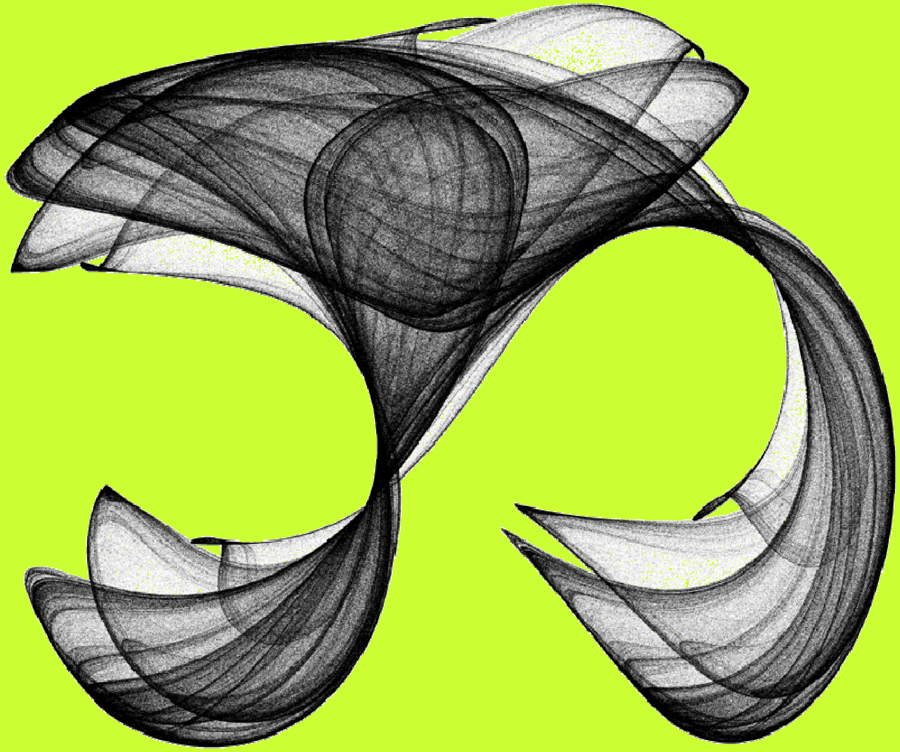
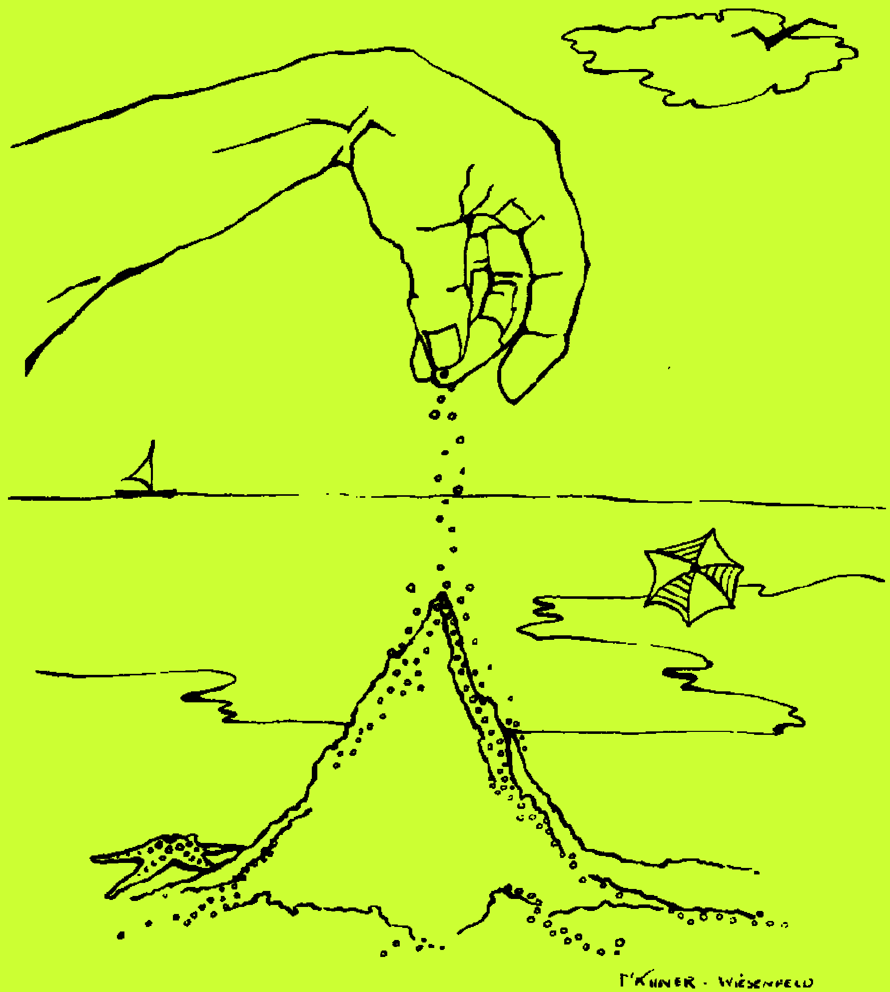
Attractors



Strange and Otherwise

SOC
Self Organized Criticality



Attractors

1. *To cause to draw near or adhere by physical force: Magnetic poles are attracted to their opposites.*
2. *To arouse or compel the interest, admiration, or attention of: We were attracted by the display of lights.*
3. *A set of physical properties toward which a system tends to evolve, regardless of the starting conditions of the system.*

Attractors: Strange and Otherwise

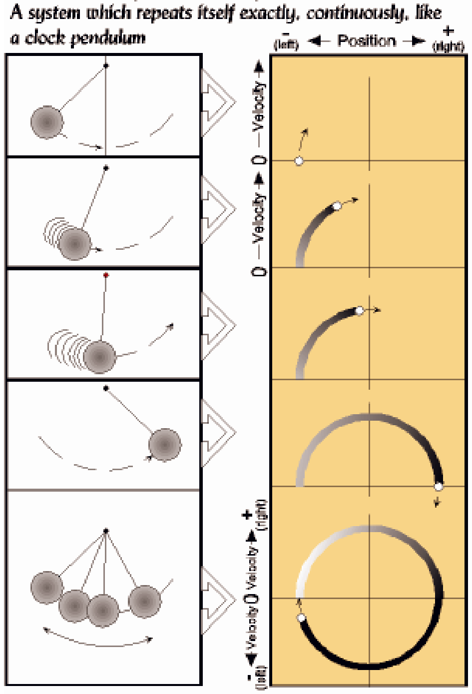
Attractor - In mathematics, an attractor is a region of phase space that "attracts" all nearby points as time passes. That is, the changing values have a trajectory which moves across the phase space toward the attractor, like a ball rolling down a hilly landscape toward the valley it is attracted to.

Phase Space - imagine a standard graph with an x-y axis; it is a phase space. We plot the position of an x-y variable on the graph as a point. That single point summarizes all the information about x and y. If the values of x and/or y change systematically a series of points will plot as a curve or trajectory moving across the phase space. Phase space turns numbers into pictures. There are as many phase space dimensions as there are variables. The strange attractor below has 3 dimensions.

P 38

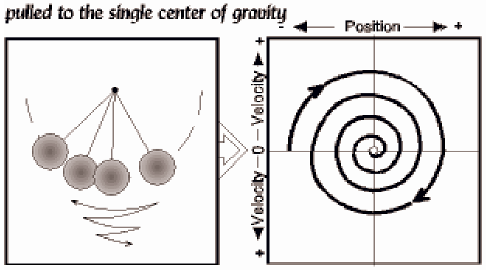
Limit Cycle (or Periodic) Attractor

A system which repeats itself exactly, continuously, like a clock pendulum



Fixed Point (or Steady State) Attractor

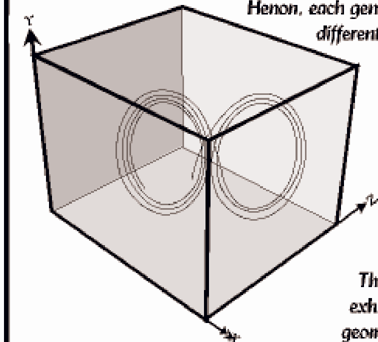
The attractor is a single point; all trajectories spiral in toward it, like a pendulum slowing down and coming to rest, pulled to the single center of gravity



Strange (or Complex) Attractor

A strange (or chaotic) attractor is one in which the trajectory of the points circle around a region of phase space, but never exactly repeat their path. That is, they do have a predictable overall form, but the form is made up of unpredictable details.

More important, the trajectory of nearby points diverge rapidly reflecting sensitive dependence. Many different strange attractors exist, including the Lorenz, Julian, and Henon, each generated by a different equation.

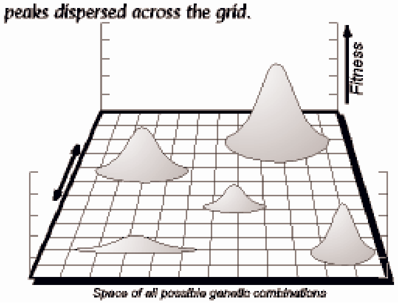


The attractors exhibit fractal geometry.

Attractors in General

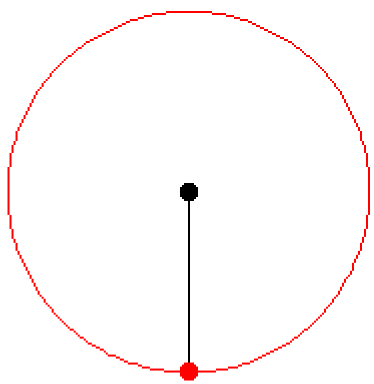
We can generalize an attractor as any state toward which a system naturally evolves. For example, biological fitness is an attractor toward which species evolve.

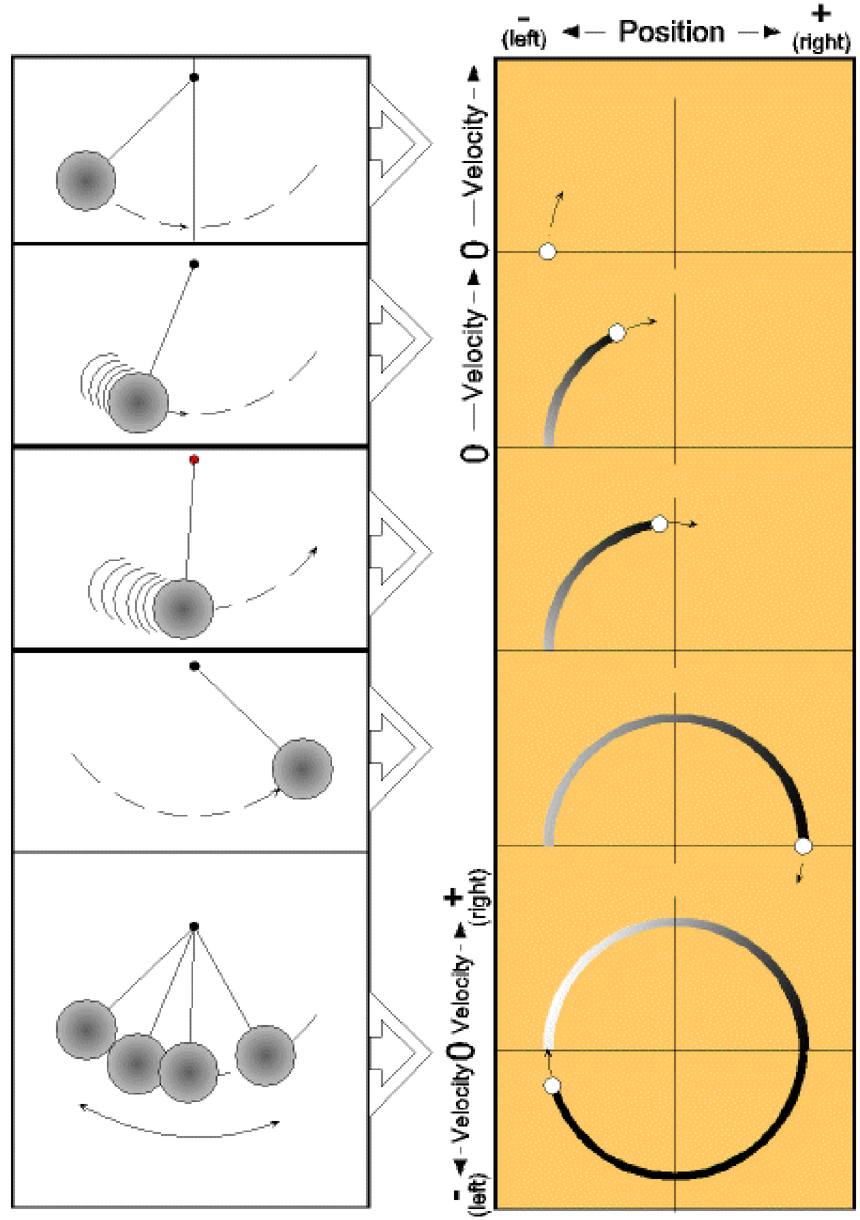
Biological fitness can be graphed by the Sewell Wright fitness landscape diagram below, where different character states are the horizontal axes, and fitness is measured by the vertical axis. Different levels of fitness are indicated by the peaks dispersed across the grid.



Real Space and Phase Space

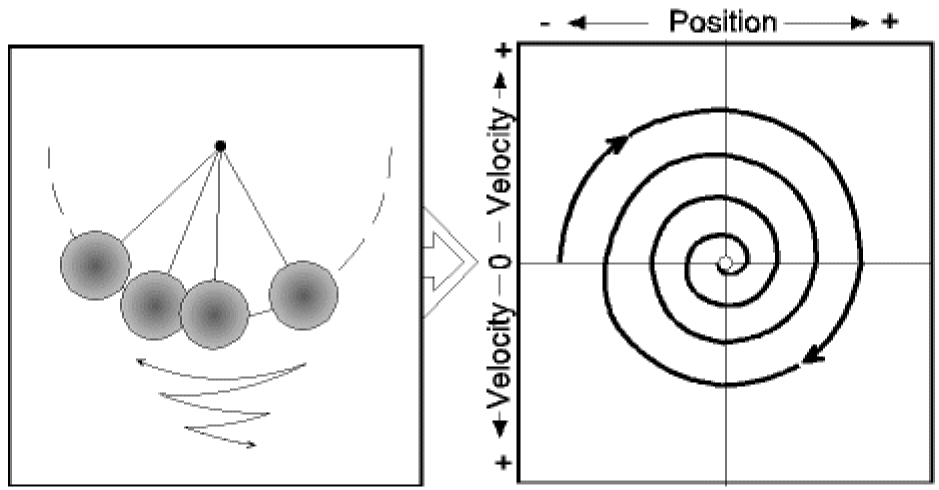
Limit Cycle Attractor



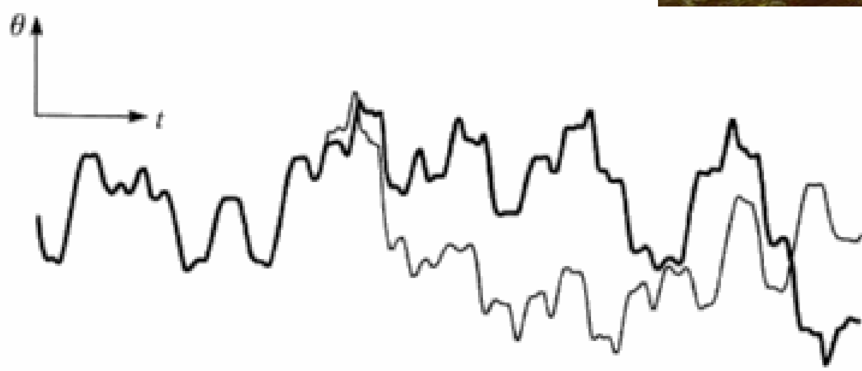


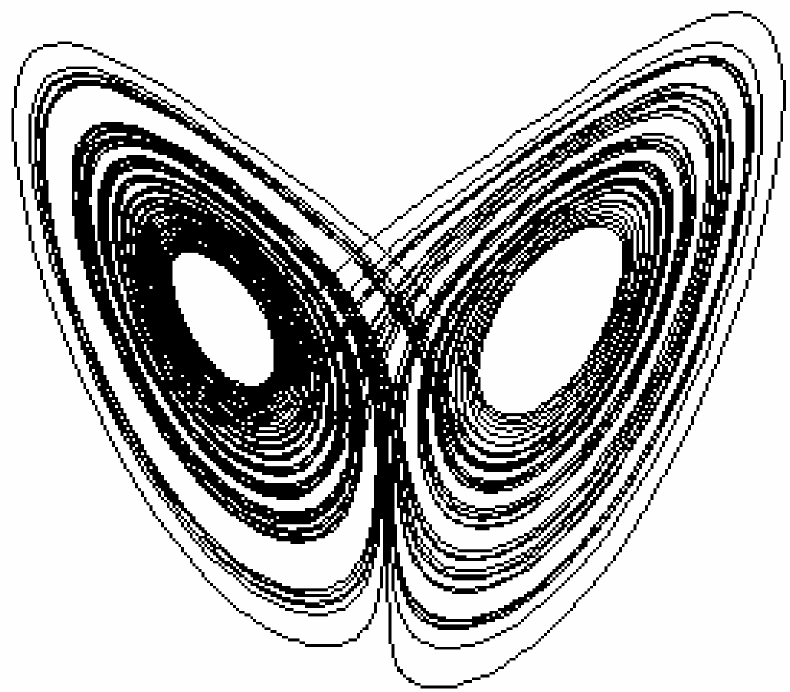
Real Space and Phase Space

Point Attractor



Sensitive Dependence on Initial Conditions:

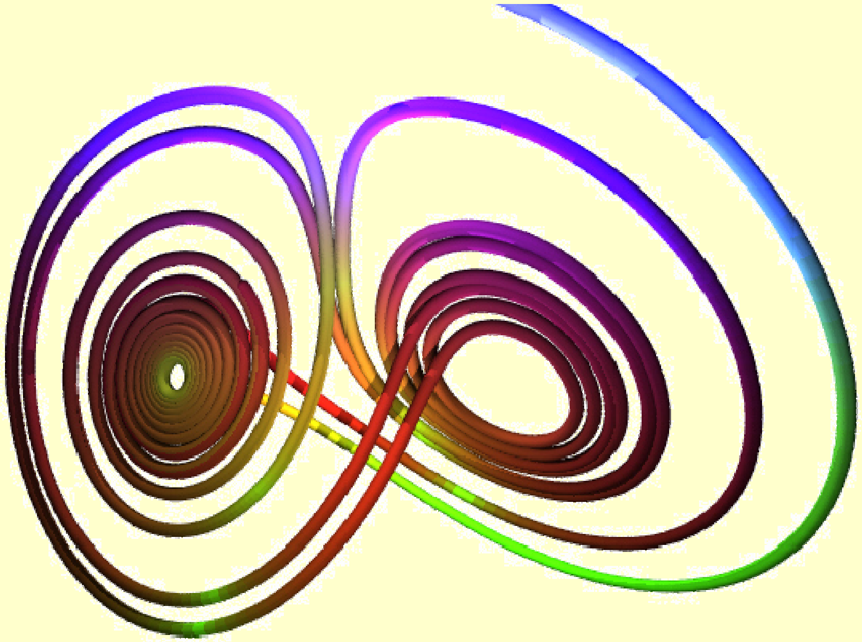


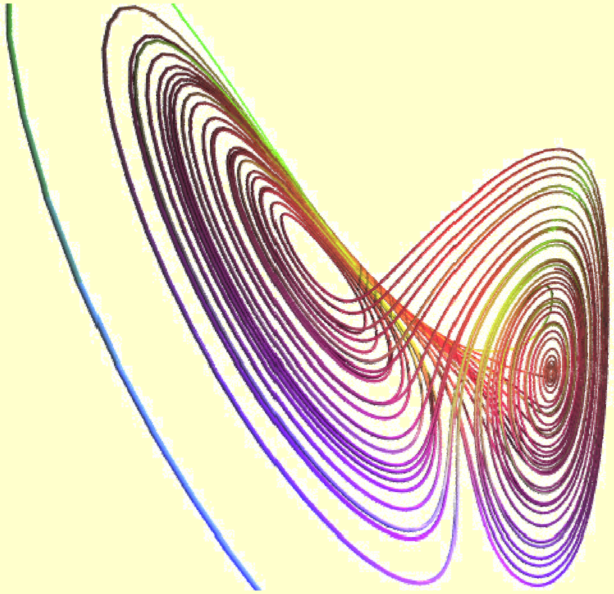


When he came back he was stunned to find that the
But after a period of time it diverged. Figure 6 show
time. When he thought about it, Lorenz realized tha
rounded off from the numbers in the actual comput
small amount of rounding error would be insignifica
show a great deal of sensitivity to initial conditions.

