Hybrid Conference

Protection and Restoration of the Environment XVI

July 5-8, 2022, Kalamata, Greece

Stochastic modelling of hydrological extremes in a perpetually changing climate

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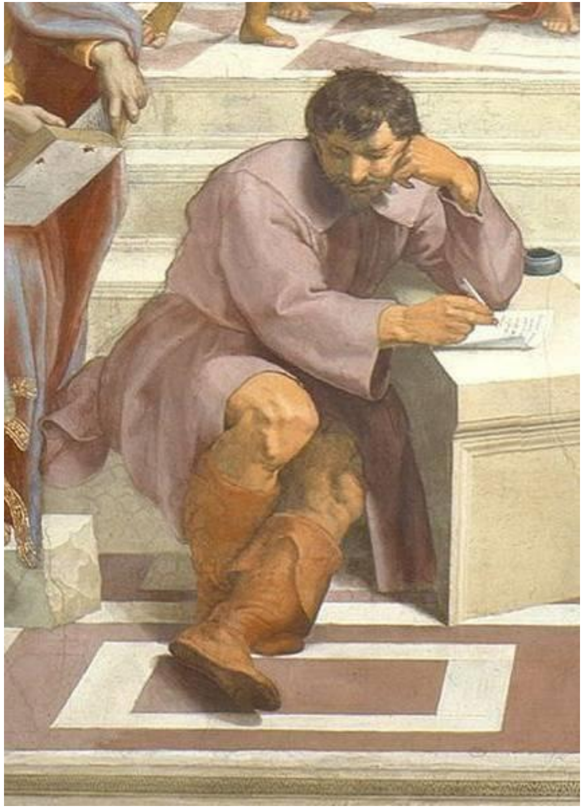
Available online: http://www.itia.ntua.gr/2217/

Apparently, our scientific community has recently discovered that things change…

Raphael's “**School of Athens**” (1509–1510; Apostolic Palace, Vatican City; http://en.wikipedia.org/wiki/School_of_Athens.



Heraclitus (figured by Michelangelo) in Raphael's School of Athens; http://en.wikipedia.org/wiki/Heraclitus.

Heraclitus (*ca.* 540-480 BC)

- *Πάντα ῥεῖ.*

  Everything flows [Quoted in Plato’s Cratylus, 339-340].
- *Τὰ ὄντα ἰέναι τε πάντα καὶ μένειν οὐδέν.*

  All things move and nothing remains still [from Plato's Cratylus, 401d].
- *Πάντα χωρεῖ καὶ οὐδὲν μένει.*

  Everything changes and nothing remains still [ibid, 402,a].
- *Δὶς ἐς τὸν αὐτὸν ποταμὸν οὐκ ἂν ἐμβαίης* .

  You cannot step twice into the same river [from Plato's Cratylus, 402a].

Aristotle in Raphael's "School of Athens"; http://en.wikipedia.org/wiki/Aristotle.

Aristotle (384-322 BC) in Meteorologica

Change

- *ὅτι οὔτε ὁ Τάναϊς οὔτε ὁ Νεῖλος ἀεὶ ἔρρει, ἀλλ' ἦν ποτε ξηρὸς ὁ τόπος ὅθεν ῥέουσιν· τὸ γὰρ ἔργον ἔχει αὐτῶν πέρας, ὁ δὲ χρόνος οὐκ ἔχει. ... ἀλλὰ μὴν εἴπερ καὶ οἱ ποταμοὶ γίγνονται καὶ φθείρονται καὶ μὴ ἀεὶ οἱ αὐτοὶ τόποι τῆς γῆς ἔνυδροι, καὶ τὴν θάλατταν ἀνάγκη μεταβάλλειν ὁμοίως. τῆς δὲ θαλάττης τὰ μὲν ἀπολειπούσης τὰ δ' ἐπιούσης ἀεὶ φανερὸν ὅτι τῆς πάσης γῆς οὐκ ἀεὶ τὰ αὐτὰ τὰ μέν ἐστιν θάλαττα τὰ δ' ἤπειρος, ἀλλὰ* ***μεταβάλλει τῷ χρόνῳ πάντα.***

  Neither the Tanais [River Don in Russia] ***nor the Nile have always been flowing, but the region in which they flow now was once dry****: for their life has a bound, but time has not… But if* ***rivers are formed and disappear*** *and the same places were not always covered by water, the sea must change correspondingly. And if the sea is receding in one place and advancing in another it is clear that* ***the same parts of the whole earth are not always either sea or land****, but that* ***all changes in course of time*** [I.14, 353a 16]

Conservation of mass within the hydrological cycle.

- *ὥστε οὐδέποτε ξηρανεῖται· πάλιν γὰρ ἐκεῖνο φθήσεται καταβὰν εἰς τὴν αὐτὴν τὸ προανελθόν.*

  Thus, [the sea] *will never dry up; for what has gone up beforehand will return to it* [II.3, 356b 26].

- *κἂν μὴ κατ' ἐνιαυτὸν ἀποδιδῷ καὶ καθ' ἑκάστην ὁμοίως χώραν, ἀλλ' ἔν γέ τισιν τεταγμένοις χρόνοις ἀποδίδωσι πᾶν τὸ ληφθέν.*

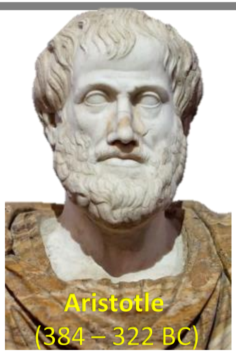
  Even if the same amount does not come back every year or in a given place, yet in a certain period all quantity that has been abstracted is returned [II.2, 355a 26].

Science (= pursuit of the truth) vs. sophistry

φίλος μέν Σωκράτης, ἀλλά φιλτάτη ή ἀλήθεια.
(Latin version: *Amicus Socrates, sed magis amica veritas*.)

Socrates is dear (friend), but truth is dearest.

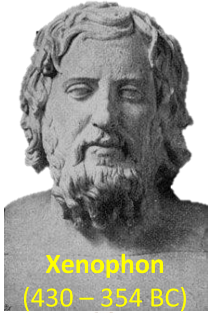
[Ammonius, Life of Aristotle]



ἔστι γὰρ ἡ σοφιστικὴ φαινομένη σοφία οὖσα δ᾽ οὔ, καὶ ὁ σοφιστὴς χρηματιστὴς ἀπὸ φαινομένης σοφίας ἀλλ᾽ οὐκ οὔσης.

Sophistry is the semblance of wisdom without the reality, and the sophist is one who makes money from apparent but unreal wisdom.

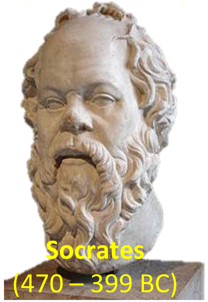
[Aristotle, On Sophistical Refutations, 165a21]



καὶ τὴν σοφίαν ὡσαύτως τοὺς μὲν ἀργυρίου τῷ βουλομένῳ πωλοῦντας σοφιστὰς ὥσπερ πόρνους ἀποκαλοῦσιν.

Those who offer wisdom to all comers for money are known as sophists, just like prostitutors.

[Xenophon, Memorabilia, 1.6.13, quoting Socrates]



Modern sophistry in support of politico-economical agendas

https://www.europarl.europa.eu/news/en/press-room/20191121IPR67110/

- Despite the decision of the European Parliament, there is no climate emergency as a physical reality.
- There is "climate emergency" as a political state.

https://www.civilprotection.gr/en

What is most frightening?
A natural climate emergency?
Or a political "climate emergency"?

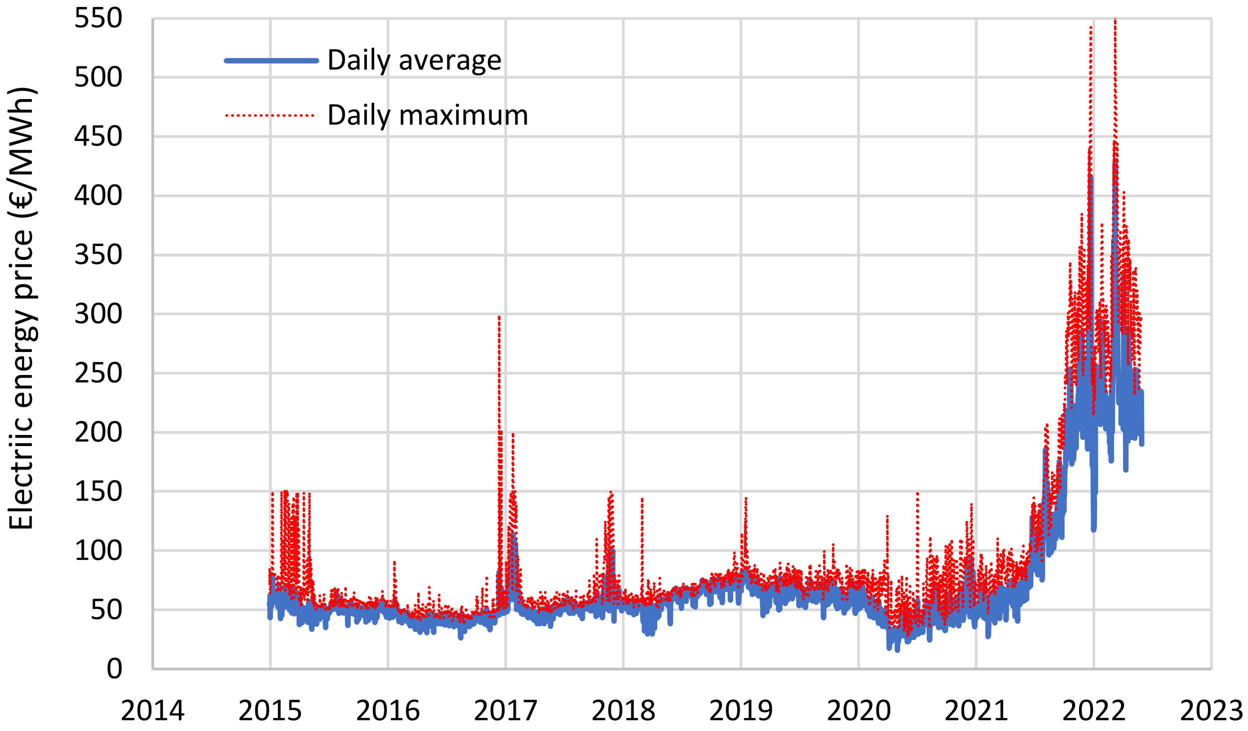
I am one of the ~1000 signatories.

https://clintel.org/world-climate-declaration/

The economic consequences of modern sophistry

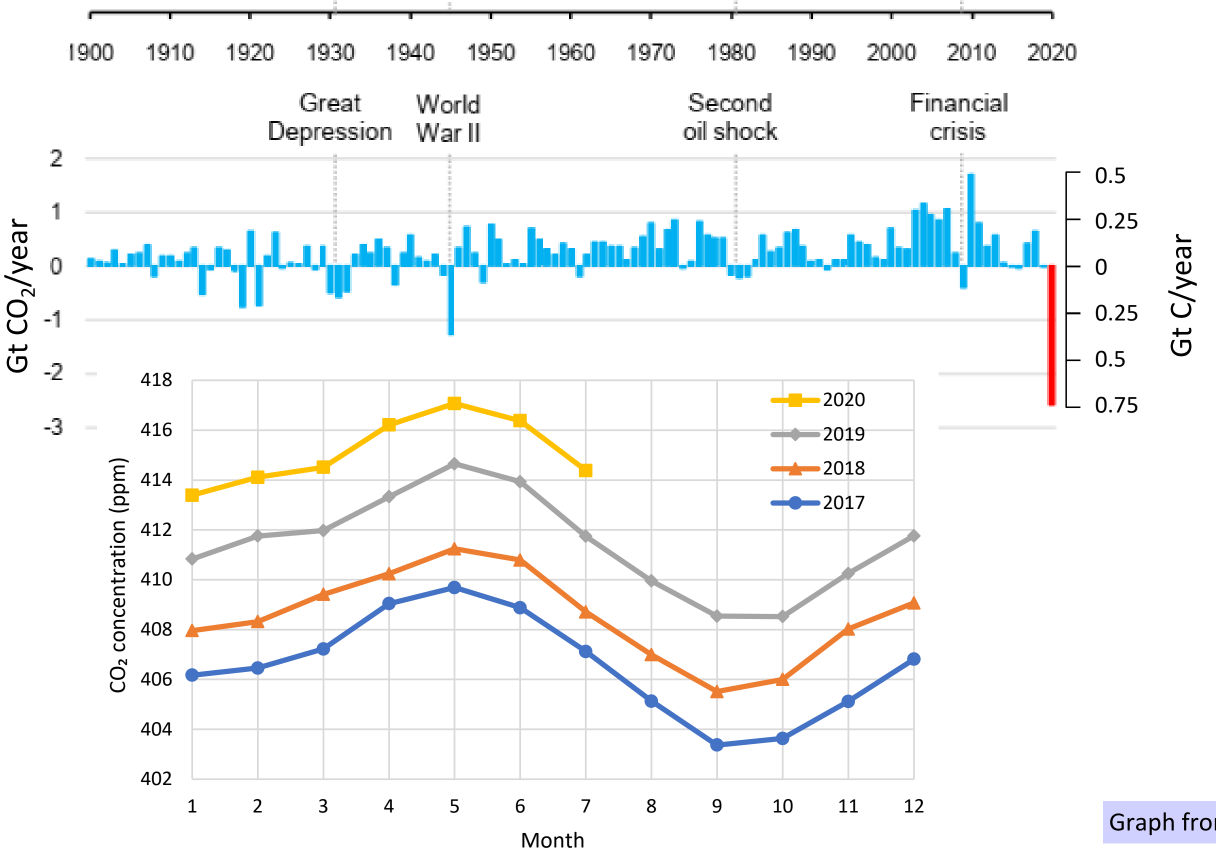
European energy strategy and energy prices in Greece

https://energy.ec.europa.eu/topics/energy-strategy_en



Data source: https://transparency.entsoe.eu/.

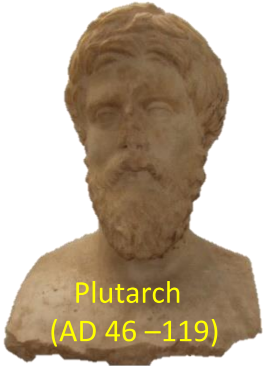
COVID and an unfortunate experiment

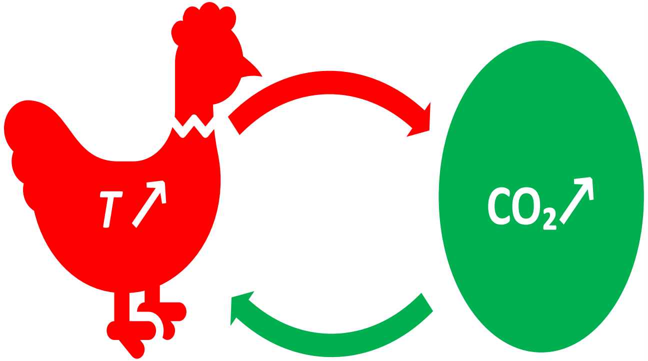


- COVID-caused lockdowns caused the greatest in history decrease of CO_2 emissions.
- The global CO_2 emissions were over 5% lower in the first quarter of 2020 than in that of 2019 (IEA, 2020).
- However, the increasing pattern of atmospheric CO2 concentration, as measured in Mauna Loa, did not change.

