Analysing the Global Carbon Cycle; The Interaction of Sources and Sinks

Why analyse the carbon cycle? Carbon is the central building block of all living organisms. On earth, carbon cycles in vast quantities through the atmosphere, biosphere and geosphere interconnected by pathways of exchange that undergo various chemical, physical, geophysical and biological processes. These exchanges are very complex and each process change has an impact on other processes within the cycle and on the total carbon balance. If an organism absorbs more carbon dioxide (CO_2) than they emit they are known as a carbon sink. If they emit more CO_2 than they absorb they are a carbon source.

Despite some recent press reports to the contrary, the vast majority of scientific evidence demonstrates that global warming is as a result of rising CO_2 levels in the atmosphere. CO_2 is a prominent greenhouse gas, acting as a blanket to prevent heat leaving the earth's atmosphere. Research suggests that atmospheric CO_2 levels have risen dramatically and at increasing rates in recent history and are now at their highest levels in at least 650,000 years. Ice core measurements indicate that ambient CO_2 was approximately 284ppm (parts per million) back in 1832. This increased to 350ppm in 1988 and is around 389ppm today.

If atmospheric CO_2 levels continue to rise global temperatures are expected to also rise. Some reports suggest that a rise in CO_2 to 700ppm would increase global temperatures by around 1.5°C, impacting on our climate, ecology and social economics.

It is widely accepted that man-made activity, by burning fossil fuels, accounts for about 50% of atmospheric CO_2. Natural biomass respiration and volcanic activity account for the remainder. Natural carbon sinks such as plant photosynthesis and ocean biota take up about half of this released CO_2.

Increased uptake of CO_2 by the world's oceans has its own environmental impact as the seas become more acidic and so potentially damaging the marine life and ecology. There are also questions as to whether the oceans can sustain current CO_2 uptake levels due to the effects of the climate change.

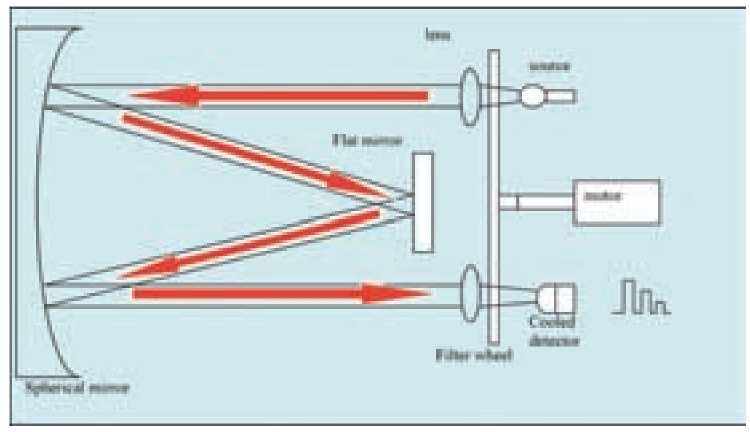
The concerns regarding rapidly rising atmospheric CO_2 concentrations and its potential impact on future climate is an issue of global, economic and political significance. Much emphasis, therefore, is being placed on CO_2 exchange research. Due to the complexities of these flux exchanges, the research draws on expertise from a number of geoscience disciplines requiring a variety of high quality and versatile gas exchange instrumentation. ADC Bioscientific is one of the world leaders in the development and manufacture of this environmental research instrumentation employed in carbon exchange research.

Infrared Gas Analyser

ADC BioScientific instrumentation measures CO_2 concentrations by Infrared Gas Analysis. Infrared gas analysers, often affectionately known by researchers as IRGAs, measure the energy absorbed by heteroatomic gases, such as CO_2, at very precise wavelengths within the infrared region.

First produced in the UK in the 1940s, IRGAs were initially simple, bulky, mains powered and laboratory based instruments. However, researchers' requirements and expectations have lead to these instruments becoming ever more powerful, sophisticated, reliable and

ADC OPEC system at CFERN field station Jianxi Province, China.



