Invited lectures at Beijing, China

- **National Institute of Natural Hazards, Haidian District – 11 July 2025**
- **Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences – 12 July 2025**

A cool look at hydroclimatic risk

Demetris Koutsoyiannis and Theano Iliopoulou
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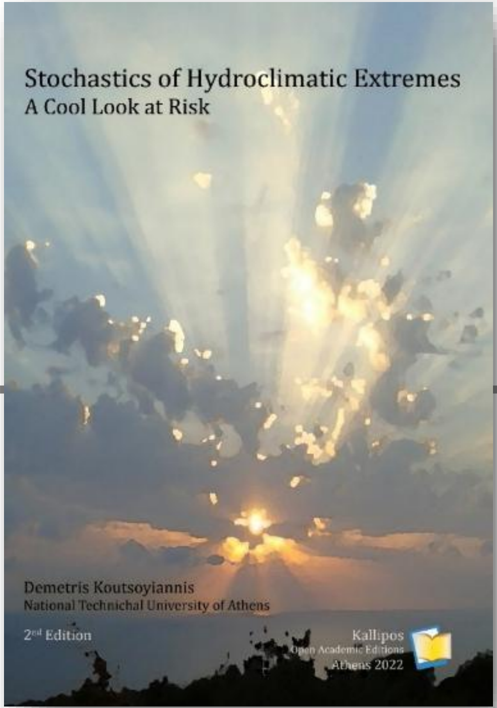
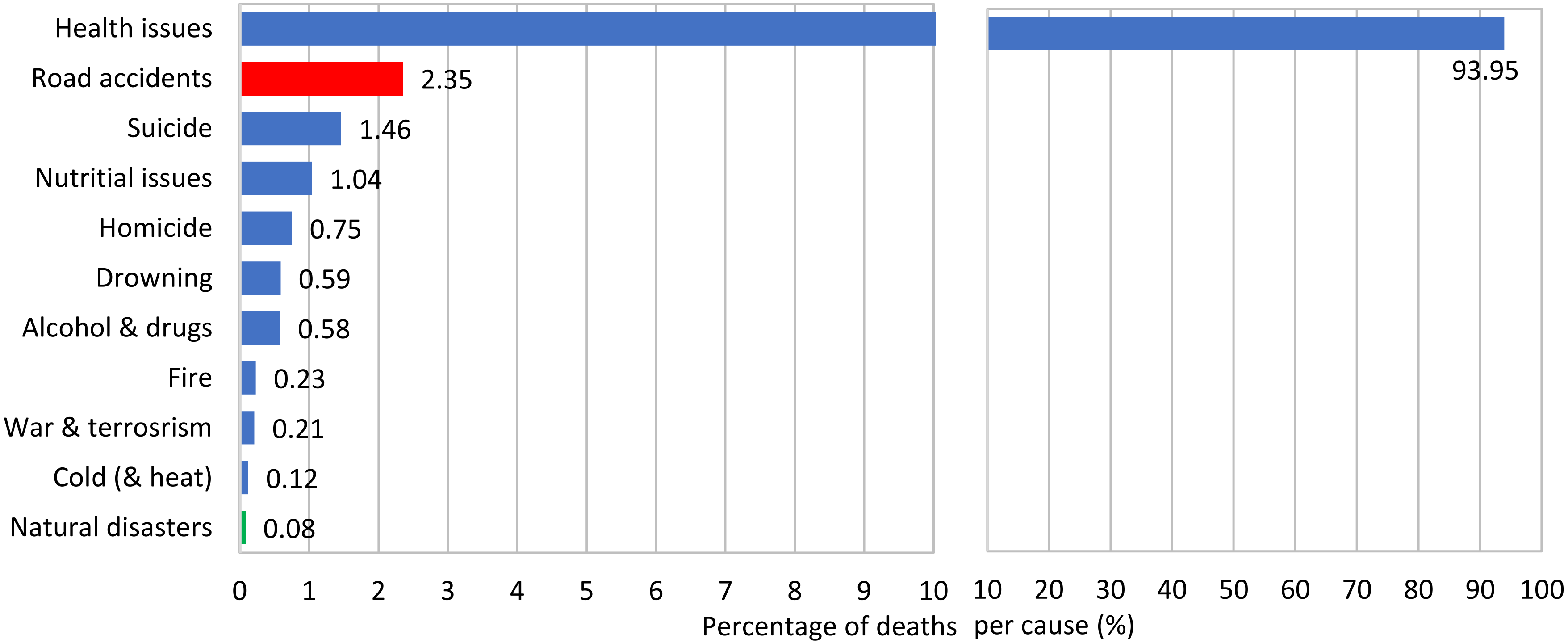
Available online: http://www.itia.ntua.gr/2546/

Part A
Introduction



https://www.itia.ntua.gr/2000/

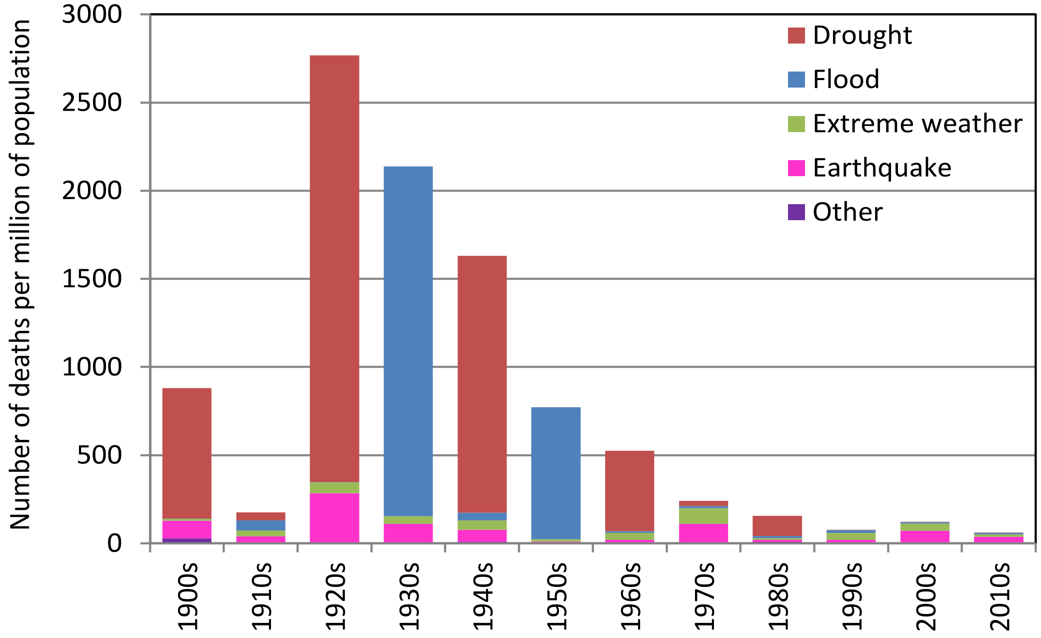
The ultimate risk index: deaths and classification of their causes



Source: Koutsoyiannis (2024) – Reference decade 2010

Question for thought: Why has the last risk category on the list been elevated as the greatest global policy issue?

Are fatalities from natural disasters increasing?



Source: Koutsoyiannis (2024).
Data from https://ourworldindata.org/world-population-growth;
https://ourworldindata.org/ofdacred-international-disaster-data

- Floods, droughts and other natural disasters have always occurred and will always do.
- The **risk from natural disasters** has been **spectacularly decreased**.
- 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.

Climate crisis is not a scientific issue; it's a political doctrine

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

https://civilprotection.gov.gr/klimatiki-krisi

https://press.un.org/en/2022/sgsm21228.doc.htm

- This assertion is illustrated by
  - (a) the decision of the European Parliament (Nov. 2019),
  - (b) the creation of the Ministry of Climate Crisis in Greece (Sep. 2021) and
  - (c) the announcement of the UN (Apr. 2022)
- **Question**: Which one is a bigger threat?
  - ❑ A natural climate crisis?
  - ❑ Or a political "climate crisis"?

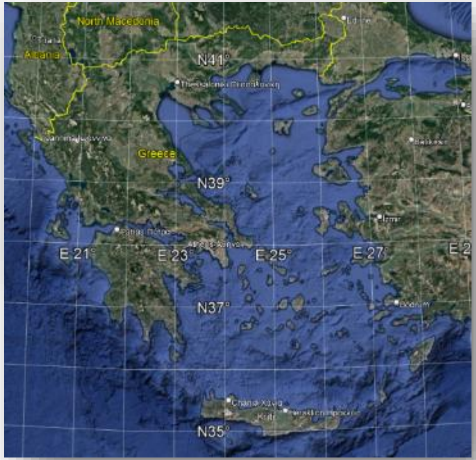
See also:
https://climath.substack.com/p/introducing-climath

Domains of climate analysis for this presentation

Global

Mediterranean

Greece



Why Mediterranean?

ipcc
INTERGOVERNMENTAL PANEL ON climate change

Climate Change 2021
The Physical Science Basis

10.6.4.6 Future Climate Information From Global Simulations

The Mediterranean is expected to be one of the most prominent and vulnerable climate change hotspots (Diffenbaugh and Giorgi, 2012). CMIP5, CMIP6, HighResMIP and CORDEX (Section 10.6.4.7)

Geophysical Research Letters

Climate | Free Access

Heat stress intensification in the Mediterranean climate change hotspot

sustainability MDPI

Review

A Literature Review of Climate-Related Coastal Risks in the Mediterranean, a Climate Change Hotspot

EGU European Geosciences Union — Earth System Dynamics

Article

Articles / Volume 13, issue 1 / ESD, 13, 321–340, 2022

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Article | Assets | Peer review | Metrics | Related articles

https://doi.org/10.5194/esd-13-321-2022

Research article | 08 Feb 2022

The Mediterranean climate change hotspot in the CMIP5 and CMIP6 projections

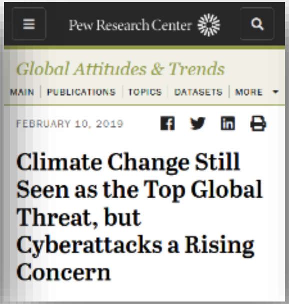
Why Greece?

- The Greek government is proud for the important innovation of establishing the Ministry of Climate Crisis.
- A Deep Search by Grok 3 suggested that Greece is the only country with a ministry titled "climate crisis“.
- Also, there are no countries with ministries including “climate emergency” in their title.

https://civilprotection.gov.gr/klimatiki-krisi
(Automatically translated to English)

Why Greece (2): «Golden Raspberry Awards» to Greeks

- The table on the right shows the results of the most recent (2022) polls on the percentage of the population of various countries that feel fear for the alleged climate threat.
- Greeks consistently top the list with the following percentages. 2007-08: 82%, 2010: 87%, 2013: 87%, 2019: 90%, 2022: 86%



Sources:
https://www.pewresearch.org/global/2022/08/31/climate-change-remains-top-global-threat-across-19-country-survey/
https://www.pewresearch.org/global/2019/02/10/climate-change-still-seen-as-the-top-global-threat-but-cyberattacks-a-rising-concern/
https://www.pewresearch.org/global/2013/06/24/climate-change-and-financial-instability-seen-as-top-global-threats/
https://news.gallup.com/poll/147203/Fewer-Americans-Europeans-View-Global-Warming-Threat.aspx

THE TOP FOUR	
Greece	86%
Italy	82%
Japan	82%
South Korea	82%
THE MIDDLE FOUR	
The Netherlands	77%
Belgium	75%
United Kingdom	75%
Germany	73%
THE BOTTOM FOUR	
Singapore	57%
USA	54%
Israel	47%
Malaysia	44%

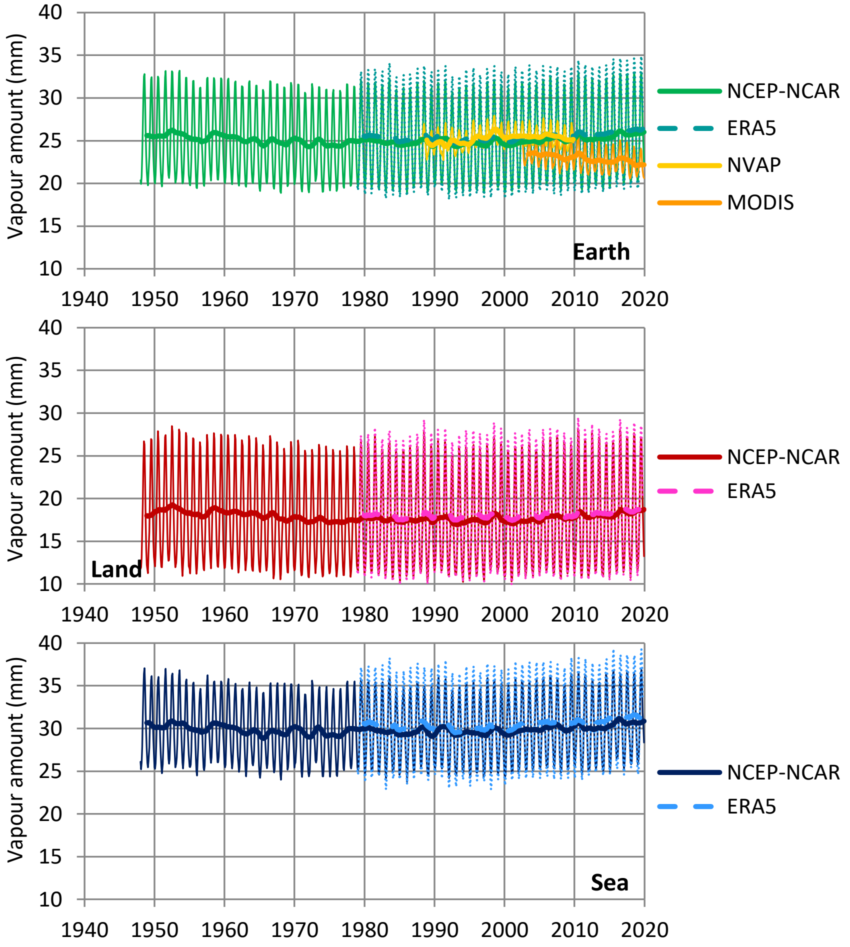
Part B
Global hydrology

Does atmospheric water show intensification of hydrological cycle?

- IPCC (2013,2021) 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**).

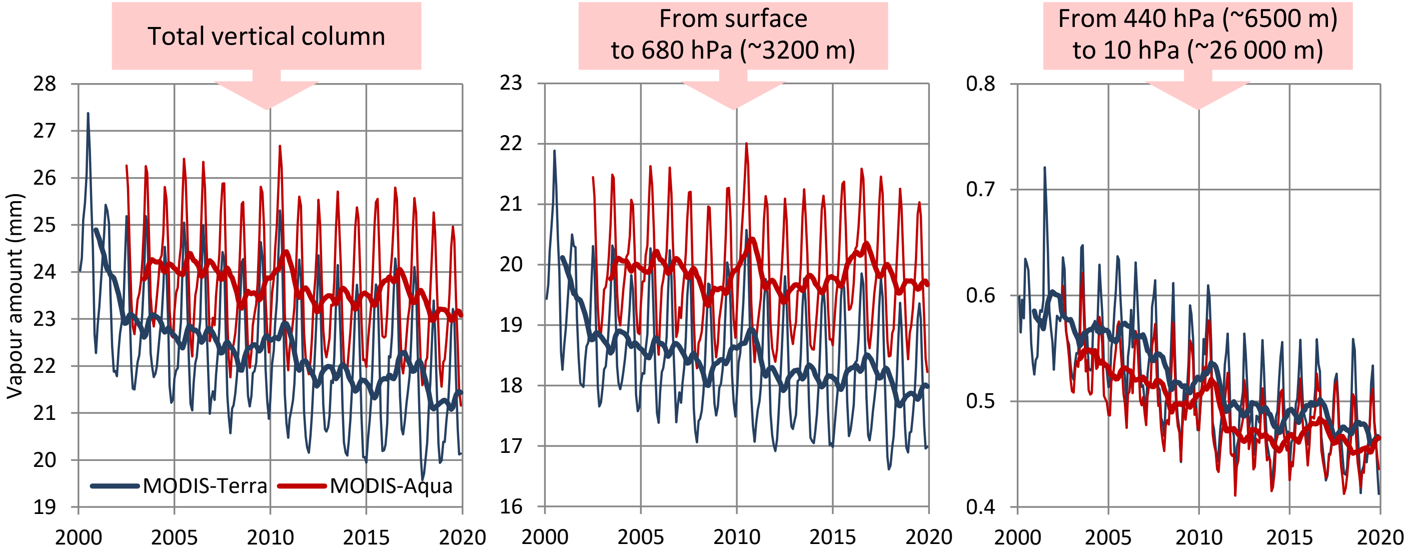
Thin and thick lines of the same colour represent monthly values and running annual averages (right aligned), respectively.

