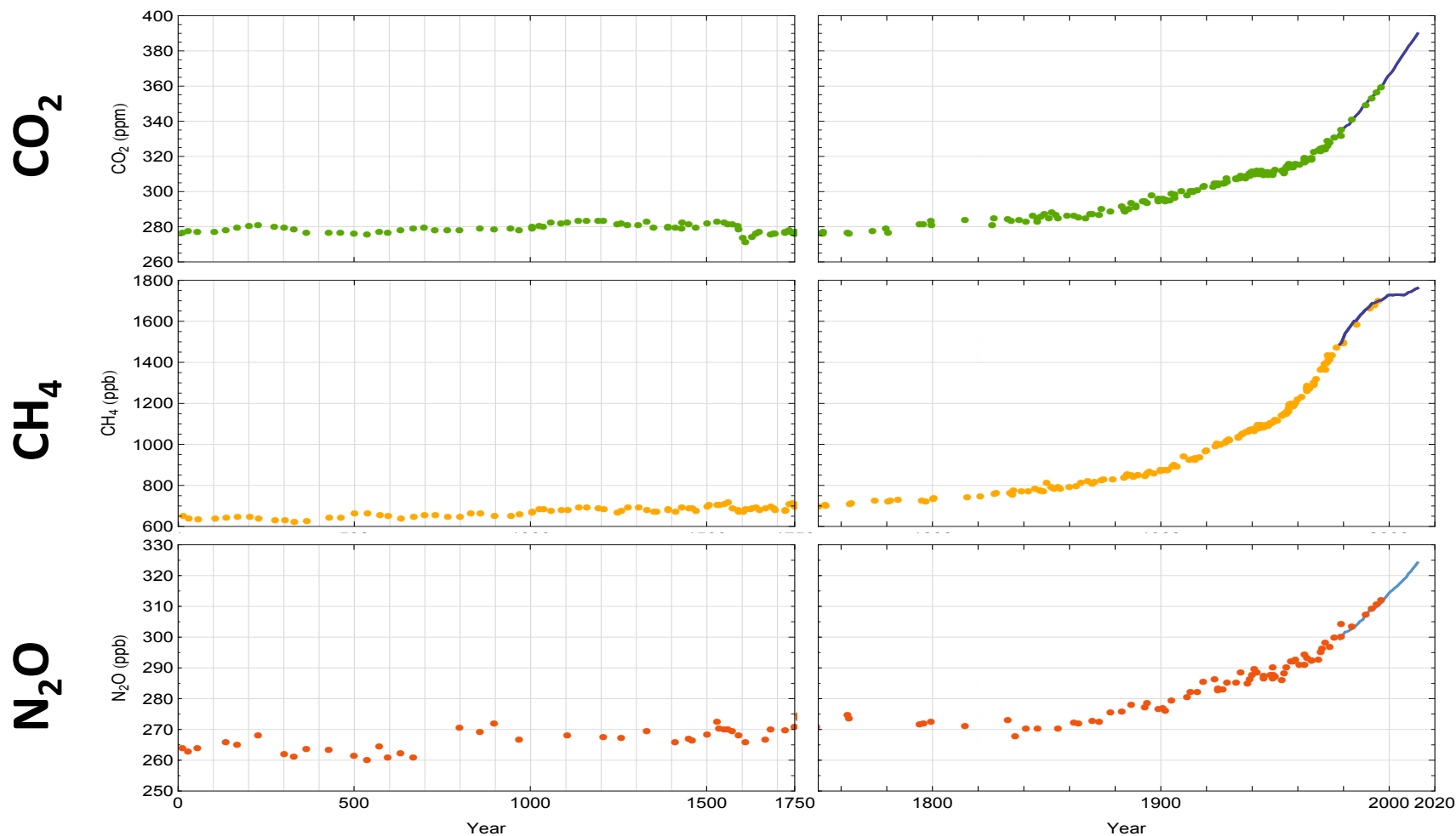


Observation et tendance des émissions et des flux naturels de CO₂

Philippe Ciais

Laboratoire des sciences du Climat et de l'Environnement

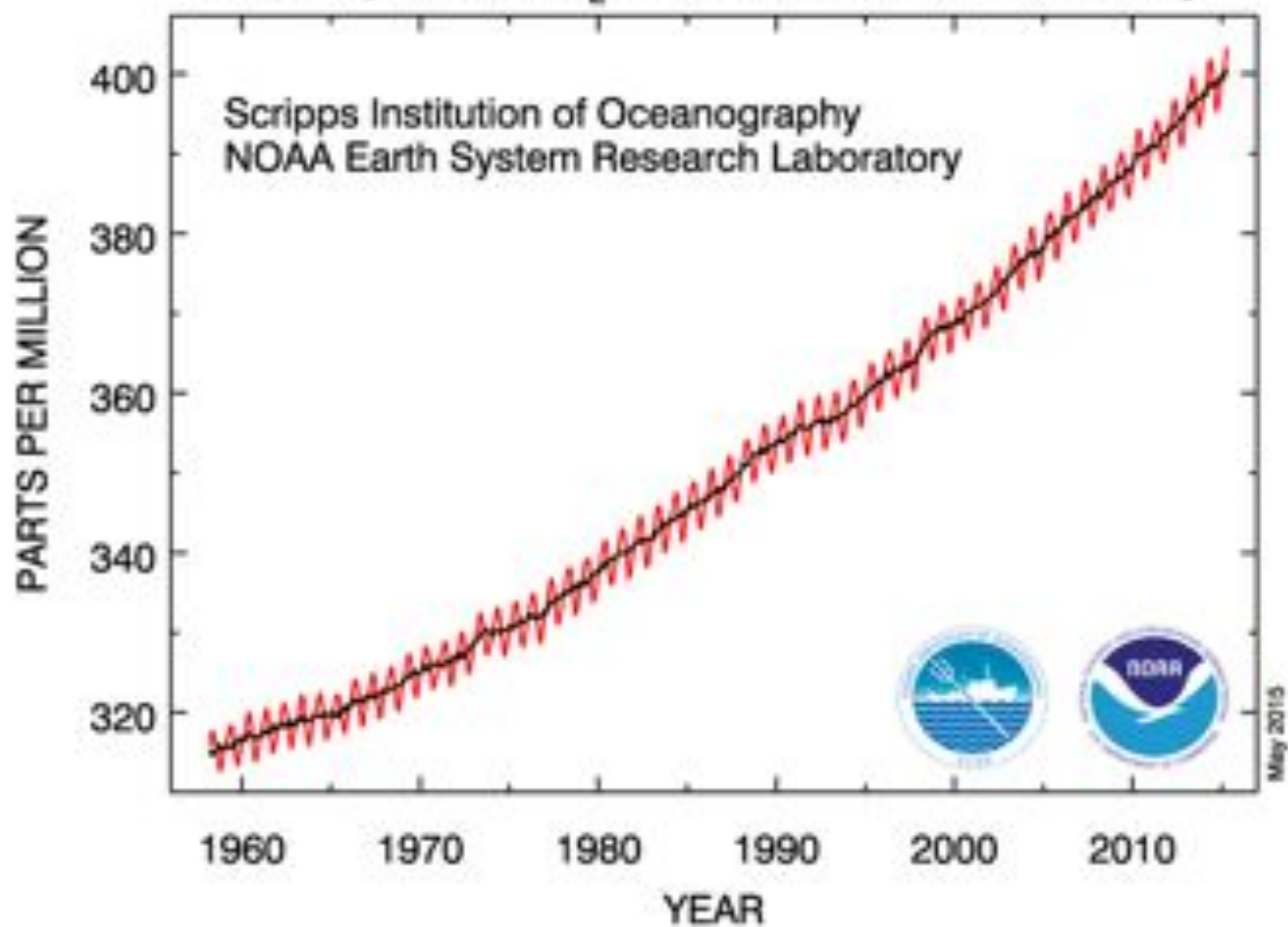
Augmentation des gaz à effet de serre



Points : Carottes de glace

Trait : Mesures atmosphériques

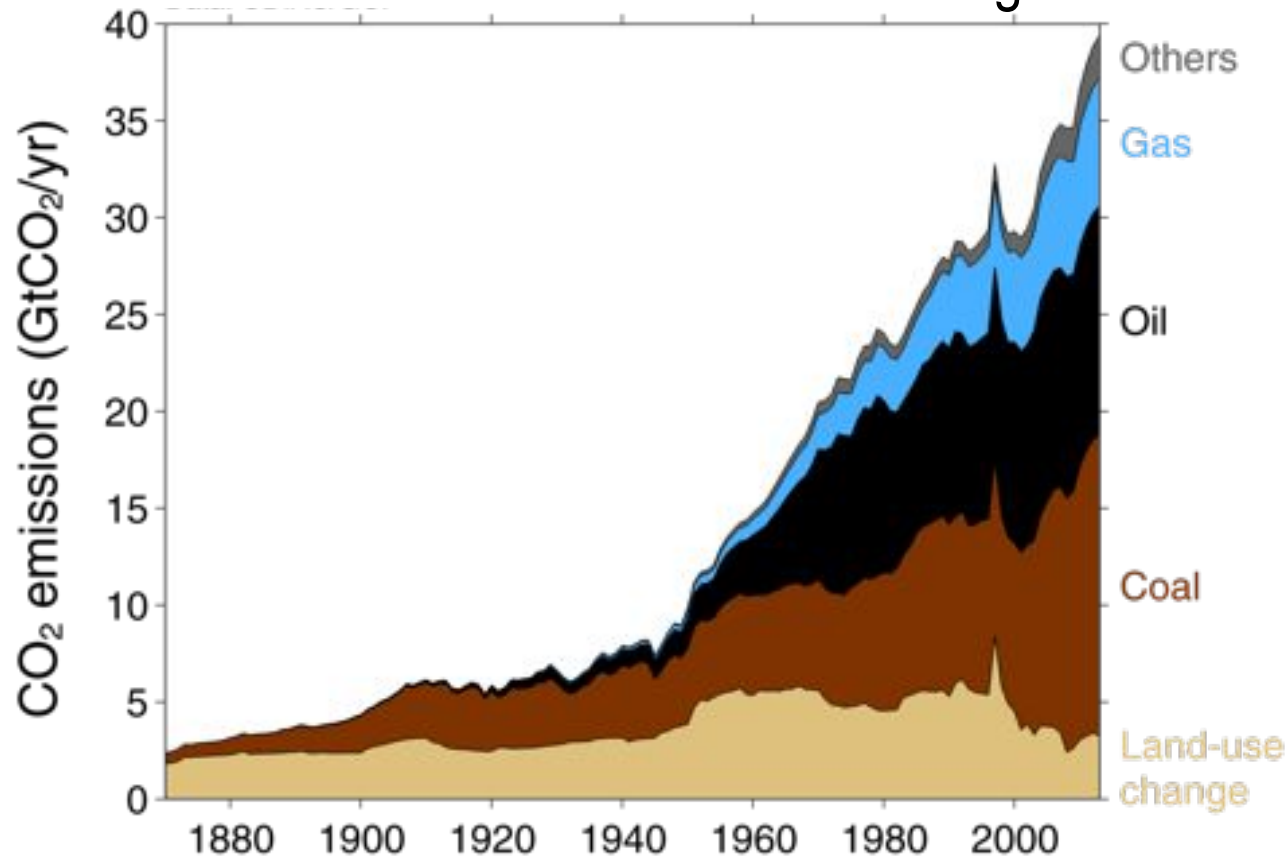
Atmospheric CO₂ at Mauna Loa Observatory



Les émissions de CO₂

La déforestation a été la source principale de CO₂ jusqu'en 1950

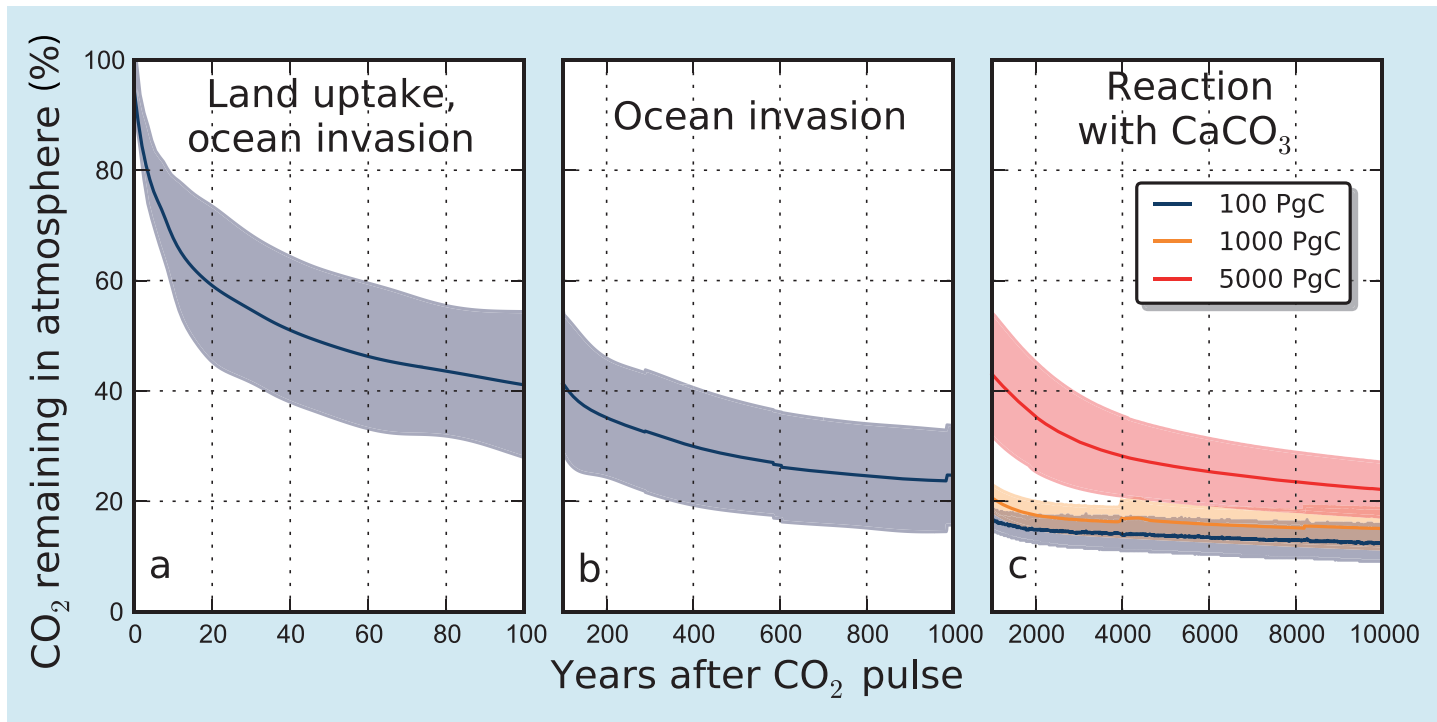
L'utilisation du charbon continue à augmenter



Others: Emissions from cement production and gas flaring

Source: [CDIAC](#); [Houghton et al 2012](#); [Giglio et al 2013](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

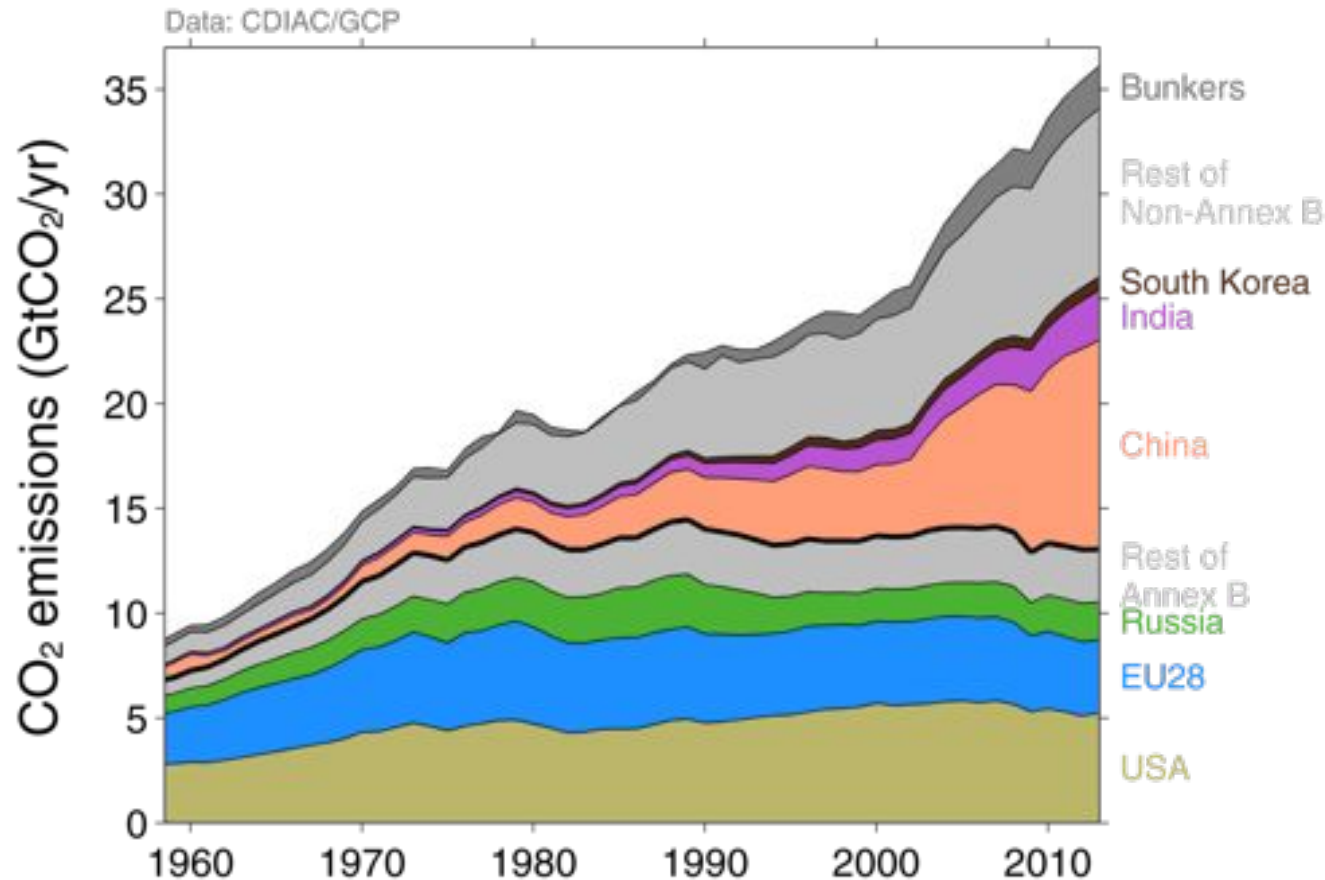
Le CO₂ un gaz à (très) longue durée de vie



