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Assessing model dependency in CMIP5 and CMIP6 based on their spatial dependency structure with probabilistic network models

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Probabilistic network models (PNMs) are well established data-driven modeling and machine learning prediction techniques used in many disciplines, including climate analysis. These techniques can efficiently learn the underlying (spatial) dependency structure and a consistent probabilistic model from data (e.g. gridded reanalysis or GCM outputs for particular variables; near surface temperature in this work), thus constituting a truly probabilistic backbone of the system underlying the data. The complex structure of the dataset is encoded using both pairwise and conditional dependencies and can be explored and characterized using network and probabilistic metrics. When applied to climate data, it is shown that Bayesian networks faithfully reveal the various long‐range teleconnections relevant in the dataset, in particular those emerging in el niño periods (Graafland, 2020).

In this work we apply probabilistic Gaussian networks to extract and characterize most essential spatial dependencies of the simulations generated by the different GCMs contributing to CMIP5 and 6 (Eyring 2016). In particular we analyze the problem of model interdependency (Boe, 2018) which poses practical problems for the application of these multi-model simulations in practical applications (it is often not clear what exactly makes one model different from or similar to another model). We show that probabilistic Gaussian networks provide a promising tool to characterize the spatial structure of GCMs using simple metrics which can be used to analyze how and where differences in dependency structures are manifested. The probabilistic distance measure allows to chart CMIP5 and CMIP6 models on their closeness to reanalysis datasets that rely on observations. The measures also identifies significant atmospheric model changes that underwent CMIP5 GCMs in their transition to CMIP6.

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