Fondazione Eni Enrico Mattei (FEEM) Milano, 15 Nov. 2012

Impacts of Natural Disasters on a Dynamic Economy

Michael Ghil (ENS, Paris, & UCLA)

with B. Coluzzi, A. Groth & G. Weisbuch (ENS)
P. Dumas, S. Hallegatte (+World Bank) & J.-Ch. Hourcade (CIRED),
M. Bocquet (EP-ParisTech), L. Sella, P. Terna & G. Vivaldo (U. of Torino)
and R. Hillerbrand (TU Delft)

LETTRES SCIENCES
ÉCOLE NORMALE SUPÉRIEURE

THE UNIVERSITY OF CALIFORNIA UCLA

Pls. see these sites for further info.

http://www.atmos.ucla.edu/tcd/ (TCD);

http://www.environnement.ens.fr/(CERES); http://e2c2.ipsl.jussieu.fr/ (E2C2)

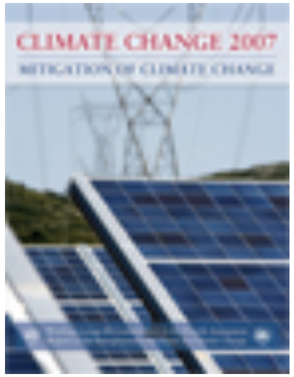
Motivation

- The IPCC process: Fourth Assessment Report (AR4)
- 3 working groups: various sources of uncertainties

  - Physical Science Basis

  - Impacts, Adaptation and Vulnerability

  - Mitigation of Climate Change



- Physical and socio-economic modeling

  - separate vs. coupled
- Ethics and policy issues

Outline

A. Climate change and other natural hazards

- global warming
- extreme events: atmosphere, ocean, solid earth
- which kind of economy do they impact?

B. Dynamic coupling of the climate and socio-economic systems

- endogenous business cycles (EnBCs) vs. "real" business cycles (RBCs)
- vulnerability paradox and nonlinear FDT
- data studies vs. model studies

C. Conclusions and bibliography

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Global warming and its socio-economic impacts

Temperatures rise:

- What about impacts?
- How to adapt?

The answer, my friend, is blowing in the wind, *i.e.*, it depends on the accuracy and reliability of the forecast …

Source : IPCC (2007), *AR4, WGI, SPM*

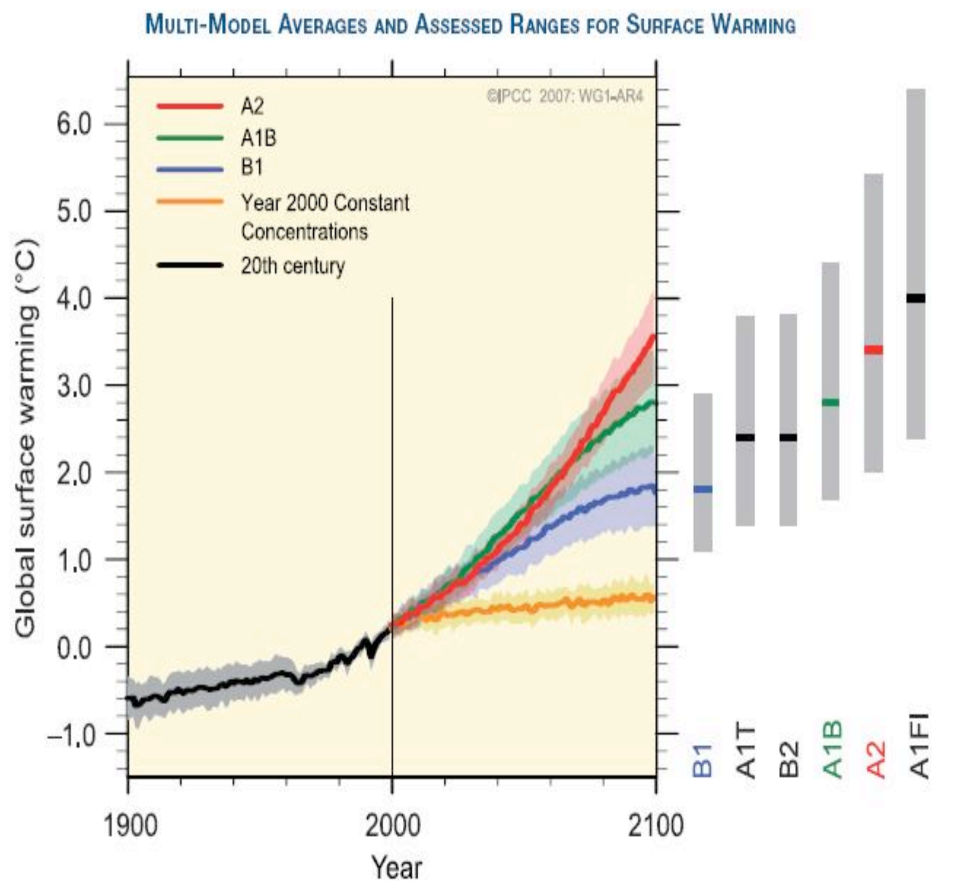
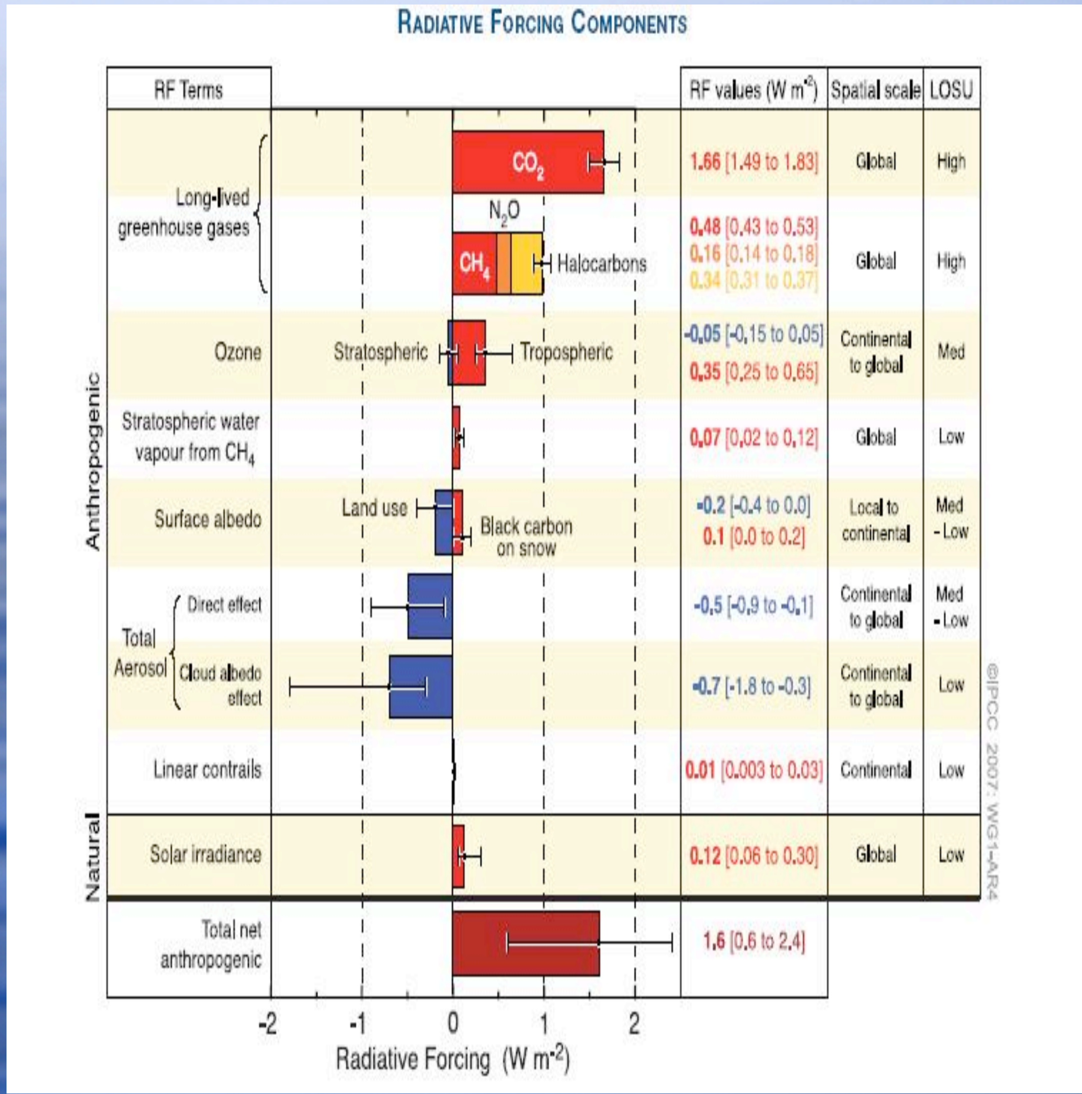


Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* ***likely*** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* ***likely*** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

GHGs rise

It's gotta do with us, at least a bit, ain't it?

But just how much?



IPCC (2007)

Unfortunately, things aren't all that easy!

What to do?

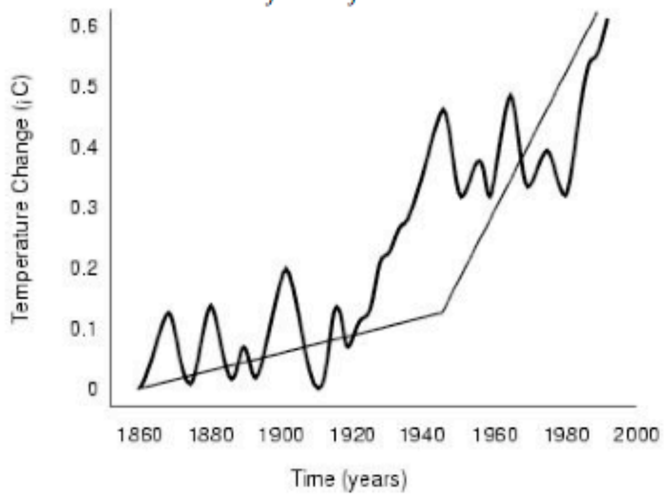
Try to achieve better interpretation of, and agreement between, models …

Ghil, M., 2002: Natural climate variability, in *Encyclopedia of Global Environmental Change*, T. Munn (Ed.), Vol. 1, Wiley

Natural variability introduces additional complexity into the anthropogenic climate change problem

The most common interpretation of observations and GCM simulations of climate change is still in terms of a scalar, linear Ordinary Differential Equation (ODE)

$$c\frac{dT}{dt} = -kT + Q \qquad \begin{array}{l} k = \sum k_i - \text{feedbacks (+ve and -ve)} \\ Q = \sum Q_j - \text{sources \& sinks} \\ Q_j = Q_j(t) \end{array}$$



Linear response to CO_2 vs. observed change in T

Hence, we need to consider instead a system of nonlinear Partial Differential Equations (PDEs), with parameters and multiplicative, as well as additive forcing (deterministic + stochastic)

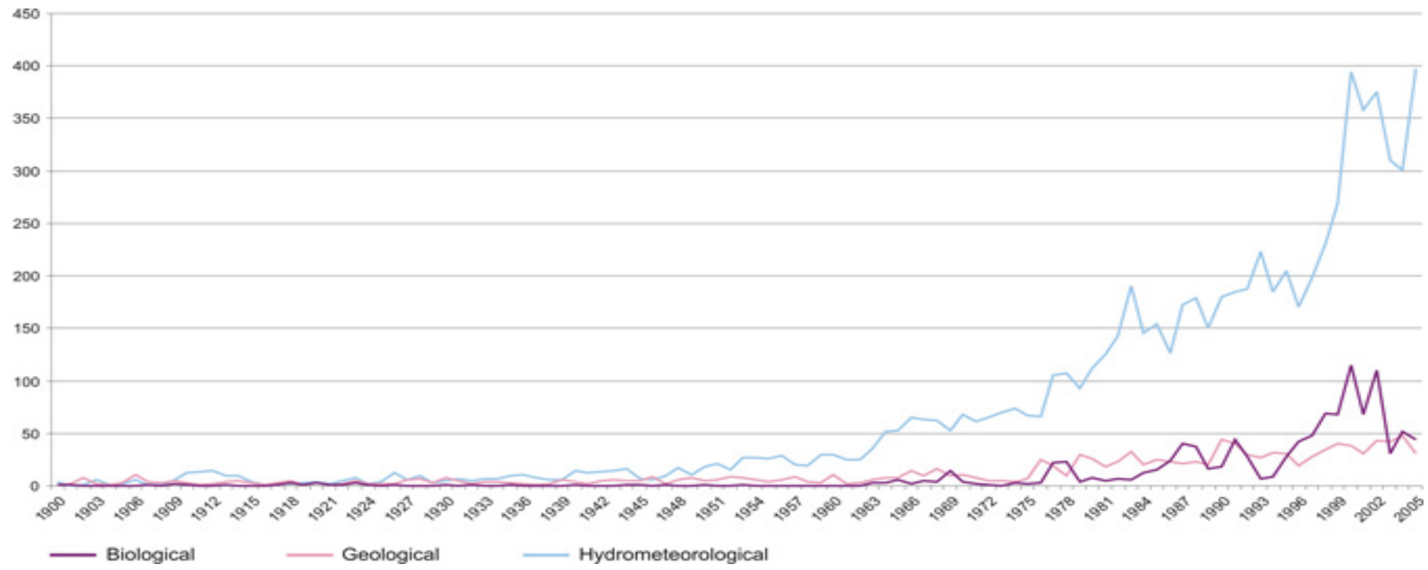
$$\frac{d\boldsymbol{X}}{dt} = \boldsymbol{N}(\boldsymbol{X}, t, \mu, \beta)$$

So what's it gonna be like, by 2100?

