ECOSSE – a globally applicable model of carbon and nitrogen dynamics in soil?

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Background

- QUEST
  - Quantifying and Understanding the Earth System
  - A NERC initiative designed to improve our understanding of the large-scale processes taking place on the Earth
- QUERCC
  - QUantifying Ecosystem Roles in the Carbon Cycle
  - focussed on the land surface processes
  - aimed primarily at improving our understanding of the carbon cycle
- ECOSSE
  - Provides the soil modelling component, to be linked to oceans/atmosphere
  - Includes soil nitrogen (N_2O, NH_4, NO_4) and carbon (CH_4, CO_2, DOC)
  - Modular structure, incorporating multiple processes and soil characteristics
  - Uses predefined vegetation and soil ‘types’ to simulate biomes

ECOSSE design

- Designed to be applied to mineral and organic soils
- Works well with agricultural & grassland, yet to implement forestry & other land cover types
- Limited success with organic soils
- Aim is to get ECOSSE to work for all major biome types
  - Tropical/temperate/arctic climates
  - Forest/arable/grassland/moorland vegetation types
  - Multiple management strategies

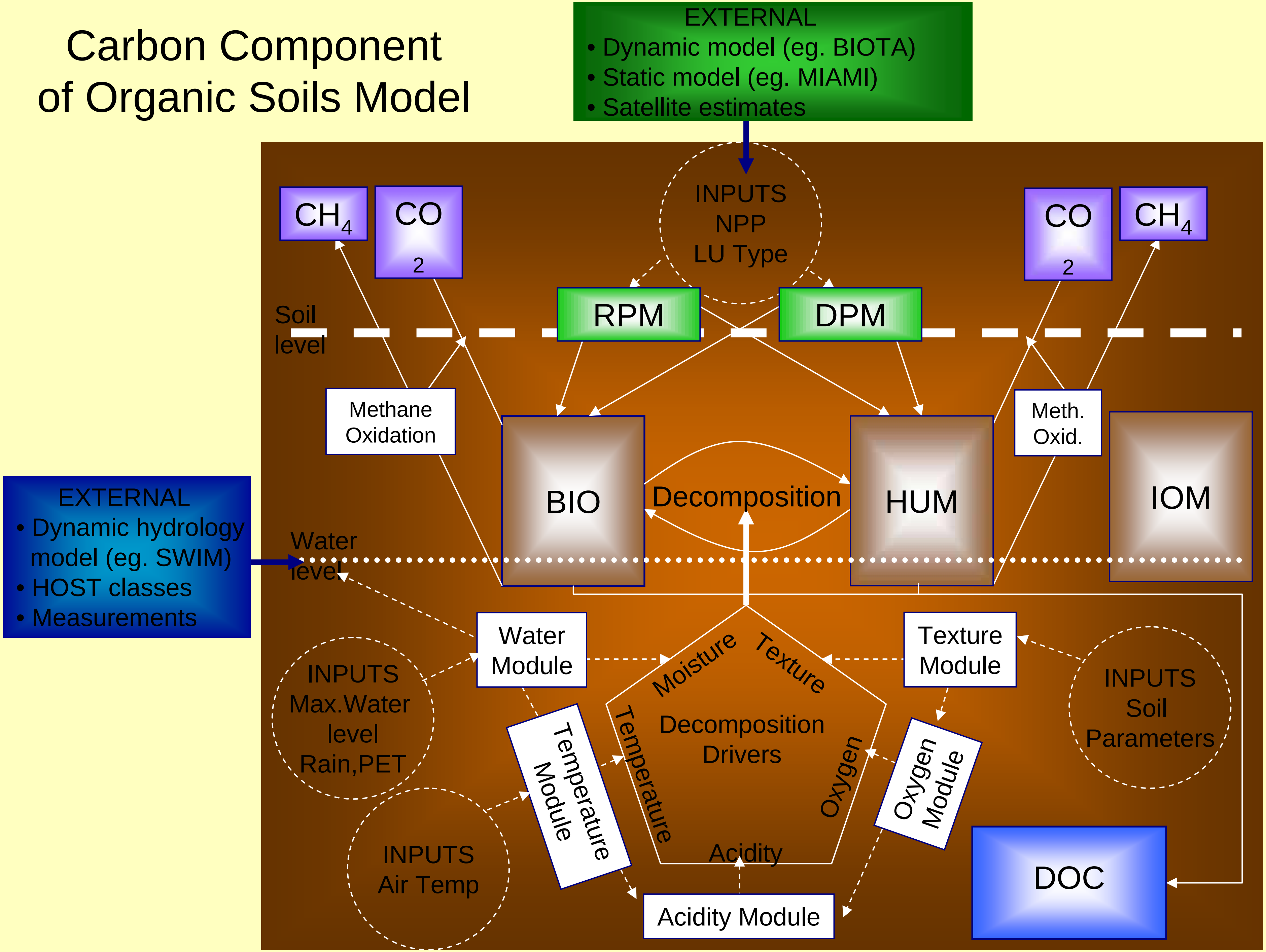
ECOSSE design

- Modular design
  - Processes can be switched on/off
  - Different models of the same process can be run
- Soil composed of 5cm layers
- Input files set soil up, runs for several years to stabilise soil
- Processes are limited by specific factors (e.g. pH, water, temperature, nutrient supply)
- Runs daily, weekly or monthly
- Automated creation of setup files from spreadsheet / macro / executable combo
- Working on GUI to make it more easy/accessible to run