Oscillating Systems

The Lorenz Strange Attractor system



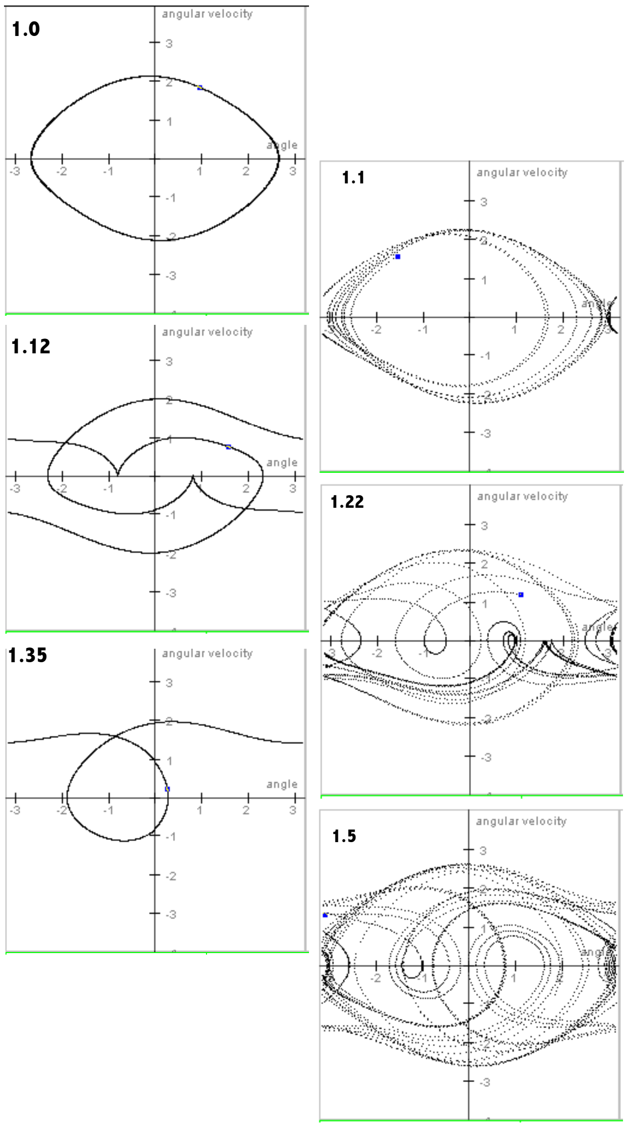


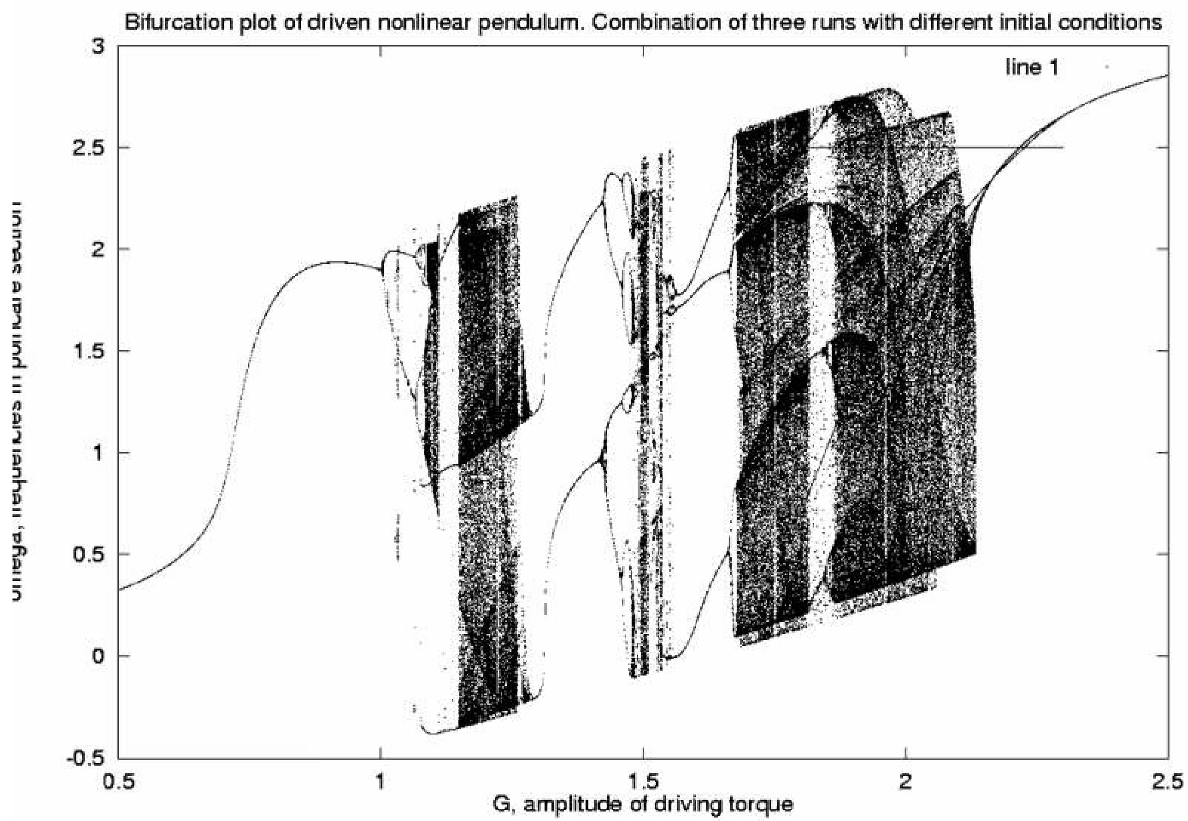
Run Lorenz Attractor

Lorenz Applet

http://www.csounds.com/mastering/em_10.html

The Pendulum as a Strange Attractor





http://hubble.physik.uni-konstanz.de/jkrueger/phsi362/

Hysteresis, or Bistable Behavior

The Ubiquity of Oscillating Systems in the World

One of the very common phenomena in the world are systems that oscillate between two or more states, like . . .

1 The, the daily heating and cooling cycle,

2 Or, the seasonal cycles,

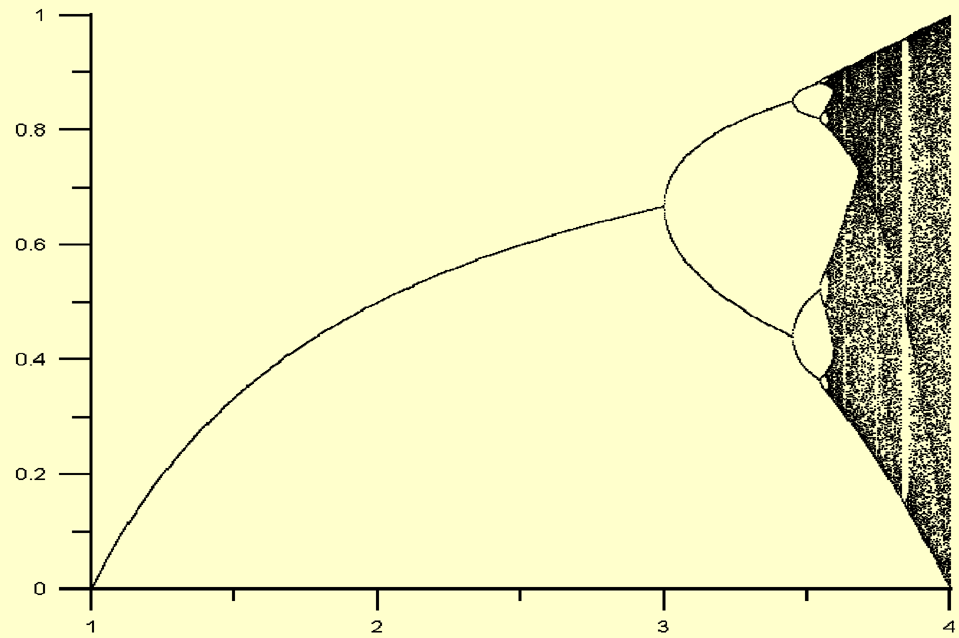
3 Or cycles of populations,

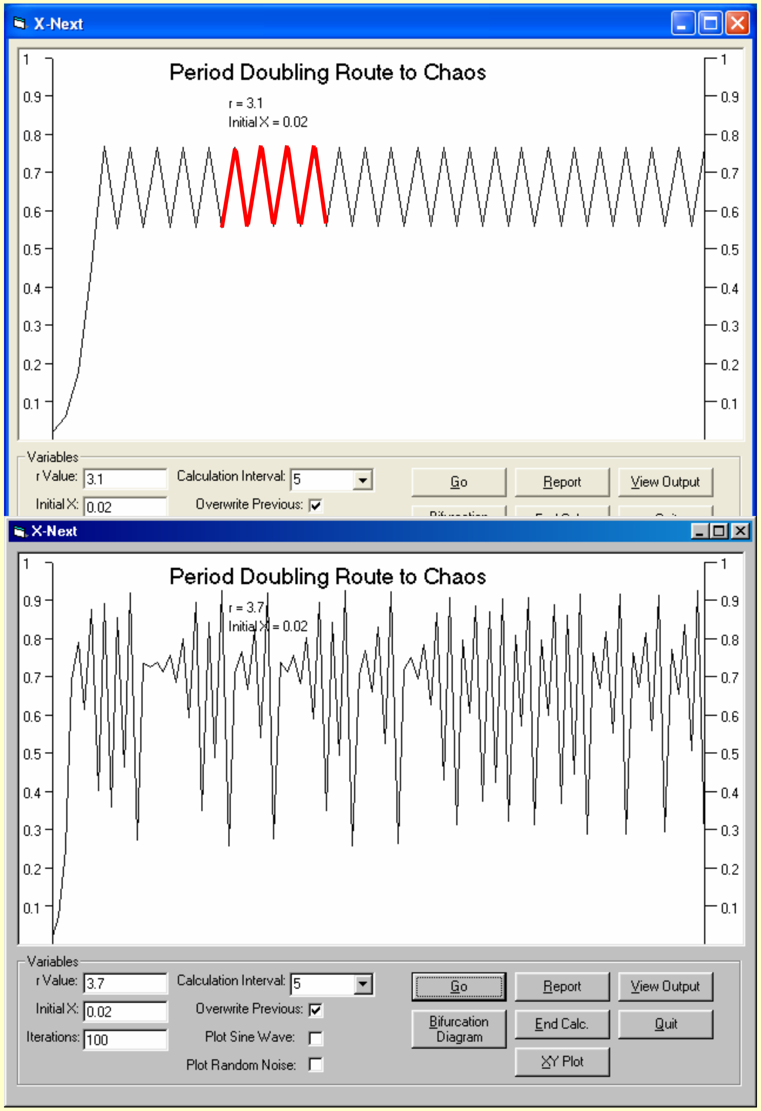
4 Or waves of economic expansion followed by recession.

5 Or, sleeping and waking.

Oscillating Systems

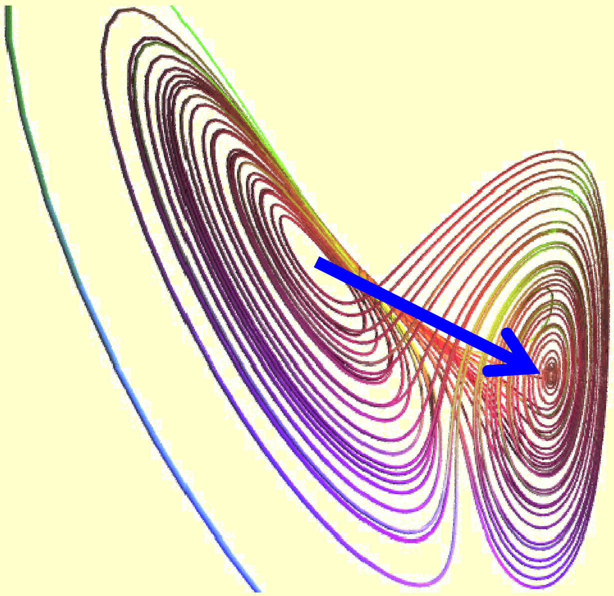
OR, AS IN THE LOGISTIC SYSTEM

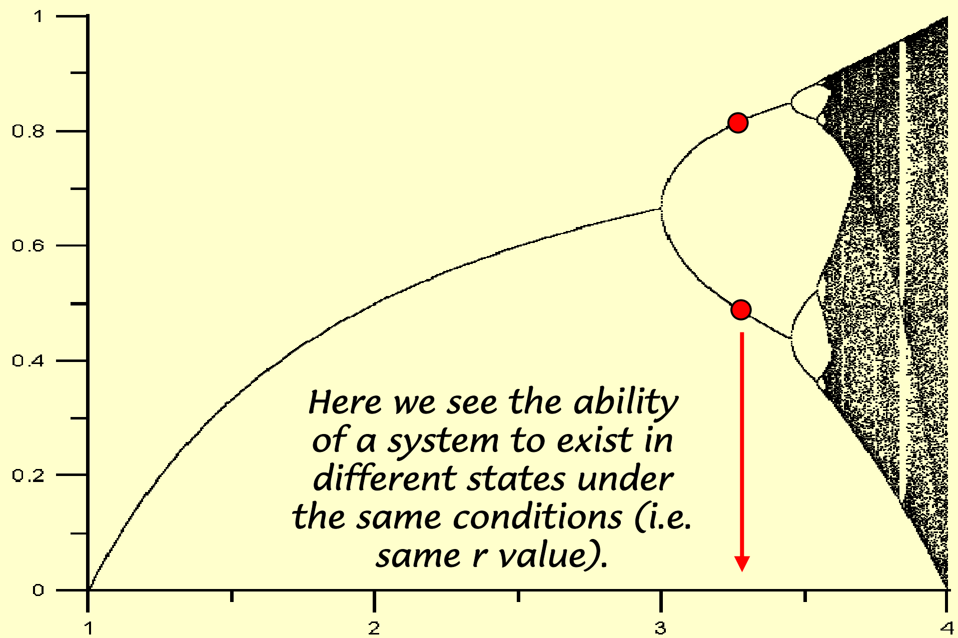




Oscillating Systems

Which leads to the more pertinent question - when a system has more than one path available to it, and periodically switches between them, when and how does it choose to make the switch?





Hysteresis

a.k.a.

Bistable Behavior

Has two different meanings, and we need to understand both.

1. The lag in response between a cause and its effect.

AND

2. The ability of a system to exist in different states under the same conditions.

Hysteresis as the Lag Between Cause and Effect

Description One

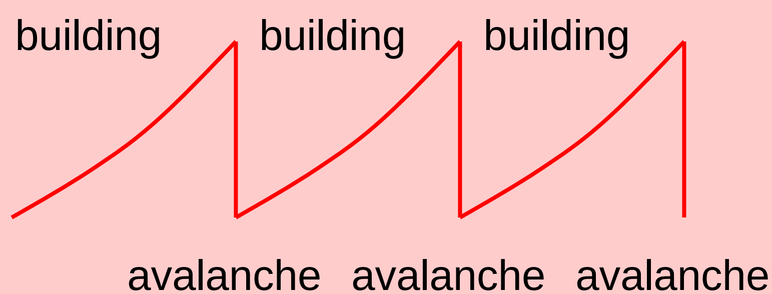
The sand pile builds . . . grain . . . by grain . . .

by grain . . . by grain . . . by grain . . .

by grain . . . by grain . . . by grain . . .

building toward the critical state . . .

