Analogues Methods for Attribution of Extreme Events to climate change: The Exceptional 2022 European Drought

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The Po River in July 2022. Credits: A Grassani for The New York Times

OUTLINE

1. **Introduction :** Understanding the role of Antrhopogenic Climate Change in exacerbating the droughts
2. **Case Study:** Overview of the 2022 drought in Western Europe and the Mediterranean region
2. **Methodology :**Description of the "circulation analogs" method
3. **Results :** Analysis of the event with the analogues methodology
4. **Conclusion :** Summary of the different natural versus forced contributions in modifying the 2022 drought intensity

DROUGHTS AND CLIMATE CHANGE

- **Droughts are characterized by a prolonged lack of precipitation**, leading to water scarcity and negative impacts on ecosystems, agriculture, and human communities.
- The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) highlights **that climate change is already affecting the frequency and intensity of droughts**
- **Climate change is projected to increase the frequency and severity of droughts in many regions** of the world.
- The IPCC AR6 also states that the **combined effects of changes in temperature and precipitation patterns will likely increase the risk of drought in some regions.**

DROUGHTS AND CLIMATE CHANGE: THE IPCC AR6

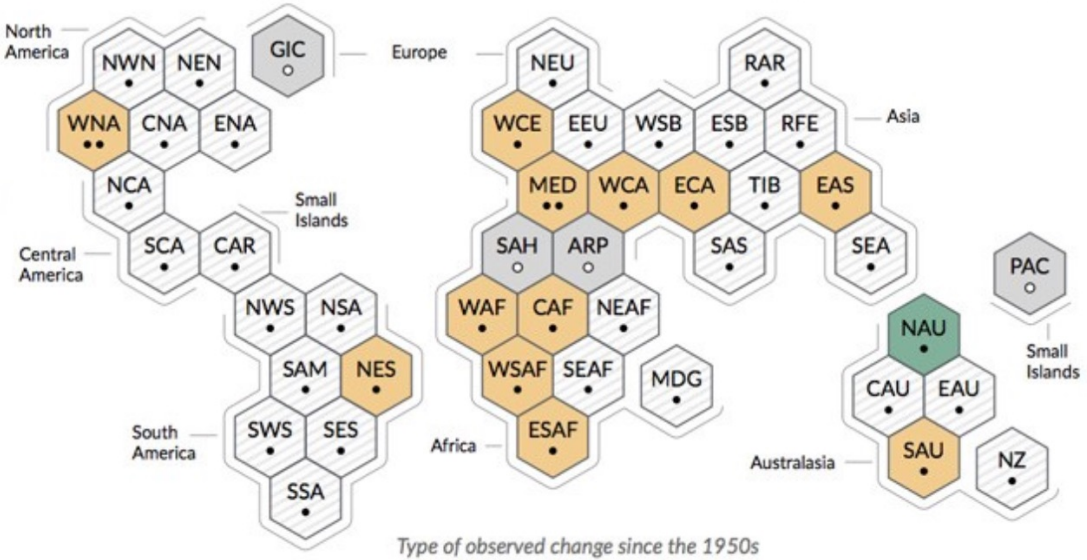
c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions

Type of observed change in agricultural and ecological drought

- Increase (12)
- Decrease (1)
- Low agreement in the type of change (28)
- Limited data and/or literature (4)

Confidence in human contribution to the observed change

- ●●● High
- ●● Medium
- ● Low due to limited agreement
- ○ Low due to limited evidence