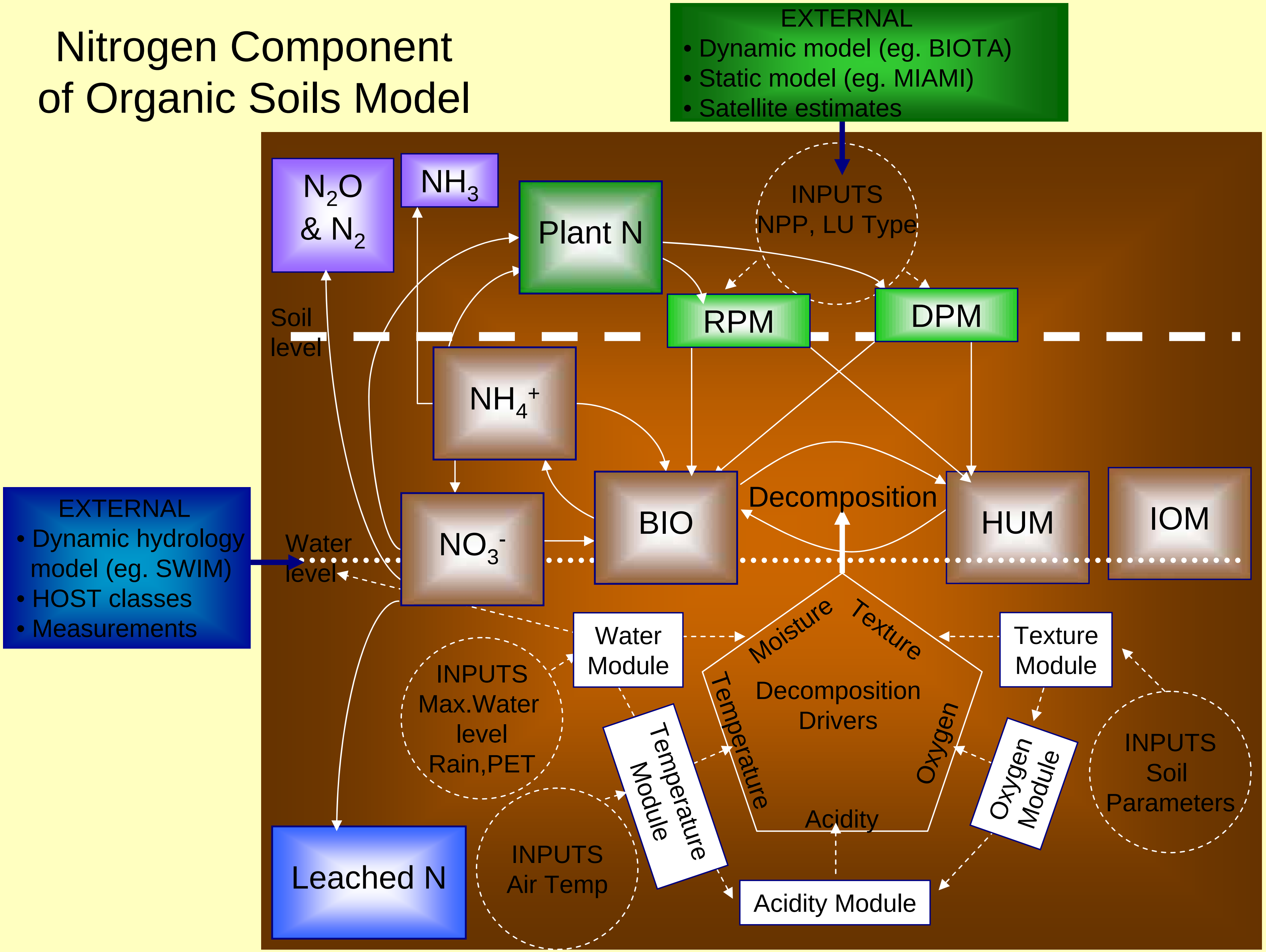
Components & subroutines

1. SUNDIAL/MAGEC modularised
2a. N_2O production
2b. Layering of soil profile
3. N_2O production & layering
4a. SOM initialised by equilibrium run to measured soil C
4b. pH effect on stable C:N ratio
4c. pH effect on rate constant
4d. pH effect on stable C:N and rate constant
5. ECOSSE3 + SOM initialised & pH effect
6a. Water table input
6b. Physical mixing on ploughing
6c. Freeze/thaw effect
7. ECOSSE5 + water table input, physical mixing & freeze/thaw
8a. Physical protection of SOM
8b. Layering of soil parameters
9. ECOSSE7 + physical protection & layered soil parameters

