

Climate Change and Action Workshop

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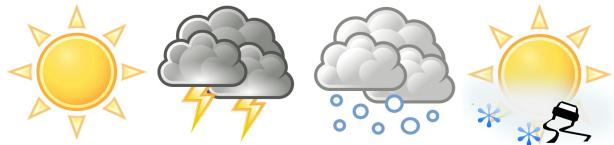


Arctic ice
on Sept. 12, 2013

The background image shows a wide expanse of clouds stretching to a distant horizon under a sky transitioning from deep blue to warm orange and yellow hues near the sun.

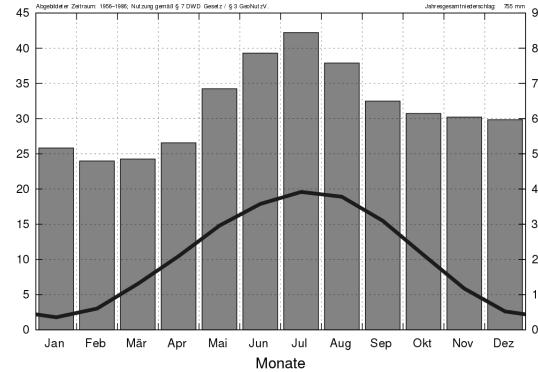
What is climate?

Weather



Current state of the atmosphere
minute-by-minute

Climate



Average weather/state of the atmosphere
in a region
over a long period of time

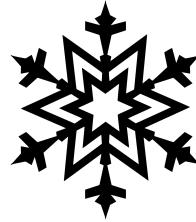
The climate system



Atmosphere



Hydrosphere



Cryosphere



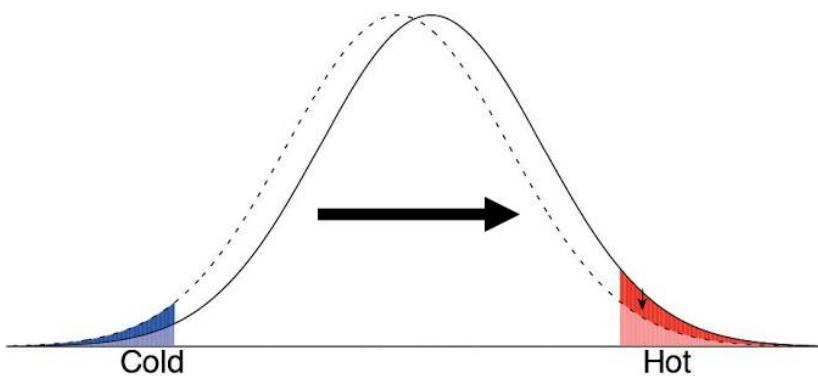
Biosphere



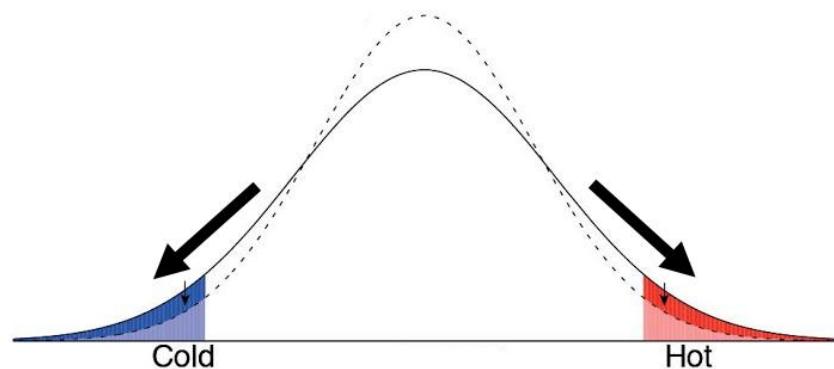
Lithosphere

Parts of the Earth affected by climate and affecting each other

What is climate change?

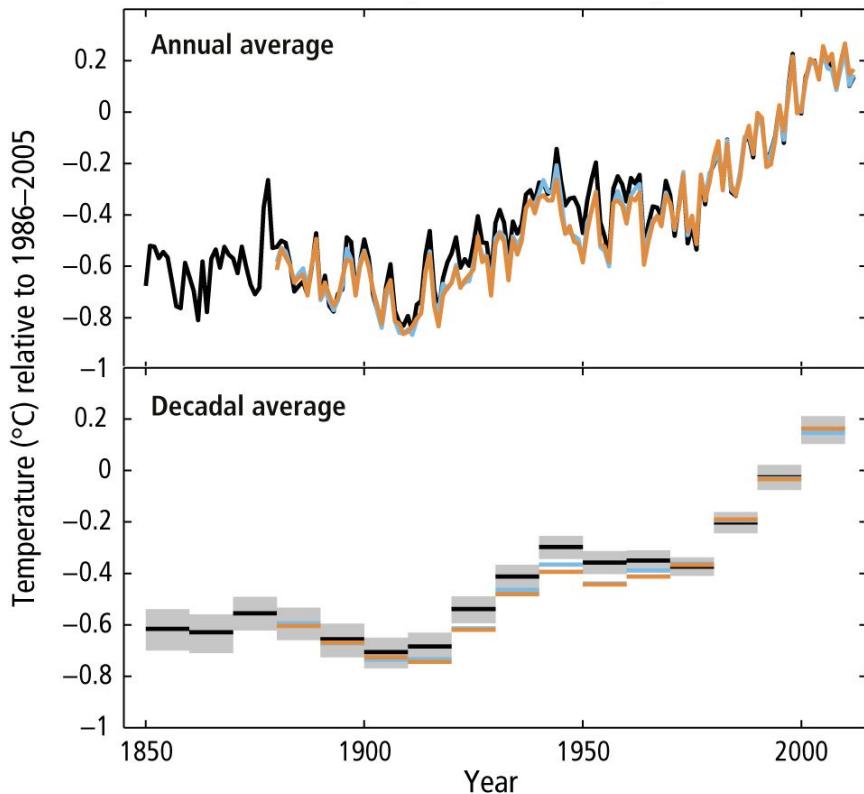


Increase in mean



Increase in variance

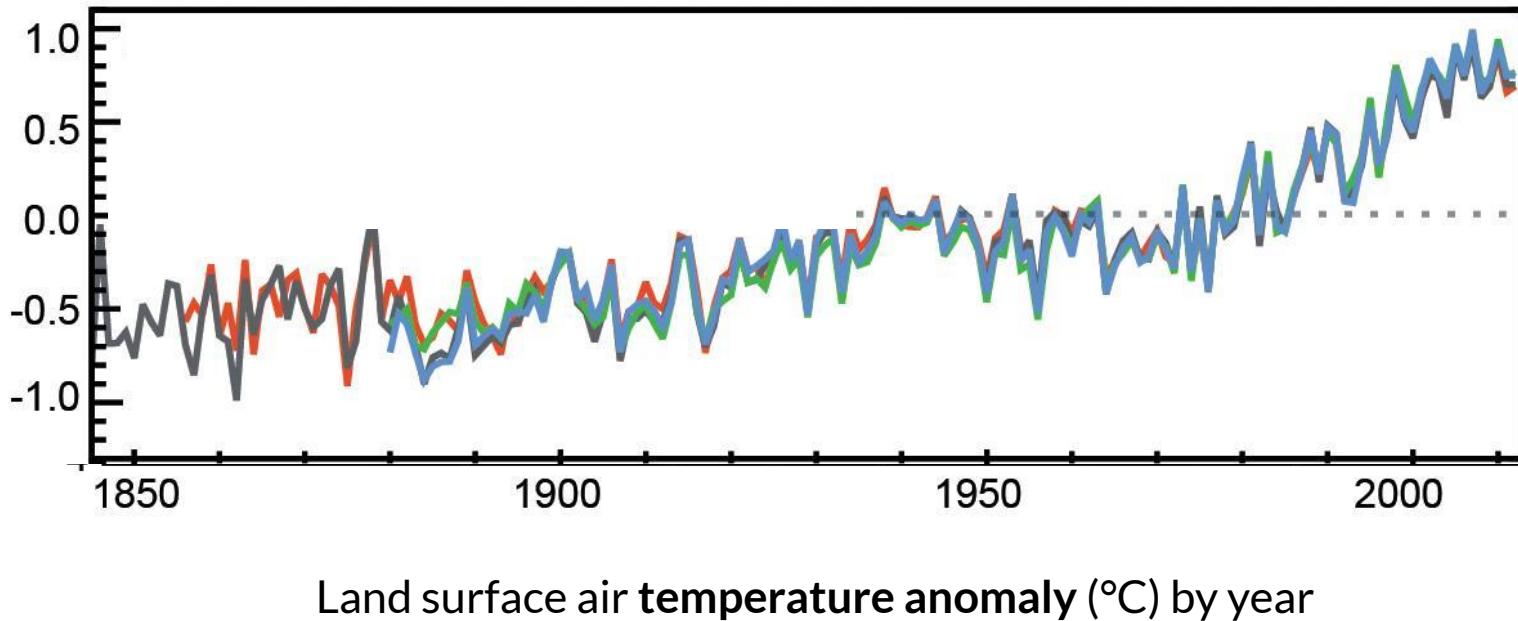
How do we observe climate change?



- **Globally averaged temperature anomaly**
combining land and ocean surface:
 - 3 independent land datasets
(5000 to 7000 stations each)
 - 2 independent interpolated
marine data sets based
on historic observations

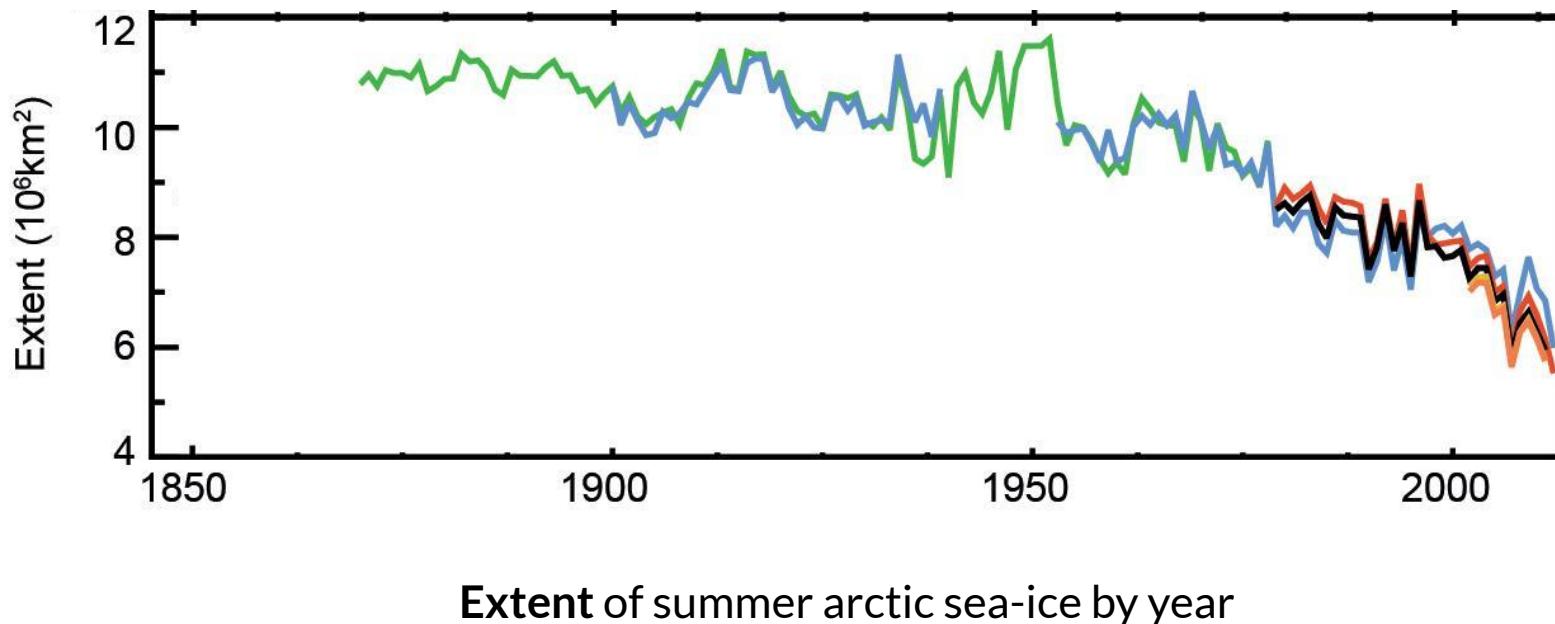
Source: IPCC WG1 2013
Morice et al. 2012
Vose et al. 2012
Hansen et al. 2010

How do we observe climate change?

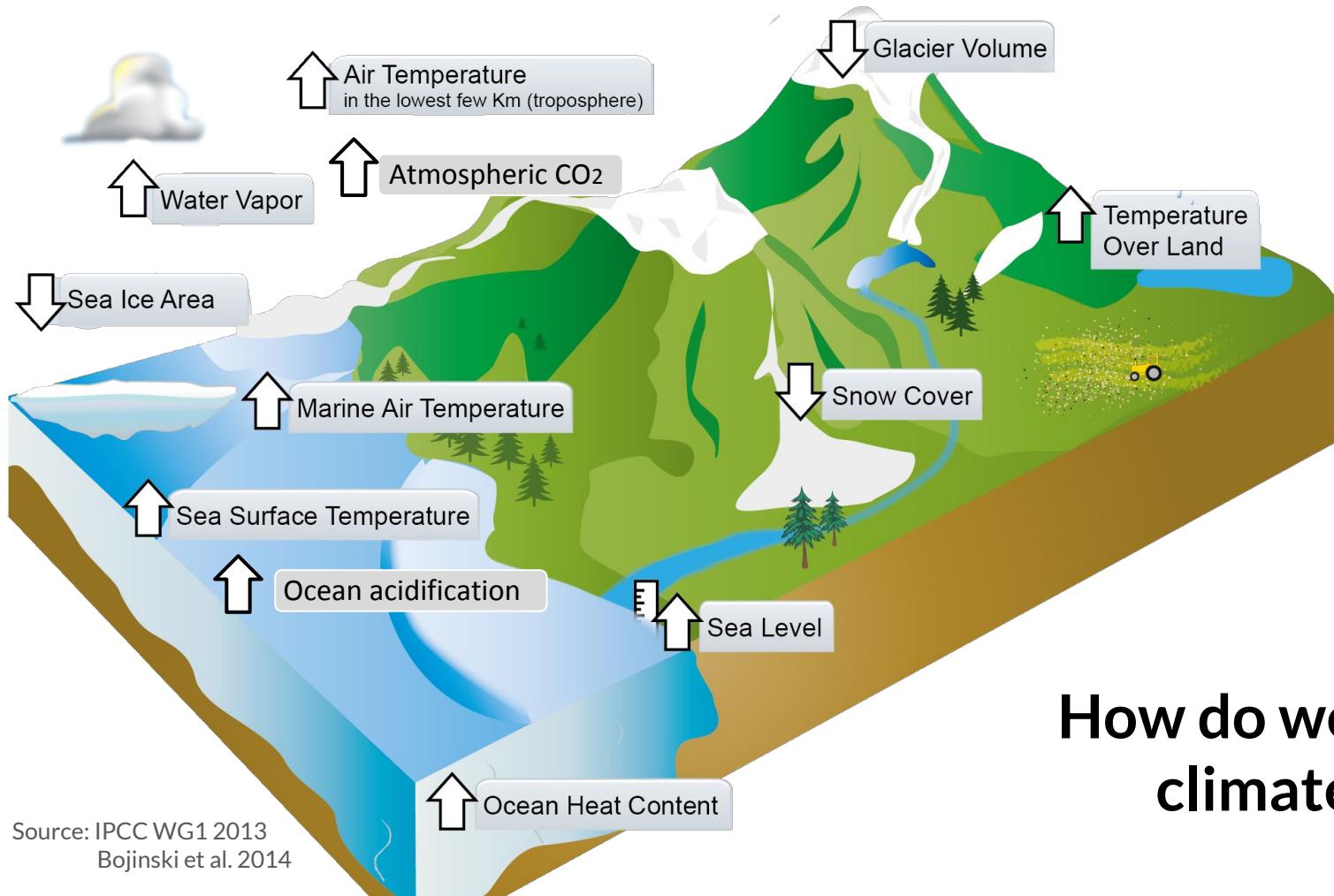


Source: IPCC WG1 2013

How do we observe climate change?

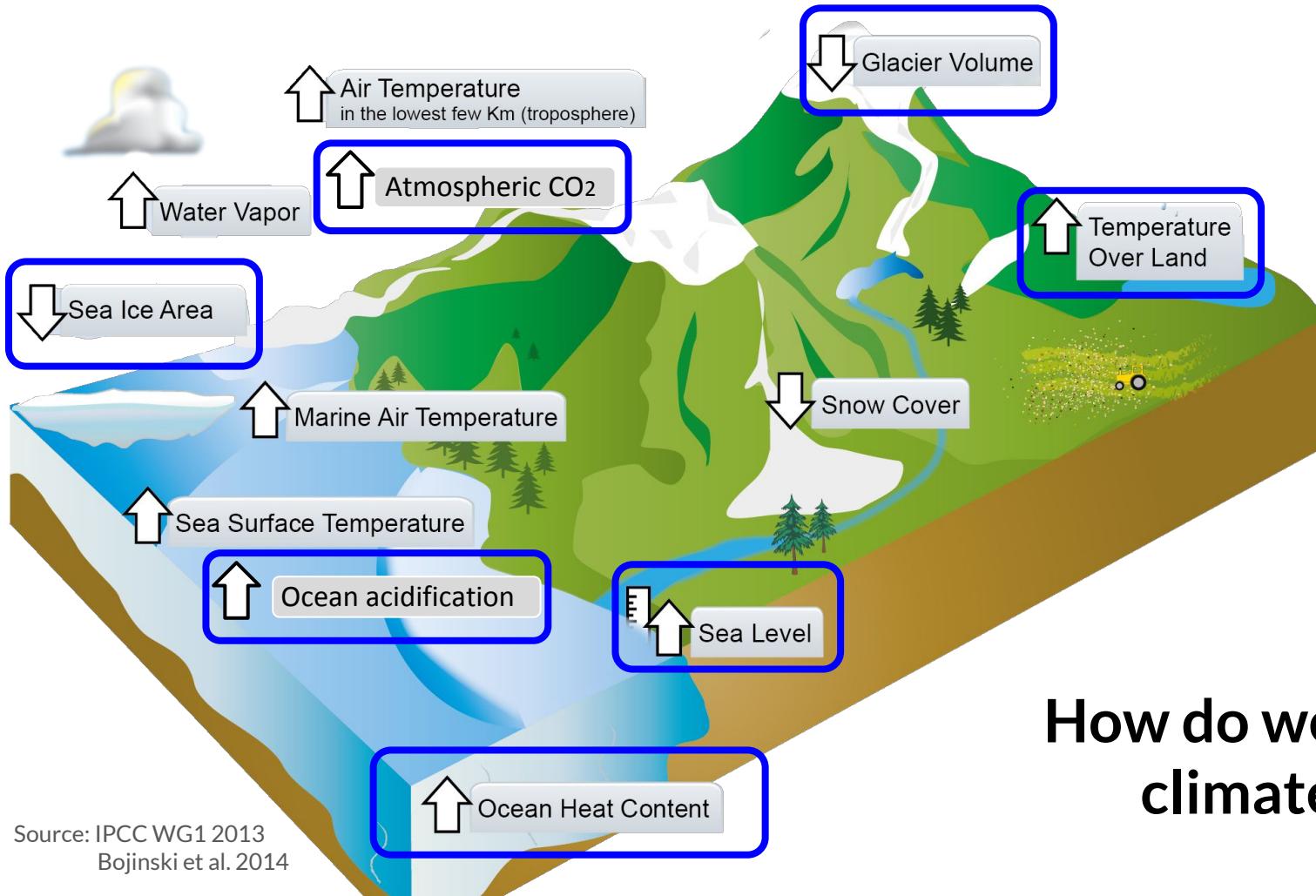


Source: IPCC WG1 2013



How do we observe climate change?

Source: IPCC WG1 2013
Bojinski et al. 2014

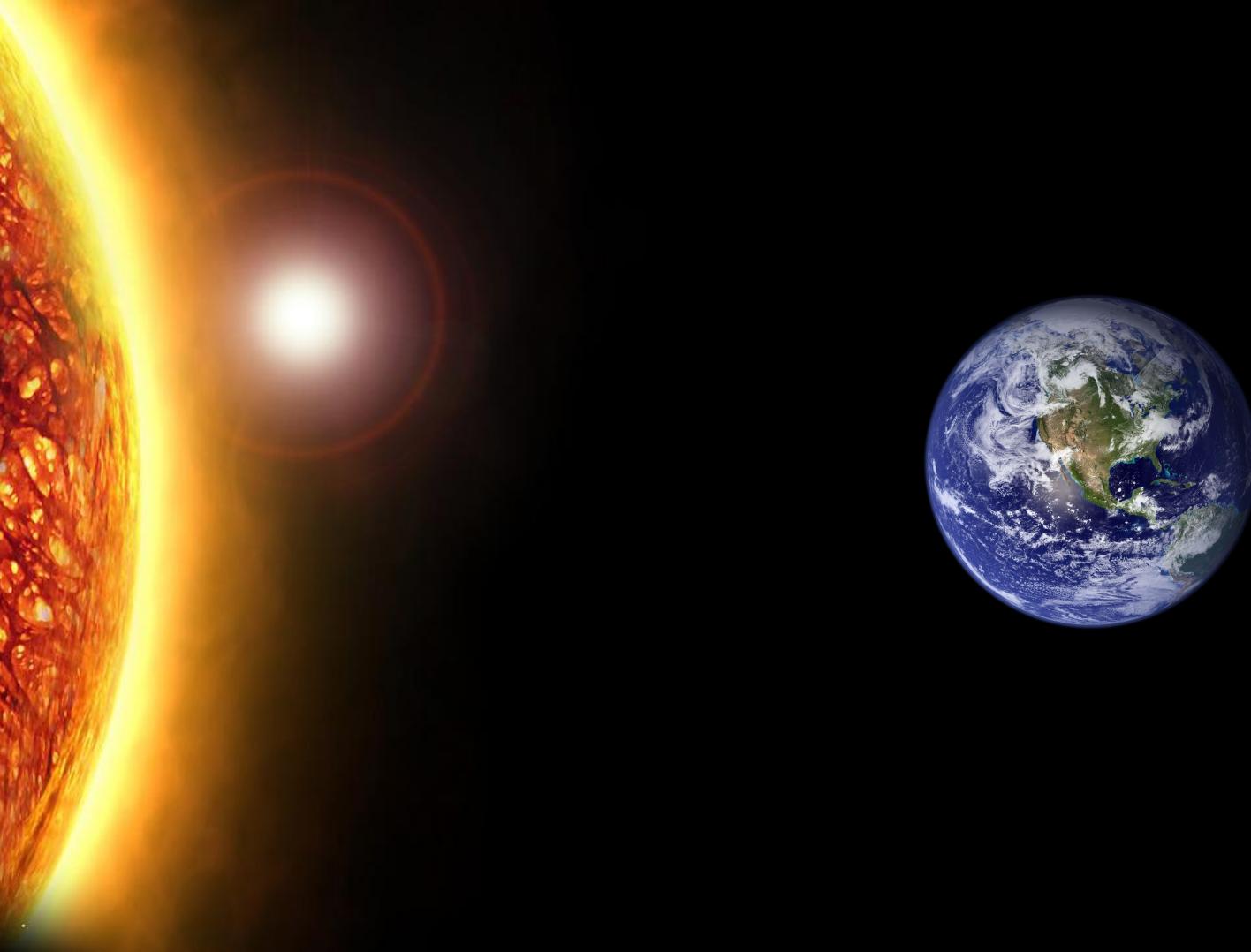


How do we observe climate change?

Earth's energy budget

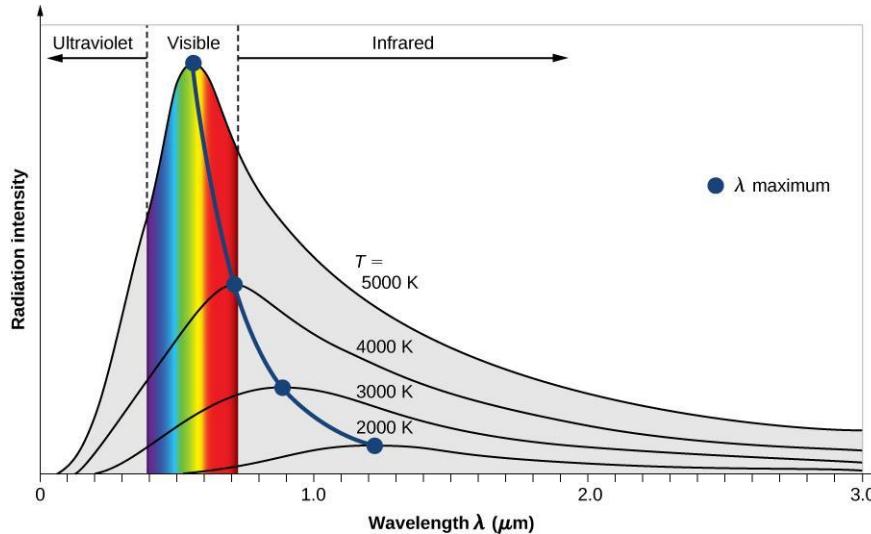


Source: NASA - https://science-edu.larc.nasa.gov/energy_budget/pdf/EEB_StoryBoard_0616.pdf



Source: NASA

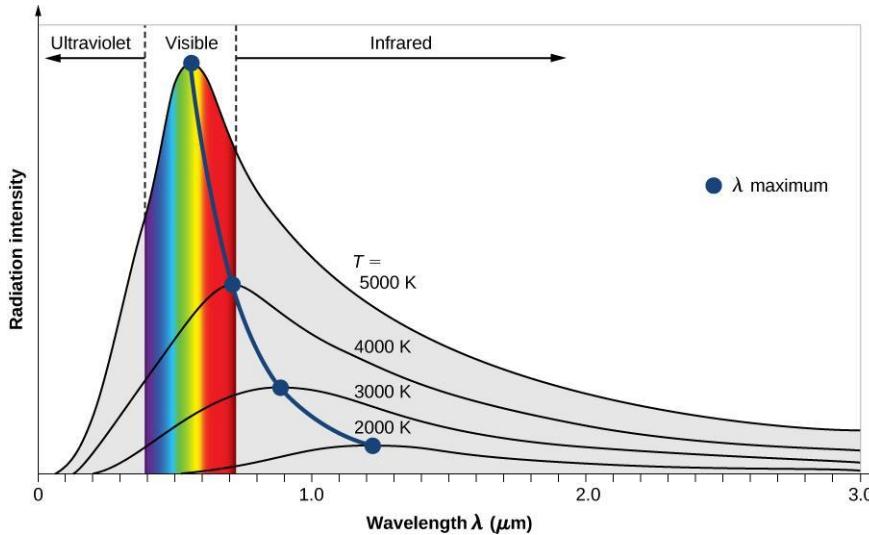
Matter emits energy as electromagnetic radiation



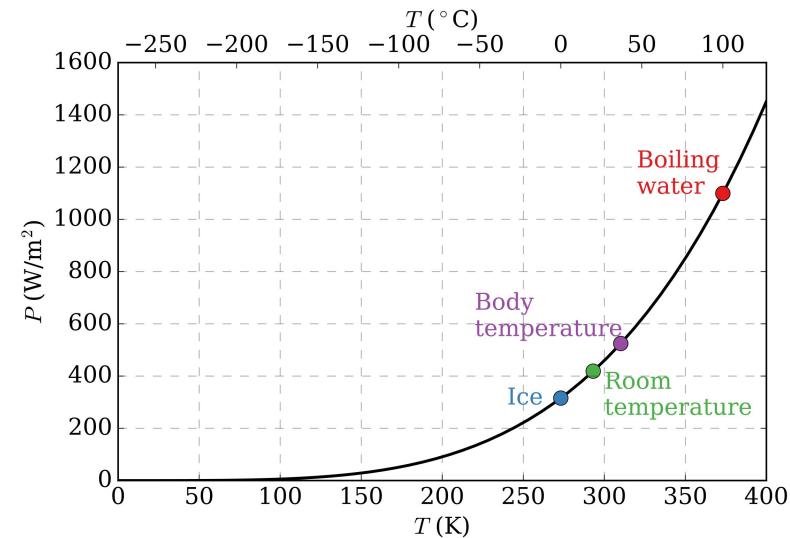
Source: Wikipedia

Temperature determines
wavelength (colour)

Matter emits energy as electromagnetic radiation

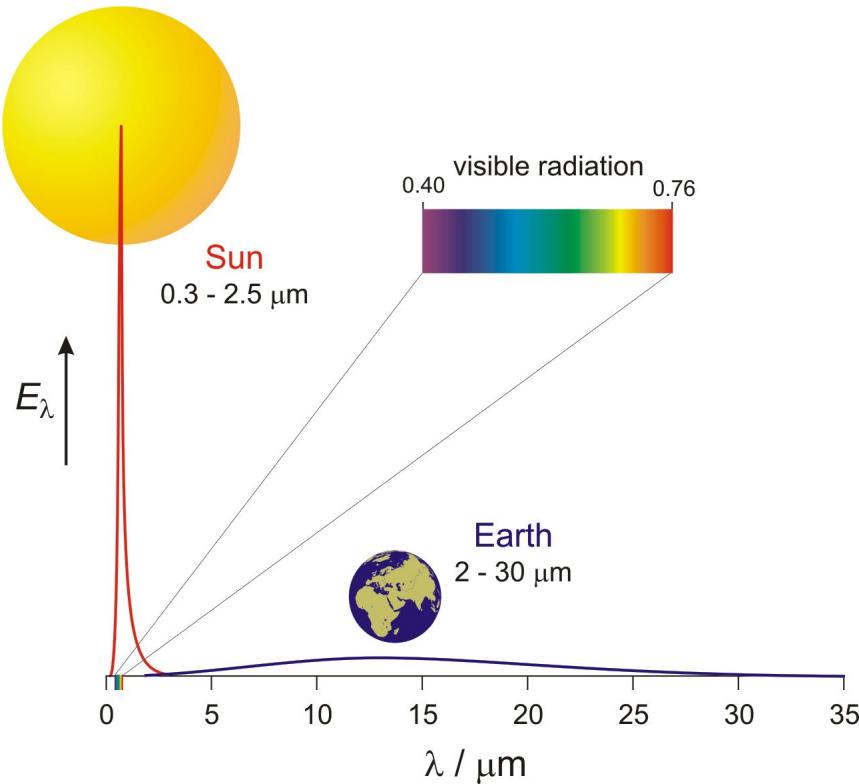


Temperature determines wavelength (colour)

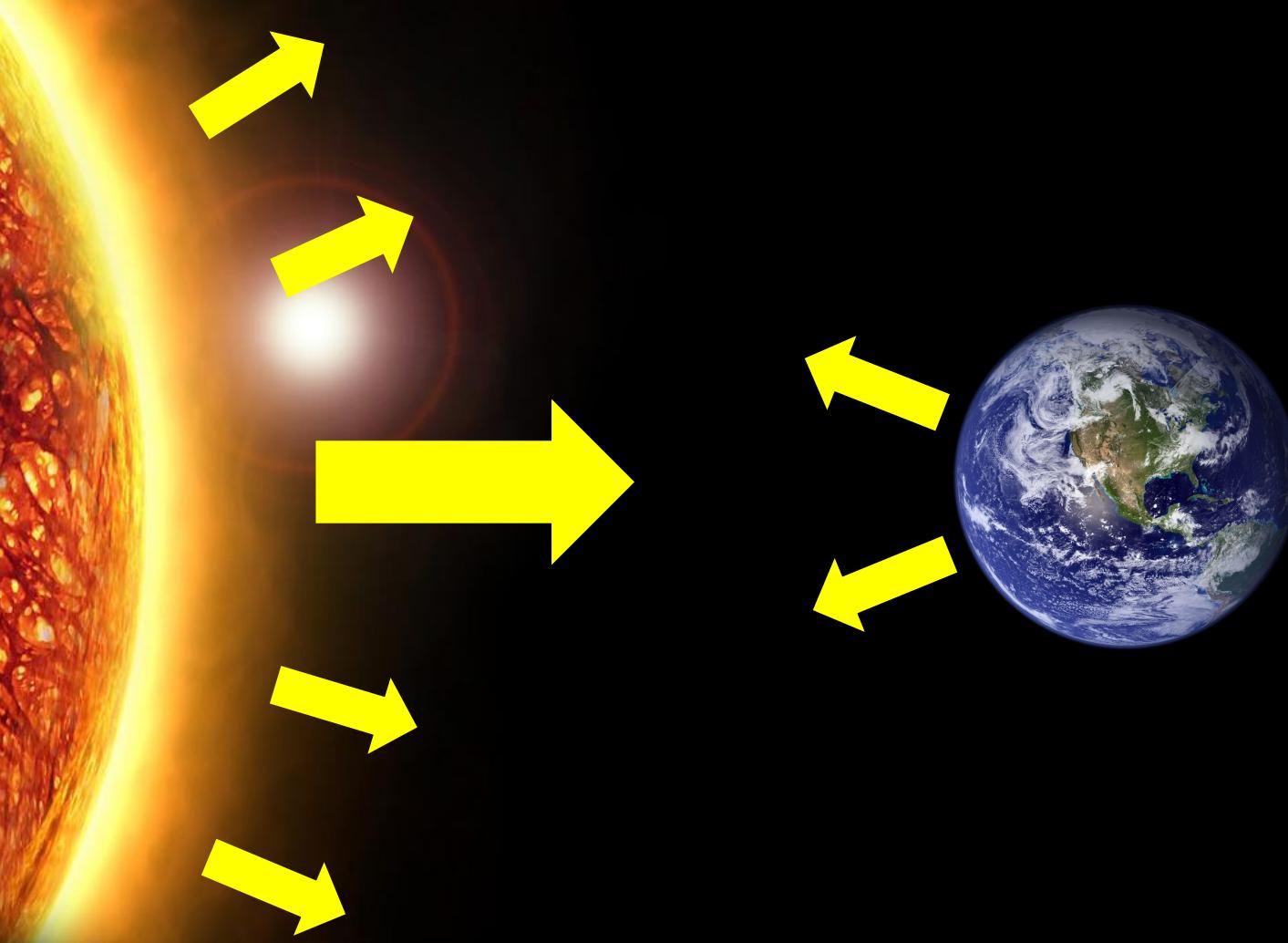


Temperature determines emitted power $P \propto T^4$

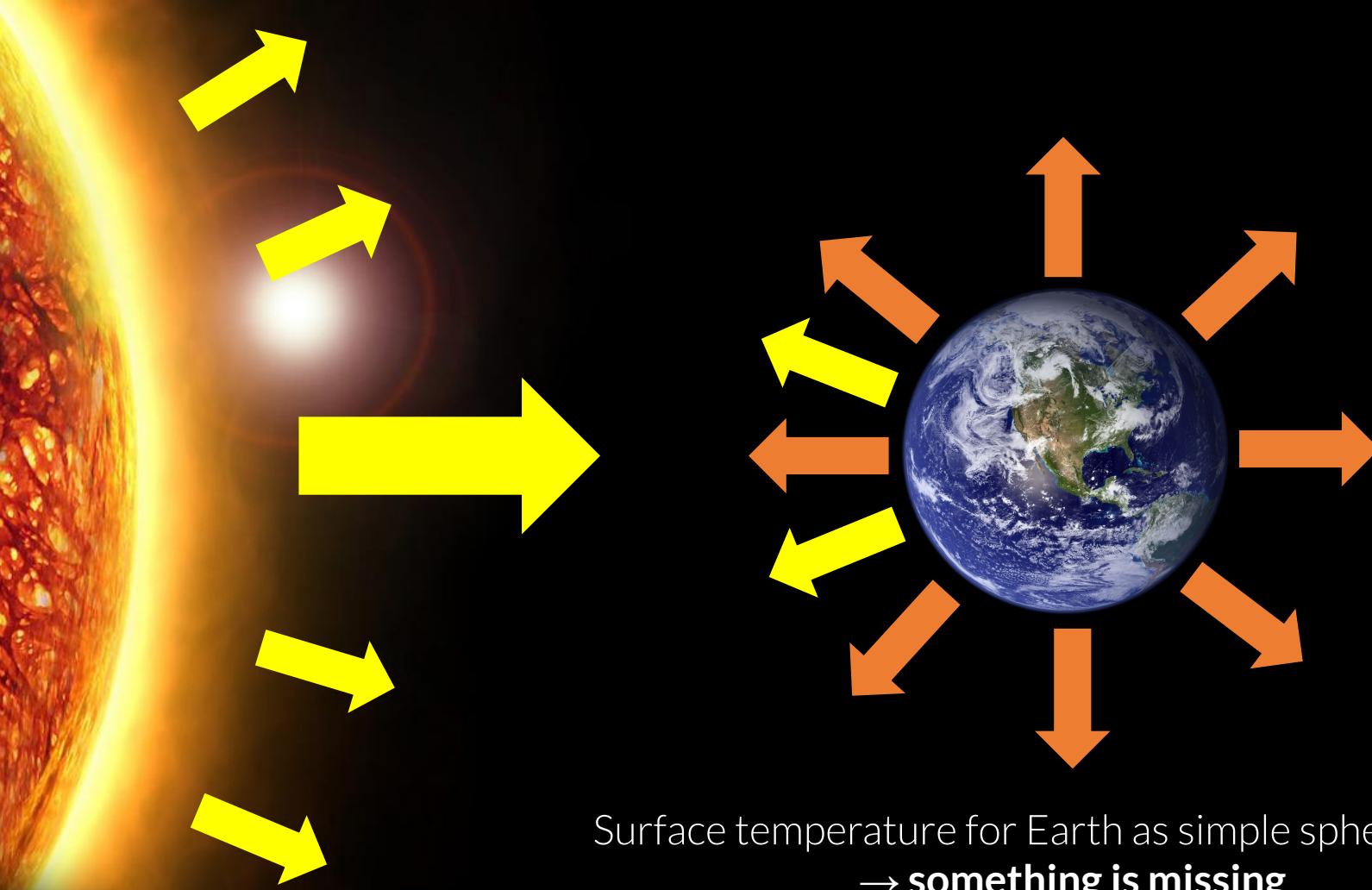
Energy emissions of Sun and Earth



Like every piece of matter, the Sun and the Earth emit an **electromagnetic spectrum** depending on their respective temperatures



