Climate change: The scientific basis

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Twitter: @JPvanYpersele

European Commission, DEVCO Environment and Climate Week, Brussels, 17 February 2020

Thanks to the Government of Wallonia, supporting the Walloon Platform for IPCC and to my team at the Université catholique de Louvain

The Essential Truth About Climate Change in Ten Words

The basic facts of climate change, established over decades of research, can be summarized in five key points:

IT'S REAL

Global warming is happening.

IT'S US

Human activity is the main cause.

EXPERTS AGREE

There's scientific consensus on human-caused global warming.

IT'S BAD

The impacts are serious and affect people.

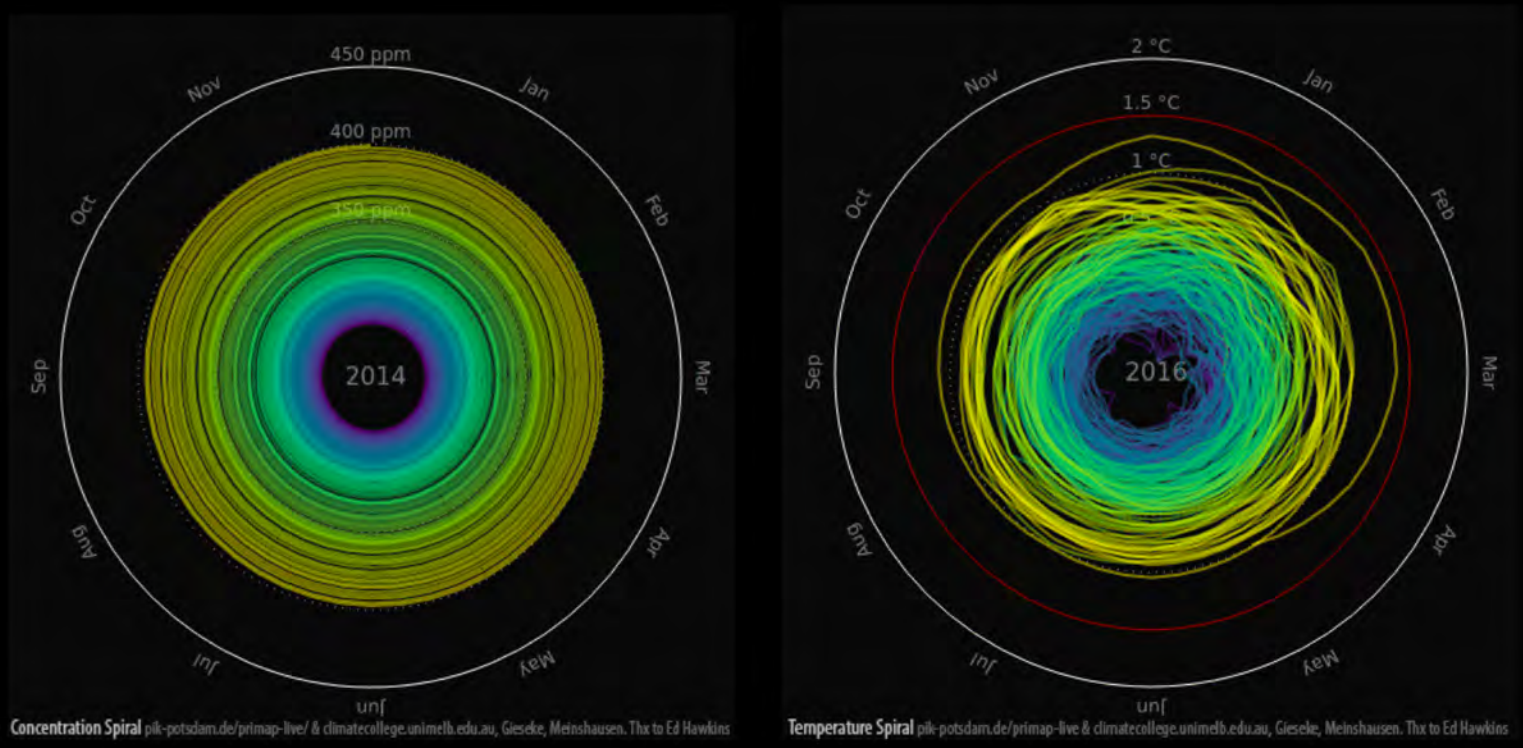
THERE'S HOPE

We have the technology needed to avoid the worst climate impacts.

Source: @JohnfoCook

I want you to panic… and act

CO_2 Concentration and Temperature spirals



CO_2 Concentration since 1850 and Global Mean Temperature in °C relative to 1850 – 1900
Graph: Ed Hawkins (Climate Lab Book) – Data: HadCRUT4 global temperature dataset
Animation available on http://openclimatedata.net/climate-spirals/concentration-temperature/

Because we use the atmosphere as a dustbin for our greenhouse gases, we thicken the insulation layer around the planet

That is why we must cut emissions to (net) ZERO as soon as possible

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Since 1950, extreme hot days and heavy precipitation have become more common

There is evidence that anthropogenic influences, including increasing atmospheric greenhouse gas concentrations, have changed these extremes

95

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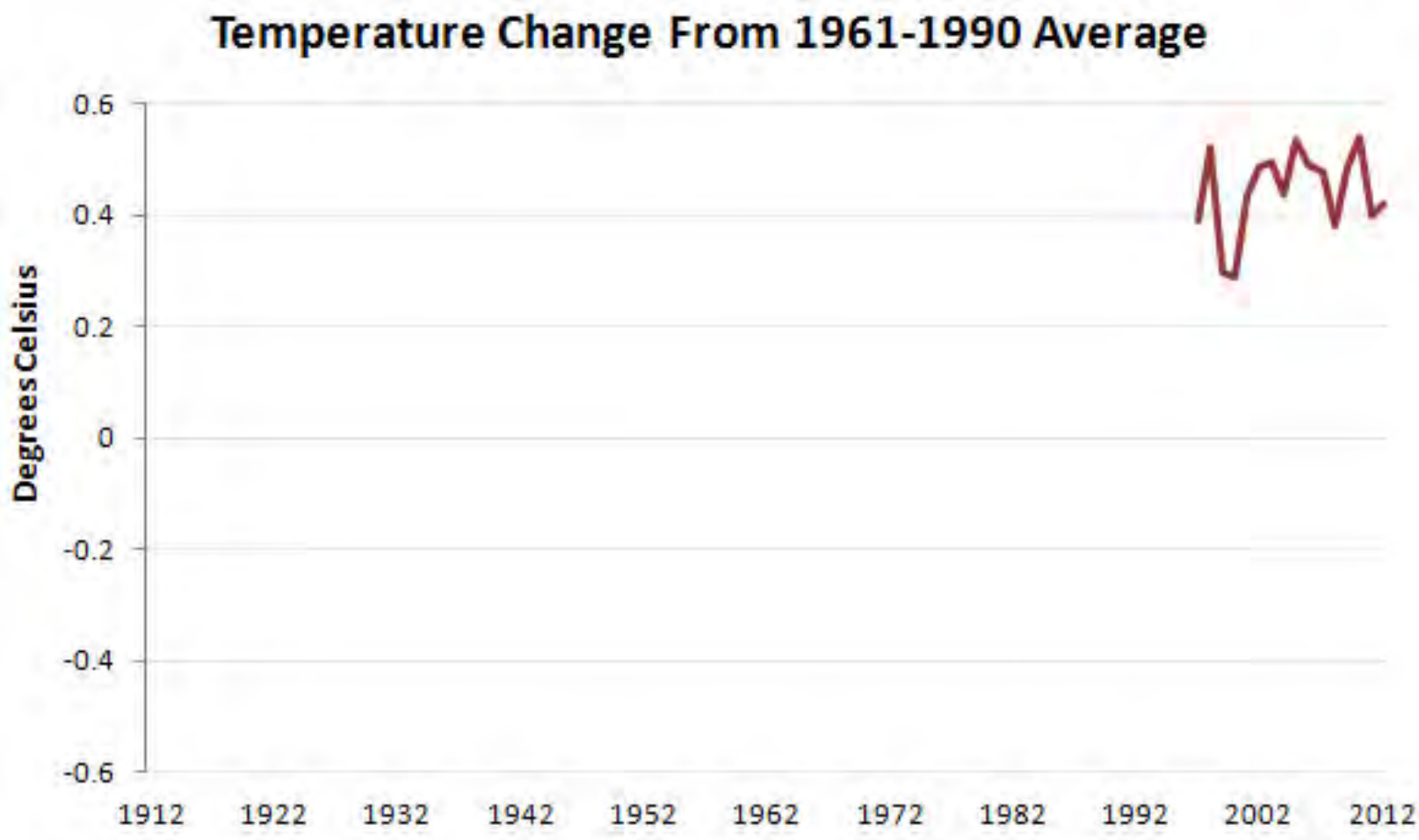
Basic climate physics

Modelling

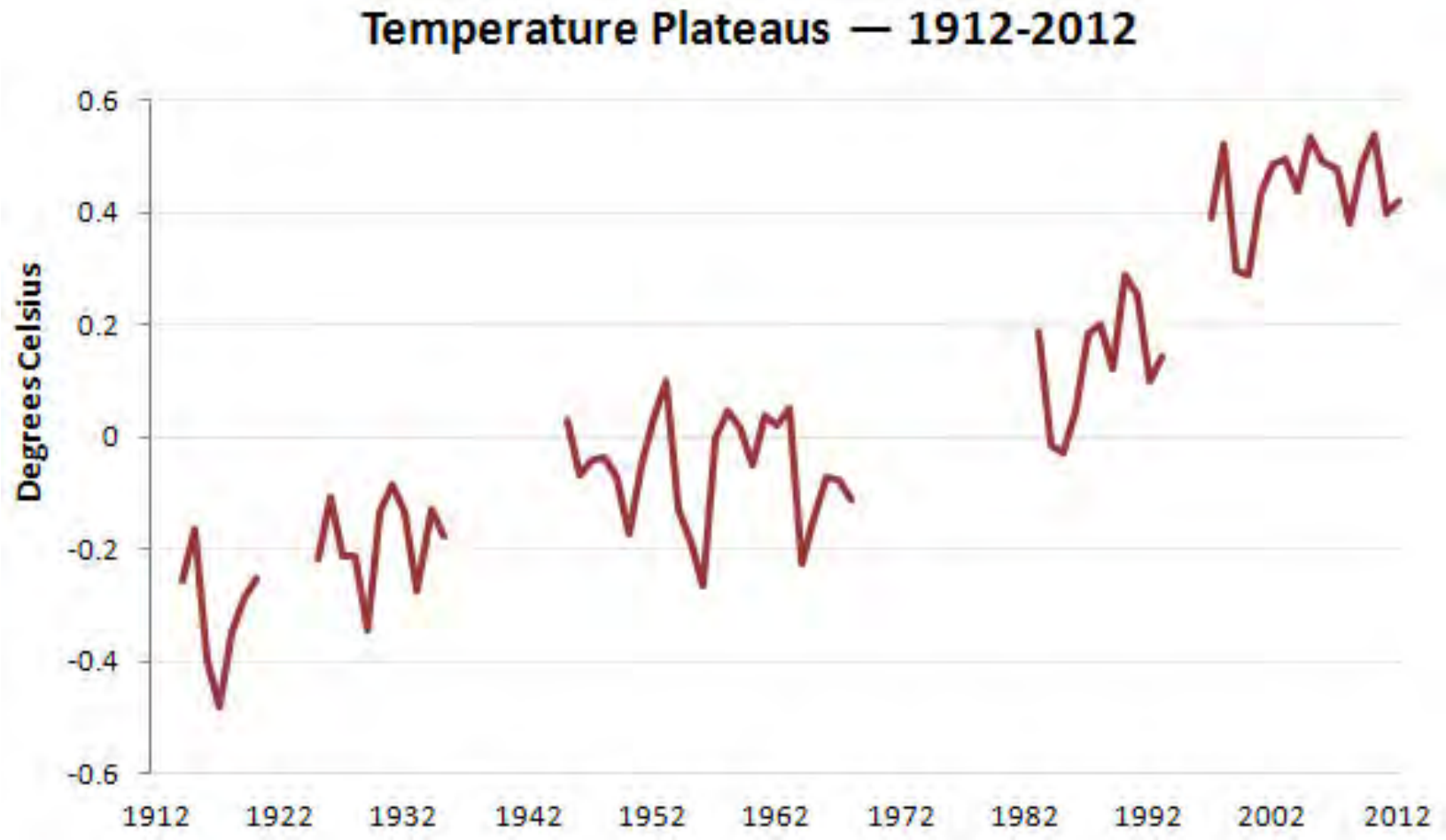
Scenarios and projections

Impacts and risks



http://www.motherjones.com/kevin-drum/2012/10/lying-statistics-global-warming-edition

Lying With Statistics, Global Warming Edition



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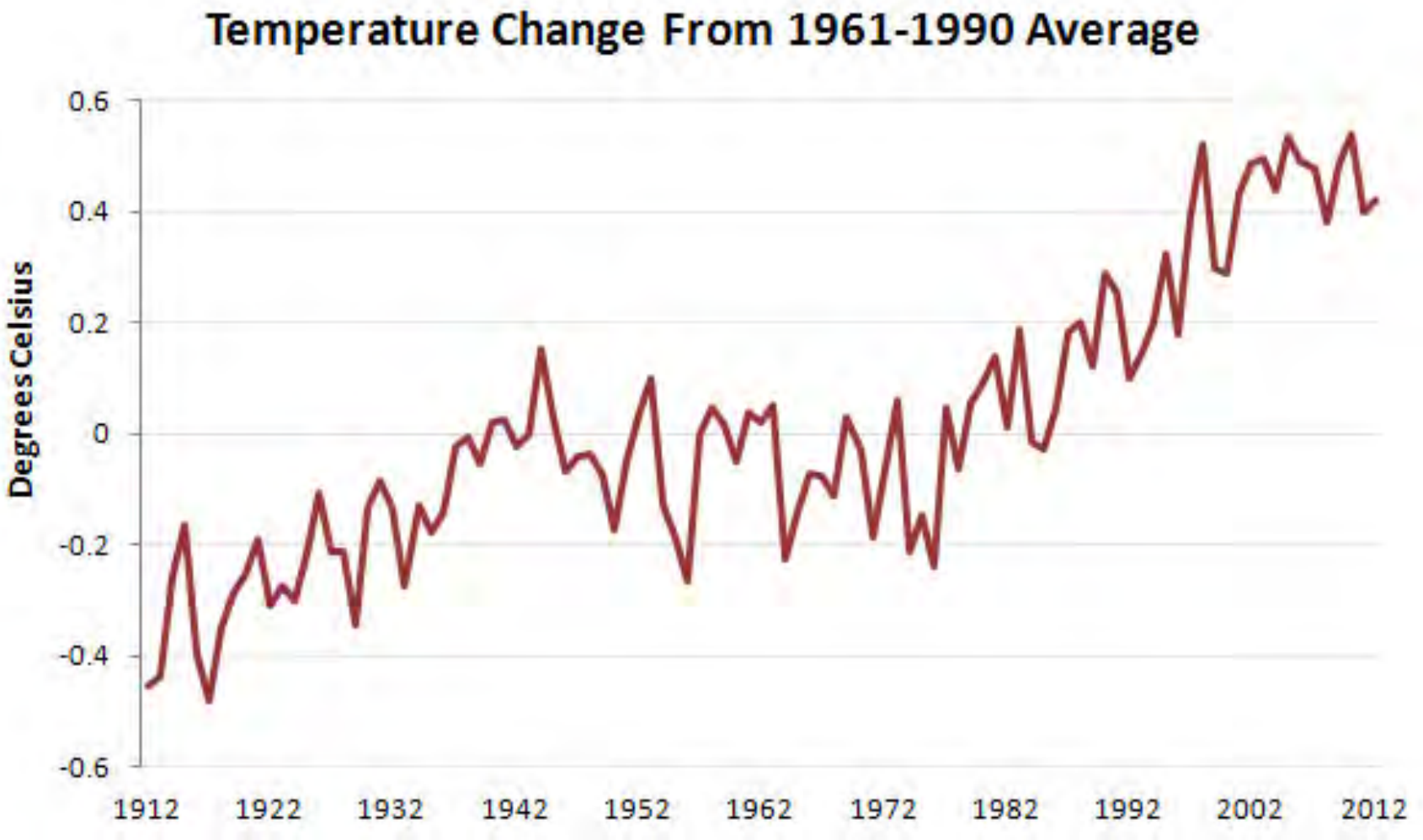


http://www.motherjones.com/kevin-drum/2012/10/lying-statistics-global-warming-edition

In the USA alone, organizations which sow doubt about climate change spend almost a billion dollars/year! (Brulle 2014, average numbers for 2003-2010)

The European Union fares a little better, but many Brussels lobbyists try to dilute the EU environmental efforts (see the car industry…)

@JPvanYpersele

Why the IPCC ?

