Emerging research findings: How to achieve the long-term climate-change goal of 2^{o}C?

Rik Leemans, Martin Rice, Ghassem Asnar, Bruce Campbell, Pep Canadell, Anantha K. Duraiappah Rob Jackson, Anne Larigauderie, Sybil Seitzinger, Barbara Solich and Ruben Zondervan

UNFCCC-SBSTA meeting Bonn

19-5-2012

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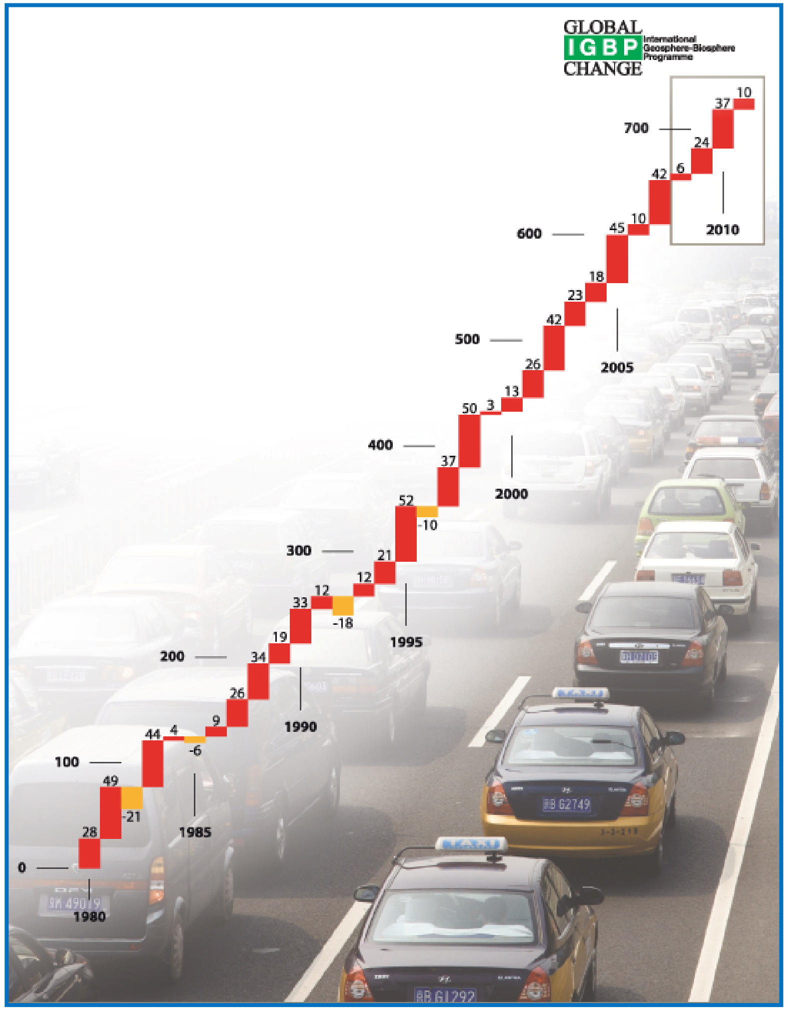
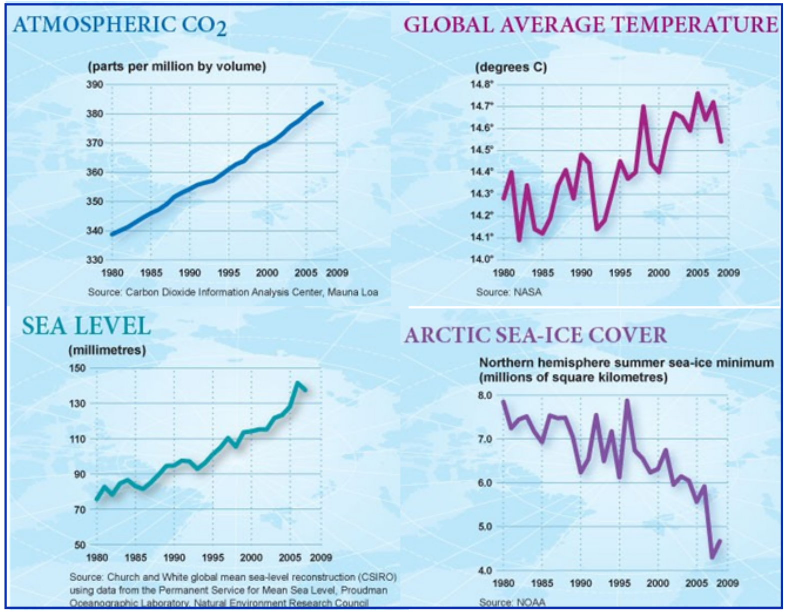
The Global Environmental Change Programmes and ESSP provide timely policy relevant information and scientific understanding to deal with climate change.





This is illustrated by the IGBP climate-change index, which It combines key indicators for CO_2, temperature, sea level and sea ice. The index rises steadily and its change is unequivocal, it is global, and, significantly, it is in one direction.

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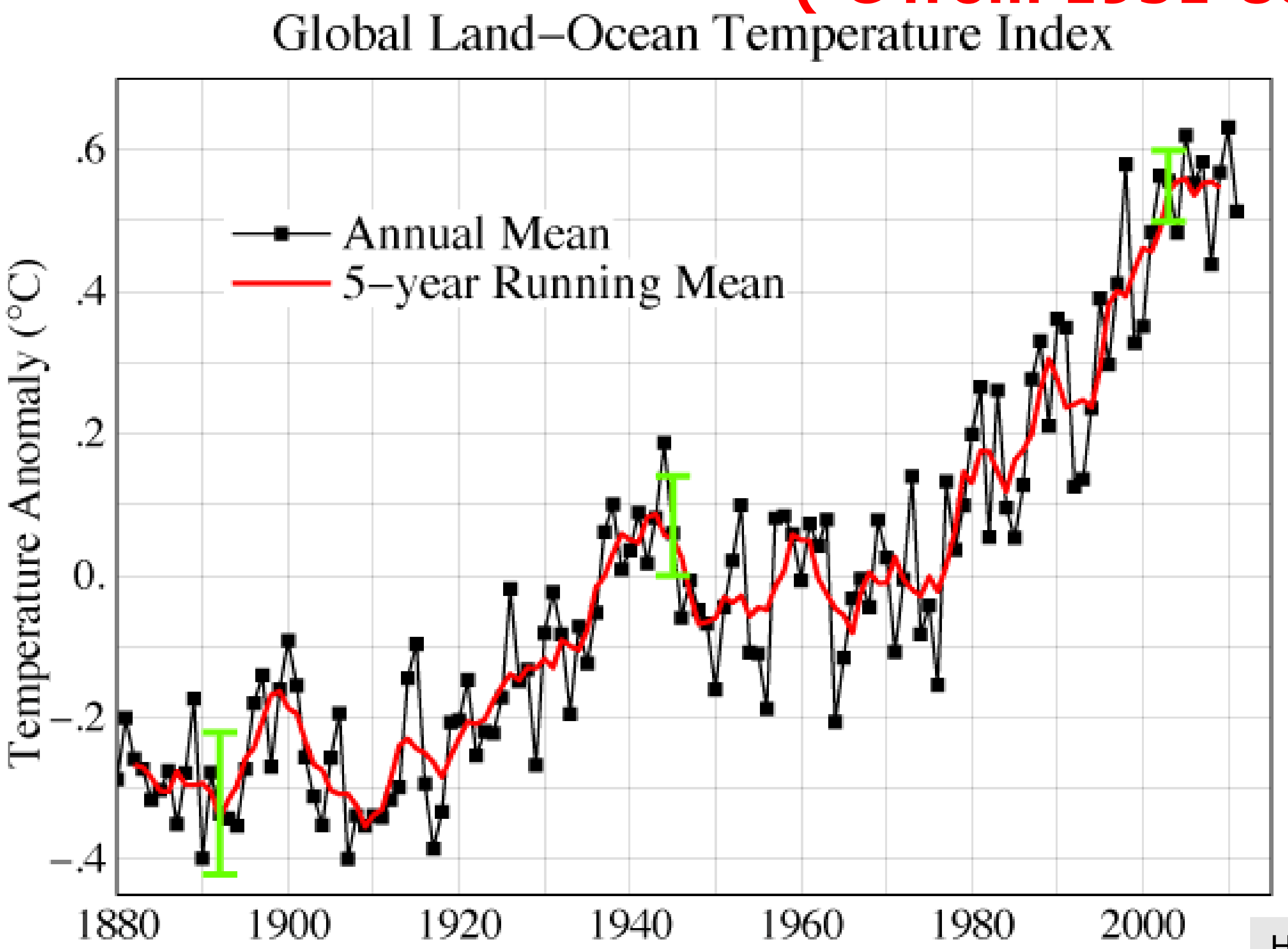
Globally averaged increase in temperature anomaly
(ºC from 1951-80)



2011 was the 11th warmest since records began in 1850. This is in spite of a cooling La Niña.

Hansen, J., R. Ruedy, M. Sato, and K. Lo. 2010. Global surface temperature change. Review Geophysics 48:RG4004.

A new assessment of global temperatures: The Berkeley Earth Surface Temperature Study (BEST)

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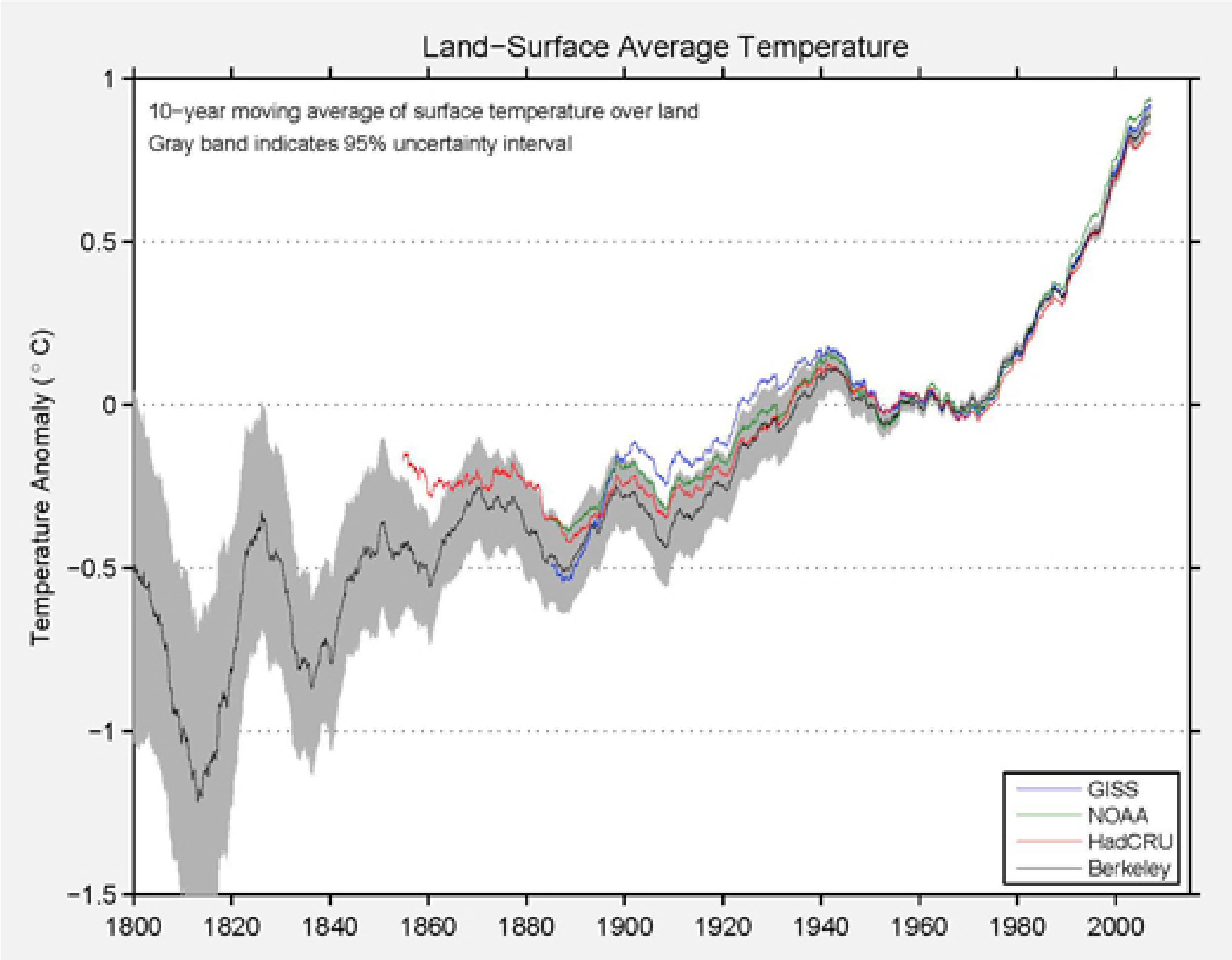
The most important indicator of global warming, the temperature record has been criticized for the choice of stations and the methods for correcting systematic errors. The BEST study did a new analysis of the surface temperature record to address these criticisms. They used over 39,000 unique stations and advanced interpolations schemes.

