

**From Turbulence to Hydrology
and Beyond
or
From Plato to Borges and ...**

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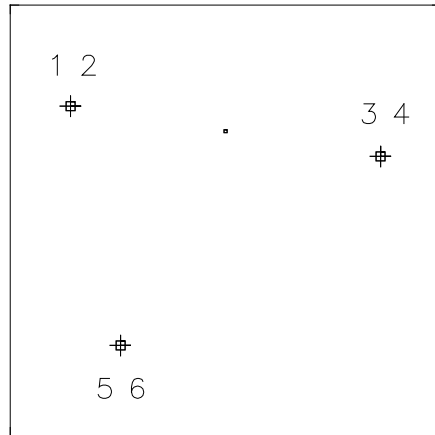
“Science is nothing but perception”

PLATO (427 AC – 347 AC)

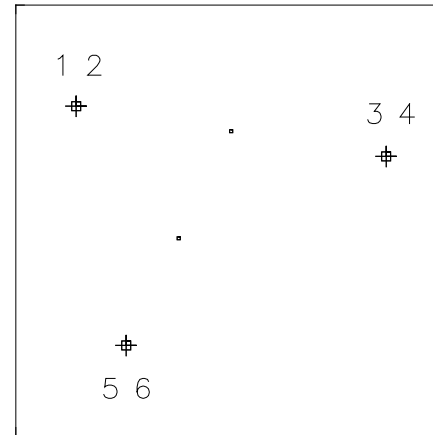
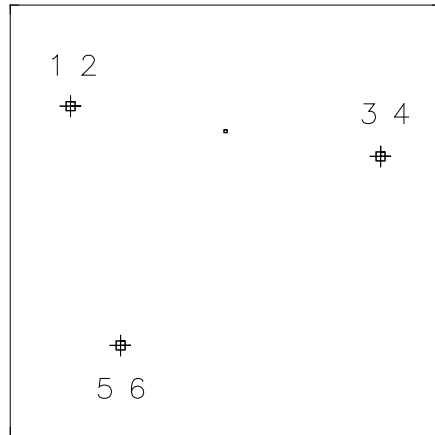
“I have always imagined that Paradise will be a kind of library”

JORGE LUIS BORGES (1899 – 1986)

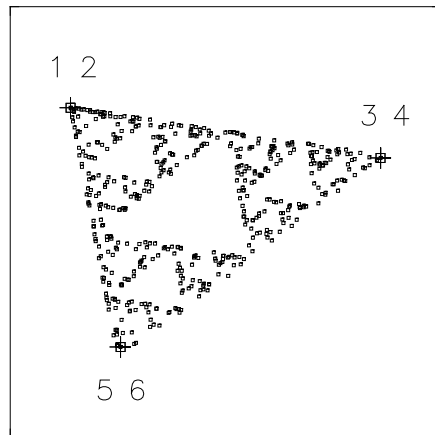
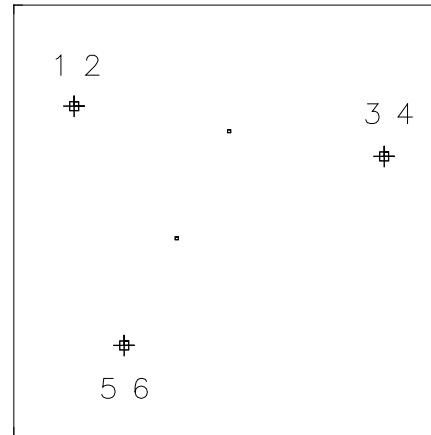
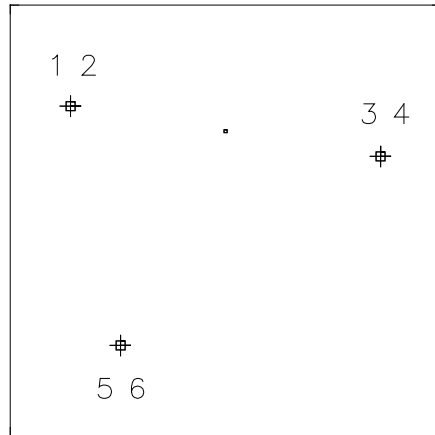
The chaos game



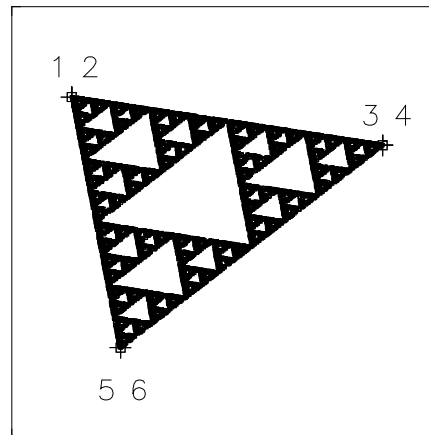
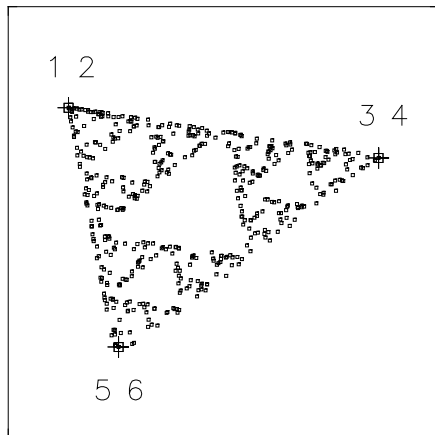
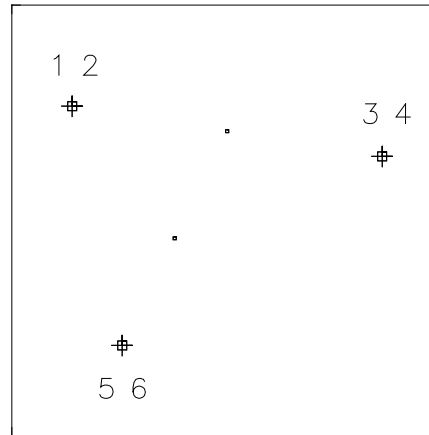
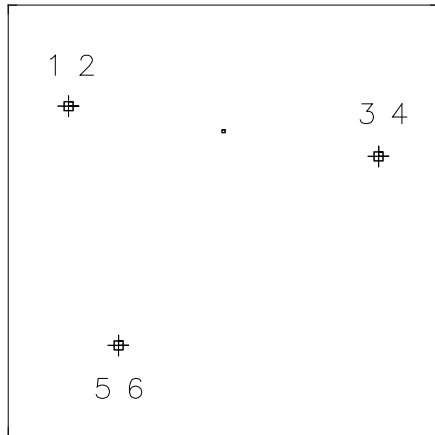
The chaos game



The chaos game



The chaos game



a fractal

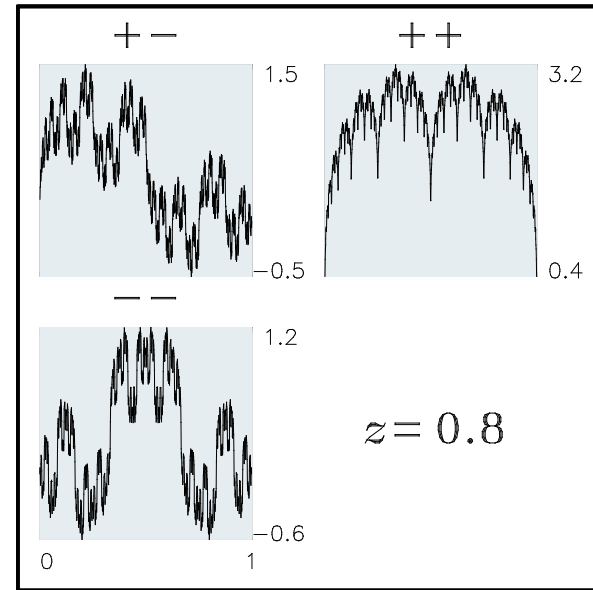
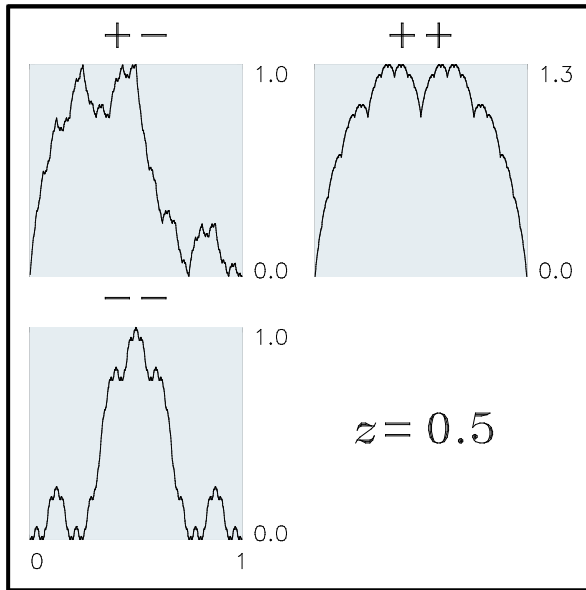
With other rules and a coin

$$w_1(x, y) = \left(\frac{x}{2}, x + d_1 \cdot y \right), w_2(x, y) = \left(\frac{x}{2} + \frac{1}{2}, 1 - x + d_2 \cdot y \right)$$

With other rules and a coin

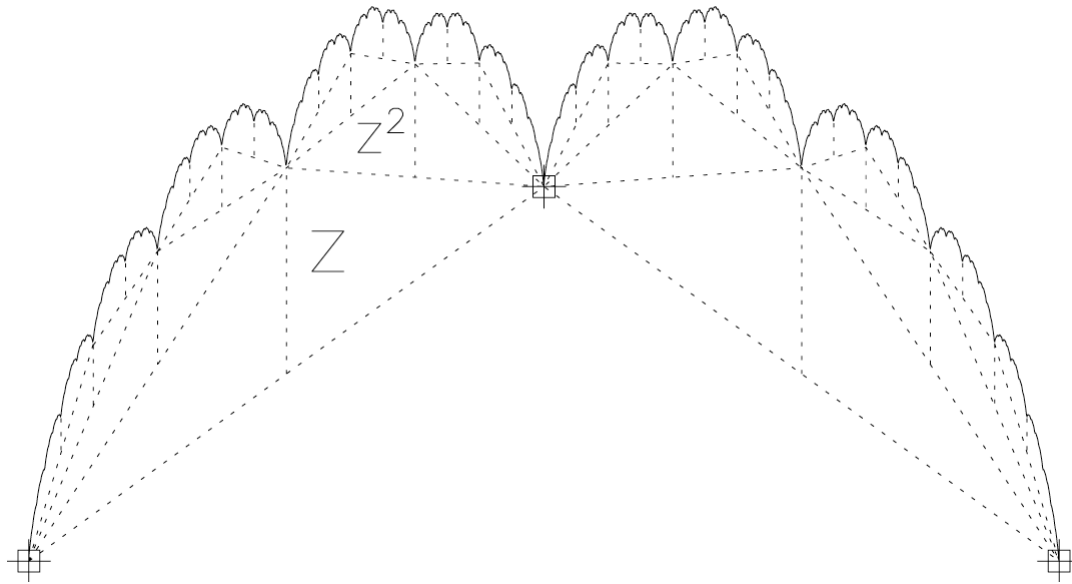
$$w_1(x, y) = \left(\frac{x}{2}, x + d_1 \cdot y \right), w_2(x, y) = \left(\frac{x}{2} + \frac{1}{2}, 1 - x + d_2 \cdot y \right)$$

$$z = |d_1| = |d_2| < 1$$

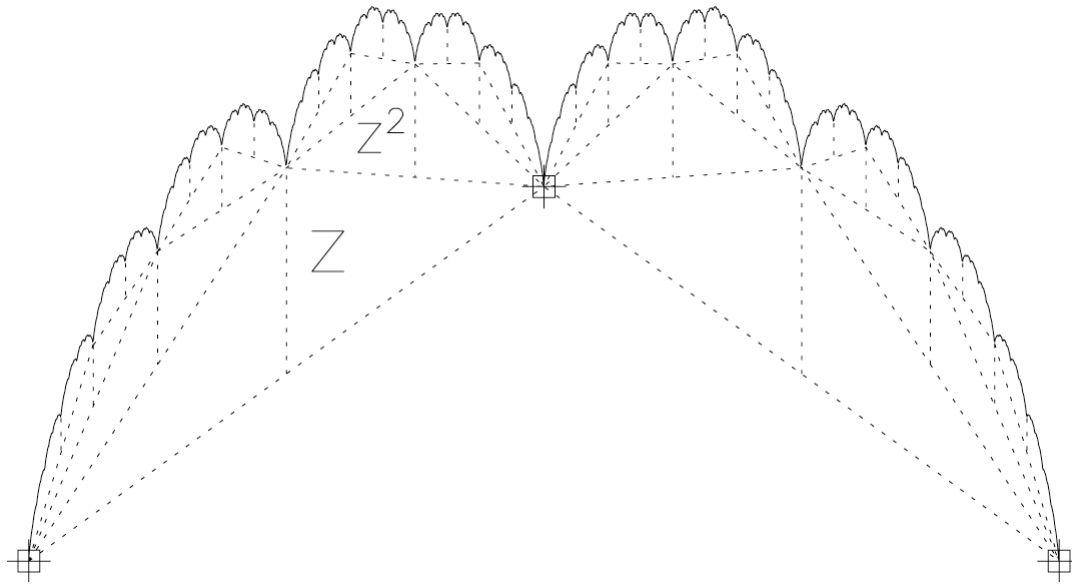


fractal wires...

Deterministic profiles



Deterministic profiles

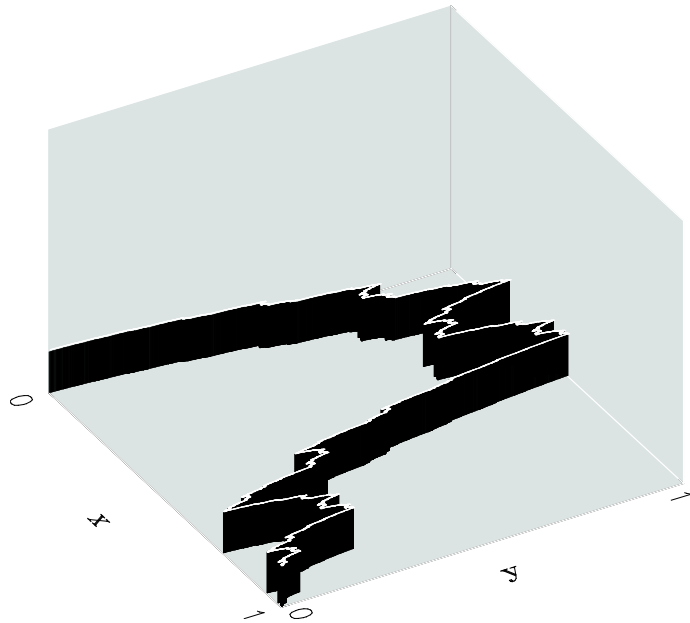


case + -: up and down at the same level

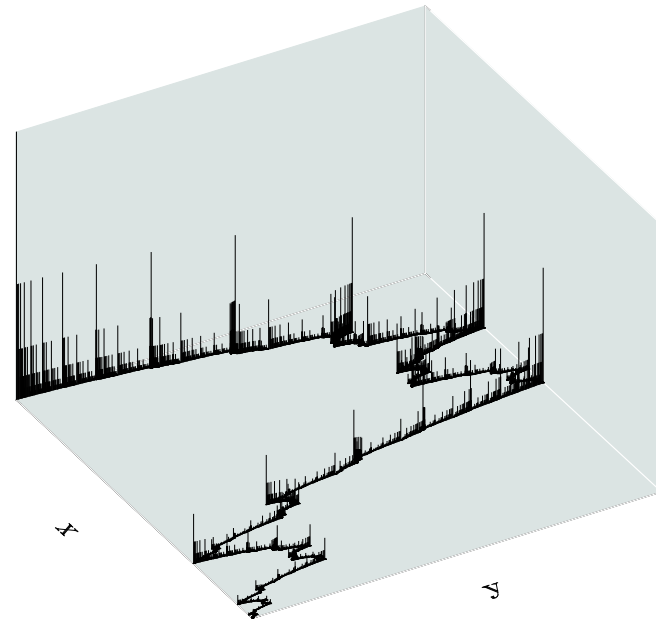
case - -: all down for first level, all up for second level, etc.

