

Seminar cycle on environmental transition

*Discussion on planetary boundaries
and climate change*

Master WAVES 2025



Laboratoire de Mécanique et d'Acoustique



by Antonin Coutant

Seminar cycle on environmental transition



[<https://climatevisuals.org> (credit: Neil Palmer / CIAT)]

Aim of the seminar cycle:

**Trigger discussions/curiosity on
environmental transition**

Seminar cycle on environmental transition



Programme:

- Sept. 30 on *solar powered sound systems*: visit at Pikip
- Oct. 7 on *Climate change*: Antonin Coutant
- Nov. 12 & 25 on *Environmental impact of numerics*:
 - Julien Lefevre
 - Constance Douwes
- Nov. on *Art-Science*: Damien Beyrouthy

Disclaimer:

- I am **not** an expert in this field
- It is not a lecture
- It is an invitation to **read/discuss more**

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Also: **don't hesitate to ask questions!**

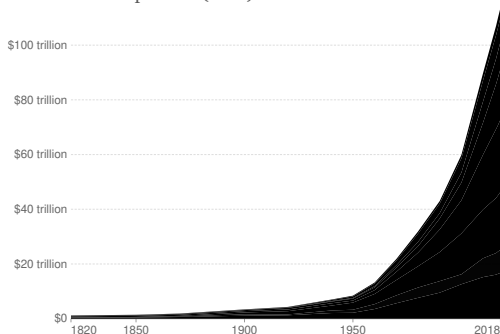
How is it going to work?

- ① My presentation: $\approx$ **45 min**
- ② Set of general questions
 - to work in small groups: 4-5 people
 - you are given one document to discuss the question
 - **20 min**
- ③ Summary of the group work for all: **5 min** each

- ① Planetary boundaries and the doughnut
- ② Climate change in a nutshell
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- Economic growth: recent but key to our societies
 - Infinite growth in finite planet → impossible
- [Meadows et al. “*The Limits to Growth; A Report for the Club of Rome’s Project on the Predicament of Mankind*” (1972)]

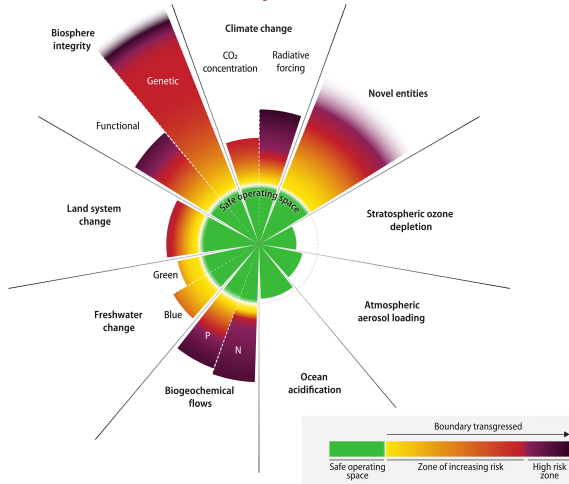
Gross domestic product (GDP)



Source: Maddison Project Database 2020 (Bolt and van Zanden, 2020)
Note: This data is expressed in international-\$ at 2011 prices.

OurWorldInData.org/economic-growth • CC BY

Planetary boundaries

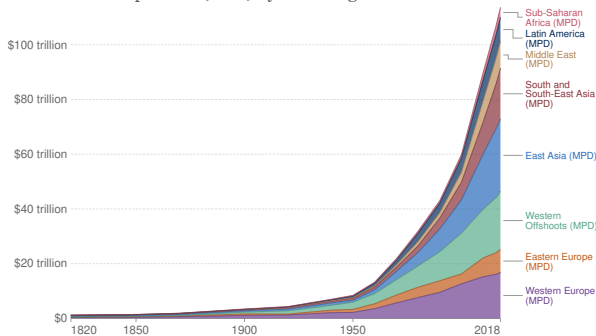


[more in Richardson et al., Science Advances (2023)]

Today's discussion focuses on **Climate Change**

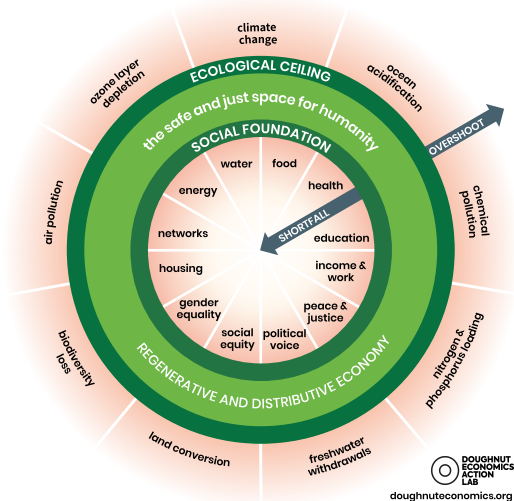
- Of course: Economic growth is unevenly spread
- Important to discuss **inequalities**

Gross domestic product (GDP) by world region



Source: Maddison Project Database 2020 (Bolt and van Zanden, 2020)
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Interesting concept: The doughnut economy

- Fullfill social needs
- Stay below planetary boundaries

[*“Doughnut economics” by Kate Raworth (2017)*]

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What is the climate?

