Le dérèglement climatique. Cours , École Bordeaux Sciences Agro 2e année

Denis Loustau

The climate disturbance. Section 2

1. Past and recent changes

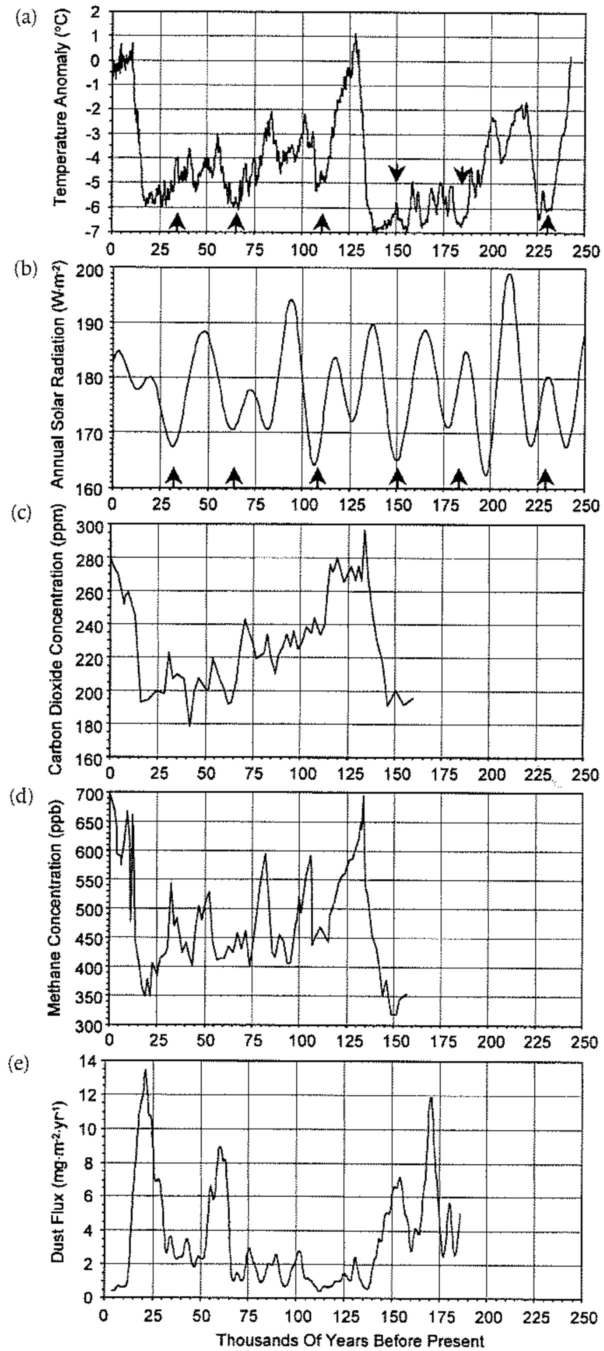
2. The drivers of the present climate

3. Scenarios for 2022-2120

- Resources:
  - IPCC report 6th (AR6), WG1 technical summary, WG1 report, SPM.
  - Global Carbon Project.
  - MeteoFrance, NASA and NWS web pages

Part 1.

Past changes: 250 000 yrs



Temperature

Radiation

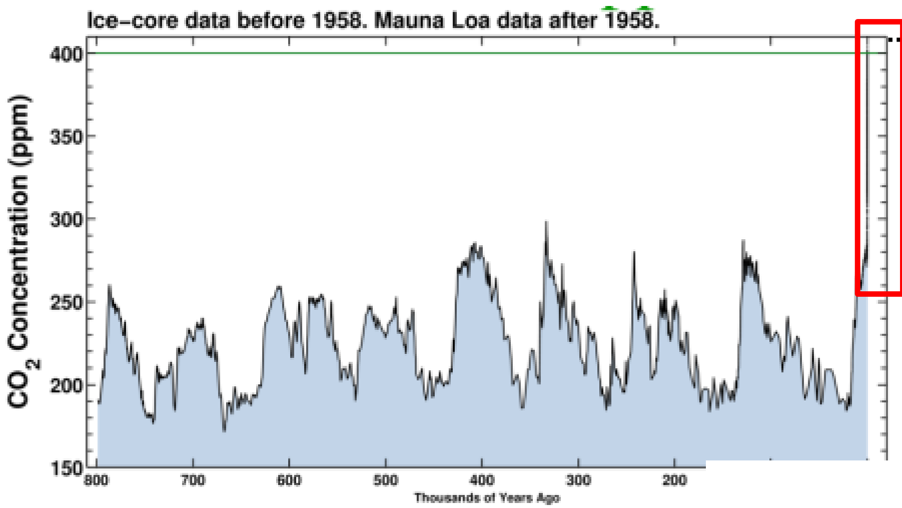
CO2

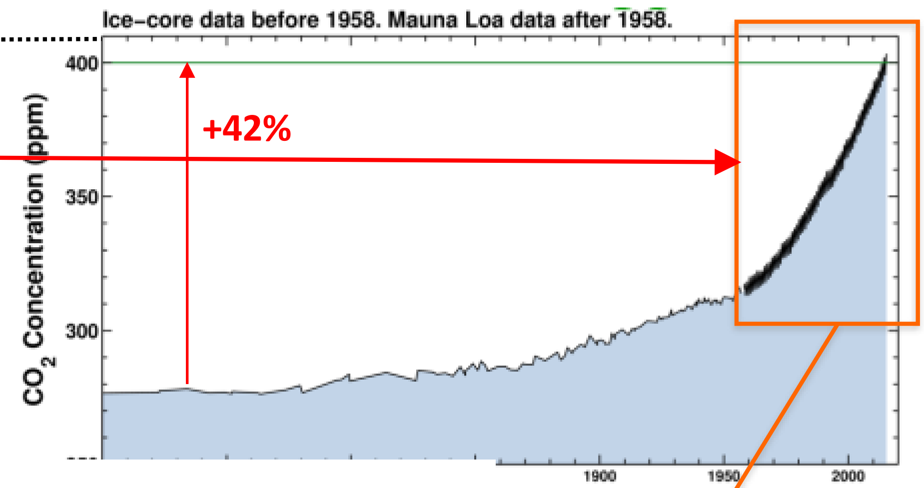
CH4

Figure 4.1. Climate history reconstructed from the Vostok ice core over the past 250 000 years: (a) Temperature deviation from present (Jouzel *et al.* 1996). (b) Annual solar radiation at latitude 60° N (Berger 1978; Berger and Loutre 1991). This latitude is used because solar radiation at high latitudes in the Northern Hemisphere is critical to glacier dynamics. Arrows show periods of low solar radiation. (c) Atmospheric CO_2 concentration in parts per million by volume (Barnola *et al.* 1987). (d) Atmospheric methane concentration in parts per billion (Chappellaz *et al.* 1990). (e) Dust flux (Petit *et al.* 1990; Jouzel *et al.* 1993). Data provided by the National Geophysical Data Center (National Oceanic and Atmospheric Administration, Boulder, Colorado).

Part 1.

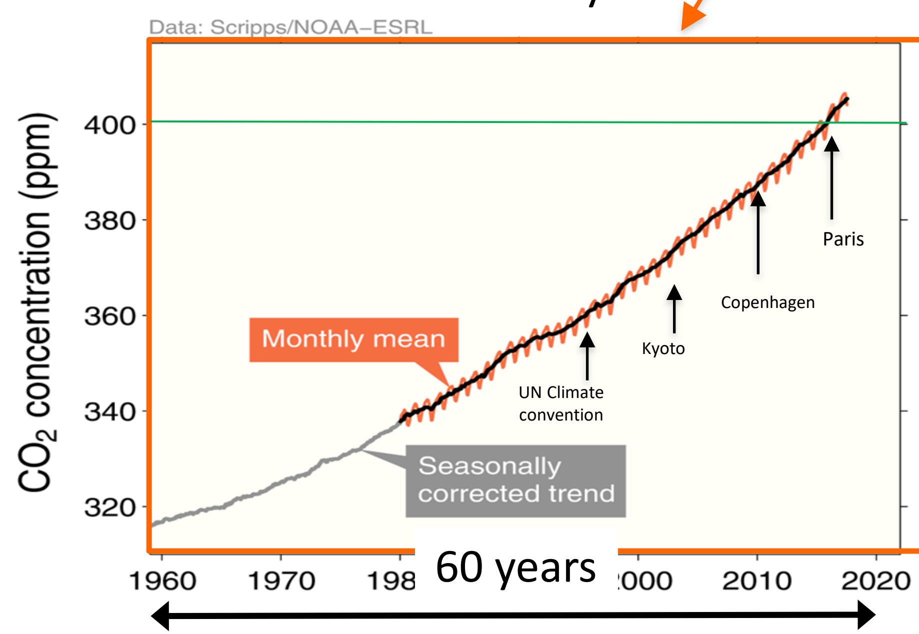
Atmospheric carbon for the last 800 000 years.





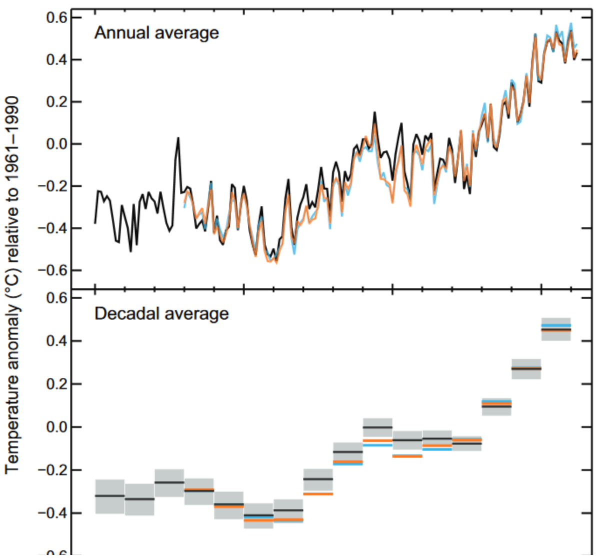
800.000 years

315 years

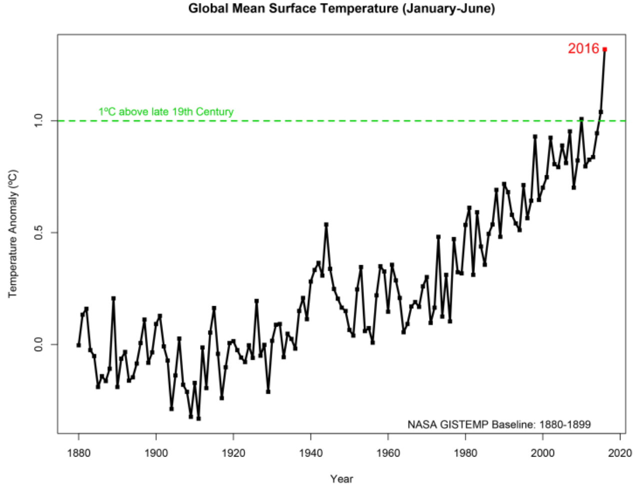


Part 1.

More recent climate changes: last 120 yrs



Global Mean Surface Temperature (January-June)



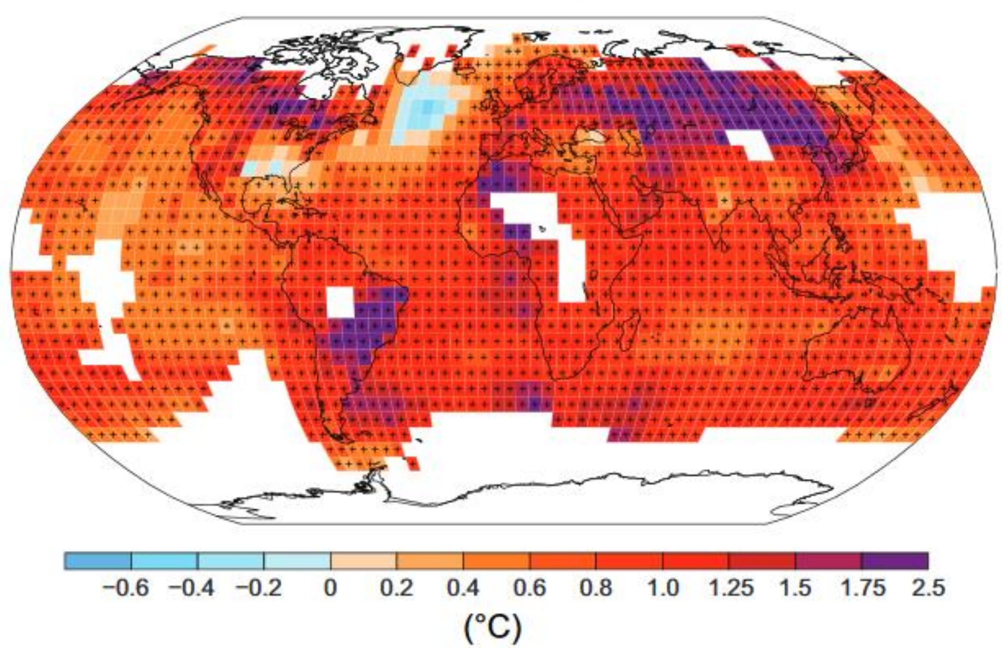
Globally:

- Global T increase by 1.07 K between 1850 and 2010 (2010-19 vs 1850-1900),

- Geographical variations:
  0 à + 2.5 degC

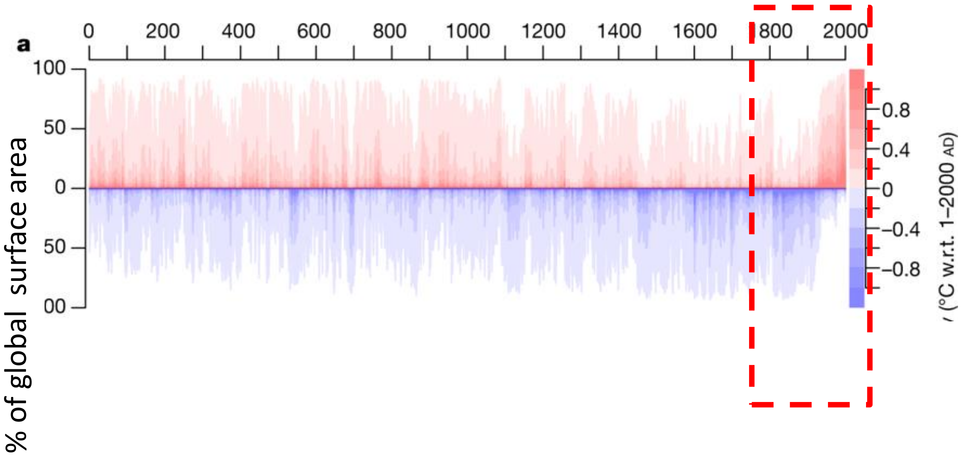
  + 1.25 degC in SW France

(b) Observed change in surface temperature 1901–2012



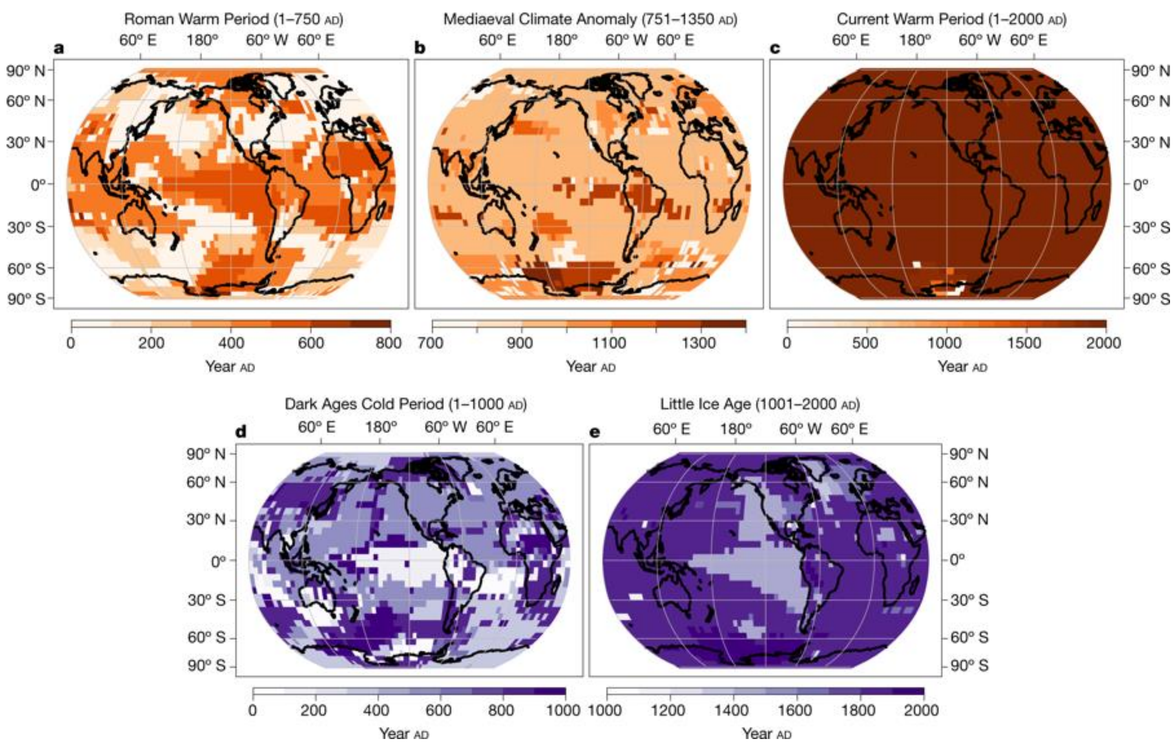
Part 1.