Table SPM.2. *Recent trends, assessment of human influence on the trend and projections for extreme weather events for which there is an observed late-20th century trend. {Tables 3.7, 3.8, 9.4; Sections 3.8, 5.5, 9.7, 11.2–11.9}*

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend[b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]	*Virtually certain*[d]
Warm spells/heat waves. Frequency increases over most land areas	*Likely*	*More likely than not*[f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*[f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[f,h]	*Likely*[i]

Natural Disasters



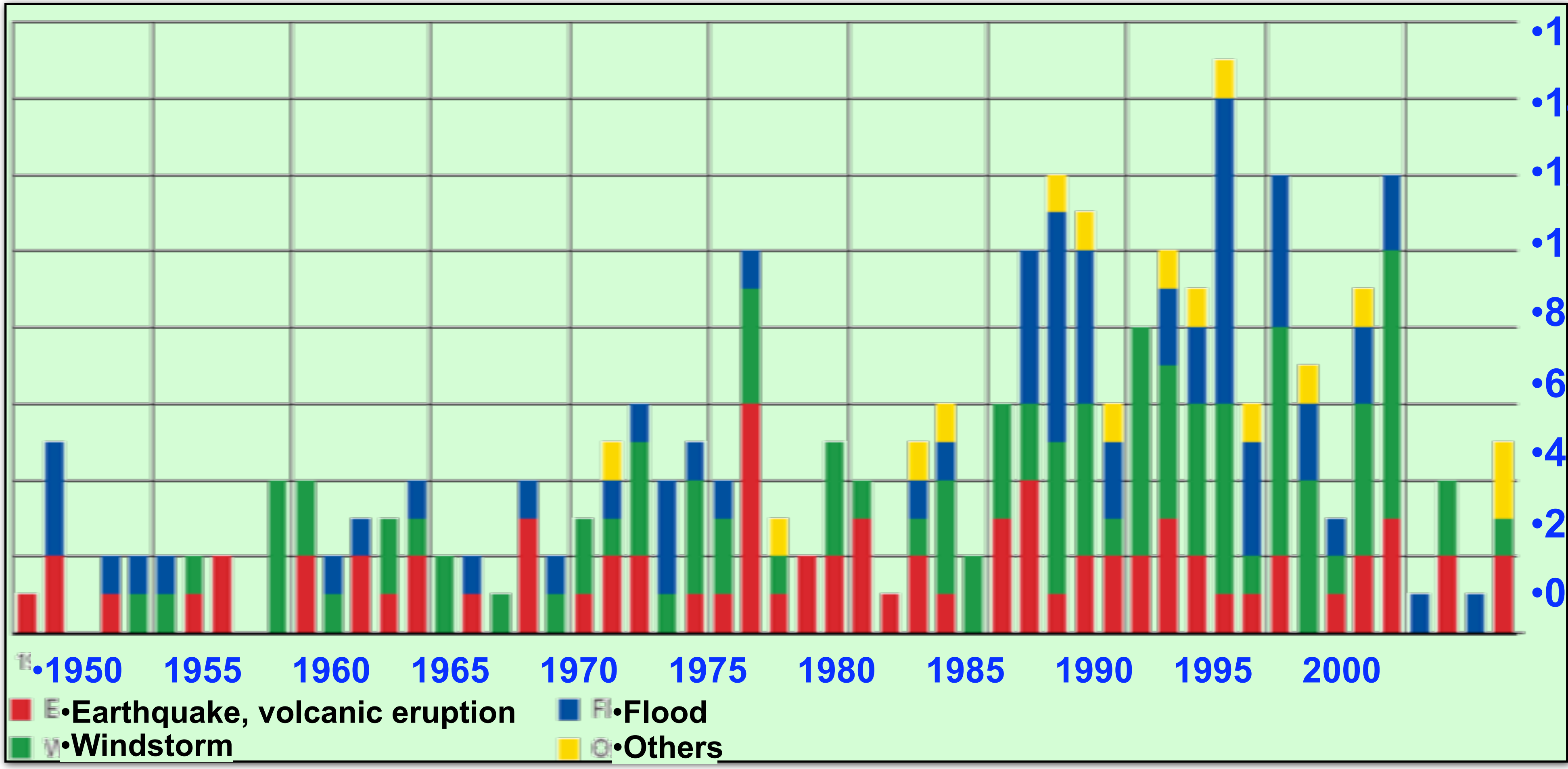
	1900-1909	1910-1919	1920-1929	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2005	Total
Hydrometeorological	28	72	56	72	120	232	463	776	1 498	2 034	2 135	7 486
Geological	40	28	33	37	52	60	88	124	232	325	233	1 252
Biological	5	7	10	3	4	2	37	64	170	361	420	1 083
Total	73	107	99	112	176	294	588	964	1 900	2 720	2 788	9 821

Number of natural disasters (1900–2005)

UN International Strategy for Disaster Reduction (ISDR)

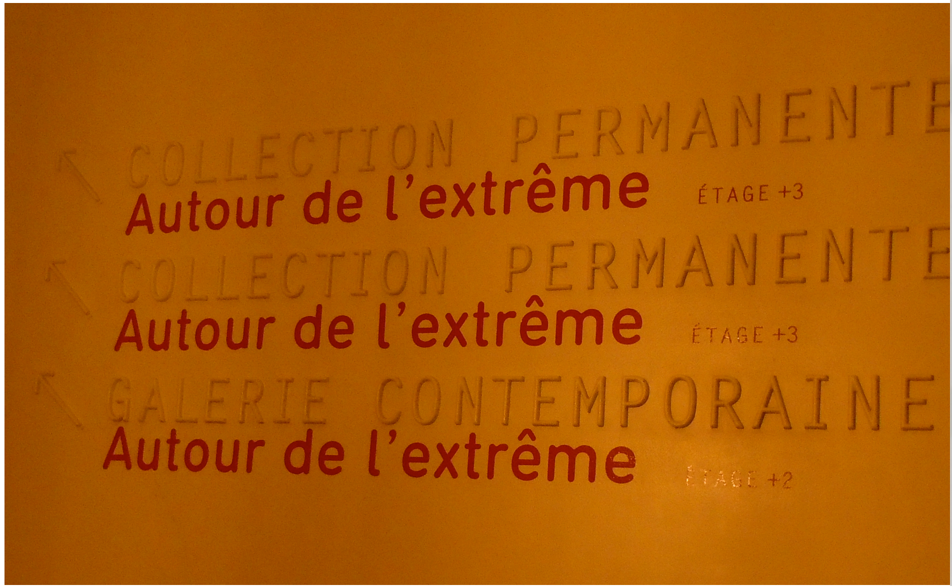
OFDA/CRED International Disasters Database (EM-DAT)

Great Natural Catastrophes 1950–2003



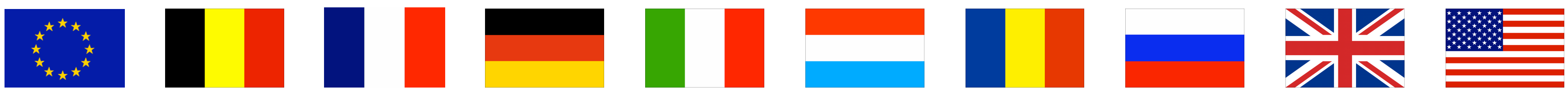
Number of major natural catastrophes, by year and type of event (from *Munich Re, Topics Geo 2003*)

A few fashionable extremes



Extreme Events:
Causes and Consequences (E2-C2)

- EC-funded project bringing together researchers in mathematics, physics, environmental and socio-economic sciences.
- €1.5M over 3.5 years (March 2005–August 2008).
- Coordinating institute: Ecole Normale Supérieure.
- 17 'partners' in 9 countries.
- 72 scientists + 17 postdocs/postgrads.
- PEB: M. Ghil (ENS, Paris, P.I.), S. Hallegatte (CIRED), B. Malamud (KCL, London), A. Soloviev (MITPAN, Moscow), P. Yiou (LSCE, Gif s/Yvette, Co-P.I.)



Belgium *France* *Germany* *Italy* *Luxembourg* *Romania* *Russia* *UK* *USA*

Extreme events: Review paper

Manuscript prepared for J. Name
with version 2.3 of the LaTeX class copernicus.cls.
Date: 3 December 2010

Extreme Events: Dynamics, Statistics and Prediction

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Nonlin. Processes Geophys., 108 pp., accepted with (very) minor revisions

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The need for models with endogenous dynamics

"The currently prevailing paradigm, namely that financial markets tend towards equilibrium, is both false and misleading; our current troubles can be largely attributed to the fact that the international financial system has been developed on the basis of that paradigm."

George Soros,
The New Paradigm for Financial Markets:
The Credit Crisis of 2008 and What It Means,
BBS, PublicAffairs, New York, 2008

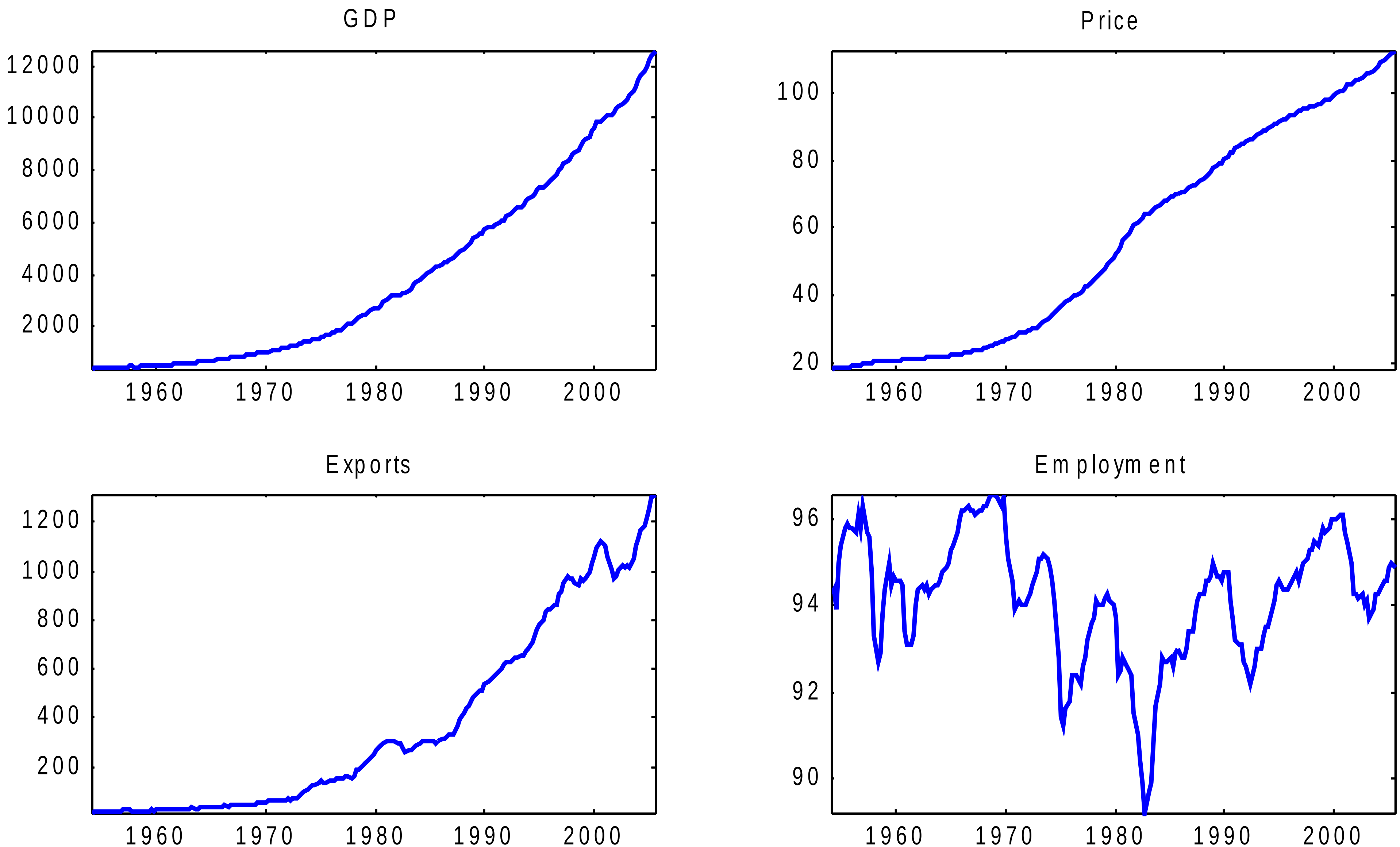
What is macroeconomics?

- **Economic subdisciplines**
  - macroeconomics: national or regional economy as a whole
  - microeconomics: individual households and firms
  - econometrics: methodology of both macro- & microeconomics
- **Macroeconomic variables and indicators**
  - gross domestic product (GDP) – produit intérieur brut (PIB)
  - production, demand
  - capital, profits (gross, net)
  - price level, wages
  - unemployment rate, number of employed workers
  - liquid assets (of banks, companies)
  - consumption, investment, stock

N. B. Some of these are in physical units, others are monetary;
some are observable (time series), some are not

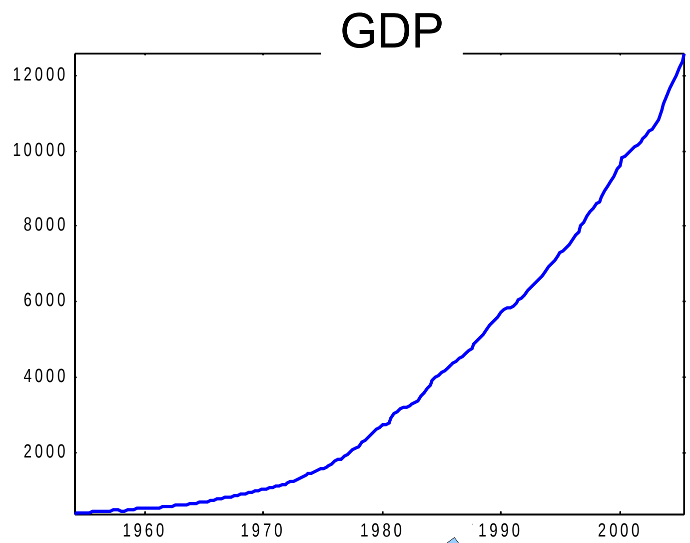
Macroeconomic time series

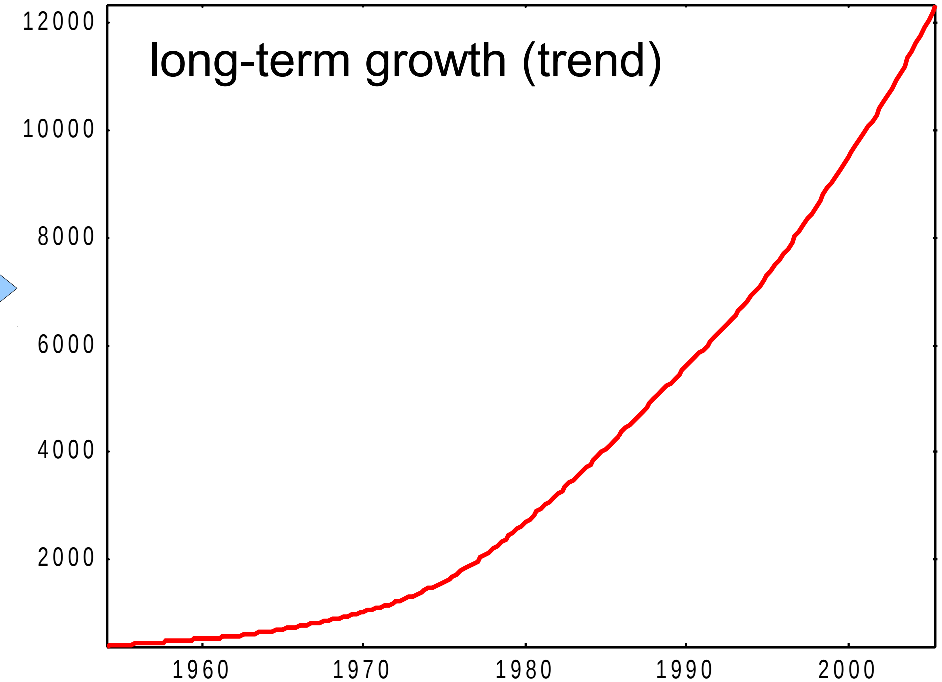
Macroeconomic indicators of the U.S.

