Measuring N_2O and CH_4 exchange between the soil and atmosphere

Stephen Livesley

Department of Forest and Ecosystem Science

Key references:

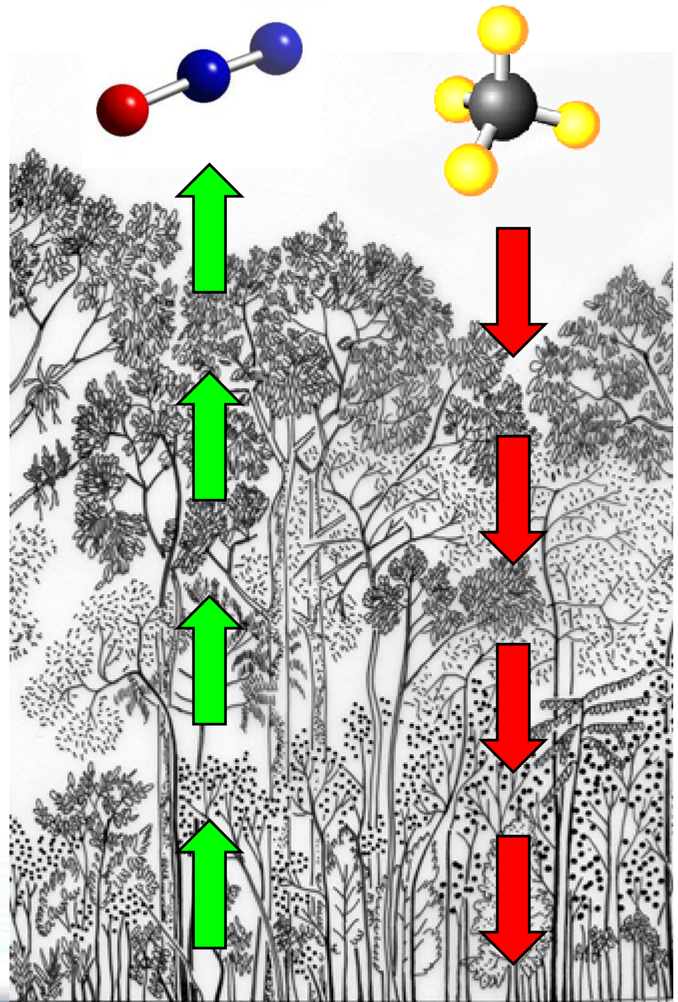
Matson & Harriss (1995) Biogenic trace gases: measuring emissions from soil & water

Denmead (2008) Plant and Soil 309

Parkin et al. (2003) http://gracenet.usda.gov/GRACEnetTraceGasProtocol.pdf

Soils & non-CO_2 exchange

- N_2O and CH_4 , GWP and CO_2-e
- Processes controlling N_2O & CH_4 flux
- Ways to measure N_2O and CH_4 flux
- Chamber measurement approaches
- Chamber measurement issues
- Examples of N_2O & CH_4 flux measures
- Conclusions

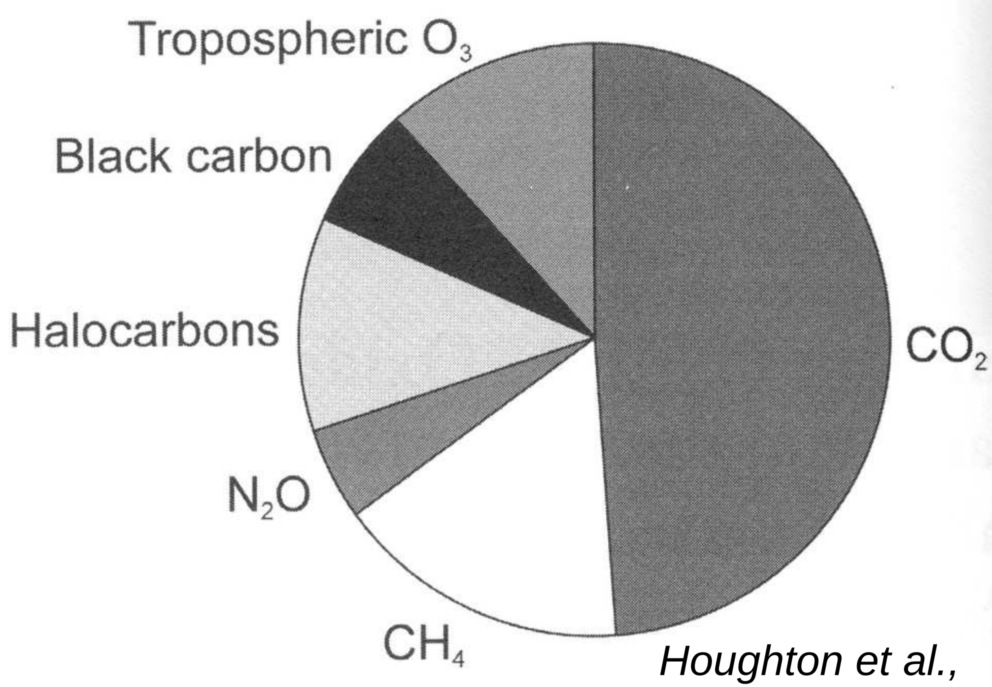


Global C cycle and non-CO_2

- Non-CO_2 gases rarely included in global C budgets,
- Sources and sinks not well understood.

- **CO_2** represents < 50% of current atmospheric radiative forcing.

- **Methane** (**CH_4)** and **Nitrous oxide** (**N_2O)** represent ~25% of radiative forcing.



Houghton et al., (2001)

Global C cycle and non-CO_2

- **Global warming potential** (**GWP**) relates all GHG's to the radiative forcing of CO_2, based on absorbtion of radiation and persistence in atmosphere.

	Pre-ind.	Current	*GWP*
CO_2	280	375	1
CH_4	0.80	1.78	21
N_2O	0.28	0.31	310

- **Carbon dioxide equivalents** (**CO_2-e**), normalise all gases to that of CO_2 using their GWP.

