Weighting CMIP3 & CMIP5 models with respect to Mediterranean precipitation in a statistical downscaling framework

Irena Kaspar-Ott[1], Elke Hertig[1], Severin Kaspar[1], Felix Pollinger[2], Christoph Ring[2], Heiko Paeth[2], Jucundus Jacobeit[1]

[1] Institute of Geography, University of Augsburg
[2] Institute of Geography and Geology, University of Wuerzburg

Vienna, EGU 2019
Abstract: EGU2019-1833
Session AS1.4

1. Topic

- **Climate projections of individual models differ considerably**, particularly at the regional scale and with respect to certain climate variables such as precipitation.
- However, **climate protection and adaptive measures require reliable estimates of future climate change**.
- The aim of this study is to derive **more reliable estimates of future precipitation changes in the Mediterranean region** for the multi-model ensemble from CMIP3 and CMIP5.
- Why the Mediterranean area? It represents a so-called **hot spot of climate change.**
- **The novelty of this weighting metric consists in avoiding the use of the precipitation bias by itself as a weighting basis**, as the modelling of precipitation amounts and their spatial distribution is still a highly insufficient subject.

2. Data and methods

- Time periods: 1950-1999 and 2070-2099; monthly data, pooled to seasons DJF, MAM, JJA, SON.
- **EOBS** (version 12) for precipitation, **NCEP-NCAR** reanalysis for atmospheric variables.
- **All available CMIP3 and CMIP5 models** for the 20c3m / historical simulations and **A1B** & **A2** / **rcp4.5** & **rcp8.5** scenarios.
- **Predictors**: geopotential heights (zg, 700&500 hPa), sea level pressure (psl), atmospheric layer thickness between 925 and 500 hPa (thick500-925), zonal and meridional wind velocities (ua&va, 700 hPa), specific&relative humidity (hus&hur, 850&700 hPa).
- **Predictand**: monthly precipitation sums.

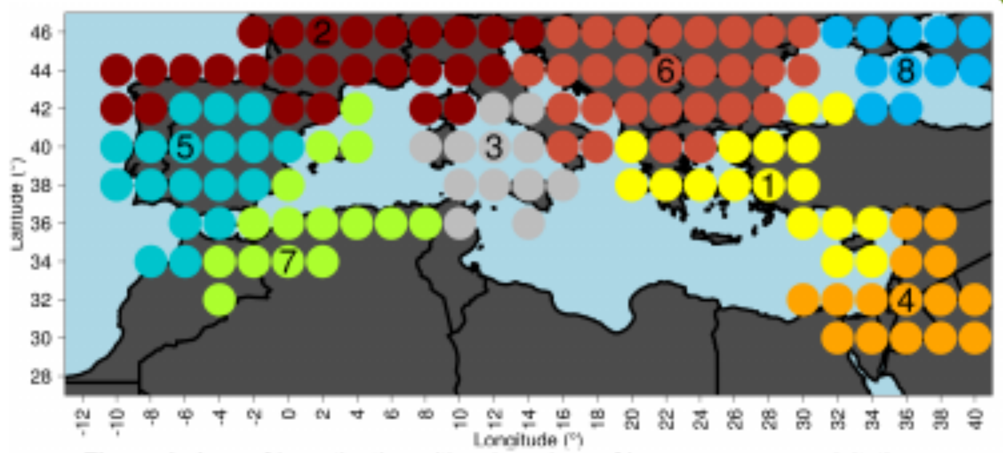


Figure 1: Area of investigation with sub-regions of homogeneous precipitation variability. Greece-Turkey (1), North-western area (2), Tyrrhenian Sea riparians (3), Eastern Mediterranean (4), Iberian Peninsula (5), Balkans (6), Maghreb (7) and Eastern Black Sea (8).

3. Downscaling approach & generation of weights

- DOWNSCALING: To determine the most important atmospheric predictor variables from the reanalysis data for the eight precipitation sub-regions (= predictands, i.e., the seasonal and spatially averaged precipitation time series from EOBS), **multiple linear regressions (MLRs)** are computed.
- To reduce the predictor variables to a set of manageable and physically meaningful predictors, seasonal (single-monthly) s-mode PCAs are computed for each variable (1950-1999, based on correlation matrix, Varimax rotated).
- To overcome possible instationarities in the predictor-predictand-relationship, a **bootstrapping** method is applied.
- A **stepwise method of predictor reduction** is developed to find the optimal set of independent predictors, called **key predictors**.