Established by WMO and UNEP in 1988

to provide **policy-makers** with an **objective source of information** about

- causes of climate change,
- potential environmental and socio-economic impacts,
- possible response options (adaptation & mitigation).

WMO=World Meteorological Organization

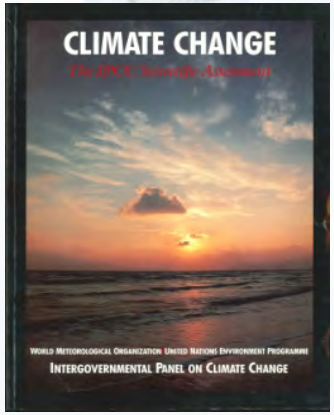
UNEP= United Nations Environment Programme

IPCC writing cycle (4 years, 831 Lead authors)

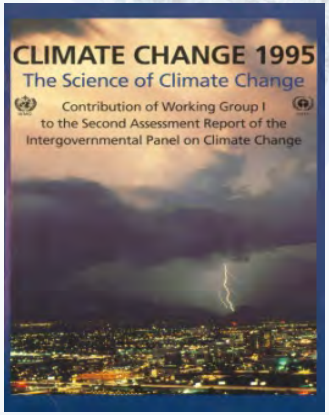
- **Plenary decides table of content of reports**
- **Bureau appoints world-class scientists as authors, based on publication record**
- **Authors assess all scientific literature**
- ***Draft* – Expert review (+ Review editors)**
- ***Draft 2 (+ Draft 1 Summary for Policy Makers (SPM)* – Combined expert/government review**
- ***Draft 3 (+ Draft 2 SPM)*– Government review of SPM**
- **Approval Plenary (interaction authors – governments) – *SPM and full report***
- ***NB: the scientists have the last word!***

Jean-Pascal van Ypersele
(vanyp@climate.be)

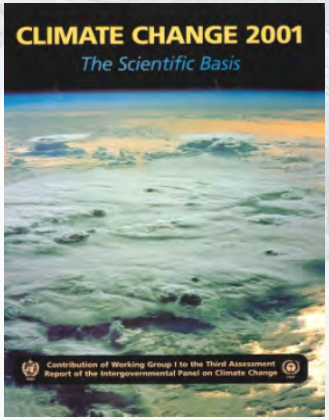
IPCC Assessment Reports



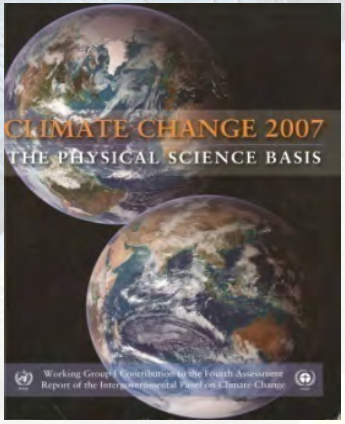
FAR 1990



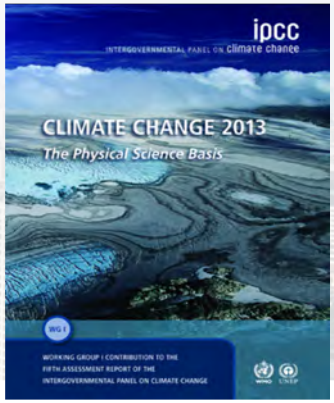
SAR 1995



TAR 2001

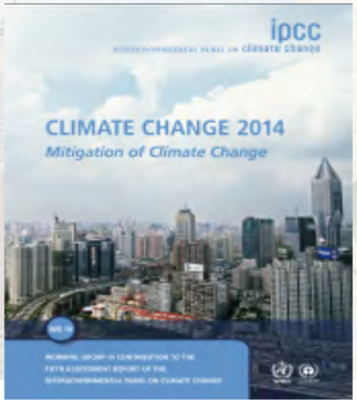


AR4 2007

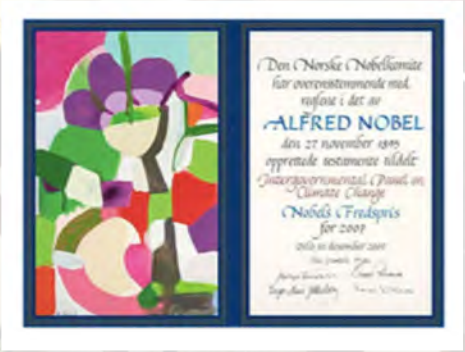


AR5 WGI 2013

AR5 WGII 2014



AR5 WGIII 2014



ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

The IPCC assessments have influenced global action on an unprecedented scale

1. The First Assessment Report (FAR, 1990) had a major impact in defining the content of the UNFCCC
2. The Second Assessment Report (SAR, 1996) was largely influential in defining the provisions of the Kyoto Protocol
3. The Third Assessment Report (TAR, 2001) focused attention on the impacts of climate change and the need for adaptation
4. The Fourth Assessment Report (AR4, 2007) informed the decision on the ultimate objective (2° C) and is creating a strong basis for a post Kyoto Protocol agreement
5. The Fifth Assessment Report (AR5, 2013-14) has informed the review of the 2° C objective, and the preparation of the Paris 2015 agreement

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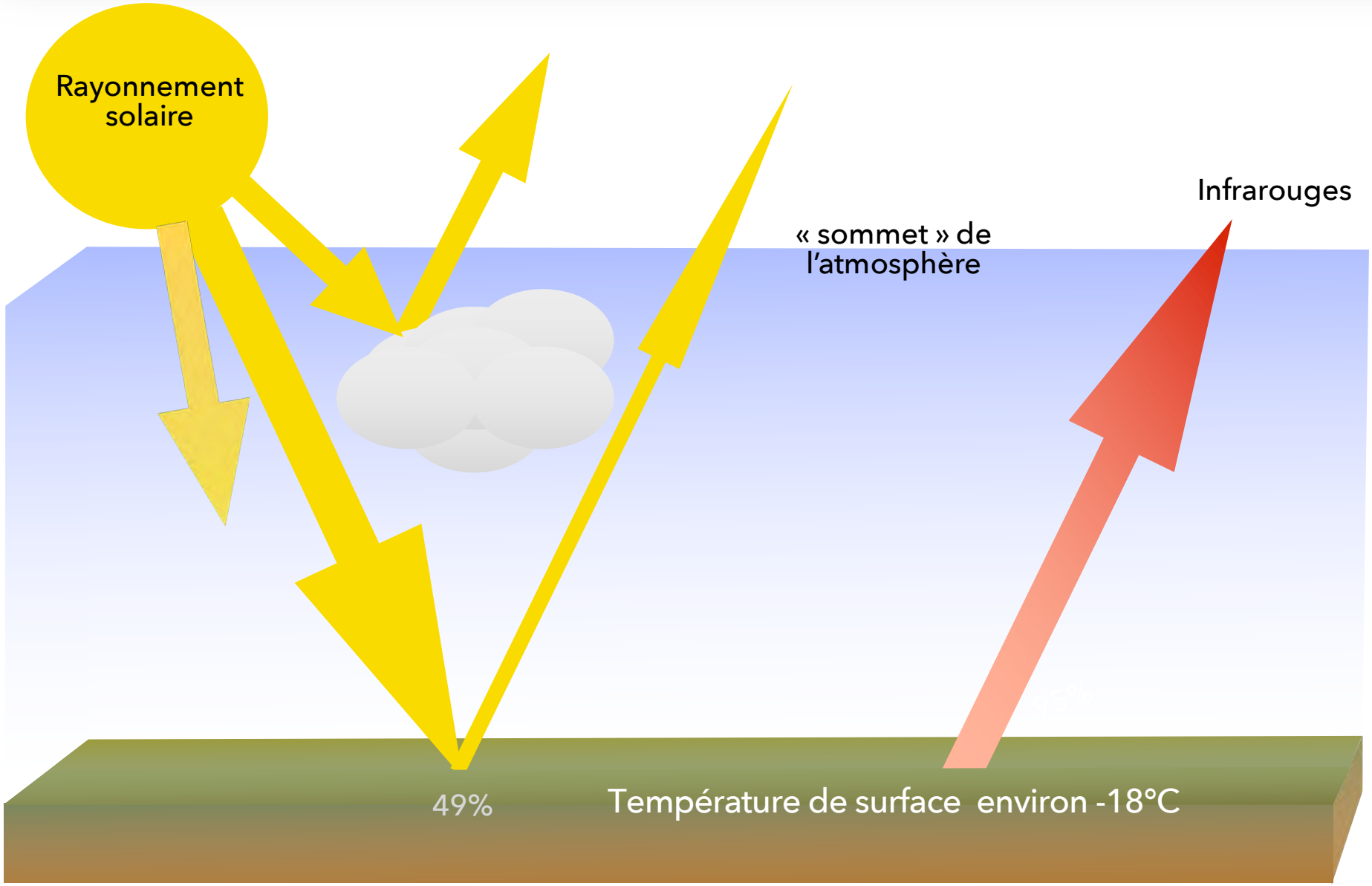
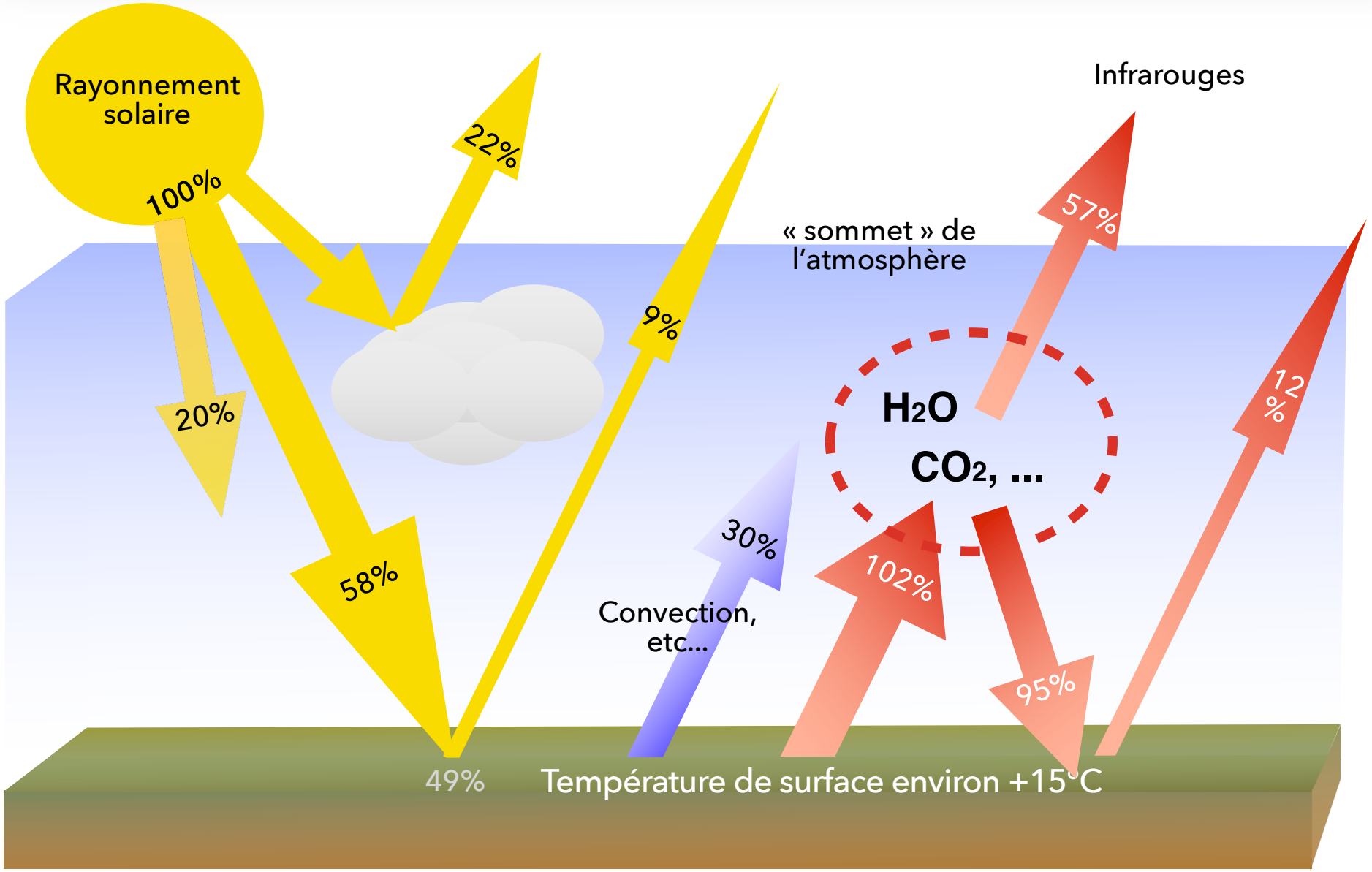
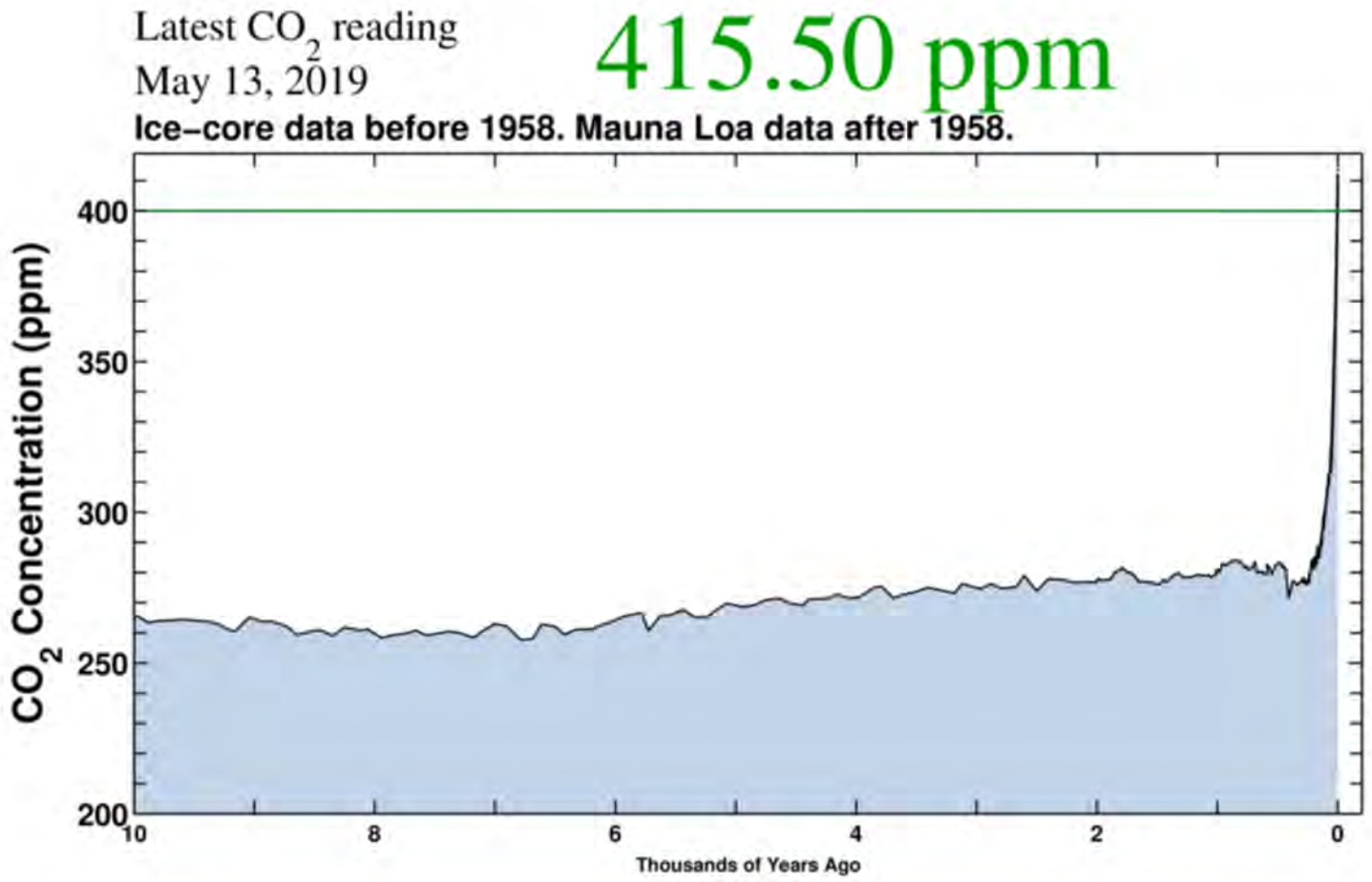
Energie et effet de serre



