CROPLANDS GROUP

GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

Cross-cutting session

Chair: Peter Grace

Co-chairs: Emma Suddick & Ward Smith

Key note lecture – Steve Del Grosso

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GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

Key note lecture

What are the key processes which must be considered to account for the effect of management practices on N2O?

Stephen Del Grosso, Bill Parton, Steven Ogle, Keith Paustian

SOIL PLANT NUTRIENT RESEARCH

What are the key processes to consider?

Nitrification

Denitrification

Nitrifier denitrification

Plant growth

NO3 leaching

N mineralization

Snow melting

Lateral transport of water and nutrients

Enzyme kinetics

Etc.

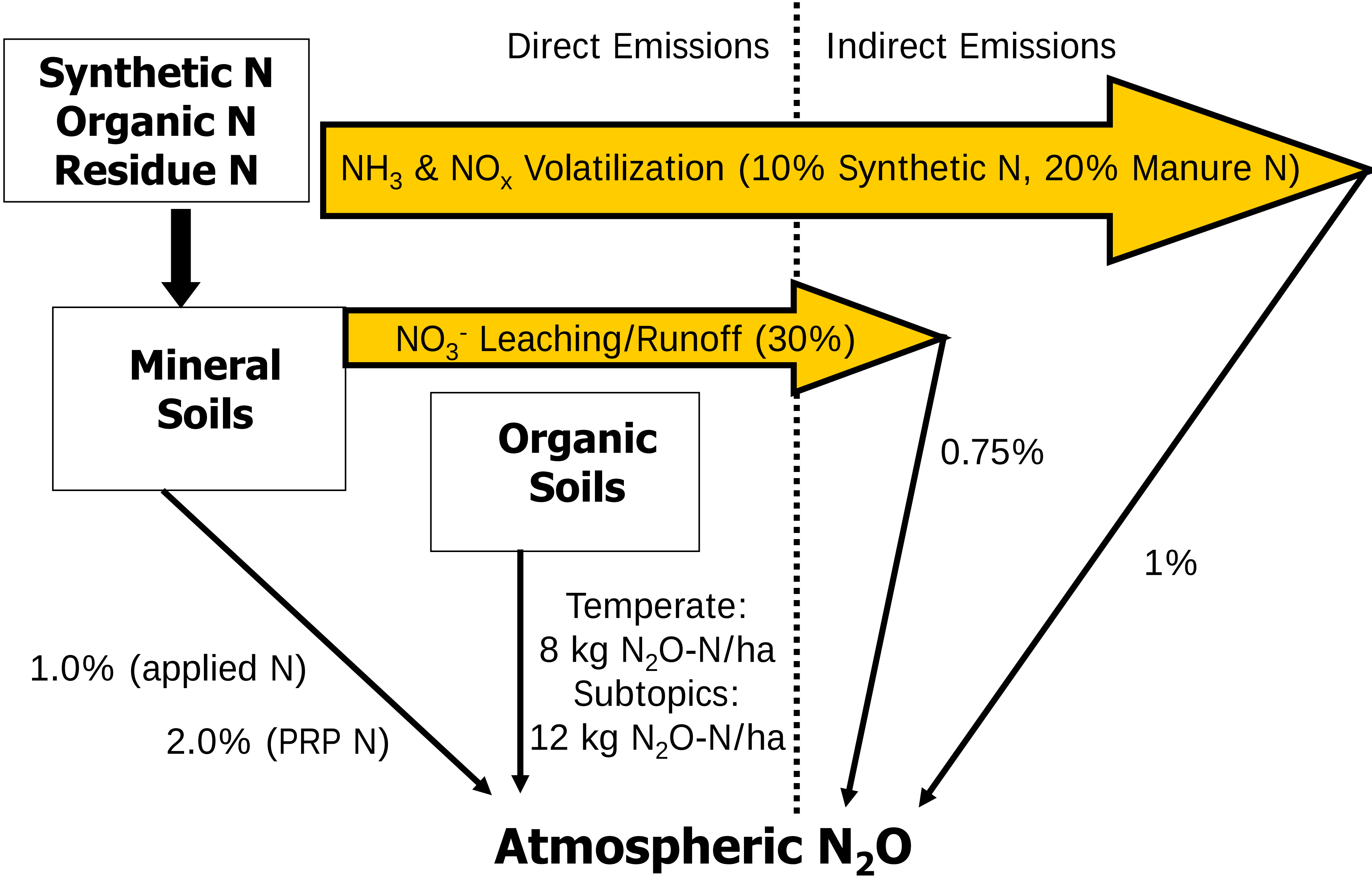
Model Continuum

Empirical

Process-based

Simple Empirical

IPCC Tier 1 METHODOLOGY FOR N_2O



More Complex Empirical: Qtool:

Practice-Scaled Soil N2O Emission Rate for Mineral Soils

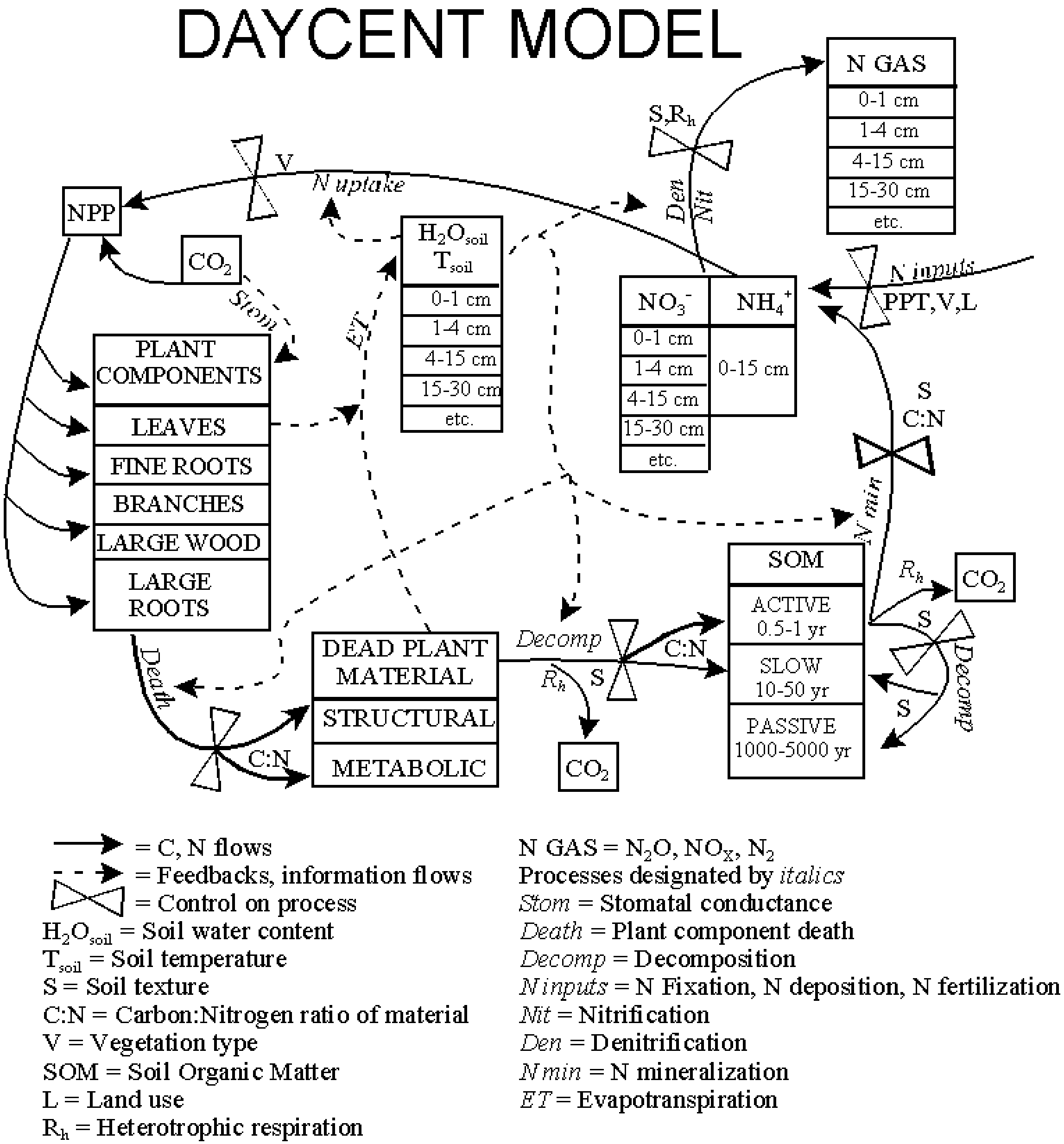
(http://www.usda.gov/oce/climate_change/techguide/USDA_CCPO_GHG_draft_082213.pdf)

$$ER_p = ER_b \times \{1 + [S_{sr} \times (N_{sr}/(N_t + N_{min}))]\} \times \{1 + [S_{prp,cps} \times (N_{prp,cps}/(N_t + N_{min}))]\} \times (1 + S_{inh}) \times (1 + S_{till}) \times (1 + S_{irr})$$