The **climate system** is the interaction between 5 sub-parts of planet earth:

- the atmosphere (air)
- the hydrosphere (water)
- the cryosphere (ice and permafrost)
- the lithosphere (earth's upper rocky layer)
- the biosphere (living things)



[Wikipedia (Author: Femkemilene)]

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- **Meteorology**: weather on the daily scale

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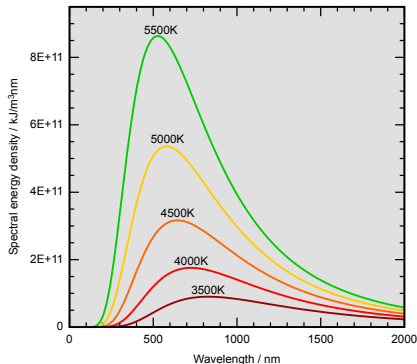


[Wikipedia (Author: Femkemilene)]

Important to distinguish:

- **Meteorology**: weather on the daily scale
- **Climate**: Same aspect/physical quantities but on a **larger temporal scale** (typically averages over ~ 30 years)

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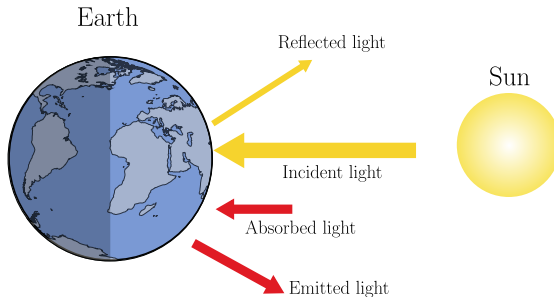
Little bit of physics:

- A body at a given temperature T emits light
- Emitted power per unit area:

$$W = \sigma T^4 \quad (\text{Stefan-Boltzmann law})$$

- The hotter, the higher frequencies (“bluer”) emitted

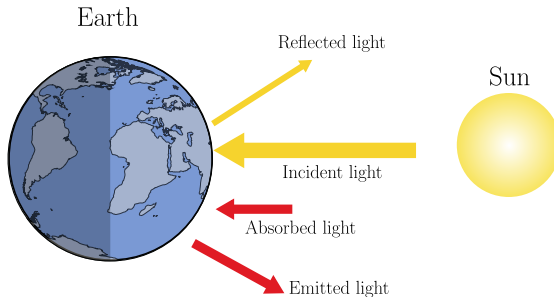
$$\lambda_{\text{max}} = \frac{b}{T} \quad (\text{Wien's displacement law})$$



- Sun emits mostly visible light
- Earth emits mostly infrared light
- **Radiative equilibrium:**
Earth absorbs as much as it emits
- This fixes earth (mean) temperature

$$F \sigma T_{\text{sun}}^4 = \sigma T_{\text{earth}}^4$$

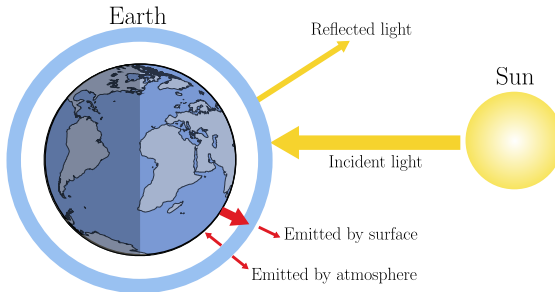
- This gives $T_{\text{earth}} \approx -18^\circ\text{C}$