The <u>globality</u> of warming (Neukom et al. Nature, 2019)



Percentages of global area with warm (red shading) and cold (blue shading) temperature anomalies with respect to a 1–2000 ad reference period. Shading intensity indicates the magnitude of warmth and cold. **a**, Annual unfiltered data. **b**, 51-year lowpass filtered data

The last century records show a global consistency in temperature rising that was not observed in the past climate epoch.



a–**e**, Centuries with the highest ensemble probability of containing the warmest (**a**–**c**) and coldest (**d**, **e**) 51-year period within each putative climatic epoch.
The full time ranges over which the search was performed for each epoch are indicated in parentheses. The numbers on the *y* axis and upper *x* axis are degrees latitude and longitude.

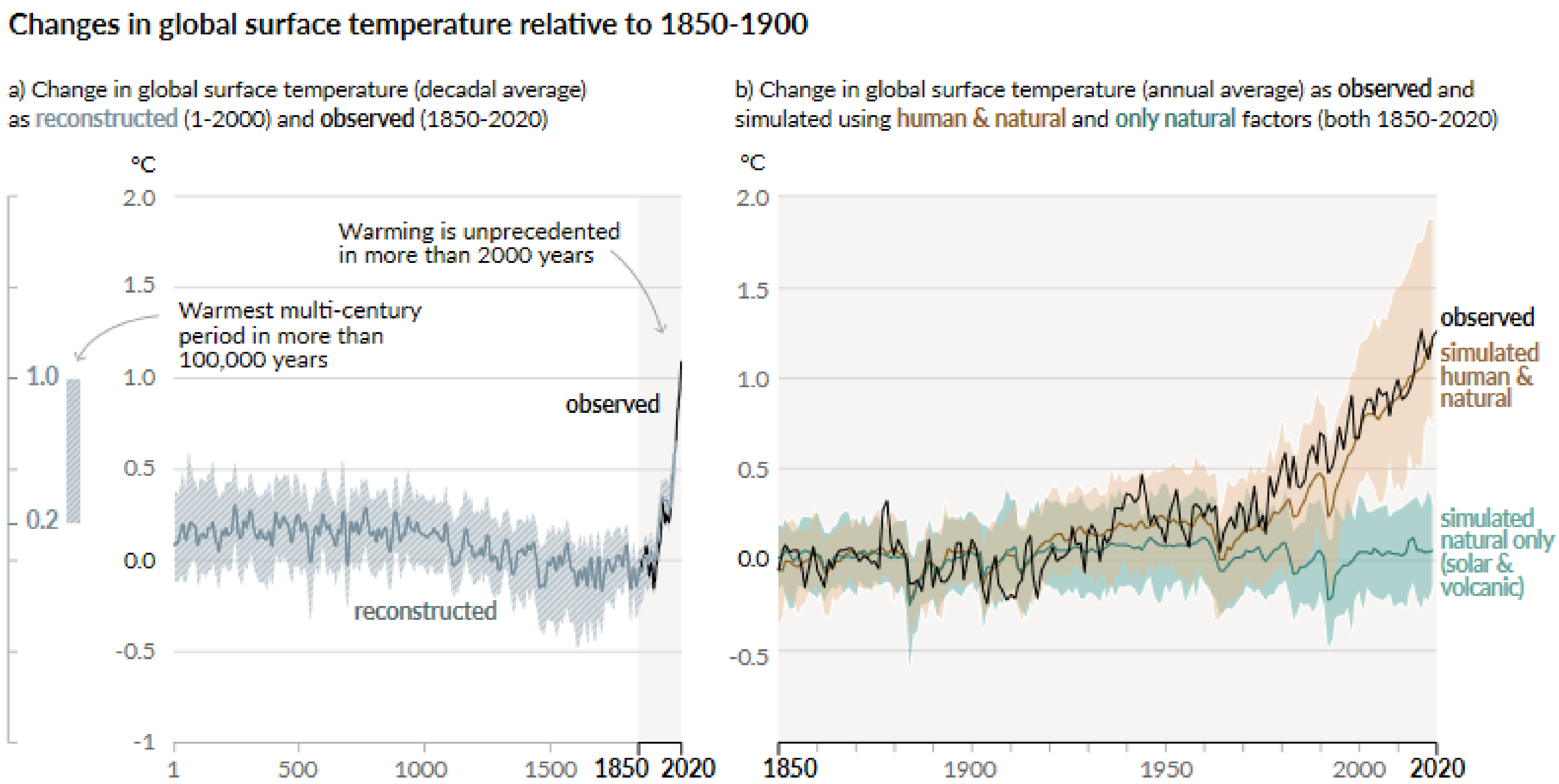
Part 1.

Recent climate changes: the mean global temperature concept

NASA's temperature analyses incorporate surface temperature measurements from 6,300 weather stations, ship- and buoy-based observations of sea surface temperatures, and temperature measurements from Antarctic research stations.

These raw measurements are analyzed using an algorithm that considers the varied spacing of temperature stations around the globe and urban heating effects that could skew the conclusions. These calculations produce the global average temperature deviations from the baseline period of 1951 to 1980.
The full 2017 surface temperature data set and the comp

The temperature rise is unprecedented and clearly attributed to human activity



Part 1.

Recent climate changes: precipitations for the last 120 yrs

France, Aug. 2022

- Geographical trends increasingly marked
- Enhanced high precipitation events
- Consistent with model predictions

Pakistan, Aug. 2022.

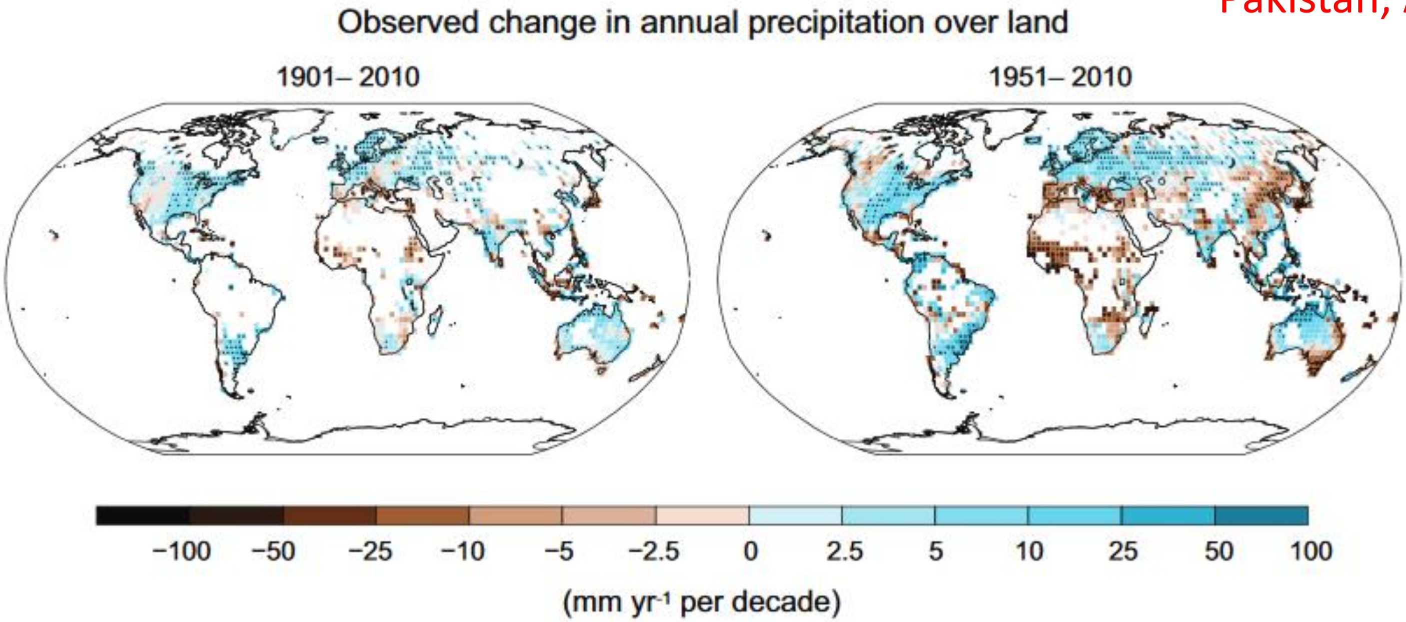
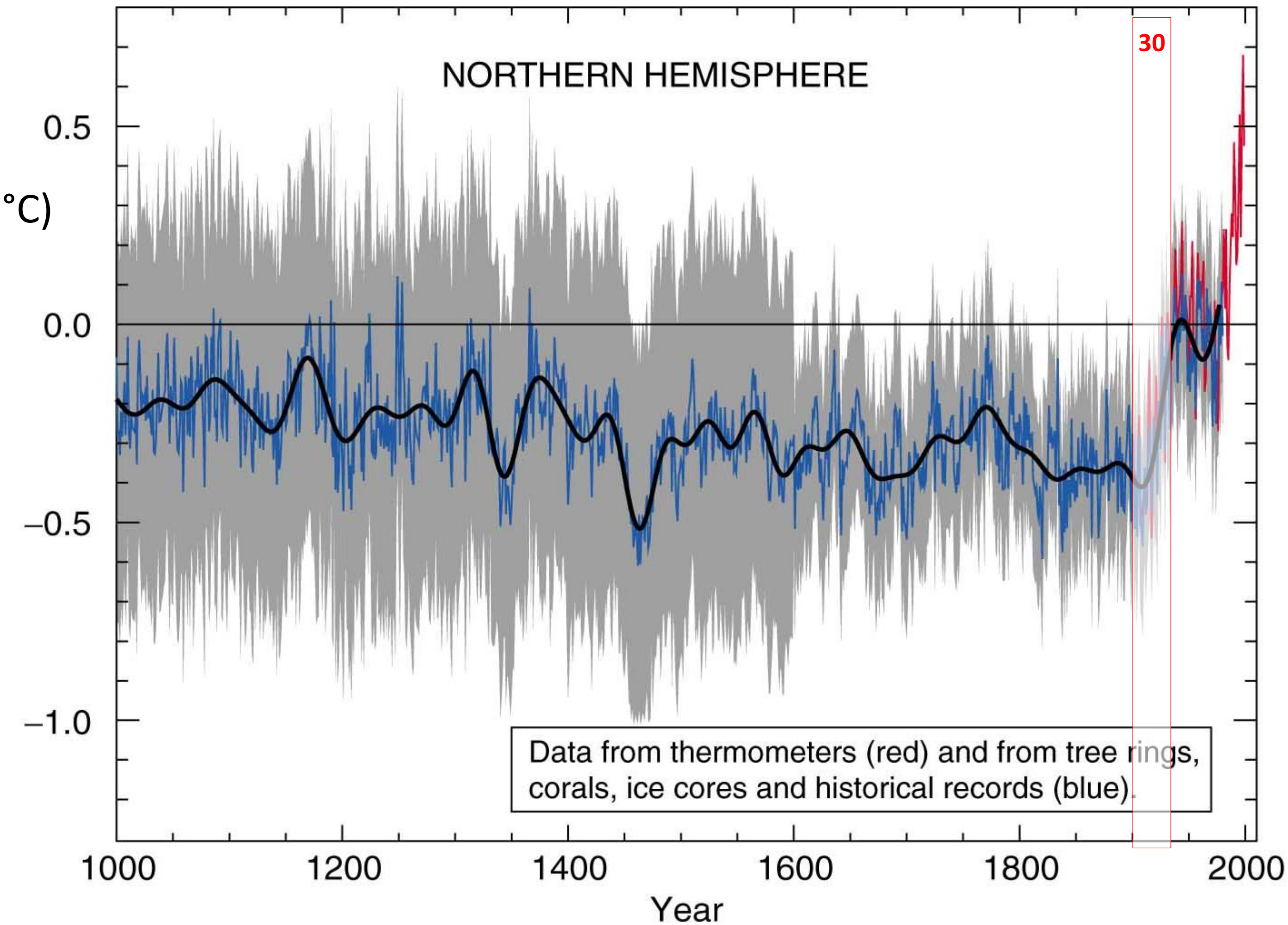


Figure SPM.2 | Maps of observed precipitation change from 1901 to 2010 and from 1951 to 2010 (trends in annual accumulation calculated using the same criteria as in Figure SPM.1) from one data set. For further technical details see the Technical Summary Supplementary Material. {TS TFE.1, Figure 2; Figure 2.29}

Part 1.

The 30-year temperature average is not conserved for the last 130 years.

Anomaly to the
1961-90 normal (°C)



Temperature Changes at earth surface from year 1000 to 2000.

https://www.ncdc.noaa.gov/cag/global/time-series/globe/land/ytd/7/1880-2018?trend=true&trend_base=10&firsttrendyear=1880&lasttrendyear=2018

Part 1.

Tipping points in climate dynamics

Geophysical Research Letters 10.1002/2015GL066560

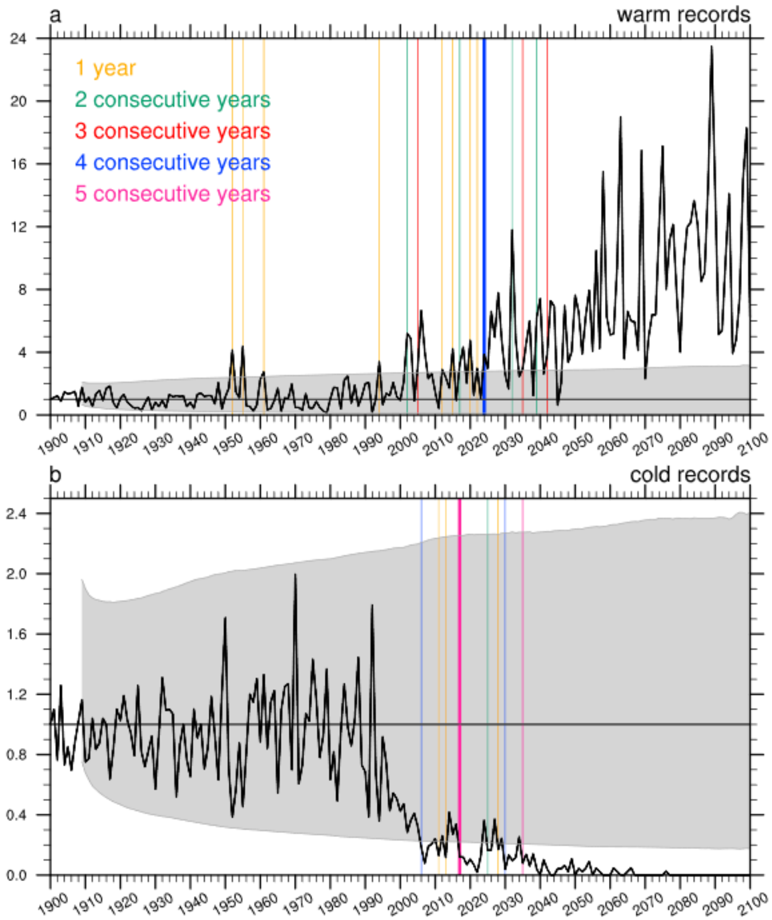


Figure 1. HIST and RCP8.5 evolutions of the annual number of summer (a) warm and (b) cold records in Europe from a random member (black line) of the CanESM2 model. Shaded grey areas correspond to the 90% confidence interval of the record evolutions driven by internal variability only. Vertical thin colored lines refer to the first year of an exceeding event (see the color-duration relation in Figure 1a). The vertical thick line refers to the detected ToE.

When do a time series break out of its normal range ?

EX. Simulated time series of warm and cold records across Europe 1900-2100

Grey area is the normal range, vertical coloured lines are first time of emergence of abnormal values.

Bador, Terray and Boé, 2016. Geophysical Research Letters.