Using fair or biased coins

50-50



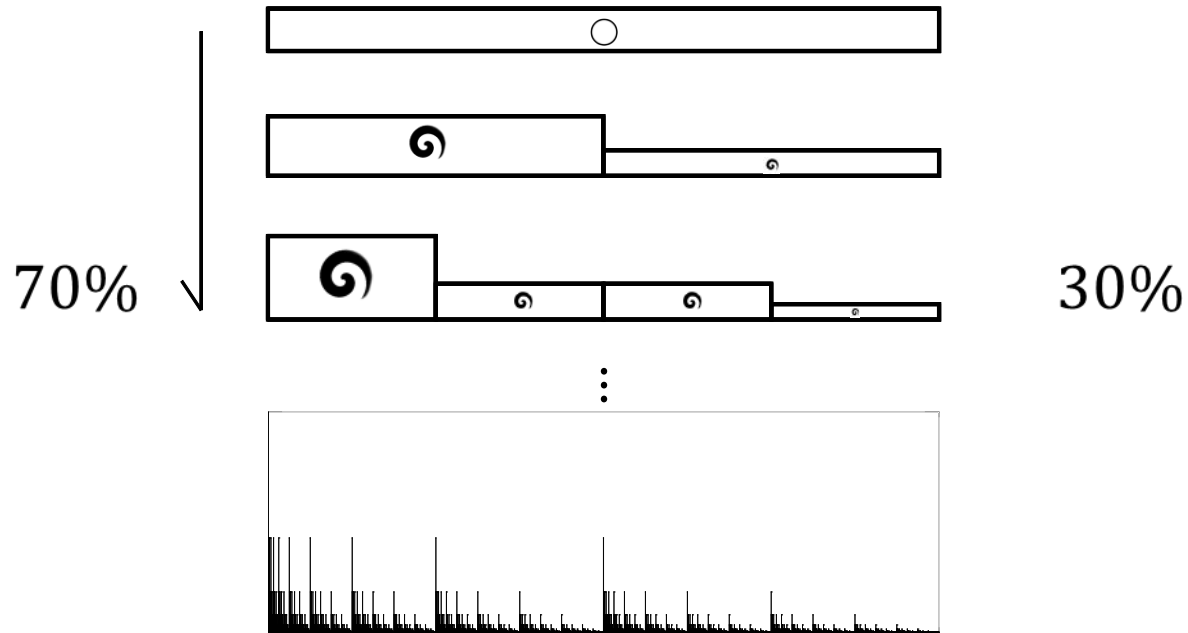
70-30



different textures over the same wire

From x : a turbulent cascade

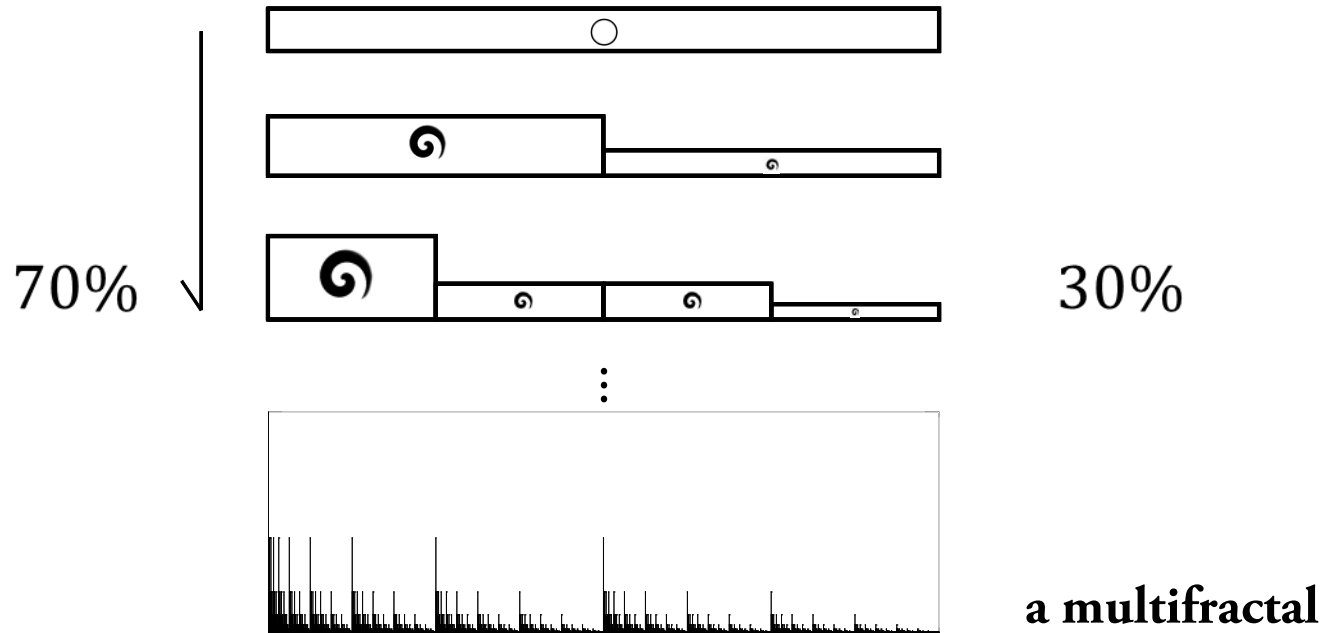
(Meneveau and Sreenivasan, 1987)



a sequence of **eddies** that divide the energy **universally**

From x : a turbulent cascade

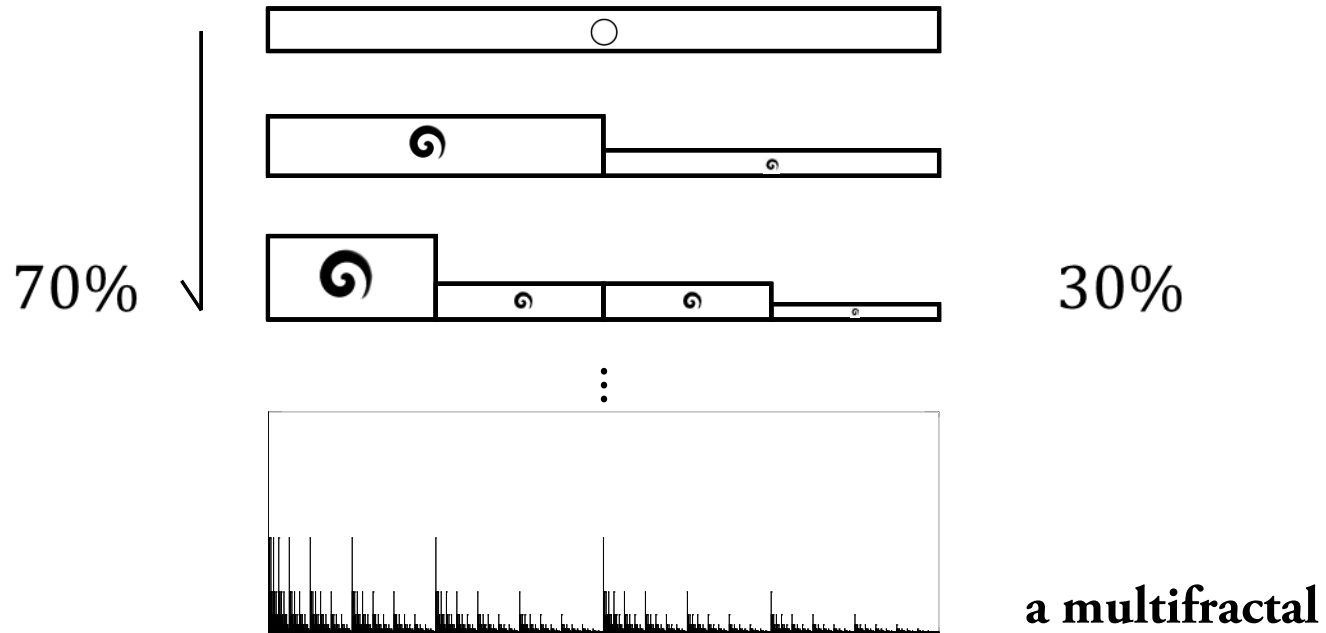
(Meneveau and Sreenivasan, 1987)



a sequence of **eddies** that divide the energy **universally**
a collection of intertwined **thorns** with **dusty** supports

From x : a turbulent cascade

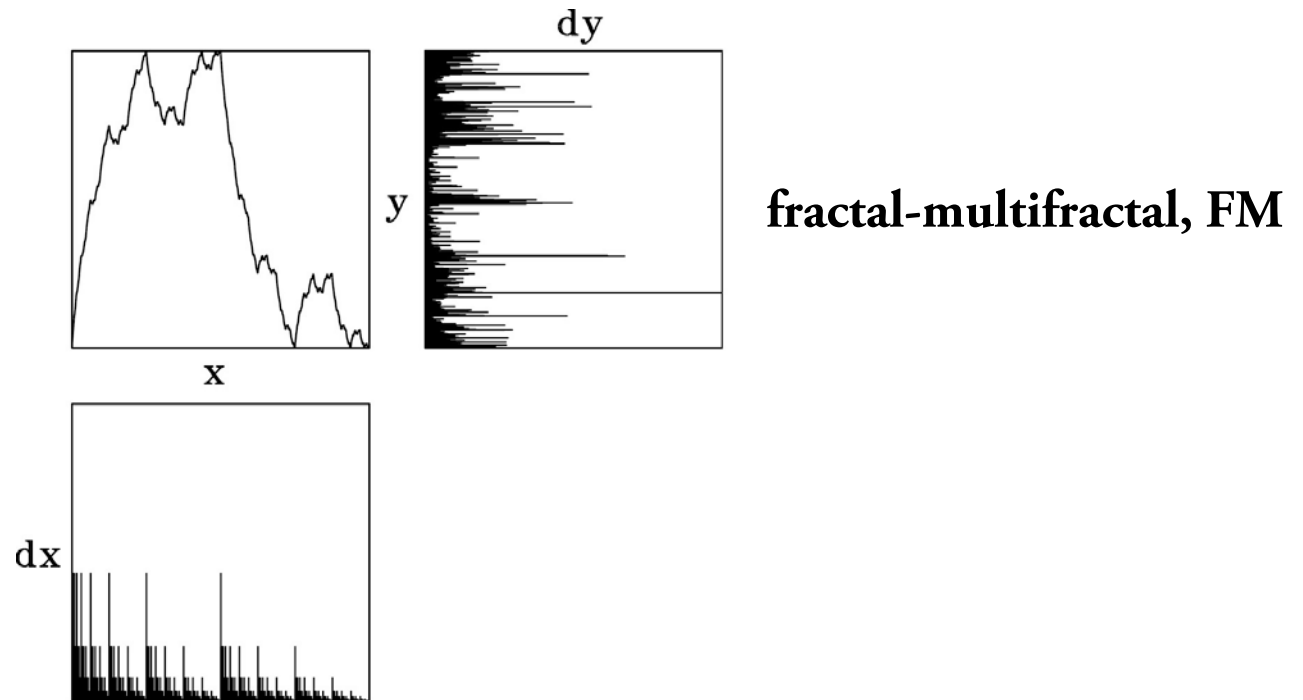
(Meneveau and Sreenivasan, 1987)



a sequence of **eddies** that divide the energy **universally**
a collection of intertwined **thorns** with **dusty** supports
the same **fractured** object reflects biased wealth distributions

From y : a Platonic vision to complexity

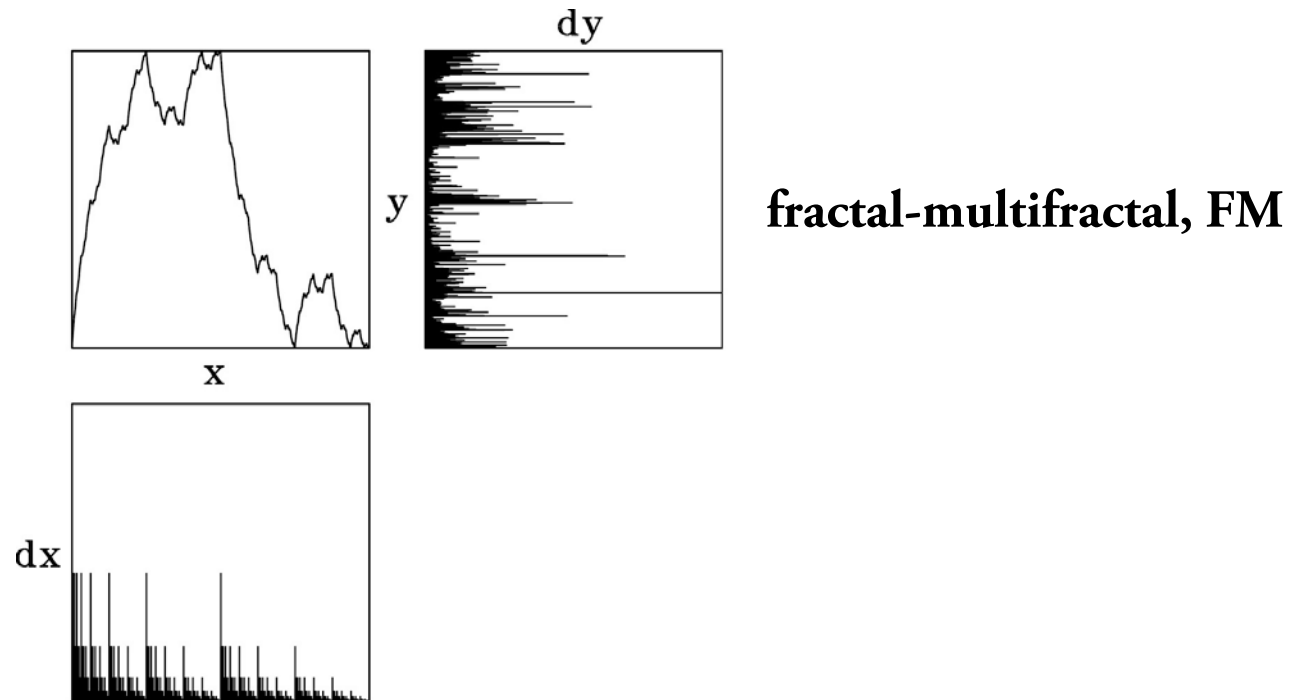
(Puente, 1992, 1994)



dx is the “illumination” of the **wire** and dy is its **derived** projection

From y : a Platonic vision to complexity

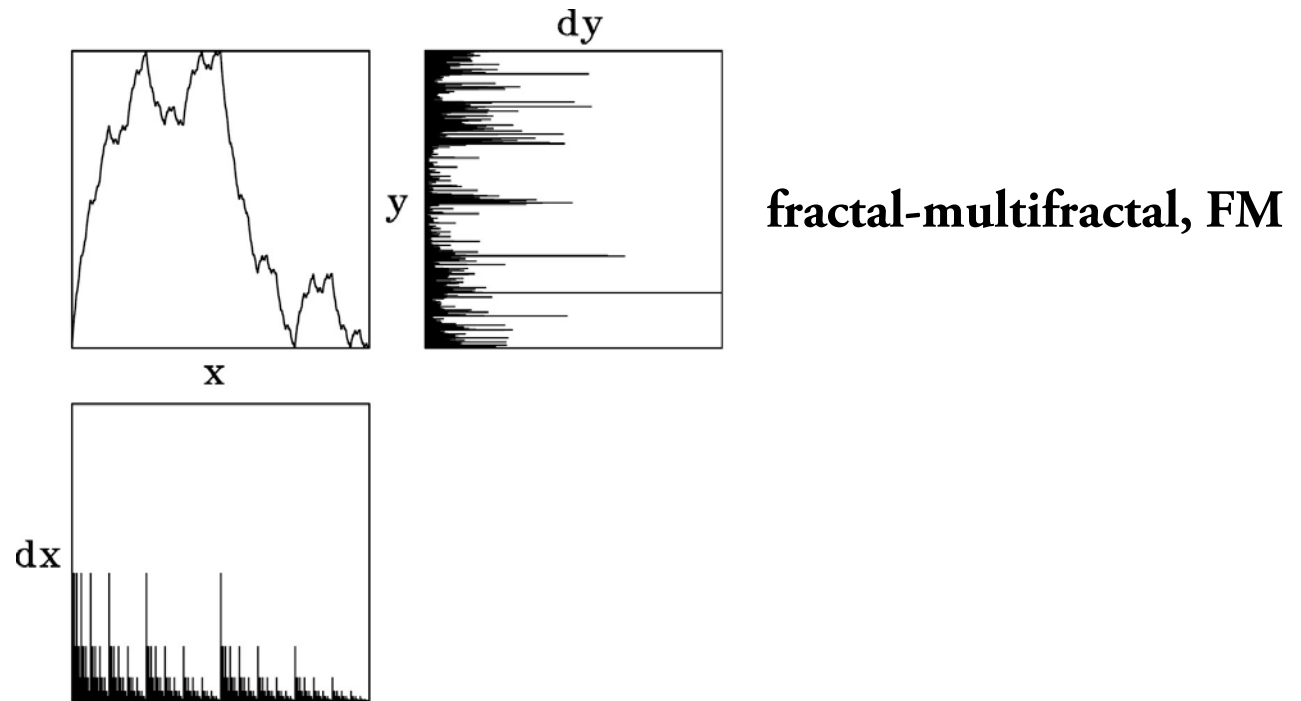
(Puentes, 1992, 1994)



dx is the “illumination” of the **wire** and dy is its **derived** projection
 dy is a **transformation** of turbulence, a non-trivial **physical** cascade