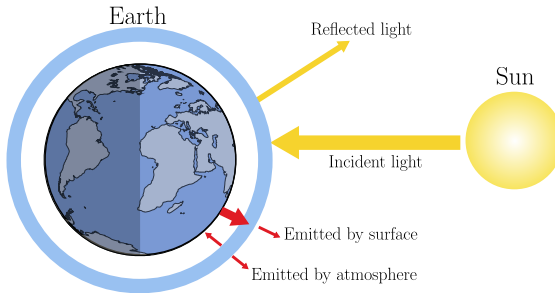
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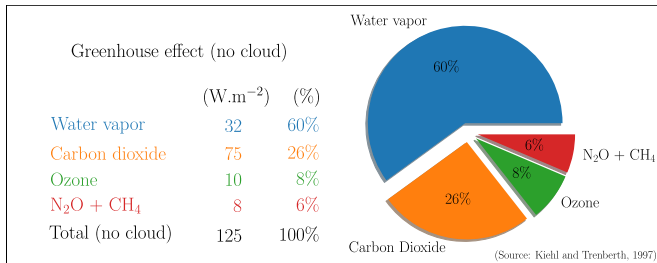
- This gives $T_{\text{earth}} \approx -18^\circ\text{C} \rightarrow$ forgot effect of **atmosphere**



- **Atmosphere** absorbs and re-emits IR light
- This is the **greenhouse effect**
- It warms the earth

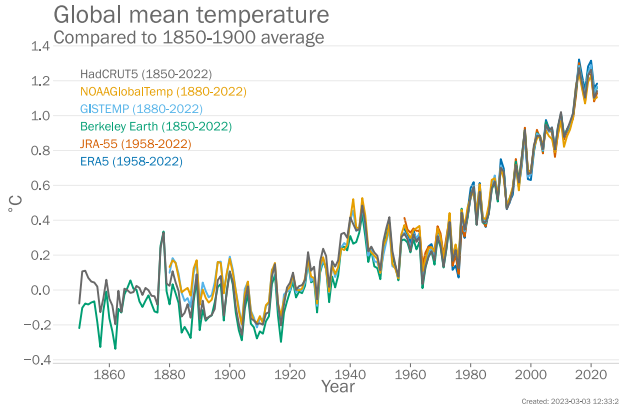


- **Atmosphere** absorbs and re-emits IR light
- This is the **greenhouse effect**
- It warms the earth $\rightarrow$ now we find $T_{\text{earth}} \approx 16^{\circ}\text{C}$

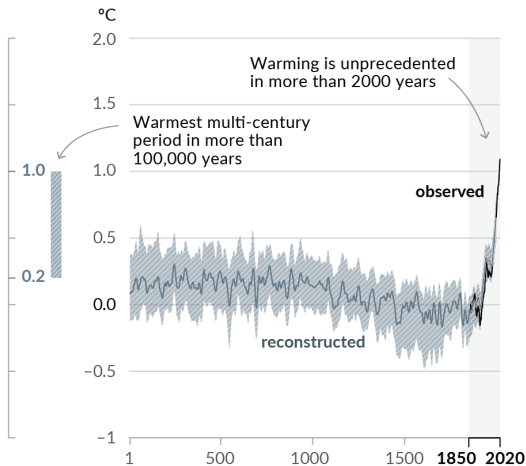


- Atmosphere greenhouse effect divides into 2:
 - Natural
 - Added (by human activities)
- GreenHouse Gas (GHG): gas capable of absorbing **IR** light
- Although the anthropic greenhouse effect is small compared to the natural one, it **dramatically affects the climate**

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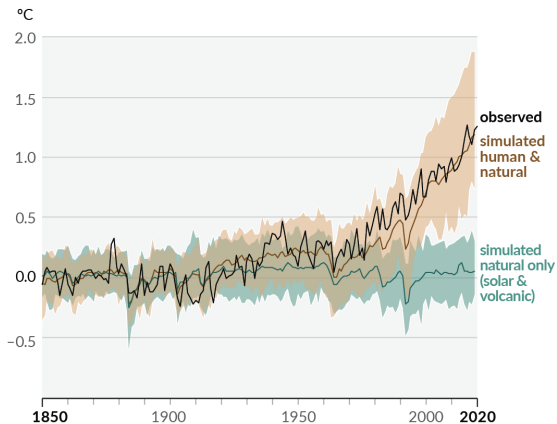


- **Earth climate is warming**
- This is observation (from multiple sources)
- Here from 1850 (~ start industrial era) to 2023



[IPCC, AR6, WGI (2021)]

- Warming is happening at **unprecedented rate**
- You have to go back 100 000 years to find +1°C change



[IPCC, AR6, WGI (2021)]

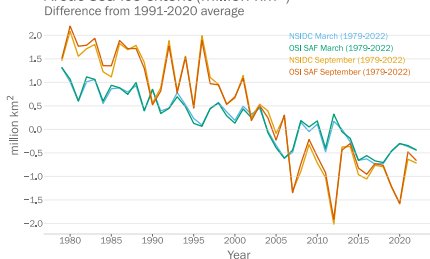
- **Human activities** is the **main driver**

