Climate change:
From modelling to school strikes

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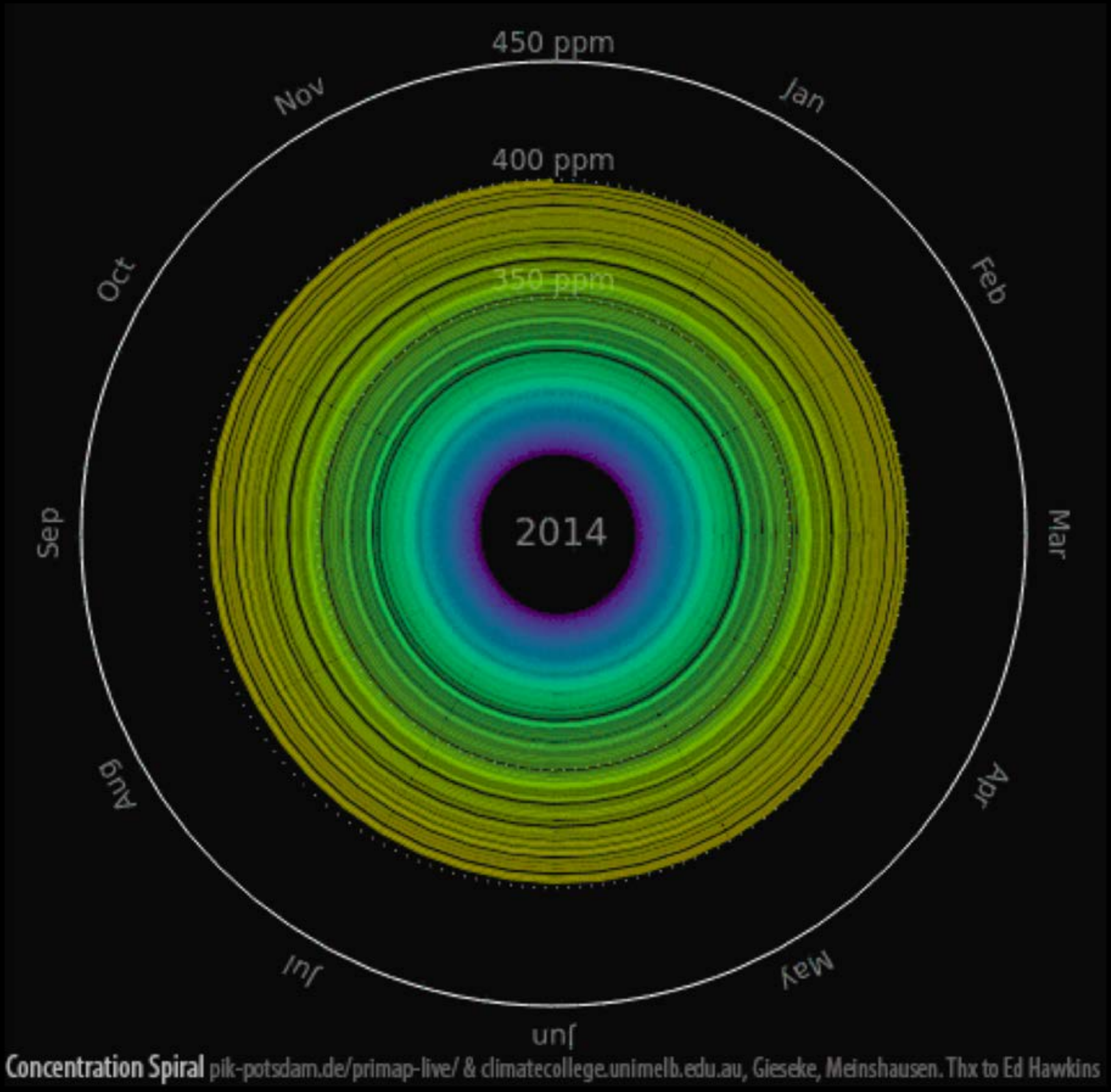
Physics Colloquium, Antwerp Young Minds, Universiteit Antwerpen, 20 May 2019

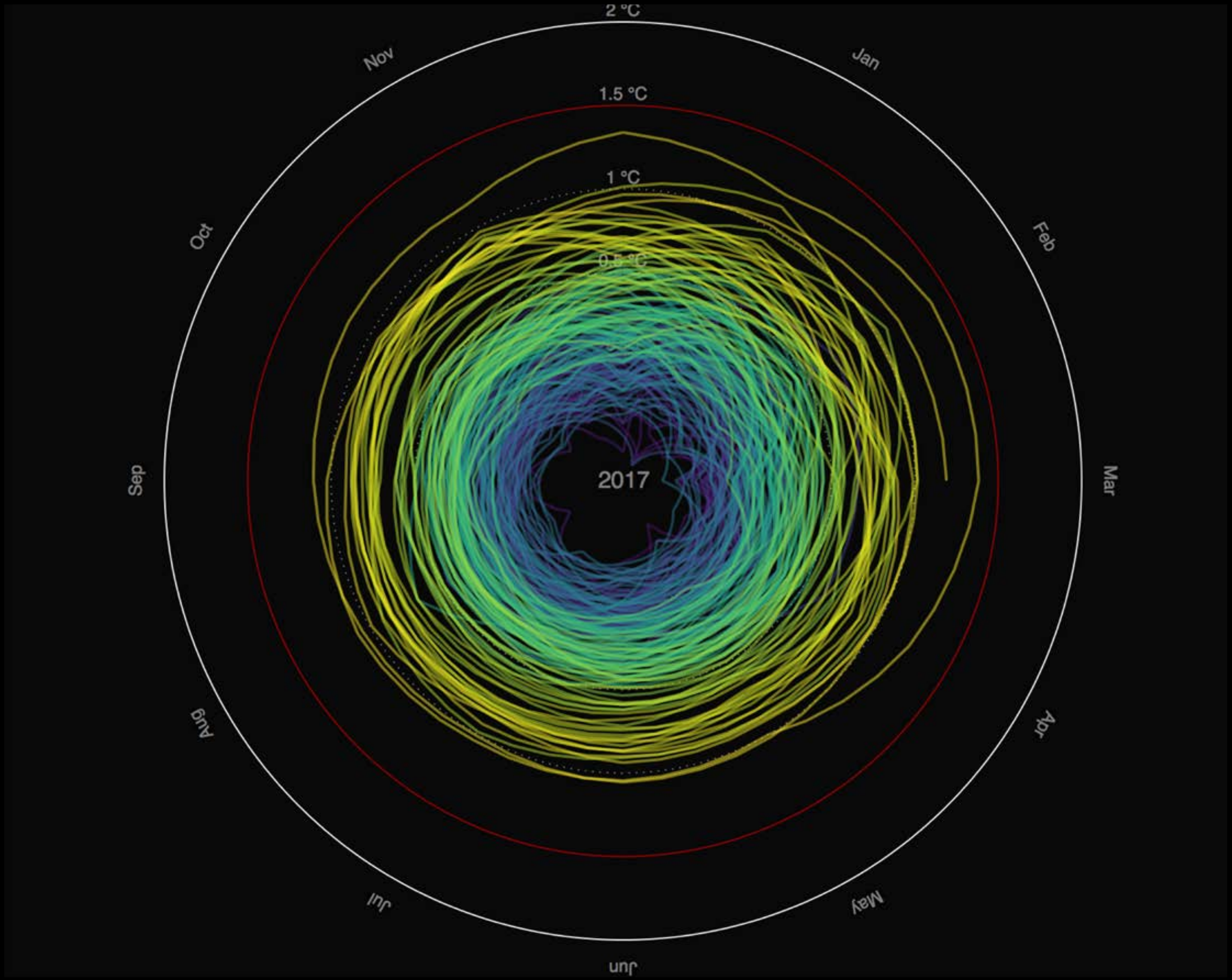
Thanks to the Government of Wallonia, supporting the Walloon Platform for IPCC and to my team at the Université catholique de Louvain

CO_2 concentration spiral: the insulation thickens!



CO_2 concentration spiral 1851-2014 (ppm), by Gieseke & Meinshausen,
Available on http://pik-potsdam.de/primap-live

Temperature spiral



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

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

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

@JPvanYpersele

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IPCC

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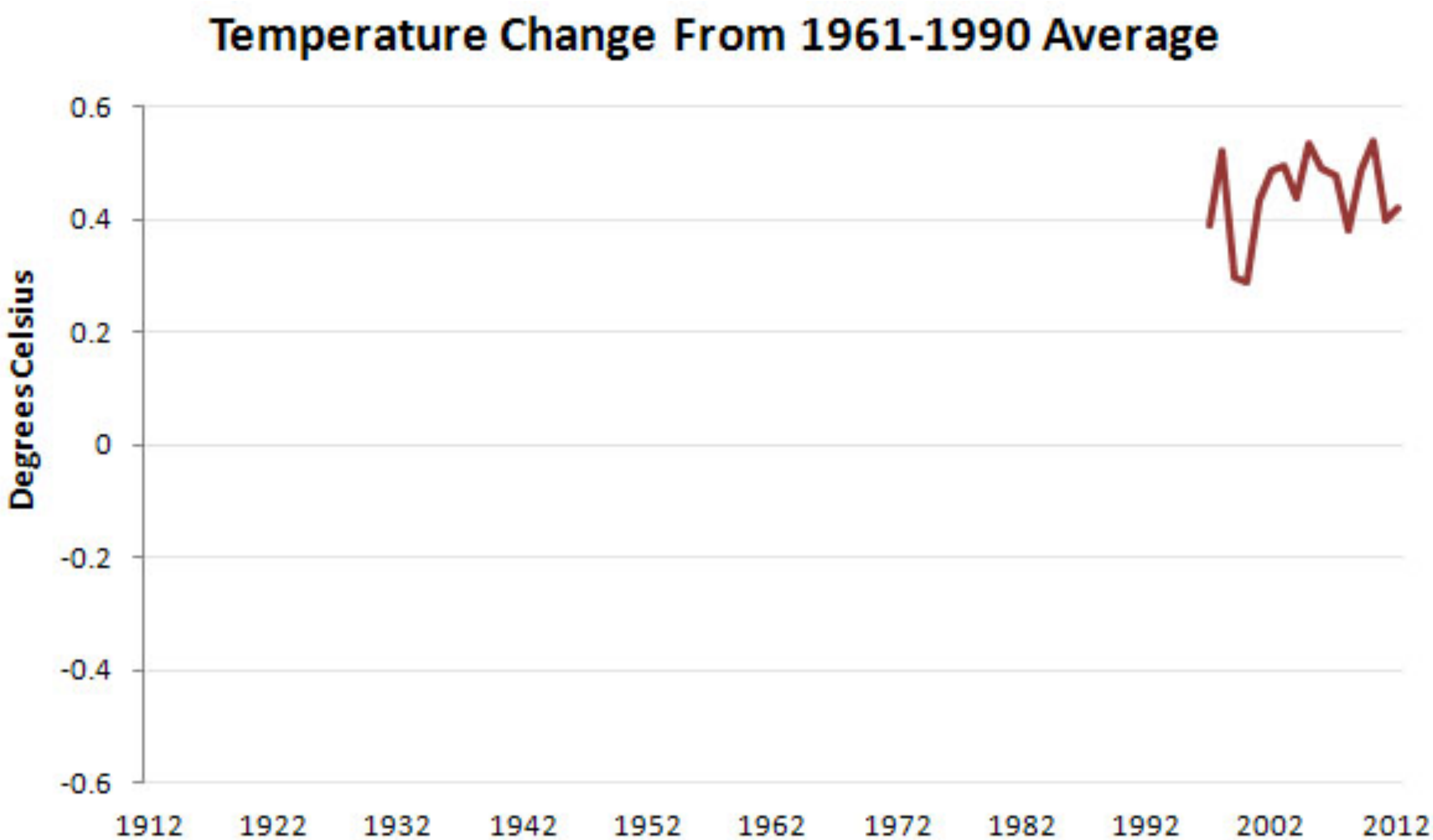
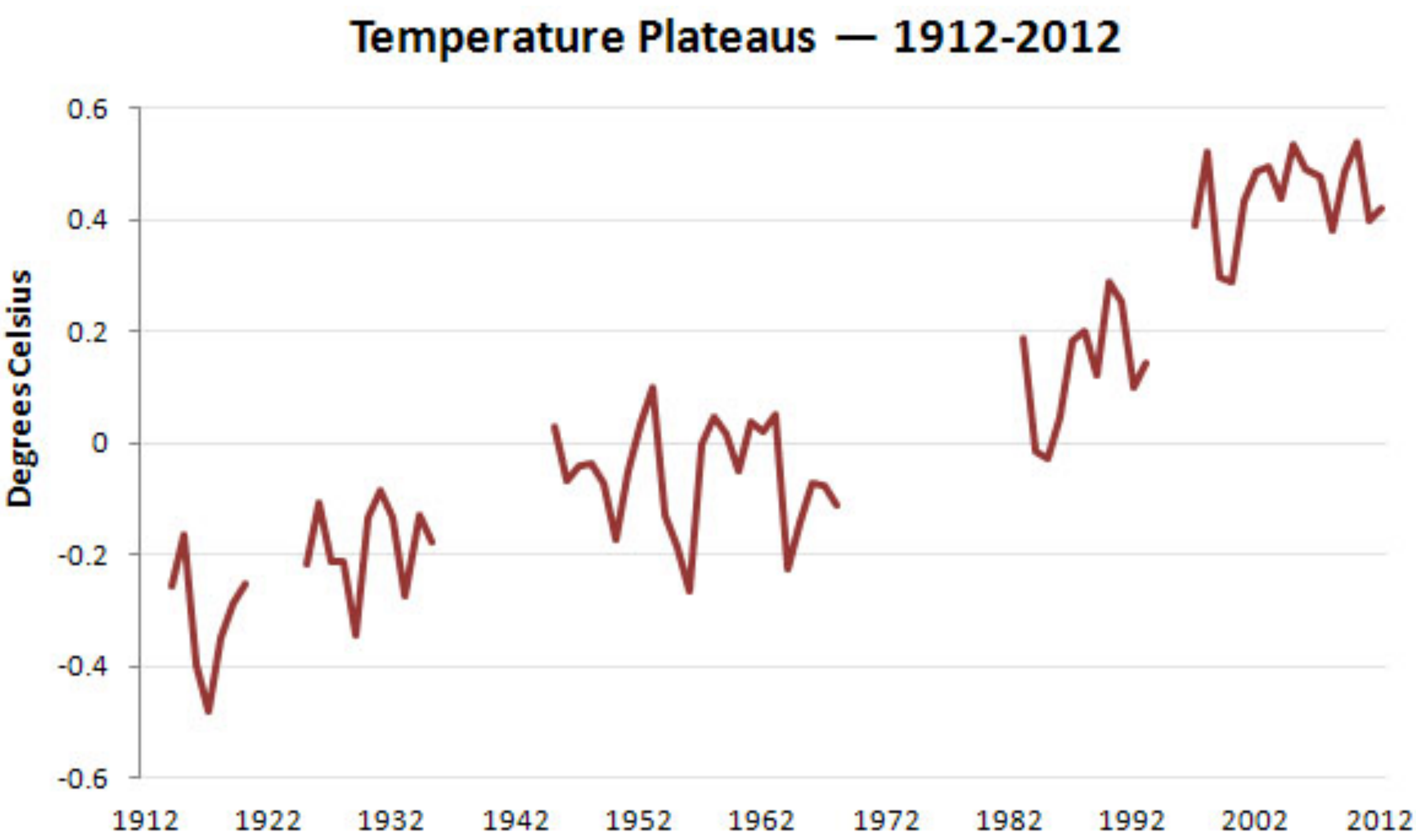


http://www.motherjones.com/kevin-drum/2012/10/lying-statistics-global-warming-edition

Lying With Statistics, Global Warming Edition



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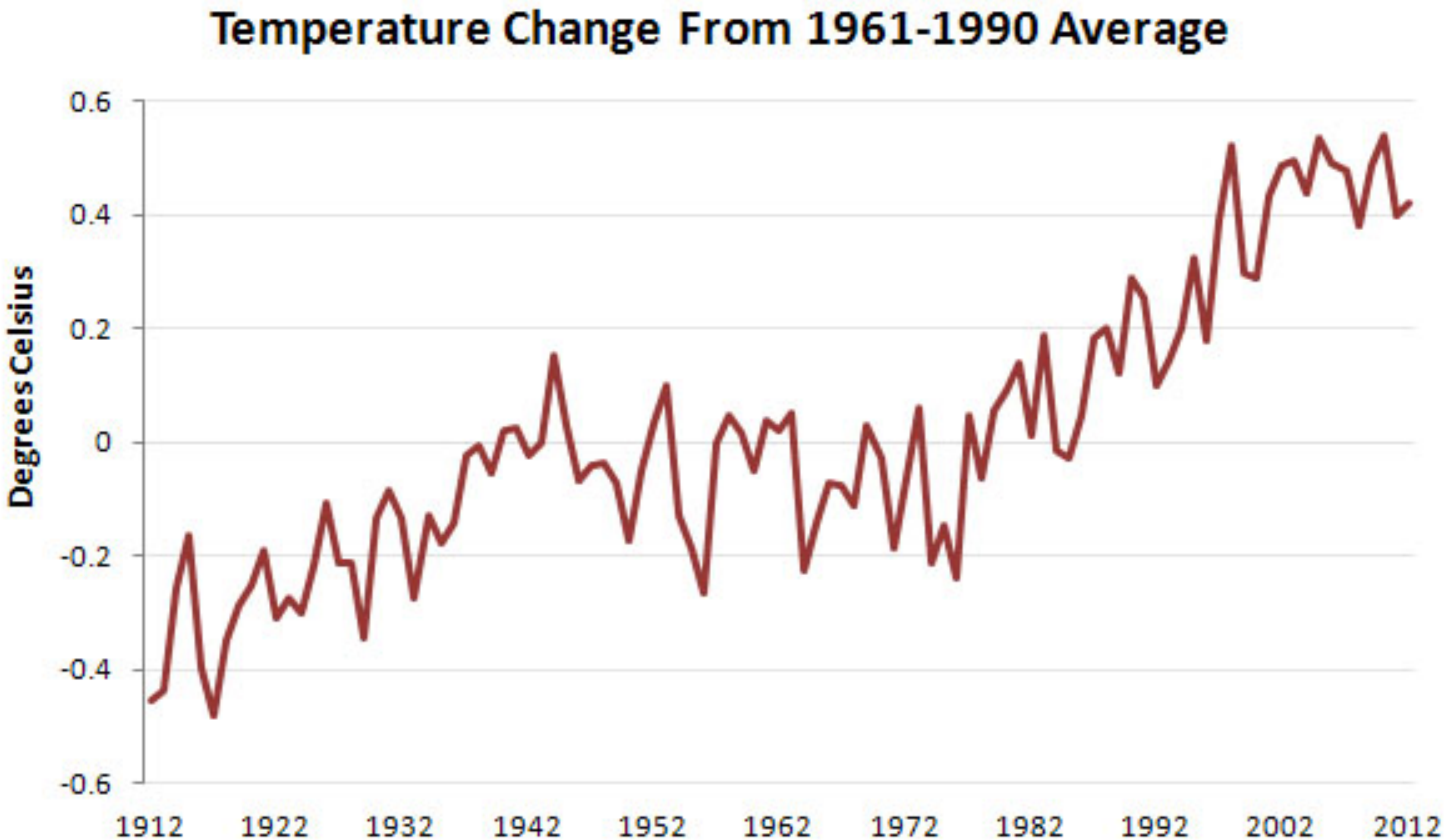
Lying With Statistics, Global Warming Edition



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…)

The « merchants of doubt » have evolved in their arguments:

- Existence of global warming
- Human responsability in the warming
- Uncertainties around the science
- More research needed before taking measures
- Cost of decarbonization
- Drawbacks from alternatives

