Geophysical Research Abstracts
Vol. 15, EGU2013-11666, 2013
EGU General Assembly 2013

Addressing deterministic and stochastic variance in statistical downscaling

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Downscaling seeks to add appropriate temporal and spatial variance to low resolution GCM predictor fields. In doing so, there is a deterministic component that is conditioned by the GCM, and a residual component which may be considered as undetermined and/or stochastic variance. For application in many sectors, such as hydrology, extreme events, or multi-year drought, a downscaling method that ignores aspects of the sources of variance risks providing significantly misleading results. Different statistical downscaling approaches deal with this situation in different ways. Analogue pattern-perturbation approaches inherently accommodate the range of temporal and spatial variance, although are vulnerable to spatial stationarity issues. Transfer function based downscaling is very good at capturing the deterministic component but may lose the high-frequency stochastic variance. Weather generator approaches are excellent at the capturing the spectrum of variance, but may require special approaches to handle the low-frequency deterministic variance, and their weather generator parameters may be particularly vulnerable to stationarity. Thus in practice, most statistical downscaling methods (should) include some explicit treatment to accommodate the spectrum of variance on different time scales, and that includes both the deterministic and stochastic components.

We present a method that uses the daily observed data as a sample set spanning the continuum of possibilities in an n-dimensional predictor-space. The nature of the distribution of predictand response values (the downscaling target variable, e.g. precipitation) within the local domain of a position within the predictor space describes the balance between deterministic and stochastic variability. A response distribution within a local domain of the predictor-space with high variance reflects a dominance of stochastic variability within that region of the predictor space. In contrast, a response distribution with low variance reflects a dominance of deterministic variability.

By explicitly using both information aspects within the predictor space a downscaled response time series may be created that captures the continuum of variance on different time scales. Because the method explicitly determines the mean deterministic and the stochastic components within the predictor space, the method allows for disaggregating the balance of variance as a function of predictor state, geographic place, and time. Examples of each of these disaggregations are presented, leading to a mapping of the mean ratio between the deterministic and stochastic variance across the Africa CORDEX region. The results show that the ratio has notable spatial and temporal dependencies, and highlights regional issues of downscaling robustness.