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Deliverable 2B.30: Journal paper on the refined Reliability Ensemble Averaging framework applied to Europe

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Dissemination Level		
PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	

Work for this deliverable consisted of an upgrade of the Reliability Ensemble Averaging (REA) method to produce PDFs of climate change variables. The general framework of the original REA method is described by Giorgi and Mearns (2002, 2003). It calculates reliability weights for different models based on the following two criteria:

(1) Model's ability to reproduce the observed 20th century climatology, i.e. reliability measured in terms of the model performance ("performance criterion"); in particular, this component of reliability is calculated from the model bias, and is referred to as RB;

(2) Model convergence with other models in terms of simulated climate change signal ("model convergence" criterion); this component is calculated from the distance of a model climate change signal from the corresponding ensemble mean change, and is referred to as RD.

The assumption underlying the model performance criterion is that a model's reliability is deemed higher and thus the model weight larger, if the model shows a good performance in reproducing present day climate. The model convergence criterion stems from the notion that increased reliability can be placed on an ensemble of model projections if there is a good agreement across models in terms of the simulated change signal. By this notion, in the original REA method the weight of a model is decreased if the change simulated by that model is far from the ensemble average change, i.e. if the model is an "outlier". Given a model i, the model weight is thus expressed as the product of two reliability factors, one based on the model performance as measured by the bias (RBi) and the other on the model convergence as measured by the distance of the i-model projected change from the ensemble average change (RDi). Giorgi and Mearns (2002) show how the weight is calculated, while Giorgi and Mearns (2003) describe how PDFs of climate change variables can be produced by compounding information from a weighted ensemble of models

The upgrades to the REA method implemented as part of RT2B are described in a paper by Xu, Gao and Giorgi, Climate Research, in press (reported in Appendix). The main upgrades concern the calculations of model weight. In the original REA method the model weight is given by the multiplication of two reliability factors which are measures of the model performance and convergence criteria. This has two limitations. First, the model convergence criterion has the potential of artificially narrowing the PDF of changes by weighting less the model outliers. Second, in the original formulation the weight for a variable, say T, depends only on the model performance in simulating the mean value of that variable, i.e. it depends on a single variable and a single statistic.

Both these limitations were addressed in the revised version of the REA method. First we abandoned the use of the convergence criterion by eliminating the convergence-based reliability factor from the definition of the overall weight. Second, we included multiple variables and multiple statistics in the definition of the reliability weight. In particular, in its general form the weight depends on temperature, precipitation and sea level pressure, and on the mean and interannual variability. The full description of the new weight is reported in the paper by Xu et al. (in press), which can be found in the Appendix.

For illustrative purposes, Xu et al (in press) first applied the augmented REA method to the calculation of temperature and precipitation changes based on ensembles of global model simulations for the East Asia region. The dataset employed is the ensemble of coupled Atmosphere-Ocean General Circulation Model (AOGCM) simulations conducted in the Phase 3 of the Coupled Model Intercomparison Project (CMIP3) in support of the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC AR4). It consists of simulations of 20th and 21st century climate (IPCC A1b scenario) by 18 models from laboratories worldwide spanning a horizontal grid spacing in the range of about 1 to 4 degrees (~120 to 500 km). The models are CCMA-3-T47, CNRM-CM3, CSIRO-MK3, GFDL-CM2-0, GFDL_CM2_1, GISS_AOM, GISS_EH, GISS-ER, INMCM3, IPSL-CM4, MIROC3-2H, MIROC3-2M, MIUB-ECHO-G, MPI-ECHAM5, MRI-CGCM2, NCAR-CCSM3, NCAR-PCM1, and UKMO-HADCM3, respectively. Some models include multiple realizations for the same scenario simulation, in which case only one realization is used in the calculations, so that each model is treated in the same way. The weights were calculated using as observations the dataset from the Climatic Research Unit (CRU) of the University of East Anglia (New et al. 2000). Xu et al. (in press) calculated Cumulative Density Functions (CDFs) of changes in temperature and precipitation for 2081-2100 with respect to 1961-1980 over 6 Chinese sub-regions as well as the entire China territory (see Appendix).