(recent example: so-called enormous needs of cobalt for electric mobility reported on CNN; see critical analysis on https://www.desmogblog.com/2018/05/02/cnn-wrongly-blames-electric-cars-unethical-cobalt-mining)

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 Reports are policy-relevant, NOT policy-prescriptive

Jean-Pascal van Ypersele
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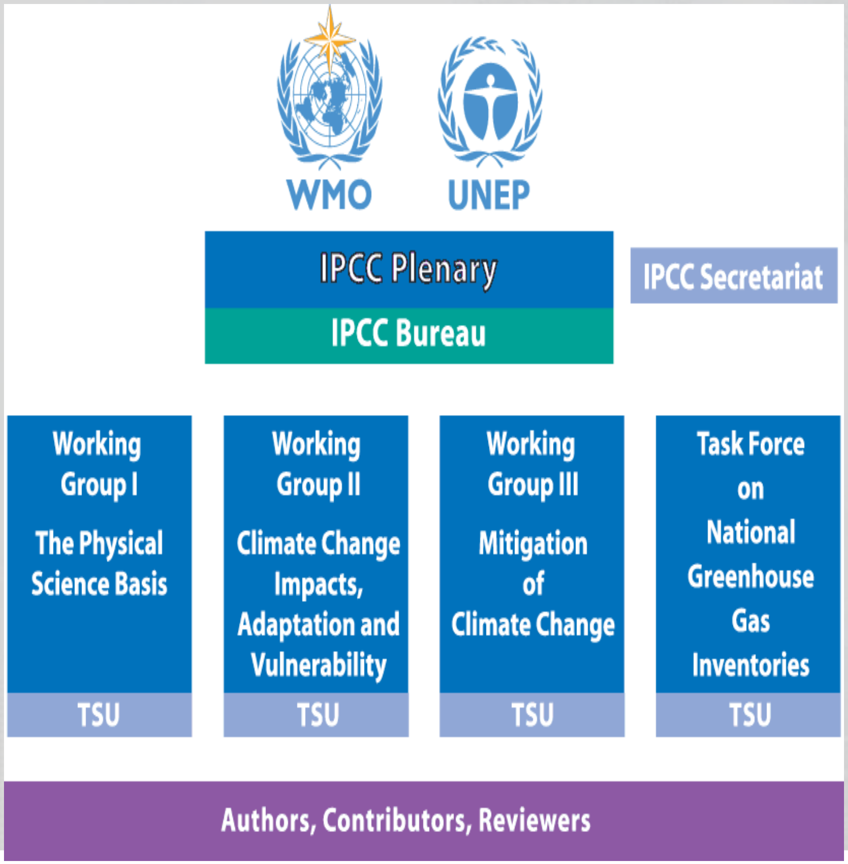
Inter-governmental Panel on Climate Change (IPCC): Organization Structure



- IPCC plenary comprises of all countries in the world
- IPCC Bureau comprises of 34 elected members; IPCC elects its Bureau every 6-7 years
- 3 Working Groups & a Task Force on National Greenhouse Gas Inventories
- Authors, Contributors, Reviewers, Review Editors

ipcc INTERGOVERNMENTAL PANEL ON climate change

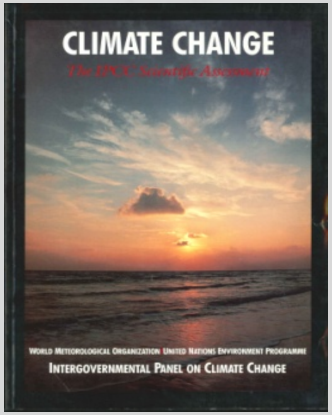
WMO UNEP

IPCC writing cycle (4 years, 831 Lead authors)

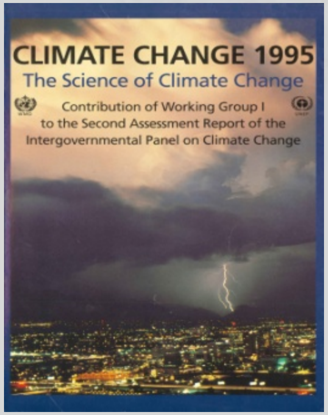
- **Plenary decides table of content of reports**
- **Bureau appoints world-class scientists as authors, based on publication record**
- **Authors assess all scientific literature**
- ***Draft* – Expert review (+ Review editors)**
- ***Draft 2 (+ Draft 1 Summary for Policy Makers (SPM)* – Combined expert/government 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)

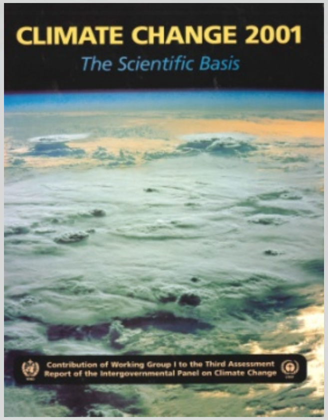
IPCC Assessment Reports



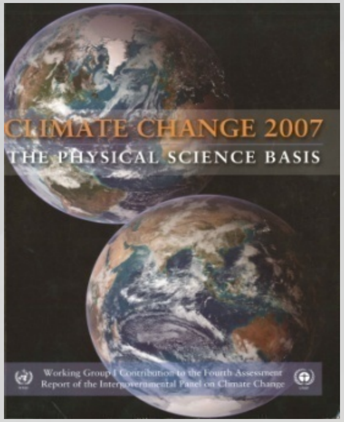
FAR 1990



SAR 1995

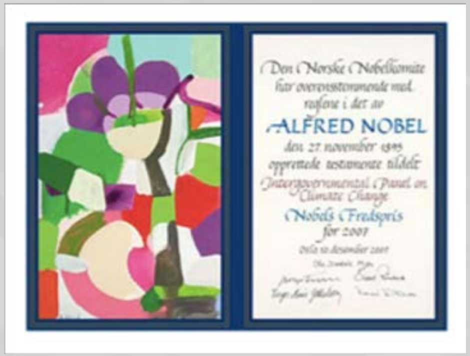


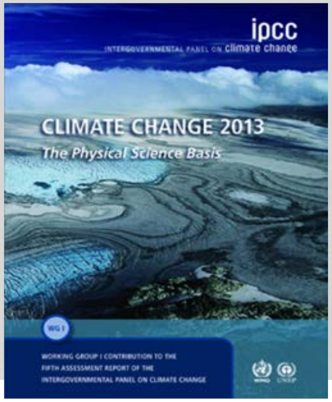
TAR 2001



AR4 2007

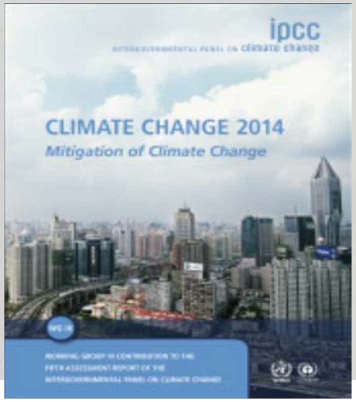
Nobel Peace Prize 2007





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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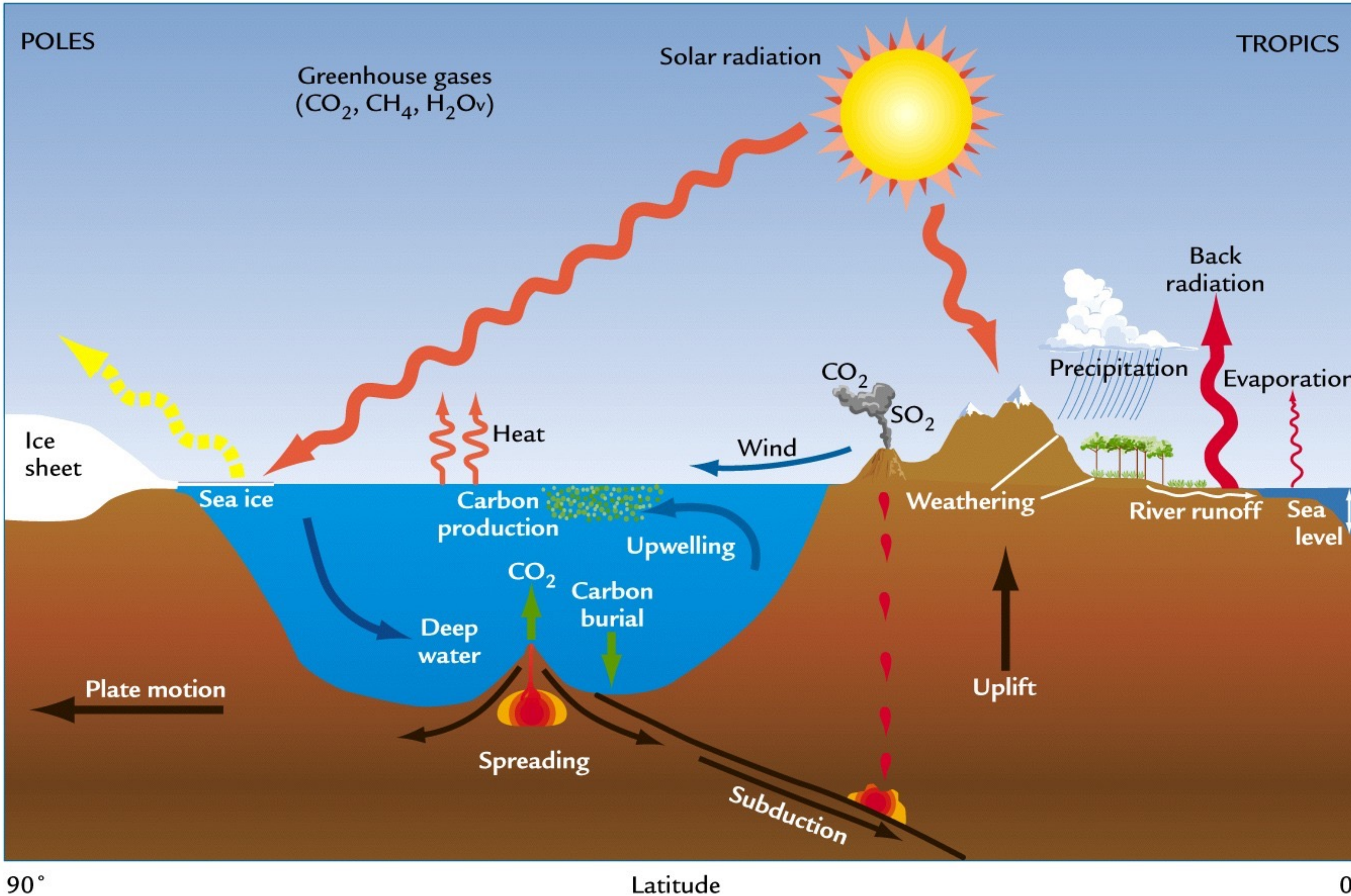
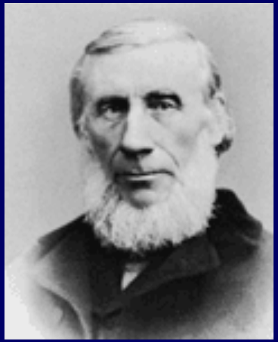

POLES
TROPICS
Solar radiation
Greenhouse gases
(CO_2, CH_4, H_2Ov)
Back
radiation
Precipitation
Evaporation
CO_2
SO_2
Heat
Wind
Ice
sheet
Sea ice
Carbon
production
Upwelling
Weathering
River runoff
Sea
level
CO_2
Carbon
burial
Deep
water
Plate motion
Uplift
Spreading
Subduction
90°
Latitude
0°

Discovery of the Greenhouse Effect

Joseph Fourier (1827)

Recognized that gases in the atmosphere might trap the heat received from the Sun.

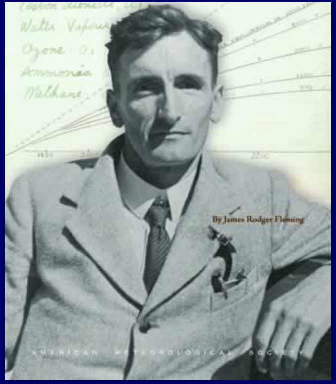


John Tyndall (1859)

Careful laboratory experiments demonstrated that several gases could trap infrared radiation. The most important was simple water vapor. Also effective was carbon dioxide, although in the atmosphere the gas is only a few parts in ten thousand.

Svante Arrhenius (1896)

Performed numerical calculations that suggested that doubling the amount of carbon dioxide in the atmosphere could raise global mean surface temperatures by 5-6°C. (not reliable yet : errors & lack of appropriate data)



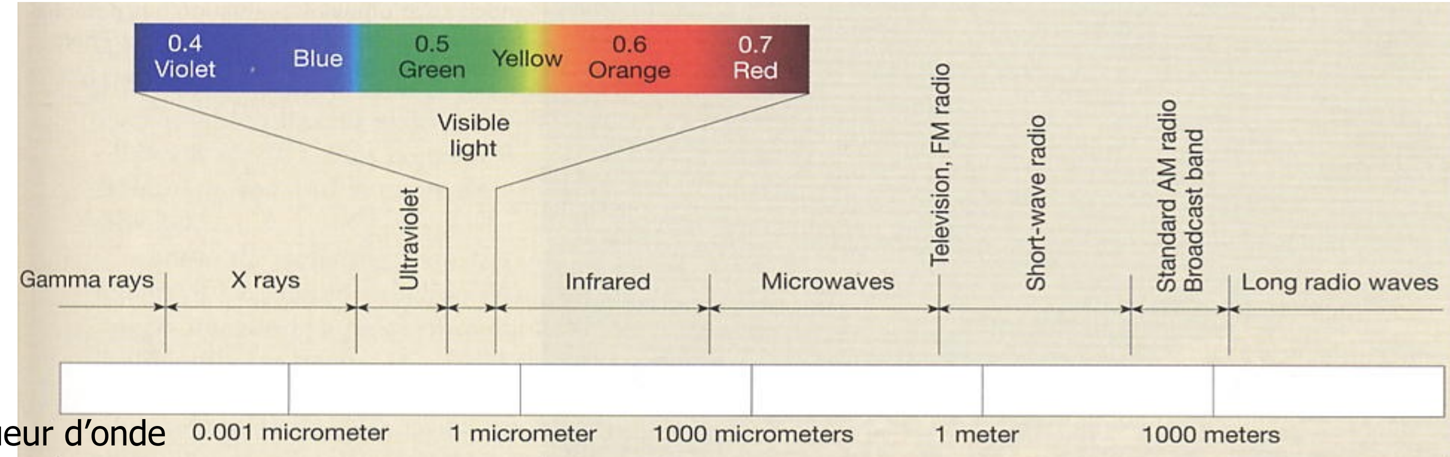
Guy Callendar (1939)

Argued that rising levels of carbon dioxide were responsible for measurable increases in Earth surface temperatures. Estimated that doubling the amount of CO_2 in the atmosphere could raise global mean surface temperatures by 2°C.

GREENHOUSE EFFECT?

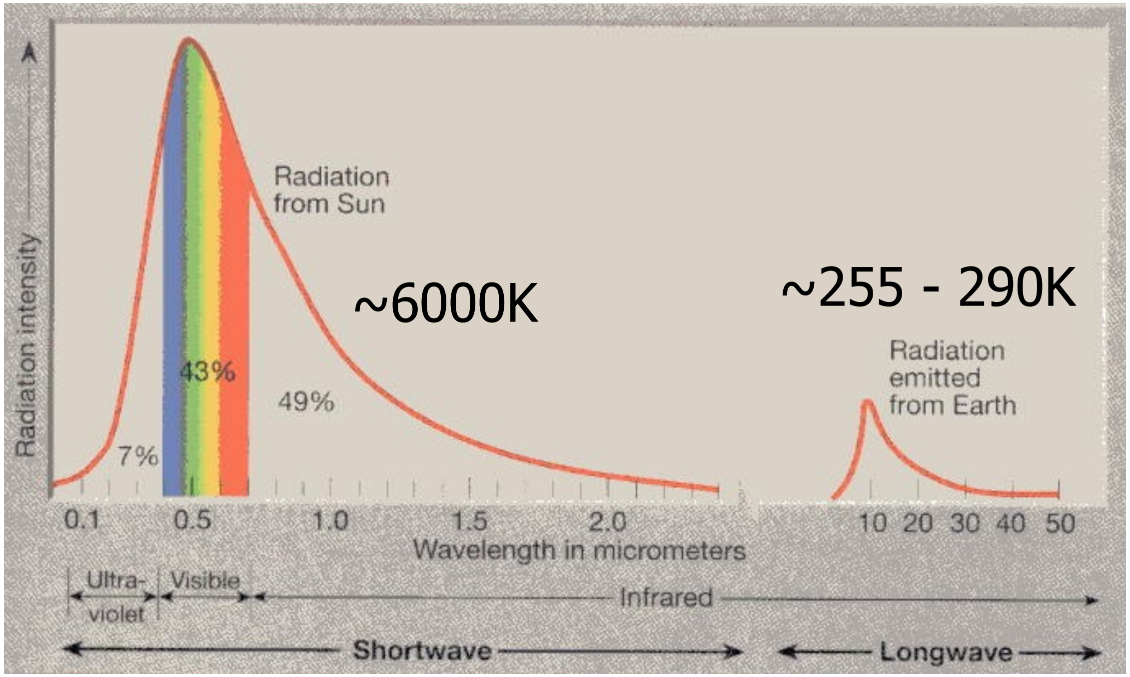
… un peu d'analogie, mais grande différence de principe

Spectre du rayonnement électromagnétique



Longueur d'onde

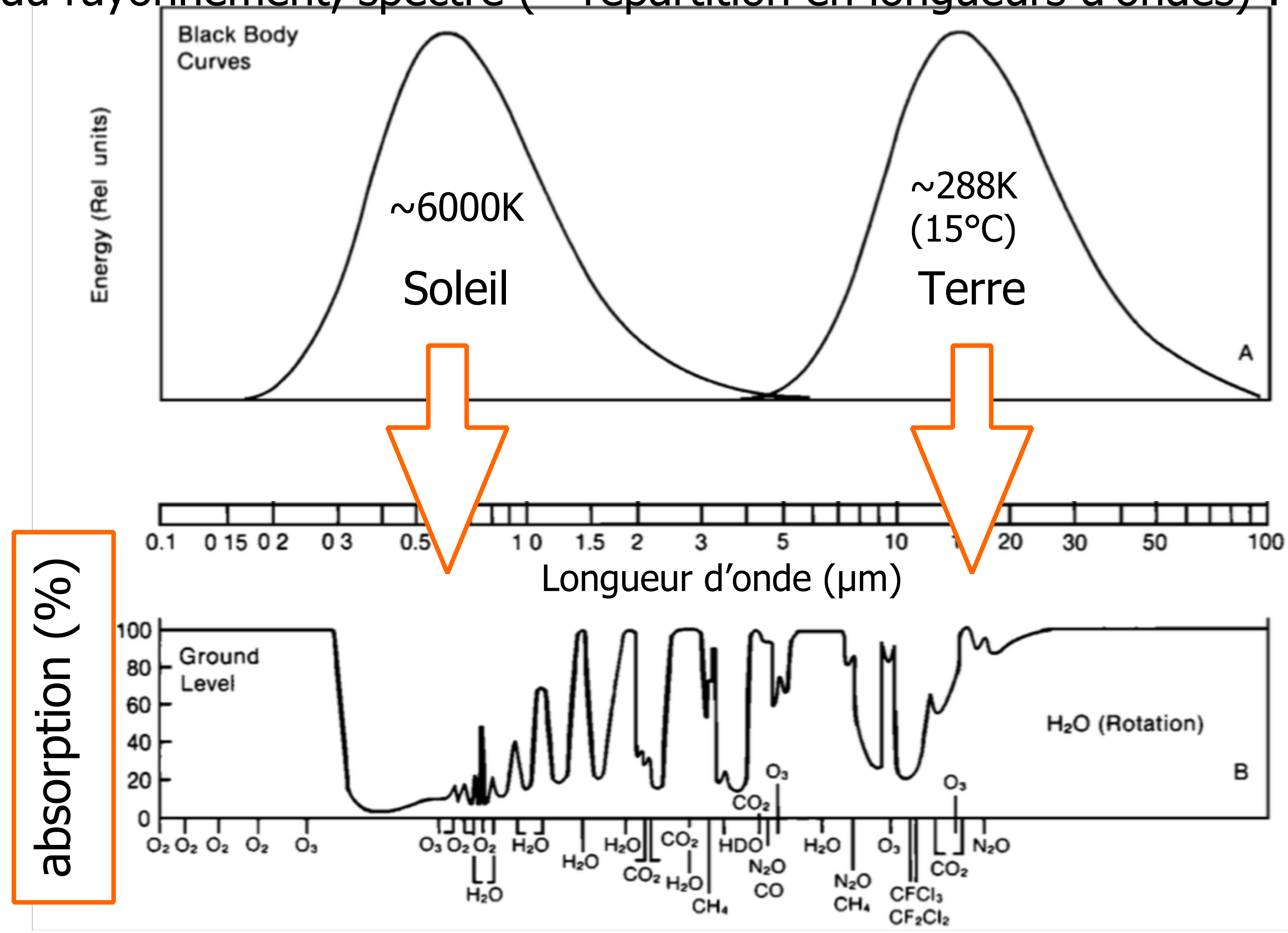
Spectres des rayonnements solaire et terrestre



