Improvements in Micrometeorological Instrumentation – Integrated CO_2/H_2O Flux Measurement Systems

Eddy Covariance Technique

For many years scientists working in the field of micrometeorology have used the 'Eddy Covariance' technique to study the transfer of carbon dioxide and other greenhouse gases (GHG) between plants, soils, bodies of water and the atmosphere at the boundary layer. This complex statistical technique uses high frequency measurements of the movement of air in three dimensions along with the analysis of an air sample taken from the same position at the same time to determine the net exchange, or flux, of carbon dioxide, water vapour and sensible heat. Monitoring stations are typically installed above a forest canopy, field of crop or grassland where some of the prerequisites of meaningful readings such as homogeneity of terrain can be attained. Increasingly scientists are also studying fluxes in urban environments and above water.

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Like any statistical method a large volume of data is required and so measurements are made at high frequency, typically 10 or 20 Hz over extended periods of time.

The basic measurement tools for Eddy Covariance are a sonic anemometer capable of measuring speed and direction in three dimensions, a gas analyser and a method to capture and store the data at high speed – usually either a pc, or, more typically, a data logger.

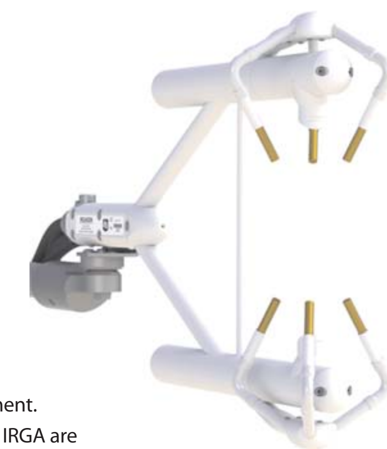
Synchronising Sensor Data

One technical challenge of the Eddy Covariance measurement process that is worth discussion is sensor data synchronisation. It is important that the sample of air under analysis can be exactly matched with the speed and direction of its movement at the precise moment it was taken - in other words the wind data and gas sample must be taken at exactly the same location and time.This might seem obvious and you might consider easy to achieve but it isn't as simple as it might first appear. Let's consider the position aspect first – on systems to date the gas analyser and the sonic anemometer are separate instruments, often not even manufactured by the same company and so the two devices will have no specific mechanism to connect them together in any neat and tidy manner and this alone can make positioning the measurement volumes close to each other difficult. Secondly, the two separate instruments can interfere with the aerodynamics of the other and disrupt the airflow so positioning needs to be carefully considered. Measurements taken when the wind is in a direction whereby the instruments, instrument tower or other nearby obstruction disrupts the airflow significantly have to be filtered from the results. Having two instruments side-by-side might narrow the angle of usable wind direction which reduces the volume of data available for statistical analysis.

Why do measurements need to be synchronised anyway, you might wonder? Well, the reason is that these systems are sampling turbulent air rotating in eddies of various sizes; at the point of measurement air will be moving at a specific speed and in a specific direction. By sampling the air at the exact same time we can say at that precise moment whether CO_2 or H_2O was moving upwards or downwards and at what velocity – by taking 10 or 20 such measurements every second for extended periods we can average the net movement over time. If our measurements are not synchronised then we do not know how fast or in which direction the air sample we are analysing was moving.

So what makes synchronising measurements a challenge – firstly the analyser, anemometer and any other sensors in use will have different response times which will need to be taken into account. Additionally, on some closed path systems, the air sample is pumped down a tube from the air intake to a separate analyser unit which introduces a delay relational to the tube length and this also has to be taken into account. Once these delays and differences in response times are understood then measurements can be synchronised by the data logger or computer – but remember that this is all happening at up to 20 times per second.

Open Path Eddy Covariance - IRGASON



Igrason - The IRGASON co-locates measuerment volumes of both 3D sonic anomemter and IR gas analyser by combining then in a single instrument

The IRGASON is a major step forward in micrometeorological instrumentation because it uniquely incorporates an open path infra-red gas analyser (IRGA) and a 3D sonic anemometer in a single instrument. For the first time a sonic and an IRGA are not just made by a single manufacturer to fit and work together but are totally integrated in a single device. It simultaneously measures absolute carbon-dioxide and water-vapour densities, air temperature, barometric pressure, three-dimensional wind speed, and sonic air temperature.

This eliminates one of the issues mentioned above because the measurement volumes for wind and gas samples are exactly co-located. Additionally, building the two high level instruments into a single low-profile, aerodynamic body minimises air flow disruption around both sensors. The IRGASON connects to a single electronics control box, the EC100, for simple installation and, importantly, better power efficiency. The IRGASON draws just 5W during steady state operation and power-up which means that EC stations can now realistically be operated using solar panels in many situations.