This exercise was repeated for the eight European regions used in the PRUDENCE project (Christensen and Christensen 2007). In particular, PDFs of changes in temperature and precipitation for the A1B scenario based on the 18 CMIP3 models listed above were produced for the periods 2021-2050 and 2071-2100 with respect to the reference period 1961-1990. Figures 1 - 4 below show these PDFs.

Concerning temperature (Figure 1 for 2021-2051, Figure 2 for 2071-2100), the largest warming occurs in the Scandinavian region in winter and the southern European regions in summer and the warming increases in the latter part of the 21st century. Both these results are generally in agreement with previous findings (e.g. Giorgi and Coppola, 2007). We can observe different widths of the distributions for the different regions, reflecting varying levels of inter-model uncertainty in the projections. It is interesting to note that for the near term period 2021-2050 the left tail of some distributions is close to, or crosses the zero line, indicating a very small probability of negligible warming or even slight cooling.

For precipitation (Figure 3 for 2021-2050, Figure 4 for 2071-2100), in the near term future 2021-2050 all PDFs cross the zero line, indicating probabilities of changes in both directions as inferred by the ensemble of models. However, the prevailing tendency for reduced summer precipitation in the southern European regions and increased winter precipitation in the northern European ones is evident. These tendencies are more pronounced in the far future (2071-2100) precipitation change PDFs. Over the southern European regions (IP, MD) the summer precipitation change PDFs lie entirely below the zero line, indicating a full inter-model agreement in simulating a decrease in precipitation. Similarly, in winter, only very small portions of the northern European change PDFs lie below the zero line, indicating an almost full inter-model agreement in projecting increased precipitation. An interesting feature shown by the PDFs of Figure 2 is the occurrence of multi-modal distributions. These are caused by the clustering of models within the CMIP3 ensemble in the precipitation change space.

The augmentations introduced to the general framework of the REA method represent an important development in its generality and robustness. The REA method represents a simple and flexible tool to investigate the issue of model weighting within the context of producing ensemble based PDFs of changes in relevant climatic variables of interest. As discussed in Xu et al. (in press), the issue of model weighting is a much debated one, particularly in the fact that a subjective component is present in the selection and use of specific weights. Therefore, the weighting itself should be viewed as an element of uncertainty that needs to be explored. In this regard, the REA method can provide a useful framework for testing different weighting schemes and thus exploring this uncertainty.

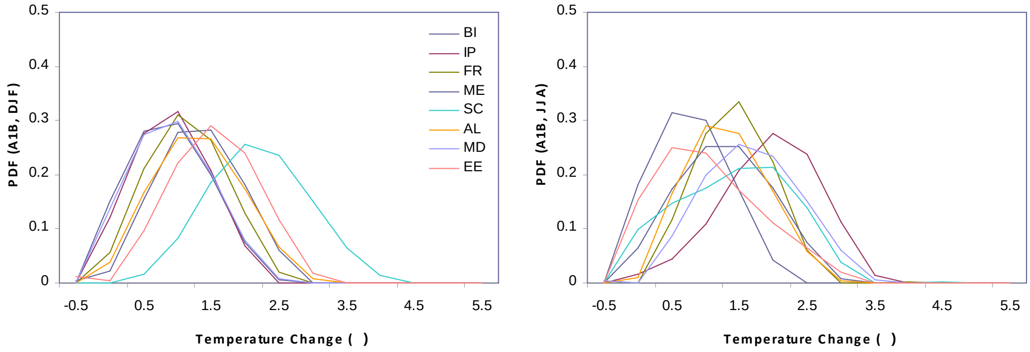

Figure 1. Temperature change (°C) PDF for 2021-2050 vs. 1971-2000 for DJF (left panel) and JJA (right panel) over the 7 European PRUDENCE regions: BI = British Isles, IP = Iberian Peninsula, FR = France, ME = Mid-Europe, SC = Scandinavia, AL = Alps, MD = Mediterranean, EA = Eastern Europe