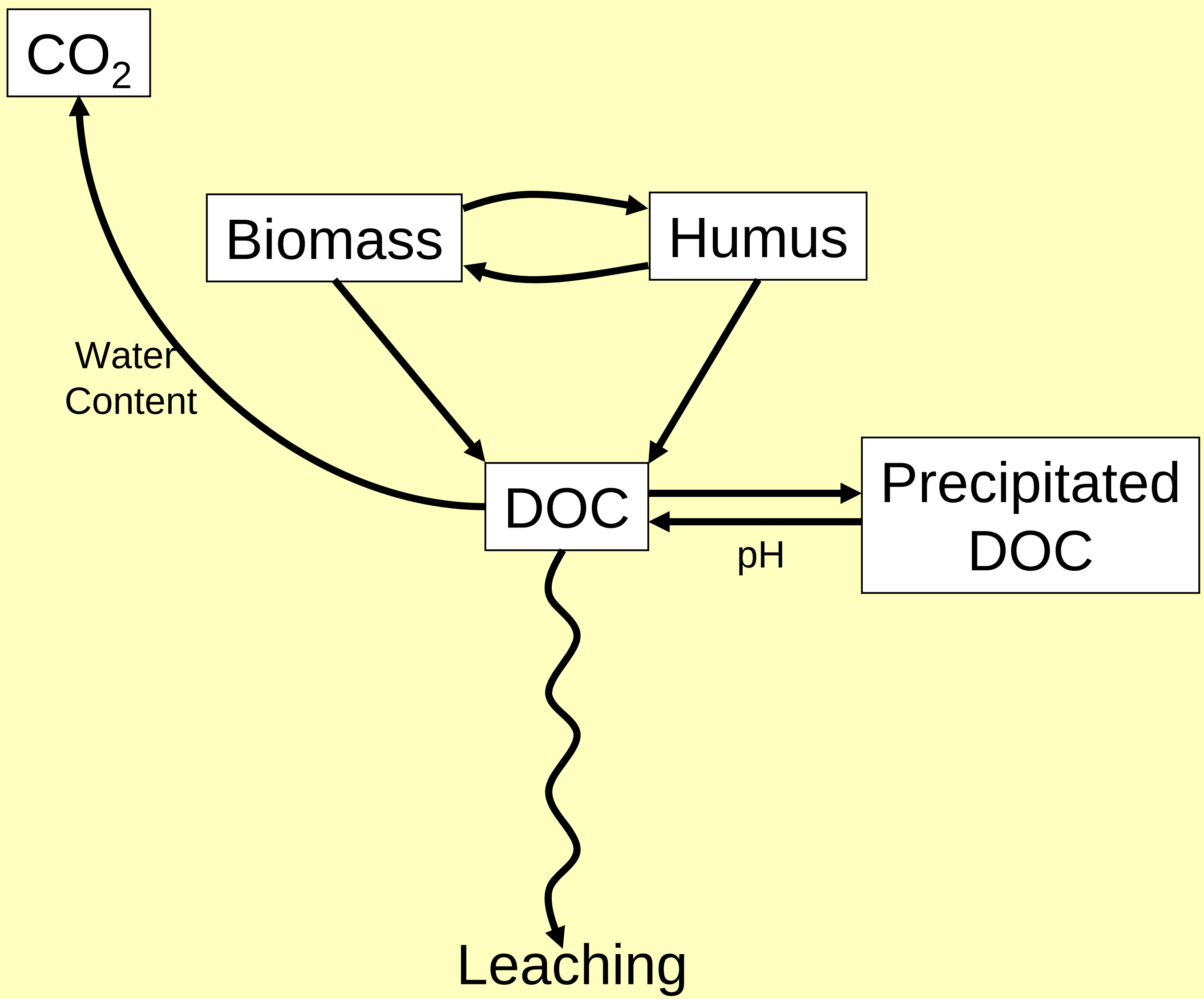
Carbon Component of Organic Soils Model



Nitrogen Component of Organic Soils Model



DOC



CO_2
Biomass
Humus
Water Content
DOC
Precipitated DOC
pH
Leaching

ECOSSE walkthrough

Initialisation of variables & arrays

Creation of output files

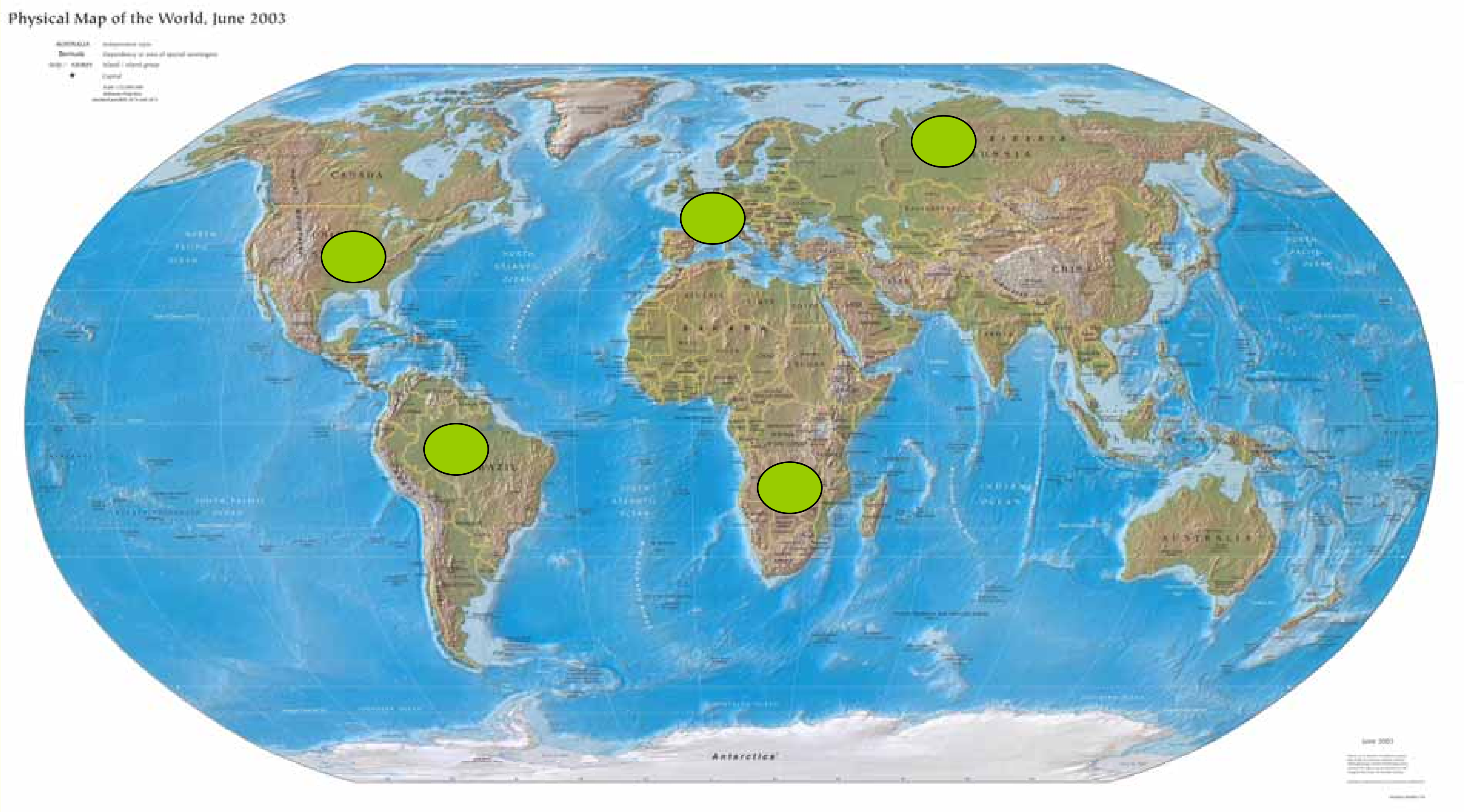
Reads data from input files

Enter loop for each year

- Set crop & fertiliser parameters for that year
- Enter loop for each day/week/month
    - Add fertiliser
    - Calculate dry deposition, mineralisation, nitrification, denitrification, DOC production
    - Grow crop (crop debris, sow new crops, N & C turnover)
    - Calculate water movement (leaching, movement between layers, evapotranspiration)
    - Output results
- End day/week/month loop