BEST found similar warming and patterns, comparable to all other studies.



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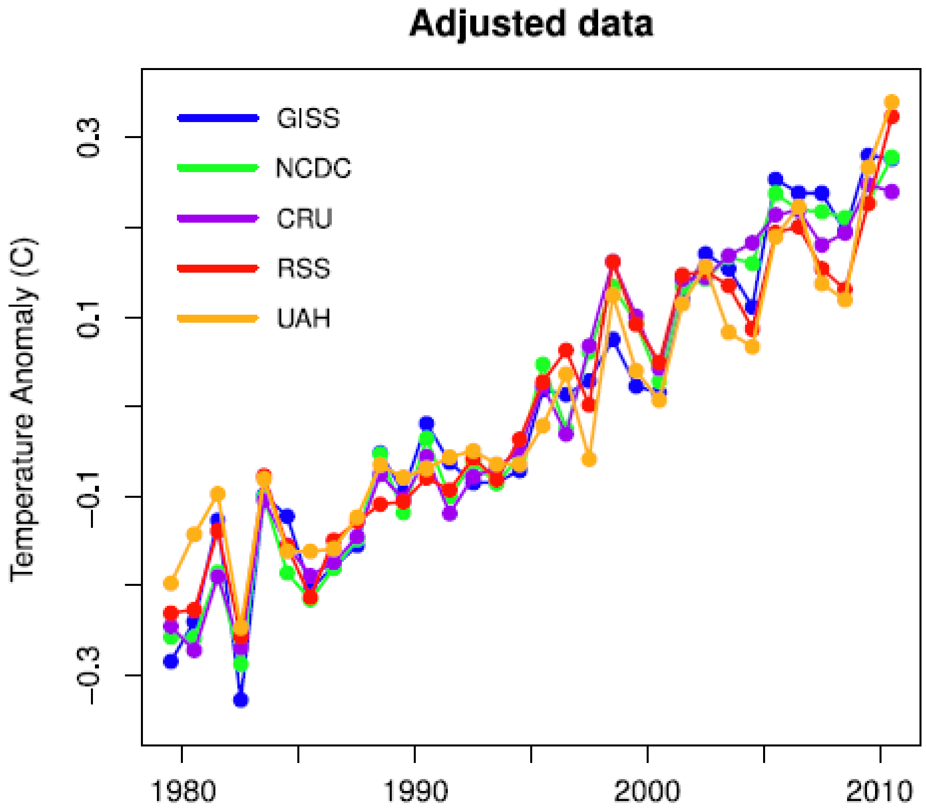
Removing non-GHG factors from temperature records



IOP Publishing — Environmental Research Letters
Environ. Res. Lett. 6 (2011) 044022 (8pp) — doi:10.1088/1748-9326/6/4/044022

Global temperature evolution 1979–2010

Grant Foster[1] **and Stefan Rahmstorf**[2]

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Online at stacks.iop.org/ERL/6/044022

Abstract
We analyze five prominent time series of global temperature (over land and ocean) for their common time interval since 1979: three surface temperature records (from NASA/GISS, NOAA/NCDC and HadCRU) and two lower-troposphere (LT) temperature records based on satellite microwave sensors (from RSS and UAH). All five series show consistent global warming trends ranging from 0.014 to 0.018 K yr^{-1}. When the data are adjusted to remove the estimated impact of known factors on short-term temperature variations (El Niño/southern oscillation, volcanic aerosols and solar variability), the global warming signal becomes even more evident as noise is reduced. Lower-troposphere temperature responds more strongly to El Niño/southern oscillation and to volcanic forcing than surface temperature data. The adjusted data show warming at very similar rates to the unadjusted data, with smaller probable errors, and the warming rate is steady over the whole time interval. In all adjusted series, the two hottest years are 2009 and 2010.

Keywords: climate, global warming, El Niño/southern oscillation, solar cycles

1. Introduction

The prime indicator of global warming is, by definition, global mean temperature. Time series of global temperature show a well-known rise since the early 20th century and most notably since the late 1970s. This widespread temperature increase is corroborated by a range of warming-related impacts: shrinking mountain glaciers, accelerating ice loss from ice sheets in Greenland and Antarctica, shrinking Arctic sea ice extent, sea level rise, and a number of well-documented biospheric changes like earlier bud burst and blossoming times in spring (IPCC 2007).

Despite the unequivocal signs of global warming, some public (and to a much lesser extent, scientific) debate has arisen over discrepancies between the different global temperature records, and over the exact magnitude of, and possible recent changes in, warming rates (Peterson and Baringer 2009). To clarify these issues, we analyze the five leading quasi-global temperature data sets up to and including the year 2010. We focus on the period since 1979, since satellite microwave data are available and the warming trend since that time is at least approximately linear.

Much of the variability during that time span can be related to three known causes of short-term temperature variations: El Niño/southern oscillation (ENSO, an internal quasi-oscillatory mode of the ocean–atmosphere system) (Newell and Weare 1976, Angell 1981, Trenberth *et al* 2002), volcanic eruptions (IPCC 2007), and solar variations including the solar cycle (IPCC 2007, Lean and Rind 2008, 2009). This complicates both comparison and trend analysis of the temperature records. Since independent measures of these variations are available, their influence can to a large extent be removed, leading to adjusted, less noisy global temperature data sets. Therefore we will remove the influence of these factors on the temperature data sets, not only to isolate the longer-term changes, but also to identify whether different data sets show meaningful differences in their response to these factors. The influence of exogenous factors will be approximated by multiple regression of temperature against ENSO, volcanic influence, total solar irradiance (TSI) and a linear time trend to approximate the global warming that has occurred during the 32 years subject to analysis.

Lean and Rind (2008) performed a multivariate correlation analysis for the period 1889–2006 using the CRU temperature data (Brohan *et al* 2006), and found that they could explain 76% of the temperature variance over this period from anthropogenic forcing, El Niño, volcanic aerosols and solar variability. The long-term warming trend almost exclusively stems from anthropogenic forcing. They

1748-9326/11/044022+08$33.00

When the estimated impact of El Niño/SO, volcanic aerosols and solar variability are removed, the global warming signal becomes even more evident. The adjusted data show warming at very similar rates to the unadjusted data with smaller probable errors but the warming rate is steady over the whole time interval. The two hottest years are 2009 and 2010.

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Proof of intensification of the global water cycle

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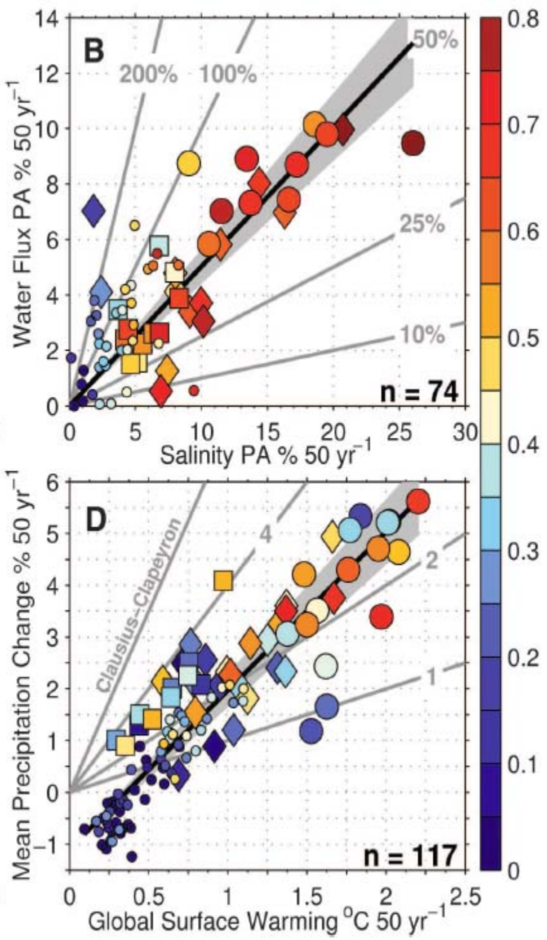

Fundamental thermodynamics and climate models suggest that dry regions will become drier and wet regions will become wetter in response to warming. Our 50-year observed global surface salinity changes, combined with changes from global climate models, present **robust** evidence of an intensified global water cycle at a rate of 8±5% per degree warming. This rate is double the response projected by climate models and suggests that a 16 to 24% intensification of the global water cycle will occur in a future 2° to 3° warmer world.

REPORTS

Ocean Salinities Reveal Strong Global Water Cycle Intensification During 1950 to 2000

Paul J. Durack,[1,2,3,4*] Susan E. Wijffels,[1,3] Richard J. Matear[1,3]

Fundamental thermodynamics and climate models suggest that dry regions will become drier and wet regions will become wetter in response to warming. Efforts to detect this long-term response in sparse surface observations of rainfall and evaporation remain ambiguous. We show that ocean salinity patterns express an identifiable fingerprint of an intensifying water cycle. Our 50-year observed global surface salinity changes, combined with changes from global climate models, present robust evidence of an intensified global water cycle at a rate of 8 ± 5% per degree of surface warming. This rate is double the response projected by current-generation climate models and suggests that a substantial (16 to 24%) intensification of the global water cycle will occur in a future 2° to 3° warmer world.

www.sciencemag.org SCIENCE VOL 336 27 APRIL 2012 455

Durack, P. J., S. E. Wijffels, and R. J. Matear. 2012. Ocean Salinities Reveal Strong Global Water Cycle Intensification During 1950 to 2000. Science 336:455-458.

