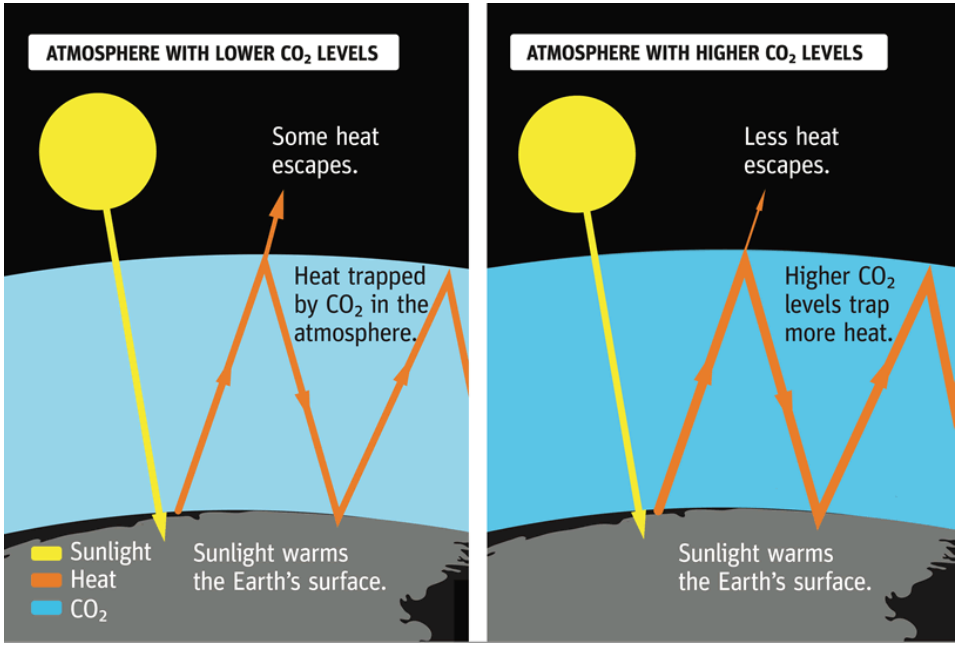
Climate change: from the attribution of extreme weather events to impacts on society

D.Faranda (CNRS), Coral Salvador (Univ. Bern)

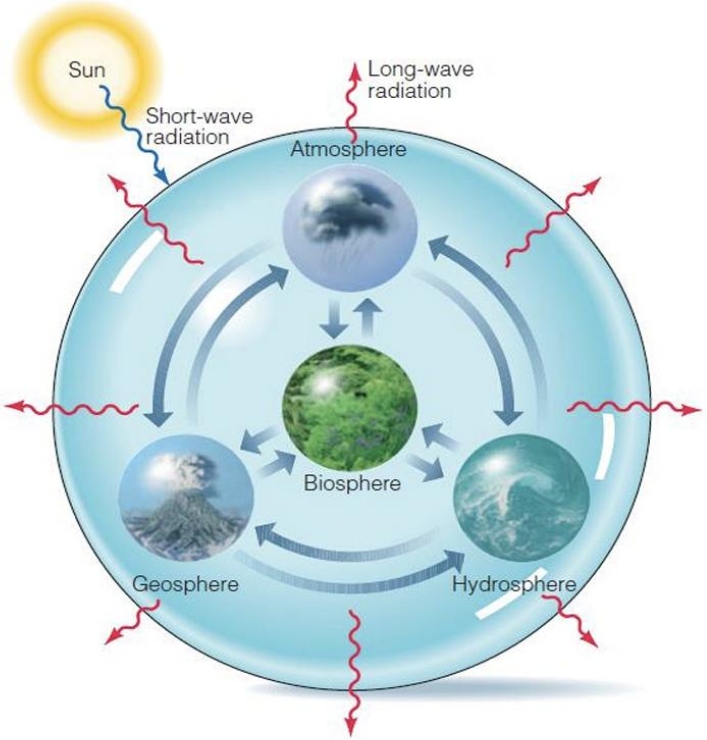
CLIMATE CHANGE: THE MAIN DRIVER IS GREENHOUSE GASES



Sunlight warms the surface of the Earth. But Earth stays warm even at night because of a layer of carbon dioxide, or CO2, in our atmosphere. CO2 acts like a heat-trapping blanket, absorbing the heat and holding it in.

There are other heat-trapping gases. These include methane (CH4), water vapor, nitrous oxide (N2O), and some fluorinated gases.

CLIMATE AS A PHYSICAL CLOSED SYSTEM

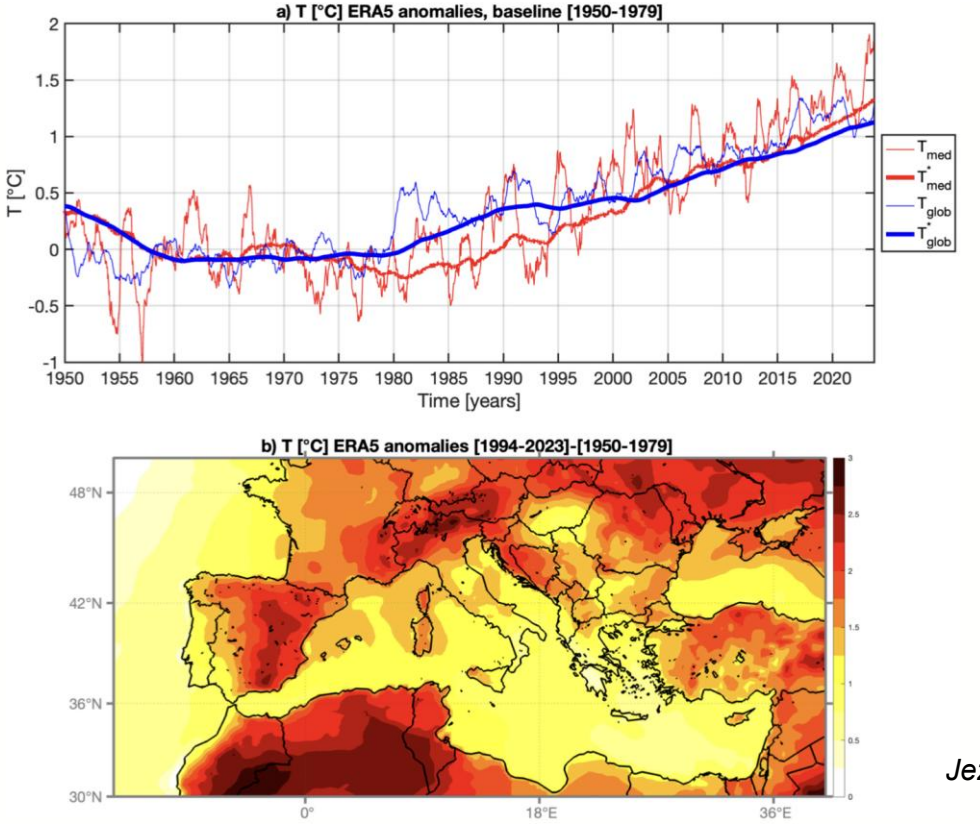


Earth is a closed system, but all of its innumerable smaller parts are interconnected;

When CO2 disturbs this steady state, the atmosphere, hydrosphere, biosphere, and geosphere react creating extreme events in each sphere

Source: bbec.ac.in

CLIMATE CHANGE IN THE MEDITERRANEAN



(a) Mean air temperature anomalies (1950–2023) relative to 1950–1979 for the Mediterranean (red) and globe (blue); thick lines: 10-yr running mean.
(b) Spatial anomalies between 1994–2023 and 1950–1979, after removing the seasonal cycle at each grid point.

Jezequel, Faranda, Drobinski, Lionello, 2024 JOC

WHAT ARE EXTREME EVENTS?

- ⛈️ **Extreme Events:** unusual weather or climate conditions that significantly deviate from the normal. They can occurr because of Natural Variability or Anthropogenic Climate change

- 🌎 The picture shows examples of extreme events and their impact related to key atmospheric variables.

EXTREME EVENTS IN THE MEDITERRANEAN

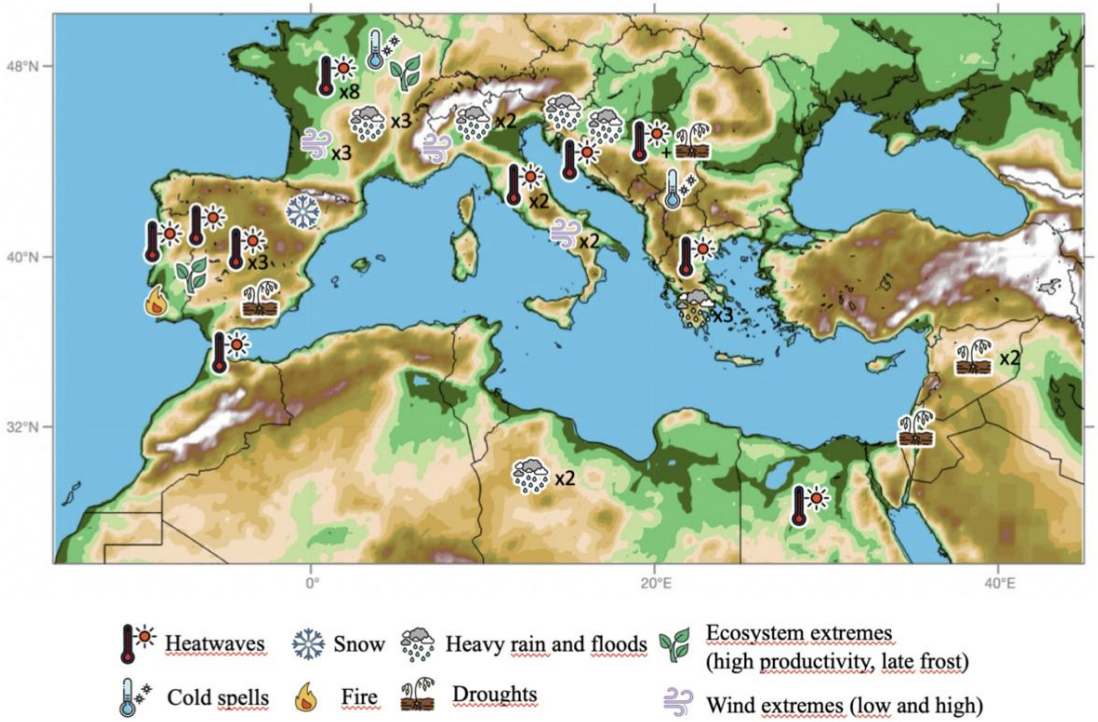
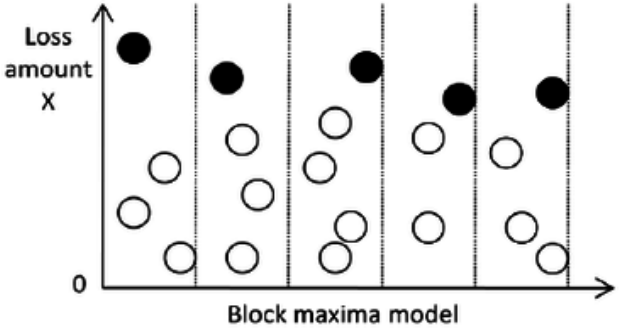


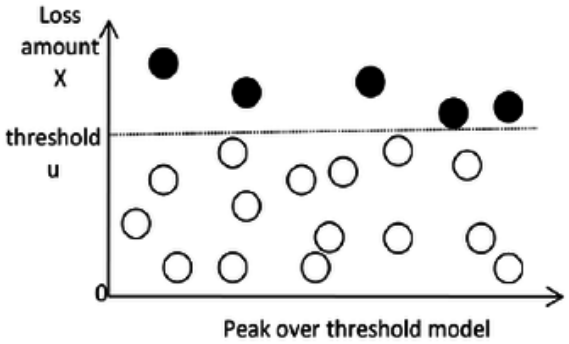
FIGURE 3 | Map of extreme event attribution studies applied to specific countries or neighbouring countries in the Mediterranean for different types of events. Each symbol represents a single study (one article or report can include several studies for different events, or attribution of the same

Jezequel, Faranda, Drobinski, Lionello, 2024 JOC

HOW DO WE DEFINE EXTREME EVENTS?



Block maxima approach: A method of extreme value analysis that involves grouping observations into blocks and selecting the largest value within each block as a representative extreme value.