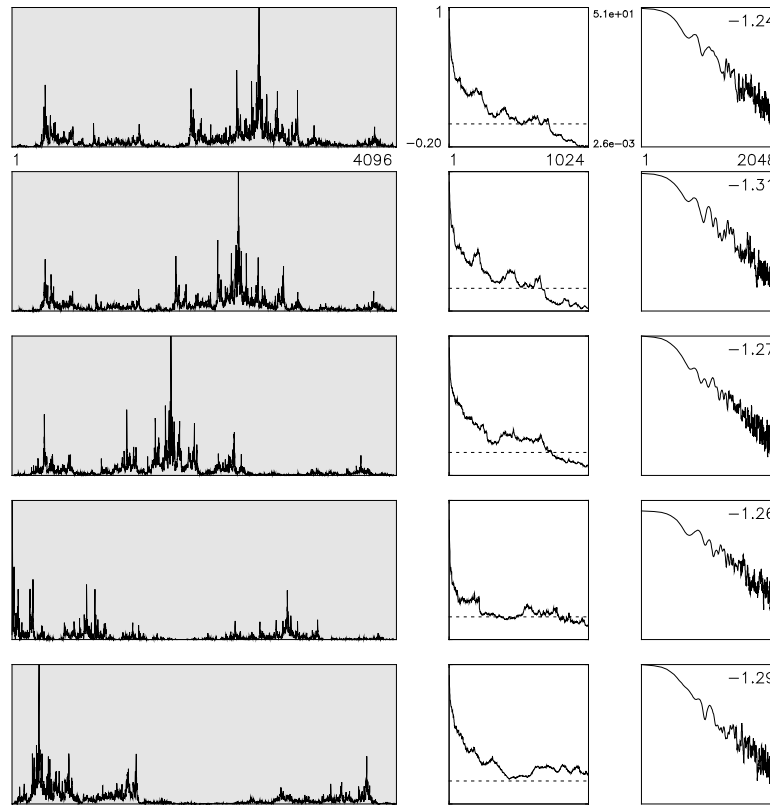
From y : a Platonic vision to complexity

(Puentes, 1992, 1994)



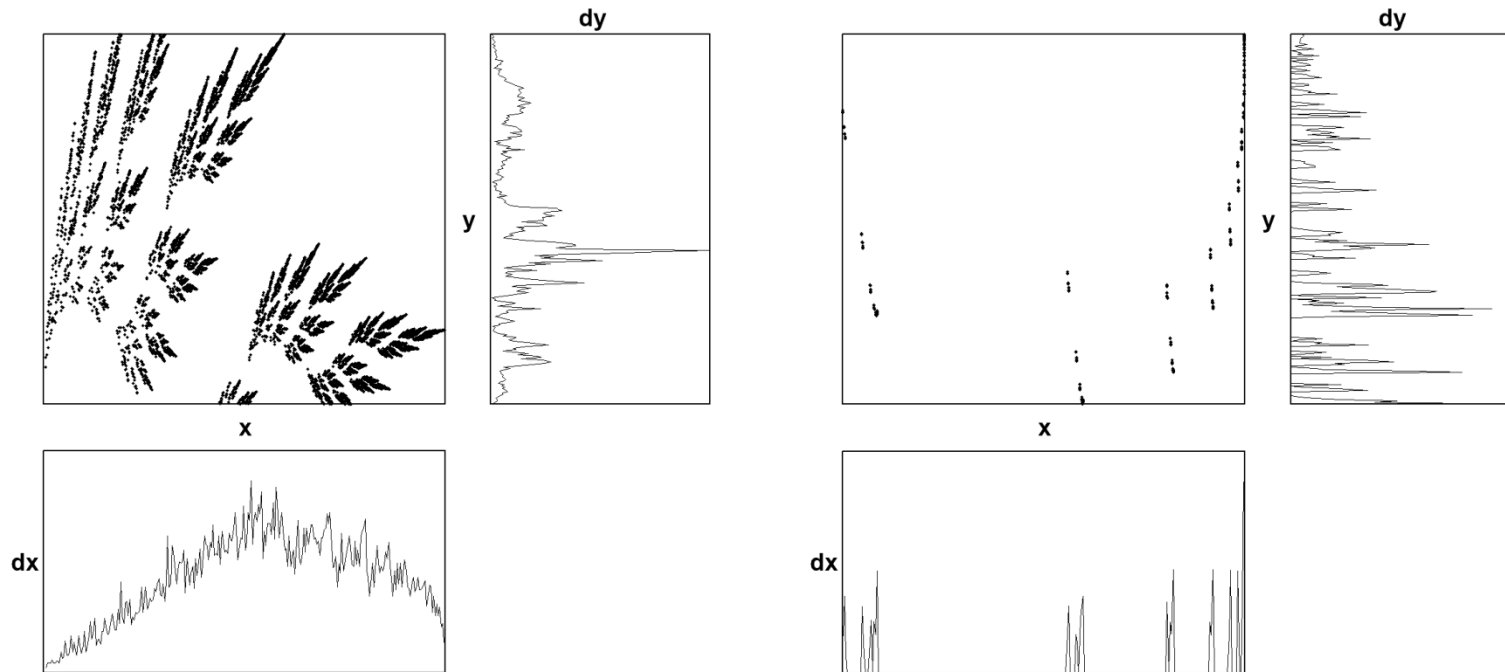
dx is the “illumination” of the **wire** and dy is its **derived** projection
 dy is a **transformation** of turbulence, a non-trivial **physical** cascade
the “shadow” dy appears to be **random**, but it is not

Projections galore



complex data sets are thought of as distributions
varying FM parameters yields similar statistics as **natural** sets

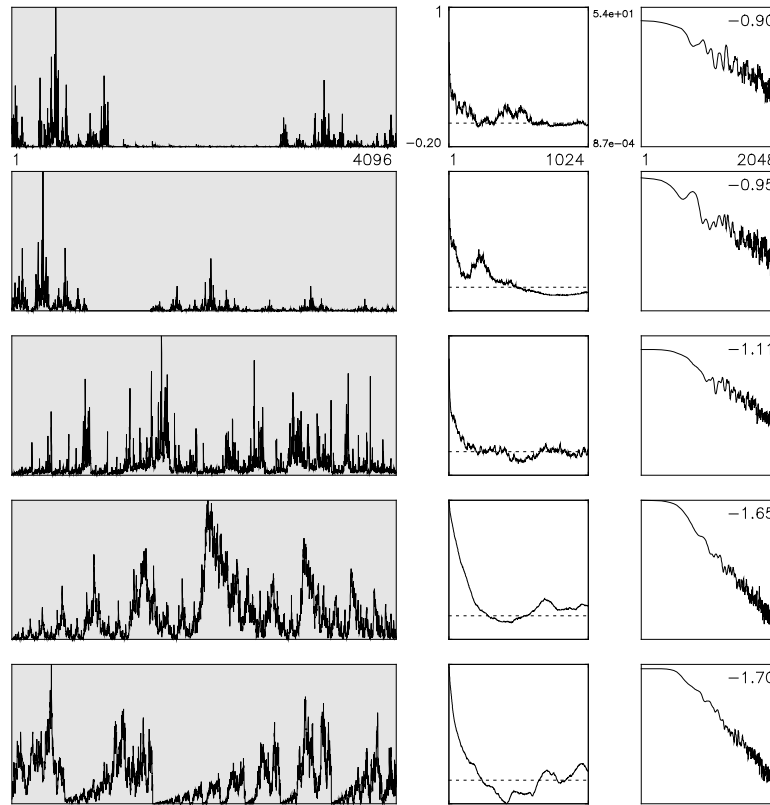
Some beautiful generalizations



“leaves” from maps that overlap in x

Cantor attractors if no overlap

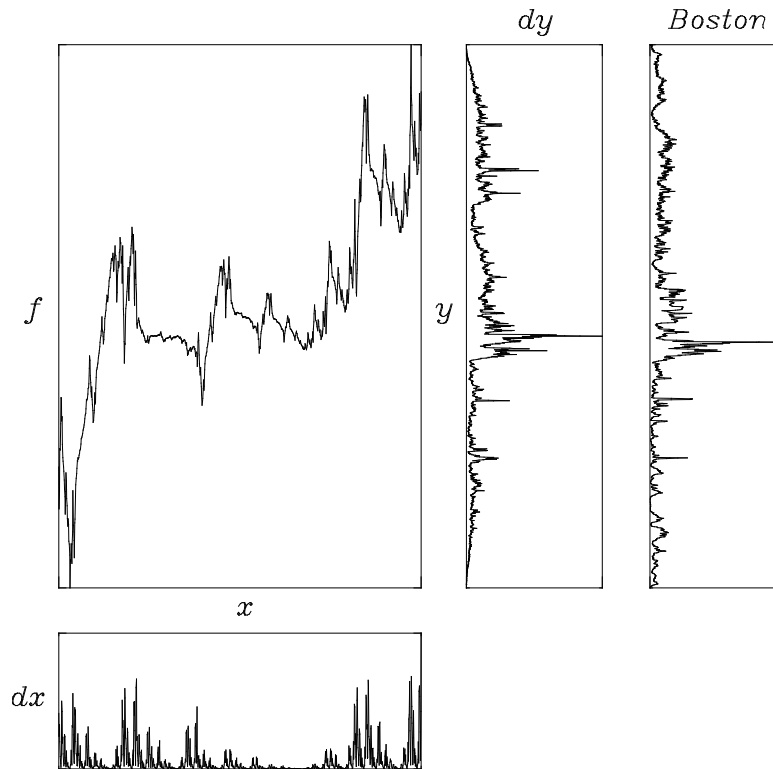
More Platonic designs



with periods of inactivity
“chance” and ramps

Encoding a storm in Boston

(Puente and Obregón, 1996)

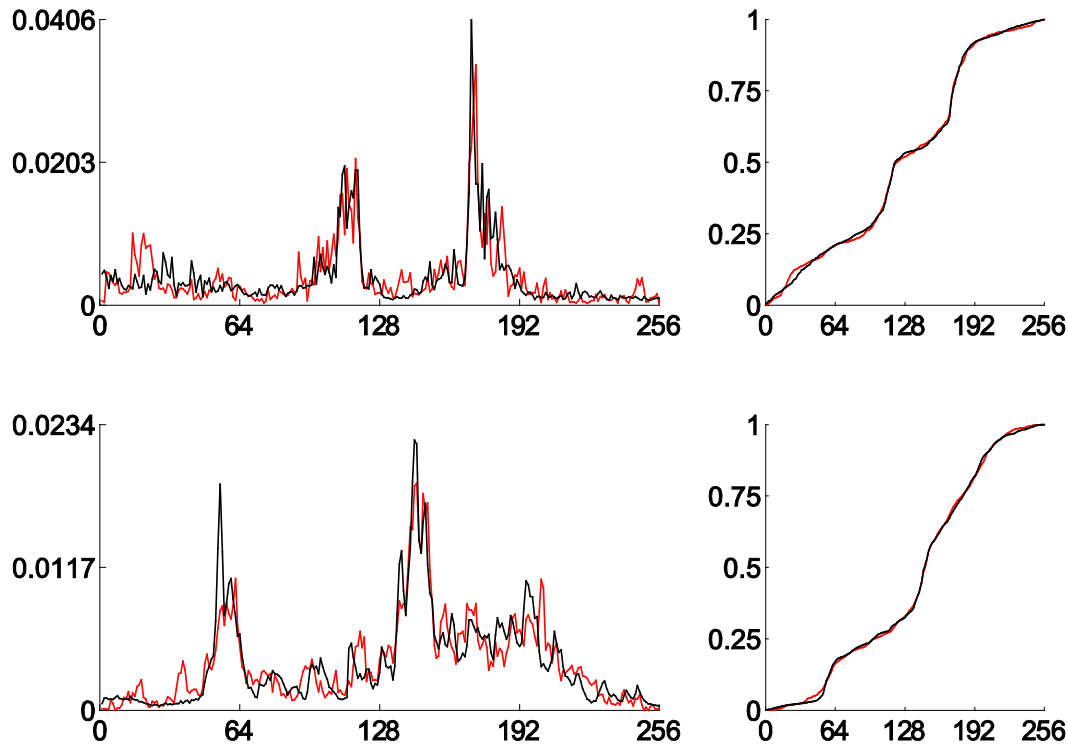


a model (center) of real data in 1980 (right)

the model preserves **statistical** and **chaotic** characteristics

Encoding storms in Iowa City

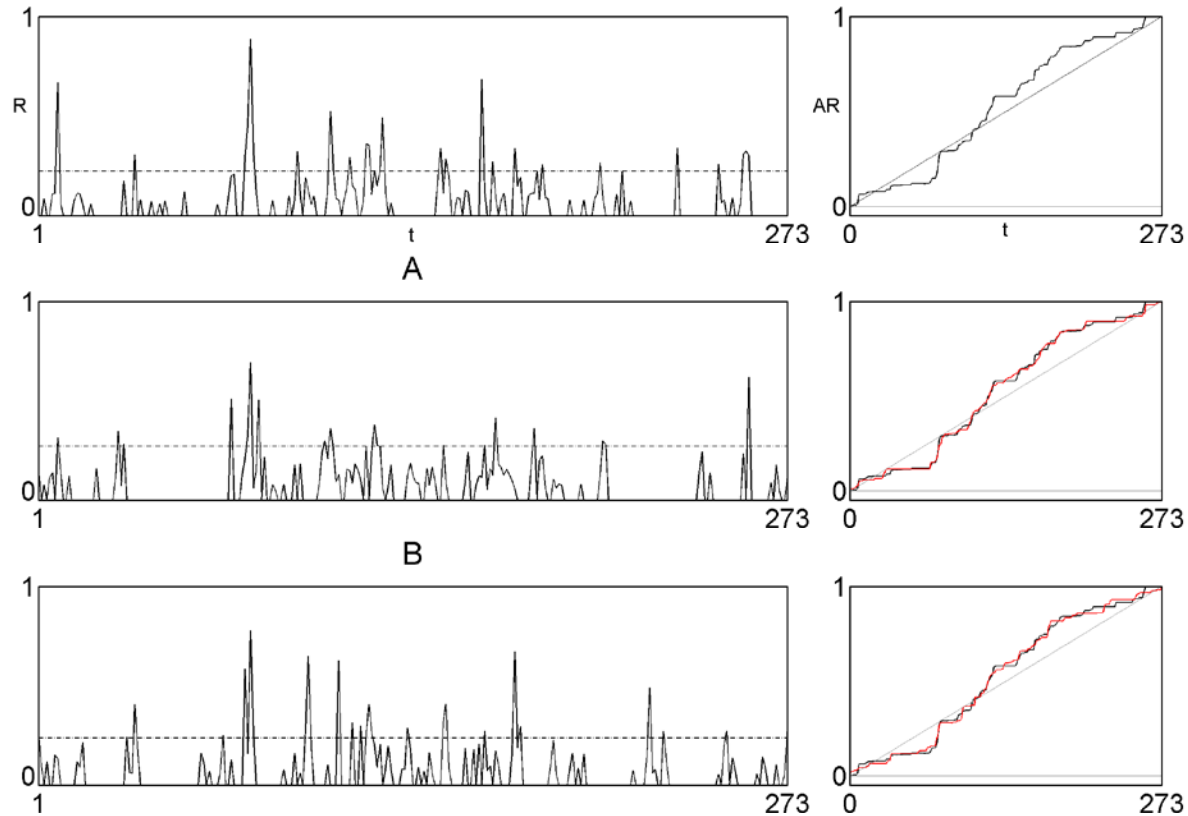
(Huang et al., 2012)



RMSEAR 0.98%, 0.76%; MAXEAR 3.52%, 2.12%
measured in 1990, compressions greater than 350:1

Encoding rainfall in Laikakota, Bolivia

(Maskey et al., 2015)