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Global mean sea level change



Arctic sea-ice extent (million km²)



These are observed consequences today:

- Sea levels rise
- Ice cover melts
- Coral reef are threatened

More observed consequences:

Attribution of observed physical climate changes to human influence:

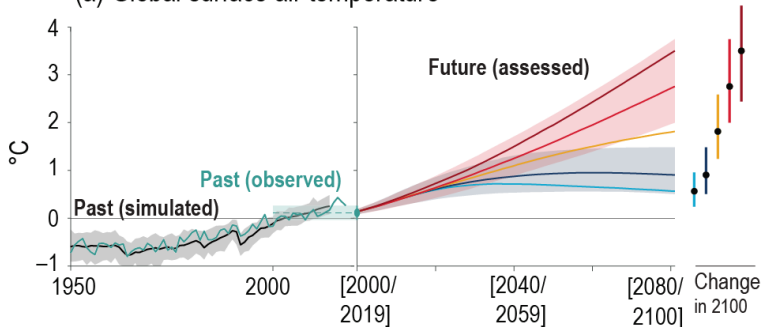
Medium confidence			Likely	Very likely		Virtually certain	
							
Increase in agricultural & ecological drought	Increase in fire weather	Increase in compound flooding	Increase in heavy precipitation	Glacier retreat	Global sea level rise	Upper ocean acidification	Increase in hot extremes

[IPCC, AR6, SYR (2023)]

- More heatwaves: 10-years event occurs 2.8 times more often
- More droughts
- More megafires
- More etc.

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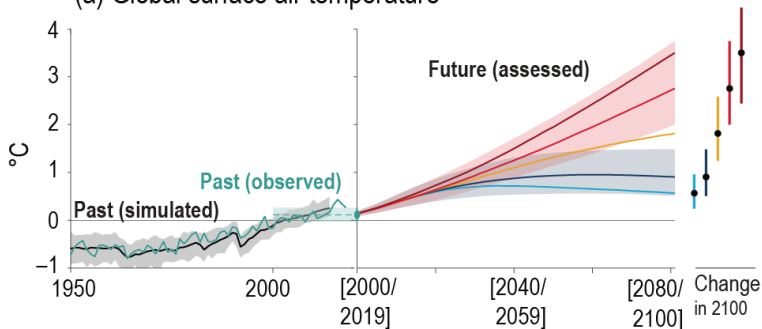
(a) Global surface air temperature



[IPCC, AR6, WGI (2021)]

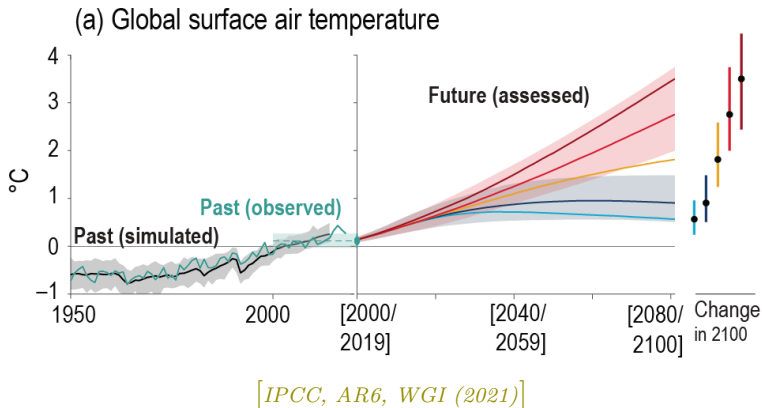
- Researchers build **general circulation models**

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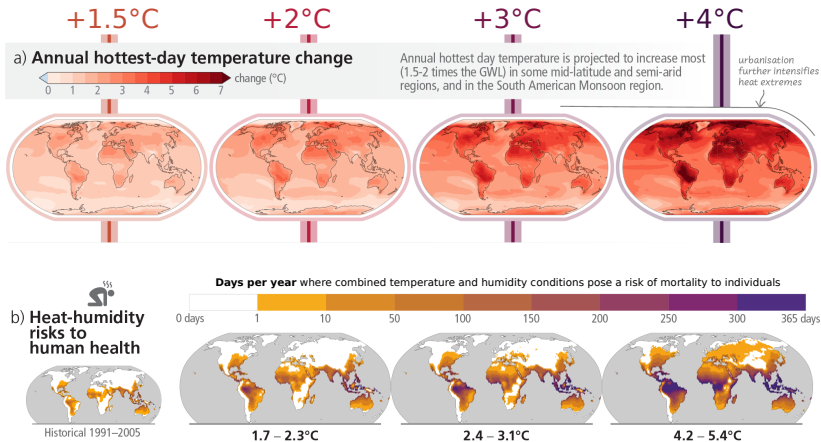
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- Researchers build **general circulation models**
- Simulate past → confront to data → validate model