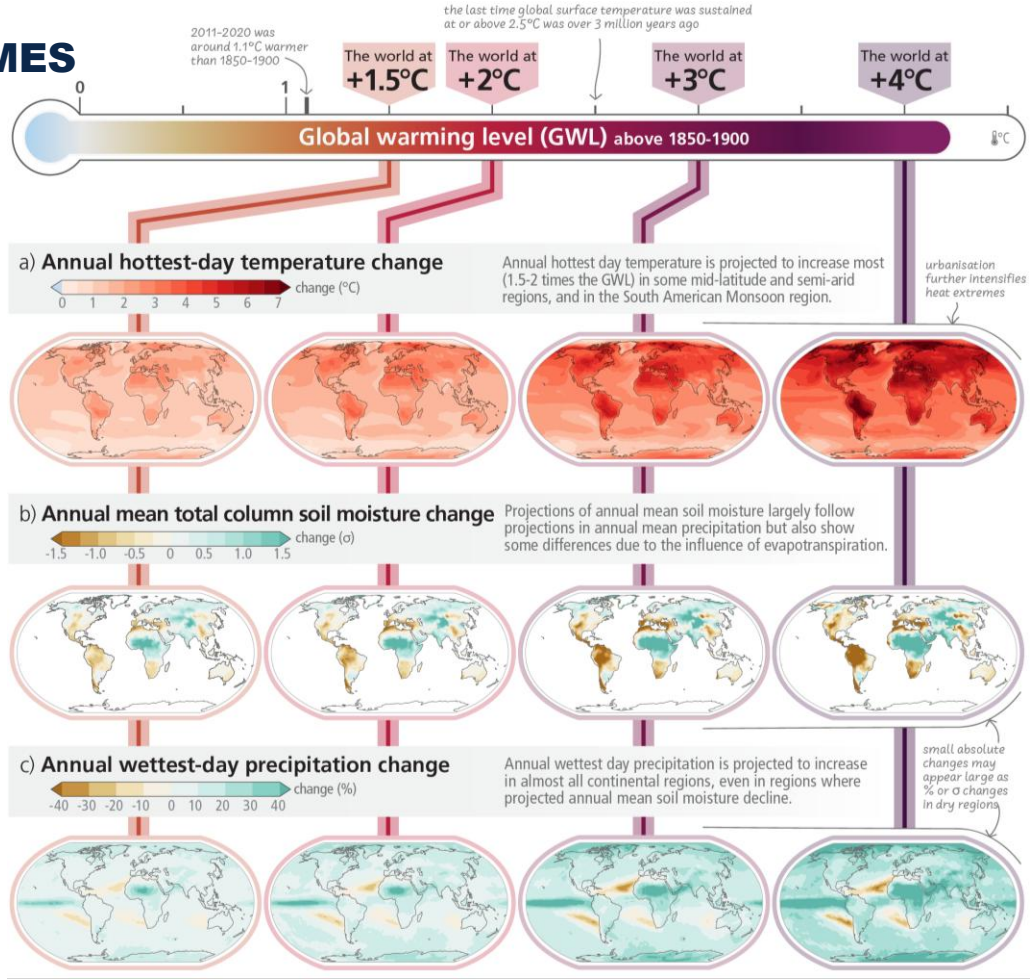


Peak over threshold approach: A method of extreme value analysis that involves selecting all observations that exceed a threshold value and analyzing the properties of these "peak" observations.

CLIMATE CHANGE EXTREMES

Every increment of global warming is making climate extremes more impactful

- The warmer the planet gets, the more pronounced the changesin extreme will become.
- Average climate and weather extremes will shift further and further away from what we currently recognize as “normal”,
- This will cause widespread disruption and damage to populations, livelihoods and the environment.



https://futuremedaction.eu/en/

CLIMATE CHANGE AND ATTRIBUTION

Attribution: The process of determining the causes of observed changes in climate and extreme events in terms of natural climate variability or greenhouse gases emissions

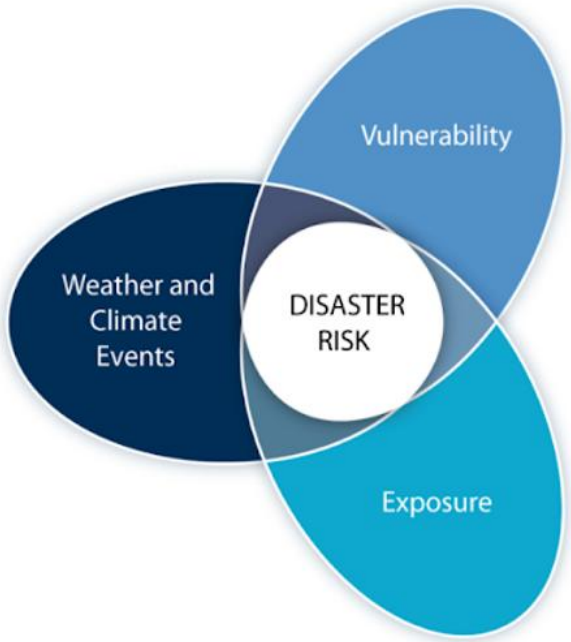
"I wonder what would happen if I halved the global warming...?"

WHICH EXTREME EVENTS NEED ATTRIBUTION?

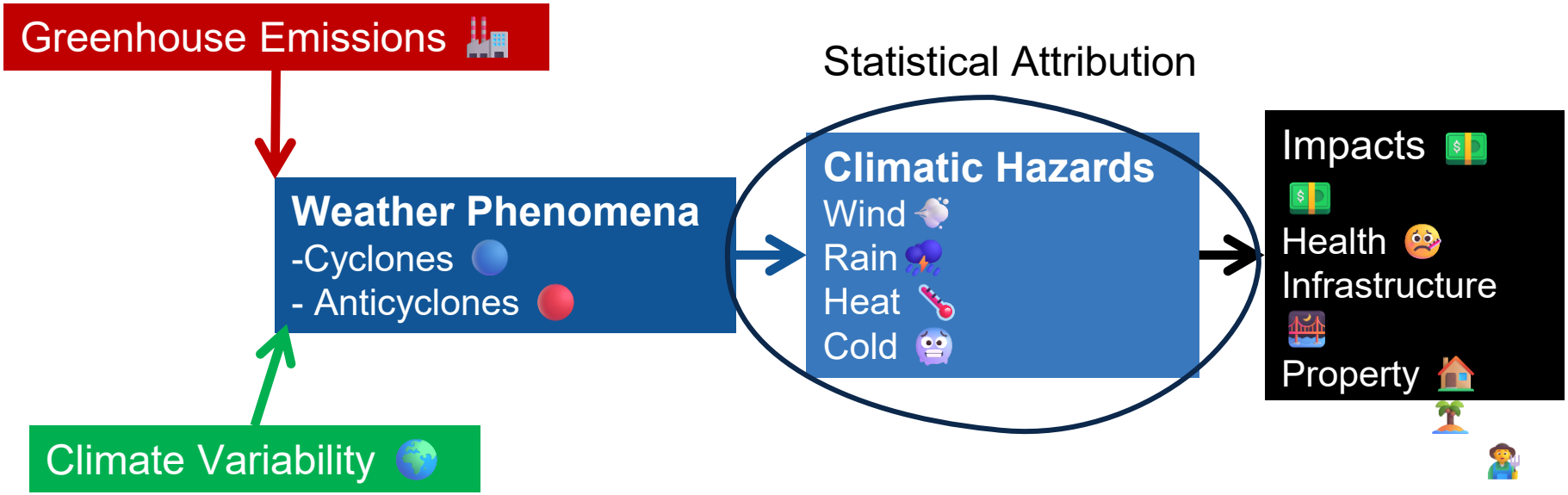
Weather extreme events may disrupt daily life, damage infrastructure, and have long-lasting effects on communities and ecosystems. This depends on:

Vulnerability: accounts for the susceptibility to damage of the assets exposed to the forces generated by the hazard.

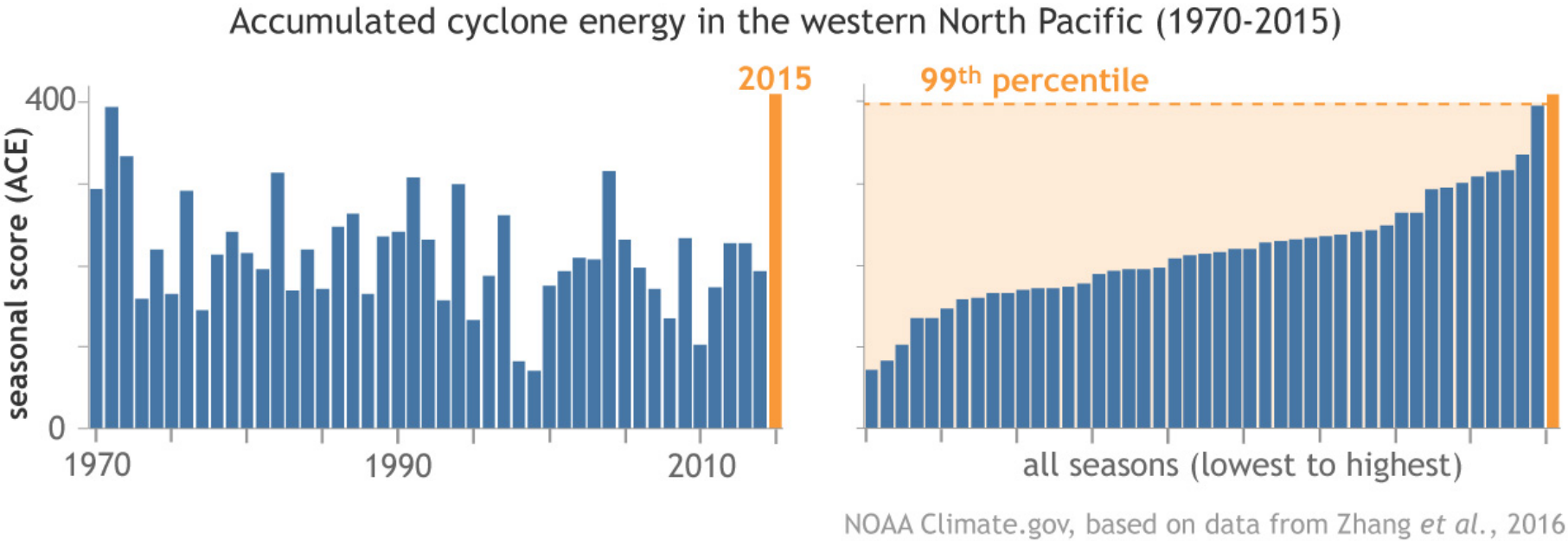
Exposure: represents the stock of property and infrastructure exposed to a hazard, and it can include socioeconomic factors.



A GENERAL PATHWAY TO ATTRIBUTION

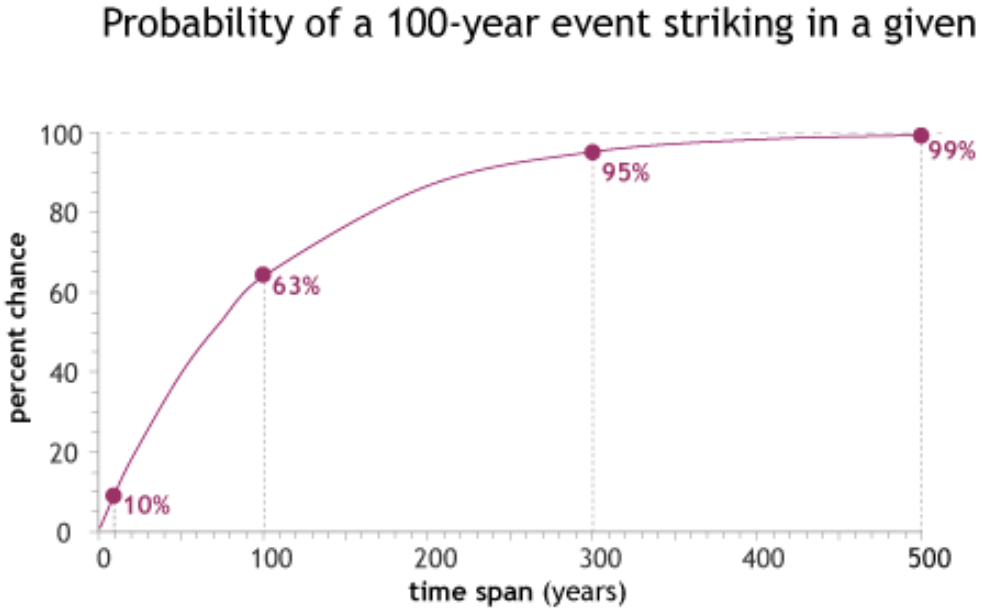


STATISTICAL ATTRIBUTION #1 : DETECTION



1. Define a quantiy that can track the extreme events: here cyclone energy
2. Sort our record and locate the percentile of our event

STATISTICAL ATTRIBUTION #2 : CHARACTERIZATION OF THE EVENT



TIME SPAN years	PROBABILITY % chance
1	1
5	5
10	10
20	18
50	40
75	53
100	63
200	87
300	95
400	98
500	99.3
800	99.97
1000	99.996