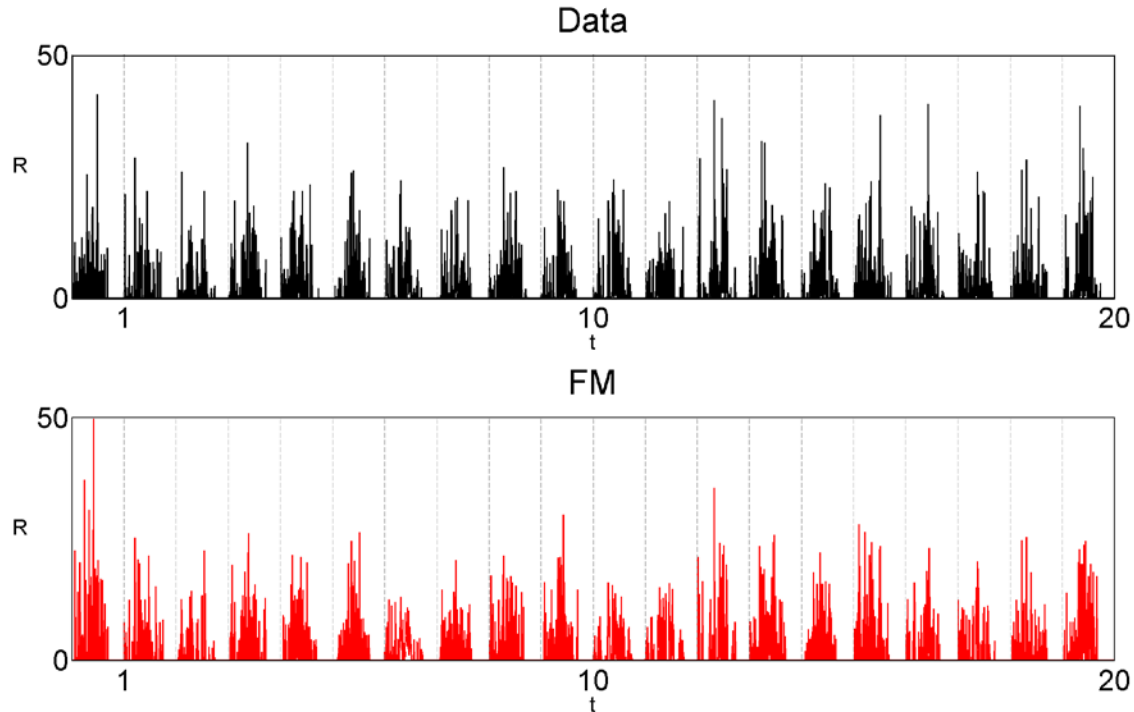
Cantorian input
plus threshold

RMSEAR 1.4, 1.8%; MAXEAR 4.4, 3.5%

gathered in 1965-66, compressions 25:1

Encoding rainfall in Laikakota, Bolivia

(Maskey et al., 2015)



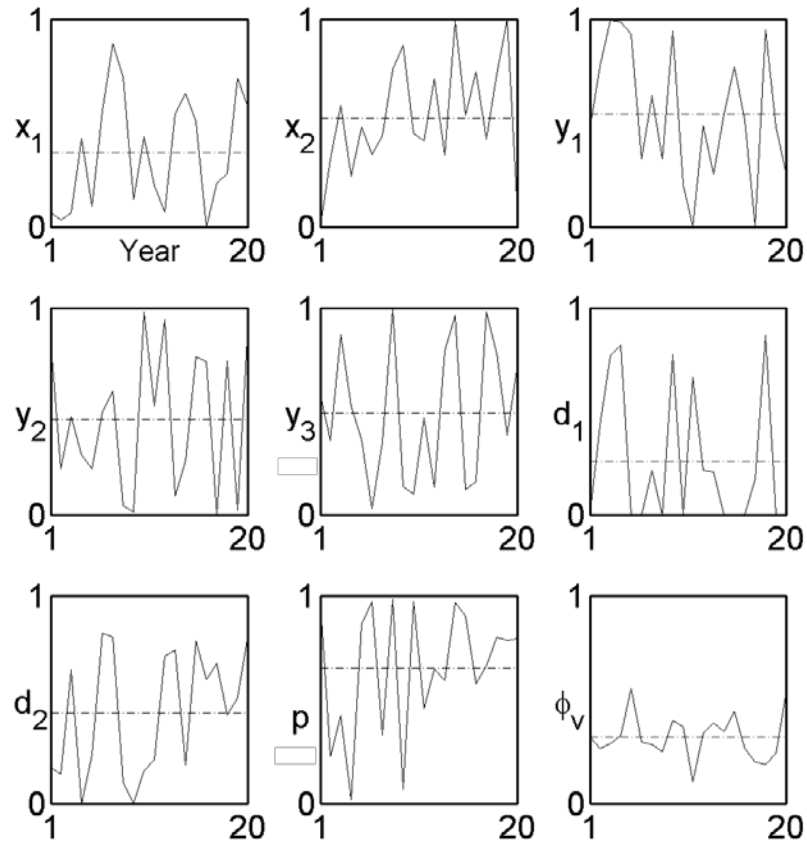
Cantorian input
plus threshold

scale in mm/day

RMSEAR $1.8 \pm 0.3\%$; MAXEAR $5.6 \pm 1.3\%$
from 1964-65 to 1983-84, compressions 25:1

Dynamics of rainfall in Laikakota, Bolivia

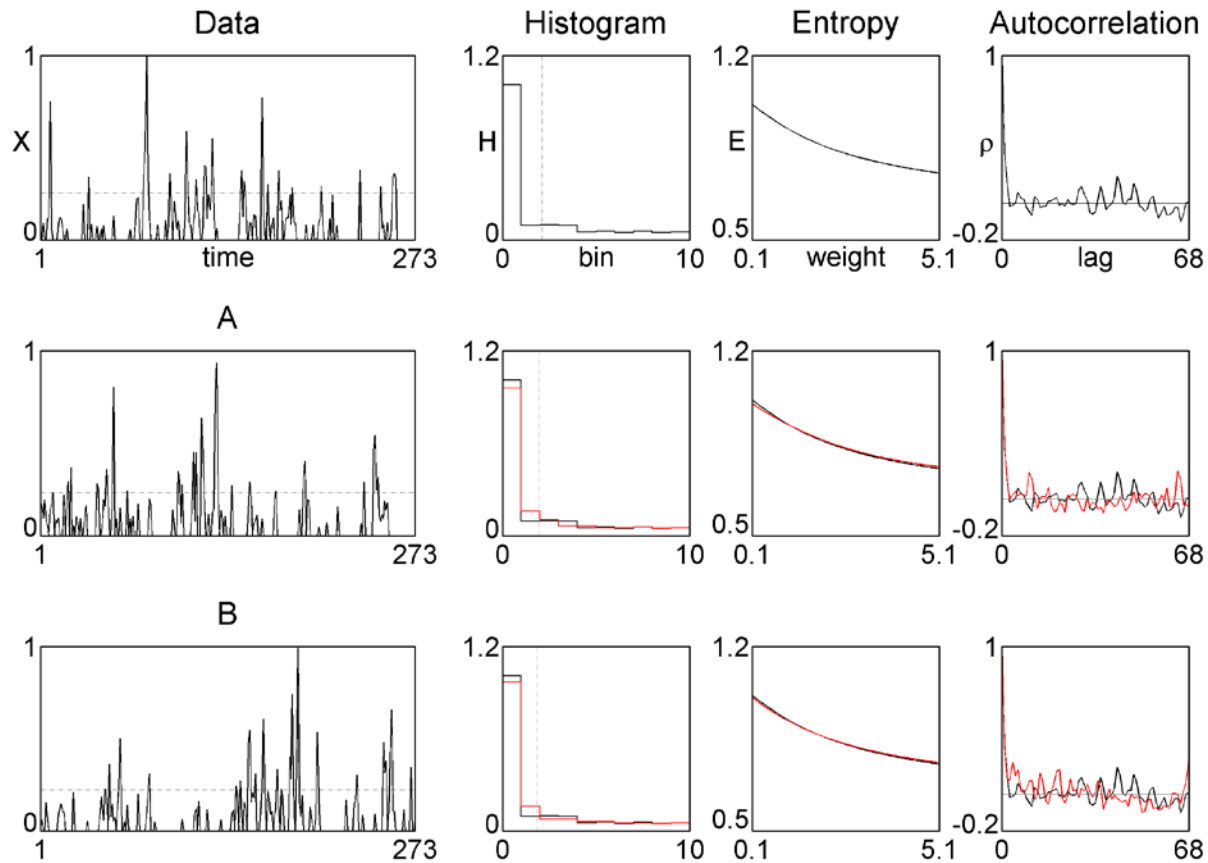
(Maskey et al., 2015)



to assess rainfall complexity and climate change, also temperature...

Simulating rainfall in Laikakota, Bolivia

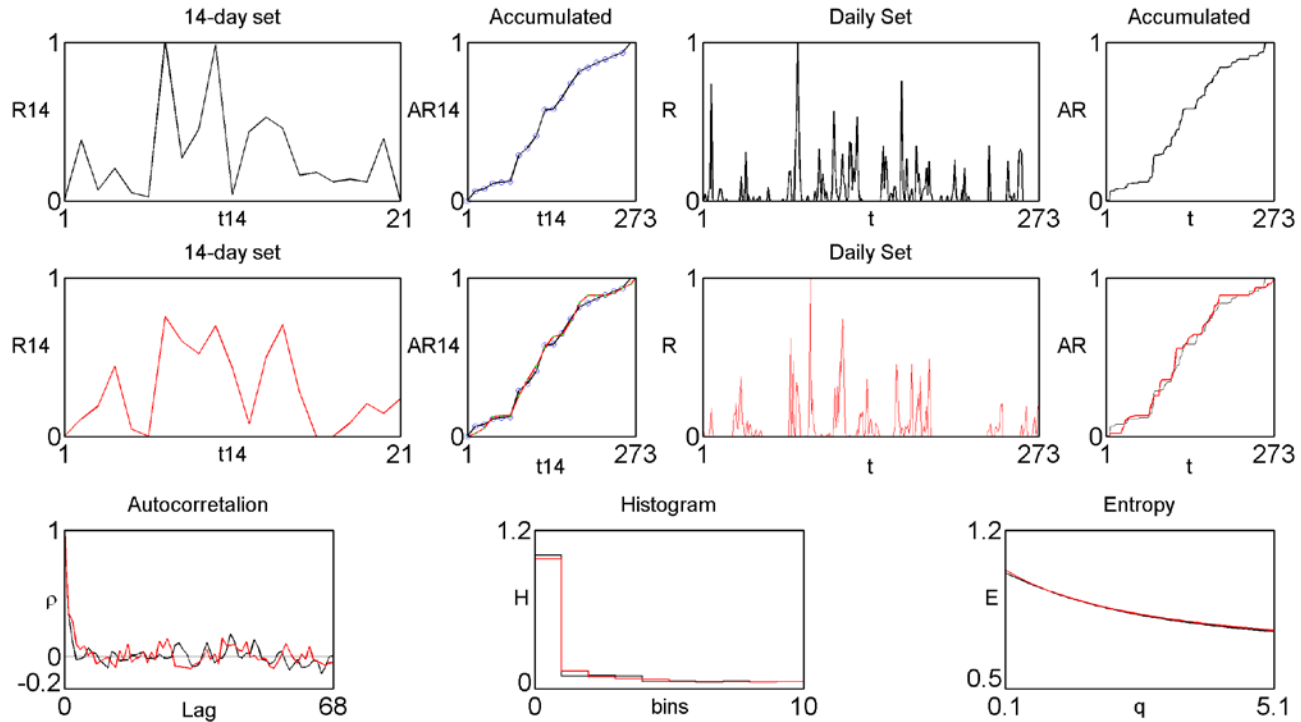
(Maskey et al., 2016a)



based on histogram, entropy and consecutive zeroes

Downscaling rainfall in Laikakota, Bolivia

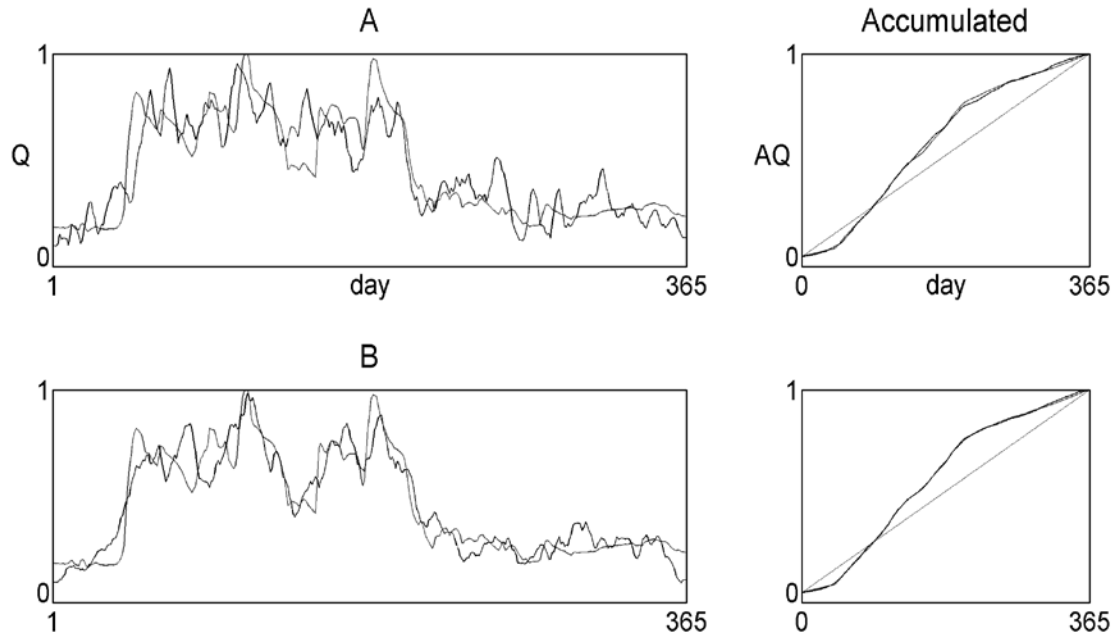
(Maskey et al., 2016b)



based on cumulative set every 14 days

Encoding streamflow in Sacramento River

(Maskey et al., 2016c)



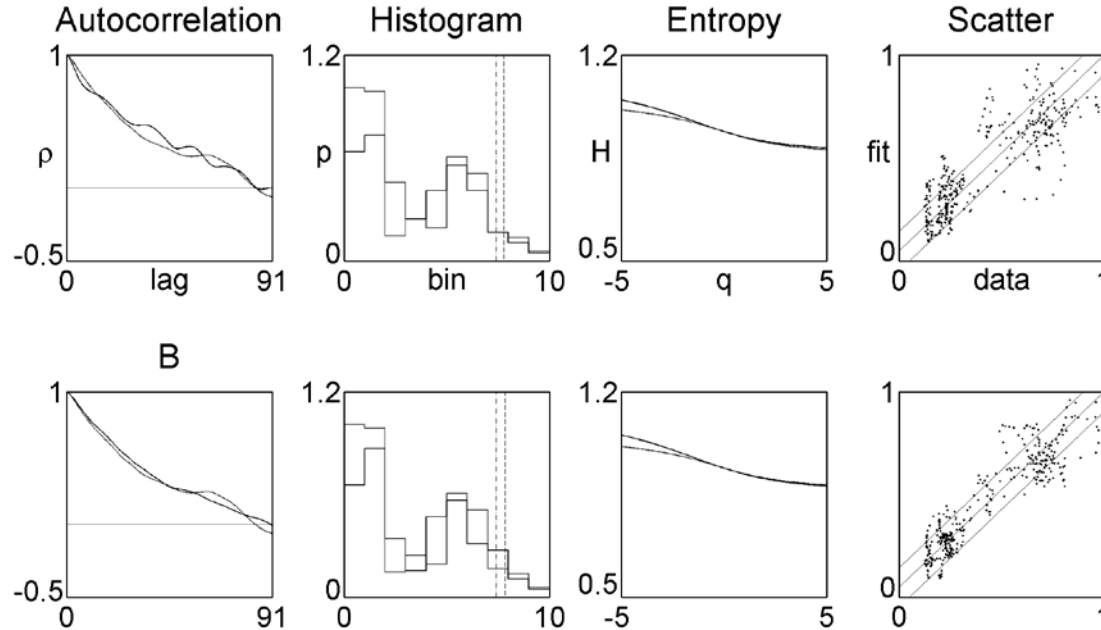
A: wire 2 maps, B: wire 3 maps

RMSEAR 1.0%, 0.5%; MAXEAR 2.3%, 1.1%

water year 1973-74, compressions greater than 40:1

Encoding streamflow in Sacramento River

(Maskey et al., 2016c)