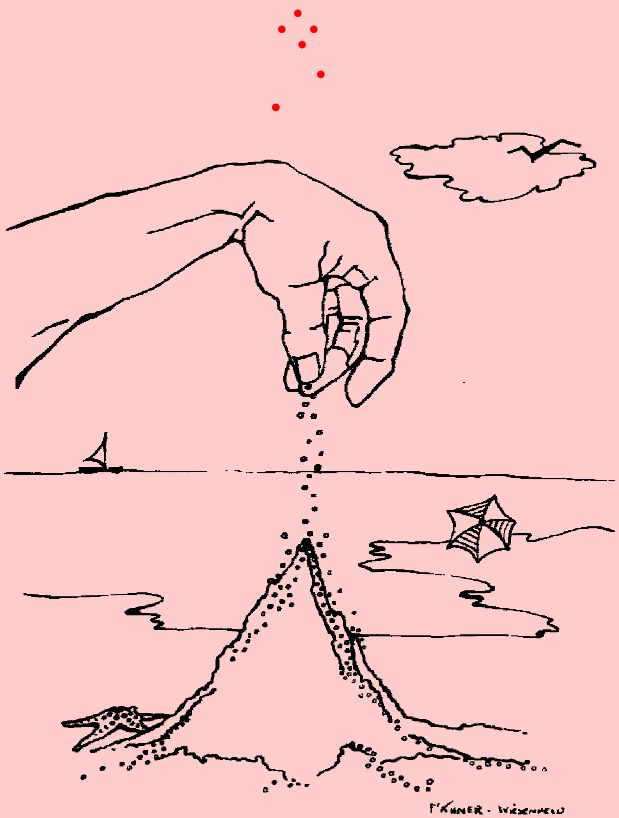
Where it avalanches



Thus we see there is a lag between cause (accumulation of individual sand grains), and the effect (avalanche).

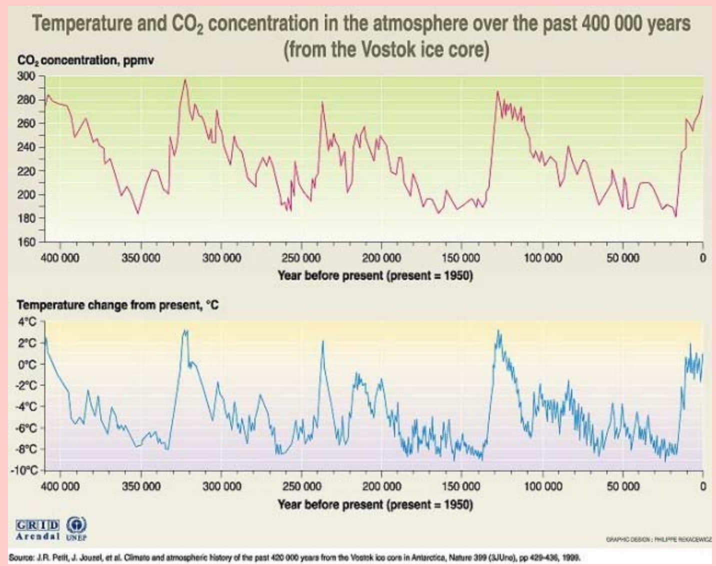
Hysteresis as the Lag Between Cause and Effect

Fractal sand supply



Now, imagine the sand supply follows a power law (or is fractal), with different numbers of grains falling at different times.

Avalanches will also be fractal, and follow a power law distribution.

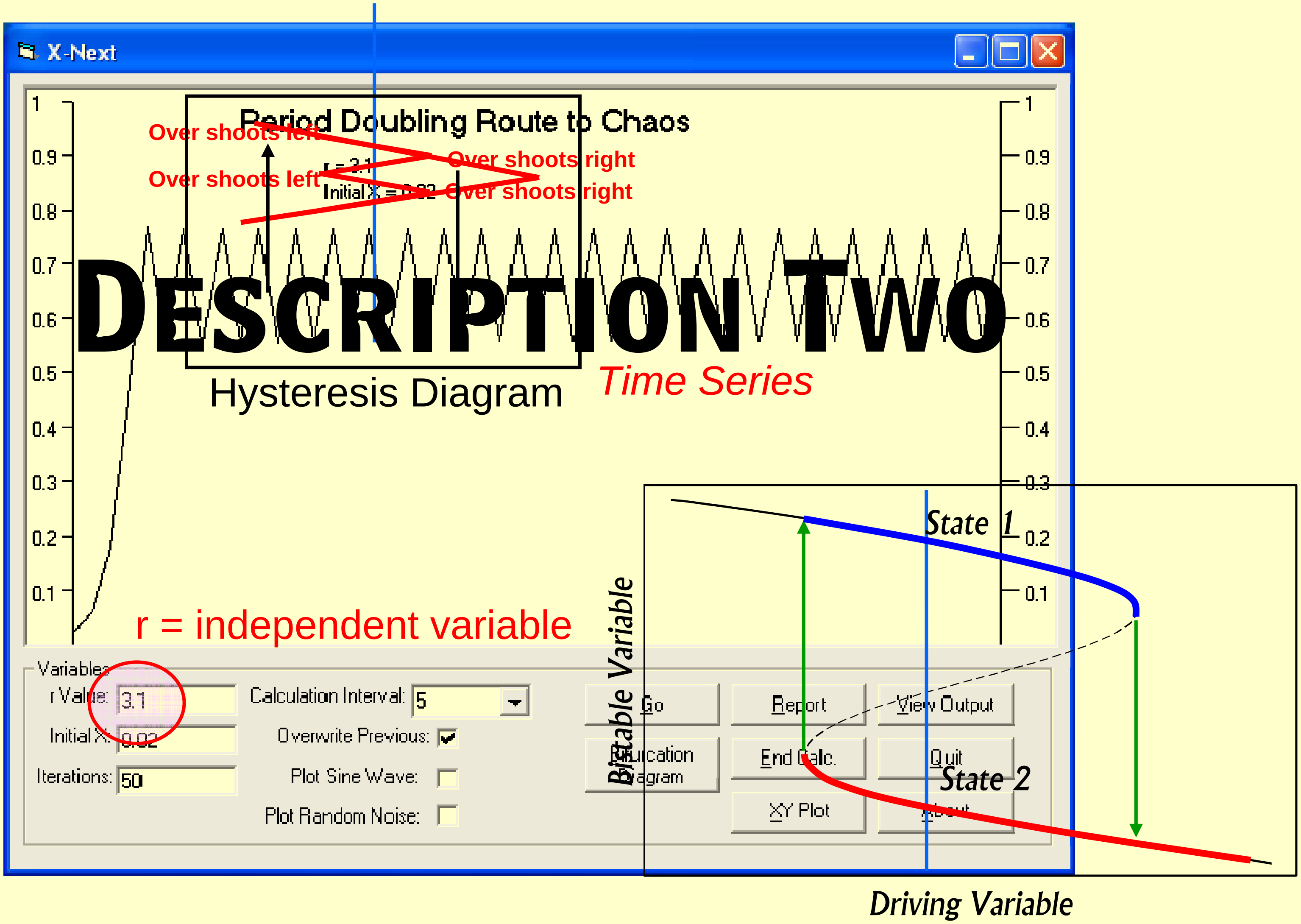


Earth Temp. curve over the past 400,000 years

http://atlas.gc.ca/maptexts/topic_texts/english/images/TemperatureCO2.jpg

Bistable – How a System Can Exist In Distinctly Different States Under the Same Conditions

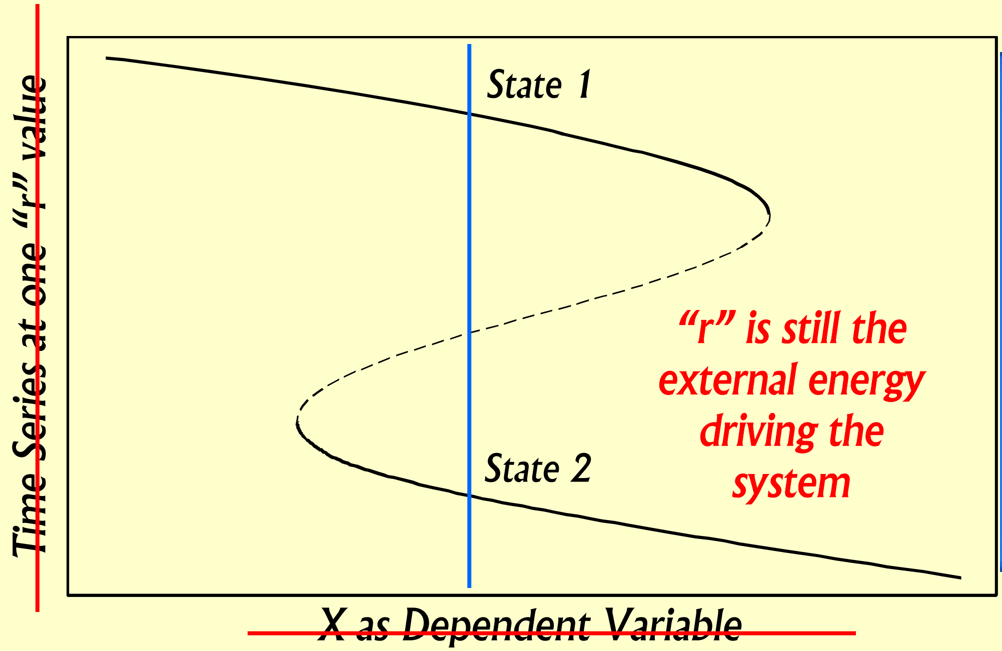
X = dependent variable

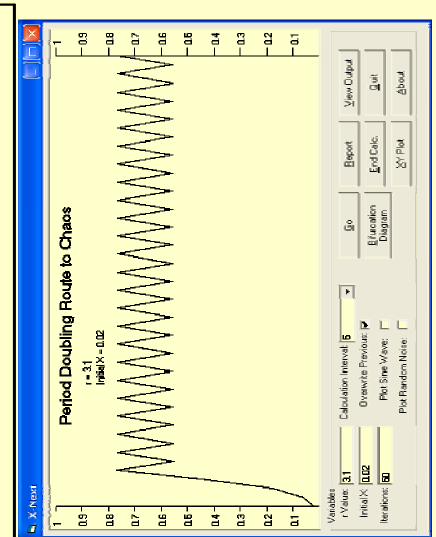


Bistable – How a System Can Exist In Distinctly Different States Under the Same Conditions

First, a little slight of hand . . .

Time Series is now the Bistable Variable





X is now the Driving Variable

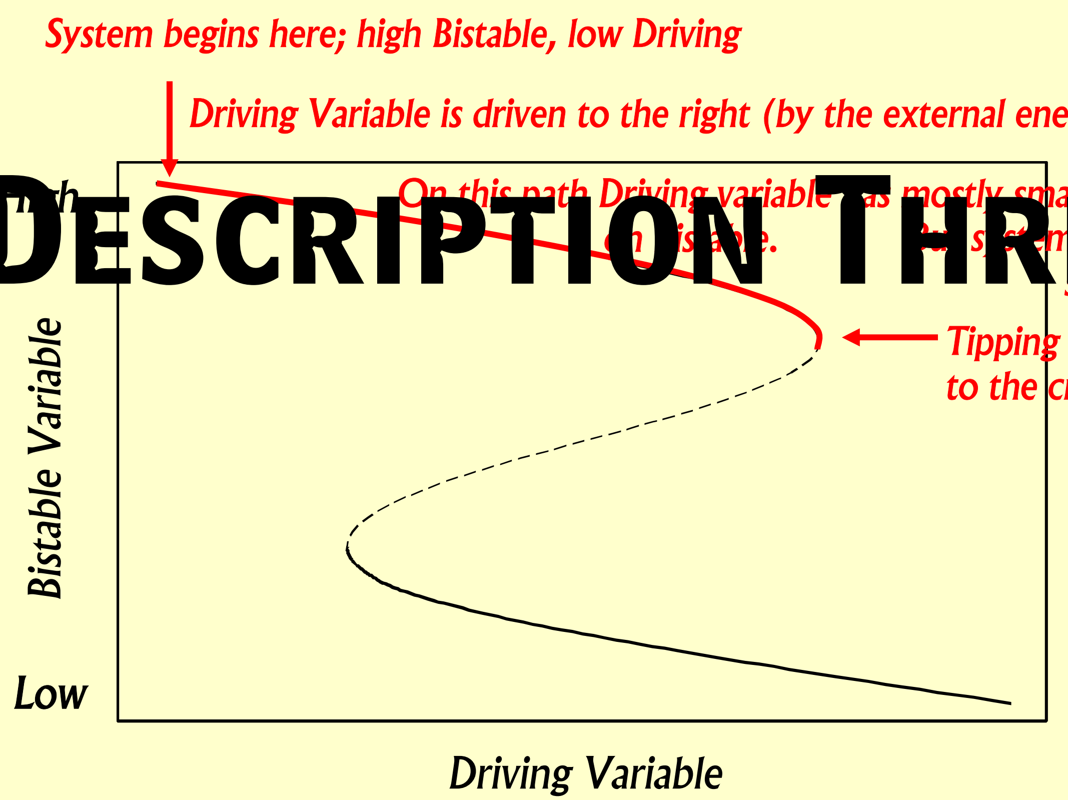
Bistable behavior requires that two variables be coupled in a positive/negative feedback loop.

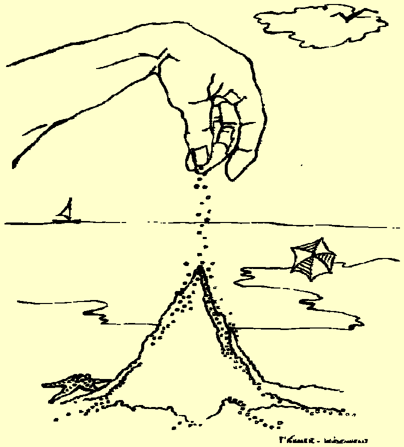
- A rise in one variable causes the other variable to fall, and vice versa.
- Cannot speak of independent and dependent variables since they are coupled.

Mechanisms of Bistable Behavior

How the system "decides" to change from one state to another

Description Three



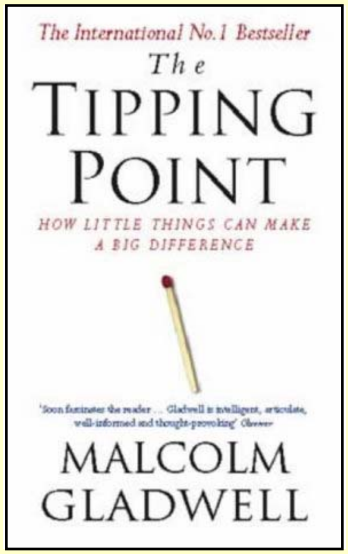


Mechanisms of Bistable Behavior

How the system "decides" to change from one state to another

The Tipping Point

The prevalence of this phenomena of lags between cause and effect was explored by Malcolm Gladwell **in "The Tipping Point"**



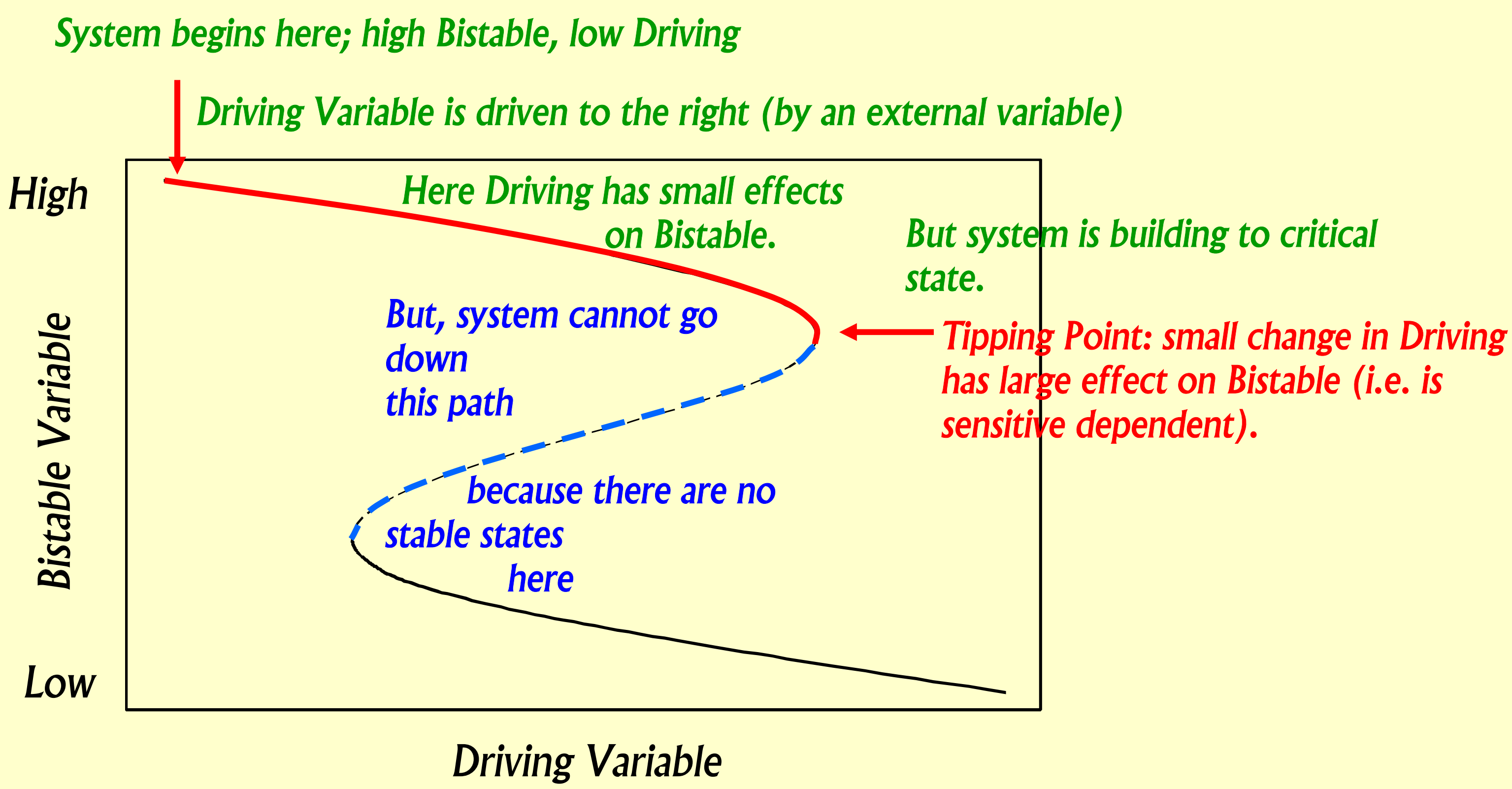
"The best way to understand the dramatic transformation of unknown books into bestsellers, or the rise of teenage smoking, or the phenomena of word of mouth or any number of the other mysterious changes that mark everyday life, is to think of them as epidemics. Ideas and products and messages and behaviors spread just like viruses do."

