Challenges in forecasting and responding to urban floods associated with extreme events

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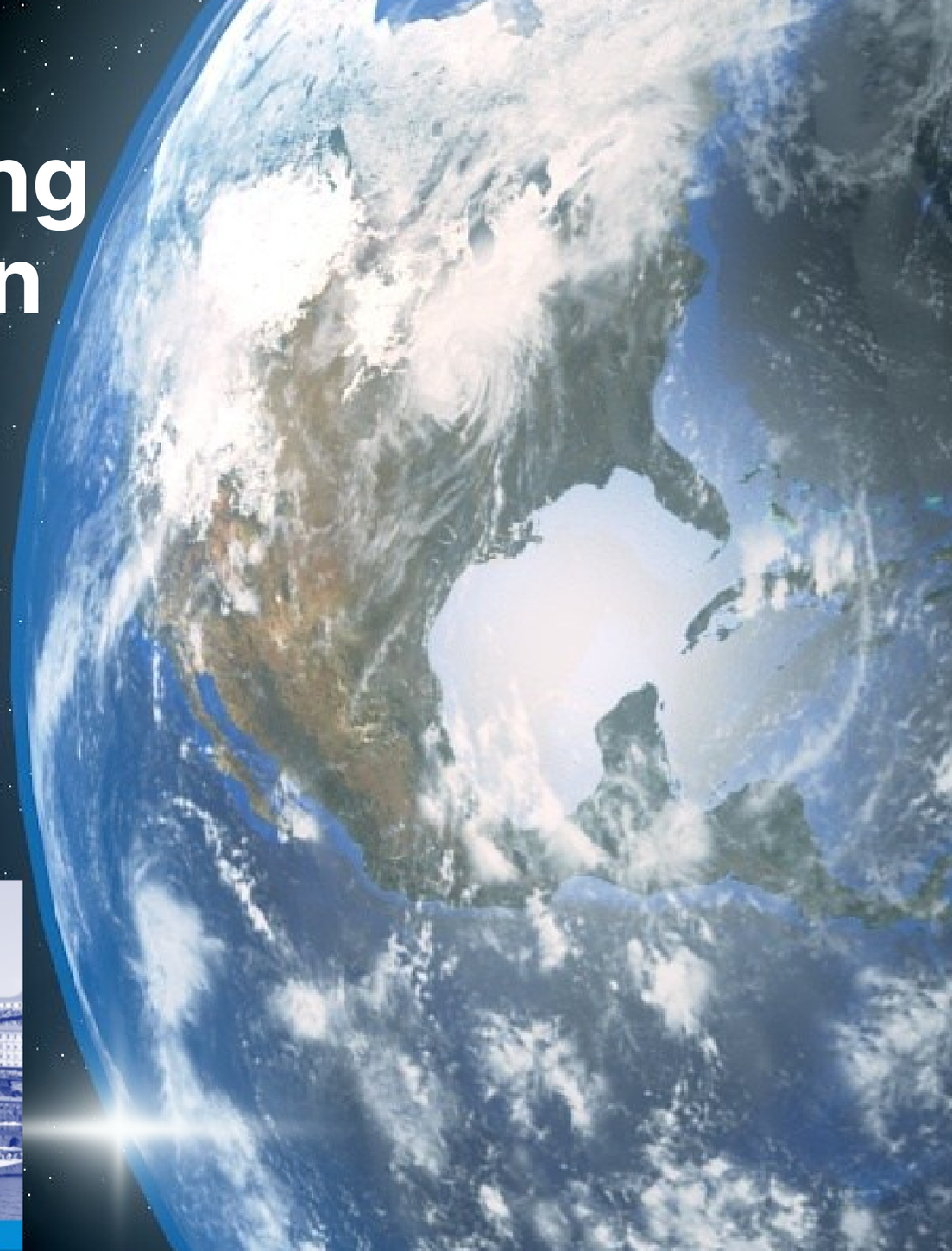

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NOVOS DESAFIOS NA ADAPTAÇÃO E PRESERVAÇÃO DO PATRIMÓNIO EDIFICADO
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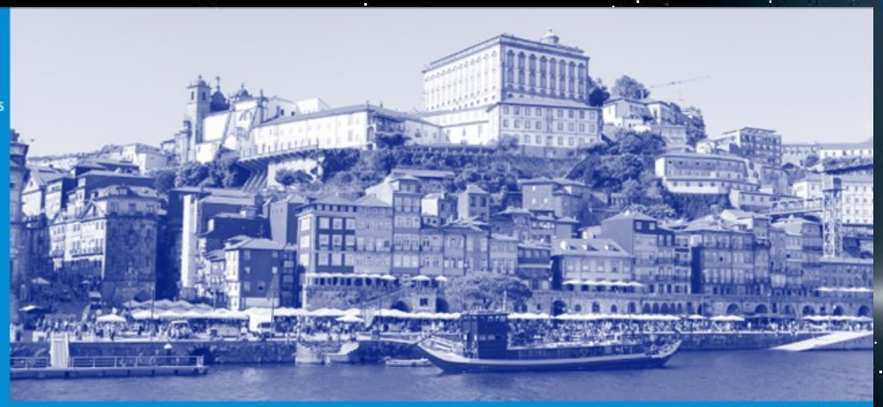
ISEP P.PORTO UNIVERSIDADE BEIRA INTERIOR UFRJ Politécnica UFRJ



