Global Warming: The physical science basis.

Understanding what has happened and what we can expect.

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Preamble:
do you see what I see?

(we all are goldfish)

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It's hot

…or is it?

- "I remember it was hot too *when I was young*"
- "Of course it is hot: it's called *SUMMER*, you know?"
- "You see? *This year* was very wet/cold/snowy: where is this supposed climate change?"
- "You see? *Where I live* it's colder than it used to be: where is this supposed climate change?"

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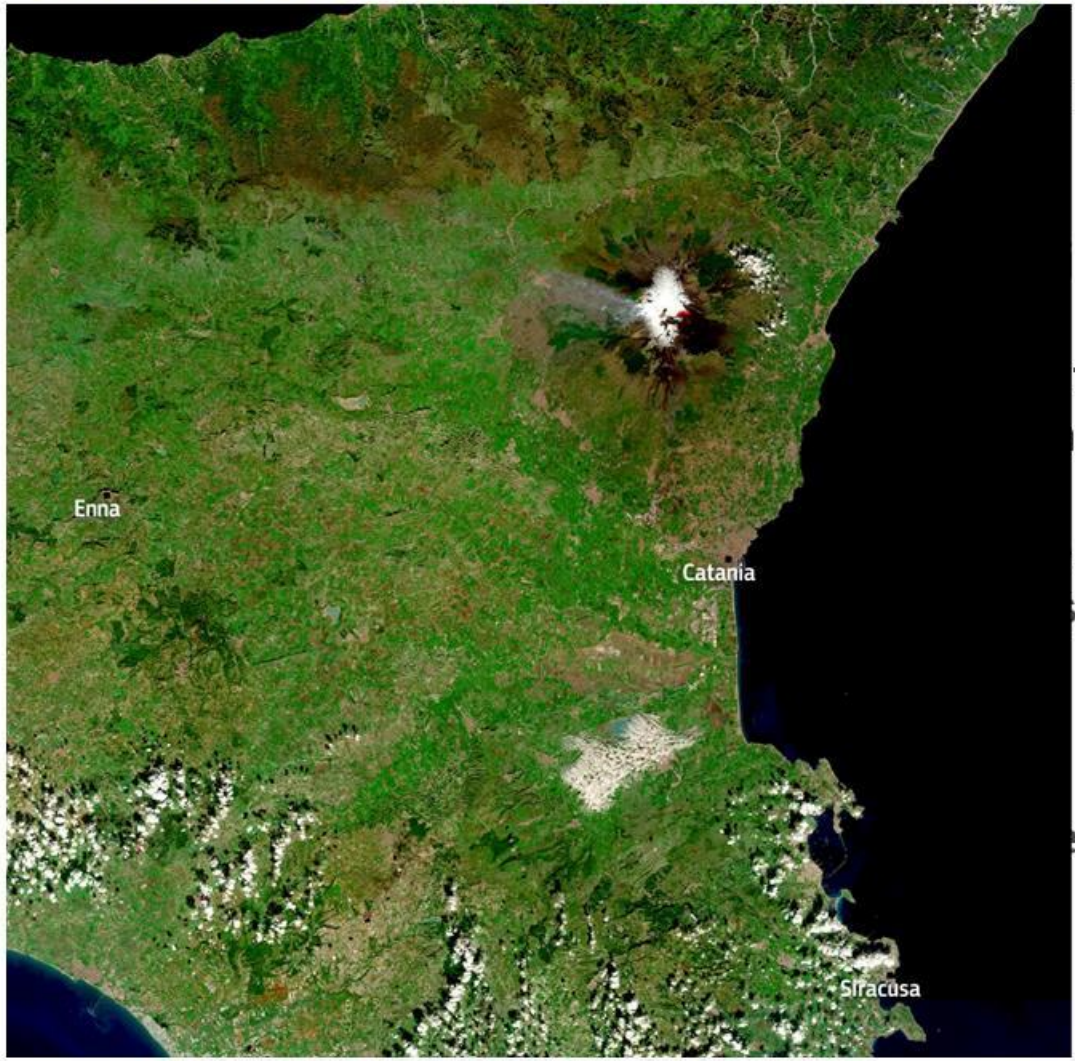
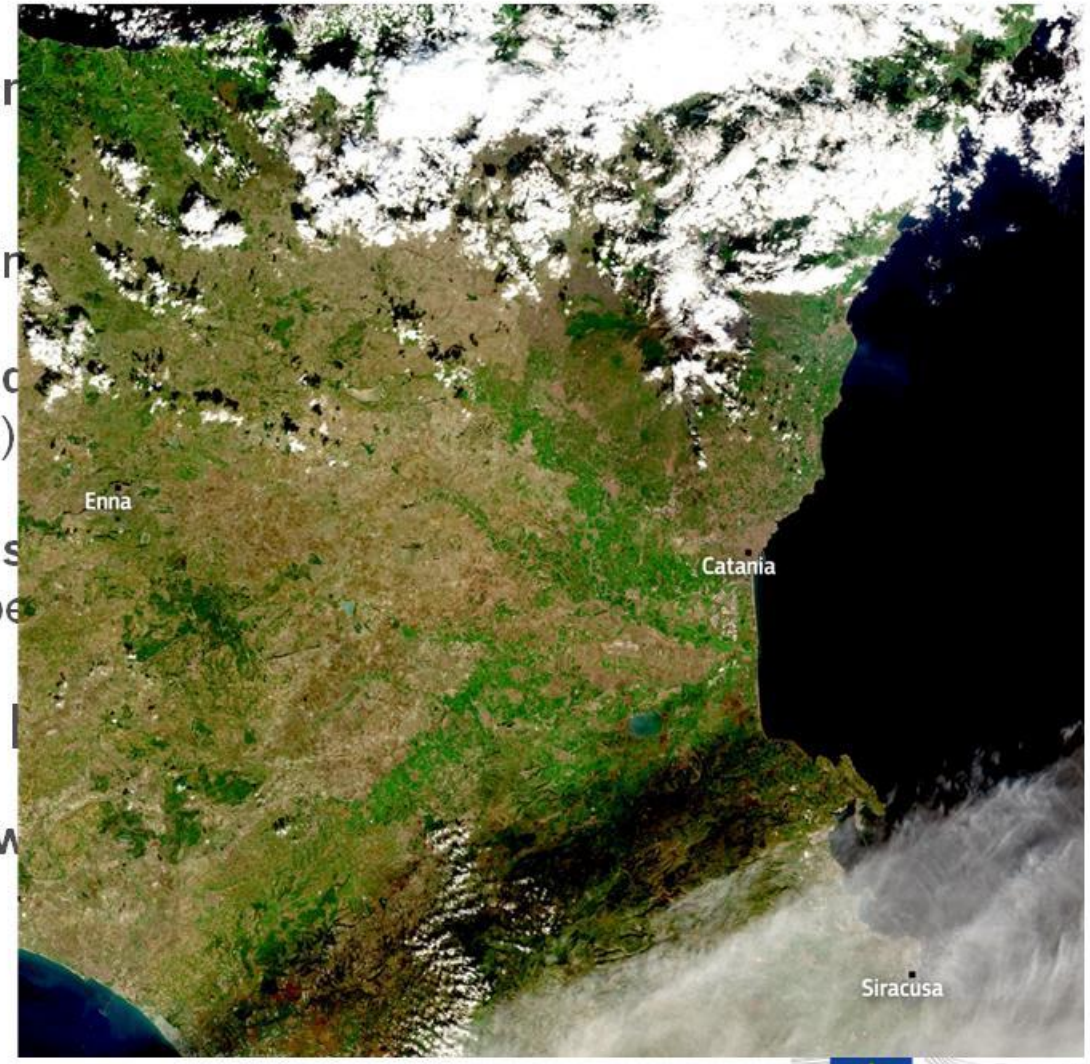
https://www.nicolaporro.it/il-grande-bluff-del-cambiamento-climatico/





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Let’s clear some (basic) concepts

So we understand each other

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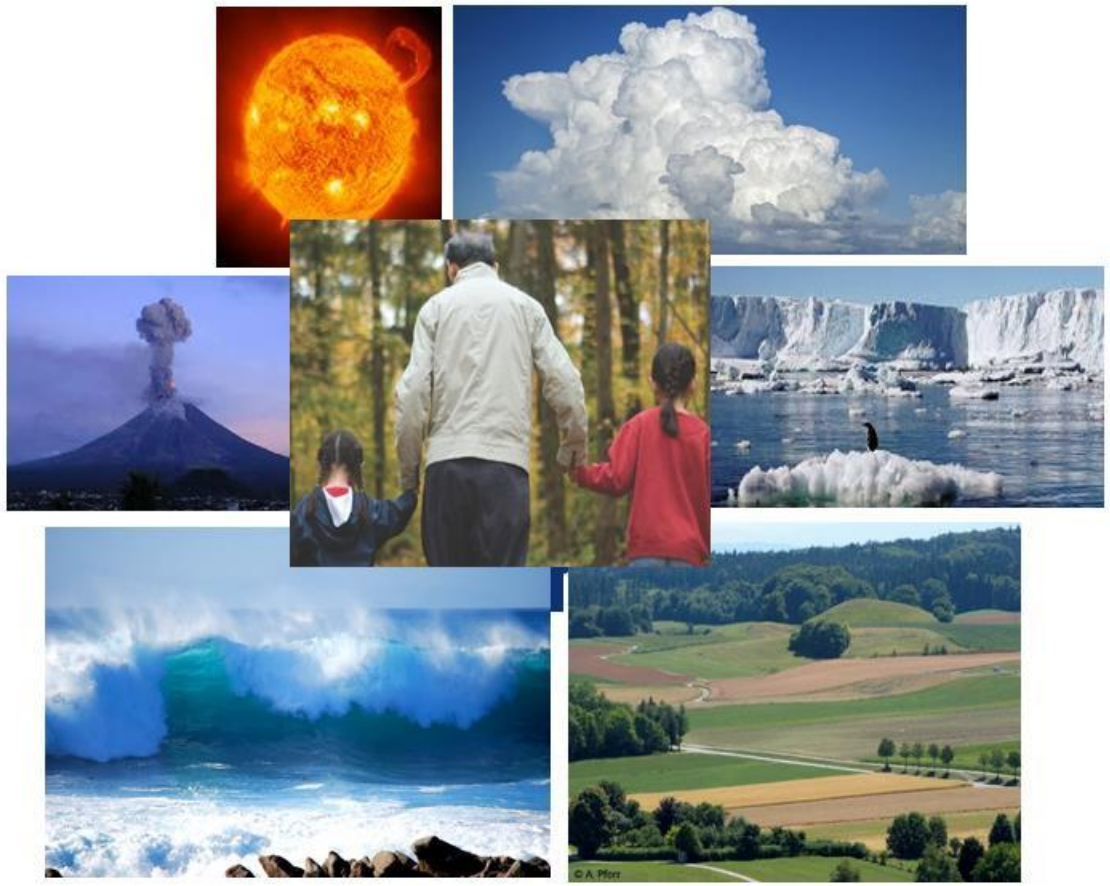
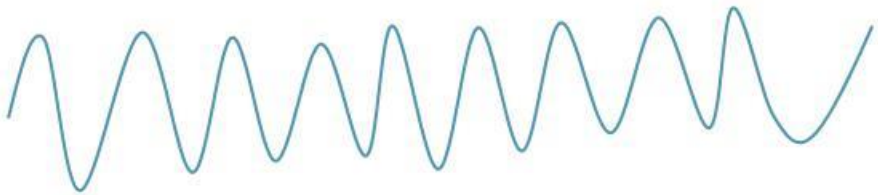
Weather vs climate

What influences the climate and its variability?



Natural variability.

Daily timescale (day/night)



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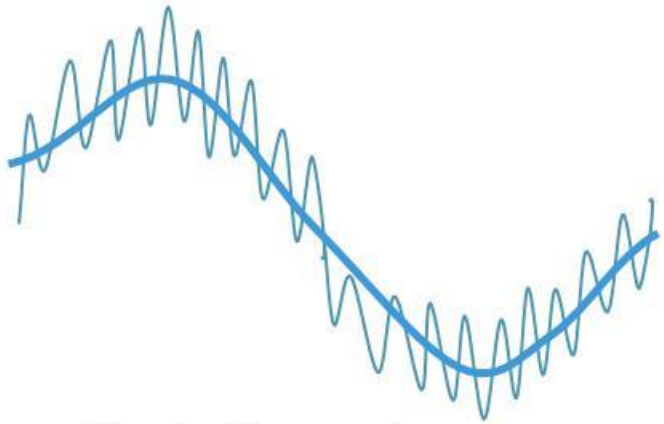
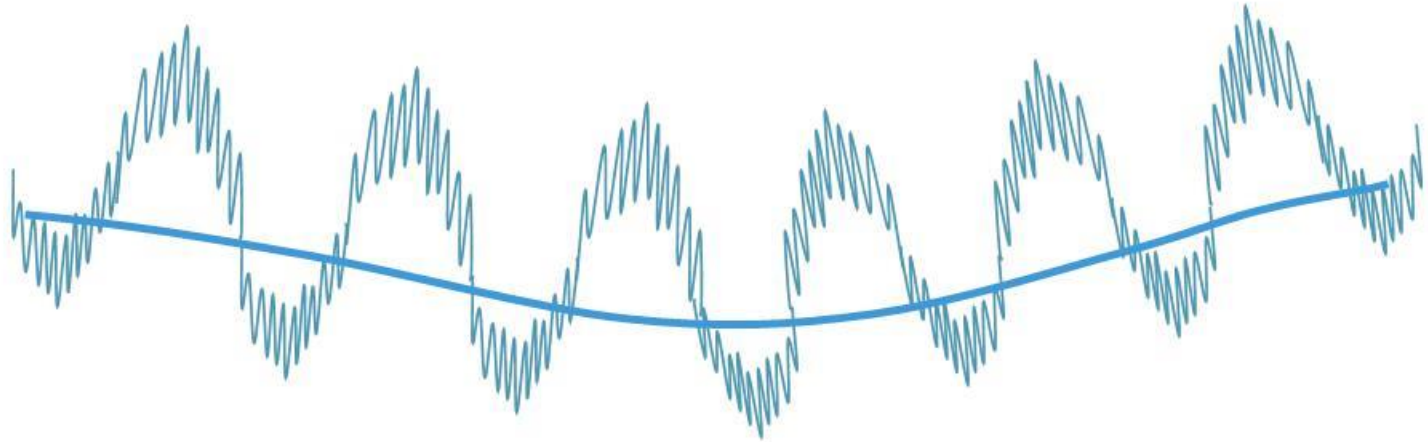
Seasonal timescale