Little changes can have big effects; when small numbers of people start behaving differently, that behavior can ripple outward until a critical mass or "tipping point" is reached, changing the world.

Return to Systems

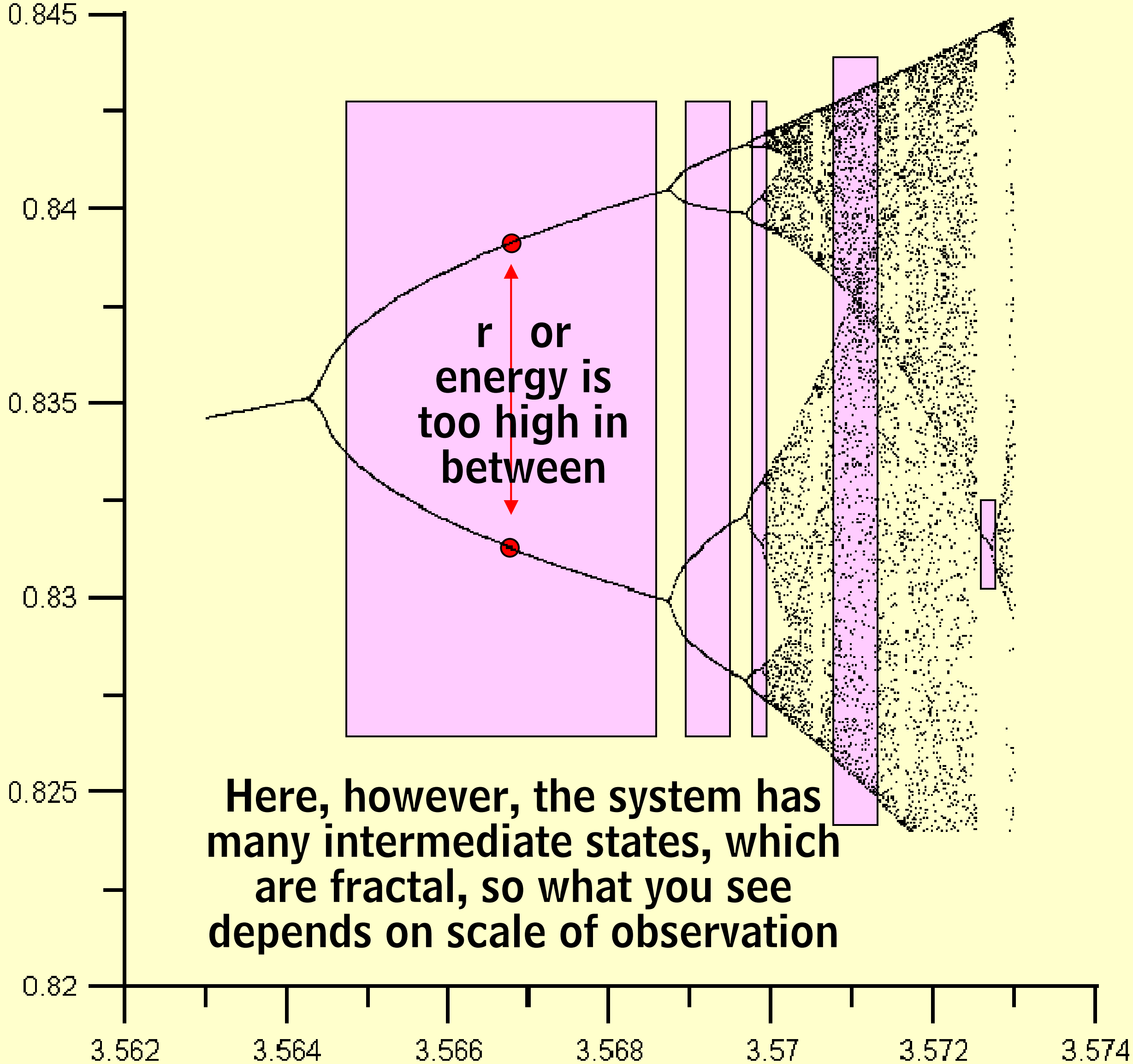
Mechanisms of Bistable Behavior

How the system "decides" to change from one state to another



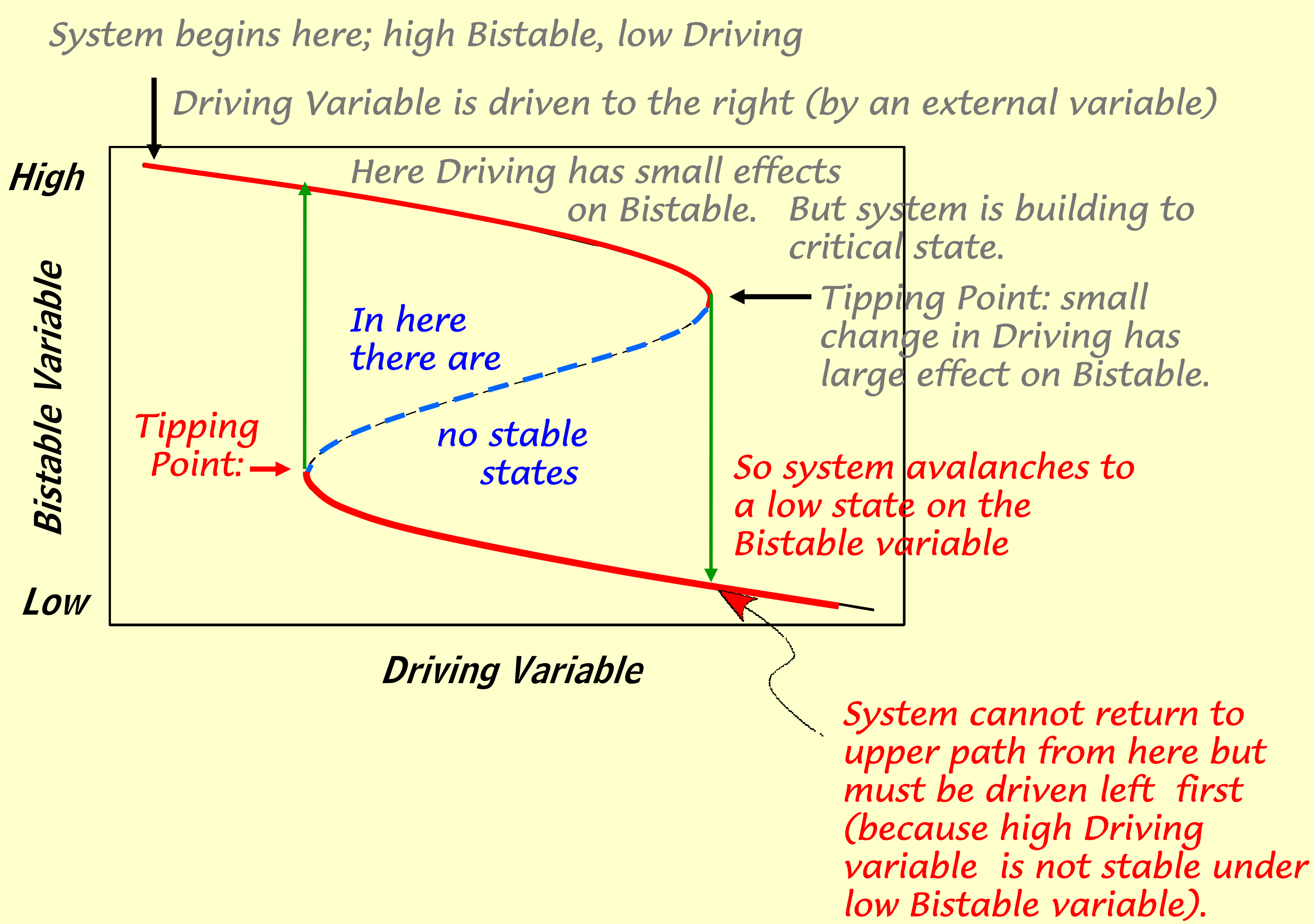
Mechanisms of Bistable Behavior

How the system "decides" to change from one state to another



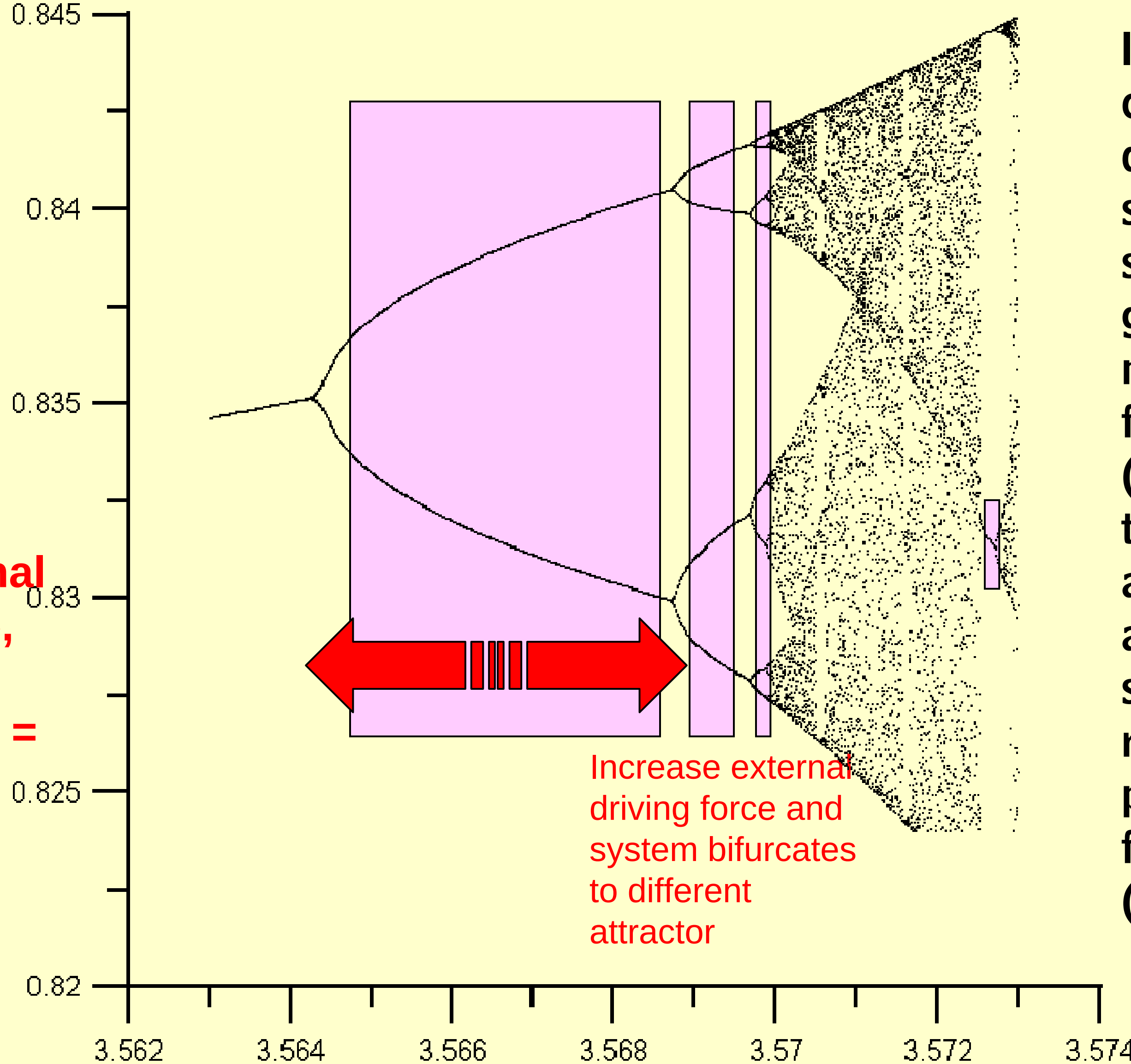
Mechanisms of Bistable Behavior

How the system "decides" to change from one state to another



Stability of the Bistable System

The bistable behavior is stable only within a narrow range of "r" values.



Lower external driving force, and system closes down = equilibrium

If one variable comes to dominate the system, the system either goes runaway negative feedback (closes down to point attractor, or an earlier state), or run away positive feedback (chaos).

Hysteresis

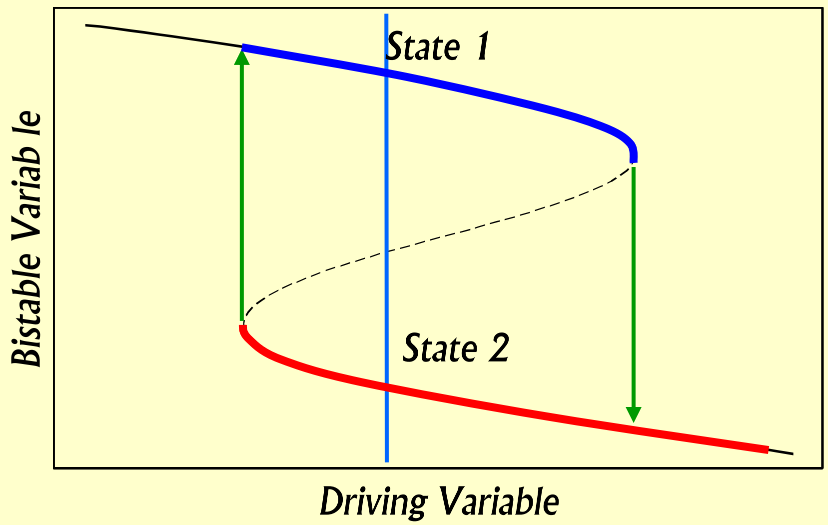
Caveats: warnings and cautions

Hysteresis loop *describes* the *behavior* of the system . . .

It does not *explain* the cause-effect relationships behind the behavior.

And it does not *explain* the source of the energy driving everything.

These systems are driven by processes and energy sources outside the diagram.



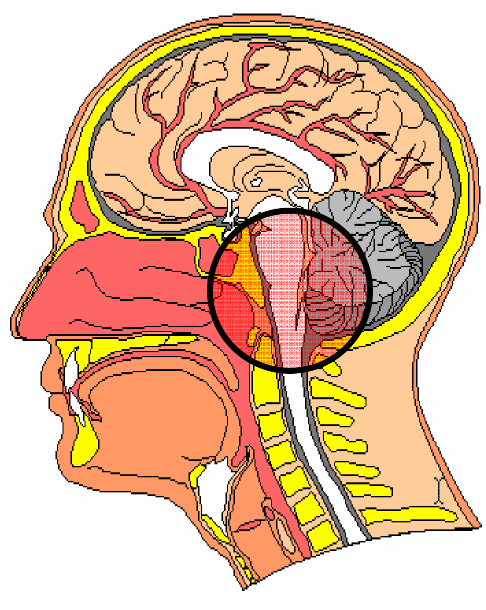
- Ultimately things like social stresses, fear, bigotry, economic gyrations, etc.
- The hysteresis Driving Variable is itself being driven.
- Or, *"everything is connected with everything else by positive and negative feedback."*
- We can isolate the bistable system to discern the relationships among the variables, but what keeps the system "open" with enough "r" value comes from outside the system.

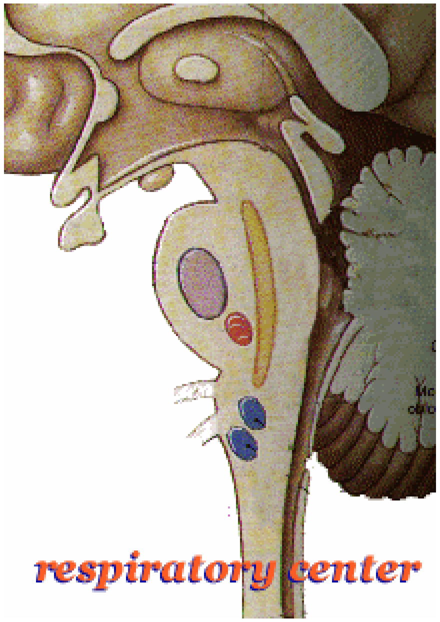
Physiologic Hysteresis:

The Breathing Cycle

The Breathing Cycle

rhythmicity center of the medulla:

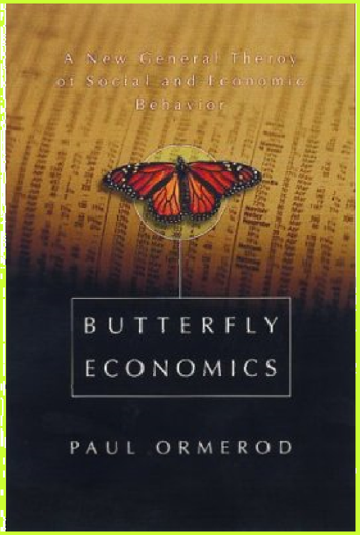




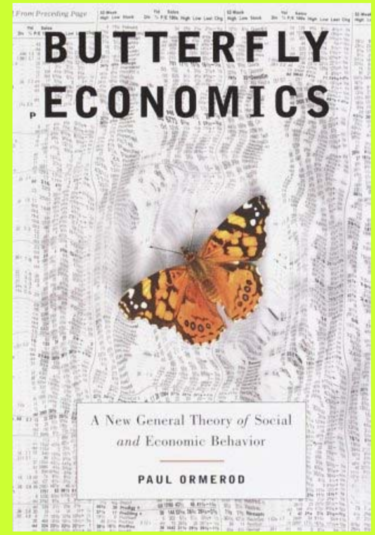
Chemoreceptors - located in aorta & carotid arteries (peripheral chemoreceptors) & in the medulla (central chemoreceptors)

What triggers breathing is not a lack of oxygen, but a buildup of carbon dioxide in the bloodstream. "When the carbon dioxide pressure in the blood gets to 60 to 70 millimeters of mercury, the need to breathe gets very intense." That is because the carbon dioxide triggers breathing centers in the brain, forcing the person to take a breath.

