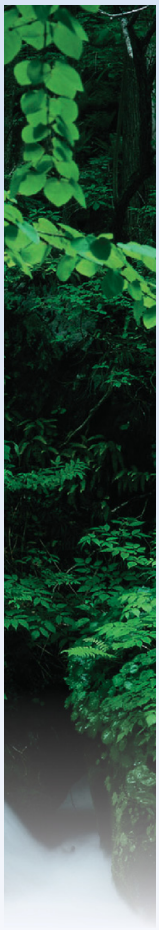
Earth System
Science Partnership

Global
Carbon
Project

Global Carbon Project

10 Years of Advancing Knowledge on the Global Carbon Cycle and its Management

The Global Carbon Project

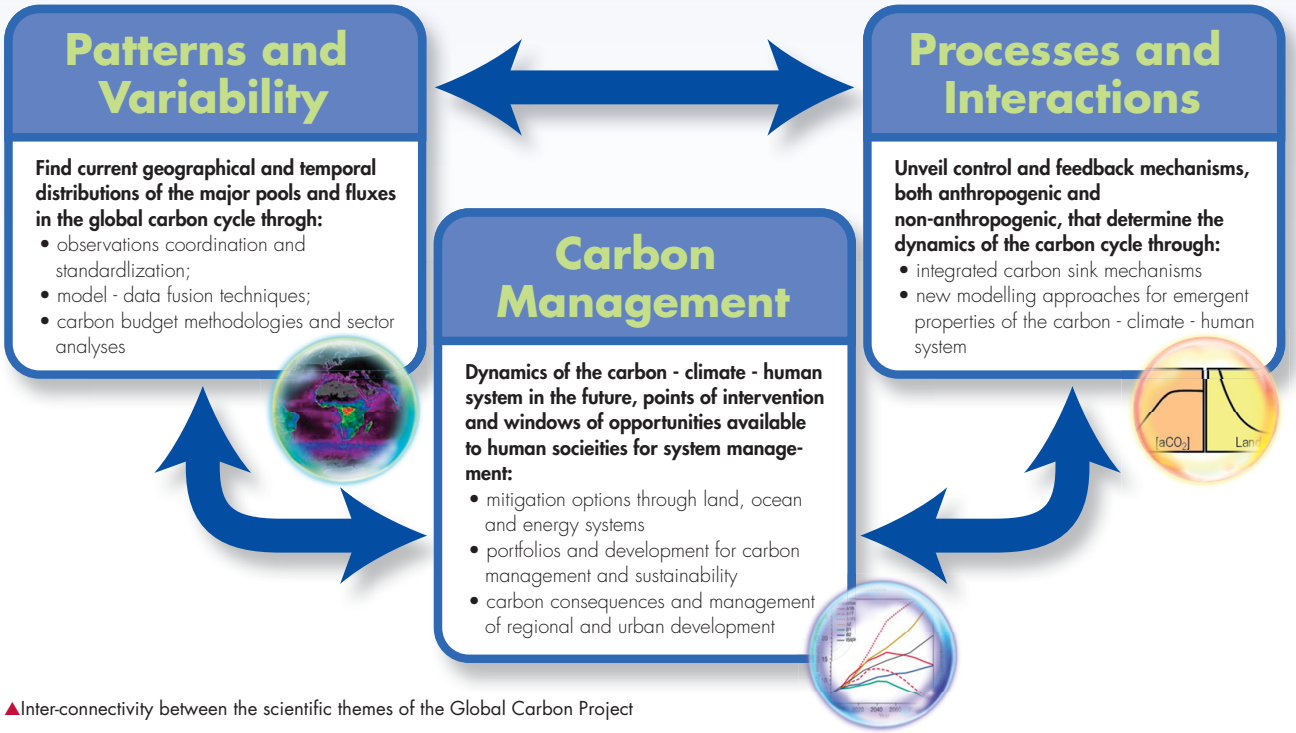


The Global Carbon Project (GCP) was established in 2001 in recognition of the enormous scientific challenge and critical nature of the carbon cycle for the Earth's sustainability. It was formed to establish a framework for international coordinated research on the global carbon cycle that advances fundamental understanding and supports policy development towards the stabilization of greenhouse gases in the atmosphere.

The GCP conducts comprehensive and global research of the carbon cycle and its interactions with the human, biophysical and climate system, facilitates the coordination of national and regional carbon programs and activities, and leads a number of global assessments to support international conventions and national agendas. GCP has established two International Project Offices (IPO) to coordinate global efforts (CSIRO-Australia and NIES-Japan) and several regional affiliated offices in China, Europe, the USA and most recently in Korea.

The Global Carbon Project was formed as a shared partnership between the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP), the World Climate Research Programme (WCRP) and Diversitas. This partnership constitutes the Earth Systems Science Partnership (ESSP).

The scientific goal of the Global Carbon Project is to develop a complete picture of the global carbon cycle, including both its biophysical and human dimensions together with the interactions and feedbacks between them. Focus is placed on three research areas: *patterns and variability, processes and interactions and carbon management.* Activities of the project are organized around these three topics in addition to the GCP-wide High-Level Synthesis.

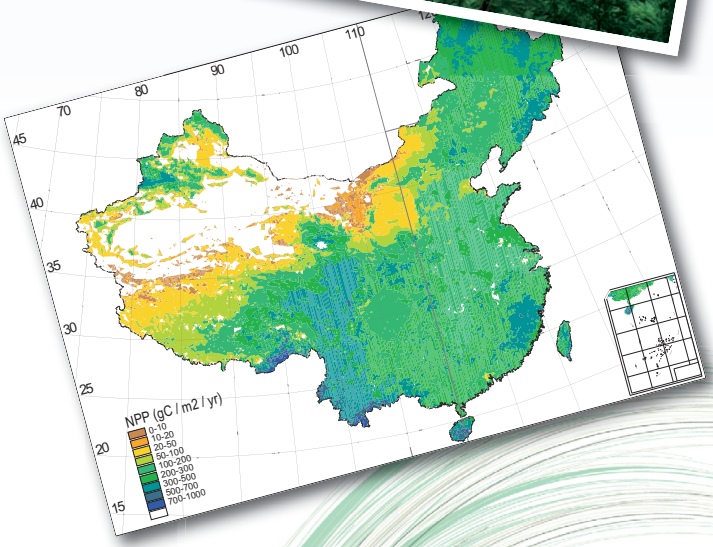


▲Inter-connectivity between the scientific themes of the Global Carbon Project

©Irabel8, Shutterstock.com

© Christian Naval | Dreamstime.com

©Robert Kerton



Source: Shilong Piao et al 2009

Mandate

1. To develop a research framework for integration of the biogeochemical, biophysical and human components of the global carbon cycle.

2. To synthesize current understanding of the global carbon cycle and to provide rapid feedback to the research and policy communities, and to the general public.

3. To provide a global coordinating platform for regional/national carbon programs to improve observation network design, data standards, information and tools transfer, and timing of campaigns and process-based experiments.

4. To work towards a Global Carbon Observation Strategy with the Group on Earth Observations (GEO).

5. To develop a number of timely new research initiatives on highly interdisciplinary problems of the carbon cycle.

6. To foster new carbon research and engagement in regions of global importance for the carbon cycle but with limited capacity [1].

Quotation

[1] Global Carbon Project. 2003. Science framework and Implementation. Edited by Canadell JG, Dickson R, Hibbard K, Raupach MR & Young O. Earth System Science Partnership (IGBP, IHDP, WCRP, DIVERSITAS) Report No. 1; Global Carbon Project Report No. 1, 69pp, Canberra.