Les émissions de différents pays

Pays de l'Annexe B - diminution depuis 1990

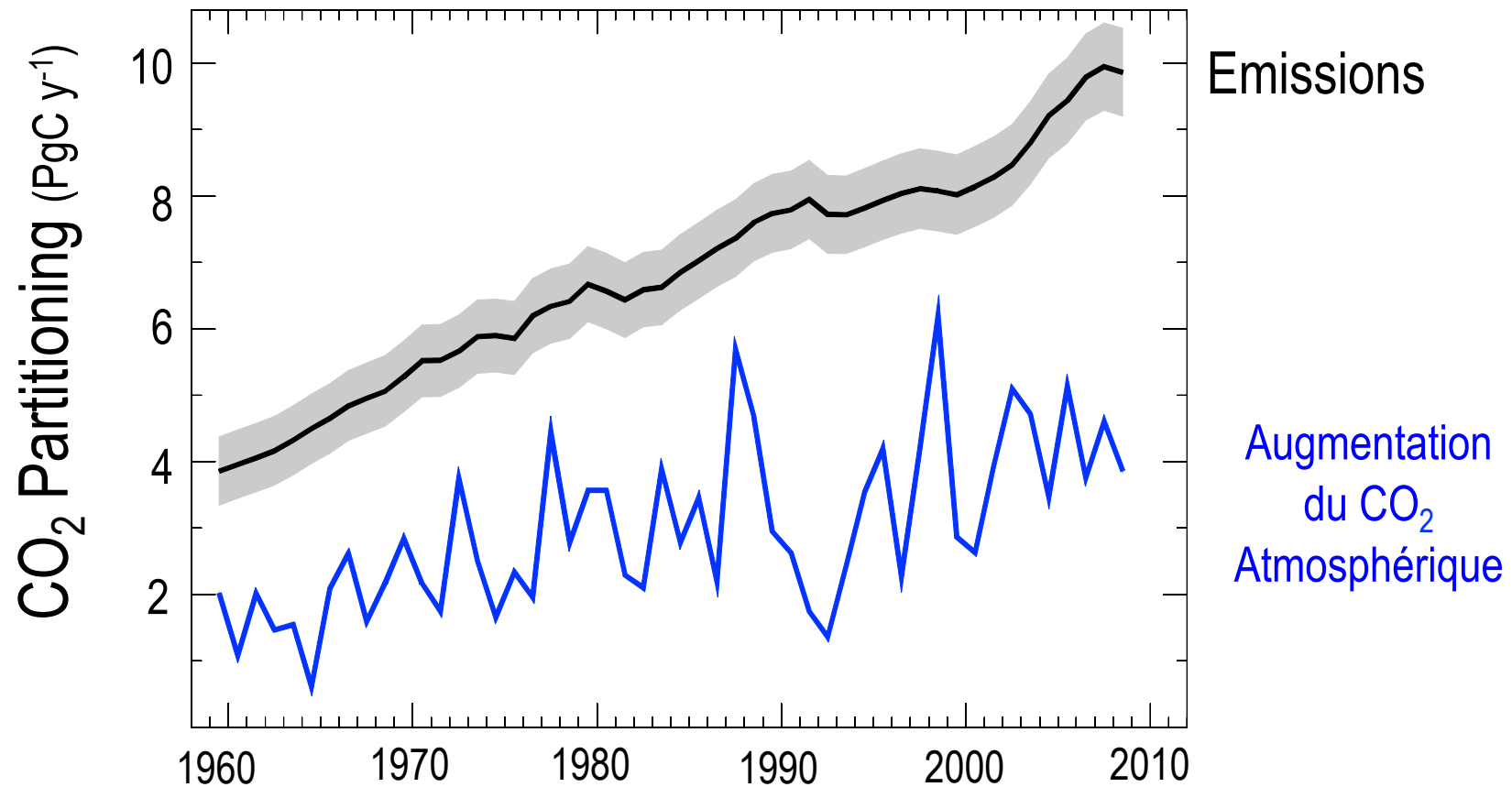
Non-Annex B countries (grand émergents) – forte augmentation depuis dix ans



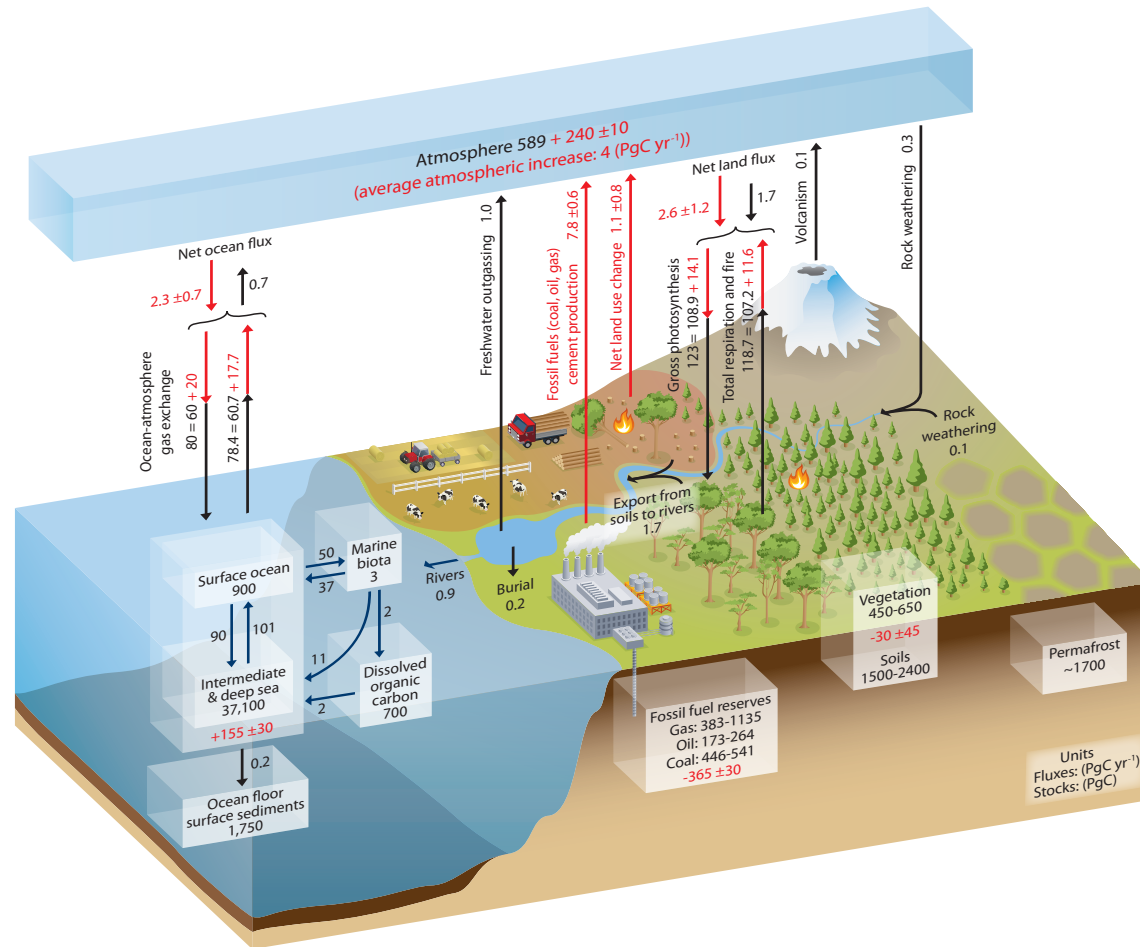
Annex B countries have emission commitments in the Kyoto Protocol (excluding Canada and USA)

Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

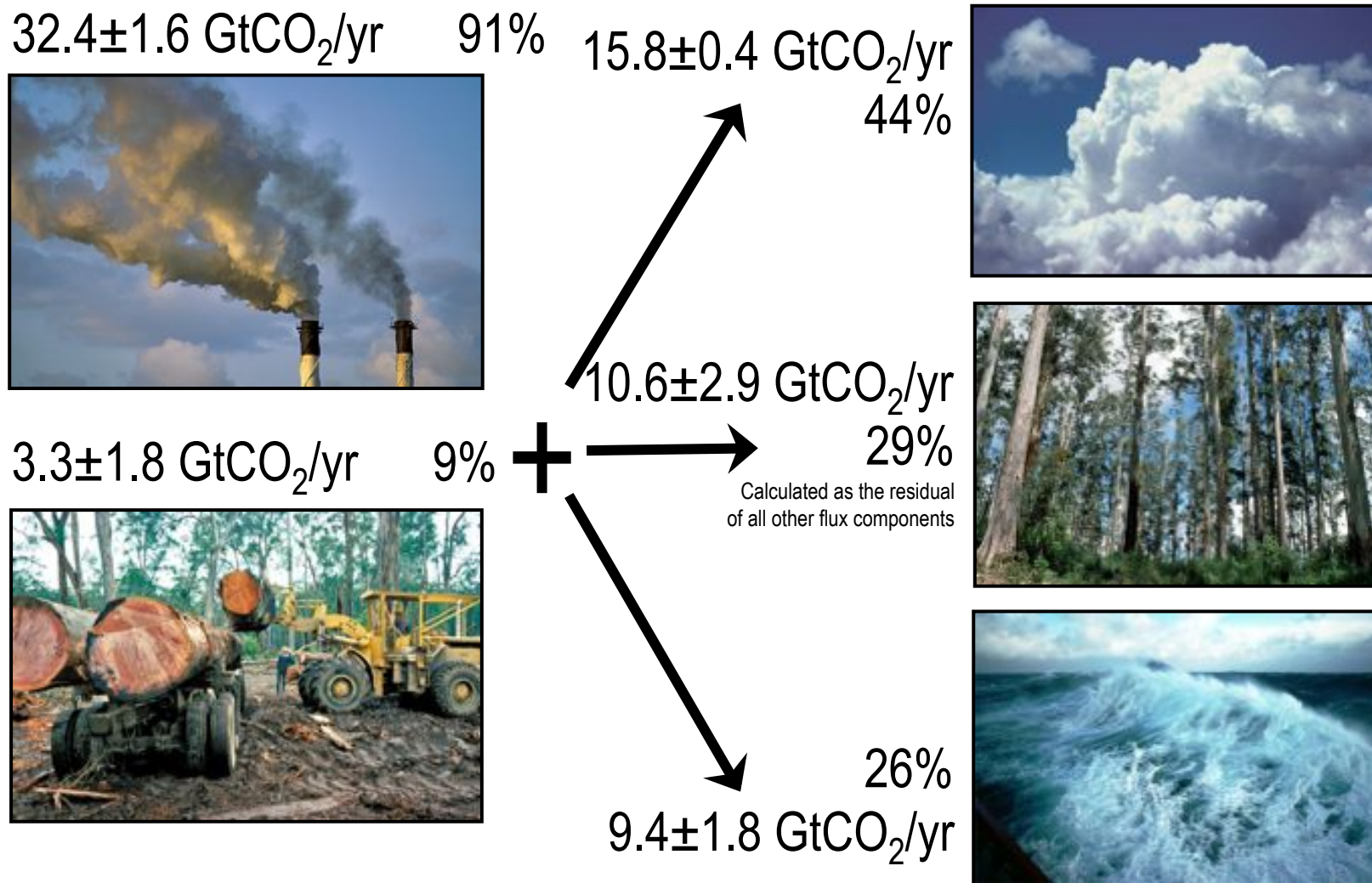
Seulement la moitié des émissions s'accumule dans l'atmosphère



Les émissions sont en partie ré-absorbées par l'océan et la biosphère terrestre



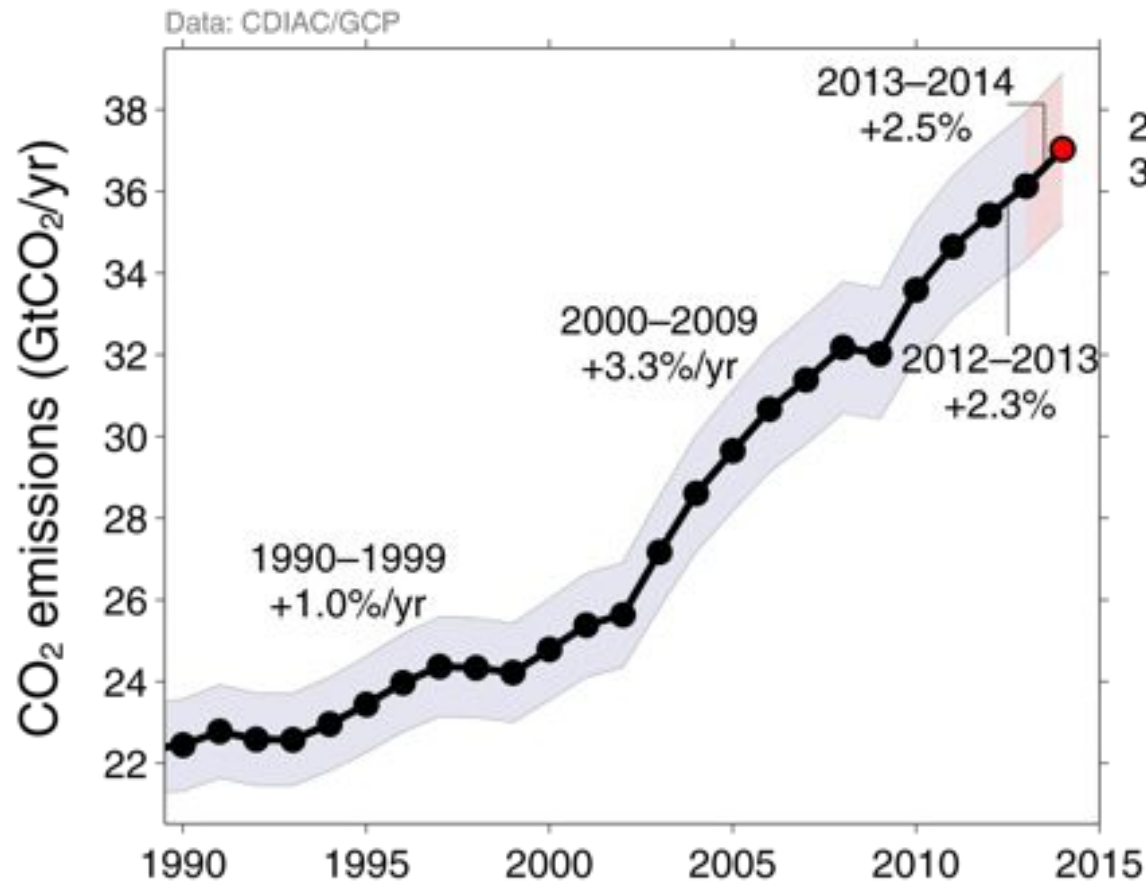
Bilan global du CO₂ anthropique moyenne 2004-2013



Source: [CDIAC](#); [NOAA-ESRL](#); [Houghton et al 2012](#); [Giglio et al 2013](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Accélération récente des émissions de CO₂ fossile

