[1] *Swedish Meteorological and Hydrological Institute, Norrköping, Sweden* (* ilias.pechlivanidis@smhi.se)
[2] *Department of Hydrology and Water Resources, University of Arizona, Tucson, Arizona, USA*

Ilias G. Pechlivanidis[1*], Hoshin V. Gupta[2], and Thomas Bosshard[1]

Identification of representative hydroclimatic projections based on the MIMR concept

ABSTRACT

A combination of numerous climate projections is usually needed to quantify the total uncertainty, however practical impact modeling investigations can only handle a limited number of scenario combinations. Given the fact that all climate projections are subject to considerable uncertainty, it is crucial to know a representative subset with regard to the uncertainty span, in an available ensemble. The proposed framework is based on the Maximum Information Minimum Redundancy (MIMR) concept aiming in here to identify the representative subset from an ensemble of 16 climate projections for precipitation and temperature for the entire Sweden. The projections were further used to force the HBV hydrological model and simulate river discharge. We identify the representative subsets for precipitation, temperature and discharge and assess the sensitivity of the identification at different seasons and future periods.

MOTIVATION

Entropy-based measures provide a promising avenue to identify where information is present and/or conflicting [1].

Key scientific questions:

i) if one had to select N projections from a larger set, which one should one choose? and

ii) if one has N projections, how could one quantify their representativeness with respect to a larger set of projections.

EXPERIMENT

Region: Sweden

Seasons: 'DJF', 'MAM', 'JJA', 'SON', 'Annual'

Variables: Precipitation, Temperature, Discharge

Resolution: 1007 basins

Hydrological model: HBV

Projections: 16 members

Table 1. *Projections used in the larger ensemble to produce hydrological climate impact projections with the hydrological model HBV.*

ID	Emission scenario	GCM	RCM	Reference data
1	A1B	ECHAM5r1	RCA3, 50 x 50 km	PTHBV, 4 x 4 km
2	A1B	ECHAM5r2	RCA3, 50 x 50 km	PTHBV, 4 x 4 km
3	A1B	ECHAM5r3	RCA3, 50 x 50 km	PTHBV, 4 x 4 km
4	A1B	ECHAM5r3	RCA3, 25 x 25 km	PTHBV, 4 x 4 km
5	B1	ECHAM5r1	RCA3, 50 x 50 km	PTHBV, 4 x 4 km
6	A1B	ARPEGE	RCA3, 50 x 50 km	PTHBV, 4 x 4 km
7	A1B	CCSM3	RCA3, 50 x 50 km	PTHBV, 4 x 4 km
8	A1B	ARPEGE	ALADIN, 25 x 25 km	PTHBV, 4 x 4 km
9	A1B	ECHAM5r3	RACMO, 25 x 25 km	PTHBV, 4 x 4 km
10	A1B	ECHAM5r3	REMO, 25 x 25 km	PTHBV, 4 x 4 km
11	A2	ECHAM5r3	RCA3(C4I), 25 x 25 km	PTHBV, 4 x 4 km
12	A1B	HadCM3Q0	HadRM3, 25 x 25 km	PTHBV, 4 x 4 km
13	A1B	HadCM3Q16	RCA3(C4I), 25 x 25 km	PTHBV, 4 x 4 km
14	A1B	BCM	HIRHAM, 25 x 25 km	PTHBV, 4 x 4 km
15	A1B	HadCM3Q0	HIRHAM, 25 x 25 km	PTHBV, 4 x 4 km
16	A1B	ECHAM5r3	HIRHAM, 25 x 25 km	PTHBV, 4 x 4 km

