A complex systems approach to MSFD? A very short Introduction

Sandro Azaele

What is a healthy ecosystem?

Qualitative descriptors for determining good environmental status (MSFD)

Biological diversity is maintained.

Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.

Populations of all commercially exploited fish and shellfish are within safe biological limits.

All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity.

Human-induced eutrophication is minimized,

Sea-floor integrity.

Alteration of hydrographical conditions.

Concentrations of contaminants are at levels not giving rise to pollution effects.

Contaminants in fish and other seafood for human consumption.

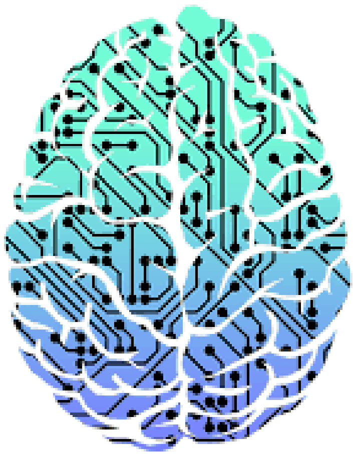
Properties and quantities of marine litter.

Introduction of energy.

What is an ecosystem?

What is a healthy ecosystem?

Do we really need theory?



Data is what we need, that's it!

H. Poincaré (1901)

Science is build up of facts, as a house is with stones.
But a collection of facts is no more a science
than a heap of stones is a house.

Dealing with Complex Systems - concepts

Understanding the dynamics of a complex system: theory, models and data
A. Vulpiani, Università La Sapienza, Italy.

From single individual body mass - metabolic rate scaling to community patterns
A. Maritan, Università degli Studi di Padova, Italy.

Balancing ecological, social and economic concerns – an ethical perspective
Siri Granum Carson (NTNU Oceans, Norway)

Governance of complex systems
P.F. Moretti, JPI Oceans, Belgium

Panel Discussion 13:10 - 13: 35

Understanding the dynamics of a complex system: theory, models and data

Angelo VULPIANI

Dipartimento di Fisica, Universit a Sapienza, Roma,
<angelo.vulpiani@roma1.infn.it>

COVID time, December 2020

THE AIM OF THIS TALK

An introduction to the di culties one has to face in the modeling of complex systems

* Chaos

* Troubles with a mere inductive approach

* Multiscale structure

* Necessity of eective equations

Our main starring actors

Isaac NEWTON

Pierre Simon LAPLACE

Ludwig BOLTZMANN

Henri POINCARE

William THOMSON (alias Lord KELVIN)

Edward LORENZ

Lewis F. RICHARDSON

John von NEUMANN

Floris TAKENS

Isaac NEWTON (1642- 1727)

Apples, the Moon and the Planets are ruled by the same laws:
the equations of the mechanic and the gravitational force.

Pierre Simon LAPLACE (1749 - 1827)

We must consider the present state of Universe as the eect of its past state and the cause of its future state. An intelligence that would know all forces of nature and the respective situation of all its elements, if furthermore it was large enough to be able to analyze all these data, would embrace in the same expression the motions of the largest bodies of Universe as well as those of the slightest atom: nothing would be uncertain for this intelligence, all future and all past would be as known.

The dierent cases

Given a certain phenomenon, we can have dierent possibilities:

A : We know the evolution laws (e.g. astronomy and meteorology)

B : There are evolution laws, but we do not know them (e.g. earthquakes)

C: We do not know whether there exist evolution laws (e.g. social peace, phenomena)

The "easy" case

We know the "proper" variables, and the evolution law is known (and it is deterministic) usually a dierential equation

$$\frac{dx}{dt} = F(x) \; ;$$

under general hypothesis we have a unique solution

$$x(0) \; ! \quad x(t) = G[t; x(0)]$$

Two possibilities
A the solution is known, only in few special cases;
B the solution is not know, this is the most common case.

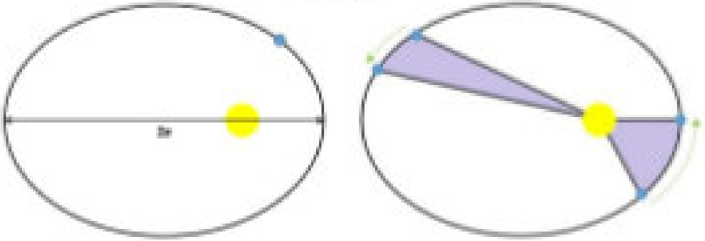
A case where everything is clear and simple

Two body problem: a planet interacting only with the Sun
One has a regular (periodic) behavior

Kepler's laws of planetary motion

1. The orbit of a planet is an ellipse with the Sun at its focus.
2. The line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.
3. The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

$$T^2 \propto a^3$$



Possible Troubles...

In general the scenario is not simple as in the two body problem.

* The system can be chaotic.

* The system can be "complex"

For instance in the systems many relevant variables are involved. This is the case of the geophysics, where one has to face the problem of the modeling at small scale phenomena.

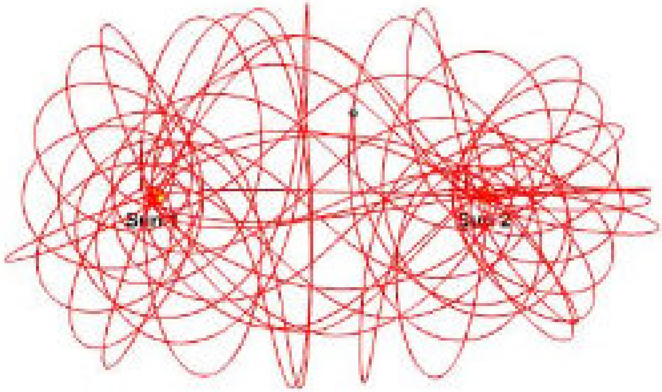
* The system can be ruled by non deterministic laws.

However this does not add particular extra di culties.

Three body problem

Now the situation is not simple at all...

The motion of a Planet in a binary system with two Suns



Deterministic chaos

A very small cause which escapes our notice determines a considerable e ect that we cannot fail to see, and then we say that the e ect is due to chance. If we knew exactly the laws of nature and the situation of the universe at the initial moment, we could predict exactly the situation of the same universe at a succeeding moment. But even if it were the case that the natural laws had no longer any secret for us, we could still know the situation approximately. If that enabled us to predict the succeeding situation with the same approximation, that is all we require, and we should say that the phenomenon had been predicted, that it is governed by the laws. But it is not always so; it may happen that small dierences in the initial conditions produce very great ones in the nal phenomena. A small error in the former will produce an enormous error in the latter. Prediction becomes impossible and we have the fortuitous phenomenon. (Poincar e)

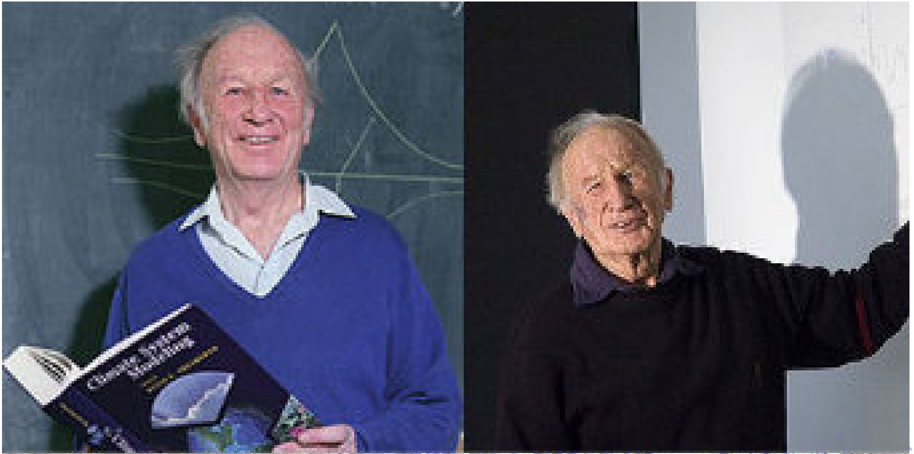
This is nothing but the butter y a ect

Edward LORENZ (1917-2008) and his celebrated model

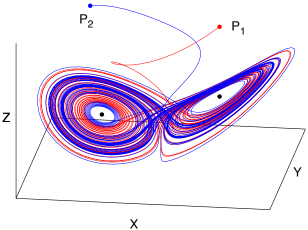
In 1963 E. Lorenz, in his study on the motion of the atmosphere, (re)discovered the chaos.

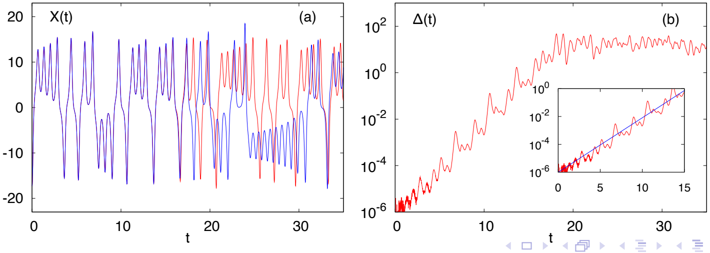
The (apparently) simple model, with just 3 variables

$dx=dt= \ (y \ \ x), \ dy=dt= \ \ xz+ rx \ \ y, \ dz=dt= \ \ bz+ xy$



* "Complex behaviour" can appear even is a system with just 3 variables
* Determinism does not imply the possibility of accurate prediction.





An alternative to the use of equations?

INFERE ONLY FROM THE DATA

Petabytes allow us to say: \Correlation is enough". Therefore we can stop looking for models. We can analyse the data without hypotheses about what it might show. We can throw the numbers into the biggest computing clusters the world has ever seen and let statistical algorithms

nd patterns where science cannot.

The Data Deluge Makes the Scienti c Method Obsolete

(C. Anderson, the prophet of the Big Data revolution)

We'll see that both the above points of view do not work.

The basic idea of an inductive approach ! BIG DATA

It seems natural to believe that
a If a system behaves in a certain way, it will do so again
b From the same antecedents follow the same consequents

Such claims are also supported by Biblical tradition:
What has been will be again, what has been done will be done again; there is nothing new under the sun.
(Qohelet's Book 1:9)

BIG DATA philosophy: forget the theory, now the data are enough.

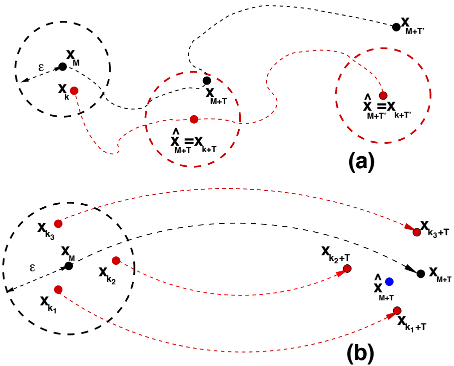
A formalisation of the idea \from the same antecedents follow the same consequents"

The method of the analogs

*- we know that the state of the system is given by a vector x
*- we know the past of the system, i.e. a time series $(x_1; x_2; ::::; x_M)$ where $x_j = x(j \quad t)$
*- we want to predict the future, i.e. x_{M+t} for t> 0.

If the system is deterministic, in order to understand the future it is enough to look to the past for an \analog" i.e. a vector x_k with k< Msuch that $jx_k \quad x_M j <$, therefore, since \from the same antecedents follow the same consequents",we can \predict" the future at times M+ t> M:

$$x_{M+t} \; ' \; x_{k+t}$$



A sketch of the method of the analogs

Conceptually everything sounds, however it is not so obvious at all that determinism holds, and it is easy to
nd and analog

It is a metaphysical doctrine that from the same antecedents follow the same consequents. ... But it is not of much use in a world like this, in which the same antecedents never again concur, and nothing ever happens twice. ... The physical axiom which has a somewhat similar aspect is \That from like antecedents follow like consequents."

(James Clerk Maxwell)

The forecast is based on the supposition that what the atmosphere did then, it will do again now
The \ Nautical Almanac", that marvel of accurate forecasting, is not based on the principle that astronomical history repeats itself in the aggregate. It would be safe to say that a particular disposition of stars, planets and satellites never occurs twice. Why then should we expect a present weather map to be exactly represented in a catalogue of past weather?

(Lewis Fry Richardson)

Attempts to the forecasting using the analogs

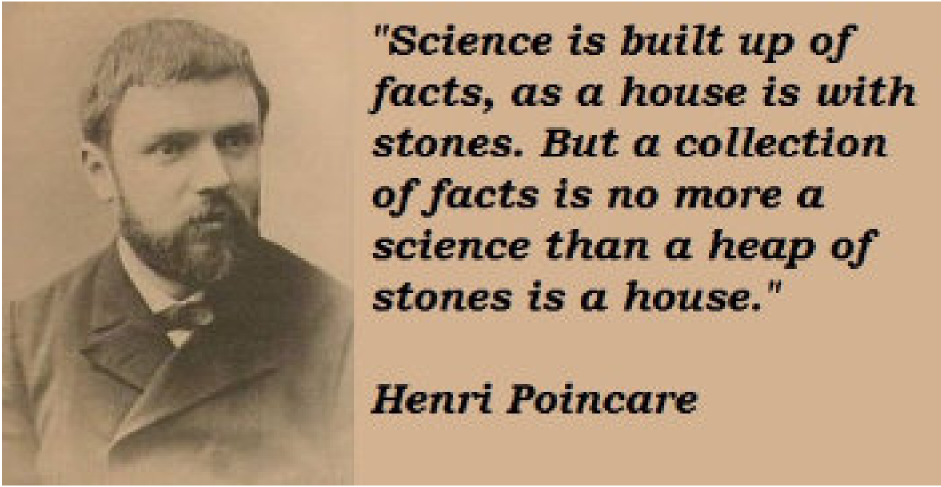
Lorenz tried to use the meteorological charts of the past to perform a weather forecasting. Applying the method of the analogs he realised that the intuition of Richardson is correct.

In practice, this procedure may be expected to fail, because of the high probability that no truly good analogues will be found within the recorded history of the atmosphere.

Also the methods used in
nance (where the state x is not known) for the
prediction basically, are (stochastic) versions of the analogs.

Now we are in the DATA DELUGE age.
Can we hope to success using just data?

Big Data: cornucopia or Pandora's box?



Looking back to an apparently very far topic

The Poincar erecurrence theorem
In a deterministic system with a bounded phase space, after a certain time, the system must be close to its initial state

Such a theorem had a great historical relevance in the hot debate, at the end of the 19-th century, between Boltzmann and Zermelo on the irreversibility.
Boltzmann had been able to show, with probabilistic arguments, that in a system with $N \quad 1$ particles the recurrence is not a real problem: the return time is very large

$$T_R \qquad {}_0 C^N$$

where ${}_0$ is a characteristic time and $C> \quad 1$, in a macroscopic system $(N \quad 10^{20} \quad 10^{25})$, T_R is gigantic, much larger that the age of the universe.

The intuition of Boltzmann had been formalised by the Kac Lemma
In an ergodic ergodic system the average return time h (A)i in a set A is

$$h\ (A)i = \frac{0}{P(A)}$$

where P(A) is the probability to be in A.
Consider a system of linear sizes O( ), therefore P(A) $(\frac{}{L})^D$ so

$$h\ (A)i \quad {}_0 \left(\frac{L}{\ }\right)^D$$

where L is the excursion of each component of the vector describing the state and D the attractor's dimension.

Consequences of the Kac Lemma

Irreversibility The Boltzmann's intuition was correct.
Since D N 1, macroscopic irreversibility is not in disagreement with the Poincar erecurrence theorem, the return time is too large:

$$ {}_0 \quad \frac{L}{\ }^{D} $$

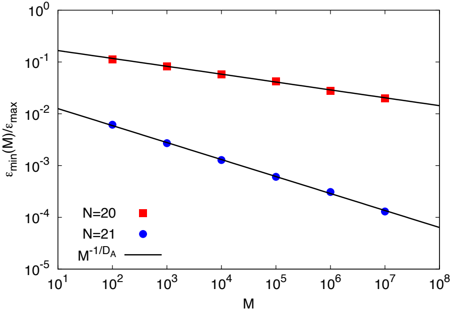
Forecasting In order to
nd an analog, the size M of the time series must
be, at least, of the same order of the recurrence time:

$$ M_{min} \quad \frac{0}{t} \quad \frac{L}{\ }^{D} $$

Since in the atmosphere D is not small, Lorenz had no chance to
nd an
analog. Even with a limited precision, say 5%, i.e. L= = 20, one has that, if D is large, say 6 or 7 it is pretty impossible to
nd an analog.

A toy model (proposed by Lorenz) for the weather, helps to understand the difficulty

$$\frac{dx_n}{dt} = x_{n-1}(x_{n+1} - x_{n-2}) - x_n + F; \quad n = 1, 2, \ldots, N$$



The relative precision of the best analog as function of the size of the time series. Two systems with $F = 5$, for $N = 21$ one has $D' \simeq 3.1$ (circles), for $N = 20$, $D' \simeq 6.6$ (squares).

