Global Carbon Budget

2015

Published on 7 December 2015

PowerPoint version 1.02 (updated 25 January 2016)

Global Carbon Budget

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Fate of anthropogenic CO_2 (2005-2014 average)

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33.0 $GtCO_2$/yr
91%

9%
3.4 $GtCO_2$/yr

Sources = Sinks

16.0 $GtCO_2$/yr
44%

30%
10.9 $GtCO_2$/yr

26%
9.5 $GtCO_2$/yr

Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

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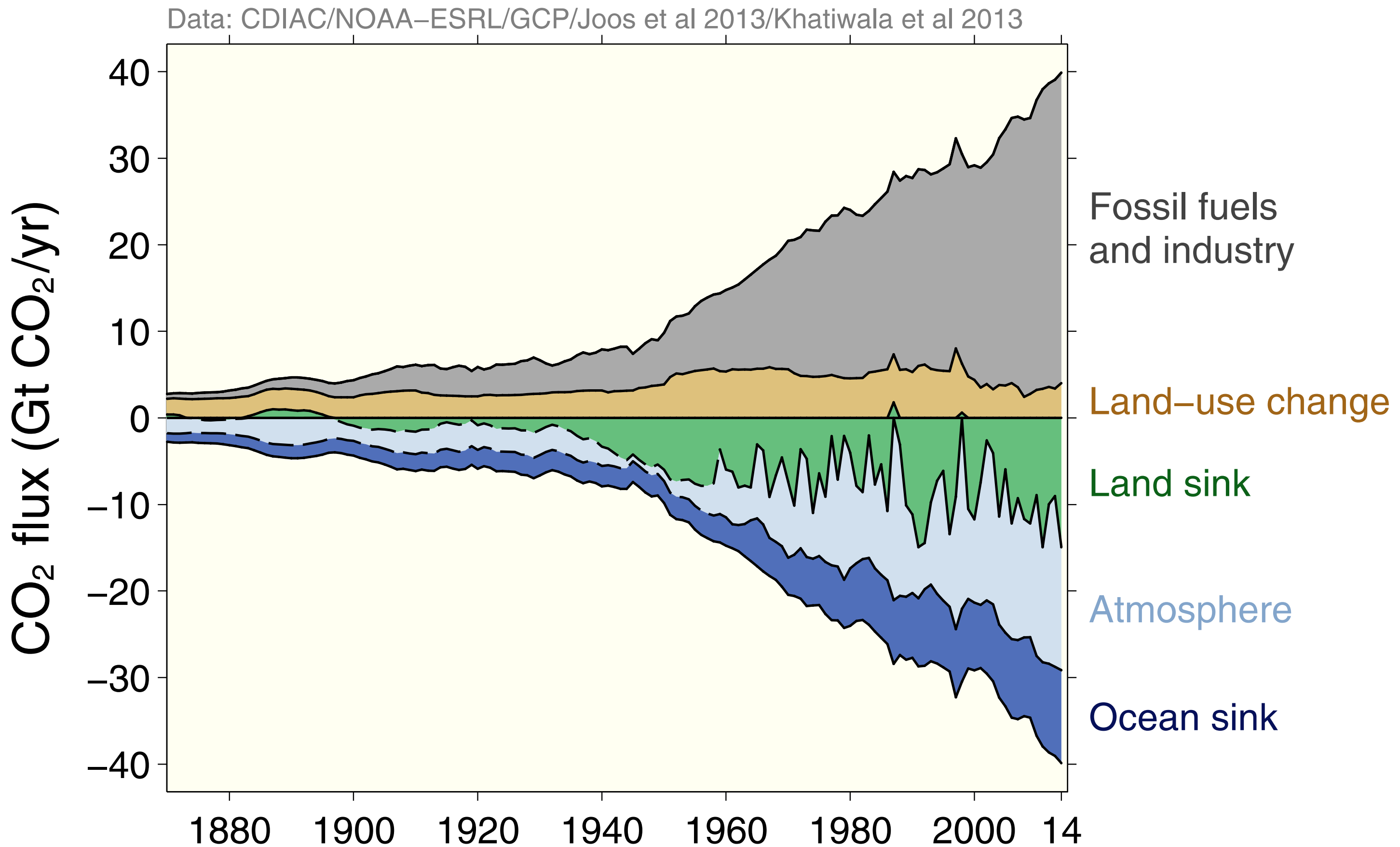
The carbon sources from fossil fuels, industry, and land use change emissions are balanced by the atmosphere and carbon sinks on land and in the ocean



Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Joos et al 2013; Khatiwala et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

Acknowledgements

The work presented here has been possible thanks to the enormous observational and modeling efforts of the institutions and networks below

Atmospheric CO_2 datasets
NOAA/ESRL (Dlugokencky et al. 2015)
Scripps (Keeling et al. 1976)

Fossil Fuels and Industry
CDIAC (Boden et al. 2015)
USGS, 2015
UNFCCC, 2015
BP, 2015

Consumption Emission
Peters et al. 2011

Land-Use Change
Houghton et al. 2012
van der Werf et al. 2010

Atmospheric inversions
CarbonTracker (Peters et al. 2010)
Jena CarboScope (Rödenbeck et al. 2003)
MACC (Chevallier et al. 2005)

Land models
CLM4-5BGC | ISAM | JSBACH | JULES | LPJ-GUESS | LPJ | LPJmL | OCNv1.r240 | ORCHIDEE | VEGAS | VISIT

Ocean models
NEMO-PlankTOM5 | NEMO-PISCES (IPSL) | CCSM-BEC | MICOM-HAMMOC | MPIOM-HAMMOC | NEMO-PISCES (CNRM) | CSIRO | MITgem-REcoM2

SOCAT
SOCATv3 (Bakker et al. 2014, 2015)

Ocean Data products
Jena CarboScope (Rödenbeck et al. 2014)
Landschützer et al. 2015

Full references provided in Le Quéré et al 2015

Atmospheric Concentration

Atmospheric concentration

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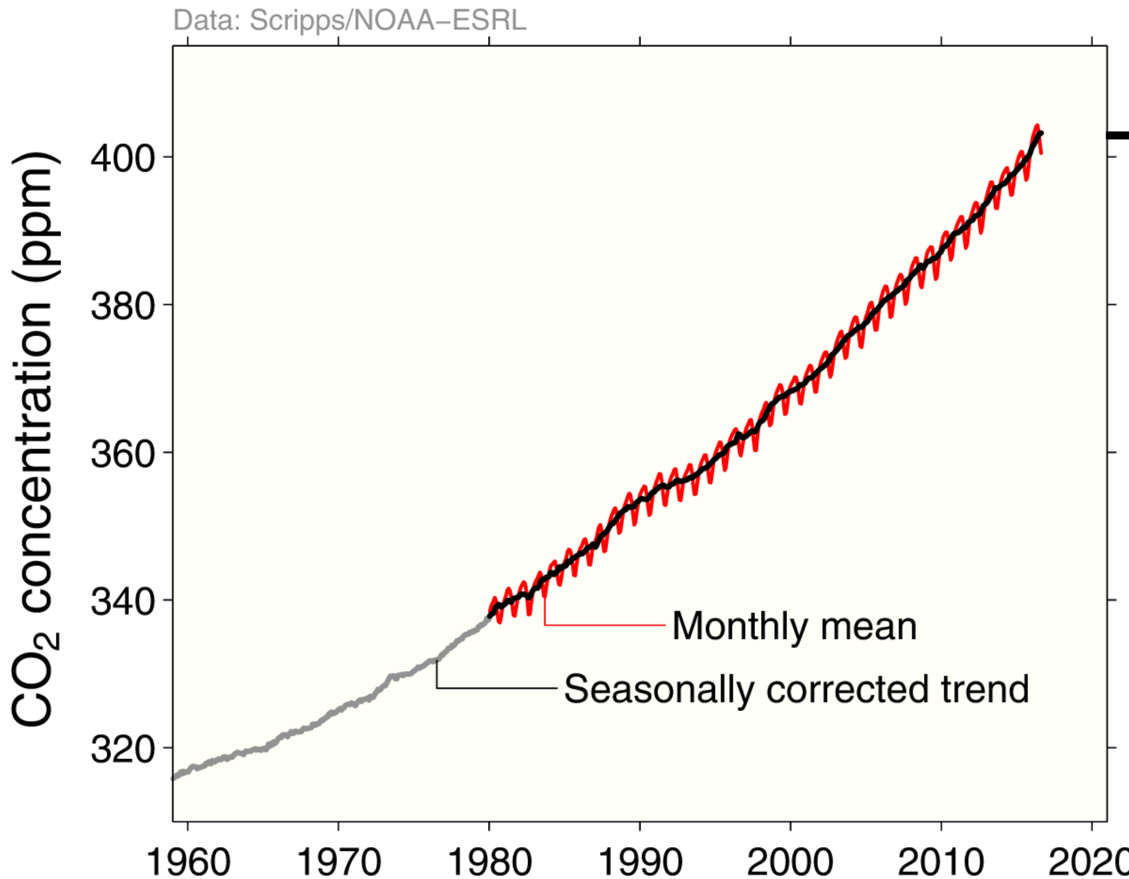
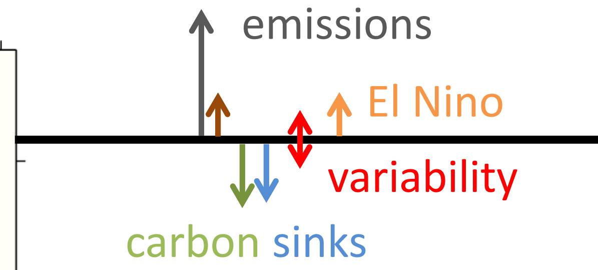
The global CO_2 concentration increased from ~277ppm in 1750 to 399ppm in 2015 (up 44%)