Farm level tool that calculates a base N_2O EF then scales this up or down based on management practices:

- N source
- Irrigation
- tillage

Intermediate Complexity

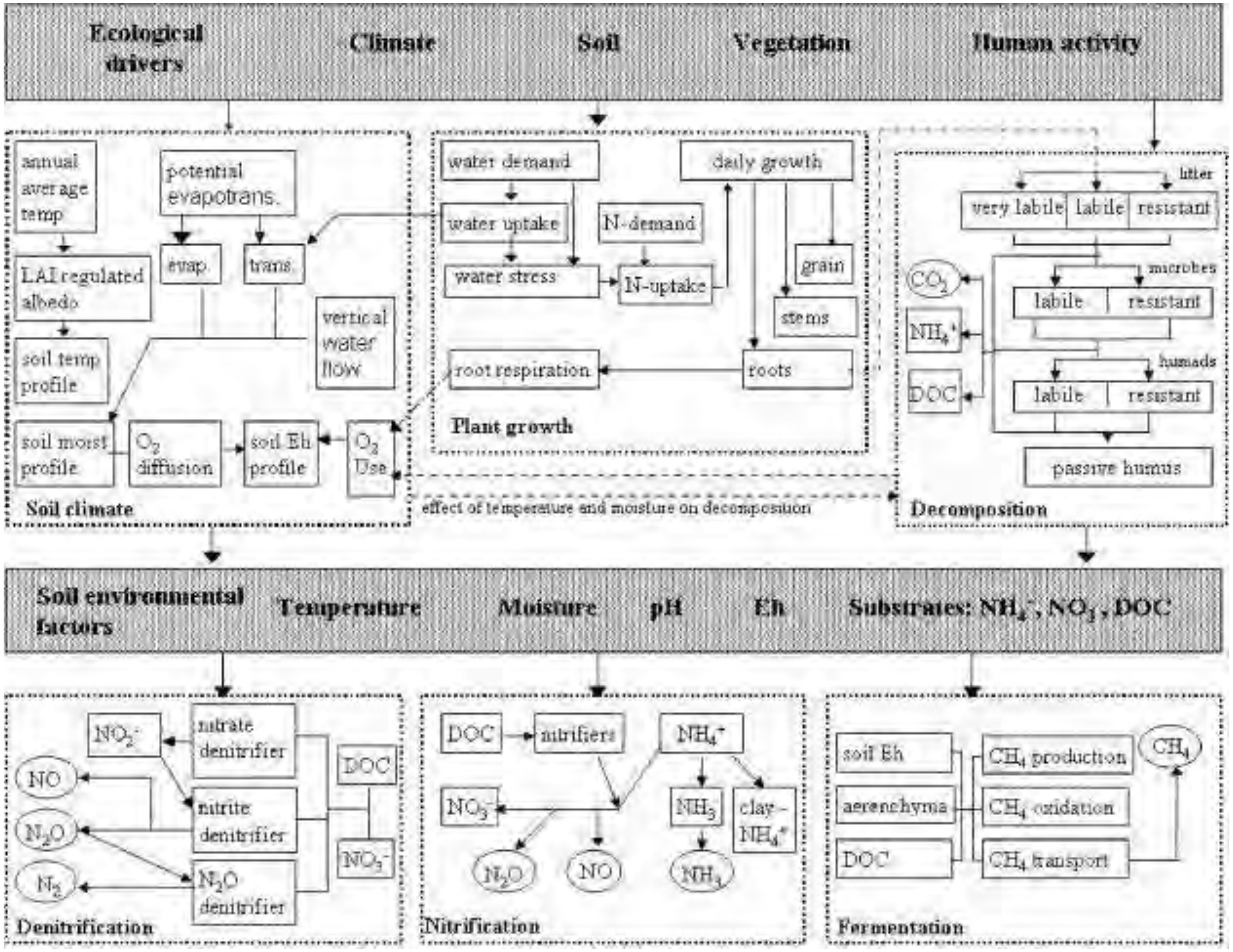


Inputs

- Type of system (grass, crop, savanna, forest)
- Daily precip (cm)
- Daily mean Min/Max temperature (ºC)
- Site latitude and longitude (degrees)
- Fraction sand, silt, and clay of the mineral soil, by layer (0.0-1.0)
- Bulk density of the soil, by layer (g/cm^3)
- Rooting depth/distribution of the vegetation (in cm)
- Annual wet and dry N deposition
- Productivity of vegetation (gC/m^2 per year or growing season)
- C:N ratio of above- and belowground vegetation
- Root to shoot ratio
- Lignin content

DelGrosso et al. 2011

More Complex: DNDC



- •Thermal–hydraulic
- •Aerobic balloon
- •Denitrification
- •Fermentation
- •Soil redox potential
- •Plant growth
- •Land-management

Li et al. (1992, 1994,2000, 2007)

Agriculture, Ecosystems & Environment, Volume 136, Issues 3–4, 2010, 292 - 300

http://dx.doi.org/10.1016/j.agee.2009.06.014

Most Complex: Ecosys

Photosynthesis
- Biochemistry and physics of CO_2 fixation at leaf and canopy levels
- Different soil and management conditions
- Muli-biome (including forests, grasslands and tundra)

Water and Energy Transfer
- Heat flux equation
- Diurnal temperature cycles in soils
- Transport of water through snowpacks, surface covers and soils

Microbial Activity
- Microbial populations in rhizosphere, plant/animal residues, and native organic matter
- Energetics of oxidation-reduction reactions
- Mineralization-immobilization
- Heterotrophic growth/decay
- Autotrophic nitrifier populations
- Microbial links to reduction of O_2, NO_3^-, NO_2^- and N_2O during C oxidation
- Methanotrophic and methanogenic microbial populations
- Coupling microbial activity to exchange/transfer of C, O, N and P in aqueous and gaseous phases

Mass and Energy Exchange
- Eddy correlation and Bowen ratios
- Soil H_2O deficits on plant water status/growth
- Simulation of soil-plant water relations at hourly and seasonal levels

Plant Growth
- Plant activity at organ, population and community levels
- Competition
- Partitioning of C, N and P among different root/shoot organs
- Root length density and N content
- Size, mass and N content of leaves, sheaths, internodes and grains

Solute and Gas Transfer
- convective-dispersive transport
- ion speciation, exchange and transport

Grant and Pattey 2008; grant et al. 2010

How can we tell which processes are necessary?