Folded open path IRGA design of ADC OP-2.

field portable. ADC BioScientific gas exchange instrumentation is regarded as market leaders in portability and ease of use.

This highly specialised instrumentation is utilised in various areas of CO_2 exchange research.

Atmospheric CO_2

There are many instruments and techniques available for measuring the absolute atmospheric CO_2 concentration. However few are able to directly analyse the relationship and interaction between the atmosphere and terrestrial carbon sinks.

Eddy covariance is a technique, used by meteorologists, biologists and ecologists, that determine the momentum of 3-dimential vertical CO_2 fluxes within atmospheric boundary layers, for instance directly above a crop, grassland or forest canopy. The methodology is mathematically complex and requires highly specialised field instrumentation. This fundamentally includes a fast response, high resolution CO_2/H_2O analyser synchronised with a fast sampling sonic anemometer providing combined data at 20Hz. It is common for this instrumentation to be located on flux towers many meters high above a forest canopy or even on an aircraft or blimp.

Typically the analysis cell of an infrared gas analyser is of a closed construction with gas being pumped through it. Unfortunately this design is not completely suitable for Eddy covariance experimentation as there is a lag time between the sampling point and the analysis cell that may be several meters of gas tubing away. To overcome these delays an analyser is designed with an analysis cell directly open to the environment, so any changes in atmospheric CO_2 is measured instantaneously. One such instrument is the ADC BioScientific OP-2 CO_2/H_2O open path analyser.

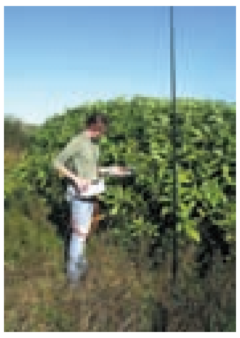
The longer the path length of an infrared gas analyser cell, the higher the possible resolution. With a path length of 80cm the OP-2 is able to resolve CO_2 to 0.02ppm. At the same time the novel folded path design, where the energy signal is reflected back 4 x 20cm, maintains the compact nature of the instrument.

The ADC OPEC (Open Path Eddy Covariance) system is a complete, fully integrated and synchronised measurement station. In addition to the OP-2, it also features the highly regarded Windmaster sonic anemometer, manufactured by Gill Instruments Ltd. and EDDYSOFT, Eddy covariance data collection and calculation software written by flux researchers at the Max Plank Institute.

Plant Photosynthesis

Vegetation is a prime natural carbon sink absorbing CO_2 for photosynthesis, a key biochemical process, providing essential energy and building materials for plant tissue.

Improving our understanding of plant growth and crop production is an ongoing necessity for the global community. By measuring photosynthesis, by CO_2 uptake, it is possible to monitor plant health and efficiency. There is now the added environmental aspect of this research regarding how crops will respond to rising CO_2 concentrations and how their anticipated increased photosynthesis rates could impact on the carbon balance.



Researcher from University of Aberdeen investigating photosynthesis using the ADC LCi.

There are many environmental and physiological factors that affect photosynthesis and the latest gas exchange instrumentation is de-signed to enable researchers to analyse these parameters in relation to CO_2 uptake.

The ADC BioScientific LCi and LCpro+ are two truly portable photosynthesis systems designed to carry out these experiments even in the most remote and harsh field locations. To ensure the fastest possible response times, a miniaturised IRGA is positioned directly next to the chamber where the leaf is analysed. With ambient air being circulated around the system a CO_2 measurement is performed prior to the air flow reaching the leaf and then again after the leaf. The difference in the CO_2 concentration is therefore due to the activity of the leaf.

Both the LCi and the LCpro+ are battery operated systems providing up to 16 hours of continuous operation from a single charge. To analyse environmental effects of photosynthesis the LCpro+ is able to automatically control the temperature, light, water vapour and particularly CO_2, at elevated levels (>700ppm), within the leaf chamber.

