

## *Extreme Events*

David Sanders

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### Agenda

- Geophysical Events
  - Reserving Pricing Management
- Extreme Geophysical Events
- Financial Events

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### Lisbon Earthquake 1755



Rousseau

The price mankind paid for civilization

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### Pricing/Reserving/Managing

- Collect Data
- Look at pricing/ reserving models
  - EVT
  - Cat Modelling
  - Others
- Look at Management Issues
- Measure Risk

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### Actuarial/Mathematical Modelling

- Edmund Halley
  - World's first meteorological map (1686)
- d'Alembert
  - creation of partial derivatives to determine law of governing winds (1746)

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### A reflection

- Tectonic Plate theory is less than 40 years old
- Catastrophe theory and Morphogenesis (Rene Thom) is just over 30 years old
- Chaos Theory is less than 30 years old
- Extreme Value Theory is about 20 years old
- Computer modelling is less than 10 years old

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### Data

- Understand the issues - what are likely losses
- Try and understand sources/limitations of data
- Are certain geophysical events connected

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### Connections

- Hurricanes spawn tornadoes
- Earthquakes sometimes occur after cyclones
  - Kanto/Hugo
- Earthquakes and volcanoes are connected
- Earthquakes can trigger consecutive earthquakes (Lomnitz 1996 statistical study)
- Volcanoes can trigger volcanoes
  - 1902 Mount Pelee/la Soufriere of St Vincent

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### Catastrophe Models

- These are essentially ground up models
- The results are as good as the models
  - need for calibration
- The results differ for different models
- Still learning
- Not good at predicting events in time
  - gives probability and cost
  - Integrate to give price

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### Catastrophe Models

- Predictive Models are not very good
- Meteorological models
  - Fine grids
  - Difficulty in predicting long into future
  - Blamed on Chaos Theory/Butterfly effect
- BUT Prediction error grows linearly
  - suggests model error

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### Catastrophe Models

- Rapid growth in models
- Complex/black box
- Data in paper you can build your own hurricane model (hints see Karen Clarke's original CAS paper)
- They will get better - but need more events
- Likely to be VERY wrong at Extreme Events

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### Extreme Value Theory

- Top down approach
- Not used for fitting the whole distribution
- Generalised Extreme Value Distribution
  - Gumbell
  - Frechet
  - Weibull
  - depends on shape

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### Extreme Value Function Examples

- In mortality, the population a time age  $x$  is half that at age  $x-1$
- The log return period of an earthquake is proportional to the size
- and so on

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### Generalised EV Distribution

$$P(Y < y) = \text{GEV}(y; \xi, \mu, \sigma) \\ = \exp(-[1 + \xi(y - \mu)/\sigma]_+^{-1/\xi})$$

- Estimate  $y_p$  where  $\text{GEV}(y_p) = 1-p$
- $y_p$  is return level associated with return period  $1/p$ 
  - $\mu$  is location parameter
  - $\sigma$  is the scale parameter
  - $\xi$  is the shape parameter
- **Compare with Craighead Curve!**

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### Generalised Pareto

$$\Pr(Y < y) \sim 1 - \lambda_u [1 + \xi(y-u)/\sigma]_+^{-1/\xi}$$

- Relationship between Pareto family and GEV Distribution
- Threshold Distribution
  - high exceedence
  - mean residual life plots

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### Example

- How big is a San Franciscan Earthquake
- Data exhibits linearity at lower ends to support the log period /intensity ratio
- BUT
- at top end of scale this doesn't apply
- EVT suggested maximum of 8.6-8.7
- Geophysical evidence supports that number

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### Management - Theory

- Pre event
  - Loss scenarios
  - Underwriting control
  - Good internal Management
- Post event
  - Claims estimation
  - Claims management

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### Management Theory

- Clarity of roles and responsibilities
- Underwriting issues should go beyond the technical underwriter
  - **some of the issues they face require additional skill sets that can be more readily be brought to bear by others**

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### Management in Practice

- There is no check and balance within the underwriting group
  - in a number of cases, individuals have proved to apply insufficient professionalism.
- Others are more concerned with tactical issues than strategies issues - which a broader group should bring to bear.