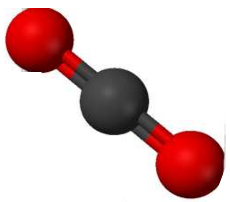
Global C cycle and non-CO_2

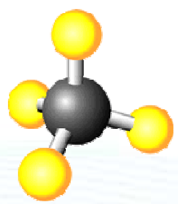
- Both CH_4 and N_2O sink-source mechanisms are vulnerable to human interference and feedback responses.
- A **multi-gas approach** is necessary. *(Robertson et al., 2000)*

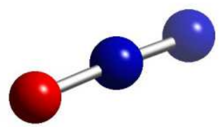
  e.g - N fertiliser may increase crop NPP and C sink. *(Crutzen 2008)*

  BUT this may be offset by concurrent N_2O emissions.
- An **Imbedded** or **System** CO_2-e cost should be considered,

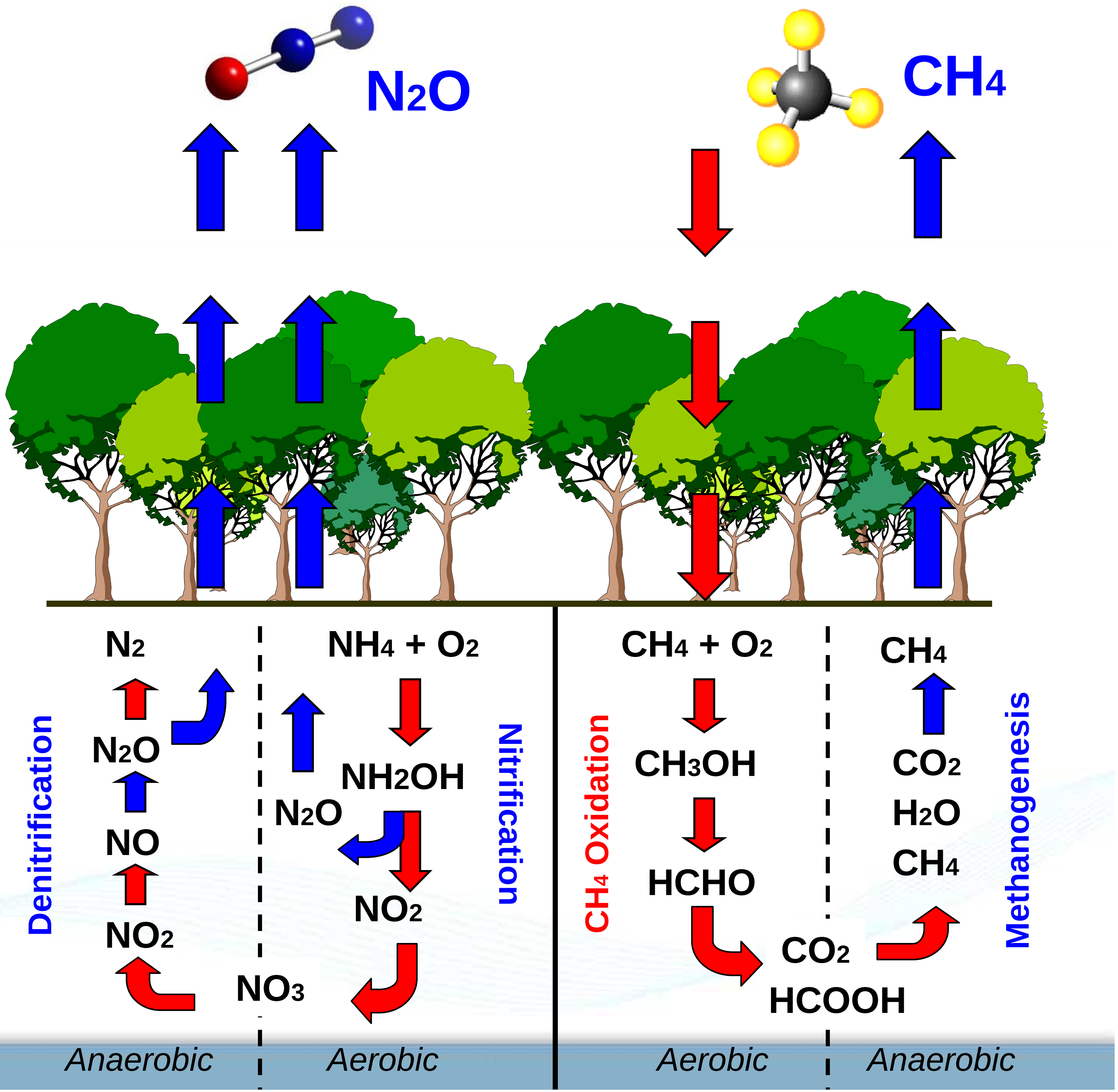
  e.g. the C cost of fertiliser manufacture.







- CO_2 CH_4 N_2O



N2O
CH4
N2
N2O
NO
NO2
NO3
Denitrification
NH4 + O2
NH2OH
N2O
NO2
Nitrification
CH4 + O2
CH3OH
HCHO
CO2
HCOOH
CH4 Oxidation
CH4
CO2
H2O
CH4
Methanogenesis
Anaerobic
Aerobic
Aerobic
Anaerobic

Measuring soil GHG exchange

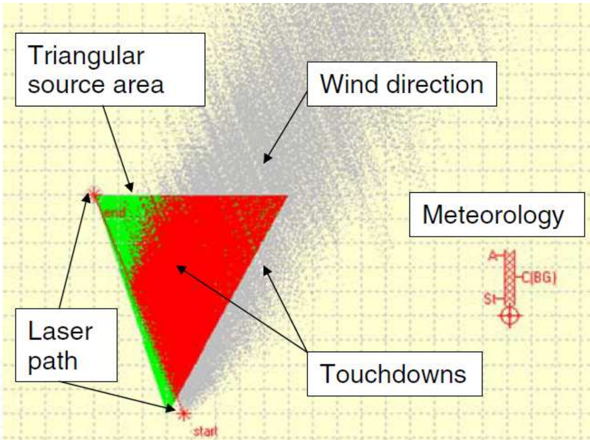
Chambers

Manual
- low temporal
- high spatial
- low flux
- CO_2, N_2O & CH_4

Automated
-high temporal
- low spatial
- low flux
- CO_2, N_2O & CH_4

Open

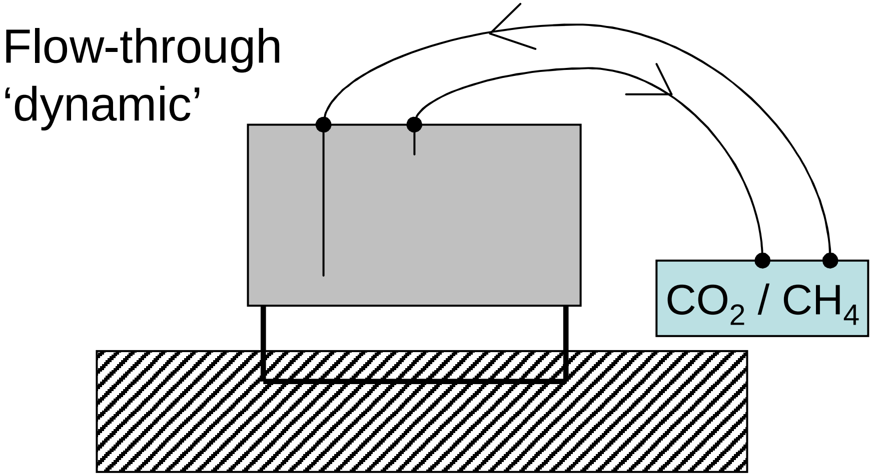
Mass balance
Eddy covariance
Flux gradient
- high temporal resolution
- low spatial
- medium-high fluxes
- CO_2, **CH_4 ?, N_2O ??**