By definition, the probability that a 100-year event will occur in any single year is 1%. That means the probability that it won't happen that year is 99%

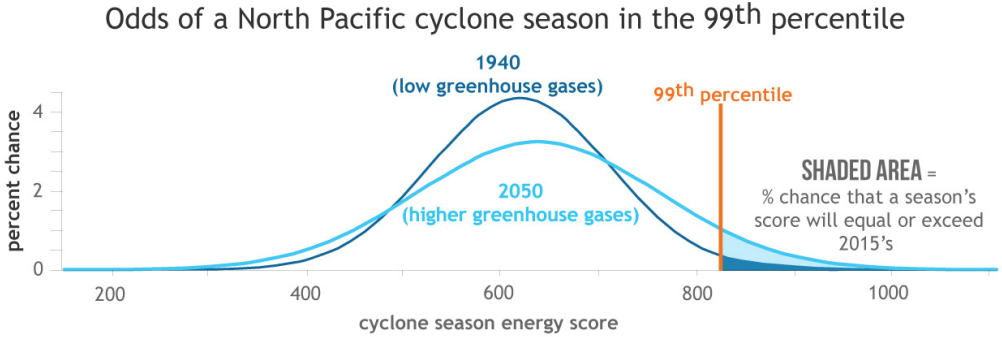
STATISTICAL ATTRIBUTION #3 : RESULTS

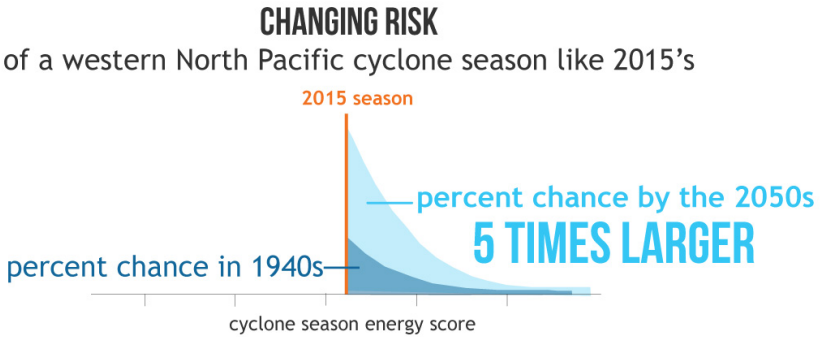
For attribution we can use changes in model projections of identiftied observables:

-1940-1970 (dark blue line) show cyclone energy for the world with low greenhouse gases emissions

-2020-2050 (light blue line) showt he changing frequency of 99th percentile events.

We conclude that Global warming due to rising greenhouse gases has increased the risk of an extreme North Pacific hurricane season like 2015's by a factor of 5





NOAA Climate.gov graphic adapted from Zhang *et al*., 2016.

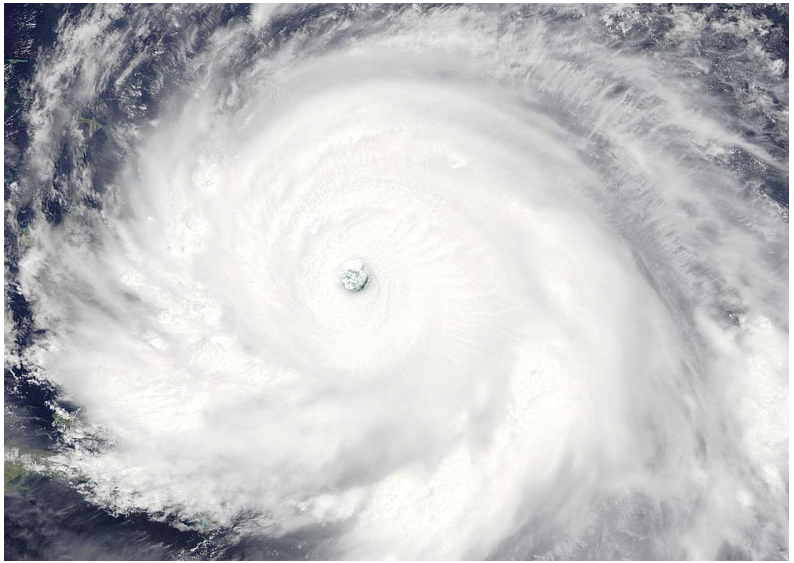
STATISTICAL ATTRIBUTION IS THAT ALL?

Statistical Attribution is useful for events that can be defined as averaged of quasi-homogenous observables over a certain area

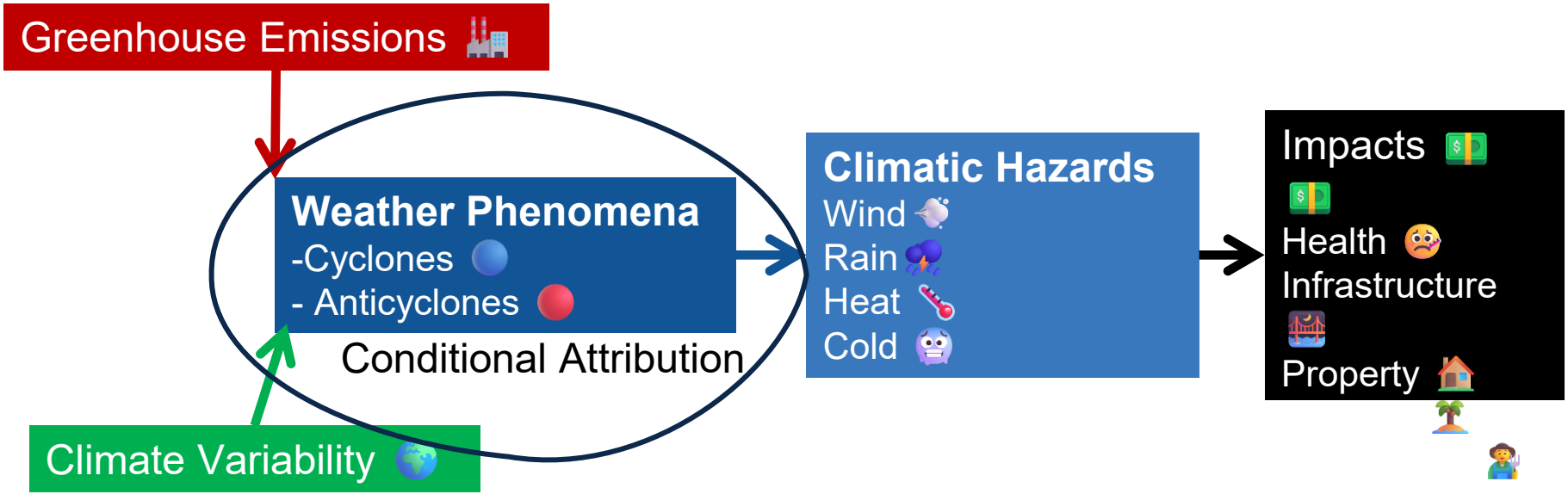
Most of the events, such as the Hurricane Irma that we analyse here, have complex hazards, impacts, very scattered geographycally

=>Attribution conditioned to circulation

=>Spatial Attribution => Climameter



CONDITIONAL ATTRIBUTION PATHWAY



ANALOGUES METHOD FOR CONDITIONAL ATTRIBUTION

🌐 **Data**: gridded data from reanlayses MSWX (1979 Present)

🌀 **Event Definition**: Time averaged Surface Pressure Anomalies map in a lon-lat box

🔍 **Analogues Analysis**: Assess differences in Present vs. Past Analogues

⏰ **Periods**: Split into two periods

- 🏞️ Past: Barely affected by Climate Change
- 🏜️ Present: Highly affected by Climate Change

📊 **Diagnosed Changes:** Pressure, Temperature, Precipitation, Winds

🌎 **Natural Variability Modes Change of phase in analogues:** ENSO, AMO, PDO

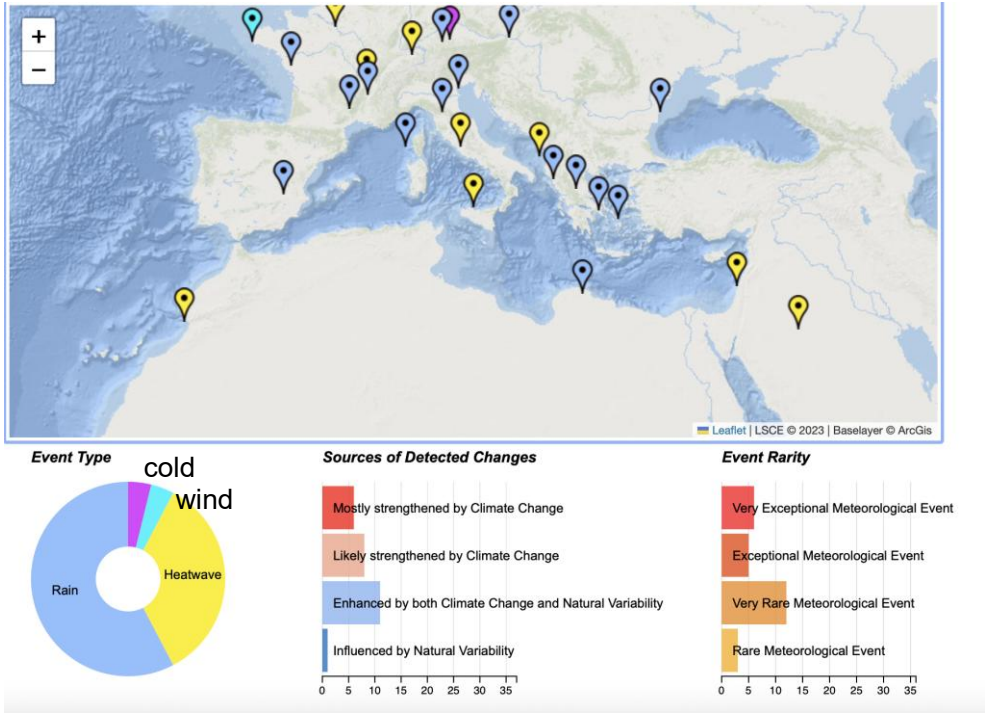
CLIMAMETER

🌎 ClimaMeter is a rapid attribution framework to place weather extremes in a climate perspective, developed by IPSL-CNRS FR

📃 It is a consortium of scientists from multiple international institutions

⌛ Reports are ready about 48 hours after an event. An event analyzed every two weeks

Events analysed in the MED

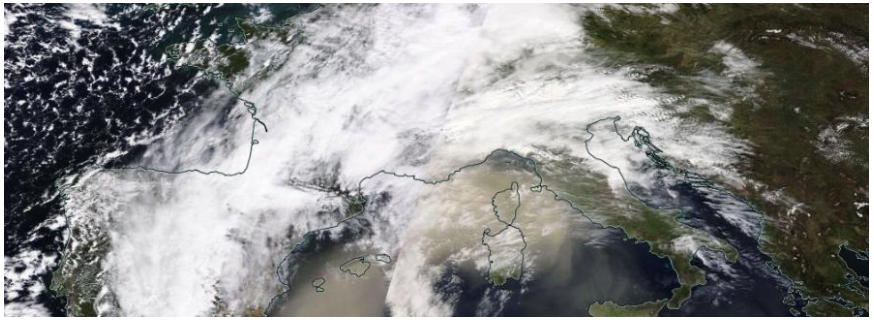


CLIMAMETER THROUGH AN EXAMPLE : COMPOUND EXTREMES IN EUROPE

🌀 From March 29 to April 1, 2024, extreme weather swept Europe over Easter.