2016 will be the first full year with concentration above 400ppm





Drivers of recent changes (carbon-cycle feedback)

CO_2 driver of long-term changes

Globally averaged surface atmospheric CO_2 concentration. Data from: NOAA-ESRL after 1980; the Scripps Institution of Oceanography before 1980 (harmonised to recent data by adding 0.542ppm)

Source: NOAA-ESRL; Scripps Institution of Oceanography; Global Carbon Budget 2015

Drivers of CO_2 concentrations

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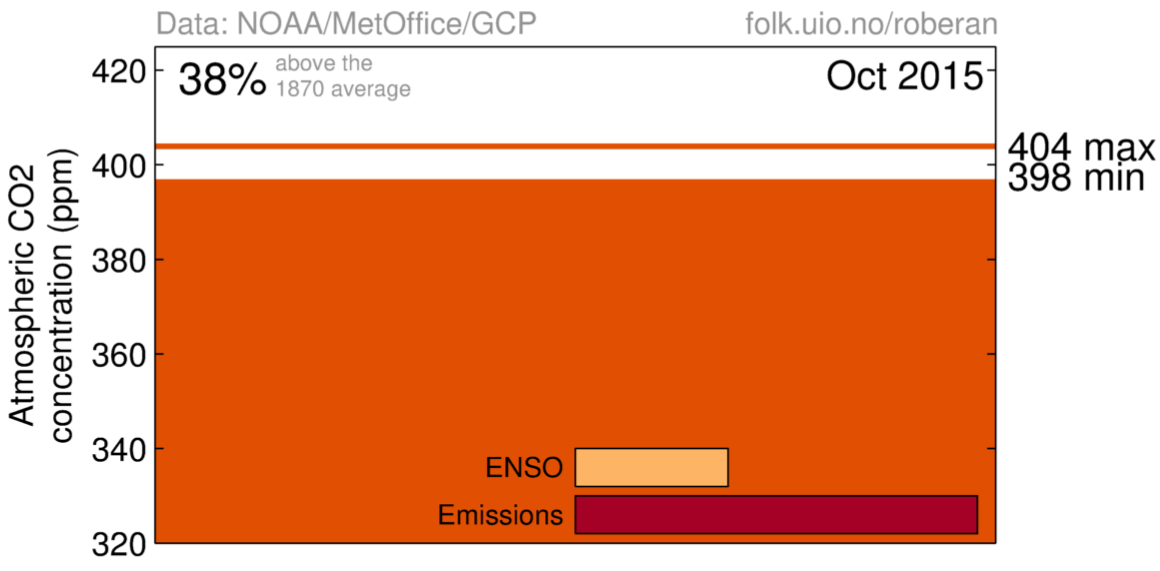
The CO_2 concentration is driven by changes in:
the seasonal cycle (short), volcanos (short), ENSO (interannual), CO_2 emissions (long)



Source: http://folk.uio.no/roberan/t/CO2_drivers.shtml

Sinks

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Ocean sink

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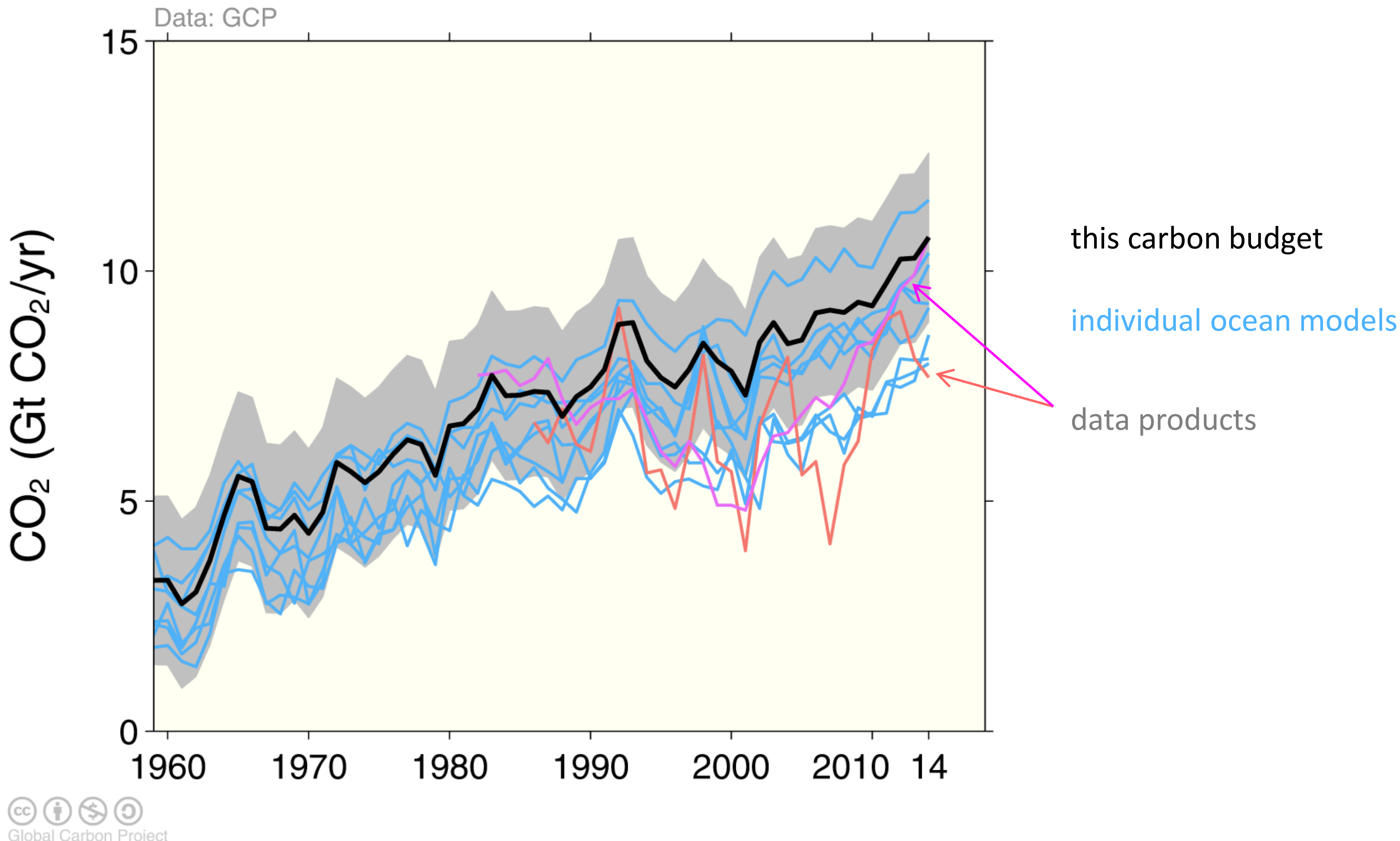
Ocean carbon sink continues to increase
9.5±1.8 $GtCO_2$/yr for 2005-2015 and 10.7±1.8 $GtCO_2$/yr in 2014