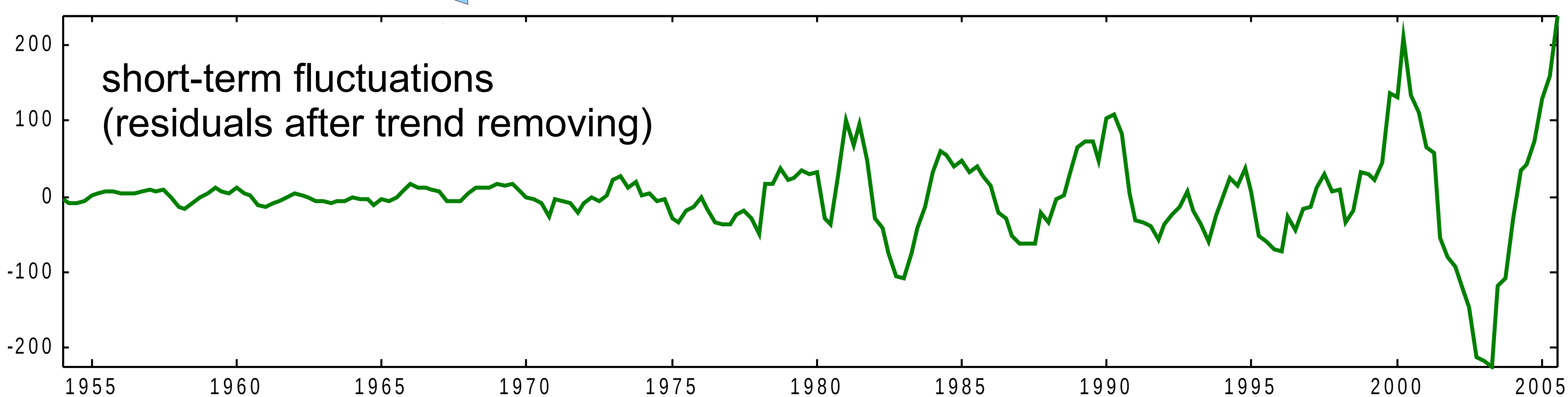


Macroeconomic modeling

Two main areas of research







A tale of two theories: the "real" cycle and the endogenous cycle theories

- ***In the real cycle theory, business cycles and economic fluctuations arise from exogenous "real" (i.e. not monetary) shocks, like changes in productivity or in energy prices, or from fiscal shocks.***

  Aside from these exogenous shocks, the economic system is stable:
  all markets are at equilibrium, and there is no involuntary unemployment.
  Deviations from equilibrium are damped more or less rapidly.
  Acting on the economy, therefore (e.g., recovery policies), is not useful.

- ***In endogenous business cycle (EBC) models, cyclical behavior originates from endogenous instabilities in the economic system.***

  Several instabilities have been proposed:
    - profitability-investment instability
    - delays in investment
    - income distribution

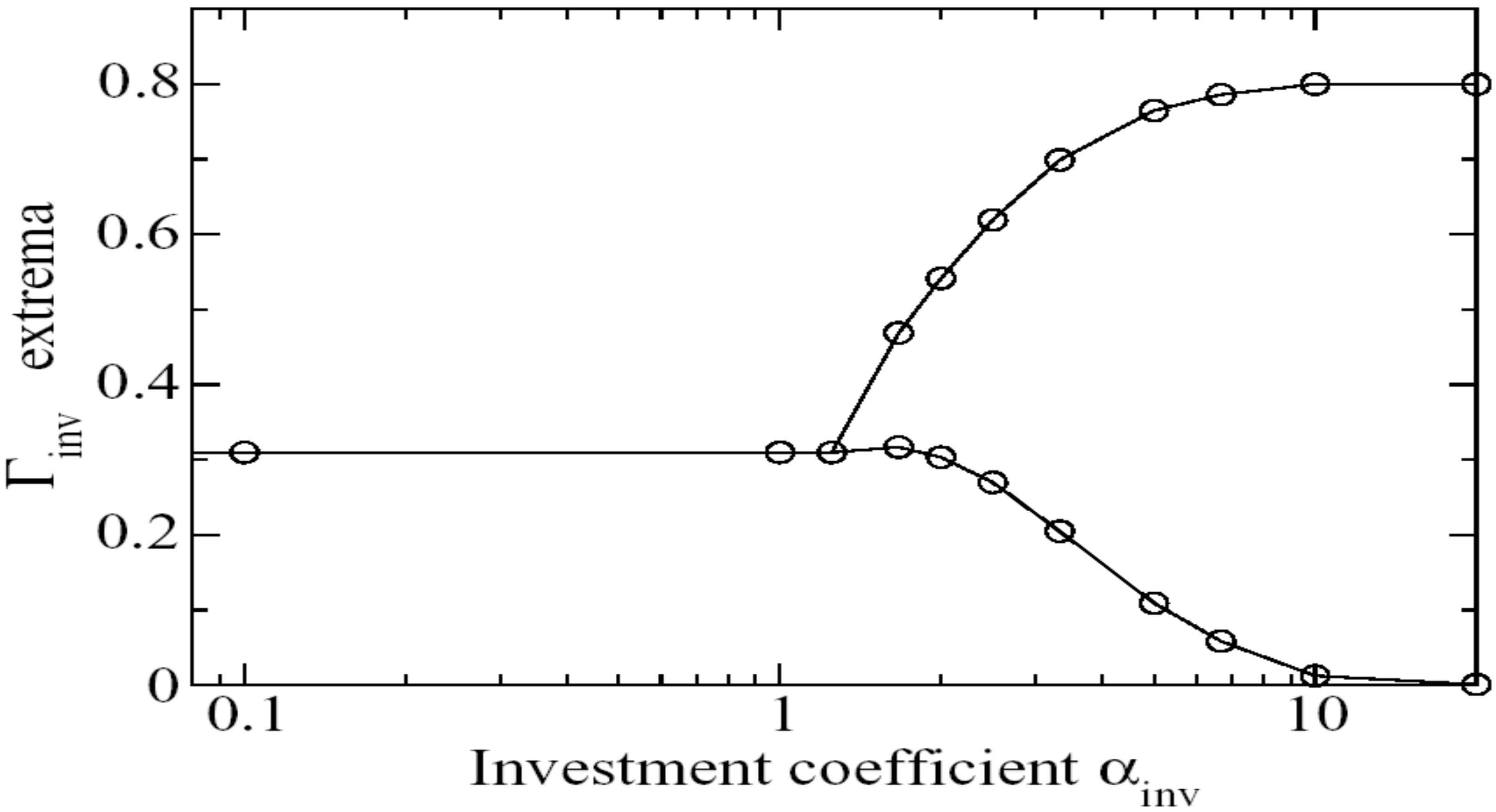
  Acting on the economy can, therefore, have positive effects,
  by stabilizing it or by shifting its mean state.

NEDyM (Non-equilibrium Dynamic Model)

- Represents an economy with one producer, one consumer, one goods that is used both to consume and invest.
- Based on the Solow (1956) model, in which all equilibrium constraints are replaced by dynamic relationships that involve adjustment delays.
- The NEDyM equilibrium is neo-classical and identical to that in the original Solow model. If the parameters are changing slowly, NEDyM has the same trajectories as the Solow model.
- Because of market adjustment delays, NEDyM model dynamics exhibits Keynesian features, with transient trajectory segments, in response to shocks.
- NEDyM possesses endogenous business cycles!

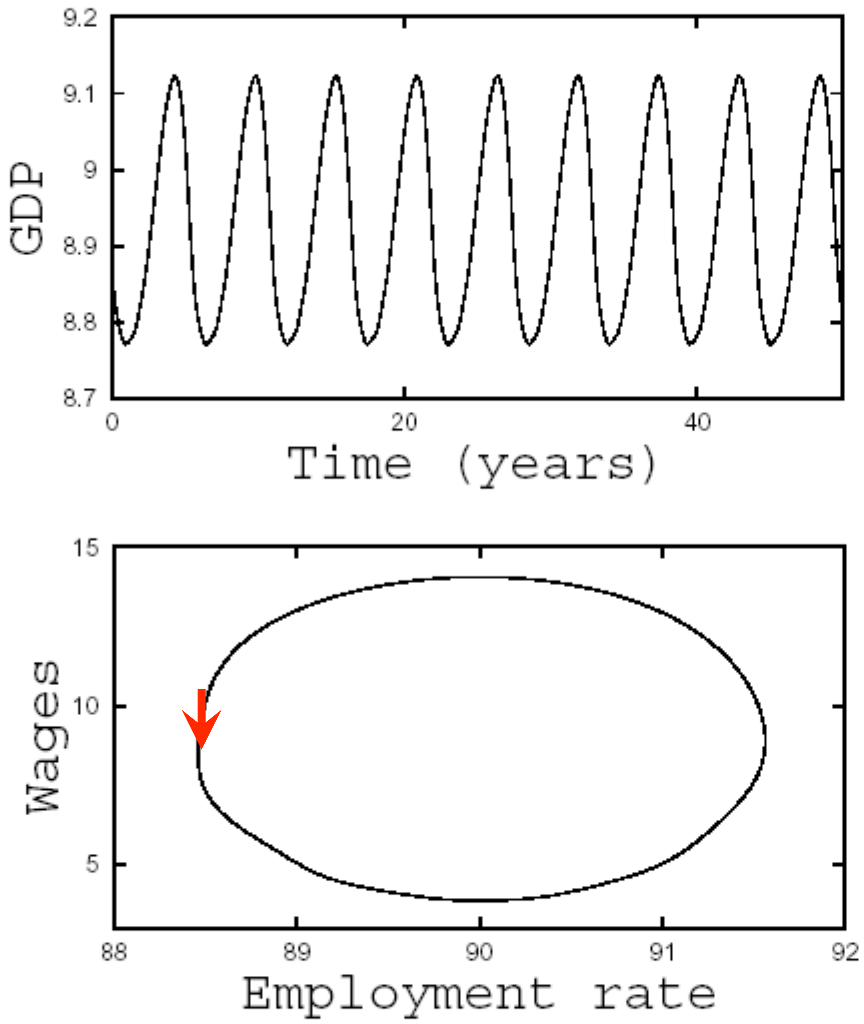
Hallegatte, Ghil, Dumas & Hourcade (*J. Econ. Behavior & Org.*, 2008)

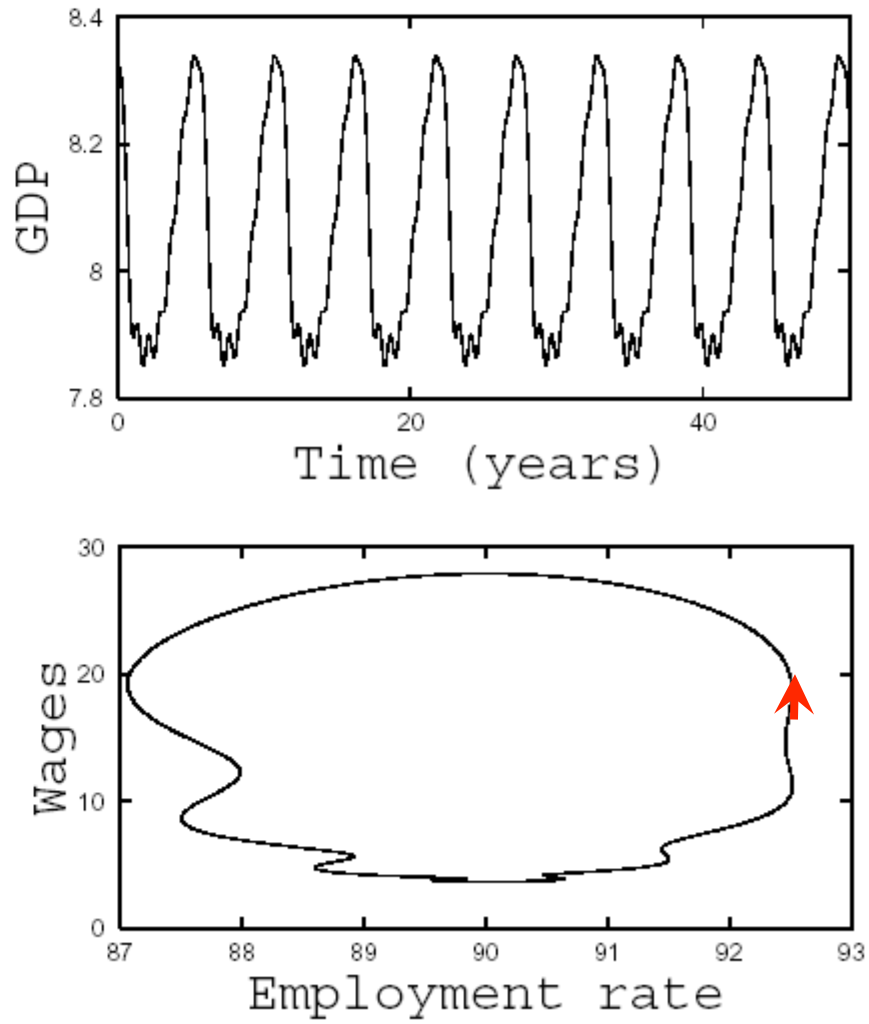
Hopf bifurcation (“tipping point”) from stable equilibrium to a limit cycle (“business cycle”)



α_{inv} = 1.7: purely periodic behavior (limit cycle)

