Klima og fremtiden

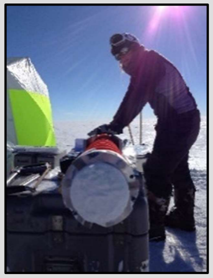
- *Frokost inkluderet*
- *Kaffe I nærmeste the køkken - venligst efterlad som fundet*
- *Kantine og udgang ved -1*
- *Toilet ved siden af køkken*

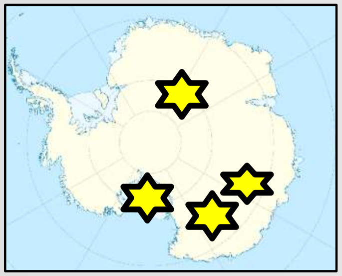
Helle Astrid Kjær
Is og Klima, Niels Bohr Instituttet
Københavns Universitet
https://helleastridkjaer.com/

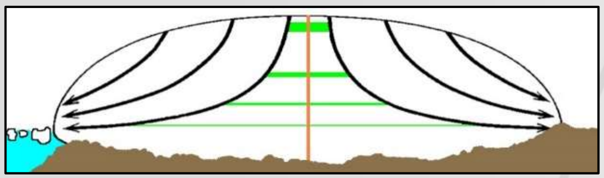
Helle Astrid Kjær

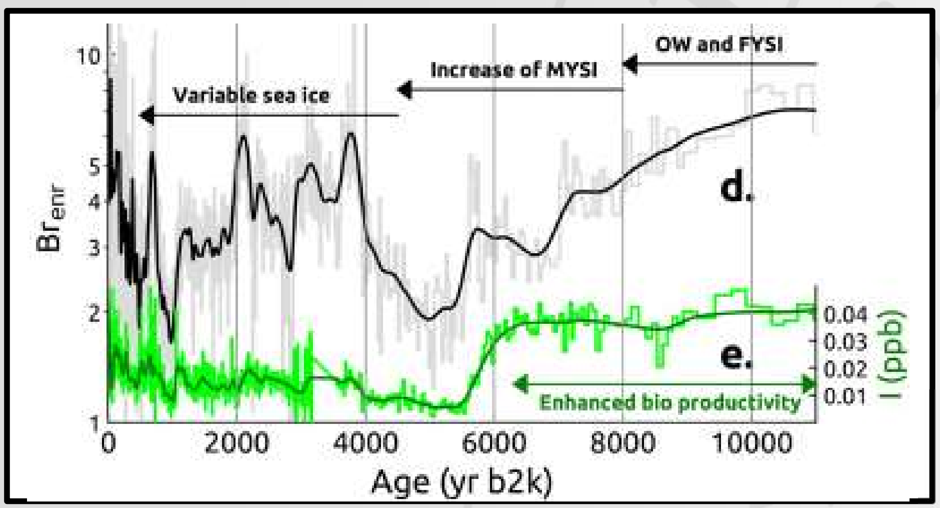
Hellek@nbi.ku.dk

Associate professor
Niels Bohr Institute









Primært arbejde med iskerner

Kontinuert kemisk analyse, som kan informere om havis, skovbrænde, tørke, storme med mere

PhD: syre I iskerner
MSc: fosfor

2015-2019 Postdoc I havis foranringer.

2019-2024 focus på Tipping points I klimasystemet

2020-adjunct at UTAS

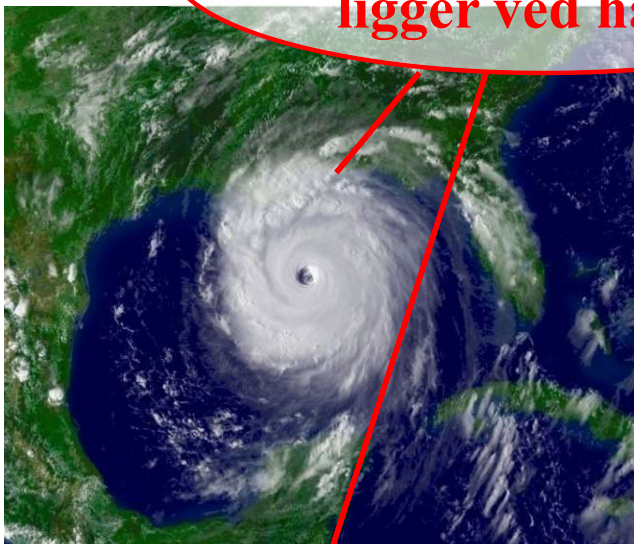
2024-present Havis og tipping points

Hvilke klimafaglige termer kender i?

https://www.mentimeter.com/app/presentation/alvusjpsefvzizs1zc2dd68ghon632wf/edit?question=rtqdswwwqzwb

Hvorfor er det vigtigt at lære om klimaet allerede i folkeskolen?

75% af verdens megabyer ligger ved havet!

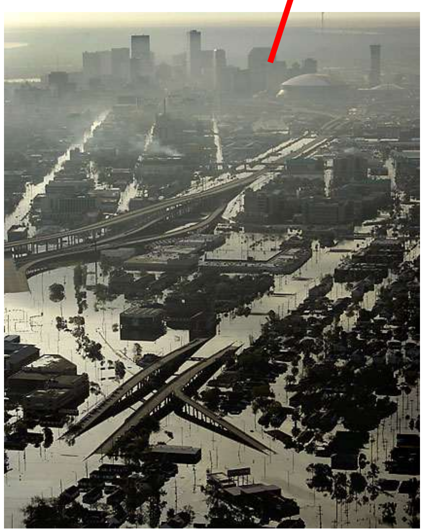


Orkaner

Stigende havniveau

Smeltende havis

Hvorfor er klimaet vigtigt?



Oversvømmelser

Skovbrand

Tørke

Gletcher smeltning

Program

- Klimasystemet
- Observationer
  - Sidste 150 år
- Klima modeller
  - Klimaatlas
- Geo engeneering
- Kryosfæren
  - Øvelse og lab rundvisning

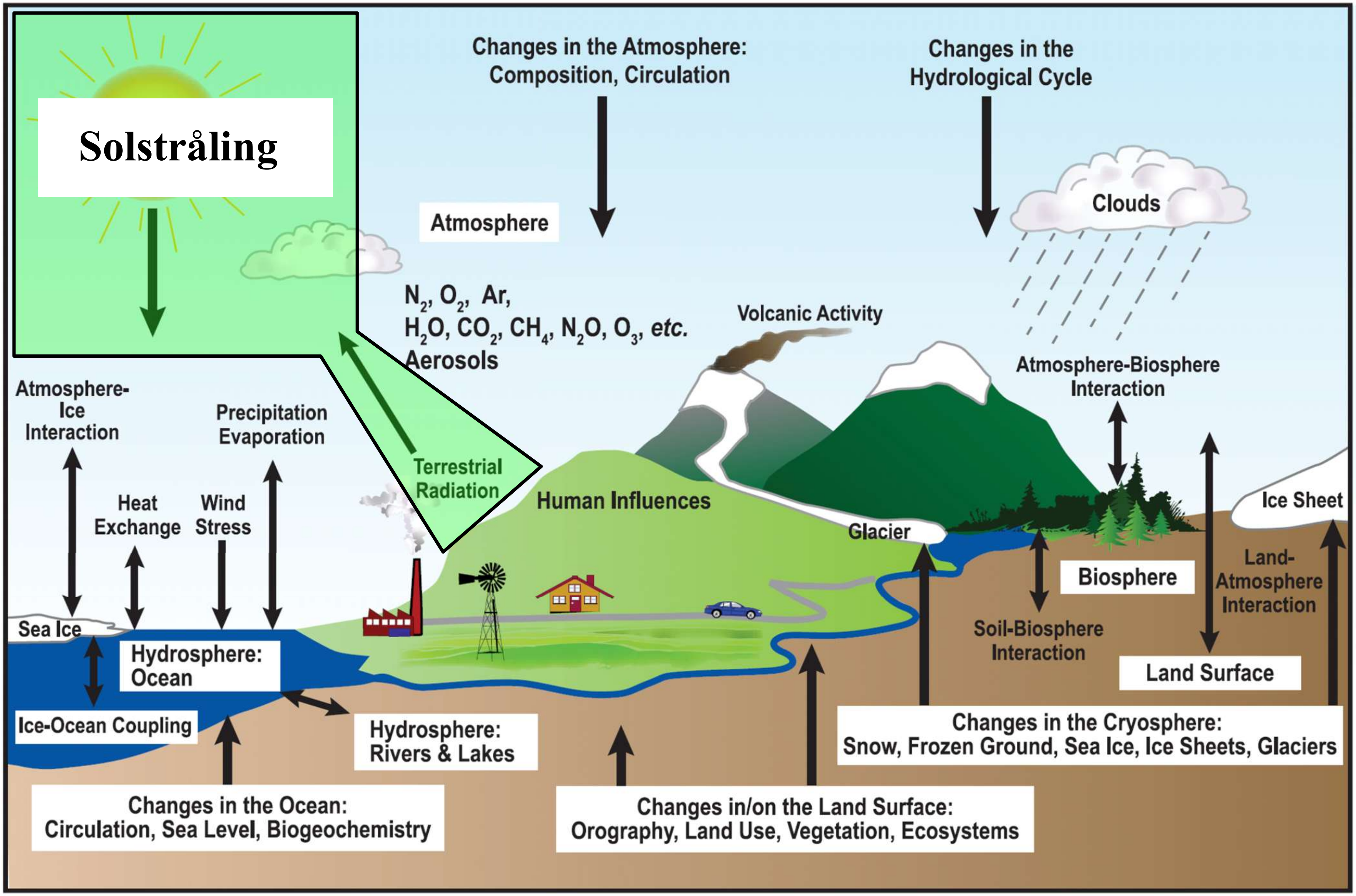
- P2F
- IPCC og COP
- Case study Island og kunst
- Tipping points og AMOC
- Metaforer og klima undervisning
- Egen undervisning

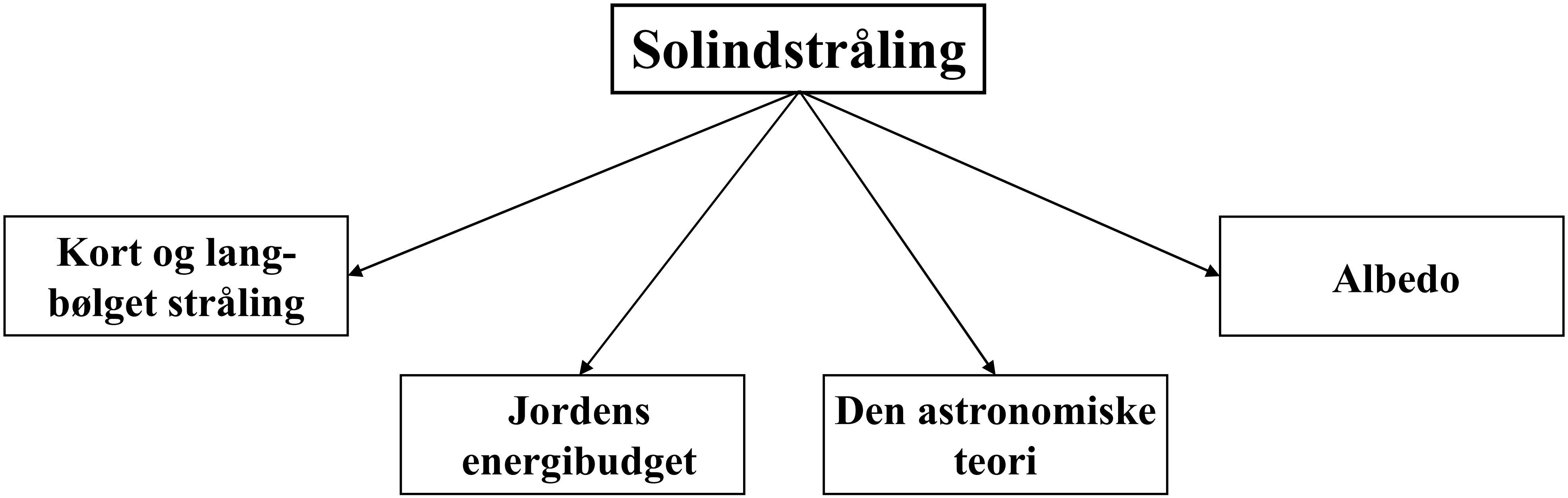
- CLUVEX
- Egen undervisning
- Klimabekymringer
- Feedback og farvel

Klima systemet

- 15 min tegn jeres eget klimasystem

Hvad ved vi om Klimasystemet?

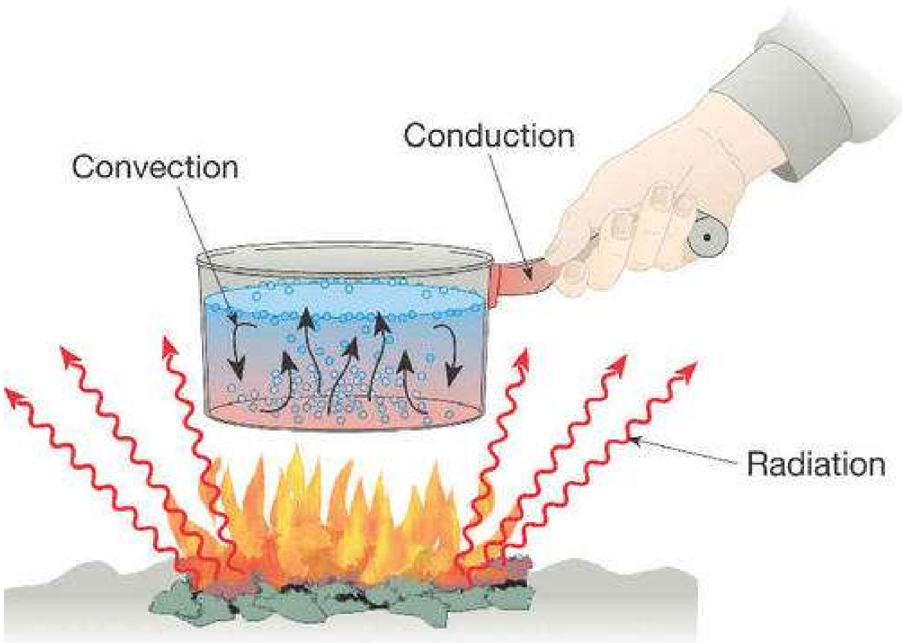



Solindstråling
Kort og lang-bølget stråling
Jordens energibudget
Den astronomiske teori
Albedo

Kort og langbølget stråling

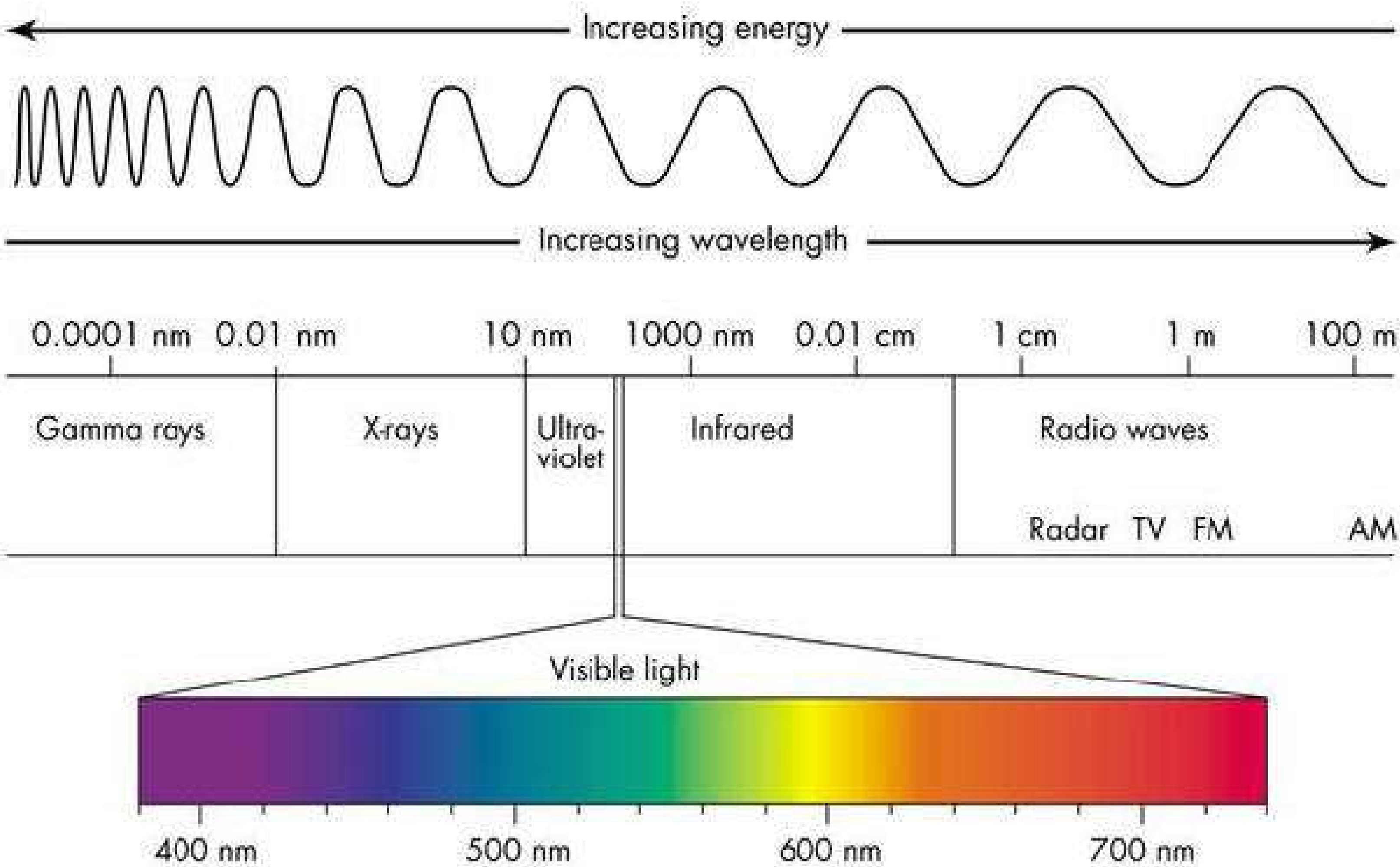
Alle objekter med temperatur større end absolut nul, udsender stråling!

’Temperatur’ skyldes bevægelse af atomer



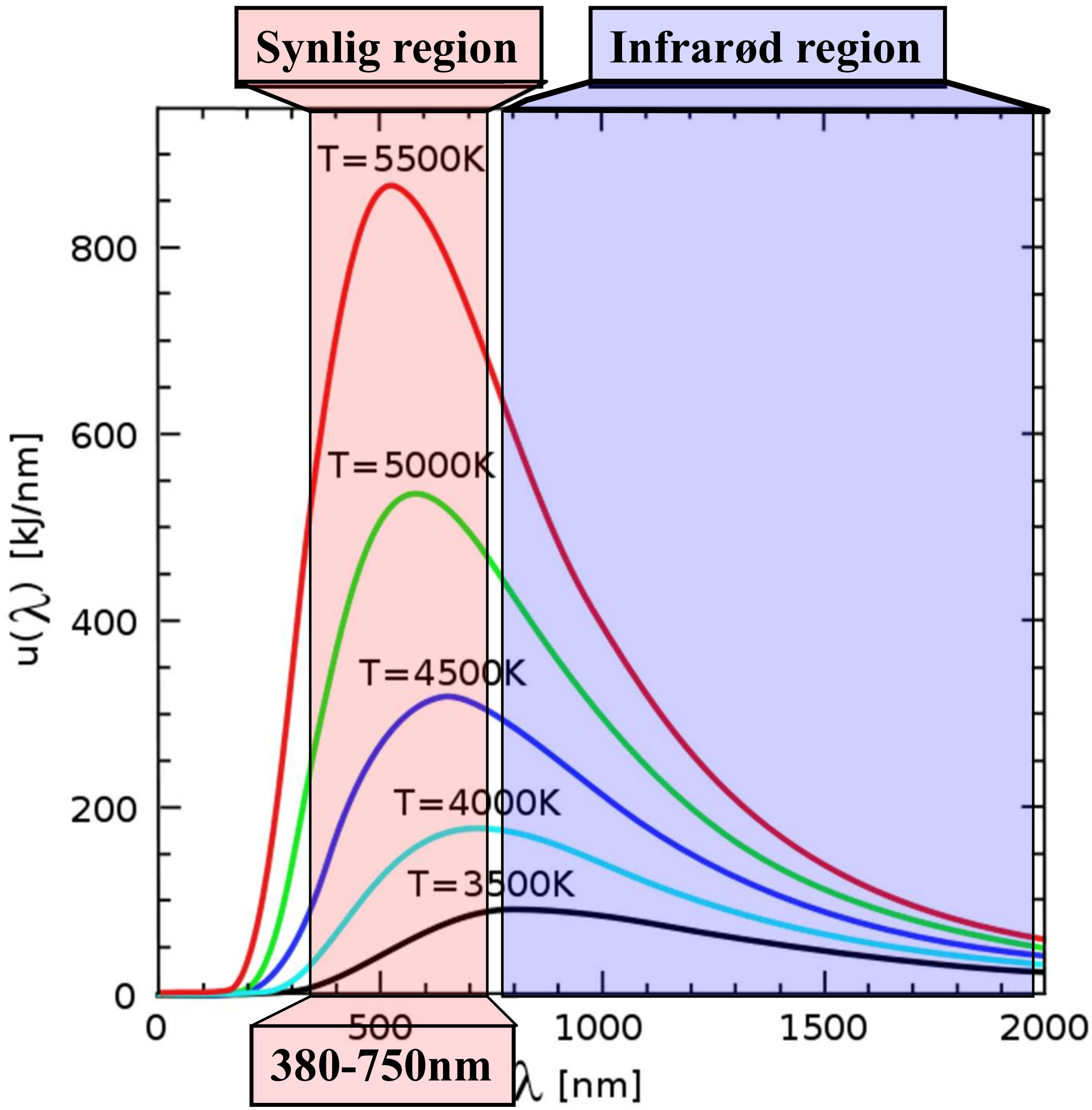
Konvektion, varmeledning og varmestråling søger at opvarme koldere områder

Kort og langbølget stråling

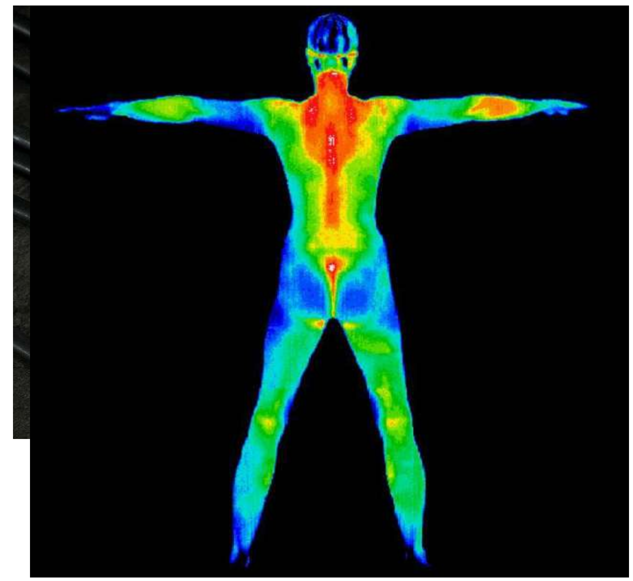


nanometer=10^{-9}m=0.000000001m=1 milliardenedel m

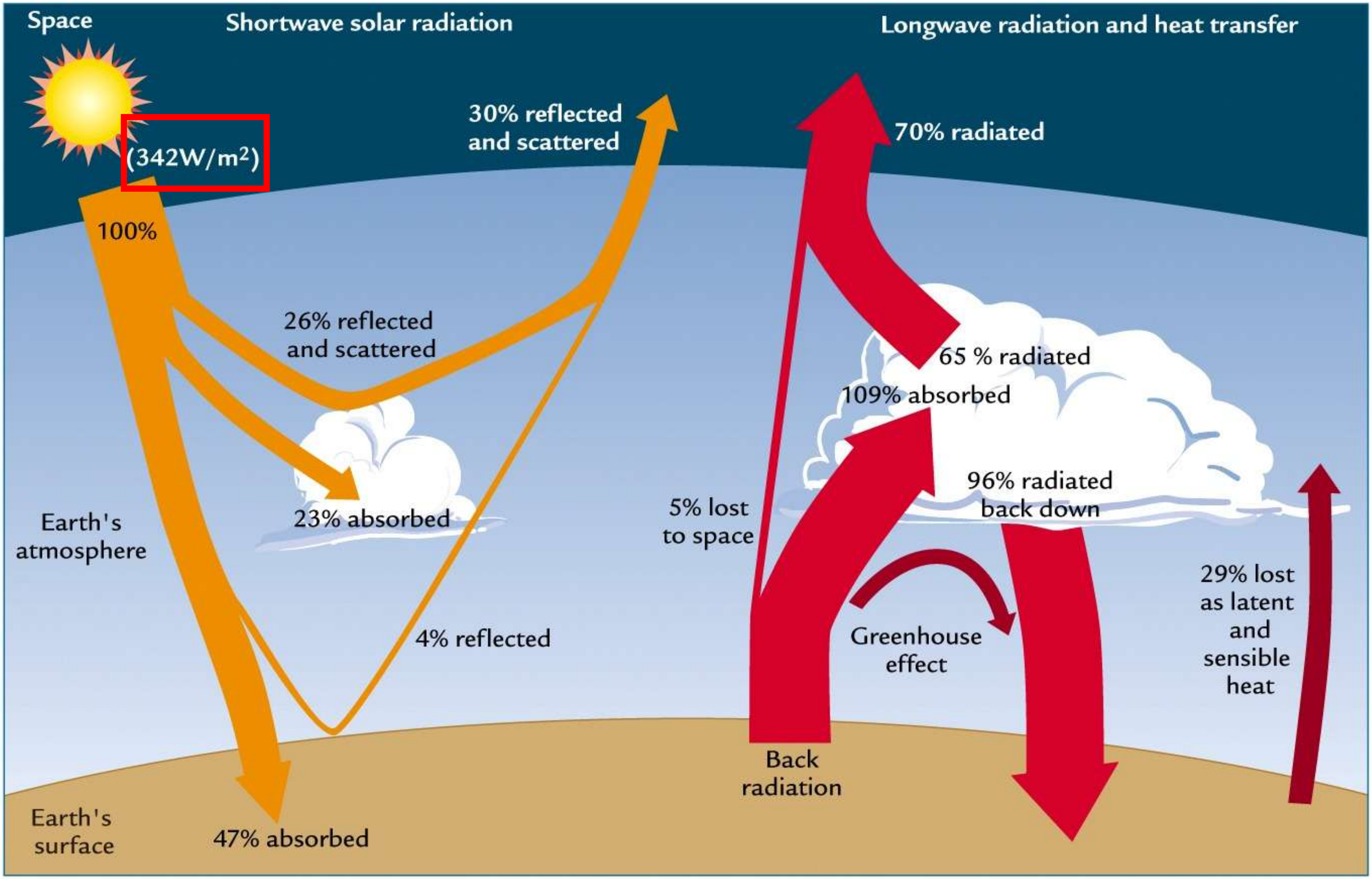
Kort og langbølget stråling



Thermografiske billeder

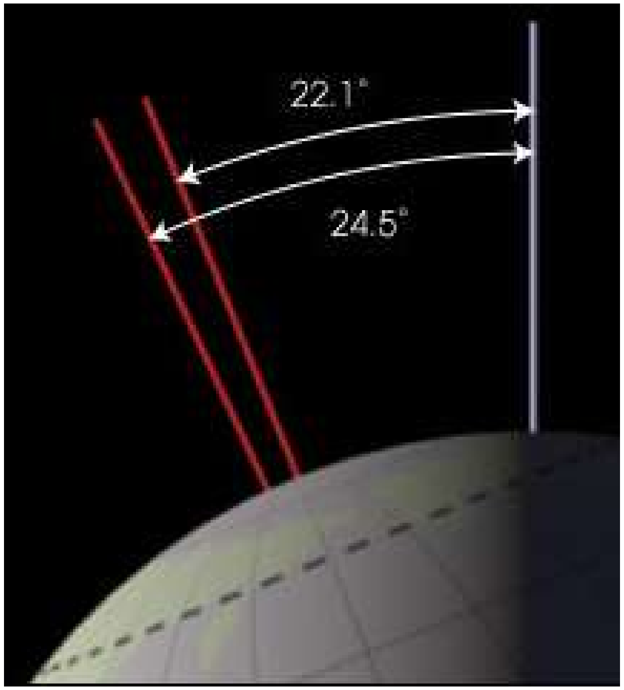


Jordens energi budget

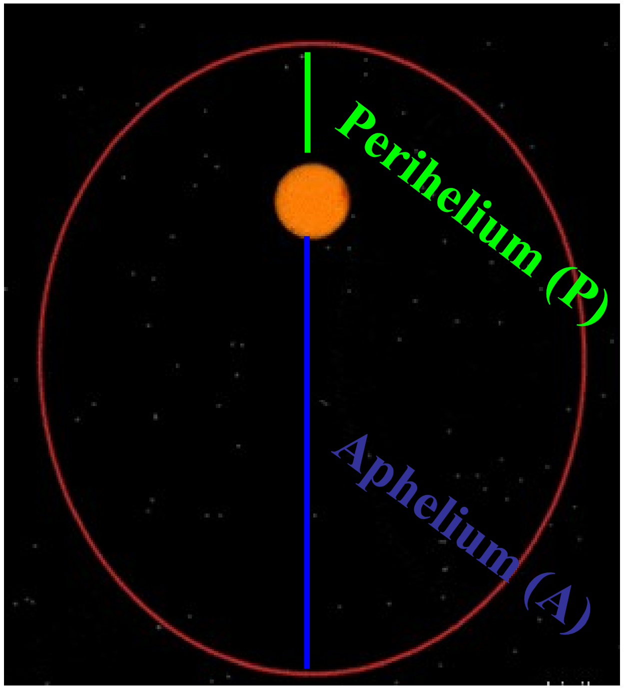


Den Astronomiske Teori

Jordakse hældning
Cyklus: ~41 kyr

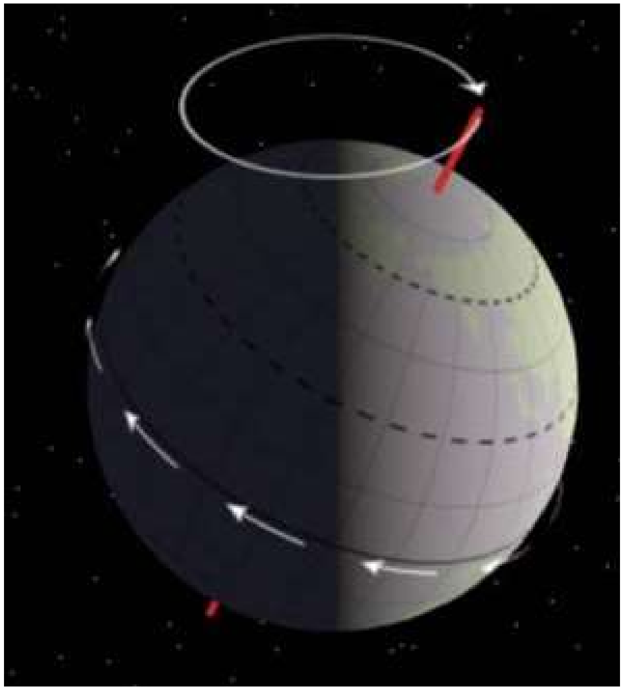


Jordbane eccentricitet
Cyklus: ~95, 125, 400 kyr

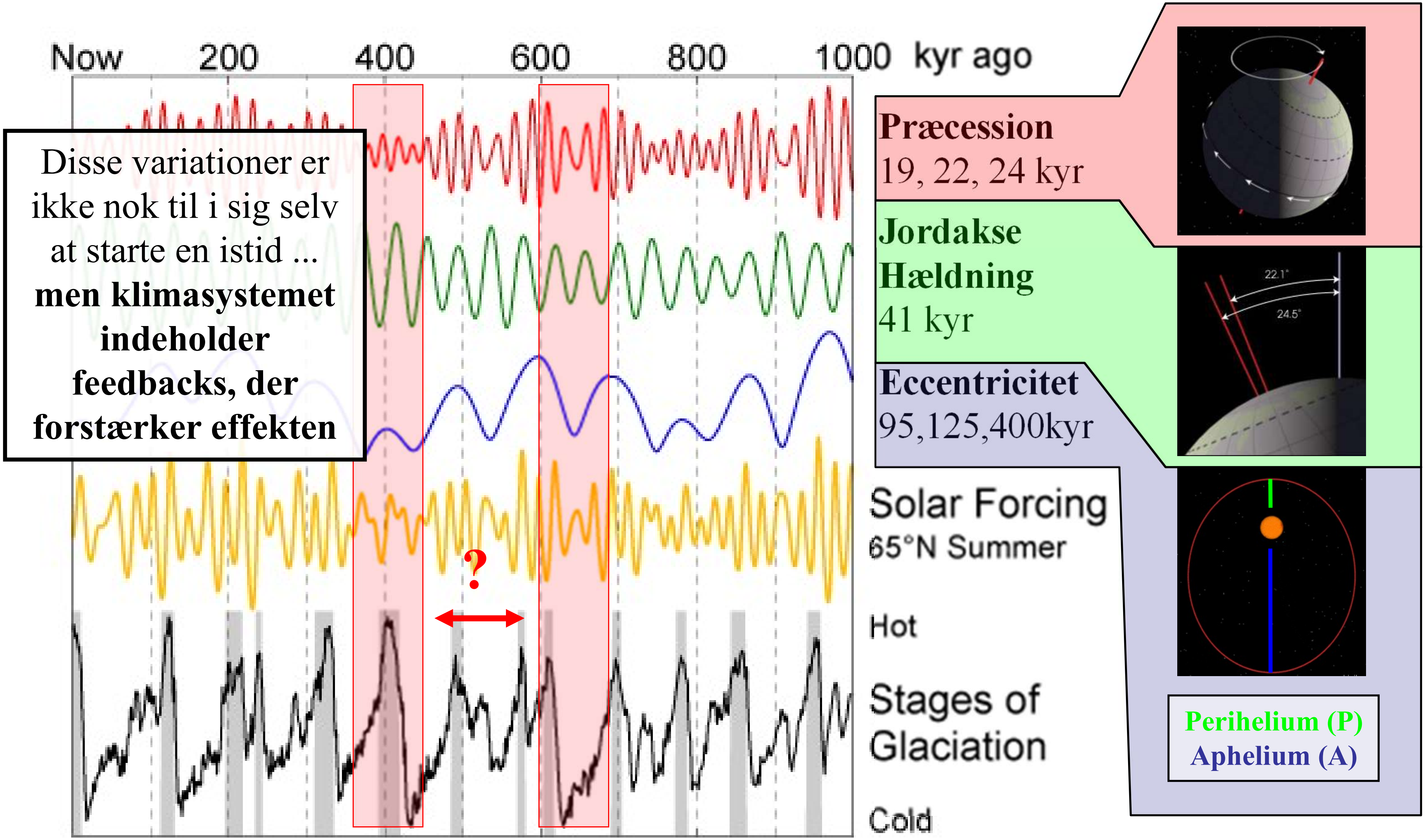


Strålingsforskel og jordakse hældning → sæsoner!

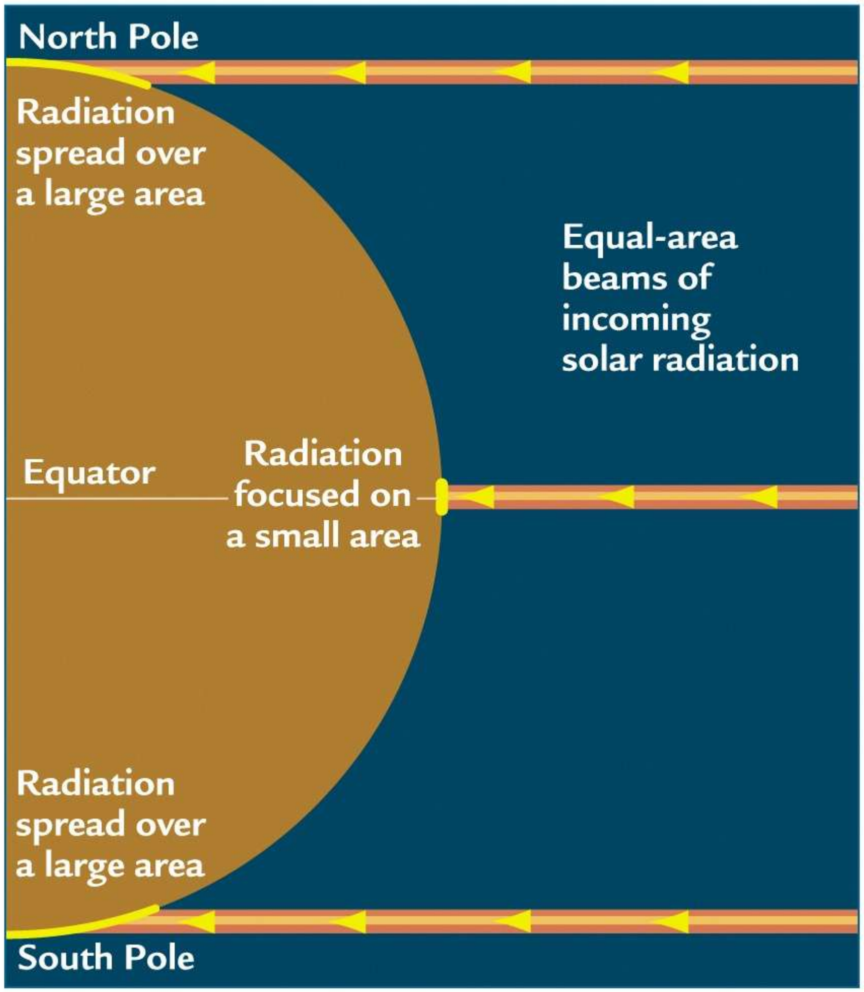
Præcession
Cyklus: ~19, 22, 24 kyr

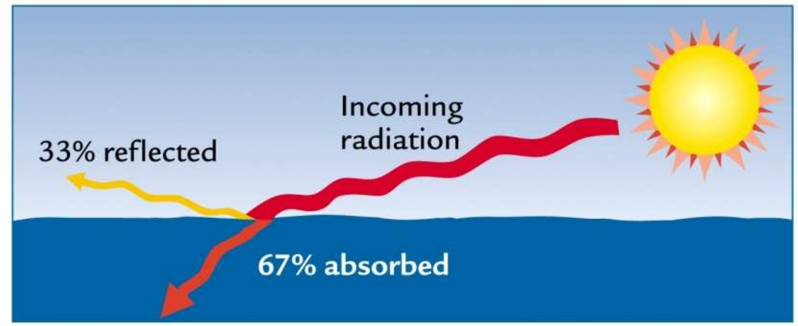


Den Astronomiske Teori

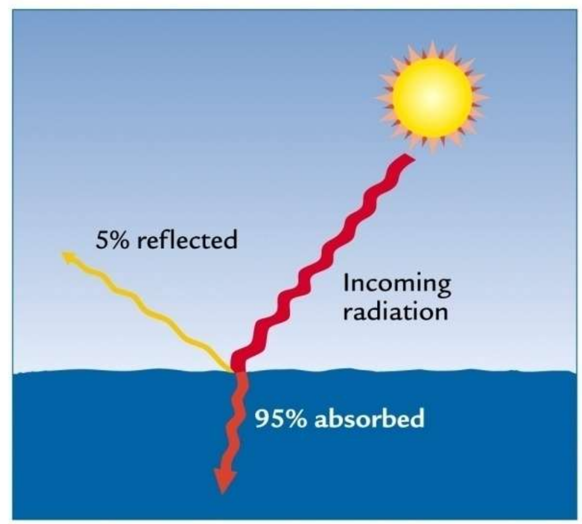


Konsekvens af sfærisk planet



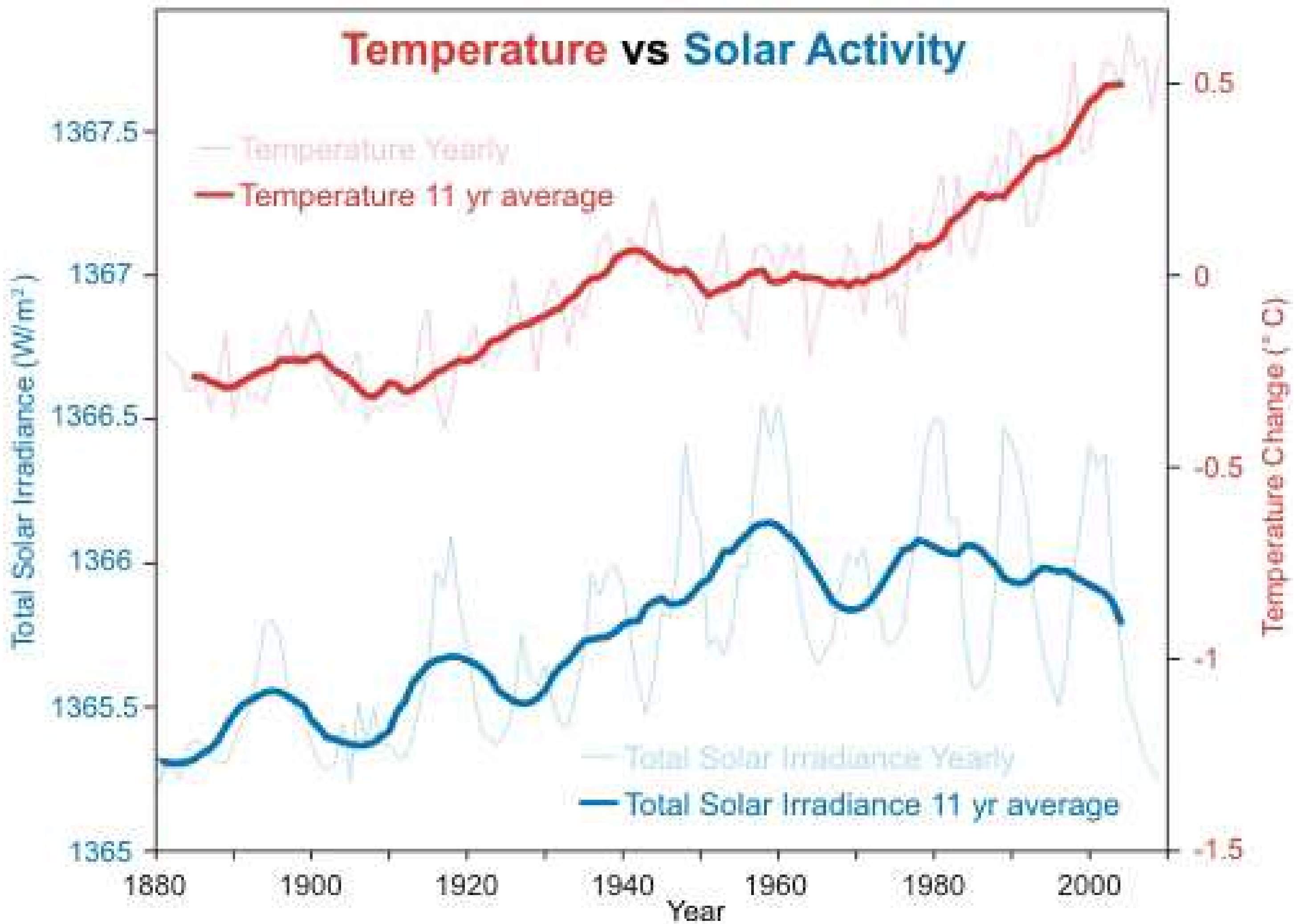


B High latitude

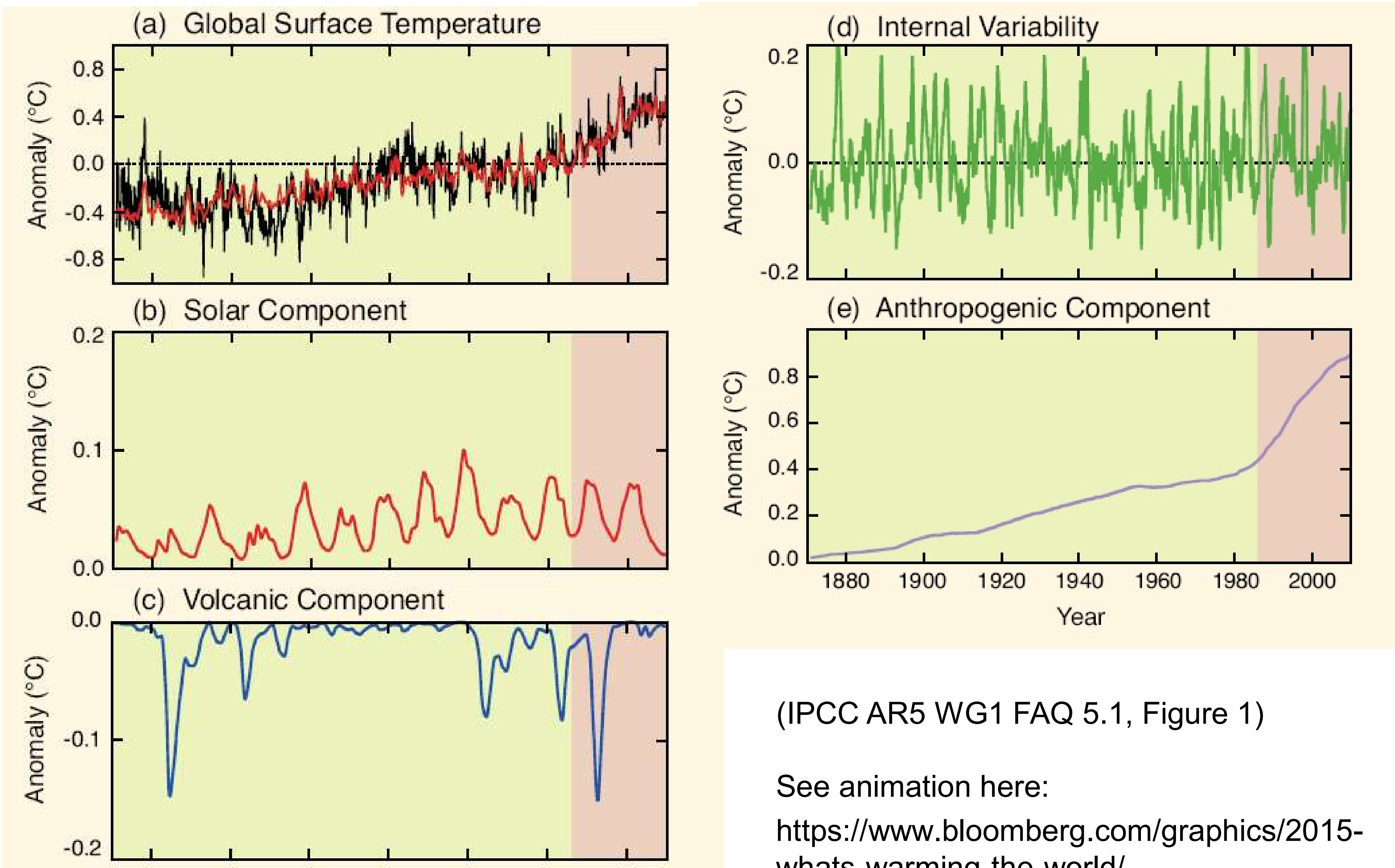


A Low latitude

Energi vs. Temperatur



FAQ 5.1 | Is the Sun a Major Driver of Recent Changes in Climate?

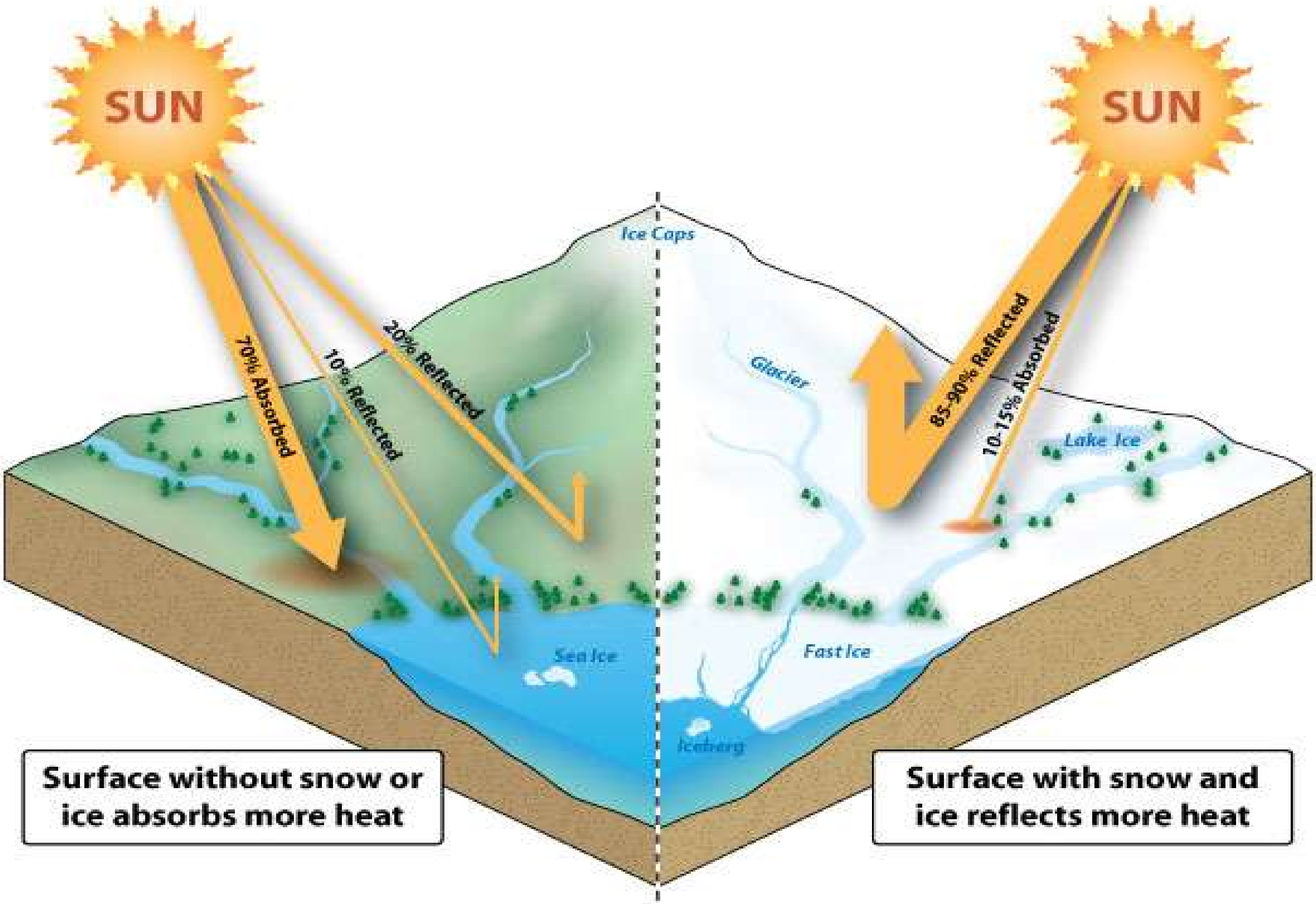


(IPCC AR5 WG1 FAQ 5.1, Figure 1)

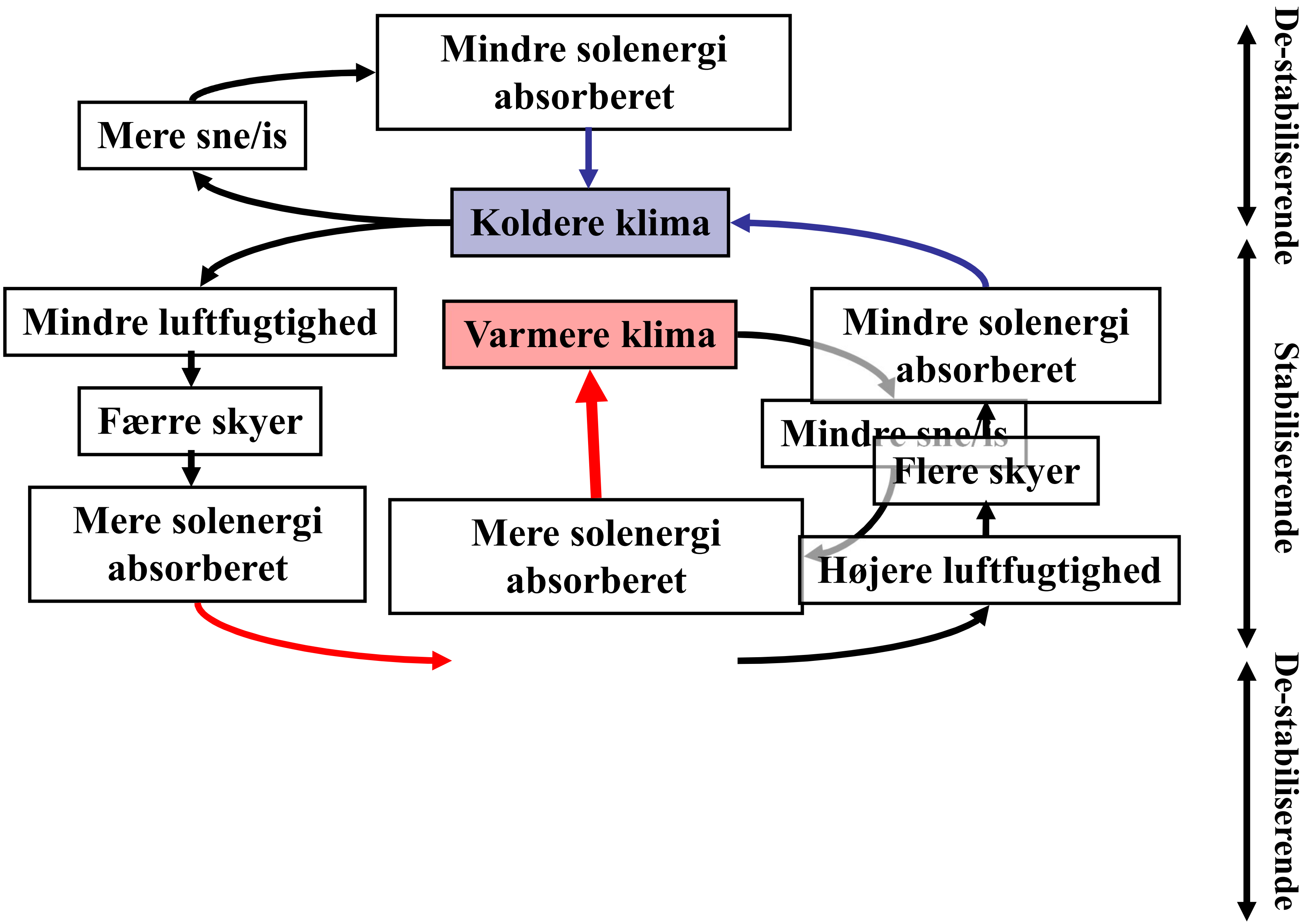
See animation here:
https://www.bloomberg.com/graphics/2015-whats-warming-the-world/

Feedback: Albedo

Albedo er en værdi mellem 0 og 1, tilsvarende 0-100% reflection



Feedback: Albedo



Konklusion: Solstråling

Hvad har vi lært?

Alle objekter med temperatur større end absolut nul, udsender stråling.

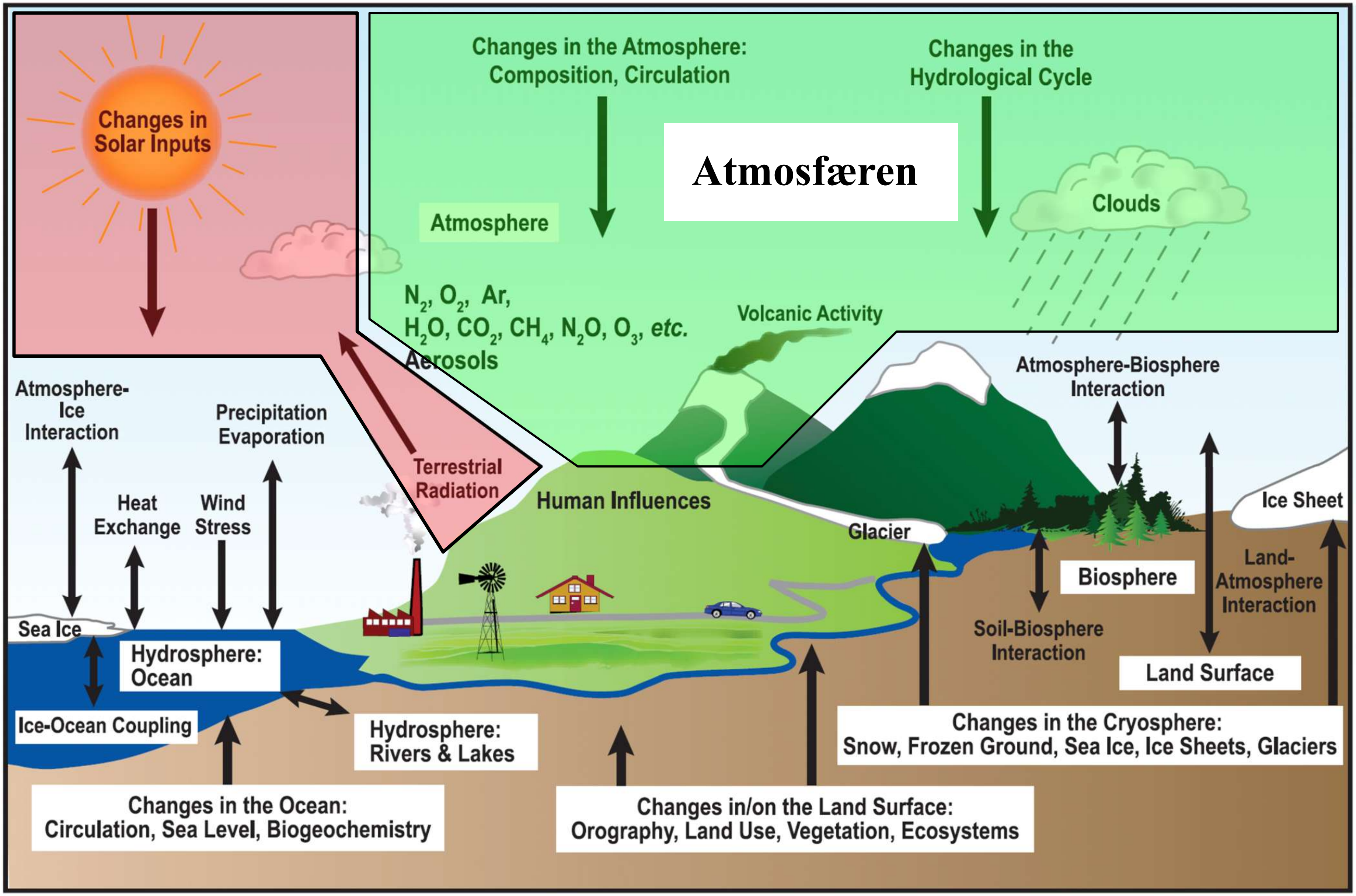
Jordens energibudget varierer på baggrund af flere faktorer, herunder:

- **Jordens astronomiske tilstand (ikke nok til at starte en istid)**
- **Drivhusgasser**
- **Geologiske varmekilder**

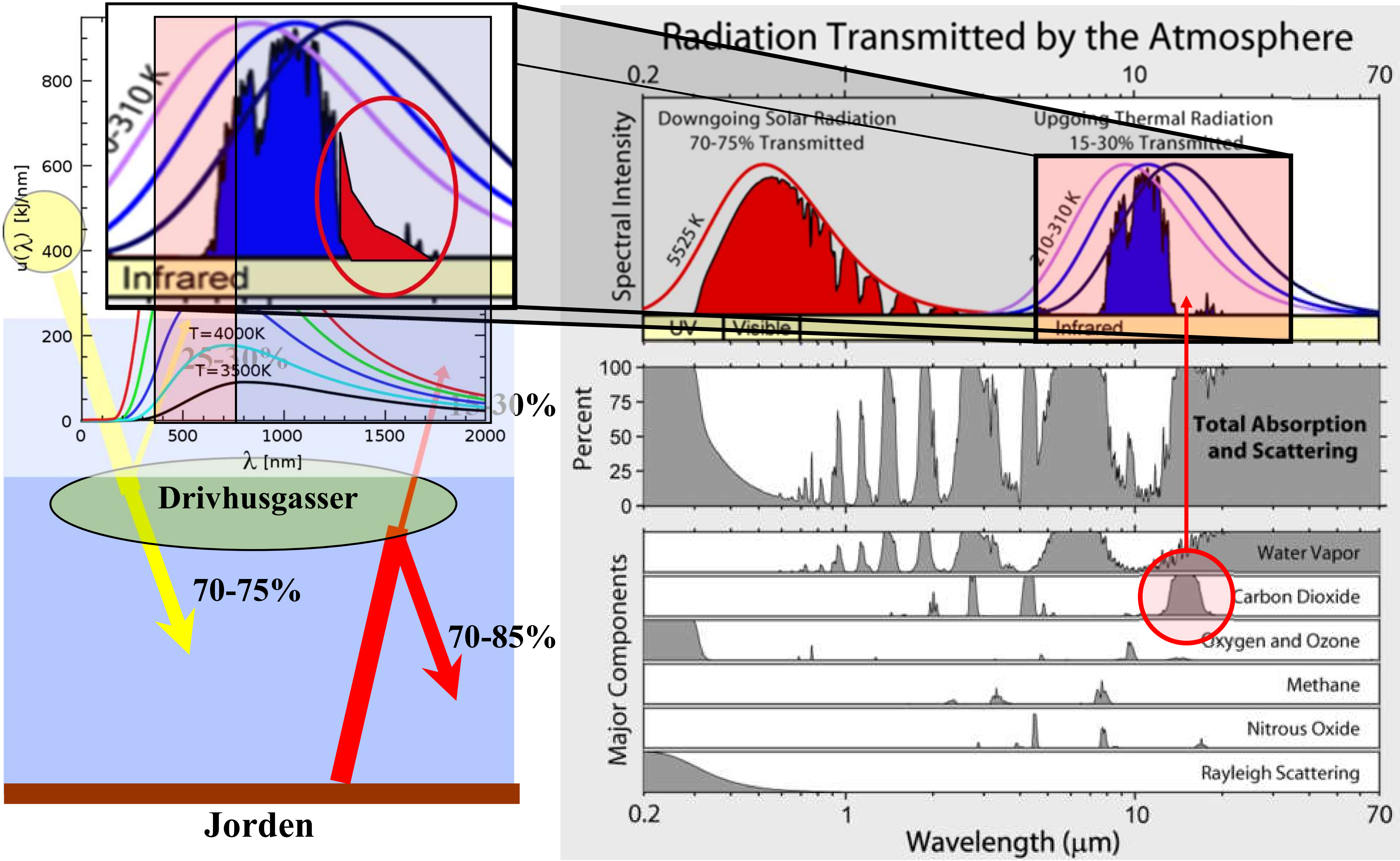
Interne feedbacks er sandsynligvis den største kilde til ændringer i klimaet

- **Albedo feedback'en er en nøglespiller**

Hvad ved vi om Klimasystemet?



Drivhusgasser

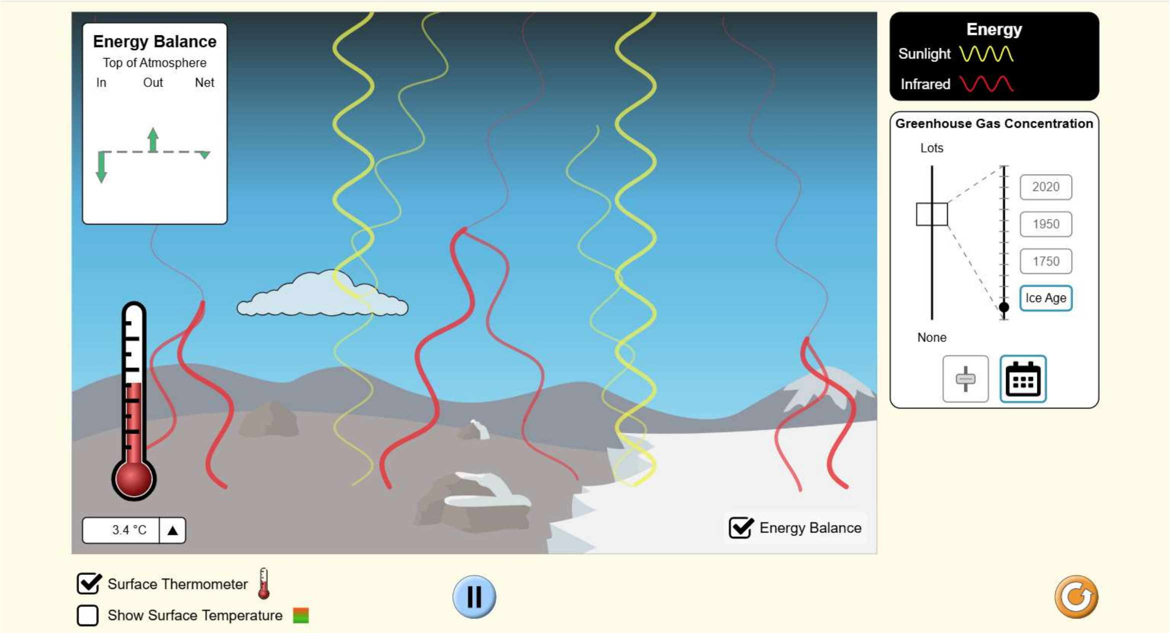


Strålingsbalance

KASTEM 2025- Jakob Warming, Mick Kristensen

Eleverne undersøger effekterne ved kortbølget og langbølget stråling (20min):

Undersøgelsesspørgsmål:
Undersøg hvad temperaturen vil være uden nogen drivhusgasser i atmosfæren. Hvordan har temperaturen ændret sig fra 1750 – 2020? Hvad symboliserer de røde stråler? Og hvad symboliserer de gule?
Overvej og giv en forklaring på forskellen på de røde stråler ved lav drivhusgaskoncentration og ved høj drivhusgaskoncentration?



https://phet.colorado.edu/sims/html/greenhouse-effect/latest/greenhouse-effect_all.html

Strålingsbalance leg

KASTEN2025-Kasper Nielsen, Lea Rylander-Kjær

- 1) Forklar eleverne, at de skal forestille sig, at de er solens stråler, der rejser fra solen mod jorden. Nogle af strålerne bliver reflekteret tilbage, og nogle bliver fanget af forhindringer på vejen tilbage mod rummet

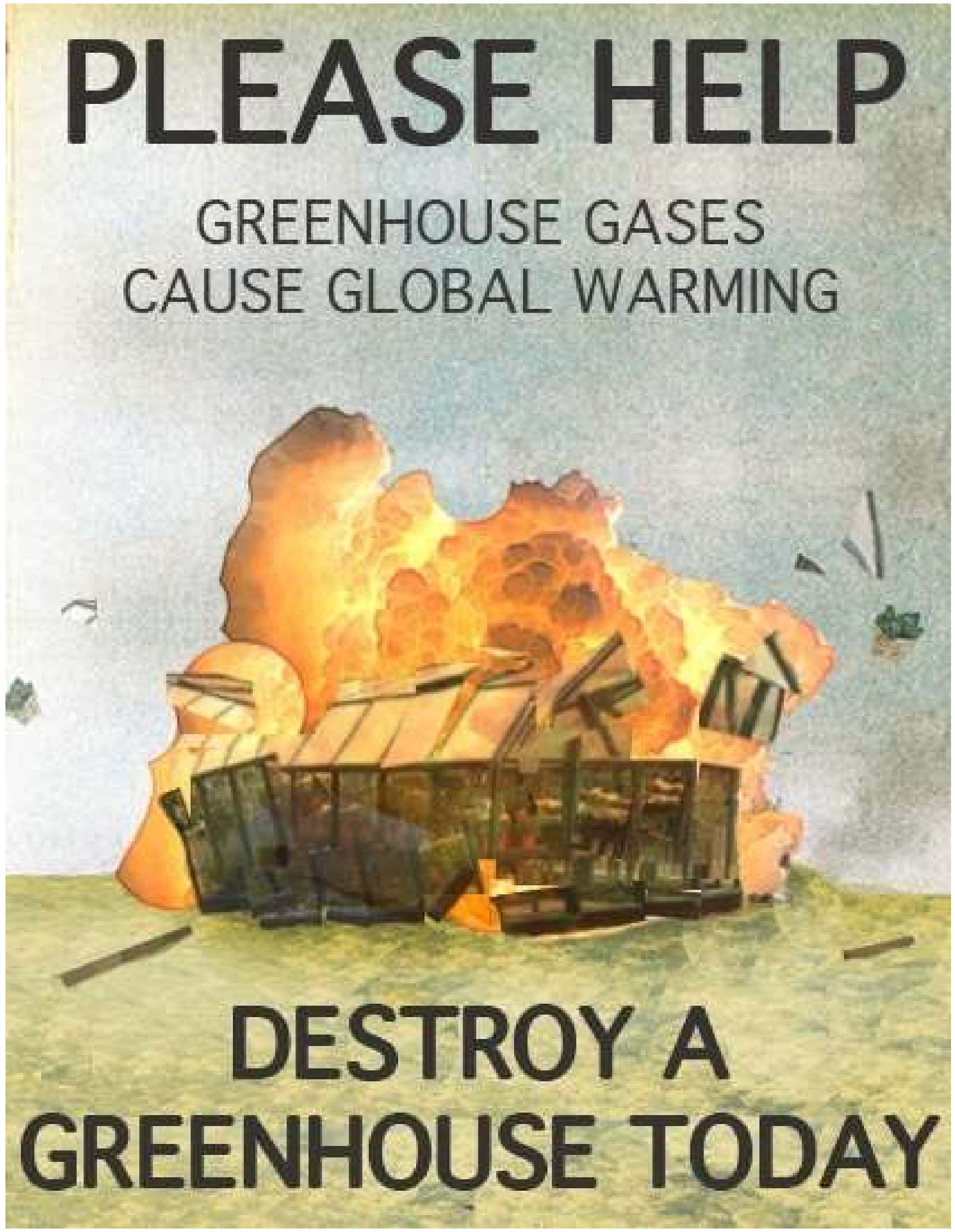
- 2. Opsæt rummet: ○ Den ene ende af rummet eller skolegården = solen, Midten = atmosfæren, Den anden ende (væg eller linje) = jorden 3.

- 3) Første runde (uden drivhusgasser): Eleverne ("solstrålerne") starter ved solen og løber i lige linje mod jorden. De rammer jorden, vender deres skilt og løber straks tilbage mod solen (universet). Forklar, at energien her frit kan bevæge sig ud igen – balancen er stabil.

- 4) Læg nogle "drivhusgas"-papirer (CO_2, CH_4, H_2O) ud i atmosfæren. Når strålerne rammer jorden og løber tilbage, bliver nogle "fanget" af drivhusgasserne – de må altså ikke løbe tilbage til solen, men bliver i området tæt på jorden. ○ Man kan evt snakke om, at dette svarer til, at varmen bliver fanget i atmosfæren – drivhuseffekten. Her kan man også allerede reflektere over, hvorfor strålingen kan komme igennem på vejen ind med ikke på vejen ud.

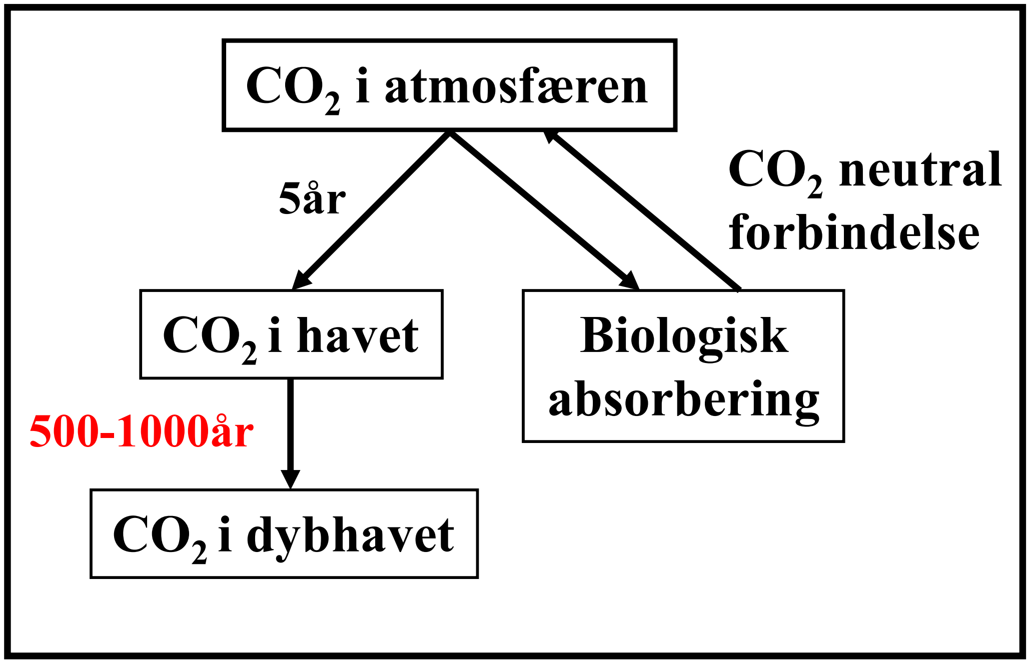
- 5) Fjerde runde (med øget CO_2 fra fossile brændsler): ○ Tilføj flere "drivhusgasser". Nu bliver flere stråler fanget. ○ Eleverne vil opleve, at "varmen" bliver i jordsystemet, og balancen ændres – jorden bliver varmere.

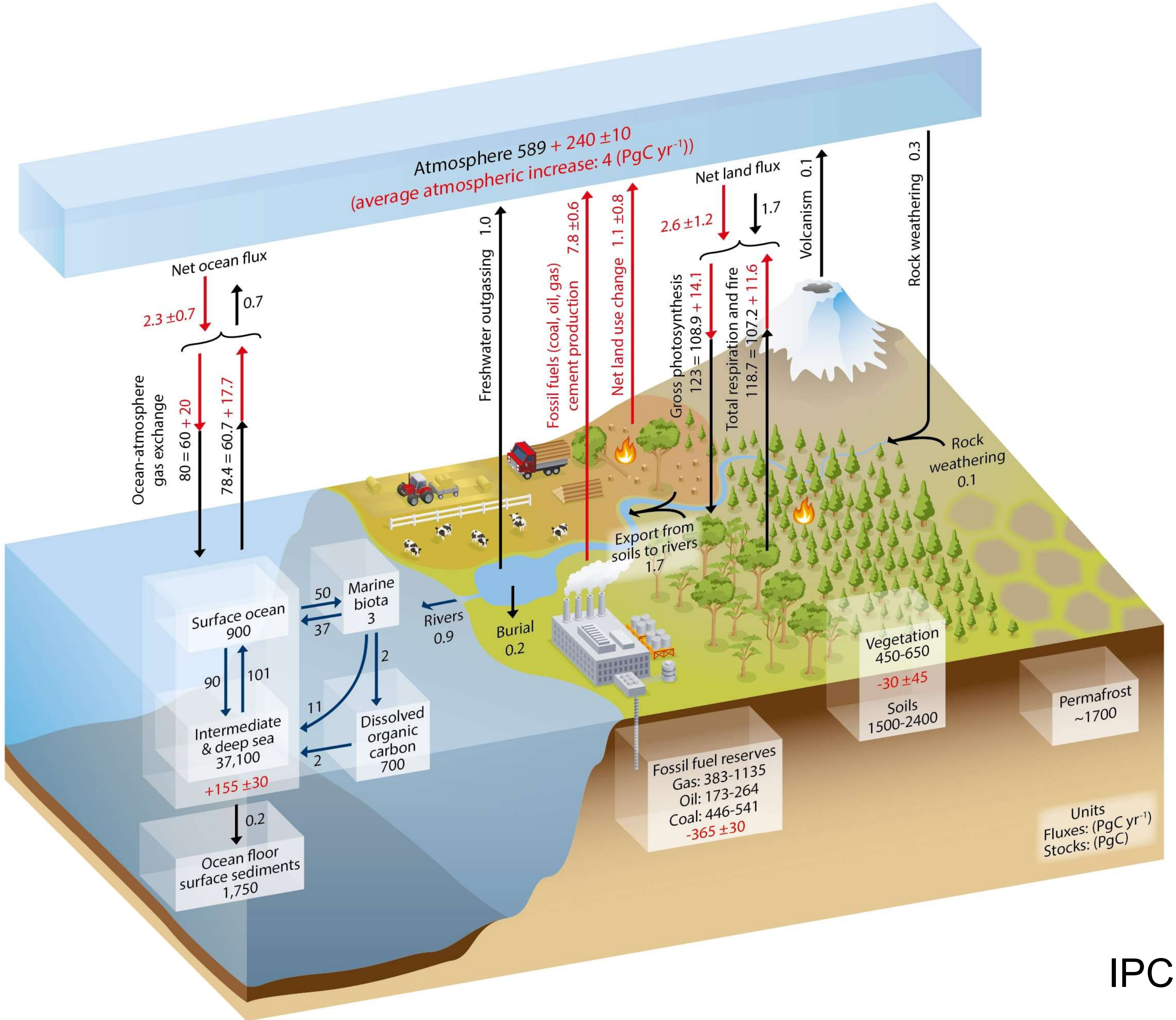
Drivhusgasser



Drivhusgasser

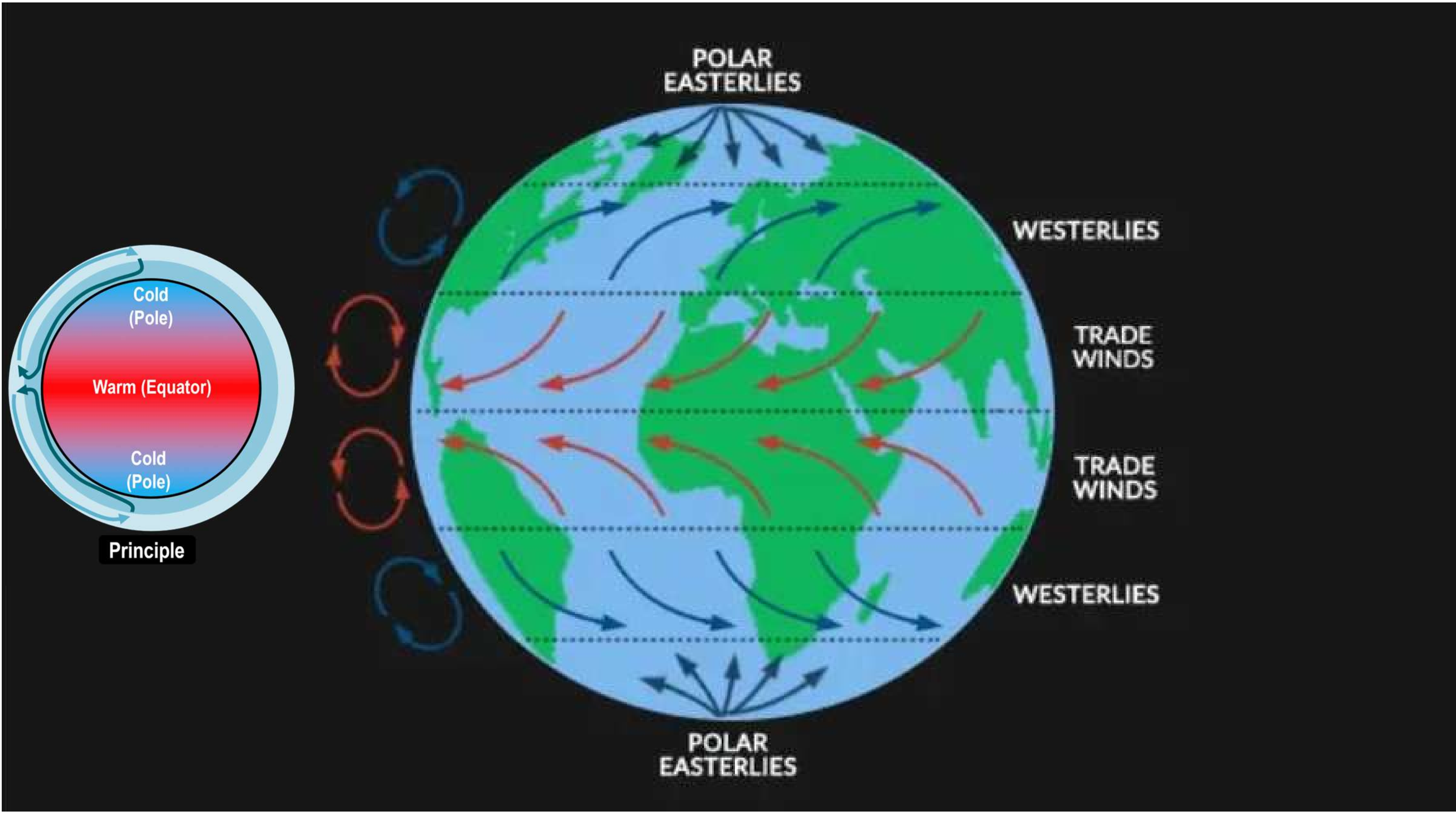
Hvordan slipper vi af med den ekstra CO_2?