Graph from Koutsoyiannis and Kundzewicz (2020); see next page.

Causal relationship between CO_2 & temperature: “ὄρνις ἢ ᾠὸν;” (“hen or egg?”)





Plutarch used the example of the hen and the egg to pose a type of causality as a philosophical problem: *“Πότερον ἡ ὄρνις πρότερον ἢ τὸ ᾠὸν ἐγένετο”* —*”Which of the two came first, the hen or the egg?”* (Plutarch, Moralia, Quaestiones convivales, B, Question III).

Sci MDPI

Article

Atmospheric Temperature and CO_2: Hen-Or-Egg Causality?

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check for updates

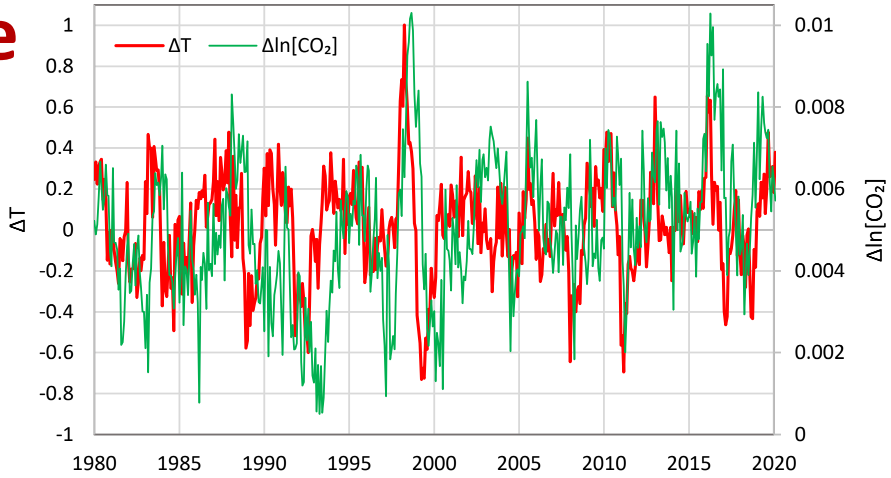
Abstract: It is common knowledge that increasing CO_2 concentration plays a major role in enhancement of the greenhouse effect and contributes to global warming. The purpose of this study is to complement the conventional and established theory, that increased CO_2 concentration due to human emissions causes an increase in temperature, by considering the reverse causality. Since increased temperature causes an increase in CO_2 concentration, the relationship of atmospheric CO_2 and temperature may qualify as belonging to the category of “hen-or-egg” problems, where it is not always clear which of two interrelated events is the cause and which the effect. We examine the relationship of global temperature and atmospheric carbon dioxide concentration in monthly time steps, covering the time interval 1980–2019 during which reliable instrumental measurements are available. While both causality directions exist, the results of our study support the hypothesis that the dominant direction is $T \rightarrow CO_2$. Changes in CO_2 follow changes in T by about six months on a monthly scale, or about one year on an annual scale. We attempt to interpret this mechanism by involving biochemical reactions as at higher temperatures, soil respiration and, hence, CO_2 emissions, are increasing.

Keywords: temperature; global warming; greenhouse gases; atmospheric CO_2 concentration

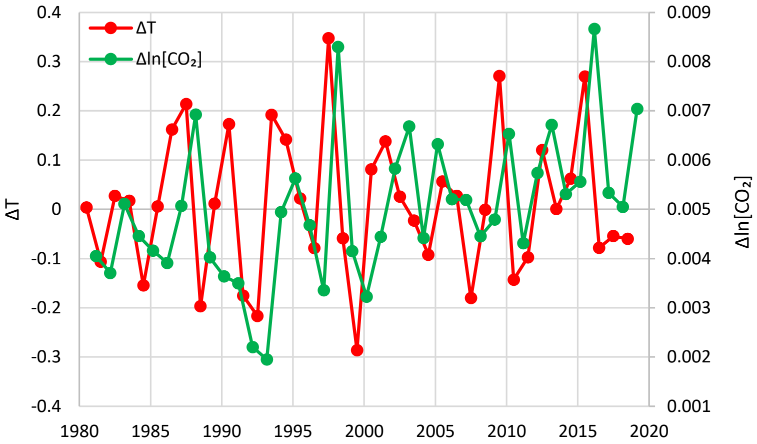
Πότερον ἡ ὄρνις πρότερον ἢ τὸ ᾠὸν ἐγένετο (Which of the two came first, the hen or the egg?).

Instrumental temperature and CO_2 data in search of causality

Differenced monthly time series of global temperature (UAH) and logarithm of CO_2 concentration (Mauna Loa).



Annually averaged time series of differenced temperatures (UAH) and logarithm of CO_2 concentration (Mauna Loa). Each dot represents the average of a one-year duration ending at the time of its abscissa.

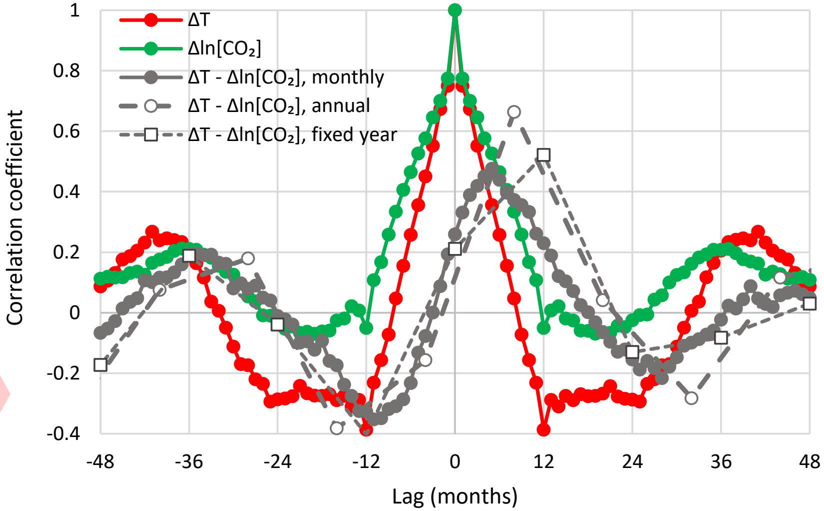


Which is the cause and which the effect?

Graphs from Koutsoyiannis and Kundzewicz (2020). Notice that logarithms of CO_2 concentration are used for linear equivalence with temperature. The differenced processes represent changes in the original processes.

Changes in CO_2 follow changes in global temperature

Auto- and cross-correlograms of the differenced time series of temperature (UAH) and logarithm of CO_2 concentration (Mauna Loa).



Which is the cause and which the effect?

Maximum cross-correlation coefficient (MCCC) and corresponding time lag in months.

	Monthly time series		Annual time series – sliding annual window		Annual time series – fixed annual window	
Temperature - CO_2 series	MCCC	Lag	MCCC	Lag	MCCC	Lag
UAH – Mauna Loa	0.47	5	0.66	8	0.52	12
UAH – Barrow	0.31	11	0.70	14	0.59	12
UAH – South Pole	0.37	6	0.54	10	0.38	12
UAH – Global	0.47	6	0.60	11	0.60	12
CRUTEM4 – Mauna Loa	0.31	5	0.55	10	0.52	12
CRUTEM4 – Global	0.33	9	0.55	12	0.55	12

Graph and table from Koutsoyiannis and Kundzewicz (2020).

Development and application of a theoretical framework for causality

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Research articles

Revisiting causality using stochastics: 1. Theory

Demetris Koutsoyiannis ✉, Christian Onof, Antonis Christofides and Zbigniew W. Kundzewicz

Published: 25 May 2022 | https://doi.org/10.1098/rspa.2021.0835

Review history

Abstract

Causality is a central concept in science, in philosophy and in life. However, reviewing various approaches to it over the entire knowledge tree, from philosophy to science and to scientific and technological applications, we locate several problems, which prevent these approaches from defining sufficient conditions for the existence of causal links. We thus choose to determine necessary conditions that are operationally useful in identifying or falsifying causality claims. Our proposed approach is based on stochastics, in which events are replaced by processes. Starting from the idea of stochastic causal systems, we extend it to the more general concept of hen-or-egg causality, which includes as special cases the classic causal, and the potentially causal and anti-causal systems. Theoretical considerations allow the development of an effective algorithm, applicable to large-scale open systems, which are neither controllable nor repeatable. The derivation and details of the algorithm are described in this paper, while in a companion paper we illustrate and showcase the proposed framework with a number of case studies, some of which are controlled synthetic examples and others real-world ones arising from interesting scientific problems.

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MATHEMATICAL, PHYSICAL AND ENGINEERING SCIENCES

Research articles

Revisiting causality using stochastics: 2. Applications

Demetris Koutsoyiannis ✉, Christian Onof, Antonis Christofidis and Zbigniew W. Kundzewicz

Published: 25 May 2022 | https://doi.org/10.1098/rspa.2021.0836

Review history

Abstract

In a companion paper, we develop the theoretical background of a stochastic approach to causality with the objective of formulating necessary conditions that are operationally useful in identifying or falsifying causality claims. Starting from the idea of stochastic causal systems, the approach extends it to the more general concept of hen-or-egg causality, which includes as special cases the classic causal, and the potentially causal and anti-causal systems. The framework developed is applicable to large-scale open systems, which are neither controllable nor repeatable. In this paper, we illustrate and showcase the proposed framework in a number of case studies. Some of them are controlled synthetic examples and are conducted as a proof of applicability of the theoretical concept, to test the methodology with *a priori* known system properties. Others are real-world studies on interesting scientific problems in geophysics, and in particular hydrology and climatology.

Mathematical representation

- Any two stochastic processes $\underline{x}(t)$ and $\underline{y}(t)$ can be related by

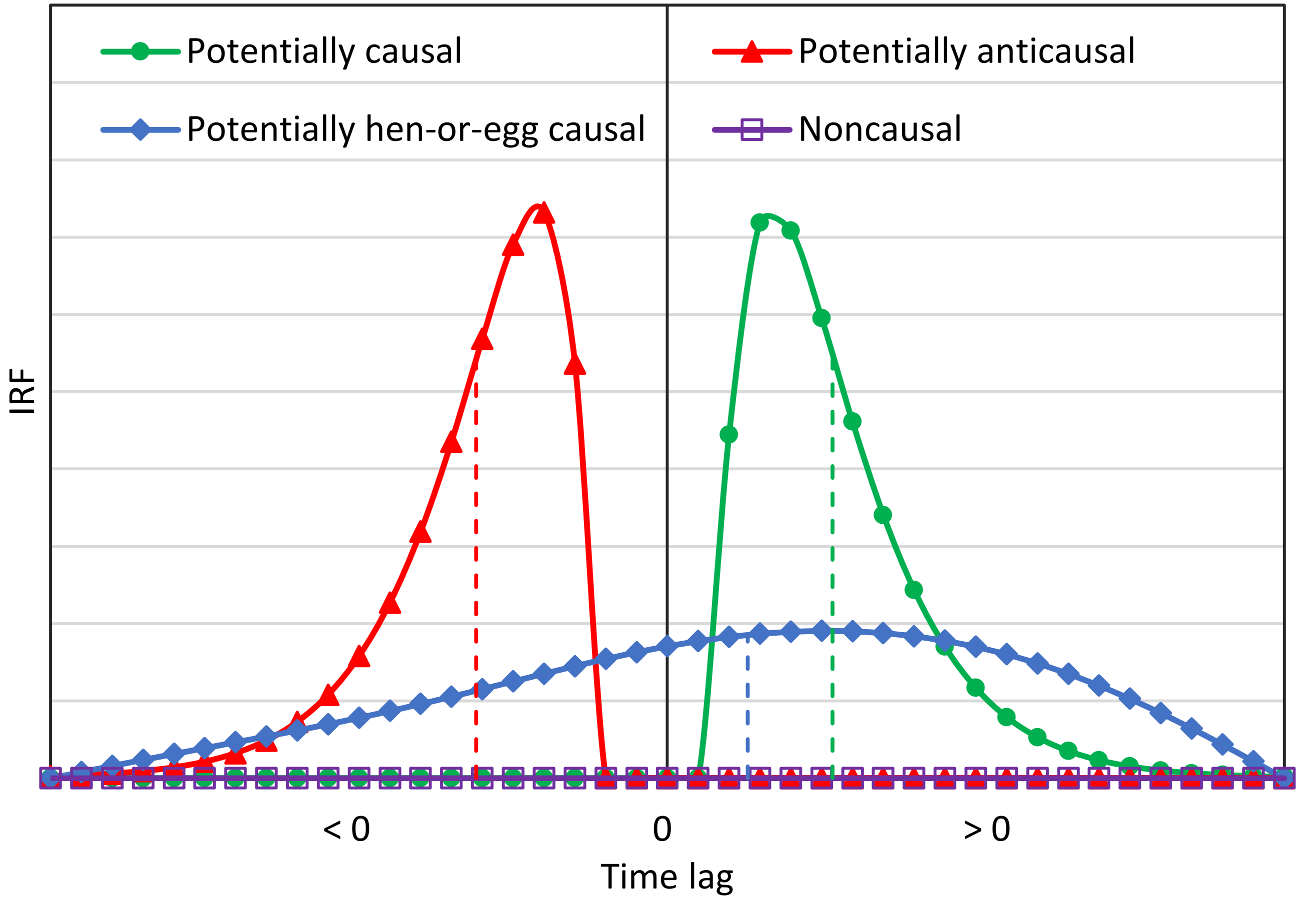
$$\underline{y}(t) = \int_{-\infty}^{\infty} g(h)\underline{x}(t-h)\mathrm{d}h + \underline{v}(t)$$

  where $g(h)$ is the **Impulse Response Function** (IRF) and $\underline{v}(t)$ is another process uncorrelated to $\underline{x}(t)$.
- There exist infinitely many pairs $(g(h), \underline{v}(t))$ of which we find the least squares solution—LSS: that resulting in the min $\mathrm{var}[\underline{v}(t)]$, or the max explained variance $e \coloneqq 1 - \mathrm{var}[\underline{v}(t)]/\mathrm{var}[\underline{y}(t)]$.
- Assuming that the LSS $g(h)$ has been determined, the system $(\underline{x}(t), \underline{y}(t))$ is:

  1. **potentially causal** if $g(h) = 0$ for any $h < 0$, while the explained variance is non negligible;
  2. **potentially anticausal** if $g(h) = 0$ for any $h > 0$, while the explained variance is non negligible (this means that the system $(\underline{y}(t), \underline{x}(t))$ is potentially causal);
  3. **potentially hen-or-egg (HOE) causal** if $g(h) \neq 0$ for some $h > 0$ and some $h < 0$, while the explained variance is non negligible;
  4. **noncausal** if the explained variance is negligible.