Part 1.

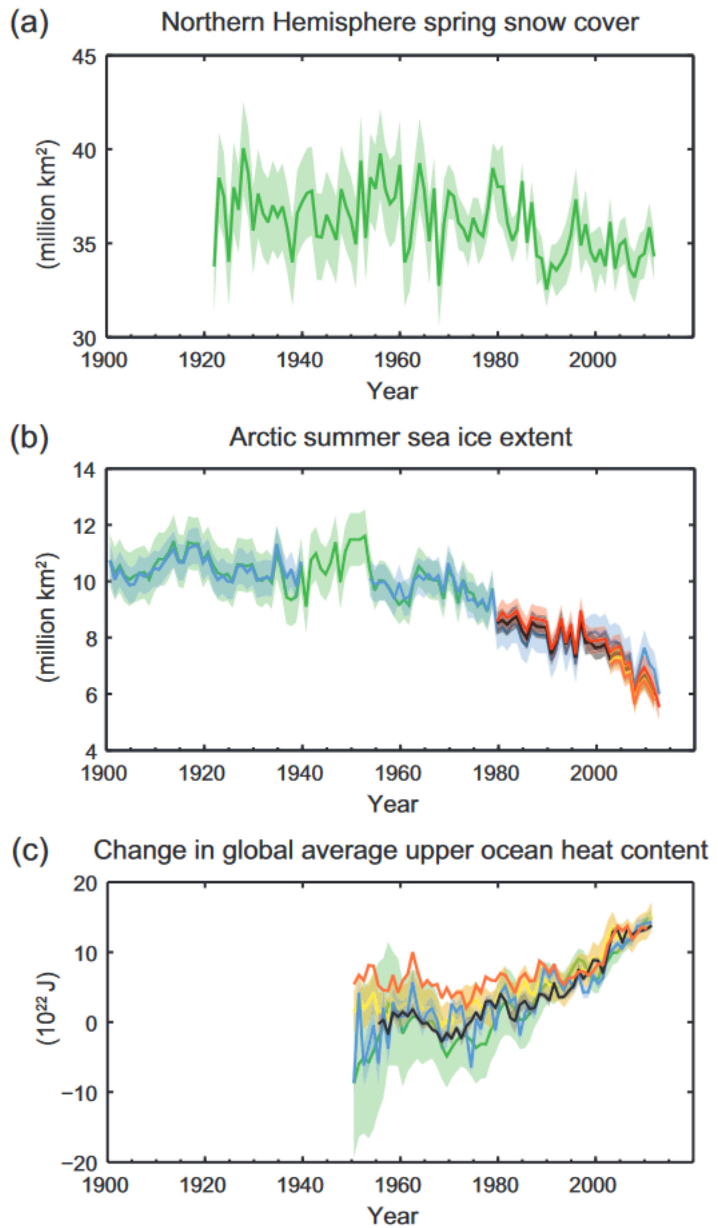
Other recent climate changes (last 120 yrs)

Snow cover and glacier ↓

Sea ice ↓

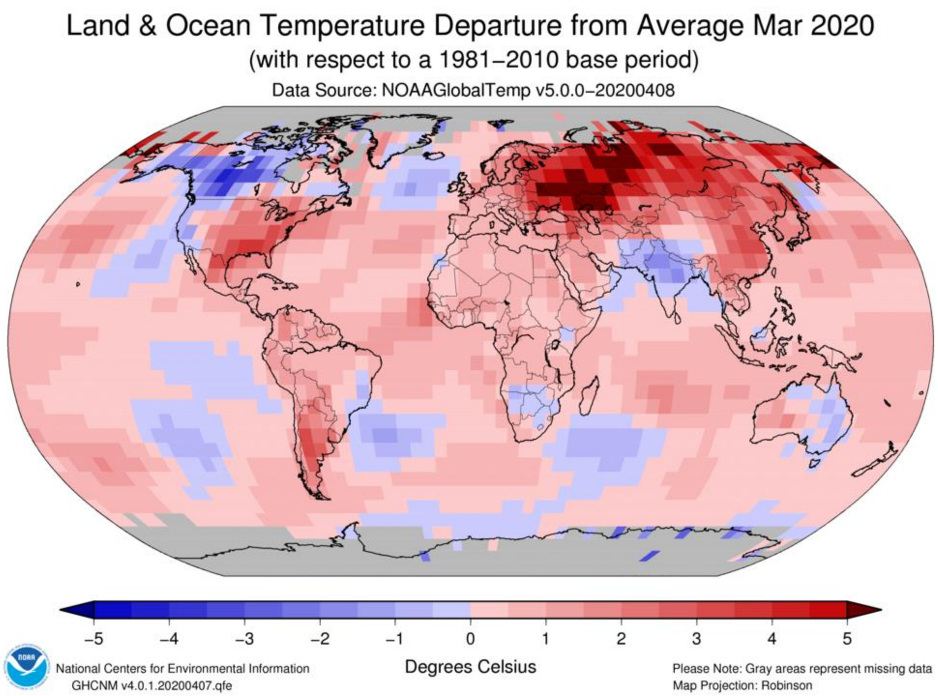
Ocean heat content ↑

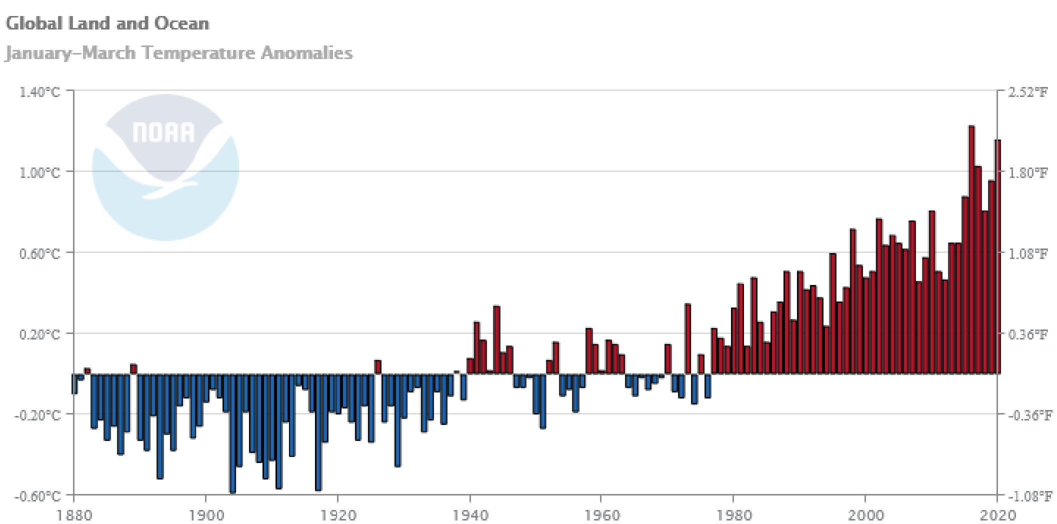
Mean ocean level ↑



Part 2.

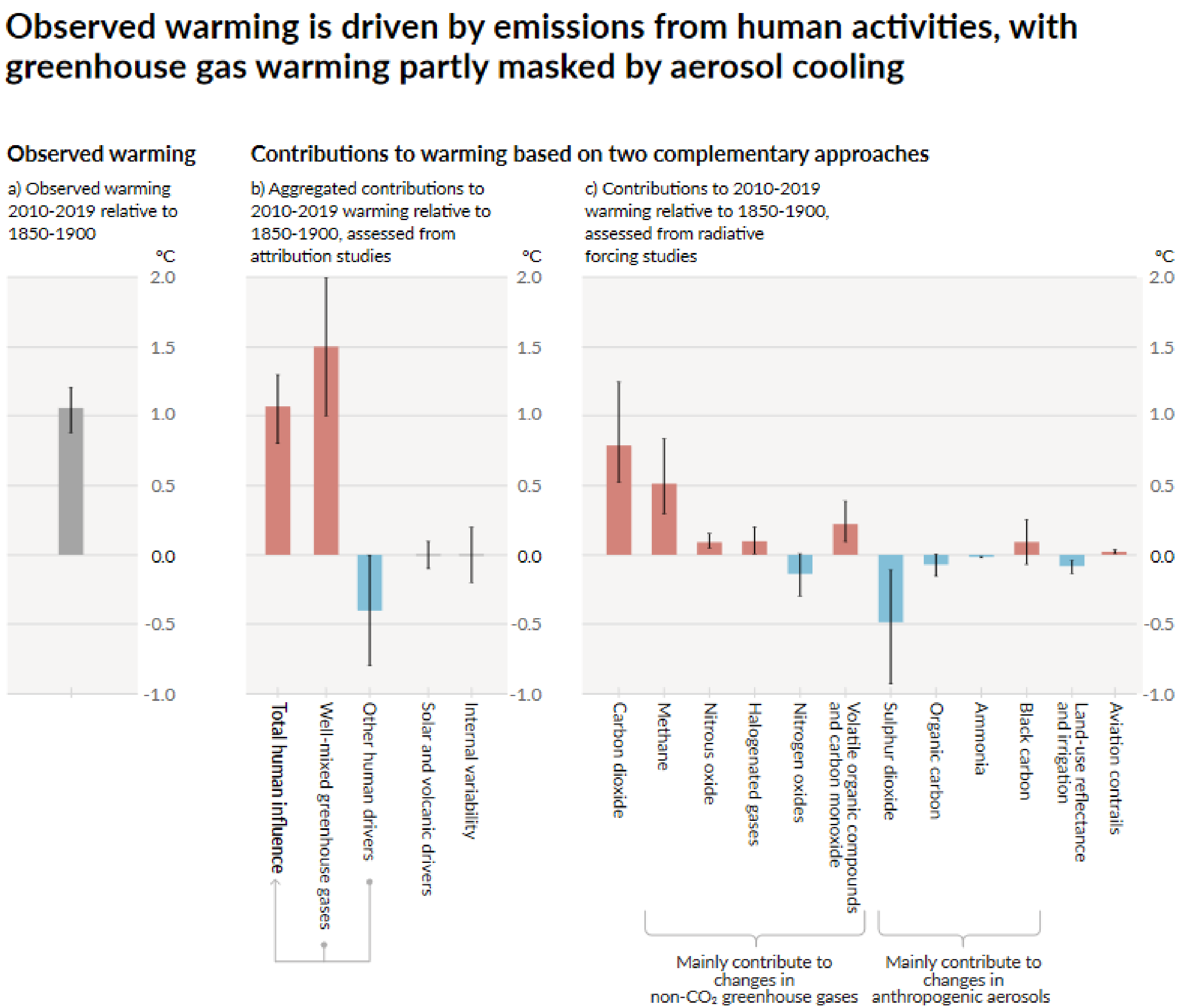
Recent climate changes: 2020





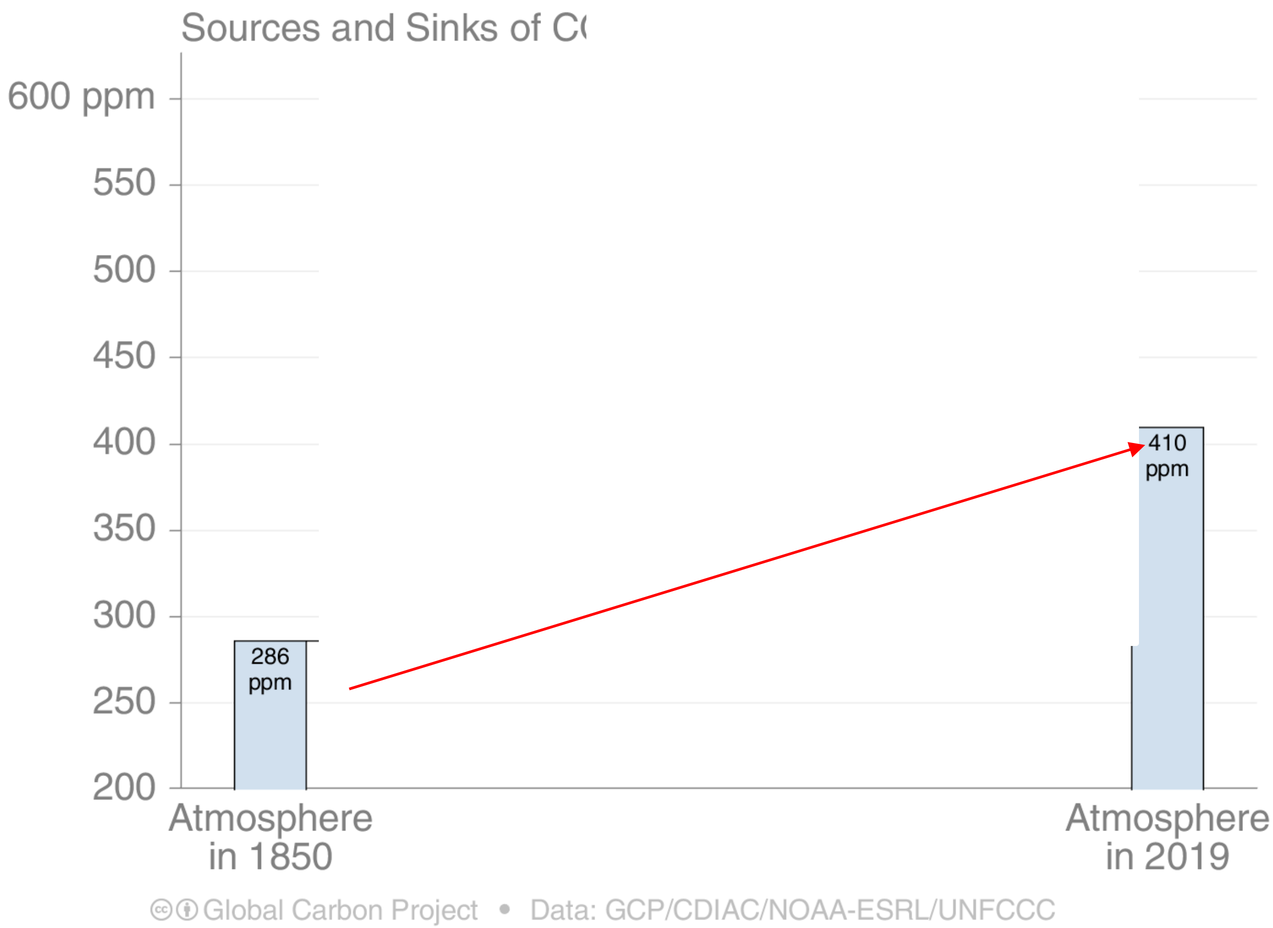
https://www.ncdc.noaa.gov/cag/global/time-series/globe/land/ytd/7/1880-2020

WHY ? Recent climate changes: the drivers (IPCC 6th report)



The present state of the Earth system (carbon cycle)

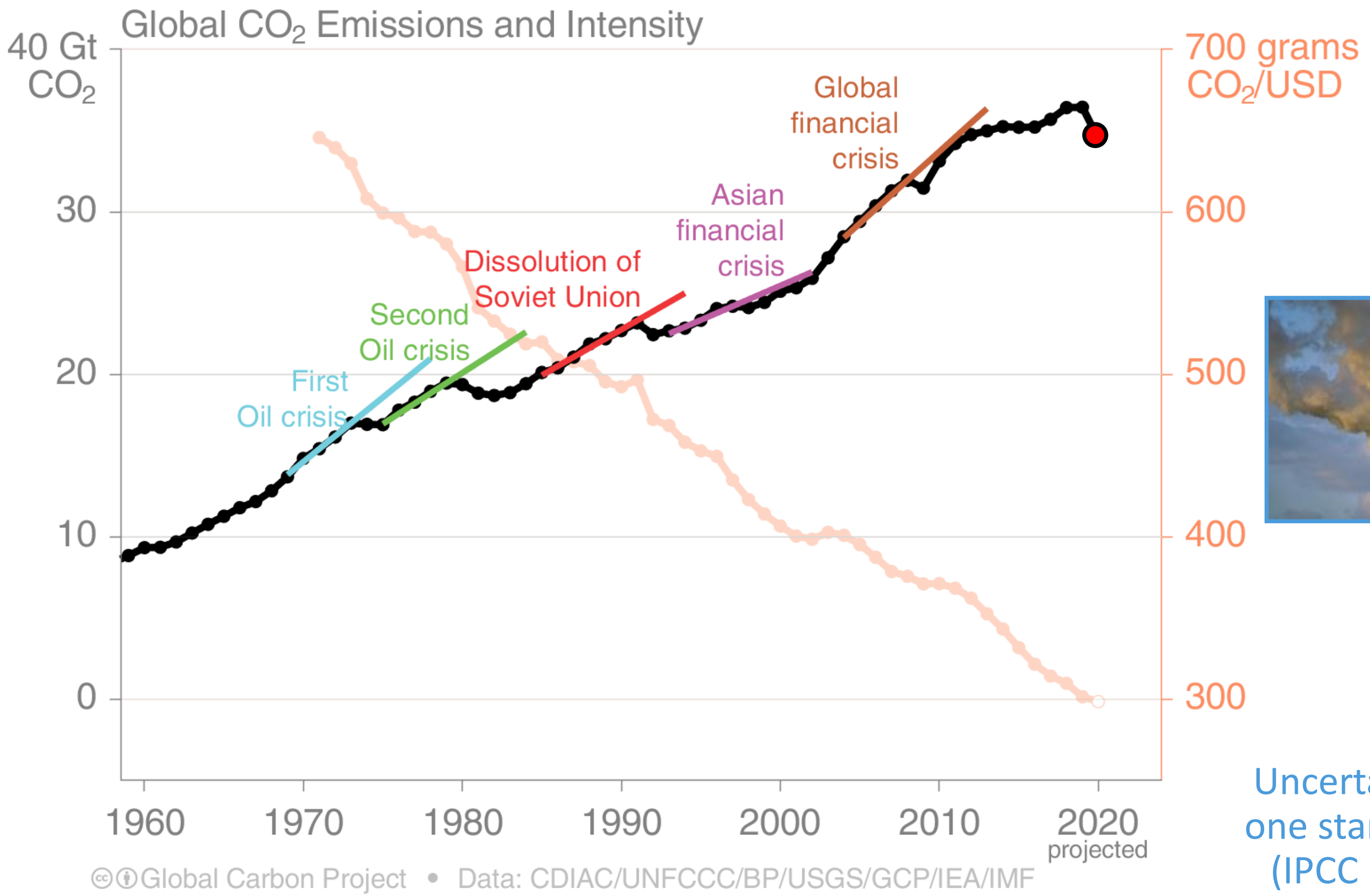
- The cumulative contributions to the global carbon budget from 1870
  The carbon imbalance represents the gap in our current understanding of sources and sinks



Source: [Friedlingstein et al 2020]; [Global Carbon Budget 2020]

Emissions from fossil fuel use and industry

Global CO_2 emissions growth has generally resumed quickly from financial crises.
Emission intensity has steadily declined but not sufficiently to offset economic growth.



