Project 124 - Quantification of Uncertainties in RCM Simulations

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Introduction

The project investigates the sensitivity of long-term regional climate simulations to modified internal and external forcing. The external forcing is given by the boundary values interpolated from the results of a global climate simulation (GCM). The internal forcing is dominated by physical processes in and above the surface which are handled by the regional model itself. Variations of the boundary values as well as modifications of soil or surface parameters used in the description of momentum, heat, and moisture transport between the surface and the atmosphere may both affect the climate conditions over a specific region in different ways. In the frame of the CORDEX initiative several various GCMs (ERA_INTERIM, MPI-ESM_LR,CNRM-CM5, EC-EARTH, HadGEM2-ES) were downscaled with COSMO-CLM on a climatological time-scale (ensemble simulations). We investigate the range of possible realizations in order to quantify the uncertainty of the regional model to reproduce the climate conditions of a certain region. A more detailed knowledge of this range of uncertainty is necessary to assess the reliability of simulated climate change signals. The water stored on land surfaces (terrestrial water storage – TWS), plays a key role in the hydrological cycle, but also serves as an indicator of quality of the coupling between atmospheric forcing (precipitation) and terrestrial response (evapotranspiration, total runoff and terrestrial water storage) from the multi-layer soil and vegetation model TERRA ML i.e. lower boundary condition in COSMO-CLM. Here we investigate decadal changes in seasonal cycle of TWS in Danube catchment area.

Coordinated regional climate Downscaling

CORDEX (COordinated Regional climate Downscaling Experiment): WCRP formed a task Force on RCD aiming to bring together efforts in GCM and RCD communities in order to better uderstand climate change. Main goals:
(i) framework to evaluate and improve RCD techniques for use in downscaling global climate projections
(ii) multi-model RCD-based high resolution climate change information for impact/adaptation work and IPCC AR5
(iii) interaction and communication between global climate modelers, the downscaling community and end-users to better support impact/adaptation activities