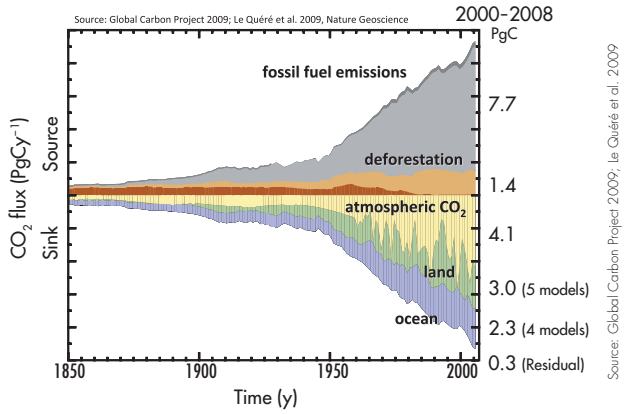
1 State of the Global Carbon Budget

In collaboration with a number of institutions and scientists, the GCP has established an international consortium of scientists and research institutions to track the major carbon fluxes and their trends, and publishes the state of global carbon cycle annually since 2007. The latest release published in *Nature Geosciences* in November 2009 attracted wide attention from both the scientific and policy communities, with a large world media coverage.

Science Highlights

Atmospheric CO_2 Growth

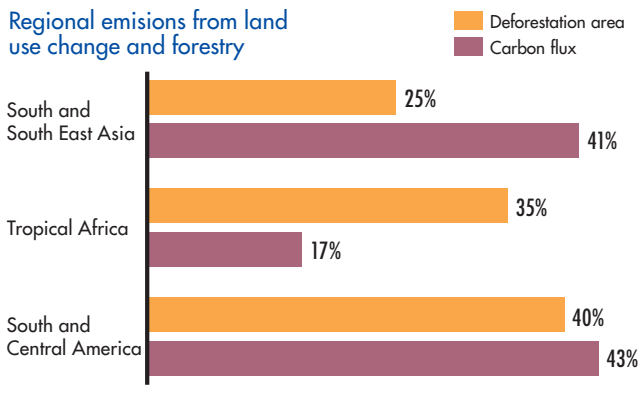
The annual growth of atmospheric CO_2 was 1.8 ppm in 2008. The mean growth rate for the previous 20 years was about 1.5 ppm per year. The atmospheric CO_2 concentration was 385 ppm in 2008, 38% higher than at the start of the industrial revolution (about 280 ppm in 1750). The present concentration is the highest during the last 2 million years.

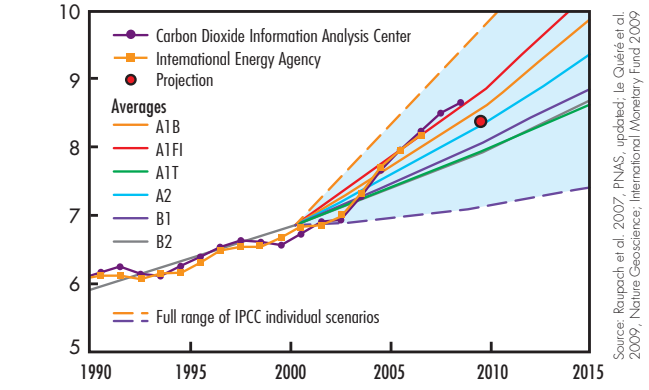


▲Human Perturbation of the Global Carbon Budget

Emissions from Fossil Fuel

Fossil fuel CO_2 emissions growth in 2008 was 2%. This growth led to an all-time high of 8.7 PgC emitted to the atmosphere (1 Pg = 1 billion tons or 1000 x million tons), 29% above the emissions level in 2000, and 41% above the Kyoto reference year 1990. Coal is now the largest fossil fuel source of CO_2 emissions. Over 90% of the growth in coal emissions in 2008 resulted from increased coal use in China and India. Global emissions per capita reached 1.3 tonnes of carbon.





▲Fossil fuel emissions: Actual vs. IPCC scenarios

Regional Fuel Emissions Drivers

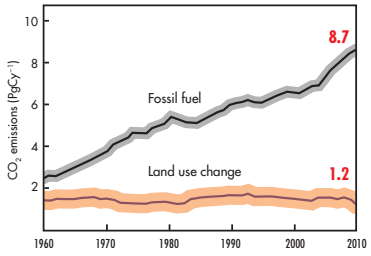
The biggest increase in emissions has taken place in developing countries while developed countries show rather steady emissions for the last decade. About one quarter of the recent growth in emissions in developing countries resulted from the increase in international trade of goods and services produced in developing countries but consumed in developed countries.

Effects of the Global Financial Crisis

The financial crisis had a small but discernable impact on the emissions growth rate in 2008: a growth rate of 2.0% down from the 3.4% per year on average over the previous 7 years. A positive growth is expected to return in 2011 as the change in global Gross Domestic Product (GDP) goes positive.

CO_2 Removal by Natural Sinks: Ocean and Land

Natural land and ocean CO_2 sinks removed 57% (or 5.3 PgC per year) of all CO_2 emitted from human activities during 1958-2008. During this period the size of the natural sinks has grown, but likely at a slower pace than emissions have grown, although the year-to-year variability is large. This could indicate a decline in the efficiency of the sinks in removing atmospheric CO_2 over time (from 60% fifty years ago down to 55% in recent years), a trend expected to continue in the future. Models suggest the sinks are responding to climate change and variability.



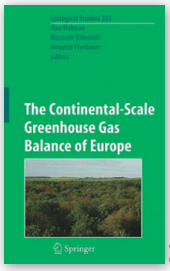
▲Land Use Change and Forestry Regional carbon emissions' shares (2000-2005) and historical emissions (1960 - 2010)

The global oceanic CO_2 sink removed 26% of all CO_2 emissions for the period 2000-2008, while terrestrial CO_2 sinks removed 29% of all anthropogenic emissions for the same period. An analysis of the long-term trend of the terrestrial sink shows a growing size of the CO_2 sink over the last 60 years, but no discernable change in the efficiency of the sink. On the other hand, the efficiency of the oceans appears to have been declining over the last two decades partially owing to the decline in efficiency of the Southern Ocean and North Atlantic Ocean where long-term field observations and model results seem to be in agreement.

Syntheses and Research Outputs

© Nature Publishing Group, division of Macmillan Publishers Ltd.
© National Academy of Sciences of the USA

Key published papers on the carbon budget are Le Quéré et al. (2009) "**Trends in the sources and sinks of carbon dioxide**", published in *Nature Geosciences*, Raupach et al. (2007) "**Global and regional drivers of accelerating CO_2 emissions**", published in *PNAS*, and Canadell et al. (2007) "**Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks**", published in *PNAS*.



© Springer

Examples of regional balances of GHGs and CO_2 studies are "**The Continental-Scale Greenhouse Gas Balance of Europe**" (2008), a book edited by Dolman, Valentini and Freibauer [2], and "**Anthropogenic CO_2 emissions in Africa**", a journal article by Canadell, Raupach and Houghton (2009) [3], published in a *Biogeosciences Discussions Journal* special issue "**Carbon cycling in Sub-Saharan Africa**" (2008), prepared in collaboration with the GCP.

© Springer

The understanding of terrestrial carbon sources and sinks and the operational monitoring of the carbon cycle dynamic evolution have been advanced through a *Climatic Change* special issue in 2004, "**Quantifying terrestrial carbon sinks**" [4]. The edition's research themes include: past and future land-use change and functioning of the terrestrial carbon cycle, quantifying regional carbon sequestration capacity and remote-sensing approaches to land carbon cycle features and drivers.