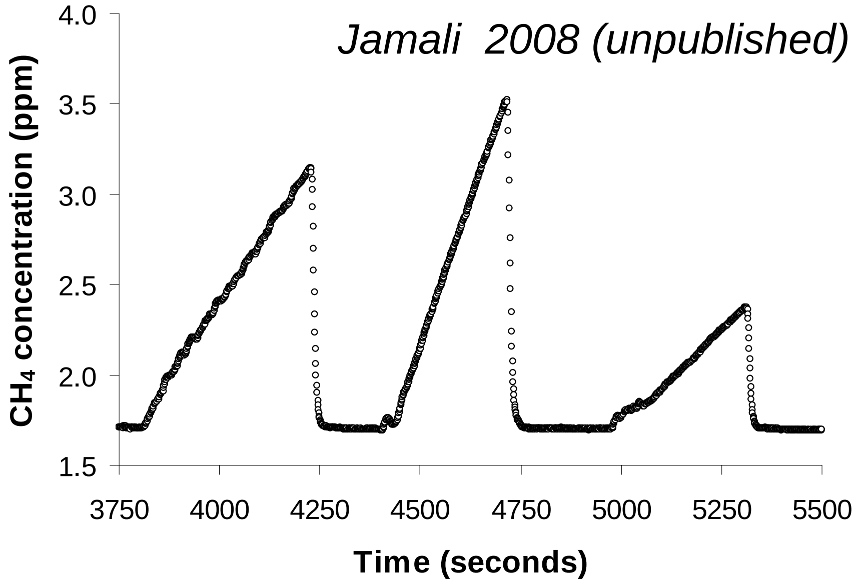


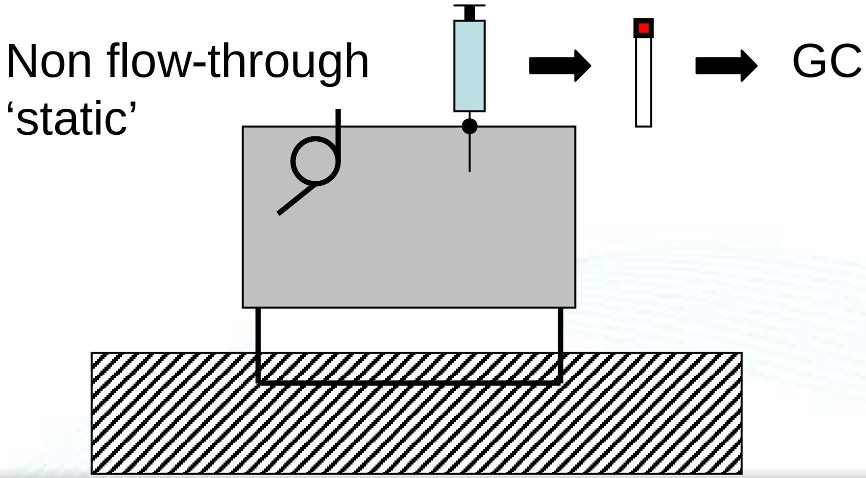
Denmead 2008

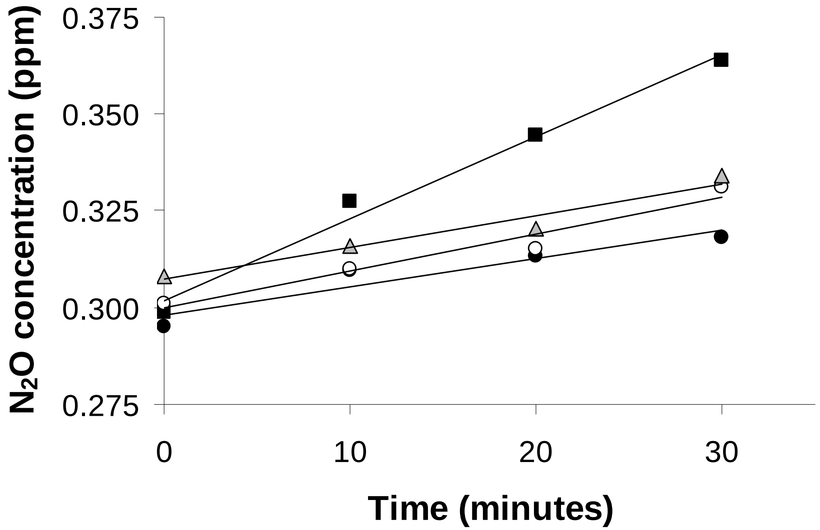
Closed chambers

- Non-steady state (i.e. conc. Increase)



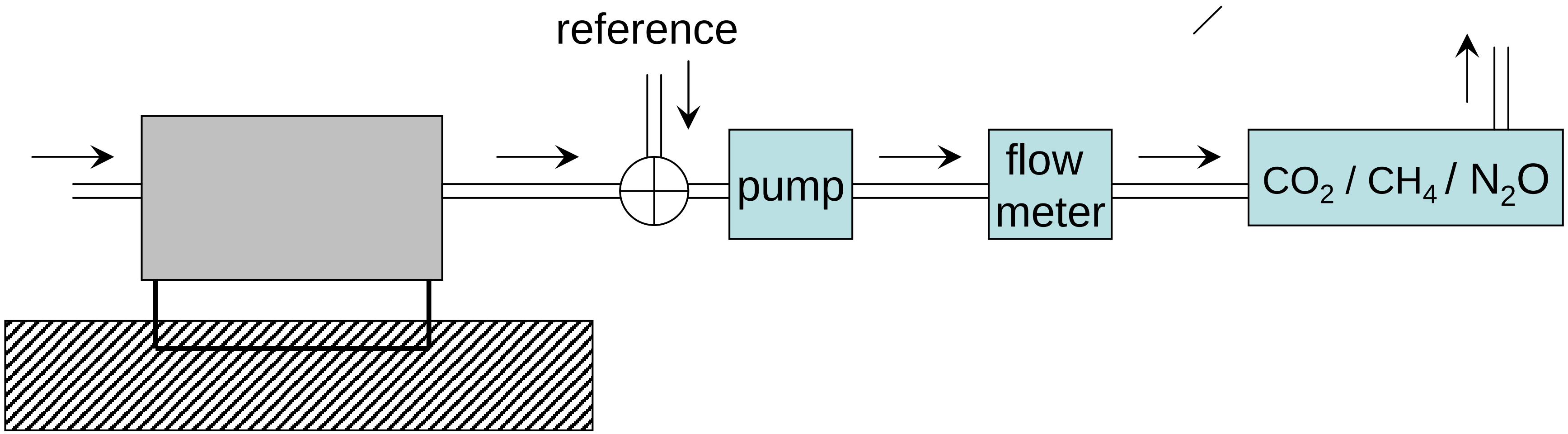






Open chambers

- Steady state (i.e. conc. stable)