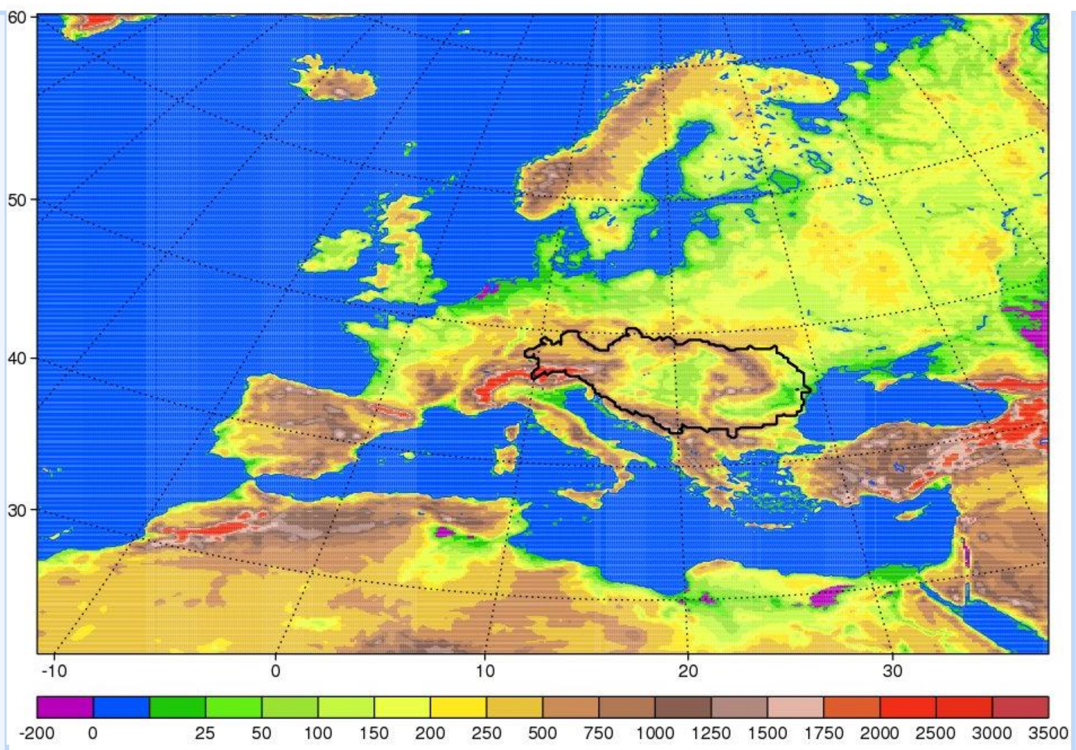

Figure 1: Topography and Danube river basin (evaluation domain). Model domain size 450x430x40, resolution 0:11 degrees, 10 soil layers down to 15 m

Motivation and previous work

Water supply and its socio-economic impacts are among the most critical challenges for the future. The assessment of the reliability of RCM to represent hydrological balance of river basins is one challenging task for climate modeling:
(i) Lucarini et al, 2007: Does Danube exist? Versions of reality given by various RCM and climatological data sets (large discrepancies among RCMs, GCM better than RCMs, resolution: increases P and E but not net balance)
(ii) Hagemann et al, 2004: Evaluation of water and energy budgets in RCMs applied over Europe (systematic errors in dynamics, deficiencies in the land surface, large-scale condensation and convection schemes)

Evaluation domain – Danube RB

Danube River Basin 801, 463 km² spread over territories of 19 countries. The ecosystems are highly valuable in environmental, economic, historical and social terms, but they are subject to increasing pressure and serious pollution from agriculture, industry and cities. Geomorphology of the Danube river basin is very diverse, and therefore climate varies from Alpine to Mediterranean.

Theoretical framework

The water balance-equations: rate of change in terrestrial water storage $\Delta TWS = P - E - R$ (P is precipitation, E is evapotranspirationa, R total runoff)

Experimental setup

Table1: GCM forcings and periods
(i) evaluation run : ERA-Interim (1989 - 2008)
(ii) historical run: 3 GCMs (1950 - 2005)

CCLM	GCM	Exp	Resolution	Vertical
CEU012	ERA-Interim (ERAINT)	eval	512 × 256 × 60	$p = a_p + b \cdot p_s$
HISCNR	CNRM-CM5	h/45/85	256 × 128 × 31	$p = a \cdot p_0 + b \cdot p_s$
HISMPI	MPI-ESM-LR (HISMPI)	h/45/85	192 × 96 × 47	$p = a_p + b \cdot p_s$
HISECE	EC-Earth	h/45/85	320 × 160 × 62	$p = a_p + b \cdot p_s$

Table2: CCLM model settings relevant for the precipitation and soil processes

parameter	value	description
dt	100s	time step
l2tls	T	2 time-level Runge-Kutta time-split scheme
lgsp	T	grid-scale precipitation scheme
lprogprec	T	prognostic treatment of rain and snow
itype_conv	0	Tiedtke scheme for convection parameterization
itype_gscp	3	grid-scale precipitation with cloud water and cloud ice
lmelt	T	soil model with melting process
lmelt_var	T	freezing temperature dependent on water content
ibot_w_so	$4m$	depth of the last hydrologicaly active soil layer
itype_trvg	2	BATS type of vegetation transpiration parameterization
itype_evsl	2	BATS type of parameterization of bare soil evaporation
itype_tran	2	TKE-based scheme type of surface to atmospher transfer
lana_rho_snow	F	ρ_{snow} values are not from analysis file but set in model

Present day (1990-1999) intercomparison between evaluation run, historical experiment and quasi-observed data