Valeur globale 36.1 ± 1.8 GtCO₂ en 2013, 61% de plus qu'en 1990

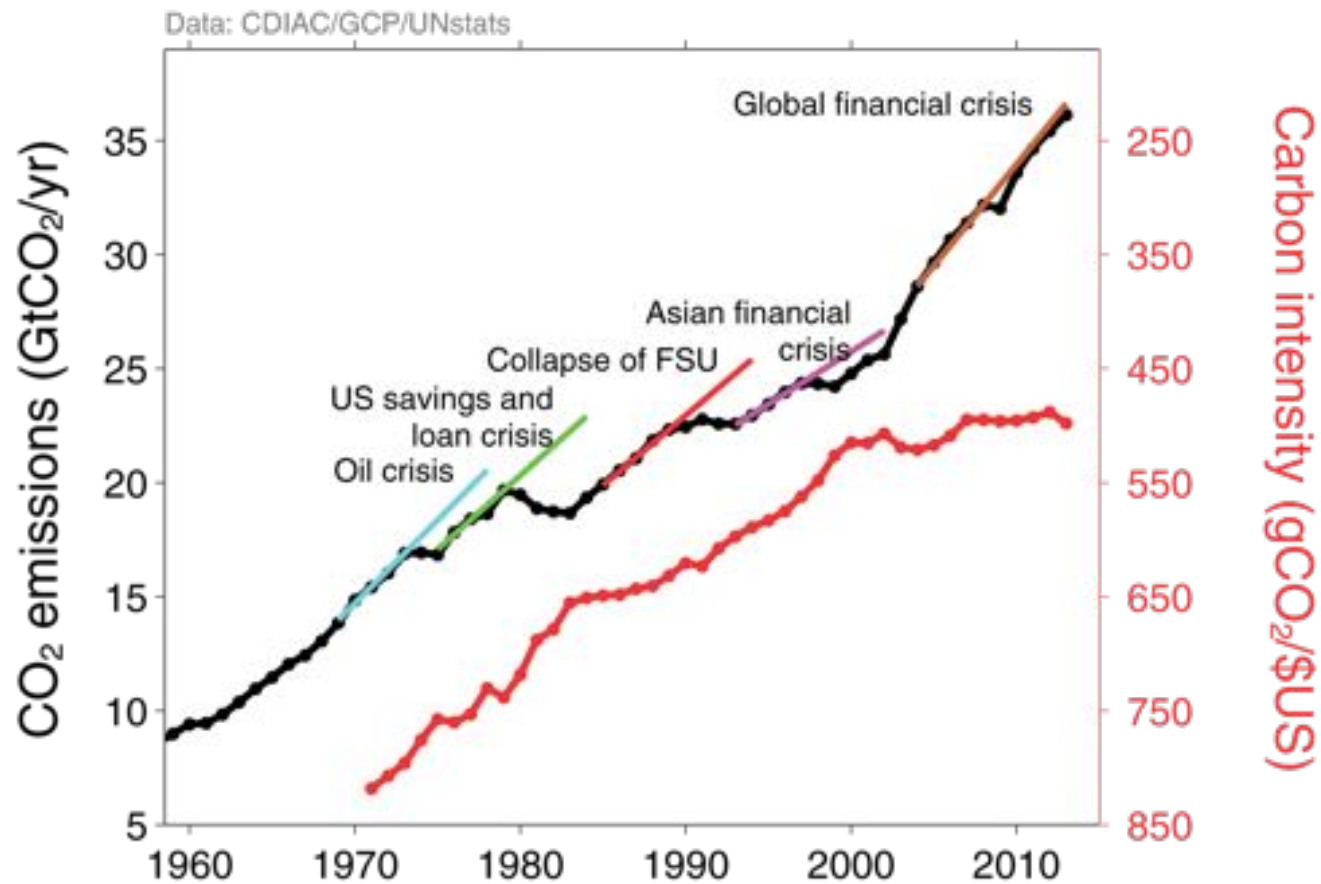


Uncertainty is $\pm 5\%$ for one standard deviation (IPCC “likely” range)

Estimates for 2011, 2012, and 2013 are preliminary

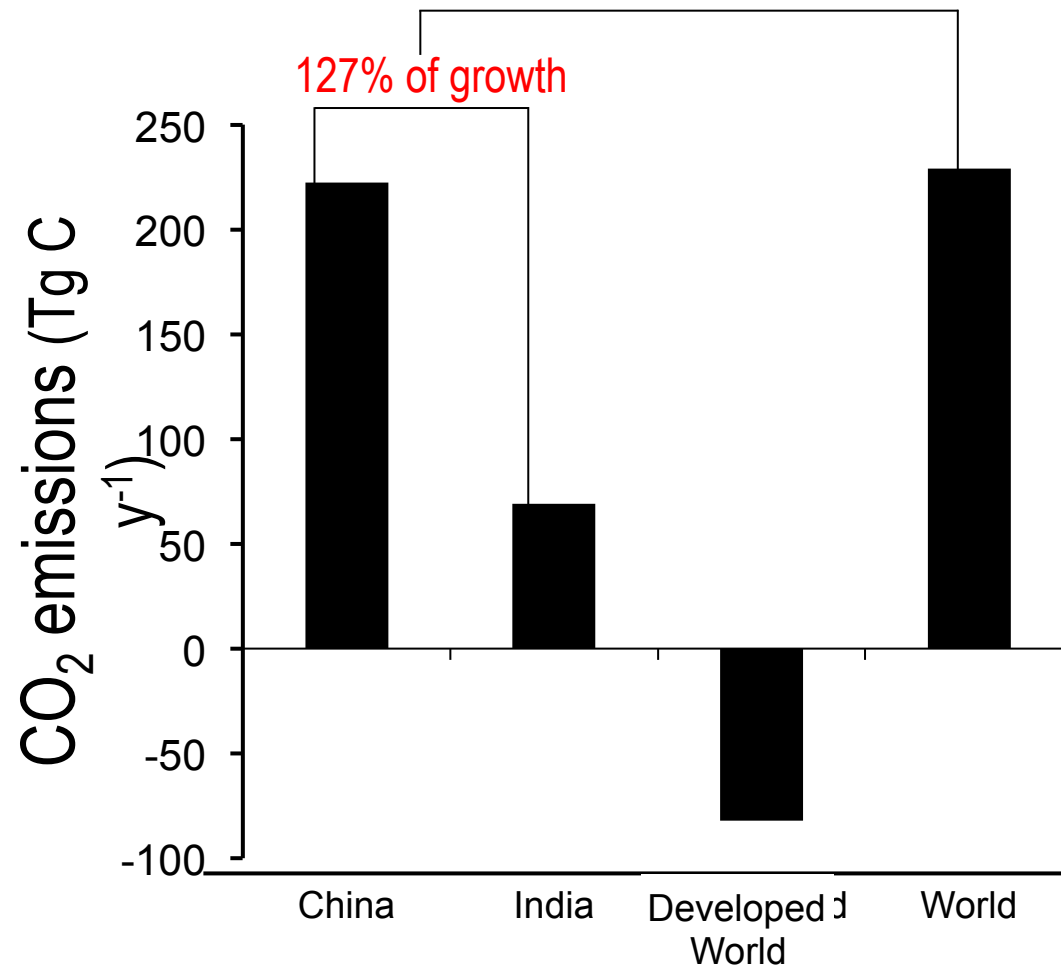
Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Une croissance mondiale intensive en émissions



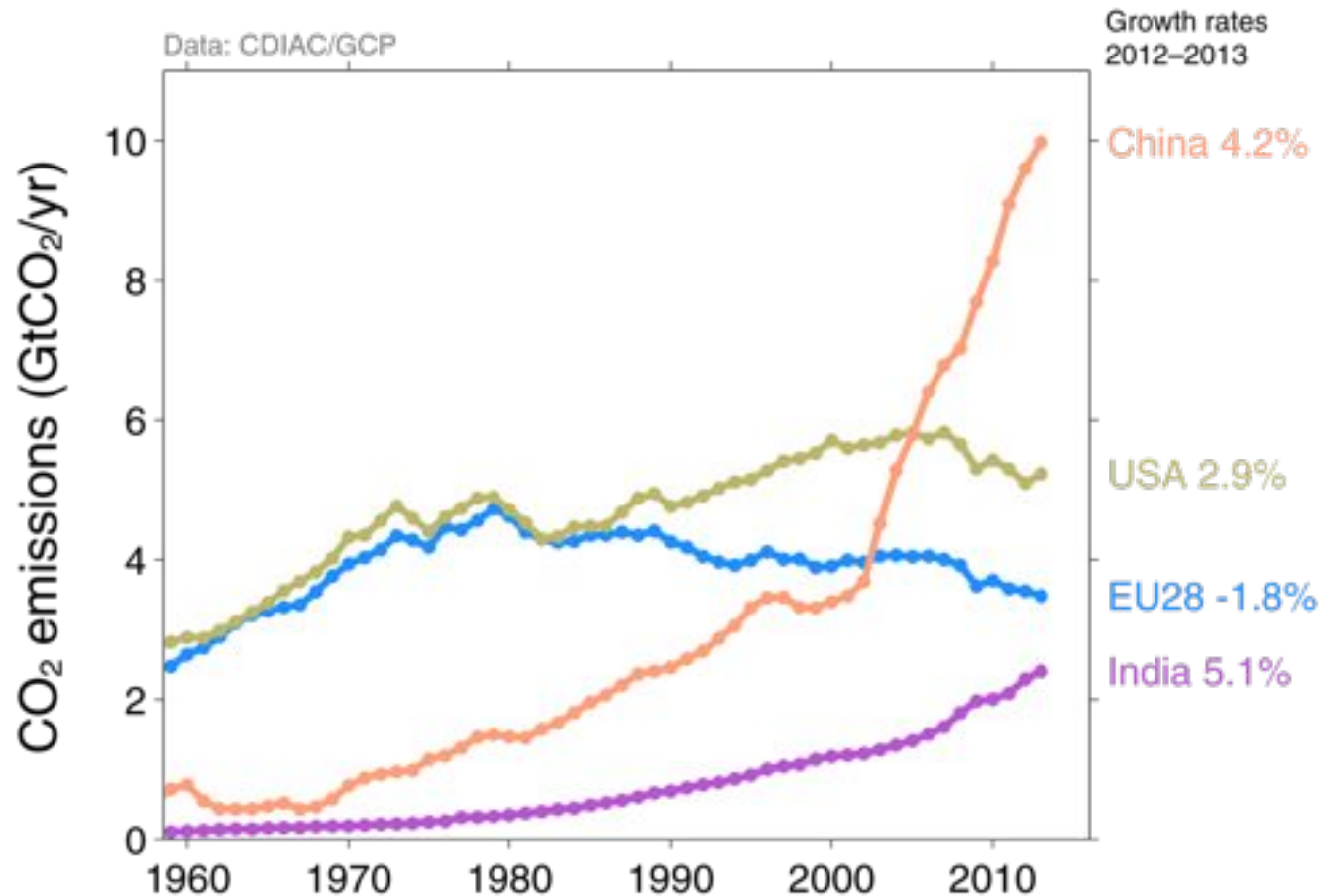
Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Augmentation des émissions de CO₂ liées au charbon (2008 to 2010)



Les quatre plus grands émetteurs

The top four emitters in 2013 covered 58% of global emissions
China (28%), United States (14%), EU28 (10%), India (7%)

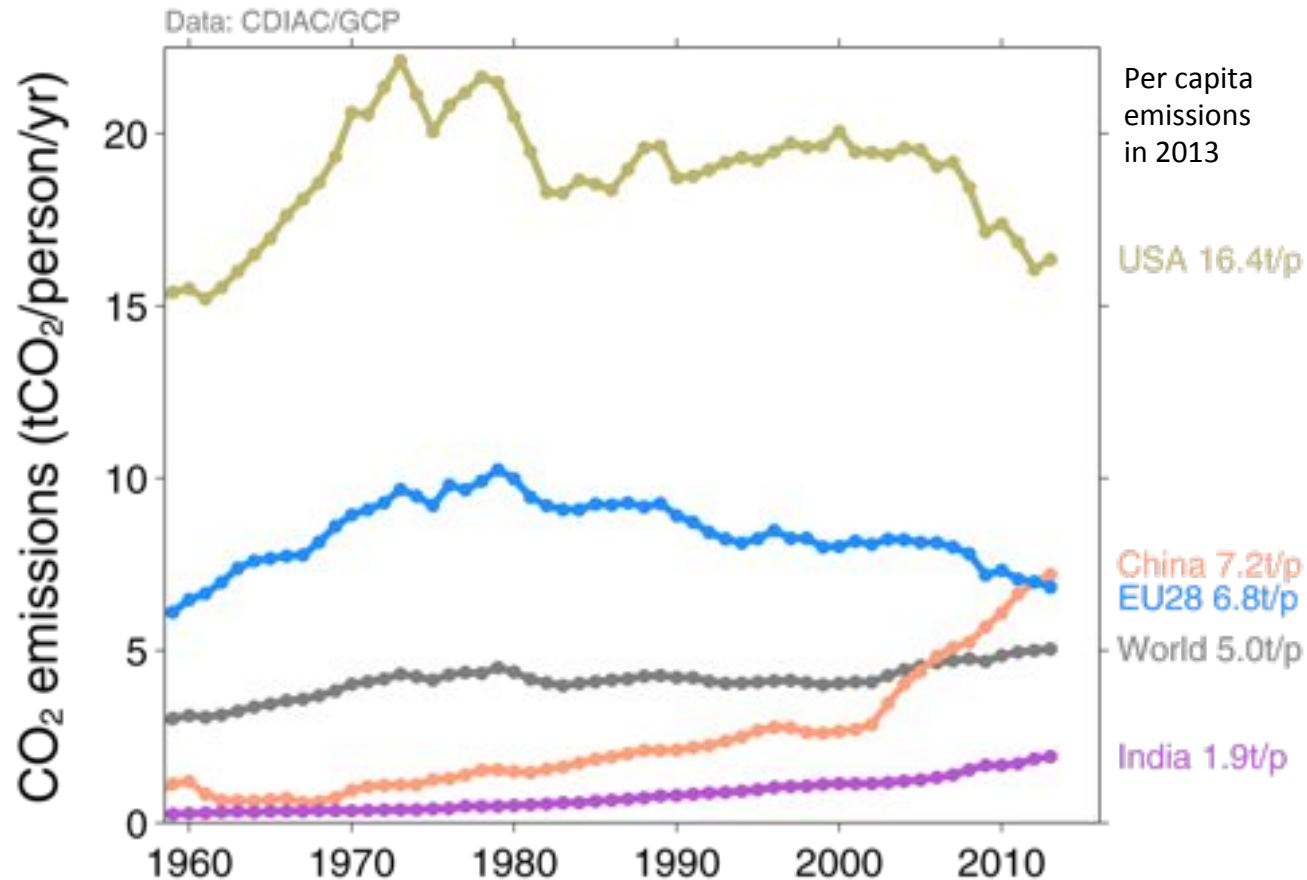


Bunkers fuel used for international transport is 3% of global emissions
Statistical differences between the global estimates and sum of national totals is 3% of global emissions

Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

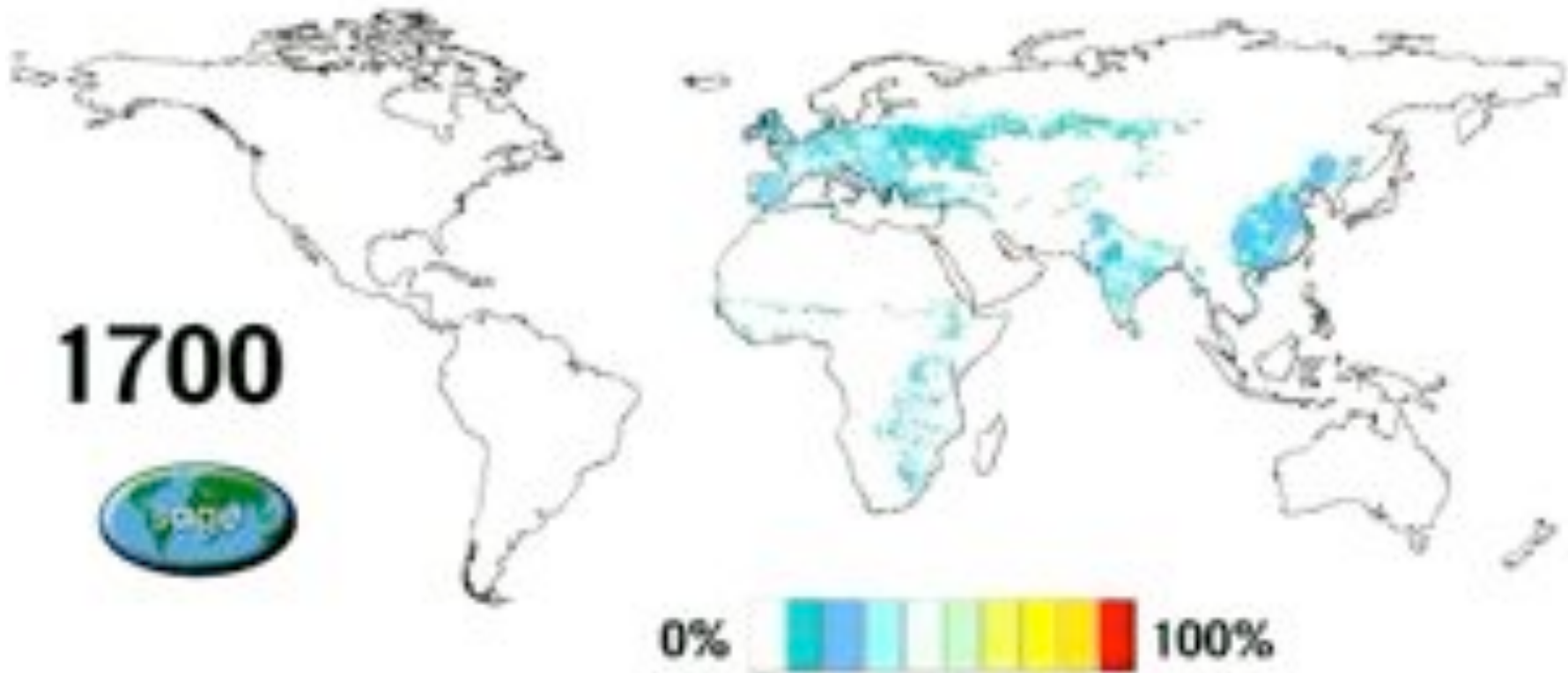
Emissions par habitant

China's per capita emissions have passed the EU28 and are 45% above the global average