Atmosphere 589 + 240 ±10
(average atmospheric increase: 4 (PgC yr⁻¹))
Net ocean flux
2.3 ±0.7
0.7
Ocean-atmosphere gas exchange
80 = 60 + 20
78.4 = 60.7 + 17.7
Freshwater outgassing 1.0
Fossil fuels (coal, oil, gas) cement production 7.8 ±0.6
Net land use change 1.1 ±0.8
Net land flux
2.6 ±1.2
1.7
Gross photosynthesis 123 = 108.9 + 14.1
Total respiration and fire 118.7 = 107.2 + 11.6
Volcanism 0.1
Rock weathering 0.3
Rock weathering 0.1
Export from soils to rivers 1.7
Rivers 0.9
Burial 0.2
Surface ocean 900
Marine biota 3
50
37
90
101
2
11
2
Intermediate & deep sea 37,100
+155 ±30
Dissolved organic carbon 700
0.2
Ocean floor surface sediments 1,750
Fossil fuel reserves
Gas: 383-1135
Oil: 173-264
Coal: 446-541
-365 ±30
Vegetation 450-650
-30 ±45
Soils 1500-2400
Permafrost ~1700
Units
Fluxes: (PgC yr⁻¹)
Stocks: (PgC)

IPCC

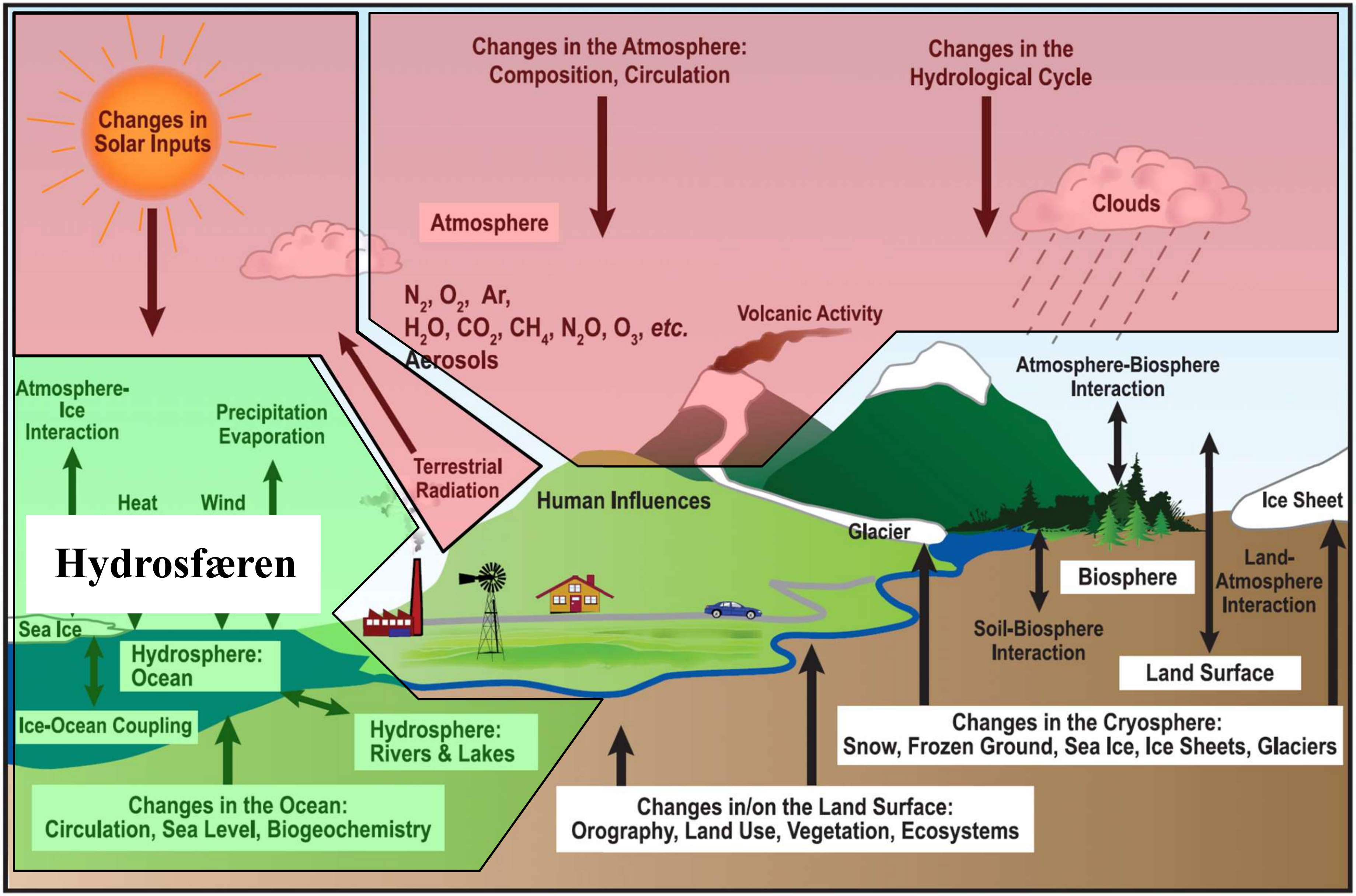

Cold
(Pole)
Warm (Equator)
Cold
(Pole)
Principle
POLAR
EASTERLIES
WESTERLIES
TRADE
WINDS
TRADE
WINDS
WESTERLIES
POLAR
EASTERLIES

GLOBAL CARBON project

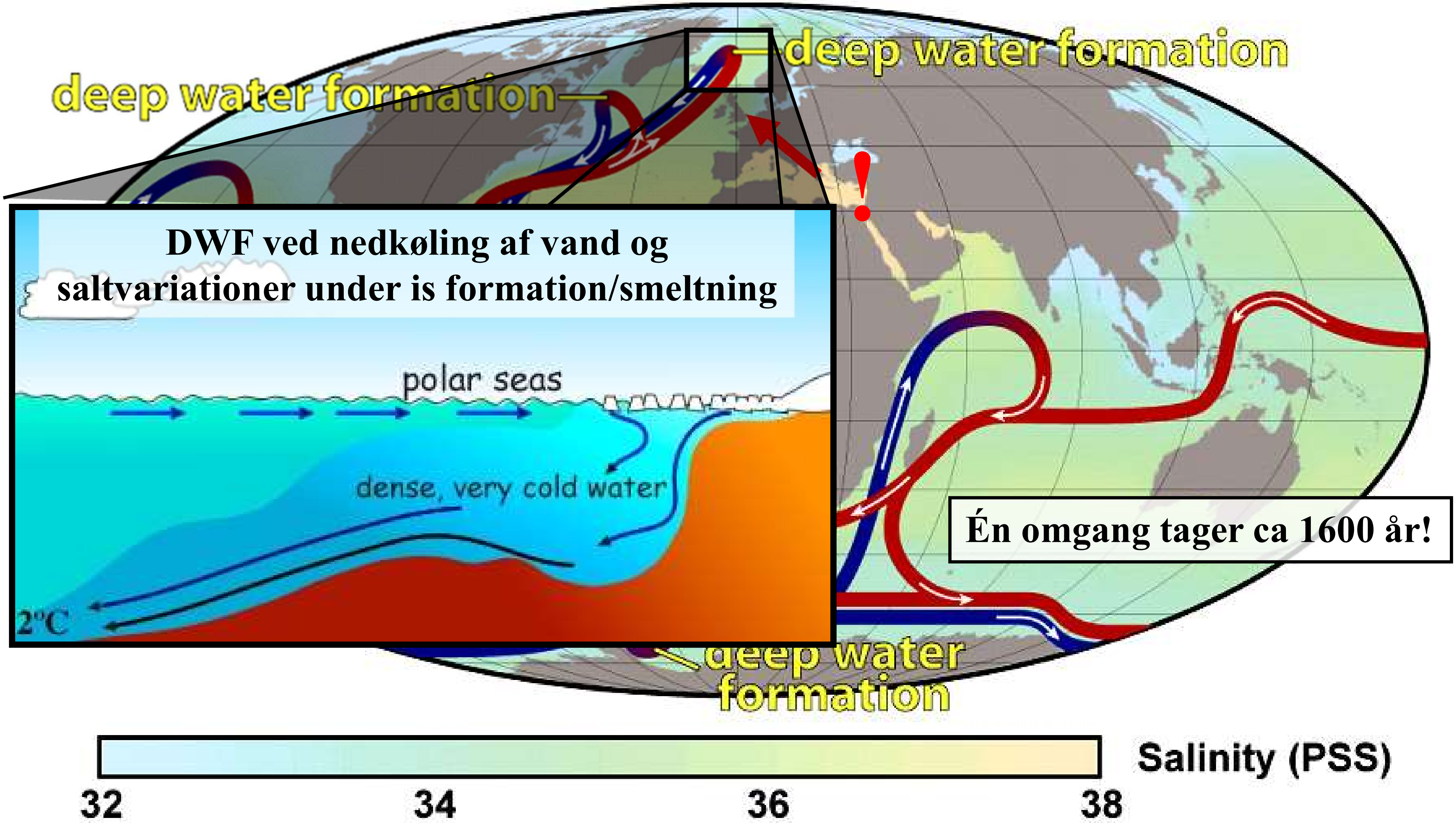
Erath wind map

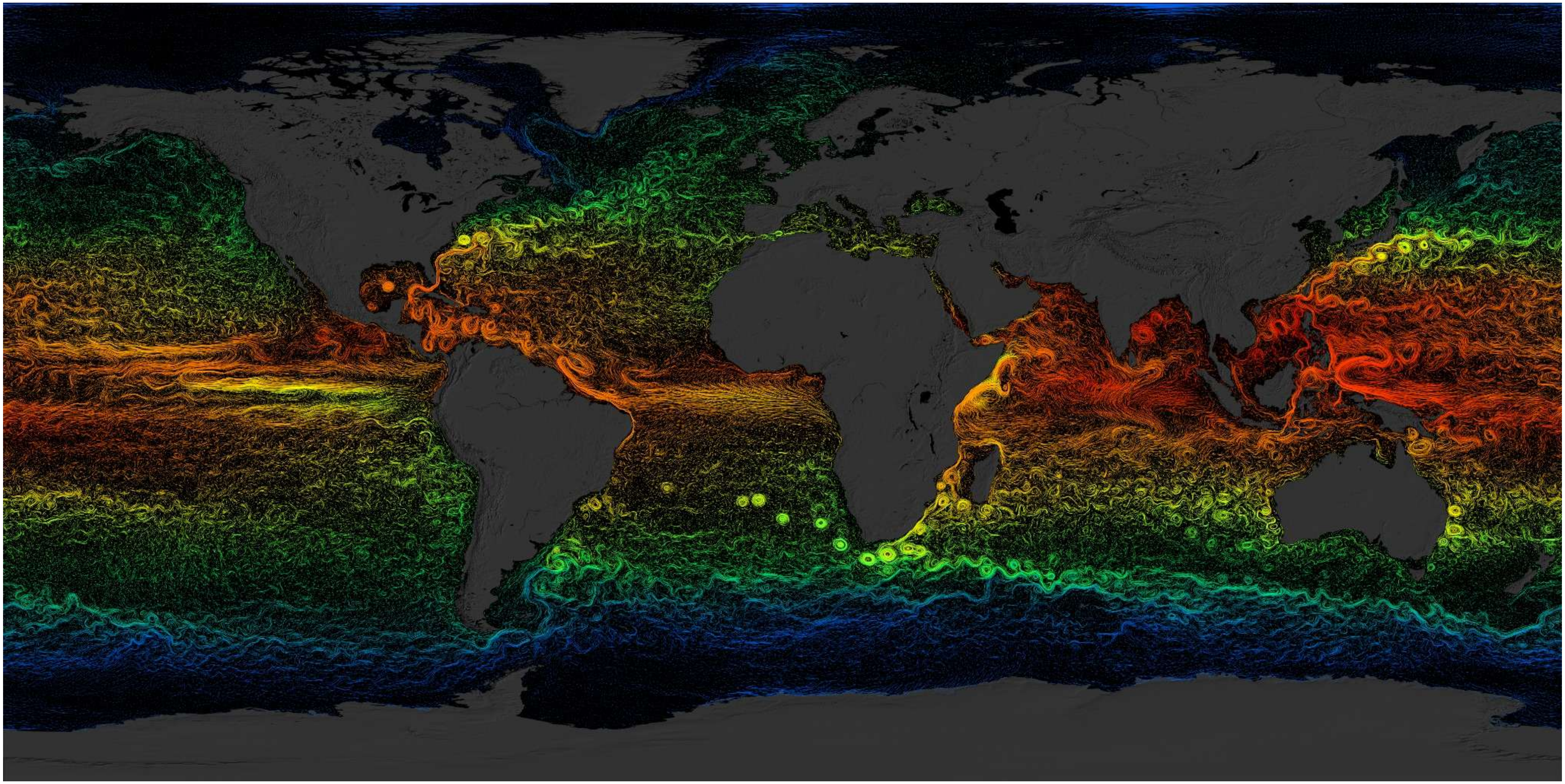
https://earth.nullschool.net/#current/wind/surface/level/orthographic=-8.29,23.94,410

Hvad ved vi om Klimasystemet?



Thermohalin Hav cirkulation





A visualization of sea surface current flows colored by corresponding sea surface temperature data. It was produced using model output from the joint MIT/JPL project entitled Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2). https://sealevel.jpl.nasa.gov/ocean-observation/why-study-the-ocean/benefits/

Dybvandsdannelse

KASTEM 2025-Sofie Hansen, August Hjort Mandal, Emilie Ea Kjerri Rasmussen

- eleverne skulle undersøge, hvordan forskelle i saltkoncentration og temperatur kunne skabe lagdeling i havvand, og eleverne ville her lave en simpel model af grønlandspumpen. Eleverne arbejdede i tomandsgrupper, hvor fokus var på at udforske og indsamle data. Eleverne havde en meget kort introduktion og skulle selv opstille deres undersøgelsesdesign ud fra materialerne på lærerbordet. Eleverne blev stilladseret i deres undersøgelse ved hjælp af et hjælpeark
- Under lærer stiladsering: eleverne skulle fremlægge deres hypoteser og metode for hinanden på tværs af grupper. Fokus var særligt på elevernes ræsonnement og argumenter for deres resultater og tilpasning af undersøgelsen.
- I forlæng-fasen arbejdede eleverne i en større gruppe med en model af grønlandspumpen. Her skulle de anvende deres fælles viden fra undersøgelserne til at forklare, hvordan modellen fungerede

Bilag

Bilag 1) Hjælpeark til "Grønlandspumpens påvirkning af Golfstrømmen"

Undersøgelse 1)

Hypotese: Jeg tror ______________________________

fordi ______________________________

	Mængde vand (i mL)	Temperatur (i grader)	Koncentration af salt (i gram)	Farve på glasset
Glas 1				
Glas 2				

Hvad gjorde vi: ______________________________

Hvad skete der: ______________________________

Hvorfor tror vi at det skete: ______________________________

Hvad vil vi gøre anderledes i næste forsøg og hvorfor: ______________________________

____

Undersøgelse 2)

Hypotese: Jeg tror ______________________________

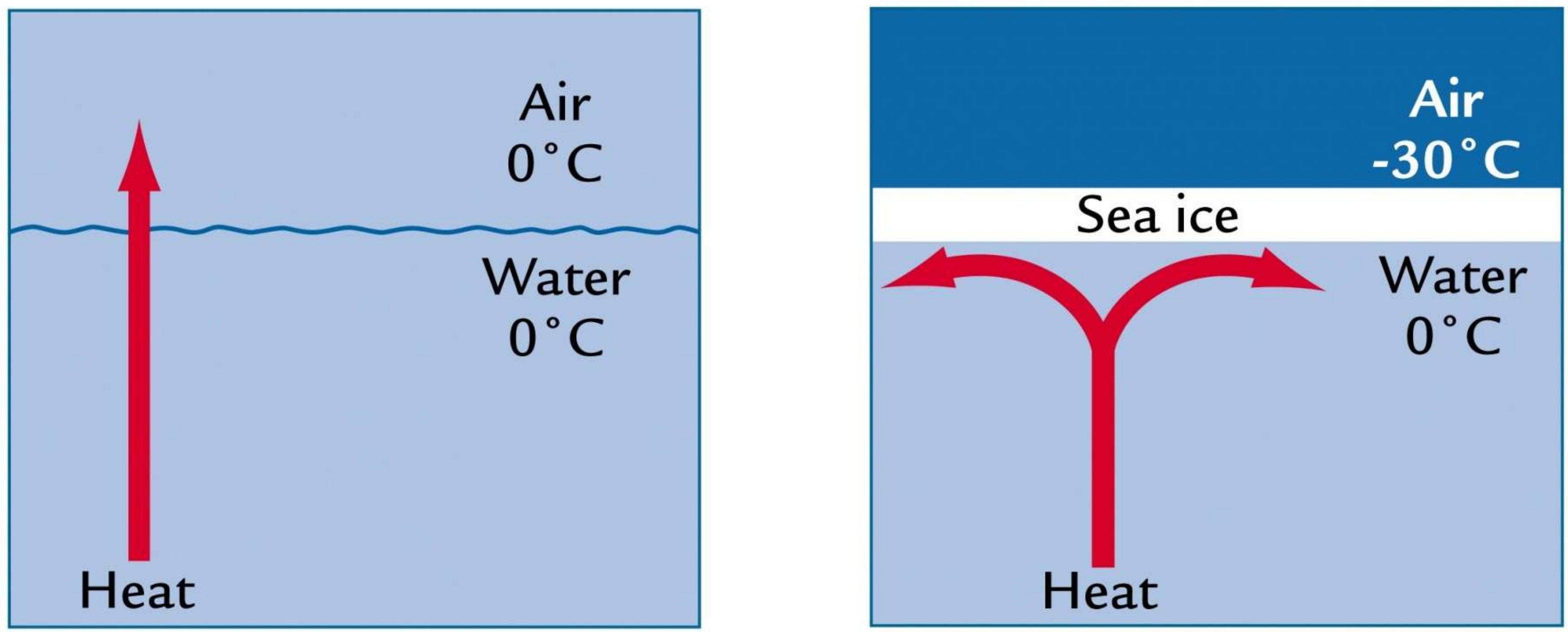
fordi ______________________________

	Mængde vand (i mL)	Temperatur (i grader)	Koncentration af salt (i gram)	Farve på glasset
Glas 1				
Glas 2				

Havisens effekt på klimaet

Havet varmer luften

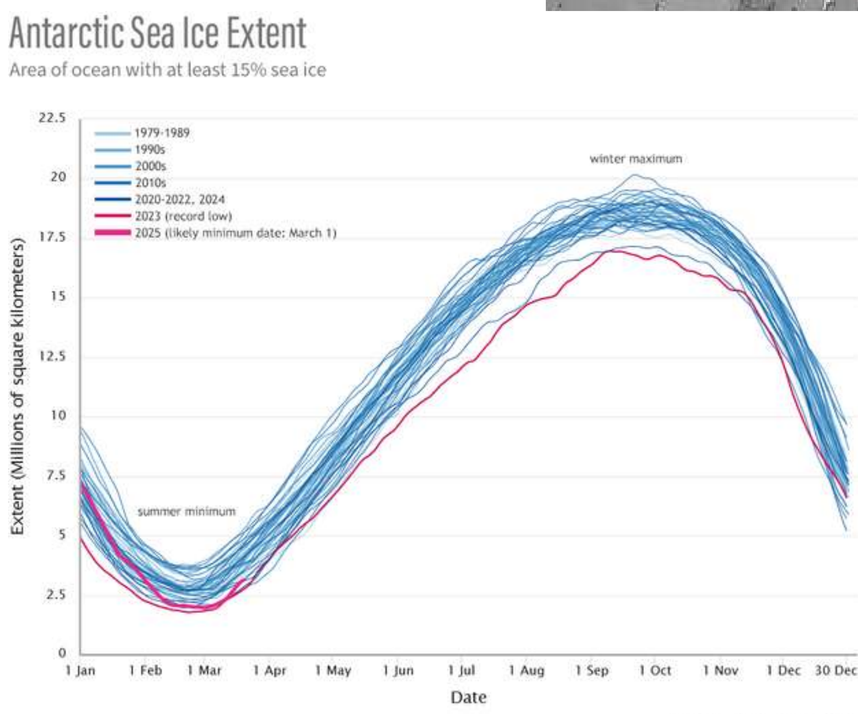
Havet varmer ikke luften, som derfor køles ned

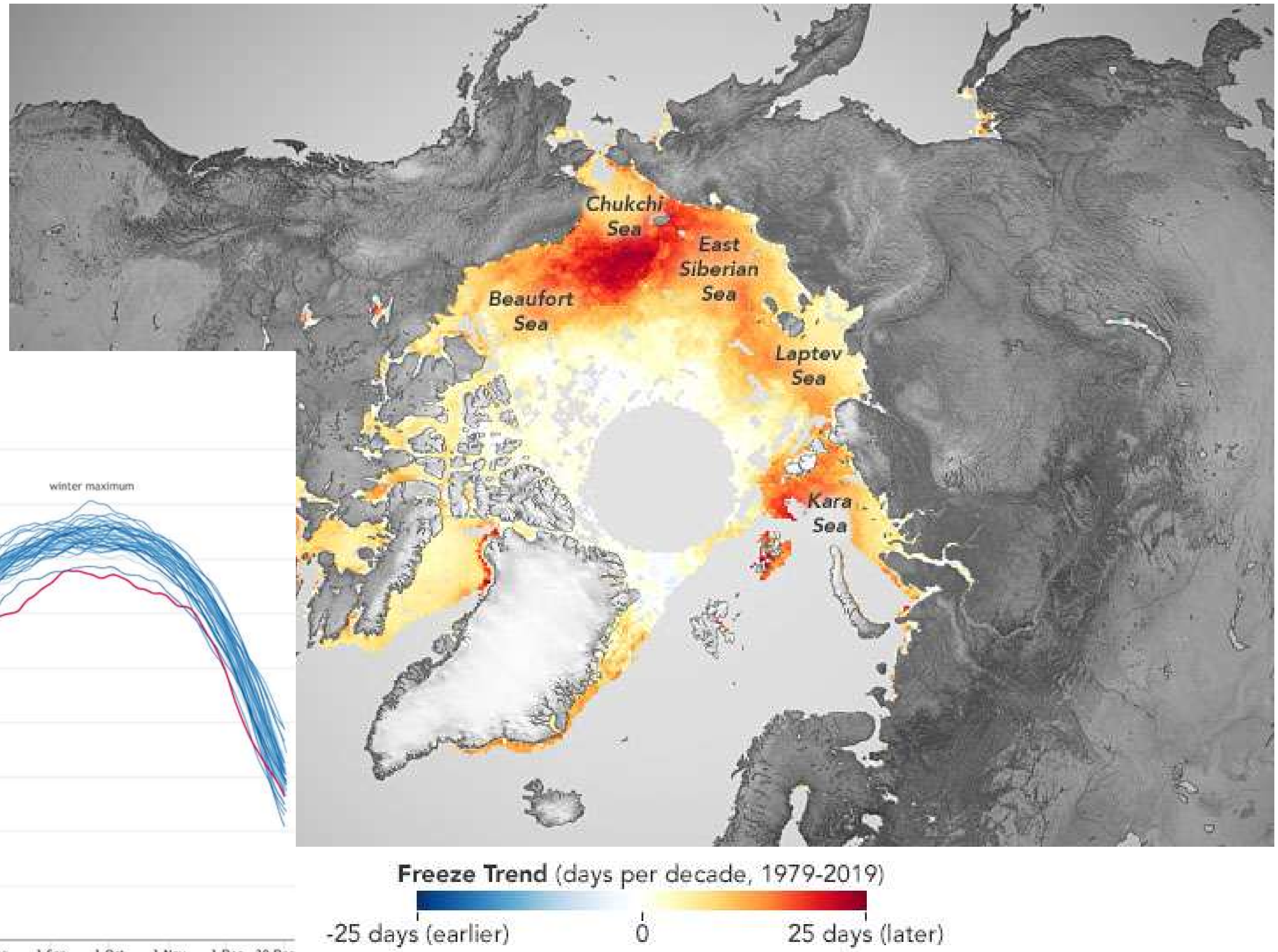


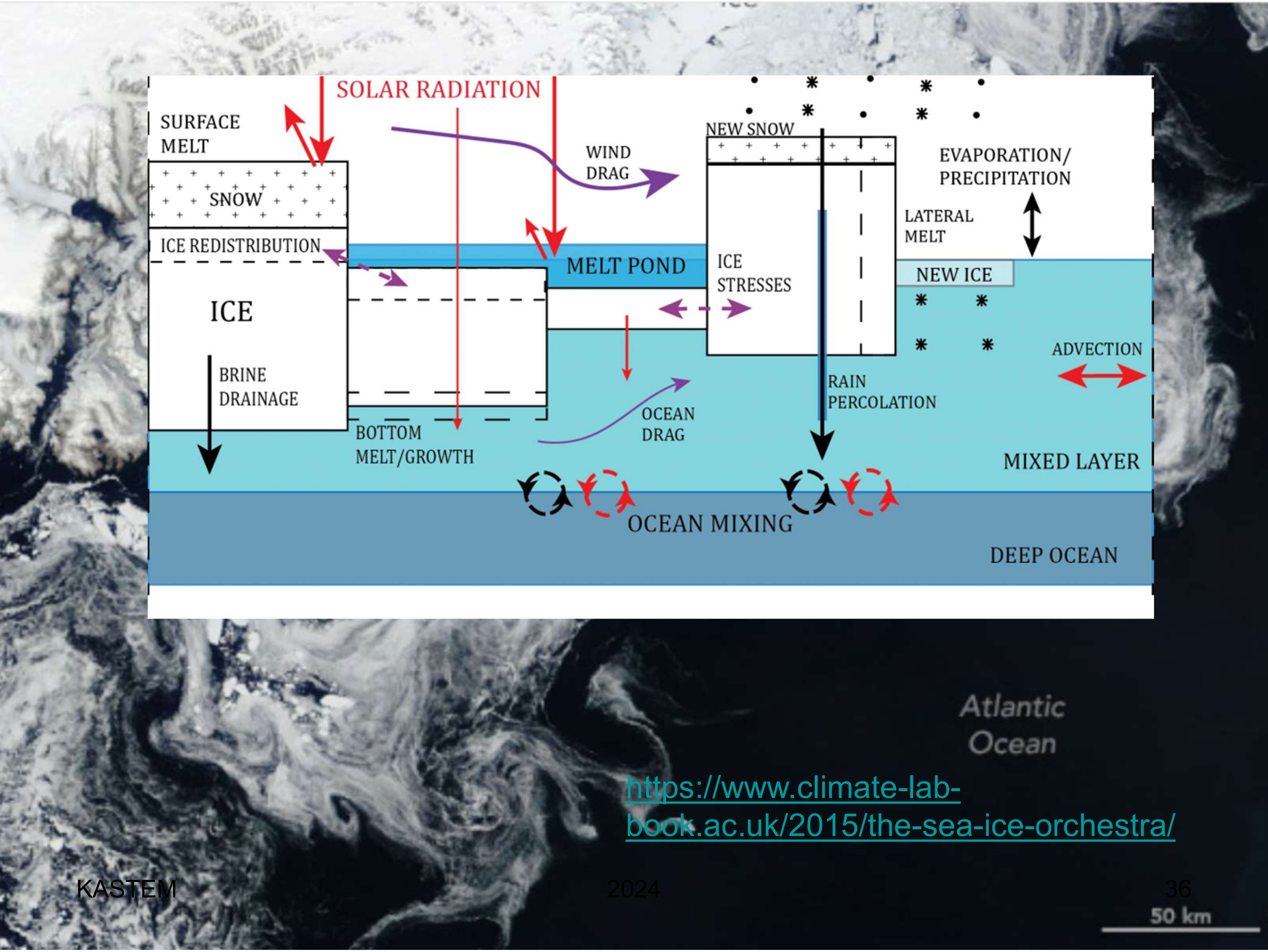
A Without sea ice

B With sea ice

Sea ice

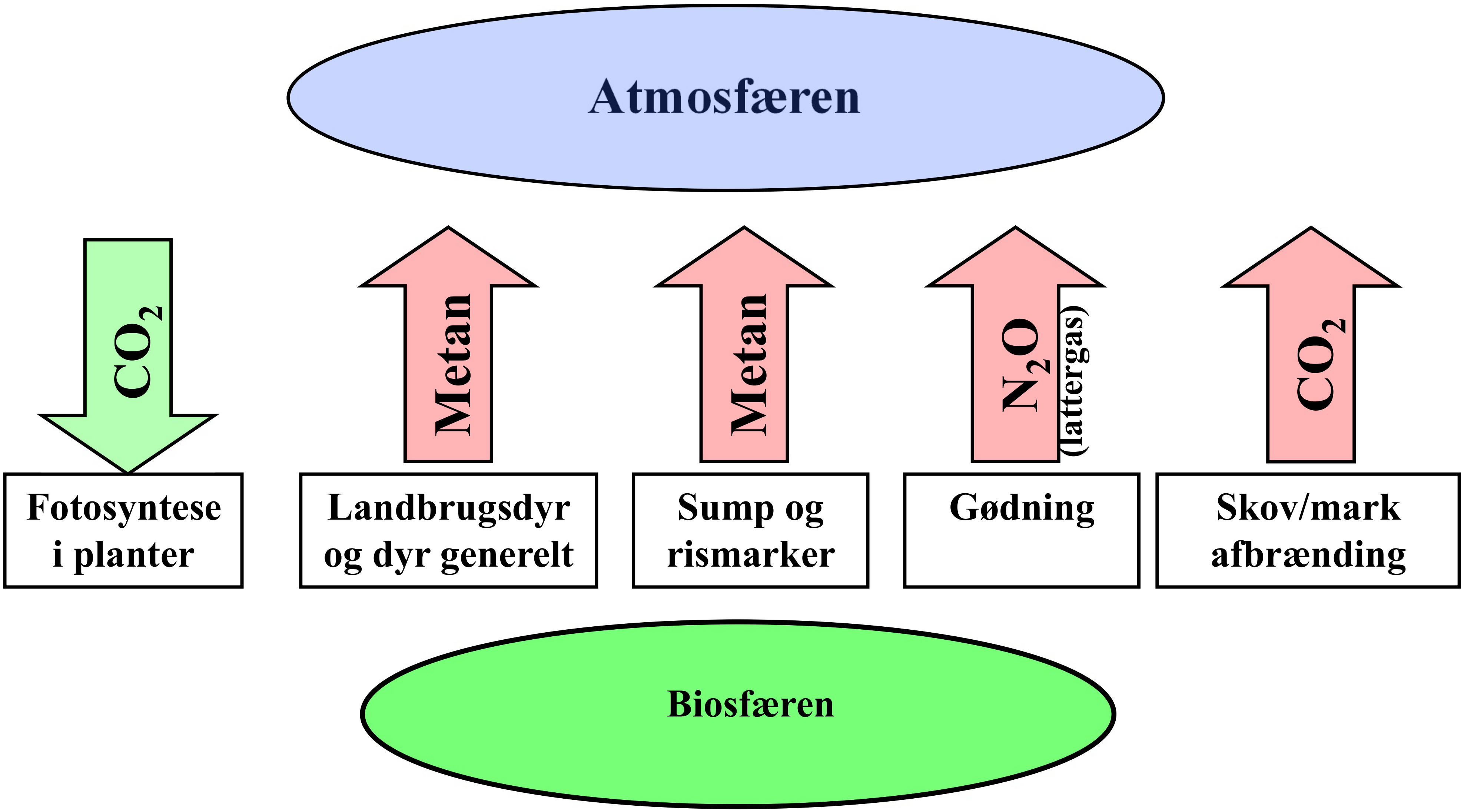

Antarctic Sea Ice Extent
Area of ocean with at least 15% sea ice
1979-1989
1990s
2000s
2010s
2020-2022, 2024
2023 (record low)
2025 (likely minimum date: March 1)
winter maximum
summer minimum
Extent (Millions of square kilometers)
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
1 Jan
1 Feb
1 Mar
1 Apr
1 May
1 Jun
1 Jul
1 Aug
1 Sep
1 Oct
1 Nov
1 Dec
30 Dec
Date
National Snow and Ice Data Center, Boulder, CO


Chukchi Sea
East Siberian Sea
Beaufort Sea
Laptev Sea
Kara Sea
Freeze Trend (days per decade, 1979-2019)
-25 days (earlier)
0
25 days (later)



https://www.climate-lab-book.ac.uk/2015/the-sea-ice-orchestra/

Biosfæren-drivhus gasser



Hvor ender CO2'en

https://www.youtube.com/watch?v=dwVsD9CiokY

GLOBAL CARBON project

Fate of anthropogenic CO_2 emissions (2013–2022)

Sources = Sinks

35.3 $GtCO_2$/yr
88%

12%
4.7 $GtCO_2$/yr

18.9 $GtCO_2$/yr
47%

31%
12.3 $GtCO_2$/yr

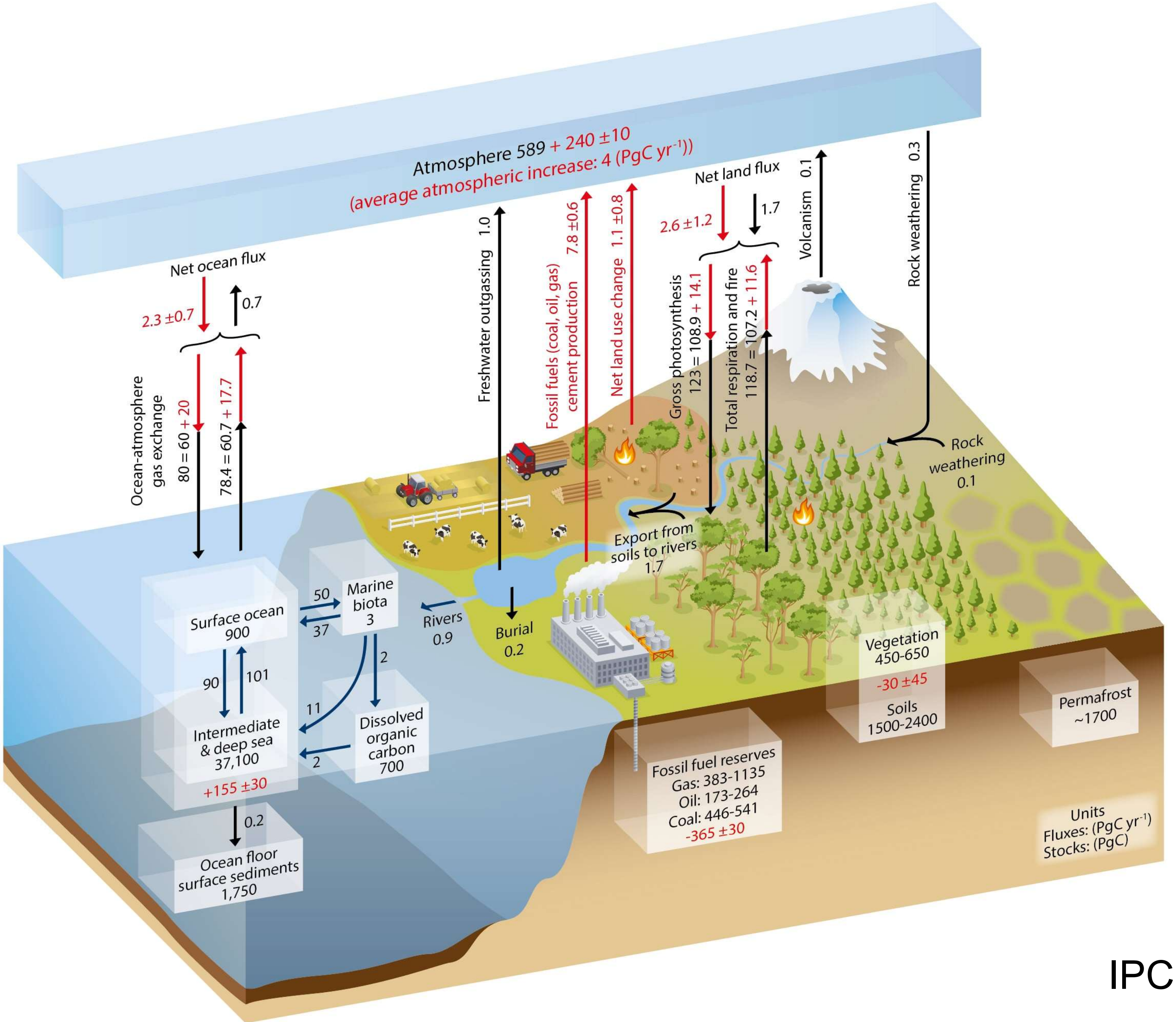
26%
10.4 $GtCO_2$/yr

Budget Imbalance:
(the difference between estimated sources & sinks)

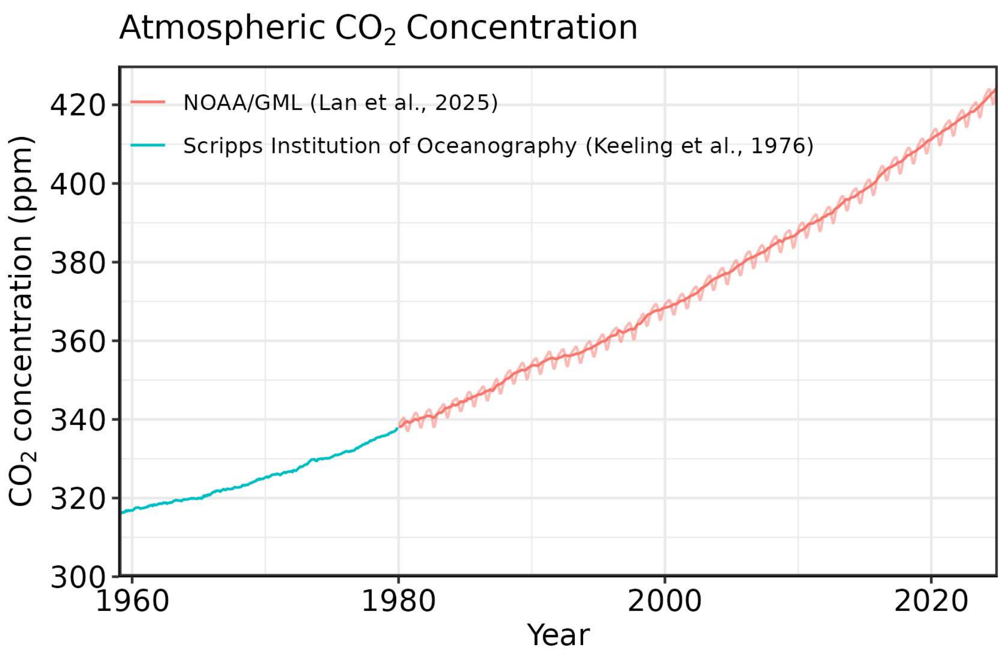
4%
-1.6 $GtCO_2$/yr

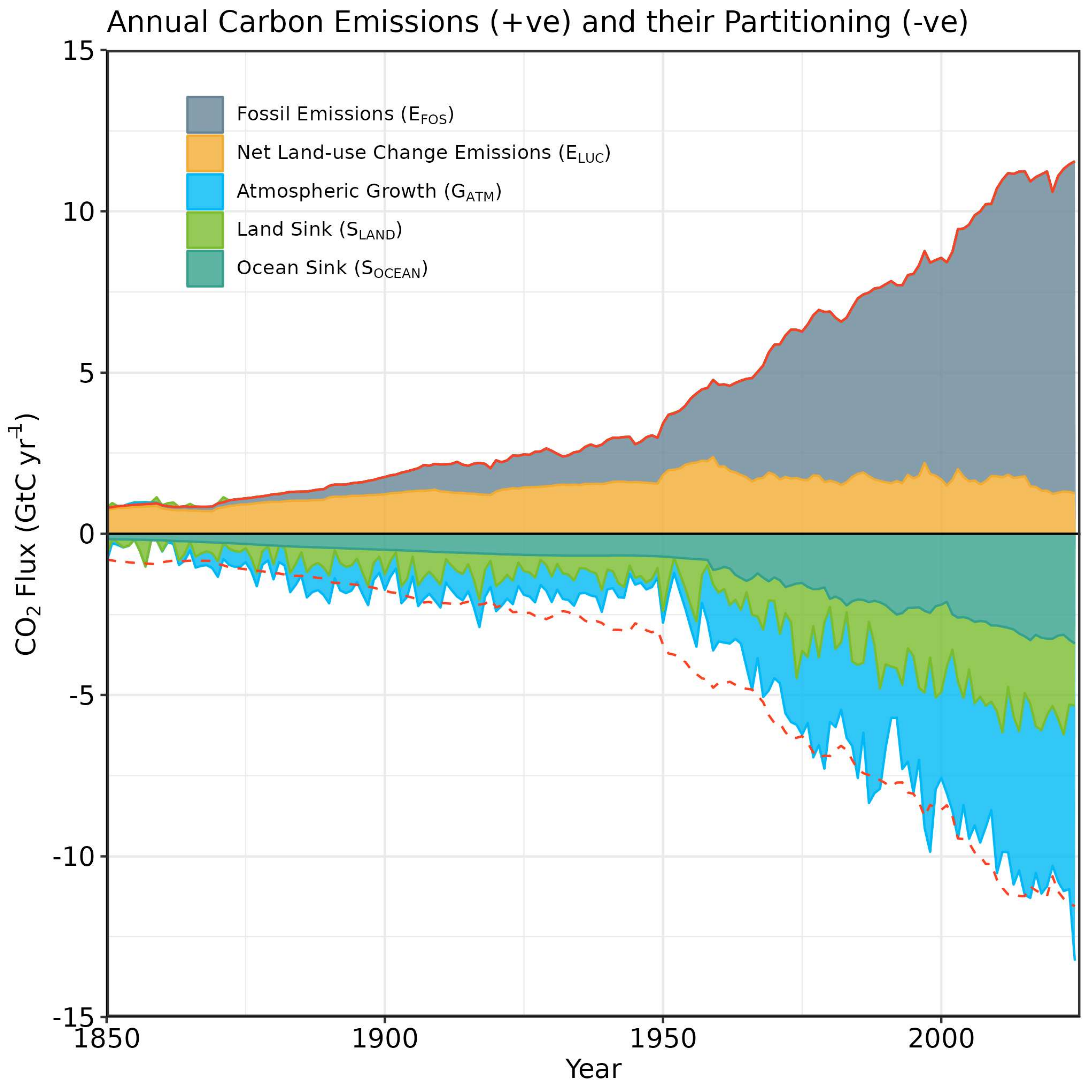
Source: Friedlingstein et al 2023; Global Carbon Project 2023

GLOBAL CARBON project

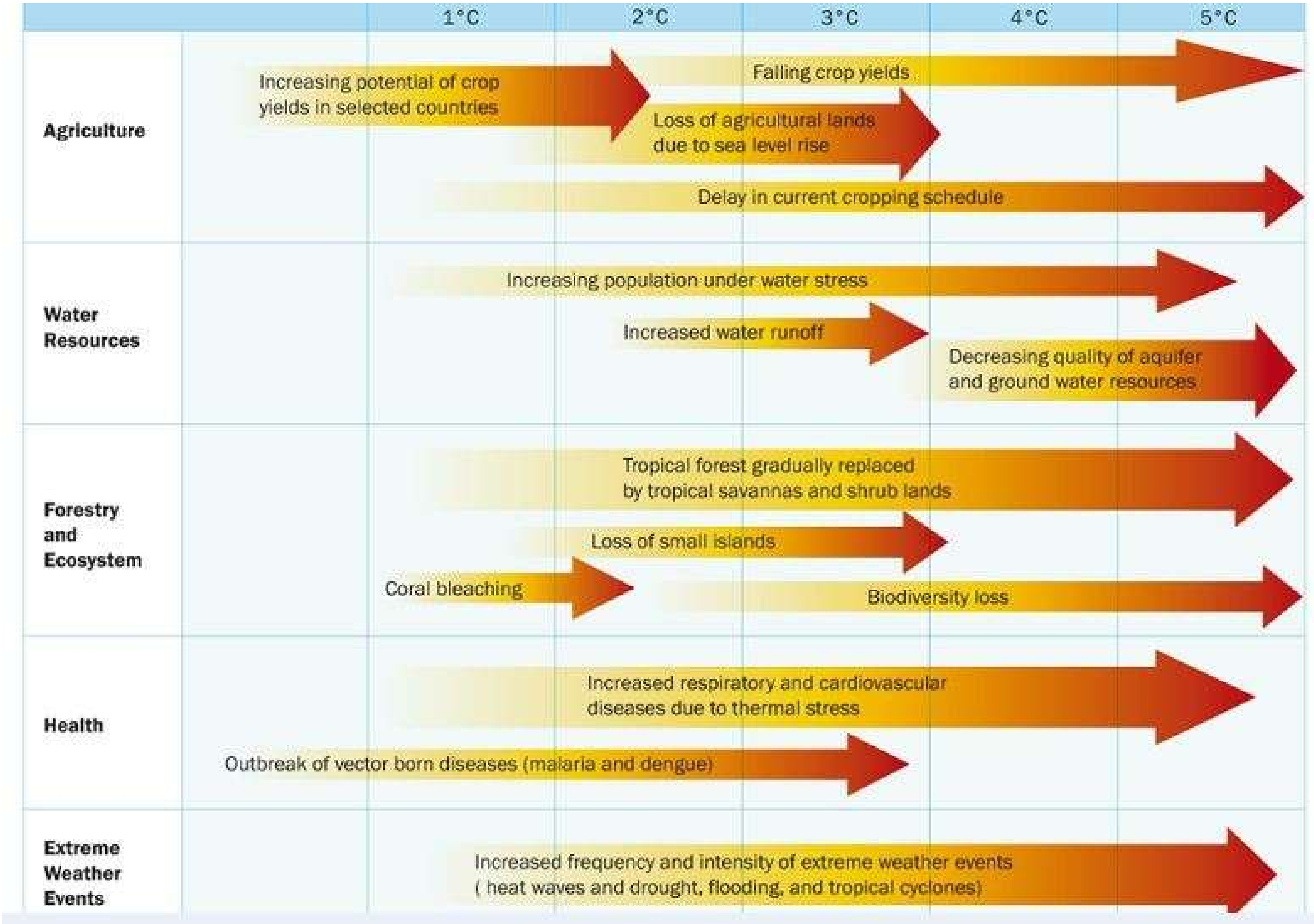


IPCC





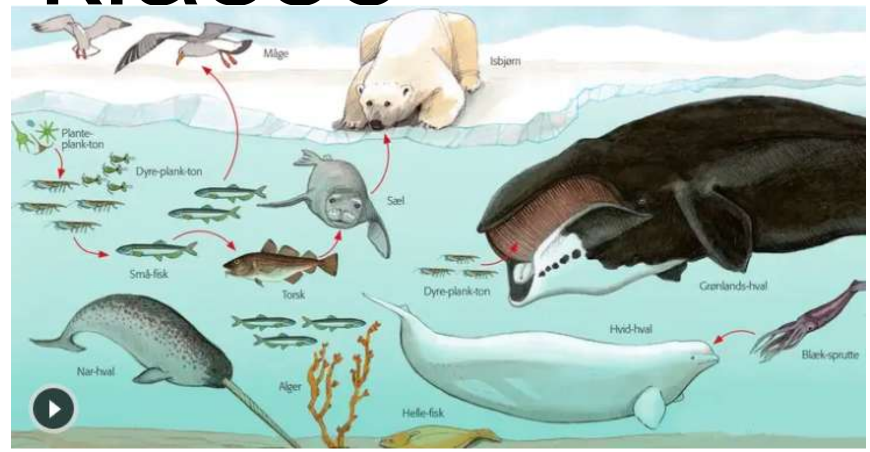
https://globalcarbonbudget.org/gcb-2025/



1°C
2°C
3°C
4°C
5°C
Agriculture
Increasing potential of crop yields in selected countries
Falling crop yields
Loss of agricultural lands due to sea level rise
Delay in current cropping schedule
Water Resources
Increasing population under water stress
Increased water runoff
Decreasing quality of aquifer and ground water resources
Forestry and Ecosystem
Tropical forest gradually replaced by tropical savannas and shrub lands
Loss of small islands
Coral bleaching
Biodiversity loss
Health
Increased respiratory and cardiovascular diseases due to thermal stress
Outbreak of vector born diseases (malaria and dengue)
Extreme Weather Events
Increased frequency and intensity of extreme weather events (heat waves and drought, flooding, and tropical cyclones)

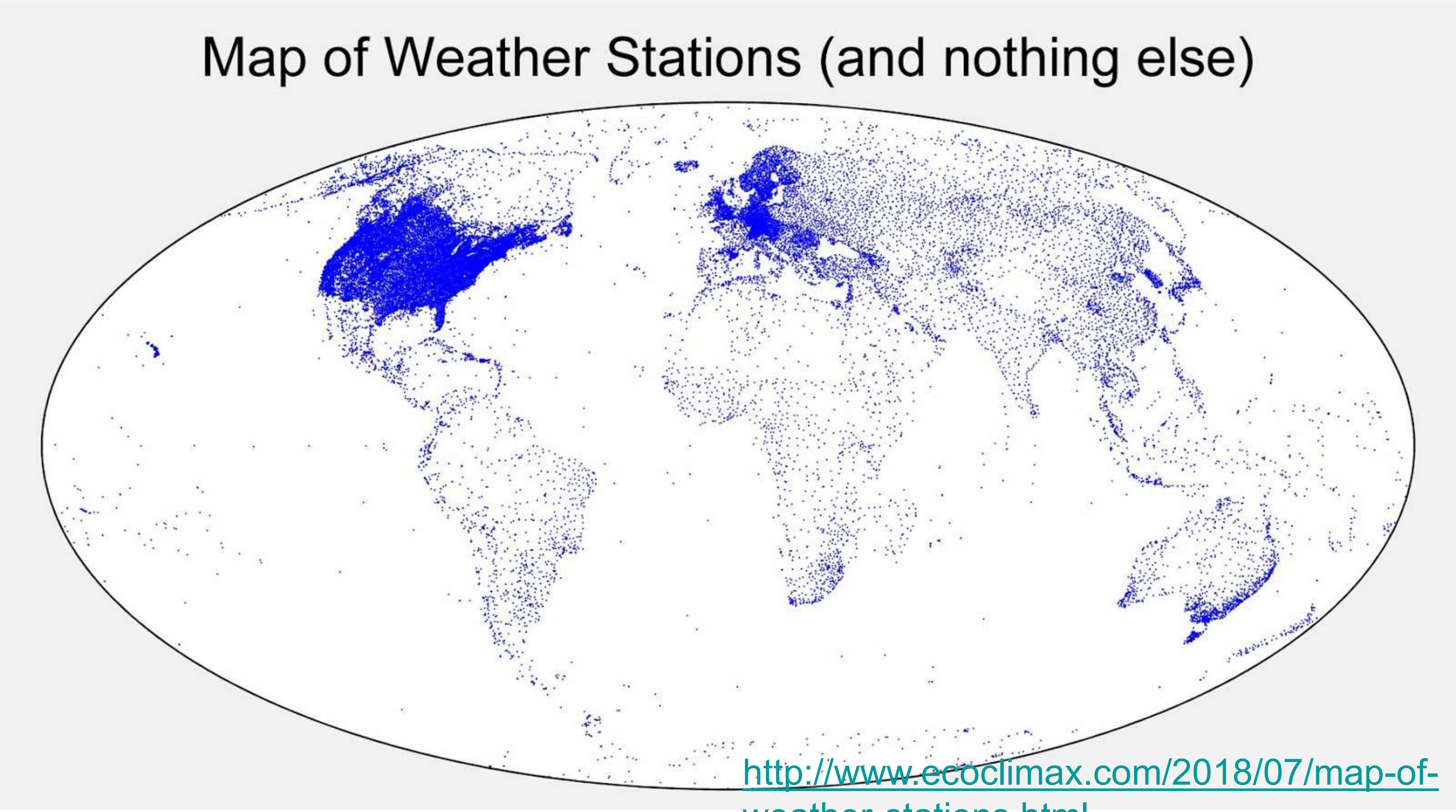
Arktisk fangeleg I 4 klasse

Kastem 2023-Mellerup, Arbjerg, Egsgaard



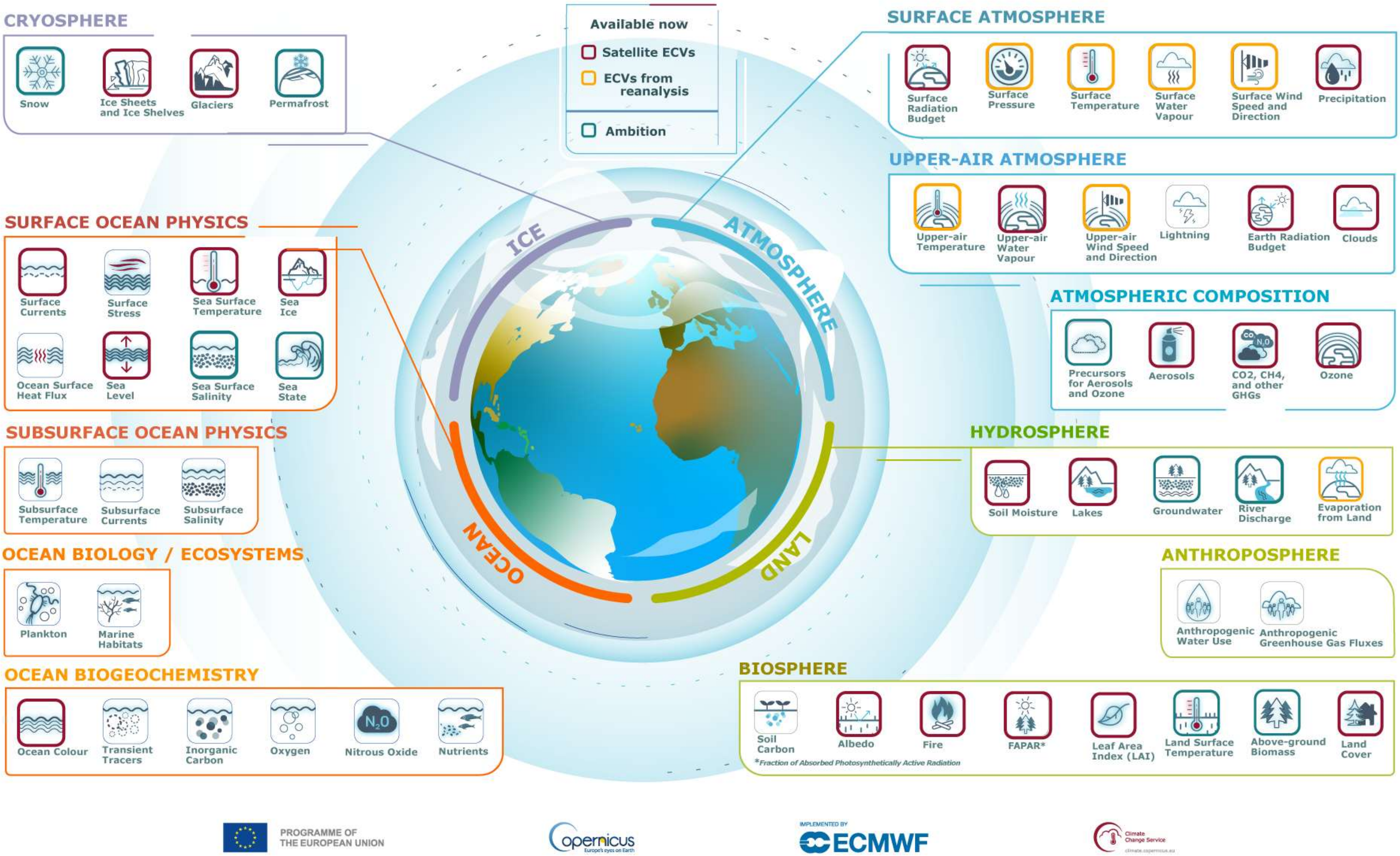
• Jeg kan fortælle hvad der vil ske, hvis et element i fødekæden forsvinder.	Forklar fasen kobler vi med kropsliggjort viden. Undervisningen flyttes fra faglokalet og ned i hallen. Her skal den nye faglige viden om fødekæder konsolideres ved brug af kropsliggjort læring. Eleverne får en lamineret brik med et dyr fra fødekæden, og de skal nu fange deres føde. Bliver man spist går man bag ved den som har spist en, dvs en elev med en sæl brik løber hen til en elev med en isbjørnebrik. Isbjørnen spiser sælen og eleven med sælbrikken går bagved isbjørne-eleven. Til sidst står alle eleverne i få lange rækker, som alle begynder med det dyr som er til sidst i fødekæden, dvs. isbjørn, måge, grønlandshval eller hvidhval. (jf. model øverst i dokumentet) Eleverne fanger lynhurtigt legen og dem som ikke er toprovdyrene prøver at gemme sig i hallen.
• Jeg kan forklare hvordan isbjørnens bevægelses mønstre vil ændre sig	I forlæng fasen ser vi på isbjørnens livsvilkår, når isen smelter. Denne øvelse bliver også til kropsliggjort viden for eleverne. I hallen er der hvide lagner på gulvet, som symboliserer isen. Nogle af eleverne får hvide malerdragter på (de elever som er isbjørne) andre elever er sæler. Sælerne skal op på isen for at hvile og sole sig. Her bliver de spist af isbjørnene, der kan camouflere sig. Næste scenarie er isen smeltet, så de hvide lagner er taget væk. Nu kan isbjørnene ikke camouflere sig og har svært ved at fange sælerne.

Observationer

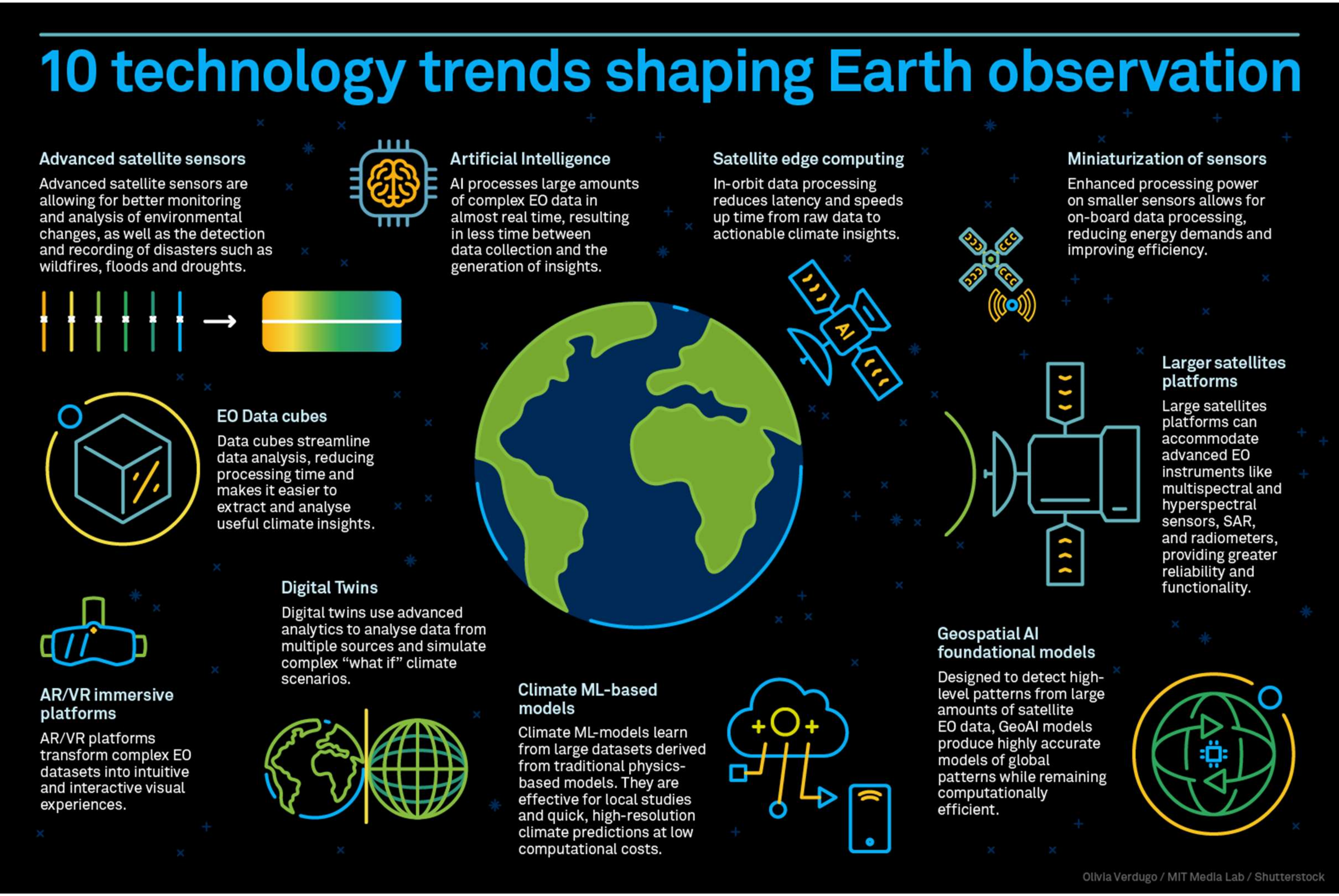


http://www.ecoclimax.com/2018/07/map-of-weather-stations.html

Observations-satelite



Copernicus CS3

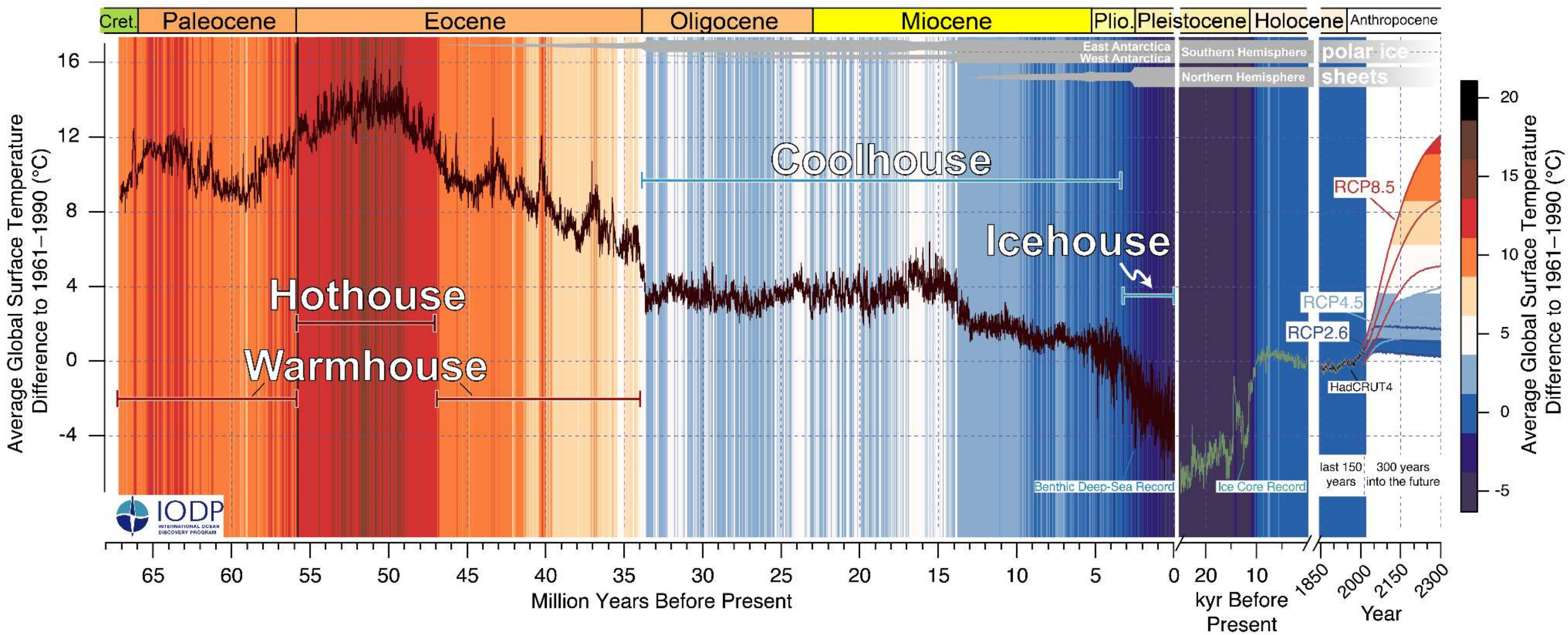

10 technology trends shaping Earth observation
Advanced satellite sensors
Advanced satellite sensors are allowing for better monitoring and analysis of environmental changes, as well as the detection and recording of disasters such as wildfires, floods and droughts.
Artificial Intelligence
AI processes large amounts of complex EO data in almost real time, resulting in less time between data collection and the generation of insights.
Satellite edge computing
In-orbit data processing reduces latency and speeds up time from raw data to actionable climate insights.
AI
Miniaturization of sensors
Enhanced processing power on smaller sensors allows for on-board data processing, reducing energy demands and improving efficiency.
EO Data cubes
Data cubes streamline data analysis, reducing processing time and makes it easier to extract and analyse useful climate insights.
Larger satellites platforms
Large satellites platforms can accommodate advanced EO instruments like multispectral and hyperspectral sensors, SAR, and radiometers, providing greater reliability and functionality.
Digital Twins
Digital twins use advanced analytics to analyse data from multiple sources and simulate complex “what if” climate scenarios.
AR/VR immersive platforms
AR/VR platforms transform complex EO datasets into intuitive and interactive visual experiences.
Climate ML-based models
Climate ML-models learn from large datasets derived from traditional physics-based models. They are effective for local studies and quick, high-resolution climate predictions at low computational costs.
Geospatial AI foundational models
Designed to detect high-level patterns from large amounts of satellite EO data, GeoAI models produce highly accurate models of global patterns while remaining computationally efficient.
Olivia Verdugo / MIT Media Lab / Shutterstock

GLOBAL CARBON PROJECT

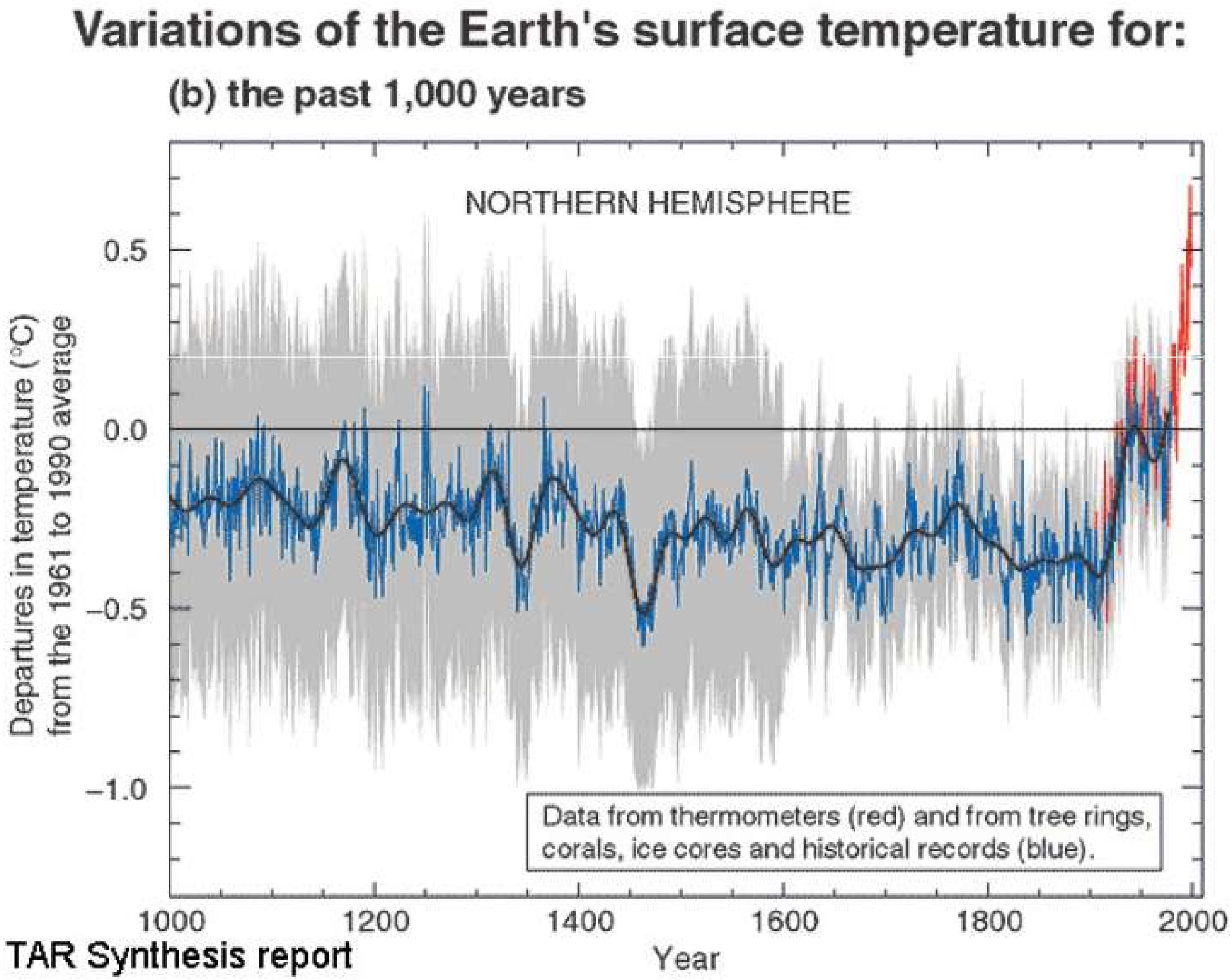
65 millioner år

Westerhold et al., Science, 2020

https://www.livescience.com/oldest-climate-record-ever-cenozoic-era.html



IPCC TAR 2001 (3rd assessment report)
The Mann curve / hockeystick curve



Forcings of Holocene climate – orbital forcing

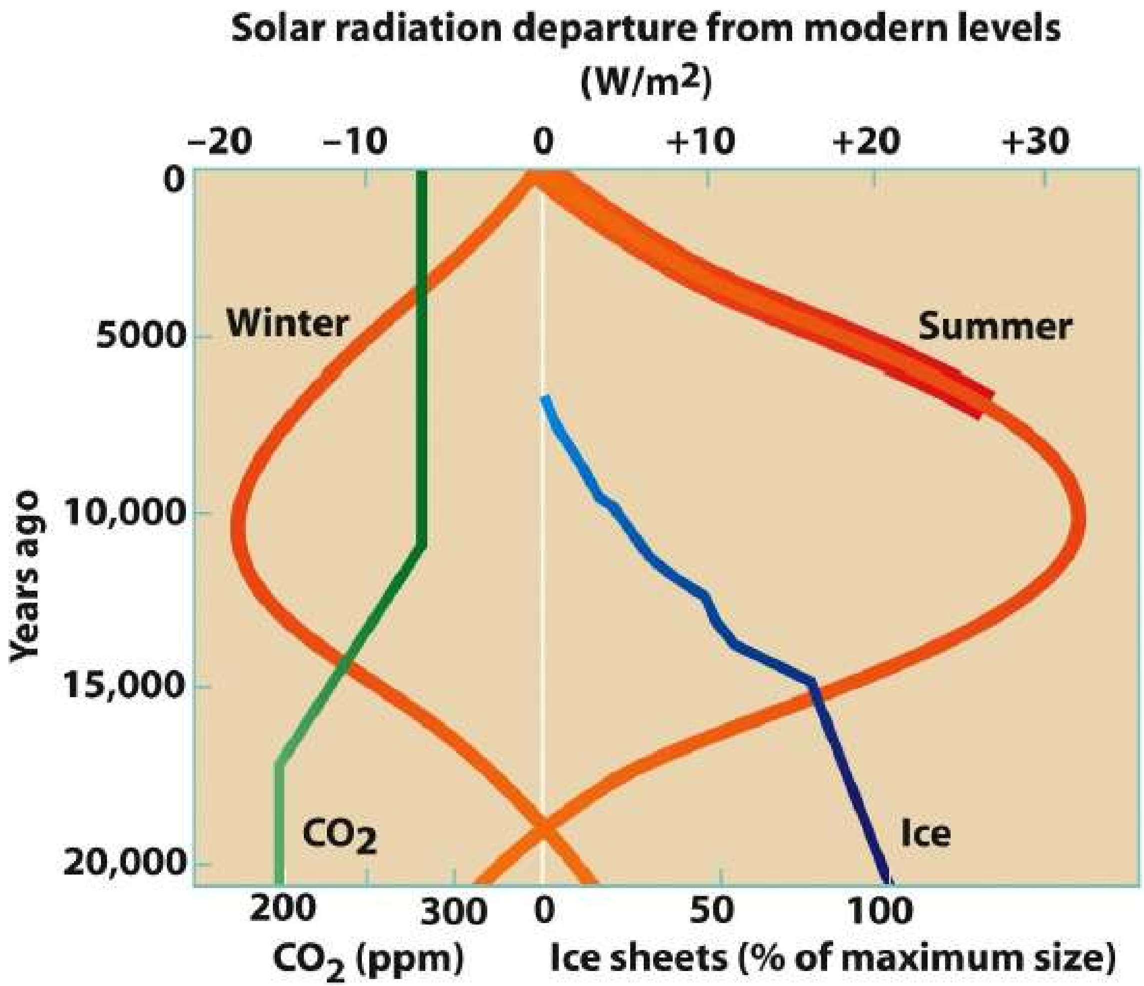
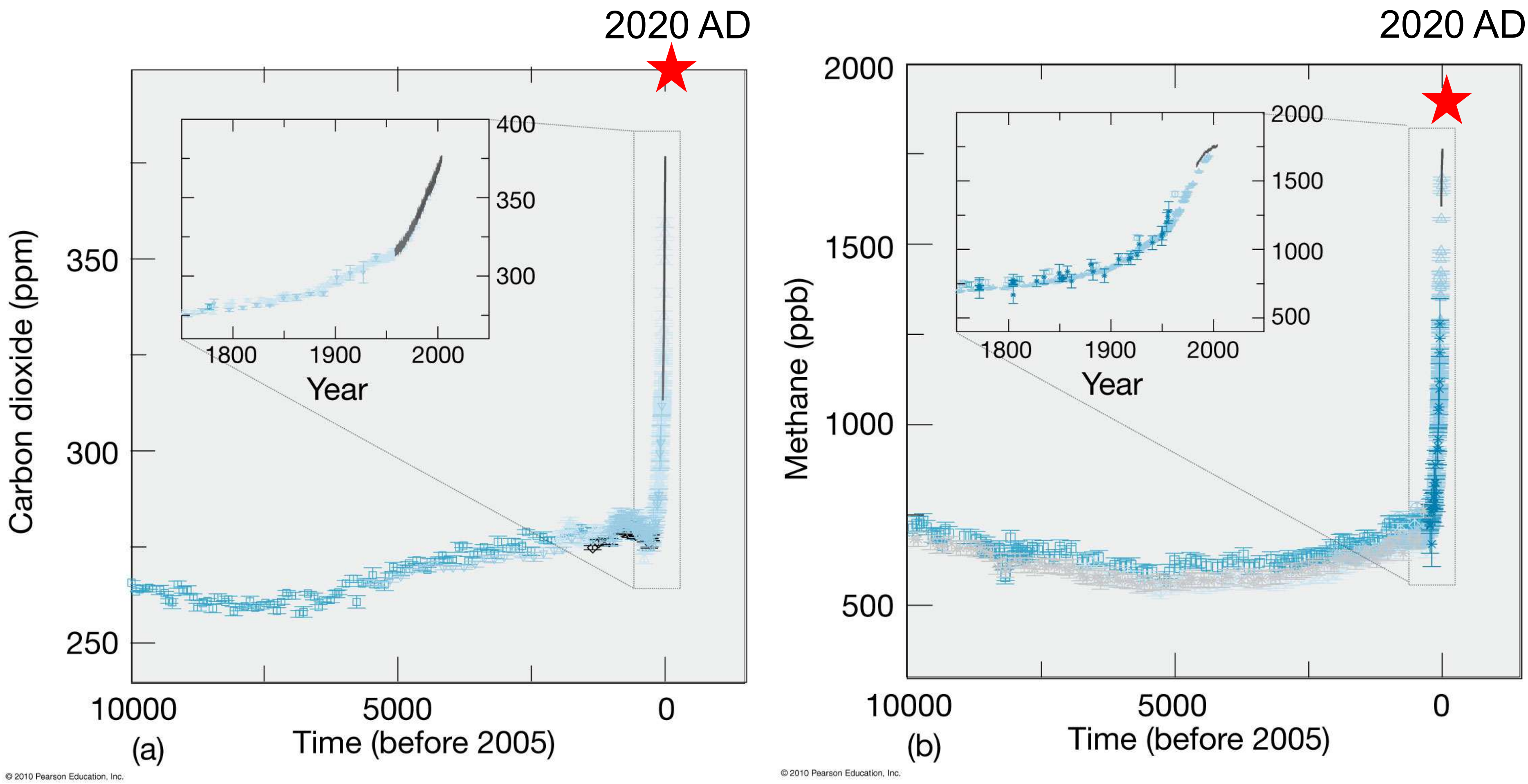
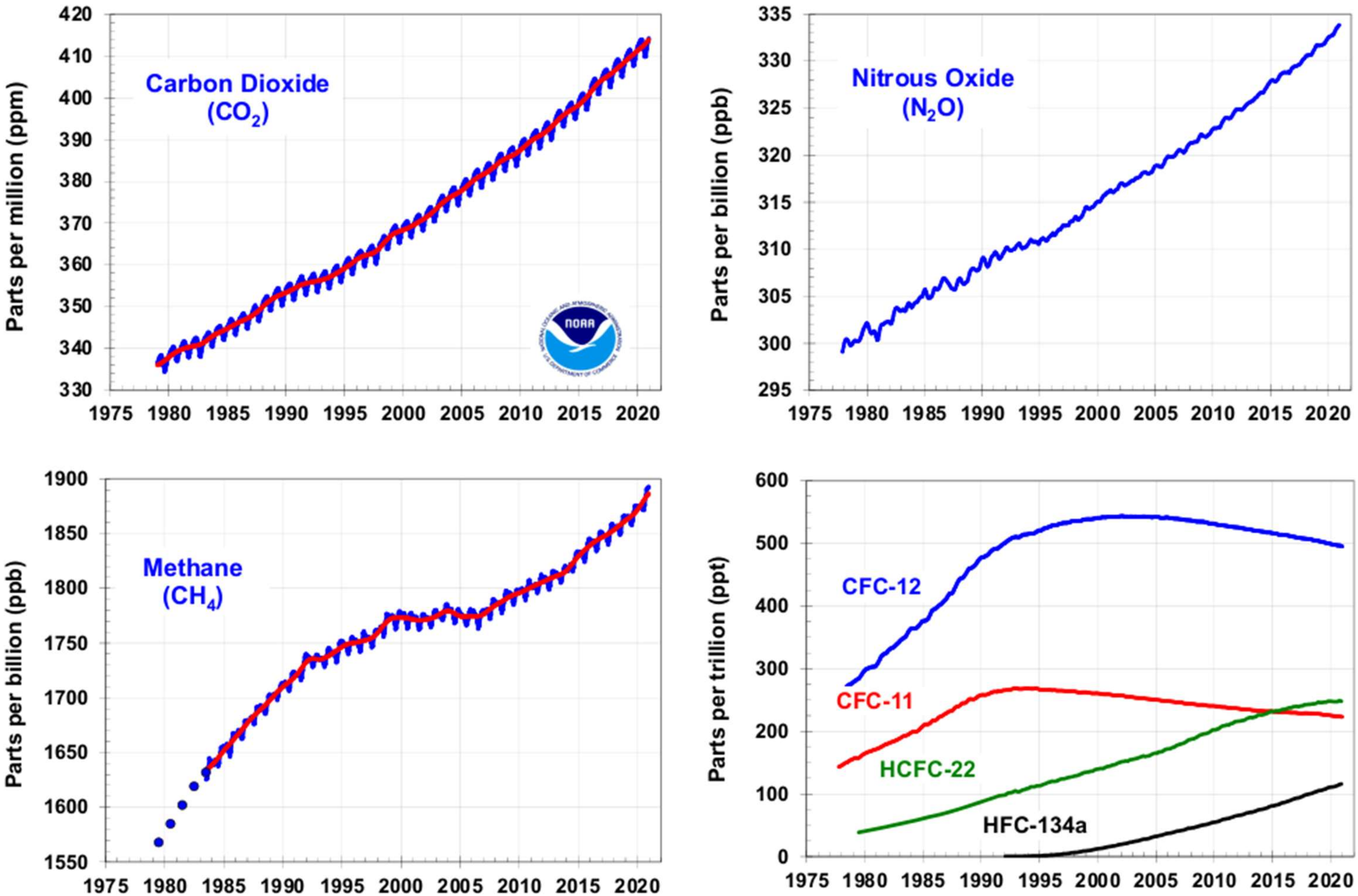