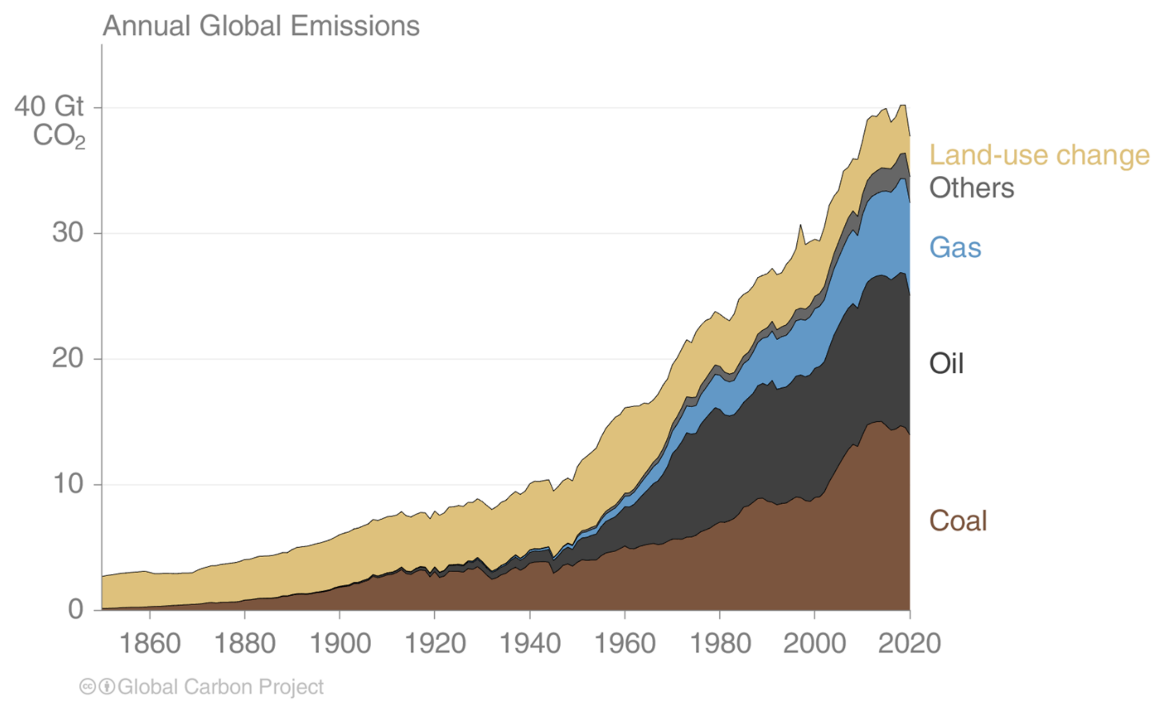
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

Economic activity is measured in purchasing power parity (PPP) terms in 2010 US dollars.
Source: [CDIAC]; [Peters et al 2012]; [Friedlingstein et al 2020]; [Global Carbon Budget 2020]

1850-2020 Reconstruction of CO_2 emissions from human activities

Total global emissions by source

Land-use change was the dominant source of annual CO_2 emissions until around 1950.
Fossil CO_2 emissions now dominate global changes.

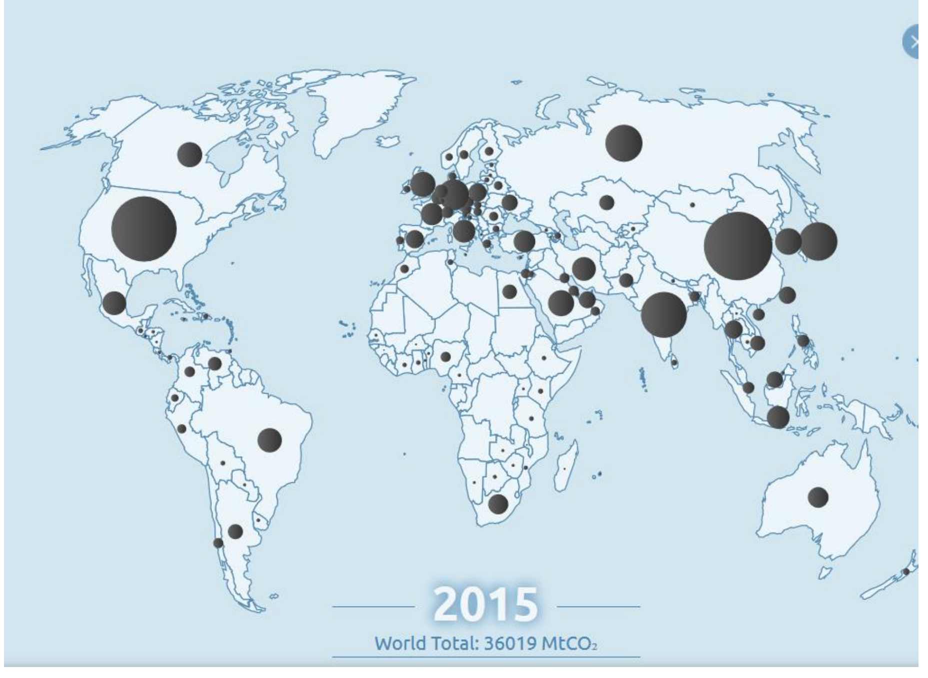


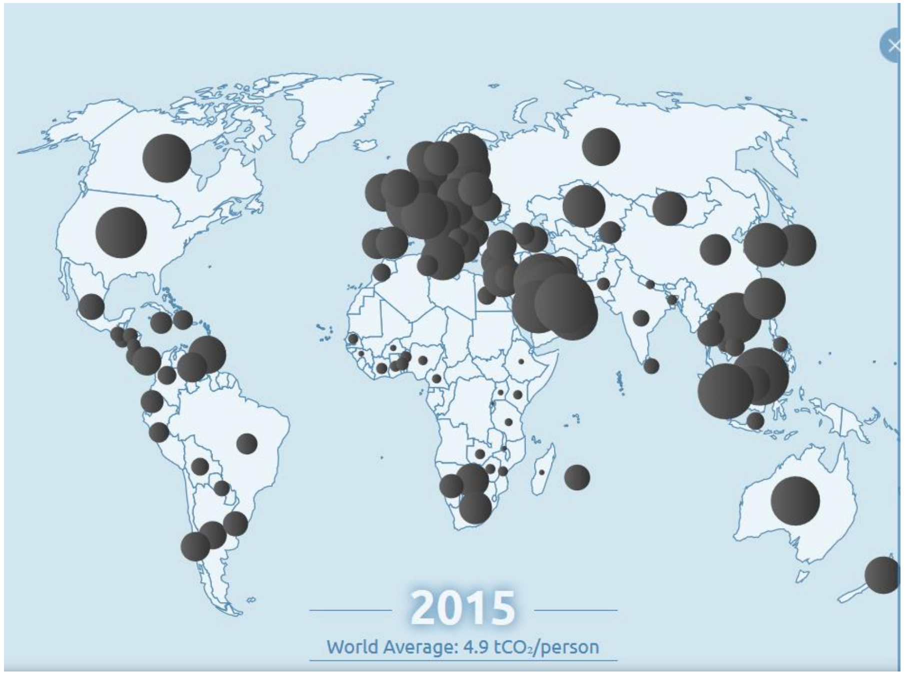
Others: Emissions from gas flaring and carbonate decomposition
Source: Friedlingstein et al 2021; Global Carbon Project 2021

The Earth system (carbon cycle)

Surface emissions.

http://www.globalcarbonatlas.org/en/CO2-emissions





On a consumption basis

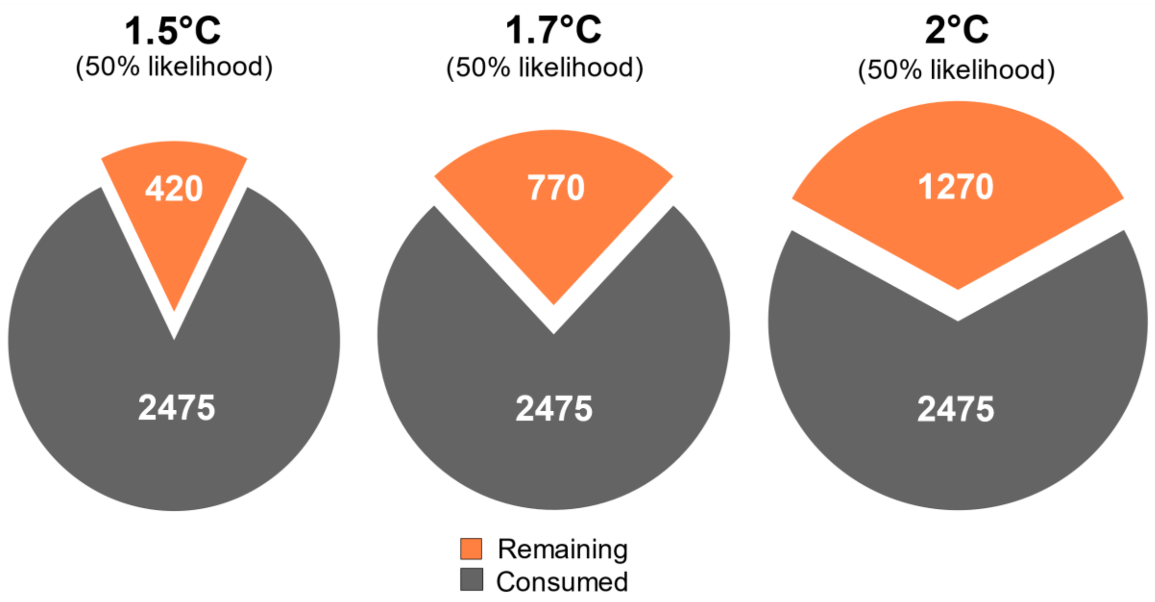
per capita

NB 2015 data

The remaining carbon allowed for containing the global warming

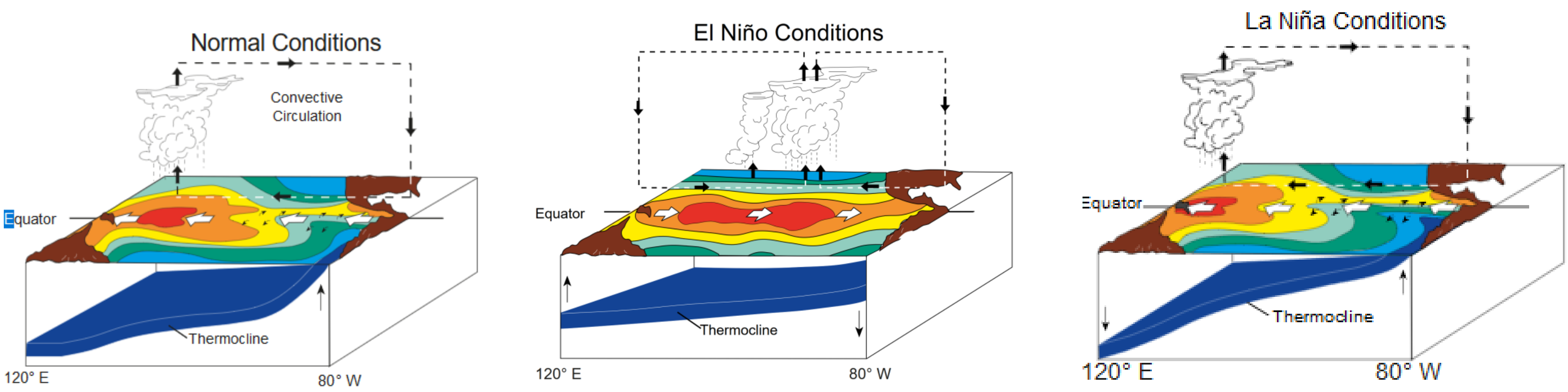
Remaining carbon budget

The remaining carbon budget to limit global warming to 1.5°C , 1.7°C and 2°C is
420 $GtCO_2$, 770 $GtCO_2$, and 1270 $GtCO_2$ respectively, equivalent to 11, 20 and 32 years from 2022.
2475 $GtCO_2$ have been emitted since 1750



Quantities are subject to [additional] uncertainties e.g., future mitigation choices of non-CO_2 emissions
Source: IPCC AR6 WG1; Friedlingstein et al 2021; Global Carbon Budget 2021

Part 2.
Other drivers of recent changes: ocean-atmosphere circulation (1/3)

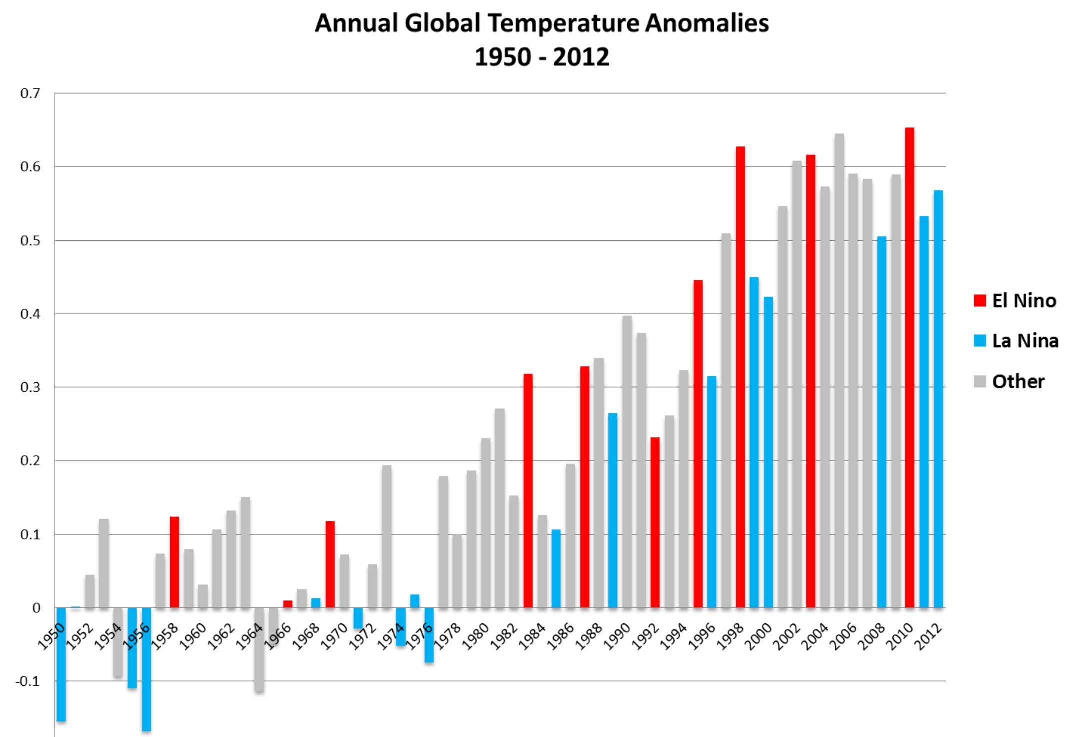


El Niño

Periodic modifications of the Pacific ocean circulation in the equatorial sector, leading to :