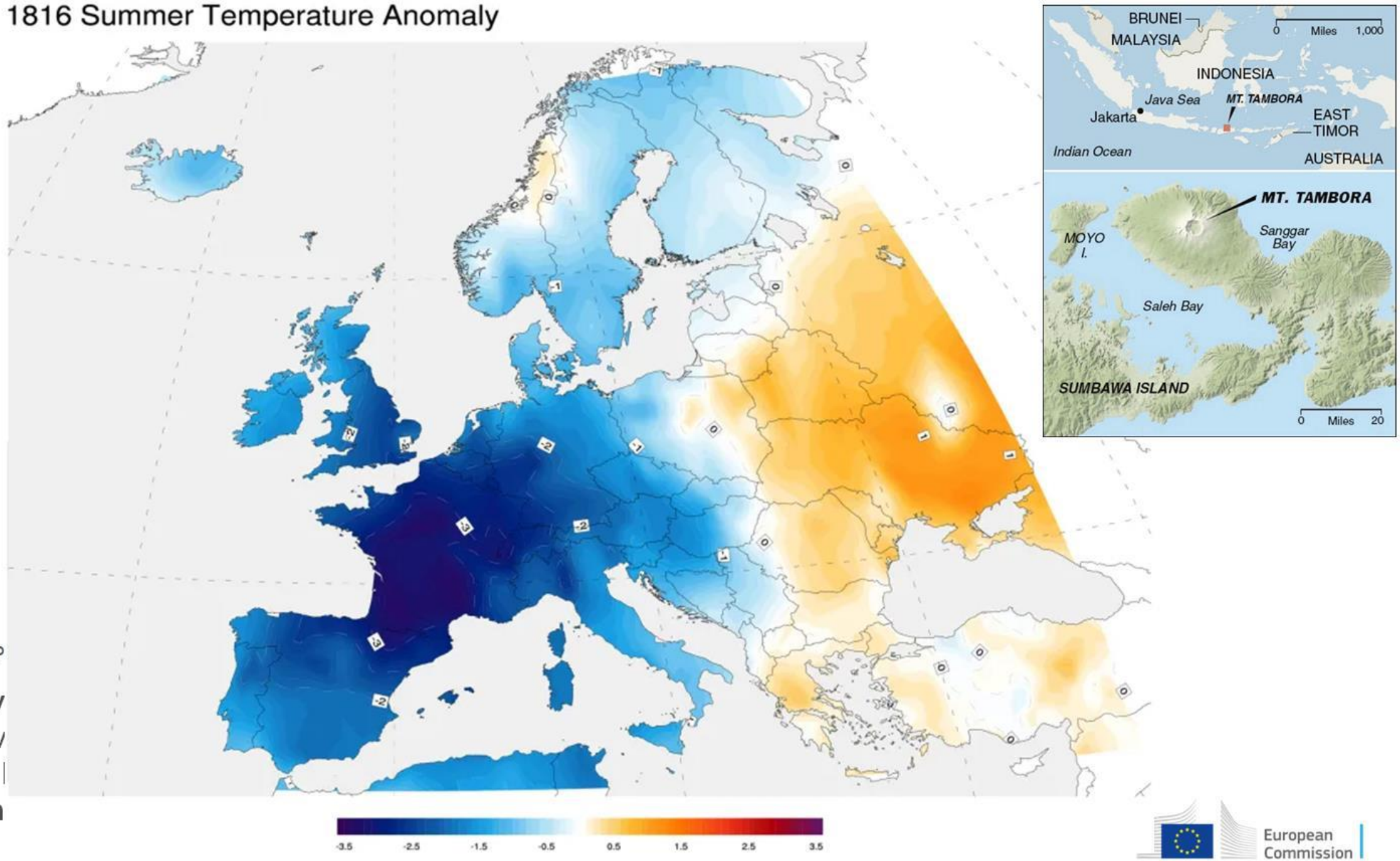
June July August



Yearly timescale



(multi-)Decadal timescale e.g. El Nino



- Source: IP

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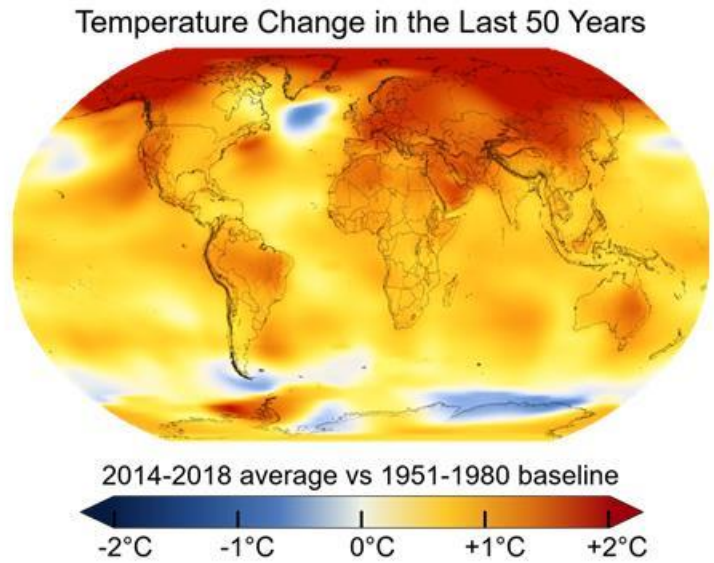
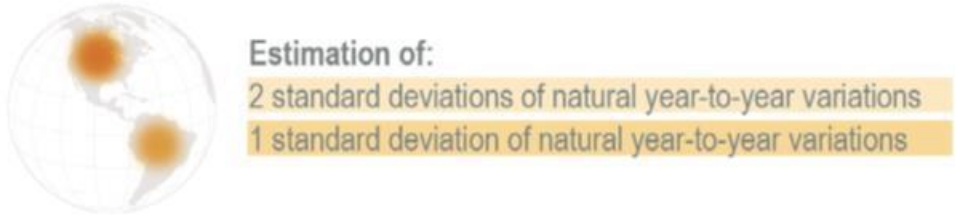
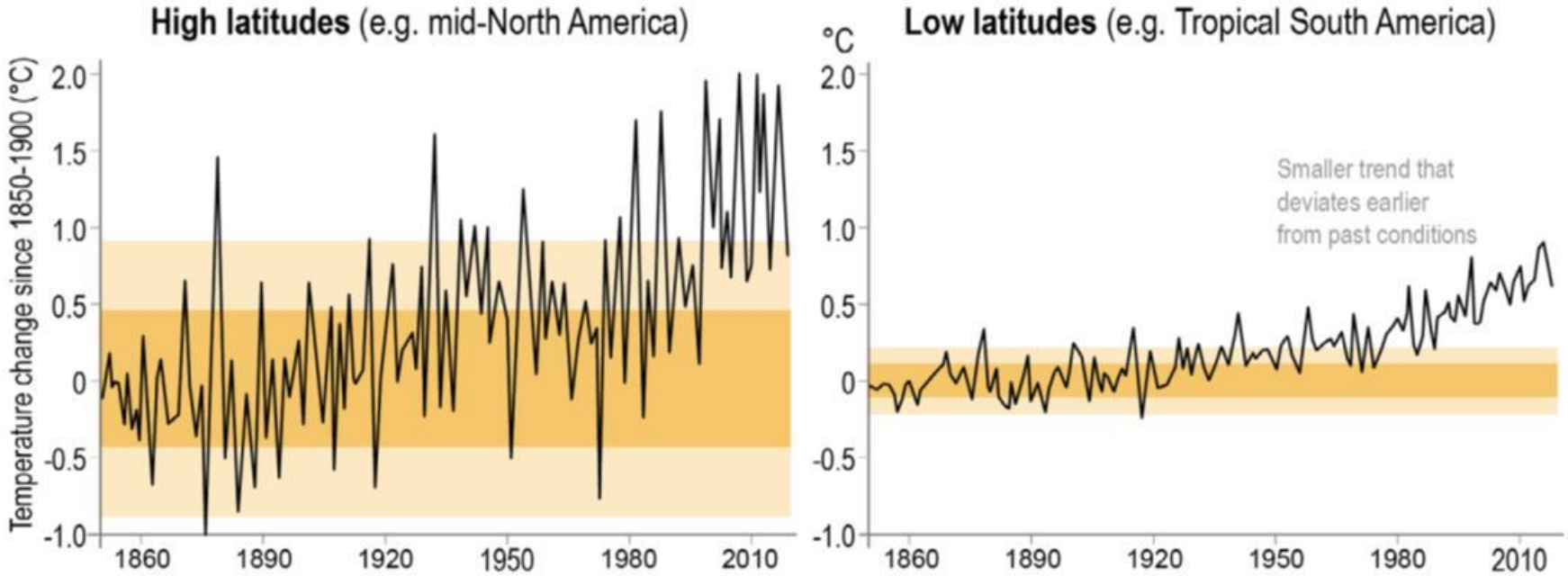
Natural variability vs climate change



Climate change is most apparent in regions with smaller natural variations





Change (Signal)

Natural variability (Noise)

Source: IAA 2022

Large signal and large noise S/N ~ 1

Small signal and small noise but S/N > 1

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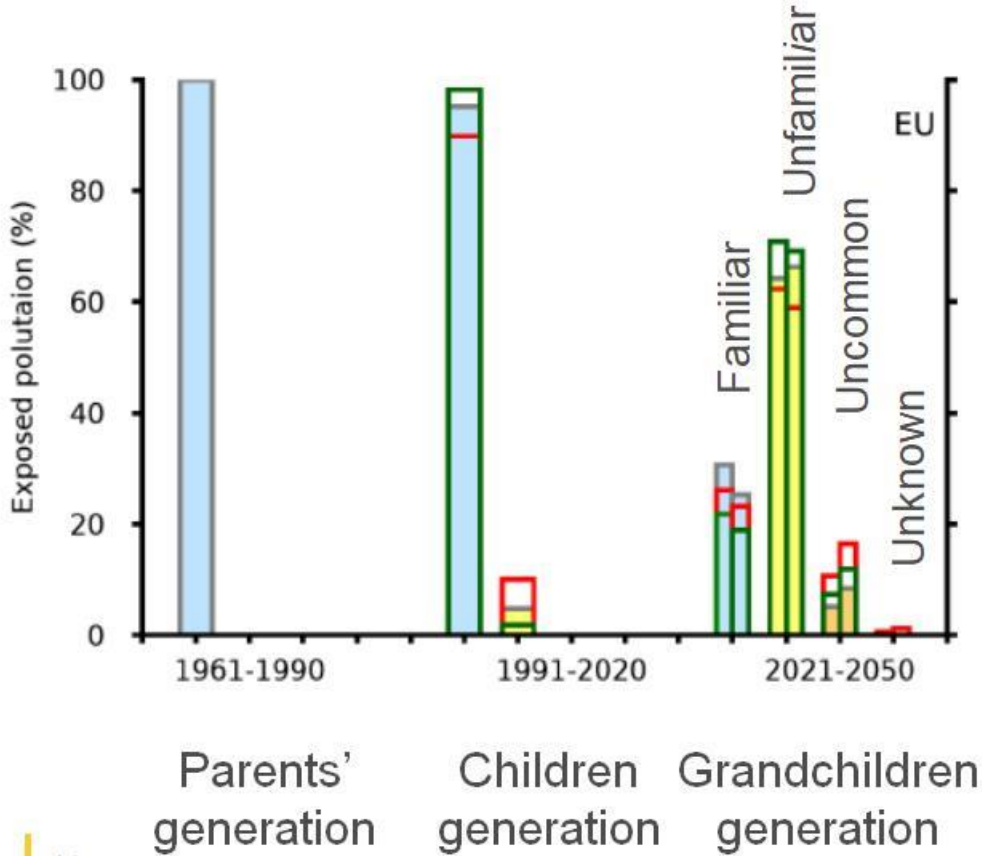
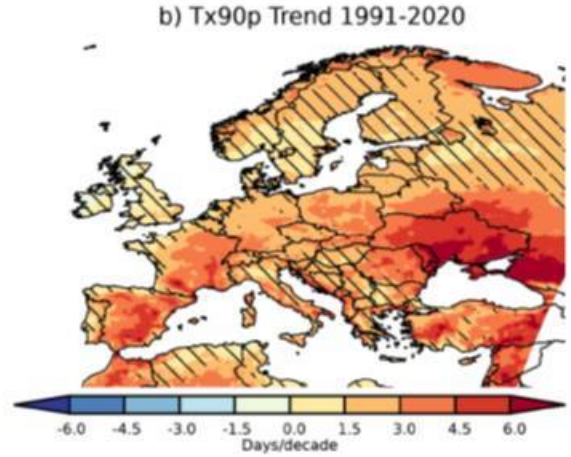
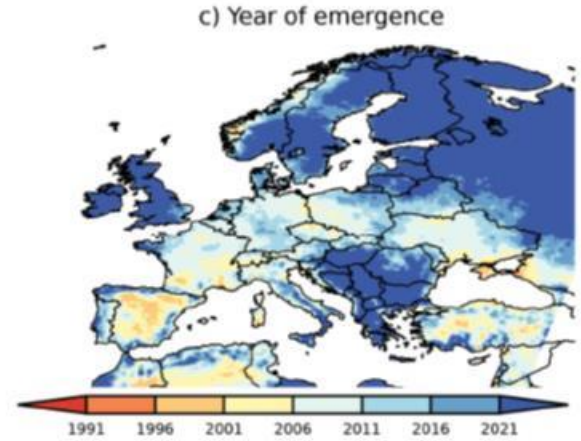
Climate is changing fast (-er than you think)

In some countries (Spain, France, Germany, Poland, etc.) the signal for heatwaves has already emerged from natural variability.







One **generation** (30 years, 2000s vs 1970s) was enough for some heatwave characteristics to emerge from natural variability.

Children (born in the 2000s) are living a climate that is unfamiliar compared to that of their parents at the same age.

The next generation (born after 2020) will experience uncommon (S/N>2) , and in some cases unknown (S/N>3) climate.

