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Linking models and measurements of soil nitrogen emissions on a field scale

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Introduction

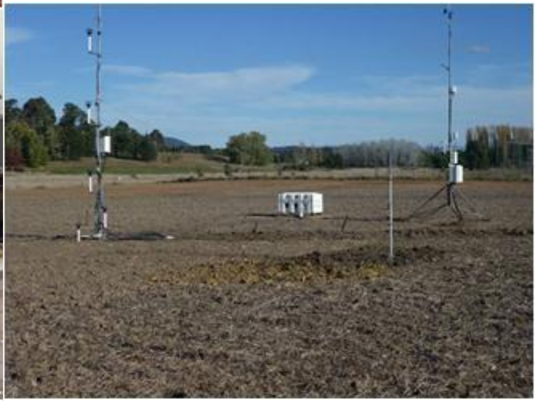
- Due to microbial action, nitrogen fertilisers undergo many transformations in soil leading to production of gases & their emission to the atmosphere
- Emitted gases include nitrous oxide (N_2O), ammonia (NH_3), the odd oxides of nitrogen (NO_x) and molecular nitrogen (N_2)
- Production processes modelled extensively, e.g. DNDC, DAYCENT
- Field tests often run in hindsight on data already collected by other groups
- Here, we describe a collaborative undertaking between modellers and field researchers to devise and operate a field experiment for which
    - modellers have stipulated beforehand the data needed to validate their model of N transformations, and
    - field researchers have tested whether and how well they can measure all the required data
- For simplicity, experiment conducted on bare soil after urea fertiliser applied and only one model tested, APSIM (Keating et al., 2003)

Experimental (above ground measurements)

Top: a circle of 25 m radius in the centre of the 2 ha field fertilised with urea at 200 kg N ha^{-1}

2.5 km airlines & power cables underground

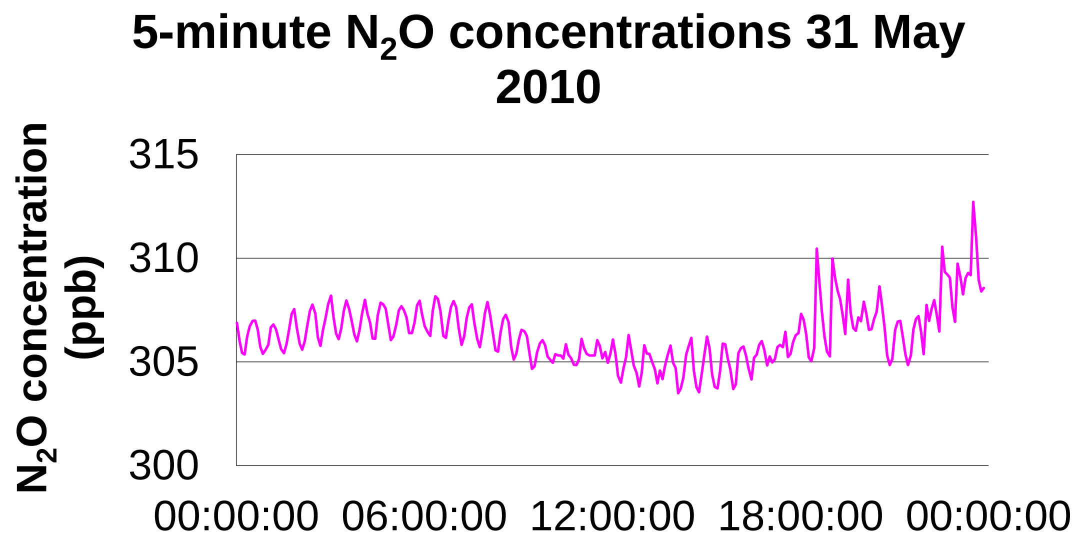
Wind speeds measured at centre of circle with sonic anemometers (left mast); 5 heights up to 4.8 m. Air intakes for gas concentrations at the same 5 heights. Evaporation measured by eddy covariance (right mast)

