# Le climat est-il prévisible ?

- Un simple problème astronomique

Les mouvements de la Terre
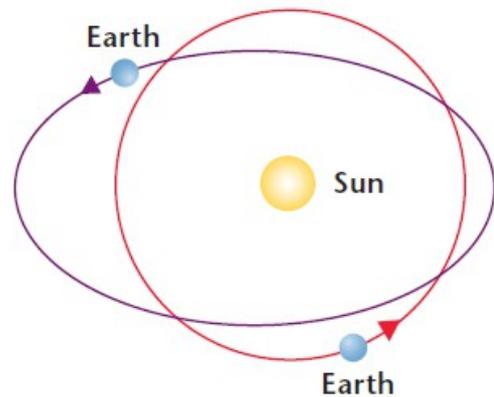
Eccentricity Earth encounters more variation in the energy that it receives from the sun when Earth's orbit is elongated than it does when Earth's orbit is more circular.
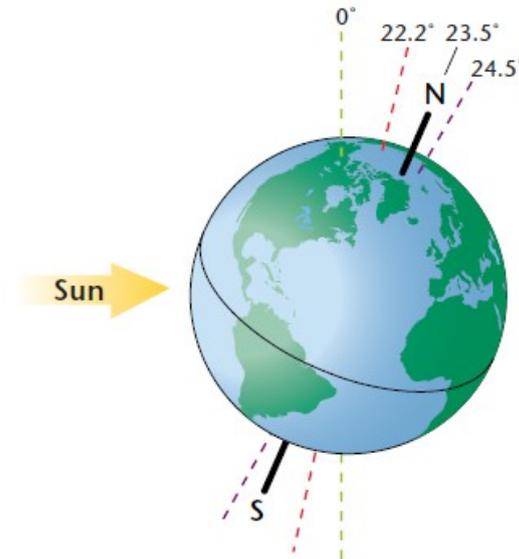
Tilt The tilt of Earth's axis varies between 22.2° and 24.5°. The greater the tilt angle is, the more solar energy the poles receive.
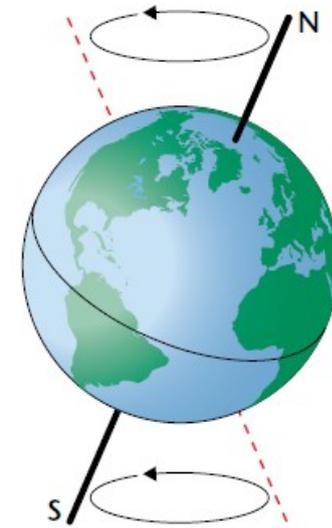
Precession A gradual change, or "wobble," in the orientation of Earth's axis affects the relationship between Earth's tilt and eccentricity.

Des rythmes différents
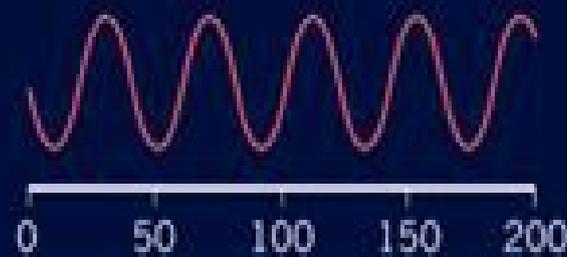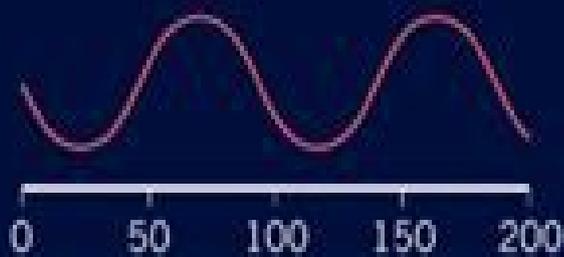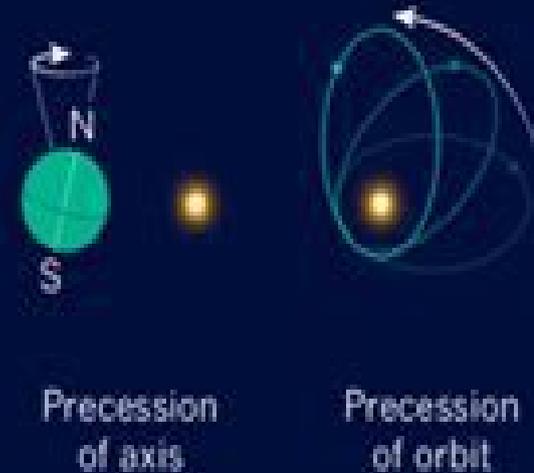
# Qui se retrouvent dans le climat !

Milankovitch Cycles Apparent in Vostok Ice Core Data

~ 100,000 year cycle

Antarctic Ice Core Data 1

Temperature Variation — CO2 Concentration
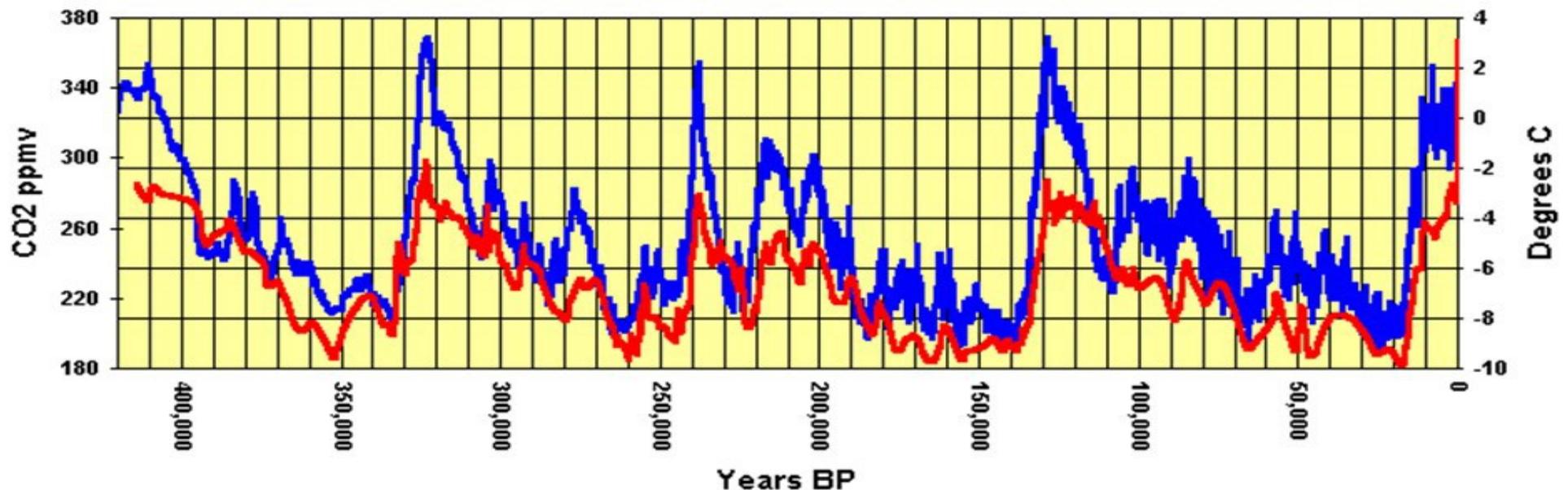
A la recherche des climats anciens: La station Vostok

Un premier zoom : stabilisation

Vostok Ice Cores   50,000 - 2,500 years ago

Temperature
Carbon Dioxide

joannenova.com.au
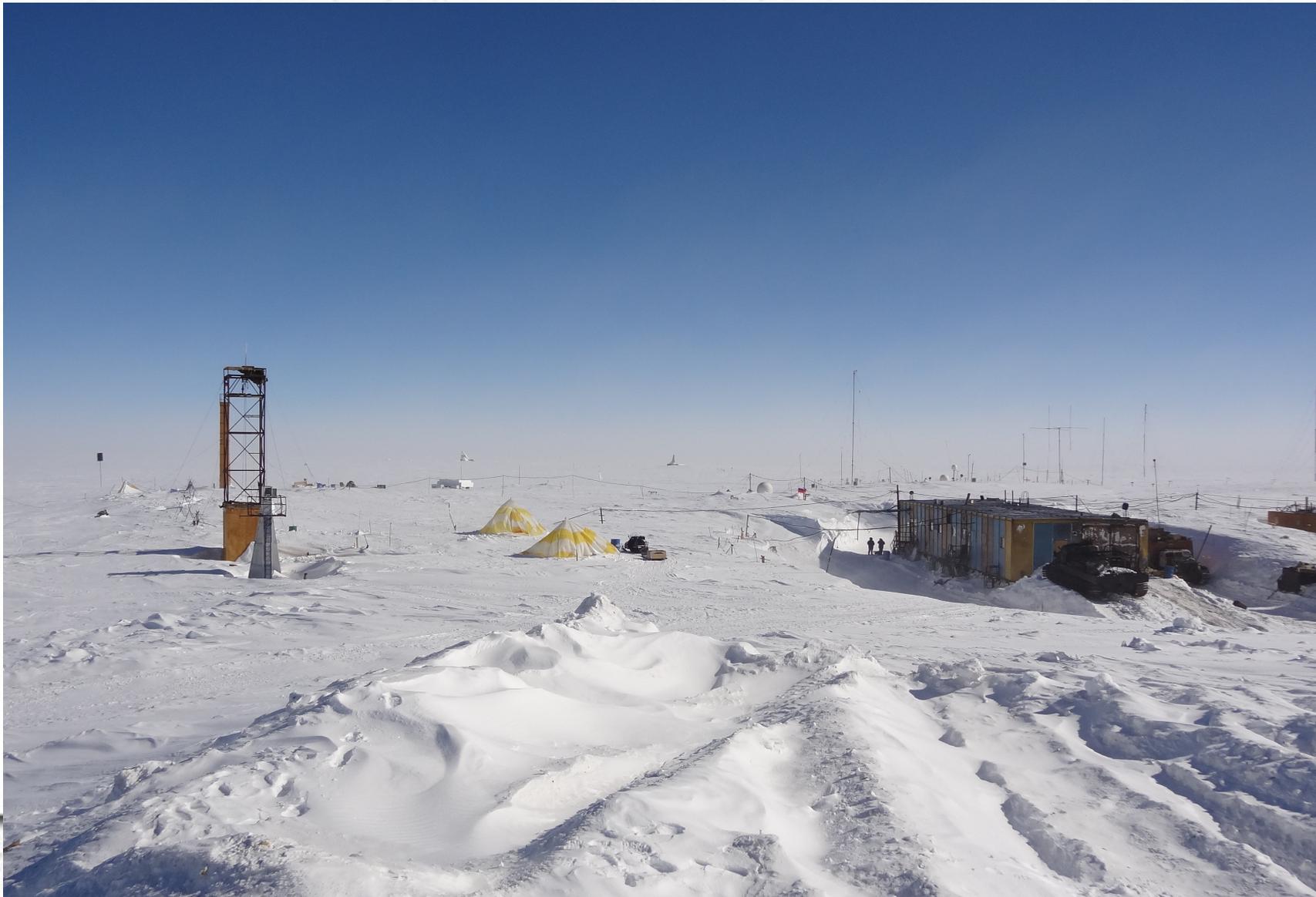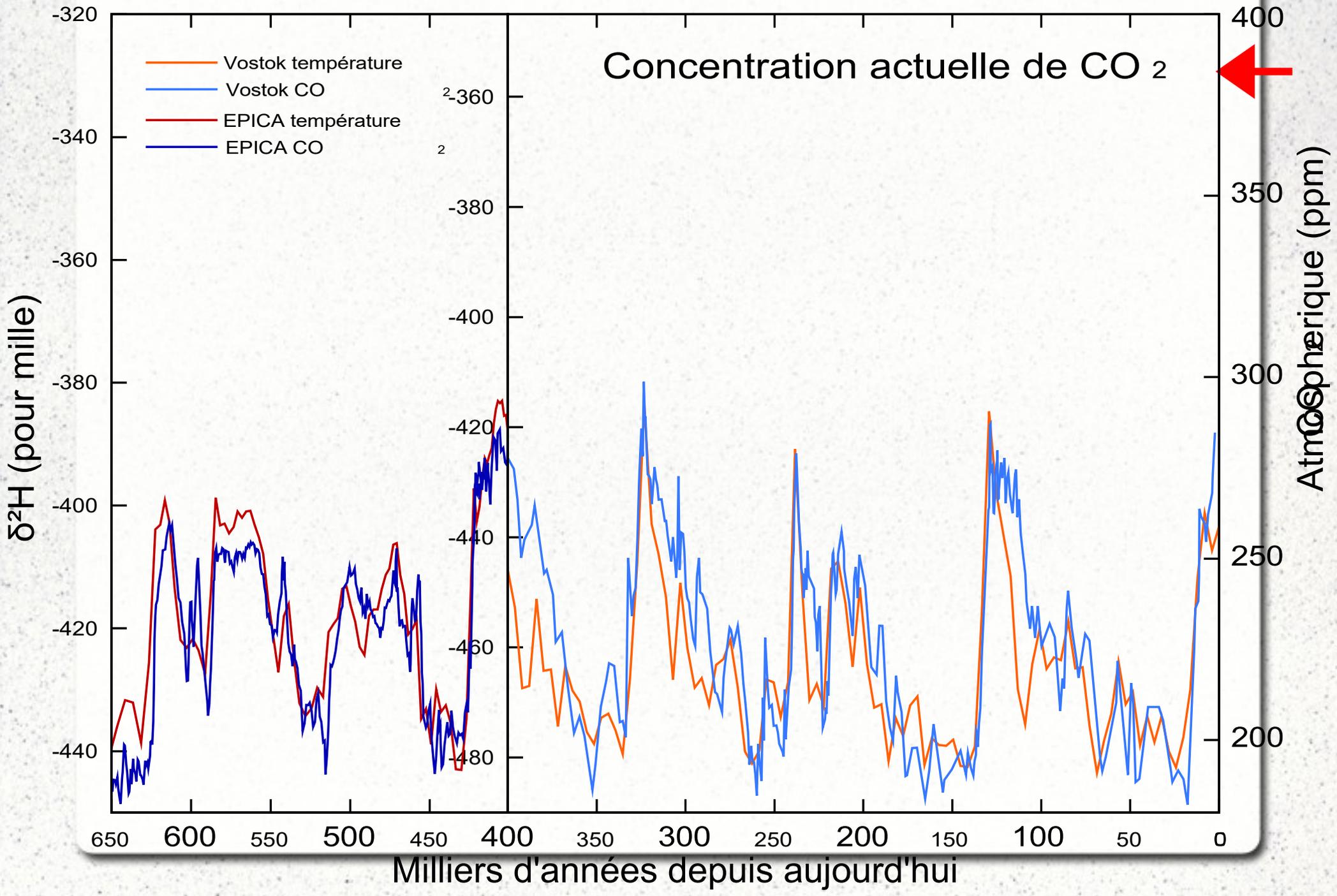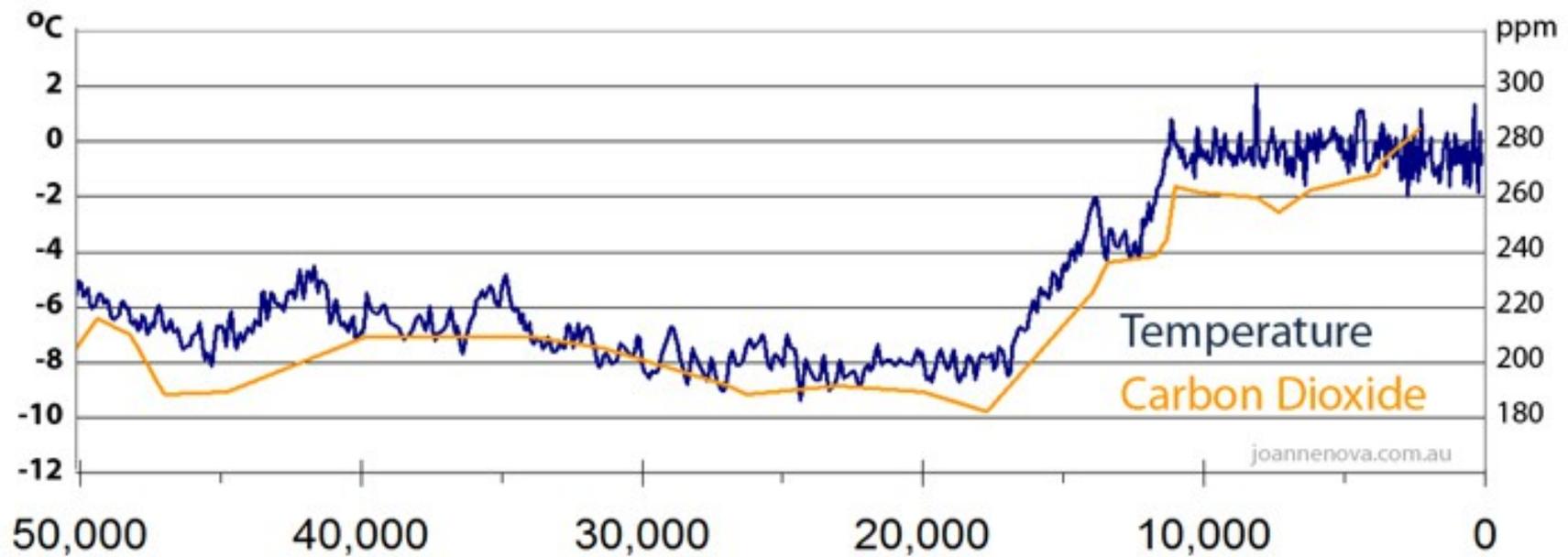
L'Europe voici 50 000 ans