End year loop

Study areas – locations



Inputs required

- Soil
  - C:N ratios of biomass pools
  - Decomposition rates between pools
  - Total biomass content of soil
  - Sand, silt, clay content
  - pH
- Vegetation
  - Yield
  - N uptake
  - N content of roots, tops
  - C, N return in litter
  - Decomposition rate of litter
  - Senescence period,

Inputs required

- Climate
  - Rainfall
  - Evapotranspiration
  - Air temperature
  - Solar radiation
  - Max/min temp
  - Vapour pressure
  - N deposition

- Management
  - Land use history (grassland/arable/forest)
  - Crop type
  - Sowing/harvesting dates
  - Fertiliser application information
    - Date of application
    - % nitrate
    - % ammonia
    - Type of manure application

Ammonium

- NH_4 created by mineralisation during decomposition of biomass (into other biomass pools, CO_2 & NH_4)
- Decomposition controlled by Q10 relationships
  - $\Delta C = -kQ_{10}^{(T/10)}C_{pool}\Delta t$
- Mineralisation controlled by various limiting factors (water, temperature, microbial activity etc.)
- NH_4 loss through nitrification calculated from Bradbury et al. (1987)

$$N_n = NH_4 \times \exp\left(-0.6 \times m_{temp} \times m'_{water}\right)$$

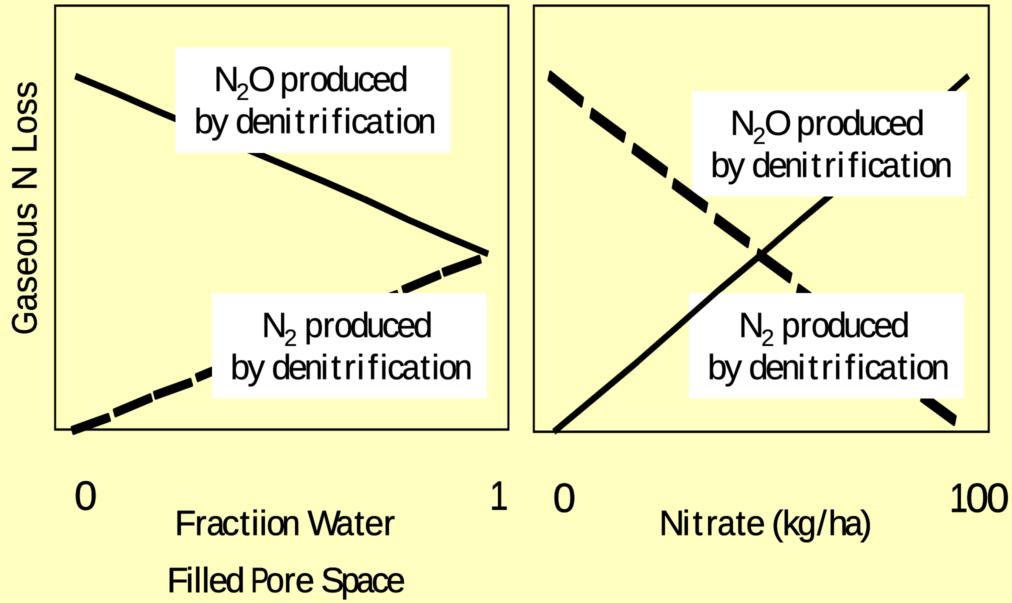
$$m_{temp} = \frac{47.9}{\left(1 - \exp\left(106 \big/ (T + 18.3)\right)\right)}$$

$$m'_{water} = \left(1 - \frac{\left(0.8 \times \left(W_{\max} - W - d_{(-1bar)}\right)\right)}{\left(W_{\max} - d_{(-1bar)}\right)}\right) \times m_{anaer}$$

$$m_{anaer} = \left(1 - W + \frac{(0.9 \times W_{\max})}{W_{\max} - (0.9 \times W_{\max})}\right)$$