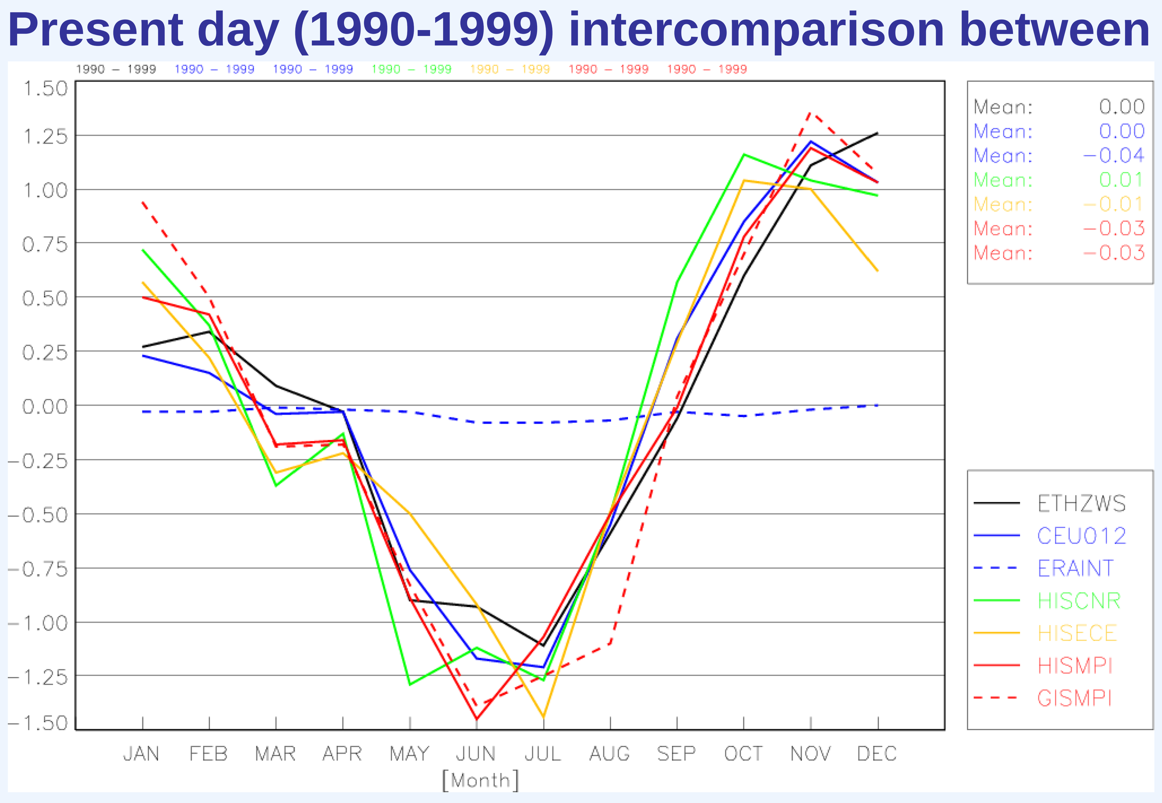

Figure 2: Annual cycle of terrestrial water storage change, absolute values of ΔTWS in mm/d.