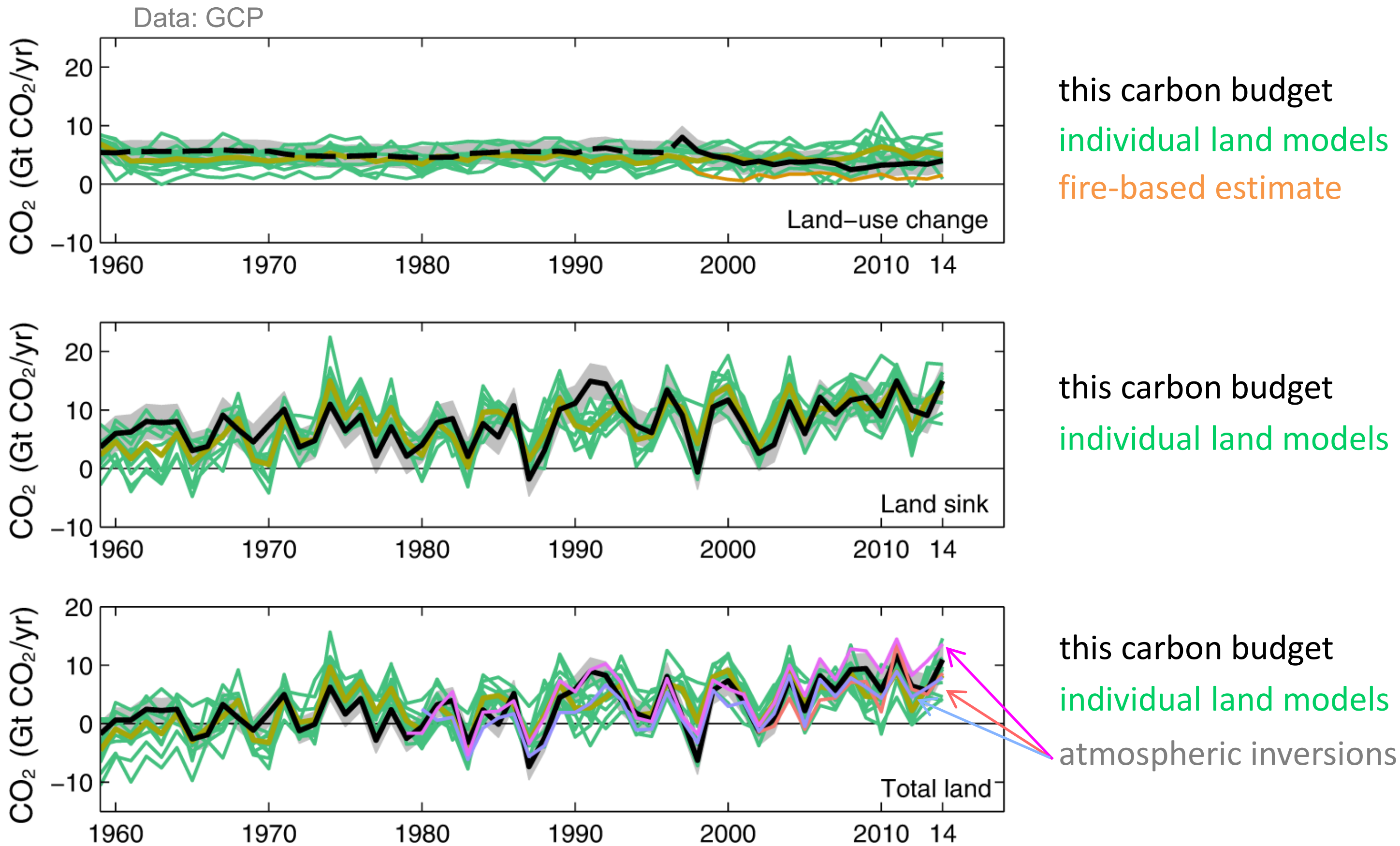


Source: [Le Quéré et al 2015](); [Global Carbon Budget 2015]()

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. (2015).

Terrestrial sink

The residual land sink is increasing with time to 15.0±2.9 $GtCO_2$/yr in 2014, large variability
Total CO_2 fluxes on land (including land-use change) are constrained by atmospheric inversions

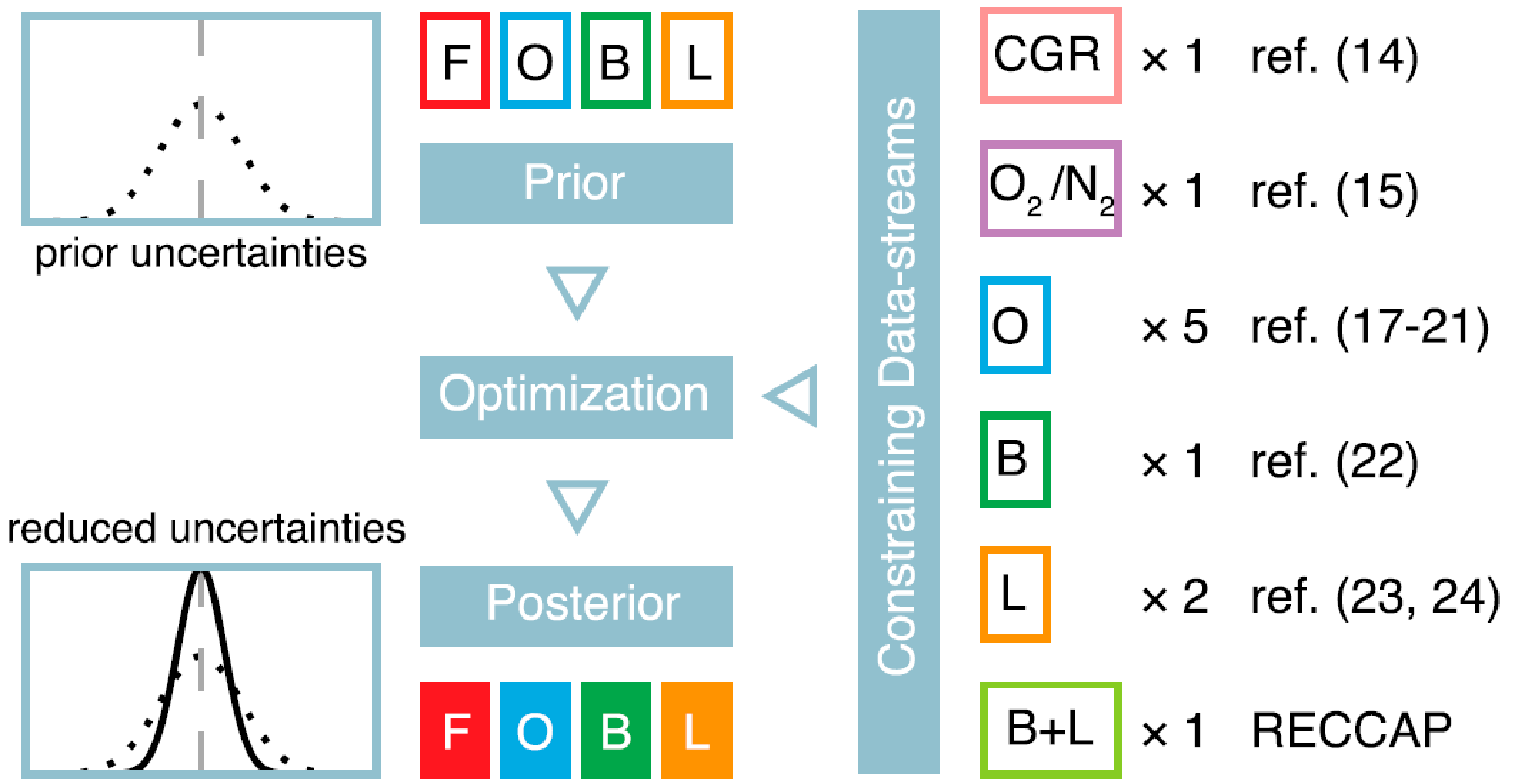


Source: Le Quéré et al 2015; Global Carbon Budget 2015

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).