Figure 13-12
Earth's Climate: Past and Future, Second Edition

Atmospheric Carbon dioxide and Methane concentrations over the past 10.000 years as determined from ice cores and direct atmospheric measurements

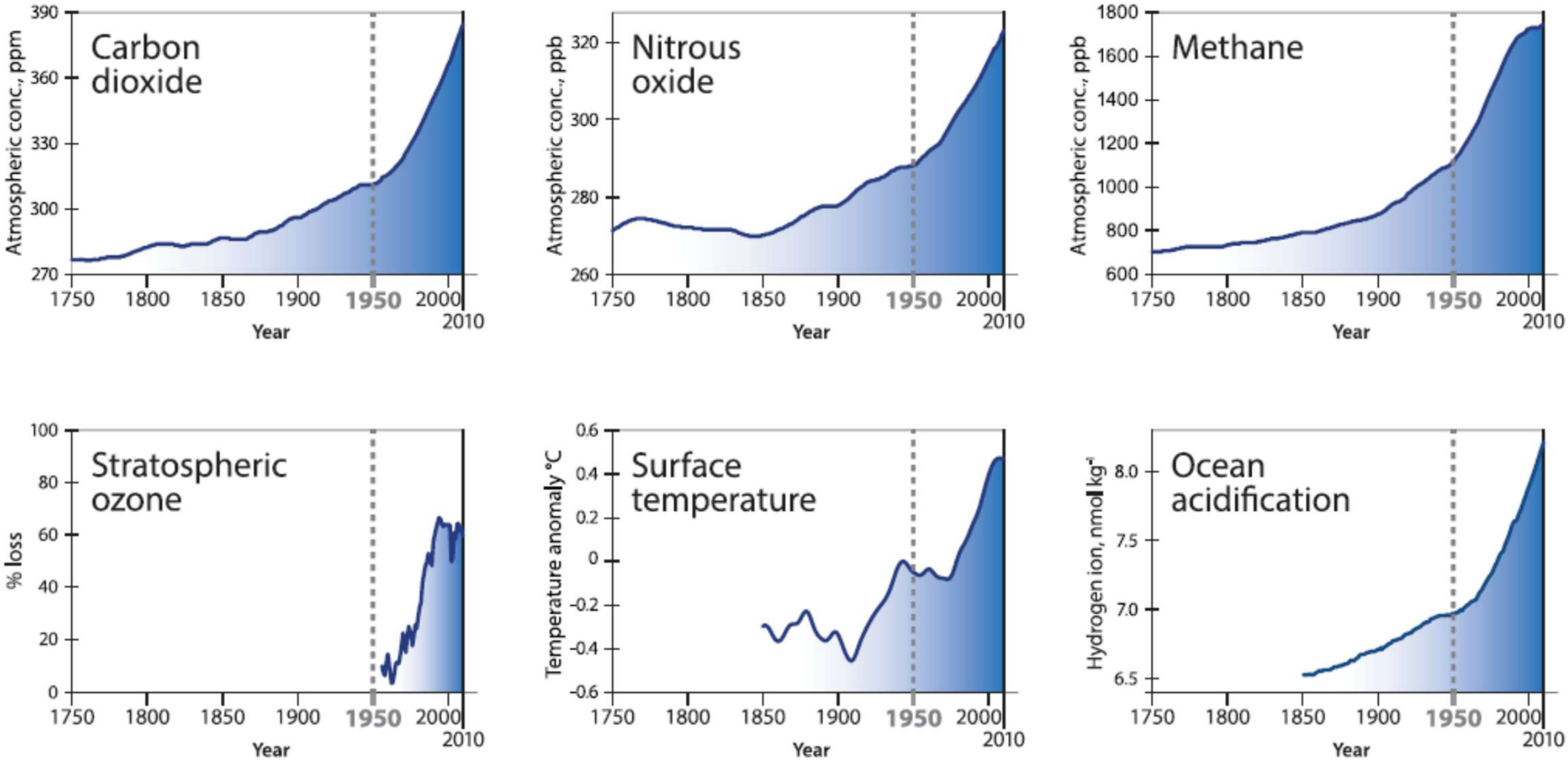


NOAA Annual Greenhouse Gas Index: http://www.esrl.noaa.gov/gmd/aggi/



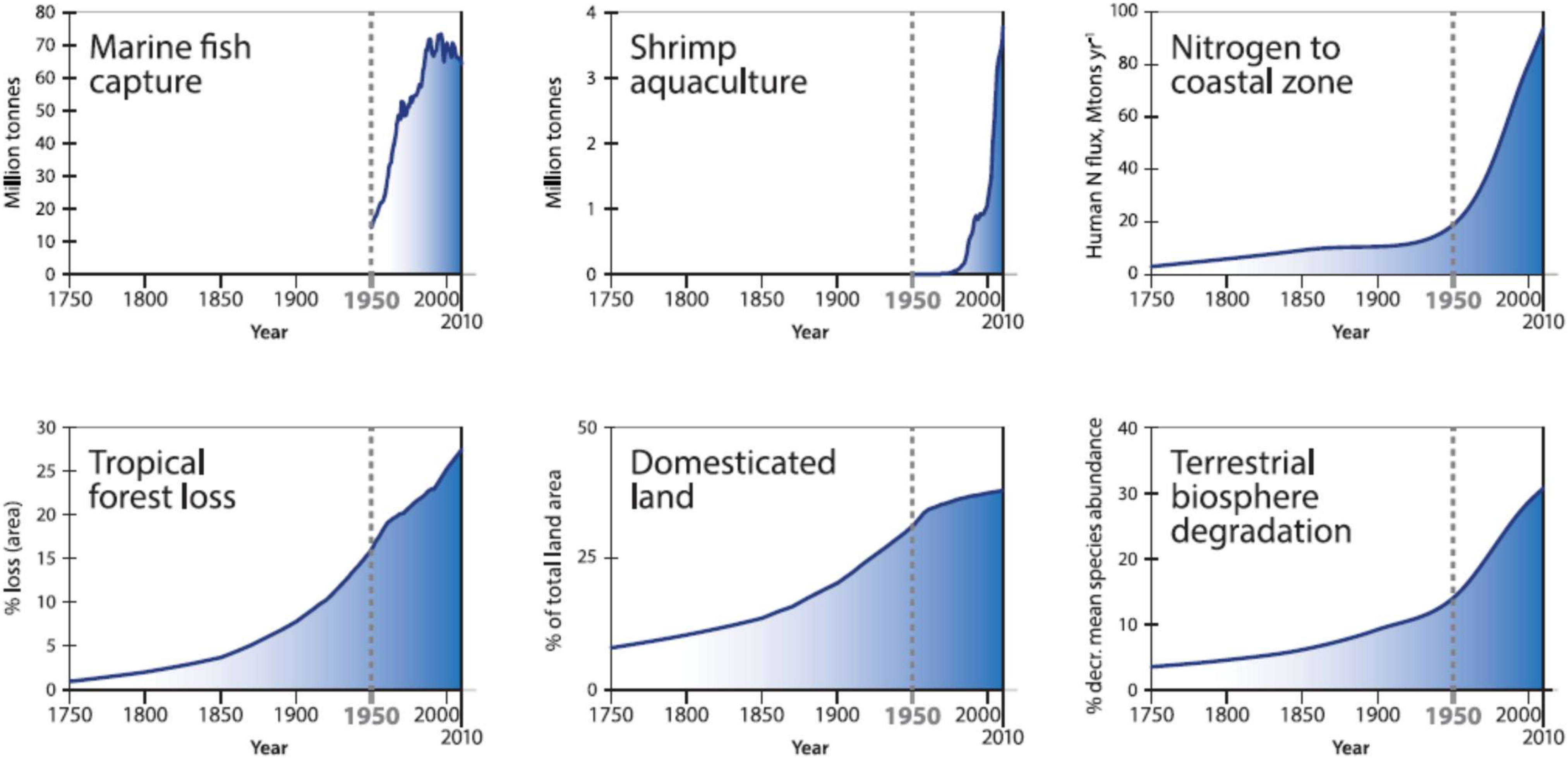
E
FOSSIL FUELS
How Much Do You Consume in a Lifetime?
We consume fossil fuels every day for transportation, heating, and manufacturing, but over a lifetime of 80 years how much does the average American consume?
192m³ (6,780 ft³)
NATURAL GAS
5.8m
19ft
The primary use for natural gas is heating and electricity generation, but it is also used as a raw material in the manufacturing of anhydrous ammonia fertilizer.
119.3 tonnes (131.5 tons)
COAL
5.2m
17.1ft
6.7m
22ft
236.8 tonnes (261 tons)
PETROLEUM PRODUCTS
Along with automotive fuels, petroleum products are also used to manufacture pharmaceuticals, textiles, plastics, and wax.
1.7m
5.6ft
AVG. PERSON
Coal is primarily used to generate electricity, but it is also used to manufacture steel, cement, and other industrial materials.
Methodology: To visualize the average American's fossil fuel consumption, we took petroleum product, coal, and natural gas yearly consumption per capita data and multiplied it by 80 to calculate a "lifetime consumption" figure. The natural gas figure was already in cubic meters/feet, however the figures for coal and petroleum were still a weight (kgs/lbs). Using the density of these materials (833kg/m³ for bulk bituminous coal and 800kg/m³ for petroleum products) and the weight of a lifetime's worth of consumption we calculated the total volume the materials would make up.
ELEMENTS
Source: National Mining Association, Worldometer
ELEMENTS.VISUALCAPITALIST.COM

Earth system trends



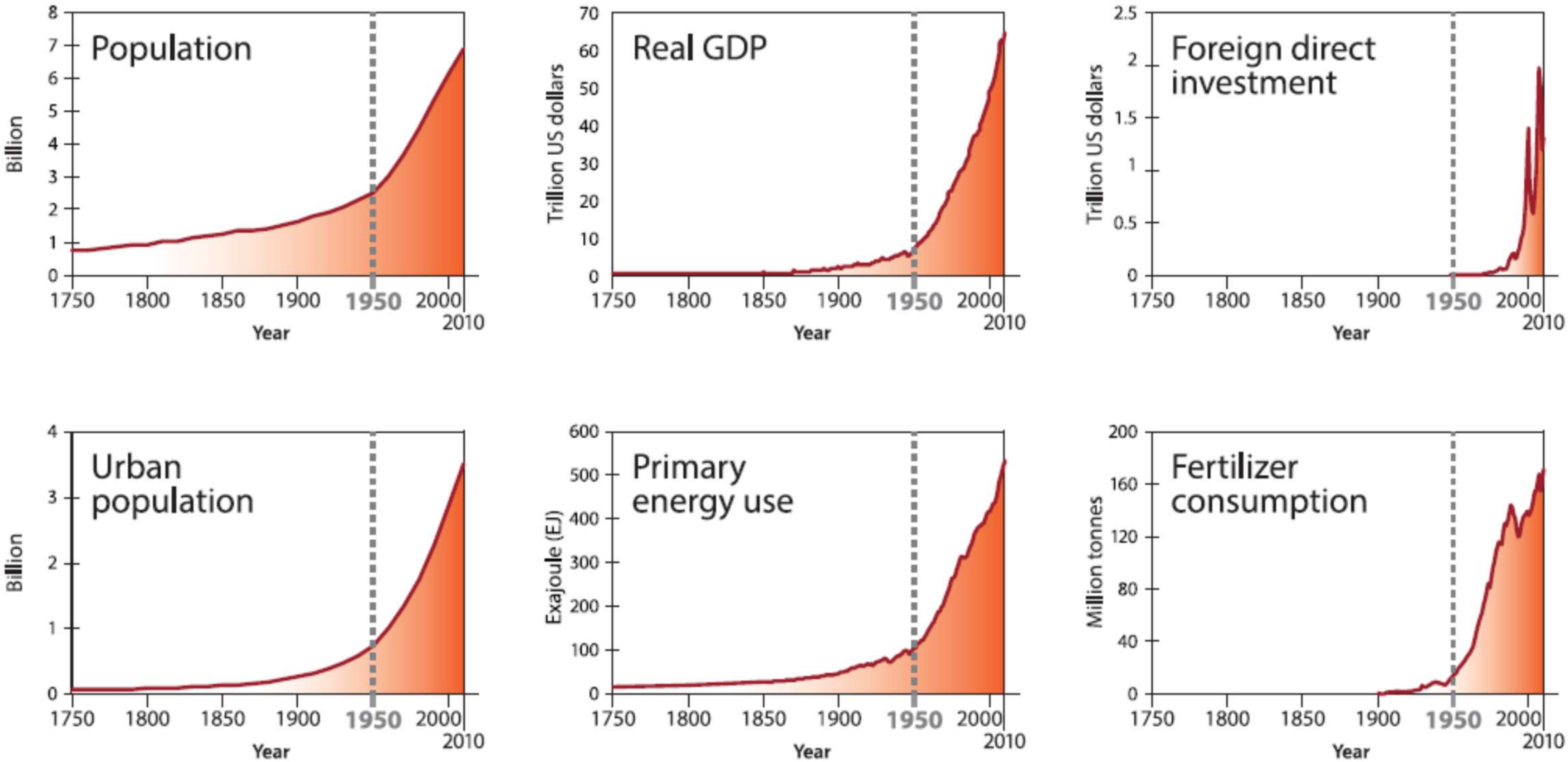
(Steffen et al., ‘The trajectory of the Anthropocene: The Great Acceleration’, The Anthropocene review, 2015)

Earth system trends



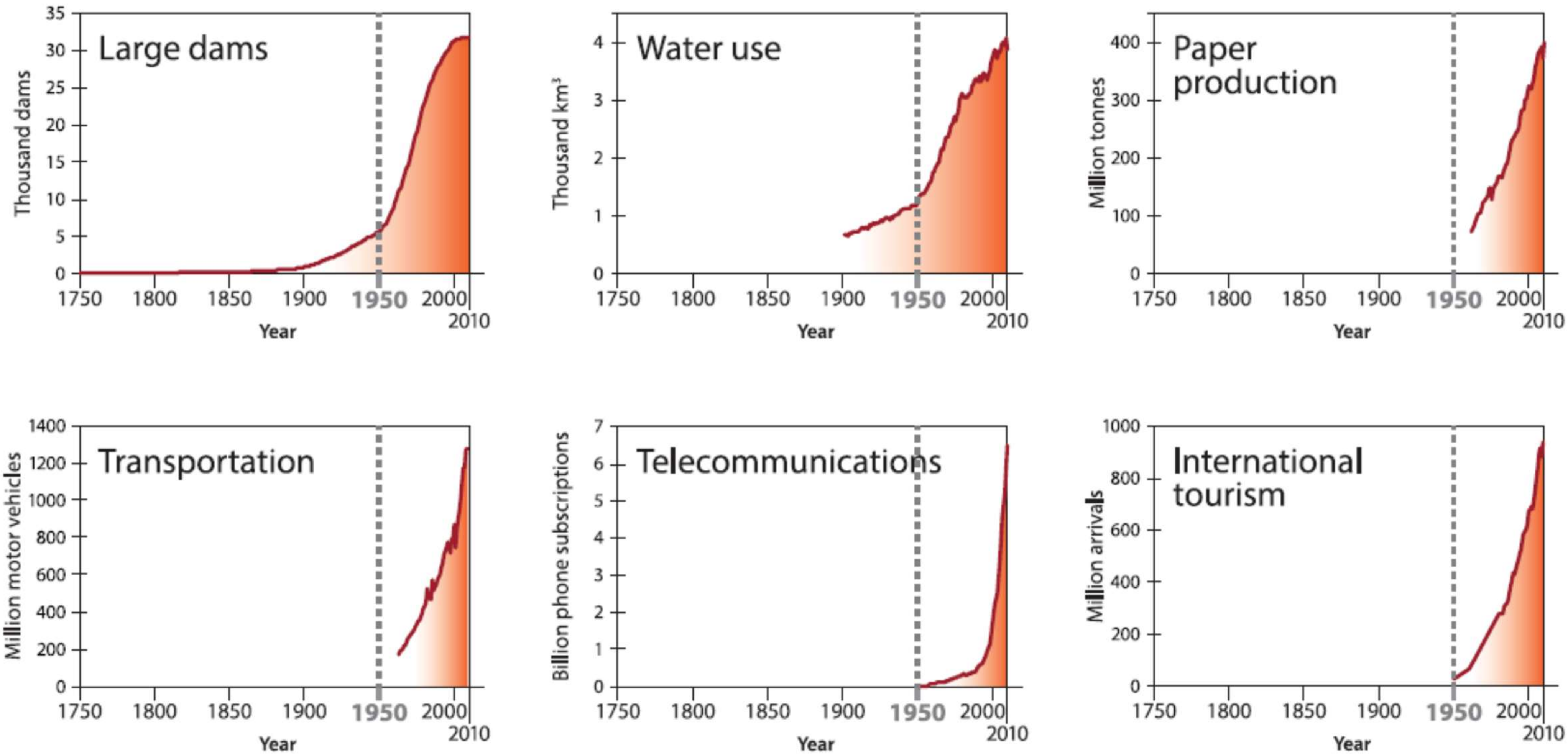
(Steffen et al., 'The trajectory of the Anthropocene: The Great Acceleration', The Anthropocene review, 2015)

Socio-economic trends



(Steffen et al., ‘The trajectory of the Anthropocene: The Great Acceleration’, The Anthropocene review, 2015)

Socio-economic trends



(Steffen et al., ‘The trajectory of the Anthropocene: The Great Acceleration’, The Anthropocene review, 2015)

Welcome to the United Nations https://population.un.org/wpp/Graphs/DemographicProfiles/Line/900

United Nations | Department of Economic and Social Affairs
Population Dynamics

World Population Prospects 2019

WPP Home | Data ▾ | Figures ▾ | Documentation ▾ | World Urbanization Prospects | Population Division | Contact Us

Graphs / Profiles

Select the location:

World ▾

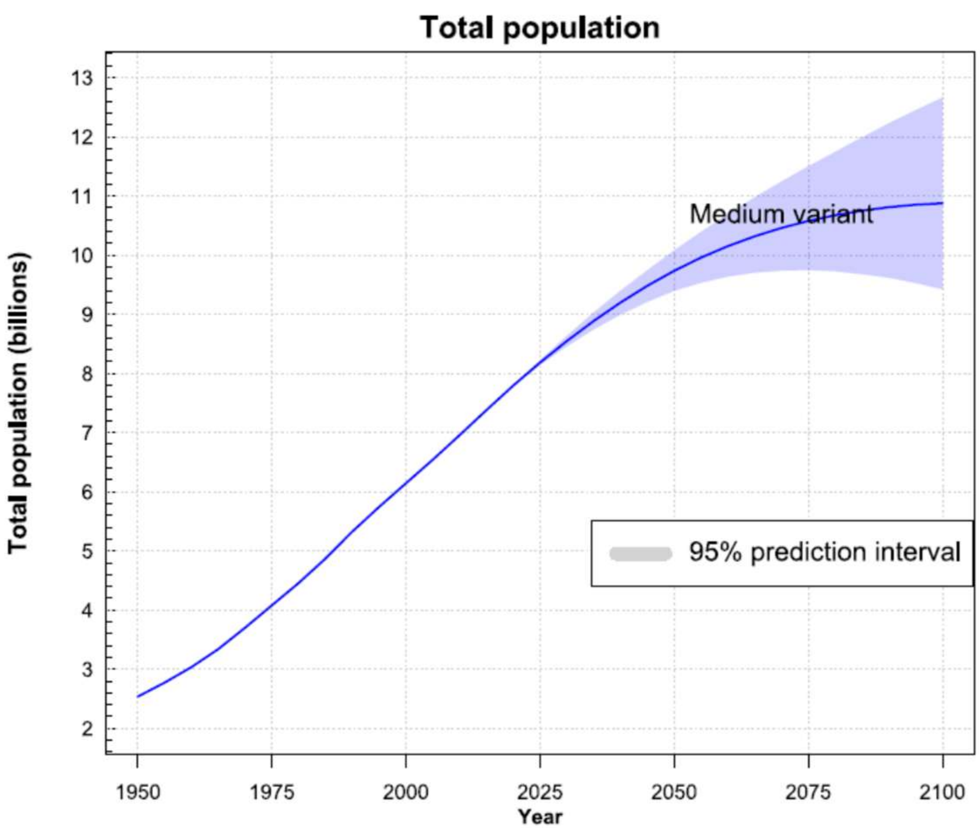
(**World** and **other aggregates** are listed at the bottom of the list)

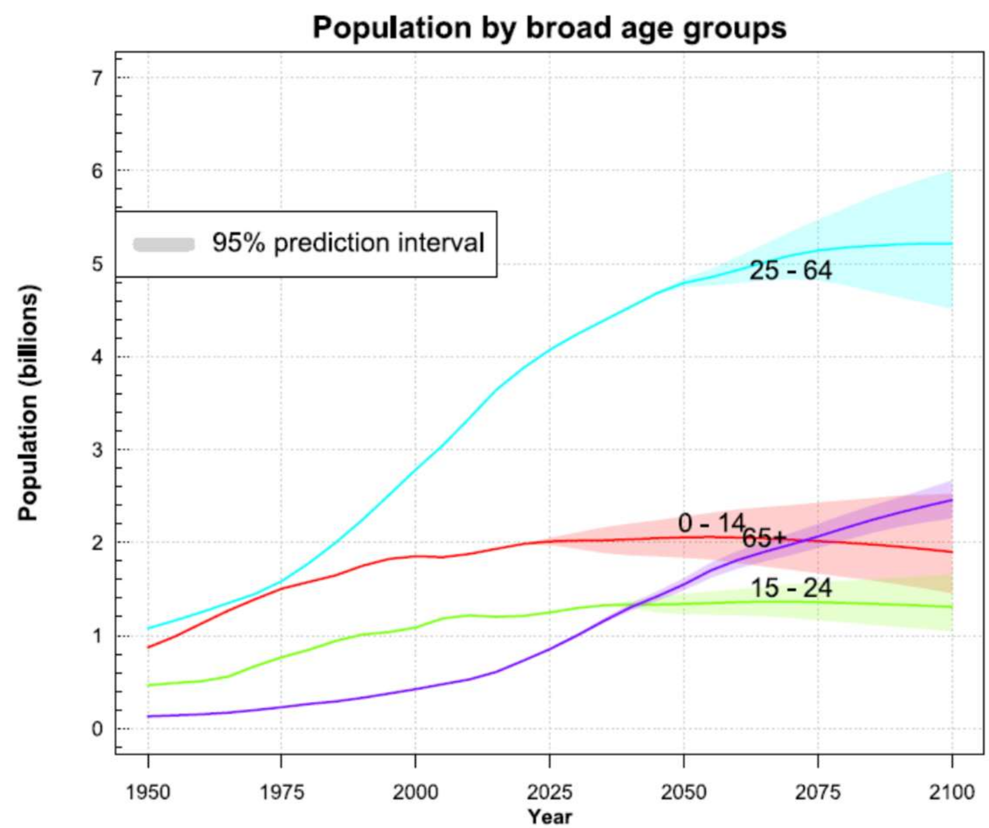
Select the graph:

Demographic Profiles | Probabilistic Projections

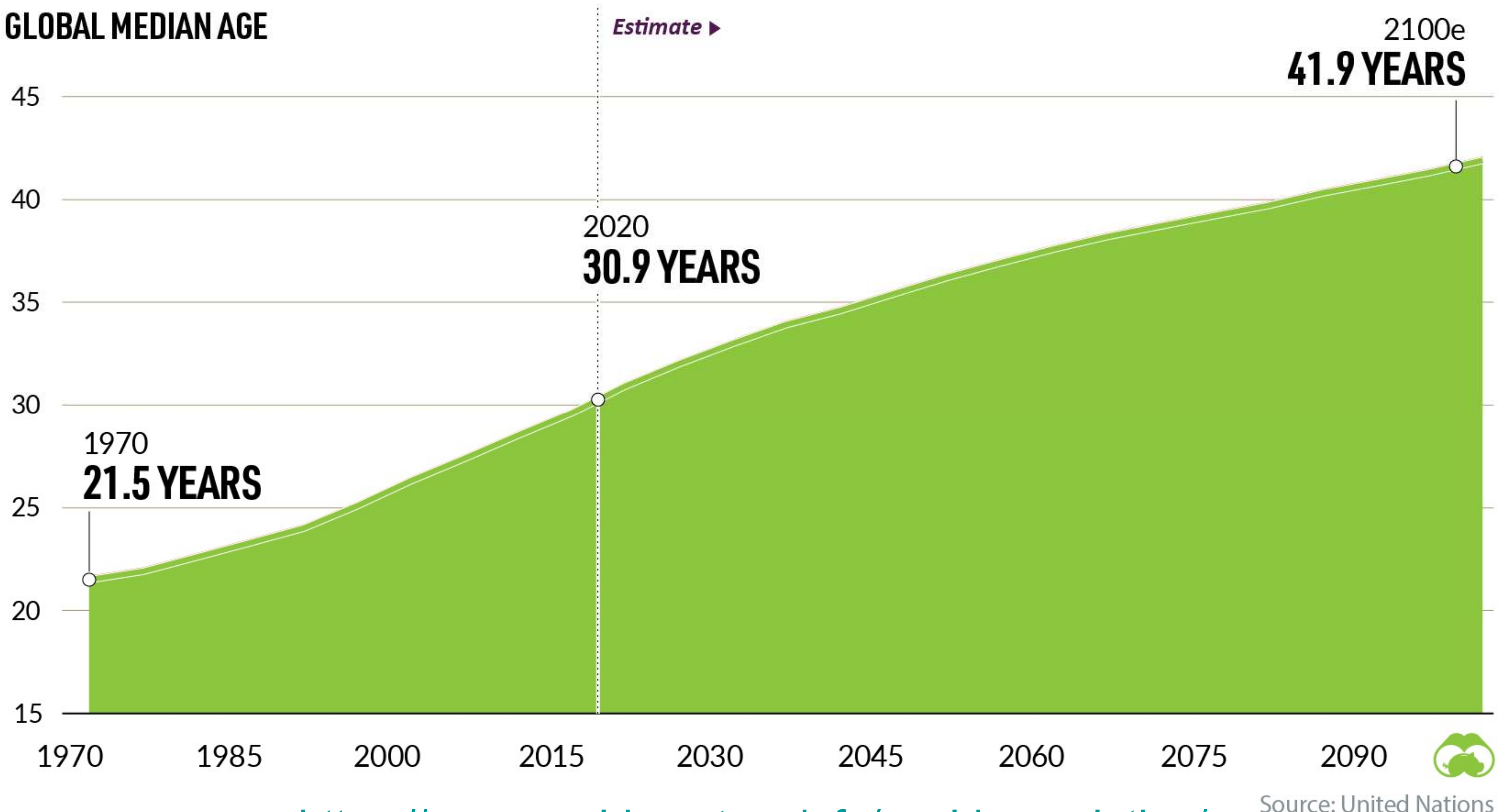
> **Line Charts** | Population Pyramids

Currently showing: World > Demographic Profiles > Line Charts

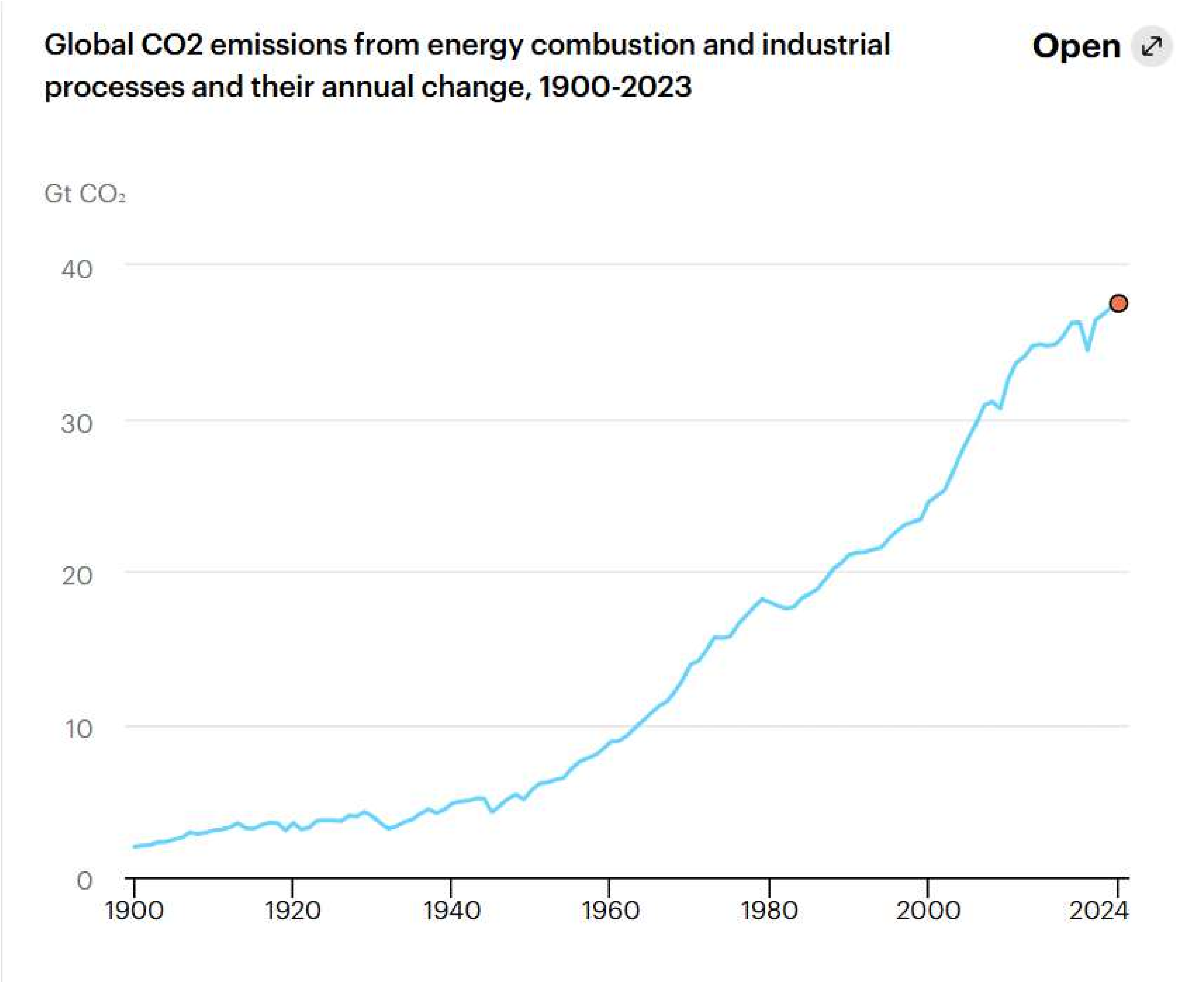




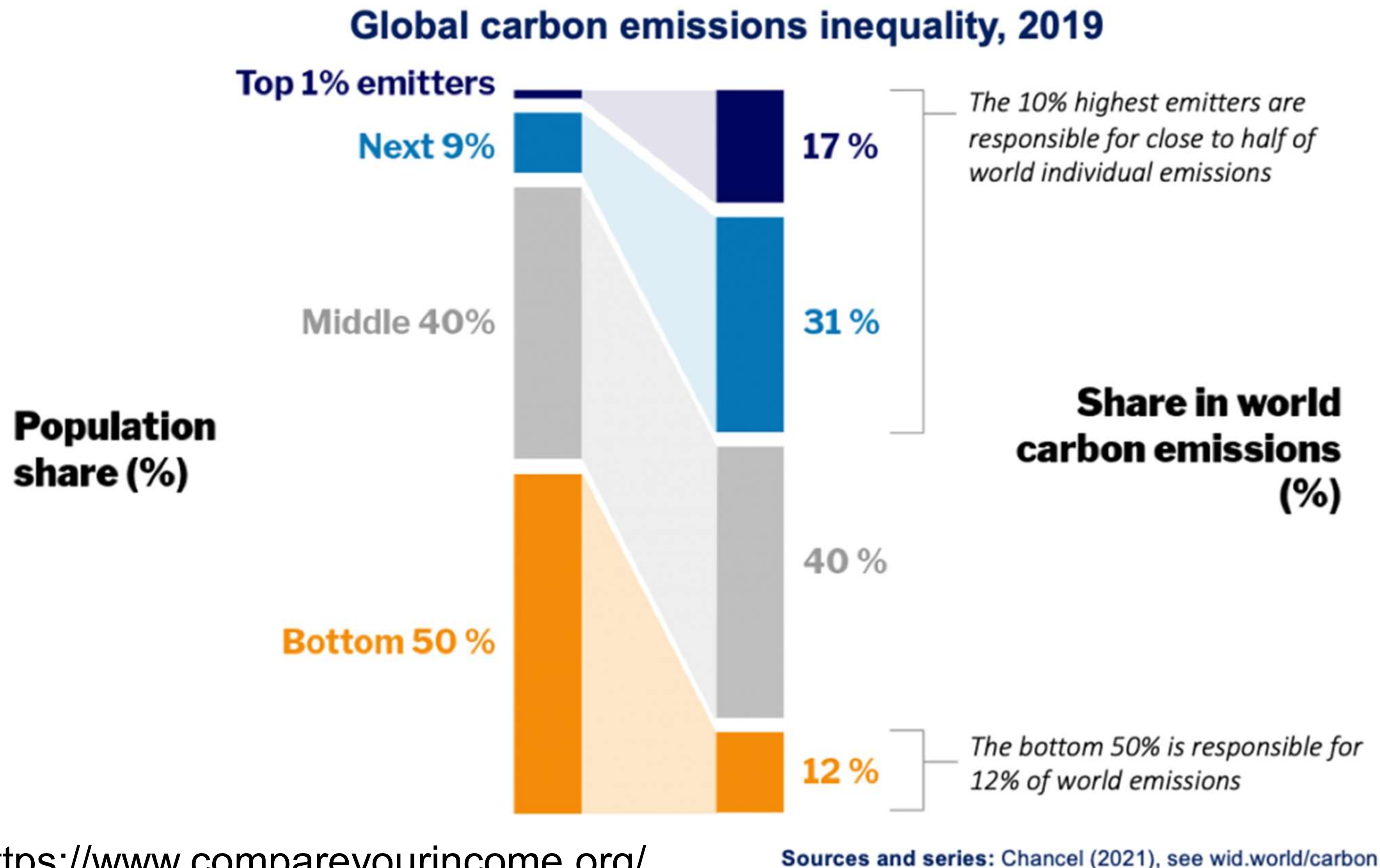
https://www.visualcapitalist.com/5-undeniable-long-term-trends-shaping-societys-future/



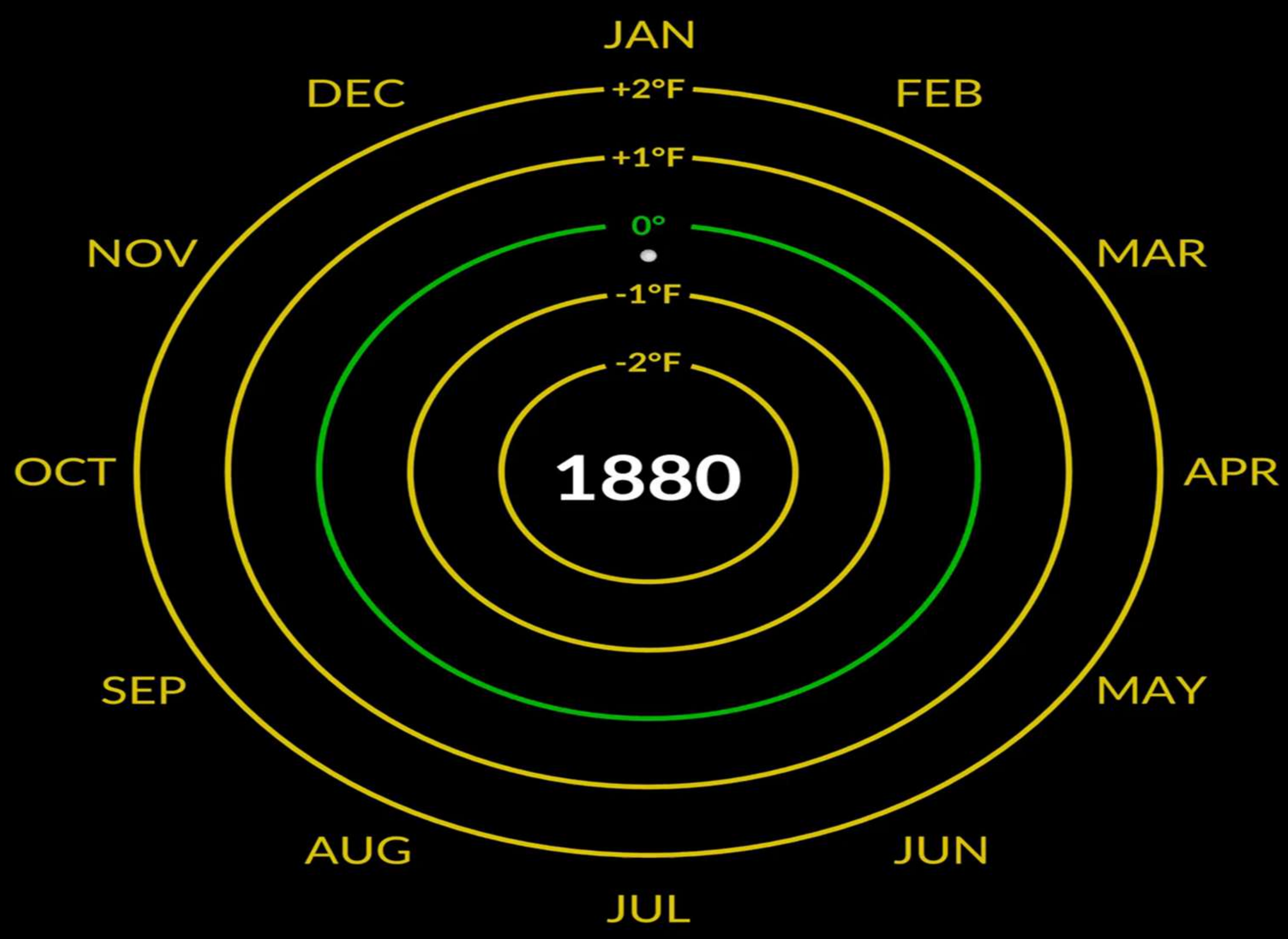
https://www.worldometers.info/world-population/



https://www.iea.org/reports/global-energy-review-2025/co2-emissions https://wid.world/news-article/climate-change-the-global-inequality-of-carbon-emissions/

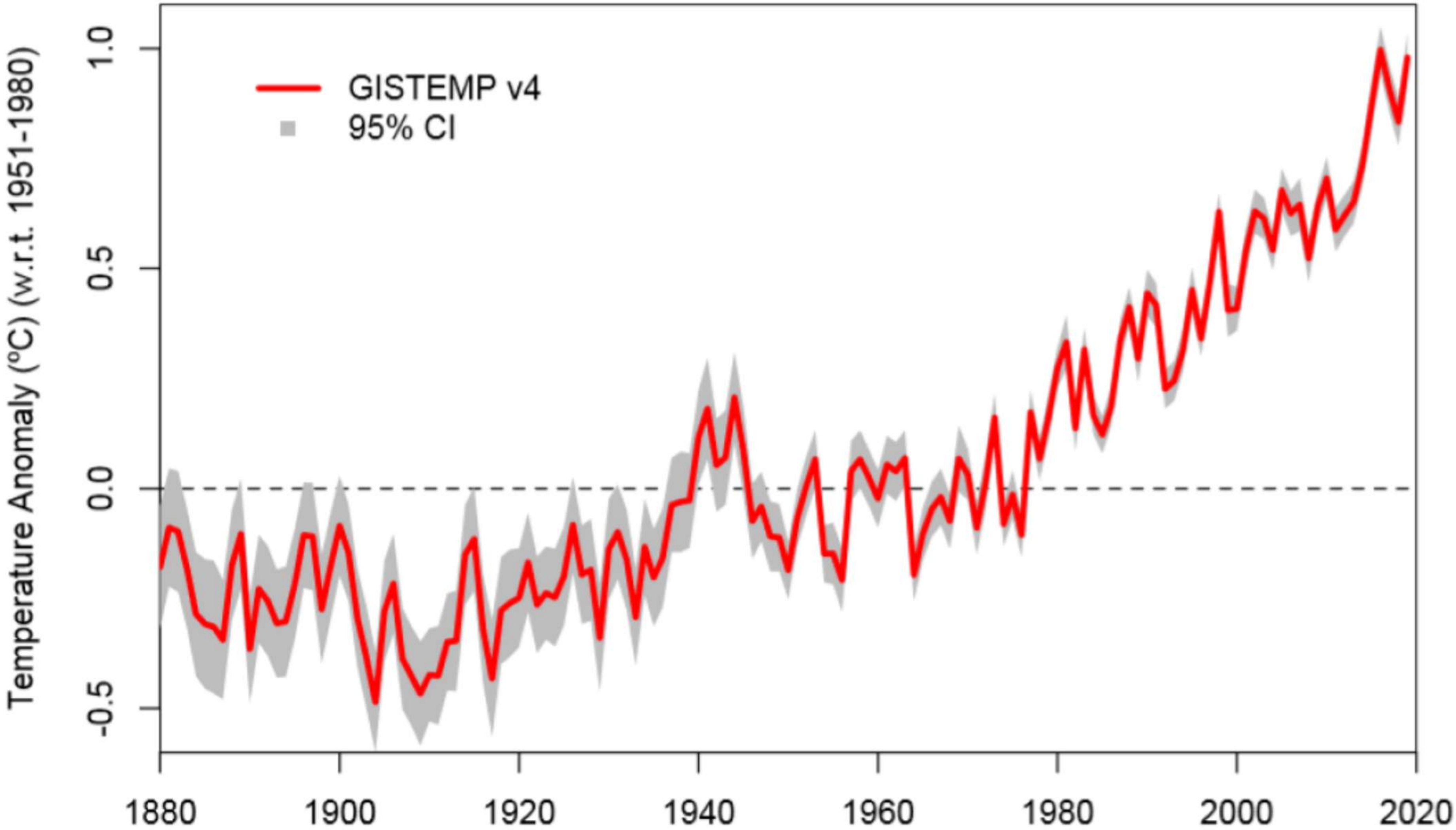


https://www.compareyourincome.org/

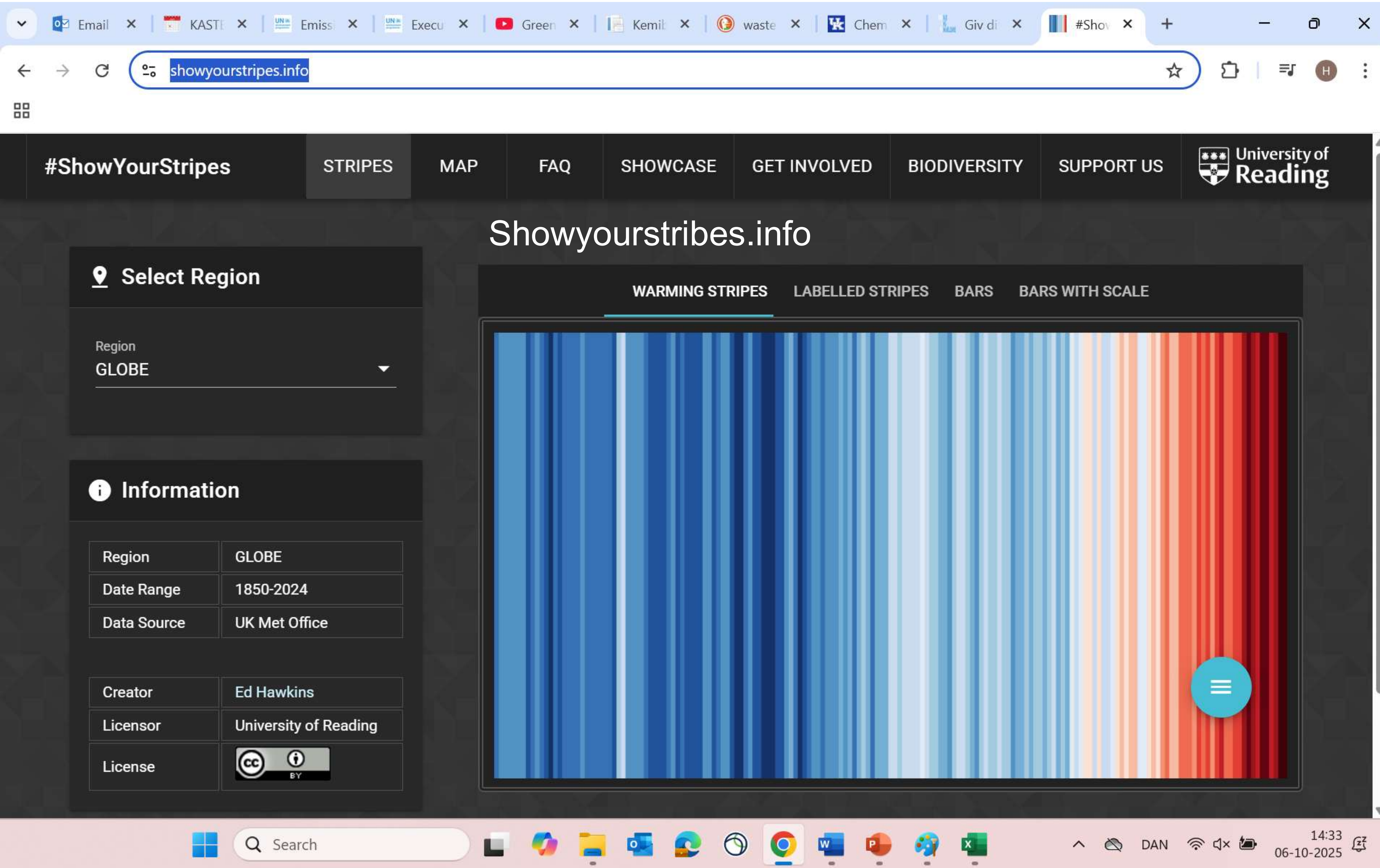


JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
+2°F
+1°F
0°
-1°F
-2°F
1880

Global Temperature Time Series
NASA GISTEMP, with Uncertainty Analysis



Showyourstribes.info

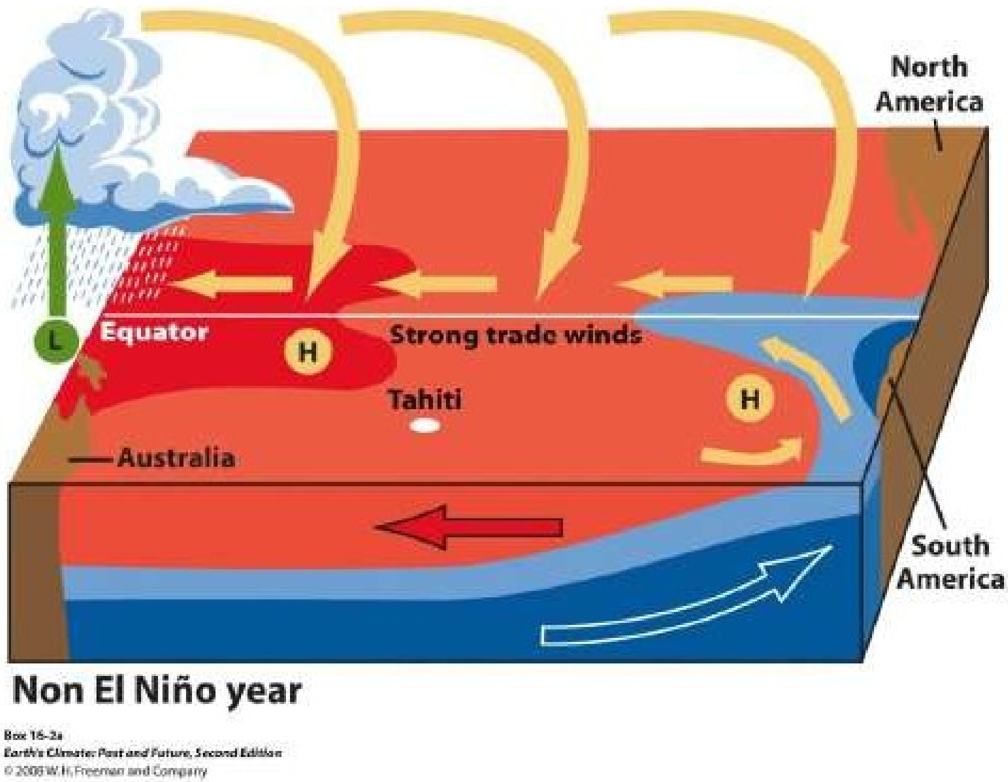


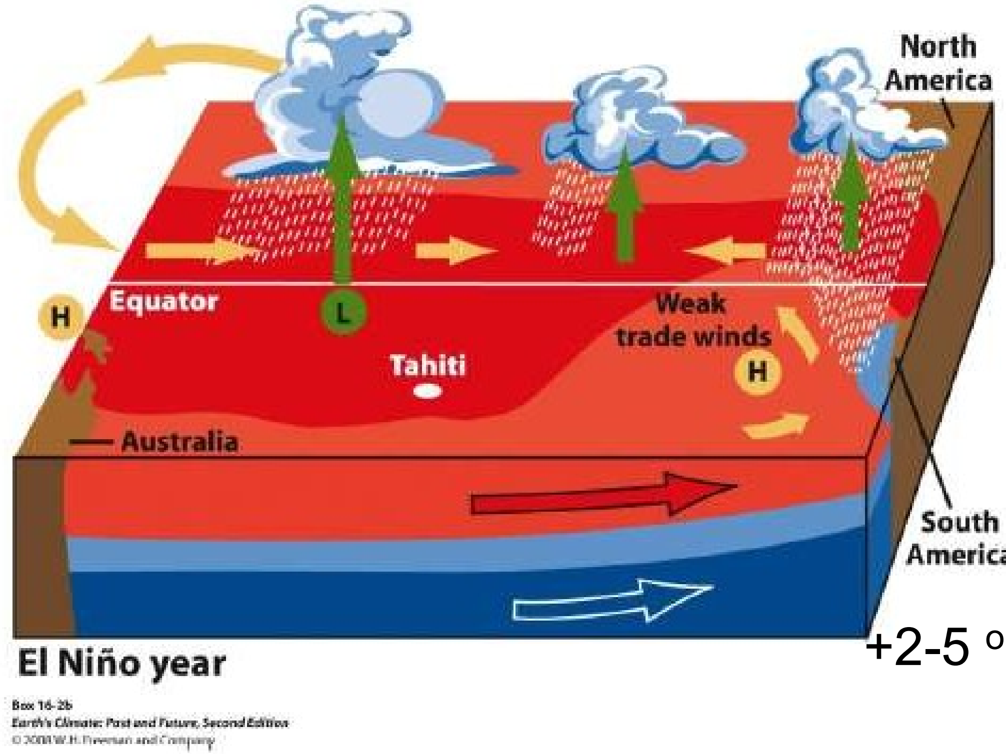
Quick intro to ENSO

more after Iceland

ENSO: El Niño Southern Oscillation

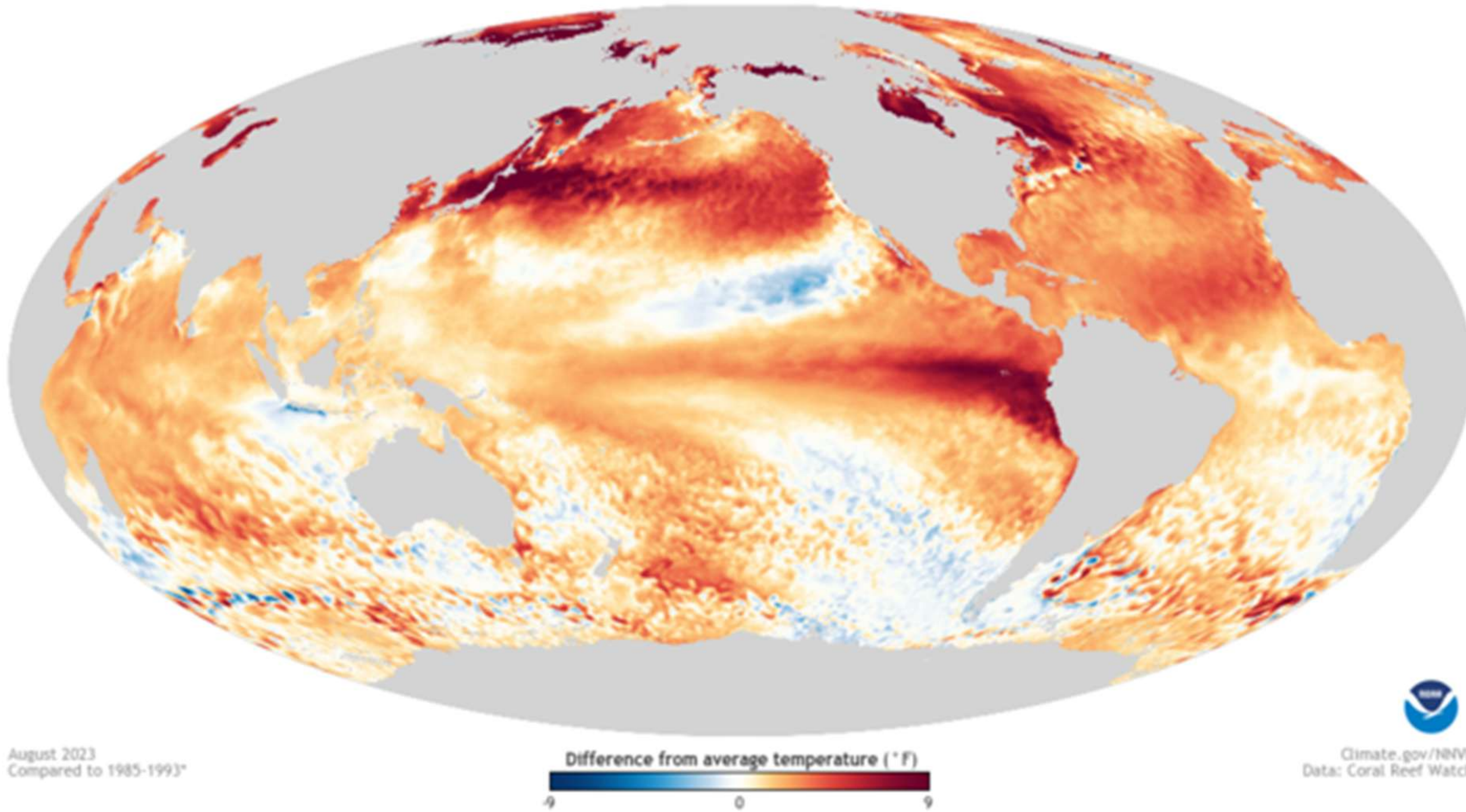
Occurs with interval of 2-7 yrs.
Predicted stronger in the future



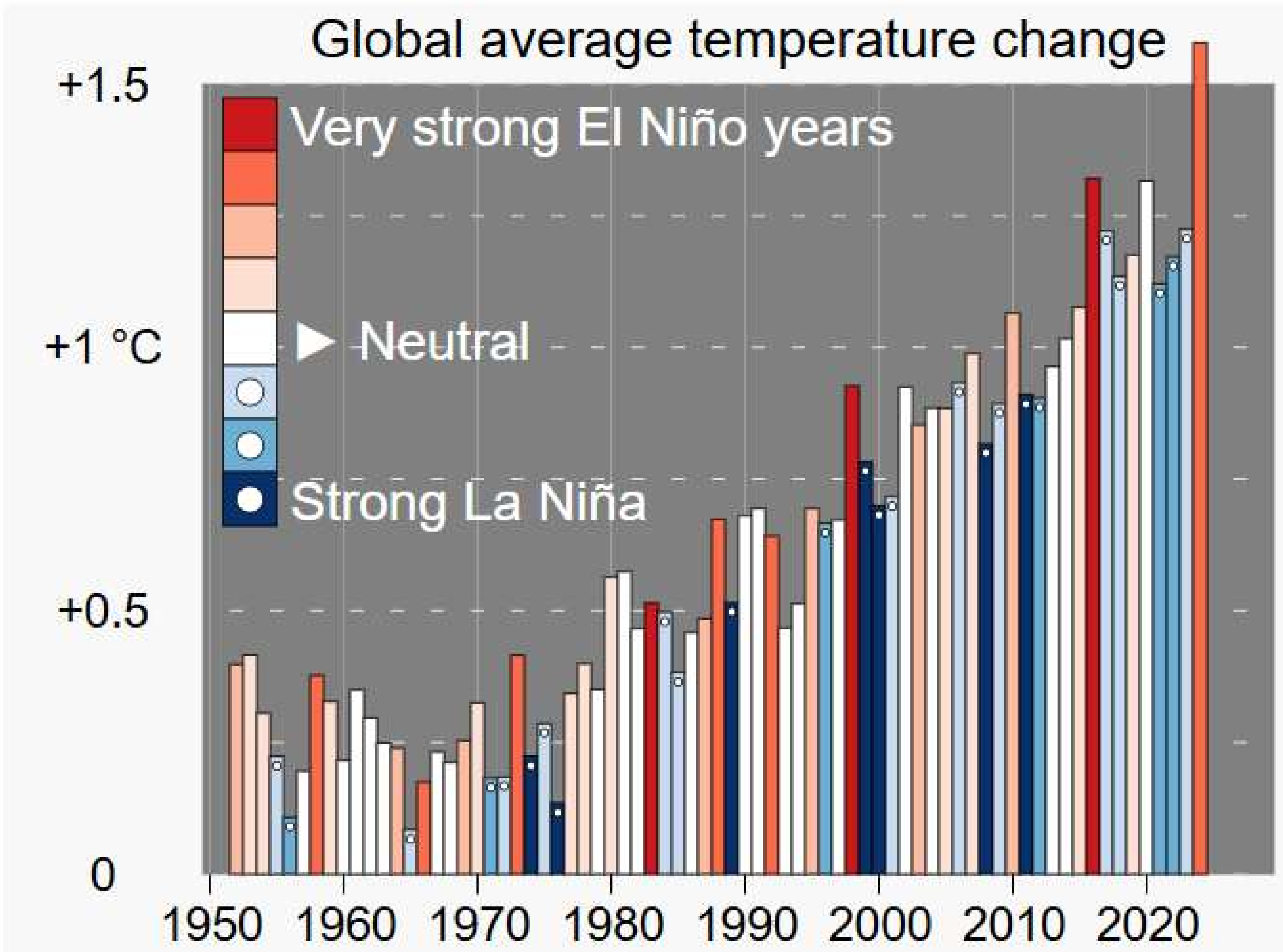


+2-5 °C

http://www.youtube.com/watch?v=tyPq86yM_Ic



El Nino forecastet to last well into 2024 summer



https://www.wuft.org/weather/2024-10-17/la-nina-winter-is-possible-drier-warmer-winter-for-florida

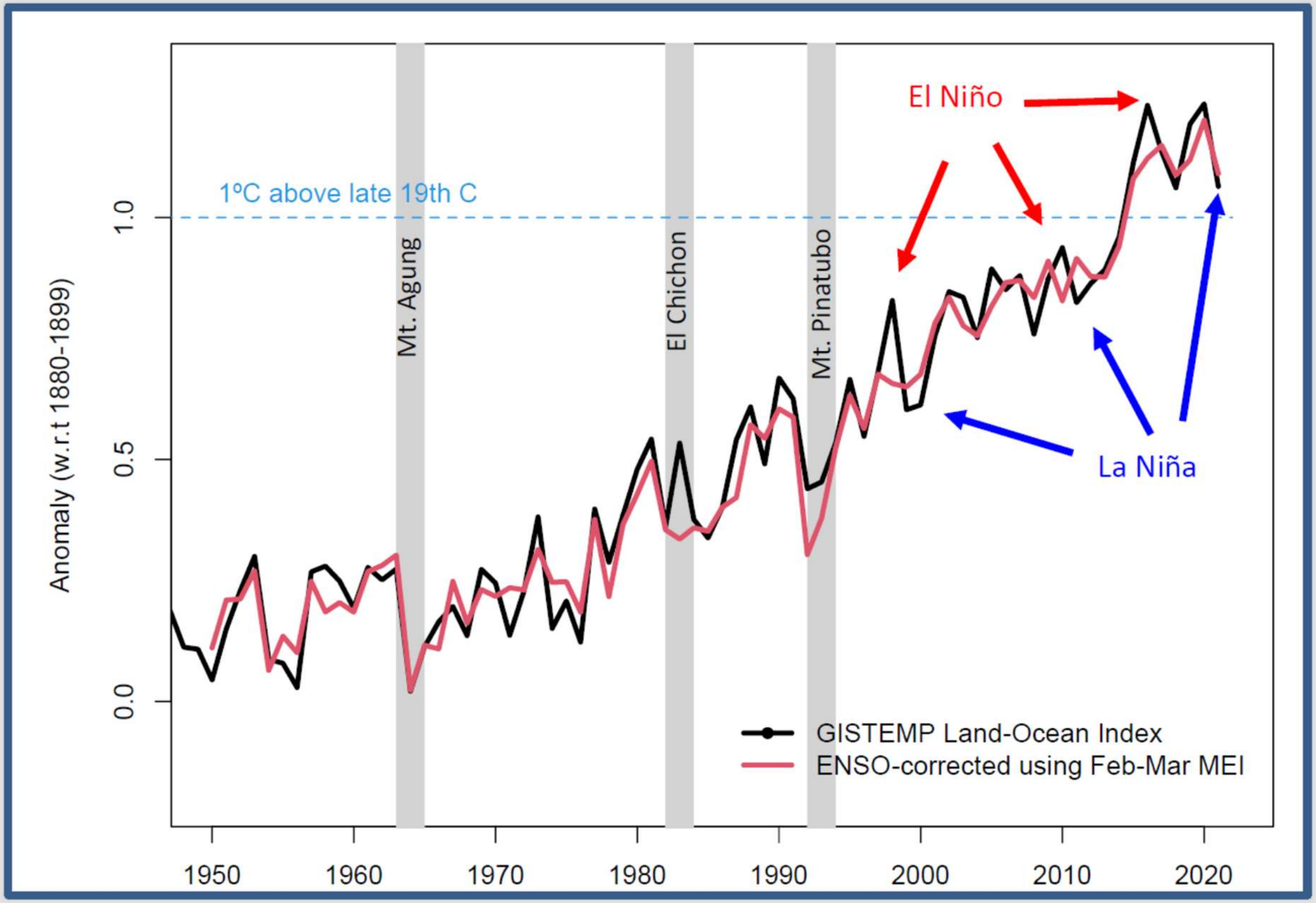
NASA: ENSO Impacts Global Temperature

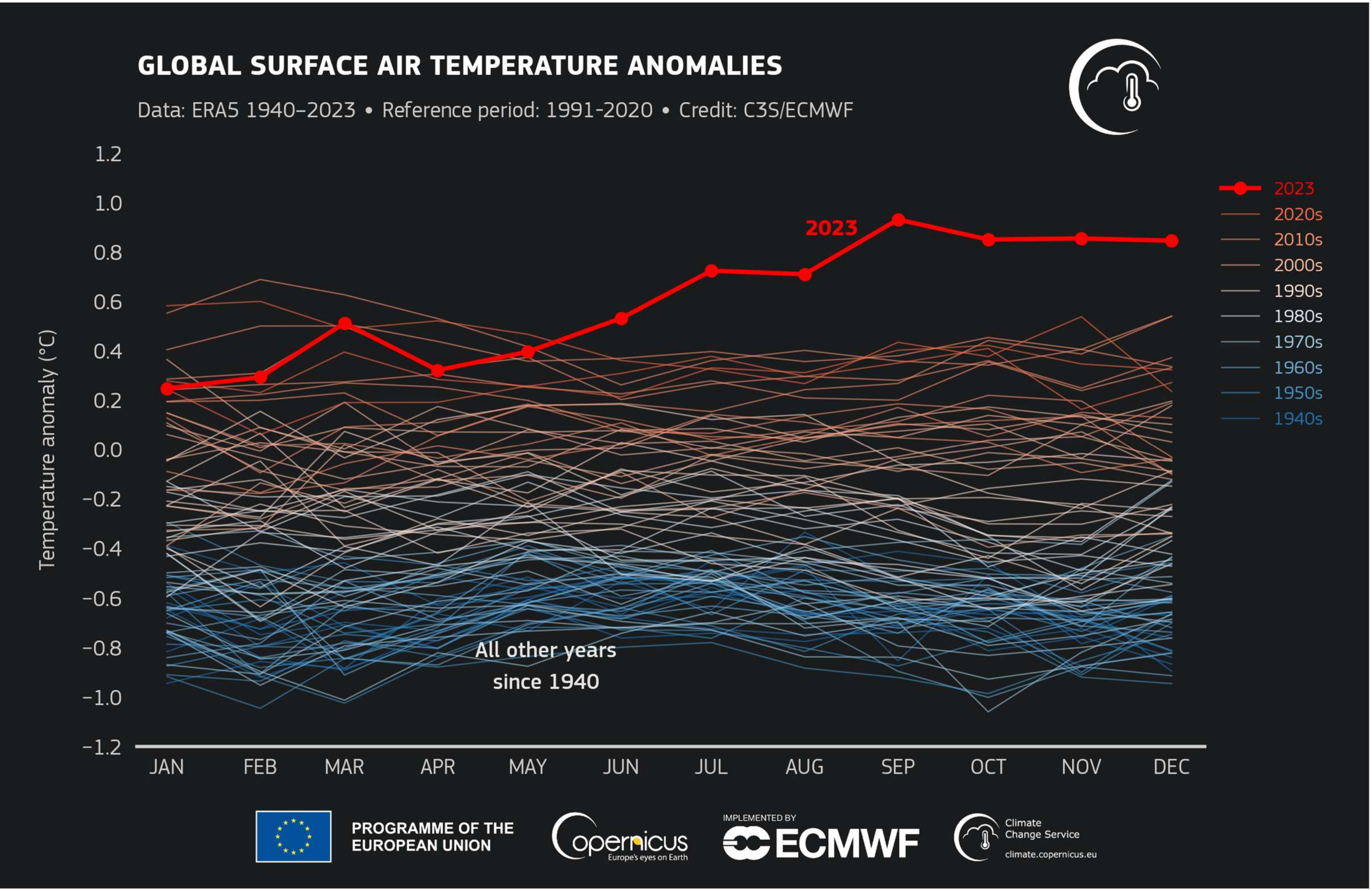
Substantial cooling influence from La Niña in the eastern Pacific

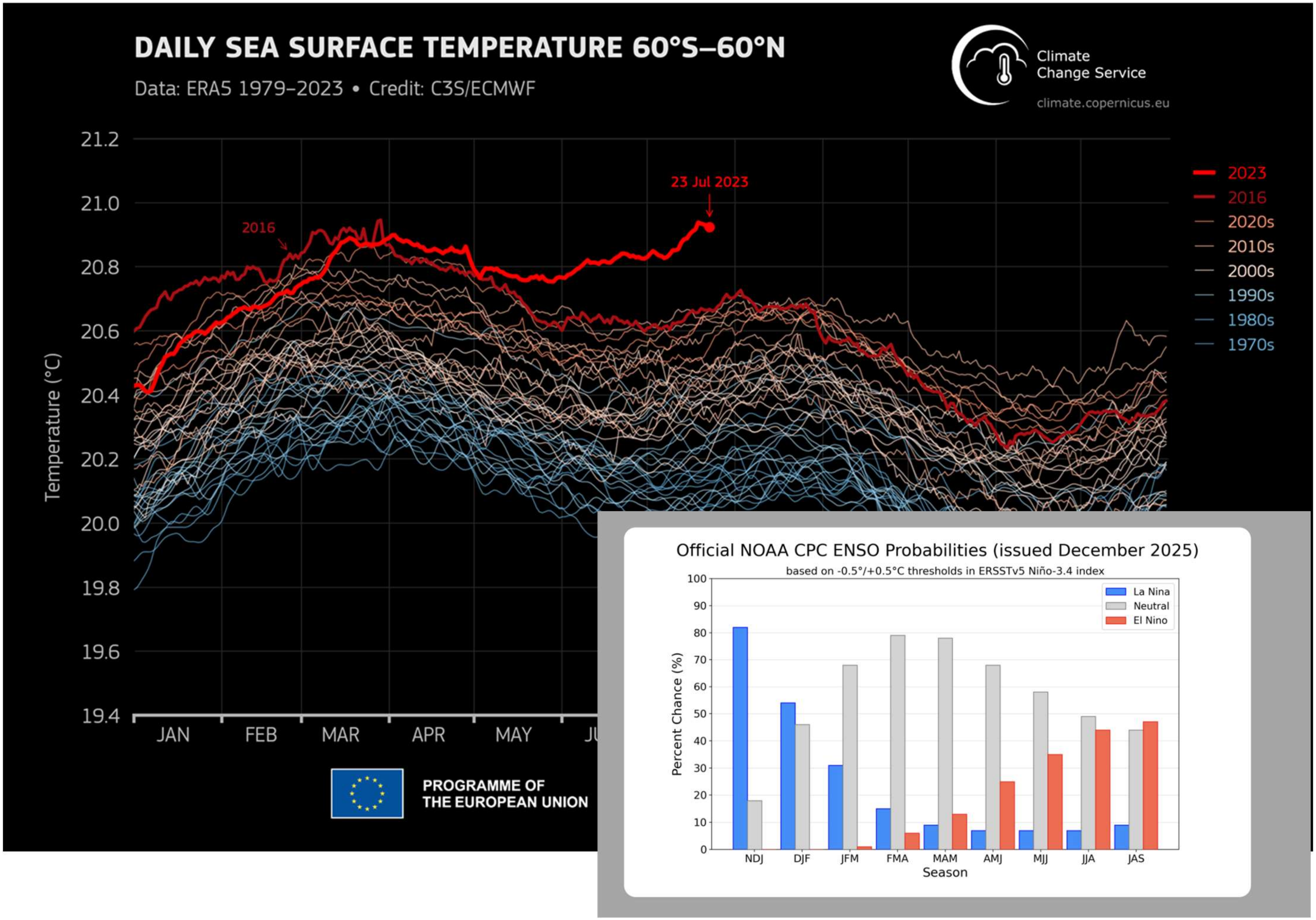
ENSO impact in specific years:

2016: 0.11°C
2017: -0.01°C
2018: -0.03°C
2019: 0.07°C
2020: 0.03°C
2021: -0.03°C

(Max. correlation with annual global mean is Feb-Mar ENSO index)



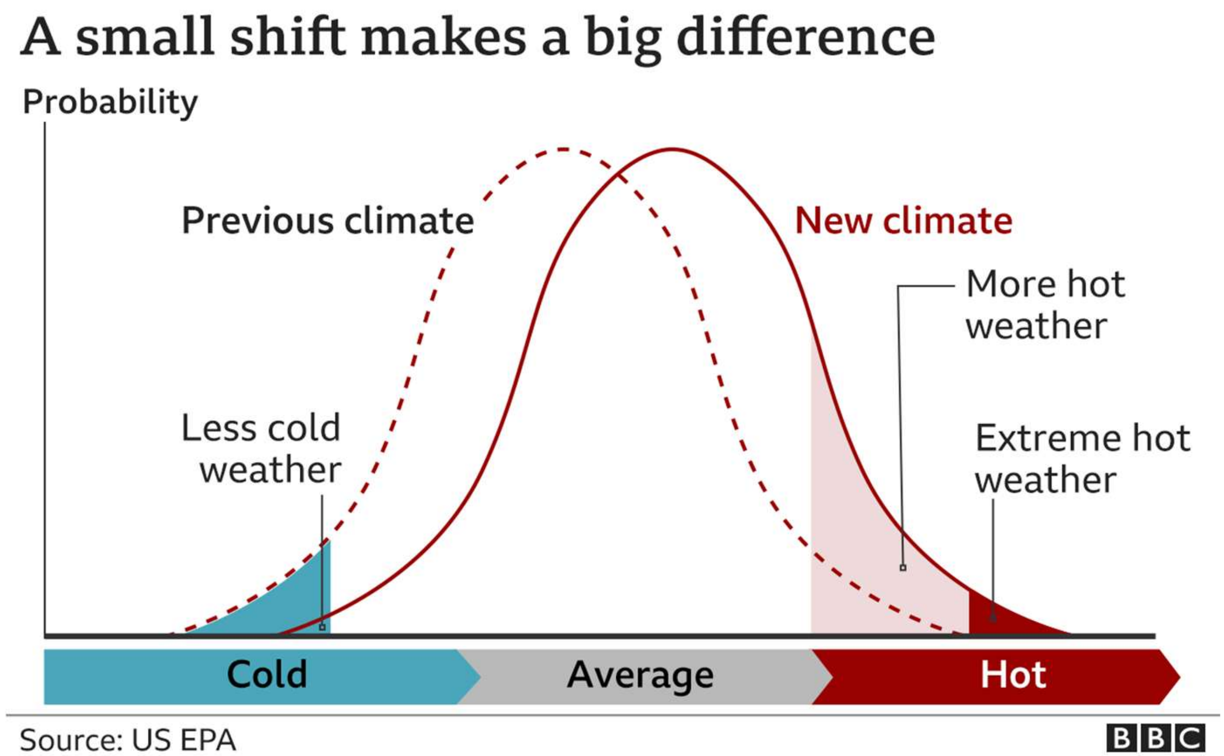

GLOBAL SURFACE AIR TEMPERATURE ANOMALIES
Data: ERA5 1940–2023 • Reference period: 1991-2020 • Credit: C3S/ECMWF
Temperature anomaly (°C)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
2023
All other years since 1940
2023
2020s
2010s
2000s
1990s
1980s
1970s
1960s
1950s
1940s
PROGRAMME OF THE EUROPEAN UNION
Copernicus
Europe's eyes on Earth
IMPLEMENTED BY
ECMWF
Climate Change Service
climate.copernicus.eu


DAILY SEA SURFACE TEMPERATURE 60°S–60°N
Data: ERA5 1979–2023 • Credit: C3S/ECMWF
Climate
Change Service
climate.copernicus.eu
23 Jul 2023
2016
2023
2016
2020s
2010s
2000s
1990s
1980s
1970s
Temperature (°C)
21.2
21.0
20.8
20.6
20.4
20.2
20.0
19.8
19.6
19.4
JAN
FEB
MAR
APR
MAY
PROGRAMME OF
THE EUROPEAN UNION
Official NOAA CPC ENSO Probabilities (issued December 2025)
based on -0.5°/+0.5°C thresholds in ERSSTv5 Niño-3.4 index
La Nina
Neutral
El Nino
Percent Chance (%)
100
90
80
70
60
50
40
30
20
10
0
NDJ
DJF
JFM
FMA
MAM
AMJ
MJJ
JJA
JAS
Season

2024 annual report

https://climate.copernicus.eu/global-climate-highlights-2024

- 2024 was the warmest year in a multi-dataset record of global temperature going back to 1850.
- 2024 had a global average temperature of 15.10°C; 0.12°C higher than the previous highest annual value in 2023.
- 2024 was 0.72°C warmer than the 1991–2020 average, and 1.60°C warmer than the pre-industrial level, making it the first calendar year to exceed 1.5°C above that level.
- The last ten years have been the warmest ten years on record.
- Each month from January to June 2024 was warmer than the corresponding month in any previous year. August 2024 equalled the record warmth of August 2023 and the remaining months from July to December were each the second warmest for the time of year, after the corresponding months in 2023.
- There were three record seasons for the corresponding time of the year: boreal winter (December 2023–February 2024), boreal spring (March–May 2024), and boreal summer (June–August), at 0.78°C, 0.68°C and 0.69°C respectively above the 1991–2020 average.
- On 22 July 2024, the daily global average temperature reached a new record high of 17.16°C.



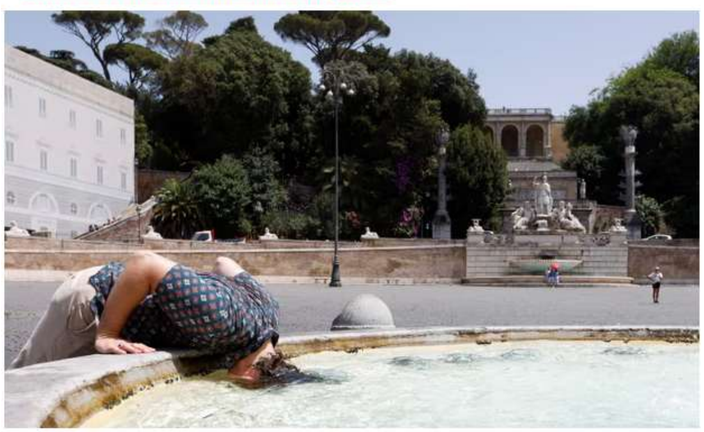
20-25% extra in hospital 2023

2024-63.000 European heat deaths

Italian hospitals report sharp rise in emergency cases as Rome hits 41.8C

Capital breaks its temperature record and a Naples A&E has its busiest day since height of Covid

Extreme heatwave - latest news updates



A man cools off at the Piazza del Popolo in Rome during a heatwave across Italy. Photograph: Remo Casilli/Reuters

Hospitals across Italy have seen a sharp rise in the number of people seeking emergency care for heat-related illnesses as a heatwave continues to grip the country, with temperatures in Rome setting a new record.

Particularly severe 2025, wildfires in the United States, over 40,000 fires reported, burning more than 3.2 million ….and the destruction of over 18,000 structures (drought.gov).

2025 Canadian wildfire 2nd worst on record (5,349 fires, 8.78 million hectares), following the unprecedented 2023 (Colorado state university) 2022

REUTERS® World Business Markets Sustainability Legal Breakingviews Technology Investiga

Climate & Energy | Environment | Climate Change

Canada wildfires: what are the causes and when will it end?