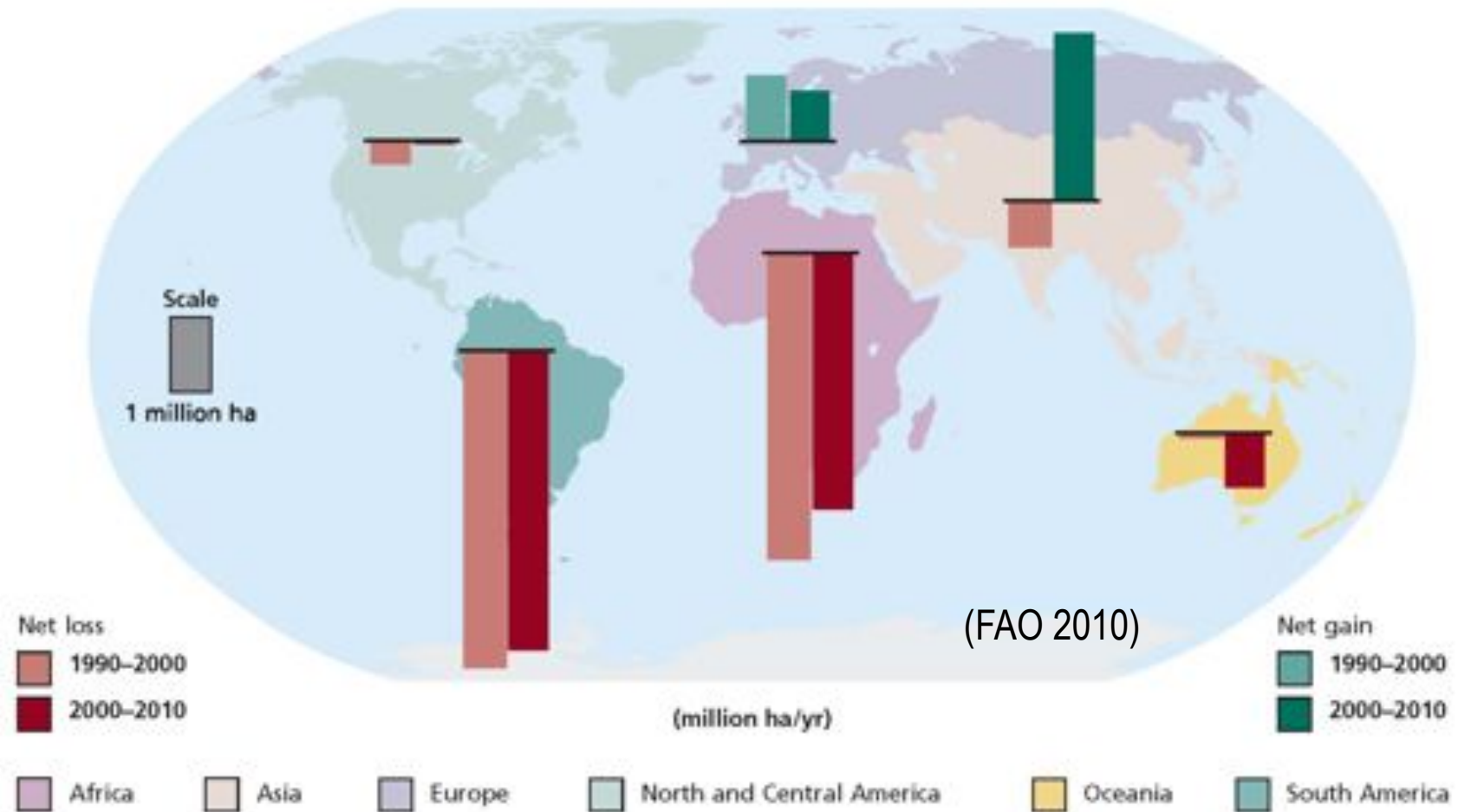


Source: [CDIAC](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Expansion des surfaces de cultures (reconstruction depuis 1700)

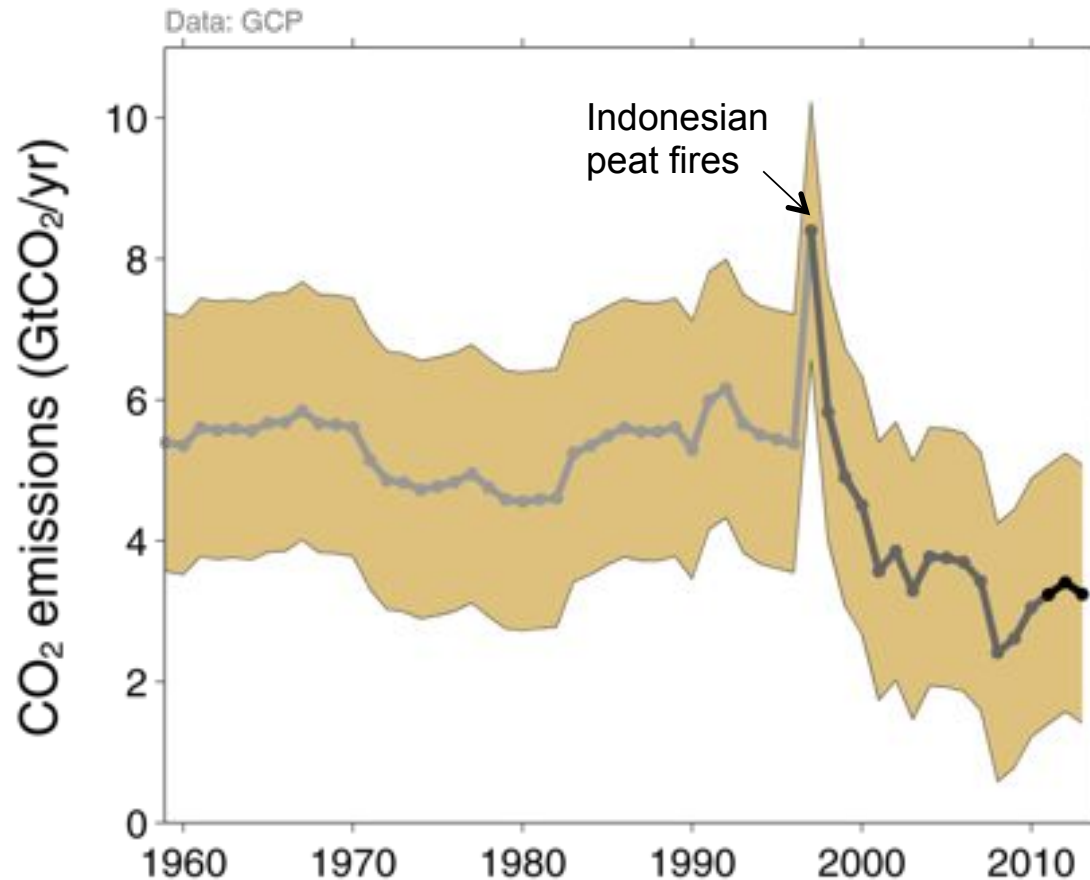


Changements des surfaces forestières (1990-2010)



Les émissions de déforestation

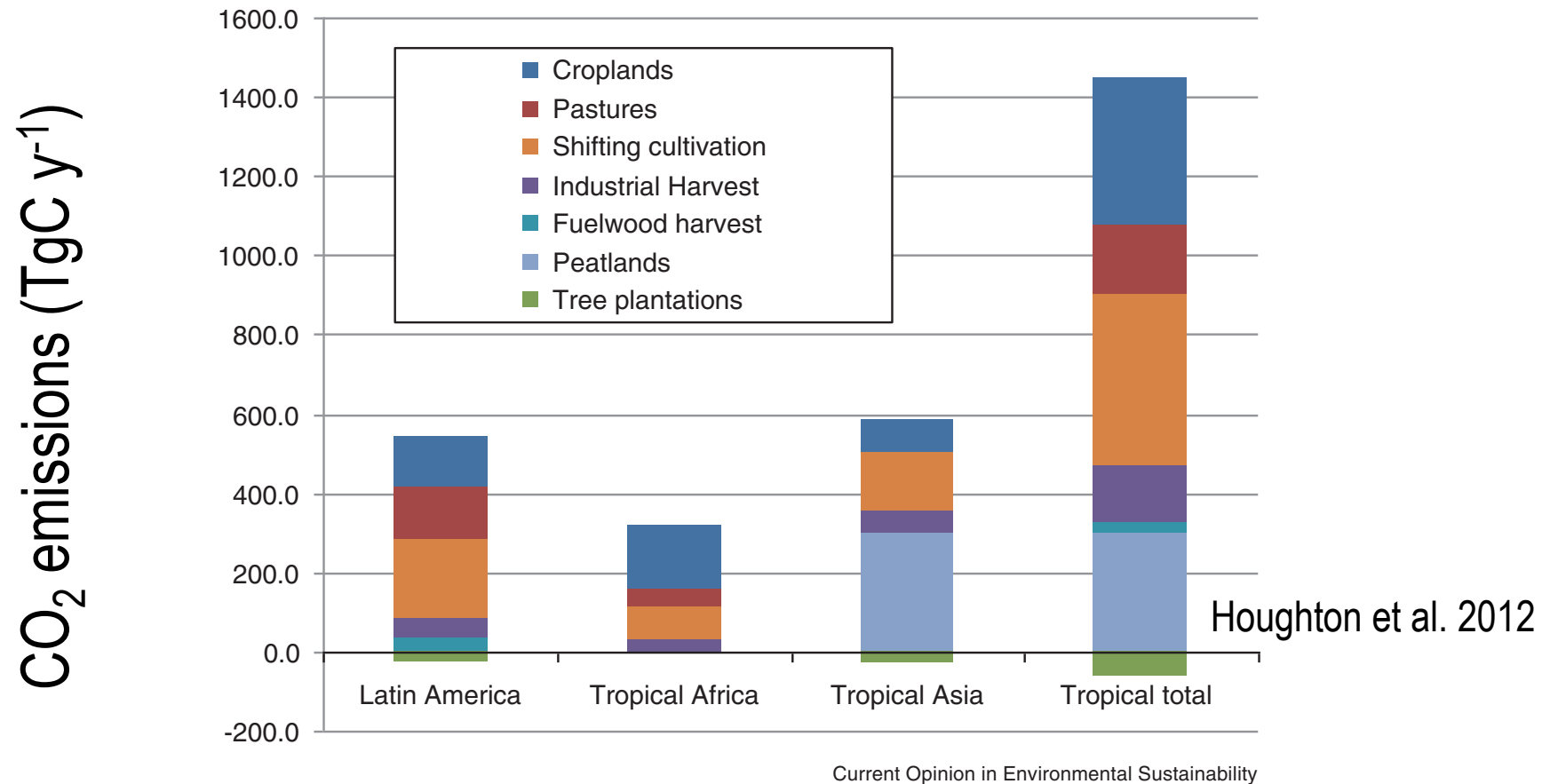
3.3 ± 1.8 GtCO₂ pendant 2004–2013, soit 15% des émissions de CO₂ fossile
Une baisse des émissions depuis 2000, principalement au Brésil



Three different estimation methods have been used, indicated here by different shades of grey
Land-use change also emits CH₄ and N₂O which are not shown here

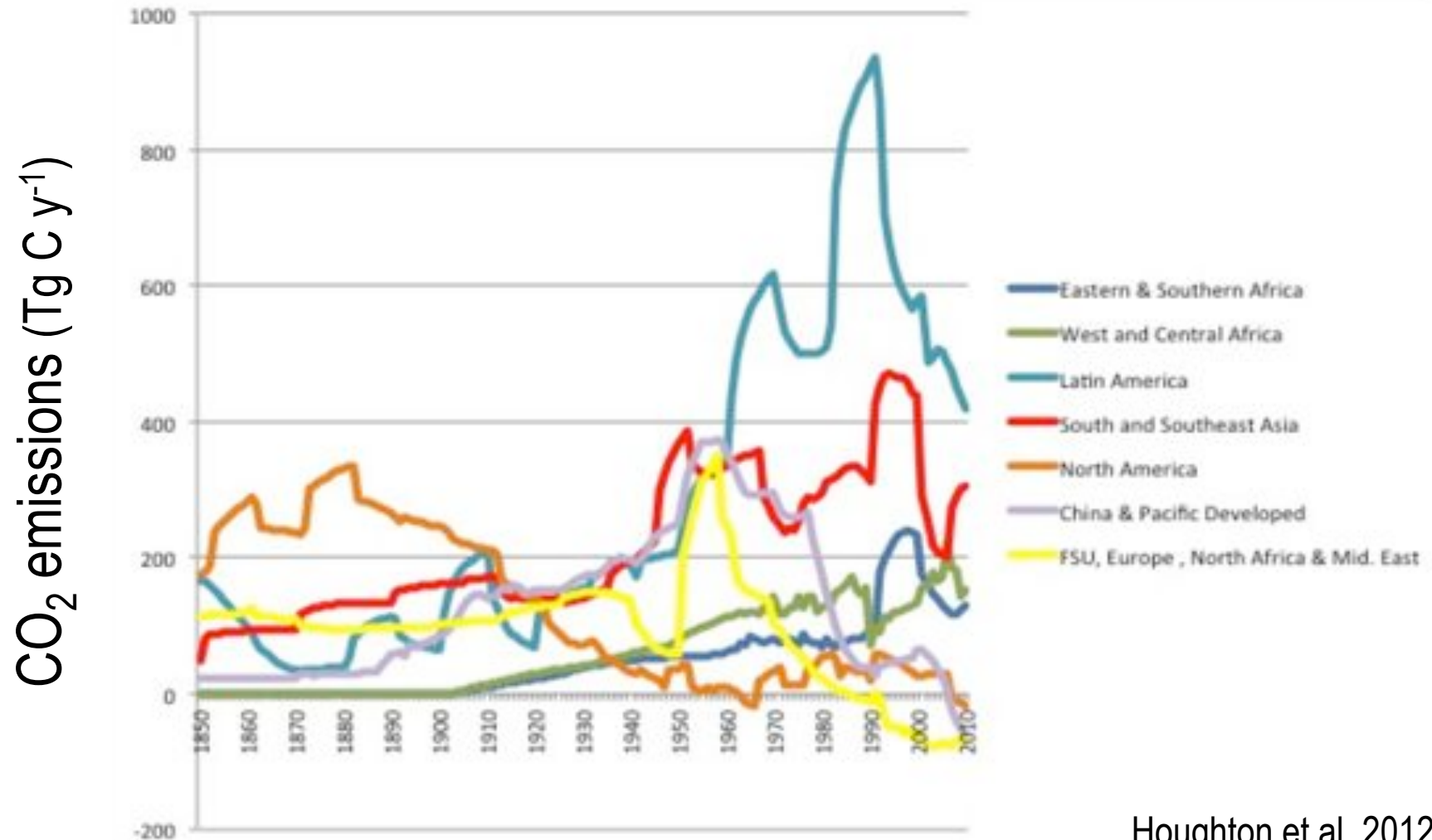
Source: [Houghton et al 2012](#); [Giglio et al 2013](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Différents modes de déforestation

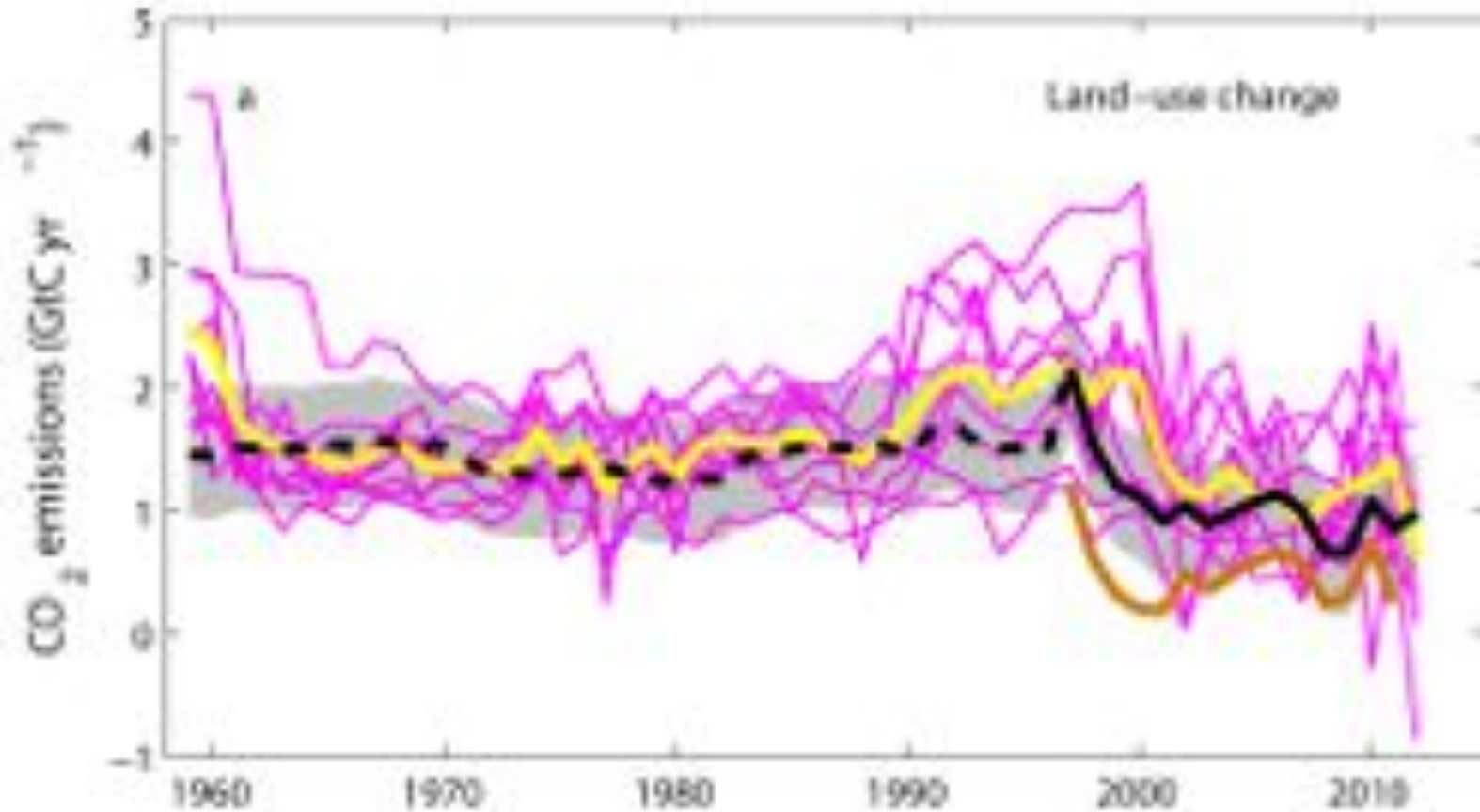


Emissions d'autres composés carbonés : CO et aérosols carbonés
Voir présentations M Kanakidou et N Marchand

