Terrestrial NPP Discussion meeting
17-18 Dec 2013, CEH Lancaster

Estimating NPP using flux towers

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Overview

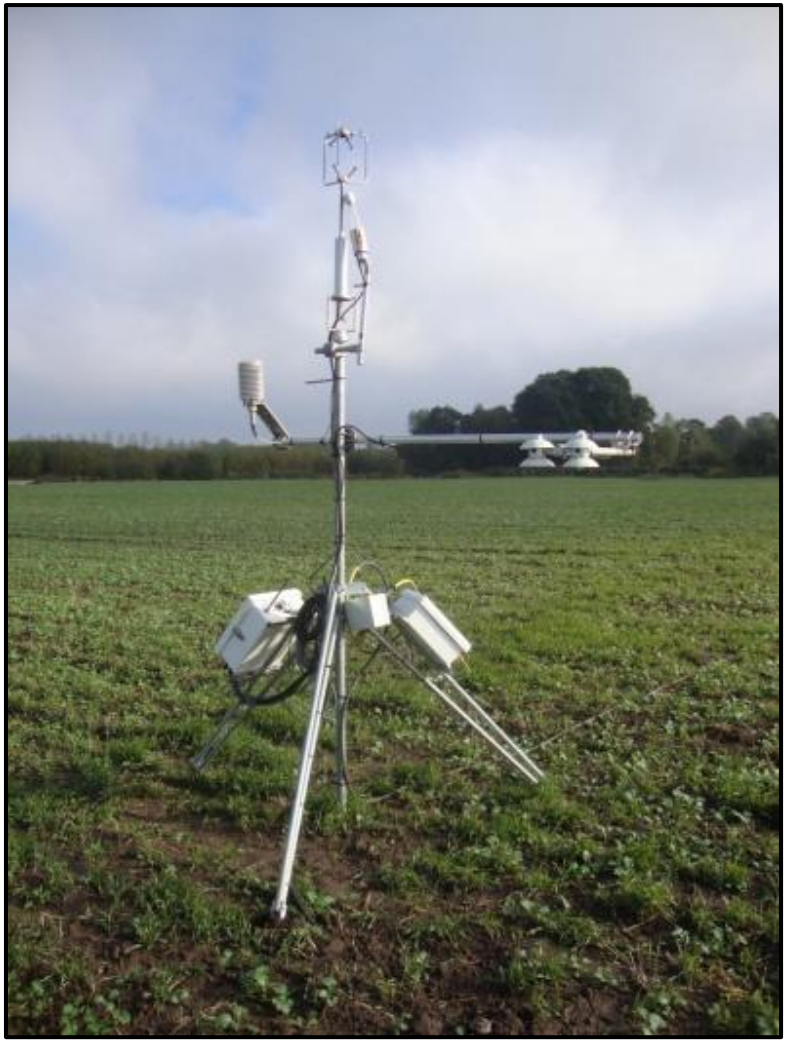
The eddy covariance technique
- theory
- instrumentation
- data processing

What do we actually measure?

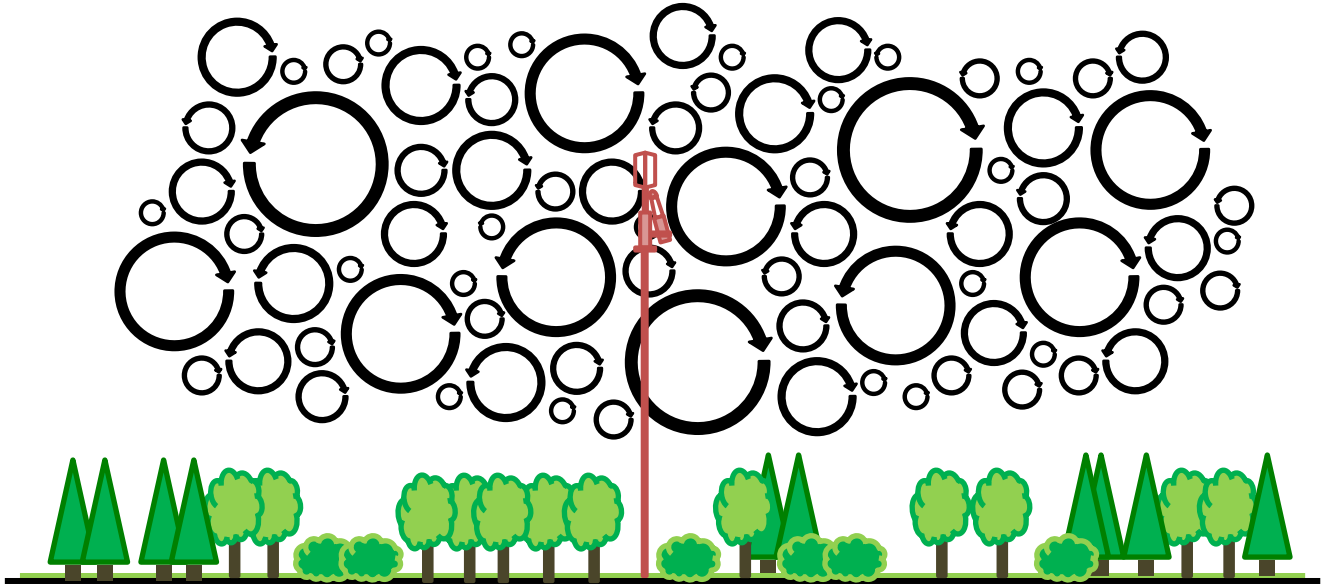
Interpretation of results
- footprint modelling