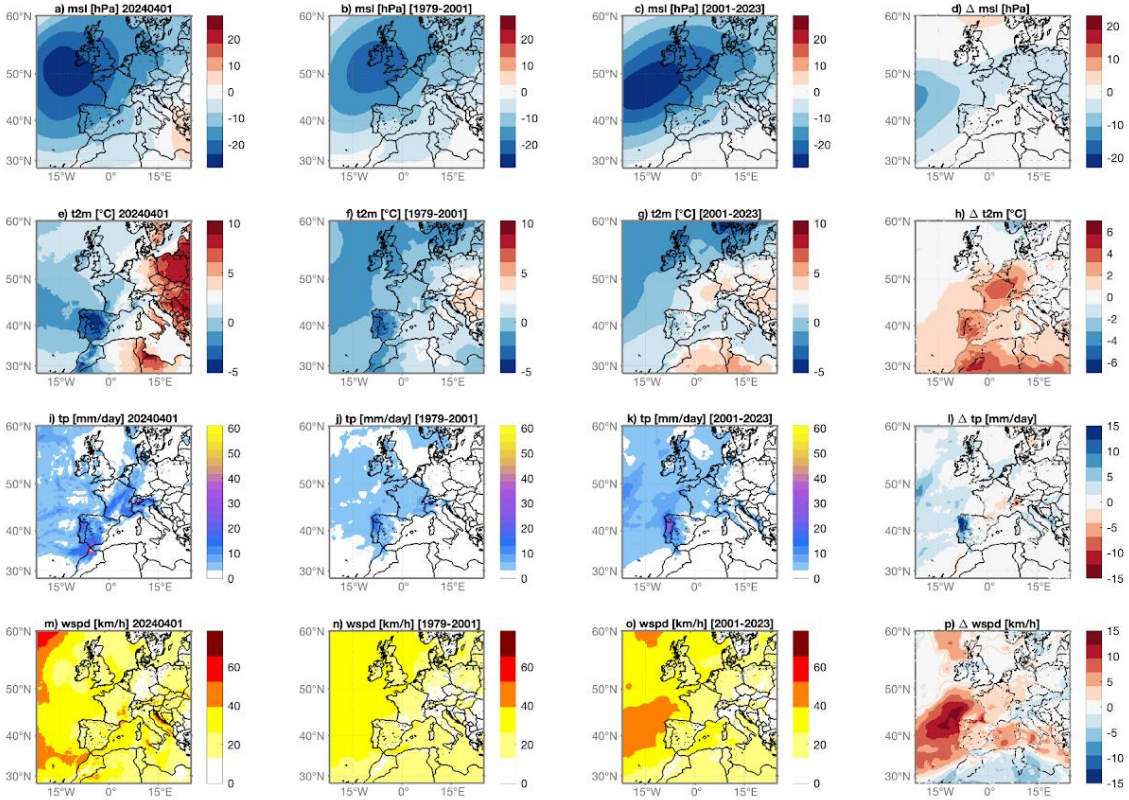
🏜️ Saharan dust covered Southern Europe from Italy to France, while France and Portugal faced severe floods and evacuations.

🌡️☂️☁️ As highlighted in IPCC AR6 WG2, climate change is compounding such extremes, heightening risks to ecosystems and health.



RESULTS FOR COMPOUND EXTREMES, EASTER 2024

EVENT | PAST | PRESENT | Δ=PRESENT-PAST



SUMMARY PROVIDED TO THE INTERNATIONAL PRESS

« Extreme Weather in Europe during Easter Weekend mostly strengthened by human driven climate change »

•Extreme weather patterns similar to the 2024 Easter Weekend in Europe are now up to 10 hPa deeper and up to 4 °C warmer. **They are up to 13mm/day (up to 30%) wetter over Portugal** and 10km/h windier along the Atlantic and Mediterranean coasts.

•This is a very uncommon event which occurs more frequently now in February/March with respect to the past.

• **Human driven climate change played a major role in** leading Easter Europe Compound Extremes and natural climate variability likely played a minor role.

🙏 THANKS FOR YOUR ATTENTION!

References

- Jézéquel et al. (2024). *Journal of Climate.*
- Faranda et al. (2024). *Weather and Climate Dynamics,*
- Pons et al. *Journal of Geophysical Research: Atmospheres.*

cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

FutureMed
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https://futuremedaction.eu/en/

PART II: CLIMATE CHANGE: FROM THE ATTRIBUTION OF EXTREME EVENTS TO IMPACTS ON SOCIETY

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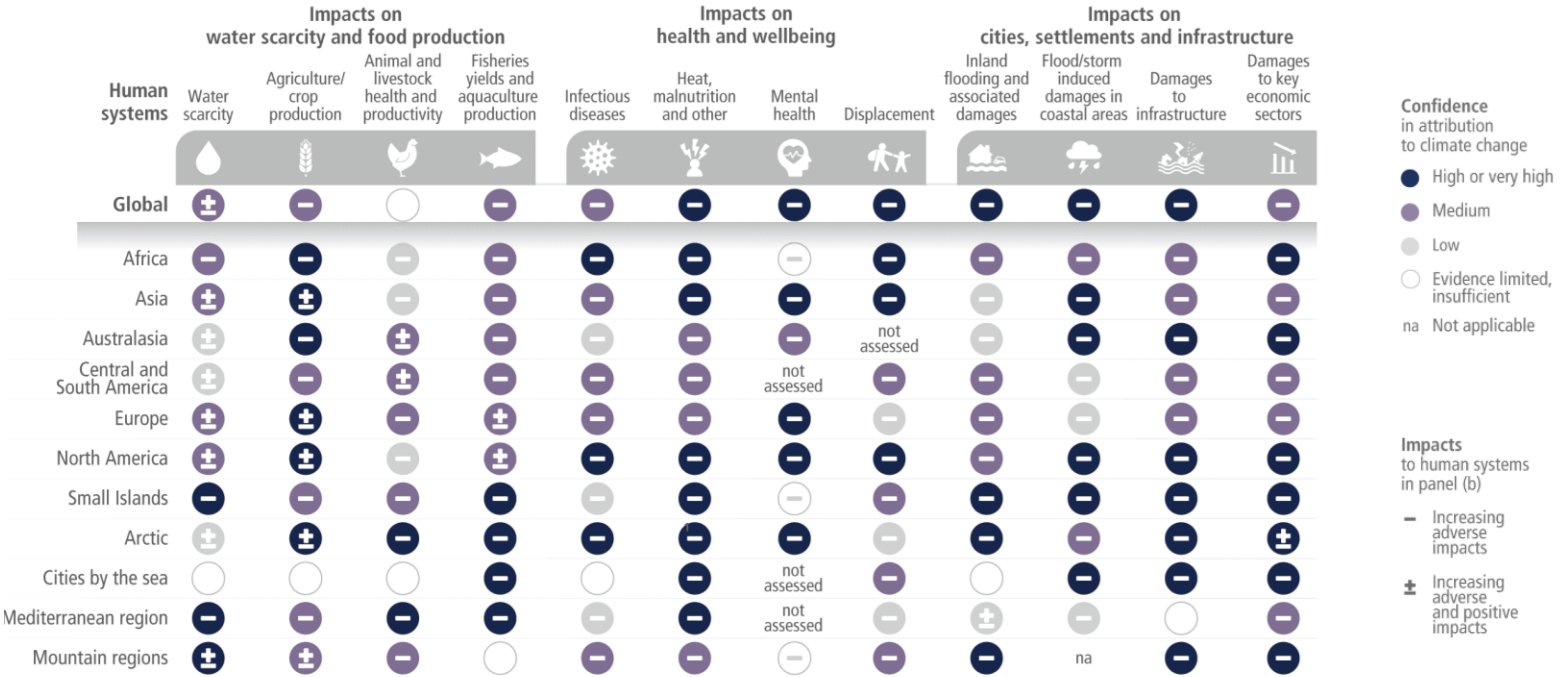
Climate change impacts

Climate change is a public health crisis – its effects on human health are already substantial and widespread, but unevenly distributed across populations

(b) Observed impacts of climate change on human systems

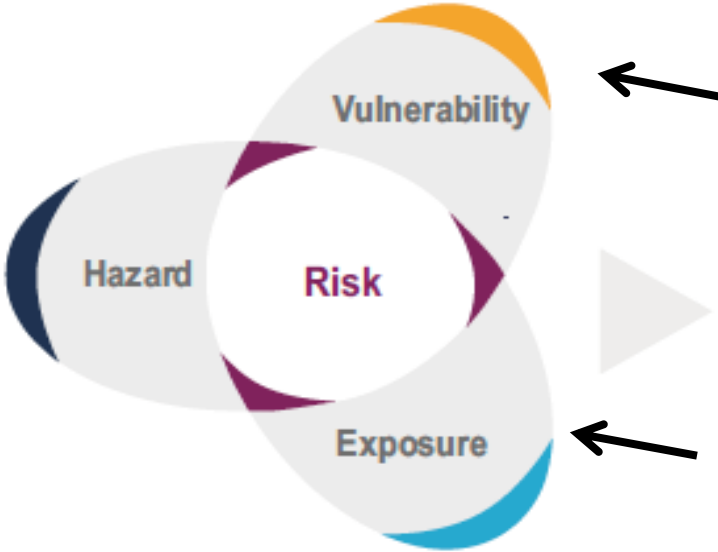


6th AR IPCC – Impacts, adaptation and vulnerability (Feb 2022)

https://futuremedaction.eu/en/

How impacts are distributed?

How health impacts are distributed in space (e.g., between populations) and time (e.g., current vs. future impacts) depends on the intersection between the magnitude of the hazard, level of exposure and vulnerability of the population.

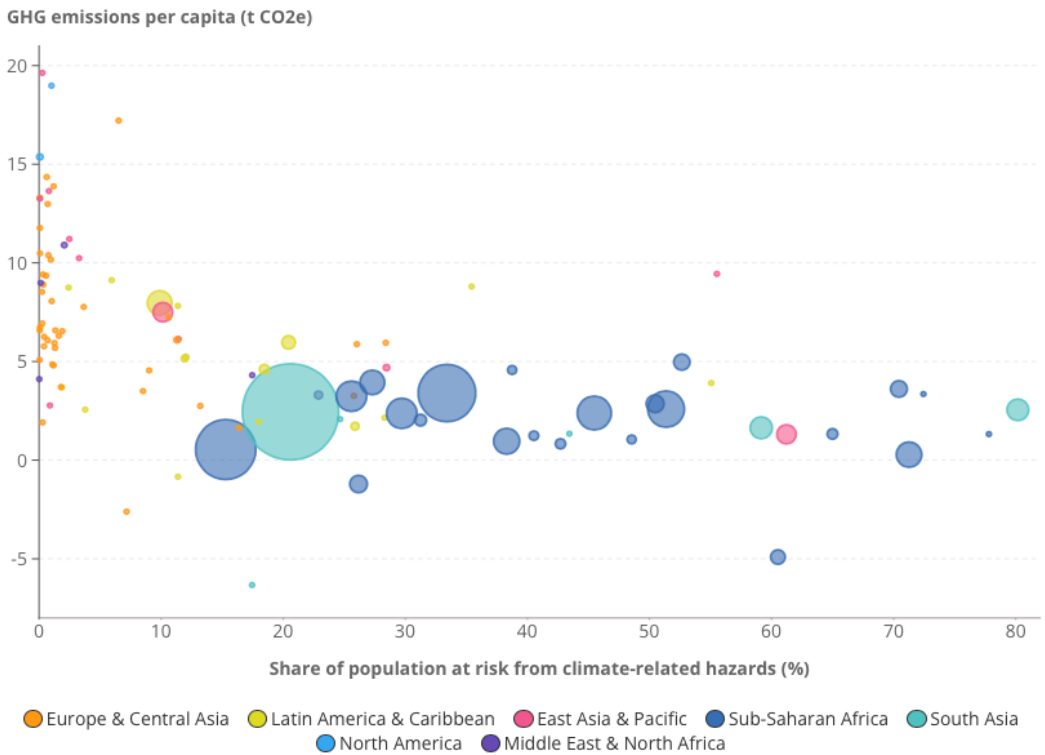


Geographical location

Adaptive capacity

Size and structure of the population (associated with population growth, ageing)

Climate change & health



Note : Bubble sizes reflect the number of people with less than $2.15 per person per day (in 2017 PPPs) in each economy in 2021. CO2e = carbon dioxide equivalent. GHG emissions per capita values are indicated in CO2e tons per person in 2021.

