Linking Chaos Theory to Jupiter’s Great Red Spot

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Chaos Theory’s Emergence

Chaos Theory emerged in the 1800’s as “cracks” appeared within Newton’s Theory

- Reality, Quantum Mechanics, Chaotic Systems
- Henri Poincare → 3-Body Problem
- Birkhoff, Kolmogorov, Cartwright & Littlewood, Smale
- Edward Lorenz → Chaos application to weather prediction
- Mitchell Feigenbaum → Chaotic Transition of Dynamic Systems
- Benoit Mandelbrot → Fractal Dimensions
A Chaotic System

Three elements must be present in a system for it to be chaotic

1. The periodic points of the function are dense
2. The function is transitive
3. The function is sensitively to its initial conditions

In order for a system to transition to chaos one of four conditions must be met

1. Period-Doubling Cascades must be present
2. Intermittency transition to chaos
3. Crises (Subcritical Instability)
4. Sequence of Bifurcations
Applications of Chaotic Systems

Nature
• Weather
• Structures
• Population Evolution
• Meteorology

Medicinal Science
• Organ Functions

Computer Science
Chemistry
Engineering
• Vibrations
  • RF
  • Orbits
Jupiter’s Great Red Spot

The Great Red Spot (GRS) – An atmospheric storm that has persisted on Jupiter for over 300 years. The GRS has cycles of shrinkage and expansion as well as color change phases.
Early Theories about the Great Red Spot

Some early Theories about the GRS included:

- Solid structure extending from the surface of the planet
- Floating “body” on ocean like of Jupiter
- Created by Taylor Columns
- Free eddies – merger of jet streams into larger storms
Chaos of the Great Red Spot

- Chaotic Mixing
- Fractal Dimension
- Contour Dynamics
Chaotic Mixing and the GRS

Chaotic Mixing occurs when a fluid tracer produces a fractal image, this is usually due to an exponential growth in fluid filament.

Chaotic Mixing Within Jupiter’s Atmosphere
- Mixing of Heat
- Chemical Mixing
Julia Set: Siegel Disk: Great Red Spot

The Julia Set Fractal was generated for $c = -0.391 - 0.587i$. This generates the siegel disk. The siegel disk is the figure on the left where the dynamics are based on irrational rotation.
Contour Dynamics of the GRS: Combining Fractal with Chaotic Mixing

Use of chaotic mixing and fractal dimensions to look at how fluids form over time related to various elements such as temperature, elevation, altitude, vorticity, etc.

\[ V^2u = V(V'u) - V \times \tau. \]
How Have these Scenarios Helped Solve the GRS Mystery?
Resources


• Linda Sundbye. Chaos & Nonlinear Dynamics, MTH 3400. Metropolitan State University of Denver, 2014