Source: NASA



Surface temperature for Earth as simple sphere: **-18 °C**
→ **something is missing**



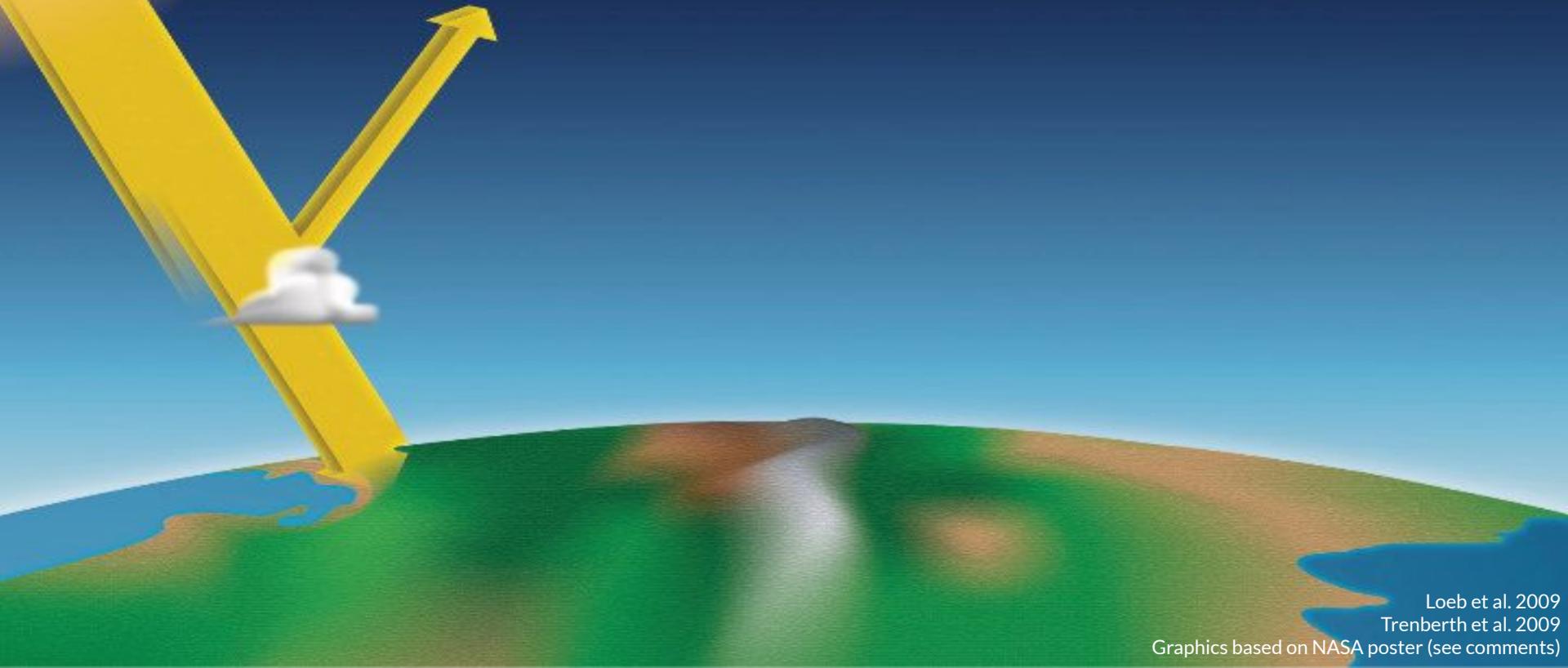
Sunlight comes into the atmosphere

Loeb et al. 2009

Trenberth et al. 2009

Graphics based on NASA poster (see comments)

A small part of the radiation is absorbed, small part is reflected by the clouds, most of it goes through the atmosphere

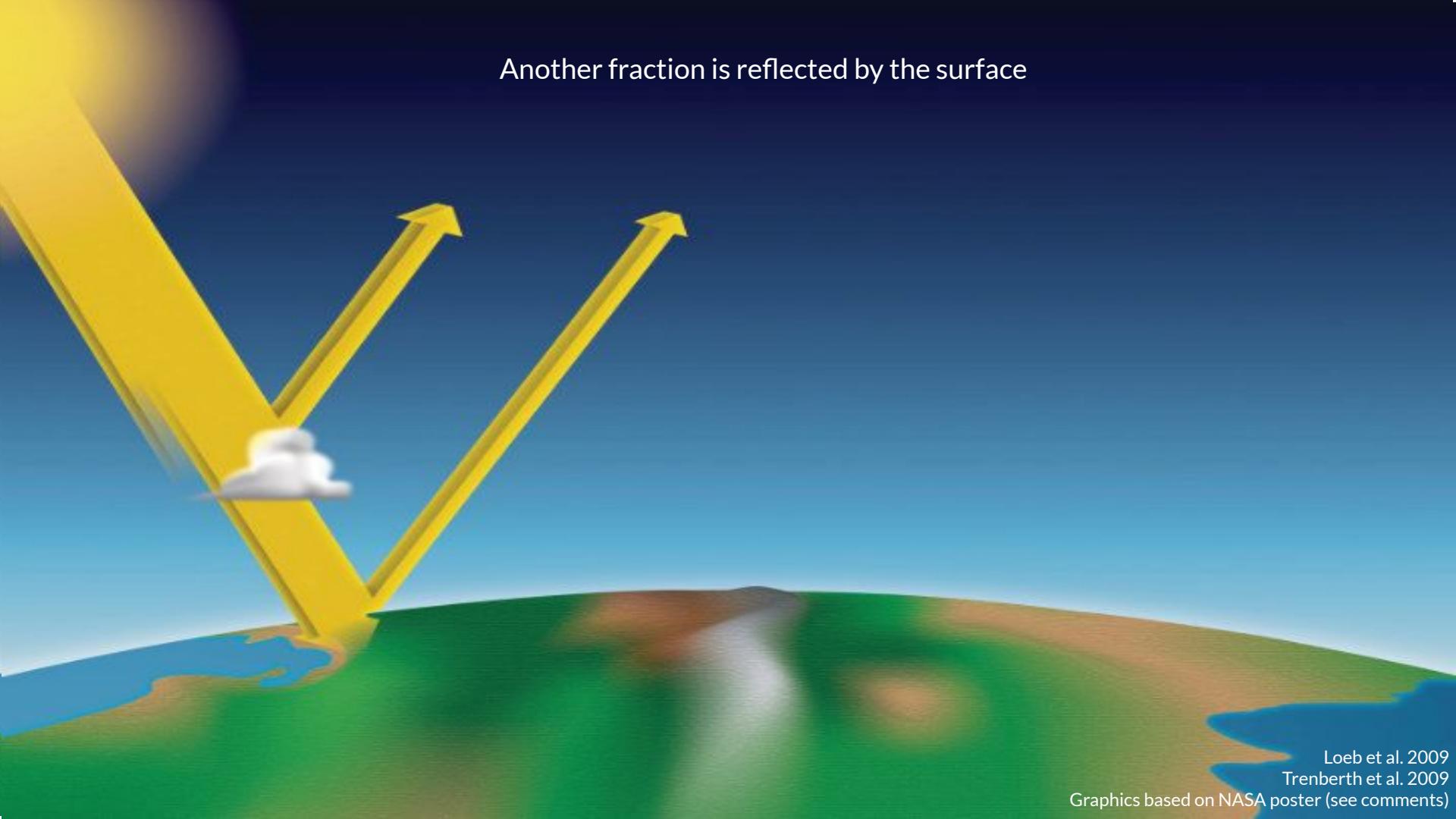


Loeb et al. 2009

Trenberth et al. 2009

Graphics based on NASA poster (see comments)

Another fraction is reflected by the surface



Loeb et al. 2009

Trenberth et al. 2009

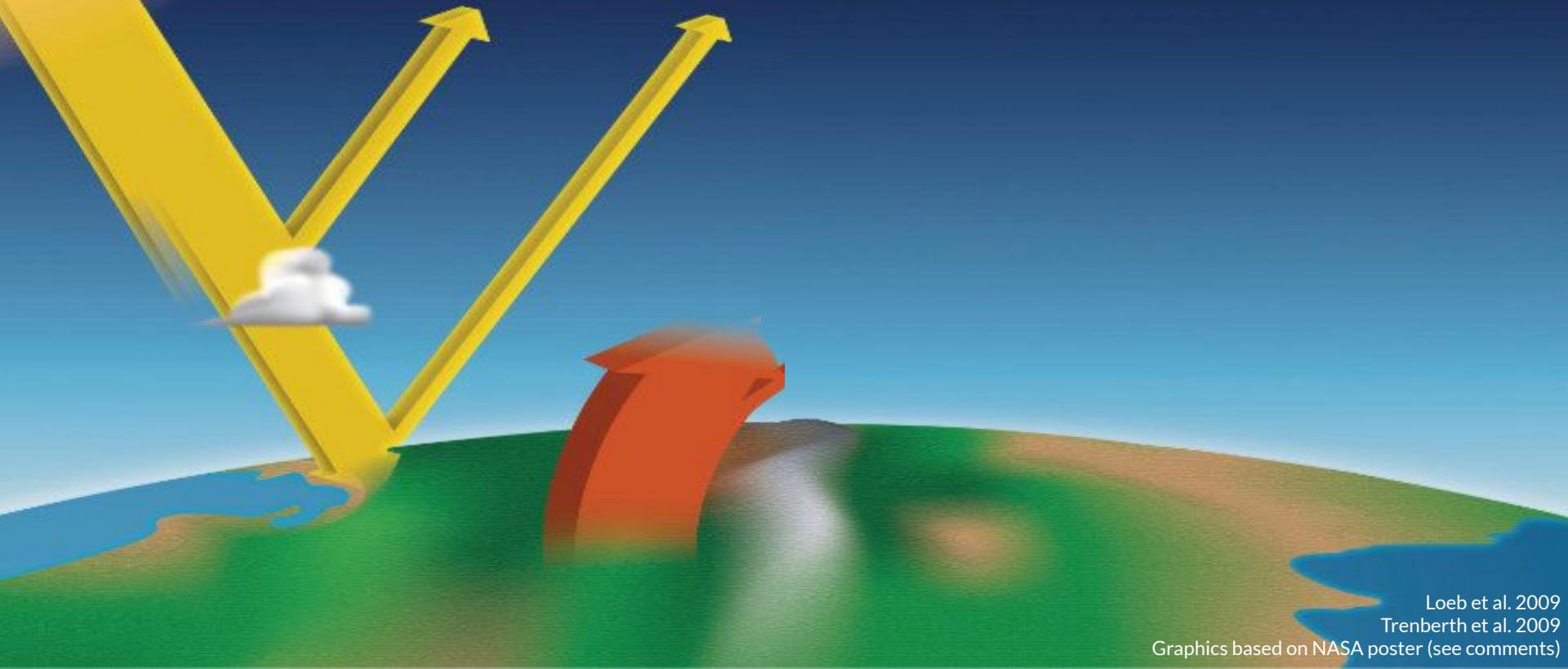
Graphics based on NASA poster (see comments)

Visible spectral range



Source: see comment

Energy is radiated towards space

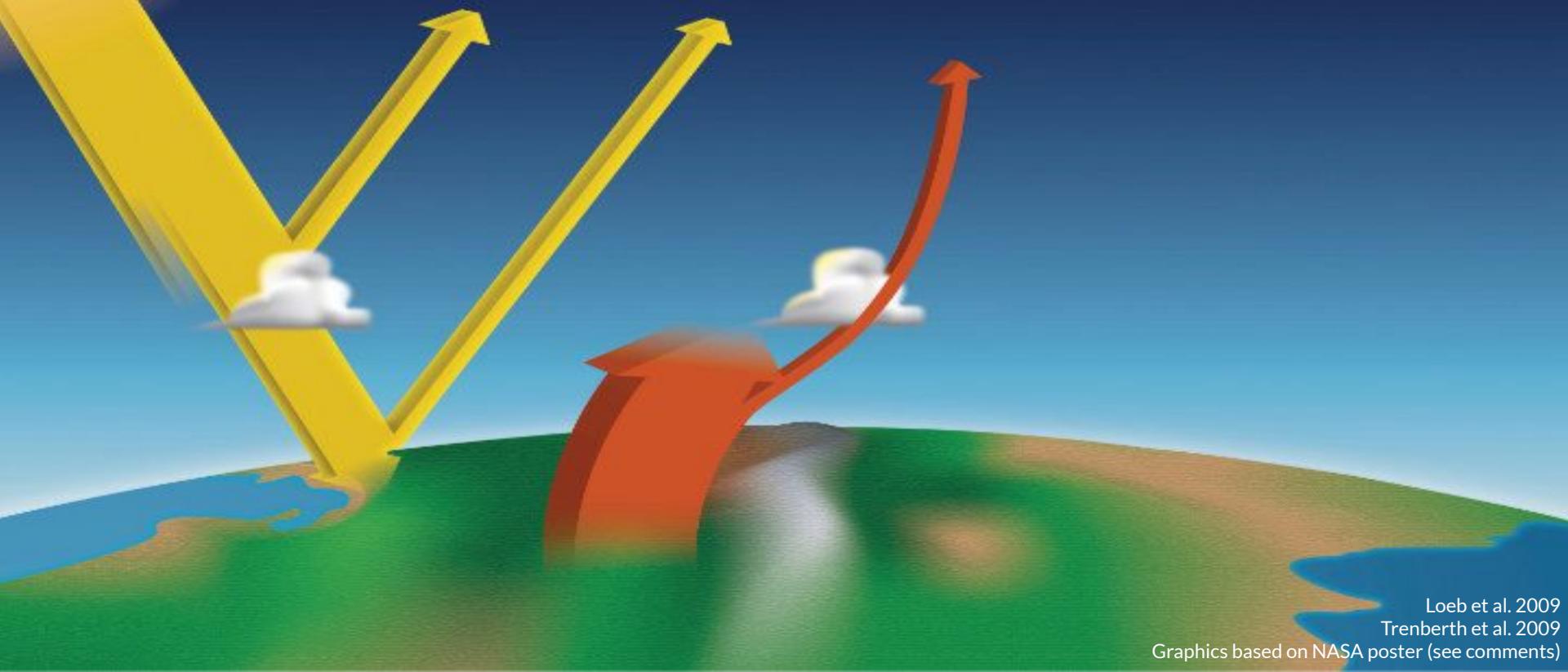


Loeb et al. 2009

Trenberth et al. 2009

Graphics based on NASA poster (see comments)

Most of the energy emitted by the surface absorbed by clouds and gases in the atmosphere

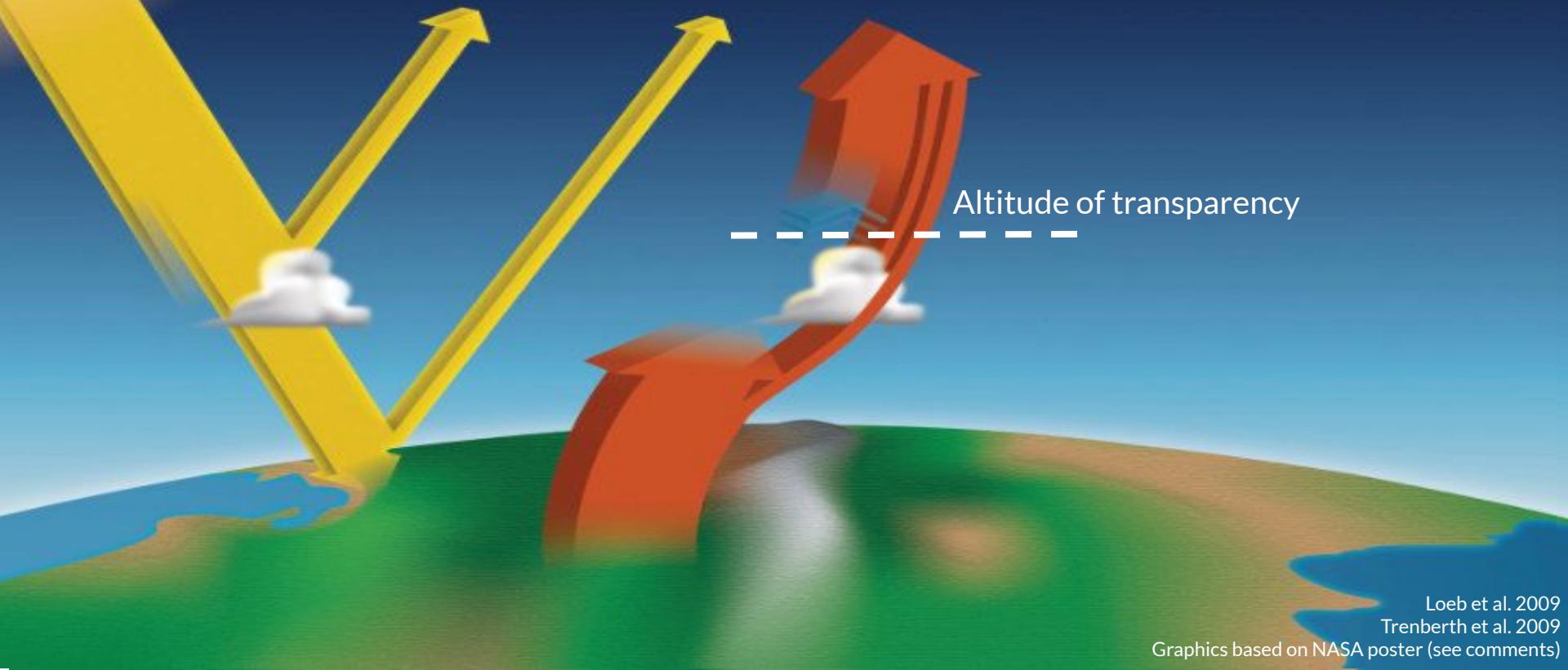


Loeb et al. 2009

Trenberth et al. 2009

Graphics based on NASA poster (see comments)

Clouds and the atmosphere emit radiation in all directions.
At a certain altitude the atmosphere becomes transparent
(again)



Loeb et al. 2009

Trenberth et al. 2009

Graphics based on NASA poster (see comments)

Visible spectral range

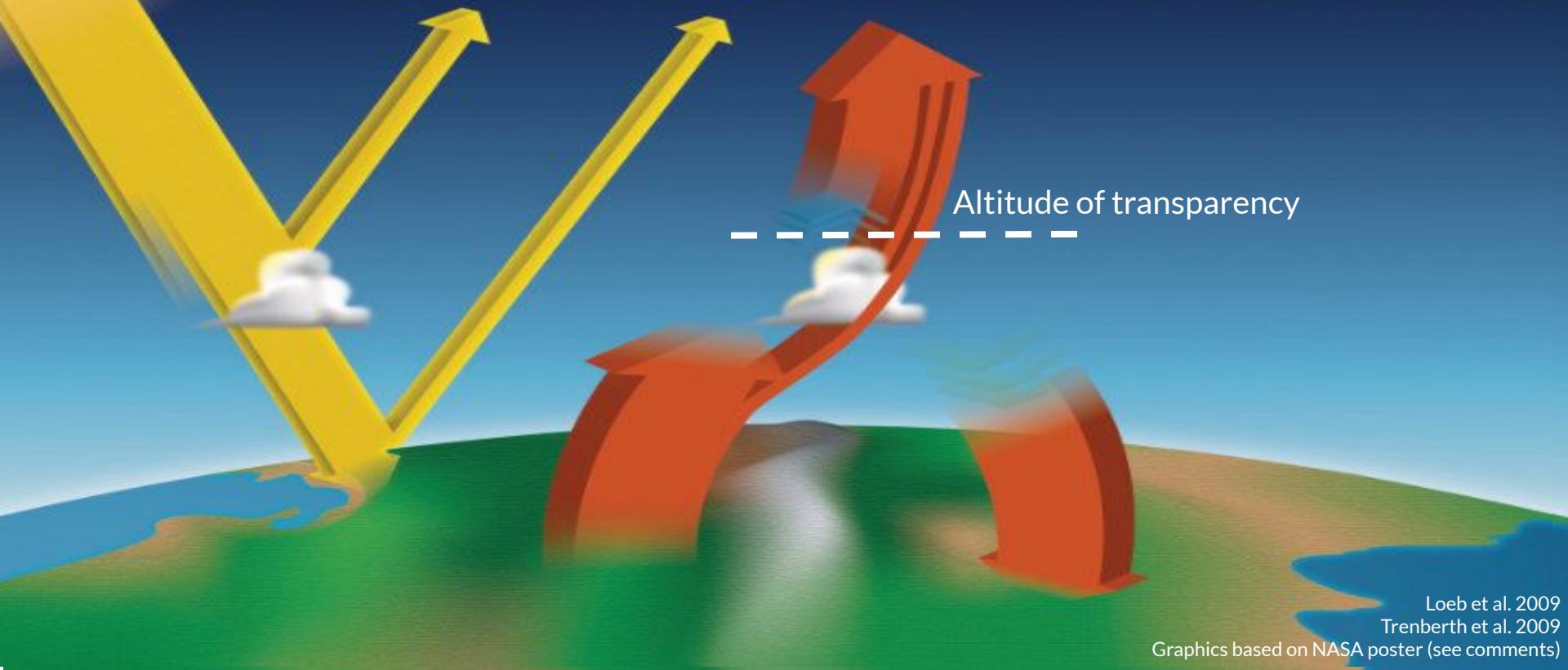


Infrared spectral range



Source: see comment

Trapped energy emitted from clouds and gases goes in all directions. Some comes back to further warm the surface.
This is the greenhouse effect.



Loeb et al. 2009

Trenberth et al. 2009

Graphics based on NASA poster (see comments)

Energy from the surface is also emitted as warm air and condensing water vapor.



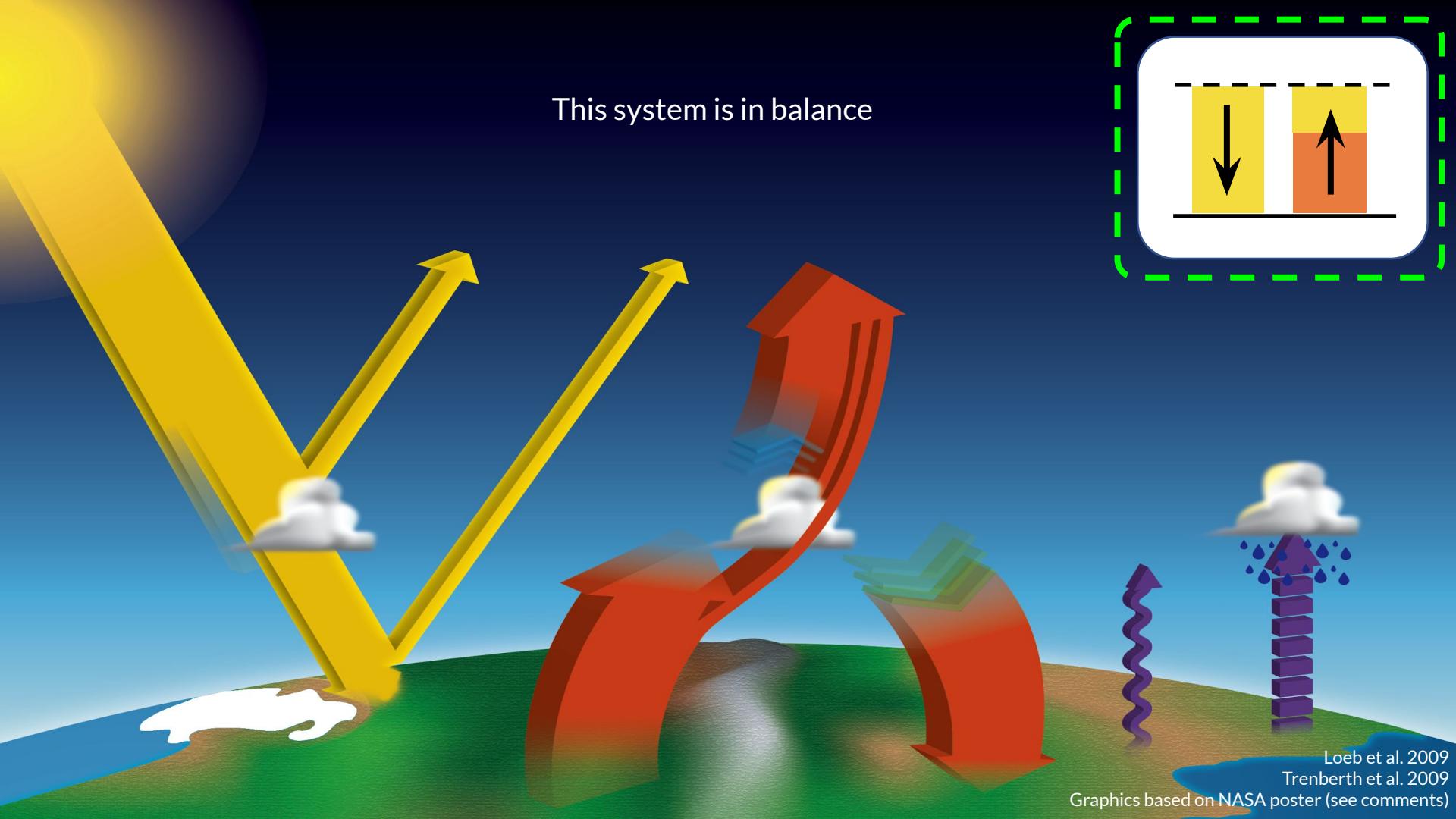
Loeb et al. 2009

Trenberth et al. 2009

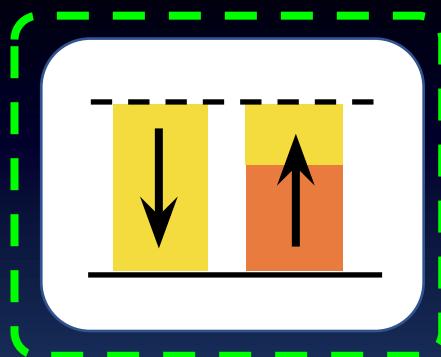
Graphics based on NASA poster (see comments)

How can climate be influenced?

A photograph of an industrial facility, likely a cement or coal processing plant, situated in a hilly, forested area. In the foreground, several long, blue conveyor belt structures extend across the frame, supported by metal towers. The sky is heavily filled with a thick, white plume of smoke or dust, obscuring much of the background. In the distance, a cluster of buildings is visible on a hillside. On the far left, a tall building with a blue cylindrical tank and a small antenna tower is partially visible through the haze.



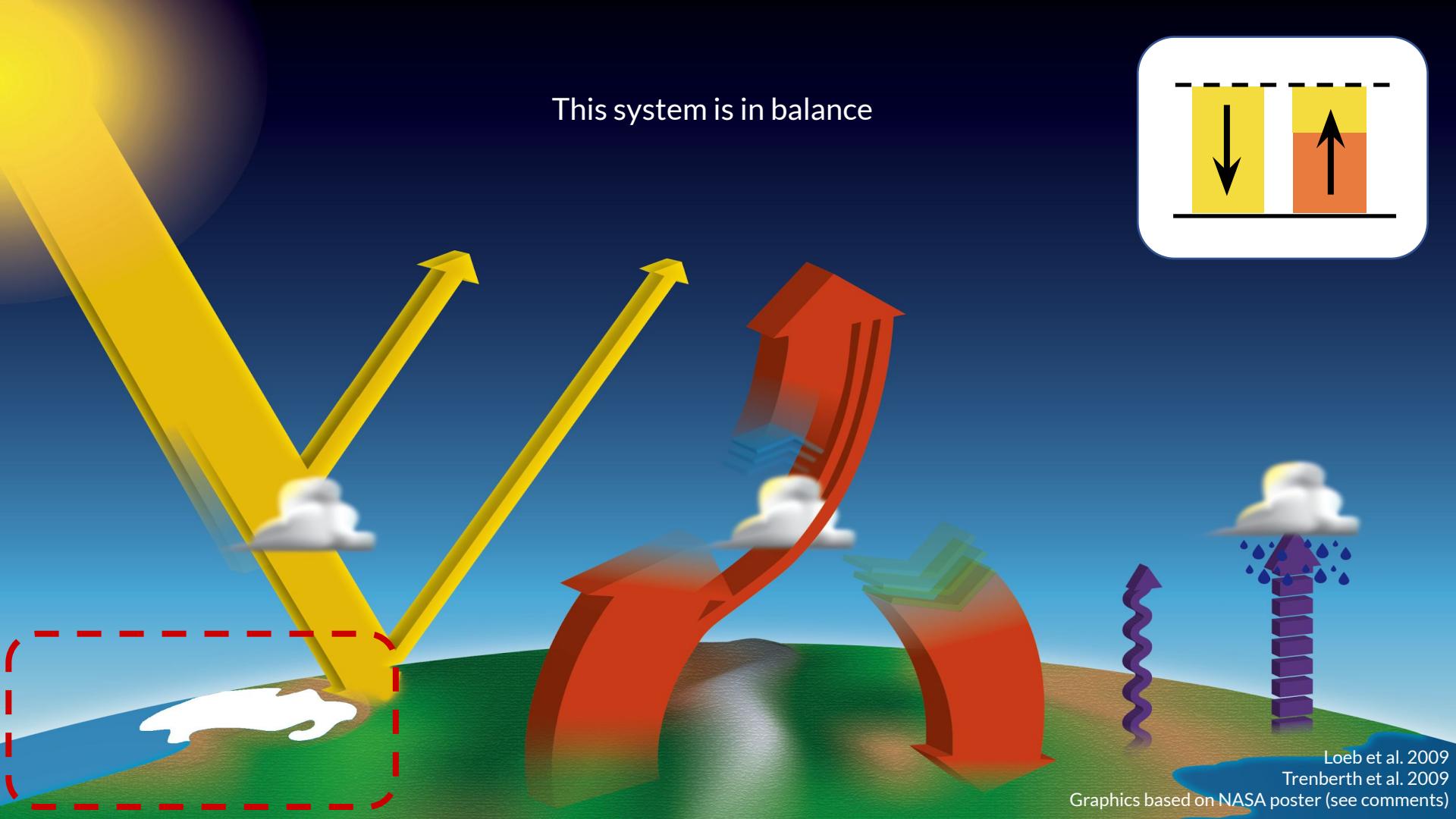
This system is in balance



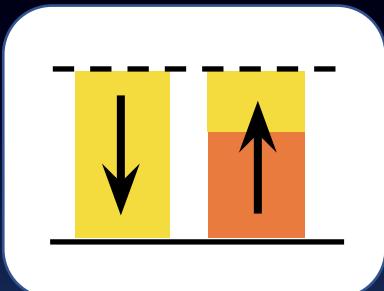
Loeb et al. 2009

Trenberth et al. 2009

Graphics based on NASA poster (see comments)

