The **CLIMSAVE** Project

Climate Change Integrated Assessment Methodology for Cross-Sectoral Adaptation and Vulnerability in Europe

Report on the European driving force database for use in the Integrated Assessment Platform

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Preface

The aim of this Deliverable was to develop a European database of scenario drivers for implementing and testing the CLIMSAVE Integrated Assessment Platform (IAP). The deliverable is divided into two parts. Part I describes the database of climate scenarios and Part II describes the database of socio-economic scenarios. The climate scenarios are based on existing scenarios from the IPCC AR4 database whereas new socio-economic scenarios have been developed within the project (see deliverables D3.1 for a description of the scenario methodology and D1.2 for a first draft of the scenarios resulting from the first set of stakeholder workshops). The quantification of these socio-economic scenarios for use within the IAP is described in Part II of this deliverable.

PART I – CLIMATE SCENARIO DATABASE

1. Methodology for climate change scenario development

The climate change scenarios were constructed using the ***pattern scaling method*** (Dubrovsky et al., 2005). In this approach, the scenario for a specific future, emissions scenario and climate sensitivity is determined as a product of the change in global mean temperature and the standardised scenario. The change in global mean temperature (for a selected emissions scenario and climate sensitivity) is determined using the MAGICC model (version 5.3). The standardised scenarios were determined from outputs of 16 Global Climate Model (GCM) simulations available from the IPCC-AR4 database (only GCMs with the SRES-A2 emissions simulation and which passed a completeness check were used; Table 1).

Table 1: Candidate GCMs (GCMs from IPCC-AR4 database, which have available SRES-A2 emissions simulation and relevant surface weather data).

Centre	Model	Resolution	
		nx	ny
Bjerknes Centre for Climate Research, Norway	BCM2	128	64
Canadian Center for Climate Modelling and Analysis, Canada	CGMR	96	48
Centre National de Recherches Meteorologiques, France	CNCM3	128	64
Commonwealth Scientific and Industrial Research Organisation, Australia	CSMK3	192	96
Met.Inst.Univ Bonn + Met. Res.Inst., Korea + Model and Data Groupe at MPI-M, Germany	ECHOG	96	48
Geophysical Fluid Dynamics Laboratory, USA	GFCM20	144	90
UK Met. Office, UK	HADCM3	96	73
UK Met. Office, UK	HADGEM	192	145
Institute for Numerical Mathematics, Russia	INCM3	72	45
National Institute for Environmental Studies, Japan	MIMR	128	64
Max-Planck-Institut for Meteorology, Germany	MPEH5	192	96
Meteorological Research Institute, Japan	MRCGCM	128	64
National Centre for Atmospheric Research, USA	NCCCSM	256	128
National Centre for Atmospheric Research, USA	NCPCM	128	64
Geophysical Fluid Dynamics Laboratory, USA	GFCM21	144	90
Institute Pierre Simon Laplace, France	IPCM4	96	72

The scenarios consist of changes in precipitation, temperature and solar radiation for each month and each 10' x 10' gridbox in the European Integrated Assessment Platform (23871 gridboxes for the whole of Europe). A simple downscaling technique was used whereby the broadscale climate change fields are directly applied to the higher resolution gridded baseline climatology. This method adds no new meteorological information and assumes that the spatial pattern of current climate remains the same into the future. Whilst more sophisticated methods are available, they are expensive to implement and are based upon their own (often unquantifiable) assumptions. Alternatively, this simple method is quick and easy to apply, enabling a range of scenarios to be explored which capture some of the uncertainty associated with different climate models and emissions scenarios.

The standardised climate change scenario for climatic characteristic X is determined by applying regression relationships to $\{[\Delta T_G, X]_i; i = 1961, ..., 2099\}$ series, where ΔT_G is the change in GCM-based global mean temperature (with respect to the baseline year 1985), and i is the year counter. The regression relation is assumed to be:

$T = a_T \times \Delta T_G + T_0$ (for temperature)
$\ln P = k_P \times \Delta T_G + \ln P_0$ (for precipitation)
$\ln R = k_R \times \Delta T_G + \ln R_0$ (for solar radiation)

The latter two equations imply $P = P_0 \times \exp(k_P \times \Delta T_G)$ and $R = R_0 \times \exp(k_R \times \Delta T_G)$. The regression coefficient a_T defines the standardised change in T ($\equiv \Delta_S T$; the change in T related to 1K change in global mean temperature). The standardised changes in P and R may be expressed as $\Delta_S P$ [%] = $100 \times [\exp(k_P) - 1]$ and $\Delta_S R$ [%] = $100 \times [\exp(k_R) - 1]$. The coefficients a_T, k_P and k_R are determined using the least-squares method.

The change in global mean temperature is determined using the MAGICC model for a set of combinations of four SRES emissions scenarios (A1b, A2, B1 and B2) and three values of climate sensitivity: 1.5 (referred to as "low"), 3 (= "middle") and 4.5K (= "high").

Application of the pattern scaling method. Having determined the standardised scenario, the climate change scenario for a future characterised by ΔT_G is determined using the following rules:

A. Temperature change: $\Delta T = \Delta T_G \times \Delta_s T$
B. Change in precipitation and solar radiation ($Y = P, R$):
- B1. If the standardised change is positive ($\Delta_S Y > 0$):
  - ΔY [%] $= 100 \times \{\exp[\ln(\Delta_S Y/100+1) \times \Delta T_G] - 1\}$ (for $\Delta T_G < 1$)
  - ΔY [%] $= 100 \times \exp[\ln(\Delta_S Y/100+1) - 1] \times \Delta T_G$ (for $\Delta T_G \geq 1$).

  Application of the above two equations implies that Y will rise exponentially over the interval $0 < \Delta T_G < 1$ and only linearly for $\Delta T_G \geq 1$. The second rule was implemented to avoid too large changes in Y for large ΔT_G.
- B2. If the standardised change is negative ($\Delta_S P < 0$) then we transform $\Delta_S P$ to $-\Delta_S$P and ΔT_G to $-\Delta T_G$ and apply the above procedure.

2. Choice of the representative subset of GCMs

2.1 *Methodology*

The Integrated Assessment Platform (IAP) will allow the user to select an emissions scenario (A1b, A2, B1 or B2), the climate sensitivity (low, medium or high) and the GCM in order to explore the effects of climate change uncertainties on the cross-sectoral impacts and vulnerabilities. In order to make the number of combinations manageable for the user, it was decided to include five GCMs within the IAP out of the 16 available from the IPCC-AR4 database. Thus, a methodology was developed to select a representative subset of GCMs that would preserve as much uncertainty as possible due to between-GCM differences.

The methodology, which was developed by M. Dubrovsky, aimed at defining a subset of five GCMs by applying two criteria: (i) quality of GCMs; and (ii) ability of the GCM subset to represent the inter-GCM variability. In the resultant subset of the five GCMs, the first GCM represents the "best" GCM, the second GCM represents the "central" GCM, and three other GCMs represent the between-GCM variability. The choice of the representative GCM subset for the whole of Europe was based on the following analysis:

(i) For each 0.5 x 0.5^o gridbox (identical with the CRU 0.5^o climatology), the GCM-based present climate means of temperature and precipitation and their standardised changes were determined for each GCM.

(ii) The GCM-based annual cycle of present climate monthly precipitation sums and monthly temperature means were compared with the gridded observed values (represented by the CRU surface climatology, CRU CL 1.0) and the GCM *vs* CRU fit (separately for temperature and precipitation, X = T, P) was quantified using the *RV* score: $RV = 1 - \sum_{i=1,...,12} (X_{obs}-X^*_{GCM})^2 / \sum_{i=1,...,12} (<X_{obs}>-X_{obs})^2)$, where $X \in \{T,P\}$(X represents temperature (T) and precipitation (P)), X^*_{GCM} is debiased GCM simulated monthly mean temperature and monthly precipitation sum and $<X_{obs}>$ is annual average of X_{obs}. The final measure of the skill of the GCM was then expressed by a single value which reflects both RV(TAVG) (Figure 1a) and RV(PREC) (Figure 1b):

$$Q(GCM) = \sum_{X\in\{T,P\}}[(RV_{GCM}(X)-<RV(X)>)\times|RV_{GCM}(X)-<RV(X)>| / var[RV(X)]$$

where <...> and var[...] are an average and variance over all GCMs. The Q score was used to find the "best GCM" in each gridbox (Figure 2a). Table 2 shows the statistics of the GCMs selected as best.

(iii) To find the central GCM and the triplet of most diverse GCMs, a similarity measure was needed. To assess the similarity of GCMs in terms of the GCM-based climate change scenario, each GCM is represented by an 8-dimensional position vector, whose components are GCM simulated changes in seasonal means of temperature and precipitation: $\boldsymbol{R}_{GCM} = [\Delta T_{DJF}, \Delta T_{MAM}, \Delta T_{JJA}, \Delta T_{SON}, \Delta P_{DJF}, \Delta P_{MAM}, \Delta P_{JJA}, \Delta P_{SON}]_{GCM}$. To quantify the distance in this space, the Euclidian distance was used: $d(R_1, R_2) = \sum(x_{1i}-x_{2i})^2$, where x_{1i} and x_{2i} are components of R_1 and R_2 vectors. The ***"Central" GCM*** is then selected as the GCM which has the smallest distance from the centroid of all GCMs ($\boldsymbol{R}_{centroid} = \sum_{\{all\ GCMs\}} (\boldsymbol{R}_{GCM})/n$, where n is number of all GCMs, n=16). Table 2 shows the number gridboxes in which individual GCMs are amongst the 1st, 2nd or 3rd closest to the centroid and Figure 2b shows the spatial distribution of these gridboxes.

The ***diverse triplet of GCMs***, is defined as the three GCMs, which maximise the sum of between-GCM distances, $D_{ijk} = d(GCM_i,GCM_j) + d(GCM_i,GCM_k) + d(GCM_j,GCM_k)$. Table 3 shows the frequency (number of gridboxes) of the 10 most frequently chosen GCM triplets in Europe and Figure 2c shows the spatial pattern of these triplets.

Table 2: Analysis of the best and central GCM for Europe. The "∈1" columns show the number of gridboxes where the GCM is the best ("B") or closest ("C") to the centroid; "∈2C" and "∈3C" show the number of gridboxes where the GCM is among the two and three best or most central GCMs.

Choosing the best GCM				Choosing the central GCM			
GCM	**∈1B**	**∈2B**	**∈3B**	**∈1C**	**∈2C**	**∈3C**	**GCM**
MPEH5	*966*	*1564*	**1950**	*679*	*1313*	**1884**	MPEH5
HADCM3	*339*	*923*	**1519**	*425*	*715*	**1038**	HADCM3
CGMR	*527*	*897*	**1209**	*73*	*333*	**706**	CGMR
HADGEM	*543*	*822*	**990**	*688*	*1120*	**1313**	HADGEM
GFCM20	*236*	*573*	**914**	*164*	*457*	**833**	GFCM20
MRCGCM	*215*	*566*	**892**	*30*	*93*	**182**	MRCGCM
CSMK3	*156*	*451*	**787**	*856*	*1478*	**1860**	CSMK3
GFCM21	*164*	*397*	**755**	*0*	*5*	**12**	GFCM21
NCPCM	*171*	*305*	**568**	*104*	*357*	**752**	NCPCM
MIMR	*126*	*308*	**493**	*77*	*292*	**604**	MIMR
BCM2	*101*	*224*	**339**	*5*	*27*	**57**	BCM2
INCM3	*80*	*169*	**286**	*108*	*202*	**369**	INCM3
NCCCSM	*39*	*100*	**215**	*133*	*322*	**576**	NCCCSM
ECHOG	*58*	*123*	**196**	*376*	*693*	**941**	ECHOG
CNCM3	*41*	*93*	**155**	*78*	*183*	**255**	CNCM3
IPCM4	*37*	*83*	**129**	*3*	*8*	**15**	IPCM4
Σ	*3799*	*7598*	**11397**	*3799*	*7598*	**11397**	**Σ**

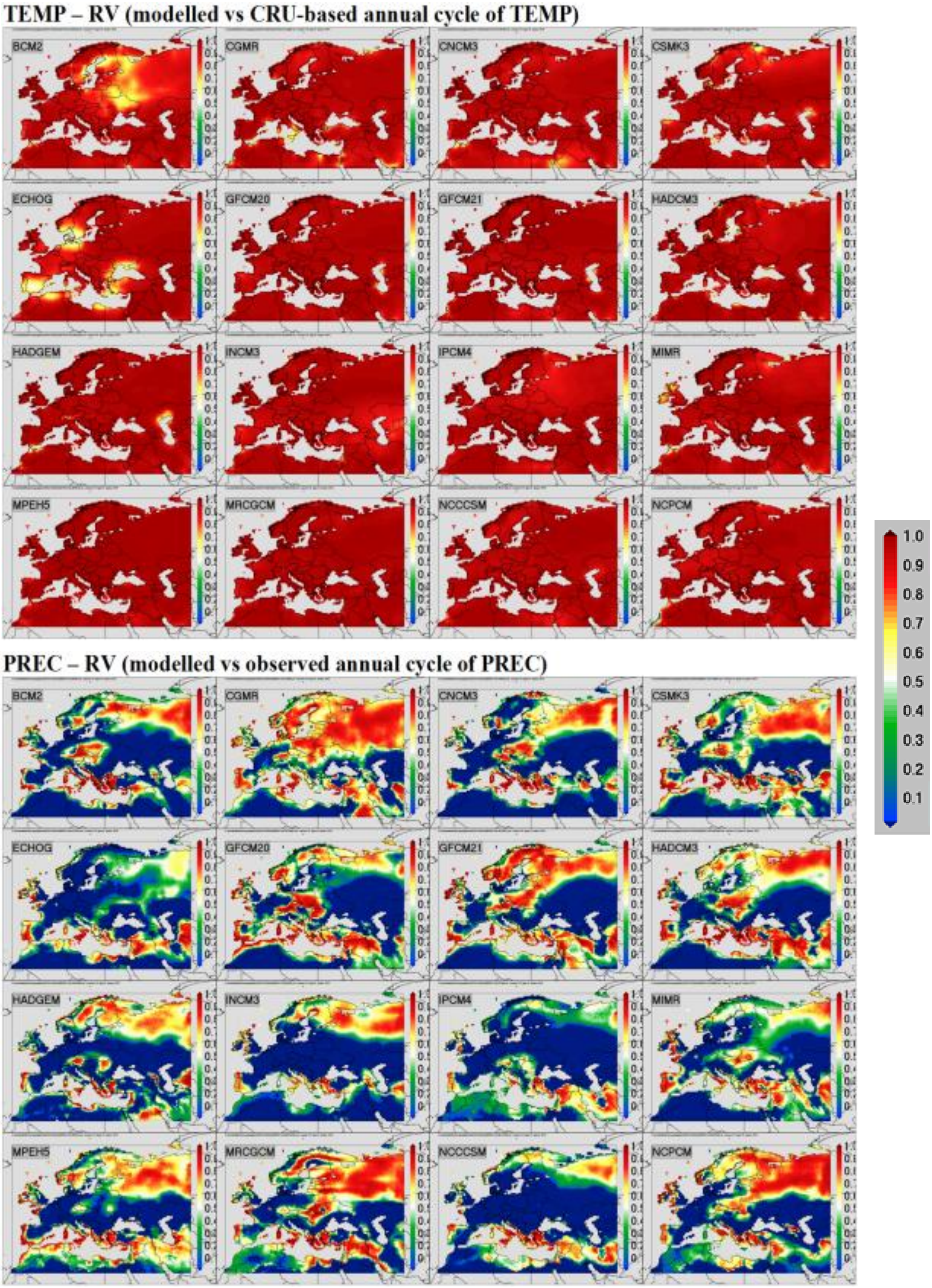

Figure 1: The ability of the 16 GCMs to reproduce the annual cycle of temperature (top panel; a) and precipitation (bottom panel; b) in terms of RV, where CRU monthly climatologies are the explanatory variable and GCM-based present climatology (debiased) is the explained variable.