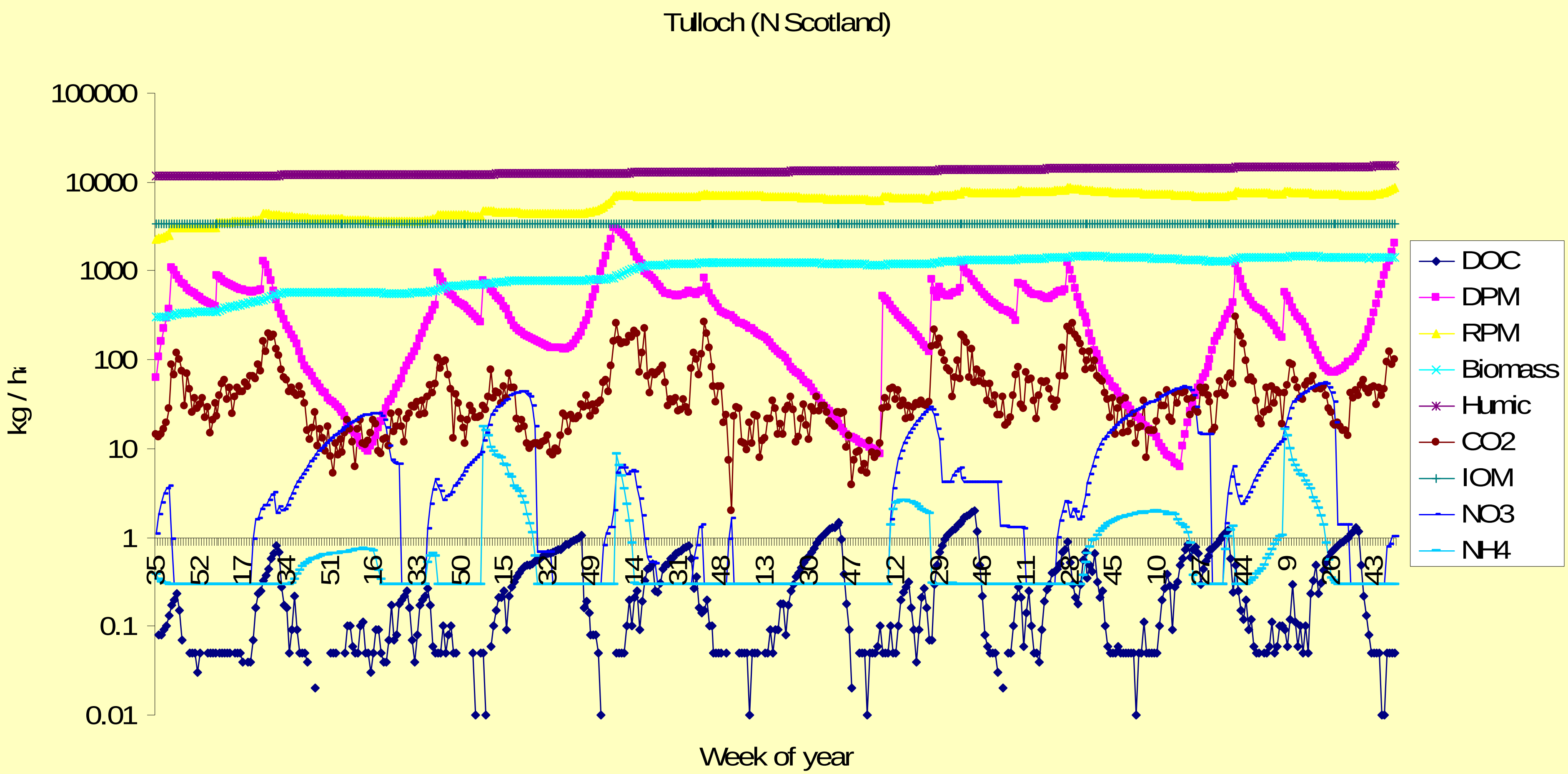
N_2O

- Partitioning of N into N_2O and N_2 based on soil water and nitrate content



$$N_{d,N2O} = \left(1 - \left(p_{water} \times p_{NO3}\right)\right) \times N_d$$

Simulation outputs



Field trials

We have data from:

- Sweden (Regina et al., 2004)
- N Germany (McVoy et al., 1995)
- Scotland (Skiba, pers. comm.)
- Wales (Skiba, pers. comm.)
- England (Macdonald et al., 1997)