Le Quéré C, Raupach MR, Canadell JG, Marland G, Bopp L et al. 2009. Trends in the sources and sinks of carbon dioxide. *Nature Geoscience* 2(12), 831 – 836.

Raupach MR, Canadell JG & Le Quéré C. 2008. Anthropogenic and biophysical contributions to increasing atmospheric CO_2 growth rate and airborne fraction. *Biogeosciences Discussions 5*(4), 2867-2896.

Canadell JG, Le Quéré C, Raupach MR, Field CB, Buitenhuis ET et al. 2007. Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. *Proceedings of the National Academy of Sciences 104*(47), 18866-18870.

Doney SC & Schimel DS. 2007. Carbon and climate system coupling on timescales from the Precambrian to the Anthropocene. *Annual Review of Environment and Resources 32*, 31-66

Canadell JG & Raupach MR. 2005. *The Challenges of Stabilising Atmospheric CO_2 Concentrations*: IHDP.

Schimel DS, House JI, Hibbard KA, Bousquet P, Ciais P et al. 2001. Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. *Nature 414*(6860), 169-172.

Falkowski P, Scholes RJ, Boyle E, Canadell JG, Canfield D et al. 2000. The global carbon cycle: A test of our knowledge of Earth as a system. *Science 290*(5490), 291-296.

Scientific Activities [5]

24-27 April 2007	Purdue University (IN), USA	Atmospheric CO_2 Inversions
11-15 December 2006	San Francisco, California, USA	Regional to Continental-Scale Carbon Cycle Science
16-18 August 2006	Beijing, China	International Conference on Regional Carbon Budgets
13-15 March 2006	Beijing, China	Dynamic Changes in Asia-Pacific Carbon Cycle within the Earth System Context
August 2005	Beijing, China	Carbon Cycle and Climate Session for the 2005 IAMAS Meeting
6-8 June 2005	Frascati, Italy	Carbon from Space, ESA-ESRIN
15-18 November 2004	Beijing, China	Regional Carbon Budgets: from Methodologies to Quantification
3-6 June 2003	Sheffield, UK	Improved Quantification of Global Carbon Cycle Fluxes

Press Releases and Coverage

The press releases and outcomes are reported and refereed worldwide by the world's major media outlets and by thousands of web-pages in all continents.

Quotation

[2] Dolman H, Riccardo V & Freibauer A (eds). 2008. *The Continental-Scale Greenhouse Gas Balance of Europe*. Ecological Studies 203. New York: Springer

[3] Canadell JG, Raupach MR & Houghton RA. 2008. Anthropogenic CO_2 emissions in Africa. *Biogeosciences Discussions 5*(6), 4395-4411.

[4] Canadell JG, Ciais P, Cox P & Heimann M (eds). 2004. Quantifying terrestrial carbon sinks. *Climatic Change Special Issue 67*(2-3)

[5] This category mentions throughout the brochure activities undertaken by the GCP or in partnership with the GCP.

2 Vulnerabilities of the Carbon Cycle

Understanding the state, processes and dynamics of large-scale vulnerable carbon pools is essential for a better understanding and managing the global carbon cycle. The GCP has focused on permafrost, methane hydrates, vegetation fires, tropical peatlands and ocean pumps in terms of their:

- carbon pool size,
- drivers and processes that can lead to destabilization of pools resulting in carbon emissions, and
- internal dynamics of these pools.

Science Highlights

Frozen Carbon

The aim of research is to quantify the carbon content of the vulnerable pools in permafrost soils and analyze the risk of sudden or chronic releases of carbon over this century. Tarnocai et al. (2009) uncovered that carbon stored in the Arctic and boreal regions of the world is over 1.5 trillion tons of frozen carbon, more than double that previously estimated and about twice as much carbon as contained in the atmosphere.

© Edward A. G. Schuur

▲Frozen soil sediment deposit in Siberia.

Methane Hydrates

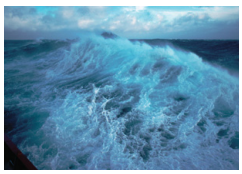
Methane hydrates have been mostly overlooked in major climate change studies, including the IPCC 4th Assessment Report. These "ice-like compounds in which methane is held in crystalline cages formed by water molecules" (Krey et al. 2009) are formed at high pressures and low temperatures and exist mostly in the permafrost of the Arctic and on underwater continental slopes. Their high potential as a fossil fuel energy source coupled with their high potential to be destabilized by climate change and, in turn, to destabilize the climate, puts them high on the priority list for future research. A GCP workshop in March 2008 explored the risks and opportunities associated with methane hydrates and produced a scoping paper calling for accurate estimates of the hydrate occurrences (distribution), calculations of their response to changing environmental conditions and analysis of their potential to become a carbon-neutral fuel. A review in *Science* magazine stated "more meetings like these are clearly needed" (based on the abstract of Krey et al. 2009 and Bohannon 2008 in *Science*[6]).

Tropical Peatlands

This activity explores how global warming and land-use change can destabilize vulnerable carbon pools stored in tropical peatlands. Destabilization of carbon pools could result in large CO_2 and CH_4 emissions with the risk for further acceleration of global warming. The activity is supported by a workshop series funded by the APN (Japan), GCP, Global Environmental Center (Malaysia), and CIFOR (Indonesia).

Oceans

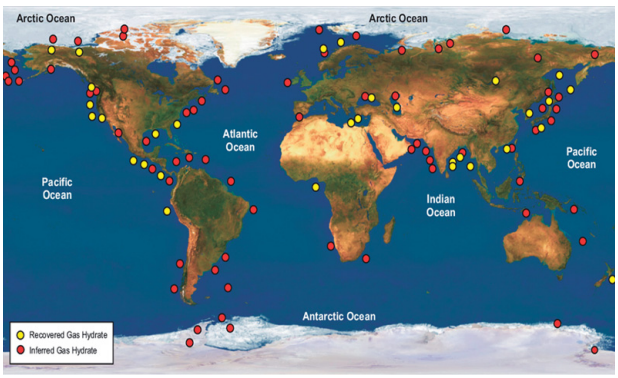
The first evidence that recent climate change has weakened one of the Earth's natural carbon 'sinks' was published in 2007 in the journal *Science*, after a four-year study. Scientists showed that an increase in winds over the Southern Ocean, caused by greenhouse gases and ozone depletion, has led to a release of stored CO_2 into the atmosphere and is preventing further absorption of greenhouse gases (Le Quéré et al. 2007).



© BAS

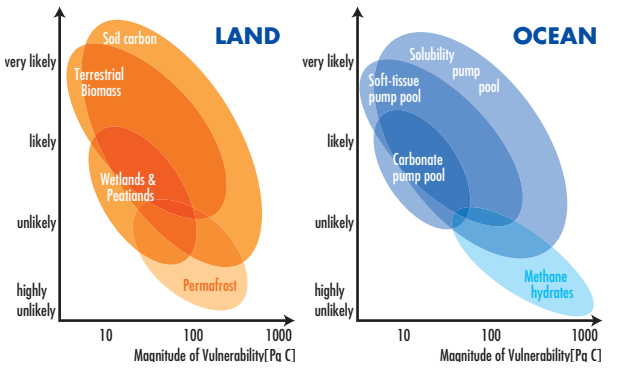
Fires and Drought

Major modifications of the water cycle are partially caused by increasing emissions of human-driven greenhouse gases (GHG), and thus, expected to become larger during the 21st



(Source: courtesy of Council of Canadian Academies (2008), data from Kvenvolden and Rogers (2005))