PORTO, PORTUGAL

1.Climate change, extreme events, and disasters

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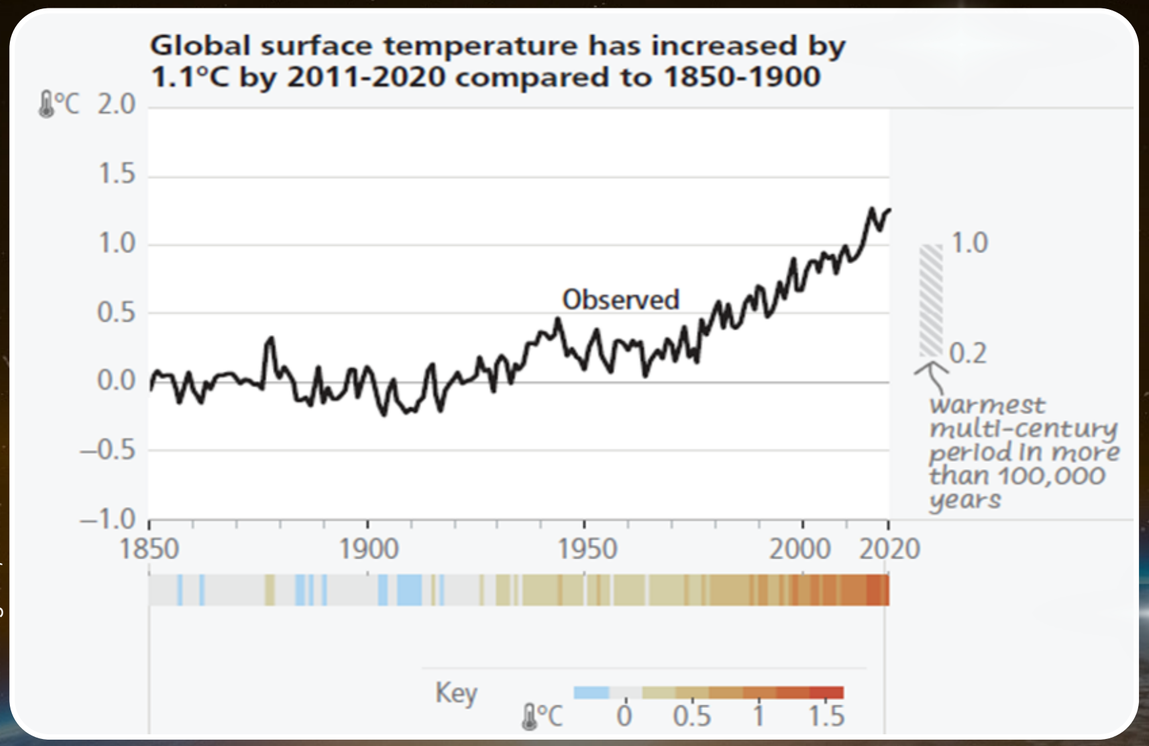