Energie et effet de serre

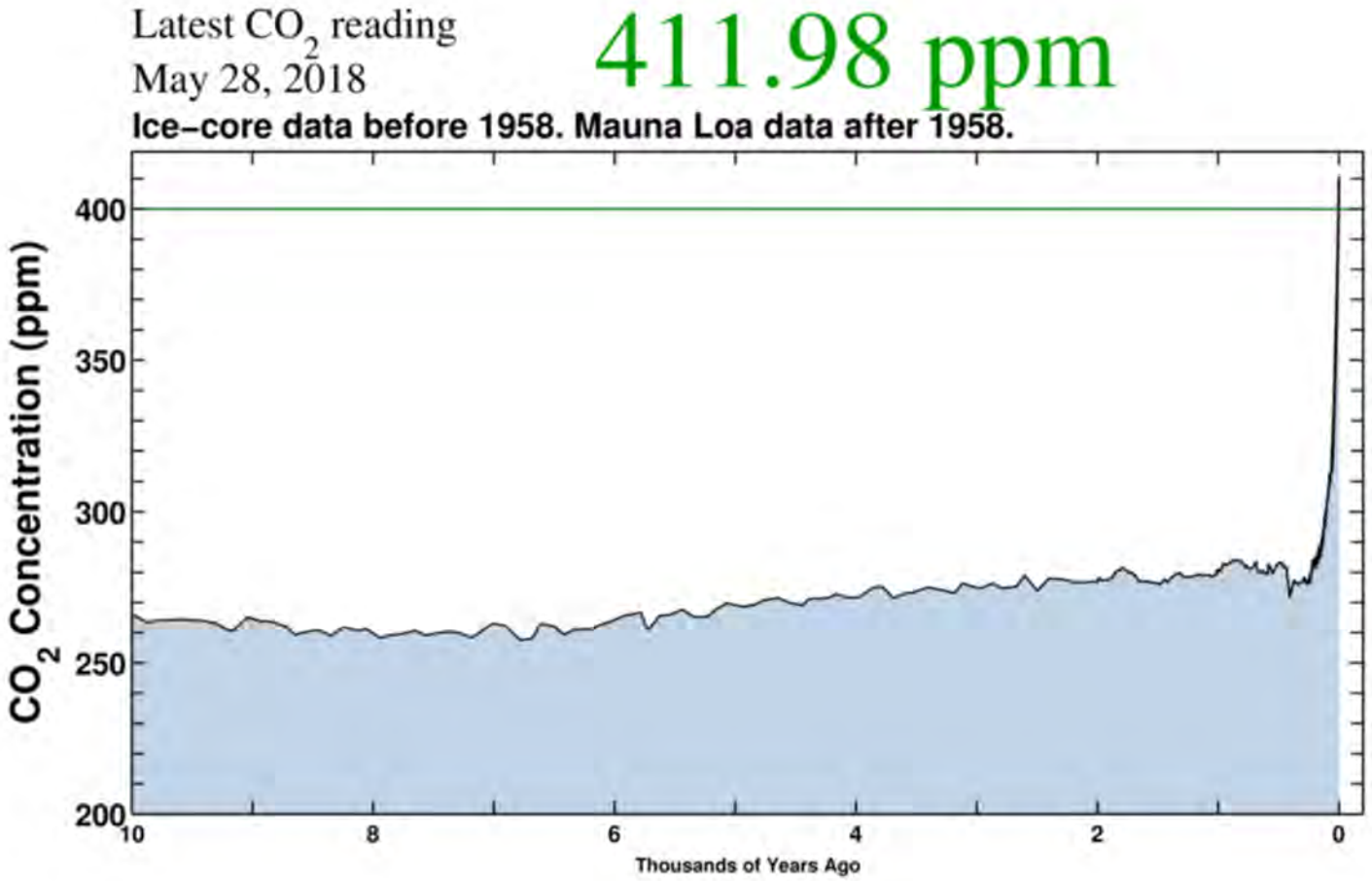


CO_2 Concentration, 13 May 2019 (Keeling curve)



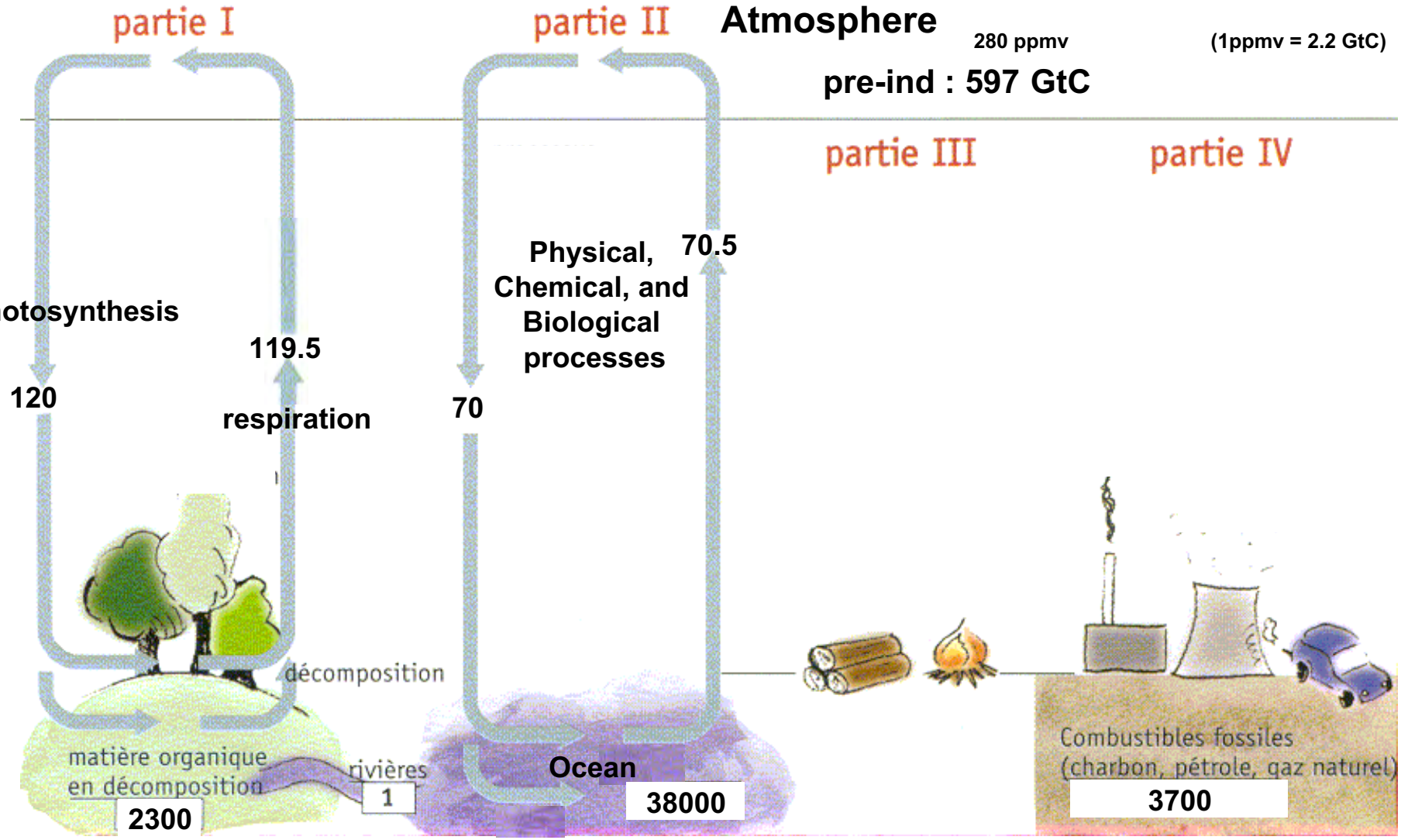
Source: scripps.ucsd.edu/programs/keelingcurve/

CO_2 Concentration, 28 May 2018 (Keeling curve)



Source: scripps.ucsd.edu/programs/keelingcurve/

Carbon cycle: unperturbed fluxes

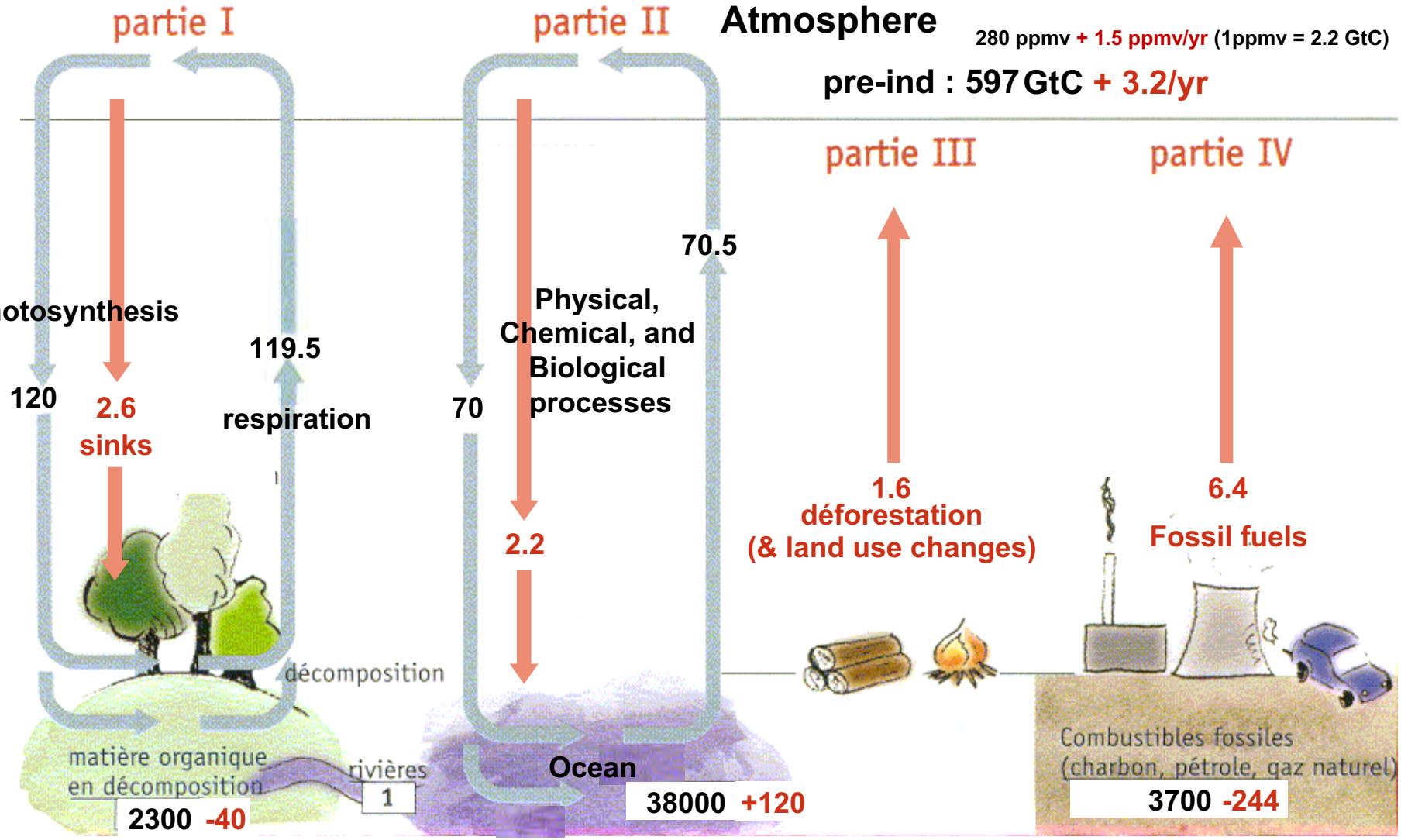


Units: GtC (billions tons of carbon) or GtC/year (multiply by 3.7 to get $GtCO_2$)

vanyp@climate.be

Carbon cycle: perturbed by human activities

(numbers for the decade 1990-1999s, based on IPCC AR4)



Stocks!

Units: GtC (billions tons of carbon) or GtC/year

vanyp@climate.be

Climatic Change: Are We on the Brink of a Pronounced Global Warming? (Broecker,1975)

Table 1. Reconstruction and prediction of atmospheric CO_2 contents based on fuel consumption data.

Year	Chemical fuel CO_2 ($\times 10^{16}$ g)	Excess atmospheric CO_2* ($\times 10^{16}$ g)	Excess atmospheric CO_2 (%)	Excess atmospheric CO_2 (ppm)	CO_2 content of the atmosphere† (ppm)	Global temperature increase‡ (°C)
1900	3.8	1.9	0.9	2	295	0.02
1910	6.3	3.1	1.4	4	297	.04
1920	9.7	4.8	2.2	6	299	.07
1930	13.6	6.8	3.1	9	302	.09
1940	17.9	8.9	4.1	12	305	.11
1950	23.3	11.6	5.3	16	309	.15
1960	31.2	15.6	7.2	21	314§	.21
1970	44.0	22.0	10.2	29	322§	.29
1980‖	63	31	14	42	335	.42
1990‖	88	44	20	58	351	.58
2000‖	121	60	28	80	373	.80
2010‖	167	83	38	110	403	1.10

*On the assumption that 50 percent of the CO_2 produced by the burning of fuel remains in the atmosphere. †The preindustrial atmospheric partial pressure of CO_2 is assumed to be 293 ppm. ‡Assumes a 0.3°C global temperature increase for each 10 percent rise in the atmospheric CO_2 content. §Value observed on Hawaii for 1960, 314 ppm; value for 1970, 322 ppm (*8*). ‖Post-1972 growth rate taken to be 3 percent per year.