Un premier zoom : stabilisation

Vostok Ice Cores   50,000 - 2,500 years ago

Temperature

Carbon Dioxide

joannenova.com.au
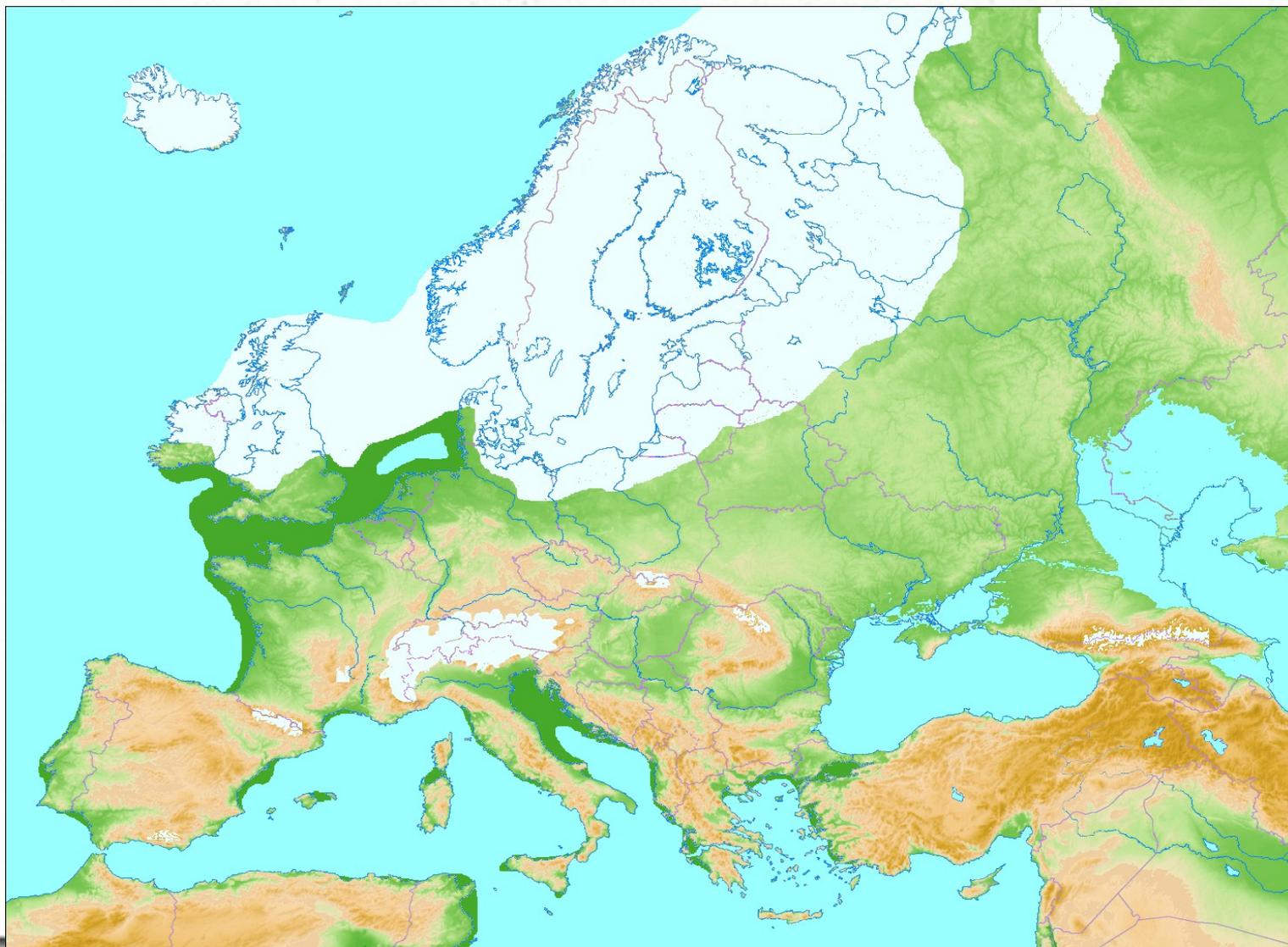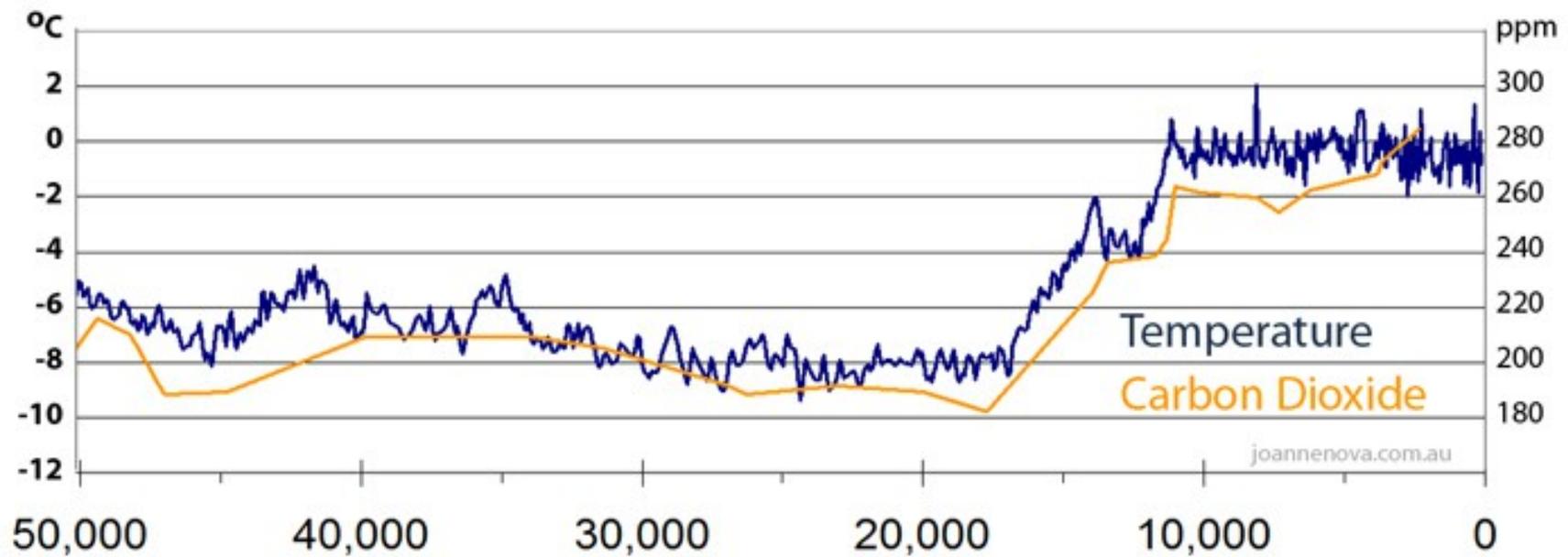
Un deuxième zoom

Average temperature anomaly, Global
Global average land-sea temperature anomaly relative to the 1961-1990 average temperature

Upper
Median
Lower

0.8 °C
0.6 °C
0.4 °C
0.2 °C
0 °C
-0.2 °C
-0.4 °C

1850   1880   1900   1920   1940   1960   1980   2000   2019
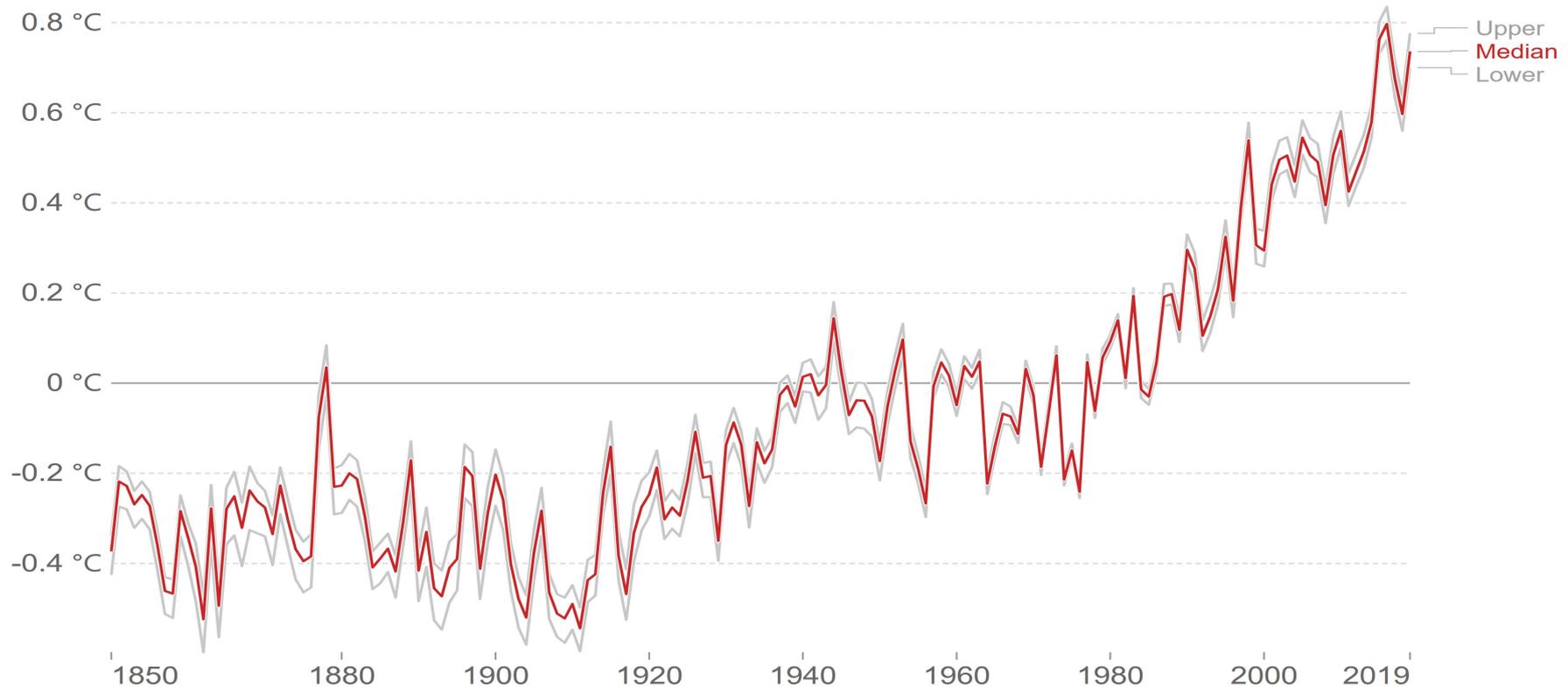
Source: Hadley Centre (HadCRUT4)
Note: The red line represents the median average temperature change, and grey lines represent the upper and lower 95% confidence intervals.
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

Le réchauffement planétaire atteint 1,1°C – inédit depuis plus de 2 000 ans

Changement **observé** de température de surface planétaire
depuis 1850-1900
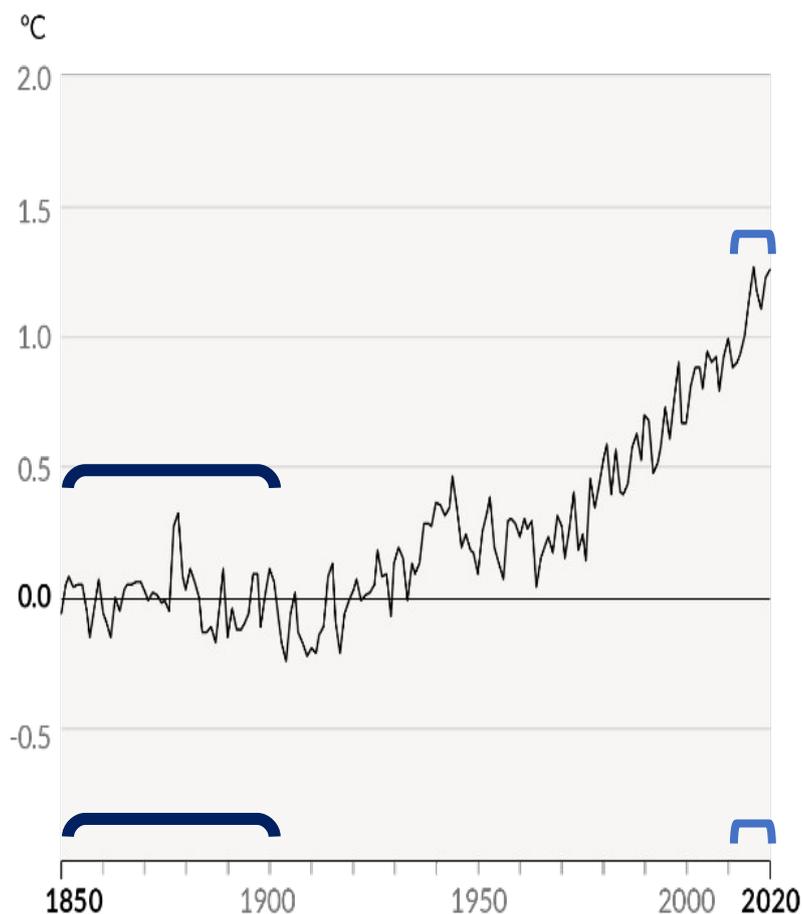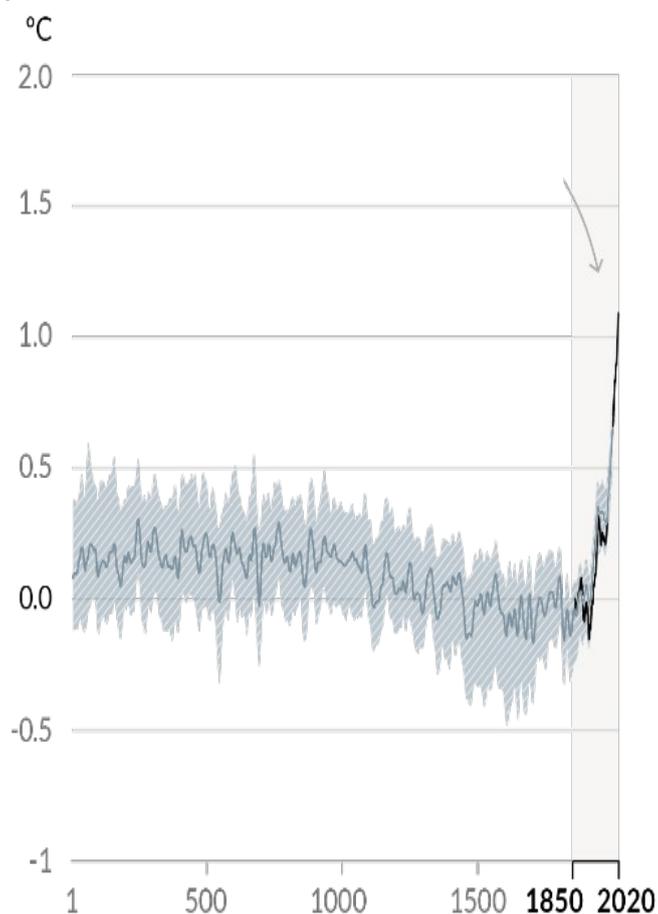
+ 1,7°C en France
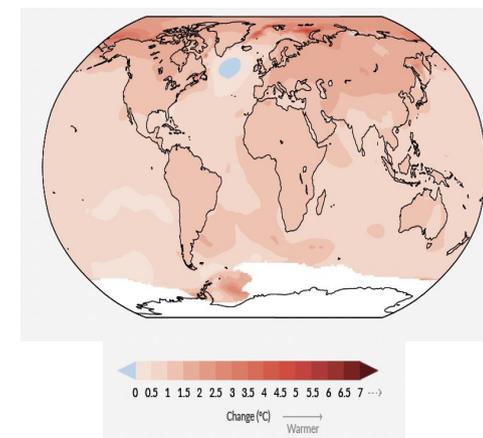
(b) Warming accelerated after the 1970s, but not all regions are warming equally