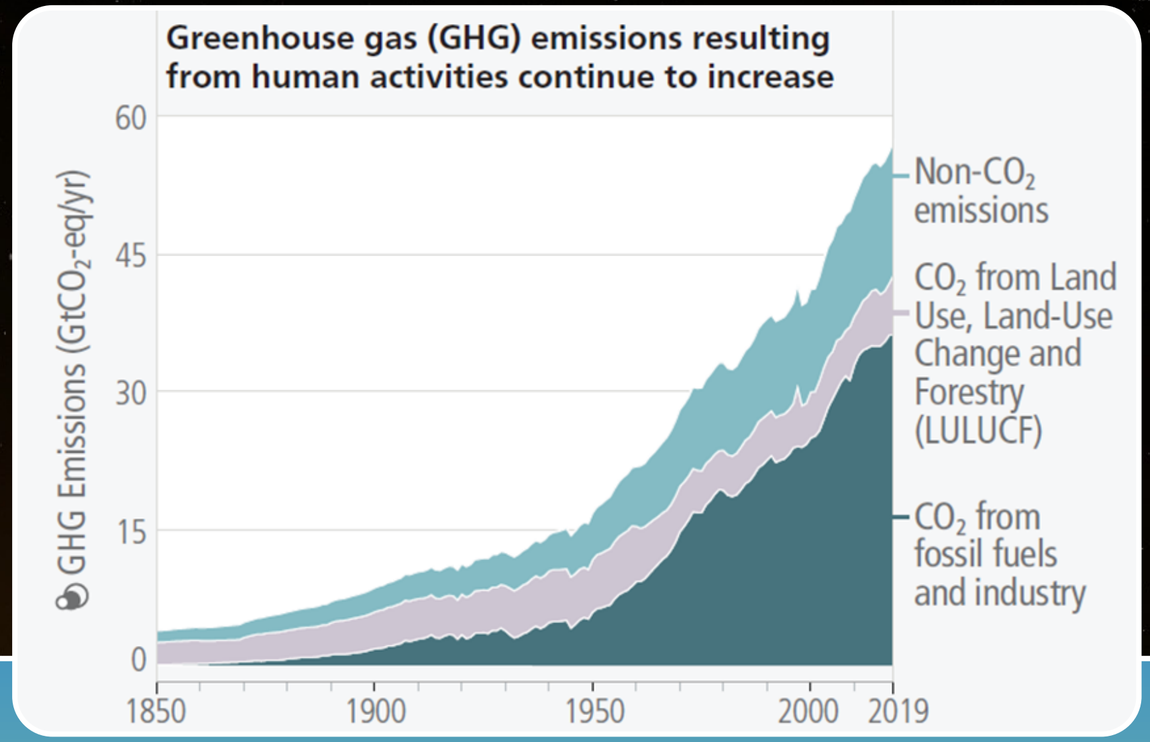
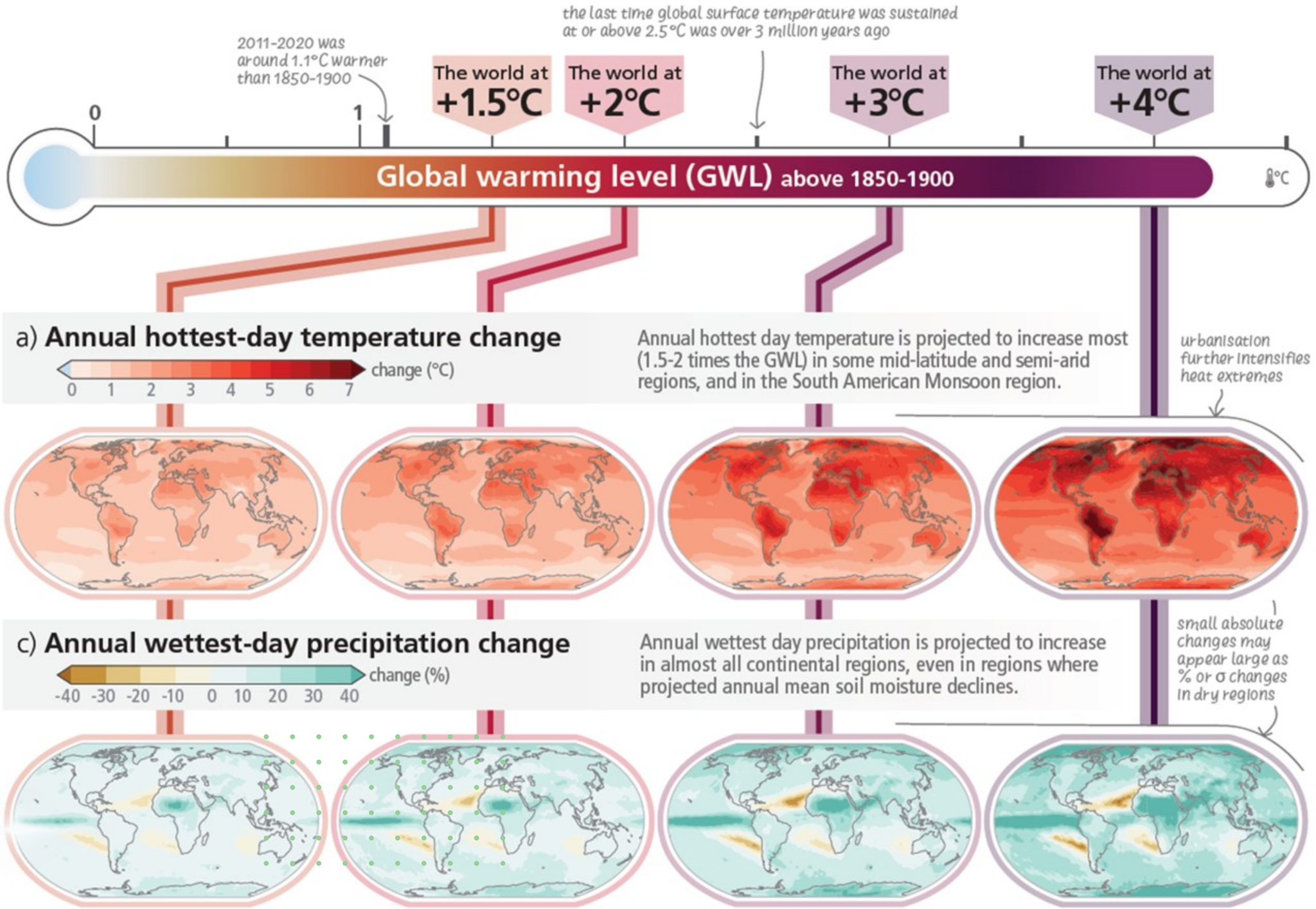
GHG emissions and the global temperature