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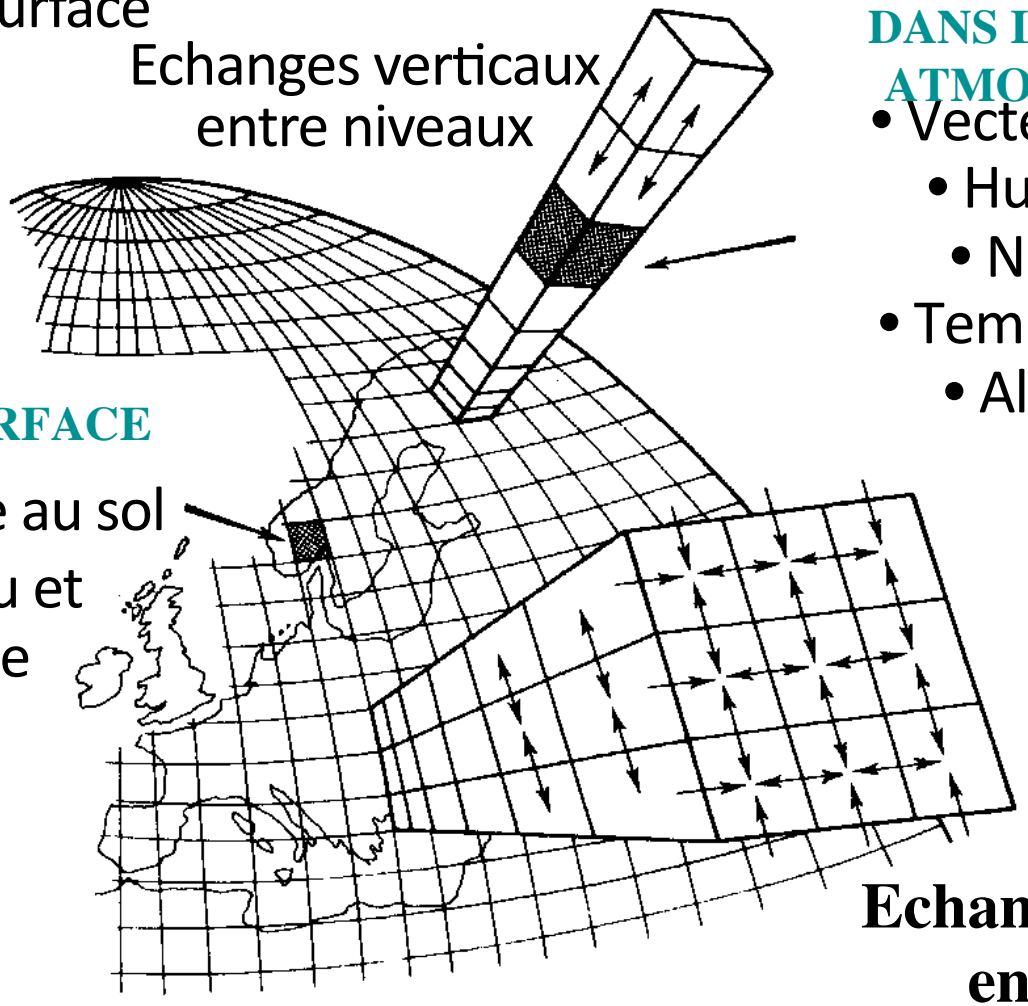
Youth concerns and school strikes

Modèles climatiques

Atmosphère et surface

Echanges verticaux entre niveaux



DANS LA COLONNE ATMOSPHERIQUE

- Vecteurs vent
- Humidité
- Nuages
- Température
- Altitude

A LA SURFACE

- Température au sol
- Flux d'eau et d'énergie

Echanges horizontaux entre colonnes

Résolution typique ~ 2°x 2°(modèle global, atmosphère)
Intervalle de temps typique : ≤ 30 minutes

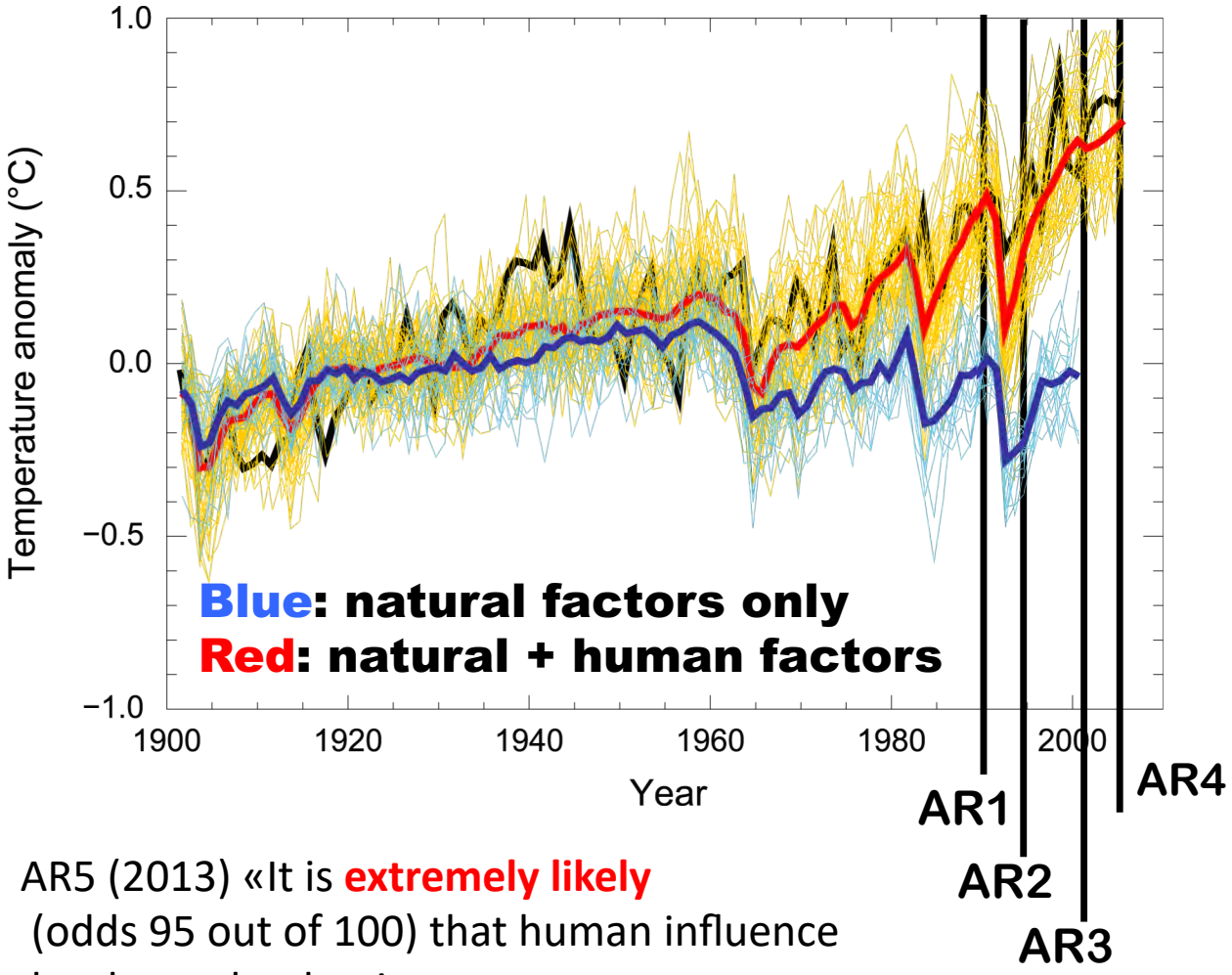
A Progression of Understanding: Greater and Greater Certainty in Attribution

AR1 (1990): "unequivocal detection not likely for a decade"

AR2 (1995): "balance of evidence suggests **discernible** human influence"

AR3 (2001): "most of the warming of the past 50 years is **likely** (odds 2 out of 3) due to human activities"

AR4 (2007): "most of the warming is **very likely** (odds 9 out of 10) due to greenhouse gases"



AR5 (2013) «It is **extremely likely** (odds 95 out of 100) that human influence has been the dominant cause… »

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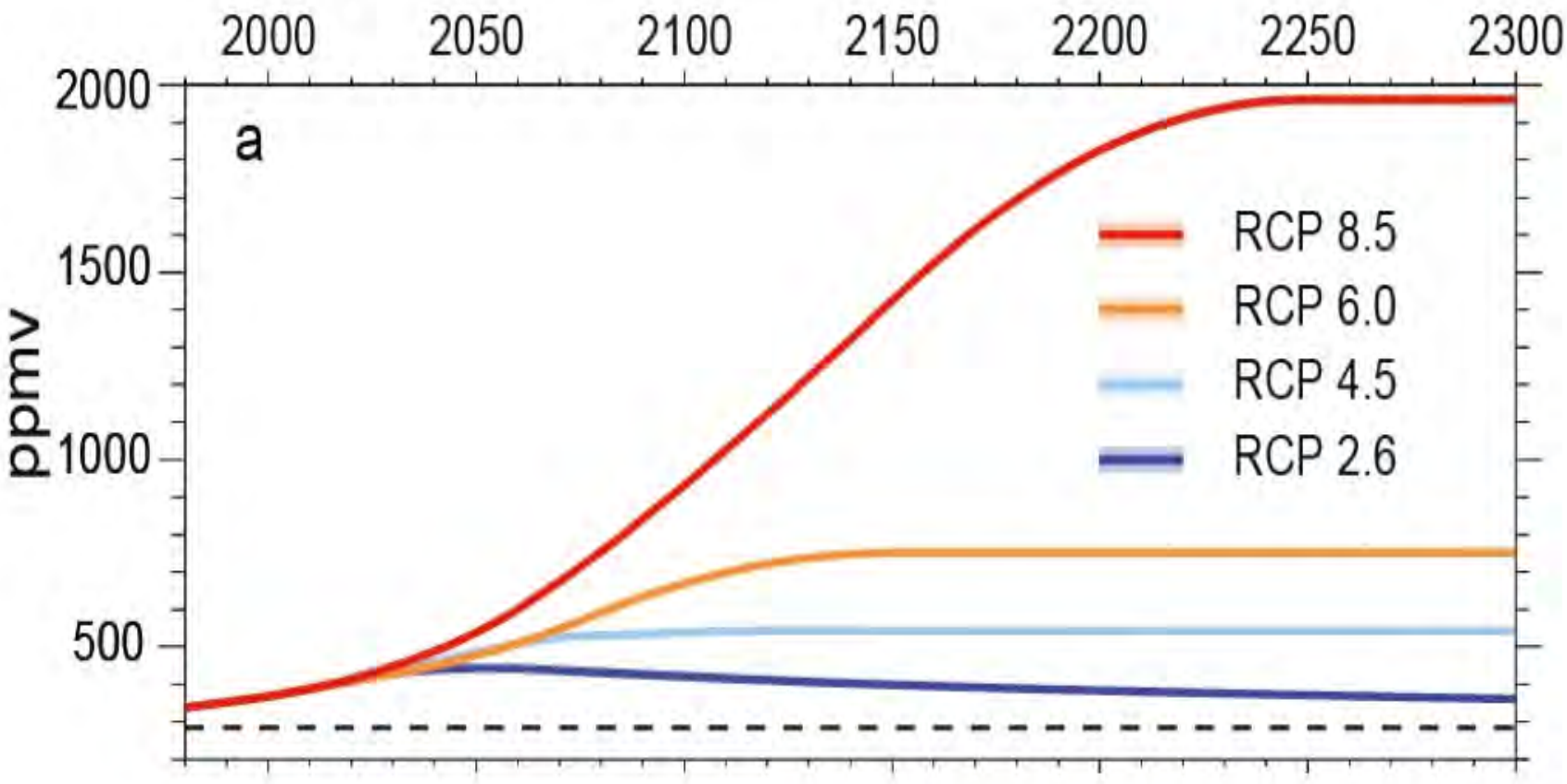
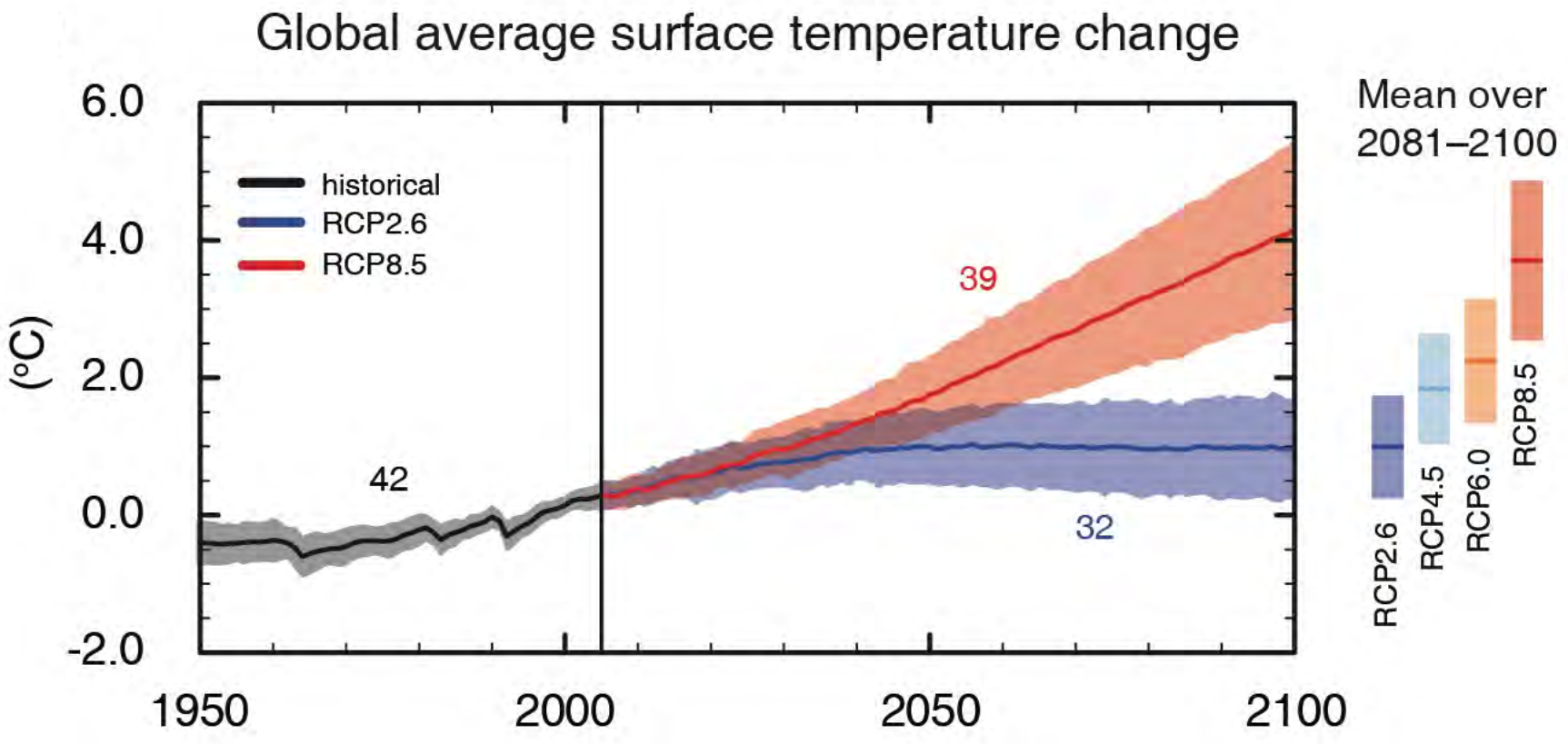
AR5 RCP: Atmospheric CO_2 concentration



Most CMIP5 runs are based on the concentrations, but emissions-driven runs are available for RCP 8.5

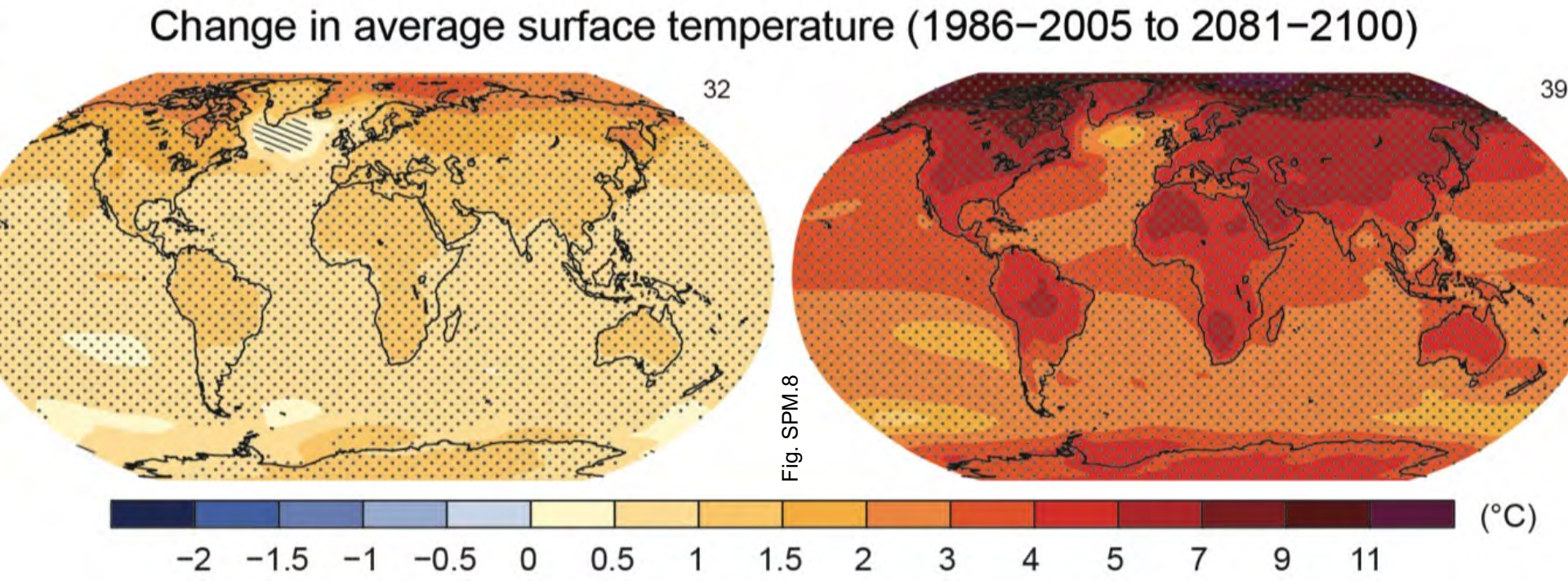
Note : « emission-driven » -> knowledge of C-cycle uncertainty

