Metrics based on fuzzy similarities between lower dimensional features for intercomparison of reanalyses

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Lower dimensional features in climate models, are subsets of subspaces of striclty less dimensionality compared to the space where the model is designed and running. These can be for example curves in a two dimensional spatial domain (sea-ice boundary, the boundary of the dry-zone) but also, existence, inexistence or in a fuzzy case, the degree of occurrence of a phenomenon (e.g. Double ITCZ, atmospheric rivers) etc. These lower dimensional features very often carry climate information of high importance for decision makers. A reliable and useful climate model has to be able to reproduce important lower dimensional features in an accurate way. To compare the ability of various models to reproduce lower dimensional features, we need to develop new metrics, as root mean square error-based techniques penalize spatially inaccurate models that predict well lower dimensional features versus models that would not be able to reproduce them at all. To better address this deficiency, one needs to develop new metrics that better reflect the agreement of a model with the climate state. These metrics can rely on fuzzy set theory.

Intuitively, a fuzzy set is a set with uncertain boundaries and it can be mathematically represented as a function with the following interpretation: $A(x)$ represents the membership grade of element x in the fuzzy set A, where $A(x) = 1$ means complete membership of x in the fuzzy set A, $A(x) = 0$ means complete non-membership of x in A, while intermediate values show partial membership of x in A. As a first step of our method we fuzzify certain lower dimensional features by transforming them into fuzzy sets. This allows a better quantification of uncertainty. For example the sea-ice boundary is transformed from a curve into a fuzzy region of sea-ice boundary by taking into account uncertainties. In the next step we can compare the fuzzy features using fuzzy similarity measures, that resolve the above mentioned drawback of root mean square error-based comparison. We propose a set of fuzzy metrics on a variety of lower dimensional features, as a tool for intercomparison of reanalyses.