Investigating Chaotic Convection Using a Lorenz Water Wheel and a Model of the Lorenz Attractors in R

Kummel, Kathryn (School: William J. Palmer High School)

For much of the history of science it has been postulated that the behavior of dynamical systems, such as atmospheric circulation via convection, can be fully predicted once the parts are correctly described and the initial conditions are correctly measured. The introduction of non-linear dynamics and resulting study of chaos upended this view. The hallmarks of chaotic dynamics are unpredictable non-periodic bounded fluctuations and extreme sensitivity to initial conditions where a slight change in the initial conditions results in exponentially divergent trajectories. This study presents an investigation of chaotic dynamics in atmospheric convection approximated by the Lorenz water wheel and a set of three differential equations. A water wheel was constructed from a bicycle wheel with a set of eight draining cups arranged along its perimeter. The cups were filled by a spout at the top of the wheel. When cups with large drainage holes were used (five experimental trials), the wheel attained a stable angular velocity. However, when cups with small drainage holes were used in a set of five experimental trials the wheel displayed chaotic dynamics including unpredictable fluctuation of velocity, abrupt stops, and reversal of the direction of spin. The author also constructed a mathematical model using three coupled differential equations in R describing the variation in angular velocity, the horizontal gradient of distribution of mass and the vertical gradient of distribution of mass. The resulting system developed clear chaotic dynamics. The chaos was lost once larger drainage rate was used, mirroring the physical experiment.

Awards Won:
Second Award of $2,000