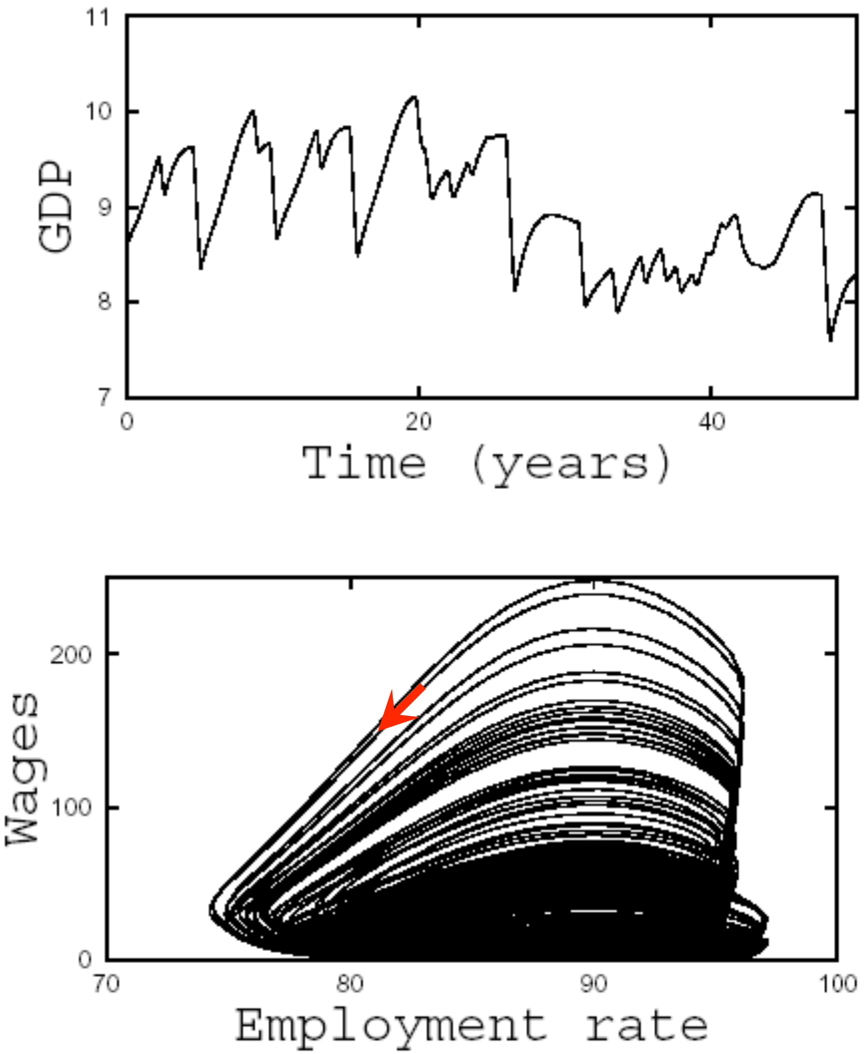
α_{inv} = 2.5: transition to chaos (irregular behavior)

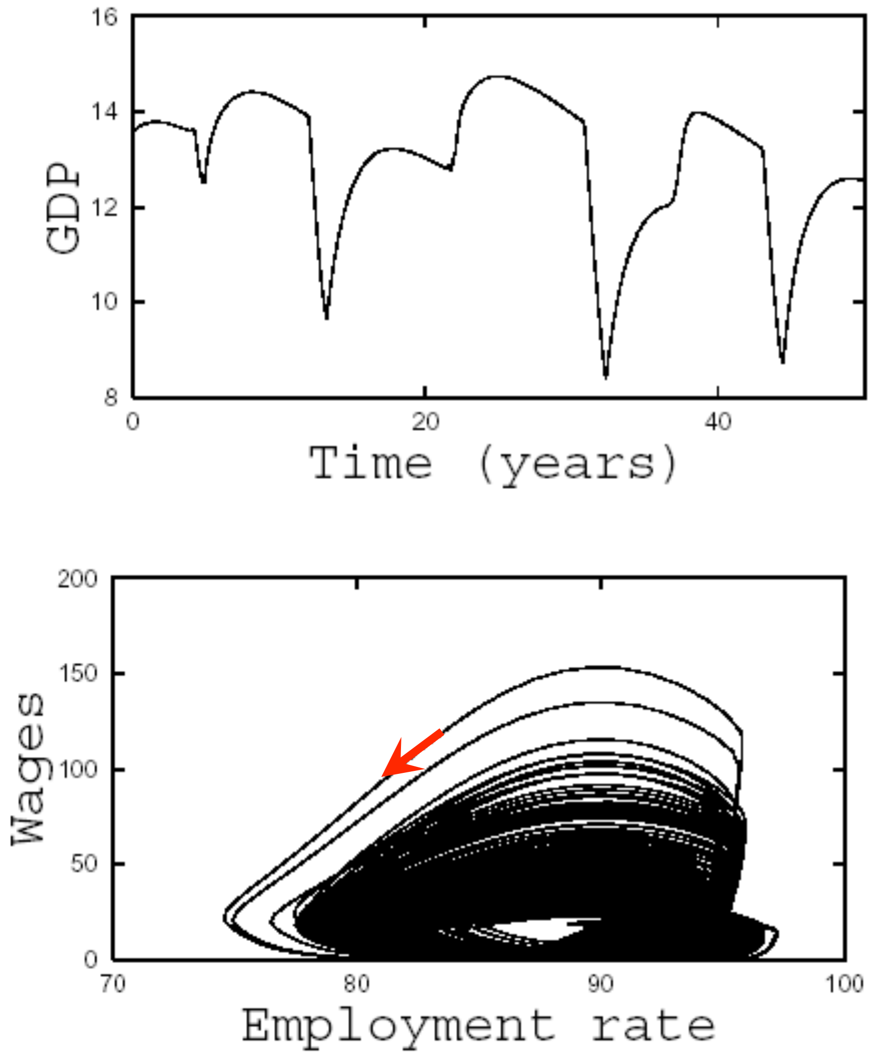




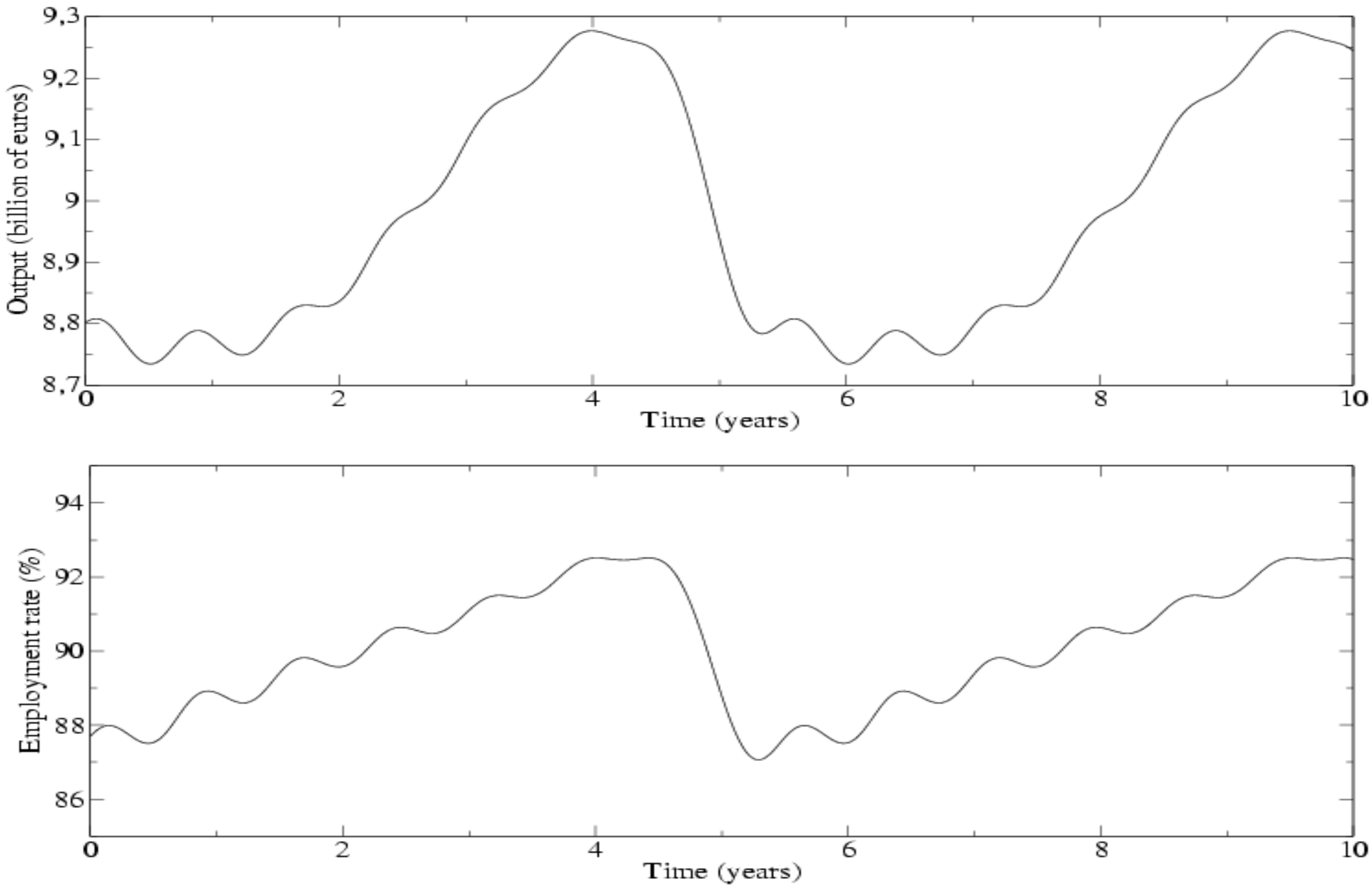
α_{inv} = 10: irregular orbit (kinky torus)

α_{inv} = 20: very asymmetric business cycle (relaxation oscillation)





Endogenous dynamics: an alternative explanation for business cycles



Endogenous business cycles (EnBCs) in NEDyM

- Business cycles originate from the profit–investment relationship
  (oscillations with a 5–6-year period) – Fukuyama (1989–92)?!

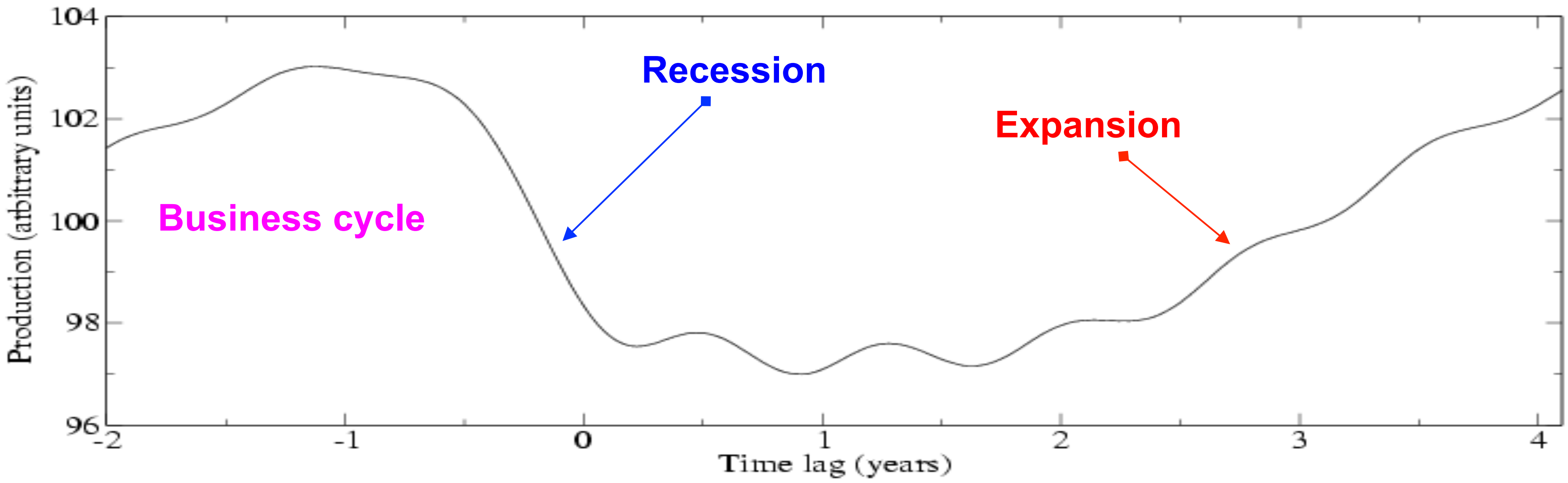
  higher profits => more investments => larger demand => higher profits

- Business cycles are limited in amplitude by three processes:
  - increase in labor costs when employment is high;
  - constraints in production and the consequent inflation in goods prices when demand increases too rapidly;
  - financial constraints on investment.

- EnBC models need to be calibrated and validated
  - harder than for real business cycle models (RBCs):
    fast and slow processes =>
    need a better definition of the business cycles =>
    study of BEA & NBER data!

Catastrophes and the state of the economy – I

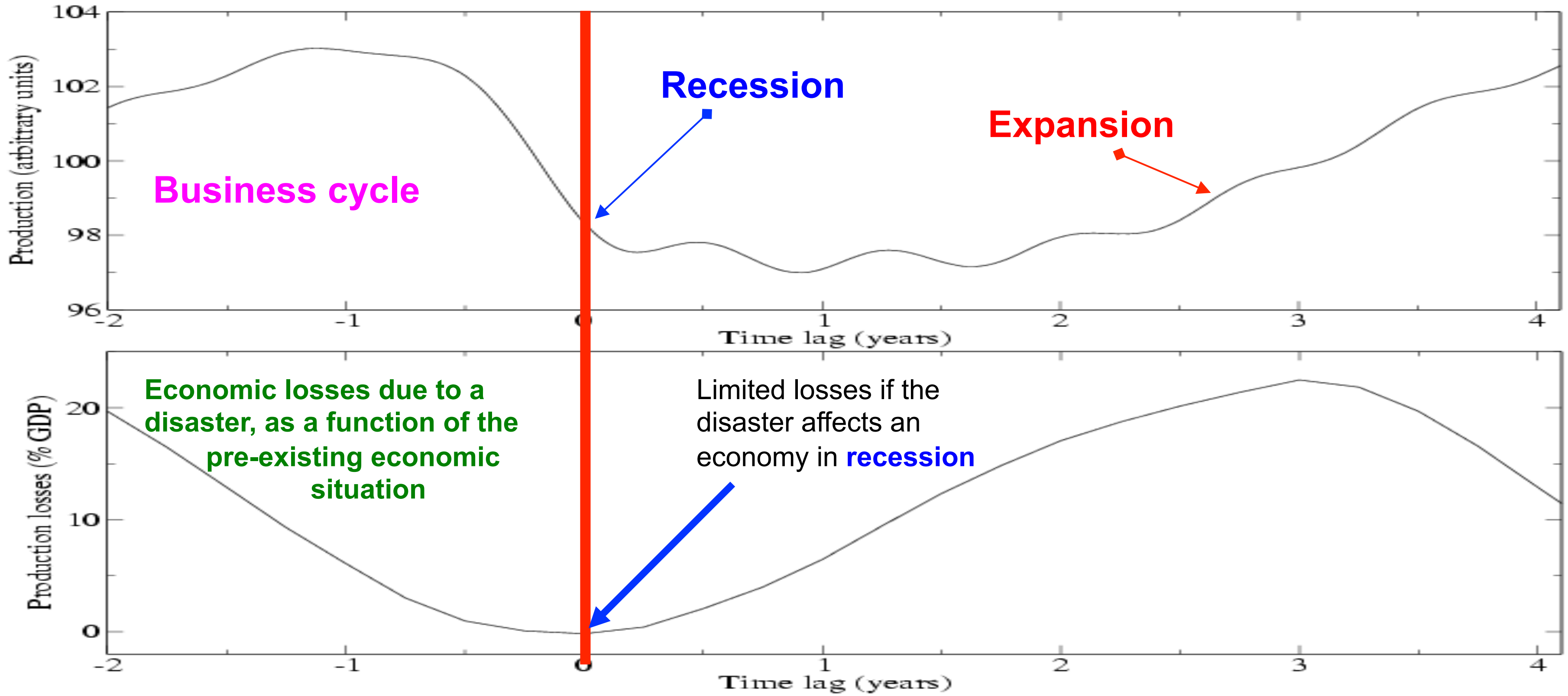
A vulnerability paradox: When does a disaster cause greater **long-term damage** to an economy, during its **expansion phase** or during a **recession**?