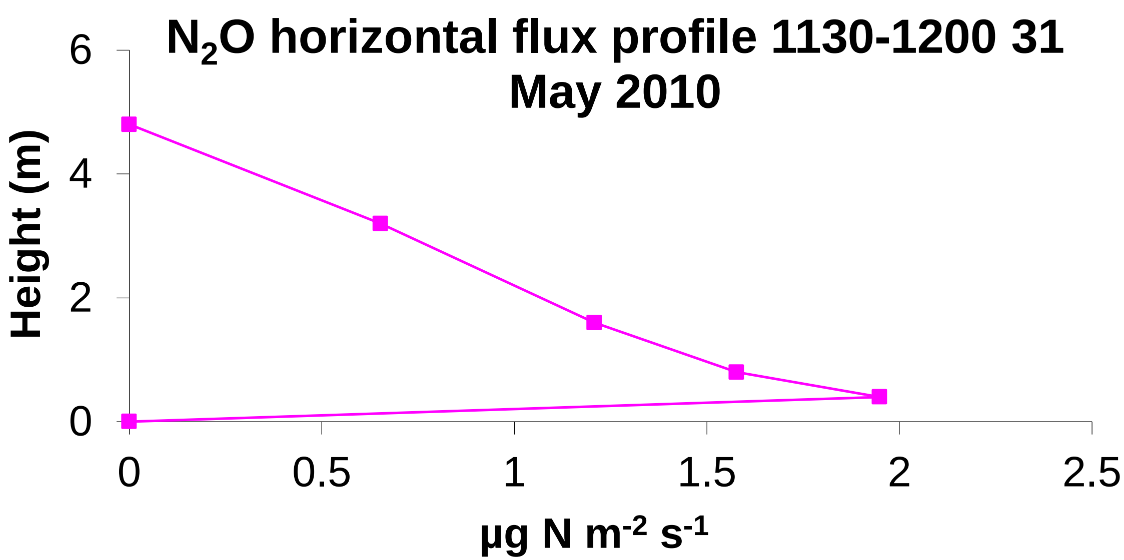


Bottom: air delivered to FTIR spectrometer for N_2O measurement, left & to chemiluminescence analyser for NH_3 and NO_x measurement (cabinet between masts), right.

Urea with ^{15}N applied nearby

Measurement of gas emissions: 1. By integrated horizontal flux (IHF) technique





- Concentration profiles measured over 30 min with changes between levels every 5 min
- This produces the saw-toothed time course
- Horizontal flux = (concentration – background) x wind speed
- IHF represented by area under pink line
- Integrate by trapezoidal rule
- Emission rate = IHF/radius of circle

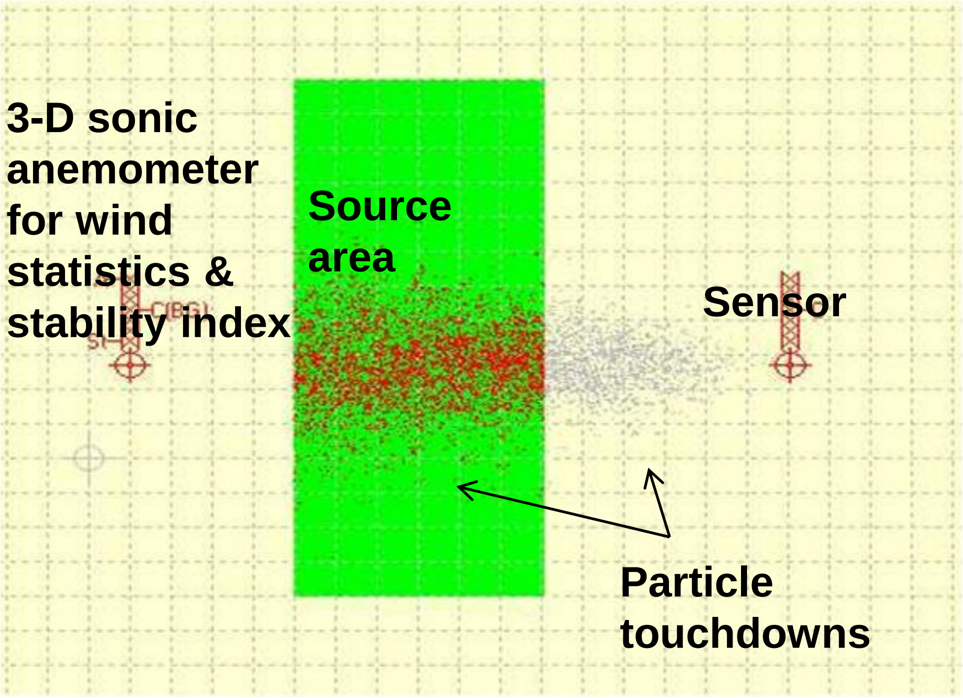
Measurement of gas emissions: 2. By backward Lagrangian stochastic (bLs) dispersion technique