Selected results (Ross Morrison)
- carbon balance in The Fens

Questions & discussion



Atmospheric turbulence 1

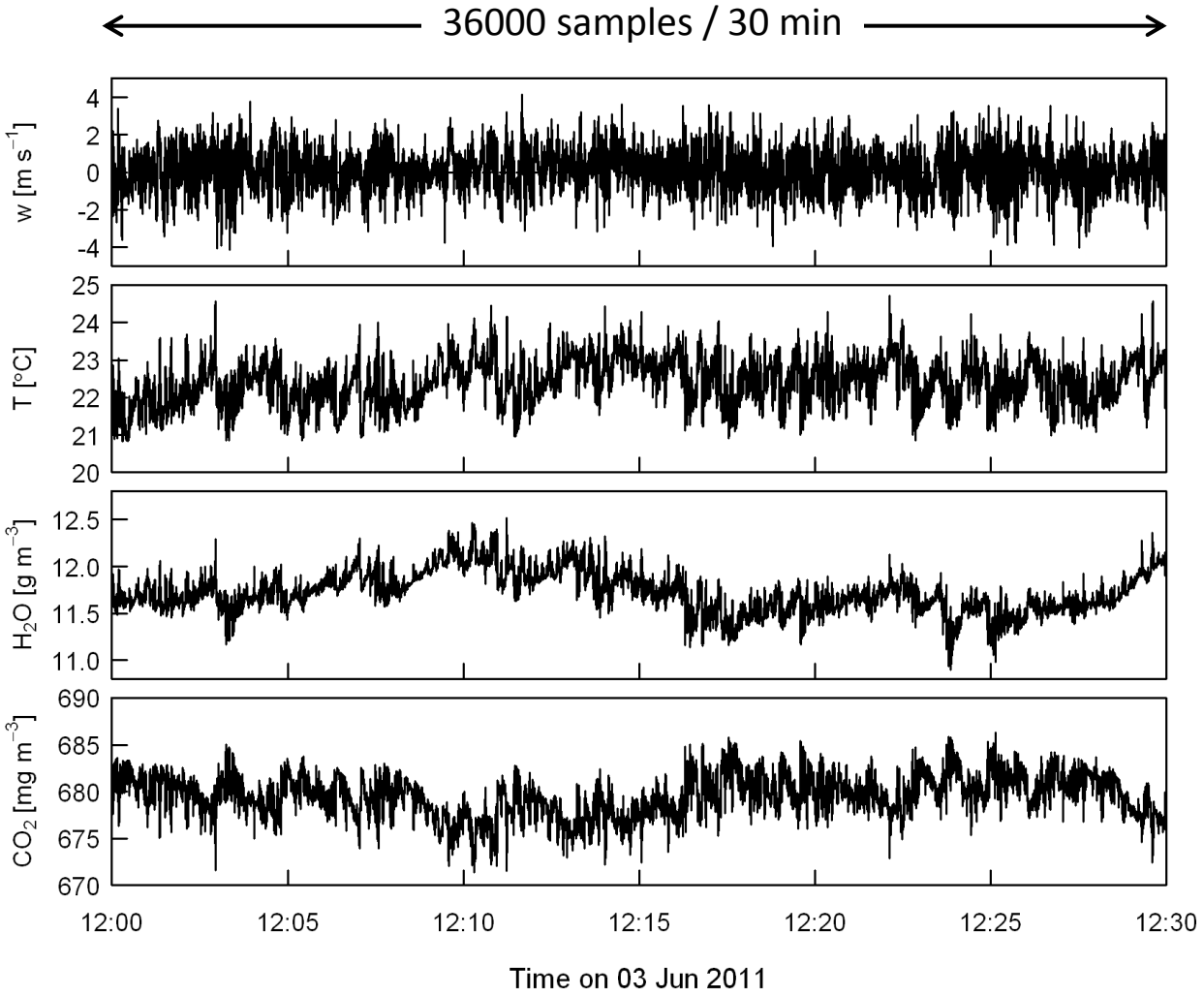


Transport of momentum, heat, water, CO_2, etc, in the atmosphere occurs via turbulent eddies.

These eddies create ‘heat haze’ seen on a hot day.

Fluctuations are seen in measurements made at a point in space.

Atmospheric turbulence 2



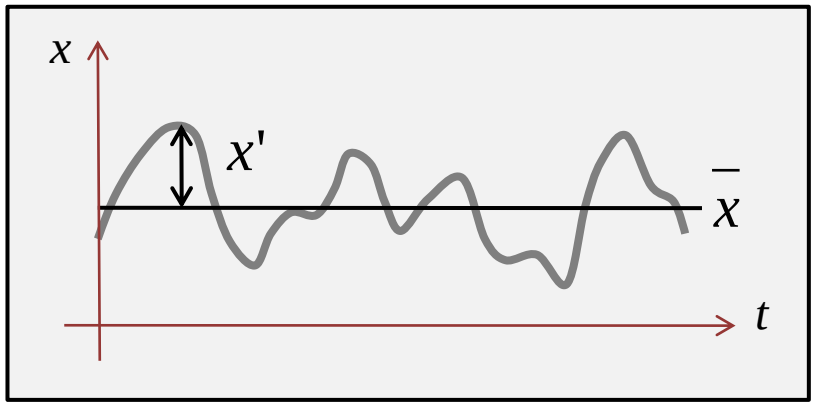
- Measurements at 10/20 Hz using fast response sensors
  - sonic anemometer
  - infra-red gas analyser (IRGA)

Eddy covariance

Turbulence consists of irregular fluctuations about a mean.
It is stochastic, i.e. it has a predictable and a random element.

Reynold's decomposition of a variable into mean and fluctuation

$$x = \bar{x} + x'$$



Measurements made

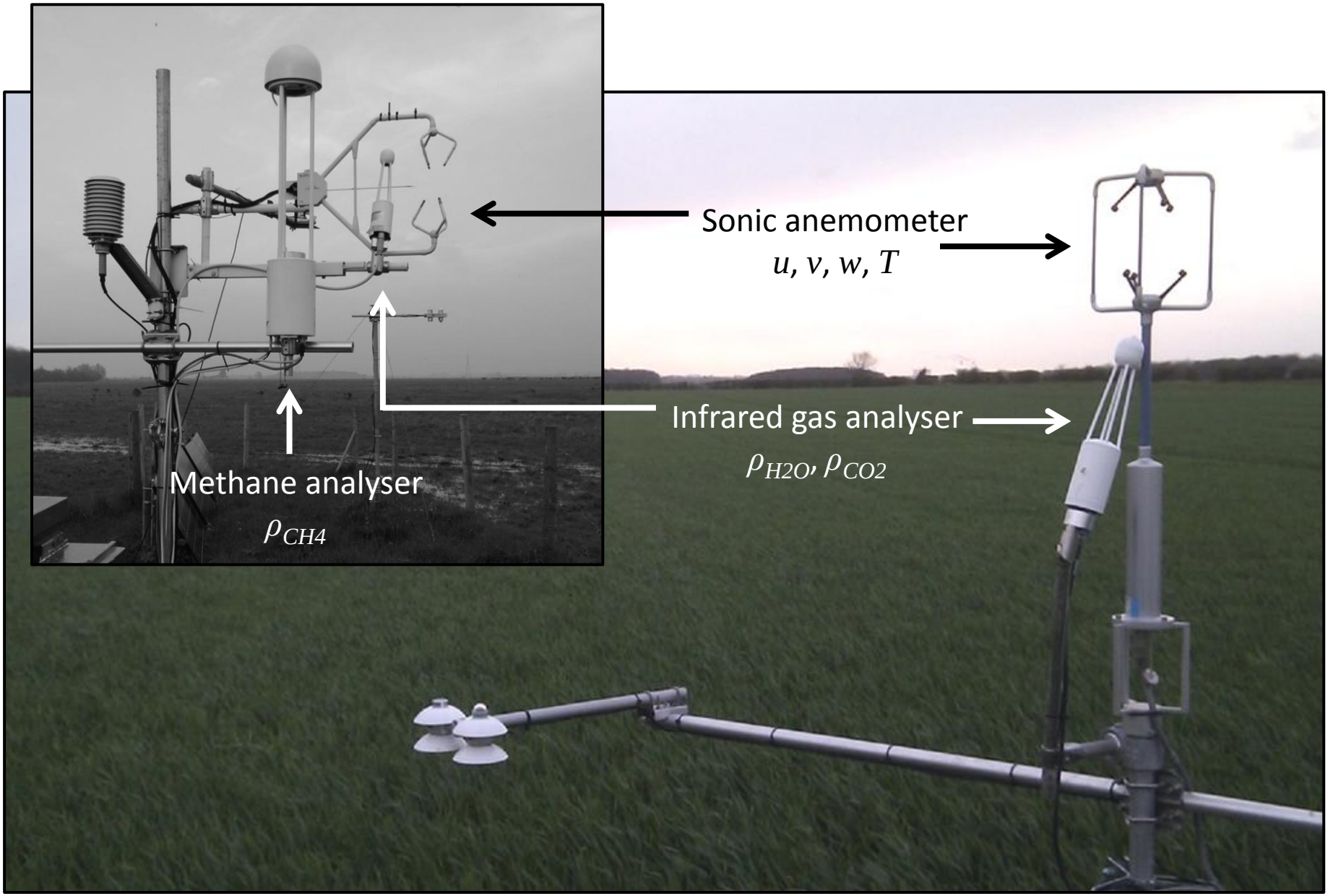
- Three wind speed components: u, v, w
- Temperature: T
- Water vapour: ρ_{H2O}
- Carbon dioxide: ρ_{CO2}
- Methane: ρ_{CH4}