Emission de deforestation par pays



De fortes incertitudes



Magenta – différents modèles globaux

Gris – modèle empirique calibré sur des observations

Source: [CDIAC](#); [NOAA-ESRL](#); [Houghton et al 2012](#); [Giglio et al 2013](#); [Joos et al 2013](#); [Khatiwala et al 2013](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)

Apport des données de télédétection

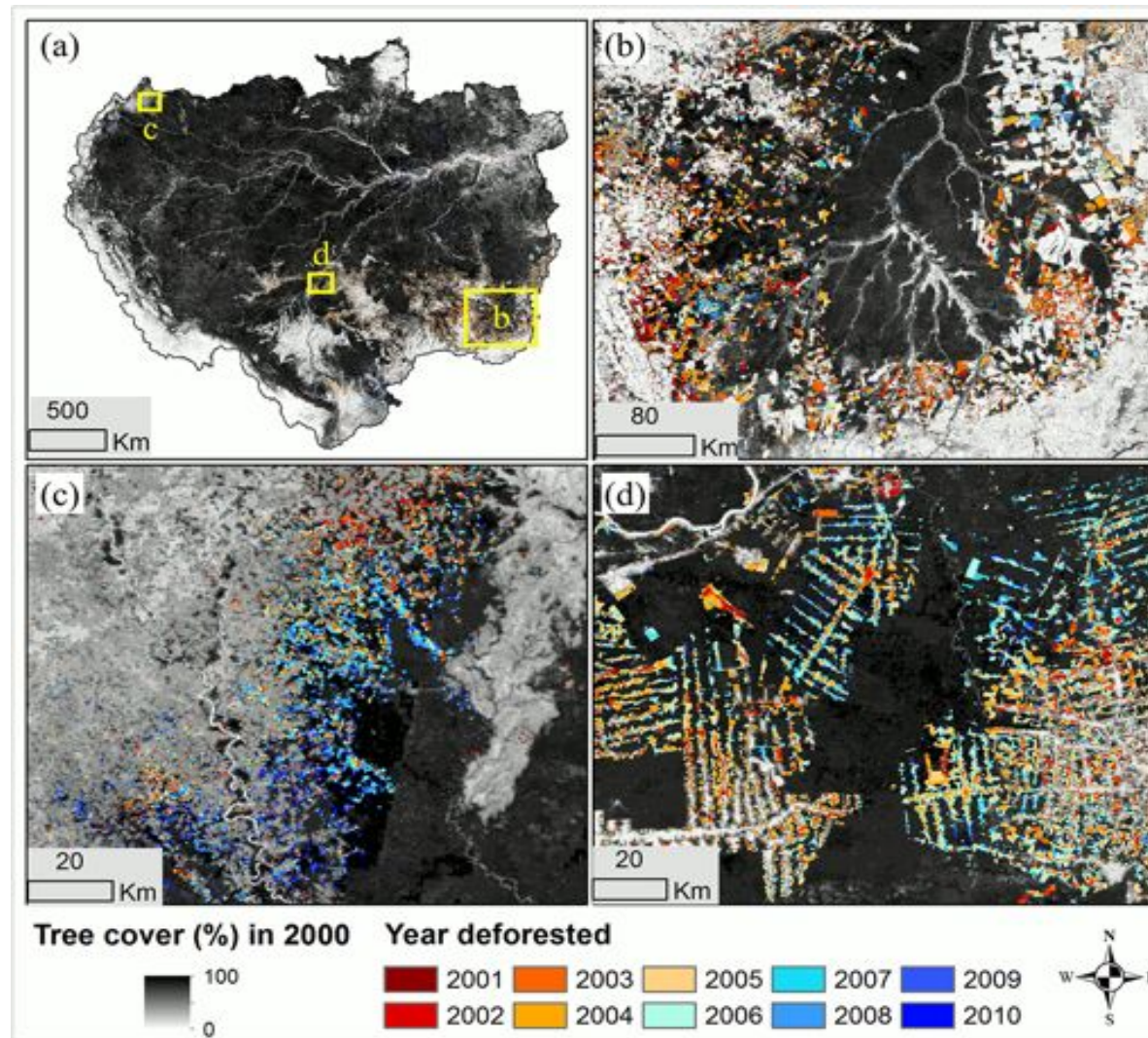
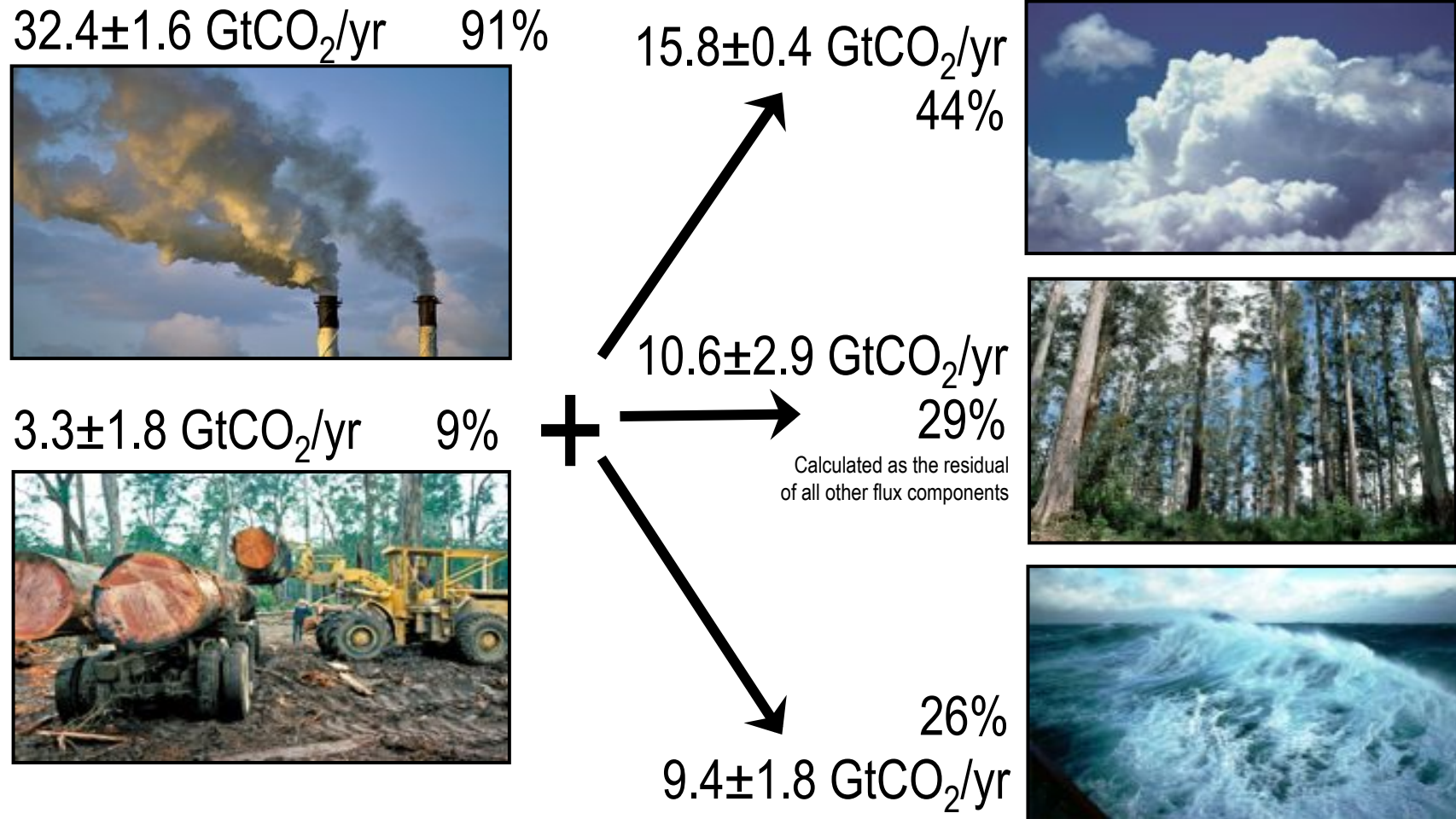
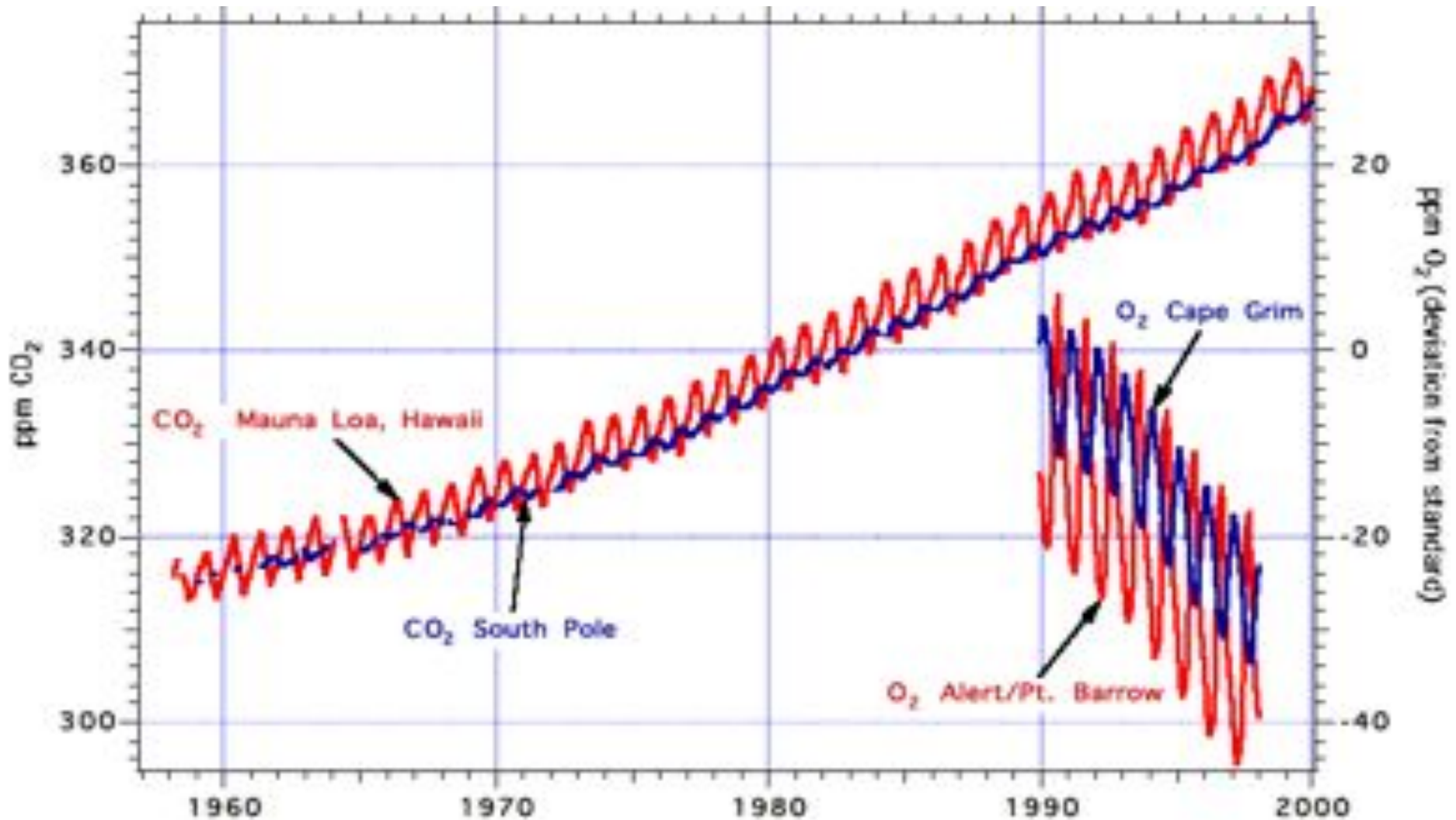


Fig 1. Deforestation year map derived from time-series of MODIS VCF tree cover dataset.

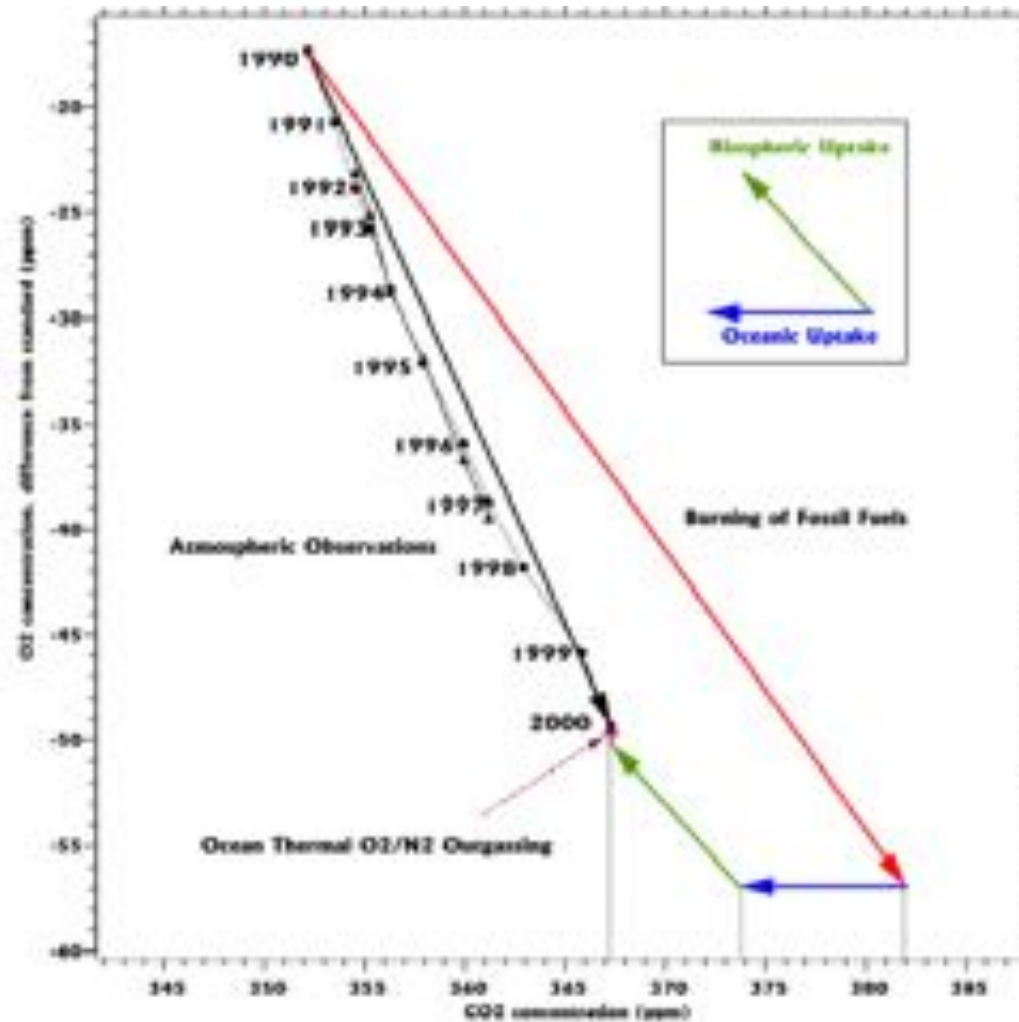
Séparer l'absorption du CO₂ entre océan et continents



Evolution du CO₂ et de l'oxygène atmosphérique

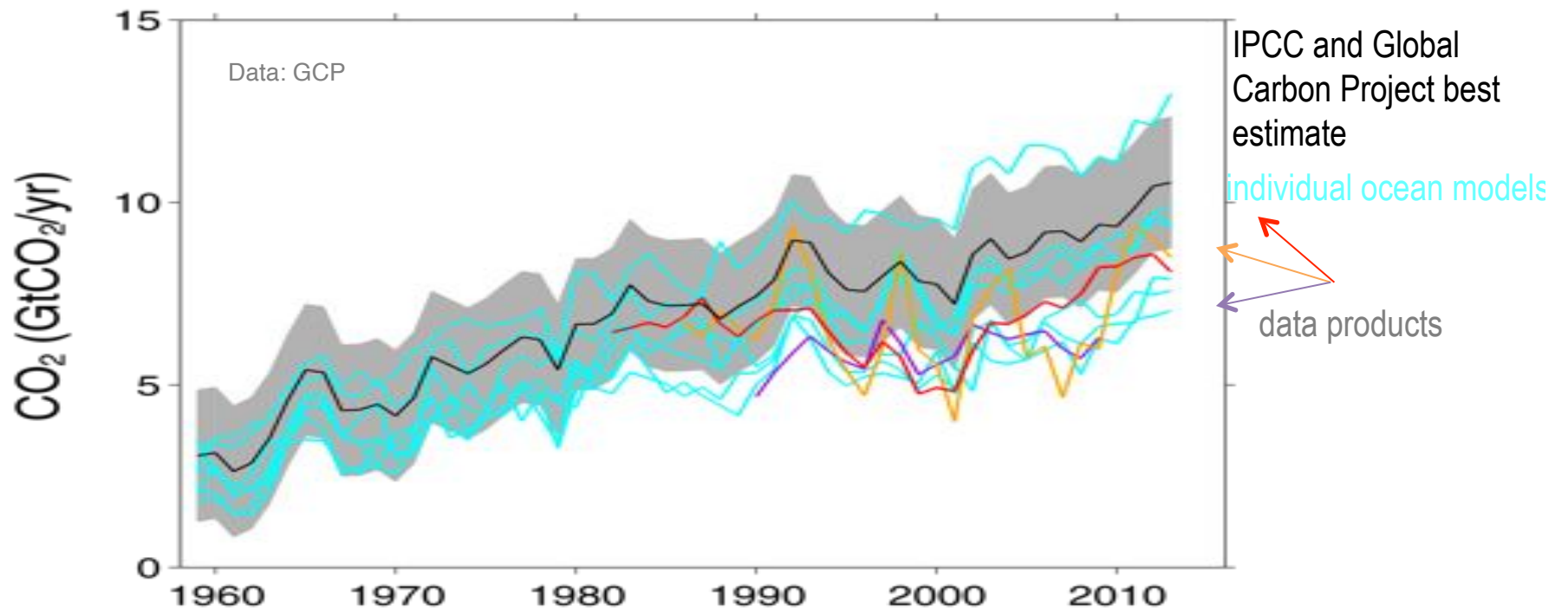


Une estimation directe des flux océaniques et terrestres



Le puits de carbone océanique

Ocean carbon sink continues to increase
 9.4 ± 1.8 GtCO₂/yr for 2004–2013 and 10.5 ± 1.8 GtCO₂/yr in 2013