Bistable Behavior
Social/Economic Example



Paul Ormerod

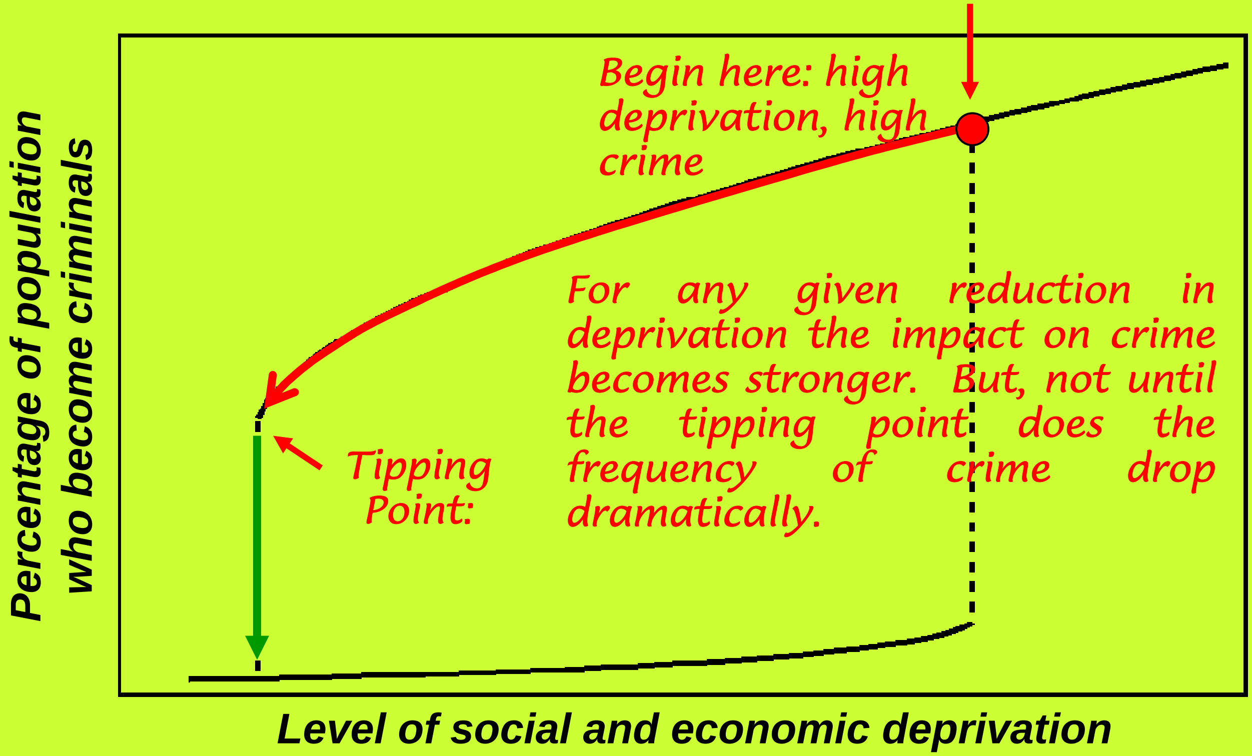


Conservative Explanations and Solutions	Liberal Explanations and Solutions
1. *Crime is an act of rational choice.* a. Remedy is to raise the cost of committing crime and to reduce its benefits by tougher penalties. 2. *Crime rises mainly from crime-prone subgroups that are not susceptible to reform* a. Remedy is repression: capital punishment and long-term imprisonment.	1. *Crime is caused by oppression and exploitation.* a. Crime is a response to capitalist exploitation in particular. The remedy is social reform 2. *Crime waves are in large part the figments of overheated conservative imaginations* a. They are instruments of social control . . . and we should study at least some types of crime in the past in terms of 'enforcement waves' rather than 'crime waves.

Bistable Behavior

Social/Economic Example

How the proportion of criminals in a population varies with the *level of social and economic deprivation*

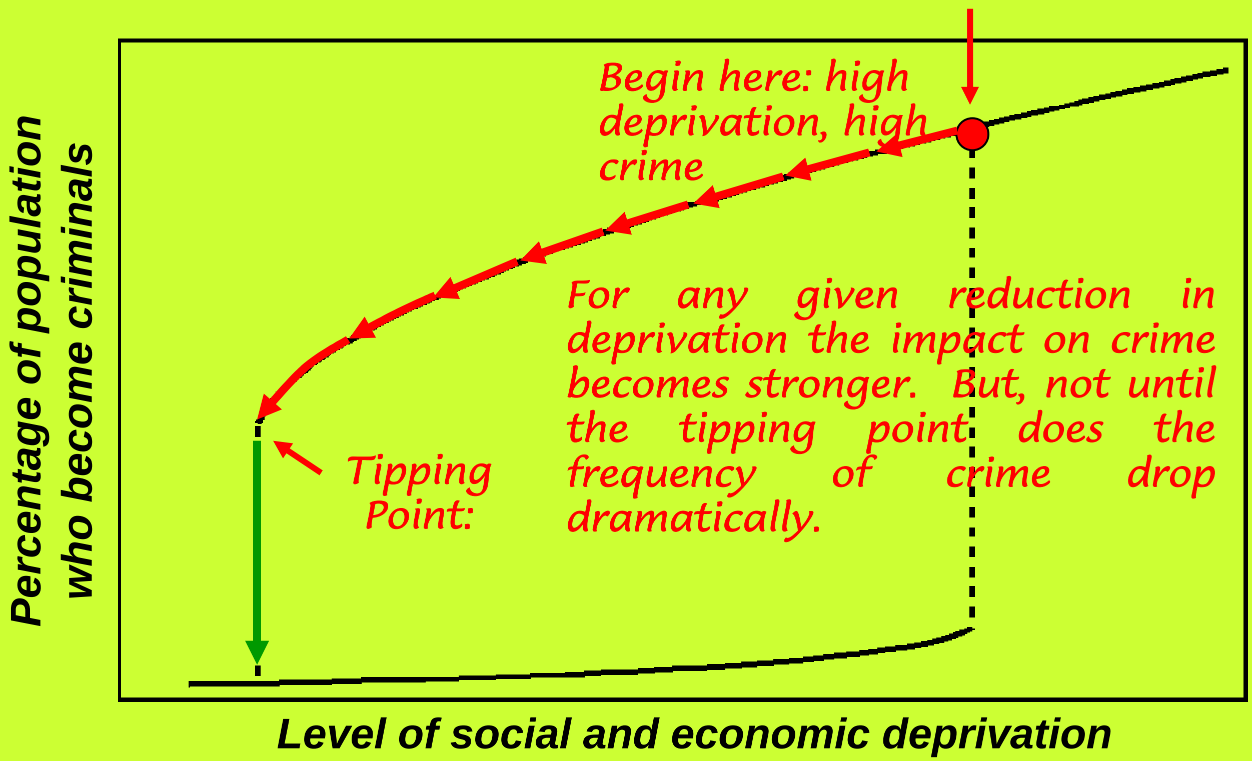


At the tipping point even a very small further reduction in the level of deprivation leads to dramatically lower crime rates. Once we are on the bottom line, additional falls in deprivation reduce crime by only small amounts.

Bistable Behavior

Social/Economic Example

How the proportion of criminals in a population varies with the ***level of social and economic deprivation***

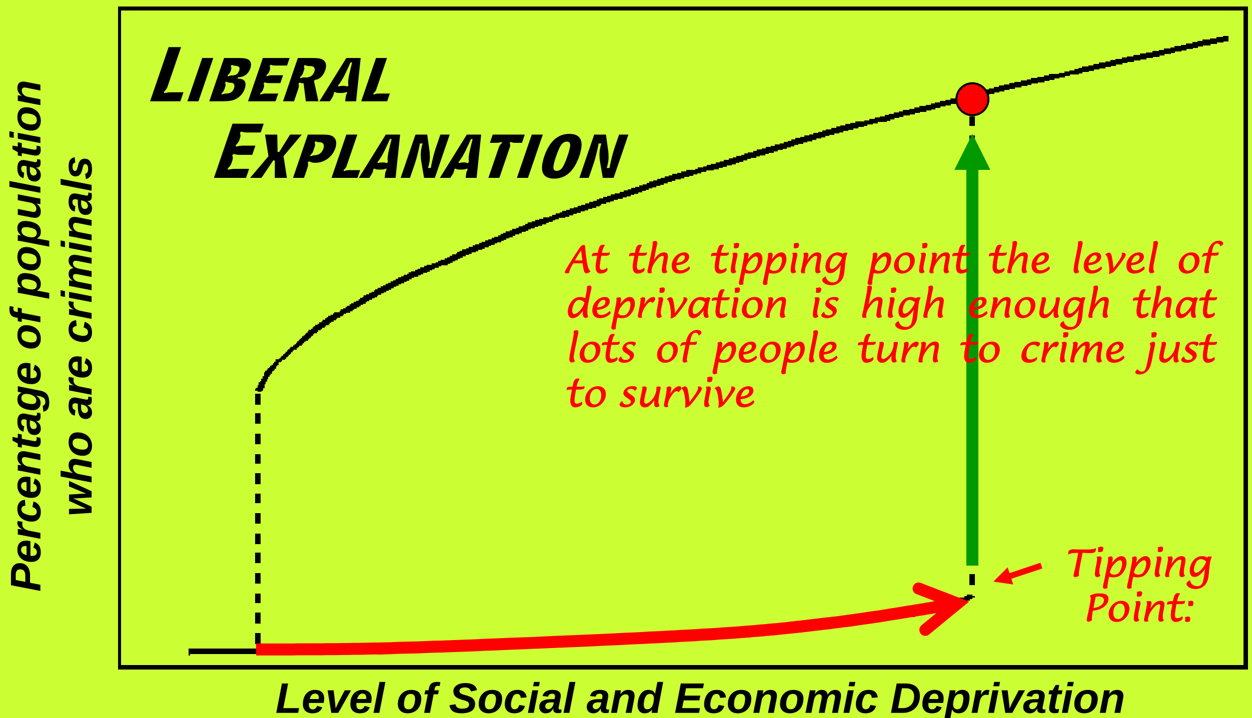


At the tipping point even a very small further reduction in the level of deprivation leads to dramatically lower crime rates. Once we are on the bottom line, additional falls in deprivation reduce crime by only small amounts.

Example of Bistable Behavior

How the proportion of criminals in a population varies with the *level of social and economic deprivation*

The bistable nature is illustrated by today when the country is rather prosperous, but crime levels are very high, in contrast with the depression of the 1930's, when deprivation was very high, but crime was low.

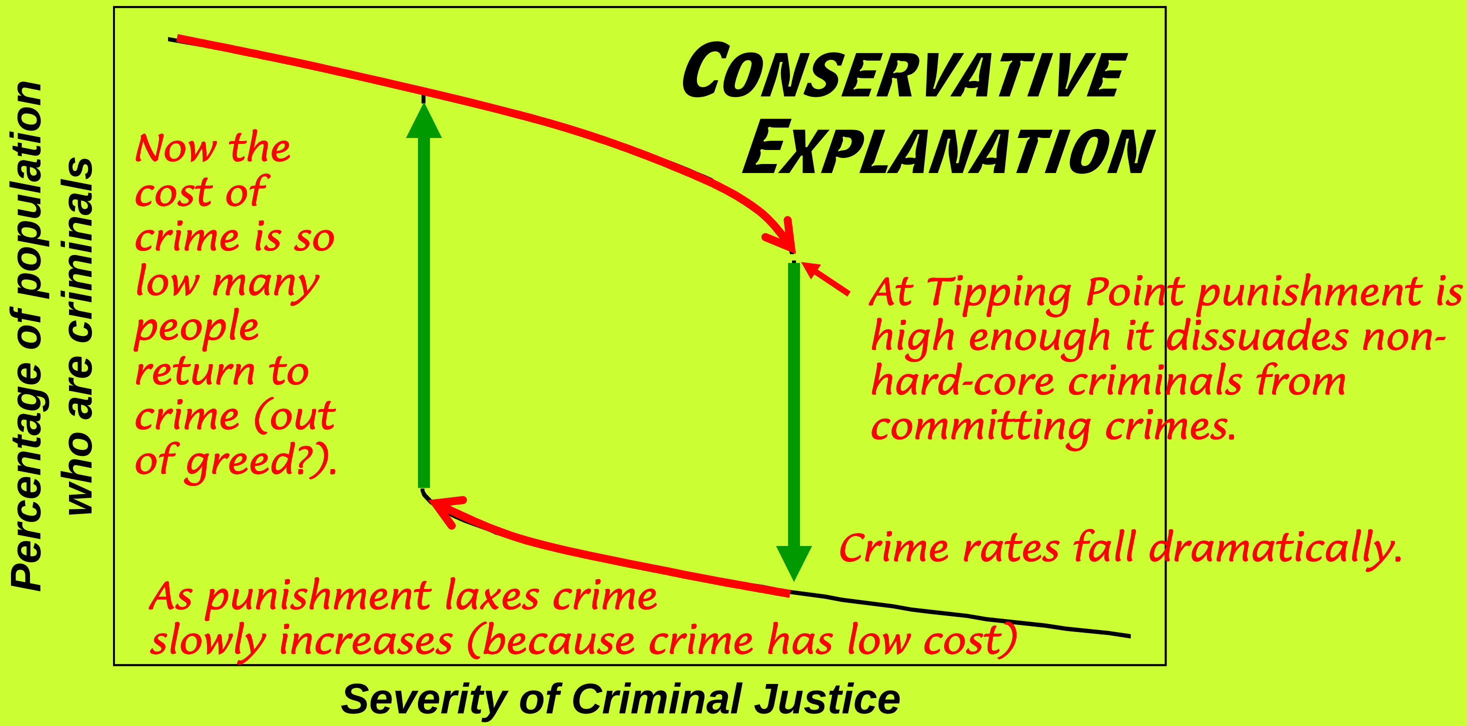


Once on the bottom line crime remains low, or rises only very slowly even as the level of economic deprivation continues to rise.

Example of Bistable Behavior

How the *severity of the criminal justice system* affects the level of crime in the population.

We assume that the effect of a more punitive criminal justice system is to reduce the proportion of criminals in the population. As the criminal justice system becomes more strict the proportion of criminals in the population falls. But the effect at first is rather minimal.