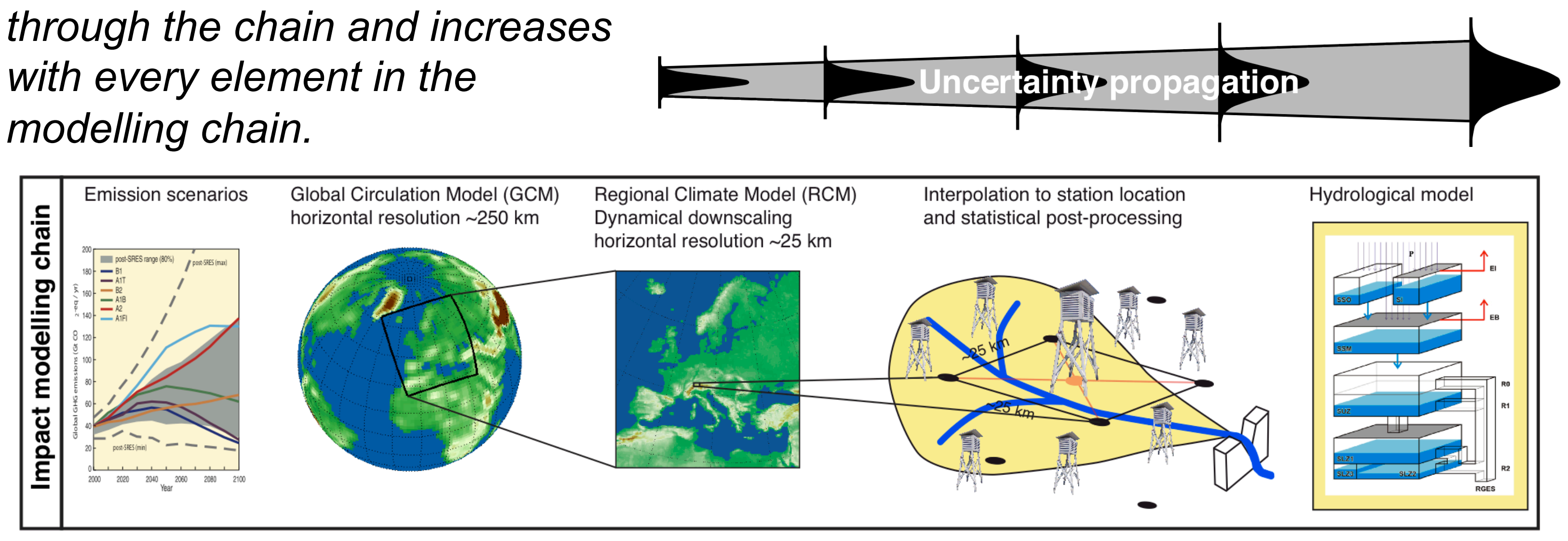

Figure 1. *Schematic depiction of the impact modeling chain (emission scenarios, GCMs, RCMs, bias-correction and hydrolocigal model). Uncertainty propagates through the chain and increases with every element in the modelling chain.*

MAXIMUM INFORMATION MINIMUM REDUNDANCY (MIMR)

The idea of MIMR criterion lies in selecting a subset from a candidate set, through which, the selected subset can: (1) maximise the overall information, (2) maximise the information transition ability, and (3) minimise the redundant information. [2]

The MIMR criterion-based objective functions are formulated as:

$$\begin{cases} \text{Max. } H(X_{S1}, X_{S2}, \ldots, X_{Sk}) & \text{Multivariate Joint Entropy} \\ \text{Max. } \Sigma_{i=1} T(<X_{S1}, X_{S2}, \ldots, X_{Sk}>; X_{Fi}) & \text{Multivariate Transinformation} \\ \text{Min. } C(X_{S1}, X_{S2}, \ldots, X_{Sk}) & \text{Total Correlation} \end{cases}$$