1900–1980

1981–2020

−0.6 −0.4 −0.2 −0.1 0.0 0.1 0.2 0.4 0.6

Colour Significant

Trend (°C per decade)

××× Non significant
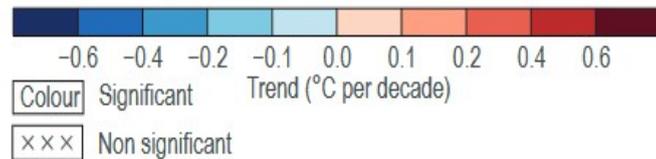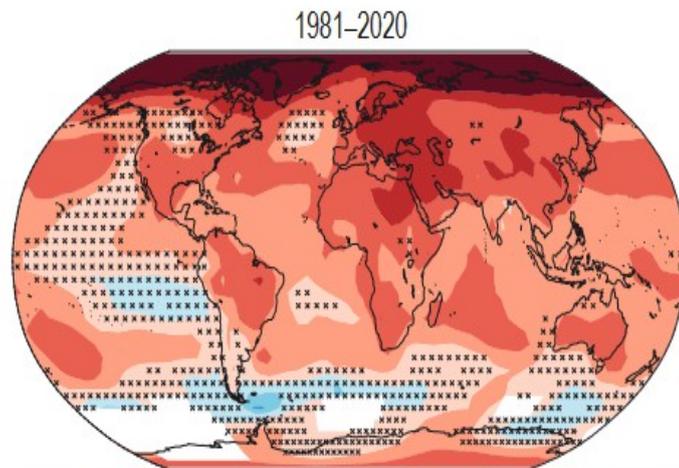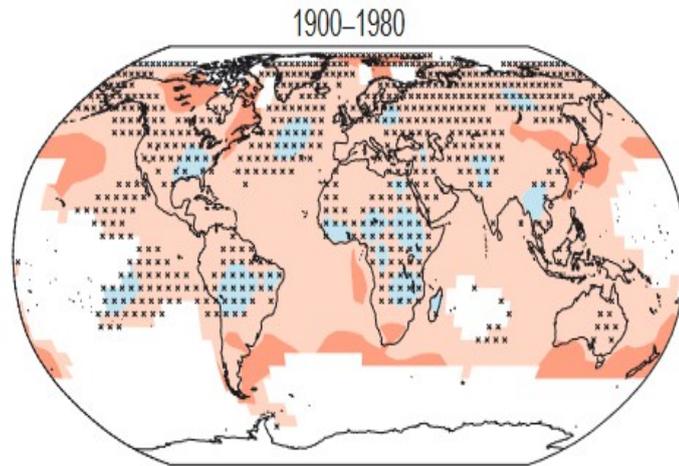
(c) Temperatures have increased faster over land than over the oceans

1.59

0.88

Land
Oceans

Annual and decadal averages

HadCRUT .5.0 NOAAGlobalTemp
Kadow et al.   Berkeley Earth

Each of the last four decades has in turn been warmer than any decade that preceded it since 1850.

Global surface temperature relative to 1850–1900 (°C)
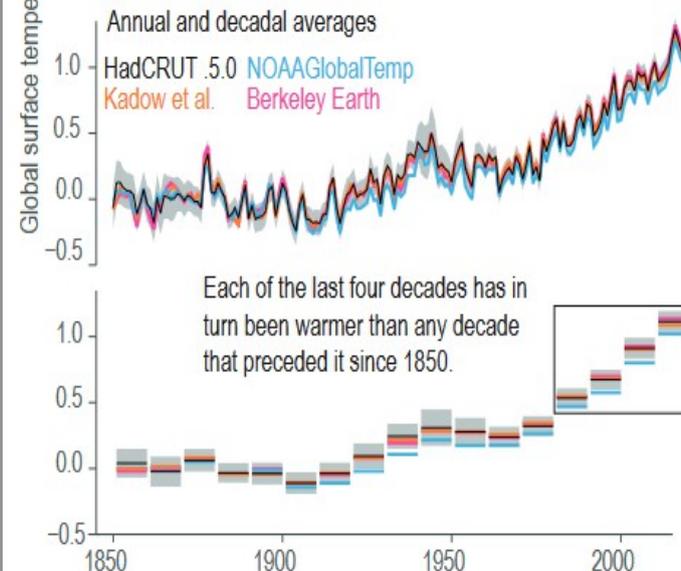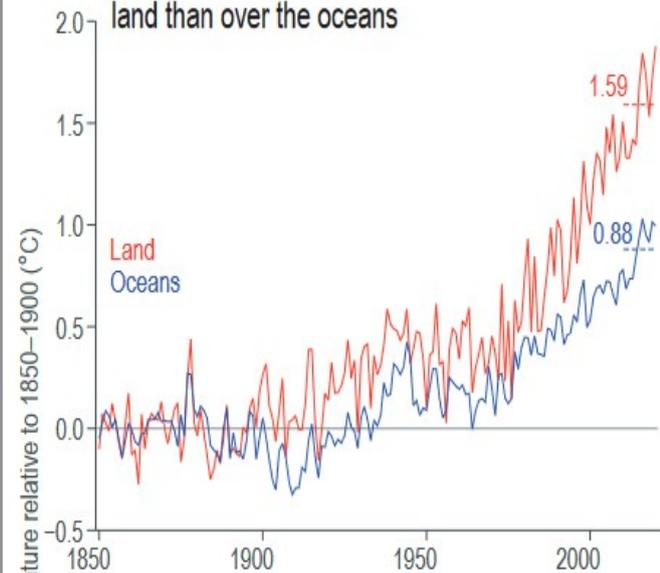
Le climat est-il prévisible ?

- Le décrochage des températures n'était pas prévu

- Pas explicable par des phénomènes astronomiques

- Quelle en est la cause ?

L'histoire du CO2
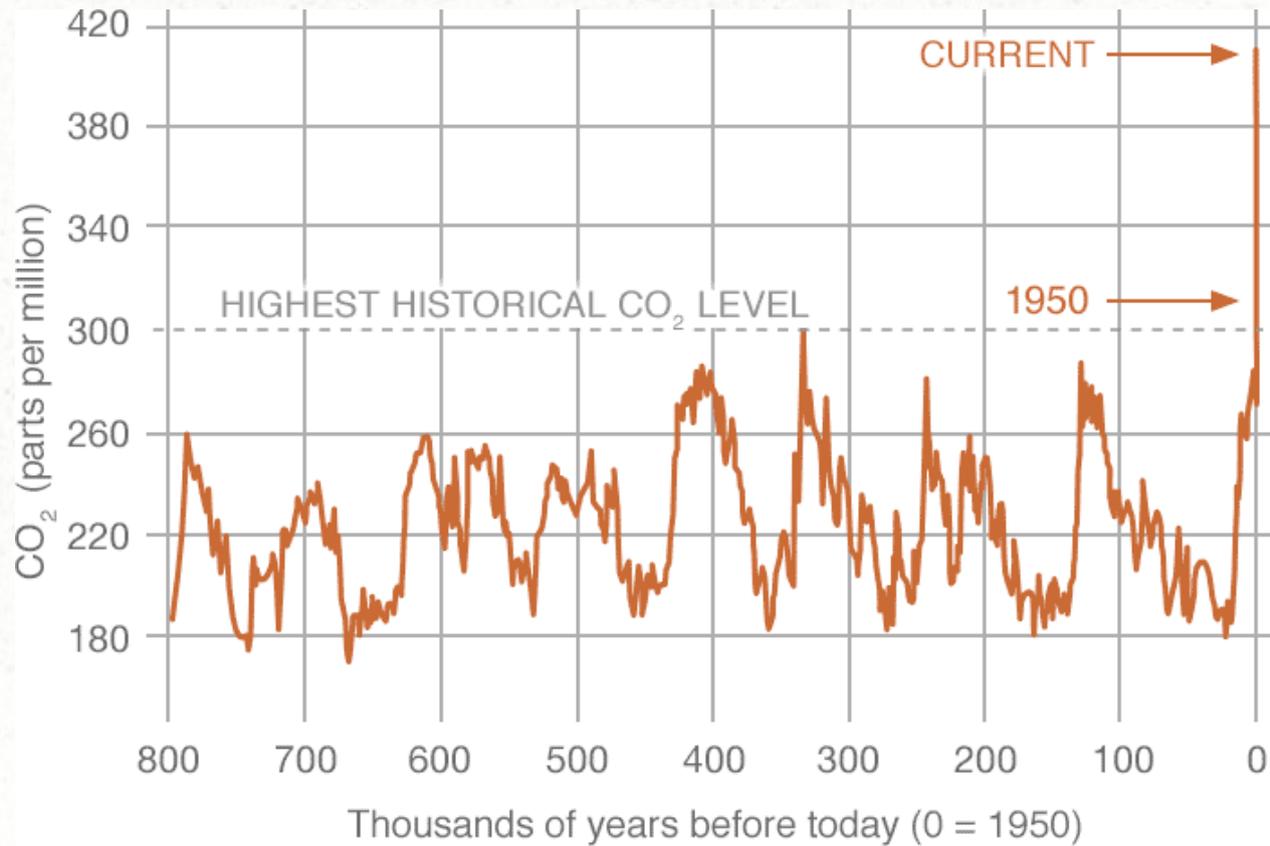
L'observatoire de Mauna Loa

La courbe de Keeling

Carbon dioxide concentration at Mauna Loa Observatory

Full record ending October 12, 2022
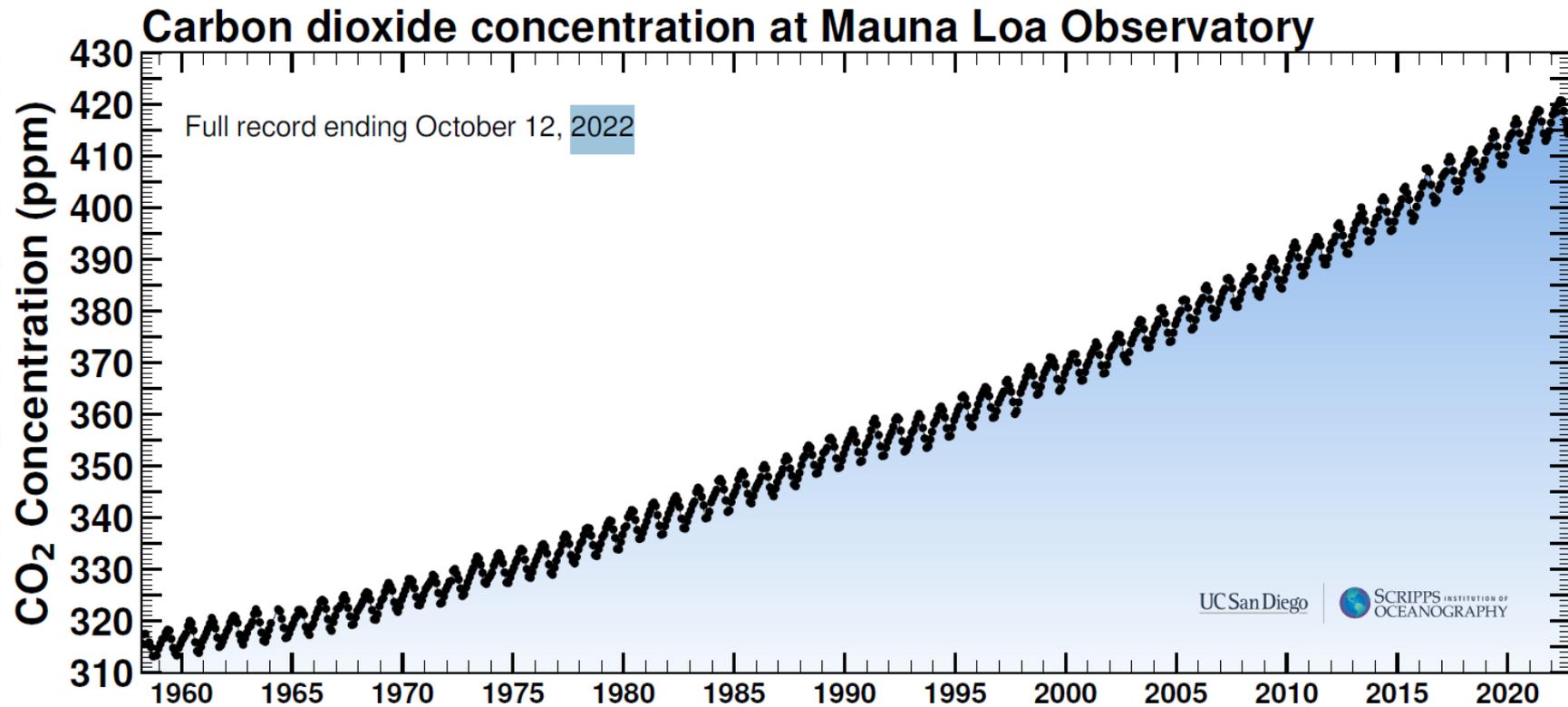
Le climat est-il prévisible ?

- Corrélation ou explication ?

- Effet ou cause ?