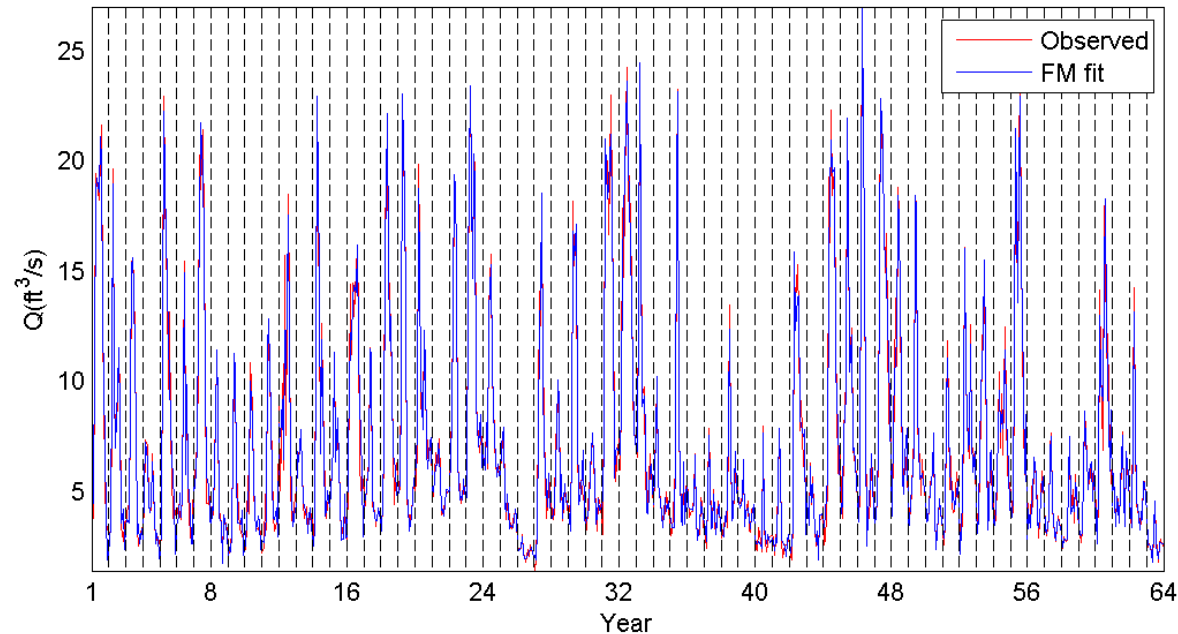


A: wire 2 maps, B: wire 3 maps

NSD 73.3%, 85.0%; NSA 95.7%, 98.1%; NSE 93.9%, 92.8%

Encoding streamflow in Sacramento River

(Maskey et al., 2016c)



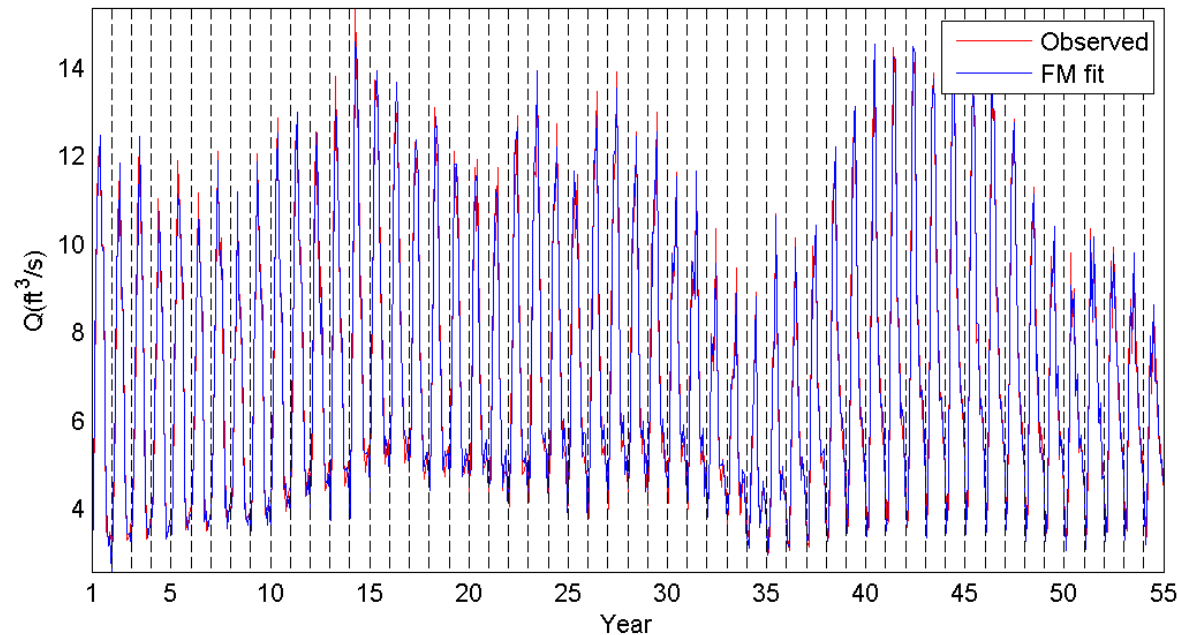
wire 3 maps, scale in $10^4 \times \text{cfs}$

RMSEAR $0.8 \pm 0.3\%$; MAXEAR $1.8 \pm 0.5\%$; NSD $63.9 \pm 19.0\%$

by year 1950-2014

Encoding streamflow in Sacramento River

(Maskey et al., 2016c)



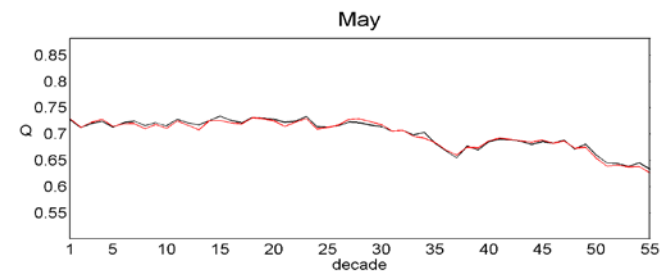
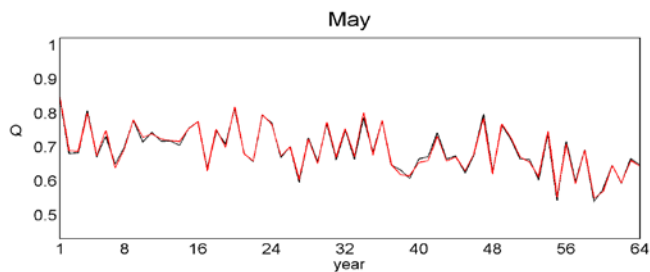
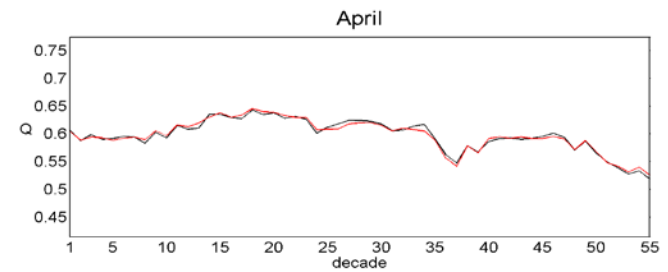
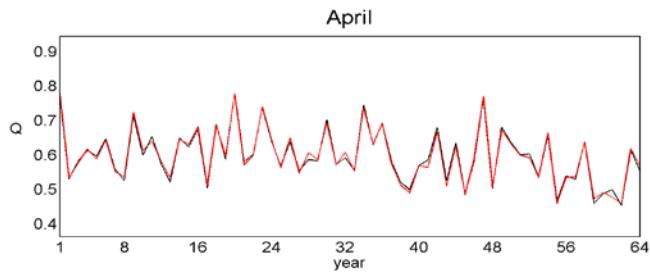
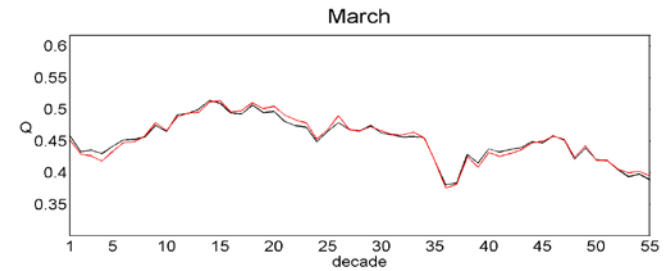
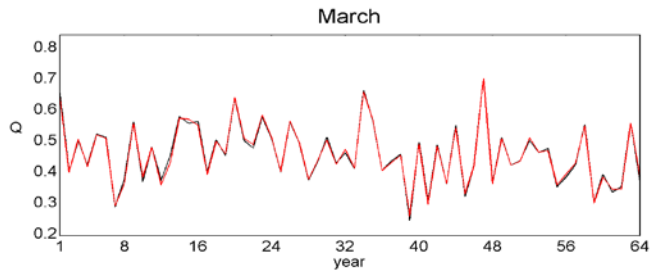
wire 3 maps, scale in 10^4 x cfs

RMSEAR $1.8 \pm 0.4\%$; MAXEAR $3.6 \pm 0.7\%$; NSD $92.2 \pm 12.5\%$

by decade 1959-2014

Encoding streamflow in Sacramento River

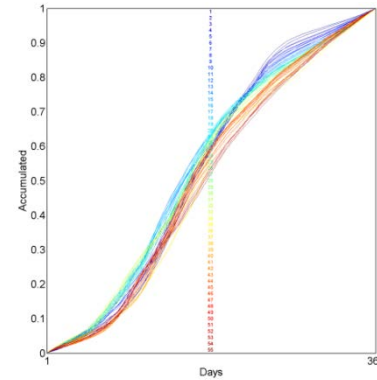
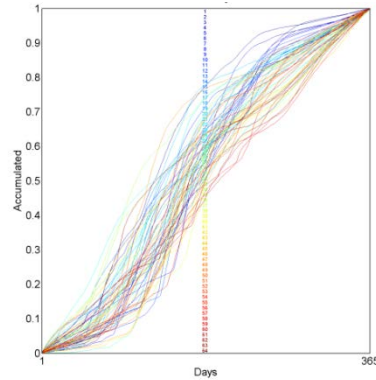
(Maskey et al., 2016c)



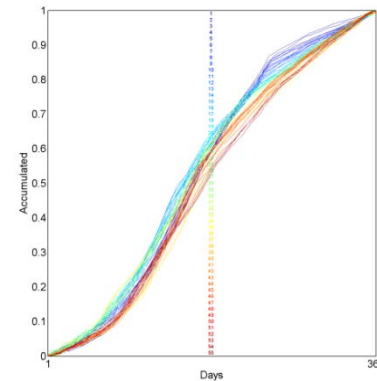
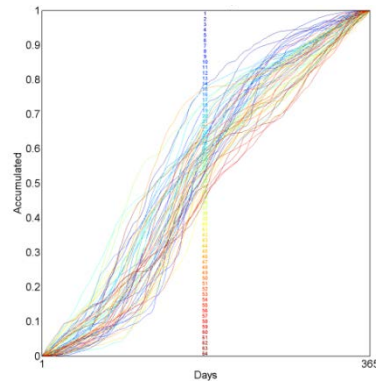
spring flows by year and by decade

Encoding streamflow in Sacramento River

(Maskey et al., 2016c)



data

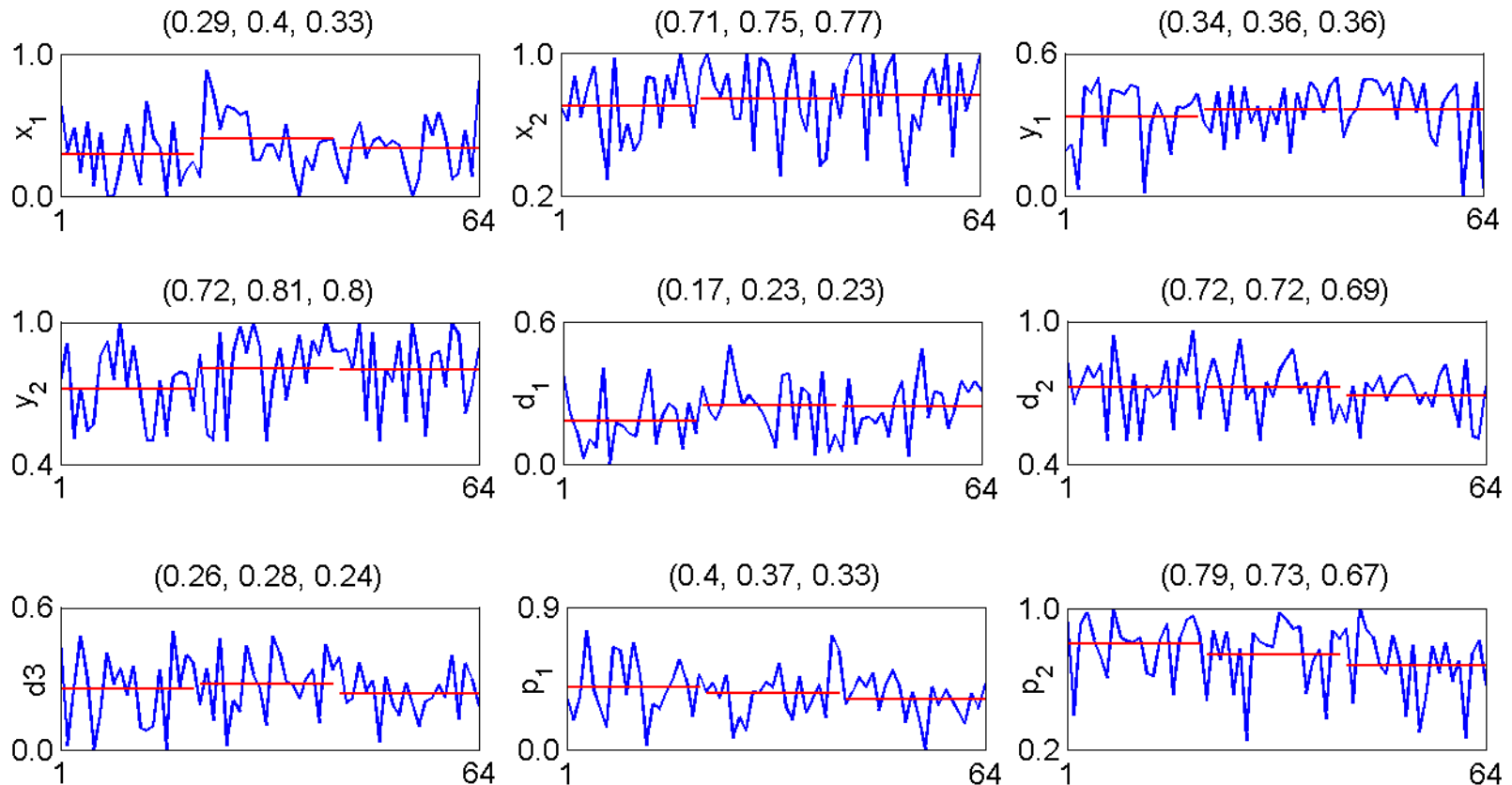


FM fit

accumulated by year and by decade

Dynamics of streamflow in Sacramento River

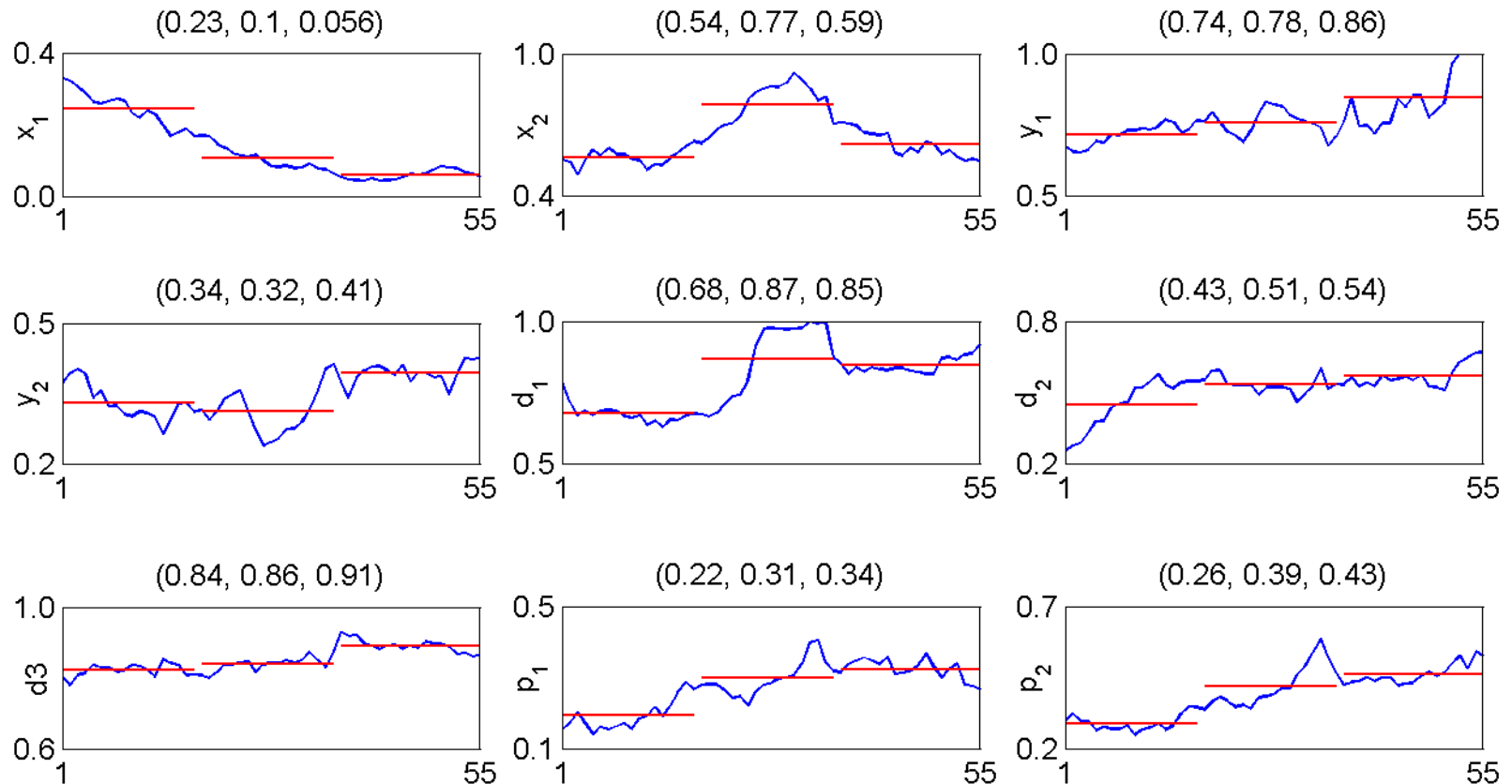
(Maskey et al., 2016d)