Forecasting using a simple approach. A success: Tidal Prediction

Already in the first half of the 19th century there existed efficient empirical methods to compile numerical tables of tides in any location where a record of past tides was known.

Lord Kelvin and George Darwin (Charles's son) showed that water levels can be well predicted by a limited number of harmonics (say 10 or 20), determining the Fourier coefficients from the past time data at the location of interest. Kelvin, with the help of his brother (an engineer), built a tide- predicting machine: a special- purpose mechanical computer made of gears and pulleys.

This machine can be considered one of the first example of successful scientific business.

An example of the tide- prediction machine by Kelvin (about 10^3 Kg)

The importance to be lucky

Lord Kelvin and George Darwin were very smart,
but also rather lucky...

Tides are chaotic, however their prediction from past records is a relatively easy task. The reason is the low number of eective degrees of freedom involved.
Investigations of tidal time series by using the method of nonlinear time series analysis (Abarbanel et at 1999) found eective attractor dimensions quite low $O(3 \quad 4)$.
That explains, a posteriori, the success of the empirical method.

Even Lorenz was very smart, but rather unlucky...

Lorenz had no chance to
nd an analog: in the atmosphere D is not
small, likely $O(10^3 \quad 10^4)$,

Lewis F. Richardson (1881- 1953), the great visionary

Weather Prediction by Numerical Process

In his seminal book Richardson proposed to use the equations regulating the evolution of the atmosphere.

The atmosphere evolves according to the equations of hydrodynamics (for the
elds describing velocity u, density , pressure p, water percentage s,
and temperature T) and the thermodynamics giving the relation (equation of state) among ; T; s and p.
So, by knowing the present state of the atmosphere, we can solve seven partial dierential equations to obtain{ at least in principle{ a weather forecast. Of course, these equations cannot by solved by pen and paper, so a numerical solution is the only option.

The rst heroic numerical attempt

The initial conditions used by Richardson consisted of a record of the weather charts observed in Northern Europe at 4 A.M. on 20 May 1910 during an international balloon day.
The numerical work by Richardson was long, taxing and wearisome: it has been estimated that, in the course of two years he worked for at least one thousand hours, computing by hand and with some rudimentary computing machine. The result, giving a six-hour forecast, was quite disappointing.

Richardson correctly understood that the scheme is complicated because the atmosphere is complicated.
Nevertheless, he was moderately optimistic in his conclusive remarks: perhaps some day in the dim future it will be possible to advance the computations faster than the weather advances. ... But that is a dream.

The failure is because the equations proposed by Richardson are too accurate!

The original Richardson's attempt, based on the rst principle, is, somehow, a form of reductionism.

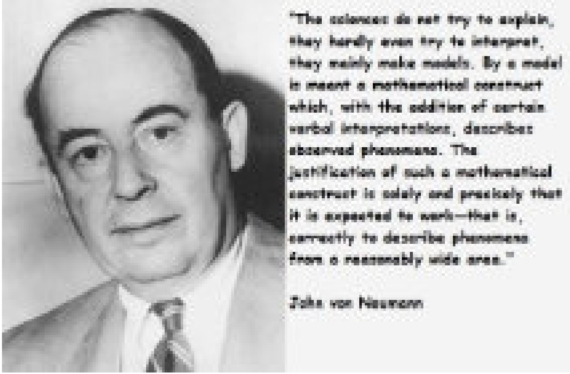
The realisation of Richardson's dream had to wait until the 1950s. Instead of the \obvious" use of the rst principles, it has been necessaryto adopt another approach which include the development of three \ingredients", all far from trivial

a) e ective equations;

b) fast numerical algorithms;

c) computers suitable for numerical calculations.

John Von Neumann (1903- 1957), a pragmatic scientist



For the weather forecasting, and more general, in any \complex" problem, it is necessary to understand which aspects have to be taken into account and which ones can be ignored.

To develop the skill of correct thinking is in the rst place to learn what you have to disregard. In order to go on, you have to know what to leave out: this is the essence of e ective thinking. (Kurt G odel)

Fast phenomena, e.g. waves, are not especially interesting for weather forecasting, but they in uence the slow variables, so they have to be somehow accounted for. The way to solve the problem was found by Charney, von Neumann and colleagues in the 1940s- 1950s, within the Meteorological Project at the Institute for Advanced Study, in Princeton. The project involved scientists from dierent elds: mathematicians, experts in meteorology, engineering, and computer science.

The eective equations

Almost all the interesting dynamic problems in science and engineering are characterised by the presence of more than one significant scale, i.e. there is a variety of degrees of freedom with very dierent time scale, e.g.
*- protein folding: the time scale of vibration of covalent bonds is $O(10^{\ 5})$s, the folding time for proteins may be of the order of seconds.
*- climate: the characteristic times of the involved processes vary from days (for the atmosphere) to $O(10^3)$yr(for the deep ocean and ice shields).

The necessity of treating the \slow dynamics" in terms of eective equations is both practical (even modern supercomputers are not able to simulate all the relevant scales involved in certain di cult problems) and conceptual: eective equations are able to catch some general features and to reveal dominant ingredients which can remain hidden in the detailed description.

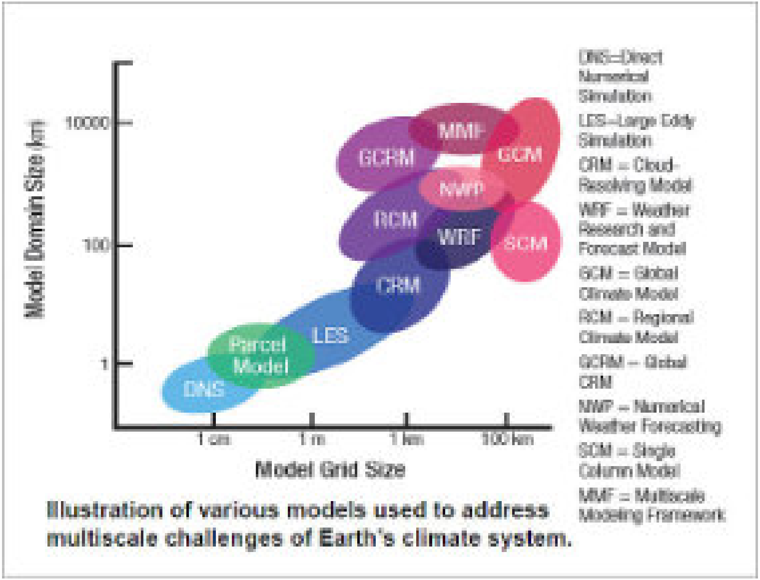


Illustration of various models used to address multiscale challenges of Earth's climate system.

For practical purposes the equations used by Richardson are appropriate just for spatial scales smaller than O(10) km.

The simplest multiscale system

The case with only two characteristic times

Consider a system whose state is given by $X = (X_f; X_s)$ where X_f and X_s are the fast and slow components.

$$\frac{dX_s}{dt} = \frac{1}{\;_s} F_s(X_f; X_s)$$

$$\frac{dX_f}{dt} = \frac{1}{\;_f} F_f(X_f; X_s)$$

with $_f \quad\quad _s$.
The aim is to derive an \eective" equation only for X_s:

$$\frac{dX_s}{dt} = \frac{1}{\;_s} F_e\ (X_s)\ :$$

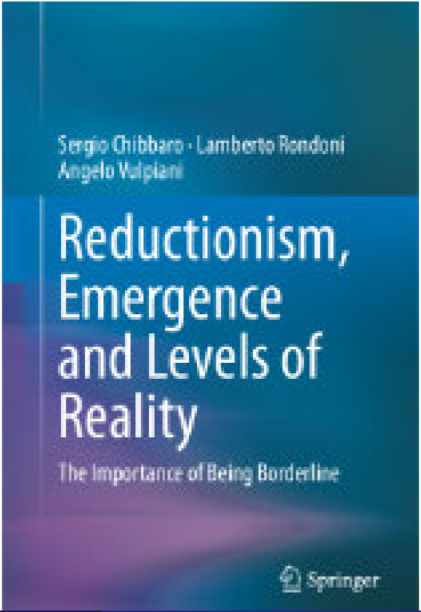
About the eective equations

A) From a computational point of view: it is possible to use larger t and x in the numerical integration;

B) Their description of the slow dynamics make it possible to detect the most important factors, which on the contrary remain hidden in the detailed description given by the original equations.

C) They are not mere approximations of the original equations, typically emergent features appear.

Levels of reality: an advertisement



Examples of levels of reality

Statistical Mechanics

I- microscopic level, - space description (Liouville equation);

II- microscopic level, - space description (Boltzmann equation);

III- mesoscopic level, - space description but at \large scale" (Fokker{ Planck equation);

IV- macroscopic level, uidynamics description (Navier{ Stokes equation, Fourier law, . . .).

Climate

I- molecular level

II- uid dynamics

III- quasi-geostro c equations

IV- e ective equations

The crossing from one level of description to another is rather delicate, it is determined by a coarse- graining and/or a projection procedure with a \loss of information".

Model from data?

If it is not possible to use models "derived" from some well based theory (e.g. classical or quantum mechanics) it seems natural to use an inductive approach.

The building of model from data

In the case (very rare) we know the vector x_t describing the state of the system, at least in principle one can adopt the method of the analogs looking back in the past and then build a map

$$x_{t+1} = G(x_t)$$

where the shape of G can be obtained with some tting/optimization procedure.

Floris TAKENS (1981) gave a nice, and important result

A very important contribution from mathematics to the understanding the problem in the case we do not know the proper variables:
From the study of a time series fu_1; :::; u_M g, where u_j is an observable sampled at the discrete times j t, it is possible (if we know that the system is deterministic and is described by a
nite dimensional vector, and
M is large enough) to determine the proper variable x.

In the practical world the Takens's result is not a panacea

The method cannot solve all the problems, there are, at practical level, rather severe limitations:
A) It works only if we know a priori that the system is deterministic;
B) The protocol fails if the dimension of the attractor is large enough (say more than 5 or 6).

In spite of the many delusions after the initial enthusiasm (the happy chaotic 1980s-1990s) due to the technical severelimitations to an inductive approach to build a model, even now somebodies insist to propose the old naive baconian dream of a science without equations, sometimes even on PNAS, Nature etc.

Trouble 1 Even in the (lucky) case we know the proper variables x_t if the dimension is larger that 5 or 6 it is pretty impossible to nd analogs, there the protocol collapses

Trouble 2 Typically we do not know the proper variables
Such rather serious di culty is well known, for instance in statistical physics:

How do you know you have taken enough variables, for it to be Markovian? [Onsager and Machlup Fluctuations and Irreversible Processes Phys. Rev. 91, 1505 (1953)]

The hidden worry of thermodynamics is: we do not know how many coordinates or forces are necessary to completely specify an equilibrium state. [Ma Statistical Mechanics (WorldScienti c, 1985)]

What about a probabilistic approach?

In the real scienti c activity the border deterministic/stochastic description does not exist

Deterministic chaotic systems are treated with stochastic methods.

The eective equations of "complex" deterministic systems often are stochastic process.

The prototipe is the diusion of colloidal particles in a uid (Brownian motion): from an high dimensional deterministic system one derives a stochastic dierential equation Langevin equation for a slow variable.

The main di culties discussed are still present in stochastic systems:
a) The Kac lemma holds.
b) A large dimension gives problems both for the method of the analogs and build of models.
c) Di culties in the selection of the "good" variables.
d) Lack of systematic protocols,

Conclusions and Remarks

The idea (dream) to avoid the theory and use only data, is too naive. Because of the Kac's lemma, the BIG DATA approach can work only for very low dimensional systems.

Old topics can be relevant even in modern practical issues: e.g. the Poincar erecurrence theorem (and Kac's lemma) for the analogs.

It is true that the nal laws of nature are not expressedin terms of cold fronts or thunderstorms, however the unique way to understand the atmosphereis to write down eective equations for the cold fronts.

The dream to build models just from data cannot work if the dimensionality of the problem if large enough (D> 5 or 6).

In the real scienti c activity the border deterministic/stochastic description does not exist.

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From Single Individual Body Mass – Metabolic Rate Scaling to Community Patterns

with

T.Anfodillo, S.Azaele, J.Banavar, S.Garlaschi, J.Grilli, D.Gupta, L.Pacciani-Mori, A.Rinaldo, G.Sellan, F.Simini, S.Suweis, ATovo, I.Volkov

UNIVERSITY OF PADOVA – ITALY

DEPARTMENT OF PHYSICS AND ASTRONOMY "Galileo Galilei"

Laboratory of Interdisciplinary Physics

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Forests represent one of the most complex systems with
a high degree of structural and functional diversity

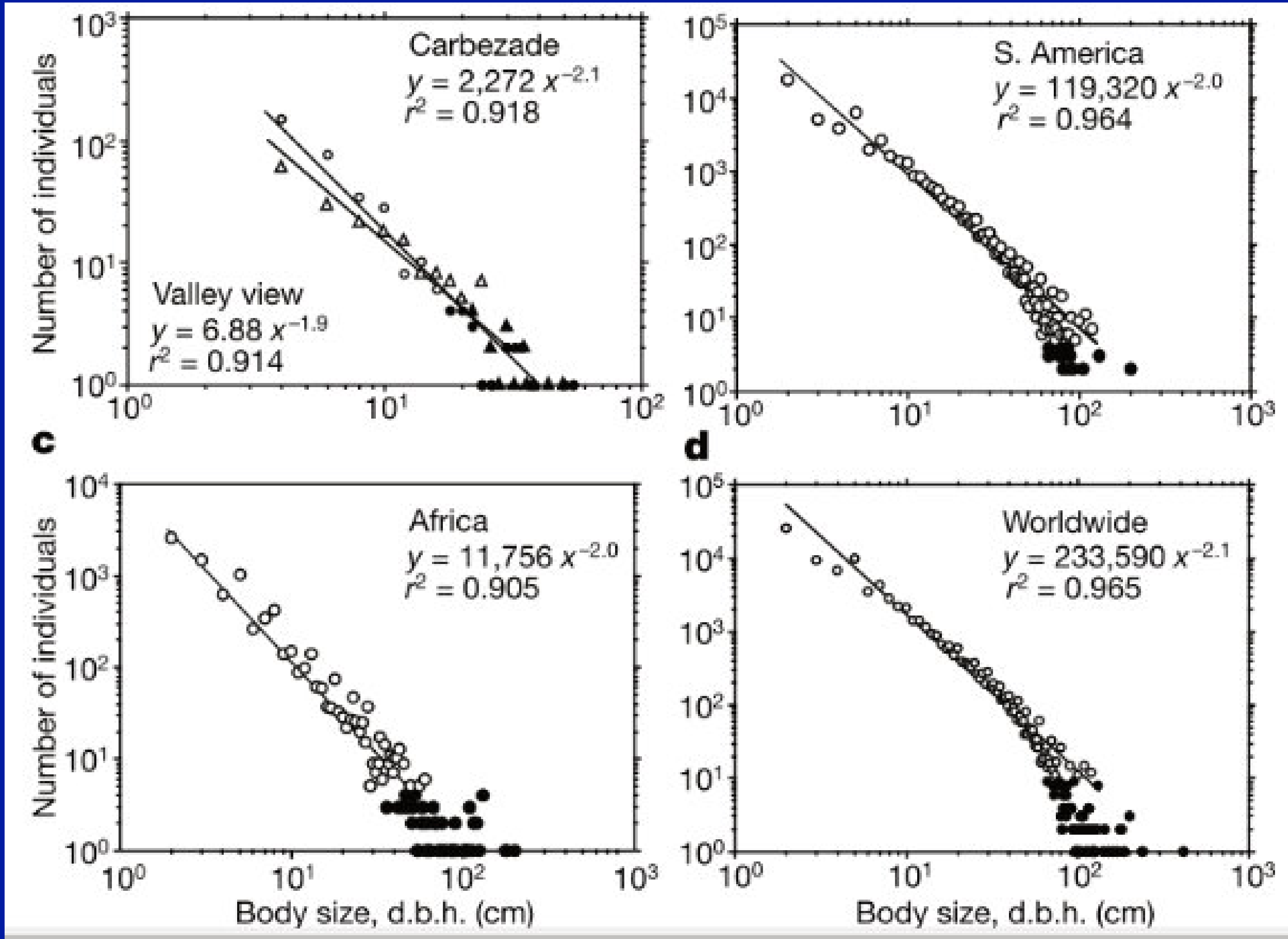
Foreststructure

Forestfunctionality

productivity,potentialevapotranspiration,
energy/matterforherbivors, Csink, C stock, etc.