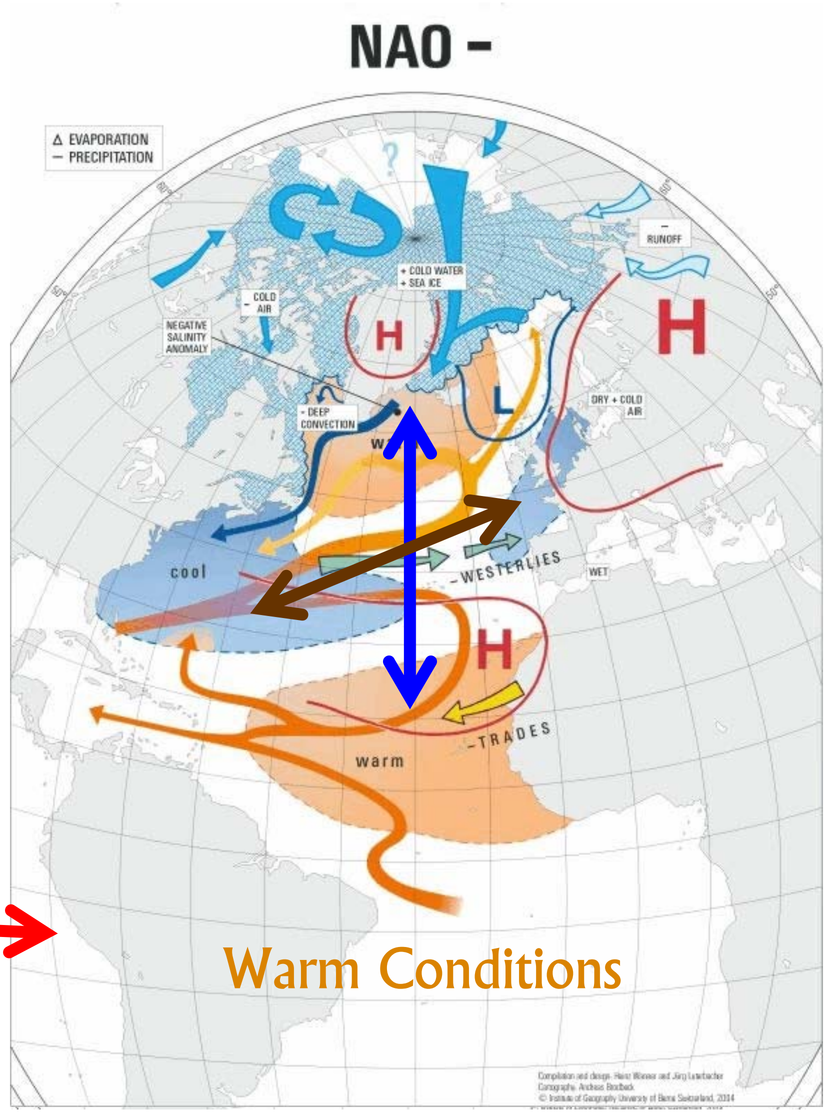


NOA
Oscillation

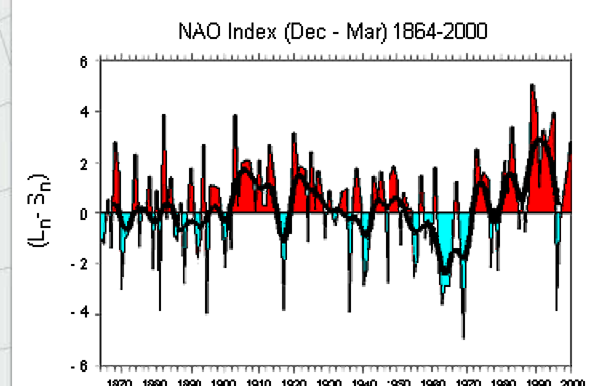
ENSO
La Nina and El Nino Oscillation

Bistable Behavior in Recent Climate

The North Atlantic Oscillation
Recent Glacial/Interglacial Cycles



El Nino
Southern Oscillation



http://www.isse.ucar.edu/signal/15/articles.html

http://sinus.unibe.ch/klimet/wanner/nao.html

The Southern Oscillation

El Nino and La Nina

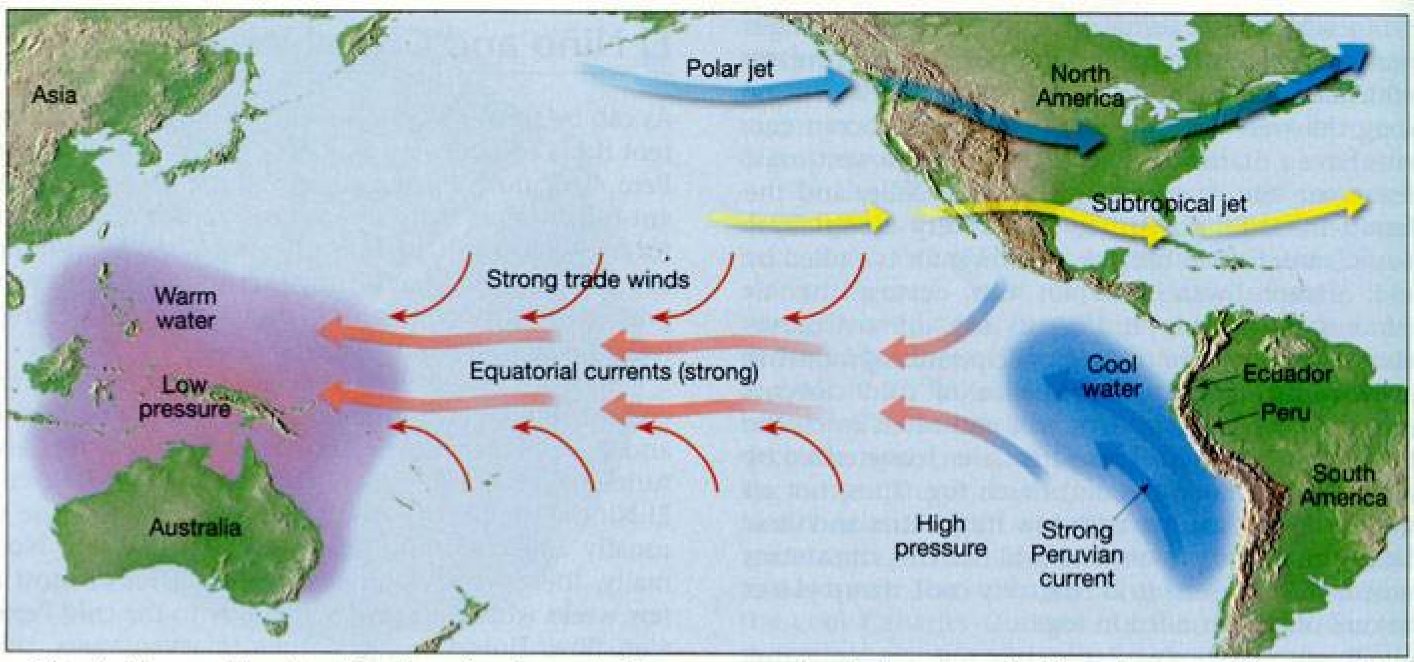


Fig.6 Normally, the trade winds and strong equatorial currents flow toward the west. At the same time, an intense Peruvian current causes upwelling of cold water along the west coast of South America.

Near the end of each year as the southern hemispherical summer is about to peak, a weak, warm counter-current flows southward along the coasts of Ecuador and Peru, replacing the cold Peruvian current. Centuries ago the local residents named this annual event El Niño (span. "the child") based on Christian theology that assigned this period of the year the name-giving Christmas season. Normally, these warm countercurrents last for at most a few weeks when they again give way to the cold Peruvian flow. However, every three to seven years, this countercurrent is unusually warm and strong. Accompanying this event is a pool of warm, ocean surface water in the central and eastern Pacific.

El Niño has made frequent appearances over the last century, with particularly severe consequences in 1891, 1925, 1953, 1972, 1982, 1986, 1992, 1993, and 1997.

http://www.sbg.ac.at/ipk/avstudio/pierofun/atmo/elnino.htm

The Southern Oscillation

El Nino and La Nina

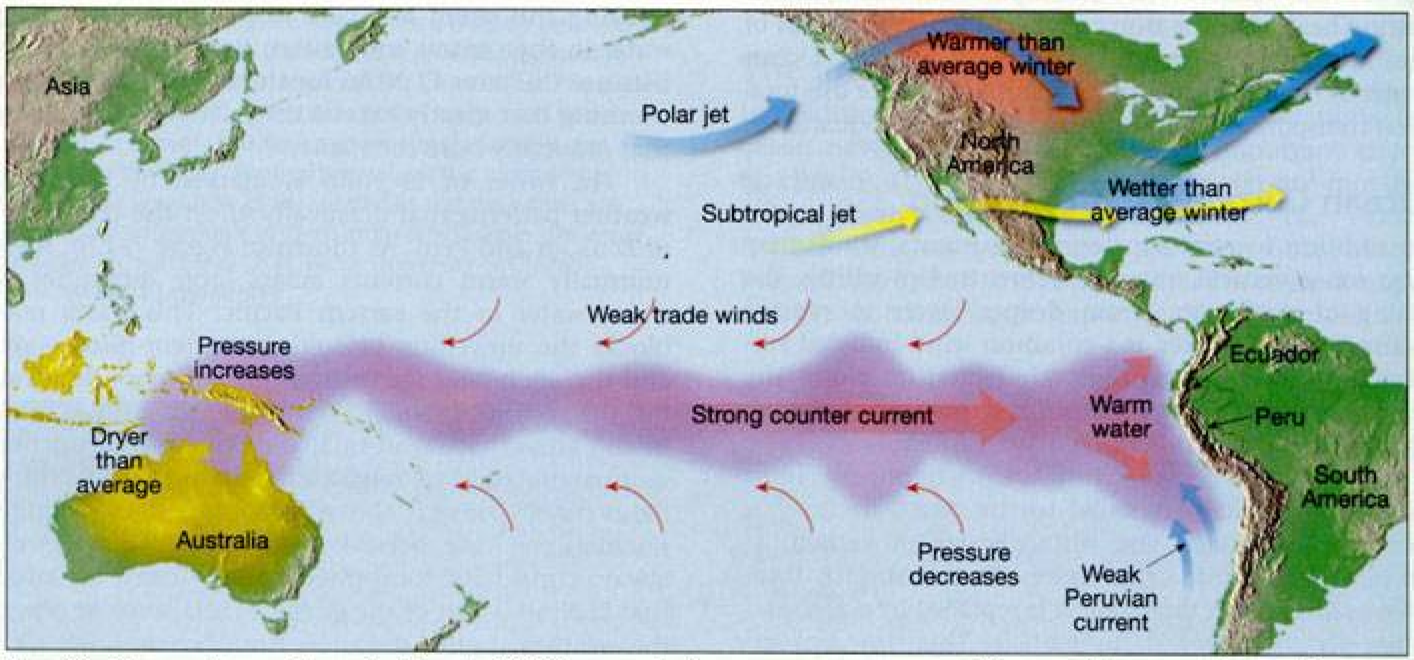
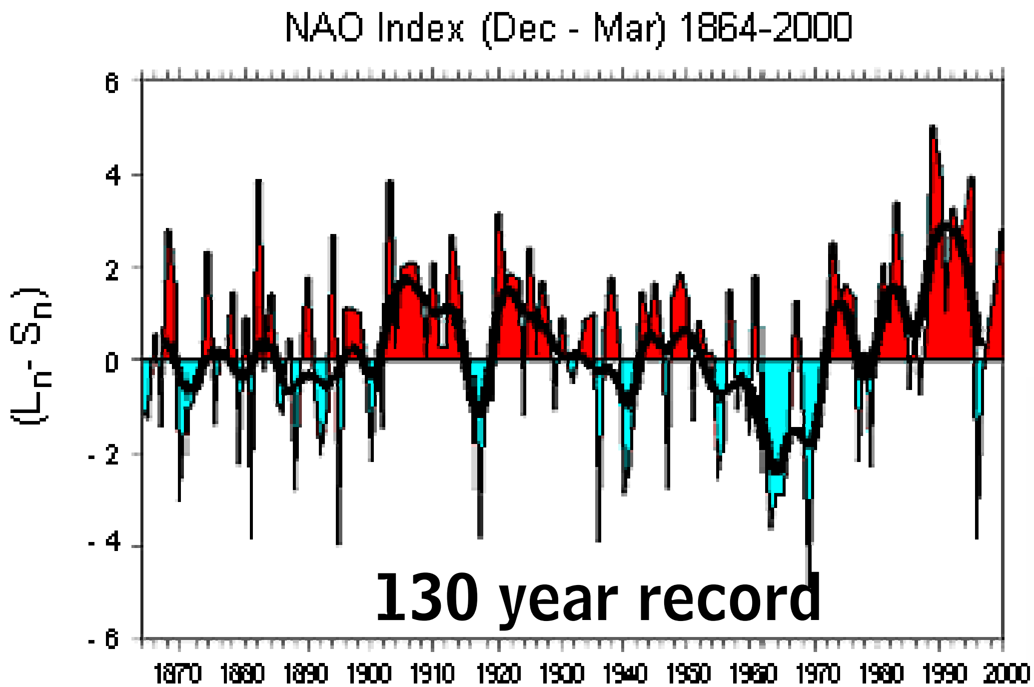


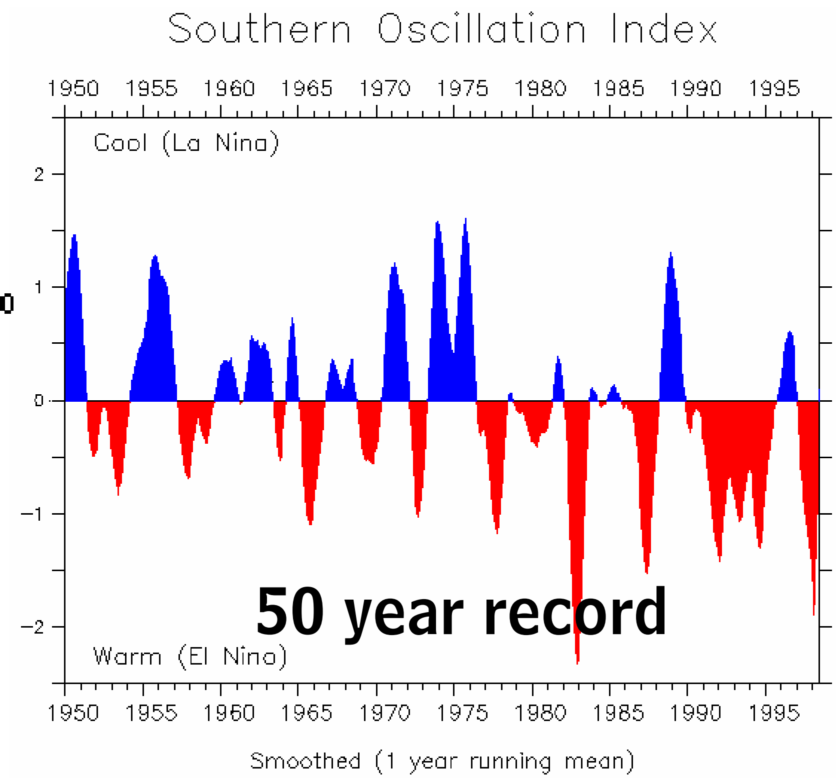
Fig.14 Upon the advent of an ENSO event, the pressure over the eastern and western Pacific flip-flops. This causes the trade winds to diminish, leading to an eastward movement of warm water along the equator. As a result, the surface waters of the central and eastern Pacific warm, with far-reaching consequences to weather patterns.

http://www.sbg.ac.at/ipk/avstudio/pierofun/atmo/elnino.htm

Bistable Behavior in Recent Climate

The Southern Oscillation



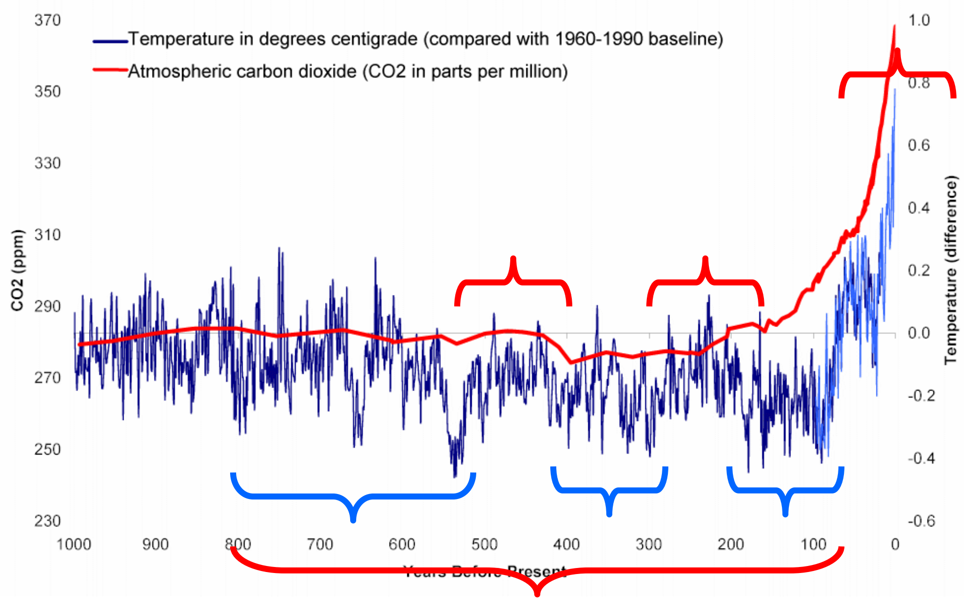


http://www.pmel.noaa.gov/tao/elnino/faq.html

Bistable Behavior in Recent Climate

A Geological Example

Recent Glacial/Interglacial Cycles



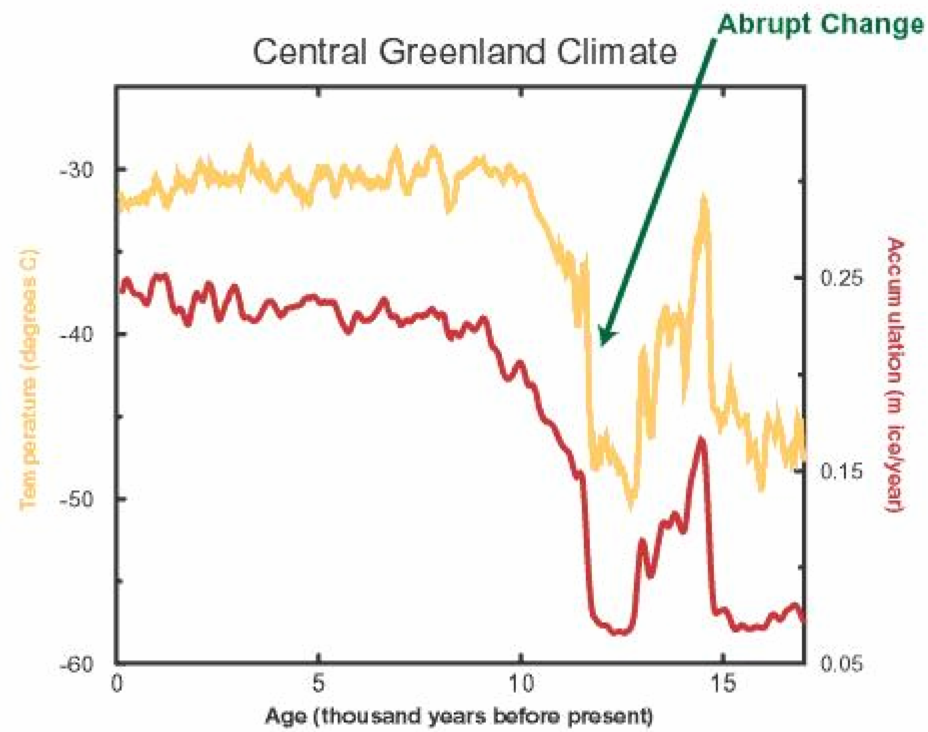
The Little Ice Age
1150-1850?