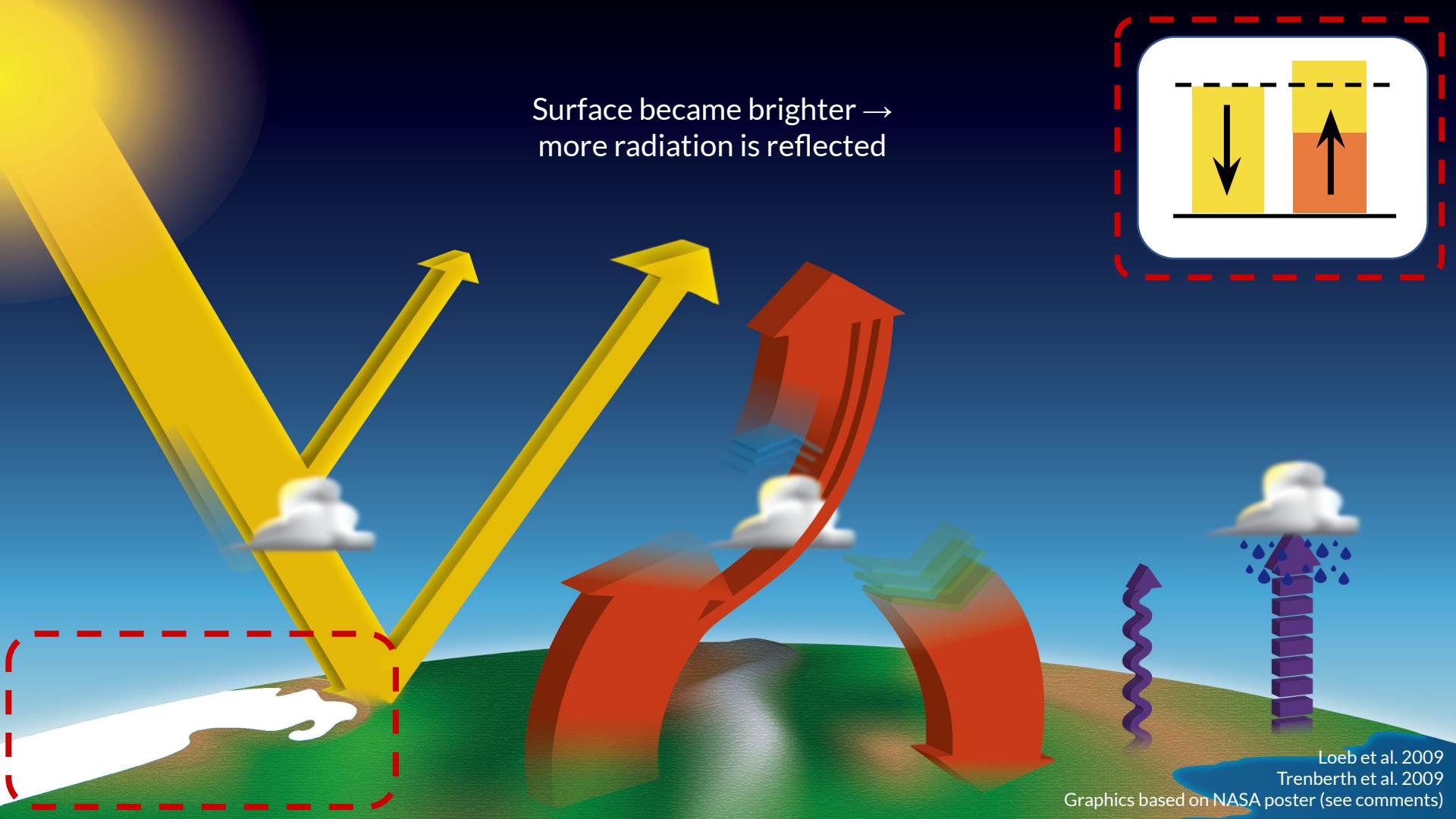


This system is in balance



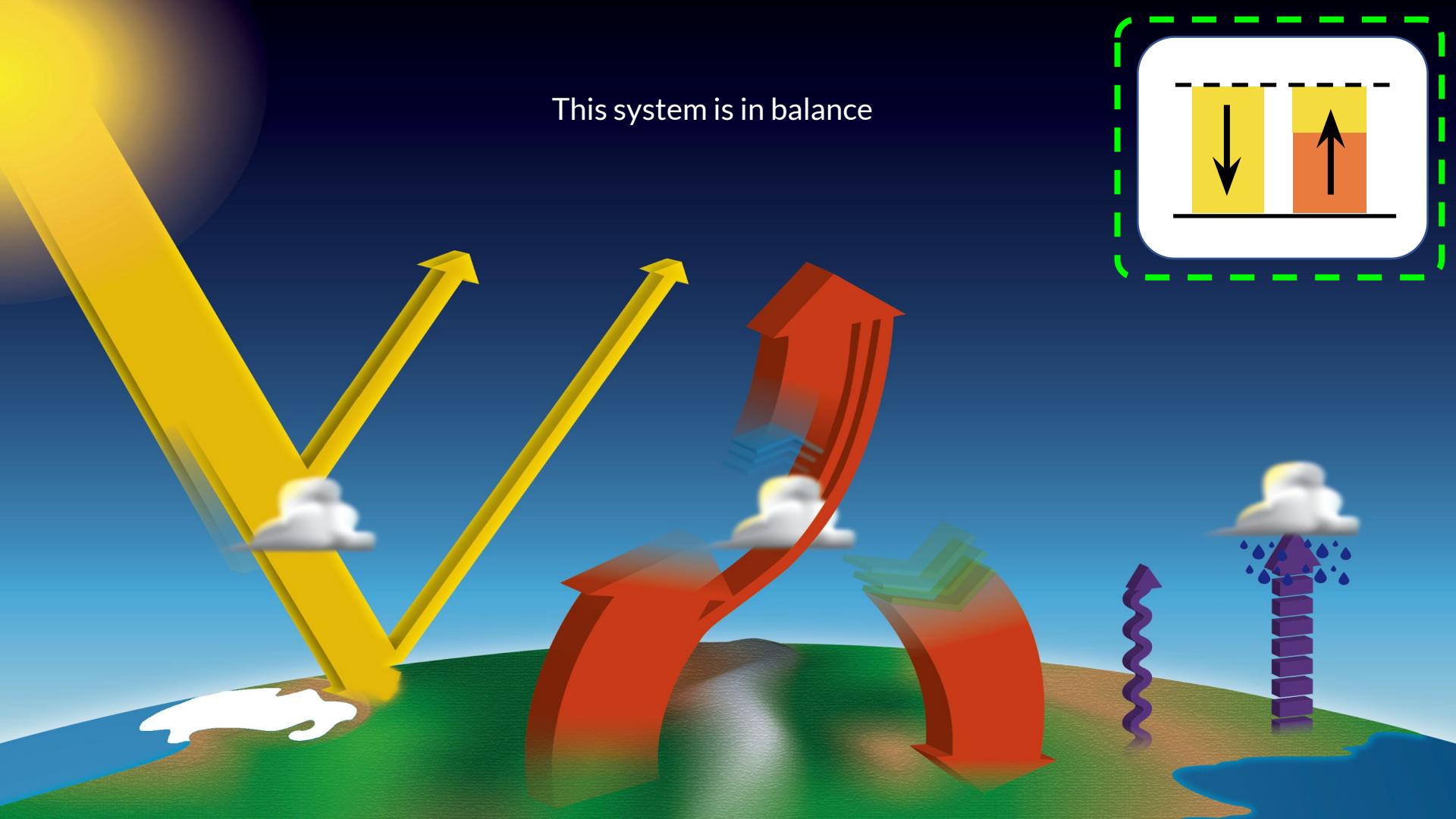
Loeb et al. 2009
Trenberth et al. 2009

Graphics based on NASA poster (see comments)

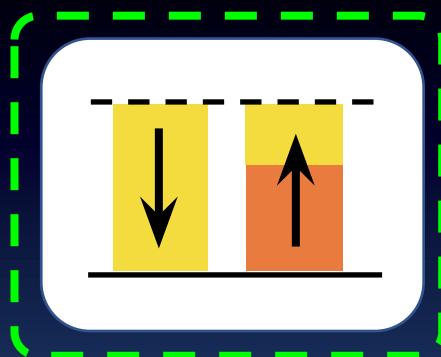


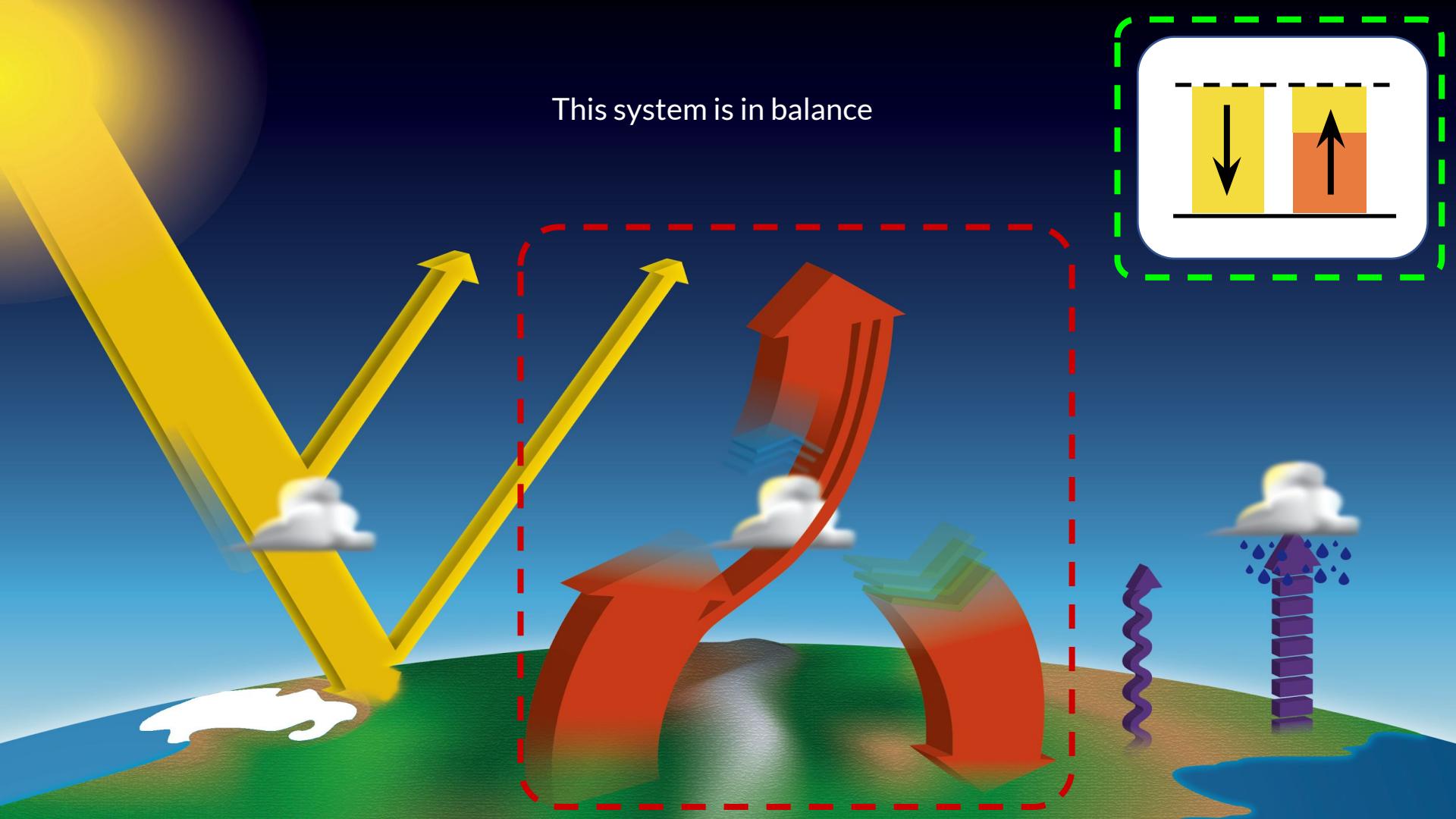
Loeb et al. 2009
Trenberth et al. 2009

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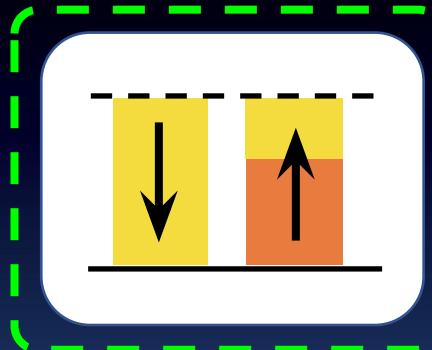


This system is in balance

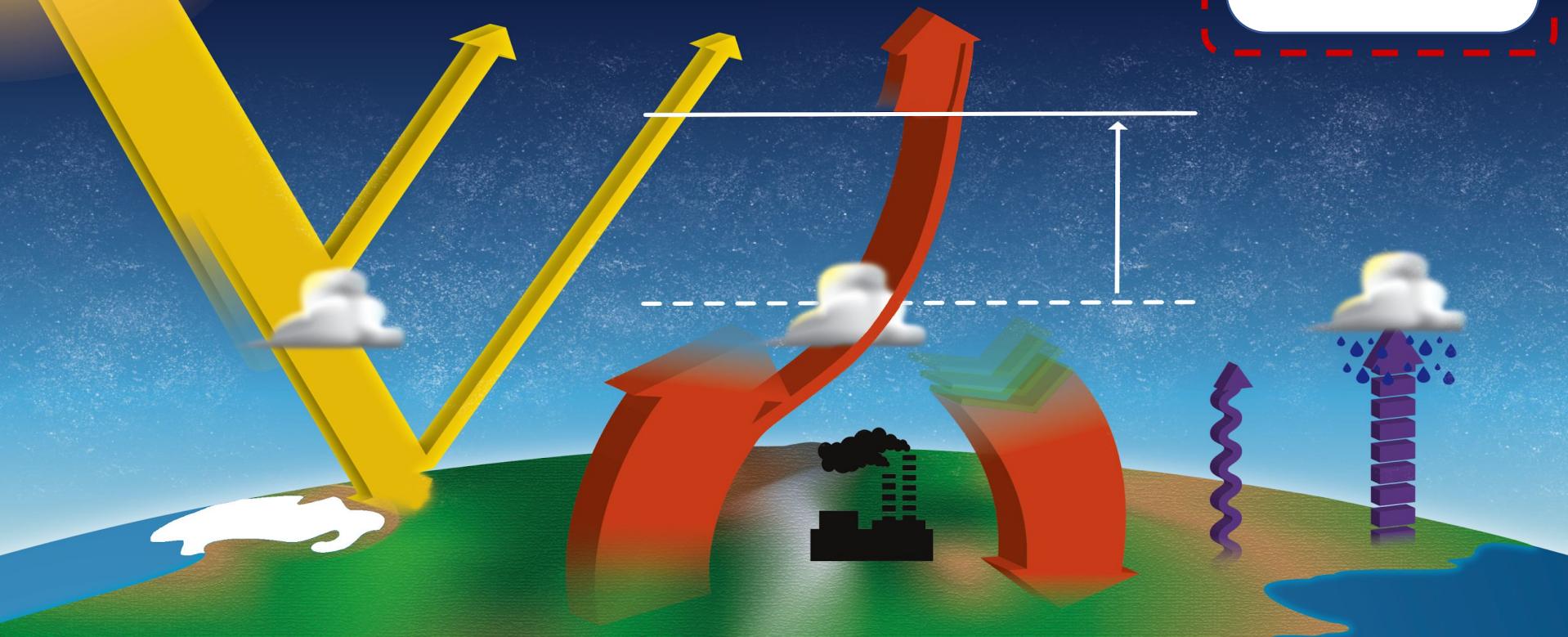
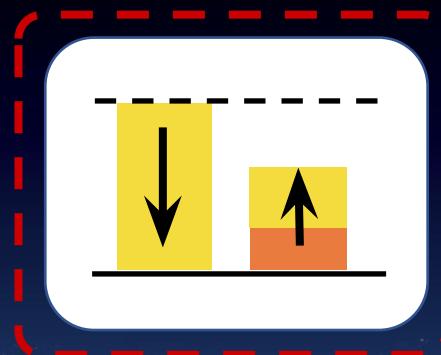




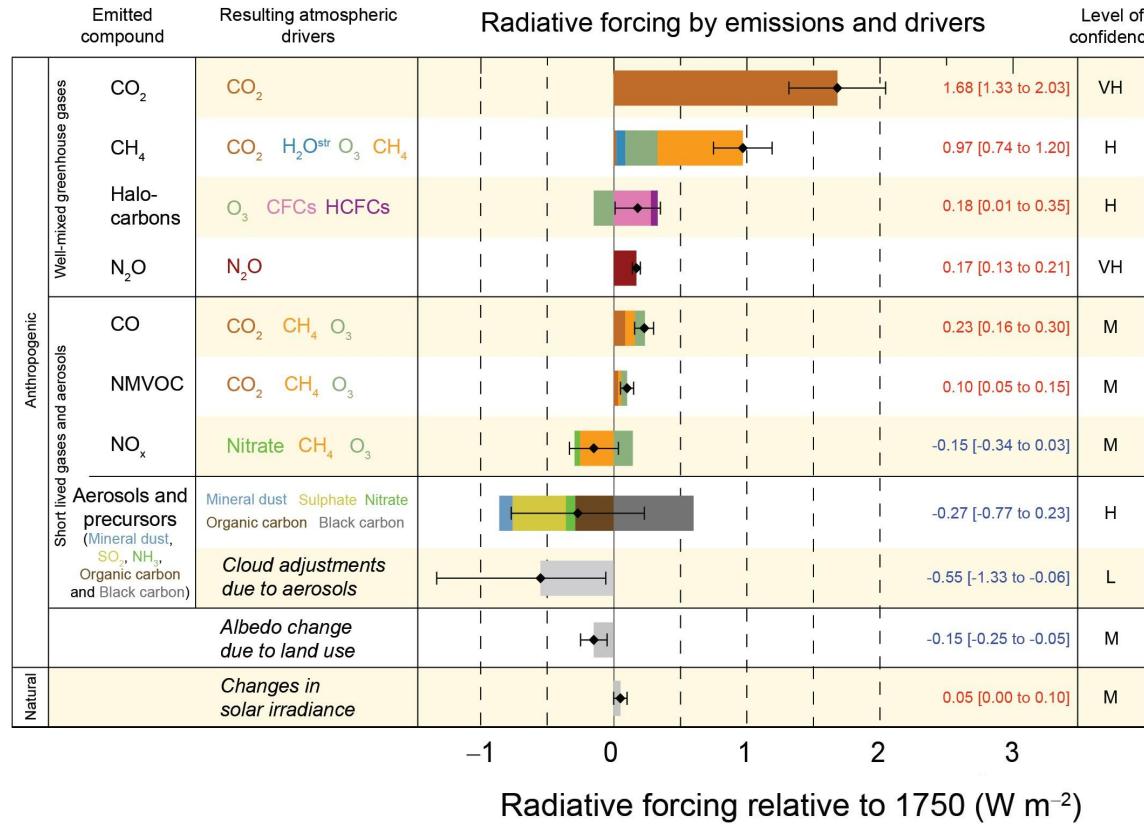
This system is in balance



Add greenhouse gases
to the atmosphere → atmosphere only becomes
transparent higher up where it is colder → less energy
emission

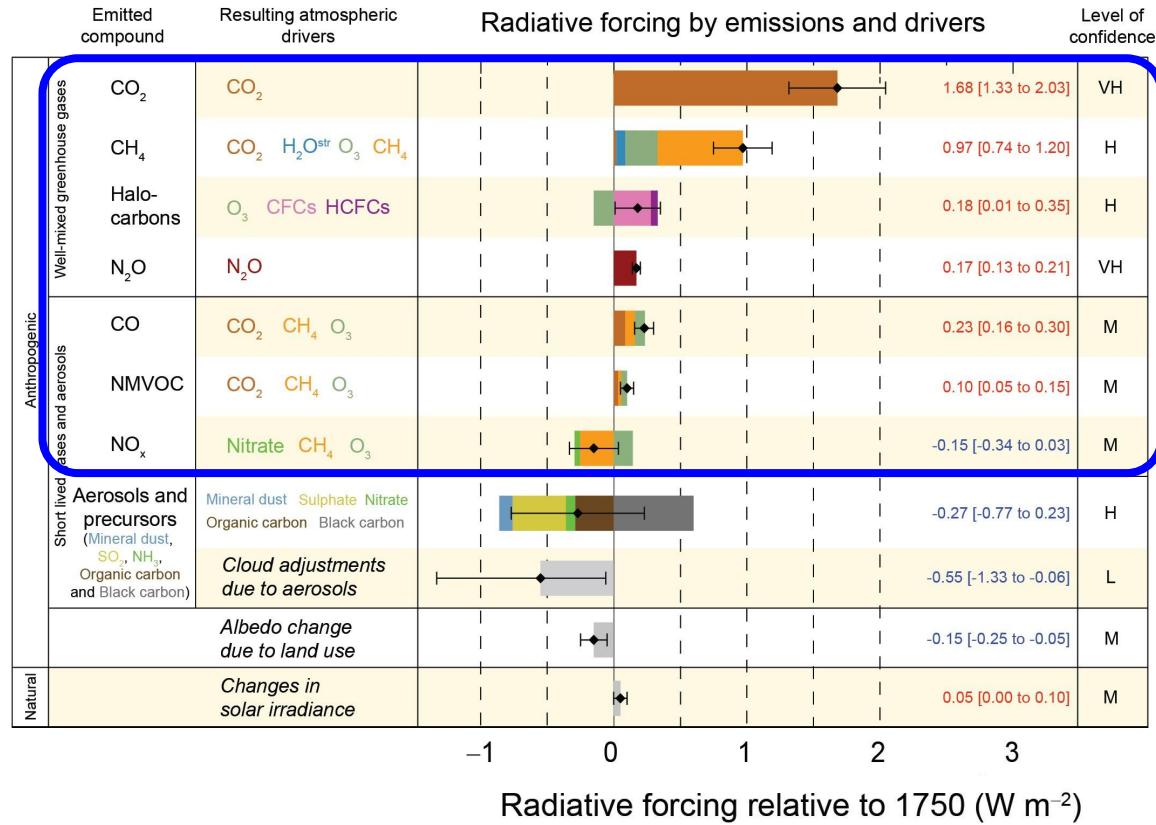


How big is the anthropogenic influence?



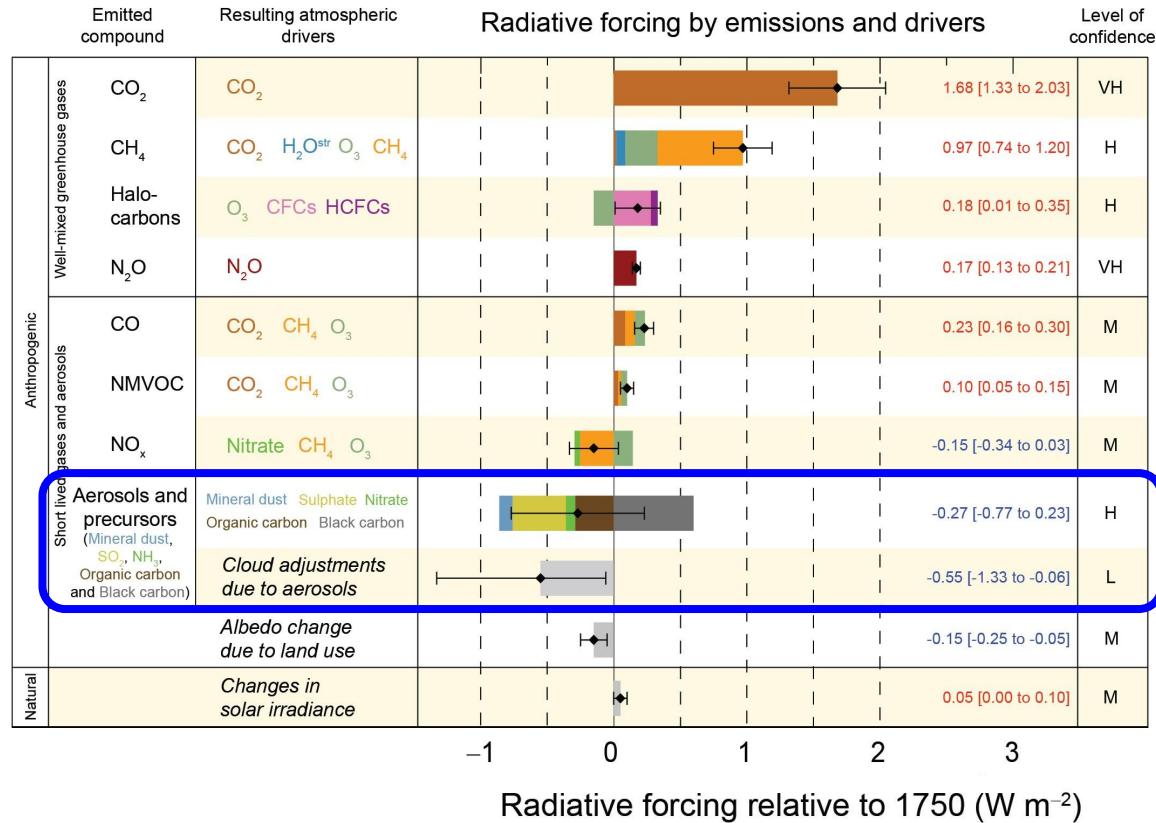
Source: IPCC WG1 2013

How big is the anthropogenic influence?



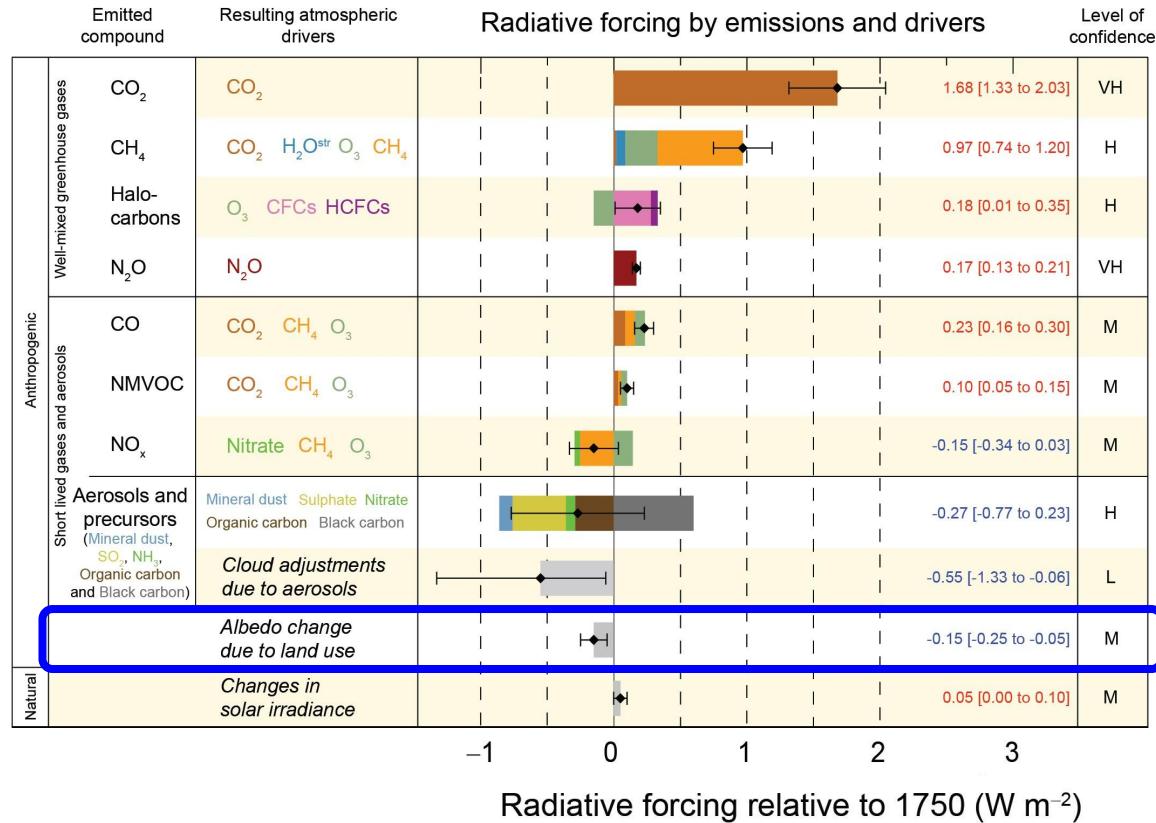
Gas emissions

How big is the anthropogenic influence?



Aerosol particles
(formation)

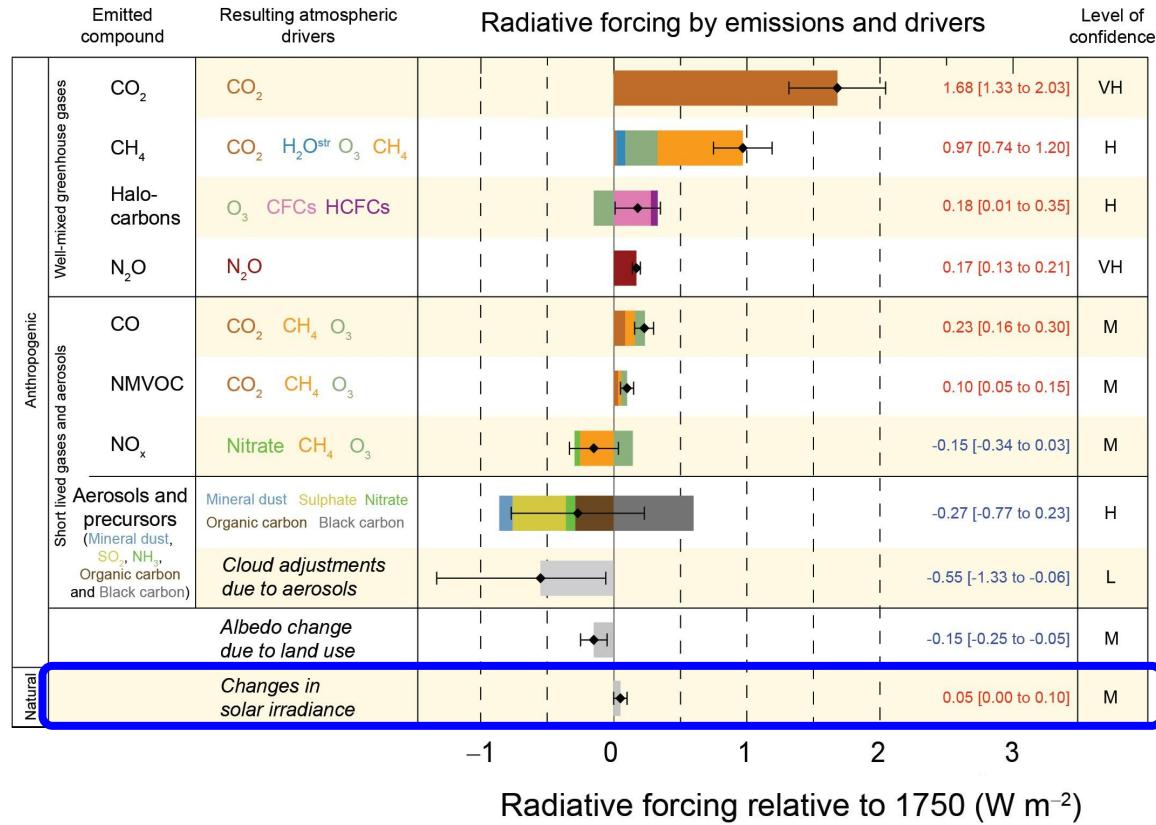
How big is the anthropogenic influence?



Land use change

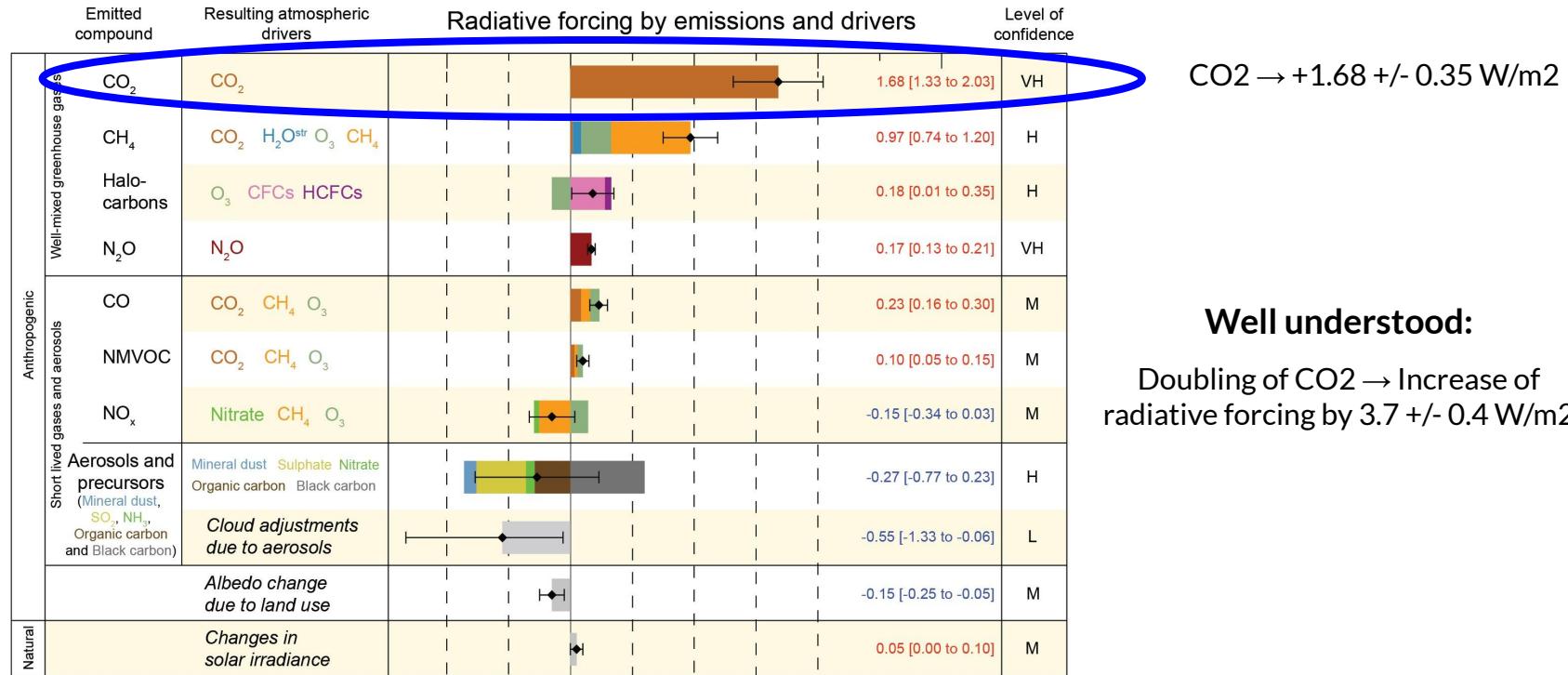
Source: IPCC WG1 2013

How big is the anthropogenic influence?



Natural solar
irradiance variation

How big is the anthropogenic influence?



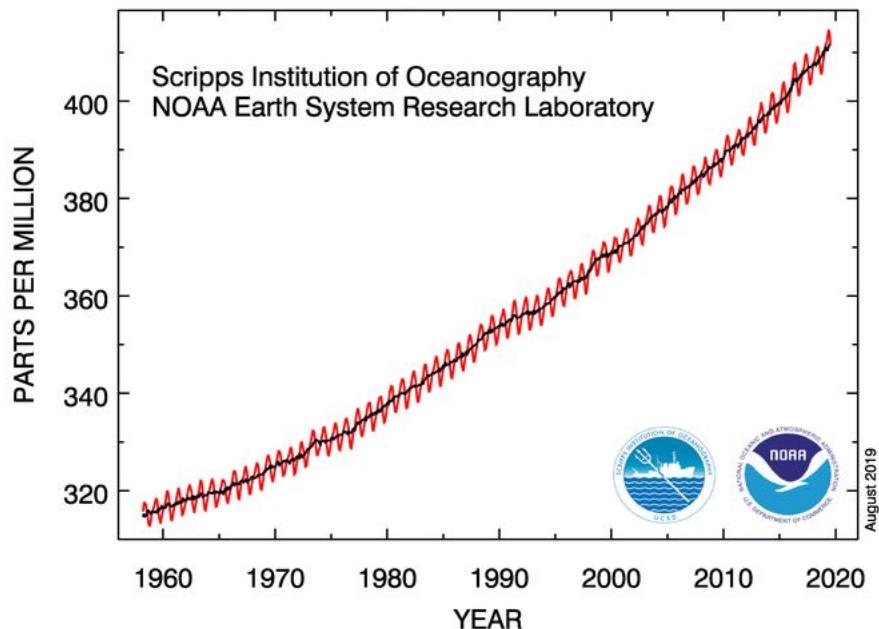
$\text{CO}_2 \rightarrow +1.68 \pm 0.35 \text{ W/m}^2$

Well understood:

Doubling of $\text{CO}_2 \rightarrow$ Increase of radiative forcing by $3.7 \pm 0.4 \text{ W/m}^2$

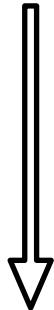
How to determine the influence of CO₂?

Atmospheric CO₂ at Mauna Loa Observatory



How to determine past CO₂ concentrations?