(0°C
= +273K)

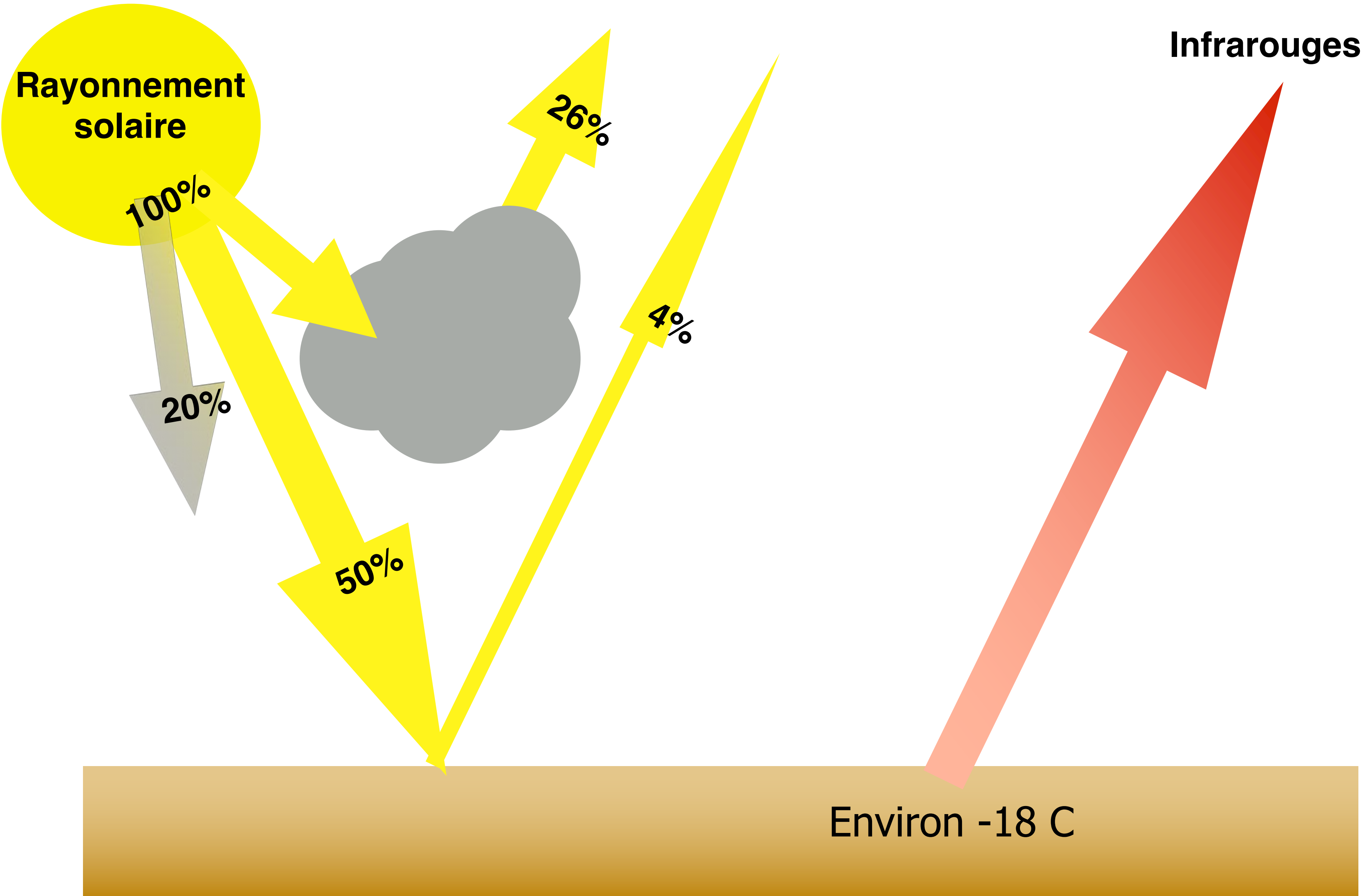
Le rayonnement solaire passe largement l’atmosphère, mais l’infrarouge est largement absorbé

Source du rayonnement, spectre (= répartition en longueurs d’ondes) :

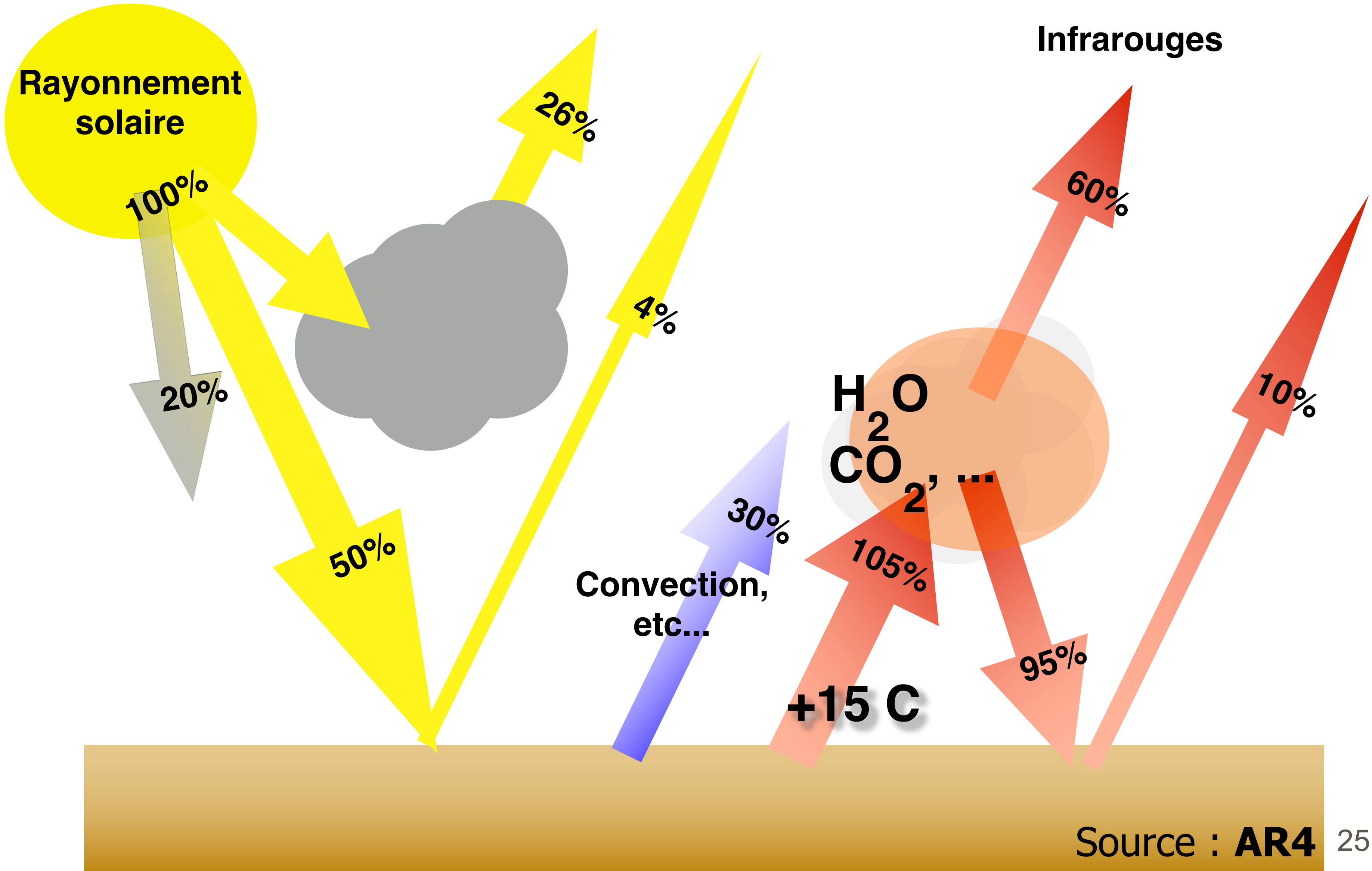


Source : J. Mitchell, Reviews of Geophysics, 1989

Energie et effet de serre

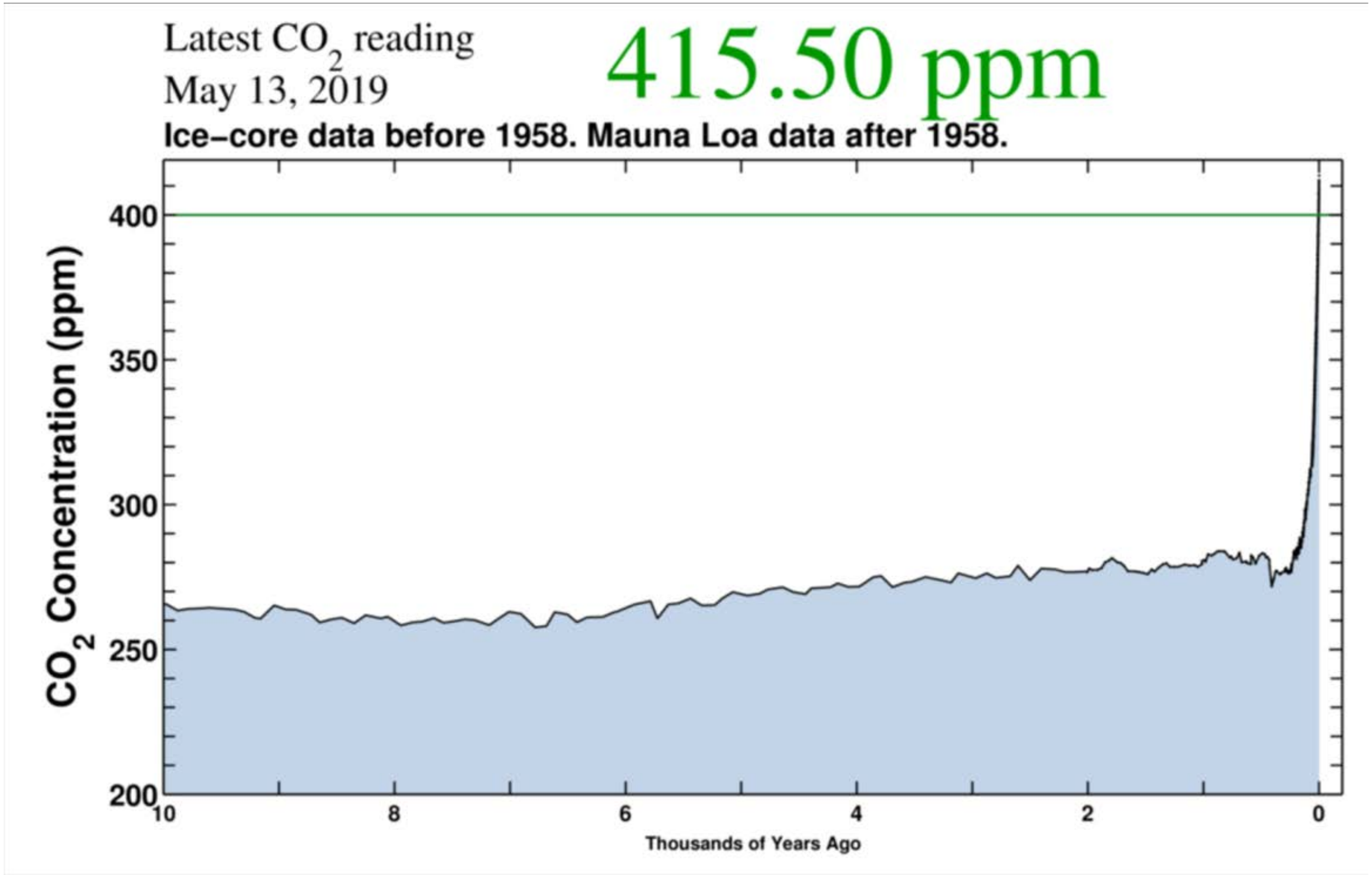


Energie et effet de serre



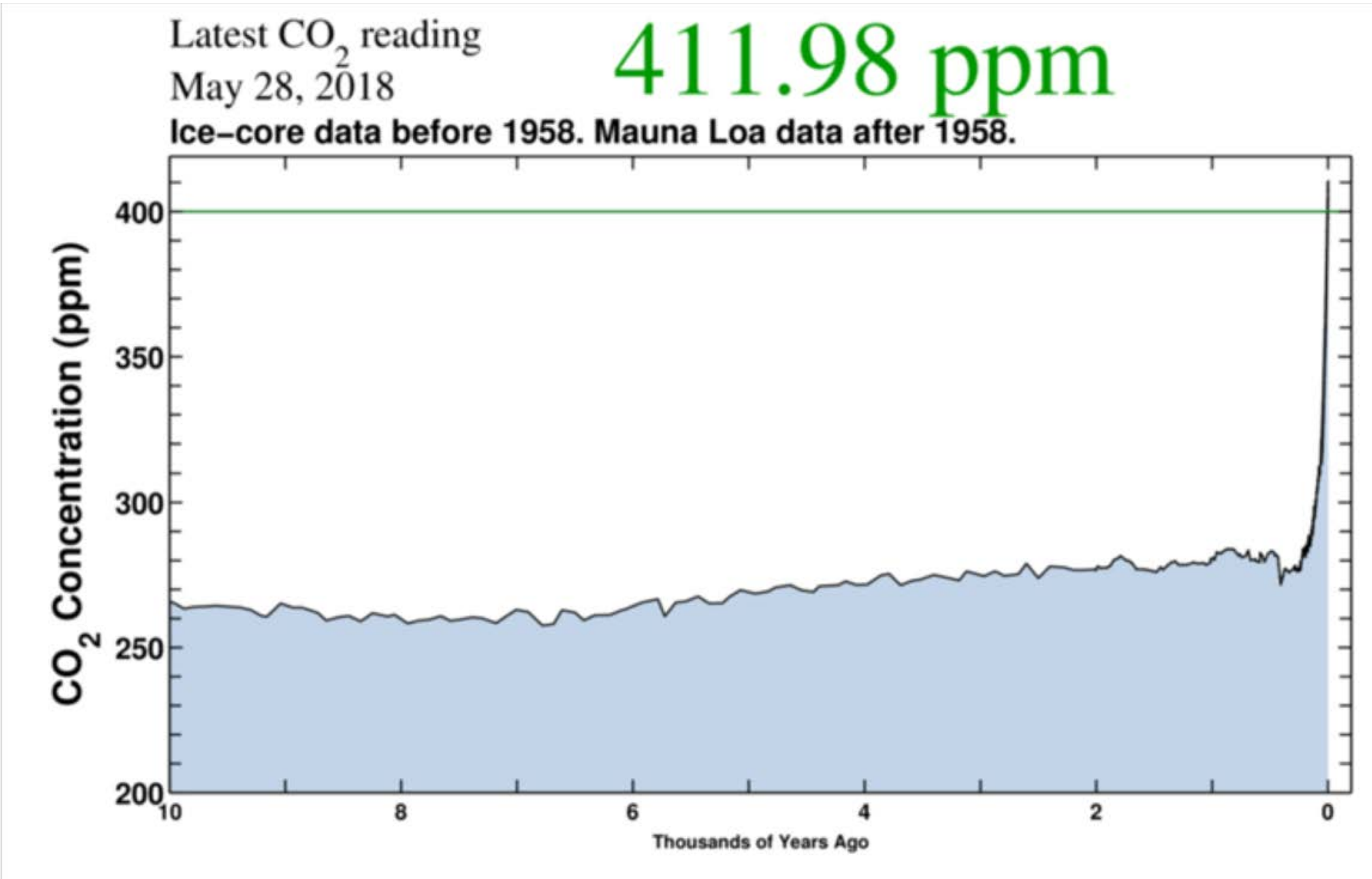
Source : **AR4**

CO_2 Concentration, 13 May 2019 (Keeling curve)



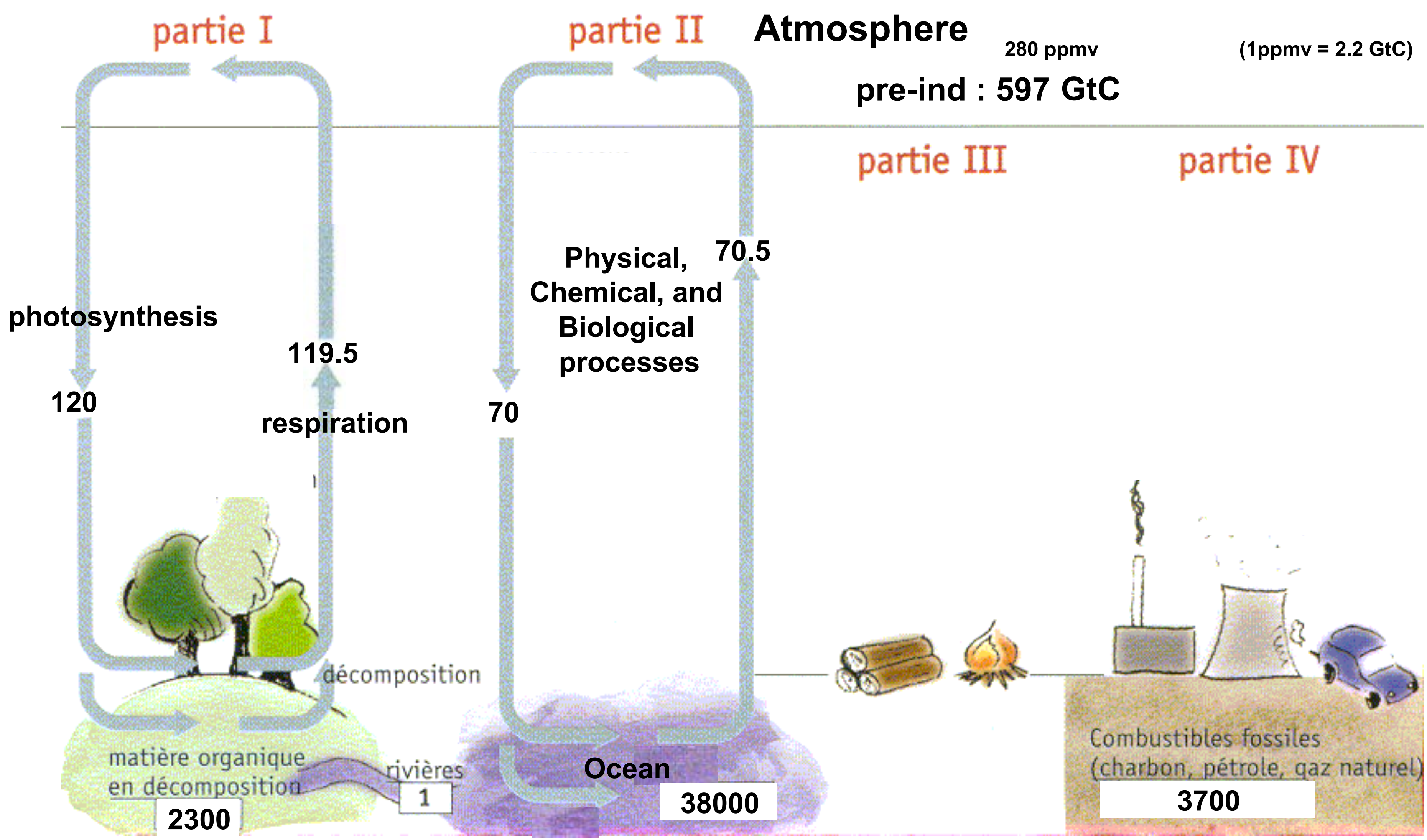
Source: scripps.ucsd.edu/programs/keelingcurve/