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Minimum arctic sea ice extent (September)

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extents. While the record low 2007 had
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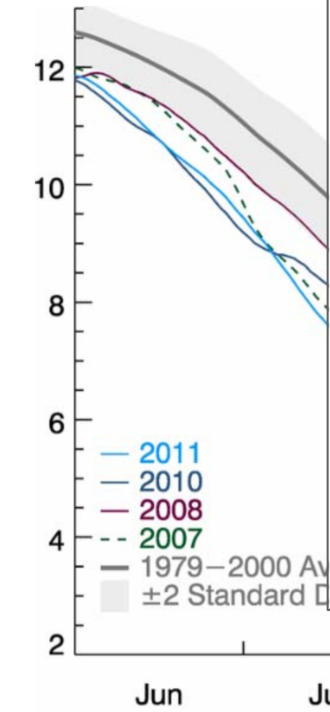

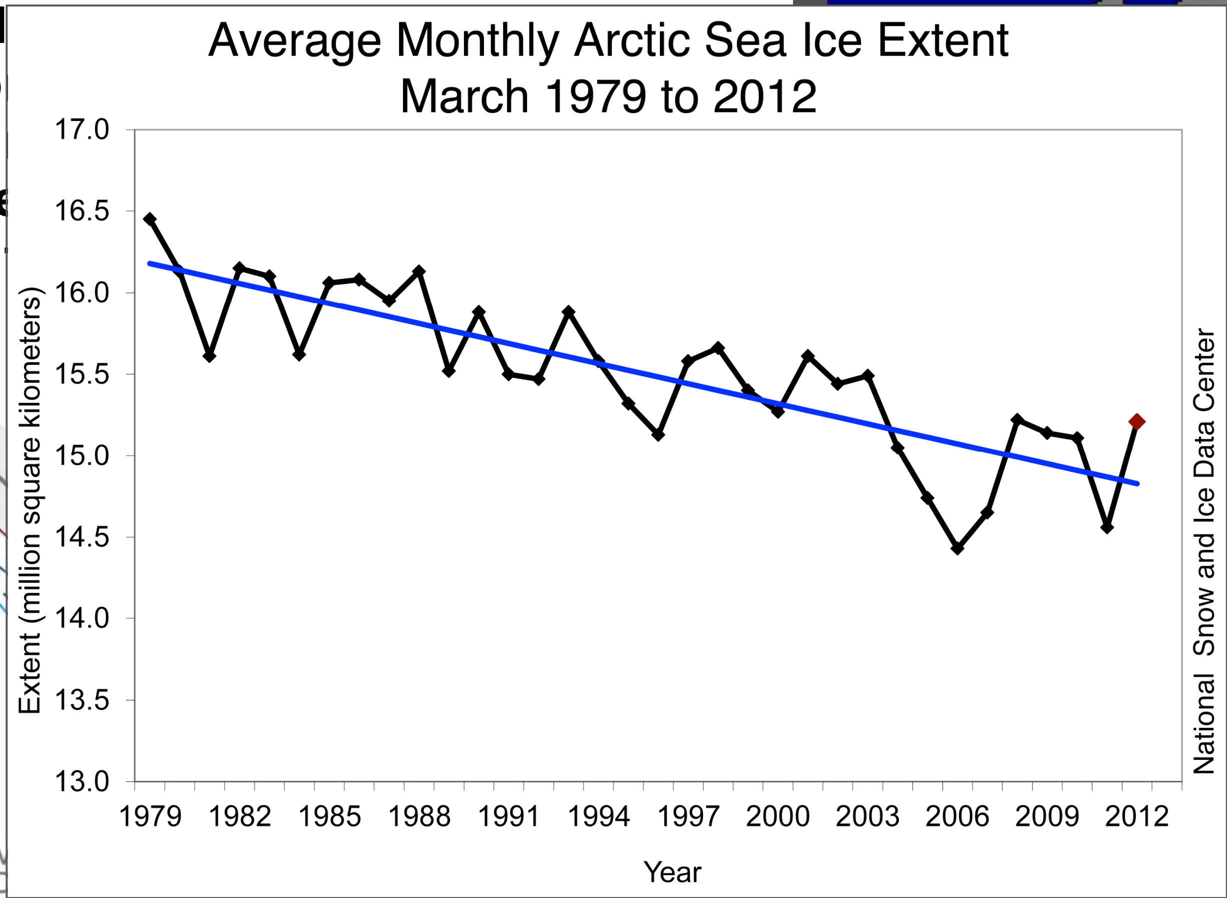

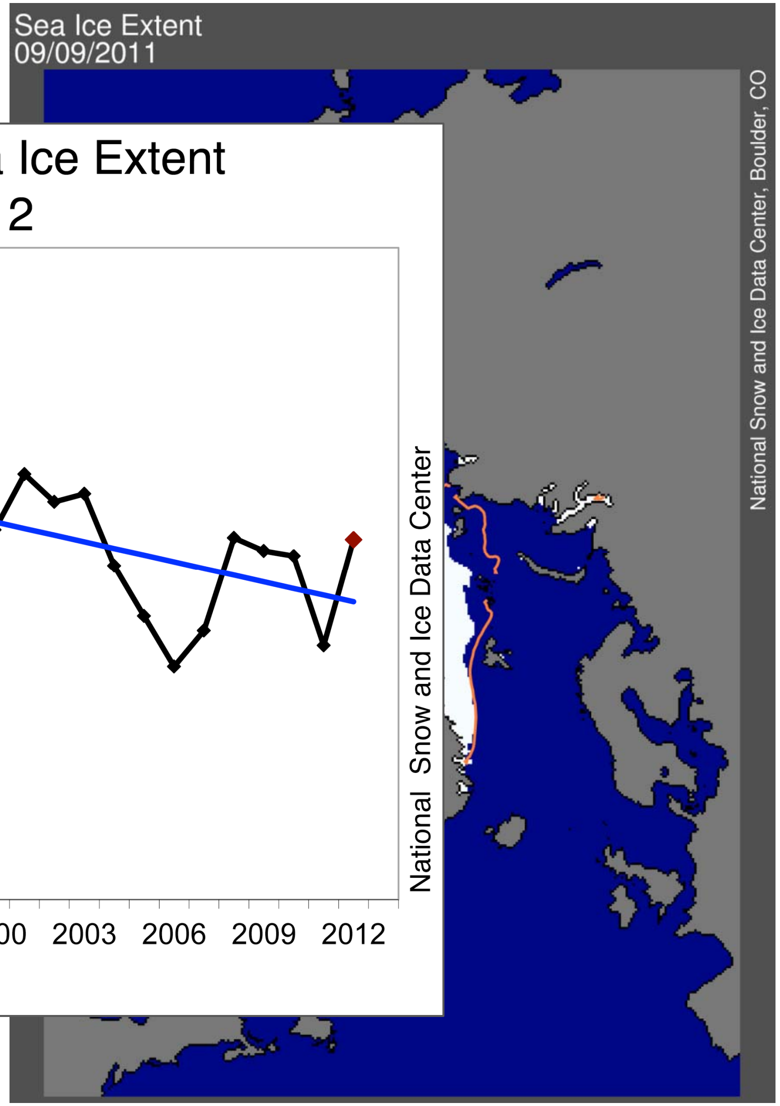

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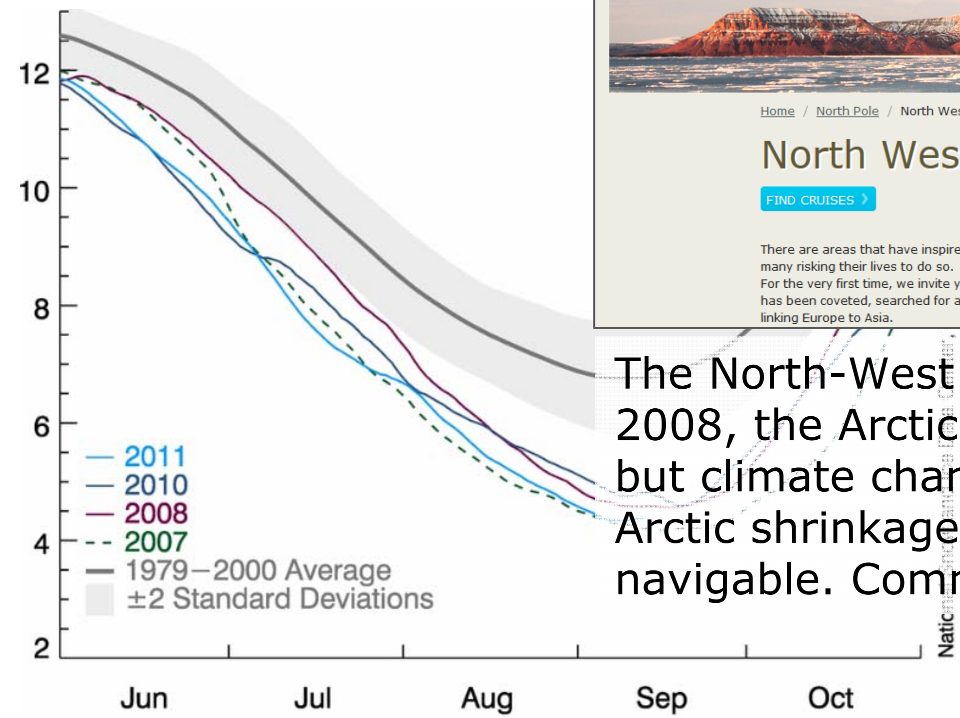
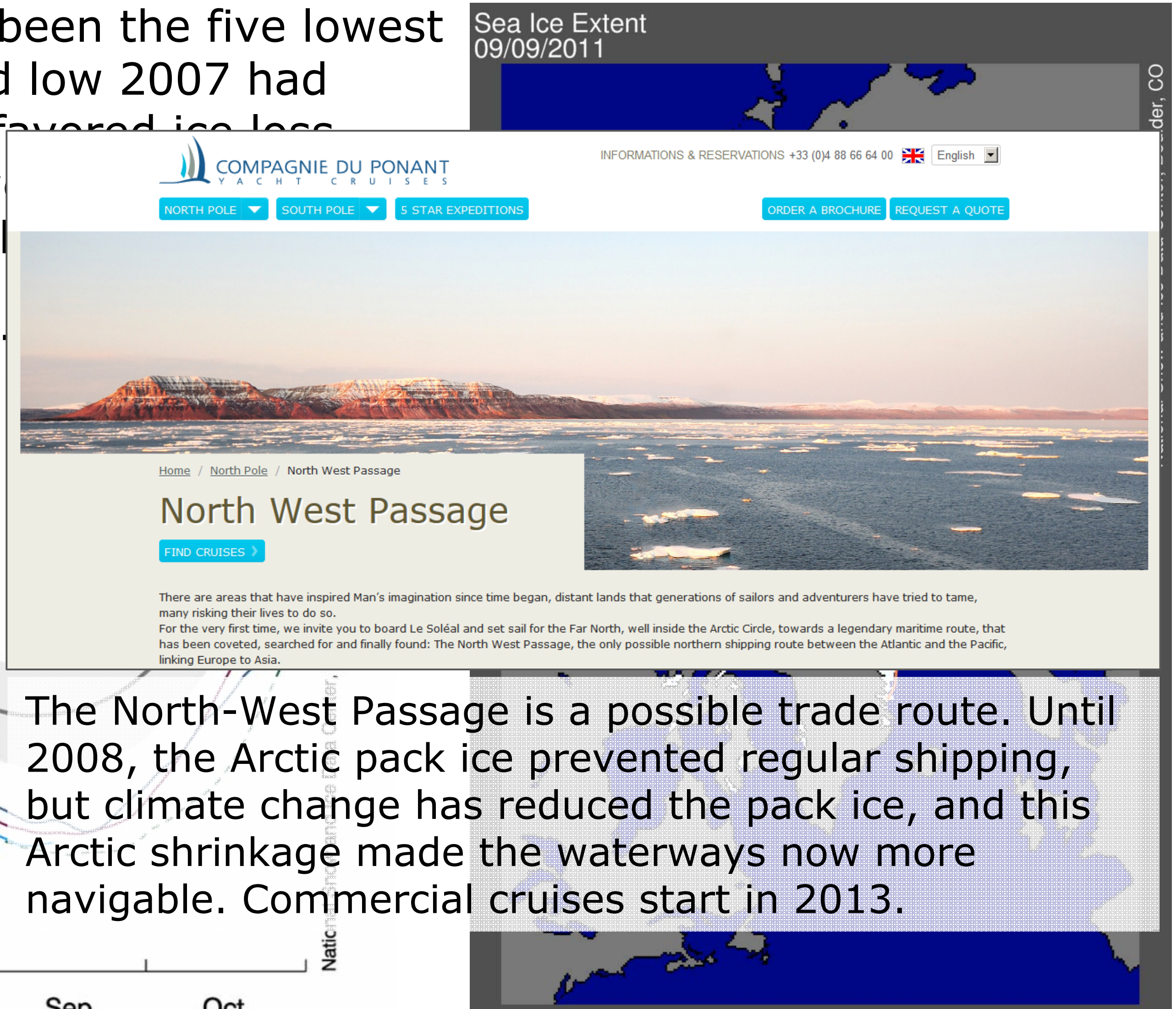
Minimum arctic sea ice extent (September)