Atmospheric observations
'Relative to 1750'

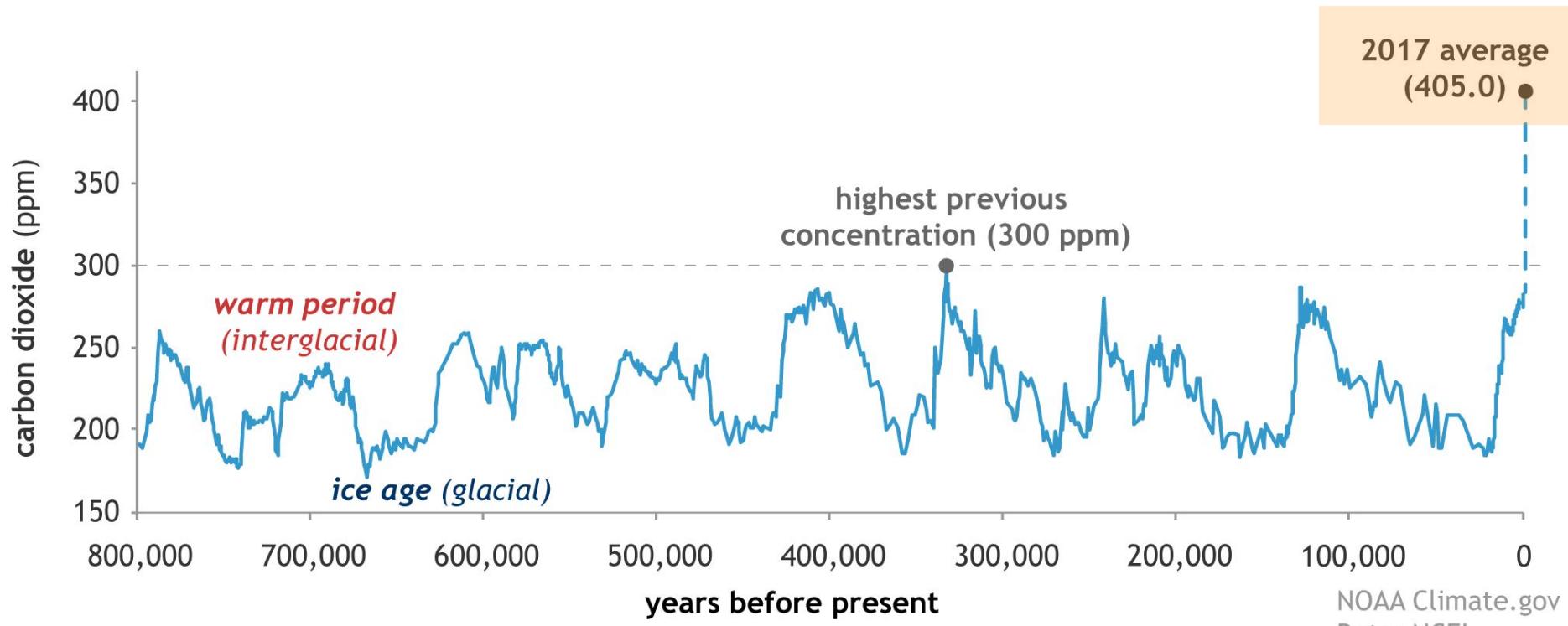


Observations in climate records

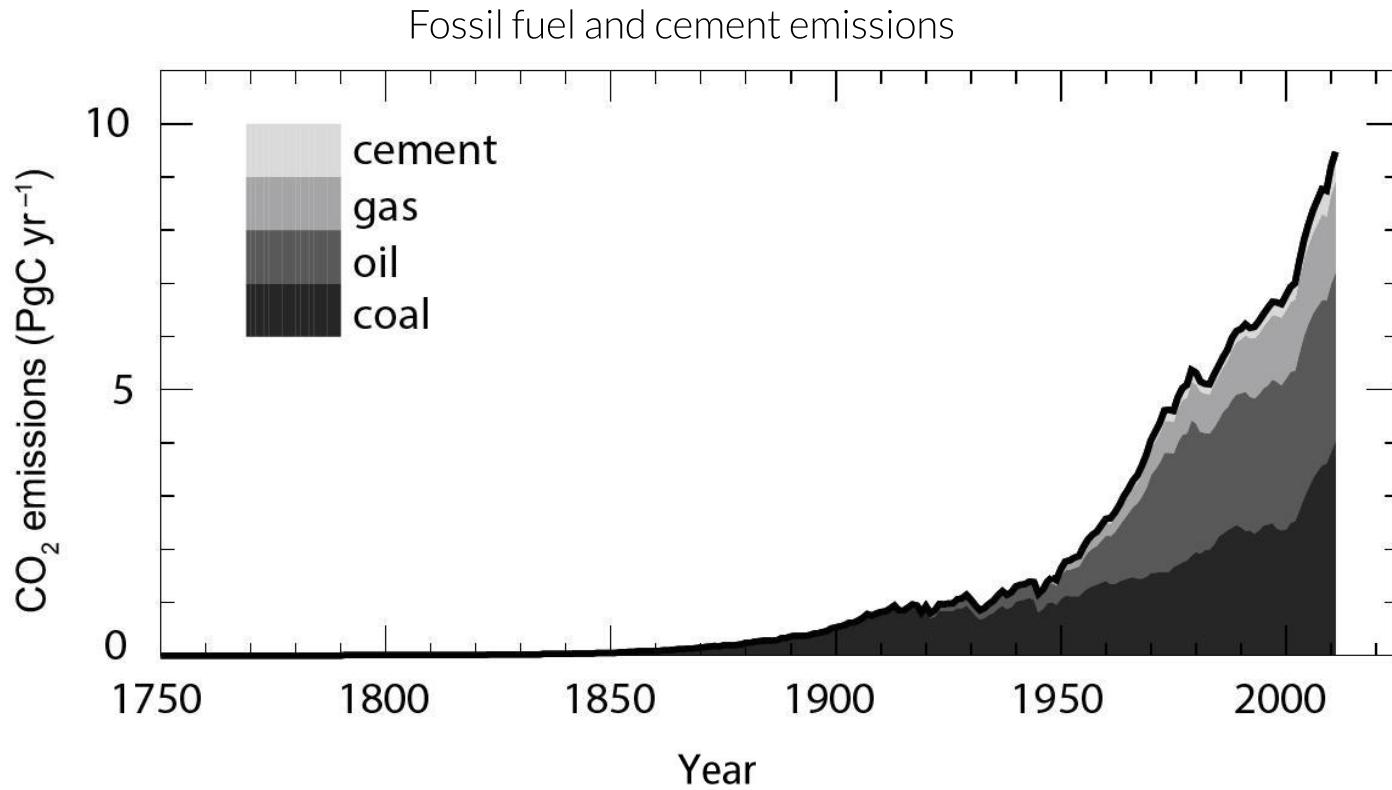


Credit: NASA's Goddard Space Flight Center/Ludovic Brucker

CO₂ dramatically increased

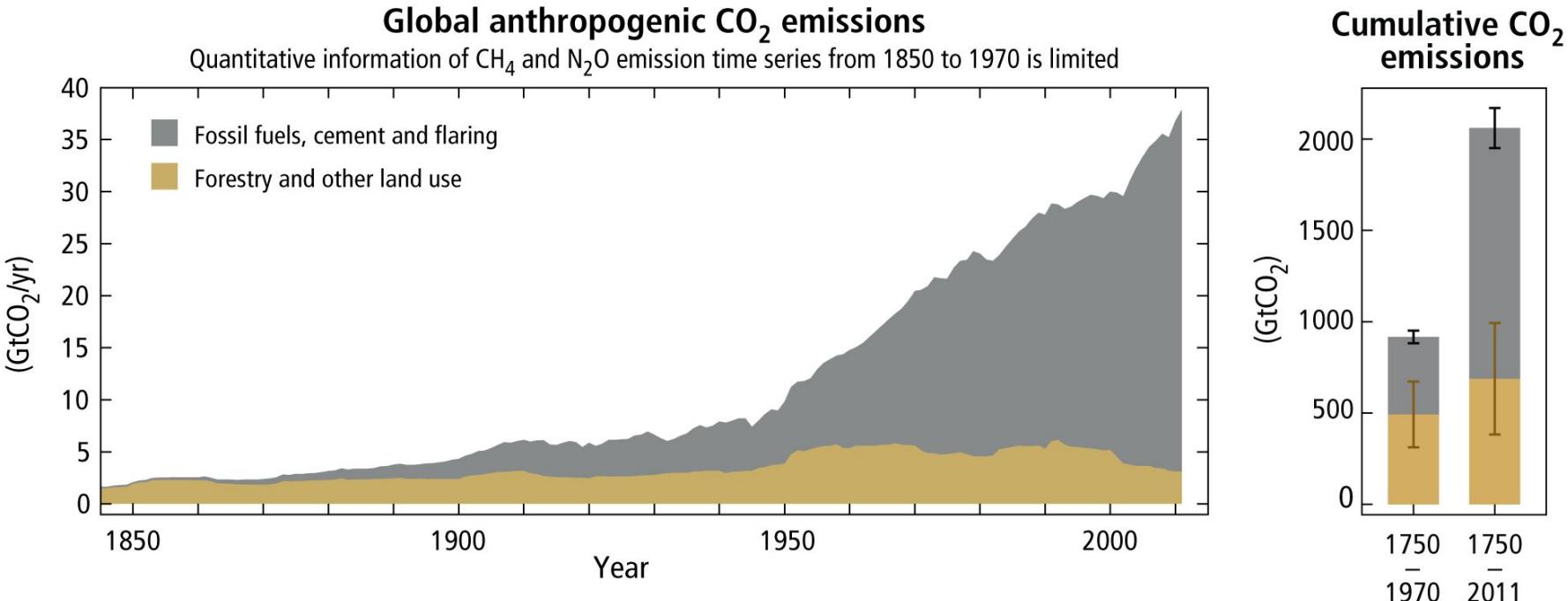


How do we know it is anthropogenic CO₂ ?



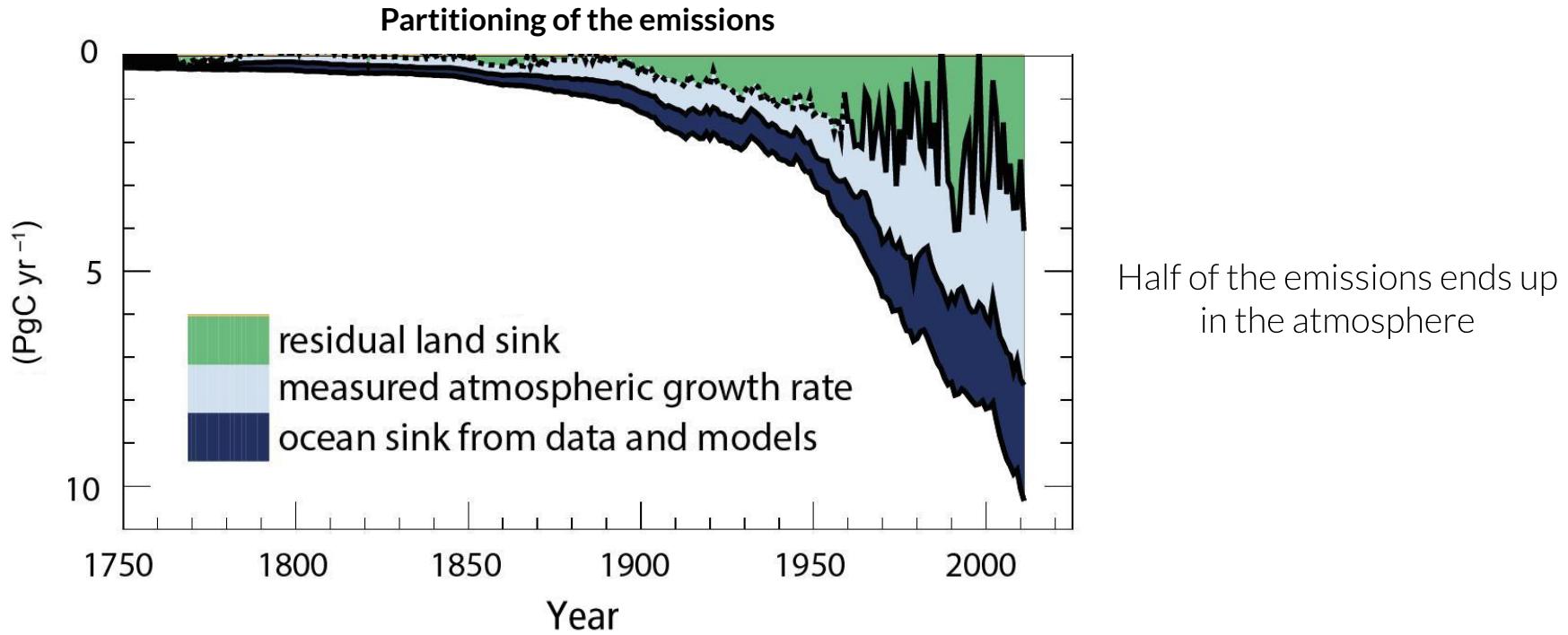
Source: IPCC WG1 2013

Anthropogenic CO₂ emissions



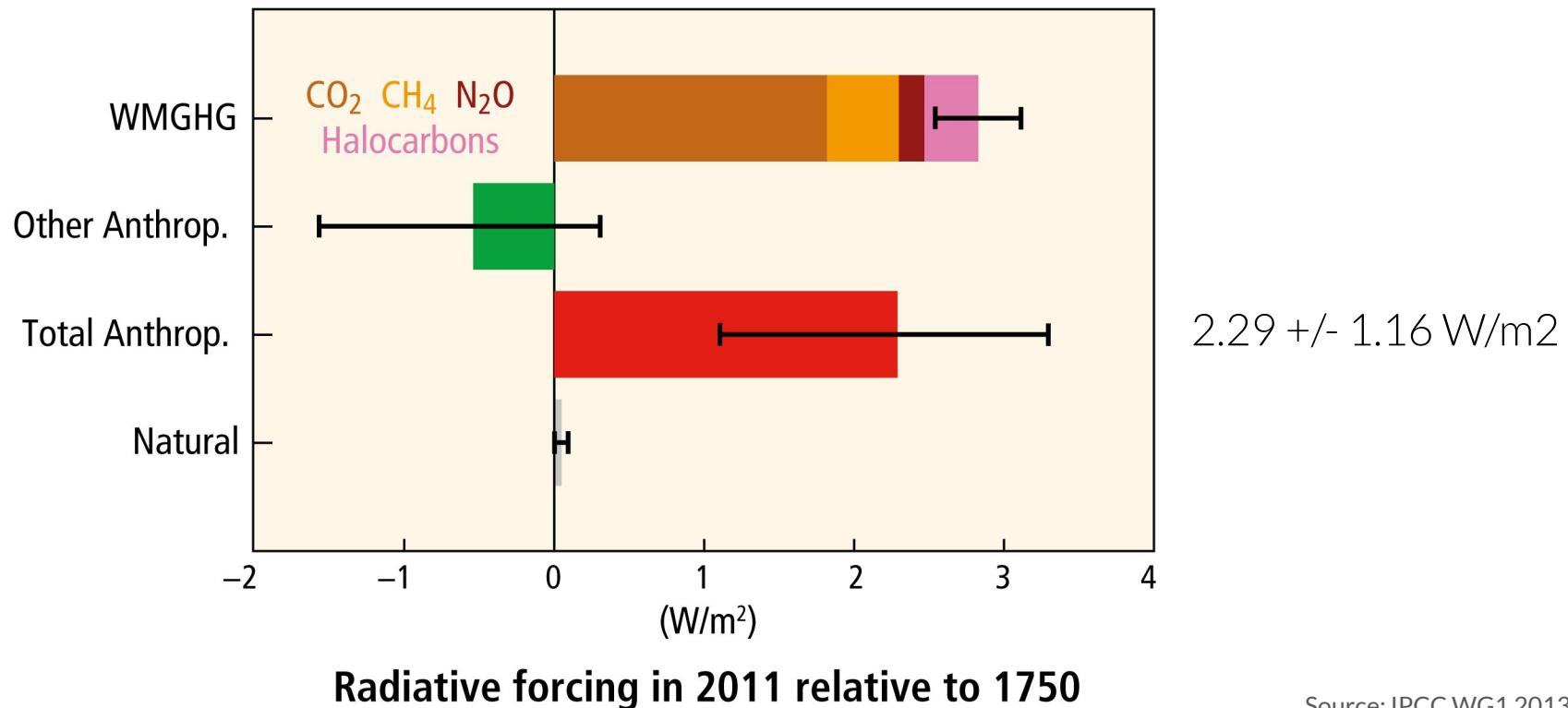
Source: IPCC WG1 2013

Anthropogenic CO₂ emissions



Source: IPCC WG1 2013

Total *anthropogenic* radiative forcing

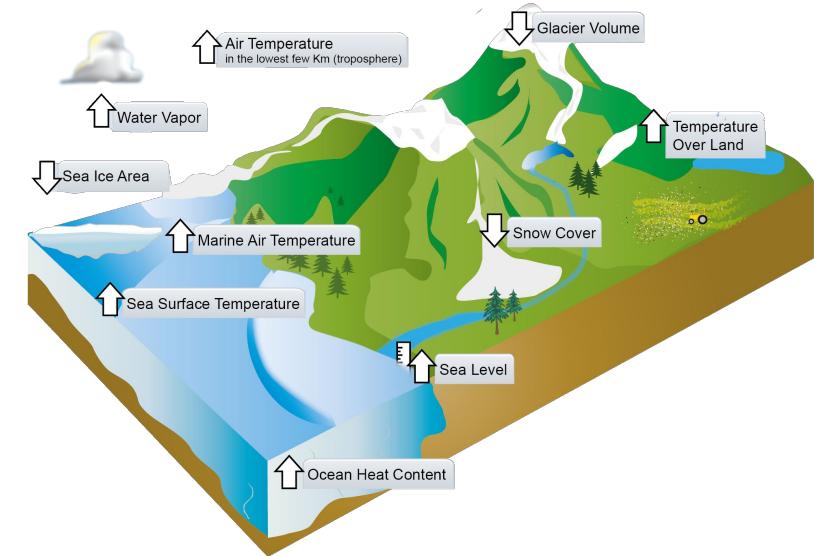
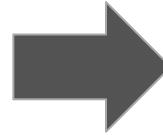
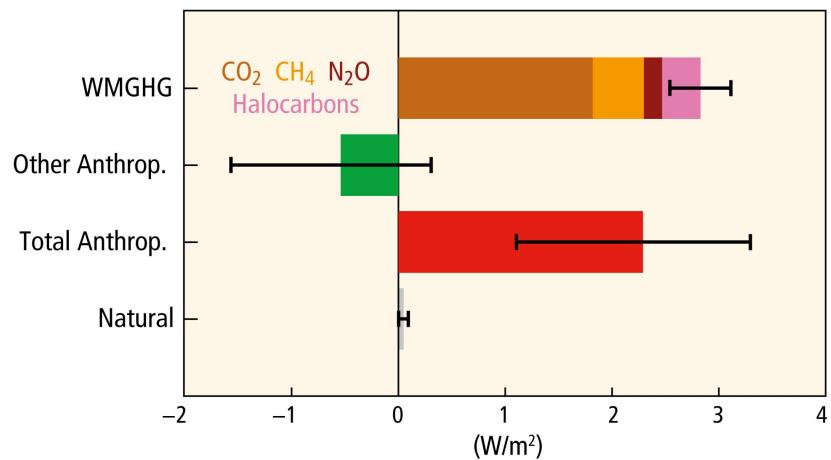


Source: IPCC WG1 2013

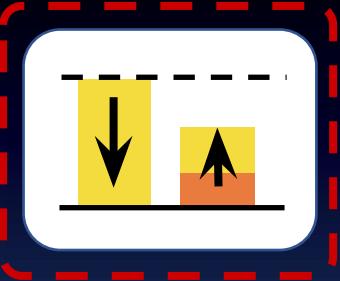
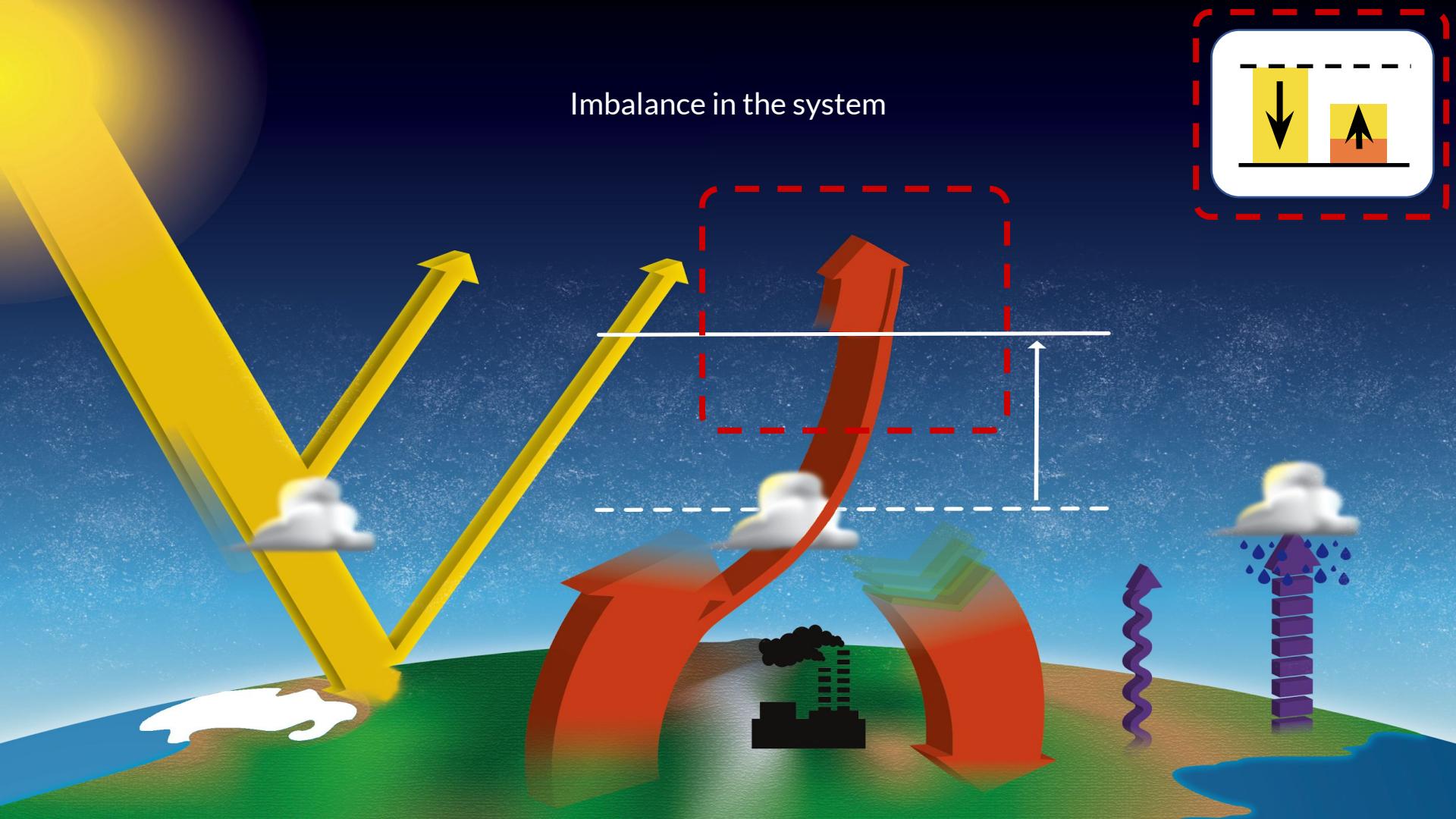
From radiative forcing to climate change



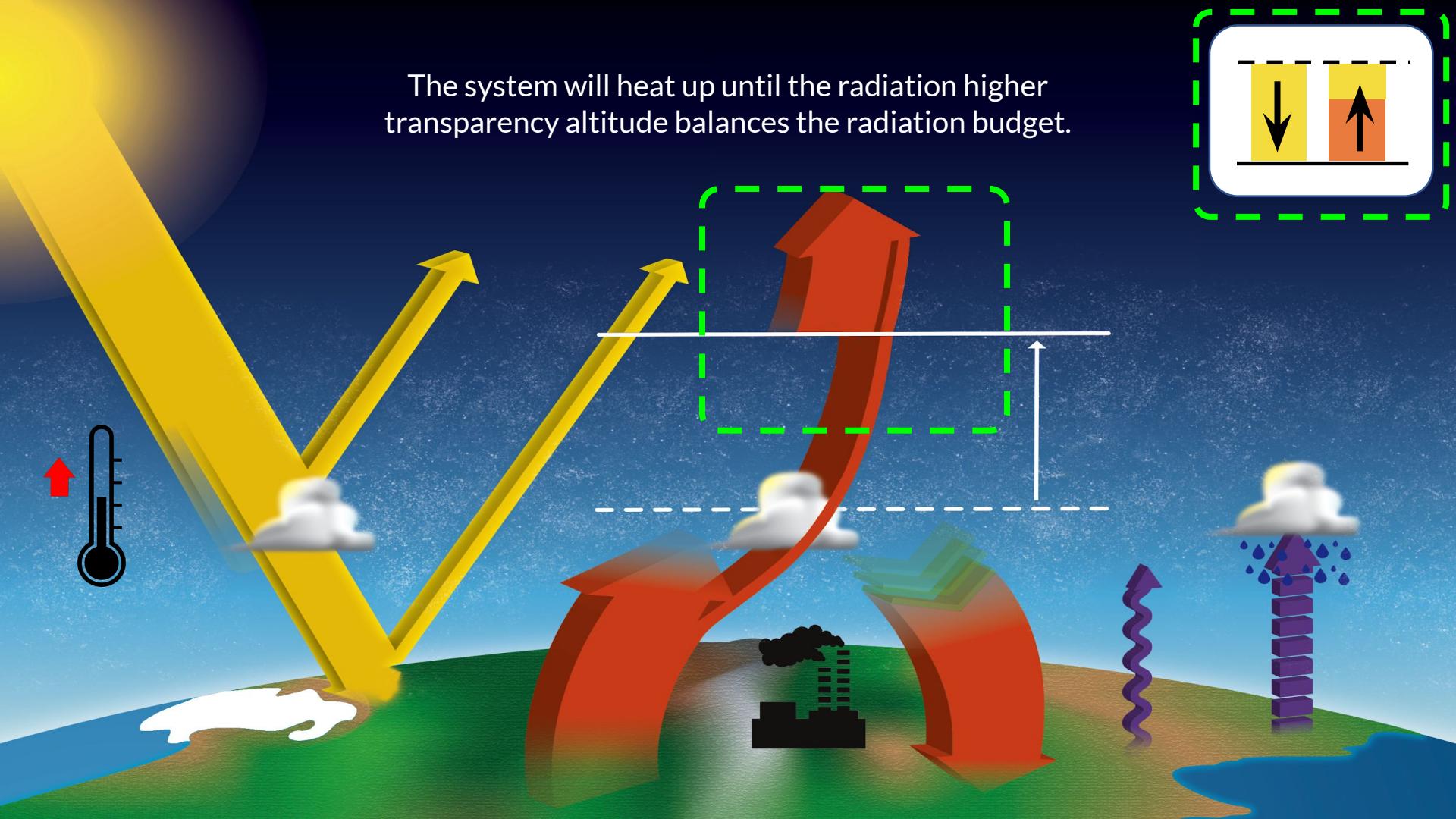
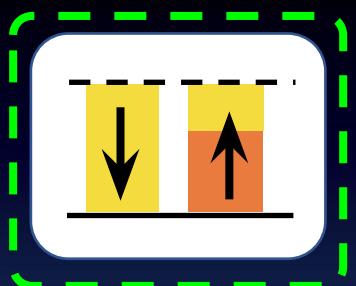
Response of the climate system: Climate sensitivity



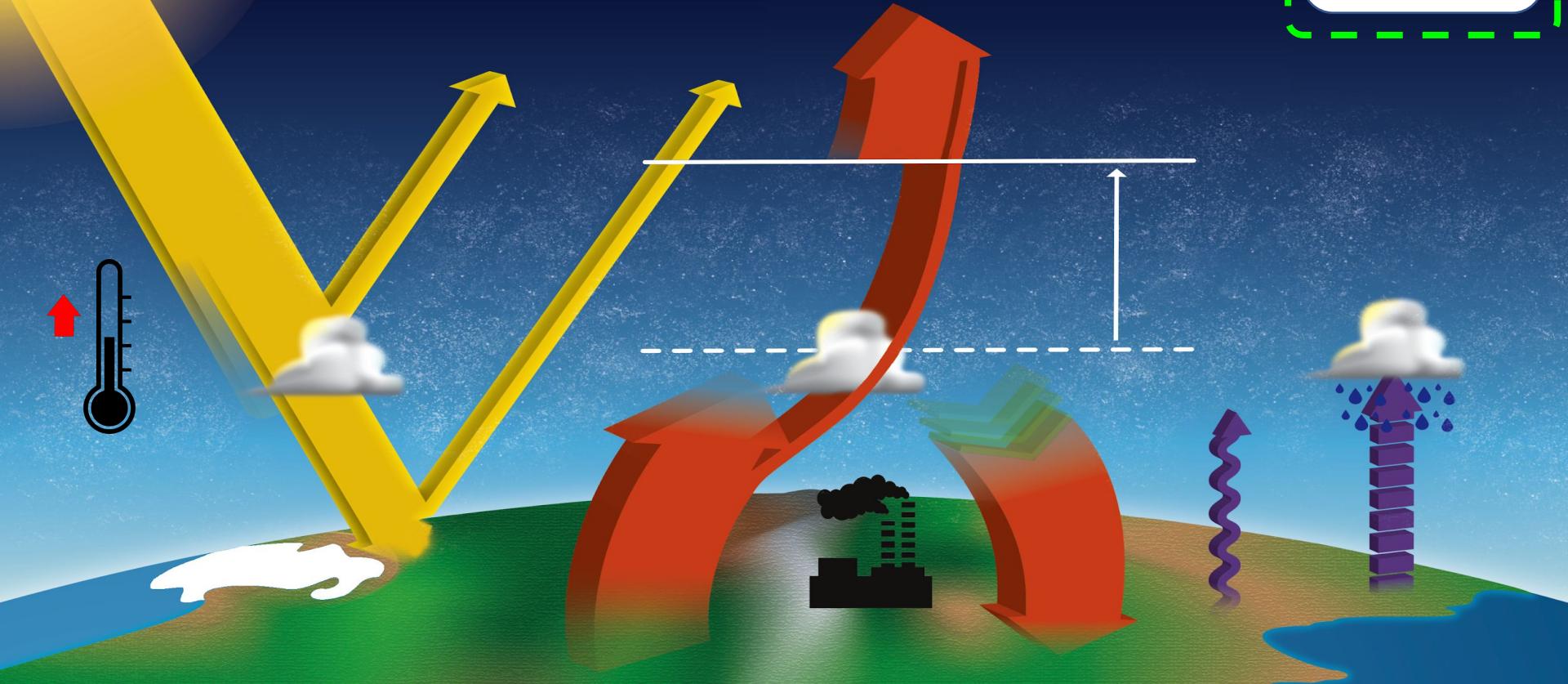
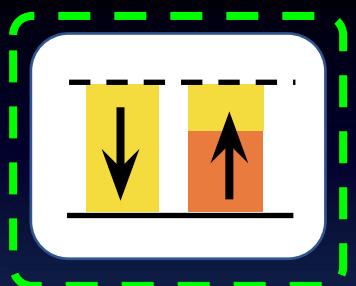
Imbalance in the system



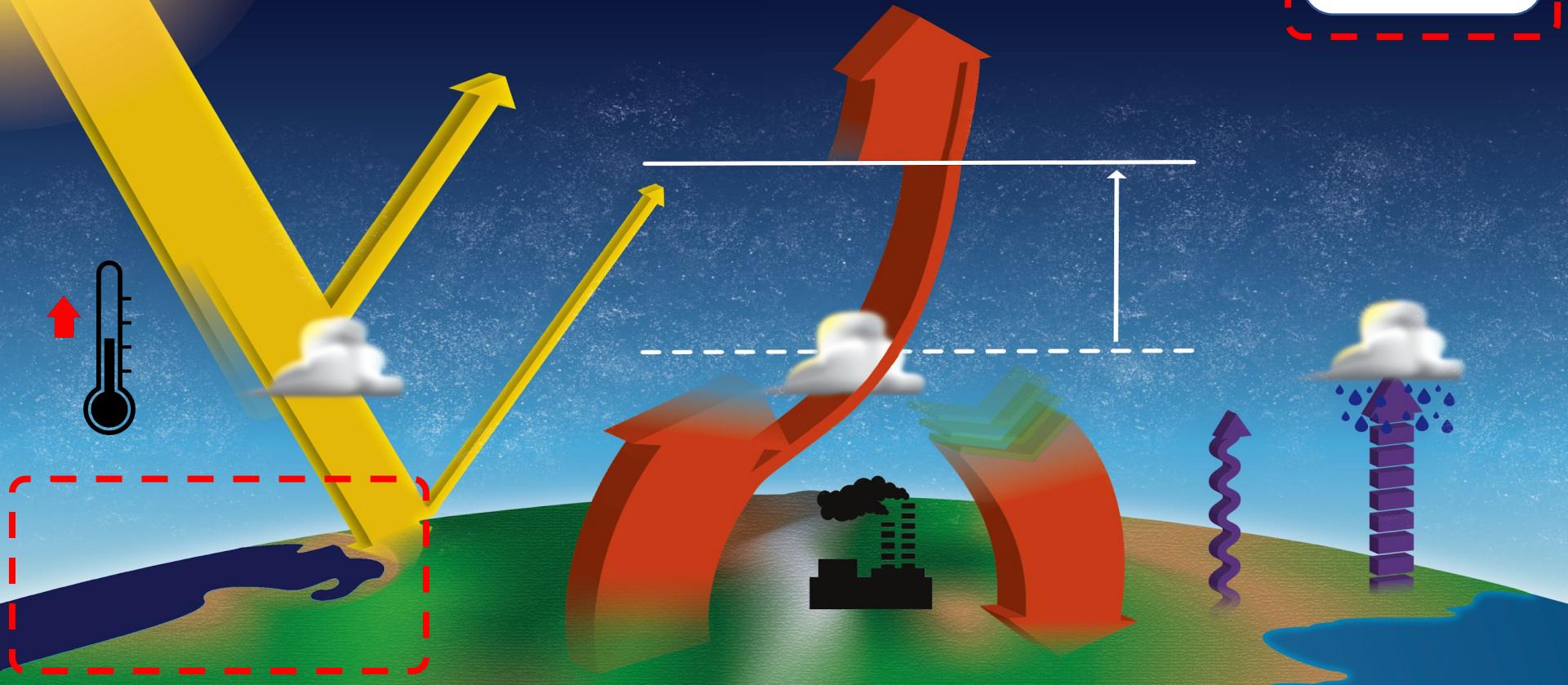
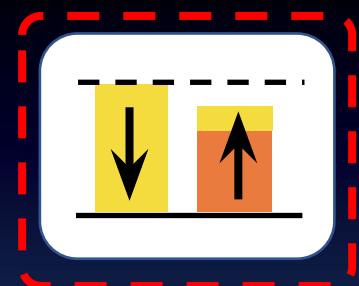
The system will heat up until the radiation higher transparency altitude balances the radiation budget.