L'effet de serre

Un phénomène à l'oeuvre naturellement

30% réfléchis

rayonnement
solaire

rayonnement infrarouge émis par
le sol en grand partie retenus par
l'atmosphère

20% absorbés

50% vers
le sol
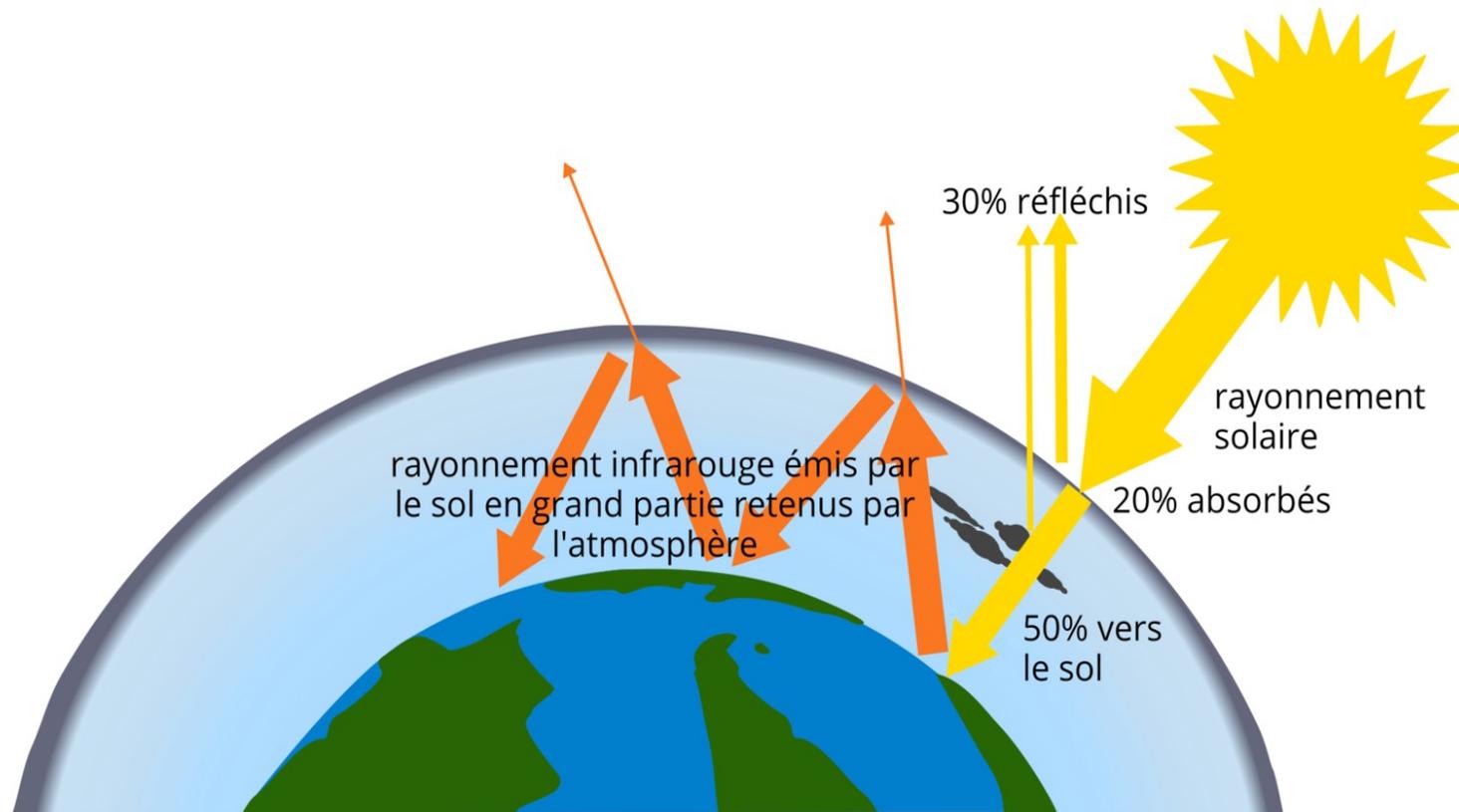
Source des données : DREAL Auvergne-Rhône-Alpes

Les gaz à effet de serre
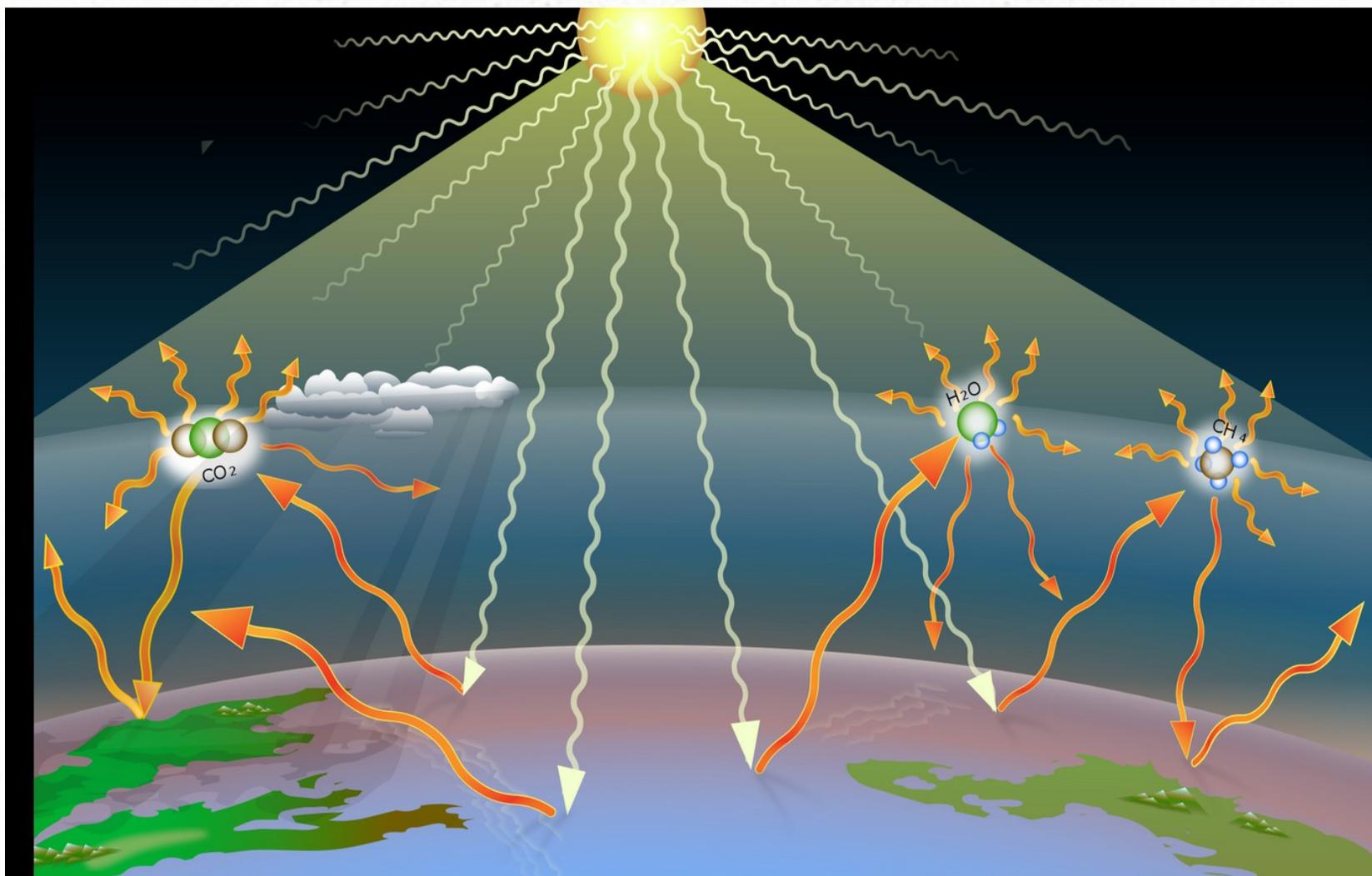
Annual CO₂ emissions

Carbon dioxide (CO₂) emissions from fossil fuels and industry. Land use change is not included.
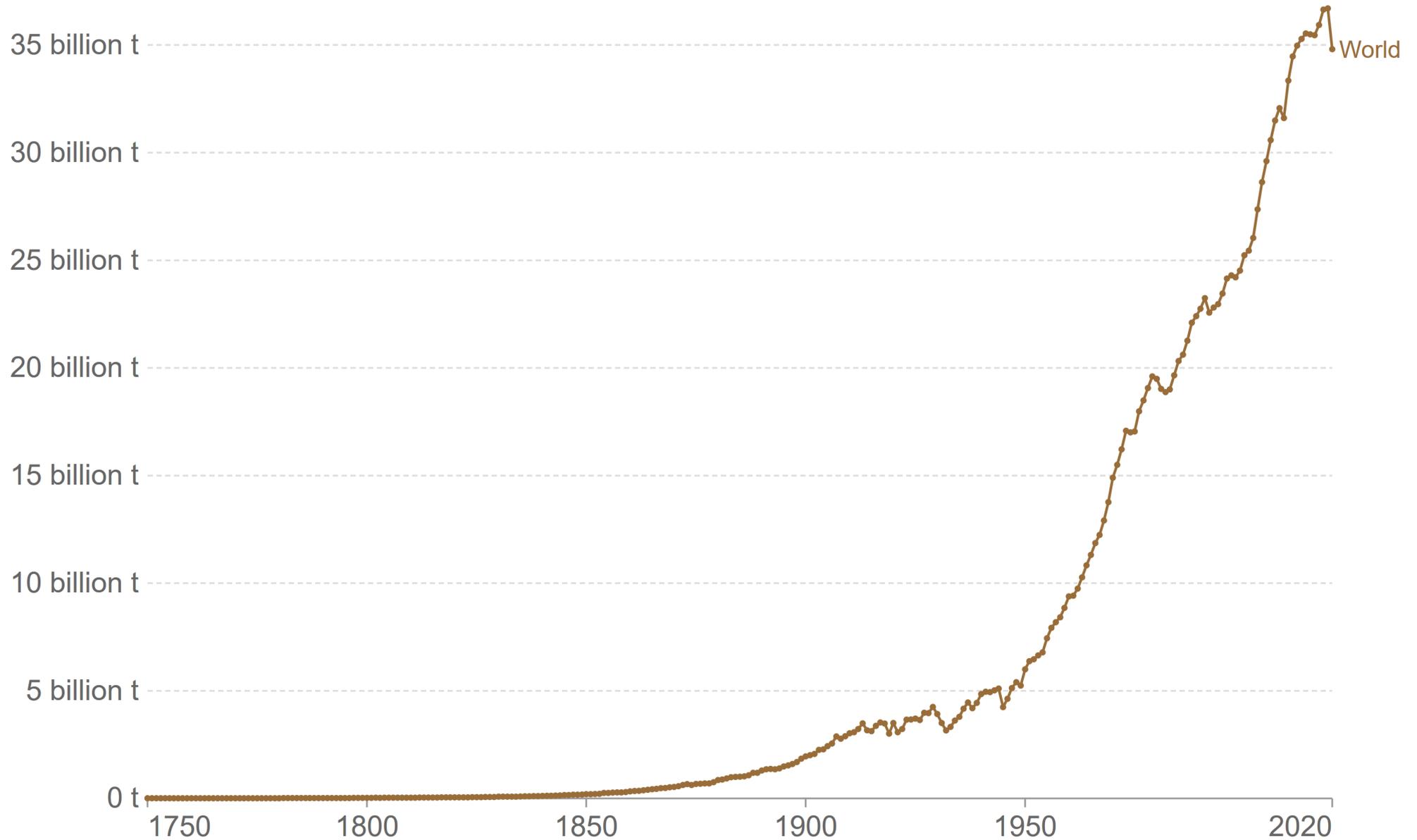
Global fossil fuel consumption

Global primary energy consumption by fossil fuel source, measured in terawatt-hours (TWh).
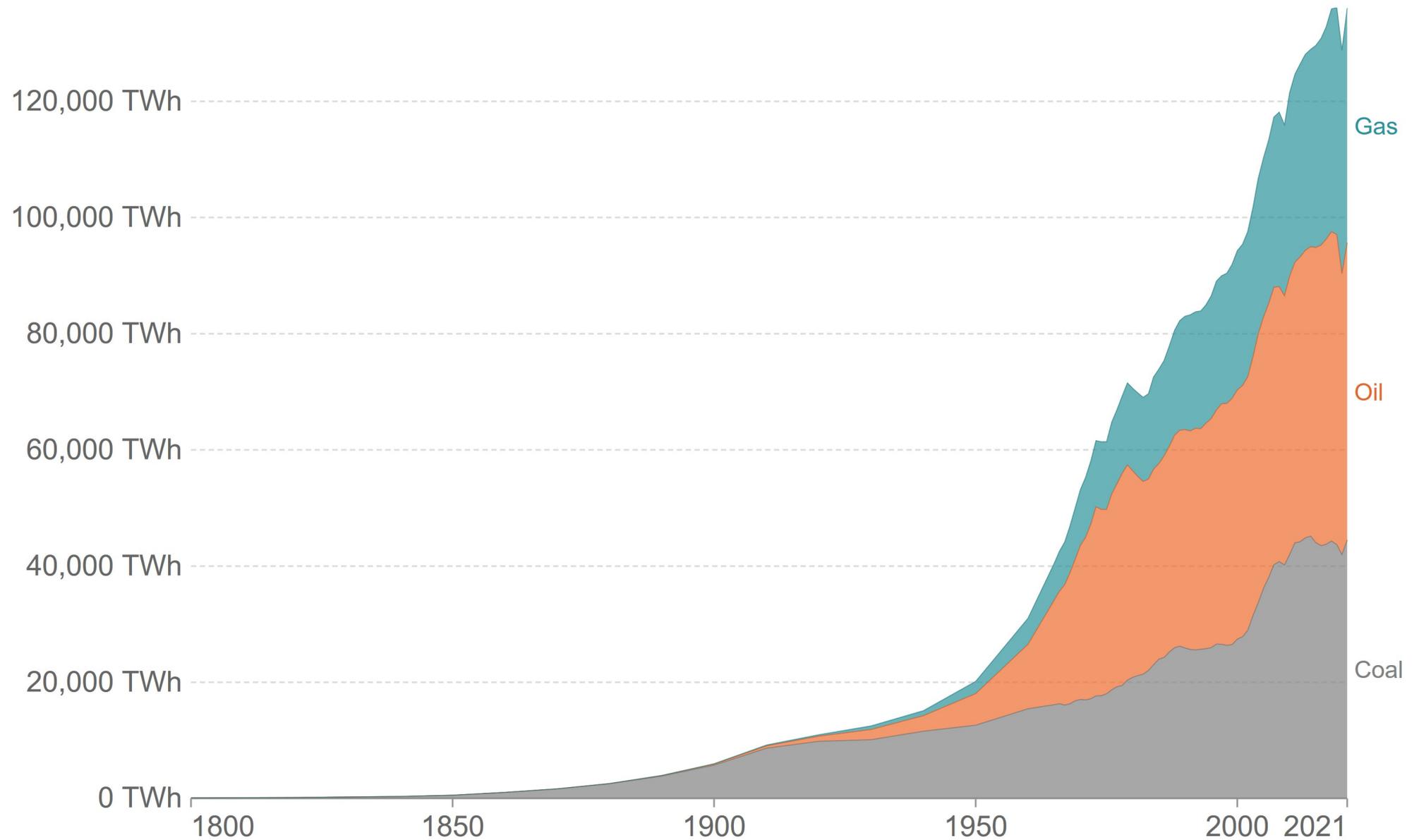
Le climat est-il prévisible ?

- Le rasoir d' Ockham

- Maintenant qu'on tient la cause, peut-on prévoir l'avenir ?

