The Lorenz Lecture 2005:
The Earth as a Complex System, and a Simple Way of Looking at It

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As observations of the Earth System expand, so does our desire to capture all its intricacies into a highly complex, coupled model of atmosphere and biosphere, cryosphere and hydrosphere, lithosphere and other spheres. At the same time, though, deeper insights and predictive understanding advance as much or more through highly simplified, conceptual models of such a system's complex behavior.

After illustrating some of the observed complexities, I will present a novel mathematical framework that allows one to represent, and maybe understand, complex, highly nonlinear feedback networks. Boolean Delay Equations (BDEs) are semi-discrete dynamical models with Boolean-valued variables that evolve in continuous time. Systems of BDEs can be classified into conservative or dissipative, in a manner that parallels the classification of ordinary or partial differential equations. Certain conservative BDEs exhibit growth of complexity in time. They represent therewith metaphors for biological evolution or human history.

Dissipative BDEs are structurally stable and exhibit multiple equilibria and limit cycles, as well as more complex, fractal solution sets, such as Devil's staircases and "fractal sunbursts." All the solutions of dissipative BDEs have stationary variance. BDE systems of this type, both free and forced, have been used as highly idealized models of climate change on interannual, interdecadal and paleoclimatic time scales.

BDEs are also being used as flexible, highly efficient models of colliding cascades in earthquake modeling and prediction, as well as in genetics. Some of the climatic and solid-earth applications will be briefly illustrated, and certain issues about massively parallel computation and operating system synchronization will be raised.