Compare field measurements with outputs from model of varying complexity

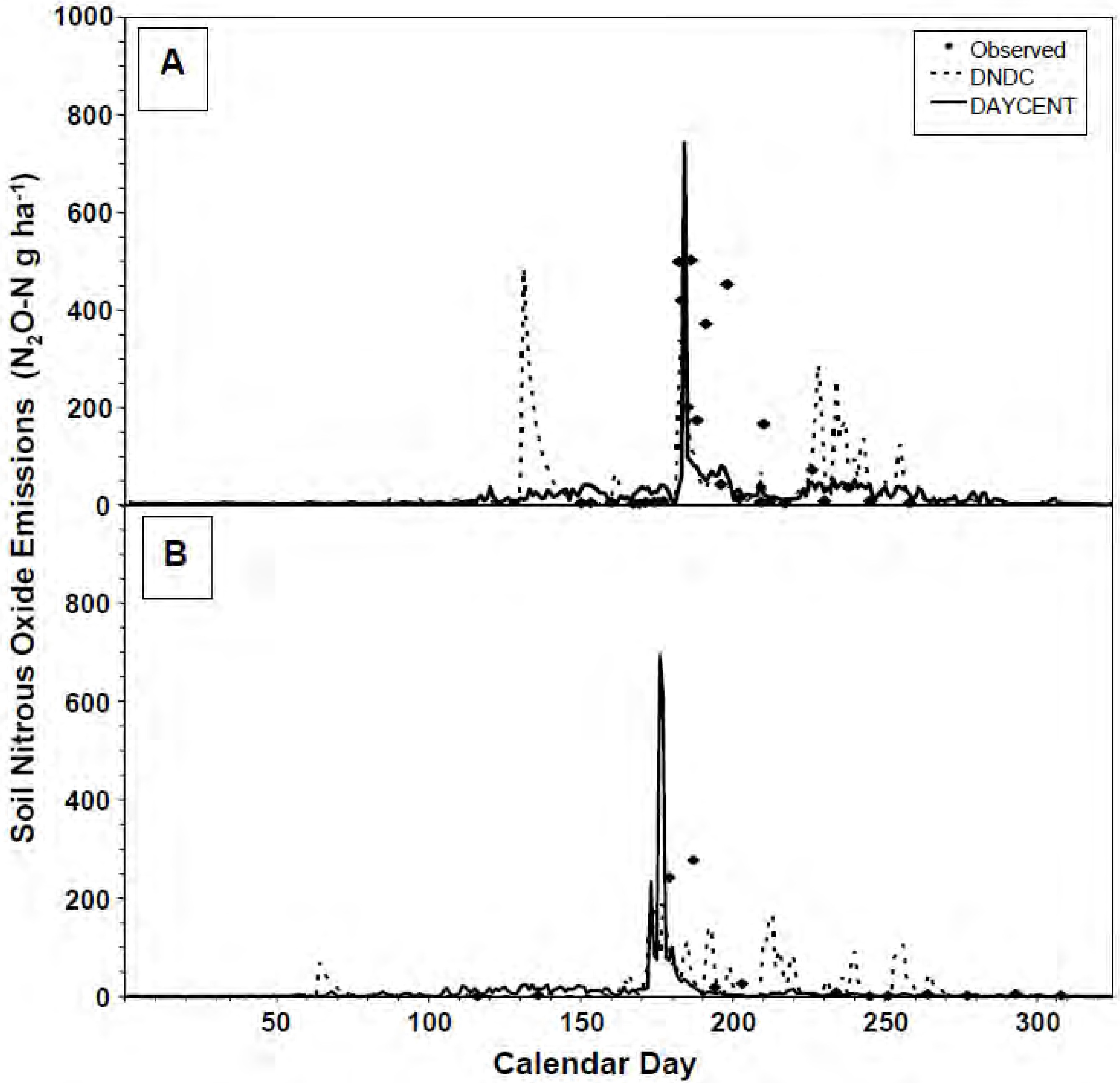
Problems:

few experiments measure with sufficient frequency and duration to fairly compare models

some models (e.g., IPCC Tier 1) only output annual N2O estimates, but without continuous yearlong sampling assumptions must be made

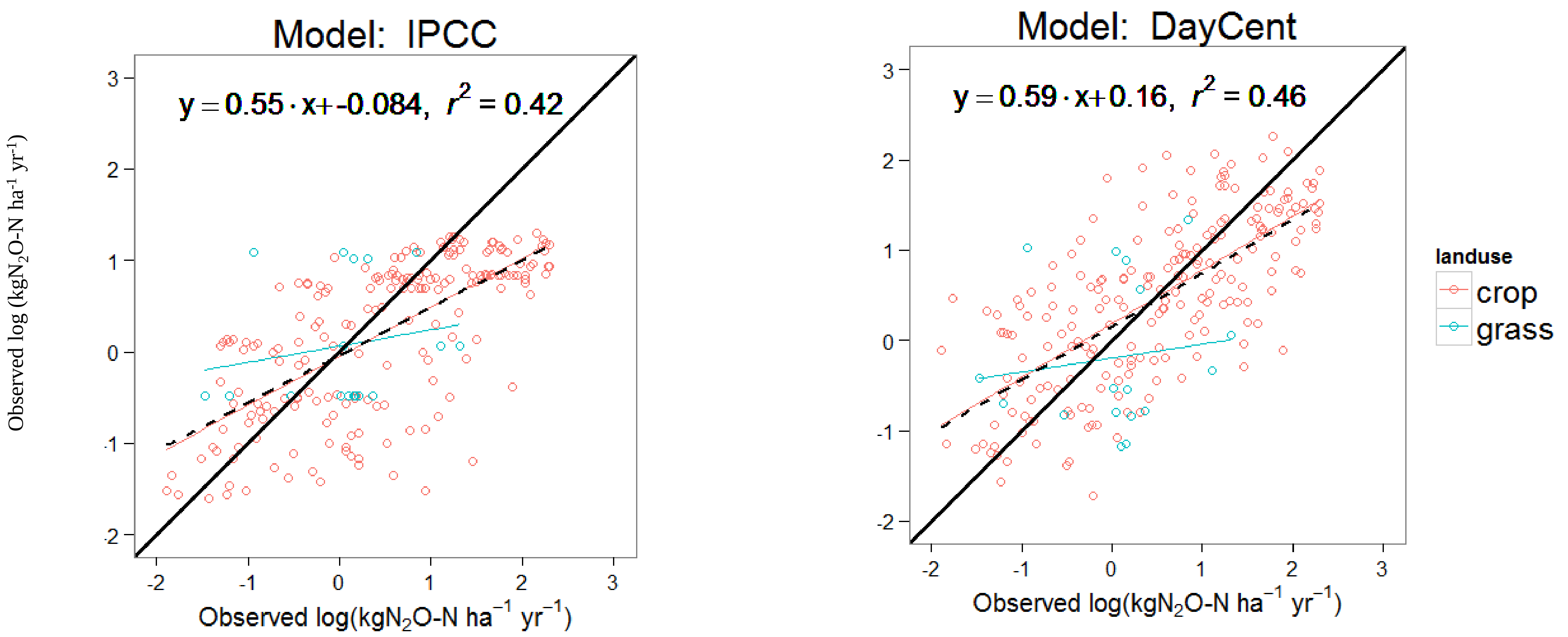
Even if a complex model does not perform better, it does not necessarily follow that processes are not important