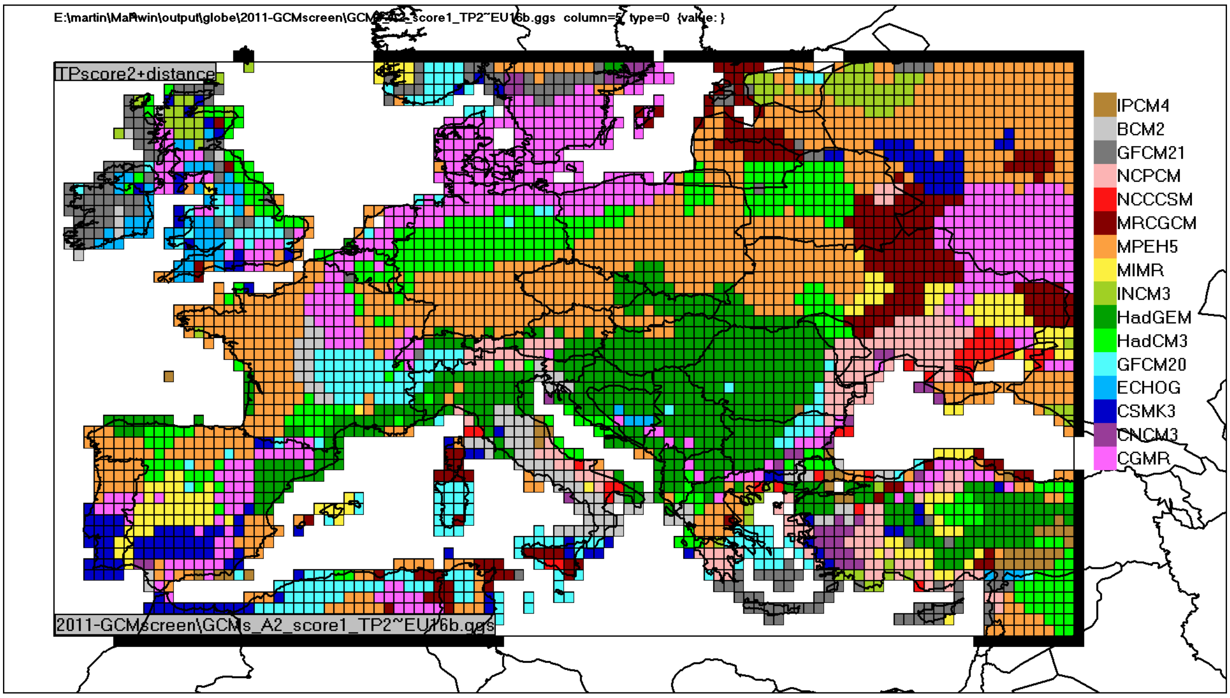

Figure 2a: The best GCM in terms of Q skill score.

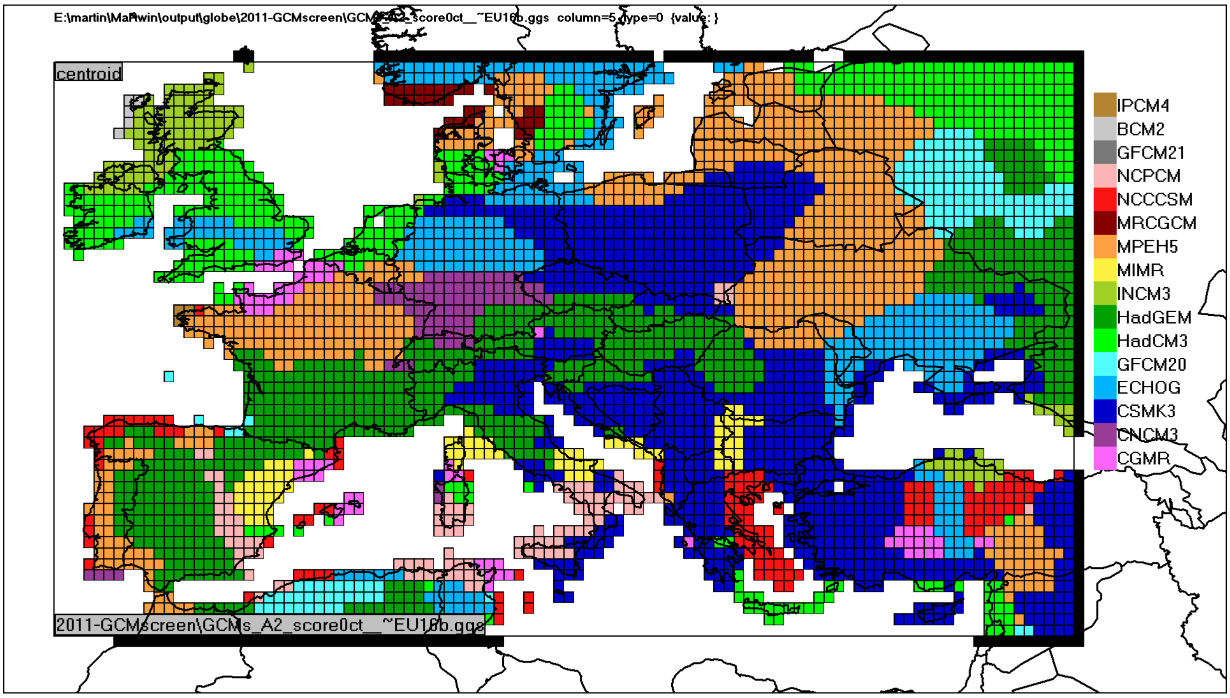

Figure 2b: The GCM closest to the centroid.

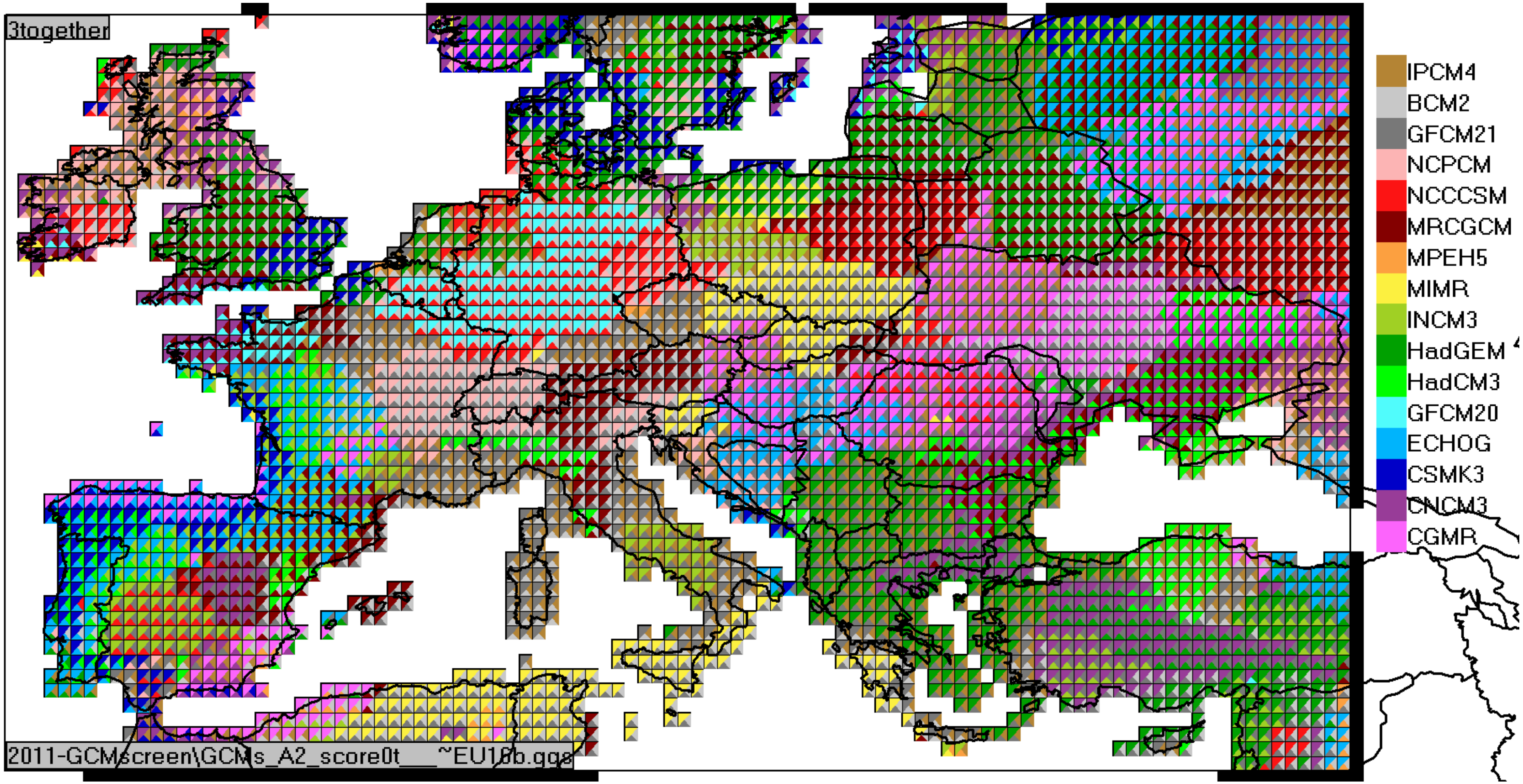

Figure 2c: The triplet of three most dissimilar GCMs (the triplet which maximises the sum of between-GCM distances).

Table 3: Choosing the triplet of most diverse GCMs for Europe. The yellow colour indicates the best GCMs and the green colour the most central GCMs from Table 2. The pink colour indicates GCMs which are least frequently found amongst the 3 most central GCMs (indicated by the value in the "Pr(∈3C)=" row).

Rank of GCM:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Pr(∈3B) =		51	40	32	26	24	23	21	20	15	13	8.9	7.5	5.7	5.2	4.1	3.4
Pr(∈3C) =		35	19	8.8	29	12	2.4	39	0.1	9.4	7.7	0.7	5.3	8.5	18	4.8	0.2
GCM abbreviation:		E	H	C	D	G	M	A	Y	N	J	B	R	S	O	F	P
# grids	triplet	**MPEH5**	**HADCM3**	**CGMR**	**HADGEM**	**GFCM20**	**MRCGCM**	**CSMK3**	**GFCM21**	**NCPCM**	**MIMR**	**BCM2**	**INCM3**	**NCCCSM**	**ECHOG**	**CNCM3**	**IPCM4**
263	DYP				X				X								X
247	YBP								X			X					X
228	JYB								X		X	X					
205	DMB				X		X					X					
129	MSB						X					X		X			
120	GSB					X						X		X			
112	MYB						X		X			X					
106	ADB				X			X				X					
98	CYP			X					X								X
97	FDY				X				X							X	
#(selected)		42	357	563	1132	190	861	336	1867	406	305	1952	408	481	647	676	1174

2.2 Defining the Europe-wide representative GCM subset.

Based on the analysis and maps of the best, central and most diverse-triplet GCMs the following selections were made for a subset representing the whole of Europe:

- The Best GCM is selected as the GCM which is best in the largest number of gridboxes (Table 2a): **MPEH5.**

- The Central GCM is selected as the GCM which is the Central GCM in the largest number of gridboxes (Table 2b): **CSMK3** (note that the MPEH5 model, which was found as the best GCM, is also among the three most central GCMs).

- The diverse triplet was selected based on Table 3. Of the ten most frequently occurring triplets shown in the table, two triplets were further tested: **HADGEM + GFCM21 + IPCM4**, which is the most frequently selected triplet; and **HadGEM + MRCGCM + BCM2**, which is a triplet of GCMs, which has the highest sum of Q-scores of individual GCMs (and it is ranked fourth in Table 3).

As a result of this analysis, we have two candidate subsets of five GCMs based on the procedure described above; these are referred to as EU5a and EU5b. One further subset was analysed which was selected by three members of the project team (Paula Harrison, Ian Holman and Kasper Kok) based on a visual assessment of maps of GCM quality and GCM-based temperature and precipitation projections with the aim to capture the maximum variability in spatial patterns of climate change whilst also accounting for the quality of individual GCMs. This subset is referred to as “3experts”. The three candidate subsets are shown in Table 4.

Table 4: Candidate subsets of five GCMs. The GCMs are ordered from left to right according to their Quality score. B = GCM selected as the “Best” GCM; C = GCM selected as the Central GCM; D = GCM selected as a member of the diverse-triplet of GCMs; X = GCM selected based on visual assessment.

	MPEH5	HADCM3	CGMR	HADGEM	GFCM20	MRCGCM	CSMK3	GFCM21	NCPCM	MIMR	BCM2	INCM3	NCCCSM	ECHOG	CNCM3	IPCM4
EU5a	**B**			**D**			**C**	**D**								**D**
EU5b	**B**			**D**		**D**	**C**				**D**					
3experts	**X**			**X**				**X**	**X**	**X**						

2.3 *Validation*

To assess the representativeness of the three candidate subsets, the climatic characteristics of the five GCMs were compared with those of the original 16 GCMs. The climatic characteristics that were analysed included: GCM projected changes in annual/winter/summer mean temperature (Figures 3a-c) and annual/winter/summer precipitation sum (Figures 3d-f). The maps show the median and the STD/median ratio for the three different subsets as well as for the 16 GCMs. The median is represented by the colour, and the STD/median ratio, which indicates the between-GCM variability, is represented by the shape of the symbol. Optimally, if the subset perfectly represents the 16 GCM set, both the colour and the shape should be the same for the subset and 16 GCM set in all gridboxes. In reality, however, differences occur as summarised below:

ΔT(annual) (Figure 3a):

- The large differences between the shape of symbols for the “3experts” subset vs “16GCMs” indicate that the subset underestimates the between-GCM variability.
- The green colour in Portugal, southern Italy and Greece indicates that the increase in temperature in the EU5b subset is lower than in the 16GCMs set.

ΔT(winter) (Figure 3b):

- The yellow colour in Spain in the EU5a and 3experts subsets indicates that the subsets overestimate the temperature increase.
- The green colour in Bulgaria in the EU5b subset indicates that the subset underestimates the temperature increase.

ΔT(summer) (Figure 3c):

- The square symbols in large areas of Europe (central Spain, central Balkan penninsula) indicate that the 3experts subset underestimates the between-GCM variability. Subset EU5a underestimates the between-GCM variability in some smaller areas (NW of the Black Sea).

- The “3experts” subset overestimates temperature increases in central UK.
- The EU5b subset underestimates temperature increases in large areas of Europe (south of 50^{th} latitude).

ΔP(annual) (Figure 3d):

- The EU5a subset overestimates precipitation decreases in the southeastern Balkan penninsula.

ΔP(winter) (Figure 3e):

- The EU5a subset overestimates precipitation decreases in the southeastern Balkan penninsula.
- Precipitation decreases in the southern Iberian penninsula are underestimated by the EU5a subset and overestimated by the 3experts subset.

ΔP(winter) (Fig.3f):

- Precipitation decreases in major southern parts of Europe are overestimated by the EU5a and 3experts subsets.
- The 3experts subset overestimates precipitation decreases in Germany.

Overall, the EU5a subset was found to be the most successful in representing the between-GCM variability and was therefore selected for integration into the European Integrated Assessment Platform.

3. Description of the European climate change drivers

The standardised changes in winter and summer mean temperature and precipitation are shown in Figures 4 a-b for the EU5a subset. In winter, most GCMs have a north-south or north-east to south-west pattern in temperature changes with the most severe changes occurring in the north/north-east of Europe. The CSMK2 model shows the most severe increases in these areas. In summer, the pattern of temperature change is reversed with the most severe increases in temperature occurring in southern Europe in all GCMs except IPCM4. GFCM21 exhibits the most severe changes and a strong north-south gradient whereas HadGEM shows a more even distribution. For precipitation in winter, all GCMs show a north to south gradient with increases in precipitation in the north and decreases in the south. HadGEM is relatively drier than the other GCMs in northern and central Europe whilst GFCM21 is driest in southern Europe. In summer, the GCMs also show a north to south pattern in precipitation changes although this is less clear in the IPCM4 model. GFCM21 stands out as being particularly dry in large parts of southern and continental Europe, whilst IPCM4 is the least extreme.