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/

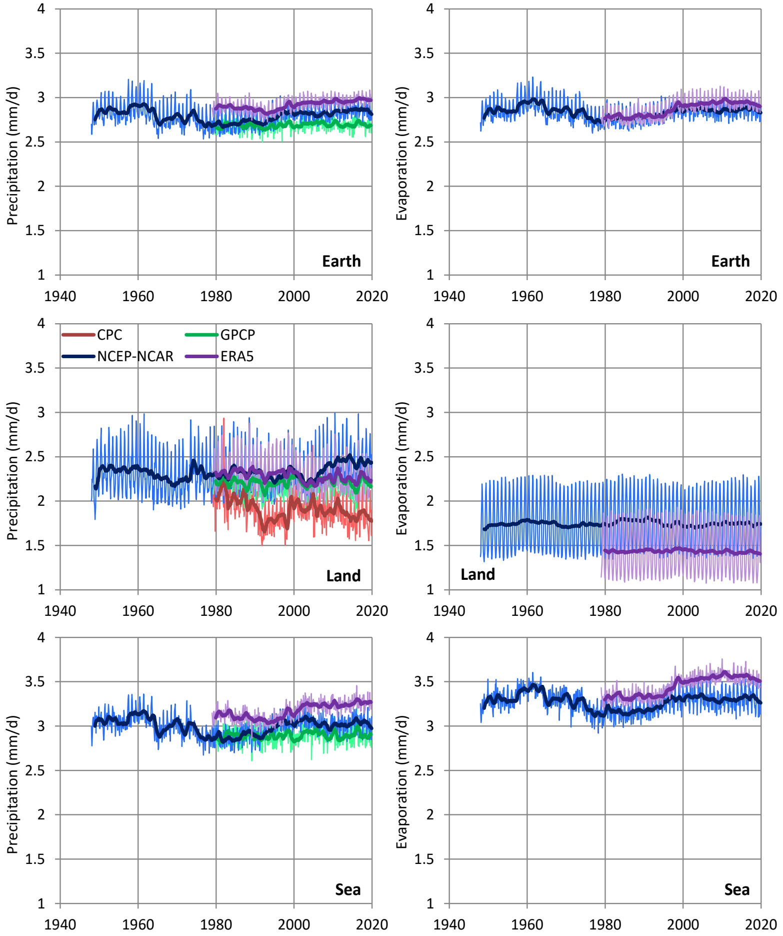
Thin and thick lines of the same colour represent monthly values and running annual averages (right aligned), respectively.

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

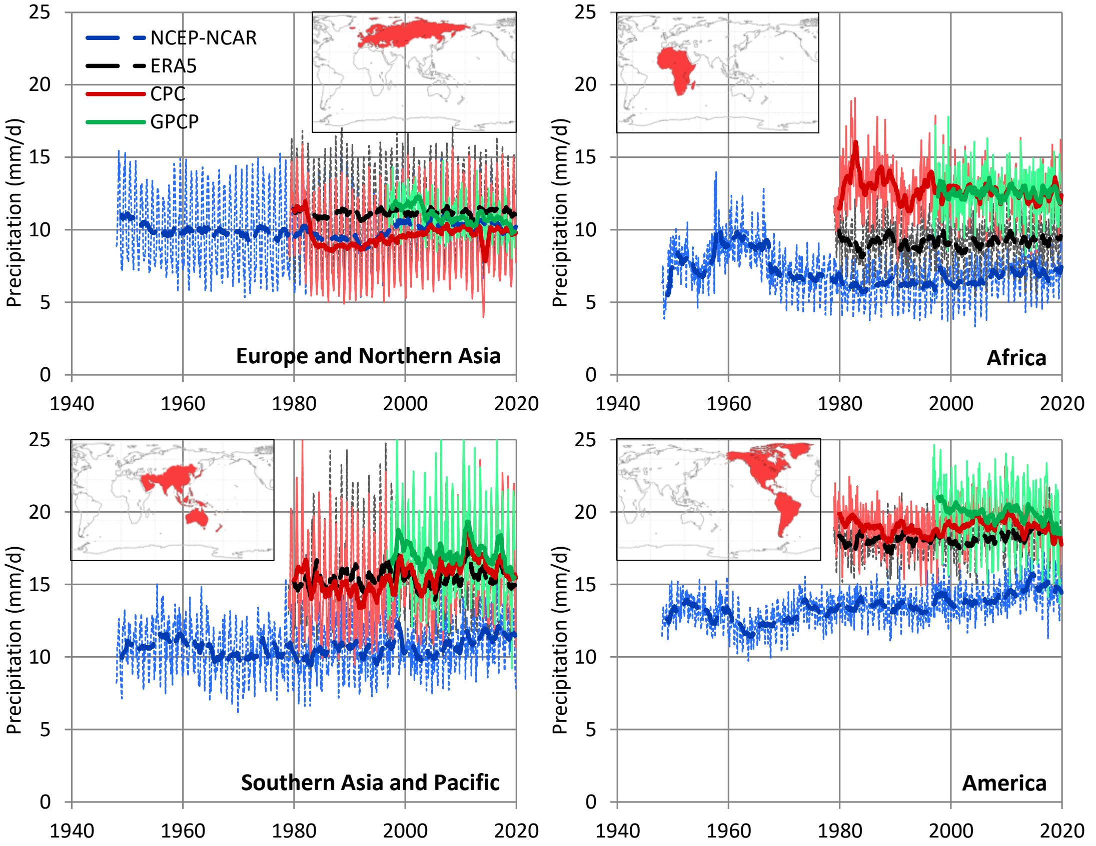


Is monthly maximum daily precipitation increasing?

- 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.

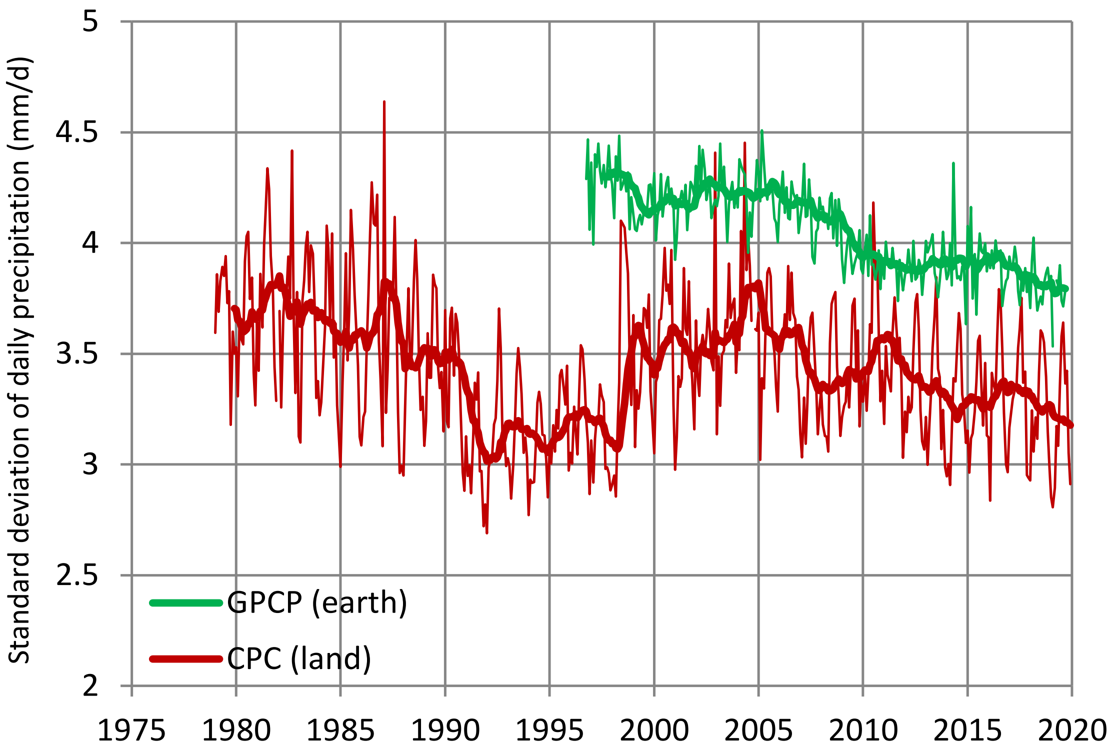
Thin and thick lines represent monthly values and running annual averages (right aligned).

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

Have droughts been affected by humans?

From the abstract: “No evidence is found for any systematic trend in precipitation deficits attributable to anthropogenic climate change…”

hydrology MDPI

The Spatial Scale Dependence of The Hurst Coefficient in Global Annual Precipitation Data, and Its Role in Characterising Regional Precipitation Deficits within a Naturally Changing Climate

by Enda O'Connell [1,*], Greg O'Donnell [1] and Demetris Koutsoyiannis [2]

Hydrology **2022**, *9*(11), 199; https://doi.org/10.3390/hydrology9110199

Hurst's seminal characterisation of long-term persistence (LTP) in geophysical records more than seven decades ago continues to inspire investigations into the Hurst phenomenon, not just in hydrology and climatology, but in many other scientific fields. Here, we present a new theoretical development based on stochastic Hurst–Kolmogorov (HK) dynamics that explains the recent finding that the Hurst coefficient increases with the spatial scale of averaging for regional annual precipitation. We also present some further results on the scale dependence of H in regional precipitation, and reconcile an apparent inconsistency between sample results and theory. LTP in average basin scale precipitation is shown to be consistent with LTP in the annual flows of some large river basins. An analysis of the crossing properties of precipitation deficits in regions exhibiting LTP shows that the Hurst coefficient can be a parsimonious descriptor of the risk of severe precipitation deficits. No evidence is found for any systematic trend in precipitation deficits attributable to anthropogenic climate change across the regions analysed. Future precipitation deficit risk assessments should, in the first instance, be based on stochastic HK simulations that encompass the envelope of uncertainty synonymous with LTP, and not rely exclusively on GCM projections that may not properly capture long-term natural variability in the climate.

4.3. Characteristics Of Precipitation Deficits For The Eight Ltp Regions

The analysis of the crossing properties of average regional precipitation deficits using the 1900–2013 data set shows that some regions encountered deficits predominantly in the early part of the 20th century, while other regions were in surplus over the same period. The averages of the D, SV and I statistics across the eight regions for each year suggest that there is a levelling up of the crossings between the first and second half of the record (**Figure 12**), and with relatively low volumes in the middle period. The grand averages for Periods 1–3 (**Table 5**(i) and **Figure 13**(i)) do not suggest that there is any intensification of precipitation deficits in Period 3 that might be attributed to ACC. On the contrary, the statistics suggest that Period 1 is characterised by more severe deficits, with the lowest deficits and intensities below the MSD level in Period 2.

4.4. Precipitation Deficits, Droughts And Anthropogenic Climate Change

In analysing the evidence for any recent global warming influence on precipitation deficits, the IPCC [32] noted that, while some regions of the world had recorded strong precipitation deficits in recent decades, other regions had not. They noted that global studies had generally shown no significant trends in SPI time series, and in derived drought frequency and severity data, and concluded that natural climatic variability is still the dominant mode of variability governing precipitation deficits and droughts, and, by implication, LTP. This conclusion is supported by our findings here, where we have not seen any clear evidence of intensification in precipitation data up to and including 2020 (**Table 5** and **Figure 13**). Moreover, the narrative on causality continues to evolve [33,34,35,36].

Scientific investigations frequently start from the premise that ACC is an explanatory factor, and set out to prove it, whereas a more conventional scientific approach would be to adopt the Null Hypothesis that natural climatic variability is a causal factor, and to test the Alternative Hypothesis that it is ACC. In this regard, the use and misuse of trend tests, and the misunderstanding of stationarity have been analysed and discussed in a number of papers (e.g., [43,44,45,46]), and it is good to see that more considered approaches are now emerging in the literature (e.g., [47,48,49]). That ACC can be a factor influencing droughts is not in question, but based on current evidence, natural climatic variability remains the main driver of precipitation deficits in regions affected by LTP, but care is needed that apparent trends resulting from LTP are not misinterpreted as evidence of ACC.

From a multi-decadal analysis of the crossing properties, no evidence was found to show that there has been any increase in precipitation deficits in recent decades that might be attributable to global warming. Precipitation deficits are a consequence of natural climatic variability/the level of LTP, so the Hurst coefficient and HK stochastic simulations conditioned on a historic data set should be used to test water resource system resilience and robustness, and not rely exclusively on GCM projections that do not reproduce the LTP in observational records.

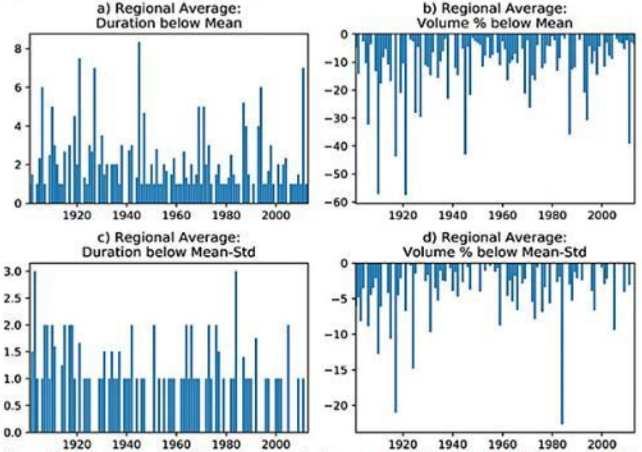


Figure 12. Regional averages of deficit duration and volume percentage for each year for the mean and MSD crossing levels, 1901–2013.

- Period 1: 1901–1938 (38 years)
- Period 2: 1939–1976 (38 years)
- Period 3: 1977–2013 (37 years)

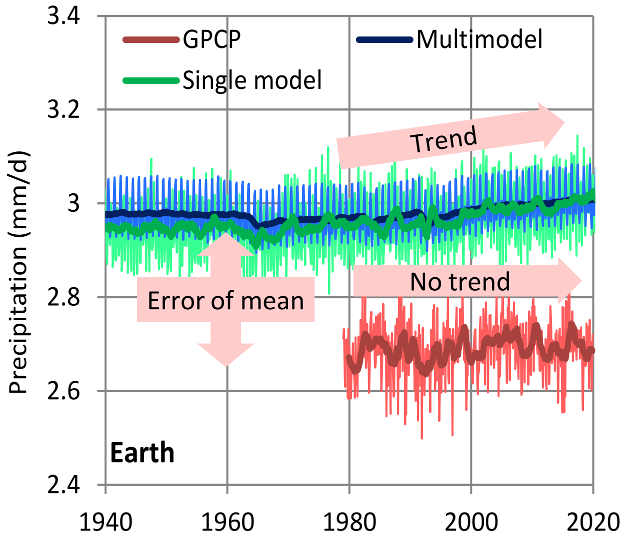
O'Connell et al. (2022); see also https://notrickszone.com/2023/02/20/random-probability-analysis-of-global-drought-data-affirm-no-pattern-can-be-linked-to-human-activity/

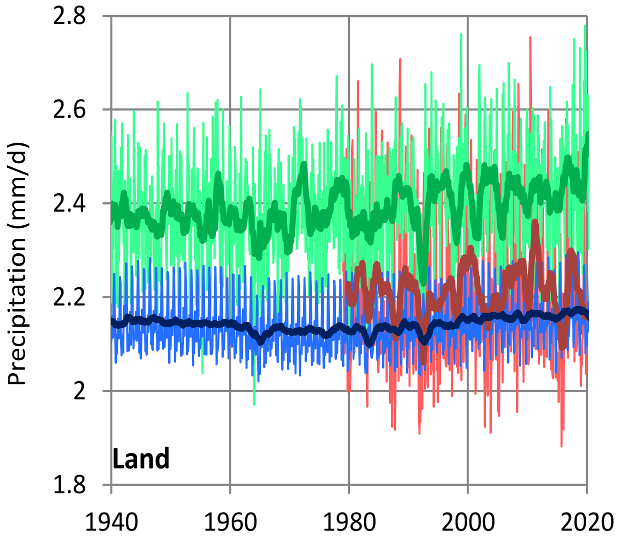
Do climate models provide guidance for the future?