Type of observed change since the 1950s

ATTRIBUTION OF EXTREME EVENTS TO CLIMATE CHANGE

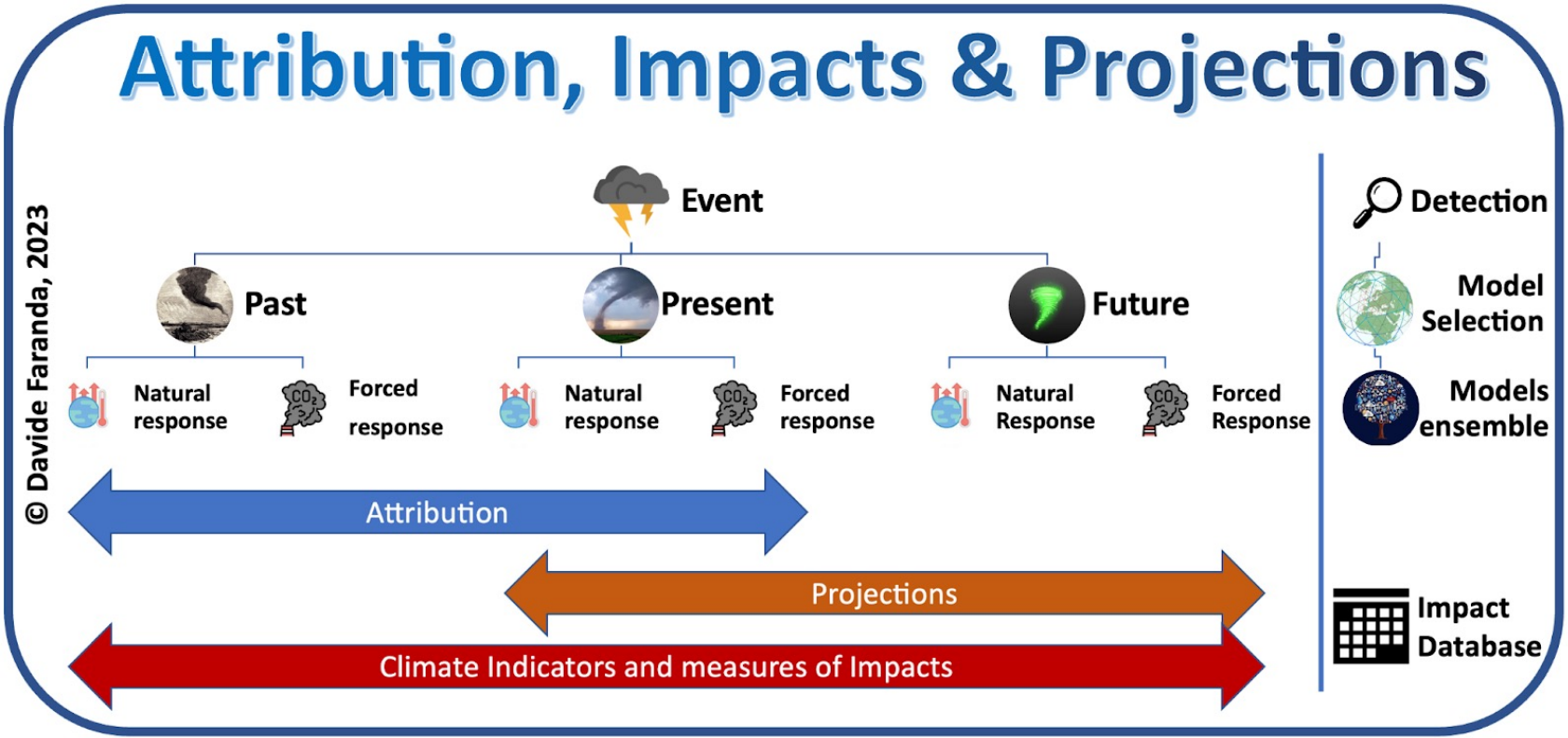
1. **Attribution** of extreme weather events to climate change involves **analysing the event and comparing it to historical data and climate models**.

2. It is based on the scientific understanding that **climate change is increasing the likelihood of certain types of extreme weather events**, such as heat waves and heavy precipitation.

3. Attribution studies use **a combination of observational data, climate models, and statistical methods to determine the role of climate change** in a specific event.

4. Attribution research aims to identify the **influence of human-caused climate change on the likelihood,** intensity, and spatial extent of an extreme event.