Table 5 shows the European area-average changes in winter and summer mean temperature and precipitation for the 2020s and 2050s time slices, the five GCMs and three scenario combinations of emissions and climate sensitivity representing a “low scenario” (based on B1 emissions and a low climate sensitivity of 1.5K), a “middle scenario” (based on B2 emissions and a mid climate sensitivity of 3.0K) and a “high scenario” (based on A1b emissions and a high climate sensitivity of 4.5K).

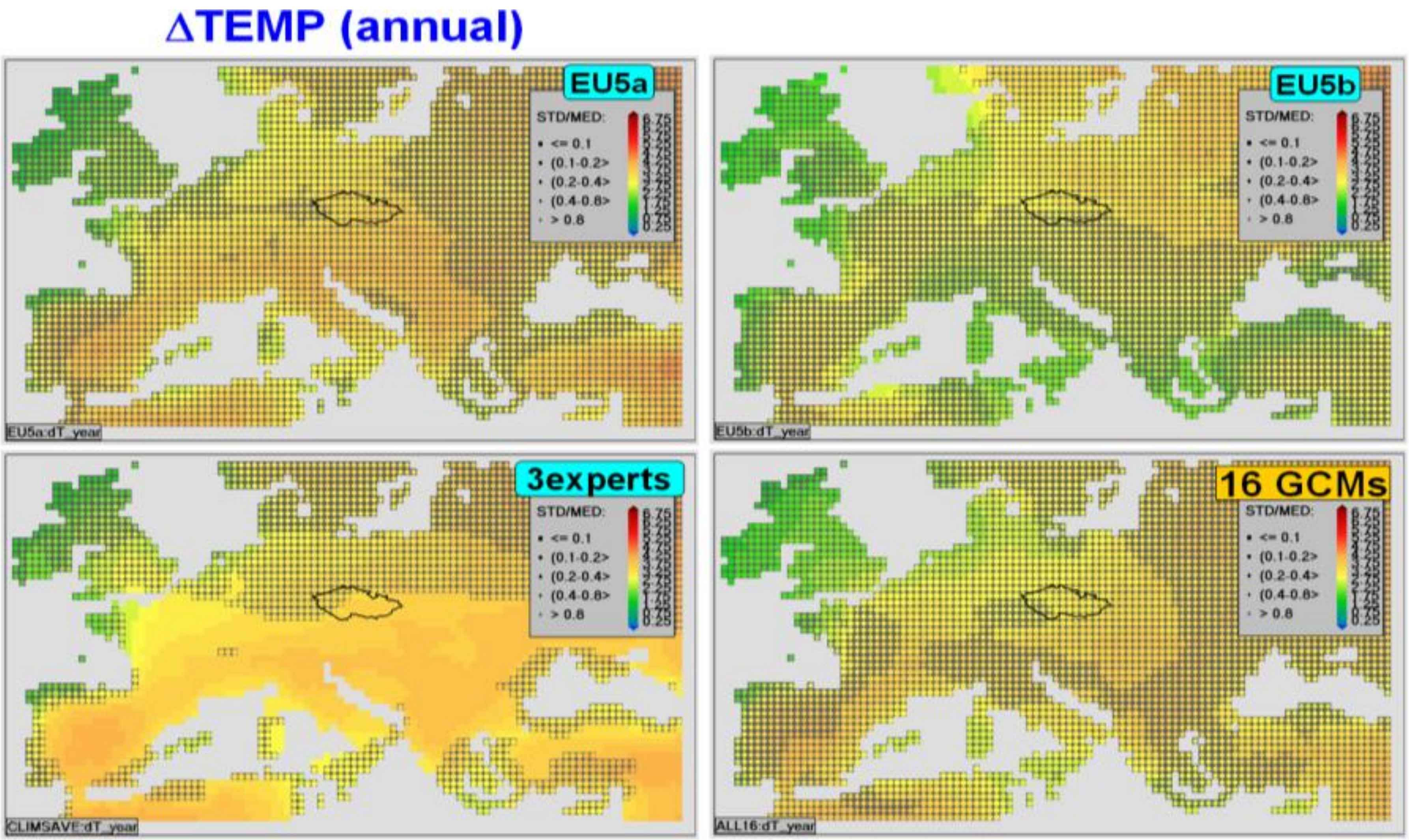

Figure 3a: Grid-specific changes in annual mean temperature in terms of the median value (represented by the colour) and (standard deviation / median) ratio (represented by the shape of the symbol) derived from GCM-specific values related to a subset of 5 GCMs (top left: EU5a subset; top right: EU5b subset; bottom left: 3experts subset) and all 16 GCMs (bottom right).

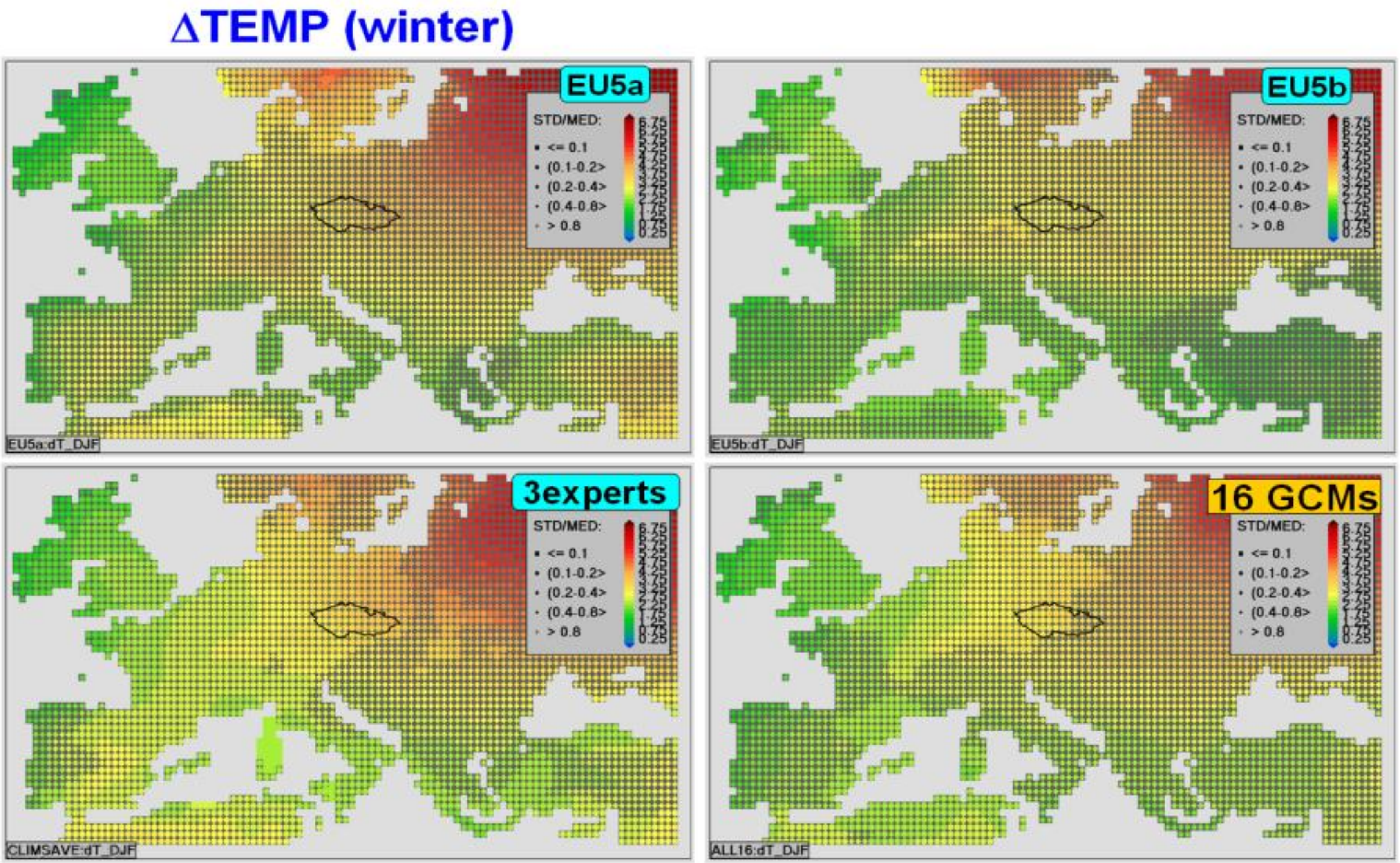

Figure 3b: The same as Figure 3a but for changes in winter mean temperature.

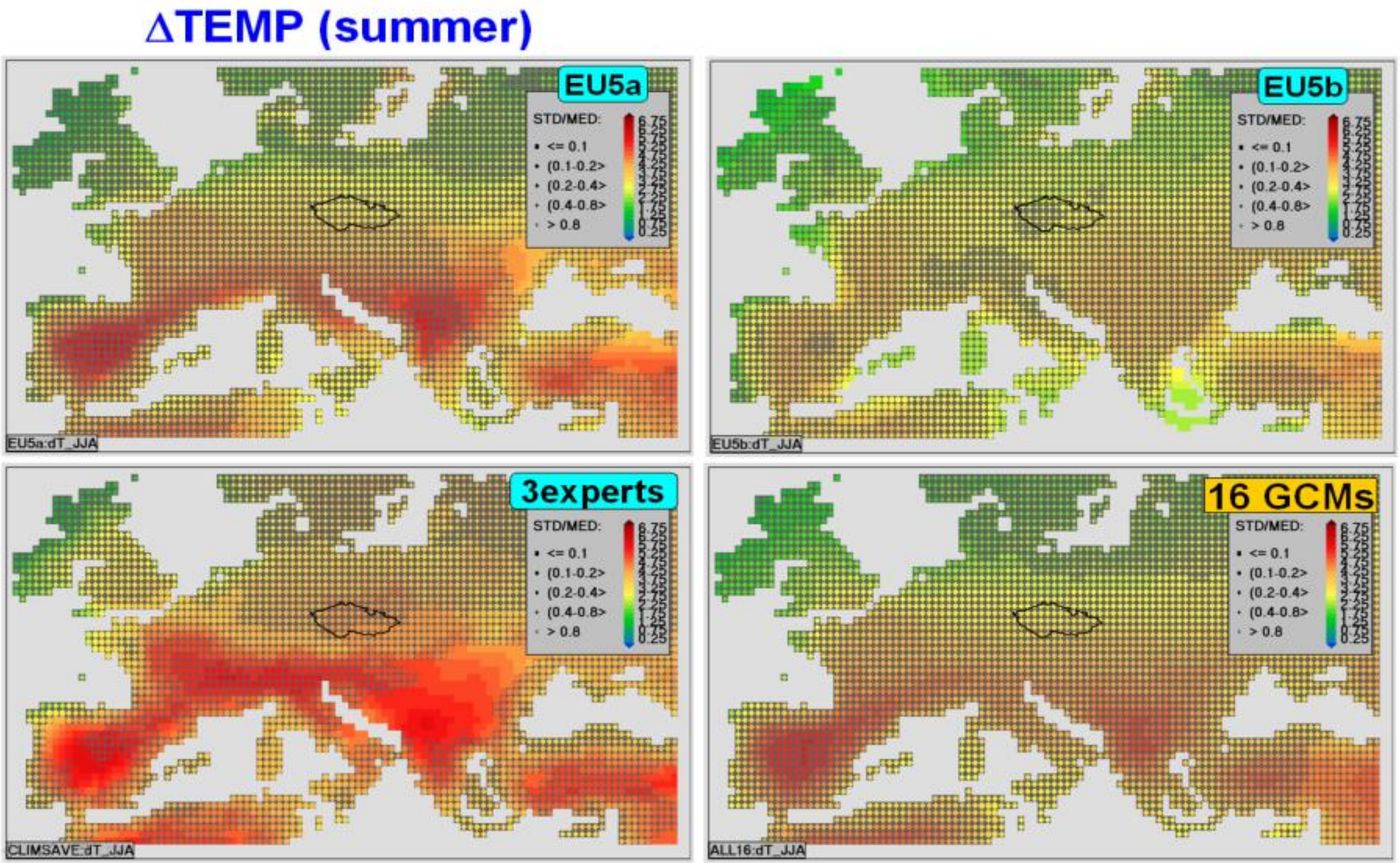

Figure 3c: The same as Figure 3a but for changes in summer mean temperature.

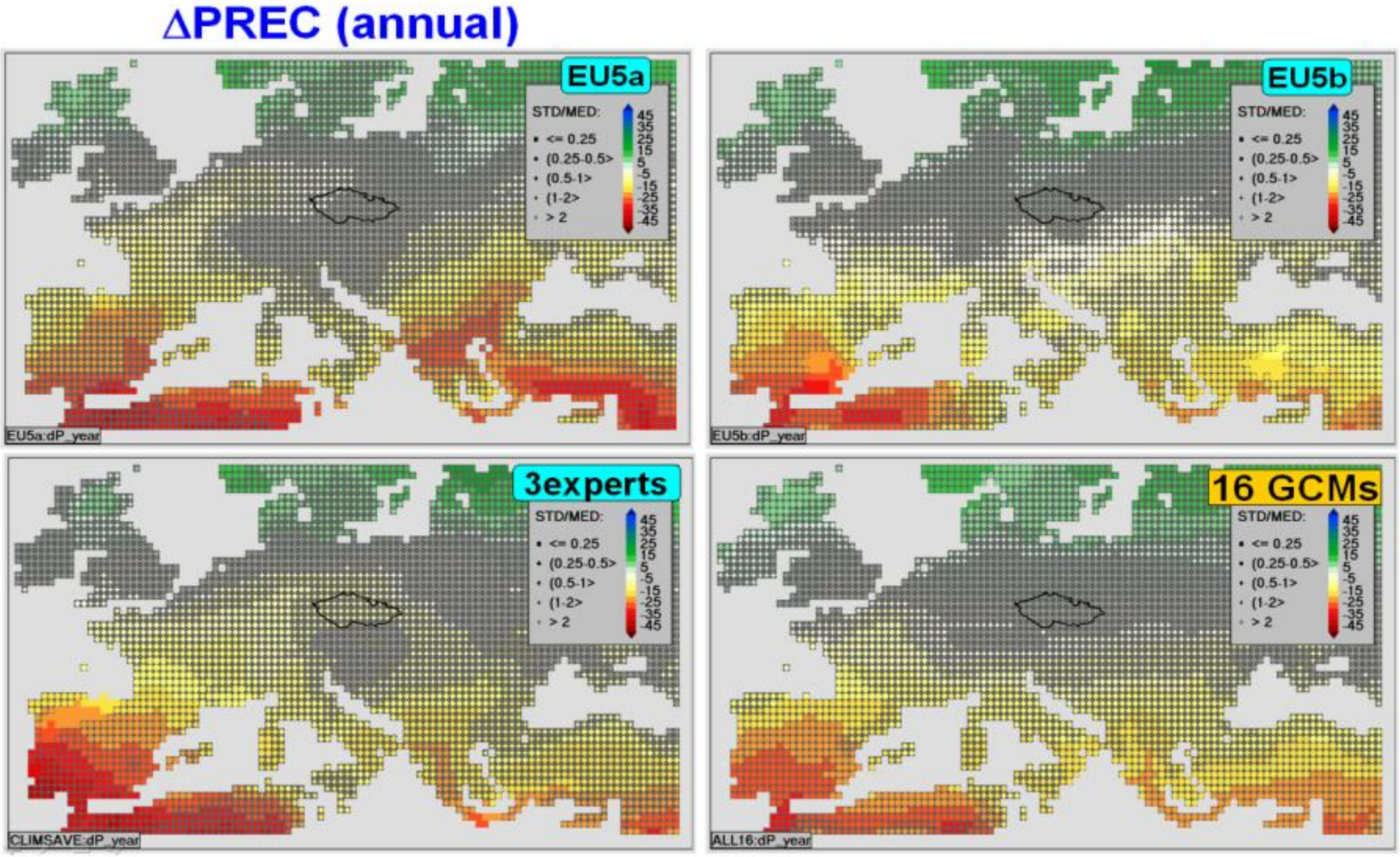

Figure 3d: The same as Figure 3a but for the changes [%] in annual precipitation.