Reducing uncertainty through Bayesian analysis

Bayesian optimization decreases the uncertainty in the land sink by 41%, ocean sink by 46%, land-use change by 47%, while fossil fuel uncertainty is marginally improved



Source: Li et al 2016

Emission sources

Emissions from fossil fuel use and industry

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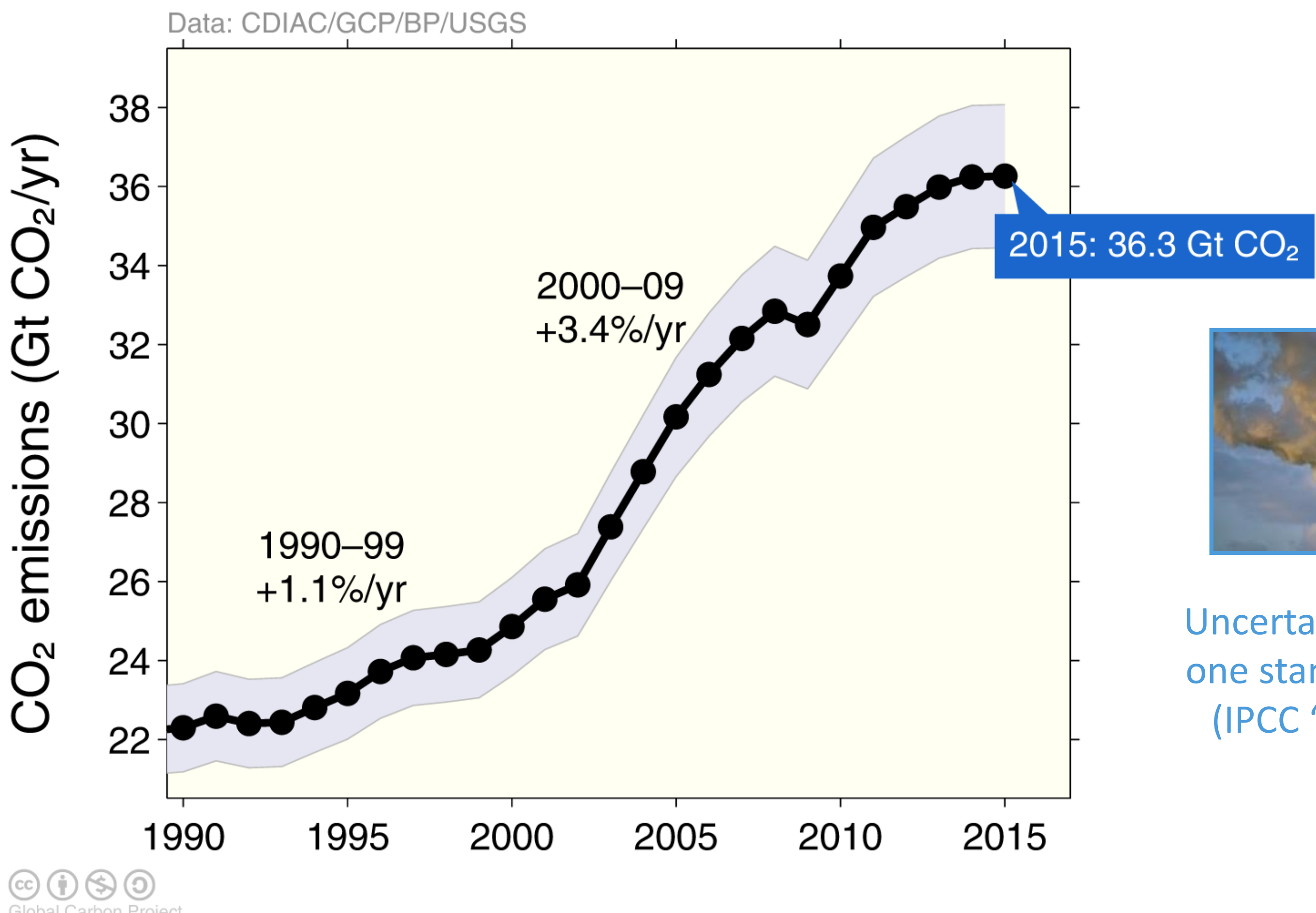
Global emissions from fossil fuel and industry: 36.3 ± 1.8 GtCO_2 in 2015, 63% over 1990



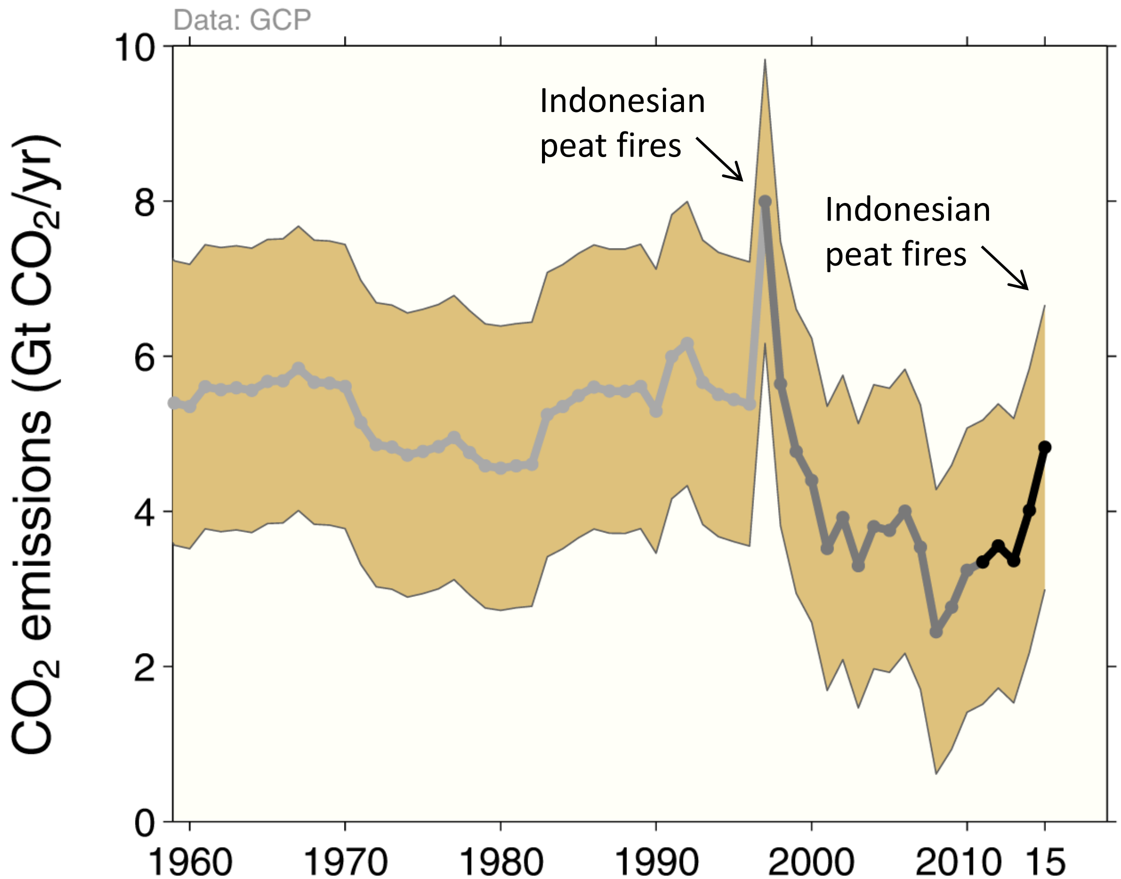
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