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### Management - Practice

- Cynical view
  - Gross loss = top of reinsurance protection
  - Net loss is fixed
- Difficulty in estimating exposure
  - Need to PML total exposure
  - Difficulty from computer records in finding where you are in the layer (retro)

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### PML

- PML is a somewhat arbitrary measure
- Post Sept 11, it was common for PMLs to be factored up by an arbitrary amount i.e. x 1.25 to x 2.0
- The value of PML as a proxy for exposure is limited for coverages that have limits or attachment points

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### Computer Records

- Rarely have quantitative data regarding the underlying portfolios.
- Actuarial discussions with underwriters are to understand
  - who is reinsured
  - what they write
  - the levels they write, backups, deductibles etc
- BUT we only tend to build up an approximate picture

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### Management Practice

- Estimates on the low side
  - Increase as required
  - Hope can hide away when there is a good year!
- BUT
- Property claims are settled faster than in 1990!

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### Management Practice

- Newer underwriters have “forgotten” disciplines of early 1990’s
- WHY
- No mega loss seriously impacting book
- September 11 has changed all that

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### Really Extreme Events



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### How Extreme ?

- Meteorite Collisions
- 65 million years ago a meteor hit
- The NORTH SEA
- About the same size as the famous Arizona impact site
- Once every 100k years`

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### Meteorite Strikes

- Meteor Clusters
- Taurid Shower (mid summer)
- Tunguska Event
- Destroyed an area equivalent to that enclosed by M25
- Average 3,000 plus deaths per annum

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## Hurricanes



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## Hurricanes

- Expectations of \$80 billion plus
- Potential for stronger hurricanes as water heat increases above 28 degrees
- 2 or more extreme hurricanes in one year
- Short memory in rating - Puerto Rico

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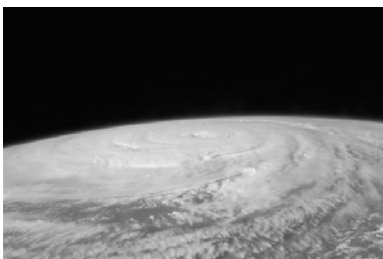
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## Hurricane from Space



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## Hurricanes

- 1986 Airic Publication
- What if two \$7 billion hurricanes hit
- Todays study
  - \$50bn? \$80 bn?
- Largest portion paid by reinsurance industry

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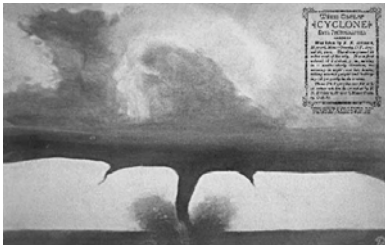
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## Tornadoes



The First Ever Tornado Photograph

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## Tornadoes

- Solve Navier Stokes equation for axisymmetric flow in a rotating cylinder!
- Cities are NOT immune
- Local extreme events

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## Earthquake

- Still little understood and not really managed
- Tsunami after earthquake
- Eventually there will be a big one and loss will depend on
  - location
  - design of building
  - fire after - See 1986 Airmic Study on Fire after Earthquake

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## Kobe



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## Earthquake

- UK has one on scale 4.5 every 10 years
- Paris is vulnerable to a one in 10,000 year quake - buildings not designed to withstand such a shock
- Concern over European quake

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## Tsunami



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## Tsunami

- Earthquake - height in meters
- Meteorite Hit- depends on size
- Land slide
  - very devastating
  - heights in 100's m
  - Canary Islands could devastate East Coast of US

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## Volcanoes



Mt St Helens with Mt Rainier

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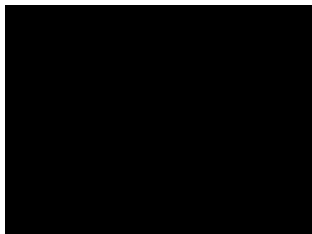
## Volcanoes