Hallegatte & Ghil, 2008, *Ecol. Econ.*, **68**, 582–592, doi:10.1016/j.ecolecon.2008.05.022

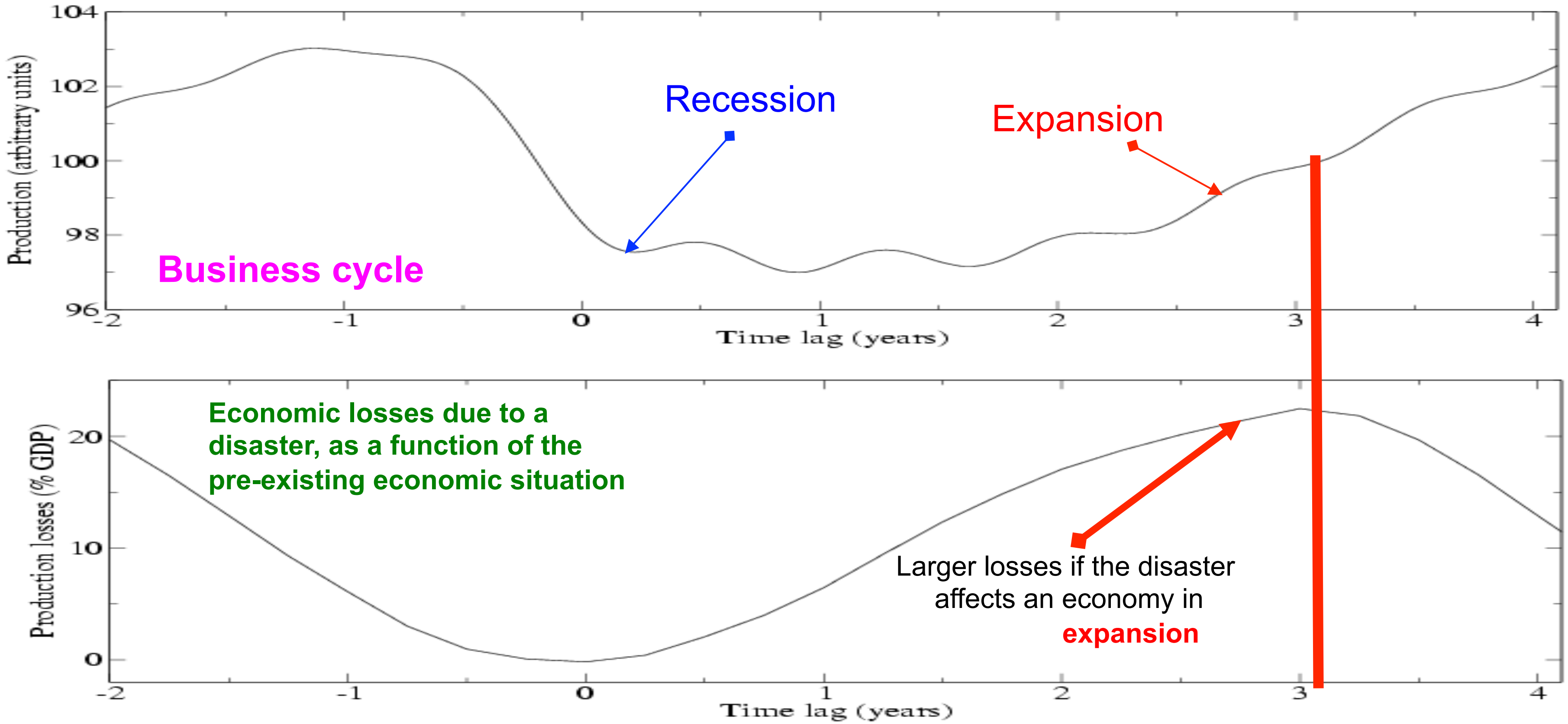
Catastrophes and the state of the economy – II

A vulnerability paradox:
A disaster that affects an economy during its **recession phase**…



Catastrophes and the state of the economy – III

… causes **fewer** long-term damages
than if it occurs during an **expansion!**



Hallegatte & Ghil, 2008, *Ecol. Econ.*, **68**, 582–592, doi:10.1016/j.ecolecon.2008.05.022

Stylized Facts of a Business Cycle – I

Need a more objective, quantitative description of the "typical business cycle." To do so we use two complementary approaches:

1. synchronization methods from dynamical systems ("chaos"); and
2. Advanced methods of time series analysis (SSA and M-SSA)

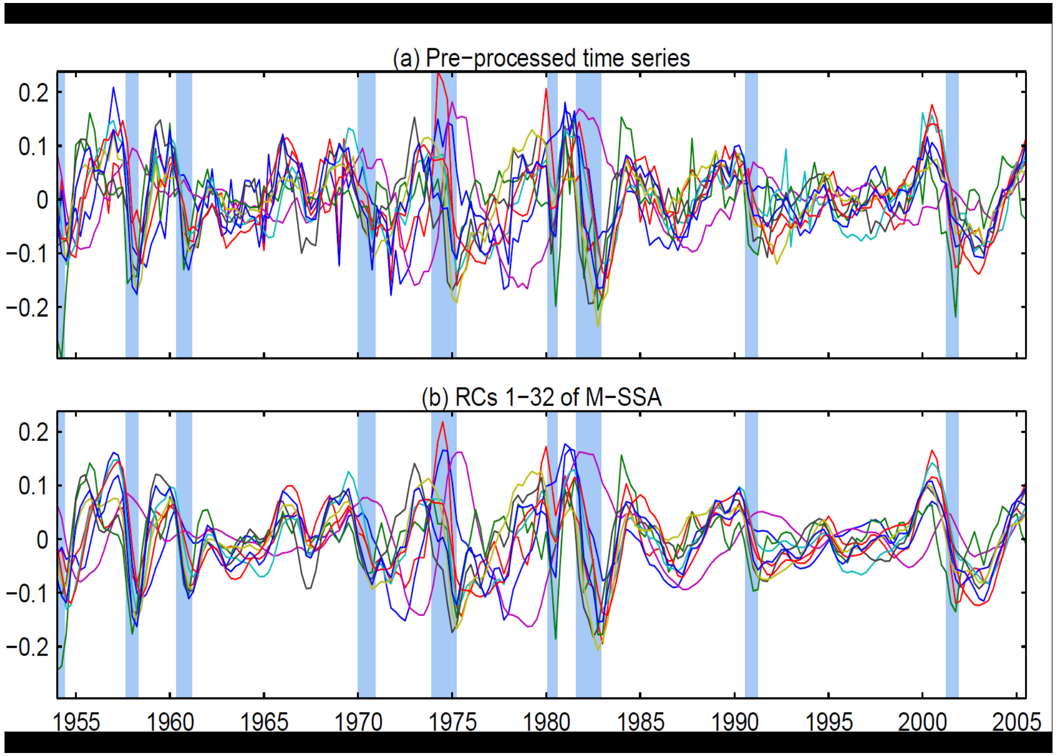
Bureau of Economic Analysis, www.bea.gov; 1947–2005.

9 variables:

gross domestic product (GDP), investment, consumption, employment rate (in %), price, total wage, imports, exports, and change in private inventories.

Groth, Ghil, Hallegatte and Dumas, submitted

Raw data, detrended and standardized



9-channel SSA ($D = 9$, $M = 24$ quarters)

Adaptive filtering, via multichannel singular-spectrum analysis (M-SSA);
vertical shaded bars are NBER-defined recessions

Singular Spectrum Analysis (SSA)

Spatial EOFs

x -- *space*

$$\phi(x,t) = \sum a_k(t) e_k(x)$$

$$C_\phi(x,y) = E\phi(x,\omega)\phi(y,\omega) = \frac{1}{T}\int_o^T \phi(x,t)\phi(y,t)\,dt$$

$$C_\phi e_k(x) = \lambda_k e_k(x)$$

Colebrook (1978); *Weare & Nasstrom* (1982);
Broomhead & King (1986: BK); *Fraedrich* (1986)

BK+VG: Analogy between Mañe-Takens embedding and the Wiener-Khinchin theorem

SSA

s -- *lag*

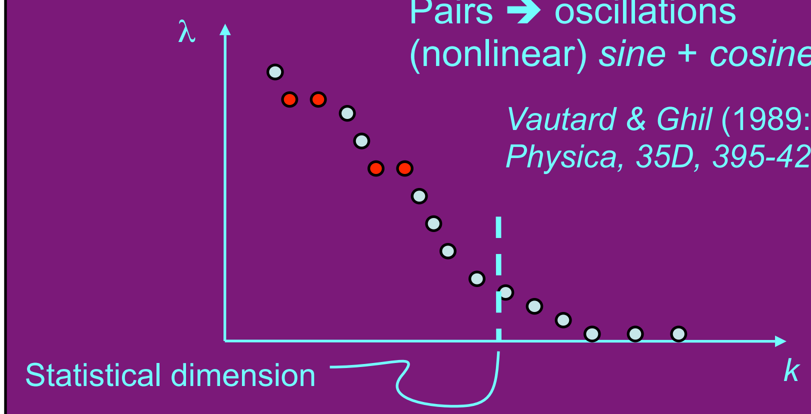
$$X(x+s) = \sum a_k(t) e_k(s)$$

$$C_X(s) = EX(t+s,\omega)\phi(s,\omega) = \frac{1}{T}\int_o^T X(t)X(t+s)\,dt$$

$$C_X e_k(s) = \lambda_k e_k(s)$$

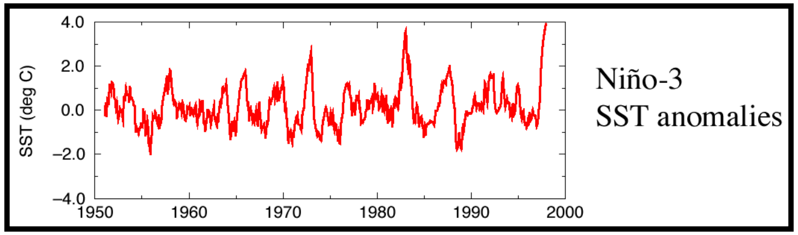
Pairs ➔ oscillations
(nonlinear) *sine* + *cosine* pair

Vautard & Ghil (1989: VG)
Physica, 35D, 395-424



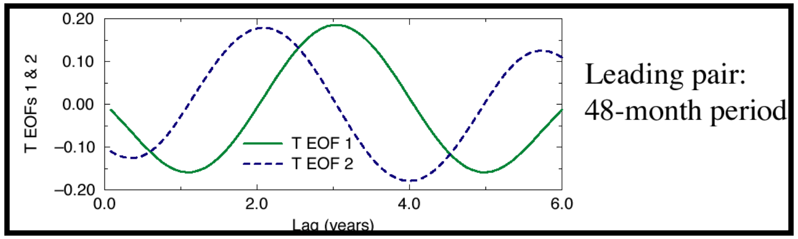
Singular Spectrum Analysis (SSA)

Time series

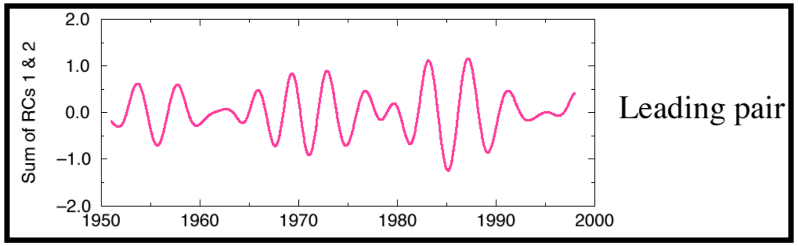


SSA decomposes (geophysical & other) time series into *Temporal EOFs* (T-EOFs) and *Temporal Principal Components* (T-PCs), based on the series' lag-covariance matrix

T-EOFs



RCs



Selected parts of the series can be reconstructed, via *Reconstructed Components* (RCs)

