

# Science of Climate Change

**Exercise  
session #10**

# Today's plan

1. Key points from this morning's lecture and any questions  
(Extreme event attribution, Carbon Budget)
2. Exercises and discussion
3. Time to work on assignment and posters

# Extreme Event attribution (EEA)

## Learning objectives

- Explain the core ideas of **extreme event attribution (EEA)**: factual vs counterfactual worlds, probability ratio, fraction of attributable risk (FAR).
- Understand, at a conceptual level, how **systematic** attribution across many events works.
- Interpret a **decomposition** of climate change impacts on heatwaves into contributions from “carbon majors” (large fossil fuel & cement producers).
- Reflect critically on the **ethical, legal, and political** implications of linking individual companies to specific extreme events (“finger-pointing”).

# Exercise 1 – PART A

Simple probability ratio and FAR

<https://www.nature.com/articles/s41586-025-09450-9>

- Consider a hypothetical heatwave similar to those analysed by Quilcaille et al. (2025):
- In a **pre-industrial** climate (no anthropogenic warming), the best estimate of the **annual probability** of such a heatwave is  $P_0 = \frac{1}{200}$
- In the **current** climate, the best estimate is  $P_1 = \frac{1}{5}$
- Compute the:
  - (a) **Probability ratio** (PR)
  - (b) **Fraction of attributable risk** (FAR)
  - (c) New **return period** in years in the current climate.
- (d) Interpret these values in words. Based on these numbers, would you say the event is “virtually impossible without climate change”? Why or why not?

# Exercise 1 – PART B

From Climate Change to Emitters

- Quilcaille et al. (2025) estimate  $\Delta T_{tot} = 1.3^\circ\text{C}$  (global mean surface temperature increase)
- Contribution of all 180 carbon majors:  $\Delta T_{CM,all} = 0.67^\circ\text{C}$
- Contribution of the 14 largest carbon majors:  $\Delta T_{CM,top14} = 0.33^\circ\text{C}$
- A heatwave's total anthropogenic intensity increase is:  $\Delta T_{event} = 2.0^\circ\text{C}$

Now:

- Assume the **event intensity scales linearly** with total warming:  $\Delta T_{event} \propto \Delta T_{tot}$
- (a) Compute the fraction of warming due to all carbon majors ( $f_{CM,all}$ ).
  - (b) Compute the fraction due to the top 14 ( $f_{CM,14}$ ).
  - (c) Compute the contribution of all major emitters to the event intensity ( $\Delta T_{event,CM,all}$  in  $^\circ\text{C}$ ).
  - (d) Compute the contribution of the top 14 emitters to the event intensity ( $\Delta T_{event,CM,top14}$  in  $^\circ\text{C}$ ).
  - (e) Compare these numbers to the conclusion that carbon majors cause roughly half the increase in heatwave intensity since pre-industrial times.

# Exercise 1 – Part C

## Reflection on “finger-pointing” & accountability (Science vs blame)

- Quilcaille et al. (2025) emphasise they are quantifying causal contributions along a physical chain (emissions → warming → heatwaves), and that their results “fill evidentiary gaps” for **climate litigation and corporate accountability**.
- In your view, where is the boundary between **scientific attribution** and **moral / legal blame**?
- Should scientists explicitly avoid language that sounds like legal “finger-pointing”? Or is it appropriate (and maybe necessary) in this context?

