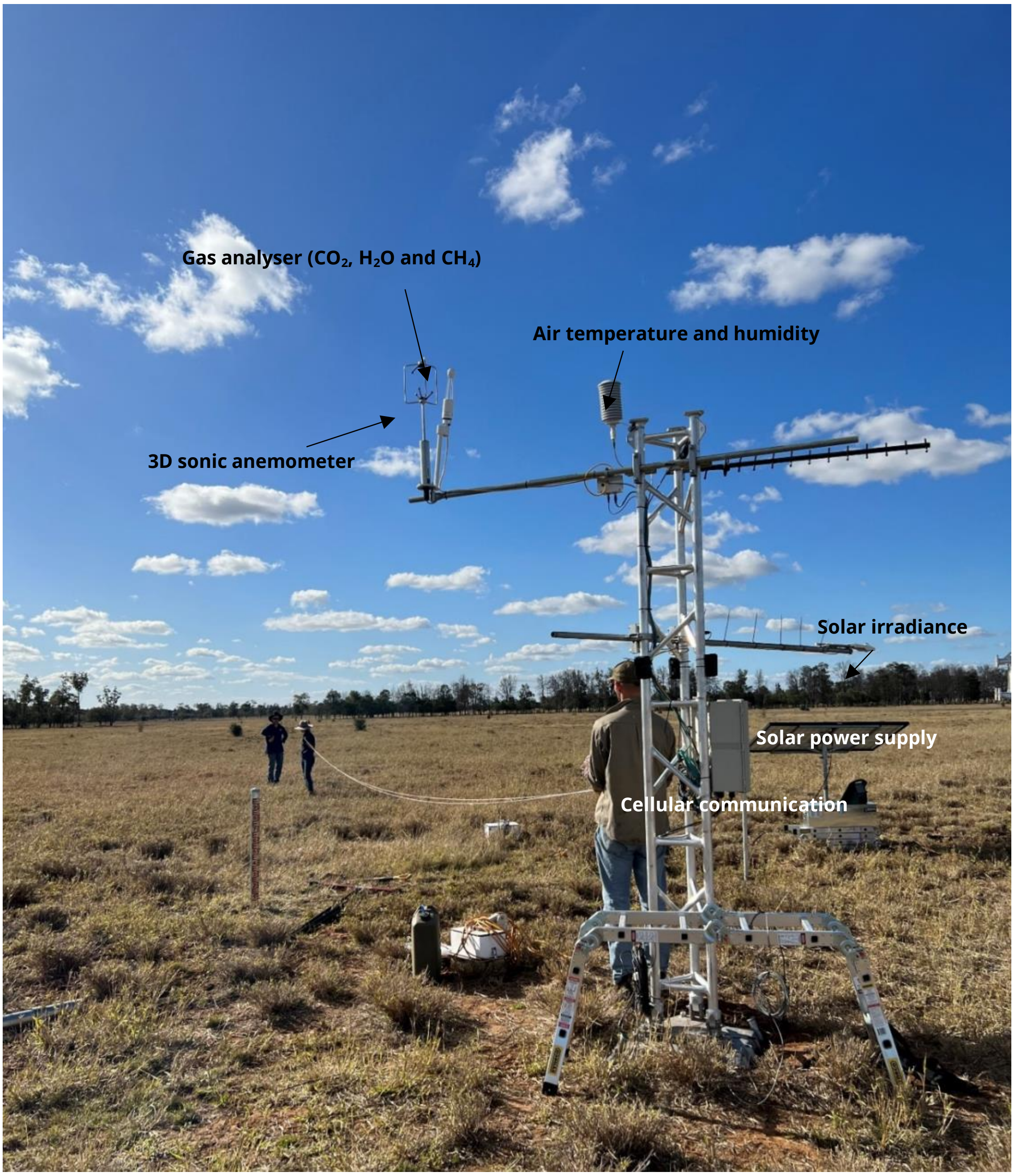
# The Eddy Covariance method: Measuring an Ecosystem's Breath

The eddy covariance method is one of the most direct and defensible ways to measure gas fluxes. Eddy covariance flux towers have been widely used for over 30 years to determine the exchange of heat, water, carbon dioxide, methane, and other trace gases. The method is mathematically complex, but this document seeks to demystify how flux towers can be used to measure the balance of carbon in our landscapes and, in turn, to determine soil organic carbon stocks.

Figure 1: Flux tower located at Packhorse property at Moolan Downs near Meandarra



Some definitions; a flux is a measure of something (e.g. $CO_2$ molecule) that moves through a volume of air per unit of time. An eddy is a circular motion of air created by temperature fluctuations. Co-variance means together, while variance means change. Eddy covariance flux towers simultaneously measure the change between the concentration of a gas and the direction of the swirling wind.

The concentration and change in the wind direction is measured by two pieces of gadgetry mounted on towers above the area of interest (as shown in Figure 1): (1) the 3D sonic anemometer measures wind speed and direction, and (2) the infrared gas analyser measures gas concentration in the air. This data is measured together ten times per second.