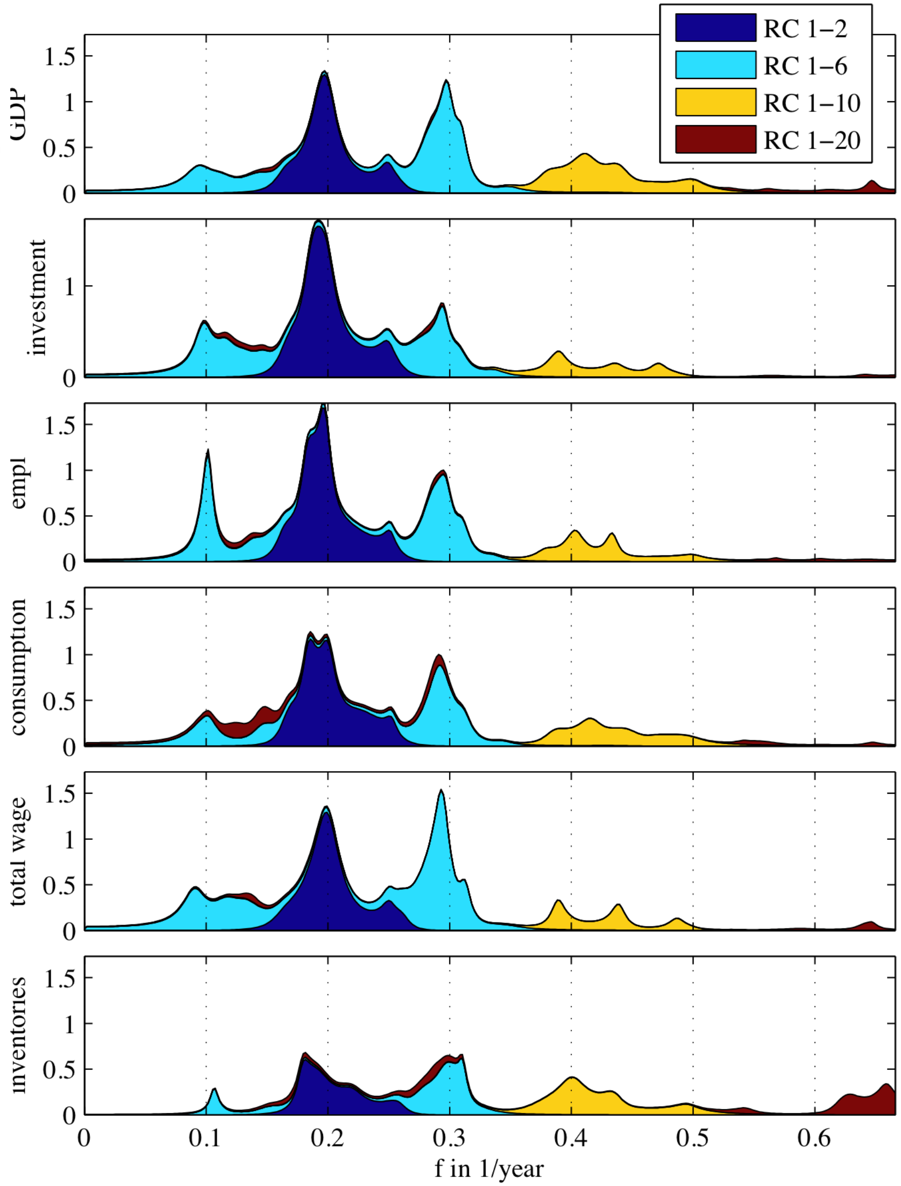
- SSA is good at isolating oscillatory behavior via paired eigenelements.
- SSA tends to lump signals that are longer-term than the window into
  - one or two trend components.

Selected References:

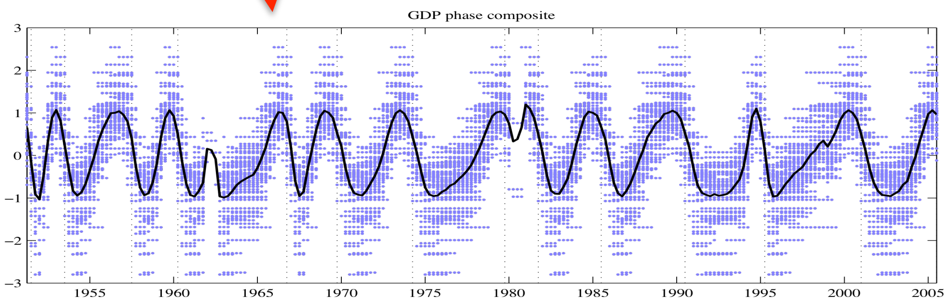
Vautard & Ghil (1989, *Physica* D);
Ghil *et al*. (2002, *Rev. Geophys.)*

Stylized Facts of a Business Cycle – II

Stack spectrum of reconstructed components (RCs)
2 distinct periodicities:
a) the dominant business cycle (5 years)
b) a 3-year cycle.



Spread of points around the "mean cycle": nonlinear fluctuation-dissipation theorem?



Dumas, Ghil, Groth & Hallegatte,
Math. Social Sci., to appear.

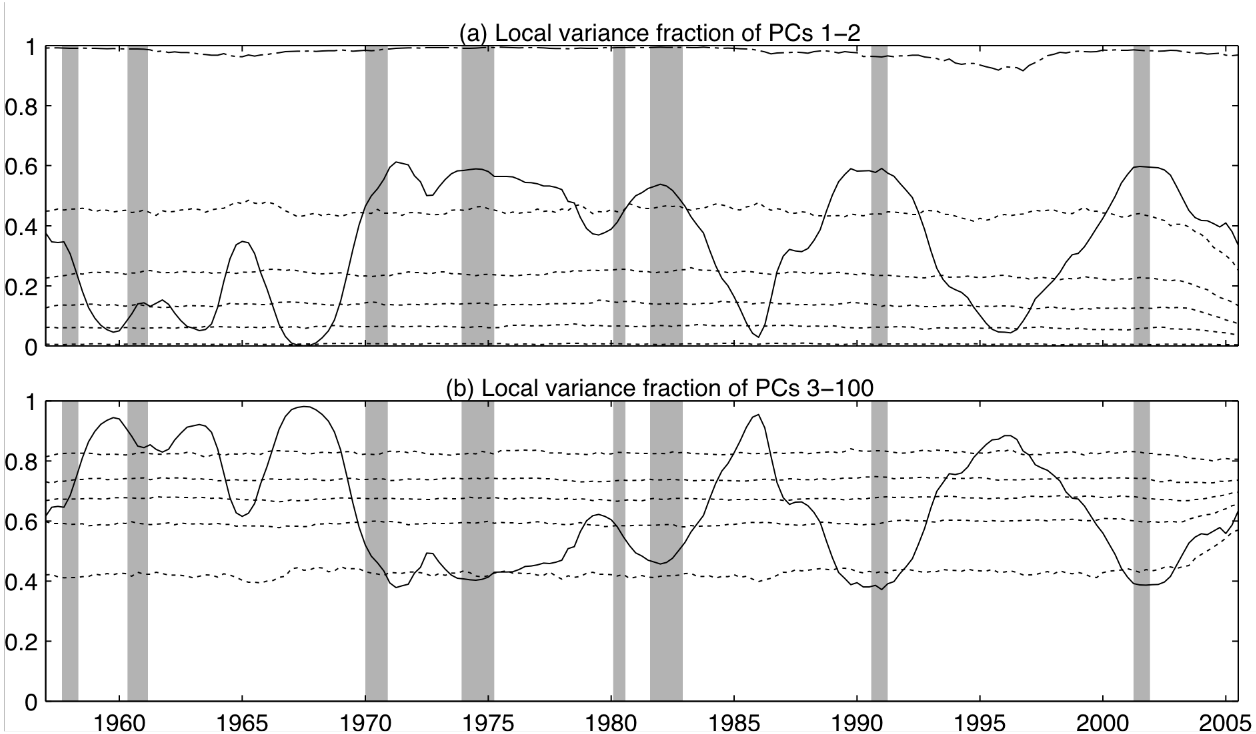
Stylized Facts of a Business Cycle – III

Consider the local variance fraction $V_{\mathcal{K}}(t)$ with $D = 9$, $M = 100$, and $A_k(t)$ the PCs:

$$V_{\mathcal{K}}(t) = \frac{\frac{\sum_{k \in \mathcal{K}} A_k(t)^2}{DM}}{\sum_{k=1} A_k(t)^2}$$

The "signal" fraction is largest during the recessions

The "noise" fraction is largest during the expansions



Vertical shaded bars are NBER-defined recessions

Groth, Ghil, Hallegatte and Dumas, submitted

Long-term averaged GDP losses due to natural disasters[*]

Calibration	Economic dynamics	Mean GDP losses (% of baseline GDP)
No investment flexibility $\alpha_{inv} = 0$	Stable equilibrium	0.15%
Low investment flexibility $\alpha_{inv} = 1.0$	Stable equilibrium	0.01%
High investment flexibility $\alpha_{inv} = 2.5$	Endogenous business cycle	0.12%

(*) calibrated on the disasters that impacted the EU in the last 30 years (Hallegatte, Hourcade & Dumas, 2007; Munich-Re, 2004)

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B. Dynamic coupling of the climate
and socio-economic systems

- endogenous business cycles (EnBCs) vs. "real" business cycles (RBCs)
- vulnerability paradox and nonlinear FDT
- data studies vs. model studies

C. Conclusions and bibliography

Conclusions and Outlook

1. **Non-equilibrium models** are alive and well: they exhibit fairly realistic, **endogenous business cycles (EBCs):** period = 5–6 years, seasaw shape, good phasing of indices.
1. They also display a **vulnerability paradox**:
   - extreme-event consequences depend on the state of the economy;
   - they are more severe during an expansion than a recession.
3. This paradox is supported by
   - consequences of **Izmit (Marmara) earthquake, 1999**;
   - reconstruction process after the **2004 and 2005 hurricane seasons in Florida**.
4. **U.S. economic data** (BEA, 1947–2005) tentatively support **a nonlinear fluctuation-dissipation theorem (FDT)** à la Ruelle.
5. Need **a better, quantitative characterization of business cycles**: U.S. + Euro-data, synchronization and spectral methods (A. Groth, L. Sella, G. Vivaldo)
6. Need more detailed, regional and sectorial models: B. Coluzzi, M. G., S.H., and G. Weisbuch are using simplified, **Boolean models to study the economy as a network of businesses** (suppliers and clients, etc.).
7. **Unanticipated consequences** – check! **Further opportunities** – check & check!!

The **Environmental Research and Teaching Institute** (CERES-ERTI) is organizing a two-day workshop at the **Ecole Normale Supériere** (ENS, Paris)

Workshop on
Coupled Climate - Economics Modelling and Data Analysis

Paris • 22 - 23 November 2012

Invited talks • Poster session • Working groups • Round table

The aim of this workshop is to advance and disseminate knowledge at the **interface of climate and economic modelling**, including a comparison with data in both areas. These topics already play an important role in the teaching and research activities of the CERES-ERTI at the ENS, and are expected to gain even more importance in the context of the *Institute of the Environment* within the new research university *Paris-Science-et-Lettres* (PSL).

The workshop should bring together distinguished personalities in the fields of economics and climate, as well as Ph.D. students and young researchers working on or interested in one or both of these fields. In the modelling of economics and climate, multiscale stochastic dynamics, as well as the study of instabilities and robustness of the models and the system itself, play an increasing role. Researchers at the *Institut des Systèmes Complexes de Paris Île-de-France* (ISC-PIF) have shed new light on these approaches, and the workshop intends to combine the area-specific expertise at CERES-ERTI with the methodological expertise at ISC-PIF in bringing to bear complex-systems concepts and research tools to the study of coupling climate and economics.

Fluctuations in climate and economics have had great impact in recent years, thus explaining the increased interest in studying stochastic stability and statistics. The ability of these approaches to characterize the robustness of the coupled climate-economic system has to be confronted with numerical studies and real data. To do so is a further goal of this event.

Finally, the dynamics on networks, whether ordered (periodic chains, regular grids) or random (Erdös-Rényi, "small-world"), as well as multi-agent models are of great interest in the modelling of (i) interactions between micro- and macroeconomics; and (ii) interactions between phenomena at the local, regional and global scale in atmospheric, oceanic and climate dynamics.

Invited speakers

Stefano Battiston (ETHZ) *Financial networks and systemic risk*
Marc Bocquet (ENPC) *Data assimilation in climate and economics*
Erik Chavez (Imperial College) *Modelling of climate change impacts*
Patrice Dumas (CIRED) *Non-equilibrium dynamic model and impacts*
Johannes Emmerling (FEEM) *Geoengineering and uncertainty*
Michael Ghil (ENS & UCLA) *Boolean delay equations and damage propagation on networks*
Andreas Groth (ENS) *Singular spectrum analysis and synchronization*
Stephane Hallegatte (CIRED & World Bank) *Endogenous business cycle models*
Klaus Hasselmann (MPI for Meteorology) *Climate change and the financial crisis*
Jürgen Kurths (PIK) *Network of networks*
Olivier Talagrand (ENS) *Data assimilation: basics and meteorological aspects*
Pietro Terna (University of Torino) *Agent-based models for exploring economic complexity*
Bert de Vries (University of Utrecht) *Integrated Assessment Modelling*

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INSTITUT DES SYSTEMES COMPLEXES
ISC
PARIS ÎLEDEFRANCE

R2DS Ile de France

Supported by grants from the
- *Réseau de Recherche sur le Développement Soutenable (R2DS), Île-de-France*
- *Domaine d'Intérêt Majeur « PROBLÉMATIQUES TRANSVERSALES AUX SYSTÈMES COMPLEXES » Institut des Systèmes Complexes de Paris Île-de-France (ISC-PIF)*

Local organizers: Michael Ghil, Andreas Groth, Gérard Weisbuch
CERES-ERTI • Ecole Normale Supérieure • 24 rue Lhomond • 75005 Paris
For further information and registration: http://environnement.ens.fr/ClimEcon2012

Commentary | Nigel Lawson

Back to Reality

Through folly or greed, many forgot that the price of a free economy is an ineradicable cycle of boom and bust

Financial institutions acted as if the economic cycle was a thing of the past, as if the longer the good times lasted the more they could be regarded as permanent

TIME October 13, 2008

Recurring nightmare *Raising cash after the crash of '29*

Lord Lawson was Britain's Chancellor of the Exchequer under Margaret Thatcher

The deeper motivations of economic modeling

"Really, Karl! Can't I mention the high price of kohlrabi without getting a manifesto?"

A few references

Charney, J., *et al*., 1979: *Carbon Dioxide and Climate: A Scientific Assesment.* National Academic Press, Washington, D.C.

Coluzzi, B., M. Ghil, S. Hallegatte, and G. Weisbuch, 2010: Boolean delay equations on networks in economics and the geosciences, *Intl. J. Bif. & Chaos*, **21**, 3511–3548.

Ghil, M., R. Benzi, and G. Parisi (Eds.), 1985: *Turbulence and Predictability in Geophysical Fluid Dynamics and Climate Dynamics*, North-Holland, 449 pp.

Ghil, M., *et al*., 2002: Advanced spectral methods for climatic time series, *Rev. Geophys*., **40**(1), pp. **3**.1–**3**.41, doi: 10.1029/2000RG000092.

Ghil, M., I. Zaliapin, and B. Coluzzi, 2008: Boolean delay equations: A simple way of looking at complex systems, *Physica D*, **237**, 2967–2986, doi: 10.1016/j.physd.2008.07.006.

Ghil, M., P. Yiou *et al*., 2011: Extreme events: Dynamics, statistics and prediction, *Nonlin. Processes Geophys.,* **18**, 295-350.

Groth, A., and M. Ghil, Multivariate singular spectrum analysis and the road to phase synchronization, *Phys. Rev. E*, **84**, 036206, doi:10.1103/PhysRevE.84.036206.

Groth, A., M. Ghil, S. Hallegatte and P. Dumas, 2012: Quantitative description of U.S. business cycles using multivariate singular spectral analysis, *AGU Monograph*, *sub judice*.