# Exercise 2: 1.5°C vs 2°C warming

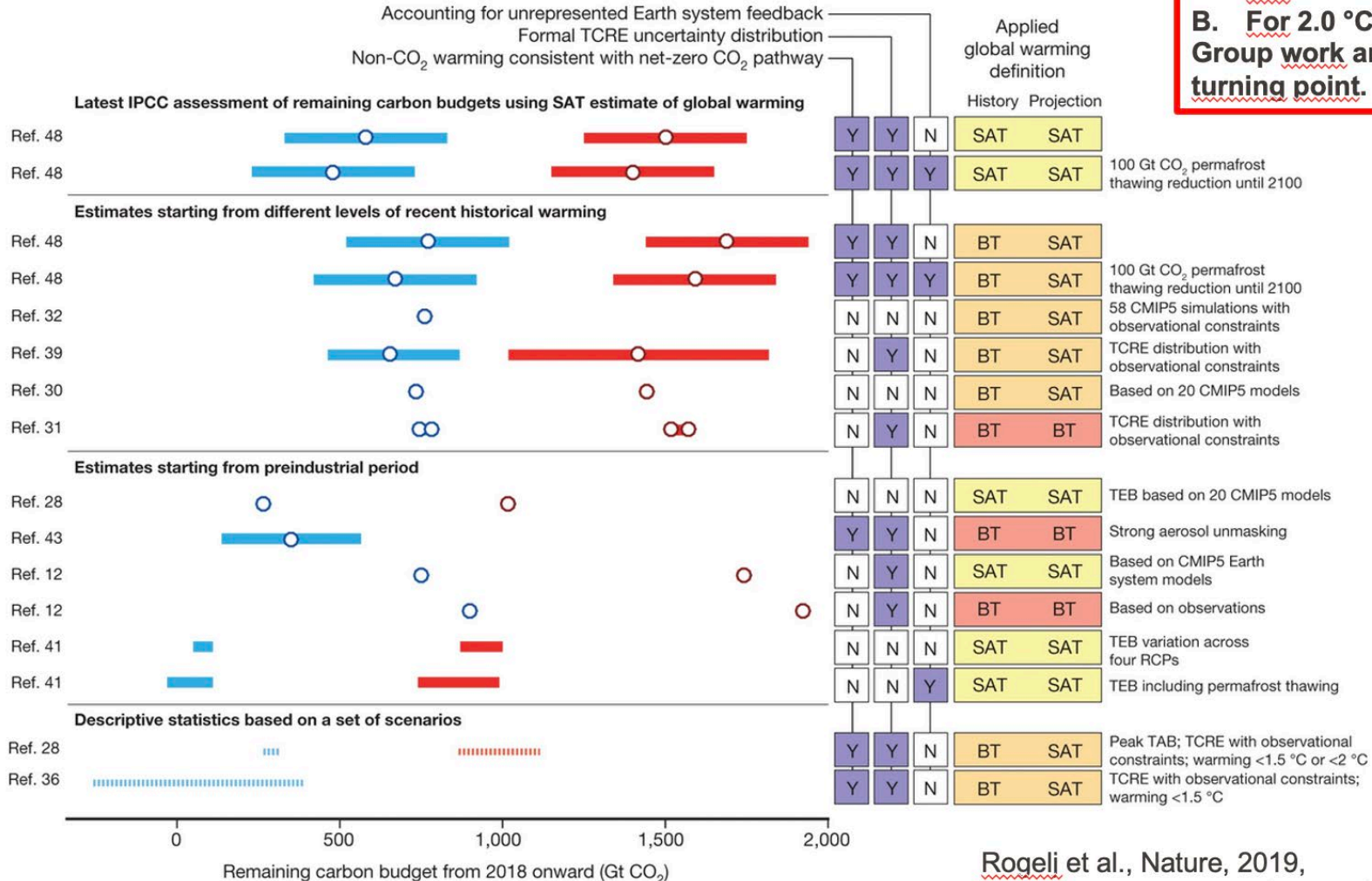
- Go on the interactive IPCC map: <https://interactive-atlas.ipcc.ch/> and click on advanced climate future
  - Which SSP scenario would allow to remain below the 1.5°C ?
  - How should anthropogenic emissions look like according to this/these scenario/scenarii?
  - What about the other scenarii? What is the temperature increase projected by 2100?
  - Now, check what are projections of sea level rise corresponding to 1.5 and 2 and 2.7°C (current path).

# Exercise 3: Remaining carbon budget

## How much carbon budget is left?

**How much time do we have left if we continue emissions at the rate of the past years?**  
**A. For 1.5 °C**  
**B. For 2.0 °C**  
**Group work and answer on turning point.**

1.5°C  
 2.0°C



N, no; Y, yes;  
 SAT, global near-surface air temperatures;  
 BT, blended temperatures (surface air temperature over land and sea-ice regions combined with sea surface temperature over open ocean)

# Exercise 4: Tipping elements

- Within the following examples, which ones represent potential tipping elements and why? Take 5 minutes to identify them and explain why they represent tipping elements.

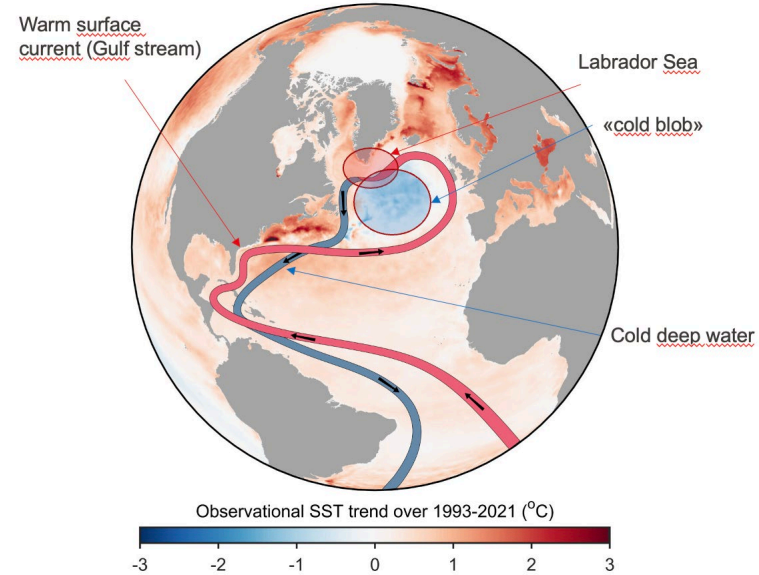
Arctic summer ice



Sea level



Atlantic meridional overturning circulation



Increased rainfall



**Time to work on the assignment/poster**