Climate projections for the XXI century over the Mediterranean area with COSMO-CLM and induced variations on hydraulic and geological hazards

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CMCC

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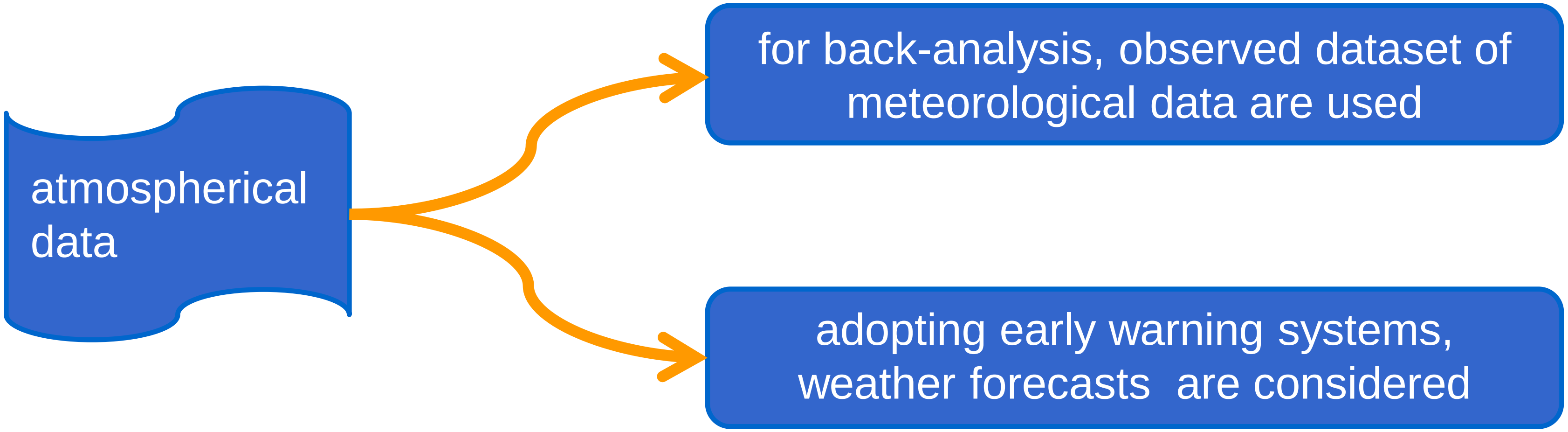
Modeling chain for weather-induced hydraulical-geological hazard

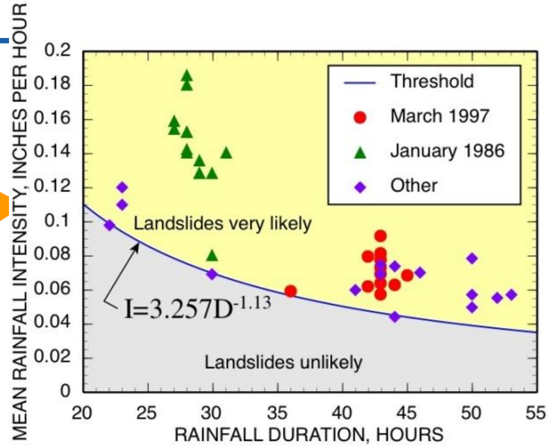


Modeling chain for weather-induced hydraulical-geological hazard

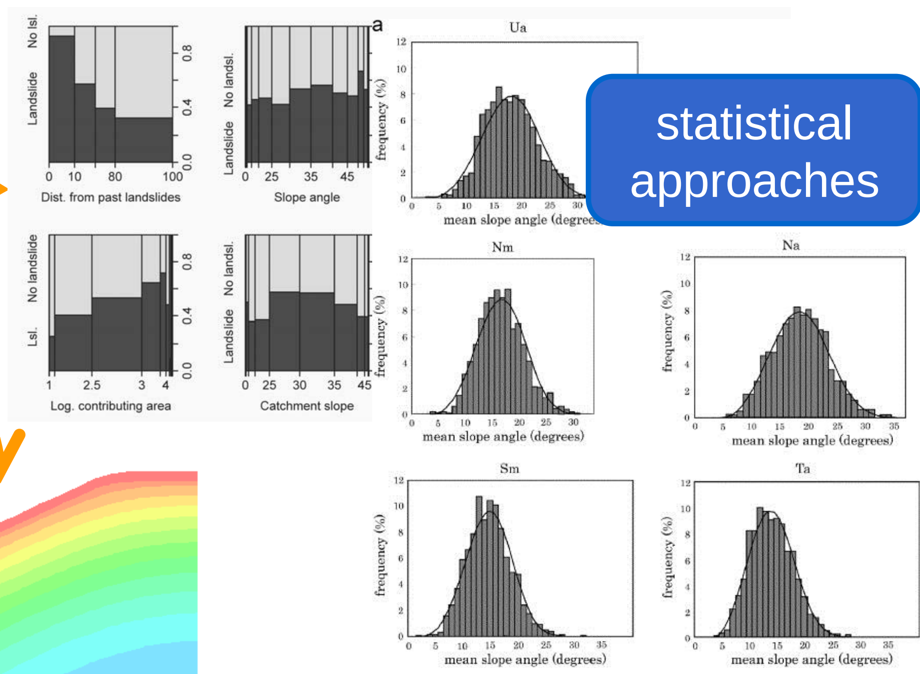
atmospherical data

Impact model

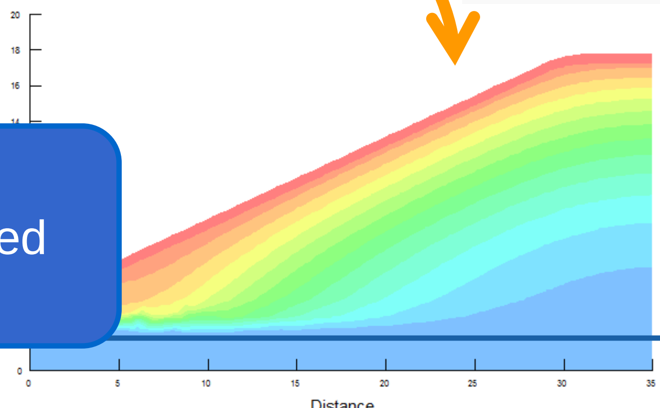
empirical model



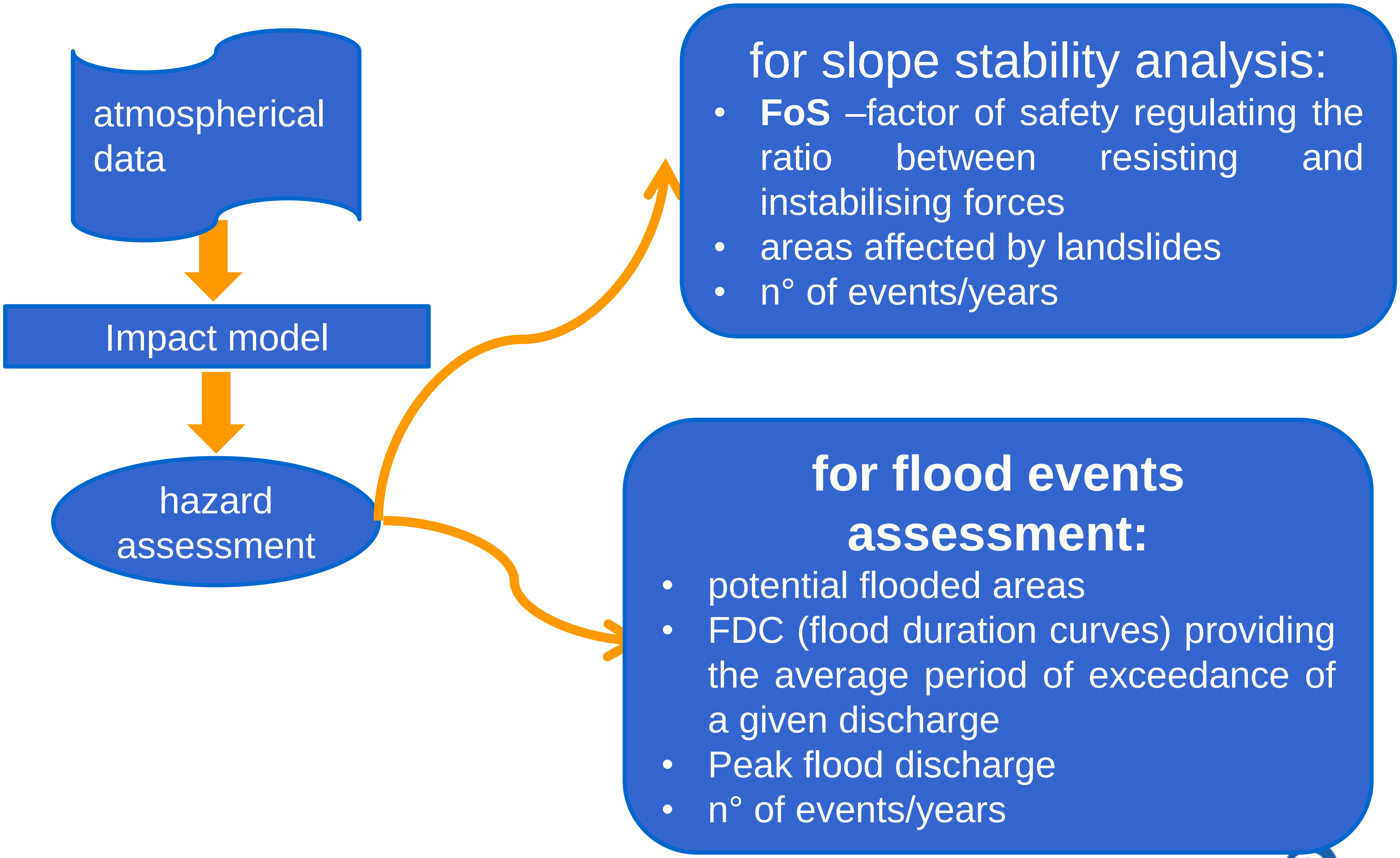
statistical approaches



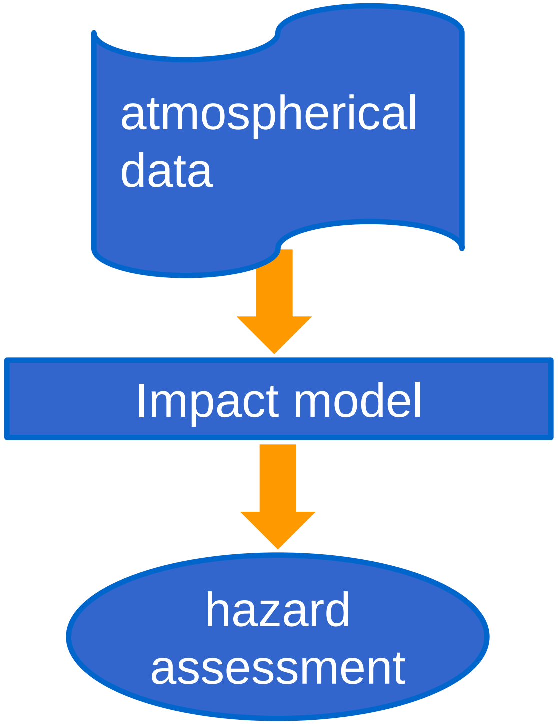
numerical/ physically-based tools



Modeling chain for weather-induced hydraulical-geological hazard

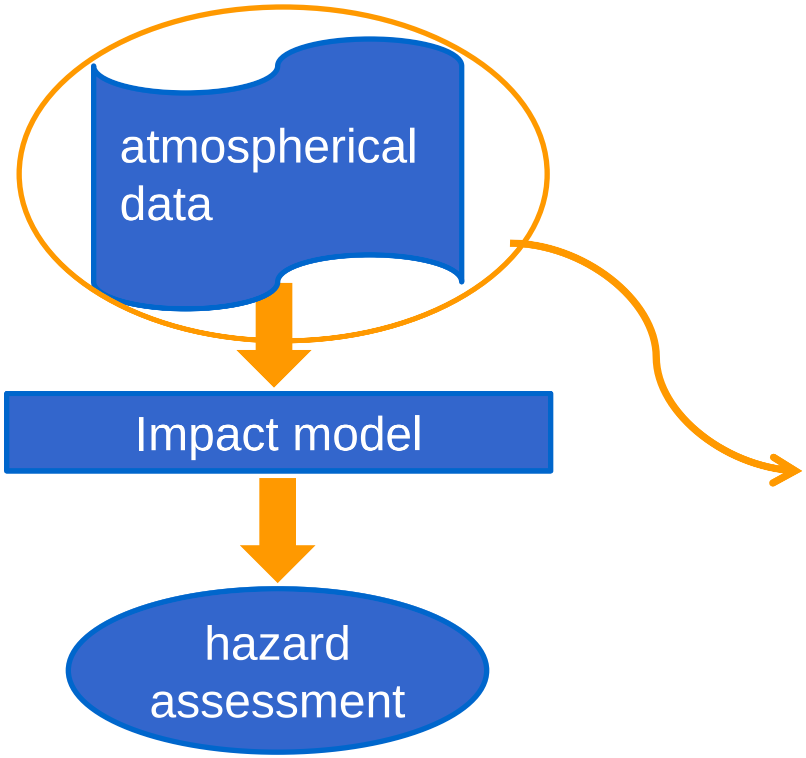


Modeling chain for weather-induced hydraulical-geological hazard



how shall the chain be adjusted in the estimation of the effects of climate change on geological/hydraulical hazard?

Modeling chain for <u>weather-induced</u> hydraulical-geological hazard



how shall the chain be adjusted in the estimation of the effects of climate change on geological/hydraulical hazard?

Climate models outputs are usually adopted as input for impact models

THIS STEP IS NOT OBVIOUS:

- at the moment, GCM spatial (20-100 km) and temporal resolutions are not appropriate for such impact studies and so the adoption of dynamical/stocastical downscaling approach is unavoidable.
- Providing an explicit representation of atmospheric mesoscale processes (e.g. usually driving heavy precipitations) dynamical downscaling through high resolution Regional Circulation models (RCM) represents, albeit marked by much higher computational effort, more consistent physical approach able to significantly improve atmospheric variables simulations (Maraun et al., 2010)
- However, further mismatches of scale for meso- and small-scale watershed and systematic biases (due to coarse representation of terrain, cloud and convective precipitation parameterization, surface albedo feedback) usually threaten the direct use of RCM outputs for assessing hydrological impacts at catchment scale..

TO OVERCOME SUCH CONSTRAINTS, TWO WAYS ARE USUALLY ADOPTED IN IMPACT STUDIES:

- use of ENSEMBLE of RCM simulations:
  - able to reduce the spread covering a more realistic range of uncertainty (Deque et al., 2007)
  - ensemble median fits observation better (Jacob et al.,2007)

- use of BIAS CORRECTION approaches:
  - ease of application, ability to allow future changes in variability, flexibility to correct climate simulations for the parameters of interest (Johnson & Sharma, 2012), low computational requirements (Li et al.,2010)

On the application of impact models in climate prospective:

Method	Variable	Short Description	Advantages (+) and Disadvantages (-)	References
Raw RCM Output Data	Precipitation Temperature	• RCM-simulated time series are used directly without any bias correction	+ simplest way to use RCM data – systematic model errors are ignored – can cause substantial errors in impact studies	
Precipitation Threshold	Precipitation	• an RCM-specific threshold is calibrated such that the number of RCM-simulated days exceeding this threshold matches the number of observed days with precipitation • rarely used as a "stand-alone" method but often combined with other correction procedures	+ wet-day frequencies are corrected – mean, standard deviation (variance) and wet-day intensities are not adjusted	Schmidli et al. (2006)
Delta-Change Correction	Precipitation Temperature	• RCM-simulated future change signals (anomalies) are superimposed upon observational time series • usually done with a multiplicative correction for precipitation and an additive correction for temperature	+ observations are used as a basis, which makes it a robust method + corrects the mean – standard deviation (variance), wet-day frequencies and intensities are not corrected – potential future changes in climate dynamics and variability are not accounted for – all events change by the same amount	Gellens and Roulin (1998) Graham et al. (2007a, b) Johnson and Sharma (2011) Lettenmaier et al. (1999) Mpelasoka and Chiew (2009) Middelkoop et al. (2001) Moore et al. (2008) Rasmussen et al. (2012) Shabalova et al. (2003)
Linear Transformation	Precipitation Temperature	• adjusts RCM time series with correction values based on the relationship between long-term monthly mean observed and RCM control run values • precipitation is typically corrected with a factor and temperature with an additive term	+ corrects the mean + variability of corrected data is more consistent with original RCM data – standard deviation (variance), wet-day frequencies and intensities are not corrected – all events are adjusted with the same correction factor	Lenderink et al. (2007)

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Teutschbein&Seibert,2012

Local Intensity Scaling (LOCI)	Precipitation	• combines a precipitation threshold with linear scaling (both described above)	+ corrects mean, wet-day frequencies and intensities + variability of corrected data is more consistent with original RCM data – standard deviation (variance) is not corrected – all events are adjusted with the same correction factor	Schmidli et al. (2006)
Power Transformation	Precipitation	• a precipitation threshold can be introduced a priori to avoid too many drizzle days (i.e., very low but non-zero precipitation) • is a non-linear correction in an exponential form ($a \times P^b$) that combines the correction of the coefficient of variation (CV) with a linear scaling	+ corrects mean and standard deviation (variance) + events are adjusted non-linearly + variability of corrected data is more consistent with original RCM data ± adjusts wet-day frequencies and intensities only to some extend	Leander and Buishand (2007) Leander et al. (2008)
Variance Scaling	Temperature	• combines standard linear scaling with a scaling based on standard deviations	+ corrects mean and standard deviation (variance) + variability of corrected data is more consistent with original RCM data – all events are adjusted with the same addends and correction factor	Chen et al. (2011)
Distribution Mapping	Precipitation Temperature	• matches the distribution functions of observations and RCM-simulated climate values • a precipitation threshold can be introduced to avoid substantial distortion of the distribution caused by too many drizzle days (i.e., very low but non-zero precipitation) • also known as "quantile-quantile mapping", "probability mapping", "statistical downscaling" or "histogram equalization"	+ corrects mean, standard deviation (variance), wet-day frequencies and intensities + events are adjusted non-linearly + variability of corrected data is more consistent with original RCM data	Block et al. (2009) Boe et al. (2007) Déqué et al. (2007) Ines and Hansen (2006) Johnson and Sharma (2011) Piani et al. (2010) Rojas et al. (2011) Sennikovs and Bethers (2009) Sun et al. (2011)

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Teutschbein&Seibert,2012

Local Intensity Scaling (LOCI)	Precipitation	• combines a precipitation threshold with linear scaling (both described above)	+ corrects mean, wet-day frequencies and intensities + variability of corrected data is more consistent with original RCM data – standard deviation (variance) is not corrected – all events are adjusted with the same correction factor	Schmidli et al. (2006)
Power [illegible] mation				
Varianc[illegible] ing				
Distribu[illegible] Mappin[illegible]		avoid substantial distortion of the distribution caused by too many drizzle days (i.e., very low but non-zero precipitation) • also known as "quantile-quantile mapping", "probability mapping", "statistical downscaling" or "histogram equalization"	with original RCM data	Piani et al. (2010) Rojas et al. (2011) Sennikovs and Bethers (2009) Sun et al. (2011)

However, the scientific issue about effectiveness, advantages and constraints of such approaches is widely debated in these years:
(Ehret et al., 2012; Maraun et al., 2010; Maraun, 2013; Teutschbein&Seibert, 2012-2013; Gudmunsson et al, 2012; Johnson & Sharma, 2012; Chen et al., 2011; Piani et al., 2010; Rojas et al., 2011; Lafon et al., 2012)