- Oui, mais c'est une nouvelle manière de pratiquer la science:
    - Ce n'est plus le savant solitaire
    - Ce sont des équipes pluridisciplinaires
    - Qui collaborent sur des modèles mathématiques et numériques

Le cycle du carbone

© UNIFA
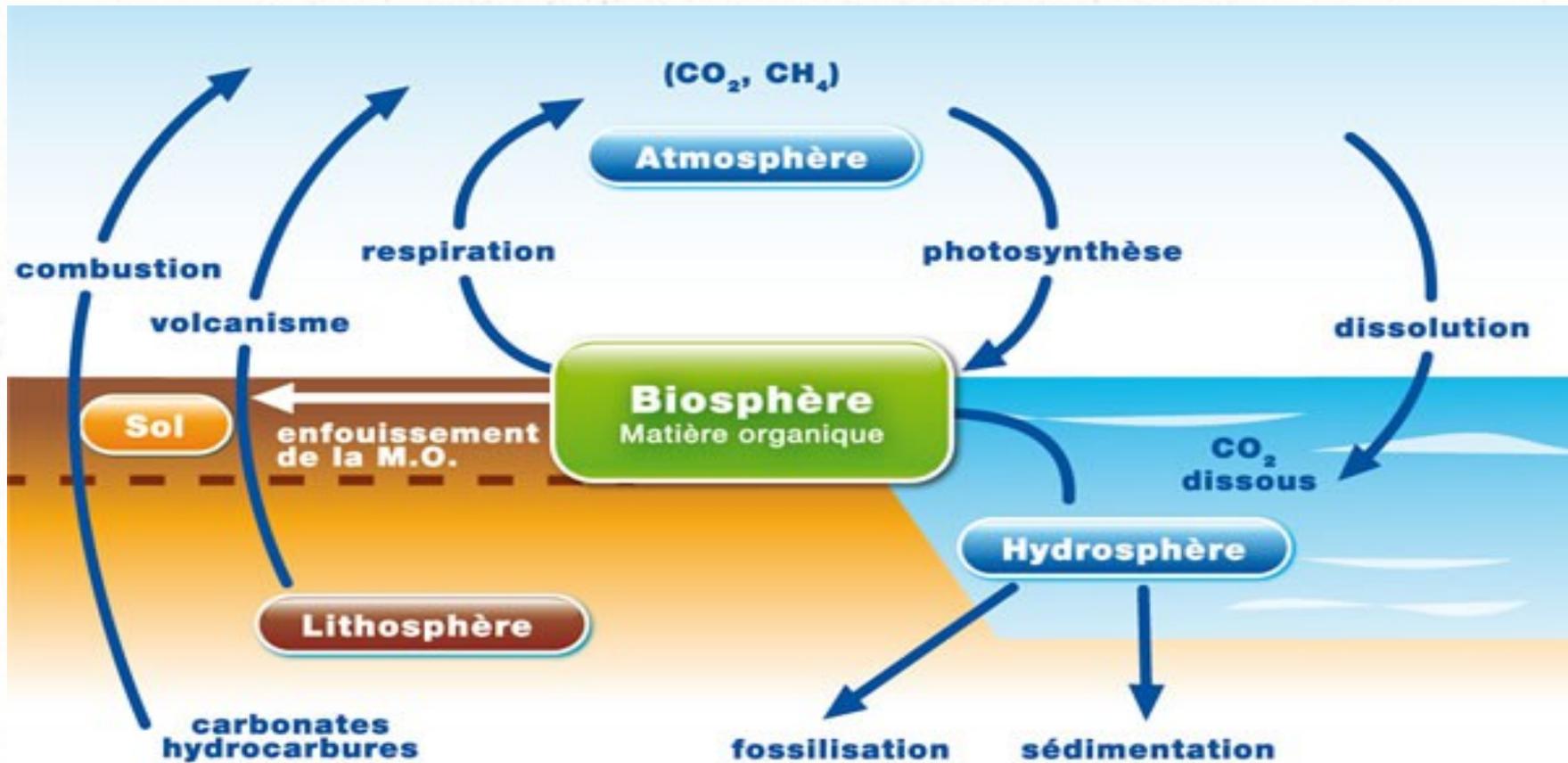
Le cycle du carbone
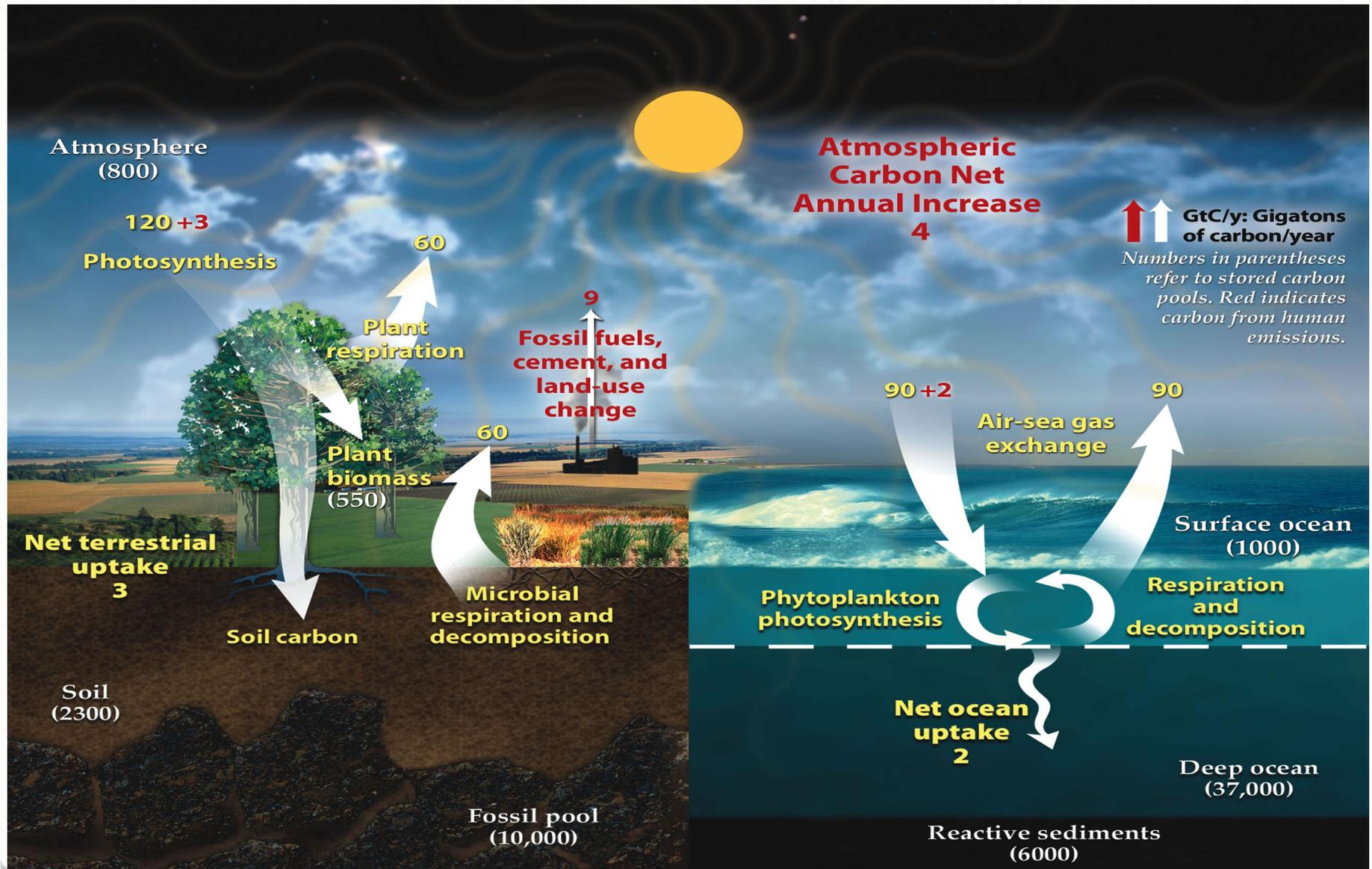
Nutrient Cycles: The Carbon Cycle

Carbon flows (exchanges) in gigatonnes per year
Natural processes →   Human activities →   1600 Carbon stores in gigatonnes

The global carbon cycle

0.1

9.4
(8.9–9.9)

1.6
(0.9–2.3)

3.4
(2.5–4.3)

Atmospheric CO_2
+5.1
860 GtC

2.5
(1.9–3.1)

120

120

Vegetation
450–650 GtC

90

90

Dissolved
inorganic carbon
38 000 GtC

Gas reserves
385–1135 GtC

Permafrost
1700 GtC

Soils
1500–2400 GtC

Rivers
and lakes

Organic carbon
700 GtC

Marine
biota
3 GtC

Oil reserves
175–265 GtC

Coasts
10–45 GtC

Surface
sediments
1750 GtC

Coal reserves
445–540 GtC

Budget imbalance -0.1

Anthropogenic fluxes 2010–2019 average GtC per year

Fossil CO_2 E_{FOS}

Land-use change E_{LUC}

+ Atmospheric increase G_{ATM}

Carbon cycling GtC per year

Land uptake S_{LAND}

Ocean uptake S_{OCEAN}

Budget Imbalance B_{IM}

Stocks GtC

Modèles climatiques
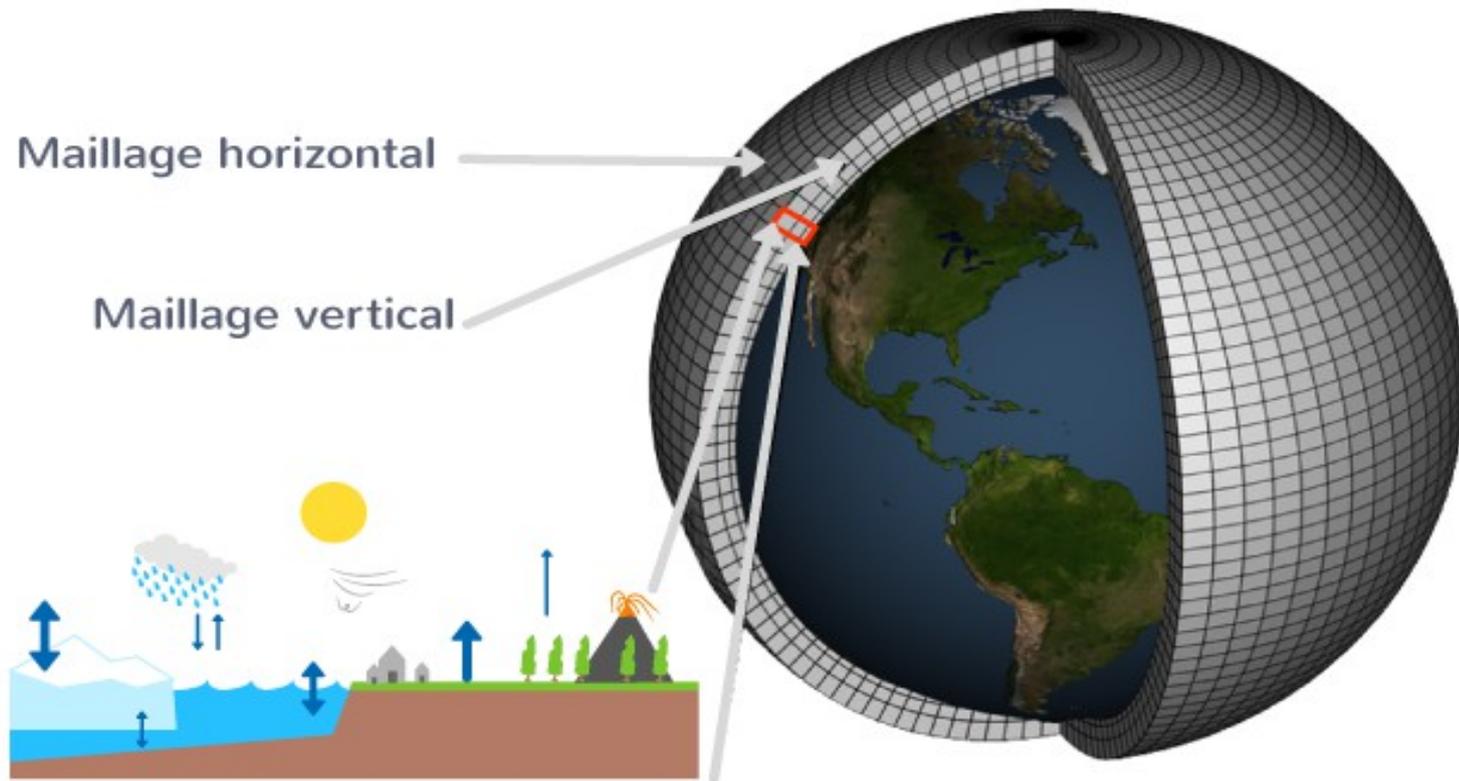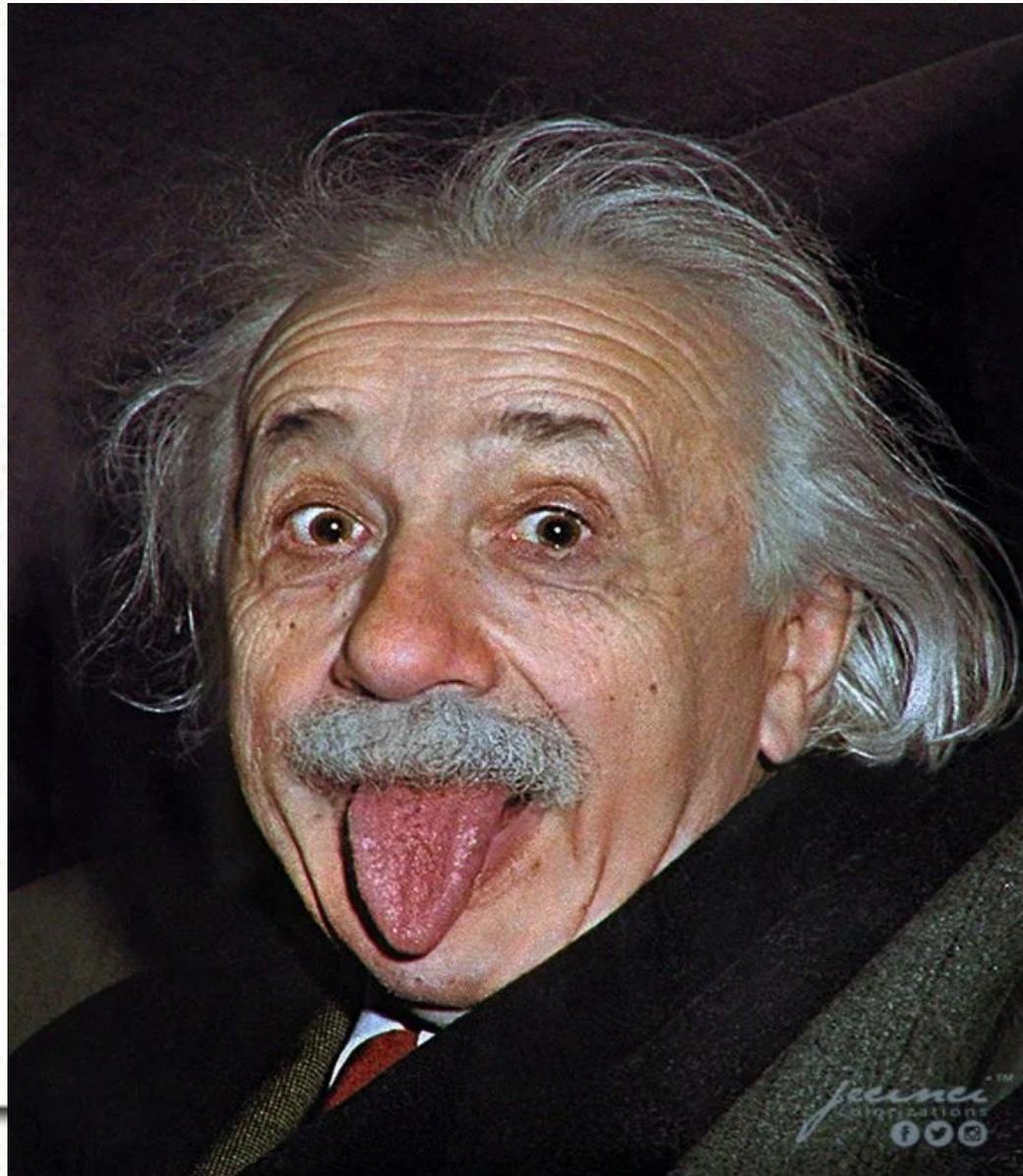
Qui est-ce ?