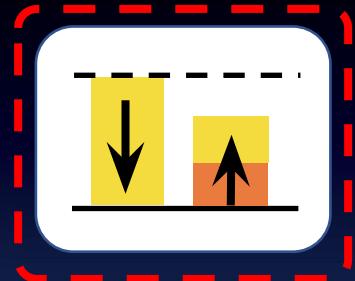
This system heated up and
is in balance

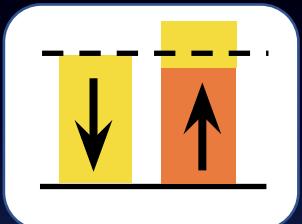


Positive feedback: temperature rises → ice melts → less reflection → imbalance

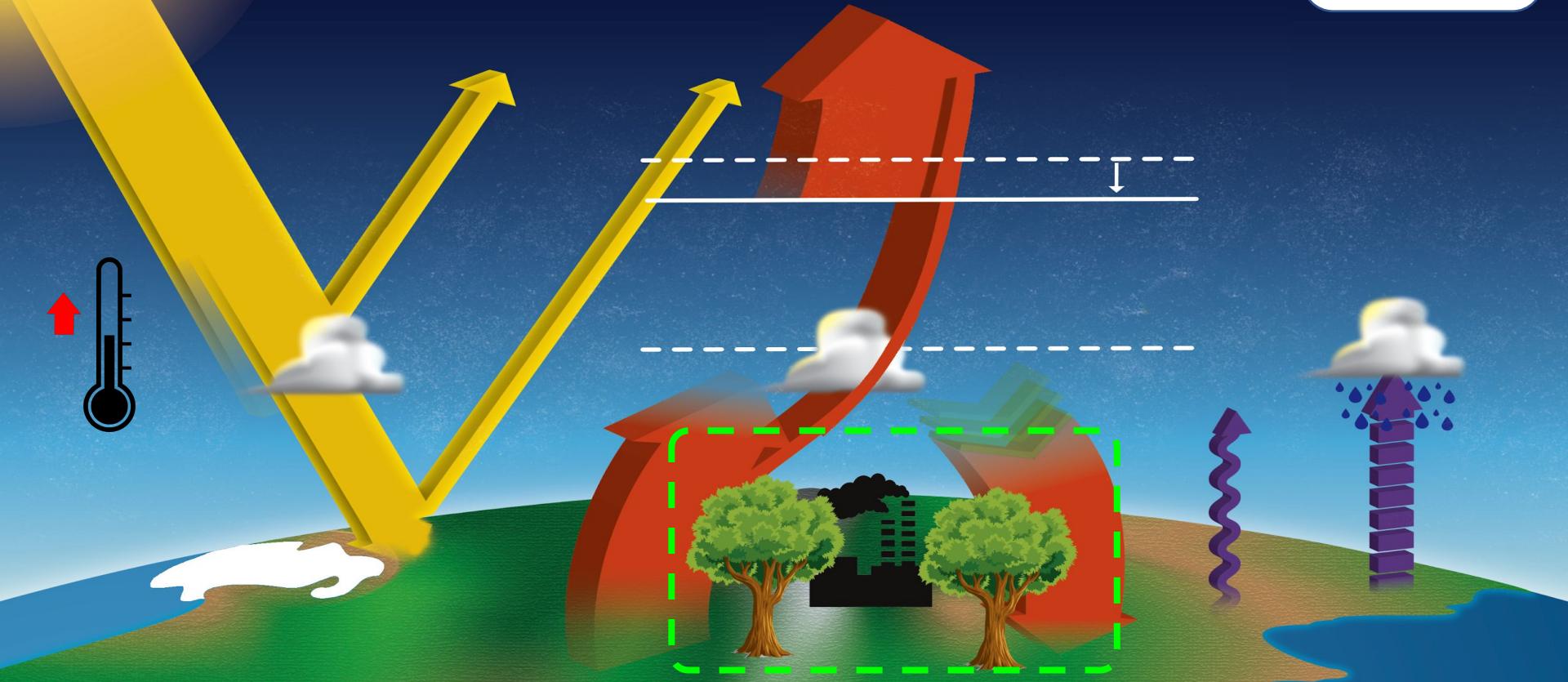


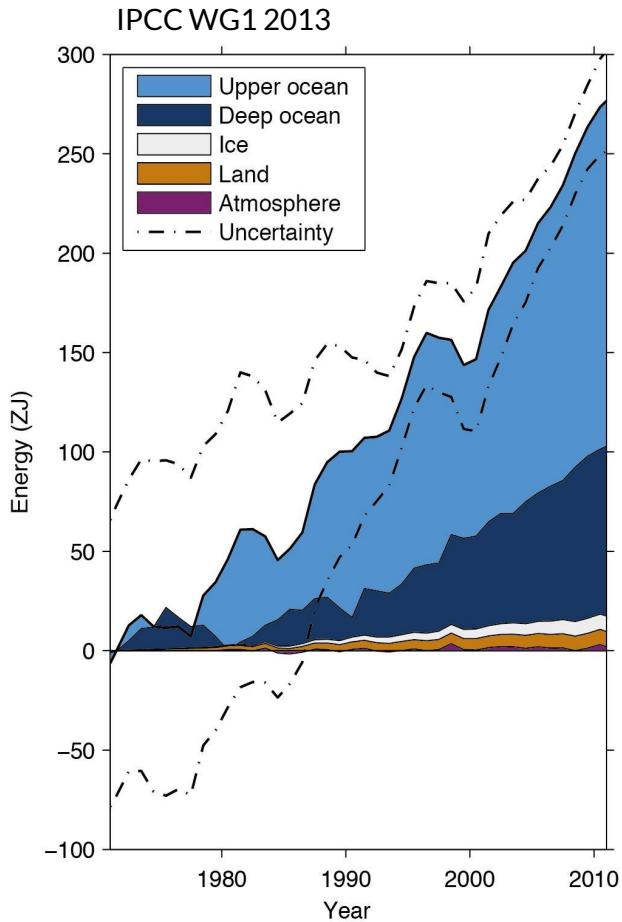
Positive feedback: temperature rises → more water vapor → transparency altitude even higher → imbalance





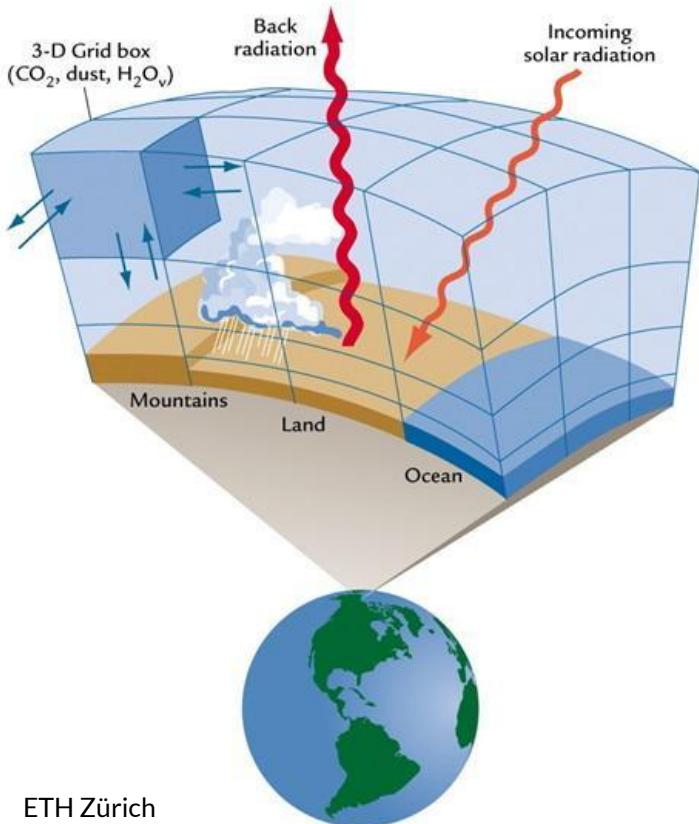
Negative feedback: temperature rises
→ trees grow faster and absorb CO₂
→ less greenhouse gases → imbalance





Can we determine the climate sensitivity from observations?

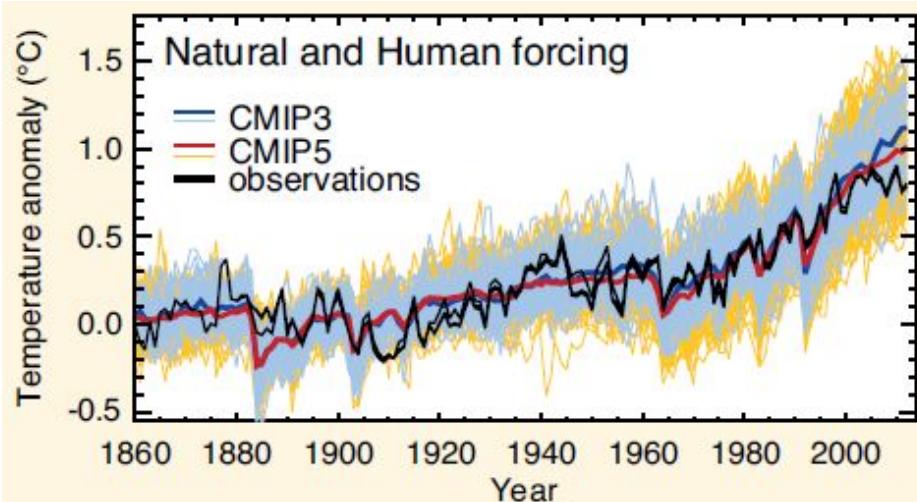
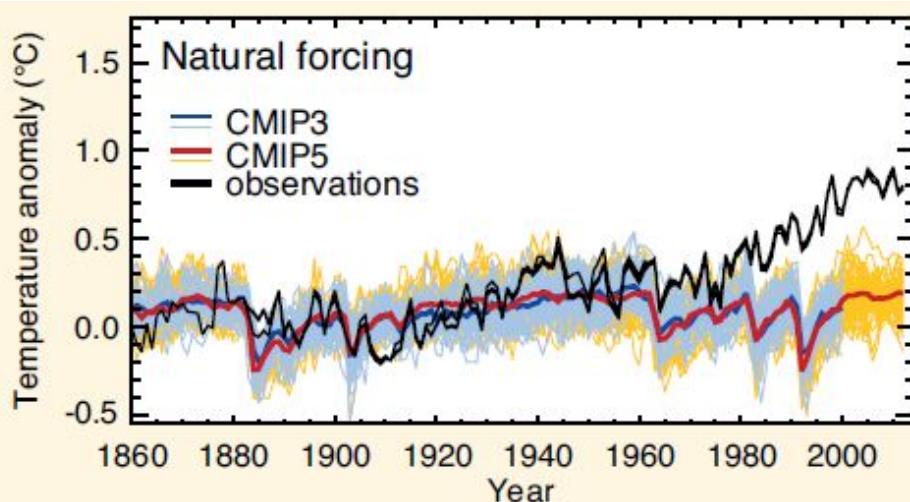
- Problem: system takes a very long time to equilibrate



Climate models

- Quantitatively simulate the influence of climate drivers in the different compartments of the climate system.
- Applications:
 - attribution of observed change
 - projections of future developments

Attribution of climate change to different factors



Simulate with and without a specific factor and
compare to observations

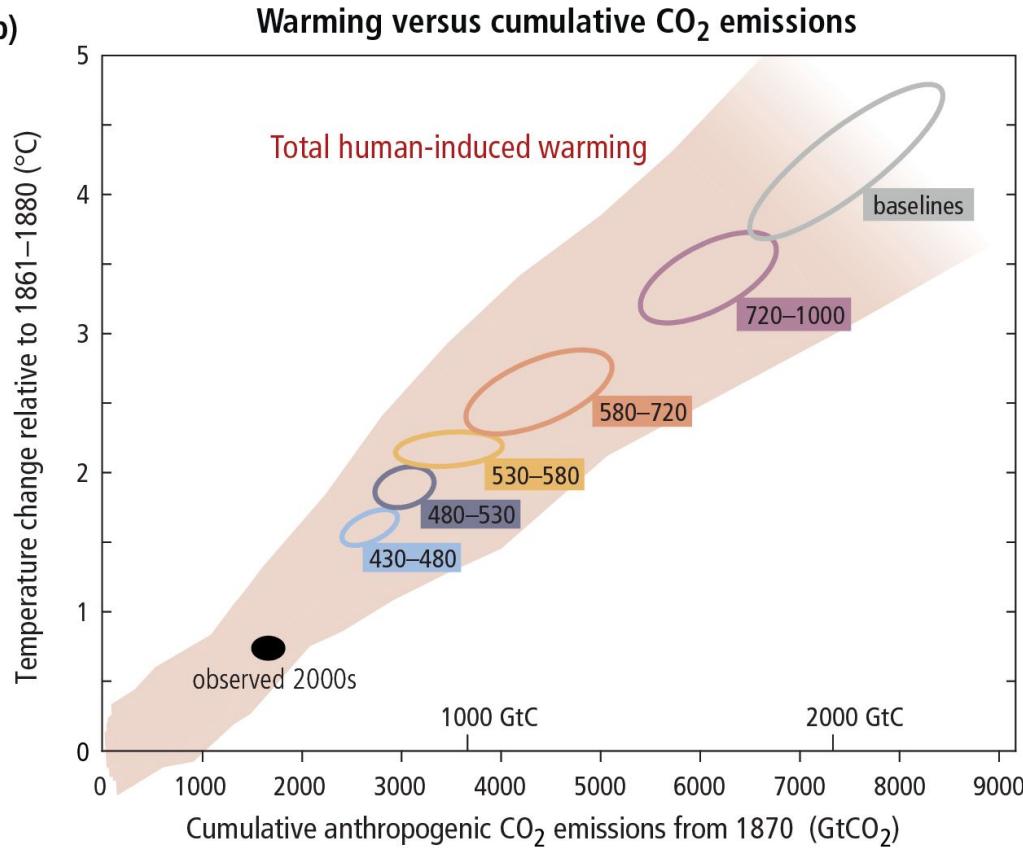
Global temperature rise limit

- **2°C target** - not exceeding max historical observations, linked to doubling of CO₂ (economist Nordhaus in 1977)
- **1,5°C target** - 2009 demand of Alliance of Small Island States based on studies of consequences of a 2° warming for their islands



Carbon budget for temperature increase below 1.5°C

(b)



Budget for increase below 1.5°C:

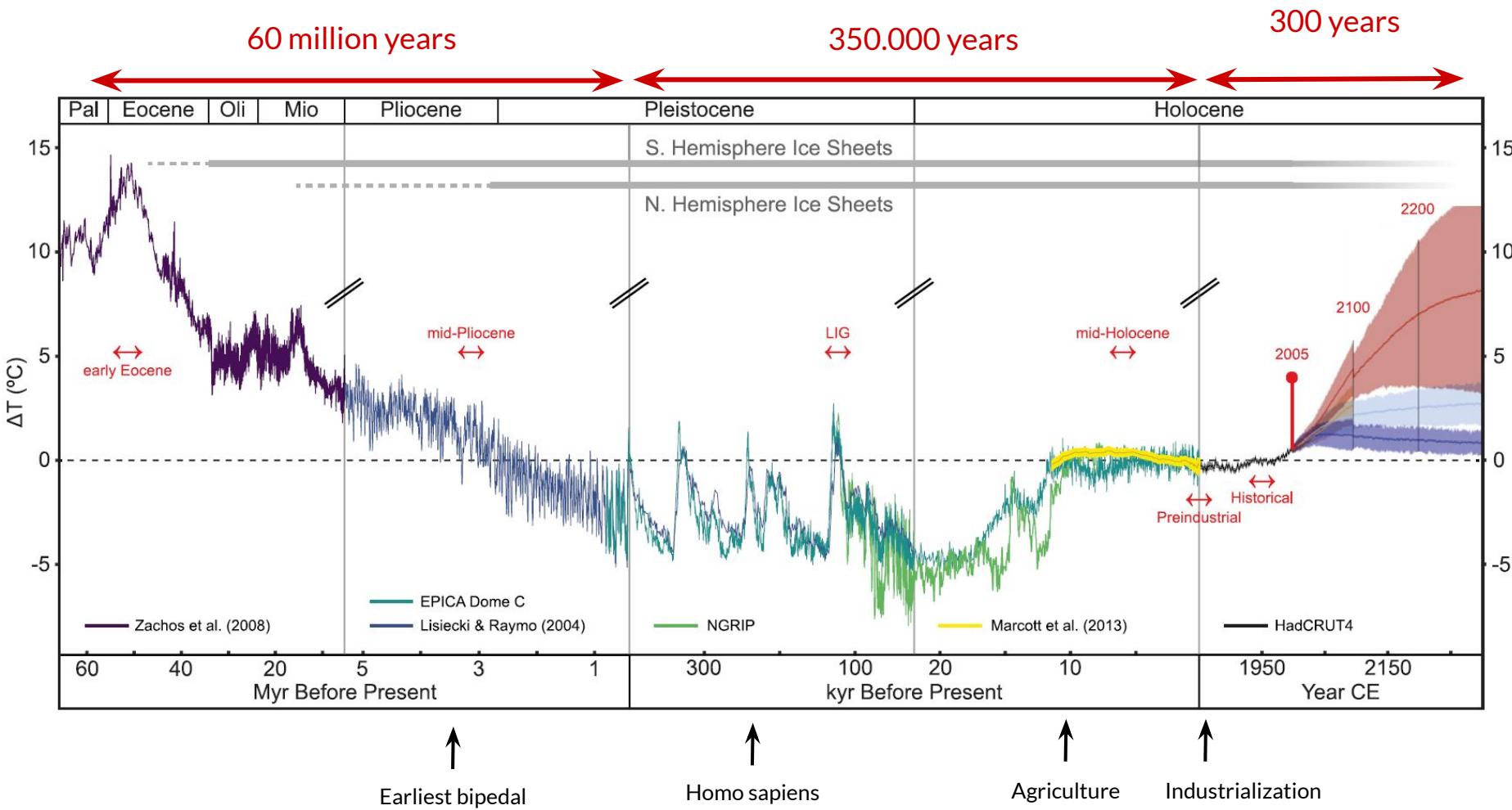
420 GtCO₂
(66% probability)

Global emissions (2017):

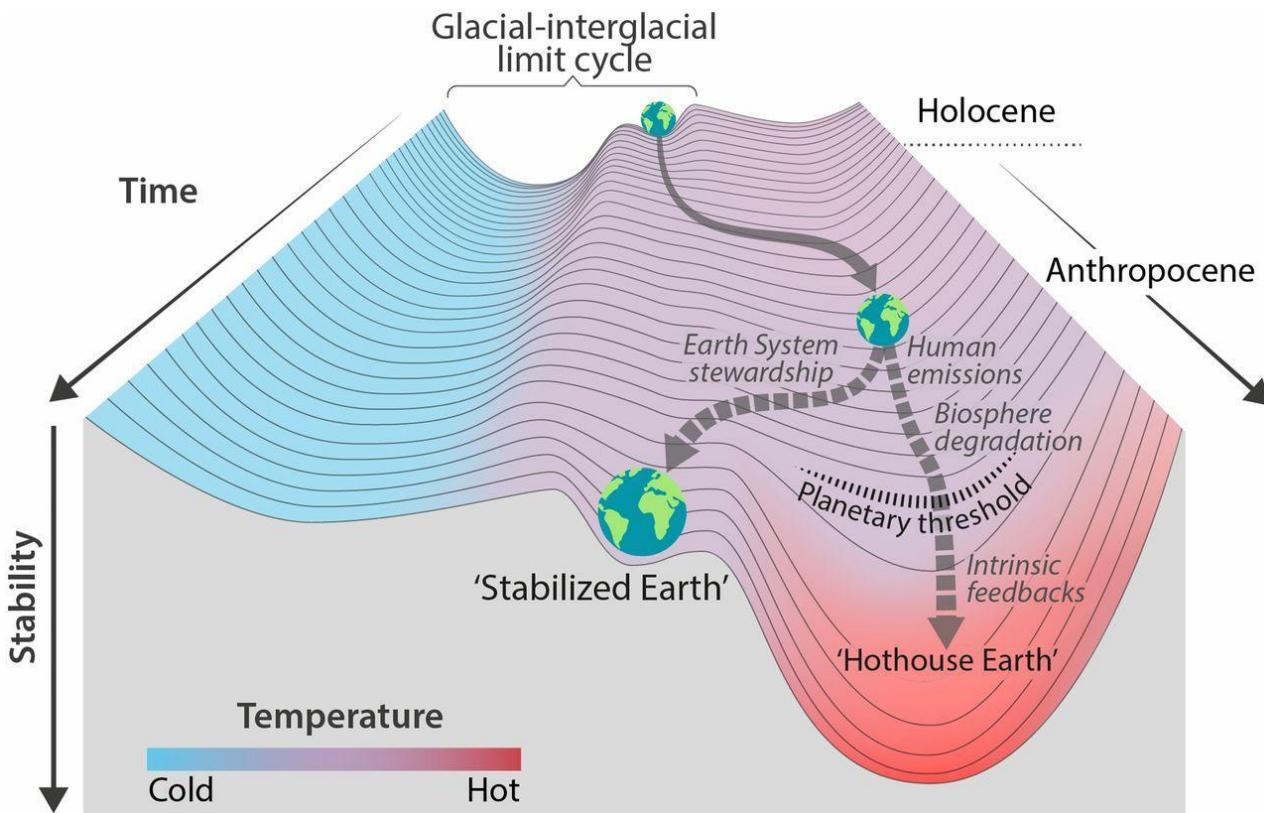
42 ± 3 GtCO₂ per year

~ 20 years left

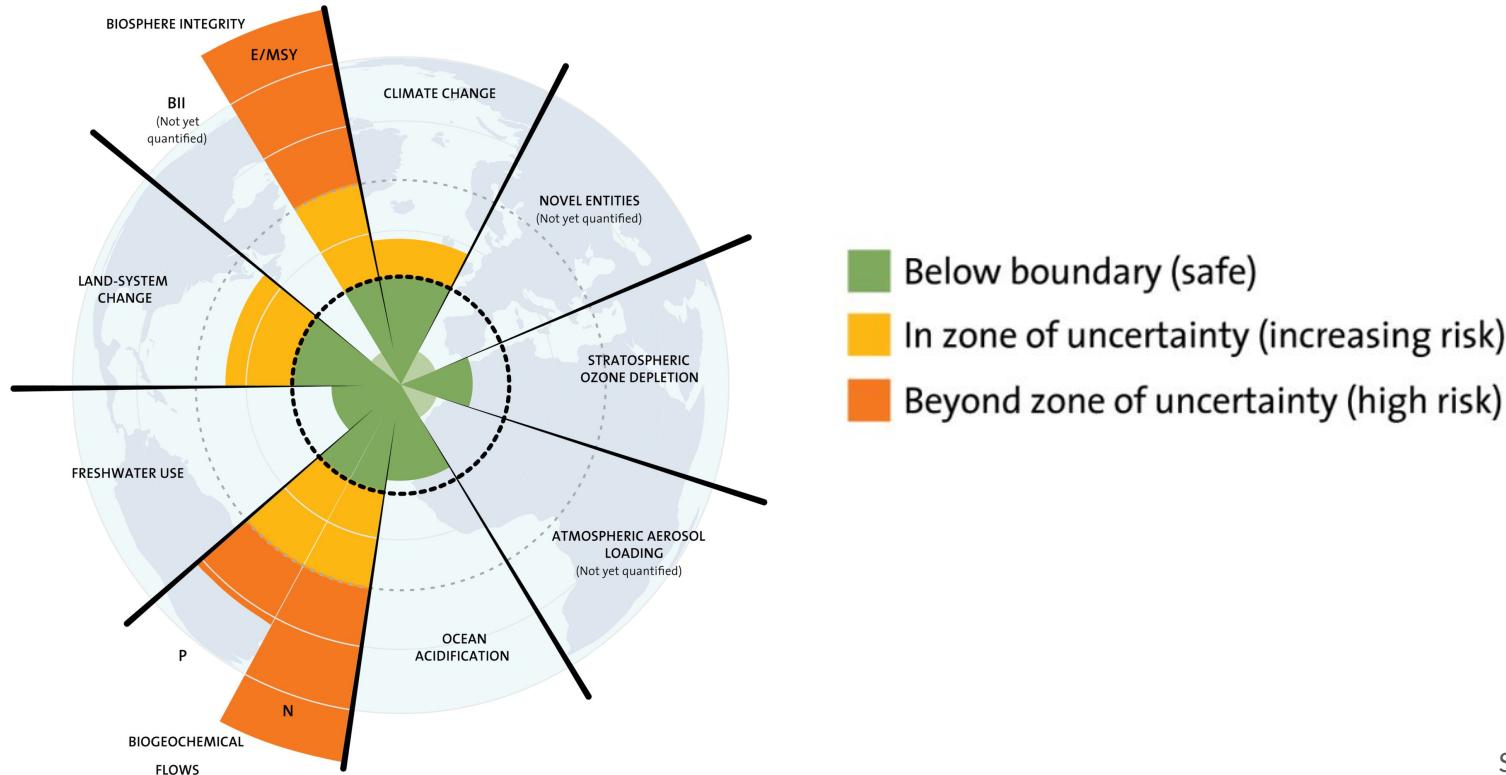
(with a linear decrease of emissions)



We risk to cross thresholds of no-return



We risk to cross thresholds of no-return

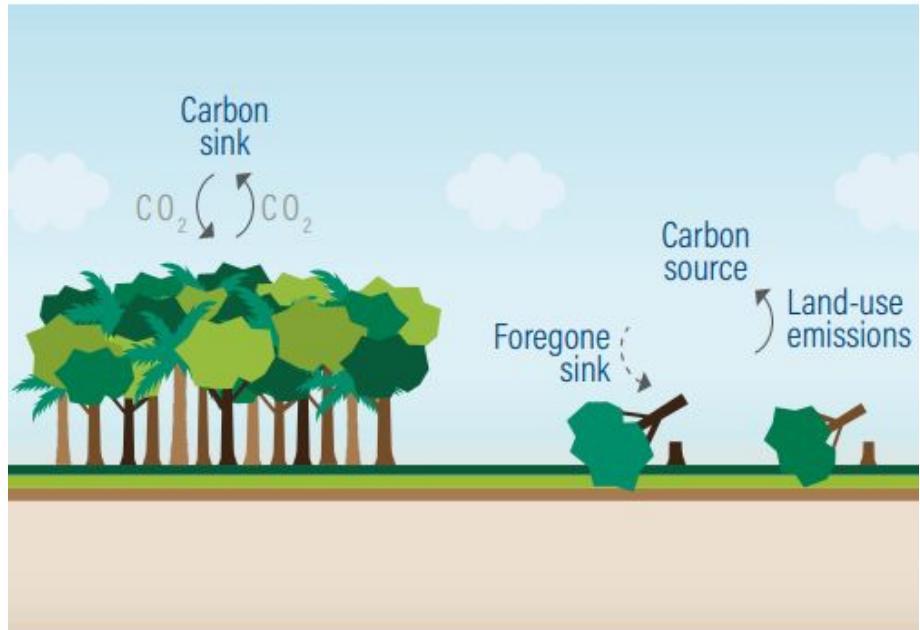


Land use change

A dark, atmospheric photograph of a forest. In the foreground, several large tree trunks are scattered across the ground, some upright and some lying horizontally. The ground is covered in dense, low-lying vegetation and fallen leaves. In the middle ground, there is a clearing where many smaller, young trees are growing in a grid-like pattern, suggesting a managed or replanted area. The background is filled with a dense line of tall, mature coniferous trees standing in the fog. The overall mood is somber and suggests a theme of environmental change or deforestation.

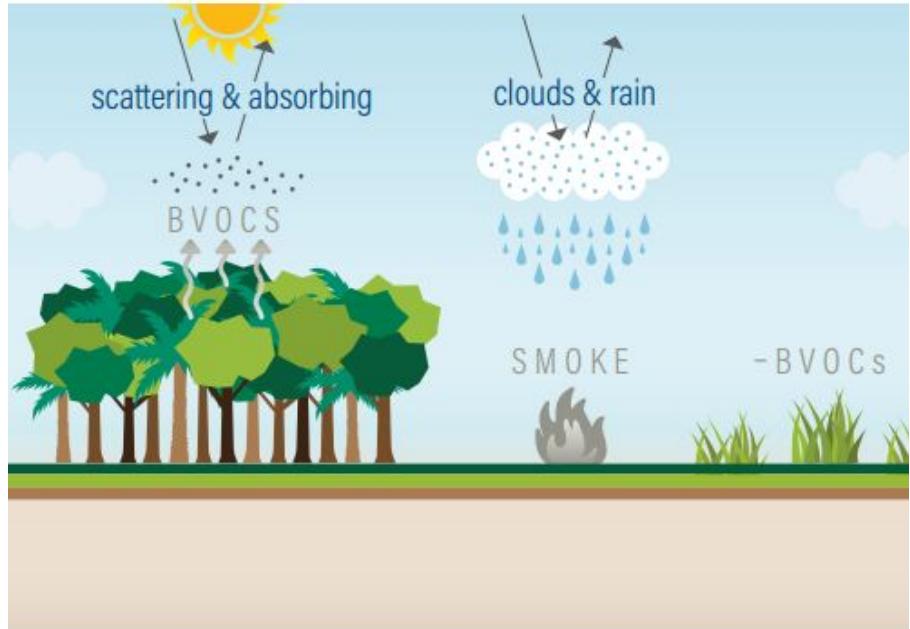
Greenhouse gases

- Forests, wetlands, peatlands, mangroves and grasslands efficiently **absorb and store CO₂**.
- Clearing forests and draining peatlands releases carbon from the land into the atmosphere.



Biogenic volatile organic compounds

Forests **release biogenic volatile organic compounds (BVOC)**, which have both positive and negative radiative forcing. In sum, lower BVOC emissions after deforestation result in warming.

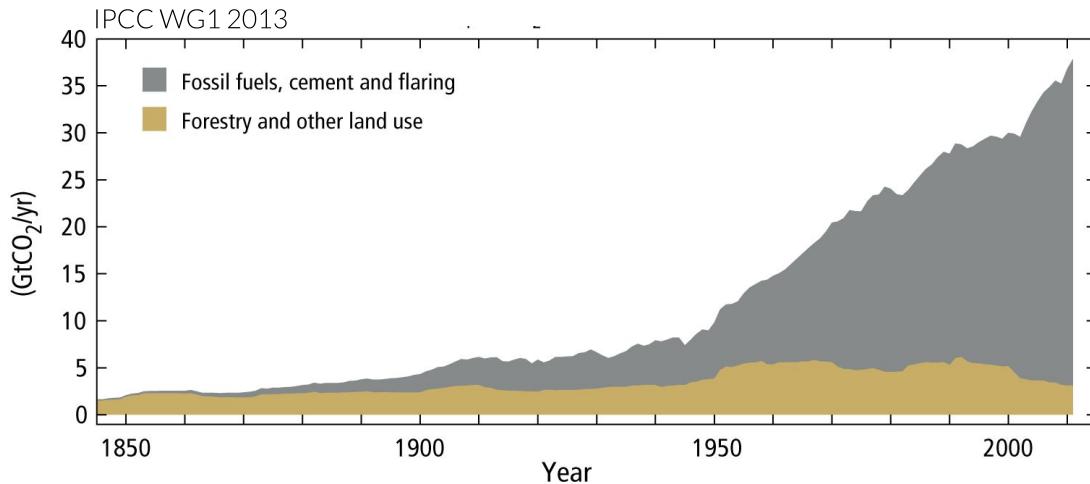


Non-radiative forcing

Forests drive movement of air, water, and heat

- Accumulating water in roots and soil, humidifying the air causes surface cooling
- Transpiration can cause building clouds and rainfall
- Impact on the texture of the Earth's surface, which influences how and where heat and water are distributed
- Nonradiative forcing impacts of deforestation in the tropics show net local warming

Land use change impact



CO₂ emissions from fossil fuels far exceed those from land use change

But:

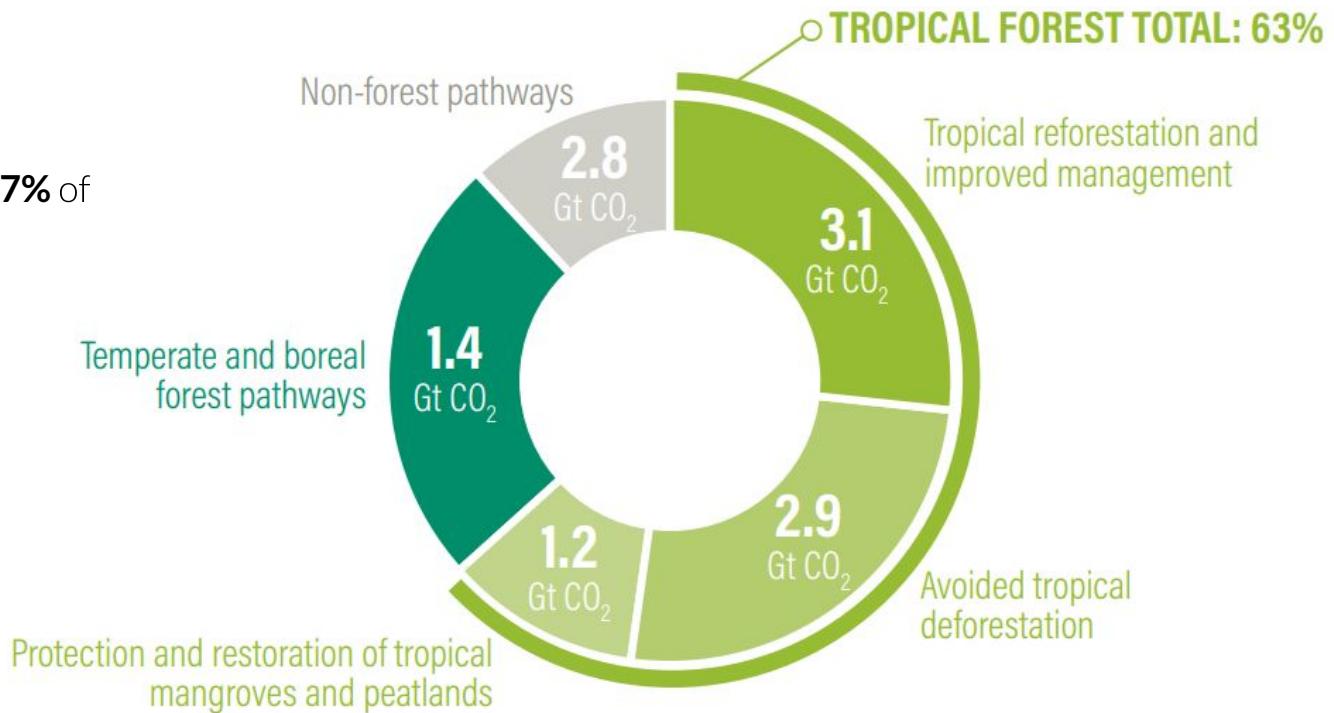
Land use change
emissions



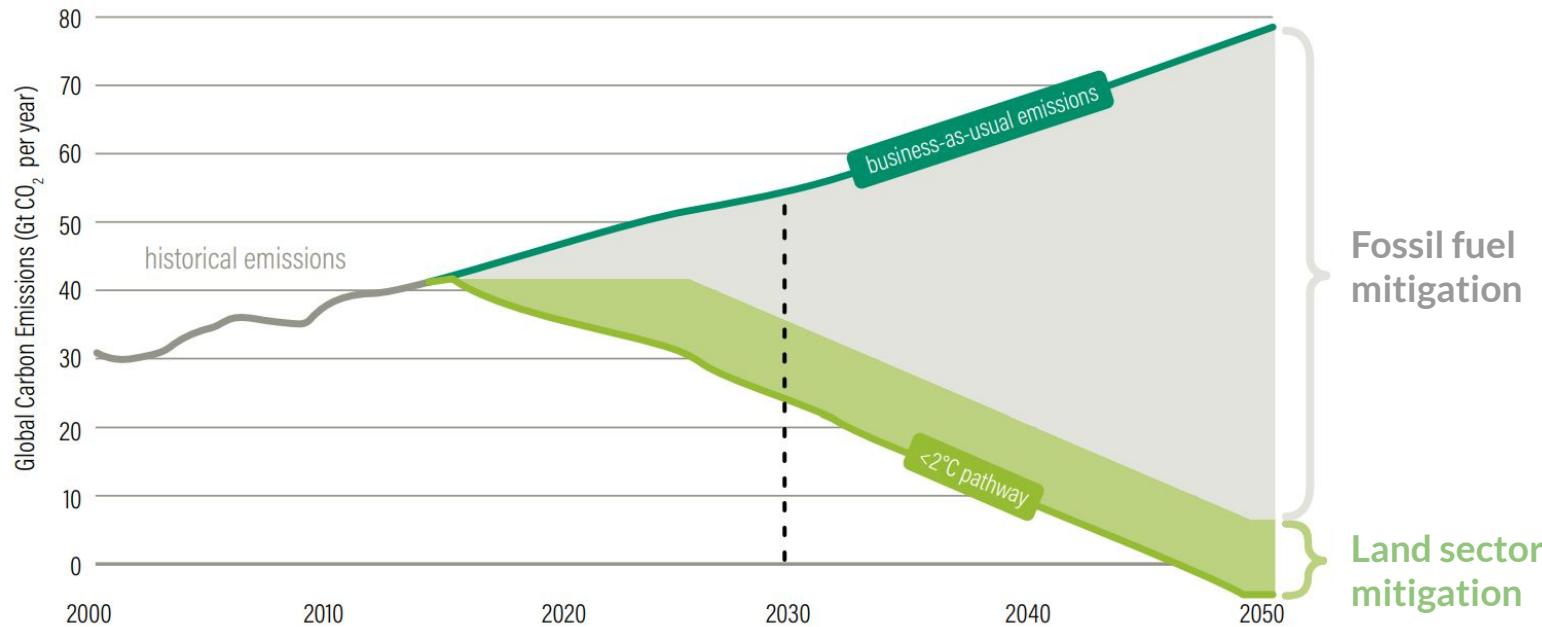
Deforestation/wetlands drainage emissions
MINUS
Carbon sequestration by forests and wetlands