Calculate **covariances** over 30 min period

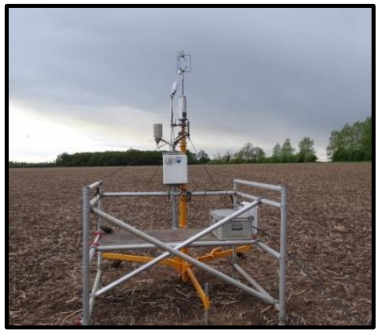
Sensible heat flux:	$H = \rho c_p \overline{w'T'}$
Latent heat flux:	$LE = L_v \rho \overline{w'q'}$
CO_2 flux:	$F_{CO2} = \rho \overline{w'c'}$

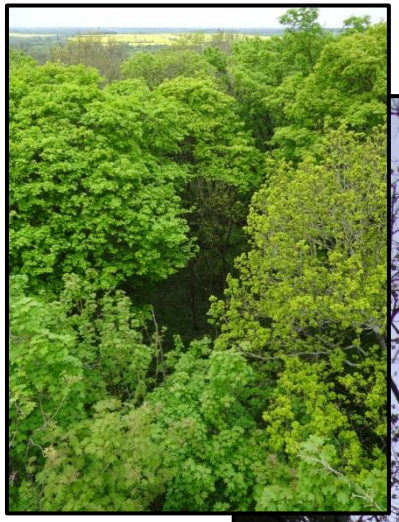
- Most accepted method for measuring fluxes.
- Several complex corrections required.

Instrumentation

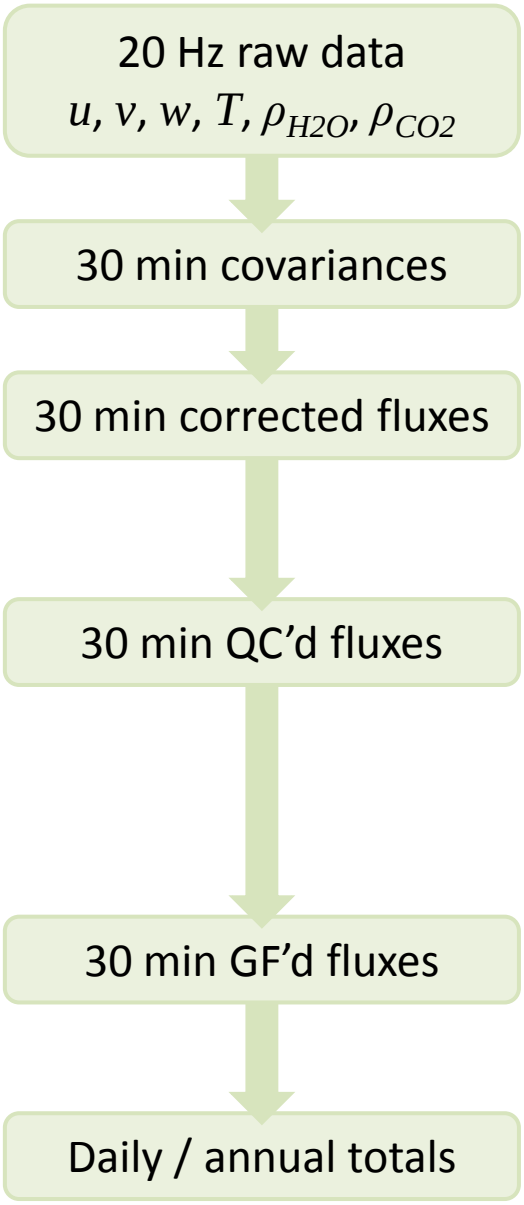


Siting





Obtaining fluxes



Flux processing

- raw data: despiking
  angle of attack correction (Gash & Dolman, 2003)
  time-lag compensation
- double co-ordinate rotation / planar fit
- correction of sonic temperature (Schotanus et al., 1983)
- frequency corrections (Moore, 1986, Moncrieff et al., 1997)
- density corrections (Webb et al., 1980)
- instrument heating (Burba et al., 2008)

Quality control

- instrument malfunction and/or bad diagnostic values
- rain or moisture adversely affecting IRGA readings
- physically reasonable threshold checks
- despiking (e.g. Papale et al. 2006)
- non-stationarity and ITC tests (Foken & Wichura, 1996)
- u_* filtering (e.g. Gu et al., 2005)

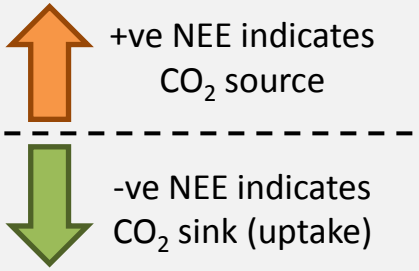
Gap filling

- linear interpolation
- mean/median diurnal cycles with/without seasonality
- neural networks
- online tools, e.g. CarboEurope (Reichstein et al., 2005)

What is actually measured?

