options ?**
- Each country has its own possibilities to save energy and raw materials and to reduce GHGs emission (nuclear energy, renewable energy sources….) !

CONCLUSIONS

- Climate change (CC) must be correctly defined, scientifically analyzed and the results properly applied by involved users, otherwise cannot be reliable any conclusion on CC
- CC impacts are expected mostly as negative and only partly as positive (differently in some regions)
- Shift of bioclimatic borders and changes in return periods of dangerous weather design values are considered as important
- Adapting and mitigation options are based on correct impacts analysis; to differentiate of natural climate changes from the anthropogenic ones and to analyze of cost/benefit is needed
- **Reduction of the atmospheric greenhouse gases concentration is the only possibility how to slow down the rapid global air temperature increase and to reduce the consequent CC impacts, adaptation measures does not solve the CC issue**
- Renewables solve the problem of CC mitigation only partially
- **Developing countries are much more vulnerable to CC impacts**

Thank You for the Attention

Further details on the websites:
www.milanlapin.estranky.sk,
www.ipcc.ch
or use
E-mail: lapin@fmph.uniba.sk