

An International Effort to Quantify Regional Carbon Fluxes

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The international carbon cycle research community is currently coordinating the largest, most comprehensive assessment it has ever undertaken: the Regional Carbon Cycle Assessment and Processes (RECCAP; <http://www.globalcarbonproject.org/reccap>). The objective is to establish the mean carbon balance and change over the period 1990–2009 for all subcontinents and ocean basins. The global coverage will provide, for the first time, opportunities to link regional budgets with the global carbon budget. Regional details on or insights into processes driving fluxes have not, to date, been incorporated into efforts addressing the global carbon budget [Canadell *et al.*, 2007; Le Quéré *et al.*, 2009]. The consistency check between the sum of regional fluxes and the global budget will be a unique measure of the level of confidence there is in scaling carbon budgets up and down.

Three key objectives justify the need for a new assessment of regional carbon fluxes and their drivers: (1) to provide higher spatial resolution for the global carbon balance with the aim of improving the quantification and understanding of drivers, processes, and hot spot regions essential for predicting the future evolution of any carbon-climate feedback; (2) to address the growing demand for the capacity to measure, report on, and verify the evolution of regional fluxes and the outcomes of climate mitigation policies; and (3) to respond to the Group on Earth Observations (GEO), a partnership of governments and international organizations, in establishing a global carbon observation strategy [Ciais *et al.*, 2010]. This also includes the development of capacity in regions that provide a significant contribution to global carbon fluxes but are poorly covered by current observation networks and expertise.

Although these broad objectives have existed over the past decade, RECCAP has been made possible by the experience gained within the European and U.S. carbon budget research programs and by the international coordination role of the Global Carbon Project (GCP) of the Earth System Science Partnership [Canadell *et al.*, 2003].

Of the 14 regions in the RECCAP synthesis, 10 are terrestrial (Africa, the Arctic tundra, Australia, Europe, Russia, East Asia, South Asia, Southeast Asia, Central and South America, and North America) and four are ocean regions (Atlantic and Arctic, Indian, Pacific, and Southern oceans). In addition, eight global syntheses will support the integration of the regional carbon budgets into a global picture and provide the link to the top-down constraints delivered by atmospheric observations and inversion models.

The fundamental tenet of RECCAP is to establish carbon budgets in each region by comparing and reconciling multiple bottom-up estimates, which include observations and model outputs, with the results of regional top-down atmospheric carbon dioxide (CO₂) inversions. The effort is guided by a methodology that includes diverse data with their uncertainties and a two-tier system that ensures a common approach and a minimum set of analyses performed by

all regions (Figure 1). Regions with limited observations and available analyses will build their syntheses upon centrally organized global data sets and global model output (tier 1). These data sets and models include output from 11 atmospheric CO₂ model inversions, six global process-based vegetation models, five ocean carbon models, and one ocean inversion model using both surface partial pressure of CO₂ (*p*CO₂) and ocean carbon cross sections. Additional input data include emissions from vegetation fires derived from satellite observations and modeling, emissions from fossil fuel and land use change, and a land CO₂ flux data-driven model for global gross primary production and net ecosystem production.

Regions with dense observational networks and preexisting data syntheses and compilations will use, and appropriately weigh, these regional estimates against those from global products (tier 2). Estimates include output from regional models, forest biomass inventories, soil carbon surveys, well-sampled ocean gyres, as well as regionally calibrated remote sensing products and data sets such as biomass, ocean column inventories of anthropogenic carbon and surface *p*CO₂, and hydrological quantities.

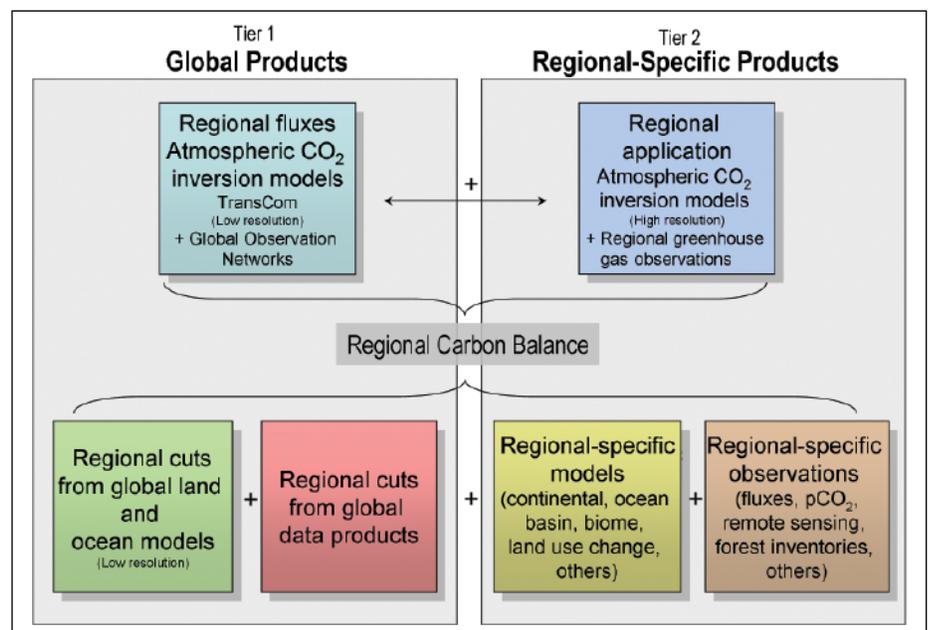


Fig. 1. Two-tier methodological approach ensuring that all regions, regardless of the level of information available to them, can develop a consistent top-down and bottom-up carbon balance.