Teutschbein&Seibert,2012

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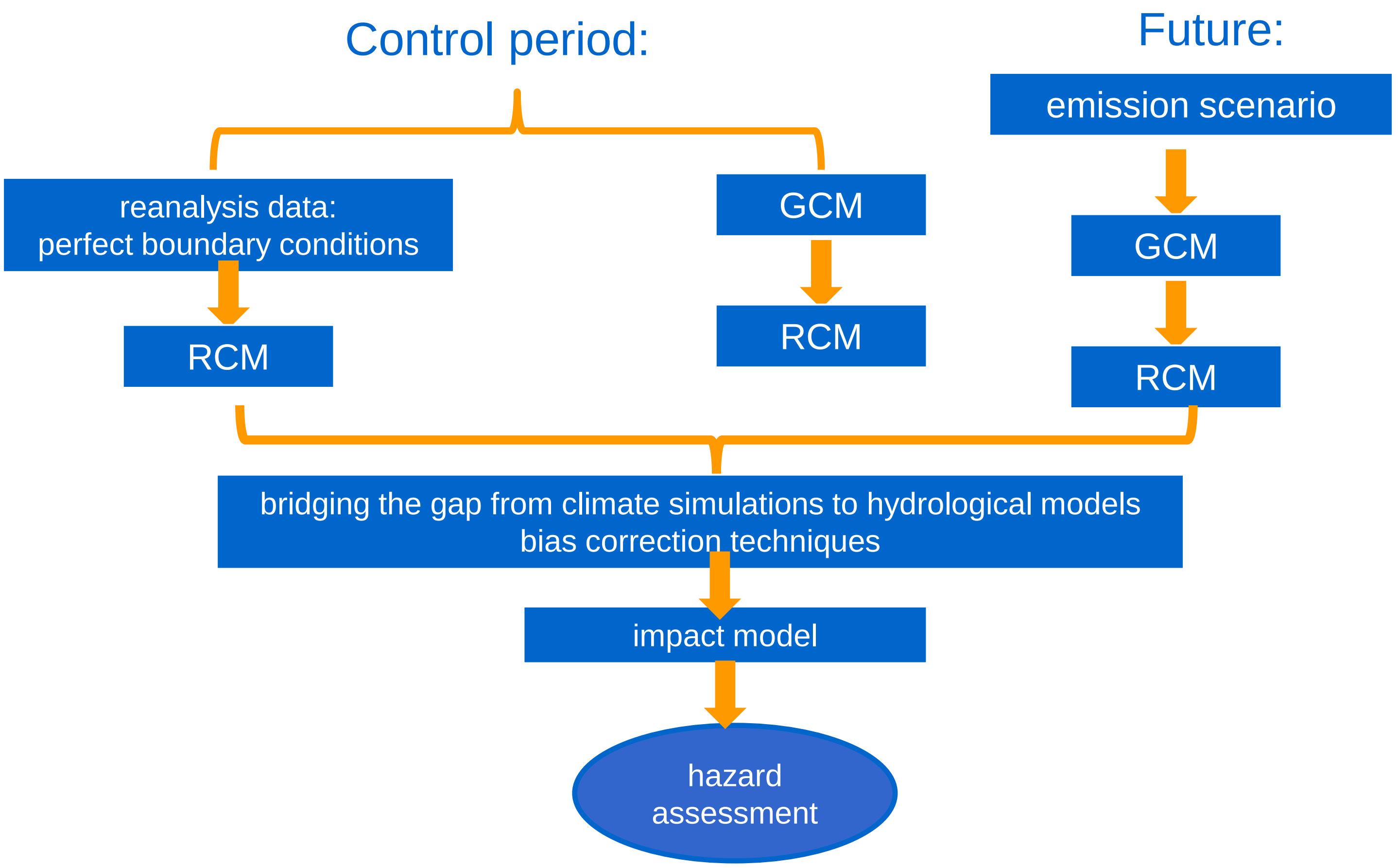
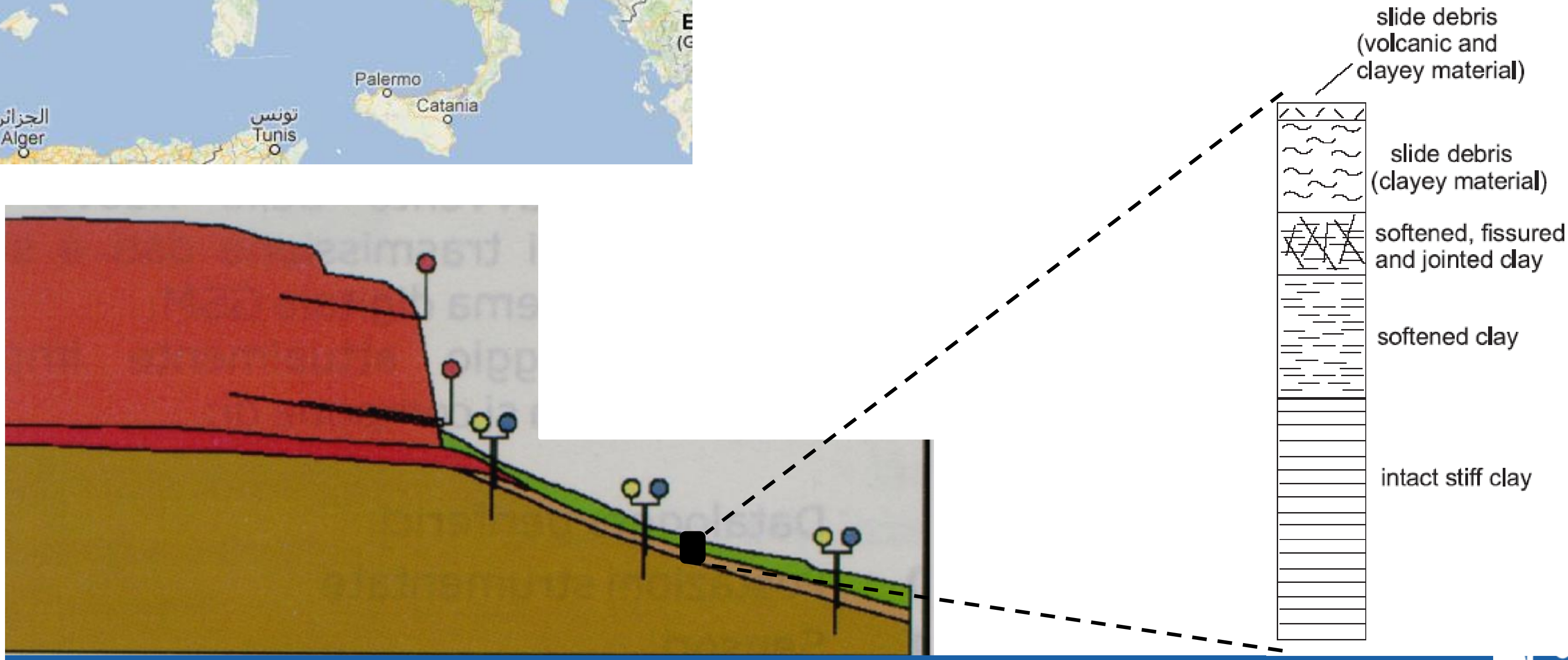
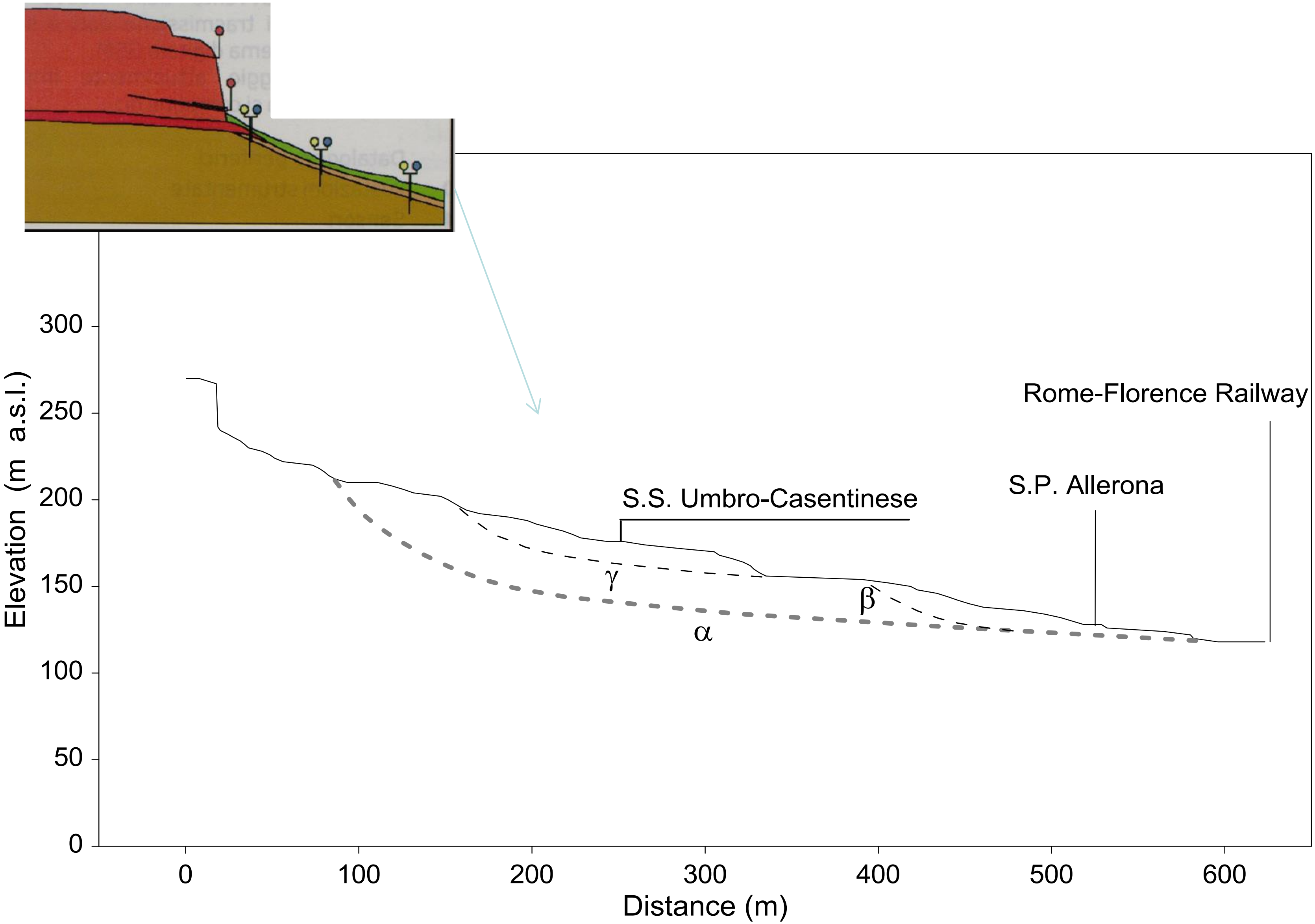


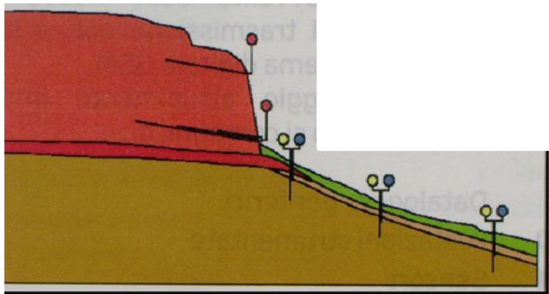
Orvieto case-history



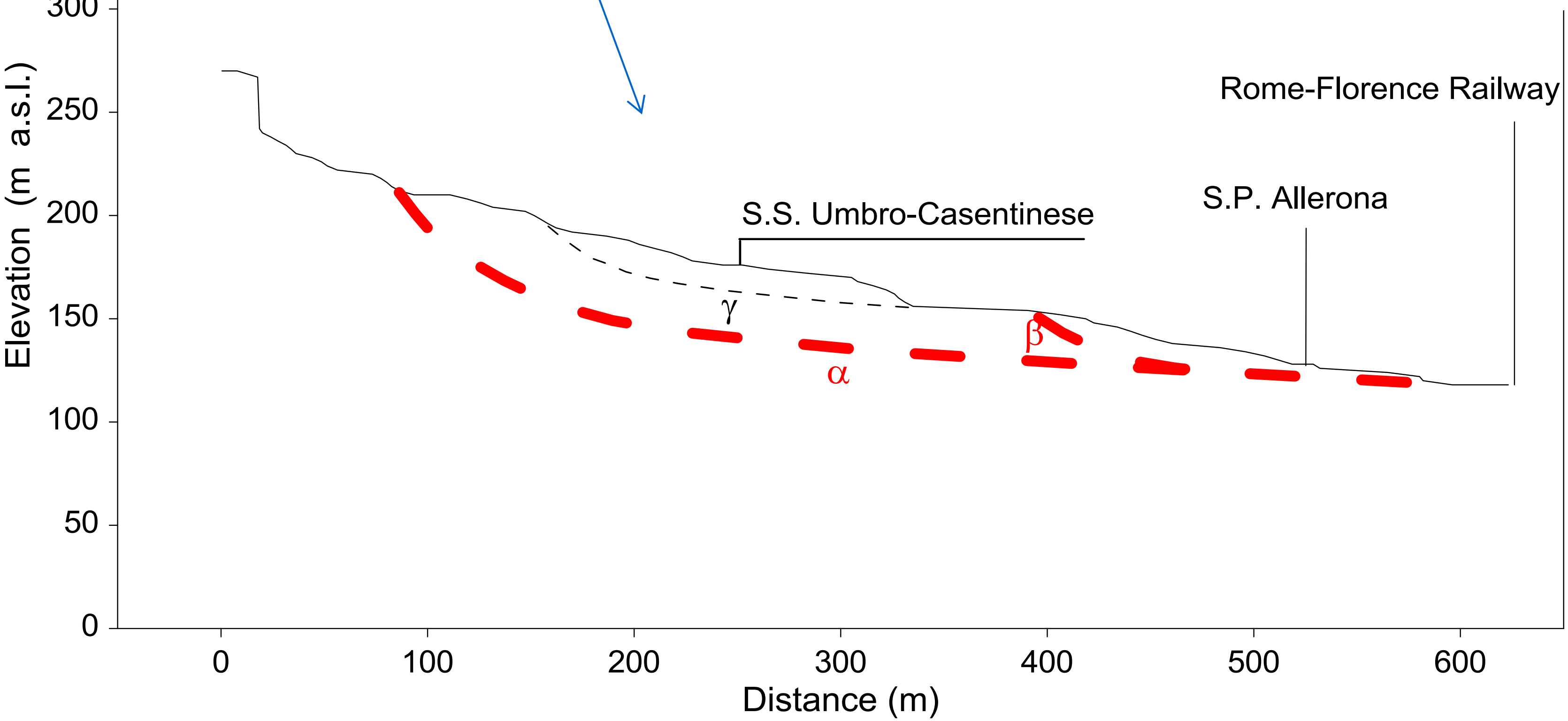
Orvieto case-history



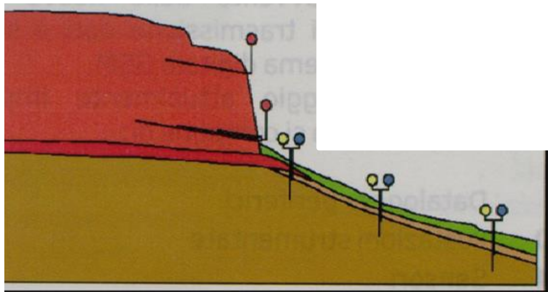
Orvieto case-history



DEEP MOVEMENTS
affecting soft part of clay formation
Displacement rates range from 2 to 8 mm/year, with maximum values of 0.7-1.5 mm/month. Maximum depth 33 meters



Orvieto case-history

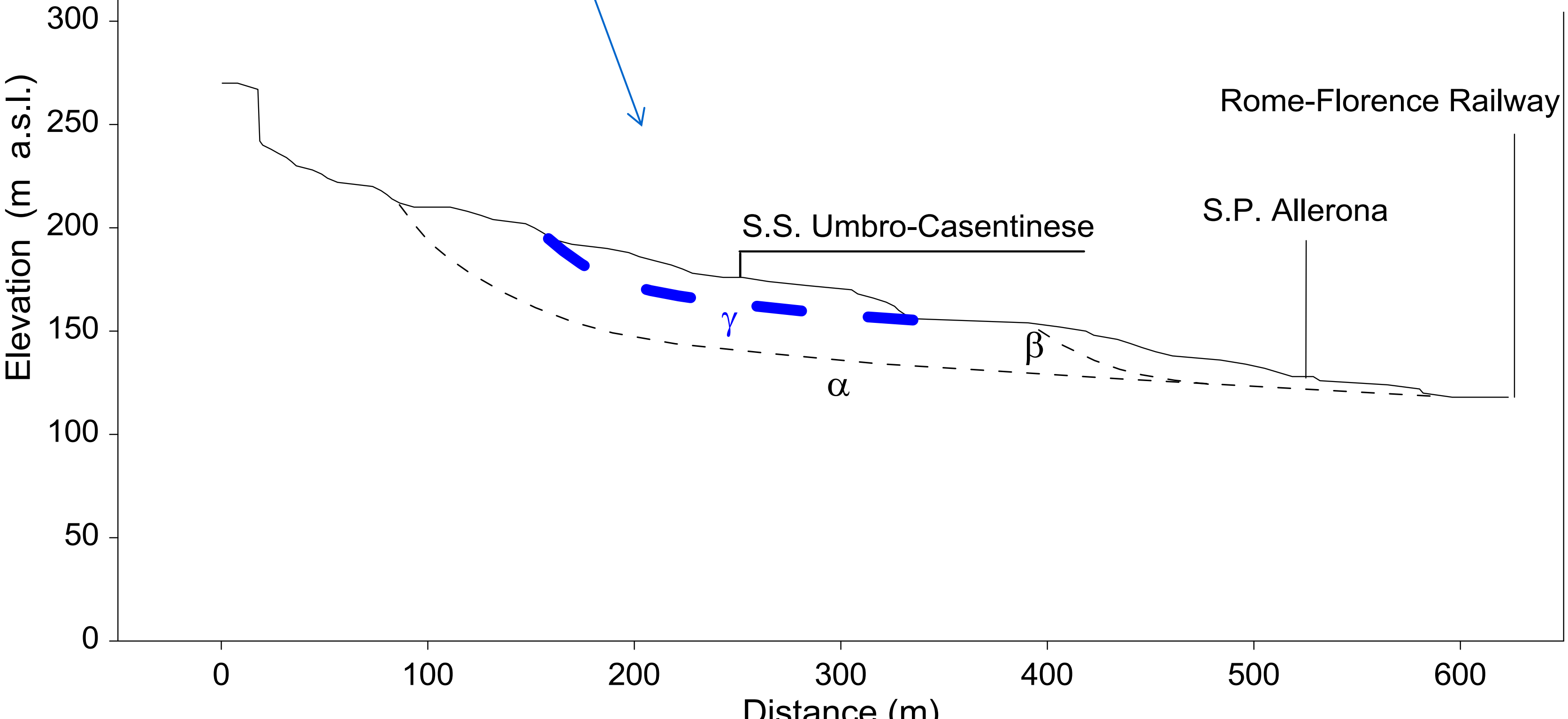


SHALLOW MOVEMENTS

superimposing to deep ones and affecting the debris cover

They have a higher velocity than the deep movements (10-42 mm/year) and seasonally reactivate more than once in a hydrologic year, at a maximum displacement rate of 7 to 12 mm/month

Maximum depth < 10 m



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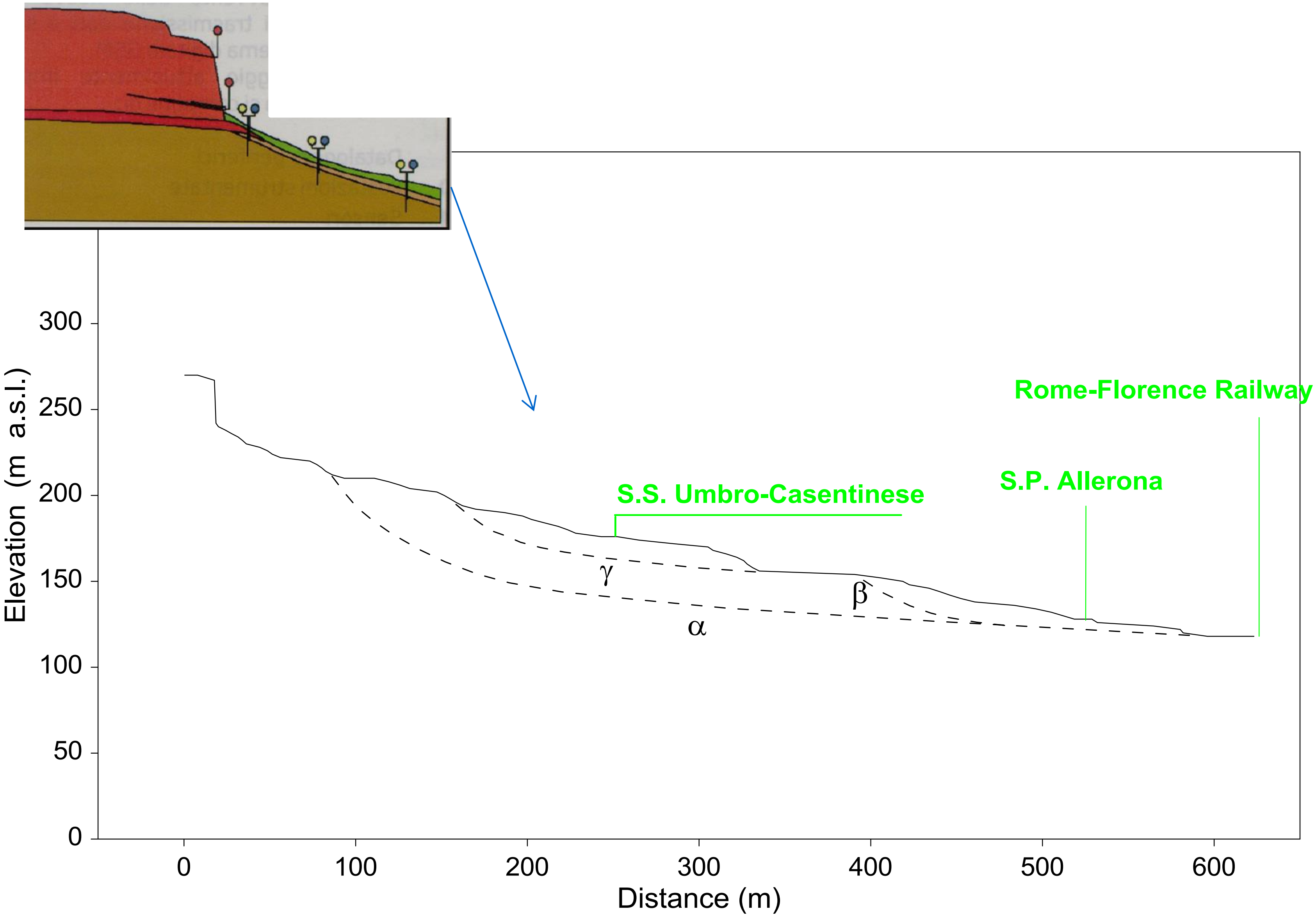

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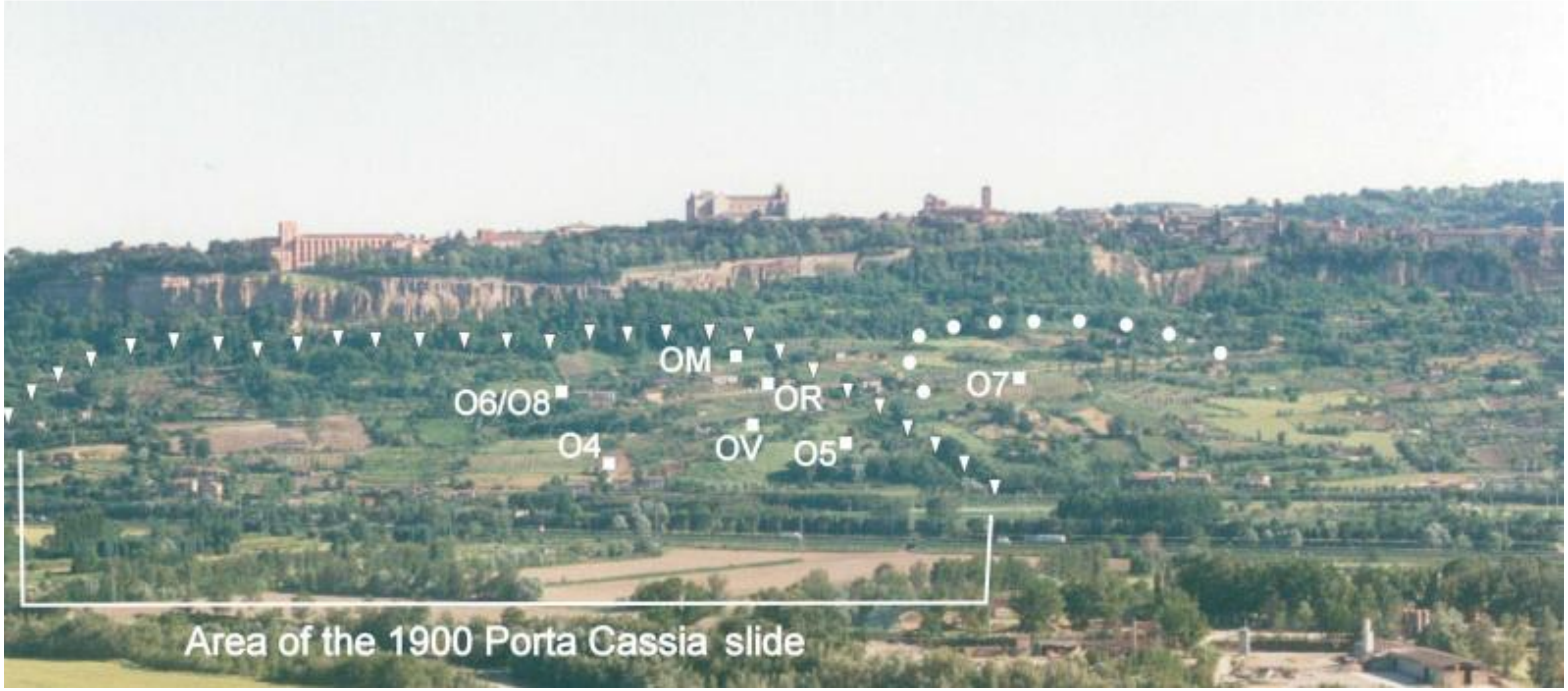
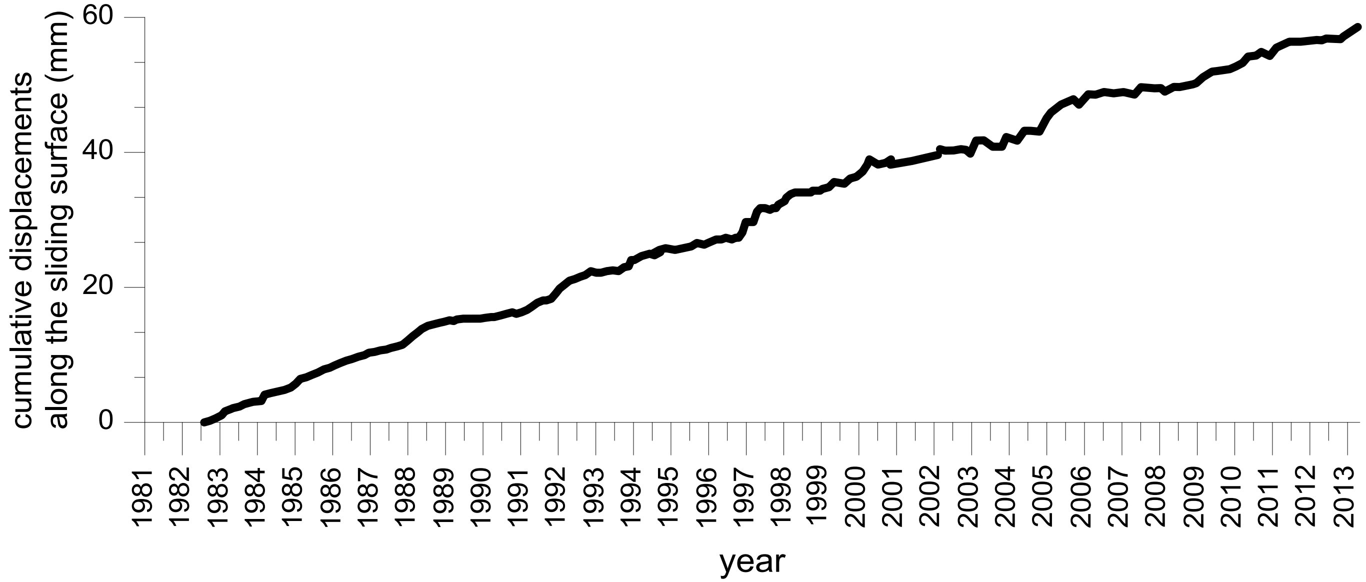


Monitoring started in 1982

for each of seven monitoring stations, instrumented boreholes provide displacements values (through inclinometers) and piezometric levels (piezometers) at several depth within the soil.