- Source: Dosio et al 2024

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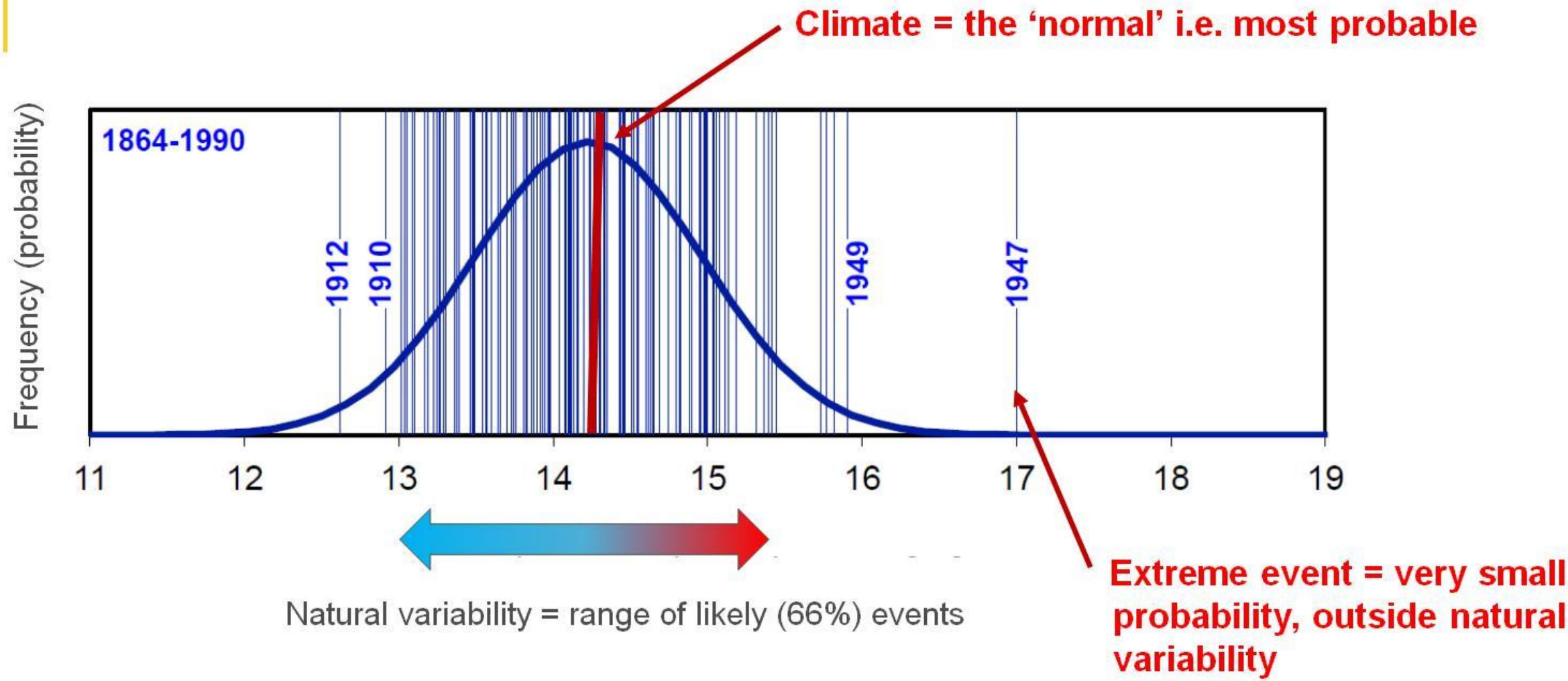
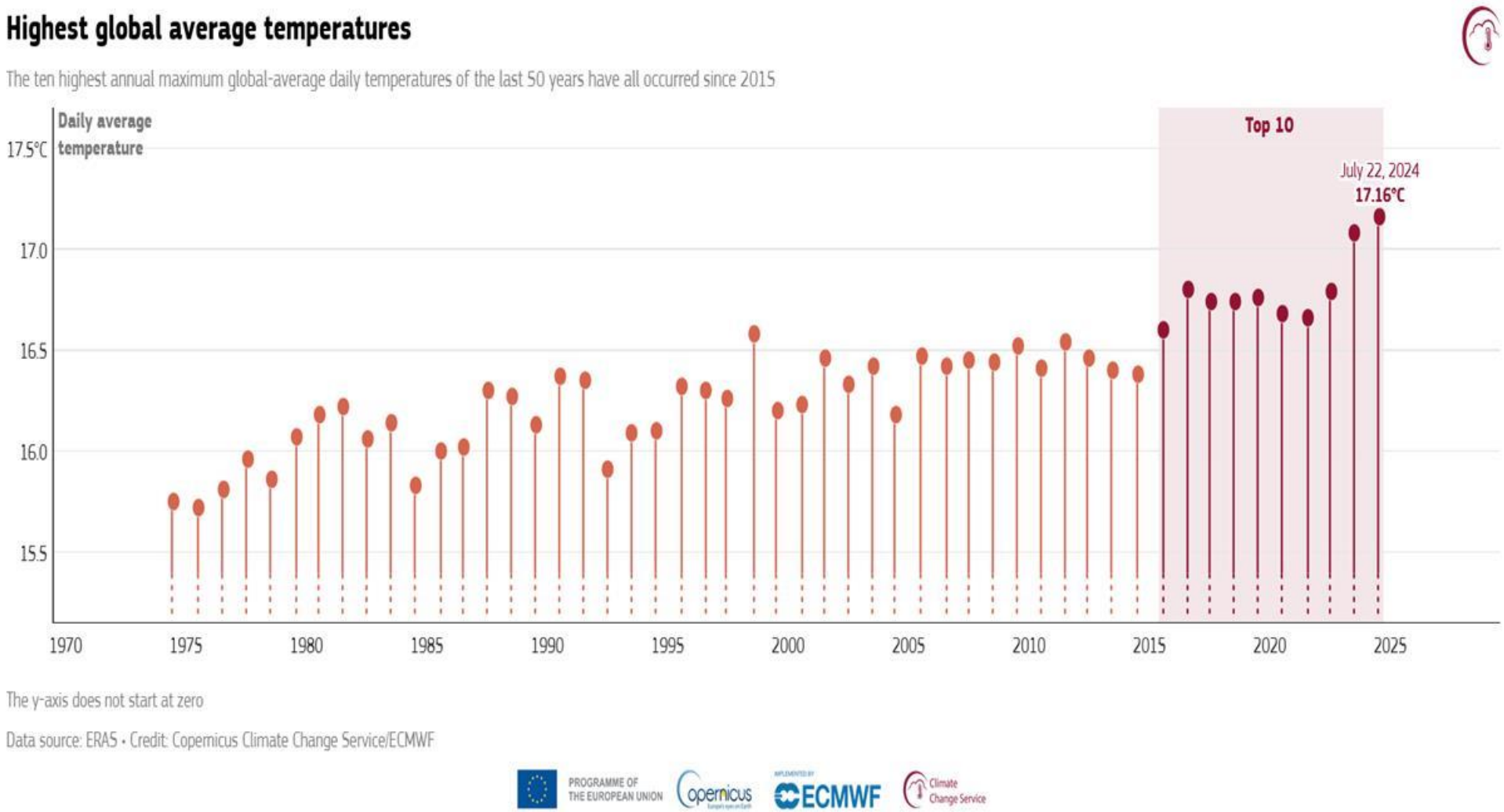
Extreme events and probability

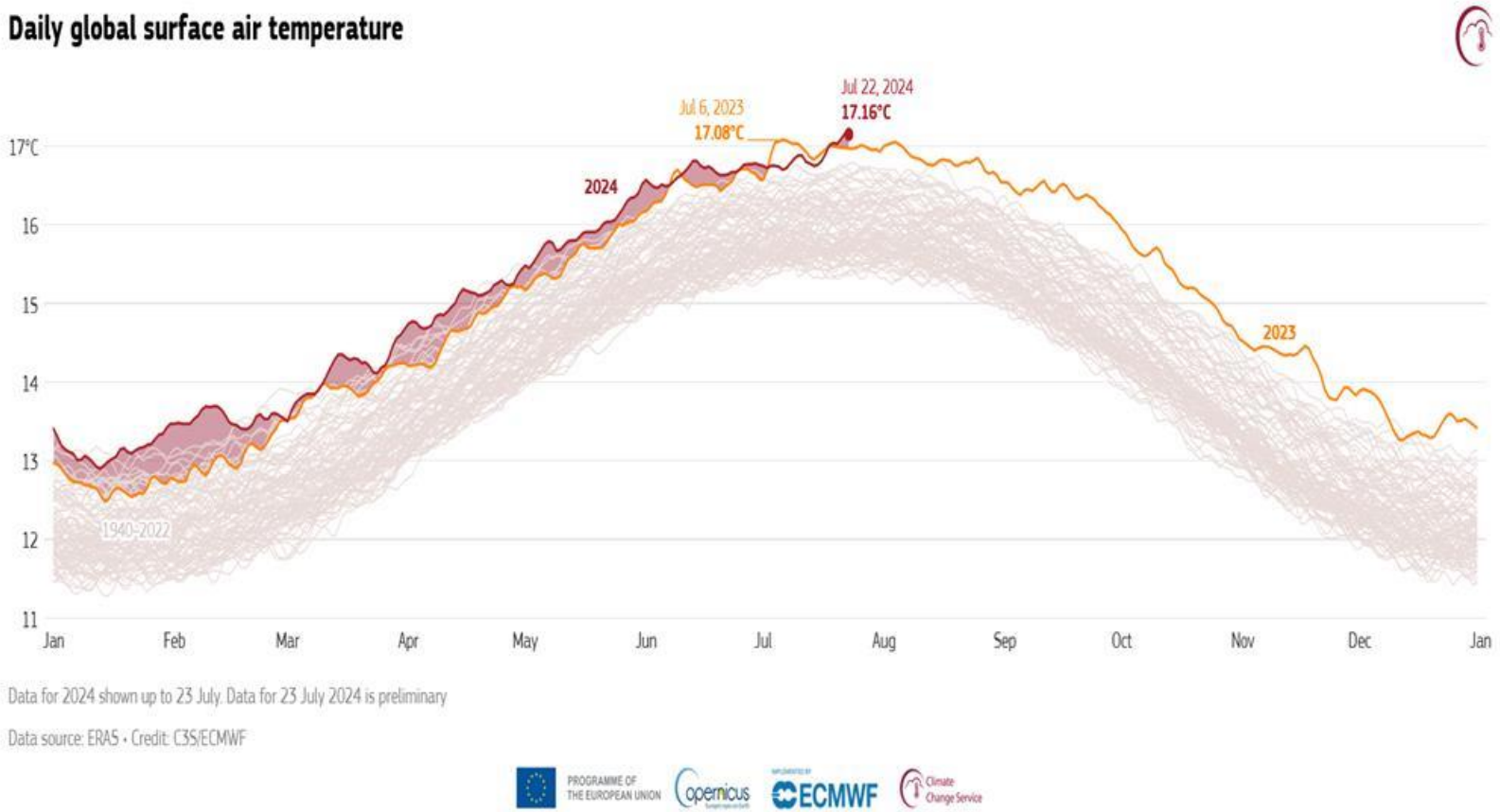


Measured temperatures in Switzerland in April to September [ºC] between 1864 and 1990.
Figure: Christoph Schär / ETH Zurich

Recorded temperatures



Recorded temperatures



On **22 July,** the world experienced its highest absolute global daily temperature on record.
63 countries experienced their warmest June on record.
The average **European** temperature for June 2024 was **1.57°C above the 1991-2020** average for June.

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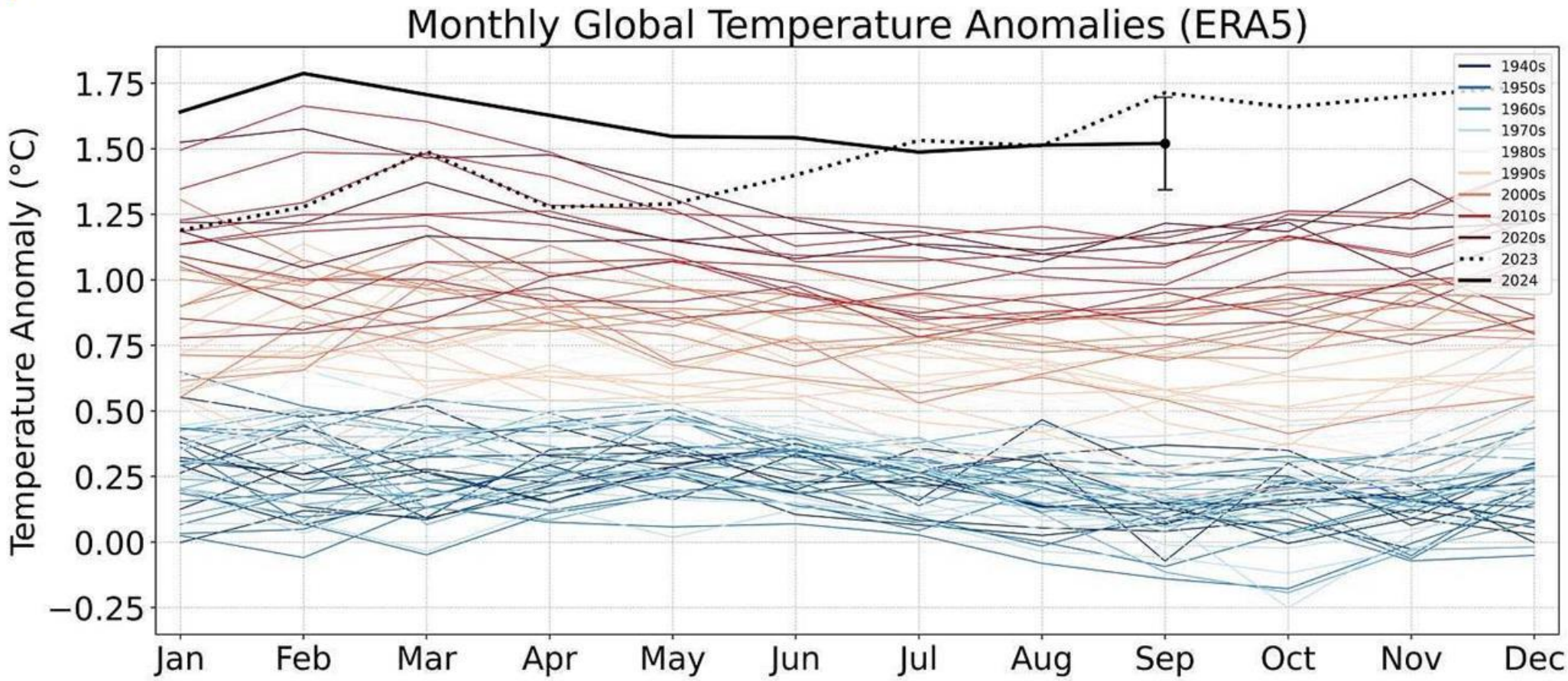
Recorded temperatures



Over the past 12 months **138 countries have recorded their hottest temperatures ever.**
The world has passed the **1.5C pre-industrial threshold for 12 consecutive months**

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It's hot

…or is it?

- "I remember it was hot too *when I was young*" ✗
- "Of course it is hot: it's called *SUMMER*, you know?" ✗
- "You see? *This year* was very wet/cold/snowy: where is this supposed climate change?" ✗
- "You see? *Where I live* it's colder than it used to be: where is this supposed climate change?" ✗