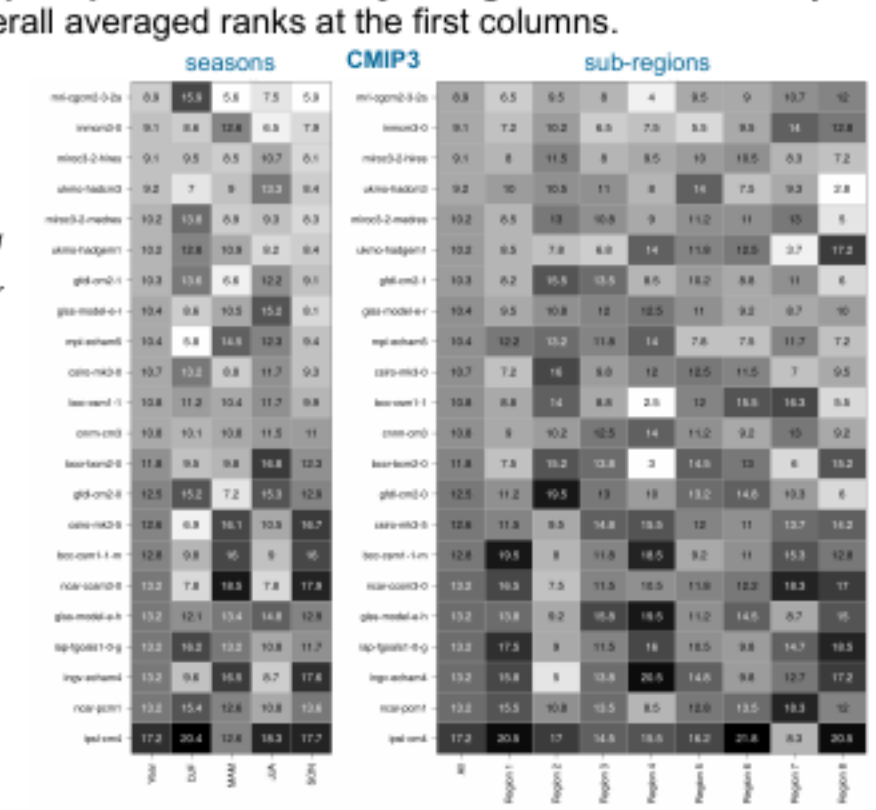
Table 1: *Percentage frequencies of predictor variables from the final MLR setups for the four seasons.*

%	zg500	zg700	Psl	Thick500-925	va700	ua700	hur700	hur850	hus700	hus850
DJF	53.8	5.0	0.0	2.5	12.5	6.3	3.8	1.3	11.3	3.8
MAM	44.3	11.4	2.5	1.3	13.9	0.0	10.1	1.3	8.9	6.3
JJA	47.8	4.3	2.2	3.3	4.3	0.0	20.7	9.8	3.3	4.3
SON	40.3	9.1	3.9	0.0	7.8	10.4	13.0	0.0	13.0	2.6
All	46.6	7.3	2.1	1.8	9.5	4.0	12.2	3.4	8.8	4.3

- WEIGHTS: Equivalent to the EOBS data and the NCEP-NCAR reanalysis, the CMIP model data is re-gridded to a 2 × 2 grid.
- The fields of the historical modelled atmospheric variables are **normalized by the corresponding mean and standard deviation of the NCEP-NCAR reanalysis** (grid box by grid box) and then projected onto the loading patterns of the PCAs from NCEP-NCAR.
- Thus, the **bias of the modelled atmospheric variables** in comparison to the reanalysis data is represented in the resulting projected PC scores of the climate models. **These biases are used to determine the weights for each investigated CMIP model**.
- Therefore, the appropriate **key predictor PC scores are used to drive the MLRs**. The absolute differences between the means of the original fitted values of NCEP-NCAR and the resulting CMIP precipitation time series are used as basis for the model weights.
- This is done separately for CMIP3 and CMIP5. The basic weights are then normalized between 0 and 1. As a result, each model has one weight per sub-region and season.