Plant response to elevated CO_2 is also conducted at whole plant level, where CO_2 is elevated (>700ppm) inside open-top chambers. These tent like structures are several meters high and in diameter allowing a researcher to analyse photosynthetic activity using the LCi or LCpro+ directly inside the chamber. Free Air CO_2 Enrichment experiments (FACE) elevate CO_2 in field sites, up to 30m in diameter, using a ring of enrichment pipes. This allows investigations of whole undisturbed ecosystems without modifying the vegetation interaction with the natural environment.

Soil Respiration

Soil respiration or soil CO_2 flux is the largest natural carbon source. It is therefore extremely important to understand its process, the effects of environmental conditions and the role it plays in global carbon cycling. Soil respiration consists of CO_2 produced by respiring soil micro-organisms during the degradation of soil biomass material. There is additional respiration from plant root tissue.

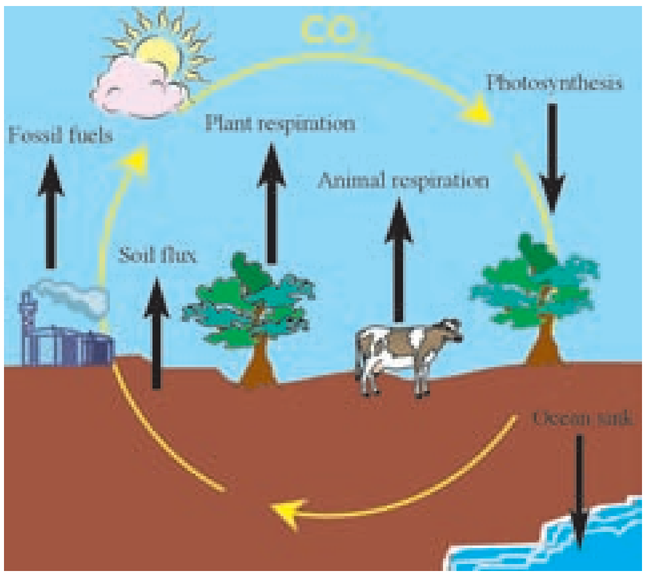
There are two major types of field soil respiration experimentation. Spatial variability consists of short-term measurements taken at a number of different sample points across a field site during a limited time period. Instrumentation for this type of work includes the ADC BioScientific SRS1000 and SRS2000. These truly field portable systems feature a CO_2 IRGA located directly next to a soil respiration chamber. As with the photosynthesis systems CO_2 concentrations are measured before and after the soil chamber to ascertain the CO_2 flux rates from the soil. The soil chamber features a detachable stainless steel collar that is placed into the soil several minutes prior to the start of measurements. By having a number of collars placed around a field site multiple soil flux determinations can be made and so spatial variability can be determined.

The second major type of field soil flux experimentation is temporal variability when flux rate changes are monitored daily, monthly or even yearly on the same area of soil.

For temporal variability research ADC BioScientific has developed ACE (Automated Soil CO_2 Exchange System) which has been designed for long-term unattended soil flux measurements. Each ACE Station features a highly accurate CO_2 IRGA housed directly next to the soil chamber, thus reducing response times, making the system easy to set up, field robust and very power efficient. Measurements are typically made once an hour by measuring the rise in CO_2 concentrations inside the chamber. The chamber then automatically opens between analysis cycles so allowing ambient conditions to reach the soil.

Multiple ACE Stations can be used independently or as part of an ACE Network. Up to 30 ACE Stations can be electrically connected together, allowing programming, data storage and power supply via a single ACE Master Control Unit.

There is a high level of scientific confidence that atmospheric CO_2 concentrations are increasing and that global temperatures are rising. However, many knowledge gaps remain regarding the processes and interactions within the carbon cycle. Therefore there are continuing expectations from the world's scientific community for manufacturers to develop ever more sophisticated and field portable gas exchange equipment. ADC BioScientific will continue to endeavour to meet these challenges.



Carbon dioxide cycle

ADC ACE system in use at Slovak Agricultural University, Nitra, Slovakia.

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