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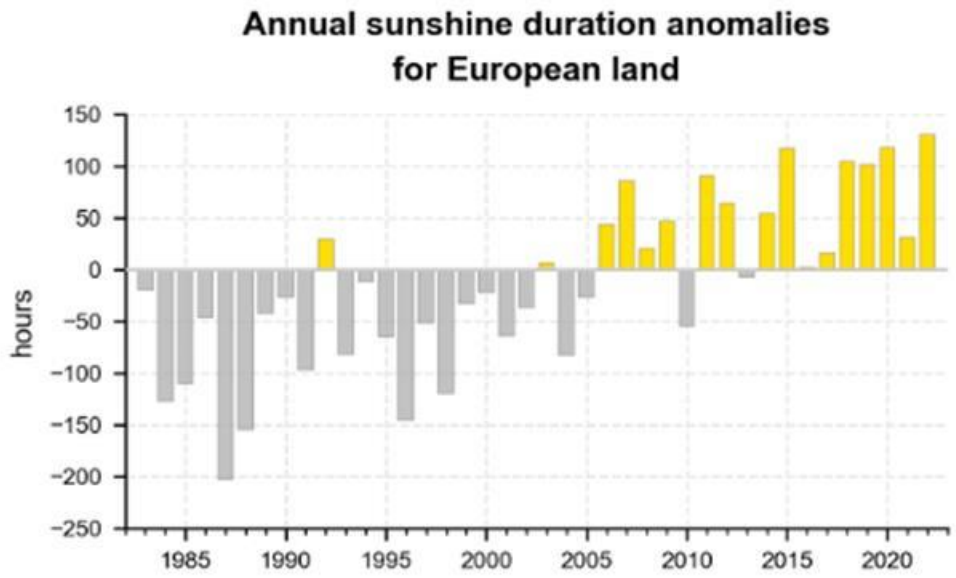
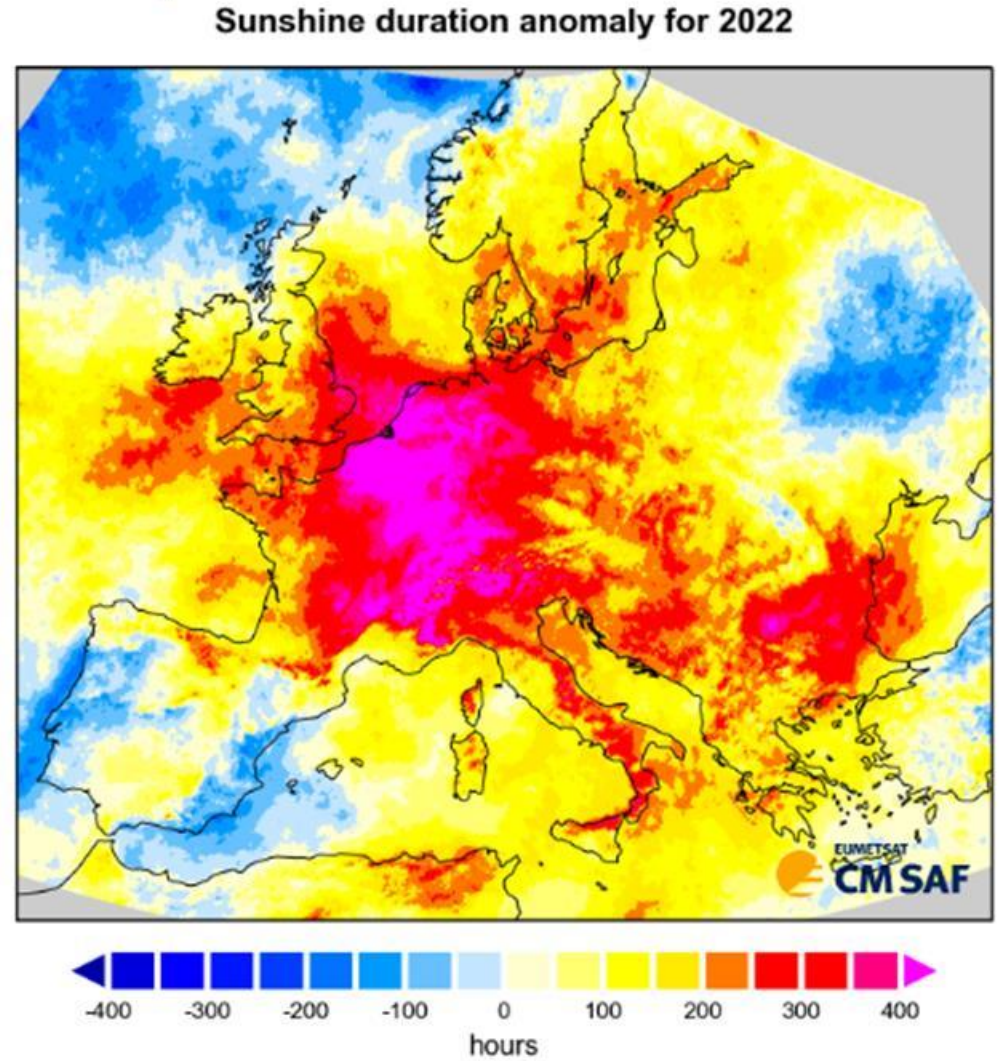
Ok, it's hotter than it used to be

- "It's the sun!" ✓
- "It's natural variability!" ✓
- "Anthropogenic CO2 is a tiny fraction in the global carbon cycle!" ✓

- "See? Then it's definitely not our fault!" ✗
- And who cares about 1 degree hotter; it would be actually nice! ✗

Trend and variability: is it us?





Data: SARAH-2.1 CDR/ICDR • Reference period: 1991-2020 • Credit: EUMETSAT CM SAF

Trend and variability: is it us?

@ESA

@Phylieb

World Weather Attribution

- **Climate change key driver of extreme drought in water scarce Sicily and Sardinia**
- - The rare 1-in-100 year drought over Sicily which is an ‘extreme’ drought would be a ‘severe’ drought without climate change.
- - The likelihood of the drought from August 2023 to July 2024 has increased by about 50% due to human-induced climate change.

@ANSA

Source: IPCC 2021

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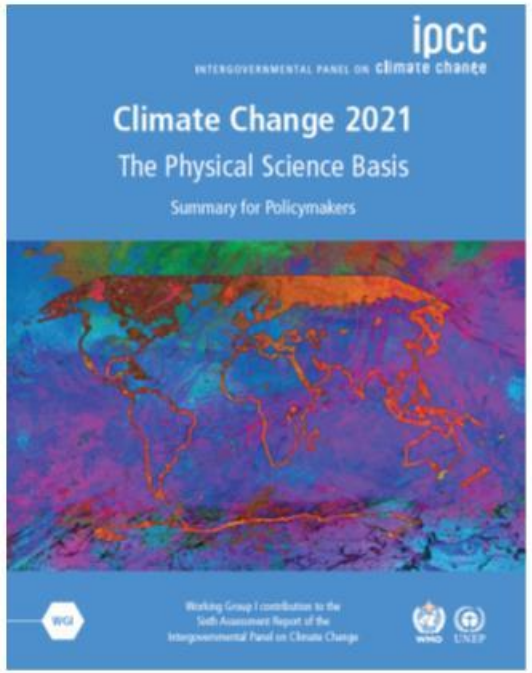
IPCC AR6 WG I : Summary for Policymakers

A.1 **It is unequivocal** that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.



The **Summary for Policymakers** is approved by the IPCC member countries (in consultation with the authors) after a detailed, **line-by-line discussion**.

Proposed by Authors

A.1 Human influence has warmed the climate system, and widespread and rapid changes in climate have occurred.

Observed changes: extreme heat

Climate change is already affecting **every inhabited region** across the globe, with **human influence** contributing to many observed changes in weather and climate extremes

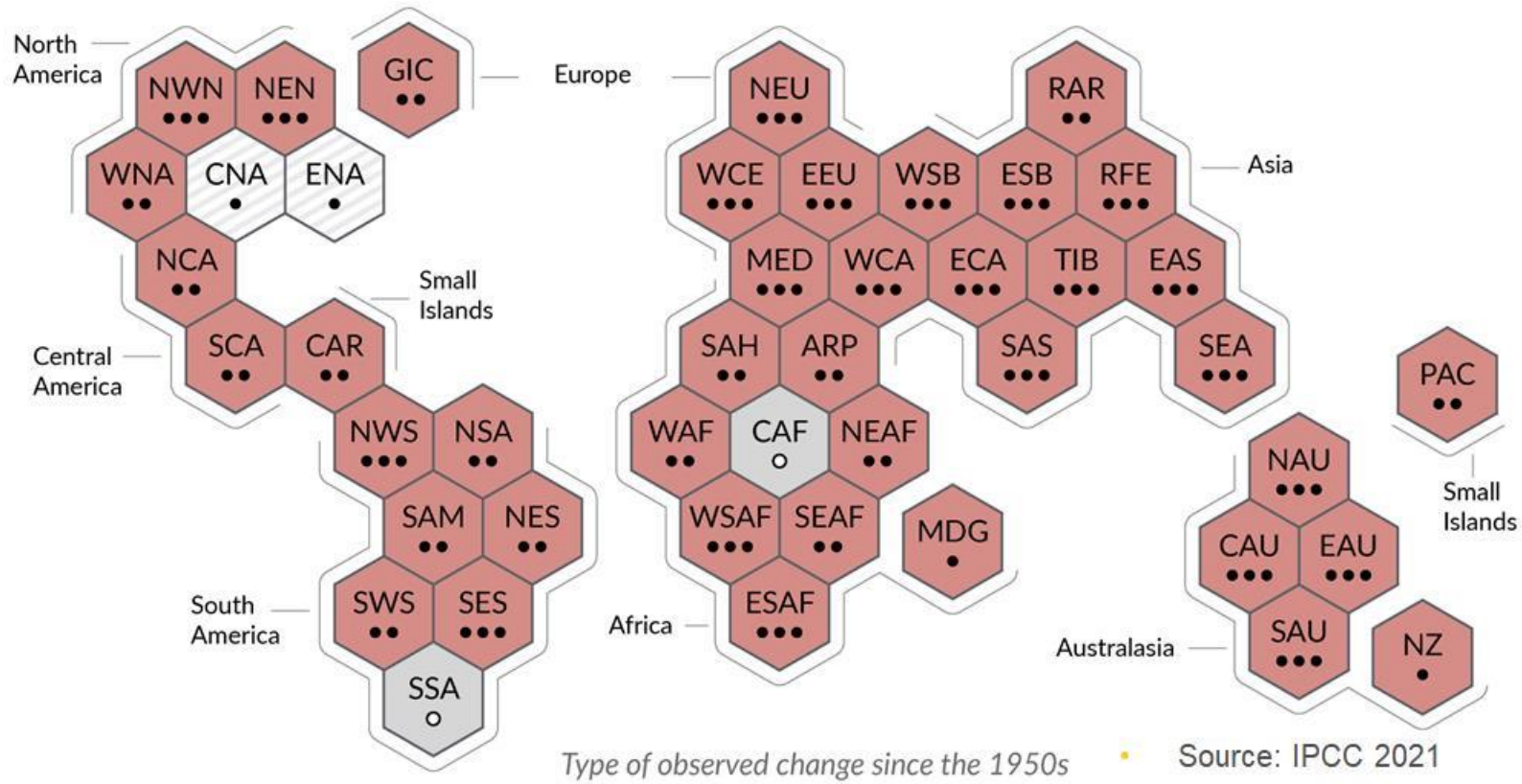
a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions

Type of observed change
in hot extremes

- Increase (41)
- Decrease (0)
- Low agreement in the type of change (2)
- Limited data and/or literature (2)

Confidence in human contribution
to the observed change

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

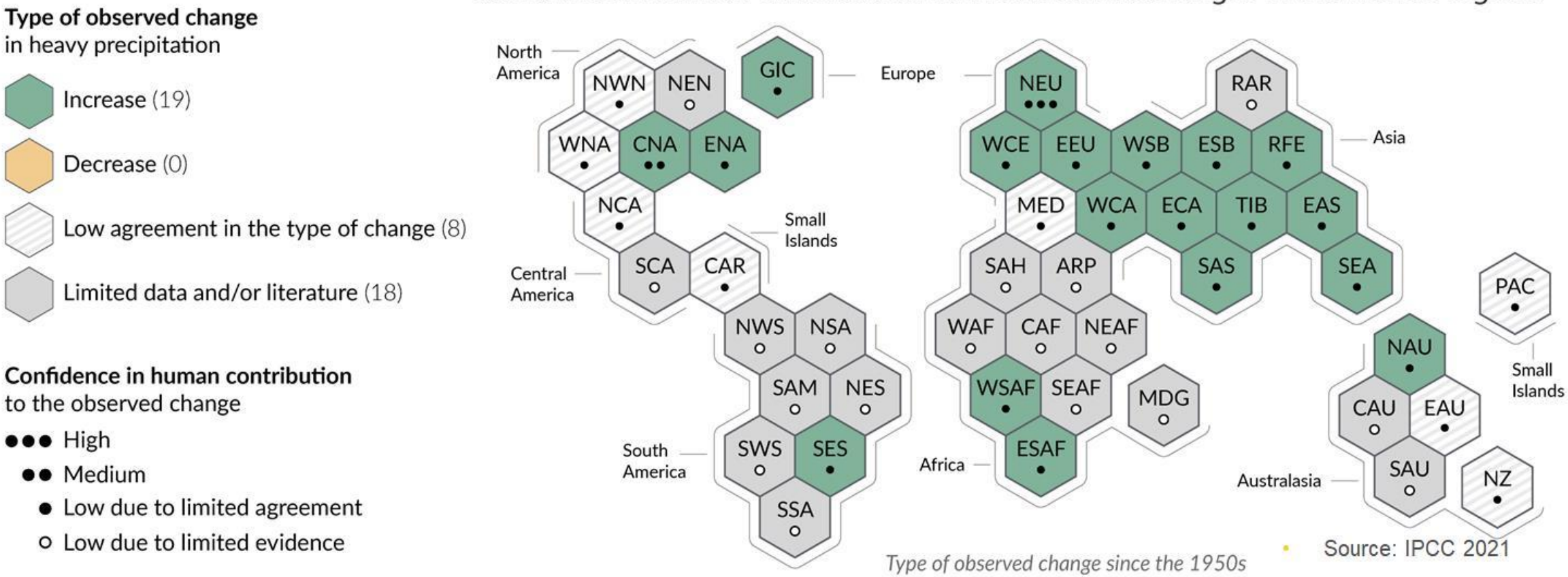


Type of observed change since the 1950s • Source: IPCC 2021

Observed changes: heavy precipitation

Climate change is already affecting **every inhabited region** across the globe, with **human influence** contributing to many observed changes in weather and climate extremes

b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions



The future

What can we expect?

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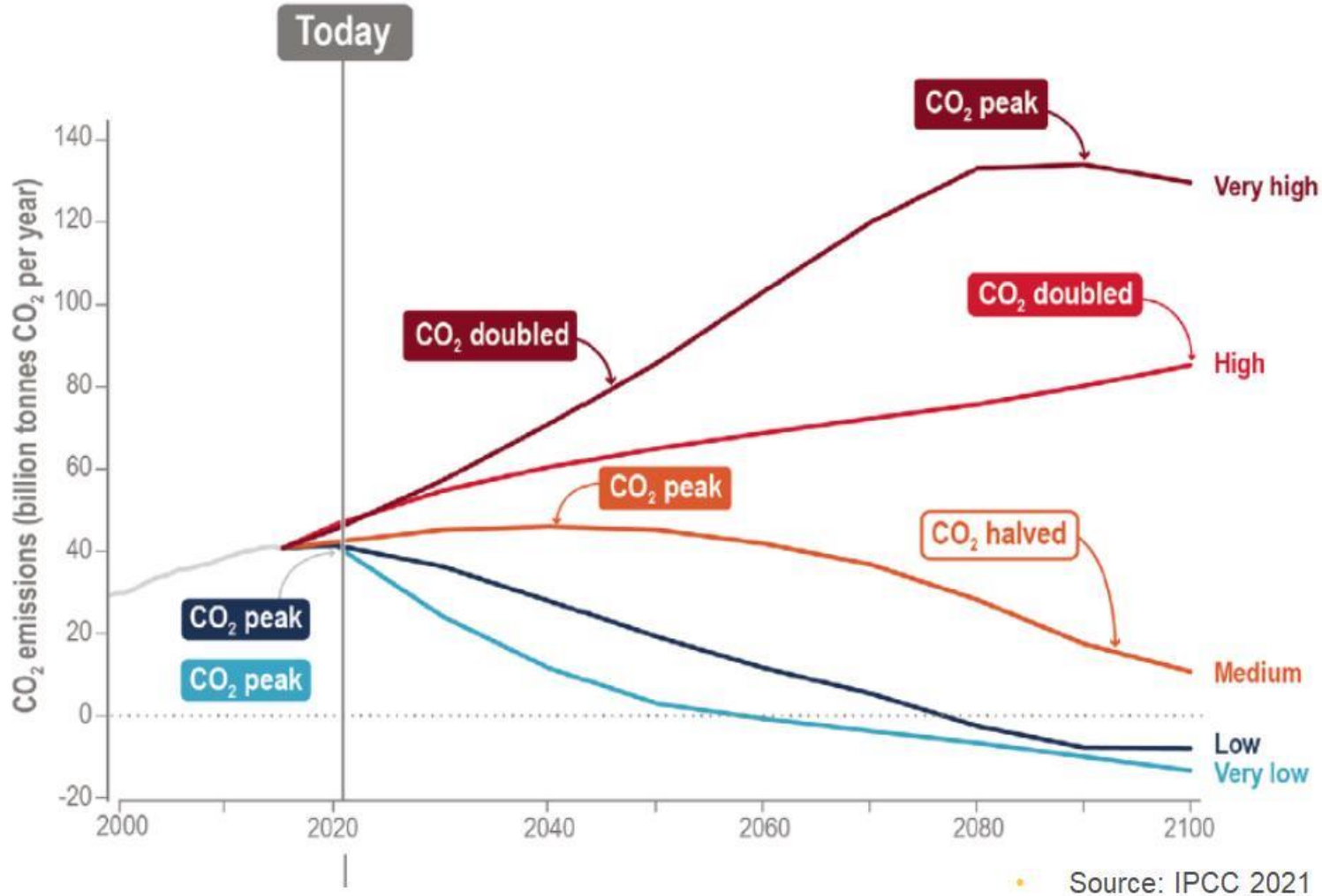
Future as ‘ensemble of opportunities’

Emissions pathways

Different social and economic developments can lead to substantially different future emissions of carbon dioxide (CO_2), other greenhouse gases and air pollutants for the rest of the century.