- Man builds on volcanoes due to fertile soil
- Most volcanic explosions are local - but have a global impact
- Tambora (1815)
  - year without summer (1816)
  - Frankenstein
- Mega eruptions

## Mega Scale

VEI	Description	Plume Height	Volume	Classification	How often	Example
0	non-explosive	<100 m	1000s m <sup>3</sup>	Hawaiian	daily	Kilauea
1	gentle	100-1000 m	10,000s m <sup>3</sup>	Haw/Strombolian	daily	Stromboli
2	explosive	1-5 km	1,000,000s m <sup>3</sup>	Strom/Vulcanian	weekly	Galeras, 1992
3	severe	5-15 km	10,000,000s m <sup>3</sup>	Vulcanian	yearly	Ruiz, 1985
4	cataclysmic	10-25 km	100,000,000s m <sup>3</sup>	Vulc/Plinian	10's of years	Galunggung, 1982
5	paroxysmal	>25 km	1 km <sup>3</sup>	Plinian	100's of years	St. Helens, 1981
6	colossal	>25 km	10s km <sup>3</sup>	Plin/Ultra-Plinian	100's of years	Krakatau, 1883
7	super-colossal	>25 km	100s km <sup>3</sup>	Ultra-Plinian	1000's of years	Tambora, 1815
8	mega-colossal	>25 km	1,000s km <sup>3</sup>	Ultra-Plinian	10,000's of years	Yellowstone, 2 Ma

## Volcano



### Mega Eruptions

- Once every 50,000 years
- Last one 72,000 years ago
- Mankind reduced to 10k individuals
- Not from typical volcanoes - but from large caldera
- Example is Yellowstone Park
- Estimates are 1 billion deaths

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### Other Issues Oil Spills



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### Other Issues Chemical Explosion



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### Where do we stand?

- Mega events are not insurable - so why pretend they are
- Concentration of risks making extreme losses more likely
  - Mega cities built in tectonic or storm areas
  - Miami, Los Angeles, Mexico City, Tokyo, New York, Naples, and so on

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### Insurance not being diversified

- Concentration in a diminishing number of major players
- Increasing reliance on A graded reinsurance
- Remember insurance needs diversification and not concentration.

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### Newer Capital

- Needed to cover most extreme risks
- Build up reserves
- Question over where invested?
  - Need for diversification

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### Comments

- There are some extreme events that cannot be insured
- How much are they?
- What do we do with the larger risks?
- Are running such risks really the price of civilisation?

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### Financial Extremes

- Concentrate on Financial Extremes
- Fundamentally differs from geophysical extremes
- Postulate they are fundamentally the result of human irrational behaviour
- If this is the case we need a new approach to understanding the issues

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### Some Examples

- Alchemy
- Tulips
- South Sea Bubble
- Internet Bubble
- Enron

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## Fundamental Drivers

- Greed
- Fraud
- Stupidity
- Irrational behaviour
- Madness of Crowds

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## Early Schemes

- Alchemy
  - Turn Lead into Gold – a super investment if it worked
  - Elixir of Life
- Tulipmania
  - Not just Dutch
  - International to seek arbitrage opportunities
  - Price completely irrational

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## South Sea Bubble



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## South Sea Bubble

- All the features
  - Conflict of interest – regulator was also the stockholder
  - Greed
  - Fraud
  - Promised excessive returns
- New Economy concept
  - Leverage through partly paid shares

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## South Sea Bubble

- South Sea Company didn't do any trade in the South Seas
  - Took over UK's National Debt
  - First Private/Public Initiative?
- Good things did arise
  - Marine and other Insurance companies with significant initial capital
  - Notes introduced (Mississippi Scheme)

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## South Sea Bubble



Figure 17.1  
Daily South Sea Share Prices, 1720. Data courtesy of Larry Neal.