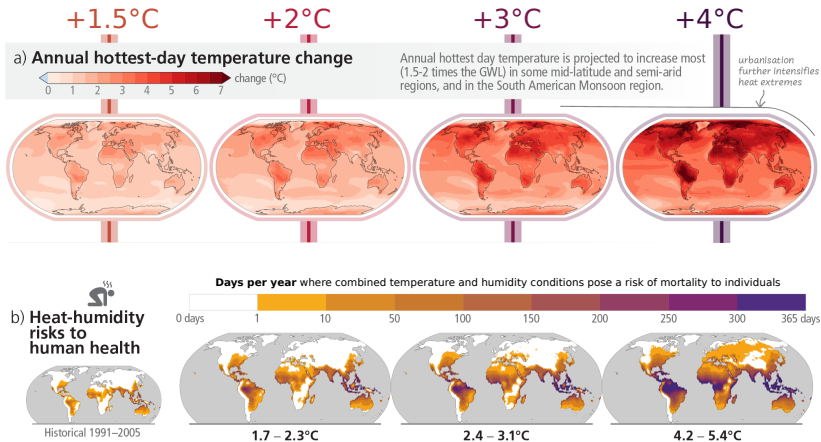
- Researchers build **general circulation models**
- Simulate past → confront to data → validate model
- Then, used to make scenarios:
 - Assumption about future GHG emissions
 - Simulate temperature evolution (or other)

- Gets worse depending on scenario



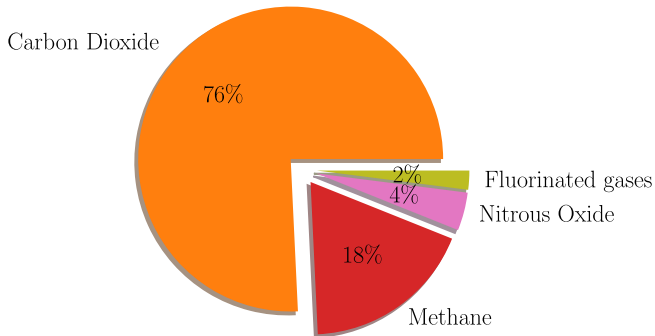
[IPCC, AR6, SYR (2023)]

- Gets worse depending on scenario
- Consequences are unequal across the globe



[IPCC, AR6, SYR (2023)]

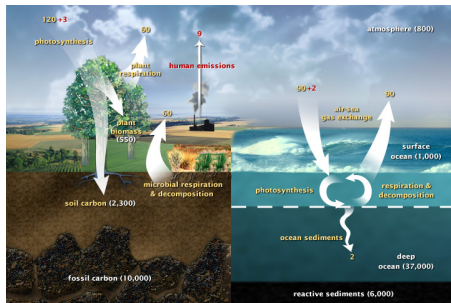
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Human activities emit Greenhouse Gases

- CO₂ is the main anthropic GHG
- Second important GHG: methane (CH₄)
- They are all **increasing over time** (CO₂ even more)

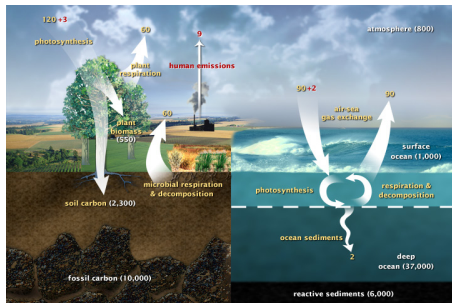
Important point: carbon cycle



[NASA, earth observatory]

- The total amount of C atoms is **conserved** (Carbon doesn't go into space)