The EC100 also takes care of the signal synchronisation which means that the output from the IRGASON does not have to be separately synchronised by the data logger simplifying programming. The IRGASON supports field set-up and configuration and field zero and span all, accomplished directly from the data logger in the field.

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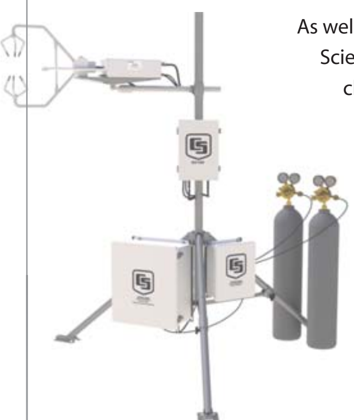
The IRGASON is the latest development in Campbell Scientific's micromet range and is a natural progression from the EC150/EC155 gas analysers and CSAT3A head released a couple of years back. These devices were designed to operate and physically connect together to closely co-locate measurement volumes, minimise air flow distortion and, because they also connect to the EC100 electronics unit, benefited from reduced system power and complexity and pre-logger temporal data synchronisation.

Whilst clearly anybody setting up an EC system from scratch would want the extra benefits of the IRGASON, the separate EC150 Open Path IRGA is still available for anybody that has an existing Campbell CSAT3 sonic anemometer or who wishes to use a sonic of another make. (Using the EC150 with another make of anemometer clearly would not co-locate the measurement volumes in the same manner).

Closed Path Eddy Covariance – CPEC200



CPEC200 - The CPEC200 is a fully integrated, turn-key closed-path Eddy Covariance system.

As well as open path systems Campbell Scientific also offer the CPEC200 closed path system. Closed path has some advantages over open, it can be used when it is raining for one thing, but typically such systems are more complex to install and more costly. The CPEC200 is an integrated closed-path Eddy Covariance system which consists of an EC155 closed-path gas analyser, the CSAT3A sonic anemometer and a pre-programmed CR3000 data logger. The system also includes a pump module, the CPEC200 enclosure and all the necessary mounting hardware, tubing and cables. An optional valve unit is available for automated zero and span. As mentioned above the CSAT3A sonic anemometer and EC155 gas analyser are designed to mount directly together, closely co-locating the measurement volume of both instruments, minimising air flow distortion and utilising shared electronics for simplicity of installation and power efficiency.

The EC155 closed-path gas analyser samples the air directly in the head of the instrument minimising any 'mixing' associated with systems where the sample is pumped from the intake to a separate analyser unit sometimes some metres away. The sample intake is heated to prevent condensation and the instruments small sample cell volume (5.8 ml) minimises the sample residence time (50 ms at the system's nominal flow rate, 7 LPM). This gives excellent frequency response (5.8 Hz half-power bandwidth).

The systems fundamental measurement frequency is 100 Hz with a user-selectable output bandwidth at 5, 10, 12.5, 20 or 25 Hz. Data can be stored on-board using CompactFlash cards up to 2 Gb, enough to record up to 2 months of data at 10Hz, or the system can be remotely interrogated with telemetry methods including Ethernet, RS-232, short haul modem, land-line and RF wireless, cellular and satellite. Overall system power is just 12W meaning that the CPEC200, like the open path IRGASON, can also be powered by solar panels in many situations.

The data logger program brings together all the components of an Eddy Covariance system and Campbell Scientific offer a library of CRBasic programmes which can be used for an Eddy Covariance station either with or without energy balance sensors.

AP200 – CO_2 & H_2O Profiler

Often used in conjunction with an eddy covariance system the AP200 is a complete, integrated CO_2 and H_2O atmospheric profile system which measures the storage term and give a more complete measure of the surface gas exchange. It measures carbon dioxide (CO_2) and water vapour (H_2O) concentration from up to eight intakes, which are normally spaced along the height of a tower to give a vertical profile.

AP200 - The AP200 is an atmospheric profiling system measuring CO_2 & H_2O concentrations from up to 8 intakes

The AP200 contains a pre-programmed CR1000 measurement and control datalogger which takes the measurements but also automates zero and span and automates the temperature and pressure control. The whole system requires just 13W (average at 25°C and 12 Vdc).

Conclusion

Campbell Scientific has been involved in micrometeorological instrumentation for many years and these latest devices are the result of ongoing commitment to product development and innovation in this area. Campbell Scientific believe that the introduction of these low power, turnkey systems, with their co-located measurement volumes will make it easier for scientists to concentrate more on taking and analysing good measurements and have to worry a little less about the instruments.