▲Distribution of known methane hydrate accumulations



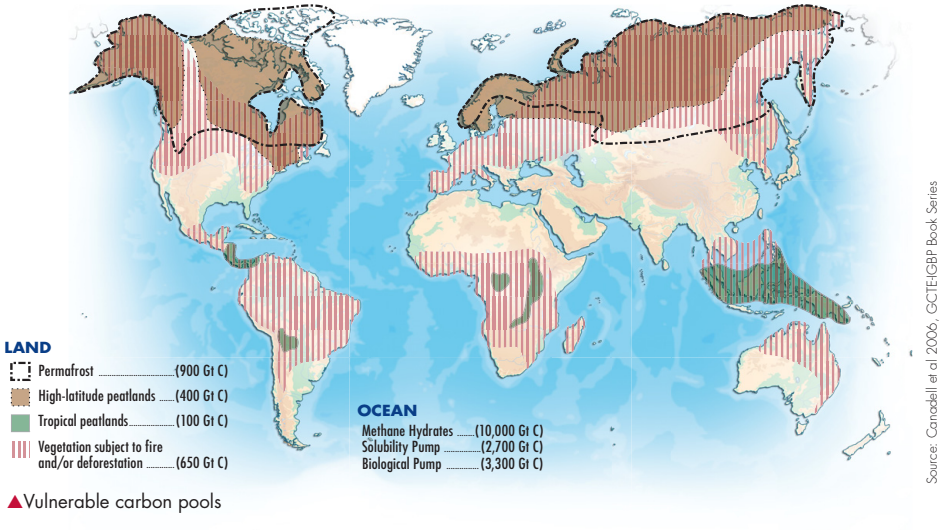
Source: Grubber et al. 2004, from SCOPE-GCP synthesis

▲Magnitude of vulnerability of carbon pools on land and in oceans

Quotation [6] Bohannon J. 2008. Weighing the climate risks of an untapped fossil fuel. *Science* 319(5871), 1753

© Kim Worm Sorensen

▲Fire in the peat forest of Central Sumatra. Indonesia



▲Vulnerable carbon pools

century. A changing water cycle has impacts on carbon stocks and fluxes (e.g. soil and ecosystem respiration, production) and disturbance regimes (e.g., fire frequency and intensity). Over the next 100 years, Global Climate Models predict an increase of global precipitation, water stress in some regions, and inter-annual variability and extreme events (e.g. droughts, floods). Average fire emissions from Indonesia, Malaysia, and Papua New Guinea during 2000 – 2006 were estimated by van der Werf et al. (2008)[7] to be comparable to fossil fuel emissions. Evidence points to the possibility that carbon emissions from fires can vary up to 30 times higher during the El Niño-Southern Oscillation than during La Niña (the wet face of the Southern Oscillation), as in the case of Borneo.

Syntheses and Research Outputs

Hooijer A, Page S, Canadell JG, Silvius M, Kwadijk J et al. 2009. Current and future CO_2 emissions from drained peatlands in Southeast Asia. *Biogeosciences 7*(5), 1505 - 1514.

Krey V, Canadell JG, Nakicenovic N, Abe Y, Andruleit H, et al. 2009. Gas hydrates: Entrance to a methane age or climate threat? *Environmental Research Letters 4*(3), 034007.

Le Quéré C, Raupach MR, Canadell JG, Marland G, Bopp L et al. 2009. Trends in the sources and sinks of carbon dioxide. *Nature Geoscience 2*(12), 831-836.

Tarnocai C, Canadell JG, Schuur EAG, Kuhry P, Mazhitova G & Zimov S. 2009. Soil organic carbon pools in the northern circumpolar permafrost region. *Global Biogeochemical Cycles 23*(2), GB2023.

van der Werf GR, Morton DC, DeFries RS, Olivier JGJ, Kasibhatla PS et al. 2009. CO_2 emissions from forest loss. *Nature Geoscience 2*(11), 737–738

Limpens J, Berendse F, Blodau C, Canadell JG, Freeman C et al. 2008. Peatlands and the carbon cycle: From local processes to global implications – a synthesis. *Biogeosciences Discussions 5*(2), 1379–1419.

Limpens J & Shaepman-Strub G (eds). 2008. Peatlands and the carbon cycle: From local processes to global implications. *Biogeosciences Special Issue*, 6-7

Raupach MR & Canadell JG. 2008. Observing a vulnerable carbon cycle. In *The Continental-Scale Greenhouse Gas Balance of Europe*. eds. Dolman AJ, Valentini R & Freibauer A. pp. 5-32. New York: Springer.

Schuur EAG, Bockheim J, Canadell JG, Euskirchen E, Field CB, Goryachkin SV et al. 2008. Vulnerability of permafrost carbon to climate change: Implications for the global carbon cycle. *BioScience 58*(8), 701-714.

Bockheim JG & Hinkel KM. 2007. The importance of "deep" organic carbon in permafrost-affected soils of Arctic Alaska. *Soil Science Society of America Journal 71*(6), 1889-1892.

Canadell JG, Pataki D, Gifford R, Houghton R, Luo Y et al. 2007. Saturation of the terrestrial carbon sink. In *Terrestrial Ecosystems in a Changing World*. eds. Canadell JG, Pataki D, Pitelka L. pp 59–80. IGBP Series. Berlin: Springer

Le Quéré C, Rodenbeck C, Buitenhuis ET, Conway TJ, Langenfelds R et al. 2007. Saturation of the Southern Ocean CO_2 sink due to recent climate change. *Science 316*(5832), 1735-1738.

Li W, Dickinson RE, Fu R, Niu G-Y, Yang Z-L & Canadell JG. 2007. Future precipitation changes and their implications for tropical peatlands. *Geophysical Research Letters 34*, L01403.

Raupach MR, Marland G, Ciais P, Le Quéré C, Canadell JG et al. 2007. Global and regional drivers of accelerating CO_2 emissions. *PNAS 104*(24), 10288-10293.

Wieder K, Canadell JG,Limpens J, Moore T, Roulet N & Schaepman-Strub. 2007. Peatlands and the carbon cycle: From local processes to global implications. *EOS 88*(29), 295.

Stitch S, Cox PM, Collins WJ & Huntingford C. 2007. Indirect radiative forcing of climate change through ozone effects on the land-carbon sink. *Nature 448*(7155), 791-794

Stephens BB, Gurney KR, Tans PP, Sweeney C, Peters W et al. 2007. Weak northern and strong tropical land carbon uptake from vertical profiles of atmospheric CO_2. *Science 316*(5832), 1732–1735

Field CB & Raupach MR (eds). 2004. *The Global Carbon Cycle: Integrating Humans, Climate and the Natural World*. Washington DC: Island Press.