Source: IPCC 2021

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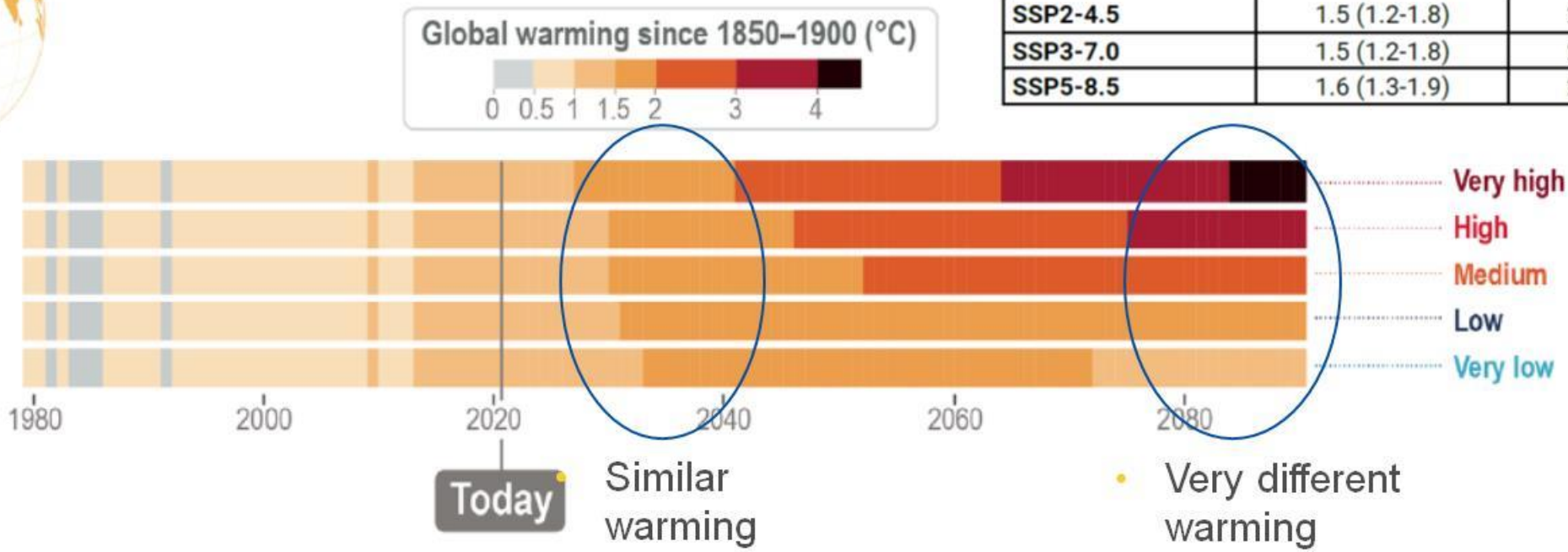
Effect on global temperature increase

	Projected global warming level (°C) at specific 20 year timeframe		
	Near term, 2021–2040	Mid-term, 2041–2060	Long term, 2081–2100
SSP1-1.9	1.5 (1.2-1.7)	1.6 (1.2-2.0)	1.4 (1.0-1.8)
SSP1-2.6	1.5 (1.2-1.8)	1.7 (1.3-2.2)	1.8 (1.3-2.4)
SSP2-4.5	1.5 (1.2-1.8)	2.0 (1.6-2.5)	2.7 (2.1-3.5)
SSP3-7.0	1.5 (1.2-1.8)	2.1 (1.7-2.6)	3.6 (2.8-4.6)
SSP5-8.5	1.6 (1.3-1.9)	2.4 (1.9-3.0)	4.4 (3.3-5.7)

Effect on surface temperature

For temperature to stabilize, CO_2 emissions need to reach net zero.



Short-term effect: Natural variability

Over short time scales (typically a decade), natural variability can temporarily dampen or accentuate global warming trends resulting from emissions.

Source: IAA 2022

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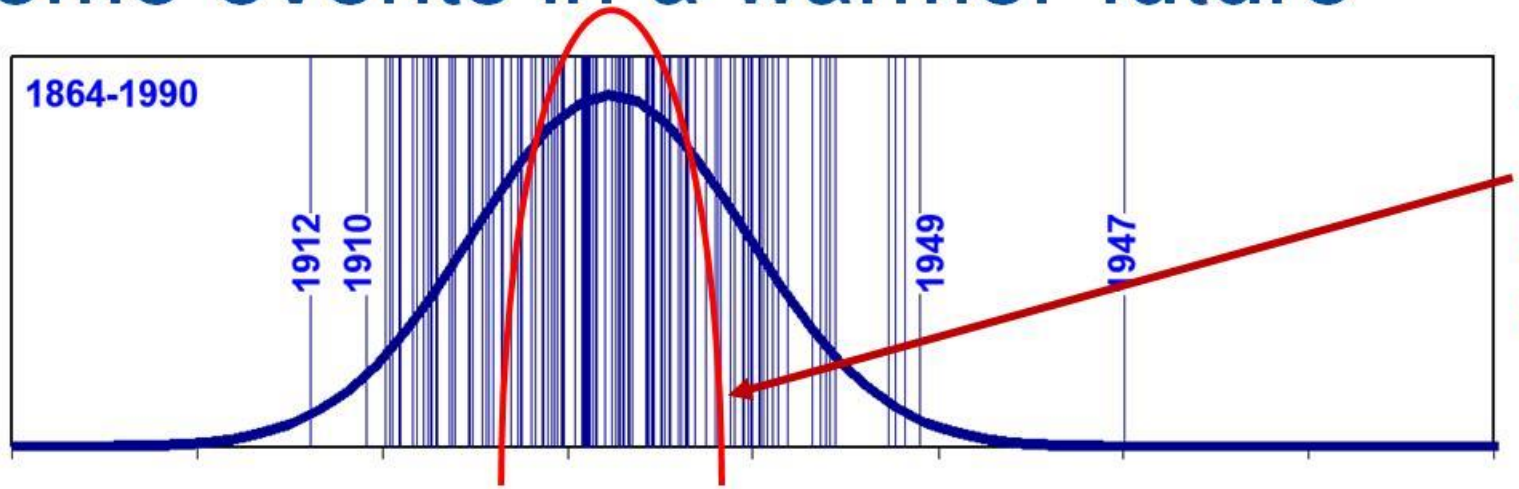
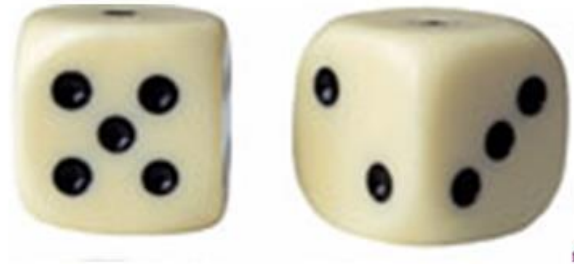
Extreme events in a warmer future



The 'normal' climate in 1864-1990 is a 'cold year' in 1991-2018



New record-breaking E events

Temperature April-September [ºC]

More Extreme events

Measured temperatures April to September [ºC] between 1864 and 1990 (blue) and between 1991 and 2018 (red).
Figure: Christoph Schär / ETH Zurich

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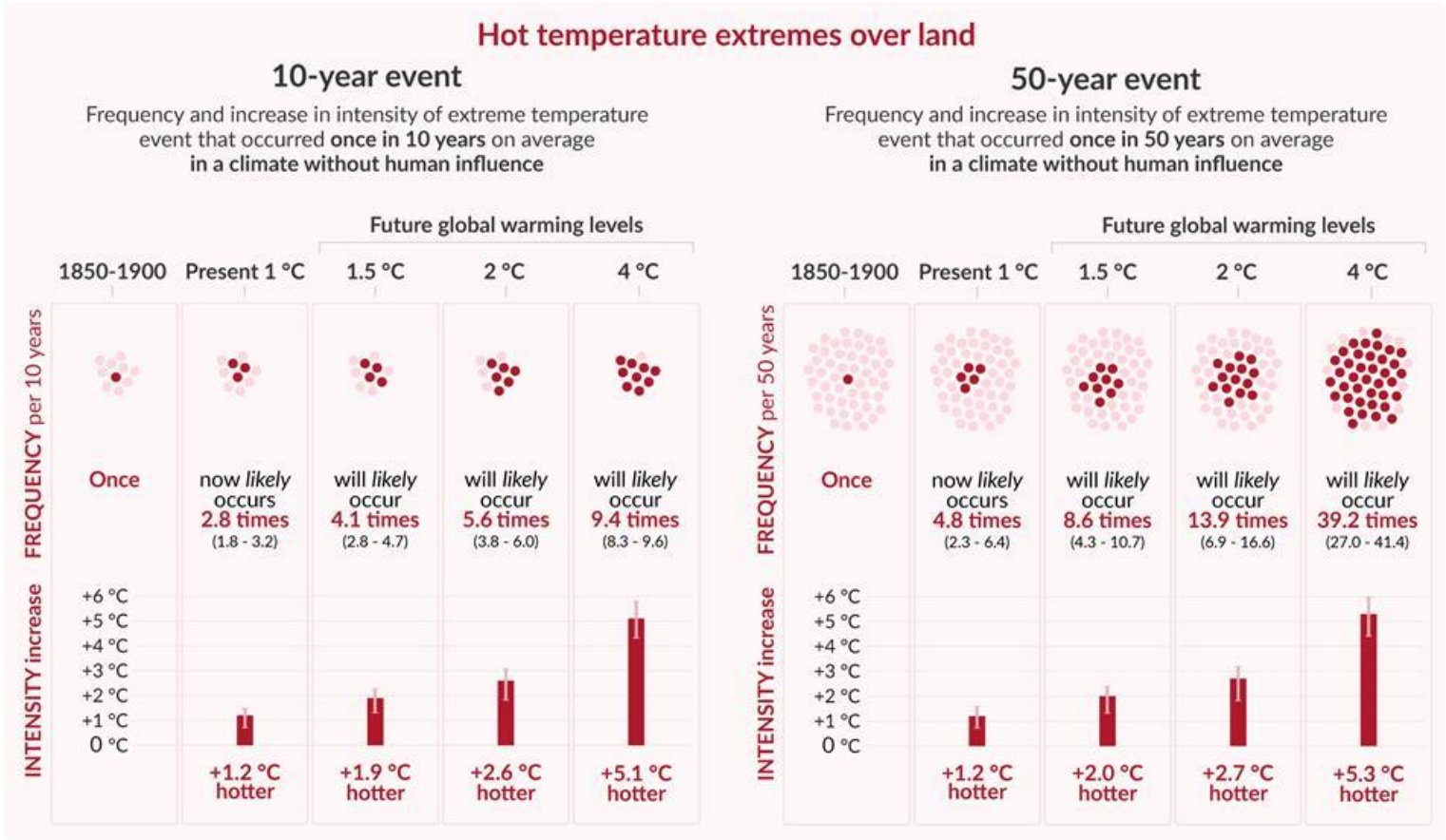
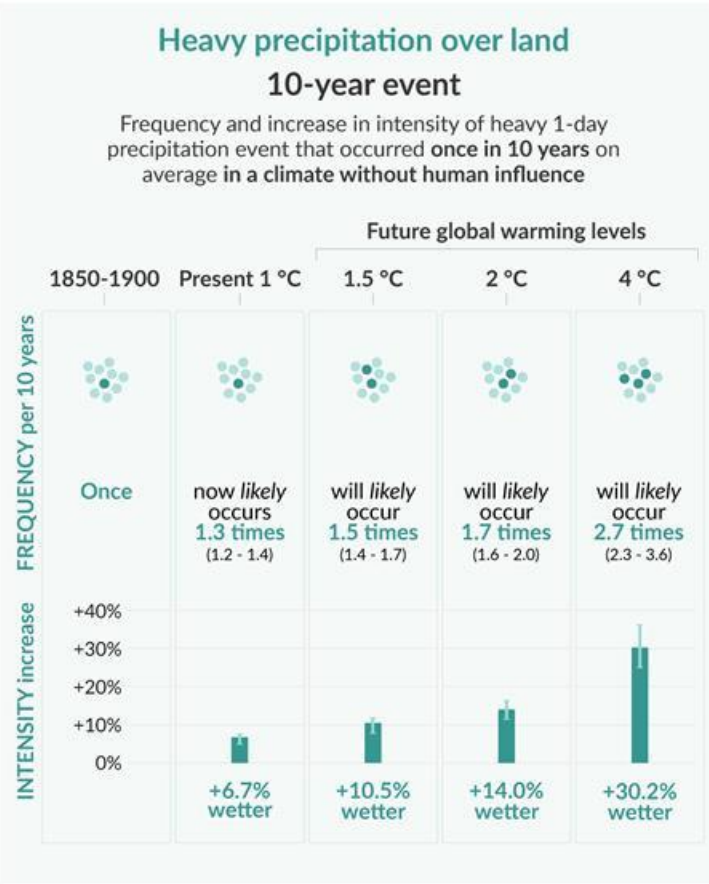
Projected changes

Projected changes in extremes are **larger in frequency** and **intensity** with every additional increment of global warming