- The framework of causality identification is constructed for case 3, with all other three cases resulting as special cases.

Illustration of the four different cases of potential causality



Premises of the developed methodology

- Our framework is for **open systems** (in particular, **geophysical** systems), in which:
  - **External influences** cannot be controlled or excluded.
  - Only a **single realization** is possible.
  - There is **dependence** in time.
- Our framework is not formulated on the basis of events, but of **stochastic processes**.
- It is understood that only **necessary conditions of causality** can be investigated using stochastics. The usefulness of this objective lies in its ability:
  - to **falsify** an assumed causality, and
  - to add statistical evidence, in an **inductive** context, for **potential causality** and its direction.
- The only "hard" requirement kept from previous studies is the **time precedence** of the cause from the effect.

Additional mathematical considerations

- We also set additional desiderata for
  - (a) an **adequate time span** $\mathbb{h}$ of h (the **causal action is not instant**);
  - (b) a **nonnegative** $g(h) \geq 0$ for all $h \in \mathbb{h}$ (replacing $\underline{x}(t)$ with $-\underline{x}(t)$ for negative correlation);
  - (c) a **smooth** $g(h)$ assured by a constraint $E \leq E_0$, where E is determined in terms of the second derivative of $g(h)$ ($E := \int_{-\infty}^{\infty} \left(g''(h)\right)^2 \mathrm{d}h$) and E_0 is a positive number.
- Although the theoretical framework is formulated in terms of **natural (continuous) time**, the estimation of the IRF relies on data in an inductive manner, and data are only available in **discrete time**. Conversion of the continuous- to a discrete-time framework results in

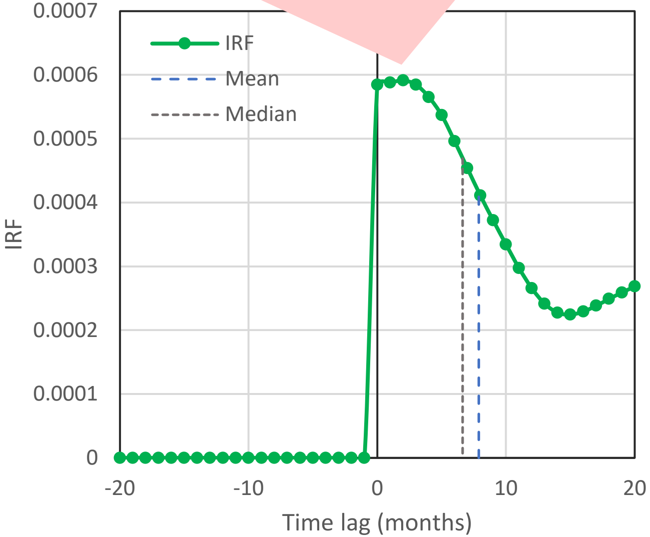
$$\underline{y}_\tau = \sum_{j=-\infty}^{\infty} g_j \underline{x}_{\tau-j} + \underline{v}_\tau$$

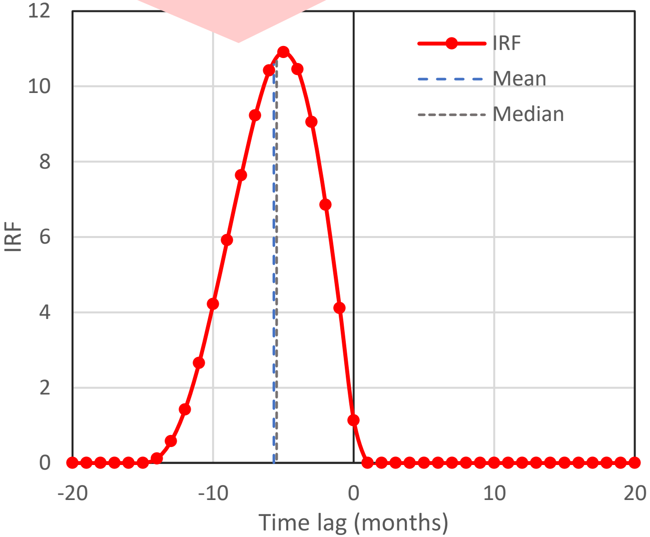
  where the sequence g_j can be determined accurately from the function $g(h)$.
- Furthermore, any data set is finite and allows only a finite number of g_j terms to be estimated. Therefore, in the applications the summation limits $\pm\infty$ are replaced by $\pm J$, assuming that $g_j = 0$ for $|j| > J$, where, J should be chosen much lower than the length of the dataset.
- A **solver** can be used to resolve the **constrained optimization problem**: The determination of g_j is based on the minimization of $\mathrm{var}\left[\underline{v}(t)\right]$ subject to the constraints.

Application to the temperature – [CO_2] problem

Treating the system (T,[CO_2]) as potentially HOE causal, we conclude that it is potentially causal (mono-directional) with explained variance 31%.

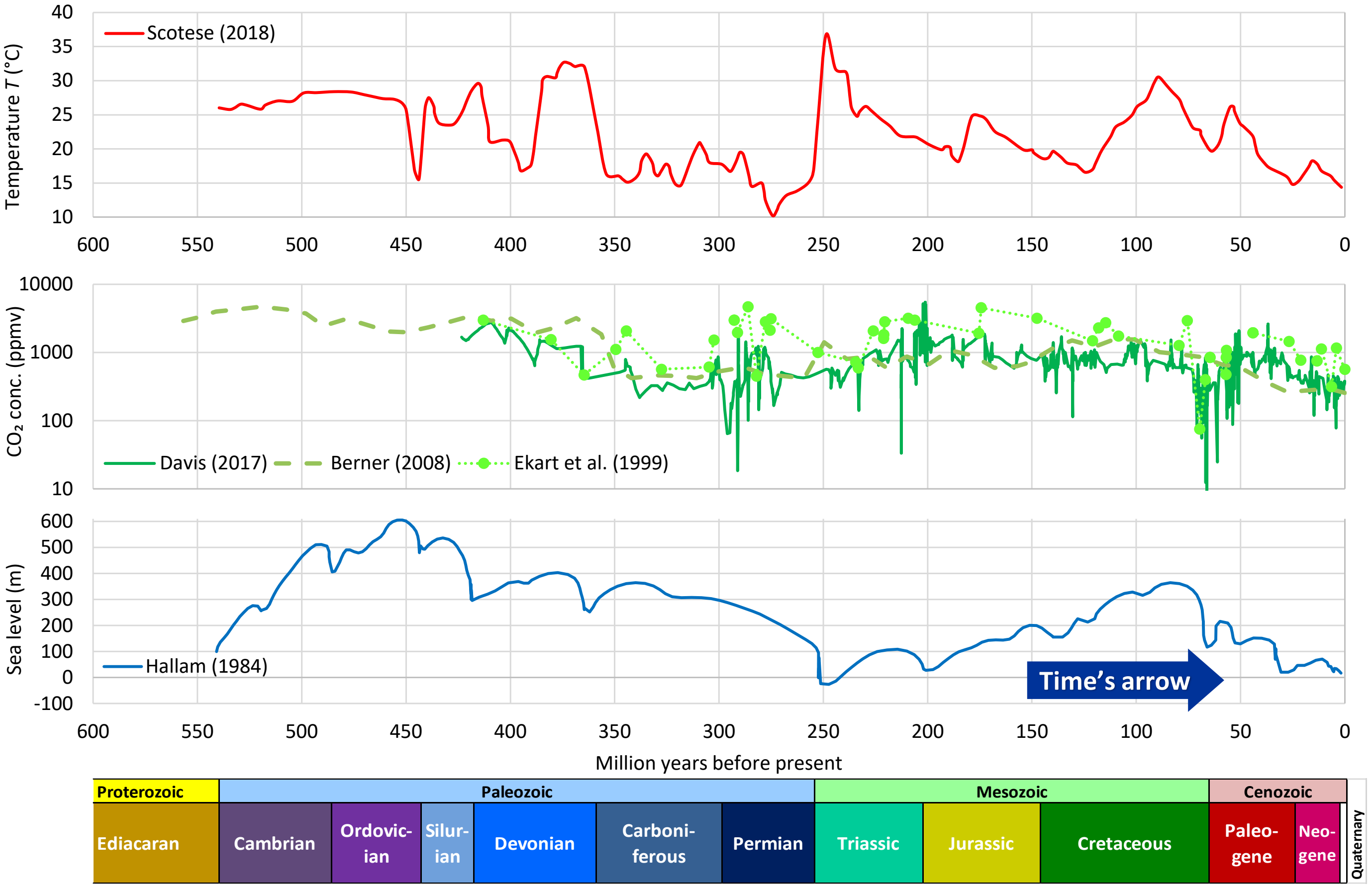
Treating the system ([CO_2], T) as potentially HOE causal, we conclude that it is potentially anticausal (counter-directional) with explained variance 23%.





Conclusion: The common perception that increasing [CO_2] causes increased T **can be excluded** as it violates the necessary condition for this causality direction.
In contrast, the causality direction $T \rightarrow$ [CO_2] is plausible.

Co-evolution of temperature, CO_2 concentration and sea level in the Phanerozoic



Digression—Offering food for thought and amusement: Science violates the rules of political correctness

Reference # 220626-003391 | View your case(s) on our Help Center

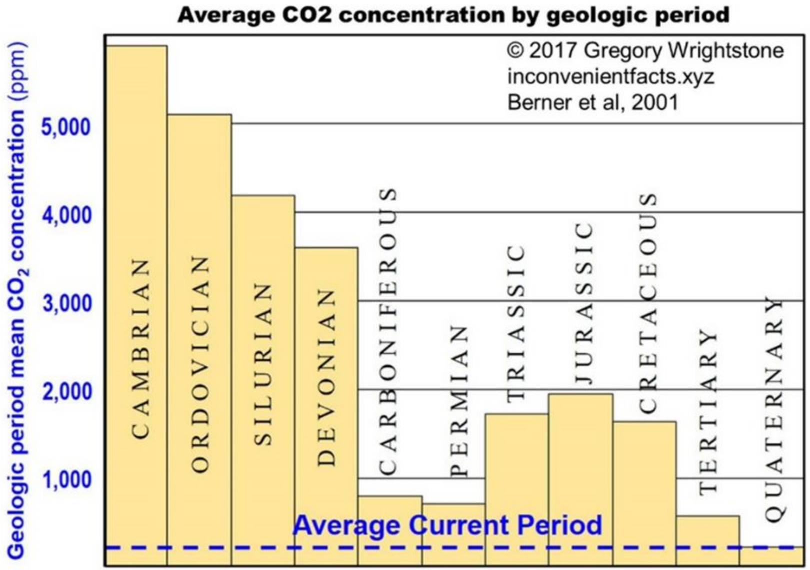
Status: Closed | You may reply to this case for up to 14 days

Response (06/28/2022 09:09 CST)

Hi Gregory,

Thanks for contacting us. Your account has violated the LinkedIn User Agreement and Professional Community Policies. Due to the number and/or the severity of these violations, this account has been permanently restricted.

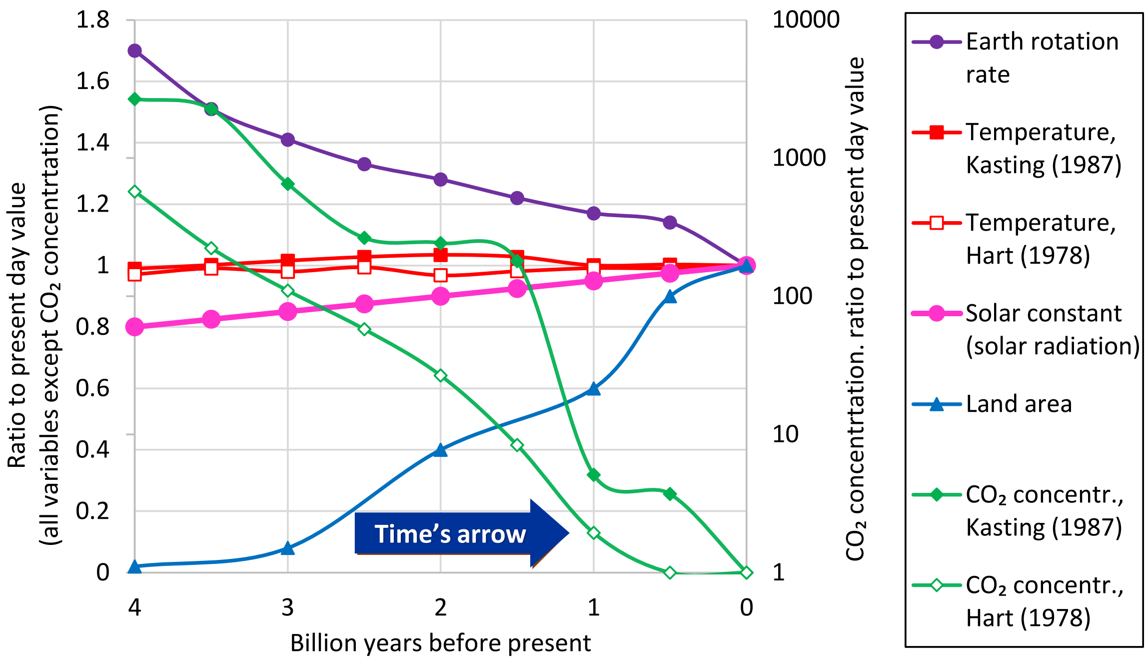
Yesterday, Gregory Wrightstone was permanently banned from LinkedIn because he posted the graph on the right, constructed from the paper by Berner and Kothavala (2001).



Berner RA, Kothavala Z (2001) GEOCARB III: A revised model of atmospheric CO2 over Phanerozoic time, IGBP PAGES and World Data Center for Paleoclimatology, Data Contribution Series # 2002-051. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

See also: Geology Banned, https://youtu.be/MkdStlTGoeU.