- 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






water

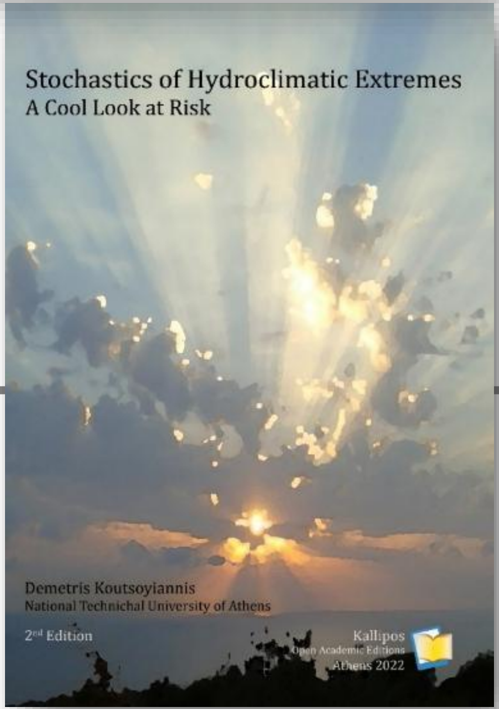
MDPI

Article

In Search of Climate Crisis in Greece Using Hydrological Data: 404 Not Found

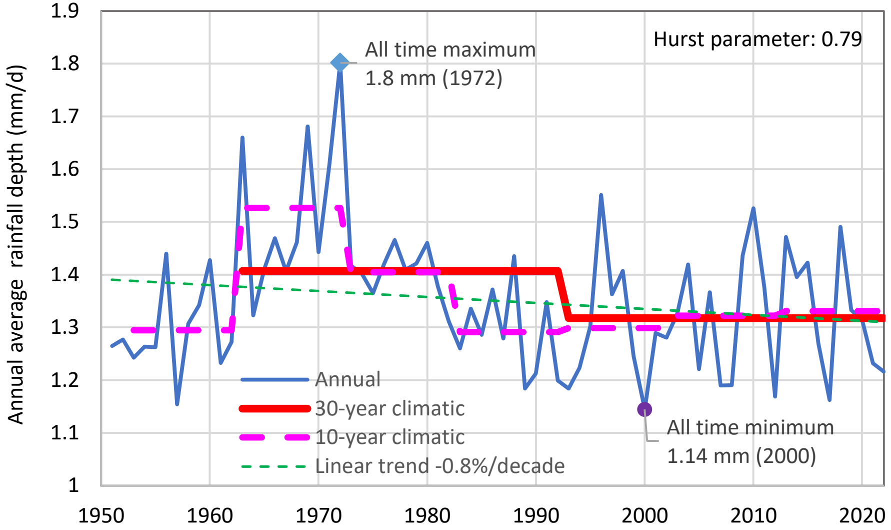
Demetris Koutsoyiannis [1,*], Theano Iliopoulou [1], Antonis Koukouvinos [1], Nikolaos Malamos [2], Nikos Mamassis [1], Panayiotis Dimitriadis [1], Nikos Tepetidis [1] and David Markantonis [1]

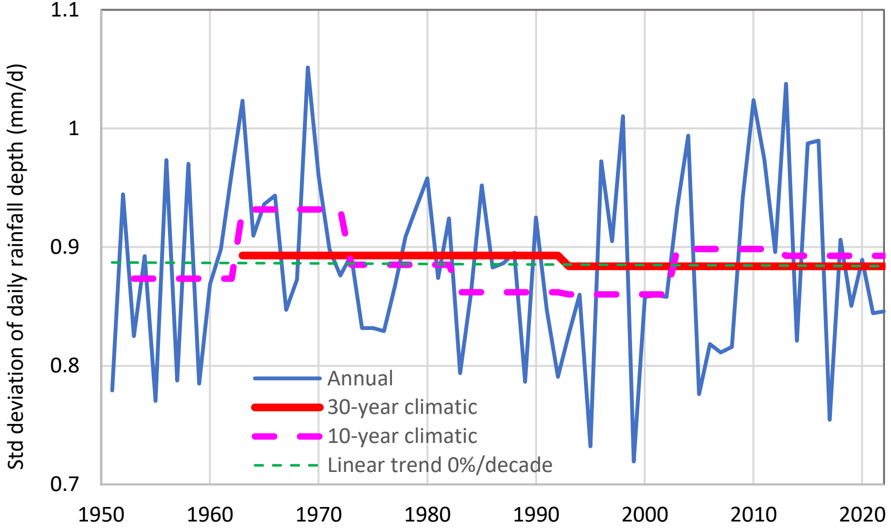
Part C
Hydrology of the Mediterranean



https://www.itia.ntua.gr/2000/

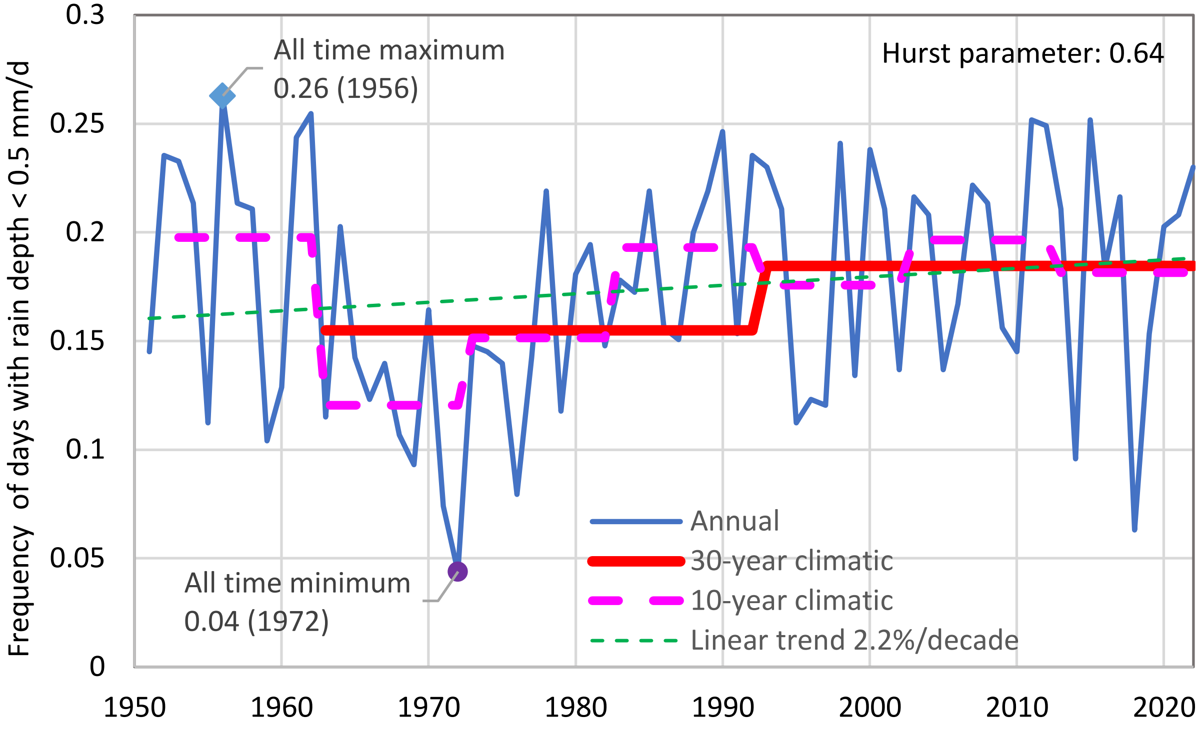
Do rainfall data of the Mediterranean suggest a climate crisis at present and recent past?





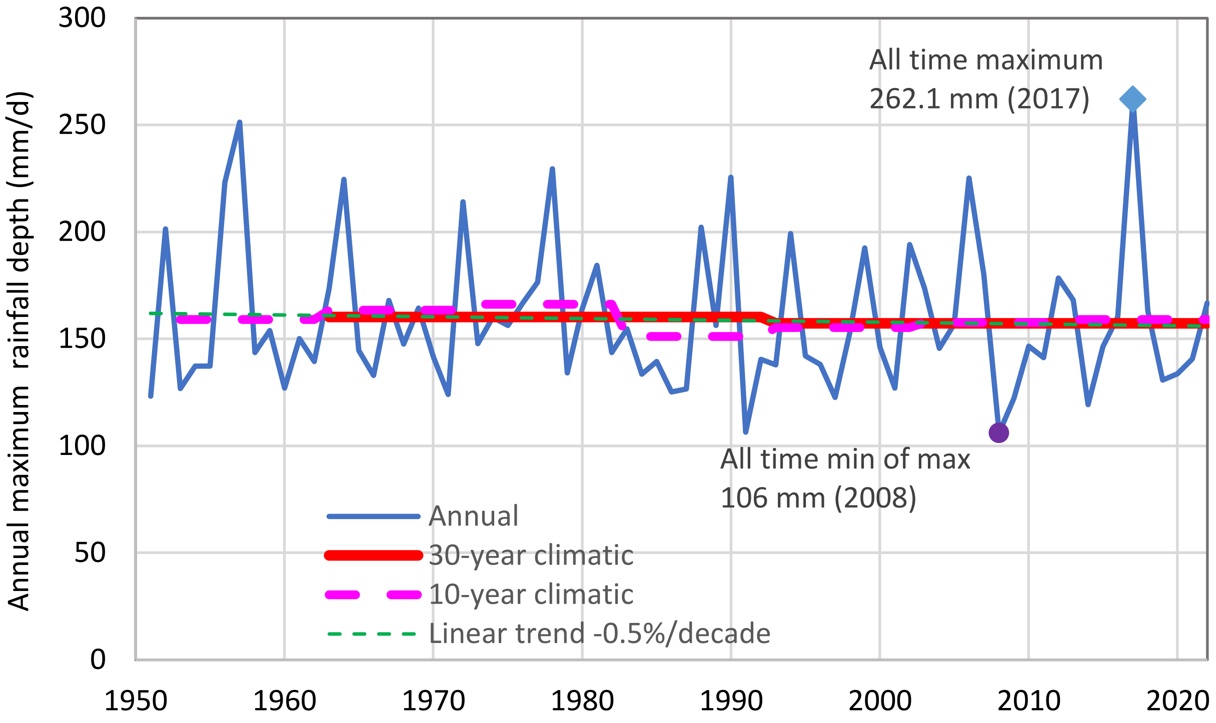
Source of data: Daily gridded data from the European ERA5 reanalysis, http://climexp.knmi.nl. The data are averages for the area 30°N-46°N, 6°W- 36°E; the graphs are for land points only, but no essential difference appears if the sea points are also considered.

Does rainfall frequency in the Mediterranean suggest unprecedented droughts at present and recent past?



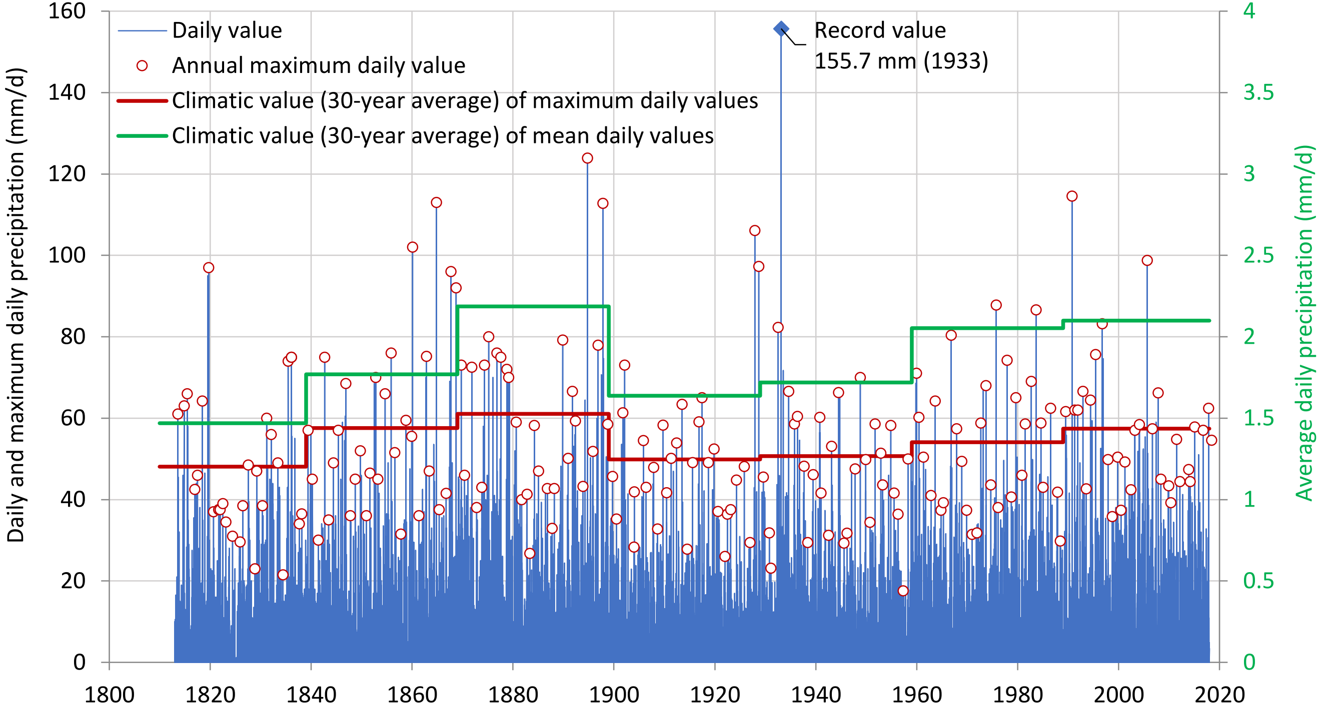
Source of data: Daily gridded data from the European ERA5 reanalysis, http://climexp.knmi.nl. The data are averages for the area 30°N-46°N, 6°W-36°, from which the number of days with average rainfall depth < 0.1 mm was calculated for each year; the graphs are for land points only, but no essential difference appears if the sea points are also considered.

Does maximum rainfall in the Mediterranean suggest unprecedented intensities at present and recent past?



Source of data: Daily gridded data from the European ERA5 reanalysis, http://climexp.knmi.nl. The data are maxima for the area 30°N-46°N, 6°W-36°E; the graphs are for land points only, but no essential difference appears if the sea points are also considered.

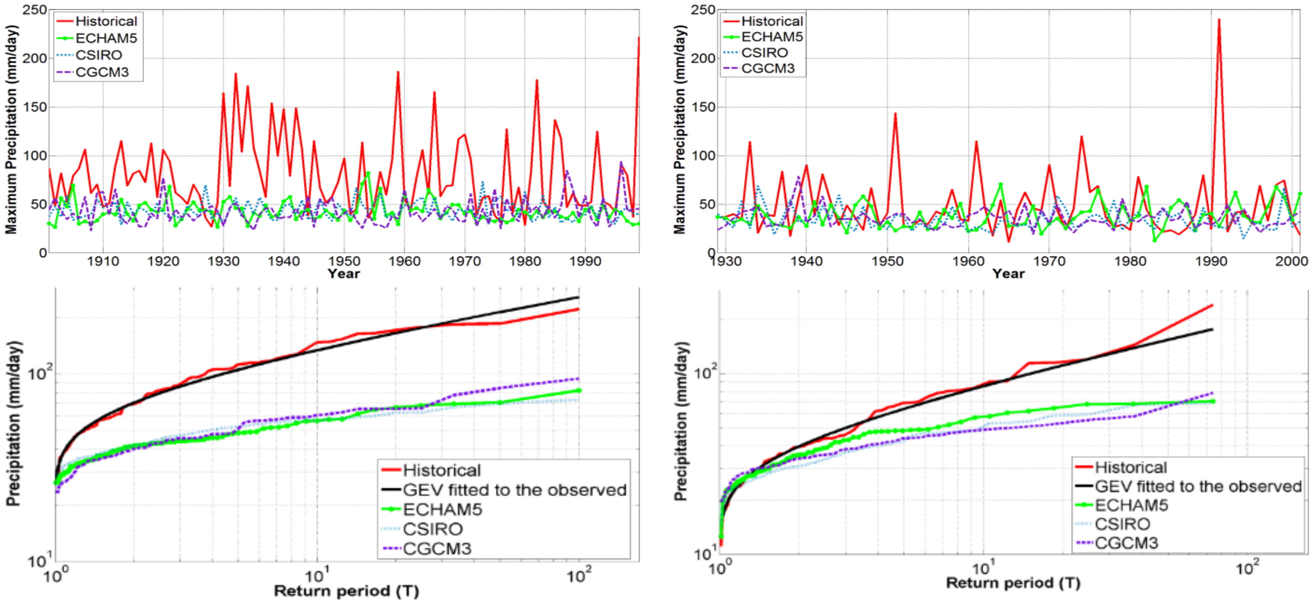
Do long rainfall records in the Mediterranean suggest unprecedented changes at present and recent past?



- Bologna, Italy: 206 years of data since 1813.
- Change is perpetual.
- This change can be described in terms of Hurst-Kolmogorov stochastic dynamics (Hurst parameter 0.86).

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)

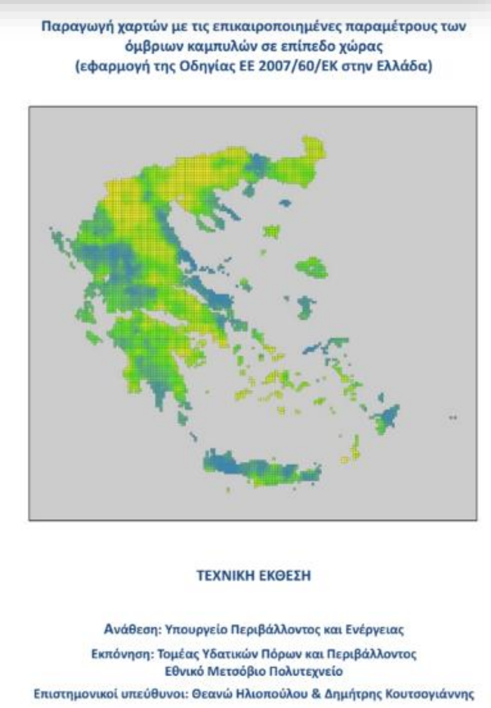
water

MDPI

Article

In Search of Climate Crisis in Greece Using Hydrological Data: 404 Not Found

Demetris Koutsoyiannis [1,*], Theano Iliopoulou [1], Antonis Koukouvinos [1], Nikolaos Malamos [2], Nikos Mamassis [1], Panayiotis Dimitriadis [1], Nikos Tepetidis [1] and David Markantonis [1]



Παραγωγή χαρτών με τις επικαιροποιημένες παραμέτρους των όμβριων καμπυλών σε επίπεδο χώρας
(εφαρμογή της Οδηγίας ΕΕ 2007/60/ΕΚ στην Ελλάδα)

ΤΕΧΝΙΚΗ ΕΚΘΕΣΗ

Ανάθεση: Υπουργείο Περιβάλλοντος και Ενέργειας

Εκπόνηση: Τομέας Υδατικών Πόρων και Περιβάλλοντος
Εθνικό Μετσόβιο Πολυτεχνείο

Επιστημονικοί υπεύθυνοι: Θεανώ Ηλιοπούλου & Δημήτρης Κουτσογιάννης

Part D
Hydrology of Greece

Acknowledgment: Special thanks to the *General Directorate of Water* of the Greek *Ministry of Environment and Energy* for the commissioning of the study and the collaboration.