The last five years have been the five lowest extents. While the record low 2007 had weather conditions that f[…]
2011 had more typical w[…]
continued warmth over t[…]
**supports the idea that […]
cover is continuing to […]**





The North-West Passage is a possible trade route. Until 2008, the Arctic pack ice prevented regular shipping, but climate change has reduced the pack ice, and this Arctic shrinkage made the waterways now more navigable. Commercial cruises start in 2013.

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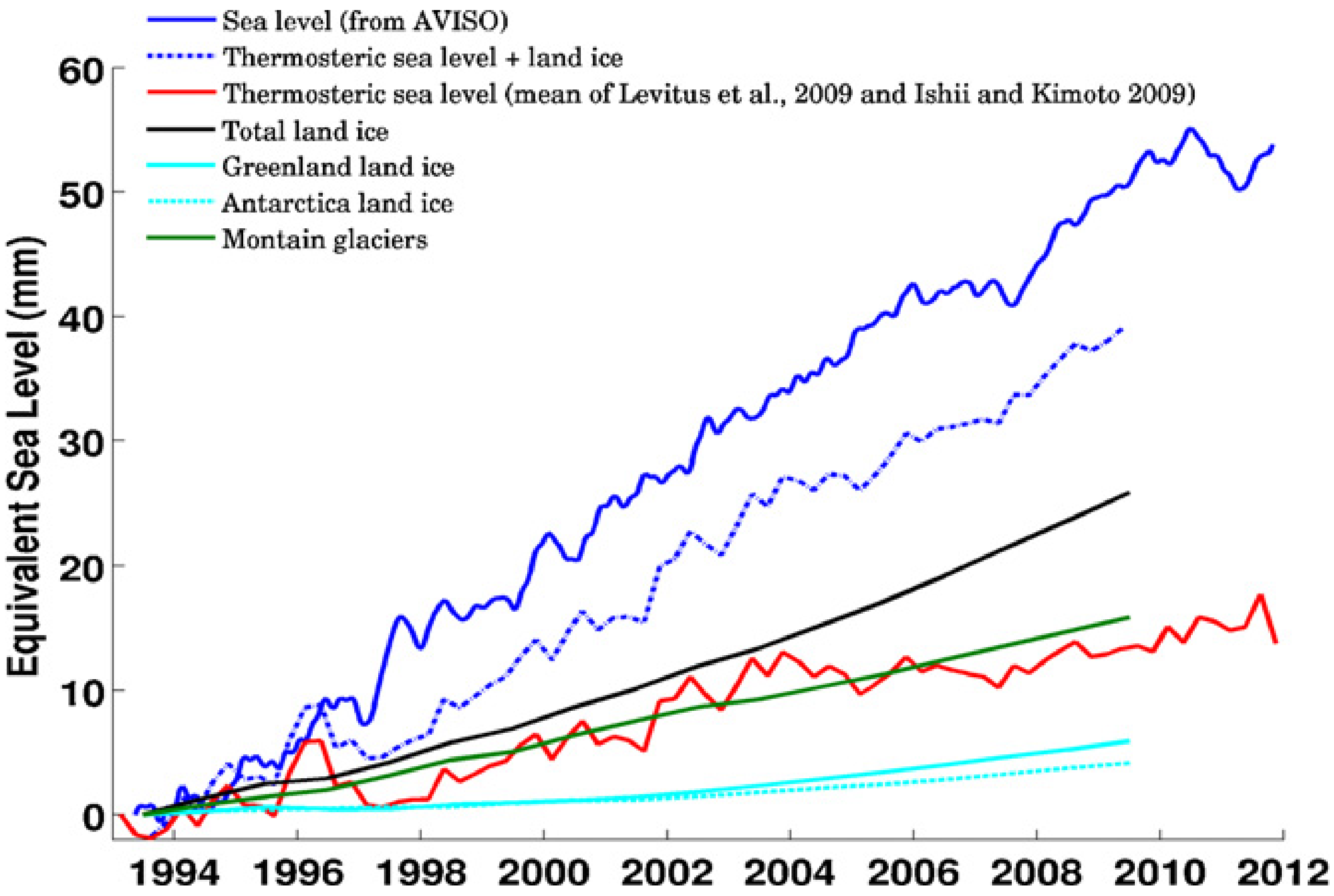
Observed global sea level



Journal of Geodynamics 58 (2012) 96–109

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Review

Sea level: A review of present-day and recent-past changes and variability

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Sea level reconstruction
Climate change

ABSTRACT

In this review article, we summarize observations of sea level variations, globally and regionally, during the 20th century and the last 2 decades. Over these periods, the global mean sea level rose at rates of 1.7 mm/yr and 3.2 mm/yr respectively, as a result of both increase of ocean thermal expansion and land ice loss. The regional sea level variations, however, have been dominated by the thermal expansion factor over the last decades even though other factors like ocean salinity or the solid Earth's response to the last deglaciation can have played a role. We also present examples of total local sea level variations that include the global mean rise, the regional variability and vertical crustal motions, focusing on the tropical Pacific islands. Finally we address the future evolution of the global mean sea level under on-going warming climate and the associated regional variability. Expected impacts of future sea level rise are briefly presented.

Contents

1. Introduction

Sea level variations spread over a very broad spectrum. The largest global-scale sea level changes (100-200 m in amplitude) occurred on geological time scales (on the order of ~100 million years) and depended primarily on tectonic processes (e.g. large-scale change in the shape of ocean basins associated with seafloor spreading and mid-ocean ridges expansion) (e.g. Haq and Schutter, 2008; Mueller et al., 2008; Miller et al., 2011). With the formation of the Antarctica ice sheet about 34 million years ago, global mean sea level dropped by about 50 m. More recently, cooling of the Earth starting about 3 million years ago, led to glacial/interglacial cycles driven by incoming insolation changes in response to variations of the Earth's orbit and obliquity (Berger, 1988). Corresponding growth and decay of northern hemisphere ice caps on time scales of tens of thousand years produced large

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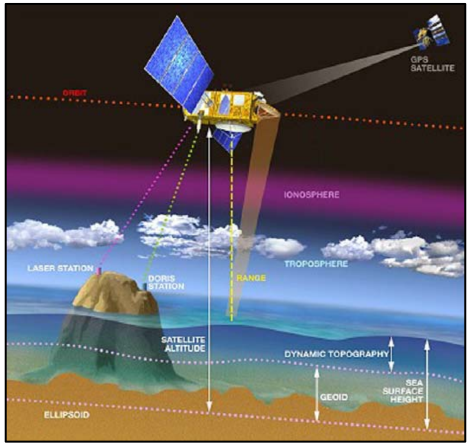
doi:10.1016/j.jog.2012.03.005



IPCC 2007:
For 1961-2003: 1.8 mm/yr; Models: 1.2 mm/yr
This study:
Last century: 1.7 mm/yr; 1990-2010: 3.2 mm/yr

Meyssignac, B. and A. Cazenave (2012). Sea level: A review of present-day and recent-past changes and variability. Journal of Geodynamics 58: 96-109.