Climate change amplifies social inequalities

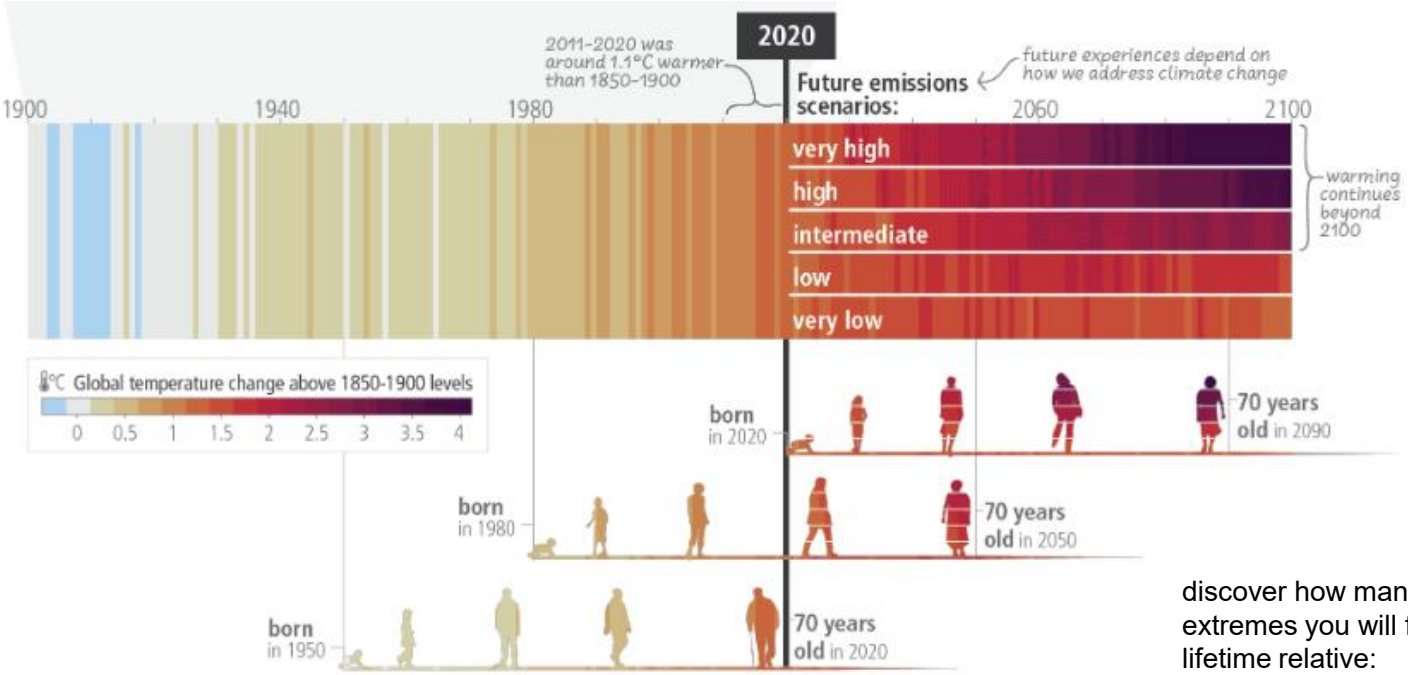
Countries with the highest share of at-risk people and highest extreme poverty rates emit the lowest amounts of GHG per person

An effective response to climate change should not only prevent increased inequality but also actively create opportunities to reduce existing health inequalities

World Bank - https://blogs.worldbank.org/en/opendata/the-disconnect-between-regions-at-risk-from-climate-related-haza

Climate change & health

Climate change is a intergenerational issue-Young populations today were born and will continue to live in a world with more extreme climate and possibly inhabitable in the future

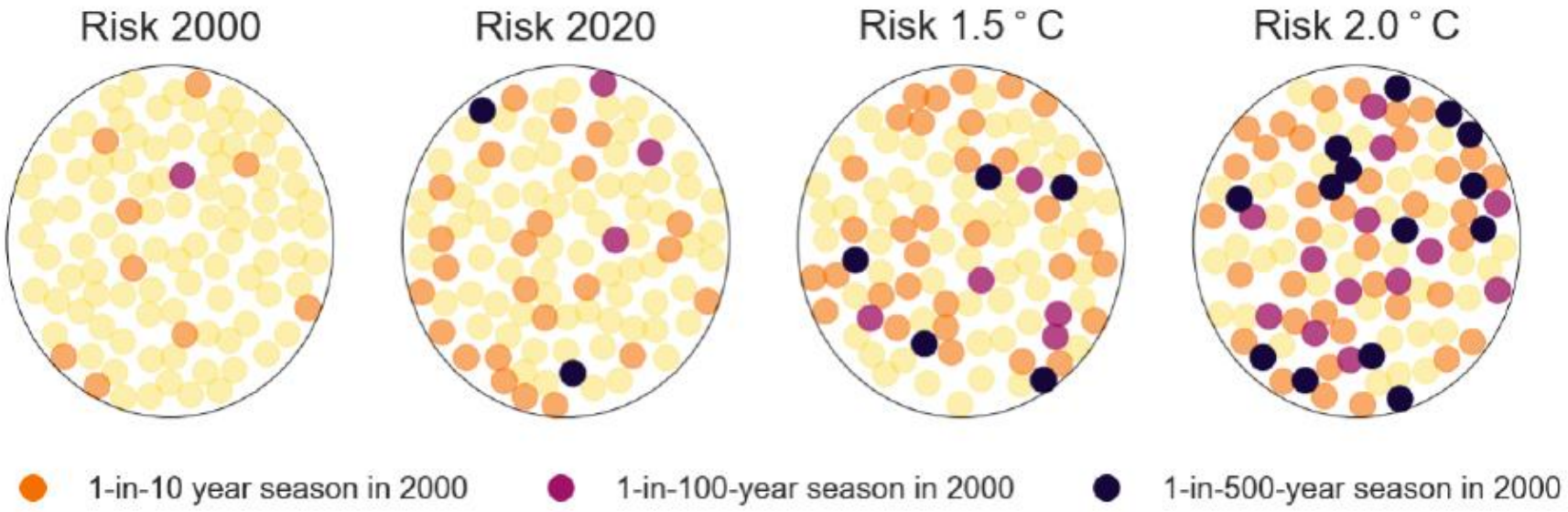


discover how many more climate extremes you will face across your lifetime relative:
Myclimatefuture.info

https://futuremedaction.eu/

Climate change & health

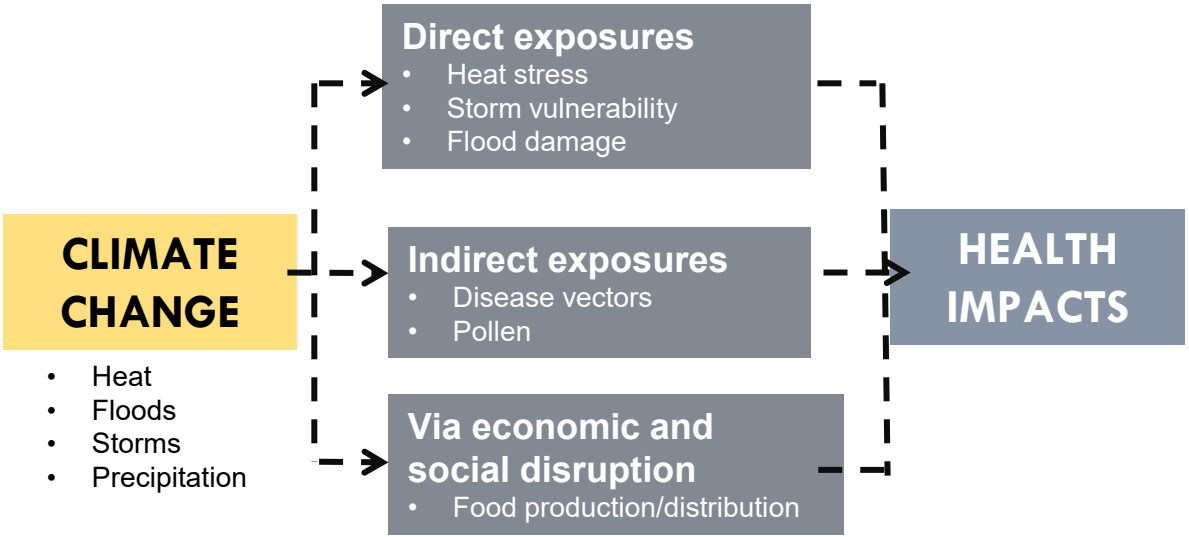
Climate change is making the **deadliest extreme weather events** we are observing today, to become the **norm in the future** & bringing us towards the unknown with even more extreme events



2003 Summer Paris

Lüthi et al. Nat Comms 2023

Mechanisms

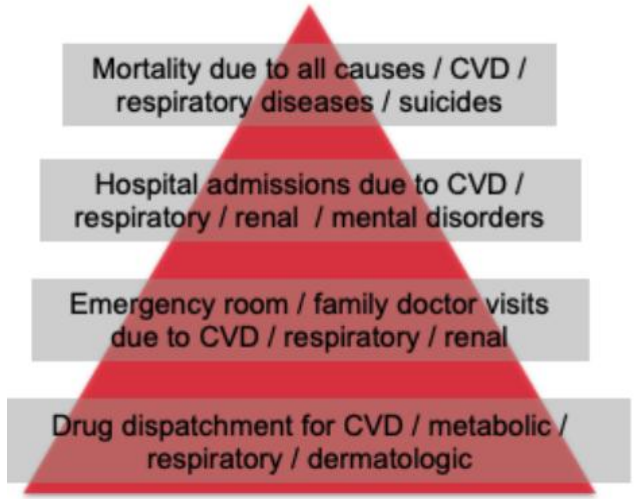


Adapted from 5th AR IPCC

DIRECT IMPACTS

Extreme weather events
- Heat / heatwaves
- Floods
- Storms

General population

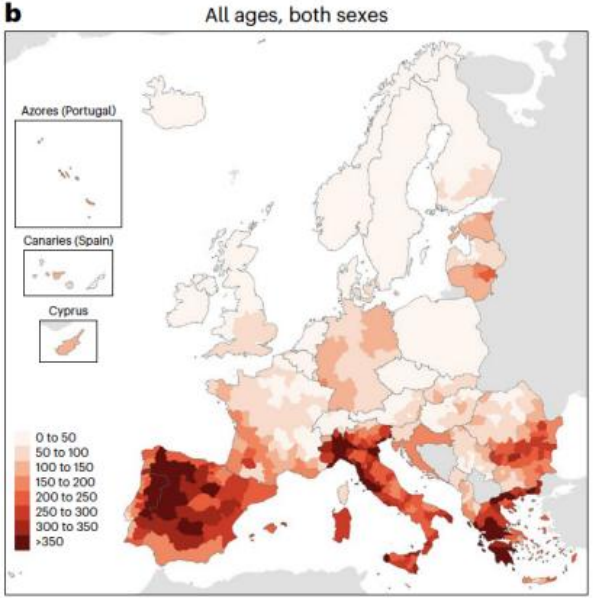


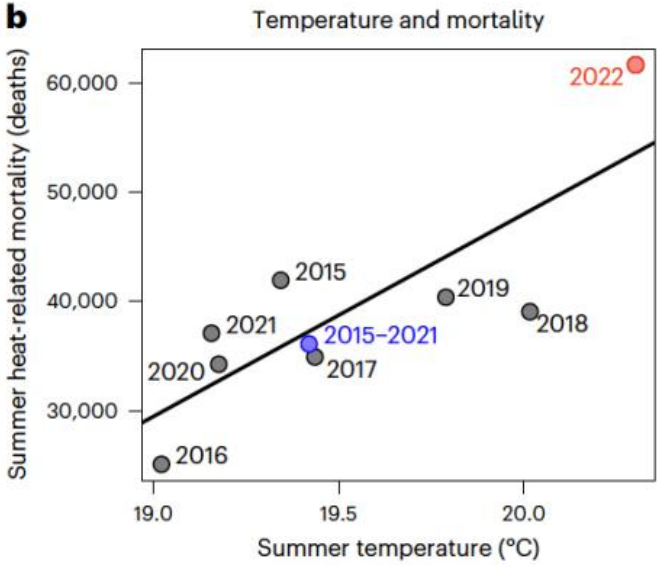
Vulnerable populations:
- Old population
- Children
- Pregnant women
- Chronic patients
- Workers (outdoors)
- Deprived population

Direct impacts

HEAT

Heat during 2022 summer in Europe resulted in more tan 60K deaths





Ballester et al., 2023 Nat Medicine

Direct impacts

HEAT

Two main mechanisms to cope with heat:
- Redistribution of blood flow towards the skin
- Sweating

→ During prolonged exposures of extreme heat, or if preexisting health conditions – mechanisms may fail

"Silent killer"