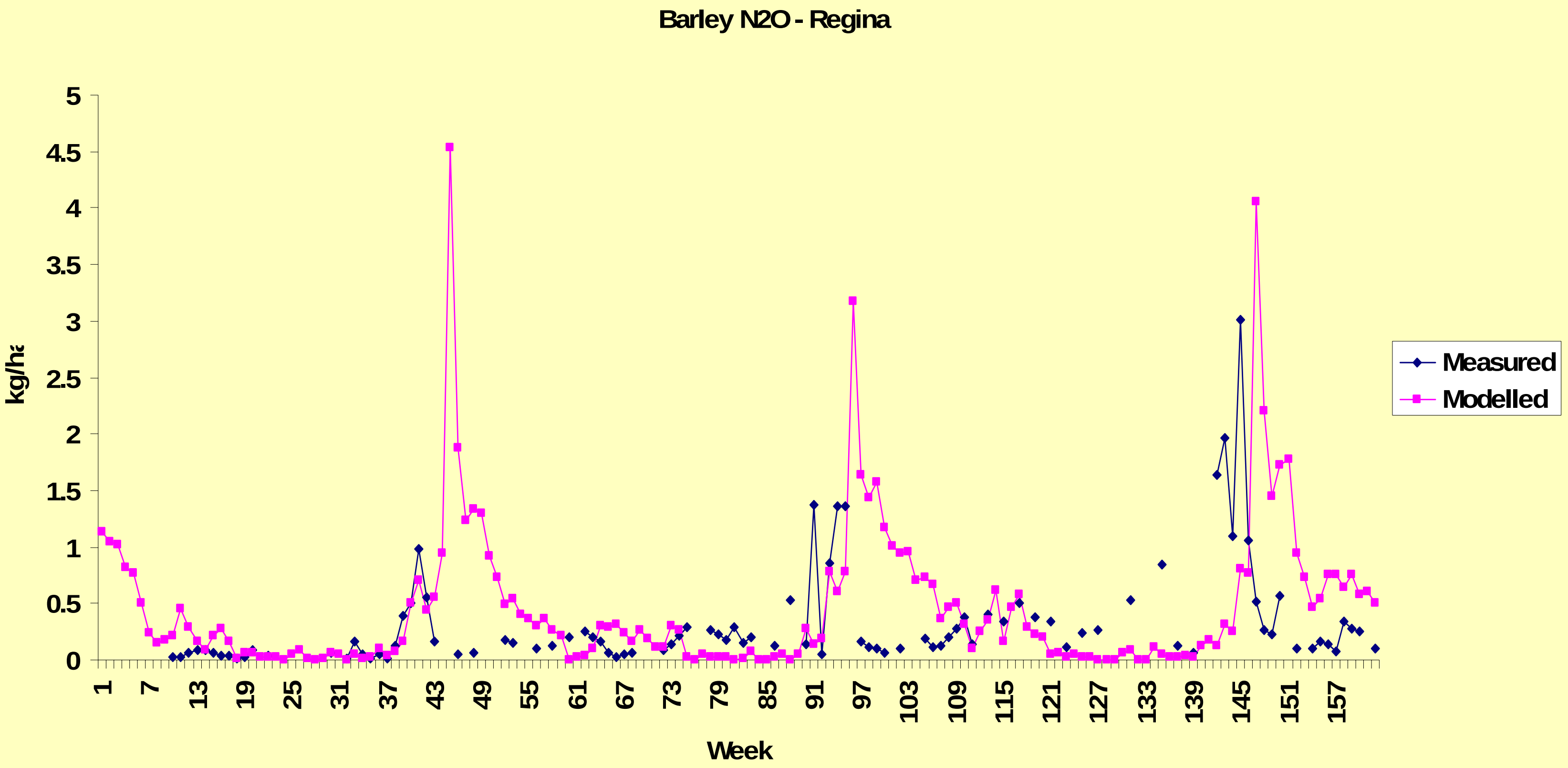
Pete Smith, Ullapool, Scotland

We will have data from:

- Wales & England again (CEH)
- Siberia
- Great Plains USA
- Amazonia, Brazil
- Sub-Saharan Africa