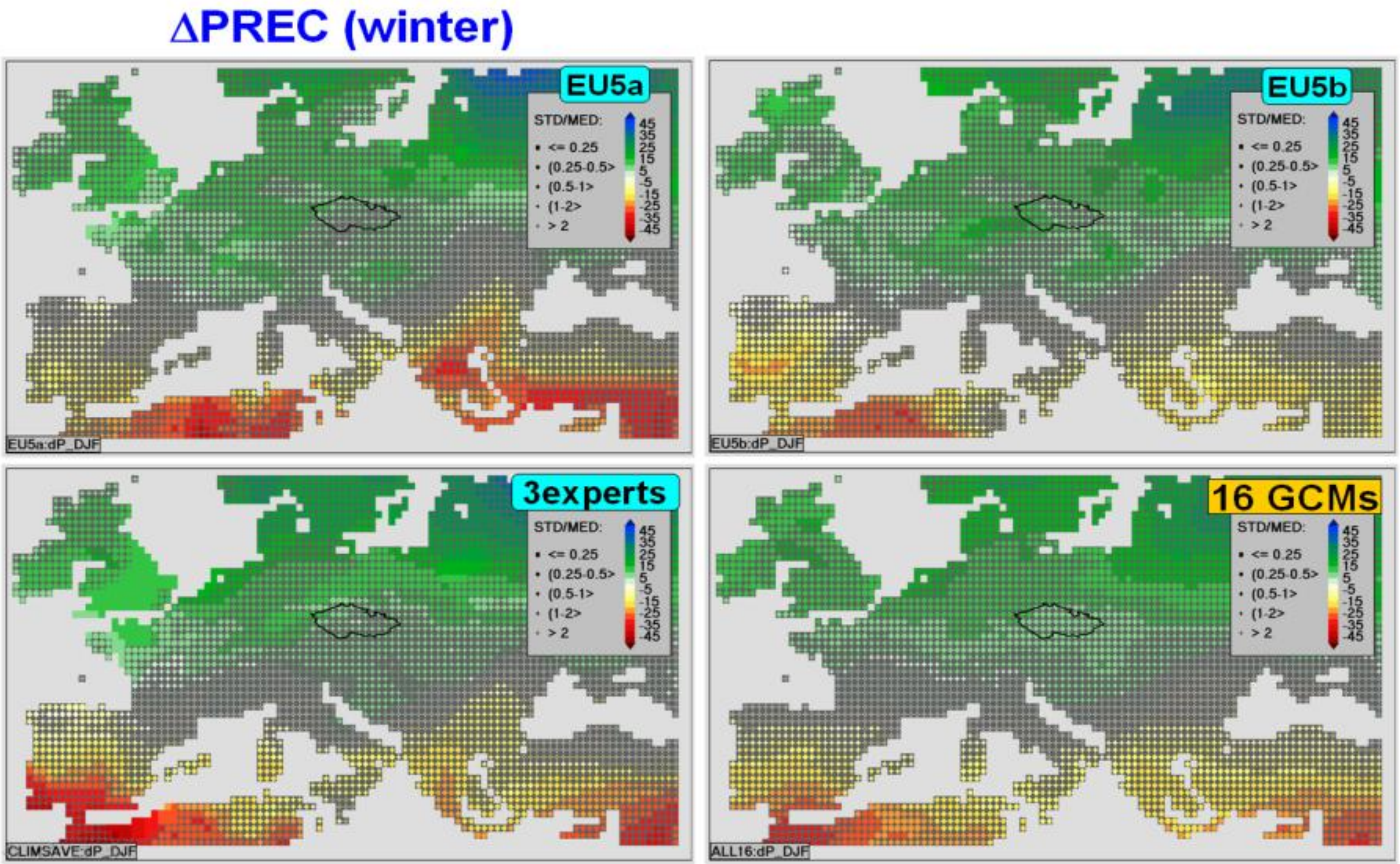

Figure 3e: The same as Figure 3a but for changes in winter precipitation.

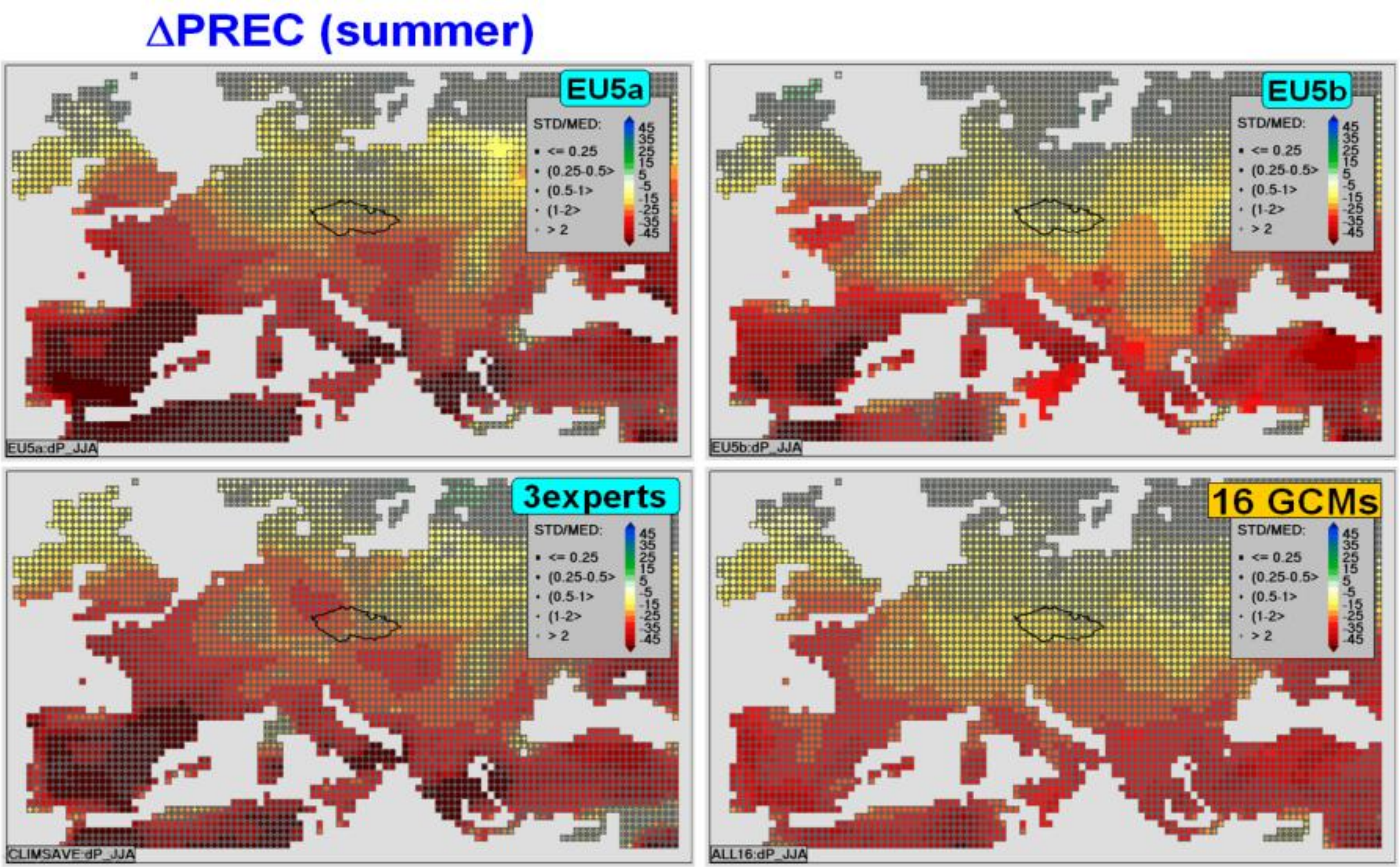

Figure 3f: The same as Figure 3a but for the changes in summer precipitation.

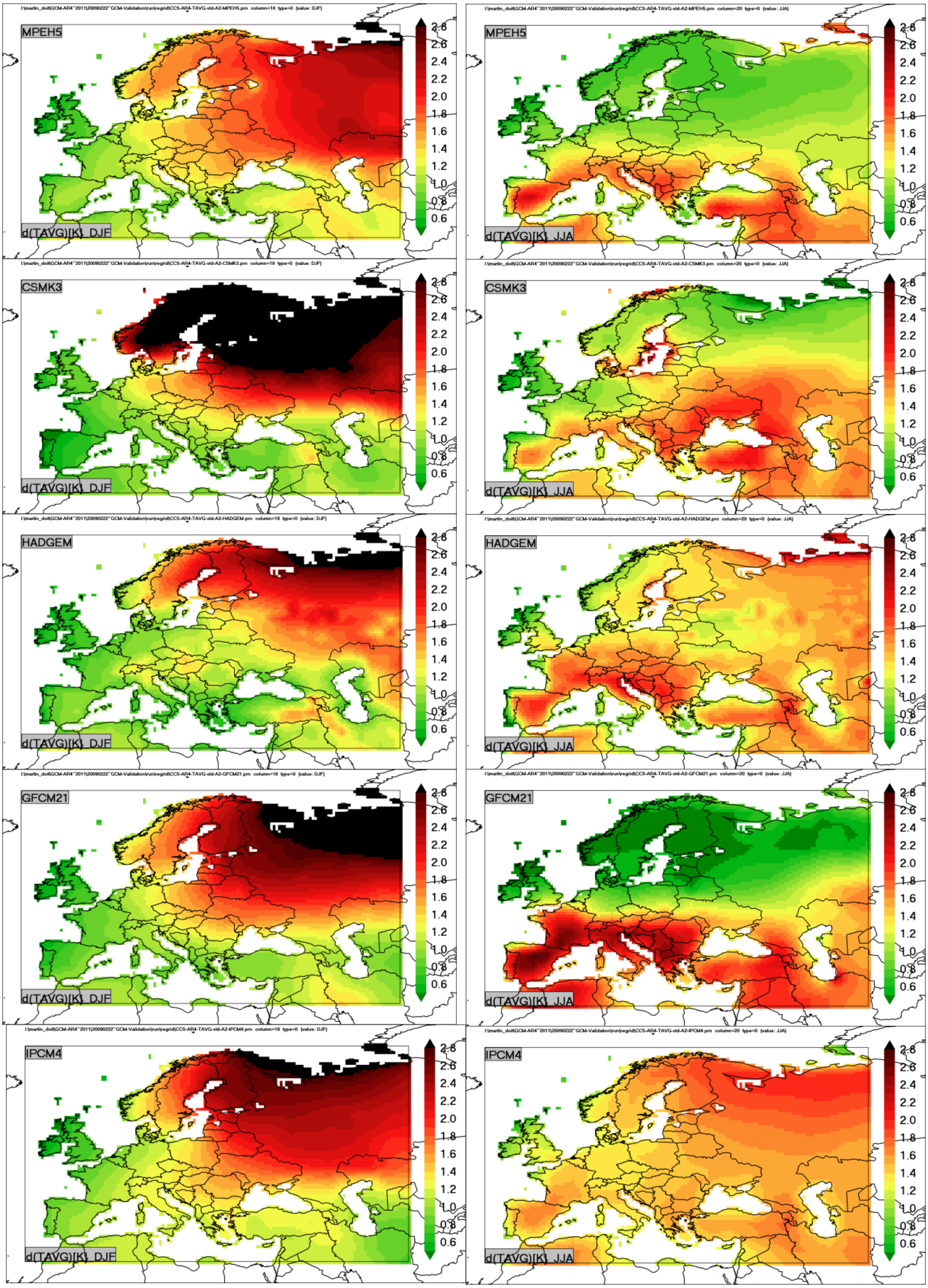

Figure 4a: Standardised changes in winter (DJF, left column) and summer (JJA, right column) mean temperature for the EU5a subset of GCMs.

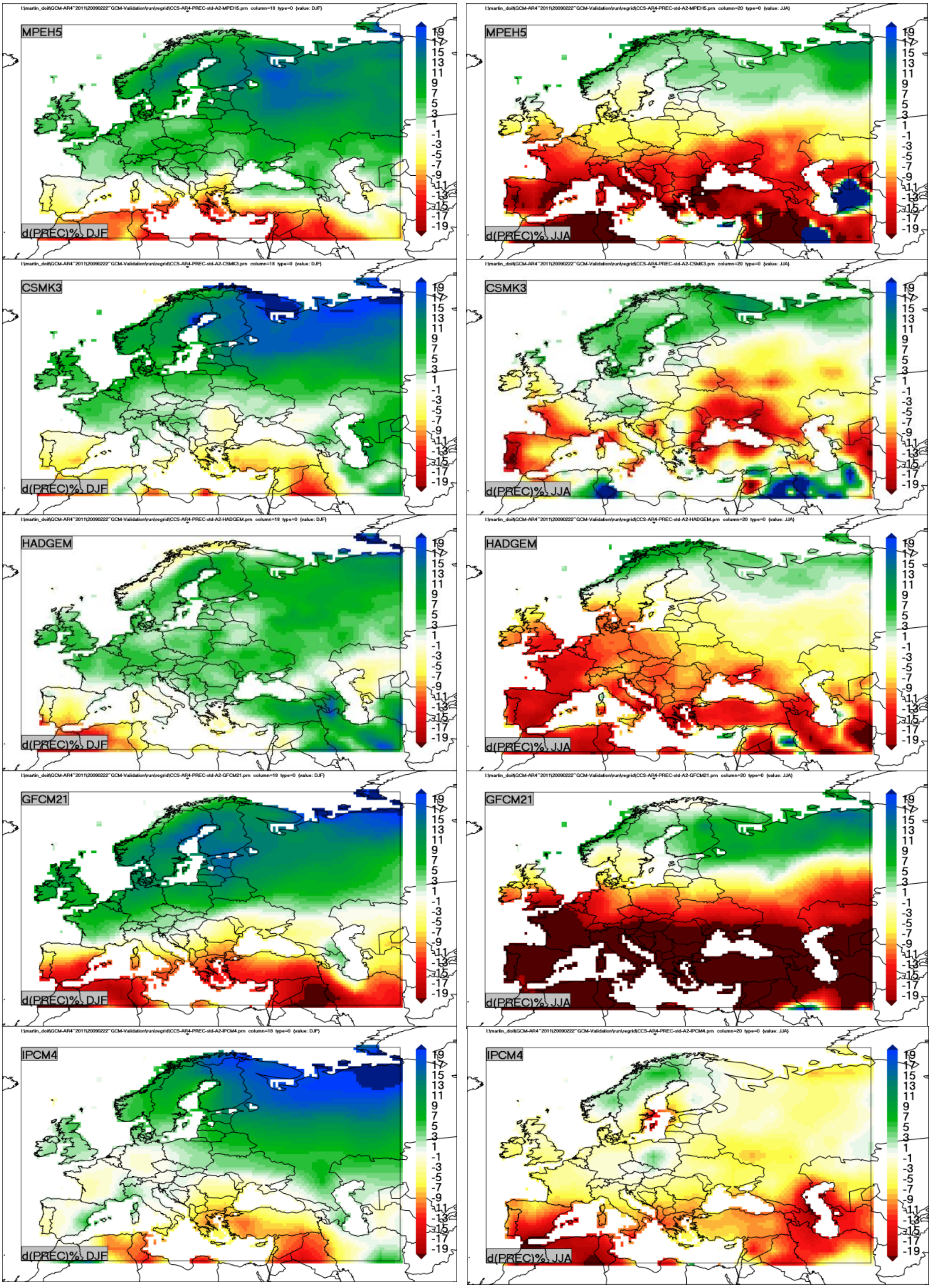

Figure 4b: Standardised changes in winter (DJF, left column) and summer (JJA, right column) precipitation for the EU5a subset of GCMs.

Table 5: European area-average changes in winter (DJF) and summer (JJA) mean temperature and precipitation for the 2020s and 2050s time slices, the five GCMs and three combinations of emissions scenario and climate sensitivity.