Estimates for 2014, and 2015 are preliminary

Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Land-use change emissions

Global land-use change emissions are estimated as 3.5 ± 1.8 $GtCO_2$ during 2006–2015
The data suggests a general decrease in emissions since 1990, but a recent uptick



Three different estimation methods have been used, indicated here by different shades of grey
Land-use change also emits CH_4 and N_2O which are not shown here
Source: Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2015; Global Carbon Budget 2014

Total global emissions by source

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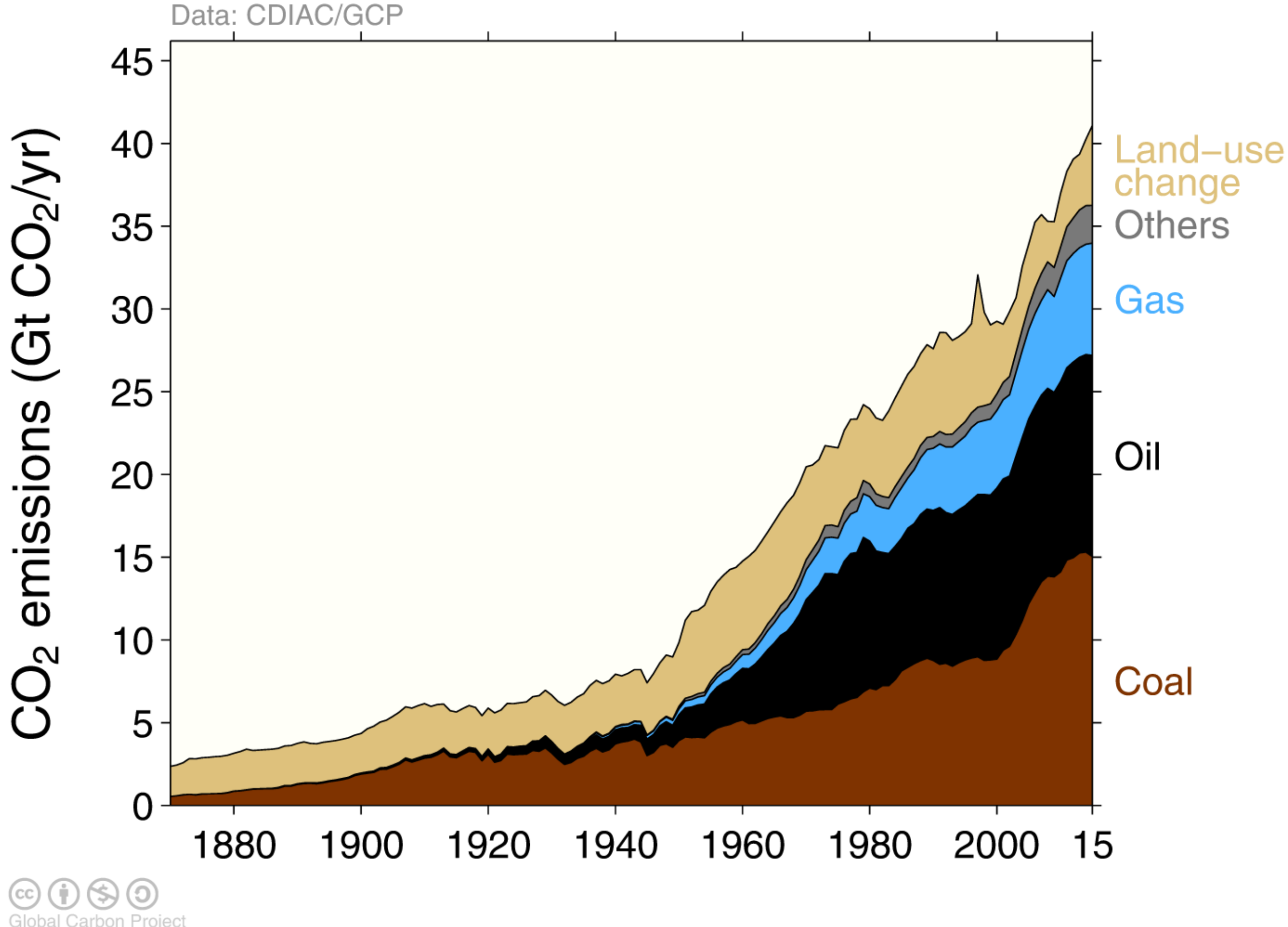
Land-use change was the dominant source of annual CO_2 emissions until around 1950



Others: Emissions from cement production and gas flaring

Source: CDIAC; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

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Top fossil fuel emitters

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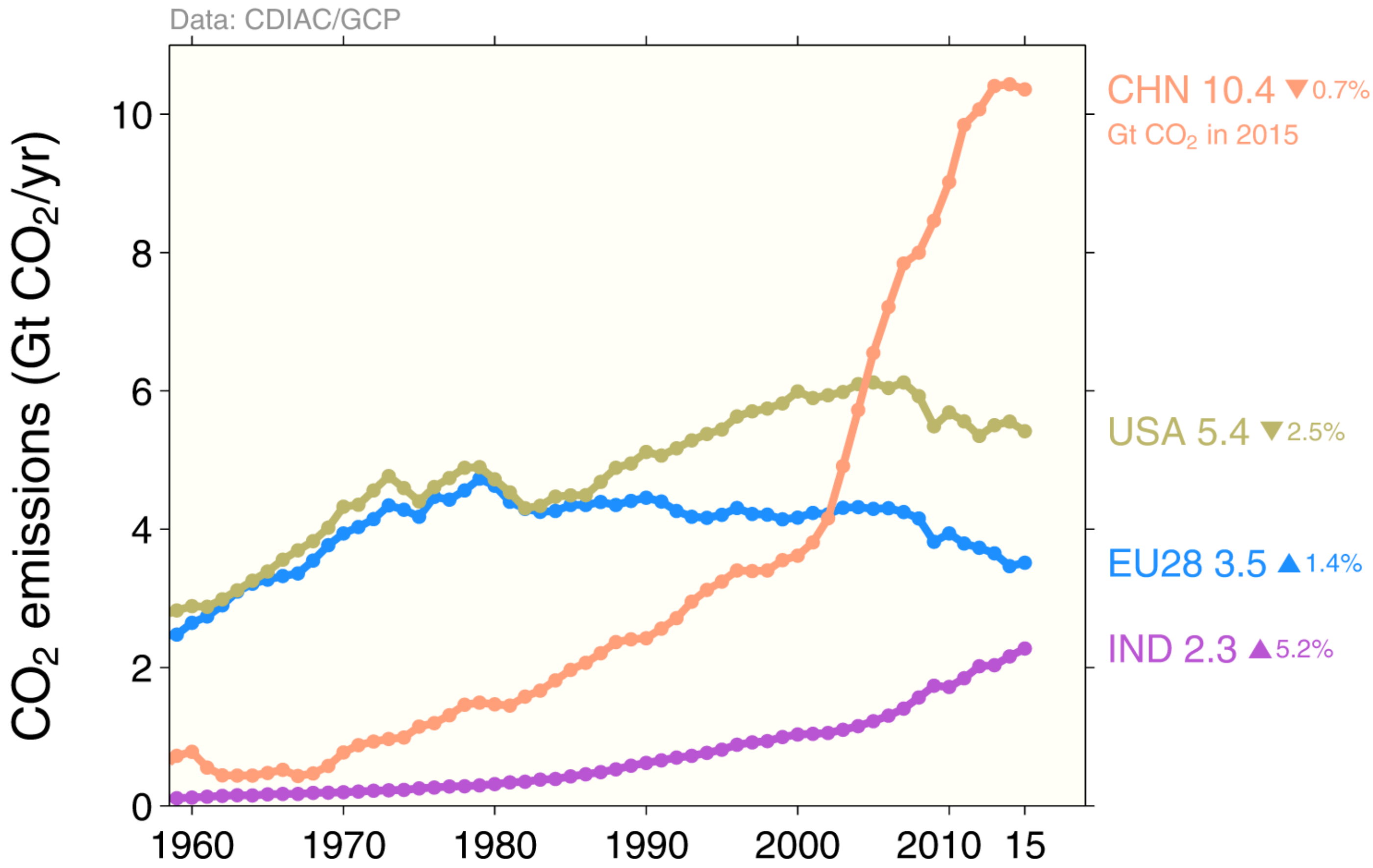
The top four emitters in 2014 covered 59% of global emissions
China (29%), United States (15%), EU28 (10%), India (6%)