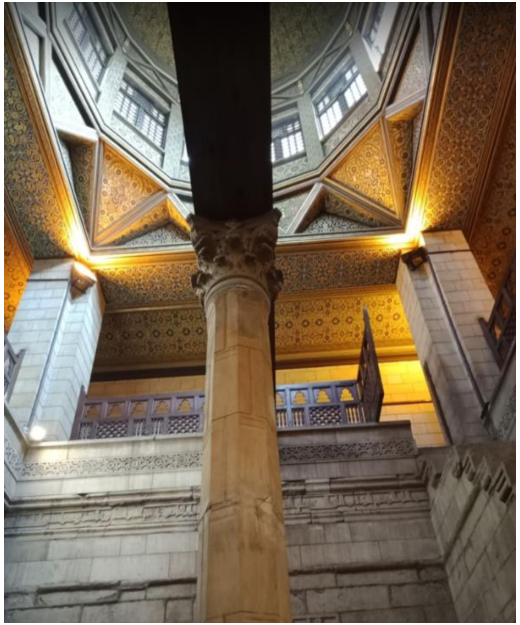
Climate is changing … since 4.5 billion years ago

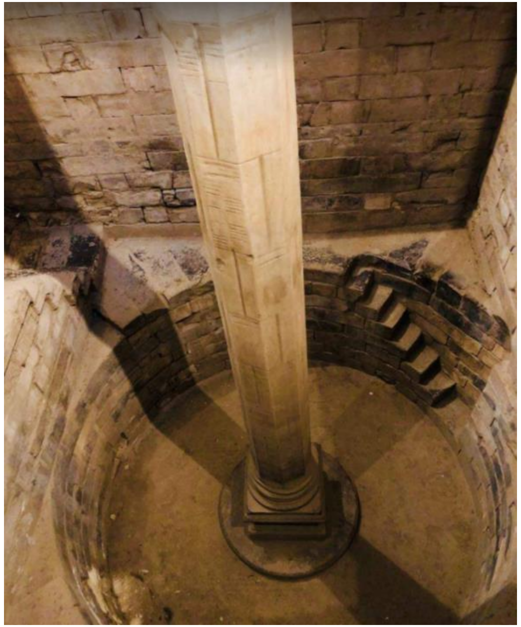


Note: The title of this slide is identical to the title of an invited lecture to the University of Bologna in 26 November 2019. The lecture was cancelled after activist reactions, based on lies promoted by a blog and covered in a newspaper. See details in Koutsoyiannis (2019).

- The graph has been constructed from estimates by Kuhn et al. (1989). Temperature is expressed in K and corresponds to 35° latitude; a change in the temperature ratio by 10% corresponds to ~29 K.
- Although the estimates are dated and uncertain, evidence shows existence of liquid water on Earth even in the early period, when the solar activity was smaller by 20-25% (the faint young Sun problem; Feulner, 2012).

Instrumental data of a long period: The Roda Nilometer

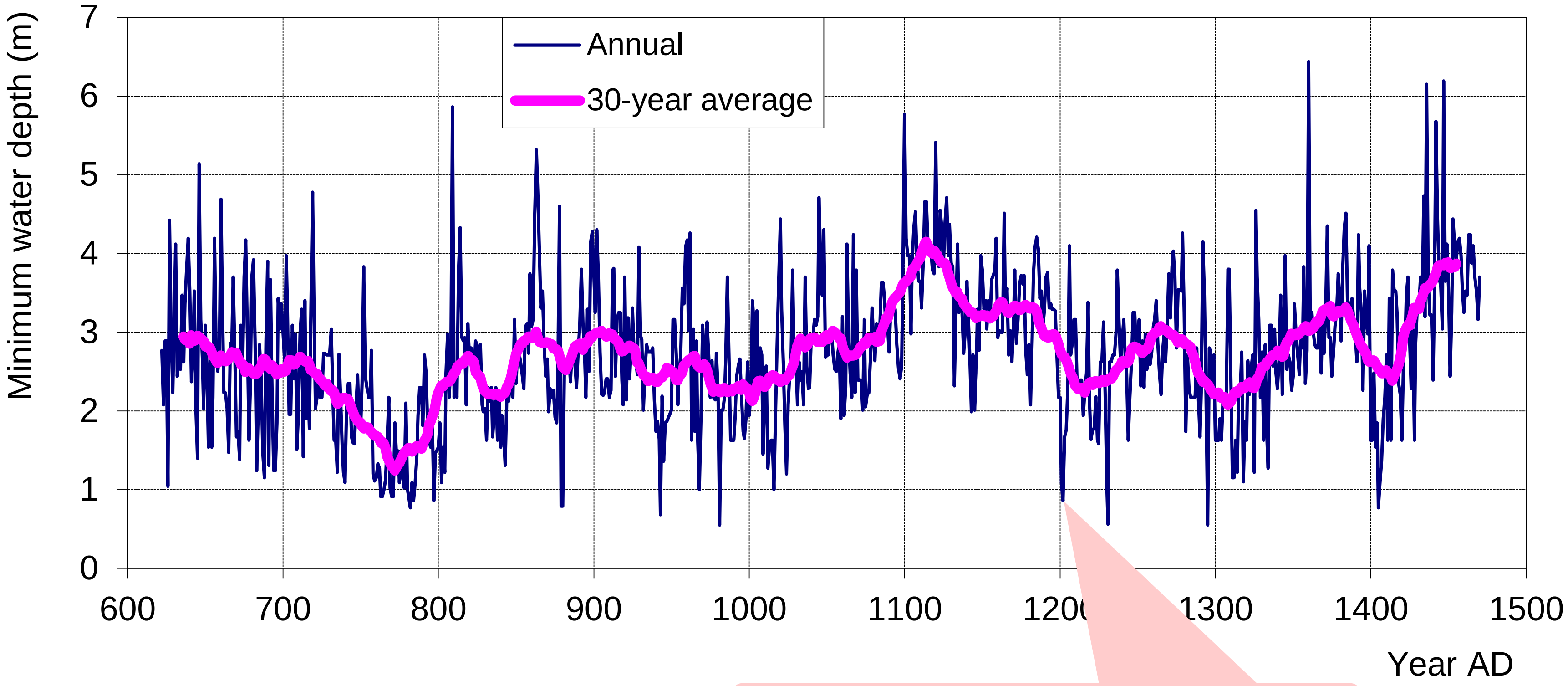




Photos by Loai Samen and Mohamd Mubarak; Google maps, https://goo.gl/maps/T8NUgoDAorK2 and https://goo.gl/maps/dsdJHJYVv572.

The Roda Nilometer, near Cairo, offers the longest instrumental data on Earth. Water entered through three tunnels and filled the Nilometer chamber up to river level. The measurements were taken on the marble octagonal column (with a Corinthian crown) standing in the centre of the chamber; the column is graded and divided into 19 cubits (each slightly more than 0.5 m) and could measure floods up to about 9.2 m. A maximum level below the 16th mark could portend drought and famine and a level above the 19th mark meant catastrophic flood.

What do the Roda Nilometer data say?

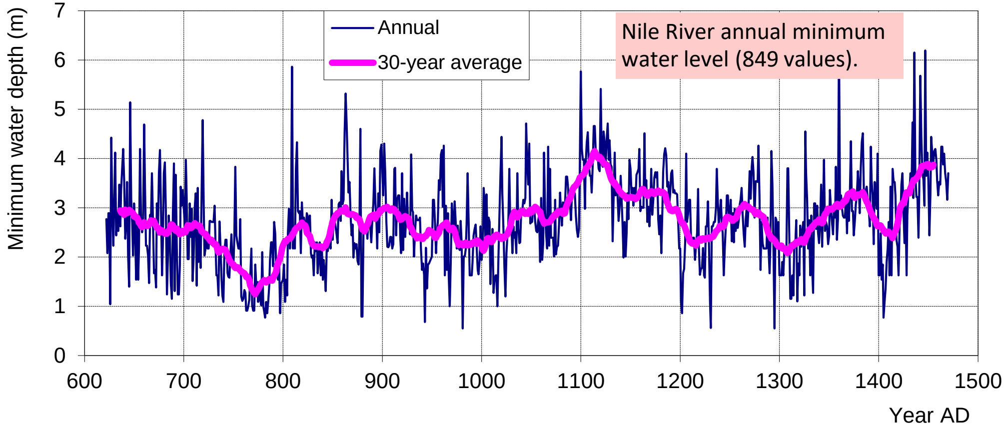


Graph and data from Koutsoyiannis (2013); the data can be downloaded from https://www.itia.ntua.gr/1351/.

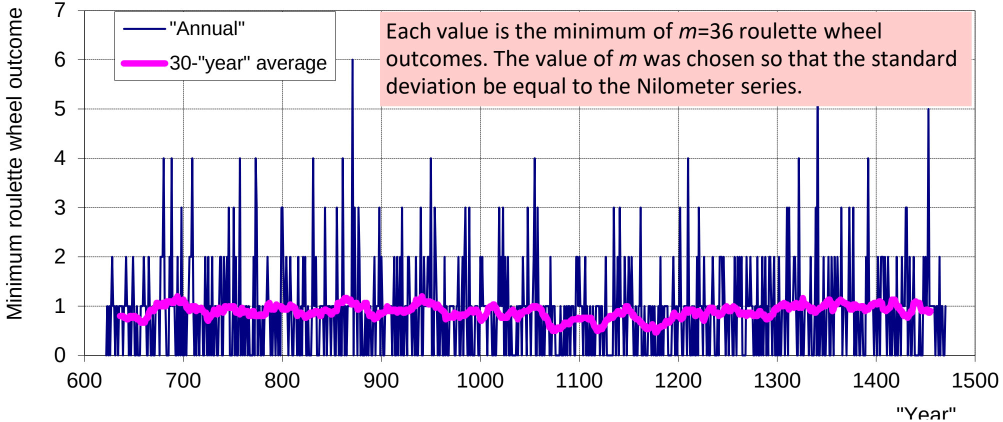
Cannibalism (as a consequence of drought) reported in Egypt ('Abd Al-Latif Al-Baghdadi, 1202).

Hurst-Kolmogorov dynamics and the perpetual change of Earth's climate

A hydroclimatic process as seen in the longest instrumental record.



A "roulette" process.



Hurst-Kolmogorov (HK) dynamics is described by a very simple equation:

$$\gamma_k = \frac{\gamma_1}{k^{2-2H}}$$

where k is time scale, γ_k is the variance of the time-averaged process at scale k and H is the Hurst parameter.

For random processes (e.g. "roulette") H=0.5.

For natural processes $0.5 < H < 1$

Climate stochastics: Kolmogorov, Hurst and the Nile

Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1940. Volume XXVI, № 2

Kolmogorov (1940)

MATHEMATIK

WIENERSCHE SPIRALEN UND EINIGE ANDERE INTERESSANTE KURVEN IM HILBERTSCHEN RAUM

Von A. N. KOLMOGOROFF, Mitglied der Akademie

Wir werden hier einige Sonderfälle von Kurven betrachten, denen meine vorhergehende Note «Kurven im Hilbertschen Raum, die gegenüber einer einparametrigen Gruppe von Bewegungen invariant sind» (1) gewidmet ist.

Unter einer Ähnlichkeits[...]

[...] des Raumes in sich

[...] vorgegebenes Paar x' und $y' \neq x'$ der Punkte, die auf derselben Kurve liegen, übergeht.

Satz 6. *Die Funktion* $B_\xi(\tau_1, \tau_2)$, *die der Funktion* $\xi(t)$ *der Klasse* $\mathfrak{A}$ *entspricht, kann in der Form*

$$B_\xi(\tau_1, \tau_2) = c\,[\,|\tau_1|^\gamma + |\tau_2|^\gamma - |\tau_1 - \tau_2|^\gamma]$$

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AMERICAN SOCIETY OF CIVIL ENGINEERS
Founded November 5, 1852
TRANSACTIONS

Hurst (1951)

Paper No. 2447

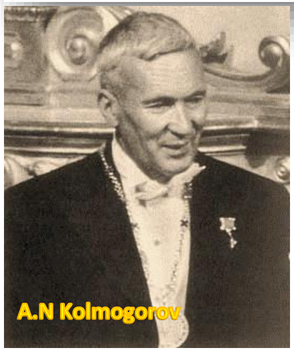
LONG-TERM STORAGE CAPACITY OF RESERVOIRS

BY H. E. HURST[1]

WITH DISCUSSION BY VEN TE CHOW, HENRI MILLERET, LOUIS M. LAUSHEY, AND H. E. HURST.

SYNOPSIS

A solution of the problem of determining the reservoir storage required on a given stream, to guarantee a given draft, is presented in this paper. For example, if a long-time record of annual total discharges from the stream is available, the storage required to yield the average flow, each year, is obtained by computing the cumulative sums of the departures of the annual totals from the mean annual total discharge. The range from the maximum to the minimum of these cumulative totals is taken as the required storage.



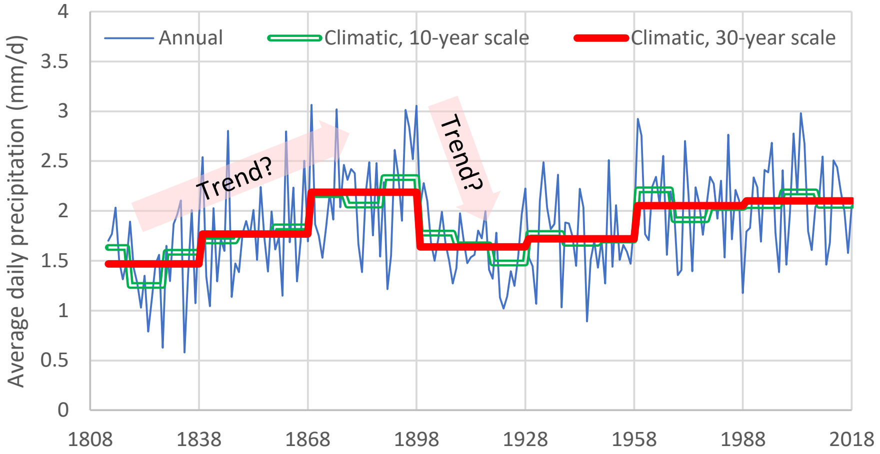
Kolmogorov proposed a stochastic process that describes a behaviour unknown at that time. It was discovered a decade later in geophysics by Hurst.

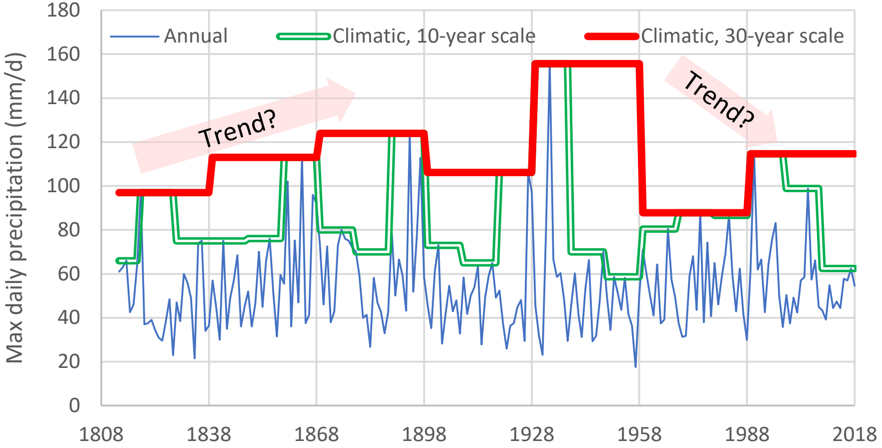
"Although in random events groups of high or low values do occur, their tendency to occur in natural events is greater. This is the main difference between natural and random events."