Réchauffement moyen – scén. RCP, 21s



(IPCC 2013, Fig. SPM.7a)

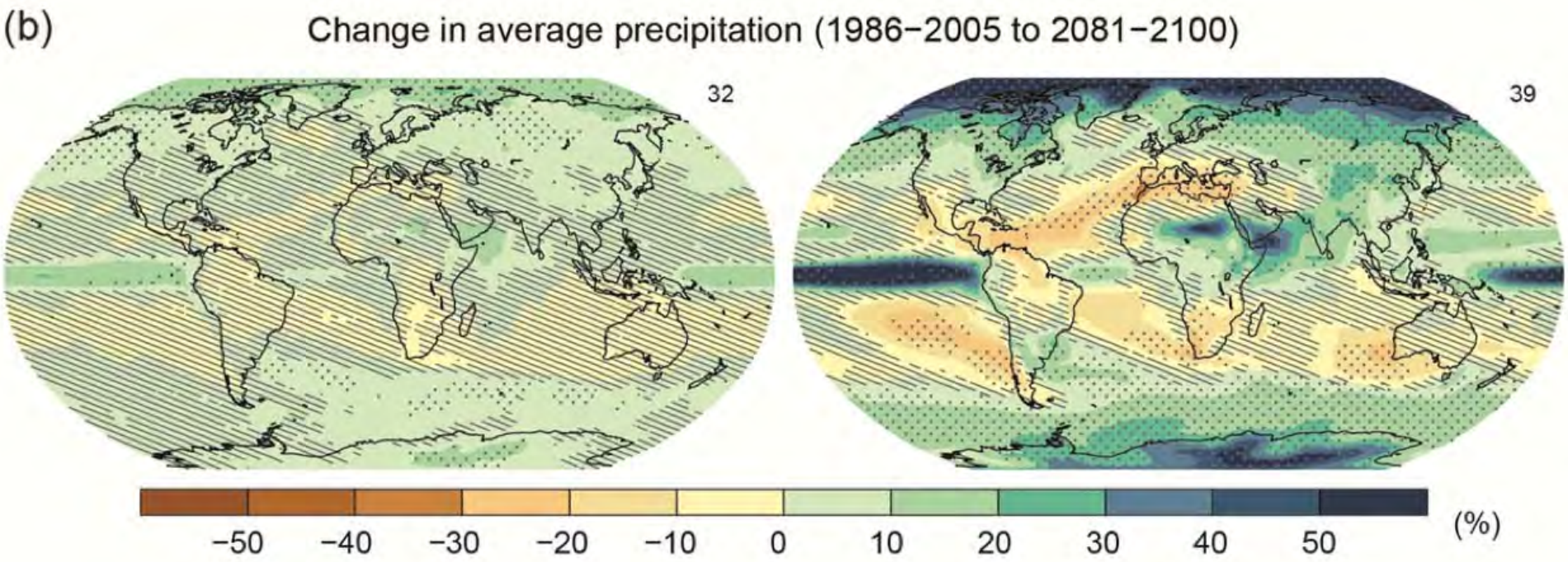
RCP2.6 RCP8.5



Hatching [hachures] indicates regions where the multi-model mean is small compared to natural internal variability (i.e., less than one standard deviation of natural internal variability in 20-year means).

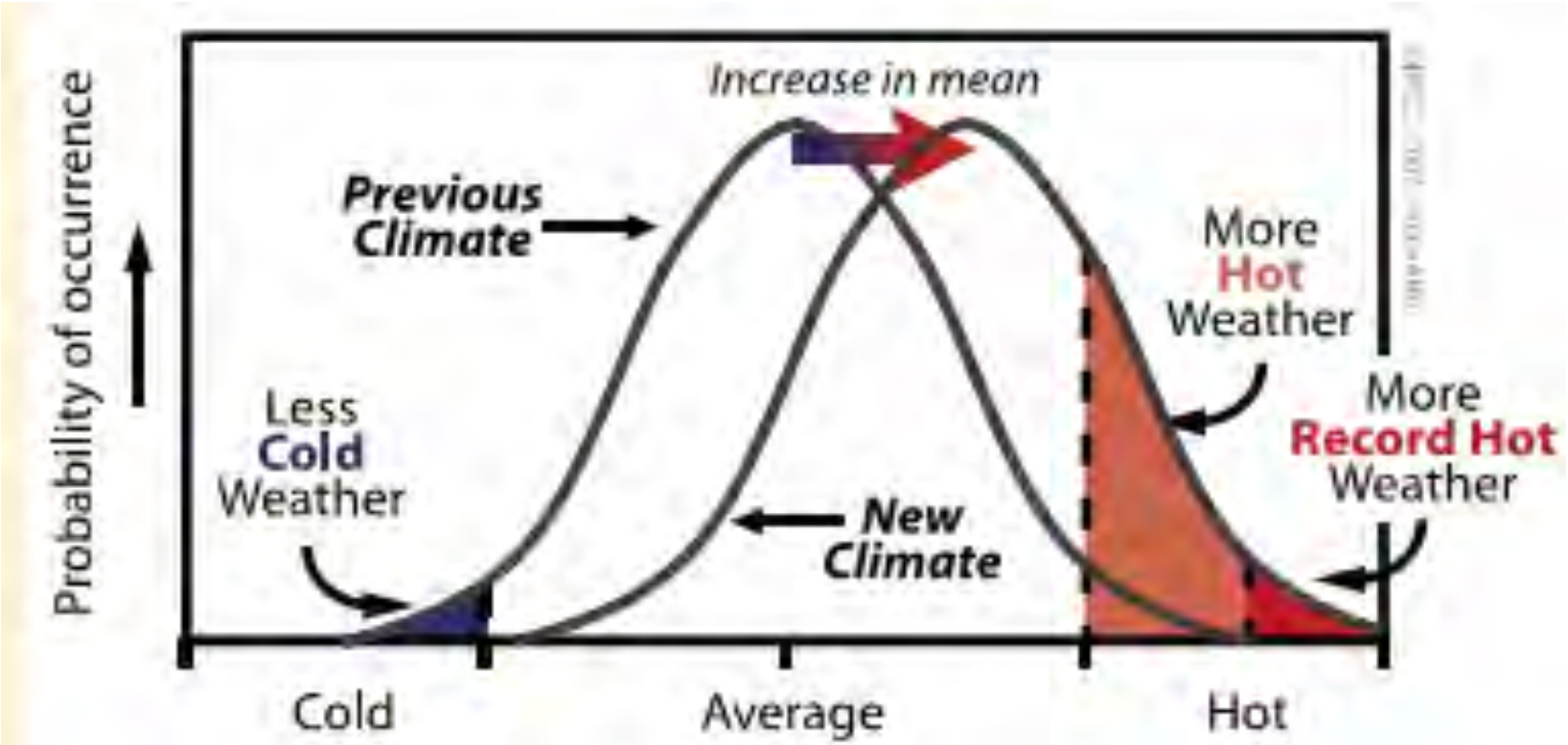
Stippling [pointillés] indicates regions where the multi-model mean is large compared to natural internal variability (i.e., greater than two standard deviations of natural internal variability in 20-year means) and where at least 90% of models agree on the sign of change

Projected Change in Precipitation



Hatching indicates regions where *the multi-model mean is small compared to natural internal variability* (i.e., less than one standard deviation of natural internal variability in 20-year means). **Stippling** indicates regions where the multi-model mean is large compared to natural internal variability (i.e., greater than two standard deviations of natural internal variability in 20-year means) and where at least 90% of models agree on the sign of change

Changes in average produce changes in probability of extremes



Box TS.5, Figure 1. *Schematic showing the effect on extreme temperatures when the mean temperature increases, for a normal temperature distribution.*

Extreme weather and climate events

Phenomenon and direction of trend	Assessment that changes occurred (typically since 1950 unless otherwise indicated)	Assessment of a human contribution to observed changes	Likelihood of further changes	
			Early 21st century	Late 21st century
Warmer and/or fewer cold days and nights over most land areas	*Very likely*	***Very likely***	*Likely*	***Virtually certain***
Warmer and/or more frequent hot days and nights over most land areas	*Very likely*	***Very likely***	*Likely*	***Virtually certain***
Warm spells/heat waves. Frequency and/or duration increases over most land areas	***Medium confidence*** on a global scale Likely in large parts of Europe, Asia and Australia	***Likely***	Not formally assessed	***Very likely***
Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation	*Likely more land areas with increases than decreases*	***Medium confidence***	*Likely* over many land areas	***Very likely*** over most of the mid-latitude land masses and over wet tropical regions
Increases in intensity and/or duration of drought	***Low confidence*** on a global scale Likely changes in some regions	***Low confidence***	*Low confidence*	***Likely*** *(medium confidence)* on a regional to global scale
Increases in intense tropical cyclone activity	***Low confidence*** in long term (centennial) changes Virtually certain in North Atlantic since 1970	***Low confidence***	*Low confidence*	***More likely than not*** in the Western North Pacific and North Atlantic
Increased incidence and/or magnitude of extreme high sea level	*Likely* (since 1970)	***Likely***	*Likely*	***Very likely***

IPCC, AR5, Table SPM.1

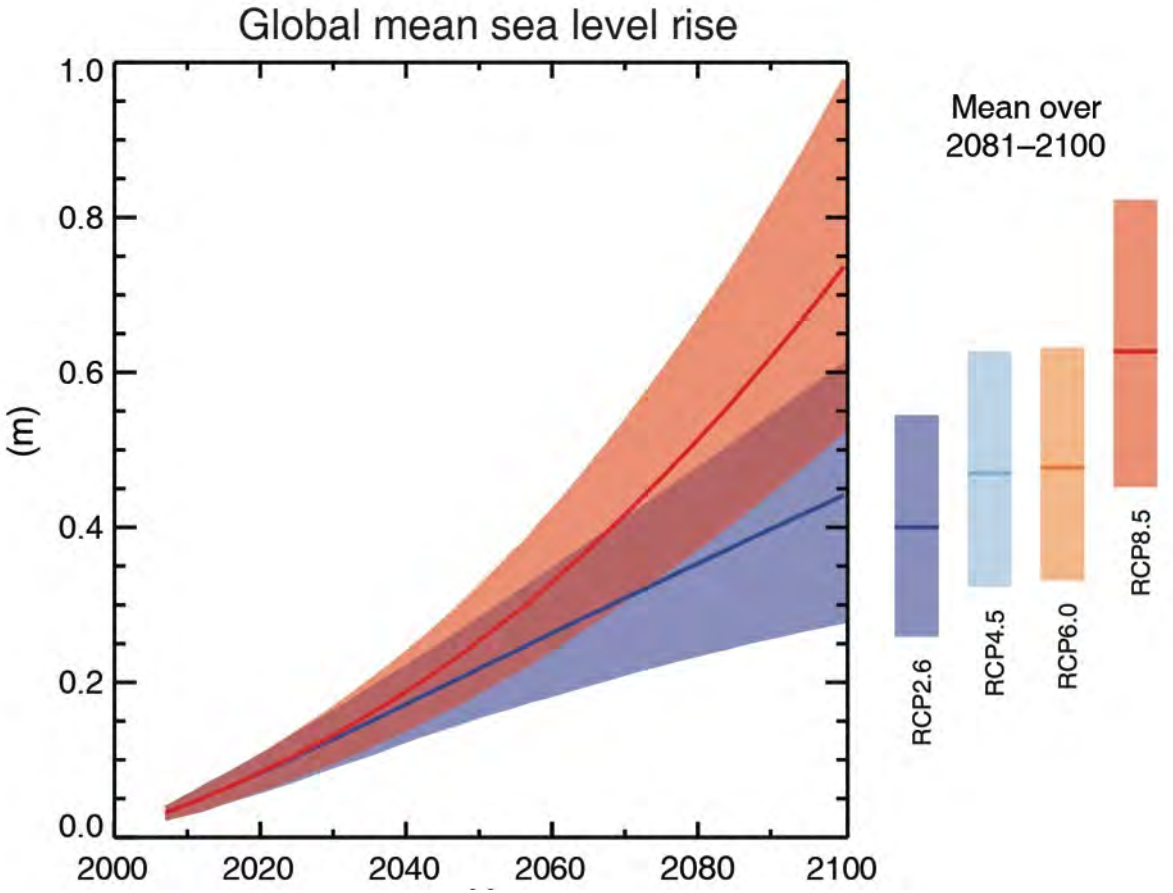


Fig. SPM.9

RCP2.6 (2081-2100), *likely* range: **26 to 55 cm**

RCP8.5 (in 2100), *likely* range: **52 to 98 cm**

La Mer de Glace (Massif du Mont-Blanc)

1919 **2019**

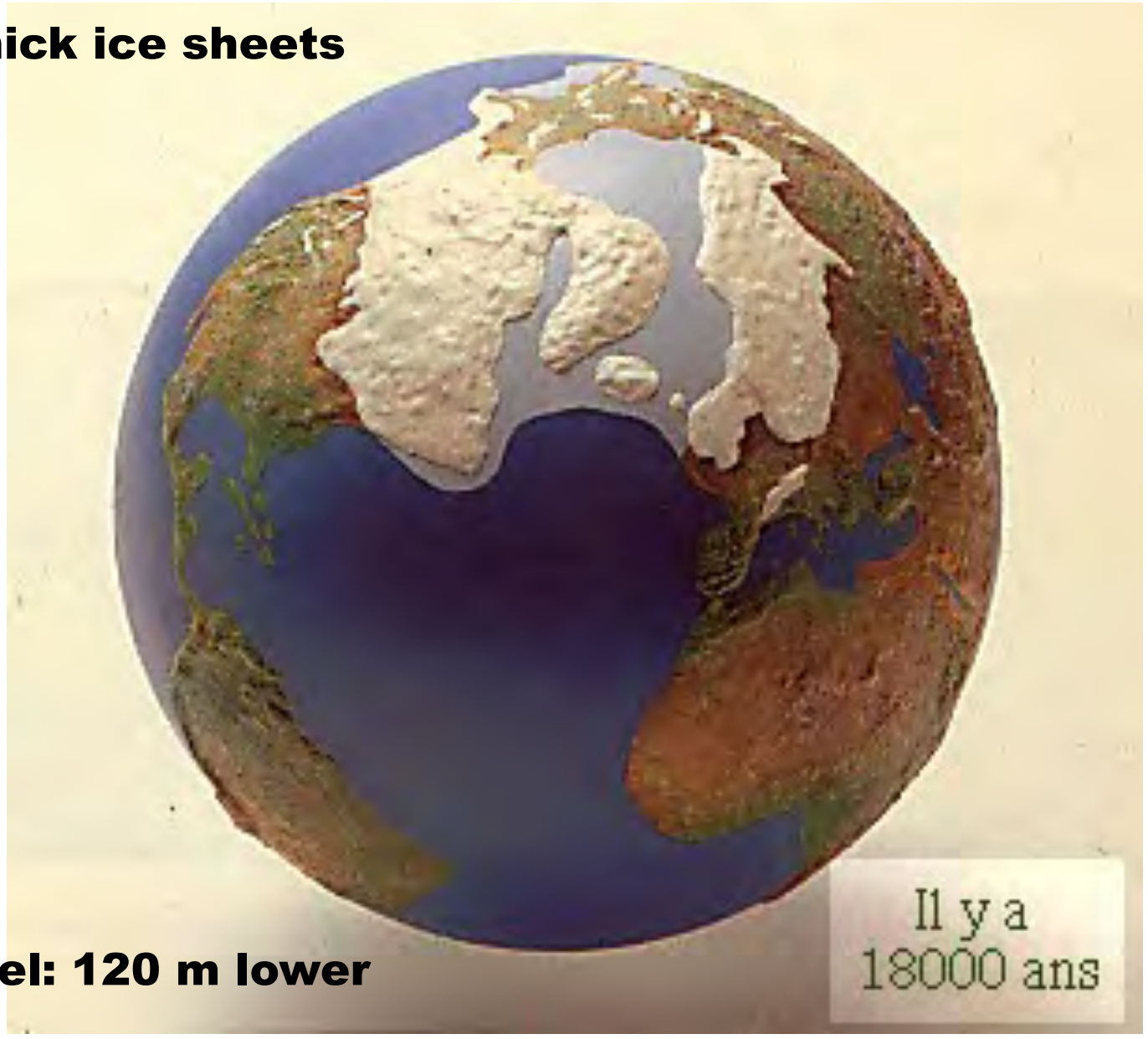
Photos disponibles à l'adresse : uod.box.com/s/qu6n9qeq4jdvfvwm0sy4ozeqtxh71etx

Voir aussi: www.dundee.ac.uk/stories/new-aerial-photographs-shed-light-dark-days-mont-blanc

18-20000 years ago (Last Glacial Maximum)

With permission from Dr. S. Joussaume, in « Climat d'hier à demain », CNRS éditions.