The technique traces particles backwards from sensor to origin using a Lagrangian dispersion model

Surface fluxes calculated from number of particle touchdowns inside and outside source area in many simulations, commonly 50,000

Technique suitable for point, line or area sources (any shape)

Inputs:
geometry of source area
height and location of sensor
wind speed and direction
atmospheric stability
gas concentrations upwind and downwind



Note: emissions can be determined from wind speed and concentration at just one point downwind

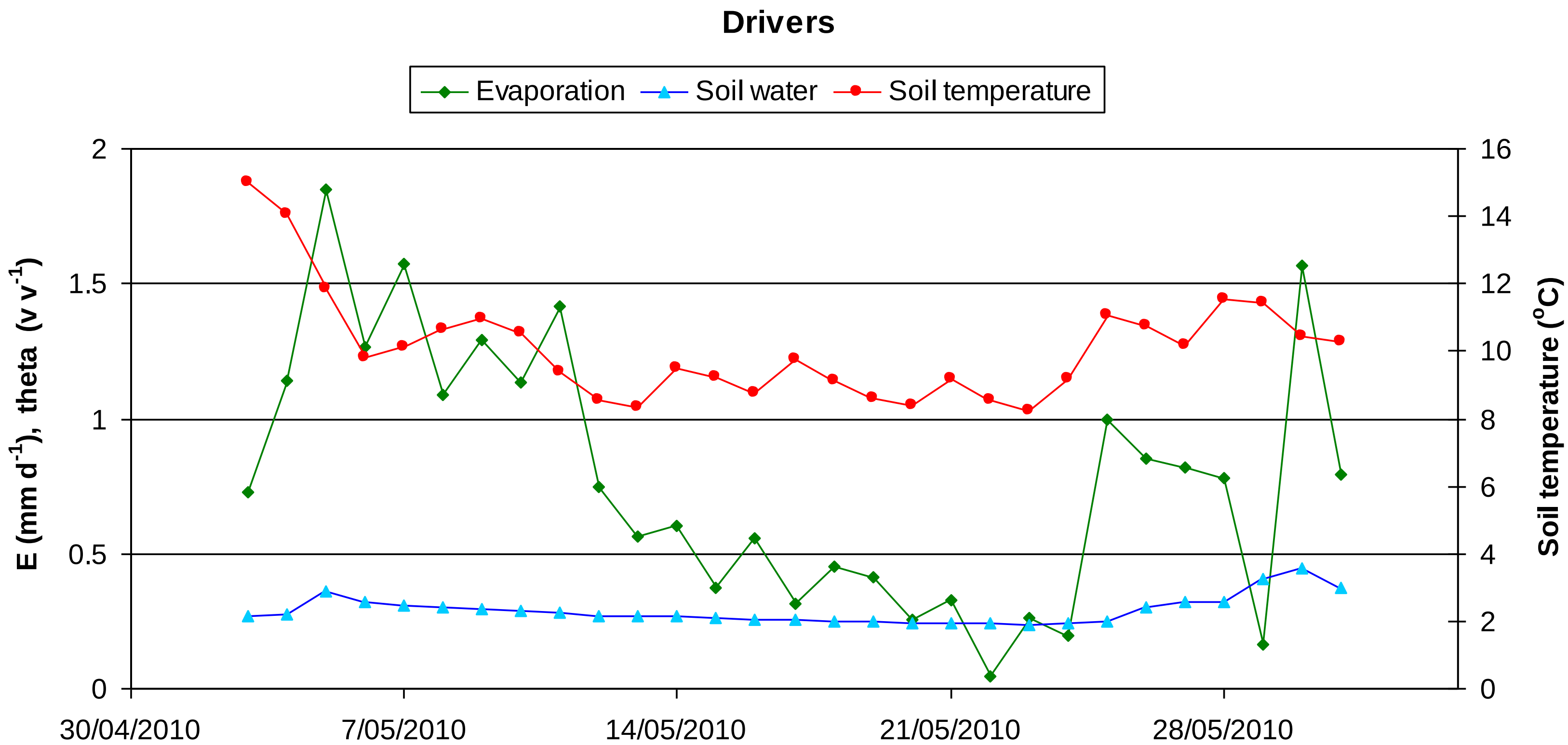
Experimental (below ground measurements)