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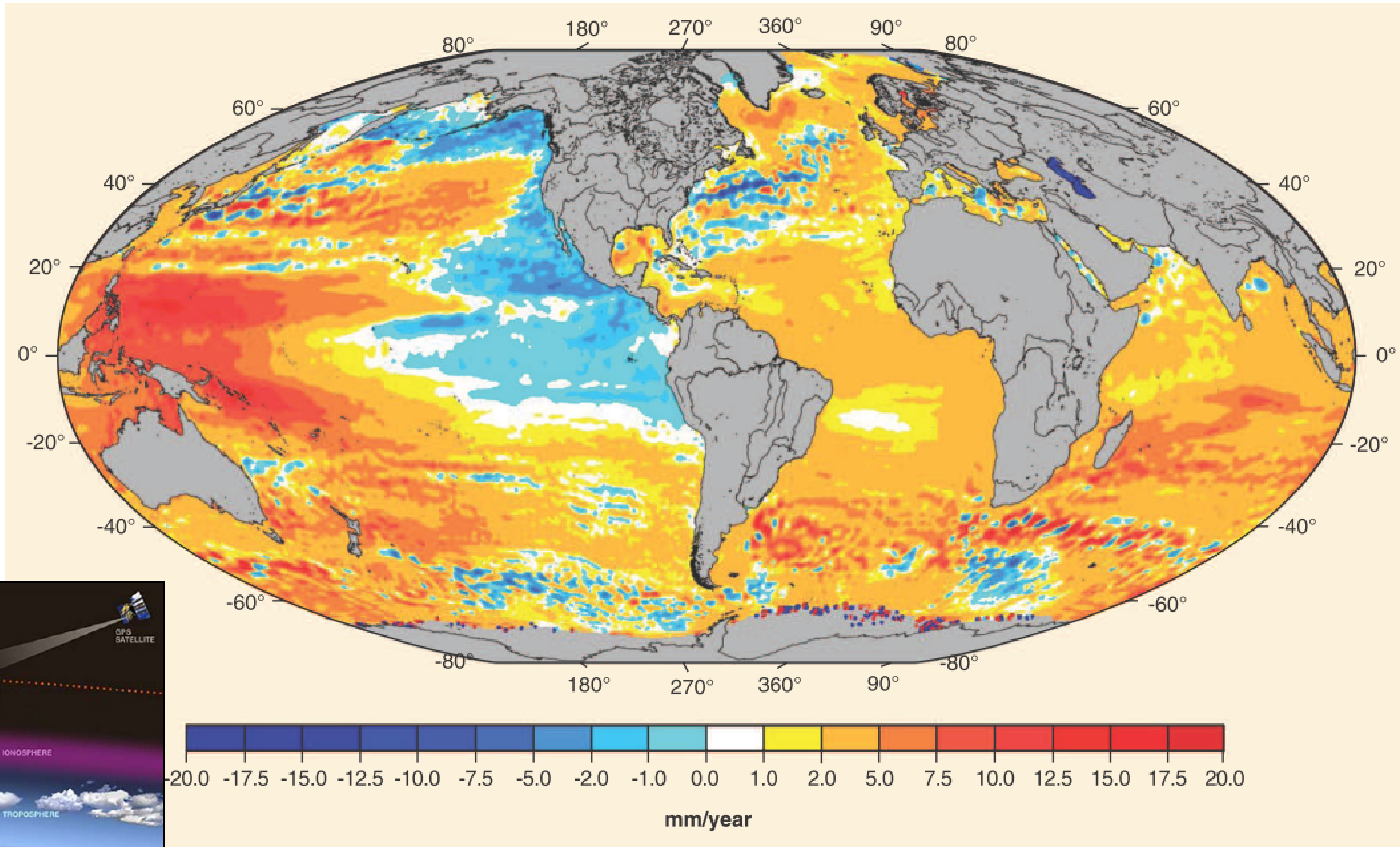
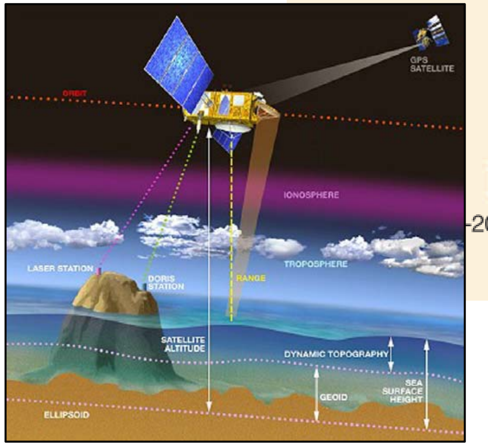
Spatial variations of sea level





Local sea-level trends up to 10 times higher than the global mean rise (but very likely **transient phenomena**). Regional sea level trends largest in the Pacific.

Nicholls, R. J. and A. Cazenave. 2010. Sea-Level Rise and Its Impact on Coastal Zones. Science 328:1517-1520.

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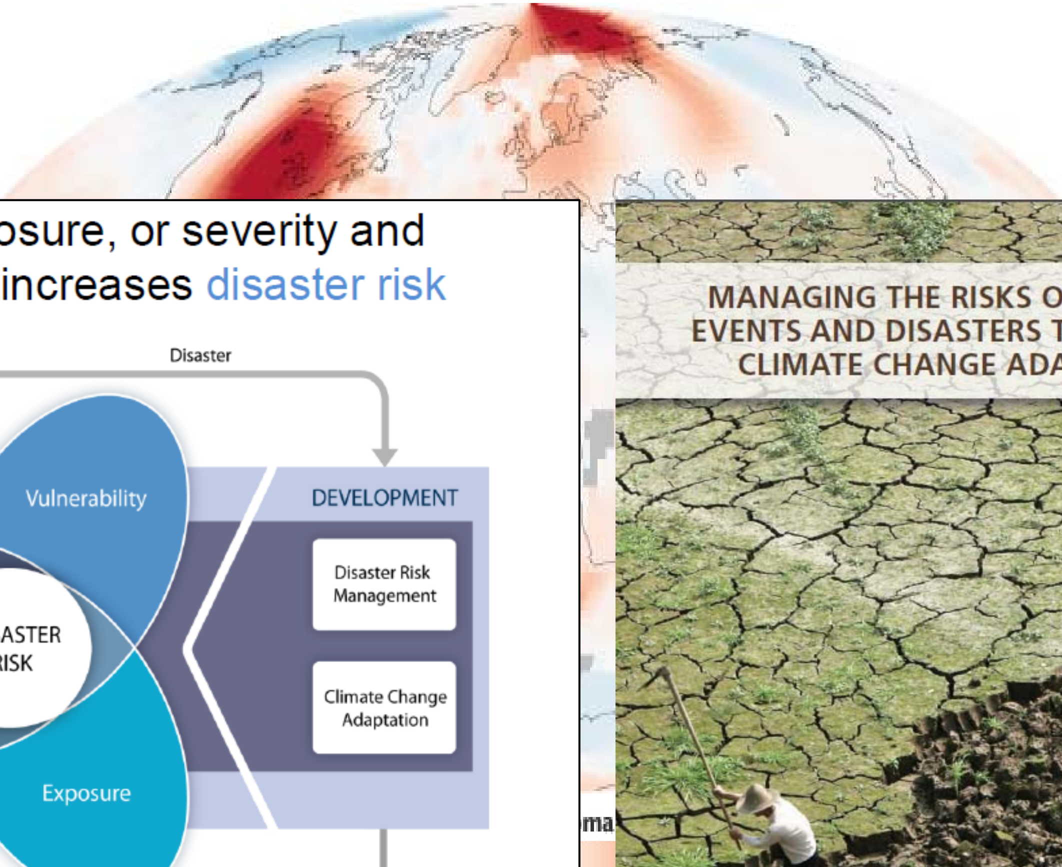
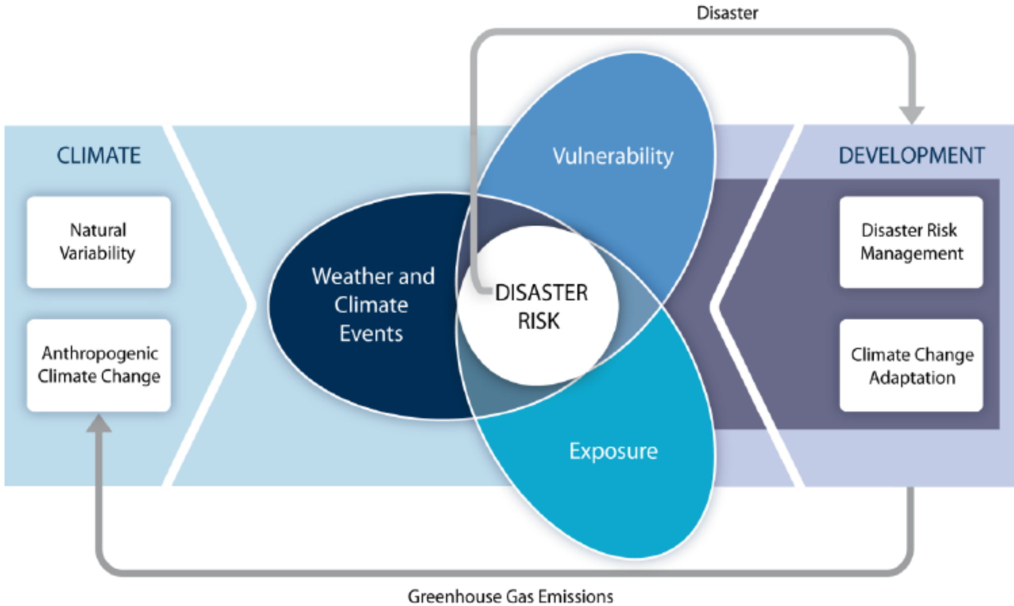
Climate extremes
(e.g. March temperatures)



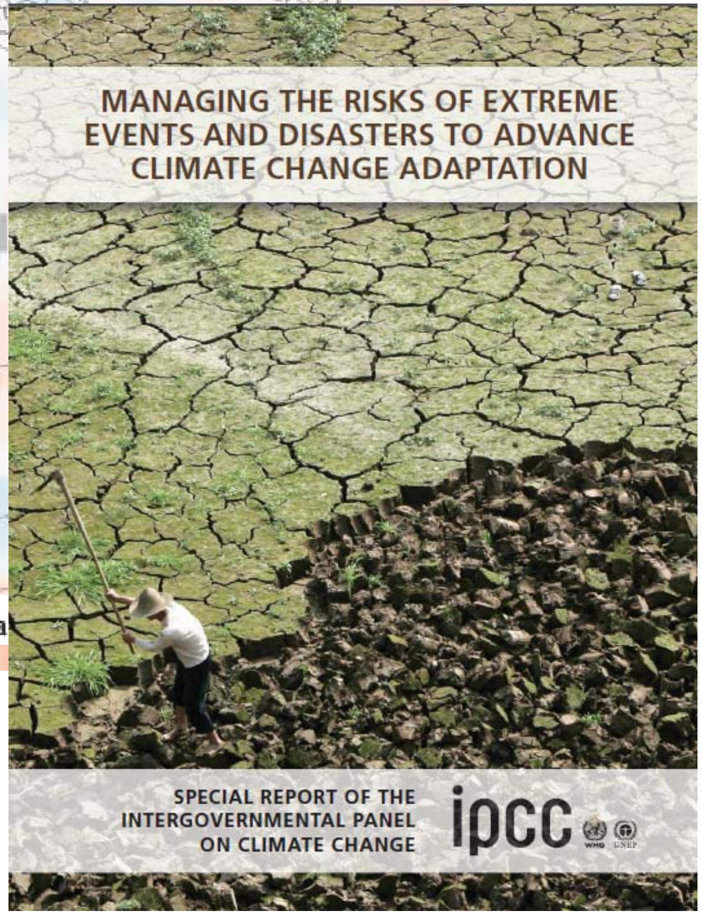
Increasing vulnerability, exposure, or severity and frequency of climate events increases disaster risk



Disaster risk management and climate change adaptation can influence the degree to which ***extreme events translate into impacts*** *and* ***disasters***