Bunker fuels are used for international transport is 3.1% of global emissions
Statistical differences are between the global estimates and sum of national totals is 1.2% of global emissions
Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

The future

Observed emissions and emissions scenarios

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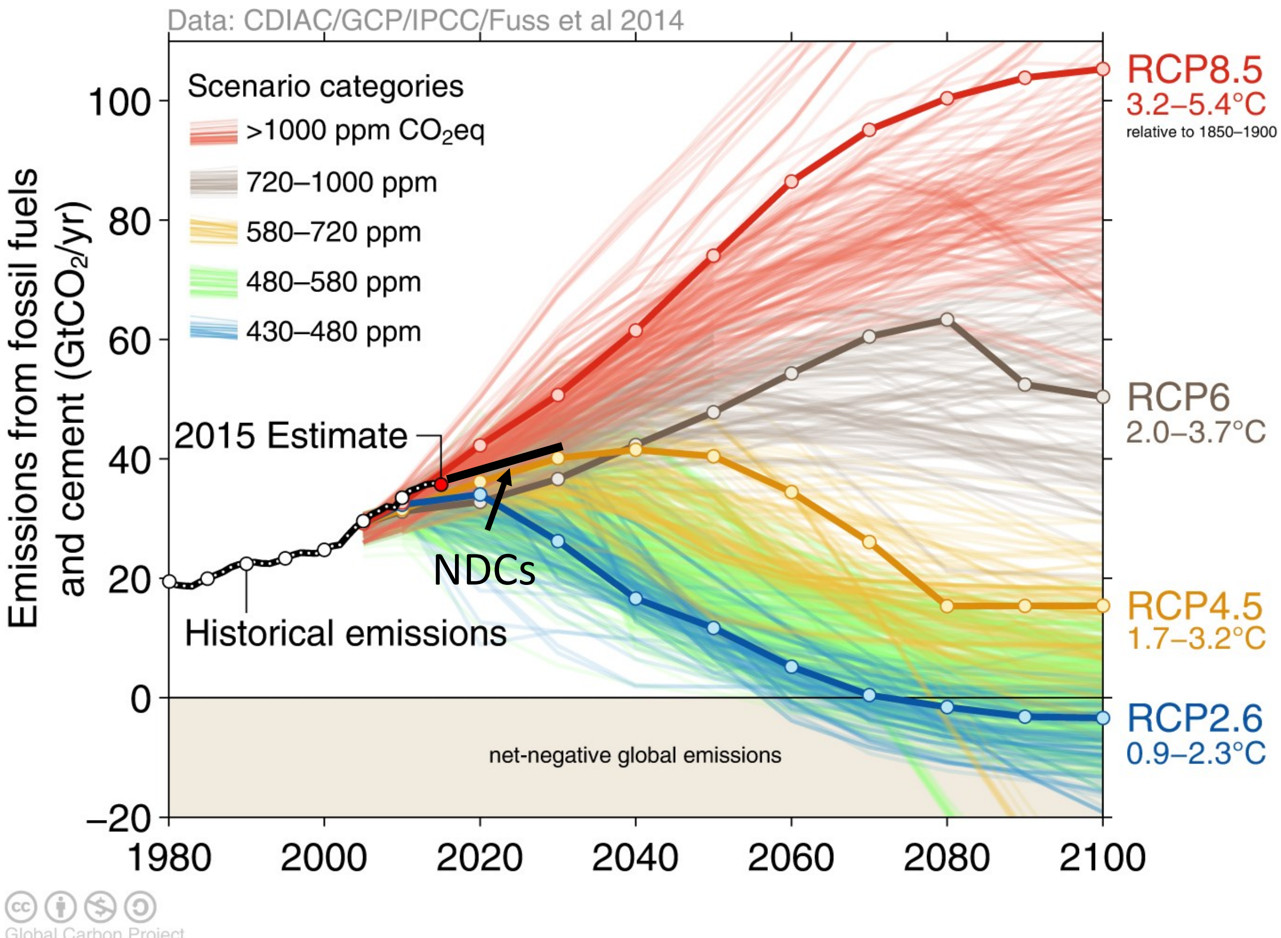
The emission pledges submitted to the Paris climate summit avoid the worst effects of climate change (red), most studies suggest a likely temperature increase of about 3°C (brown)



Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2015

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Carbon budgets from 1870 for a 66% chance

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The carbon budget from 1870 for a 66% change are:
2250 billion tonnes CO_2 for 1.5°C and 2900 billion tonnes CO_2 for 2°C

<1.5°C	<2.0°C
2250 $GtCO_2$	2900 $GtCO_2$

"Exceedance Budgets" (Rogelj et al 2016) , rounded to the nearest 50$GtCO_2$
Source: IPCC AR5 SYR (Table 2.2); Le Quéré et al 2015; Global Carbon Budget 2015

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Carbon budgets from 2017 for a 66% chance

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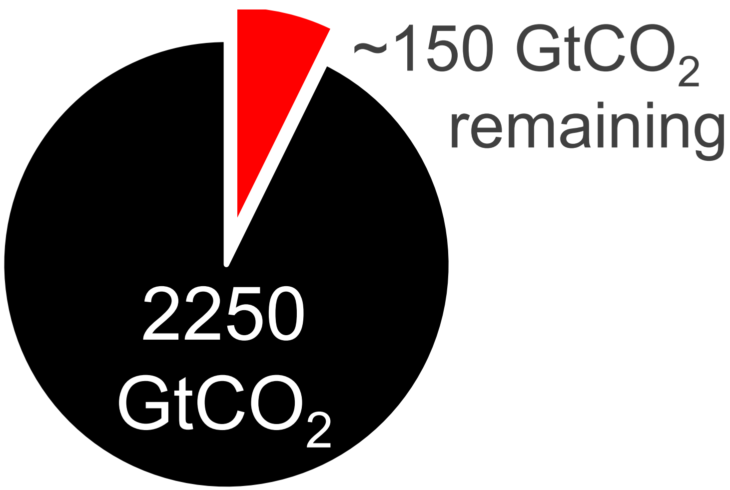
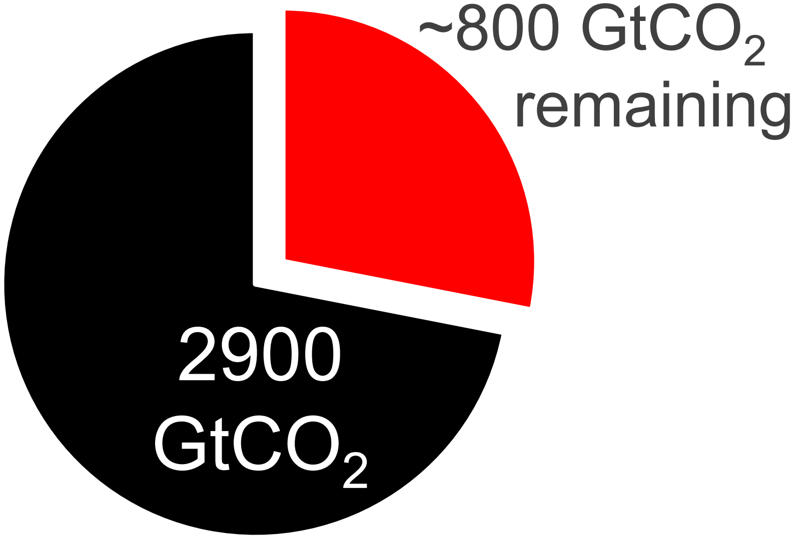
The carbon budget from 2017 for a 66% change are:
2250 billion tonnes CO_2 for 1.5°C and 2900 billion tonnes CO_2 for 2°C