Qui est-ce ?

Le GIEC

Un extrait du 6ème rapport du GIEC

Box SPM.1.2: This Report assesses results from climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the World Climate Research Programme. These models include new and better representations of physical, chemical and biological processes, as well as higher resolution, compared to climate models considered in previous IPCC assessment reports. This has improved the simulation of the recent mean state of most large-scale indicators of climate change and many other aspects across the climate system. Some differences from observations remain, for example in regional precipitation patterns. The CMIP6 historical simulations assessed in this Report have an ensemble mean global surface temperature change within 0.2°C of the observations over most of the historical period, and observed warming is within the *very likely* range of the CMIP6 ensemble. However, some CMIP6 models simulate a warming that is either above or below the assessed *very likely* range of observed warming.

Summary for Policymakers

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SPM

Le climat est-il prévisible ?

- Oui,

Le climat est-il prévisible ?

• Oui
• à condition de connaître les émissions !
• Le GIEC a défini cinq scénarios, le pire étant le "Business as Usual" qui prolonge tout simplement les tendances actuelles

Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

(a) Future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right), across five illustrative scenarios

Carbon dioxide (GtCO$_2$/yr)

Selected contributors to non-CO_2 GHGs

Methane (MtCH$_4$/yr)

Nitrous oxide (MtN$_2$O/yr)

One air pollutant and contributor to aerosols

Sulphur dioxide (MtSO$_2$/yr)
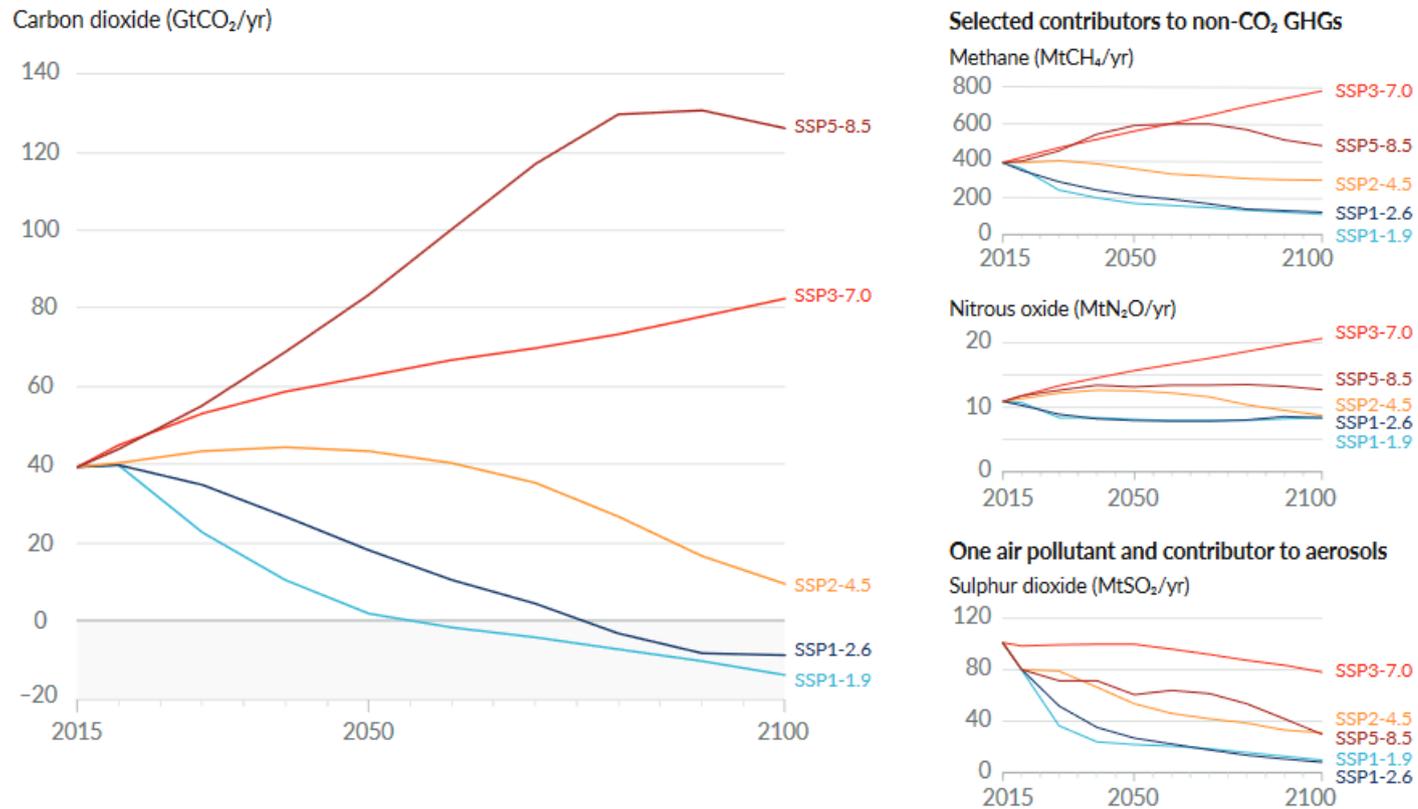
2050

Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)

The **near-linear relationship** between the cumulative CO_2 emissions and global warming for five illustrative scenarios **until year 2050**

SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

Historical global warming

Cumulative CO_2 emissions since 1850

Future cumulative CO_2 emissions differ across scenarios and determine how much warming we will experience.

SSP1-1.9
SSP1-2.6
SSP2-4.5
SSP3-7.0
SSP5-8.5

HISTORICAL
Cumulative CO_2 emissions between **1850** and **2019**

PROJECTIONS
Cumulative CO_2 emissions between **2020** and **2050**

Prévisions par scénarios

(a) Annual mean temperature change (°C) at 1°C global warming

Warming at 1°C affects all continents and is generally larger over land than over the oceans in both observations and models. Across most regions, observed and simulated patterns are consistent.

Observed change per **1°C** global warming
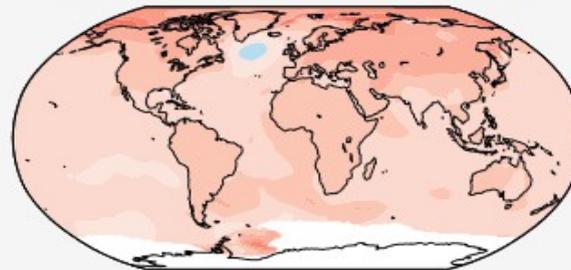
Simulated change at **1°C** global warming
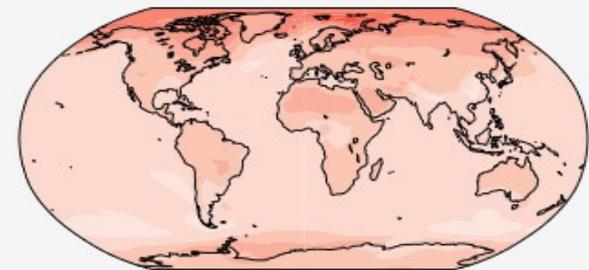
**(b) Annual mean temperature change (°C) relative to 1850–1900**

Across warming levels, land areas warm more than ocean areas, and the Arctic and Antarctica warm more than the tropics.

Simulated change at **1.5°C** global warming
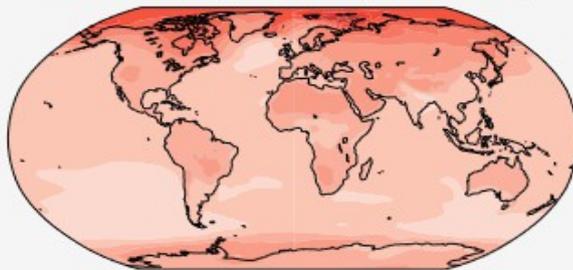
Simulated change at **2°C** global warming

Simulated change at **4°C** global warming

0   0.5   1   1.5   2   2.5   3   3.5   4   4.5   5   5.5   6   6.5   7   --->

Change (°C)

Warmer
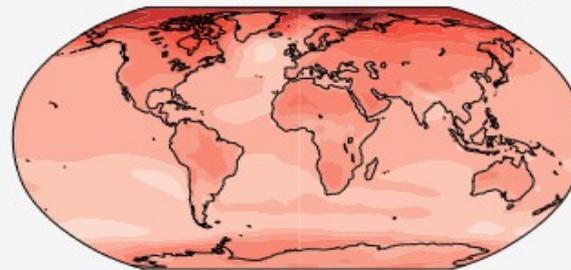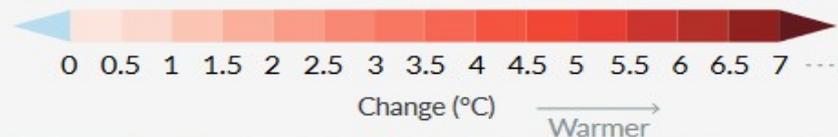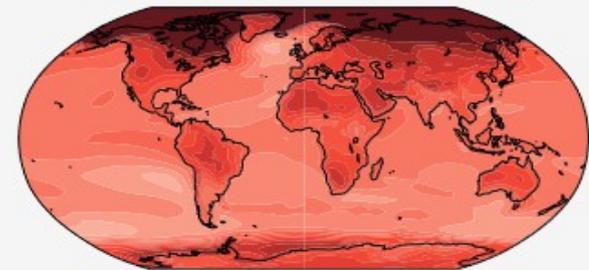
Précipitations

(c) Annual mean precipitation change (%) relative to 1850–1900

Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and in limited areas of the tropics.

Simulated change at **1.5°C** global warming
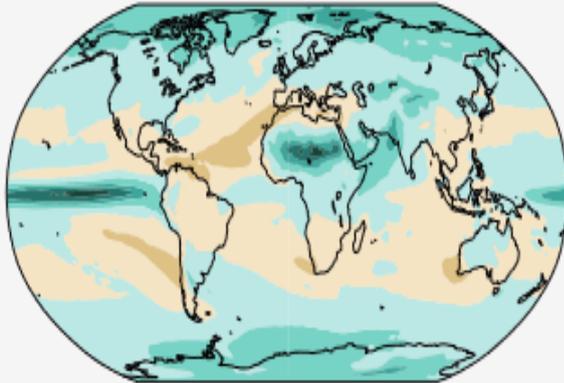
Simulated change at **2°C** global warming
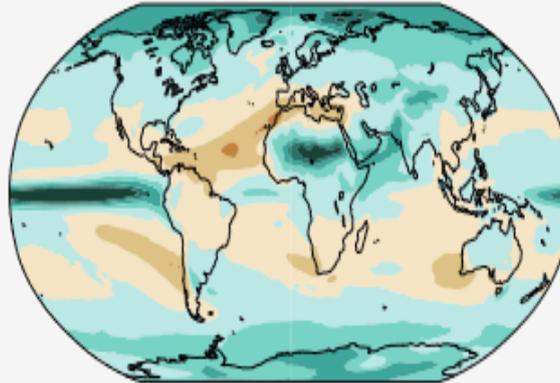
Simulated change at **4°C** global warming
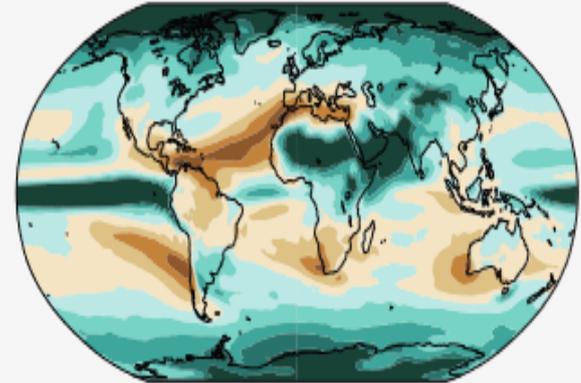
Relatively small absolute changes may appear as large % changes in regions with dry baseline conditions.

⟨··· −40   −30   −20   −10   0   10   20   30   40 ···⟩

← Drier   Change (%)   Wetter →
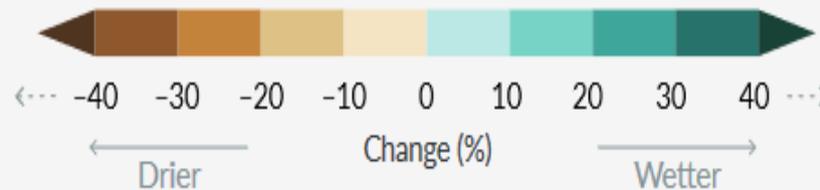
Evénements extêmes

Hot temperature extremes over land

10-year event

Frequency and increase in intensity of extreme temperature event that occurred **once in 10 years** on average in a climate without human influence

Future global warming levels

1850–1900	Present 1°C	1.5°C	2°C	4°C

FREQUENCY per 10 years

Once / now *likely* occurs **2.8 times** (1.8–3.2) / will *likely* occur **4.1 times** (2.8–4.7) / will *likely* occur **5.6 times** (3.8–6.0) / will *likely* occur **9.4 times** (8.3–9.6)

INTENSITY increase

+6°C +5°C +4°C +3°C +2°C +1°C 0°C

+1.2°C hotter / +1.9°C hotter / +2.6°C hotter / +5.1°C hotter

50-year event

Frequency and increase in intensity of extreme temperature event that occurred **once in 50 years** on average in a climate without human influence

Future global warming levels

1850–1900	Present 1°C	1.5°C	2°C	4°C

FREQUENCY per 50 years

Once / now *likely* occurs **4.8 times** (2.3–6.4) / will *likely* occur **8.6 times** (4.3–10.7) / will *likely* occur **13.9 times** (6.9–16.6) / will *likely* occur **39.2 times** (27.0–41.4)