Soil pit

Installing samplers for soil gas concentration measurements at depths of 5, 10, 20, 50 and 85 cm

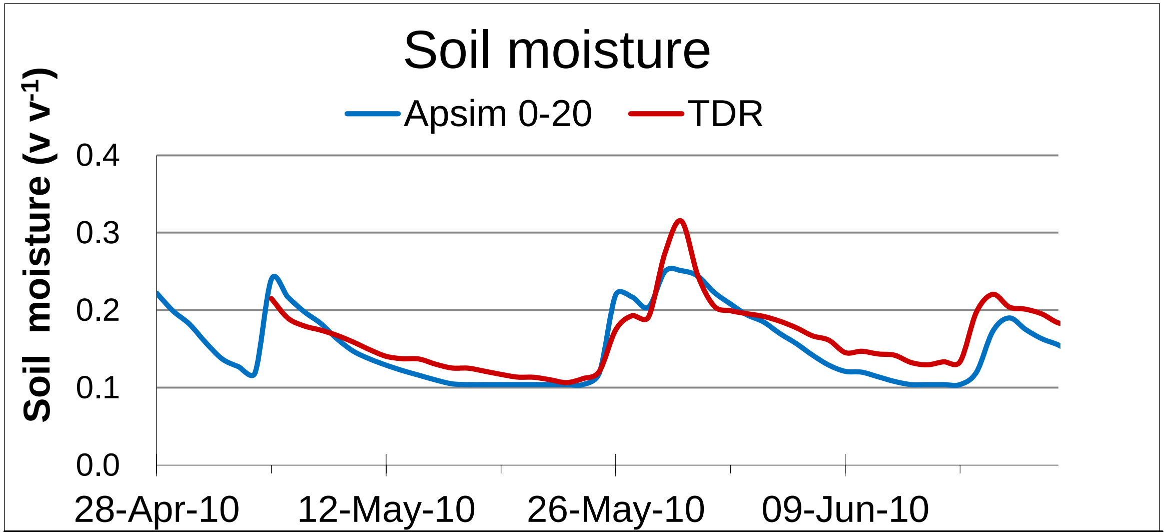
Soil moisture probes and soil thermometers

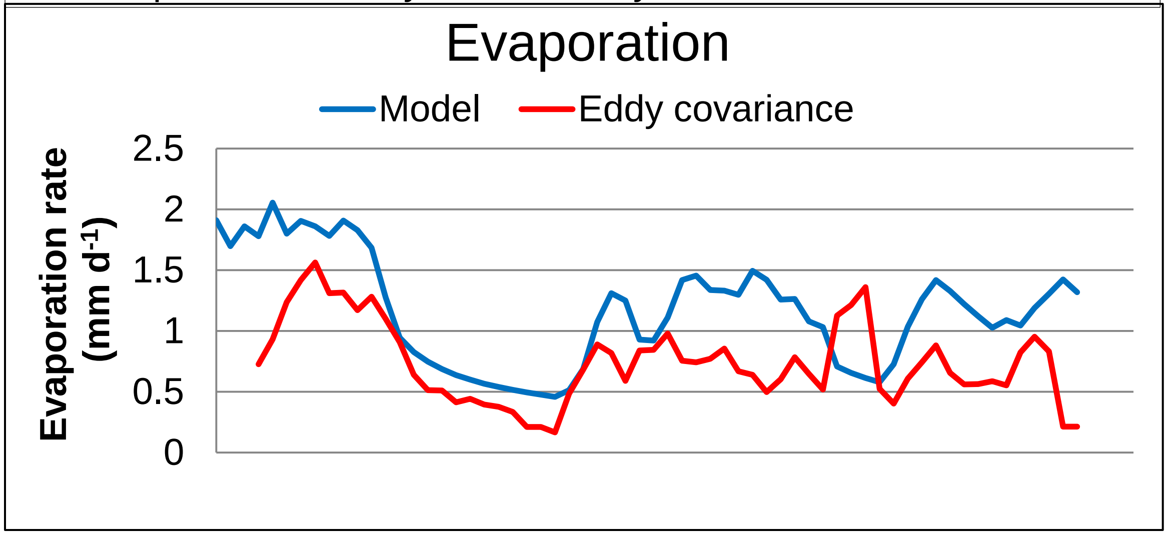
Results: Drivers of gas fluxes



Experiment conducted in late spring and winter:
Cold soil
2 periods of rainfall May 4 (17 mm) and May 25-28 (47 mm)
Rainfall promoted increased surface soil water and increased evaporation