FACTS

FACT 1 TRUNCATED POWER LAW DISTRIBUTION OF TREE SIZE



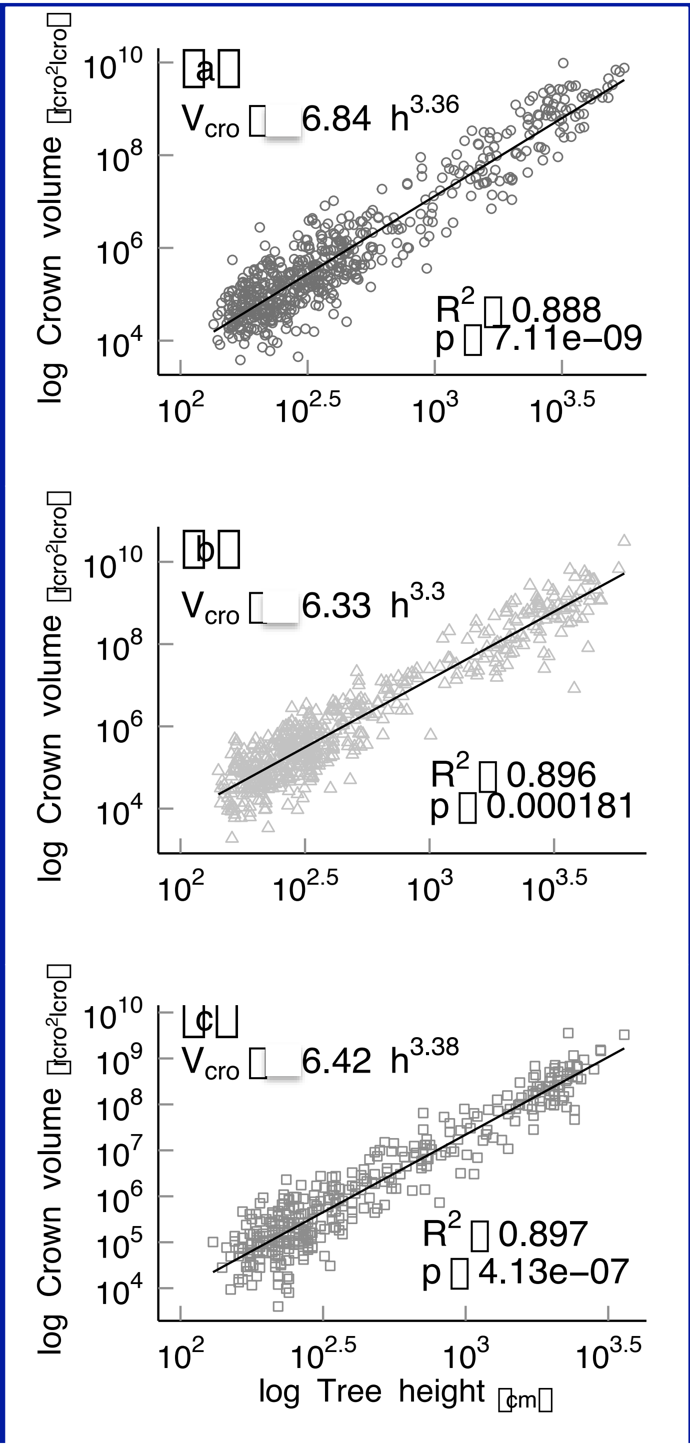
Enquistand West -*Nature*410, 2001

Fact 2

MIX
78
species

EDG
77
species

JEU
30
species



Scaling of "
V_{cro} vs. tree height

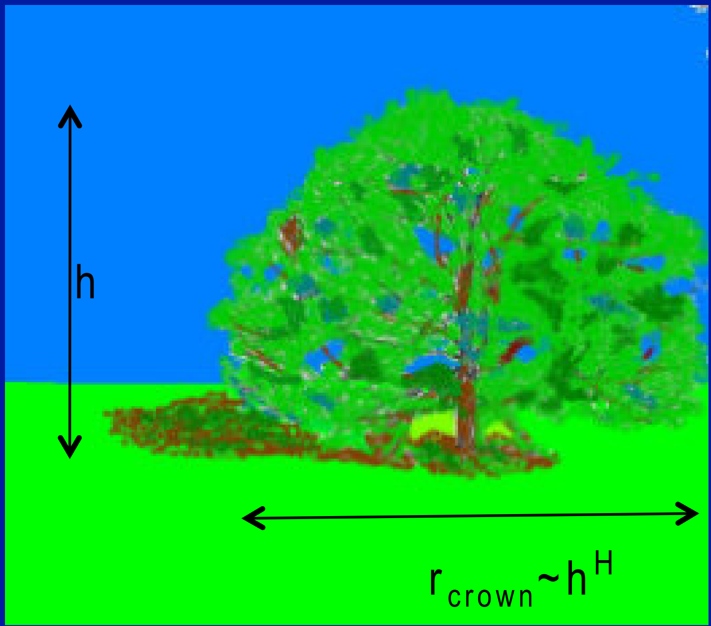
The same exponent
in all plots

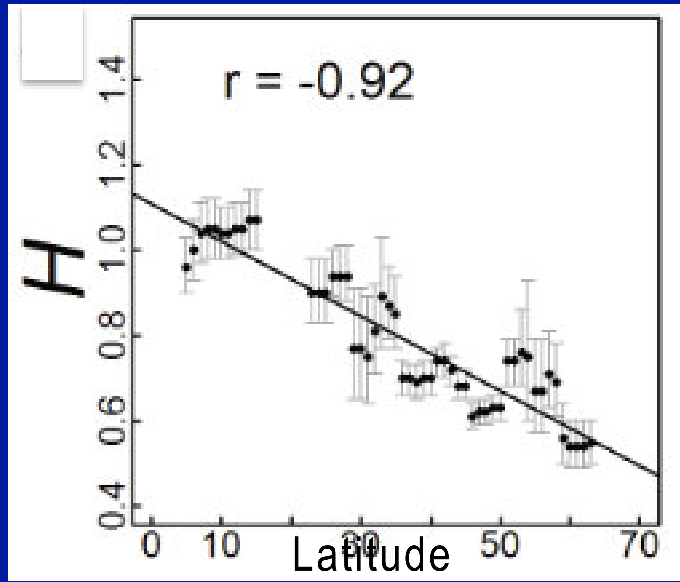
$$V_{cro} \propto h^{3.3}$$

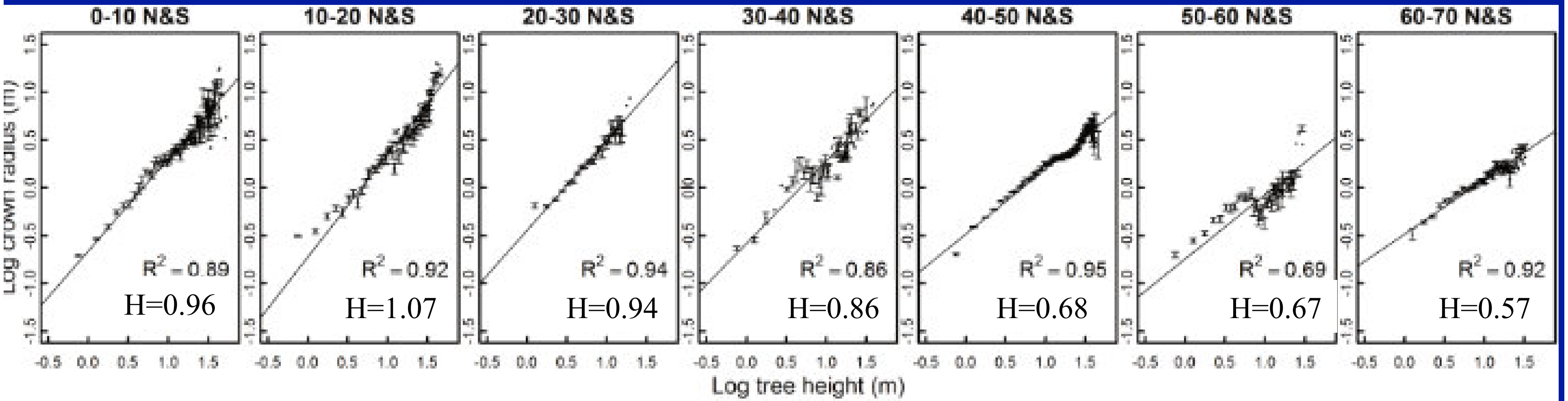
Anfodillo et al. 2019

Fact 3

Tree geometry across latitudes

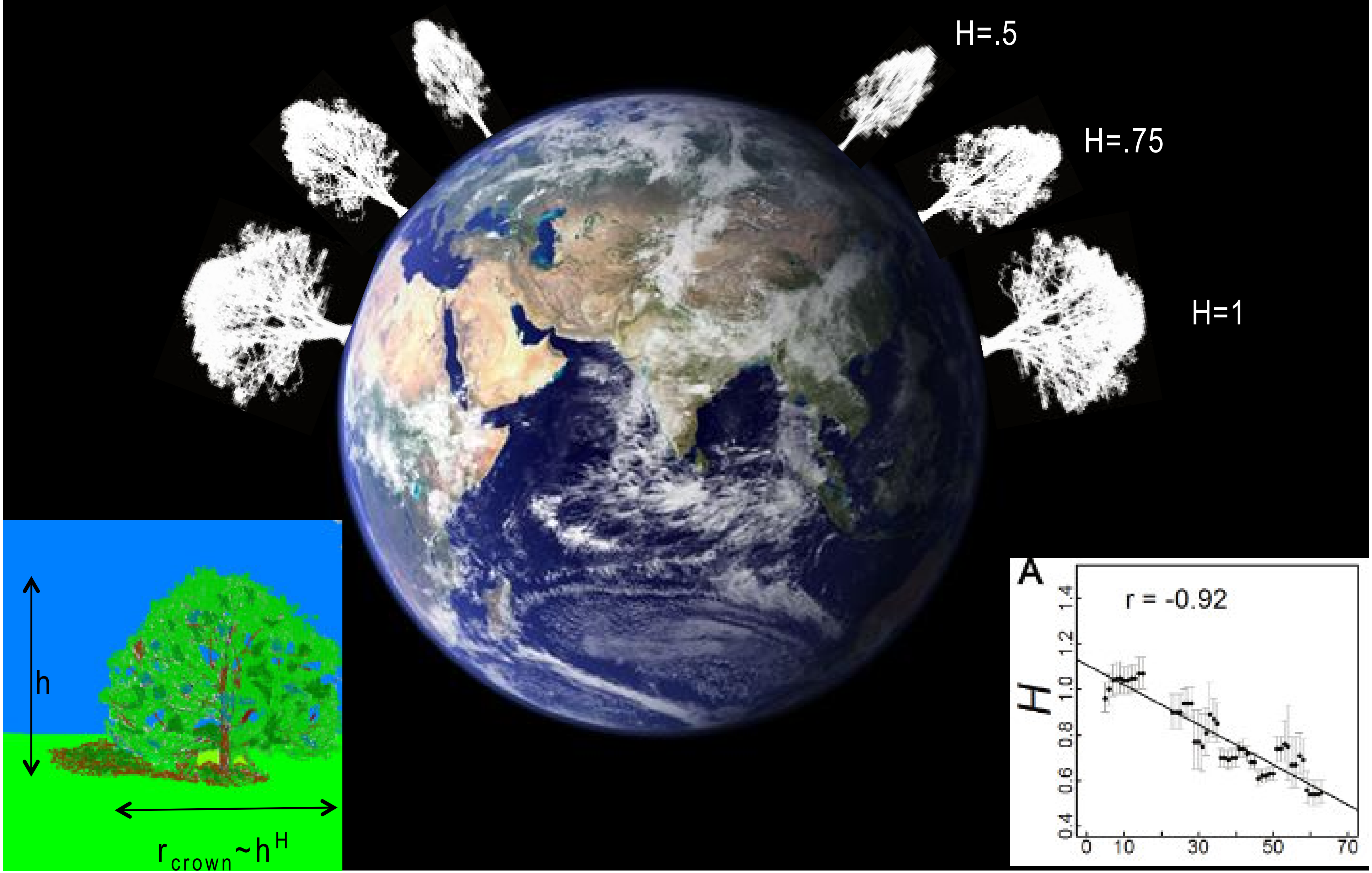






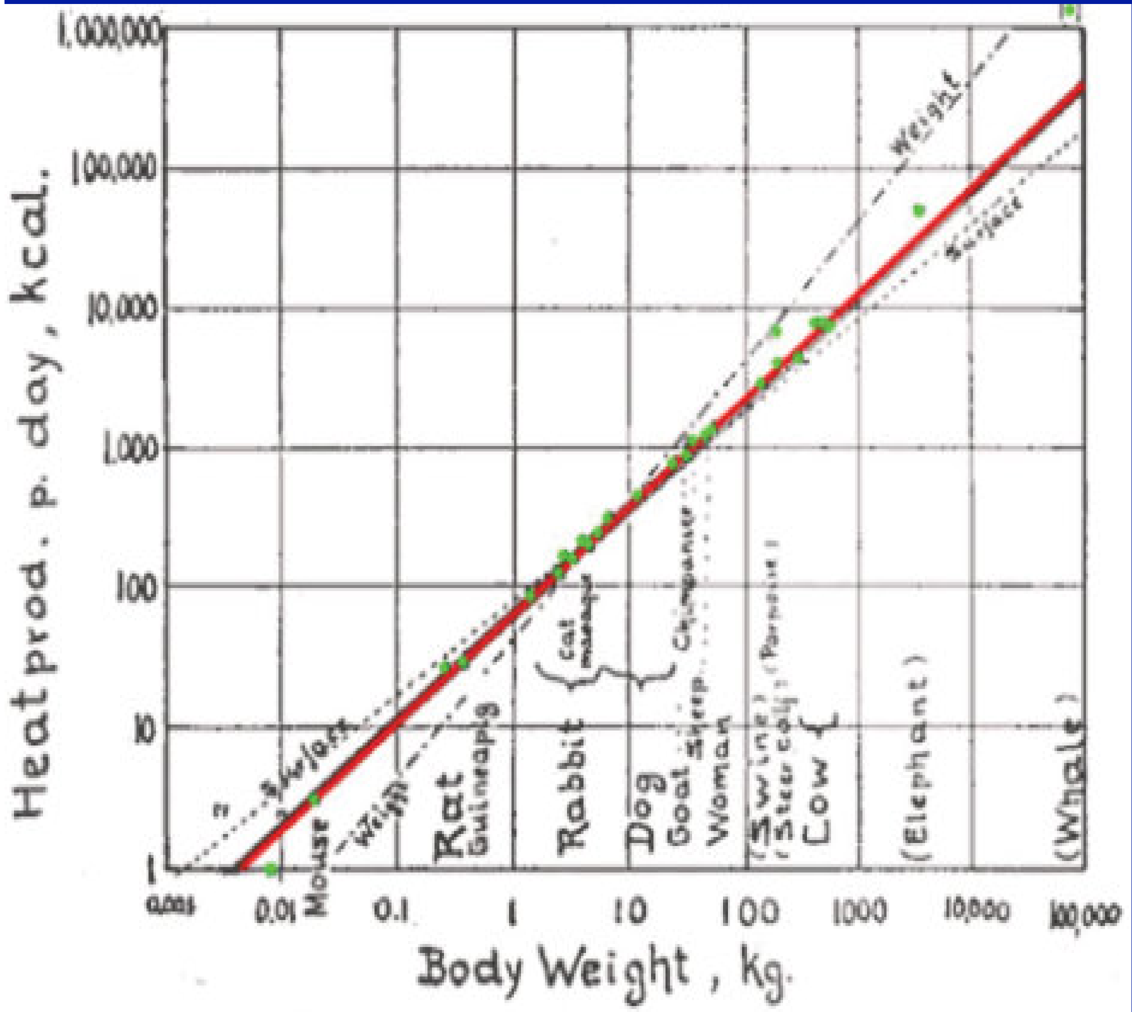
T.Anfodillo et al. 2019

Latitude dependent scaling

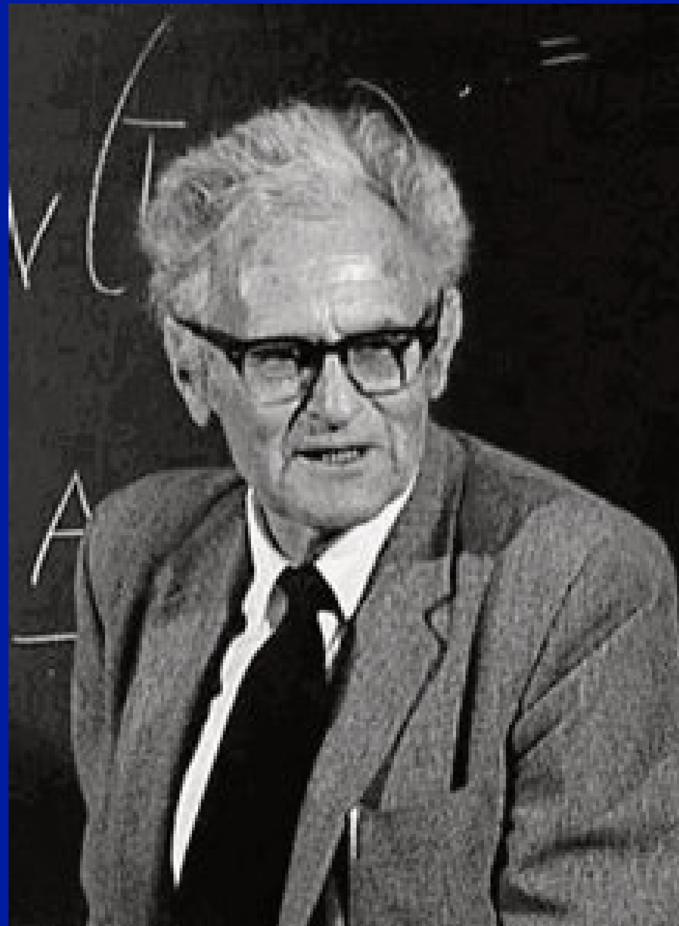


Fact 4

Kleiber and Kleiber's law (1947)