With every increment of global warming, regional changes in mean climate and extremes become more widespread and pronounced (IPCC, 2023)


the last time global surface temperature was sustained at or above 2.5°C was over 3 million years ago
2011-2020 was around 1.1°C warmer than 1850-1900
0
1
The world at +1.5°C
The world at +2°C
The world at +3°C
The world at +4°C
Global warming level (GWL) above 1850-1900
°C
a) Annual hottest-day temperature change
change (°C)
0 1 2 3 4 5 6 7
Annual hottest day temperature is projected to increase most (1.5-2 times the GWL) in some mid-latitude and semi-arid regions, and in the South American Monsoon region.
urbanisation further intensifies heat extremes
c) Annual wettest-day precipitation change
change (%)
-40 -30 -20 -10 0 10 20 30 40
Annual wettest day precipitation is projected to increase in almost all continental regions, even in regions where projected annual mean soil moisture declines.
small absolute changes may appear large as % or σ changes in dry regions

Mountainous Region of Rio de Janeiro State, Brazil, 2011

Foto: Marino Azevedo/ Governo do RJ

- Over 200 mm of rain in 24 hours
- 918 deceased (oficial); >3,000 (estimated)
- 100 missing
- Near 35,000 displaced
- Infrastructure heavily affected

Foto: Luciano Pereira/VC no G1Foto: Luciano Pereira/VC no G1

https://noticias.r7.com/rio-de-janeiro/tragedia-serrana-apos-3-anos-cidade-tem-40-mil-moradores-em-risco-e-120-vitimas-desaparecidas-11012022/

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Foto: JOSÉ PATRÍCIO/ESTADÃO

https://g1.globo.com/rj/regiao-serrana/noticia/2022/02/15/em-2011-chuva-na-regiao-serrana-deixou-mais-de-900-mortos.ghtml

Wildfires in Portugal, August 2025

Pombal

Carlos COSTA/AFP Leia mais em: https://veja.abril.com.br/mundo/portugal-tem-pior-temporada-de-incendios-da-historia-com-recorde-de-area-queimada/

Wildfires burned 3% of Portugal's territory, a new historical record for the country (Institute for Nature Conservation and Forests - ICNF)

Viseu

Pedro Sarmento Costa

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2. Disaster Risk Management

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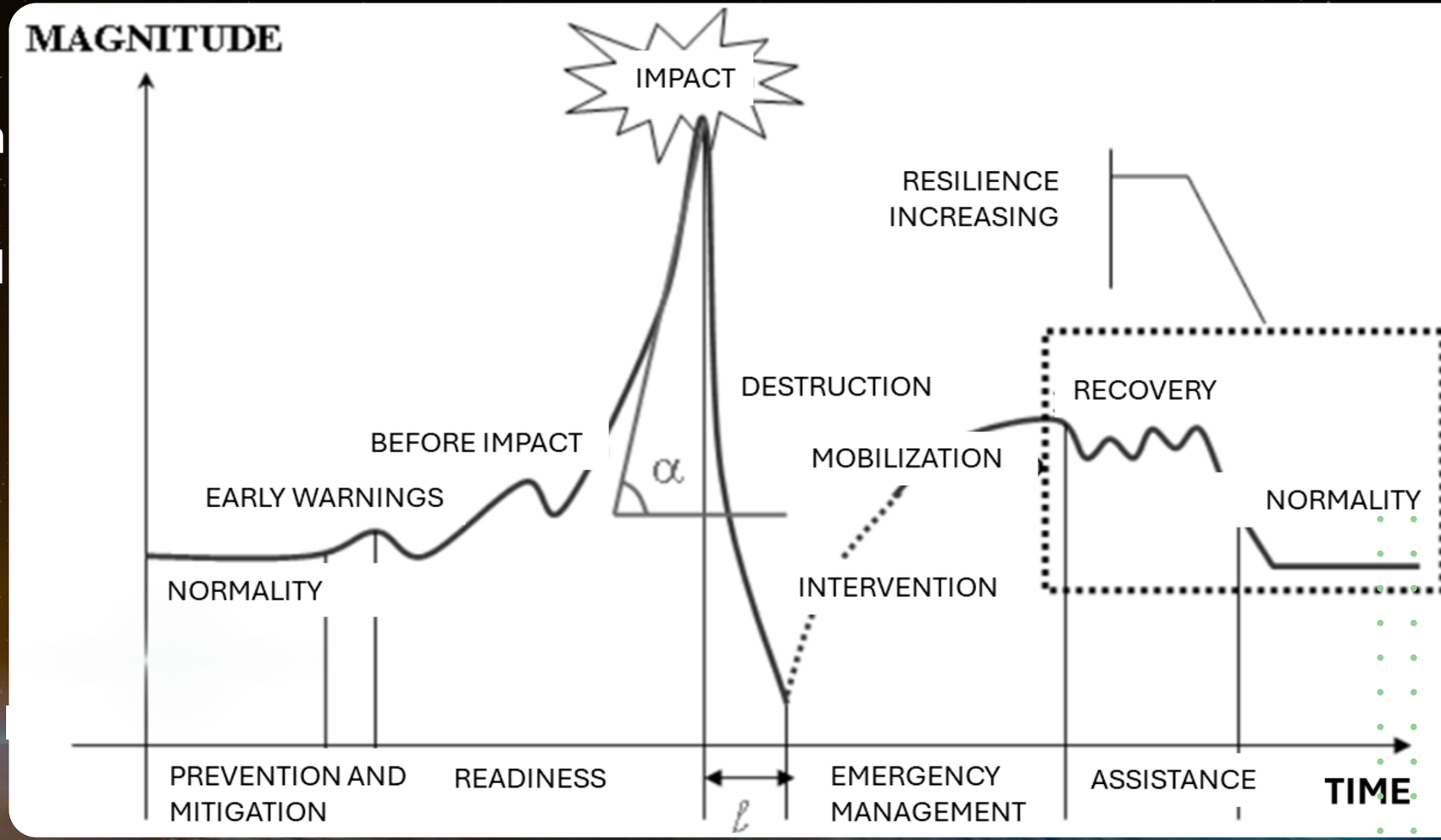
What is a DISASTER?