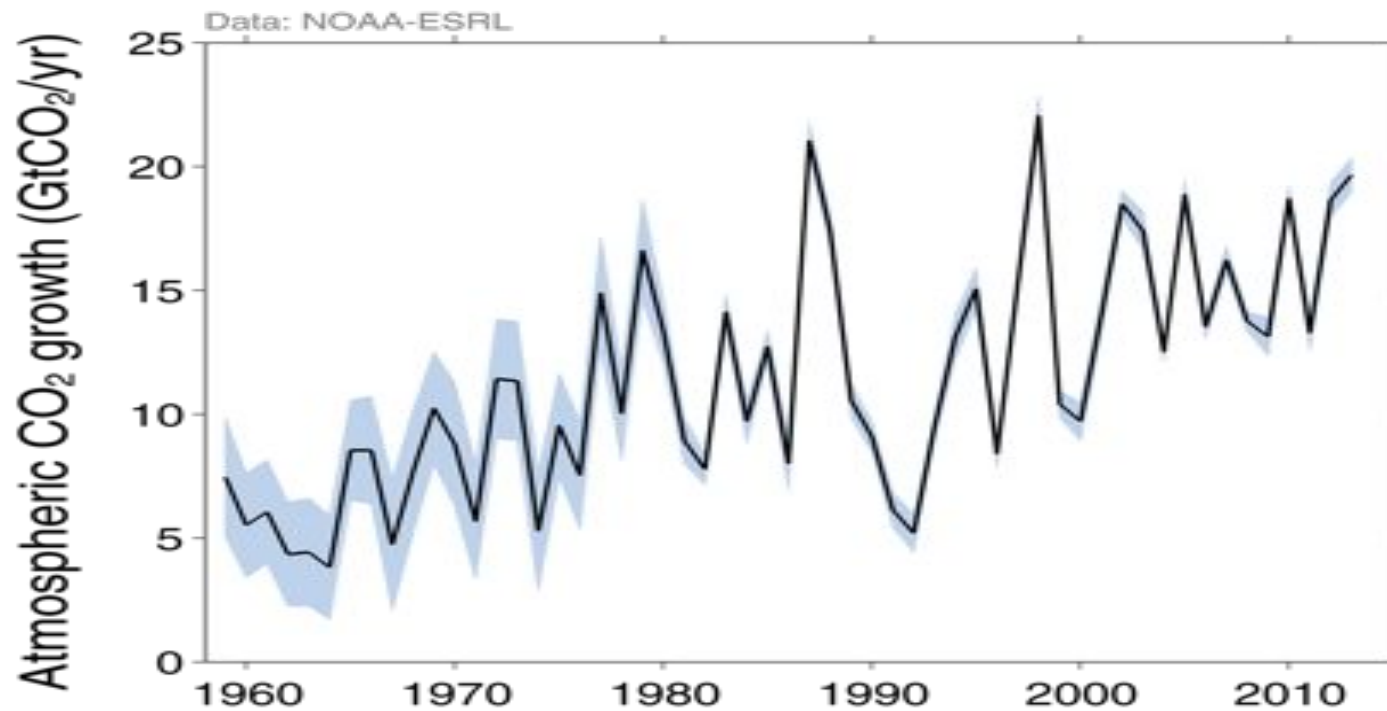


Source: [Le Quéré et al 2014](#); [Global Carbon Project 2014](#)

Individual estimates from Buitenhuis et al. (2010); Aumont and Bopp (2006); Doney et al. (2009); Assmann et al. (2010); Ilyiana et al. (2013); Sérérian et al. (2013); Oke et al. (2013); Landschützer et al. (2014); Park et al. (2010); Rödenbeck et al. (2014). References provided in Le Quéré et al. (2014).

Variations interannuelles de l'accumulation du CO₂

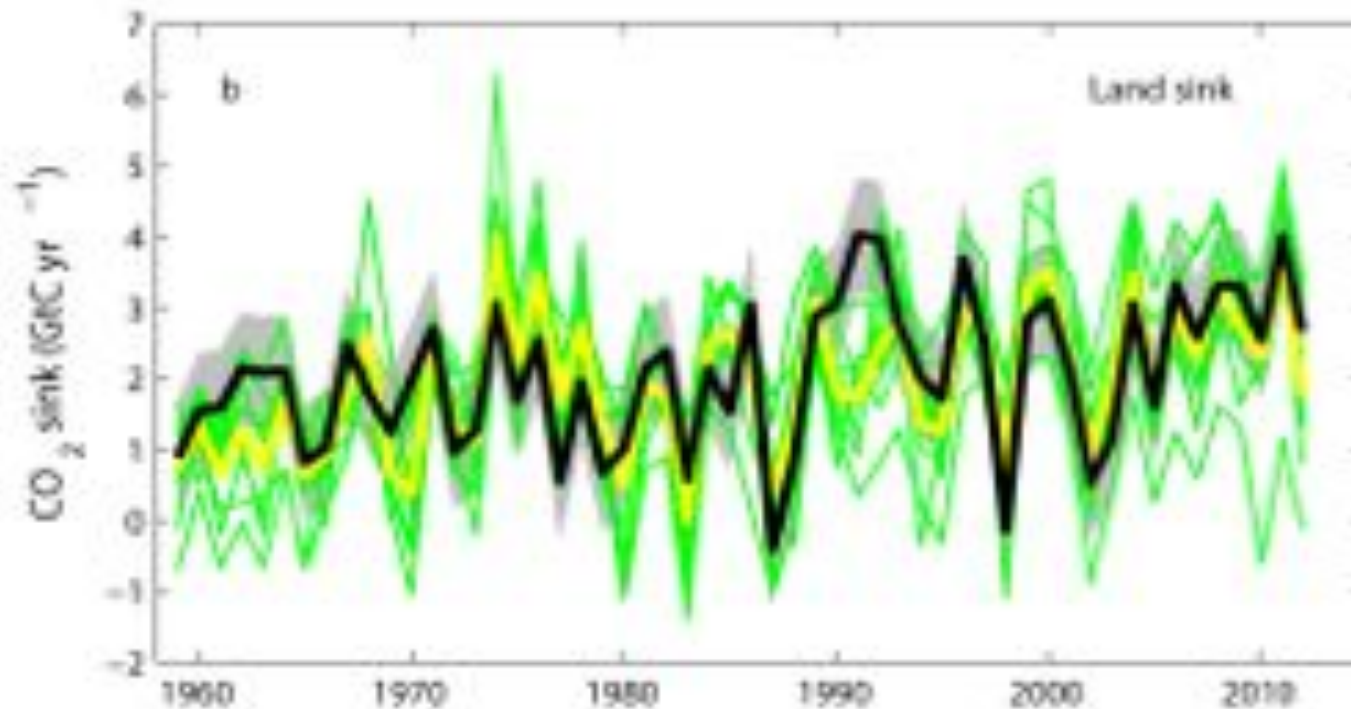
The atmospheric concentration growth rate has shown a steady increase
The growth in 2013 reflects the growth in fossil emissions, with small changes in the sinks



Source: [NOAA-ESRL](#); [Global Carbon Budget 2014](#)

Le puits de carbone terrestre

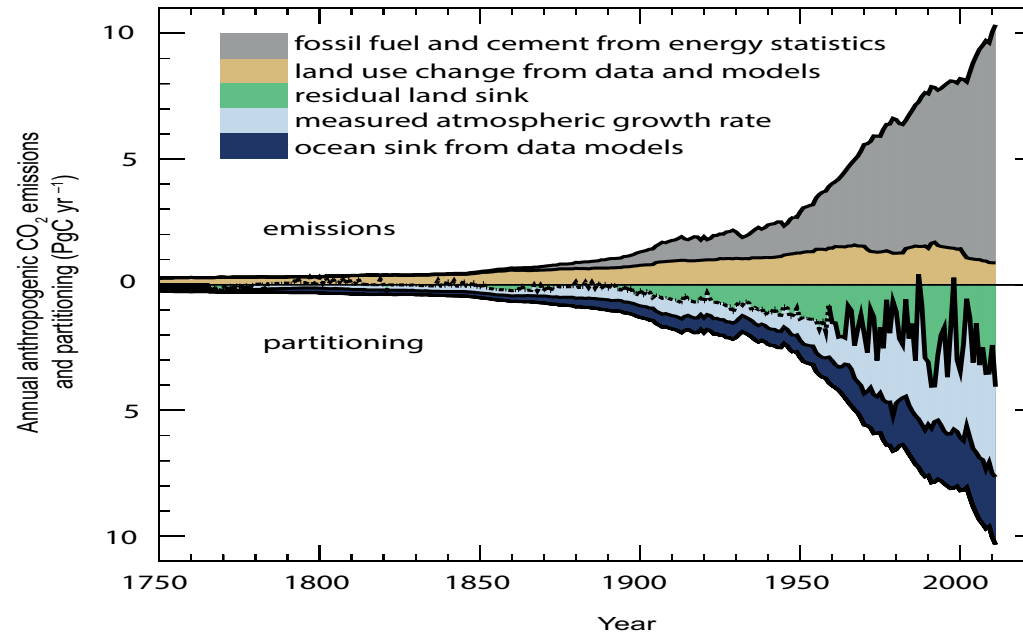
The residual land sink is increasing with time to 9.2 ± 1.8 GtCO₂/yr in 2013, with large variability
Total CO₂ fluxes on land (including land-use change) are consistent with atmospheric inversions



Source: [Le Quéré et al 2014](#); [Global Carbon Project 2014](#)

Individual estimates from Zhang et al. (2013); Oleson et al. (2013); Jain et al. (2013); Clarke et al. (2011); Smith et al. (2001); Sitch et al. (2003); Stocker et al. (2013); Krinner et al. (2005); Zeng et al. (2005); Kato et al. (2013); Peters et al. (2010); Rodenbeck et al. (2003); Chevallier et al. (2005). References provided in Le Quéré et al. (2014).

En résumé



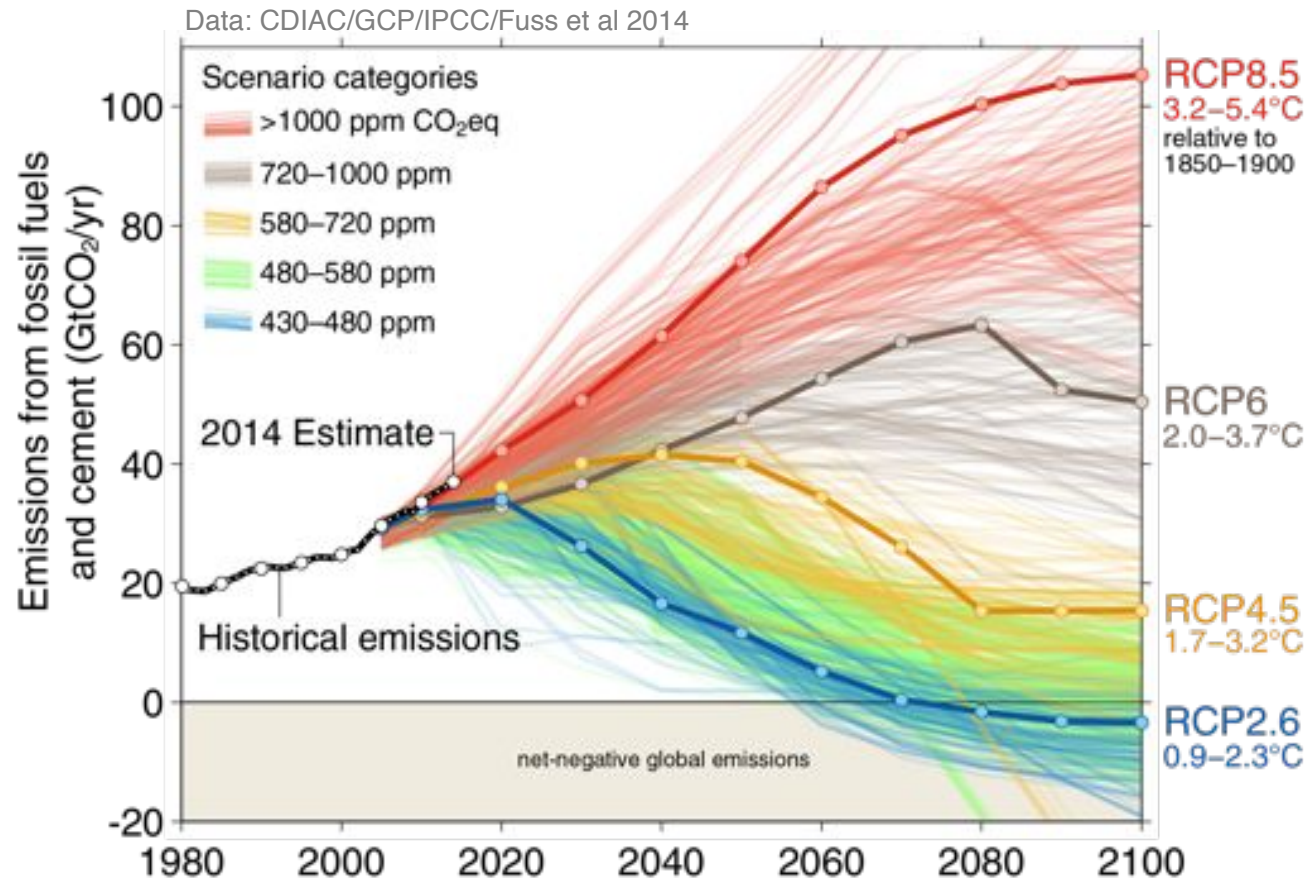
Depuis 1750, les émissions cumulées sont de 2000 ± 300 GtCO₂ soit 2/3 des émissions totales compatibles avec un réchauffement de 2°C

Les émissions de CO₂ fossile étaient de 36.1 ± 1.8 GtCO₂ en 2013, 61% plus qu'en 1990

Depuis 50 ans, environ 44% des émissions sont restées dans l'atmosphère, accroissant l'effet de serre de notre planète

Emissions historiques et climat futur

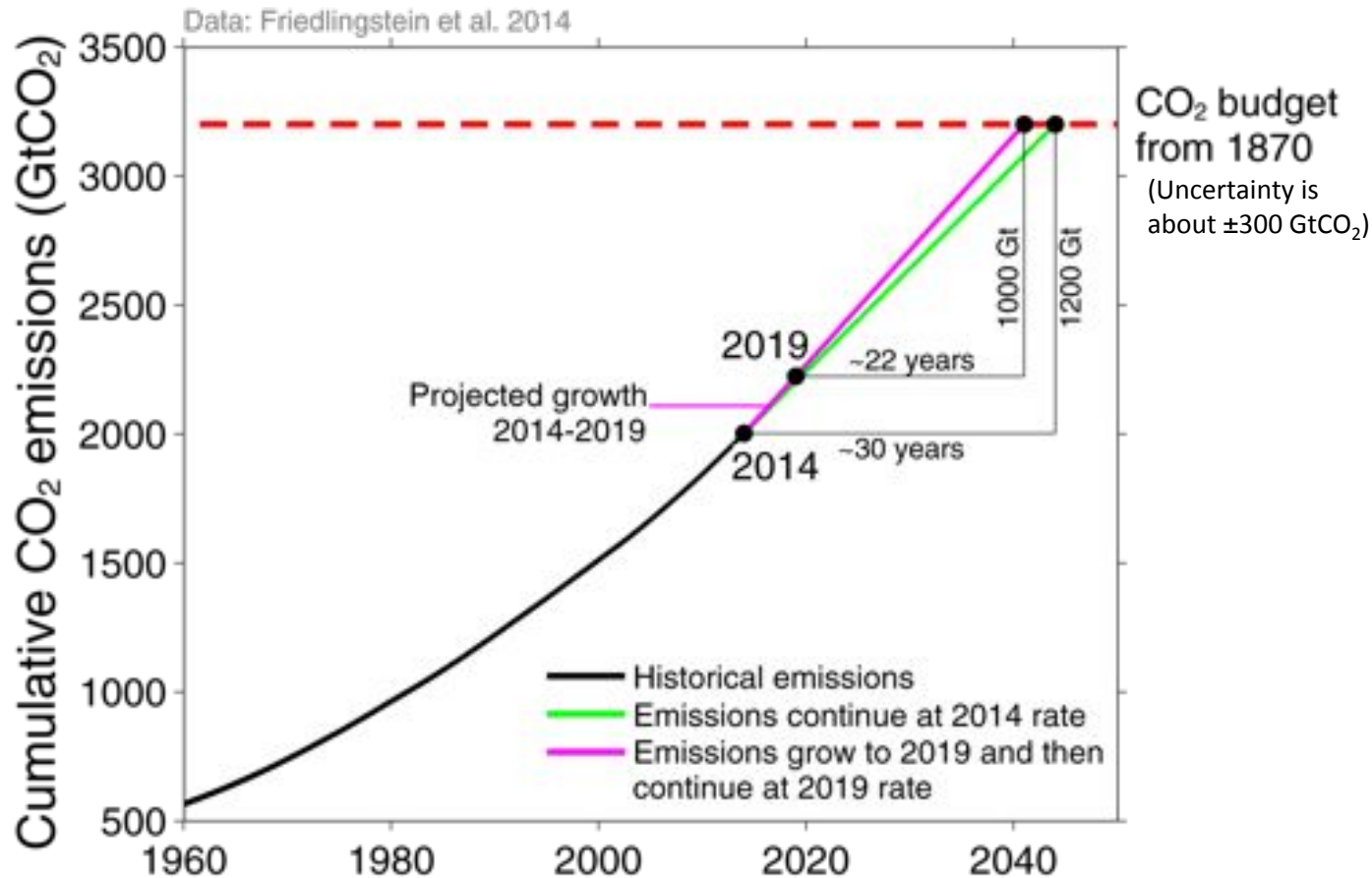
Emissions are on track for 3.2–5.4°C “likely” increase in temperature above pre-industrial
Large and sustained mitigation is required to keep below 2°C



Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

Source: [Fuss et al 2014](#); [CDIAC](#); [Global Carbon Budget 2014](#)

Combien d'émissions pour ne pas dépasser 2°C de réchauffement ?