OR cumulative displacements history

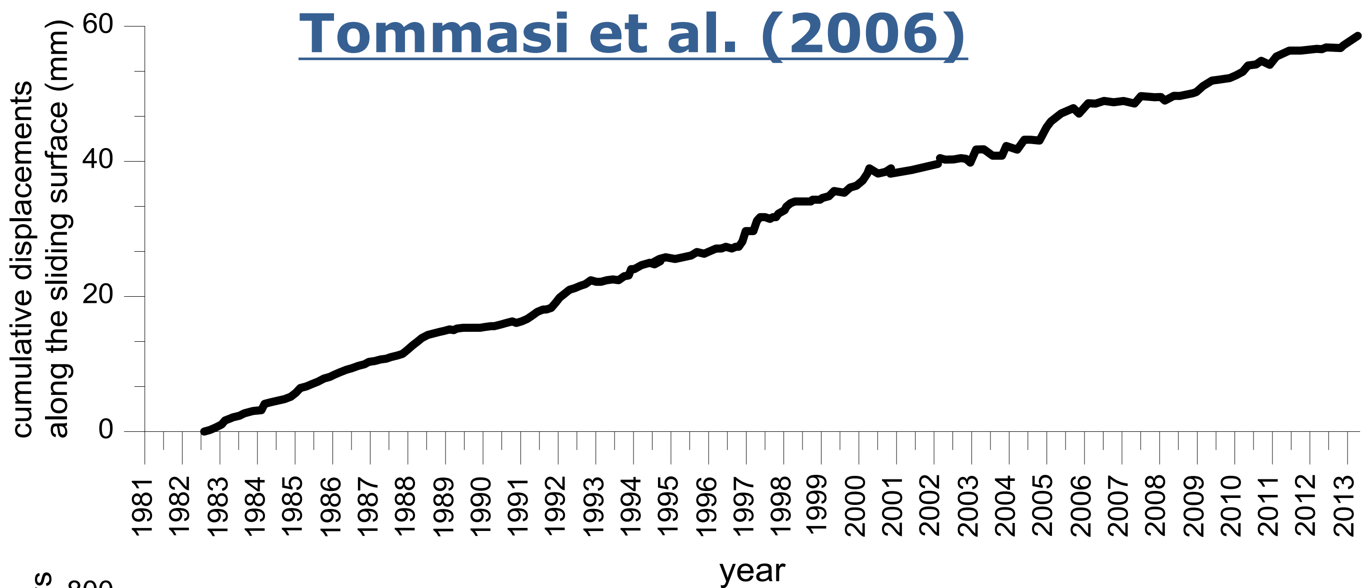


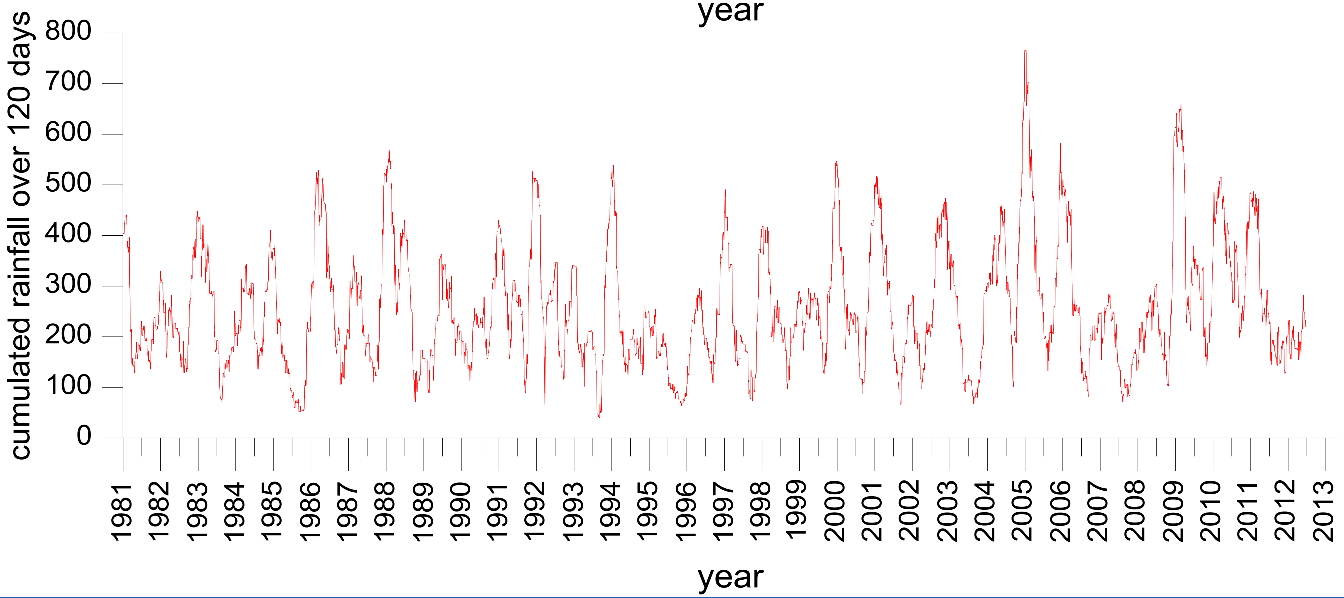
average movement rate -> 2mm/year

cumulative displacements->60mm in 30 years

max yearly displacement > 7-8mm

OR cumulative displacements history





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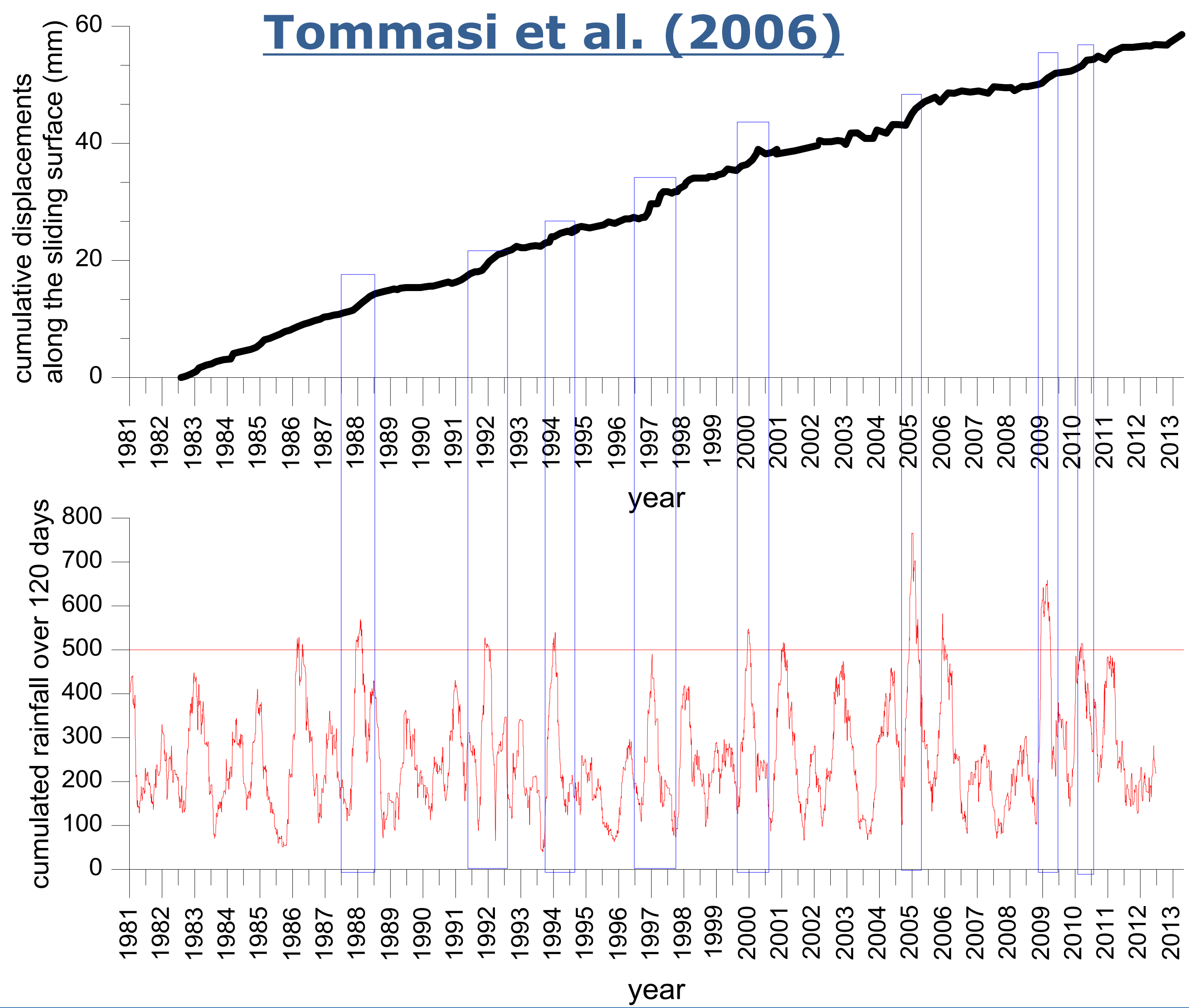
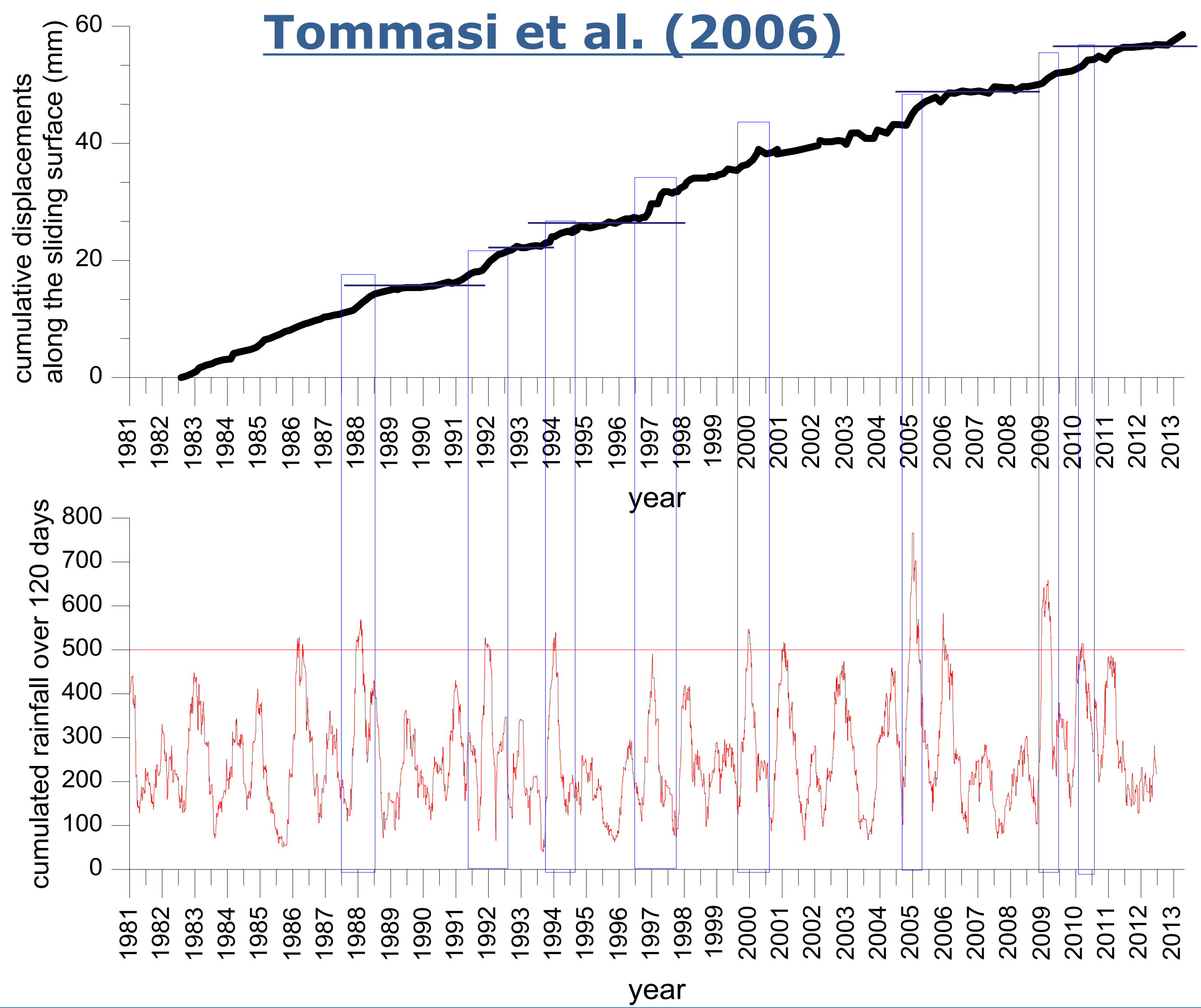
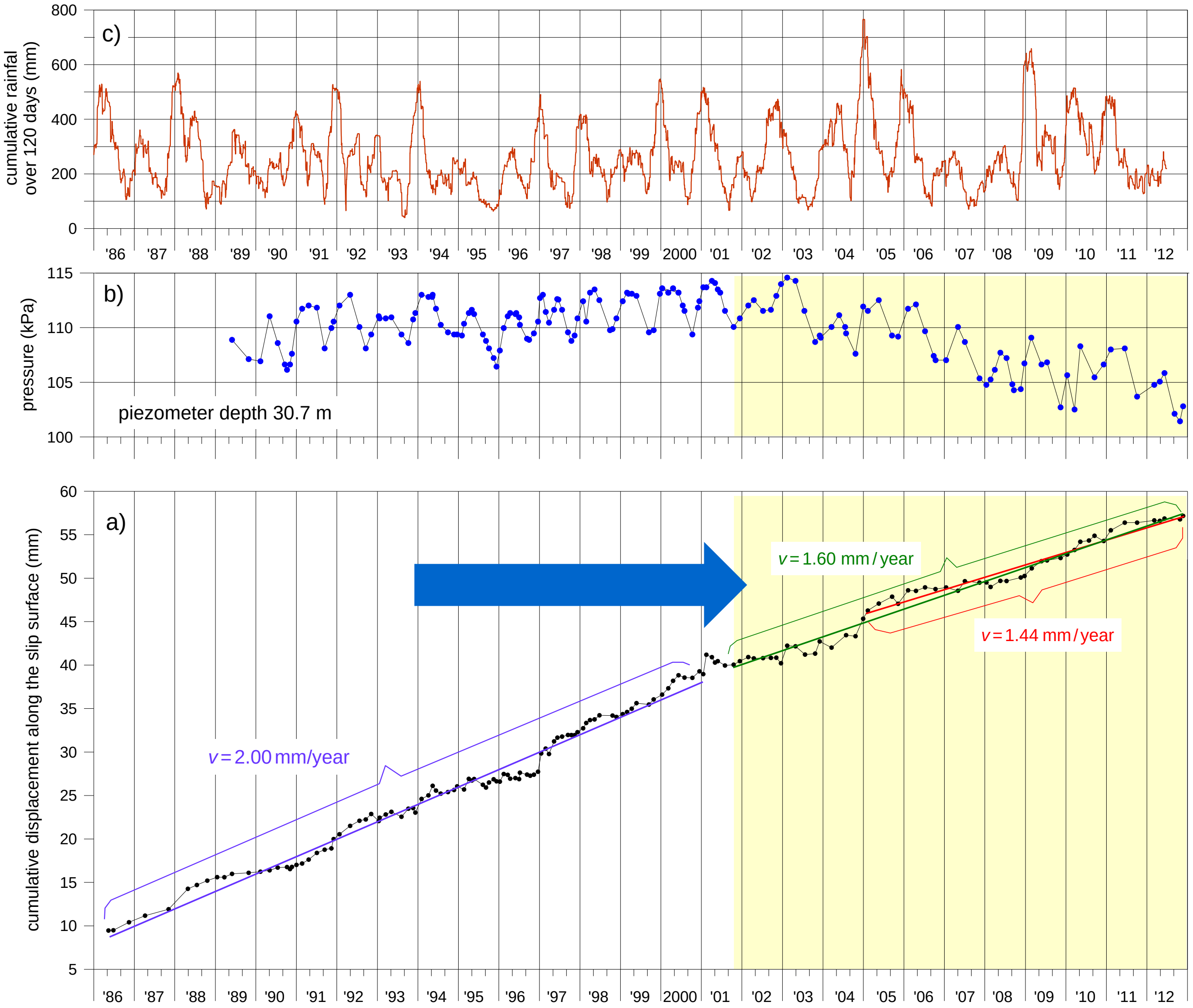


OR cumulative displacements history





c)
cumulative rainfall over 120 days (mm)
800
600
400
200
0
'86 '87 '88 '89 '90 '91 '92 '93 '94 '95 '96 '97 '98 '99 2000 '01 '02 '03 '04 '05 '06 '07 '08 '09 '10 '11 '12
b)
pressure (kPa)
115
110
105
100
piezometer depth 30.7 m
a)
cumulative displacement along the slip surface (mm)
60
55
50
45
40
35
30
25
20
15
10
5
v = 2.00 mm/year
v = 1.60 mm / year
v = 1.44 mm / year
'86 '87 '88 '89 '90 '91 '92 '93 '94 '95 '96 '97 '98 '99 2000 '01 '02 '03 '04 '05 '06 '07 '08 '09 '10 '11 '12