by year 1950 - 2014

Dynamics of streamflow in Sacramento River

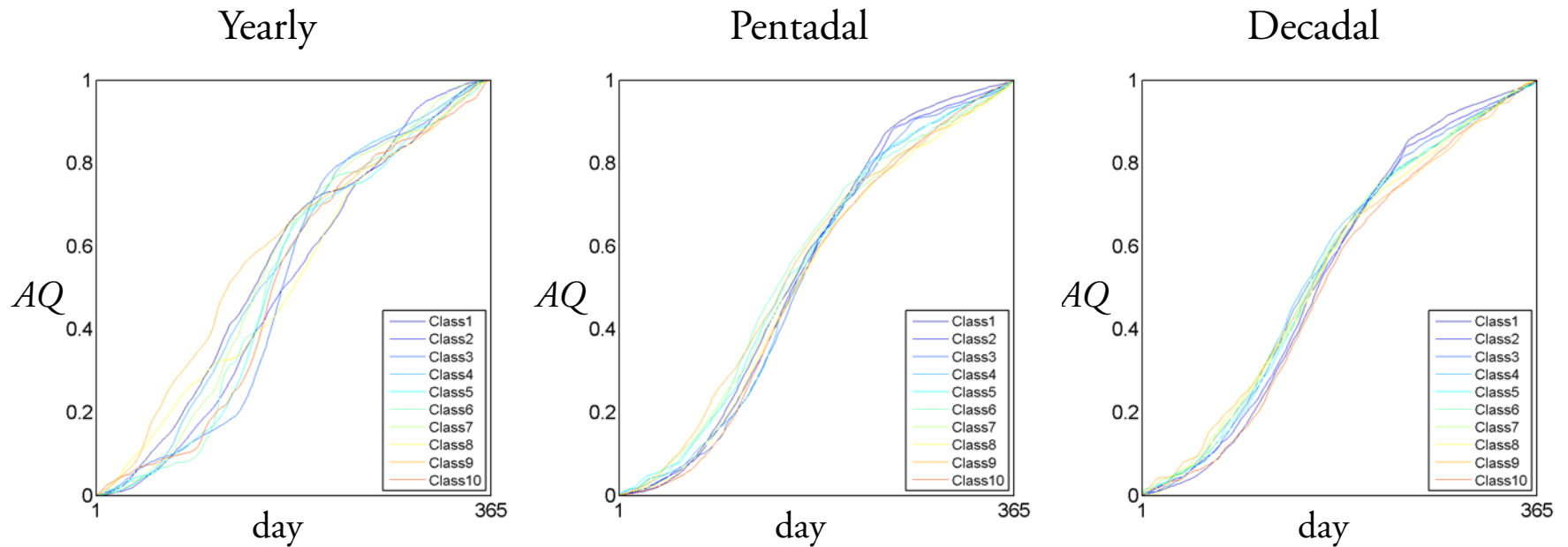
(Maskey et al., 2016d)



by decade 1959 - 2014

Classifying streamflow in Sacramento River

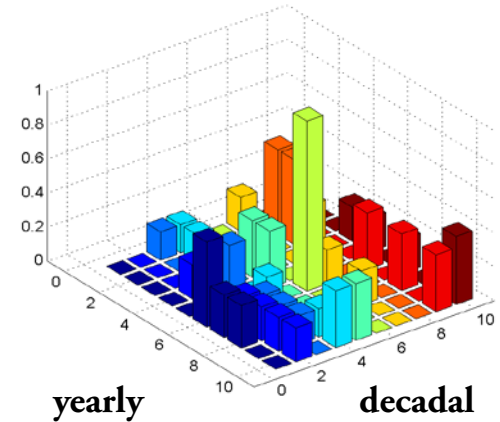
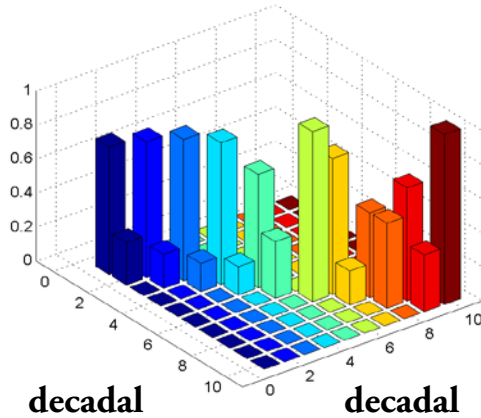
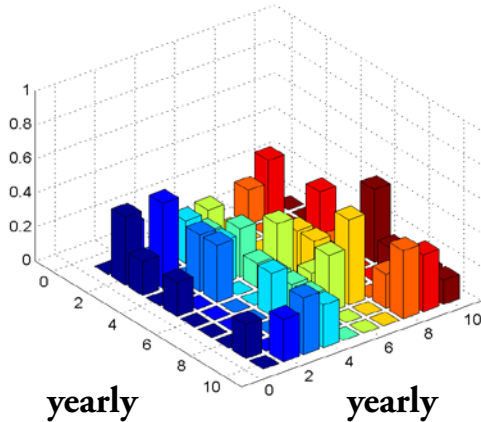
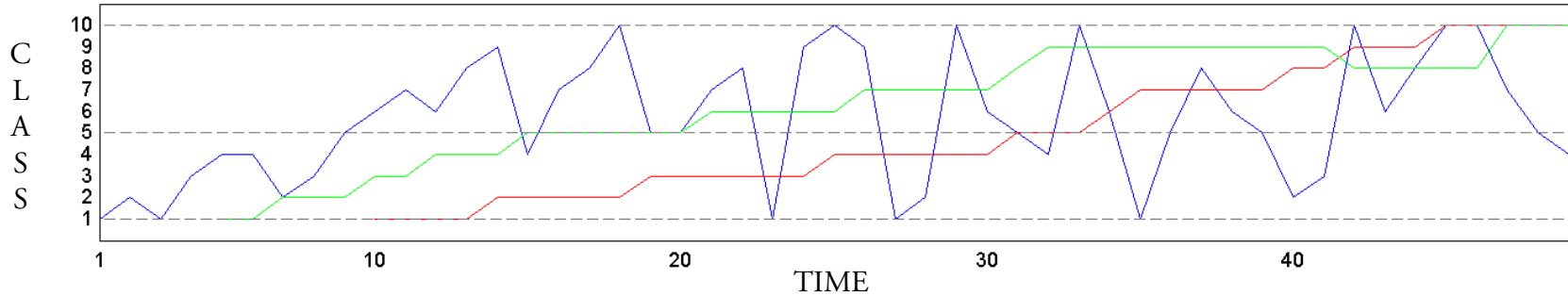
(Maskey et al., 2016d)



based on FM parameters and k-means clustering

Classifying streamflow in Sacramento River

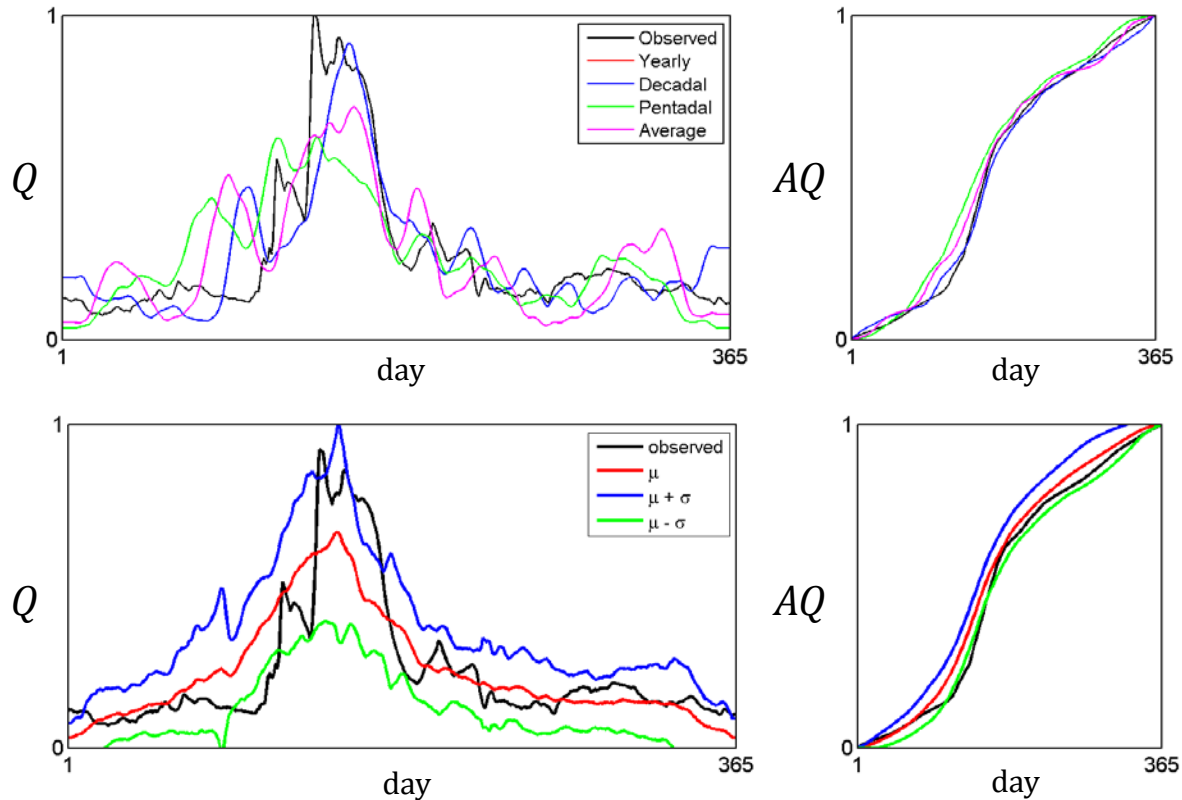
(Maskey et al., 2016d)



evolution by classes and transition matrices

Predicting streamflow in Sacramento River

(Maskey et al., 2016d)



a successful year, via trends and FM parameter sensitivity

Extension to higher dimensions

(Puente, 1994)

just having more coordinates and maintaining x uncoupled:

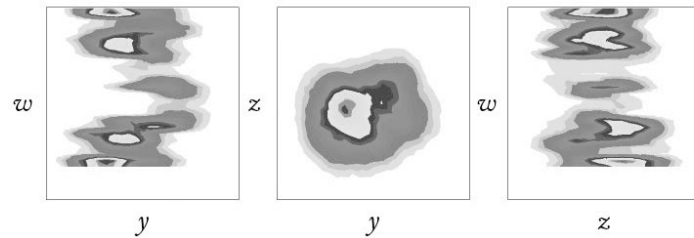
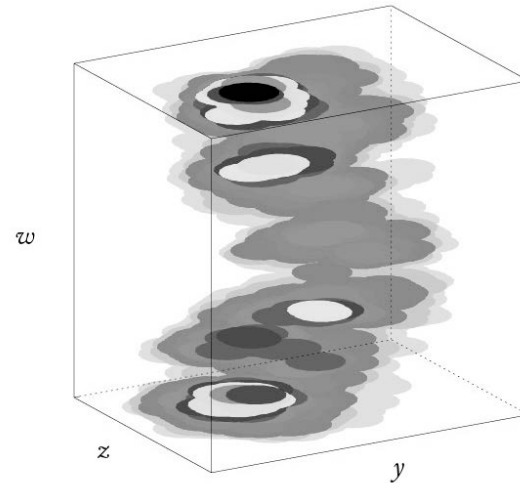
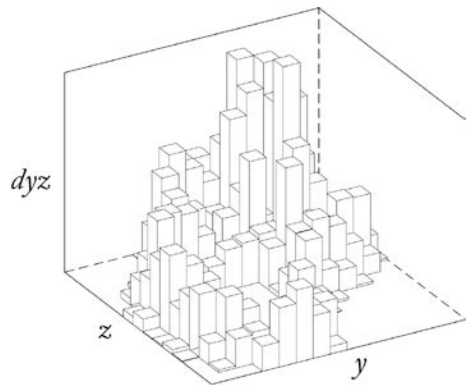
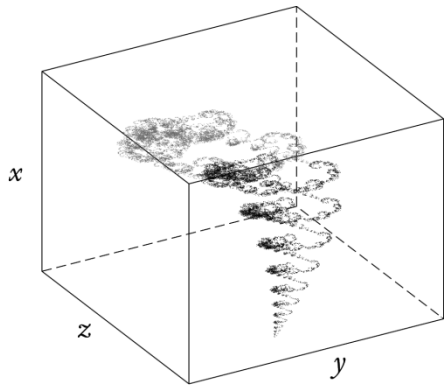
$$w_n \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} a_n & 0 & 0 \\ c_n & d_n & h_n \\ k_n & l_n & m_n \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} + \begin{pmatrix} e_n \\ f_n \\ g_n \end{pmatrix}$$

parameter matrix in polar coordinates, scalings and rotations:

$$\begin{pmatrix} d_n & h_n \\ l_n & m_n \end{pmatrix} = \begin{pmatrix} r_n^{(1)} \cdot \cos\theta_n^{(1)} & -r_n^{(2)} \cdot \sin\theta_n^{(2)} \\ r_n^{(1)} \cdot \sin\theta_n^{(1)} & r_n^{(2)} \cdot \cos\theta_n^{(2)} \end{pmatrix}$$

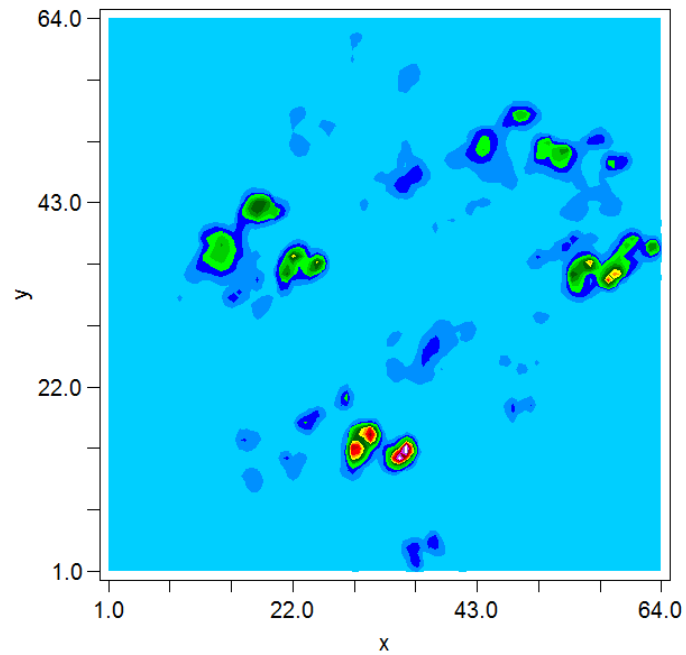
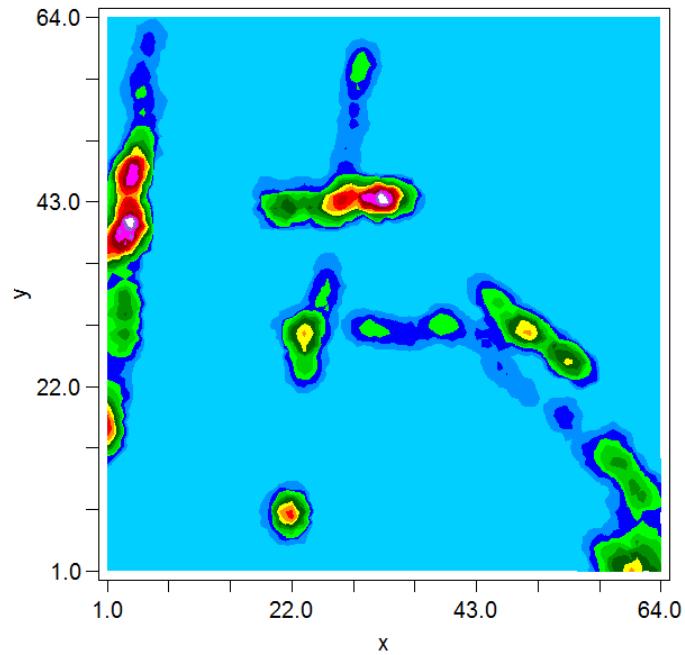
Some curious examples

(Puente, 1994)



a pollution pattern based on a 4D wire
similarly for rain and more...

