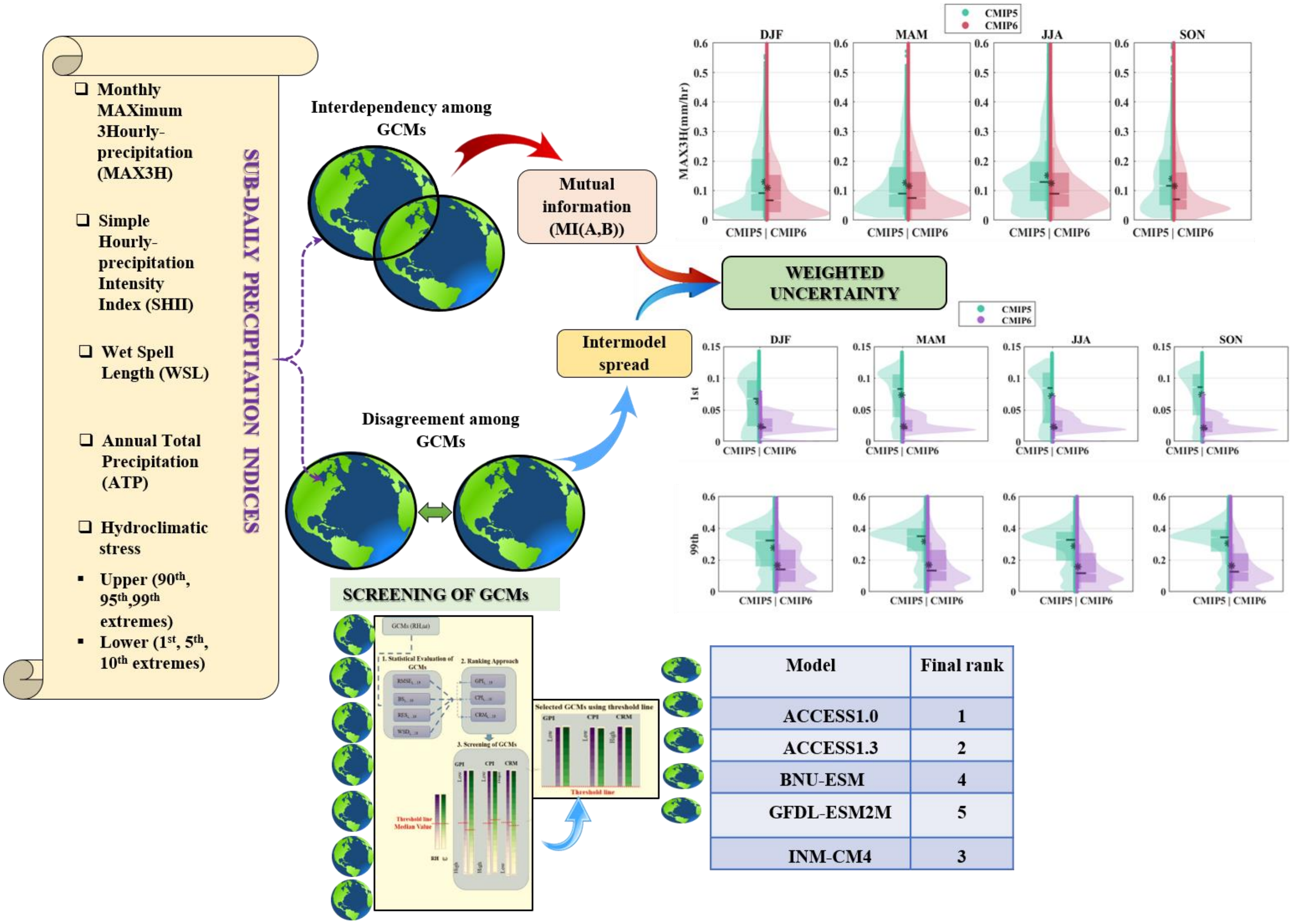
QUANTIFYING AND CONSTRAINING THE MODEL UNCERTAINTY IN FUTURE SUB-DAILY PRECIPITATION PROJECTIONS