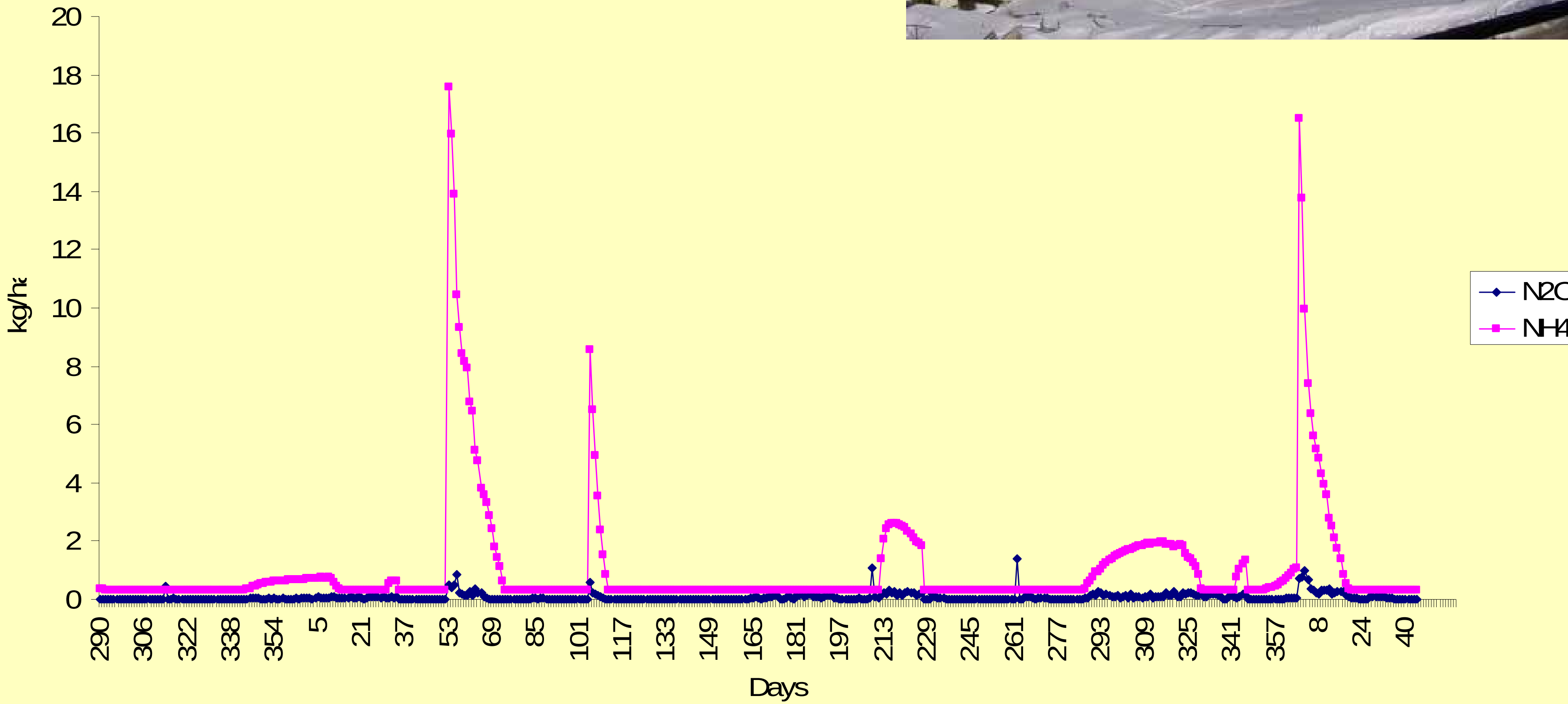
Ute Skiba, Hafren, Wales

Comparison with field trials



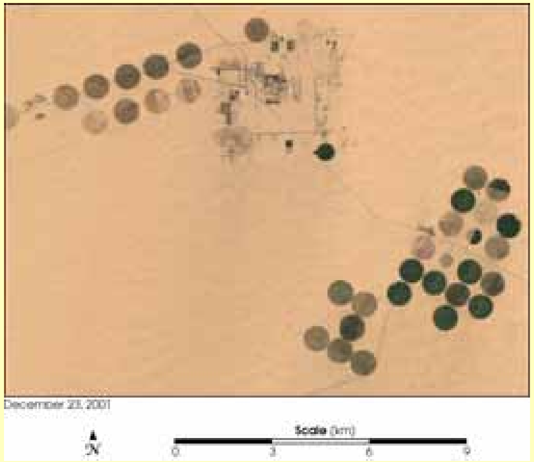
Local example

Obergurgl model



Ongoing work

- Methane
- Spatially explicit modelling
- Improved non-agricultural vegetation implementation
- Spatially explicit version
- Data acquisition from different biomes
- Moving away from cropping model
- Development of functional type database
  - Soils
  - Vegetation
  - Climate



Questions?

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This work is funded by NERC grant NE/C516160/1