Gruber N, Friedlingstein P, Field CB, Valentini R, Heimann M et al. 2004. The vulnerability of the carbon cycle in the 21st century: An assessment of carbon-climate-human interactions. In *The Global Carbon Cycle: Integrating Humans, Climate, and the Natural World*. eds. Field CB & Raupach MR. pp. 45-76. Washington DC: Island Press

Scientific Activities

13-16 October 2009	Cape Town, South Africa	Biodiversity and Carbon Symposium
13-14 March 2008	Laxenburg, Austria	Vulnerability and Opportunity of Methane Hydrates Workshop
31 October - 2 November 2007	Kuala Lumpur, Malaysia	Minimizing Impacts of Palm Oil and Biofuel Production in SE Asia on Peatlands, Biodiversity and Climate Change
11-14 April 2007	Paris, France	UNESCO: Ocean Surface: pCO_2 and Vulnerabilities
4-6 December 2006	Santa Barbara, California, USA	Second meeting of the "Vulnerability of Frozen Carbon" working group
5-9 June 2006	Canberra, Australia	Earth Systems Feedbacks: Vulnerability of the Carbon Cycle to droughts and fire
28-30 May 2006	Santa Barbara, California, USA	NCEAS: Vulnerability of Carbon in Permafrost Workshop
24-26 January 2006	Sumatra, Indonesia	Vulnerability of Carbon Pools of Tropical Peatlands in Asia
August 2005	Beijing, China	Carbon Cycle and Climate session for the 2005 IAMAS meeting
15 June 2005	Paris, France	Mini-conference on Vulnerabilities of the Carbon-Climate-Human System
June 2004	Seattle, USA	Understanding North Pacific Carbon-cycle Changes: A Data Synthesis and Modeling Workshop
14-17 January 2004	Tsukuba, Japan	Workshop on Ocean Surface pCO_2
6-11 April 2003	Nice, Italy	A session on Emergent Properties of the Carbon-Climate-Human System

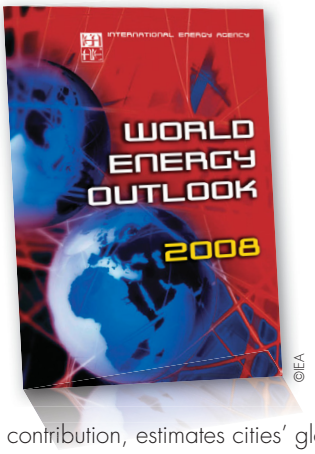
Quotation [7] van der Werf GR, Dempewolf J & Trigg SN. 2008. Climate regulation of fire emissions and deforestation in equatorial Asia. *PNAS 105*(51), 20350–20355

3 Low Carbon Pathways: Urbanization and Cities

Urban areas are responsible for the majority of global energy related CO_2 emissions. How urban areas address the carbon mitigation, both from the production and the consumption sides, determines the success of global carbon mitigation. The GCP launched the Urban and Regional Carbon Management Initiative since late 2005 in order to:

- understand urbanization and urban development pathways from top-down and bottom-up analyses, through a comparative and historical approach to urban, regional and global carbon footprints, their direct and indirect carbon flows, their determinants, trajectories and management opportunities;
- develop scientific networks, modelling forums, scientific information consolidation, synthesis, and contributions to international assessments and science-policy interaction.

Science Highlights



GCP Contribution to World Energy Outlook 2008

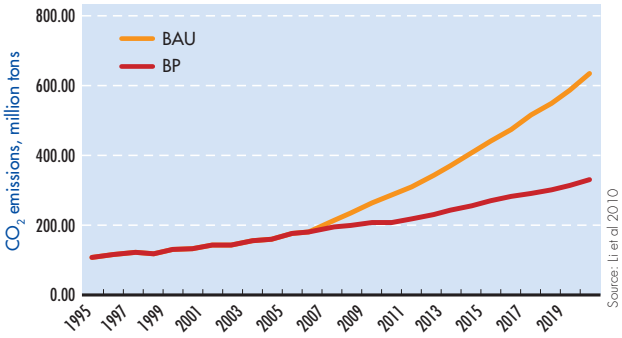
International Energy Agency's World Energy Outlook 2008 reflected the growing importance of the interrelationship between increasing energy demand, urbanization and CO_2 emissions. A dedicated chapter, written with GCP's contribution, estimates cities' global contribution to the primary energy use and CO_2 emissions to be 67% and 71% respectively. According to projections for 2030 cities' contribution is expected to increase to 73% and 76% respectively under the reference scenario. In the US, the EU, Australia and New Zealand the per capita energy consumption and carbon emissions are lower than the national average, whereas in China they are far above the national average due to the higher affordability and accessibility of commercial energy in urban areas [8].

Research on Urban Areas

Country-specific research has revealed that **urban contribution accounts for 84% of China's commercial energy usage** and CO_2 emissions from energy use. The largest 35 cities in the country, which contain 18% of the population, contribute 40% of China's energy use and CO_2 emissions [9].

Baselines for greenhouse gases (GHG) emissions for 44 urban areas (cities or metropolitan regions) underwent a review of the methodologies used to calculate the footprint of urban areas [10]. The results showed lack of uniformity in the type of gases covered, the scope of emissions sources, methodologies of emissions estimation, and the attribution of responsibility. There is clearly a potential to set up "an open, global protocol for quantifying GHG emissions attributable to urban areas".

Policy interventions scenarios have been analyzed for Shanghai and Bangkok. Together with the Shanghai



▲Trends of CO_2 emissions for two scenarios, BAU and Basic Policy, in Shanghai

Academy of Environmental Science, a bottom-up technology and activity-based model was developed and used to study the implications of Shanghai's 11th Five Year Plan related policies in mitigating CO_2 emissions [11]. Major drivers identified for the past decade's steep rise in energy use and CO_2 emissions were high economic growth rate and associated industrial and urban activities. Inaction in carbon mitigation is estimated to lead to a 3.6 times rise in energy use and 3.4 times rise in CO_2 emissions by 2020 against 2006 levels. An alternate policy scenario and carbon emissions analyses for Bangkok City and Bangkok Metropolitan Region have been carried out using the Long-range Energy Alternative Planning (LEAP) model, a technology and activity-based bottom-up model developed by the Stockholm Environment Institute (SEI). Results indicate that actions to reduce carbon emissions from energy use have high potential to reduce emissions from transportation in Bangkok city and from the industry in the five surrounding provinces by a total of 162 m tons CO_2 by 2050 [12]. The study also showed the importance of multiple urban boundaries consideration for better carbon management.

A GCP synthesis paper [13] outlined the key points of the future urban carbon research agenda. First, a better understanding and quantification of GHG emissions and mitigation potential under different definitions of urban areas globally and nationally is necessary. Second, the given urban system is essentially an open system, requiring an understanding of the carbon "footprints" accounting both direct and indirect GHGs flows and allocation principles. Third, cities' total carbon footprint areas of mitigation potential need to be clearly recognized by municipal government, urban institu-

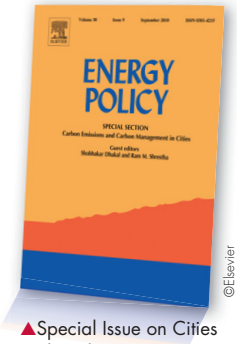
Quotation

[8] Dhakal S, Guimaraes L, Hammer S, Kenihan S, Parshall L et al. 2008. Energy use in cities. *World Energy Outlook 2008*. pp. 179-193. Paris: International Energy Agency.
[9] Dhakal S. 2009. Urban energy use and carbon emissions from cities in China and policy implications. *Energy Policy 37*(11), 4208-4219.
[10] Kennedy C, Ramaswami A, Dhakal S & Carney S. 2009. Greenhouse Gas Emission Baselines for Global Cities and Metropolitan Regions. World Bank commissioned paper for the Fifth Urban Research Symposium on Cities and Climate Change, Marseille, 28-30 June 2009

tions and other stakeholders. Fourth, a sound understanding of urban development pathways and their GHG consequences applied to various urban typologies is needed. Last but not least, it is crucial to grasp prospects for optimizing GHGs mitigation with multiple local benefits including climate change adaptation planning.

Syntheses and Research Outputs

The *Energy Policy Journal's* special issue on Carbon Emissions and Carbon Management in Cities [14] synthesizes key ongoing global research in the form of fourteen authoritative articles: implications of methodologies for developing long- and short-term urban carbon scenarios and inventories; urban carbon flows based on trade, service and material flows across boundaries; comparative analyses of cities; energy policy making at city and national governmental levels; and urban form impacts for carbon emission mitigation from the urban building and transportation sectors.