INTENSITY increase

+6°C +5°C +4°C +3°C +2°C +1°C 0°C

+1.2°C hotter / +2.0°C hotter / +2.7°C hotter / +5.3°C hotter
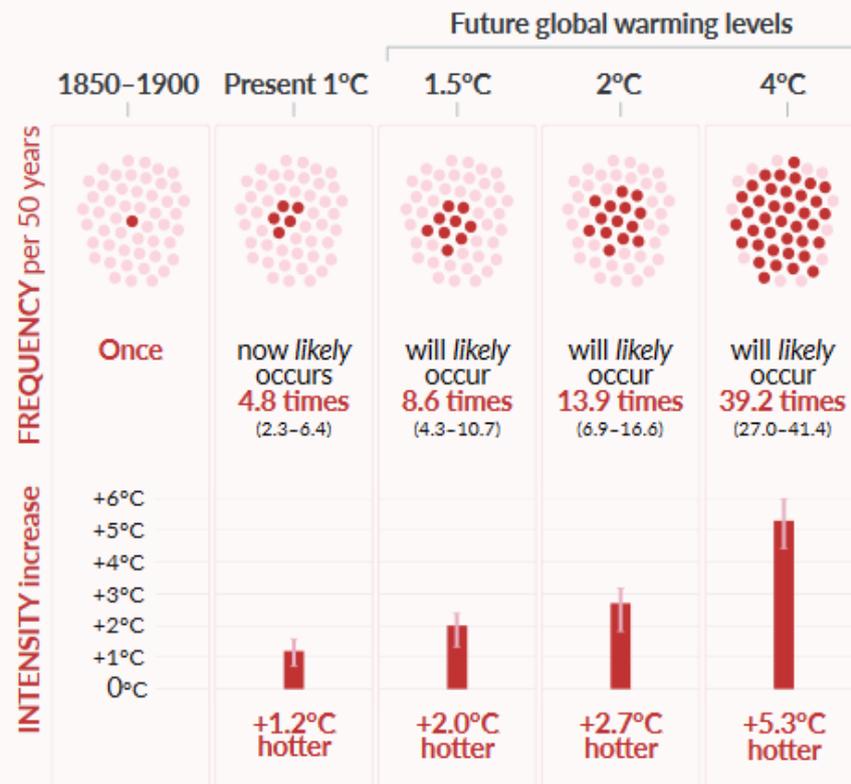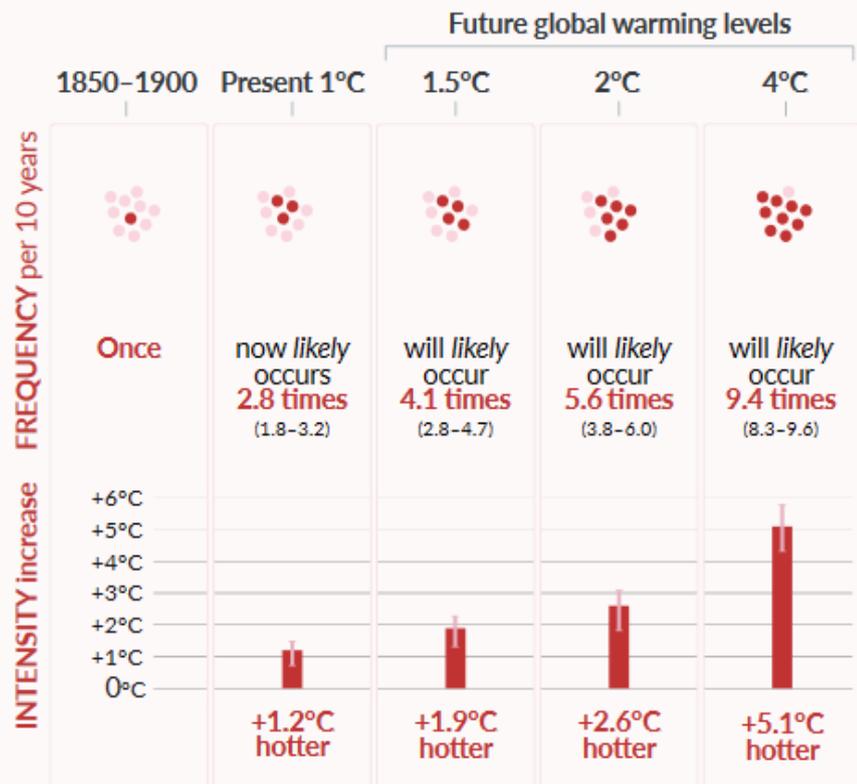
Evénements extrêmes

Heavy precipitation over land — 10-year event. Frequency and increase in intensity of heavy 1-day precipitation event that occurred once in 10 years on average in a climate without human influence.
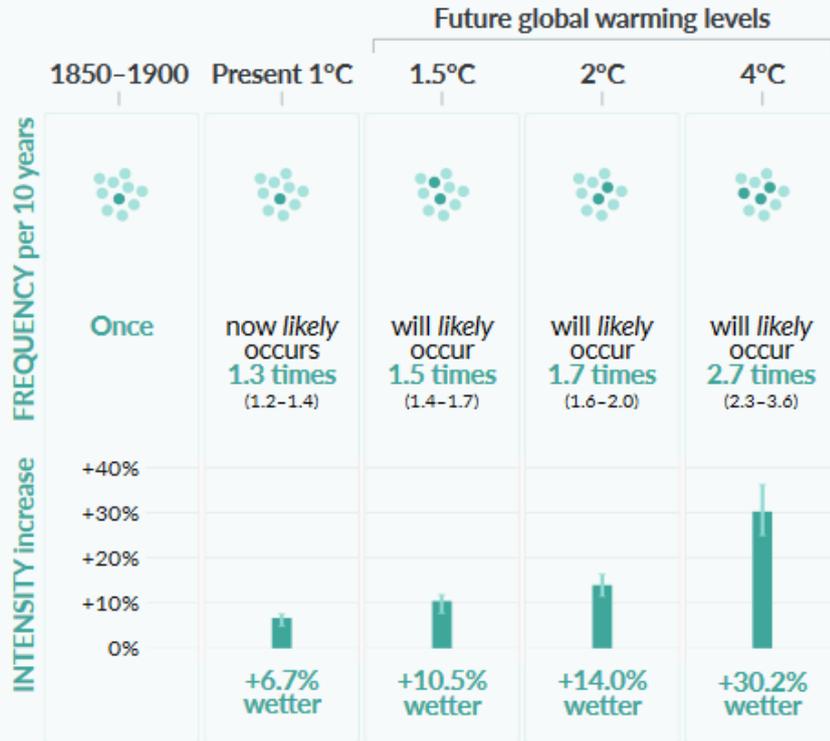
Agricultural & ecological droughts in drying regions — 10-year event. Frequency and increase in intensity of an agricultural and ecological drought event that occurred once in 10 years on average across drying regions in a climate without human influence.
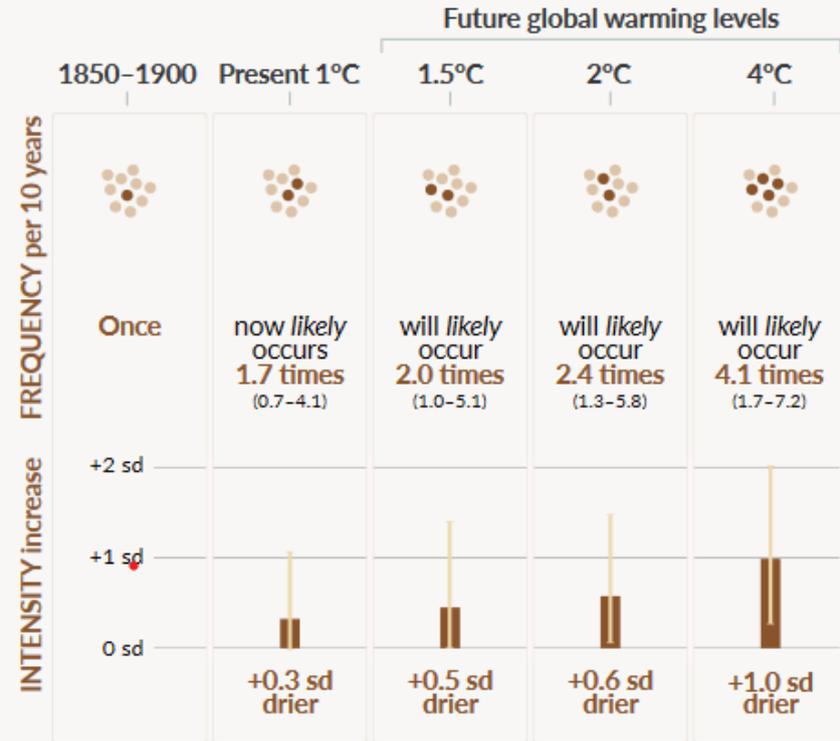
La question des seuils

- Caractéristiques:

  - Des modifications graduelles suffisent à franchir le seuil – pas besoin de sauter

  - Une fois le seuil franchi, on ne peut pas revenir en arrière

- Au-delà de 2°C le GIEC en a identifié certains seuils, mais ne sait pas quand ils seront franchis

Géométrie des seuils
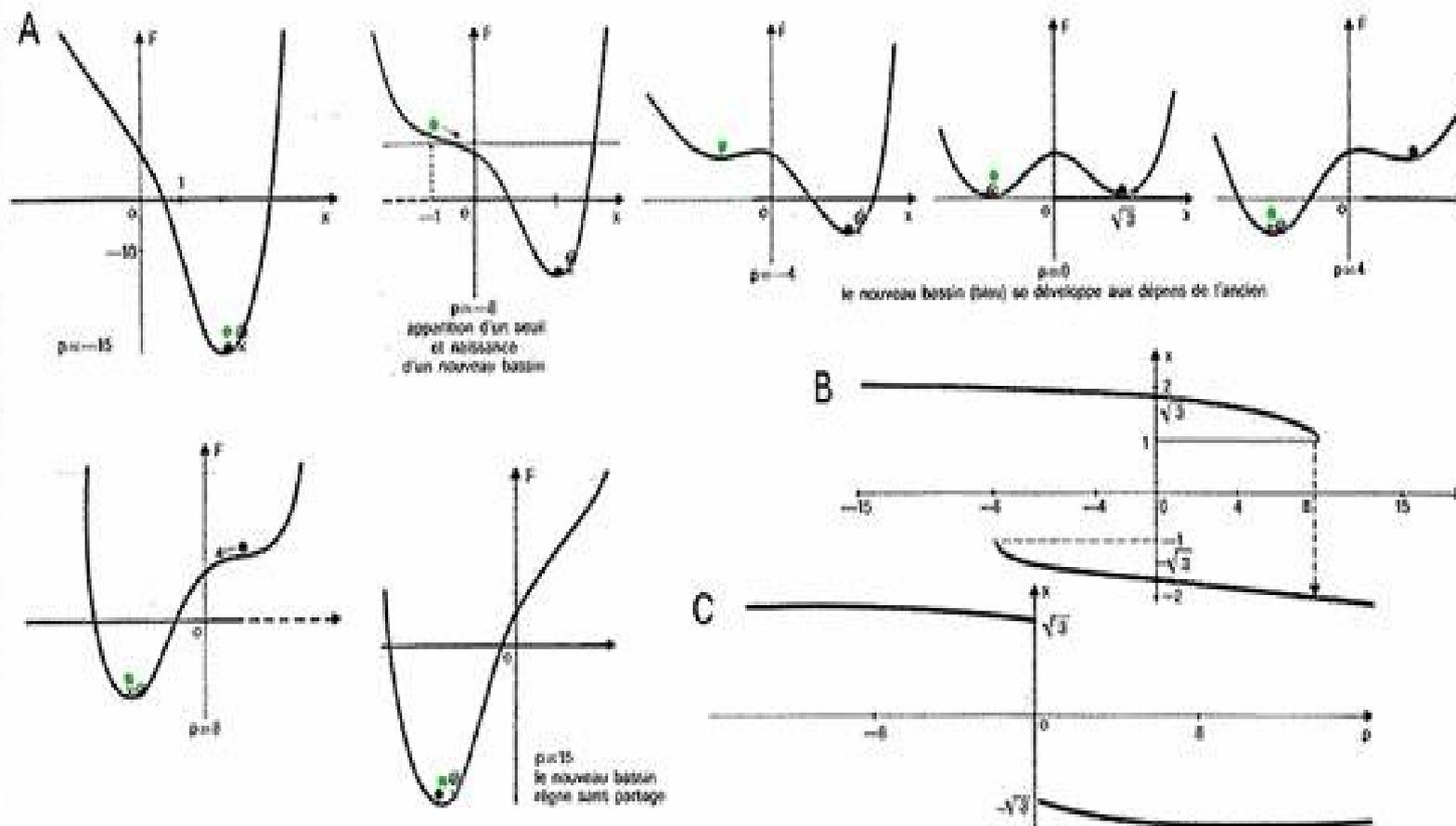
Les seuils planétaires

Tipping Elements in Earth's Climate System

Melt of Greenland Ice-Sheet

Arctic Sea-Ice Loss

Arctic Ozone Hole?

Permafrost and Tundra Loss?

Boreal Forest Dieback

Atlantic Deep Water Formation

Boreal Forest Dieback

Sahara Greening

West African Monsoon Shift

Indian Monsoon Chaotic Multistability

Change in ENSO, Amplitude or Frequency

Dieback of Amazonas Rainforest

Changes in Antarctic Bottom Water Formation?

Instability of West Antarctic Ice Sheet

based upon Lenton et al. (2008)

# *Les courants Atlantique Nord*
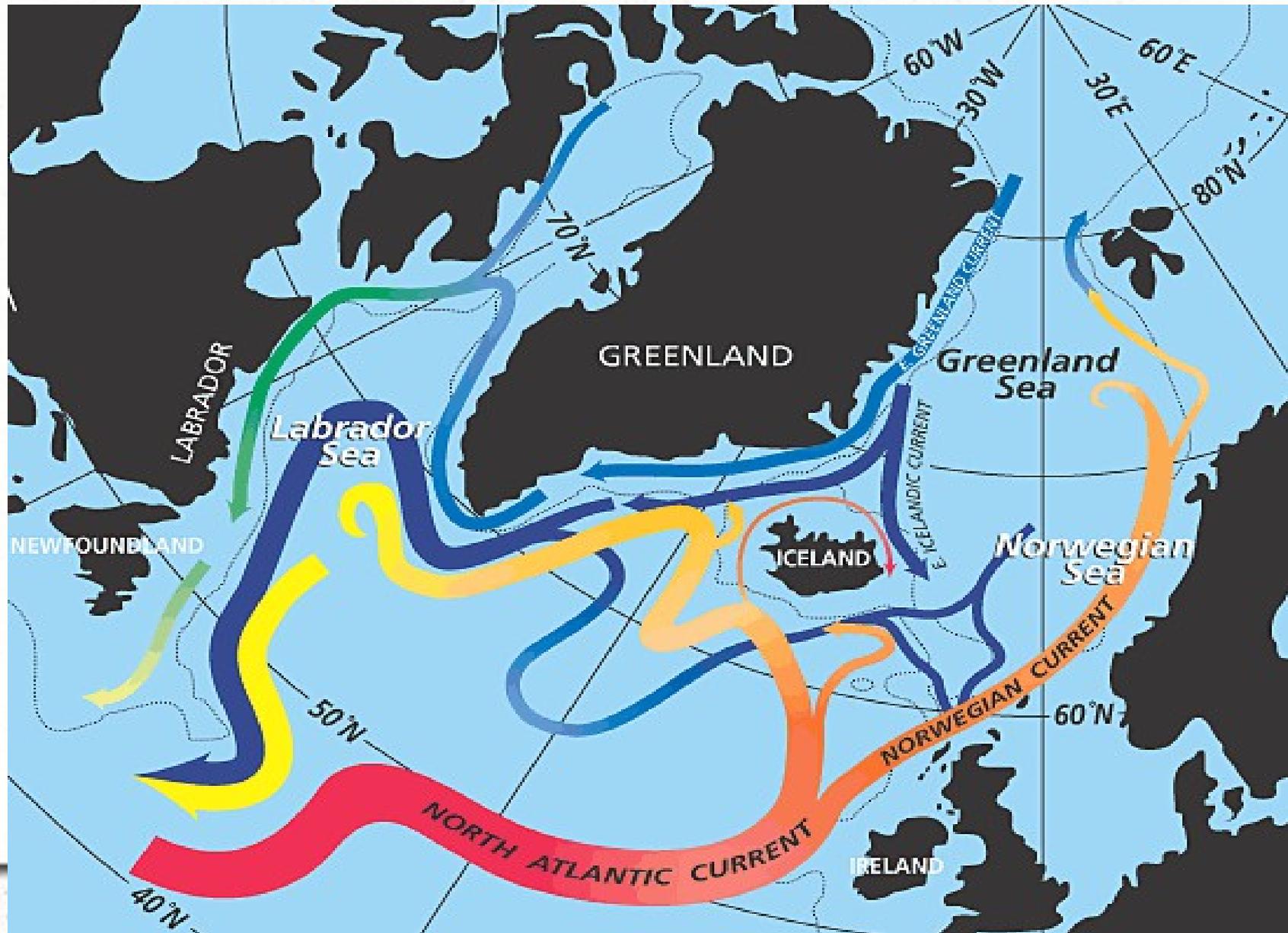
Le climat est-il prévisible ?

En définitive, l'avenir dépend de nous

Où en sommes-nous ?