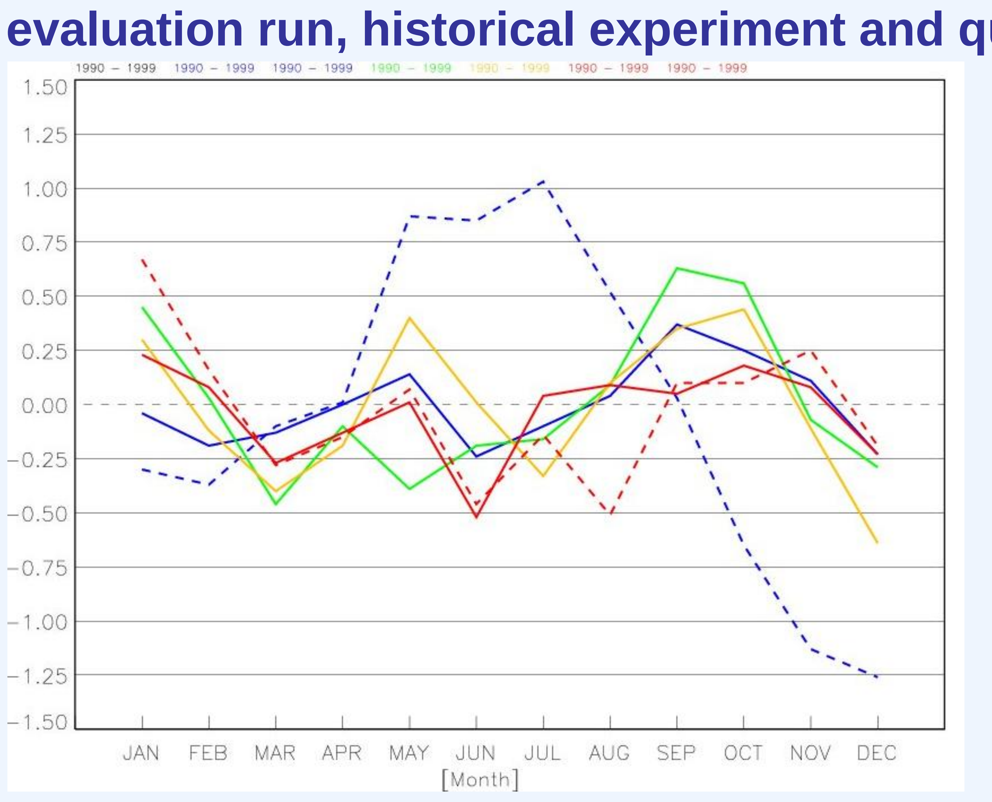

Figure 3: Annual cycle of ΔTWS difference between simulations and quasi-observed ref. data

All the models menaged to capture anual cycle except ERA-INTERIM. However, CCLM run (CEU012) forced with ERA-INTERIM shows also good agreement with quasi-observation (ETHZWS).

Quasi-observation

Data set is derived by Hirschi et al (2006) from atmospheric moisture flux convergence from ERA-INTERIM combined with Global River Discharge Center data set for Danube river basin.

Changes of annual cycle of ΔTWS-Bias for 5 successive decades (1950-1959, 1960-1969, 1970-1979, 1980-1989, 1990-1999), 3 RCM historical experiments

In comparison to quasi-observed ΔTWS for the period 1990-1999, HISMPI-CCLM realization shows slightly wetter condition through the decades in the second half of year and dryer in the first half of year going from past to the present. No such a trend can be seen in the HISCNR realization. In general it can be distinguished between parts of the year for which most of the decades are dryer (February to July) then the quasi-observed ΔTWS and wetter (August to November). For the HISECE realization all the decades are quiet similar, especially the three recent ones indicating stabile climate conditions.