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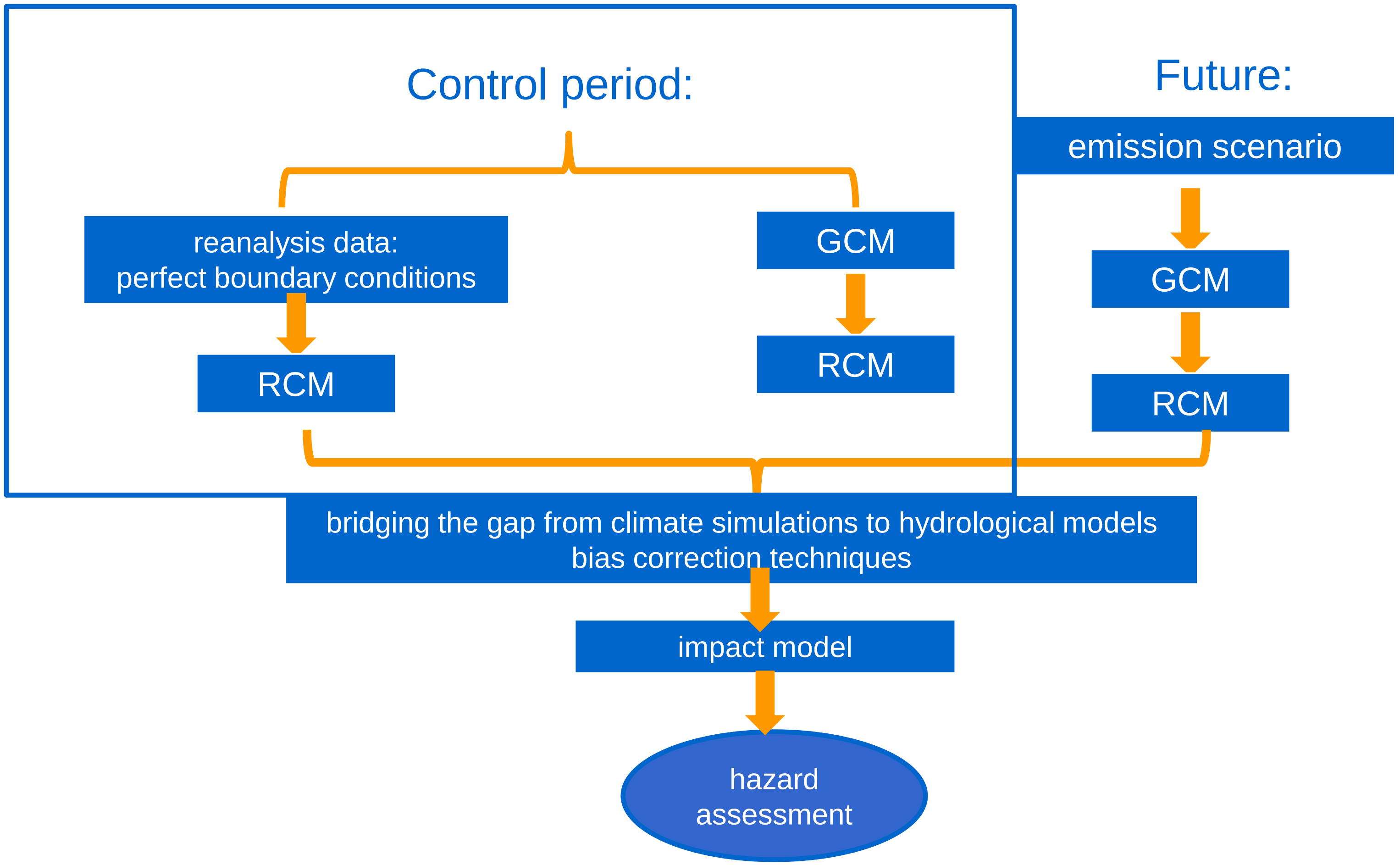
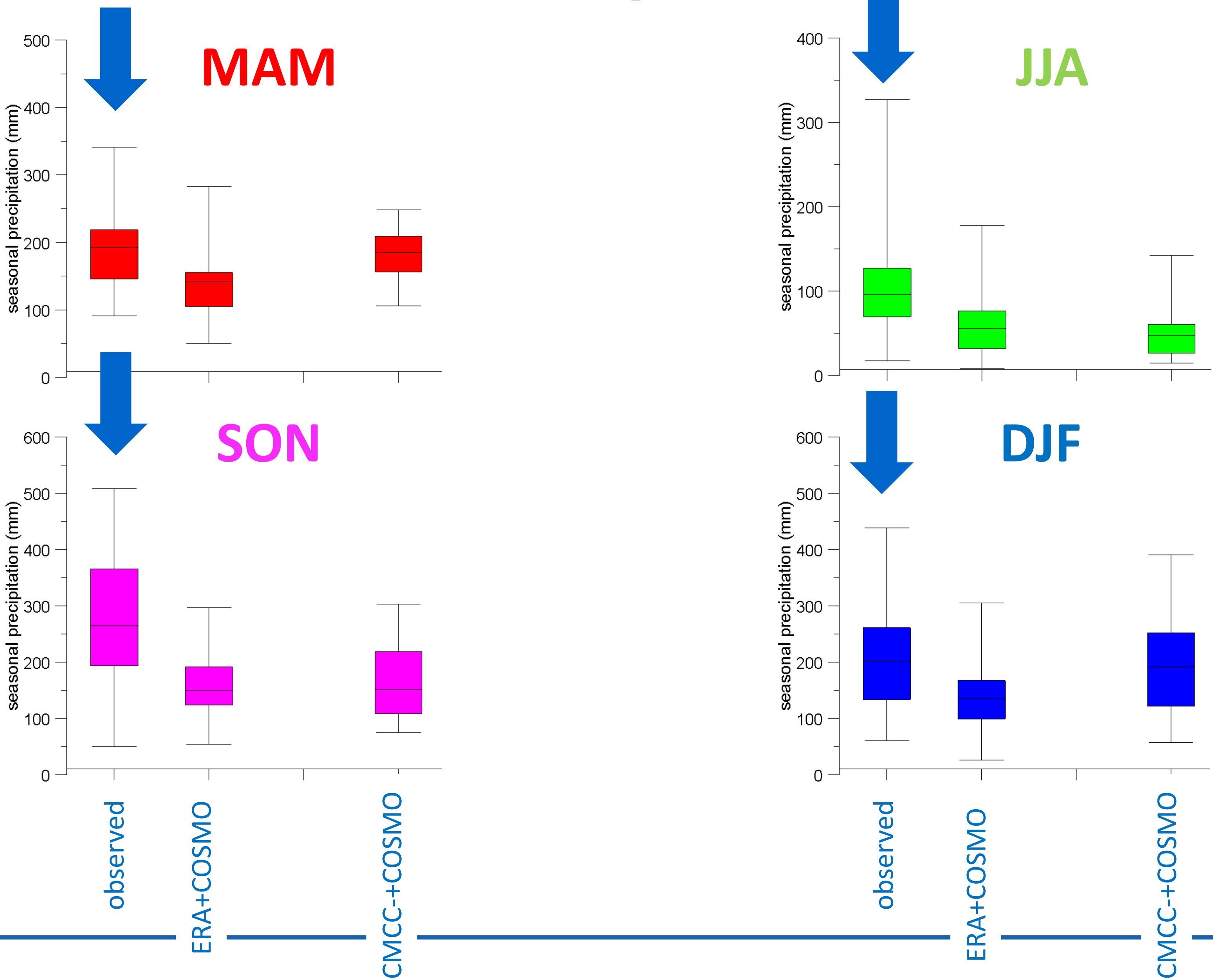
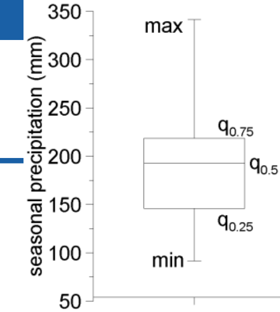


Validation on control period 1981-2010





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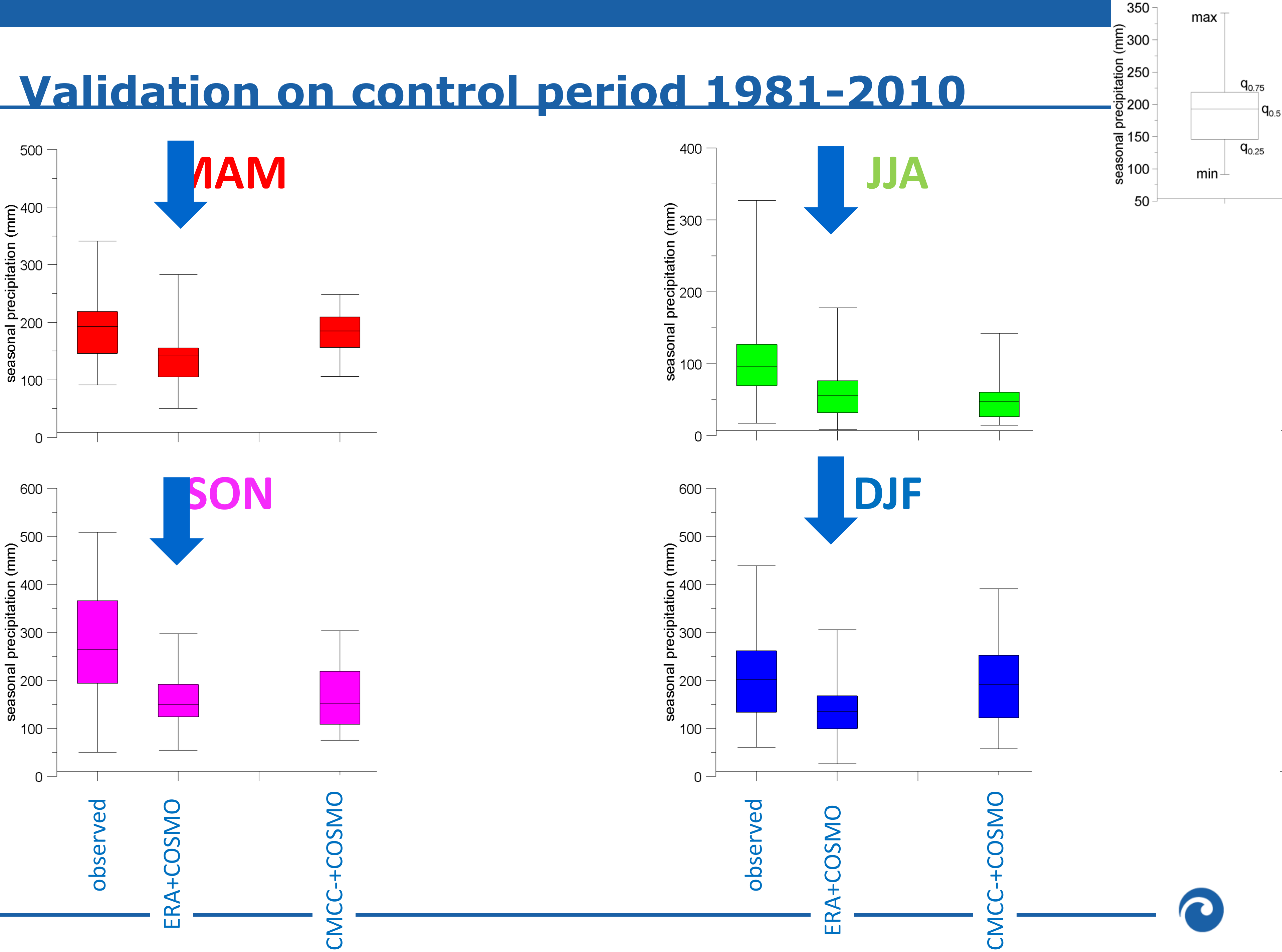

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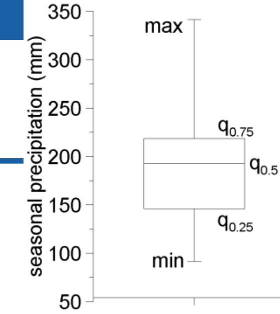

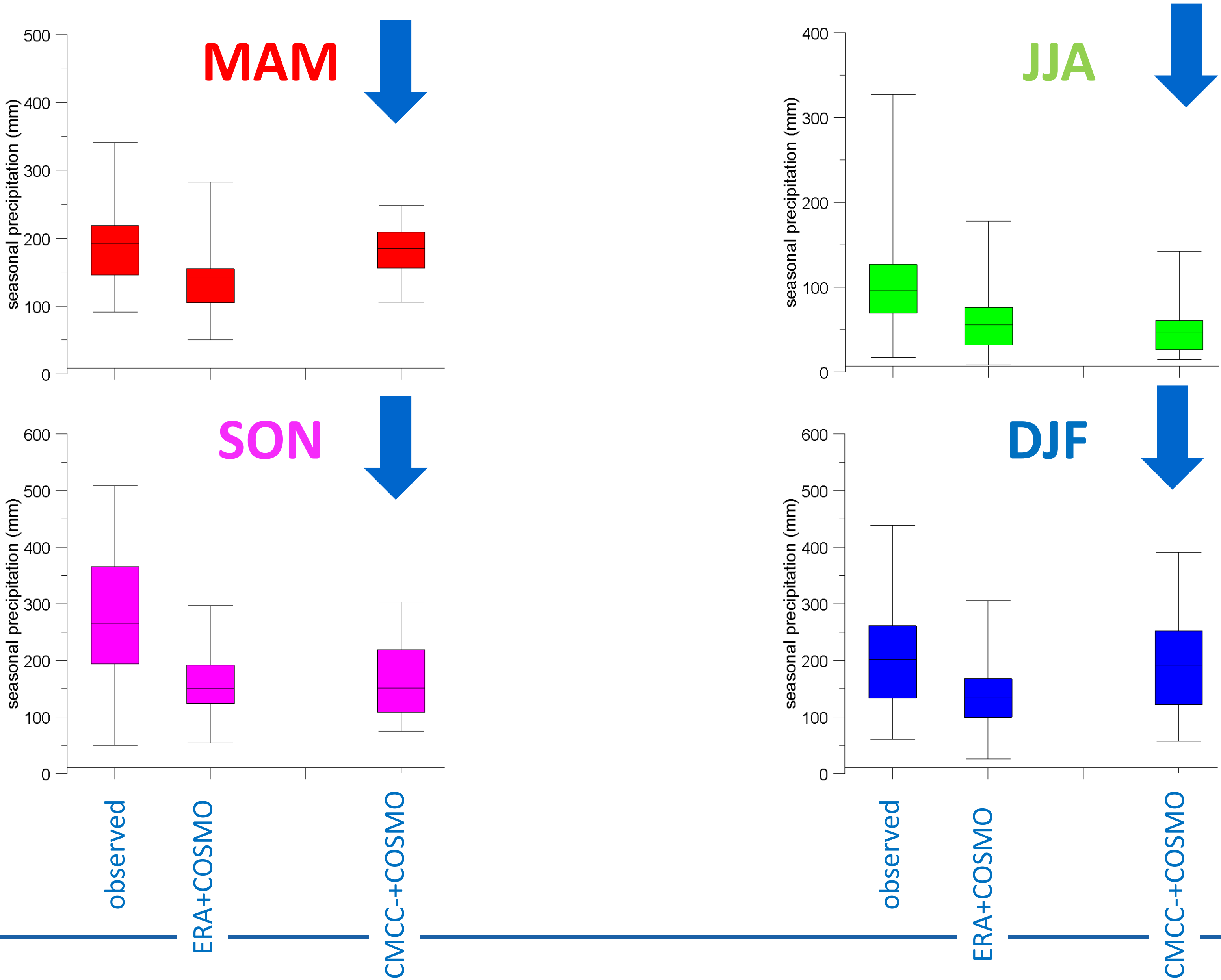

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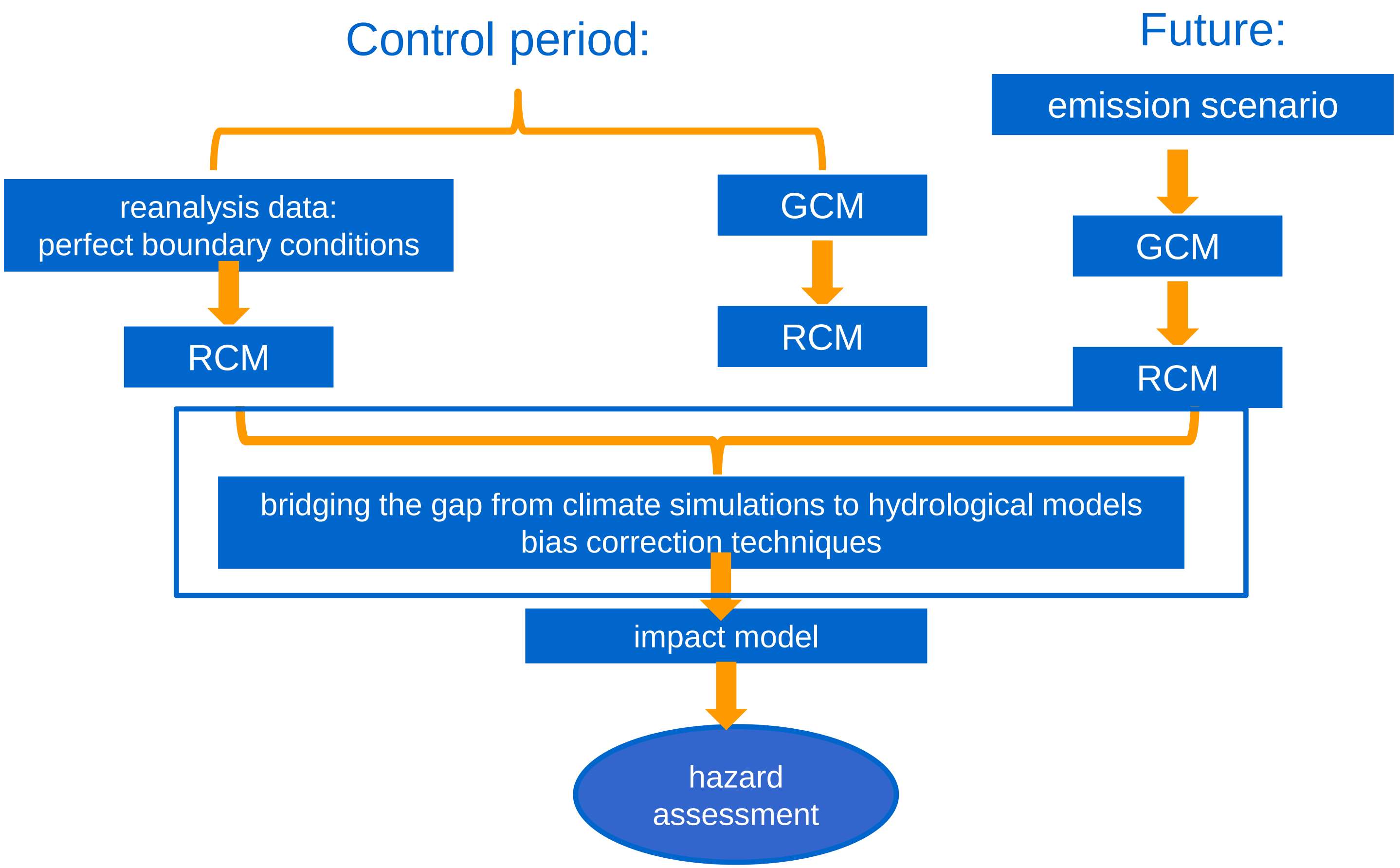

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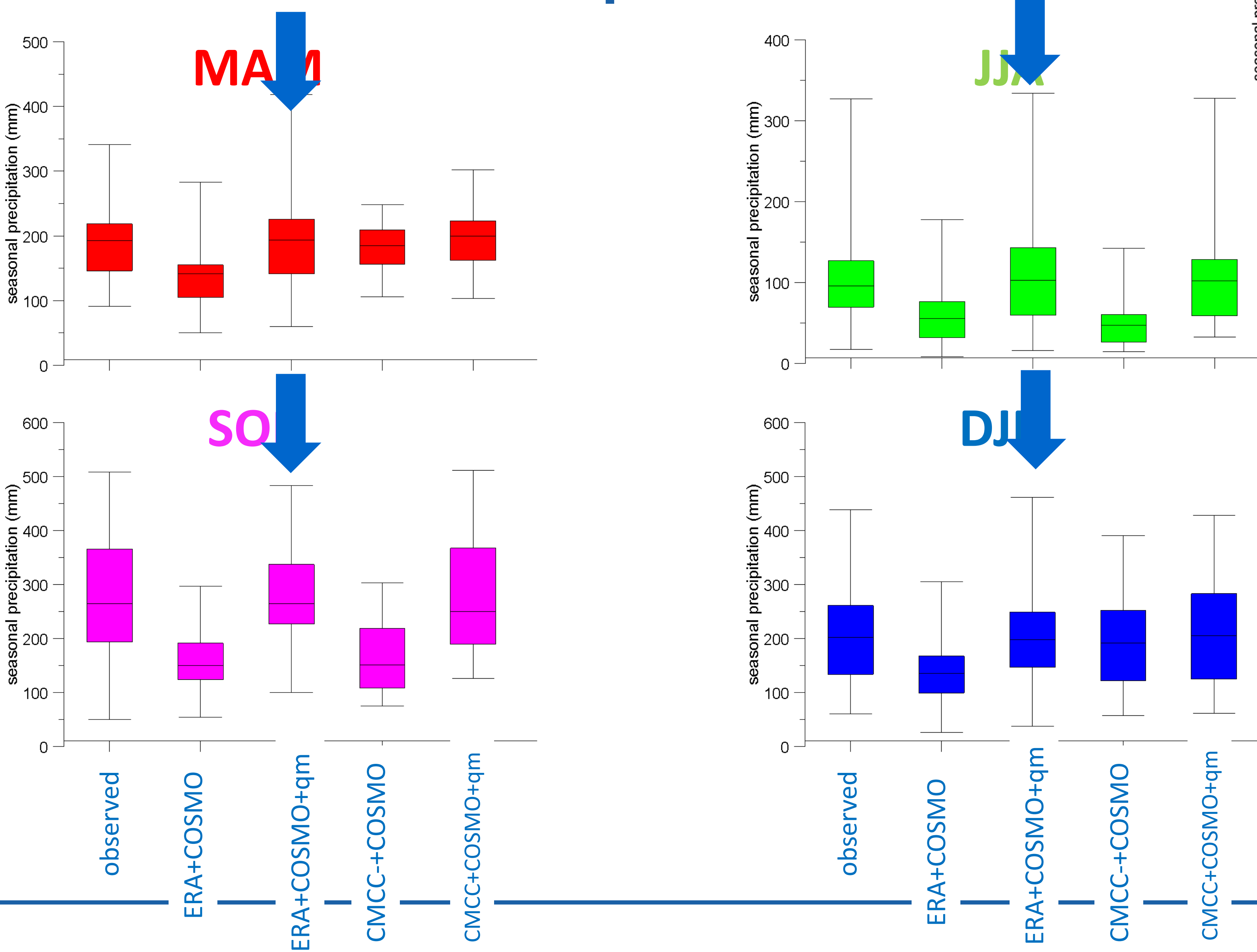

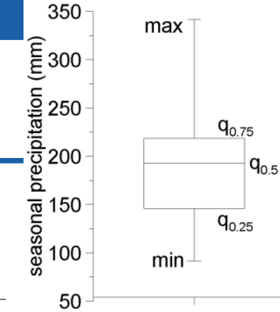

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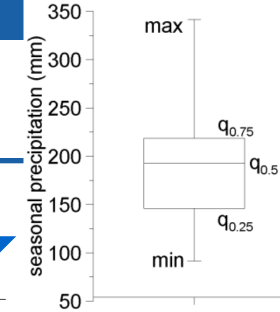