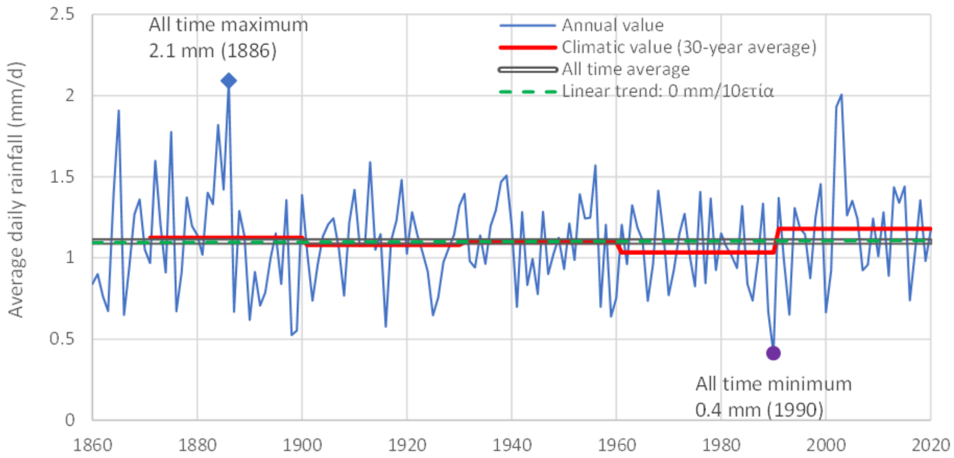
ΥΠΟΥΡΓΕΙΟ ΠΕΡΙΒΑΛΛΟΝΤΟΣ & ΕΝΕΡΓΕΙΑΣ

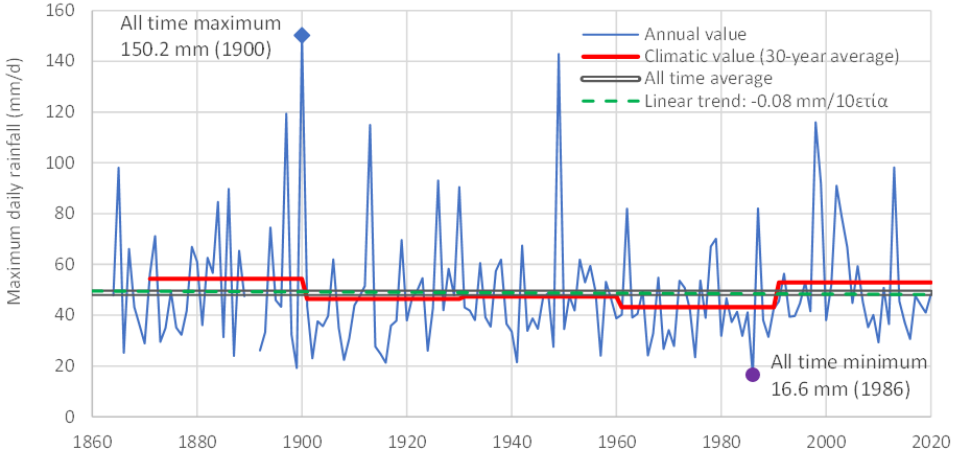
Ευρωπαϊκή Ένωση
Ταμείο Συνοχής

ΕΣΠΑ 2014-2020
ανάπτυξη - εργασία - αλληλεγγύη

The Athens rainfall time series, the longest in Greece

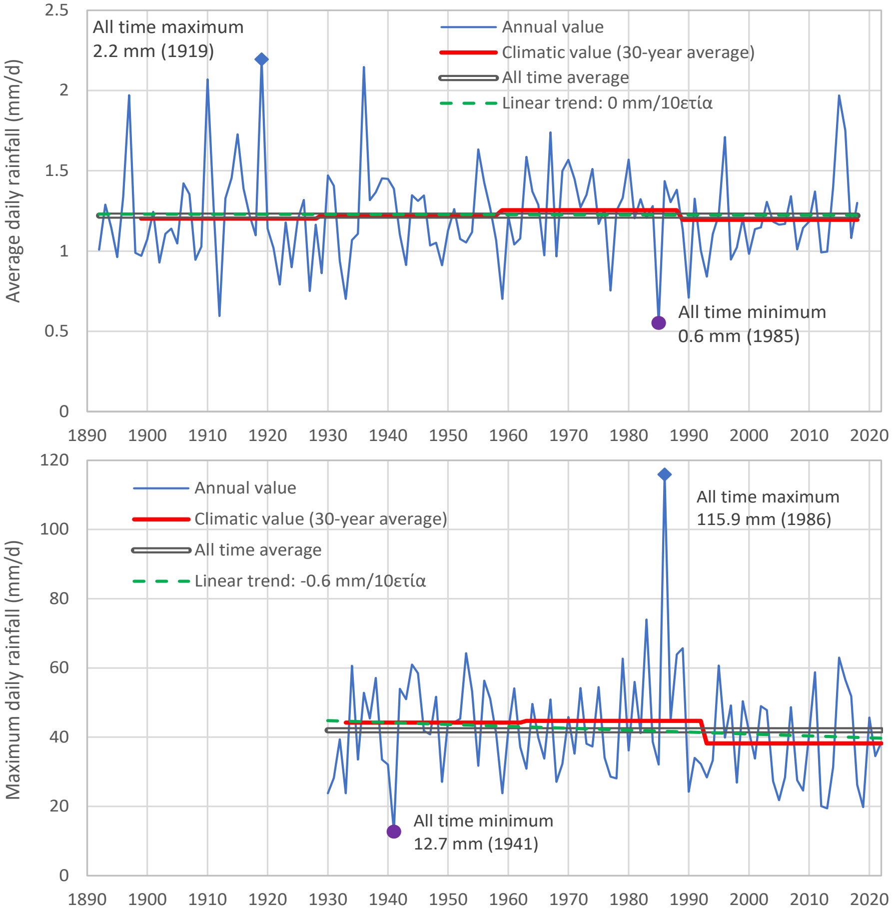
- Compared to Bologna, Athens shows climate stability.
- In the last 30 years there has been no remarkable climatic event.
- The largest annual rainfall in history was recorded in the hydrological year 1885-86, and the smallest in 1989-90.
- The all-time high record of rainfall depth, 150.2 mm/d, occurred at the end of the 19th century (1899-90).





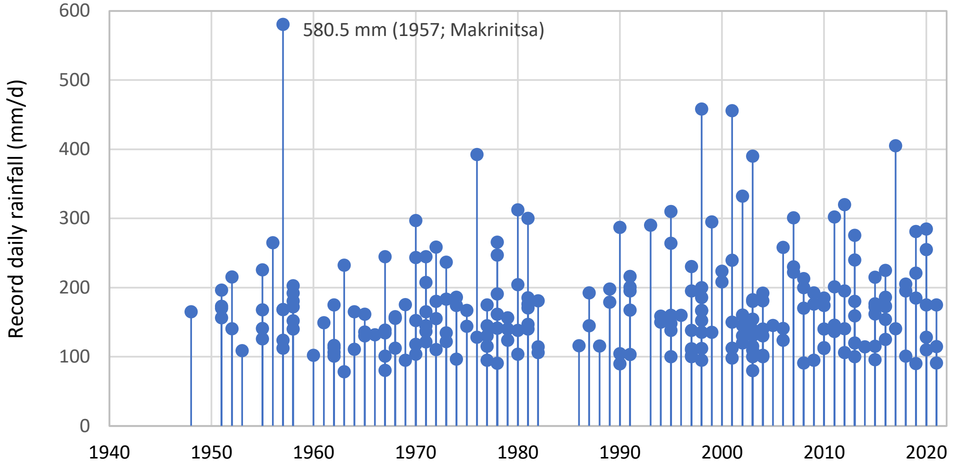
The Thessaloniki rainfall time series, the second longest in Greece

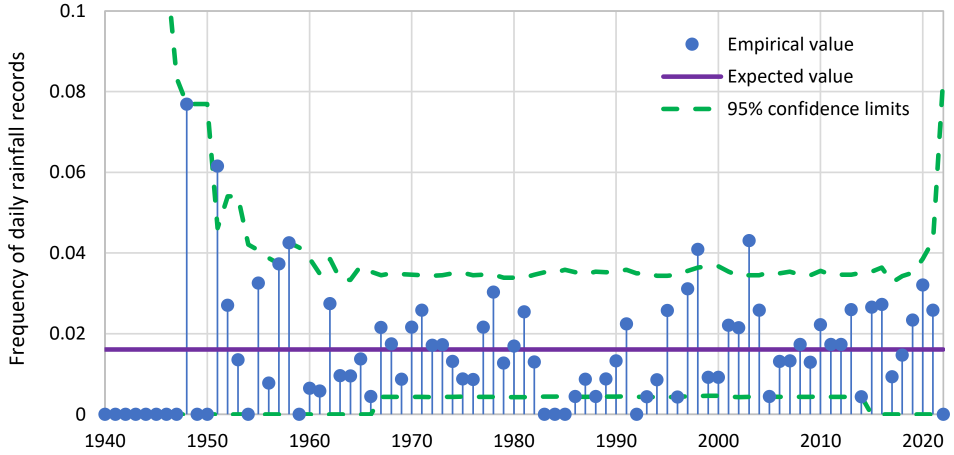
- Thessaloniki shows climatic stability, similar to Athens.
- In the last thirty years there has been no remarkable climatic event.
- The largest annual rainfall in history was recorded in the hydrological year 1918-19, and the smallest in 1984-85.
- The all-time high record of rainfall depth, 115.9 mm/d, occurred in the hydrological year 1985-86.



Record high daily rainfall occurrence in the 238 stations with longest time series in Greece

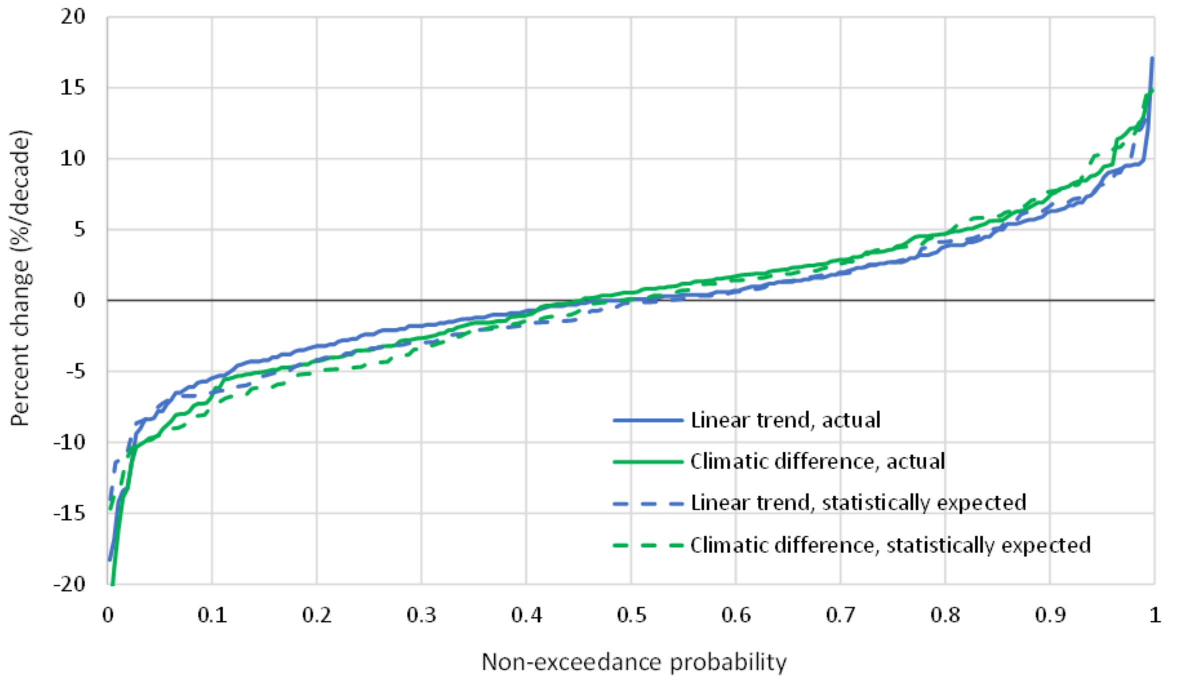
- The distribution is as statistically expected.
- An exception is the lack of a record in the three-year period 1982-83 to 1984-85.
- There are no noticeable climatic events.





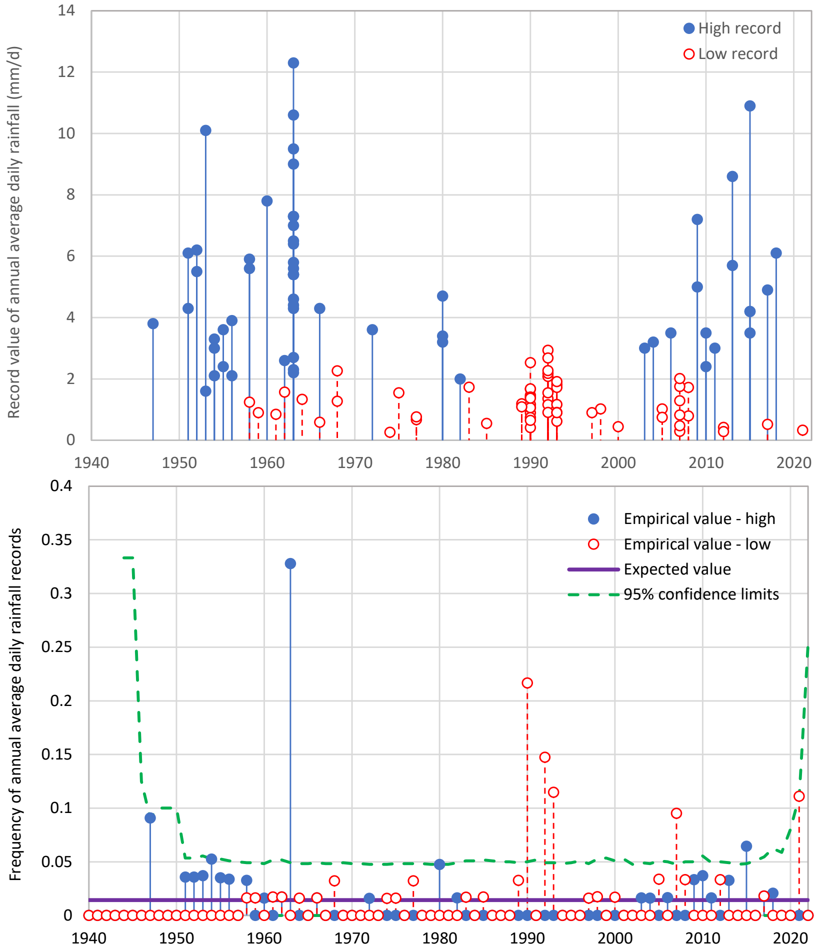
Seeking “climatic trends” in annual maximum daily rainfall

- The graph shows linear trends in the last ~60 years and differences of two consecutive 30-year climatic periods.
- The probability distribution of positive and negative trends is balanced.
- There is an impressive agreement of the empirical variations with the theoretically expected for a stationary process.



Record high and record low annual rainfall occurrence in the 62 stations with longest complete daily time series in Greece

- The 1950s and early 1960s were strongly wet.
- About 1/3 of the high records of annual rainfall occurred in a single hydrological year, 1962-63.
- The 20-year period centered in 1990 was remarkably dry.
- In particular, about half of the low records of annual rainfall occurred in the 5-year period centered in 1990.
- The other periods, including the current one, are climatically neutral.
- The entire picture suggests the presence of Hurst-Kolmogorov dynamics in time and space.