Interesting spatial patterns

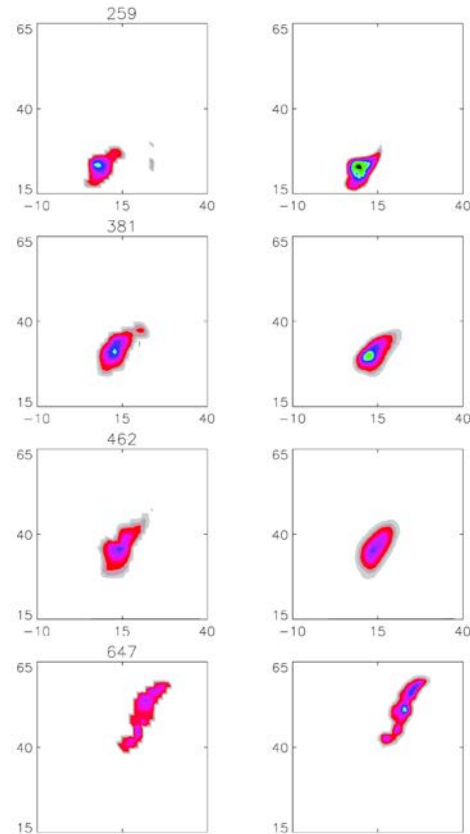


complex deterministic landscapes

...to be explored

Encoding pollution at Borden site

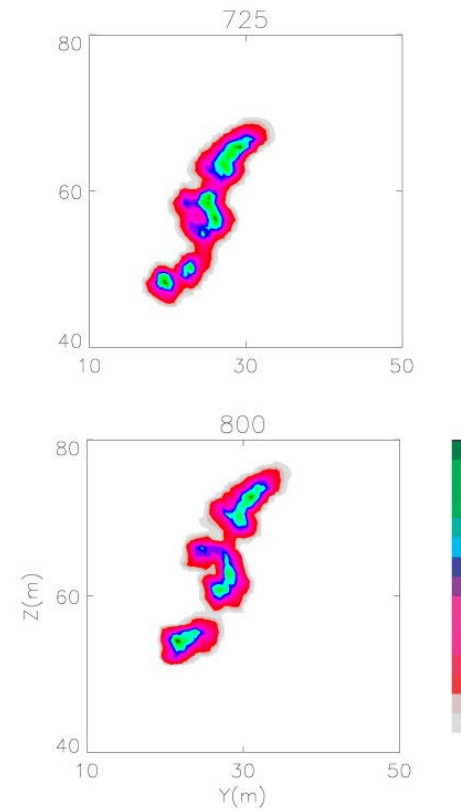
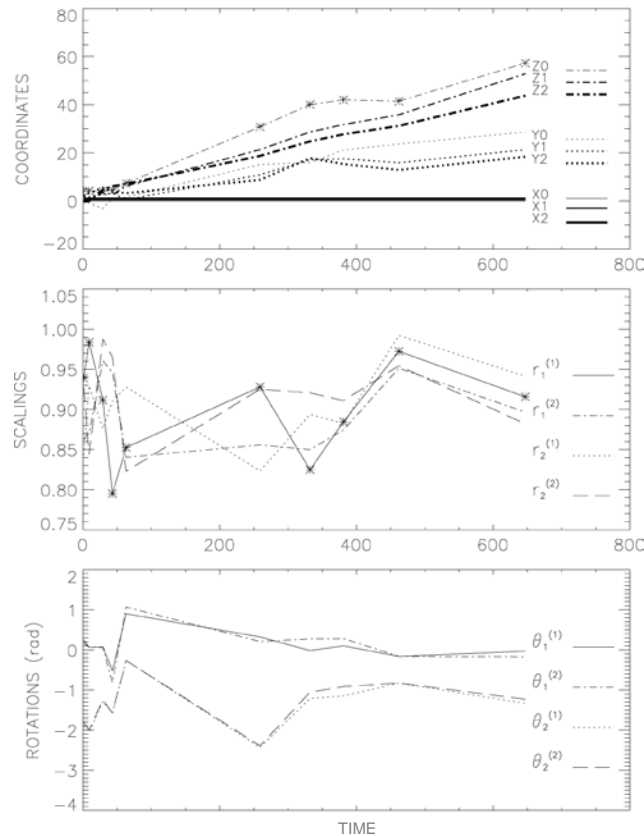
(Puente, et al., 2001)



observed (left), via wires (right)

Dynamics and predictions at Borden site

(Puente, et al., 2001)



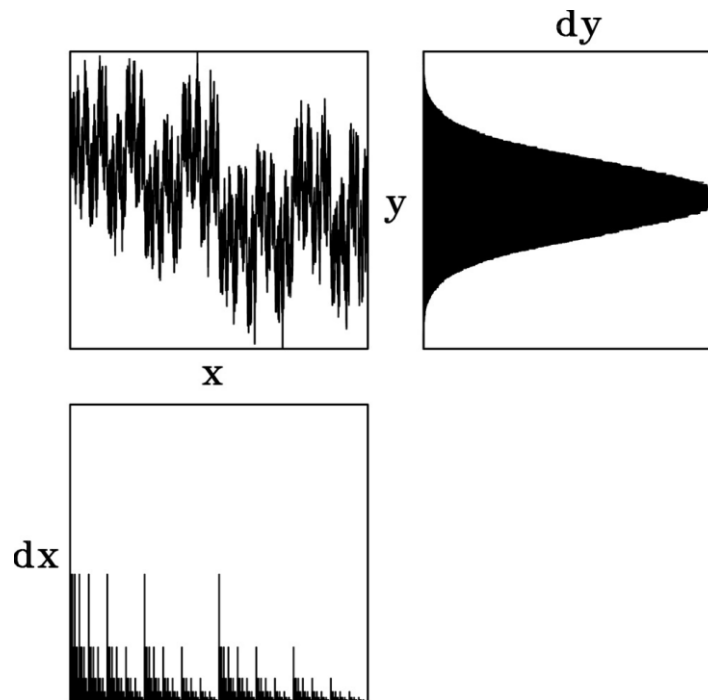
FM parameter trends and predictions

Outside the cave

- The platonic ideas may be used to model a variety of data sets, both in time and in space.
- The notions provide a compact deterministic language for some features of natural complexity.
- Perhaps the ideas may help classify patterns in different locations and also discern structural changes of qualifiers of climate change as a function of time.
- The notions may conceivably provide an alternative way to evaluate future scenarios if trends in geometric parameters may be established.

The limit of the case + -

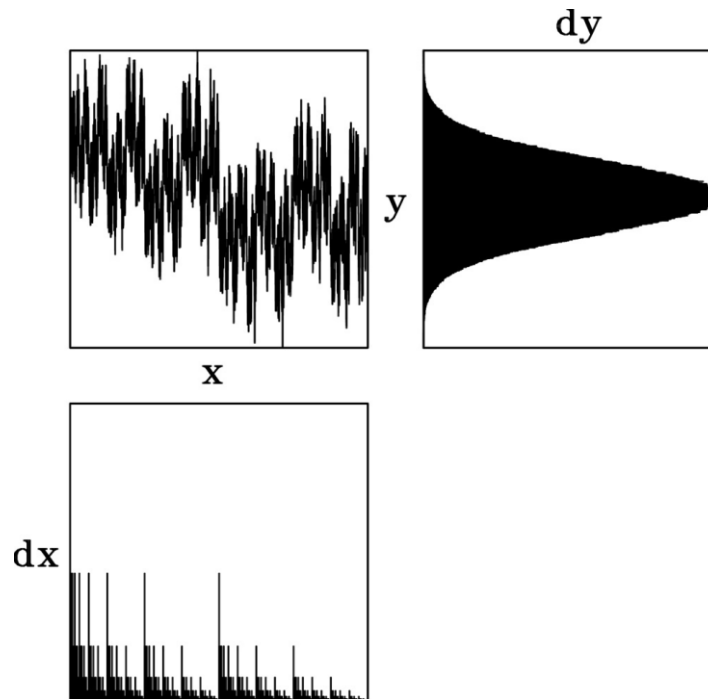
(Puenta et al., 1996)



dy is a Gaussian **bell** for **any** non-discrete dx

The limit of the case + -

(Puenta et al., 1996)

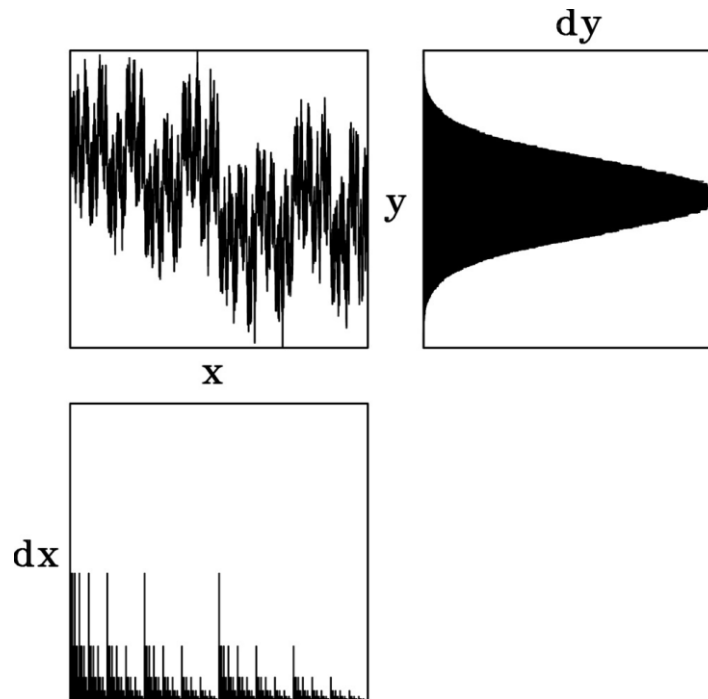


dy is a Gaussian **bell** for **any** non-discrete dx

there is an unexpected bridge from **dissipation** to **conduction**

The limit of the case + –

(Puenta et al., 1996)



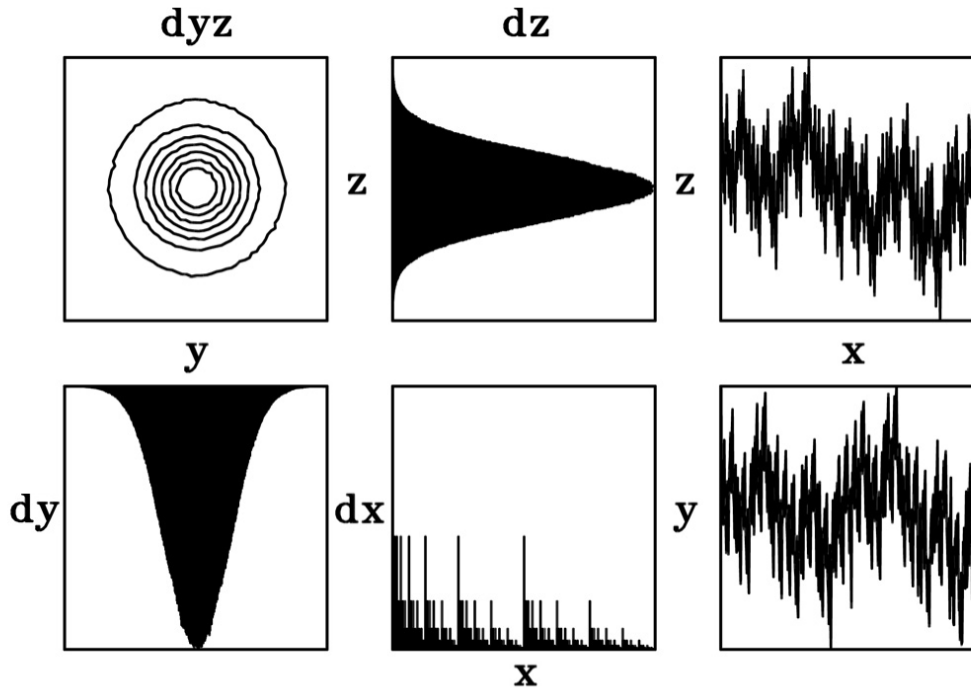
dy is a Gaussian **bell** for **any** non-discrete dx

there is an unexpected bridge from **dissipation** to **conduction**

the **case – –** yields oscillations between two bells

Gaussians everywhere!

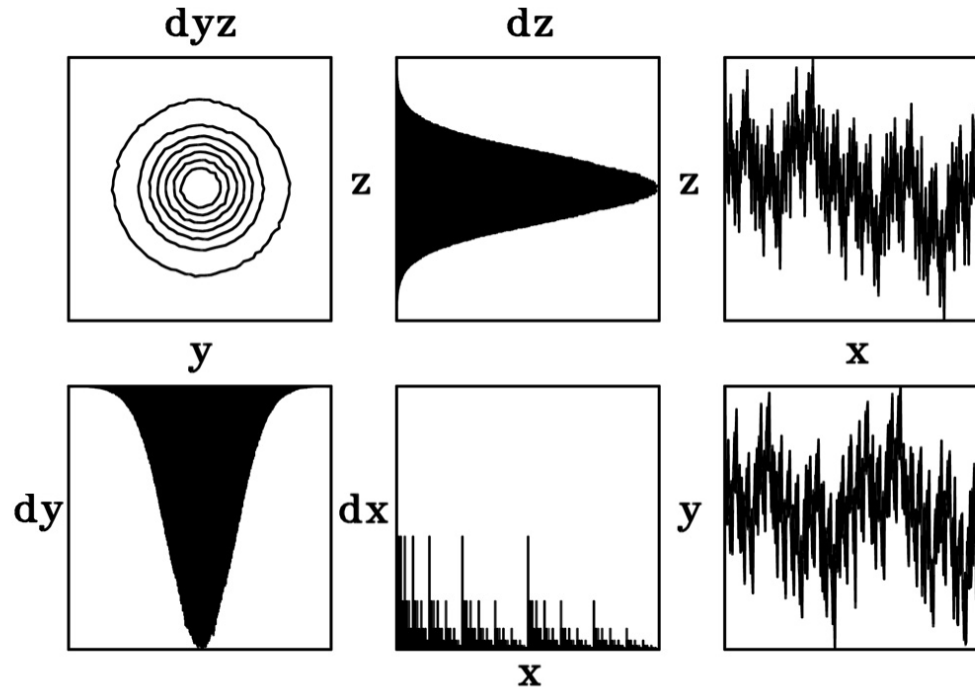
(Puenta y Klebanoff, 1994)



there are also **elliptical** bells and **oscillations** among bells

Gaussians everywhere!