A '**disaster**' is understood as the **consequences of an adverse event** (a phenomenon caused by humans and/or nature) on a **vulnerable environment**, which **exceeds the response capacity** of the affected social system.



Source: Adapted from Sérgio B. ARAÚJO. Administração de Desastres
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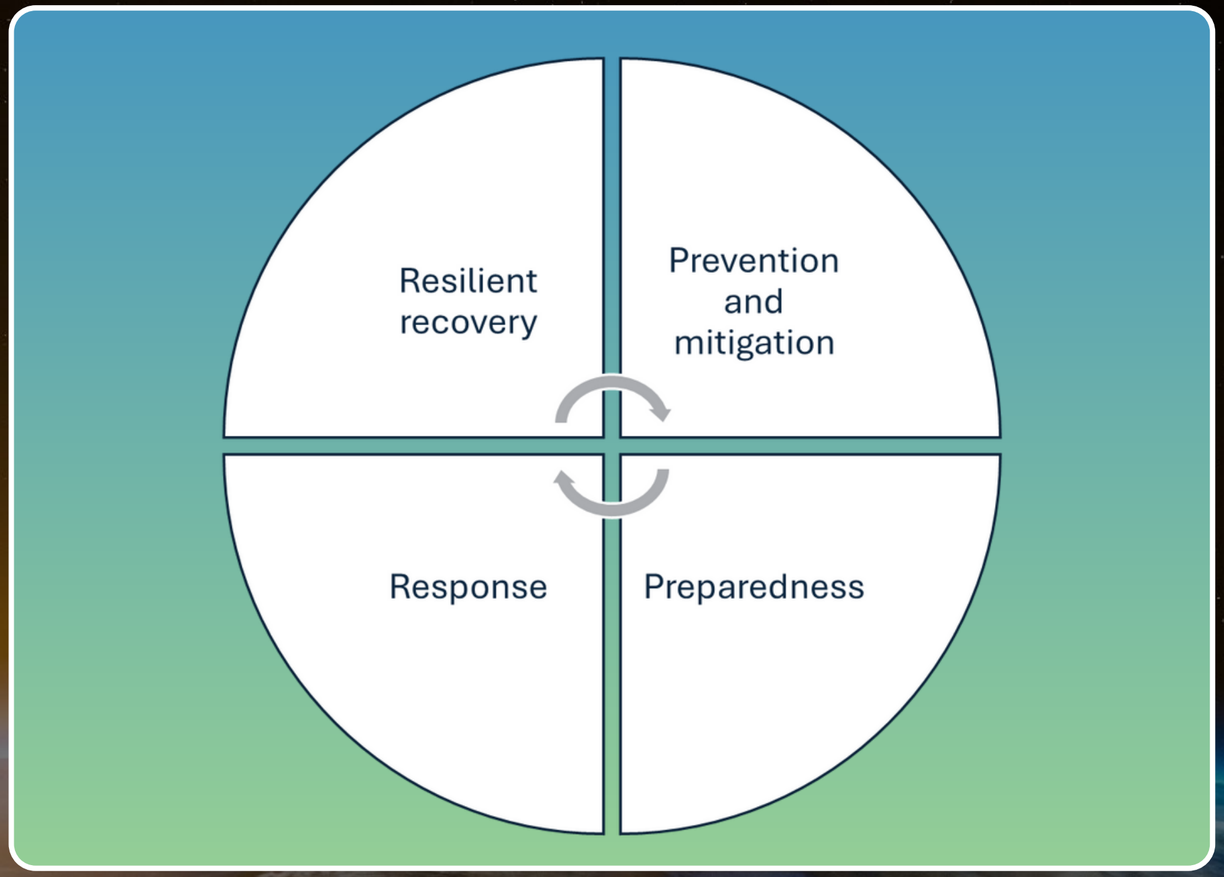
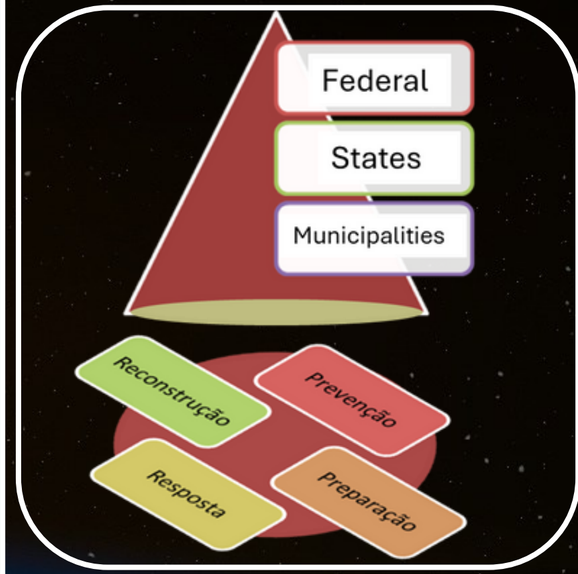
Comprehensive Disaster Risk Management