<1.5°C



Large uncertainty,
incomplete assessment

<2.0°C



"Exceedance Budgets" (Rogelj et al 2016), rounded to the nearest 50$GtCO_2$
Source: IPCC AR5 SYR (Table 2.2); Le Quéré et al 2015; Global Carbon Budget 2015

Cumulative CO_2 emissions and temperature

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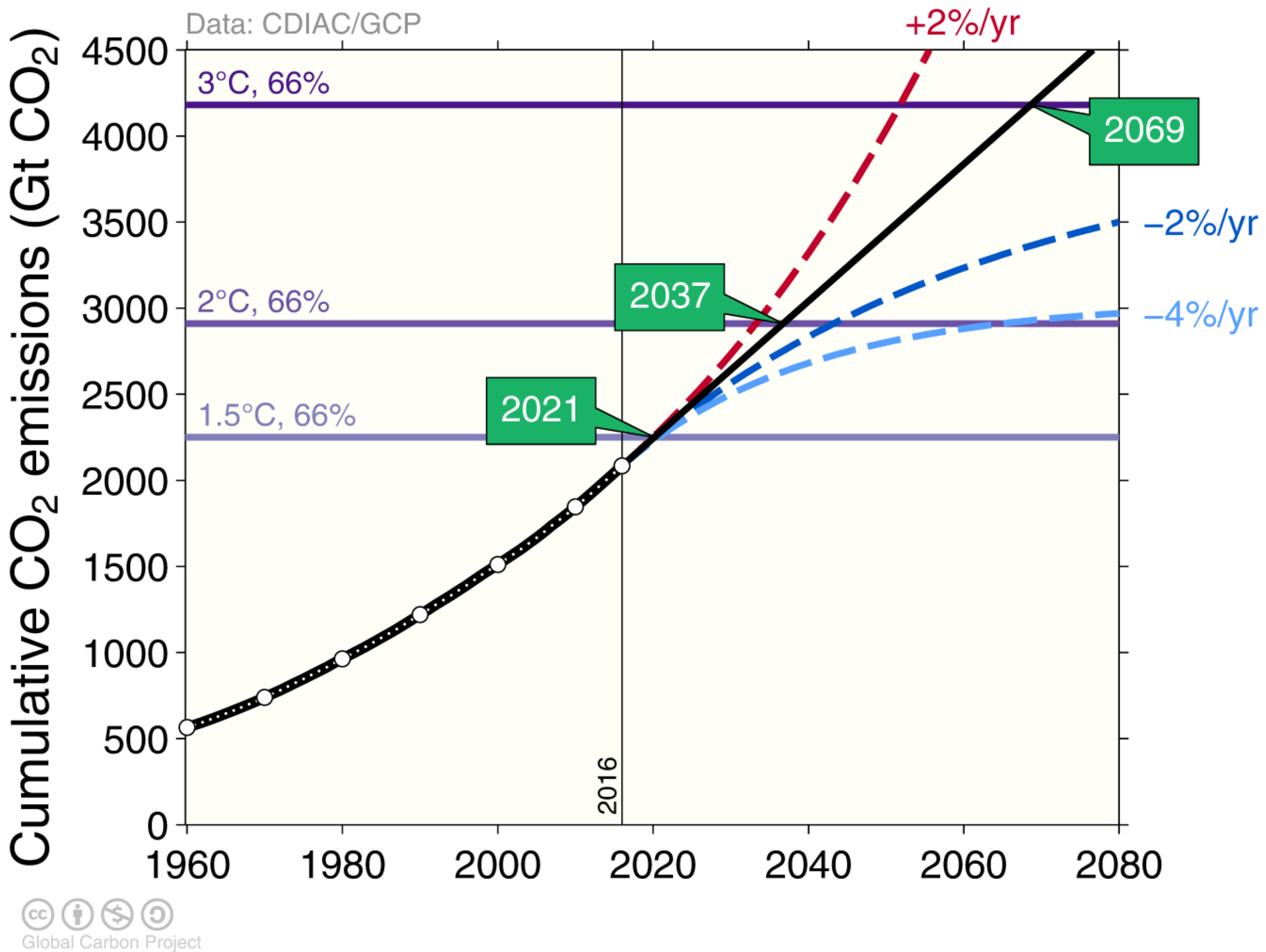
Cumulative global CO_2 emissions from fossil fuels, industry, and land use change and four simplified future pathways compared to probability of exceeding different temperatures

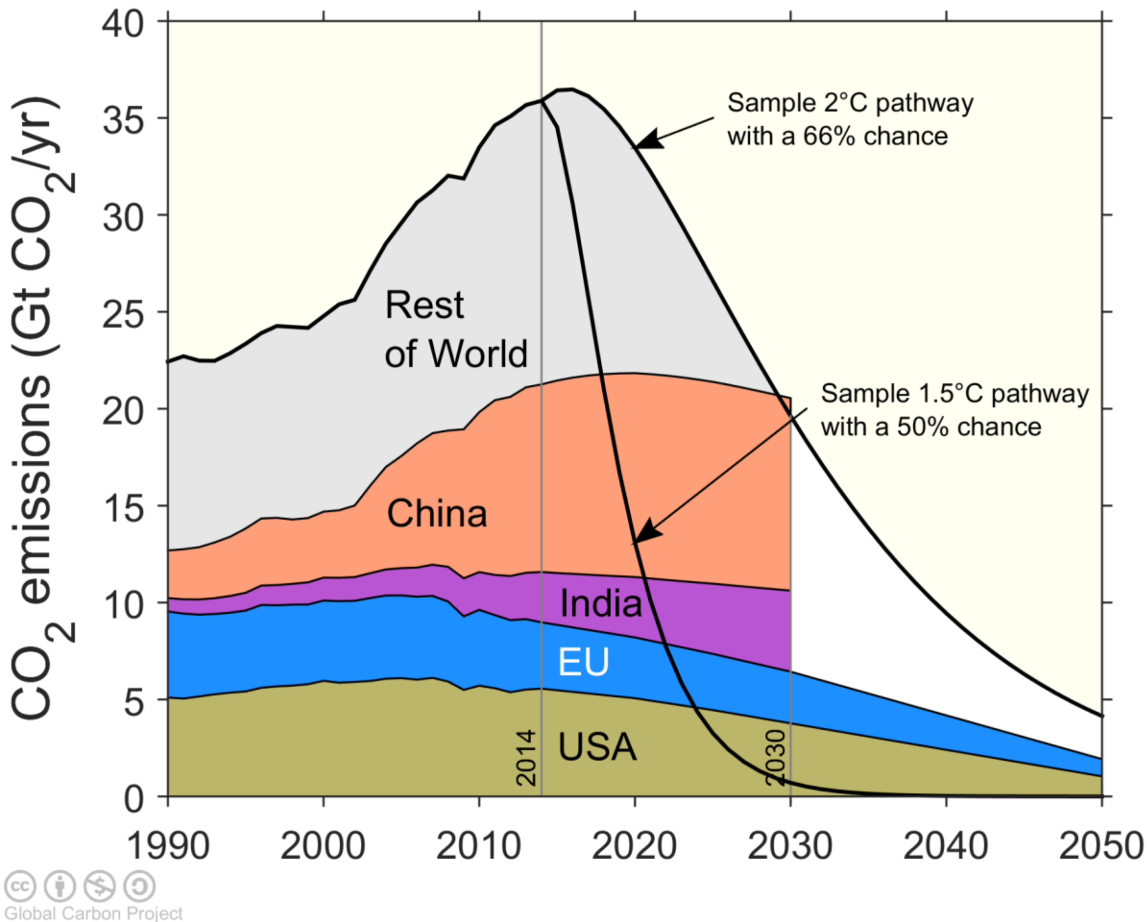


The green boxes show the year that the exceedance budgets are exceeded assuming constant 2016 emission levels