Measured and modelled daily soil moisture (0-10 cm) and evaporation rate



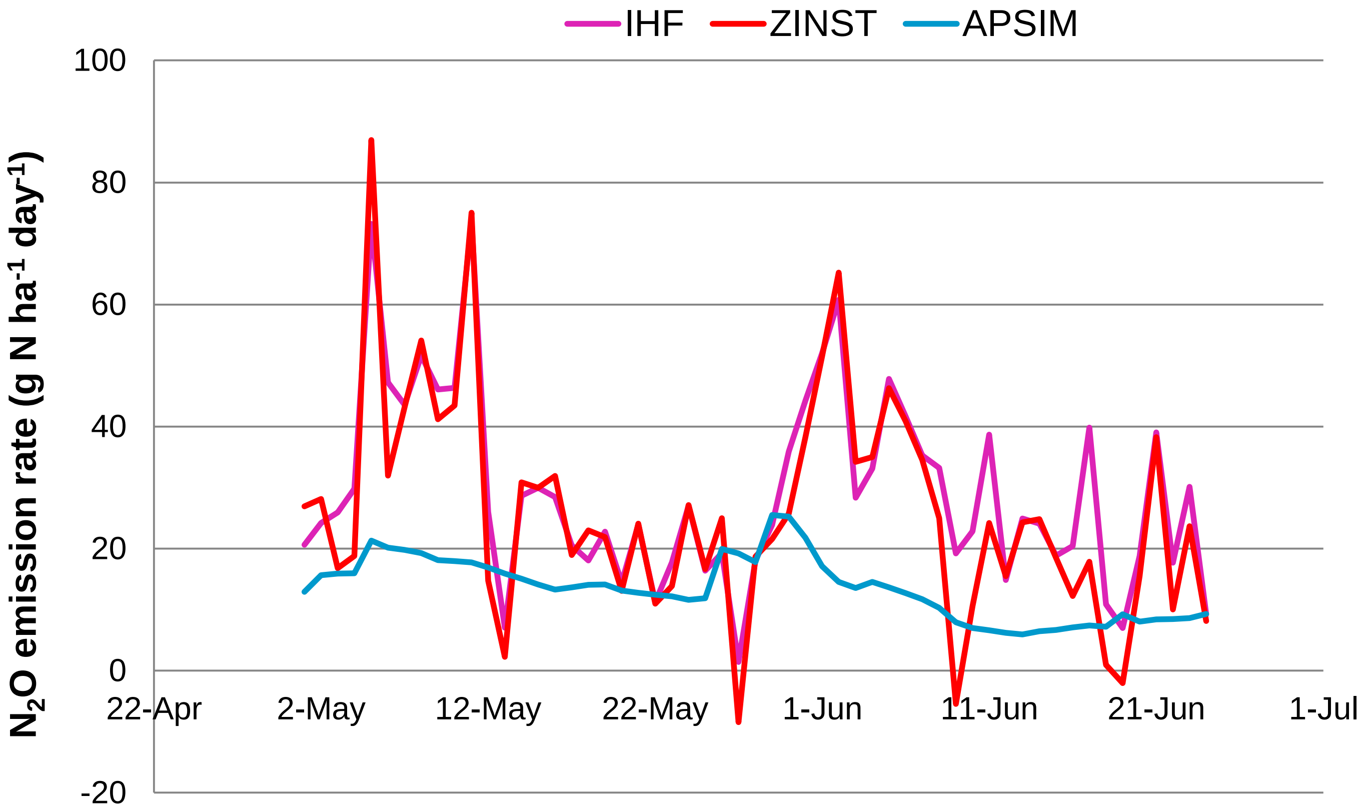


Soil moisture is a very important driver of soil N transformations.

It is essential to model it correctly.