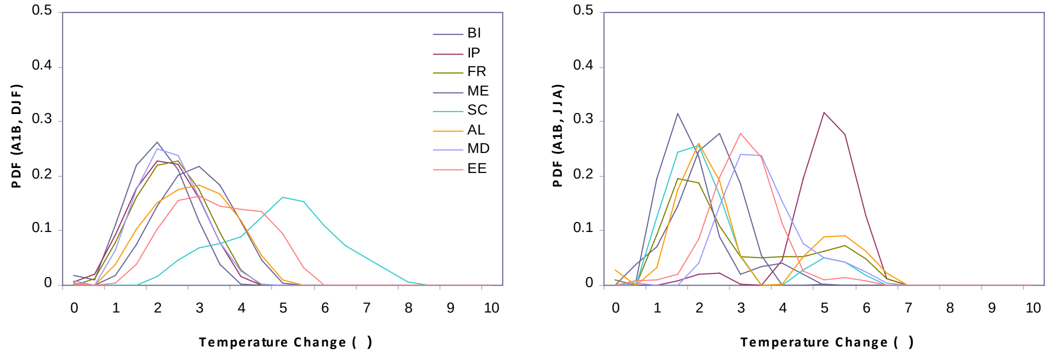

Figure 2. Same as Figure 1 but for 2071-2100 vs. 1961-1990 temperature change (°C).

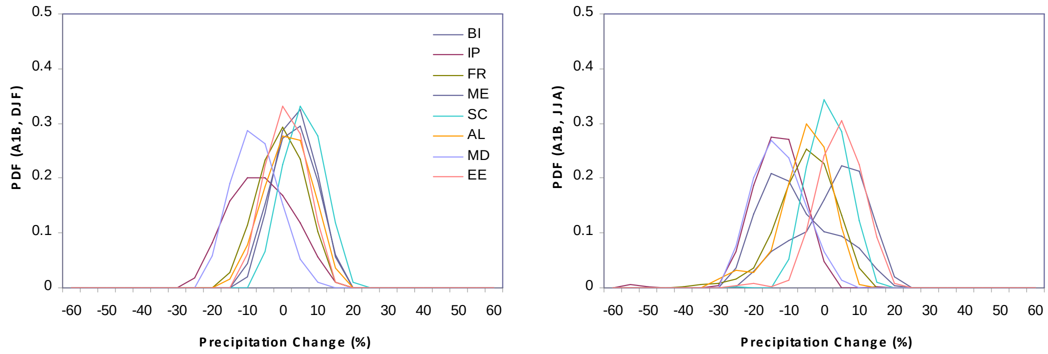

Figure 3.Same as Figure 1 but for 2021-2050 vs. 1961-1990 precipitation change (%

of present day value).

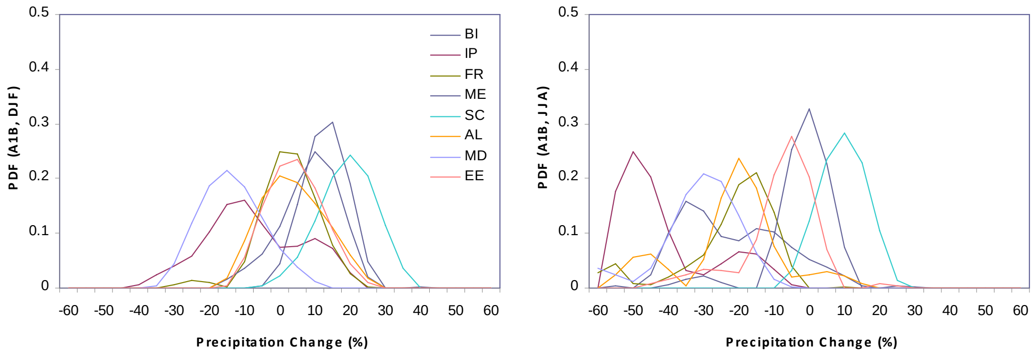

Figure 4.Same as Figure 3 but for 2071-2100 vs. 1961-1990 precipitation change (% of present day values).

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