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 $GtCO_2$)

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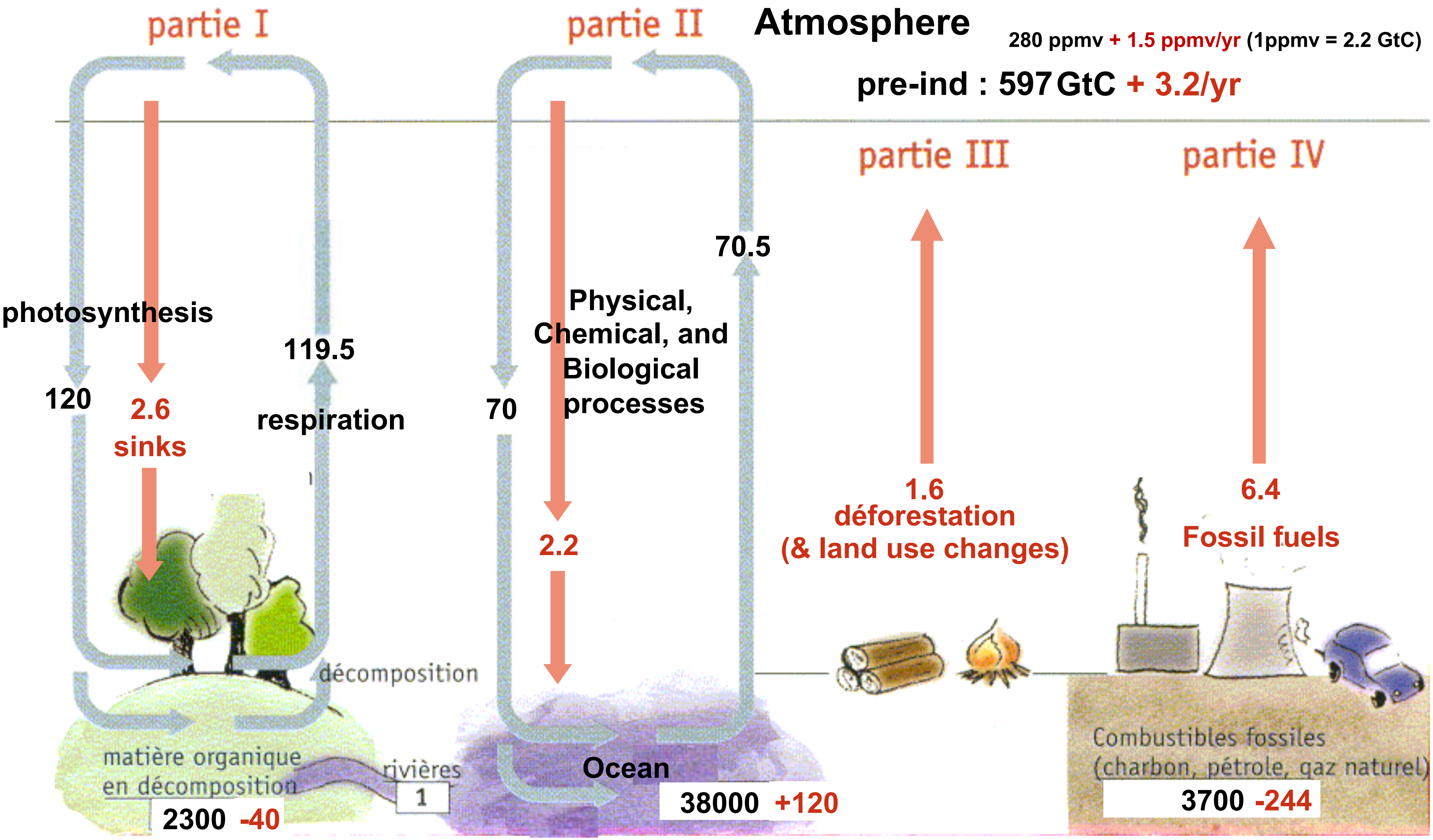
Carbon cycle: perturbed by human activities

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



Stocks!

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

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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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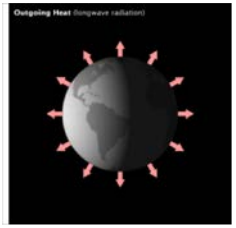
A simple climate model

What comes in..

$$S\pi r^2(1-a)$$

Solar constant
1367 W/m²

Earth's albedo
0.3



must go out

$$4\pi r^2 \varepsilon\sigma T^4$$

Effective emissivity
(greenhouse, clouds)
0.64

Stefan's constant
5.67×10^{-8} W/(K^4·m^2)

Adapted from Peter Guttorp, U. Washington

Solution

Average earth temperature is T=285K (12° C)

One degree Celsius change in average earth temperature is obtained by changing

solar constant by 1.4%

Earth’s albedo by 3.3%

effective emissivity by 1.4%

Adapted from Peter Guttorp, U. Washington

But in reality…

The solar constant is not constant

The albedo changes with land use changes, ice melting and cloudiness

The emissivity changes with greenhouse gas changes and cloudiness

Need to model the three-dimensional (at least) atmosphere

But the atmosphere interacts with land surfaces…

…and with oceans!

Adapted from Peter Guttorp, U. Washington

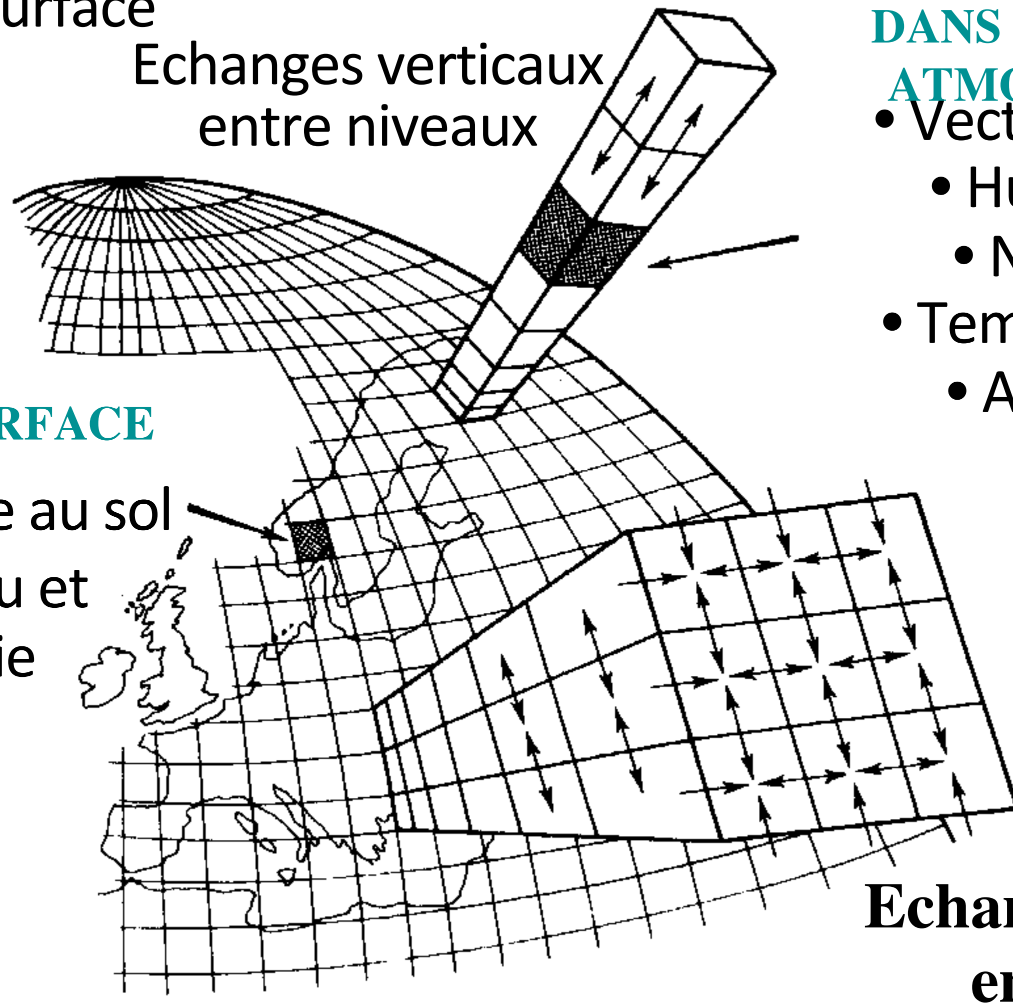
Modèles climatiques

Atmosphère et surface

Echanges verticaux entre niveaux

DANS LA COLONNE ATMOSPHERIQUE

- Vecteurs vent
- Humidité
- Nuages
- Température
- Altitude



A LA SURFACE

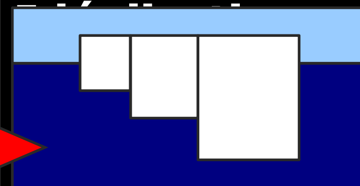
- Température au sol
- Flux d'eau et d'énergie

Echanges horizontaux entre colonnes

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

Aperçu de principe de la modélisation

Réalité



$$\rho c(S,T)\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}[k(S,T)\frac{\partial T}{\partial z}] + \kappa R_0 e^{-\kappa z}$$

Discrétisation

```
DO ji = kideb , kiut
   ztitemp(ji,layer)    = t_i_b(ji,
   zspeche_i(ji,layer) = cpic + zga
   MAX((t_i_b(ji,layer)-rtt)*(ztio
   zeta_i(ji,layer)     = rdt_ice /
                                  ze
END DO
 DO

layer = 1, nlay_s
DO ji = kideb , kiut
   ztstemp(ji,layer) = t_s_b(ji,lay
   zeta_s(ji,layer)  = rdt_ice / MA
END DO
```

Résolution

```
432586309543950923149328932589
432509534590342950439509432324
342543953042950432953245093245
435093425304295032495049504954
345904305943023914364320932193
432586309543950923149328932589
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342543953042950432953245093245
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345904305943023914364320932193
```
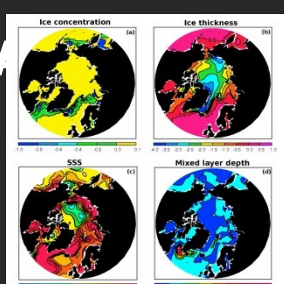
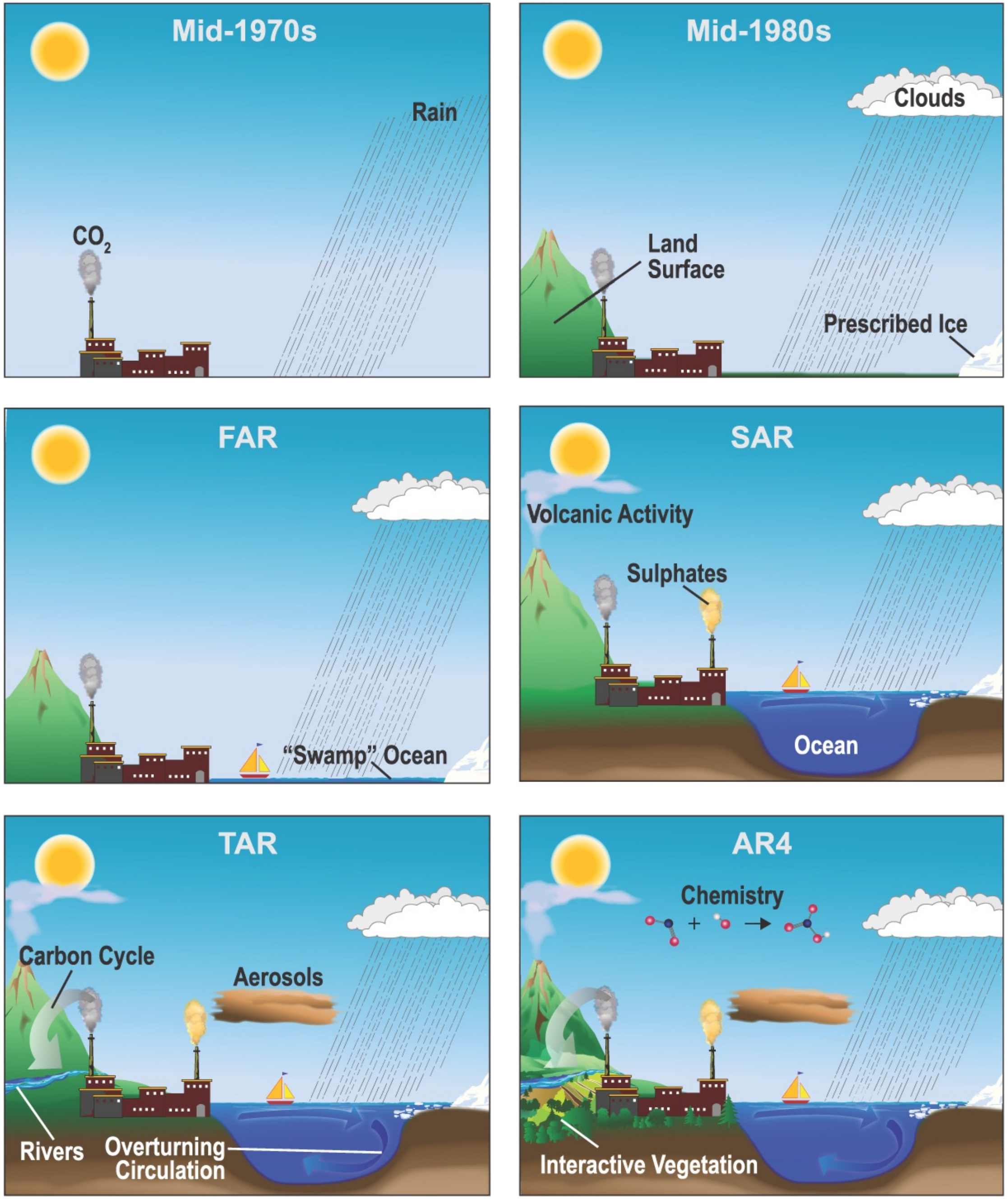



1) Validation
2) Sensibilité

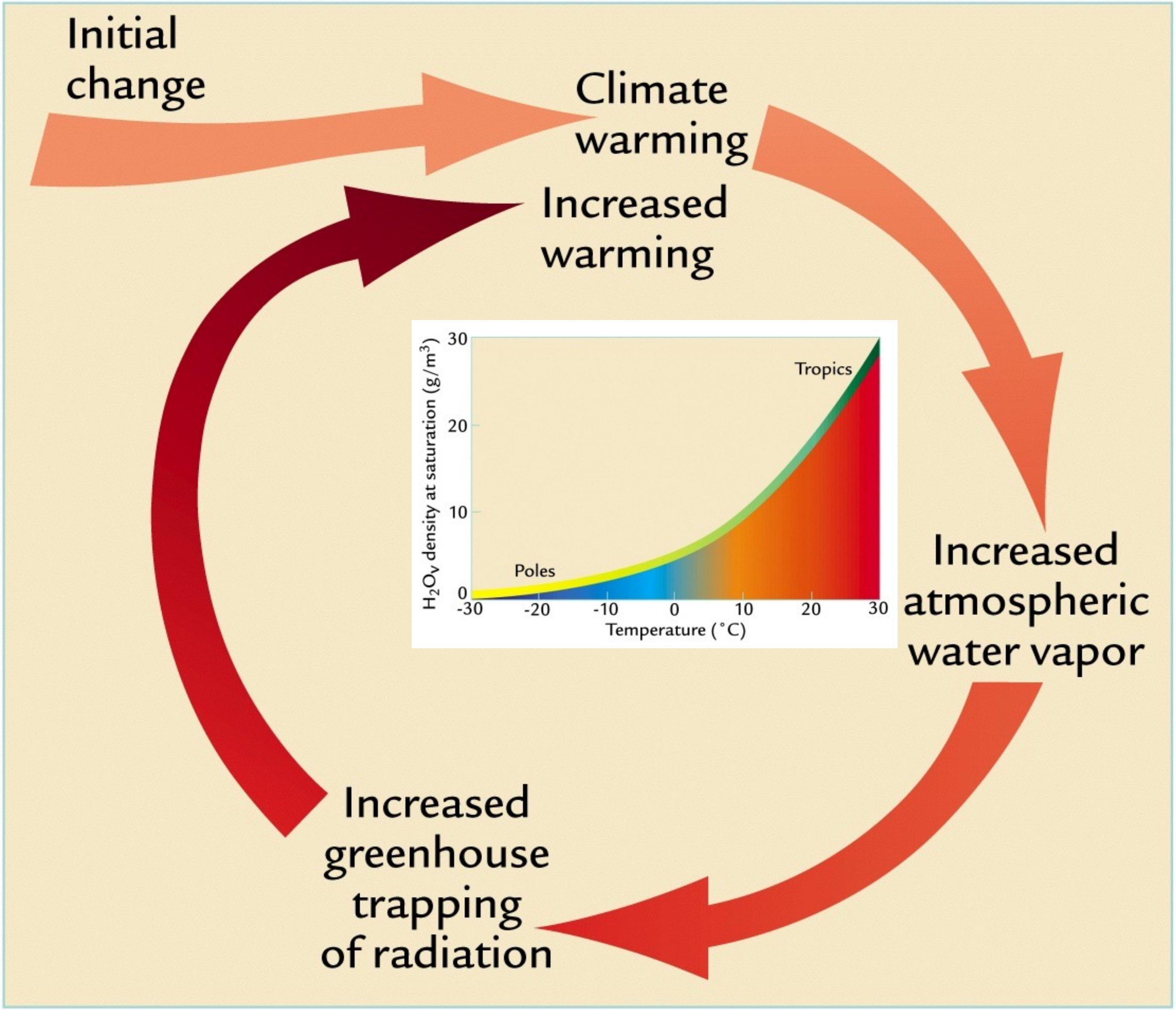
Martin Van Coppenolle (UCL)