Reuters

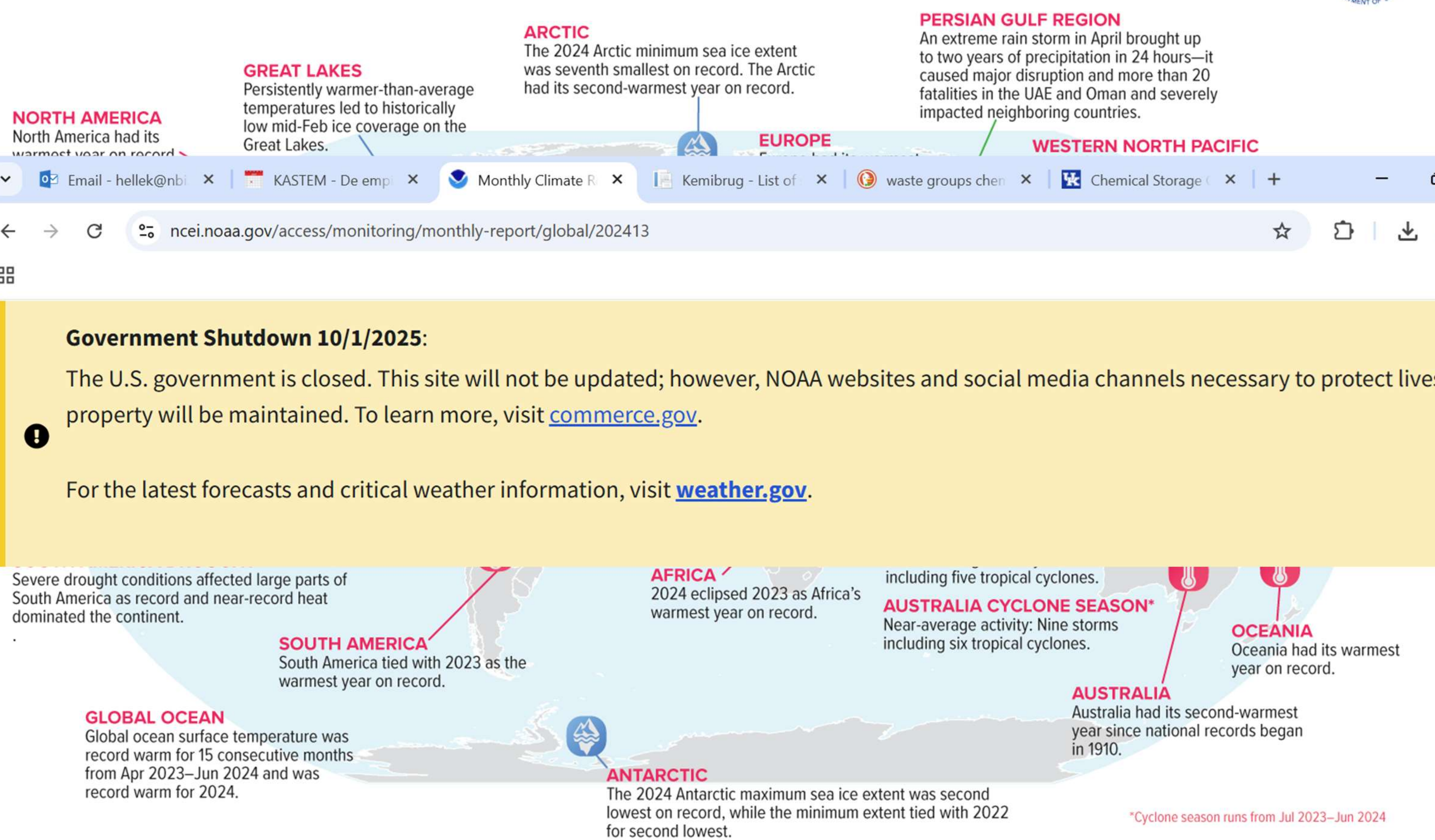
August 19, 2023 9:17 AM GMT+2 · Updated 3 months ago

Aa

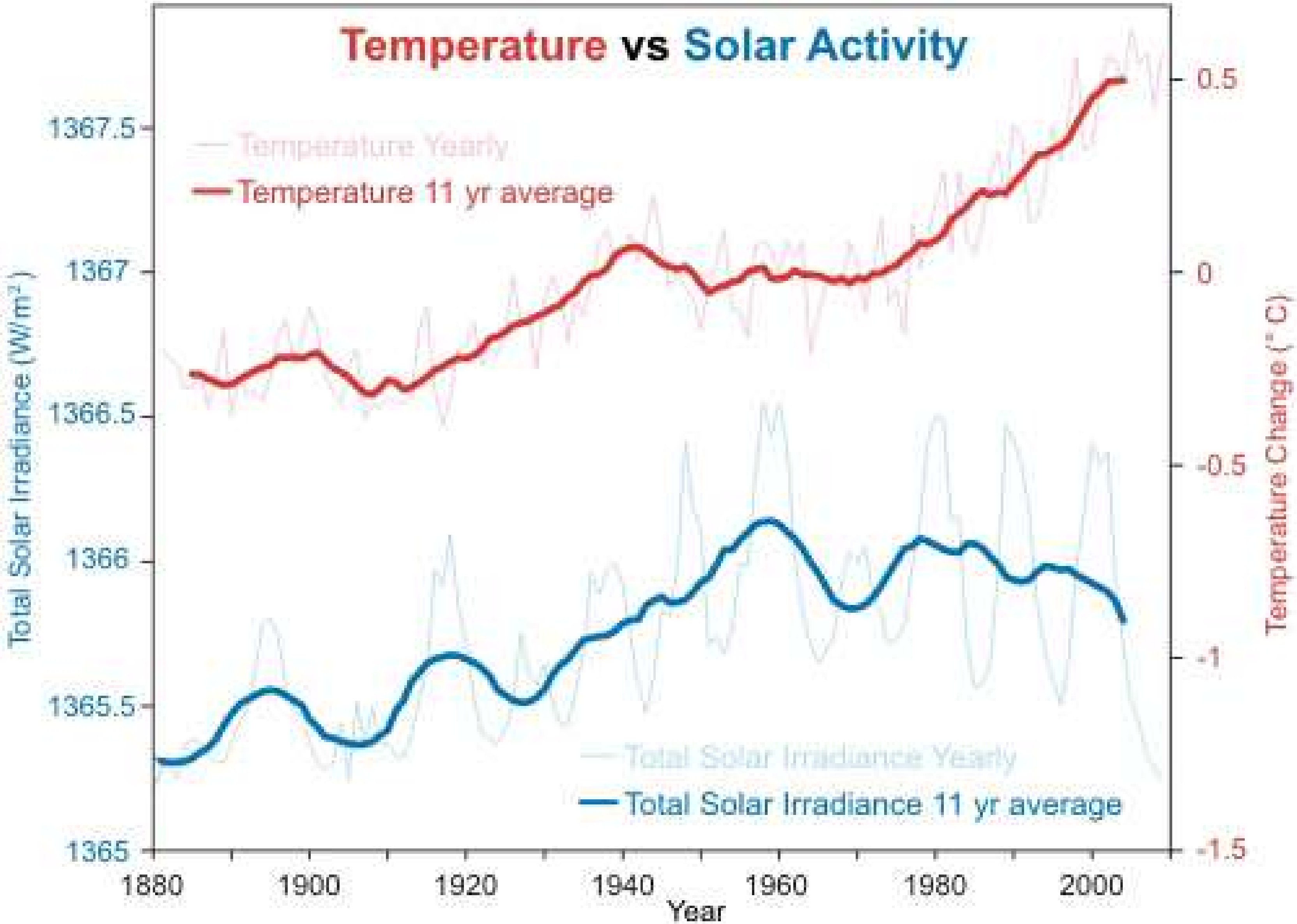
Aug 17 (Reuters) - More than 20,000 people in Yellowknife were evacuating the northern Canadian city as fire crews on Thursday battled to keep wildfires from reaching the city - the latest chapter in the country's worst fire season ever.

Selected Significant Climate Anomalies and Events: Annual 2024

GLOBAL AVERAGE TEMPERATURE
The Jan–Dec 2024 global surface temperature ranked warmest since global records began in 1850.



Please note: Material provided in this map was compiled from NOAA's State of the Climate Reports. For more information please visit: https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/



Krivova et al 2007 and NASA temepratures

Forcings of Holocene climate – Volanic effects on insolation

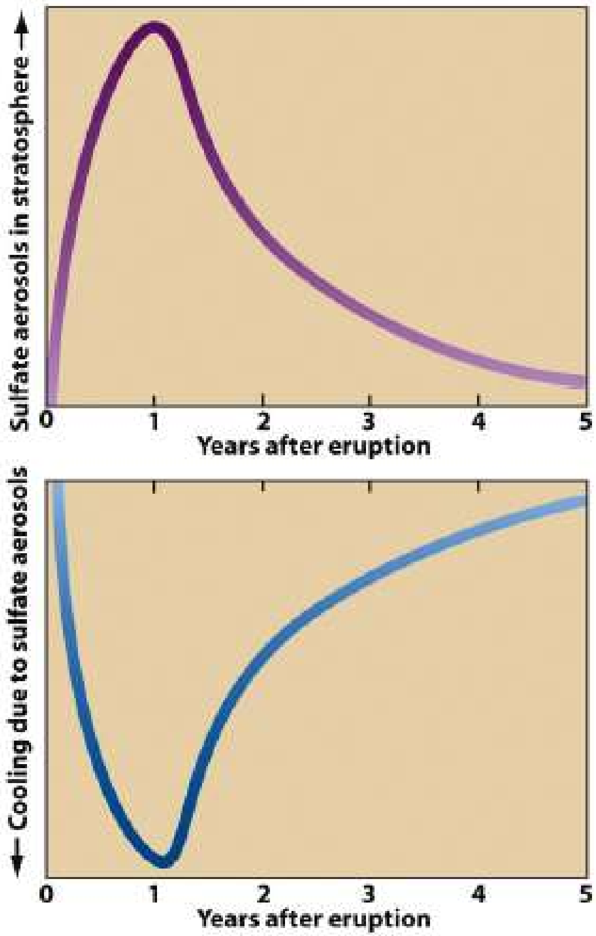
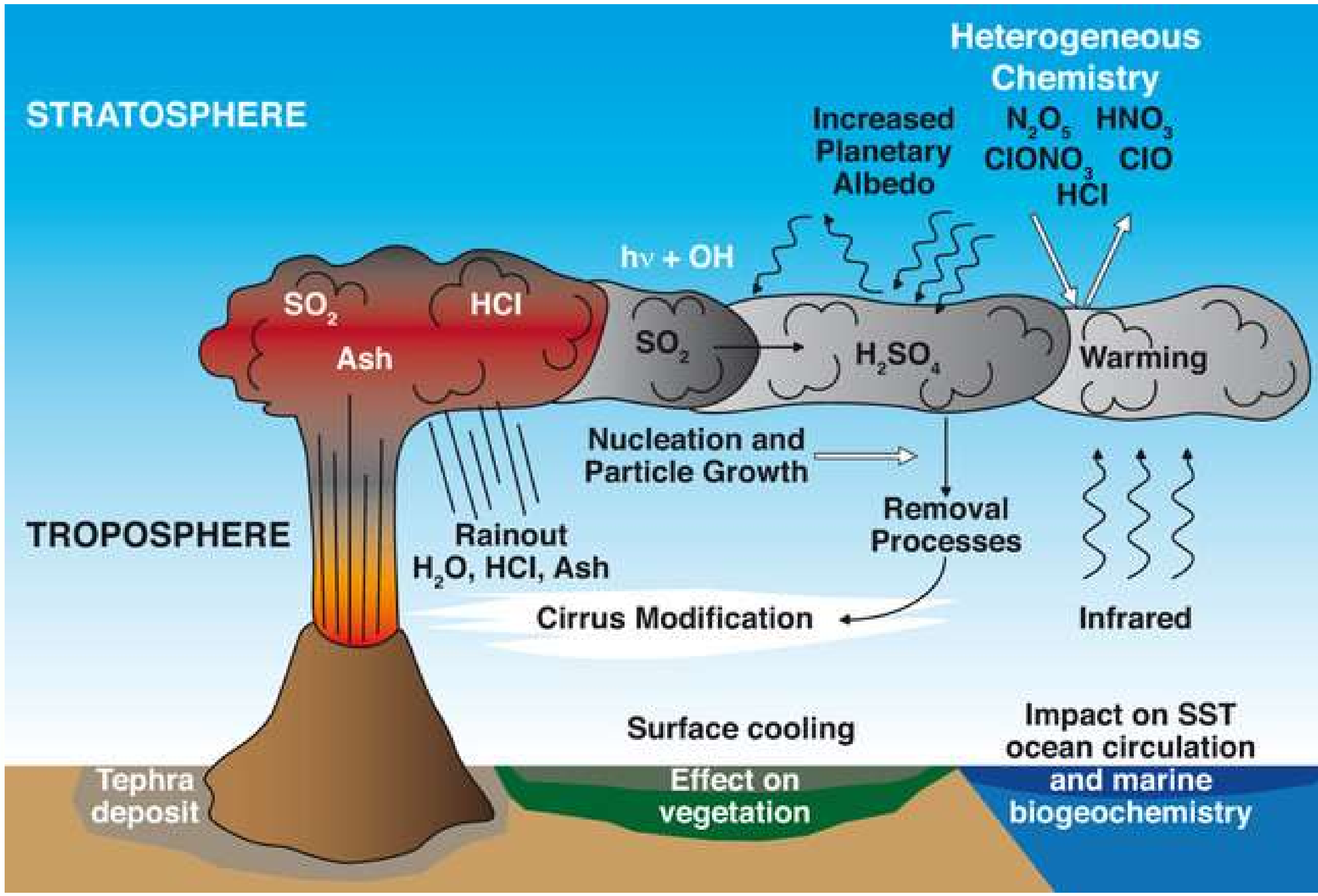


Figure 16-15
Earth's Climate: Past and Future, Second Edition



Forcings of Holocene climate – Volanic effects on insolation

Forum: But what about greenhouses gases from volcanic eruptions?

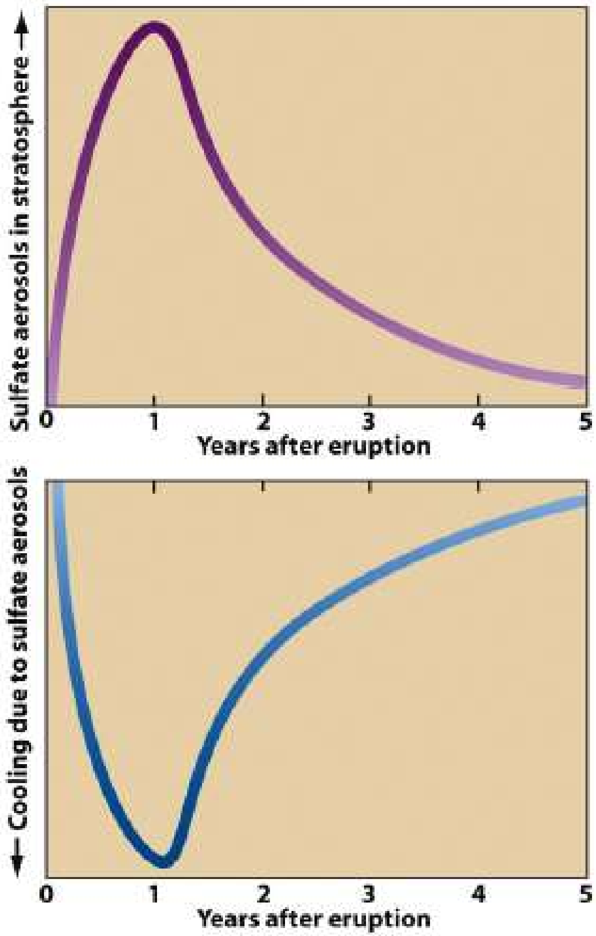


Figure 16-15
Earth's Climate: Past and Future, Second Edition

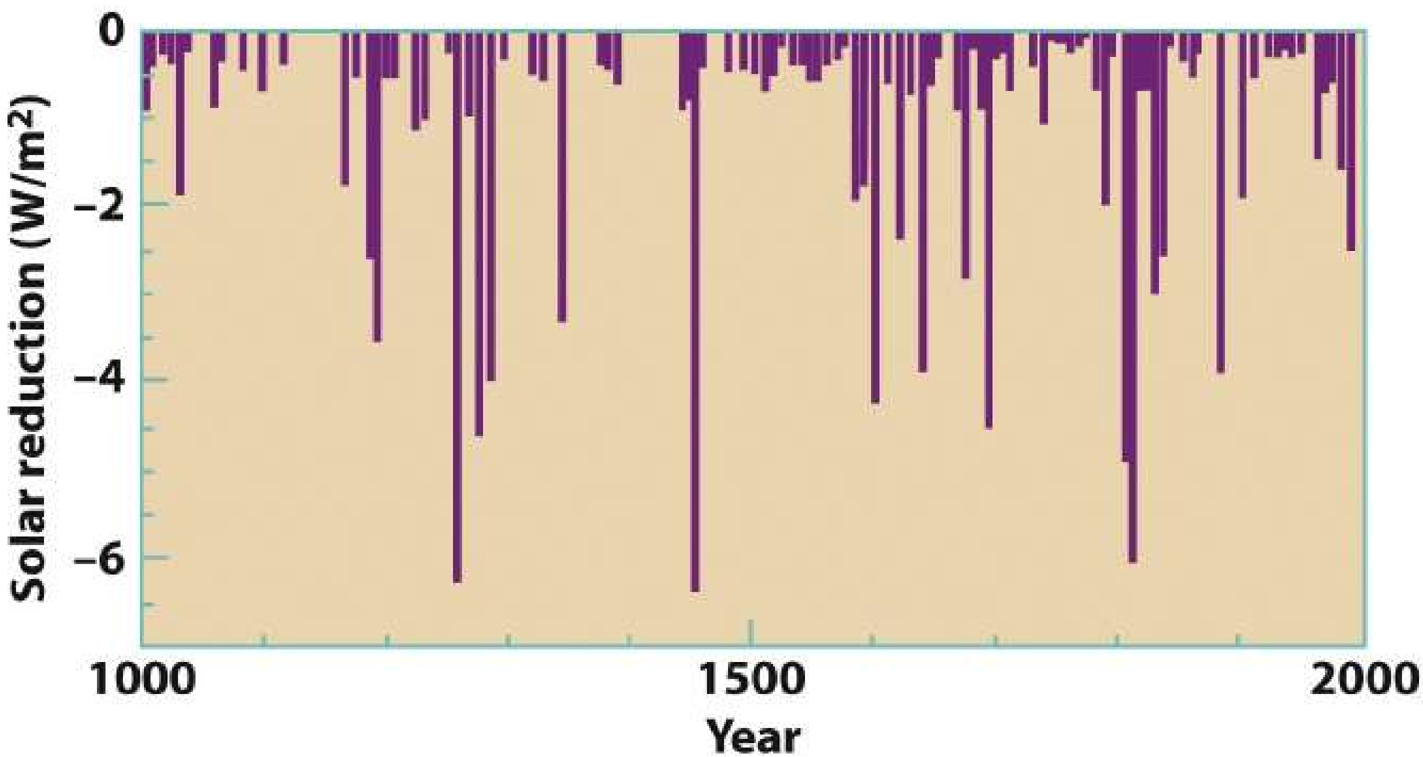
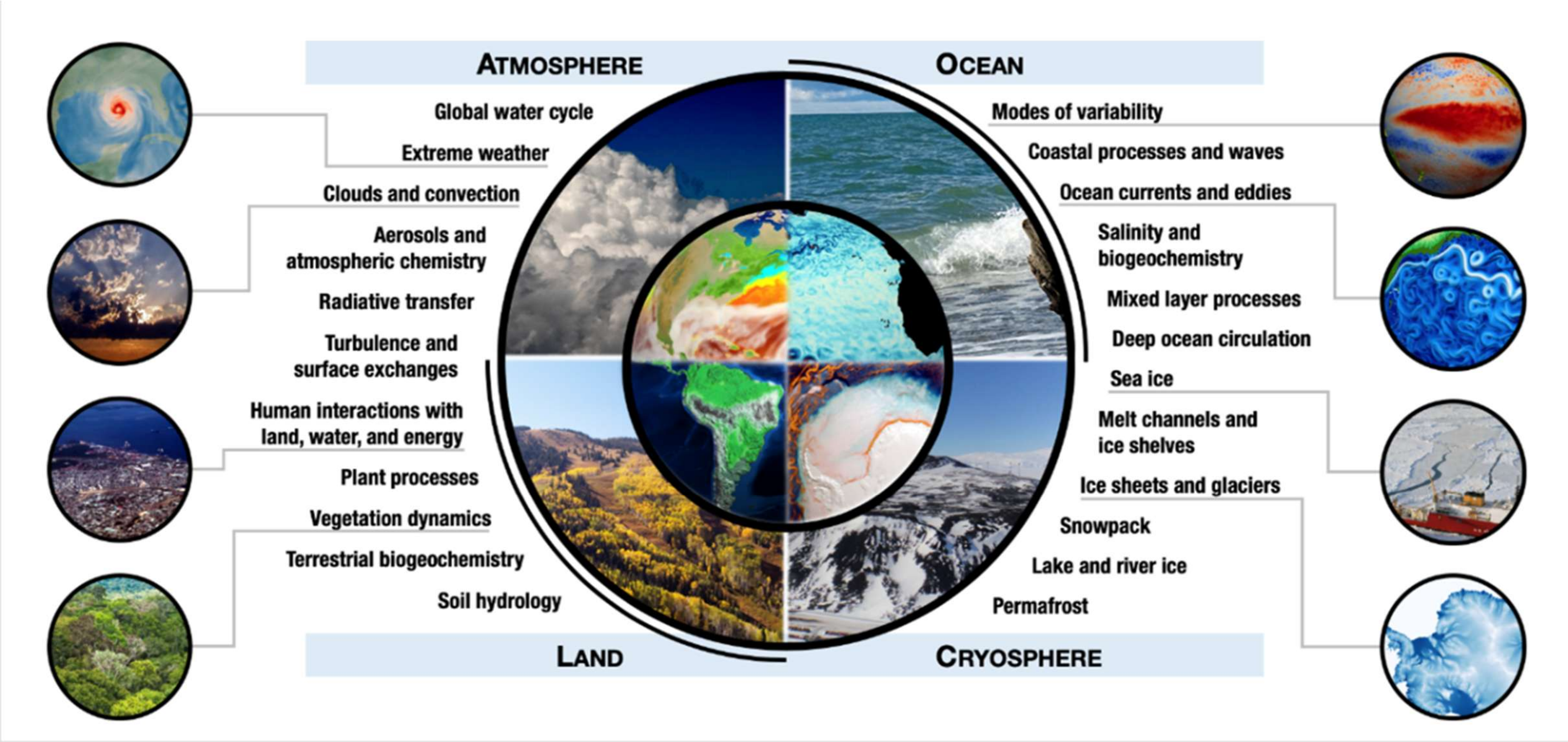


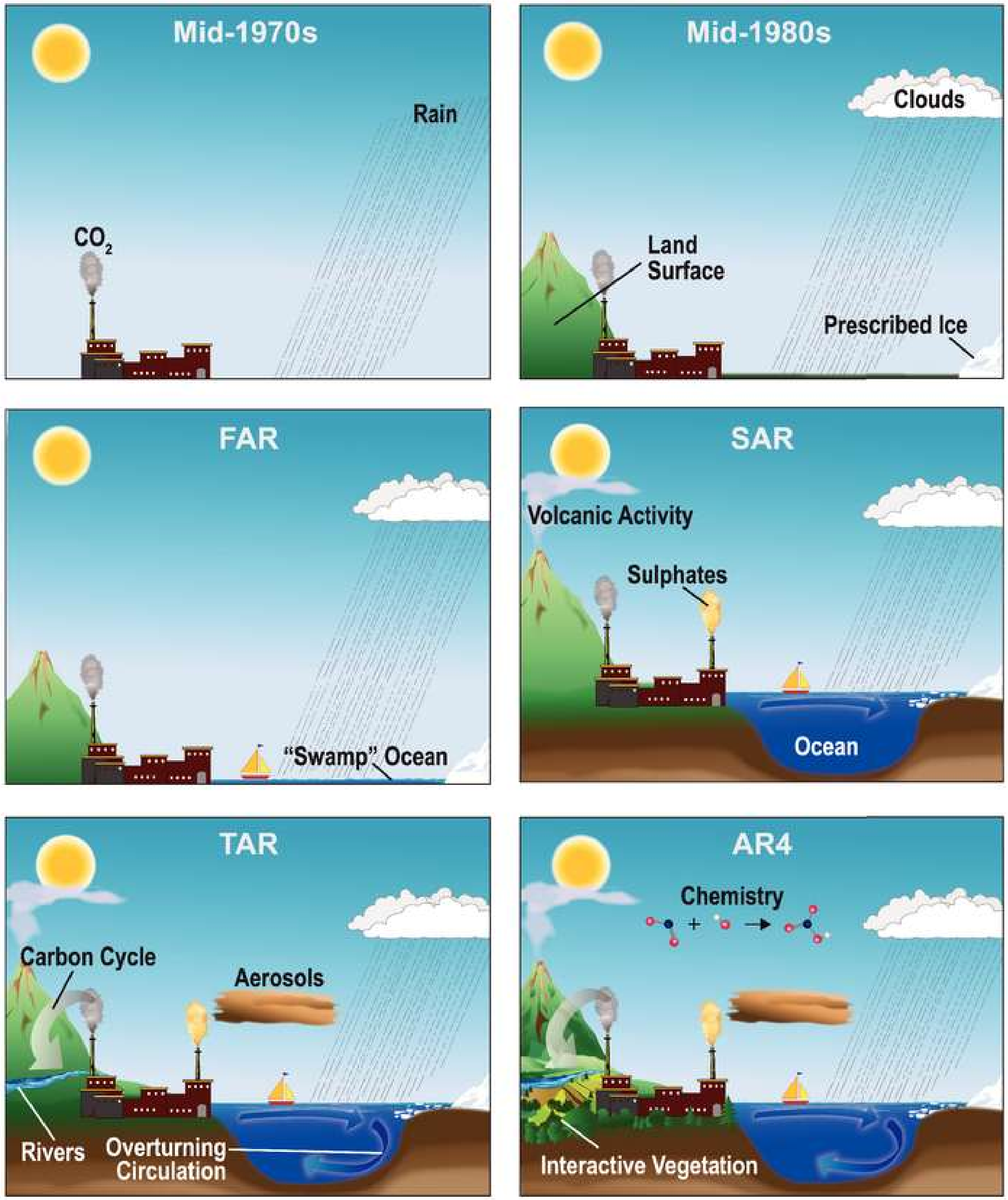
Figure 16-16
Earth's Climate: Past and Future, Second Edition

Forum: Is geoengineering with sulphate aerosol an option?

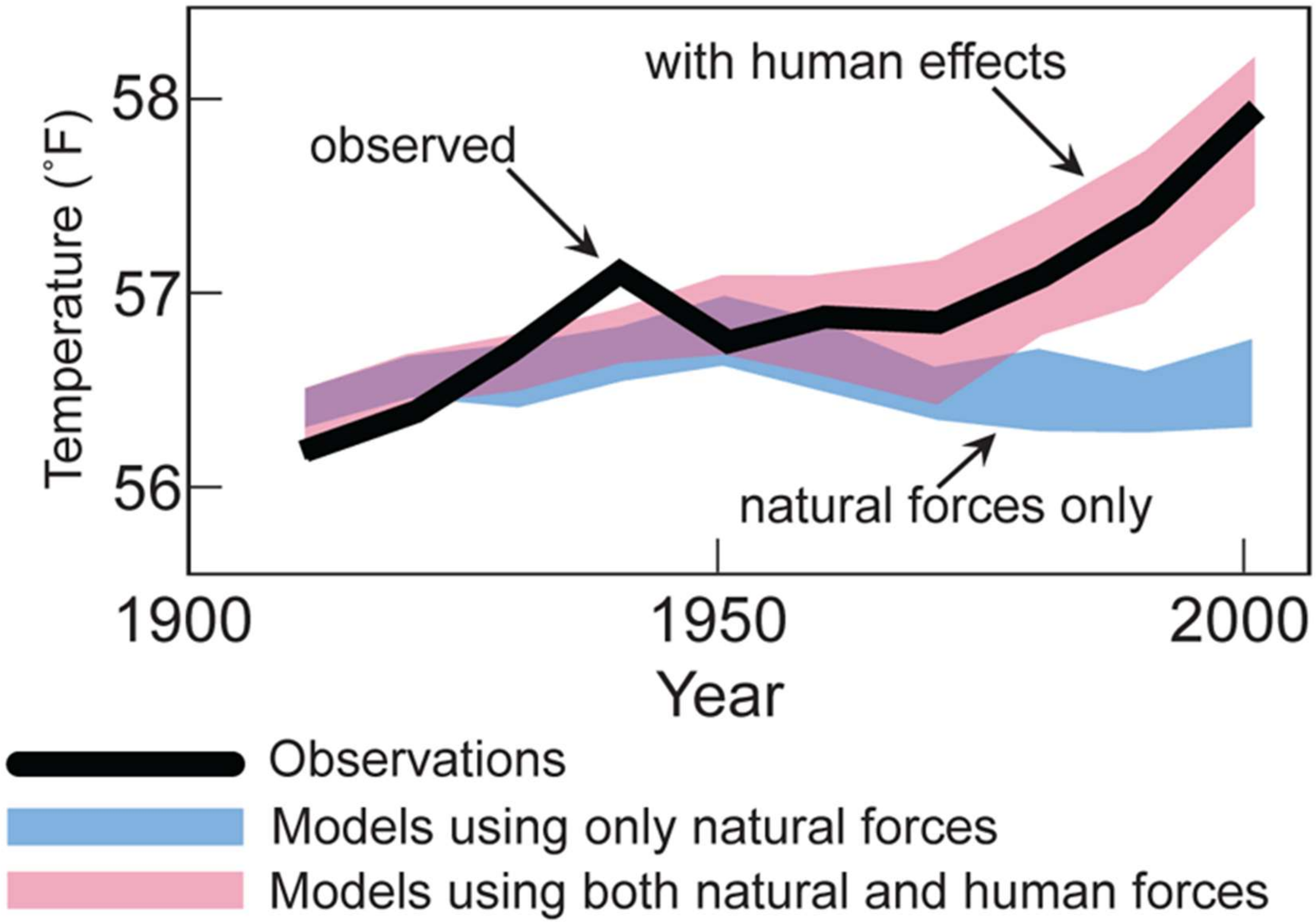
Klima modeller



The World in Global Climate Models



How do we know global warming is anthropogenic?



https://www.carbonbrief.org/qa-how-do-climate-models-work

How do we know global warming is anthropogenic?

(IPCC AR4 WG1 TS.23)

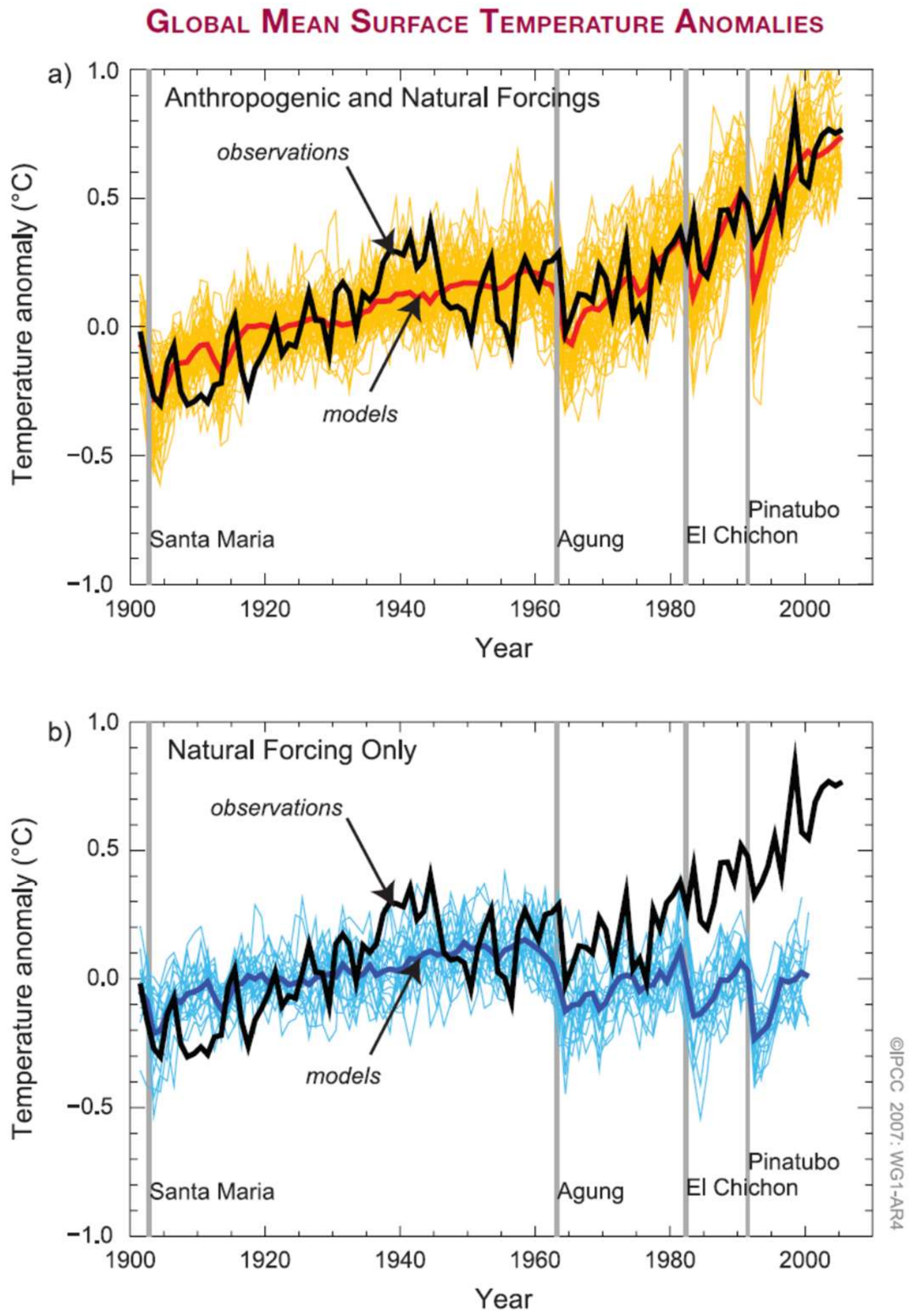


Figure TS.23. *(a) Global mean surface temperature anomalies relative to the period 1901 to 1950, as observed (black line) and as obtained from simulations with both anthropogenic and natural forcings. The thick red curve shows the multi-model ensemble mean and the thin yellow curves show the individual simulations. Vertical grey lines indicate the timing of major volcanic events. (b) As in (a), except that the simulated global mean temperature anomalies are for natural forcings only. The thick blue curve shows the multi-model ensemble mean and the thin lighter blue curves show individual simulations. Each simulation was sampled so that coverage corresponds to that of the observations. {Figure 9.5}*

What is the IPCC?

- Intergovernmental Panel on Climate Change (IPCC)
  - Leading body for assessment of climate change established by the UN Environmental Programme and the World Meteorological Organization (approved by the UN General Assembly)
  - Scientific body composed of thousands of scientists contributing on a voluntary basis, subject to review to ensure objectivity and completeness
  - Aims to be policy-relevant yet policy neutral and never policy prescriptive
  - IPCC assessment reports form the basis for the UNFCCC meetings (COPs), the Kyoto protocol and the next steps along this way

What is the IPCC?

IPCC sections

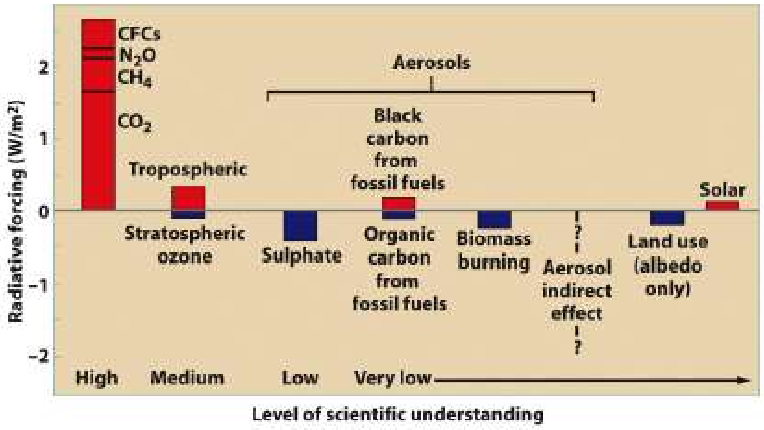
- Working Group I: Physical science basis
- Working Group II: Vulnerability of socio-economic and natural systems
- Working Group III: Options for mitigation mainly via GHG emissions and removal
- Task force on National Greenhouse Gas Inventories
- Task Group in Data and Scenario Support for Impact and Climate Analysis; Data Distribution Centre

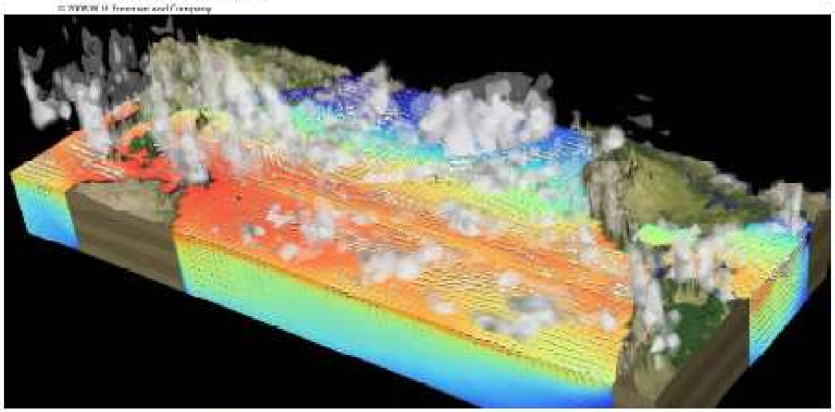
IPCC AR5 terms

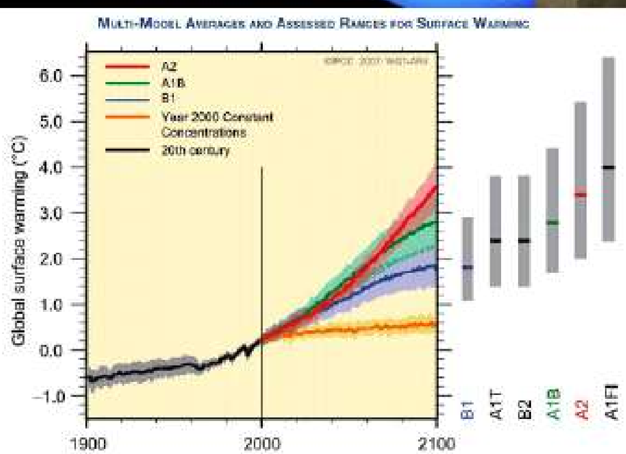
- Available evidence
  - Limited
  - Medium
  - Robust
- Degree of agreement
  - Low
  - Medium
  - High

- Level of confindence
  - Very low
  - Low
  - Medium
  - High
  - Very high
- Assessed likelihood of conclusion
  - Exceptionally unlikely 0-1%
  - Very unlikely 0-10%
  - Unlikely 0-33%
  - About as likely as not 33-66%
  - Likely 66-100%
  - Very likely 90-100%
  - Virtually certain 99-100%

Making projections







Forcing over time including uncertainties

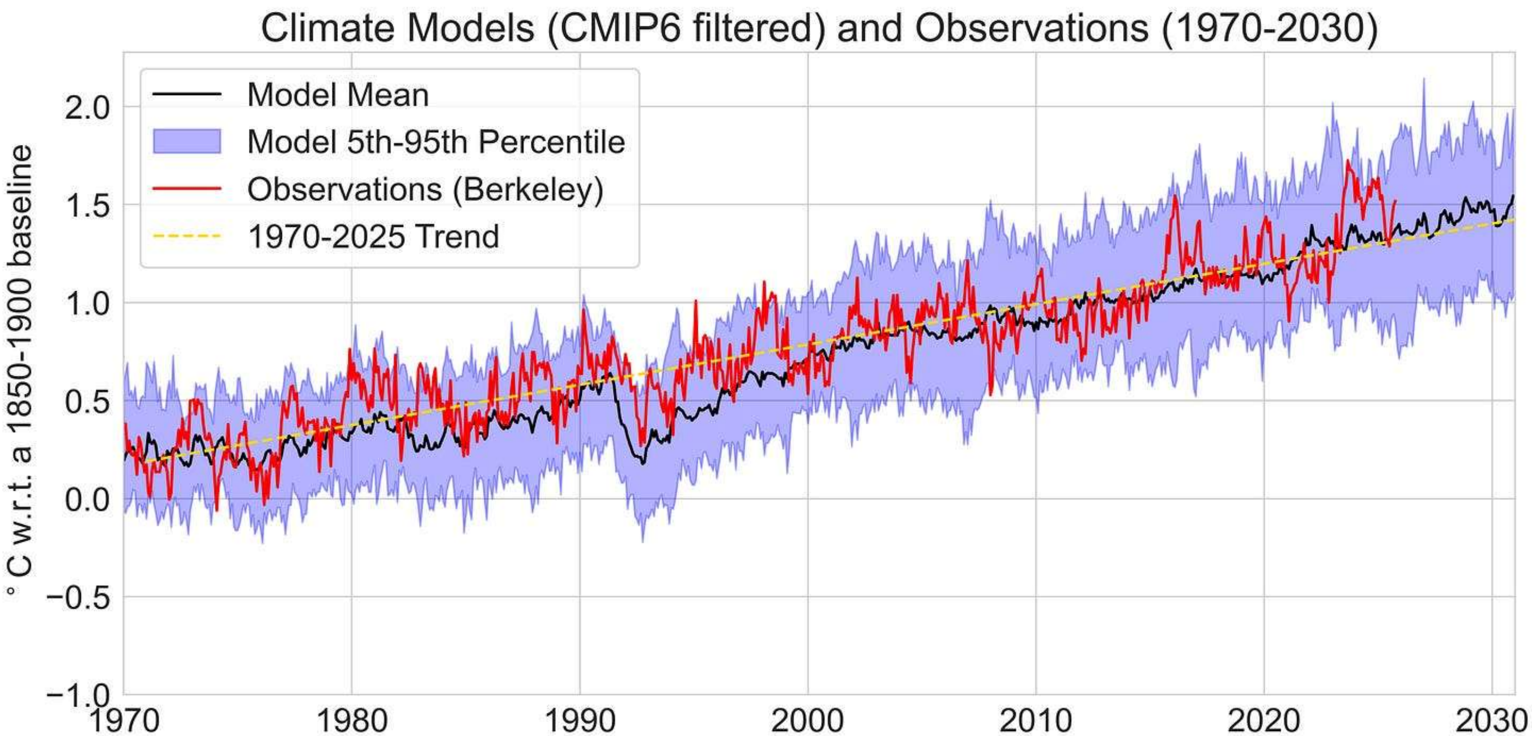
↓

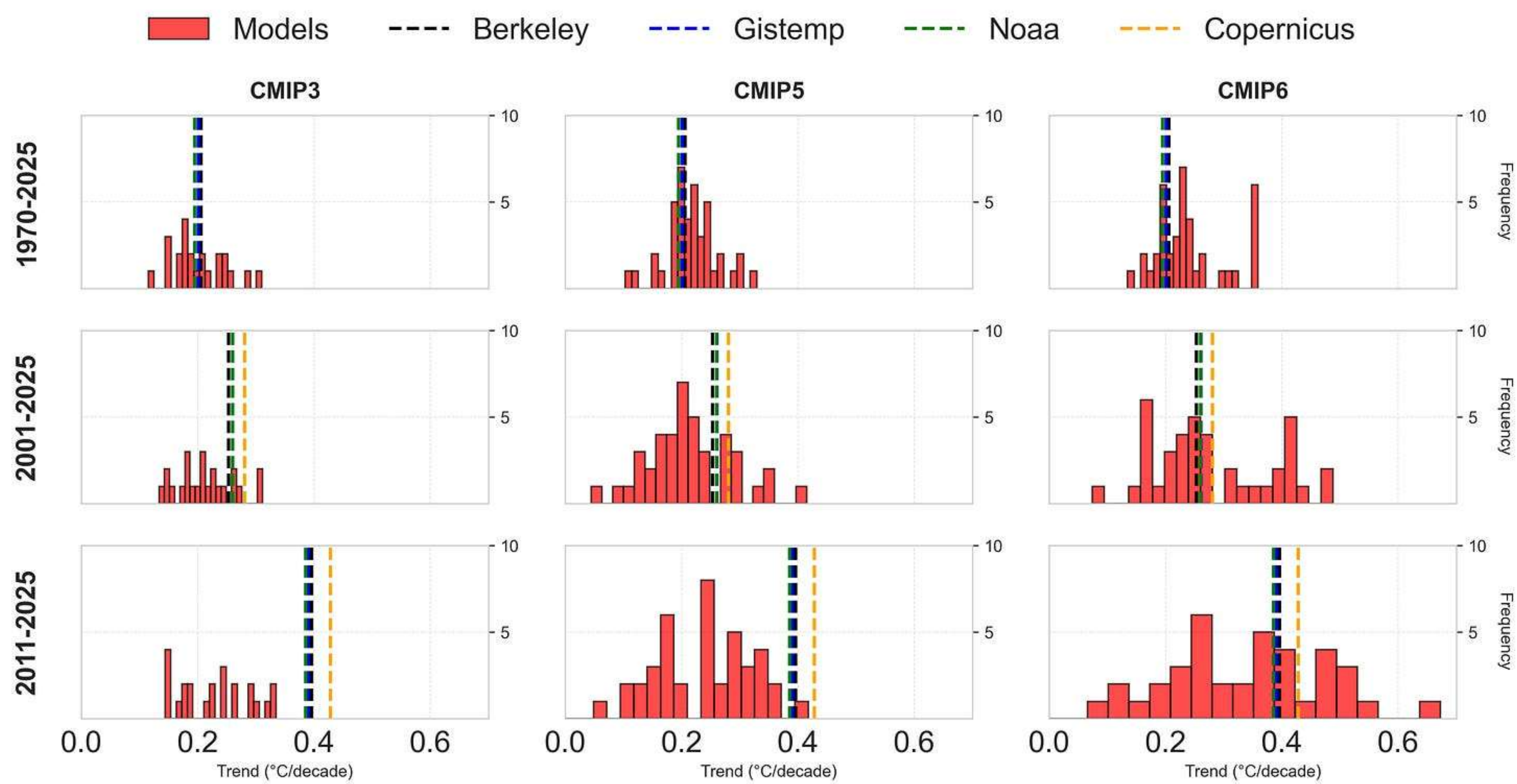
Modelling step including uncertainties and model differences

↓

Projections

CMIP 6 models (filtered)

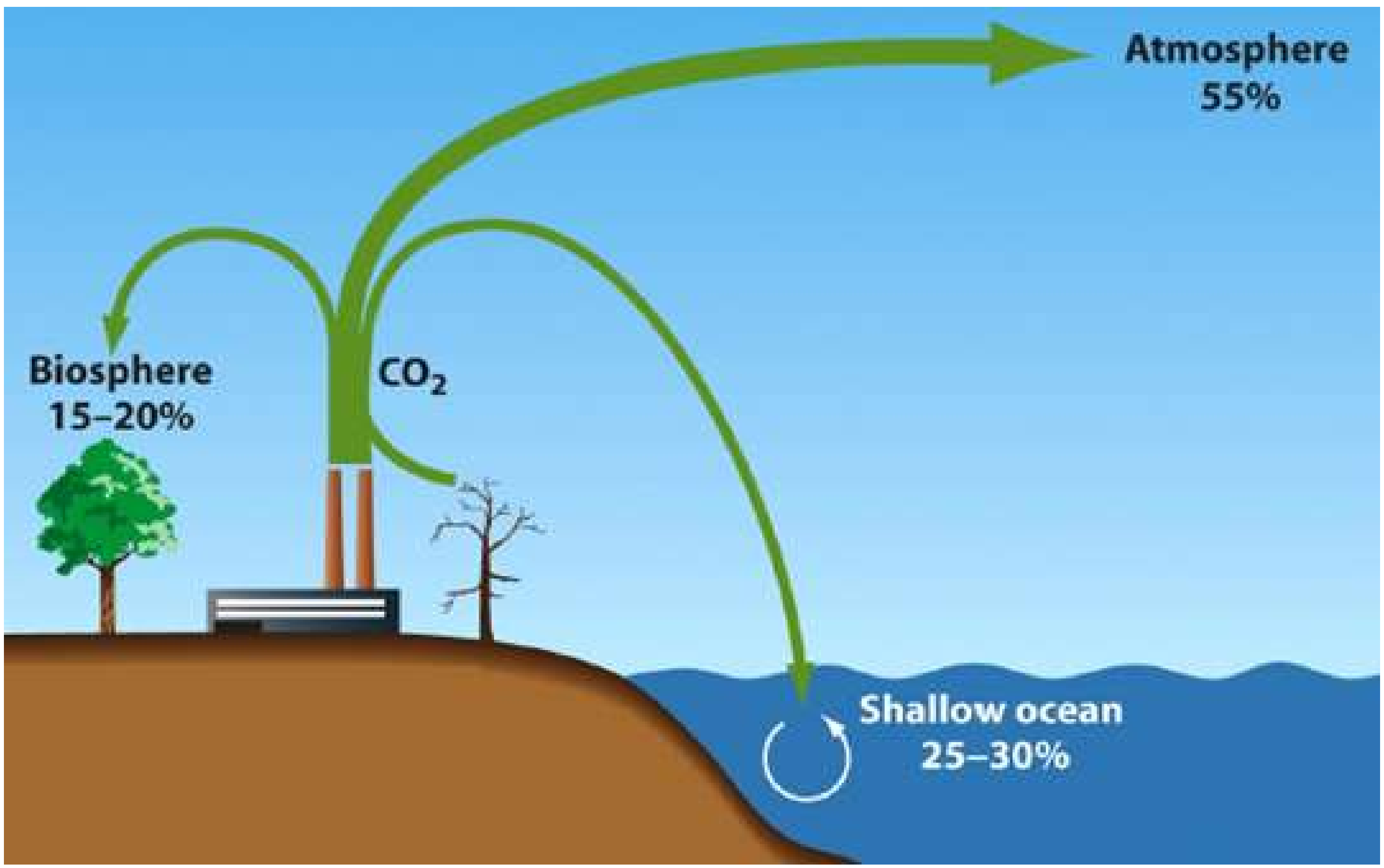




https://www.theclimatebrink.com/p/comparing-climate-models-with-observations

Future Emissions

- Uncertainties in future emissions
  - How much CO_2 will be emitted?
  - How will the climate system distribute it between the reservoirs?



The boundary conditions: Future CO_2 emmisions

CO_2 emmisions =

Population · Emissions per person

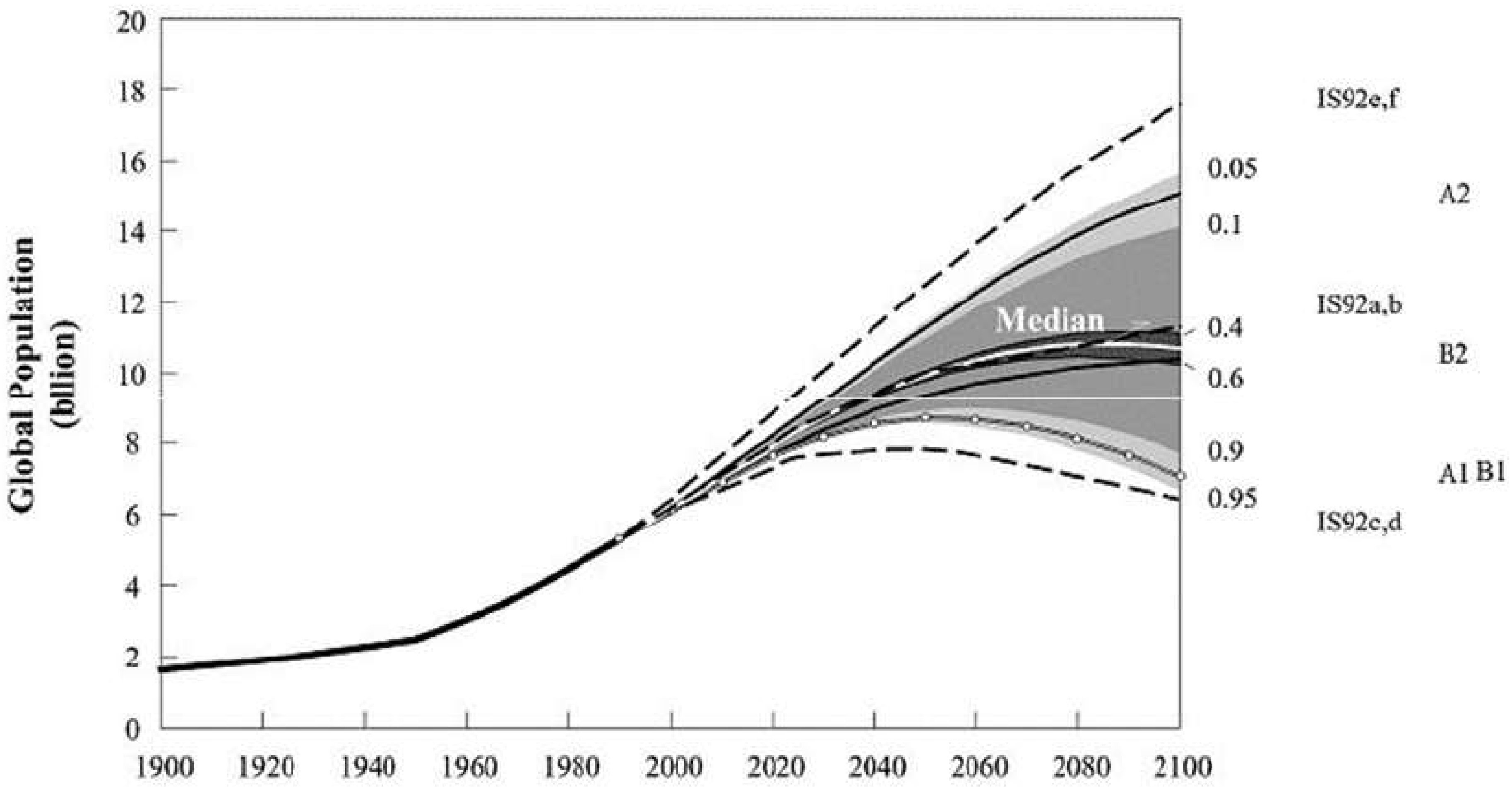
Main factors:

Population growth (a UN taboo)

Increased wealth per person (actually an aim)

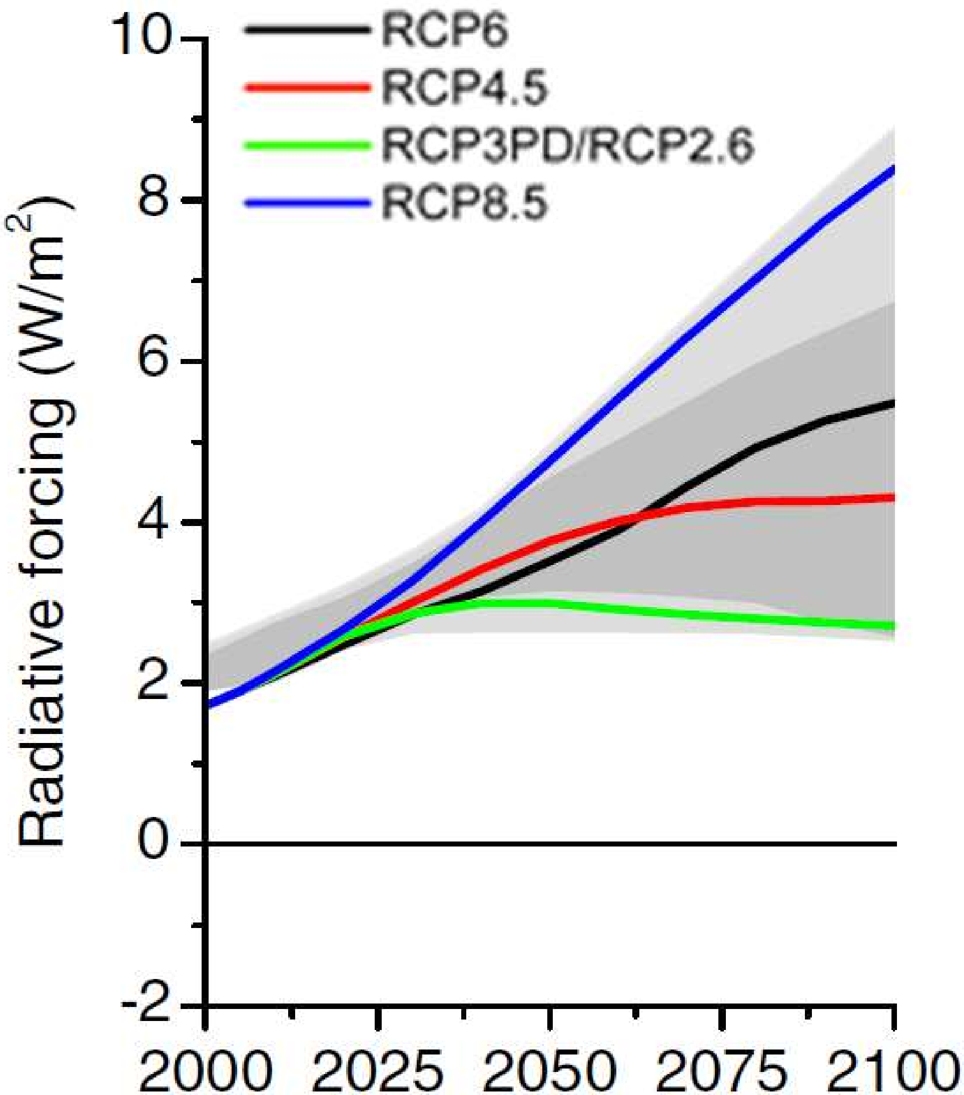
wealth/CO_2 relationship *or carbon efficiency* (the main battleground)

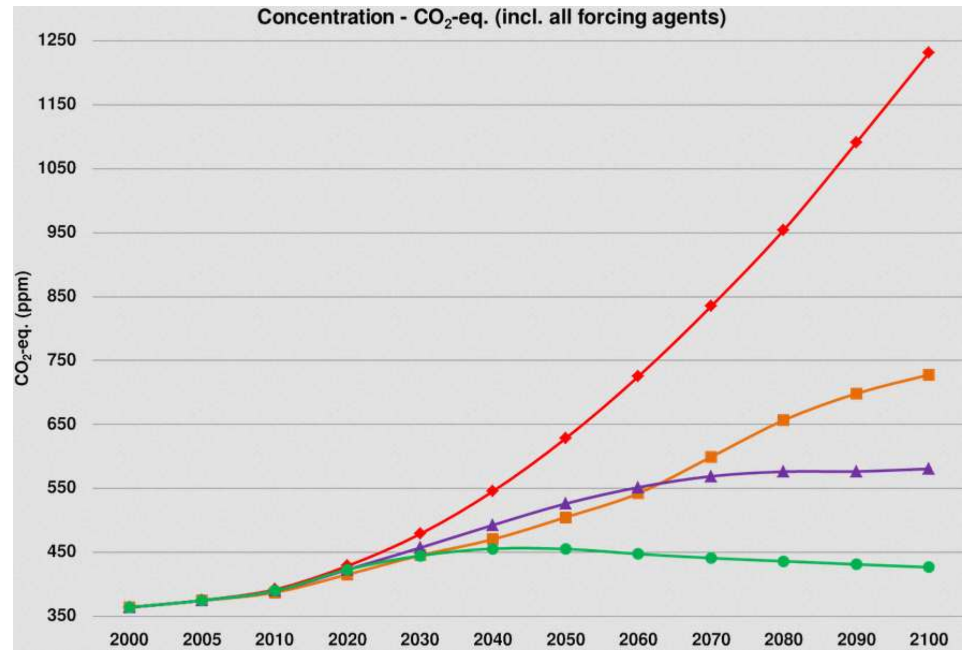
Population



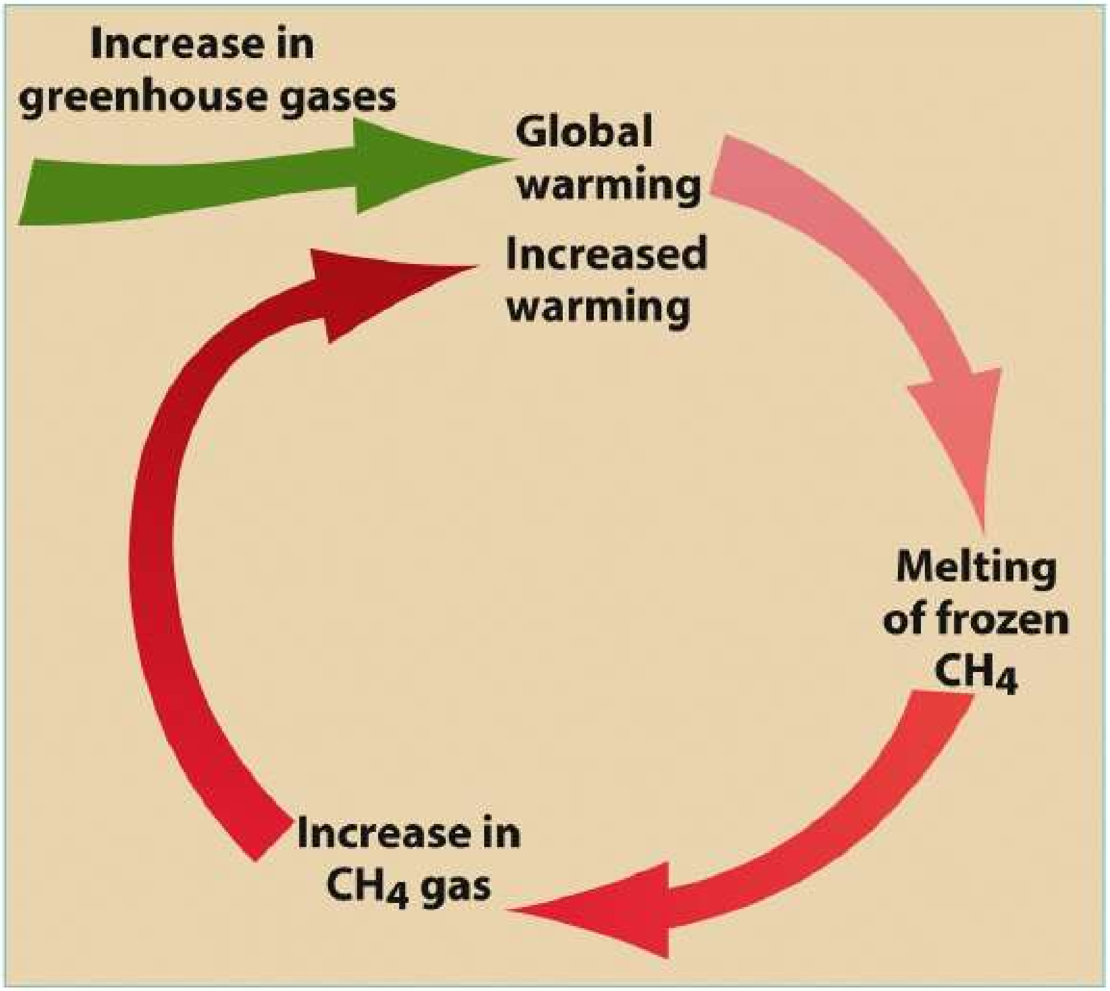
Numbers indicate probability fractiles.
IP92 is the former scenario family.

Representative Concentration Pathways (RCPs) used in AR5



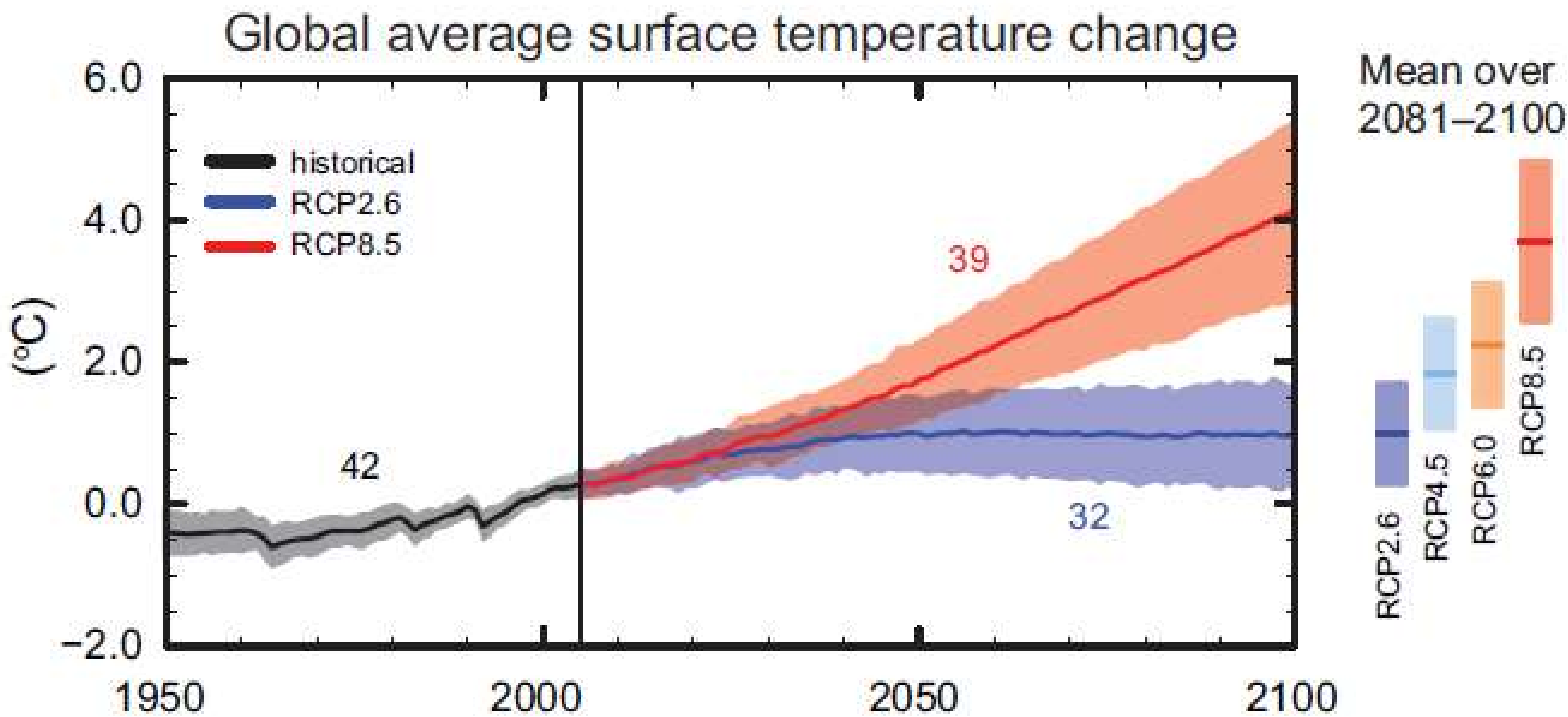


On top of the anthropogenic emission scenarios, CH_4 should be considered



Box 19-1
Earth's Climate: Past and Future, Second Edition

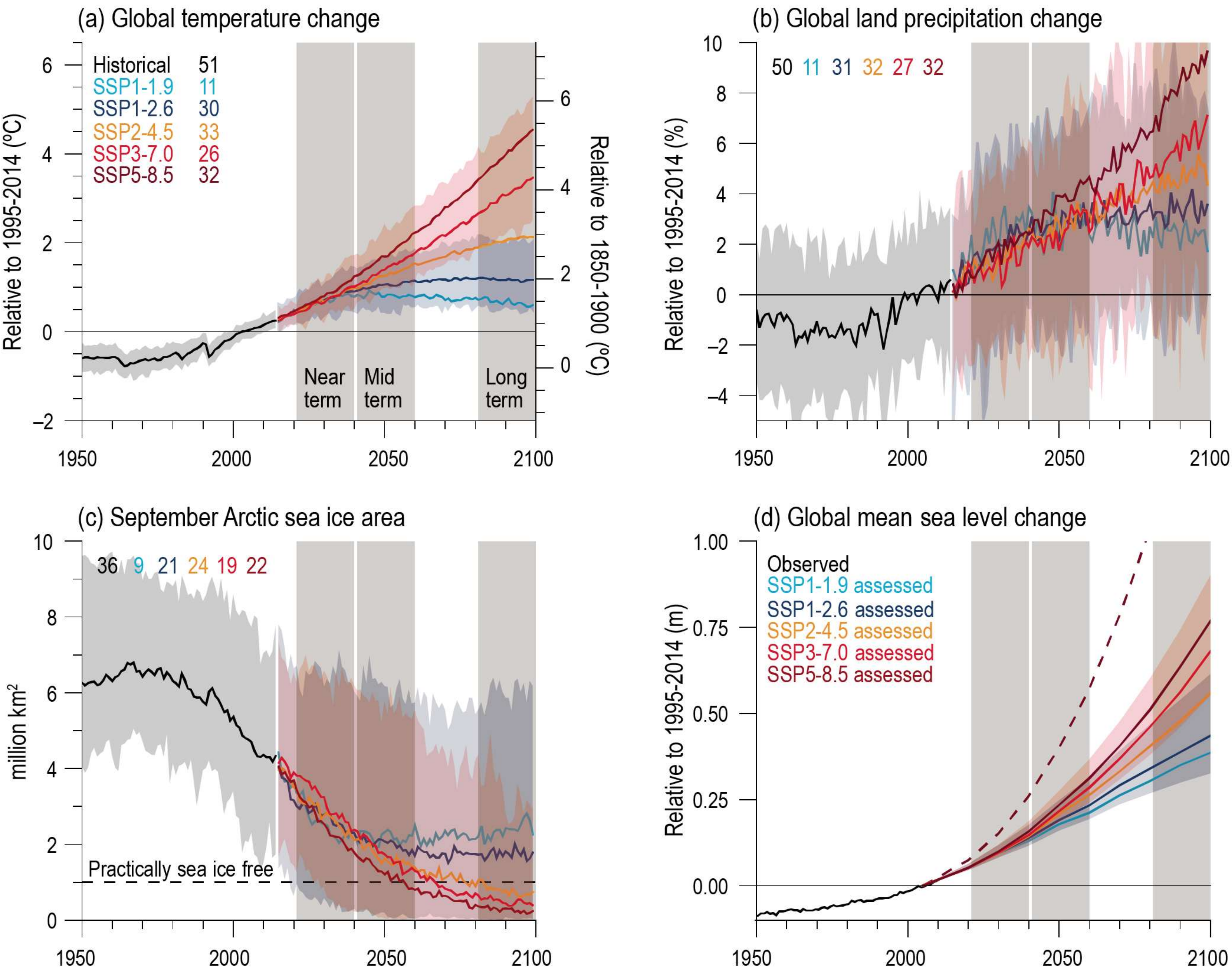
Expected future temperature rise



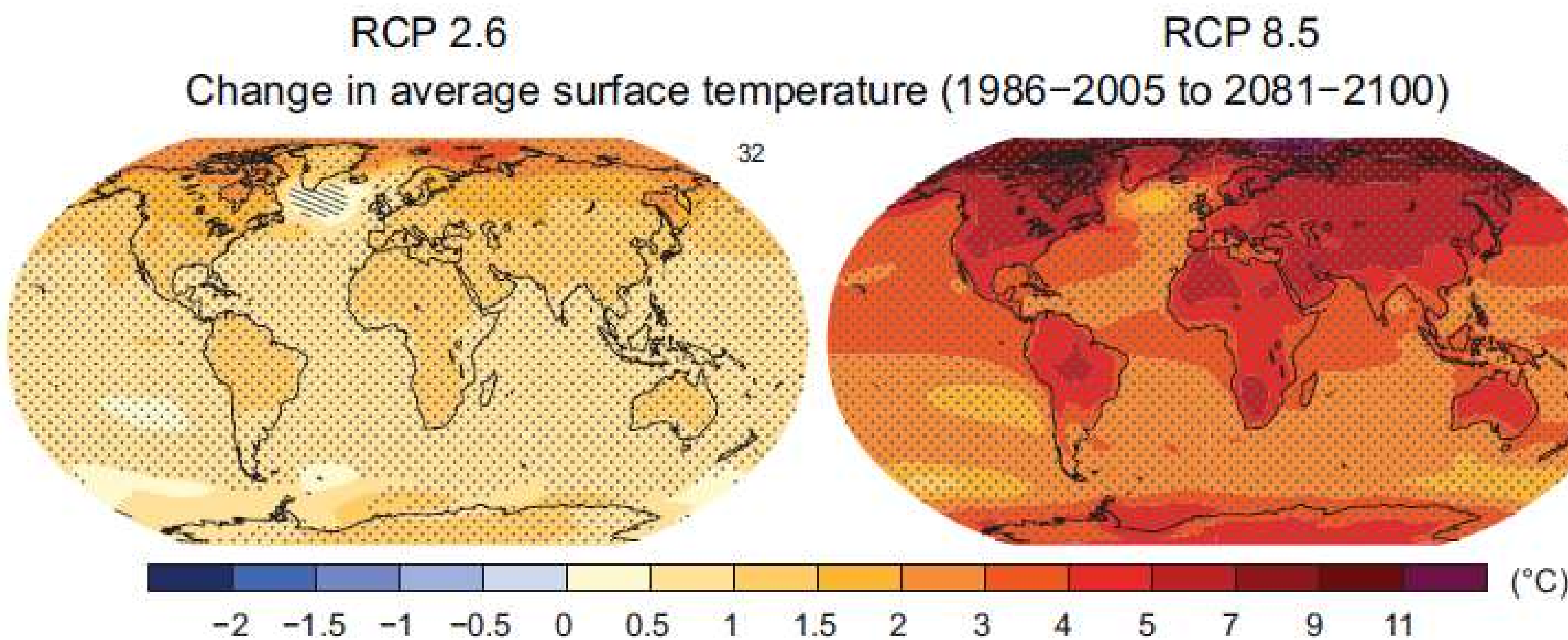
Projected future changes

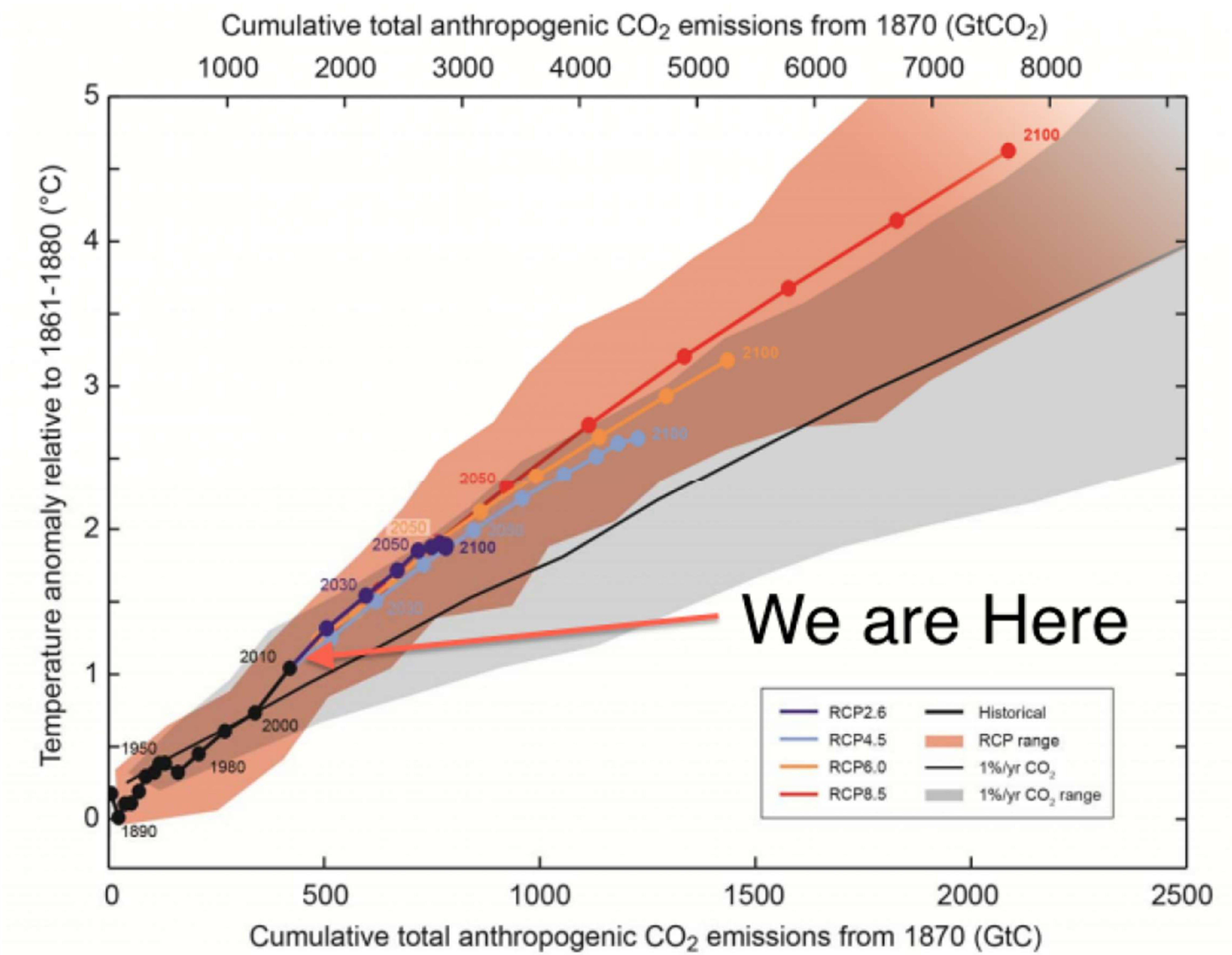
Table SPM.2 | Projected change in global mean surface air temperature and global mean sea level rise for the mid- and late 21st century relative to the reference period of 1986–2005. {12.4; Table 12.2, Table 13.5}

		2046–2065		2081–2100	
	Scenario	**Mean**	***Likely* range**[c]	**Mean**	***Likely* range**[c]
Global Mean Surface Temperature Change (°C)[a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	**Mean**	***Likely* range**[d]	**Mean**	***Likely* range**[d]
Global Mean Sea Level Rise (m)[b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82


(a) Global temperature change
Historical 51
SSP1-1.9 11
SSP1-2.6 30
SSP2-4.5 33
SSP3-7.0 26
SSP5-8.5 32
Relative to 1995-2014 (°C)
Relative to 1850-1900 (°C)
Near term
Mid term
Long term
(b) Global land precipitation change
50 11 31 32 27 32
Relative to 1995-2014 (%)
(c) September Arctic sea ice area
36 9 21 24 19 22
million km²
Practically sea ice free
(d) Global mean sea level change
Observed
SSP1-1.9 assessed
SSP1-2.6 assessed
SSP2-4.5 assessed
SSP3-7.0 assessed
SSP5-8.5 assessed
Relative to 1995-2014 (m)
1950
2000
2050
2100

Regional warming, THC and polar amplification





Cumulative total anthropogenic CO2 emissions from 1870 (GtCO2)
1000
2000
3000
4000
5000
6000
7000
8000
Temperature anomaly relative to 1861-1880 (°C)
0
1
2
3
4
5
0
500
1000
1500
2000
2500
Cumulative total anthropogenic CO2 emissions from 1870 (GtC)
1890
1950
1980
2000
2010
2030
2050
2100
We are Here
RCP2.6
RCP4.5
RCP6.0
RCP8.5
Historical
RCP range
1%/yr CO2
1%/yr CO2 range

Climate sensitivity

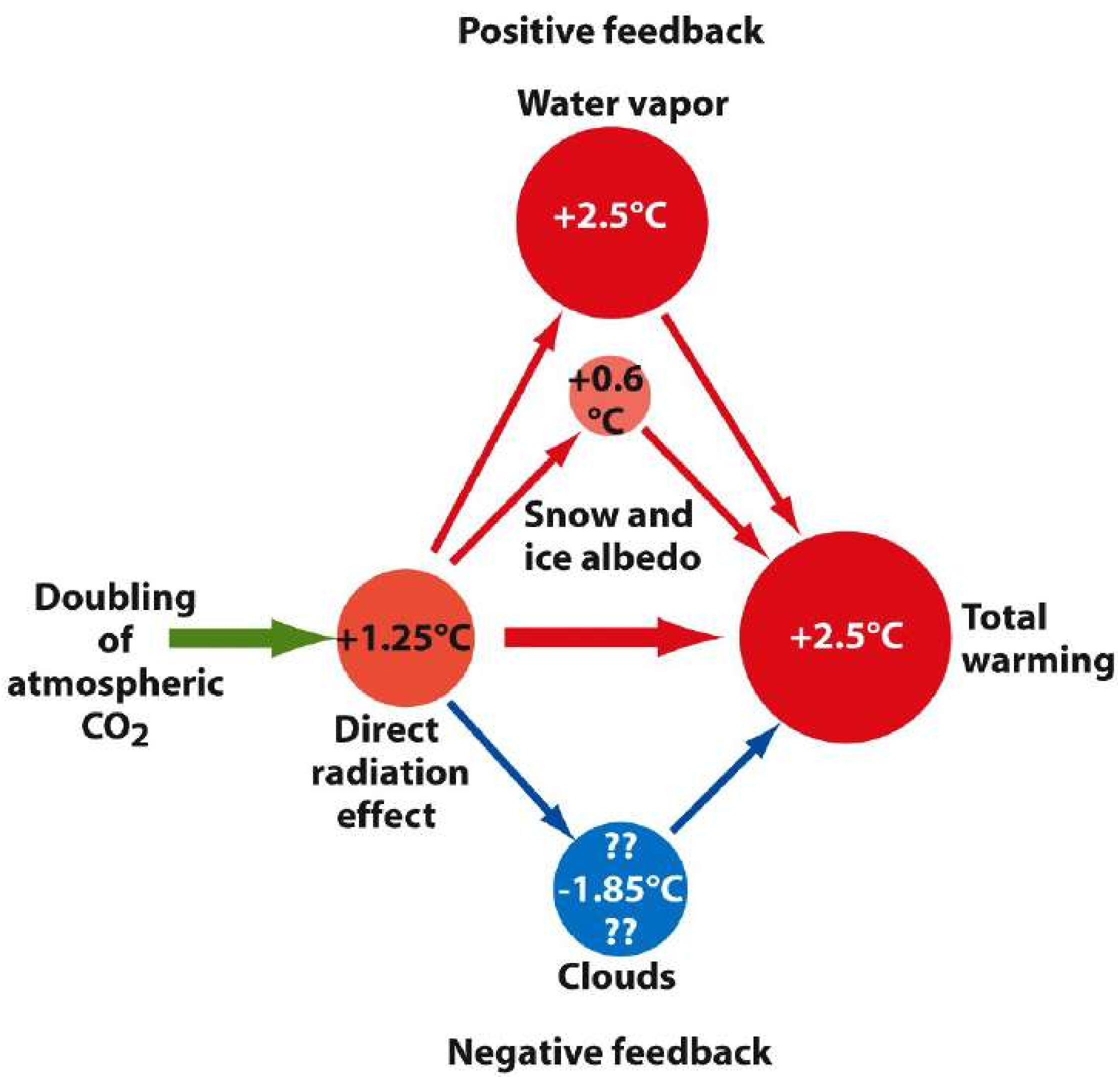


Figure 18-14
Earth's Climate: Past and Future, Second Edition

"Global average increase in simulated temp is the 2 x CO2 sensitivity for that model"

Climate sensitivity

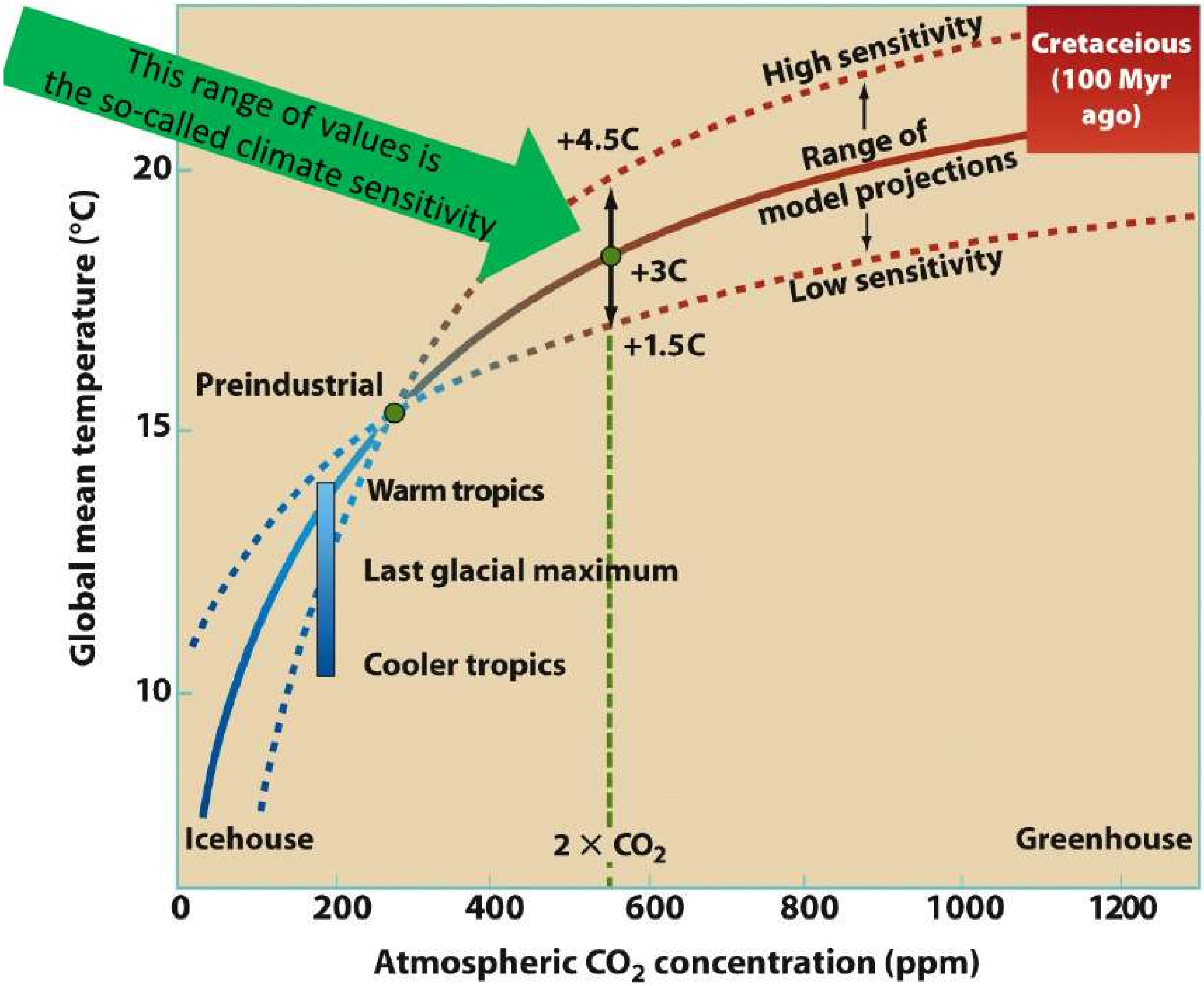
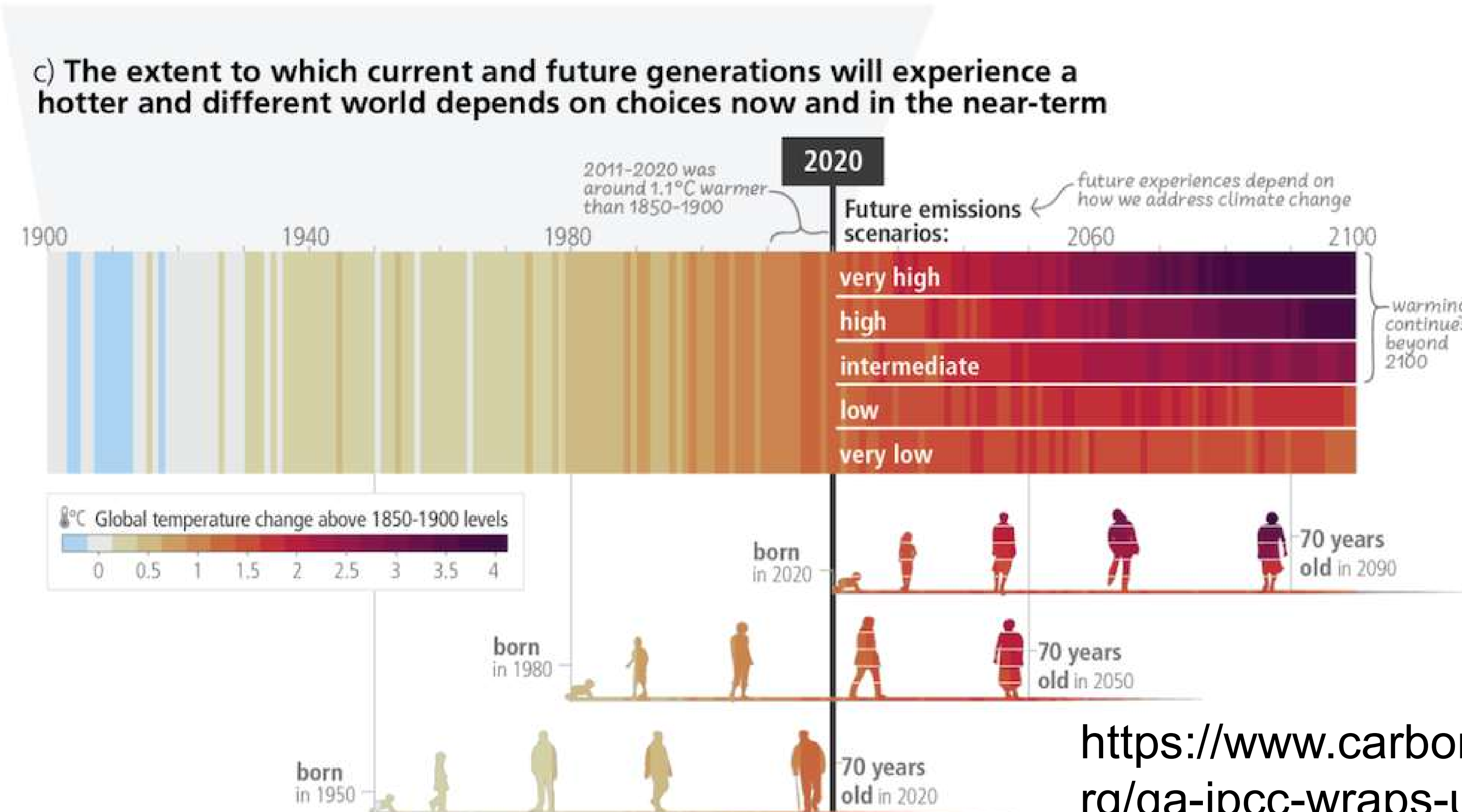


Figure 18-15
Earth's Climate: Past and Future, Second Edition

But why?