Mitigation potentials by 2030 to limit warming below 2°C

Land sector can offer **37%** of the solution



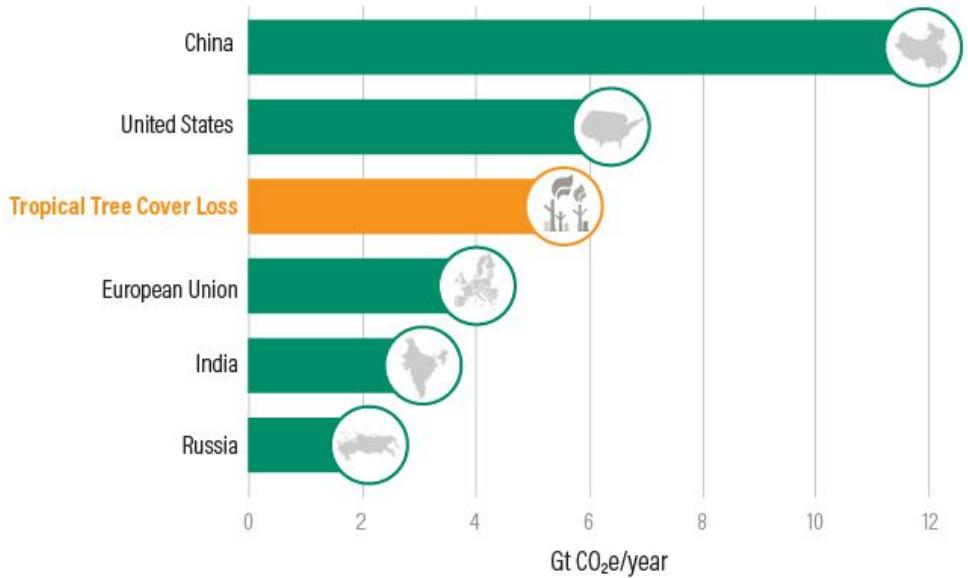
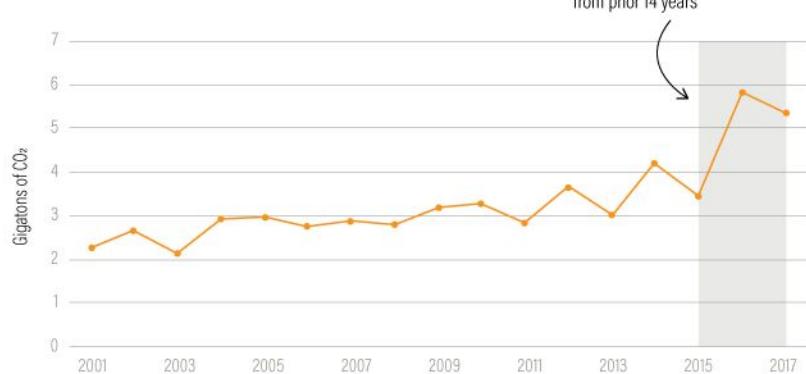
Land sector can offer 37% of CO₂ mitigation by 2030



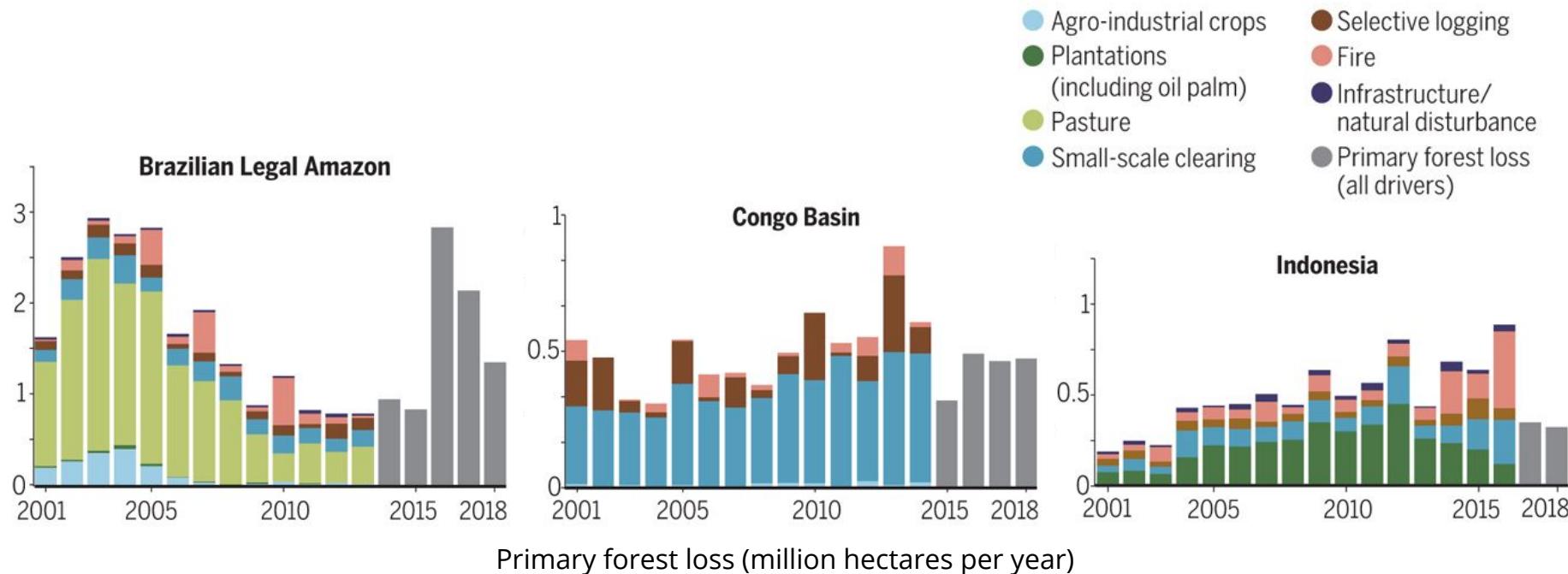
Conservation, restoration, and improved management of **tropical** forests, mangroves, and peatlands - **23%** of total mitigation till 2030.

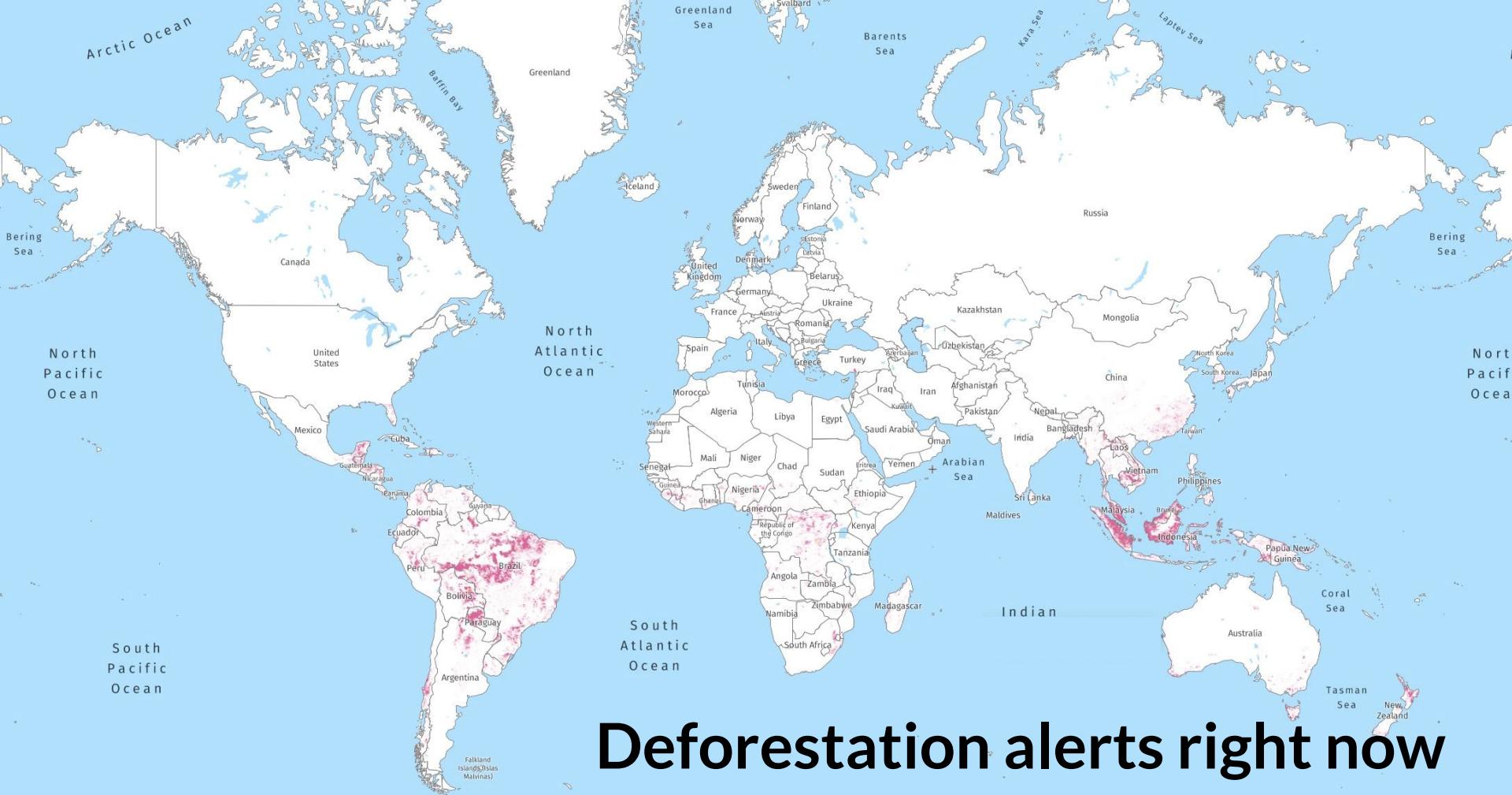
CO₂ emissions caused by tropical deforestation

CO₂ Emissions from Tropical Tree Cover Loss



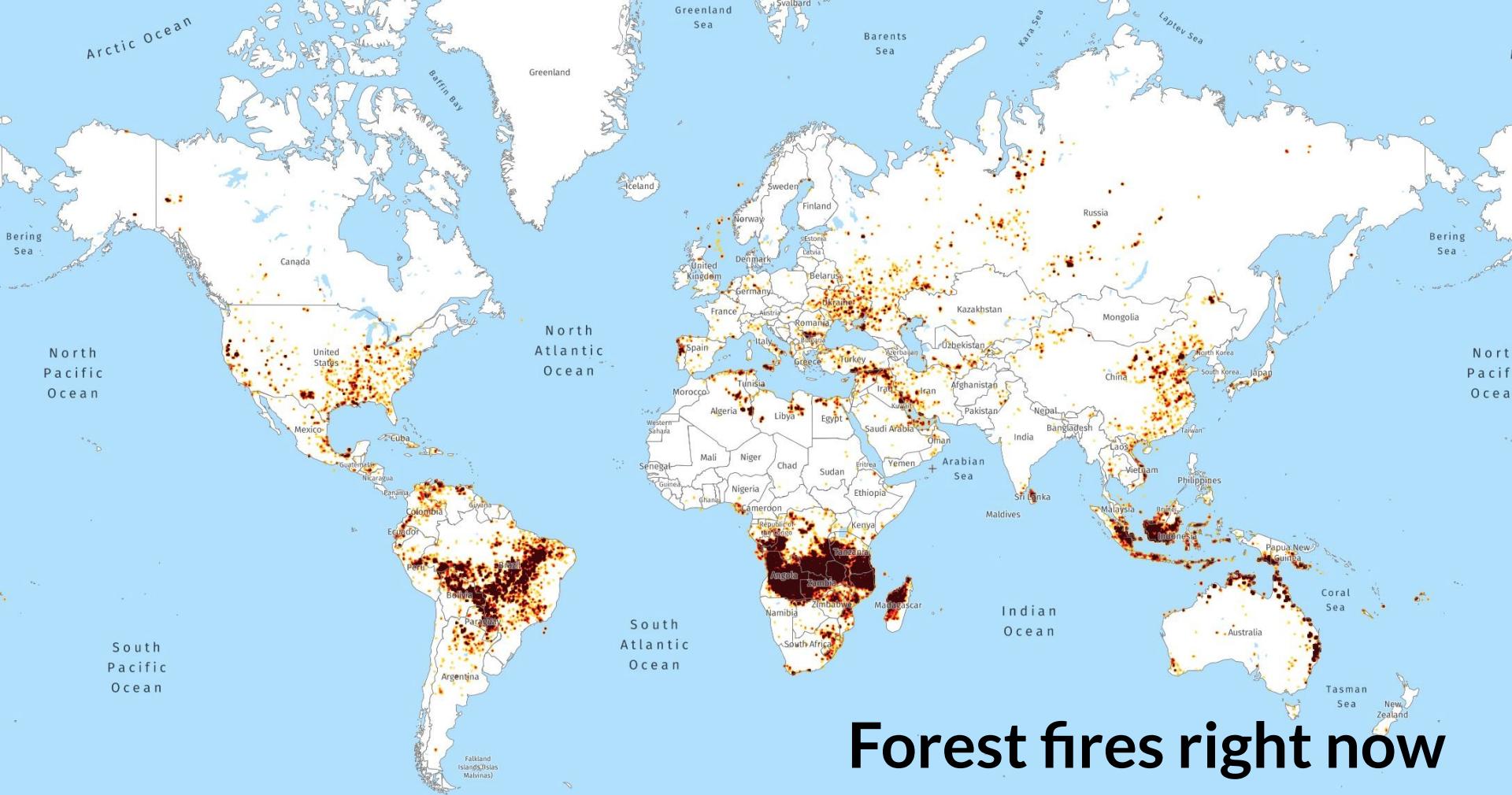
Causes of deforestation





Deforestation alerts right now

Forest Watch www.globalforestwatch.org



Forest fires right now

Forest Watch www.globalforestwatch.org

Impact of climate change

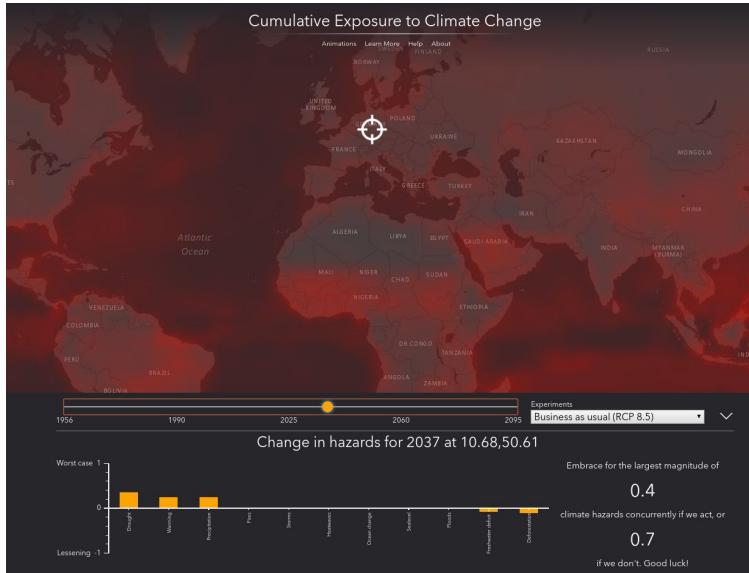


Impact on humans



IPCC report AR5: Impacts, Adaptation, and Vulnerability

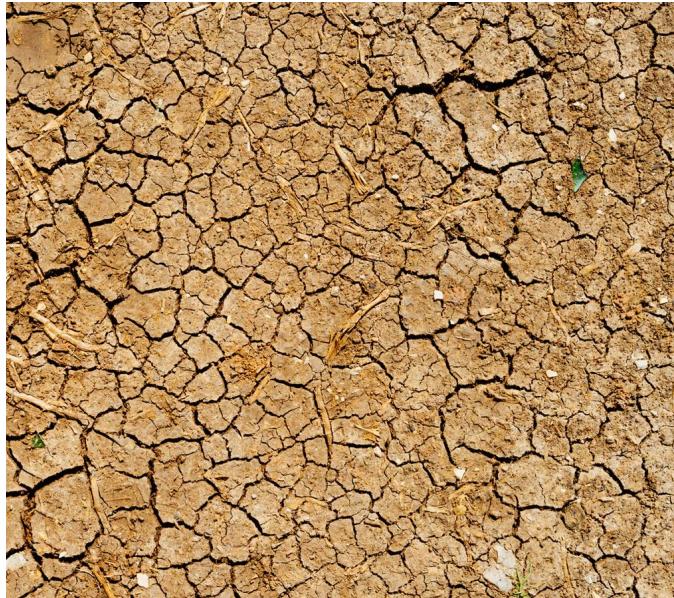
How are we affected by climate change?



- Health
 - Food and water supply
 - Infrastructure
 - Economy
 - Security

<http://impact.gocarbonneutral.org> (University of Hawaii at Manoa)
<https://maps.esri.com/MoraLab/CumulativeChange/>

Warmer temperatures, extreme heat, drought



- Death
- Insufficient water supply
- Loss of agricultural productivity
- Increased water and air pollution
- Forest fires
- Water transportation disruption
- Reduced learning and worker productivity

Sea level rise, extreme rains, floods



- Death, injury
- Loss of homes and infrastructure
- Loss of food supplies and drinking water

Ocean acidification, CO2 in the soil



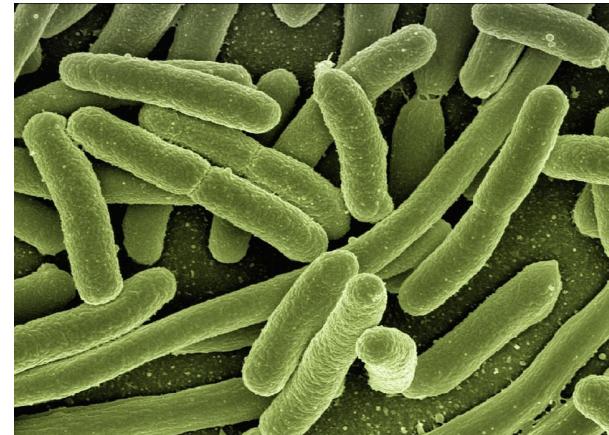
- Reduced growth and survival of commercially valuable marine animals
- Loss of agricultural productivity

Warmer climate, dirty water, more rains

Expansion of transmission season and geographical range (malaria, dengue)



Infectious diseases, including water-borne ones, spread with rising temperature (cholera, diarrhea)



Loss of homes, infrastructure, resources

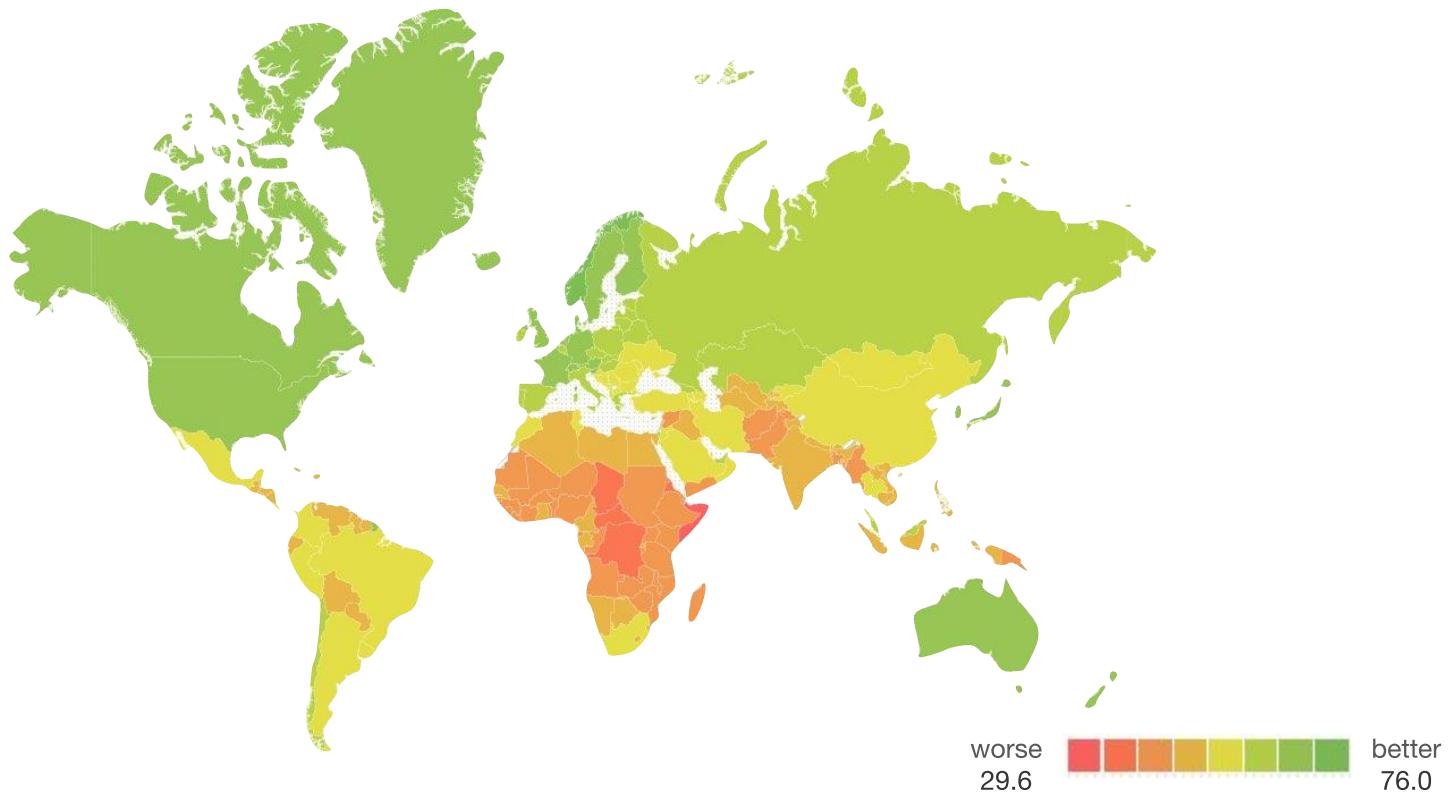
Displacement, migration, poverty



Conflicts, violence

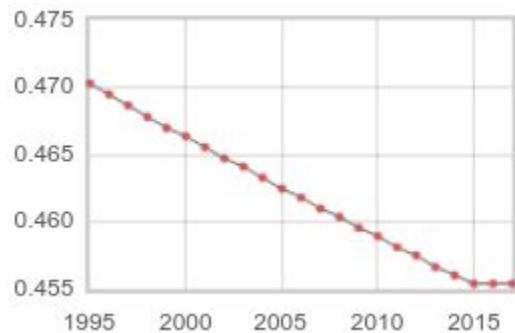


Vulnerability to climate change: ND-GAIN index (2017)

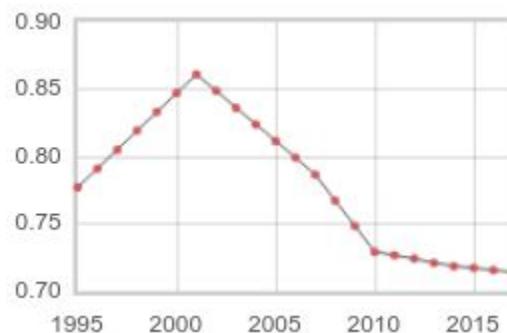


Example: Dem. Rep. of the Congo is most vulnerable

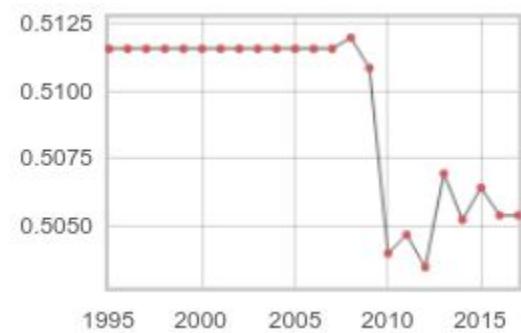
Water



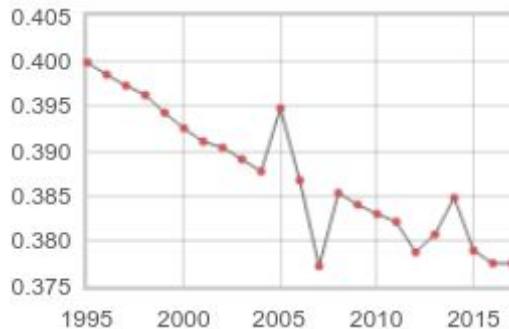
Food



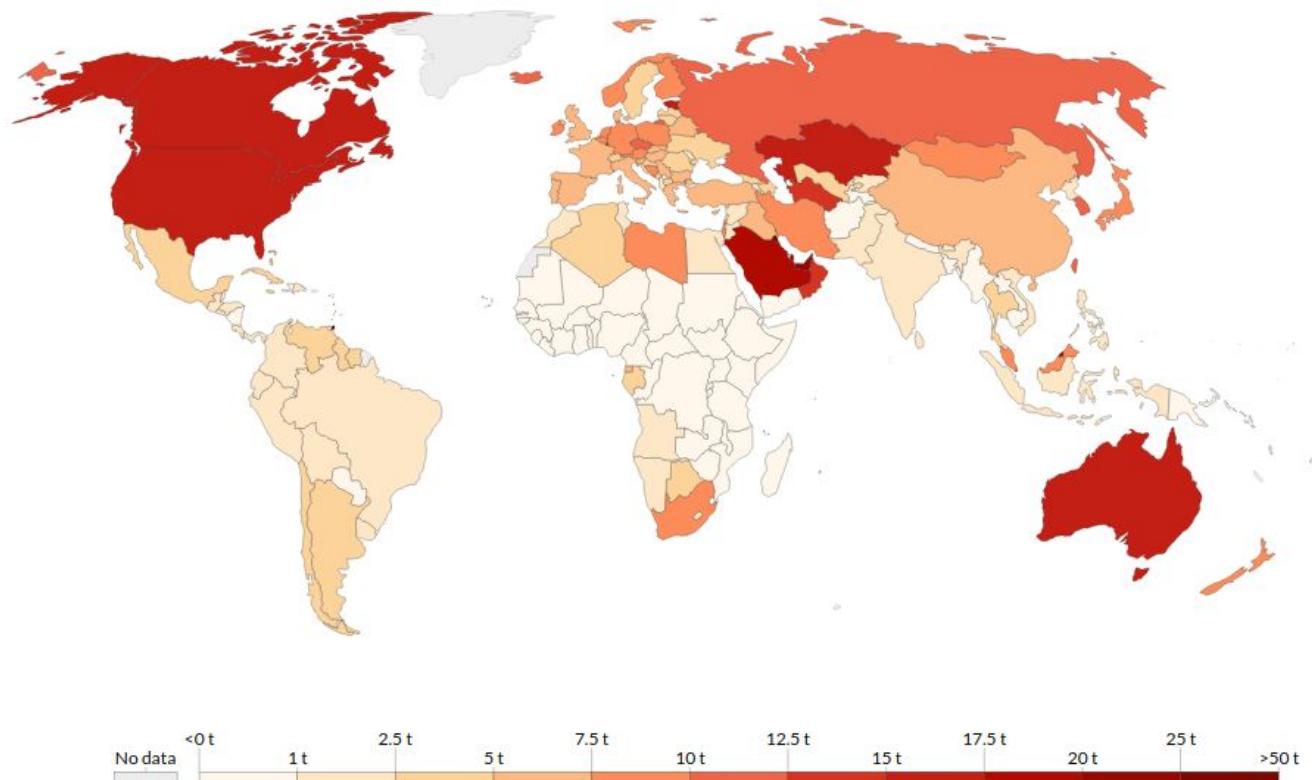
Ecosystem



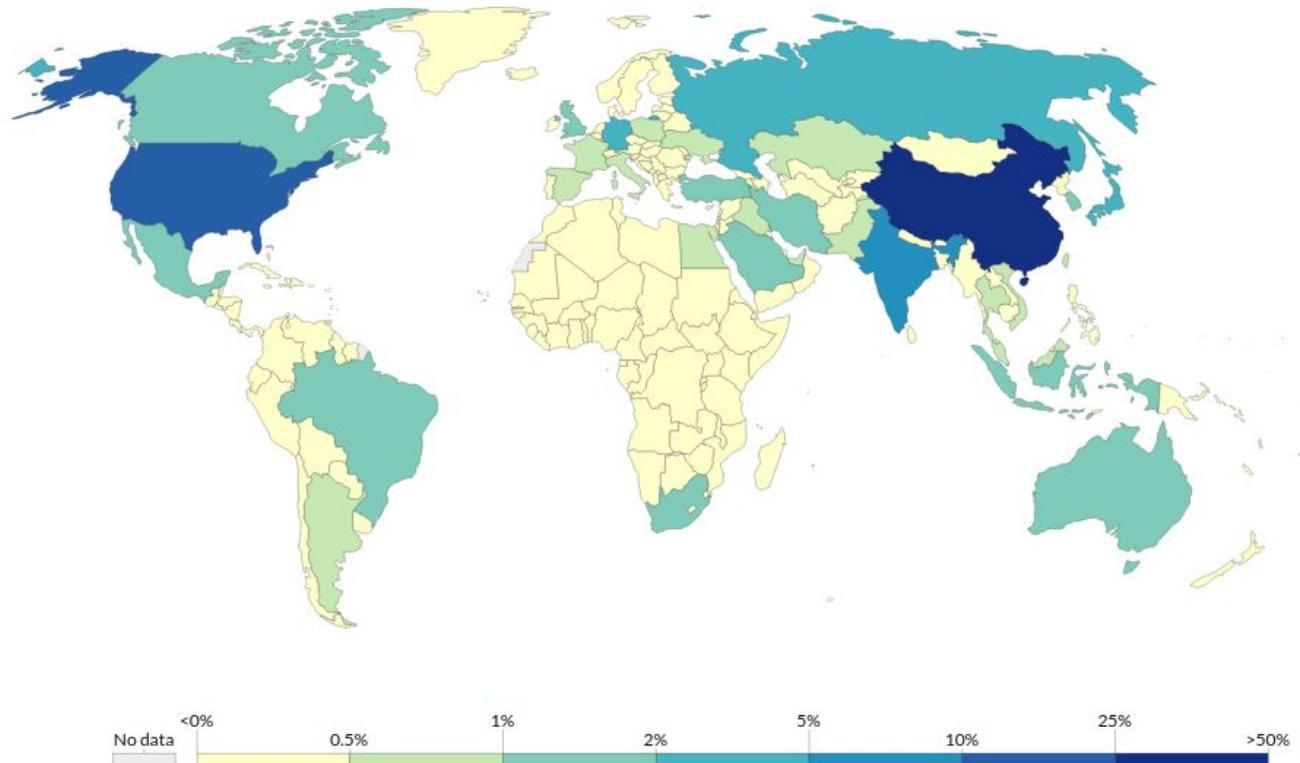
Infrastructure



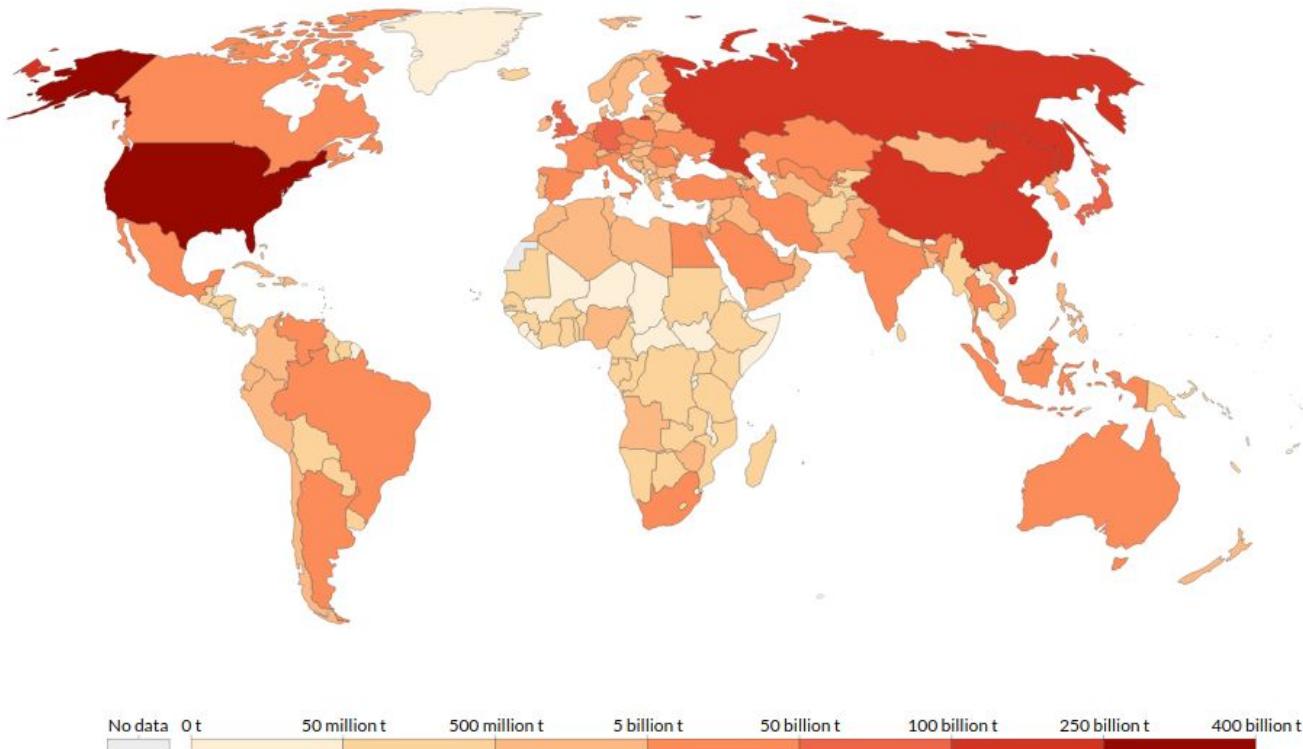
CO2 emissions per capita (2017)



Share of global CO2 emissions (2017)



Cumulative emissions from 1751 to 2017



Proposed solutions

- **Stop fossil fuel emissions**
 - Replace fossil fuels by green energy
- **Change agriculture/fishing practices**
 - Stop deforestation, start afforestation
 - Farming instead of mass production, agroforestry, no fishing zones
- **Remove CO2 from the atmosphere and ocean**
 - Plant trees
 - Bio-energy with carbon capture and storage, direct air capture, ...
- **Adapt to rising temperatures**
 - Build infrastructure (e.g. sea walls)
 - Set up emergency funds