Eddy covariance → vertical CO_2 flux = **Net Ecosystem Exchange**

– Net Ecosystem Exchange = Net Ecosystem Production
+ Inorganic CO_2 sinks – Inorganic CO_2 sources



CO_2 flux partitioning

Net Ecosystem Production = Gross Primary Production – Ecosystem Respiration

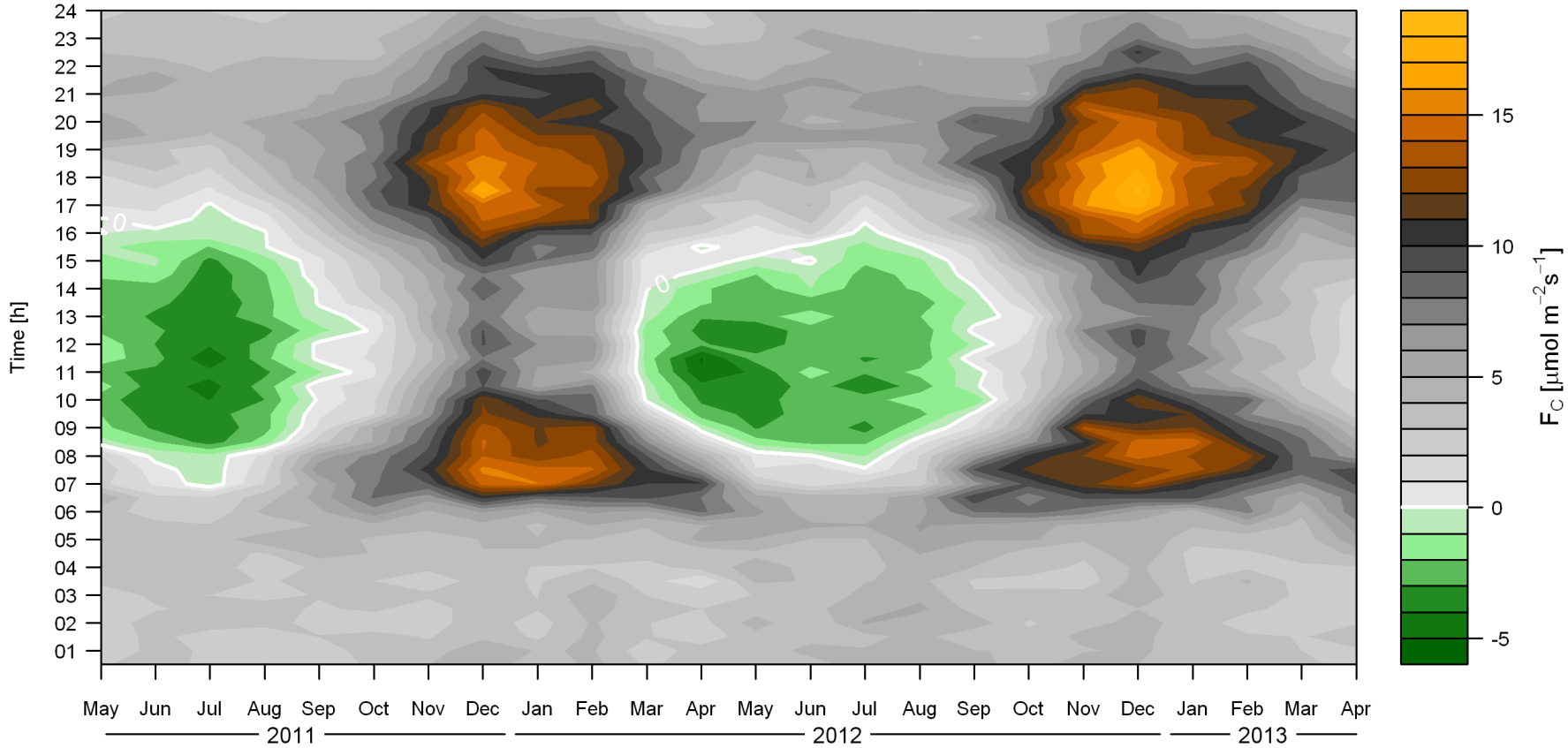
$NEP = GPP - R_{eco}$

autotrophic + heterotrophic

$NPP = GPP - R_{autotrophic}$

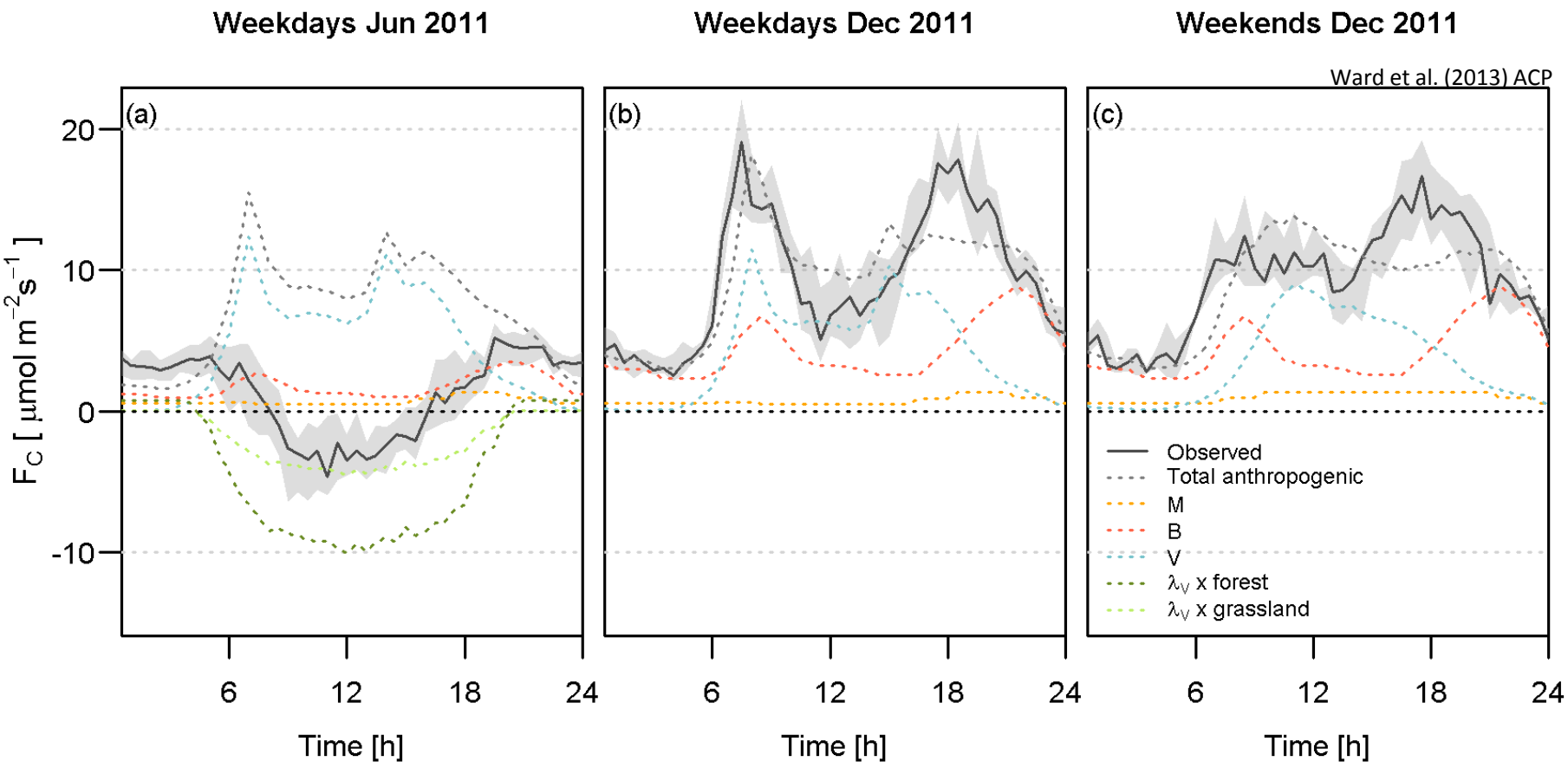
Carbon fluxes in the suburban environment 1