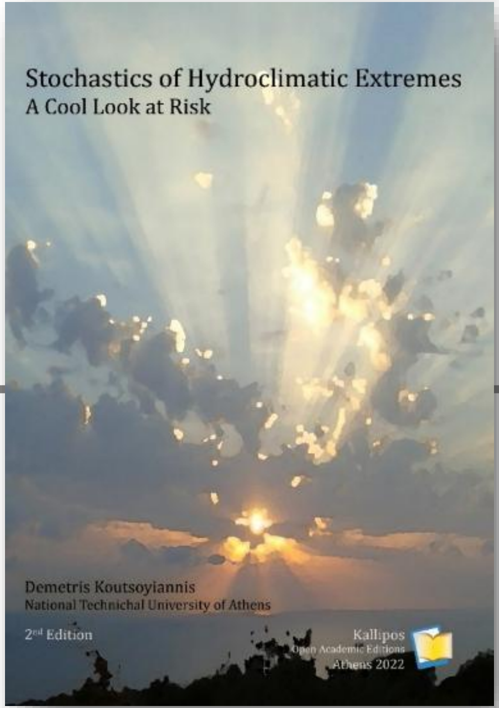


Part E

- Two main properties of natural behaviour

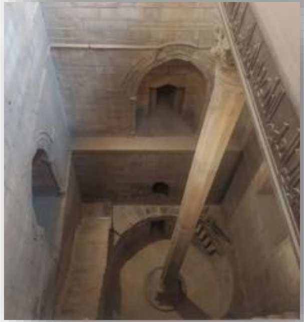
- Two main tools for modelling risk

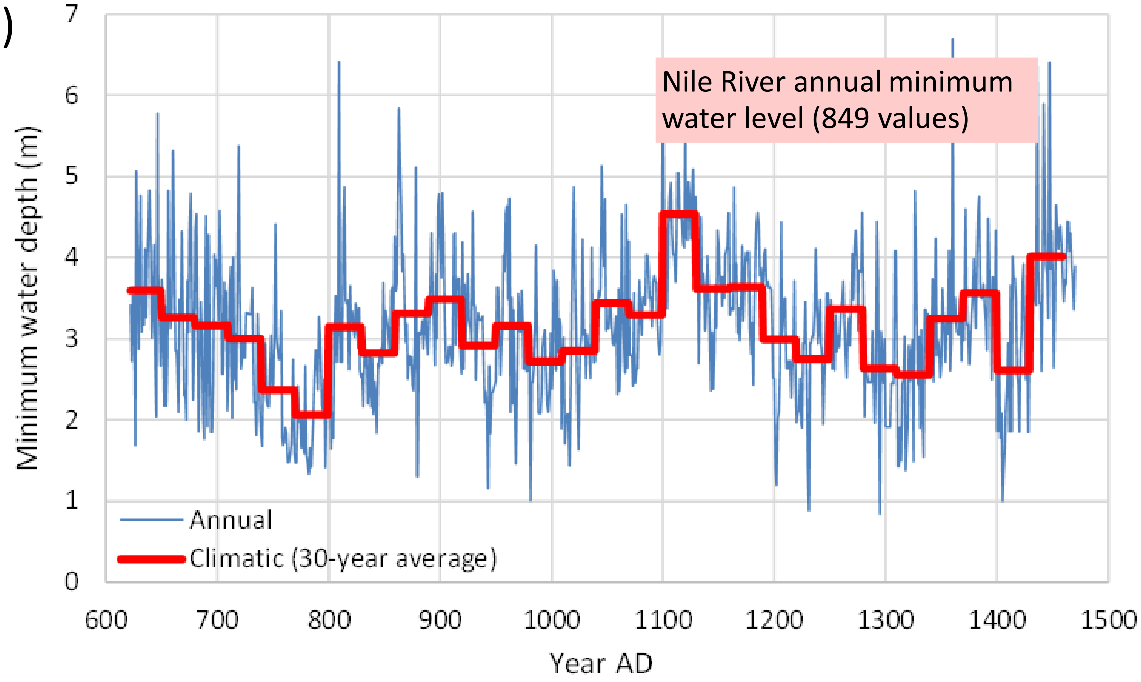
https://www.itia.ntua.gr/2000/



Property 1: Nature produces change at all time scales

The graph shows the longest instrumental record on Earth, that of the Roda Nilometer (849 years of Nile's water level)



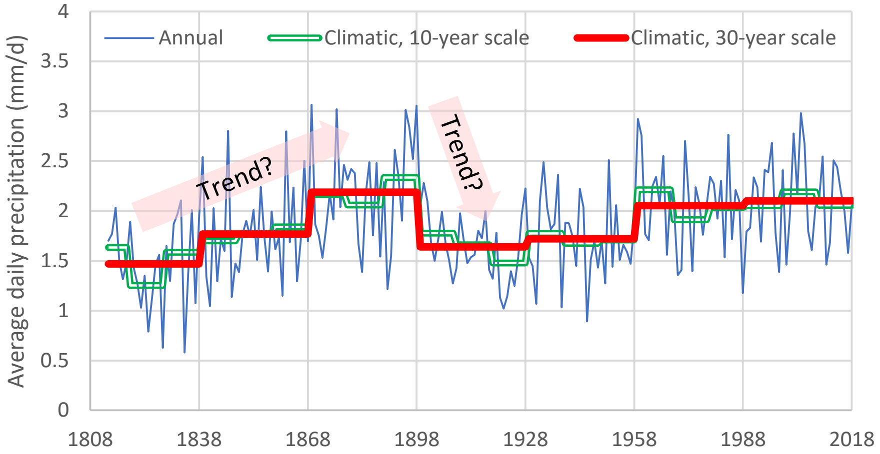


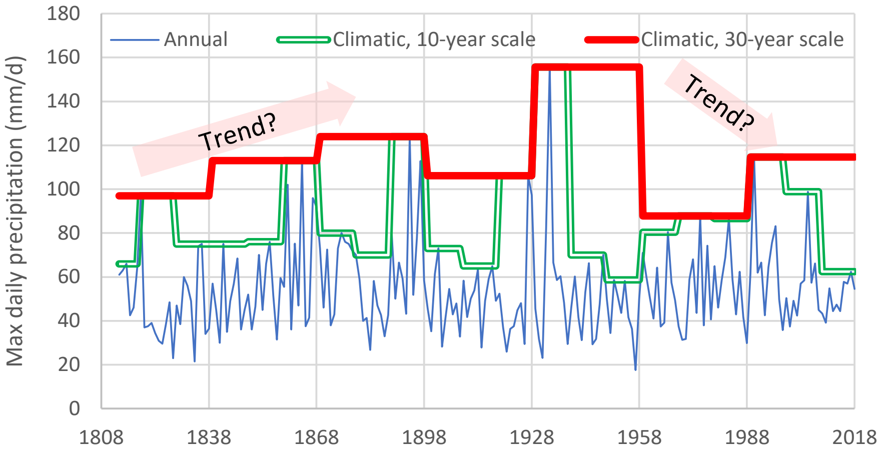
Data from Koutsoyiannis (2013), available at https://www.itia.ntua.gr/1351/; graph from Koutsoyiannis and Iliopoulou (2024); photos from Koutsoyiannis (2024), courtesy of Nikos Mamassis.

Property 1 seen in modern long records of instrumental data

- 206 years or rainfall data in Bologna, Italy show perpetual change.
- 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 (2024).
Sources of data: also detailed in Koutsoyiannis (2024).





Property 2: Extremes are worse than thought as regular

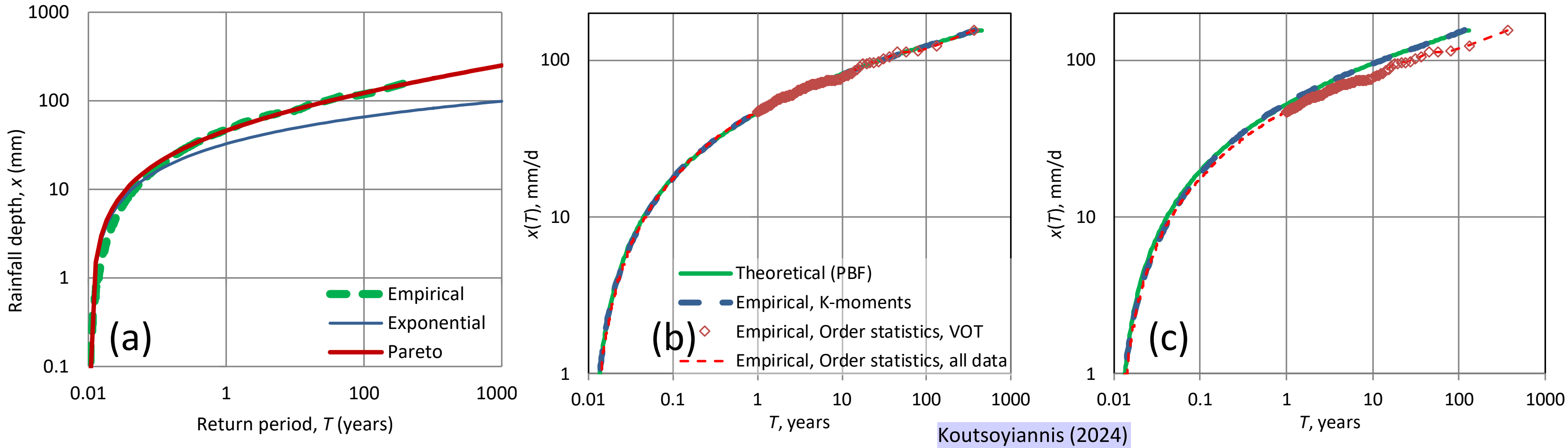
Probability plot (rainfall depth vs. return period) for Bologna based on 19 426 daily rainfall depths observed throughout 206 years. The exponential distribution, $\overline{F}(x) = \exp(-x/\mu)$ has been thought to represent a "regular" behaviour. However, the actual distribution tail is heavier than exponential, typically of Pareto type, $\overline{F}(x) = \left(1 + \xi \frac{x}{\lambda}\right)^{-\frac{1}{\xi}}$

Probability plot showing the fitting of the Pareto-Burr-Feller distribution,

$$\overline{F}(x) = \left(1 + \zeta\xi \left(\frac{x}{\lambda}\right)^{\zeta}\right)^{-\frac{1}{\xi\zeta}}, \text{ on}$$

the Bologna daily rainfall record by the indicated methods, assuming independence.

As in (b) but accounting for long-range dependence (LRD). The curves of theoretical and empirical K-moments are indistinguishable for T > 1 year. The empirical distribution from order statistics does not consider dependence so that it is the same as in (b).
Nb.: Accounting for LRD reduces the return period estimate up to an order of magnitude.



Koutsoyiannis (2024)

Tool 1, the climacogram: Quantifying change across time scales

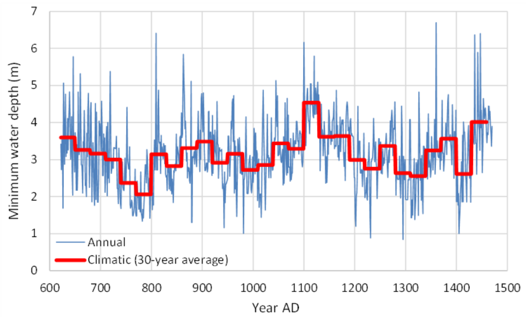
- Take the Nilometer time series, $x_1, x_2, \ldots, x_{849}$, and calculate the sample estimate of variance $\gamma(1)$, where the superscript (1) indicates time scale (1 year).
- Form a time series at time scale 2 (years):
  $x_1^{(2)} := (x_1 + x_2)/2,\ x_2^{(2)} := (x_3 + x_4)/2,\ \ldots,\ x_{424}^{(2)} := (x_{847} + x_{848})/2$
  and calculate the sample estimate of the variance $\gamma(2)$.
- Repeat the same procedure and form a time series at time scale 3, 4, … (years), up to scale 84 (1/10 of the record length) and calculate the variances $\gamma(3), \gamma(4), \ldots \gamma(84)$.
- The **climacogram** is the function of the variance $\gamma(\kappa)$ *vs*. scale κ, typically plotted in logarithmic axes.
- If the time series x_i represented a pure random process, the climacogram would be a straight line with slope -1 (the proof is very easy).
- In real world processes, the slope is different from -1, designated as $2H - 2$, where H is the so-called Hurst parameter ($0 < H < 1$).
- The scaling law $\gamma(\kappa) = \gamma(1) / \kappa^{2-2H}$ defines the **Hurst-Kolmogorov (HK) process**.
- High values of H (> 0.5) indicate **enhanced change** at large scales, else known as **long-term persistence**, or strong **clustering** (grouping) of similar values.

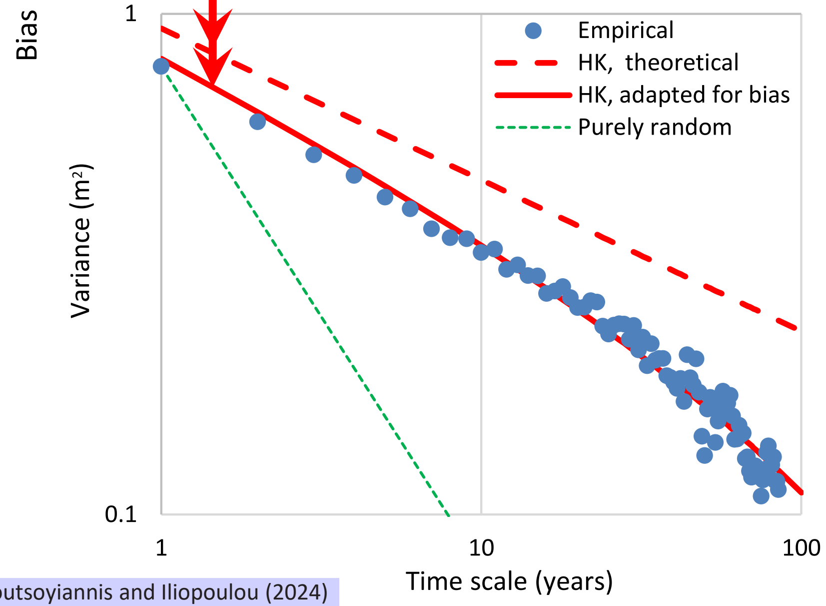
Koutsoyiannis (2010, 2013, 2024)

The climacogram of the Nilometer time series

- The Hurst-Kolmogorov process seems consistent with reality.
- The Hurst parameter is H = 0.85. (Similar H values are estimated from the simultaneous record of maximum water levels and from the modern, 131-year, flow record of the Nile flows at Aswan).
- The Hurst-Kolmogorov behaviour, seen in the climacogram, indicates that:
  - (a) long-term changes are more frequent and intense than commonly perceived, and
  - (b) future states are much more uncertain and unpredictable on long time horizons than implied by pure randomness.

The classical statistical estimator of standard deviation was used, which however is biased for HK processes





Koutsoyiannis and Iliopoulou (2024)

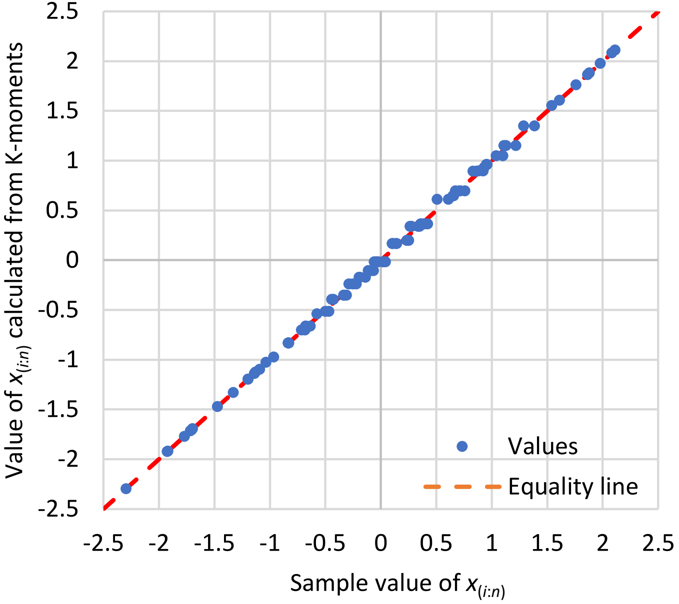
Tool 2, the knowable moments (K-moments)

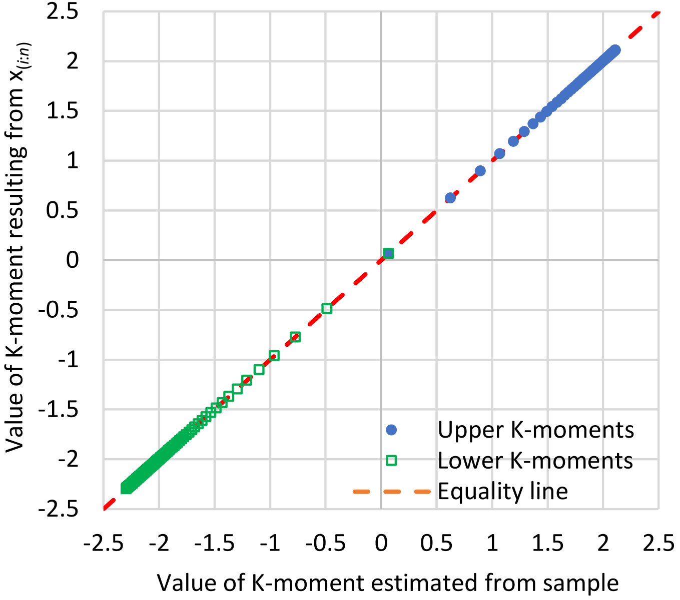
- Intuitive definition: the *K*-moment of order *p* equals the expected value of the upper or lower extreme of *p* independent stochastic variables $\underline{x}_i, i = 1, \dots, p$, identical to $\underline{x}$, i.e.,
  - Upper K-moment: $K'_p \coloneqq \mathrm{E}\left[\max\left(\underline{x}_1, \underline{x}_2, \dots, \underline{x}_p\right)\right].$
  - Lower K-moment: $\overline{K}'_p \coloneqq \mathrm{E}\left[\min\left(\underline{x}_1, \underline{x}_2, \dots, \underline{x}_p\right)\right].$
- Direct relationship to extremes, thanks to their definition.
- Substitution of classical moments, which are unknowable (not determinable from samples for $p > 2 - 3$).
- Unbiased estimators (knowable even for very large orders, up to $p = n$, where n is the sample size).
- Capable of being assigned an empirical return period
- Capable of taking account for the effect of (spatial and temporal) dependence in the estimation of the return period.

Koutsoyiannis (2019, 2024)

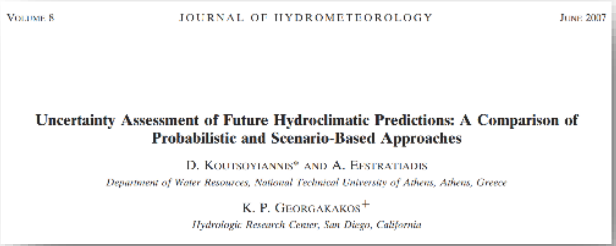
Empirical K-moments as transformations of observations

- From an observed sample of size n, $x_{(i,n)}, i = 1, \dots, n$, ordered in ascending order, we can estimate n upper K-moments $\hat{K}_i$ and n lower K-moments, $\hat{\bar{K}}_i$, with $\hat{K}_1 = \hat{\bar{K}}_1 = \mu$.
- The three series $x_{(i,n)}$, $\hat{K}_i$, $\hat{\bar{K}}_i$ are linearly equivalent; from any one of the three we can calculate any other.
- Notice that the series of $x_{(i,n)}$ is dense in the body and sparse in the tails while the opposite happens with the series $\hat{K}_i$, $\hat{\bar{K}}_i$.