Modern long records of instrumental data: Rainfall in Bologna

- The mean annual values for 50 years after 1820 show an upward trend. A classical statistical test for a linear trend using merely these data values would reject the stationarity hypothesis at a *p*-value of 7.7×10^{-4}.
- “Trends” are for kids. **Adults** use better descriptions of **long-term variability**, namely **Hurst-Kolmogorov (HK) dynamics**.

Dataset details Station: BOLOGNA, Italy, 44.50°N, 11.35°E, +53.0 m
Period: 1813-2018 (206 years).
Source of graphs: Koutsoyiannis (2021b).
Sources of data: also detailed in Koutsoyiannis (2021b).





Drought in Athens: Was it due to a "trend", possibly suggesting "climate crisis"

The historical time series of runoff up to 1986/87 at one of the rivers supplying Athens, Boeoticos Kephisos.

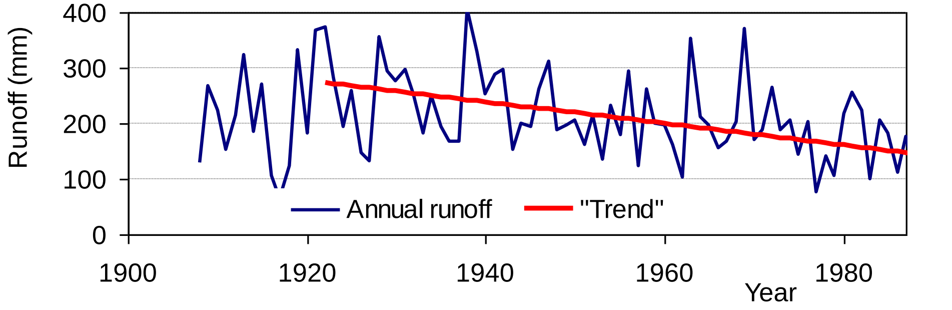
A multi-year «trend» is observed.

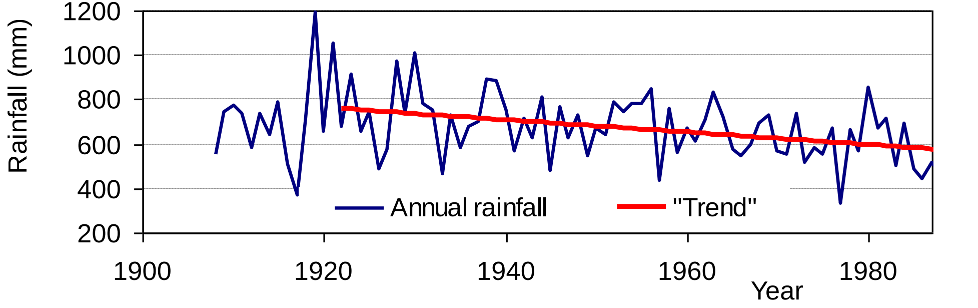
A similar «trend» in the rainfall time series.

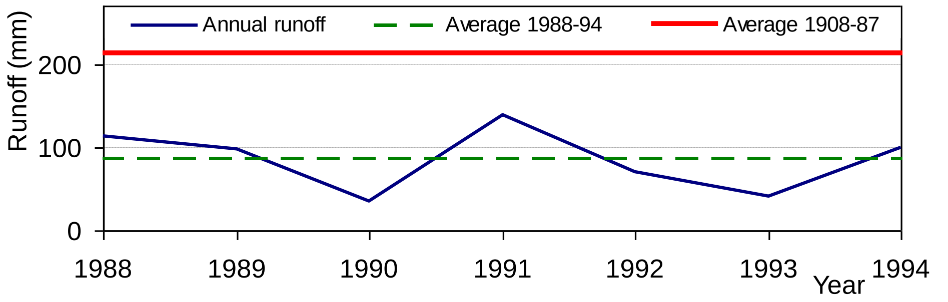
Explains the «trend» in runoff.

Next was a shocking drought.

Intense and persistent: Mean flow less than half compared to historical average; duration 7 years.







Handling the long-lasting drought in Athens

- Close collaboration of (a) the National Technical University of Athens, (b) the Athens Water Supply and Sewerage Company (EYDAP), and (c) The Ministry of Environment and Public Works.
- Understanding that droughts are **regular natural events**—not associated to human influences.
- Proper modelling the drought within a **stochastic Hurst-Kolmogorov framework** (Koutsoyiannis, 2011).
- Development of a sophisticated **decision support system** (Koutsoyiannis et al., 2003).
- Transparency and veritable information to the **population** of Athens, and its **engagement in the management of the crisis**.
- Design and implementation of an increasing block rate **pricing structure**, combined with water **conservation legislation measures** (Xenos et al., 2002).
- Increased water supply through **technological measures** (see next slide).

Results of the crisis management

- **Not even in one house in not even one day** throughout this 7-year period was there a **water supply failure** due to the drought.
- The water **consumption** of Athens was **decreased by 1/3**.
- New groundwater resources were exploited.
- **In 1.5 year**, a new tunnel was constructed and operated, **diverting water from the Evinos River** to Athens.
- In another 4 years, the new dam on the Evinos River was completed, thus increasing the water quantity transferred to Athens.
- Now Athens has a perfect water supply system.

Rejected approach 1: Trend based

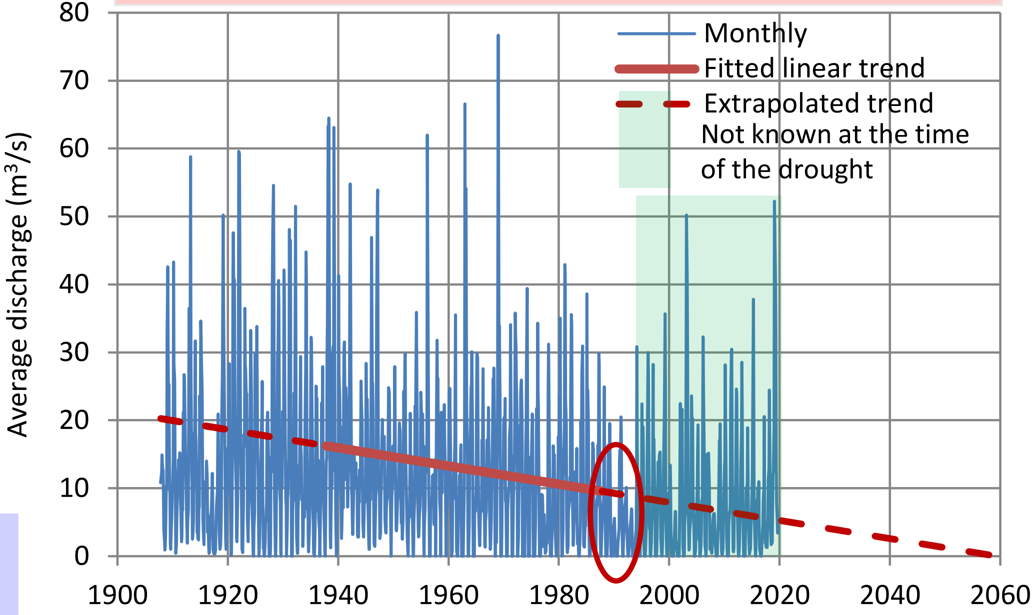
- The "trend model" is **worse than** that of a constant average (see table).
- According to the "trend model", the flows would **disappear** a little after 2050…
- In reality **all three reservoirs spilled** in 2006 and again two of them in 2020 and 2021.
- **Conclusion**: It is **absurd** to use such simplistic methods such as **trend extrapolations**.

Source: Koutsoyiannis (2021b).
See additional evidence about the inappropriateness of trends in Iliopoulou and Koutsoyiannis (2020).

Root mean square errors (in m³/s) for the two validation periods for the linear-trend model and the constant-mean model, fitted to the calibration period (1937-87)

Validation period	1907-37	1987-2019
Assuming linear trend	13.4	12.7
Assuming constant mean	9.3	10.3

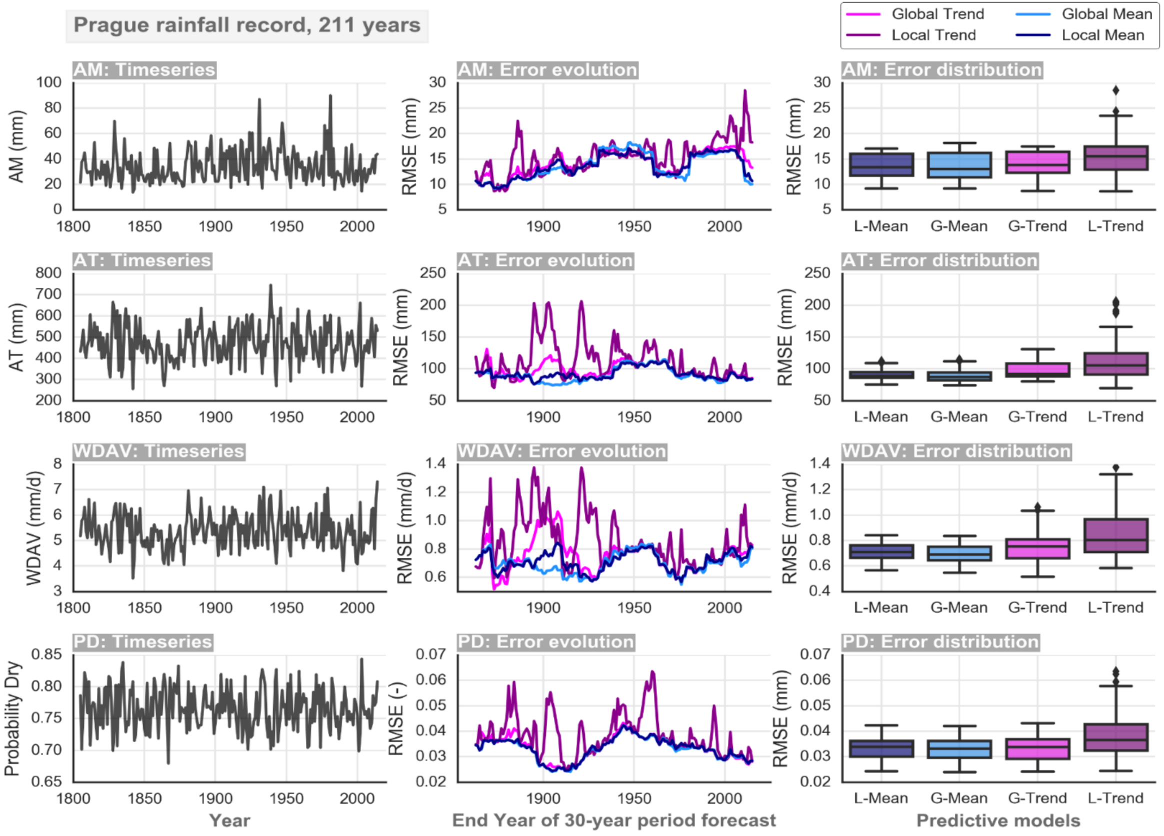
Boeoticos Kephisos runoff and projected trend.



Are trends effective for rainfall prediction?

We assess the 'trends' effectiveness in long-term projections via a **prediction-oriented evaluation framework.**

We compare the predictive performance of **global and local trend models** over climatic periods (30 years) to the one obtained by **global and local mean models.**



Source: Iliopoulou and Koutsoyiannis (2020). Explanation: AM: annual maxima, AT: annual totals, WDAV: annual wet-day average rainfall, PD: probability dry.

Extreme rainfall projections – Local mean models are the best

Fixed periods

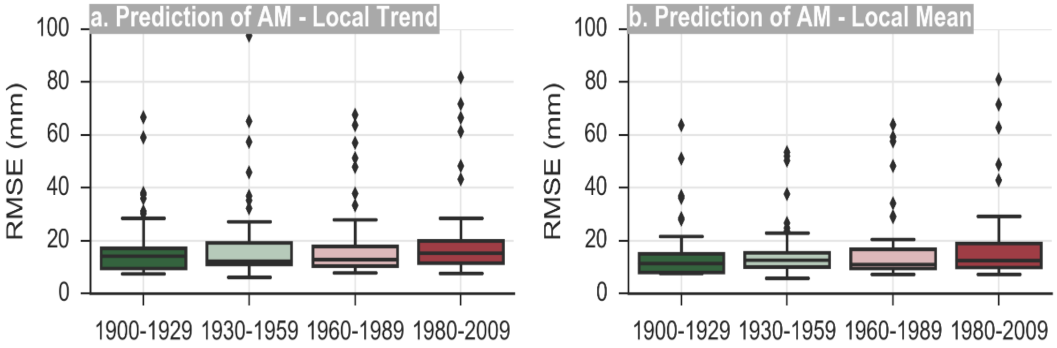
Source: Iliopoulou and Koutsoyiannis (2020).

The study includes the 60 longest available daily rainfall records worldwide, surpassing 150 years of daily values.

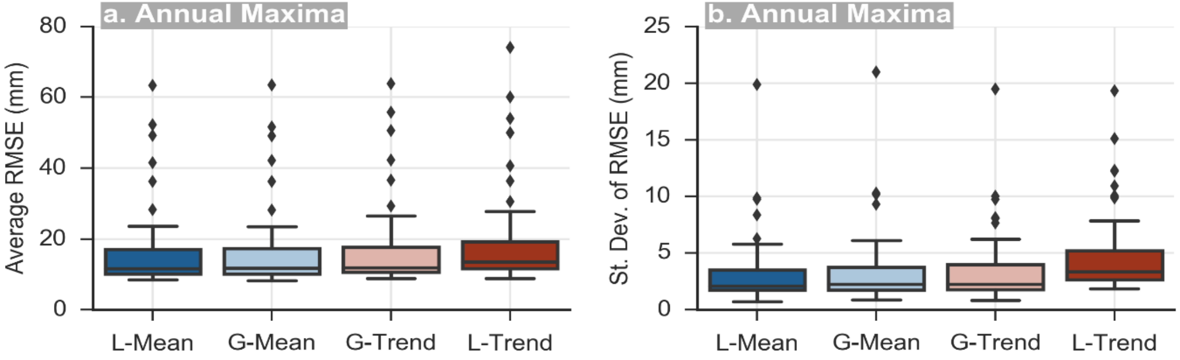
The models' predictive performance **ranks from best to worse** as follows:

1. L-Mean
2. G-Mean
3. G-Trend
4. L-Trend

In persistent processes, where clustering arises, local information is likely to be more relevant for prediction.