3 km thick ice sheets



Sea level: 120 m lower

Today, with +4-5°C globally

With permission from Dr. S. Joussaume, in « Climat d'hier à demain », CNRS éditions.

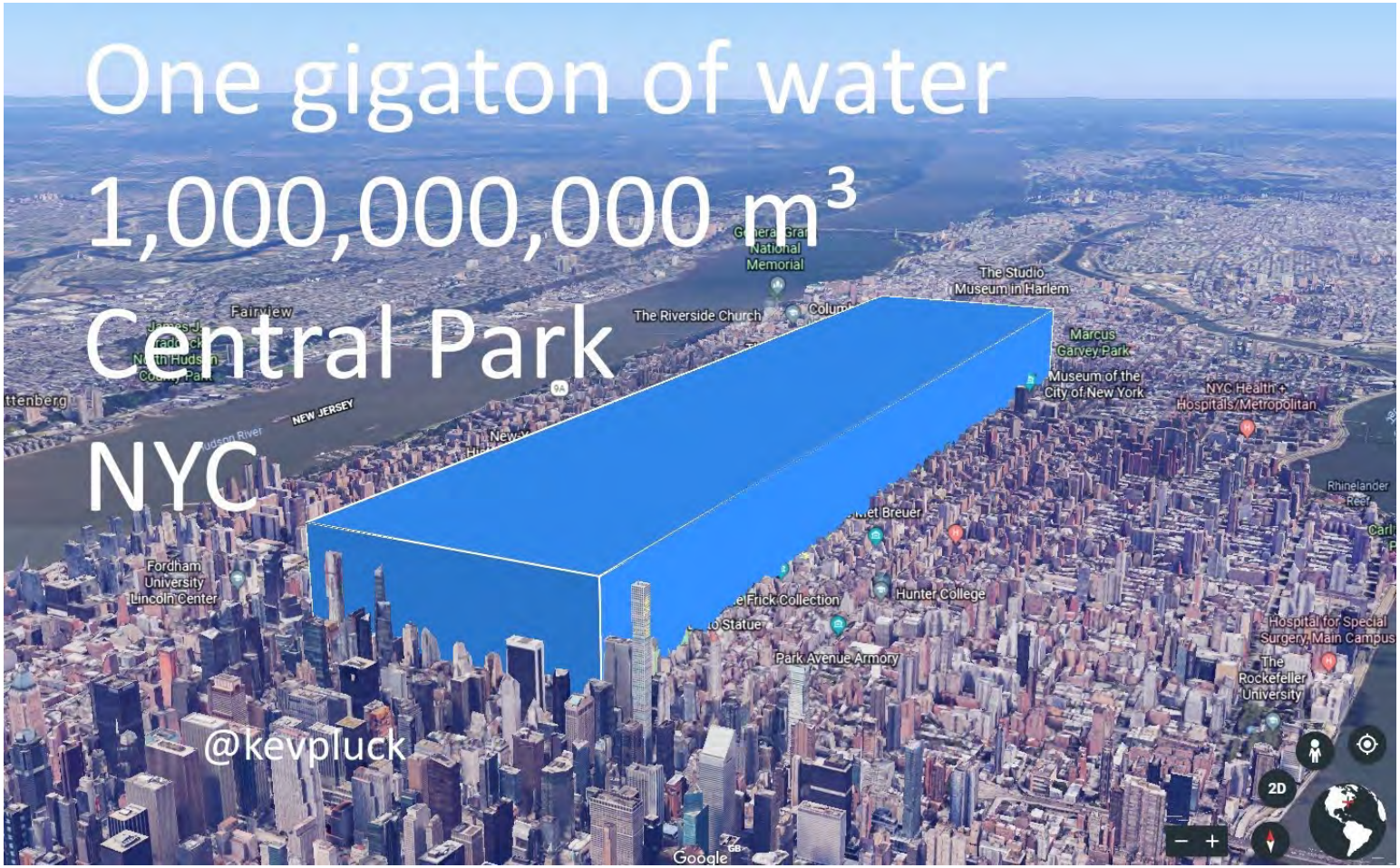
Transition took 4000 years, not 100 years

Average temperature is probably on its way to exceed the « conservation temperature » for the Greenland and (some of the) Antarctic ice sheet

There is therefore a very high risk that average sea level would increase by several metres over the next century or two

@JPvanYpersele

The Antarctic Ice Sheet presently loses on average 1 Gt of water every 1.5 day



Source: @Kevpluck, June 2018

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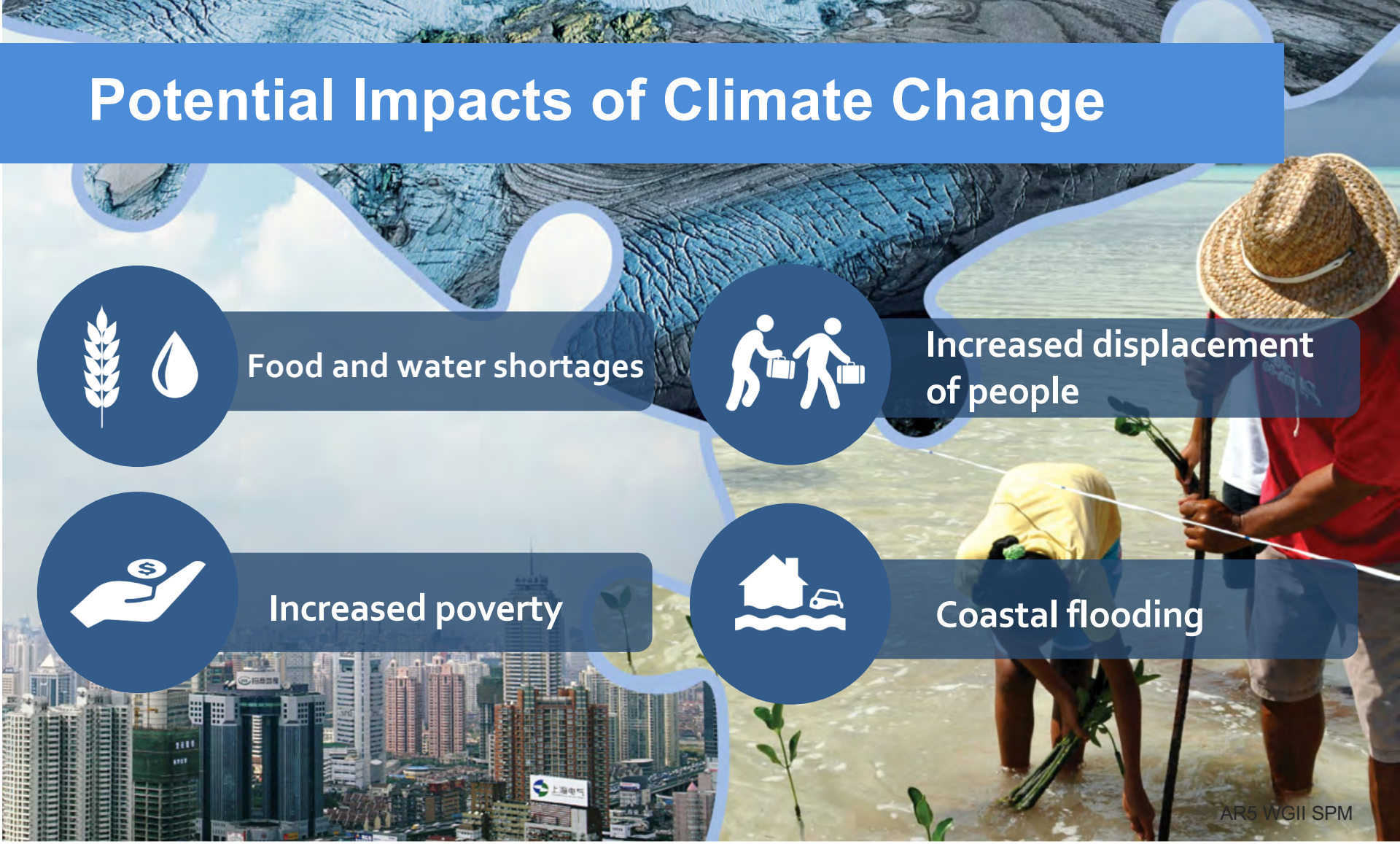
Potential Impacts of Climate Change



Risk = Hazard x Vulnerability x Exposure

(Victims of New Orleans floods after Katrina in 2005)

AP Photo - Lisa Krantz (http://lisakrantz.com/hurricane-katrina/zspbn1k4cn17phidupe4f9x5t1mzdr)

Six weeks worth of rain has fallen in three days over parts of France (May 2016)

Markus Schreiber / AP

The Louvre and Musée d'Orsay in Paris evacuated their vaults (May 2016)

Geoffroy Van Der Hasselt / Getty Images

With 1 metre sea-level rise: 63000 ha below sea-level in Belgium (likely in 22nd century, not impossible in 21st century)

(NB: flooded area depends on protection)

Source: N. Dendoncker (Dépt de Géographie, UCL), J.P. van Ypersele et P. Marbaix (Dépt de Physique, UCL) (www.climate.be/impact)

Les inondations causent beaucoup de souffrances

Kiribati, après le cyclone Pam
Source: Plan international Australie

Effects on the Nile Delta, where more than 10 million people live less than 1 m above sea level

NB: + 1 m is possible in the next 100 years…

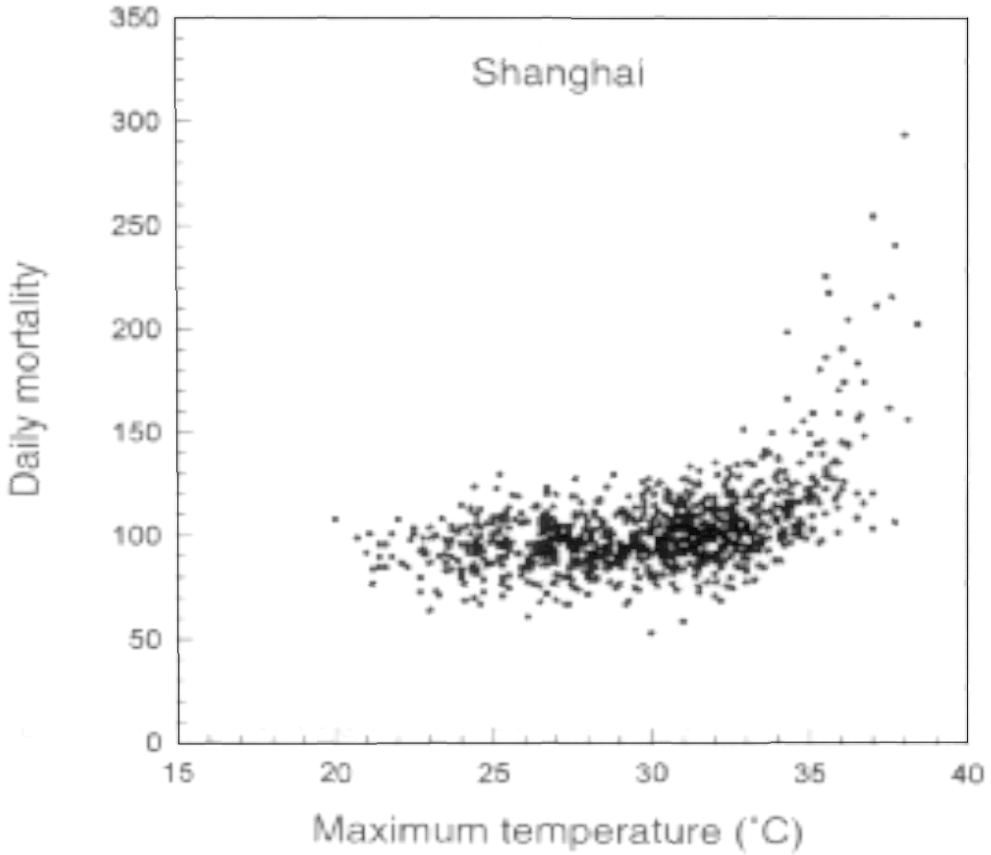
(Time 2001)

En première ligne: les Maldives

Devant le Ministère des Affaires étrangères, Maldives, août 2015


MINISTRY OF FOREIGN AFFAIRS

Relationship between maximum temperature and mortality in Shanghai, China, 1980-89



Référence : CILIMATE CHANGE AND HUMAN HEALTH, 1996

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Heat waves kill

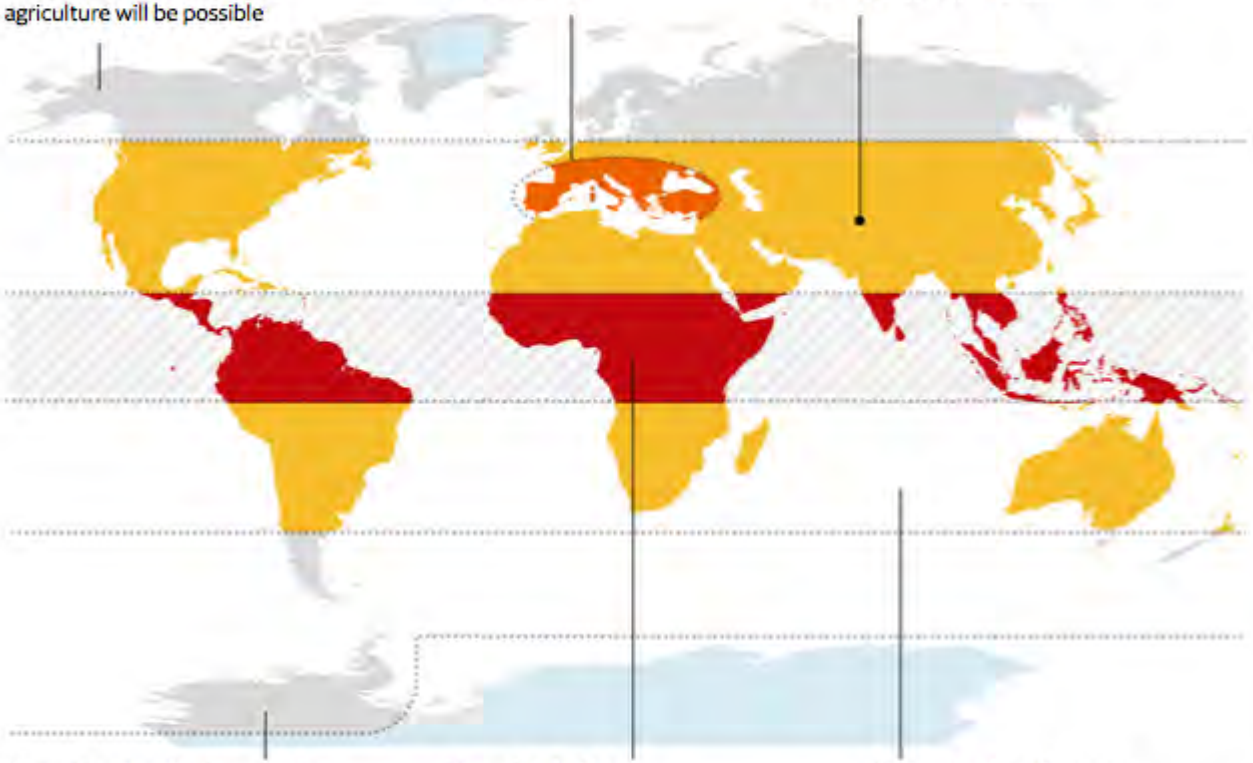
Une personne âgée dans un couloir des urgences du centre hospitalier de Versailles en août 2003. I AFP PHOTO MARTIN BUREAU