Model Comparison for daily N2O eastern Canada: insufficient sampling



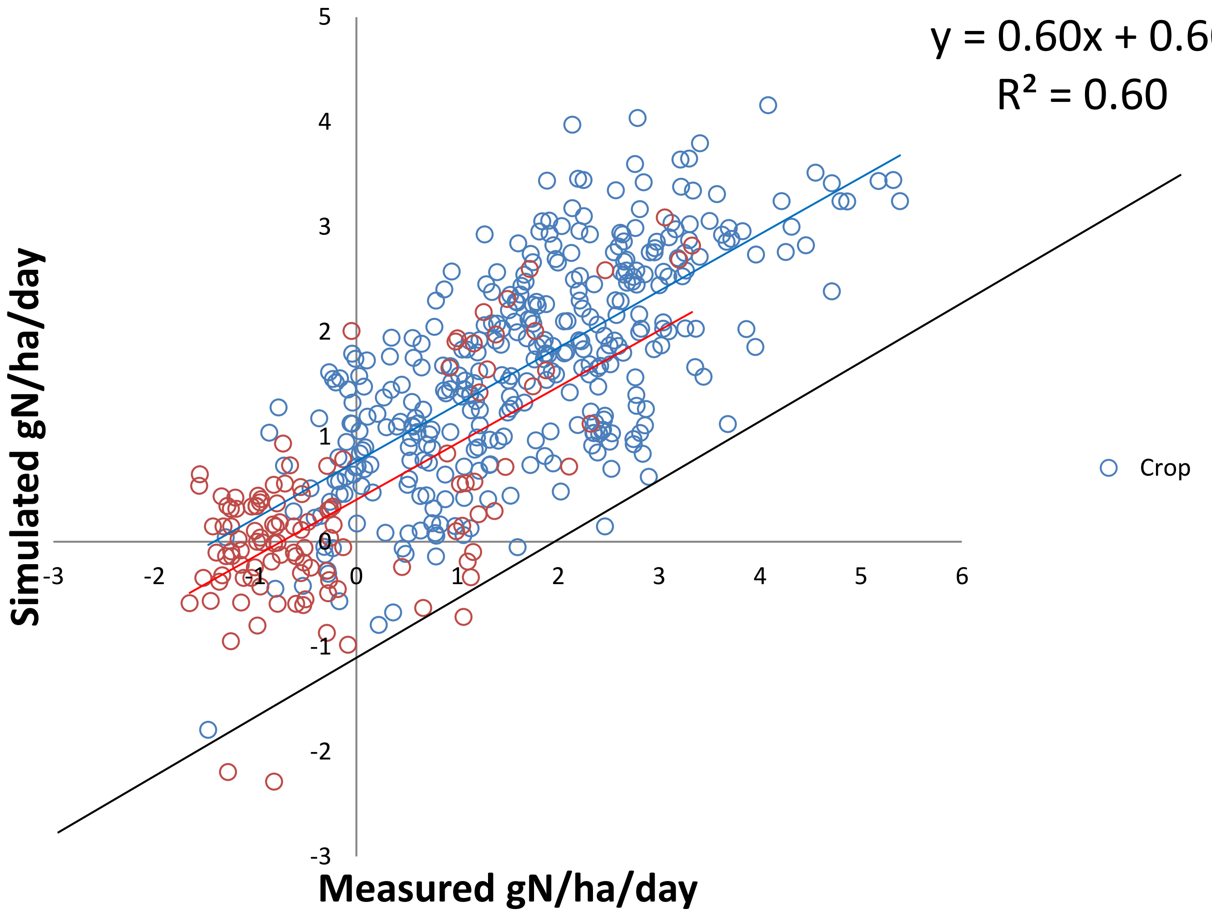
Smith et al. 2008

Model Comparison for annualized N2O from GRACEnet and other sites in US



How reliable are annualized measurements?

Model Comparison for daily N2O from global data set (better fit than annualized data)



Processes are limited by model application

At plot level, inputs are more reliable (e.g., FC and WP can be determined from soil H_2O time series

But at regional or farm level, FC and WP are approximated from soil texture

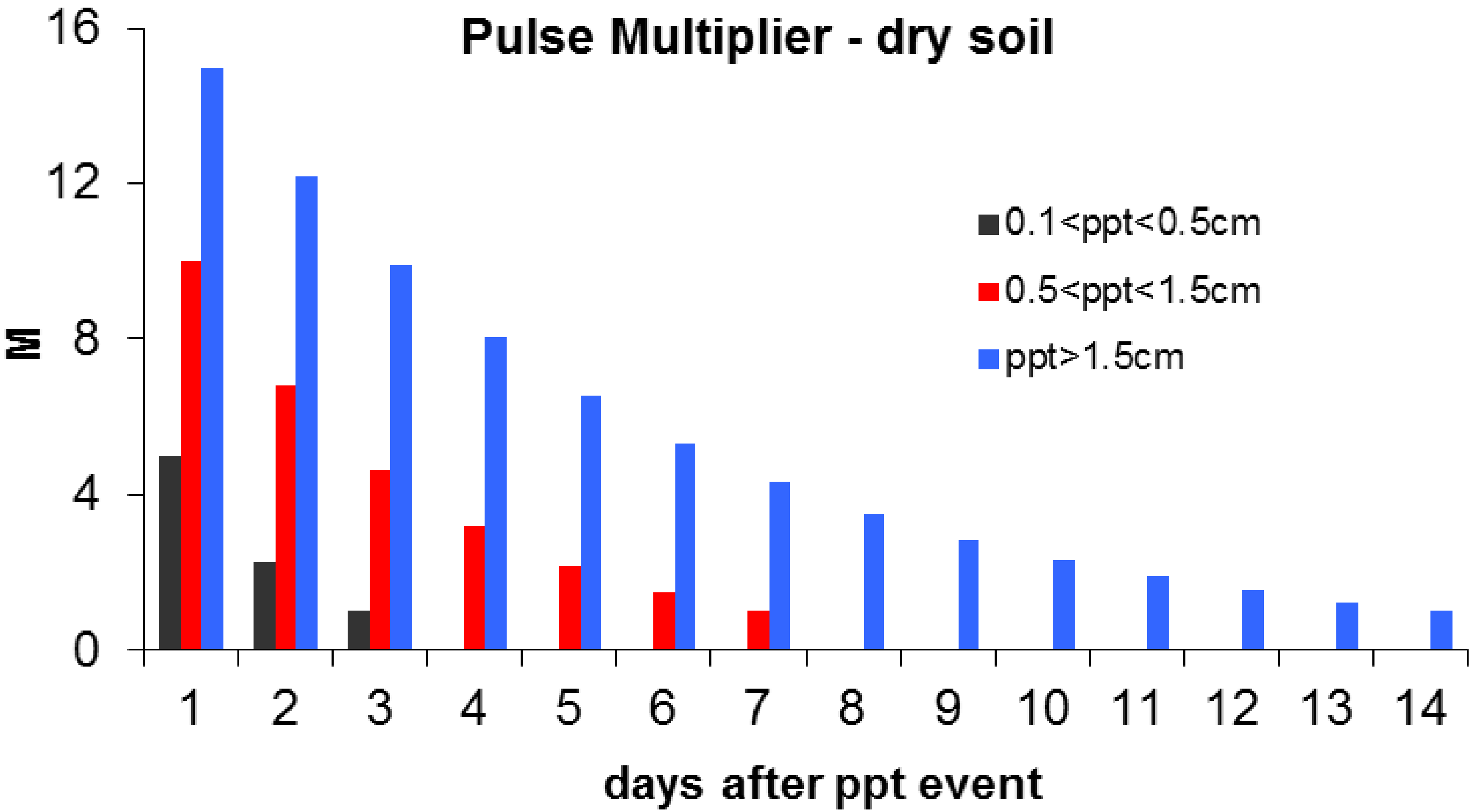
Similar problem for O_2 diffusion, pore size distribution, anaerobic volume, etc.