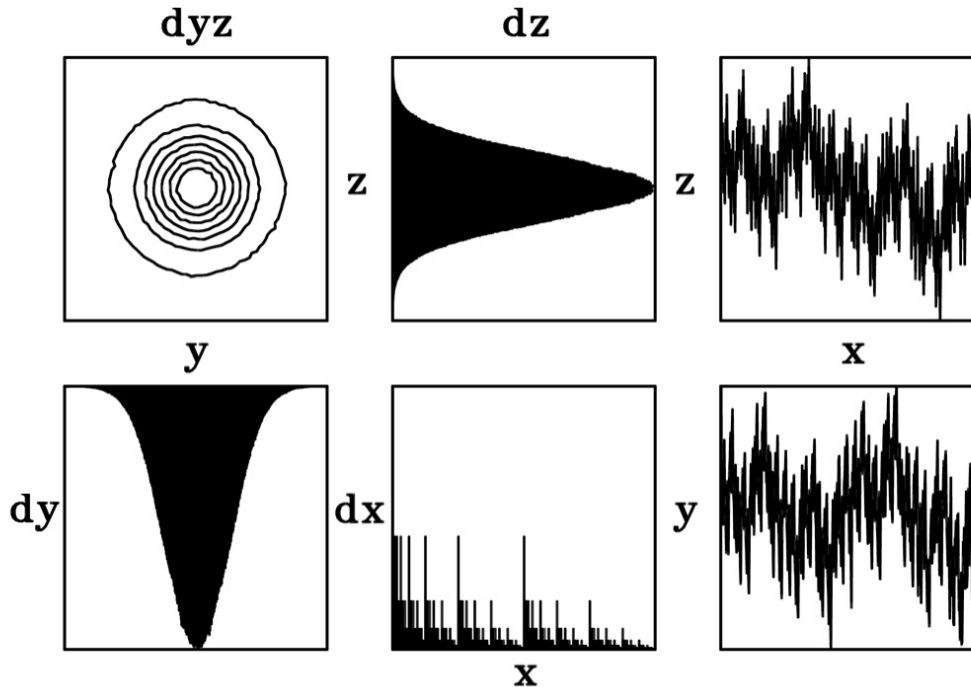
(Puente y Klebanoff, 1994)



there are also **elliptical** bells and **oscillations** among bells
portions of wires also define bells, *ad infinitum*

Gaussians everywhere!

(Puente y Klebanoff, 1994)



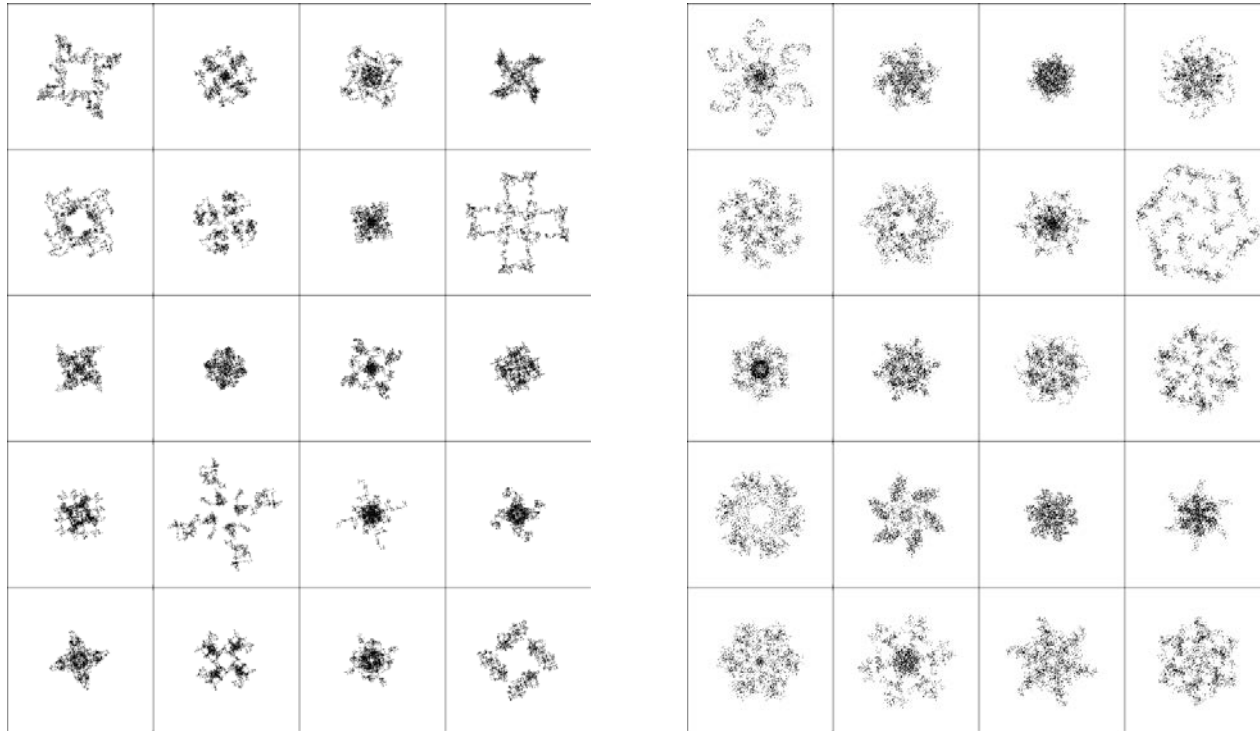
there are also **elliptical** bells and **oscillations** among bells

portions of wires also define bells, *ad infinitum*

the proof for the multi-dimensional case is unknown, but...

Treasures inside the bell

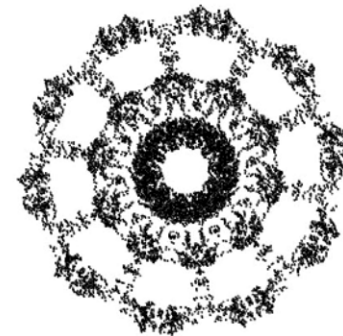
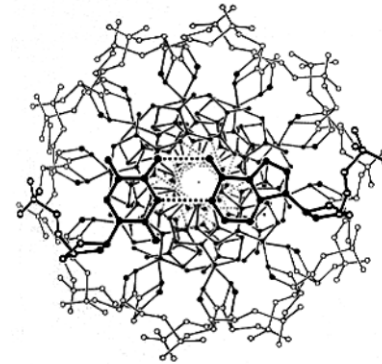
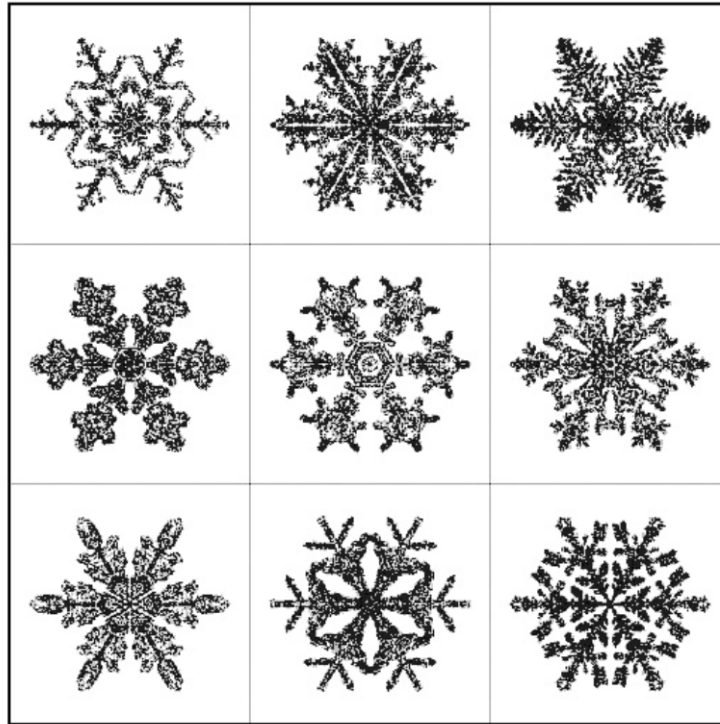
(Puenta, 2003)



superposition of a multitude of patterns yields **perfect circles**
in the limit that fills space there is hidden **order** in **chance**

Designs inside the bell

(Puente, 2003)

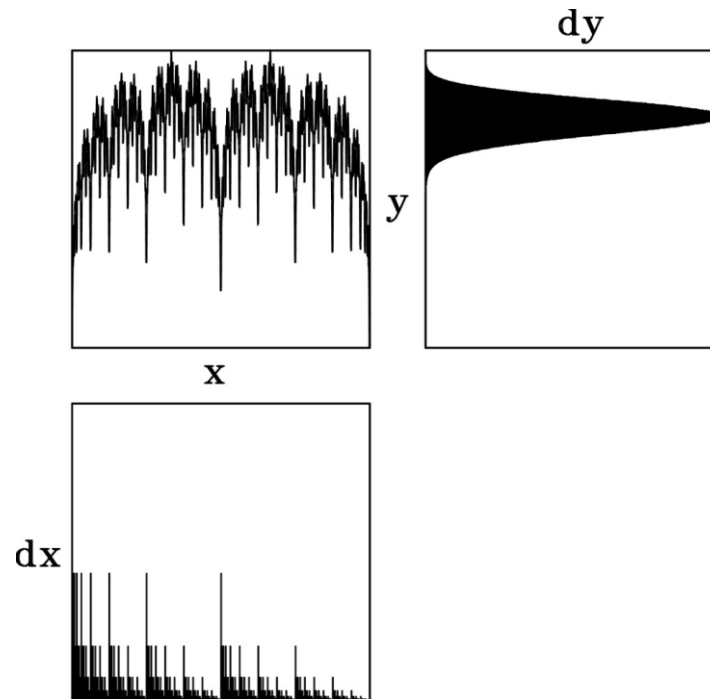


arbitrary **ice crystals** as *Borgesian* alephs

the **DNA** rosette is coded via the binary expansion of π

The limit in the case ++

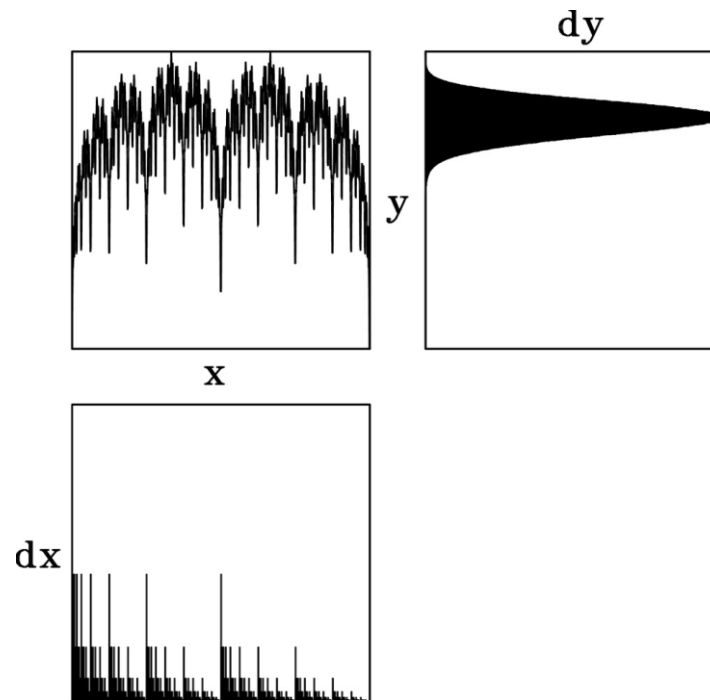
(Puente, 2011)



a **vital** non-entropic bell concentrated at **infinity**

The limit in the case ++

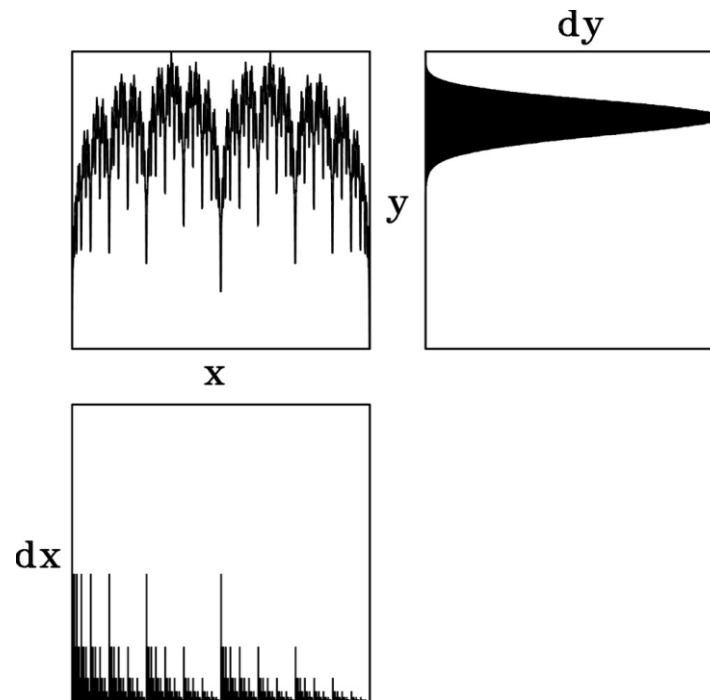
(Puente, 2011)



a **vital** non-entropic bell concentrated at **infinity**
the **most positive** wire filters almost any disorder

The limit in the case ++

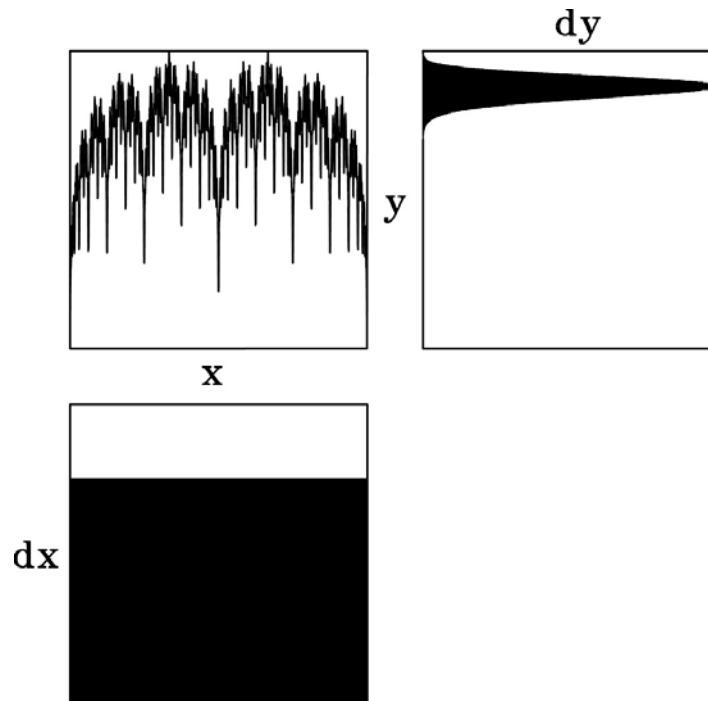
(Puente, 2011)



a **vital** non-entropic bell concentrated at **infinity**
the **most positive** wire filters almost any disorder
where o death is your victory?

The mighty three

(Puente, 2011)



filling the valleys and cutting the mountains
an ever positive and unitive transformation: cloud nine
conduction forever in the upper most location

The antidote

From x into y

as unnatural flow,
mapping immensity
leaving dust below.

From x into y

inspiring all awe,
o plus of liberty
forever aglow.

From x into y

only a tiny piece,
wired to totality
o normal release.

From x into y

o infinite fleece,
by packing vitality
no thorns but peace.

From x into y

singular the dough,
symphony of unity
breeding single row.

From x into y

by breaking a spell,
amazing simplicity
o refuge from hell.

From x into y

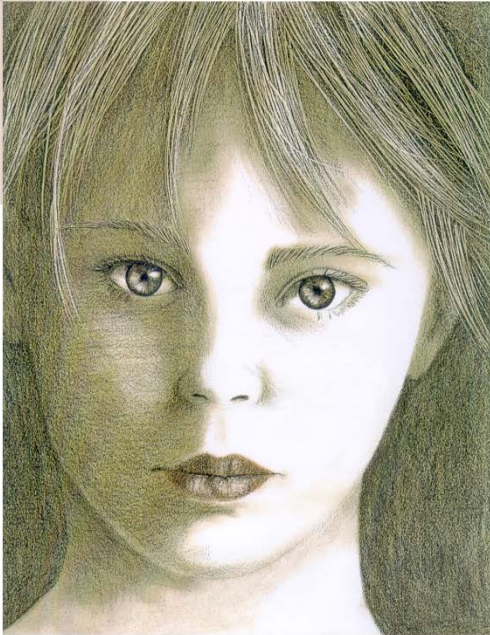
from holy plateau,
perennial immunity
o spirit on the go.

From x into y

triune is the cell,
omnipotent divinity
o sacred God's bell.

THE FIG TREE & THE BELL

Carlos E. Puente



CHAOS,
COMPLEXITY,
and CHRISTIANITY

TREASURES INSIDE THE BELL

HIDDEN ORDER IN CHANCE



CARLOS E. PUENTE