- EC measures everything!
- Many processes with various controls (biogenic and anthropogenic) such as traffic emissions, heating, respiration, photosynthesis...



- Natural ecosystems can be simpler... but still human intervention adds complexity and sudden change, such as agricultural practices and land management.

Carbon fluxes in the suburban environment 2



Anthropogenic carbon emissions estimated from statistics

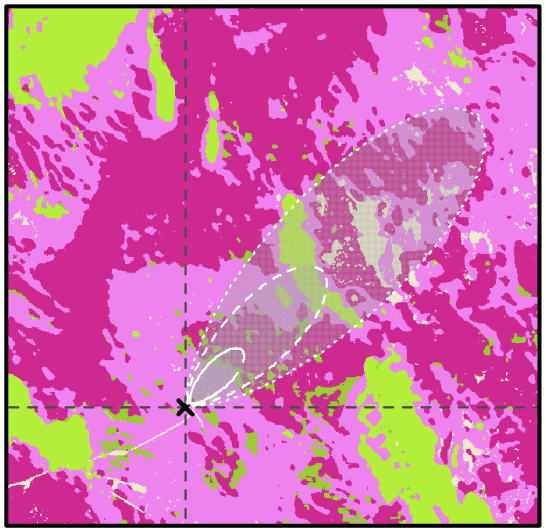
	Human metabolism, M	Building energy use, B	Vehicles, V
Emissions from:	Population data Per capita emissions	UK fuel consumption Emission factors Diurnal profile	Vehicle km in UK Emission factors Diurnal/weekly profiles

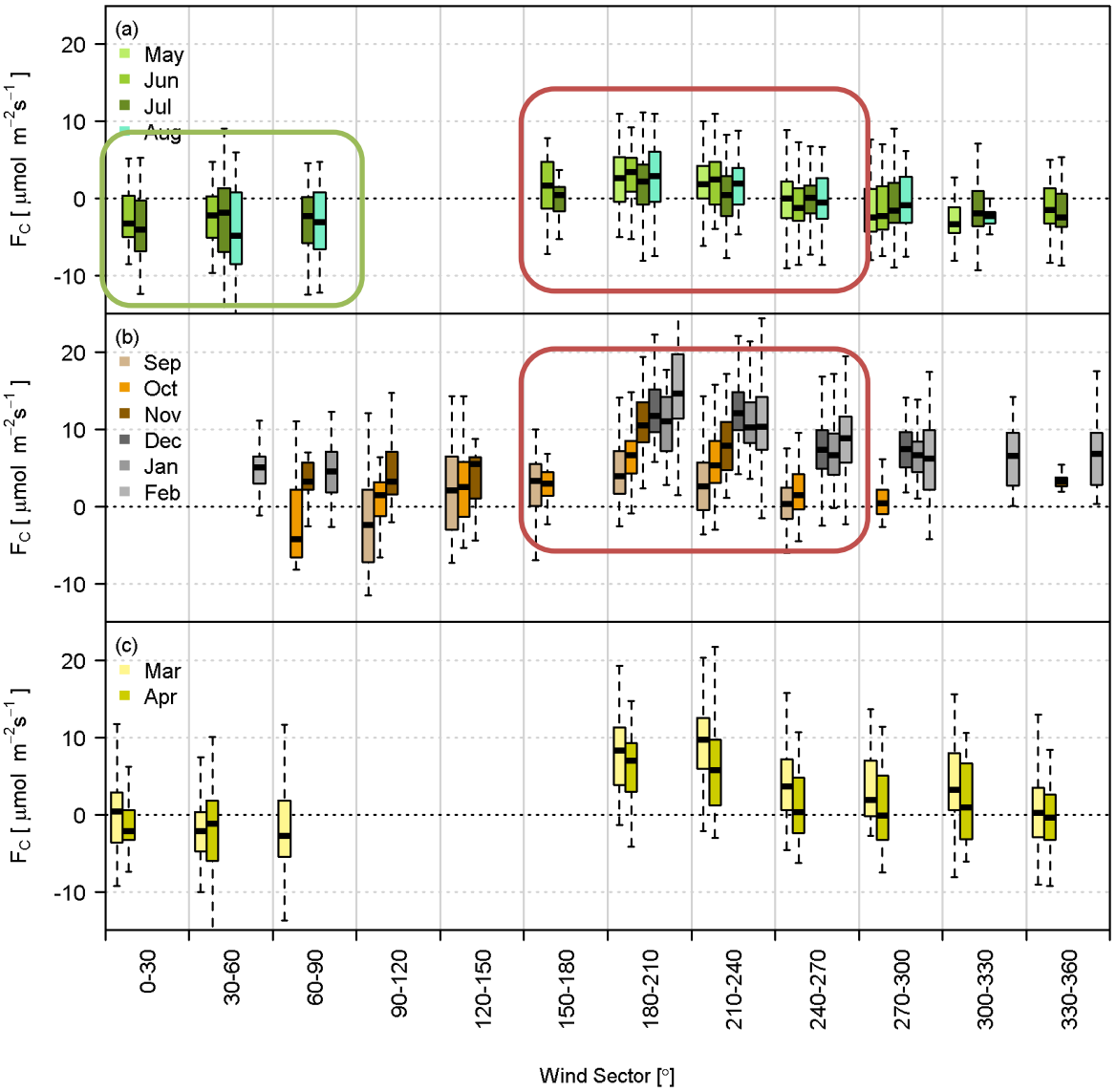
Interpretation of results

- (Simple) models or assumptions are often required to aid data interpretation.