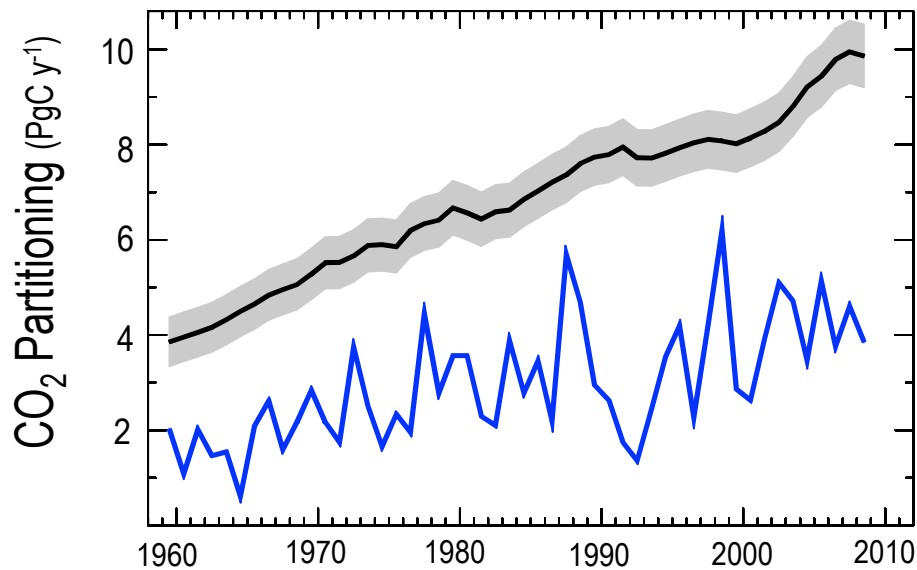


Friedlingstein et al. 2014

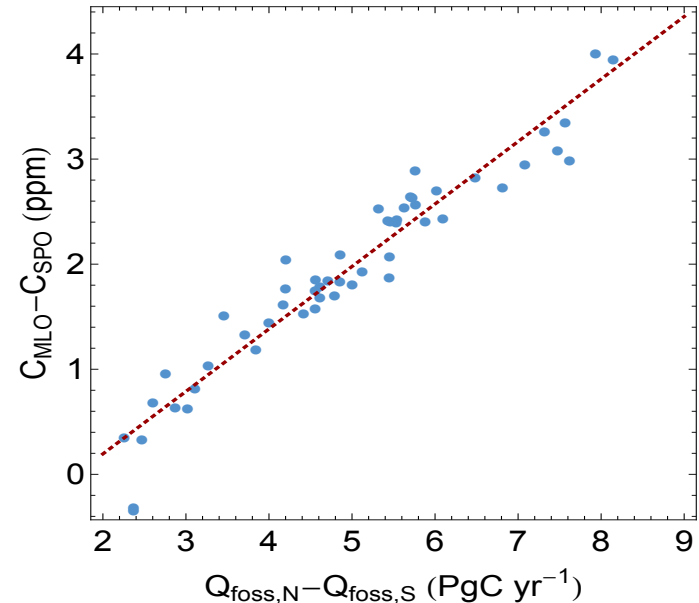
**Trois grandes questions de
recherche
sur l'évolution du cycle du
carbone depuis 150 ans**

Quasi-linéarité de la réponse globale du cycle du carbone

Evolution du gradient inter-hémisphérique de CO₂



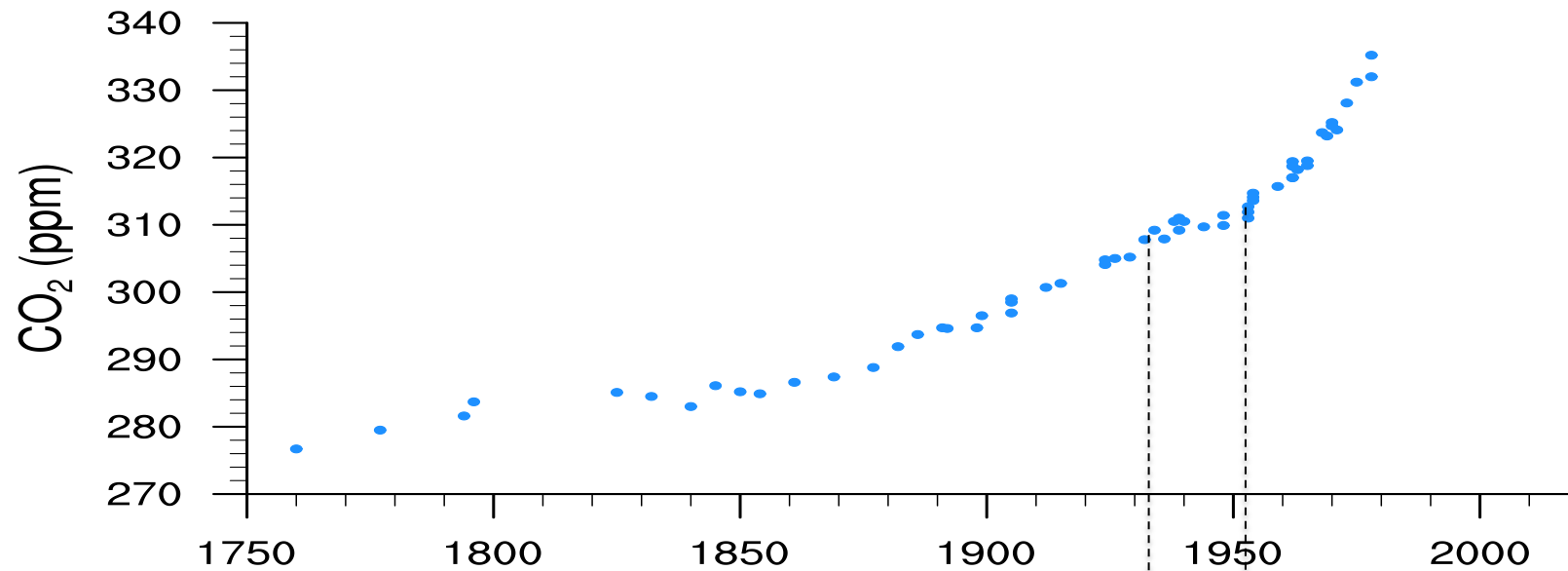
La fraction des émissions absorbée par les réservoirs naturels est très stable, malgré la très forte augmentation du forçage des émissions



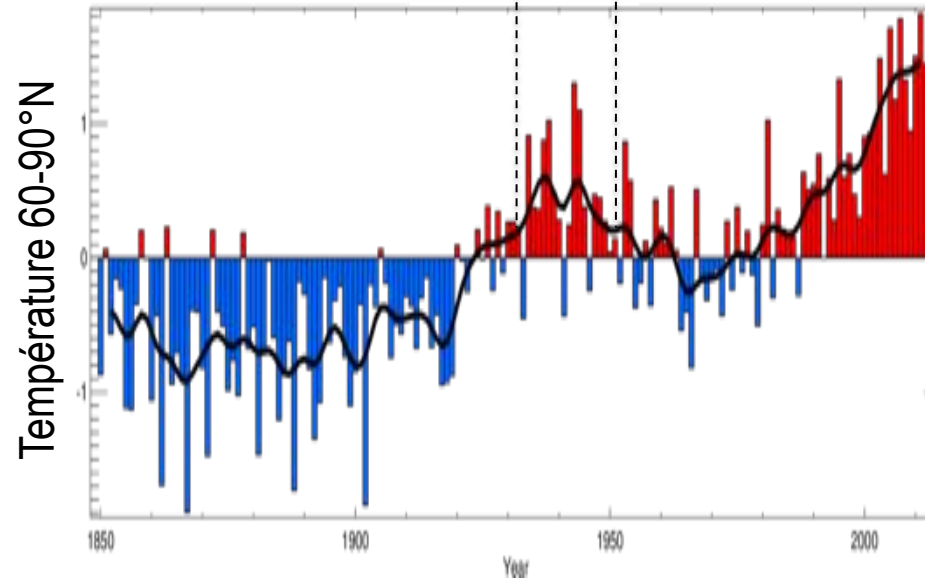
La différence de puits naturels entre les deux hémisphères a évolué proportionnellement aux émissions depuis 50 ans

**Cette linéarité va t'elle continuer dans le futur ?
Voir présentation de L. Bopp**

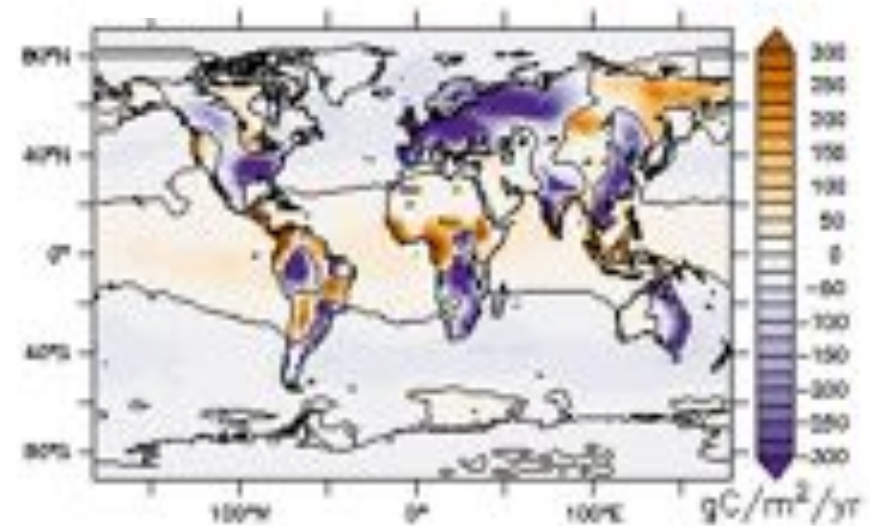
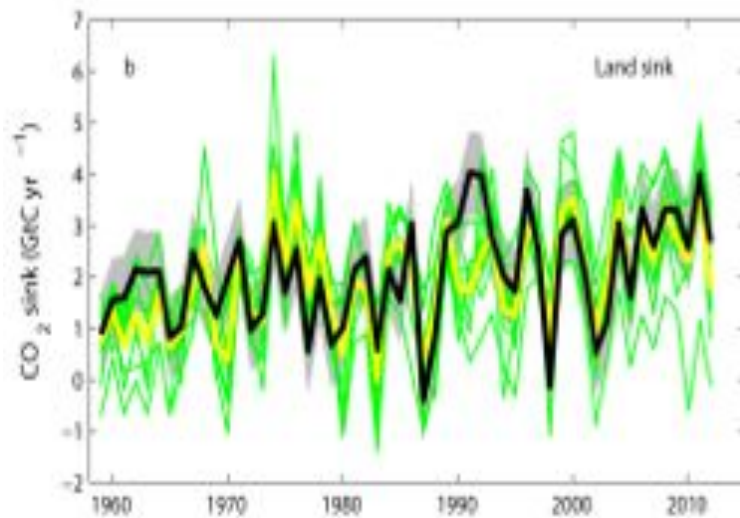
La variabilité décennale des flux de CO₂



Le plateau de CO₂
des années 1940

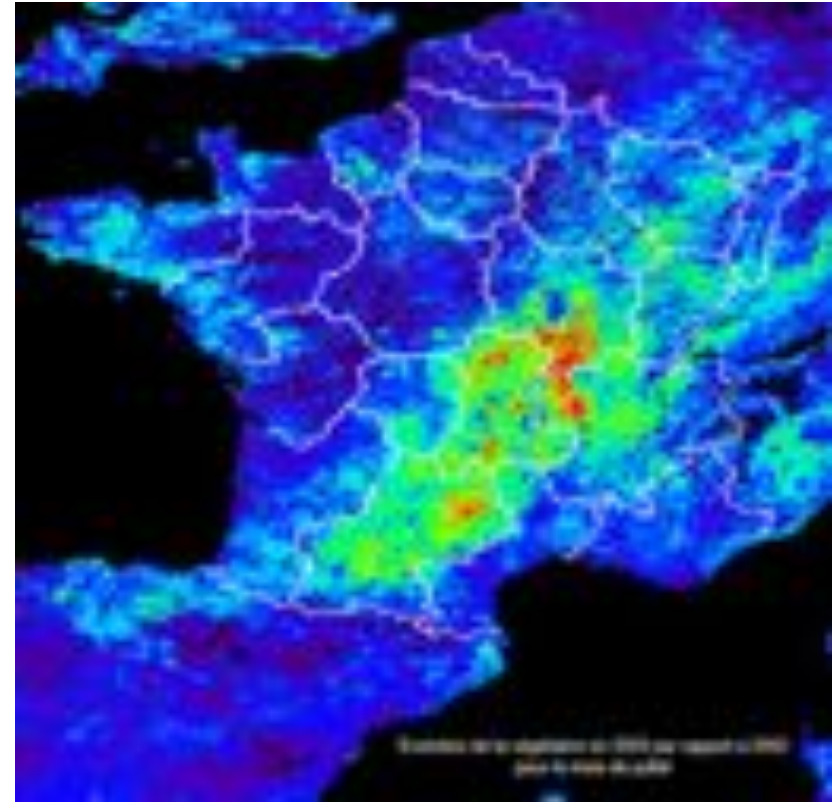
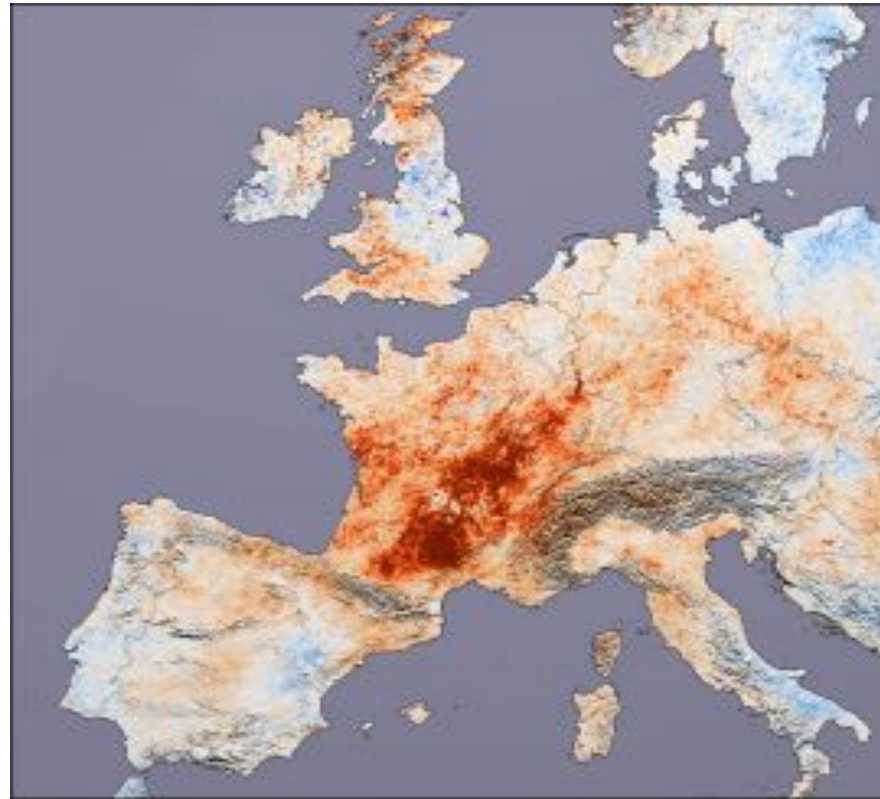