Fossil fuel consumption by fuel type, World
Fossil fuel consumption is given in terawatt-hour equivalents (TWh).

Gas

Coal

Oil

Source: BP Statistical Review of Global Energy

OurWorldInData.org/fossil-fuels • CC BY
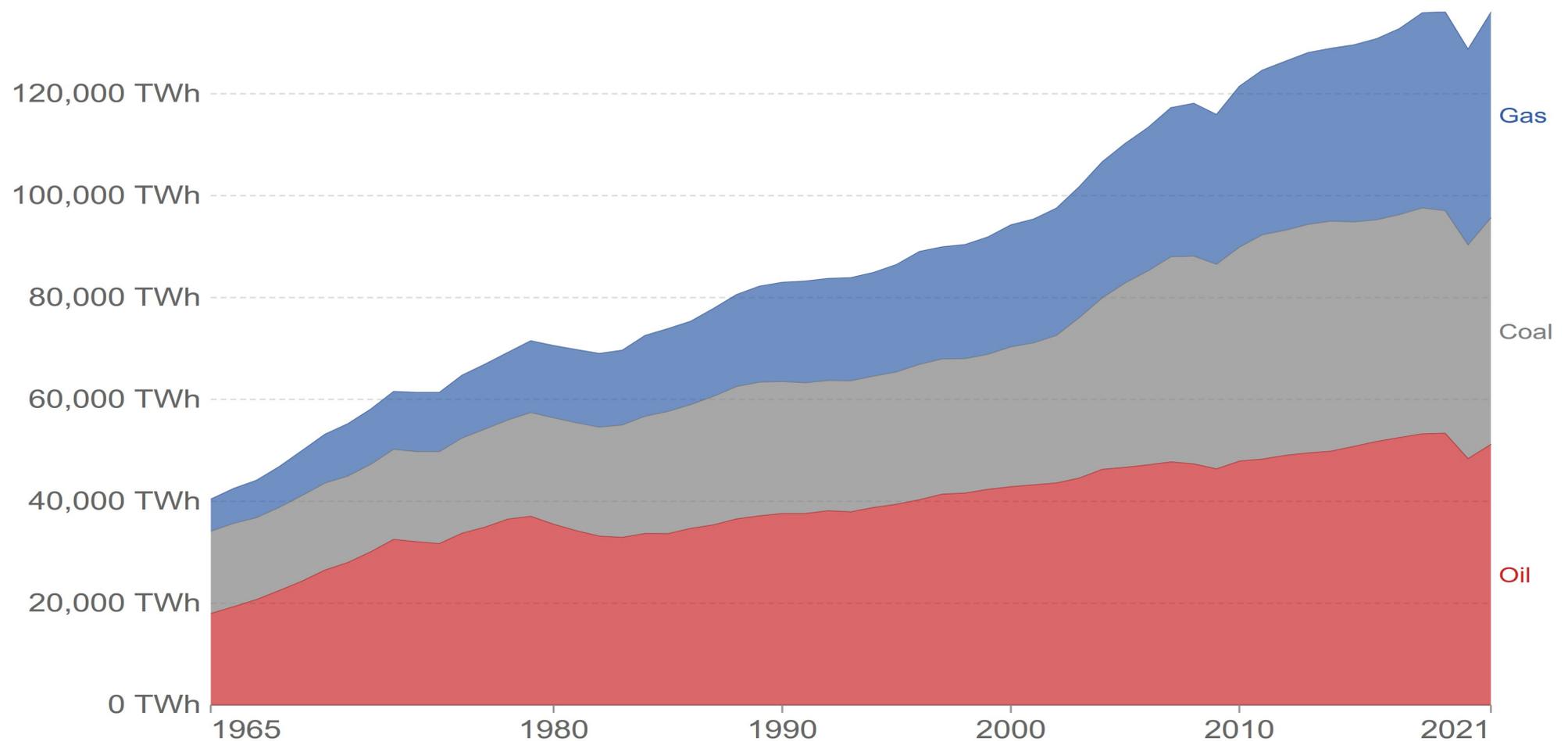
CAC 40 *5 756,87* -1.06% DOW JONES *29 210,85* -0.1% NASDAQ *10 417,1* -0.09% NIKKEI 225 *26 396,83* -0.02% BRENT *92,48* +0.08%

Les Echos

En direct   Le Journal   Newsletters   Podcasts   ...   **CONNEXION**

À la une   Idées   Économie   Politique   Entreprises   Finance - Marchés   Bourse   Monde   Tech-Médias   Start-up   Régions   Patrimoine   Le Mag W-E

DÉCRYPTAGE

Climat et énergie : le gouvernement bascule en gestion de crise 🦅

La climatologue Valérie Masson–Delmotte, membre du GIEC et du Haut Conseil pour le climat sera l'invitée du séminaire gouvernemental de ce mercredi, au cours duquel chaque ministre devra préciser sa feuille de route pour accélérer la transition écologique. Emmanuel Macron a convoqué, ce vendredi à l'Elysée, un Conseil de défense consacré à la question énergétique.

🔖 Lire plus tard   💬 Commenter   ↗ Partager   Elisabeth Borne   Emmanuel Macron

Agir face au changement climatique,
enjeux de transformations

1850   2100

NOUS

SOMMES

ICI
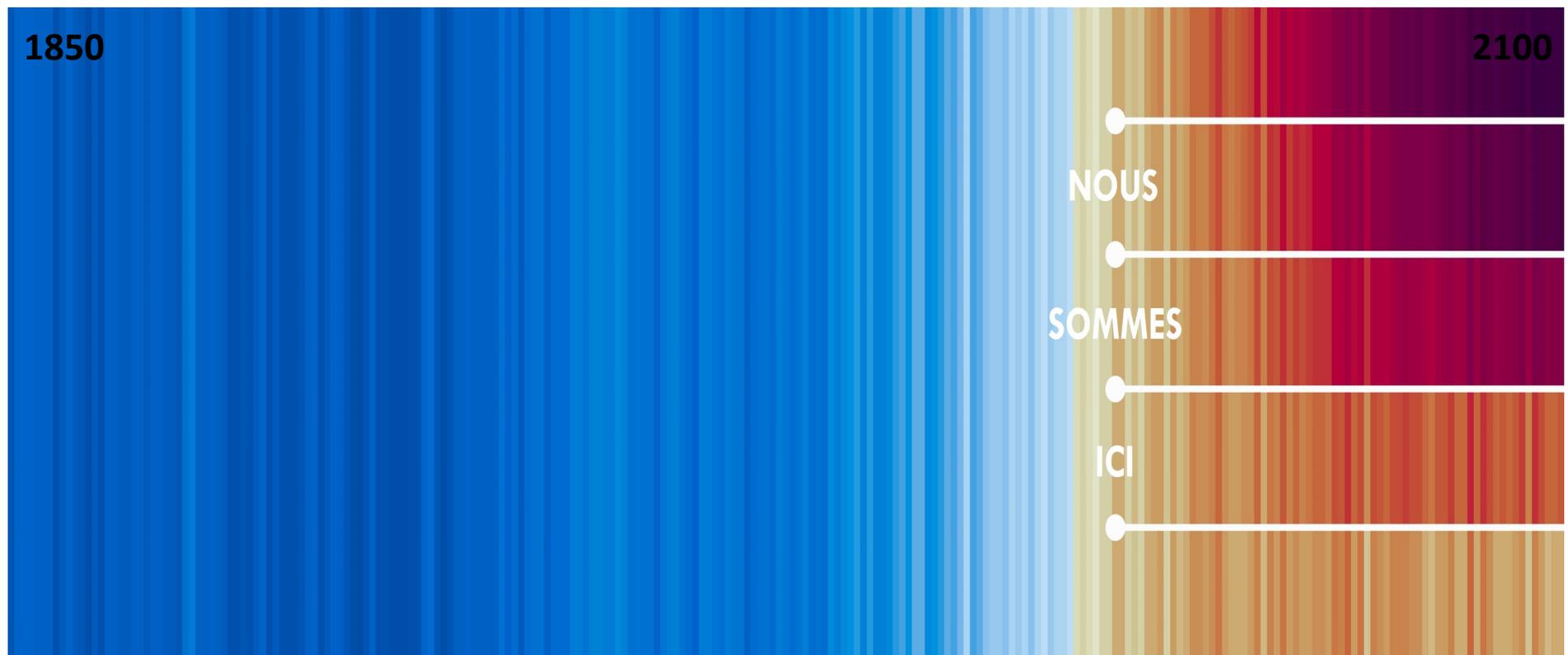
Limiter le réchauffement : chaque année compte
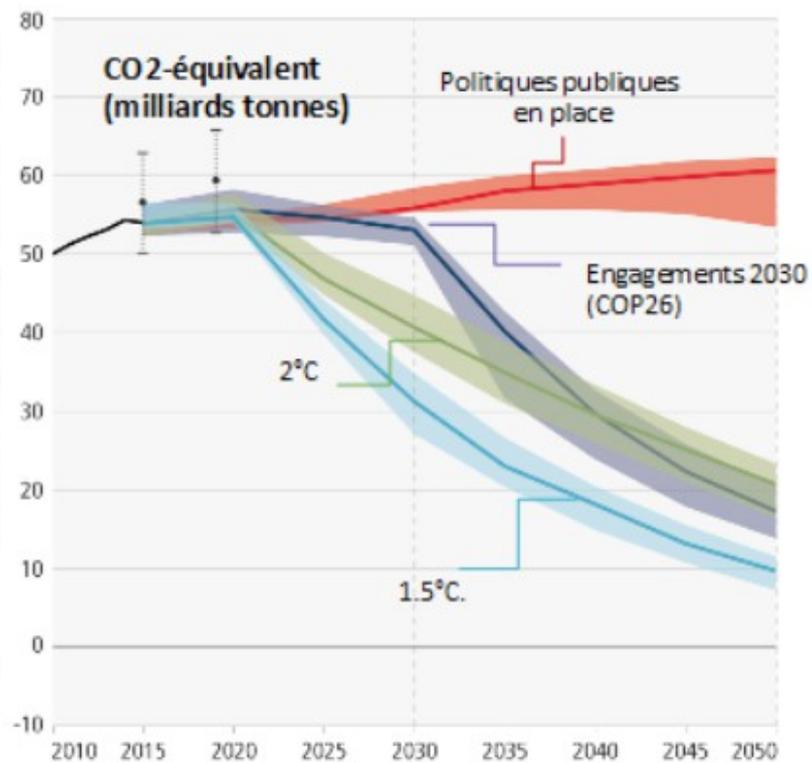
sous 2°C

↓ CO2-équivalent : 27% d'ici 2030

vers 1,5 °C

↓ CO2-équivalent : 43% entre 2019 et 2030

↓ méthane : 34%

Emissions historiques, actuelles, par pays, par personne, par génération : enjeux d'équité

10% des personnes : 40% des émissions mondiales de gaz à effet de serre
50% des personnes : < 15% des émissions

*70% des émissions
 des zones urbaines*
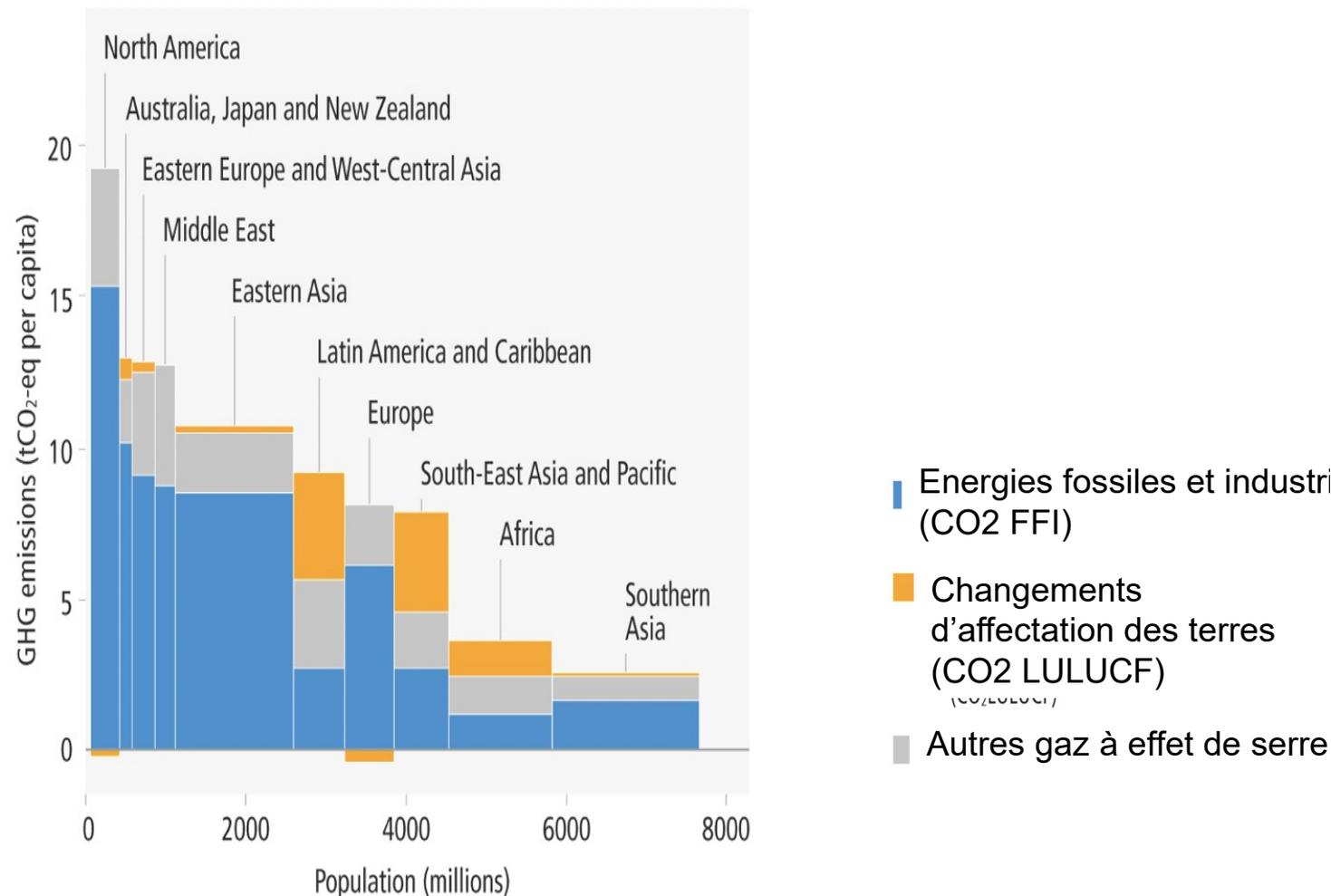
- Pour en savoir plus

- (et avoir meilleur moral)

- Merci de votre présence et de votre attention !