The World in Global Climate Models

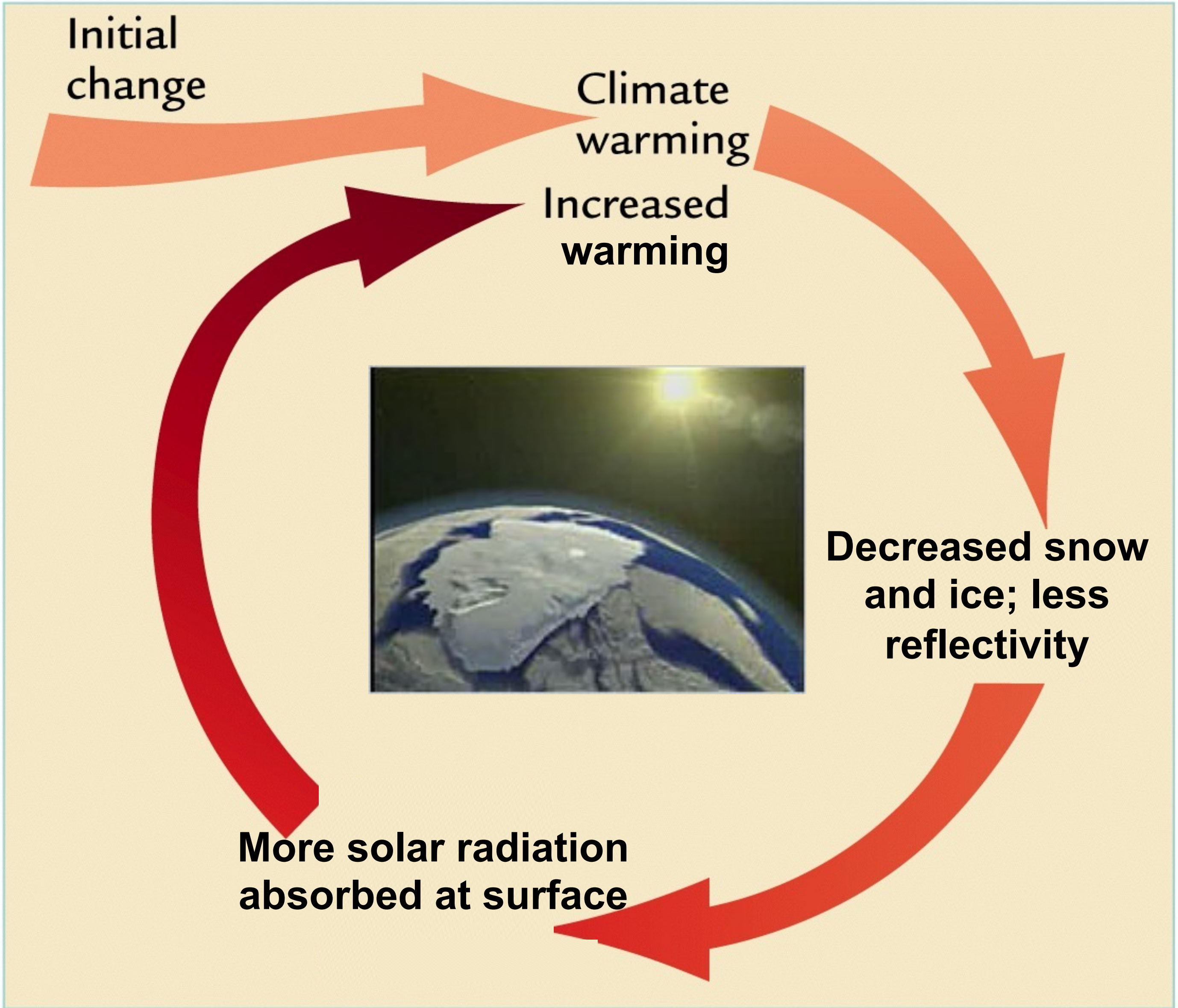


IPCC, AR4, WGI, Fig. 1.2

Water Vapor Feedback

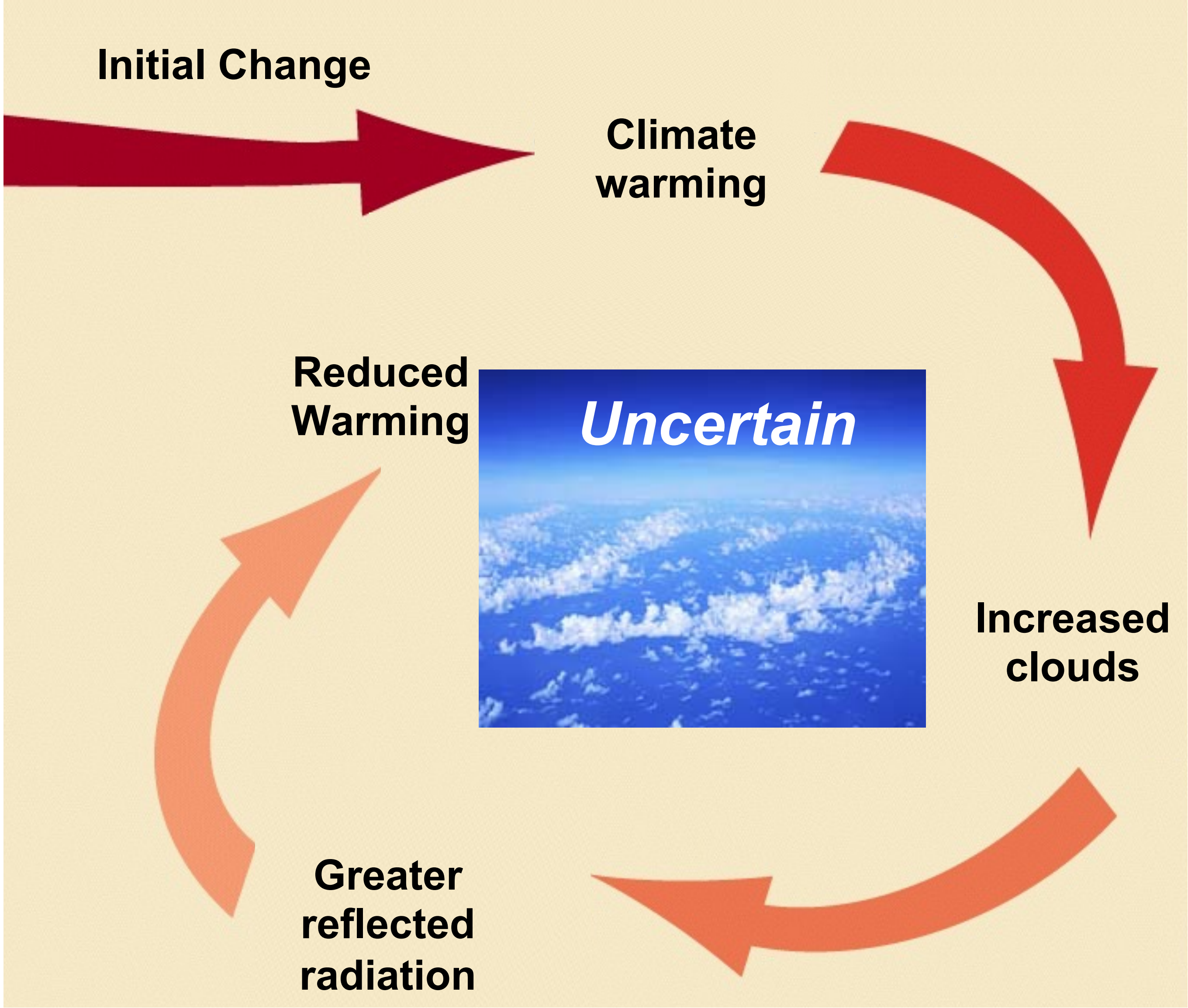


Ice-Albedo Feedback

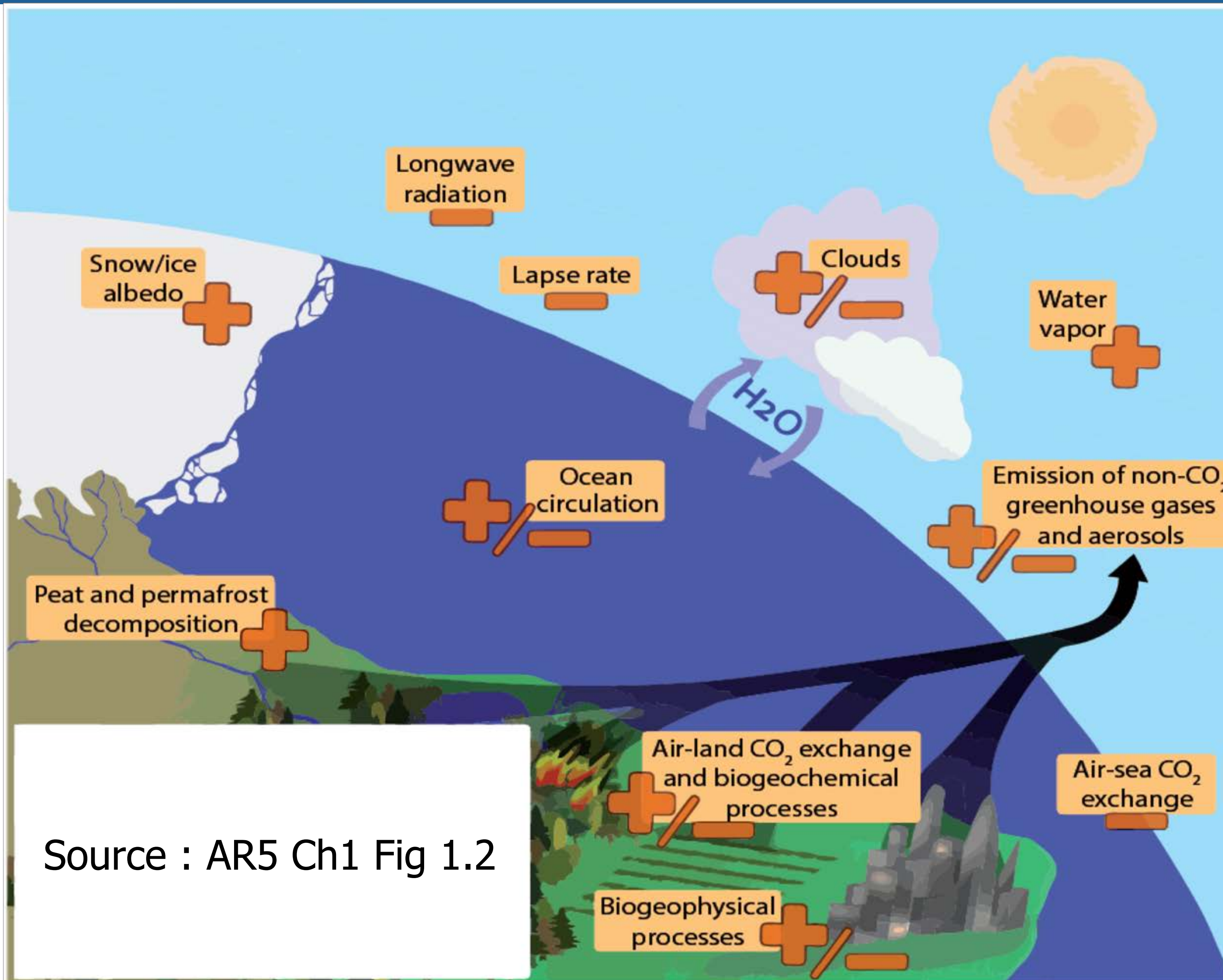


Note : il y a d’autres rétroactions, dont l’échange d’énergie air/océan facilité si pas de glace

Cloud Radiative Feedbacks

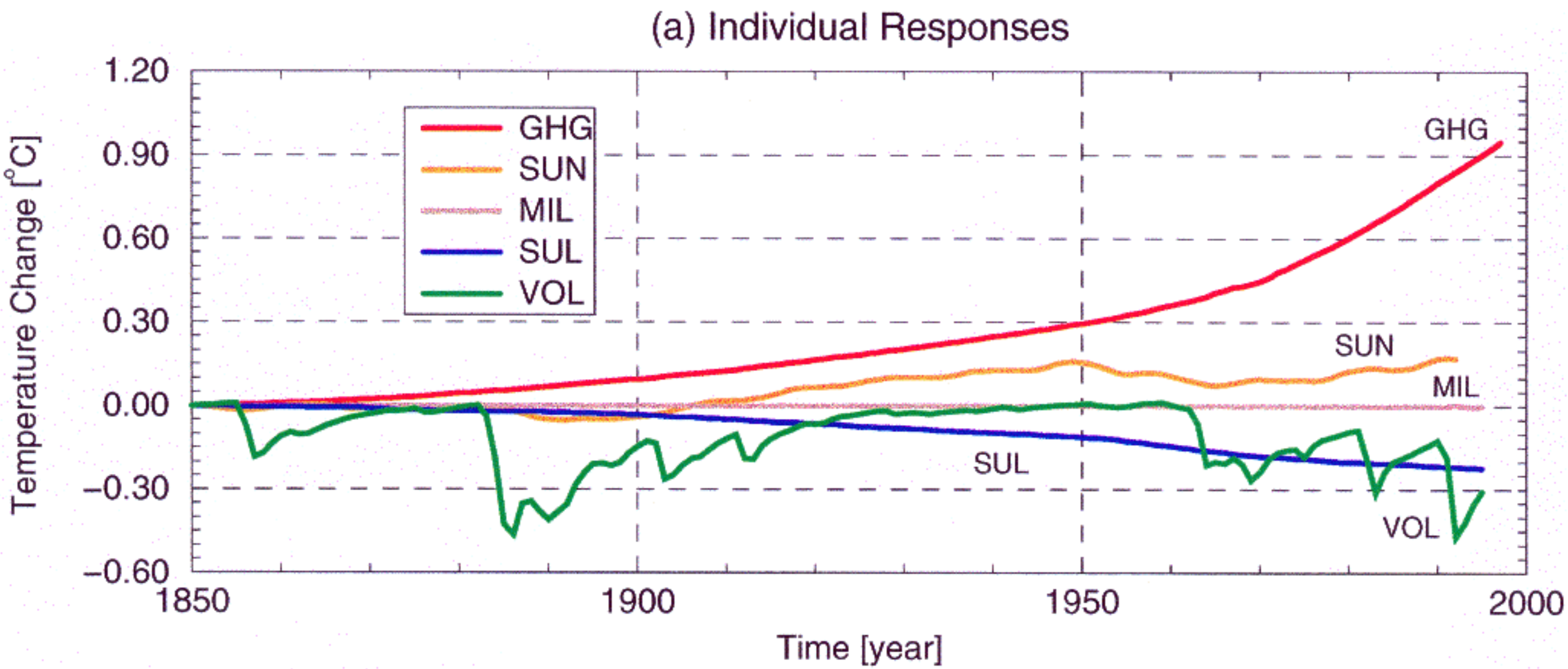


Synthèse rétroactions / GIEC AR5



Source : AR5 Ch1 Fig 1.2

Effet des différents facteurs sur le modèle 2D de LLN



Bertrand et al. 2001

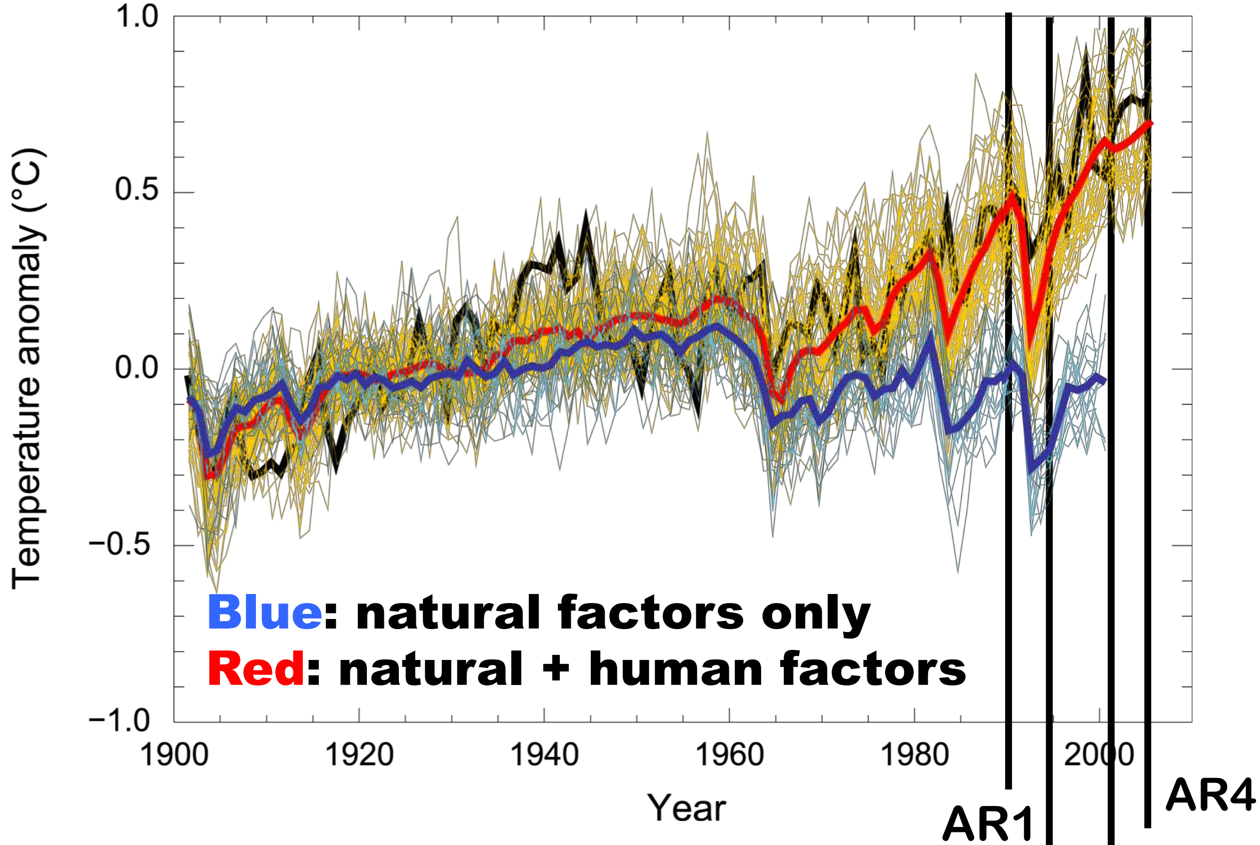
A Progression of Understanding: Greater and Greater Certainty in Attribution

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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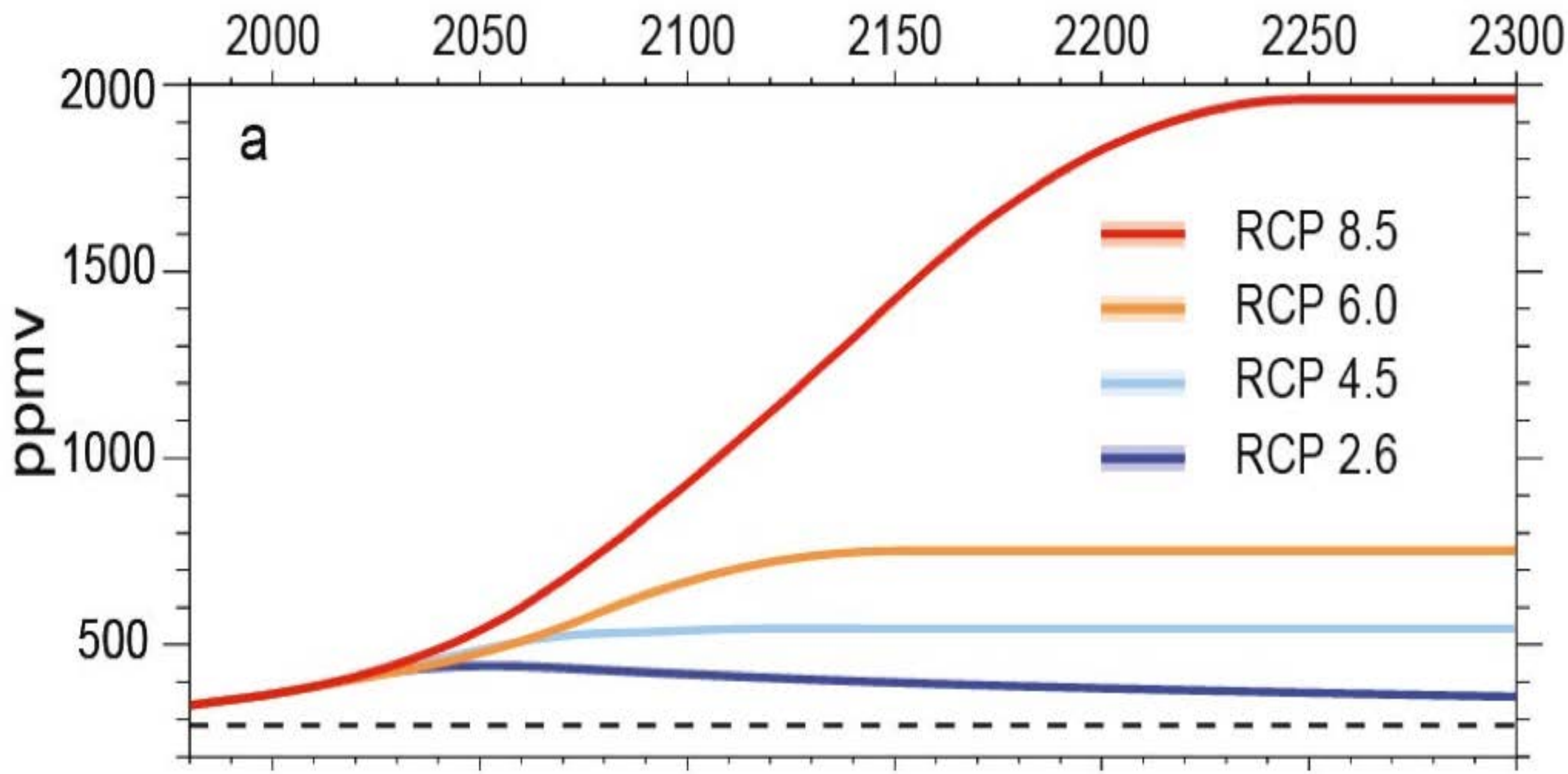
AR5 RCP: Atmospheric CO_2 concentration