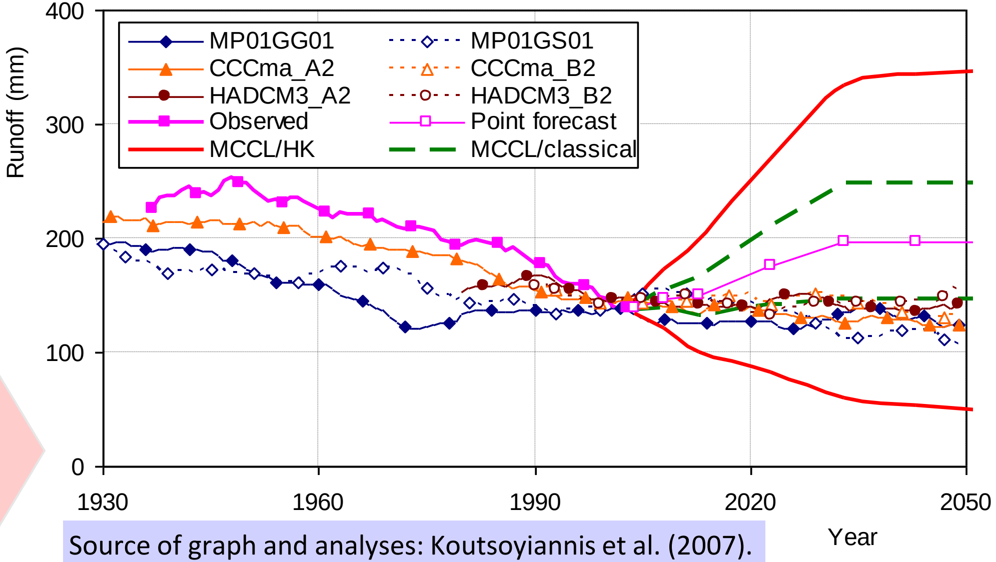
Moving-window periods



Rejected approach 2: Based on climate-models

- Outputs from **3 climate models for 2 future scenarios** were examined (Koutsoyiannis et al., 2007).
- The **original climate model outputs** (not shown) had **no relation to reality** (highly negative efficiencies at the annual time scale and above).
- After adaptations (or "**cosmetic lifting**", also known as "downscaling") the climate model outputs improved with respect to reality, thus achieving about zero efficiencies at the annual time scale.
- **For the past**, despite adaptations, the proximity of models with reality was **not satisfactory.**
- **For the future**, the runoff obtained by adapted climate models was **too stable**.
- **Conclusion: It is dangerous** (too risky) **to use climate model projections**.

Boeoticos Kephisos runoff produced with downscaled climate model outputs, superimposed to Monte Carlo confidence limits (MCCL) produced with HK statistics under stationarity.



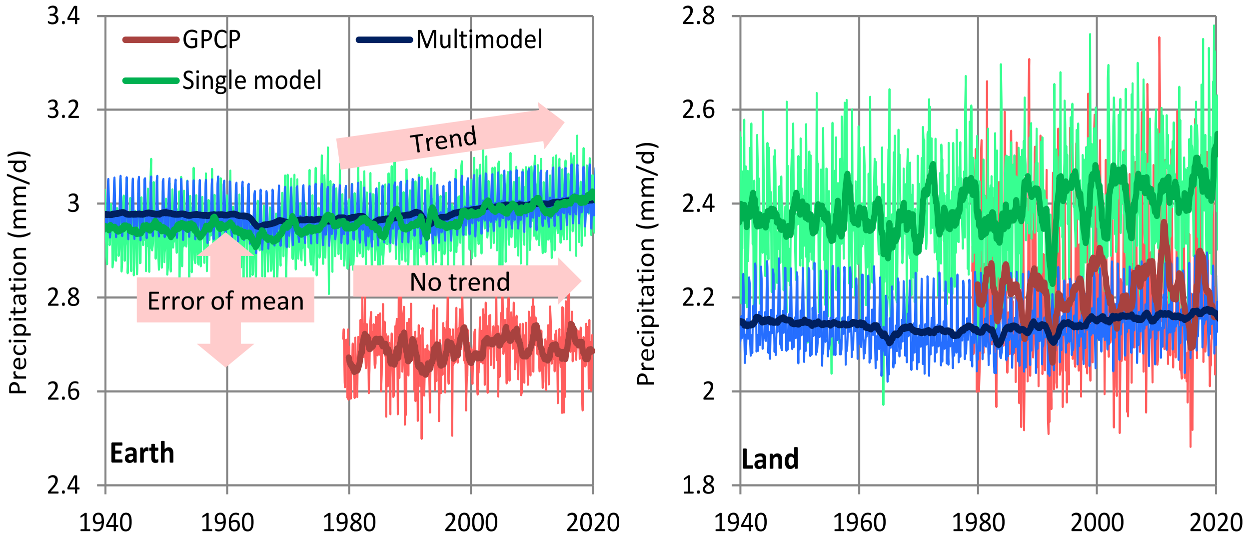
Source of graph and analyses: Koutsoyiannis et al. (2007).

Do climate models provide guidance for the future?

- Short answer: No.
- Long answer: They have not provided skill for the past. Notice: (1) the **large error** of the “Multimodel” ensemble in terms of the mean; (2) the increasing trend of climate model outputs after 1980, which **did not appear in reality**.

Thin and thick lines represent monthly values and running annual averages (right aligned).

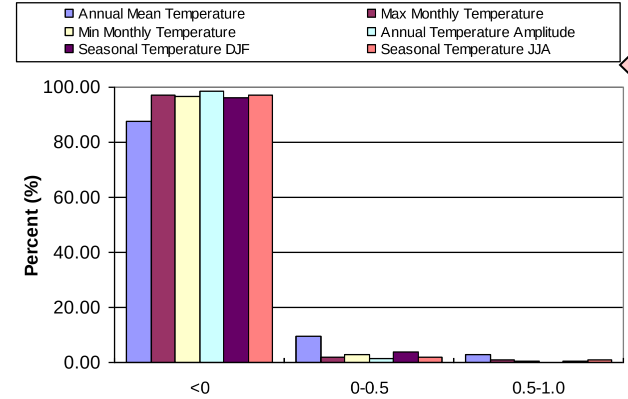
Source of graph: Koutsoyiannis (2020); observations come from the combined gauge and satellite precipitation data over a global grid (GPCP); climate model outputs are for the scenario “RCP8.5” (frequently referred to as “business as usual”); “Multimodel” refers to CMIP5 scenario runs (entries: CMIP5 mean – rcp85) and “Single model” refers to CCSM4 – rcp85 (ensemble member 0), where CCSM4 stands for Community Climate System Model version 4, released by NCAR. Data and model outputs are accessed through http://climexp.knmi.nl.



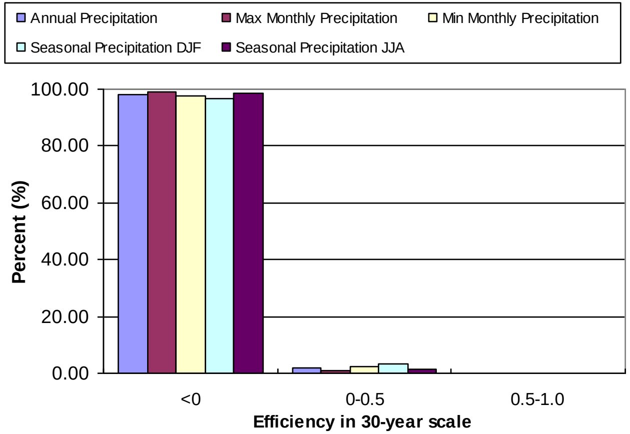
Do climate models reproduce real-world rainfall?

- Short answer: No.
- Long answer: Simulations of point rainfall have mostly **negative efficiencies**. Areal rainfall simulations are **irrelevant to reality** even at climatic scales.

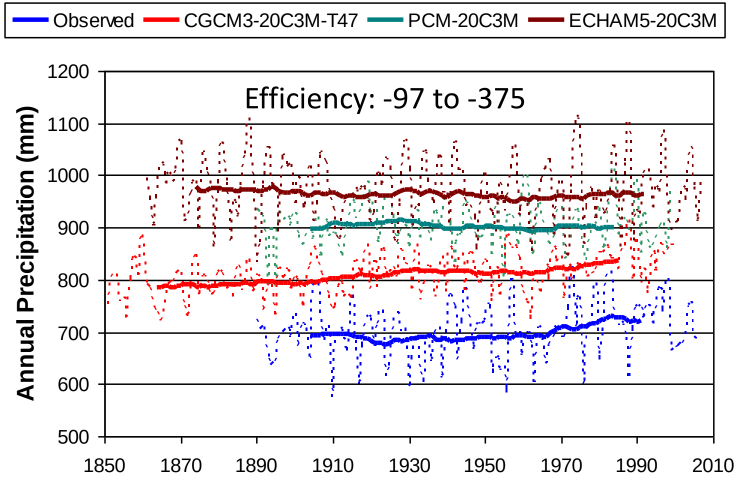
Source: Anagnostopoulos, et al. (2010); see also reviews by Pielke Sr. (2017), and Essex and Tsonis (2018)



Comparison of 3 IPCC TAR and 3 IPCC AR4 climate models with historical series of more than 100 years length in 55 stations worldwide



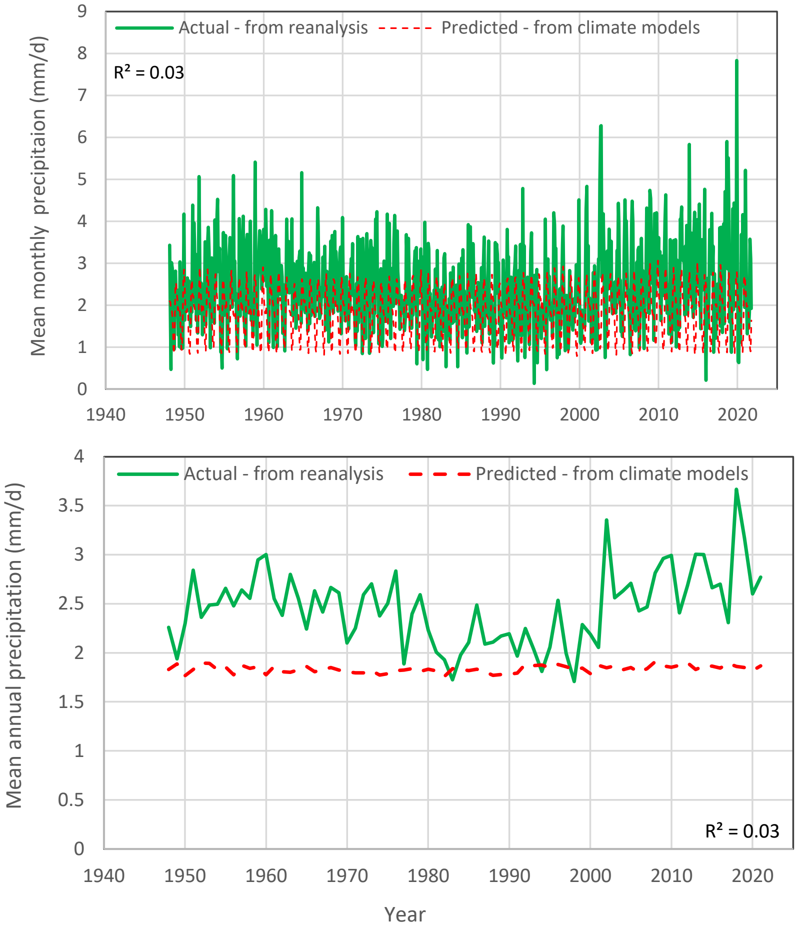
Comparison of 3 IPCC AR4 climate models with reality in sub-continental scale (contiguous USA)



Do climate models reproduce real-world rainfall? (2)

- The example in the graphs compares actual rainfall data over the entire territory of Italy (from NCEP-NCAR Reanalysis 1 data) with those predicted by climate models (mean of the output data of the Coupled Model Intercomparison Project, CMIP6).
- The climate models severely underpredict rainfall—mostly the high values—as well as its variability.
- A professional hydrologist normally would not use such incompetent model outputs.

Source: Koutsoyiannis and Montanari (2022).

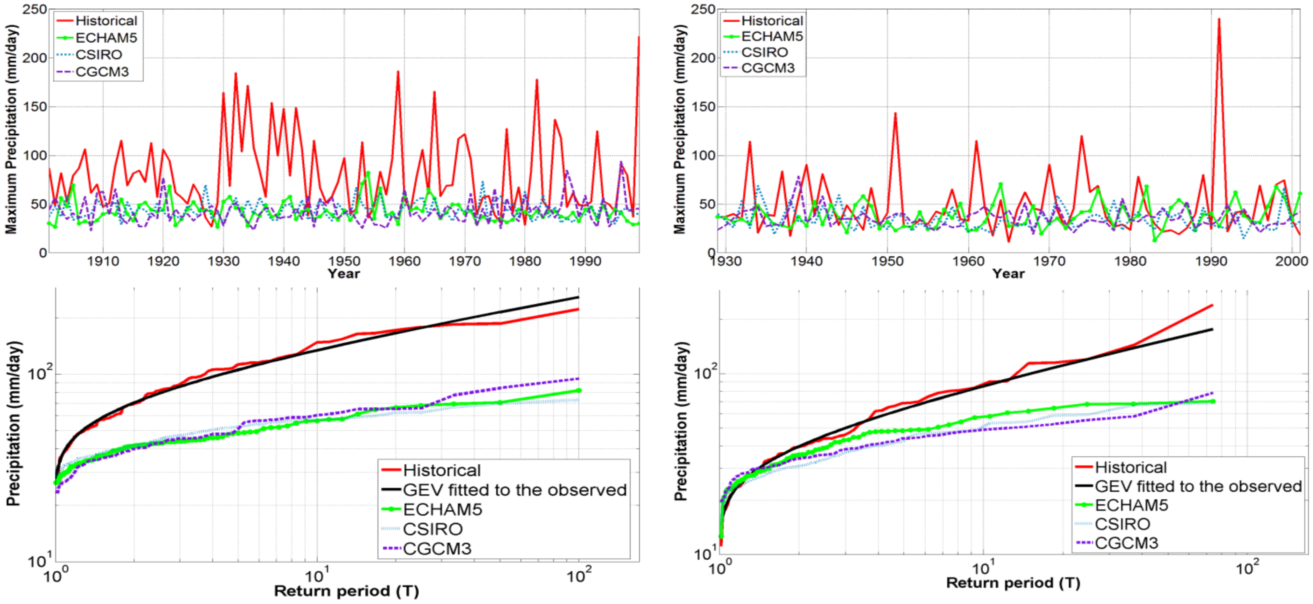


Do climate models simulate the real-world rainfall extremes?

- Tsaknias et al. (2016—multirejected paper) tested the reproduction of extreme events by three climate models of the IPCC AR4 at 8 test sites in the Mediterranean which had long time series of temperature and precipitation.
- They concluded that model results are **irrelevant to reality** as they seriously underestimate extreme events.

Upper row: Daily annual maximum precipitation at Perpignan and Torrevieja; Lower row: empirical distribution functions of the data in upper row.

Source: Tsaknias et al. (2016).