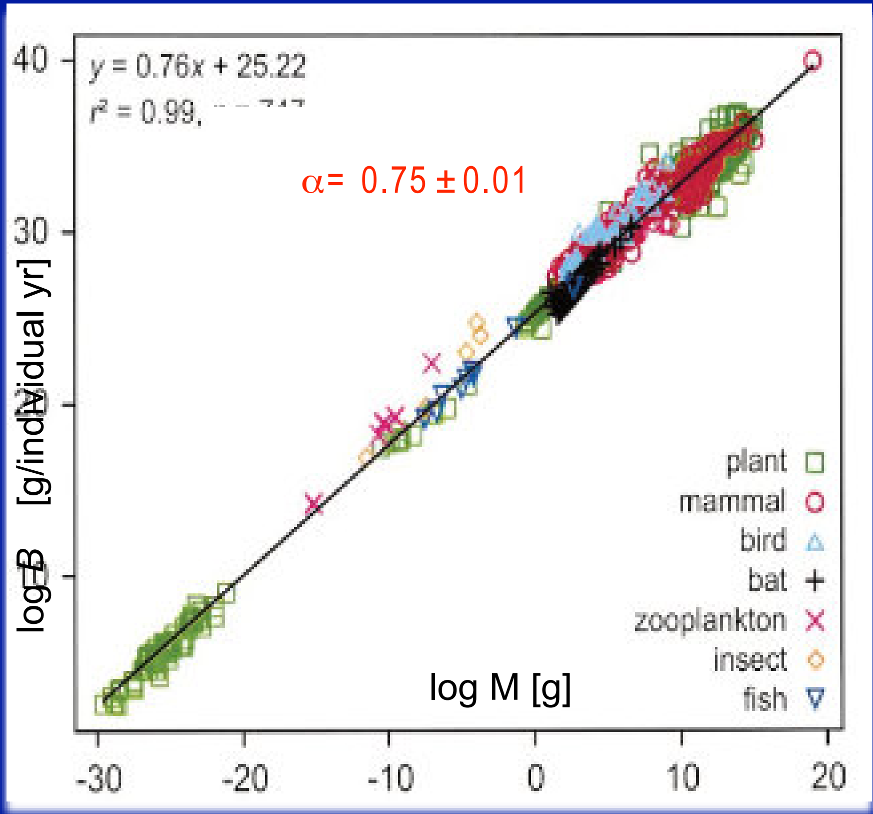
KleiberM, "Body sizeand metabolic rate", PhysiologicalReviews **27**, 511–541 (1947)



Max Kleiber (1893-1976 born and educated in Zurich. He graduated from the Federal Institute of Technology as an Agricultural Chemist in 1920. His thesis "The Energy Concept in the Science of Nutrition".

Fact 4 bis

Kleiber’s law 71 years later



mean/field metabolic rate

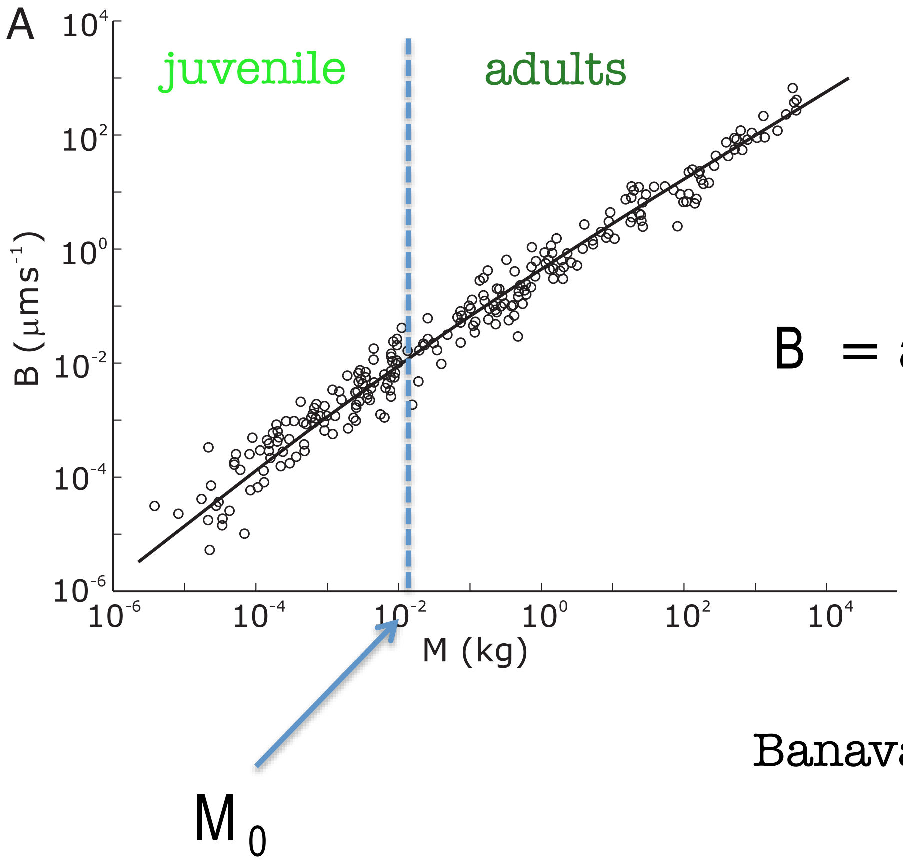
$$B = cM^{3/4}$$

species’ characteristic mass

Brown *et al*, *Ecology* 2004; West, Brown & Enquist, *Science* 1997; Banavar, Maritan & Rinaldo, *Nature* 1999; Glazier, *Biol Rev* 2015

Fact 4 ter

Mass- metabolic rate scaling for plants: crossover from juvenile to adults



$$B = aM^{\frac{3}{4}}\left[1 + \left(\frac{M_0}{M}\right)^{\frac{1}{4}}\right]$$

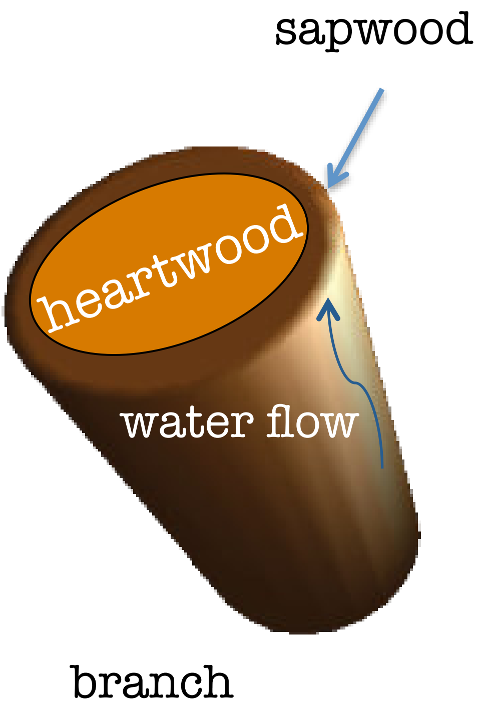
Banavar et al. PNAS 2014

From Facts to Scaling Approach

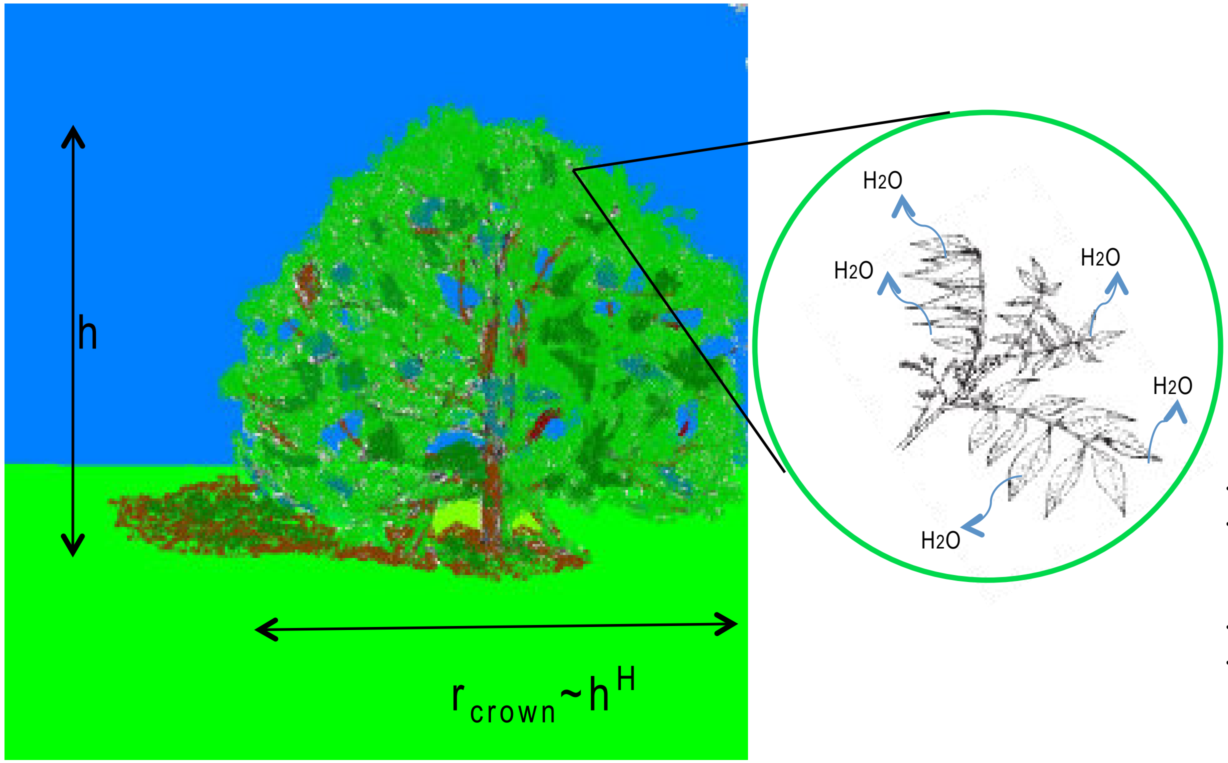
1. Derivation of scaling laws for <u>plant</u> traits

2. Derivation of scaling laws for <u>forest</u> traits

Kleiber's law from tree *geometry*



Metabolic rate of a tree



Tree volume ~ $h^{1+2\mathbf{H}}$

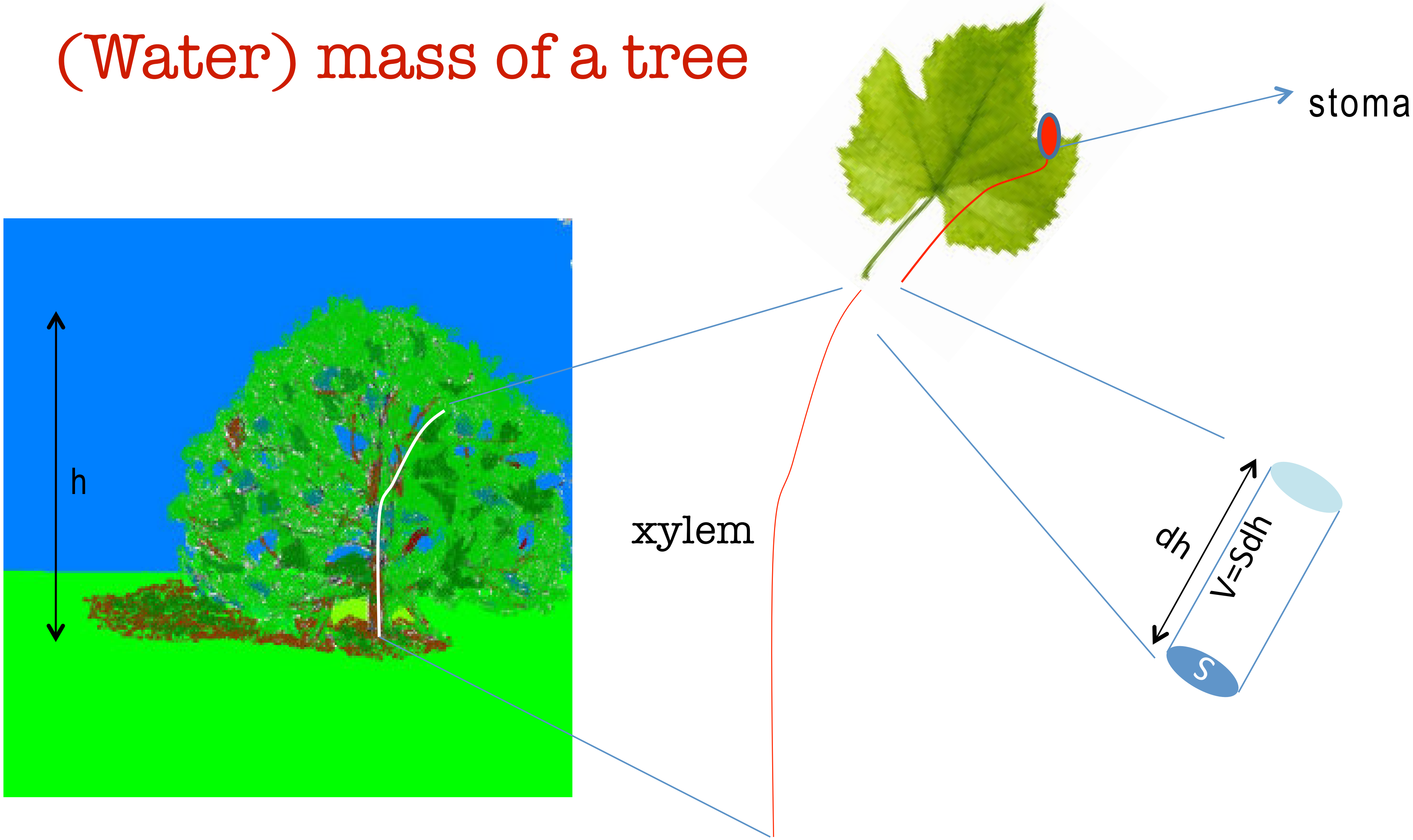
H = Hurst exponent

Leaf density ~ constant

Leaf is an invariant unit

Metabolic rate B ~ total leaf area ~ crown volume ~ $h^{1+2\mathbf{H}}$

(Water) mass of a tree



Water Mass in a Plant = (water density) x Volume‹···Volume ‹···(Leaf Area) x Treeheight‹···$h^{1+2H}h = h^{2+2H}$

Predicted B vs. M scaling

$B \propto h^{1+2H}$ $\quad$ $M \propto h^{2+2H}$ $\quad \Rightarrow \quad$ $B \propto M^{\frac{1+2H}{2+2H}}$

Only if $H = 1$ we get the Kleiber's law $\quad B \propto M^{\frac{3}{4}}$

True at tropical latitude

$$\frac{1+2H}{2+2H} = \frac{3}{4} \quad \Leftrightarrow \quad H = 1$$

Simini et al. PNAS 2010

Predicted Scaling Laws for Single Plant Traits"