Emissions	Climate sensitivity	CSMK3		IPCM4		HadGEM		GFCM21		MPEH5	
		DJF	JJA	DJF	JJA	DJF	JJA	DJF	JJA	DJF	JJA
2025 Area average temperature change (°C)											
B1	1.5	1.06	0.68	0.78	0.79	0.66	0.77	0.74	0.65	0.72	0.61
B2	3.0	1.85	1.18	1.37	1.38	1.16	1.35	1.29	1.14	1.25	1.06
A1b	4.5	2.23	1.43	1.66	1.67	1.40	1.63	1.55	1.38	1.51	1.28
2025 Area average precipitation change (%)											
B1	1.5	2.55	-1.29	1.50	-2.63	0.65	-6.13	2.13	-8.86	2.15	-5.01
B2	3.0	4.57	-2.13	2.68	-4.44	1.17	-10.25	3.89	-14.42	3.85	-8.36
A1b	4.5	5.57	-2.51	3.28	-5.27	1.42	-12.12	4.78	-16.83	4.69	-9.87
2055 Area average temperature change (°C)											
B1	1.5	1.72	1.10	1.27	1.29	1.07	1.25	1.19	1.06	1.17	0.98
B2	3.0	3.27	2.09	2.42	2.45	2.04	2.38	2.27	2.02	2.22	1.87
A1b	4.5	4.86	3.10	3.60	3.64	3.04	3.54	3.38	3.00	3.30	2.78
2055 Area average precipitation change (%)											
B1	1.5	4.23	-2.00	2.48	-4.15	1.08	-9.59	3.59	-13.56	3.56	-7.82
B2	3.0	8.27	-3.42	4.88	-7.37	2.13	-16.79	7.23	-22.55	6.99	-13.62
A1b	4.5	12.45	-4.58	7.38	-10.27	3.25	-23.03	11.12	-29.49	10.56	-18.59

Projections of Europe-wide area-average temperature change differ to a much lesser degree across emissions scenario and climate sensitivity in 2025 where differences range from 0.67 to 1.18°C than in 2055 where differences range from 1.8 to 3.14°C as might be expected. The same is true for precipitation changes where differences across emissions scenario and climate sensitivity range from 0.77 to 3.01% in 2025, but from 2.17 to 8.22% in 2055 in winter and from -1.22 to -7.97% in 2025, but from -2.58 to -15.93% in 2055 in summer.

Differences in Europe-wide area-average temperature projections between the five GCMs are also relatively small in 2025 where differences range from 0.19 to 0.39°C in summer with MPEH5 exhibiting the smallest change and IPCM4 the largest across all emission and climate sensitivity combinations. In winter differences range from 0.4 to 0.84°C with HadGEM showing the smallest change and CSMK3 the largest. In 2055 the differences across GCMs are greater ranging from 0.3 to 0.85°C in summer and from 0.65 to 1.83°C in winter.

Differences in Europe-wide area-average precipitation projections between the five GCMs are generally greater than for temperature. In summer differences range from 7.57 to 14.33% in 2025 and from 11.56 to 24.9% in 2055 with GFCM21 exhibiting the greatest decreases in precipitation and CSMK3 the least. In winter differences between GCMs range from 1.9 to 4.14% in 2025 and from 3.15 to 9.2% in 2055 with HadGEM showing the smallest increases in precipitation and CSMK3 the largest increases. These statistics summarise average changes across the whole of Europe and differences between GCMs are obviously much greater at the regional level.

PART II – SOCIO-ECONOMIC SCENARIO DATABASE

4. Development of the socio-economic stories

4.1 *Overall scenario development method*

The overall scenario development method in CLIMSAVE closely follows the so-called Story-And-Simulation approach. Alcamo (2008) describes a 10-step approach where narrative stories are developed and linked to dynamic models in an iterative procedure. Stories are developed by a stakeholder panel consisting of the relevant actors in the region under study, while models are developed and applied by experts. Essential in the Story-And-Simulation approach is the notion that the socio-economic stories that form the context for the modelling efforts are developed by stakeholders. These stories will then largely determine some of the important drivers (e.g. population or GDP growth) that form the input for mathematical models. The approach is iterative to ensure a higher level of consistency between the stakeholder-led qualitative scenarios and expert-determined quantitative model outputs. The result of the full series of workshops is a set of explorative scenarios (stories and models) that can be linked to adaptation options.

In CLIMSAVE, scenarios are being developed for two cases. The scenario method is being developed to be used at the European level with the development of a set of European scenarios. The method is simultaneously being tested for a single regional case study based on Scotland. In both cases, three stakeholder workshops of 2-3 days are being organised. The first workshops were conducted at the European level in May 2011 and in Scotland in June 2011. This deliverable focuses on the European drivers and a summary of the main objectives and results from the first European workshops in order to clarify what socio-economic scenarios entail. Further details on the scenario development method are given in Deliverable 3.1 (Kok et. al., 2011). Details on the processes of the first workshops are given for both cases in Deliverable 1.2 (Gramberger et al., 2011a, Gramberger et al., 2011b).

4.2 *Objective and process of the first stakeholder workshop*

The main objective of the first stakeholder workshop was to develop a first draft of the qualitative storylines. In order to do so, the following three steps and related products can be discerned:

1. Drafting a list of main uncertainties facing the region.
2. Selecting two key uncertainties that form the basis for four scenarios.
3. Drafting four stories.

The second objective of the first workshop was to quantify a number of (model) parameters, using the fuzzy set method. In order to do so, the following two steps can be discerned:

4. Defining the methods for quantifying socio-economic variables
5. Applying the fuzzy set approach within the first stakeholder workshop

The results of the five steps for the European workshop are summarised below.

Step 1: Drafting a list of uncertainties

A list of 11 uncertainties was presented as a starting point for the discussions. After discussions with stakeholders this list was expanded to a final list of 14 uncertainties. According to the stakeholders, the most important uncertainties included:

- Economic development
- Ability of natural systems to deliver ecosystem services
- Impact of climate change and natural hazards
- Solutions by innovation
- Societal cohesion

Overall, there is a wide variety of factors among the chosen uncertainties, covering economic, social, environmental, political and technological drivers. In the workshop there was widespread satisfaction and consensus on the final list that was decided upon.

Step 2: Selection of two main uncertainties

By a voting system, the two most important uncertainties in terms of degree of importance and the degree of uncertainty were determined. By assuming these uncertainties to be independent, and using them as axes of a coordinate system, four quadrants and thus four scenarios are predefined. The two main uncertainties selected were:

- Solutions by innovation to depletion of natural resources (effective – not effective)
- Economic development (gradual – rollercoaster)

Step 3: Qualitative stories

The group of stakeholders was divided into four groups. Each group was composed of four to six people ensuring a multi-disciplinary stakeholder group for each of the scenarios. Each group was also assigned a professional facilitator and a resource person from the CLIMSAVE research team to answer specific questions or to conduct additional research. Although the stakeholders had little time to come up with the scenario elements and scenario dynamics, the process in all four groups resulted in rather detailed information on all important aspects of their storyline. The four stories are summarised in Figure 5, by positioning them in the coordinate system formed by the two main uncertainties.

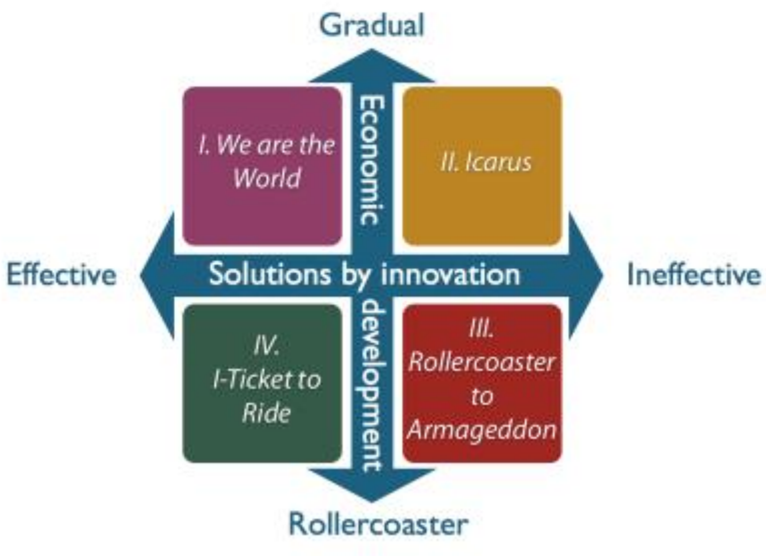

Figure 5: Qualitative scenarios as developed for Europe.

Step 4: Defining methods for quantifying socio-economic variables

In the practical application of the Story-And-Simulation approach, the translation of stories into quantified model input is often *ad hoc* and does not do justice to either the richness of the stories or the quantitative complexity of the models. The weak link between the qualitative and quantitative scenarios might well be the most problematic aspect of the Story-and-Simulation methodology. Alcamo (2008) was the first to highlight this potential drawback. Several methods have been proposed to overcome the problem, all of which have been tested to some extent in practice:

Without stakeholder involvement:

(i) *Literature review and adapting existing projections.* The standard, and still most often applied, method is to refrain from including the stakeholders in this process and use the modellers' interpretation of the storylines. The main disadvantages are the lack of communication with stakeholders and the huge influence of existing scenarios rather that the newly developed stories.

Structuring storylines with stakeholders:

(ii) *Fuzzy Cognitive Mapping*. Here it is assumed that by first adding structure to the dynamics of the system, followed by a quantification of that structure, a product is constructed that can be translated almost directly to model input. This has been experimented with in a large project on water scenarios, SCENES (see Kok, 2009; Van Vliet et al., 2010).

(iii) *Causal Loop Diagrams*. This method follows a similar logic: structuring the information that is present in a storyline will facilitate its quantification.

Both of these (and other) tools that attempt to structure the information in a storyline have a number of disadvantages. Importantly, they quickly become very complex and therefore run the risk of losing any explanatory ability and with that any ability to quantify. Additionally, quantification often concerns the relationships rather than the values of the parameters themselves. This adds to the understanding of the storylines, but hinders a straightforward quantification procedure.

Direct parameter estimation by stakeholders:

(iv) *The Delphi method.* A structured communication technique, developed as a systematic, interactive forecasting method that relies on a panel of experts. This method assumes that you can directly ask experts for their opinion on how parameters will change in the future. Key to the method is rounds of questionnaires, although it can also be used in a workshop setting. Importantly, the Delphi method does not aim at reaching consensus, which separates it from most other methods discussed here, mostly because storylines are consensus products.

(v) *Fuzzy Set approach*. This method attempts to combine the various techniques, mostly by taking two separate steps. In step 1, stakeholders are asked to reach a consensus on the rate of change of a number of parameters, expressed in *words*. This will yield results like "the population in Southern Europe in the period 2010-2025 will have a moderate increase". In step 2, stakeholders are asked to individually quantify this statement. Every stakeholder will provide for every parameter their expert judgement on what is e.g. a moderate increase. In this way, the structure of the story is included in the first step, while a direct and individual parameter estimation is given in the second step. An additional advantage is that the method is simple and fast and can thus be executed as part of a stakeholder workshop. Note furthermore that the approach allows for overlapping classes. The overall result is a collective fuzzy numerical view of the stakeholders on any set of model parameters. If needed, this view can be 'defuzzified'.

In view of the above, we decided to adopt the Fuzzy Set approach as the key instrument in the quantification of model parameters. Apart from the strong points mentioned above, its ability to provide (relatively) unambiguous and objective numbers that can be used directly as model input was seen as very important in CLIMSAVE.

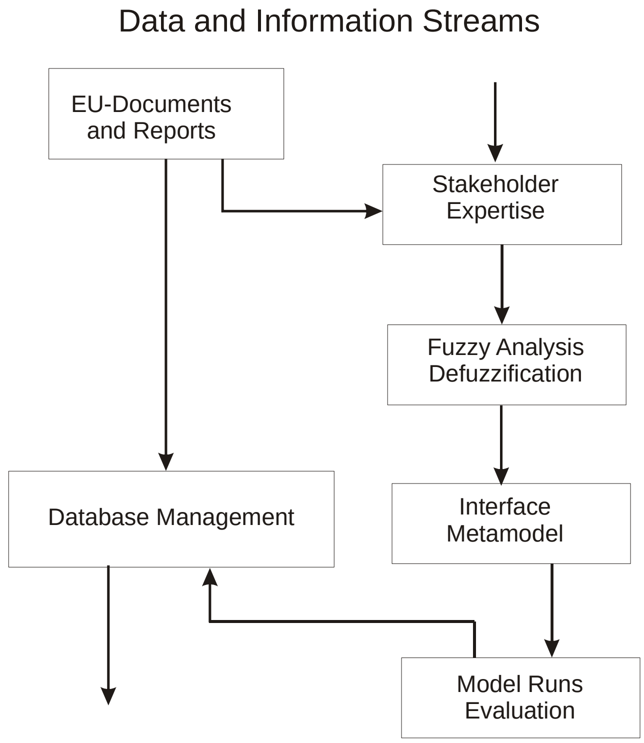

Figure 6: The two sources of information used in the quantification of the socio-economic drivers.

Step 5: Applying the fuzzy set approach within the first stakeholder workshop

As stakeholders only have a limited amount of time to undertake the two steps in the fuzzy sets approach within the first workshop, the maximum number of model parameters that could be quantified by stakeholders was estimated to be seven. In addition to these seven model variables, a further five variables relating to the capitals (natural, human, social, manufactured and financial) used in the adaptive capacity and vulnerability parts of CLIMSAVE were quantified using Step 1 of the fuzzy sets approach only. The seven model variables were selected in consultation with the CLIMSAVE modellers. A representative set of variables that could be used to inform the quantification of other socio-economic variables within the models was chosen. These included:

1. GDP
2. Population
3. Protected Area for Nature
4. Food import ratio
5. Arable land used for biofuels
6. Oil price
7. Household size

Figure 6 shows the two sources of information used in the quantification of the socio-economic drivers. In addition to eliciting stakeholder expertise by applying the fuzzy sets approach within the workshops, background information on historic changes in the seven variables (see Annexes I and II) was collected from official documents, statistics and reports to guide stakeholder discussions and to evaluate the plausibility of the assumptions. Stakeholder input to the quantification process was requested for Europe as a whole as well as for four geographically distinct European regions (North, East, South and West).

Stakeholders were divided into the same four groups used for drafting the qualitative stories in the fuzzy sets approach. Each group was given a work sheet (see Appendix I) and was asked to discuss and reach consensus on qualitative changes (e.g. "very low", "low", "medium", "high" or "very high") in each of the seven variables. Each group was supported by a CLIMSAVE expert and a facilitator. In the *fuzzy* terminology this step deals with *linguistic variables*. In order to translate these (qualitative) *linguistic variables* into (quantitative) information the stakeholders were asked in a second step to complete individually a second work sheet (see Appendix II) in which they provided information on what they meant by, for example, a "medium" value. In most cases the opinions of different stakeholders result in a certain distribution of values. These sets of values can be interpreted as a *fuzzy set* that represents the associated *linguistic variable*.

4.3. Results of the fuzzy sets approach – the translation key obtained after the first workshop

Several algorithms are available to translate, in a third step, the distribution of values in the fuzzy set into a single number (below introduced as "*translation key*") that best sums up the estimates of a group of stakeholders. The centre of gravity (Figure 7) is used to calculate the single number associated with a particular scenario and this is used to define the default position of the socio-economic slider in the Integrated Assessment Platform (IAP). As this measure takes account of the entire set of numbers and their distribution, it better considers estimates at the upper or lower edges compared to the average or median value. On the other hand, extreme unrealistic estimates can have the potential to strongly influence the entire fuzzy set analysis. This risk was reduced by the CLIMSAVE team providing assistance during the quantification process. In addition to the provision of background material, individual clarification was given whenever a stakeholder felt uncomfortable.

The minimum, median and maximum values in each minimum-maximum column pair were then defined over the *fuzzy sets*. Graphs were created where the minimum and maximum values are given degree 0 of membership and where the median value is given degree 1 of membership (see Figure 7). The triangle that is derived is used to define the centre of gravity and this is added to the graph.