Implicit vs. Explicit Representation

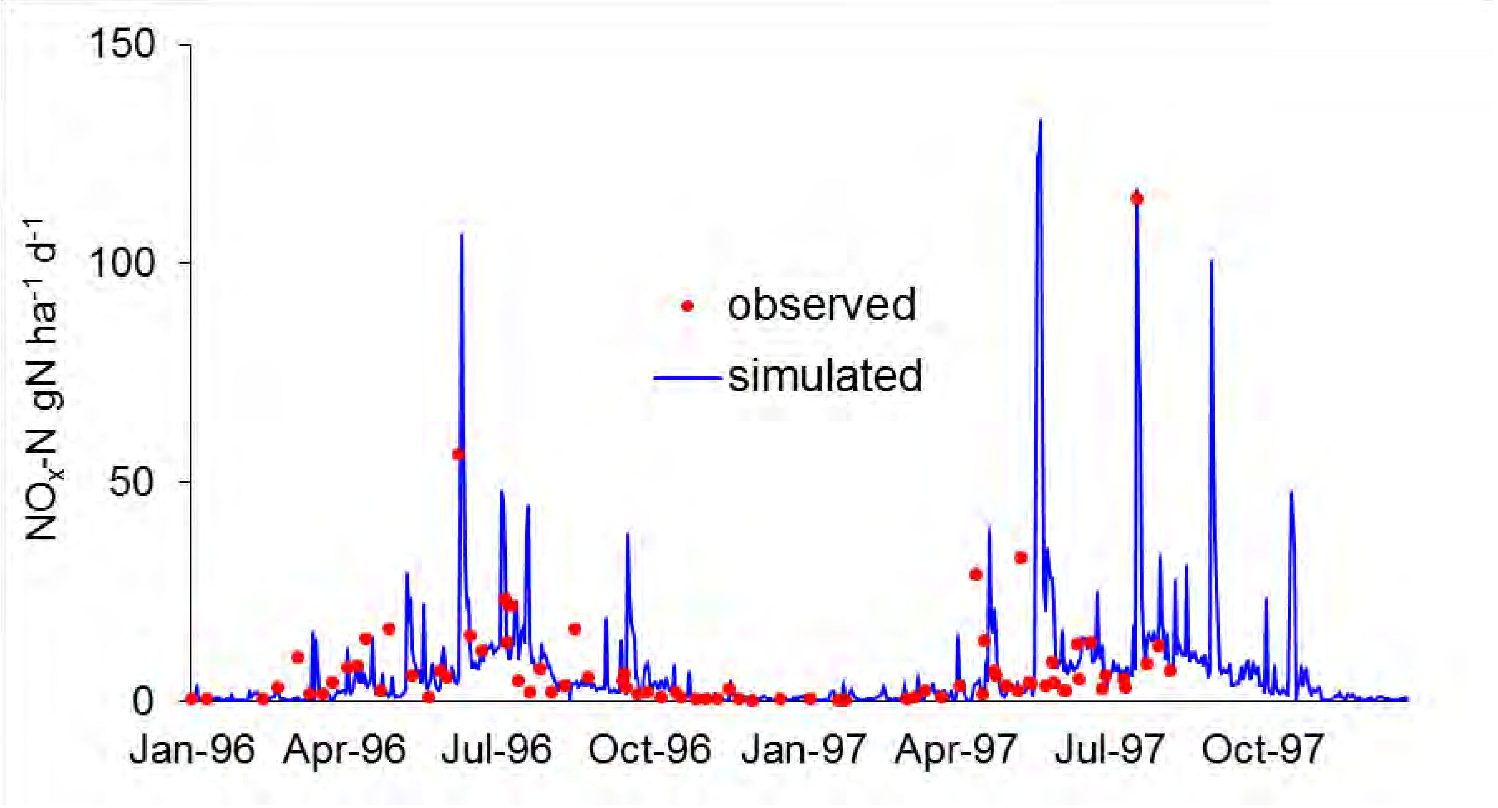
NOx example:

- **Observations show that large NOx pulses occur following wetting of dry soil**
- **Presumably due to accumulation of substrate**
- **Is it necessary to explicitly model substrate accumulation?**

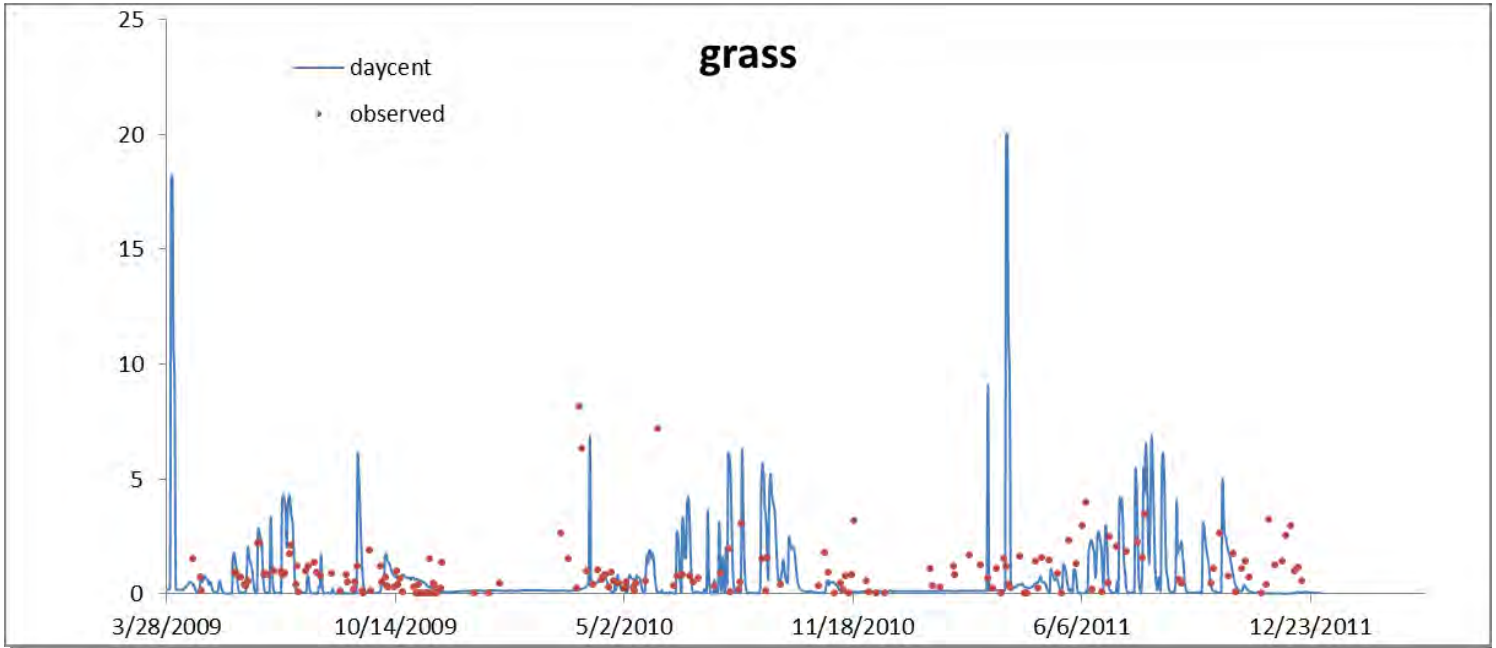
DayCent NOx representation (from Yienger and Levy 1995)