In this case, the modelled evaporation was somewhat higher than the measured rate and so the modelled soil moisture was slightly lower than the measured

Measured and modelled daily N_2O emissions

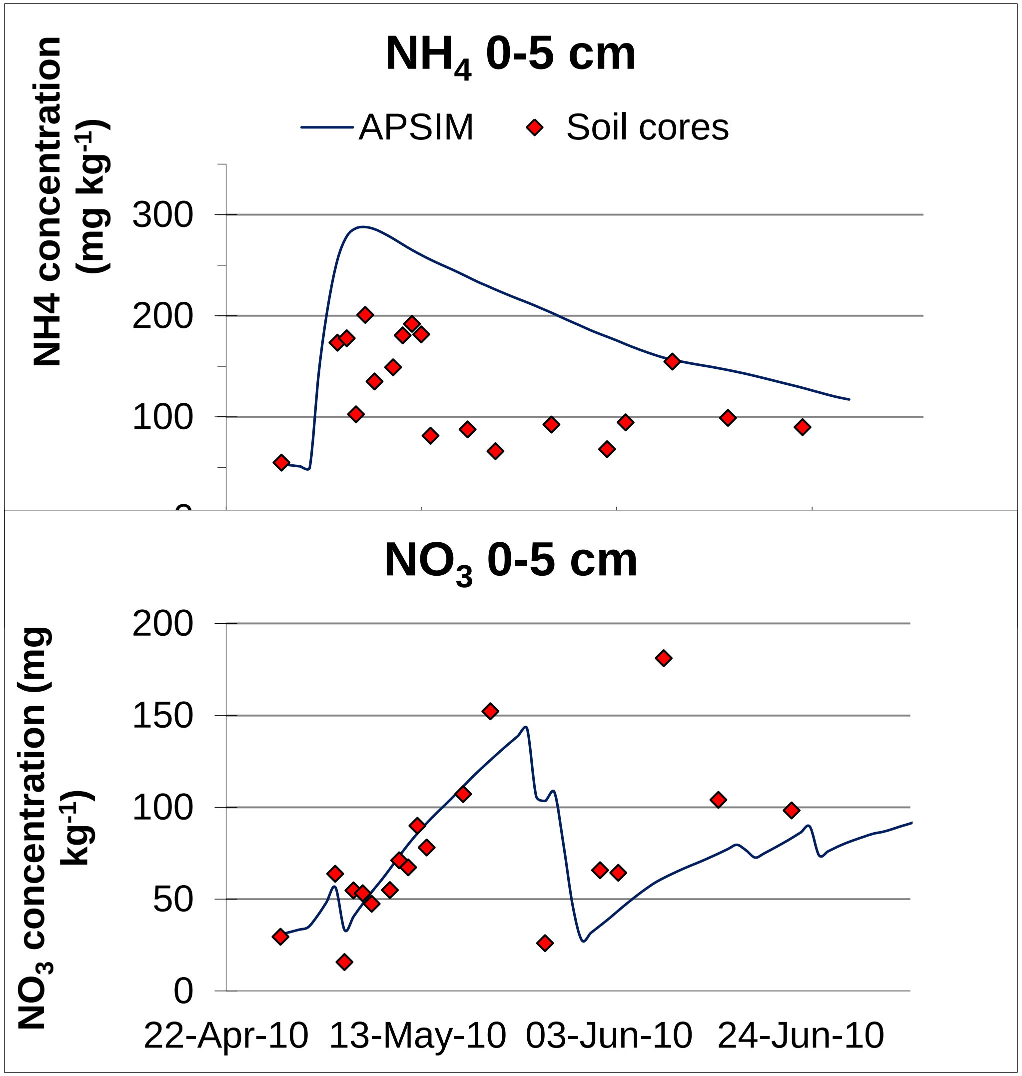


Close agreement between the 2 independent micrometeorological measurements of N_2O emission gives confidence in their integrity

Soil moisture was predicted to be lower than measured (previous slide)