The climate sensitivity is used to compare models of widely varying type and complexity



https://www.carbonbrief.org/qa-ipcc-wraps-up-its-most-in-depth-assessment-of-climate-change/

Klimaatlas

- https://www.dmi.dk/klima-atlas/data-i-klimaatlas

Hvordan bliver fremtidens klima iflg IPCC.

-Hvor meget varmere bliver Danmark under IPCC RCO 8.5 vs RCP 2.6?

-Hvor mange flere dage med ekstrem brandfare kommer der om sommeren I fremtiden?

-Bliver Danmark vådere eller tørere I fremtiden?

-Stiger risikoen for stormfloder med fremtidens klimaforandringer og hvor meget?

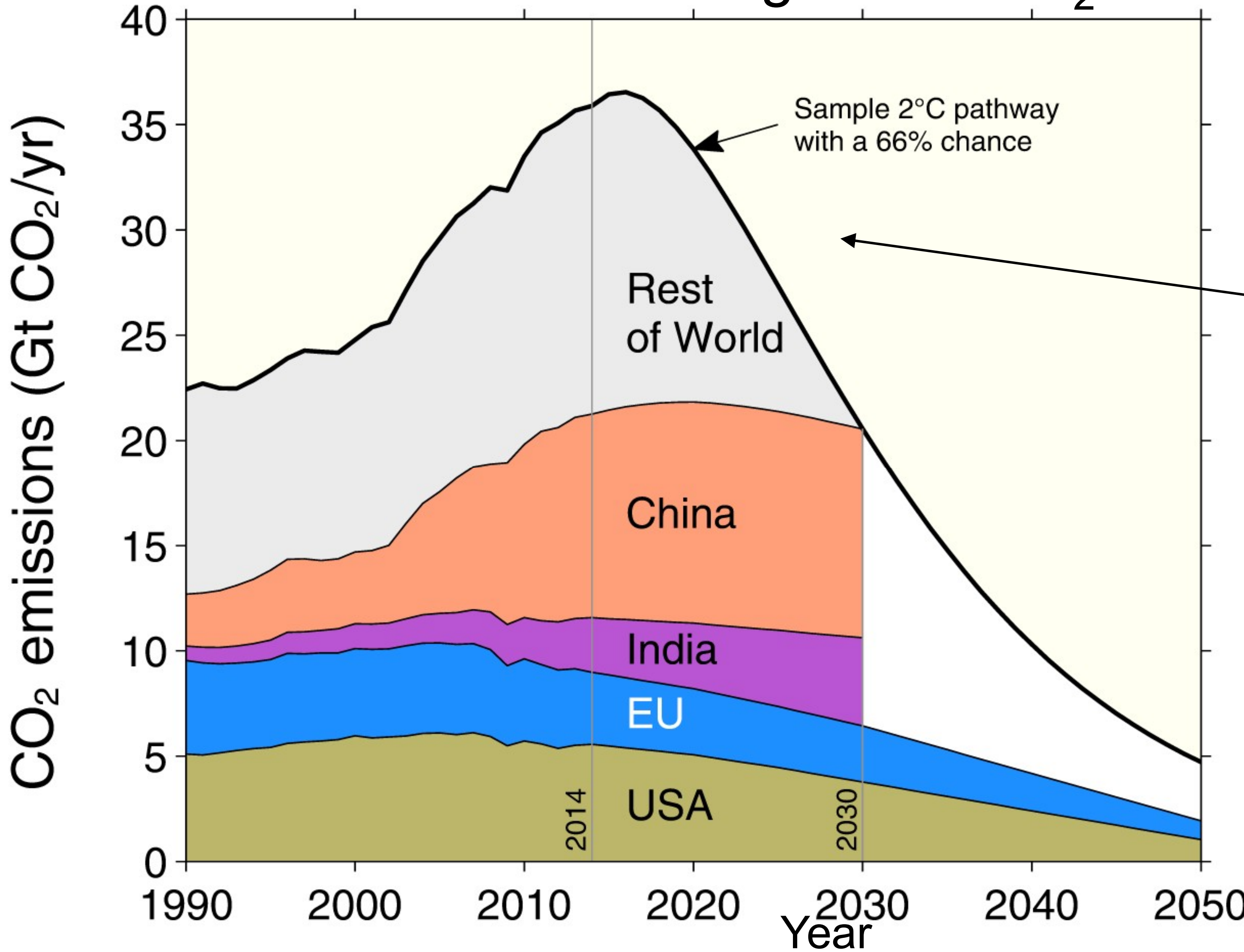
IPCC climate atlas

- https://interactive-atlas.ipcc.ch
- vælg- simple climate change
- Sammenlign områder med temp over 40C I de forskellige scenarier.
- Hvor stor er forskelllen I havets pH mellem de forskellige scenarier?

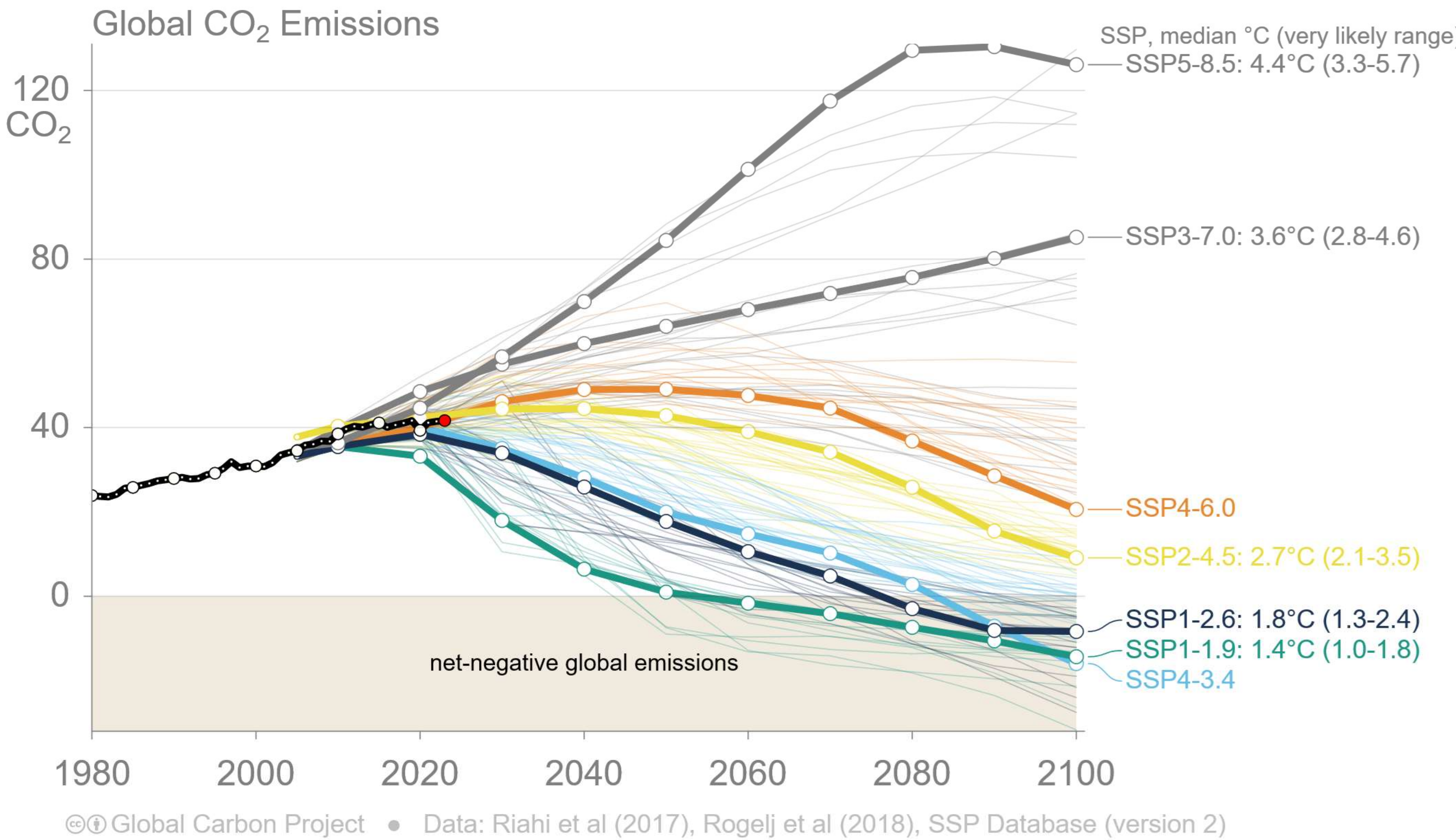
CO_2 udledning efter klimatopmødet i Paris 2015

Source: Peters et al 2015; Global Carbon Budget 2015

Sådan har landene lovet at begrænse CO_2 udledningen:



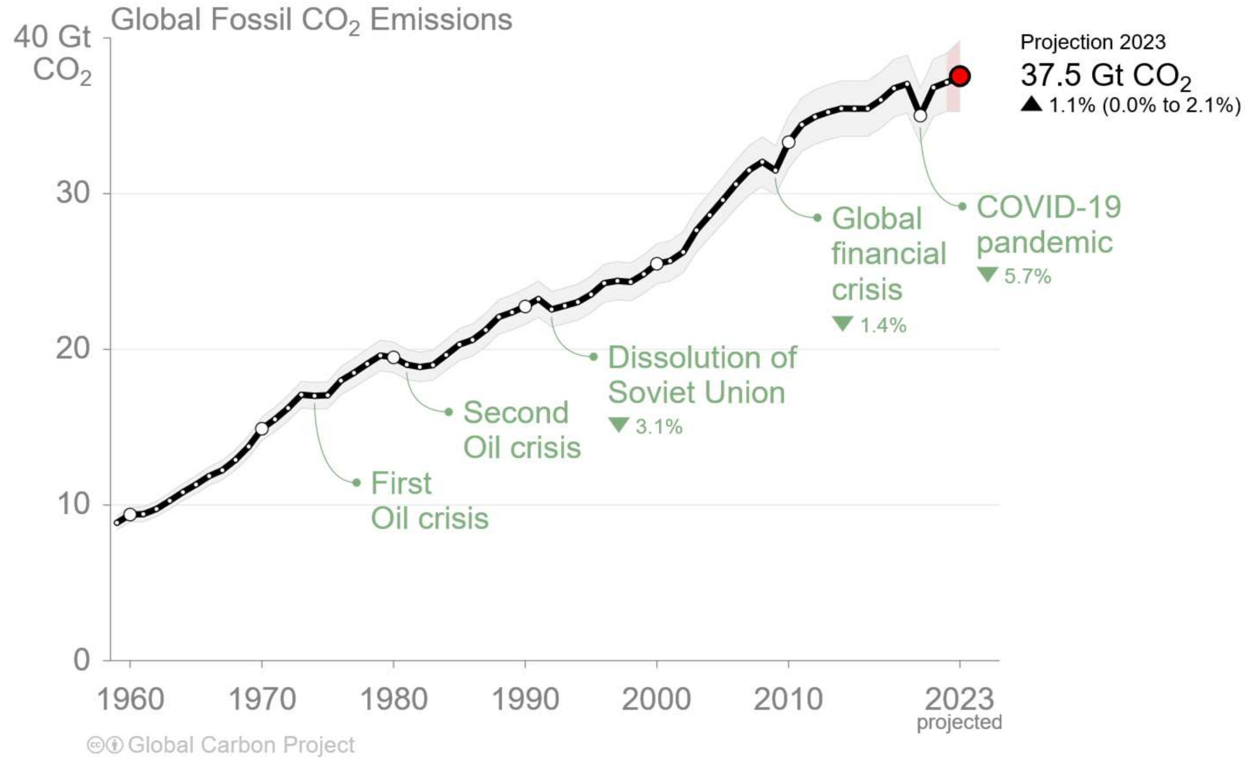
Vi skal holde os under denne linje, hvis den globale temperaturstigning skal holdes under 2°C



https://globalcarbonbudget.org/carbonbudget2023/

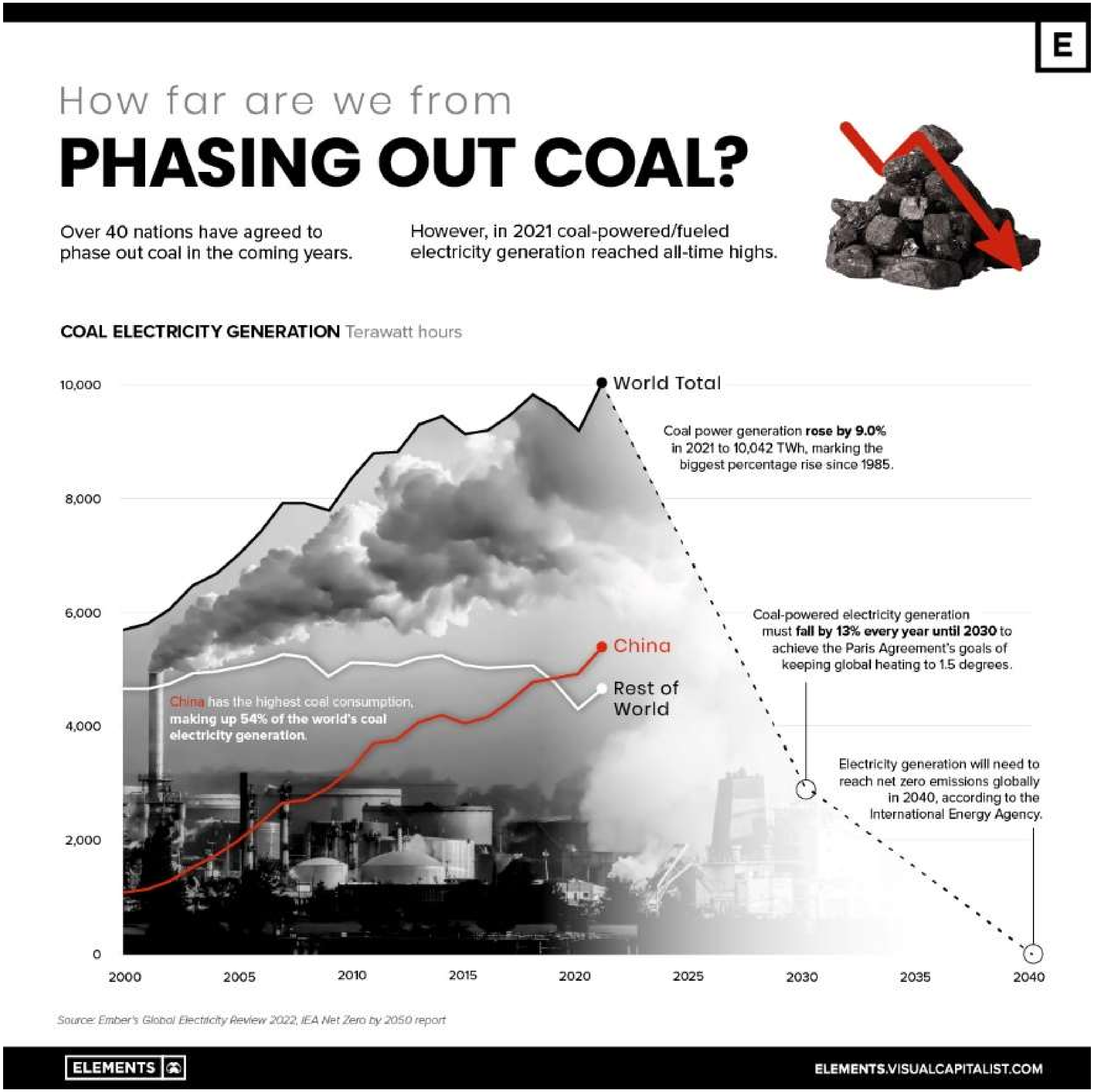
Global fossil CO_2 emissions

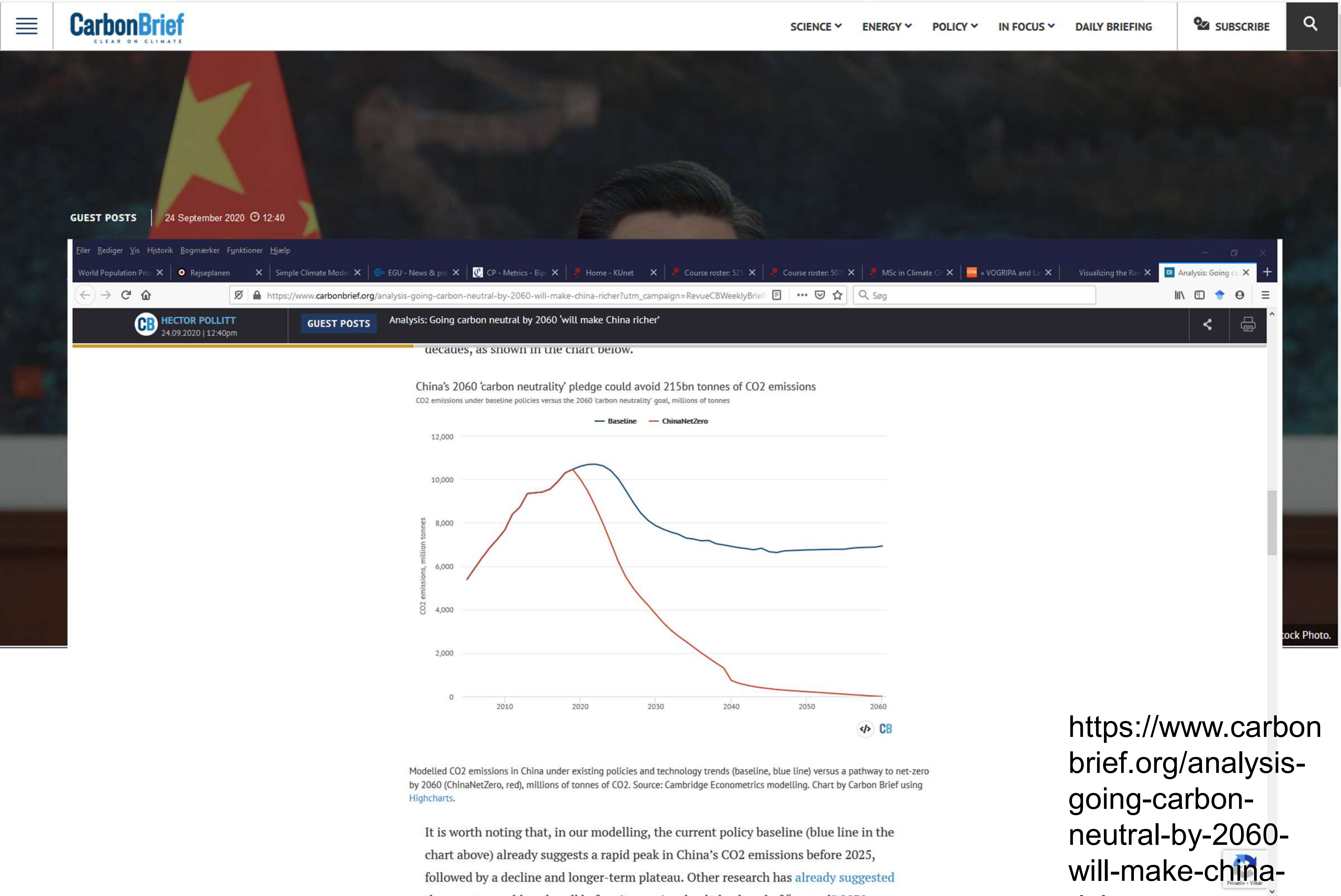
Global fossil CO_2 emissions have risen steadily over the last decades.
Emissions are set to grow again in 2023.



When including cement carbonation, the 2023 estimate is 36.8 ± 2 $GtCO_2$.
The 2023 projection is based on preliminary data and modelling.
Source: Friedlingstein et al 2023; Global Carbon Project 2023

Top six emitters in 2022 covered 67% of global emissions
China 31%, United States 14%, India 8%, EU 7%, Russia 4%, and Japan 3%

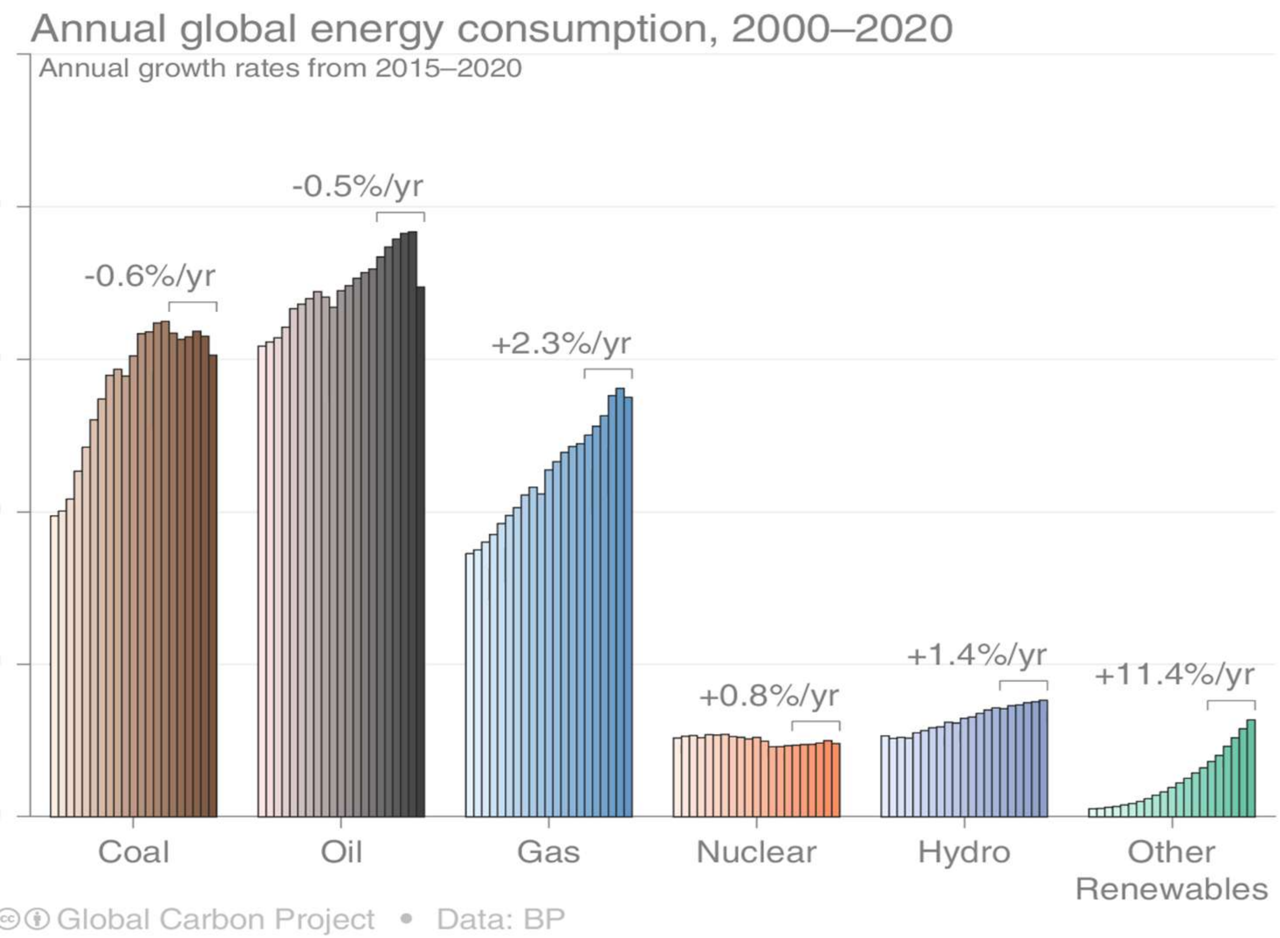

E
How far are we from
PHASING OUT COAL?
Over 40 nations have agreed to phase out coal in the coming years.
However, in 2021 coal-powered/fueled electricity generation reached all-time highs.
COAL ELECTRICITY GENERATION Terawatt hours
10,000
8,000
6,000
4,000
2,000
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
World Total
Coal power generation rose by 9.0% in 2021 to 10,042 TWh, marking the biggest percentage rise since 1985.
China
Rest of World
China has the highest coal consumption, making up 54% of the world's coal electricity generation.
Coal-powered electricity generation must fall by 13% every year until 2030 to achieve the Paris Agreement's goals of keeping global heating to 1.5 degrees.
Electricity generation will need to reach net zero emissions globally in 2040, according to the International Energy Agency.
Source: Ember's Global Electicity Review 2022, IEA Net Zero by 2050 report
ELEMENTS
ELEMENTS.VISUALCAPITALIST.COM



https://www.carbonbrief.org/analysis-going-carbon-neutral-by-2060-will-make-china-richer

Energy use by source

Energy consumption by fuel source from 2000 to 2020, with growth rates indicated for the more recent period of 2015 to 2020



This figure shows "primary energy" using the BP substitution method
(non-fossil sources are scaled up by an assumed fossil efficiency of approximately 0.38)
Source: BP 2020; Global Carbon Project 2021

More here: https://www.iea.org/reports/global-energy-review-2025/global-trends#abstract

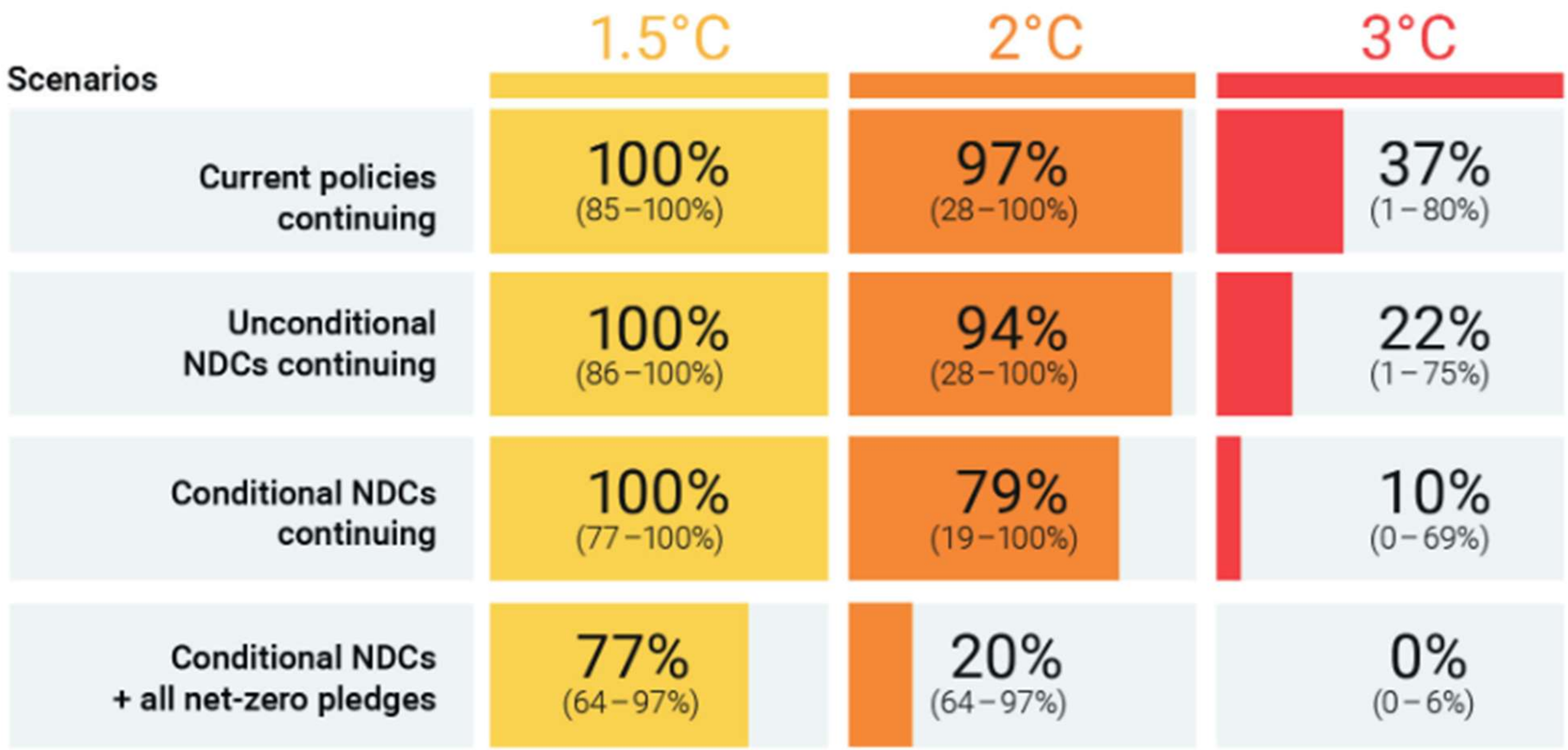
GLOBAL CARBON PROJECT

Emissions gap report 2024

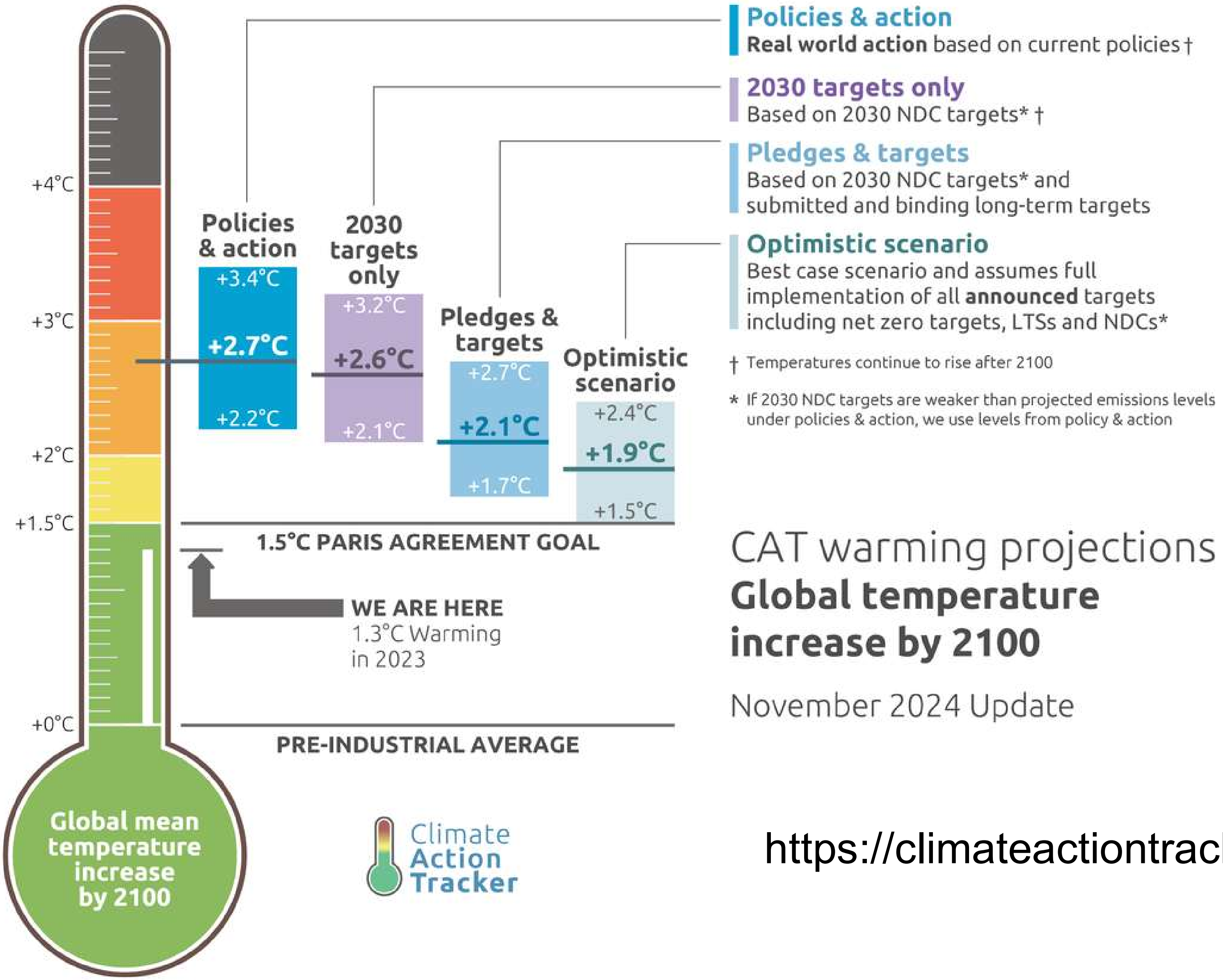
https://wedocs.unep.org/handle/20.500.11822/46443;jsessionid=F74DE914CDD261C7A091A3FD54860133

Table ES.1 Total, per capita and historical emissions of selected countries and regions

	Total GHG emissions in 2023	Change in total GHG emissions, 2022–2023	Per capita GHG emissions in 2023	Historical CO_2 emissions, 1850–2022
	$MtCO_2e$ (% of total)	%	tCO_2e/capita	$GtCO_2$ (% of total)
China	16,000 (30)	+5.2	11	300 (12)
United States of America	5,970 (11)	-1.4	18	527 (20)
India	4,140 (8)	+6.1	2.9	83 (3)
European Union	3,230 (6)	-7.5	7.3	301 (12)
Russian Federation	2,660 (5)	+2	19	180 (7)
Brazil	1,300 (2)	+0.1	6.0	119 (5)
African Union	3,190 (6)	+0.7	2.2	174 (7)
Least developed countries (45 countries)	1,720 (3)	+1.2	1.5	114 (4)
G20 (excl. African Union)	40,900 (77)	+1.8	8.3	1,990 (77)



Where are we heading?



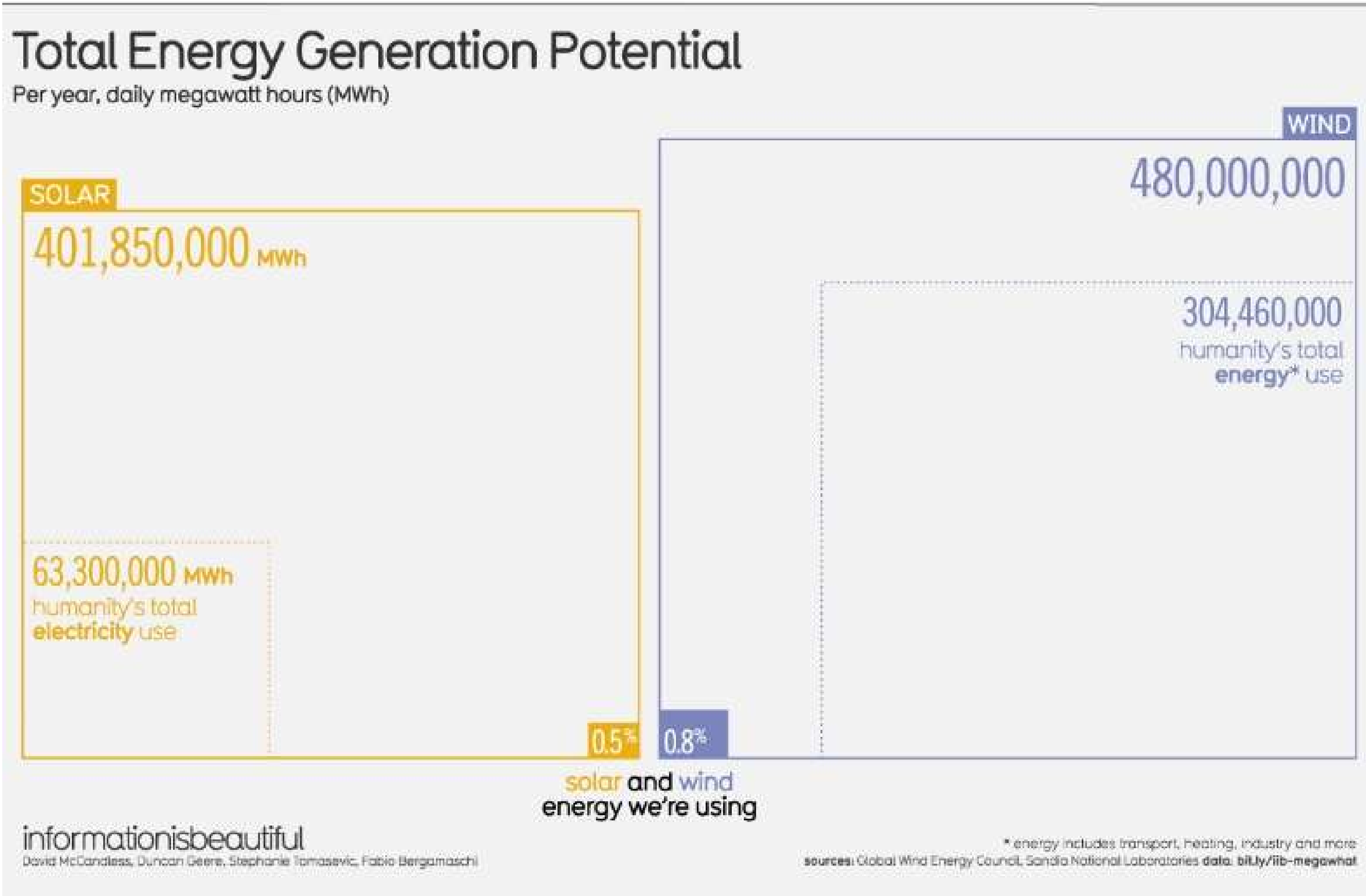
https://climateactiontracker.org/

https://www.ted.com/talks/climate_action_tracker_the_state_of_the_climate_crisis_in_2021?language=en

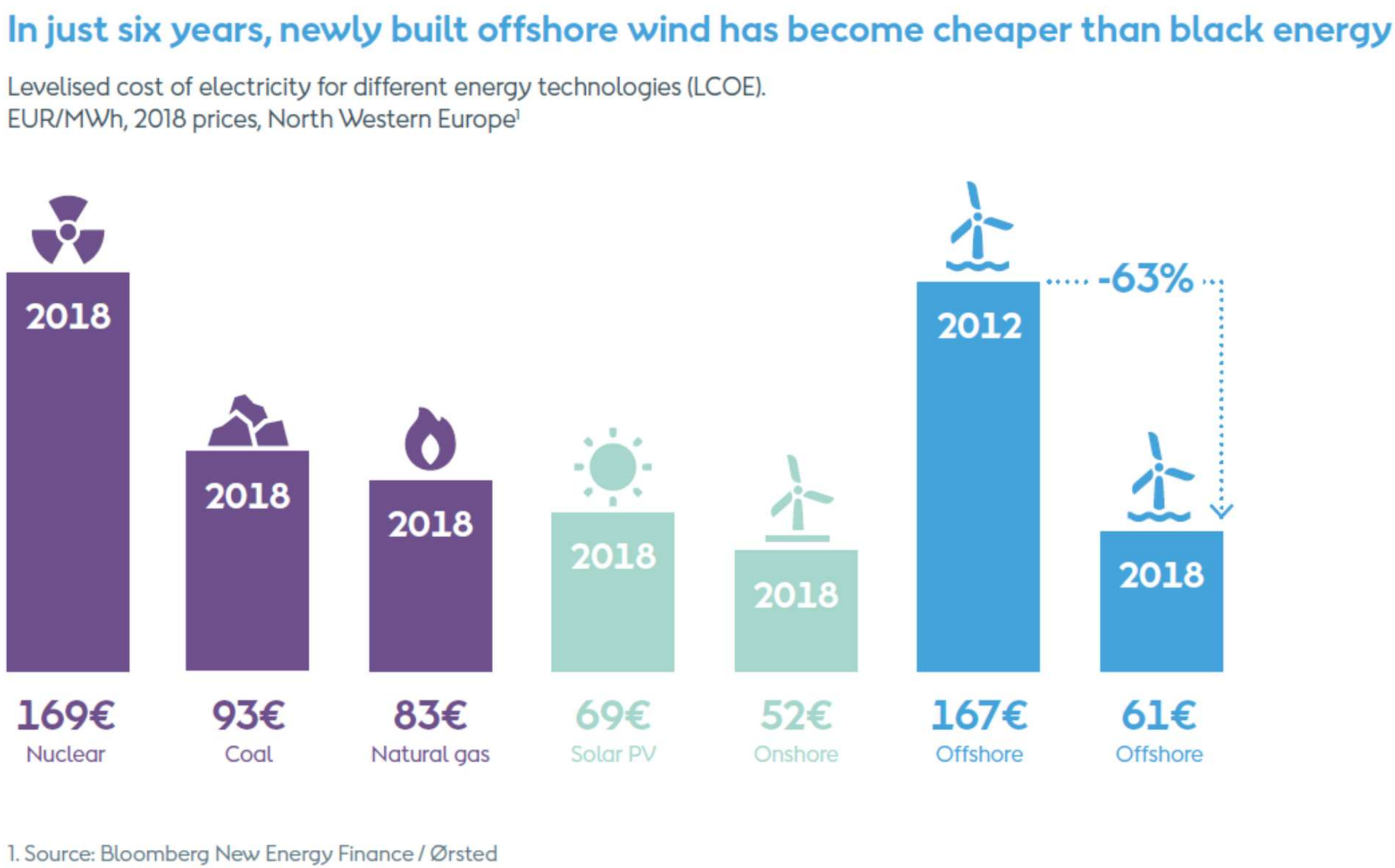
USA trækker sig fra FN's klimakonvention, der står bag COP. I forvejen var USA trådt ud af Parisaftalen.

Trump trækker USA ud af klimaorganisationer i FN

Foto: Leah Millis/Ritzau



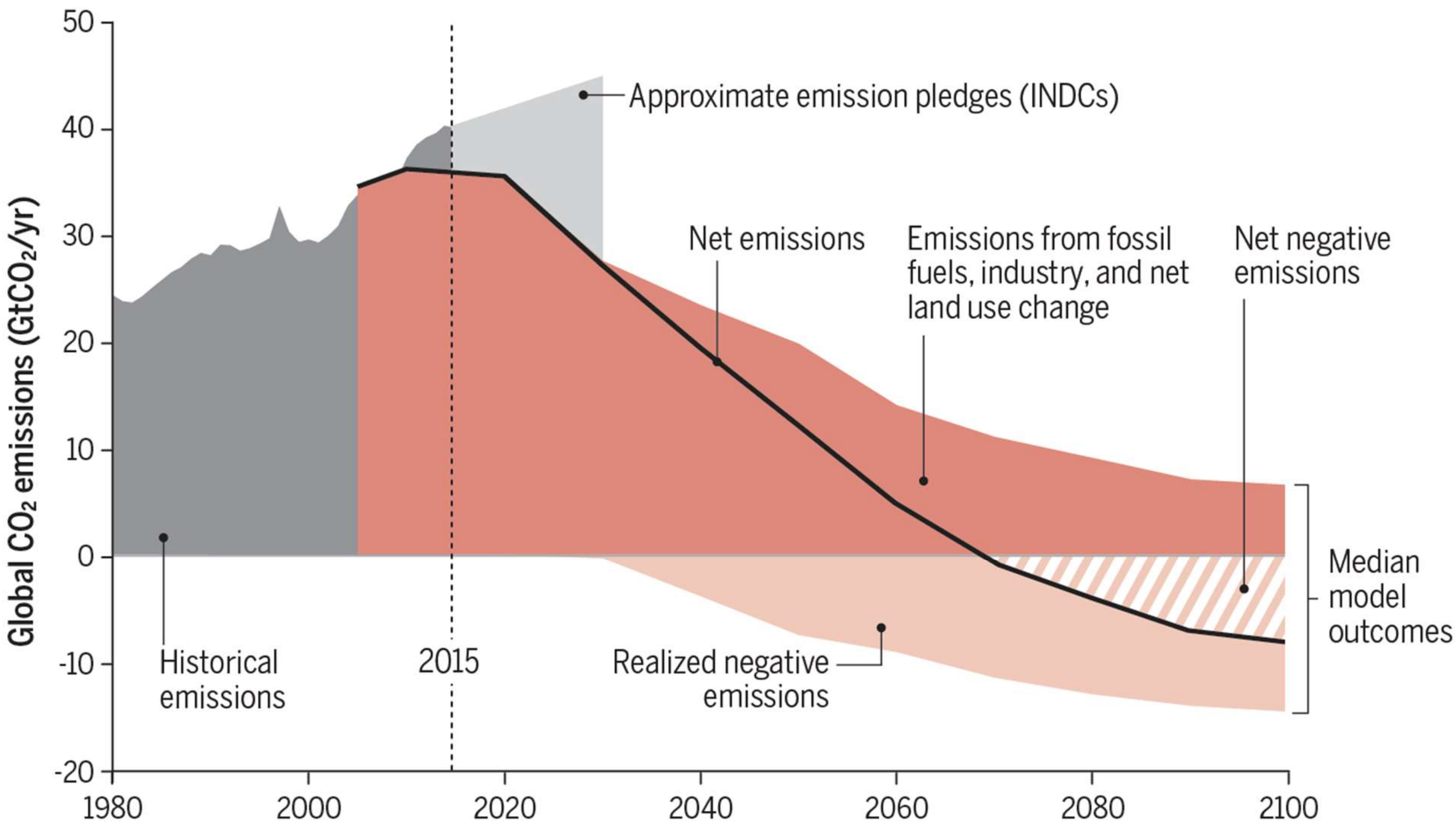
https://www.visualcapitalist.com/worlds-largest-energy-sources/



https://orsted.com/en/About-us/whitepapers/making-green-energy-affordable

Negative emissions required for 2°C

To achieve net-negative emissions globally after 2050 requires deployment as early as 2020-2030
If negative emission technologies do not work at scale, society is locked into higher temperatures



→ Time

Source: Anderson & Peters 2016

Regeringens mål

Hvad koster det for samfundet at nå forskellige mål?

	Omkostning I alt 2024-2035 *Mia. kr.*	Heraf sideeffekter *Mia. kr.*	Dyreste omstillingselement *Kr. pr. ton CO_2e*
80 pct.	0	- 4	Ca. 800
85 pct.	19	- 4	Ca. 1.200
90 pct.	45	- 6	Ca. 1.800

Anm 1: Omkostningerne i tabellen er i tillæg til, hvad det koster at nå til 78 pct. reduktion med allerede vedtagen politik.

Anm 2: Negative sideeffekter betyder, at der er en samfundsøkonomisk gevinst.

Klimarådet.

- Der er i forvejen en omkostning ved at implementere allerede vedtagen politik og nå 78 pct. reduktion i 2035.
- Den yderligere omkostning ved gå til 80 pct. ser ud til at være begrænset.
- Højere mål vil betyde udgifter for Danmark til fx tekniske anlæg og fra tabt produktionsværdi – i størrelses-ordenen 0,1-0,2 pct. af BNP.
- Sideeffekter i form af blandt andet miljøgoder ved omlægning af arealer udgør en gevinst for Danmark.

11

https://www.ft.dk/samling/20241/almdel/kef/bilag/79/2944736.pdf

"Udledningen af drivhusgasser forventes at falde med **78 pct. i 2035** med den nuværende politik. Der er derfor ikke langt til et 80-procentsmål, og i Klimarådets scenarieskitse nås det primært ved at omlægge landbrugsareal. "

Regeringen har sat Danmarks næste klimamål og løfter målet fra Klimalovens 2030-mål om 70 pct. reduktion i forhold til 1990 - til 82 pct. i 2035

Klimarådet.

Der er fordele og ulemper for samfundet ved højere 2035-mål

Samfundsmæssige hensyn

	Fordele	Ulemper
Samfundsværdi	Mulighed for mere natur og miljøgevinster Mulighed for grøn erhvervsudvikling	Tekniske omkostninger Tab af produktionsværdi i visse brancher
Fair omstilling	Højere mål kan skabe nye muligheder og opleves mere retfærdigt i et globalt klimaperspektiv	En hurtigere omstilling kan have større konsekvenser, der af nogle kan opleves som uretfærdige
Global effekt	Danmark som foregangsland	Risiko for drivhusgaslækage Risiko for øget import af biomasse

13

Tabel 1

Alle ikke-EU annex 1-landes klimamål 2035 sammenlignet med Danmarks (rangeret: højeste målt ift. 1990 øverst)

Land	Klimamål i 2035 ift. 1990 (pct.)		Klimamål i 2035 ift. 2005 (pct.)		Klimamål i 2035 ift. 2013 (pct.)	
	Ekskl. LULUCF	Inkl. LULUCF	Ekskl. LULUCF	Inkl. LULUCF	Ekskl. LULUCF	Inkl. LULUCF
Danmark	-	**82**	-	81	-	76
UK	-	**81**	-	78	-	73
		-	72-77	-	71-76	-
		-	72	-	68	-
		7,6	-	66,1	-	63,6
		65	-	65	-	64
		-71	-	**62-70**	-	58-67
		-59	-	**61-66**	-	57-63
		56	-	58	-	**60**
		-43	-	**51-55**	-	47-51
		-35	-	*Stigning*	-	*Stigning*
		-	**45-50**	**-**	44-49	-
		-	-	-	-	-
		-	-	-	-	-
		-	-	-	-	-
		-	-	-	-	-
		-	-	-	-	-

Anm: Det officielle mål er markeret med fed. Omregning af basisår er sket vha. officielle emissionsopgørelser for, at de kan sammenlignes. 1: Indmeldt før Trumps regeringsperiode. 2: Rusland har indmeldt et mål om at reducere udledningerne *til* 65-67 pct. af 1990-niveauet, svarende til en reduktion på 33-35 pct. ift. 1990. Rusland har siden 1990 reduceret med ca. 51 pct., hvormed målet er en stigning, når det omregnes til 2005- og 2013-niveau. 3: Island har ikke et mål for deres samlede udledninger. Island har et mål om at reducere udledningerne i non-ETS-sektoren med 50-55 pct. ift. 2005.

Kilde: Landenes indmeldte NDC'er til FN. https://unfccc.int/NDCREG.

Selskaber har trukket sig fra milliardudbud, så ambition om at indfange 2,3 millioner ton CO2 kan ikke nås.

Ni af ti selskaber har trukket sig fra milliardudbud om CO2-fangst

LYT TIL ARTIKLEN

GEM ARTIKLEN

KLIMA
30. DECEMBER 2025, 08.31

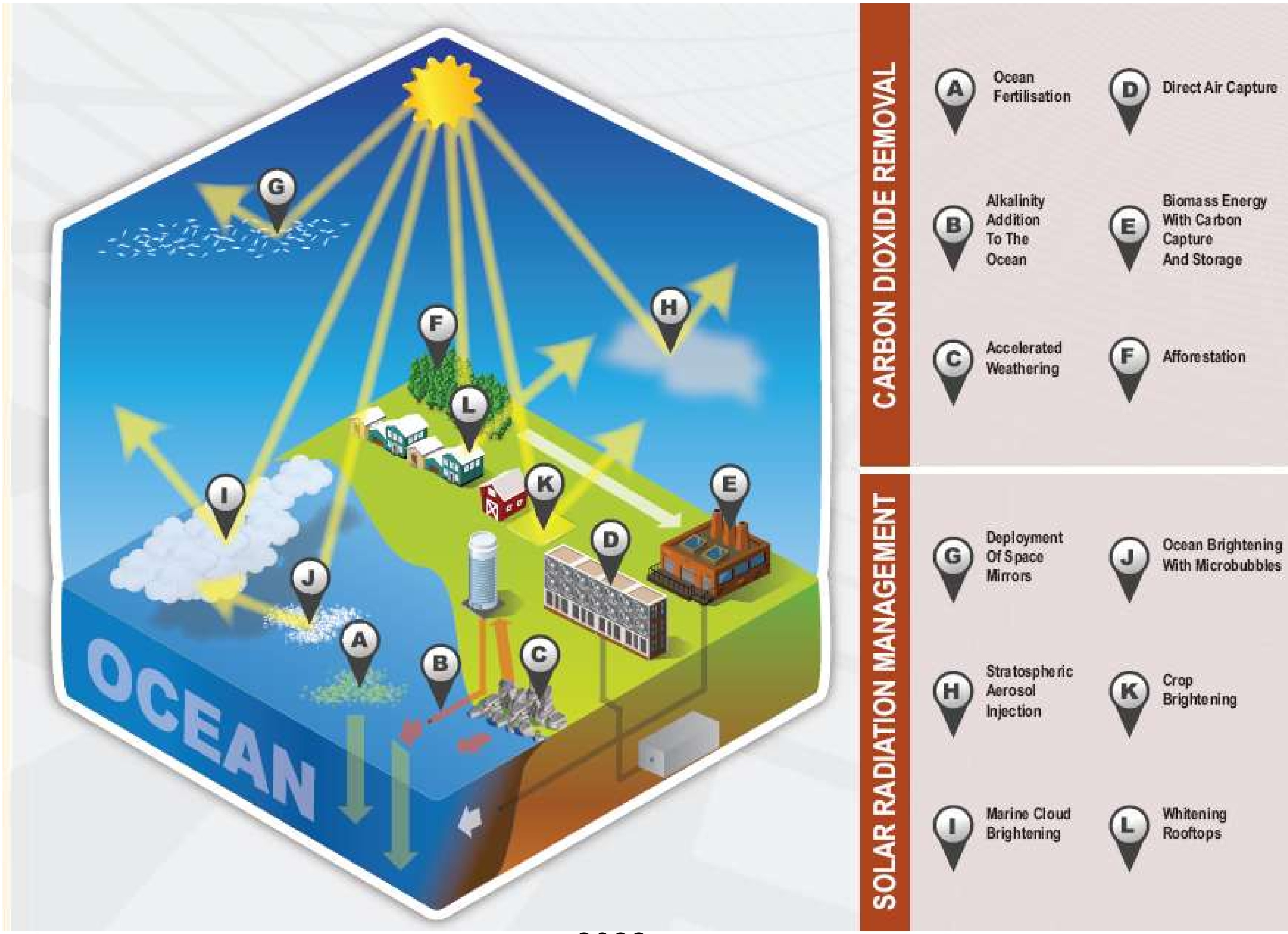
KOMMENTARER

Kun ét selskab af ti mulige byder fortsat ind på et udbud af en støttepulje i milliardklassen til at fange og lagre CO2.

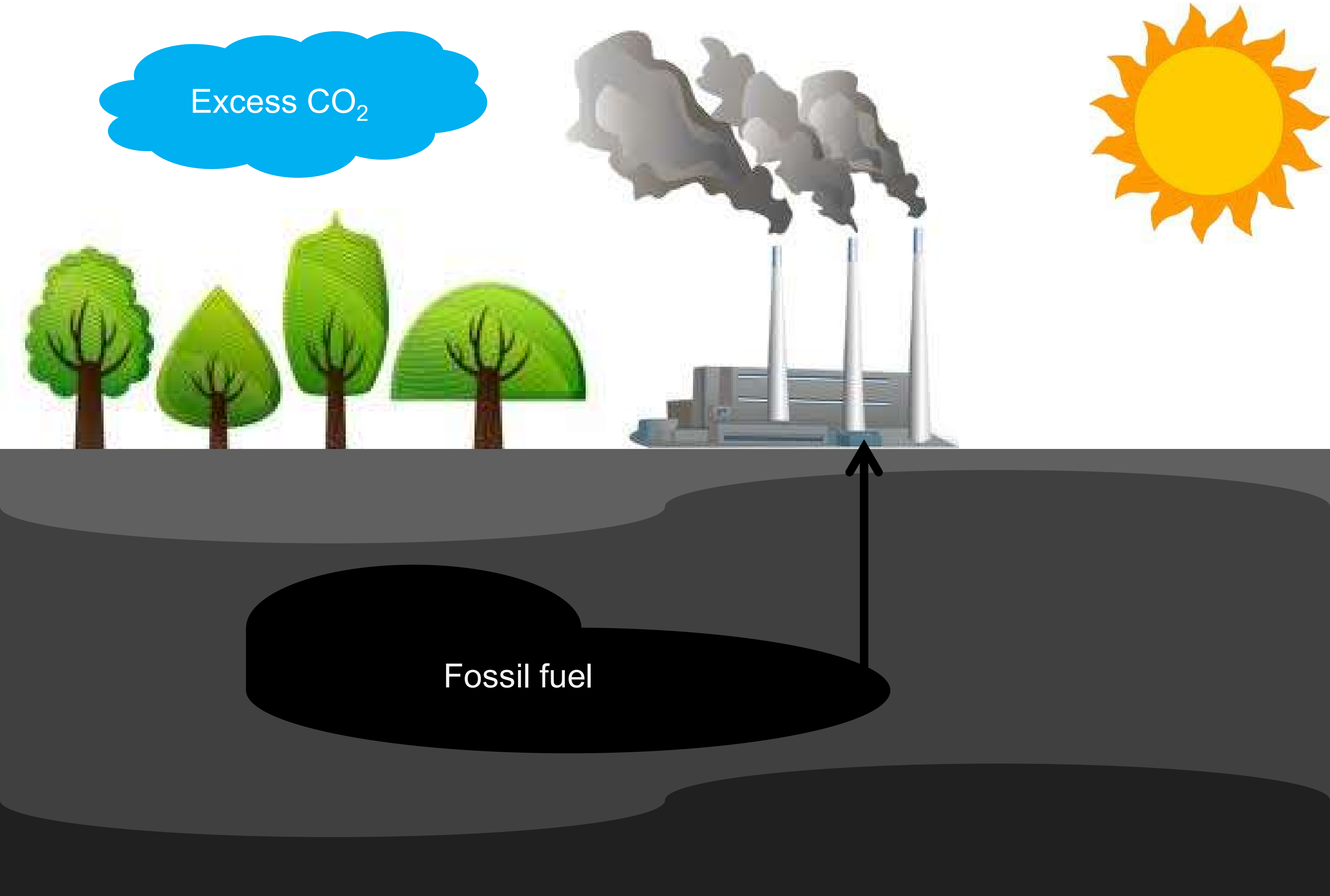
Det står klart, efter at det kommunalt ejede affaldsselskab Energnist og energiselskabet A2X har trukket sig fra udbuddet, som de har arbejdet sammen om.

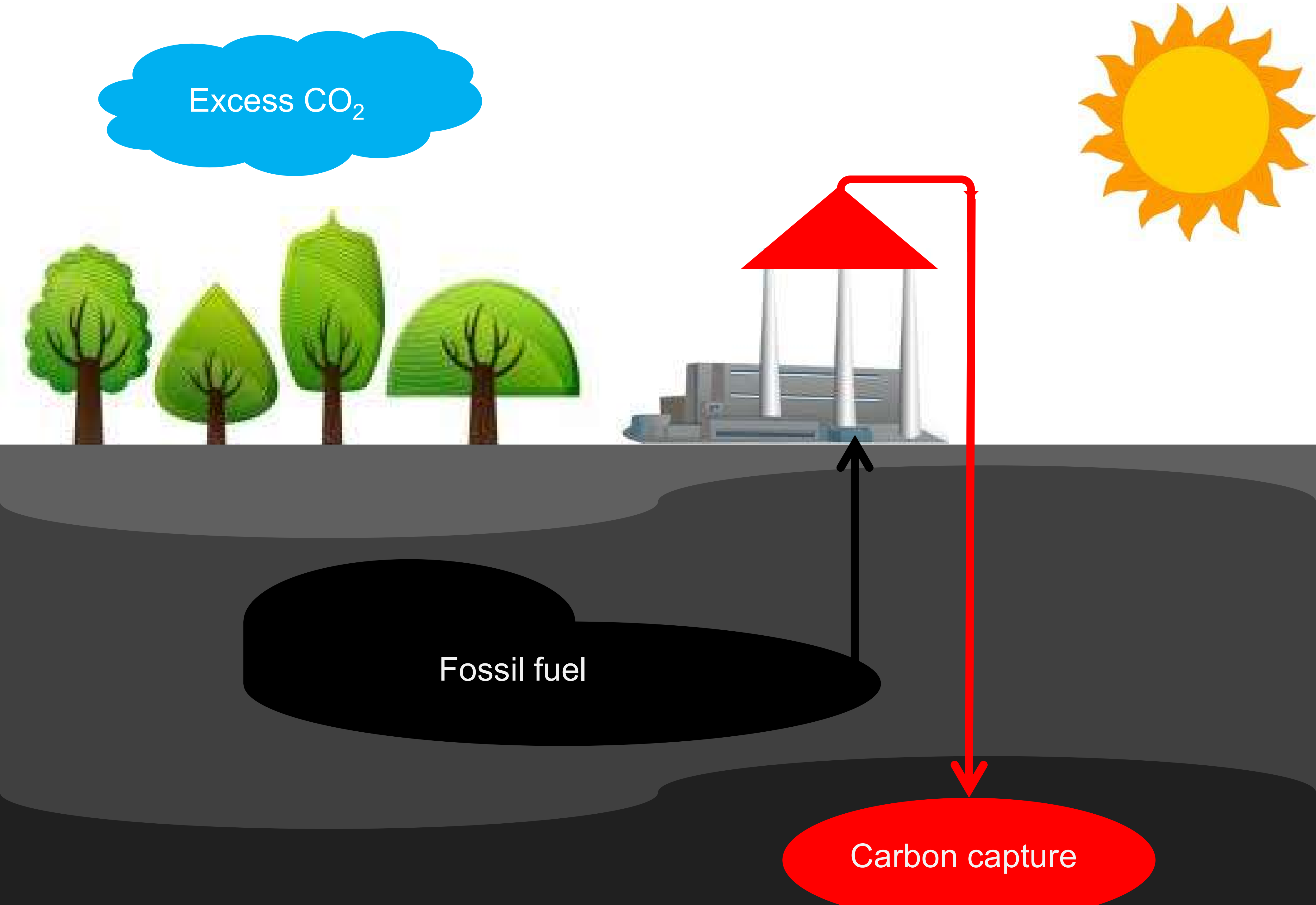
Is geoengineering / climate intervention an option?

Overview of some proposed geoengineering methods



(IPCC AR5 WG1 FAQ 7.3, Figure 1)


Excess CO_2
Fossil fuel


Excess CO_2
Fossil fuel
Carbon capture

≡ CNN Climate Solutions Weather

The 'world's largest' vacuum to suck climate pollution out of the air just opened. Here's how it works

By Laura Paddison, CNN
4 min read · Updated 2:26 PM EDT, Wed May 8, 2024

Climeworks' Mammoth plant in Hellisheiði, Iceland, started operating on May 8. Oli Haukur Myrdal/Climeworks

Ørsted: Opnår vigtig milepæl i deres CO2-fangst- og -lagringsprojekt

Energiselskabet tager det næste store skridt mod at realisere Danmarks første fuldskala CO2-fangst og -lagringsprojekt, "Ørsted Kalundborg CO2 Hub".

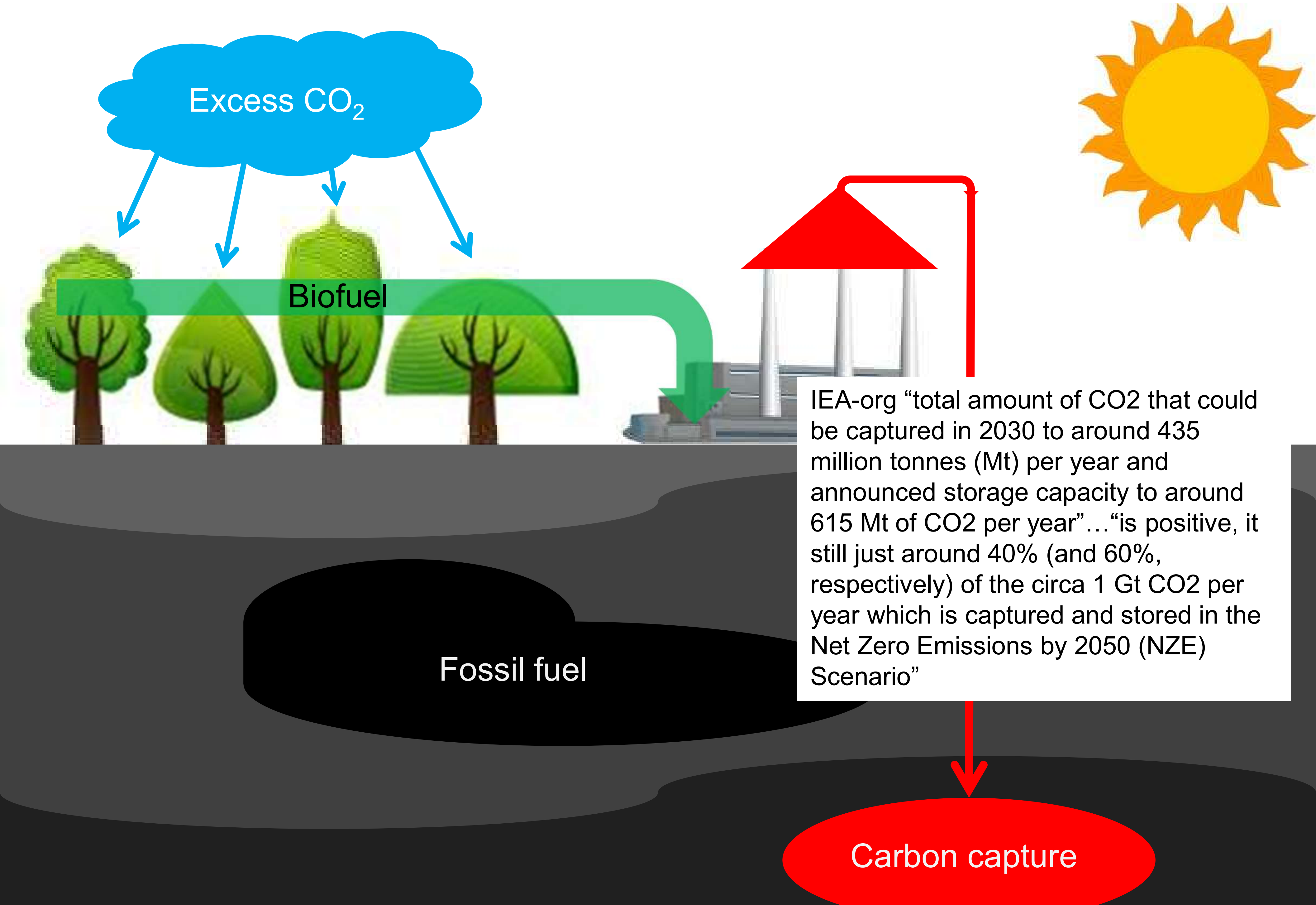
7. mar. 2025

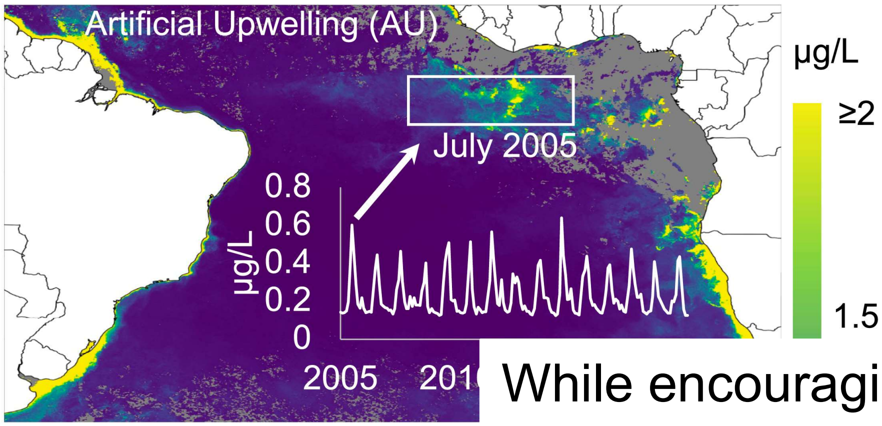
Tekst af Karen Grønning Mikkelsen, kgm@danskfjernvarme.dk

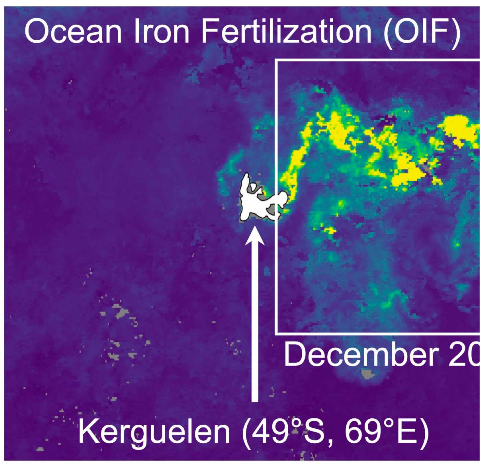
Print Forstør tekst Del

Ørsted har taget det næste store skridt på vejen mod at realisere Danmarks første fuldskala CO2-fangst og -lagringsprojekt, "Ørsted Kalundborg CO2 Hub". Dette skete, da fem sæt absorbere, desorbere og direkte kontaktkølere blev løftet på plads. Tilsammen udgør de hovedkomponenterne i de to CO2-fangstanlæg, som er under opførelse. Tre sæt er løftet på plads på Asnæsværket, to sæt på Avedøreværket.