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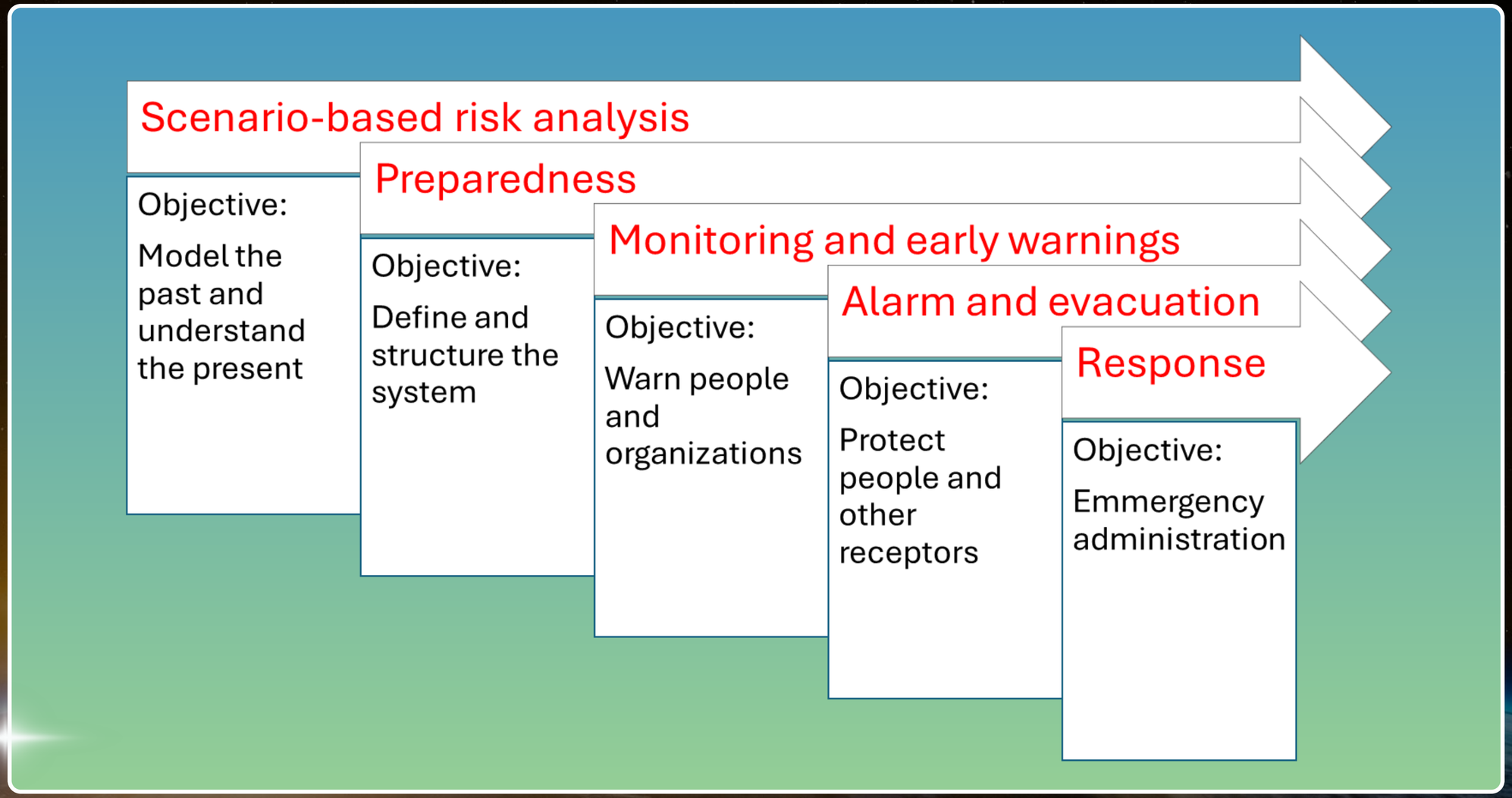
Imminent Disaster Risk Reduction | Response



3. Case studies

Floods in Derna, Libya, September 11th, 2023

- 100,000 inhabitants, 30,000 displaced.
- 5,923 deceased (official); 14,000–24,000 deceased or missing (estimated).
- 414 mm of rain in 24 hours (414 liters/m^2 in one day) in Al-Bayda, west of Derna.
- Flooding occurred within 90 minutes after the collapse of two dams upstream from Derna.
- Waves reached 7 meters high.
- Only 3 out of 10 districts were spared.