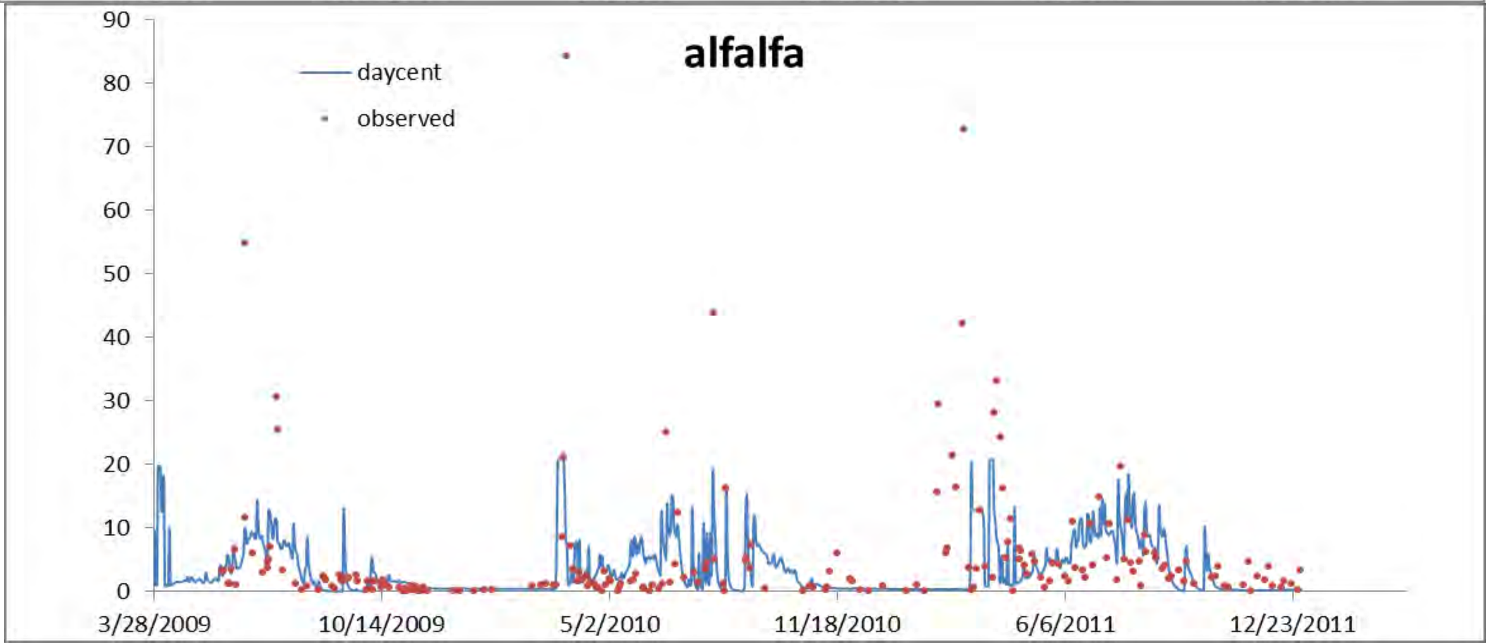


Implicit appears to work in this example for NOx



Example of the type of N2O data we need: Montana rangeland



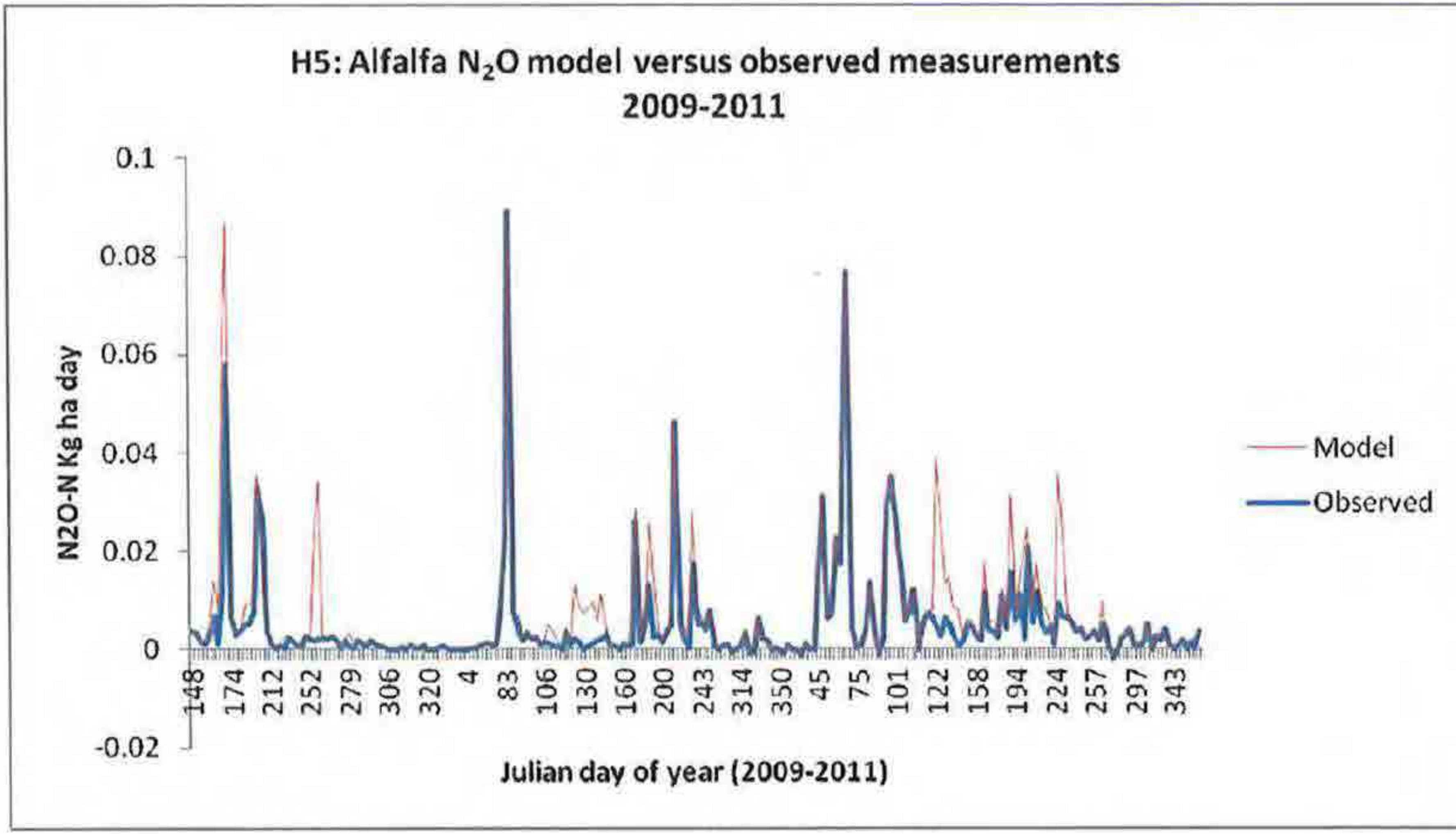


Implicit vs. Explicit Representation

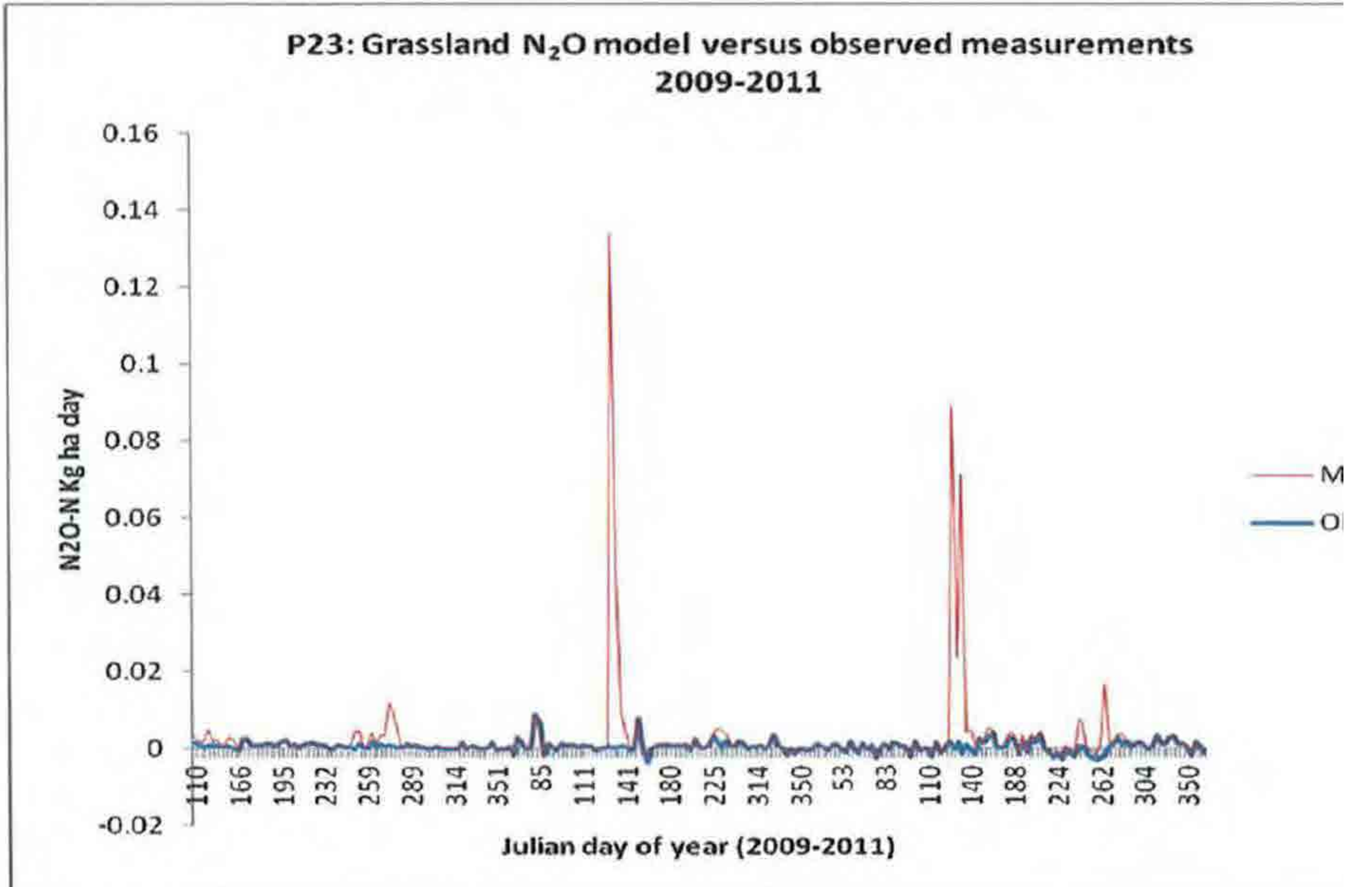
- Gas diffusivity and anaerobic volume
- DayCent uses and index of relative soil gas diffusivity (D) to partition N flows (e.g., as D increases the N2O product ratio for nitrification and N2/N2O decrease)