Koutsoyiannis (2024)


VOLUME 8 JOURNAL OF HYDROMETEOROLOGY JUNE 2007

Uncertainty Assessment of Future Hydroclimatic Predictions: A Comparison of Probabilistic and Scenario-Based Approaches

D. KOUTSOYIANNIS* AND A. EFSTRATIADIS
Department of Water Resources, National Technical University of Athens, Athens, Greece
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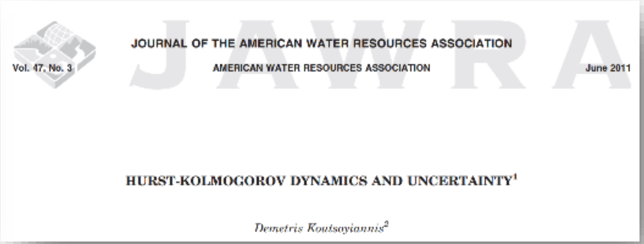
Hydrologic Research Center, San Diego, California

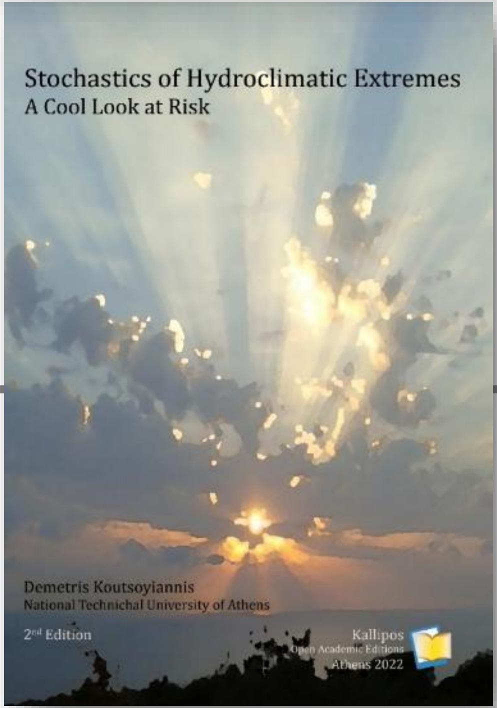

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
AMERICAN WATER RESOURCES ASSOCIATION
Vol. 47, No. 3 June 2011

HURST-KOLMOGOROV DYNAMICS AND UNCERTAINTY[1]

Demetris Koutsoyiannis[2]

Part F
Managing droughts

https://www.itia.ntua.gr/2000/



Drought in Athens: Was it due to a “trend”, possibly suggesting “climate crisis”?

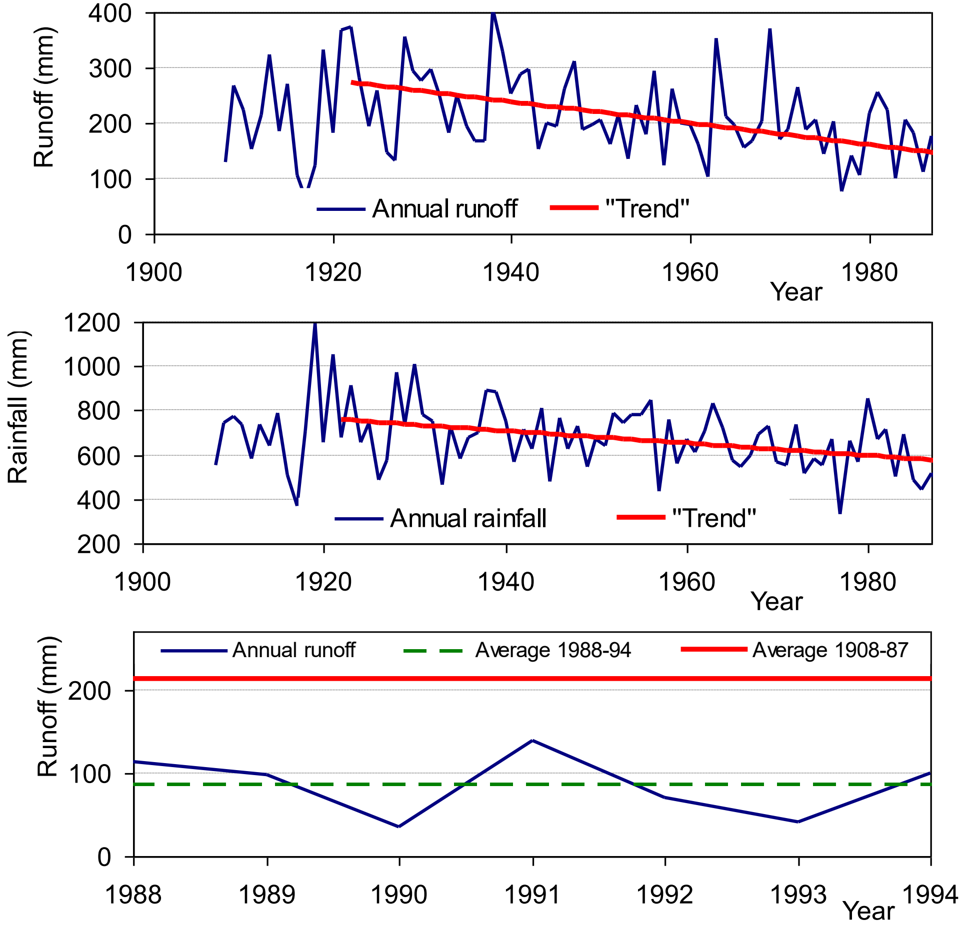
The historical time series of runoff up to 1986/87 at one of the rivers supplying Athens, Boeoticos Kephisos.

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**.
- Proper modelling of 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

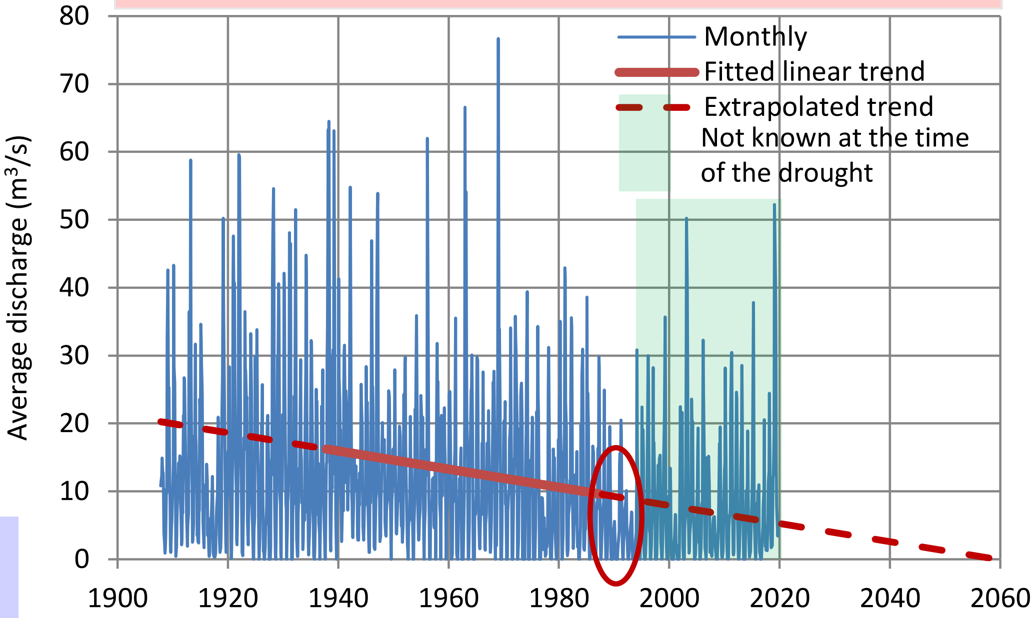
- The “trend model” is **worse than** that of a constant average (see table).
- According to the “trend model”, the flows would **disappear** a little after 2050…
- In reality **all three reservoirs spilled** in 2006 and again two of them in 2020 and 2021.
- **Conclusion**: It is **absurd** to use such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

Source: Koutsoyiannis (2024).
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

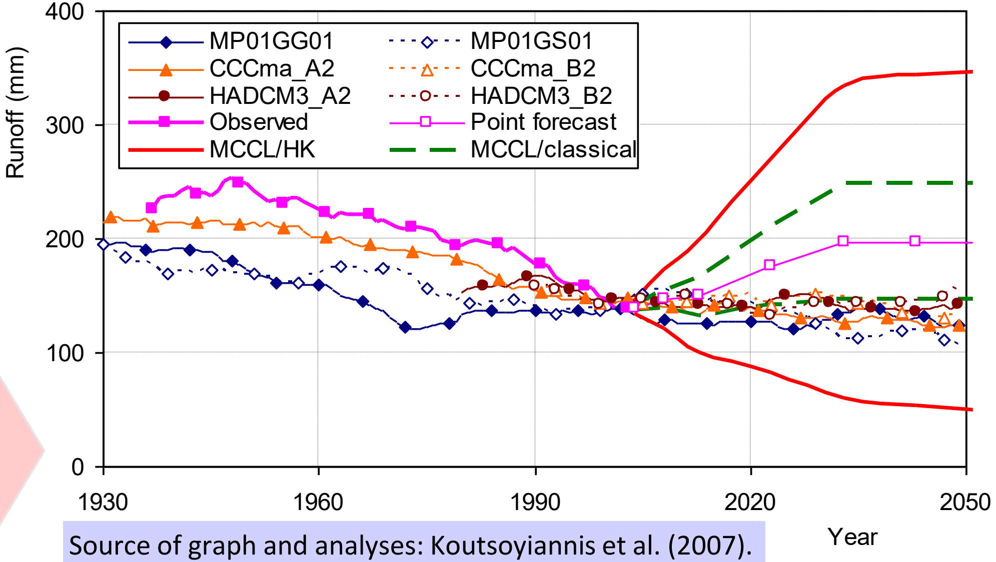
Boeoticos Kephisos runoff and projected trend.



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**.

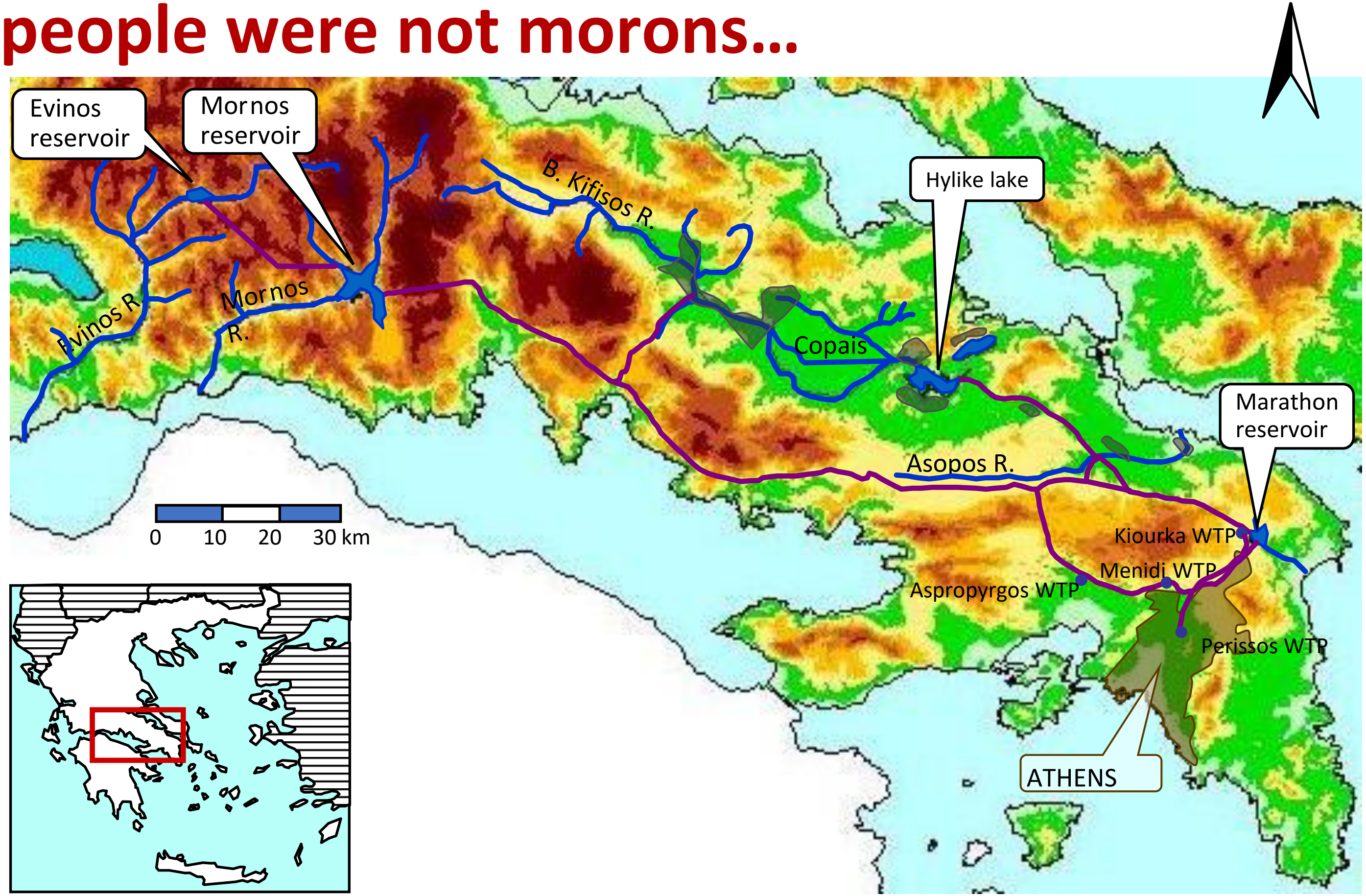
Boeoticos Kephisos runoff produced with downscaled climate model outputs, superimposed to Monte Carlo confidence limits (MCCL) produced with HK statistics under stationarity.



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

In the 1990s people were not morons…

The Athens water supply system, completed during the long-lasting drought around 1990.



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https://doi.org/10.1080/02626667.2024.2345813

A stochastic framework for rainfall intensity–time scale–return period relationships. Part I: theory and estimation strategies

Demetris Koutsoyiannis[a], Theano Iliopoulou[a], Antonis Koukouvinos[a] and Nikolaos Malamos[b]

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2024, VOL. 69, NO. 8, 1092–1112
https://doi.org/10.1080/02626667.2024.2345814

FEATURED ARTICLE

A stochastic framework for rainfall intensity–time scale–return period relationships. Part II: point modelling and regionalization over Greece

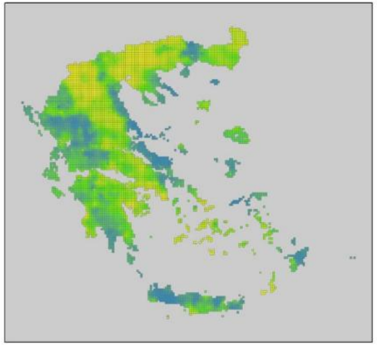
Theano Iliopoulou[a], Demetris Koutsoyiannis[a], Nikolaos Malamos[b], Antonis Koukouvinos[a], Panayiotis Dimitriadis[a], Nikos Mamassis[a], Nikos Tepetidis[a] and David Markantonis[a]

Part G

Hydrologic design of hydraulic structures

https://www.itia.ntua.gr/2287/

Παραγωγή χαρτών με τις επικαιροποιημένες παραμέτρους των όμβριων καμπυλών σε επίπεδο χώρας
(εφαρμογή της Οδηγίας ΕΕ 2007/60/ΕΚ στην Ελλάδα)



ΤΕΧΝΙΚΗ ΕΚΘΕΣΗ

Ανάθεση: Υπουργείο Περιβάλλοντος και Ενέργειας

Εκπόνηση: Τομέας Υδατικών Πόρων και Περιβάλλοντος
Σχολή Πολιτικών Μηχανικών – Εθνικό Μετσόβιο Πολυτεχνείο

Επιστημονικοί υπεύθυνοι: Θεανώ Ηλιοπούλου & Δημήτρης Κουτσογιάννης

Approaches to the hydrologic design of hydraulic structures

- The estimation of design rainfall for h**ydraulic projects is typically based on the probabilistic analysis** of observed rainfall depths (h) or (time-averaged) intensities (x), leading to the development of the intensity–timescale–return period relationships (also called ombrian relationships, or misnamed intensity-duration-frequency relationships, where duration and frequency are meant to be time scale (k) and return period (T) respectively).
- For **large-scale projects, especially dams, the method of Probable Maximum Precipitation (PMP)** used to dominate.
- For the past 25 years, it has been argued that the PMP concept is unscientific and that only probabilistic methods are scientifically valid (e.g., Koutsoyiannis, 1999, 2007).
- Recently, the new report by the American Committee on Modernizing Probable Maximum Precipitation Estimation (National Academies of Sciences, 2024) has essentially abolished PMP, retaining only the name. This is reflected in the new definition it provides:
  - “Probable Maximum Precipitation — the precipitation depth for a specific duration, location, and geographical area, such as a catchment, **with an extremely low annual exceedance probability**, for a given climate period.”
  - “The extremely low annual exceedance probabilities range from 10^{-4} to 10^{-7}”.
- Therefore, the **modern definition of the PMP method is in essence a probabilistic one**.