Heat strain

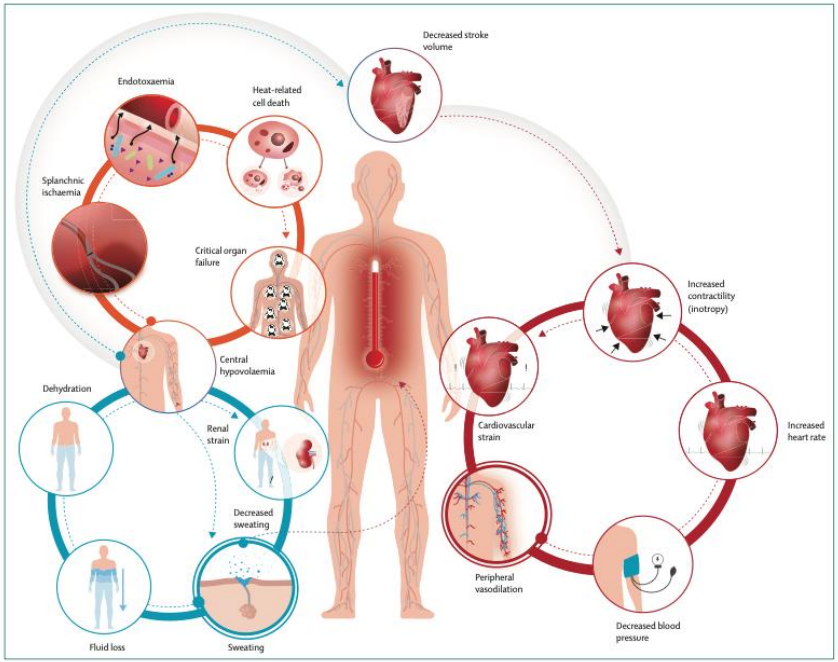


Figure: Illustration of the physiological pathways of human heat strain

Ebi et al. 2021

Table. Organs Damaged by Physiological Mechanisms Triggered by Heat Exposure

Organs	Mechanisms				
	Ischemia	Heat Cytotoxicity	Inflammatory Response	Disseminated Intravascular Coagulation	Rhabdomyolysis
Brain	①	⑦	⑬	⑳	
Heart	②	⑧	⑭		
Intestines	③	⑨	⑮	㉑	
Kidneys	④	⑩	⑯	㉒	㉕
Liver	⑤	⑪	⑰	㉓	㉖
Lungs		⑫	⑱	㉔	㉗
Pancreas	⑥		⑲		

Mora et al. 2017

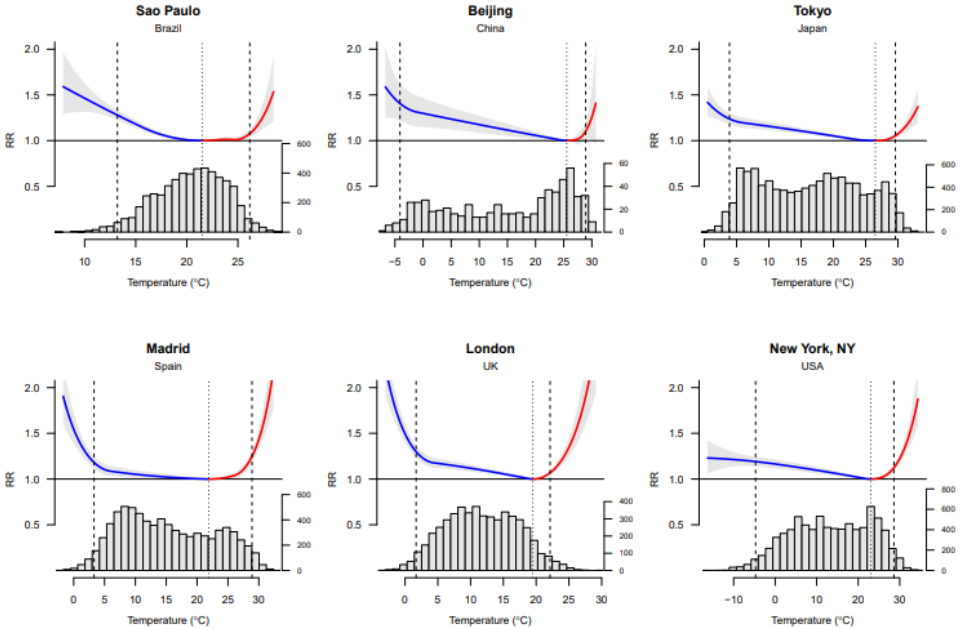
Increased risk of mortality, hospitalizations, emergency room visits due to cardiovascular, respiratory and urinary diseases, and mental disorders

HEAT

Different vulnerability to heat and cold across populations

Heat effects are

- Typically non-linear (increasing non-linearly with temperature)
- Different across population (acclimatization + adaptation)
- Short-term (within days) but slightly delayed



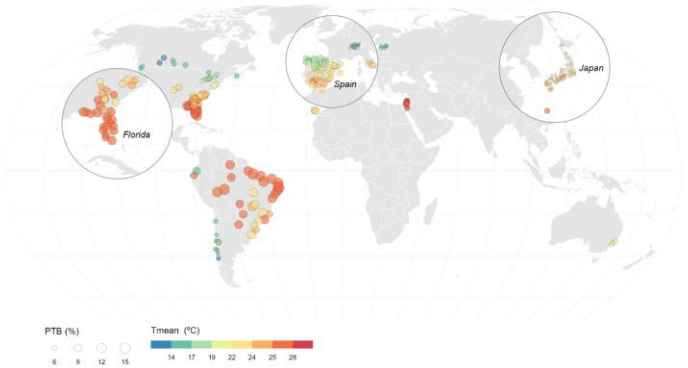
Gasparrini et al. 2015

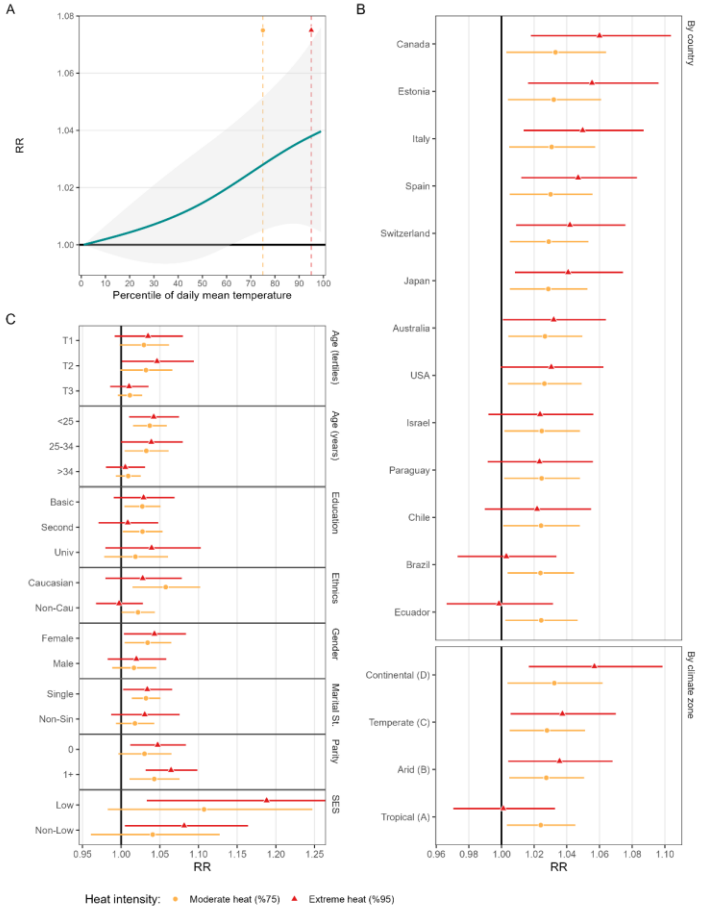
Direct impacts

HEAT

The effects of heat on premature births across 13 countries

Carmen Iñiguez[1,2], Coral Salvador[3,4,5], Keren Agayshay[6], Howard H Chang[7], Francesca de'Donato[8], Yoonhee Kim[9], Shoko Konishi[10], Eric Lavigne[11,12], Hans Orru[13], Martina S. Ragettli [14,15], Weeberb J. Requia[16], Dominic Royé[17,2], Tanya Singh[18,19], Joshua Warren[20], Nicolás Valdés[21], Ben Armstrong[22], Antonio Gasparrini[23], Francesco Sera[24], Aurelio Tobías[25], Ana Maria Vicedo-Cabrera[4,5]. MCC Collaborative Research Network.





Coordinated by the Multi-Country Multi-City collaborative research network (https://mccstudy.lshtm.ac.uk/)

Direct impacts

HEAT

The effects of heat on CV morbidity

Environmental Research 226 (2023) 115698

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Heat-related first cardiovascular event incidence in the city of Madrid (Spain): Vulnerability assessment by demographic, socioeconomic, and health indicators

Coral Salvador[a,b,c], Pedro Gullón[d,e], Manuel Franco[d,f,*,1], Ana M. Vicedo-Cabrera[b,c]

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[b] Institute of Social and Preventive Medicine, University of Bern, Bern, Switzerland
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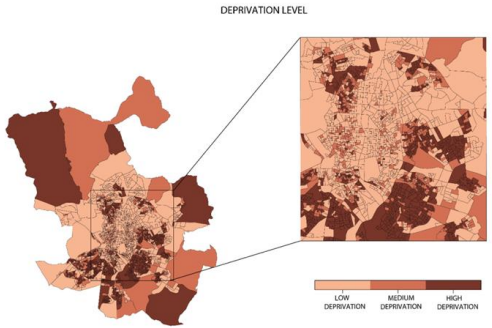
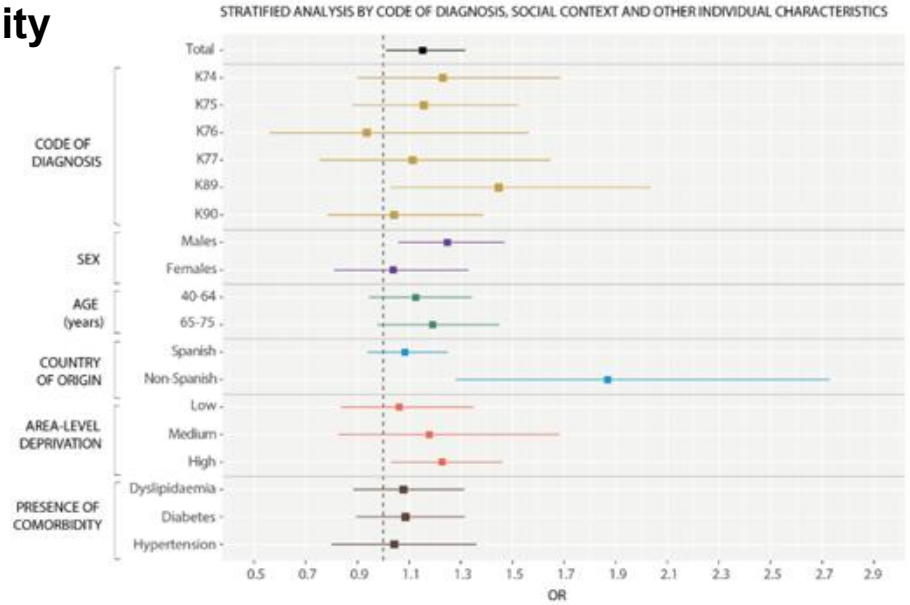
[d] Universidad de Alcalá, Grupo de Investigación en Epidemiología y Salud Pública Facultad de Medicina y Ciencias de La Salud, Alcalá de Henares, Madrid, Spain
[e] Centre for Urban Research, RMIT University, Melbourne, Australia
[f] Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, Md, 21205-2217, USA





Ischemic heart disease with angina (K74)
Acute myocardial infarction (K75)
Ischemic heart disease without angina (K76)
Heart failure (K77)
Transient cerebral ischemia (K89)
Stroke/cerebrovascular accident (K90)

Direct impacts

FLOODS

Table 1. Health Risks of Flooding, Stratified by Time After Event

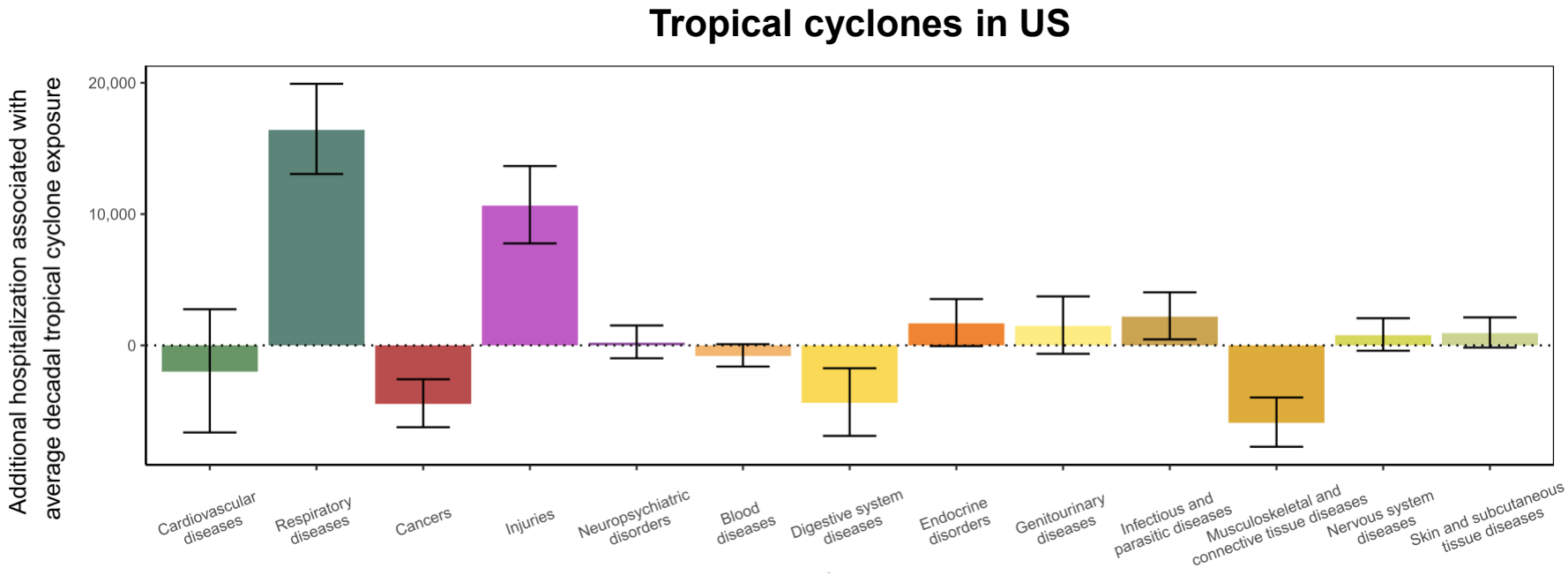
Immediate
Drowning
Trauma
Hypothermia
Electrocution
Carbon monoxide poisoning
Early (<10 d after event)
Cutaneous infection
Aspiration pneumonitis/pneumonia
Viral respiratory infections
Gastroenteritis
Late (>10 d after event)
Leptospirosis
Mosquito-borne illnesses
Cutaneous infection from atypical organisms (fungi, mycobacteria)
Hepatitis A or E virus infection
Mental health disorders, including posttraumatic stress disorder and depression
Management of chronic disease