- DNDC more explicitly models anaerobic soil volume

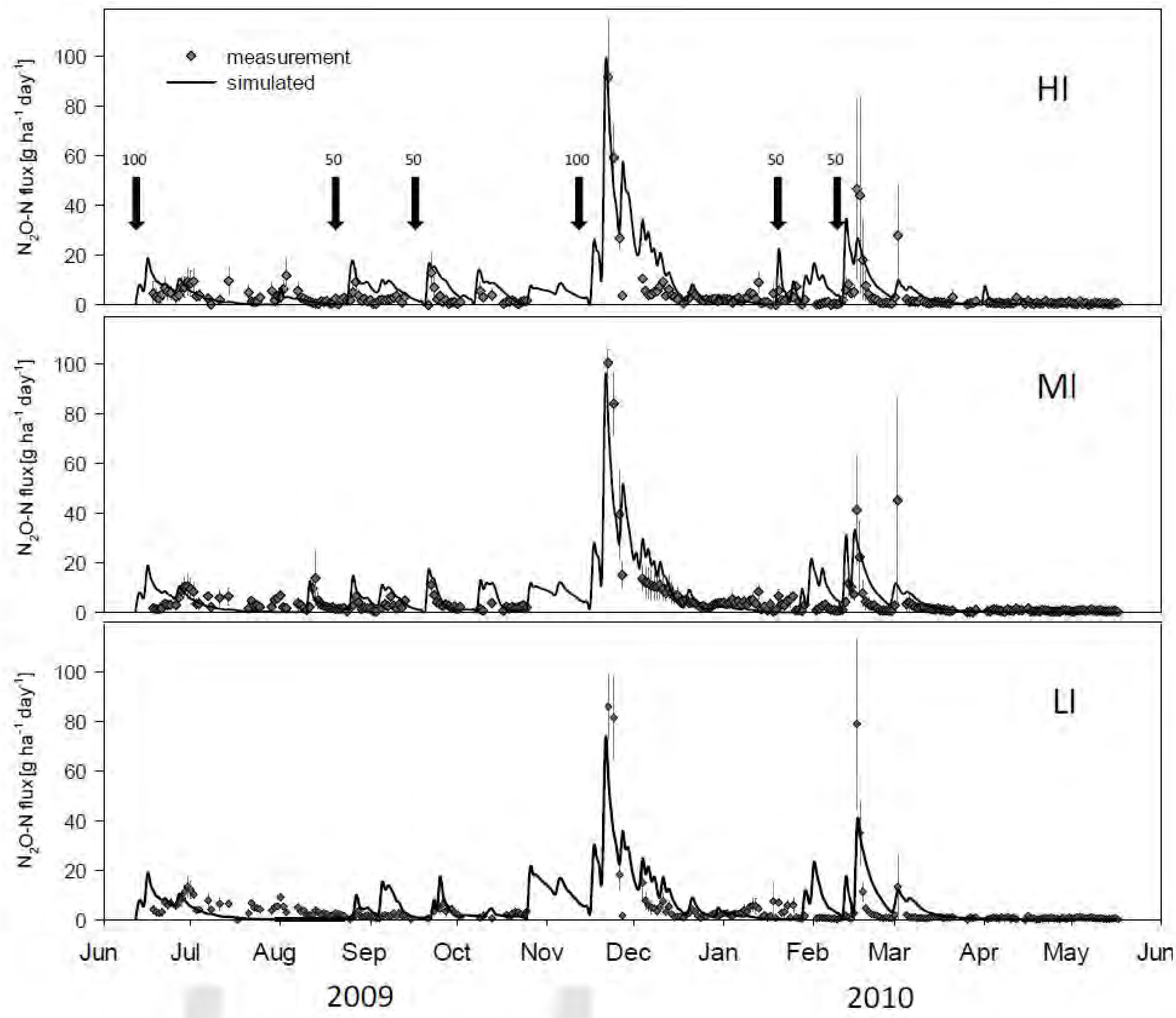
Montana site DNDC



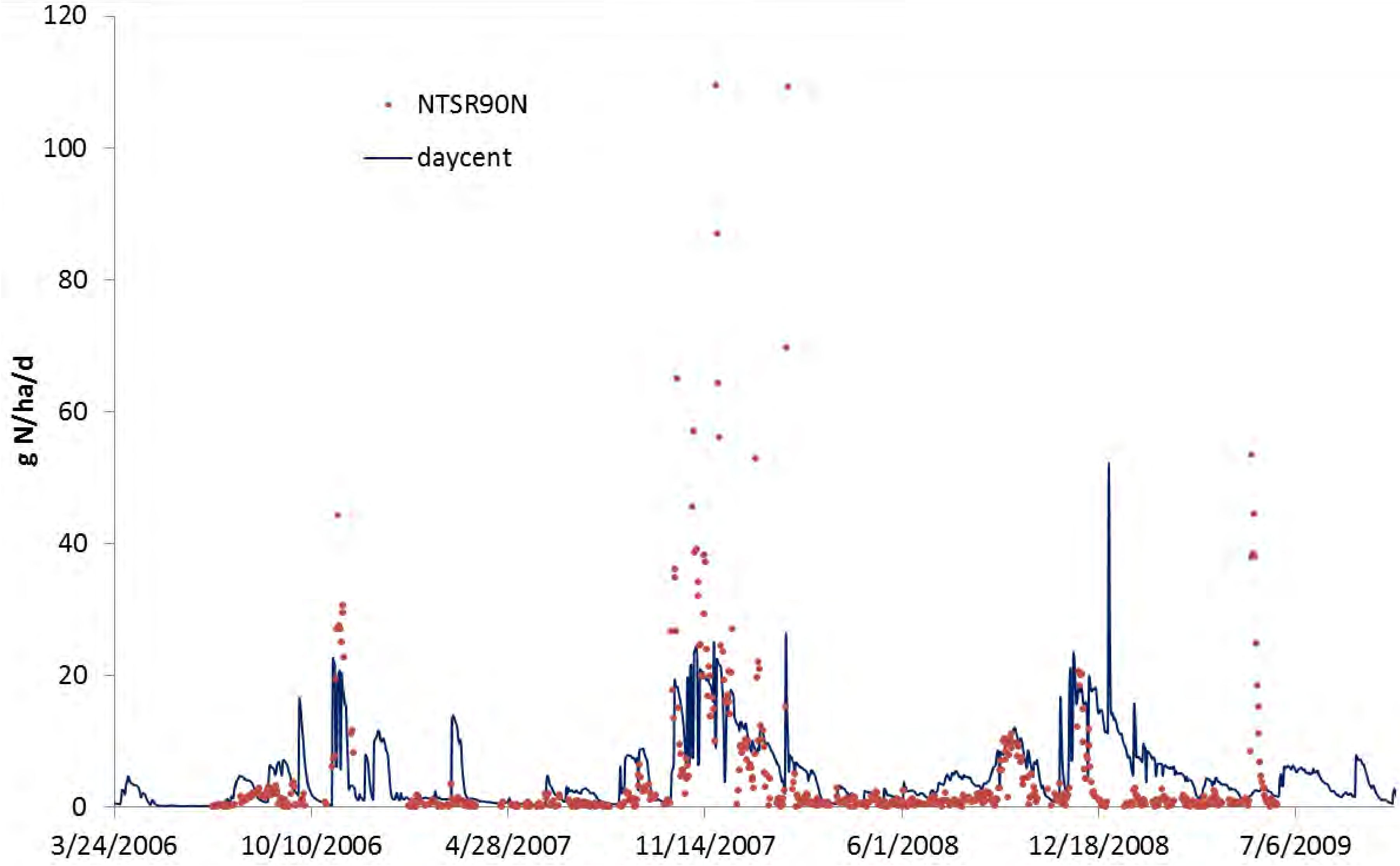
Montana site DNDC



Another Example: Australia Irrigated Wheat/cotton



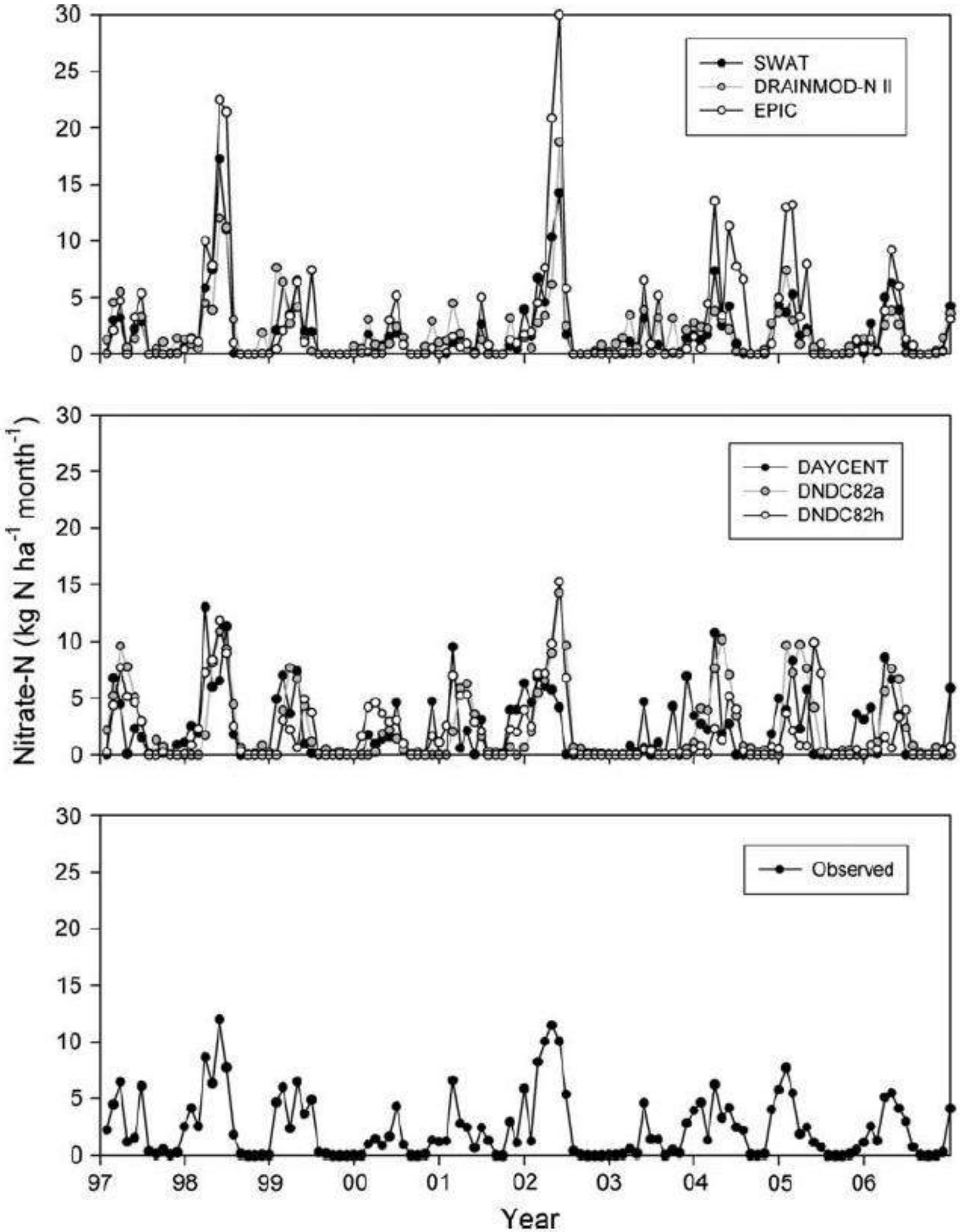
One more Example: Australia Dryland Wheat



What about other N loss vectors?

Example from tile drain water shed in Illinois

Almost all the models did pretty well for NO3 leaching



But for the N loss vectors that were not measured, wide disparity, particularly for N2

Flux	Observed	SWAT	DAYCENT	DRAINMOD-N II	EPIC	DNDC82a	DNDC82h
Corn yield (kg C ha^{-1})	4,230	4,250	4,370	4,510	4,150	3,910	3,710
Soybean yield (kg C ha^{-1})	1,400	1,440	1,500	1,460	1,420	1,400	1,390
Stream flow (cm)	30.2	30.1	30.7	28.2	31.2	30.2	20.3
Nitrate-N (kg N ha^{-1})	28	21	26	22	26	28	26
Fertilization (kg N ha^{-1})	95	95	95	95	95	95	95
N_2 Fixation (kg N ha^{-1})		49	79	96	74	72	78
Grain N harvest (kg N ha^{-1})		138	129	152	134	115	111
Denitrification (kg N ha^{-1})		17	5.6	18	11	3.8	21
N_2O (kg N ha^{-1})			3.0			2.4	8.6
N_2 (kg N ha^{-1})			2.6			1.4	13
Δ soil N storage (kg N ha^{-1})		−22	5.5	−7	−2	19	15
N balance (kg N ha^{-1})[a]		−32	13	−1	−2	20	15

David et al. 2009

Conclusions

Need year round continuous measurements for N_2O

More complete N budget data (N_2O, NO_x, N_2, NO_3 leached)

Flux tower observations

Multi model comparisons at both plot and regional levels

Link biogeochemical with hydrological models?

Conclusion of the workshop

Chair: Philippe Rochette

Co-chairs: Pierre Cellier & Sylvain Pellerin

Experimental databases and model of N_2O emissions by croplands
Do we have what is needed to explore mitigation options?

Concluding remarks

N_2O emissions by agricultural soils

- Complex, not fully elucidated underlying processes
- Very small fluxes, highly variables in space and time
- Numerous shortcomings about measurement techniques
- Remaining knowledge gaps (e.g. N_2O consumption,multiple processes…)
- Progresses are expected from new tools (isotopes, molecular biology,…)
- Better understanding of underlying processes will probably help to improve models so that they better account for the effect of management practices, but it remains debatable

Effect of agricultural practices on N_2O emissions and levers for mitigation

- This question has received attention from agronomists only recently