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.
- A stochastic ombrian model, theoretically consistent, detailed and simple, can readily be used to infer the ombrian relationships.
- For small time scales a Pareto distribution with discontinuity at the origin is assumed:

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

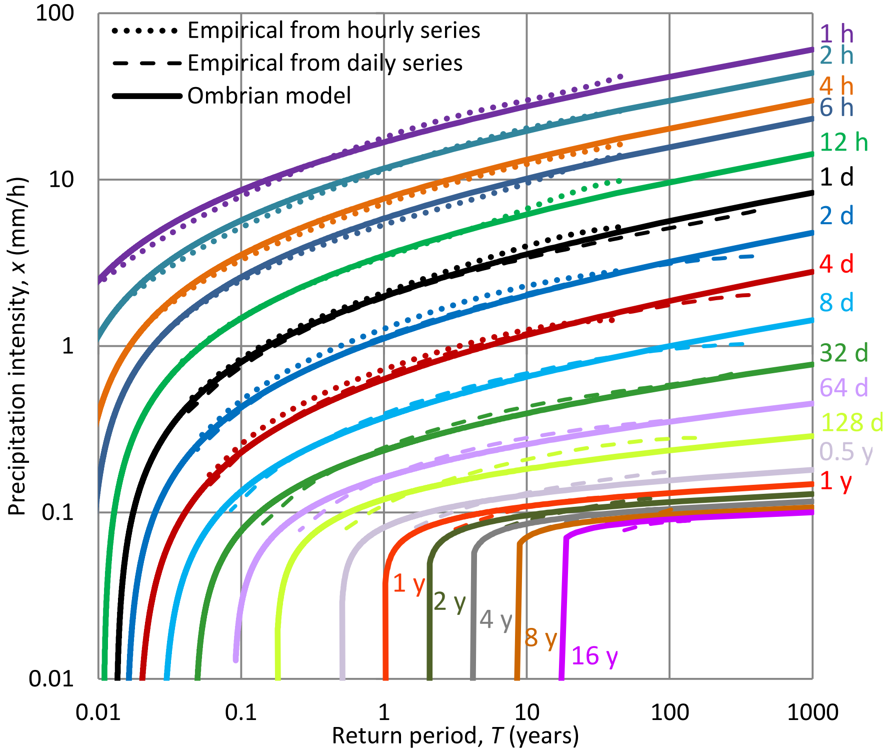
- It is shown by theoretical reasoning (Koutsoyiannis, 2024) that the tail index ξ is constant, while the probability wet, $P_1^{(k)}$, and the state scale parameter, $\lambda(k)$, are functions of the time scale k.
- For large time scales the Pareto-Burr-Feller (PBF) distribution is assumed:

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

- 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.

New theoretically consistent framework for modeling rainfall intensity for any time scale

- The recent methodological framework (Koutsoyiannis, 2024) enables the construction of ombrian curves across any time scale—large or small.
- The example shown is for Bologna, Italy (206 years of data), covering time scales from 1 hour to 16 years.
- This approach requires original high-resolution data and becomes more complex when aiming for generalization over any temporal scale.



Koutsoyiannis (2024)

The simplified framework

- Under **some simplifying assumptions** the rainfall intensity x for **small timescales** k (of the order of minutes to a few days) and return period T is given by the following relationships, resulting from the full-scale rainfall model:
  - for return period estimated from a full series or of rainfall exceedances over threshold:

$$x = \frac{b(T)}{a(k)} = \lambda \frac{(T/\beta)^{\xi} - 1}{(1 + k/\alpha)^{\eta}}, \qquad \xi > 0$$

  - from series of annual maxima (where Δ = 1 year):

$$x = \lambda \frac{(-(\beta/\Delta)\ln(1 - \Delta/T))^{-\xi} - 1}{(1 + k/\alpha)^{\eta}}, \qquad \xi > 0$$

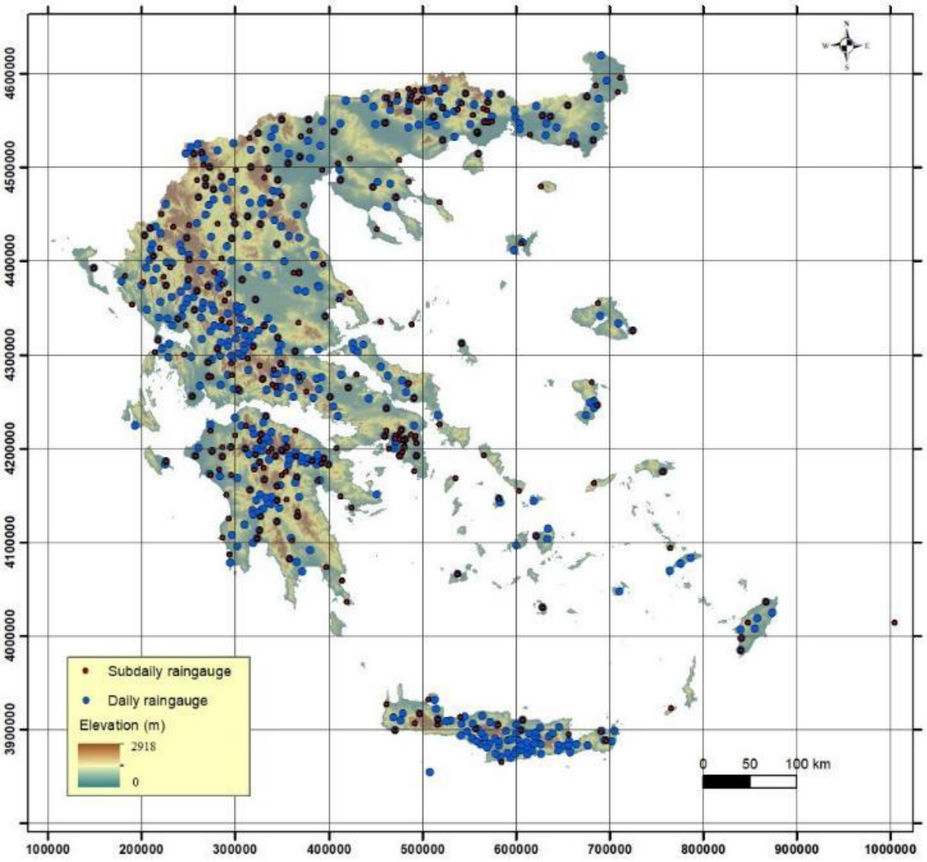
Theoretically equivalent for all *T* and for the same parameter values; giving virtually same values for *T* > 10 years

- The simplified model parameters are:
  - λ a characteristic rainfall intensity (scale parameter) in units of x (e.g., mm/h);
  - β a time parameter, related to the mean distance of wet periods, in units of the return period (e.g., years);
  - α a timescale parameter in units of timescale (e.g., h) with $\alpha > 0$;
  - η a dimensionless parameter, expressing persistence, with $0 < \eta < 1$;
  - $\xi > 0$ the tail index of the process distribution.

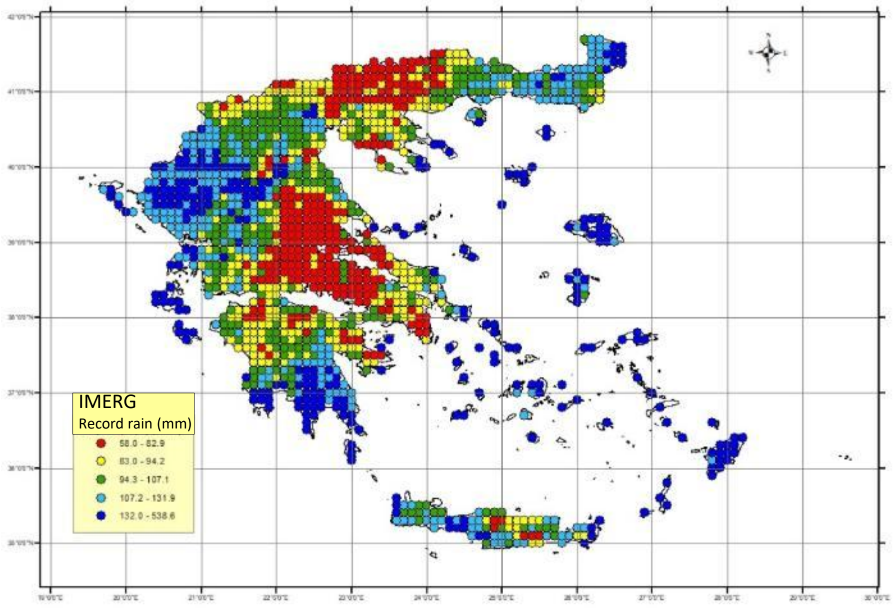
5 parameters with physical/ mathematical meaning

Greece's rainfall network

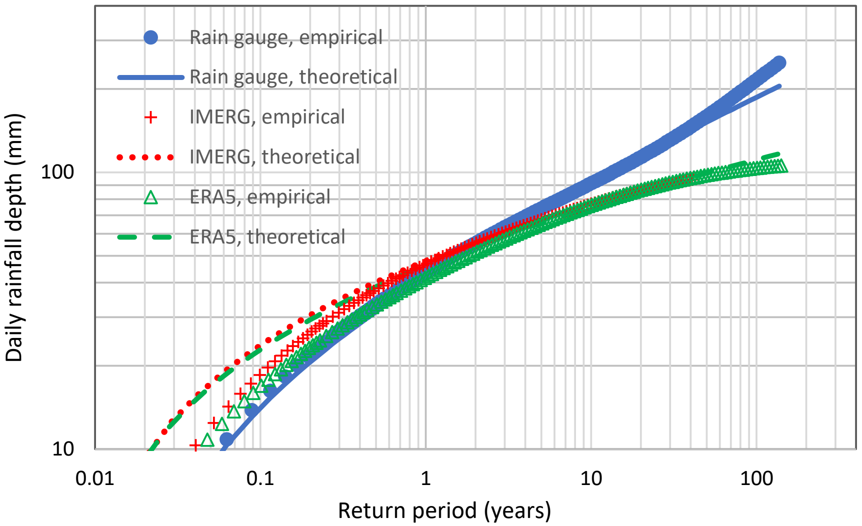
- After extensive nationwide data collection, an initial set of 940 stations was compiled.
- Following quality control, the final dataset includes 783 stations across 651 locations, including:
  - 503 daily rain gauges (130 co-located with rain recorders);
  - 280 sub-daily rain recorders.
- The longest available record (in Athens) spans the period from 1860 to 2022.



Non-conventional rainfall data

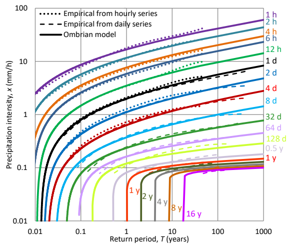


- From satellite-based information, we investigated the usefulness of the IMERG data set (half hourly time step at 0.1° spatial resolution, period 2000-today),
- From the reanalysis information we investigated the usefulness of the ERA5 data set (daily time step at 0.25° spatial resolution; period 1950-today).



- Both data sets (especially the IMERG) underestimate the highest rainfall depths (as seen in the example for the station of Karditsa) and proved not appropriate for the construction of ombrian curves.

Methodology for regionalization over the Greek Territory

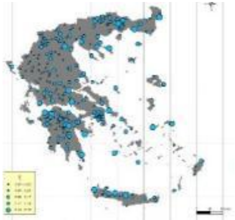


1 At-site independent estimation of parameters

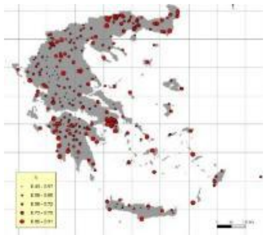
- using Koutsoyiannis’ (2024) new framework for **rainfall intensity-timescale-return period** relationships (else known as ombrian curves)

2 Evaluation of spatial variability of parameters:

- mostly **random patterns**

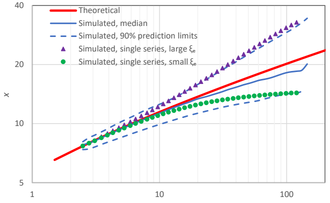


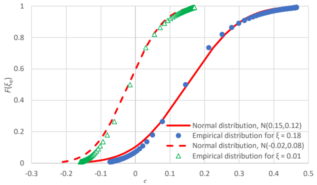
- mostly **systematic patterns**



3 Identification of **common** parameter values

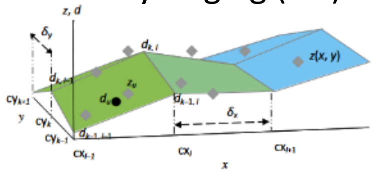
- using simultaneous optimization methods
- and stochastic simulations

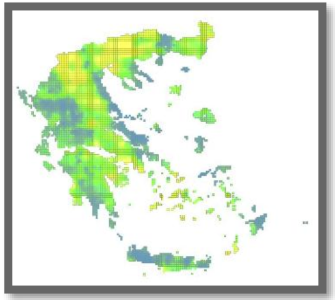




4 Regionalization using **spatial models**

- Inverse Distance Weighted (IDW)
- Bilinear surface smoothing (BSS)
- Ordinary Kriging (OK)





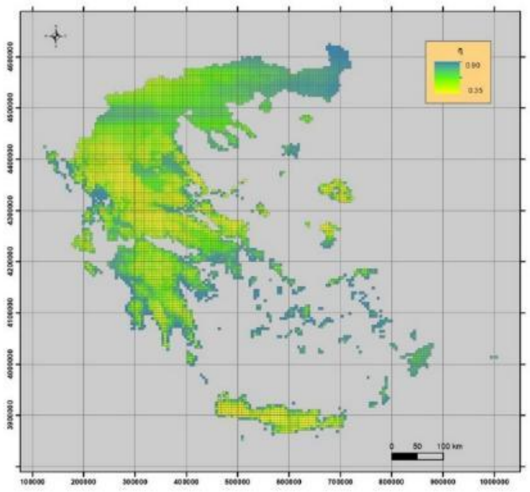
Final product

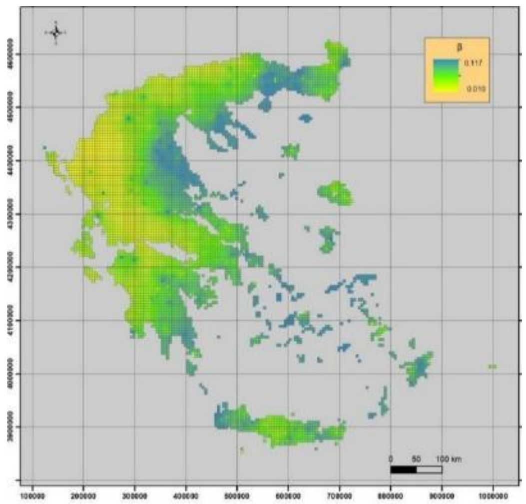
The following generalized form of ombrian curves is derived for rainfall intensity x (mm/h), return period T (years) and temporal scale k (h):

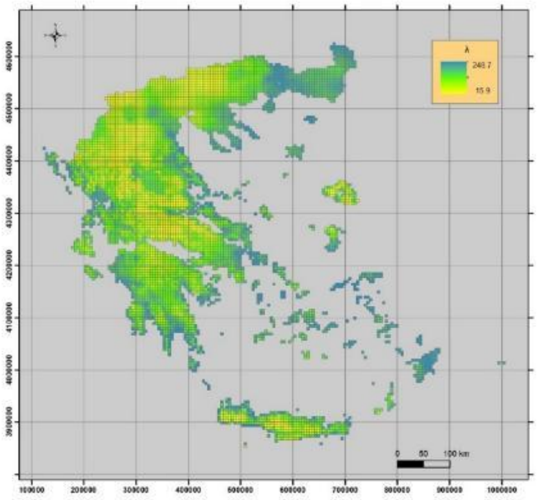
$$x = \lambda_* \frac{(T/\beta_*)^{\xi} - 1}{(1 + k/\alpha)^{\eta_*}}$$

with the following **five** parameters:

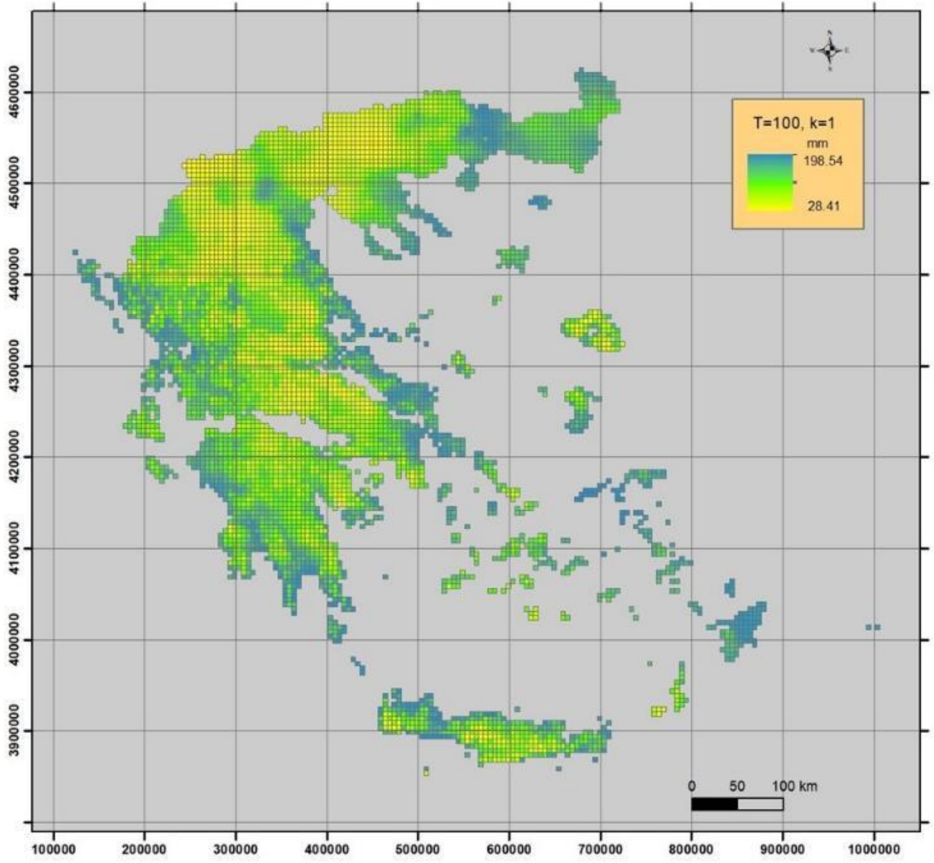
- timescale parameter α = 0.18 h
- tail index ξ = 0.18,
- three spatially varying parameters $\eta_*[-]$, β_* (years) and λ_* (mm/h) available at a 5 km grid.

