Predictability analysis and validation of a low-dimensional model – an application to the dynamics of cereal crops observed from satellite

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The global modeling approach aims to obtain parsimonious models of observed dynamics from few or single time series (Letellier et al. 2009). Specific algorithms were developed and validated for this purpose (Mangiarotti et al. 2012a). This approach was applied to the dynamics of cereal crops in semi-arid region using the vegetation index derived from satellite data as a proxy of the dynamics. A low-dimensional autonomous model could be obtained. The corresponding attractor is characteristic of weakly dissipative chaos and exhibits a toroidal-like structure. At present, only few theoretical cases of such chaos are known, and none was obtained from real world observations. Under smooth conditions, a robust validation of three-dimensional chaotic models can be usually performed based on the topological approach (Gilmore 1998). Such approach becomes more difficult for weakly dissipative systems, and almost impossible under noisy observational conditions. For this reason, another validation approach is developed which consists in comparing the forecasting skill of the model to other forecasts for which no dynamical model is required. A data assimilation process is associated to the model to estimate the model's skill; several schemes are tested (simple re-initialization, Extended and Ensemble Kalman Filters and Back and Forth Nudging). Forecasts without model are performed based on the search of analogous states in the phase space (Mangiarotti et al. 2012b). The comparison reveals the quality of the model's forecasts at short to moderate horizons and contributes to validate the model.

These results suggest that the dynamics of cereal crops can be reasonably approximated by low-dimensional chaotic models, and also bring out powerful arguments for chaos. Chaotic models have often been used as benchmark to test data assimilation schemes; the present work shows that such tests may not only have a theoretical interest, but also almost direct applicative potential. Moreover, other global models could be obtained for other regions. The model considered here is not a particular case which highlights the usefulness to investigate and to widen this field of modeling and research.

References:

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