ATTRIBUTION VS PROJECTIONS AND IMPACTS DETERMINATION



PREVIOUS STUDIES ON DROUGHTS ATTRIBUTION

- **Previous studies have used a variety of methods, including observational data analysis, model simulations, and statistical analysis**, to understand the complex interactions between natural and human-induced factors.
- Some of **the key findings** from these studies include:
  - The **relationship between drought and temperature,** with higher temperatures leading to increased evapotranspiration and soil drying.
  - The **role of atmospheric circulation patterns**, such as anticyclonic anomalies, in determining the extent and duration of droughts.
  - **The influence of climate oscillations,** such as the Atlantic Multidecadal Oscillation, on drought variability over time.

Li et al. 2017 Kreibich, et al. 2019, WWA, 2022

OUR WORK: MINIMAL INGREDIENTS FOR BAKING AN ATTRIBUTION CAKE

1. **Detection step** : define the event and be able to detect in climaotological data

2. **Factual and Counterfactual worlds**: have sufficient information to compute the probability, intensity and frequency of the event detected in a word with and without antrhopogenic emissions.

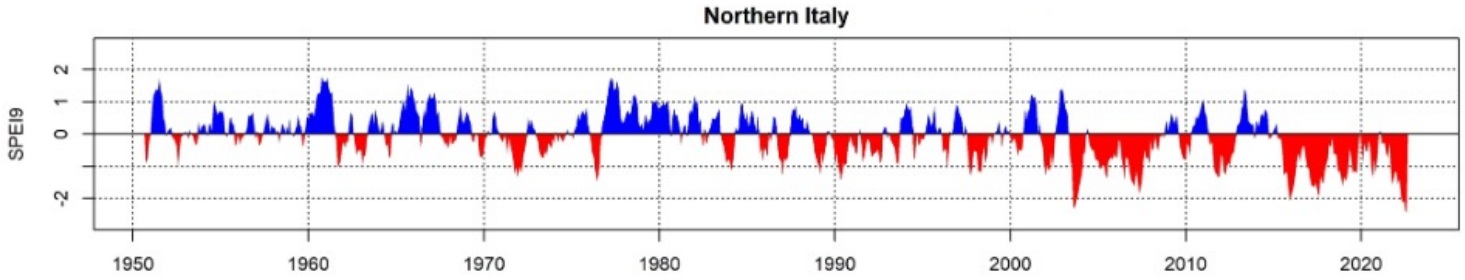
3. **Natural vs Forced Variability:** have sufficient information to separate the contribution of the antrhopogenic climate change from the natural variability

OUR CASE STUDY: THE 2022 DROUGHT

- **Intense and prolonged drought conditions affected France, Italy, and Spain in 2022**