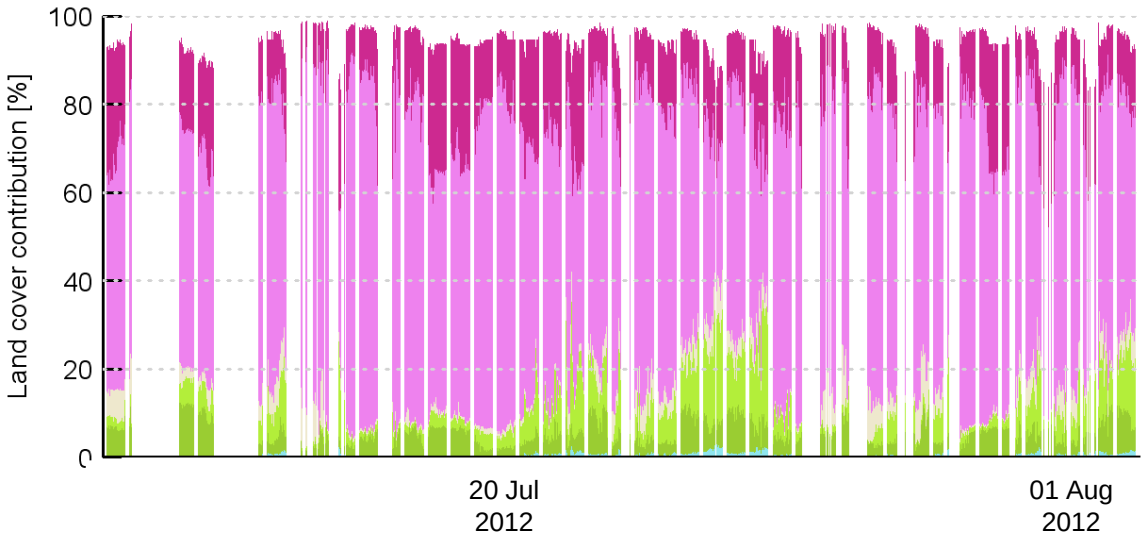
- Of particular importance:
- land cover
- surface conditions
- meteorology

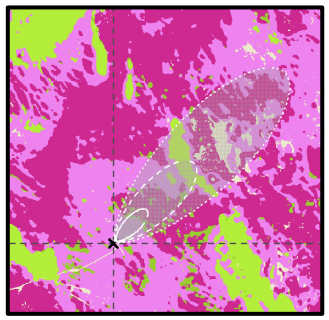
- Footprint modelling relates the measurement to the land surface.





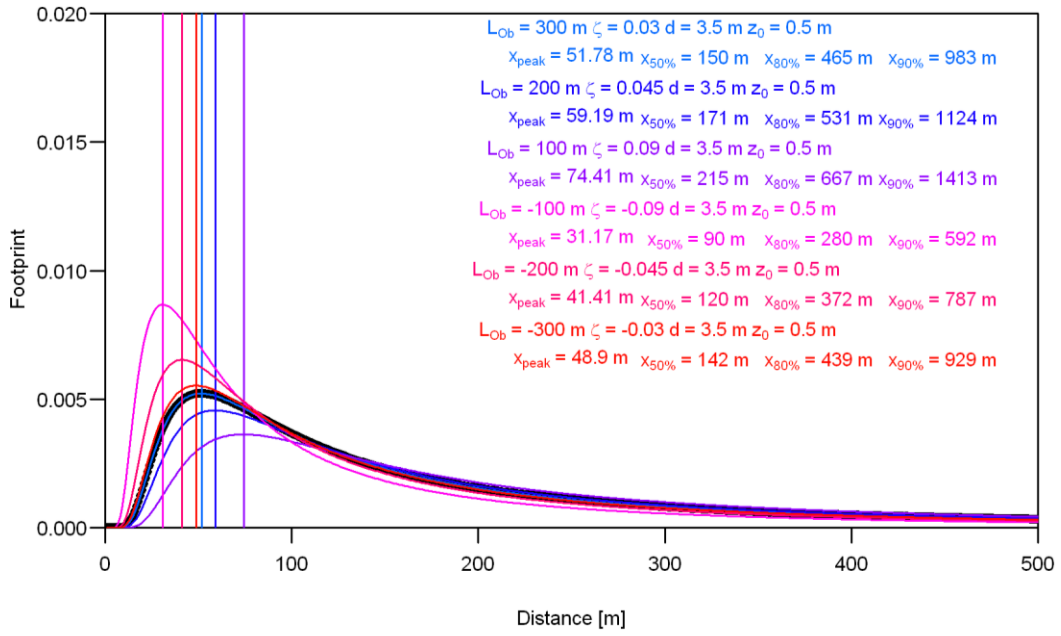
Footprint modelling





- Footprint (source area) depends on
  - wind direction
  - atmospheric stability
  - wind speed
  - measurement height
  - roughness of the surface

- Heterogeneous sites can suffer sampling bias due to prevailing weather conditions.



Selected results: The Fens

Carbon dioxide fluxes at managed lowland peatlands

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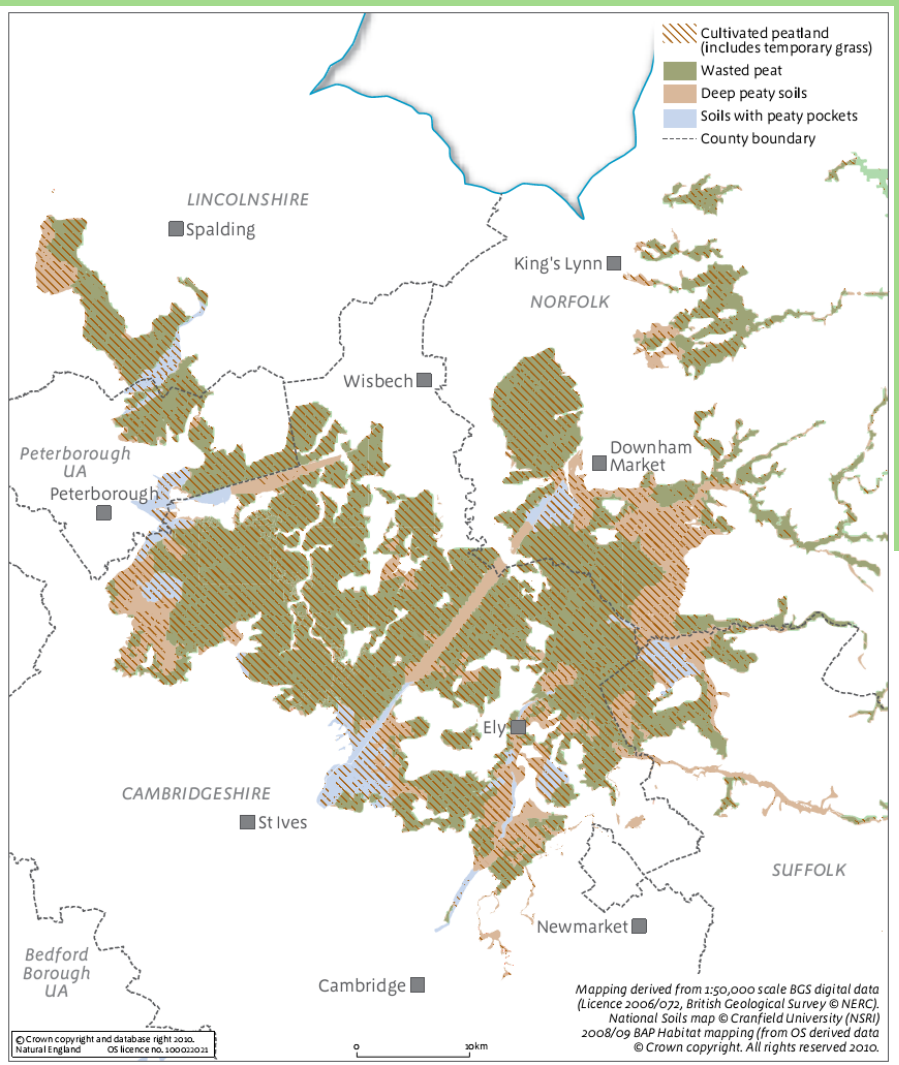
The East Anglian Fenland (The Fens)