- Constant flow of air maintained through the headspace
- The difference in concentration between the air in and out is measured.
- Good – as gas concentration increase minimal and not inhibitory
- Bas – when gas flux is small, therefore difference negligible

Chamber flux calculation

Closed chamber

Parkin et al. 2003

- Flux volume (F_v) as µL m^{-2} h^{-1} can be calculated from:

$$F_v = (V / A)\, \Delta_g / \Delta t$$

where V is volume (m^3), A is surface area (m^2), Δ_g is gas concentration change (ppm), and $\Delta\, t$ is the period of time (h) for that change.

- Universal gas law converts F_v (µL m^{-2} h^{-1}) to flux density (F_g) µMol m^{-2} h^{-1}
- Requires data of air temperature and atmos. pressure (altitude).

Open chamber

- Flux density (F_g) as uMol m^{-2} h^{-1} can be calculated from:

$$F_g = v\, (\rho_{g,out} - \rho_{g,in}) / A$$

where v is flow rate (m^{-3} h^{-1}) and $\rho_{g,out}$ or $\rho_{g,in}$ are µMol m^{-3}

Denmead 2008

Issues & solutions for chambers

1. **Soil Disturbance** *(Mosier 1989; Matson & Harris 1995; Denmead 2008)*

- *Use temporary/portable chambers.*
- *Install permanent chamber collars at least 24 h prior to flux measure*
- *Collars should be short to minimise above and below-ground perturbation.*

2. **Temperature increase**:

Can Influence biological activity & physical absorption or dissolution of dissolved gasses.

- *Use insulated, reflective chambers.*
- *Keep deployment time as short as possible.*

3. **Pressure perturbations**:

Wind may cause pressure-induced mass flow over chamber collar
Closed chamber may reduce natural mass flux.

- *Use vented chamber*
- *Use skirted chambers*

4. **Increased humidity**

Gas solubility changes but probably a minor effect
Humidity increases may dilute the gas of interest, underestimating the flux

- *Keep chamber deployment short*
- *Relative humidity can be measured to correct for dilution effects from water vapour.*

THE UNIVERSITY OF MELBOURNE

Issues & solutions for chambers

5. **Diurnal variation** in soil gas flux can follow diurnal temperature, but not universal.
   Inter-daily variation may be high due to rainfall, fertility, tillage or freeze thaw events.
   Seasonal variation (Spring and Winter fluxes can be substantial).

- *Measure flux at the time of day that most closely represents daily mean (~ mid morning)*
- *Temperature correct measured fluxes when temperature bias may occur.*
- *Measure fluxes 3 to 4 times a week, all year long (**wow** !!)*
- *Stratify sampling to take account of episodic events (e.g. summer rainfall).*

6. **Spatial variability**
   Coefficients of variation commonly exceed 100%.

- *Use chambers with larger surface area footprint to minimize small scale variability.*
- *Use as many chambers as possible.*

7. **Gas Mixing**
   Assumed molecular diffusion is sufficient to homogenise gas concentrations.
   This may not hold with large vegetation present or large volume:surface area.

- *Pump the syringe repeatedly before sampling from the headspace*
- *Fit chambers with small fans – a 12 VDC computer fan.*

Minimum detectable limit

Especially when soil fluxes are low, it is important to know the minimum detection limit (MDL).

A function of :

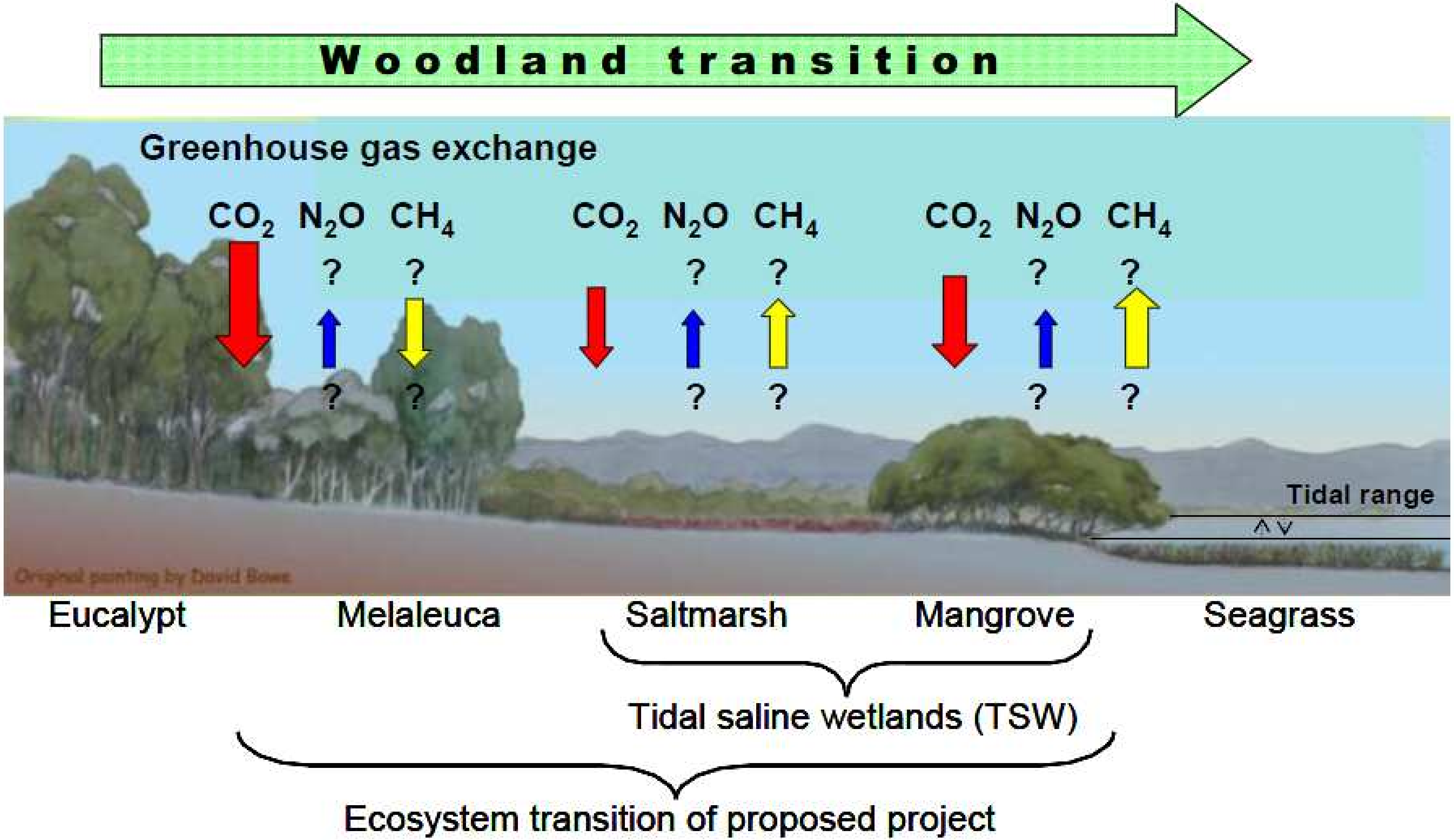
- sampling precision
- analytical precision
- chamber volume and surface area.