Consequently , predicted N_2O emissions were also lower than measured

Mineral nitrogen

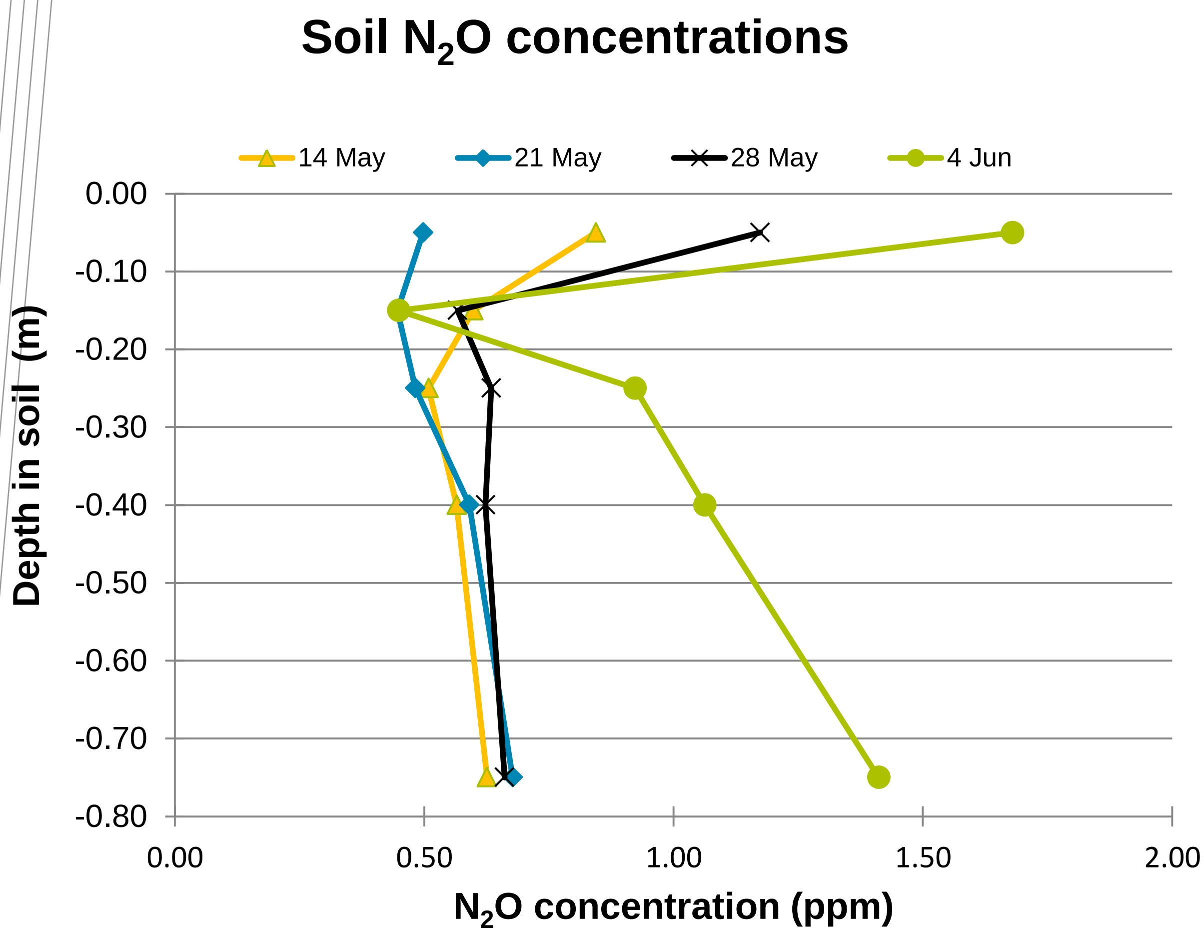


APSIM overestimated NH_4 in the top soil layer as shown here, but its predictions agreed well with measurements on soil cores in the rest of the soil profile (not shown).

Not so surprising; NH_4 formation and further transformation occurs rapidly after urea application

APSIM predicted NO_3 well throughout the profile (data for lower layers not shown)

N_2O in the soil profille



- Example soil profiles of N_2O appear to suggest some N_2O production in top layer on all occasions
- 47 mm rain from 25-27 May markedly increased production in top layer on May 28 & 4 June
- Profile on 4 June suggests leaching of nitrate to deeper depths (after rain) leading to denitrification there
- Analysis of profiles to identify production, storage and diffusion of gases still to be done

Conclusions

- Neither the model nor the measurements are perfect

- It seems that the model over-predicted soil evaporation and consequently
  - predicted lower soil water contents than were measured and
  - lower N_2O production
  - obviously, we need to get evaporation right in the model

- A major difficulty is that measurements and models operate on different time scales:
  - 30 minutes and only daytime values for the emission measurements
  - 1 day averaged weather variables for the model
  - differences in outcome are to be expected

- It is encouraging that APSIM appears to predict the processes of N_2O production well, e.g. the formation and distribution of mineral nitrogen

- The ^{15}N investigation found that around 30% of applied nitrogen was lost over the first 50 days, but measured N_2O & NO_x losses accounted for only 1.6%, compensated by a net gain of NH_3 from the atmosphere of 1.8 %; (NO_x and NH_3 exchanges not modelled, nor the losses of N_2 gas or by leaching); still some way to go

Thank you
With acknowledgements to Gordon McLachlan (CLW) and Phil Dunbar (Ginninderra Experiment Station)

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