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Wicken Sedge Fen

- Largest area of relatively semi-natural fen peatland in E. Anglia
- Hydrologically isolated from surrounding arable catchment
- Peat depth: 1 m (east) to 4 m (west)
- *Phragmites australis* & *Cladium mariscus:* three year rotational cutting
- Flux tower maintained by Dr Jon Kelvin, Dr Helen Ward, Dr Jonathan Evans between 2009 and 2011

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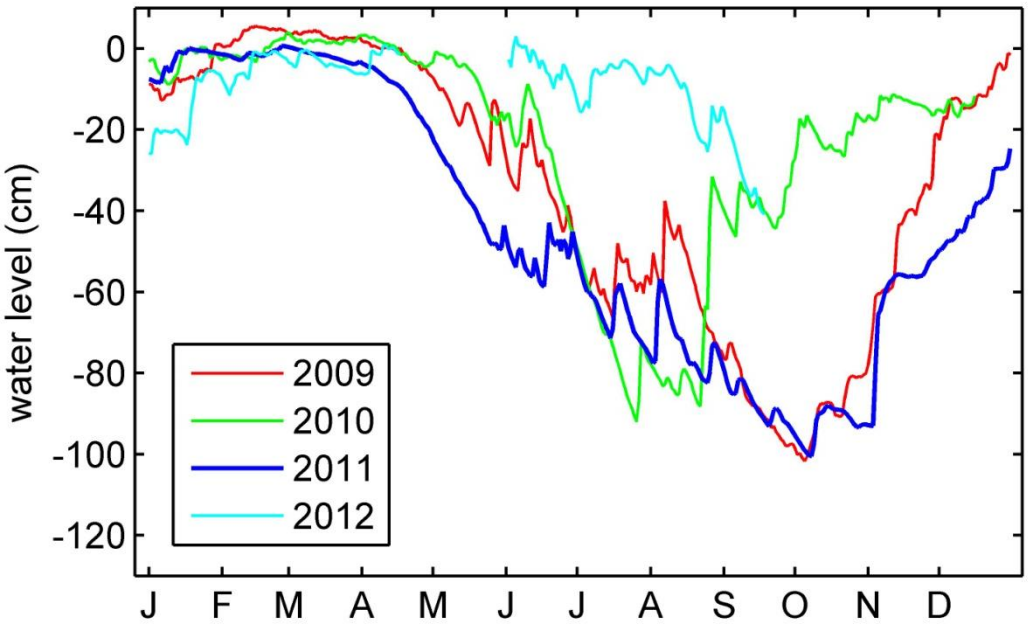
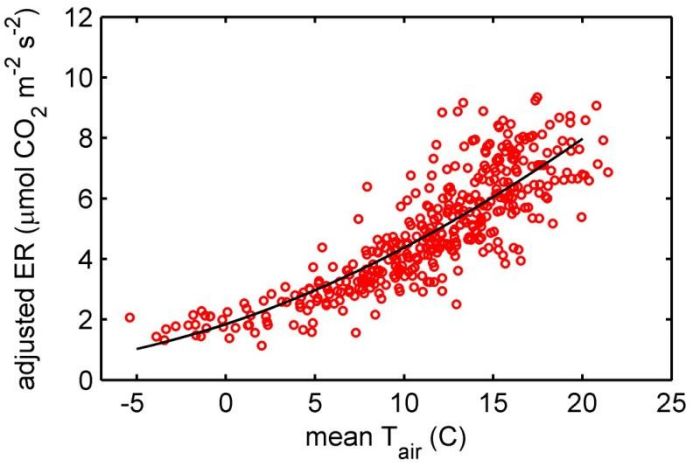
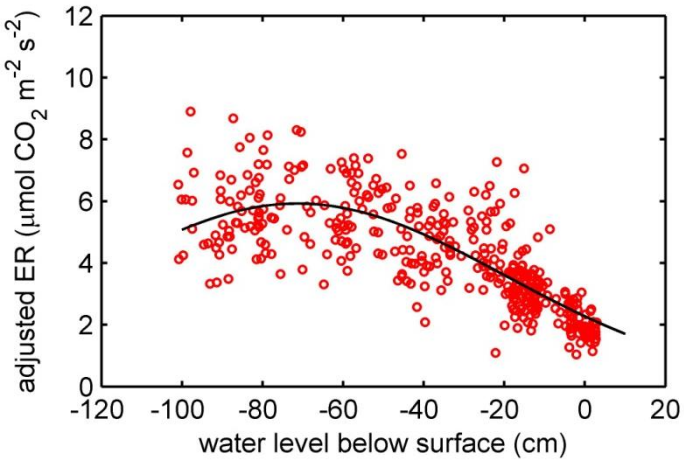
Wicken Fen National Nature Reserve

Image source: Google Earth

Water levels 2009-2012







Water level data supplied by the Environment Agency, Dr Francine Hughes, Dr Peter Stroh