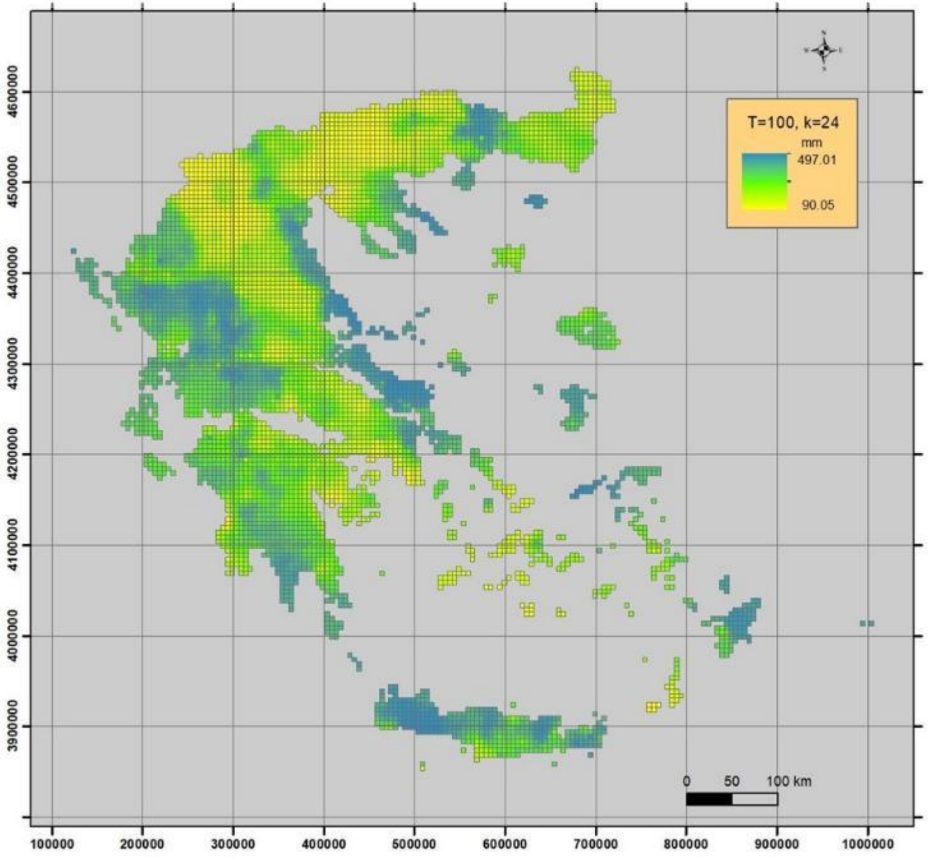






Mapping characteristic design rainfall depths

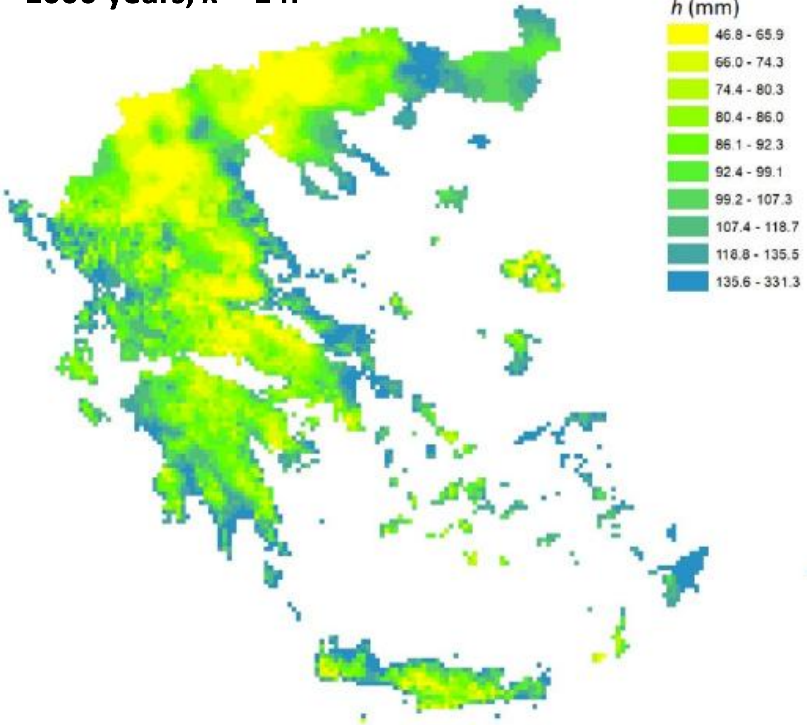




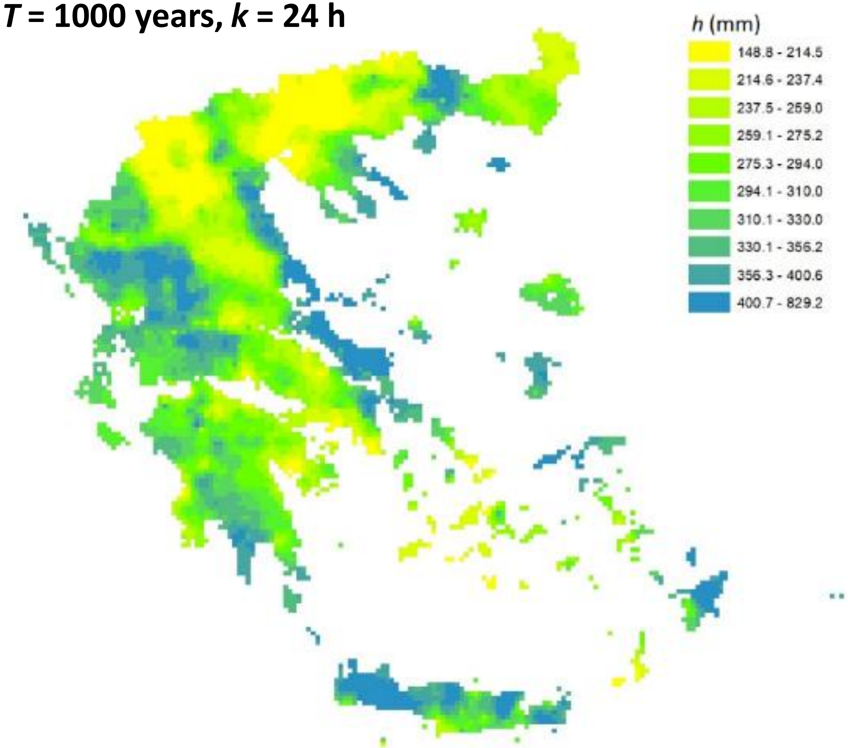
Rainfall depth maps for flood resilience assessment

Spatial rainfall estimates are easily derived for timescales up to a few days and any return period.

T **= 1000 years,** ***k*** **= 1 h**



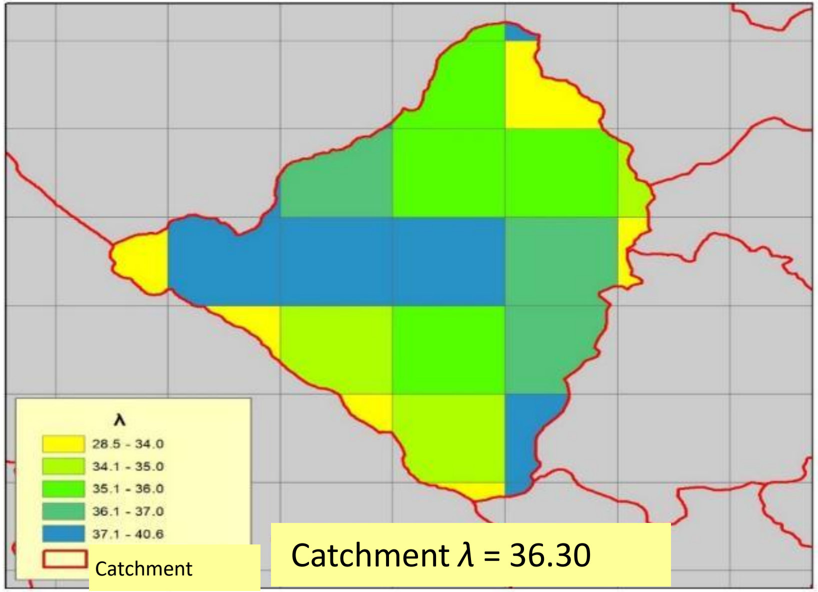
T **= 1000 years,** ***k*** **= 24 h**



Design rainfall at the catchment scale

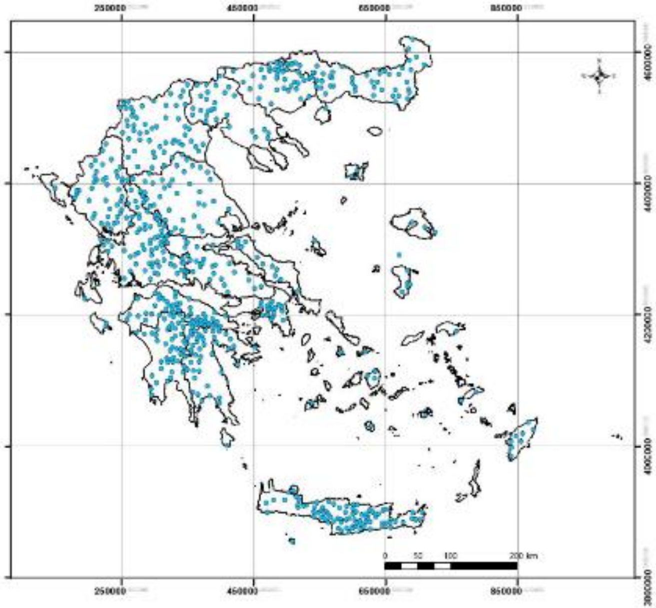
Following the new methodology, design rainfall estimates for any region or catchment in Greece are derived using:

- the two constant parameters
- three spatially varying parameters, calculated as a weighted average of the grid points within the area.



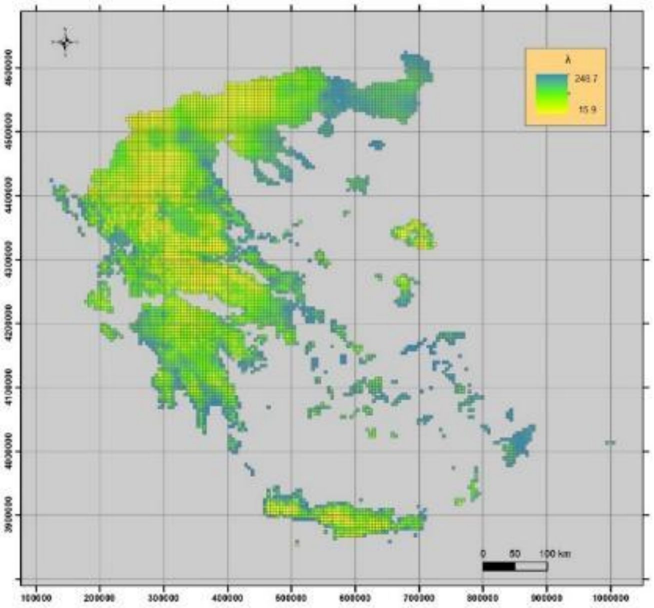
Improvements in the spatial representation of design rainfall

- This is the first time a geographically distributed design rainfall model is available for the entire Greek territory with a 5 km spatial resolution.
- Previous design rainfall relationships were estimated on a point basis (2016) necessitating post-processing and further interpolation assumptions to be applied on the regional scale.



Parameters available for specific gauged locations (Ministry of Energy and Environment, 2016)

Parameters available for any grid point in the Greek territory (Koutsoyiannis et al., 2023)



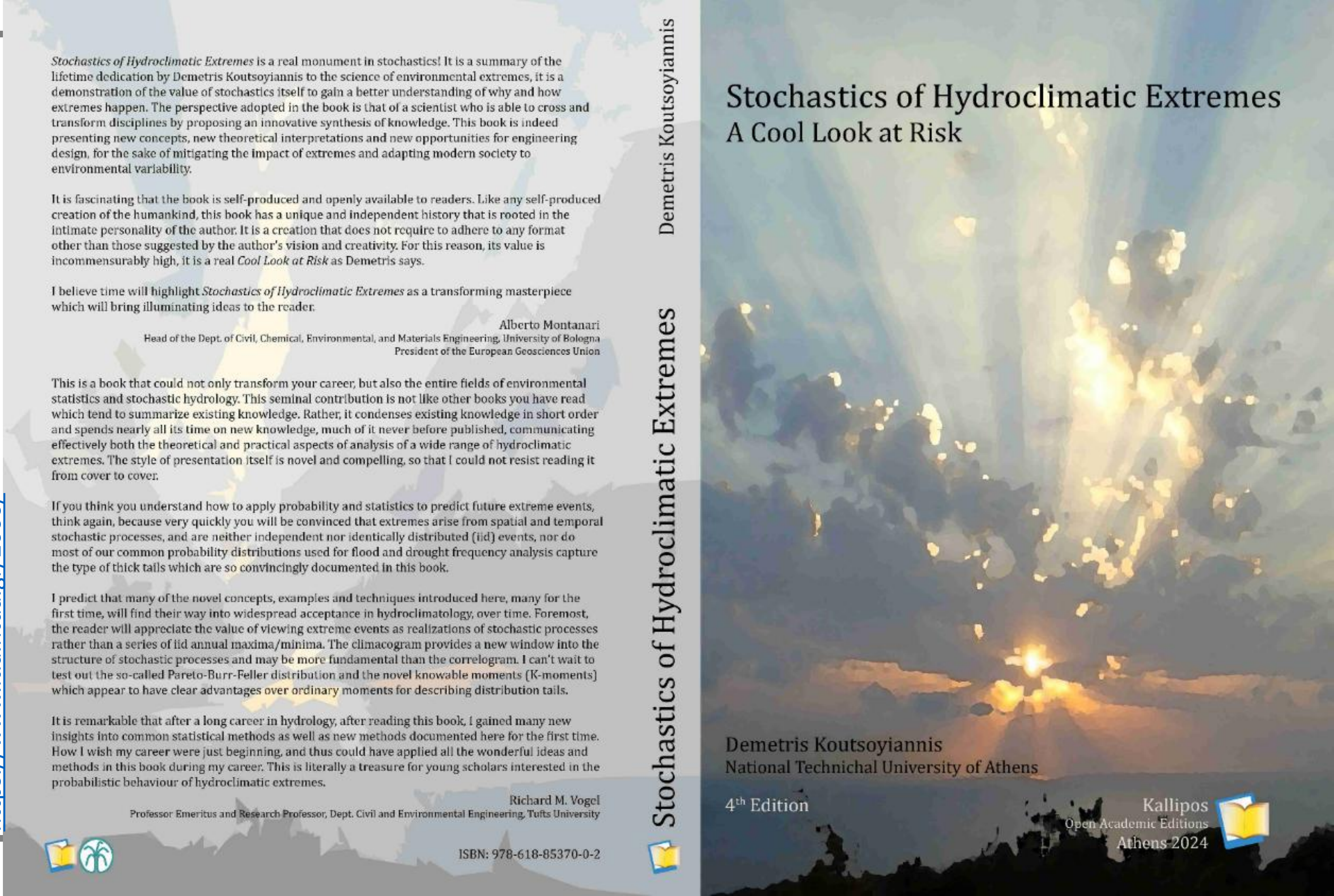
Concluding remarks

- Hydrological data do not support the political doctrine of climate crisis.
- Change is Nature’s style. It occurs at all times and all time scales, and is unpredictable.
- In the past, reason and adaptation have been the humans’ response to change.
- If we return to reason, this will also be the case in the future.
- Technology has augmented the human ability of adaptation. The results have been spectacular in the last century.
- Human adaptation requires human intelligence. In contrast, moronity results in devastation.
- Human intelligence has produced the field of probability/stochastics to deal with problems that involve uncertainty and risk.
- Recent advances in stochastics include consistent treating of extremes under temporal and spatial dependence, and changing climate, without resorting to inaccurate climate models.
- Powerful stochastic tools, easy to apply for engineering tasks, have been developed and showcased in large areas (including the entire territory of Greece).
- They can readily be applied to other countries or parts thereof.

Additional information in the book (Edition 4)

Free in open access

https://www.itia.ntua.gr/2000/



Thanks for the invitation and attention!

感谢邀请和关注

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