©Elsevier

▲Special Issue on Cities and Carbon Emissions

Dhakal S & Shrestha RM (eds). 2010. Special Section on Carbon Emissions and Carbon Management in Cities with Regular Papers. *Energy Policy 38*(9), 4753-5296 (September 2010)

Srinivasan A, Zusman E & Dhakal S (eds). 2010. Low Carbon Transport in Asia: Strategies for Optimizing Co-benefits, London: Earthscan.

Dhakal S. 2009. Urban energy use and carbon emissions from cities in China and policy implications. *Energy Policy 37* (11), 4208-4219

Dhakal S. 2008. Climate change and cities: The making of a climate friendly future. In Urban Energy *Transition - From Fossil Fuels to Renewable Power.* ed. Peter Droege. pp. 173 – 192. Amsterdam: Elsevier Publications

Dhakal S & Betsill M. 2007. Challenges of urban and regional carbon management and the scientific response. *Local Environment 12*(5), 549–555

Lankao PR. 2007. How do local governments in Mexico city manage global warming? *Local Environment 12*(5), 519–535

Lankao PR. 2007. Are we missing the point? Particularities of urbanization, sustainability and carbon emissions in Latin American cities. *Environment and Urbanization 19*(1), 159-175

© Massachusetts Institute of Technology and Yale University

Lebel L, Garden P, Banaticla MRN, Lasco, RD, Contreras A et al. 2007. Integrating carbon management into the development strategies of urbanizing regions in Asia: Implications of urban function, form and role. *Journal of Industrial Ecology 11*(2), 61-81.

Publication based on a collaboration exploring case studies of urbanization in the Asia-Pacific to address carbon management integration into development strategies for cities. Initial case studies: Chiang Mai, Manila, Delhi, and Jambi, Indonesia.

Romero P, Lopez H, Rosas A, Gunther G & Correa Z. 2005. Urban develpment and the carbon cycle in Latin America. IAI Final Report

The product of the network of case studies or urbanization in the Americas questions how specific pathways of development in Latin American cities interact with two components of the carbon cycle, land and energy use, explicitly focusing on the linkages between urban development and the carbon cycle at separate analytical levels.

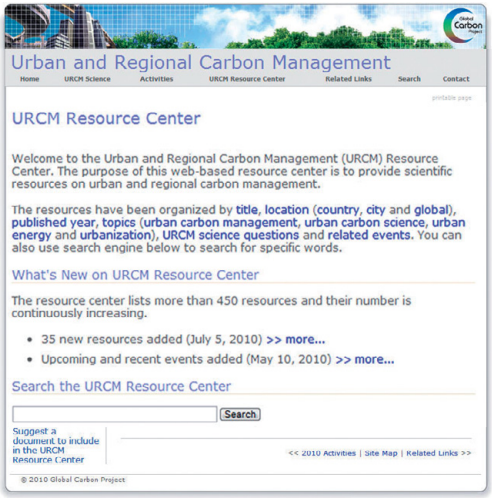
© Universidad Autonoma Metropolitana Xochimilco

Scientific Activities

The GCP has contributed to many international activities on urban carbon issues, among which:

- Global Energy Assessment
- Modelling effort of the IEA on contribution of cities to global carbon emissions
- Consensus panel on low carbon cities of the Academy of Science of South Africa
- Assessment Report on Cities' and Climate Change
- Strong commitment to support and contribute to IPCC AR5 Working Group III for urban carbon and human settlement syntheses.

The Urban Energy and Climate Modelling Forum is an informal forum of urban energy and carbon modelling researchers facilitated by GCP and meeting once a year since 2006 to share knowledge and expertise on urban energy and carbon modelling approaches, models and their results.



▲Visit the GCP-URCM initiative at www.gcp-urcm.org

Urban Carbon Scientific Resource Platform. GCP provides a web-portal to the community that provides key scientific information in the form of a sorted and indexed database comprised of hundreds of entries of journal articles, books, conference papers, presentations or reports and events. In addition, it shows key research nodes, research institutions and a comprehensive list of city action plans.

Strong ties between the GCP and the Japanese research community have made possible the organization of numerous events with the contribution of the National Institute for Environmental Studies (NIES) and several Japanese universities.

16 November 2009	Tokyo, Japan	Cities and Carbon Management: Towards Enhancing Science-Policy Linkages Symposium
17-18 February 2009	Nagoya, Japan	Towards Low Carbon Cities: Understanding and Analyzing Urban Energy and Carbon Workshop
16 February 2009	Nagoya, Japan	Realizing Low Carbon Cities: Bridging Science and Policy Symposium
4-6 February 2008	Pathumthani, Thailand	Urban Energy and Carbon Management: Challenges for Science and Policy, International Symposium, and, Urban Energy and Carbon Modeling Workshop
6 December 2007	Bali, Indonesia	Carbon Management in Cities: Gaps in Policy Discussions and Scientific Understanding. UNFCCC COP-13 Side Event
28-30 March 2007	Tsukuba, Japan	Urban and Regional Development Pathways and their Carbon Implications Workshop
5 December, 2006	Bali, Indonesia	Institutional Dimensions of Carbon Management at the Urban and Regional Levels Workshop
4-8 September 2006	Mexico City, Mexico	International Conference on Carbon Management at Urban and Regional Levels
8-9 October 2005	Tsukuba, Japan	Regions, Cities, Carbon, Climate Change and Consequences

Quotation

[11] Li L, Chen C, Xie S, Huang C, Cheng Z et al. 2010. Energy demand and carbon emissions under different development scenarios for Shanghai, China. *Energy Policy 38*(9), 4797-4807

[12] Phdungsilp A & Dhakal S. 2009. Modelling 2050 Energy and CO_2 Scenarios for Bangkok. Paper presented at the International Workshop: Towards Low Carbon Cities: Understanding and Analyzing Urban Energy and Carbon, Nagoya, Japan, February 17-18 (manuscript under preparation)

[13] Dhakal, Shobhakar. 2010. GHG emissions from urbanization and opportunities for urban carbon mitigation. *Current Opinion in Environmental Sustainability*

4 Forest, Land Use and Carbon

The land-based carbon management, especially forests, has been a key area in science and policy development globally. The GCP community has contributed to the:

- Assessment of global potentials for the development of Reduced Emissions from Deforestation and Degradation (REDD);
- Consolidation of scientific information on carbon accounting methods consistent with policy requirements;
- Monitoring, Reporting, and Verification (MRV) for land-based carbon management, such as REDD.

Science Highlights

©ELSEVIER

Land use, land-use change and forestry (LULUCF) is a critical topic for climate research and the post-2012 framework. In 2007, GCP co-sponsored the publication of a **special issue in the *Environmental Science and Policy Journal*** to identify limitations in the rules for inclusion of the LULUCF activities under Kyoto Protocol and critical features needed in a post-2012 framework, where Canadell et al. (2007) presented options for factoring out natural and indirect human-induced effects on carbon sources and sinks [1.5]. In the same year, GCP contributed to Gullison et al. (2007) paper in the *Science Journal* estimating that cutting deforestation rates in half by mid-century would account for up to 12% of the total emissions reductions needed to keep concentrations of heat-trapping gases in the atmosphere at safe levels. GCP also put together a ***Science in China* special issue** on the effects of land use/cover change on the terrestrial carbon cycle for the Asia-Pacific (see Canadell, Zhou and Noble 2002). Concerted research efforts of the GCP community include the work of Yamagata and Obersteiner who have inquired into the mitigation potential of carbon sequestration policies and its role in the global portfolio of climate change mitigation options showing a tight link between carbon sequestration potential and the market price of carbon (Rokityanskiy et al. 2007).