1000 Year Record

Patterns, within patterns, within patterns

i.e. its fractal

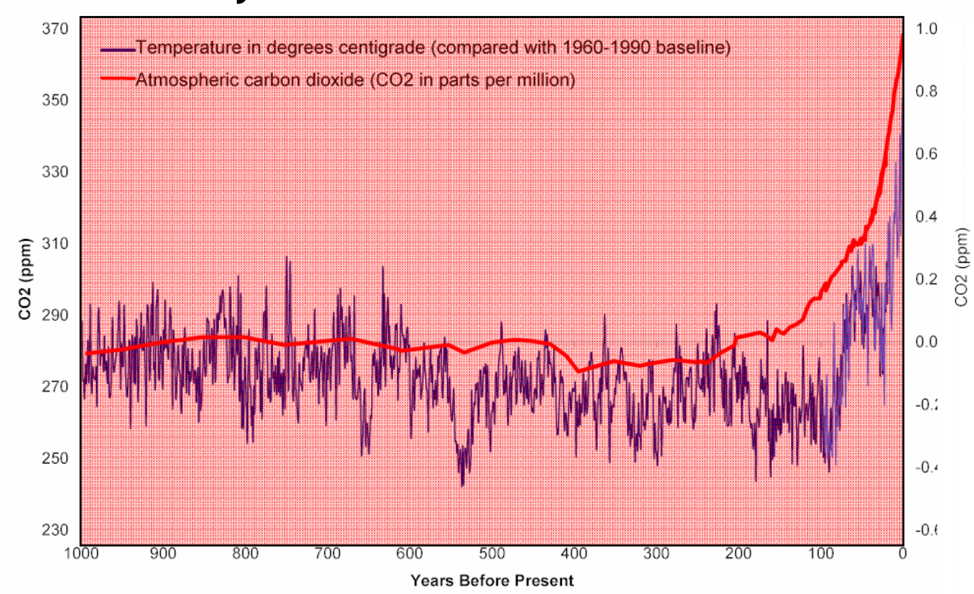
The Younger Dryas
A Geological Example



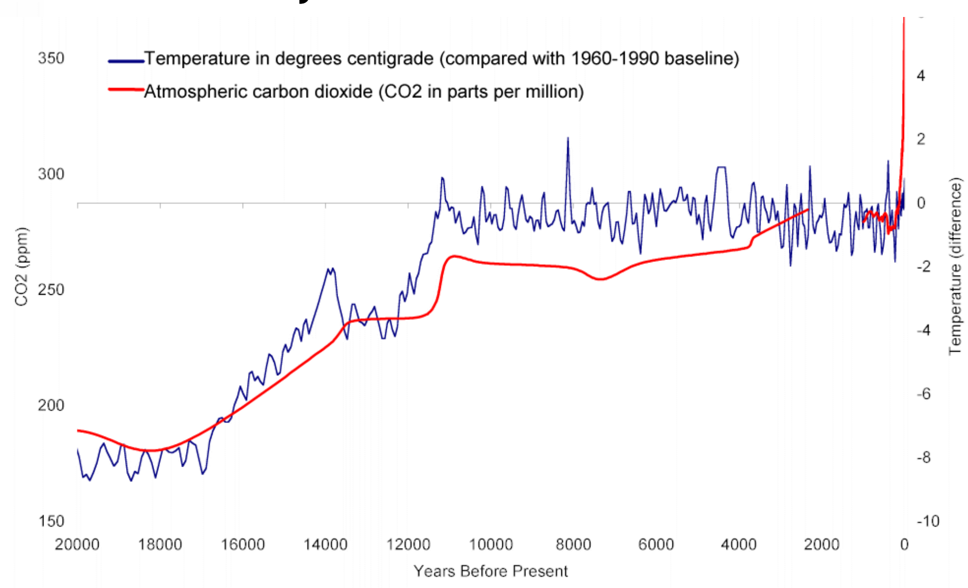
The Younger Dryas
A Geological Example

Fractal Temperature Patterns in Time

1,000 Year Record

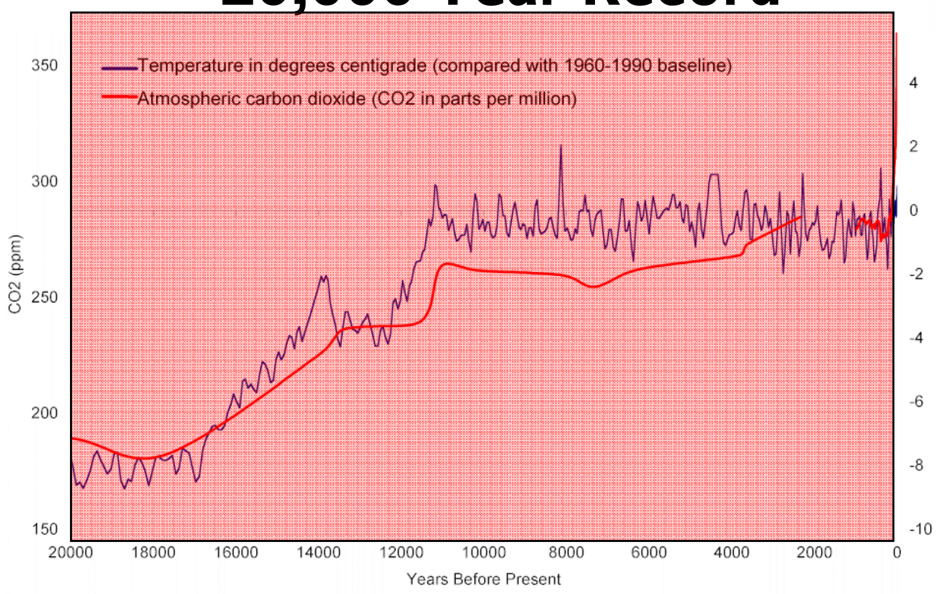


20,000 Year Record

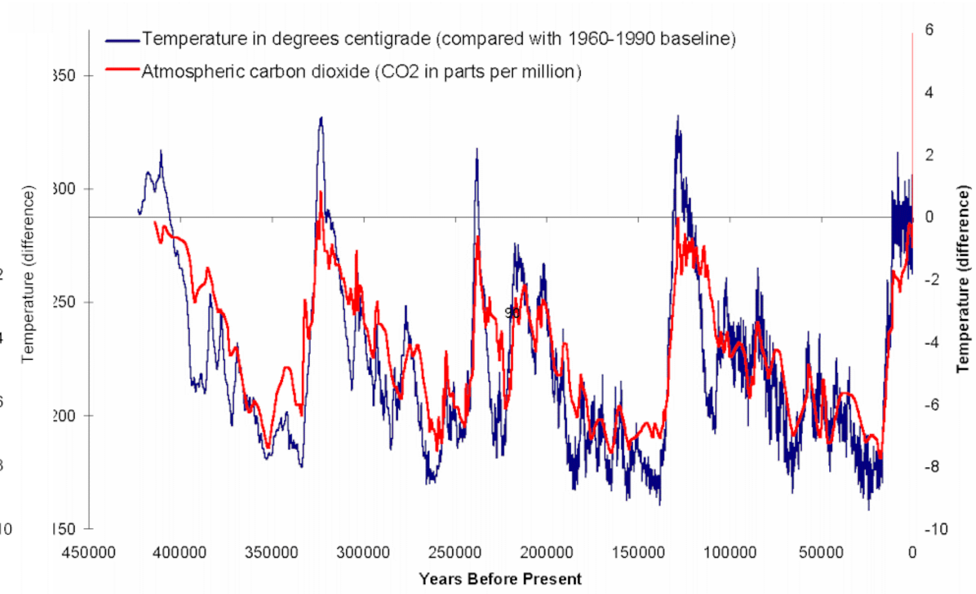


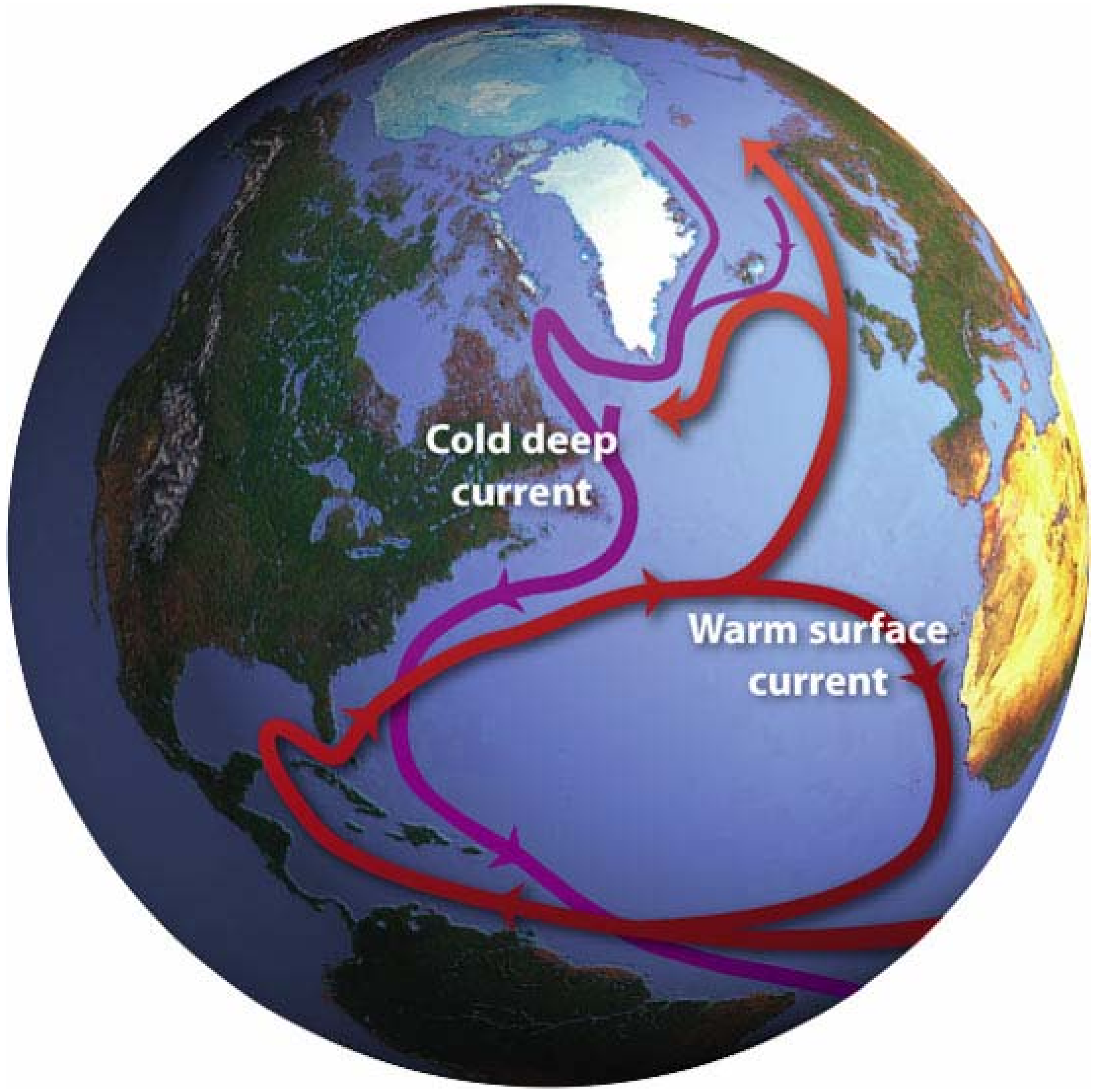
Fractal Temperature Patterns in Time

20,000 Year Record



450,000 Year Record





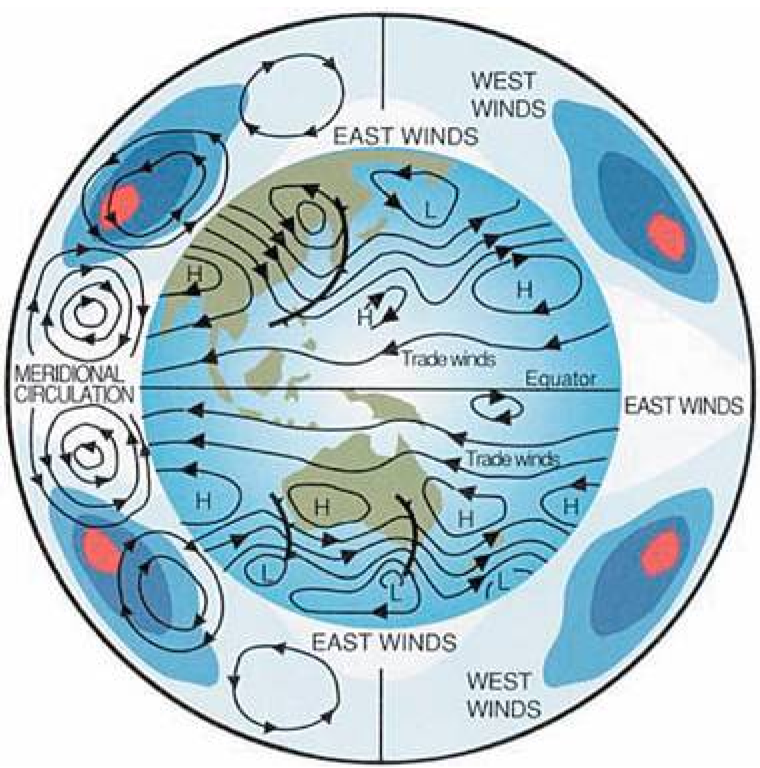
A global system of currents, often called the "ocean conveyor," carries warm surface waters from the tropics northward. At high latitudes, the waters cool, releasing heat to the atmosphere and moderating wintertime climate in the North Atlantic region. The colder (and denser) waters sink and flow southward in the deep ocean to keep the conveyor moving.

Bistable Behavior in Recent Climate
The Day After Tomorrow

BISTABLE BEHAVIOR IN RECENT CLIMATE
THE DAY AFTER TOMORROW

What Causes the NAO and ENSO?

ENSO is a set of specific interacting parts of a single global system of coupled ocean-atmosphere climate fluctuations that come about as a consequence of oceanic and atmospheric circulation.



It exists . . .

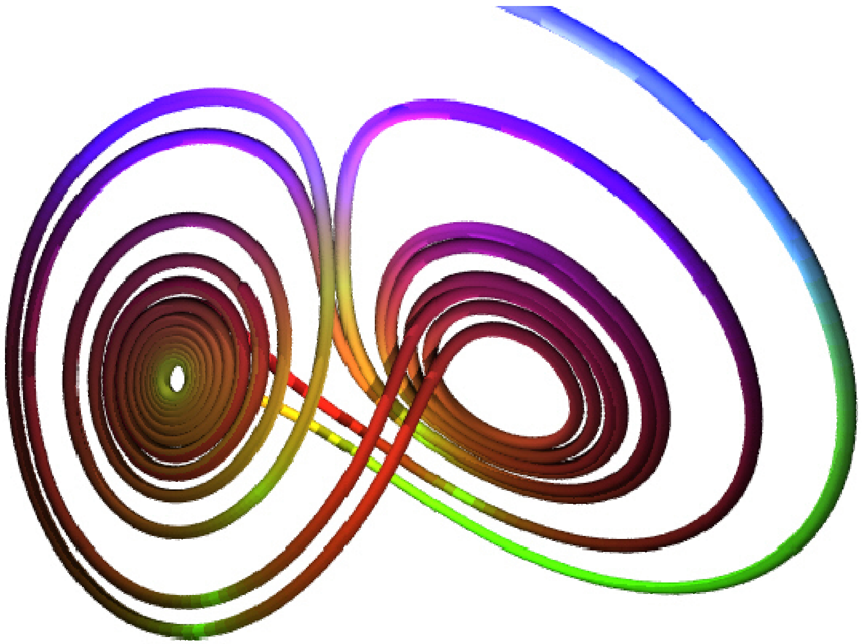
Far from equilibrium

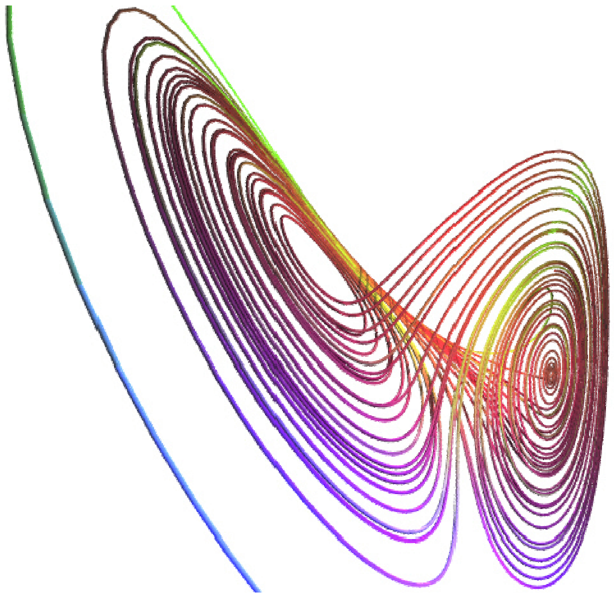
Is sensitive Dependent

And behaves as a strange attractor

Oscillating Systems

Or, as in the Lorenz strange attractor system

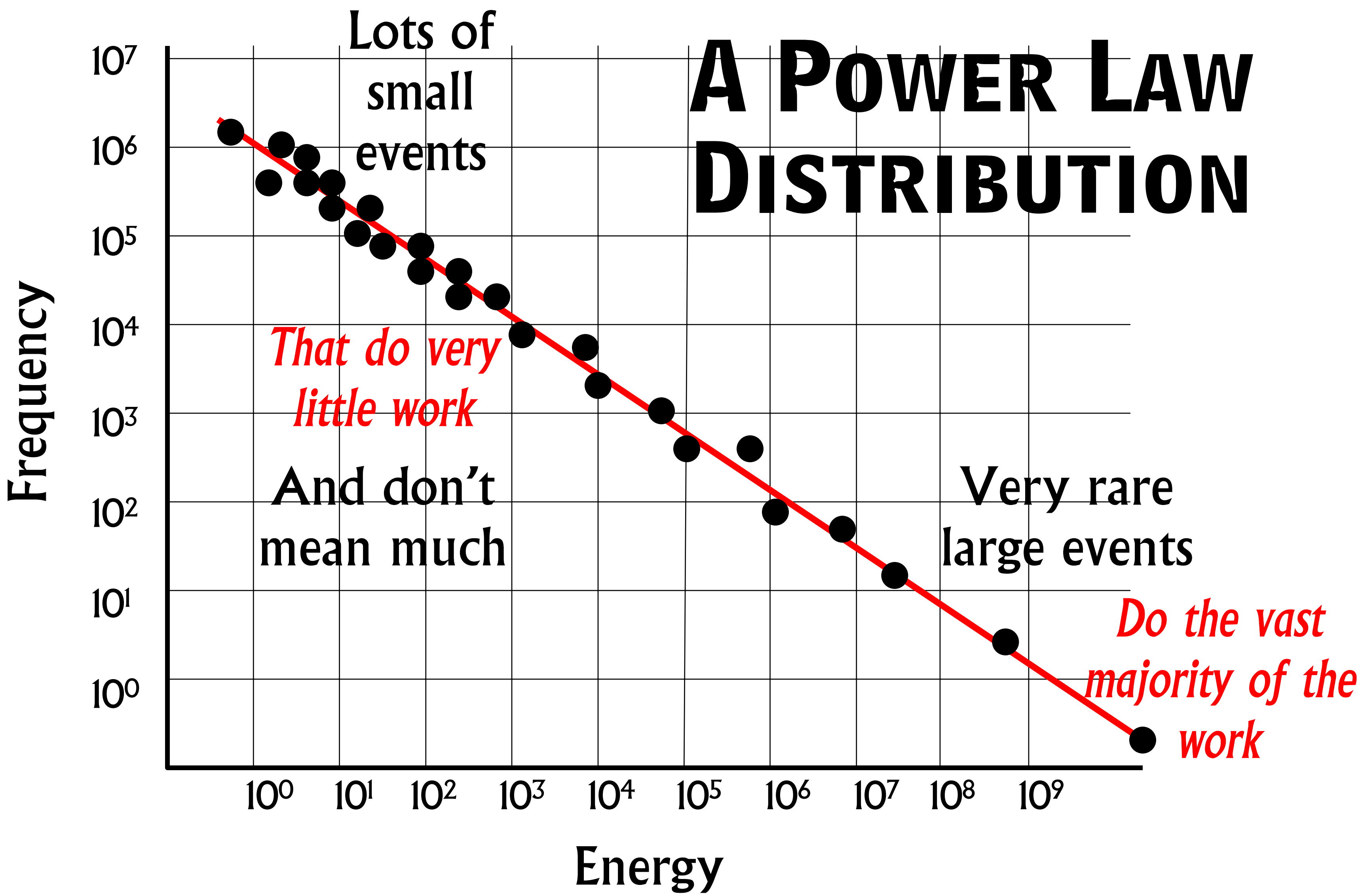




And strange attractors do not have a cause;
they just are.

http://www.csounds.com/mastering/em_10.html

Comparing Linear and Non-Linear Changes



Bistable Behavior
A Geological Example
Glacial/Interglacial Cycles

Bistable Behavior

Snowball Earth - A Geological Example

Between 750 – 580 million years ago Earth underwent four extremely severe, global-wide, glaciation events, each lasting about 10 million years.