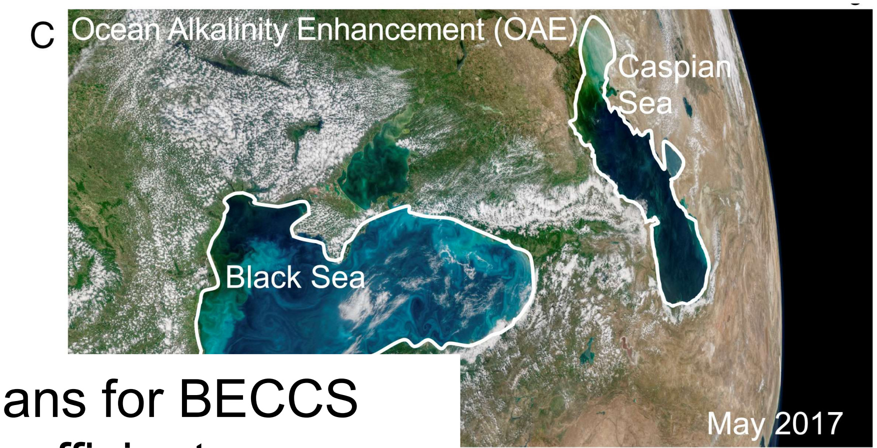
KASTEM

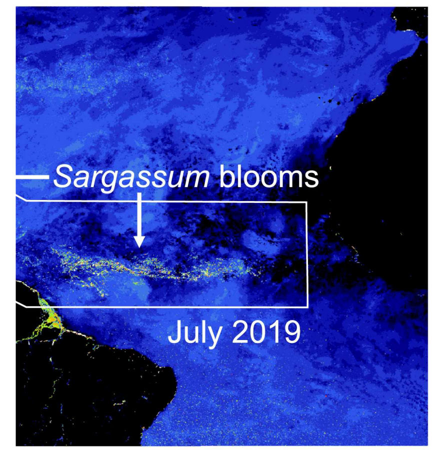

Excess CO_2
Biofuel
Fossil fuel
IEA-org “total amount of CO2 that could be captured in 2030 to around 435 million tonnes (Mt) per year and announced storage capacity to around 615 Mt of CO2 per year”…“is positive, it still just around 40% (and 60%, respectively) of the circa 1 Gt CO2 per year which is captured and stored in the Net Zero Emissions by 2050 (NZE) Scenario”
Carbon capture





While encouraging, plans for BECCS deployment remain insufficient across all sectors to get on track with the Net Zero Scenario. Development of the necessary infrastructure to transport and store the captured CO2 also lags behind what is needed in this scenario, despite growing support in recent years.-IEA.org



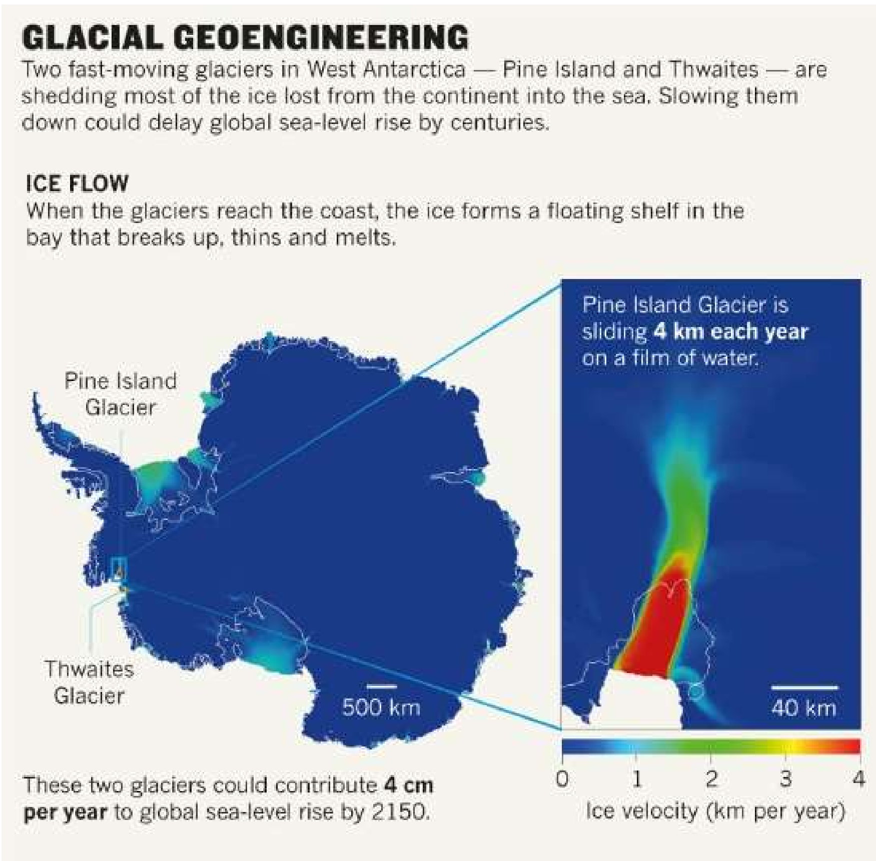


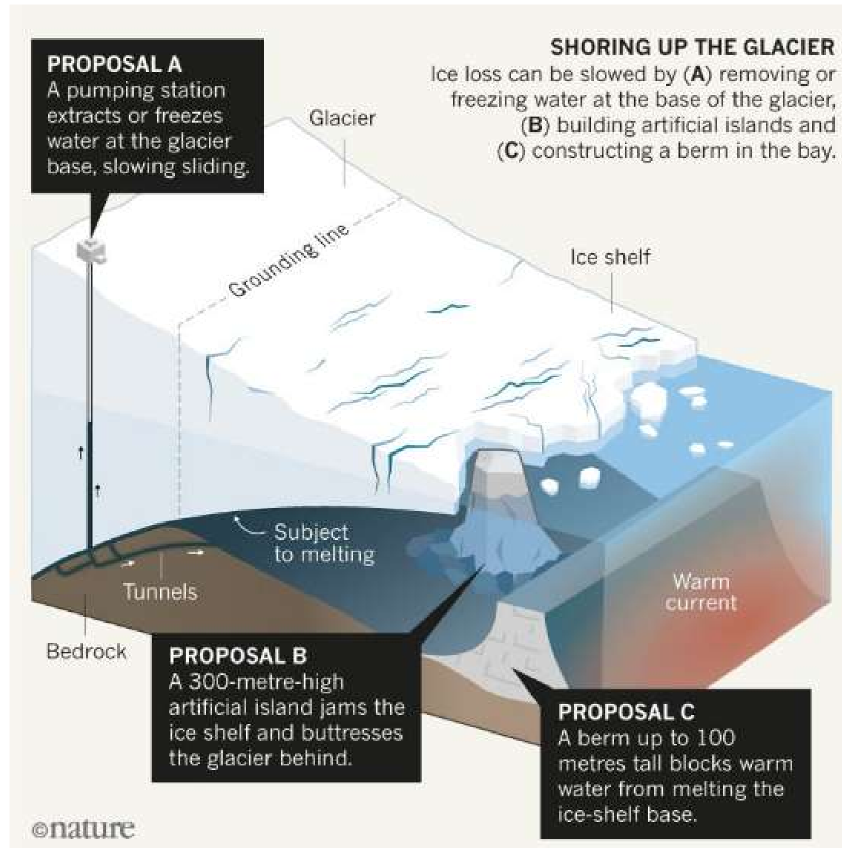
- ***(A) Equatorial upwelling in the Atlantic***
- ***(B) Natural iron fertilization downstream of Kerguelen in the Indian sector of the Southern Ocean****.*
- ***(C) The Black and Caspian Seas in Eurasia have 1.4- and 1.7-fold higher alkalinity than the average surface ocean, making them useful end members for a highly alkalinity perturbed future ocean****. The data for this satellite image was captured by MODIS-Aqua. Image credit: NASA/Norman Kuring.*
- *(**D) Satellite image of floating seaweeds of the genus Sargassum bloom in (sub)tropical Atlantic in July 2019**, recorded with the Ocean and Land Color Imager on the Sentinel-3A satellite of the European Space Agency (74). Blooms occur in the open ocean, making them useful natural analogs for ocean afforestation. Image credit: European Space Agency/Jim Gower.*

 https://www.pnas.org/doi/full/10.1073/pnas.2106147118#sec-2

Geoengineer polar glaciers to slow sea-level rise

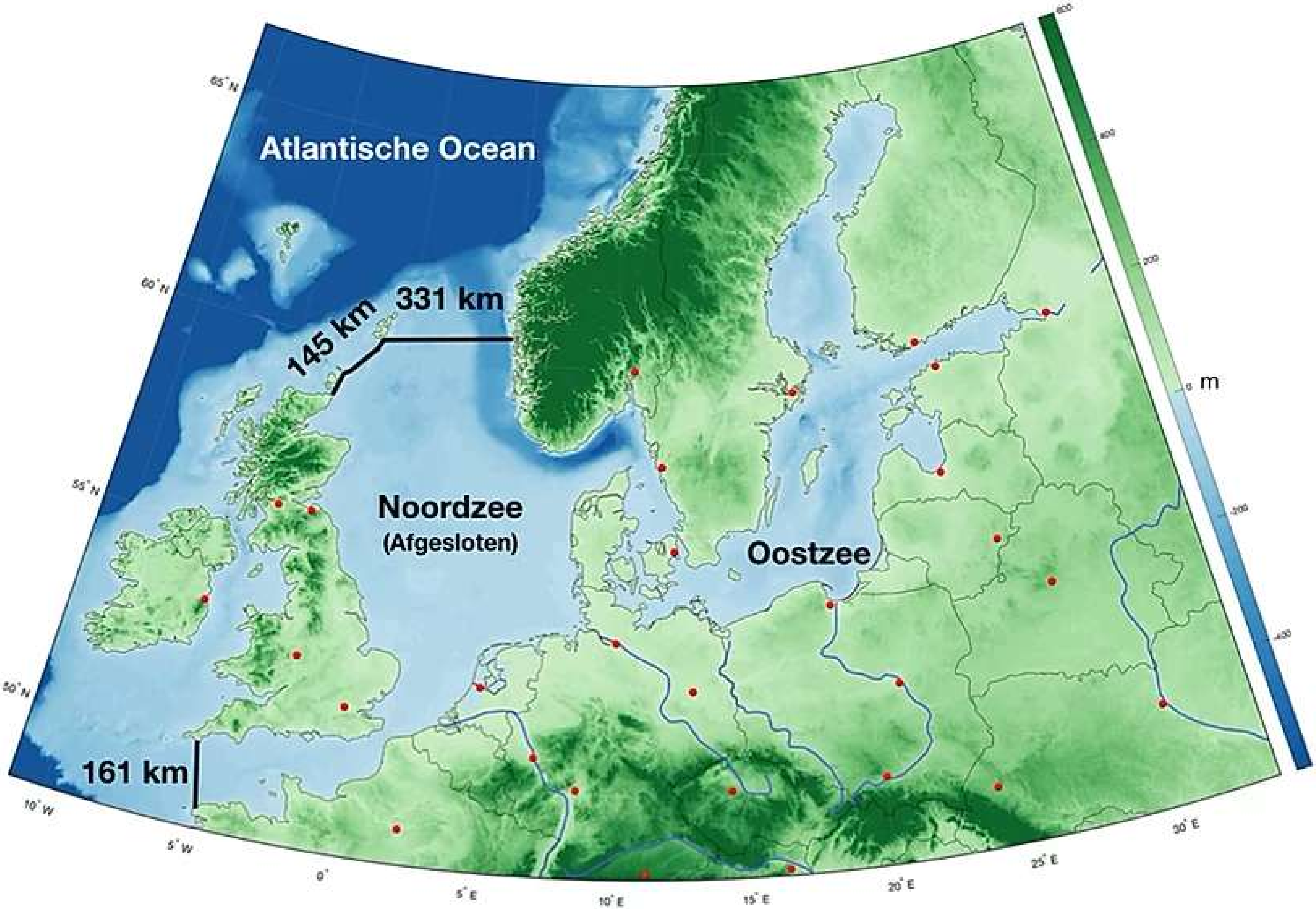
Stalling the fastest flows of ice into the oceans would buy us a few centuries to deal with climate change and protect coasts, argue **John C. Moore** and colleagues.



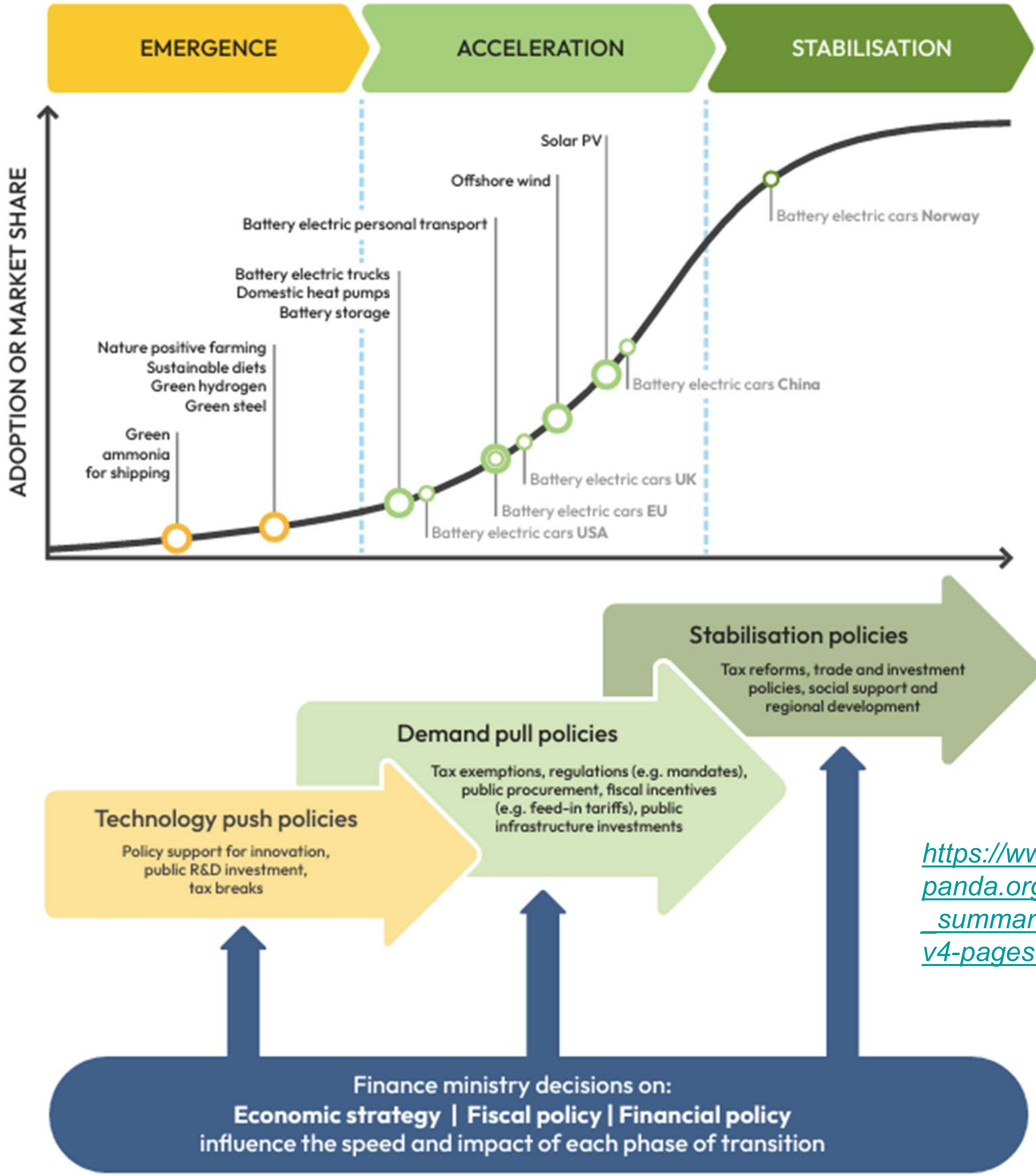


(Comment by Moore et al., Nature, March 2018) https://www.nature.com/articles/d41586-018-03036-4

The Northern European Enclosure Dam - NEED



https://www.sjoerdgroeskamp.com/



https://wwflac.awsassets.panda.org/downloads/gtp_summary_report_2025-v4-pages-lo-res--1-.pdf

Klima og bekymringer

Privat.

Bachelorer: Undervisning om klima og bæredygtighed skal give håb og handlemuligheder

Samfundsfag rummer et stort potentiale i forhold til at klæde eleverne på til at gøre en forskel for klimaet, skriver Laura Mikkelsen og Frida Nordahl.

”Flere af lærerne påpeger, at de ønsker at afslutte timen med en form for håb, hvis de har adresseret menneskabte forandringer i deres undervisning. Nogle lærere undgår helt at undervise i klodens tilstand, fordi de ikke ved, hvordan de skal adressere det på en forsvarlig måde”

FOLKeSKOLeN Nyheder Debat & blogs Anmeldelser Faglige netværk

StockPlanets

Hver tredje skoleelev oplever bekymringer om klimakrisen i hverdagen

37 procent af danske skoleelever svarer i ny undersøgelse, at klimabekymringer påvirker dem i deres hverdag.

folkeskolen.dk
FAGBLAD FOR UNDERVISERE

LOGIN SØG

DEBAT | LÆRER TIL LÆRER | ANMELDELSER | FAGLIGE NETVÆRK | BLOGS | ARRANGEMENTER | LÆSERTILBUD

FAGLIGE NETVÆRK Matematik Tysk og fransk It i undervisningen Danskundervisning Børnehaveklassen PLC

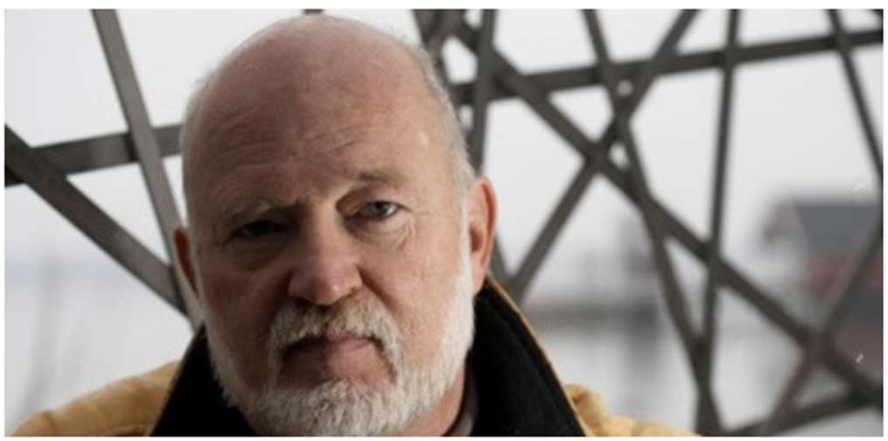
BLOG 5. sep. 2020 | kl. 16:09 3 7

Skal børn lære om klimakrisen?

JOHN AASTED HALSE har bidraget med | 4 INDLÆG | 0 ANBEFALINGER | 0 KOMMENTARER

Abonner på nyt om Skolens sociale dimension i dit personlige nyhedsbrev. ABONNER

Det er for mange voksne et mål, at børn skal bevidstgøres om de farer, klimaforandringerne indebærer. Men er det nu en så god ide?



Fra kommentatorsporet:

VAGN MADSEN (PENSIONERET VICESKOLEINSP.)

06. sep. 2020 16:50 3

Skolebørn skal selvfølgelig lære om klimakrisen

Ja, selvfølgelig skal skolebørn lære om klimaet. Men udgangspunkt i en konstatering af, at klimaet i hvert fald tre gange i Jordklodens historie har ændret sig markant, skal børnene lære, at klimaet er et naturfænomen, der altid har ændret sig og sandsynligvis vil fortsætte med at ændre sig uafhængigt af, hvad mennesker ellers foretager sig. Klimaet ændrer sig ligesom Jordens magnetiske poler har det med uafbrudt at flytte sig. Tre kendte istider har i tidens løb dækket dele af Jordkloden med massive ismasser og to mellemistider har afløst istiderne med varmt subtropisk klima. Og sådan vil klimaet mest sandsynligt fortsætte med at skifte fra varme til kulde

Og selvfølgelig skal skolebørn lære, at en konstateret klimatisk opvarmning er blevet spændt for en politisk dagsorden, hvorved politikerne har fået en enestående chanse for at lægge store afgifter på næsten alt oven i købet med befolkningens fulde billigelse. Angiveligt er hensigten at begrænse CO2-udslippet, medens enorme skovbrande og et utal af over- og undersøiske vulkaner til stadighed øser CO2 ud i atmosfæren. Men skovbrande og vulkanudslip kan jo ikke begrænses med afgifter. Så skovbrande og vulkaner snakker vi ikke så meget om. Og hvad en næsten overbefolket Jordklode øser ud af CO2 gennem menneskers udåndingsluft, taler vi heller ikke noget om. Kun alt det, der kan pålægges afgifter, taler vi om. Og således er klimakrisen nærmest en gave til politikerne. Og det bør skolebørn da selvfølgelig lære om.

Bekymringer

Jeg er en pige på 15 år, og jeg er bange for at leve. Jeg er rigtig bange for klimaforandringerne. Jeg er meget opmærksom på at gøre mindst muligt skade, men hvad nytter det at jeg prøver når ingen andre prøver. Det gør mig helt panisk at tænke på, at vi kun har indtil år 2030, før vi ikke kan rette op på ødelæggelserne.

- Hvis barnet bekymrer sig om klimaforandringer eller ting det har set og hørt i for eksempel medierne, er det vigtigt, at det kan fortælle om det. Tankerne kan for eksempel opstå i forbindelse med et nyhedsindslag eller nogle billeder, som barnet har set
- Sig for eksempel *"Der er mange børn, der har det som dig. Som også tænker på, at vi skal passe godt på jorden".* Eller at *"der er mange mennesker i verden, der arbejder for at passe på jorden og vores samfund"*
- det kan hjælpe på bekymringerne, at børnene mærker, at man handler. Det kan man gøre på en rar måde, og i fællesskab. For eksempel ved at samle skrald på stranden, øve sig i at finde de flotteste genbrugsjulegaver, lave sjove figurer ud af genbrugsmaterialer, eller finde lækre retter uden kød.

https://bornsvilkar.dk/klimabekymringer/
https://orsted.com/da/explore/is-this-my-home/empowering-your-kids

Sådan (kan du) tænke psykologien ind i din undervisning

- Hold fokus på det konstruktive, men vær ærlig om alvoren. Mange børn og unge er dybt bekymrede og har brug for at tale om klimakrisen.
- Inddrag inspirerende cases som mennesker, der har startet en organisation mod madspild, opfundet grøn teknologi eller har samlet deres naboer om grønne fællesspisninger. Det kan hjælpe eleverne med at se, at der også er muligheder i den grønne omstilling.
- Sæt billeder på en positiv fremtid. Inddrag alle de fordele, der er ved en grøn omstilling af samfundet, så eleverne kan se, at de kan få gode liv.
- Vær ikke bange for, at der kommer følelser ind i klasselokalet. Det værste, vi kan gøre, er ikke at tale om elefanten i rummet.
- Brug børnenes naturlige nysgerrighed og vær konkret. Inddrag lokalområdet, så klima og omstilling bliver håndgribeligt.
- Lad eleverne arbejde med emner, der relaterer sig til deres egen hverdag, som f.eks. tøj, mad, elektronik eller mental sundhed. Det gør klimadiskussionen mere personlig og meningsfuld for dem.
- I undervisningen bør der lægges vægt på de positive valg (cykel frem for bil giver sundere kroppe, genbrugte ting er billigere, og grøn mad er sundere), som eleverne kan træffe i hverdagen, fremfor at fokusere på, hvad de ikke må gøre. Det skaber en mere konstruktiv og motiverende tilgang til klimaadfærd.
- Respektér altid de negative følelser, også når du ikke forstår dem. Nogle børn og unge er meget bekymrede og har ikke brug for at få at vide, at det nok skal gå, at det ikke er så slemt, eller at deres egne handlinger ikke betyder noget. Mød dem der, hvor de er - og hjælp dem til at se, hvordan de kan spille en rolle uden at opleve, at de skal bære ansvaret alene.

https://www.alinea.dk/tvaerfagligt/artikel/hvordan-vi-laerer-born-om-en-krise-de-voksne-ikke-kan-forholde-sig-til

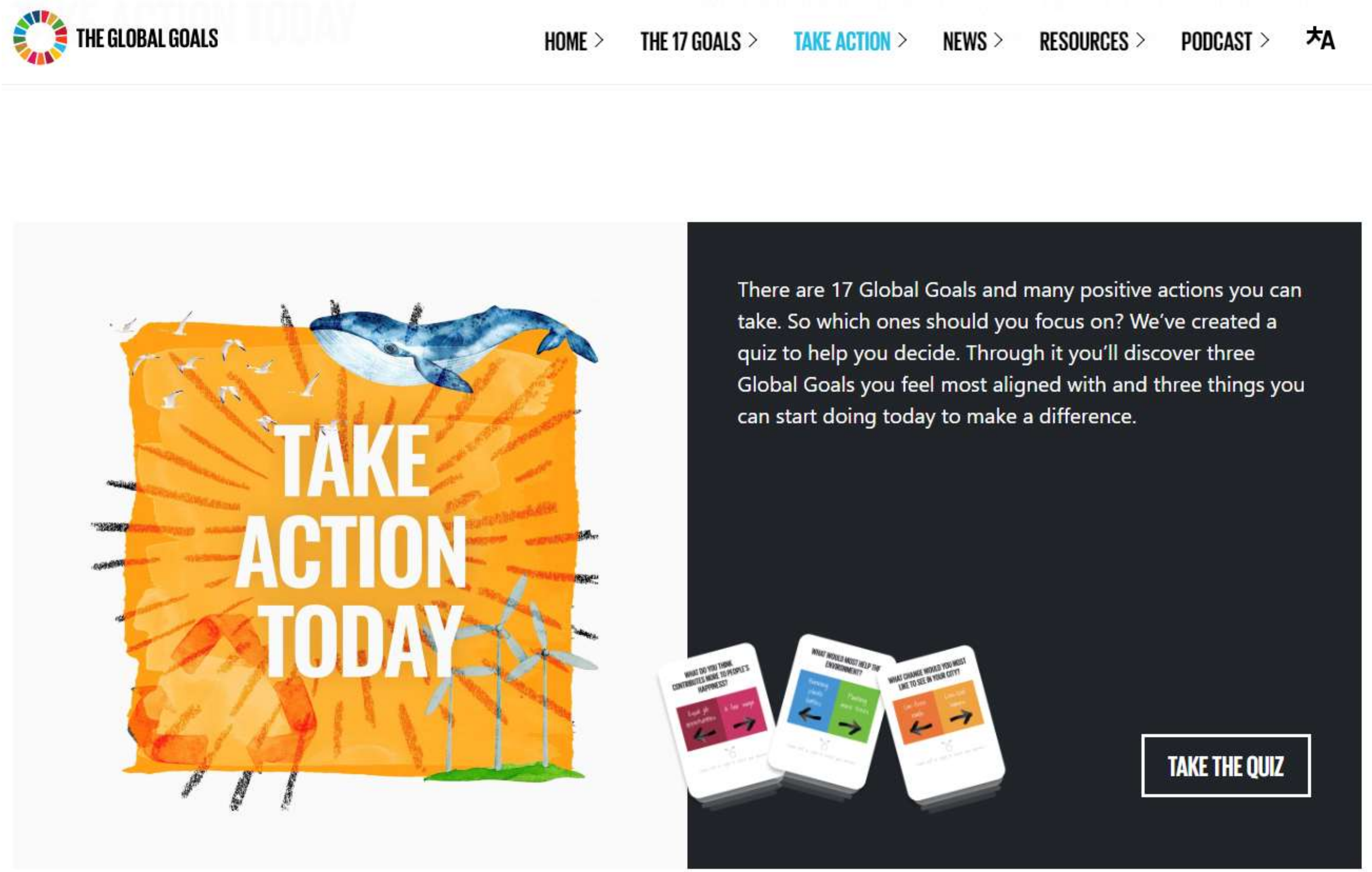
Don’t be depressed because of Climate Change – Do something about it!

Watch those TEDs:

Britt Wray: How climate change affects your mental health: https://www.voicetube.com/videos/79963/37020608?word=our%20survival&ref=definition

Per Espen Stoknes: How to transform apocalypse fatigue into action on global warming: https://www.youtube.com/watch?time_continue=349&v=F5h6ynoq8uM

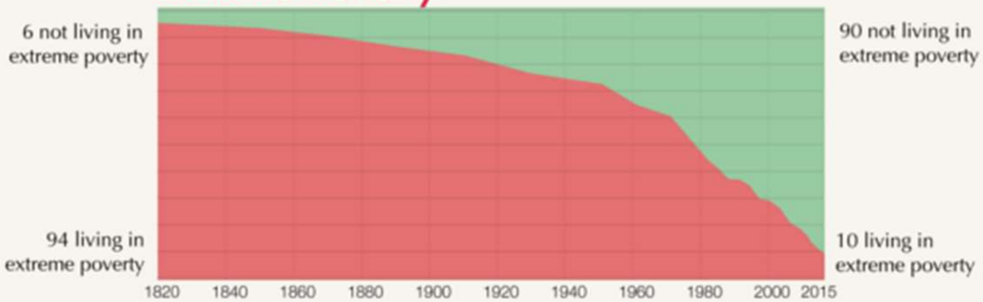
https://www.globalgoals.org/take-action/



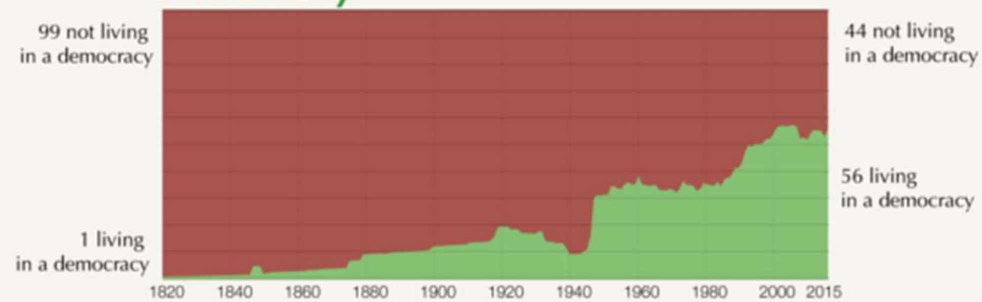
App with suggested actions at home: https://actnow.aworld.org/

The World as 100 People
over the last two centuries

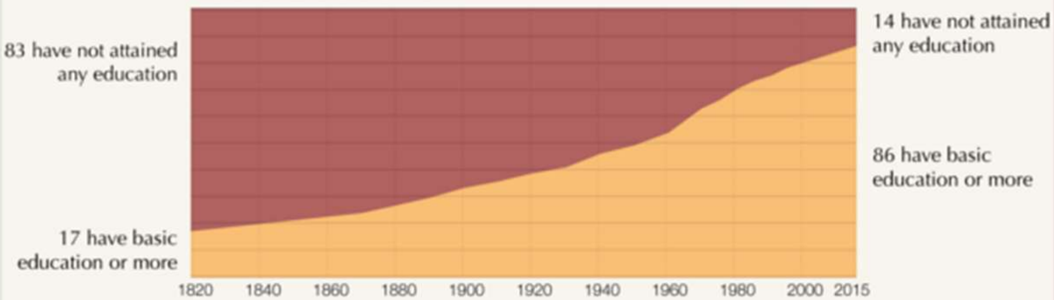
Extreme Poverty



Democracy

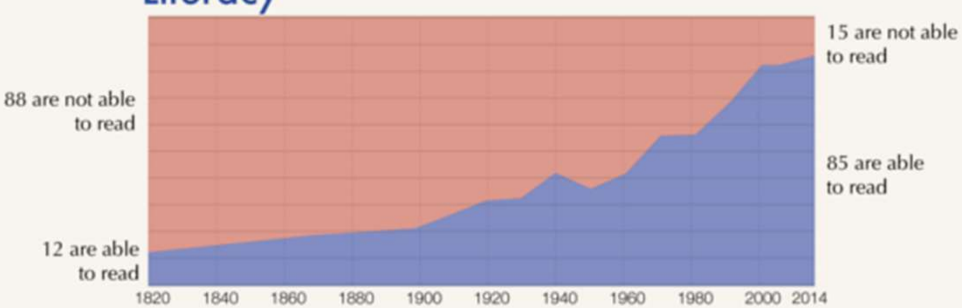


Basic Education

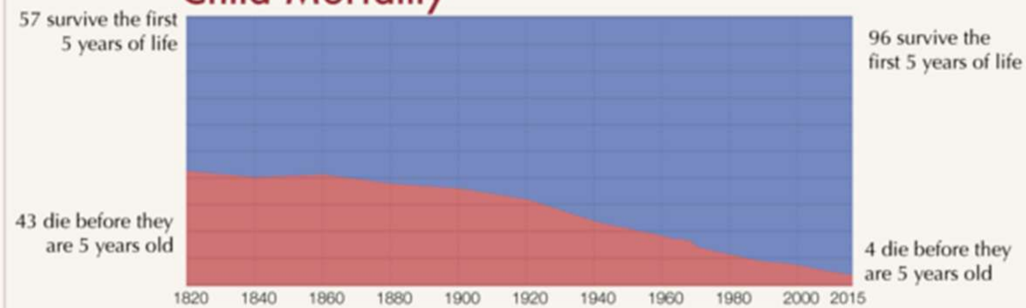


Vaccination against diphtheria, pertussis (whooping cough), and tetanus

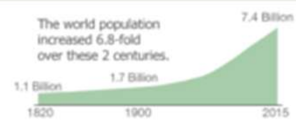
Literacy



Child Mortality



Data sources:
Extreme Poverty: Bourguignon & Morrison (2002) up to 1970 – World Bank 1981 and later (2015 is a projection).
Vaccination: WHO (Global data are available for 1980 to 2015 – the DPT3 vaccination was licenced in 1949)
Education: OECD for the period 1820 to 1960. IIASA for the time thereafter.
Literacy: OECD for the period 1820 to 1990. UNESCO for 2004 and later.
Democracy: Politiy IV index (own calcluation of global population share)
Colonialism: Wimmer and Min (own calcluation of global population share)
Continent: HYDE database
Child mortality: up to 1960 own caluclations based on Gapminder; World Bank thereafter



All these visualizations are from OurWorldInData.org an online publication that presents the empirical evidence on how the world is changing.

The good news

- Low cost solar, wind, and battery technologies are on profitable, exponential trajectories that if sustained, will be enough to halve emissions from electricity generation by 2030.
- In 2015, world leaders from 196 countries came together in Paris to sign the first truly global deal to fight the climate crisis.
- Nearly half of the largest companies in the US now recognize that it is everyone's responsibility to tackle climate change and preserve our planet for future generations.
- People like you are in the streets, demanding action
- You can take action!


Green > Green News

Major new UN pact reaffirms global commitment to transition away from fossil fuels

Share this article | Comments

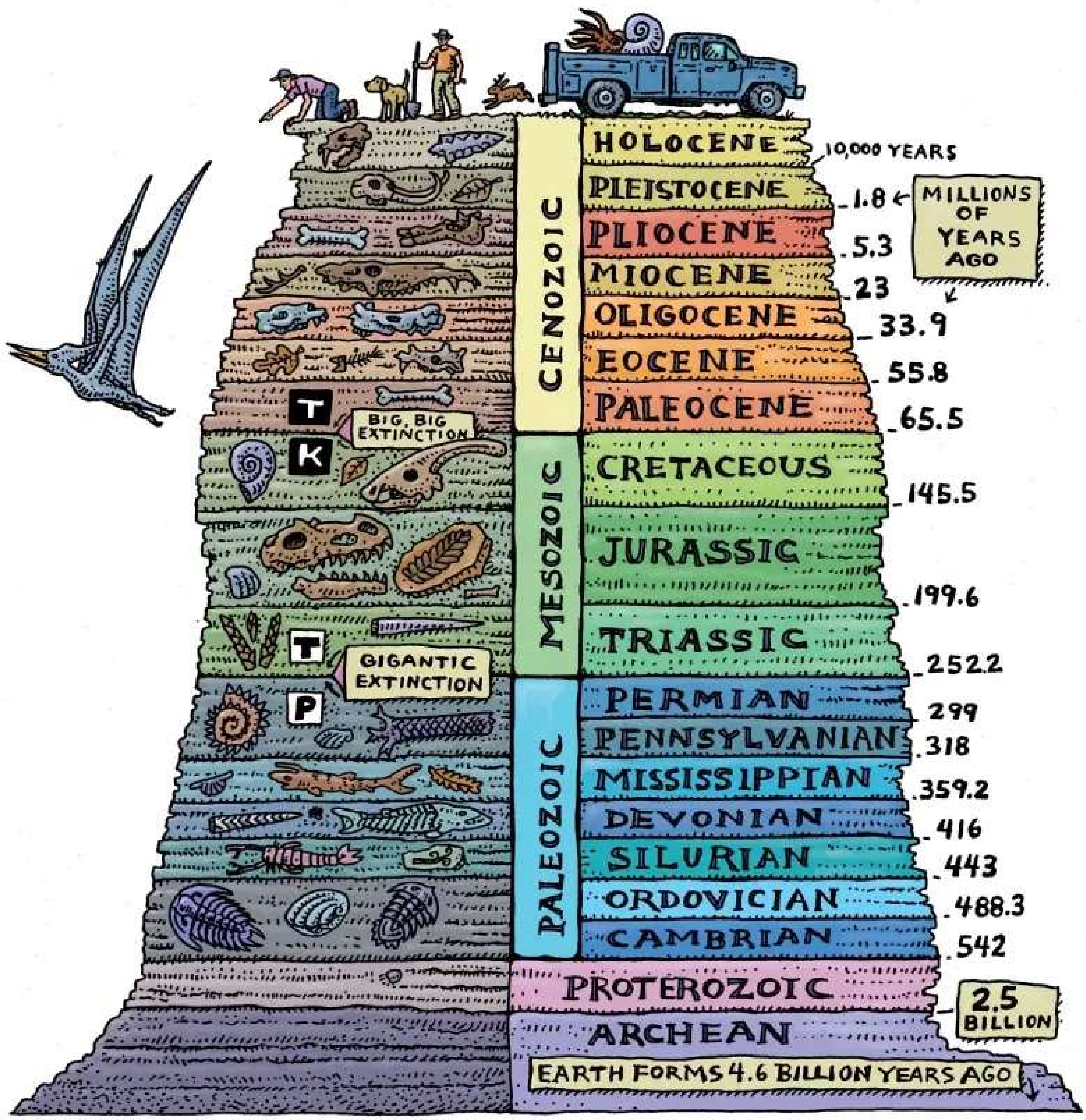
The 42-page plan for the UN's 193 member states to work together in addressing the most significant global challenges has been years in the making.

https://www.worldwildlife.org/stories/the-good-news-about-climate-change
https://www.dailyclimate.org/Good-News/
https://www.euronews.com/green/2024/09/27/positive-environmental-stories-from-2024

Global Warming Critical Statements

- Climate has changed before
- It's the sun
- There is no consensus
- Models are unreliable
- Temp record is unreliable
- Animals and plants can adapt
- It hasn't warmed since 1998
- Antarctica is gaining ice
- Ice age predicted in the 70s
- CO_2 lags temperature
- Climate sensitivity is low
- Ocean acidification isn't serious
- Hockey stick is broken
- Climategate CRU emails suggest conspiracy
- Hurricanes aren't linked to global warming
- Al Gore got it wrong
- Glaciers are growing
- It's cosmic rays

Find more statements and the answers at: http://www.skepticalscience.com



HOLOCENE
10,000 YEARS
PLEISTOCENE
1.8
MILLIONS OF YEARS AGO
PLIOCENE
5.3
MIOCENE
23
OLIGOCENE
33.9
EOCENE
55.8
PALEOCENE
65.5
CENOZOIC
T
K
BIG, BIG EXTINCTION
CRETACEOUS
145.5
JURASSIC
199.6
TRIASSIC
252.2
MESOZOIC
T
P
GIGANTIC EXTINCTION
PERMIAN
299
PENNSYLVANIAN
318
MISSISSIPPIAN
359.2
DEVONIAN
416
SILURIAN
443
ORDOVICIAN
488.3
CAMBRIAN
542
PALEOZOIC
PROTEROZOIC
2.5 BILLION
ARCHEAN
EARTH FORMS 4.6 BILLION YEARS AGO

Fortidens klima og hvad vi kan lære derfra

Vores direkte observationer er korte

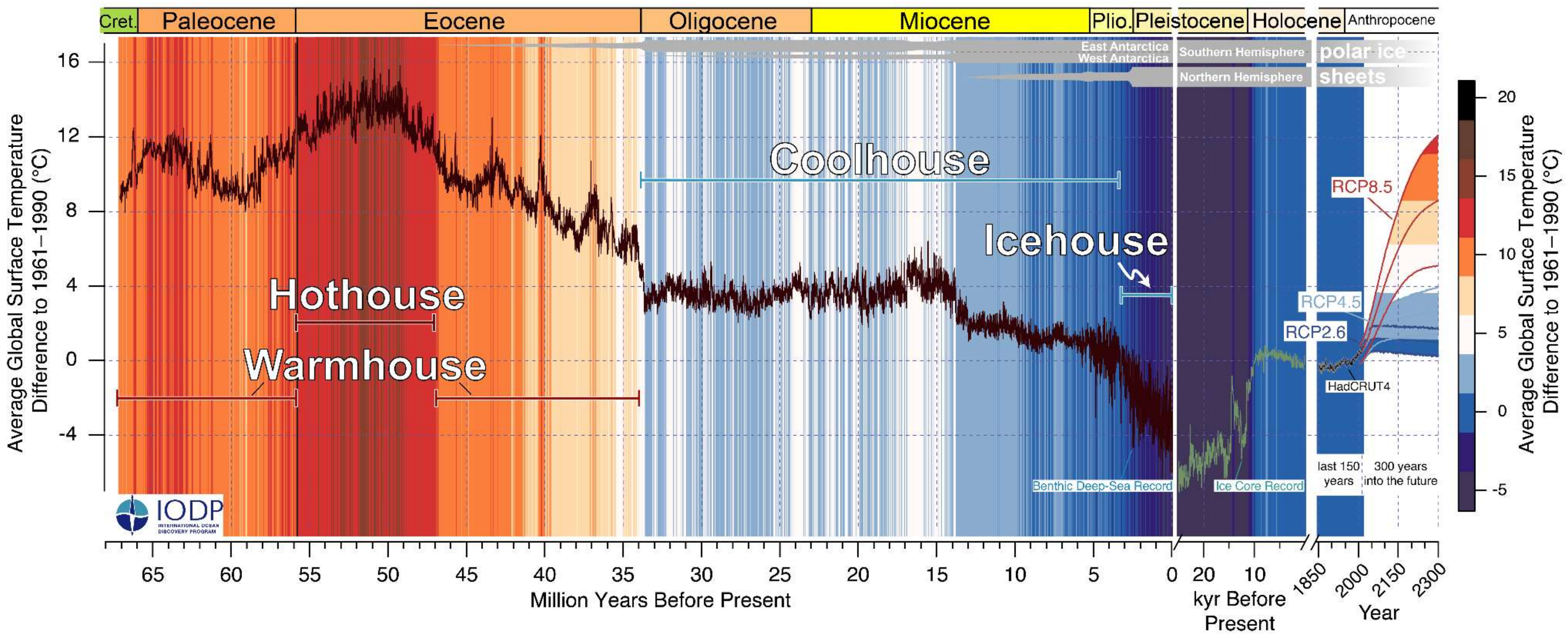
Vi har brug for at finde ud af hvad "normalen" er

Vi bruger fortidens forandringer som analoge til nutidens klimaforandringer

65 millioner år

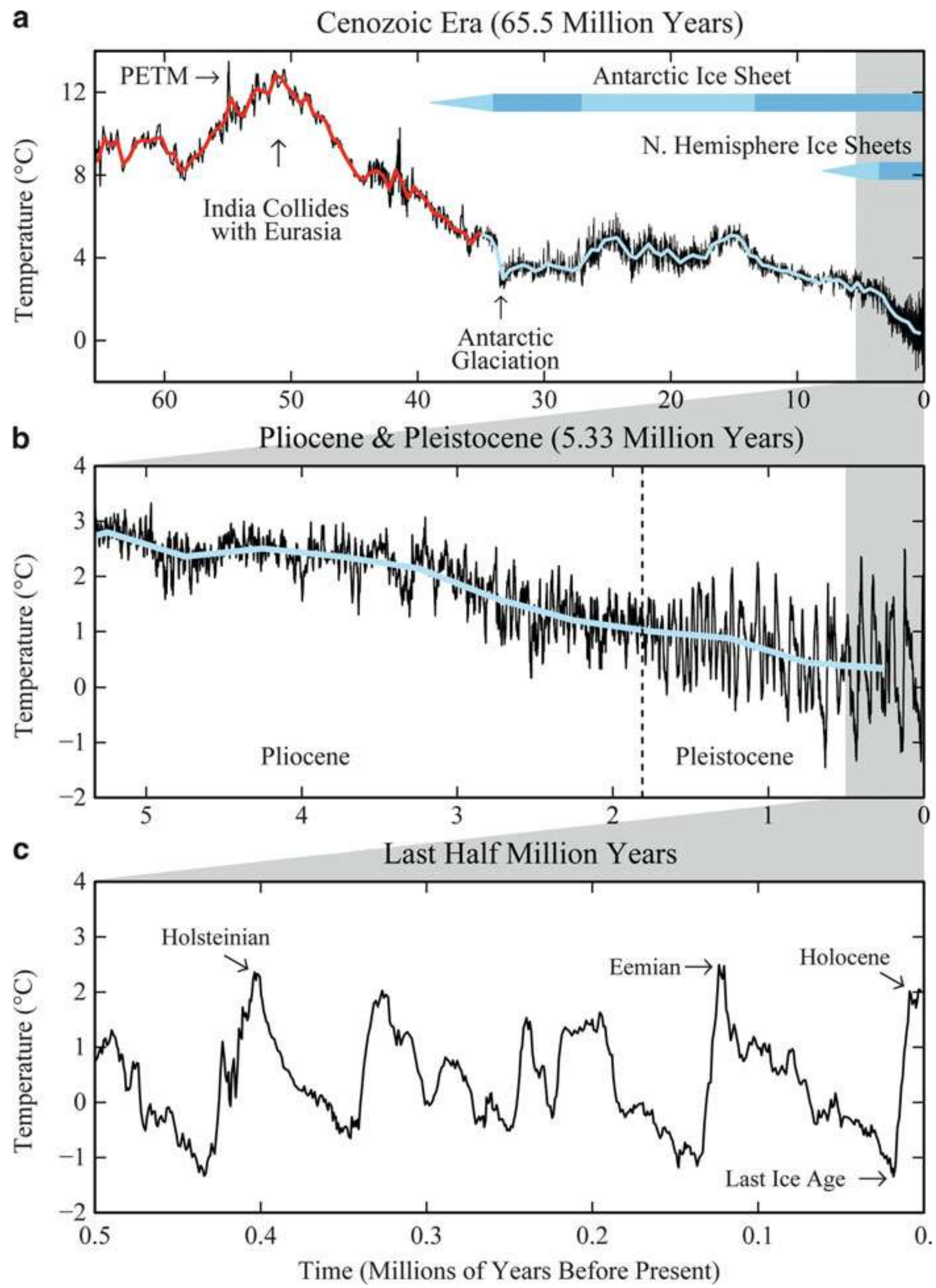
Westerhold et al., Science, 2020

https://www.livescience.com/oldest-climate-record-ever-cenozoic-era.html



Climate variability on different time scales

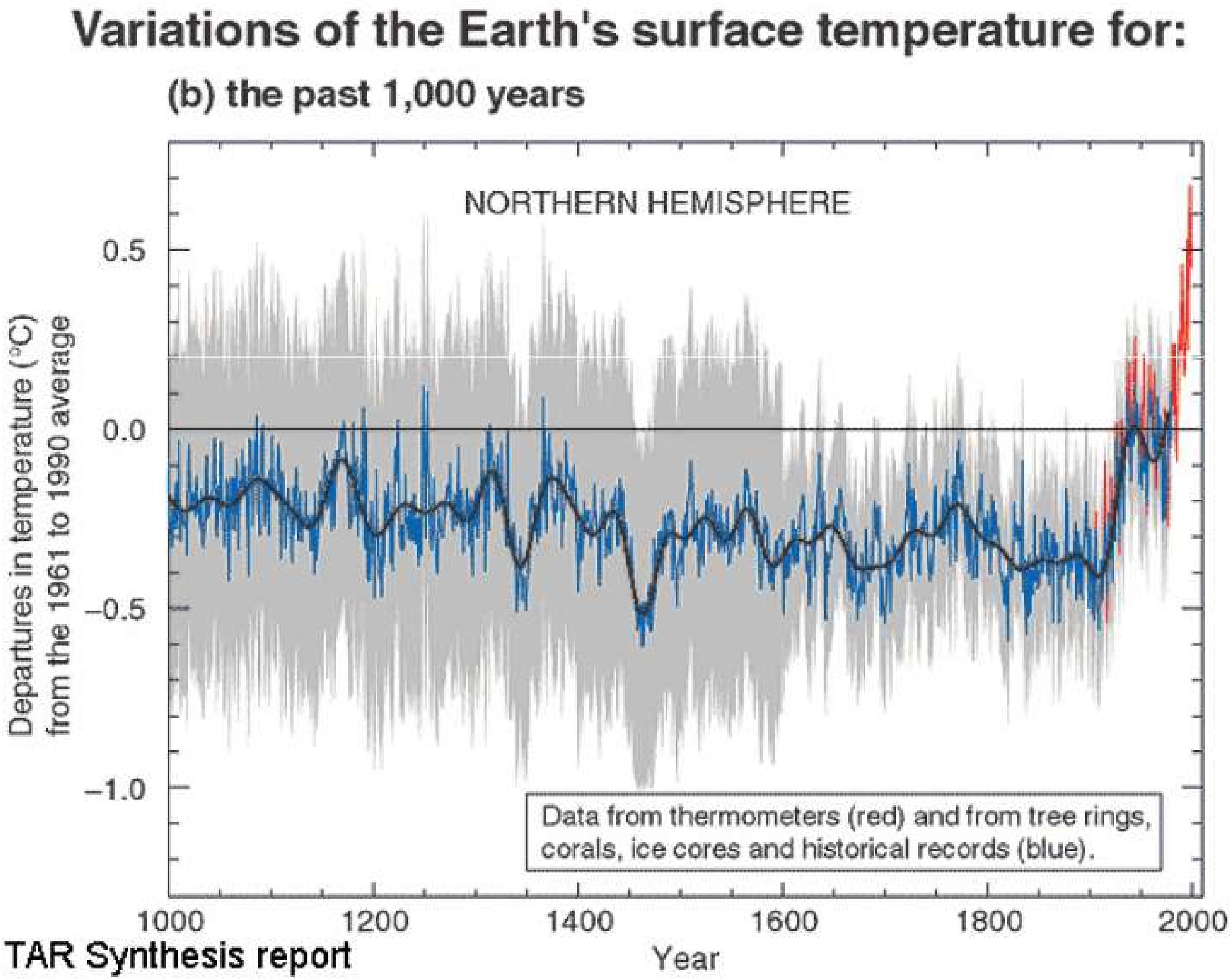
Global mean temperature estimates relative to today



→ Time

(Hansen and Sato, Climate Change, 2012)

IPCC TAR 2001 (3rd assessment report)
The Mann curve / hockeystick curve



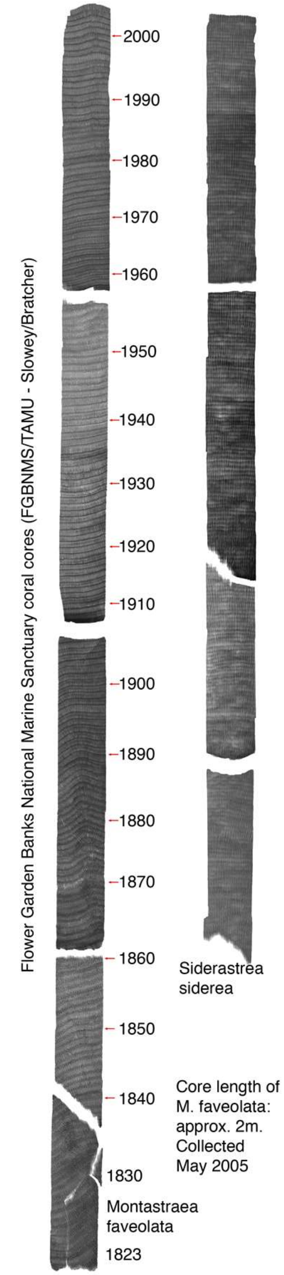
TAR Synthesis report

Proxies

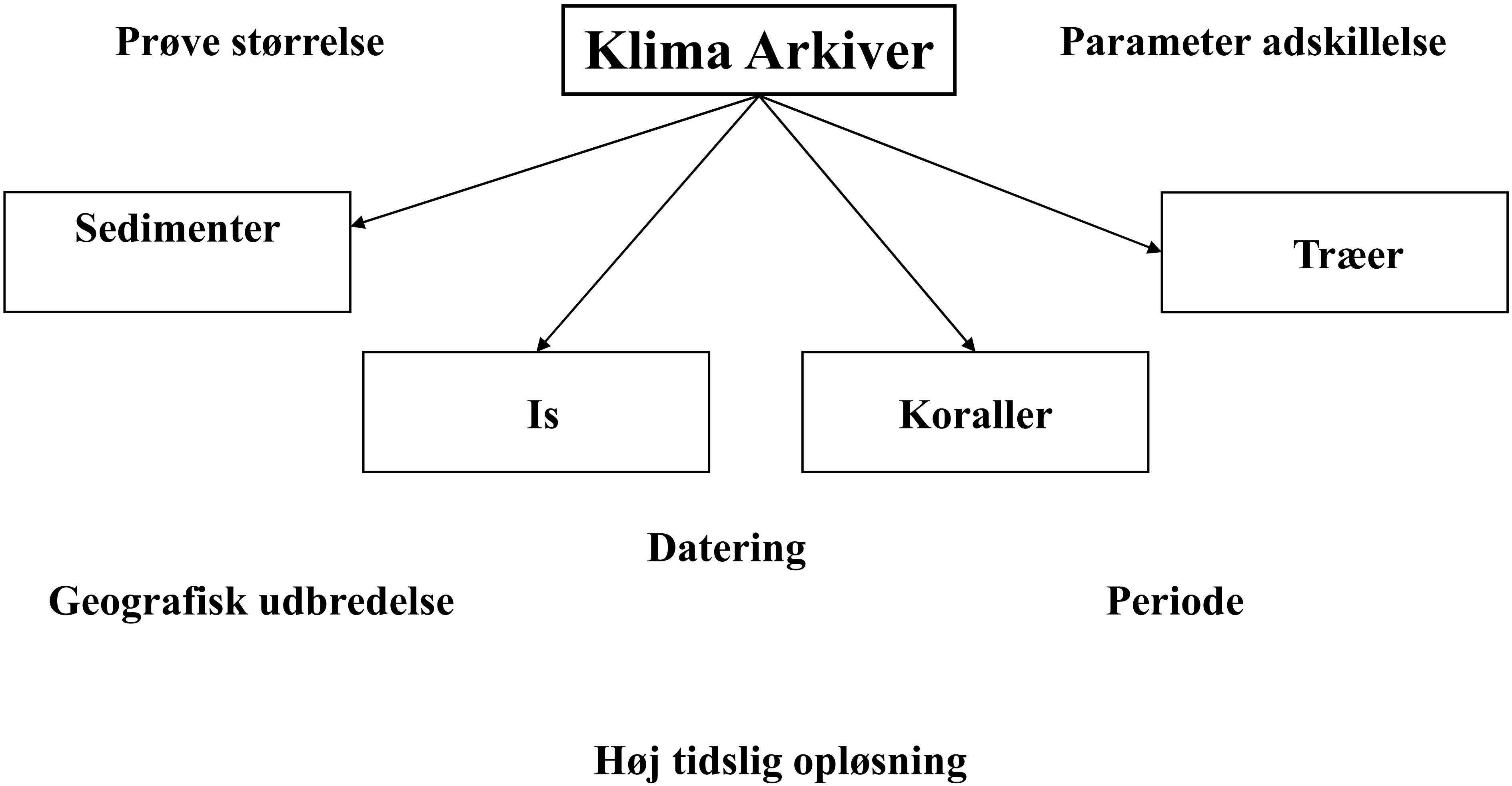
- Hvis du ikke kan få det du gerne vil have, må du nøjes med det du har

- For proxier er brugbare skal der være en fysisk/biologisk forstået mekanisme for hvordan klima påvirker proxien.

- Eksempel: Et gammeldags termometer (volumen af kviksølvog ikke direkte temperaturen)



https://flowergarden.noaa.gov/doc/education/coralcores.pdf


Prøve størrelse
Klima Arkiver
Parameter adskillelse
Sedimenter
Træer
Is
Koraller
Datering
Geografisk udbredelse
Periode
Høj tidslig opløsning

Key types of paleoclimate archives

- Trees
- Continental deposits, loess, glacial features
- Lake sediments
- Speleothems (cave deposits)
- Marine sediments
- Coral reefs
- Glacial ice

Datering-ofte meget usikker

- Orbital synchronisations
- Radioaktive isotoper – absolut tællinger
- Årlagstællinger-relative

(træringe, iskerner, muslinger med flere)

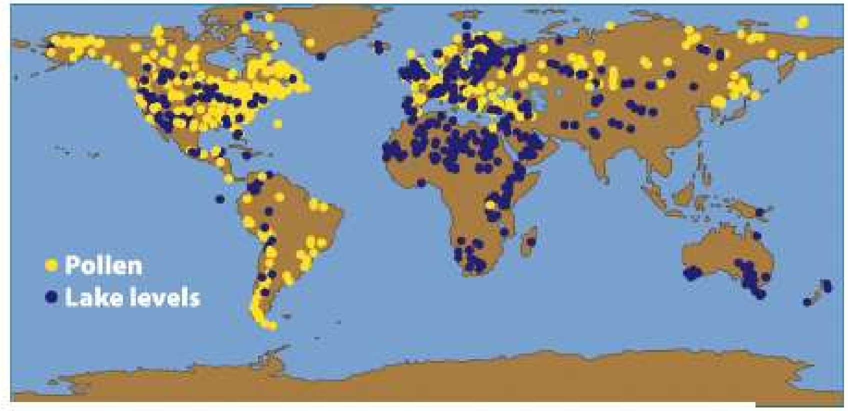
- Kryds arkiv synkronisering (fx vulkan udbrud og beryllium)

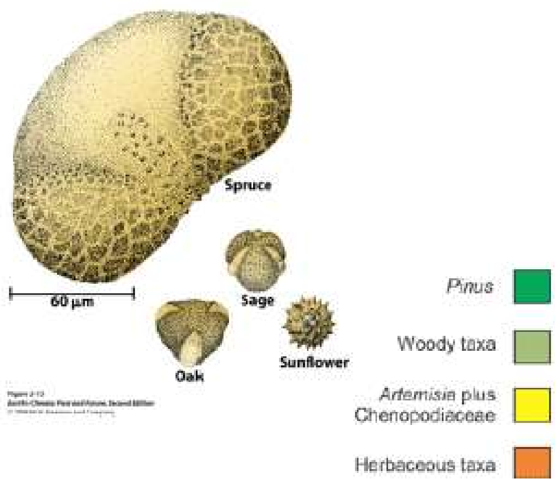
radioaktive isotoper		halverings tid (år)	effektivt dateringsinterval (år)
moder	datter		
rubidium-87	strontium-87	48,8 mia.	10 mio.-4,6 mia.
samarium-147	neodym-143	106,0 mia.	
thorium-232	bly-208	14,0 mia.	10 mio.-4,6 mia.
uran-238	bly-206	4,5 mia.	10 mio.-4,6 mia.
kalium-40	argon-40/calcium-40	1,3 mia.	100.000-4,6 mia.
uran-235	bly-207	0,7 mia.	
kulstof-14	kvælstof-14	5730	nutid-50.000

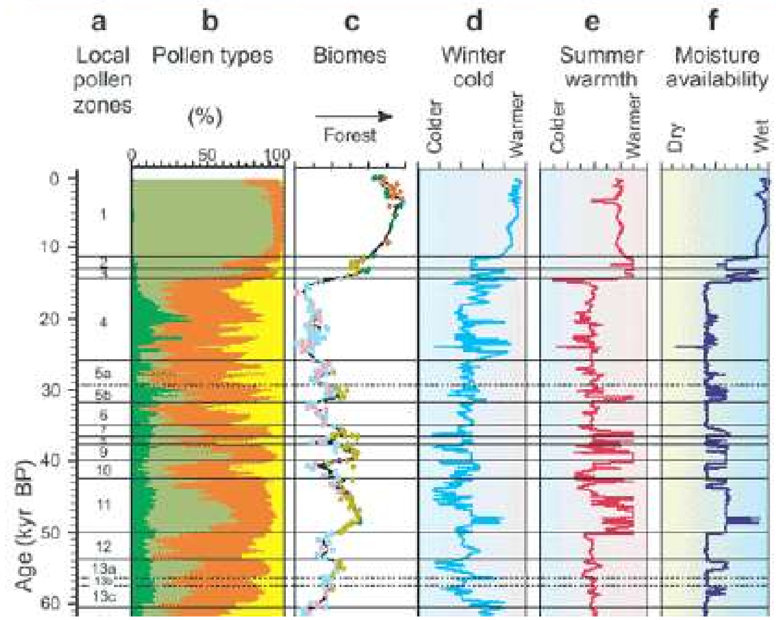
Kontinentale sedimenter

Continental sediments

Plant remains (pollen and macrofossils) mineral sediments / runoff from local catchment, aeolian deposits, proxies of evaporation strength ...these are the oldest we have...







Marine kerner

Marine Sediments

Plankton (type and composition), mineral sediments / runoff with weathering products, ice rafted debris, aeolian deposits....

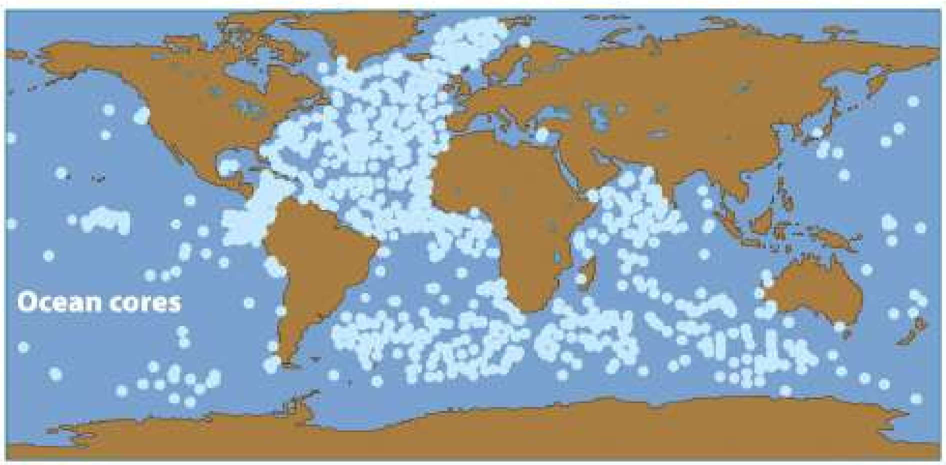
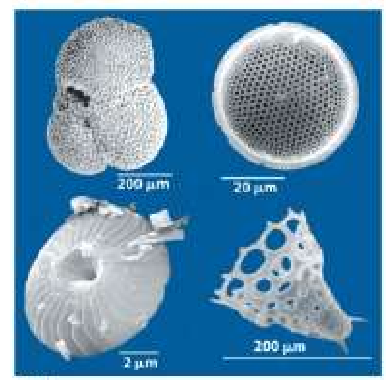


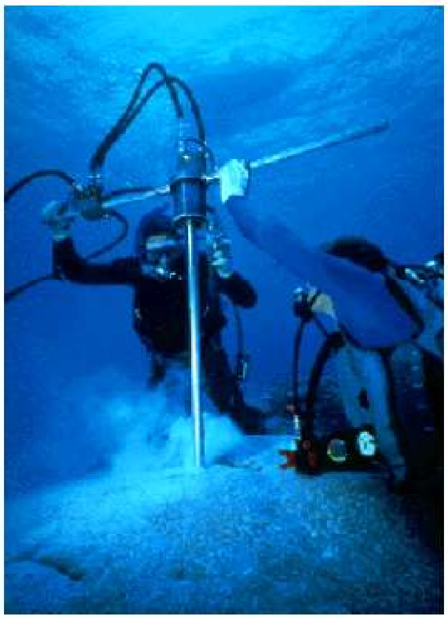
Figure 2-4a
Earth's Climate: Past and Future, Second Edition

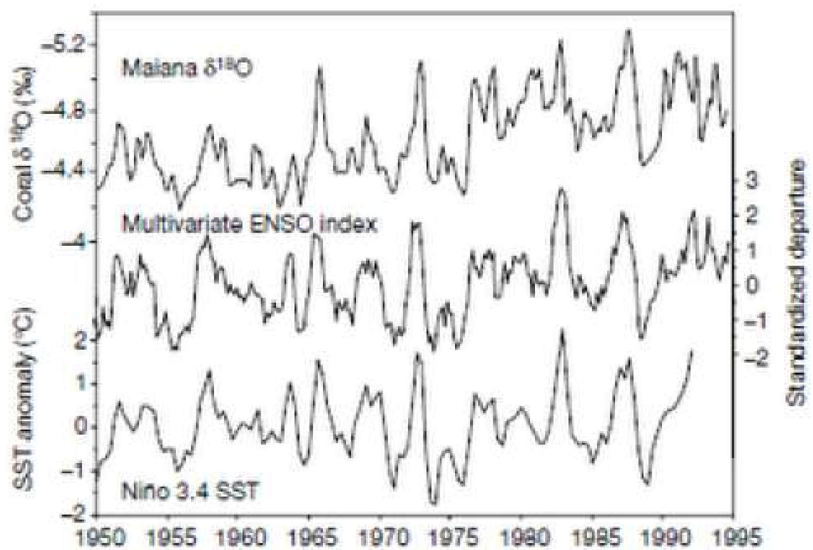


Coraler og huler

Coral and cave archives

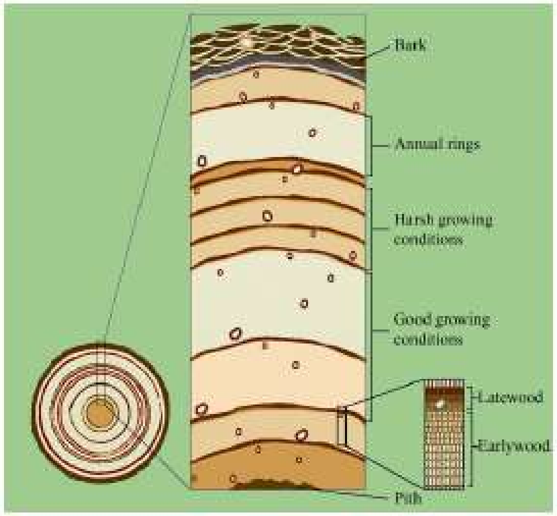
Record isotopic flucuations ($CaCO_3$)

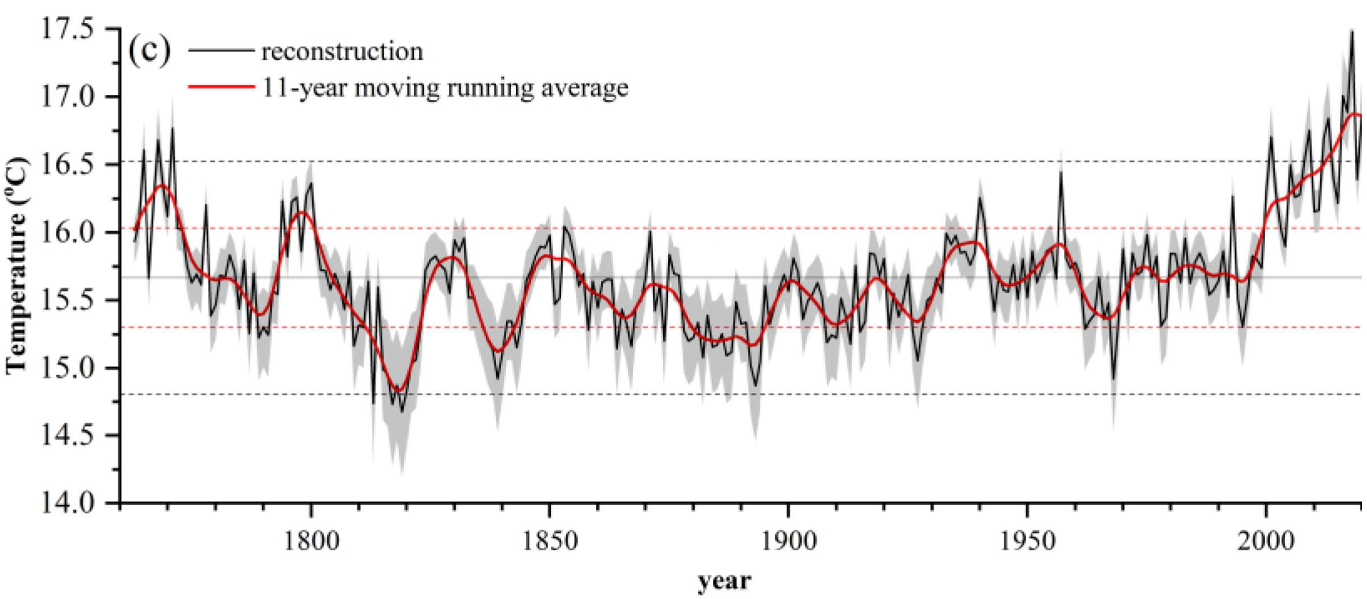


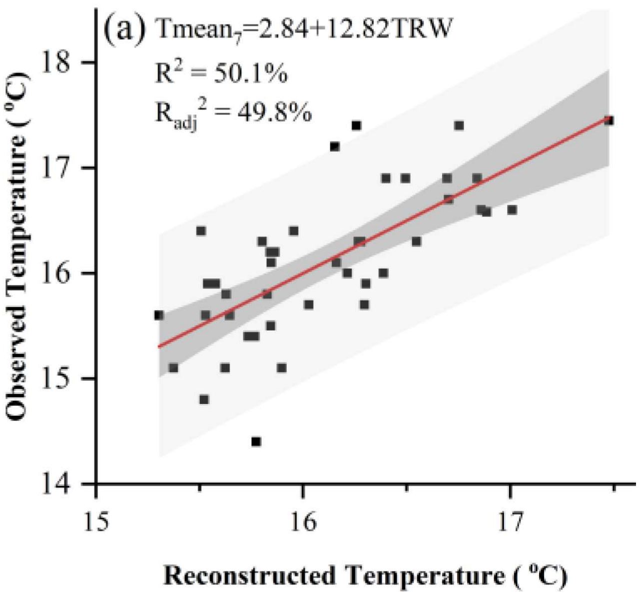


Træringe

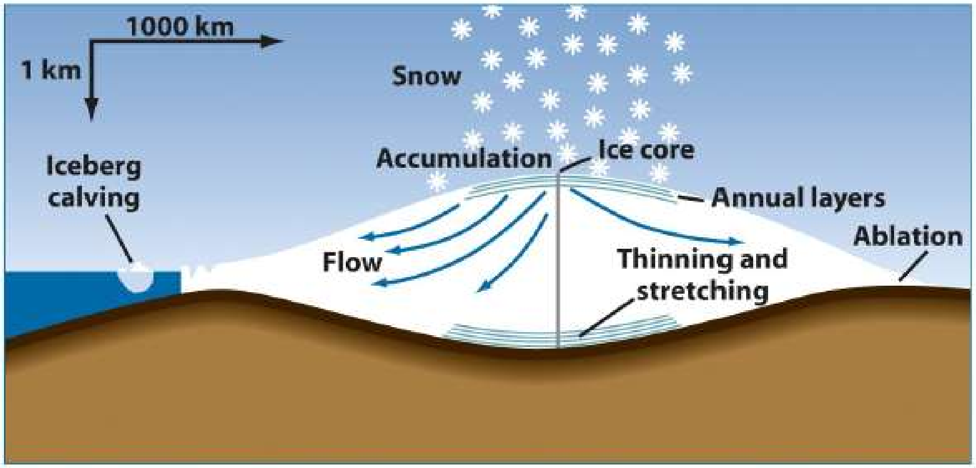

first year growth
rainy season
dry season
scar from forest fire


Bark
Annual rings
Harsh growing conditions
Good growing conditions
Latewood
Earlywood
Pith


(c)
reconstruction
11-year moving running average
Temperature (°C)
year
17.5
17.0
16.5
16.0
15.5
15.0
14.5
14.0
1800
1850
1900
1950
2000

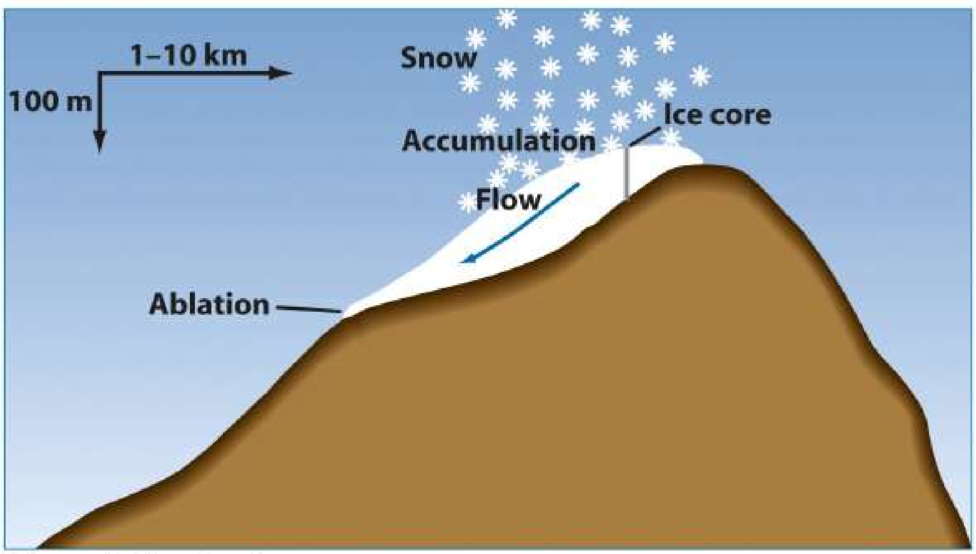

(a) Tmean7=2.84+12.82TRW
R2 = 50.1%
Radj2 = 49.8%
Observed Temperature (°C)
Reconstructed Temperature (°C)
18
17
16
15
14
15
16
17

Glacier ice



Continental ice sheets

Figure 2-5b
Earth's Climate: Past and Future, Second Edition

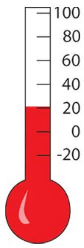


Mountain glaciers

Figure 2-5a
Earth's Climate: Past and Future, Second Edition

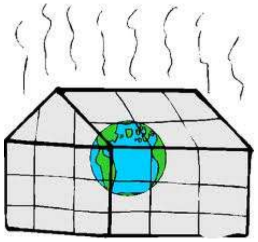
Årlagstællinger

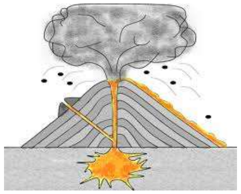
Iskerner



Climate and precipitation

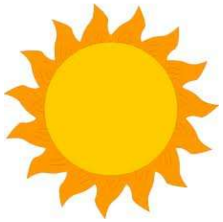
Greenhouse gasses





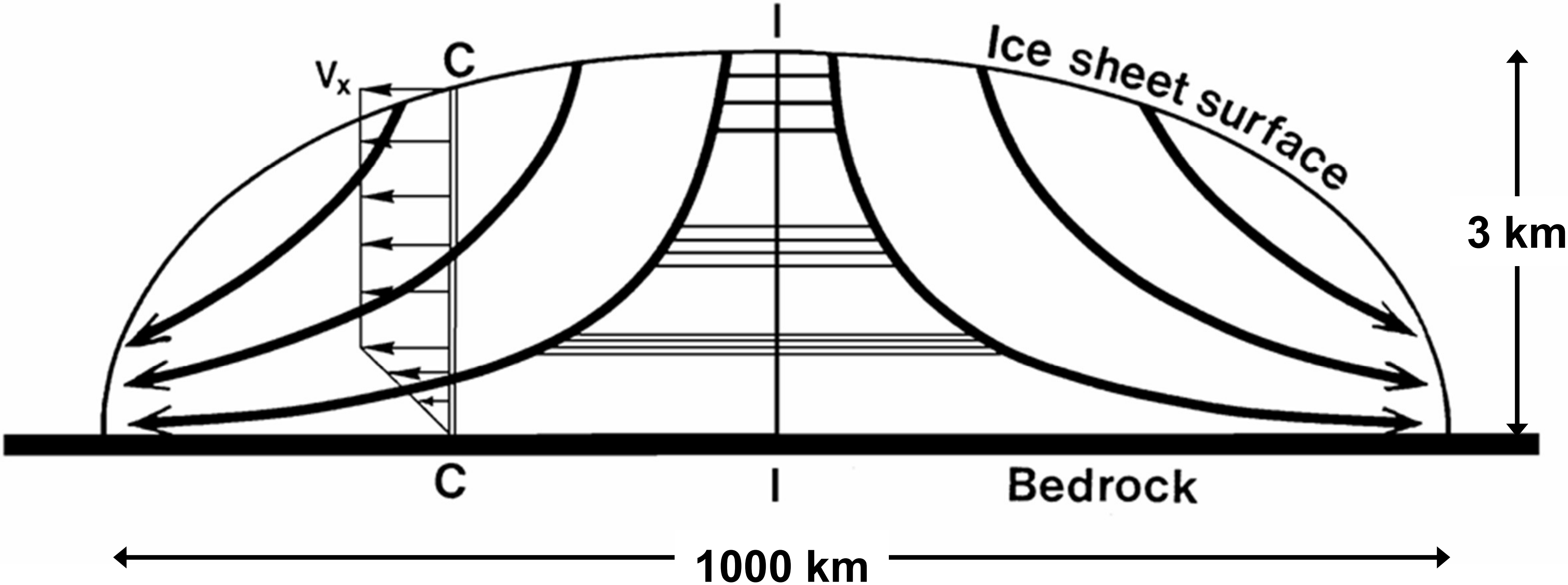
Past volcanism

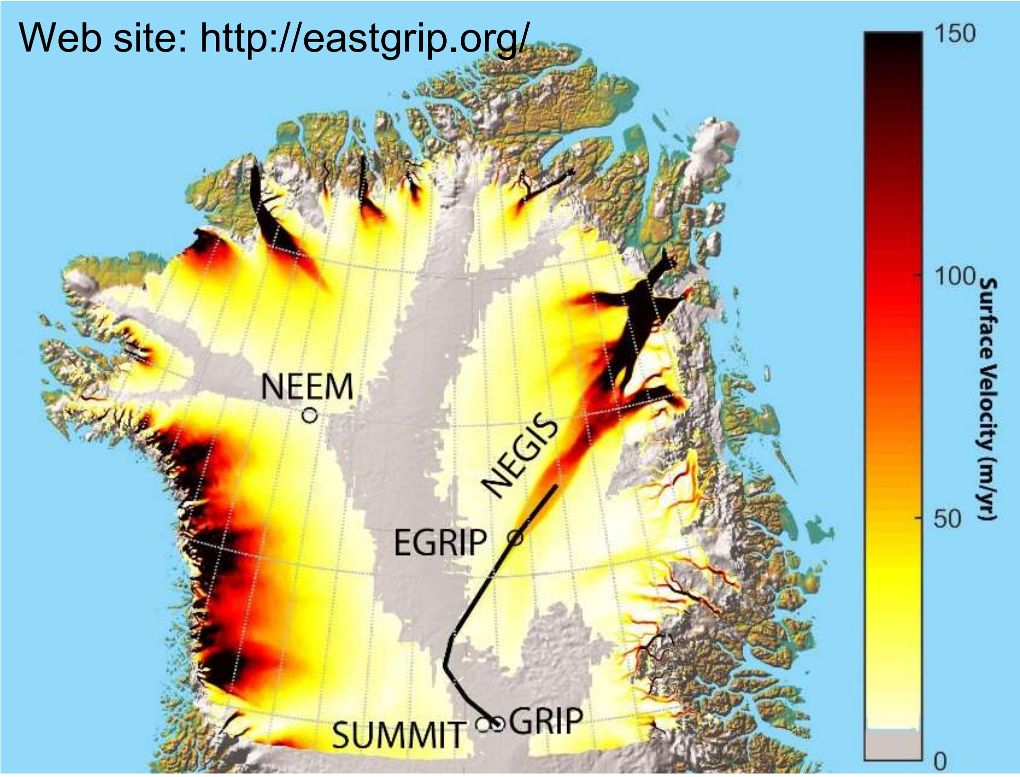
Solar activity (proxy)



Atmospheric transport

Cross-section of the Greenland ice sheet





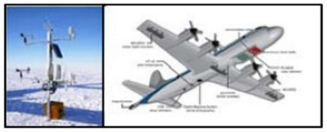
The main purpose of the project is to study the properties of an ice stream.
The drill site is located at an ice stream where the surface velocity is 65 m/yr.

2013

Planlægning

Projektet planlægges og en ansøgning til NSF indsendes.

2014



Forundersøgelser

Greenland Climate Network har placeret en vejrstation ved EGRIP og NASA Operation IceBridge har haft overflyvninger med radar. En NSF bæltekøretøj er placeret ved NEEM.

2015

Lejren etableres

Dome og slæder med udstyr fra NEEM trækkes til EGRIP. Skiway etableres.

2016

Boring begynder

Snehallerne til boring og processering af iskernerne etableres og der bores til 600 m. Overfladeprogrammer begynder.

2017

Iskernerne måles

Der bores videre mens målingerne på iskernerne begynder. Overfladeprogrammerne fortsætter.

2018

Bunden nås

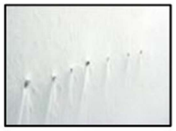
Vi forventer at kunne nå bunden og begynde monitering af bundforholdene.

2019

Logning

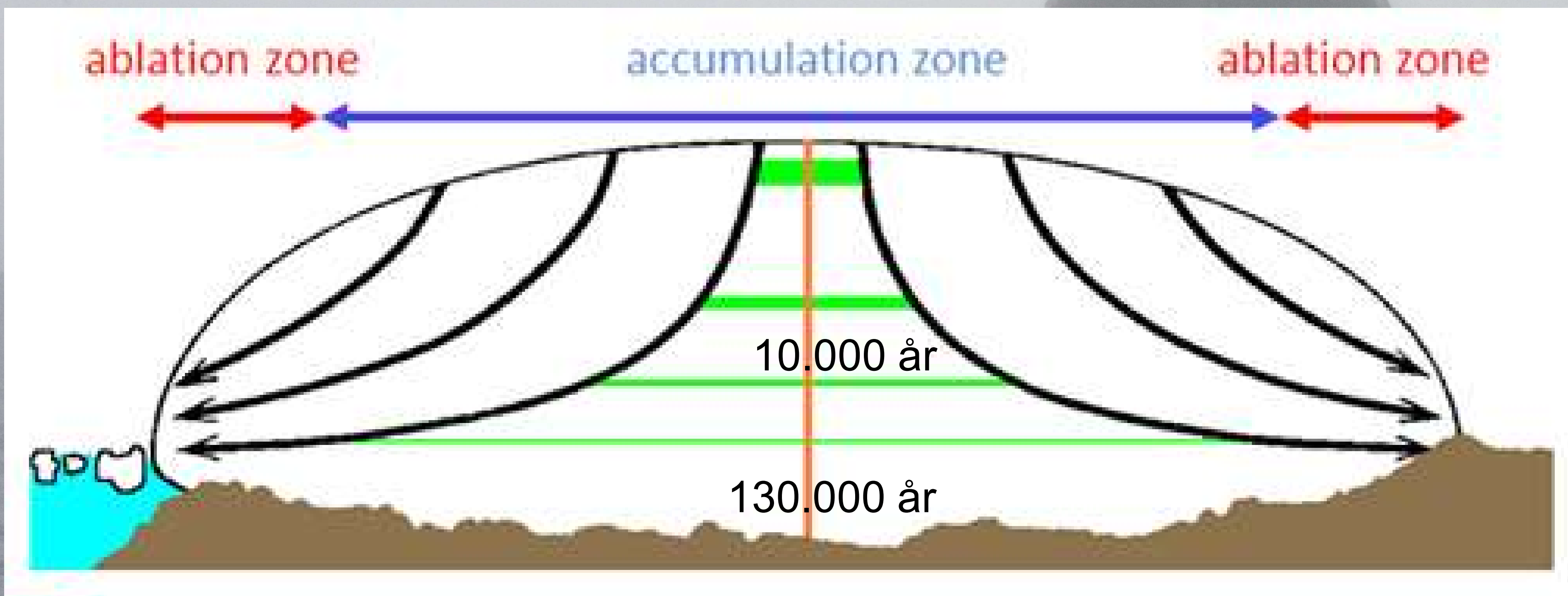
Der fokuseres på undersøgelser af isens flydning og glidning. Målinger af de hydrologiske forhold og sammenligning mellem overflade og bund forhold.