7

ipcc
INTERGOVERNMENTAL PANEL ON climate change



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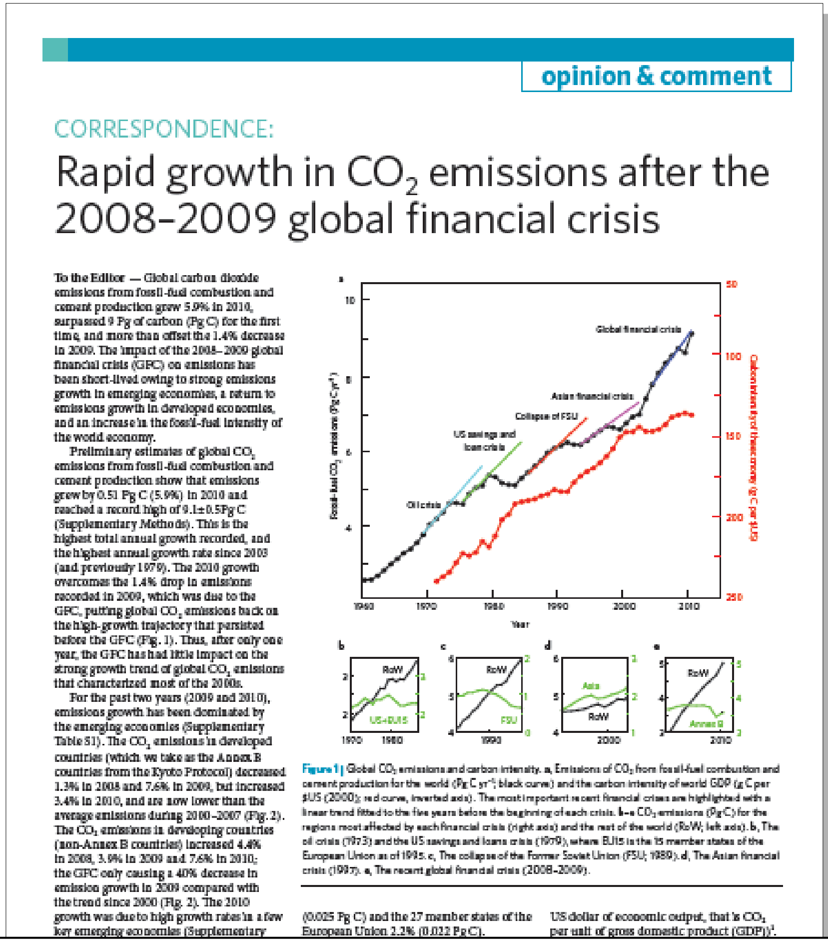
Carbon Budget 2010



opinion & comment

CORRESPONDENCE:

Rapid growth in CO_2 emissions after the 2008–2009 global financial crisis

To the Editor — Global carbon dioxide emissions from fossil-fuel combustion and cement production grew 5.9% in 2010, surpassed 9 Pg of carbon (Pg C) for the first time, and more than offset the 1.4% decrease in 2009. The impact of the 2008–2009 global financial crisis (GFC) on emissions has been short-lived owing to strong emissions growth in emerging economies, a return to emissions growth in developed economies, and an increase in the fossil-fuel intensity of the world economy.

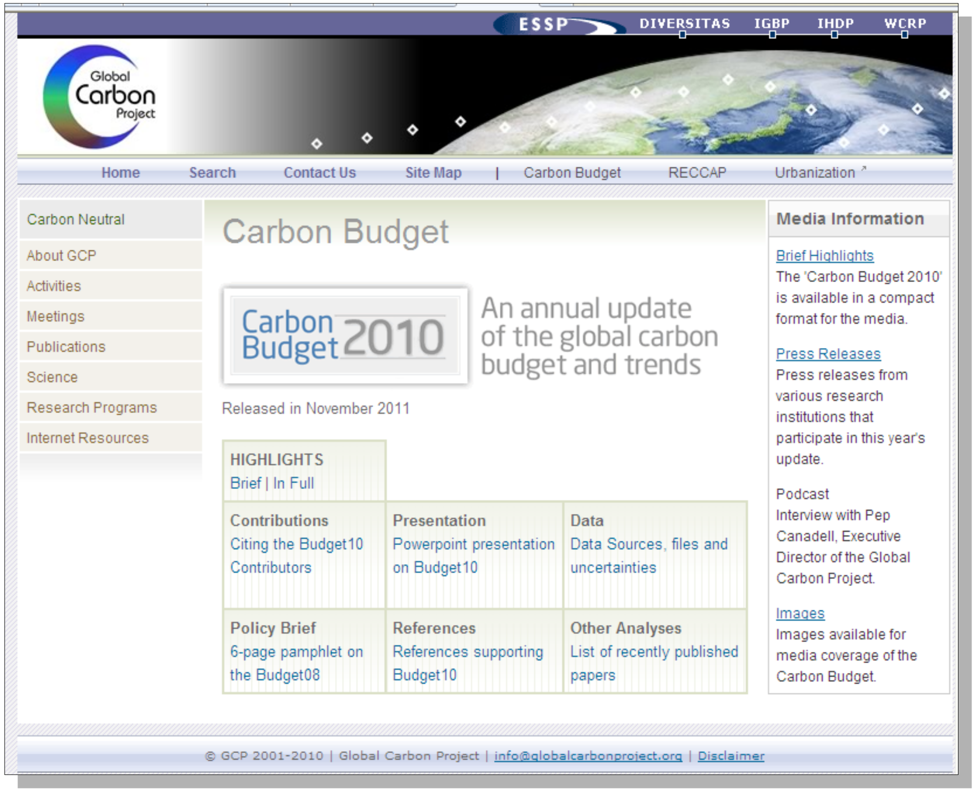
Preliminary estimates of global CO_2 emissions from fossil-fuel combustion and cement production show that emissions grew by 0.51 Pg C (5.9%) in 2010 and reached a record high of 9.1±0.5 Pg C (Supplementary Methods). This is the highest total annual growth recorded, and the highest annual growth rate since 2003 (and previously 1979). The 2010 growth overcomes the 1.4% drop in emissions recorded in 2009, which was due to the GFC, putting global CO_2 emissions back on the high-growth trajectory that persisted before the GFC (Fig. 1). Thus, after only one year, the GFC has had little impact on the strong growth trend of global CO_2 emissions that characterized most of the 2000s.

For the past two years (2009 and 2010), emissions growth has been dominated by the emerging economies (Supplementary Table S1). The CO_2 emissions in developed countries (which we take as the Annex B countries from the Kyoto Protocol) decreased 1.3% in 2008 and 7.6% in 2009, but increased 3.4% in 2010, and are now lower than the average emissions during 2000–2007 (Fig. 2). The CO_2 emissions in developing countries (non-Annex B countries) increased 4.4% in 2008, 3.9% in 2009 and 7.6% in 2010; the GFC only causing a 40% decrease in emission growth in 2009 compared with the trend since 2000 (Fig. 2). The 2010 growth was due to high growth rates in a few key emerging economies (Supplementary

Figure 1 | Global CO_2 emissions and carbon intensity. a, Emissions of CO_2 from fossil-fuel combustion and cement production for the world (Pg C yr^{-1}; black curve) and the carbon intensity of world GDP (g C per $US (2000); red curve, inverted axis). The most important recent financial crises are highlighted with a linear trend fitted to the five years before the beginning of each crisis. b–e CO_2 emissions (Pg C) for the regions most affected by each financial crisis (right axis) and the rest of the world (RoW; left axis). b, The oil crisis (1973) and the US savings and loans crisis (1979), where EU15 is the 15 member states of the European Union as of 1995. c, The collapse of the Former Soviet Union (FSU; 1989). d, The Asian financial crisis (1997). e, The recent global financial crisis (2008–2009).

(0.025 Pg C) and the 27 member states of the European Union 2.2% (0.022 Pg C).

US dollar of economic output, that is CO_2 per unit of gross domestic product (GDP))[1].



http://www.globalcarbonproject.org/carbonbudget

1 Pg = 1 Petagram = $1x10^{15}$g = 1 Billion metric tons = 1 Gigaton

1 Tg = 1 Teragram = $1x10^{12}$g = 1 Million metric tons

1 Kg Carbon (C) = 3.67 Kg Carbon Dioxide (CO_2)

Peters GP, Marland G, Le Quéré C, Boden T, Canadell JG, Raupach MR (2011) Rapid growth in CO_2 emissions after the 2008-2009 global financial crisis. Nature Climate Change, doi. 10.1038/nclimate1332.

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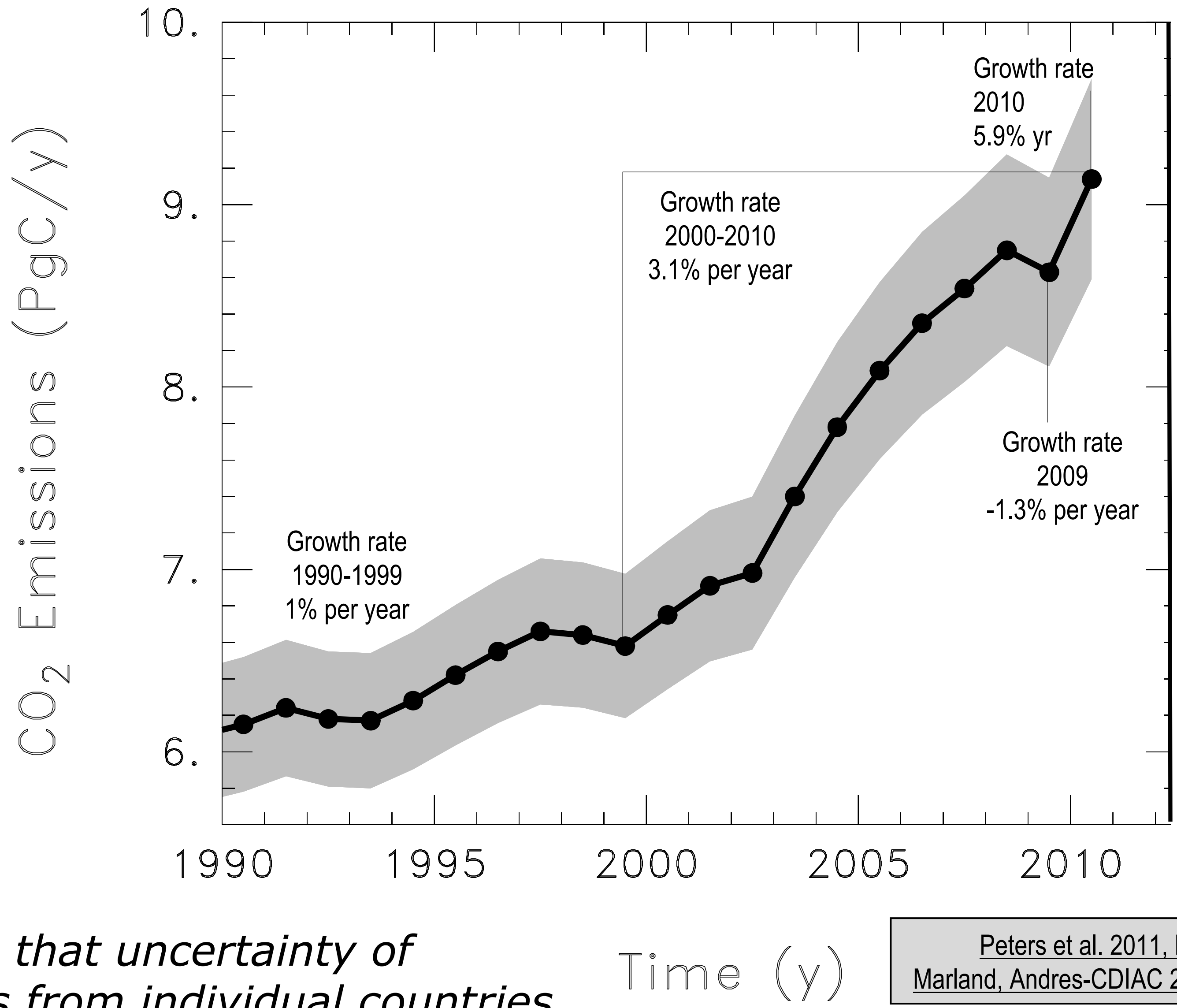
Fossil Fuel & Cement CO_2 Emissions



Be aware that uncertainty of emissions from individual countries can be several-fold bigger