Simini et al. 2010

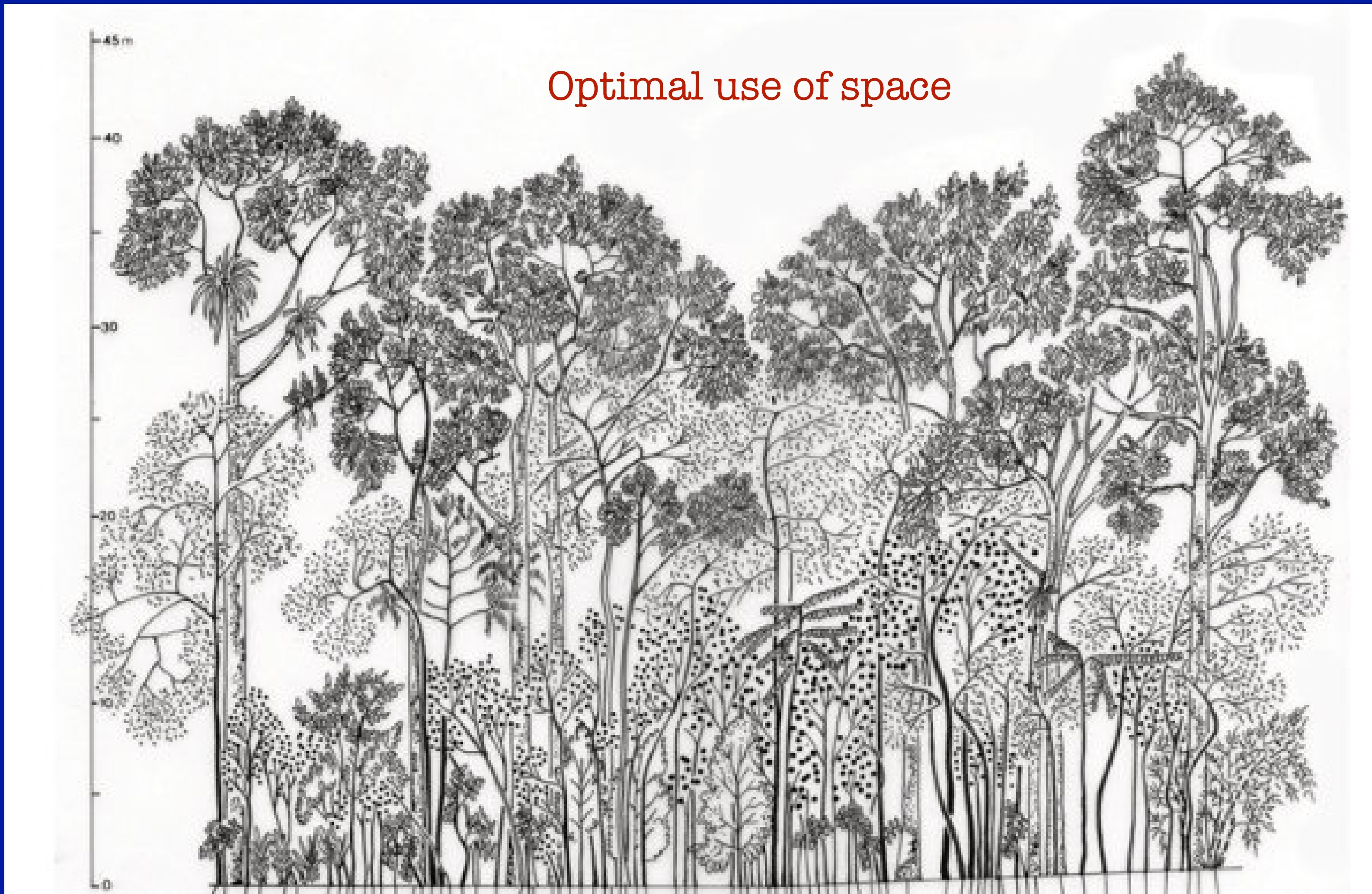
Metabolic rate *vs* tree height, h, and trunk radius, r	$B \sim h^3 \sim r^2$
Tree mass is concentrated mainly in the trunk	$M \sim h\, r^2$
Trunk radius (OK with buckling too)	$r \sim h^{3/2}$
Crown radius	$r_{crown} \sim h \sim r^{2/3}$
Total (water) mass	$M \sim h^4$
Total leaf area	$S \sim h^3$

From Single Individual to "

Community Scaling

Scaling Laws for Forest Traits

From one tree to a community



Optimization Principle:

Tree crowns occupy as much space as possible

Constraint:

Resourcesare limited, i.e.

total metabolic rate of the whole community <

<Resource availability

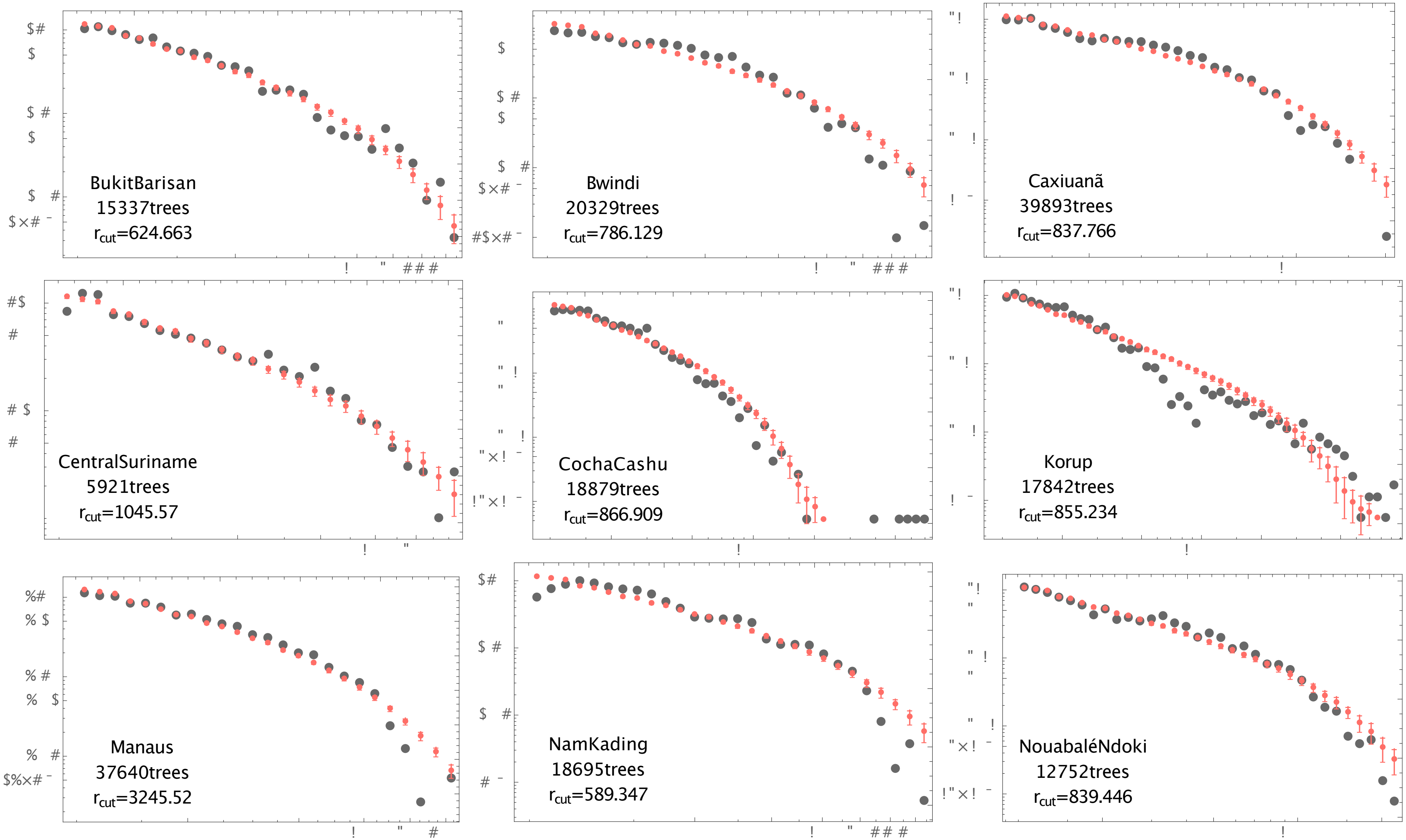
Maximum Entropy

Finite Size Scaling for trunk radius distribution &
all plant traits

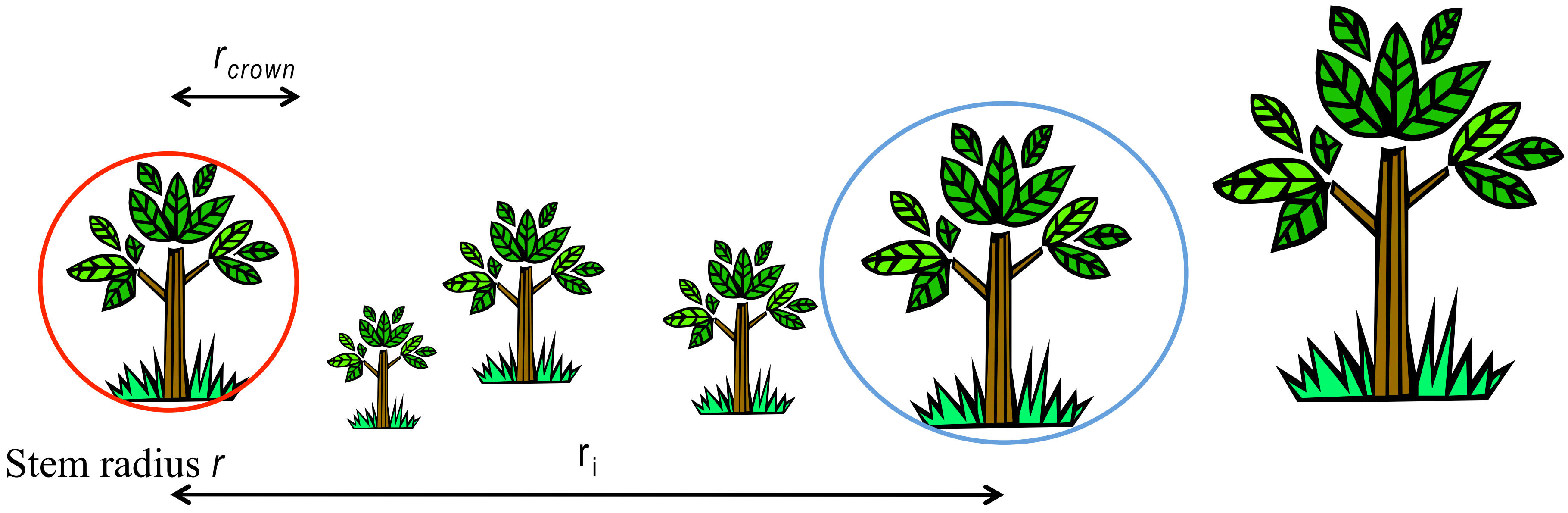
$$P(r) = r^{-7/3} \exp\{-(r/r_c)^2\}$$

Trunk radius distributions: data vs. predictions"

Volkovet al. 2020



Scaling and data collapse for interaction ranges

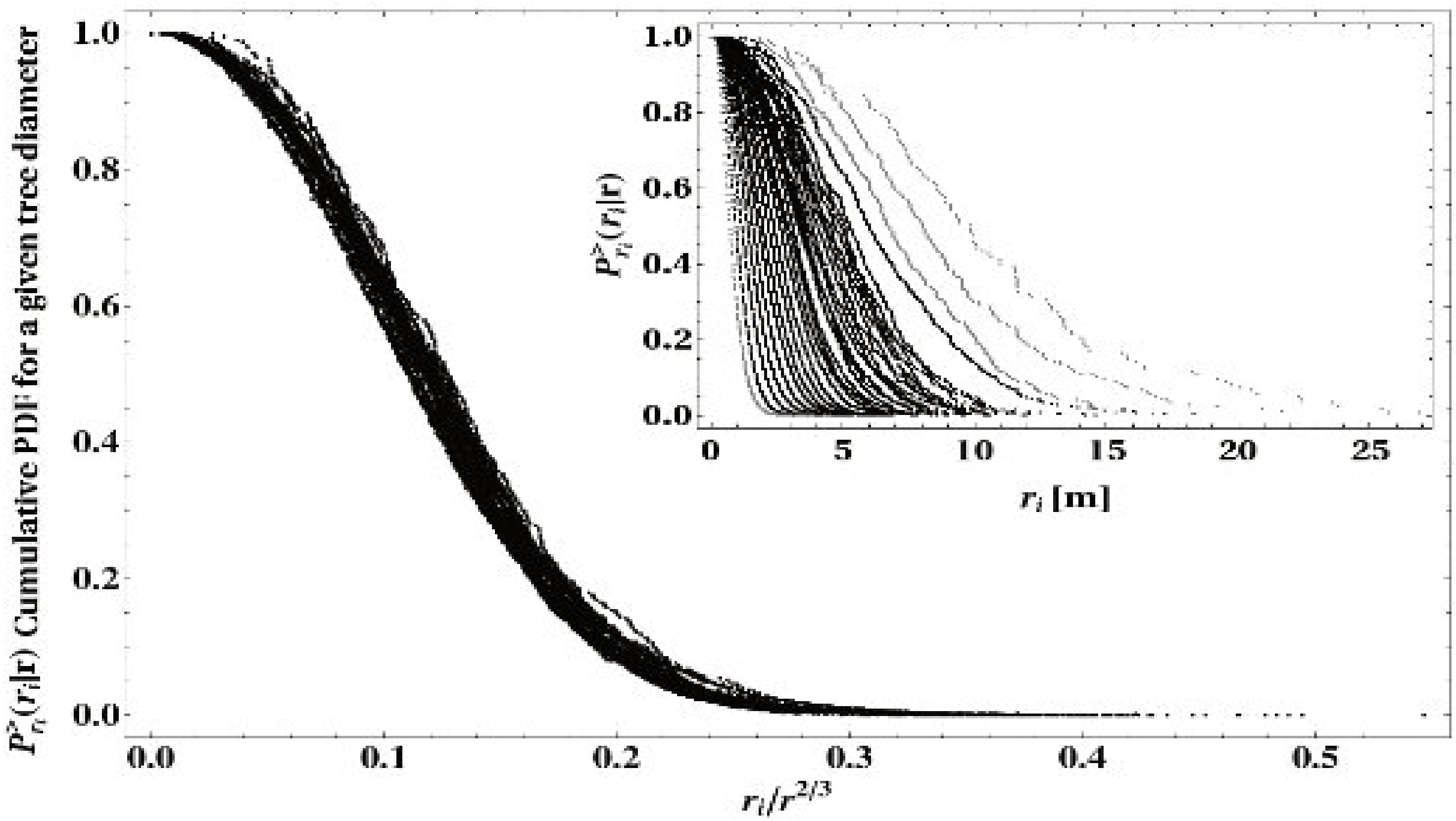


Range of influence $= r_i$, distance from the nearest bigger tree

$P(r_i|r)$ = Conditional PDF of range of influenc

Scaling and data collapse for interaction ranges

Simini et al. PNAS 2010



Scaling ansatz

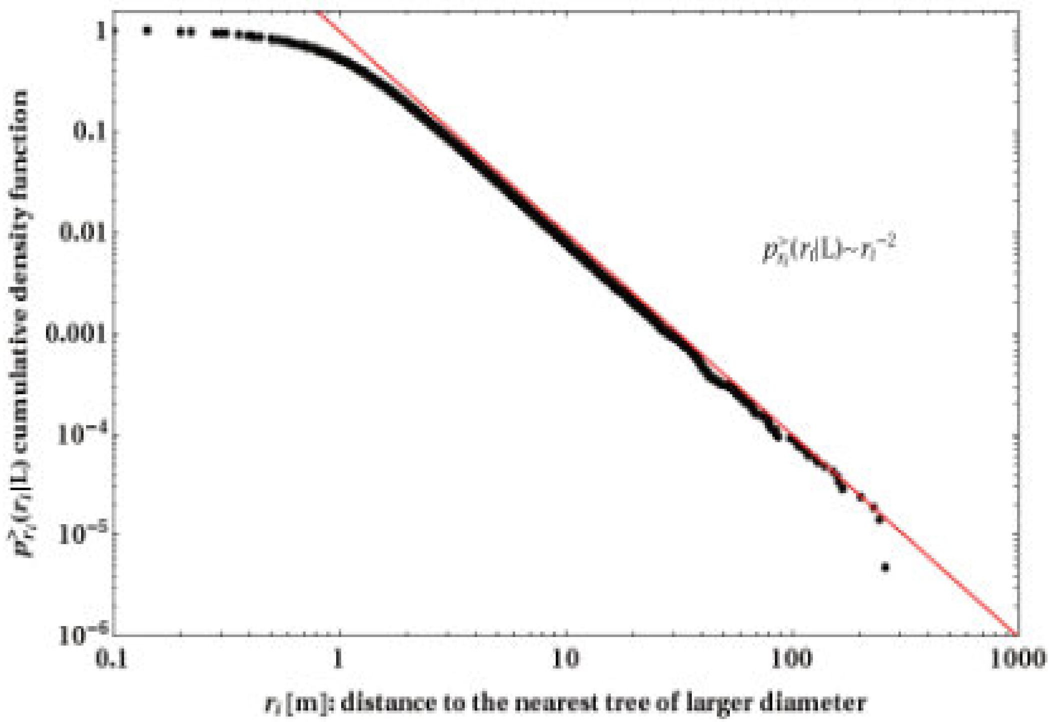
$P^{>}(r_i|r) = F\left(\frac{r_i}{r_{crown}}\right) \quad r_{crown} \propto r^{2/3} \qquad H = 1$ BCI fores

Interaction Range Distribution

Simini et al. PNAS 2010

$$P(r_i) = \int\int P(r_i|r)P(r|r_c)\ dr = \frac{1}{r_i^3} f\left(\frac{r_i}{r_c}\right)$$