2020

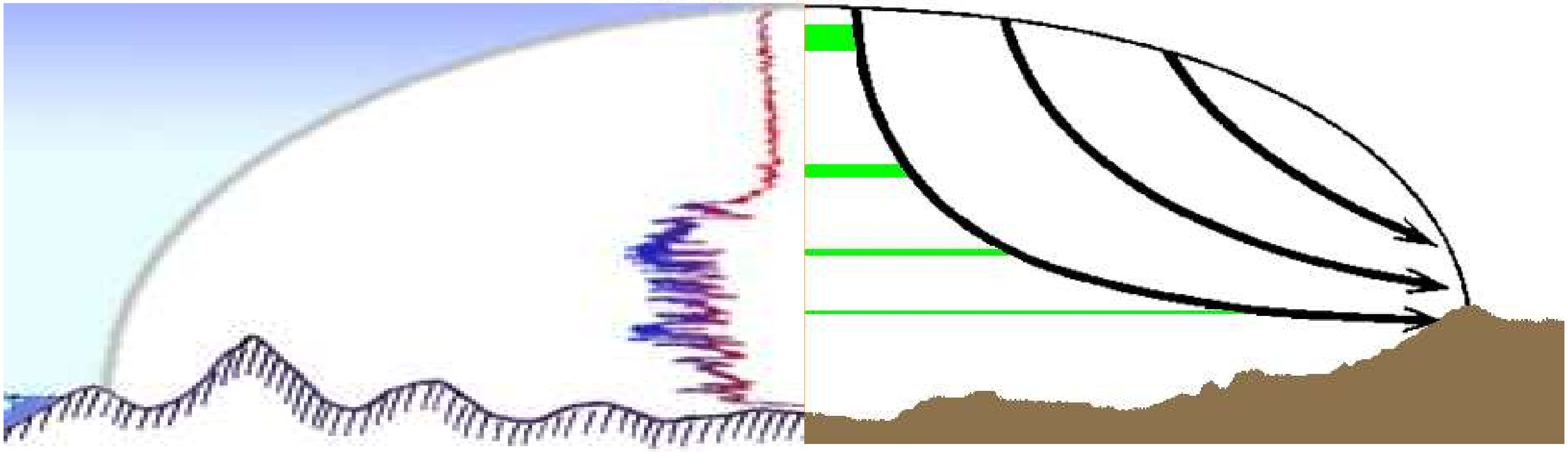


EGRIP lukkes

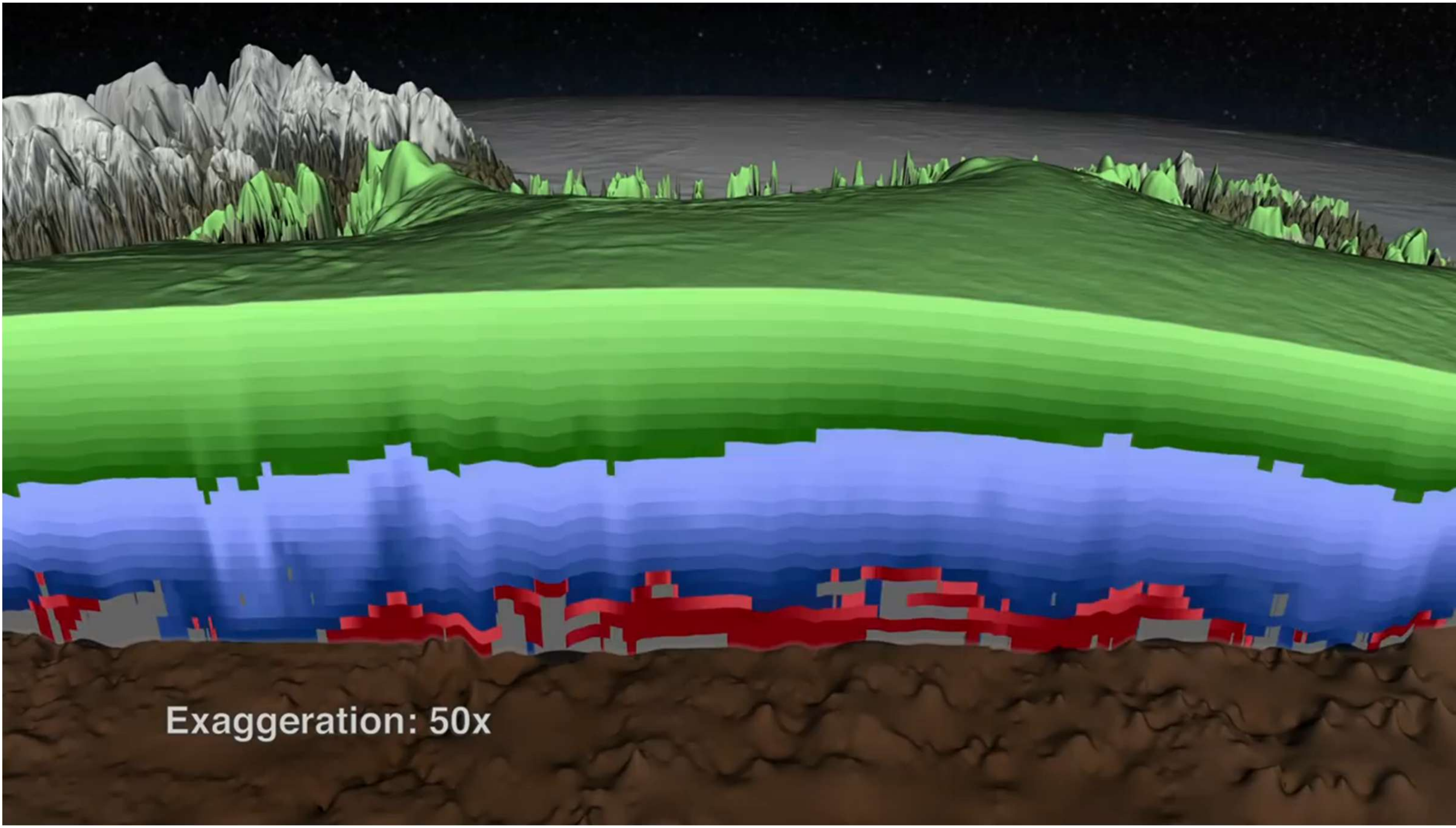
Alt udstyr pakkes og flyttes til kysten eller efterlades på slæder, i overensstemmelse med aftaler lavet med Selvstyret i Grønland.


ablation zone
accumulation zone
ablation zone
10.000 år
130.000 år

Iskerner – en hurtig introduktion



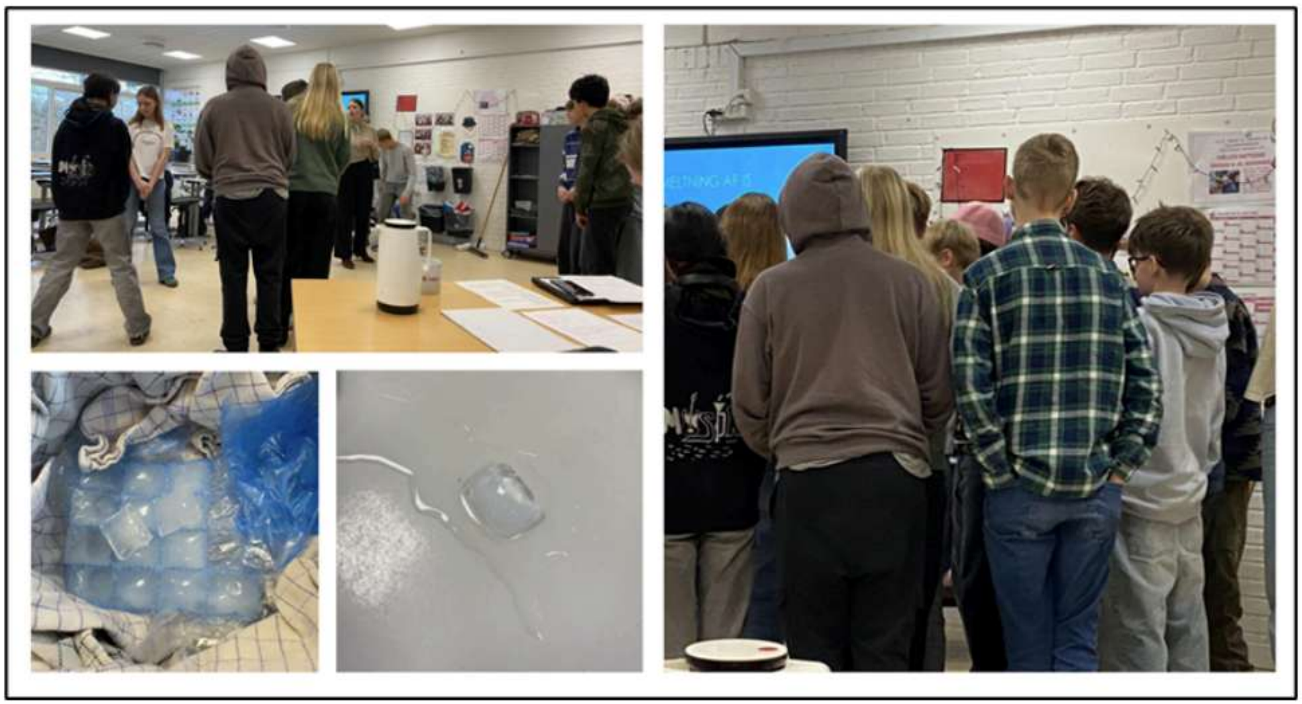
- Grønlandske iskerner rækker tilbage til sidste mellemistid (123.000 yr BP)
- Den årlige nedbør er 30-50 cm is/yr, men lagene bliver tyndere med tiden
- Vi kan skelne de enkelte årlag fra hinanden ca. 80000 år tilbage

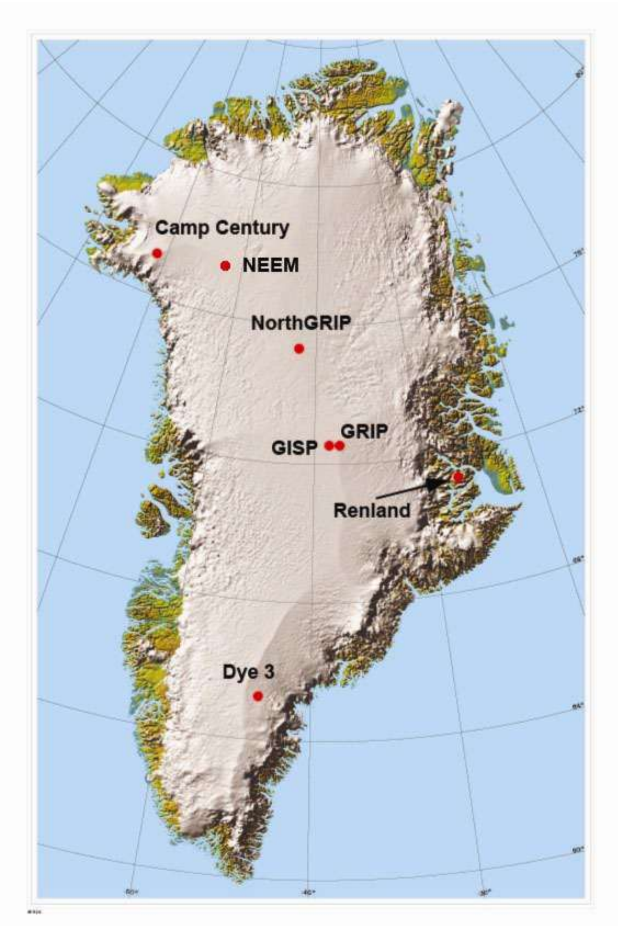

Exaggeration: 50x

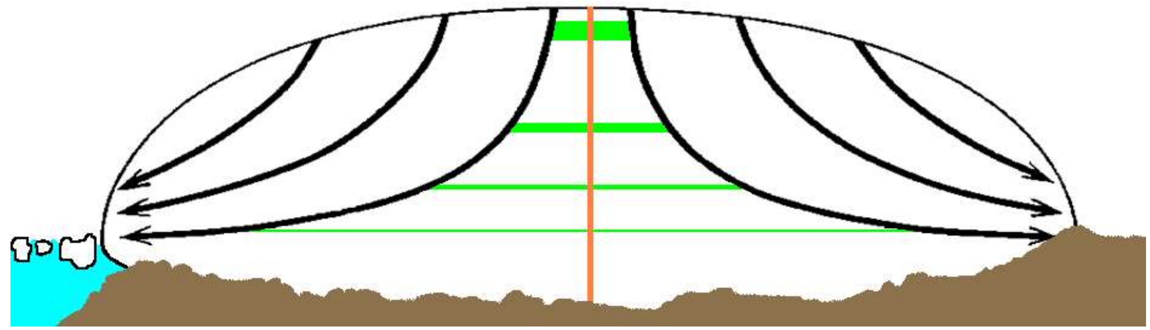
Gletscher øvelse

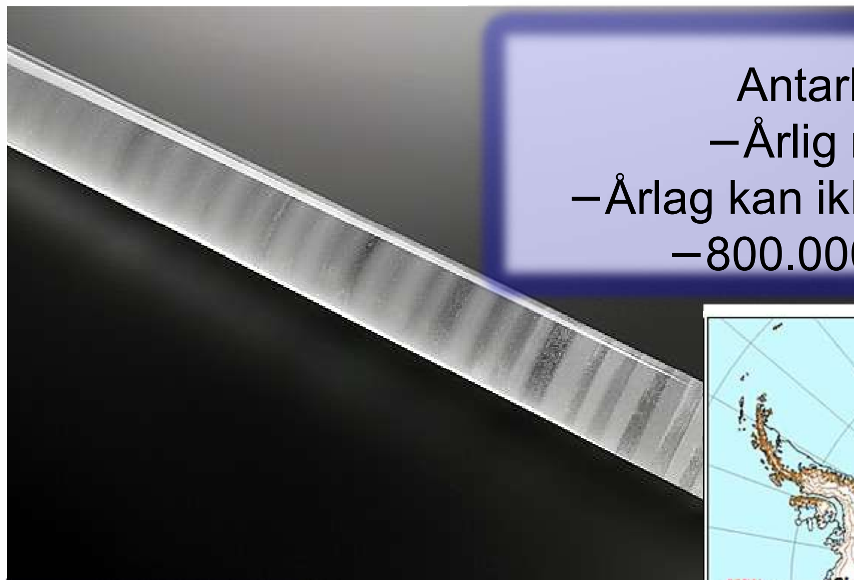
Aska Maria Ono Bjerresø, Jens Boje Pedersen, Julie Blessing, Stine Guldberg Graungård Petersen (KASTEM 2025)

Fang-fasen er delt op i tre elementer: 1) Eleverne lavede i fællesskab en kropslig øvelse, hvor de skulle agere en gletsjer, 2) Eleverne lavede et isterningeforsøg, og 3) Eleverne lavede gletsjerøvelsen igen. I gletsjerøvelsen skulle hver elev symbolisere et vandmolekyle, og sammen skulle de symbolisere en gletsjer i balance mellem afsmeltning og nedbør. Derefter blev eleverne udfordret til at smelte en isterning hurtigst muligt, hvorefter der blev lavet en opsamling med de vigtigste pointer. Afslutningsvis brugte de erfaringerne fra isterningeforsøget til at gentage gletsjerøvelsen.

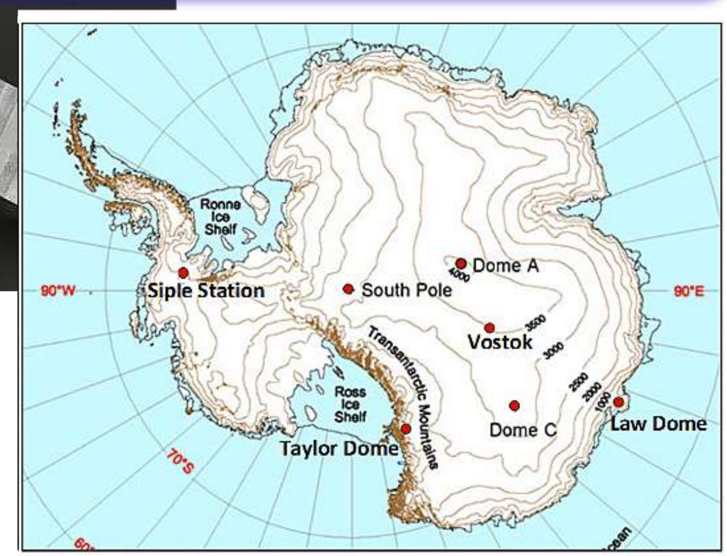




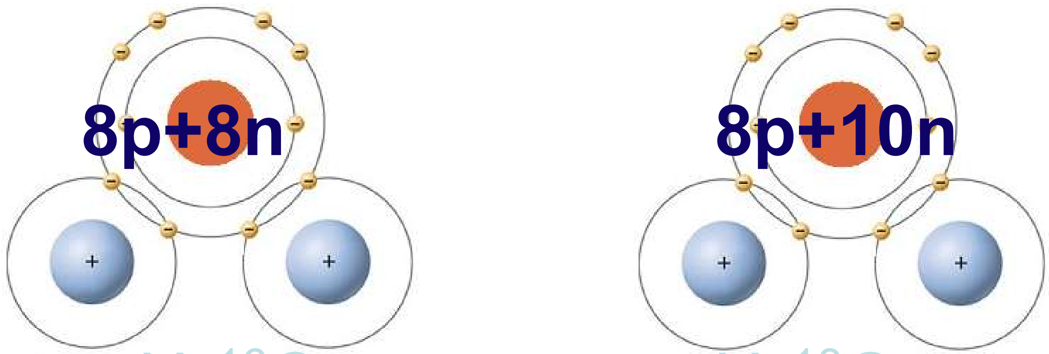




Antarktiske iskerner:
- Årlig nedbør 2-25 cm.
- Årlag kan ikke skelnes fra hinaden.
- 800.000 år tilbage i tiden.



Grønlandske iskerner:
- Årlig nedbør 19-50 cm.
- Årlag kan skelnes 80.000 år tilbage
- 123.000 år tilbage i tiden.



$H_2{}^{16}O$ $H_2{}^{18}O$

Vand kan bestå af forskellige stabile isotoper:

^{16}O, ^{17}O, ^{18}O, ^{1}H, ^{2}H (a.k.a. D)

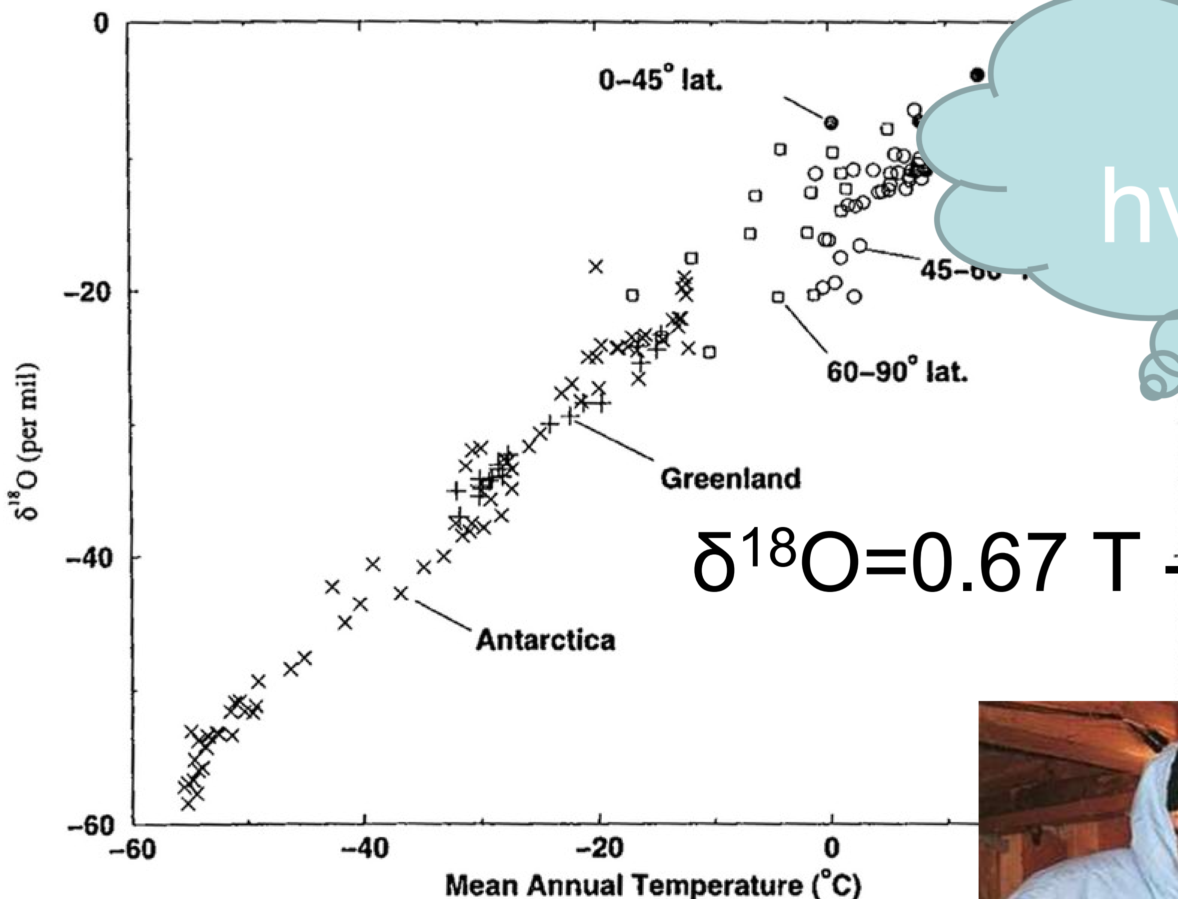
De findes i forskellige mængder naturligt på vores jord

$H_2{}^{16}O$	$H_2{}^{18}O$
99.73%	0.20%

$R=[H_2{}^{18}O]/[H_2{}^{16}O]$ ~2 permil

$$\delta^{18}O = \left(\frac{\frac{[H_2^{18}O]}{[H_2^{16}O]}_{Sample}}{\frac{[H_2^{18}O]}{[H_2^{16}O]}_{VSMOW}} - 1 \right) \times 1000‰$$

$$\delta^{18}O = \left(\frac{\frac{[H_2^{18}O]}{[H_2^{16}O]}_{Sample}}{\frac{[H_2^{18}O]}{[H_2^{16}O]}_{VSMOW}} - 1 \right) \times 1000‰$$



Men hvorfor?

$\delta^{18}O = 0.67\ T - 13.7$

Dansgaard, 1964

Iskerne
med QR forsker suppo

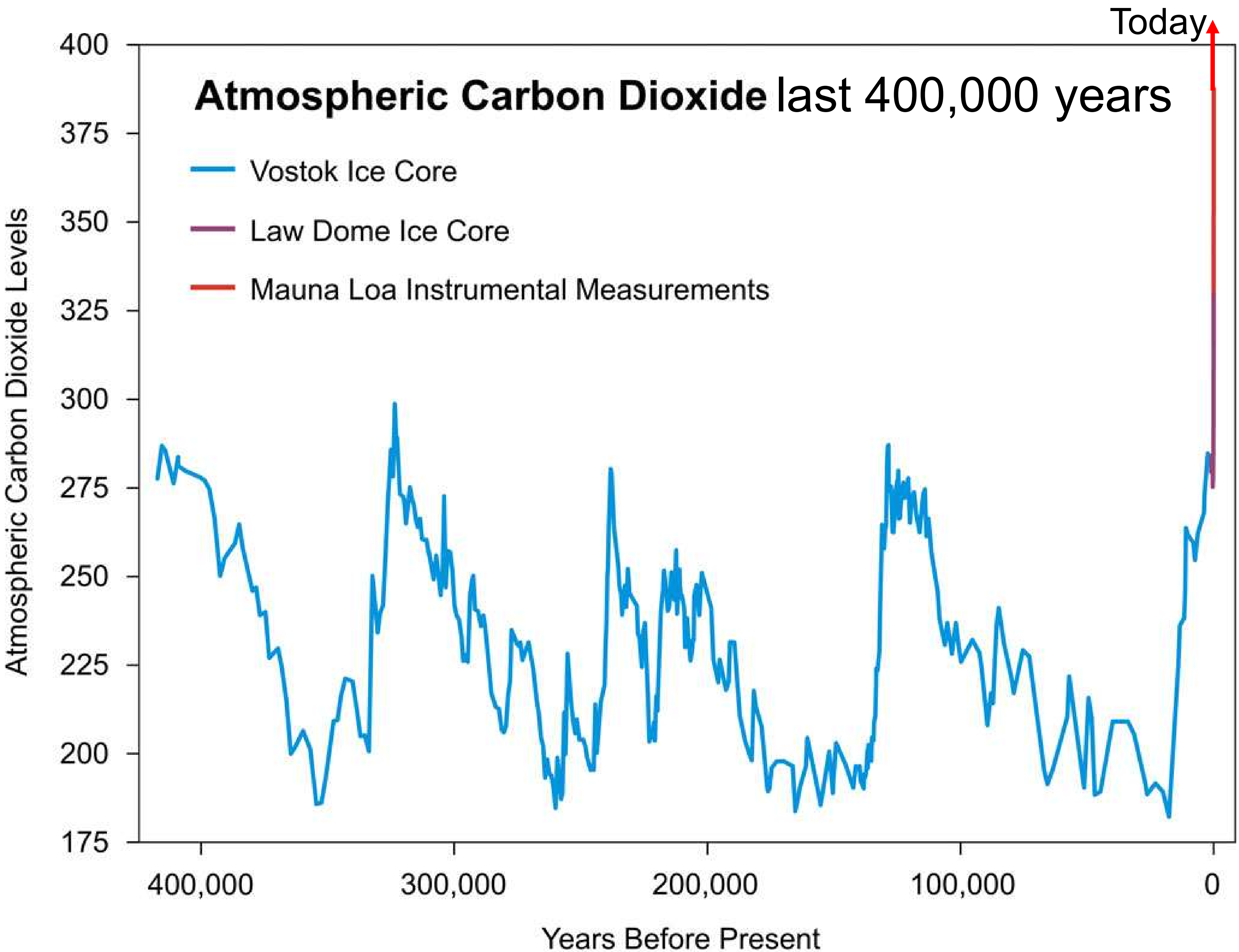
KASTEM 2023 -Anna Henriksen Bregendahl, Carsten Ewald Kaa Larsen, Mette Faber-Madsen, Sarah Bundgaa
Jacobsen

QR kodernes indhold

Vulkanudbrud	
Hvis i bruger pH-indikator papir, og lader det komme i kontakt med et af islagene i jeres iskerne, vil I se, at indikator-papiret måske skifter farve. Det er vigtigt at I ikke bruger den samme strimmel indikatorpapir til flere af iskernens lag. Hvis I identificerer et lag i jeres iskerne, som har en pH-værdi lavere end 7, så vil papiret skifte farve til en gul- orange- eller rødlig farve. Dette betyder, at I har identificeret et surt lag, som følge af et vulkanudbrud. Hvis I er i tvivl om hvilken pH-værdien farven indikerer, kan i følge pH-skalaen. Grunden til, at laget i iskernen er surt er, at der under et vulkanudbrud bliver kastet gas, lava, klipper og små askepartikler højt op i atmosfæren. Nogle gange kan disse vulkanske lag identificeres i iskernerne, men for det meste indeholder lagene kun forhøjede koncentrationer af syre - hovedsageligt svovlsyre, og nogle gange også saltsyre og flussyre. Ved store vulkanudbrud bliver enorme mængder af syre spyet op i atmosfæren, og derved fordelt over store områder som sur regn, også kaldet syreregn, og det er altså denne sure regn, som nu er frosset ned som et lag i jeres iskerne. Identificerer I et sådant surt lag i iskernen, er det med stor sandsynlighed de mere lokale vulkaner i Island og Alaska, som har været i udbrud, og sat et stærkt aftryk. Men hvis et vulkanudbrud er kraftigt nok til at blæse syre helt op i stratosfæren, kan selv vulkanudbrud fra troperne, eller endda fra den sydlige halvkugle, også identificeres i iskerner fra Grønland.	Læs QR koden som sender jer ind på Københavns Universitets hjemmeside. Læs og bemærk, at vulkaner sender store mængder af et eller andet materiale op i atmosfæren. Kan du finde ud af hvad den sender op? **Hint:** Bemærk at der i slutningen af siden, står hvordan man ser vulkanske udbrud i en iskerne. Læs dertil! Du skal nu bruge pH-papir til at finde disse lag i iskernen.

Opbygningen og indhold af iskernen

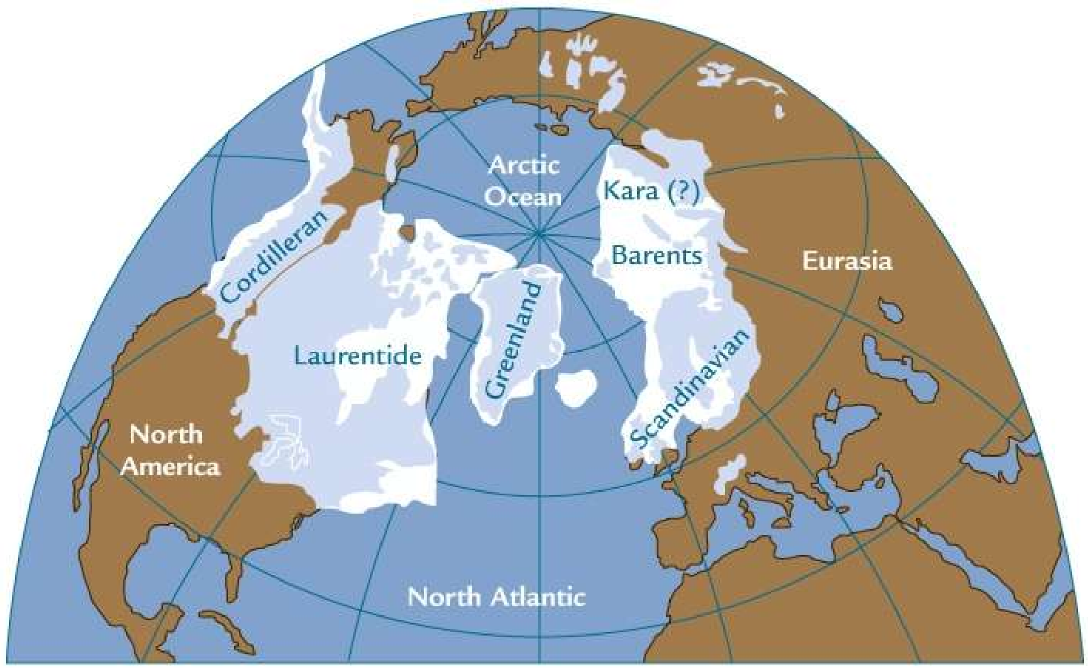
Lagene i iskernen	**Indhold i iskernen**	**QR-koderne**	**Identificeres i iskernen**
	1 ½ dl alm. vand	Klimatisk tid	Brug en lommelygte til at se forskelle mellem istid og klimatisk tid
	¾ dl citronsyreopløsning	Vulkanudbrud	Måling med pH-papir
	10 g kaffegrums	Skovbrand	Mærk med kroppen – find et lag organisk materiale
	1 dl alm. vand	Klimatisk tid	Brug en lommelygte til at se forskelle mellem istid og klimatisk tid
	¾ dl citronsyreopløsning	Vulkanudbrud	Måling med pH-papir
	10 g sand	Støvstorm	Mærk med kroppen – find et lag sand
	1 dl alm. vand	Klimatisk tid	Brug en lommelygte til at se forskelle mellem istid og klimatisk tid
	¾ citronsyreopløsning	Vulkanudbrud	Måling med pH-papir
	1 ½ dl alm. vand + mælk	Istid	Brug en lommelygte til at se forskelle mellem istid og klimatisk tid


Today
Atmospheric Carbon Dioxide last 400,000 years
Vostok Ice Core
Law Dome Ice Core
Mauna Loa Instrumental Measurements
400
375
350
325
300
275
250
225
200
175
Atmospheric Carbon Dioxide Levels
400,000
300,000
200,000
100,000
0
Years Before Present

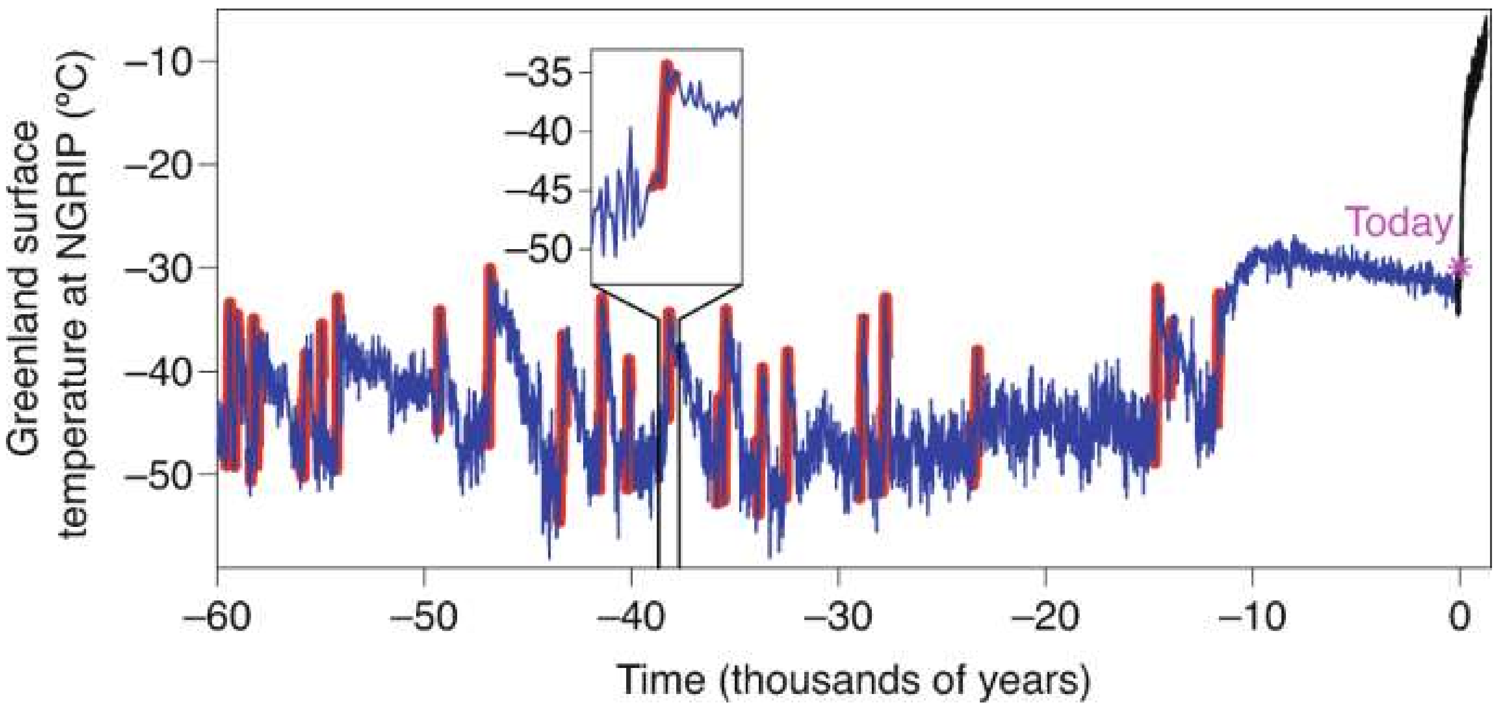
The last Glaciation (11.5 – 115.0 ka)

ka = kilo-year = thousands of years

- Large Northern Hemisphere continental ice sheets
- Global mean temperature some 6°C lower than pre-industrial
- Sea level down to some 120m lower than today
- Atmospheric CO_2 some 80 ppm lower than pre-industrial



Tipping I fortiden-proxy data

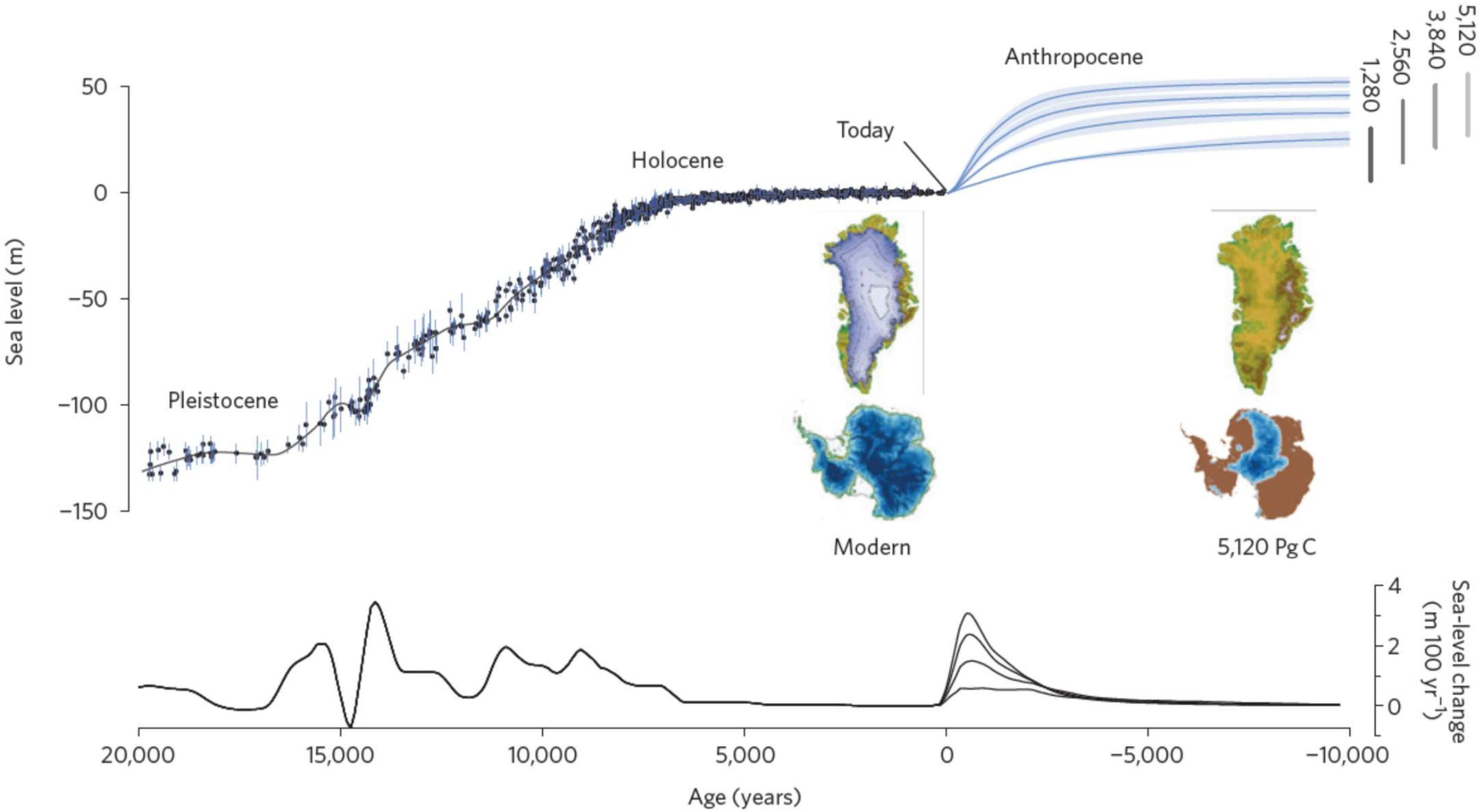


RCP 8.5

I rød - 1 °C per 10 år i mindst 40 år uden en retur til koldt klima

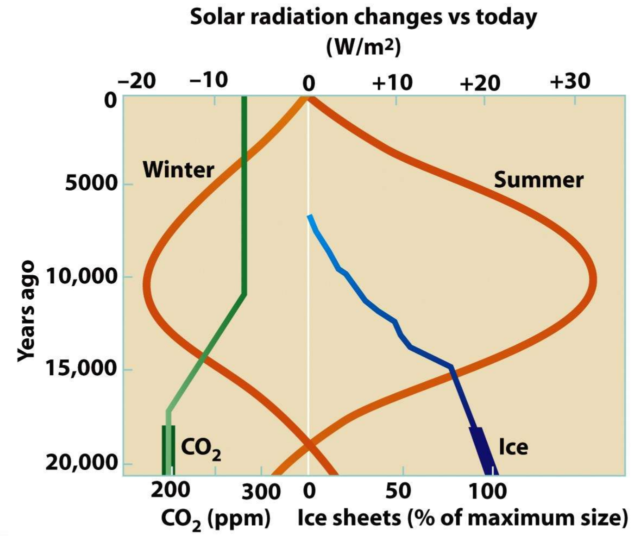
Jansen *et al.* *Nat. Clim. Chang.* **10**, 714–721 (2020).

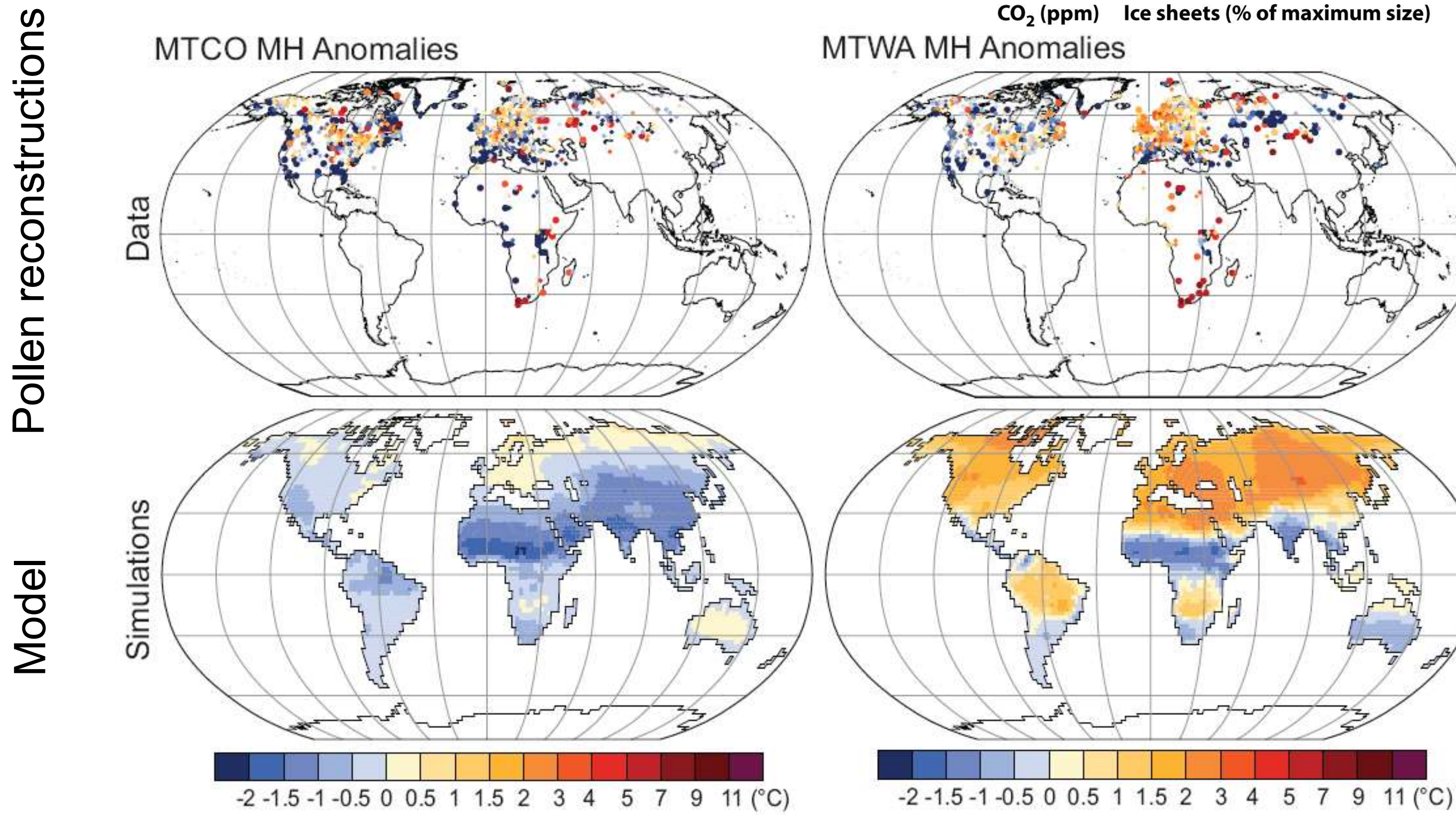
Past and future changes in global mean sea level



(Clark et al., NatureCC, 2016)

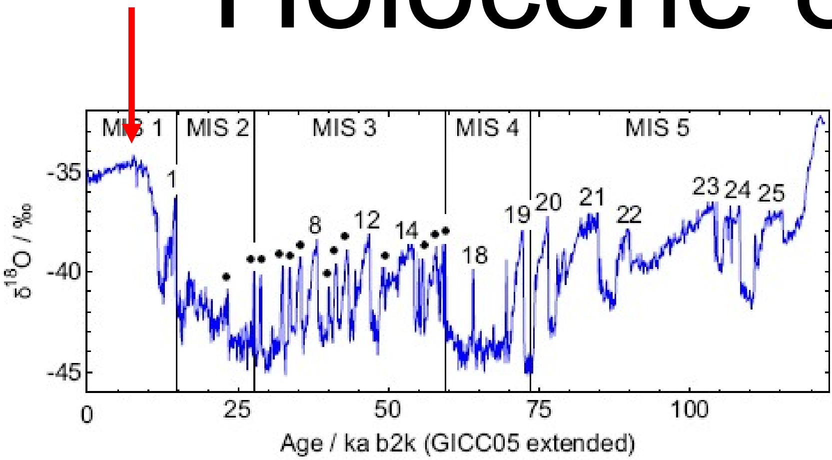
Holocene optimum (6 ka vs pre-industrial)

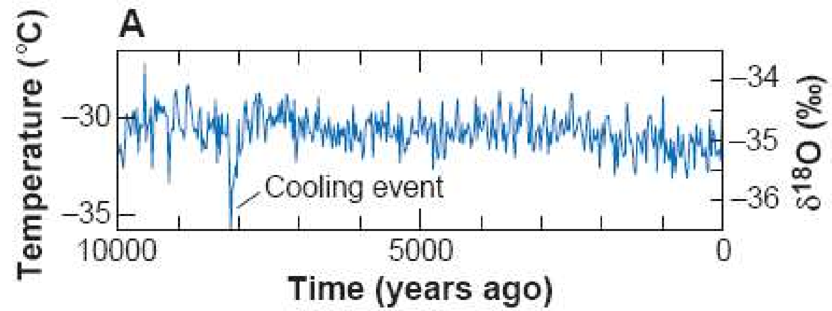


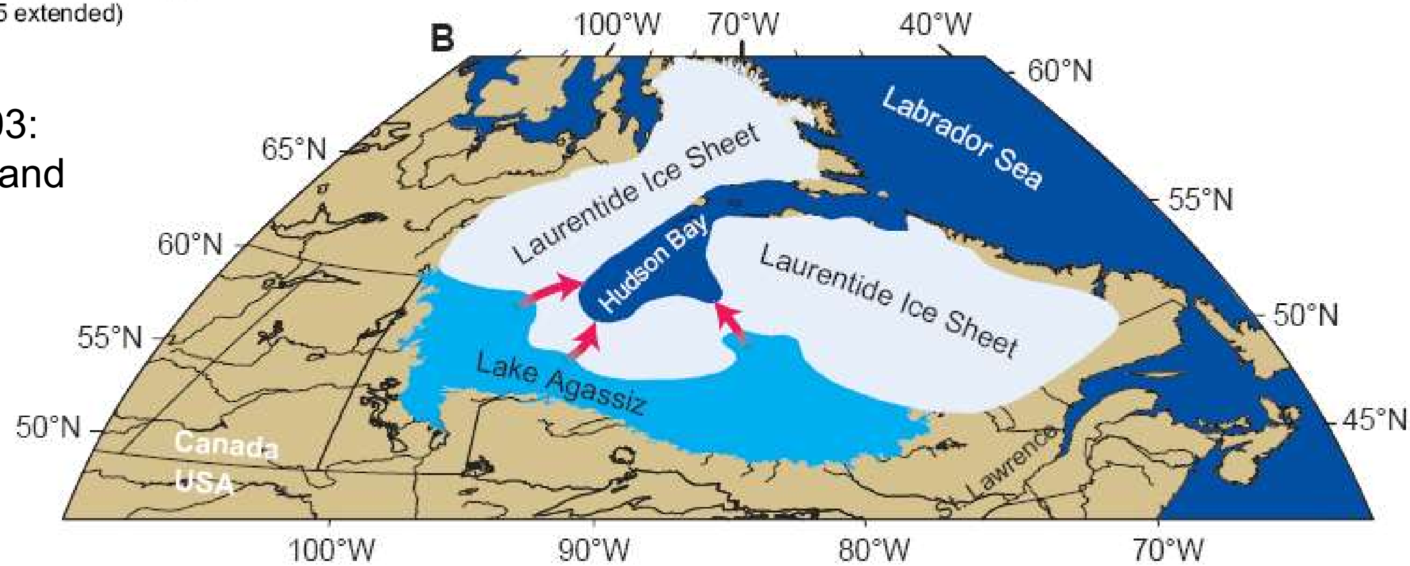


(IPCC AR5 WG1 Figure 5.11)

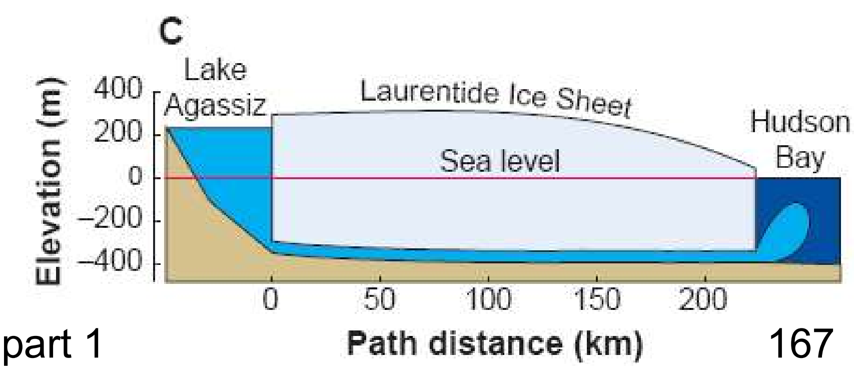
Holocene 8.2 ka cold event







Clarke et al., Science, 2003: 'Superlakes, Megafloods, and Abrupt Climate Change'



Lake Agassiz formed at the southern margin of the disintegrating Laurentide Ice Sheet and released its stored water to Hudson Bay.
Three possible flood routes are indicated by red arrows. Many more routes are possible

Forcings of Holocene climate – Volanic effects on insolation

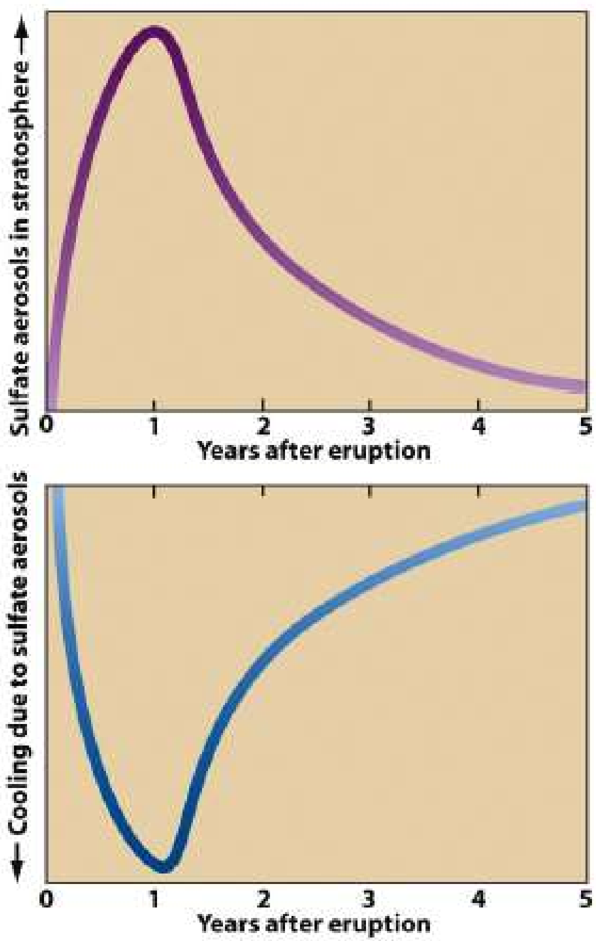
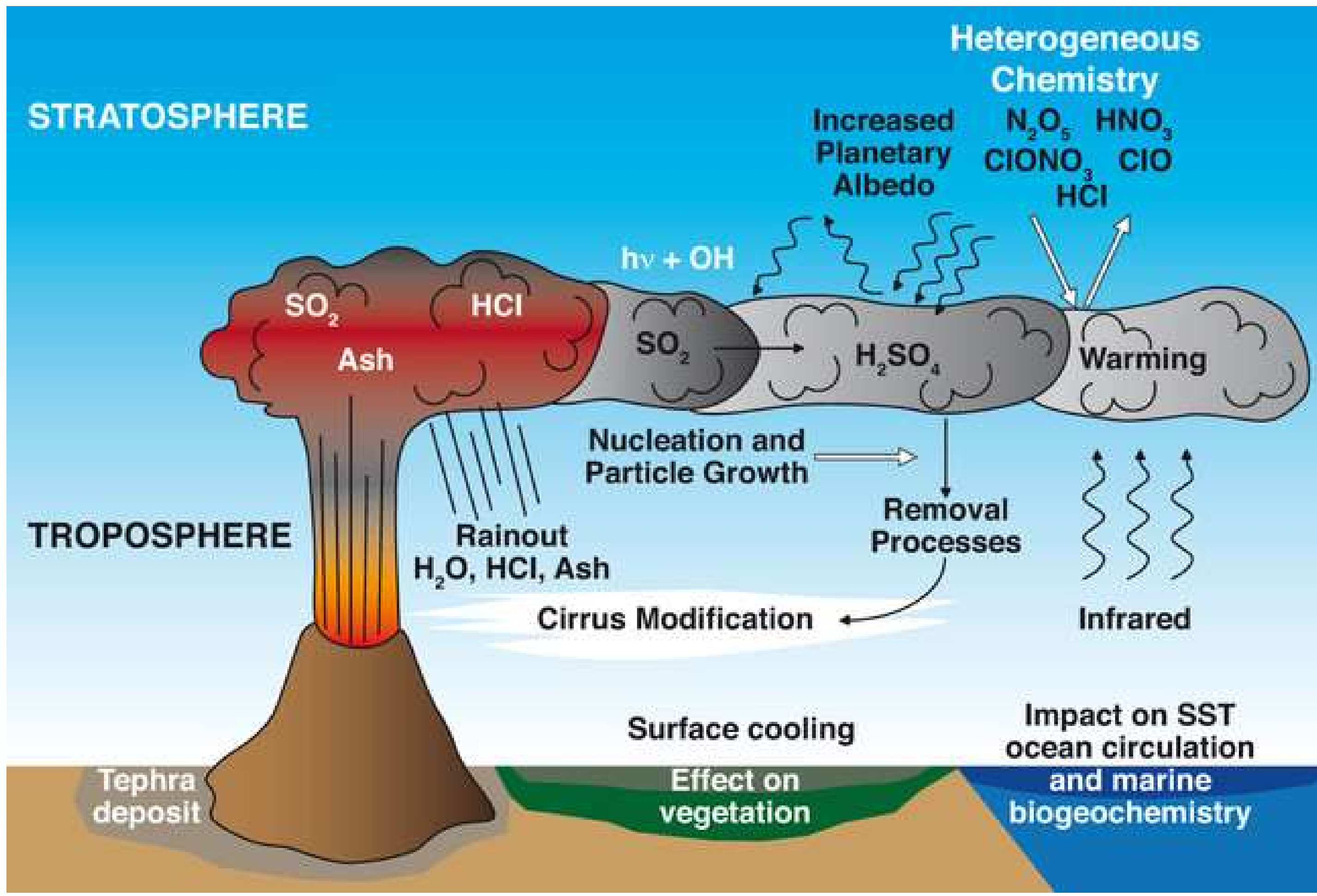


Figure 16-15
Earth's Climate: Past and Future, Second Edition



Forcings of Holocene climate – Volanic effects on insolation

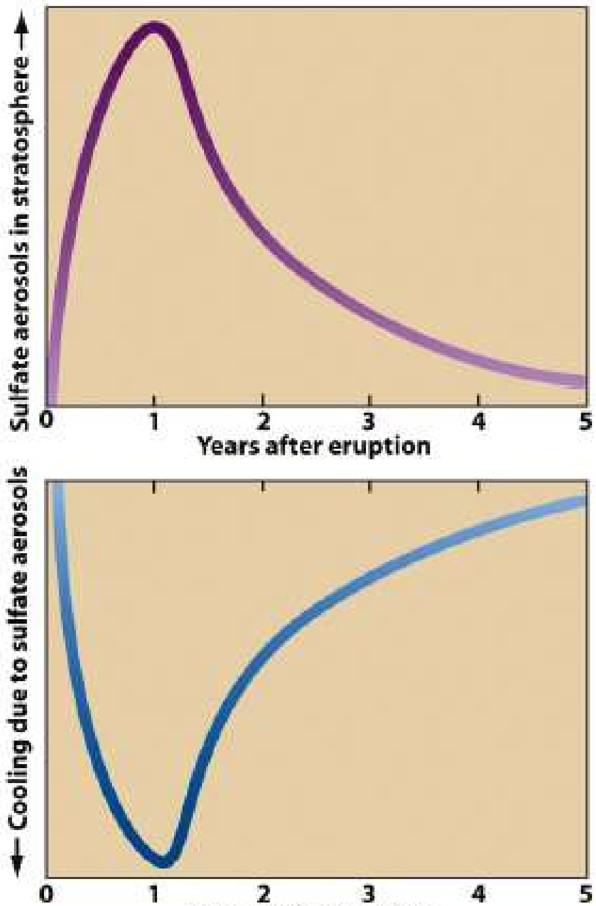


Figure 16-15
Earth's Climate: Past and Future, Second Edition

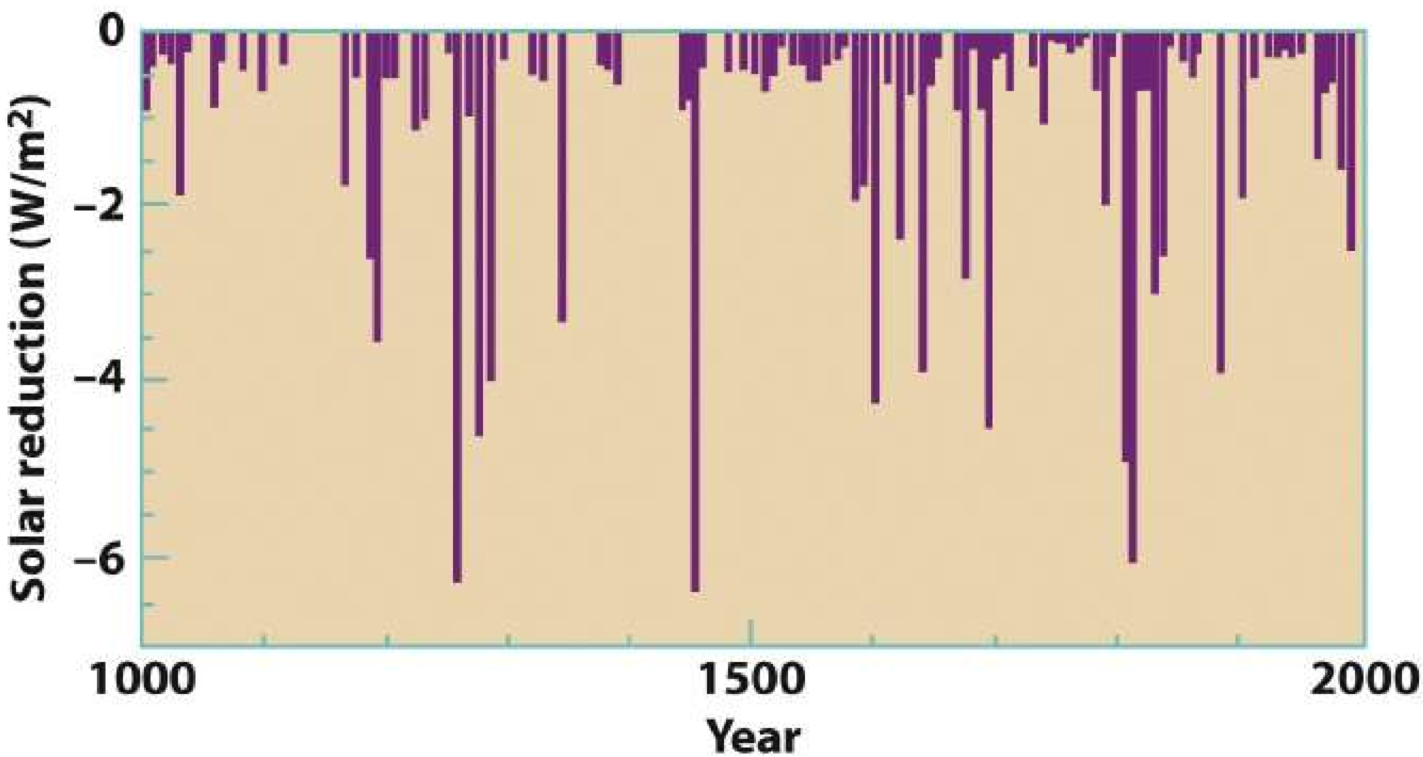
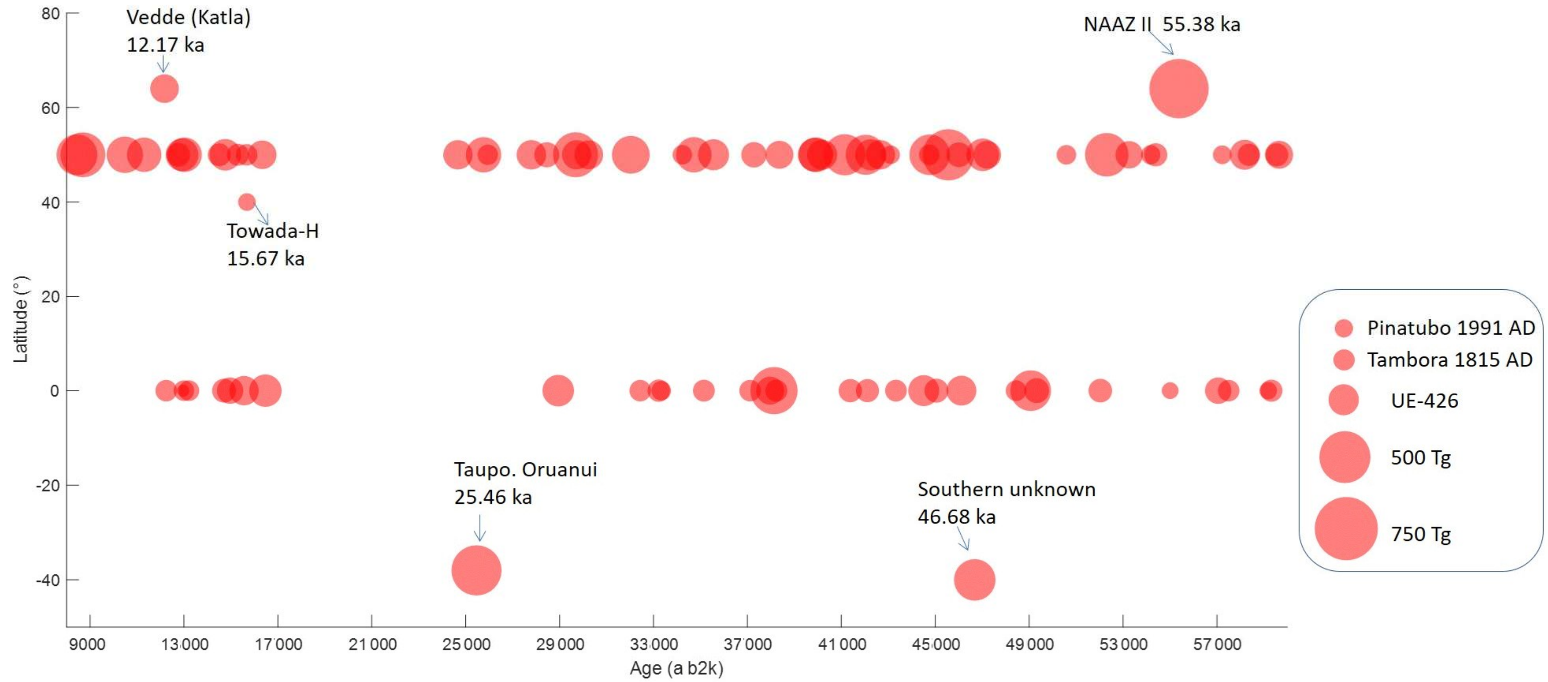
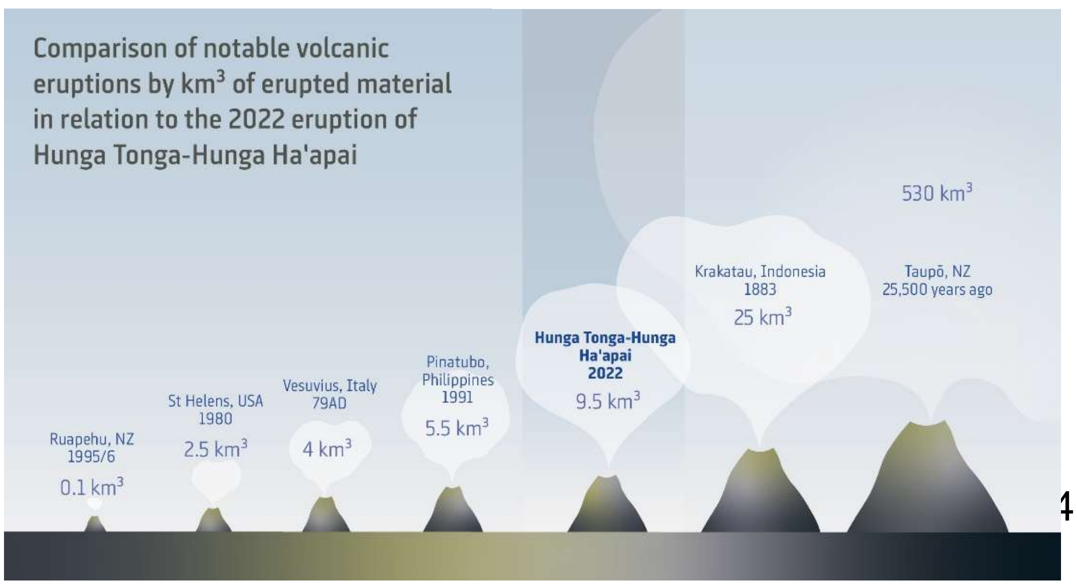


Figure 16-16
Earth's Climate: Past and Future, Second Edition

Vulkaner





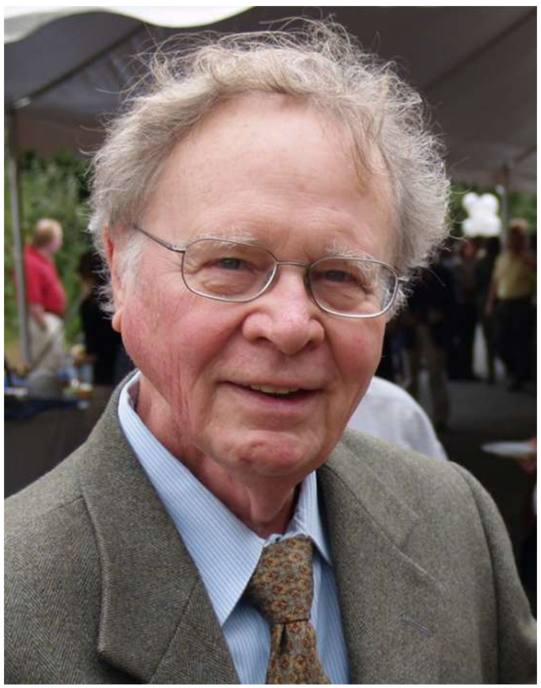
Jiamei Lin et al. 2022
Svensson et al. 2025

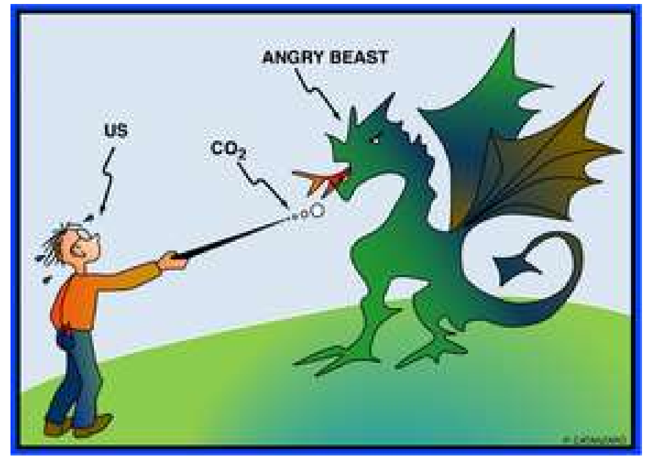
Mennesker og klimavariationer

- Mesopotanien (tørke)-2334 – c. 2154 BC
- Mayaerne (tørke)-8th and 10th centuries CE
- Indus valley 3300-1300 BCE (tørke)

Tippping points og AMOC

Abrupt climate change





- Dr. Wally Broecker:
- "The climate system is an angry beast, and we are poking it."

Abrupt klima forandring

- ”...when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than its cause”

- ”...a climate change that occurs so rapidly and unexpectedly that human or natural systems have difficulty adapting to it”

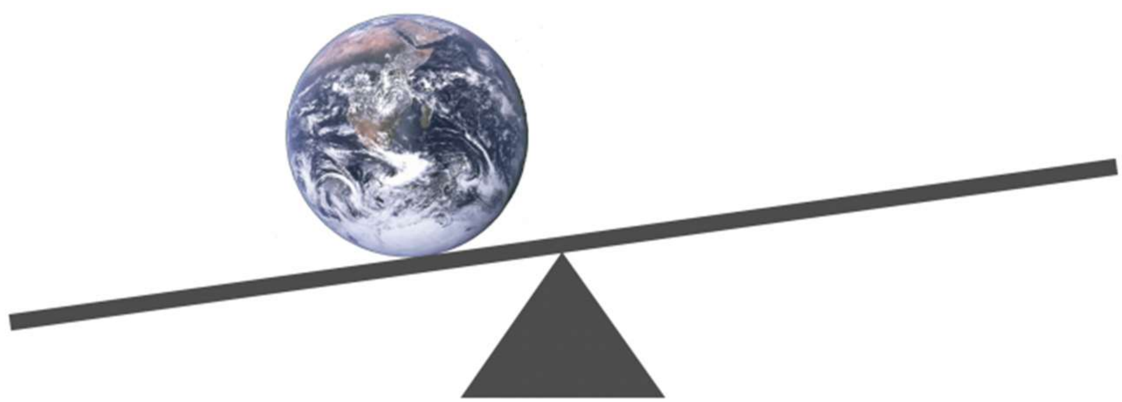
Der er ingen universel accepteret formulering

In general, one needs:

A fast change (much less than a human lifetime)

A big change (in average or in variability)

A change that seems out of proportion (too big) relative to the suspected cause



What ACCs are and what they are not

Abrupt climate changes (ACCs) are clearly seen in the Greenland ice core records, but ACCs can manifest themselves in ways not seen in the ice cores. Predicting how ACCS will happen in the future and what parts of the climate will be affected is largely unknown.

- Hurricane Katrina vs hurricane frequency and intensity
- Volcanic eruptions vs volcanic frequency and intensity
- Destructive flooding vs flooding frequency and intensity
- A long stretch of sunny days vs a prolonged drought

- An abrupt climate change requires a new state to be reached that persists for some time...

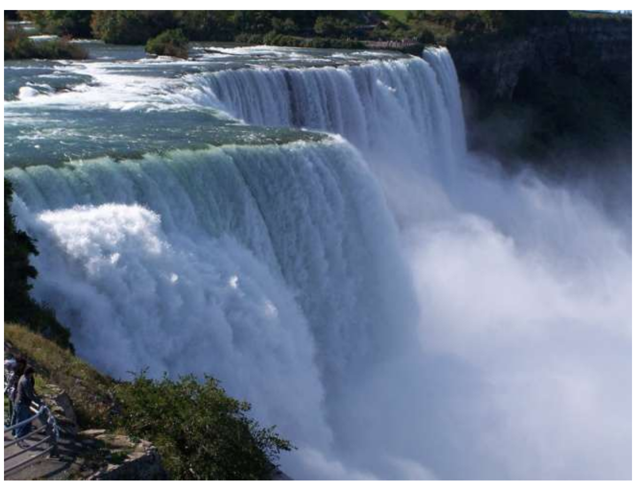
Requirements of a mechanism

- **A trigger:** Where and when does an ACC start?
- **An amplifier:** How is it enhanced
- **Globalizers:** Mechanisms to spread to other regions?
- **A source of persistance:** How can the new state of affairs last for decades, centuries or millennia?

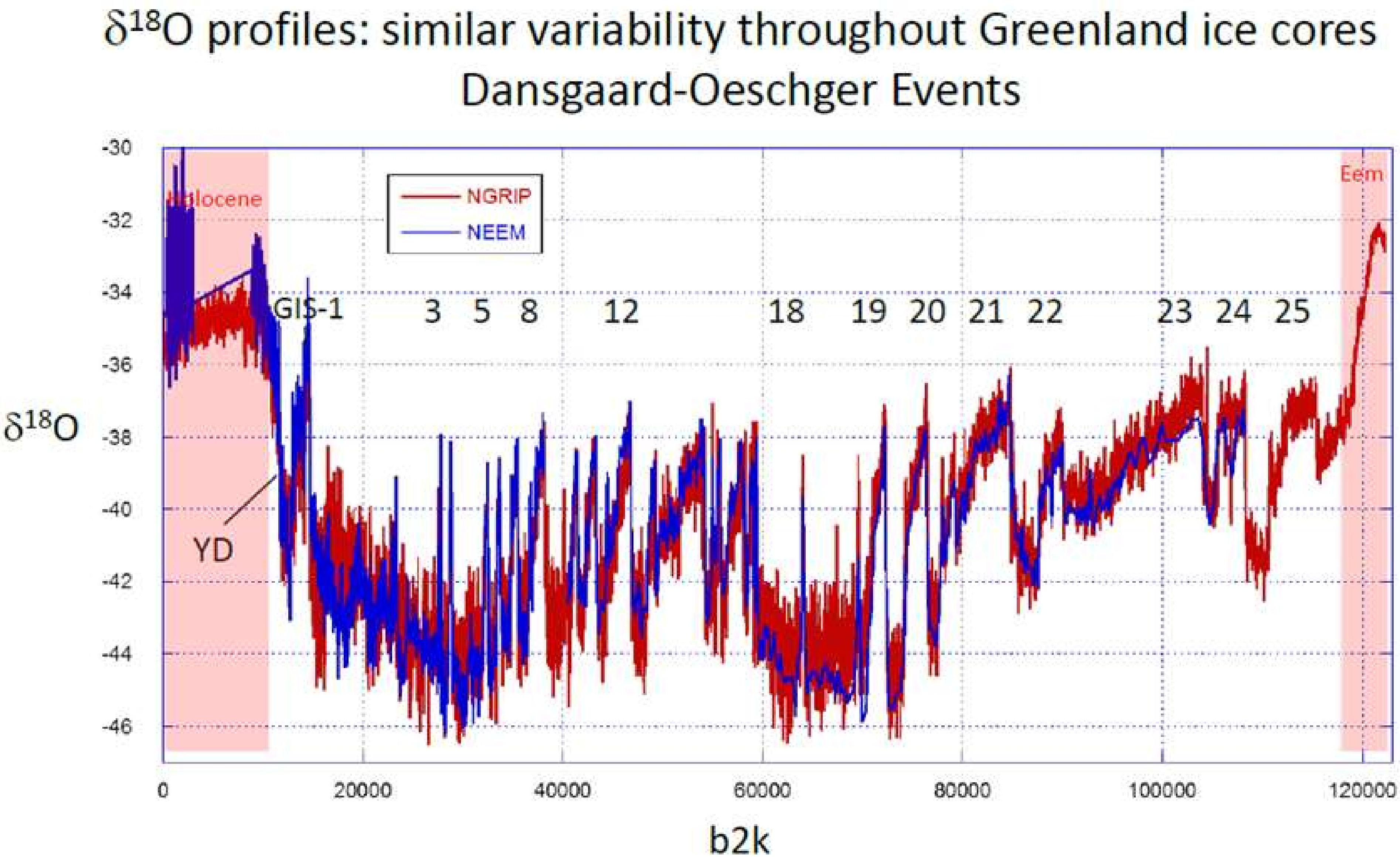
- We observe and expect *nonlinear* responses with *multiple equilibria:*
  - Linear: double forcing = double response
  - Nonlinear: small forcing = small OR big response
  - These characteristics have been observed and modelled for the THC. Thus abrupt transitions and the evolution of DO like events have been linked to ocean circulation...the prevailing paradigm...should this be the case in the future?

Change won't always be obvious: Timing and tipping points

- Abrupt changes, tipping points… a point of no return is crossed resulting in large, inevitable change.
- The"canoe on the Niagara River" type events: strong positive feedbacks



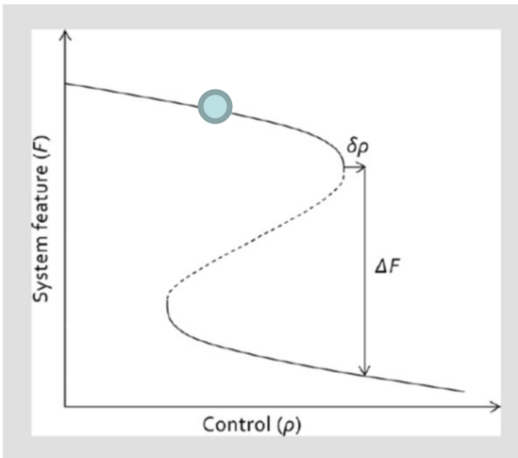
You have seen ACCs already



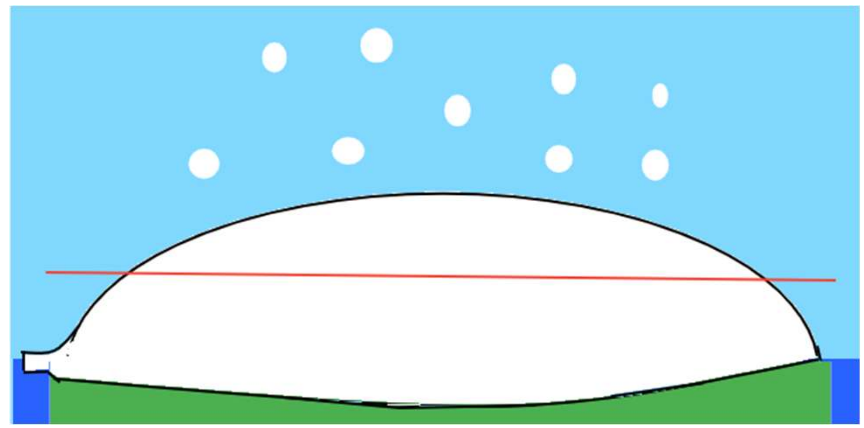
The paleoclimatic records show us that abrupt climate change is not only possible - it is the normal state of affairs.