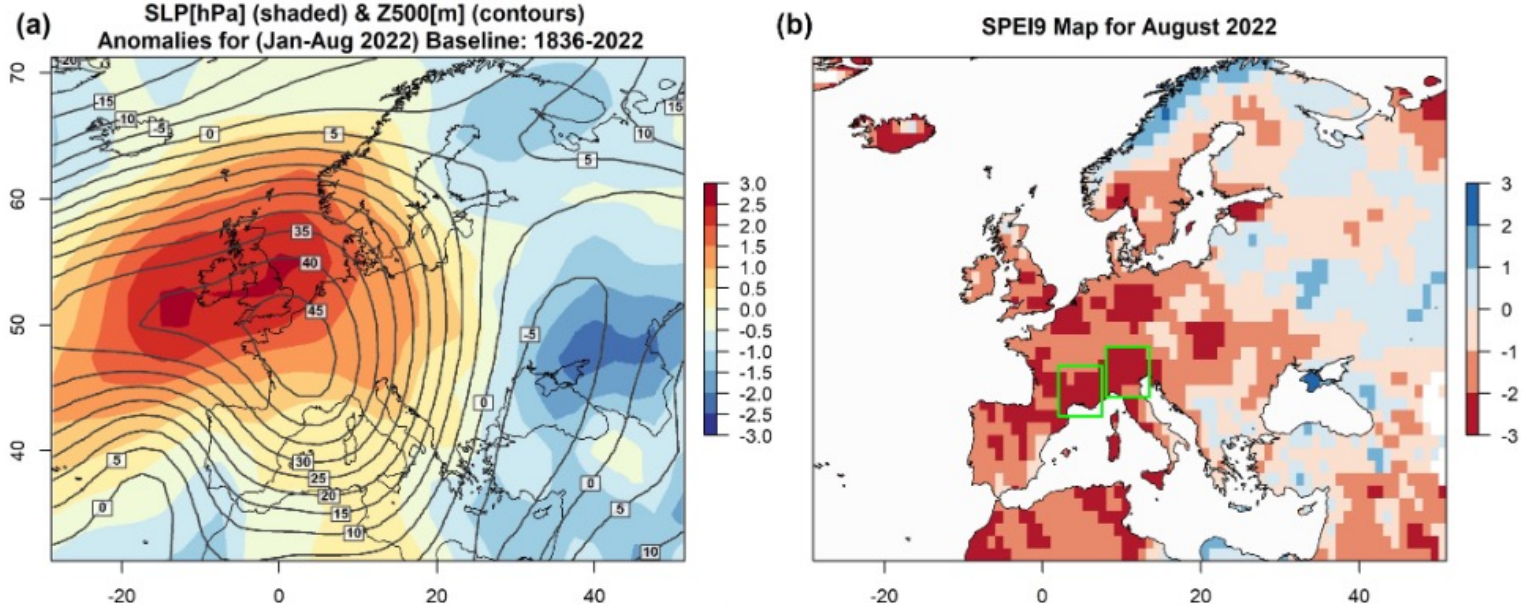
- **Record-breaking negative values of the 9 month Standardized Precipitation Evapotranspiration Index (SPEI9)** in August 2022, with area-average below -2

- Socio-ecological impacts: **reduced crop yields, emergency water restrictions, salt intrusion, wildfires, impacted energy and water usage**



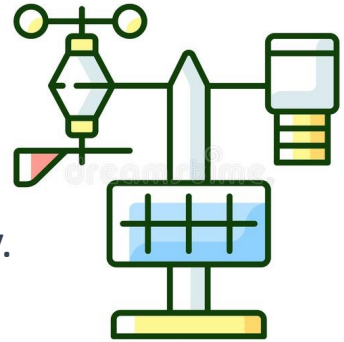
OUR CASE STUDY: THE 2022 DROUGHT

The large scale atmospheric circulation over the North Atlantic-European sector is investigated through the 500 hPa geopotential height (Z500)



DATA

•To study the 2022 drought and its relationship with atmospheric circulation over the North Atlantic-European sector, the **NOAA-CIRES-DOE Twentieth Century Reanalysis (20CRv3) is used as the primary data source.**



•20CRv3 reanalyses are created using surface pressure observations and boundary conditions from sea ice and sea surface temperature distributions. 80 ensemble members provide estimates of uncertainty.

