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Developing guidelines for working with climate multi-model ensembles in CMIP7

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The Earth system models (ESMs) of the WCRP Coupled Model Intercomparison Project (CMIP) are a key tool for making future climate projections and have been continuously developed by various climate modeling communities all over the world over the past decades. The resulting contemporary ESMs are sophisticated tools encoding numerous processes occurring in multiple components of the Earth System such as the atmosphere, ocean, cryosphere, land, and produce a large amount of simulation output data. It remains challenging to analyze, evaluate and interpret the results of such an ensemble of climate models, commonly referred to as the climate multi-model ensemble (MME), to derive actionable information for policy makers and society. Within the international Fresh Eyes on CMIP initiative we have conducted a comprehensive literature review summarizing the newest research studies addressing various issues related to working with climate MMEs. This spans a wide range of matters such as model evaluation including process-oriented assessment, systematic model biases, model selection, model dependencies, weighting methods accounting for model performance and interdependence, uncertainty sources and their characterization, as well as downscaling approaches to acquire regional climate change information. We also discuss how to utilize MMEs to study high-impact weather and climate extreme events, as well as emerging machine learning techniques for analyzing MMEs, single model initial-condition large ensembles (SMILES), and computational resource considerations. We finally give an overview of available open-source software tools and tutorials developed by a broader climate science community which facilitate the MME analysis. We thereby strive to provide

guidance on how to best exploit the climate MME in future phases of CMIP particularly in the upcoming CMIP7.