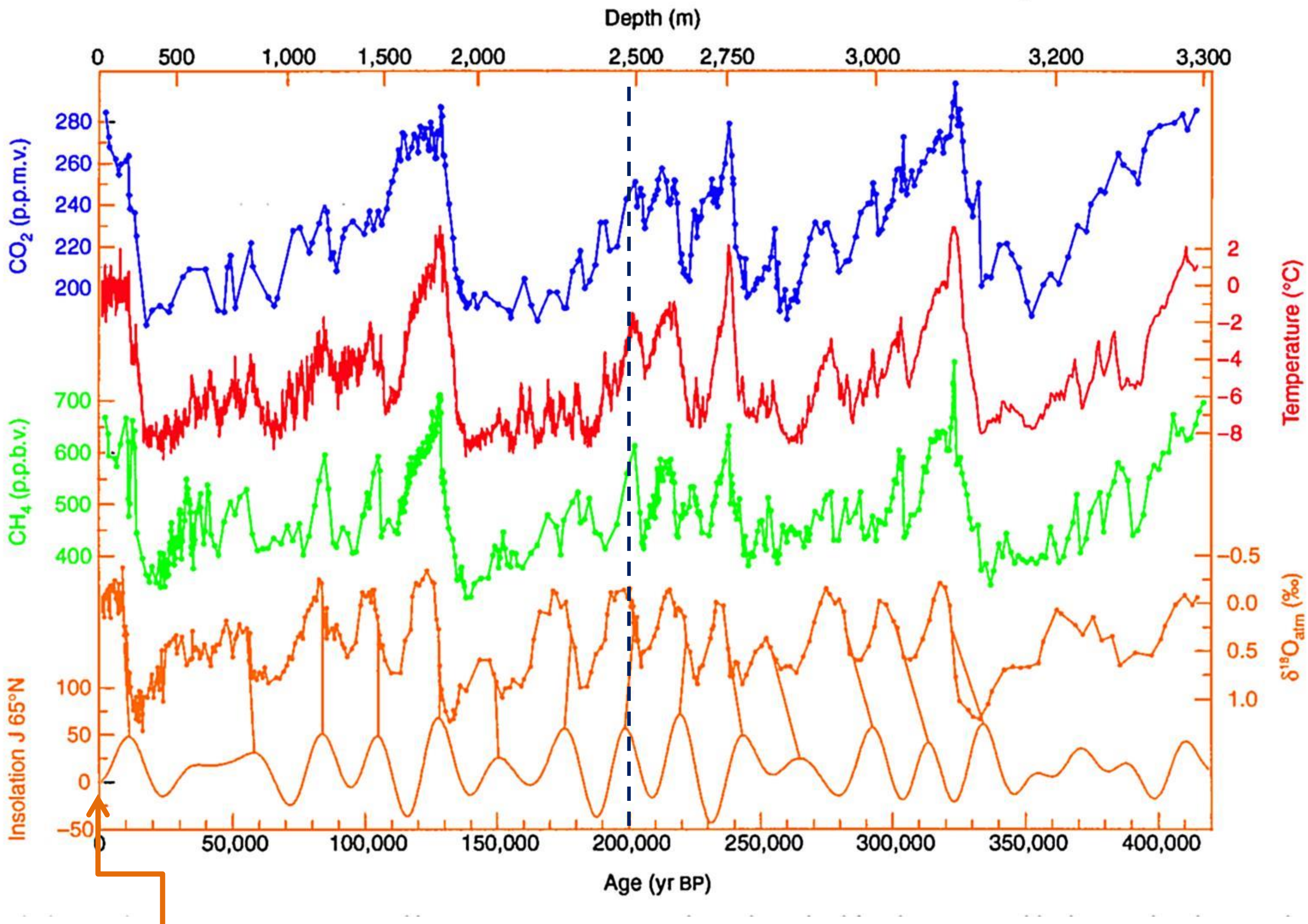
- Drought in Southeastern Asia
- Storms in Eastern America
- Global changes in the atmosphere with delayed effects.
- Positive mean temperature anomaly

No clear connection with other drivers of recent climate changes.



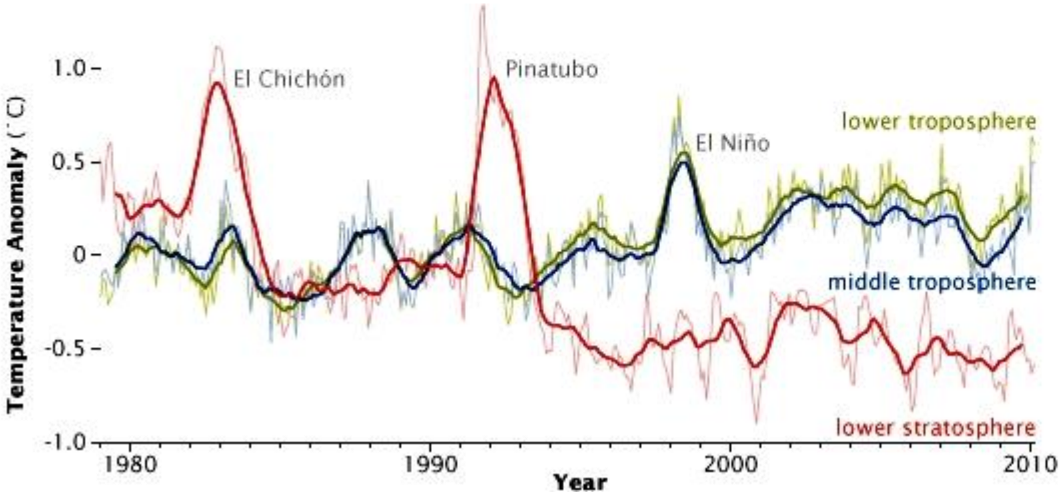
Part 2.

Natural drivers : Astronomic drivers (2/3)



- Milankovich cycles : would cold the earth for the last 50 years

Part 2. Natural drivers of recent changes: volcanic eruptions (3/3)

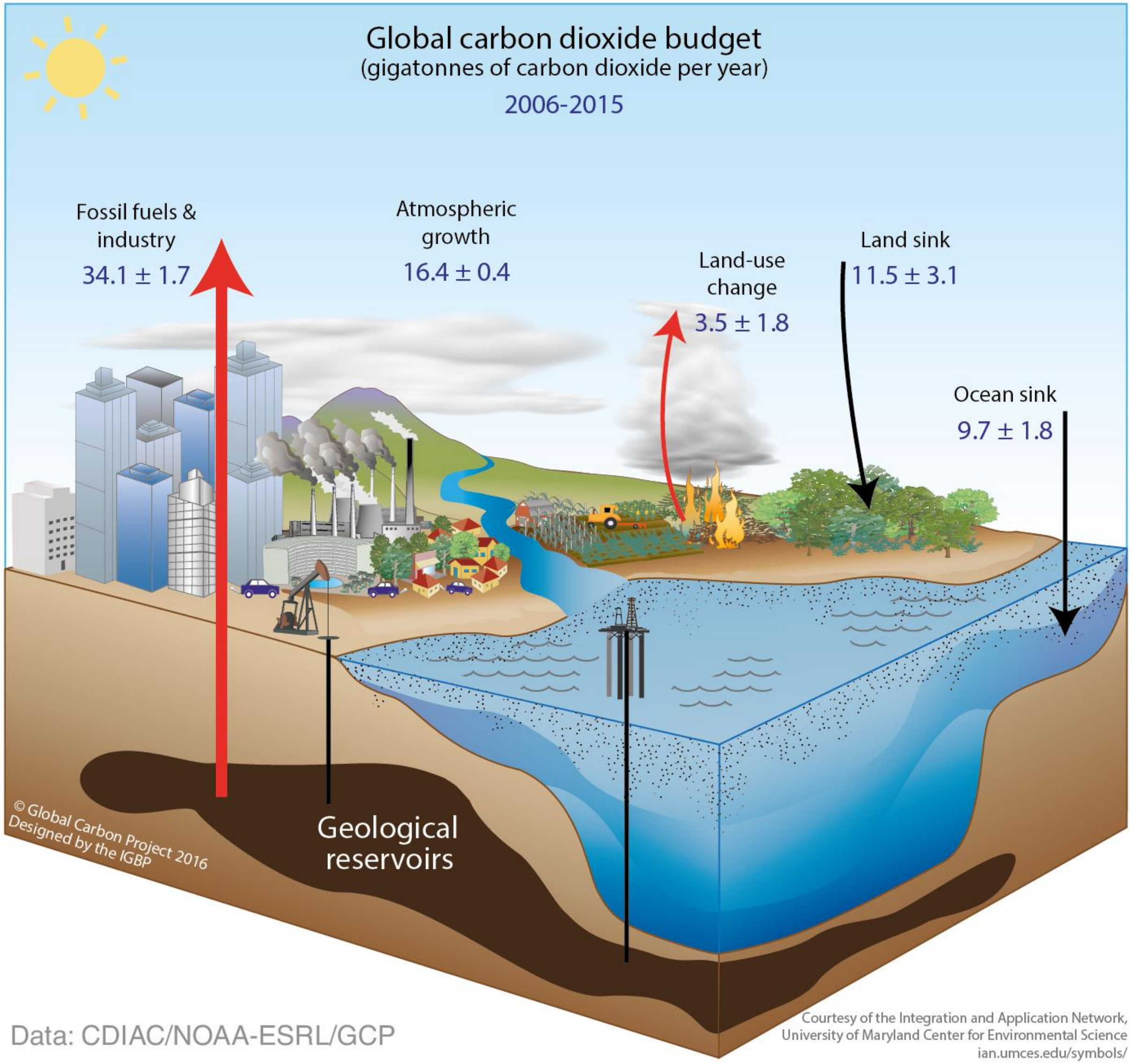


Temperature anomaly measured from NASA satellites in the upper and middle Troposphere and lower Stratoshere as affected by volcanic eruptions and El Niño event.

Volcanic eruptions emit large amounts of particles in the atmosphere, that deems the incoming solar radiation and increases its diffuse fraction with colding effects lasting for months – years in the lower troposphere.

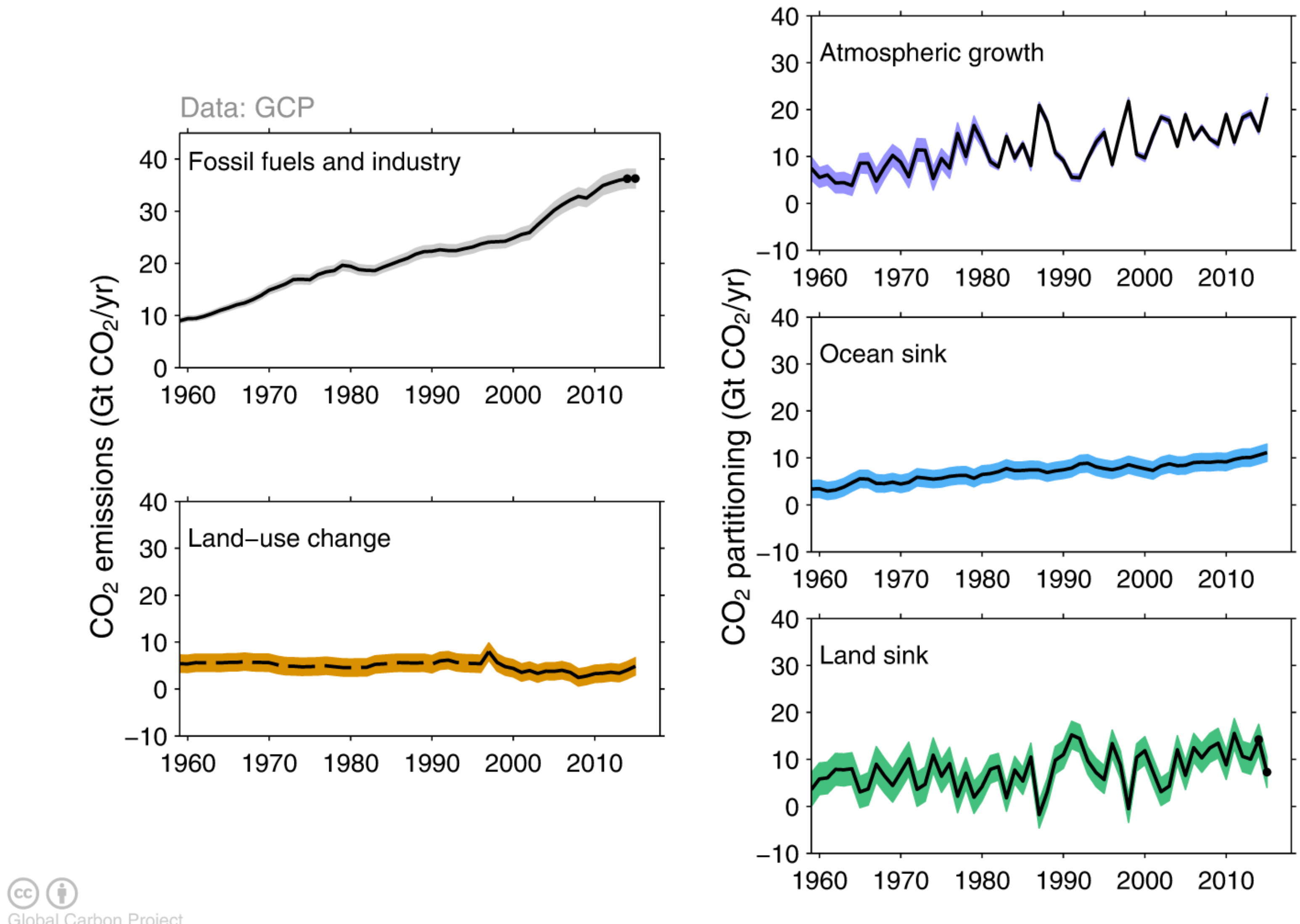
Part 2.

The present state of the Earth system (carbon cycle)



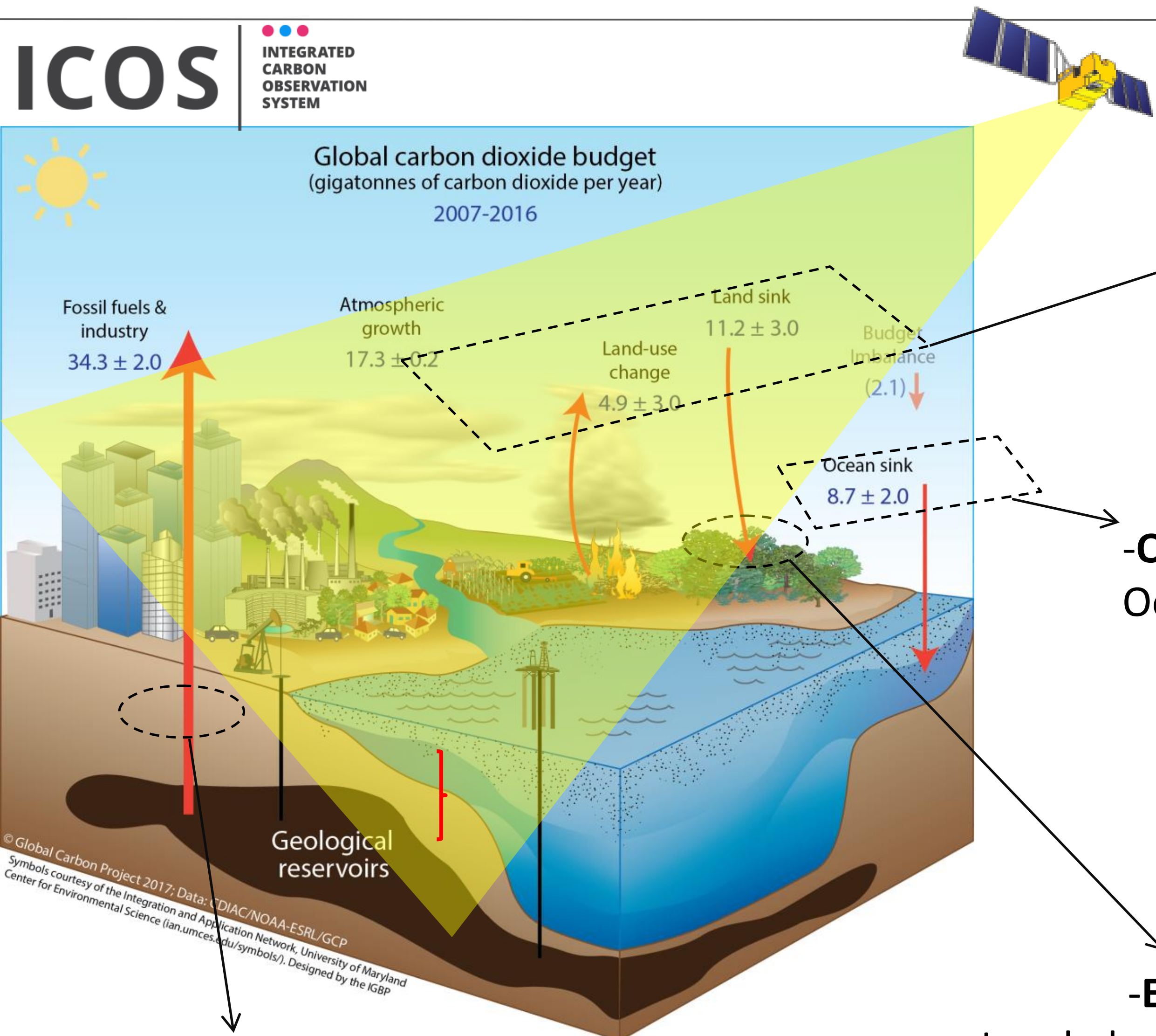
Part 2.