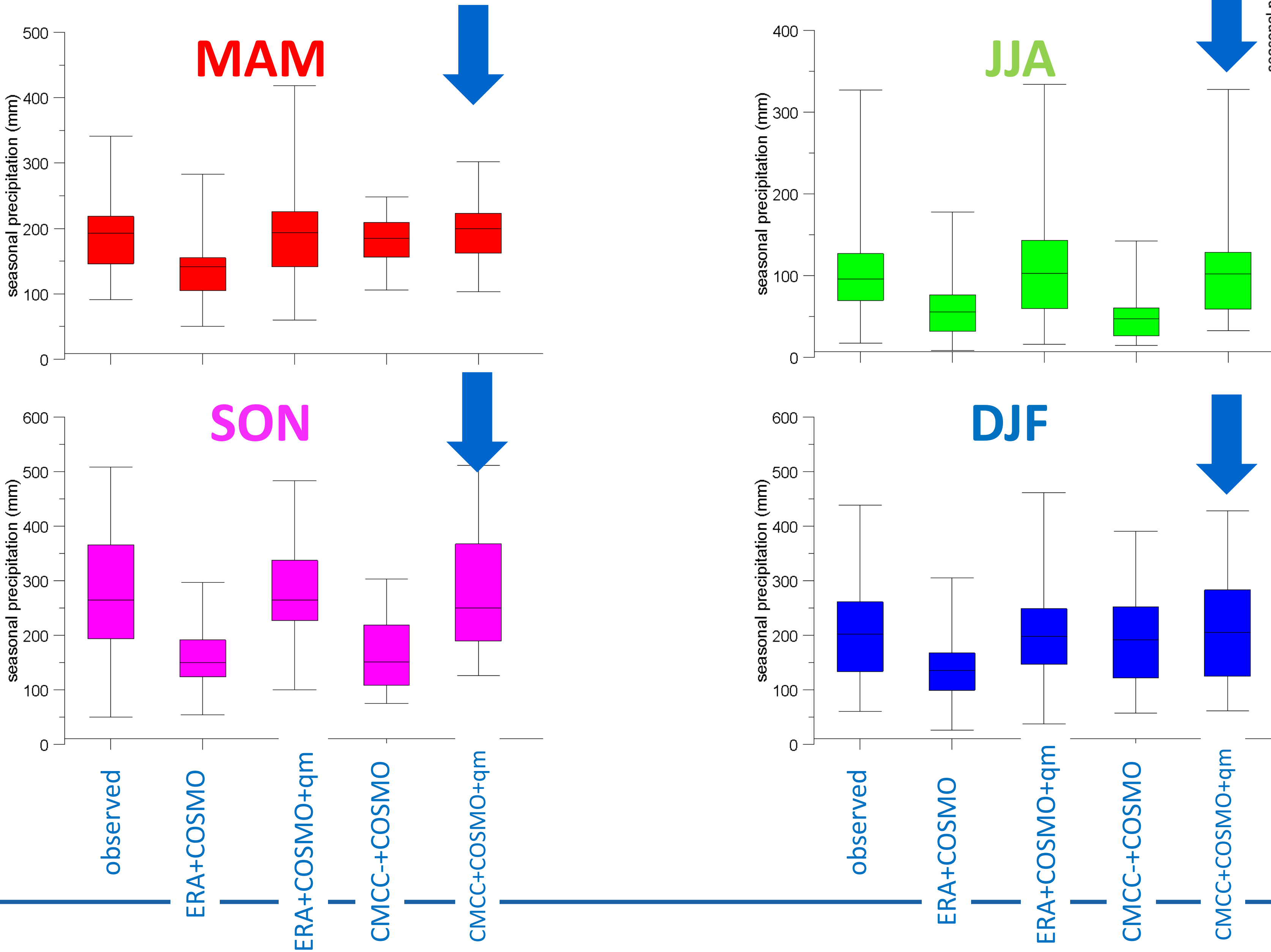

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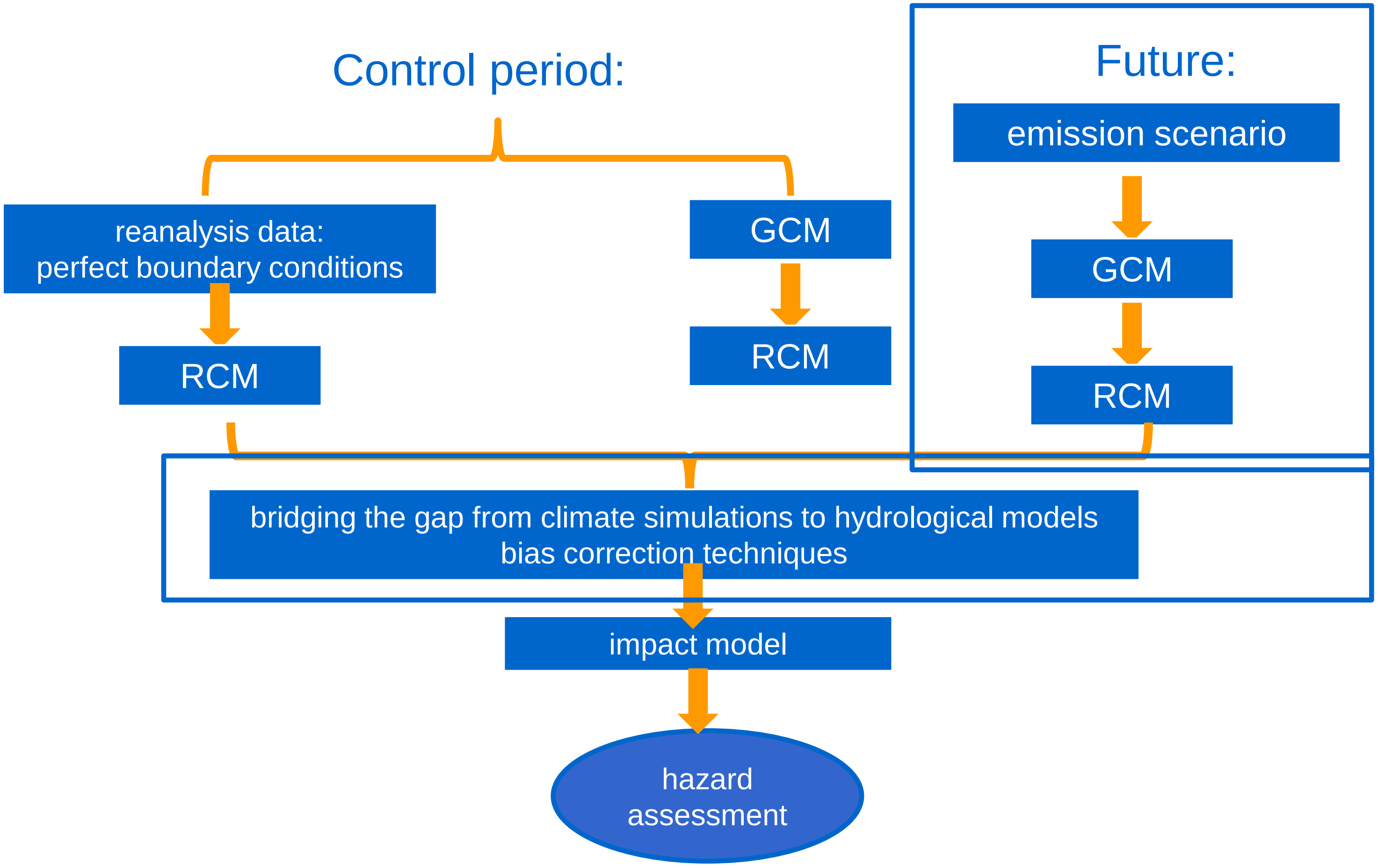
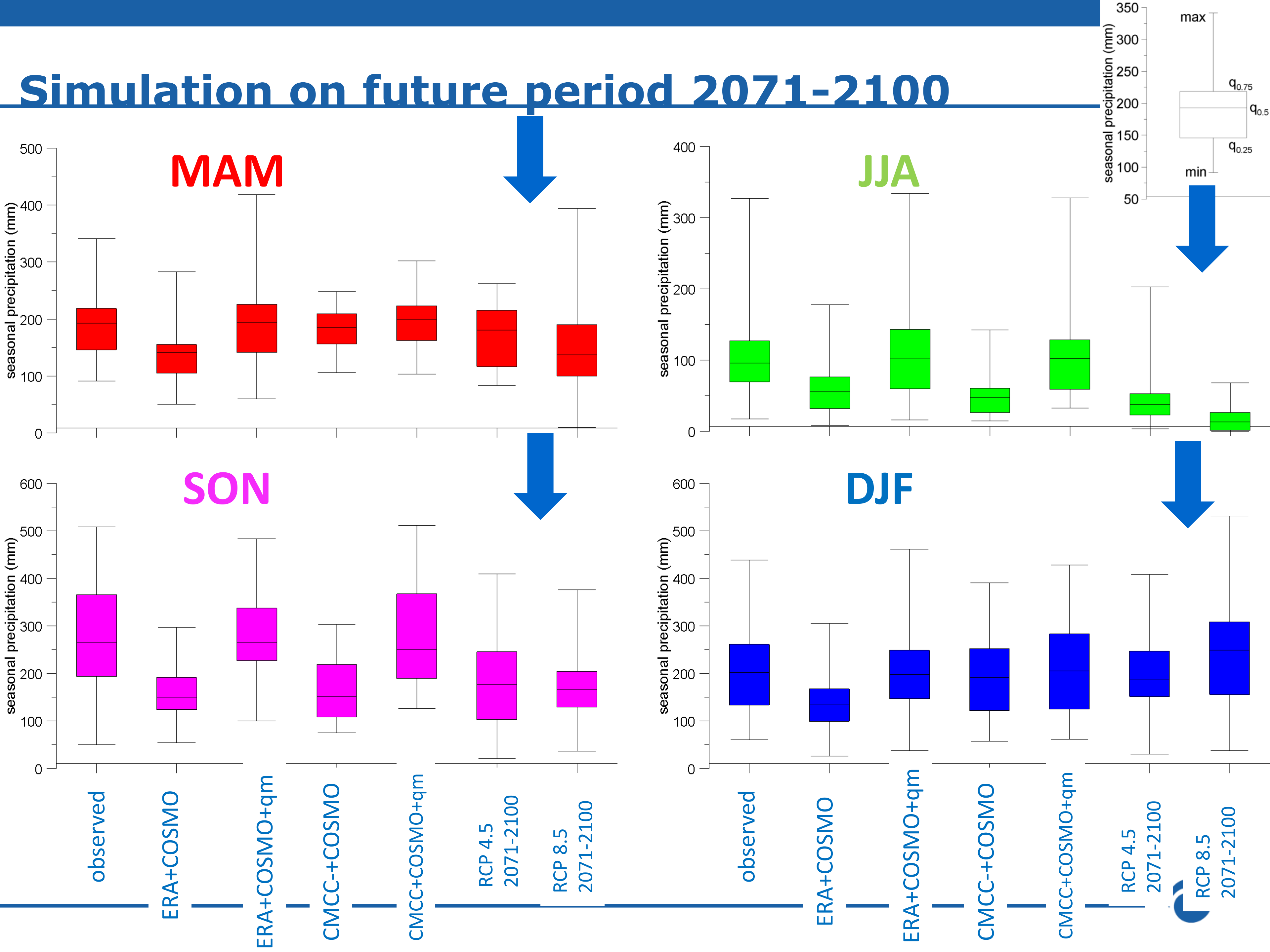


Simulation on future period 2071-2100



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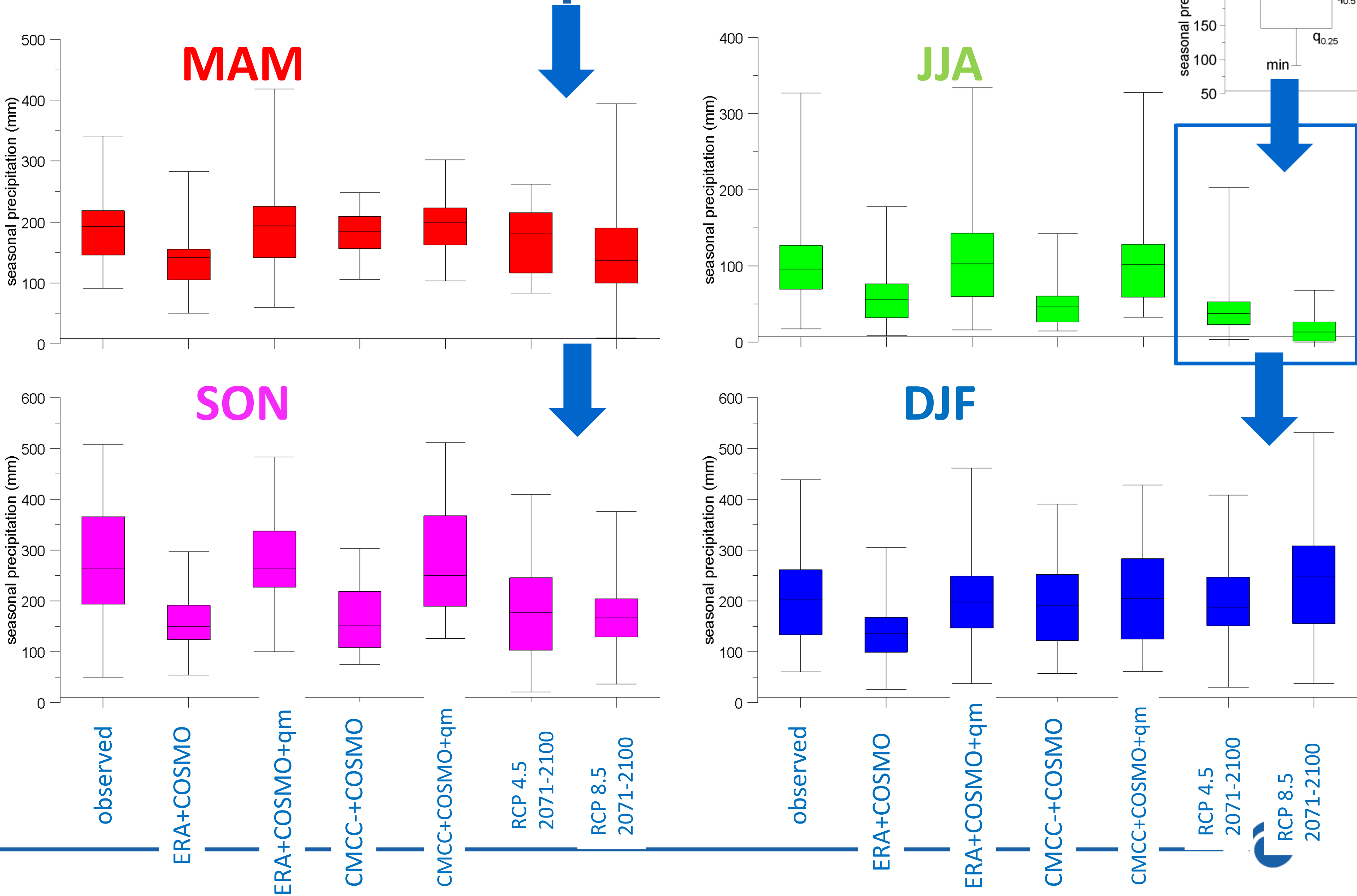

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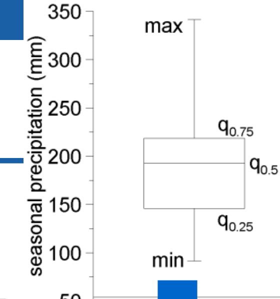

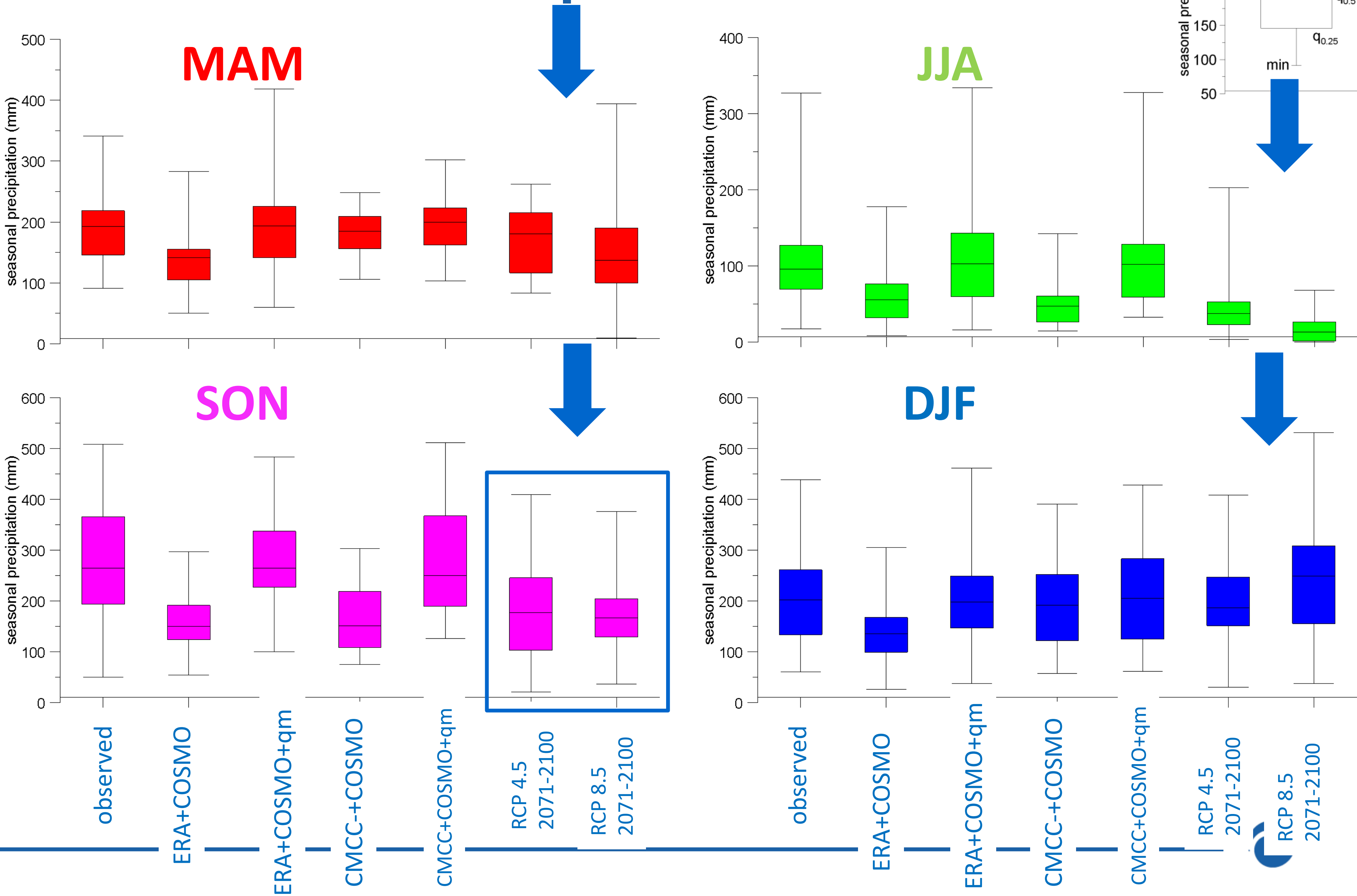

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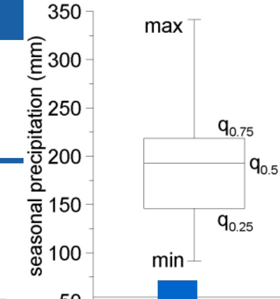

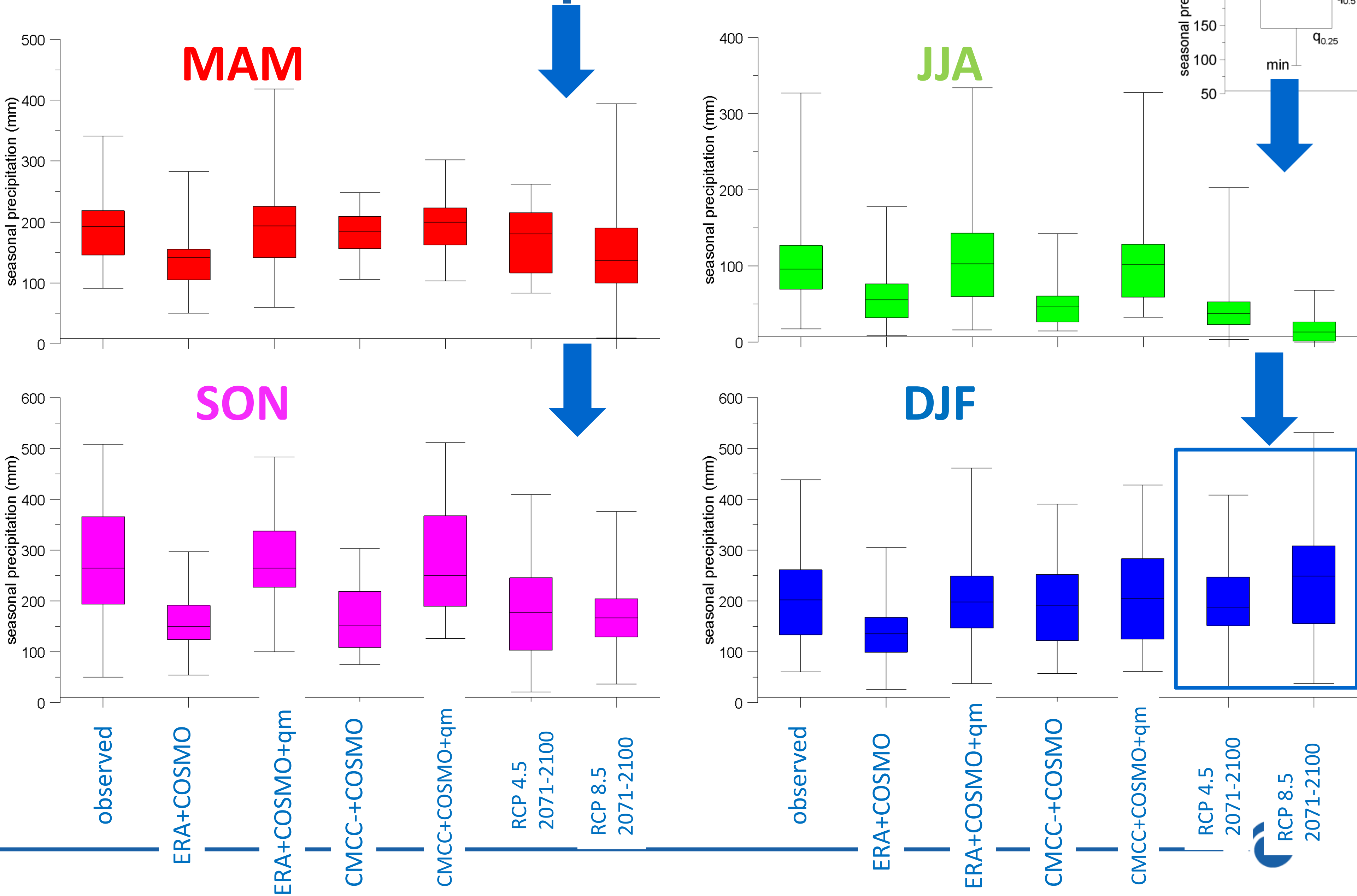

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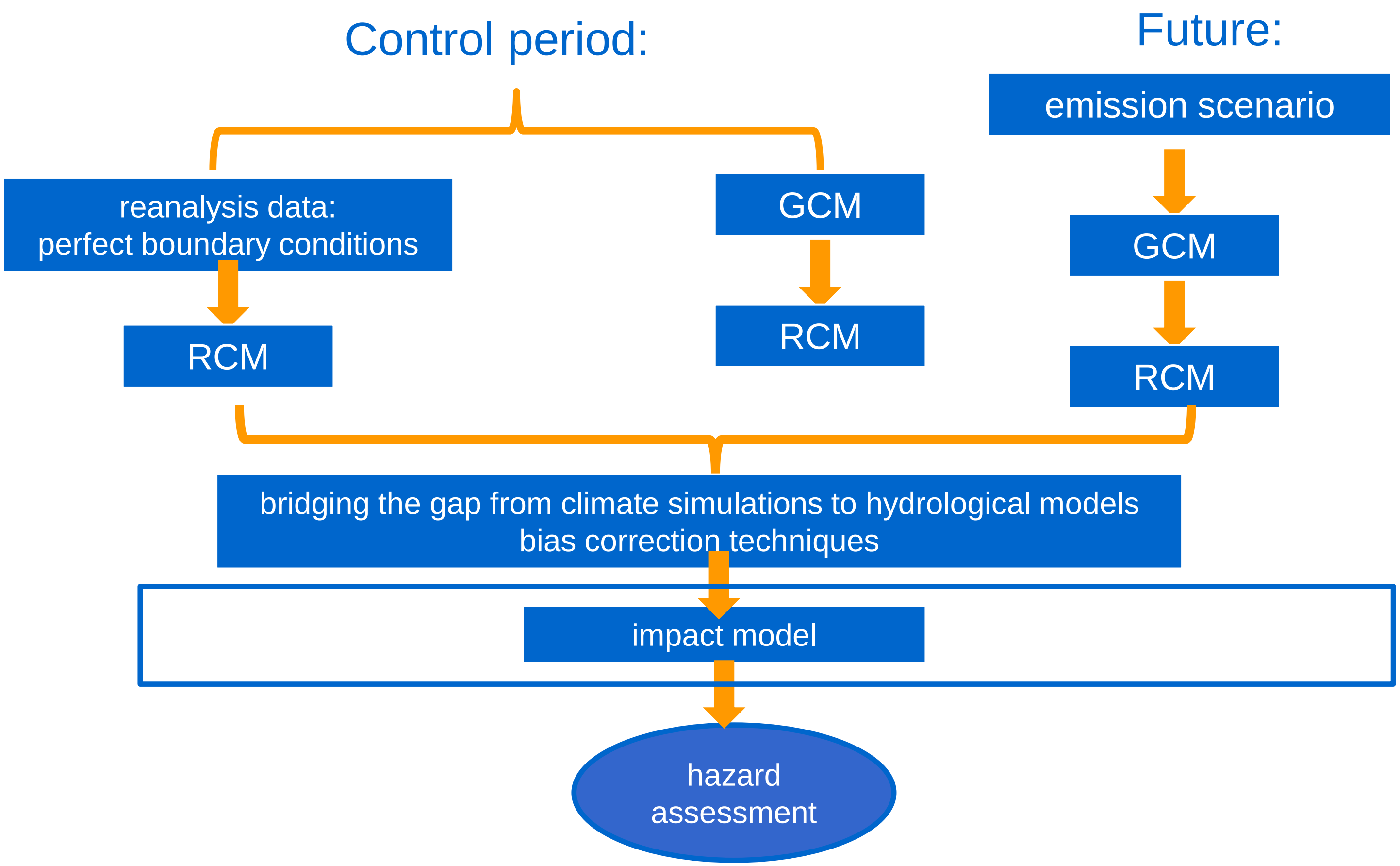