Paterson et al. 2018

Various health impacts at different time scales and level of severity affecting different populations

Dana in Valencia (Spain, October 2024) caused 223 fatalities, 15000 displacements, long-term health consequences and financial losses

CYCLONES



Parks et al., 2021 Nat Comms

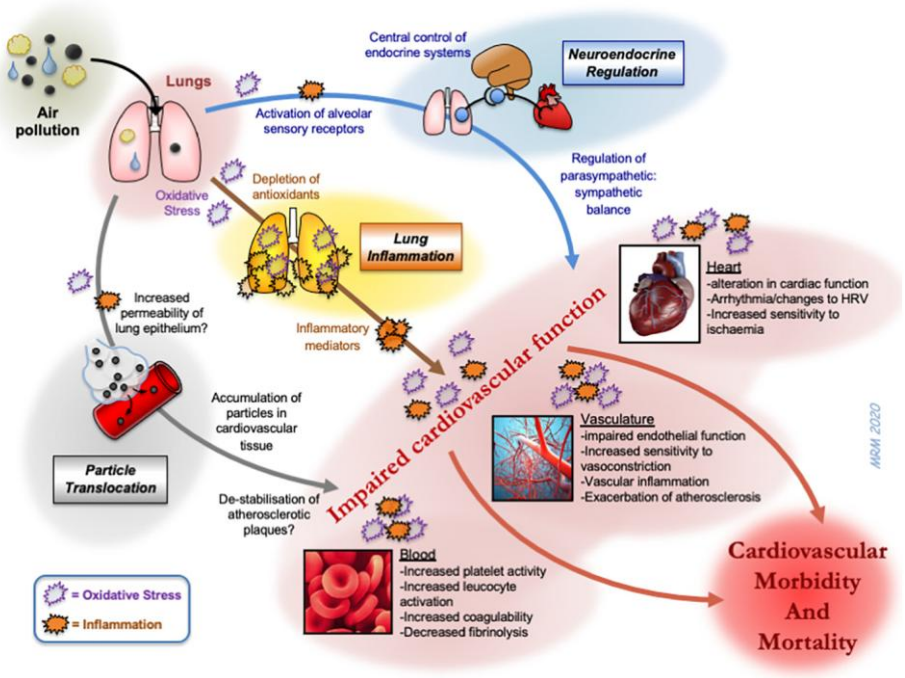
Indirect impacts

Climate change alters existing environmental and biological risk factors

- Worse air quality (air pollution / wildfires)
- Alteration of pollen patterns (composition / dispersion / timing)
- Changes in the spread of infectious diseases (i.e., vector-borne diseases, food-borne diseases and water-borne diseases)

Indirect impacts

Air pollution and human health



Miller, 2022

Table 1. Characteristics and Health Risks of Wildfire Particulate Matter.*

Short-term health effects	
Mortality	There is consistent evidence of an increased risk of death from any cause but uncertain evidence of an increased risk of death from specific causes.[8,9,36] Wildfire particulate matter may have a stronger effect on mortality than urban particulate matter,[8,9,36,37] owing to the smaller particle size,[31] more abundant oxidative and proinflammatory components,[33] and amplifying effects of high temperature[17] and ozone.[38]
Morbidity	There is consistent evidence of an increased risk of respiratory events, including hospitalizations and emergency department visits due to asthma, chronic obstructive pulmonary disease, and respiratory infection.[8,9,36,39] Wildfire particulate matter has a stronger effect on the risk of asthma-related events than urban particulate matter.[33,40,41] Data are inconsistent regarding the risk of cardiovascular events,[8,9,36] but the effect may be similar to that of urban particulate matter.[41]
Risk of other health effects	Risks of low birth weight and preterm birth are increased.[8,9] Rates of influenza are increased.[42] Ambulance dispatches among people with diabetes are increased.[43]
Long-term health effects	Effects are largely unknown; wildfire particulate matter might impair lung capacity, self-reported general health, and physical functioning several years later.[44]
Vulnerable populations	Older adults, children, and pregnant women are more susceptible. People with preexisting cardiac or respiratory conditions (or both) have increased risks. People living in low-income areas have increased risks. Outdoor workers have increased exposure.

Xu et al., 2020

Pollen

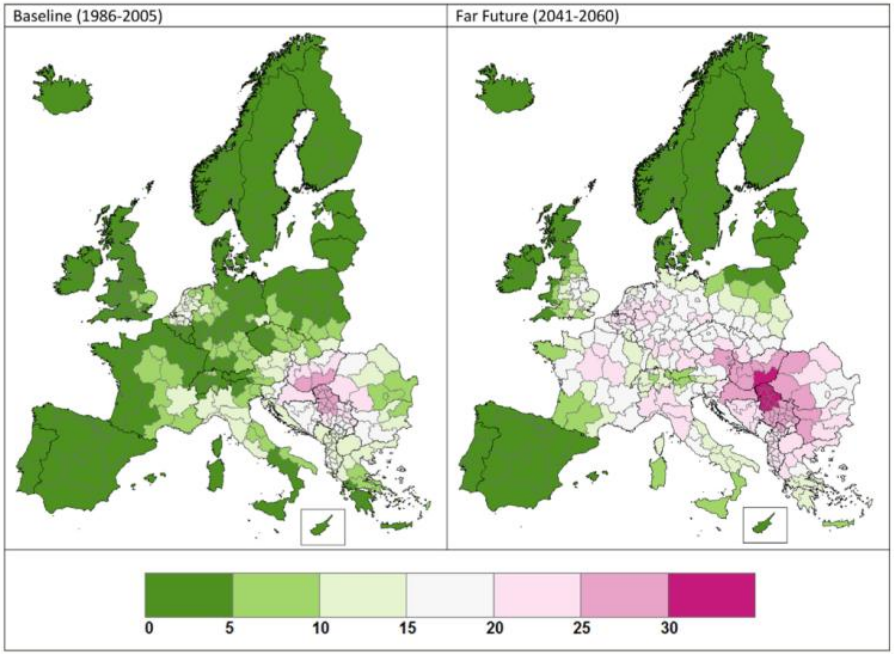


Figure 2. Percentage of population sensitized to ragweed pollen at baseline and in the far future; averaged results for WRF/RegCM and CHIMERE, RCP4.5, and reference invasion scenario. © EuroGeographics for the administrative boundaries.

Lake et al., 2017

climate change is causing an earlier onset and increased intensity of the pollen season for many allergenic plants. It is also increasing the sensitivity of allergies and pollen allergenicity

Ragweed pollen allergy will become a common health problem across much of Europe. Sensitization to ragweed is expected to increase from the current total of 33 million to 77 million people by 2041–2060

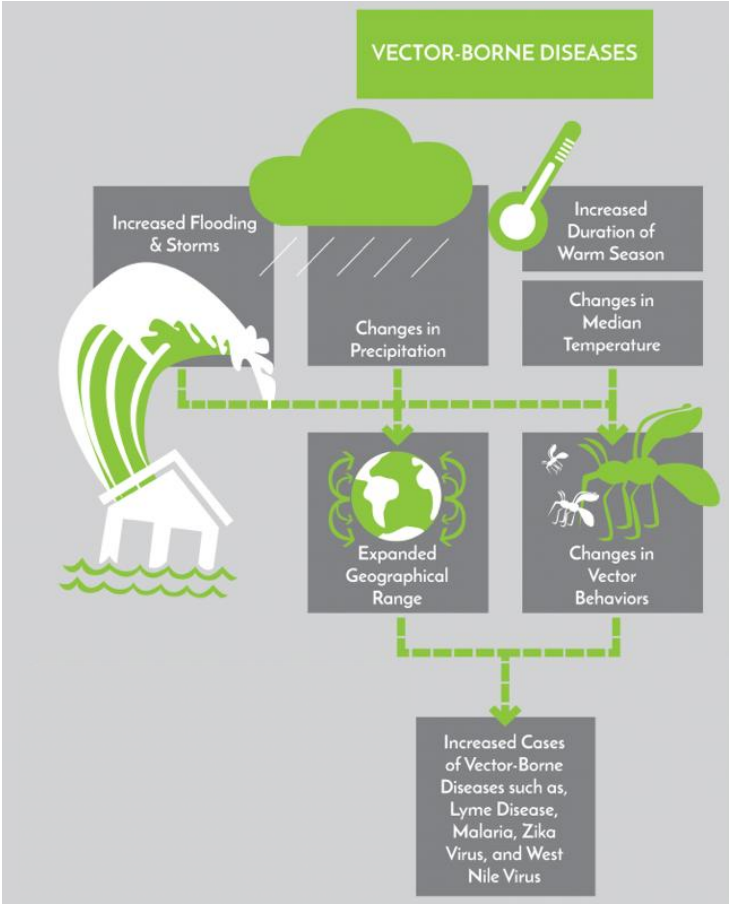
Indirect impacts

VECTOR-BORNE DISEASES

>80% of the global population is at risk of a vector-borne disease

CLIMATE CHANGE

- vector and host abundance
- local prevalence of disease-causing parasites and pathogens
- human population behaviour and disease resilience



https://climatenexus.org/climate-issues/health/climate-change-and-vector-borne-diseases/