Proposed solutions

Stop fossil fuel emissions



Change agriculture/fishing practices



Remove CO₂ from atmosphere and ocean



Adapt to rising temperatures



Conférence sur les Changements Climatiques 2015

COP21/CMP11

Paris, France

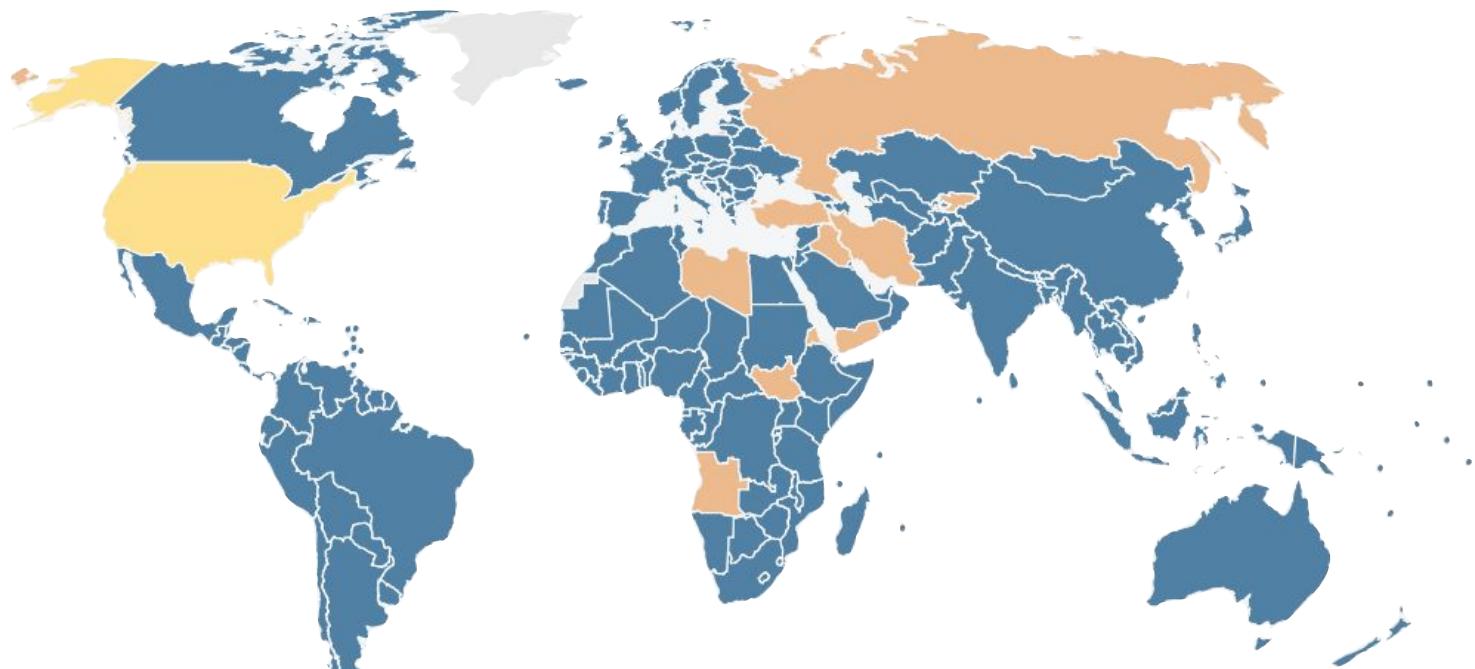


PARIS AGREEMENT 2015

Paris agreement: key points

- Keep global temperature increase well below **2°C**, try to **limit to 1.5°C**
- Achieve carbon neutrality (no increase of greenhouse gases)
- Set goals for each country and review contributions every 5 years
- Developed countries set up “Climate Fund” for developing countries:
at least \$100 billion a year
- Adaptation: reduce vulnerability to climate change, address damage
- Climate change education, public awareness

In Paris agreement: 179 parties, 89% of emissions



- Not Applicable
- Signed Agreement
- Intent to withdraw
- Joined Agreement

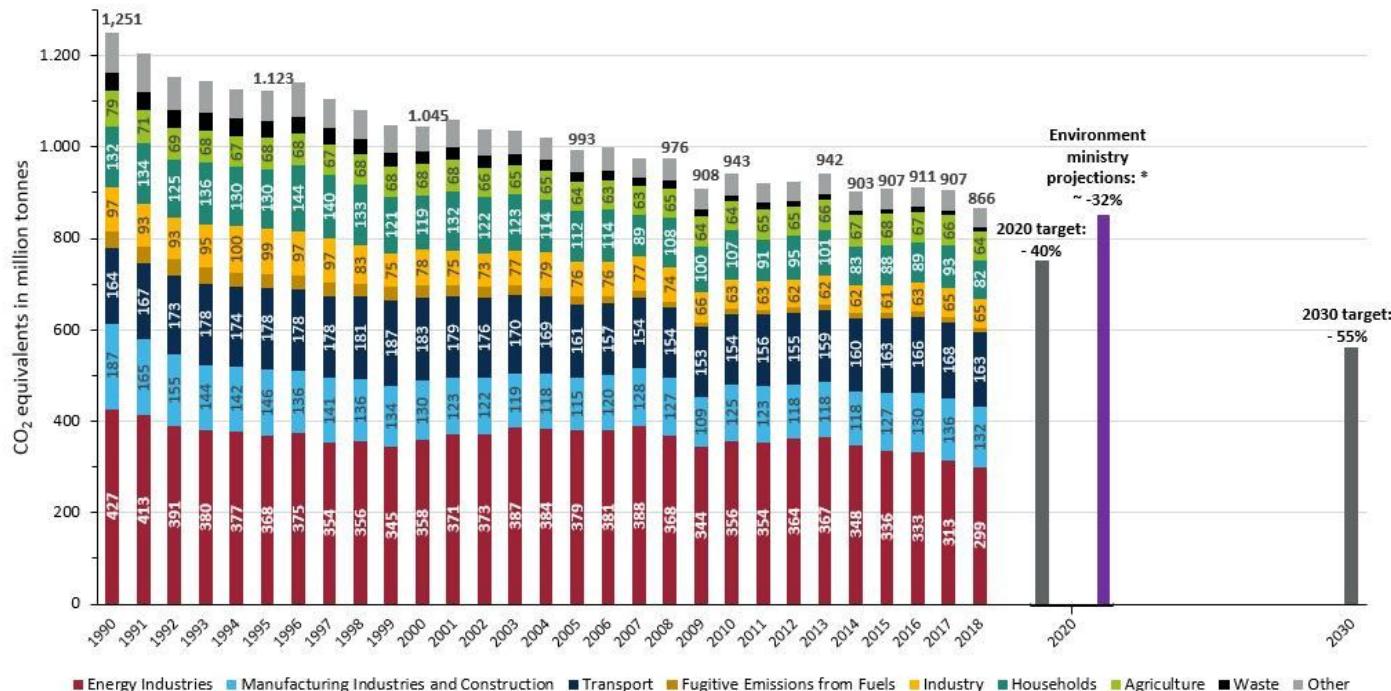
Paris agreement pledges

- Countries submit their goals (pledges)
- There's no penalty for not meeting the goals



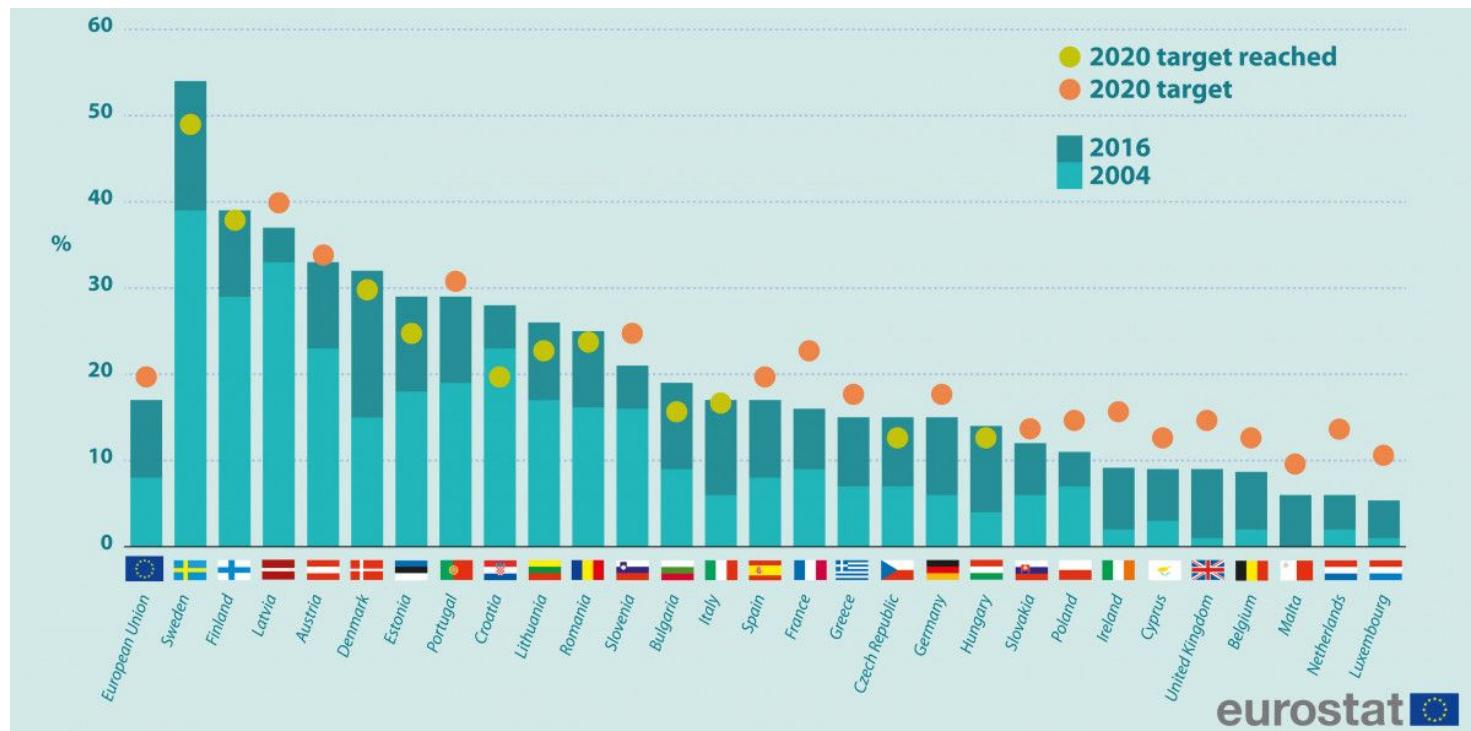
Pledge Submitted
 No Pledge Submitted

Germany misses the goal of 40% emission reduction by 2020

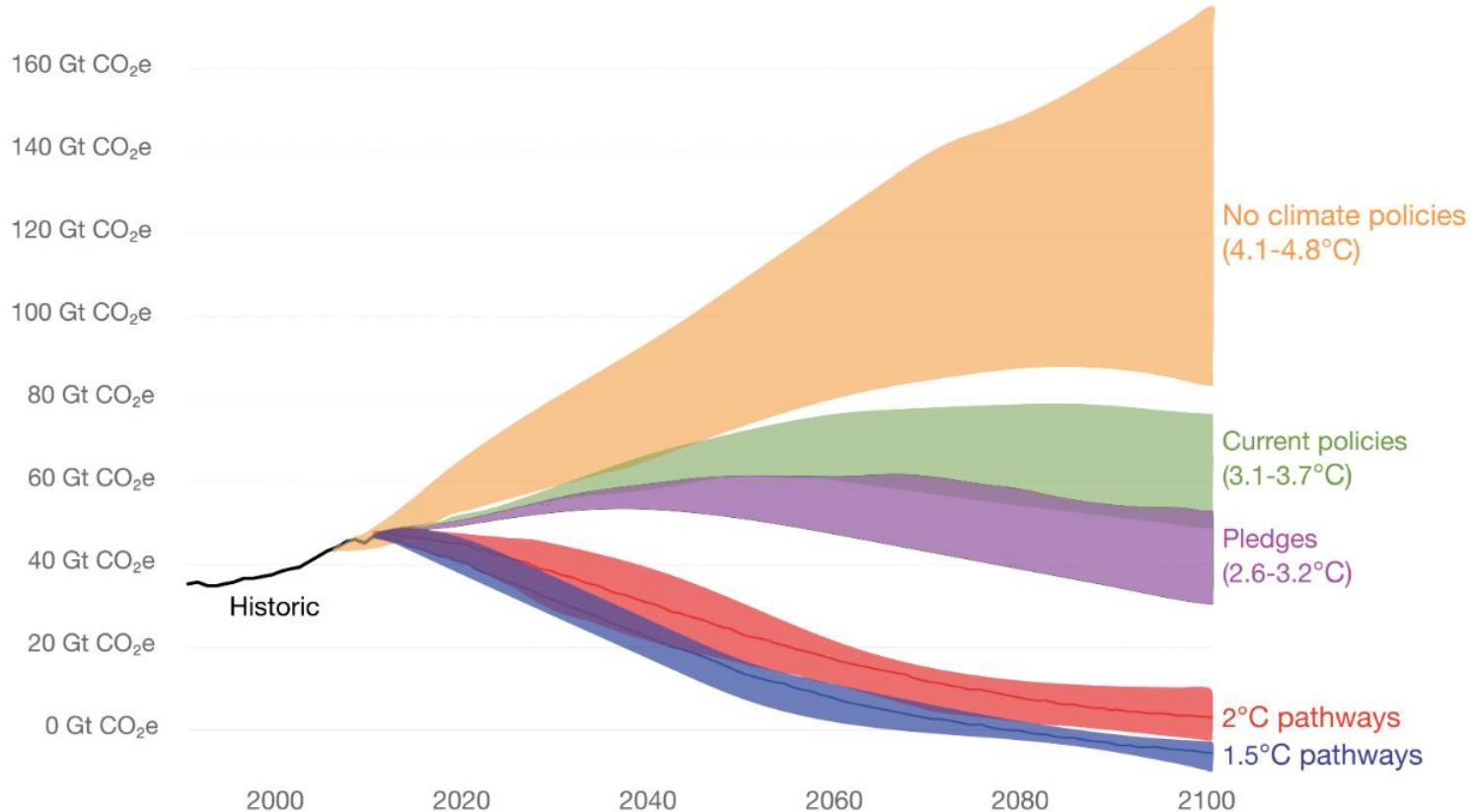


Renewable energy consumption in EU

(% of gross final energy consumption, 2016)



CO2 emission scenarios









<https://www.fridaysforfuture.org/events/map>

FFF demands in Germany

- **Long term:**

- By 2035, Germany should have net-zero greenhouse gas emissions
- By 2030, Germany should cease all coal mining
- By 2035, all of Germany's energy should come from renewable sources

- **Till the end of 2019:**

- Cut government subsidies for fossil-fuel energy sources
- Shut 1/4 of German coal power plants
- Introduce tax on CO2 emissions, 180 Euro per CO2 tonne

How to reduce individual carbon footprint?

Germany 2014
11 tonnes per capita
per year

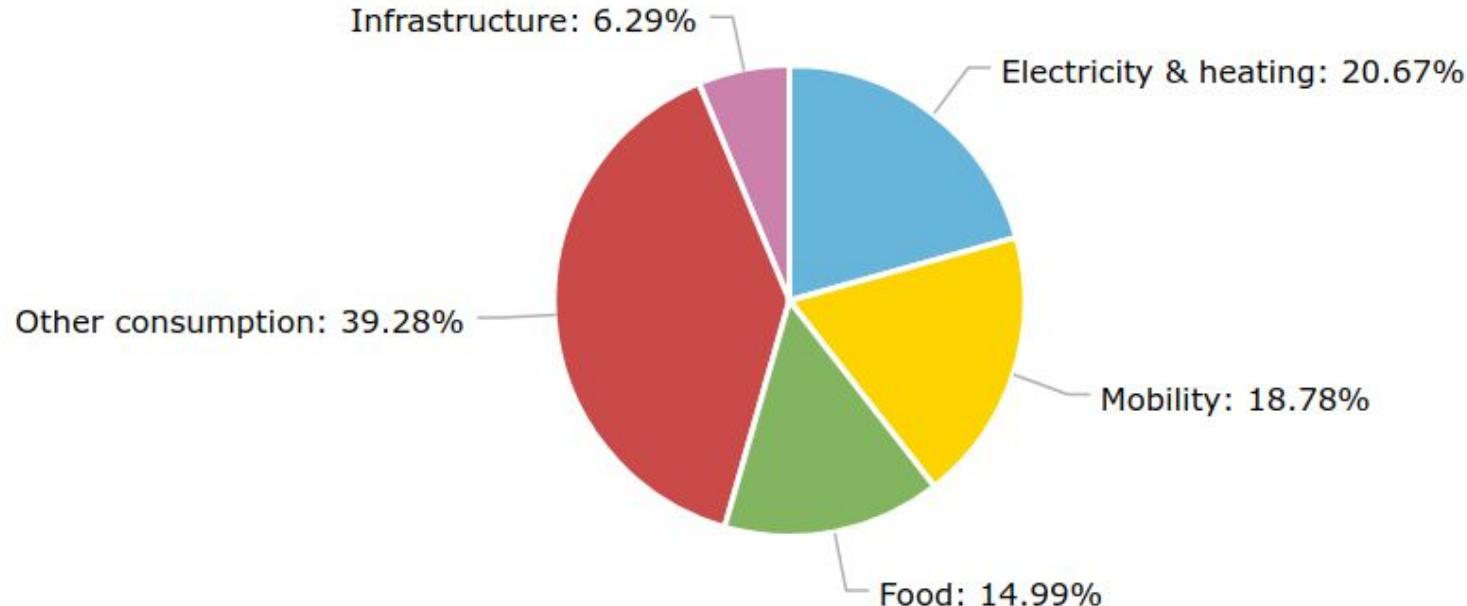


Globally 2050
2 tonnes per capita
per year

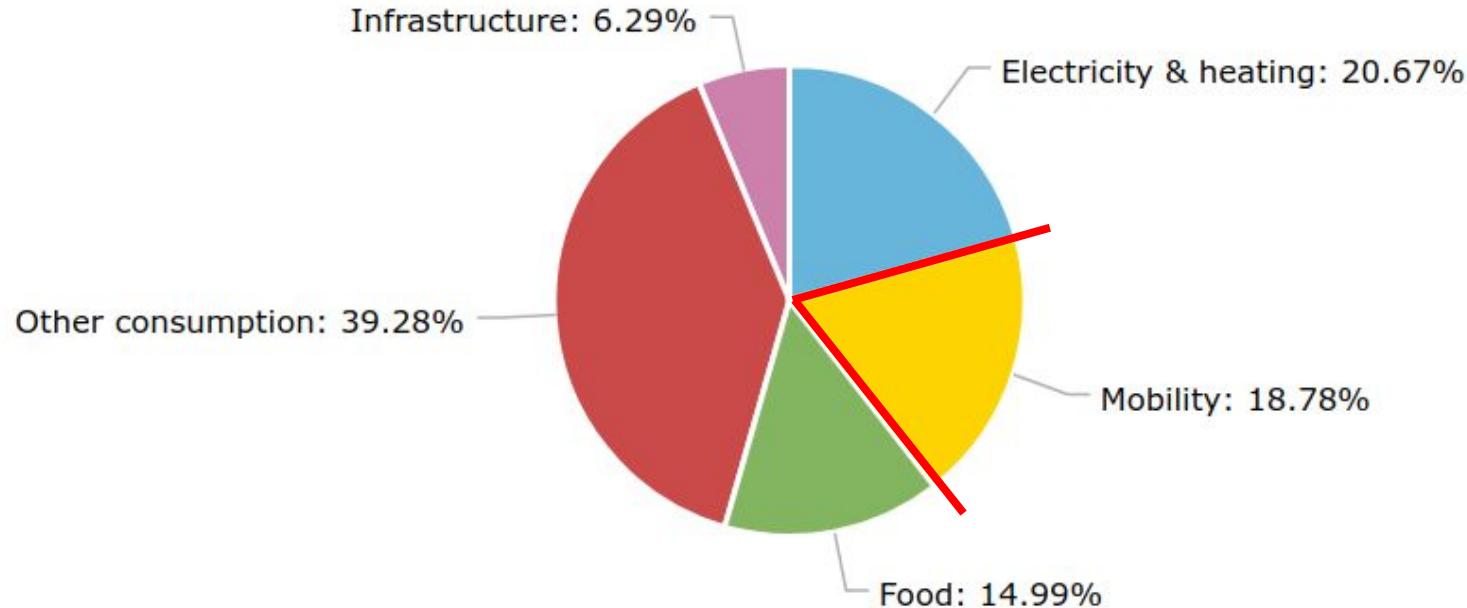


Calculate your CO2 footprint:
<https://offset.climateneutralnow.org/footprintcalc>
<https://uba.co2-rechner.de>

Average individual CO2 footprint in Germany

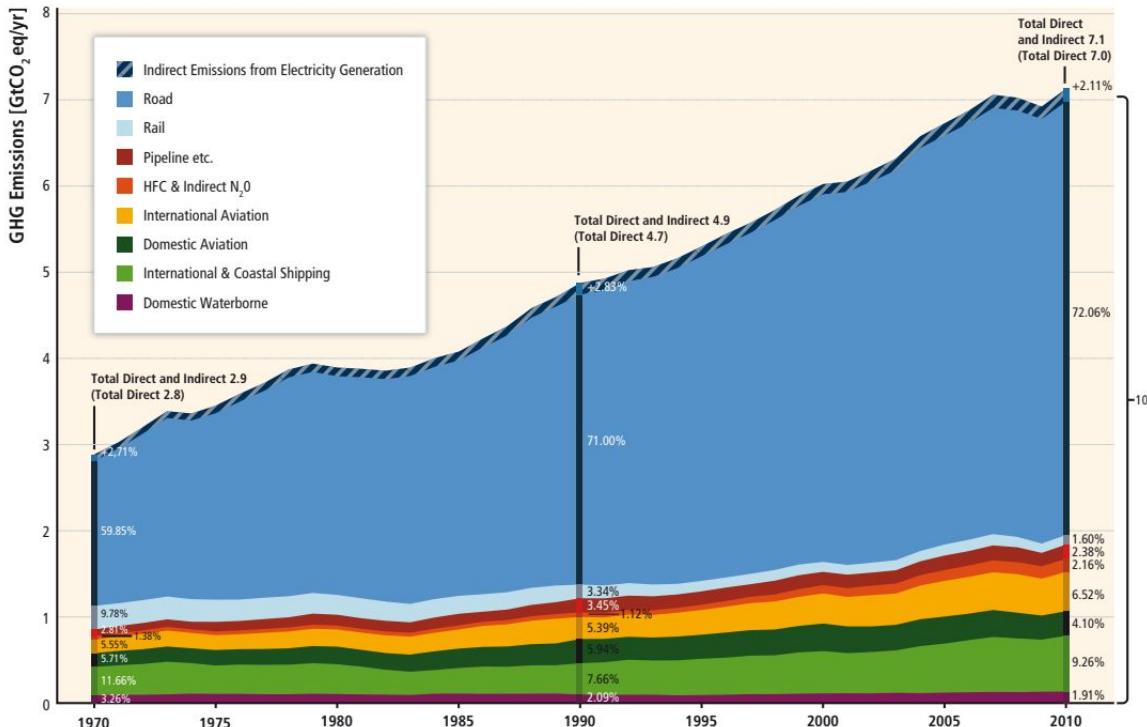


Mobility



Transportation

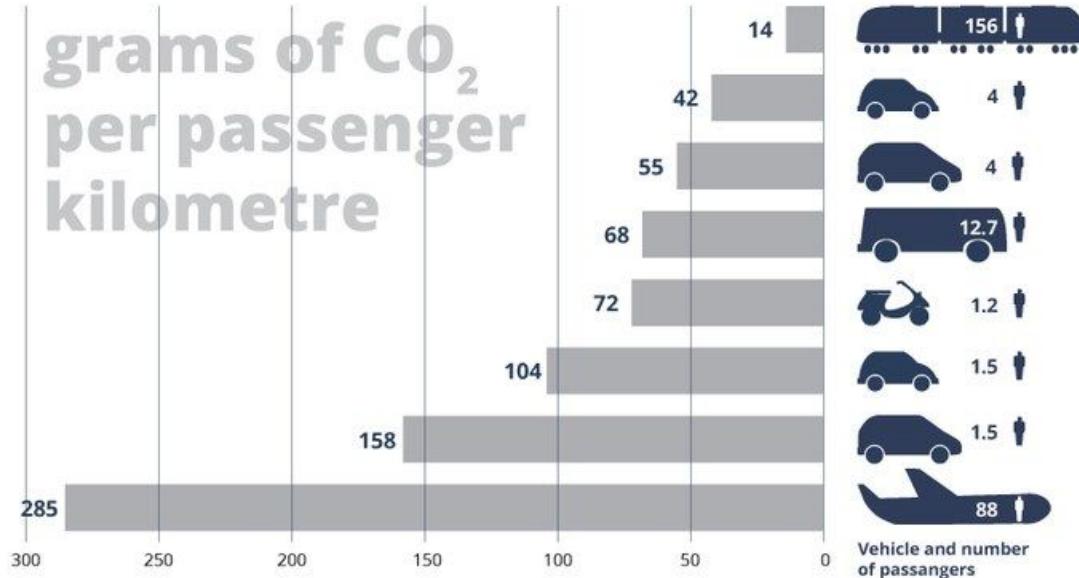
23% of total energy-related CO₂ emissions + indirect emissions of manufacturing of vehicles, infrastructure, etc.



**Which ways of traveling leave the least
carbon footprint?**

🚲 Travel

grams of CO₂
per passenger
kilometre



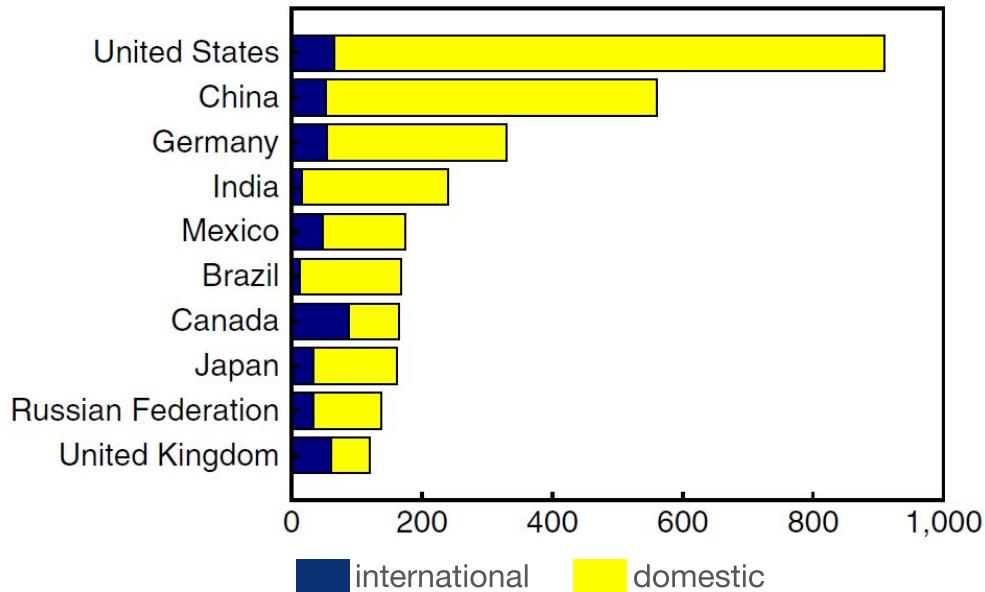
European Environment Agency, 2014

Carbon dioxide (or equivalent) emissions for one-way trip
in kilograms per passenger



IFEU <http://www.ecopassenger.org>

Tourism - 8% of global CO2 emissions and growing



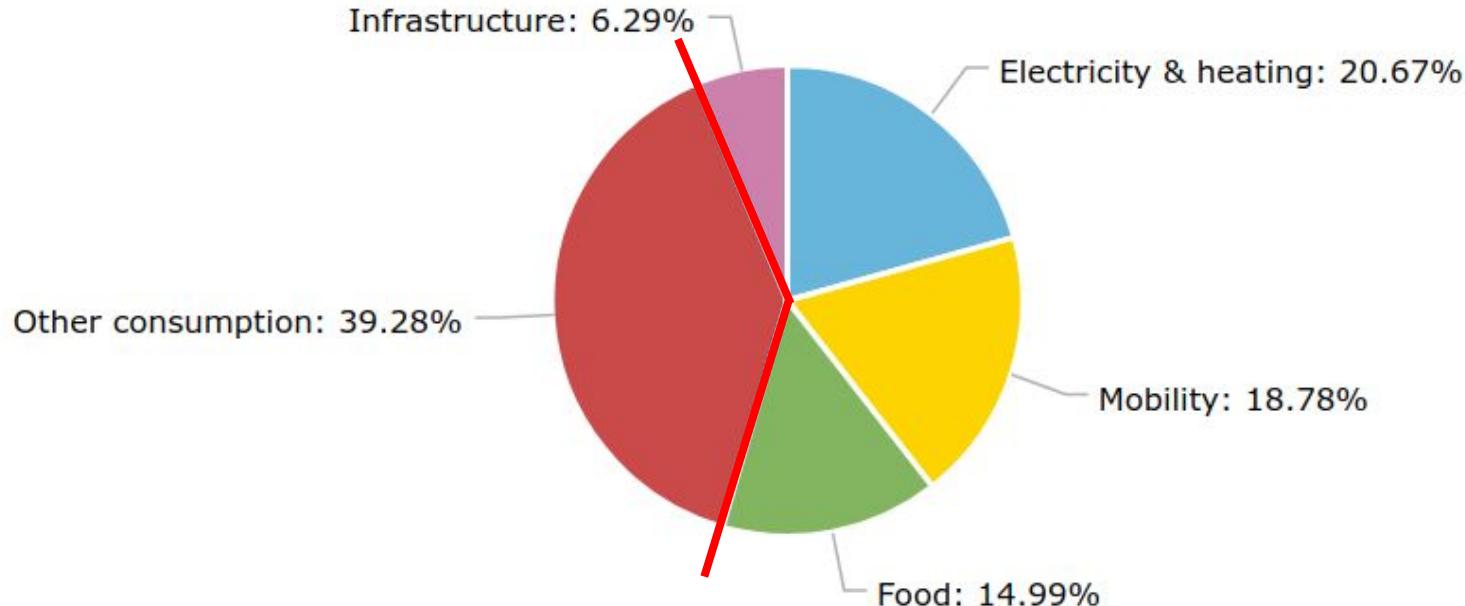
> 50% of emissions caused by tourism are related to **transportation**

Residence-based total CO2 footprint (MtCO2), top-ranking countries (2013)

Travel - what can we do?

- Travel less
- Fly less
- Drive less
- Use transportation powered by green energy

Other consumption



Shopping - what can we do?

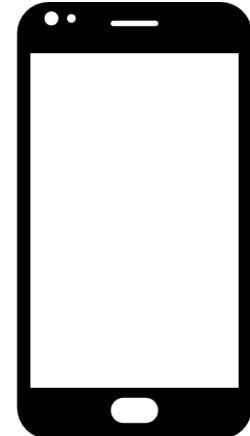
- Buy:
 - local (freight transport ca. 45% of total transport energy, biggest impact - last kilometers)
 - environmentally friendly manufactured
 - second hand
 - long lasting things
- Repair instead of buying

🛒 Shopping - IT sector

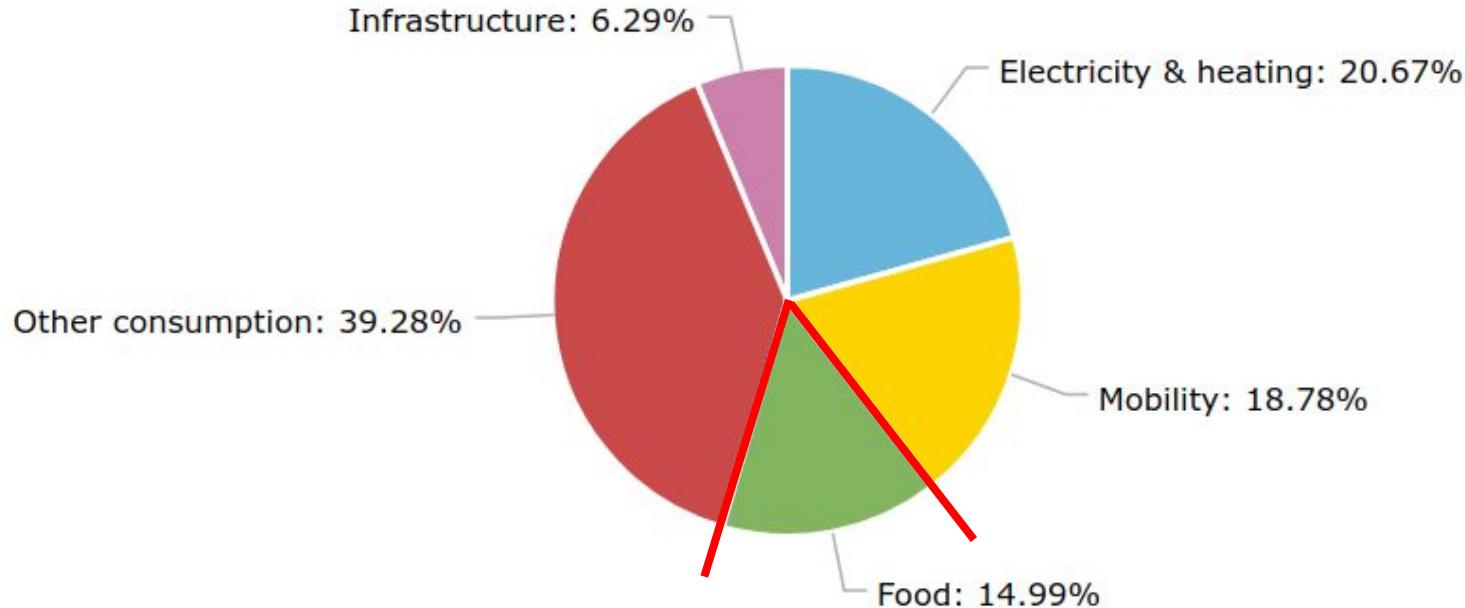
- CO2 footprint of devices like PCs, laptops, monitors, smartphones, tablets **> 2.5%** of global emissions in 2017 and rapidly growing (14% by 2040)