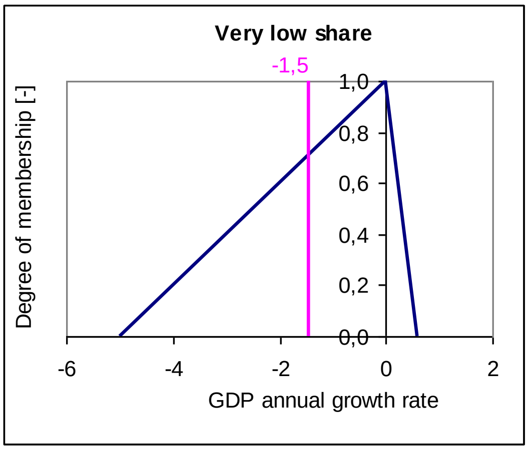

Figure 7: Defuzzification using the *centre of gravity (in pink)* algorithm.

In addition, the centre of gravity is analysed separately over the minimum column as well as the maximum column for the *linguistic variables* in order to define the upper and lower "*credible slider margins*". These credible ranges are applied in the Integrated Assessment Platform. This allows the user to investigate uncertainty associated with the socio-economic variable that is still considered to be consistent with the underlying story. User defined slider settings beyond this credible margins are assumed to be not consistent with the underlying scenario/storyline assumptions. Nonetheless, the IAP provides *extended slider settings* to allow users the flexibility to test the implications of extreme variable values on the Integrated Assessment Platform performance in a kind of extended sensitivity analysis. The absolute slider limitations are defined using the lowest and highest value in each minimum-maximum column pair of the *fuzzy sets*. This analysis (step three) was carried out between workshop one and workshop two.

Table 6 shows the *translation key* for the centre of gravity (default slider values) derived from this method and Table 7 shows, as an example, the slider margins for the "medium" category for the six socio-economic variables.

Table 6: Translation key for the six[1] IAP default slider positions (centre of gravity) obtained from the fuzzy set approach.

	GDP growth per year [%]	Population growth per year [%]	Food import [%]	Arable land for biofuel [%]	Oil price [$/barrel]	Household size [heads]
Very Low	-1.47	-1.53	6.67	1.75	72.50	1.13
Low	0.00	-0.47	14.00	6.67	98.33	1.97
Medium	1.45	0.33	26.67	10.67	138.33	3.12
High	2.85	0.53	40.00	15.00	162.50	3.88
Very High	4.38	1.05	58.33	26.00	210.00	4.40

Table 7: IAP default slider position and slider range values for the "medium" category.

	Absolute minimum	Credible minimum	Default	Credible maximum	Absolute maximum
GDP growth per year [%]	0.00	0.87	1.45	1.67	3.00
Population growth per year [%]	0.00	0.23	0.33	0.38	0.70
Food import [% consumed food]	10.00	19.17	26.67	31.67	50.00
Arable land for biofuel [%]	2.00	7.83	10.67	11.83	20.00
Oil price [$/barrel]	30.00	100.00	138.33	153.33	300.00
Household size [heads]	2.00	2.33	3.12	3.27	4.80

[1] After the first workshop, the protected area variable was removed from the list of socio-economic model drivers. In addition, only Europe as a whole geographic region is further considered in the scenario development and quantification process.

4.4. Revision of the Integrated Assessment Platform driver during the second stakeholder workshop

During the second workshop stakeholder were asked to revise step one of the fuzzy set approach. This was required for two reasons. First, the storylines were further developed in the second workshop and, second, each scenario group had agreed on linguistic terms during the first workshop without knowing the associated quantitative values (that were obtained in step three of the fuzzy set analysis). The obtained *translation key* (see Table 6) and the scenario specific variable changes that are associated with the agreed linguistic variables during the first workshop (e.g. Figure 8) were illustrated on posters. This procedure increased the transparency of the fuzzy set approach for stakeholders and provided a reference for how the chosen qualitative class and the associated (quantitative) rate of change would affect the variable states for the 2020s and the 2050s periods.

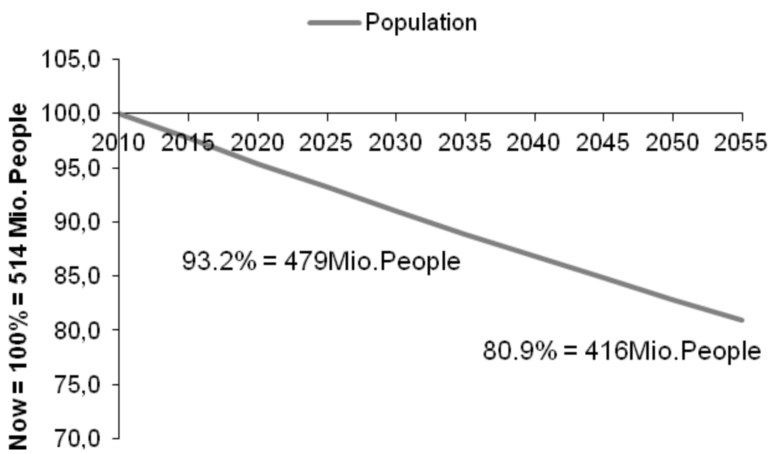

Figure 8: Example of the illustration of variable changes in the second workshop according to the selected qualitative class defined during step one of the first workshop: Population development for the Icarus scenario with "low" changes = -0.47 %/annum towards the 2020s and the 2050s.

The translation keys are common for the four socio-economic scenarios and remained unchanged between the workshops. However, stakeholders had the opportunity to revise the six model variables by changing the linguistic class of a variable. This revision was based on the translation keys which were provided on posters as well as any further developments to the storylines. See Appendix III for the revised and final set of the six IAP slider position values for the four socio-economic scenarios.

5. Conclusions

A European database of scenario drivers has been developed for implementation and testing with the meta-models within the CLIMSAVE Integrated Assessment Platform (IAP). Climate change scenario drivers were based on a representative subset of GCMs from the IPCC AR4 database, whilst socio-economic drivers were developed with stakeholders using a fuzzy sets approach within workshops. Both sets of drivers were integrated into the IAP and stakeholders were able to use an advanced prototype of the IAP for testing (robust) climate change adaptation options in their scenario groups during the third workshop held in December 2012.

6. References

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Appendix I: Worksheet for group exercise in the first step of the fuzzy sets approach[2]

Storylines to Models

Quantification of driving forces for modelling

Group Exercise

Scenario: ……………………………………………………………………………………

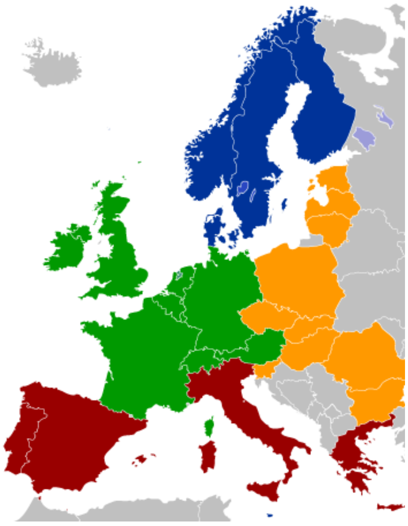
Group members: ……………………………………………………………………………

[2] The number of variables was reduced in later working steps and the EU regions were not considered explicitly in quantifying variables.

Introduction

The purpose of the exercise is to provide input to the Integrated Assessment Platform (IAP). We consider 12 key variables and two time scales. We provide you with one page for each of the variables where you can fill in your best estimates of how that variable might develop under specific storyline assumptions. The first time scale ranges from the present to the 2020s and the second ranges from the 2020s to the 2050s.

The CLIMSAVE project considers the EU27 plus Switzerland, Norway and Lichtenstein as one geographical unit. All variables must be defined at least for this aggregated CLIMSAVE region. However, please make regionally specific (northern, eastern, southern or western) estimates, if you think that one or more regions will develop significantly differently than the others.



Overview on the variables

1 GDP

2 Population

3 Protected areas for nature

4 Food import ratio

5 Arable land used for biofuels

6 Oil price

7 Household size

8 Natural capital

9 Human capital

10 Social capital

11 Manufactured capital

12 Financial capital

How to fill in your best estimates?

Example 1: valid for variables 1–7.

GDP: What is the annual growth rate of GDP in the 2020s/2050s?

Please fill in:
vl = very low
l = low
m = medium
h = high
vh = very high

	EU+	North	East	South	West
2020s	e.g. **m** (medium)	e.g. **m** (medium)	e.g. **m** (medium)	e.g. **vh** (very high)	e.g. **l** l(ow)
2050s	e.g. **l** (low)	e.g. **vl** (very low)	e.g. **l** (low)	e.g. **h** (high)	e.g. **l** (low)

Example 2: valid for the five capital variables (variables 8-12)

Natural capital: What are the changes in human capital in the 2020s/2050s compared to 2010?

Please fill in:
h+ = high increase
m+ = moderate increase
0 = no changes
m- = moderate decrease
h- = high decrease

	EU+	North	East	South	West
2020s	e.g. **m-** (moderate decrease)	e.g. **m-** (moderate decrease)	e.g. **0** (no changes)	e.g. **h-** (high decrease)	e.g. **m-** (moderate decrease)
2050s	e.g. **m+** (moderate increase)	e.g. **h-** (high decrease)	e.g. **m+** (moderate increase)	e.g. **h+** (high increase)	**0** (no changes)

1

Gross Domestic Product

What is the annual growth rate of GDP in the 2020s/2050s?

Please fill in:
vl = very low
l = low
m = medium

h = high
vh = very high

	EU+	North	East	South	West
2020s					
2050s					

For your reference:

Fig. 1: *GDP growth per year for selected countries from 1980-2010. Source: IMF 2011.*

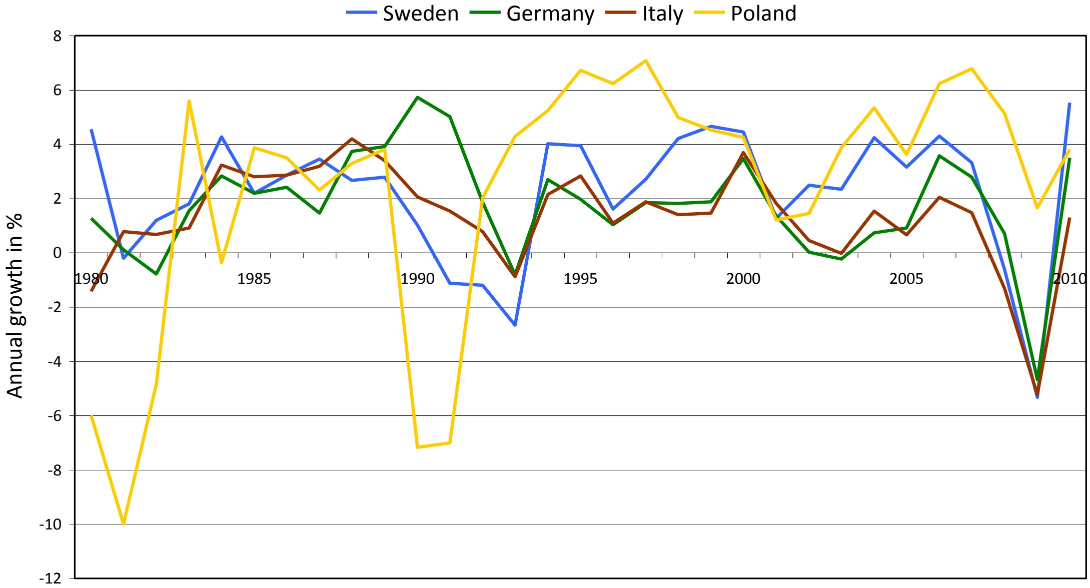
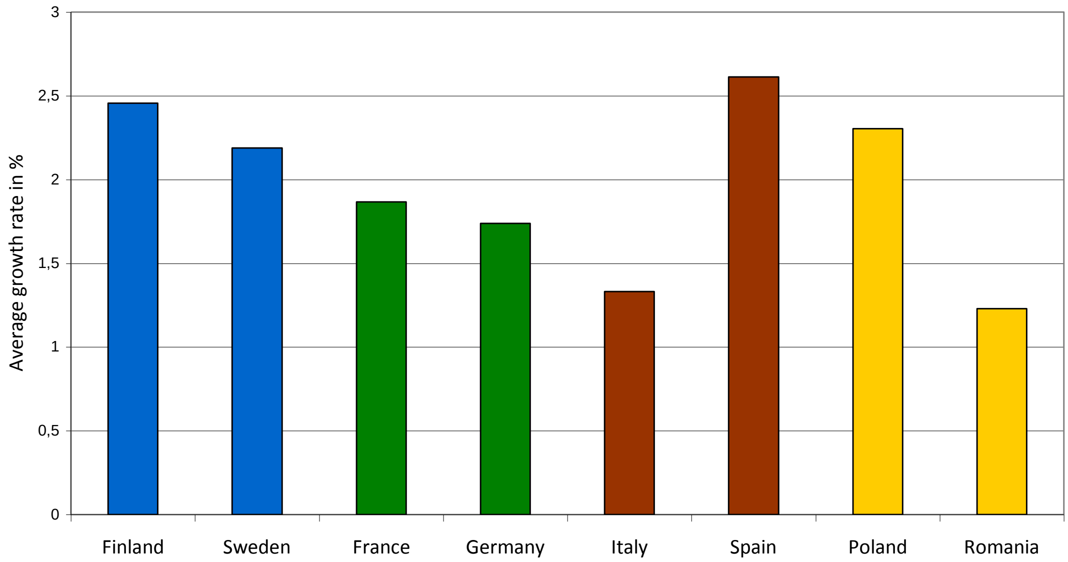


Fig. 2: *Average GDP growth per year for selected countries from 1980-2010. Source: IMF 2011.*



2

Population

What is the annual growth rate of population in the 2020s/2050s?