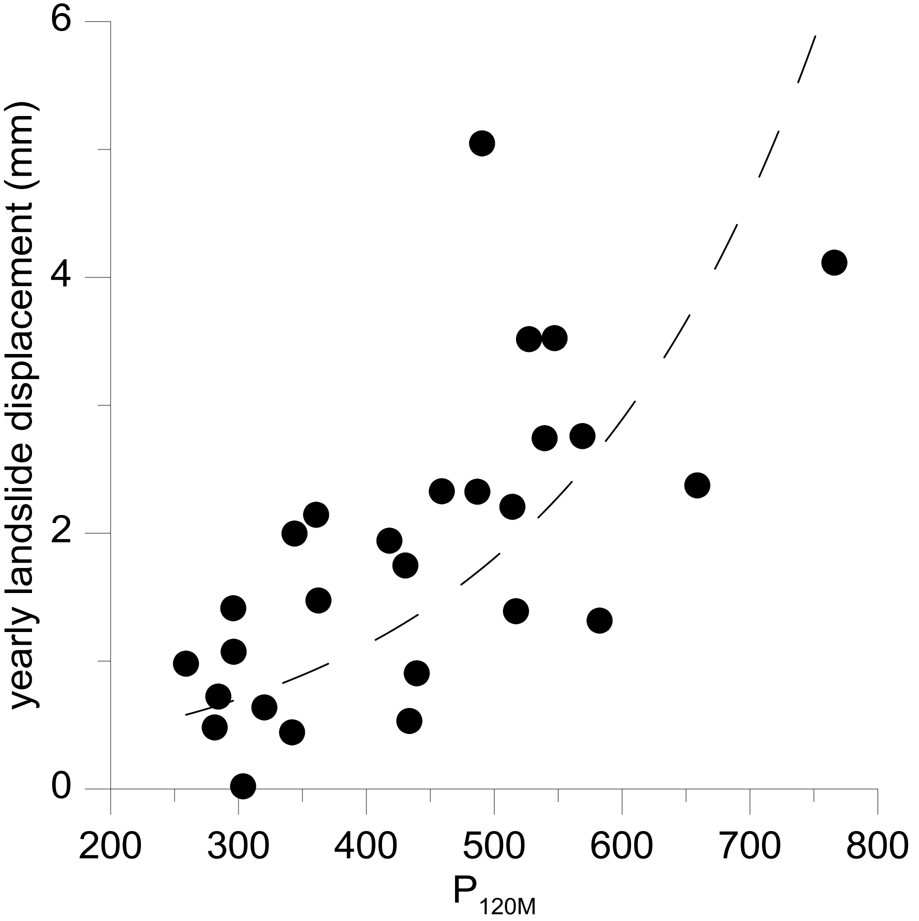

$$y = 0.17 * \exp(4.7 * 0.001 * P_{120M})$$

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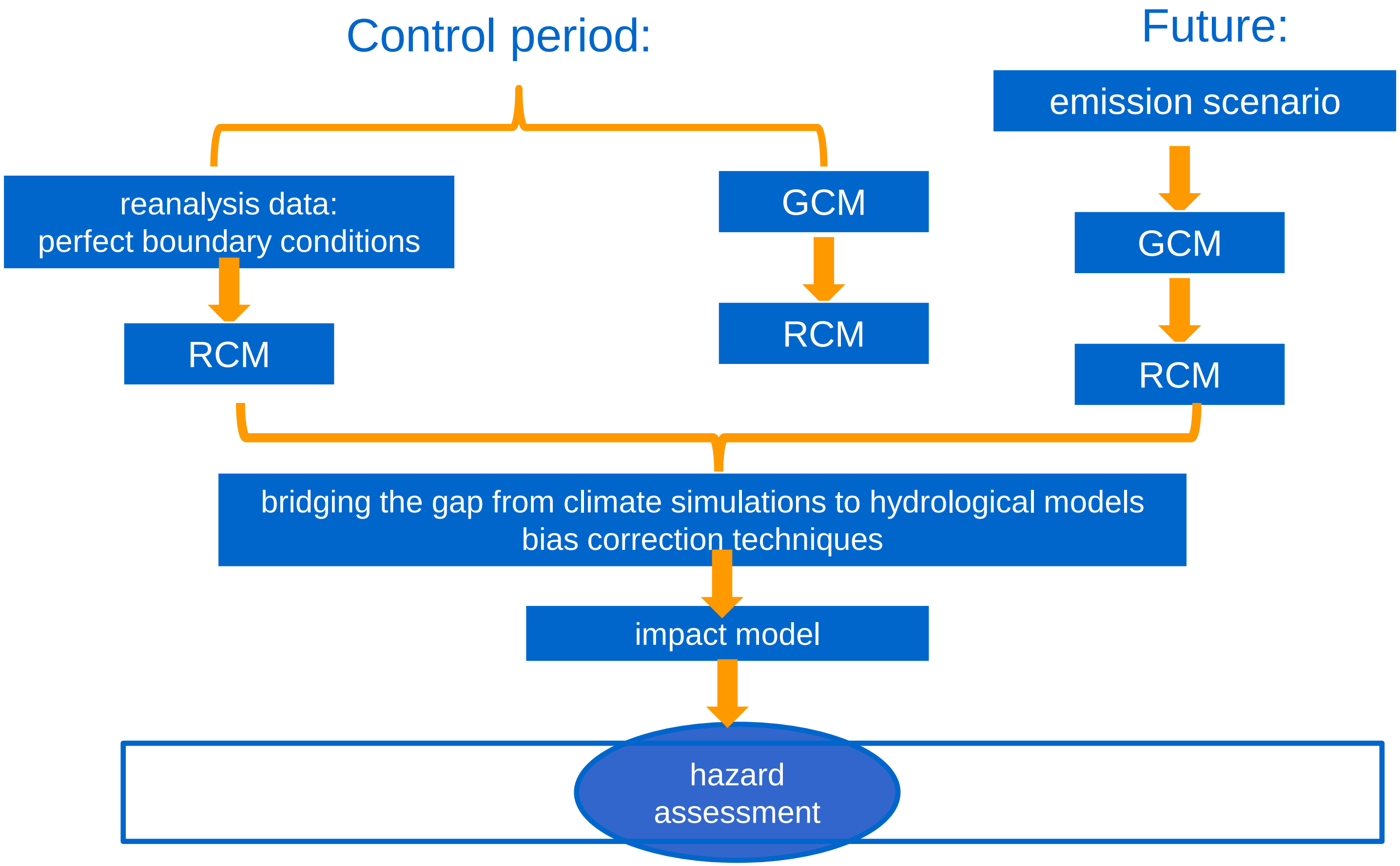
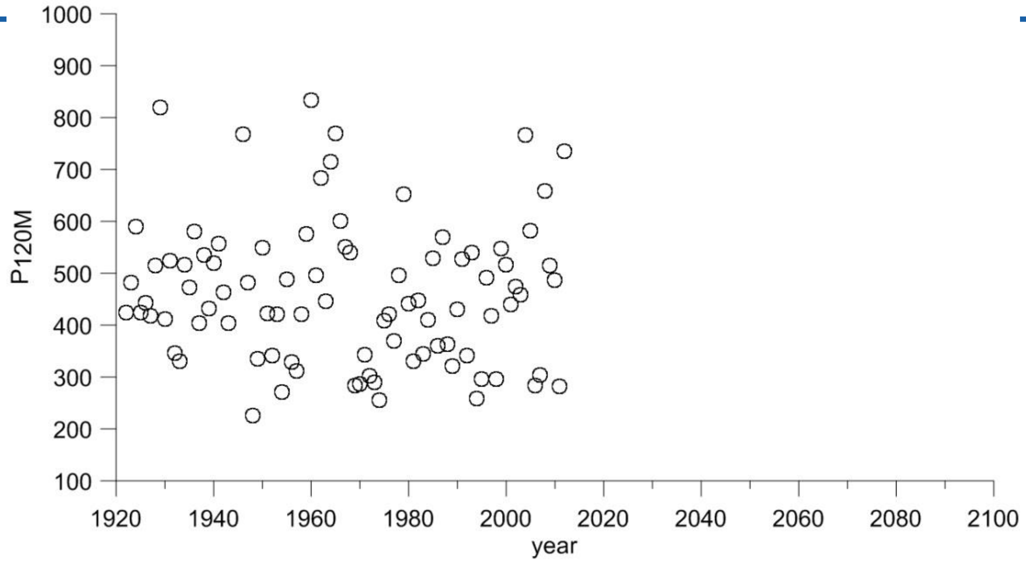
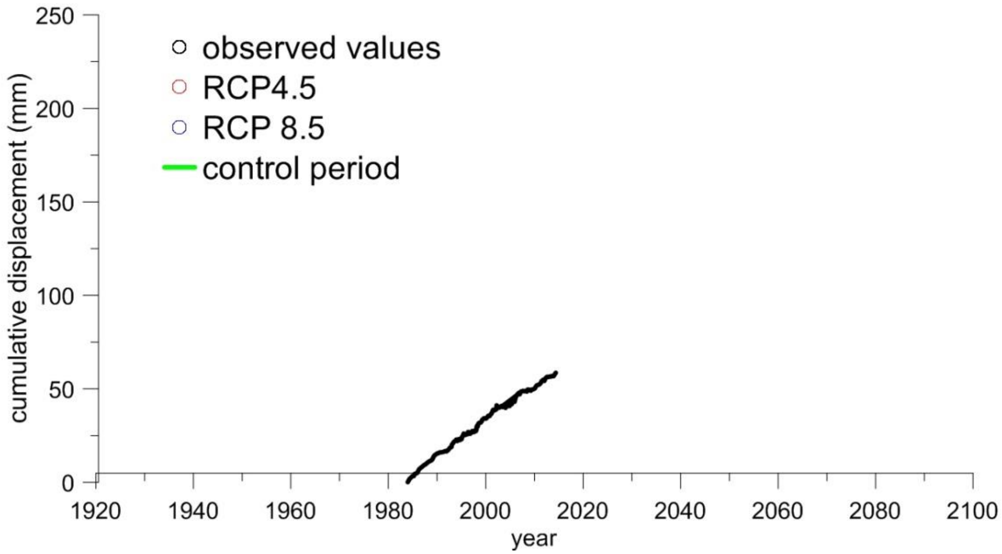
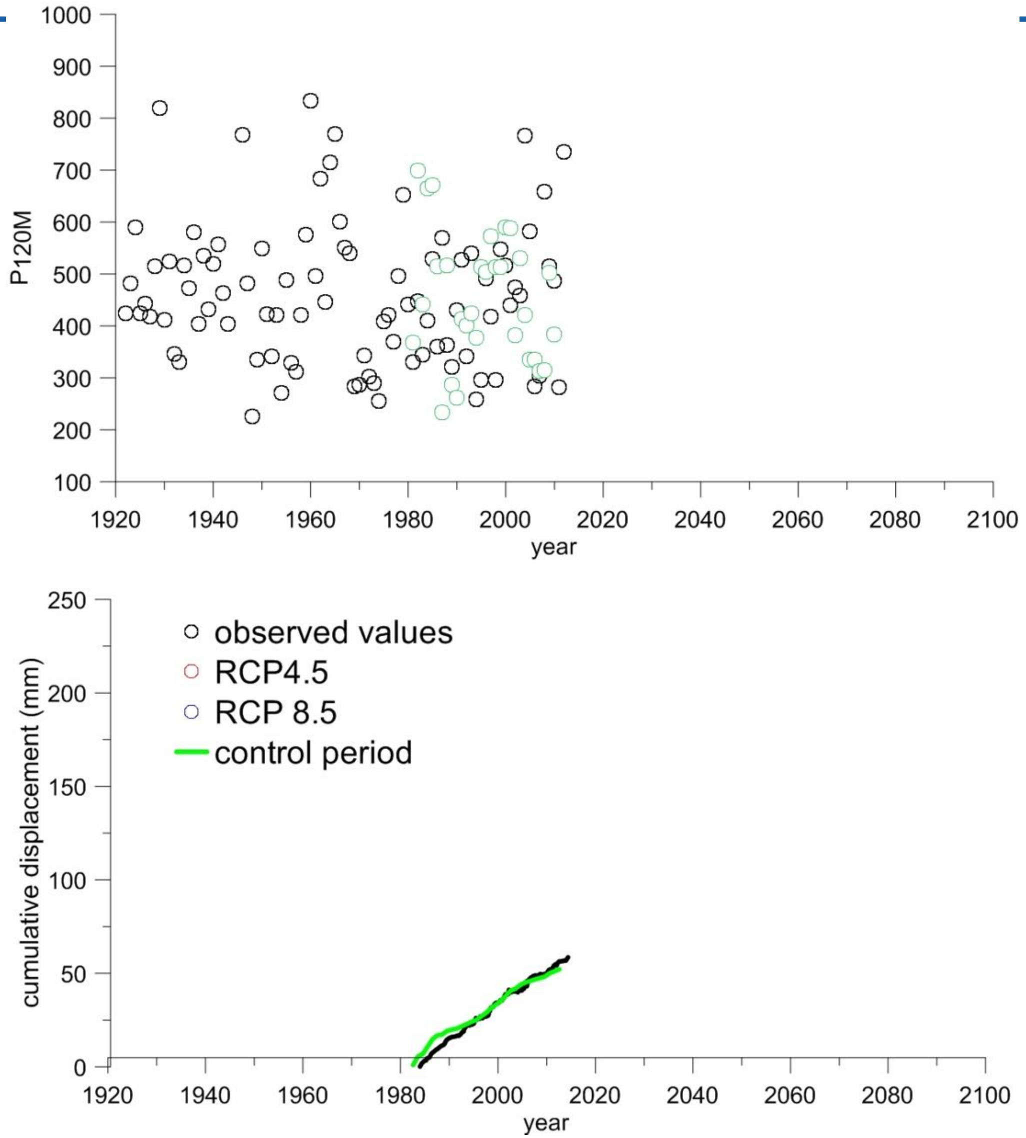




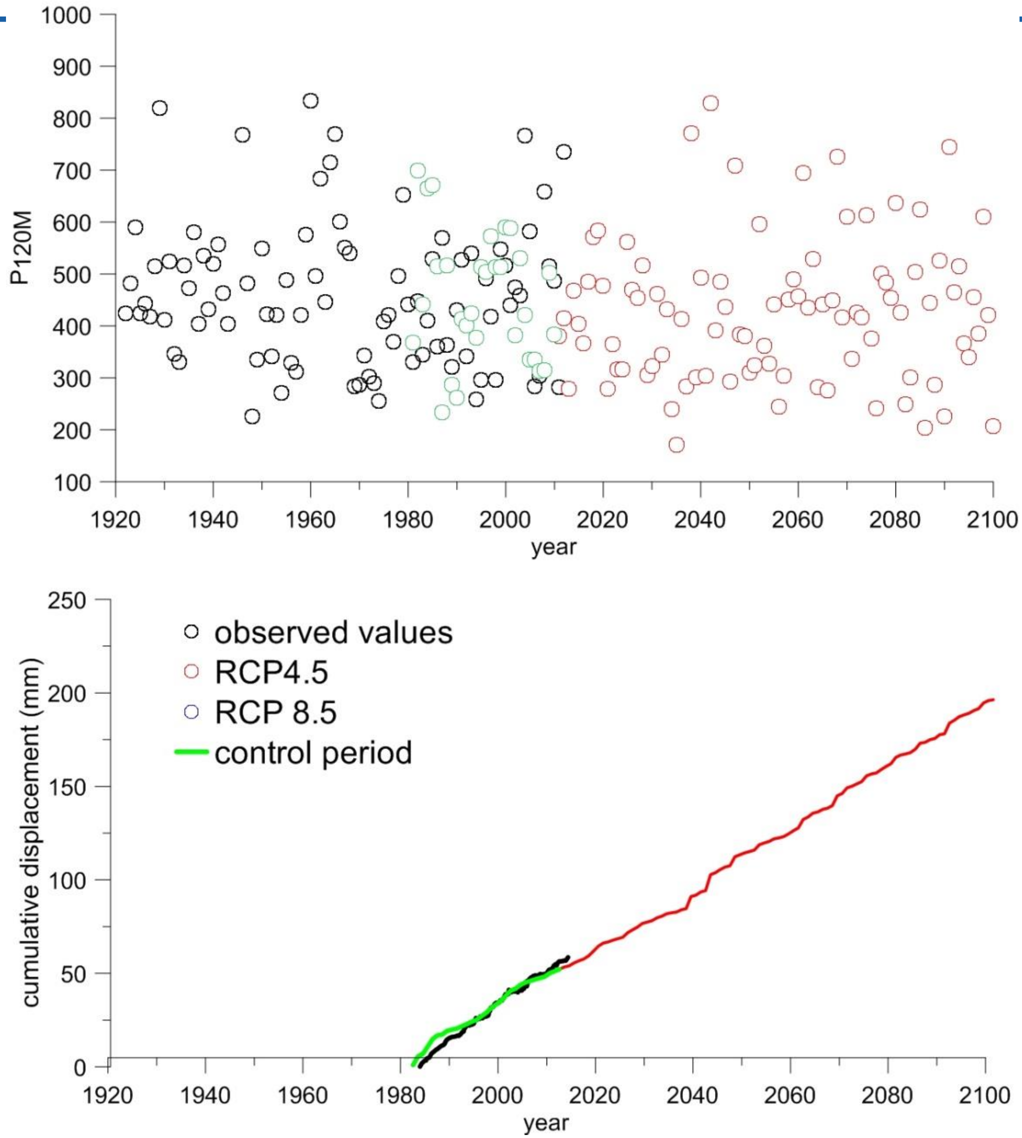
1000
900
800
700
600
500
400
300
200
100
P120M
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
year



250
200
150
100
50
0
cumulative displacement (mm)
observed values
RCP4.5
RCP 8.5
control period
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
year



P120M
year
cumulative displacement (mm)
year
observed values
RCP4.5
RCP 8.5
control period