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### Greater Fool Theory

- Increased over indebtedness
- Bank deposits give higher yield than stock dividend
- Only reason to hold stock is to sell at a higher price
- Ford – when the lift operator “knows” more than you its time to get out

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### Wall Street Crash and Recession

- Claim that no one could predict EVEN AFTER the event
- Over Optimism turned to extreme pessimism
- Money under beds and not in banks
  - No investment
  - Economy needed a kick start – New Deal

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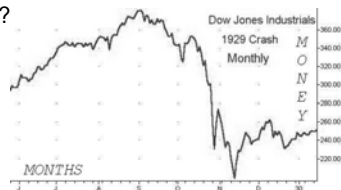
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### Wall Street Crash

Unpredictable – even after the event?



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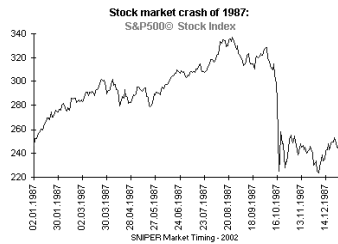
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## 1987 Crash



Once in every 10 universes!  
Once in every 10 Universes

## Internet Bubble – New Economy

- Economic Value versus Financial Value
- They should approximately equate
- In a bubble the investors “assume” different economic scenarios to those outside the bubble
  - Interest rates are decreasing so use lower discount rate
  - What does risk adjusted mean?

## Internet Bubble – New Economy

- So much paper is sold at so high a price to so many investors
- The market must be OK as it regulates itself!
- Banks goal (set by SEC) to protect retail and institutional investors...but...
- Banks didn't want to loose their fees

### Nick Leeson – winner of Ignoble Prize for Economics



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### Other Ignoble Prizewinners

- The Copper Trader who didn't know his buy button from his sell button (Cost 5% Chilean GDP)
- The investors of Lloyds
- Michael Milken
- Honorable Mention
  - The IT Department of a Bank who put the Training Room computers on line

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### 2002 Prize

To the executives, corporate directors and auditors of Enron,.....,HIH Insurance, .....WorldCom, Xerox and Arthur Anderson, for adapting the mathematical concept of imaginary numbers for use in the business world

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## Decline and Fall of Ignoble winners




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## Enron - "Laying" It on




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## Enron Venture Capitalism

- You have two cows.
- You sell three of them to your publicly listed company, using letters of credit opened by your brother-in-law at the bank,
- then execute a debt/equity swap with an associated general officer so that you get all four cows back,
- with a tax exemption for the five cows.
- The milk rights of the six cows are transferred via an intermediary to a Cayman Island company secretly owned by the majority shareholder
- who sells the rights to all seven cows back to your listed company.
- The annual report says the company owns eight cows, with an option on one more.

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## Noble Prize Winners

- Not immune – LTCM
- Assumed volatility didn't vary
- Markets were perfect
- Infinite Capital available (what's leverage in any case ?)
- No arbitrage
- Whoops apocalypse

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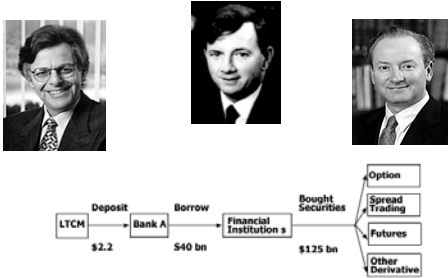
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## LTCM – A Noble Venture



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## The Regulator

- Throughout all the examples where was the regulator?
- Six sigma does not work in these events
  - Never seen a Normal distribution in Financial Mathematics
- Either self regulation or over regulation

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## The Regulator

- Self regulation – seen as opportunity to push business to the limit (and beyond)
- Over regulation – prevents economic development and often an (over) reaction to a specific event
- Corporate Governance – the latest buzzword
- Acts like Sarbanes-Oxley

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## The Regulator

- Can't happen in UK
  - Accounting more an art than a science
  - No GAAP
- Reliance on Efficient Market Hypothesis
  - Prices move in a well defined way
  - No arbitrage
  - No bubble