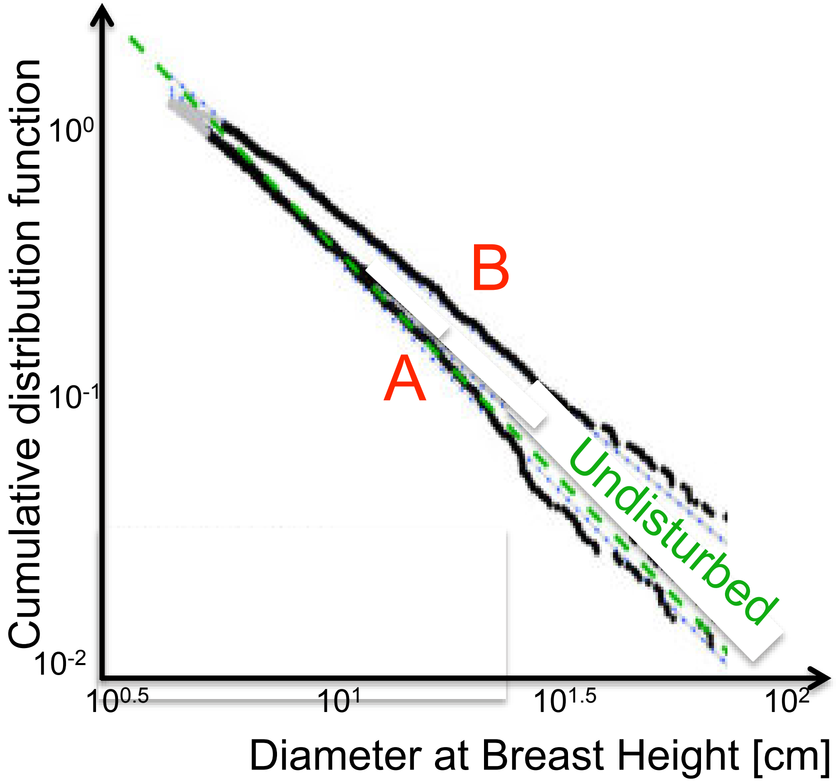
Conditional PDF of range of influence — Trunk radius distribution



FOREST MACROECOLOGICAL PATTERNS

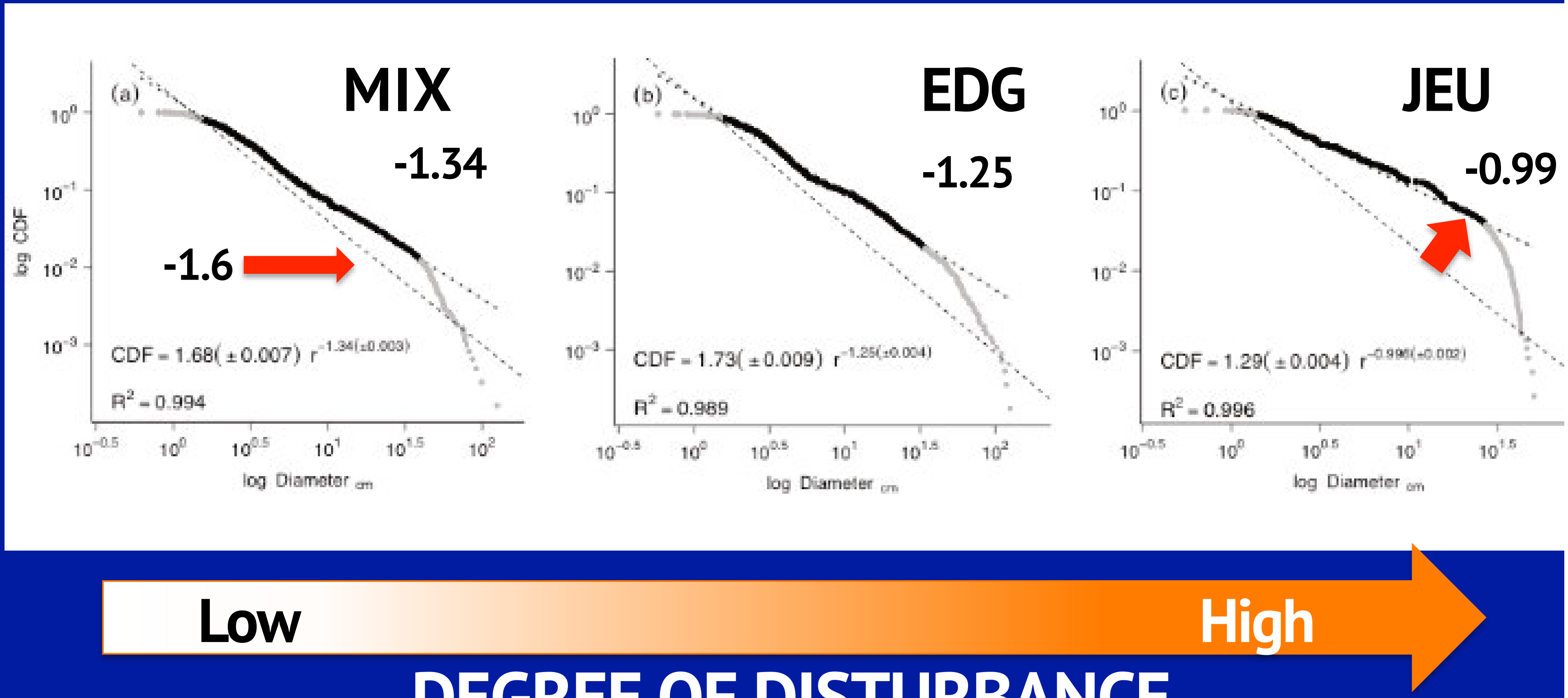
GOALS: Measure size and metabolic rate distributions in forest ecosystems. Evaluate the role of anthropogenic disturbance and relation with carbon sink

T. Anfodillo



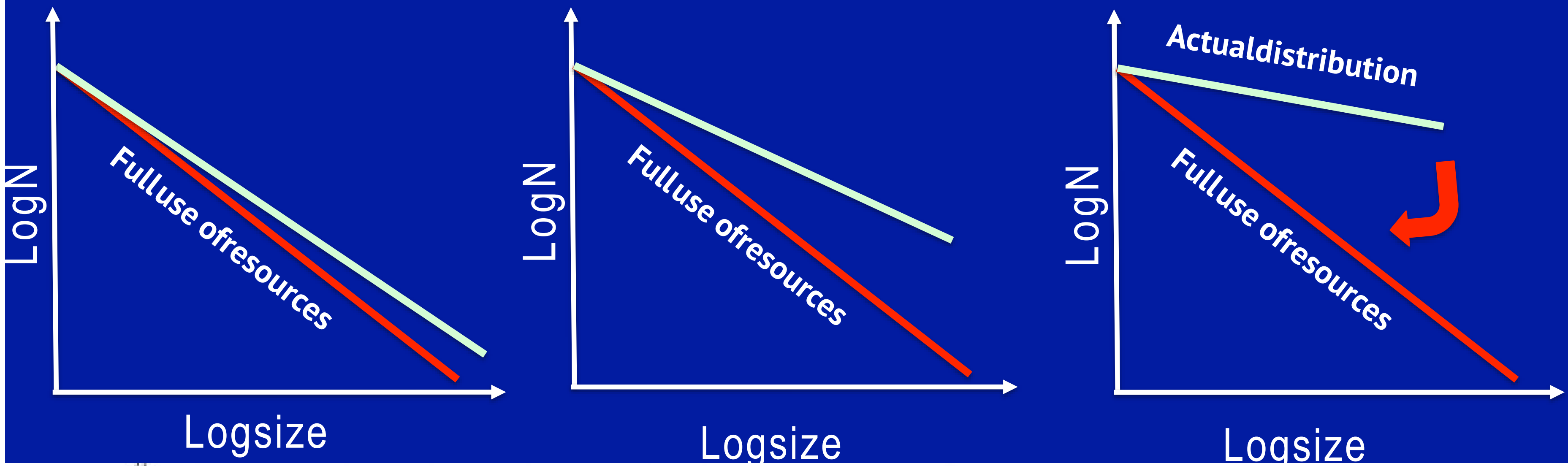
Disturbance and forest carbon sink, respiration and soil bacteria

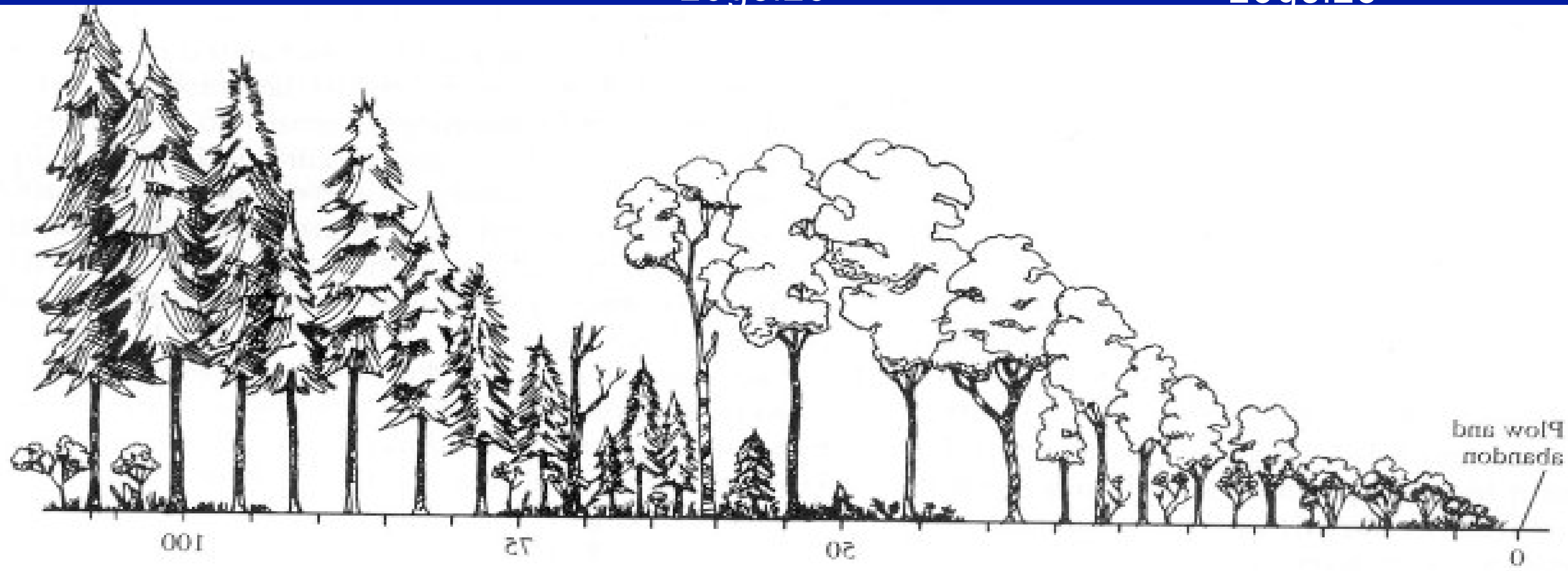
Idealpredictedexponentfor CDF= -1.6



Sellanet al.2017 J. Veg. Sci.

Slopeasmetricof thesuccessionalstage (degreeofold-growthness)





Main conclusions

- Astounding simplicity underlying the complexity of forests
- Crown width scaling *vs* tree height & optimization principle predict scaling of the single plant traits and the whole forest traits including pair correlation function
- Predictions are tested for plants and forests at various latitudes
- Deviations from the predictions are used to quantify degrees of disturbances in forests
- Plant and animal communities behave similarly

NTNU | Kunnskap for en bedre verden

OCEANS

Balancing ecological, social and economic concerns

– an ethical perspective

JPI Oceans S4GES workshop Dec. 2, 2020

Siri Granum Carson | Director NTNU Oceans

Climate change severely damaging world's oceans, UN report warns

IPCC predicts increased deadly heatwaves and losses of sea ice

about an hour ago | Updated: 49 minutes ago

Kevin O'Sullivan Environment & Science Editor

The UN report predicts record losses of polar sea ice. Photograph: Chris Larsen/ NASA/AFP/Getty Images

Greenhouse gas emissions from human activity are destabilising oceans, leading to more intense superstorms, increased deadly heat heatwaves and record losses of polar sea ice, according to a United Nations report.

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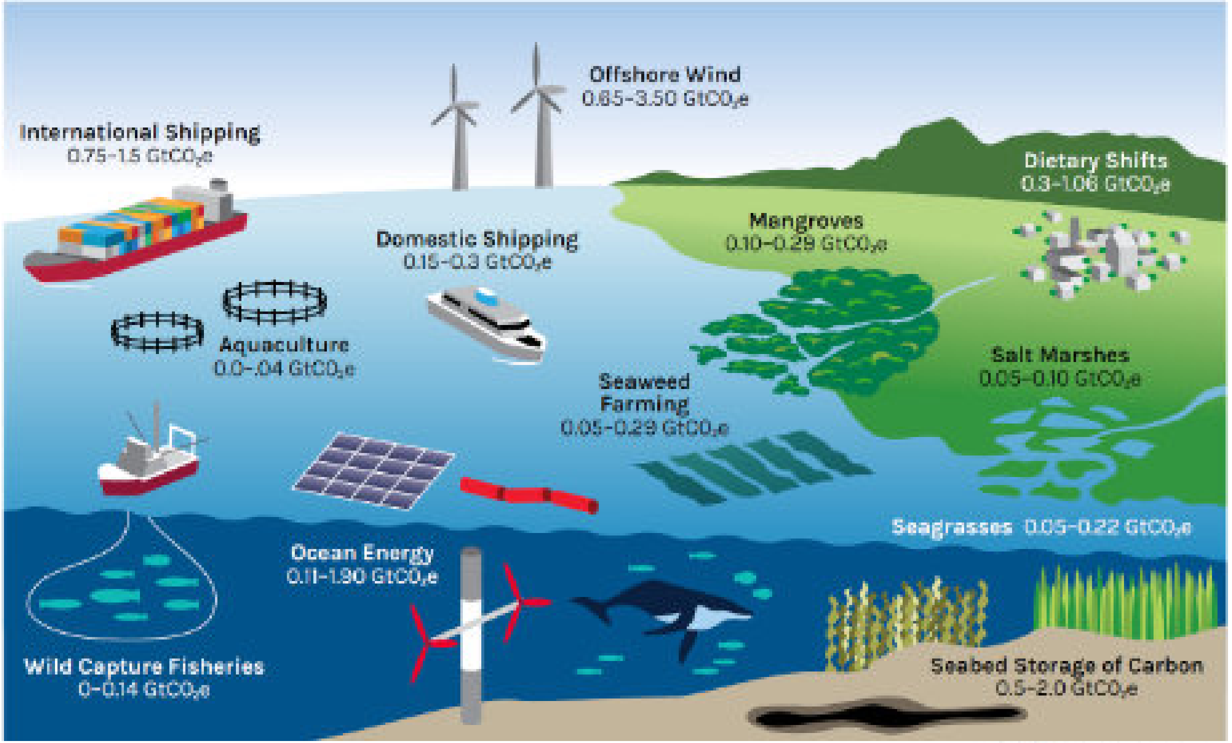
The ocean as a solution to climate change?



HIGH LEVEL PANEL for A SUSTAINABLE OCEAN ECONOMY

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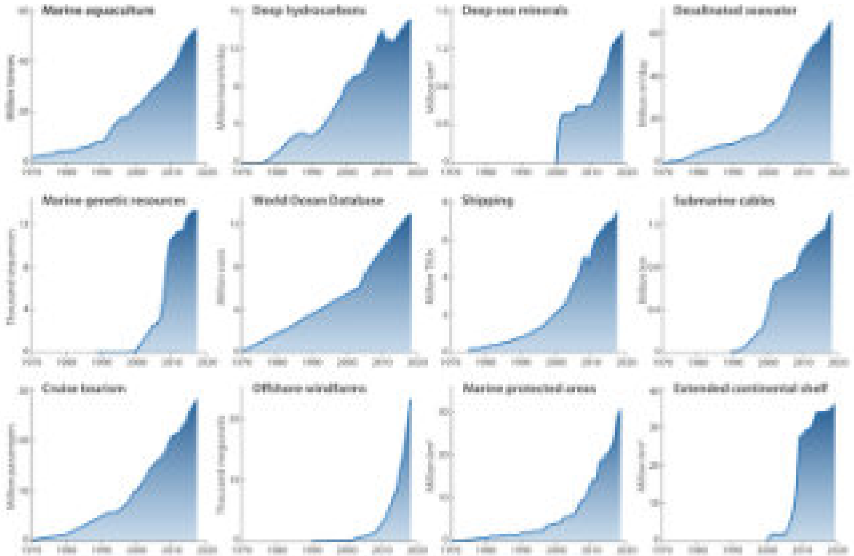
«Blue accelleration»

- The ocean as solution to “all” our sustainability challenges?