Source: IPCC 2021

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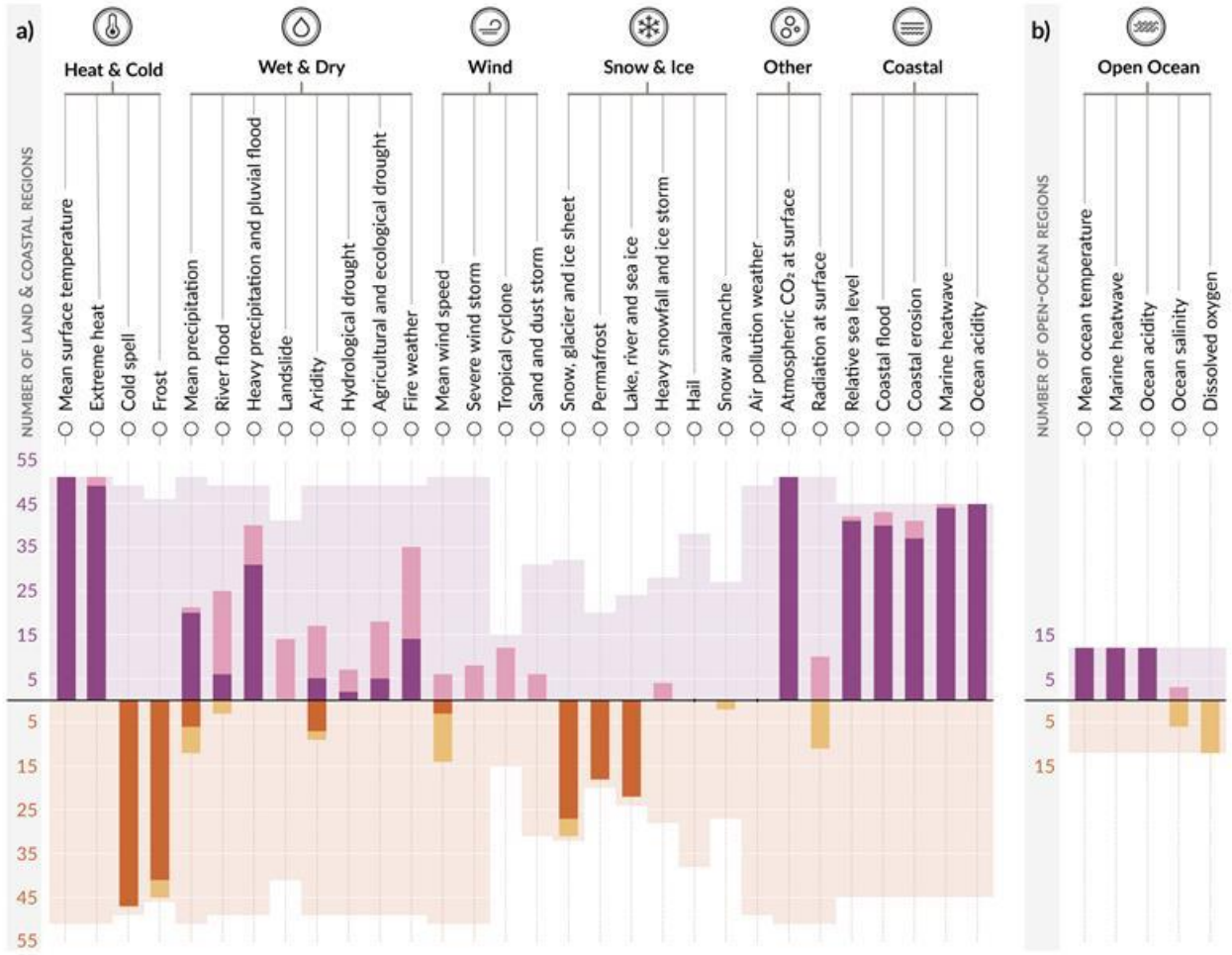
Projected changes under 2°C warming

Multiple climatic impact-drivers (compound extreme events) are projected to change in **all regions** of the world

Number of land & coastal regions (a) and **open-ocean regions** (b) where each **climatic impact-driver** (CID) is projected to increase or decrease with ***high*** *confidence* (dark shade) or ***medium*** *confidence* (light shade)



ASSESSED FUTURE CHANGES

Changes refer to a 20–30 year period centred around 2050 and/or consistent with 2°C global warming compared to a similar period within 1960-2014 or 1850-1900.

BAR CHART LEGEND

- Regions with ***high*** *confidence* **increase**
- Regions with ***medium*** *confidence* **increase**
- Regions with ***high*** *confidence* **decrease**
- Regions with ***medium*** *confidence* **decrease**

LIGHTER-SHADED 'ENVELOPE' LEGEND

The height of the lighter shaded 'envelope' behind each bar represents the maximum number of regions for which each CID is relevant. The envelope is symmetrical about the x-axis showing the maximum possible number of relevant regions for CID increase (upper part) or decrease (lower part).

Source: IPCC 2021

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Impact of climate change

Not only temperature

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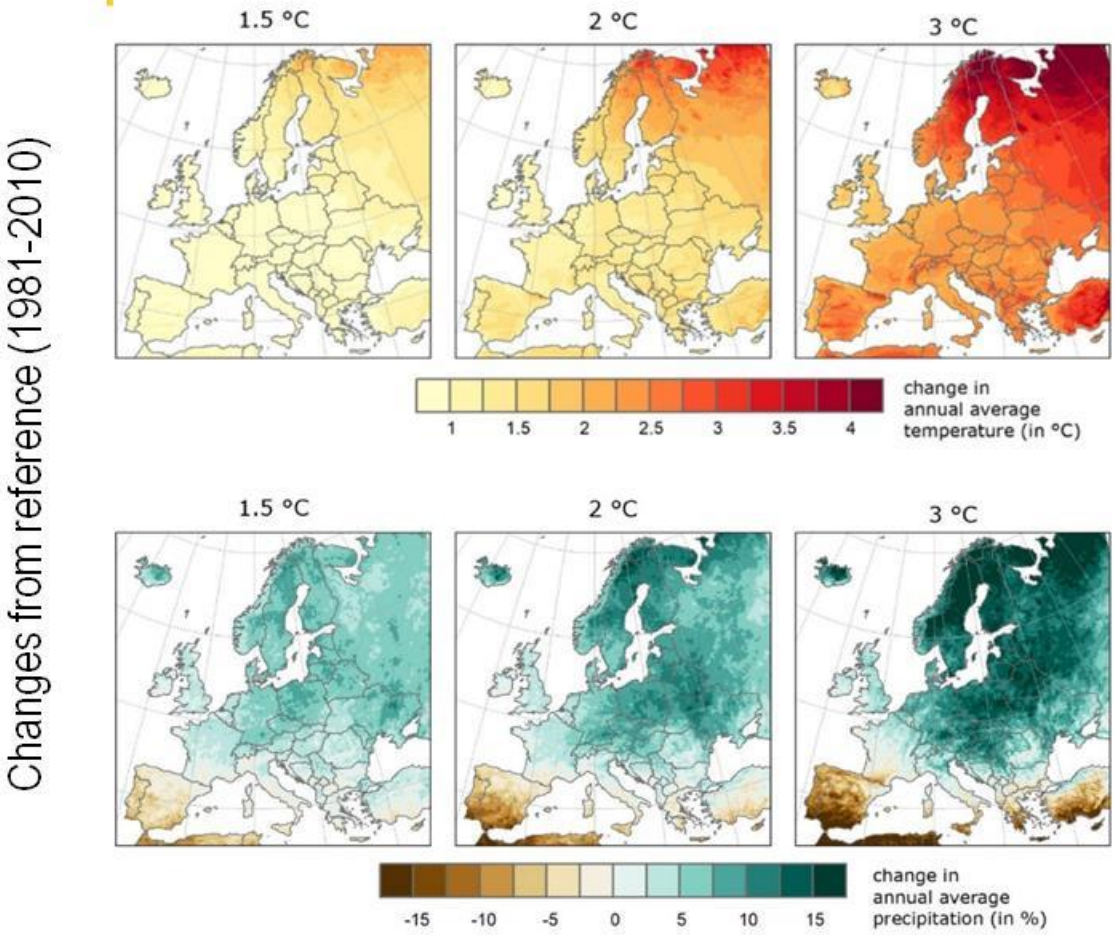
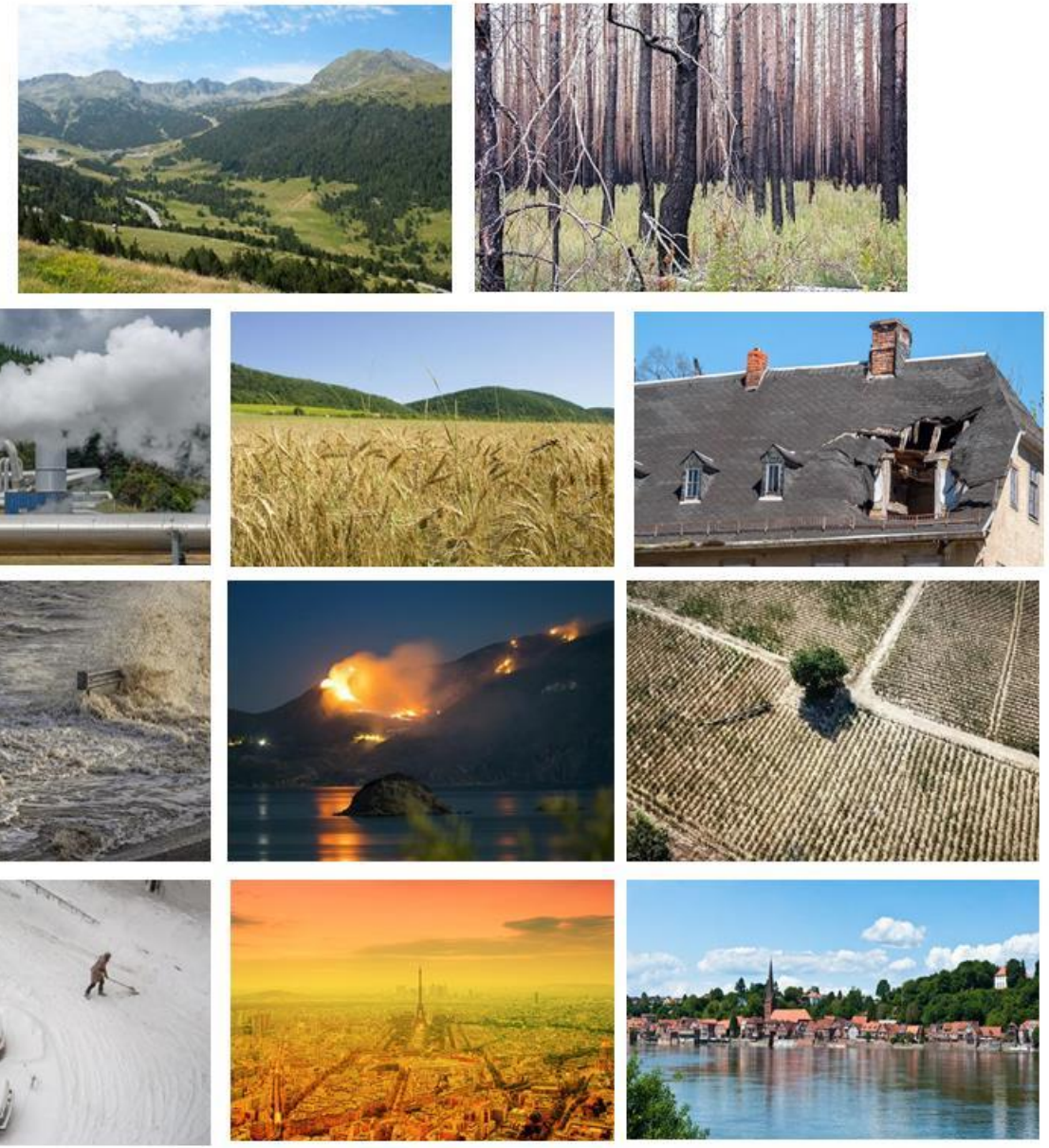
The PESETA (IV) project



Changes from reference (1981-2010)



benefits of mitigation policy Paris Agreement

no climate policy actions

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Mitigation: avoid the unmanageable

base	1.5˚C	2.0˚C	3.0˚C
People annually exposed to a 50-year heatwave (million)			
9.6	103	168	288
Annual fatalities from heatwaves (x1000)			
2.7	28.8	49.4	89.0

base	1.5˚C	2.0˚C	3.0˚C
People living in areas with water stress (million)			
52	59	60	65

base	1.5˚C	2.0˚C	3.0˚C
Drought losses (€ billion)			
9.0	9.7	12.2	17.3
Drought losses (% of GDP)			
0.07	0.08	0.10	0.14

base	1.5˚C	2.0˚C	3.0˚C
Wind losses (€ billion)			
4.6	4.5	4.6	4.6

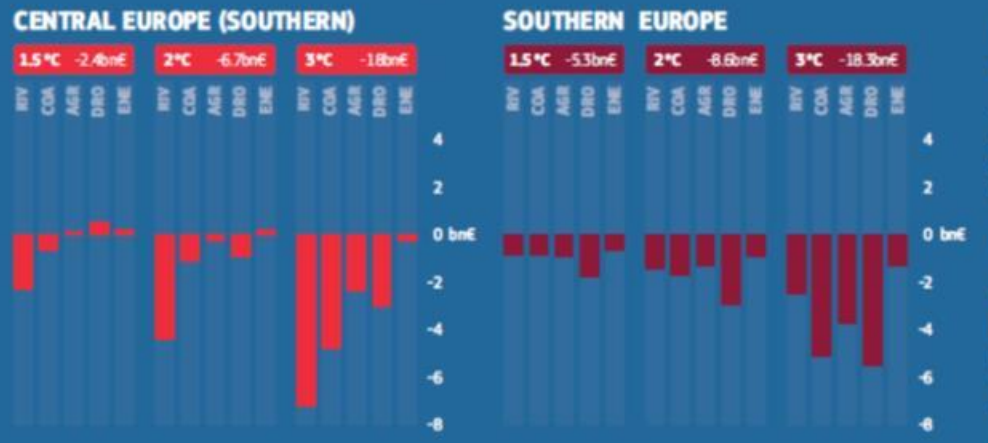
Adaptation: manage the unavoidable

	Today	High emissions		Moderate mitigation	
		No adapt	Adapt	No adapt	Adapt
Damage (€ billion/year)	1.4	239	23	111	12
People exposed (million/year)	0.1	2.2	0.8	1.4	0.6

	Today	2100 - no adaptation			2100 - adaptation		
		1.5°C	2°C	3°C	1.5°C	2°C	3°C
Damage (€ billion/year)	7.8	24	33	48	8.6	9.6	8.6
People exposed (1000/year)	172	252	338	482	92	100	90

Welfare loss from climate change impacts

JRC PESETA IV conducted an economic analysis of climate change impacts on river and coastal flooding, agriculture, droughts and energy supply.
Welfare impacts are estimated as if the future climate affects the economy of nowadays.



The assessment does not evaluate the full economic impacts of climate change in Europe as not all possible climate impacts were analysed.