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## UK Insurers



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## The Regulator



- US Laissez faire gave false feeling of wealth
- Premises that Central bankers are supposed to control inflations and not set price
  - Prices inflated because interest falling and hence bubble
- Inactivity by regulator oversees a fundamental change of wealth
  - Honey – they shrunk my pension

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## Mathematical Models

- Extreme Value Theory based on concept of continuous distribution with some relationships between events
- I suggest that base on the analysis of irrational behaviour and the madness of crowds we need something else

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## Mathematical Models

- The Efficient Market Hypothesis is rigorous but false because it is an artifact of the early years of econometrics
- Economists sought to fit economic models into equations they could solve, possibly not realizing — being at best mediocre mathematicians — that linear and exponential equations, those soluble by mid-century economists, represented only a tiny fraction of the possible mathematical relationships that occur in nature.

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## Mathematical Models

- Simple equations they had studied in school adequately reflected reality in only a small fraction of situations
- the Efficient Market Hypothesis rested on a number of assumptions, made to simplify the equations into solubility, that were in fact demonstrably untrue
- This leads to non linear assumptions – Catastrophe & Chaos Theory

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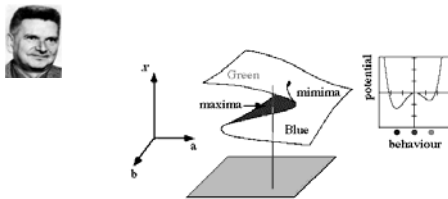
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## Rene Thom – Catastrophe Theory



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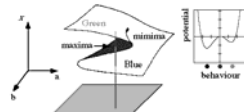
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## Catastrophe Theory



- Thom's Theory itself could be considered a bubble
- Chris Zeeman used the catastrophe to explain many things!
- The financial model used in his paper used fundamentalists and chartists
- But
- We know from experience that crashes are a result over over optimism reverting to pessimism

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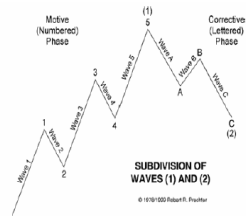
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## Elliott Waves




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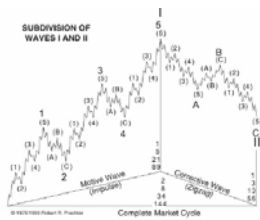
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## Elliott Waves




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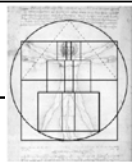
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## Elliott Waves



- 5 up and 3 down
- The 5-3 pattern is the minimum requirement for, and therefore the most efficient method of, achieving both fluctuation and progress in linear movement when the only constraint is that the lengths of odd-numbered waves of each degree be longer than those of the even-numbered ones.
- The Fibonacci is the mathematical basis for the Wave principle
- The Golden Ratio

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## Elliot Waves

- Strong connection with complexity theory
- Maybe not the perfect solution (it is the simplest)
- Finance is a Complex Dynamical System

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## Dynamical Systems

- Insurance and Finance are nonlinear Complex Dynamic Systems
- Standard deviation is not a measure of variability or management control
  - Six Sigma is inappropriate
- Entropy is a better measure

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## Why Entropic Measures

- Black Scholes equation is really a special example of an entropic formula and has been generalised
- Generalise CAPM
- Risk measures used in papers can be derived from entropic measures
  - Hazard Transform
  - Wang transform
- Coherent risk measures can be easily generated from relative entropic measures

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### Entropy – the Way forward

- Operational Risk measurements
- Pricing – Choquet Integral
- A possible new tool for the profession
- Brings geophysical and financial risks together

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### Mathematics of 30 years ago

- Catastrophe Theory Struggling
- Chaos slowly becoming recognised leading eventually to complexity theory
- Entropy understood
  - Shannons Theorem
  - Fisher Information Criteria
- No computers

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### Mathematics Today

- q More Computer power
- q More mature
- q But should look back to find useful tools for todays issues

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