The assessment builds upon a number of regional carbon research programs and contributions by more than 150 scientists as lead and contributing authors. Draft manuscripts of all regional and global syntheses are expected by April 2011, in time for the second all-authors meeting that will take place on 23–27 May 2011 at the U.S. Fish and Wildlife Service National Conservation Training Center in Shepherdstown, W. Va.

The largest legacies of RECCAP are expected to be (1) an interdisciplinary approach to utilize multiple constraints from independent and overlapping estimates of carbon fluxes to build confidence in regional knowledge of carbon sources and sinks and (2) a distributed open-access database (to be updated in the future) of carbon fluxes from the regional and global estimates.

The assessment process is coordinated by the GCP International Project Office

in Canberra, ACT, Australia, hosted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Two major sponsors of RECCAP are the European Union Coordination Action on Carbon Observation System and the U.S. Carbon Cycle Science Program.

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Exploring the Continental Margin of Israel: “Telepresence” at Work

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A multidisciplinary team of American and Israeli scientists conducted ocean exploration with a “telepresence” component offshore Israel in September 2010 on board the new E/V *Nautilus*, which is a reincarnation of the former East German R/V *Alexander von Humboldt*. This was the first comprehensive geological and biological exploration of the Israel continental margin using deep submergence vehicle systems.

Diverse seafloor environments in water depths between 500 and 1300 meters were sampled and imaged using two remotely operated vehicle (ROV) systems, *Hercules* and *Argus*. The ROV dives within three areas (Figure 1) investigated high-priority acoustic targets representing geological, biological, or archaeological features as identified by the onboard scientific team. During the dives, biological and geological samples and more than 100 kilometers of high-resolution side-scan sonar data were collected.

High-speed satellite connectivity enabled real-time voice and video communication with the ship through the dedicated Web site *Nautilus Live* (<http://www.nautiluslive.org>). E/V *Nautilus* is owned and operated by the Ocean Exploration Trust, a private Connecticut-based nonprofit organization. The ROV systems are owned and operated by the Institute for Exploration (IFE) at Mystic Aquarium, in Connecticut; both the institute and the aquarium are divisions of Sea Research Foundation. The foundation has developed telepresence Internet technology that distributes streaming video and data and two-way voice communications between the ship and the ROVs. This live feed went first to the University of Rhode Island's Inner Space Center (ISC) and then

to distributed exploration command consoles (ECCs), which are combinations of high-definition TV screens and intercoms available at a number of schools, research laboratories, and universities, both in the United States and in Israel. Telepresence also enabled shore-based scientists to participate in the exploration program in real time.

Geologic Setting

The Israel margin (Figure 1) is bounded to the north and east by the Cypriot arc and the margins of Syria and Lebanon and to the south and west by the Egyptian margin and the Nile fan. This region is tectonically active, with the Carmel fault emanating from the African-Arabian plate boundary along the Dead Sea Transform and crossing the margin [Schattner and Ben-Avraham, 2007]. Large slump and slide features occur as a result of this ongoing tectonism, as evidenced in part by the Dor and Palmachim disturbances that are associated with downslope sedimentation in slope canyons and buried salt movements, respectively [Ben-Avraham et al., 2006].

ROV and side-scan sonar surveys aboard *Nautilus* relied on previously collected and processed bathymetric data from various sources, including the Geological Survey of Israel and the hydrocarbon industry; existing high-quality seafloor maps allow efficient placement of the ROVs on or near interesting seafloor features. *Nautilus* is equipped with a dynamic positioning system to facilitate precise location control of the ROVs on the seafloor. The *Hercules-Argus* ROV system, developed by IFE as an advanced imaging and sampling platform for geological, biological, and archaeological

investigations, can be deployed to 4000-meter depths, and the system is equipped with high-definition video cameras, high-powered hydrargyrum medium-arc iodide (HMI) daylight-simulating lights, scanning and profiling sonars, grasping and holding claws/manipulators, and auxiliary cameras and sensors. *Hercules* is also capable of collecting biological and geological samples. *Argus* is used in tandem with *Hercules* to provide a high-definition camera “eye-in-the-sky” perspective for overall site imaging and vehicle-piloting assistance.

Nautilus explored three regions in area 1 (Figure 1): the Achziv Canyon along the border with Lebanon; the Dor disturbance, a region of disturbed seafloor associated with the offshore extension of the Carmel fault; and several small submarine canyons lying along the central margin's slope. The Achziv Canyon floor is sedimented and gently undulating, composed of fine silt and clay often bioturbated by worms, fish, and small crabs. The small submarine canyons are characterized by steeper walls and narrower widths; near-vertical canyon walls and possible gas vent structures were imaged and sampled.

Area 2 includes a deep, meandering channel and an adjacent sedimentary ridge in water depths up to 1800 meters (Figure 1). Within the deep meander, sedimentary mounds up to a few meters in diameter and less than a meter high were discovered, heavily bioturbated and containing possible gas-escape structures. These mounds may be the result of biological activity associated with gas venting along the eroded sedimentary channel system.

The Palmachim disturbance (Figure 1, area 3) represents older seafloor deposits slumping seaward down the modern slope, likely the result of the mobilization of approximately 5-million-year-old salt underlying the slope [Garfunkel et al., 1979], perhaps triggered by intermittent seismic activity. Hard, rocky outcrops and possible gas-charged sediments were encountered; turbid