Far greater impact on southern Europe

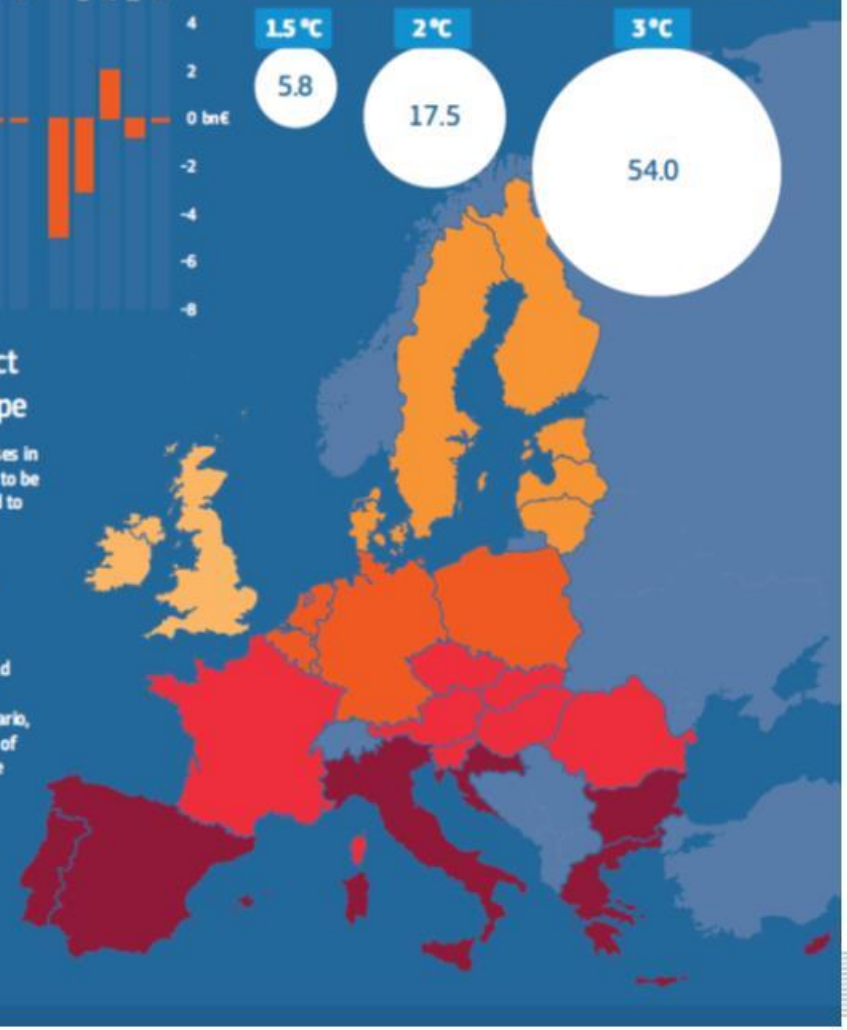
The magnitude of welfare losses in southern regions is estimated to be several times larger compared to northern regions.

Mitigation makes a difference

Limiting warming to 2 °C would reduce the welfare losses by 70% compared to a 3 °C scenario, while achieving the Paris goal of 1.5 °C would lower the welfare losses by 90%

Welfare losses in EU & UK (bn€)

If human mortality impacts were included, the estimated welfare losses in EU & UK would become much larger for all scenarios (an increase to 41.9€bn at 1.5 °C, 82.6€bn at 2 °C and 175.9€bn at 3 °C)



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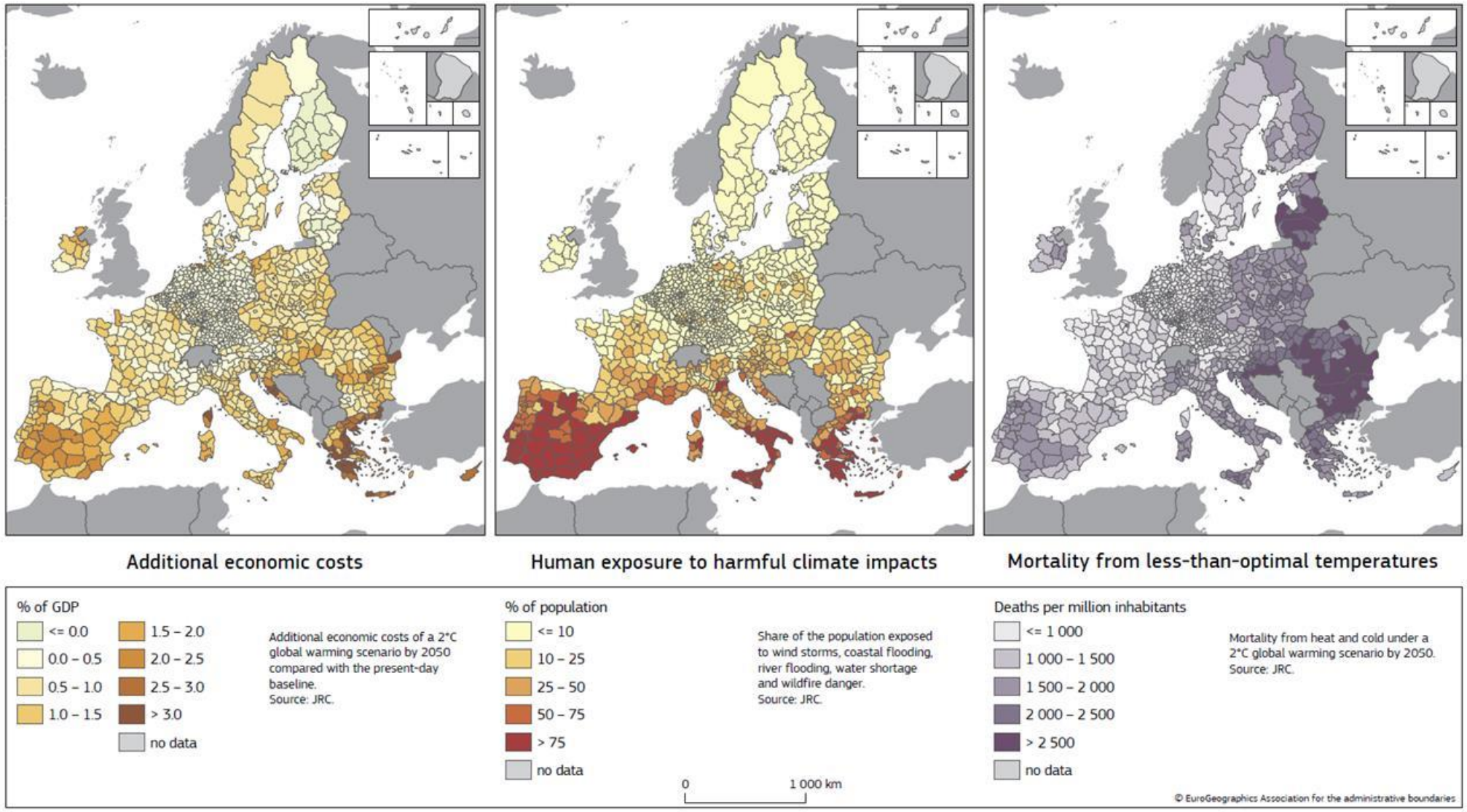
EC Ninth report on economic, social and territorial cohesion (2024): 2050s (2C) vs 1991-2020

economic impact (aggregated damage from river & coastal floods, drought, windstorms, labour, energy demand, transport)



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Prevention is better than cure (better safe than sorry)

Prevenire è meglio che curare

Lessons to be learned

The next generation

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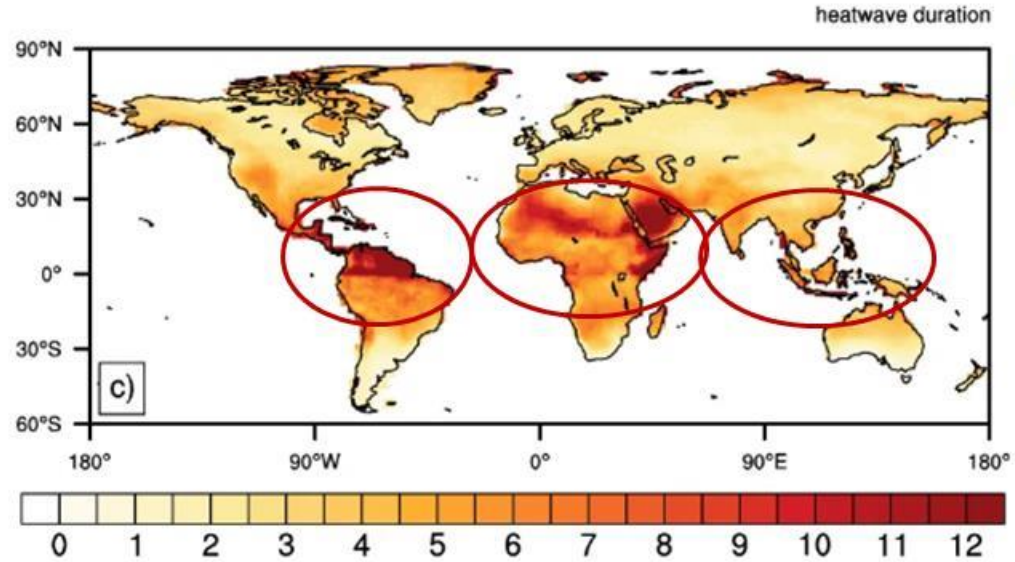
Global problem: it will affects all of us



Perkins-Kirkpatrick & Gibson (2017)

but it will impact most the poorest countries

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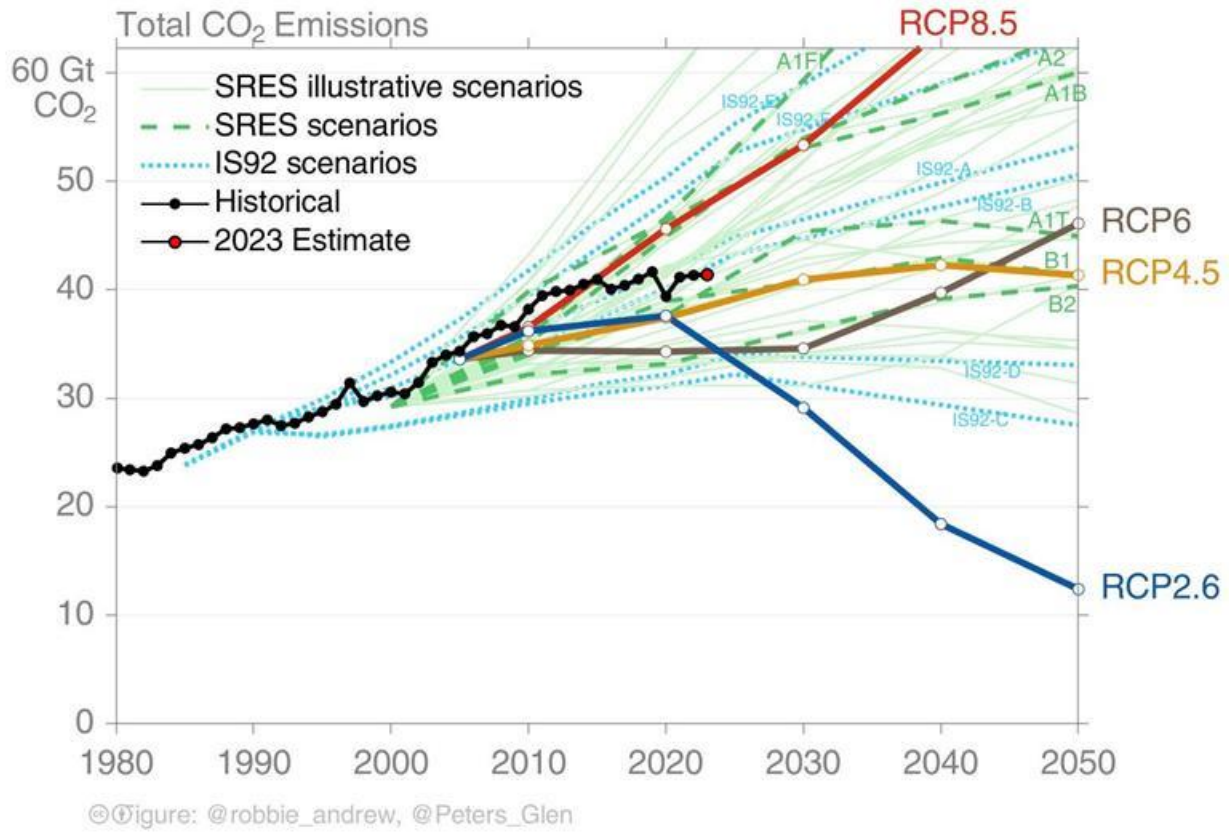
Economic problem



Carbon economy

Low-Carbon economy

De-Carbonized economy

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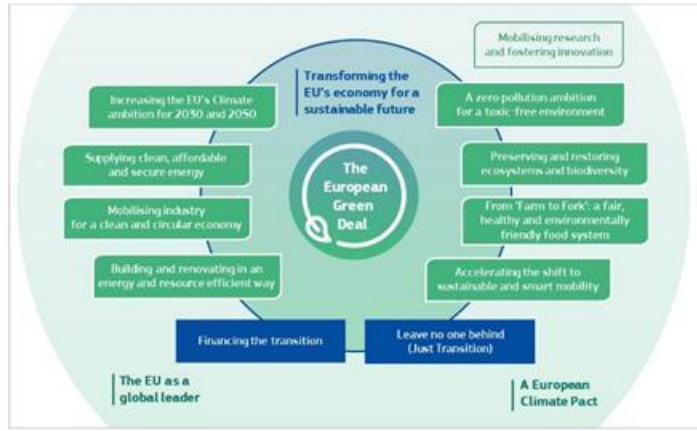
Political problem: drastic measures are unpopular/costly



EUROPEAN COMMISSION

Brussels, 11.12.2019
COM(2019) 640 final

COMMUNICATION FROM THE COMMISSION

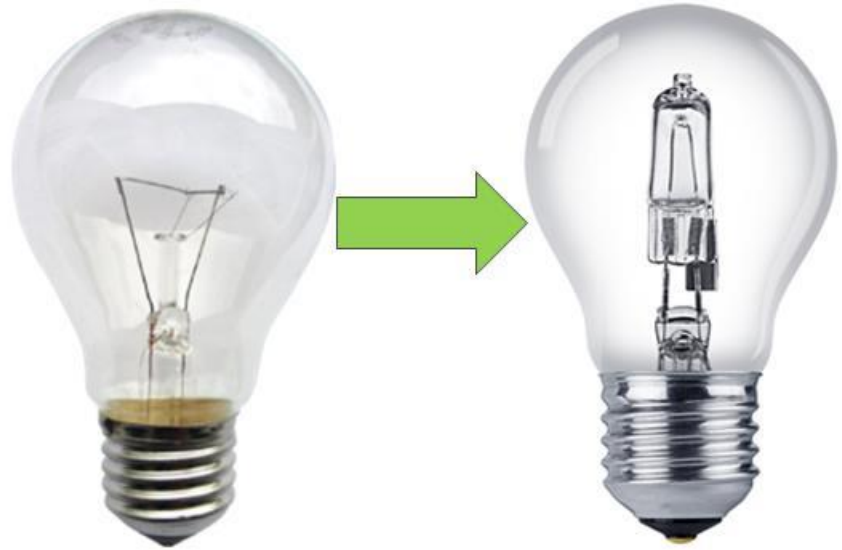
The European Green Deal

1. INTRODUCTION - TURNING AN URGENT CHALLENGE INTO A UNIQUE OPPORTUNITY

This Communication sets out a European Green Deal for the European Union (EU) and its citizens. It resets the Commission's commitment to tackling climate and environmental-related challenges that is this generation's defining task. The atmosphere is warming and the climate is changing with each passing year. One million of the eight million species on the planet are at risk of being lost. Forests and oceans are being polluted and destroyed [1].

The European Green Deal is a response to these challenges. It is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use.