<u>Please fill in:</u>
vl = very low
l = low
m = medium
h = high
vh = very high

	EU+	North	East	South	West
2020s					
2050s					

For your reference:

Fig. 3: *Population development for the period 1960-2008 (absolute numbers in Mio). Source: UNPD (2011).*

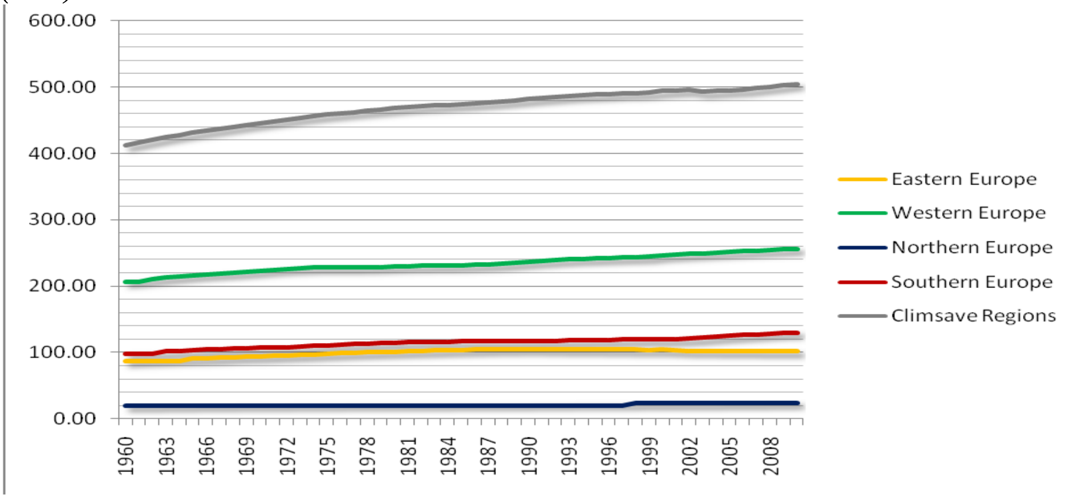
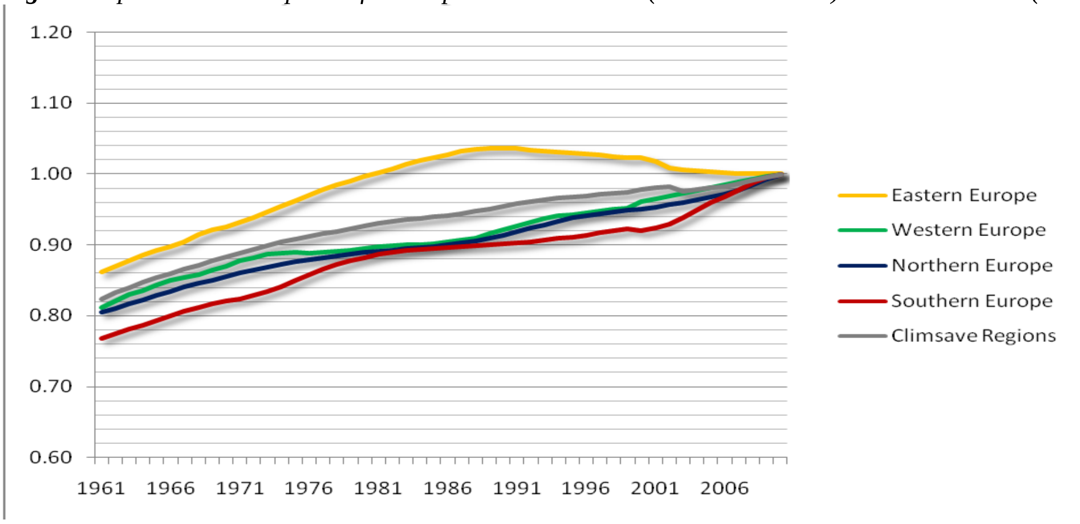


Fig. 4: *Population development for the period 1960-2008 (relative to 2010). Source: UNPD (2011).*



3

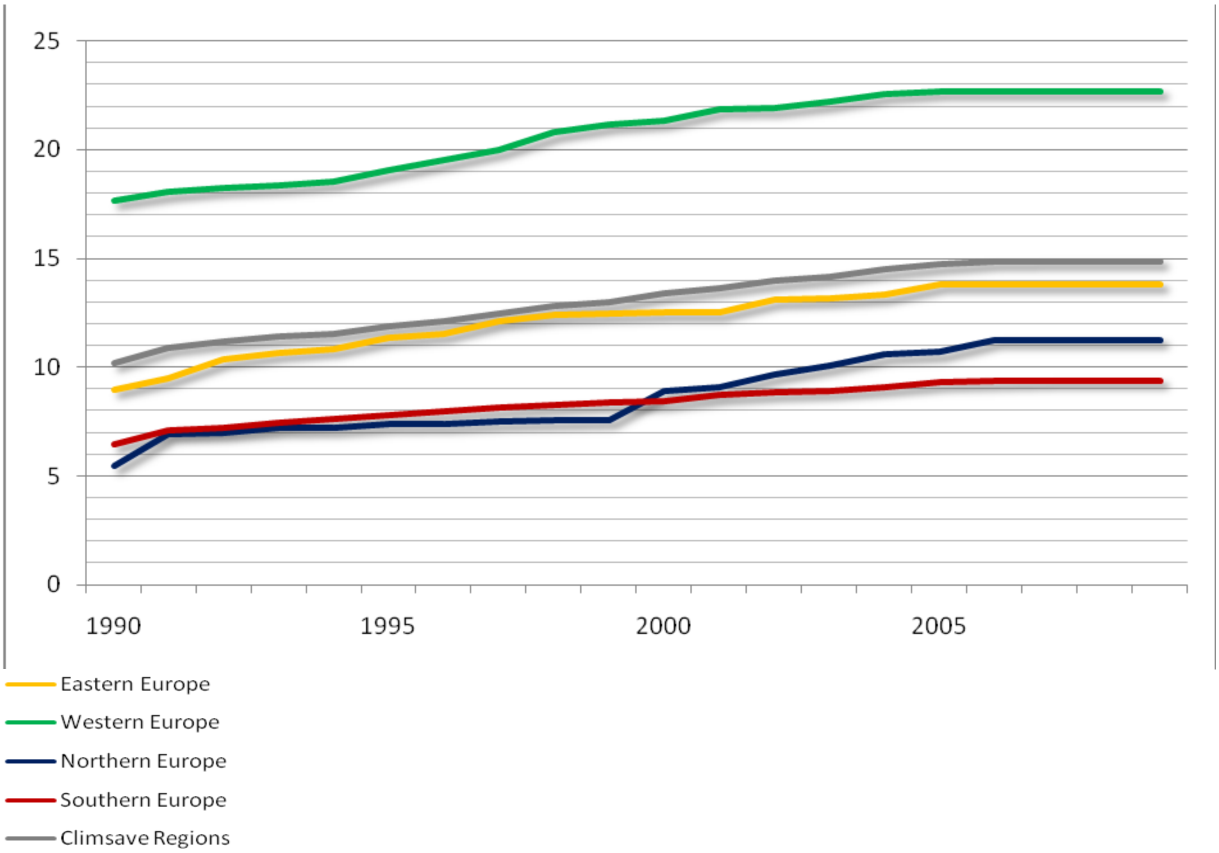
Areas protected for nature

What is the percentage of land protected for nature in the 2020s/2050s?

Please fill in:
vl = very low
l = low
m = medium
h = high
vh = very high

	EU+	North	East	South	West
2020s					
2050s					

For your reference:
Fig. 5: *Proportion of Protected areas for the period 1990-2009 in % of total area (all categories of protected areas for nature) Source: IUCN and UNEP-WCMC (2010) WDPA: January 2010. Cambridge, UK: UNEP-WCMC.*



4

Food import

What is the ratio of food imported in the 2020s/2050s?

Please fill in:
vl = very low
l = low
m = medium
h = high
vh = very high

	EU+	North	East	South	West
2020s					
2050s					

5

Biofuel production

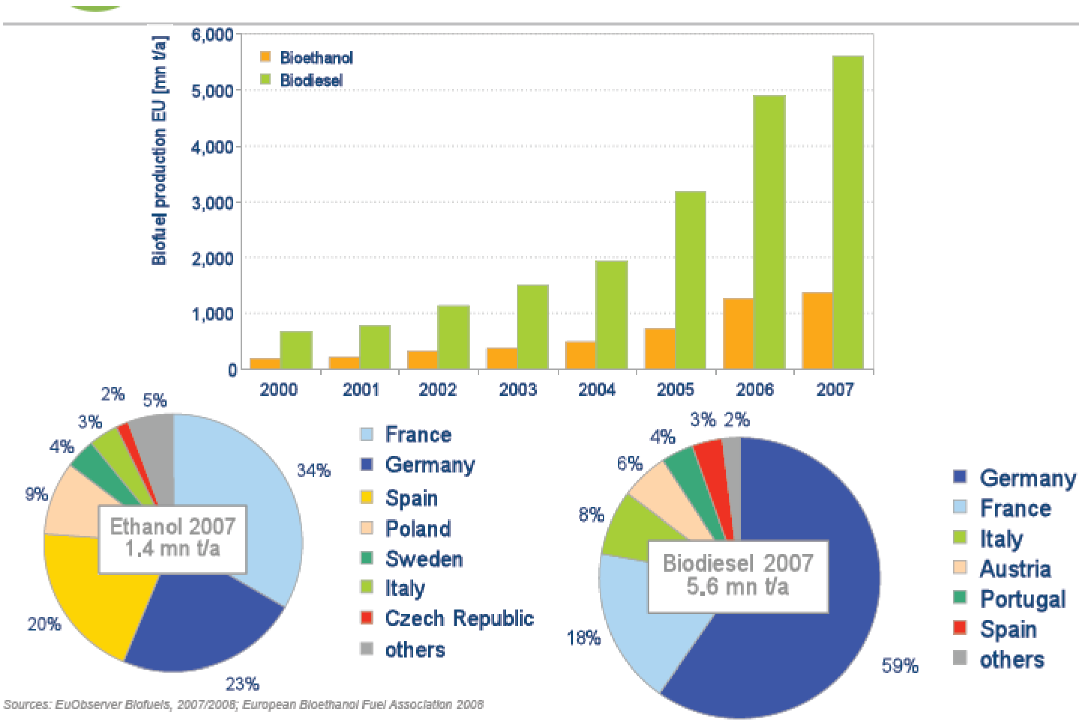
What is the % of arable land used for biofuel production?

Please fill in:
vl = very low
l = low
m = medium
h = high
vh = very high

	EU+	North	East	South	West
2020s					
2050s					

For your reference:
Note: Figure 6 is on biofuel production, hence, influenced by potential yield changes.

Fig. 6: *Share of biofuel production. Sources: EuObserver Biofuels,2007/2008.*



6

Oil price

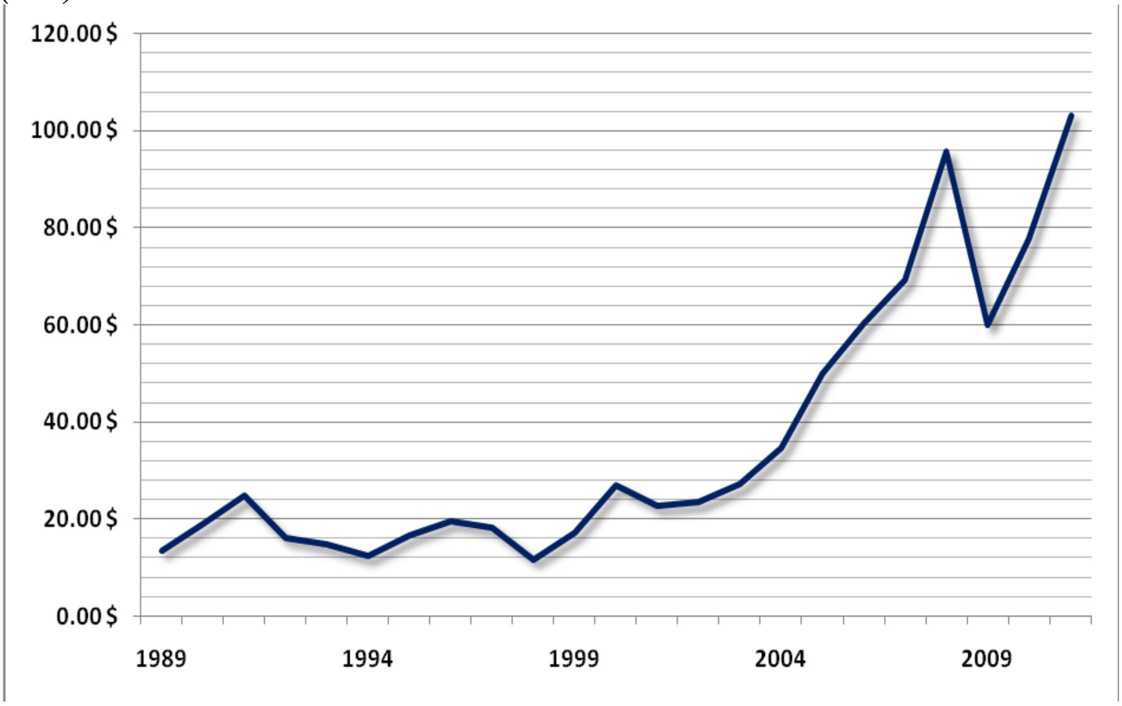
What is the oil price in the 2020s/2050s?

Please fill in:
vl = very low
l = low
m = medium
h = high
vh = very high

	Global
2020s	
2050s	

For your reference:

Fig. 7: *Oil price in US$ per barrel from 1989-2010. Source: U.S. Energy Information Administration (2011).*



7

Household size

What is the average household size in the 2020s/2050s?

Please fill in:
vl = very low
l = low
m = medium
h = high
vh = very high

	EU+	North	East	South	West
2020s					
2050s					

For your reference:

Table 1: *Household size development for the EU-27 from 2004-2009. Source: EURO_STAT 2011*

	2004	2005	2006	2007	2008	2009
Denmark	2,0	2,0	2,0	2,0	2,0	2,0
Finland	2,1	2,1	2,1	2,1	2,1	2,1
Sweden	2,1	2,1	2,1	2,1	2,1	2,0
Norway	2,1	2,1	2,1	2,1	2,1	2,1
Austria	2,4	2,3	2,3	2,3	2,3	2,3
Belgium	2,3	2,3	2,3	2,3	2,3	2,3
France	2,3	2,3	2,3	2,3	2,3	2,2
Germany	:	2,1	2,1	2,1	2,1	2,0
Ireland	2,9	2,8	2,8	2,8	2,8	2,7
Luxembourg	2,5	2,5	2,5	2,5	2,5	2,5
Liechtenstein						
Netherlands	:	2,3	2,3	2,3	2,3	2,2
United Kingdom	:	2,3	2,3	2,4	2,4	2,4
Switzerland	:	:	:	:	:	2,3
Cyprus	:	3,0	3,0	2,9	2,9	2,9
Greece	2,7	2,7	2,7	2,7	2,7	2,7
Italy	2,5	2,5	2,5	2,4	2,4	2,4
Malta	:	2,9	2,8	2,9	2,9	2,9
Portugal	2,8	2,8	2,8	2,8	2,7	2,7
Spain	2,8	2,8	2,8	2,8	2,7	2,7
Bulgaria	:	:	2,9	2,9	2,9	2,9
Czech Republic	:	2,5	2,5	2,5	2,5	2,5
Estonia	2,4	2,4	2,4	2,3	2,3	2,3
Hungary	:	2,5	2,6	2,6	2,6	2,6
Latvia	:	2,6	2,6	2,6	2,6	2,6
Lithuania	:	2,5	2,6	2,6	2,6	2,5
Poland	:	2,8	2,8	2,8	2,8	2,8
Romania	:	:	:	3,0	2,9	2,9
Slovenia	:	2,8	2,8	2,8	2,8	2,8
Slovakia	:	2,9	2,9	2,8	2,9	2,8
European Union (EU27)	:	2,4	2,4	2,4	2,4	2,4

Capitals

For the purposes of the CLIMSAVE project, the interest in capital is threefold:

- as a performance measure of the overall wealth of society, showing the ability to sustain standards of human welfare, and that can be altered by the adaptation options taken;
- as an indicator for the vulnerability of a system. The higher the exposure to a pressure and the lower the capital stocks, the higher is the vulnerability of this system to the pressure;
- as an indicator of the ability of a society (or region, or sector) to adapt to changing circumstances (such as the increasing exposure to weather extremes). That indicator can be altered by the adaptation options taken.

Please use the boxes to fill in your best estimates

At the end of the boxes we provide you a table on wealth estimates for selected EU countries. The table refers to 2005 and might help you making your estimates on future developments.

8

Natural Capital

Natural capital is any stock or flow of energy and matter that yields valuable goods and services. This includes resources, some of which are renewable (e.g. timber, grain) and others that are not (e.g. fossil fuels). Natural capital also includes sinks that absorb, neutralize or recycle waste. Natural capital can be used for adaptation by, for example, planting trees, growing new crops, providing irrigation, etc.

What will be the changes in natural capital in the 2020s/2050s?

Please fill in:
h+ = high increase
m+ = moderate increase
0 = no changes
m- = moderate decrease
h- = high decrease

	EU+	North	East	South	West
2010-2025					
2025-2055					

9

Human Capital

Human capital includes the health, knowledge, skills and motivation of an ecosystem service beneficiary, as well as their individual emotional and spiritual capacities. Human capital can be used for adaptation by, for example, using the skills of humans to provide early warning or providing training. It characterizes the abilities that lie within an individual member of society. It broadly covers areas of education, job experience, skills and health (Burt 1997, Beckley et al. 2002).

What will be the change in human capital in the 2020s/2050s?

Please fill in:
h+ = high increase
m+ = moderate increase
0 = no changes
m- = moderate decrease
h- = high decrease

	EU+	**North**	**East**	**South**	**West**
2010-2025					
2025-2055					

10

Social Capital

Social capital consists of the structures, institutions, networks and relationships of ecosystem service beneficiaries that enable individuals to maintain and develop their human capital in partnership with others, and to be more productive when working together than in isolation. It includes families, communities, businesses, trade unions, voluntary organizations, legal/political systems and educational and health institutions. Social capital can be used for adaptation by, for example, setting up voluntary organizations for emergency help. It includes informal and often local relationships as well as more formalized ones, like the political regime and civil and political institutions (Lehtonen 2004) and basically refers to the networks and social relations of people.