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Floods in Derna, Libya, September 11th, 2023

- Evacuation focused on the wrong part of the city.
- Inadequate shelter locations predictions.
- There was no reliable list of areas to be evacuated.
- There were no flood alerts, only sea level alerts.
- Only those near the beach were warned to evacuate.
- Some were evacuated to more dangerous areas.
- Problems with the dams were known.
- Infrastructure was affected by wars.
- Political turbulence hindered coordination efforts.

Credits: Halil Fidan/AA/Picture alliance

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Floods in Rio Grande do Sul State, Brazil, May 2024

- ‘The Greatest Climate Catastrophe in the RS State's History’
- Between April 27 and May 2, rainfall ranged from 500 to 700 mm, equivalent to one-third of the state's historical annual average.
- More than 60% of the state's territory was affected.
- The flooding of Lake Guaíba (Porto Alegre) reached 5.37 meters, surpassing the historic floods of 1941 and 2023.
- State highways were blocked due to landslides, flooding, dam failures or destruction, and fallen trees.
- Approximately 2.4 million people were affected.
- There were 185 confirmed casualties, while 25 people remained missing.
- More than 442,000 people were displaced.
- Damages may have exceeded $2 billion.

Floods in Rio Grande do Sul State, Brazil, May 2024

- In Porto Alegre, the flood containment system, consisting of a wall and a series of dikes, experienced operational failures.
- Water pumping stations that return water to Lake Guaíba stopped functioning.
- Porto Alegre International Airport was affected, and flights were suspended indefinitely.
- Over 3,000 healthcare facilities were affected.
- The shutdown of water treatment plants—either flooded or preemptively deactivated—left 85% of the capital's population without water.
- Flooded neighborhoods had their electricity cut off as a precaution, affecting 138,000 people.
- Local business owners expressed surprise at the immediate need for evacuation.

Floods in Texas, USA, July 4th, 2025

- 40 Years after a similar disaster.
- 135 casualties.
- Floods just three weeks earlier in San Antonio had killed 13 people.
- Over 750 children and teenagers were at Camp Mystic.
- Rainfall exceeding 300 mm/m^2 occurred between Thursday afternoon and the early hours of Friday morning.
- Between 2 a.m. and 7 a.m. on July 4, the Guadalupe River in Kerrville reached nearly 12 meters, according to a local flood gauge.
- The water level rose more than 8 meters in just 45 minutes — a flash flood.

Reuters

Floods in Texas, USA, July 4th, 2025

- Weather service messages were sent on July 2 and 3 to the western and central areas of the state, warning of flood risks — but none predicted 50 centimeters of rain.
- The U.S. National Weather Service issued a flash flood warning for Kerr County more than 12 hours in advance.
- Many local residents said they did not receive any emergency alerts on their phones or did not understand the severity of the warnings they saw.
- According to the Kerr County government, reports on July 5 indicated that the Guadalupe River level could reach 12 meters or more, surpassing the second-largest flood in modern county history, which occurred in 1987.
- No alerts were sent by local government authorities in Kerr County or neighboring Bandera County to the south; they relied on warnings from the National Weather Service.
- ‘There are areas with no cell coverage, so no matter how many alert systems you subscribe to, you won’t receive a single message.’ — Nim Kidd, Director of the Texas Division of Emergency Management (TDEM).
- Six years ago, the county considered installing a flood alert system along the Guadalupe River, but it was never implemented due to cost. — Rob Kelly, Kerr County Judge.

Photo: Wikipedia

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Floods in the Valencia Region, Spain – October 29th, 2024

- In Just 8 Hours, some parts of Valencia received a year's worth of rainfall (445 mm). Valencia, Spain's third-largest city, was severely affected.
- At least 231 people died.
- The storm was caused by a meteorological phenomenon locally known as a 'Depresión Aislada en Niveles Altos' (DANA).
- Experts say the increasing frequency of DANAs and the growing intensity of rainfall are linked to climate change.
- This is one of the most densely populated and tourist-heavy regions in the country, where construction has taken place for decades in flood-prone areas.

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Floods in the Valencia Region, Spain – October 29th, 2024

- Many of the people who died were on the roads when the floods began — in many cases, returning from work.
- ‘They didn’t warn us’, said Julia Chisert.
- ‘My neighbors told me to run as fast as I could. The water was chasing me — very, very fast. I stayed at home for three days with no electricity, no water, no phone, nothing’, said Amparo.
- Although the State Meteorological Agency had raised the alert level to maximum on the morning of Tuesday, the 29th, warning of ‘a very high level of risk for the population’, the authorities reportedly failed to take exceptional measures.
- By the time Civil Protection sent an emergency alert message to residents’ phones, floodwaters had already inundated several areas, and many people were clinging to trees or taking refuge on rooftops to escape the unstoppable storm.
- ‘We feel abandoned. There are many people who need help’, they told Reuters.

What to expect if the threshold of 1.5ºC is surpassed?