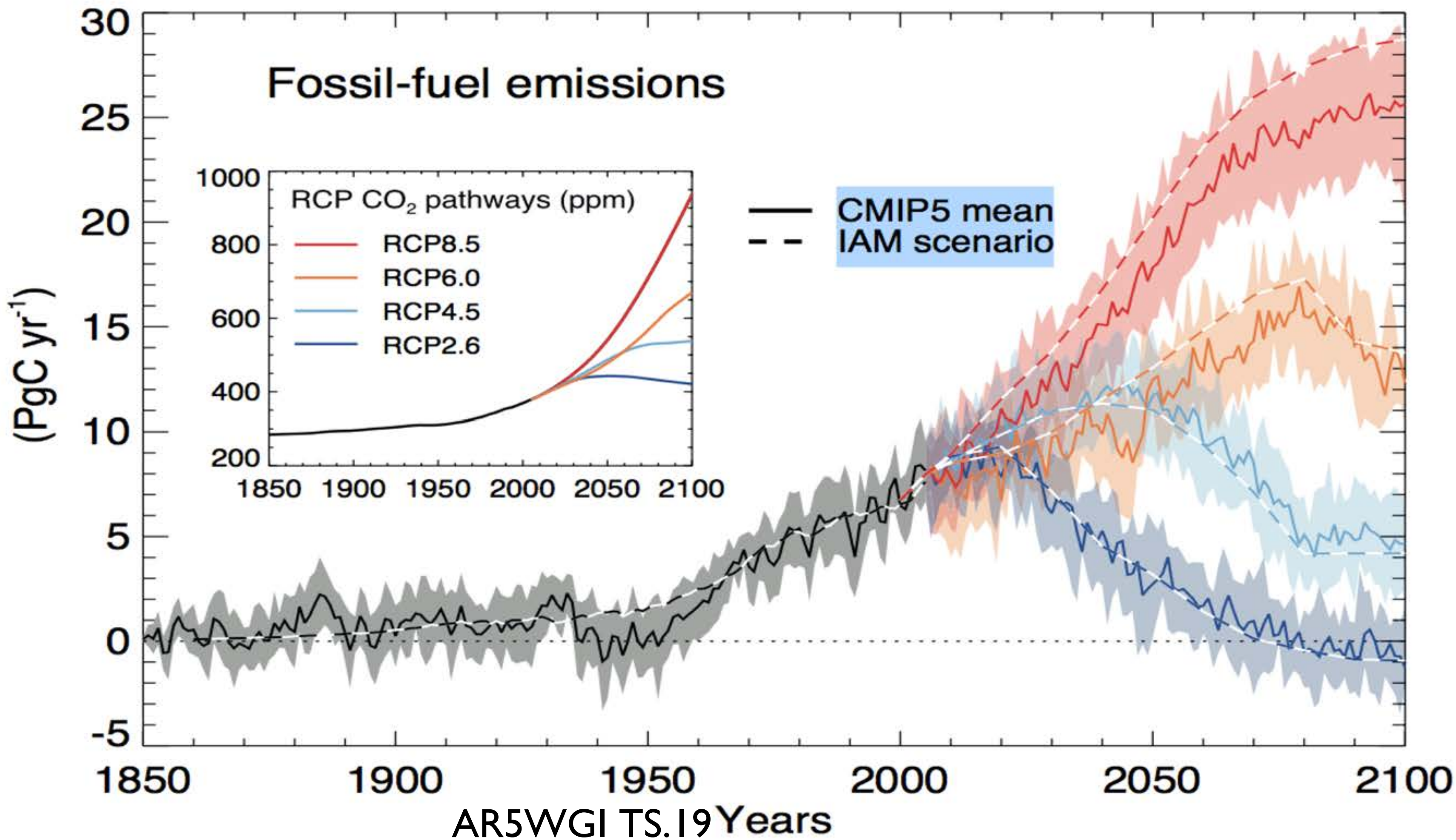


Most CMIP5 runs are based on the concentrations, but emissions-driven runs are available for RCP 8.5

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

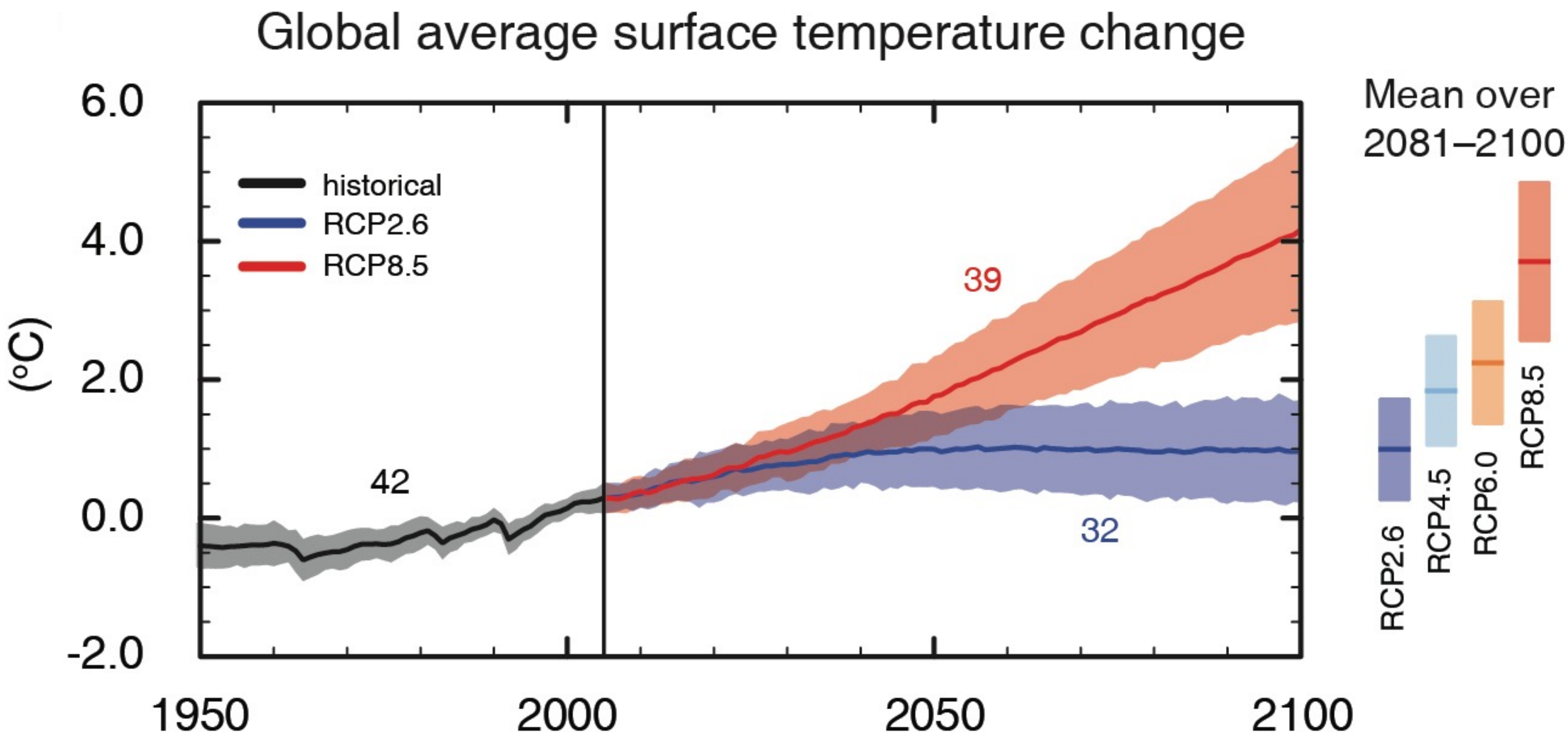
Compatible fossil fuel emissions simulated by the CMIP5 models for the four RCP scenarios (détail)

Les traits pleins donnent les émissions qu'il faudrait mettre dans les modèles climatiques complexes pour obtenir la concentration de chaque RCP, en comparaison des émissions associées à chaque RCP par les modèles simples



AR5WGI TS.19

Réchauffement moyen – scén. RCP, 21s



(IPCC 2013, Fig. SPM.7a)

Global mean surface temperature change projections

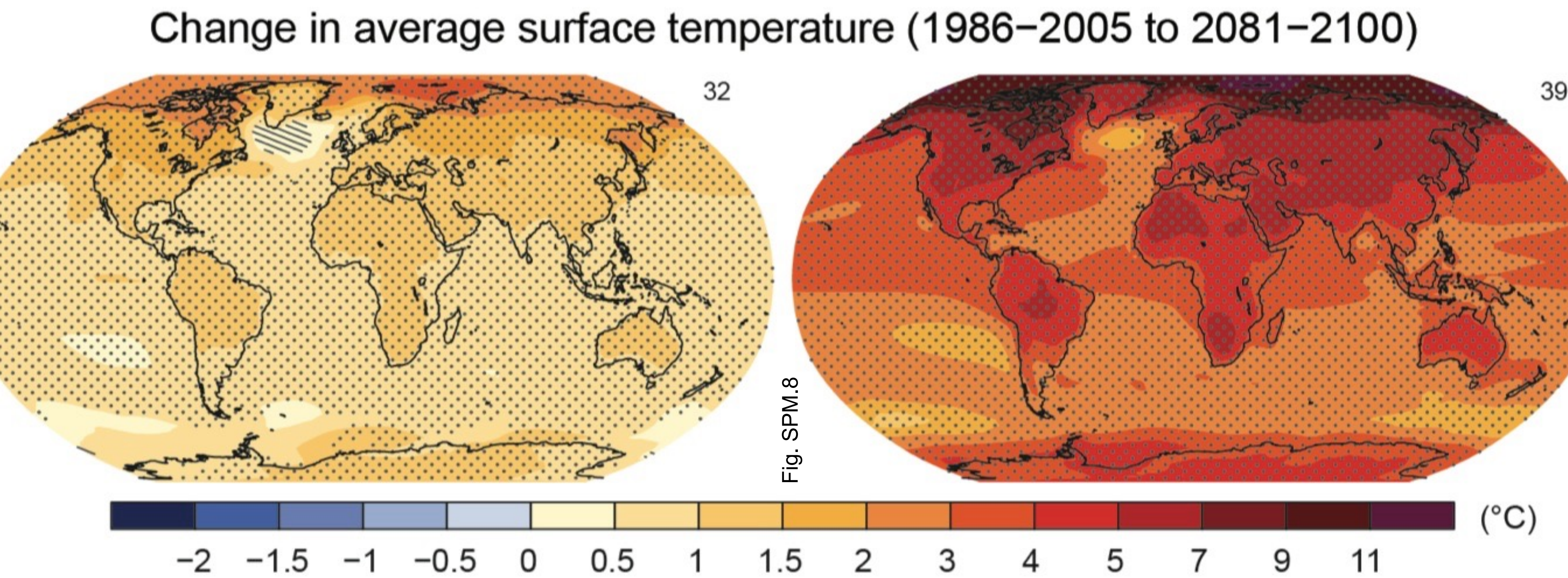
Increase over 21st century, from 1986-2005 to 2081-2100

	mean	likely range
RCP2.6	1.0 (°C)	0.3 to 1.7 (°C)
RCP4.5	1.8	1.1 to 2.6
RCP6	2.2	1.4 to 3.1
RCP8.5	3.7	2.6 to 4.8