- Vital: A holistic evaluation of the effects, and a crossdisciplinary and cross-sectorial examination of possibilities and limitations.

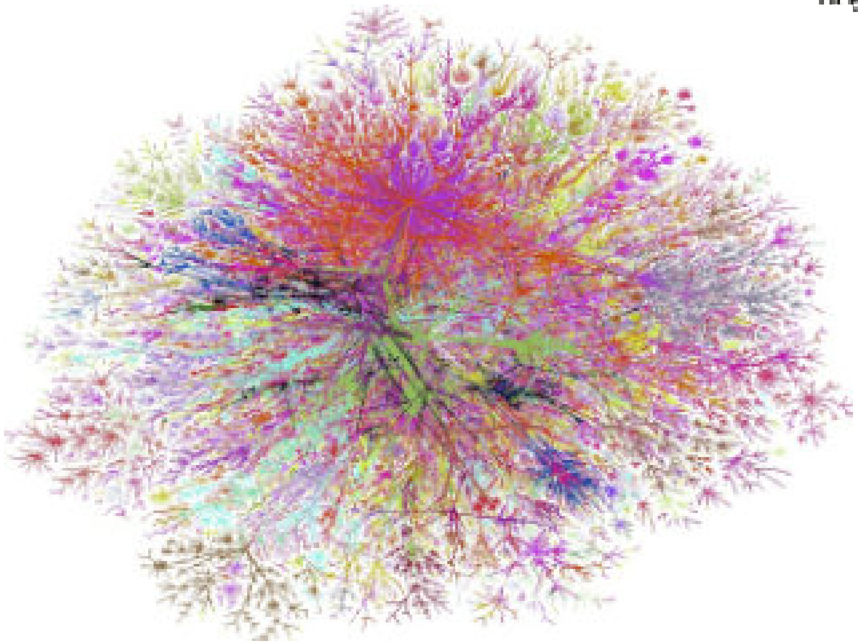


Jouffray et al (2020): The Blue Acceleration: The Trajectory of Human Expansion into the Ocean.

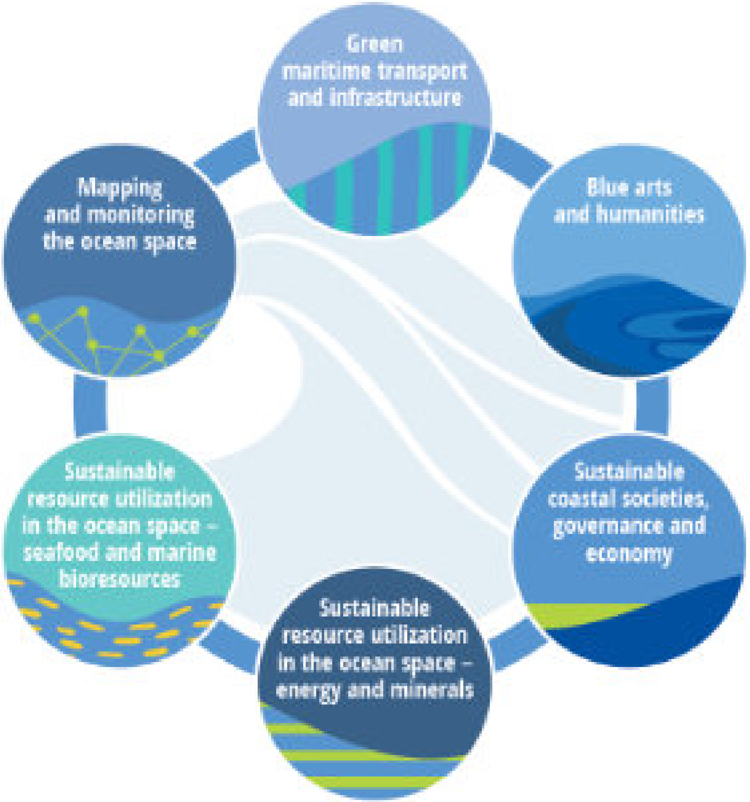
Climate change as a «super wicked problem»*

- *Why is this happening?*
- *Who is responsible?*
- *What should be done?*

➢ Complexity at multiple levels.



* Rittel and Webber; cf. Levin et al.


Green maritime transport and infrastructure
Blue arts and humanities
Sustainable coastal societies, governance and economy
Sustainable resource utilization in the ocean space – energy and minerals
Sustainable resource utilization in the ocean space – seafood and marine bioresources
Mapping and monitoring the ocean space

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Sustainability in the MSFD context

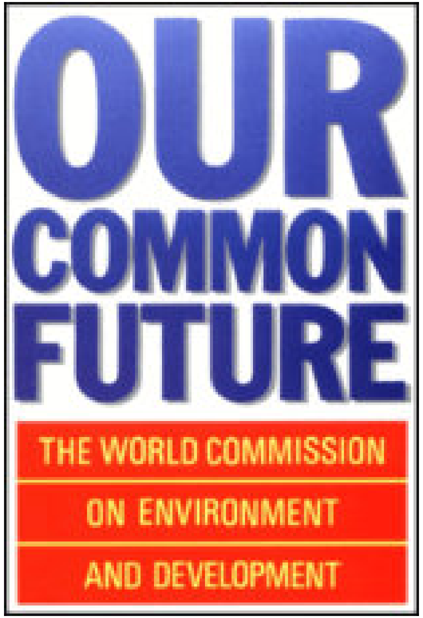
- Good Environmental Status (GES) means "that the different uses made of the marine resources are conducted at a sustainable level, ensuring their continuity for future generations."

Sustainability as a normative concept

- Brundtland commission, UN 1987:

  "Sustainability is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

- The perspective from ethics: Sustainability is an inherently *normative* concept – it expresses certain ethical demands about how certain things *should* be.
- …but what exactly does it demand, and on whom are these demands placed?



Weak vs. strong sustainability

OCEANS

- Sustainability is about balancing economical, social and ecological concerns.
- But can one form of “capital” be exchanged with another?

Sustainability for whom? Part 1

- Key question: Is the world worth saving for humans only, or do other species/ecosystems count morally?

- In other words: *If you were the last person on earth, would it be ok if you trashed whatever's left of it?* (cf. Last Man Argument, Routley 1973)

Anthropocentrism vs. non-anthropocentrism

- Peter Singer: «The expanding circle», vs. «specism»
- Arne Næss (1912-2009): Deep ecology – human beings do not have a privileged right to existence and well-being – we exist primarily as part of ecosystems
- Danger of this line of thinking: What about the rights of individuals?
- Callicott: All value originates in (human) subject, but we can distinguish between *instrumental* and *intrincic* values.

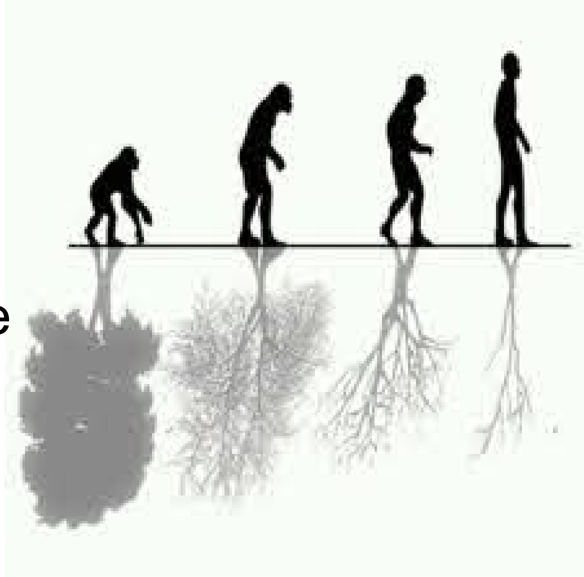


Image: Lintas Filsafat

Sustainability for whom? Part 2

- Key question: Do we have moral obligation towards generations that come after us?
- First intuition: This is implied by the concept of sustainability.
- But maybe not so simple – how can we have an obligation towards someone who does not (yet) exist?

Intergenerational justice

- Do justice considerations apply to intergenerational relations, that is, to relations between non-contemporaries?
- What, if anything, speaks against this view?
- Brian Barry (1997): Sustainability is a normative notion - disagreements over its meaning are disagreements about what should be sustained and for whom.
- His answer: ‘Some notion of equal opportunity across generations’ = a protection of nature consistent with the provision of intergenerational equality of opportunity (the biggest obstacle is population growth since any given generation cannot be responsible for future population growth.

Is (can) aquaculture (become) sustainable?

OCEANS

Final comments

- Main point: Sustainability is a normative concept that concerns the distribution of goods, rights and disadvantages.

- Decisive question: Sustainability *for whom*?

- Sustainable development of the oceans means the balancing of conflicting interests.

- Our interpretation of this concept will have practical implications on marine governance issues.

- *Thank you!*
- *Questions? Comments?*

Governance of complex systems

Pier Francesco Moretti

JPI Oceans and CSA BLUEMED internationalworkshop

Musing on the concept of Good Environmental Status: the complexity of the status & the status of complexity

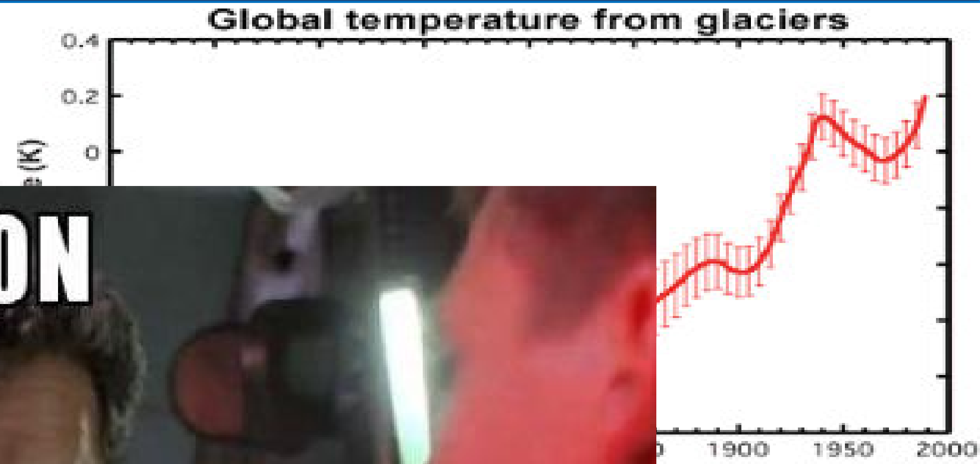
2 December 2020

Content of "governance et al."

- Scientific support to decisions
- The concepts[s] of "governance"
- "Governance" of complex systems
- Clues, pros and cons

"Aim":
are you ready to give back the throne?

Scienceand policy, policy of science, political scientist, what else?



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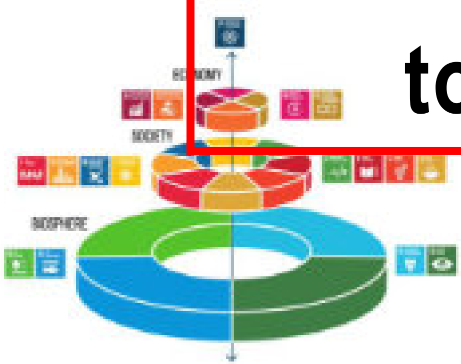
Diversity in objectives, assumptions, capacities etc.

1) Why does anything seem so complicated, or complex?
2) Is it possible to find solutions? For whom, for how long?
3) The magical words: synergies, integrated holistic approach, multi-disciplinary, co-design…BLABLA BLA!
4) Can ”simplification” (linearization) be effective?

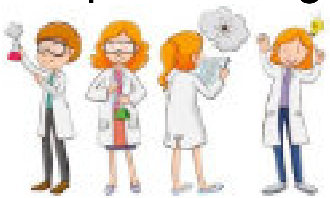
Can we adopt a scientific methodology to design and manage the process towards solutions/objectives?

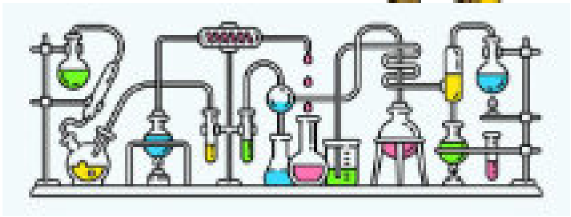


Basics:the process for the product


Recipes


Ingredients:
people, things, resources





Courses:
documents, solutions, tech etc.



Different people bring roles, objectives, assumptions, interests, resources...

Any ingredient is a an "agent" [lobby]




MEDIA

SCIENCE INDUSTRY POLICY FINANCE Other...

N PANIC

How science can support?

Who to select?
How to interconnect?

Expert 1 discipline 1

Expert 2 disc

Expert 3 disc

Expert 1 disc

Expert1 disc

discipline 1

discipline 1

discipline 1

discipline 2

discipline 3

CONSULTATION:
sequential and/or additive

discipline 1

discipline 1

discipline 1

discipline 2

discipline 3

discipline n
or usually
a “communicator”
or a
brick player

USE of INTERFACES

WHY it is so difficult and WHY governance is crucial?

You can't believe: a lot of things, arguments, people, I don't understand anything about robotics, least of all about jurisprudence, and all intertwined with each other. Here it can happen that the situation escapesus out of hand and we suddenly find ourselves in another world! These are greater things than us, but everyone must do their part. Shall we call the boss, or do we do as we like? There is no more time, we have to do something but everything is so vague ... pause ... Do we copy from the Germans? Or look for a piece of support!!!!"

Many heterogeneous interacting parts, multiple scales, transition laws, unpredicted emergence, path-dependent dynamics, networked hierarchical connectivity, interaction of autonomous agents, self organization, non-equilibrium dynamics.

The concept[s] of governance

What is governance ?

Wikipedia: Governance comprises all of the processes of governing - whether TOP-DOWN e government of a state, by a market, a network- over a social system (family, tribe, formal or info s) and whether through the la Already organized? uage of an organized society.

It relates to the processes of interaction and decision-making among the actors involved in a collective problem that lead to the creation, reinforcement, or reproduction of social forr Formal? itions.

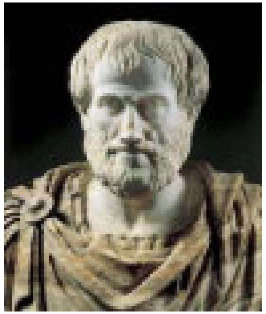
In lay terms, it could be d the political processes that exist in and between formal institutions.

Perceived as a hierarchy

Gubernare, regere….

Control, prediction (weather, route…)
Roles(competences) & functions

If storms….



Reflection 1: **how the concept can be tracked back?**

Aristotle's Categories…Physics& Metaphysics et al.!

Hierarchy vs functions : who does what (in a very simplified approach!).

Reflections 2: Are there "levels" of governance or management?…state, market, family, networks:

structure and relationship and dynamics.

Reflection 3: how are different forms adopted? business as usual, workarounds…

Reflection 4: Is the governance a goal or an instrument?

"Traditional" concept for governance: politics, polity, policy

POLITICS=choices! Diversities of interests to converge
Simplifying: the management of the state intervention in addressing the autonomy of society. In the EU Union: "**network governance**" is assumed to be dominant with respect to "statism", "pluralism" and "corporatism" ,and it is mainly focused on the links between private and public. IS IT WORKING?

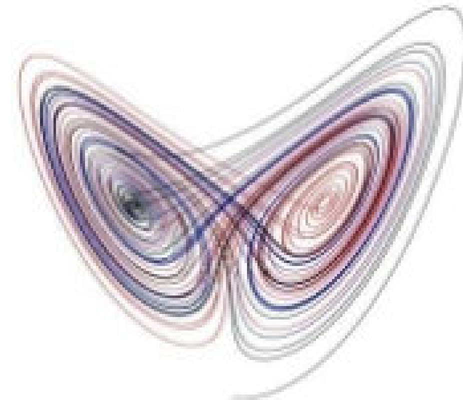
POLITY=rules and frames!
Main aspects: hierarchy vs market-based. Centralized vs diffused. Institutional vs non. Negotiation, persuasion, diplomacy.

POLICY=Instruments and…
Incentives vs penalties. Binding vs soft law. Procedures vs guidelines. Standards vs threesholds.

Complexity at policy level: trans-nationality is only one of the non-independent aspects

Characteristics of complex systems

Interconnected factors
The sum of parts could not be representative
Difficulty in accurate predictions, abrupt changes



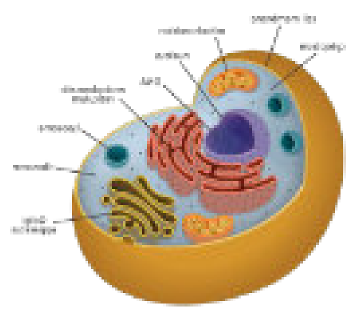
Usual drivers, objectives, aspects at policy level

Stability, control (cause-effect), risk assessments: in true complex systems...?