1000
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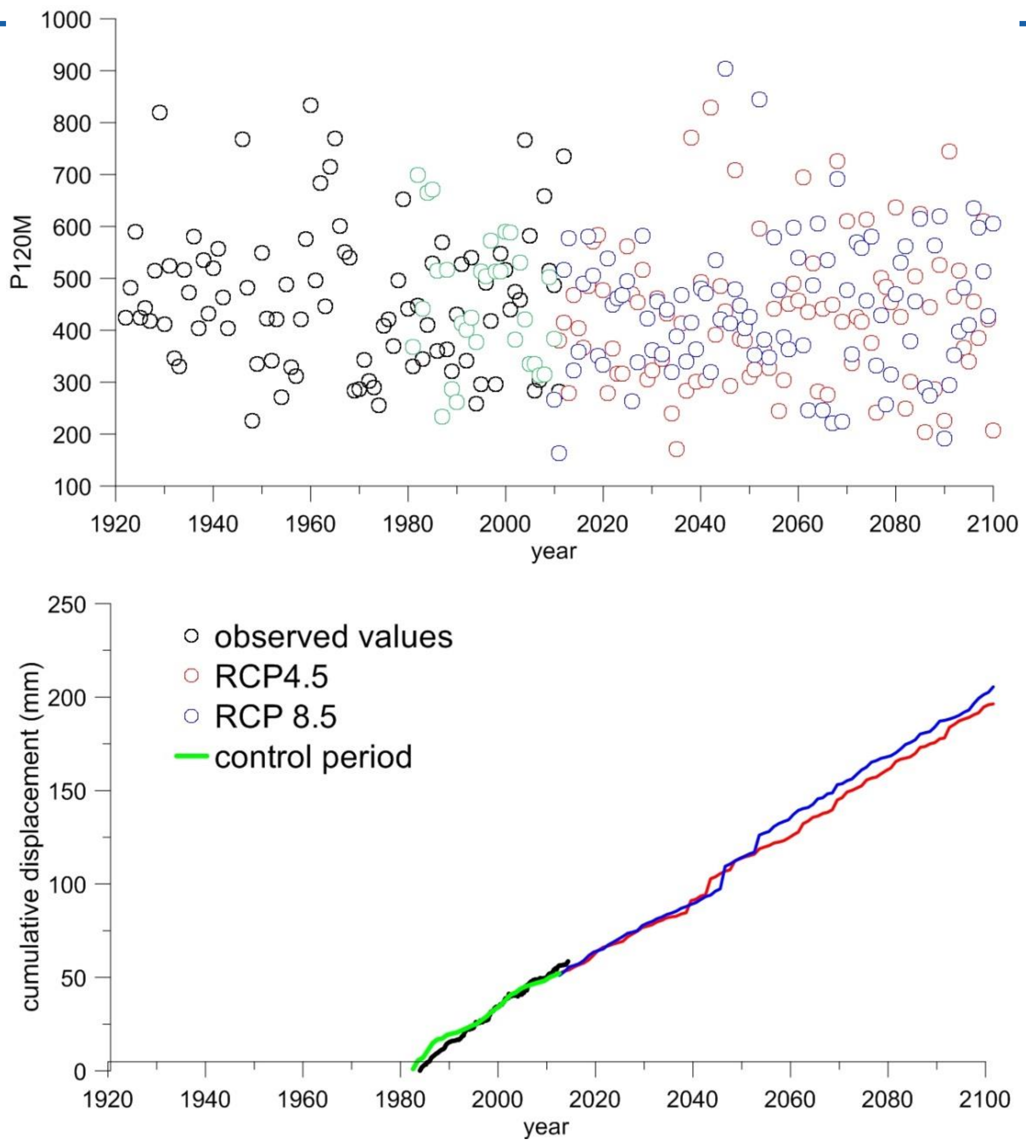
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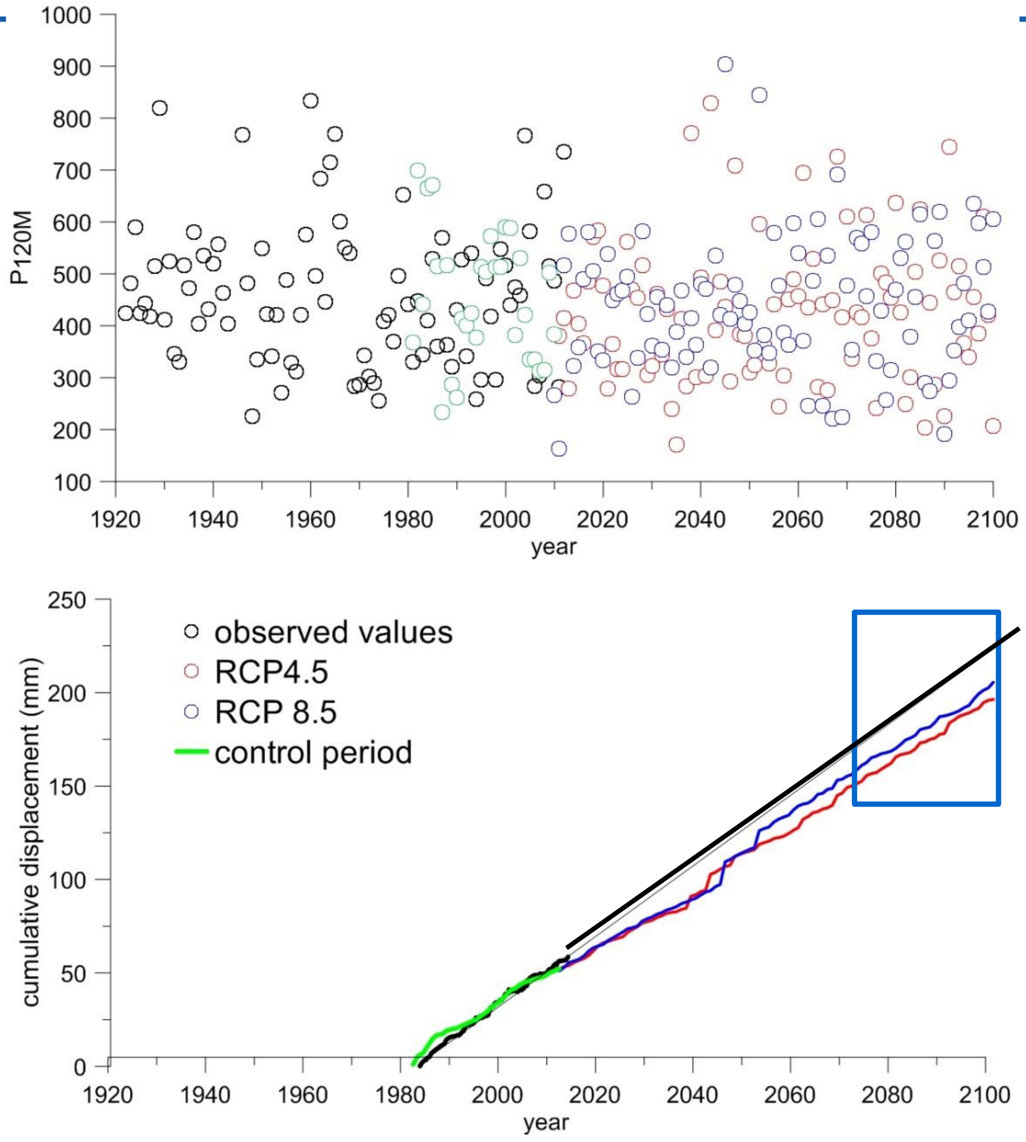
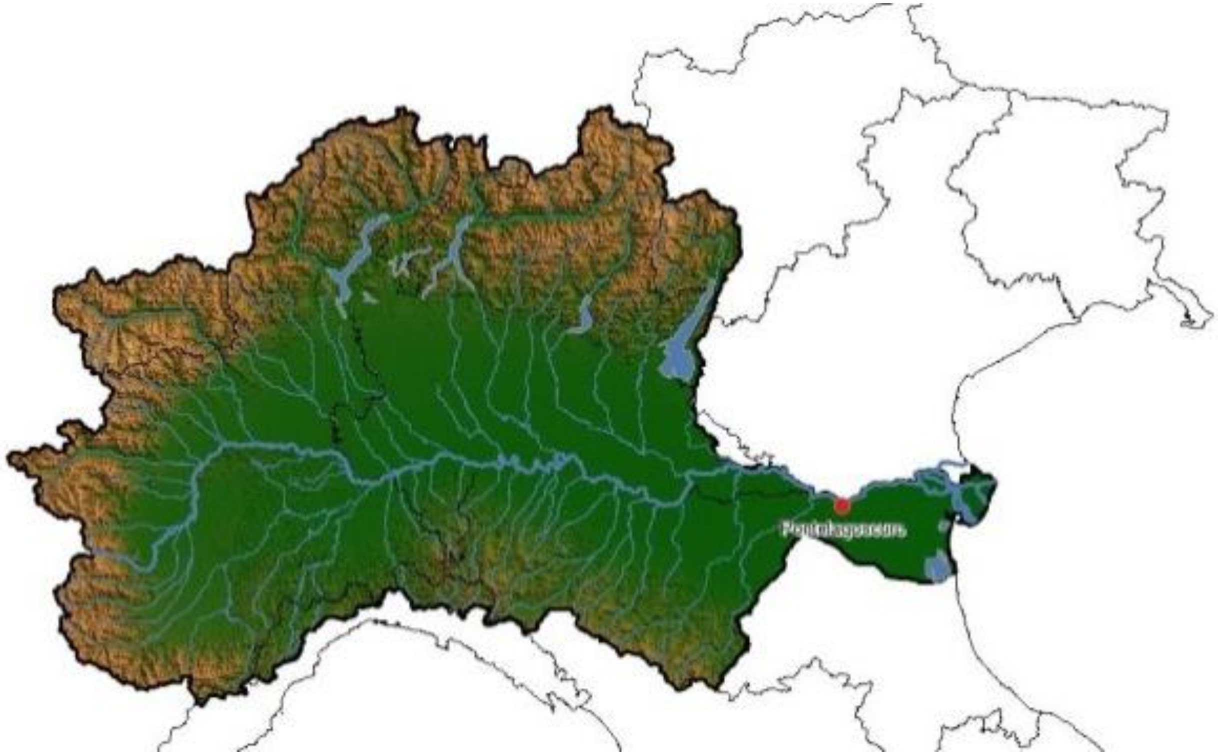
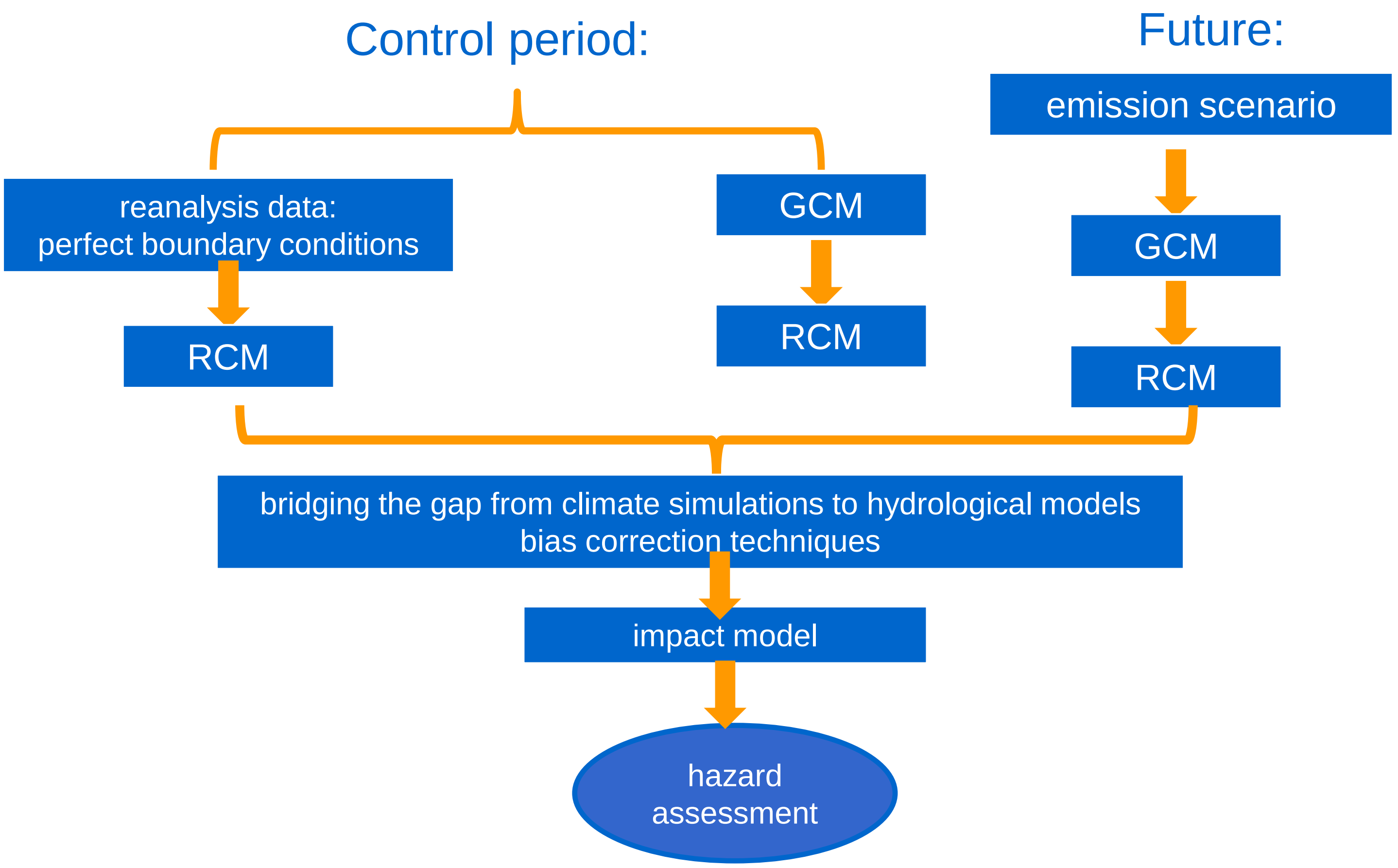


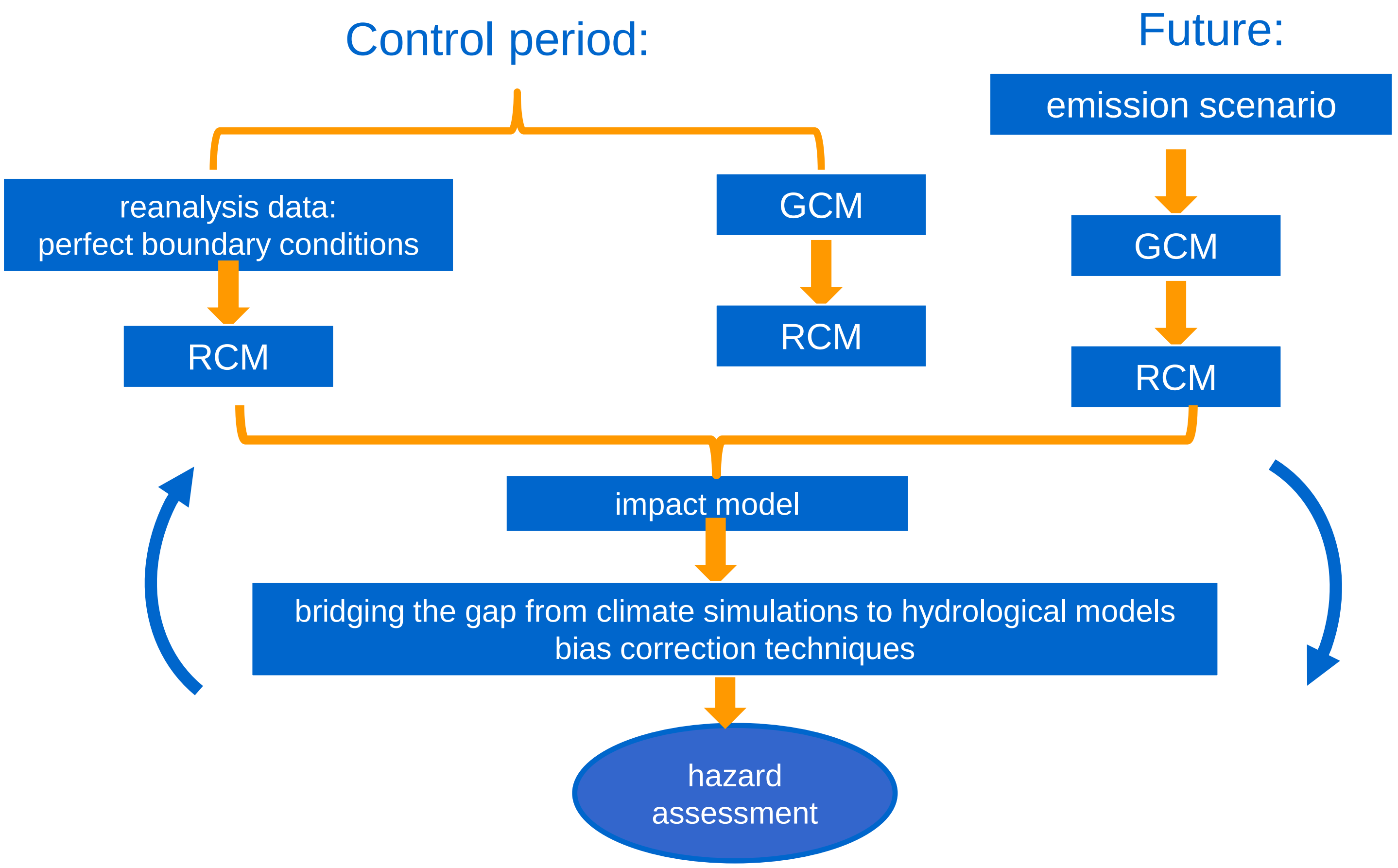
P120M
year
cumulative displacement (mm)
year
observed values
RCP4.5
RCP 8.5
control period



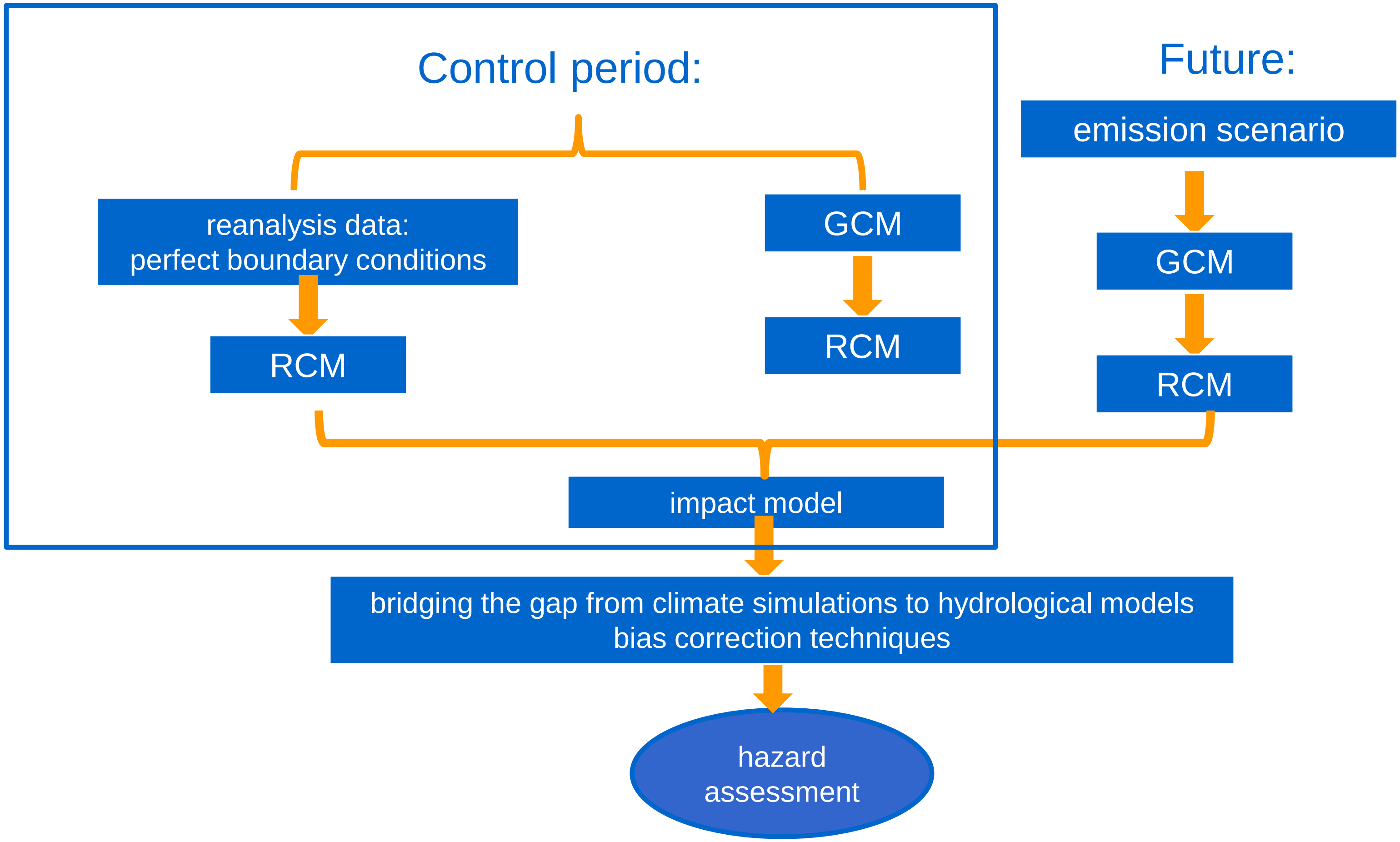
On the application of impact models in climate prospective:



On the application of impact models in climate prospective:



On the application of impact models in climate prospective:



Hydrological model: TOPKAPI

Distributed and physically based

Hydrographs are obtained from:

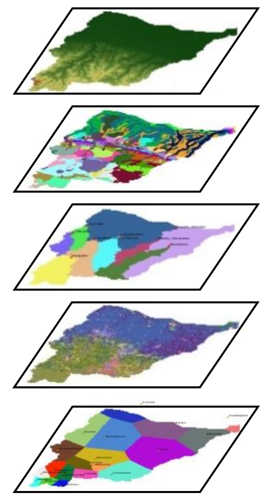
-climate (weather) inputs

-basin features (morphology)

-land use

-etc

Thematic Maps:



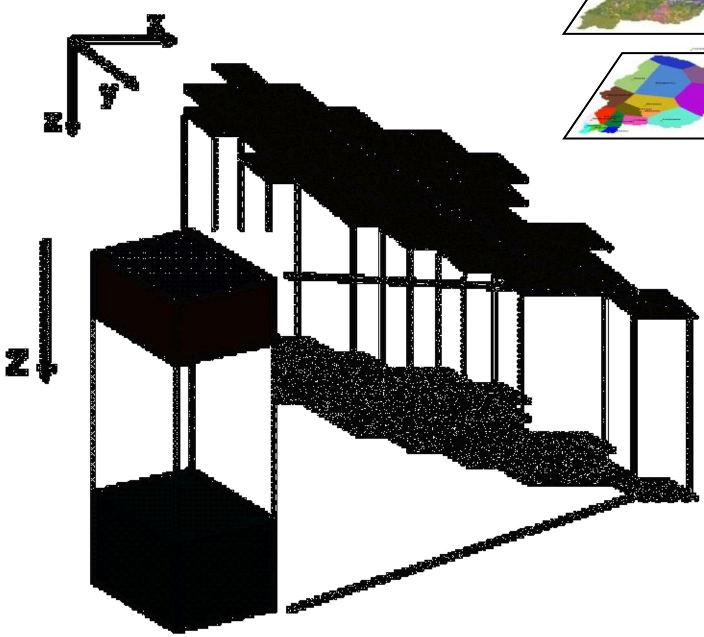
DEM

Soil type

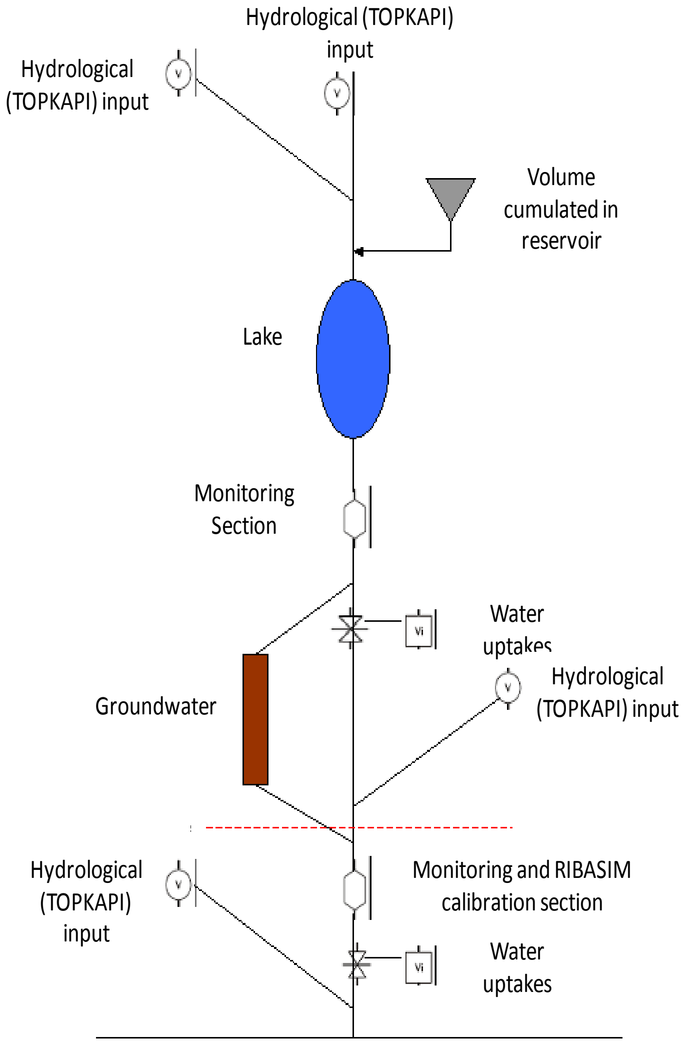
Drainage coefficients

Land use and vegetation type

Climate



River basin balance: RIBASIM

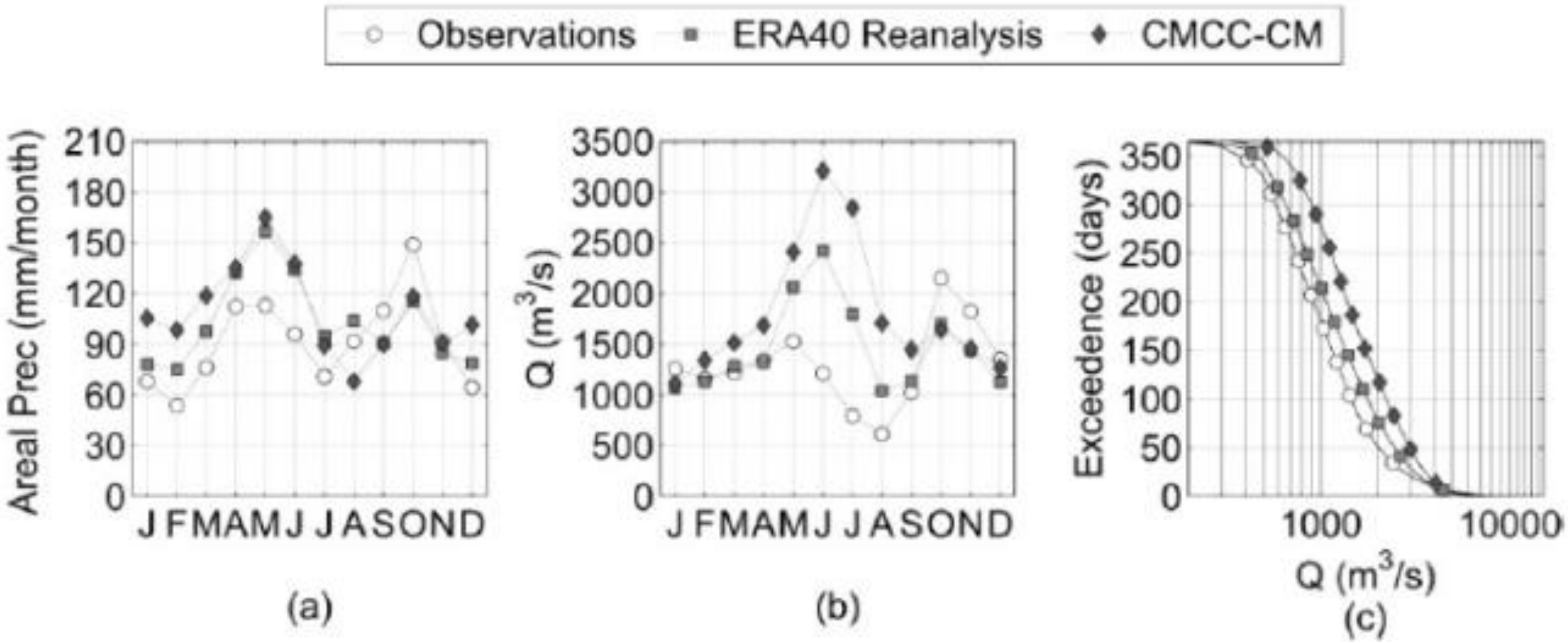


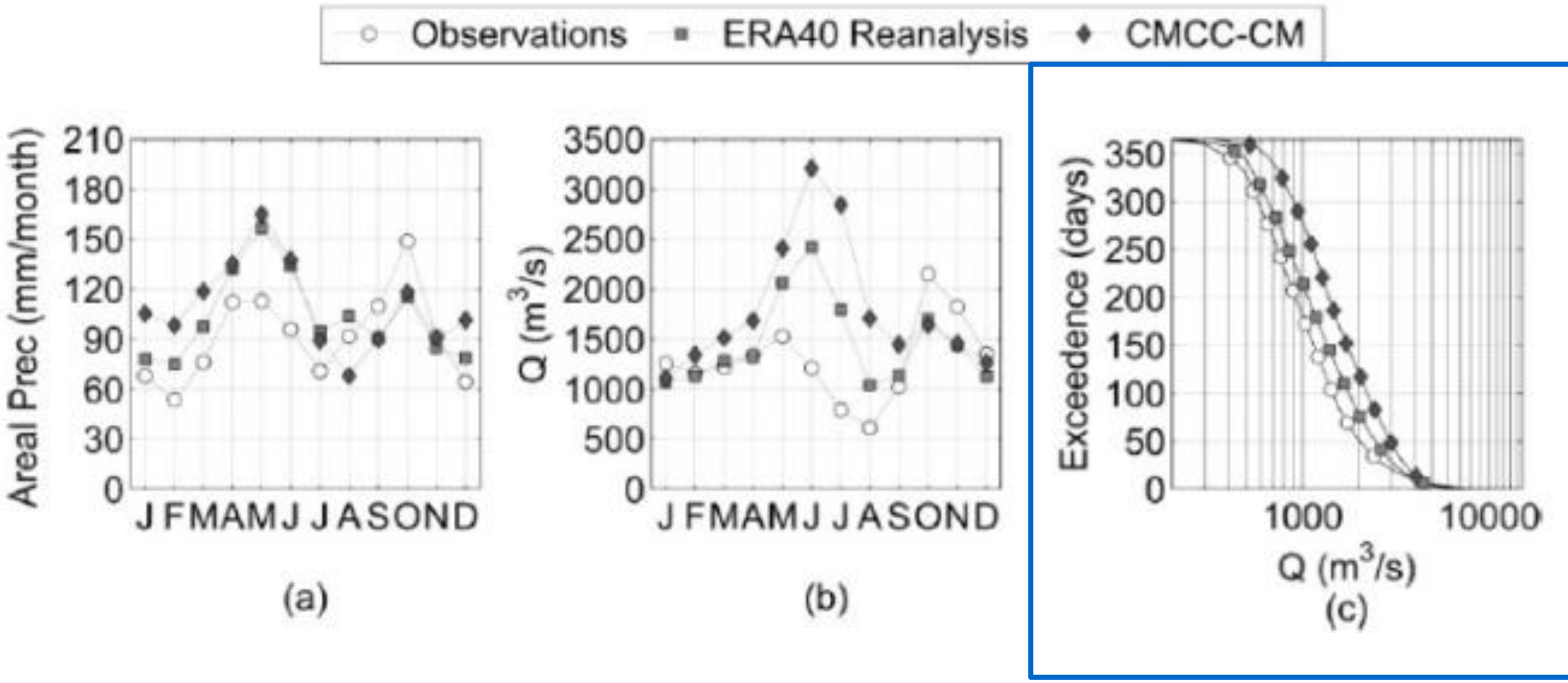
RIBASIM (RIver Basin SIMulation) is a water balance model developed by DELTARES on the basis of MITSIM model from MIT

The hydrological network is defined by links and nodes and water is distributed through links according to schematization and water demand at the nodes.

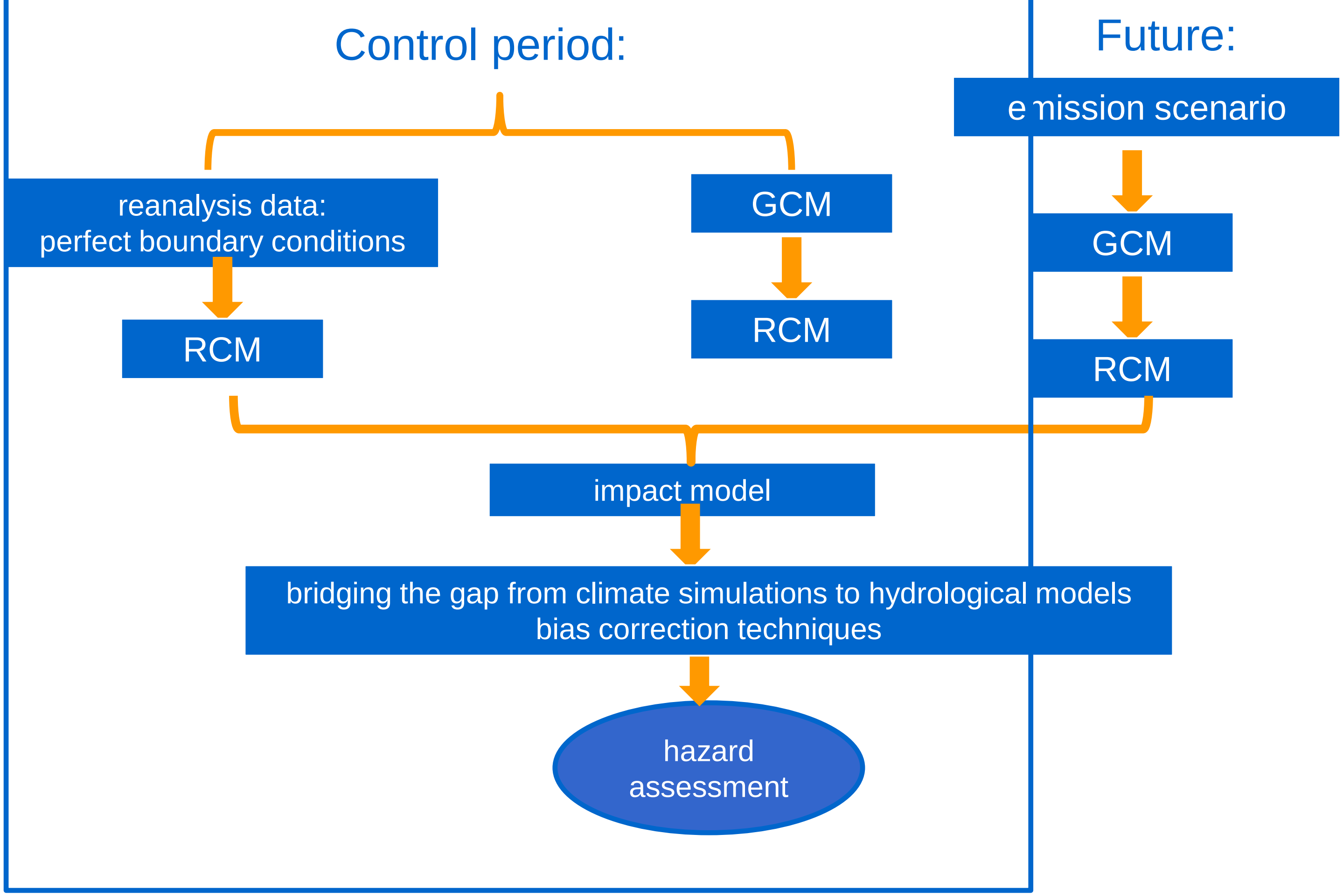
Nodes represent flow input sites (coupling between TOPKAPI and RIBASIM), groundwater and surface water reservoirs, irrigation areas, pubblic water supply points, control/ calibration section where verify the model performances

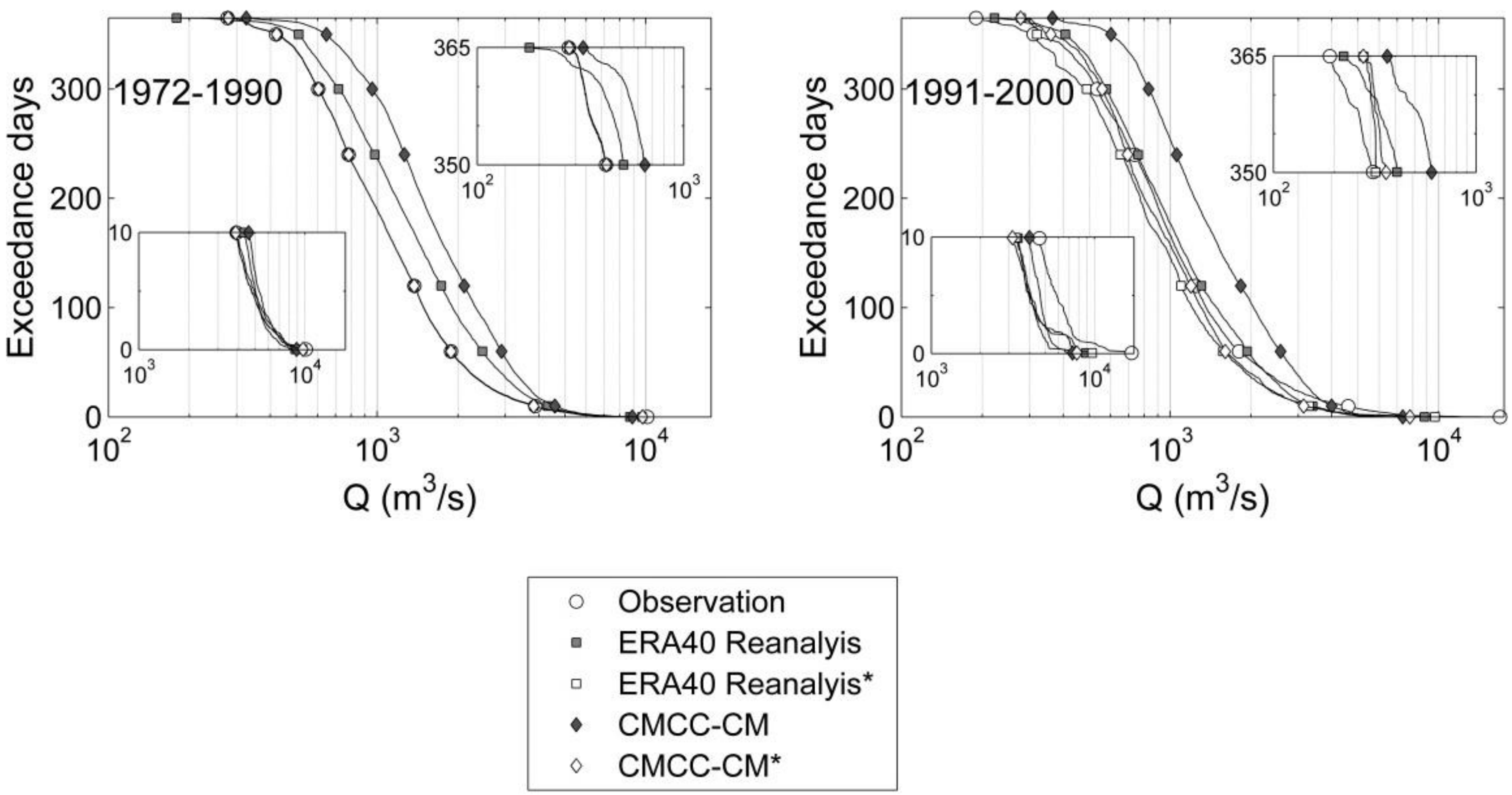
Links represent spatially homogenous river or channels, recharge, abstraction and outflow of groundwater diverted flow, backwater flow of the surface reservoir to end users


Observations
ERA40 Reanalysis
CMCC-CM
Areal Prec (mm/month)
210
180
150
120
90
60
30
0
J F M A M J J A S O N D
(a)
Q (m3/s)
3500
3000
2500
2000
1500
1000
500
0
J F M A M J J A S O N D
(b)
Exceedence (days)
350
300
250
200
150
100
50
0
1000
10000
Q (m3/s)
(c)

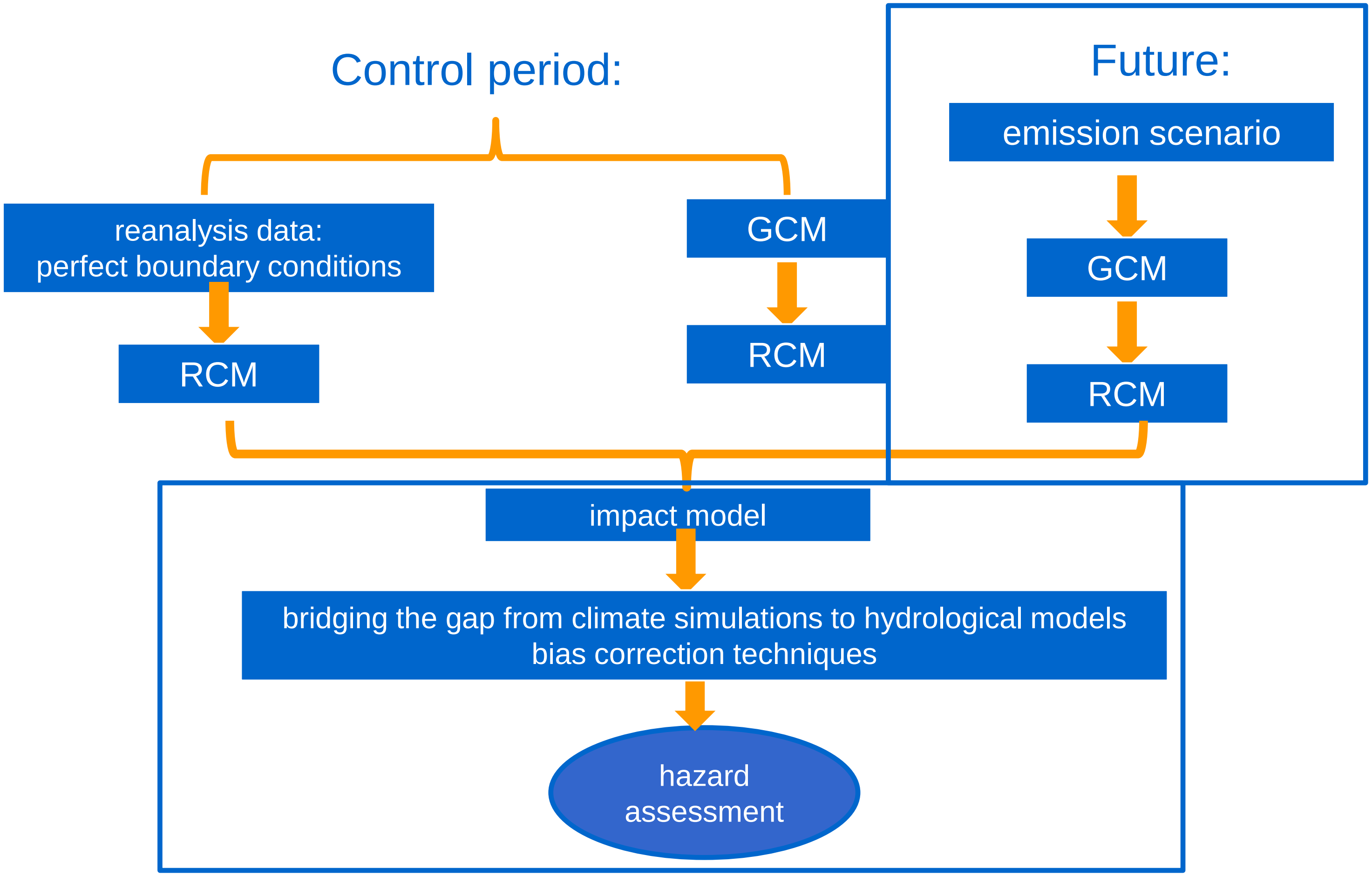

Observations
ERA40 Reanalysis
CMCC-CM
Areal Prec (mm/month)
J F M A M J J A S O N D
(a)
Q (m3/s)
J F M A M J J A S O N D
(b)
Exceedence (days)
1000
10000
Q (m3/s)
(c)

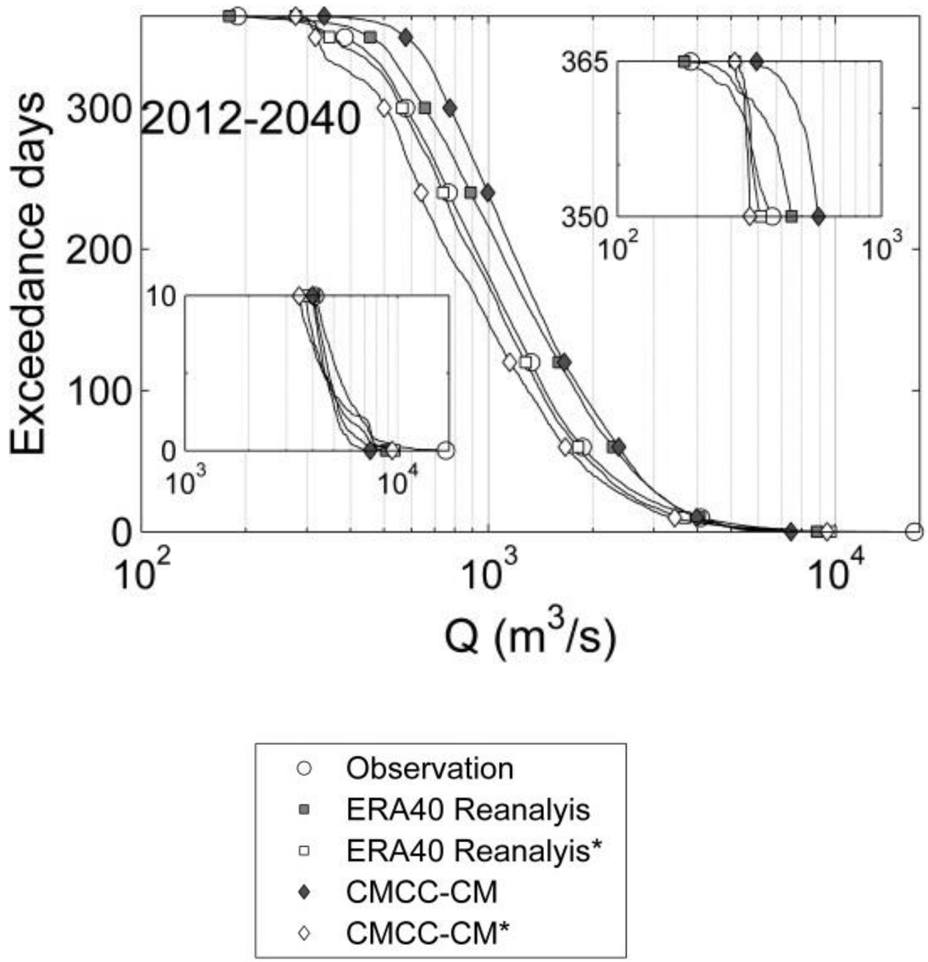
On the application of impact models in climate prospective:




1972-1990
1991-2000
Exceedance days
Q (m³/s)
Observation
ERA40 Reanalyis
ERA40 Reanalyis*
CMCC-CM
CMCC-CM*

On the application of impact models in climate prospective:





Exceedance days
2012-2040
Q (m^3/s)
Observation
ERA40 Reanalyis
ERA40 Reanalyis*
CMCC-CM
CMCC-CM*

THANK YOU FOR YOUR ATTENTION

Boldini D., Comegna L., Rianna G., Tommasi P. (2014) Evapotranspiration estimate in a clayey slope affected by landslide phenomena (Rivista Italiana di Geotecnica Italian Geotechnical Journal Special Issue on Slope- Atmosphere Interaction)

Zollo A.L., Rianna G., Mercogliano P., Tommasi P., Comegna L.(2014) Validation of a simulation chain to assess climatechange impact on precipitation induced landslides (III World Landslides Forum, Beijing June 2014)

Rianna G., Tommasi P., Mercogliano P., Comegna L. (2013) Preliminary assessment of the effects of climate change on landslide activity of Orvieto clayey slope (Proceedings of First Annual Conference of SISC Società Italiana Scienze del Clima Climate Changes and its implications on ecosystem services and society)ISBN 978 – 88 – 97666 – 08 – 0

Rianna G.,Zollo A.L., Tommasi P., Comegna L. (2013) Definition of a procedure to evaluate the effect of climate changes on landslide activity of Orvieto clayey slopeIII IWL Italian Workshop on Landslides Napoli, 23-24 October 2013

Tommasi P., Boldini D., Comegna L., Rianna G. (2013) Some hints on the comprehension of the mechanics of slow movements in clay slopes coming from long-term monitoring III IWL Italian Workshop on Landslides Napoli, 23-24 October 2013

Vezzoli et al. (in prep) Depth-Duration-Frequency curves: The impact of climate change in Emilia Romagna region (Italy) using COSMO-CLM

Vezzoli et al. (2014) Hydrological simulations driven by RCM climate scenarios at basin scale in the Po river, Italy Evolving water resources systems: understanding, predicting and managing water–society interactions proceedings of ICWRS2014, (IAHS publ. 364, 2014)

RESEARCH PAPERS AVAILABLE ON www.cmcc.it

Climate simulation analysis

Rainfall Depth-Duration-Frequency (DDF) curves

- ✓ quantify a precipitation event in function of its duration and rarity (ie frequency)
- ✓ tool to design urban infrastructures (like sewerage systems or flood protection structures) thus they may be used to check/quantify vulnerability and adaptability of infrastructures to climate change

COSMO-CLM data are available with 6 hours time step, we investigate the DDF curves variability at 6, 12, 24 hours under RCP4.5 and RCP8.5 in 2071-2100 with respect to 1981-2010

Changes in extreme precipitation affects the peak flood distribution with consequent impacts on the infrastructures on rivers. The example reported here is for Secchia River in Emilia Romagna and it accounts for both climate and land use changes

Vezzoli et al. (in prep) Depth-Duration-Frequency curves: The impact of climate change in Emilia Romagna region (Italy) using

Projected variations in peak flood