The present state of the Earth system (carbon cycle)

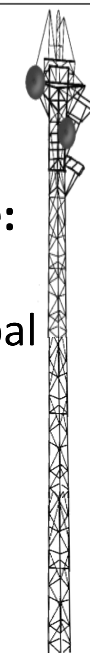


The GHG cycle observation strategy

ICOS INTEGRATED CARBON OBSERVATION SYSTEM

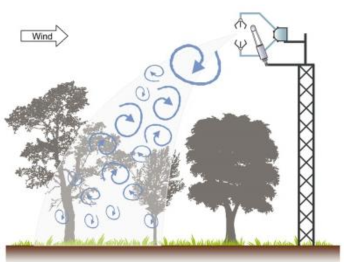


-From space:
Atmospheric GHG content
Carbon stocks in biomass



-**Atmosphere:**
Data for regional/global inversion modelling

-**Ocean**: observations of Ocean – Atmosphere flux



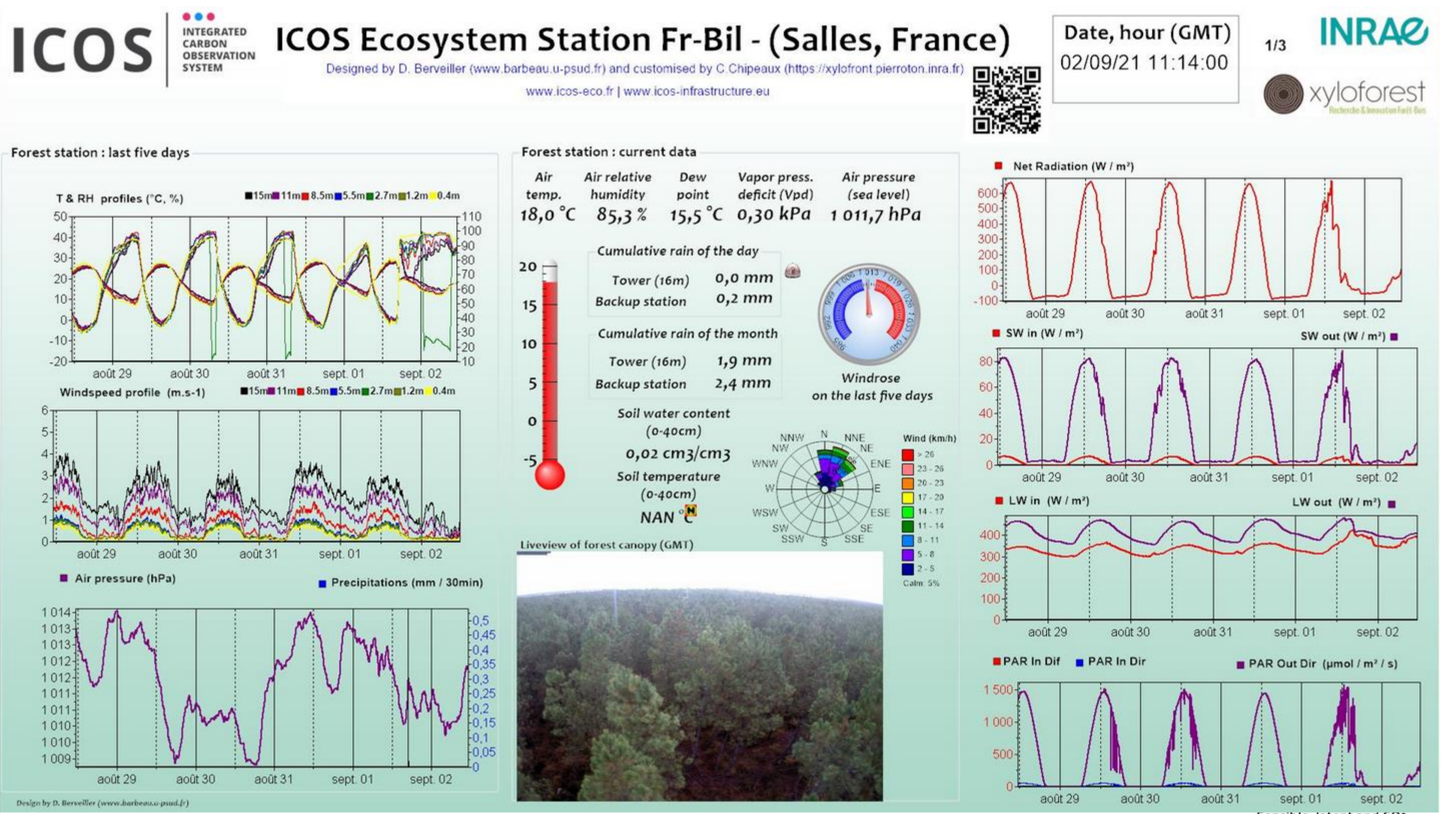
-**Ecosystems**:
Local observations of Land- Atmosphere flux

Country inventory
Bookkeeping models

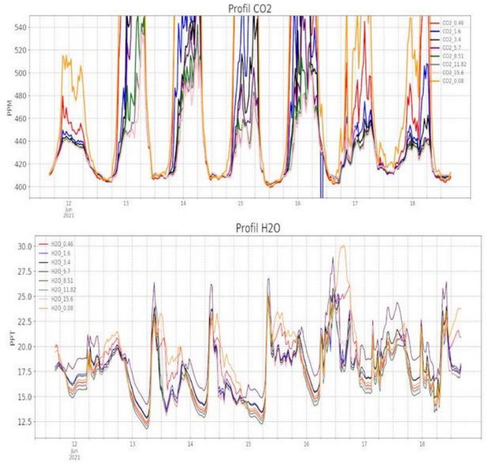
Monitoring the surface energy balance, micrometeorology, GHG and heat flux over continental ecosytems: the FR-Bil ICOS station

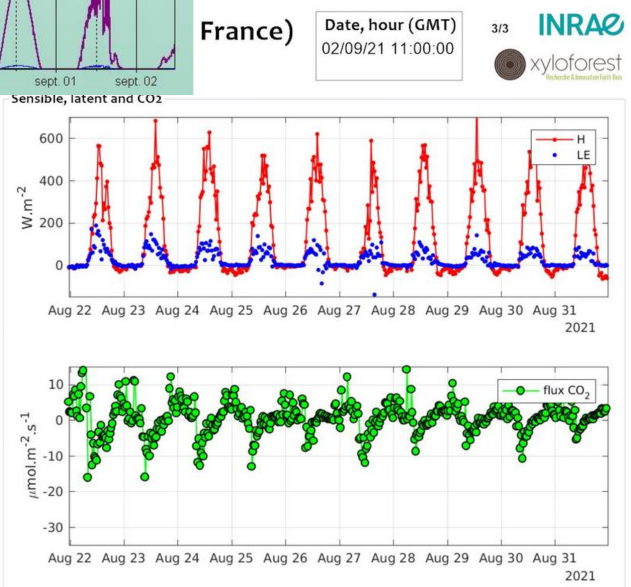
- Field visit by Thursday 9 - 12 am
- Flux of heat, momentum, CO_2, water vapour, at 30mn resolution
- + 120 variables monitored fro 1sec to 1mn since 2002.
- Part of the ICOS Ecosystem network (80 stations in Europe on crops, grasslands, mires, forest, lakes, urban areas).

On line data from the site

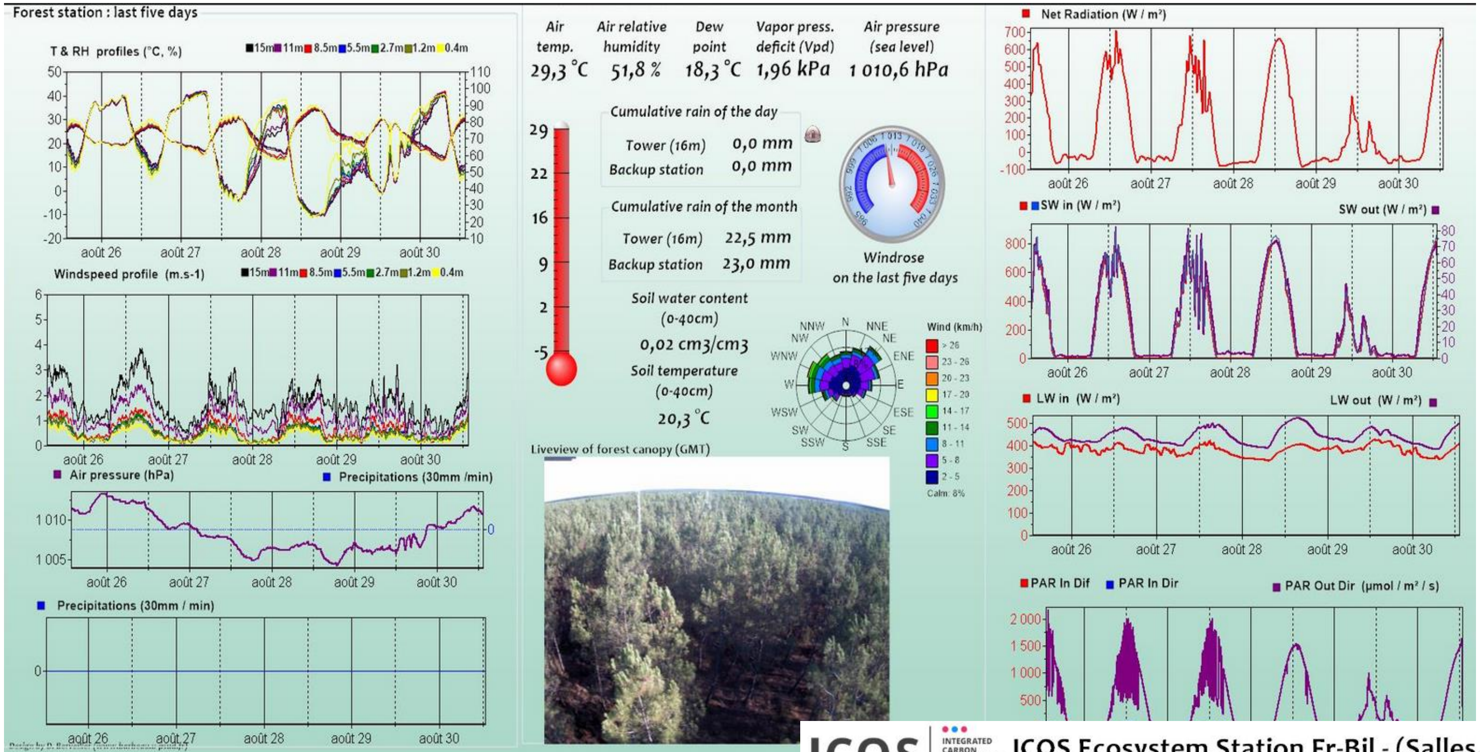


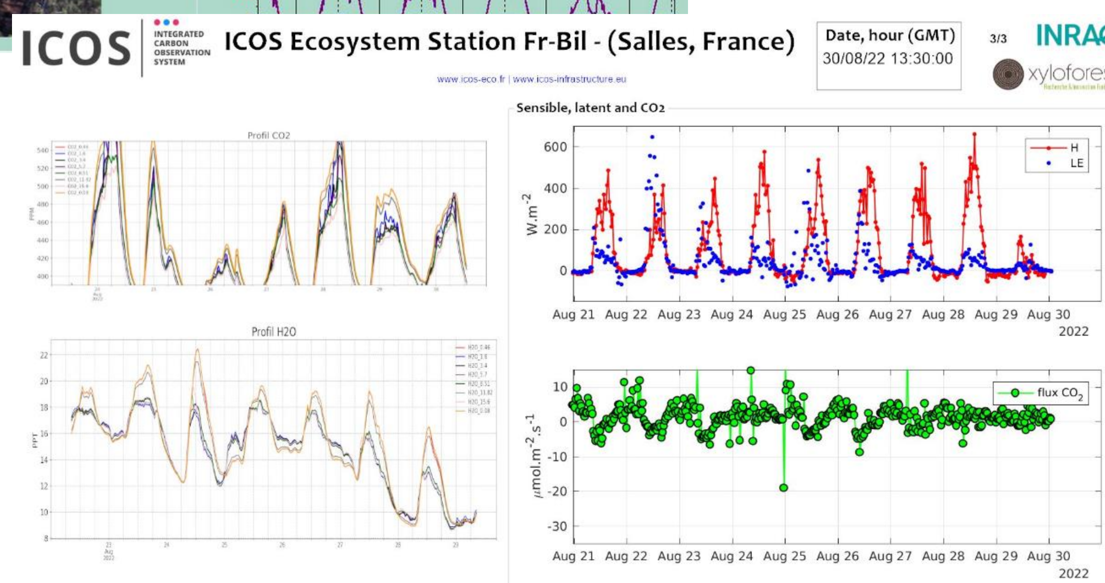
https://xylofront.pierroton.inra.fr/Salles2.html





On line data from the site





https://xylofront.pierroton.inra.fr/Salles2.html

What does exactly mean « climate change »?

Is it justified to define a new geologic era:
the « Anthropocene » ?

Can we still observe a « climate » in 2020 ?

Part 3.

How can we project future changes ?
Climate scenarios

the CMIP initiative (World Climate Research Program)

Climate simulations performed by different models
21 models used in the 6th round (last IPCC WG1 report (AR6)):

- ✓ Benchmarked using a standard protocol
- ✓ Runs along standardised forcing scenarios (RCPs → SSPs)
- ✓ Ensemble modelling assesses the uncertainty (CMIP6 project)
- ✓ Comparison with observed data over the historical period (1950-2000).

http://www.wcrp-climate.org/index.php/wgcm-cmip/about-cmip

Part 3.