Complexity: how to approach within governance

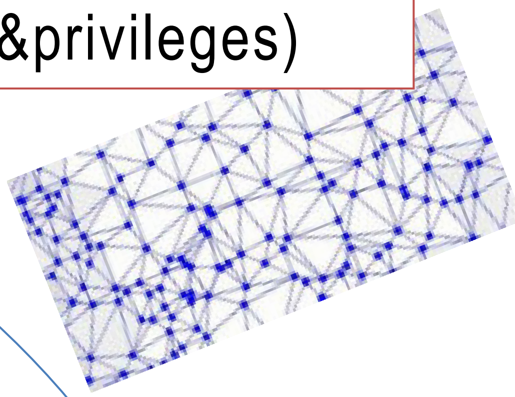
From stability to robustness or resiliency
From top-down to self-organization
Functions vs responsibilities (&privileges)

CHALLENGE 1



Openness
(information/energy/exchanges)
vs
closeness
(identity/structure/organization)

CHALLENGE 2



A fluid within a crystal
From bilateral to multi-lateral
From formal to agent-based

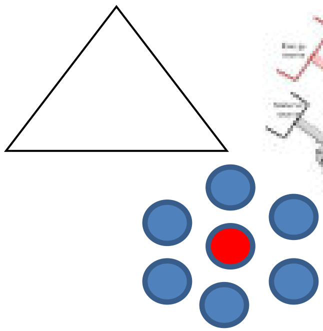
The state of the art

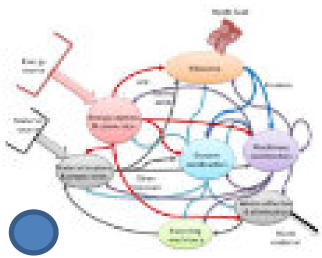
Evolution

From stability to robustness or resiliency
From top-down to self-organization
Functions vs responsibilities
[vs privileges and authority]

The concepts of robustness and resiliency translated into governance

Different modes of governance of complexity: from hierarchy to self-organizations
Different theoretical frameworks:

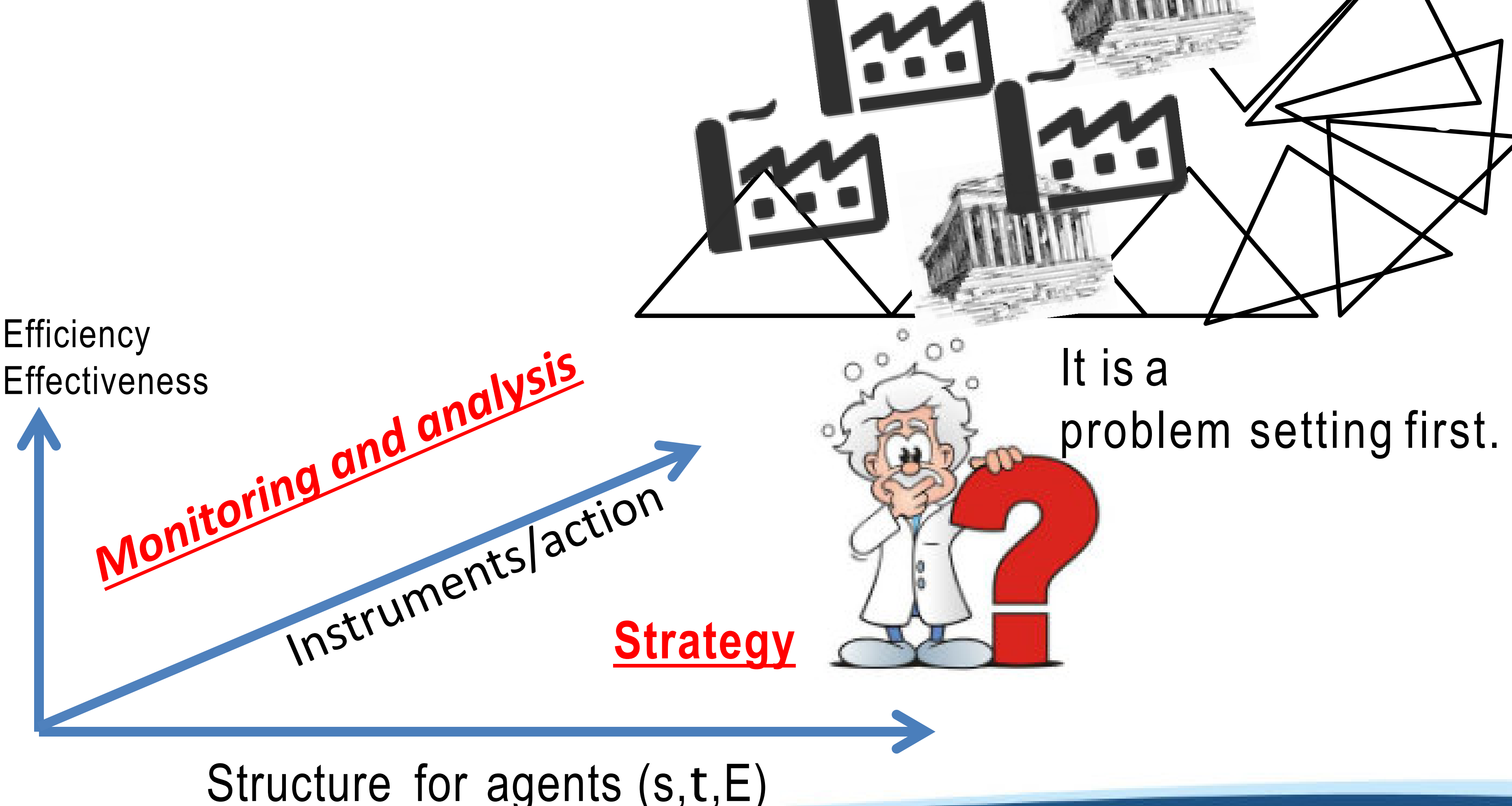




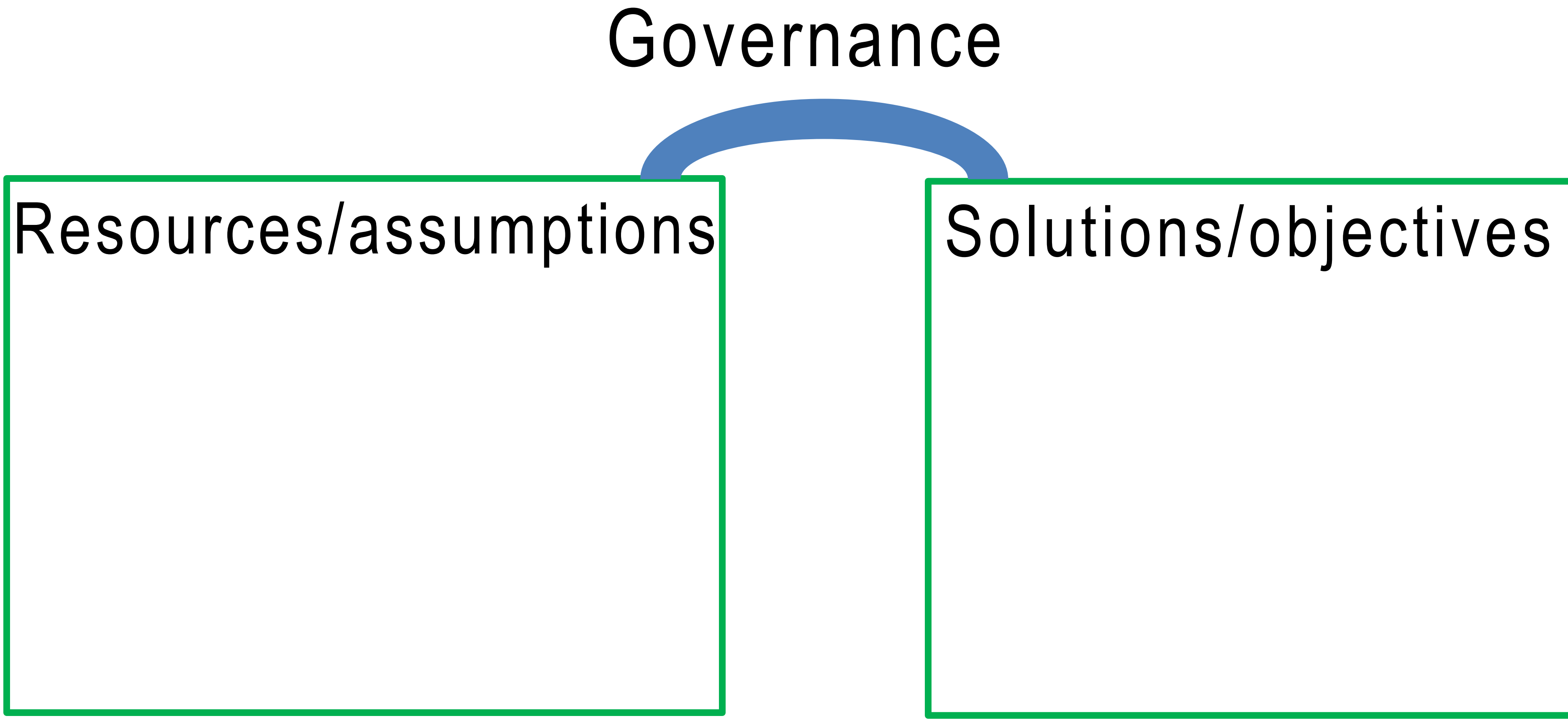
Training vs specialization
Job enlargement (horizontal/roles) vs enrichment (vertical/responsibility)

The concept of network.
Different pros&cons.

Can be simplified?



The governance is a recipe to structure the process, but...



<u>NO recipe fits all, but a scientific methodology helps</u>

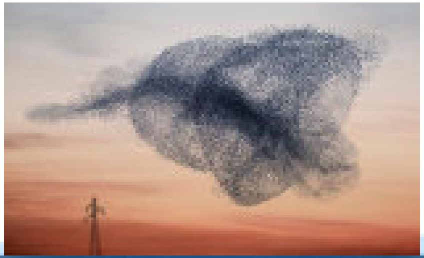
Are primates/homines used to address linearity or complexity? Clues?

Primates have evolved in environmental conditions where events occur temporally as successive and localized in space. Globalization and hyper-connection have transformed the concept of space-time, towards “simultaneous and ubiquitous” events.

Primates adopt "multi-level" societies (in family contexts, clans, etc.), other mammals have less rigid boundaries between levels.

Hierarchy is mainly associated with a military organization.
During WWII, the 6-day war, the invasion of Iraq, organizations other than hierarchical ones were adopted to deal with complex situations.

Organisms considered less complex than humans adopt different strategies and organizations to ensure the survival of the system. Rules and roles are dynamic and functional, often "explained" with network theory.



Resiliency...frombla bla bla to action

In Latin: reilire = bouncing back

The ability to respond, absorb, and adapt to, as well as recover in a disruptive event.

In Engineering

The adaptability to changesin environment or differences between various habitats.

In Biology

The process of adapting well in the face of ..omissis...,trauma, omissis,,,or significant sources of stress. It means "bouncing back" from difficult experiences.

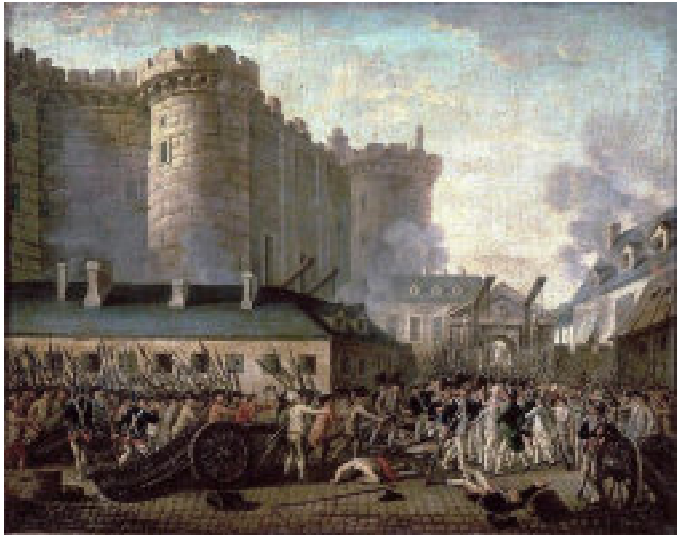
In Psycology

Are you ready to change/adapt? Do you really want?

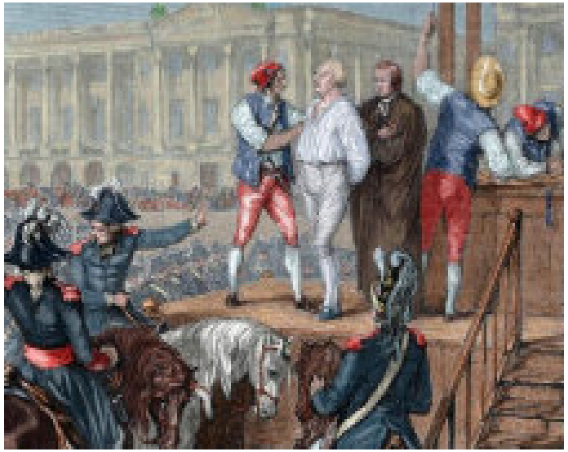
What happens if the governance structure has to be modified/adapted?

NOT to substitute in the roles

Break the system?

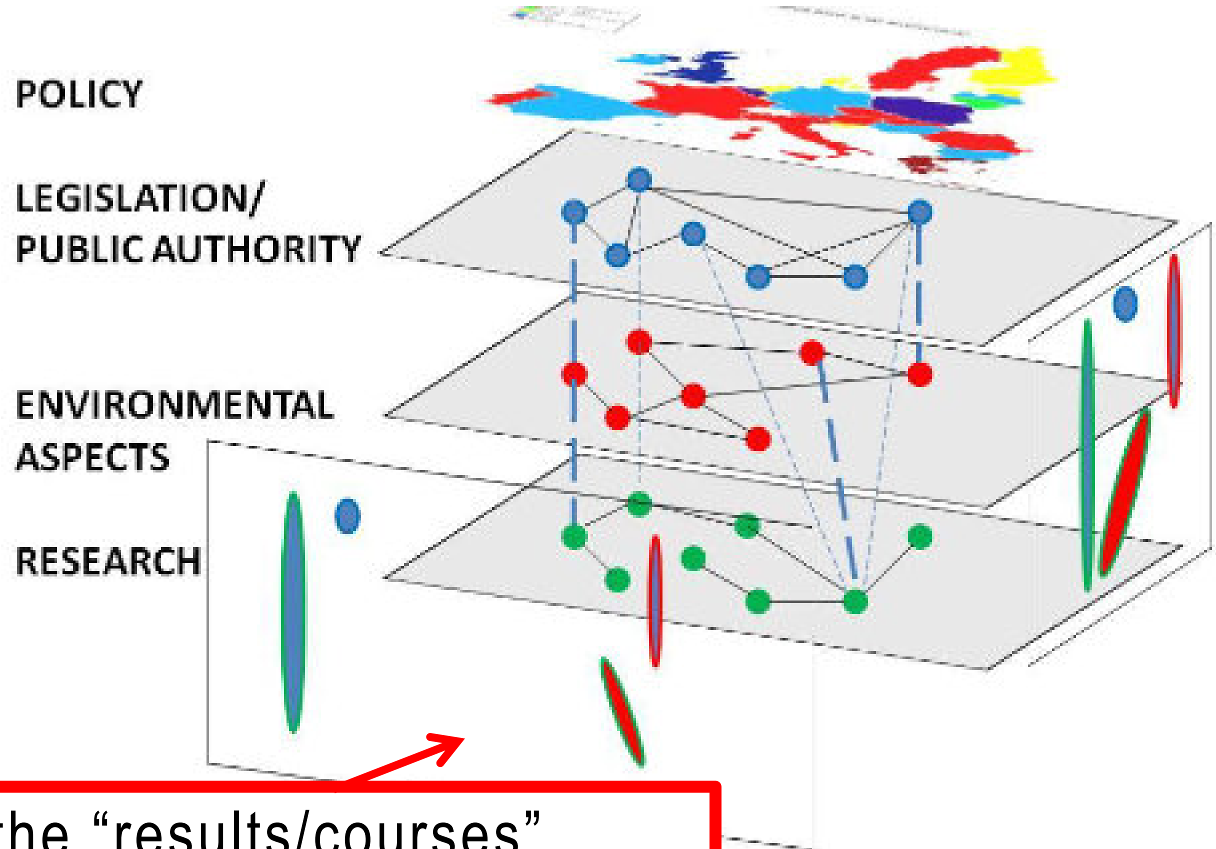


Counter-measures



It is a multi-dimension multi-level problem

Possible dimensions:
LEGISLATION
RESEARCH
ECONOMY
CULTURE
ENVIRONMENT
FINANCE
MEDIA (web, tv, etc.)
Possible levels:
State, regions, competent authority, companies, institutions, ONG, etc.



Projections are the "results/courses", depending on the topology and dynamics of the networks...that is, on governance