A 4C rise in global average temperatures would force humans away from equatorial regions

Canada, Siberia, Scandinavia, and Alaska
The vast majority of humanity will live in high-latitude areas, where agriculture will be possible

Southern Europe
Saharan deserts will expand into southern and central Europe

Hindu Kush, Karakoram and Himalayas
Two-thirds of the glaciers that feed many of Asia's rivers will be lost



New Zealand, Tasmania, Western Antarctica and Patagonia
Some of the only habitable parts of the southern hemisphere – likely to be very densely populated

Equatorial belt
High humidity causing heat stress across tropical regions will render them uninhabitable for much of the year. To the north and south will lie belts of inhospitable desert

Oceanic dead zones
Coral reefs, shellfish and plankton will be wiped out by rising acidity and algae starving the oceans of oxygen. Without prey, larger sea life will decline rapidly

Guardian graphic

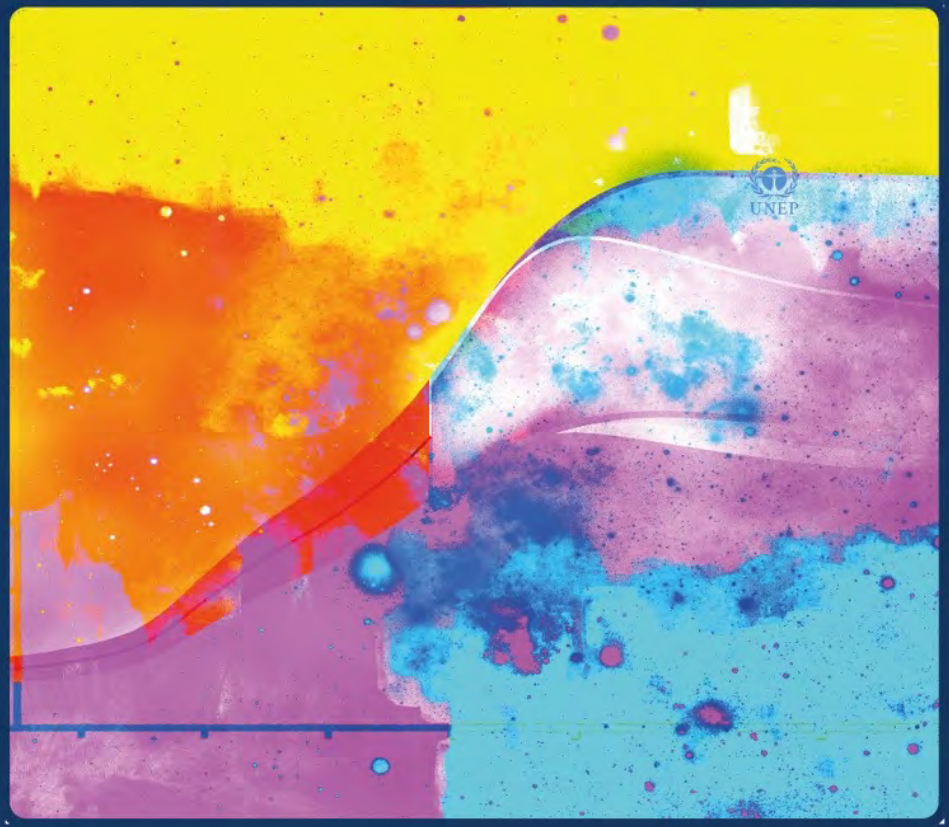
The SR15

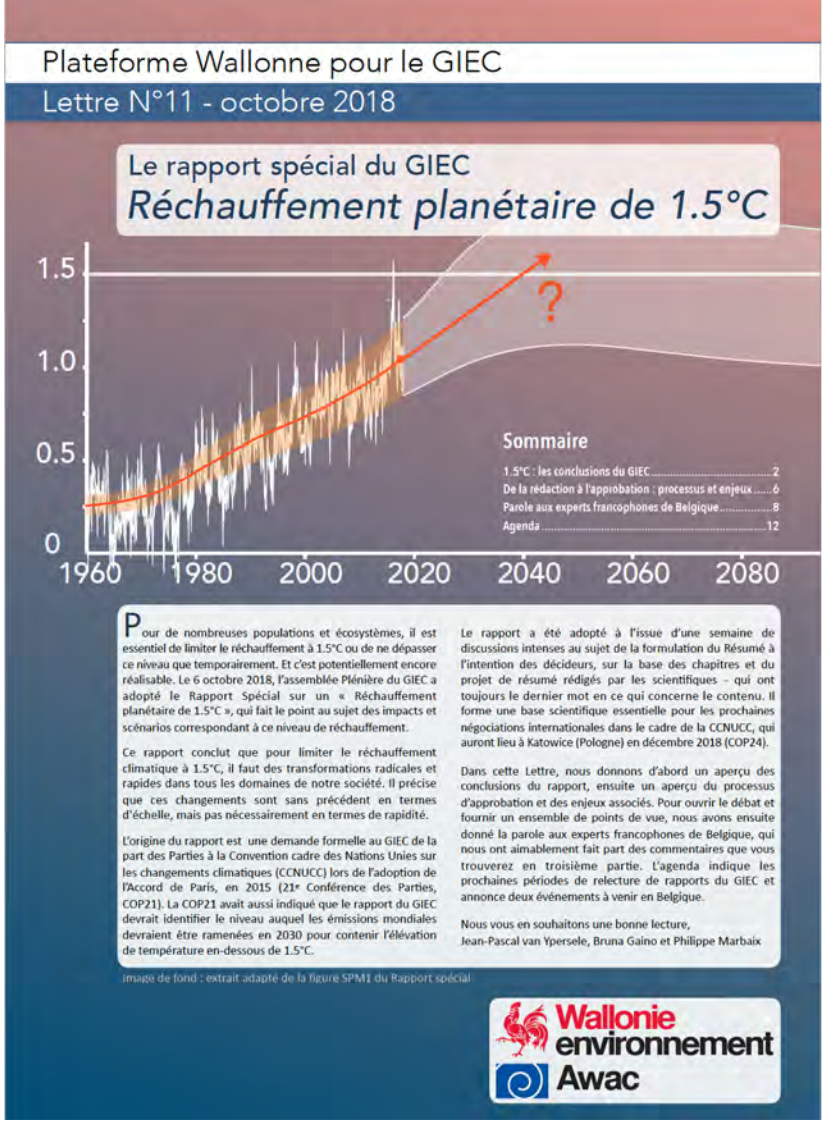
ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

Global Warming of 1.5°C

An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.



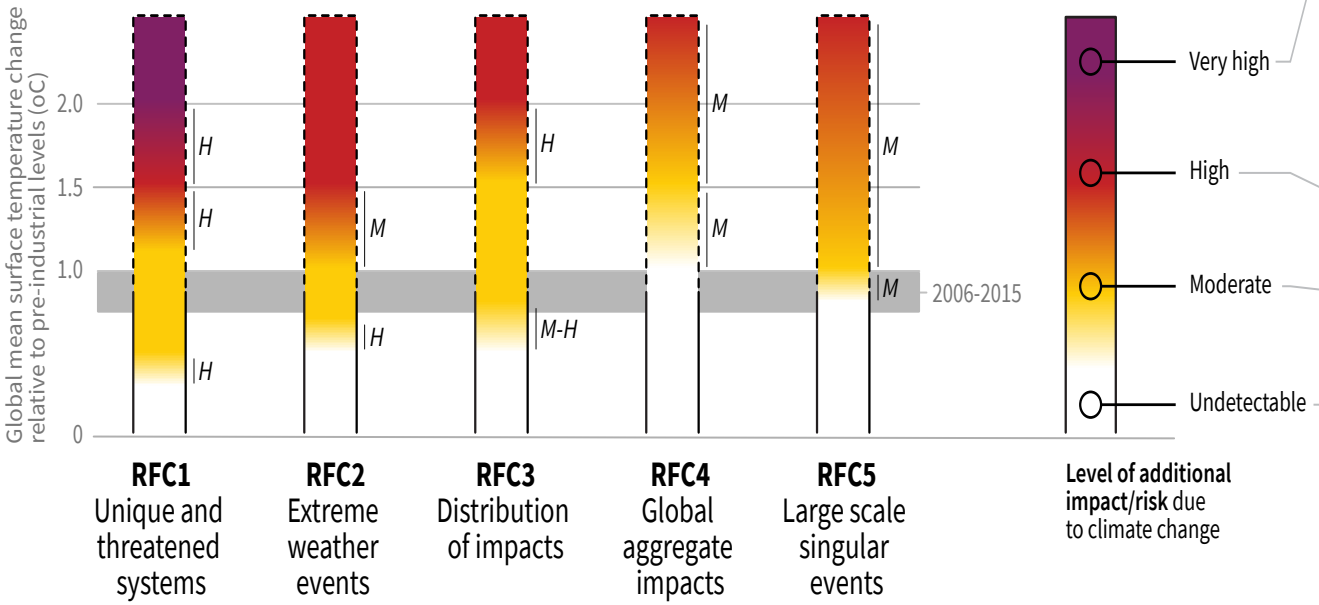


Disponible gratuitement, 6X/an: www.plateforme-wallonne-giec.be

How the level of global warming affects impacts and/or risks associated with the Reasons for Concern (RFCs) and selected natural, managed and human systems

Five Reasons For Concern (RFCs) illustrate the impacts and risks of different levels of global warming for people, economies and ecosystems across sectors and regions.

Impacts and risks associated with the Reasons for Concern (RFCs)



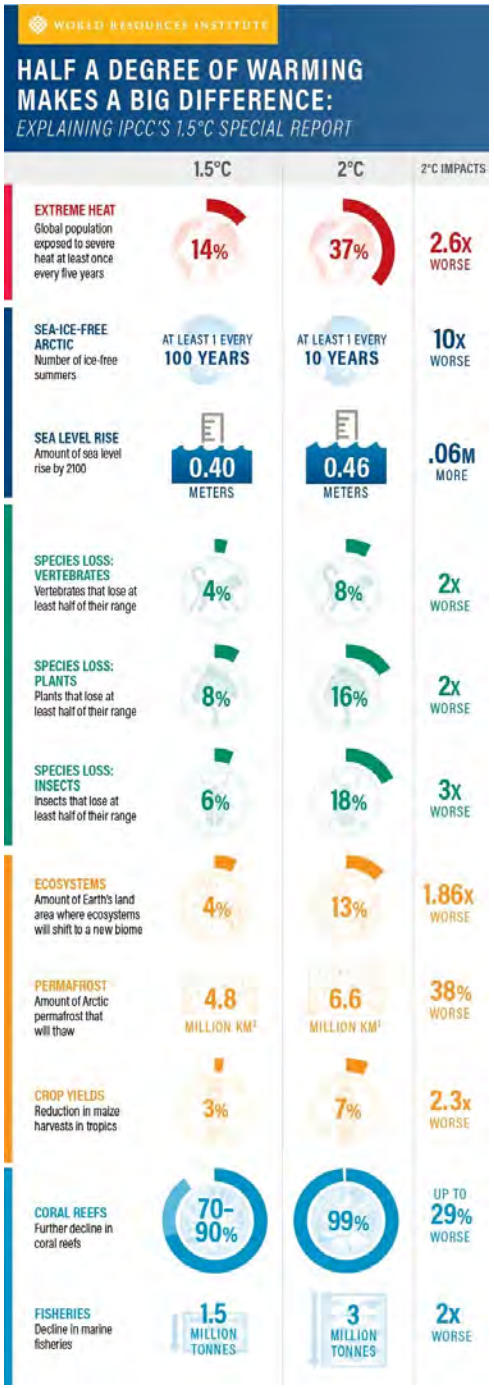
Purple indicates very high risks of severe impacts/risks and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks.

Red indicates severe and widespread impacts/risks.

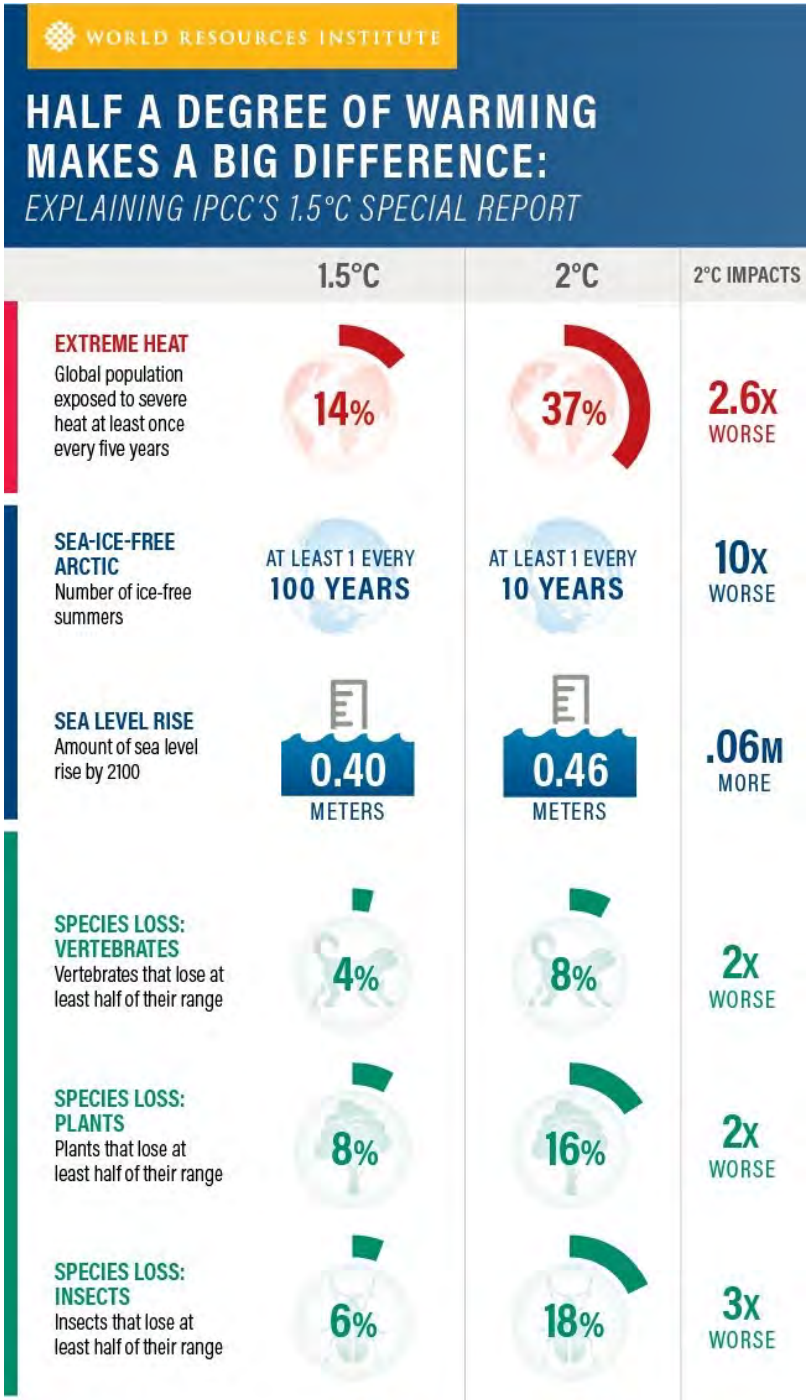
Yellow indicates that impacts/risks are detectable and attributable to climate change with at least medium confidence.

White indicates that no impacts are detectable and attributable to climate change.