Syntheses and Research Outputs

Ravindranath NH, Manuvie R, Fergione J, Canadell JG, Brendes G et al. 2009. Greenhouse gases implications of land use and land conversion to biofuel crops. In *Biofuels: Environmental Consequences and Interactions with Changing Land Use*. eds. Howarth R & Bringezu S. pp. 111 – 125. New York: Island Press.

Canadell JG & Raupach MR. 2008. Managing forests for climate change mitigation. *Science 320*(5882), 1456-1457.

Gullison RE, Frumhoff PC, Canadell JG, Field CB, Nepstad DC et al. 2007. Tropical forests and climate policy. *Science*, 1136163

Rokityanskiy D, Benitez PC, Kraxner F, McCallum I, Obersteiner M et al. 2007. Geographically explicit global modeling of land-use change, carbon sequestration, and biomass supply. *Technological Forecasting & Social Change, Special Issue: Greenhouse Gases – Integrated Assessment 74*(7), 1057-1082

Schlamadinger B, Bird N, Johns T, Brown S, Canadell JG et al. 2007. A synopsis of land use, land-use change and forestry (LULUCF) under the Kyoto Protocol and Marrakech Accords. *Environmental Science & Policy 10*(4), 271-282

Benitez PC, McCallum I, Obersteiner M and Yamagata Y. 2006. Global potential for carbon sequestration: Geographical distribution, country risk and policy implications. *Ecological Economics 60*(3), 572-583

Raupach MR, Rayner PJ, Barrett DJ, DeFries RS, Heimann M et al. 2005. Model–data synthesis in terrestrial carbon observation: Methods, data requirements and data uncertainty specifications. *Global Change Biology 11*(3), 378-397.

Canadell JG, Zhou G & Noble I (eds). 2002. Land use/cover change effects on the terrestrial carbon cycle in the Asia-Pacific region. *Science in China Special Issue 45*

Scientific Activities

27-29 January 2009	Santa Barbara, California, USA	Full Radiative Forcing of Forests
8-11 January 2009	Khon Kaen, Thailand	Monsoon Asia Tropical Forest Carbon Dynamics and Sustainability Workshop
22-24 January 2008	Santa Barbara, California, USA	Terrestrial Ecosystems and Climate Policy
10-12 May 2006	Bad Blumau, Austria	Reducing Emissions from Deforestation in Developing Countries
5-6 May 2005	Graz, Austria	Options for Including LULUCF Activities in a Post-2012 International Climate Agreement
20-21 March 2003	Lisbon, Portugal	CarboEurope-GCP Conference

6 Policy Links and Outreach

Online Platform

▲Visit the GCP at www.globacarbonproject.org

GCP online platform shows the activities and research outcomes of the project and acts as a scientific resources center for the broader carbon cycle research and policy communities. The website is a one-stop shop for scientific information on the carbon cycle. Science highlights, activities, meetings, products and Internet scientific resources are compiled according to GCP's main research topics. Internet scientific resources link to climate and carbon overview reports, carbon data, figures and maps, and global initiatives according to carbon pool.

UNESCO-SCOPE-UNEP Policy Briefs

GCP worked with UNESCO, SCOPE and UNEP to prepare overviews of the dynamics of the carbon-climate-human system in the form of policy briefs to highlight a systems approach to managing these interactions. Emphasis is placed on the gap between current carbon emissions and those needed to stabilize atmospheric CO_2, including components of system vulnerability and inertia.

Quotation

[1.5] Canadell JG, Kirschbaum MUF, Kurz WA, Sanz M-J, Schlamadinger B & Yamagata Y. 2007. Factoring out natural and indirect human effects on terrestrial carbon sources and sinks. *Environmental Science & Policy 10*(4), 370-384.

[1.6] Field CB & Raupach MR (eds). 2004. *The Global Carbon Cycle: Integrating Humans, Climate and the Natural World*. Washington DC: Island Press.

[1.7] Canadell JG (eds). Carbon and nitrogen cycles. *Current Opinion in Environmental Sustainability Special Issue 2*(4), 209 - 312

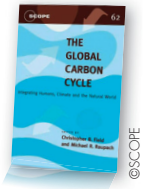
5 Global Assessments and Synthesis

Science Highlights

GCP has initiated the **REgional Carbon Cycle Assessment and Processes (RECCAP)** initiative, a large global coordination effort among researchers and institutions planning to:

- establish the mean carbon balance of large regions of the globe, including their component fluxes;
- test the compatibility of regional bottom-up estimates with global atmospheric constraints;
- evaluate the regional 'hot-spots' of inter-annual variability and possibly the trends and underlying processes over the past decades by combining available long-term observations and model results.

The assessment is ongoing and results will be published in reputed, peer reviewed research journals and contribute to the 5th Assessment of the IPCC. An anticipated product is an open access carbon fluxes database from regional and global estimates. Global datasets and model runs available so far to regional groups are: ocean inversions and ocean biogeochemical models, atmospheric inversions, terrestrial biogeochemical models and fire emissions. For more information: www.globalcarbonproject.org/reccap



©SCOPE

Every few years the GCP delivers a global synthesis on the integrated view of the carbon–climate–human system and its specific components. In 2004 the first global synthesis was published as a collaborative effort between the **Scientific Committee on Problems of the Environment (SCOPE)** and the GCP [16]. The volume comes as a complement of the Intergovernmental Panel on Climate Change reports on the scientific basis of climate change, the impacts of climate change, and the potential for mitigation of climate change.

In 2010, the *Journal of Current Opinion in Environmental Sustainability* published a collection of GCP high-level synthesis papers as part of the first 10-year project activity review [17]. The issue foresees key emerging research directions and needs expected to shape up the next 10 years of GCP activity and the broader scientific community. In it, a comprehensive review and prioritization of the carbon cycle and management research is presented [18].

Syntheses and Research Outputs

GCP Report No. 1. Canadell JG, Dickson R, Raupach M, Young O (eds). 2003. *The GCP Science framework and Implementation*. Global Carbon Project, Earth Science System, Partnership (ESSP) Report Series No.1, GCP Report Series No 1, Canberra, pp. 69

GCP Report No. 6. Coulter L, Canadell JG, Dhakal S. 2007. *Carbon Offsets and Reductions*. A GCP report prepared for the ESSP.

Leemans R, Asrar G, Busalacchi A, Canadell JG, Ingram J et al. 2009. Developing a common strategy for integrative global environmental change research and outreach: the Earth System Science Partnership (ESSP). *Current Opinion in Environmental Sustainability 1*(1), 4-13.

Scholes RJ, Monteiro PMS, Sabine CL & Canadell JG. 2009. Systematic long-term observations of the global carbon cycle. *Trends in Ecology & Evolution 24*(8), 427-430.

Klepper G, Canadell JG, Leemans R, Ometto J, Patwardhan A & Rice M. 2008. *ESSP Research on Bioenergy and Earth Sustainability: Tapping GEC Programme-Wide Expertise for the Benefit of Science and Society*: IHDP.