ABSTRACT

Changes in climate as a result of rising greenhouse gas emissions, is one of the major concerns for earth's ecosystem, as it has induced frequent occurrences of extreme precipitation events all across the globe. More importantly, sub-daily precipitation is projected to intensify more rapidly with global warming, that in turn may lead to frequent disasters such as flash floods, landslides, etc. However, the precipitation projections from Global Climate Model (GCMs) are known to be highly uncertain, with an increasing magnitude at finer spatio-temporal scales. Given the fact that GCMs are ill equipped to represent extreme precipitation events as compared to convection permitting models, as the simulation of these fine-resolution phenomena are computationally expensive, it is unclear to what extent the results from such experiments can be applied globally. At the same time, it is known that due to warming climate, short intense spells will increase in the future over many parts of the world. Considering these two factors, GCMs remain the only option for obtaining a global perspective on the future intensification of sub-daily precipitation events. However, the associated uncertainty in GCM projections hinder their application in analysing the climate change impact on global scale. Therefore, the current study attempts for realistic quantification of the inherent uncertainty to improve the confidence in these projections, for the mitigation/adaptation applications. Given the availability of global sub-daily precipitation projections, uncertainty is quantified in the extreme indices proposed by INTENSE (INTElligent use of climate models for adaptatioN to non-Stationary hydrological Extremes) project. It will help in assessing the confidence to be put in different mitigation/adaptation measures pertaining to various water resources management activities such as drainage infrastructure systems, deriving future water management practices, risk management etc.

In the present study, the model uncertainty in sub-daily (3-hourly) precipitation extremes is estimated, by considering Coupled Model Intercomparison Project Phase (CMIP5/6) GCMs, during four different seasons for the near (2026-45) and far-future (2081-99) periods. While quantifying the uncertainty, often the possible dependency between the GCMs due to their shared common model code, literature, ideas of representation processes, parameterization schemes, evaluation datasets etc., are ignored. As this will lead to wrong conclusions, the inter-model dependency and the respective independence weights need to be considered, for a realistic quantification of uncertainty. Here, we present the detailed step-wise methodology of a "mutual information based independence weight" framework, that accounts for the linear and nonlinear dependence between GCMs and the equitability property. A brief illustration of the utility of this method is provided by applying it to the multi-model ensemble of CMIP GCMs. The weighted variance approach seemingly reduces the uncertainty about one GCM given the knowledge of another. Analysis of the heterogeneity in seasonal model uncertainty with various spatial domain-related aspects confirms the spatio-temporal variability of uncertainty. The model uncertainty on a particular region is found to be most sensitive to the observed magnitude of different precipitation characteristics of that location. Among the geophysical factors, elevation has more effect than land cover, on the uncertainty range.

The model uncertainty is found to be more dominant over tropical regions for precipitation projection. Therefore, there is need for selecting a reduced set of models having least biases so that effective decision on climate change mitigation and adaptation strategies can be taken based on the minimum possible outcomes of the future events. In this study, we tried to select the models based on their performance in relative humidity and vertical velocity since these variables plays an important role in precipitation simulation and hence contribute towards the intermodel spread. The models are evaluated by using various statistical performance measures and also ranked using

multiple approaches such as global performance indicator (GPI), compromise programming index (CPI) and comprehensive rating metric (CRM). The variability in the ranking is observed among the approaches. After selecting the better performing GCMs from the whole ensemble, the best possible subset of GCMs is chosen using Jenks natural breaks optimization algorithm.

Moreover, the quantification should be based on the newly released updated projections available from CMIP6 to enhance the effectiveness. The recently released CMIP6 includes a number of advances relative to its predecessor (CMIP5), in terms of horizontal resolution, physical parameterization schemes and concept of specifying shared socioeconomic pathways (SSPs). The question, however, is do these modifications indeed reduce the uncertainty in the projected sub-daily precipitation at global scales? The question is addressed by using CMIP5 and CMIP6 models for quantifying the uncertainty in sub-daily extreme precipitation indices for near and far-future period. The results indicate a noticeable reduction in the uncertainty in CMIP6 precipitation relative to CMIP5. It indicates the improved simulation of extreme indices in CMIP6 models relative to its predecessor (CMIP5). The study provides information about the regions, seasons and indices where model agreement is improved for CMIP6 models. Despite, uncertainty in models is inherent and this calls for further research on the sources of persistent systematic biases and a prerequisite for identifying GCMs with robust features that can accurately simulate observed sub-daily precipitation for future usage. Overall, the current study of uncertainty will be useful to understand the reliability that can be placed in the sub-daily precipitation projections. Such uncertainty quantification can do the needful in the field of risk assessment, by providing better interpretation of climate change impacts as well as for informed policies to mitigate the associated consequences.