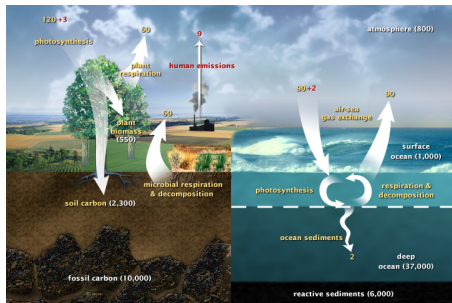
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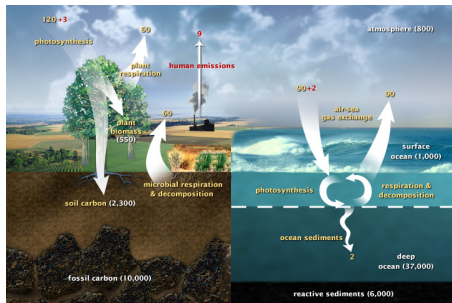
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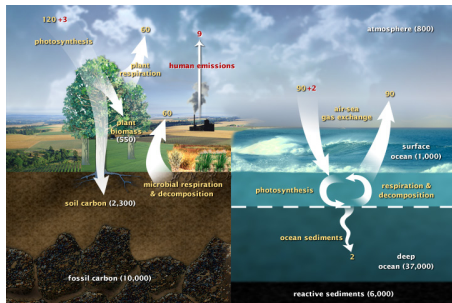
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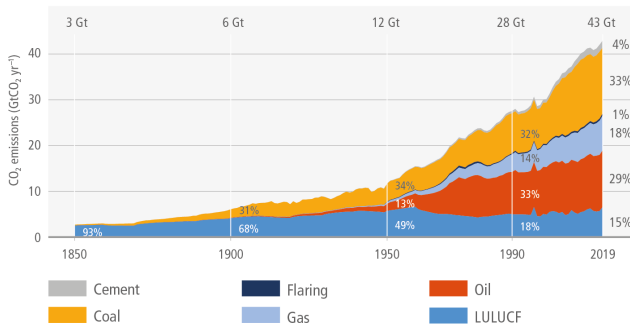
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- CO₂ density in the atmosphere increases if **more is emitted** than the system can absorb

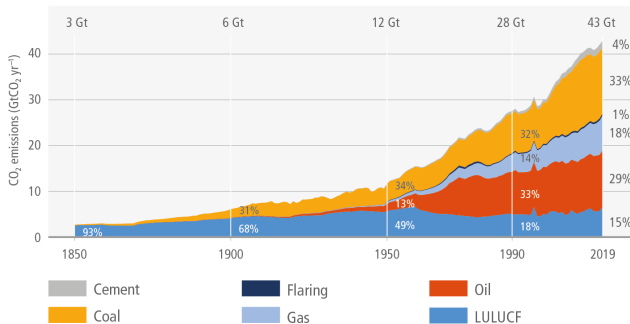
(a) Long term trend of anthropogenic CO₂ emissions sources



[IPCC, AR6, WGII (2022)]

Where is CO₂ coming from?

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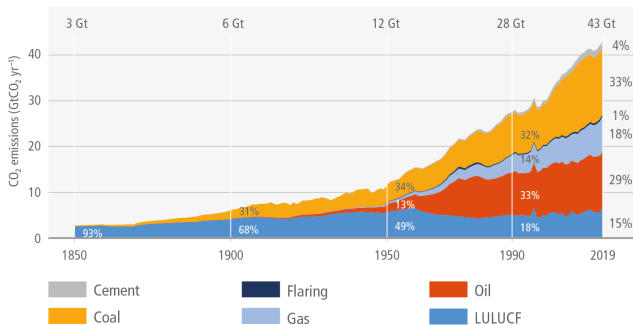


[IPCC, AR6, WGII (2022)]

Where is CO₂ coming from?

- Burning of fossil fuels:
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 - Gas

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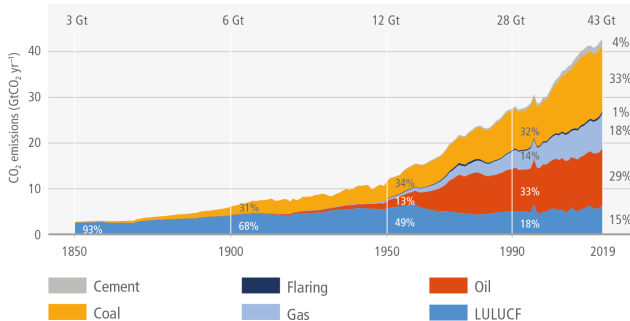


[IPCC, AR6, WGII (2022)]

Where is CO₂ coming from?

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 - Gas
- Deforestation (LULUCF)

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[IPCC, AR6, WGII (2022)]

What about CH₄?