For 1850-1900 reference : add +0.61 [0.55 to 0.67] °C

Source : AR5 WGI SPM. Note : résultats de modèles très proches AR4

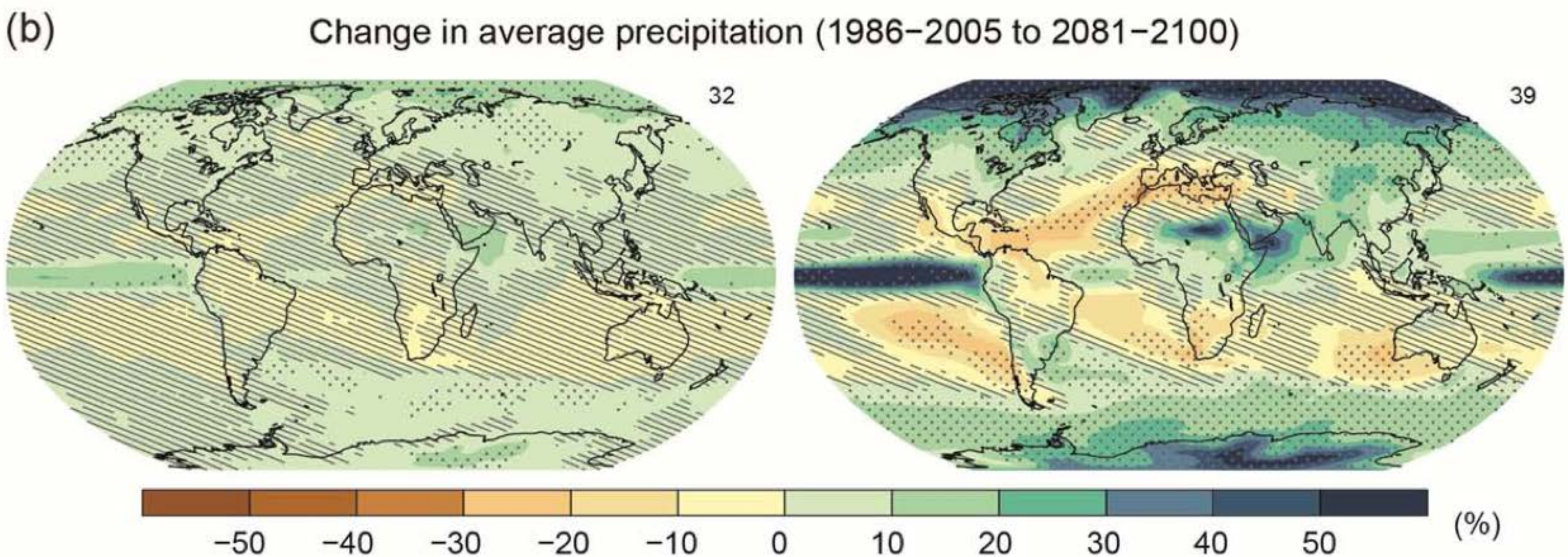
RCP2.6 **RCP8.5**



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

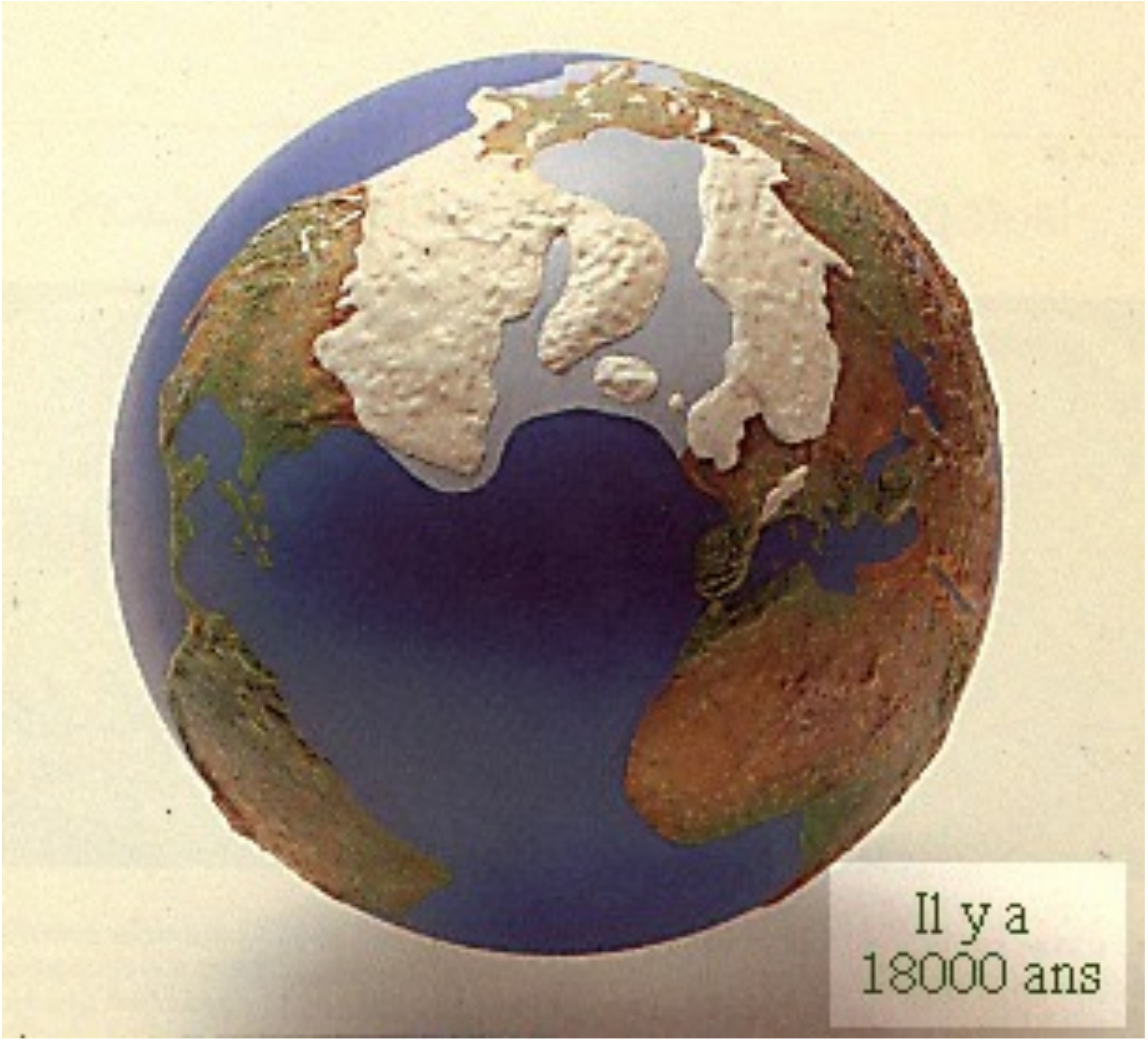
Projected Change in Precipitation



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

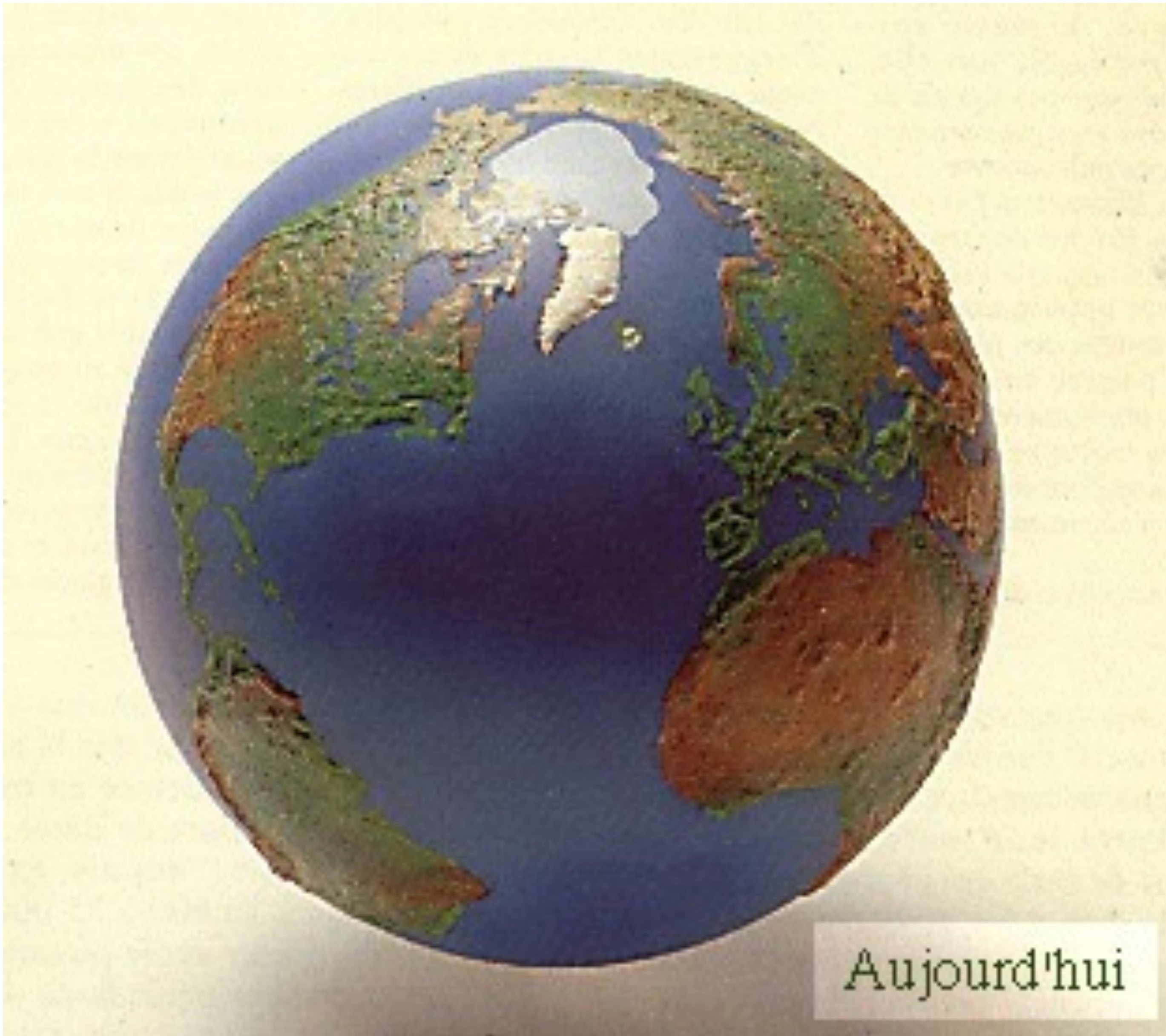
18-20000 years ago (Last Glacial Maximum)

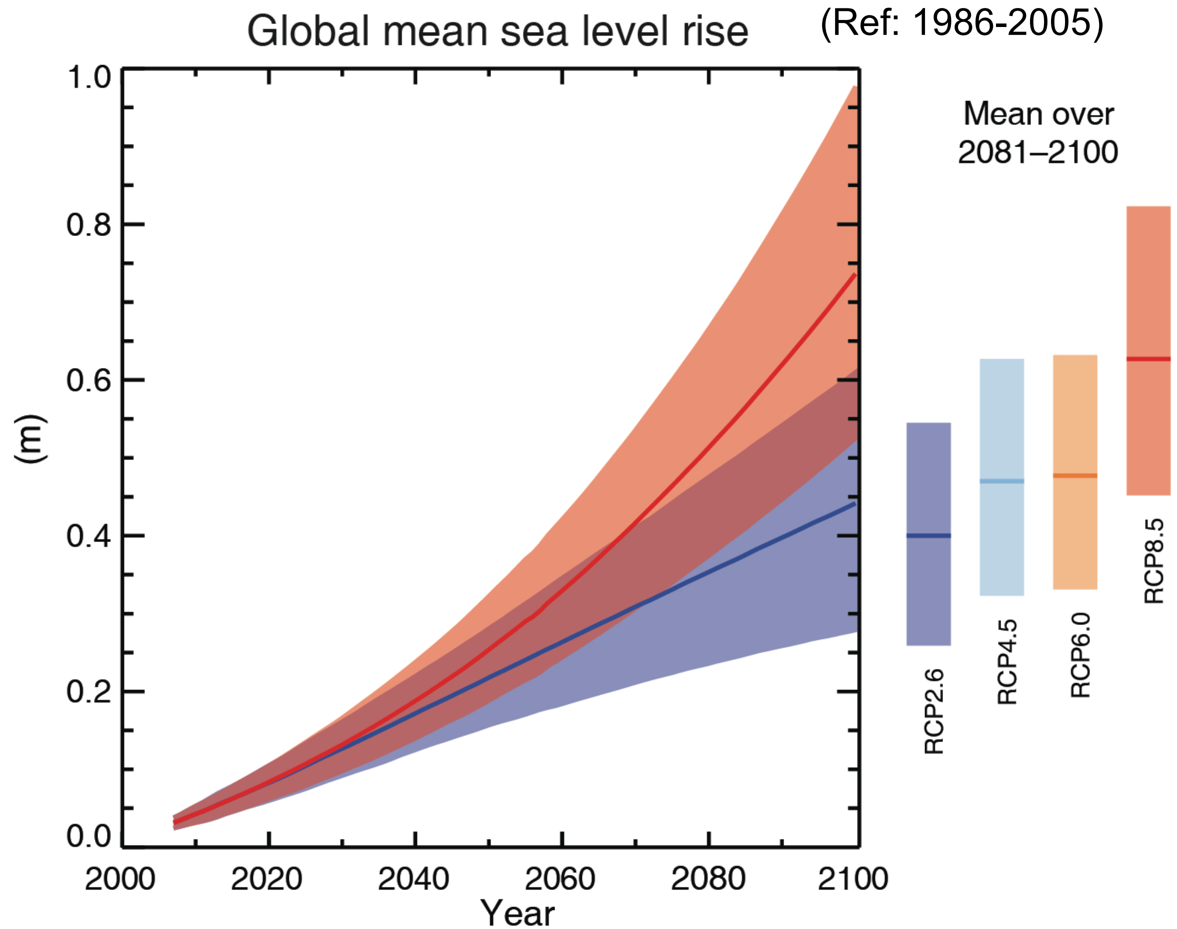
With permission from Dr. S. Joussaume, in « Climat d'hier à demain », CNRS éditions.



Today, with +4-5°C globally

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





(IPCC 2013, Fig. SPM.9)

Sea level due to continue to increase

Plan

IPCC

Basic climate physics

Modelling

Scenarios and projections

Impacts

Youth concerns and school strikes

Risque = Aléa x Vulnerabilité x Exposition (Victimes des inondations après Katrina)

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

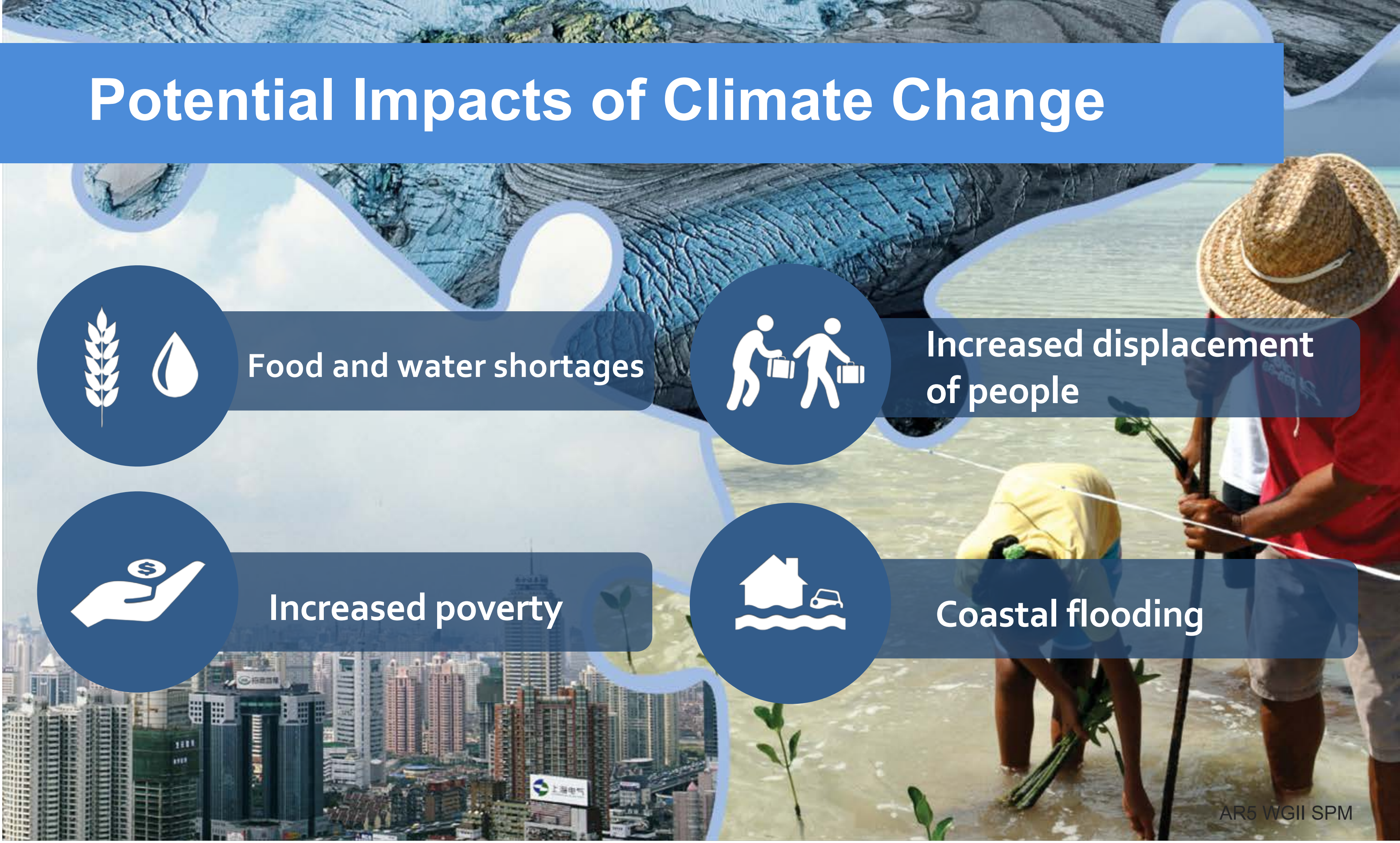
With 1 metre sea-level rise: 63000 ha below sea-level in Belgium (likely in 22nd century, not impossible in 21st century)

(NB: flooded area depends on protection)

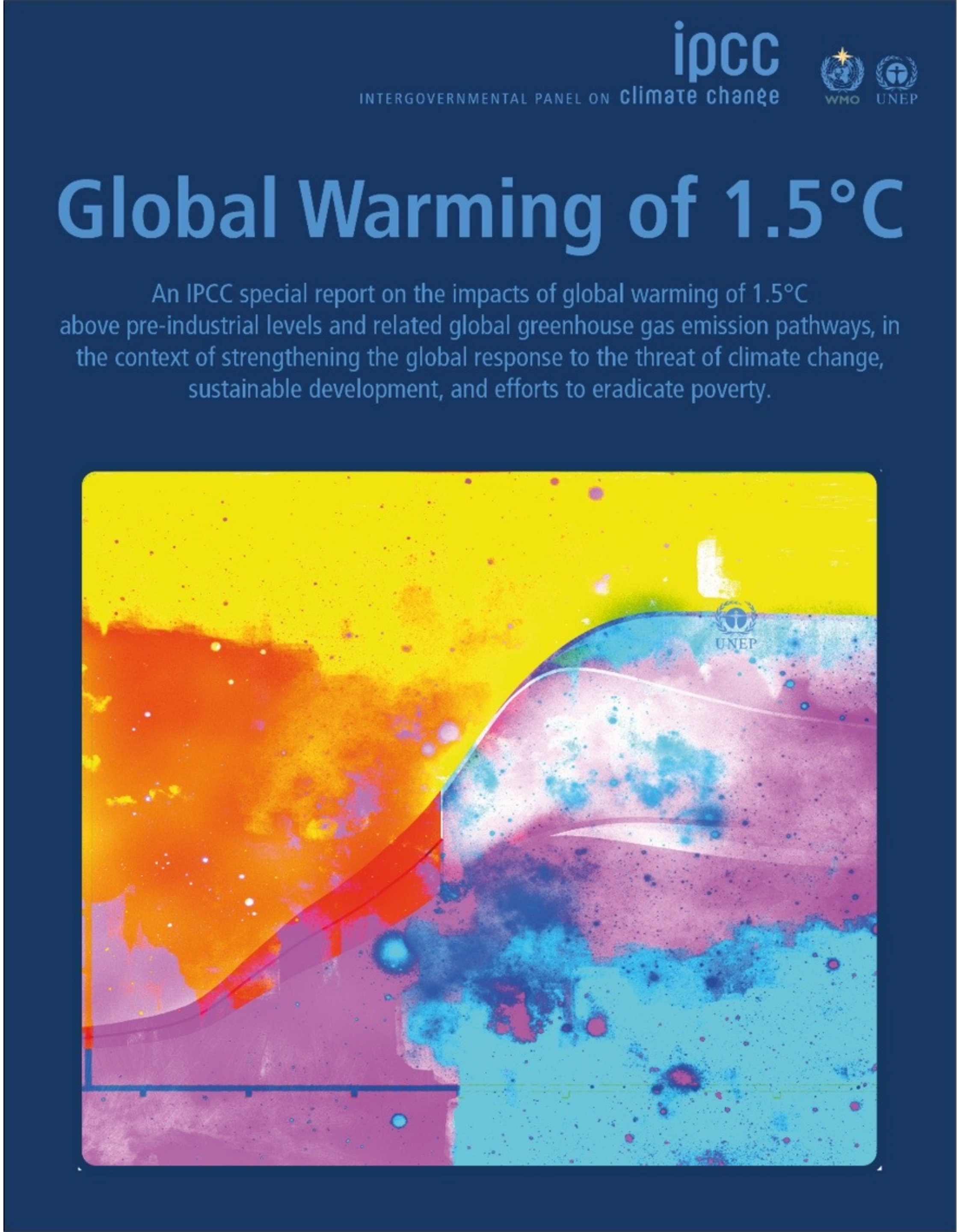
Source: N. Dendoncker (Dépt de Géographie, UCL), J.P. van Ypersele et P. Marbaix (Dépt de Physique, UCL) (www.climate.be/impact)

With 8 metre sea-level rise: 3700 km² below sea-level in Belgium (very possible in year 3000)
(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)


Potential Impacts of Climate Change
Food and water shortages
Increased displacement of people
Increased poverty
Coastal flooding
AR5 WGII SPM

The SR15

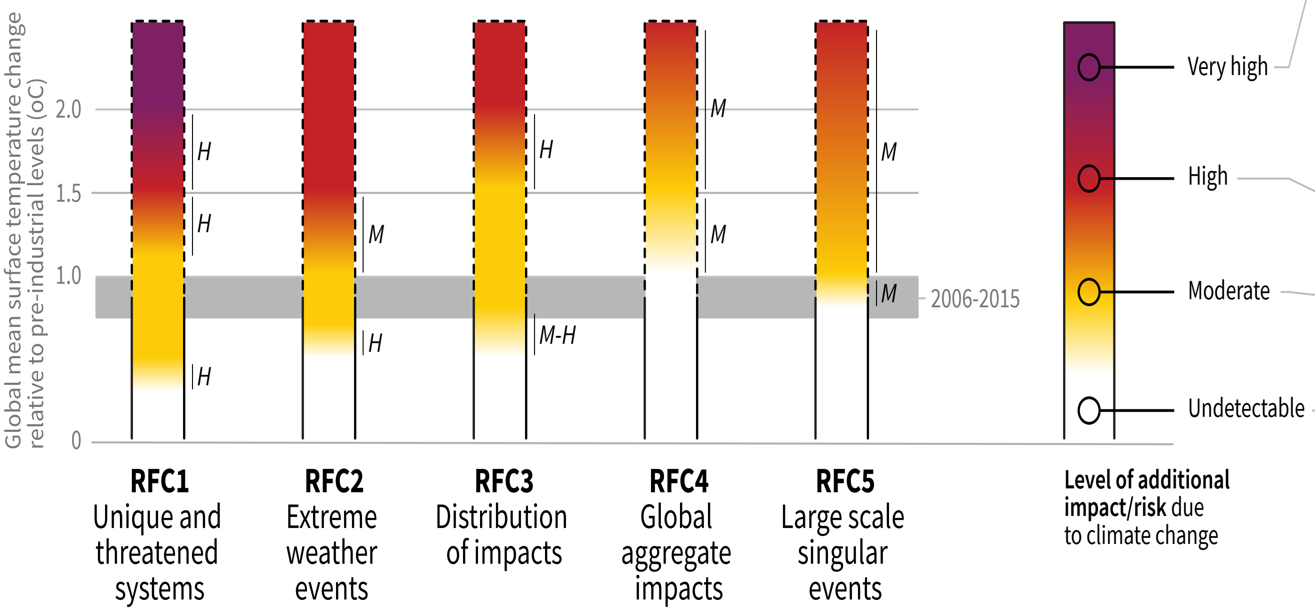

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO
UNEP
Global Warming of 1.5°C
An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate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

Responsibility for content: WRI

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.