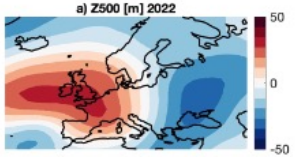
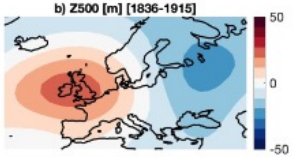
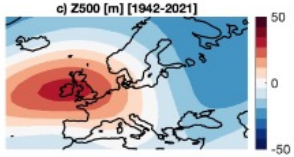
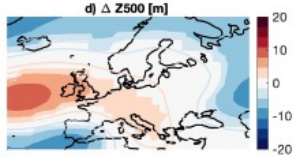
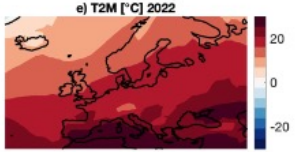
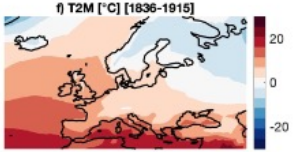
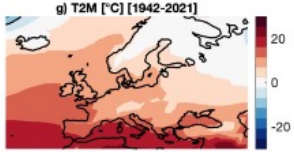
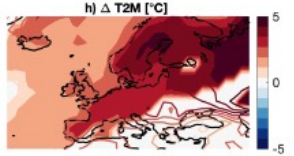
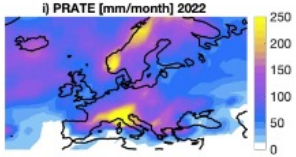
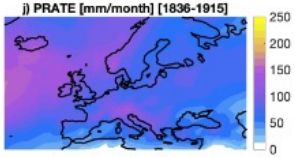
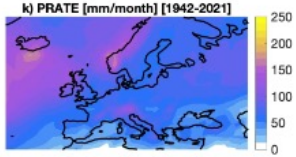
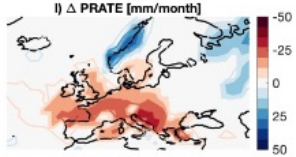
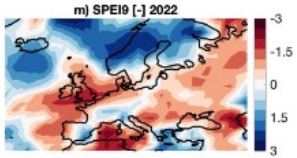
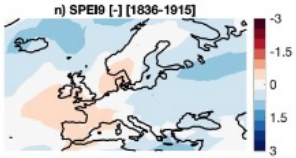
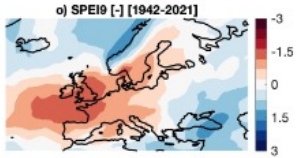
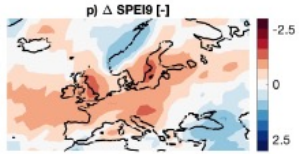
•**The period 2016-2022 is complemented with NCEP reanalysis data and a bias correction is applied to eliminate differences between 20CRv3 and NCEP reanalysis datasets.**

•The **combined reanalyses are used to calculate the Standardized Precipitation Evapotranspiration Index aggregated at 9 months (SPEI9)** using the R package SPEI9 and the Thornthwaite equation.

METHODS

- This study **modifies the method in Faranda et al (2022, WCD) to apply to slow-evolving events** like droughts, which can last several months
- The **Z500** anomalies **are smoothed using a 9-month backward moving average** to isolate the slow-evolving component
- **Analogs of the anomalies observed in August 2022 are searched in the factual period 1941-2021 and counterfactual period 1836-1915**
- The **best 29 analogs** (smallest 3‰ Euclidean distances) **are selected from each period**
- **The event itself is suppressed** in the factual period, and analogs from 2022 are prohibited
- **The extraction of analogs was tested between 15 to 30, without significant differences in results.**

RESULTS : PATTERN CHANGES

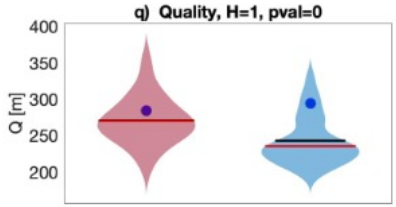
	Event	Counterfactual	Factual	Change
Z500				
2m Temperatures				
Precipitations				
SPEI9				

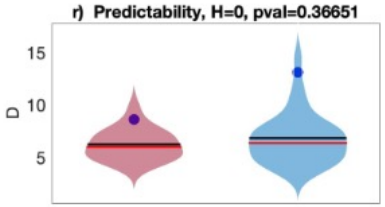
Summary: Event more intense in the factual world