- Mostly intensive farming (not shown)

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INTERGOVERNMENTAL PANEL ON
climate change



- Create by United Nations (UN) in 1988



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- Aim: synthesize scientific knowledge on Climate Change



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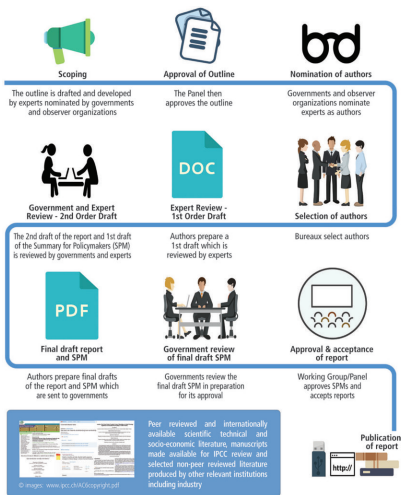
INTERGOVERNMENTAL PANEL ON
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- Create by United Nations (UN) in 1988
- Aim: synthesize scientific knowledge on Climate Change
- IPCC **does not conduct research**
- It **assesses scientific literature**
- Produce **regular reports**:
 - AR1 to AR6: every 6-7 years
 - Special Reports: +1.5°C (2018), oceans and cryosphere (2019), and more

[<https://www.ipcc.ch>]

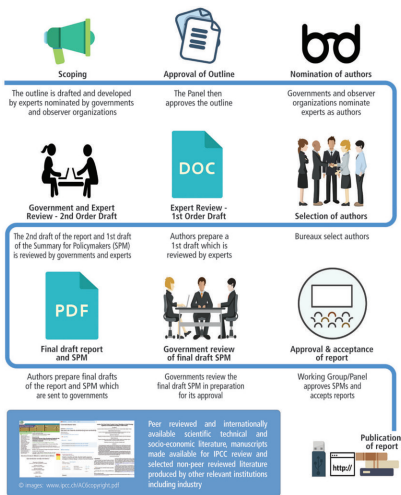
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 - Expert authors write the report
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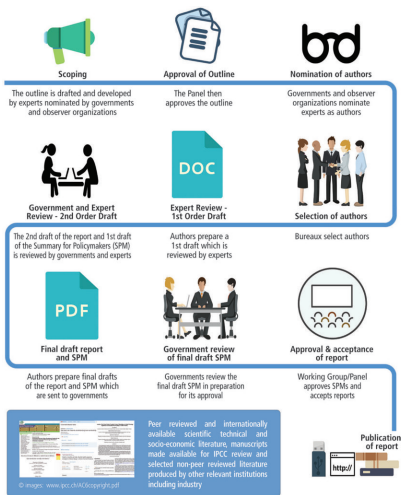
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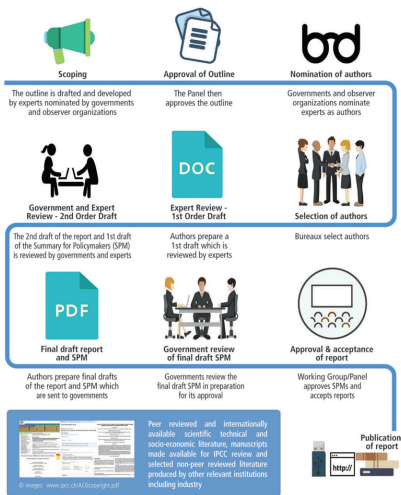
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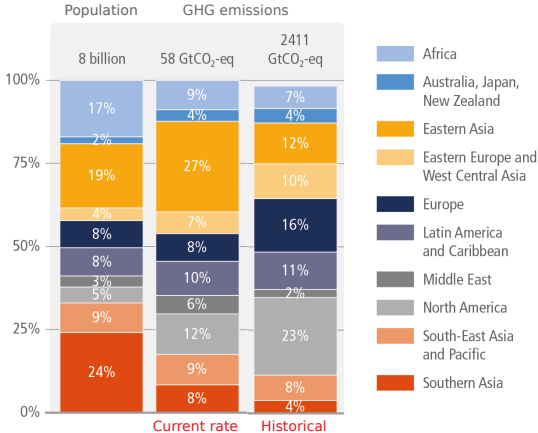
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- Often also a **Technical Summary**

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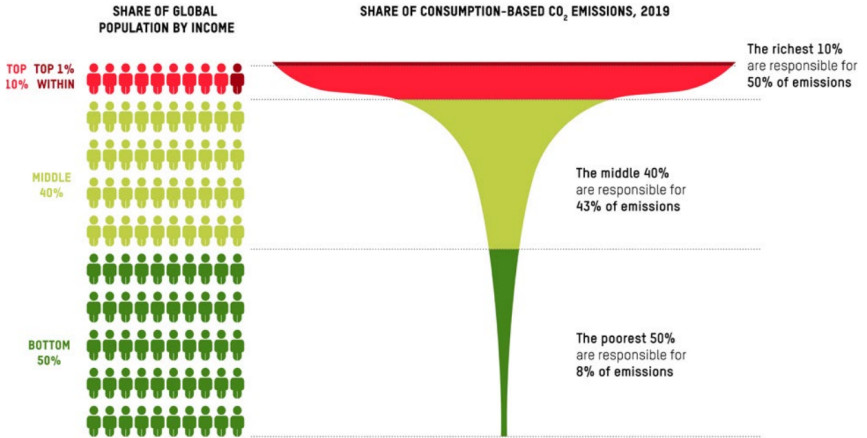
Again: not all regions are equal