Source: Jackson et al 2015b; Global Carbon Budget 2015

The emission pledges of the top-4 emitters

The emission pledges from the US, EU, China, and India leave little room for other countries to emit in a 2°C emission budget (66% chance), no chance in 1.5°C budget



Source: Peters et al 2015; Global Carbon Budget 2015

Side-event: Monday 14 November, 16:45-18:15 (Arabian)

Carbon Budget 2016

Free access to data (updated annually)

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Earth Syst. Sci. Data, 7, 349–396, 2015
www.earth-syst-sci-data.net/7/349/2015/
doi:10.5194/essd-7-349-2015

Open Access Earth System Science Data

Global Carbon Budget 2015

C. Le Quéré[1], R. Moriarty[1], R. M. Andrew[2], J. G. Canadell[3], S. Sitch[4], J. I. Korsbakken[2], P. Friedlingstein[5], G. P. Peters[2], R. J. Andres[6], T. A. Boden[6], R. A. Houghton[7], J. I. House[8], R. F. Keeling[9], P. Tans[10], A. Arneth[11], D. C. E. Bakker[12], L. Barbero[13,14], L. Bopp[15], J. Chang[15], F. Chevallier[15], L. P. Chini[16], P. Ciais[15], M. Fader[17], R. A. Feely[18], T. Gkritzalis[19], I. Harris[20], J. Hauck[21], T. Ilyina[22], A. K. Jain[23], E. Kato[24], V. Kitidis[25], K. Klein Goldewijk[26], C. Koven[27], P. Landschützer[28], S. K. Lauvset[29], N. Lefèvre[30], A. Lenton[31], I. D. Lima[32], N. Metzl[30], F. Millero[33], D. R. Munro[34], A. Murata[35], J. E. M. S. Nabel[22], S. Nakaoka[36], Y. Nojiri[36], K. O'Brien[37], A. Olsen[38,39], T. Ono[40], F. F. Pérez[41], B. Pfeil[38,39], D. Pierrot[13,14], B. Poulter[42], G. Rehder[43], C. Rödenbeck[44], S. Saito[45], U. Schuster[4], J. Schwinger[29], R. Séférian[46], T. Steinhoff[47], B. D. Stocker[48,49], A. J. Sutton[37,18], T. Takahashi[50], B. Tilbrook[51], I. T. van der Laan-Luijkx[52,53], G. R. van der Werf[54], S. van Heuven[55], D. Vandemark[56], N. Viovy[15], A. Wiltshire[57], S. Zaehle[44], and N. Zeng[58]

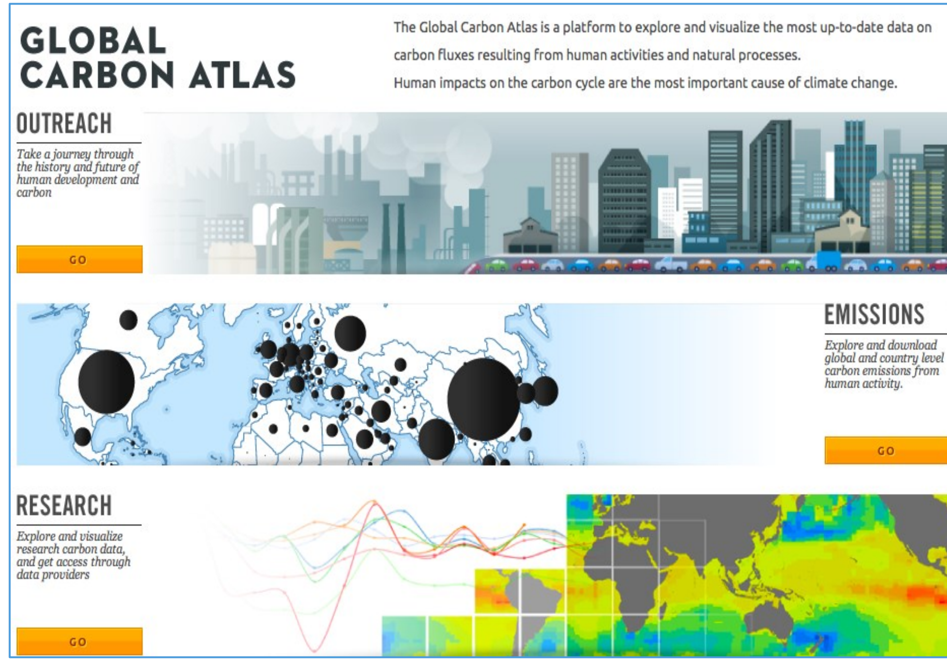
Earth Syst. Sci. Data Discuss., doi:10.5194/essd-2016-25, 2016
Manuscript under review for journal Earth Syst. Sci. Data
Published: 20 June 2016

Open Access Earth System Science Data Discussions

The Global Methane Budget: 2000-2012

Marielle Saunois[1], Philippe Bousquet[1], Ben Poulter[2], Anna Peregon[1], Philippe Ciais[1], Josep G. Canadell[3], Edward J. Dlugokencky[4], Giuseppe Etiope[5], David Bastviken[6], Sander Houweling[7,8], Greet Janssens-Maenhout[9], Francesco N. Tubiello[10], Simona Castaldi[11,12], Robert B. Jackson[13], Mihai Alexe[9], Vivek K. Arora[14], David J. Beerling[15], Peter Bergamaschi[9], Donald R. Blake[16], Gordon Brailsford[17], Victor Brovkin[18], Lori Bruhwiler[4], Cyril Crevoisier[19], Patrick Crill[20], Charles Curry[21], Christian Frankenberg[22], Nicola Gedney[23], Lena Höglund-Isaksson[24], Misa Ishizawa[25], Akihiko Ito[25], Fortunat Joos[26], Heon-Sook Kim[25], Thomas Kleinen[18], Paul Krummel[27], Jean-François Lamarque[28], Ray Langenfelds[27], Robin Locatelli[1], Toshinobu Machida[25], Shamil Maksyutov[25], Kyle C. McDonald[29], Julia Marshall[30], Joe R. Melton[31], Isamu Morino[25], Simon O'Doherty[32], Frans-Jan W. Parmentier[33], Prabir K. Patra[34], Changhui Peng[35], Shushi Peng[1], Glen P. Peters[36], Isabelle Pison[1], Catherine Prigent[37], Ronald Prinn[38], Michel Ramonet[1], William J. Riley[39], Makoto Saito[25], Ronny Schroeder[29,40], Isobel J. Simpson[16], Renato Spahni[26], Paul Steele[27], Atsushi Takizawa[41], Brett F. Thornton[20], Hanqin Tian[42], Yasunori Tohjima[25], Nicolas Viovy[1], Apostolos Voulgarakis[43], Michiel van Weele[44], Guido van der Werf[45], Ray Weiss[46], Christine Wiedinmyer[28], David J. Wilton[15], Andy Wiltshire[47], Doug Worthy[48], Debra B. Wunch[49], Xiyan Xu[39], Yukio Yoshida[25], Bowen Zhang[42], Zhen Zhang[2,50], and Qiuan Zhu[51]

More information, data sources and data files:
www.globalcarbonproject.org



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