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A hyperchaotic multi-wing attractor of a 4-D atmospheric system and its chaos control

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1. ABSTRACT

Research into the dynamic aspects related to environmental phenomena has attracted considerable attention across various scientific disciplines. One prominent environmental phenomenon of concern is global warming, which has detrimental effects on our ecosystem. The primary culprits behind global warming are the excessive levels of greenhouse gases and rising surface temperatures. Given the significance of this climatic event, our study has connected the hyperchaotic 4D model to three key climatic components: sea temperature, surface temperature, sea ice, and sea water. We have represented these relationships in the form of a Caputo fractional differential equation and conducted a thorough analysis of their dynamics. Our investigation extends to several theoretical aspects, including the examination of the existence and uniqueness of the solutions obtained. Furthermore, we have developed two distinct sliding mode controllers to manage chaos within this fractional-order system. We have scrutinized the impact of these controllers in the presence of uncertainties and external disturbances. In the process, we have derived new sets of controlled equations, accounting for both deterministic dynamics and those influenced by uncertainties and external disturbances. The global stability of these newly introduced systems has also been established. Our analysis encompasses both commensurate and non-commensurate fractional-order derivatives. To confirm the chaotic behaviour of the system, we have employed the Lyapunov exponent and constructed bifurcation diagrams with respect to the fractional derivative. Through numerical simulations, we have identified specific parameter values that lead to chaotic behaviour within the system. Subsequently, we have empirically validated the theoretical claims regarding the influence of the controller on the system dynamics through these simulations.