NOTES AND CORRESPONDENCE

Comments on ''The Southern Oscillation as an Example of a Simple, Ordered Subsystem of a Complex Chaotic System''

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As Dr. Steppeler states in the beginning of his paper (Steppeler 1997), infinite dimensional spatially extended systems that are described by a set of partial differential equations may often contain subsystems characterized by a much smaller dimensionality. Back in 1989, Tsonis and Elsner in an endeavor to explain the different estimated dimensions in weather and climate suggested the idea of subsystems in the climate system that operate at different space and/or time scales. Lorenz (1991) in his study of low dimensions in weather and climate concurred with the Tsonis and Elsner (1989) suggestion of subsystems. Moreover, the possibility that El Niño–Southern Oscillation (ENSO) exhibits nonlinear structure has been suggested by many in the past (Vallis 1986; Hense 1987; Tsonis and Elsner 1992; Bauer and Brown 1992; Elsner and Tsonis 1993). That ENSO may be a subsystem of the climate system has been explicitly stated in Tsonis (1996).

It appears that Dr. Steppeler is unaware of this pertinent literature as he makes no reference to any of the above studies. As such, his study misses a fundamental aspect of the general framework of the theory of subsystems: that of the connectivity of a particular subsystem to the rest of the system. As explained in Tsonis (1996) in a spatially extended system, subsystems ''crystalize'' at different time–space scales and each of the subsystems is connected to all other subsystems. However, the degree of connectivity that determines the degree of communication between subsystems may vary. This is a crucial aspect since if the connectivity of a subsystem to the rest of the subsystems is weak, then the subsystem may exhibit low-dimensional chaos or even regular behavior. An example of such a subsystem is the one that describes the orbits of the planets in our solar system. If the connectivity is strong, the input of the other subsystems becomes important as it ''contaminates'' the low-dimensional or regular behavior, thus affecting the predictability of the subsystem in question. This is probably the category into which most subsystems of the climate system, including ENSO, fall. In fact, Tsonis and Elsner (1996) and Tsonis and Elsner (1997) have presented experimental evidence on how the predictability of the subsystem ENSO may be affected by signals from the ''grand'' climate system (such as global temperature). Finally, if the connectivity is strong, then the input from other subsystems affects the subsystem greatly. In such cases the behavior of the subsystem approaches the stochastic regime and, if an outside fluctuation is larger than some critical value, self-organization may ensue. The above general framework explains all the various processes observed in nature: regular behavior, low-dimensional chaos, contaminated chaos (signal plus noise), and self-organization.

In his study Dr. Steppeler ignored the aspect of connectivity between subsystems. As such he assumed that the connectivity is zero, which is likely unrealistic. Consequently, while Dr. Steppeler's study is in the right direction it fails to properly treat the problem. Possibly a modification of his equations to include the effect of connectivity will be more promising.

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