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Empirical Distortions in Climate Networks

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Climate networks have become a popular tool for detecting complex structures in spatio-temporal data. However, they require to estimate correlation values on many edges based on limited and noisy time series. Consequently any constructed network likely contains false and missing edges. To measure how severely and in which ways estimated networks are distorted by statistical errors, we simulate time-dependent isotropic random fields on the sphere. We comprehensively present several patterns of distortion in local as well as global network characteristics and demonstrate which network construction methods enhance statistical robustness. When the data has a locally coherent correlation structure, spurious link bundle teleconnections and spurious high-degree clusters have to be expected. Anisotropic estimation variance can also induce severe biases into empirical networks. We validate all our findings with ERA5 reanalysis data. Finally, we explain why commonly applied resampling procedures are insufficient for evaluating statistical significance of network structures, and introduce a new ensemble construction framework that aims to alleviate most of the discussed shortcomings.