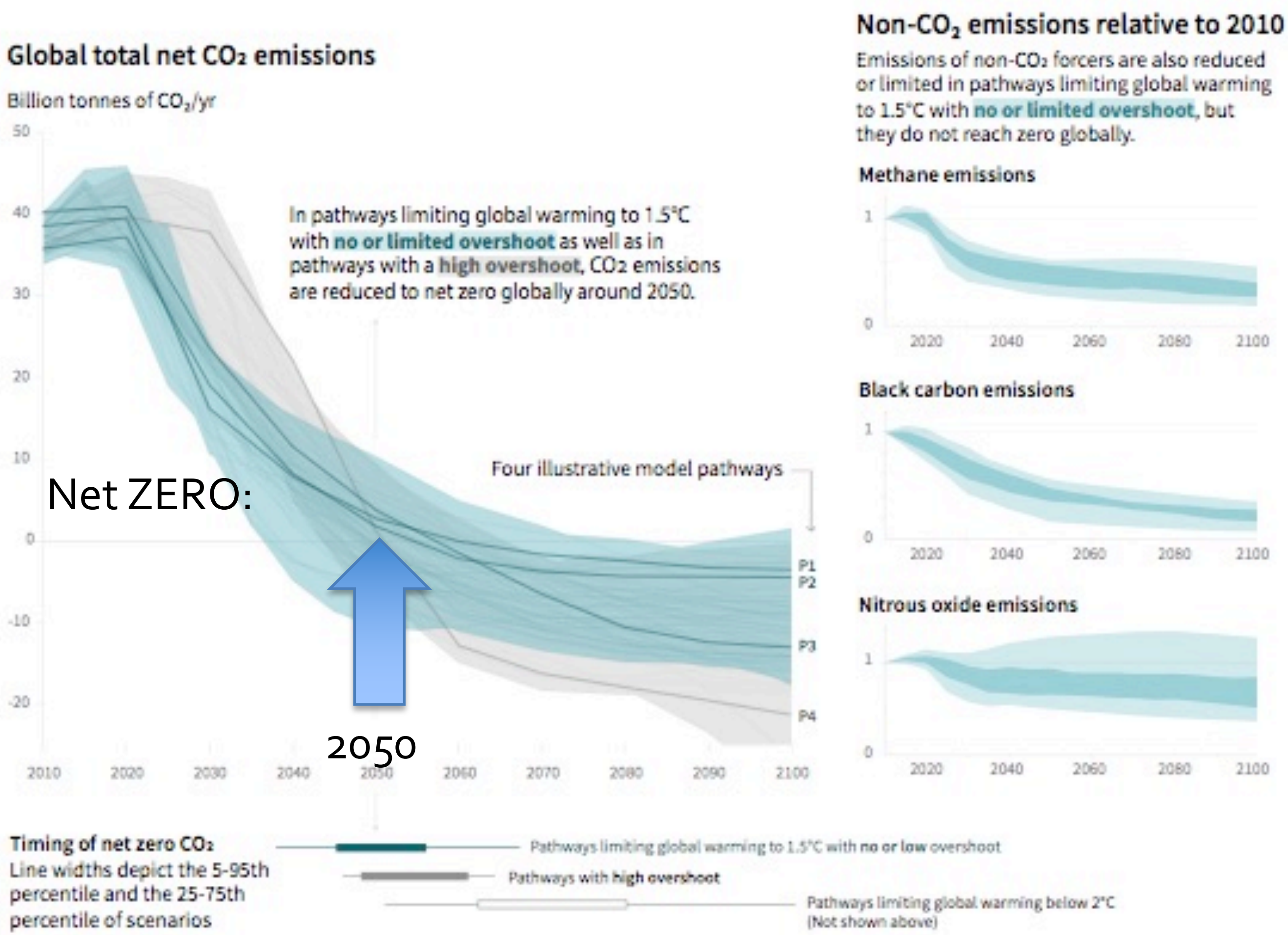
Red indicates severe and widespread impacts/risks.

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.

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

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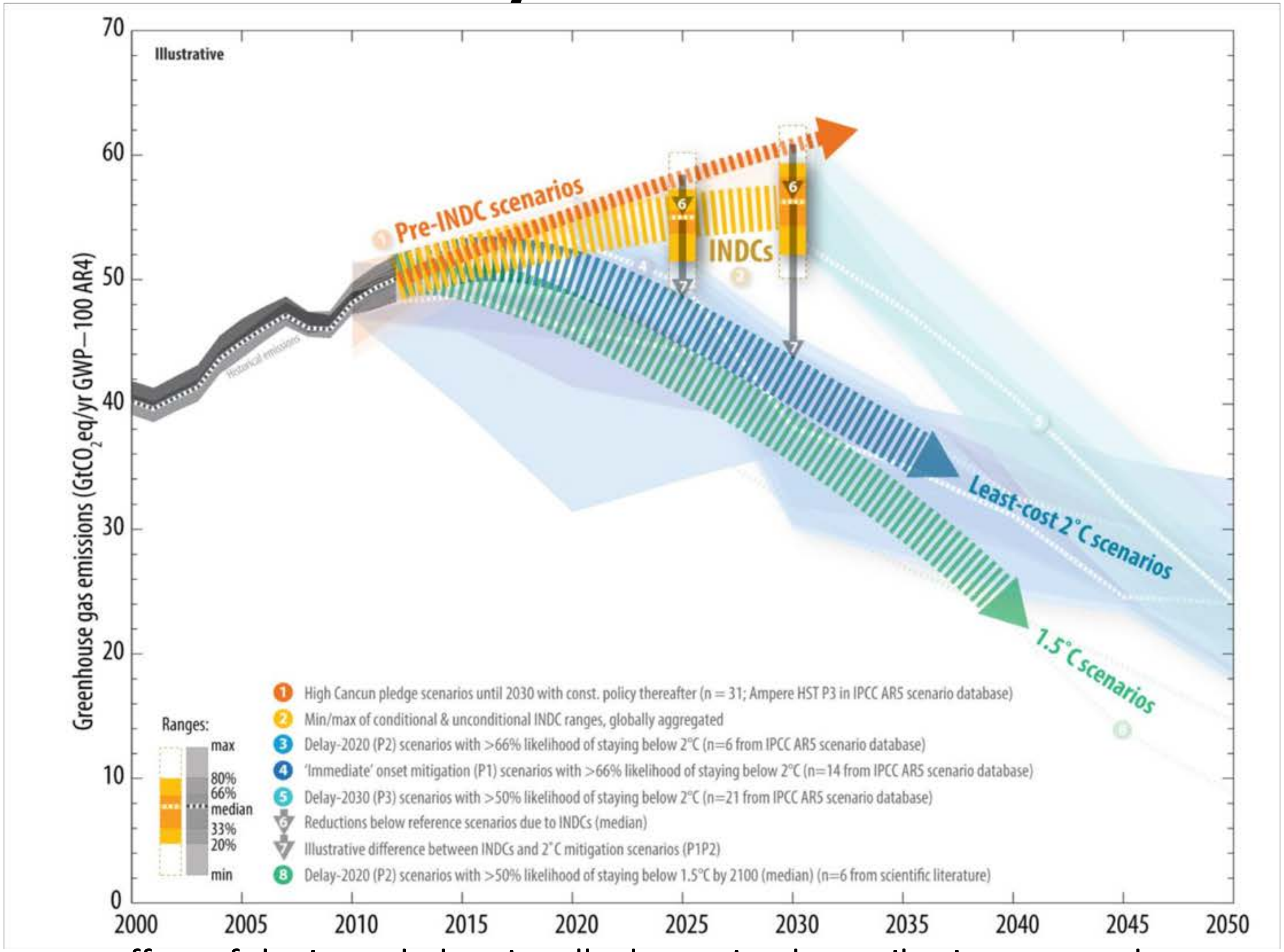
Comparison of global emission levels in 2025 and 2030 resulting from the implementation of the intended nationally determined contributions



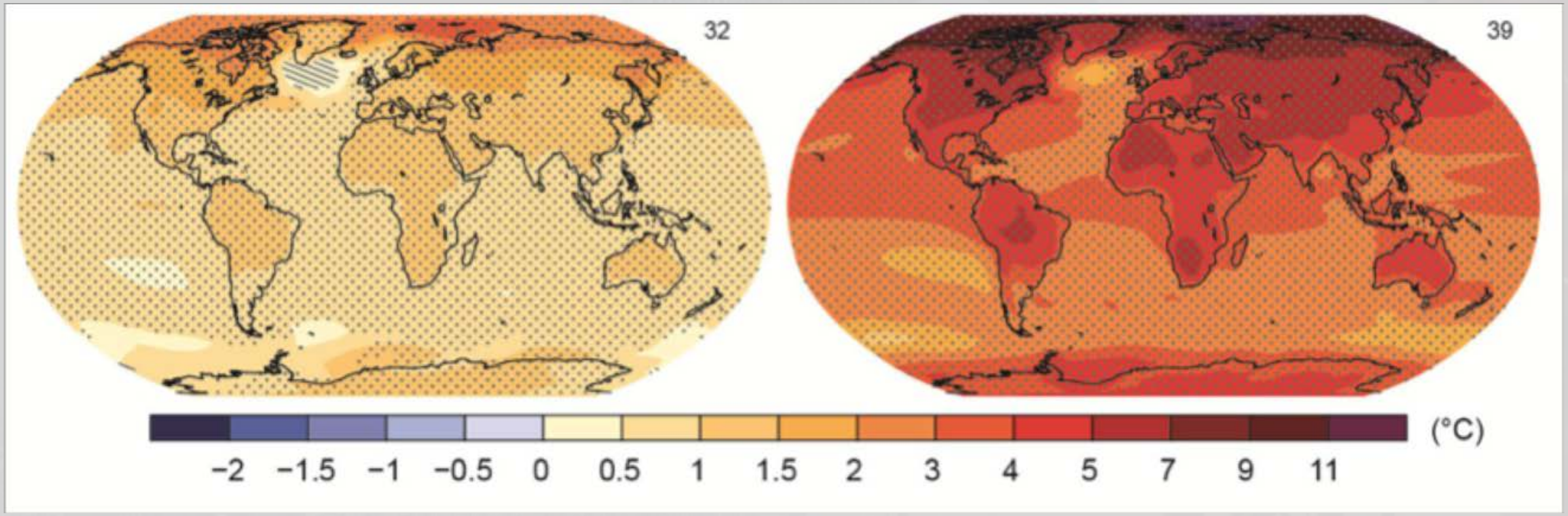
UNFCCC, Aggregate effect of the intended nationally determined contributions: an update
http://unfccc.int/resource/docs/2016/cop22/eng/02.pdf

I want you to panic… **and act**

Humanity still has the choice

With substantial mitigation

Without additional mitigation



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

AR5 WGI SPM

Om meer te weten:

Bij EPO (2018)

Voorwoord:
Jill Peeters

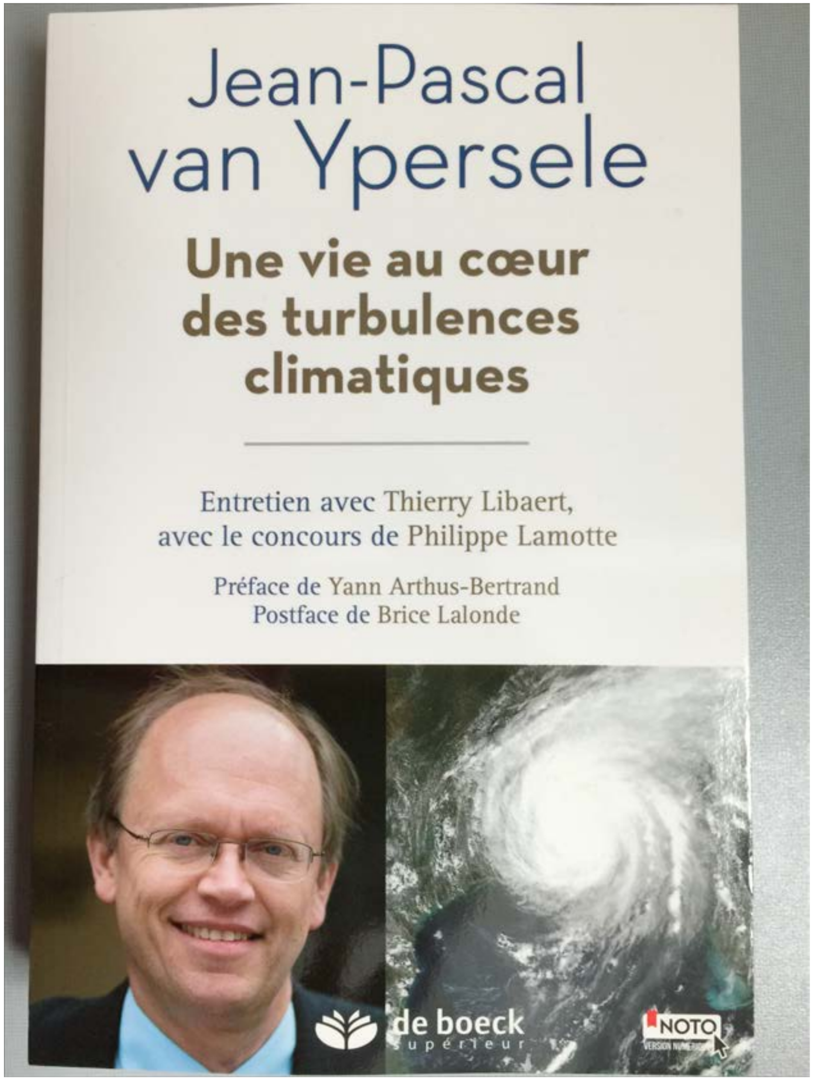
Pour en savoir plus:

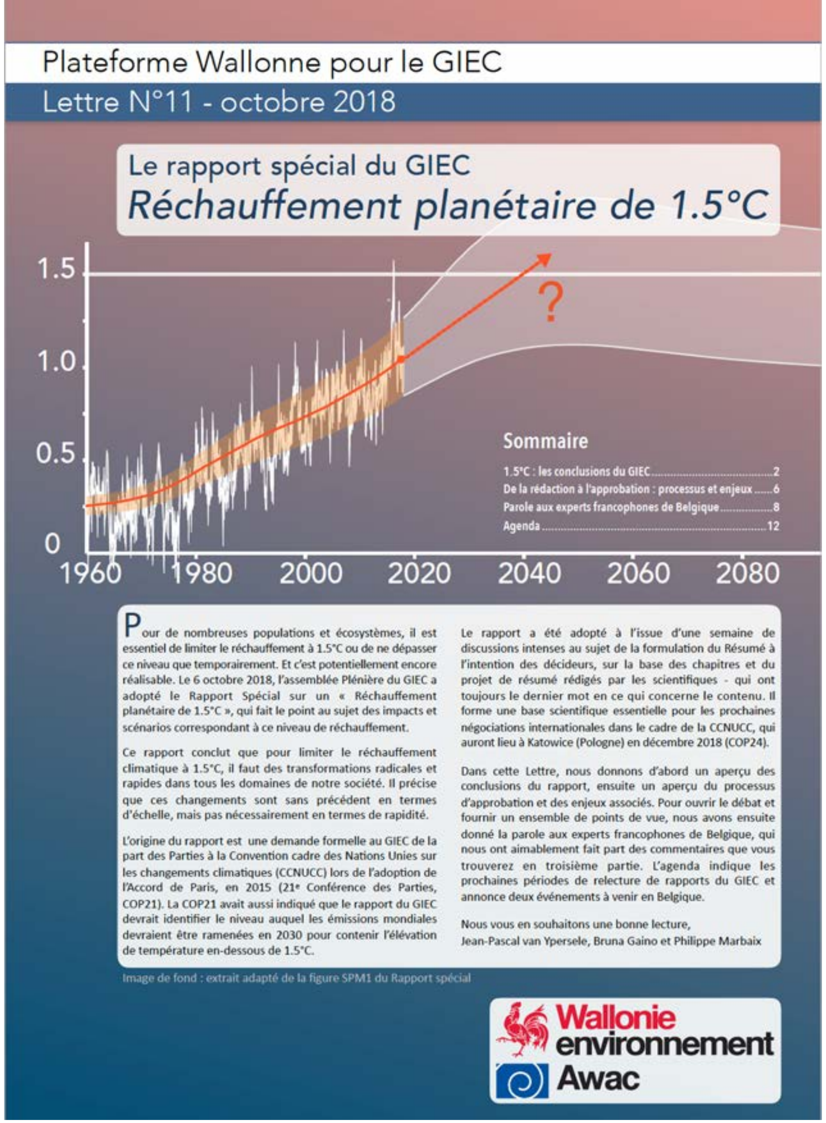
Lisez mon livre, où j'aborde tous ces sujets

Publié chez De Boeck supérieur

Préface:Yann Arthus-Bertrand

Postface: Brice Lalonde





Plateforme Wallonne pour le GIEC

Lettre N°11 - octobre 2018

Le rapport spécial du GIEC

Réchauffement planétaire de 1.5°C

Sommaire

Pour de nombreuses populations et écosystèmes, il est essentiel de limiter le réchauffement à 1.5°C ou de ne dépasser ce niveau que temporairement. Et c'est potentiellement encore réalisable. Le 6 octobre 2018, l'assemblée Plénière du GIEC a adopté le Rapport Spécial sur un « Réchauffement planétaire de 1.5°C », qui fait le point au sujet des impacts et scénarios correspondant à ce niveau de réchauffement.

Ce rapport conclut que pour limiter le réchauffement climatique à 1.5°C, il faut des transformations radicales et rapides dans tous les domaines de notre société. Il précise que ces changements sont sans précédent en termes d'échelle, mais pas nécessairement en termes de rapidité.

L'origine du rapport est une demande formelle au GIEC de la part des Parties à la Convention cadre des Nations Unies sur les changements climatiques (CCNUCC) lors de l'adoption de l'Accord de Paris, en 2015 (21e Conférence des Parties, COP21). La COP21 avait aussi indiqué que le rapport du GIEC devrait identifier le niveau auquel les émissions mondiales devraient être ramenées en 2030 pour contenir l'élévation de température en-dessous de 1.5°C.

Le rapport a été adopté à l'issue d'une semaine de discussions intenses au sujet de la formulation du Résumé à l'intention des décideurs, sur la base des chapitres et du projet de résumé rédigés par les scientifiques - qui ont toujours le dernier mot en ce qui concerne le contenu. Il forme une base scientifique essentielle pour les prochaines négociations internationales dans le cadre de la CCNUCC, qui auront lieu à Katowice (Pologne) en décembre 2018 (COP24).

Dans cette Lettre, nous donnons d'abord un aperçu des conclusions du rapport, ensuite un aperçu du processus d'approbation et des enjeux associés. Pour ouvrir le débat et fournir un ensemble de points de vue, nous avons ensuite donné la parole aux experts francophones de Belgique, qui nous ont aimablement fait part des commentaires que vous trouverez en troisième partie. L'agenda indique les prochaines périodes de relecture de rapports du GIEC et annonce deux événements à venir en Belgique.

Nous vous en souhaitons une bonne lecture,
Jean-Pascal van Ypersele, Bruna Gaino et Philippe Marbaix

Image de fond : extrait adapté de la figure SPM1 du Rapport spécial

Wallonie environnement Awac

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

Ecrit pour les jeunes (et moins jeunes), avec des liens vers des ressources utiles


Plateforme Wallonne pour le GIEC

Lettre N°13 - avril 2019

'Sauver le climat' : les bases

Suite à l'intense mobilisation des jeunes, les changements climatiques ont fait l'objet de beaucoup d'attention au cours des derniers mois. Elèves du secondaire, étudiants, professeurs, parents et grand-parents sont descendus dans la rue pour montrer leur désarroi face à la lenteur de l'action vis-à-vis des changements climatiques.

Nous nous réjouissons de cette mobilisation, car notre rôle nous met encore plus fréquemment que l'ensemble de la population en position de témoin des risques que font courir les changements climatiques, ainsi que de l'ampleur des efforts nécessaires pour mettre en œuvre les objectifs que se sont fixés les membres des Nations Unies à Paris en 2015 (COP21).

Une démarche essentielle en faveur de ces jeunes est de les aider à se former, à appréhender les principaux éléments de la problématique du climat, et plus largement, de l'influence de nos activités sur notre environnement et sur le futur de l'humanité. L'éducation est un des instruments essentiels pour évoluer vers une société plus durable et plus juste.

Pour y contribuer, nous présentons ici une brève synthèse de la problématique et une sélection de références commentées. Nous espérons que cette Lettre aidera enseignants et élèves à disposer d'une base d'information solide et ainsi à prendre leur part dans la solution à ce problème planétaire : agir à leur niveau et favoriser l'action dans leur entourage et au niveau sociétal.

Plusieurs témoignages d'élèves ou de professeurs sont également présentés.

Nous vous souhaitons une bonne lecture !

Jean-Pascal van Ypersele, Philippe Marbaix et Bruna Gaino

Sommaire

Wallonie environnement

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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**

New:

- www.wechangeforlife.org :

250 Belgian experts speak

- **www.panelclimat.be www.klimaatpanel.be :**

Report asked by #YouthForClimate

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