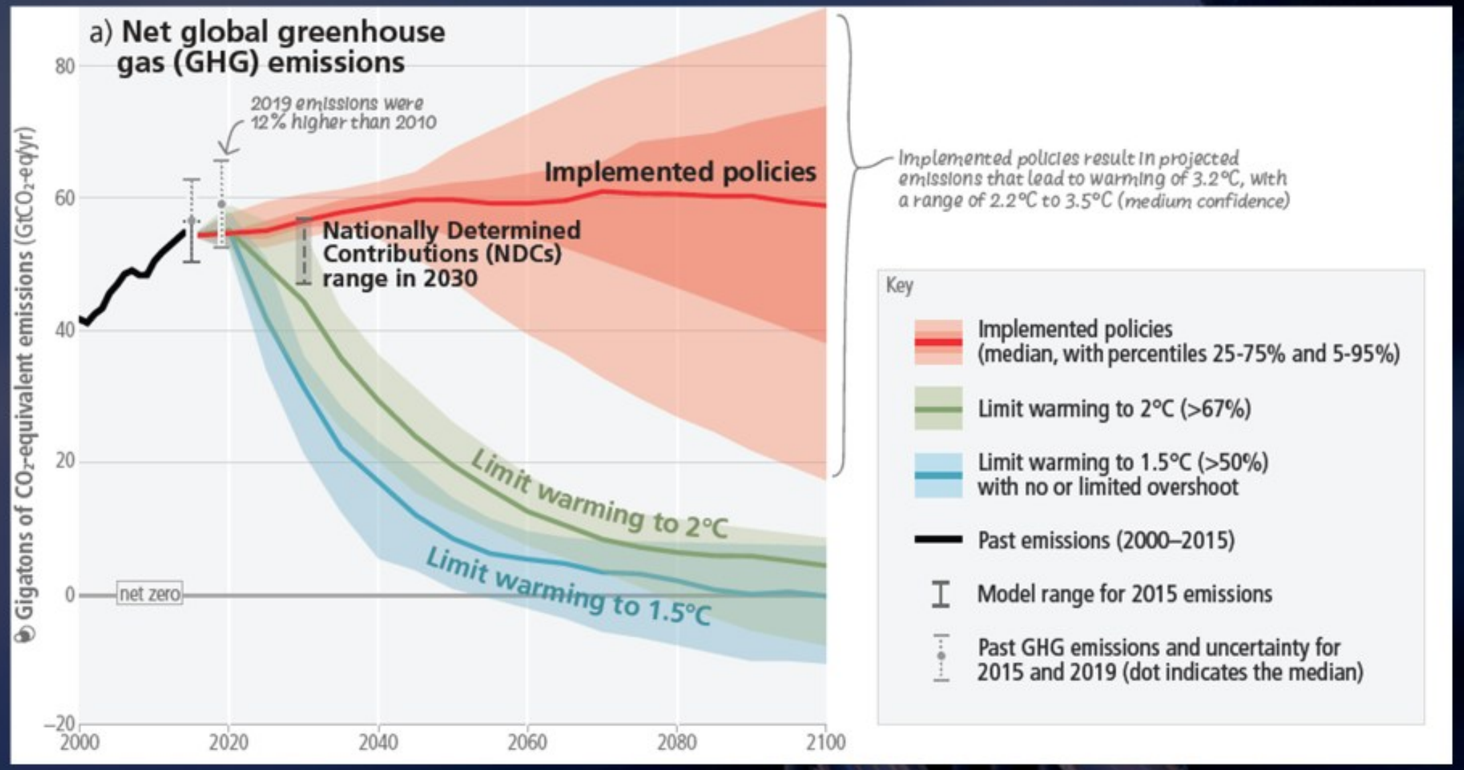
- Near 1 billion people would be exposed to hydrological stress and desertification.
- Estimated costs of $ 63 billion in adaptation and damage to agricultural cultures.
- 14% of species would be exposed to extinction risks.
- 24% more people would face extreme floods.
- 70%-90% reduction in coral reefs in tropical regions.
- Much more malaria cases diseases.
- High risk that some non-return climate points be reached.

… and if the threshold of 2ºC is surpassed?

- Extreme heat waves in the south of Africa would double.
- 160% more wildfires burned areas in Mediterranean Europe.
- Additional $ 17 billion in in adaptation and damage to the main agricultural cultures.
- Destruction of coral reefs ecosystems in tropical regions.
- Heavy impacts on human health and productivity, mainly in Africa and south Asia.
- Rapid defrosting of boreal permafrost, releasing significant amounts of methane.
- Collapse in frozen layers in Greenland and West Antarctica.
- Various non-return climate points are reached (i.e. Amazon forest into savanna).

Conclusion

Limiting warming to 1.5°C and 2°C involves rapid, deep and in most cases immediate greenhouse gas emission reductions (IPCC, 2023)



Our choices will reverberate for hundreds, even thousands, of years.

Where do we want to go?

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Urban Engineering Graduate Programme
Environmental Engineering Graduate Programme
Civil Construction Department
Polytechnic School
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La persistencia de la memoria, Salvador Dalí, 1931.

Thank You