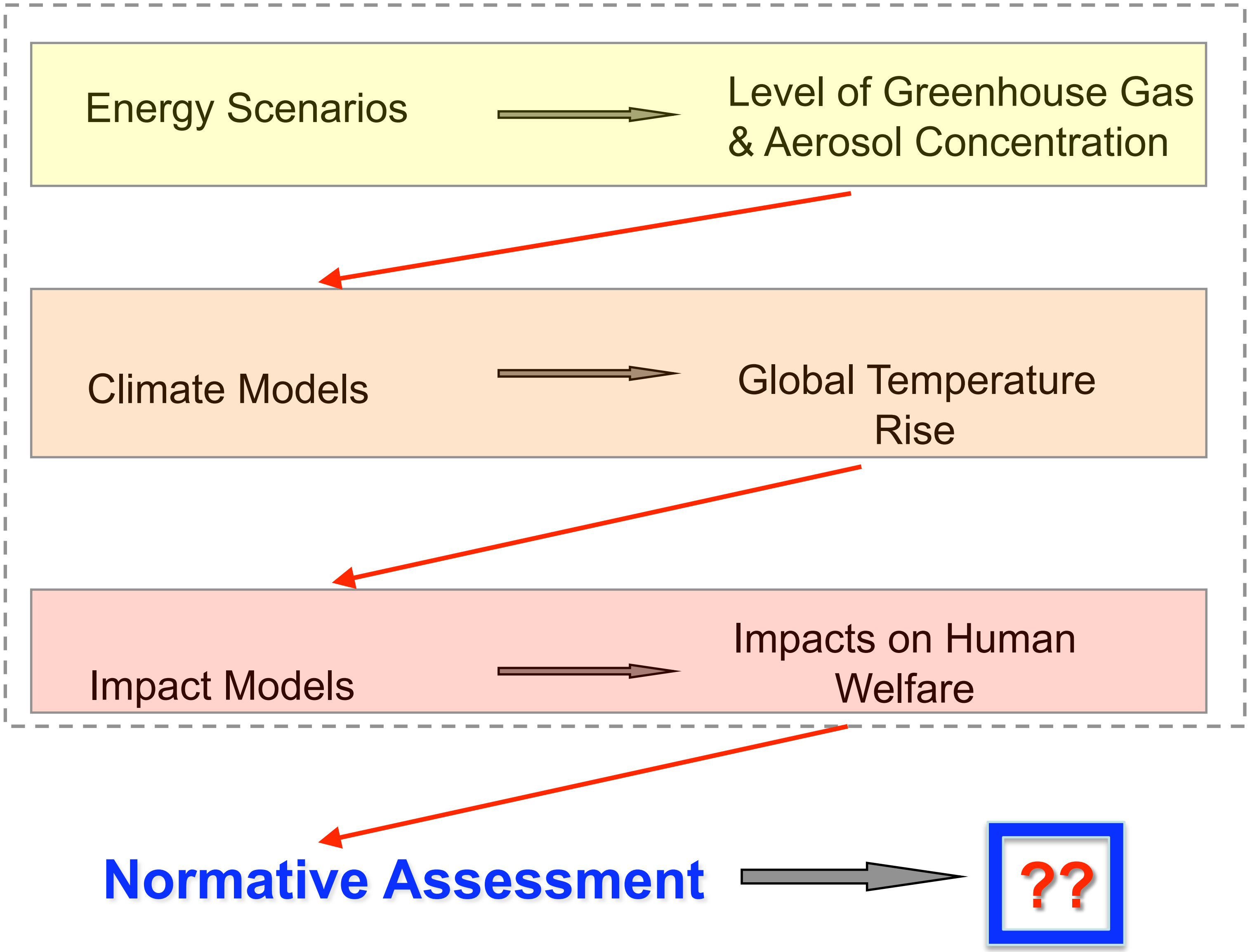
Hallegatte, S., M. Ghil, P. Dumas, and J.-C. Hourcade, 2008: Business cycles, bifurcations and chaos in a neo-classical model with investment dynamics, *J. Econ. Behavior & Organization,* **67**, 57–77, doi: 10.1016/j.jebo.2007.05.001.

Hallegatte, S., and M. Ghil, 2008: Natural disasters impacting a macroeconomic model with endogenous dynamics, *Ecological Economics*, **68**, 582–592.

Sella, L., G. Vivaldo, A. Groth, P. Dumas, and M. Ghil, 2012: Eurpean economic cycles and their synchronization: A survey of spectral properties, in preparation.

Reserve slides

Jumping to Conclusions?



Hillerbrand & Ghil, *Physica D*, **237** (2008): 2132–2138, doi:10.1016/j.physd.2008.02.015.

Ecole thématique du CNRS "Michael Ghil"

Rétroactions dans les systèmes environnementaux

Coordinateurs : Denis-Didier Rousseau et David Claessen

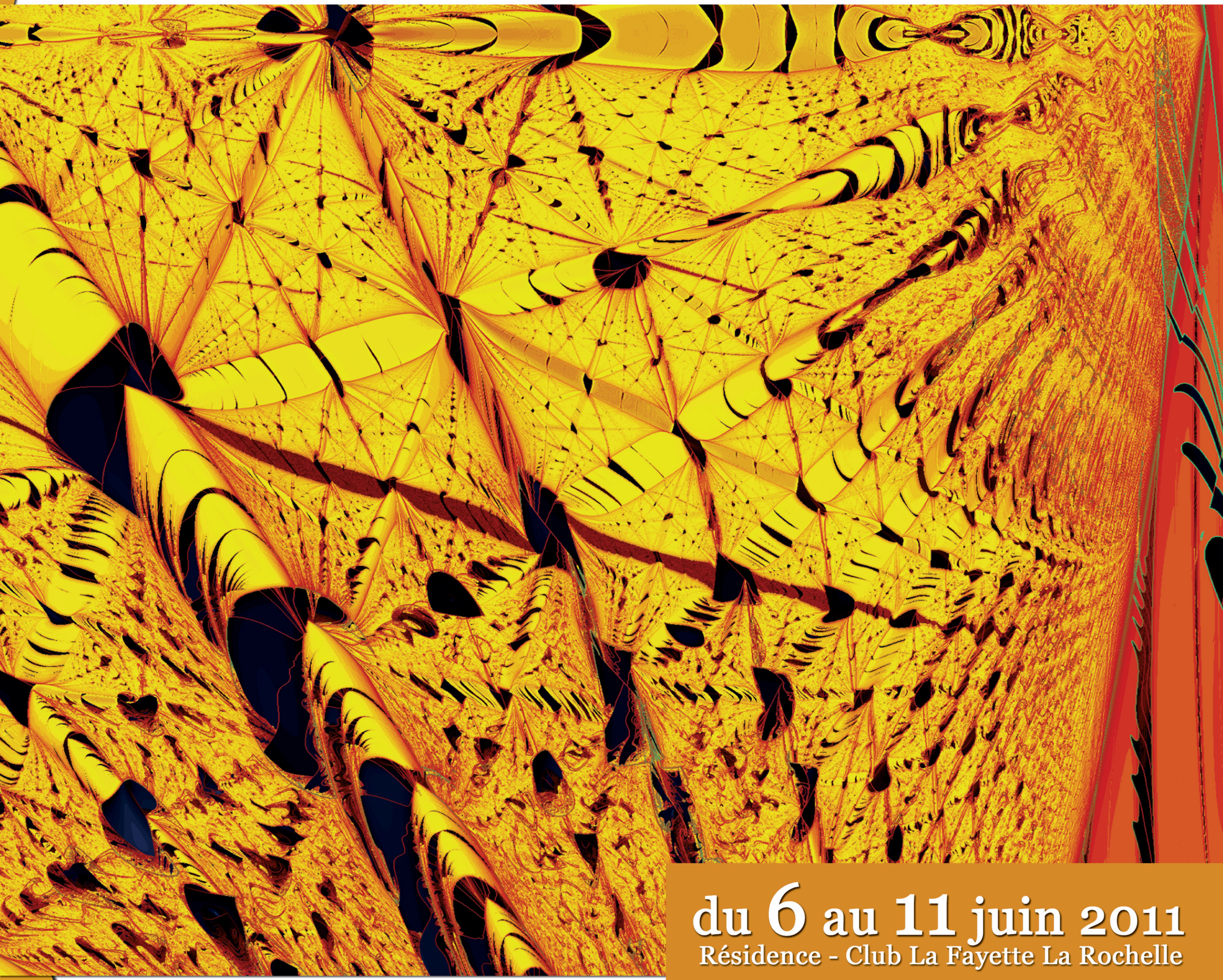


Illustration originale : Eric Simonnet & Mickaël Chekroun

du 6 au 11 juin 2011

Résidence - Club La Fayette La Rochelle

Climat

Systèmes dynamiques

Enveloppes fluides

Economie

Evénements extrêmes

Sols

Systèmes complexes

Océanographie

Contact et renseignements : Mme Ionela Tranca

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INSTITUT DES SYSTÈMES COMPLEXES ISC PARIS ÎLE DE FRANCE

cnrs INSU Observer & comprendre

Ecole thématique du CNRS « Michael Ghil »
(INSU, ENS, ISC-PIF)
« Rétroactions dans les Systèmes environnementaux »
Programme 2011

Mots clés : Climat, Enveloppes fluides, Economie, Notions fondamentales (Systèmes dynamiques et complexes), Evénements extrêmes

arrivée le dimanche 5 et départ le 12. juin

Lundi 6 juin matin
- Systèmes Dynamiques, Introduction (Michael Ghil)
- Introduction Climatologie (Hervé Le Treut)

Lundi 6 juin après-midi
- Systèmes Complexes, Introduction (Paul Bourgine)
- Groupe de travail I

Mardi 7 juin matin
- Introduction Macroéconomie (**)
- Systèmes Dynamiques, Applications au Climat et à l'Economie (Michael Ghil)

Mardi 7 juin après-midi
- Introduction Météorologie (Hervé Le Treut)
- Groupe de travail II

Mercredi 8 juin matin
- Systèmes Complexes, Applications au Climat et à l'Economie (Paul Bourgine)
- Introduction Evénements Extrêmes (Pascal Yiou)

Mercredi 8 juin après-midi
- Dynamique Climat - Sol (Fabio D'Andrea)
- Groupe de travail III

Jeudi 9 juin matin
- Principes Variationnels (Didier Paillard)
- Equations Booléennes à Effets de Retard (BDE) : Applications au Climat, à l'Economie et aux Tremblements de Terre (Michael Ghil)

Jeudi 9 juin après-midi
- Introduction Océanographie (Eric Guilyardi)
- Groupe de travail IV

Vendredi 10 juin matin
- Couplage Océan - Atmosphère (Eric Guilyardi)
- Localisation et Evénements Extrêmes (Pascal Yiou)

Vendredi 10 juin après-midi
- Climat - Economie (Roger Guesnerie)
- Posters et discussions

Samedi 11 juin matin
- Rendu des projets labo (5 à 6) (¼h présentation + ¼h discussion par groupe)

Samedi 11 juin après-midi
- Table ronde « Rétroactions dans les Systèmes Environnementaux »

*** à confirmer*

Vulnerability of Economic Systems to Climatic Impacts

Andreas Groth (Post-Doc)
Project coordinator Michael Ghil

Partner:
Centre d'Enseignement et de Recherches sur l'Environnement et la Société (CERES,ENS)
Centre International de Recherche sur l'Environnement et le Developpement (CIRED), Nogent-sur-Marne
Department of Economics, Turin, Italy

Réseau francilien de recherche sur le développement soutenable

Preceding CNRS-supported project "Climate change and coupled climate-economics modeling"

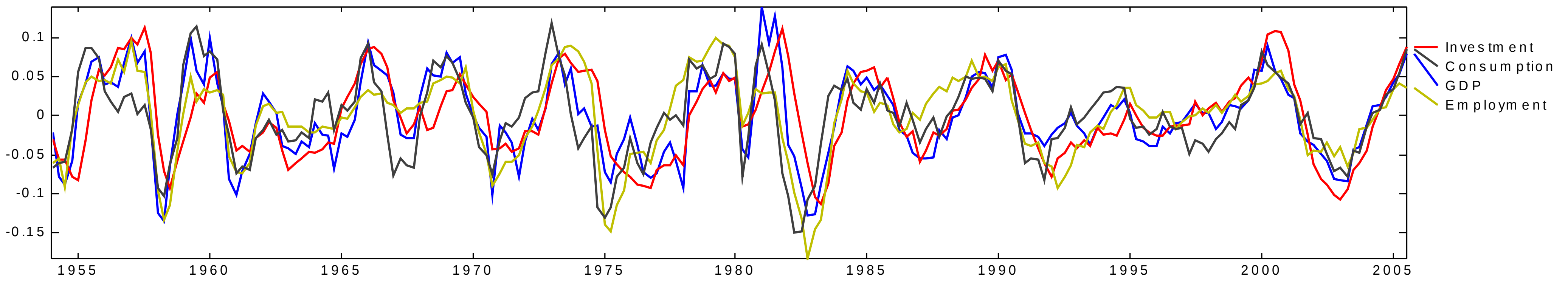
Macroeconomic modeling

- The project concentrates on the **short-term fluctuations**
- These fluctuations are referred to as „**business cycles**"
- The origin of these fluctuations is discussed in controversy
  - Real business cycle theory (fluctuations arise from exogenous shocks)
  - Endogenous business cycle theory (fluctuations are intrinsic = endogenous)

> Business cycles are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximating their own.

Burns, A. F. & Mitchell, W. C. Measuring Business Cycles, NBER, New York, 1946

Endogenous dynamics?!



Questions/tasks

Understand the origin of these short-term fluctuations (endogenous dynamics, pure exogenous shocks, mixture) and the response to exogenous impacts, including those of climatic hazards

- Extraction of dynamical behavior from short and noisy time series with **multivariate singular spectrum analysis**
- Data assimilation: Bring "simple" **non-equilibrium dynamical model** and complex data closer
- Generalization to a multiple-country scenario: Consider **synchronization** effects in a coupled network to study propagation of exogenous shocks
- Provide experimental information on the **vulnerability** of economic systems in order to help developing truly coupled climate-economy systems

Literature

Papers in preparation

- P. Dumas, M. Ghil, A. Groth & S. Hallegatte (2009), "*Dynamic coupling of the climate and macroeconomic systems*," Math. Social Sci., to appear.
- A. Groth, M. Ghil, S. Hallegatte & P. Dumas, "*Evidence for genuine periodicity and deterministic causes of U.S. business cycles",* submitted
- A. Groth & M. Ghil*, "Multivariate singular spectrum analysis and the road to phase synchronization,"* to be submitted
- A. Groth, P. Dumas, M. Ghil & S. Hallegatte, *"Impacts of natural disasters on a dynamic economy,"* in preparation
- L. Sella, G. Vivaldo, M. Ghil & A. Groth, *"Economic cycles and their synchronization: Spectral analysis of macroeconomic series from Italy, The Netherlands, and the UK,"* in preparation

The Curious Capitalist | Justin Fox

Riding the Waves

Believers in financial-market cycles can seem a little nutty. That doesn't mean they're wrong

- M. Armstrong: prediction based on π → jail
- R. Prechter: waves of social mood → "socionomics"
- C. Dow*: Dow theory of market waves, with W.P. Hamilton
- R.N. Elliott: "The Wave Principle" based on Fibonacci sequence

* *Wall Street Journal* co-founder, known for the Dow-Jones industrial index; E. D. Jones, a statistician.