IPCC SR15



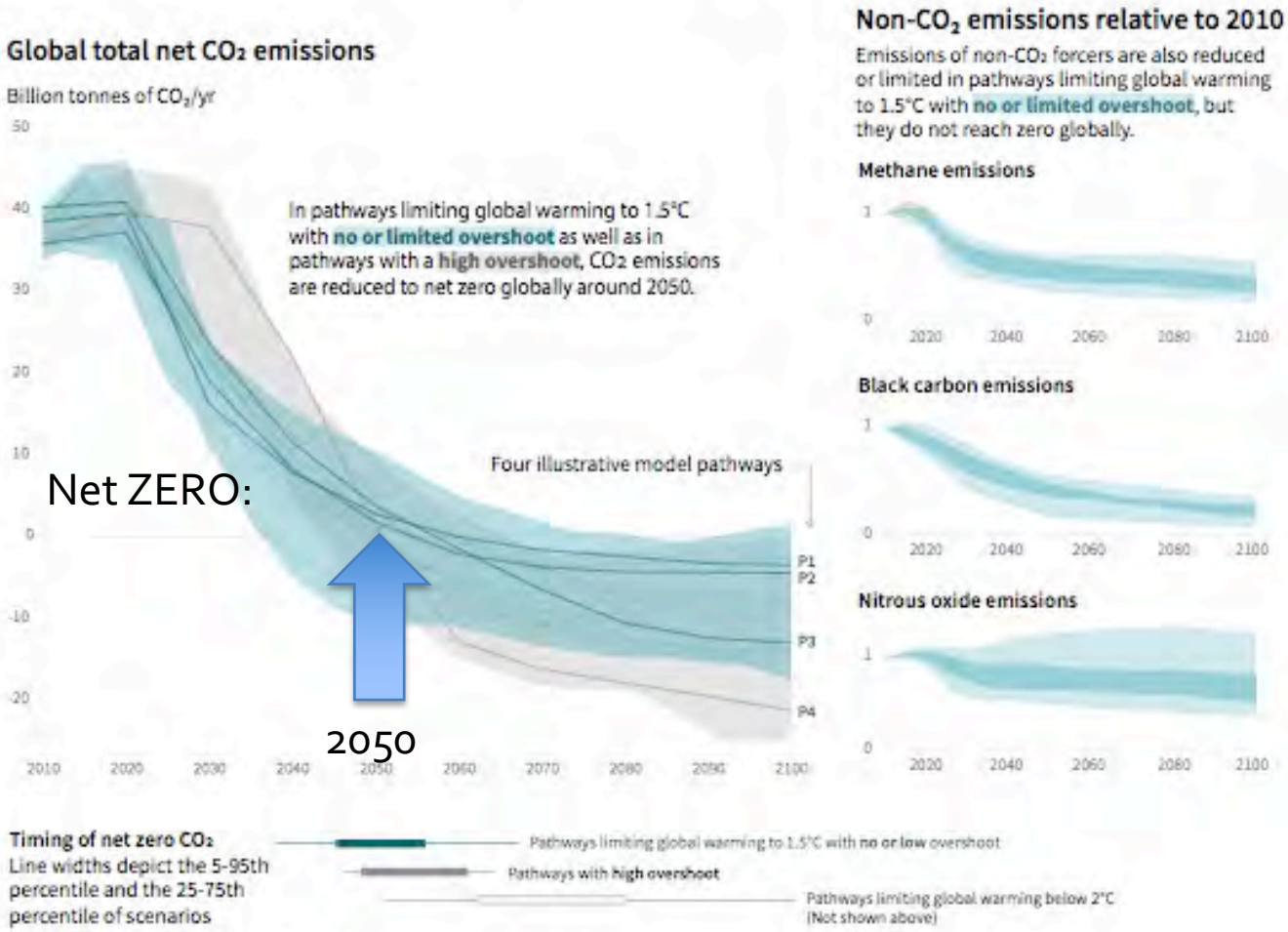
Responsibility for content: WRI



Responsibility for content: WRI

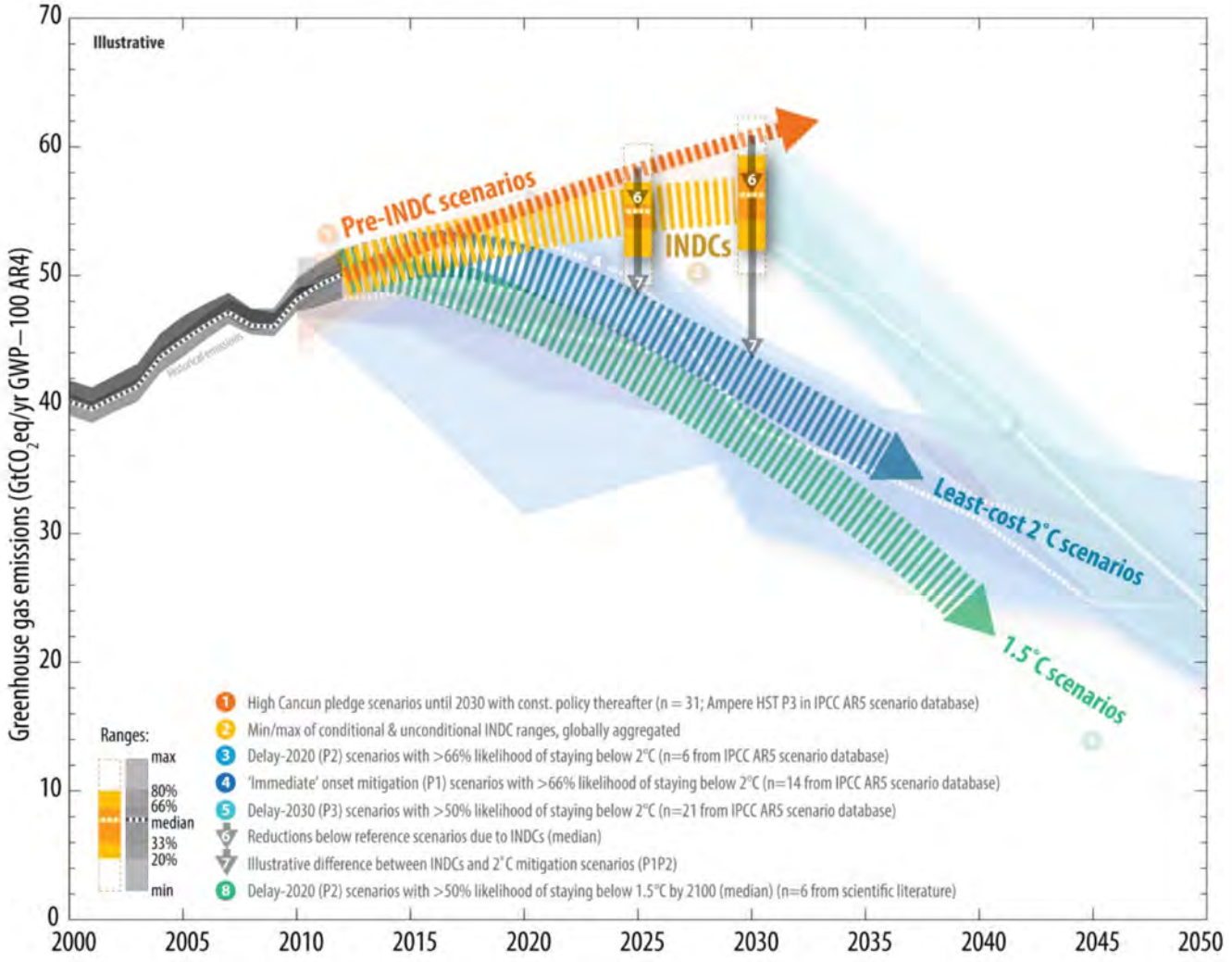
Global emissions pathway characteristics

General characteristics of the evolution of anthropogenic net emissions of CO_2, and total emissions of methane, black carbon, and nitrous oxide in model pathways that limit global warming to 1.5°C with no or limited overshoot. Net emissions are defined as anthropogenic emissions reduced by anthropogenic removals. Reductions in net emissions can be achieved through different portfolios of mitigation measures illustrated in Figure SPM3B.



Source: IPCC Special Report on Global Warming of 1.5°C

Comparison of global emission levels in 2025 and 2030 resulting from the implementation of the intended nationally determined contributions



UNFCCC, Aggregate effect of the intended nationally determined contributions: an update http://unfccc.int/resource/docs/2016/cop22/eng/02.pdf

The Paris Agreement (COP21, December 2015)

- **Vision**
- « …strengthen the **global response to the threat of climate change**, in the context of **sustainable development** and efforts to **eradicate poverty** »
- **Objectives**

a) Holding the increase in the global average temperature:

- « ***to well below 2°C*** *above pre-industrial levels* »
- « ***pursuing efforts to limit the temperature increase to 1.5°C*** *above pre-industrial levels,*
  recognizing that this would significantly reduce the risks and impacts of climate change »

b) Adaptation and Mitigation

- « ***Increasing the ability to adapt*** *to the adverse impacts of climate change and* ***foster climate resilience*** *and*
- ***low greenhouse gas emissions development****, in a manner that does not threaten food production»*

c) Finances

- *« Making* ***finance flows consistent*** *with a pathway towards low greenhouse gas emissions and climate-resilient development. »*

Climate Change and Land

an IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.

Agricultural landscape between Ankara and Hattusha, Anatolia, Turkey (40°00' N – 33°35' E)
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Climate change is making a **challenging situation worse and undermining food security**.

Agriculture, food production, and deforestation are major drivers of climate change.

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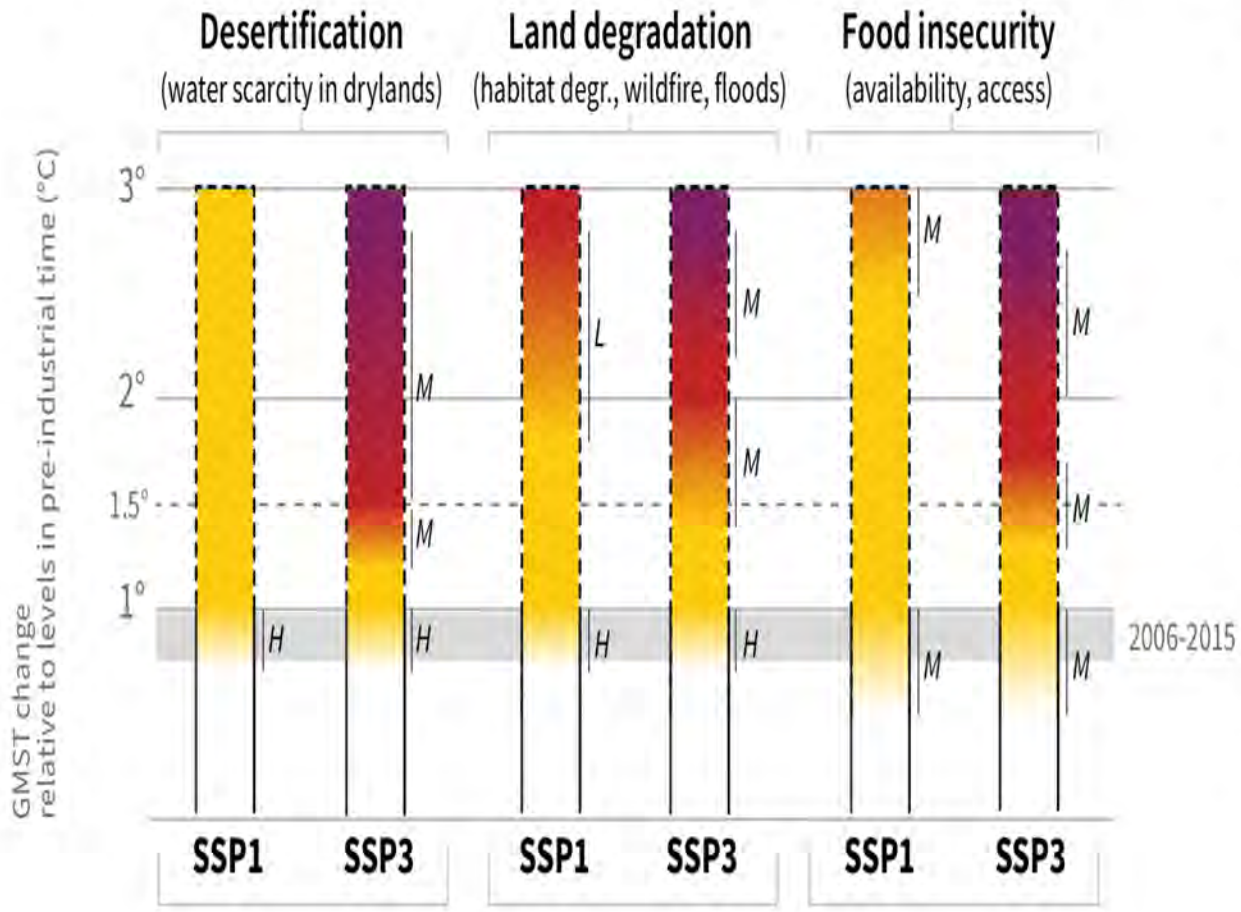
“ Coordinated action to tackle climate change can **simultaneously improve land, food security and nutrition, and help to end hunger.**

The **way we produce our food matters**; dietary choices can help reduce emissions and pressure on land.

B. Different socioeconomic pathways affect levels of climate related risks



Socio-economic choices can reduce or exacerbate climate related risks as well as influence the rate of temperature increase. The **SSP1** pathway illustrates a world with low population growth, high income and reduced inequalities, food produced in low GHG emission systems, effective land use regulation and high adaptive capacity. The **SSP3** pathway has the opposite trends. Risks are lower in SSP1 compared with SSP3 given the same level of GMST increase.

“ **The land that we are already using could feed the world in a changing climate and provide biomass for renewable energy**, but it would require early, far-reaching action across several fronts.

Better land management also supports **biodiversity conservation**

“ **Better land management can play its part** in tackling climate change, but it can’t do it all.

Land is where we live

Land is under growing human pressure

Land is a part of the solution

But land can't do it all

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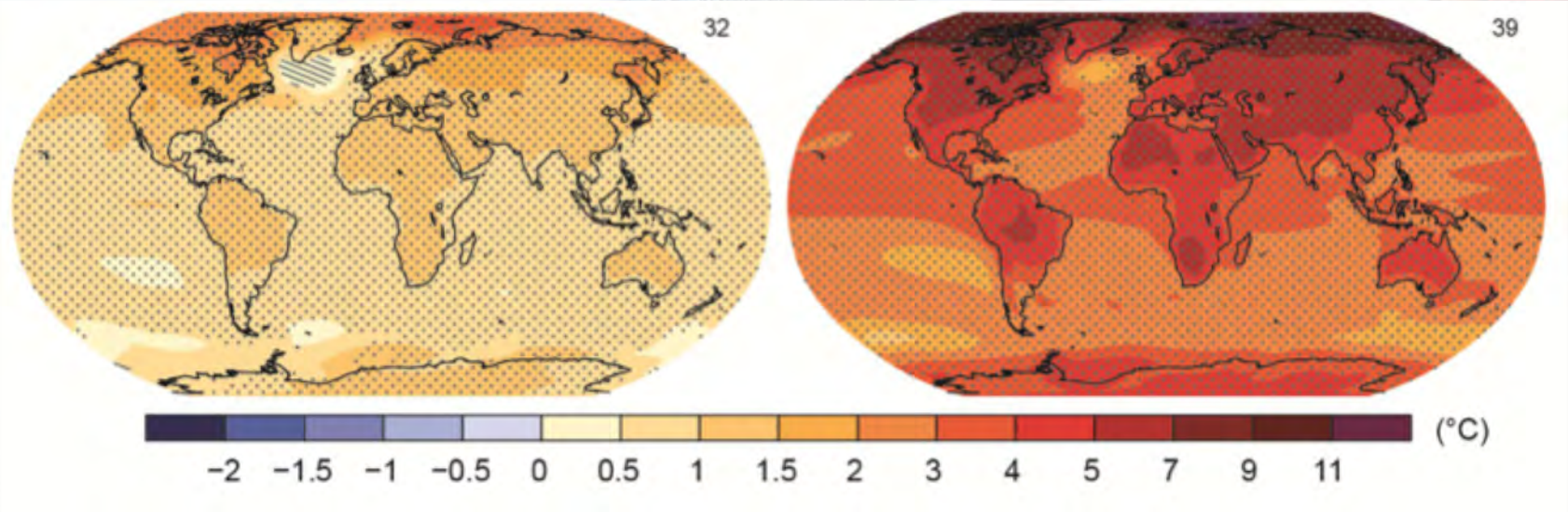
SUSTAINABLE DEVELOPMENT GOALS

Humanity still has the choice

With substantial mitigation

Without additional mitigation



Change in average surface temperature (1986–2005 to 2081–2100)

AR5 WGI SPM

This gives me hope:

Well-informed young people speaking truth to power

With @GretaThunberg at COP24

Useful links:

- www.ipcc.ch : IPCC (reports and videos)
- www.climate.be/vanyp : e.g., my slides
- www.skepticalscience.com: excellent responses to contrarians arguments
- www.desmogblog.com: analysis of contrarians strategies
- **On Twitter: @JPvanYpersele and @IPCC_CH**