Participating modelling groups

	Institution	Country		Institution	Country		Institution	Country
1	AWI	Germany	12	DOE	USA	23	MRI	Japan
2	BCC	China	13	EC-Earth-Cons	Europe	24	NASA-GISS	USA
3	BNU	China	14	FGOALS	China	25	NCAR	USA
4	CAMS	China	15	FIO-RONM	China	26	NCC	Norway
5	CasESM	China	16	INM	Russia	27	NERC	UK
6	CCCma	Canada	17	INPE	Brazil	28	NIMS-KMA	Republic of Korea
7	CCCR-IITM	India	18	IPSL	France	29	NOAA-GFDL	USA
8	CMCC	Italy	19	MESSY-Cons	Germany	30	NUIST	China
9	CNRM	France	20	MIROC	Japan	31	TaiESM	Taiwan, China
10	CSIR-CSIRO	South Africa	21	MOHC	UK	32	THU	China
11	CSIRO-BOM	Australia	22	MPI-M	Germany	33	Seoul Nat.Uni	Republic of Korea

New in CMIP:

2 new model groups from Germany (AWI, MESSY-Consortium)
4 new model groups from China (CAMS, CasESM, NUIST, THU)
1 new model group from Brazil (INPE)
1 new model group from India (CCCR-IITM)
1 new model group from Taiwan, China (TaiESM)
1 new model group from USA (DOE)
2 new model group from Republic of Korea (NIMS-KMA, SAM0-UNICON)
1 new model group from South Africa / Australia (CSIR-CSIRO)
==

⇒ **13 new model groups so far**

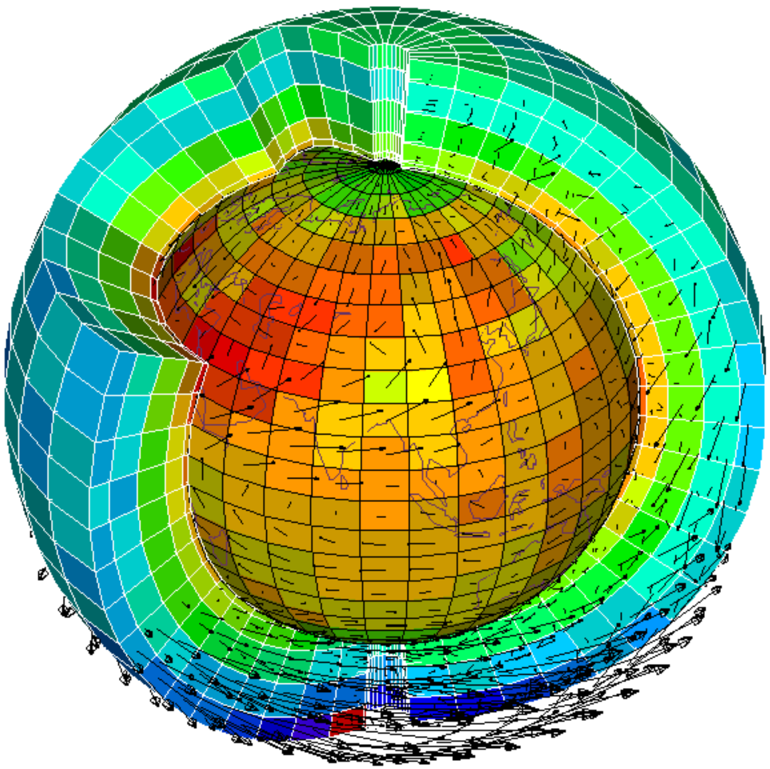
More models (>70)
New models
More complex models
Higher resolution models

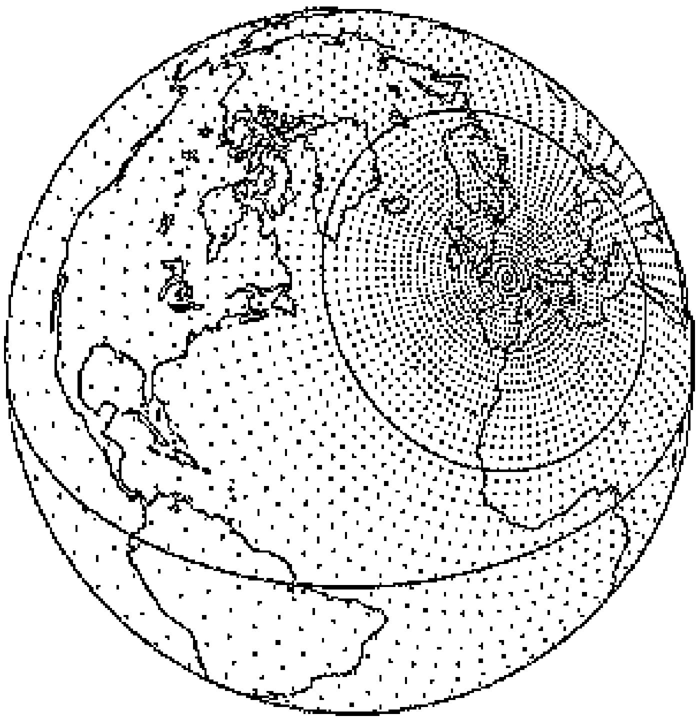
* Other models can join providing DECK and historical simulations are submitted

CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

Conversion of GHG forcing into climate scenarios

1. Global circulation models(MCG/GCM)

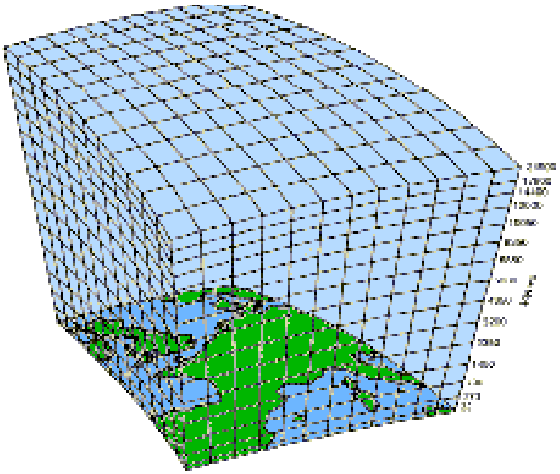




EX. ARPEGE Météo France :
20km (France) → 250 km (antipodes)

Sources :
http://sawww.epfl.ch/SIC/SA/publications/FI98/fi-sp-98/sp-98-page103.html
(*Hervé Le Treut, Laboratoire de Météorologie Dynamique du CNRS, Univ.Pierre et Marie Curie, Paris)*
Météo France
http://www.meteofrance.com/FR/pedagogie/dossiers_thematiques/prevision_numerique2.jsp

Conversion of GHG forcing into climate scenarios



2. Regional Climate Models (or fine scale GCM)

3. Bias correction & statistical downscaling method (see e.g. Quantile quantile method by Déqué *Glob. Plan. Change*, 2007)

align the distribution of simulated values on observations.

CMIP initiative : overviews and dissemination

CMIP6 Special Issue in Geosc. Model Devt at https://www.geosci-model-dev.net/special_issue590.html

A Short Introduction to Climate Models - CMIP & CMIP6 Video produced by WCRP

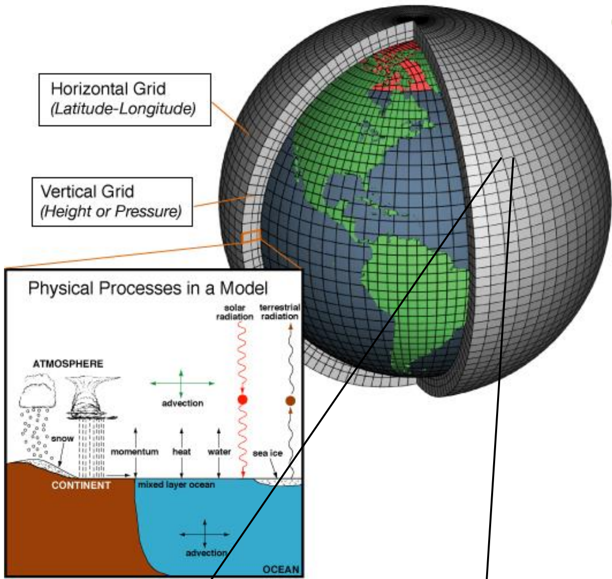
- Short version on Youtube at https://www.youtube.com/watch?v=wTBkq9nWNEE
- Long version on Youtube at https://www.youtube.com/watch?v=WdRiYPJLt4o

Geosc. Model Devt. Highlight Article by David Carlson, Veronika Eyring, Narelle van der Wel, and Gaby Langendijk

Nature Climate Change Interview on CMIP6 at http://www.nature.com/nclimate/journal/v7/n10/full/nclimate3398.html

Model output will be published at the Earth System Grid Federation (ESGF)
Monitor results of CMIP5/CMIP6 model evaluation with the ESMValTool at http://cmip-esmvaltool.dkrz.de/

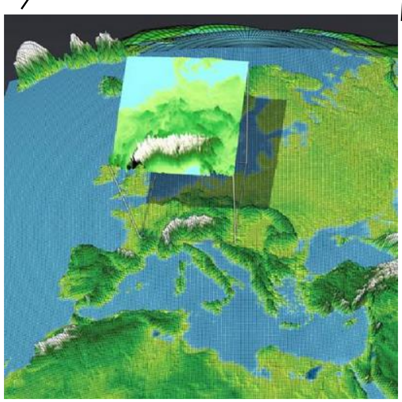
Climate modelling: the uncertainty cascade



Global Circulation Model

(Atmosphere Ocean Global Circulation Model)

- Parameterisation
- Spatial Resolution
- Complexity (earth system components, boundary limits, processes, feed backs)
- Stochasticity

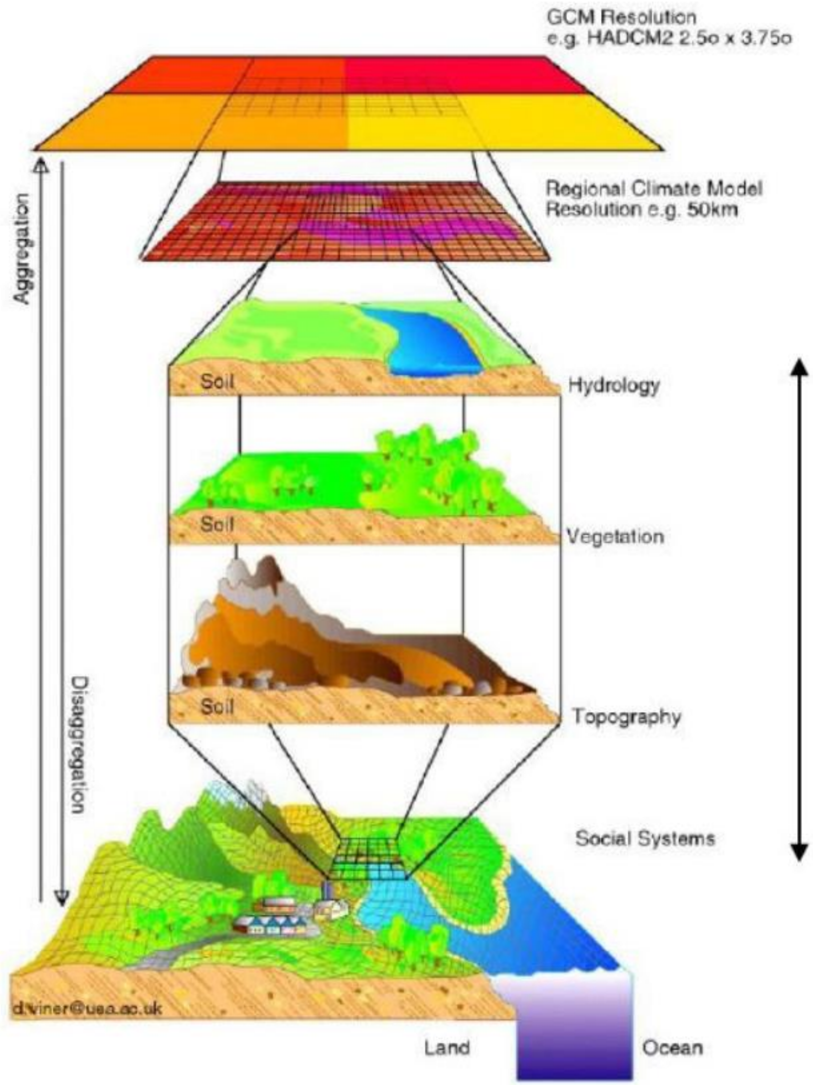


Downscaling models

(Regional Climate Model)

- Spatial resolution
- AGCM data assimilation
- Internal variablity

Climate modelling: the uncertainty cascade (continued)



GCM

RCM

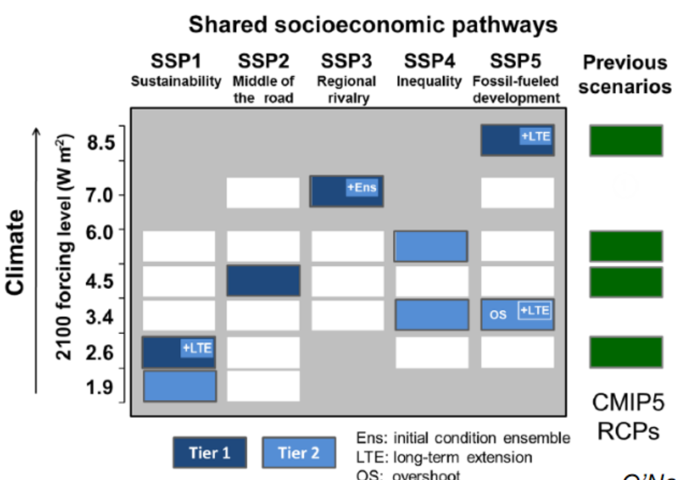
Impact modelling
(surface feed backs)

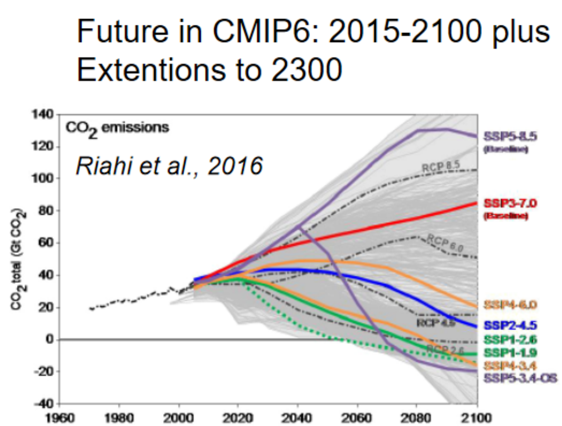
Climate scenarios: assessing the possible futures

The climate scenarios RCP (2.6, 4.5, 6.0, 8.5);SSP (2.6, 4.5, 6.0, 8.5); :

- Provide a range of consistent scenarios of the Earth system until 2100;
- Cover a range of possible futures:
    - Demography, energy and economy policies
    - Governmental Climate policies (cf. COP 21): Europe, China, USA, etc…
- Account for natural and anthropogenic drivers and feed backs of the Earth system;

SSPs: set of baselines, with future developments in absence of new climate policies beyond those in place today





O'Neill et al., ScenarioMIP for CMIP6, GMD, 2016

Part 3.

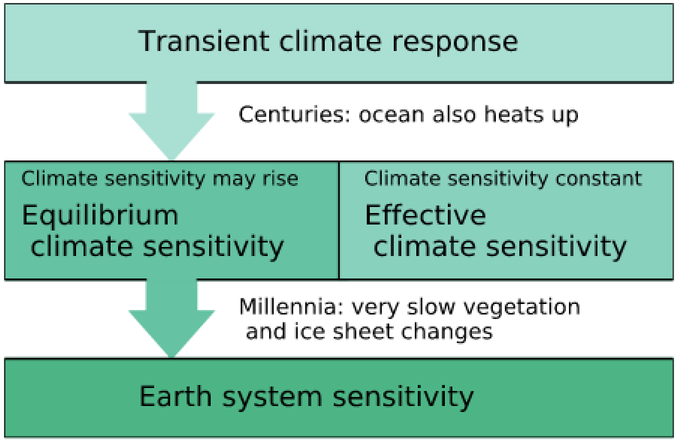
Climate sensitivity

Climate sensitivity is defined as follows:

the global temperature change, averaged over 20 years, in response to a doubling of [CO_2] i.e. from 260 to 520 ppm at +1% yr^{-1}

- **Transient** climate sensitivity: temperature change at the time when 520ppm is reached.
  [1 to 2.5°C] (AR6)

- **Equilibrium** climate sensitivity. Temperature change after stabilization of the Climate System.
  3°C [2.5 – 4.0 °C] (AR 6) vs [1.5-4.5] (AR 5)



https://commons.wikimedia.org/wiki/File:Schematic_climate_sensitivity.svg#/media/File:Schematic_climate_sensitivity.svgclimate sensitivity to anthropogenic drivers

Part 3.

Climate change reversibility

- The primary determinants of climate remain unchanged: solar energy
- Some secondary drivers maybe restored in 10-100 years. Ex.
  - Atmospheric concentrations in GHG
  - Land use
- Some changes cannot be reverted before 100-1000 years.
  - Globally:
    - Sea ice
    - Continental glaciers
    - Ocean heat content, pH, volume
  - Regionally:
    - Amazonian deforestation if left unstopped.

