



Similarities between the Lorenz Related Systems

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Abstract: In this paper, the dynamic behaviour of all the Lorenz related systems is examined in a previously unexplored region of parameter space. The Lorenz, hidden chaotic, Chen and broken butterfly attractors can be generated at any desired size, with different equilibria. We focus on the attractors smaller or larger than the original one, we call them *mini* and *maxi*, and study their global dynamic behaviour to demonstrate that they are similar or equivalent to the original chaotic attractor. We finally examine their phase portraits, bifurcation diagrams, the largest Lyapunov exponents and their multiscale entropy MSE_{1D} . The analysis results show that the mini, original and maxi Lorenz related attractors have the same MSE_{1D} values and are independent of the scale factor. We can conclude that the MSE_{1D} analysis can be used successfully to quantify the complexity of the dynamic response.

Keywords: *attractors; bifucation; equilibria; Lyapunov; entropy.*

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1 Introduction

Since the Lorenz system was discovered, chaos and many phenomena in nonlinear dynamic systems have been developed and studied. This allowed to explore more chaotic systems and to discover new chaotic systems with a more complex dynamic behaviour. Chen and Lü [1] found a similar but not equivalent chaotic attractor, the dual of the Lorenz system. After that, Lü [2] reported a new chaotic system which is the transition between the Lorenz and Chen systems. [3] presented a comparative analysis of the Lorenz and Chen systems in order to understand better what distinguishes them. It is

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