Sampling + analytical precision determined from SD of ~ambient standards (n>20).

± 2 SD provides sampling + analytical precision .

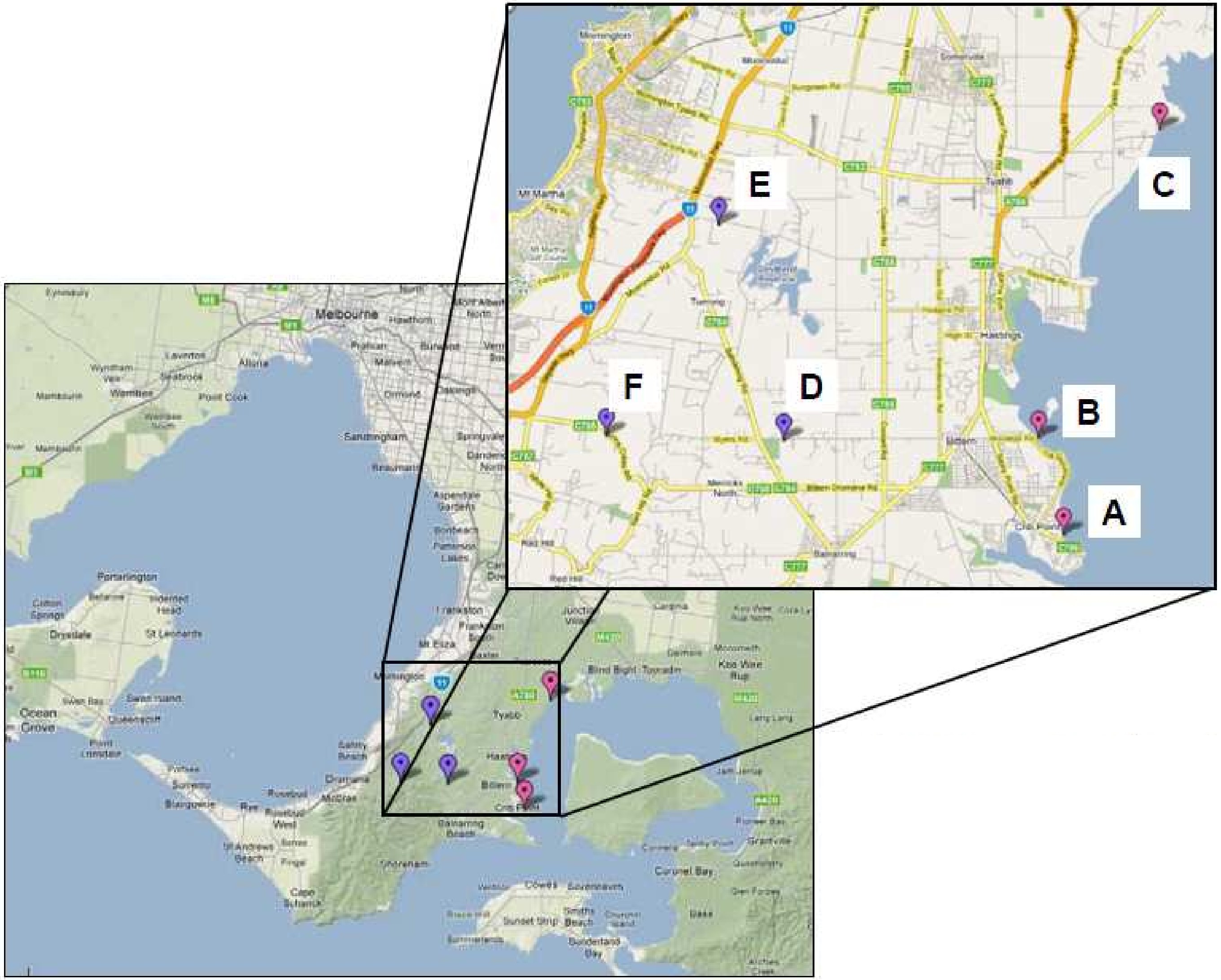
MDL = x2 SD * volume (L) / area(m^2) / deployment time (min)