RESULTS

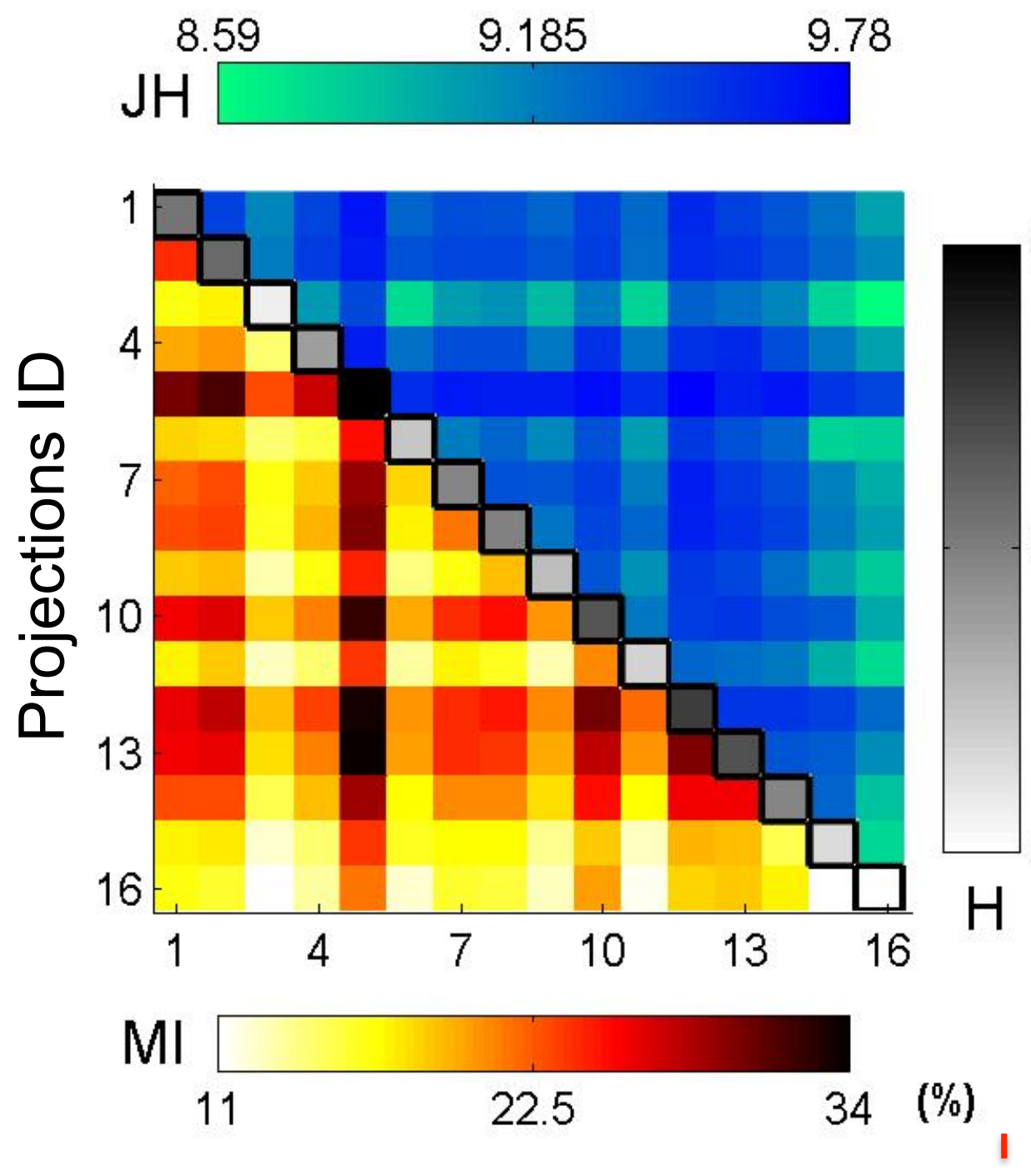

Figure 2. *Mutual information (MI), marginal entropy (H) and joint entropy (JH) between projections - Annual precipitation during 2021-2050.*