TIME, November 30, 2009

Motivation

- The ***climate system*** is highly ***nonlinear and*** quite ***complex***.
- Its ***major components*** — the atmosphere, oceans, ice sheets — ***flow*** on many time and space scales.
- Its ***predictive understanding*** has to rely on the system's physical, chemical and biological modeling,

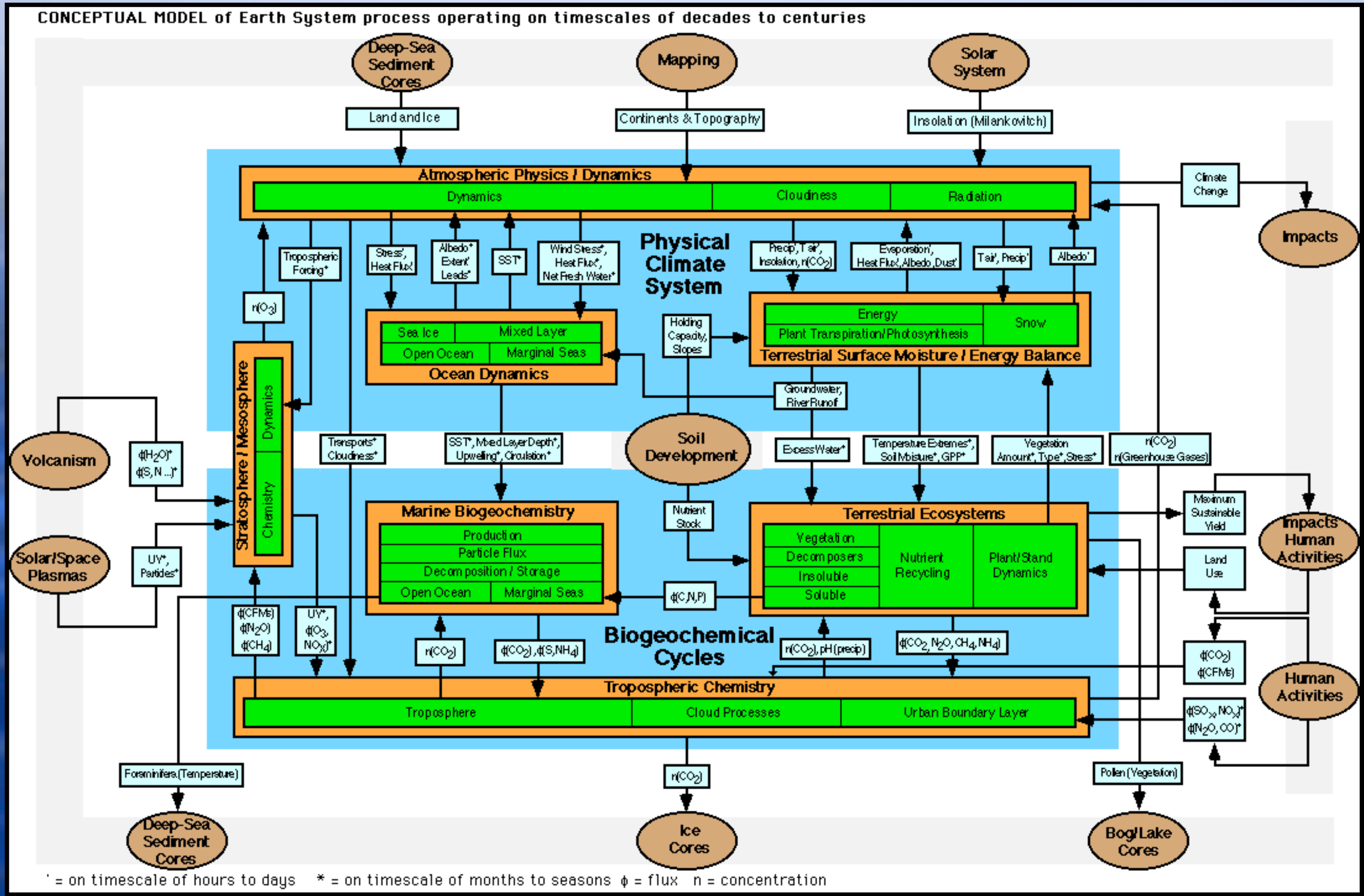
  but also on the mathematical analysis of the models

  thus obtained.
- The ***hierarchical modeling*** approach allows one to

  give proper weight to the understanding provided by the

  models vs. their realism, respectively.
- This approach facilitates the evaluation of ***forecasts (pognostications?)*** based on these models.
- Back-and-forth between ***"toy"*** (conceptual) and ***detailed*** ("realistic") ***models***, and between ***models*** and ***data***.

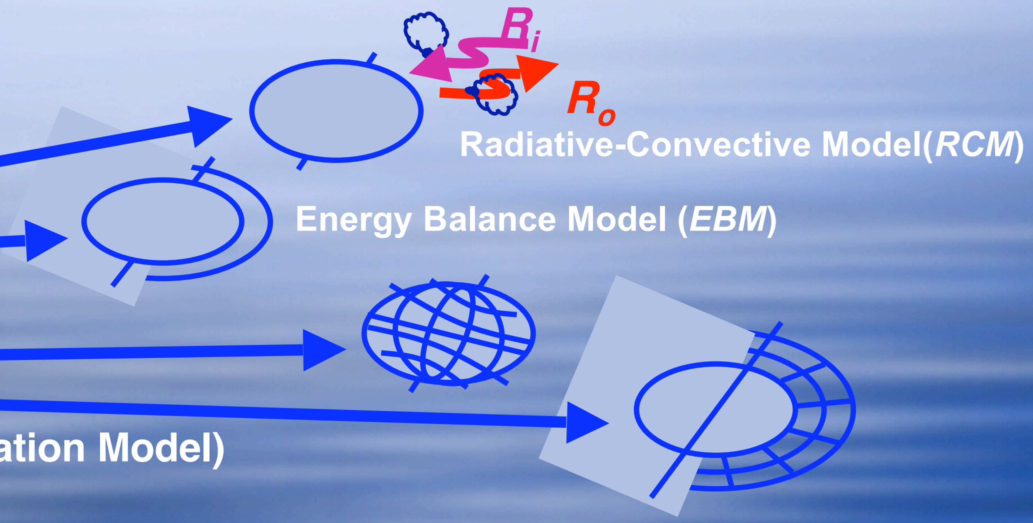
F. Bretherton's "horrendogram" of Earth System Science



Earth System Science Overview, *NASA Advisory Council*, 1986

Climate models (atmospheric & coupled) : A classification

- ***Temporal***
  - stationary, (quasi-)equilibrium
  - transient, climate variability
- ***Space***
  - 0-D (dimension 0)
  - 1-D
    - vertical
    - latitudinal
  - 2-D
    - horizontal
    - meridional plane
  - 3-D, GCMs (General Circulation Model)
    - horizontal
    - meridional plane
  - Simple and intermediate 2-D & 3-D models

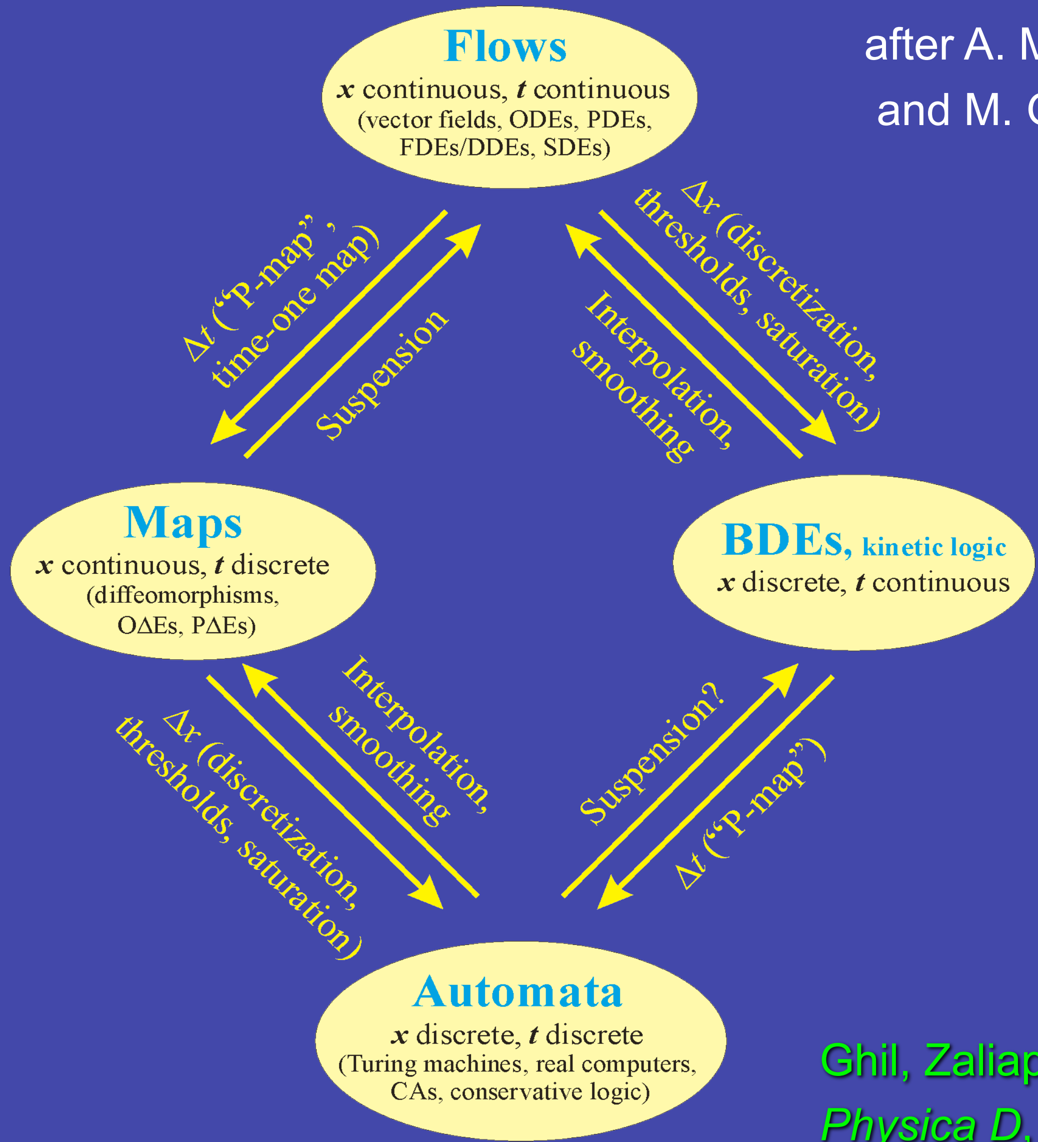


- ***Coupling***
  - Partial
    - unidirectional
    - asynchronous, hybrid
  - Full

Hierarchy: from the simplest to the most elaborate,
iterative comparison with the observational data

The place of BDEs in dynamical systems theory

after A. Mullhaupt (1984) and M. Ghil *et al*. (2008)



Ghil, Zaliapin & Coluzzi, 2008: *Physica D*, **237**, 2967–2986.

Climatic uncertainties & moral dilemmas

♥ … *keep today's climate for tomorrow?*

♥ *Feed the world today or…*

Davos, Feb. 2008, photos by *TIME Magazine*, 11 Feb. '08;
see also Hillerbrand & Ghil, *Physica D*, 2008, in press.

The Biofuel Myth

- Fine illustration of the moral dilemmas (*).
- Conclusion: "**festina lentae**," as the Romans used to say..

(*) Hillerbrand & Ghil, *Physica D*, 2008, doi:10.1016/j.physd.2008.02.015, available on line.

Some conclusions &/or questions

What do we know?

- It's getting warmer.
- We do contribute to it.
- So, we should act as best we know and can!

What do we know less well?

- How does the climate system really work?
- How does natural variability interact with anthropogenic forcing?

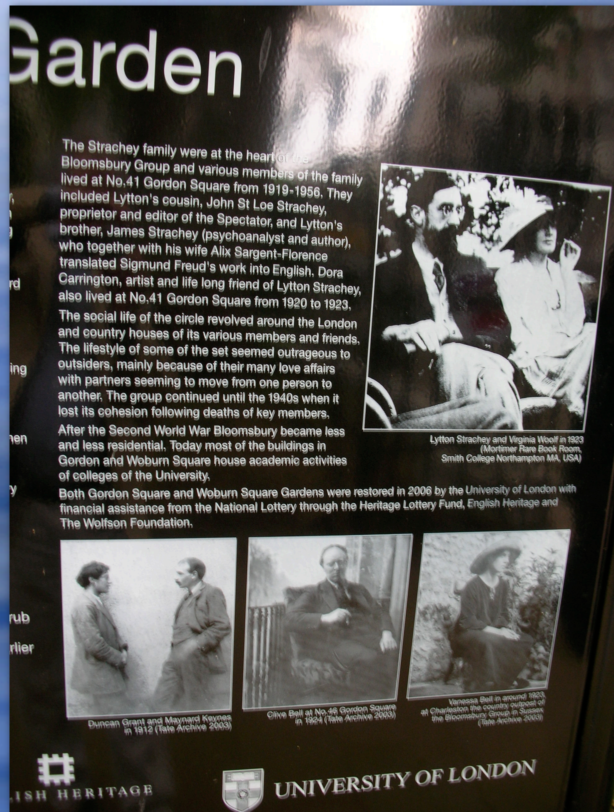
What to do?

- Better understand the system and its forcings.
- Better understand the effects on economy and society, and vice-versa.
- Explore the models', and system's, stochastic structural stability.

The blessings of interdisciplinarity

♥ *John M. Keynes's home in Bloomsbury*

♥ *Photo with lover Duncan Grant*



photos M.G., May 2008

Climate Change 1816–2008

M. Gillot, 2008,
Le Monde

T. Géricault, 1819,
Le Louvre