Scientific Activities

6-8 October 2010	Viterbo, Italy	Examination of Existing Approaches for Construction of Regional Carbon Budgets for both Land and Ocean Areas Workshop and 1st workshop of RECCAP
19-22 July 2008	Piracicaba, Brazil	The Bioenergy and Earth System Sustainability Meeting
23-25 August 2007	Kruger National Park, South Africa	Symposium on African Carbon Cycle
8 December 2003	Milan, Italy	Toward CO_2 Stabilization: Issues, Strategies and Consequences, SCOPE-GCP Side event in FCCC-COP9
3-7 February 2003	Ubatuba, Brazil	Toward CO_2 Stabilization: Issues, Strategies and Consequences
30-31 May 2002	Boulder, Colorado, USA	Carbon Data-Model Assimilation (C-DAS) Summer Institute

Science-Policy Interface

16 November 2009	Tokyo, Japan	Cities and Carbon Management: Towards Enhancing Science-Policy Linkages Symposium
6 December 2007	Bali, Indonesia	Carbon Management in Cities: Gaps in Policy Discussions and Scientific Understanding. UNFCCC COP-13 Side Event
5-6 May 2005	Graz, Austria	Options for Including LULUCF Activities in a Post-2012 International Climate Agreement

The GCP has made a concerted effort to establish communication between science providers and users, particularly international and national policy communities. It creates opportunities for linkage with high-level decision making forums and scientific bodies to which it also contributes, such as the UNFCCC's Subsidiary Body on Scientific and Technical Advice (SBSTA) and the Conference of the Parties (COP), numerous national governmental bodies and agencies, and interactions with the World Bank, Asian Development Bank and other institutes. The urban initiative of GCP in particular has initiated several research–policy dialogues.

Media Communication

26 September 2008	Capitol Hill Washington, D.C., USA & Paris Observatory, France	Launch of 2007 Carbon Budget
2-4 June 2005	Tokyo, Japan	Science Journalism Partnership Forum and Workshop

GCP carries out regular press releases on key findings and scientific knowledge for the benefit of a broad spectrum of stakeholders. Those press releases have generated thousands of media articles in newspapers, radio and television over the world.

Quotation

[18] Canadell JG, Ciais P, Dhakal S, Dolman H et al. 2010. Interactions of the carbon cycle, human activity, and the climate system: A research portfolio. *Current Opinion in Environmental Sustainability 2*(4), 301 – 311

The Global Carbon Project works under the Global Change Science Programs. It operates based on voluntary contribution of hundreds of scientists' time and effort to contribute to the development and execution of the carbon cycle research.

The Global Carbon Project is an initiative of the Earth System Science Partnership (ESSP), which consists of the International Geosphere-Biosphere Programme (IGBP), International Human Dimensions Programme on Global Environmental Change (IHDP), World Climate Research Programme (WCRP) and Diversitas, an International Programme of Biodiversity Science.

NIES

Tsukuba, Japan

National Institute for Environmental Studies,
Center for Global Environmental Research

Address: 16-2 Onogawa,
Tsukuba, 305-8506, Japan
Phone: +81-29-850-2672
Fax: +81-29-850-2960

CSIRO

Canberra, Australia

Commonwealth Scientific and Industrial Research Organisation,
Marine and Atmospheric Research

Address: GPO Box 3023
Canberra, ACT 2601, Australia
Phone: +61-2-6246-5631
Fax: +61-2-6246-5988

www.globalcarbonproject.org

Supporters

The GCP International Project Offices are hosted and supported by the Department of Climate Change and Energy Efficiency, Australian Government, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia and the National Institute for Environmental Studies (NIES), Japan.

Earth System Science Partnership

MNHN, 57 rue Cuvier - CP 41
75231 Paris Cedex 05, France
Phone: +33 1 4079 8042
Fax: +33 1 4079 8045

GLOBAL CHANGE IGBP

Royal Swedish Academy of Sciences, Box
50005, 104 05 Stockholm, Sweden
Phone: +46 (0)8-166 448

IHDP

IHDP Secretariat
United Nations University, UN Campus
Hermann-Ehlers-Str. 10, D-53113 Bonn
Phone: +49 (0)228 815 0600
Fax: +49 (0)228 815 0620
Email: secretariat@ihdp.unu.edu

WCRP World Climate Research Programme

WCRP Joint Planning Staff
c/o World Meteorological Organization
7 bis, Avenue de la Paix, Case Postale 2300
1211 Geneva 2, Switzerland
Phone: +41 22 730 81 11
Fax: +41 22 730 80 36
Email: wcrp@wmo.int

DIVERSITAS an international programme of biodiversity science

DIVERSITAS
Museum National d'Histoire Naturelle (MNHN)
57 Rue Cuvier – CP 41
75231 Paris Cedex 05, France
Phone : +33 (0)1 40 79 80 40
Fax: +33 (0)1 40 79 80 45
Email: secretariat@diversitas-international.org

Authors: Lavinia Poruschi, Shobhakar Dhakal, Josep (Pep) Canadell / Proofreading: Edit Nagy-Tanaka / Editor: ISEBU Co., Ltd. / Printed: October 2010 / Printed in Japan

Reference to this publication should be made as: GCP. 2010. Ten Years of Advancing Knowledge on the Global Carbon Cycle and its Management (Authors: Lavinia Poruschi, Shobhakar Dhakal and Josep Canadell). Tsukuba: Global Carbon Project.

GCP Scientific Steering Committee

Co-Chairs

Philippe Ciais

Commissariat à L'Energie Atomique
Laboratoire des Sciences du Climat et de l'Environnement
Centre d'Études de Orme des Merisiers, France

Corinne Le Quéré

University of East Anglia/British Antarctic Survey
School of Environment Sciences, UK

Anand Patwardhan

Indian Institute of Technology-Bombay
S.J Mehta School of Management, India

Executive Directors

Josep Canadell

Global Carbon Project
CSIRO Marine and Atmospheric Research, Australia

Shobhakar Dhakal

Centre for Global Environment Research
National Institute for Environmental Studies, Japan

SSC Members

Ken Caldeira

Department of Global Ecology
Carnegie Institution, USA

Pierre Friedlingstein

IPSL, Laboratoire des Sciences du Climat et de l'Environment, France

Kevin Gurney

Department of Earth and Atmospheric Sciences &
Department of Agronomy, USA

Keisuke Hanaki

Department of Urban Engineering
The University of Tokyo, Japan

Thomas B Johansson

International Institute for Industrial Environmental Economics, Sweden

Elisabeth Malone

Pacific Northwest National Laboratory
Joint Global Change Research Institute at the University of Maryland, USA

Guy Midgley

Kirstenbosch Research Center
South African National Biodiversity Institute, South Africa

Nebojsa Nakicenovic

International Institute for Applied Systems Analysis, Austria

Ye Qi

Institute of Public Policy
Tshinghua University, China

Michael Raupach

CSIRO Marine and Atmospheric Research, Australia

Yoshiki Yamagata

(Associate Member)
Centre for Global Environment Research
National Institute for Environmental Studies, Japan

International Project Offices

Japan

Shobhakar Dhakal

Executive Director of GCP
Center for Global Environmental Research
National Institute for Environmental Studies
Email: shobhakar.dhakal@nies.go.jp

Lavinia Poruschi

Research Assistant Fellow
Center for Global Environmental Research
National Institute for Environmental Studies
Email: lavinia.poruschi@nies.go.jp

Yukako Ojima

Project Officer
Center for Global Environmental Research
National Institute for Environmental Studies
Email: ojima.yukako@nies.go.jp

Address: 16-2 Onogawa,
Tsukuba, 305-8506, Japan
Phone: +81-29-850-2672
Fax: +81-29-850-2960

Australia

Josep (Pep) Canadell

Executive Director of GCP
CSIRO Division of Atmospheric Research
Email: pep.canadell@csiro.au

Natalie Barnett

Project Officer
CSIRO Marine and Atmospheric Research
Email: natalie.barnett@csiro.au

Rowena Foster

Finance Manager
Global Carbon Project
CSIRO Marine and Atmospheric Research
Email: Rowena.Foster@csiro.au

Address: GPO Box 3023
Canberra, ACT 2601, Australia
Phone: +61-2-6246-5631
Fax: +61-2-6246-5988

Global Carbon Project

www.globalcarbonproject.org