Peters et al. 2011, Nature CC; Data: Boden, Marland, Andres-CDIAC 2011; Marland et al. 2009

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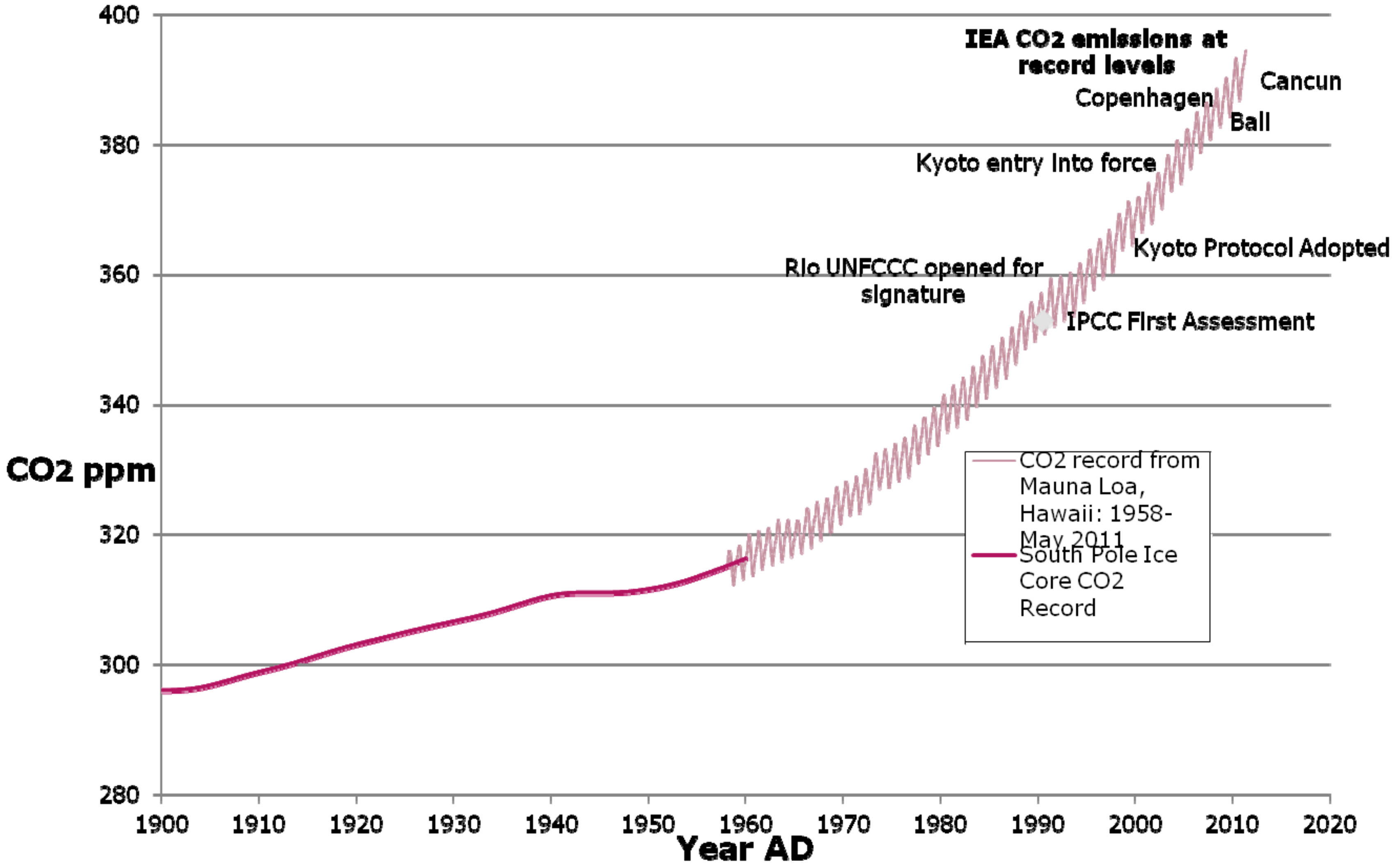
CO_2 concentration rising



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Consequent warming may be higher than earlier estimates

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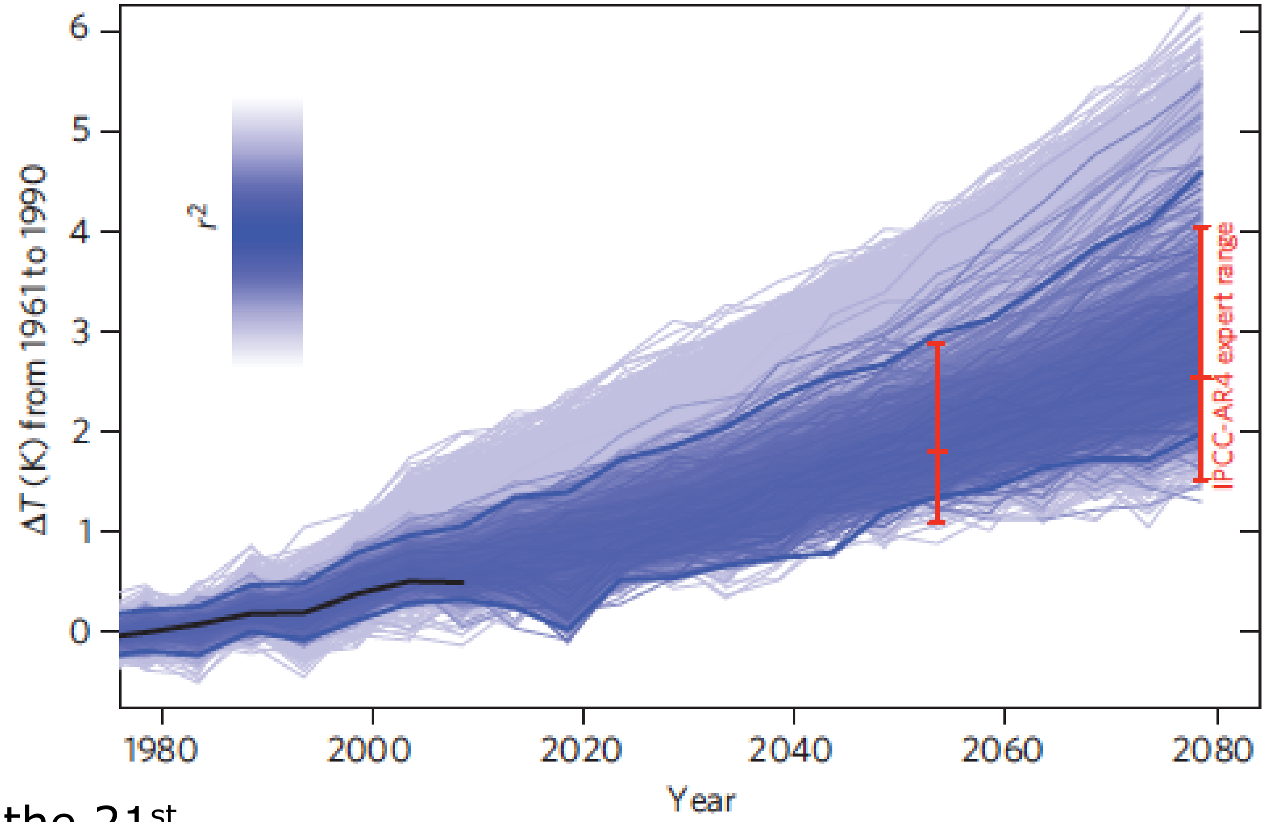

Warming by the middle of the 21st century that is stronger than earlier estimates is consistent with recent observed temperature changes and a mid-range 'no mitigation' scenario for greenhouse-gas emissions

Rowlands, D. J., D. J. Frame, et al. (2012). "Broad range of 2050 warming from an observationally constrained large climate model ensemble." Nature Geoscience 5(4): 256-260.

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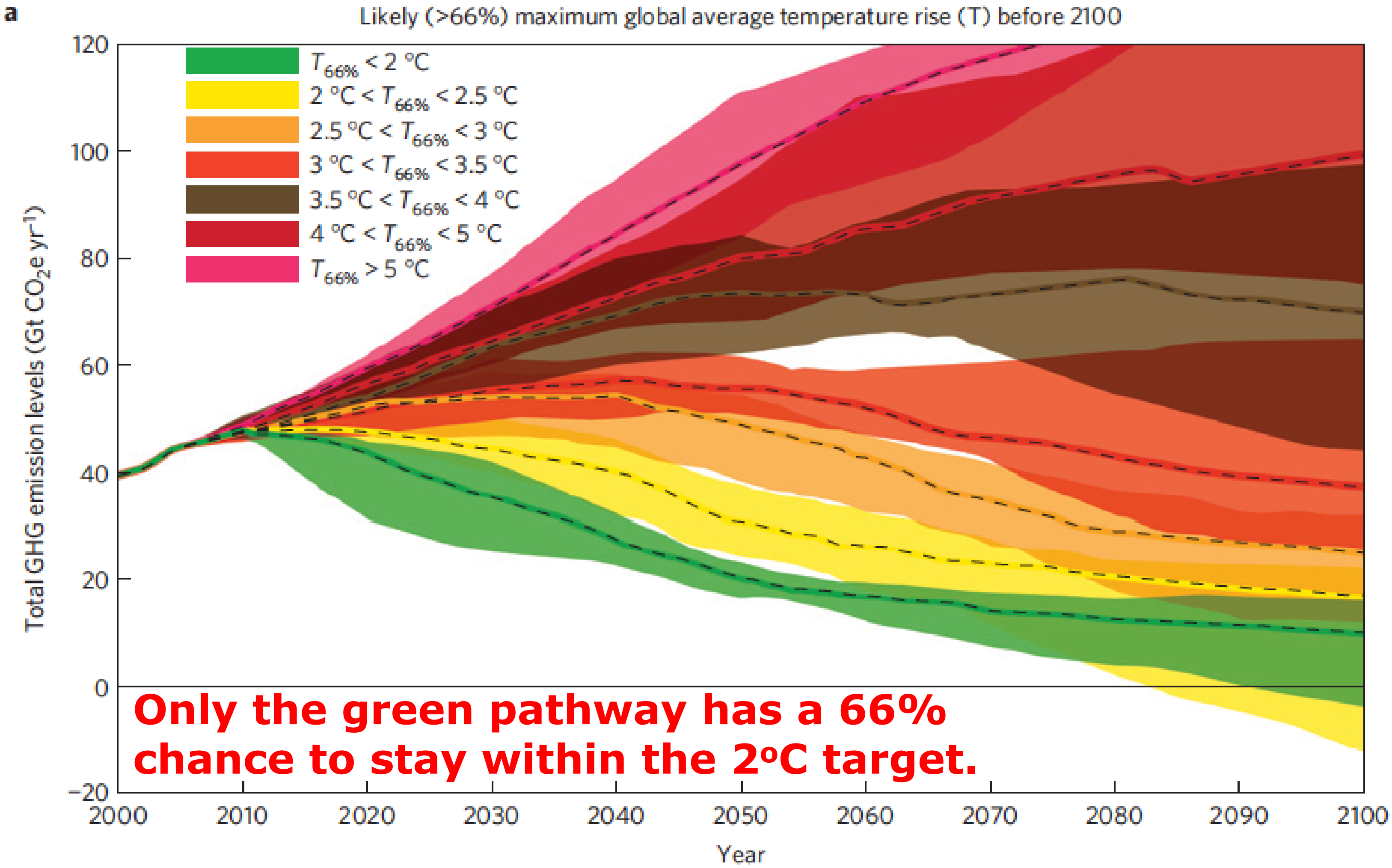
Emission pathways and warming limits



Rogelj, J., W. Hare, J. Lowe, D. P. van Vuuren, K. Riahi, B. Matthews, T. Hanaoka, K. Jiang & M. Meinshausen. 2011. Emission pathways consistent with a 2oC global temperature limit. Nature Climate Change 1:413-418.