[IPCC, AR6, WGII (2022)]

- No good correlation population/emissions
- Some regions emit a lot per person, some regions emit few per person
- Inequalities get worse when looking at **historical emissions** (cumulative)

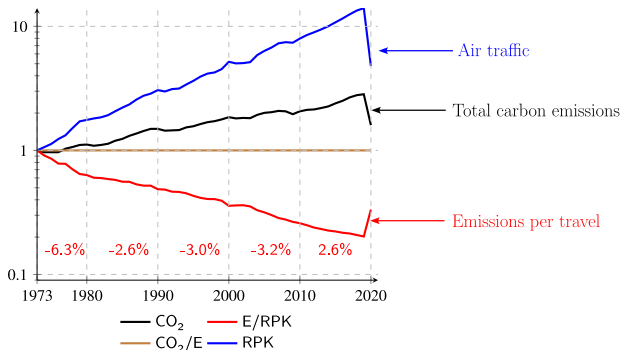
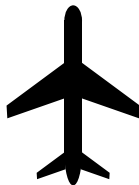
Worst when compared to income:



[Oxfam, SEI "Climate equality: a planet for the 99%." (2023)]

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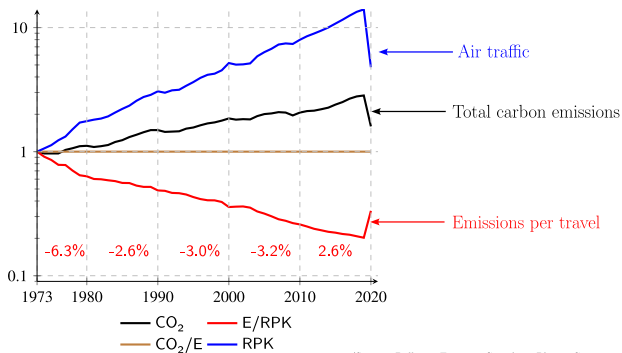
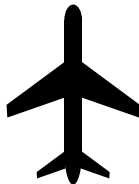
Energy efficient new technology?



(Source: Delbecq, Fontane, Gourdain, Planes, Simatos 2023)

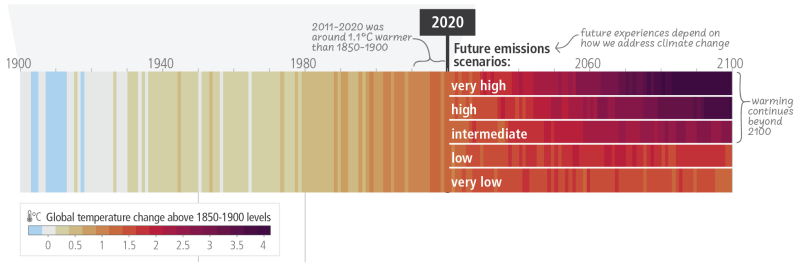
- Example of **aviation**:
 - Efficiency +3.4%/y
 - Traffic +5.6%/y
- Careful of **rebound effect** (also called Jevons paradox)

Energy efficient new technology?



(Source: Delbecq, Fontane, Gourdain, Planes, Simatos 2023)

- A more efficient tech. + more use = no energy saving
⇒ no decrease in GHG emissions or other pollutions!



[IPCC, AR6, SYR (2023)]

Take home message

- Human activity affects climate
- Consequences of climate change are uneven across the globe
- Responsibilities in climate change are uneven across the globe
- The future depends on our choices

Some references:

- Planetary boundaries and donught economy:

[Richardson et al., *Science Advances* (2023)]

[Meadows et al. “*The Limits to Growth; A Report for the Club of Rome’s Project on the Predicament of Mankind*” (1972)]

[“*Doughnut economics*” by Kate Raworth (2017)]

- IPCC reports:

[All available on <https://www.ipcc.ch>]

- Inequalities:

[Oxfam, SEI “*Climate equality: a planet for the 99%.*” (2023)]

Group work: 5 possible questions

- ① What consequences of climate change are already visible?
- ② Is an energy transition possible?
- ③ Interactions between planetary boundaries?
- ④ Is research good for the environment?
- ⑤ How can we account for inequalities?