A scientific approach to extreme rainfall: The ombrian model

- An ombrian model (from the Greek ombros, meaning rainfall) describes the stochastic properties of the distribution of rainfall at any time scale.
- From an ombrian model that is simple enough, the ombrian relationships, also known with the misnomer rainfall intensity (x) – duration – frequency curves are directly extracted. Duration and frequency are meant to be time scale (k) and return period (T) respectively.
- For small time scales a Pareto distribution with discontinuity at the origin is assumed:

$$F^{(k)}(x) = 1 - P_1^{(k)} \left(1 + \xi \frac{x}{\lambda(k)}\right)^{-1/\xi}$$

- It is shown by theoretical reasoning (Koutsoyiannis, 2021b) that the tail index ξ is constant, while the probability wet, $P_1^{(k)}$, and the state scale parameter, $\lambda(k)$, are functions of the time scale k.
- For large time scales the Pareto-Burr-Feller (PBF) distribution is assumed:

$$F^{(k)}(x) = 1 - P_1^{(k)} \left(1 + \xi \left(\frac{x}{\lambda(k)}\right)^{\zeta(k)}\right)^{-1/\xi}$$

- In this case a new parameter $\zeta(k)$ is introduced, which is again a function of time scale. The Pareto distribution is a special case of PFB for $\zeta(k) = 1$. In contrast to the Pareto distribution, whose density is a decreasing function of x, the PBF tends to be bell-shaped for increasing $\zeta(k)$. Here we sacrifice the constancy of tail index ($= \xi/\zeta(k)$) to assure simplicity and ergodicity.

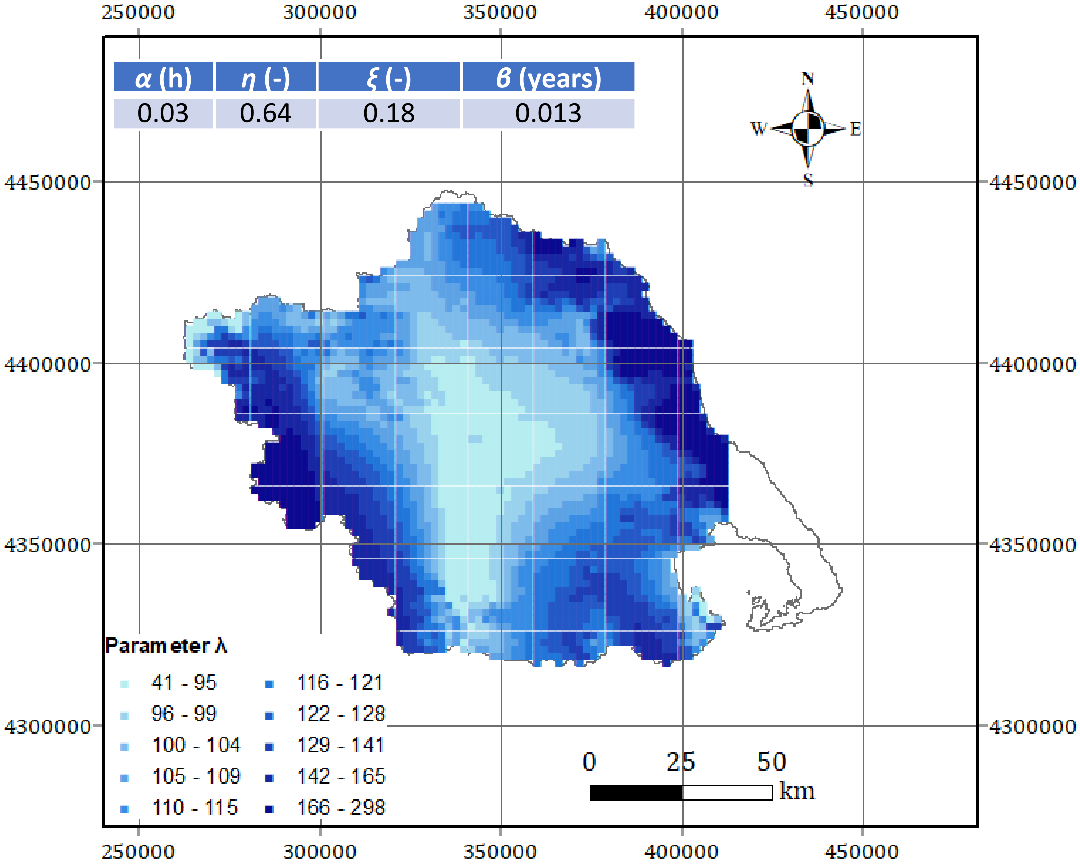
Ombrian model simplification and regionalization

- For small time scales (up to a few days), a simplification of the ombrian model is possible:

$$x = \lambda \frac{b(T)}{a(k)}, \; a(k) = \left(1 + \frac{k}{\alpha}\right)^{\eta}, \\ b(T) = \left(\frac{T}{\beta}\right)^{\xi} - 1$$

- This involves four parameters, $\alpha, \eta, \xi, \beta, \lambda$, with η related to the Hurst parameter and ξ being the tail index.
- Some of the parameters can be constant in large geographical areas, as in the example shown for Thessaly, Greece.

α (h)	η (-)	ξ (-)	β (years)
0.03	0.64	0.18	0.013



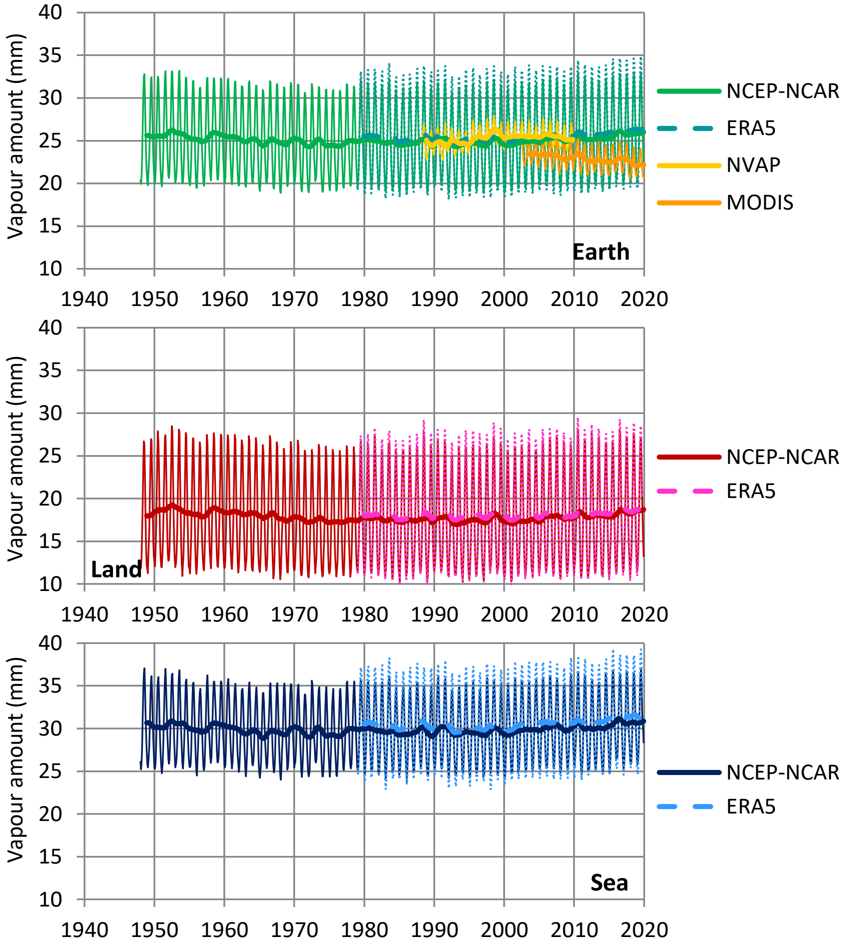
Source: Iliopoulou et al. (2022).

Are there alternative approaches? – The poor hydrological performance of climate models

- IPCC (2013a) conjectured that the **water vapour** amount in the atmosphere **would increase** and the **hydrological cycle would intensify**.
- However, the water vapour amount is fluctuating—not increasing monotonically (**prediction falsified**).

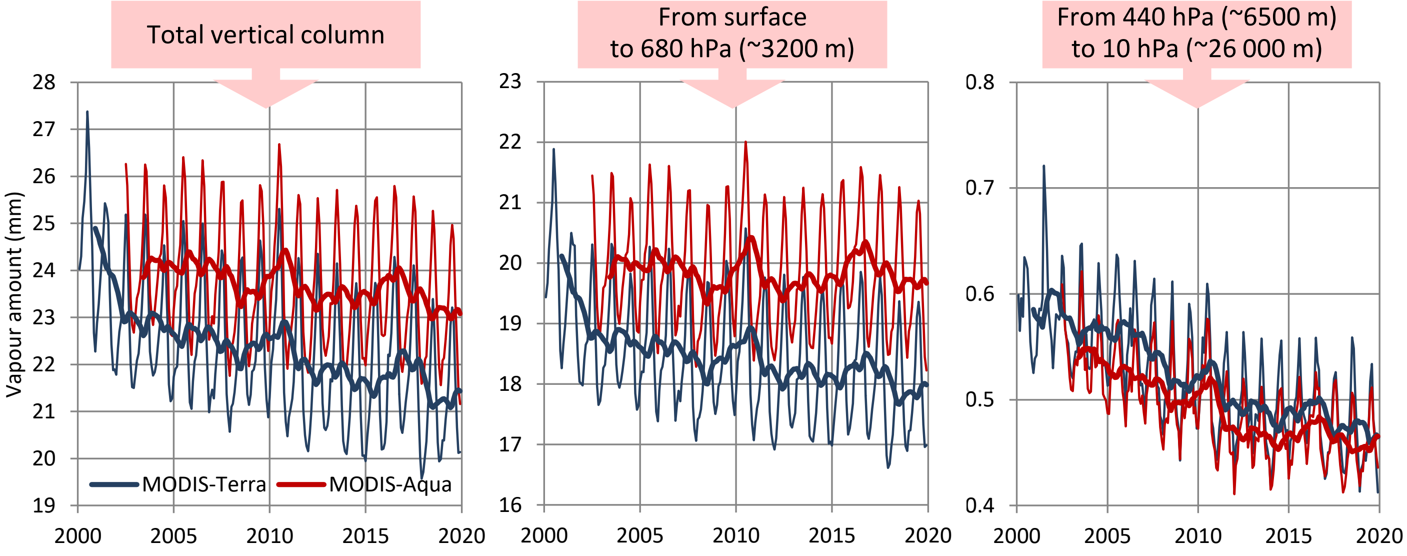
Thin and thick lines of the same colour represent monthly values and running annual averages (right aligned), respectively.

Source of graph: Koutsoyiannis (2020); reanalysis data (NCEP-NCAR & ERA5): http://climexp.knmi.nl; satellite data, NVAP: Vonder Haar et al. (2012) (Figure 4c, after digitization); satellite data, MODIS: https://giovanni.gsfc.nasa.gov/giovanni/; averages from Terra and Aqua platforms.



Do satellite data of the 21st century show increasing presence of water vapour amount?

- Both Terra and Aqua satellite platforms for all atmospheric levels suggest **decreasing** trends.
- Hence, the data are **opposite to the IPCC conjecture**. Apparently this suggests that climate models do not represent the physics correctly.



Source of graph: Koutsoyiannis (2020); MODIS data: https://giovanni.gsfc.nasa.gov/giovanni/ .

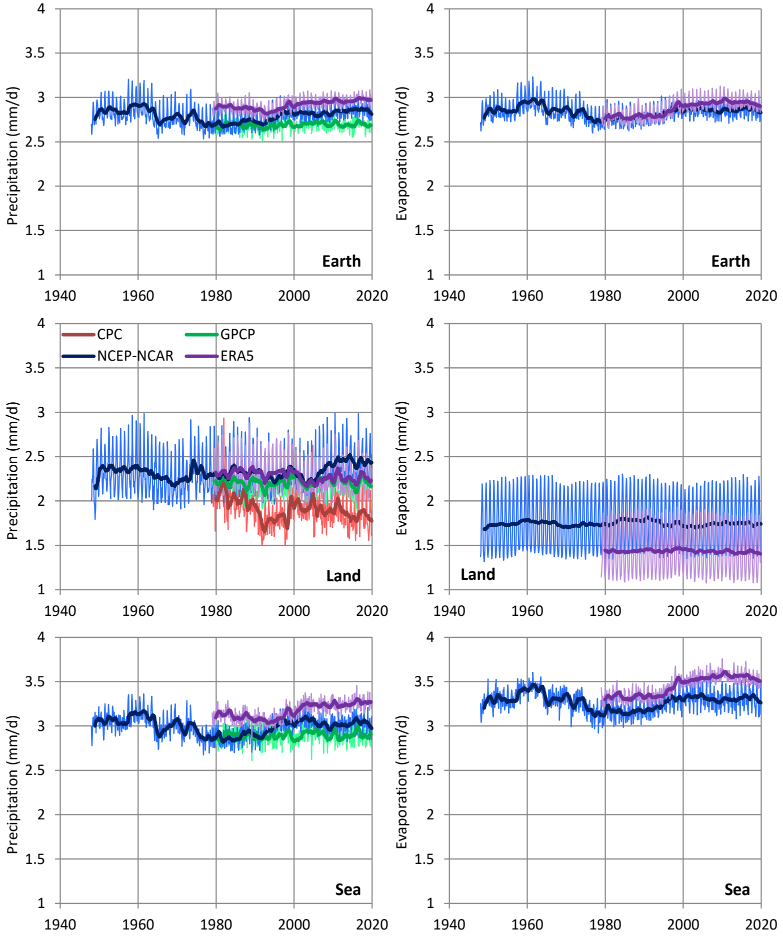
Thin and thick lines of the same colour represent monthly values and running annual averages (right aligned), respectively.

Do precipitation and evaporation increase?

- Both precipitation and evaporation are **fluctuating**—not increasing monotonically.
- Hence, **the IPCC conjecture is falsified**.

Thin and thick lines of the same colour represent monthly values and running annual averages (right aligned), respectively.

Source of graph: Koutsoyiannis (2020); reanalysis data (NCEP-NCAR & ERA5), gauge-based precipitation data gridded over land (CPC), and combined gauge and satellite precipitation data over a global grid (GPCP): http://climexp.knmi.nl.