Iskapper- et eksempel på et ireversibel Tipping point

Iskappe volumen

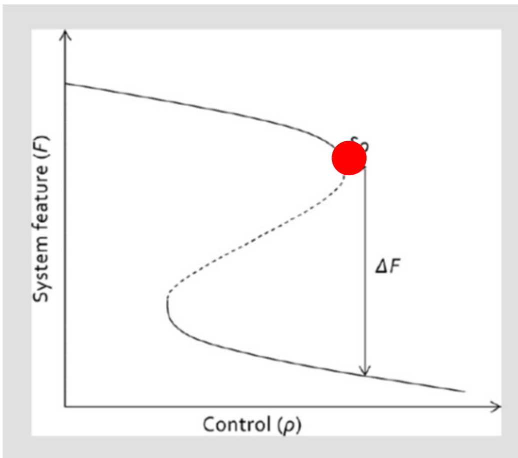


Lokal temperatur

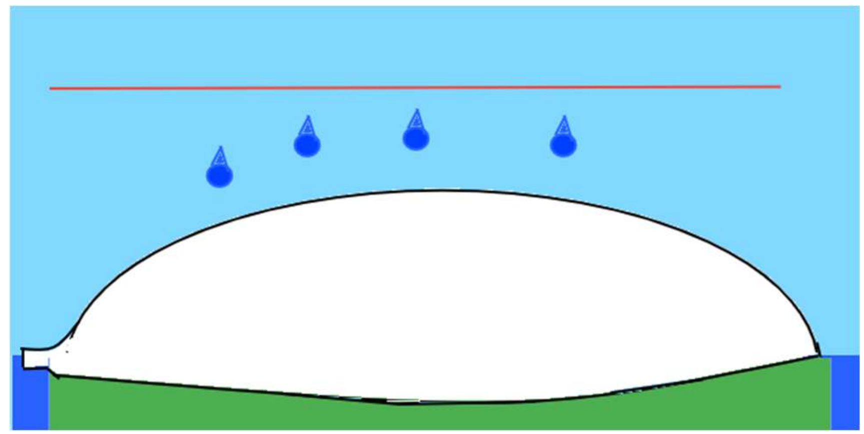


Iskapper- et eksempel på et ireversibel Tipping point

Iskappe volumen

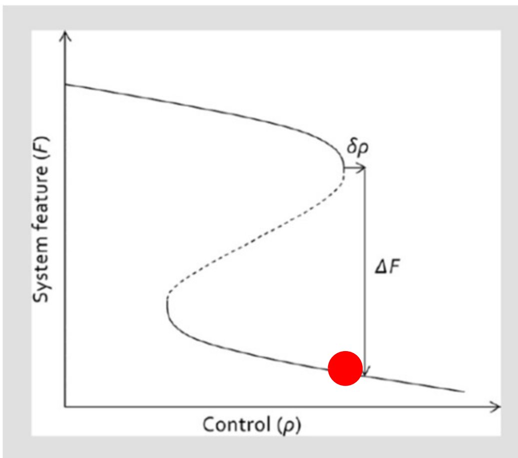


Lokal temperatur

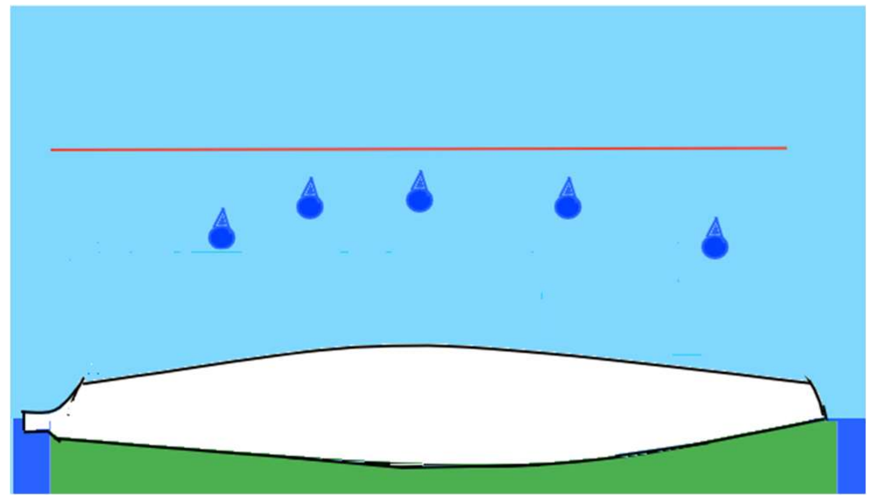


Iskapper- et eksempel på et ireversibel Tipping point

Iskappe volumen

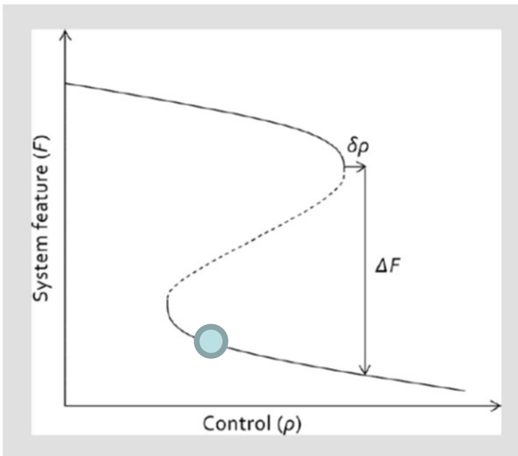


Lokal temperatur

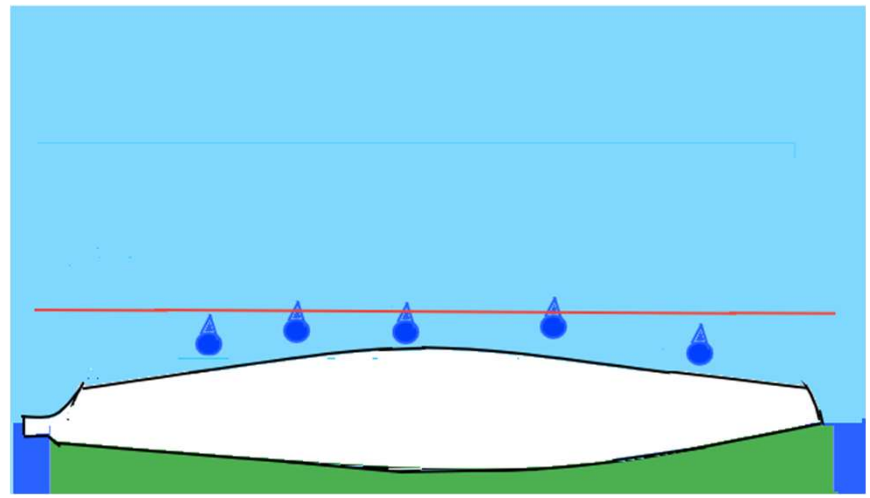


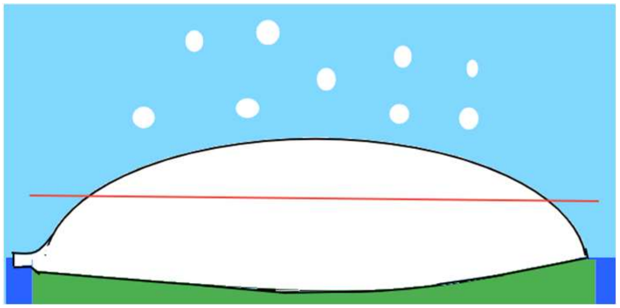
Iskapper- et eksempel på et ireversibel Tipping point

Iskappe volumen

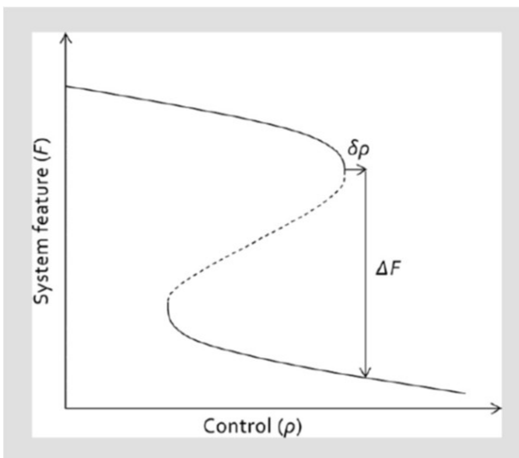


Lokal temperatur

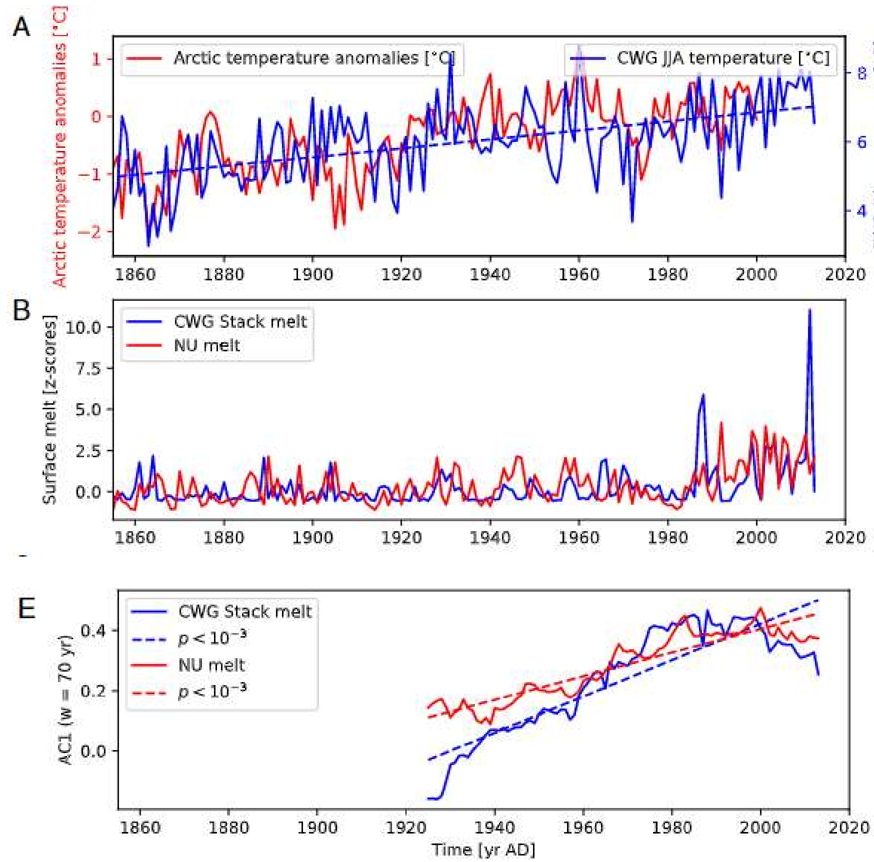




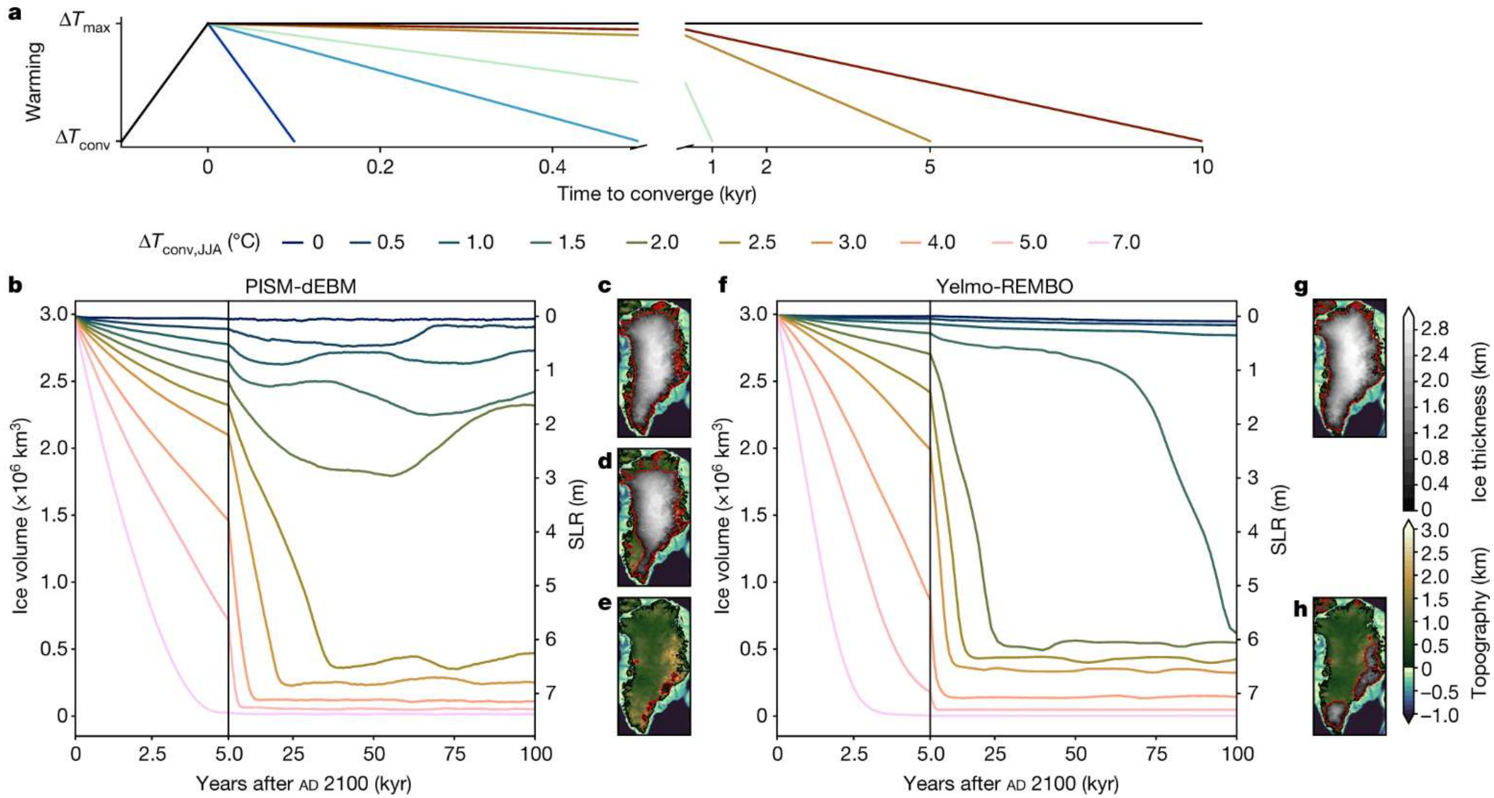
Iskappe volumen



Lokal temperatur

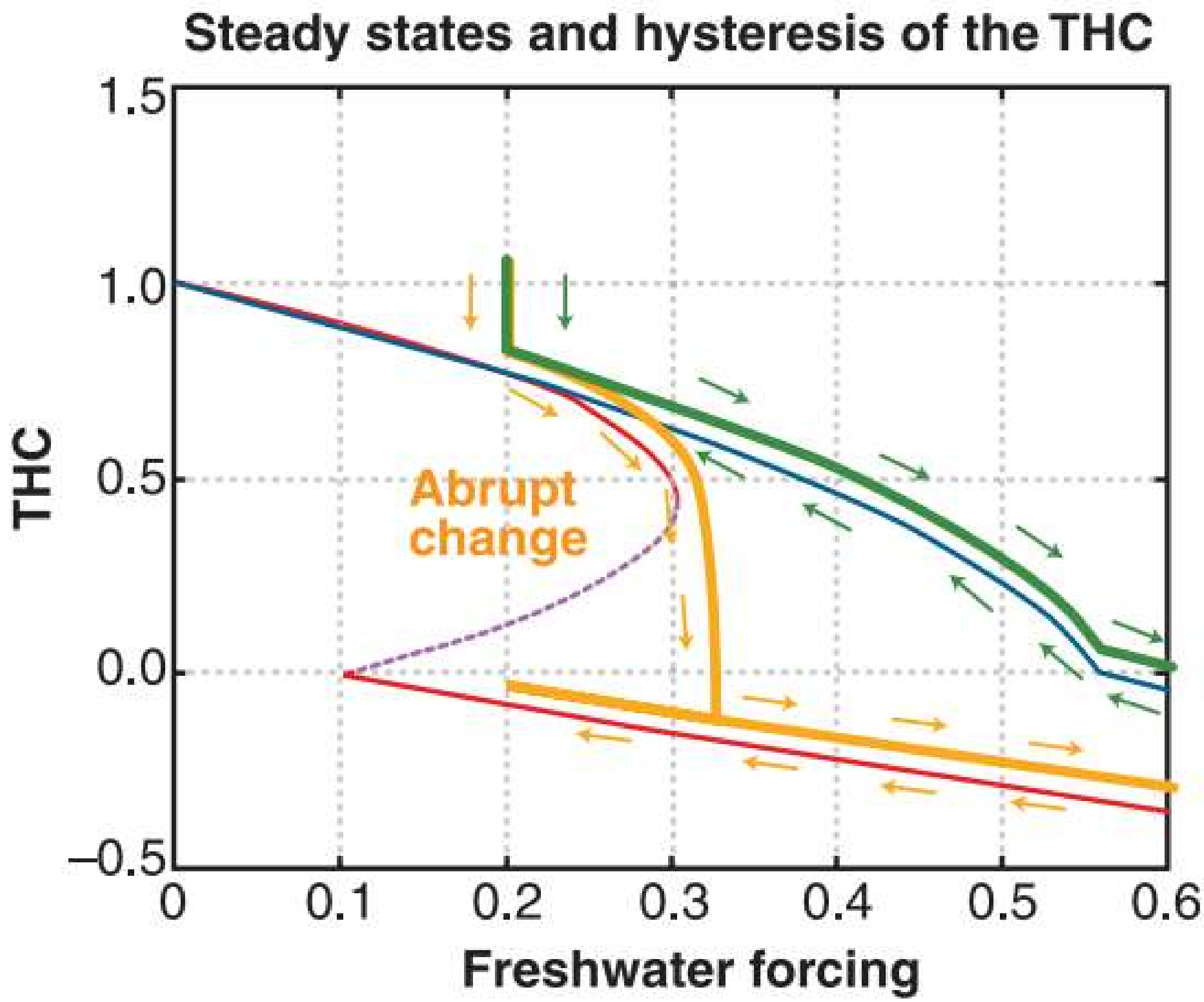


Boers &Rypdal, PNAS, **2021,**
118 (21) e2024192118
https://doi.org/10.1073/pnas.202419211

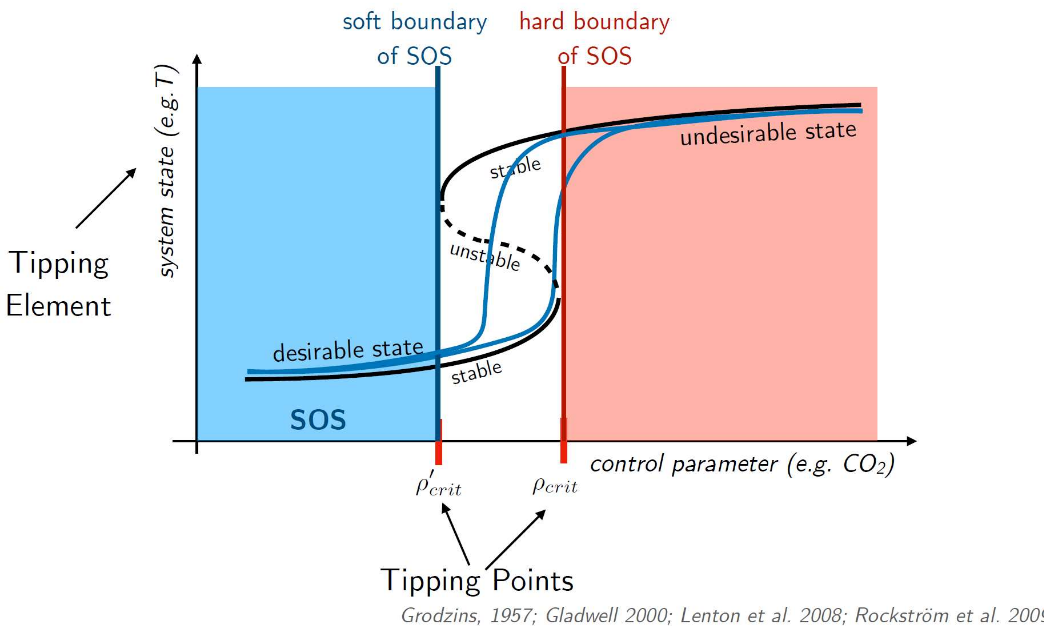


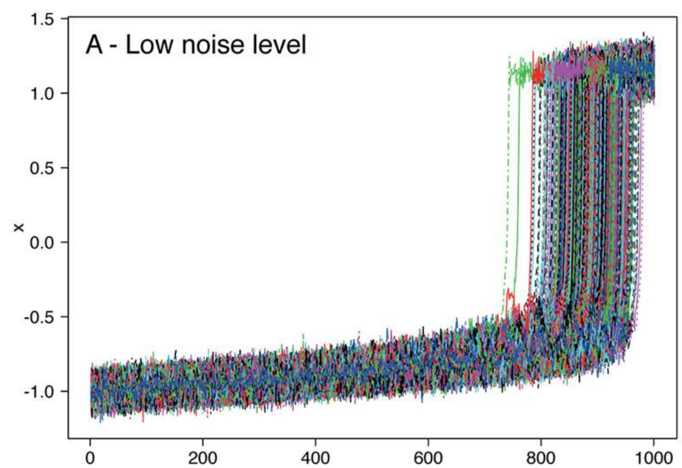
Bochow *et al.* Overshooting the critical threshold for the Greenland ice sheet. *Nature* **622**, 528–536 (2023). https://doi.org/10.1038/s41586-023-06503-9

Hysteresis


Steady states and hysteresis of the THC
1.5
1.0
0.5
0.0
–0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
THC
Freshwater forcing
Abrupt
change

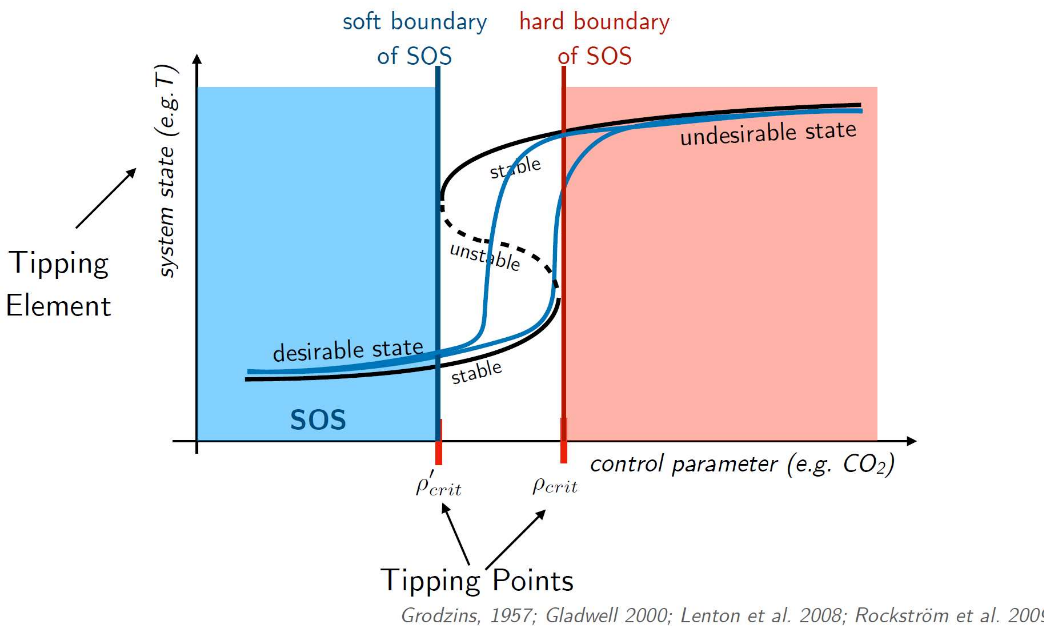
Støj I systemet

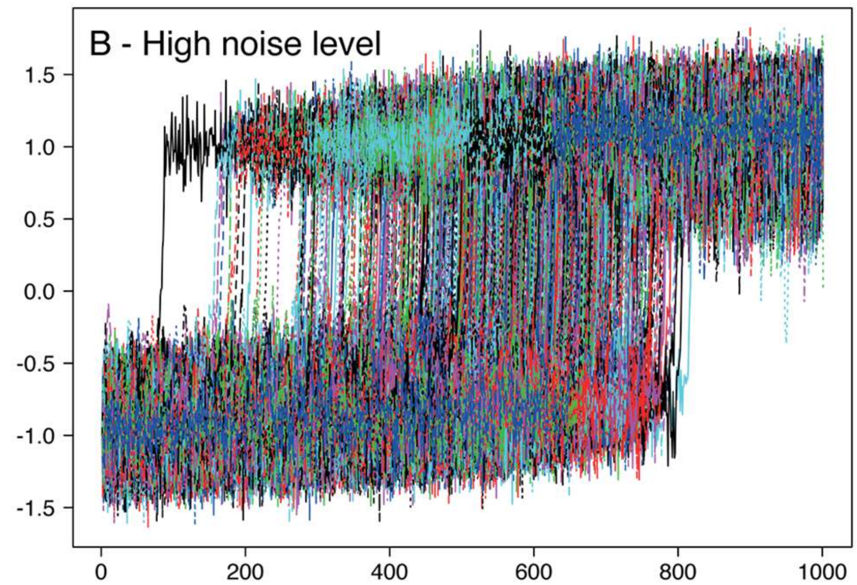




Thomas & Jones, *Tipping points in the past: the role of stochastic noise*, PAGES, 2016

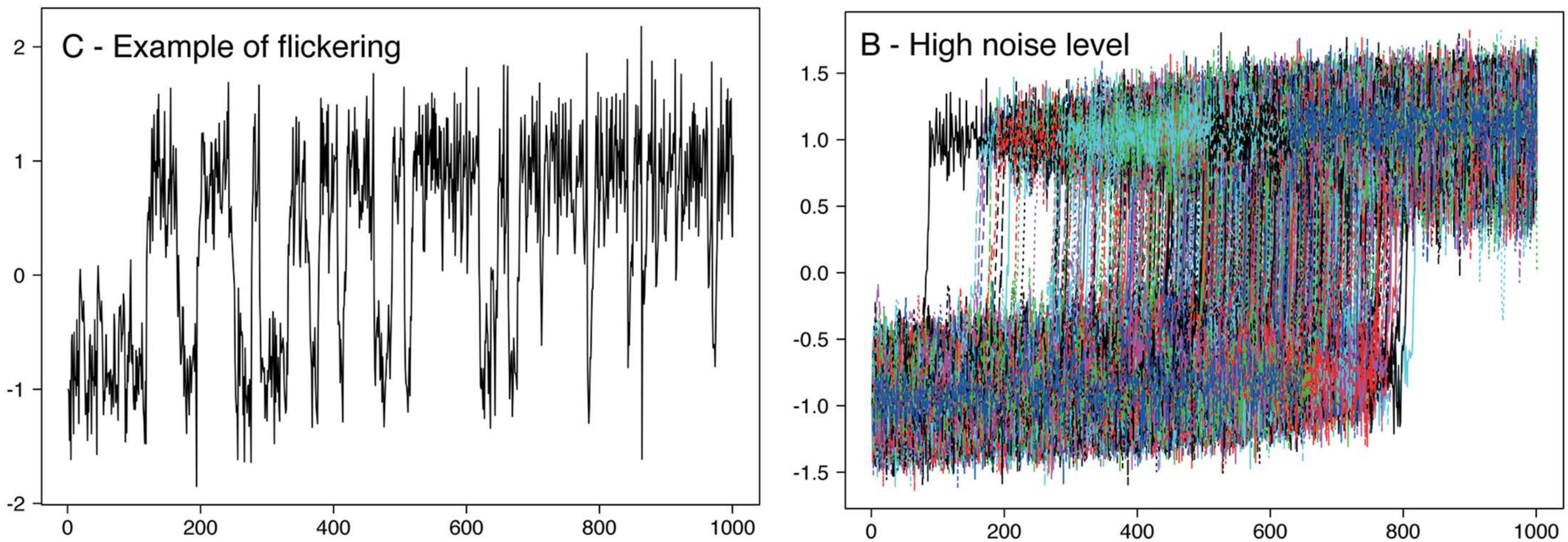
Støj I systemet





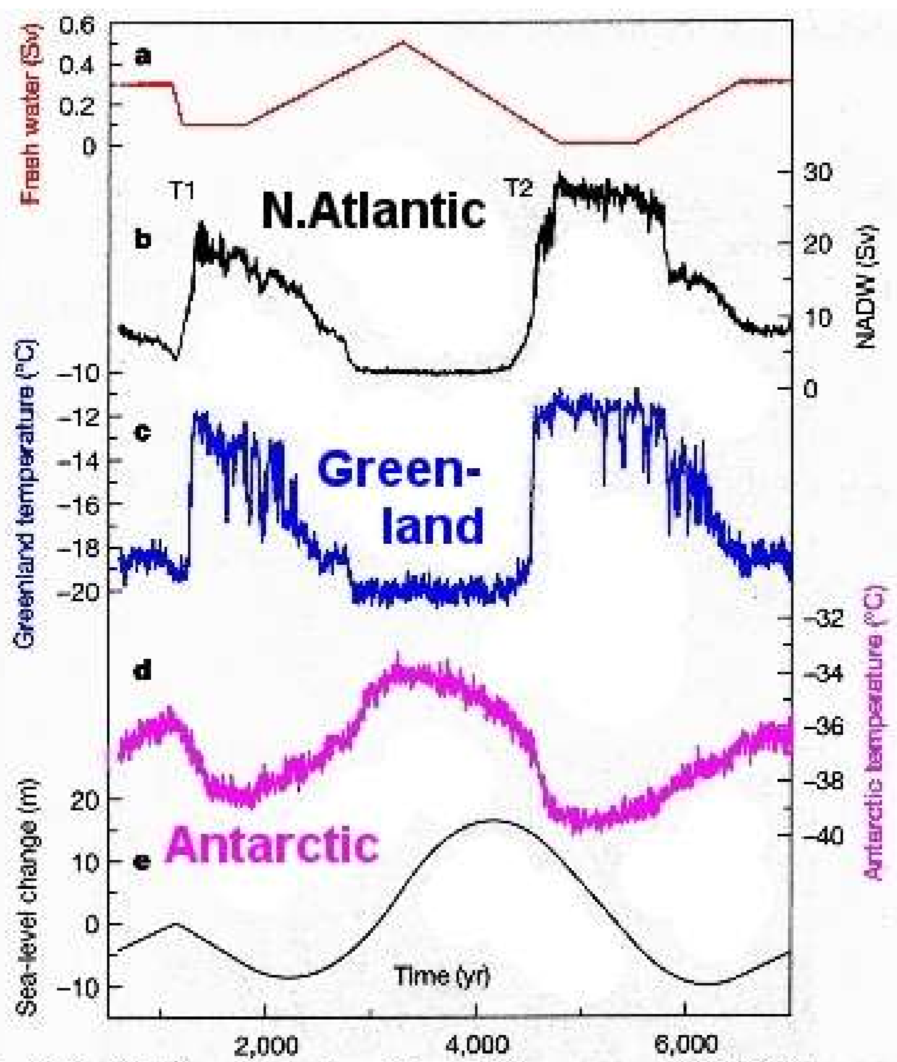
Thomas & Jones, *Tipping points in the past: the role of stochastic noise*, PAGES, 2016

Støj I systemet

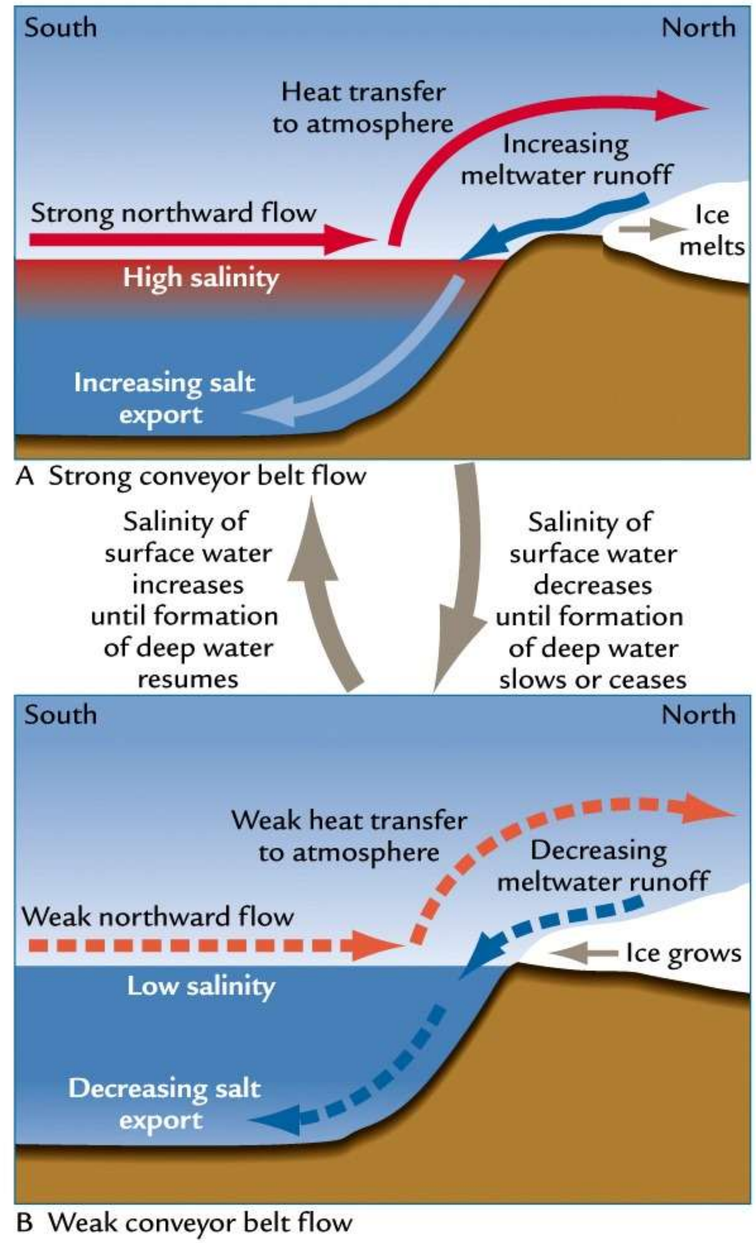


Thomas & Jones, *Tipping points in the past: the role of stochastic noise*, PAGES, 2016

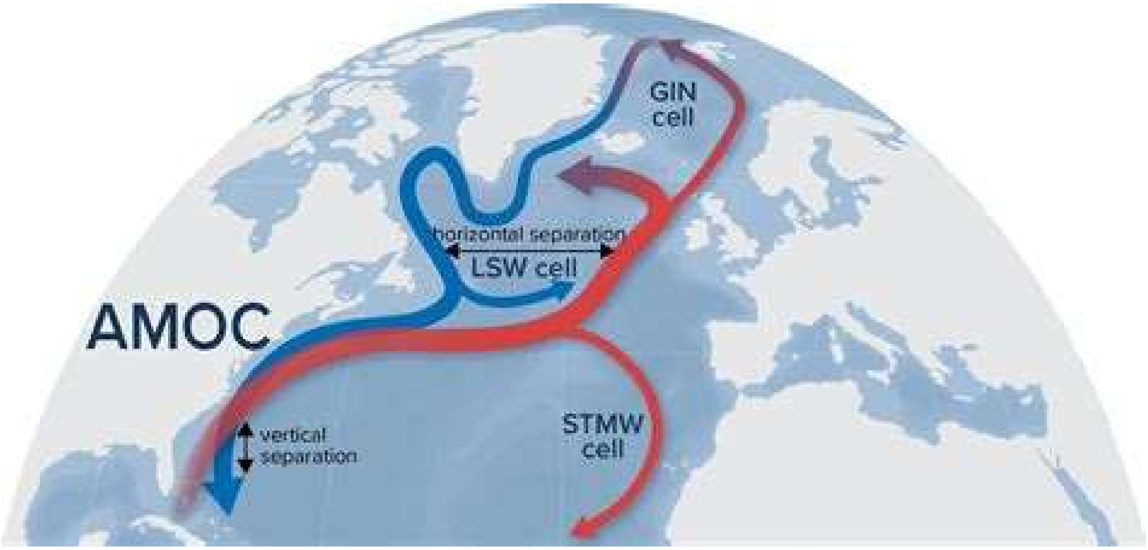
Sea saw

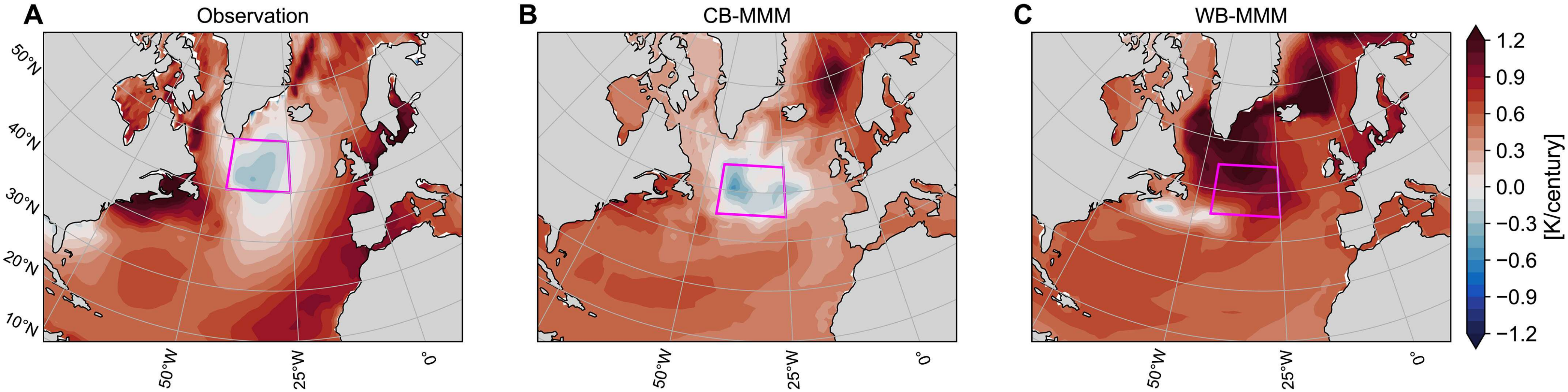


Knutti, R., Flückiger, J., Stocker, T.F. and Timmermann, A. 2004. Strong hemispheric coupling of glacial climate through freshwater discharge and ocean circulation. Nature 430: 851-856.

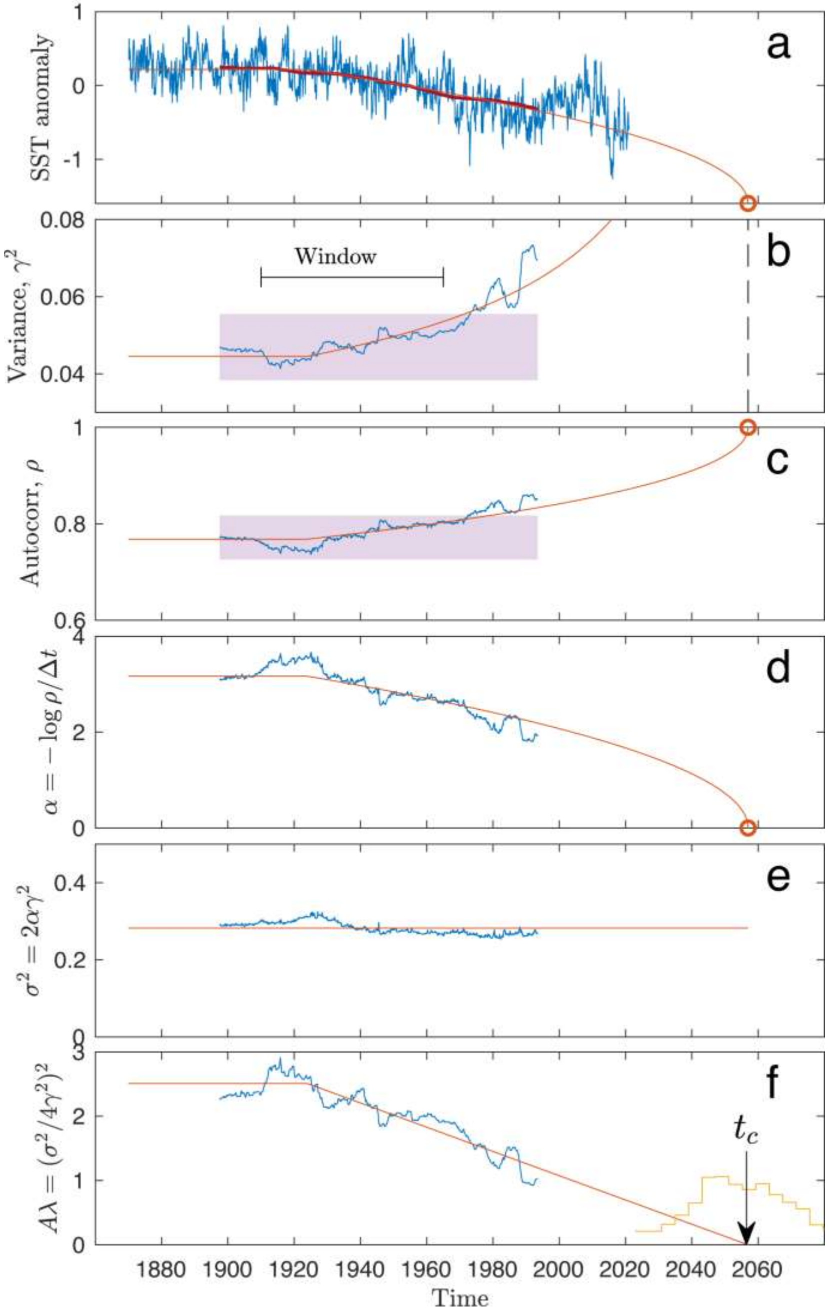


AMOC
& the“Cold blob”





Fan et al. Science advances (2025)



Information

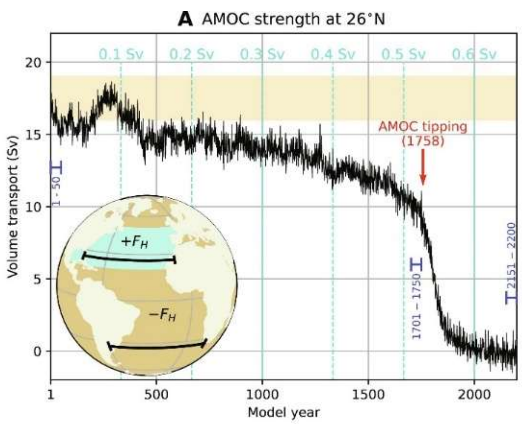
Annonce

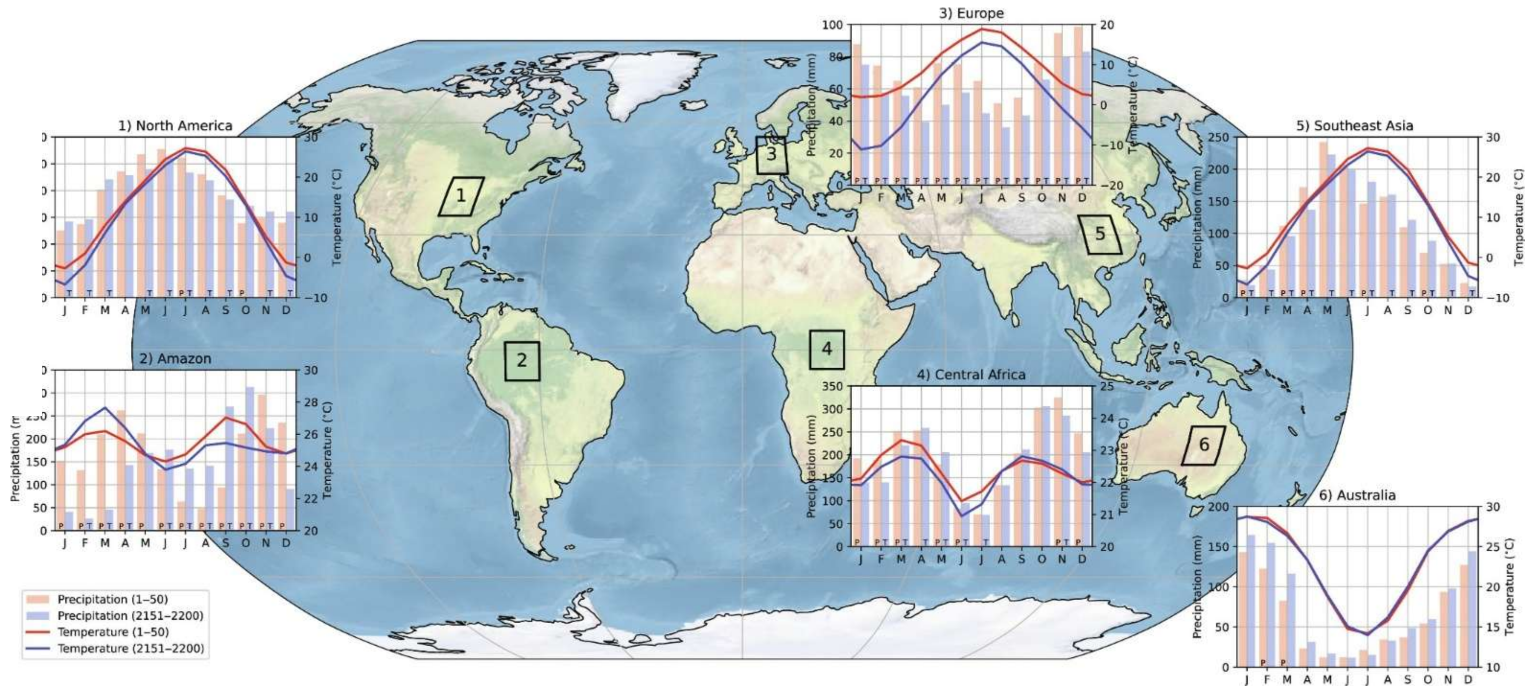
KLIMA Læsetid: 4 min.

Forskere ser tegn på muligt forestående kollaps for Golfstrømmen

Golfstrømmen risikerer at ebbe ud. Den varme atlantiske havstrøm kan simpelthen stoppe – et skrækscenarie, som vil få katastrofale følger over hele verden, også i Danmark. »Vi kan ikke tillade, at det sker,« erklærer forskere bag ny undersøgelse

Ditlevsen og Ditlevsen , Nature, 2023
Podcast:
https://s368.podbean.com/pb/6b86a8446940137cec648fe8a3b6ca84/67313dac/data1/fs59/6694220/uploads/Ditlevsen_AMOC__midcenturytip7rw4g.mp3?pbss=989aabe0-2183-5295-a8be-d9fd104e3c42





" temperature trends of more than 3°C per decade" …"no realistic adaptation measures can deal with such rapid temperature changes under an AMOC collapse"

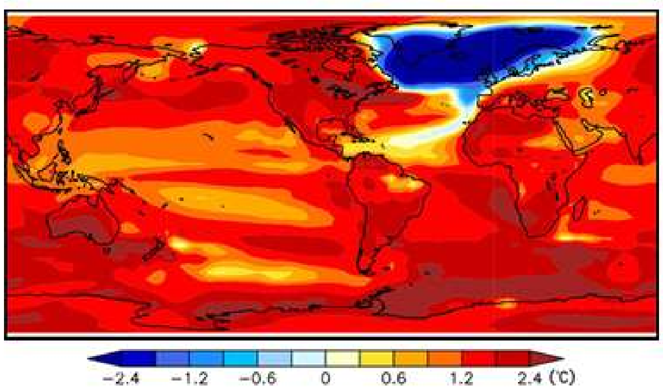
VAN WESTEN ***SCIENCE ADVANCES,*** 2024. Vol 10, Issue 6
DOI: 10.1126/sciadv.adk118

AMOC

Open Letter by Climate Scientists
to the Nordic Council of Ministers

Reykjavik, October 2024

We, the undersigned, are scientists working in the field of climate research and feel it is urgent to draw the attention of the Nordic Council of Ministers to the serious risk of a major ocean circulation change in the Atlantic. A string of scientific studies in the past few years suggests that this risk has so far been greatly underestimated. Such an ocean circulation change would have devastating and irreversible impacts especially for Nordic countries, but also for other parts of the world.



Annual mean temperature change in an idealised future CO2 doubling scenario in which the AMOC has fully collapsed. Source: Science[1].

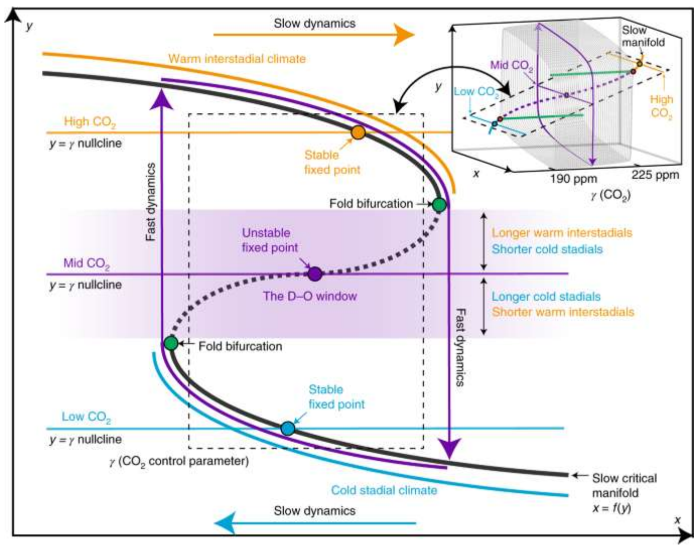
https://en.vedur.is/media/ads_in_header/AMOC-letter_Final.pdf

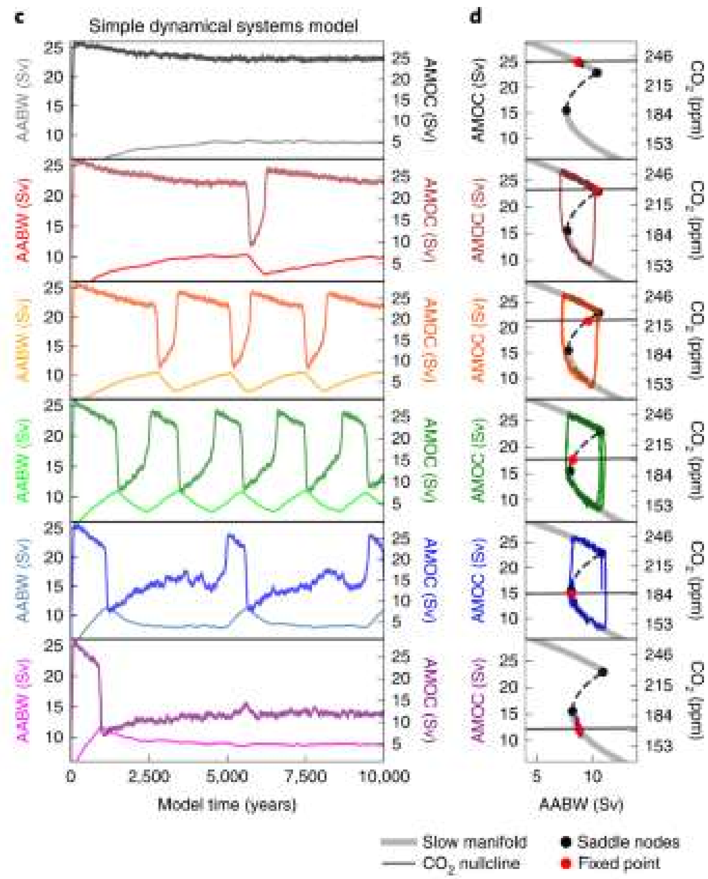
KASTEM 2024

Risk assessment 2025

- The Atlantic Meridional Overturning Circulation (AMOC) and Subpolar Gyre (SPG) have different tipping points and timescales of transition but are strongly coupled via influencing stratification of the northern North Atlantic ocean.
- Crossing either tipping point has numerous impacts, including much harsher northwestern European winters, disruption of the West African Monsoon, decreased agricultural yield and marine ecosystem shifts.
- The conditions under which SPG and AMOC can tip remain uncertain, due to a limited observational record and biases in climate models, but we cannot exclude that an AMOC tipping point may already have been passed.
- Deep winter mixing in both the SPG and Greenland-Iceland-Norwegian Seas is projected to collapse in the North Atlantic before 2050 in many CMIP6 models causing AMOC to decline to weak states without a deep circulation.
- The likelihood of tipping for both systems increases with global temperature.

Tipping I fortiden-modeler





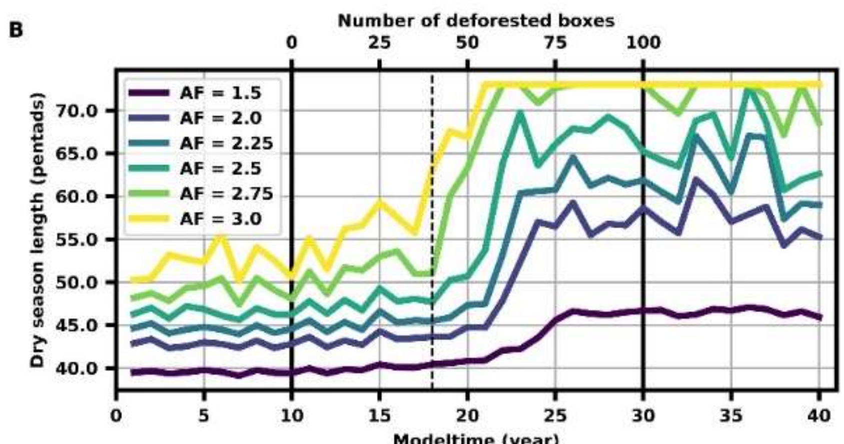
225 ppm C

Tipping

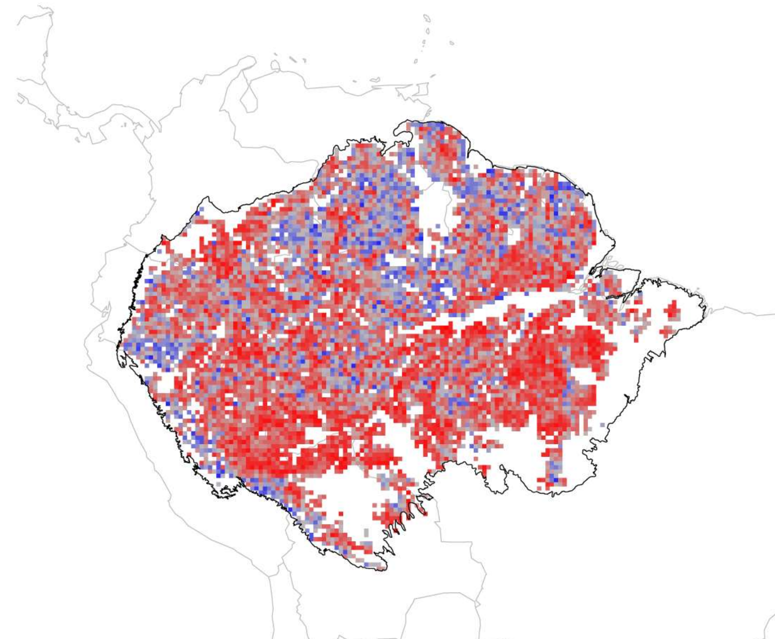
190 ppm C

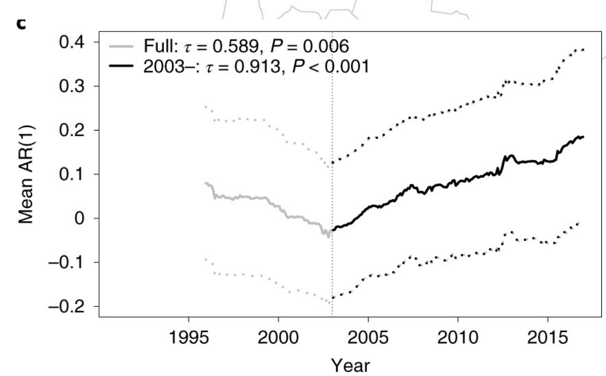
Amazonas

- Reduceret nedbør og længere tørke perioder pga af anthropogen opvarmning.
- Siden 2000 et tab af vegetationens modstandsdygtighed (stigende lag-one autocorrelation and varians)-set I Vegetation optical depth (VOD)
- Ses stærkere I tørere områder og tættere ved mennesker (veje, farme, byer etc.)
- Et decideret kollaps sker omkring 40% tab af skoven (T111, Bochow and Boers, in revision)
- Ved at lave analyse også af ERA5 data (vejrdata) finder de yderligere at det sydamerikanske monsoon system har tabt stabilitet I nord og vest Amazonas særligt



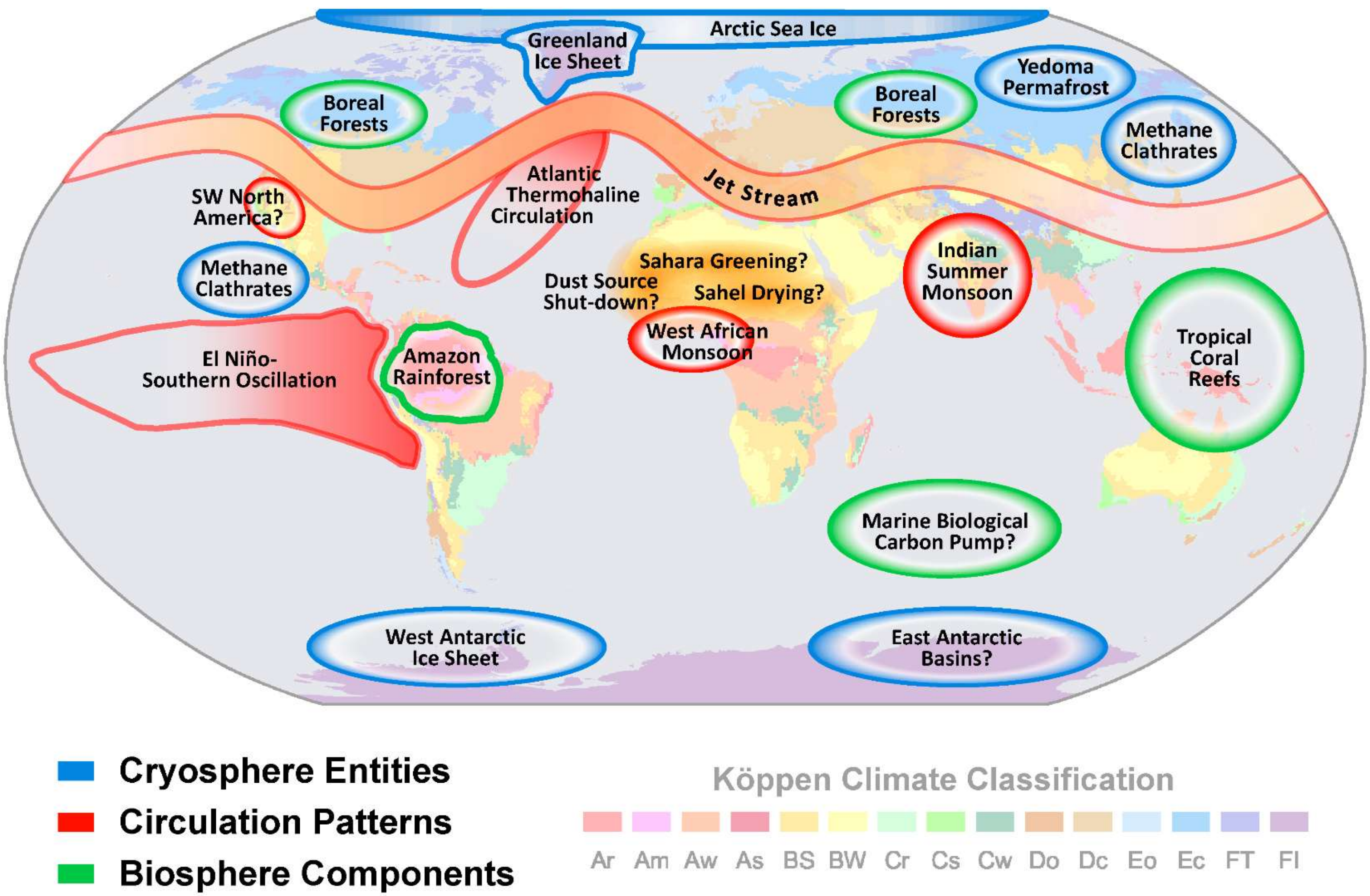
BOCHOW & BOERS ***SCIENCE ADVANCES*** 2023 Vol 9, Issue 40 DOI:0.1126/sciadv.add99





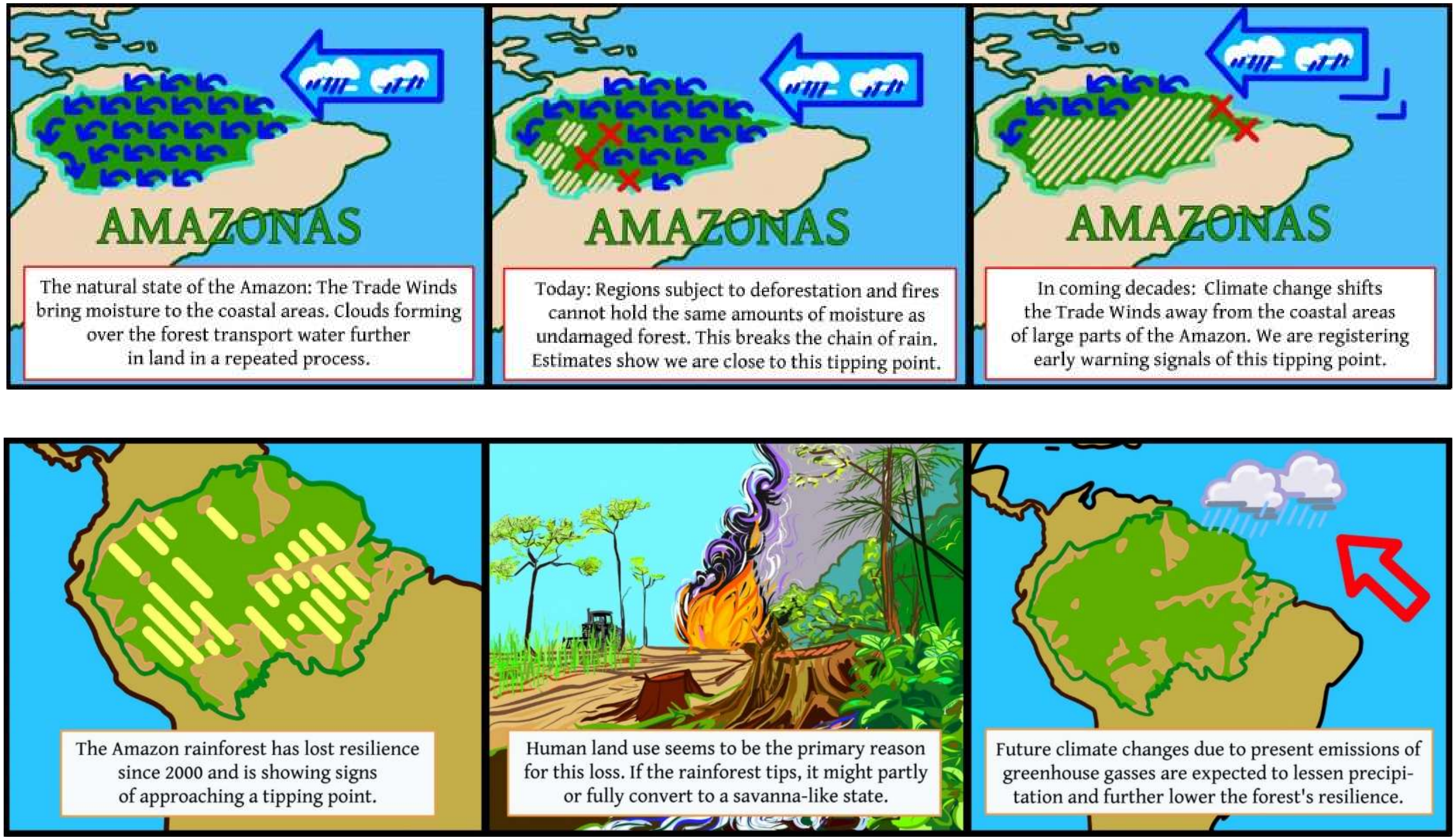
Boulton, Lenton, and Boers. *Nature Climate Change* 12.3 (2022): 271-278.)

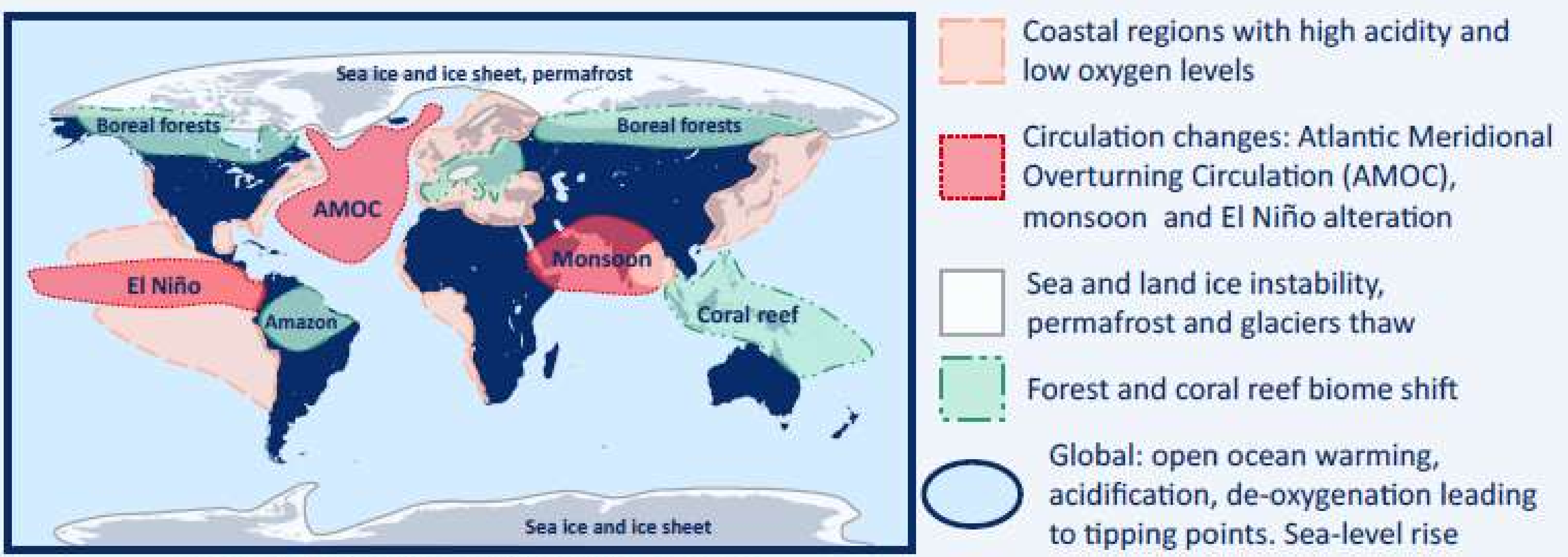
Potential policy-relevant tipping elements in the climate system



https://www.pik-potsdam.de/services/infodesk/tipping-elements/kippelemente

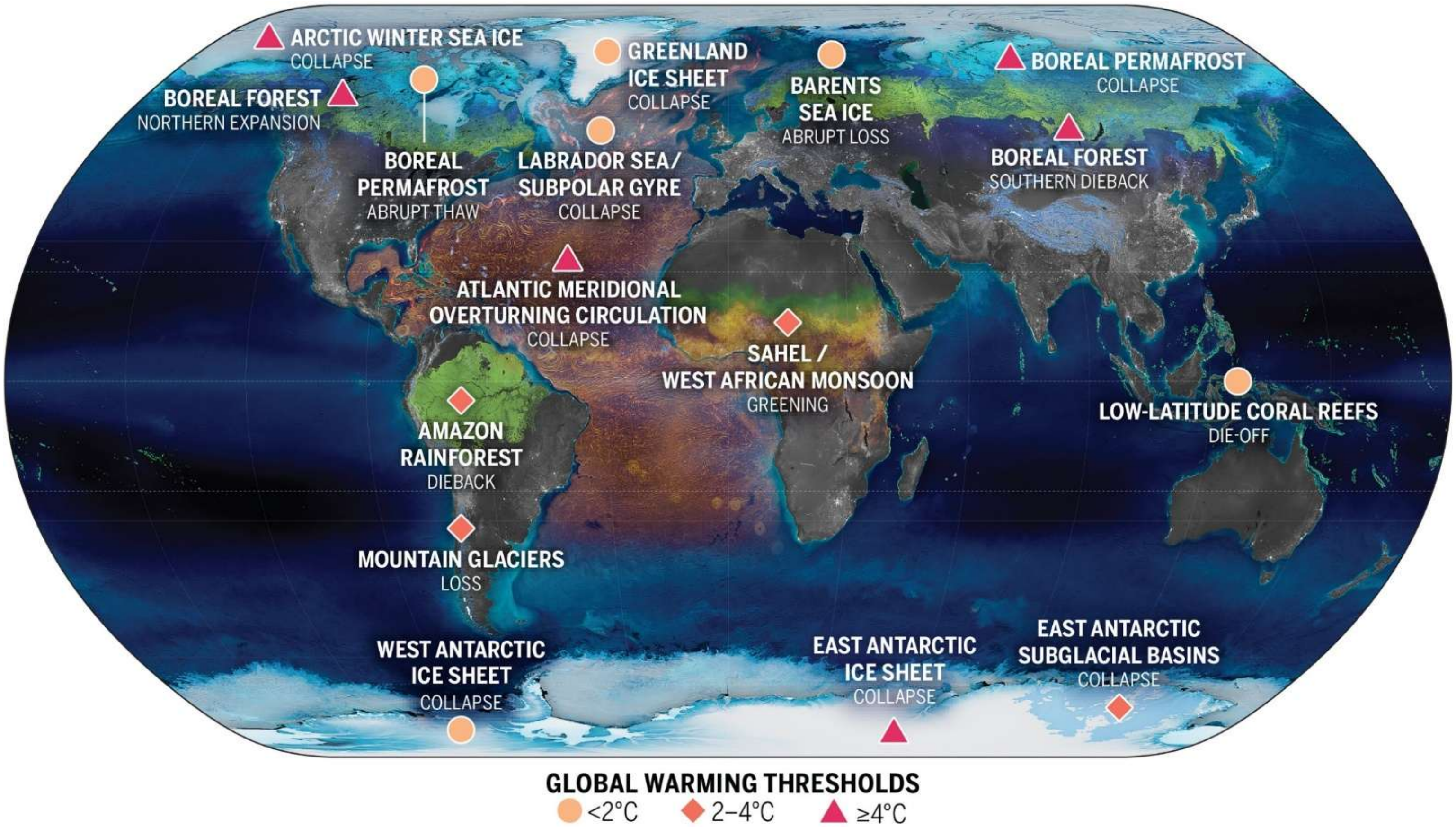
Tipper amazonas?



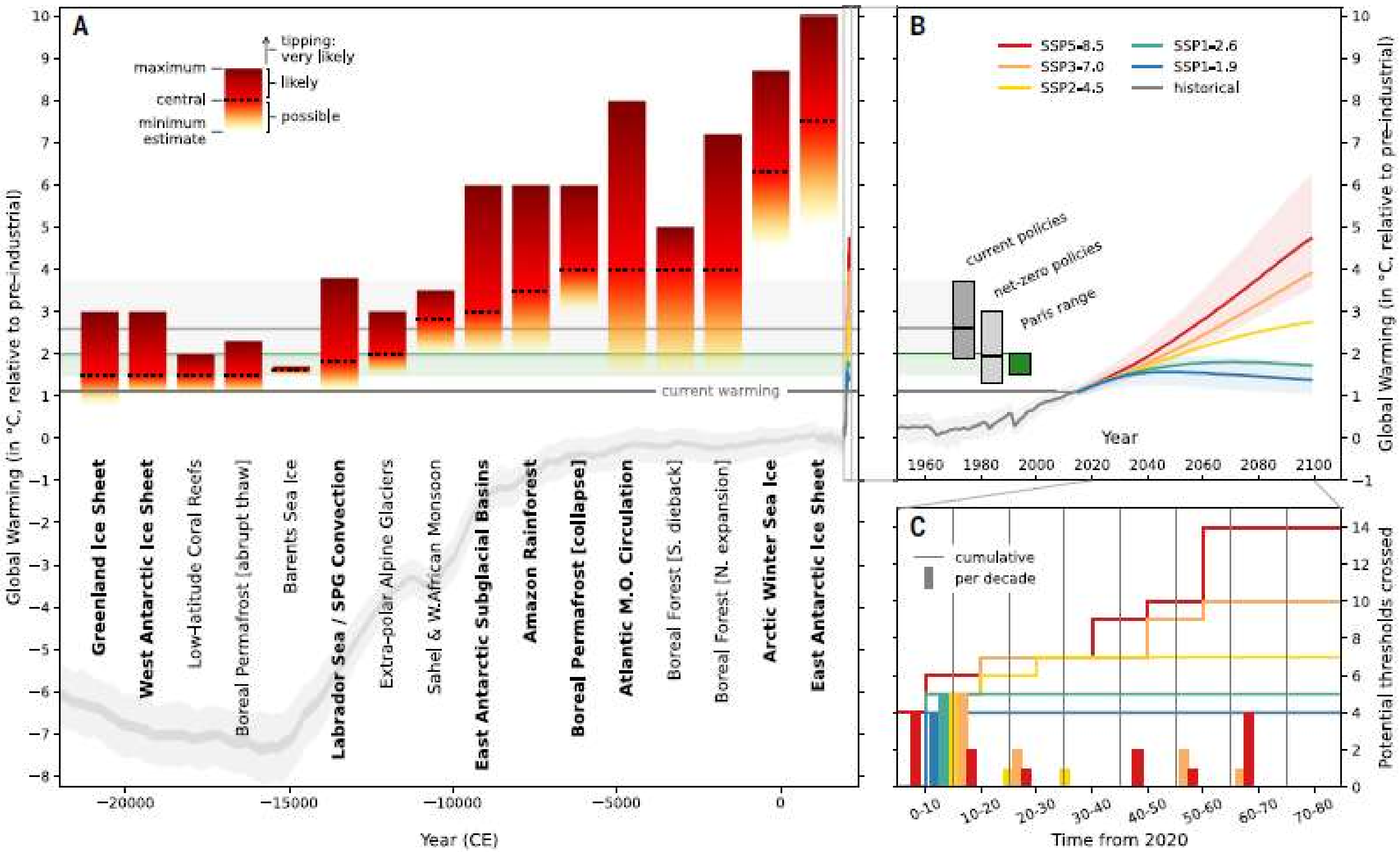


Please note that regions are only indicative, not precise.

Figure modified from Heinze et al., PNAS 2021. Licence: 4.0 (CC BY)

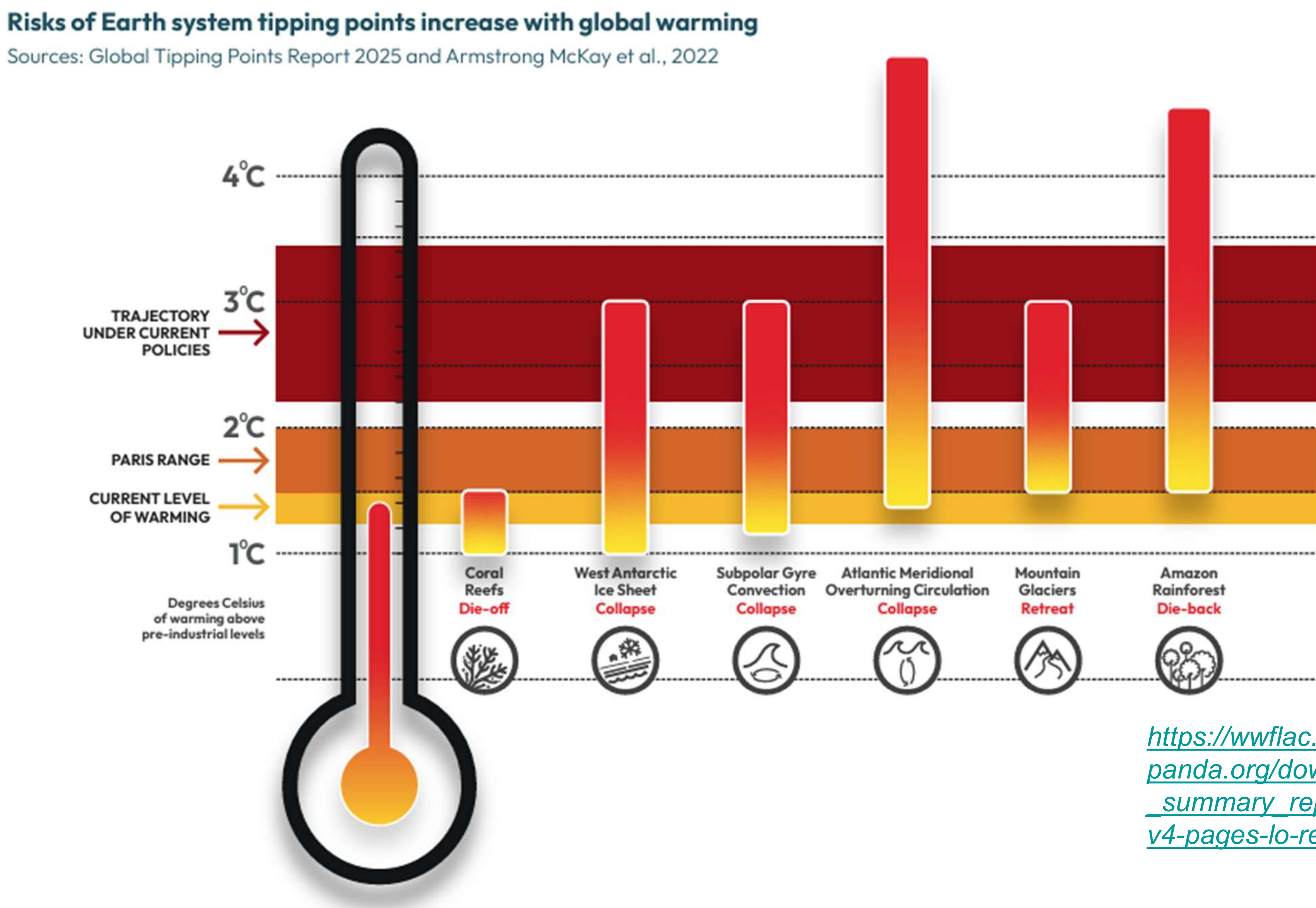


Armstrong McKay et al., Science 377, 1171 (2022)

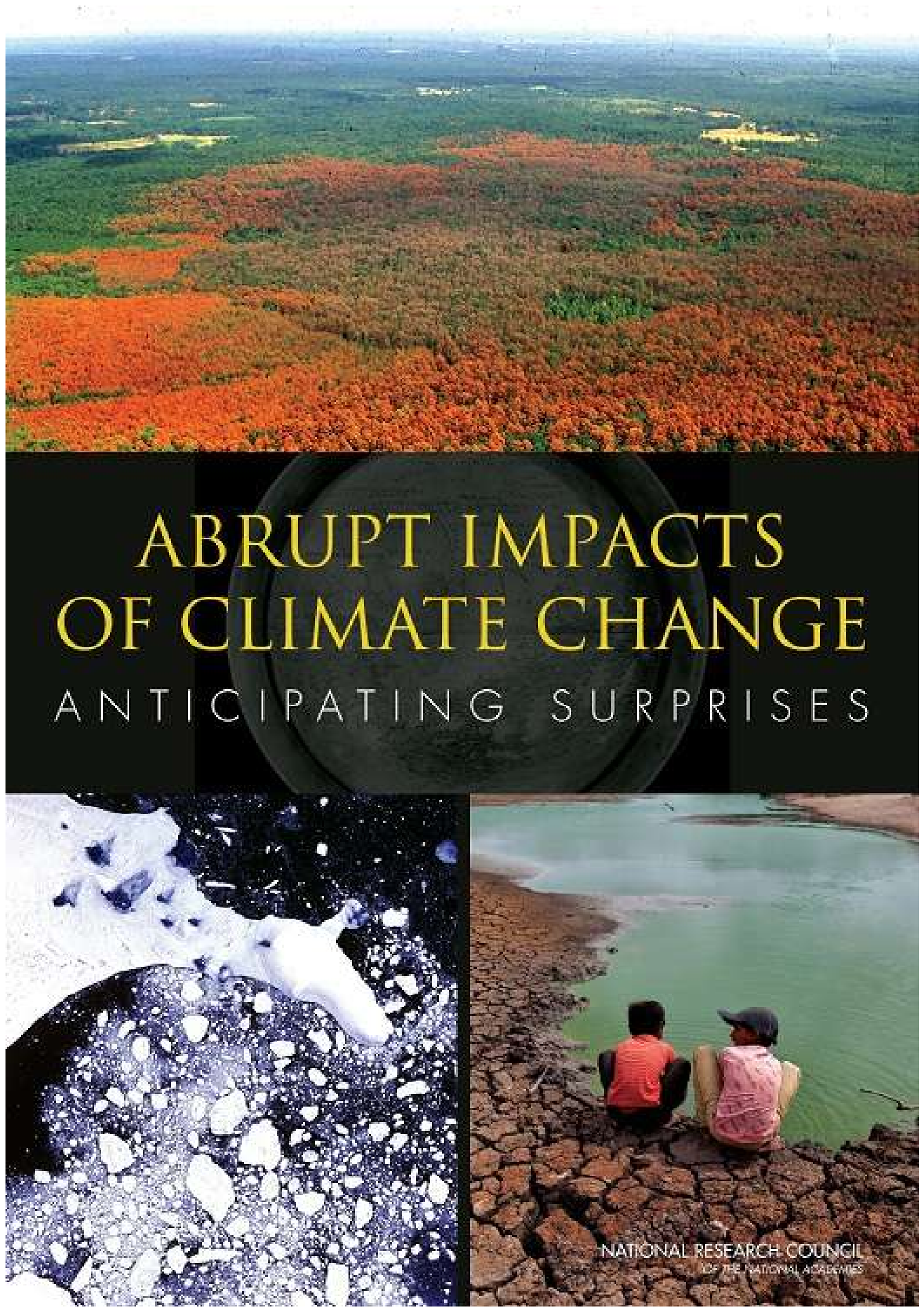


Armstrong McKay et al., Science 377, 1171 (2022)

2025 tipping point report



https://wwflac.awsassets.panda.org/downloads/gtp_summary_report_2025-v4-pages-lo-res--1-.pdf


ABRUPT IMPACTS
OF CLIMATE CHANGE
ANTICIPATING SURPRISES
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

Klima topmøde i 7 klasse

Aska Maria Ono Bjerresø, Jens Boje Pedersen, Julie Blessing, Stine Guldberg Graungård Petersen

Topmødet var bygget op som et scenarie, hvor eleverne havde forberedt en tale, hvor de repræsenterede et dyr fra Arktis. Derefter startede topmødet, hvor eleverne tjekkede ind og blev sat i en halvcirkel. Eleverne præsenterede deres tale for alle. Efterfølgende blev de præsenteret for fire løsningsforslag, hvor de afslutningsvis skulle begrunde, hvilket handlingstiltag de ville vælge - stadig med fokus på deres dyr

Figur 5. Klimatopmøde som scenariedidaktisk ramme i gletsjerforløbet.