Situations favouring chambers

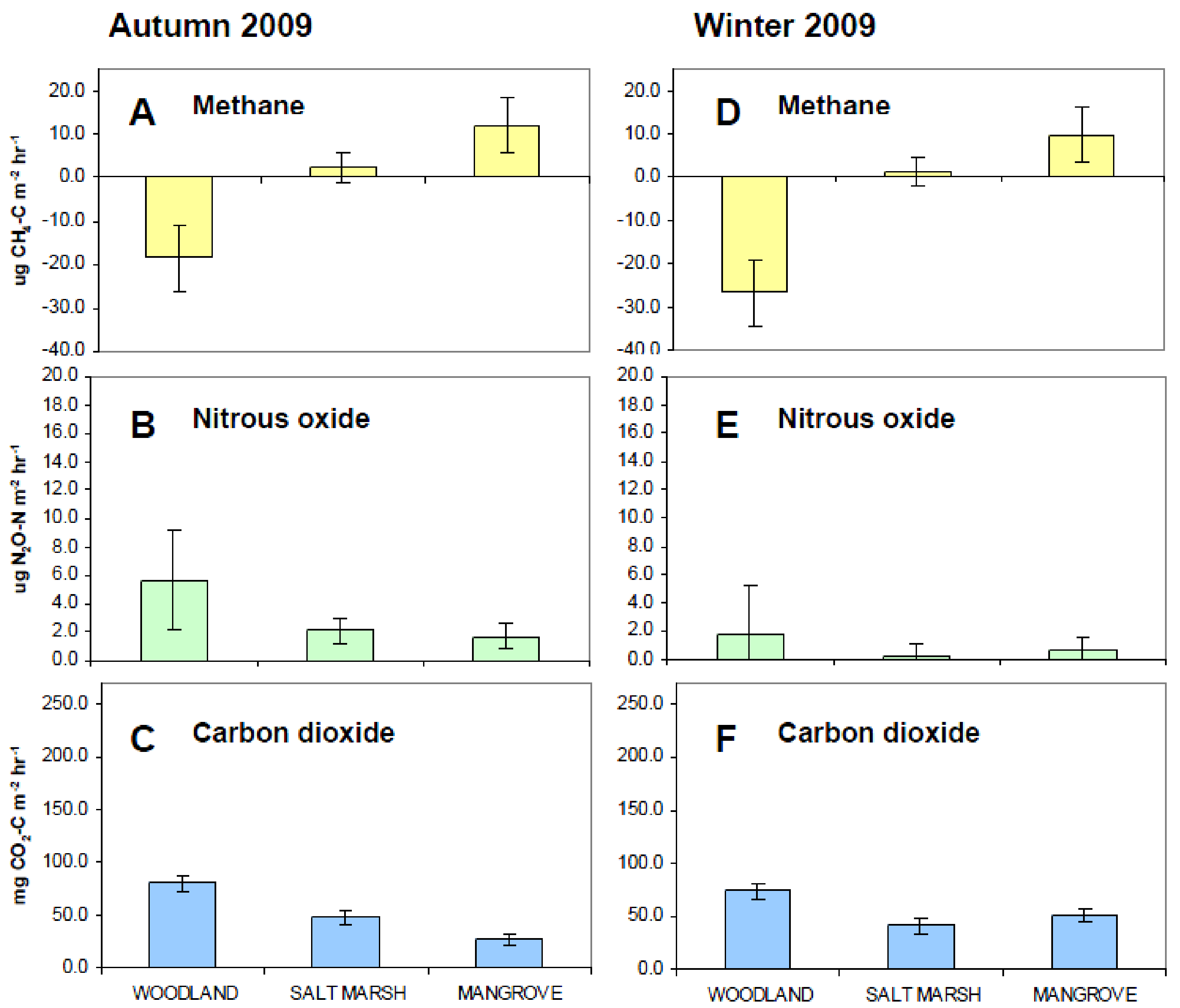


THE UNIVERSITY OF MELBOURNE

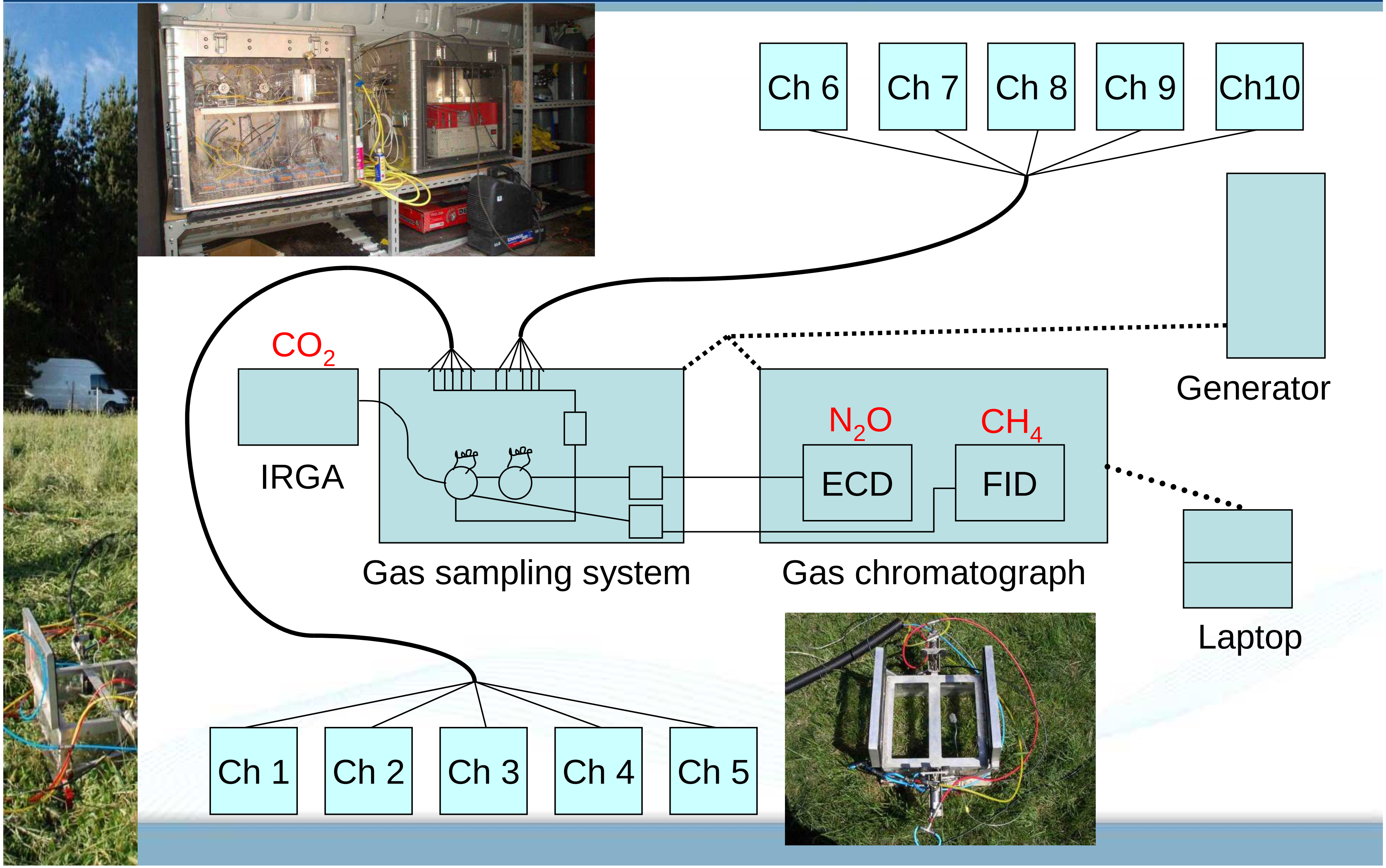
Mornington Peninsula, VIC



Closed chamber fluxes

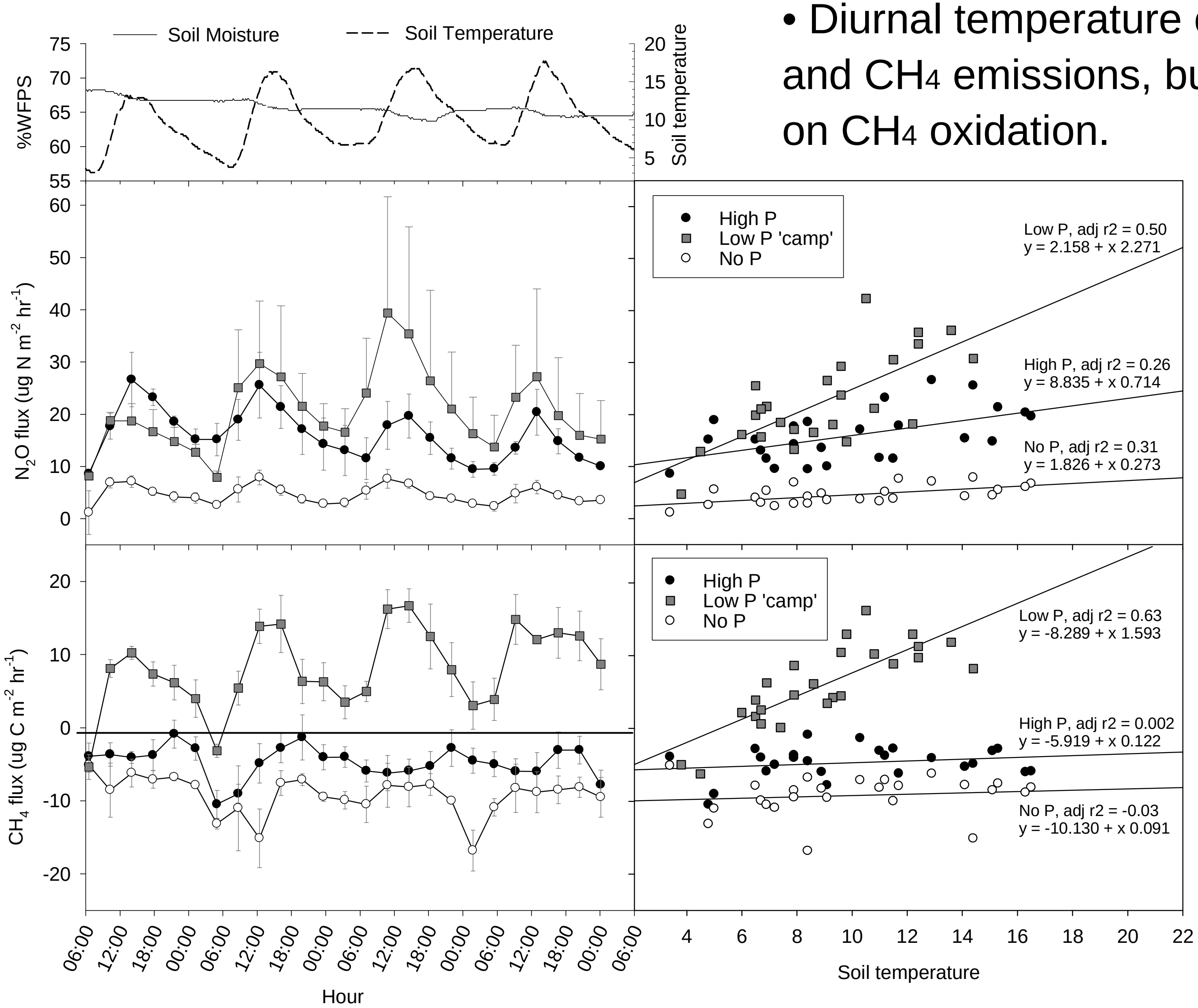


Automated chambers

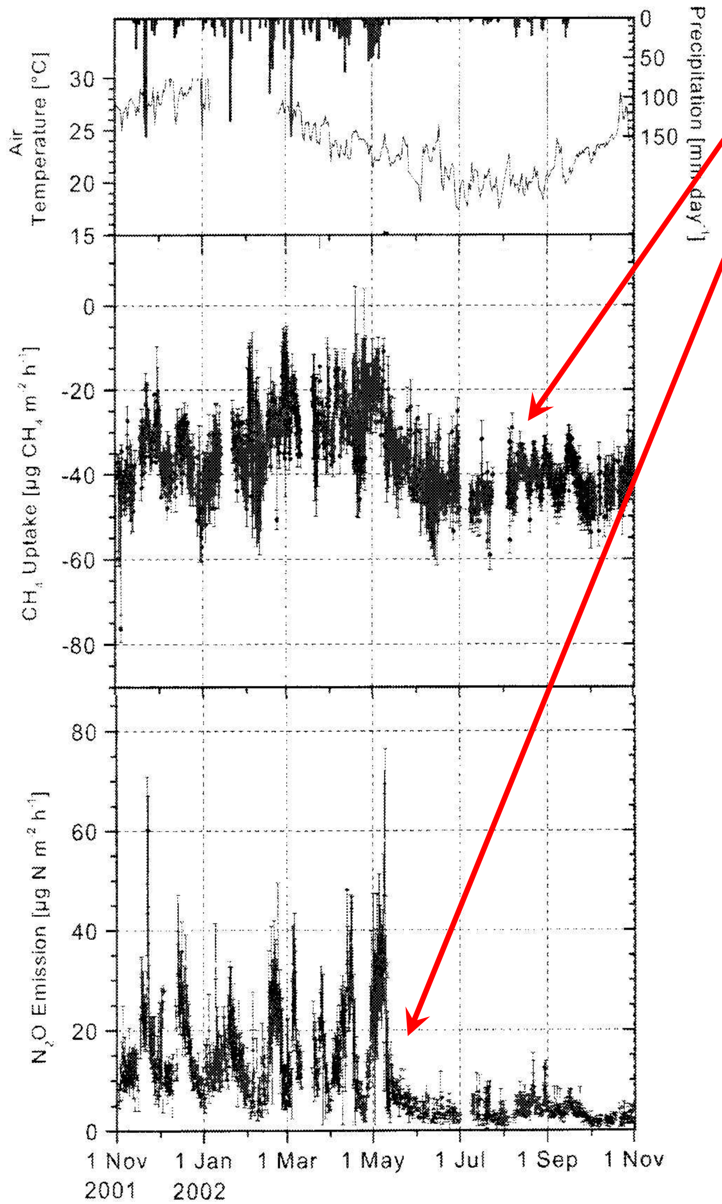


Diurnal N_2O and CH_4 flux

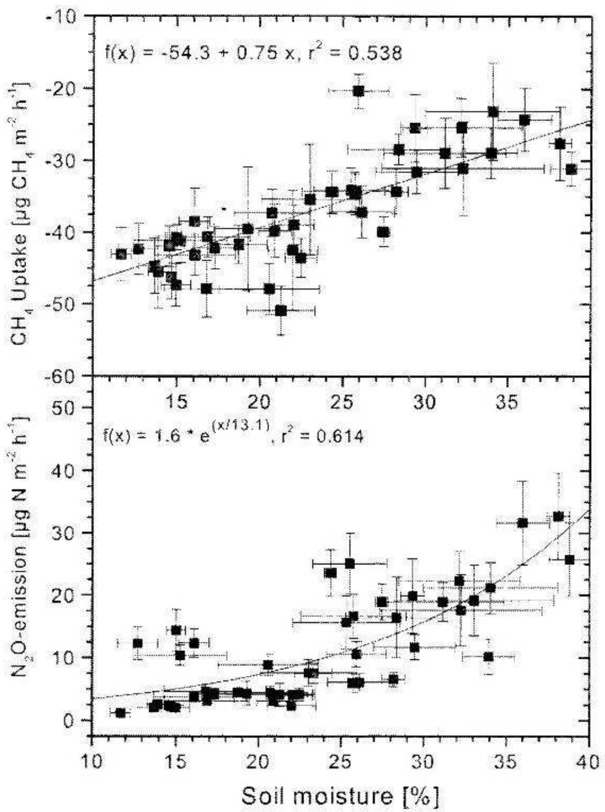