https://futuremedaction.eu/en/

Indirect impacts

VECTOR-BORNE DISEASES

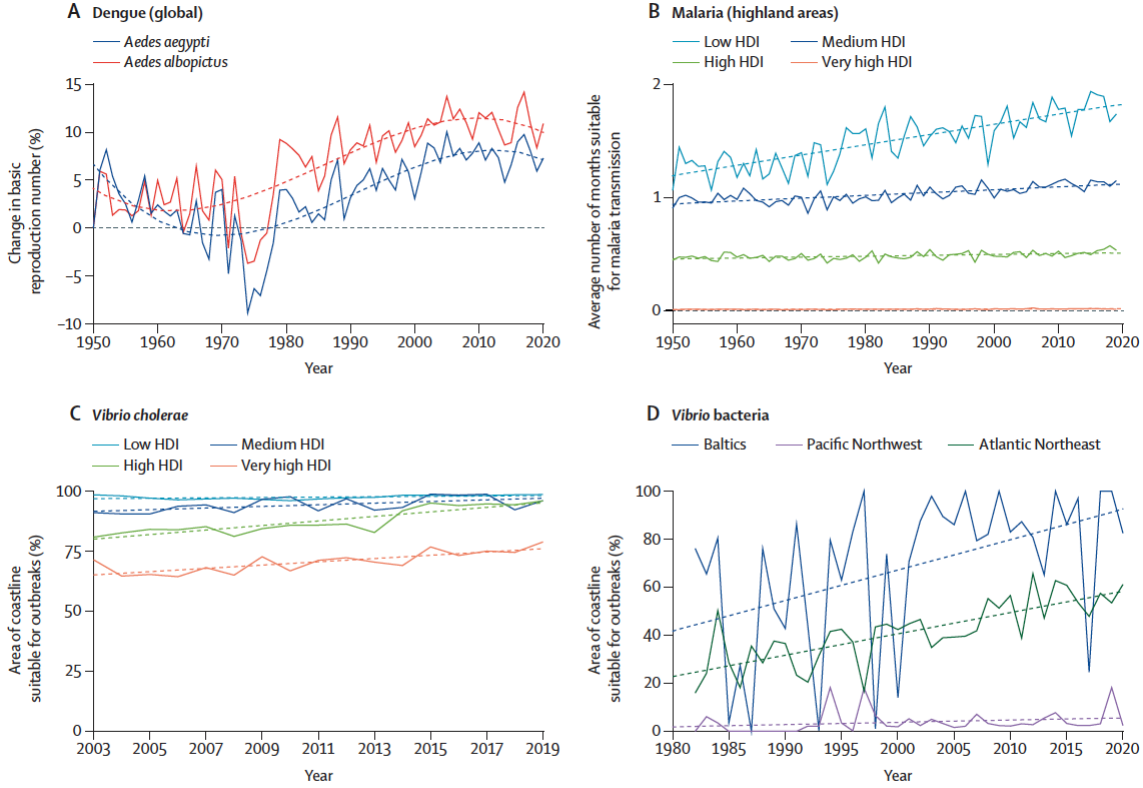


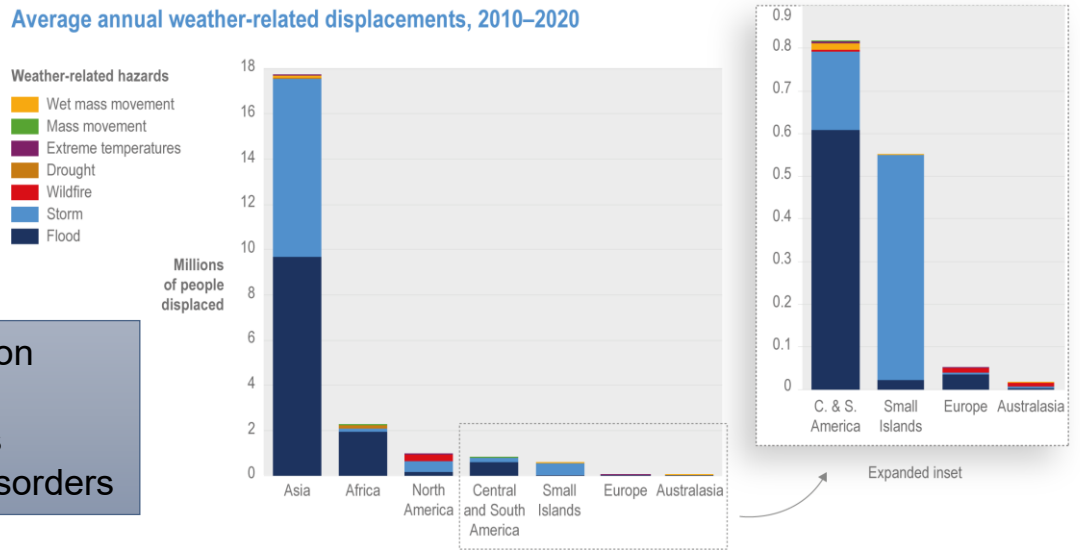
Figure 8: **Change in climate suitability for infectious diseases**
Solid lines represent the annual change. Dashed lines represent the trend since 1950 (for dengue and malaria), 1982 (for *Vibrio* bacteria), and 2003 (for *Vibrio cholerae*). HDI=human development index.

Via socioeconomic/social disruption

Climate change

- Loss of productivity /quality of the crops
- Economic losses
- Conflicts
- Migration

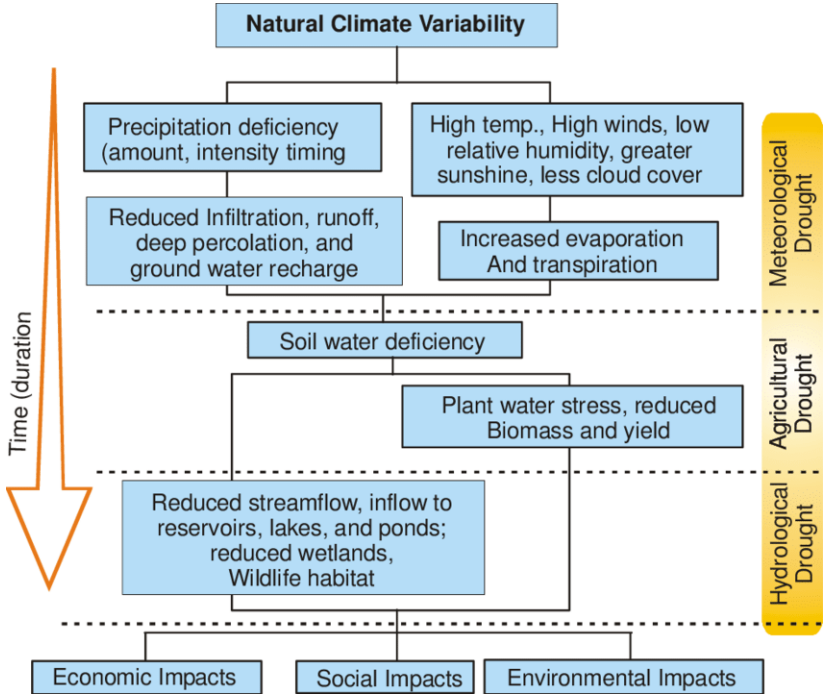
- Malnutrition
- Poverty
- Refugees
- Mental disorders



IPCC 6AR- WG2 Chapt 7

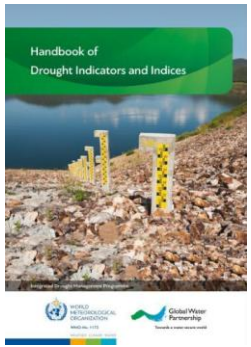
Droughts and Health

Drought is the most complex and devastating phenomena affecting around 55 million people every year and causing more deaths and human displacements than any other natural hazard (UNDRR, 2021; WHO, 2022)



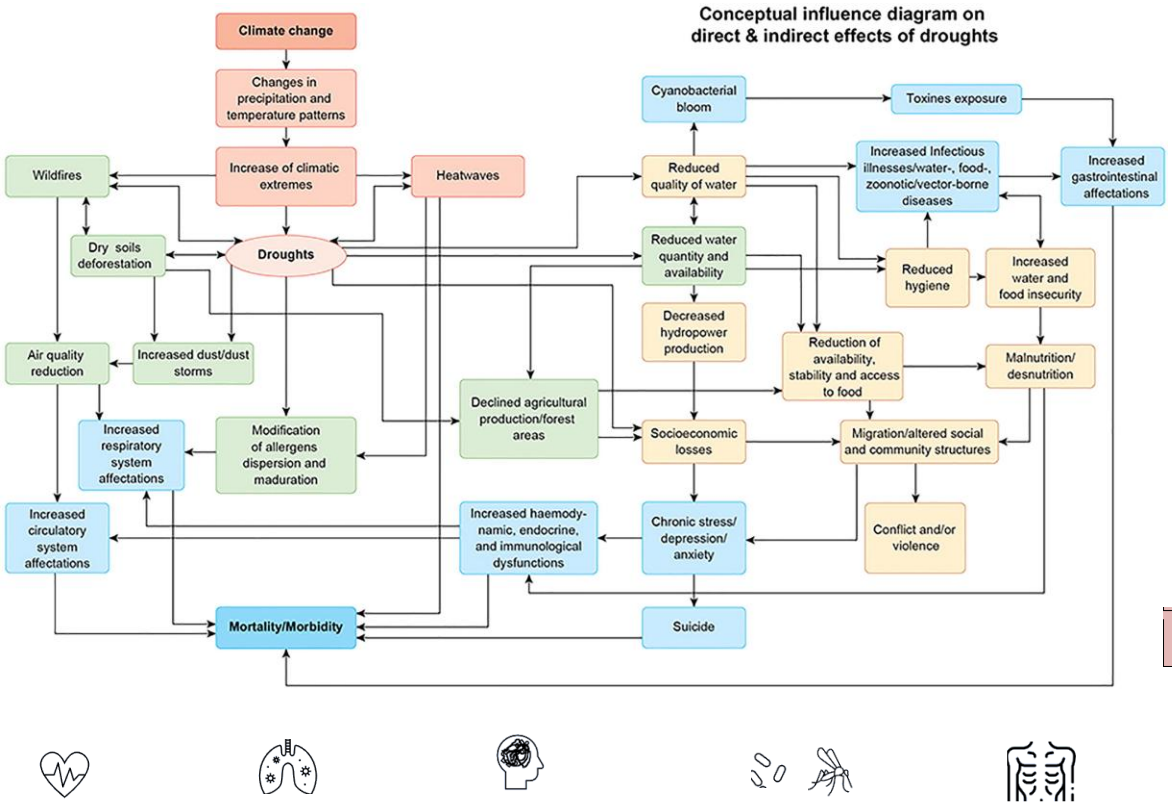
Jeyaseelan, A.T., 2014

- ✦ No universal definition of drought
- ✦ different types of droughts and metrics
- ✦ multiple sectors affected
- ✦ most of the impacts are accumulated and indirect



https://futuremedaction.eu/en/

Droughts and Health



- Few studies address drought impacts on the public health field
- Inconsistences between studies
- Vulnerability profiles?

IGIA-SETH project: Unraveling the Impacts of droughts on human health. SNSF Ambizione grant (PI: Coral Salvador)

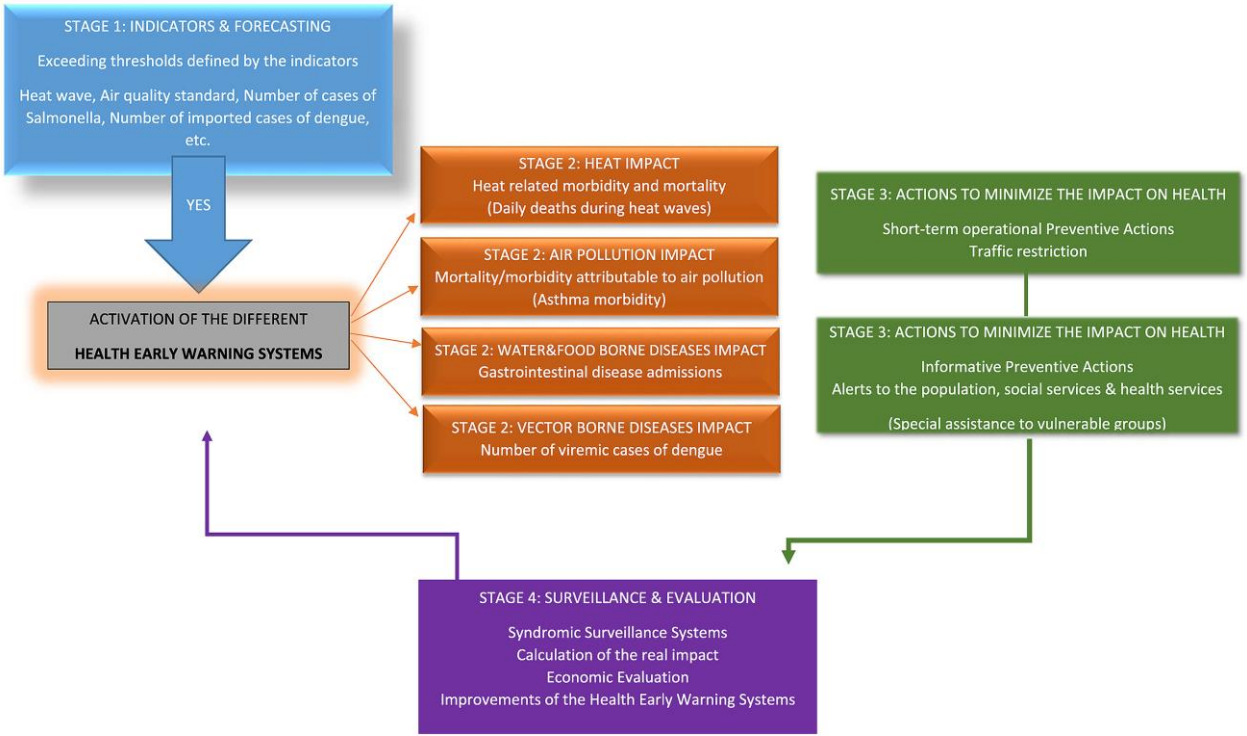
Monday, 29 september

17:35 – 17:55	O1.2 - Assessing mortality risk patterns associated with droughts in a multi-location study *C. Salvador*

Salvador et al. 2020

Climate change & health

Climate change causes or aggravates a wide range of exposures with multiple impacts on health



Integrated prevention and action plans for climate change and health addressing synergies across various climate-related exposures

Linares et al., 2020

🙏 THANKS FOR YOUR ATTENTION!

D.Faranda (CNRS), Coral Salvador (Univ. Bern)