It also aims to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts. At the same time, this transition must be just and inclusive. It must put people first, and pay attention to the regions, industries and workers who will face the greatest challenges. Since it will bring substantial change, active public participation and confidence in the transition is paramount if policies are to work and be accepted. A new pact is needed to bring together citizens in all their diversity with national, regional, local authorities, civil society and industry



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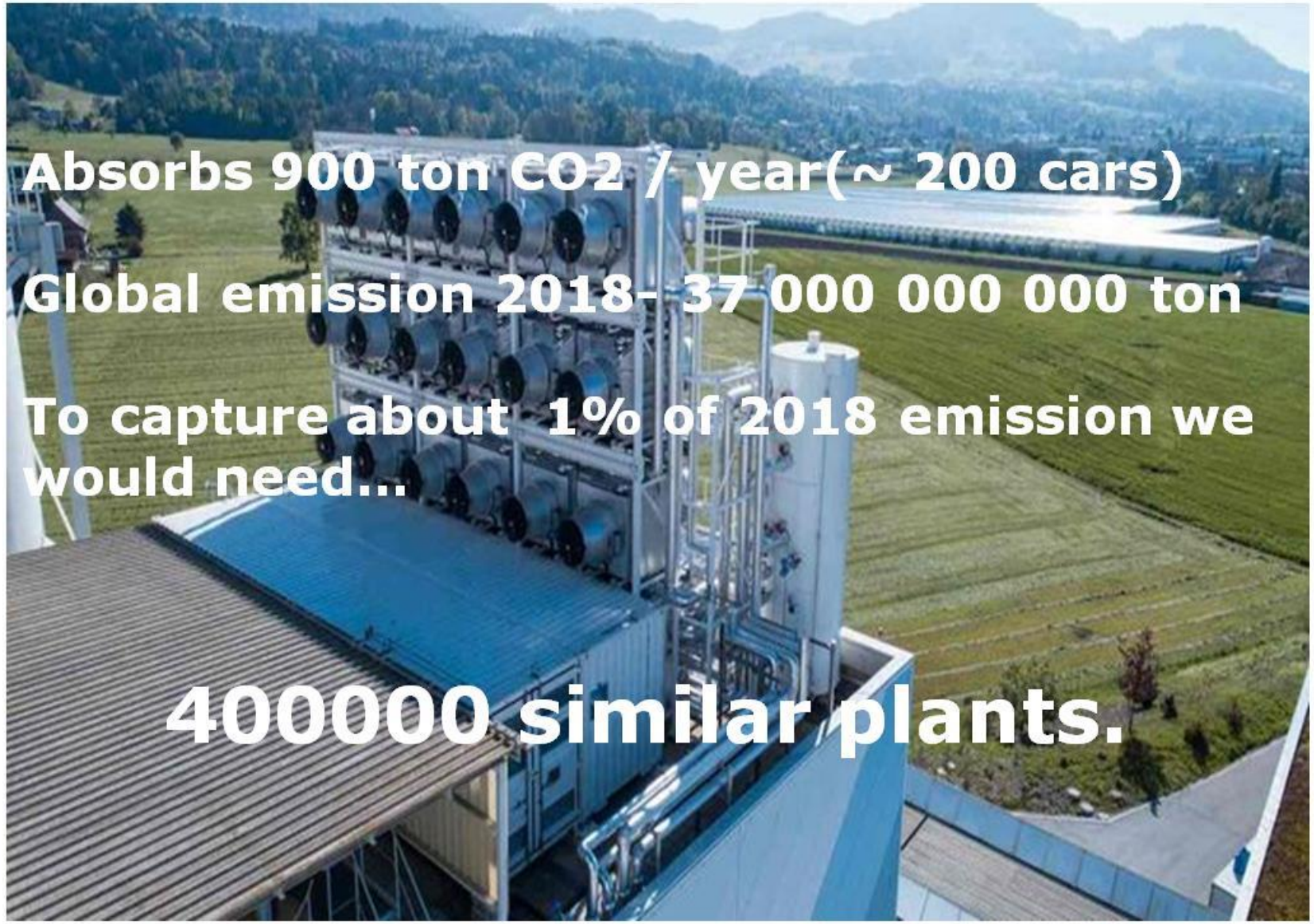
Technological problem (not the solution)



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Ethical problem

Everyone can do his share

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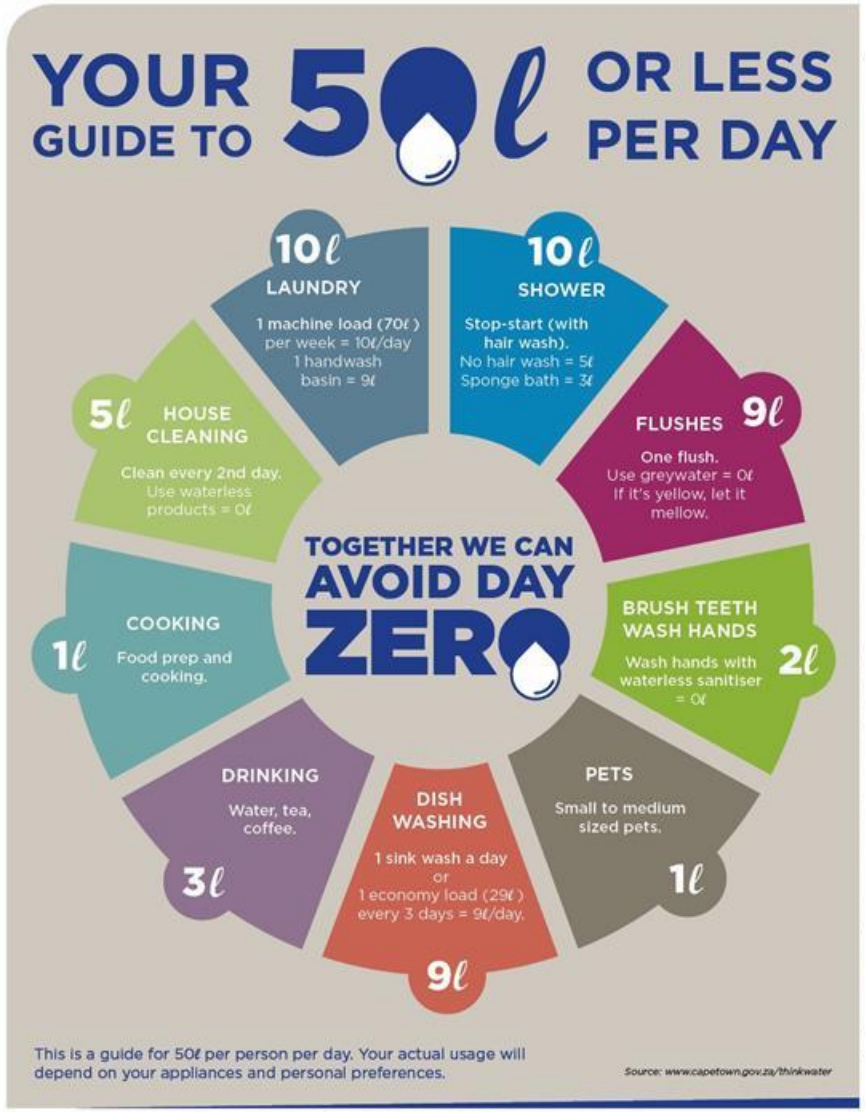
We cannot afford to waste resources



Suggested readings

If you hadn’t enough

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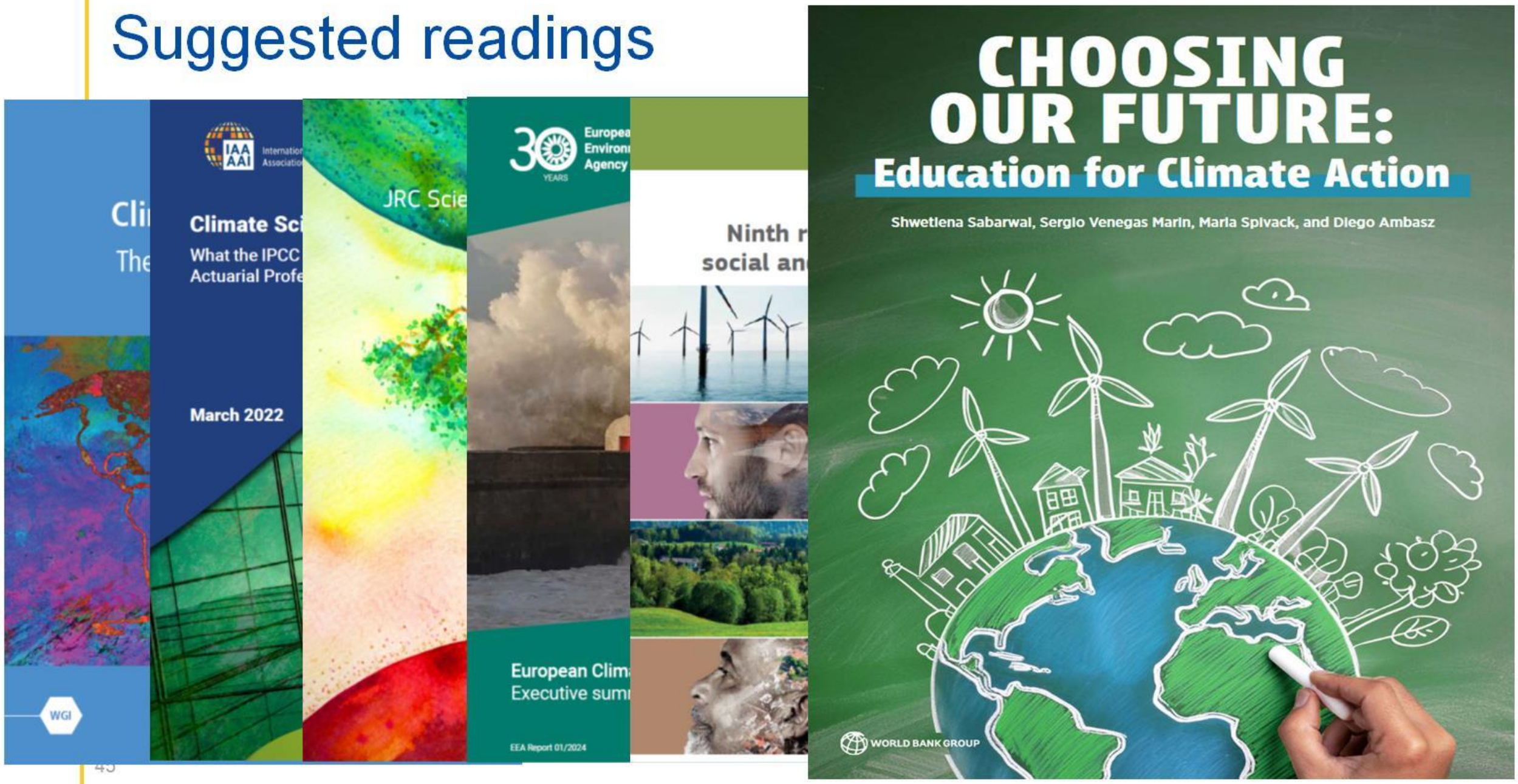
Suggested readings

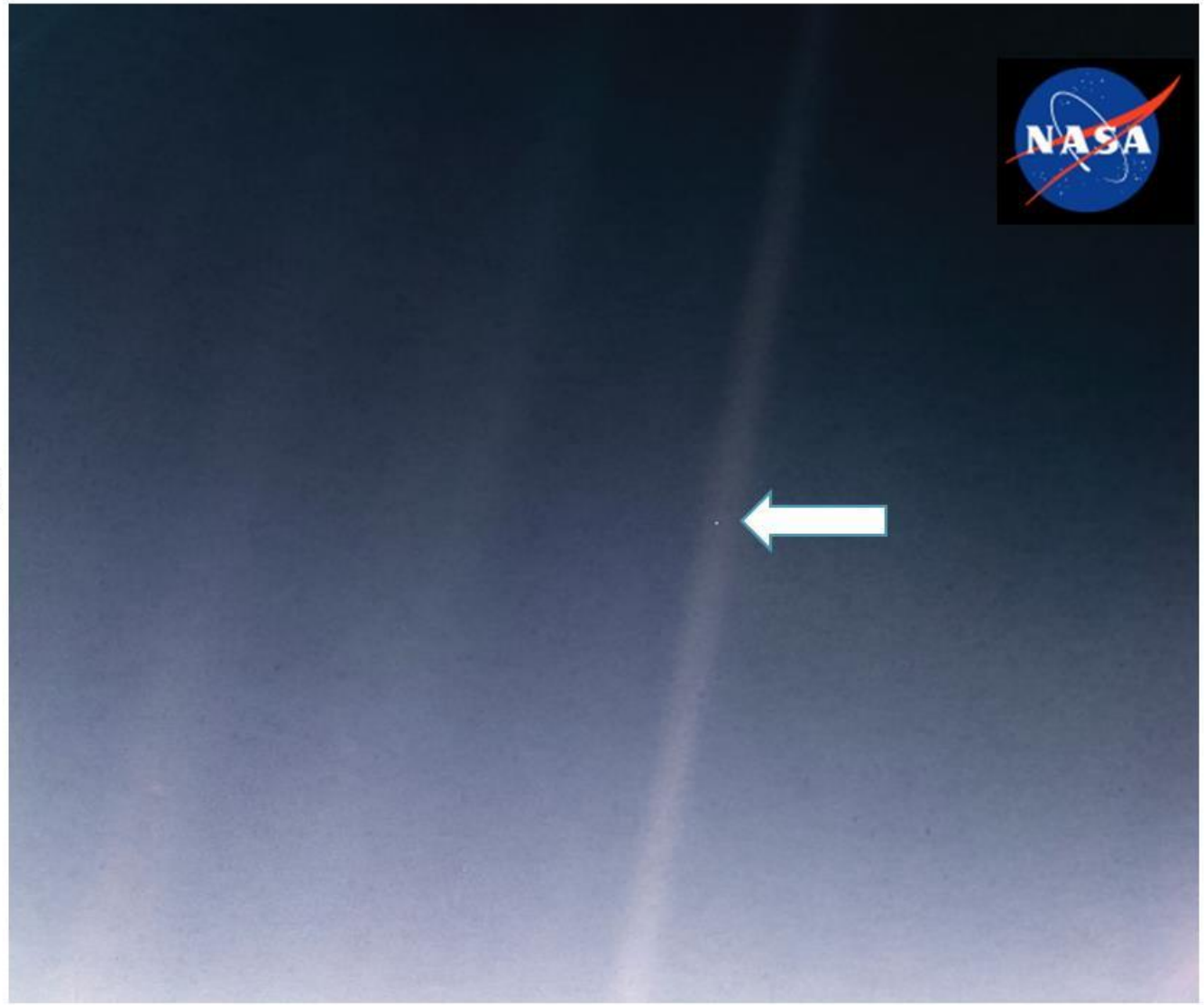


The pale blue dot

…if you look at it, you see a dot.
That's here. That's home. That's us.

On it, everyone you ever heard of, every human being who ever lived, lived out their lives. […] every hero and coward, every king and peasant, every young couple in love, every hopeful child, every mother and father, every inventor and explorer, every corrupt politician, every superstar, every supreme leader, every saint and sinner in the history of our species, lived there on a mote of dust, suspended in a sunbeam.

Our planet is a lonely speck in the great enveloping cosmic dark. To me, [this image] underscores our responsibility to deal more kindly and compassionately with one another and to preserve and cherish that pale blue dot, the only home we've ever known.



Voyager 1, 14 February 1990.
For the first time, humankind could see itself in perspective from the edge of our solar system (6,054,587,000 Km).

Thank you

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