What will be the change in social capital in the 2020s/2050s?

Please fill in:
h+ = high increase
m+ = moderate increase
0 = no changes
m- = moderate decrease
h- = high decrease

	EU+	North	East	South	West
2010-2025					
2025-2055					

11

Manufactured Capital

Manufactured capital consists of material goods, tools, machines, buildings and other forms of infrastructure - that contribute to the production process but do not become embodied in its output. Manufactured capital can be created for adaptation by building dams, water pipelines, sea-walls, hospitals, roads, etc.

What will be the change in manufactured capital?

Please fill in:
h+ = high increase
m+ = moderate increase
0 = no changes
m- = moderate decrease
h- = high decrease

	EU+	North	East	South	West
2010-2025					
2025-2055					

12

Financial Capital

Financial capital reflects the productive power of the other forms of capital and enables them to be owned and traded. However, unlike other types, it has no or only little intrinsic value - its value is mainly representative of natural, human, social or manufactured capital. It reflects the ability of a nation to claim resources by calling in debts from overseas.

What will be the change in financial capital?

Please fill in:
h+ = high increase
m+ = moderate increase
0 = no changes
m- = moderate decrease
h- = high decrease

	EU+	North	East	South	West
2010-2025					
2025-2055					

For your reference:

Table 2: Capital share in 2005.

		Total Wealth	Intangible Capital *	Financial Capital	Produced Capital	Natural Capital
North		$685,596	$528,264	$2,906	$119,139	$35,287
East		$126,111	$99,575	-$3,510	$22,625	$7,420
South		$440,247	$358,724	-$8,811	$83,090	$7,243
West		$596,049	$488,475	$2,654	$97,606	$7,315

* Intangible capital: this is measured as a residual (the difference between total wealth and produced and natural capital) and *implicitly* includes measures of human capital and social/institutional capital

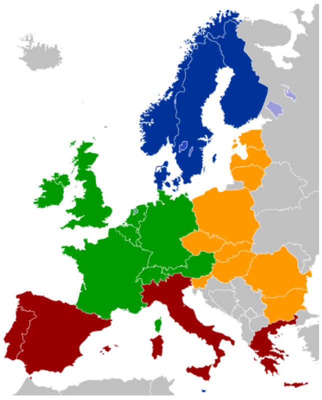


Fig. 8: CLIMSAVE regions.

Why consider capitals?

Accounting for wealth is in principle a core part of the System of National Accounts (SNA) that is the basis for measuring economic progress. It is possible to think of the flow of benefits to human societies – "consumption", in a wide sense - as deriving from the use of a number of capital stocks, together forming the "wealth" of the society. Wealth accounts are not nearly as widely implemented or understood as the measures of production and income e.g. gross domestic production (GDP). However GDP treats both the production of goods and services and the value of asset sales as part of the product of the nation. Thus, a country can enjoy high GDP by depleting stocks of forests and fossil fuels, for example, but this would not be sustainable.

Therefore, the World Bank report "The Changing Wealth of Nations" (2011) seeks to measure the Total Wealth (TW) with the principle that current wealth must constrain future consumption. It requires adjusting levels of consumption to take account of rates of saving adjusted for depletion of produced and natural capital: when depletion-adjusted saving is negative, countries are consuming natural resources, jeopardizing the prospects for future consumption.

Development can be viewed as a process of building and managing a portfolio of capital assets. The key challenges are:

- balancing consumption and wealth: deciding how much to save versus how much to consume; and
- balancing the composition of the asset portfolio: how much to invest in or make use of different types of capital.

Appendix II: Worksheet for individual exercise in the second step of the fuzzy sets approach

Storylines to Models

Quantification of driving forces for modelling

Individual Exercise

- The Translation Key -

The scenario/storyline you worked with: ………………………………………

Your name: …………………………………………………………………......

Introduction

In this exercise we will ask you to link quantitative statements such as “high” or “low” to numbers that can drive the Integrated Assessment Platform (IAP).

Please give your best estimate in numbers for the boundaries of **what you mean** by “low”, “medium”, etc.

References to historic data are provided in this document as well as in the hand out for the group exercise. The references are intended to help you choose your own boundaries.

Please use the boxes to fill in numbers in the units specified.

Overview on the variables

1. Population
2. GDP
3. Protected areas for nature
4. Food import ratio
5. Arable land used for biofuels
6. Oil price
7. Household size

How to quantify your estimates?

Example: valid for variables 1–7.

What is the annual growth rate of GDP in the 2020s/2050s?

Very low		***Low***		***Medium***		***High***		***Very high***	
-1	*0.5*	*0.4*	*1.5*	*1*	*2.5*	*2.5*	*3.5*	*3.0*	*5.0*

OVERLAPPING OF CLASSES POSSIBLE!

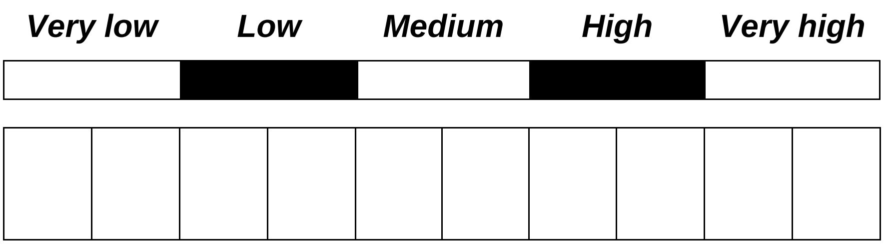
Please note: We do not quantify the capital variables in this exercise!

1

Gross Domestic Product

What is the GDP growth in the 2020s/2050s in percent per annum?

Unit = Growth rate per annum in percent



OVERLAPPING OF CLASSES POSSIBLE!

For reference:

Table 1: Average annual change in GDP (constant prices).
Source: International Monetary Fund (2011).

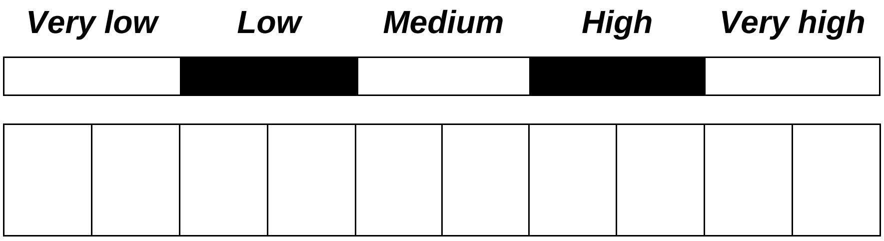
	Mean growth per year (1980-2010)
Finland	2,46%
Sweden	2,19%
France	1,87%
Germany	1,74%
Italy	1,33%
Spain	2,61%
Poland	2,30%
Romania	1,23%

2

Population

What is the annual growth rate in population in the 2020s/2050s?

Unit = Growth rate per annum in percent



OVERLAPPING OF CLASSES POSSIBLE!

For reference:

Table 2: Annual growth rates in population. Source: UNPD (2011).

		1960s (mean in Mio)	**2000s** (mean in Mio)	**Changes** (from the 1960s-2000s)	**Annual growth rate** (1960-2010)
Northern Europe		20,78	24,35	17,19%	0,40%
Western Europe		216,06	252,21	16,73%	0,39%
Southern Europe		102,69	124,20	20,94%	0,48%
Eastern Europe		97,74	103,90	6,30%	0,15%
CLIMSAVE Regions		437,28	504,66	15,41%	0,36%

3

Protected areas for nature

What is the ratio of land that is protected for nature in the 2020s/2050s?

Unit = Percentage of land that is protected for nature

Very low	***Low***	***Medium***	***High***	***Very high***

OVERLAPPING OF CLASSES POSSIBLE!

For reference:

Table 3: Ratio of protected areas from 1990-2009 (in %).

		1990	**2009**	**Change from 1990-2009**
North Europe		5,5	11,29	105,33%
Western Europe		17,67	22,68	28,33%
South Europe		6,51	9,42	44,73%
Eastern Europe		8,98	13,85	54,20%
CLIMSAVE Regions		10,2	14,9	46,12%

4

Food import ratio

What is the percent of food that is imported?

Unit= percentage of food consumed that is imported

Very low	***Low***	***Medium***	***High***	***Very high***

OVERLAPPING OF CLASSES POSSIBLE!

5

Arable land used for biofuel production

What is the percentage of arable land used for biofuel production?

Unit= percentage of arable land used for biofuel production

Please fill in fractions between 0 and 30%

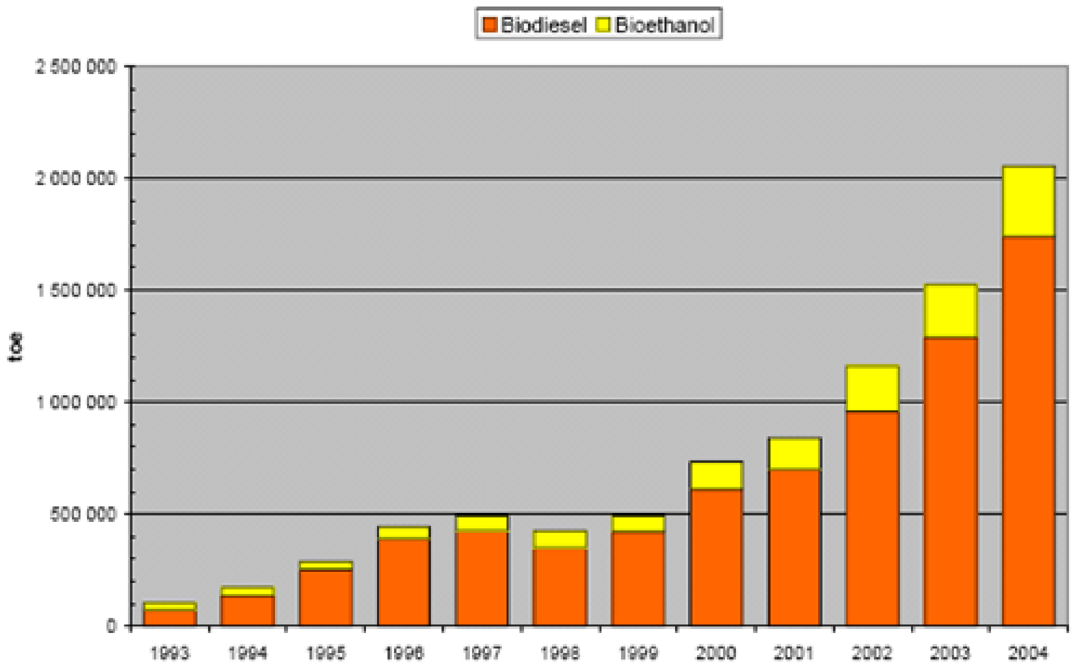
Very low	Low	Medium	High	Very high

OVERLAPPING OF CLASSES POSSIBLE!

For your reference:

Note: Figure 1 is on biofuel production and, hence, is influenced by potential yield changes.

Figure 1: Example of biofuel production in the EU-25 from 1993-2004. Sources: Eurobserver 2005.



6

Oil price

What is the oil price per barrel in the 2020s/2050s?

Unit: US $/barrel

Very low	***Low***	***Medium***	***High***	***Very high***

OVERLAPPING OF CLASSES POSSIBLE!

For reference:

Table 4: Oil price changes between 1990 and 2010

	1990	**2010**	**Change from 1990-2010**
Oil price	$13,58	$77,68	+472,01 %

7

Household size

What is the household size in the 2020s/2050s?

Unit: heads per household

Very low	***Low***	***Medium***	***High***	***Very high***

OVERLAPPING OF CLASSES POSSIBLE!

Appendix III: Final IAP slider position values for the six IAP variables, the two time scales and the four socio-economic scenarios.

We are the world					
2020s	**Absolute minimum**	**Credible minimum**	**Default**	**Credible maximum**	**Absolute maximum**
GDP [% growth/year]	0.00	0.87	1.45	1.67	3.00
Population [% growth/year]	-2.00	-0.53	-0.47	0.20	0.50
Food imports [% of consumed food]	2.00	10.67	14.00	17.67	30.00
Arable land for biofuels [%]	0.00	4.25	6.67	7.50	15.00
Oil price [US$/barrel]	80.00	173.33	210.00	221.67	400.00
Household size [heads]	2.00	2.33	3.12	3.27	4.80
2050s					
GDP [% growth/year]	0.00	0.87	1.45	1.67	3.00
Population [% growth/year]	0.00	0.23	0.33	0.38	0.70
Food imports [% of consumed food]	0.00	3.33	6.67	8.67	15.00
Arable land for biofuels [%]	0.00	0.33	1.75	2.42	5.00
Oil price [US$/barrel]	0.00	46.67	72.50	80.00	180.00
Household size [heads]	2.40	3.40	3.88	4.23	6.20
Rollercoaster to Armageddon / Should I stay or should I leave					
2020s	**Absolute minimum**	**Credible minimum**	**Default**	**Credible maximum**	**Absolute maximum**
GDP [% growth/year]	-2.00	-0.27	0.00	0.50	1.50
Population [% growth/year]	0.00	0.23	0.33	0.38	0.70
Food imports [% of consumed food]	2.00	10.67	14.00	17.67	30.00
Arable land for biofuels [%]	0.00	4.25	6.67	7.50	15.00
Oil price [US$/barrel]	30.00	100.00	138.33	153.33	300.00
Household size [heads]	2.00	2.33	3.12	3.27	4.80
2050s					
GDP	-5.00	-1.83	-1.47	-0.63	0.60

[% growth/year]					
Population [% growth/year]	0.10	0.38	0.53	0.65	1.00
Food imports [% of consumed food]	0.00	3.33	6.67	8.67	15.00
Arable land for biofuels [%]	0.00	0.33	1.75	2.42	5.00
Oil price [US$/barrel]	50.00	143.33	162.50	180.00	320.00
Household size [heads]	2.40	3.40	3.88	4.23	6.20
I ticket to ride / Riders on the storm					
2020s	**Absolute minimum**	**Credible minimum**	**Default**	**Credible maximum**	**Absolute maximum**
GDP [% growth/year]	-2.00	-0.27	0.00	0.50	1.50
Population [% growth/year]	0.00	0.23	0.33	0.38	0.70
Food imports [% of consumed food]	10.00	19.17	26.67	31.67	50.00
Arable land for biofuels [%]	0.00	4.25	6.67	7.50	15.00
Oil price [US$/barrel]	80.00	173.33	210.00	221.67	400.00
Household size [heads]	2.00	2.33	3.12	3.27	4.80
2050s					
GDP [% growth/year]	0.00	0.87	1.45	1.67	3.00
Population [% growth/year]	0.00	0.23	0.33	0.38	0.70
Food imports [% of consumed food]	0.00	3.33	6.67	8.67	15.00
Arable land for biofuels [%]	0.00	0.33	1.75	2.42	5.00
Oil price [US$/barrel]	80.00	173.33	210.00	221.67	400.00
Household size [heads]	2.00	2.33	3.12	3.27	4.80
Icarus					
2020s	**Absolute minimum**	**Credible minimum**	**Default**	**Credible maximum**	**Absolute maximum**
GDP [% growth/year]	-2.00	-0.27	0.00	0.50	1.50
Population [% growth/year]	0.00	0.23	0.33	0.38	0.70
Food imports [% of consumed food]	15.00	31.67	40.00	45.00	70.00
Arable land for biofuels [%]	2.00	7.83	10.67	11.83	20.00

Oil price [US$/barrel]	30.00	100.00	138.33	153.33	300.00
Household size [heads]	1.00	1.50	1.97	2.13	2.90
2050s					
GDP [% growth/year]	-2.00	-0.27	0.00	0.50	1.50
Population [% growth/year]	-2.00	-0.53	-0.47	0.20	0.50
Food imports [% of consumed food]	2.00	10.67	14.00	17.67	30.00
Arable land for biofuels [%]	0.00	4.25	6.67	7.50	15.00
Oil price [US$/barrel]	80.00	173.33	210.00	221.67	400.00
Household size [heads]	2.40	3.40	3.88	4.23	6.20