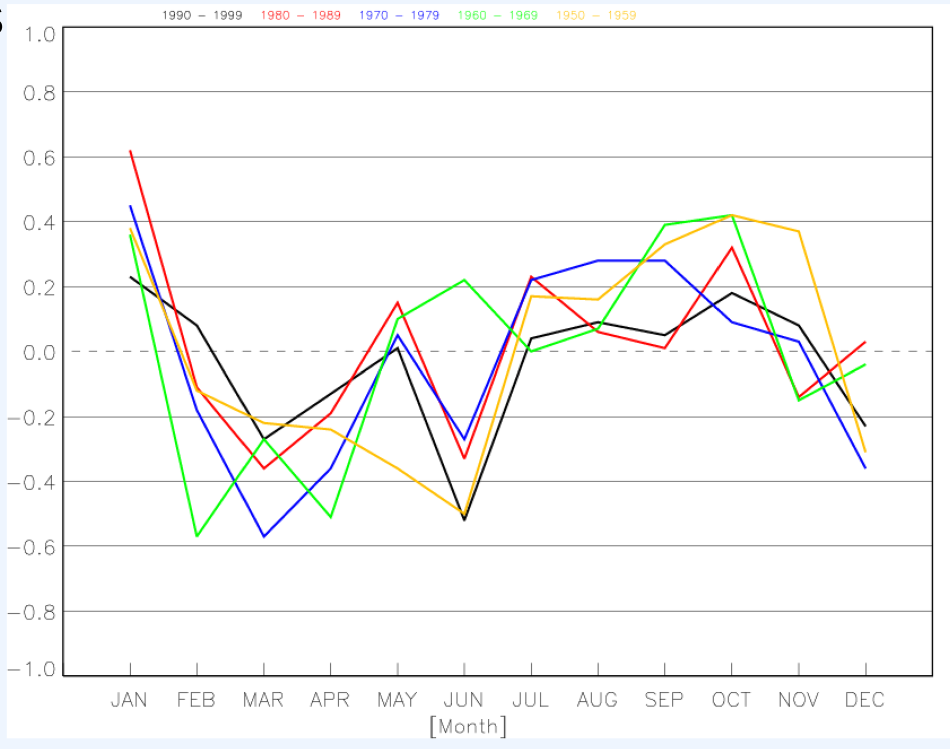

Figure 4: HISMPI, interdecadal change of ΔTWS annual cycle (mm/d), relative to quasi-observation.

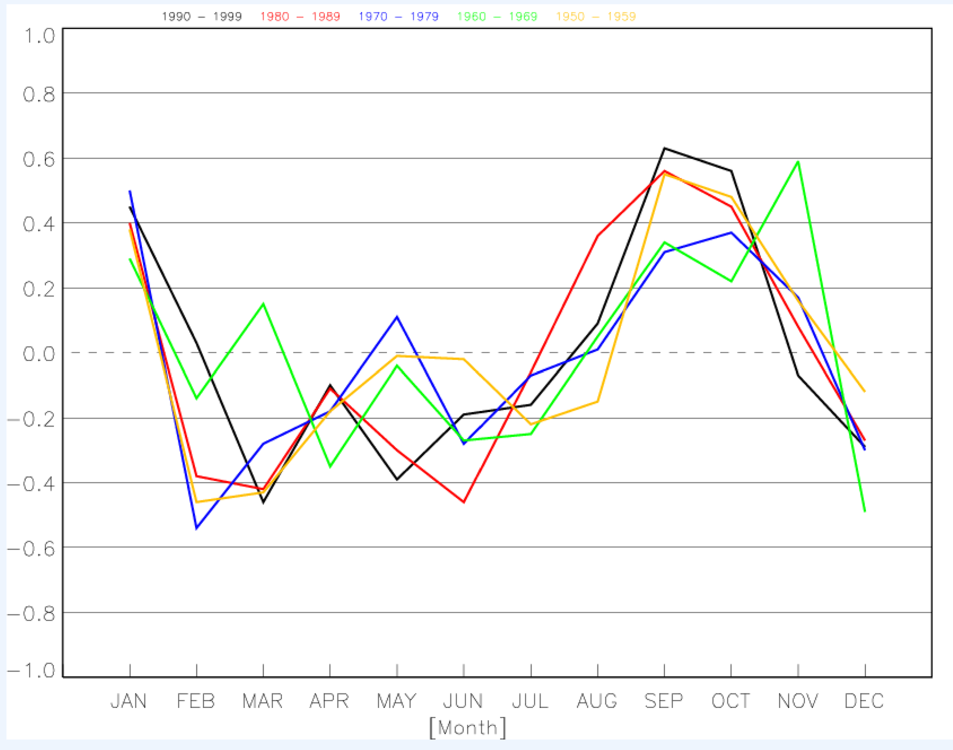

Figure 5: HISCNR, interdecadal change of ΔTWS annual cycle (mm/d), relative to quasi-observation.