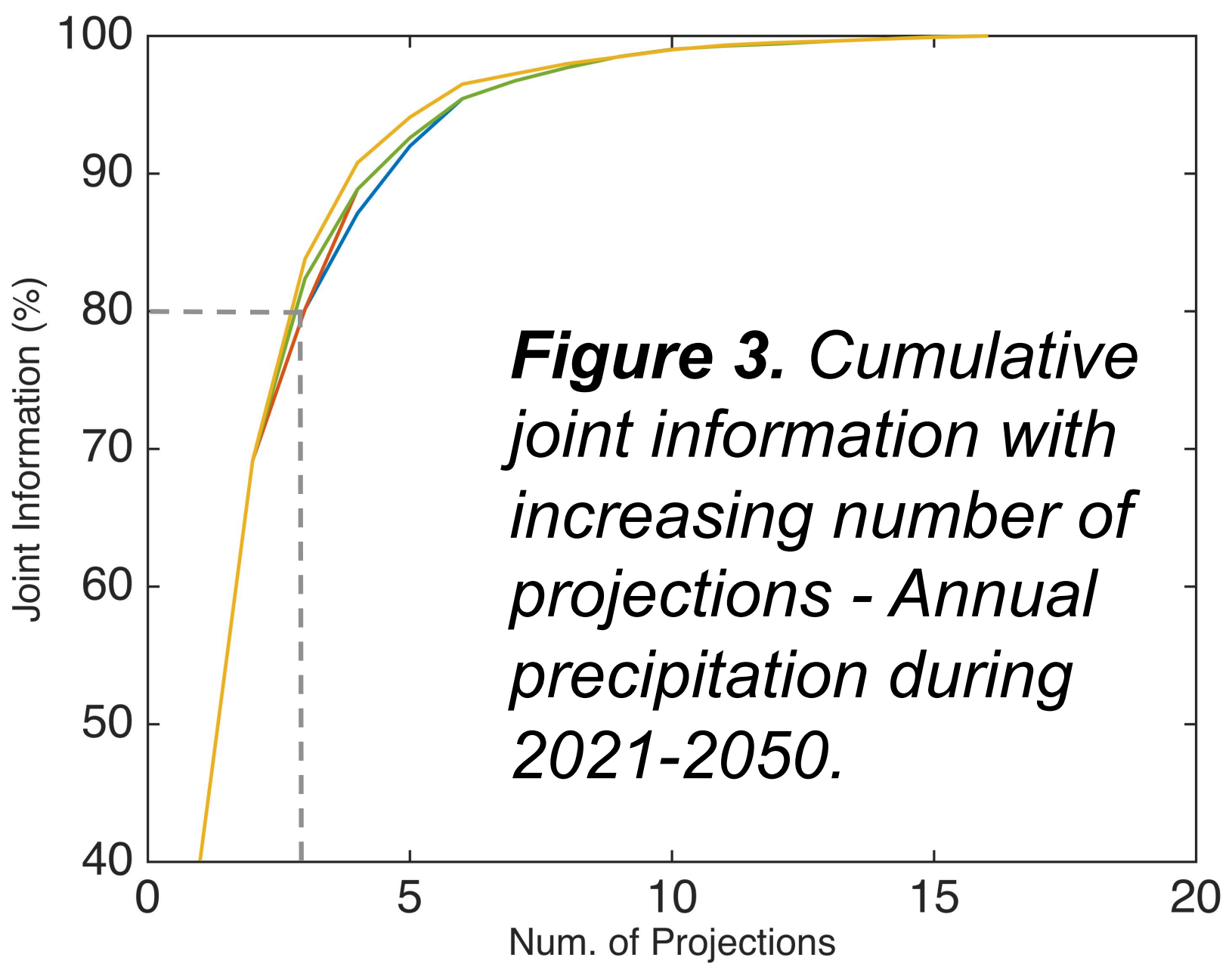

Figure 3. *Cumulative joint information with increasing number of projections - Annual precipitation during 2021-2050.*