4. Results: Ranking of CMIP3 and CMIP5

- The presented weighting metric results in eight (sub-regions) by four (seasons) different assessments of model performance for the entire Mediterranean area with respect to their skill in representing Mediterranean precipitation.
- Despite the variability within the ranking of one model in time and space, sub-groups of **better and worse models for the representation of Mediterranean precipitation are clearly recognizable**, indicated by the range of the overall averaged ranks at the first columns.



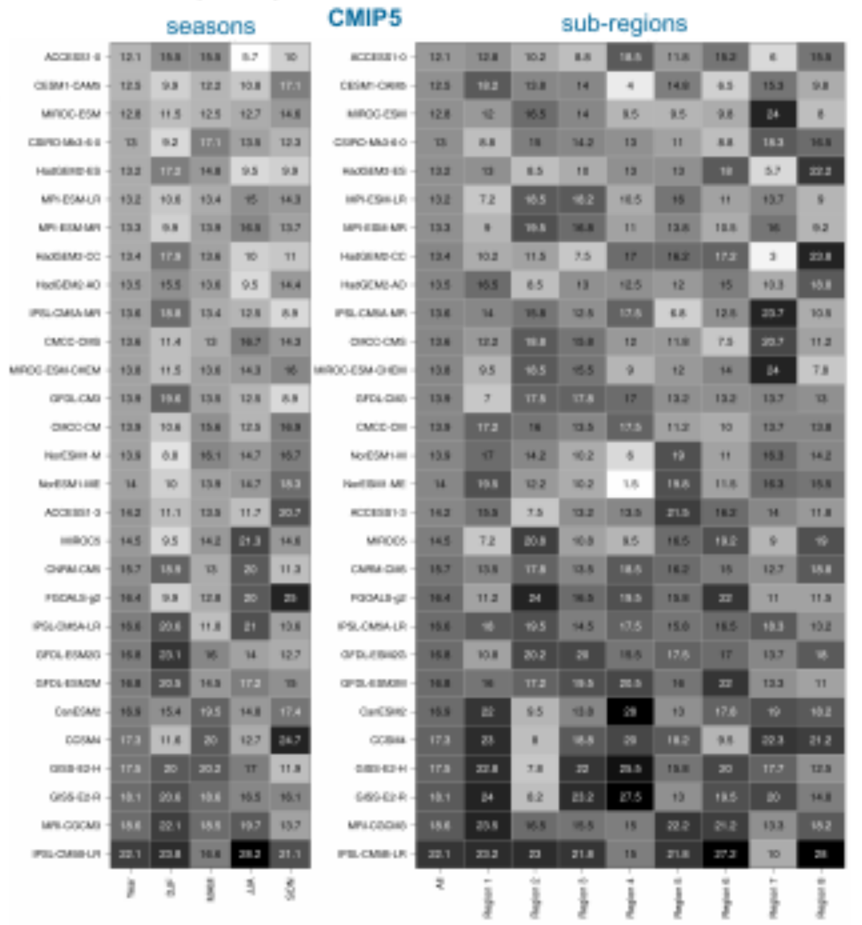


Figure 2: *Ranking lists of all used CMIP3 (left) and CMIP5 (right) models, resulting from the weighting metric. Single ranking results are aggregated over all sub-regions and over all seasons, respectively. Bright background colour indicates better ranking results than a dark background. The numbers denote the overall ranking result.*

5. Results: Weighted future precipitation changes

- The fields of the modelled atmospheric variables are normalized over the investigated time period 1950–1999/2070–2099 (separately for each scenario) and then projected onto the loading patterns of the PCAs from NCEP-NCAR. The key predictors are used to drive the MLRs → **no direct use of CMIP precipitation necessary**!
- The resulting **downscaled precipitation data from CMIP3 and CMIP5** models for the historical and the four future scenario runs are used to calculate the **precipitation change signals** in the eight Mediterranean sub-regions and additionally **weighted according to the ranking results**.

