The development of a disjunct eddy accumulation system for the determination of ecosystem level fluxes of CO$_2$, CH$_4$ and N$_2$O
Outline of Honours Project

Two Phases:
1. Development of a Disjunct Eddy Accumulation (DEA) system for the measurement of greenhouse gas fluxes.

2. Deployment in the field for evaluation of:
   – The DEA system
   – Greenhouse gas fluxes
Outline of Presentation

1. Greenhouse Gas Fluxes
   Note on the importance of CO$_2$, CH$_4$ & N$_2$O fluxes.

2. Flux Measurement Techniques
   Micrometeorological techniques, Disjunct Eddy Accumulation (DEA), development of DEA system, implementation of technique.

3. Results
   Measured fluxes, verification of the DEA technique

4. Conclusions and Future Directions
1. Greenhouse Gas Flux Estimation

- Currently there are large uncertainties in the source and sink estimates for greenhouse gases

Table: Sources, Sinks and Atmospheric Budgets of CH$_4$ (Tg(CH$_4$)yr$^{-1}$)

<table>
<thead>
<tr>
<th>References</th>
<th>Wuebbles and Hayhoe, 2002</th>
<th>J. Wang et al., 2004</th>
<th>Mikaloff Fletcher et al., 2004a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Sources</td>
<td>145</td>
<td>200</td>
<td>260</td>
</tr>
<tr>
<td>Anthropogenic Sources</td>
<td>358</td>
<td>307</td>
<td>350</td>
</tr>
<tr>
<td>Total Sources</td>
<td>503</td>
<td>507</td>
<td>610</td>
</tr>
<tr>
<td>Total Sinks</td>
<td>515</td>
<td>492</td>
<td>577</td>
</tr>
<tr>
<td>Imbalance</td>
<td>-12</td>
<td>+15</td>
<td>+33</td>
</tr>
</tbody>
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- Compared to measured 0.6 Tg (CH$_4$) yr$^{-1}$ average annual increase, 2000-2005 (IPCC, 2007).
- Desirable to obtain more accurate greenhouse gas flux estimates in order to:
  - provide better data for modelling
  - decrease the uncertainty in source sink estimates
  - allow for more effective mitigation strategies.

IPCC, 2007
2. Principles of Micrometeorological Flux Measurement Techniques

Transport via Turbulent Eddies

Greenhouse Gas Emission

Micrometeorological Tower

Concentration Profile (Emission)

Concentration in Eddies (Emission)

Downdraft

Updraft

Note: Updraft conc. > Downdraft conc.
2. Disjunct Eddy Accumulation (DEA)

- DEA - innovative technique with potential to provide simultaneous measurement of CO₂, CH₄ and N₂O fluxes.
- ‘Disjunct sampling’ – samples are taken periodically from a continuous data series; expect a similar result but larger statistical uncertainty.
- Further experimental verification of the technique is required (Turnipseed et al., 2009)

<table>
<thead>
<tr>
<th>Benefits of Disjunct Eddy Accumulation</th>
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<tr>
<td><strong>Non-intrusive</strong> technique</td>
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<tr>
<td><strong>Slow response analytical sensor capability</strong> – allows for analysis of CO₂, CH₄ &amp; N₂O</td>
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<tr>
<td><strong>Long-term</strong> measurement capabilities e.g. full growing or seasonal cycle</td>
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<tr>
<td><strong>Large spatial resolution</strong> e.g. paddock/ecosystem scale</td>
</tr>
</tbody>
</table>
Principles of The DEA Technique

1. Measure the instantaneous vertical wind velocity (w’) of air sample (~0.1s) to be captured.

2. Quickly capture the sample of air.

3. Quantitatively transfer a volume of the sample into an updraft or downdraft reservoir, (volume proportional to the measured w’).

4. Disjunct sampling every 12s, Accumulation over 30mins.

\[
Flux = \frac{|w'_{\text{disj}}|}{2} (c^+ - c^-)
\]
Development of DEA system

1. **DEA manifold**
   - Hardware: valves, flow meters, main line and sampling line, bypasses
Development of DEA system

2. DEA program
   • Controlled valve timing to carry out sampling based on the instantaneous vertical wind velocity ($w'$)
   • Retrieved $w'$ measurements from sonic anemometer (20Hz)
   • Logged data e.g. $w_{\text{disj}}$
   • Technical assistance by Graham Kettlewell
Field Setup

- Circular grass paddock 1km in diameter
- Location: Shoalhaven Starches Environmental Farm, near Nowra
- Measurement Period – 28\textsuperscript{th} August onwards

Two flux measurement techniques:
1. Eddy Covariance – Used for experimental verification DEA
2. Disjunct Eddy Accumulation
3. Results – Raw CO\textsubscript{2} Data

- Reservoir CO\textsubscript{2} concentrations measured by the DEA technique (13th – 16th of October).

\[ \text{Night: Net CO}_2 \text{ Emission [Updraft] > [Downdraft]} \]

\[ \text{Day: Net CO}_2 \text{ Uptake [Downdraft] > [Updraft]} \]

\[ \text{Flux} = \left| \frac{w'_{\text{disj}}}{2} \right| (c^+ - c^-) \]
Results – CO₂ Flux

- CO₂ fluxes measured by the DEA and EC techniques (12th – 16th of October).

Night: Net CO₂ Emission (Respiration)
Day: Net CO₂ Uptake (Photosynthesis)
Results – CO₂ Flux

- CO₂ fluxes measured by the DEA and EC techniques over entire record (28/8 to 5/11)

Decreased CO₂ Uptake (Harvest)
Increased CO₂ Uptake (Regrowth, Water, Temp, Sunlight)
Results – CO$_2$ Flux (DEA vs EC)

- Linear regression plot of DEA vs EC-measured CO$_2$ fluxes (28/8 to 5/11)

- DEA generally underestimated EC flux by ~6%
- Better agreement than other literature results
Results – DEA Simulation

- **Top Graph**: CO$_2$ fluxes measured by the DEA and EC techniques (2 days).
- **Bottom Graph**: DEA-simulated flux – provided by ‘disjunct’ sampling of 10Hz EC flux measurements every 12s i.e. 1 in every 120 EC data points was sampled.

1. DEA flux appears more noisy than EC flux (statistics)

2. DEA-simulated flux shows DEA noise actually better than one might expect

Simulation provided by Thorsten Warneke.
4. Conclusions

- Good agreement between DEA and EC measurement techniques; Slope=0.94, $R^2=0.79$.
- Long term measurements provided insight regarding seasonal and climatic drivers of the flux (e.g. sunlight, temp.).
- DEA has the ability to provide reasonably accurate measurements of $\text{CO}_2$, $\text{CH}_4$ and $\text{N}_2\text{O}$ fluxes over complete seasonal or growing cycles (months, years).
Future Directions

• Long-term deployment where detectable and significant fluxes of $CO_2$, $CH_4$ and $N_2O$ occur e.g. Australian wheat belt and sugar cane growing regions (heavily fertilised), rice fields (high $CH_4$ emission)
• Develop greenhouse gas budget estimates for agricultural systems and ecosystems.
• Refine the DEA system and optimise its measurement capabilities
• Determine the minimum detectable fluxes of $CO_2$, $CH_4$ and $N_2O$ using DEA.
Acknowledgements

• Centre for Atmospheric Chemistry (CAC), in particular: D. Griffith (supervisor), M. Riggenbach, G. Kettlewell and T. Warneke.
• Glenys Lugg and those working at the Manidra Group Shoalhaven Starches Environmental Farm
• Thankyou for listening… are we wasting our time?