La variabilité interannuelle et la distribution régionale des flux



Voir présentations de M. Ramonet, F. Chevallier et F. Vogel

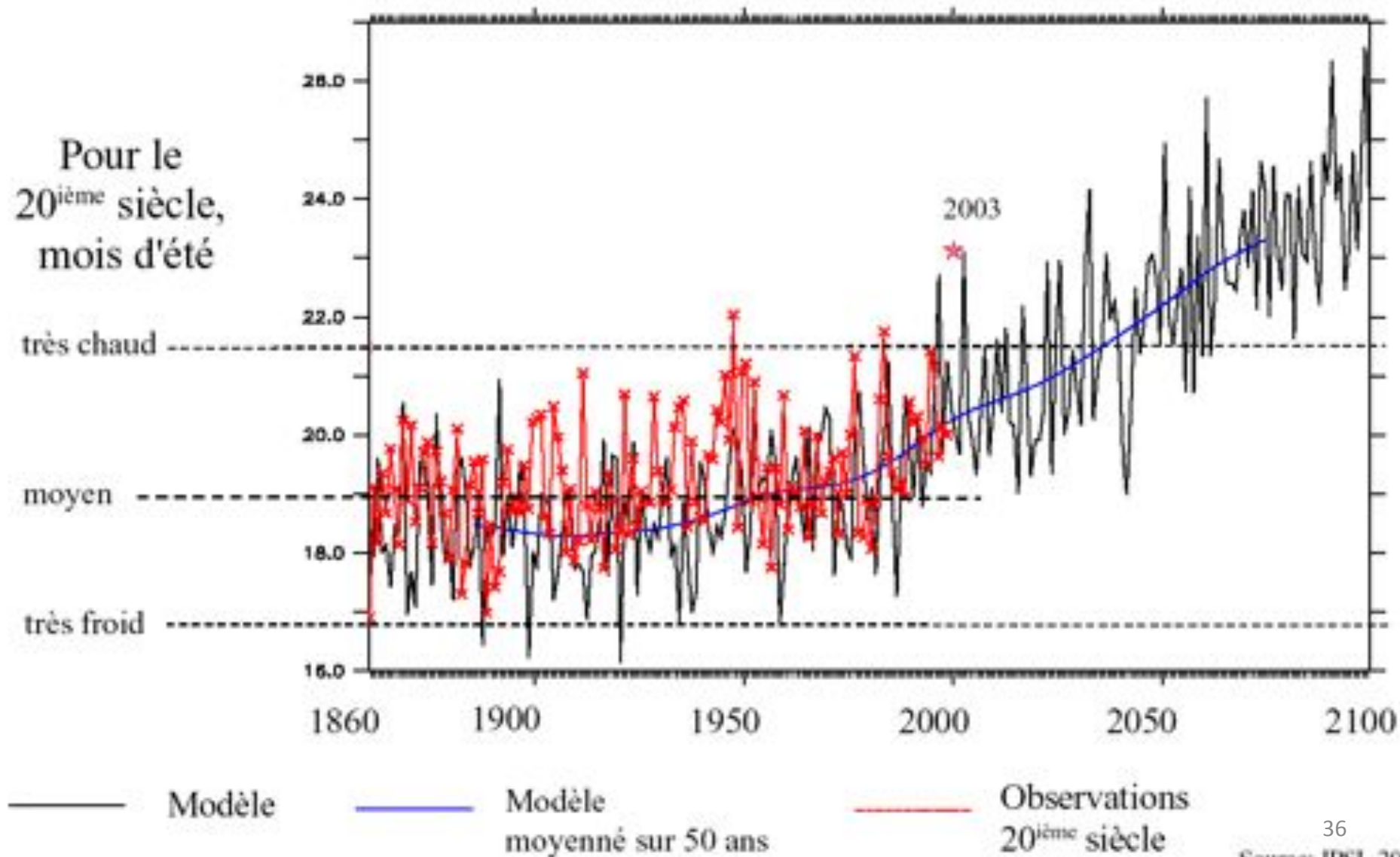
L'impact des événements extrêmes sur les flux de CO₂



Voir présentations de D Loustau

Evolution de la température moyenne en été en France de 1860 à 2100

(modèle de l'IPSL, scénario SRES A2, sans aérosols)



Earth Syst. Sci. Data Discuss., 6, 1–30, 2014
 www.earth-syst-sci-data-discuss.net/6/1/2014/
 doi:10.5194/essdd-6-1-2014
 © Author(s) 2014. CC Attribution 3.0 License.

Open Access Earth System Science Data

This discussion paper is/has been under review for the journal Earth System Science Data (ESSD). Please refer to the corresponding final paper in ESSD if available.

Global carbon budget 2014

C. Le Quéré¹, R. Moriarty¹, R. M. Andrew², G. P. Peters², P. Ciais³, P. Friedlingstein⁴, S. D. Jones¹, S. Sitch⁵, P. Tans⁶, A. Arneeth⁷, T. A. Boden⁸, L. Bopp³, Y. Bozec^{9,10}, J. G. Canadell¹¹, F. Chevallier³, C. E. Cosca¹², I. Harris¹³, M. Hoppema¹⁴, R. A. Houghton¹⁵, J. I. House¹⁶, J. K. Jain¹⁷, T. Johannessen^{18,19}, E. Kato²⁰, R. F. Keeling²¹, V. Kitidis²², K. Klein Goldewijk²³, C. Koven²⁴, C. Landa^{18,19}, P. Landschützer²⁵, A. Lenton²⁶, I. D. Lima²⁷, G. Marland²⁸, J. T. Mathis¹², N. Metz²⁹, Y. Nojin²⁰, A. Olsen^{18,19}, T. Ono³⁰, W. Peters³¹, B. Pfeil^{18,19}, B. Poulter³², M. R. Raupach³³, P. Regnier³⁴, C. Rödenbeck³⁵, S. Saito³⁶, J. E. Salisbury²⁷, U. Schuster⁵, J. Schwinger^{18,19}, R. Séférian³⁸, J. Segschneider³⁹, T. Steinhoff⁴⁰, B. D. Stocker⁴¹, A. J. Sutton^{42,12}, T. Takahashi⁴³, B. Tilbrook⁴⁴, G. van der Werf⁴⁵, N. Viovy³, Y.-P. Wang⁴⁶, R. Wanninkhof⁴⁷, A. Wiltshire⁴⁸, and N. Zeng⁴⁹

More information, data sources and data files:

www.globalcarbonproject.org

Contact: c.lequere@uea.ac.uk

The Global Carbon Atlas is a platform to explore and visualize the most up-to-date data on carbon fluxes resulting from human activities and natural processes.
 Human impacts on the carbon cycle are the most important cause of climate change.

GLOBAL CARBON ATLAS

OUTREACH
 Take a journey through the history and future of human development and carbon.

EMISSIONS
 Explore and download global and country level carbon emissions from human activity.

RESEARCH
 Explore and visualize research carbon data, and get access through data providers.

More information, data sources and data files:

www.globalcarbonatlas.org

Contact: philippe.ciais@lsce.ipsl.fr

Contributors 88 people - 68 organisations - 12 countries

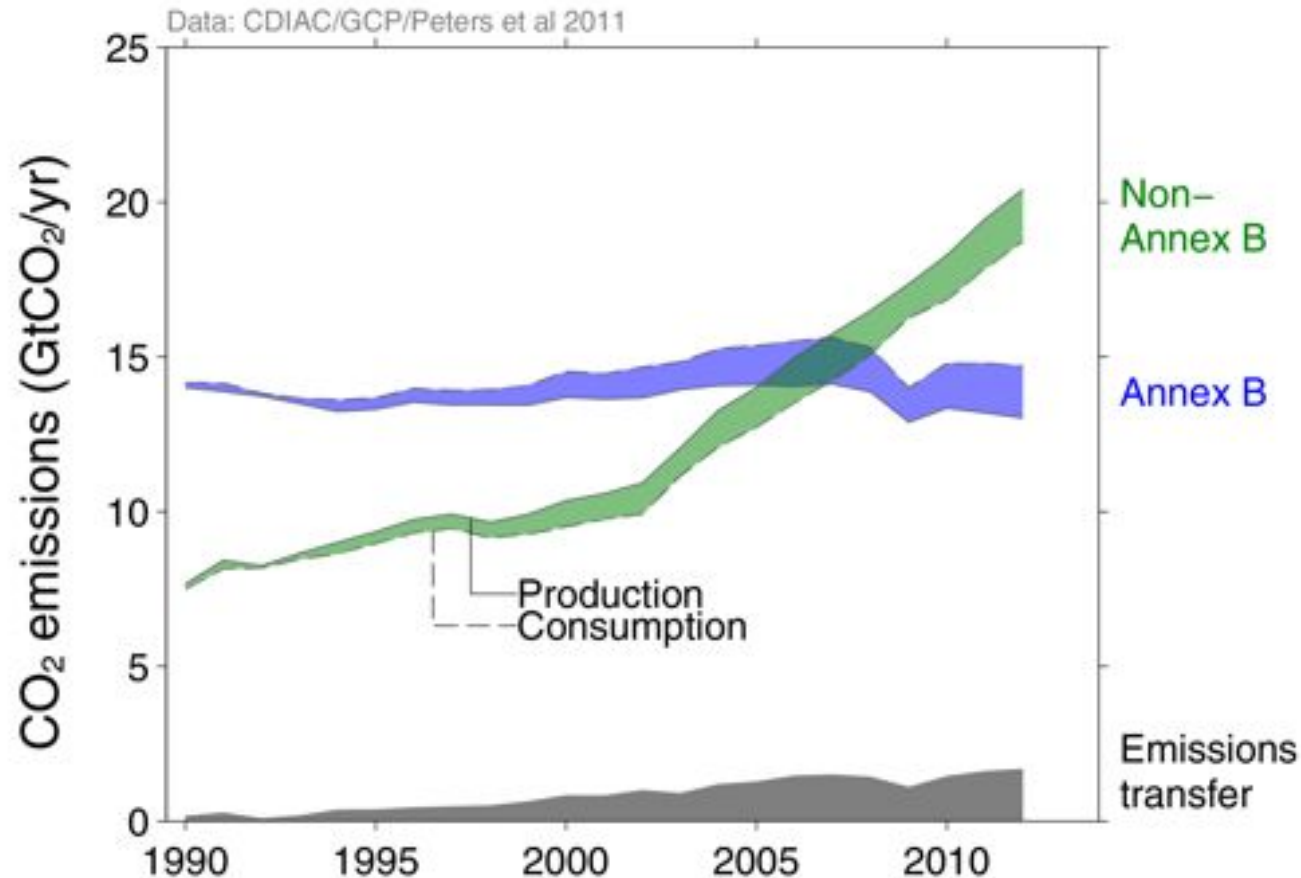
Corinne Le Quéré Tyndall Centre for Climate Change Research, Uni. of East Anglia, UK
Róisín Moriarty Tyndall Centre for Climate Change Research, Uni. of East Anglia, UK
Robbie Andrew Center for International Climate & Environmental Research - Oslo (CICERO), Norway
Glen Peters Center for International Climate & Environmental Research - Oslo (CICERO), Norway
Pierre Friedlingstein College of Engineering, Mathematics & Physical Sciences, Uni. of Exeter, UK
Mike Raupach Climate Change Institute, Australian National University, Australia
Pep Canadell Global Carbon Project, CSIRO Marine & Atmospheric Research, Australia
Philippe Ciais LSCE, CEA-CNRS-UVSQ, France
Steve Jones Tyndall Centre for Climate Change Research, Uni. of East Anglia, UK
Stephen Sitch College of Life & Environmental Sciences Uni. of Exeter, UK
Pieter Tans Nat. Oceanic & Atmospheric Admin., Earth System Research Laboratory (NOAA/ESRL), US
Almut Arneth Karlsruhe Inst. of Tech., Inst. Met. & Climate Res./Atmospheric Envir. Res., Germany
Tom Boden Carbon Dioxide Information Analysis Center (CDIAC), Oak Ridge National Laboratory, US
Laurent Bopp LSCE, CEA-CNRS-UVSQ, France
Yann Bozec CNRS, Station Biologique de Roscoff, Roscoff, France
Frédéric Chevallier LSCE, CEA-CNRS-UVSQ, France
Cathy Cosca Nat. Oceanic & Atmospheric Admin. & Pacific Mar. Env. Lab. (NOAA/PMEL), US
Harry Harris Climatic Research Unit (CRU), Uni. of East Anglia, UK
Mario Hoppema AWI Helmholtz Centre for Polar and Marine, Bremerhaven, Germany
Skee Houghton Woods Hole Research Centre (WHRC), US
Jo House Cabot Inst., Dept. of Geography, University of Bristol, UK
Atul Jain Dept. of Atmospheric Sciences, Uni. of Illinois, US
Truls Johannessen Geophysical Inst., Uni. of Bergen & Bjerknes Centre for Climate Research, Norway
Etsushi Kato Center for Global Envir. Research (CGER), Nat. Inst. for Envir. Studies (NIES), Japan
Ralph Keeling Uni. of California - San Diego, Scripps Institution of Oceanography, US
Kees Klein Goldewijk PBL Netherlands Envir. Assessment Agency & Utrecht Uni., Netherlands
Vassillis Kitidi Plymouth Marine Laboratory, Plymouth, UK
Charles Koven Earth Sciences Division, Lawrence Berkeley National Lab, US
Camilla Landa Geophysical Inst., Uni. of Bergen & Bjerknes Centre for Climate Research, Norway
Peter Landschützer Environmental Physics Group, IBPD, ETH Zürich, Switzerland
Andy Lenton CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia
Ivan Lima Woods Hole Oceanographic Institution (WHOI), Woods Hole, US
Gregg Marland Research Inst. for Environment, Energy & Economics, Appalachian State Uni., US
Jeremy Mathis Nat. Oceanic & Atmospheric Admin. & Pacific Mar. Env. Lab. (NOAA/PMEL), US
Nicholas Metzler Sorbonne Universités, CNRS, IRD, MNHN, LOCEAN/IPSL Laboratory, Paris, France
Yukihiro Nojiri Center for Global Envir. Research (CGER), Nat. Inst. for Envir. Studies (NIES), Japan
Are Olsen Geophysical Inst., Uni. of Bergen & Bjerknes Centre for Climate Research, Norway
Tsuneo Ono Fisheries Research Agency, Japan
Wouter Peters Department of Meteorology and Air Quality, Wageningen Uni., Netherlands
Benjamin Pfeil Geophysical Inst., Uni. of Bergen & Bjerknes Centre for Climate Research, Norway
Ben Poulter LSCE, CEA-CNRS-UVSQ, France

Pierre Regnier Dept. of Earth & Environmental Sciences, Uni. Libre de Bruxelles, Belgium
Christian Rödenbeck Max Planck Institute for Biogeochemistry, Germany
Shu Saito Marine Division, Global Environment & Marine Dept., Japan Meteorological Agency, Japan
Joe Sailsbury Ocean Processes Analysis Laboratory, Uni. of New Hampshire, US
Ute Schuster College of Engineering, Mathematics & Physical Sciences, Uni. of Exeter, UK
Jörg Schwinger Geophysical Inst., Uni. of Bergen & Bjerknes Centre for Climate Research, Norway
Roland Séférian CNRM-GAME, Météo-France/CNRS, Toulouse, France
Joachim Segschneider Max Planck Institute for Meteorology, Germany
Tobias Steinhoff GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
Beni Stocker Physics Inst., & Oeschger Centre for Climate Change Research, Uni. of Bern, Switzerland
Adrianna Sutton Joint Inst. for the Study of the Atm. & Ocean, Uni. of Washington & NOAA/PMEL, US
Taka Takahashi Lamont-Doherty Earth Observatory of Columbia University, Palisades, US
Brönte Tilbrook CSIRO Marine & Atm. Res., Antarctic Cli. & Ecosystems Co-op. Res. Centre, Australia
Guido van der Werf Faculty of Earth and Life Sciences, VU University Amsterdam, The Netherlands
Nicolas Viovy LSCE, CEA-CNRS-UVSQ, France
Ying-Ping Wang CSIRO Ocean and Atmosphere, Victoria, Australia
Rik Wanninkhof NOAA/AOML, US
Andy Wiltshire Met Office Hadley Centre, UK
Ning Zeng Department of Atmospheric and Oceanic Science, Uni. of Maryland, US
Friedlingstein et al. 2014, Raupach et al. 2014 & Fuss et al. 2014 (not already mentioned above)
J Rogelj Inst. for Atm. and Climate Science ETH Zürich, Switzerland & IIASA, Laxemburg, Austria
R Knutti Inst. for Atm. and Climate Science ETH Zürich, Switzerland
G Luderer Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany
M Schaefer Climate Analytics, Berlin, Germany & Env. Sys. Anal. Agency, Wageningen Uni., Netherlands
Detlef van Vuuren PBL Netherlands Env. Assess. Agency, Bilthoven & CISD, Utrecht Uni., Netherlands
Steven David Department of Earth System Science, University of California, California, US
Frank Jotzo Crawford School of Public Policy, Australian National University, Canberra, Australia
Sabine Fuss Mercator Research Institute on Global Commons & Climate Change, Berlin, Germany
Massimo Tavoni FEEM, CMCC & Politecnico di Milano, Milan, Italy
Rob Jackson School of Earth Sci., Woods Inst. for the Env., & Percourt Inst. for Energy, Stanford Uni, US.
Florian Kraxmer IIASA, Laxemburg, Austria
Naki Nakicenovic IIASA, Laxemburg, Austria
Ayyoob Sharifi National Inst. For Env. Studies, Onogawa, Tsukuba Ibaraki, Japan
Pete Smith Inst. Of Bio. & Env. Sciences, Uni. Of Aberdeen, Aberdeen, UK
Yoshiki Yamagata National Inst. For Env. Studies, Onogawa, Tsukuba Ibaraki, Japan
Science Committee | Atlas Engineers at LSCE, France (not already mentioned above)
Philippe Peylin | Anna Peregón | Patrick Brockmann | Vanessa Maigné | Pascal Evano
Atlas Designers WeDoData, France
Karen Bastien | Brice Terdjman | Vincent Le Jeune | Anthony Vessière
Communications Team
Asher Minns | Owen Gaffney | Lizzie Sayer | Michael Hoevel

Merci de votre attention

Attribution des émissions à la consommation de produits

The net emissions transfers into Annex B countries more than offsets the Annex B emission reductions achieved within the Kyoto Protocol



In Annex B, production-based emissions have had a slight decrease while consumption-based emissions have grown at 0.5% per year, and emission transfers have grown at 11% per year

Source: [CDIAC](#); [Peters et al 2011](#); [Le Quéré et al 2014](#); [Global Carbon Budget 2014](#)