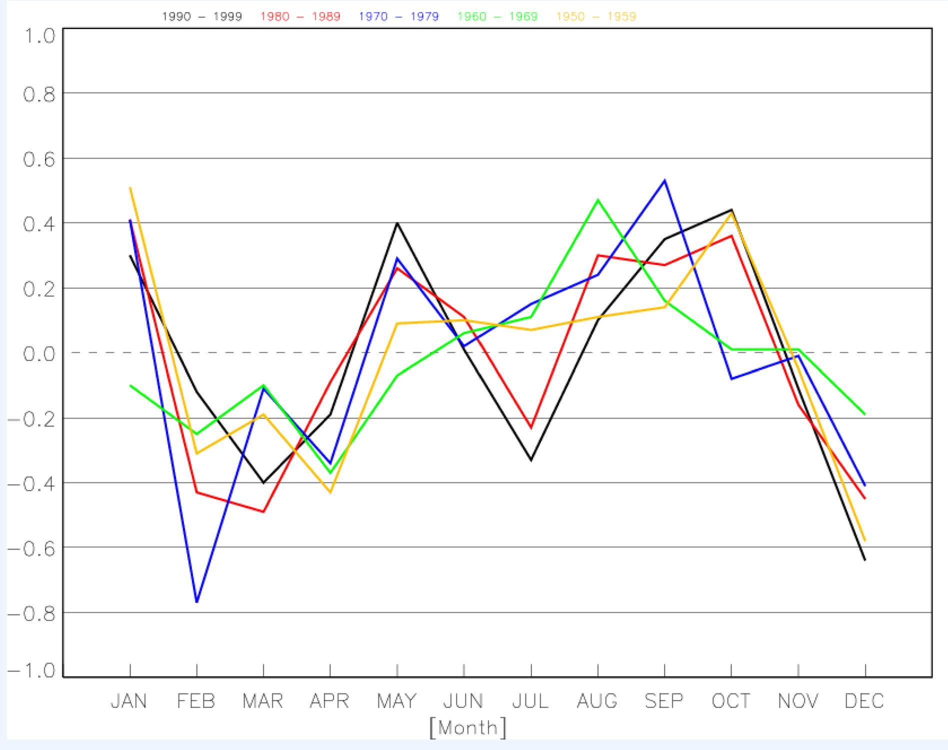

Figure 6: HISECE, interdecadal change of ΔTWS annual cycle (mm/d), relative to quasi-observation.

Comaprison between RCM and GCM (HISMPI vs GISMPI)

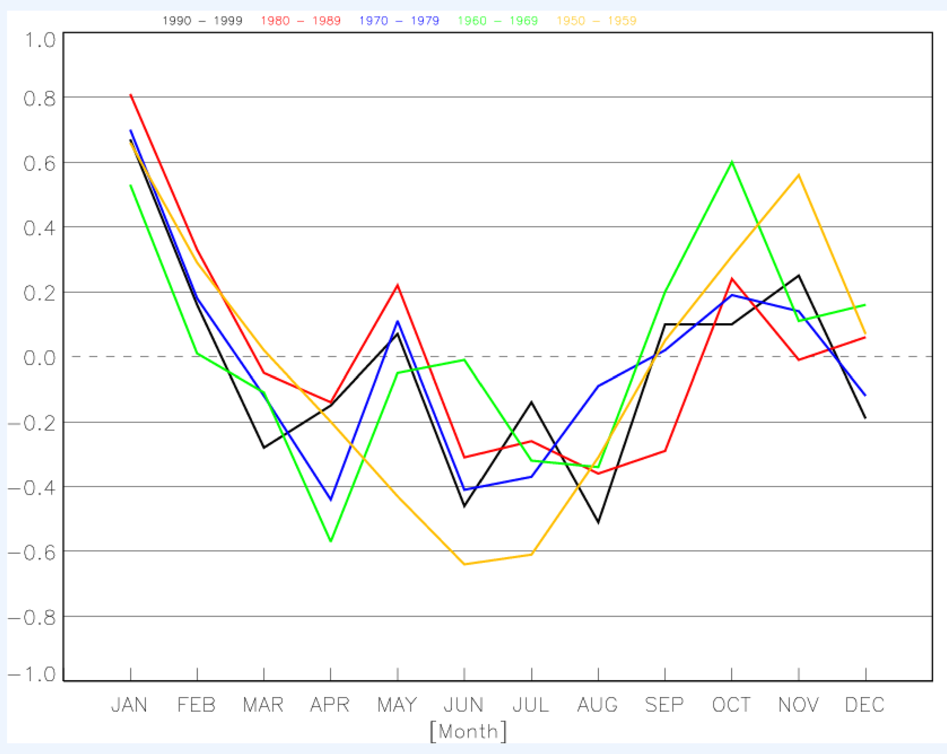

Figure 7: GISMPI, interdecadal change of ΔTWS annual cycle (mm/d), relative to quasi-observation. It shows stable climate similar as HISECE (Fig. 6).