Climate scenarios: the radiative forcing concept

The radiative forcing concept

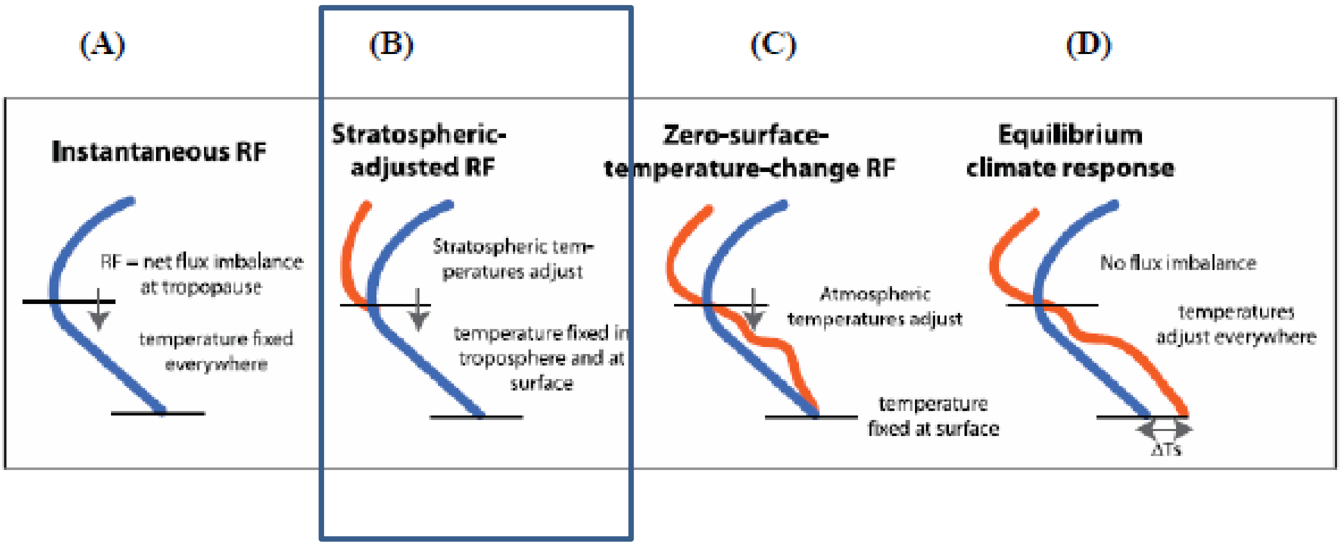


Fig. 2 : Schéma comparatif des différentes méthodes de calcul du forçage radiatif. Le forçage radiatif au sens de l'IPCC est calculé dans la situation décrite par la figure (B). ***(Source : Forster et al., 2007)***

- The radiative forcing concept is used for comparing the impacts of various drivers on the atmospheric energy balance.
- Units: W.m-2
- Equivalent to the energy added (or substracted) at the top of the troposphere following a change in forcing (GHG, albedo, …)

Future climate scenarios: the representative concentration pathways (RCP)

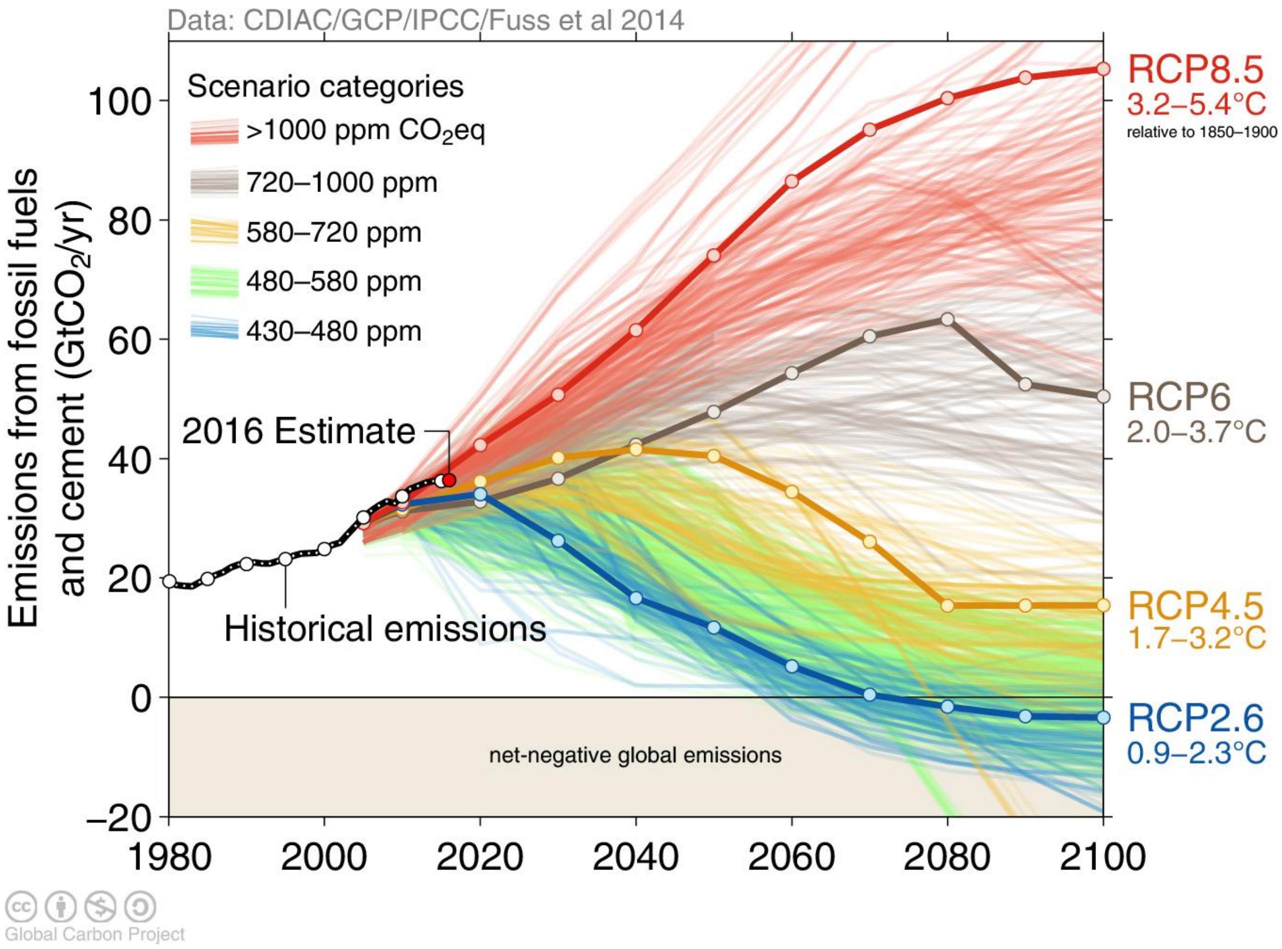
Les profils représentatifs d'évolution de concentration (RCP : representative concentration pathway) sont des scénarios de référence de l'évolution du forçage radiatif sur la période 2006-2300.

Nom	Forçage radiatif	Concentration de GES (ppm)	Trajectoire
RCP 8.5	>8,5Wm^{-2} en 2100	>1370 eq-CO_2 en 2100	croissante
RCP 6.0	~6Wm^{-2} au niveau de stabilisation après 2100	~850 eq-CO_2 au niveau de stabilisation après 2100	Stabilisation sans dépassement
RCP 4.5	~4,5Wm^{-2} au niveau de stabilisation après 2100	~660 eq-CO_2 au niveau de stabilisation après 2100	Stabilisation sans dépassement
RCP 2.6	Pic à ~3Wm^{-2} avant 2100 puis déclin	Pic ~490 eq-CO_2 avant 2100 puis déclin	Pic puis déclin

Tableau 1 : Caractéristiques principales des RCP (Moss et al, Nature 2010)

Le forçage radiatif, exprimé en W/m^2, est le changement du bilan radiatif (rayonnement descendant moins rayonnement montant) au sommet de la troposphère (10 à 16 km d'altitude), dû à un changement d'un des facteurs d'évolution du climat comme la concentration des gaz à effet de serre. La valeur pour 2011 est de 2,84 W/m^2

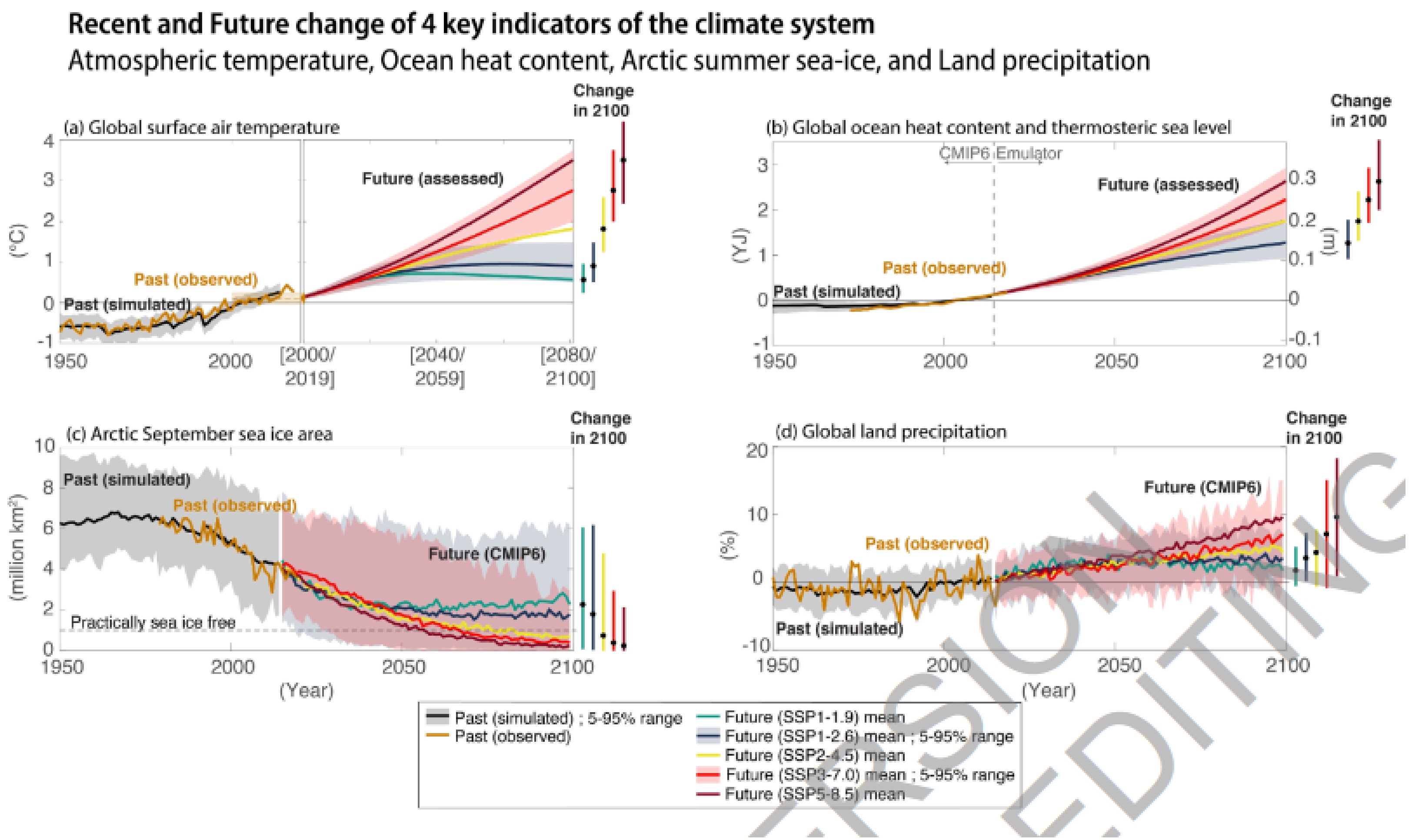
Climate scenarios: assessing the possible futures of GHG emissions



The IPCC Fifth Assessment Report assessed about 1200 scenarios with detailed climate modelling on four Representative Concentration Pathways (RCPs)

Source: Fuss et al 2014; CDIAC; IIASA AR5 Scenario Database; Global Carbon Budget 2016

Climate modelling



IPCC technical Summary WG1 report (AR6)

Part 3.

Climate scenarios: the French case.

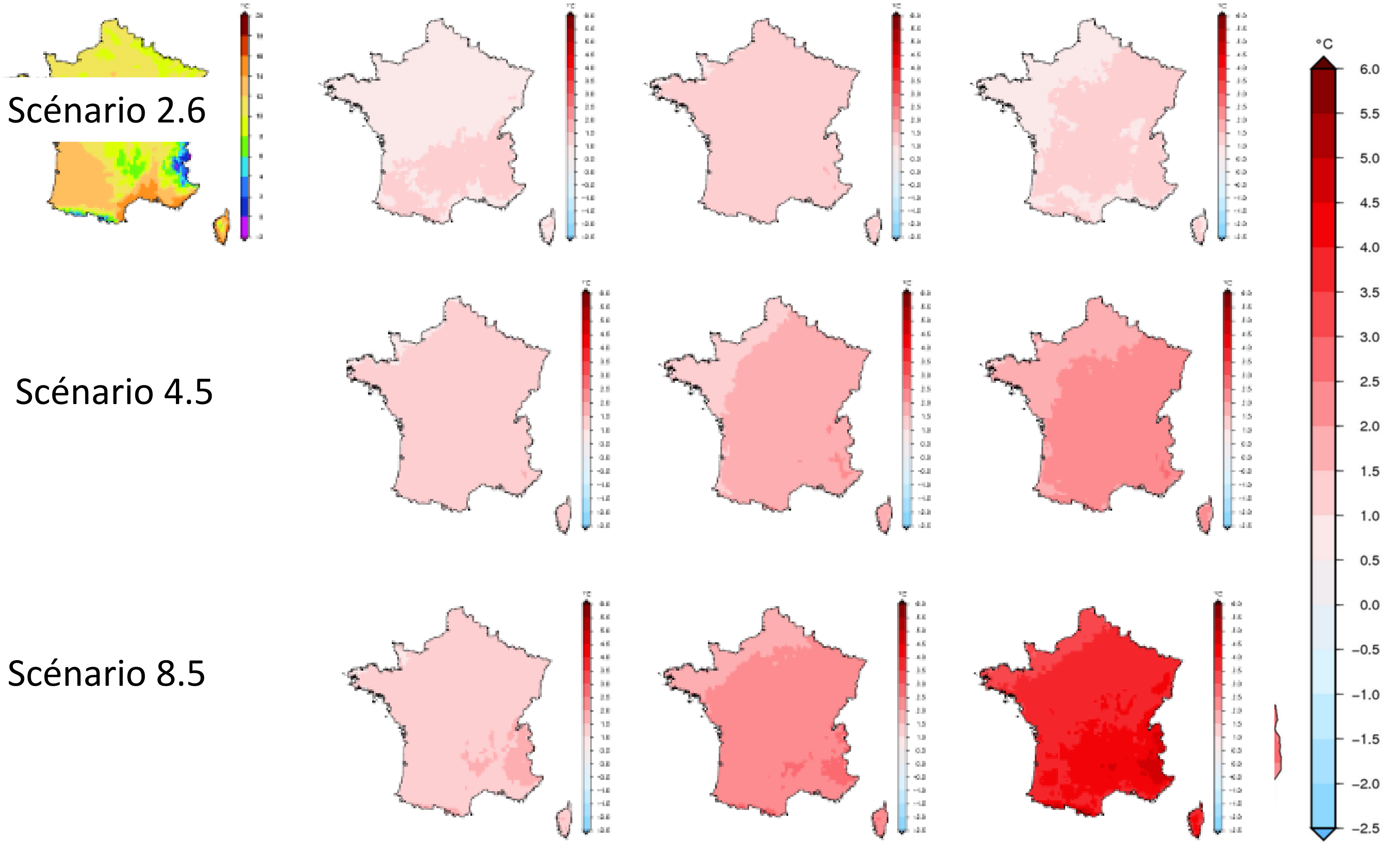


Figure 1.
Anomaly of the mean annual temperature over France simulated under three RCPs scenarios. DRIAS dataportal, DRIAS 2020 simulations. Median of 8 models GCM/RCM.

General Conclusions

The earth system is deeply disturbed by human activities, that delimits a new epoch, the Anthropocene.

The climate concept, as a usual succession of atmospheric states over a region in equilibrium with a vegetation community has no more observable reality.

The « climate change » concept is misleading and should be substituted by **climate disturbance**.

Take home the **last WGI IPCC (AR 6 2021) highlights :**

- Refined future climate projections : climate sensitivities, scenarios, feedbacks
- Addressed extreme events issue : storms, droughts,
- Defined specific targets in terms of « remaining fossil carbon to emit » to reach a given temperature increase
- And much more…

Lessons for agriculture and forestry

What can offer the retrospective approaches in a changing world :
- agronomical and forest models
- genetic improvement strategies ?

→ Predictive approach based upon processes and using projections

The climax : the equilibrium paradigm is challenged by the present climate perturbation

→ Dynamic modeling driven by scenarios

How can we manage croplands, grasslands and forests to mitigate the greenhouse effects ?

→ Biogeochemical cycle of GHG (carbon storage, CH_4 emission reductions etc.)
→ Biophysical effects (albedo)
→ Forests, cropland, soil and grasslands in the low-carbon national strategy
→ The 4p 1000 initiative for soils