No ice, lots of land, low *albedo* (sunlight absorbed, not reflected). Earth warm.

CO_2 removed from atmosphere by weathering of vast open land areas, reducing *greenhouse effect*. Negative feedback on warm conditions; Earth cools.

CO_2 cooling leads to ice formation, which increases albedo which increases cooling; + feedback = increased cooling.

Reflective cooling (albedo) leads to more ice, which increases albedo even more, which leads to runaway positive feedback. Earth cools even more quickly.

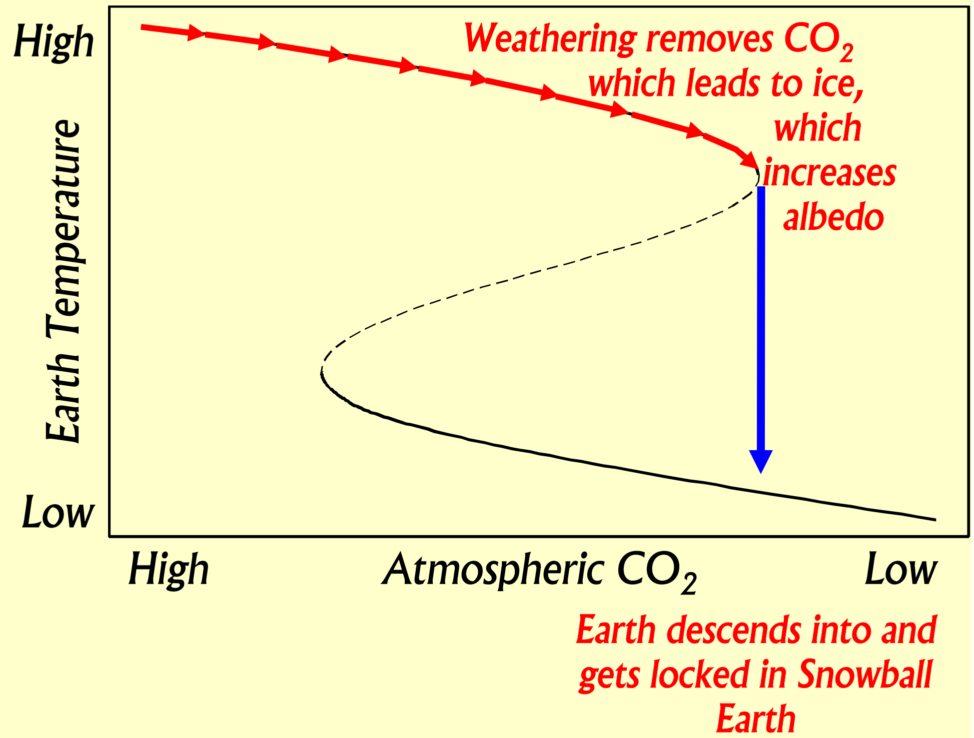
Snowball Earth: cooling maximized (-50º C below zero). Entire Earth, including oceans, frozen solid.

Bistable Behavior in Bifurcation Diagrams
A Geological Example
Glacial/Interglacial Cycles

Cooling Part of Cycle

When continents are exposed, abundant weathering of exposed rock sucks down CO_2 from atmosphere, slowly at first but with increasing effect with time.

- Lower CO_2 concentrations in atmosphere lowers the greenhouse effect of CO_2 leading to cooling.
- When it is cool enough for ice sheets to begin forming the increasing albedo causes temp-erature to drop even more.



Albedo (ice reflection of sunlight) becomes a positive feedback system driving Earth deeper and deeper into the ice age.

Bistable Behavior
A Geological Example
Reversal of Snowball Earth

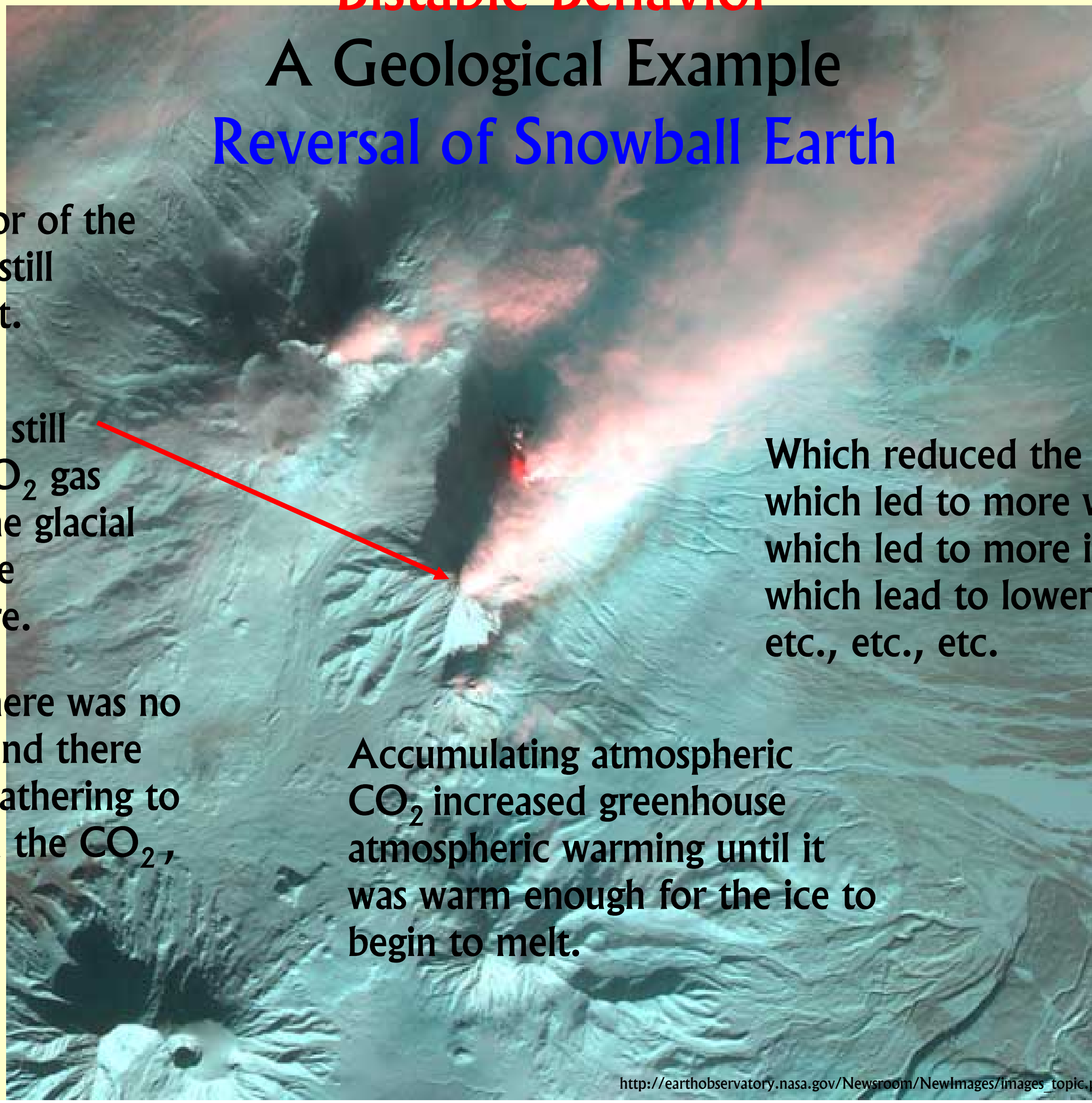
There is no *extrinsic* reason for Snowball Earth to have come to an end. Once locked into the positive feedback loop of cooling, leading to more cooling, leading to more cooling the Earth should have become stuck there.

The reason it did not become stuck was *Intrinsic*, the Earth is an open, dissipative system, and what it dissipates is tectonic energy – energy from its molten interior.

Bistable Behavior

A Geological Example

Reversal of Snowball Earth



The interior of the Earth was still molten hot.

Volcanoes still spewed CO_2 gas through the glacial ice into the atmosphere.

Because there was no exposed land there was no weathering to suck down the CO_2, so . . .

Accumulating atmospheric CO_2 increased greenhouse atmospheric warming until it was warm enough for the ice to begin to melt.

Which reduced the albedo, which led to more warming, which led to more ice melting, which lead to lower albedo, etc., etc., etc.

http://earthobservatory.nasa.gov/Newsroom/NewImages/images_topic.php3?img_id=16833&topic=heat

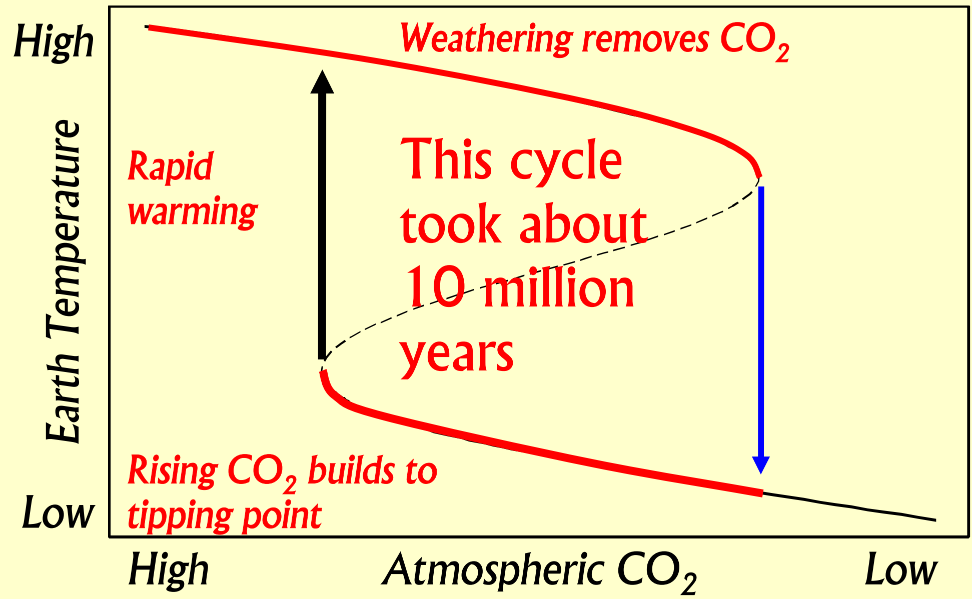
Bistable Behavior
A Geological Example
Reversal of Snowball Earth

Warming Part of Cycle

Expanded ice sheets lead to rise of CO_2 in atmosphere.

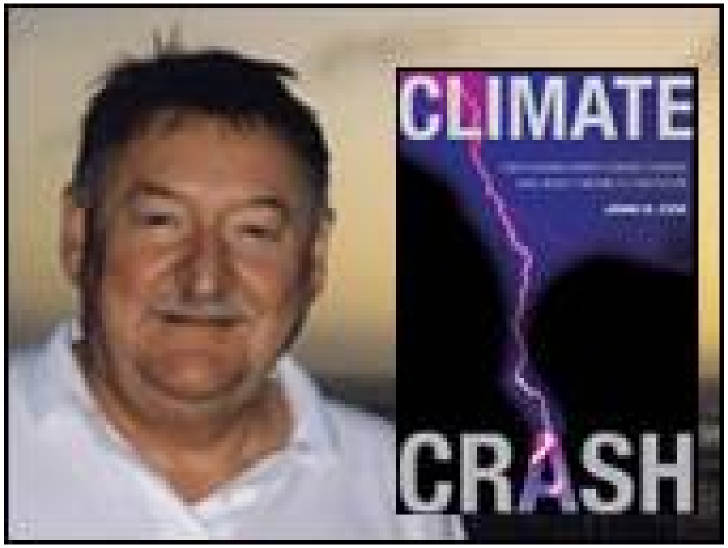
- Ice sheets decrease area of exposed rock, reducing weathering rates, decreasing loss of CO_2 from atmosphere.
- Ongoing volcanic outgassing puts CO_2 back into atmosphere.

At first these trends have minimal effect on Earth Temperature.



But, when CO_2 rises high enough its concentration in the atmosphere crosses a threshold leading to rapid warming trends leading to glacial melting.

Return to Systems



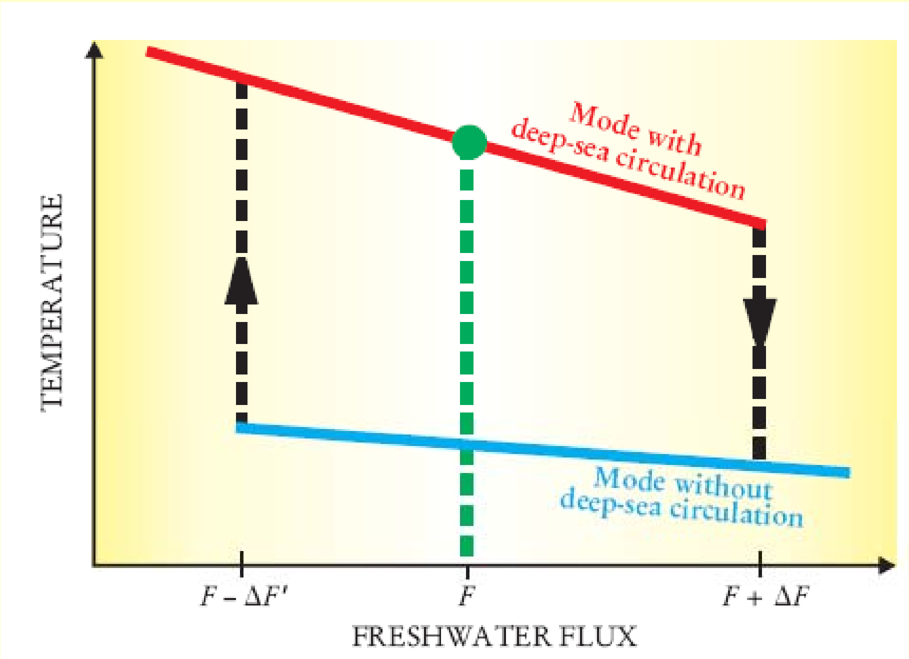
John D. Cox, 2005, Climate Crash: Abrupt Climate Changes and What It Means for Our Future

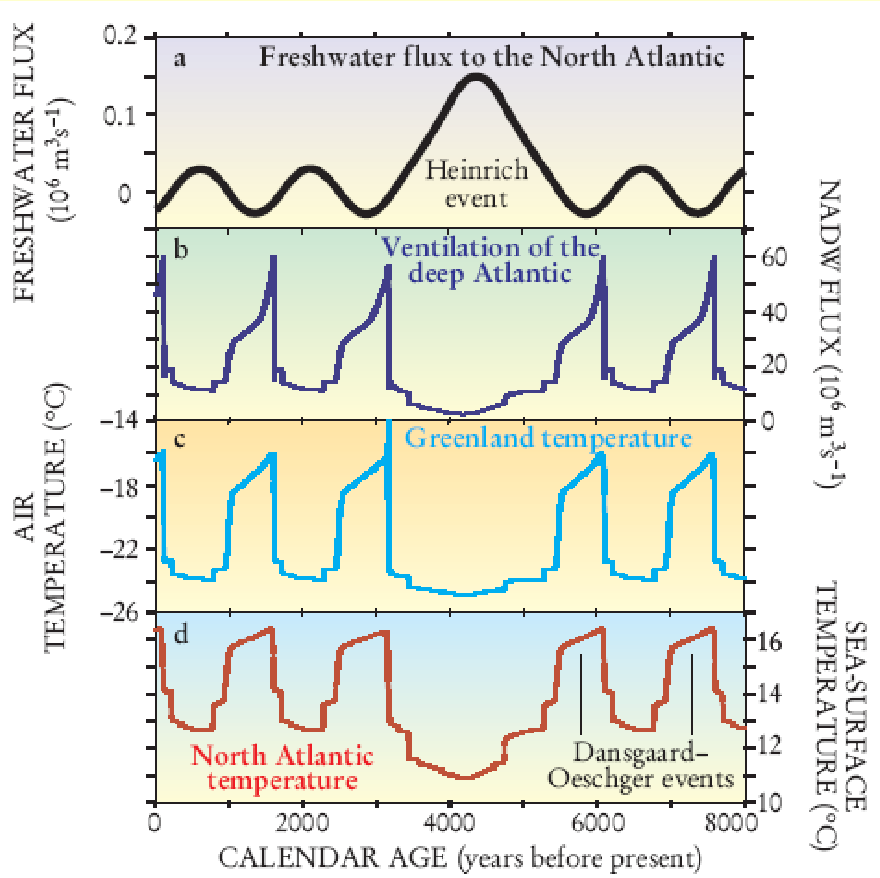
"The old idea of stable, slowly evolving climate was so widespread through the twentieth century – and died such a slow death – because it seemed to make the most sense. Abrupt change, in contrast, is so counterintuitive and so elusive that it is like a concert being played at a pitch beyond the range of human hearing." p 150

Bistable Behavior in Recent Climate

A Geological Example

Pleistocene Glacial/Interglacial Cycles





Bard E. Abrupt climate changes over millennial time scales: climate shock. Physics Today 55, 32-37 (2002) (link)

Return to Systems

The significant problems we face today cannot be solved with the same level of thinking we were at when we created them.

Albert Einstein

Maxim for the Day

You can only see what you are looking for . . .

And, you can't see what you are not looking for . . .

If you are trained to believe that all systems go to equilibrium, . . . you will not see complex behavior.

But, any system that is dissipating enough energy/information will of necessity behave as a strange attractor, and will exhibit hysteresis behavior.