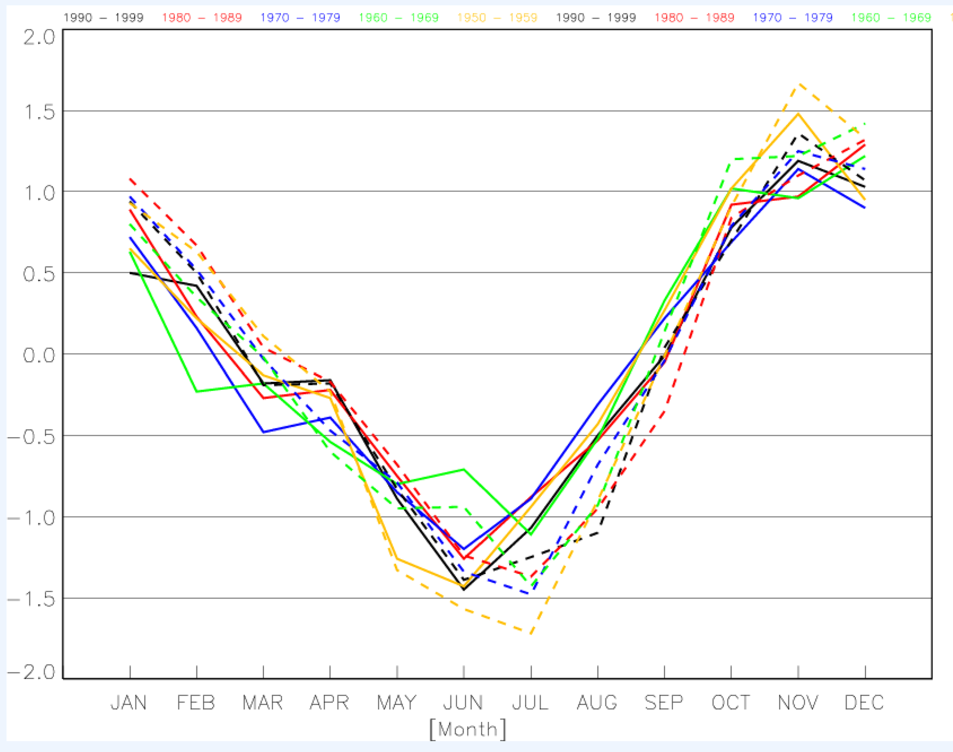

Figure 8: HISMPI vs GISMPI, interdecadal change of ΔTWS annual cycle in mm/d. GCM dryer than RCM in dry part of year and wetter during the wet part of the year.

Summary

ΔTWS was examined for several realizations of CCLM downscaling with evaluation domain in Danube catchment area. Present day (1990-1999) seasonal cycle qualitatively fits quasi observed data for all simulations except ERA-Interim. One of the three historical downscaling experiments shows a trend (dryer present days second half of the year, and wetter first half of the year) in TWS for the past 50 years (HISMPI). HISCNR shows dryer and wetter parts of the year but in no particular order, while HISECE shows stabile climate, especially for the past 3 decades. In comparison GCM vs. RCM, GISMPI is dryer than the RCM simulation (HISMPI) in dry part of the year and wetter during the wet part of the year.

Reference

Hagemann S., B. Machenhauer, R. Jones, O. B. Christensen, M. Déqué, D. Jacob and P. L. Vidale, 2004: Evaluation of water and energy budgets in regional climate models applied over Europe. Climate Dynamics Volume 23, Issue 5, pp 547-567.
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