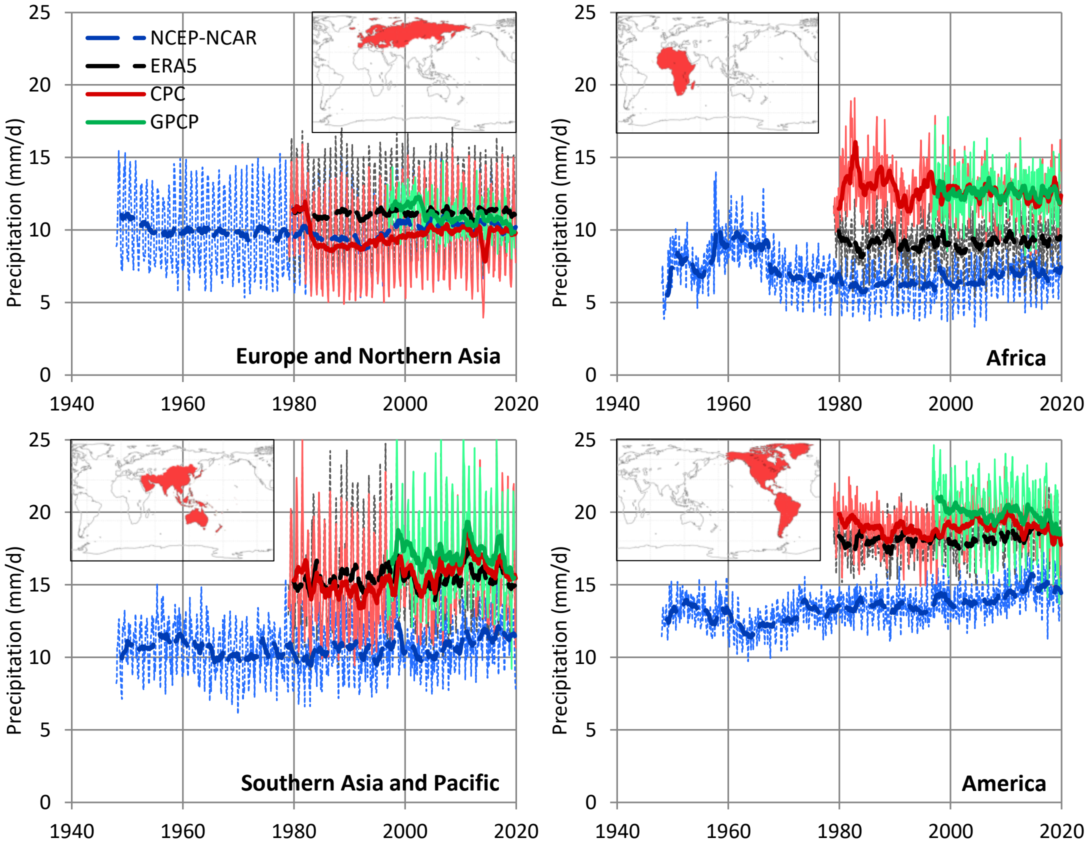


Is monthly maximum daily precipitation increasing?

- The graphs show the variation of an index of **extreme rainfall**, which is the monthly maximum daily precipitation, areally averaged over the continents.
- In all continents, this index is **fluctuating**—not increasing monotonically.
- In particular, the satellite observations show **decreasing**, rather than increasing trends in the 21st century.

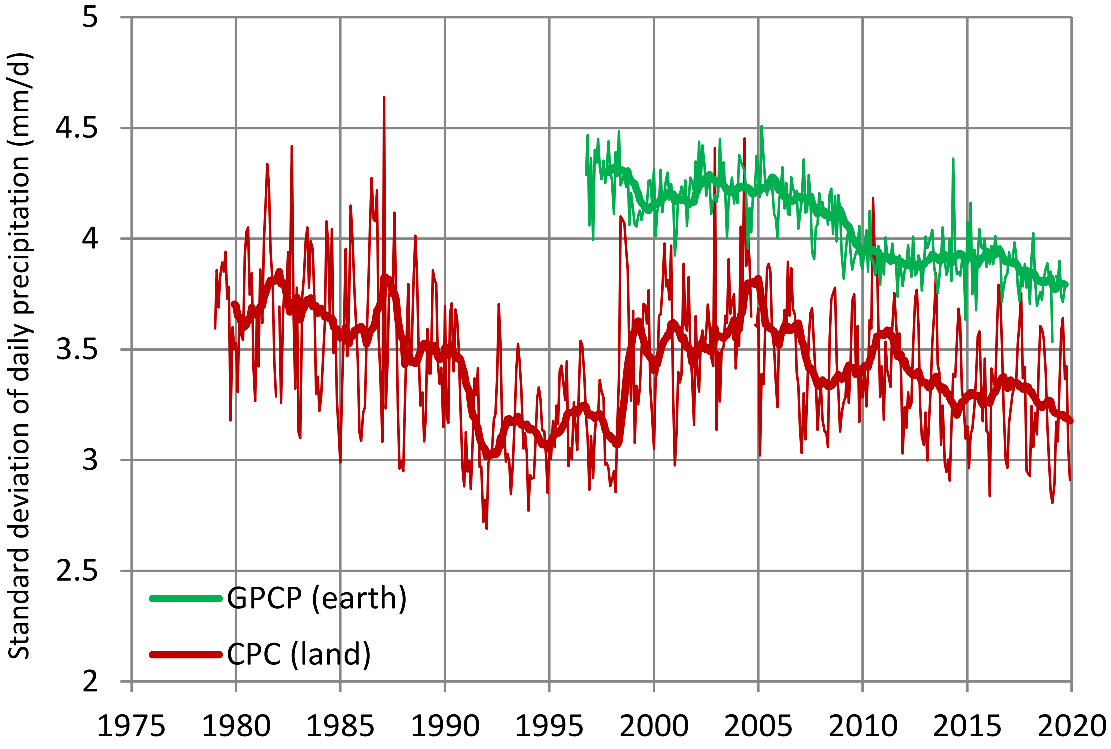
Thin and thick lines represent monthly values and running annual averages (right aligned).

Source of graph: Koutsoyiannis (2020); reanalysis data (NCEP-NCAR & ERA5, gauge-based precipitation data gridded over land (CPC), and combined gauge and satellite precipitation data over a global grid (GPCP): http://climexp.knmi.nl.



Is daily precipitation variability increasing?

- The standard deviation of daily rainfall, areally averaged, as seen both from CPC and GPCP observational data, decreases, thus **signifying deintensification of extremes** in the 21st century.
- Again, it will be more prudent to speak about **fluctuations** rather than deintensification.

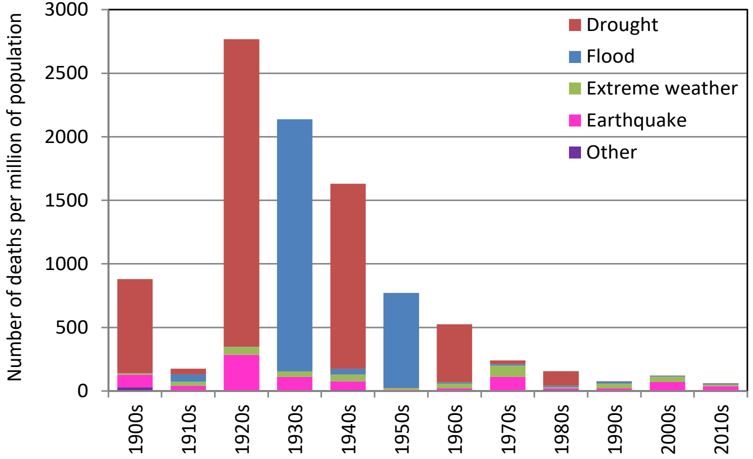


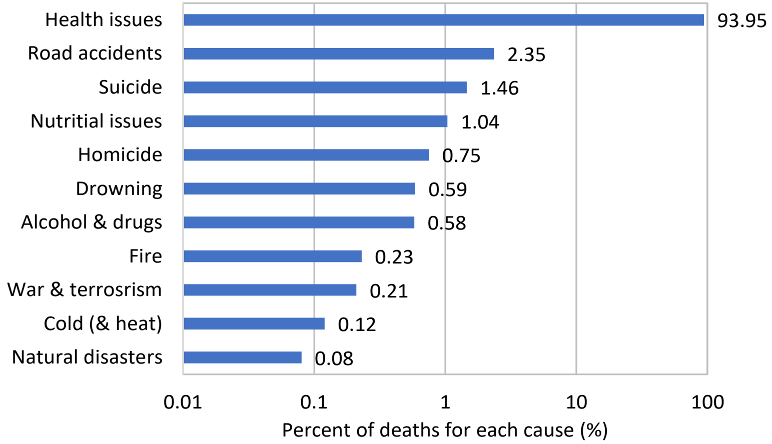
Thin and thick lines of the same colour represent monthly values and running annual averages (right aligned), respectively.

Source of graph: Koutsoyiannis (2020); gauge-based precipitation data gridded over land (CPC), and combined gauge and satellite precipitation data over the entire Earth (GPCP): http://climexp.knmi.nl.

Has the risk from extremes increased in the last century?

- The **risk from natural disasters** has been **spectacularly decreased**.
- Currently, it is in the bottom of the list of risks from all hazards.
- We **owe that decrease to engineering and technology**.
- Instead of casting pessimistic prophesies for the future, in the last century engineers improved hydro-technology, water management, and risk assessment and reduction.





Source: Koutsoyiannis (2021b).
Data from https://ourworldindata.org/world-population-growth; https://ourworldindata.org/ofdacred-international-disaster-data.

Final suggestions

- Let’s do science.
  - Abstain from the propaganda of “climate emergency”.
  - Abstain from supporting political agendas by turning science to sophistry.
- Let’s disregard climate model outputs, as well as trendy approaches inspired by the “climate crisis” agenda.
- Let’s base our estimates and predictions on observational data.
  - Exploit long time series even from sites at a distance from that of interest.
  - Study geographical variations.
  - Give more emphasis on most recent data.
- In dealing with droughts, let’s give importance to the Hurst-Kolmogorov behaviour
- In dealing with floods, let’s additionally give importance to the heavy distributional tails.
- Let’s be attentive on important statistical tasks.
  - Use robust techniques for parameter estimation of models to avoid biases.
  - Include faithful representation of uncertainty.
- Let’s be aware that a scientific approach to extremes relies on advanced stochastics.

More details in my book

In open access for free

Stochastics of Hydroclimatic Extremes is a real monument in stochastics! It is a summary of the lifetime dedication by Demetris Koutsoyiannis to the science of environmental extremes, it is a demonstration of the value of stochastics itself to gain a better understanding of why and how extremes happen. The perspective adopted in the book is that of a scientist who is able to cross and transform disciplines by proposing an innovative synthesis of knowledge. This book is indeed presenting new concepts, new theoretical interpretations and new opportunities for engineering design, for the sake of mitigating the impact of extremes and adapting modern society to environmental variability.

It is fascinating that the book is self-produced and openly available to readers. Like any self-produced creation of the humankind, this book has a unique and independent history that is rooted in the intimate personality of the author. It is a creation that does not require to adhere to any format other than those suggested by the author's vision and creativity. For this reason, its value is incommensurably high, it is a real *Cool Look at Risk* as Demetris says.

I believe time will highlight *Stochastics of Hydroclimatic Extremes* as a transforming masterpiece which will bring illuminating ideas to the reader.

Alberto Montanari
Head of the Dept. of Civil, Chemical, Environmental, and Materials Engineering, University of Bologna
President of the European Geosciences Union

This is a book that could not only transform your career, but also the entire fields of environmental statistics and stochastic hydrology. This seminal contribution is not like other books you have read which tend to summarize existing knowledge. Rather, it condenses existing knowledge in short order and spends nearly all its time on new knowledge, much of it never before published, communicating effectively both the theoretical and practical aspects of analysis of a wide range of hydroclimatic extremes. The style of presentation itself is novel and compelling, so that I could not resist reading it from cover to cover.

If you think you understand how to apply probability and statistics to predict future extreme events, think again, because very quickly you will be convinced that extremes arise from spatial and temporal stochastic processes, and are neither independent nor identically distributed (iid) events, nor do most of our common probability distributions used for flood and drought frequency analysis capture the type of thick tails which are so convincingly documented in this book.

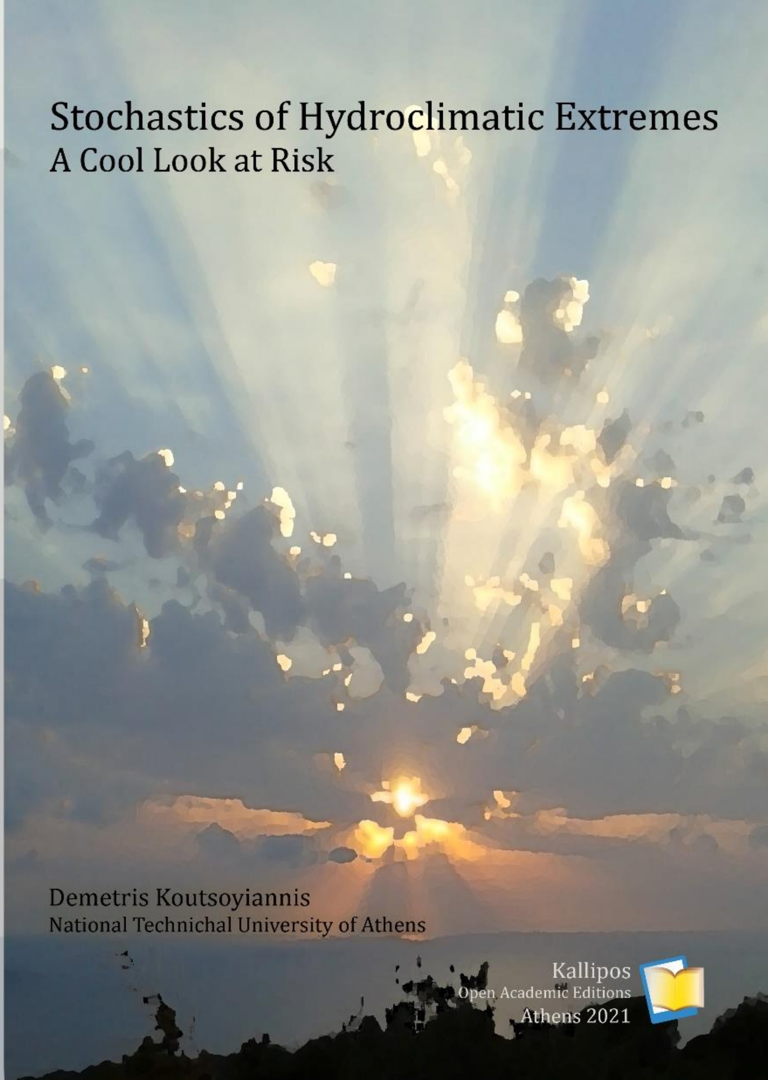
I predict that many of the novel concepts, examples and techniques introduced here, many for the first time, will find their way into widespread acceptance in hydroclimatology, over time. Foremost, the reader will appreciate the value of viewing extreme events as realizations of stochastic processes rather than a series of iid annual maxima/minima. The climacogram provides a new window into the structure of stochastic processes and may be more fundamental than the correlogram. I can't wait to test out the so-called Pareto-Burr-Feller distribution and the novel knowable moments (K-moments) which appear to have clear advantages over ordinary moments for describing distribution tails.

It is remarkable that after a long career in hydrology, after reading this book, I gained many new insights into common statistical methods as well as new methods documented here for the first time. How I wish my career were just beginning, and thus could have applied all the wonderful ideas and methods in this book during my career. This is literally a treasure for young scholars interested in the probabilistic behaviour of hydroclimatic extremes.

Richard M. Vogel
Professor Emeritus and Research Professor, Dept. Civil and Environmental Engineering, Tufts University

ISBN: 978-618-85370-0-2

Demetris Koutsoyiannis Stochastics of Hydroclimatic Extremes



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