CO2 footprint increase from 2010 to 2020

Smartphones	735%
Data centers	310%



Food

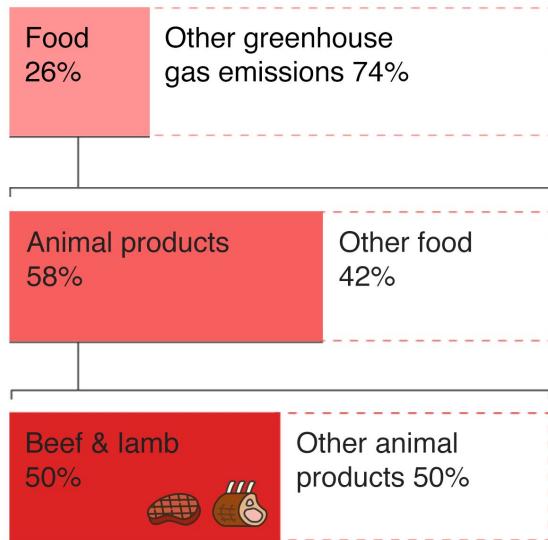


**Which food products leave the most
carbon footprint?**

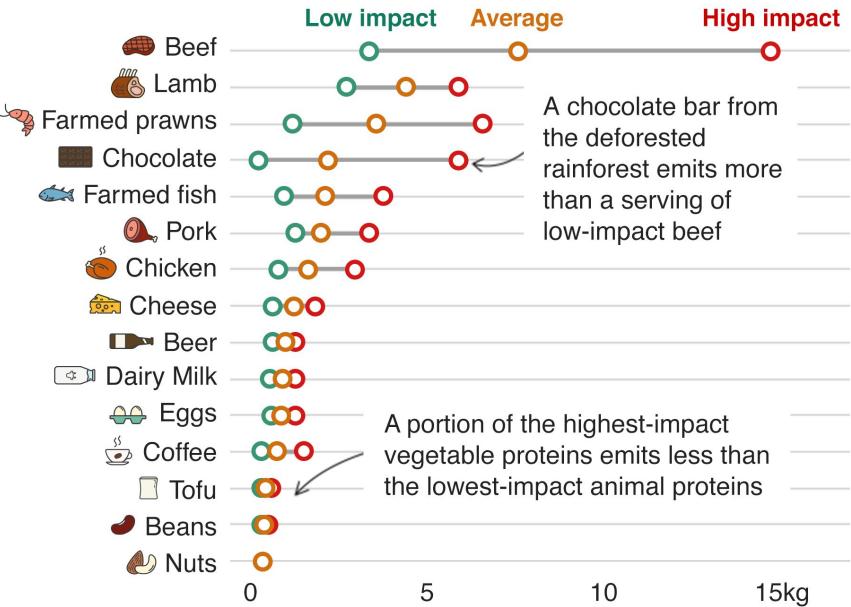


Food

CO₂ emissions from food



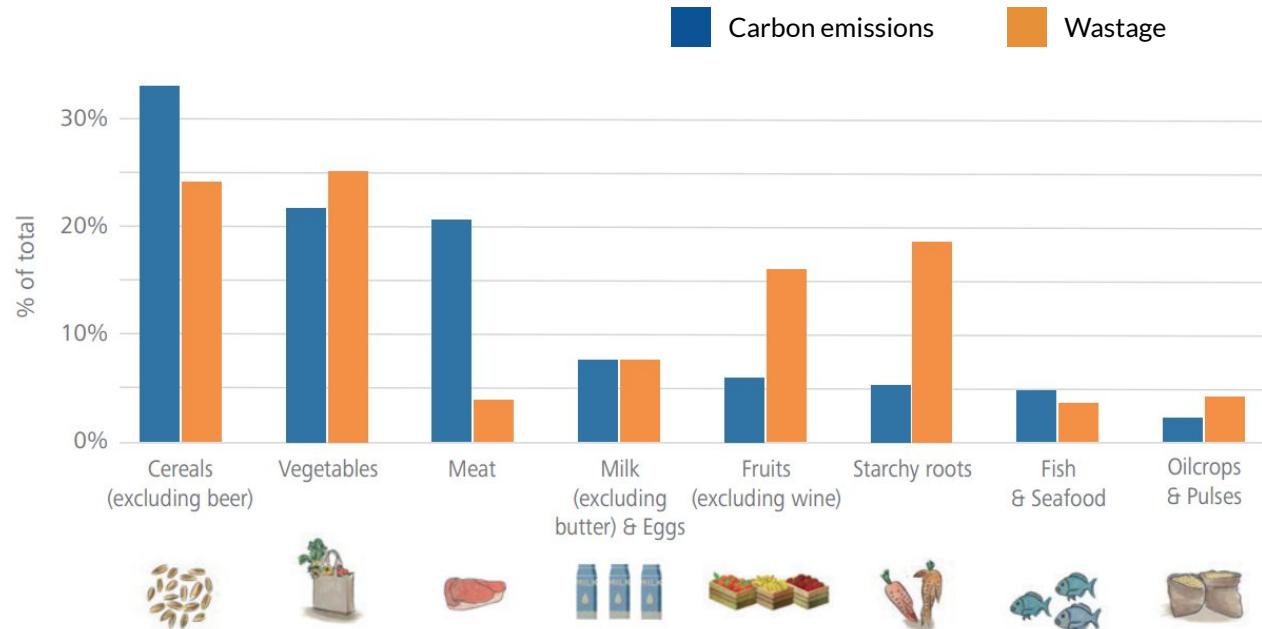
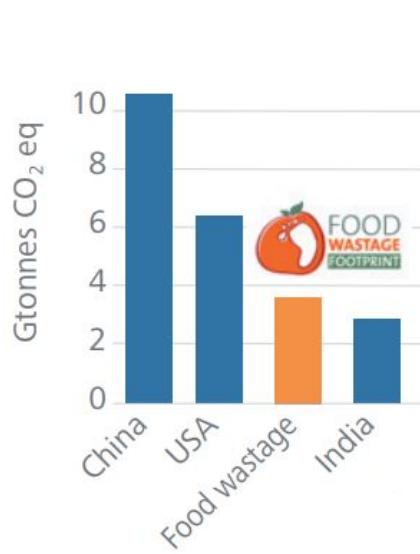
Kg of emissions per serving





Food waste

Waste - **5%** of global emissions, food waste - **44%** of waste emissions



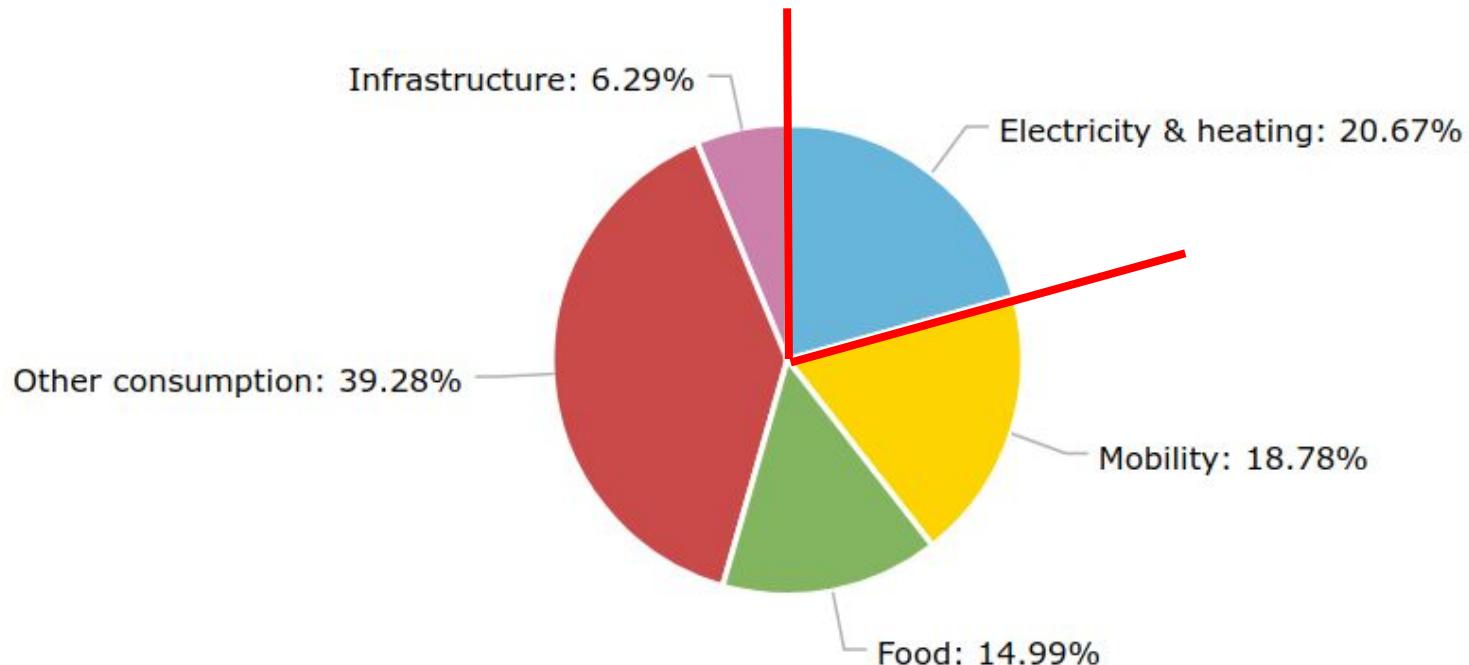


Food - what can we do?



- Eat less meat
- Buy local
- Choose diet with less carbon footprint
- Don't waste food

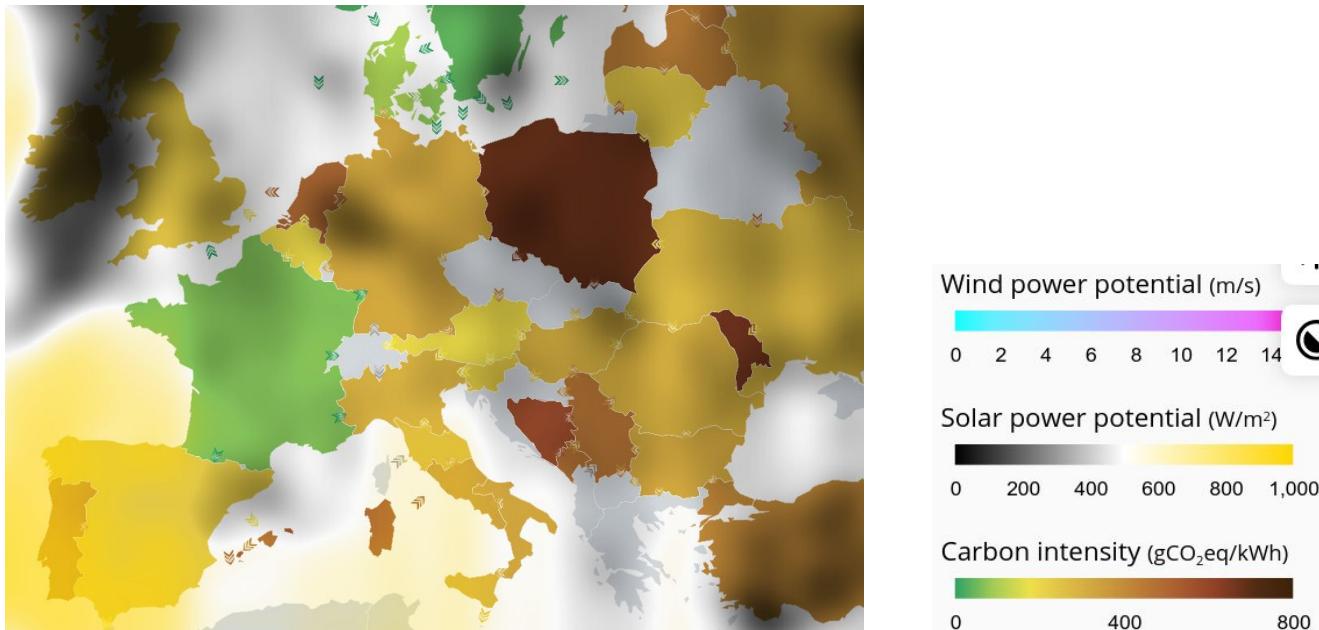
Electricity & heating





Electricity and heating

42% of global CO₂ emissions



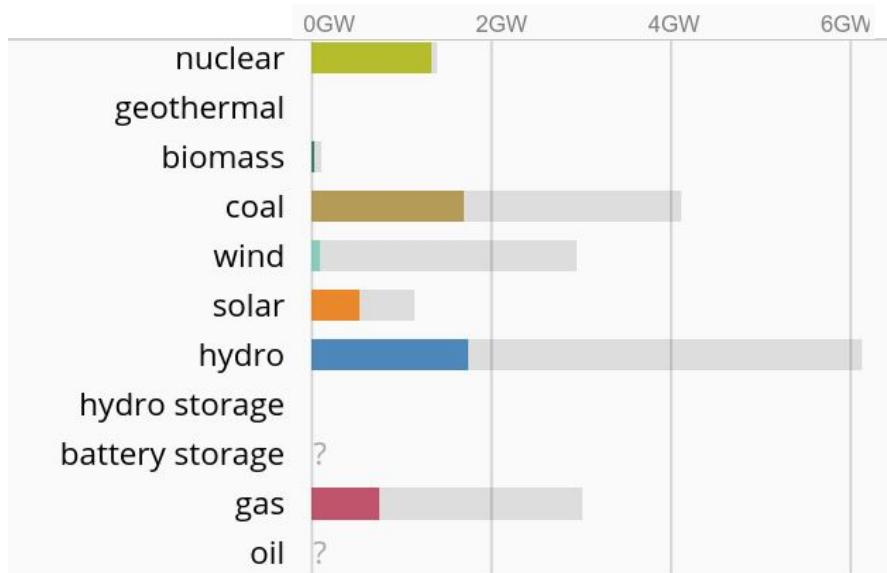
**Which energy source produces the
most carbon emissions?**



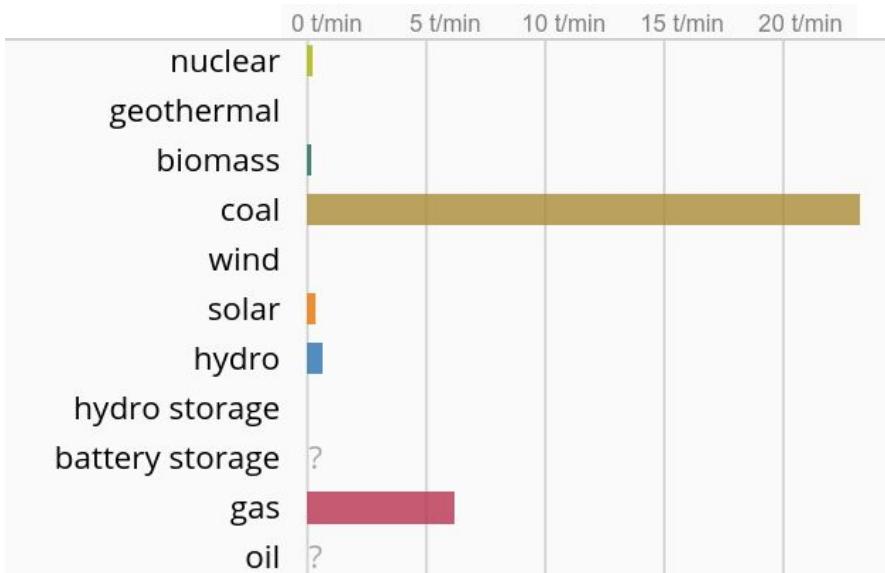
Electricity and heating

Germany, 24 hours

consumption



CO2 emissions





Electricity and heating - what can we do?



- Employ green electricity providers (Ökostrom)
- Save energy (use less electricity, heating, water)
- If we own a house, insulate it, install solar panels



Investment - what can we do?



- “Green” banks (Ökobanken)
- “Green” pension funds
- ...

What is carbon offsetting?



Carbon offsets

Financial contributions to projects reducing CO₂ emissions that are made in order to compensate for emissions made elsewhere.

Typical projects:

- Planting trees
- Supporting renewable energy
- Methane collection from farms, landfills, industrial waste
- Energy efficiency (e.g. passive buildings, low-energy lightbulbs)
- ...



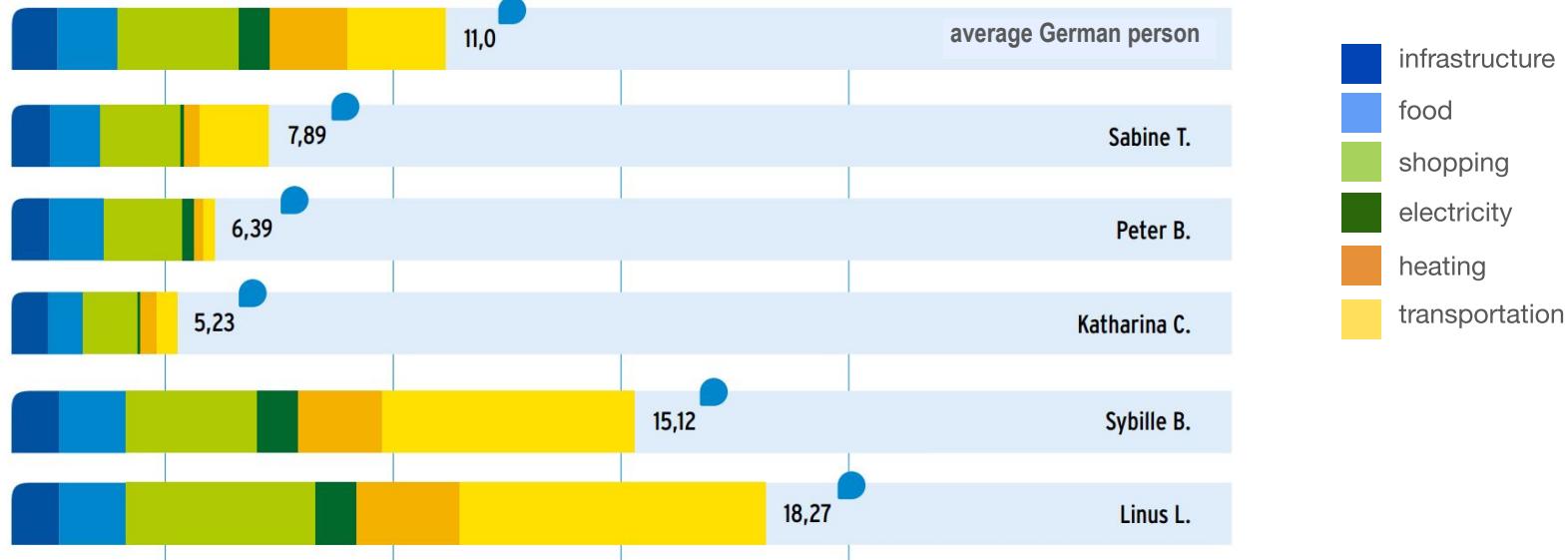
Carbon offsets

How to choose a project:

- How can the project impact be evaluated?
- Would the project occur anyway without selling carbon offset credits?
- Does the project cause higher emissions/other side effects outside its boundary?
- Does the project permanently reduce emissions?
- Are there other benefits in addition to the carbon emissions reduction?
- Certification: Quality Assurance Standard

Lifestyles and carbon footprint

CO2 emissions per person





Activism - what can we do?

- Participate in protests (<https://www.fridaysforfuture.org/events/map>)
- Vote for environmentally conscious politicians
- Influence our organization
- Educate ourselves and our colleagues/neighbours/family/friends (IPCC reports, <https://skepticalscience.com>)

Upcoming events





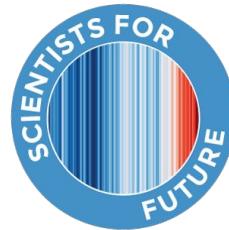
Changes are needed on the level of

- global politics
- countries
- organizations
- individuals

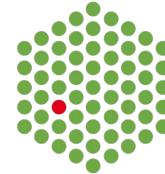


Our hearty thanks for

feedback and promotion to colleagues and friends from



EMBL



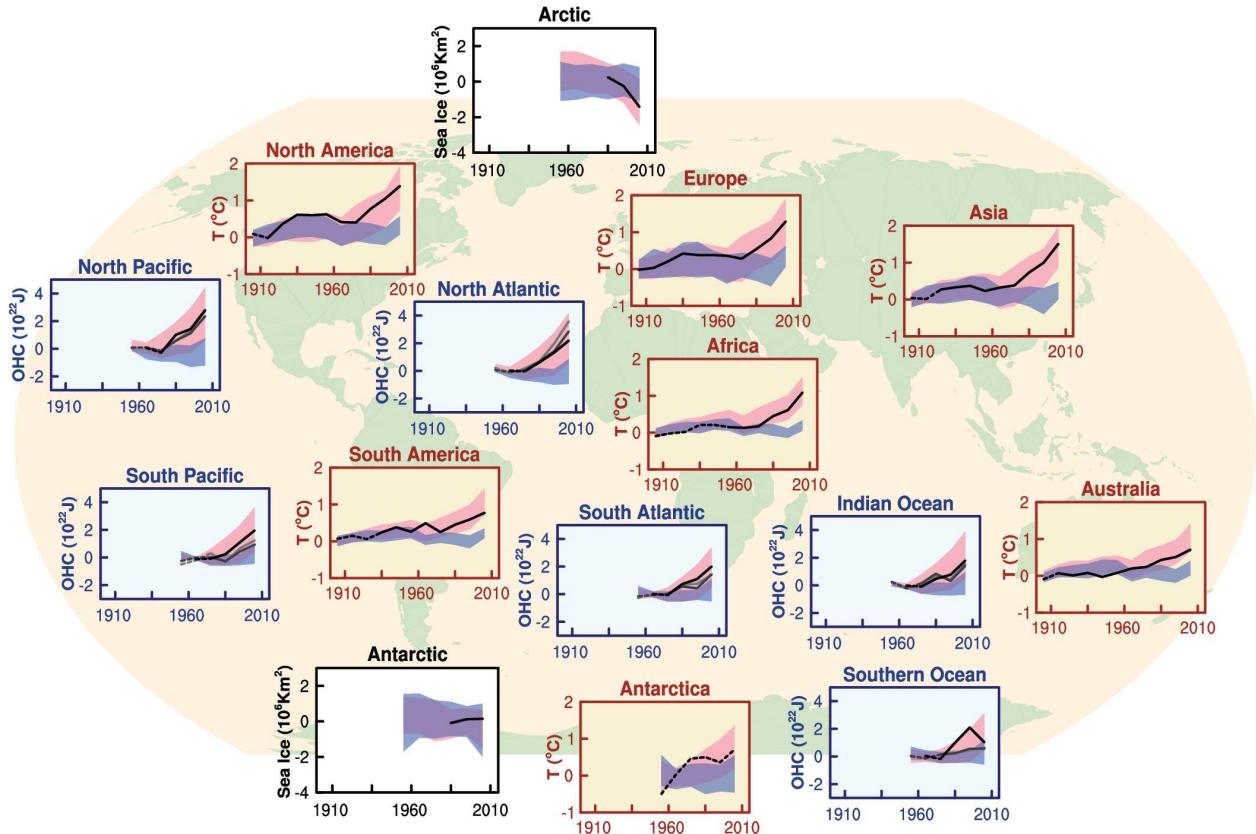
UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

role game materials to



Backup slides

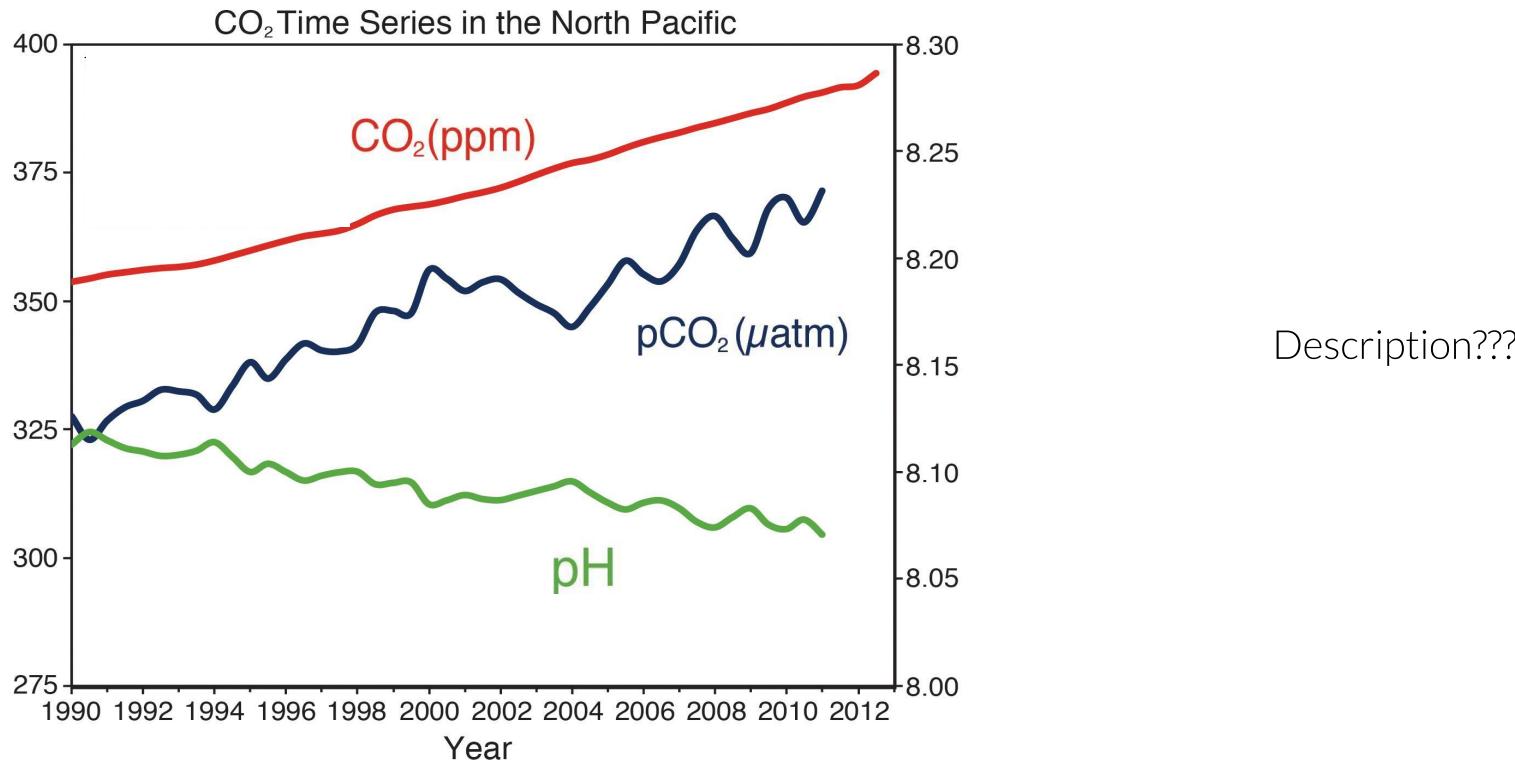
Attribution of climate change to anthropogenic activities



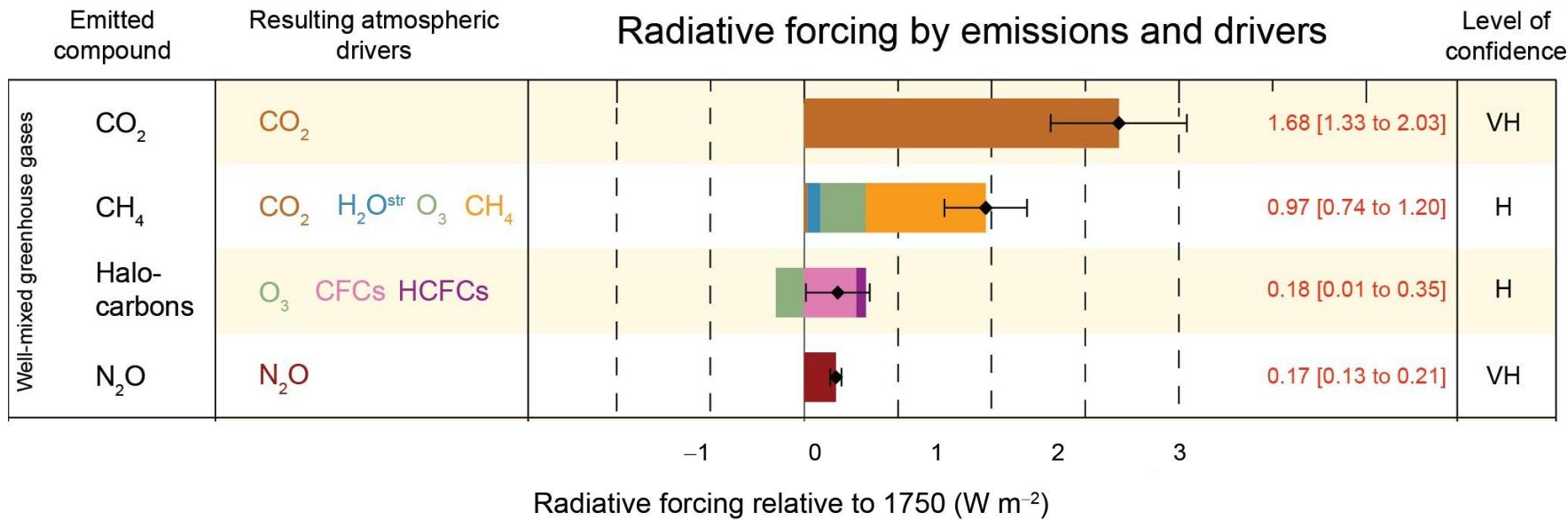
≡ Observations

Models using only natural forcings
Models using both natural and anthropogenic forcings

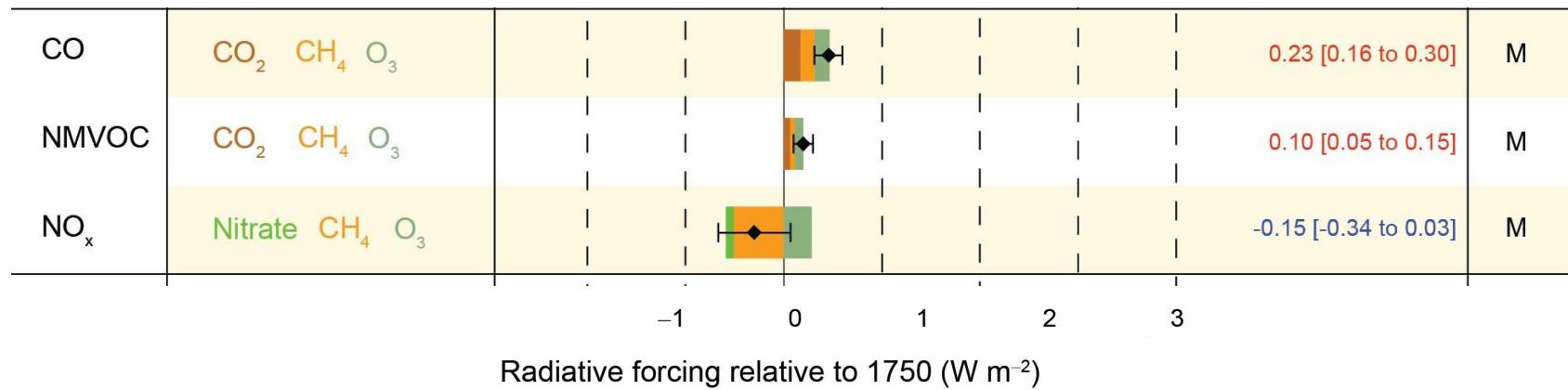
How do we know it is anthropogenic CO₂ ?



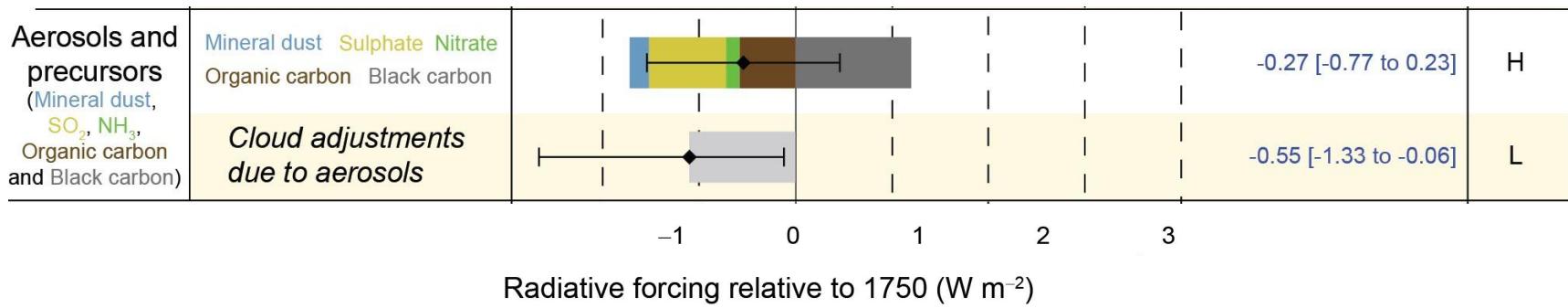
Forcing through well mixed GHGs



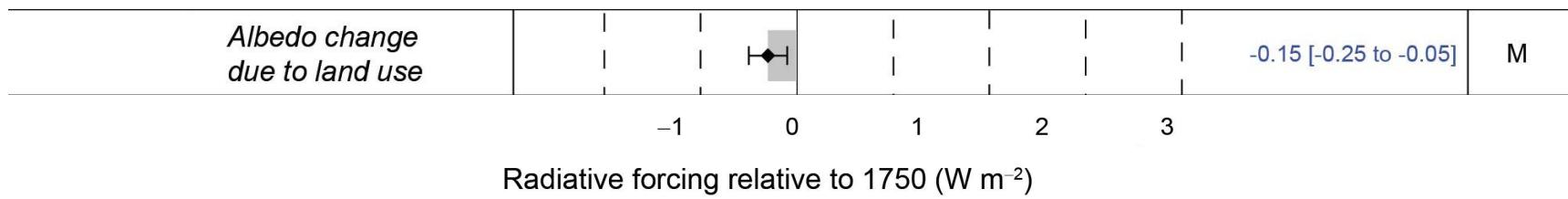
Forcing through short lived gases



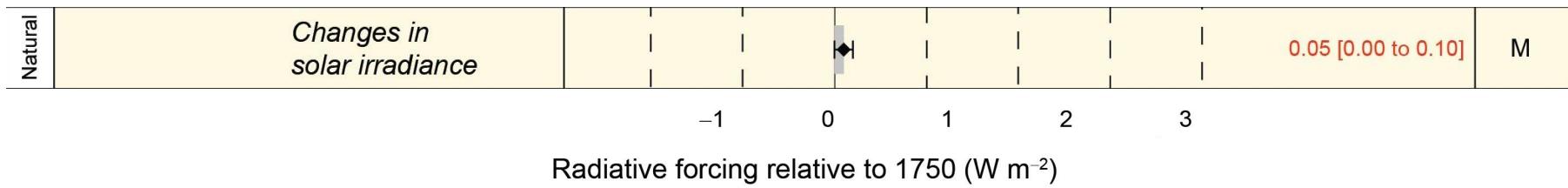
Forcing through aerosols



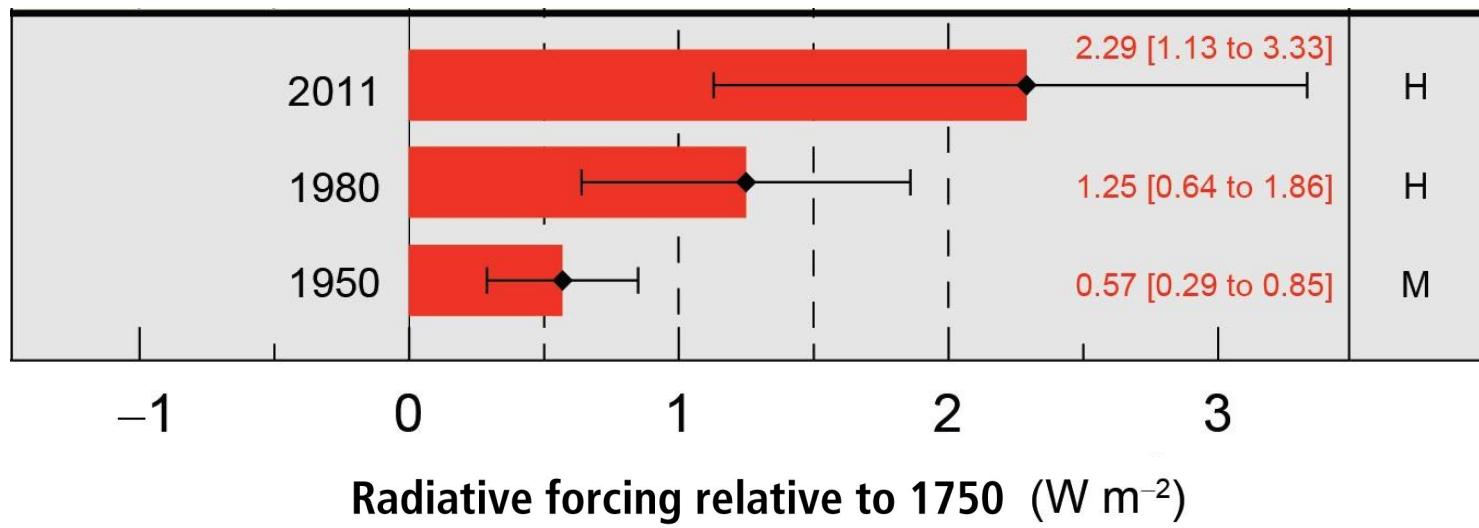
Forcing through land use change



Forcing through natural influence



Total *anthropogenic* radiative forcing



Climate change and anthropogenic activities