- Diurnal temperature cycle affects N_2O and CH_4 emissions, but has little effect on CH_4 oxidation.



Seasonal N_2O and CH_4 flux



- Seasonal shift in CH_4 uptake rates
- Strong seasonal shift in N_2O emission
- Good correlation between flux and soil moisture.



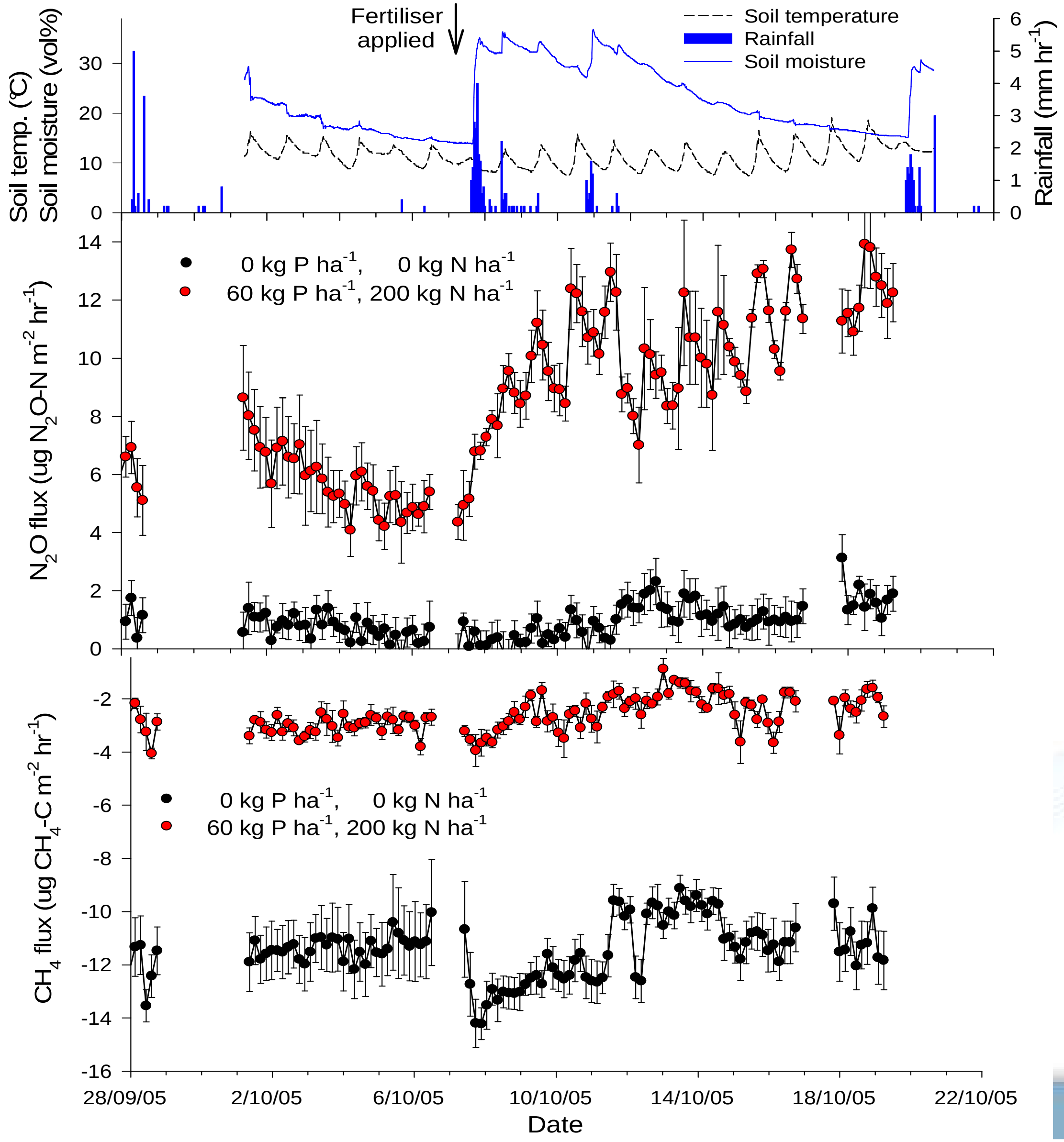
Kiese et al., (2003) & (2005)

Fertiliser and forest N_2O and CH_4 flux

Annual fertiliser since 1998 @ 200 kg N, 60 kg P ha^{-1}

N_2O flux small (<20 µg N m^{-1} hr^{-1}) Despite large NO_3 and NH_4 pools, up to 250 mg N kg^{-1}.

X4 less CH_4 uptake with N fertiliser.



CH_4 and N_2O mitigation opportunities

- There are few opportunities to increase non-CO_2 sinks, except through enhanced CH_4 uptake with agricultural abandonment or active afforestation – *benefit small*

- Mitigation of CH_4 and N_2O flux rests solely at managing the natural and anthropogenic sources.