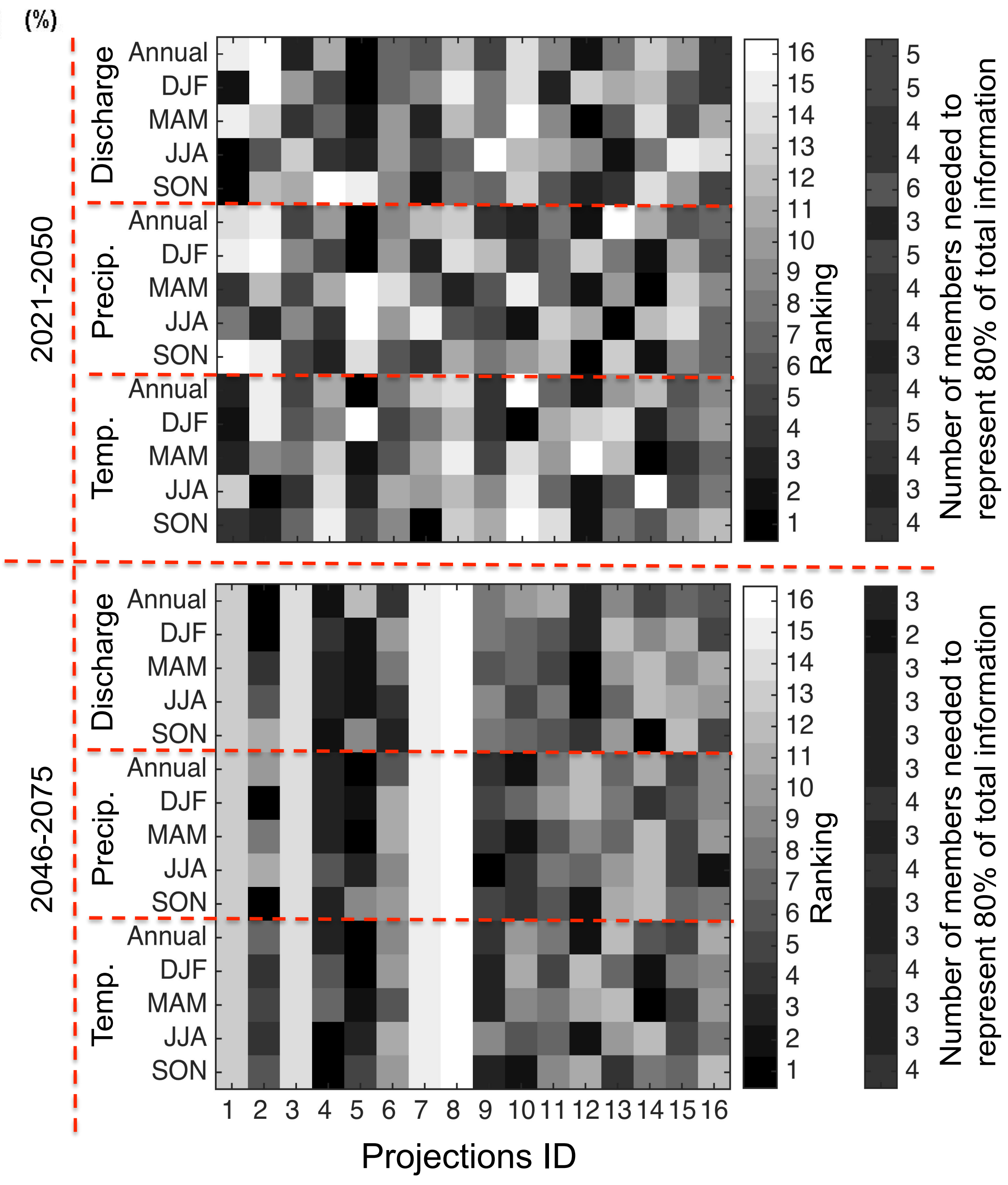

Figure 4. *Ranking (from 1 to 16 with 1 being the most important) of projection members for different hydroclimatic variables, seasons and future periods. The identified subset to represent 80% of total information is given on the right side of the figure.*

CONCLUSIONS

- Methods rooted in information theory concepts can be used to identify representative hydroclimatic projections and overcome artefacts/biases from hand-picking projections for climate change impact assessments.
- Redundant information is present in large model ensembles and hence a suggested subset should target towards maximising independence and minimising redundancy.
- A subset of 20-35% of the total available projections can represent a large fraction of the ensemble range for changes in precipitation, temperature and discharge.
- The identified subsets are sensitive to the choice of variables, seasons and future periods. Identification of subsets should not be solely based on climatic information but rather consider hydrological information as well.

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