- The metrics which is used to compare agricultural practices is a key issue (area-scaled N_2O? Yield-scale N_2O?,…)
- Important to have complete N budget data and other GHG. Important to consider (multi)year round measurements
- Some levers for mitigation have been clearly identified (reduce N excess, legumes, cover crops,…).
- Need for synthetic papers, for the most widely studied practices (*e.g.* N fertilisation)
- Some techniques, which may offer levers for mitigation in the mid-term, need further studies (e.g. fertiliser placement, biochars, liming, …)
- The biodegradation of organic products (crop residues, manure) and associated N_2O emissions must be better understood
- The effect of highly disturbing management practices (land use change) or events (freeze-thaw) must be quantified
- We need more studies in dryland contexts
- There is a strong need to design and assess cropping systems with a multicriteria approach (not only GHG but also crop production, reduced use of pesticides,…)

Models

- Models are definitely an appropriate tool
  - to decipher the relative effects of soil properties, climate, agricultural management practices;
  - to interpret and compare data from different experiments;
  - to make prediction
- They don’t work so bad
- Process based model (e.g. DNDC, Daycent, Stics,…) successfully simulate the effect of several key agricultural practices, although not always the accurate temporal dynamic. Clarify how they do the job ?
- We should not fear model failure
- Could we still improve synergy between data collection and modelling efforts in a win-win process
  - For experimentalists: Better interpretation of their results
  - For modellers: Model evaluation in a wider range of contexts
  - But intermediate variables should be measured (e.g. NO_3^-, NO_2^-, WFPS) and how model account for the effect of management practices must be made more transparent
- Models don’t simulate long term, cumulative effects of cropping systems on important variables (pH, soil porosity,…)
- Upscaling at large scale (which is the relevant scale for policy making) is an important objective

What will happen now?

- Workshop 2 will start just after. The key word is model intercomparison.
- Ppt presentation will be available on the GRA website (if authors agree for that)

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