## But how does this measure over large spatial scales?

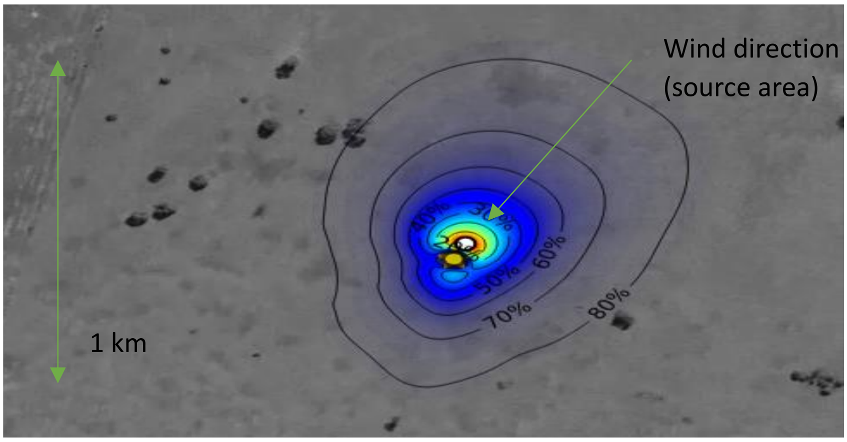
To really simplify, the system works by measuring how many gas molecules pass through a defined volume over a specific time. Imagine that we place a box over the top of an ecosystem. The wind moves air through this 'box' (Figure 2). The gas moving in and out of the top of the box is calculated as fluctuations around the mean.

Figure 2: The measurement 'box' of the flux tower measuring $CO_2$ entering and leaving a defined area (Source: LICOR user manual)


For example, the system might capture a measurement of 7 $CO_2$ molecules being carried upward towards the atmosphere by an eddy, then in the next moment (remember ten measurements per second), only 5 of these molecules are recorded travelling downward towards the ground. The net flux over this specific time period is equal to 2 molecules of $CO_2$ emitted into the atmosphere.

The resultant flux measurements are derived from source areas upwind of the measurement location, referred to as the flux 'footprint'. An example of a flux tower footprint is shown in Figure 3. The footprint of the tower in Figure 3 is around 50 hectares. The spatial extent over which measurements are made can be manipulated by adjusting instrument height above the ground. Sites must be carefully selected to include topographically flat and even terrain containing uniform vegetation in the footprint area.

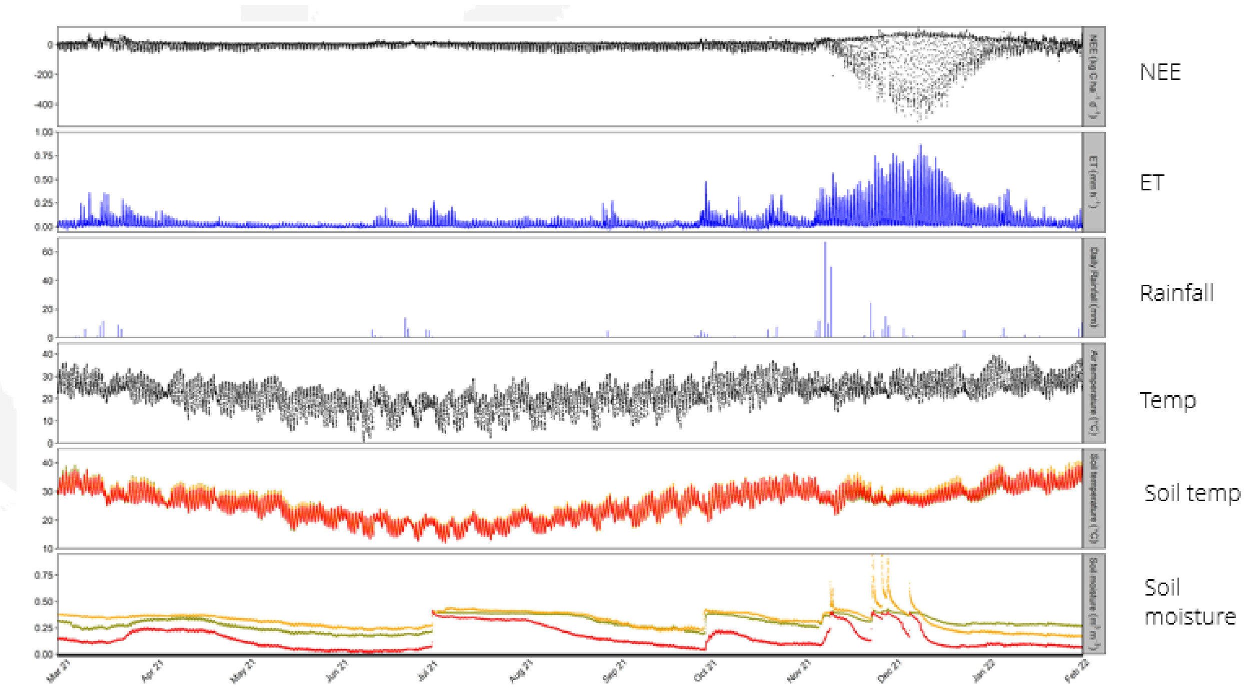
Figure 3: Footprint of a flux tower. In this instance, around 50 hectares. Note the source area of measurement upwind of the instrument.




## How is the net ecosystem exchange translated into soil organic carbon?

The flux tower gives a measurement of net ecosystem exchange (NEE) of carbon, i.e. it measures the balance of carbon being drawn into or released from plants and soil. Therefore, to determine the amount of carbon sequestered in the soil at a particular point in time, the above-ground vegetation must be accounted for and subtracted from the NEE. Vegetation can be accounted for using a combination of on-the-ground sampling and remote sensing.

Figure 4: Micrometeorological measurements from a flux tower. The top measurement shows NEE. Carbon in vegetation must be subtracted from this amount to determine soil carbon.



In summary, eddy covariance towers are emerging as a high-resolution, real-time way to cost-effectively sample carbon exchange over large areas. While towers will not be able to cover the entire landscape, models (which have been supercharged with data from the flux towers), combined with remote sensing data can be used to interpolate the remaining landscape. Flux tower measurements will always be verified against some on-the-ground soil sampling. The proposed hybrid measure-model approach will dramatically reduce sampling costs from around $20-$30ha to around $3/ha.