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Sources: Rogelj J. et al., 2011, Nature Climate Change

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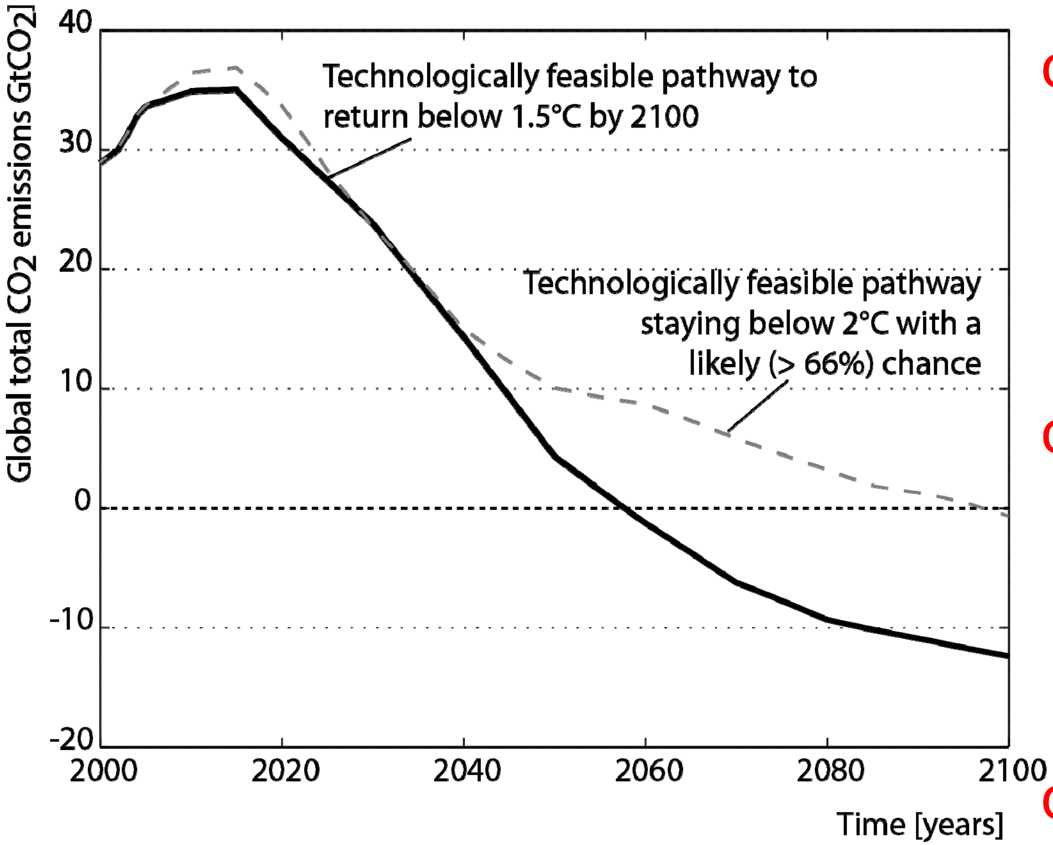
Implications for staying below 2°C (or 1.5°C)



The two scenarios shown are from ADAM project (www.adamproject.eu)

- Emission should peak before 2020 and then rapidly reduced by 70% in 2050 and going to zero in 2100.
- Until 2050 the 1.5°C pathway is similar to a likely 2°C pathway, but with deep reductions afterwards.
- Emissions are constrained by the terrestrial and oceanic sources and sinks!

Hulme, M., H. Neufeldt, and H. Colyer. 2009. Adaptation and mitigation strategies: Supporting European Climate Policies. Final Report from the ADAM Project, Tyndell Centre for Climate Change Research, Norwich, UK.

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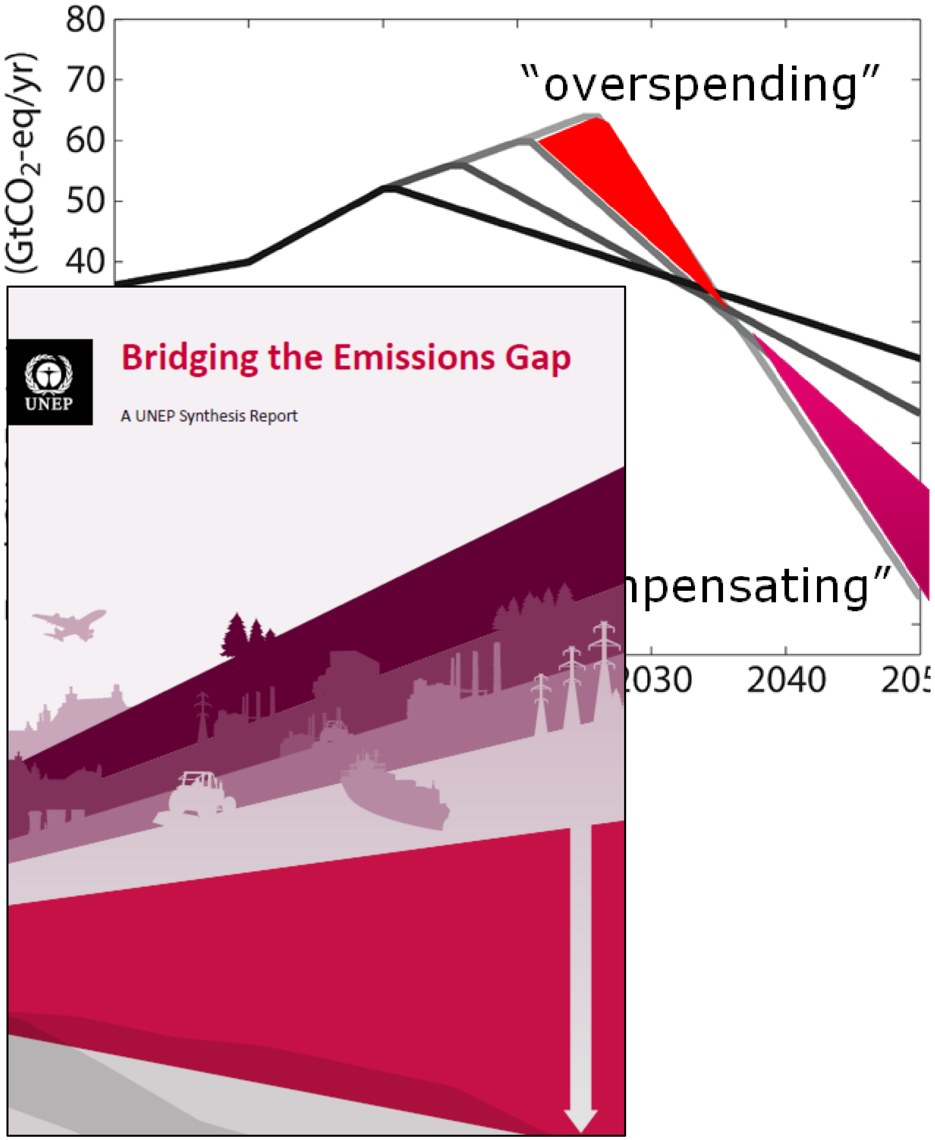
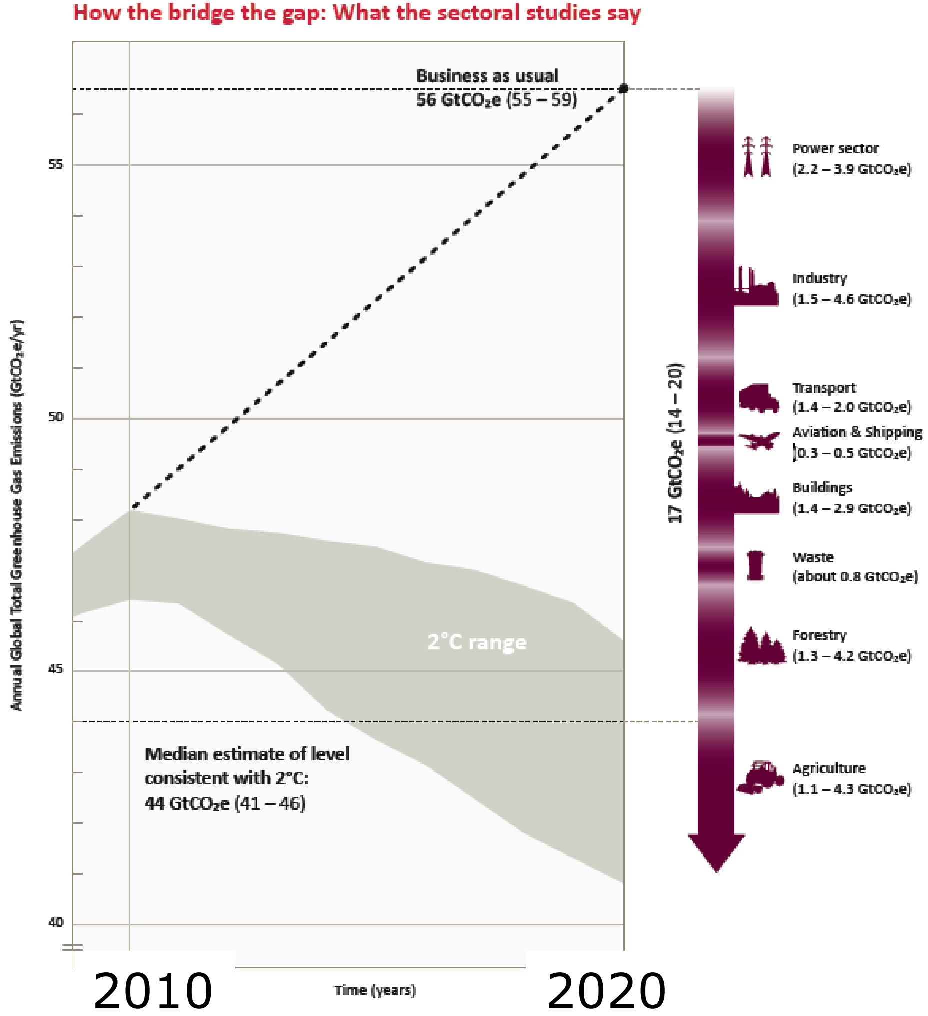
Major lesson on delays: Later reductions require faster AND deeper reductions





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Main final conclusions

- To keep within your 2^{o}C climate-change target, global greenhouse gas emissions have to be more than halved by 2050 and should peak no later than 2020.
- **The next years are thus a crucial to change course towards a sustainable future for all nations.**
- If this is not achieved risks will increase rapidly and food, water and energy security cannot be guaranteed
- The long term solutions involve rethinking fundamental aspects of international and national economic, technical, institutional and social developments. This requires major innovations, capacity building and political will.

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