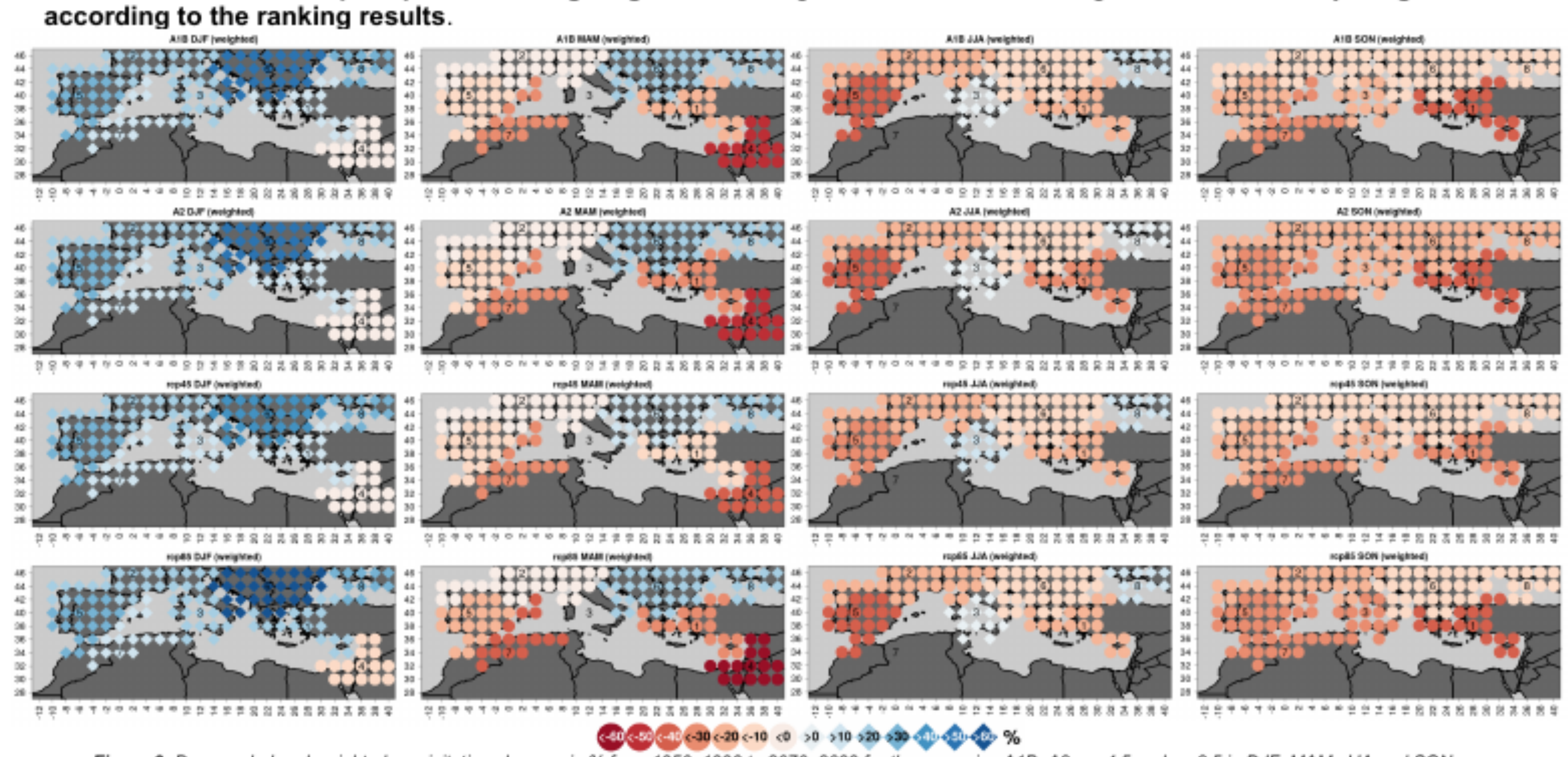


Figure 3: Downscaled and weighted precipitation changes in % from 1950–1999 to 2070–2099 for the scenarios A1B, A2, rcp4.5 and rcp8.5 in DJF, MAM, JJA and SON.

➔ The application of the model weights leads mostly to either a **shift** or a **concretion of the change signals** and thus to more reliable results. At a few sub-regions and seasons, the weighting resulted in a broadening of the change signal distribution.

Contact:

Dr. Irena Kaspar-Ott
irena.kaspar-ott@geo.uni-augsburg.de
www.geo.uni-augsburg.de

Recently published in:

Kaspar-Ott I, Hertig E, Kaspar S, et al. Weights for general circulation models from CMIP3/ CMIP5 in a statistical downscaling framework and the impact on future Mediterranean precipitation. *Int J Climatol.* 2019;1–16. https://doi.org/10.1002/joc.6045