Ecosystem respiration data are for 2009 and 2010 only

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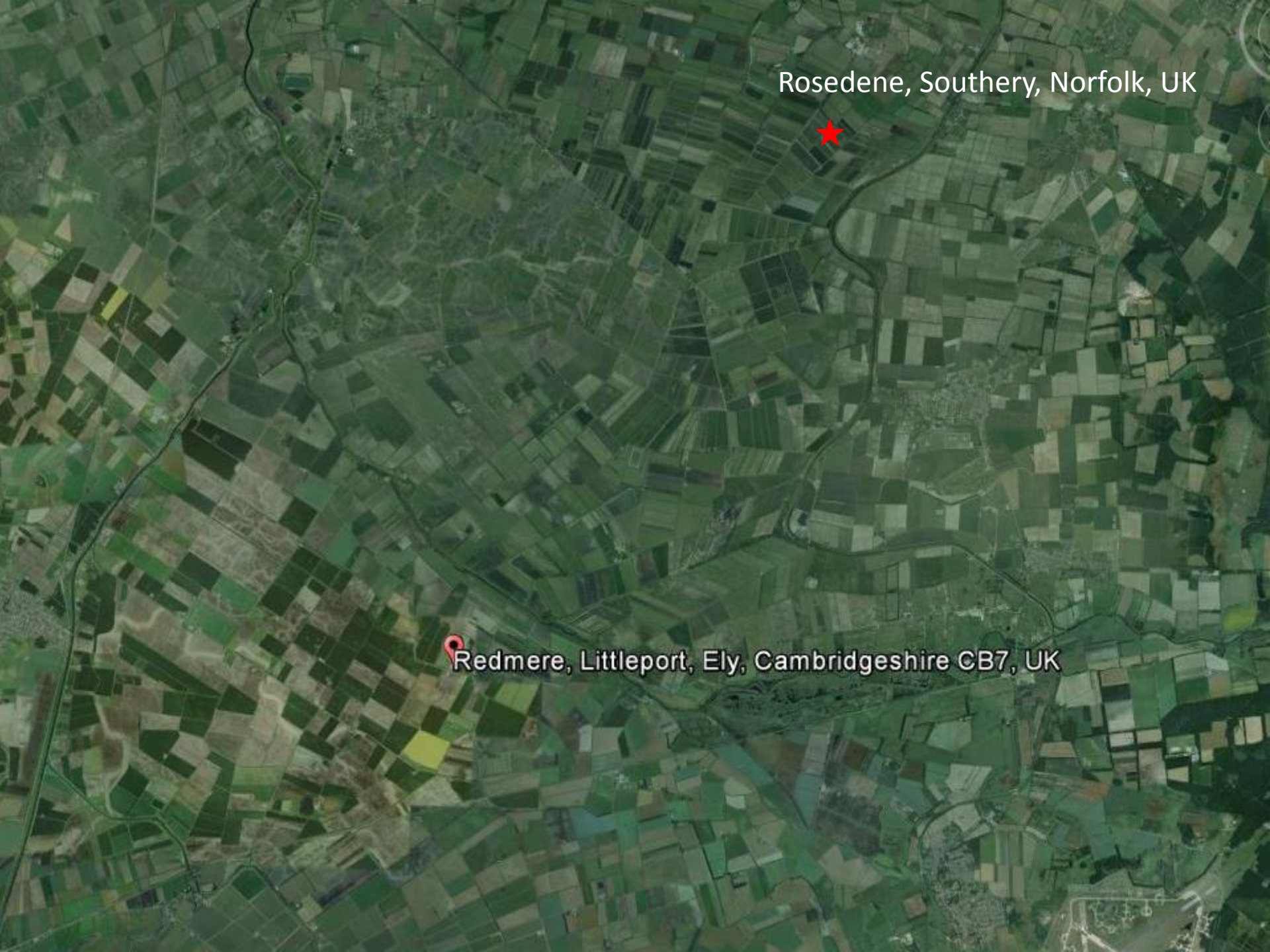
Rosedene, Southery, Norfolk, UK
Redmere, Littleport, Ely, Cambridgeshire CB7, UK

Rosedene & Redmere Farms

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Photographs: Dr Helen Ward, Dr Jon Evans, Dr Ross Morrison

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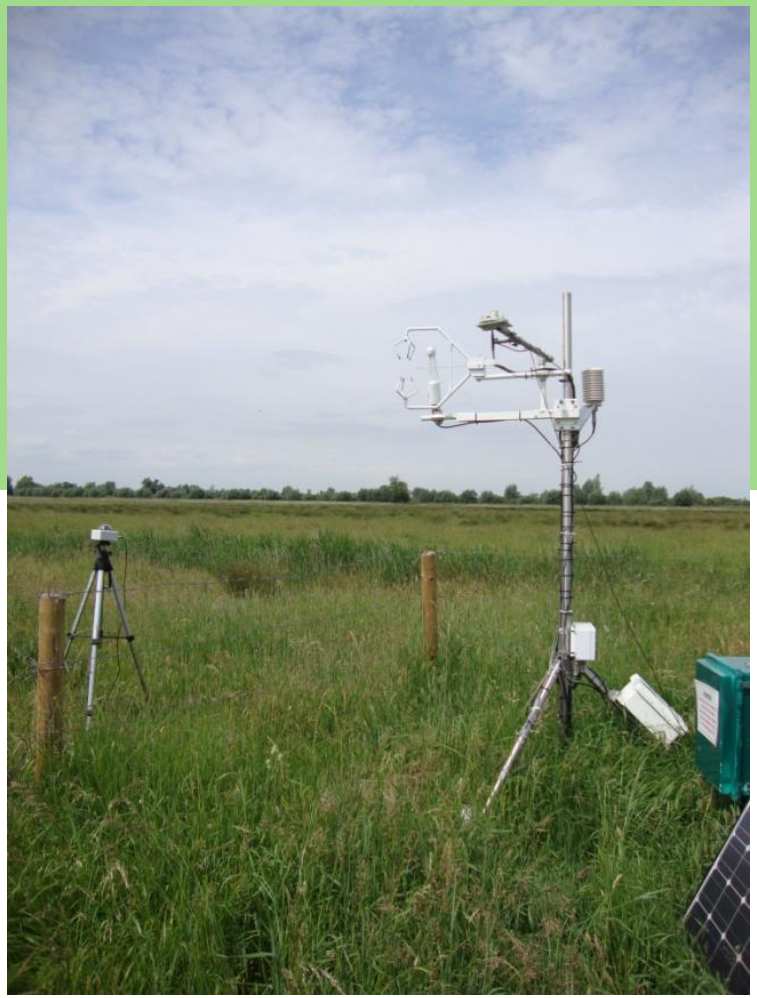
Bakers Fen: Fenland restoration site



- Former arable land – acquired by the National Trust in 1994
- Peat depth: ~0.6 m – surface 1.5 to 2 m lower than adjacent semi-natural Wicken Fen
- Water abstraction between November and March (but not in 2010!)
- Extensive grassland with conservation grazing

Bioenergy & arable crops (mineral soils)

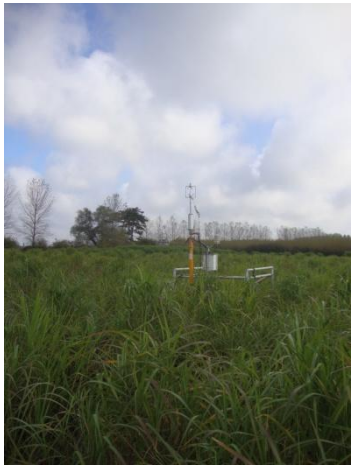


Image source: Google Earth

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