Dear Sir,

Proper models help us to analyse and understand the behaviour of real systems, as well as to predict them in different situations. There are some parameters in each model that should be tuned in order to increase the similarity of the model to the real system as much as possible. In models of chaotic systems, changing these parameters not only changes model behaviour quantitatively, but also may change it qualitatively (i.e. may cause bifurcation). In these cases, before anything, we need an indicator to show the amount of this similarity.

In previous studies, some methods have been introduced for this purpose, most of them under the topic of synchronization, which seem to have some limitations. In Tao et al. (2007), for example, the mean square error between real time series and model time series has been used as an indicator for the similarity between the system and its model. For this purpose, initial conditions of the real signal are calculated and then fed to the model to generate the rest of the signal.

Obviously, it is not possible to know the exact value of real signals due to the measurement and observation error, noise, etc. (the error may be very small, but not zero). Consequently, since chaotic systems are sensitive to initial conditions and may have random-like behaviour, even if there is no mismatch between the system and its model, the correlation between their time series will be zero, which means that they have no similarity in time space (Hilborn 2001).

Another way, which is used in more studies, is that the system and the model are controlled simultaneously, and then in the new situation, which is not in chaotic mode, parameters are estimated (Lan and Li 2010). However, this method is not useful for uncontrollable systems such as weather and biological systems.

In the field of chaos and complex systems, some tools have been introduced to extract quantitative features of the chaotic behaviour. From them, the largest Lyapunov exponent and correlation dimension can be outlined (Hilborn 2001). In the first glance, it may seem that we can use these tools as similarity indicators. Although these are more meaningful than the previous ones, they have some limitations as well. For example, many sets of parameters with the same largest Lyapunov exponent can be found for a single chaotic system such as the logistic map (Hilborn 2001). It means that if we know values of these indicators in a real system, there will be many sets of model parameters that exhibit the same values of those indicators. Therefore, it will be difficult to choose the best parameter set.

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Although chaotic systems have pseudo-random behaviour in time, they are ordered in phase space and have a specific topology. In other words, there exists a strange attractor from which the system trajectories do not escape, even though the initial conditions change. We propose that for such parameter estimation in chaotic systems, a novel similarity indicator should be designed according to the similarity between the attractors of the system and the model, i.e. the similarity in phase space instead of time. Using Poincaré section may be a good tool for this purpose. If so, there is no concern about the sensitivity to initial conditions. Moreover, it is possible to estimate parameters in a wide range of systems especially uncontrollable ones like living organisms (Hindmarsh and Rose 1984).

References