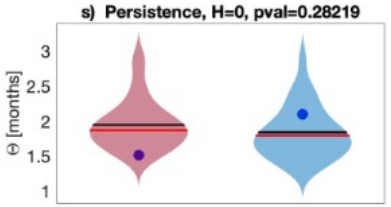
DIAGNOSTICS FOR THE ANALOGS

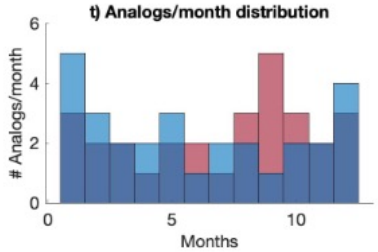
I. **Analog Quality Q** : Average Euclidean distance of event's pattern from closest 33 analogs and indicates similarity to analogs
II. **Predictability Index D :** Local dimension of Z500 map as a proxy for the unpredictability of temporal evolution of the circulation
III. **Persistence Index Θ :**Number of subsequent months with similar maps
IV. **Seasonality of Analogs** :Count analogs per month to detect shifts in circulation and potential changes in thermodynamics.

Factual vs Counterfactual





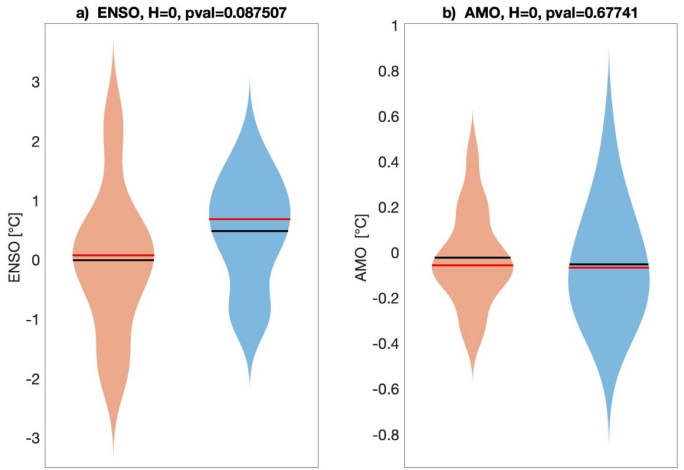




ROLE OF THE INTERANNUAL VARIABILITY

- We examine the a**ssociation of analogs with two major climate modes**: ENSO and AMO by looking at the Probability Distributions of ENSO and AMO indices selected at analog months.
- There is **no significant change in ENSO (AMO) distributions between counterfactual and factual world for Z500**.
- **A moderate role of interannual variability cannot be completely rejected:** can be found in the single 20CRv3 member ensemble analysis

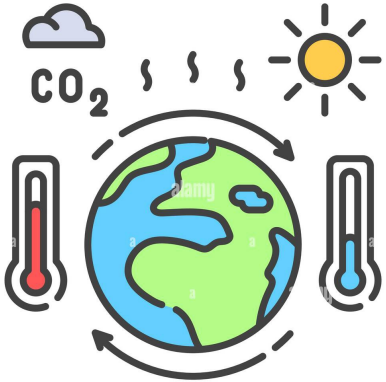
Factual vs Counterfactual



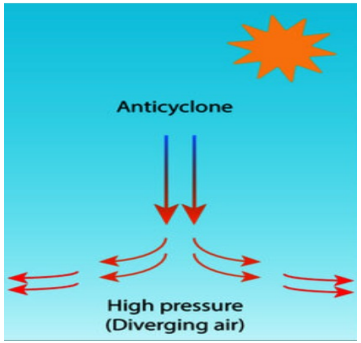
THE INFLATING BALLOON EFFECT

- Strong correspondence between 2022 drought and atmospheric circulation (Z500) higher and larger positive anomaly area in factual vs counterfactual periods.
- **Expansion effect (inflating balloon) of Z500 increases severity of drought.**
- **Higher near-surface temperature leads to more negative SPEI.**
- Change in shape of anticyclonic structure from Atlantic to Mediterranean.
- **No trends in frequency of patterns.**
- **Modest influence of ENSO and AMO** on drought cannot be ruled out.

CONCLUSIONS



- Anthropogenic Climate Change played a role in exacerbating the 2022 drought in Western Europe



- Persistent anticyclonic anomaly are associated with higher temperatures and more negative SPEI9 index in recent period

- The analogues based methodology can be adapted to study long-lasting events such as droughts

Thanks for your kind attention 🙏

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