Using Measurements and Models to Investigate Soil C and N Cycling

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Questions Addressed

- Why is this difficult?
- What controls C and N cycling?
- How are soil C and N fluxes quantified?
- How is uncertainty quantified?
- Land use and climate change impacts
- How can we improve?

Why is it difficult?

- Can only measure state variables
- But need to know rates and fluxes
- Ground based measures disturb system
- Top down measures have large footprint
- Models simulate rates and fluxes
- But are far from perfect

Major Processes

- NPP
- Biomass senescence, harvest, predation
- Organic matter decomposition
- Nutrient mineralization (net vs. gross)
- Nitrification/Denitrification

How are flows quantified?

- Concentrate on soil GHG fluxes

Sampling Methods

Bottom Up

•Appropriate for plot level
•But requires disturbance of vegetation/soil
•Snapshot of emissions in small slices of time/space

Tower Top Down

•Cannot distinguish emissions from plots receiving different treatments
•Impacted by wind velocity
•Appropriate for field scale
•Almost continuous sampling through time

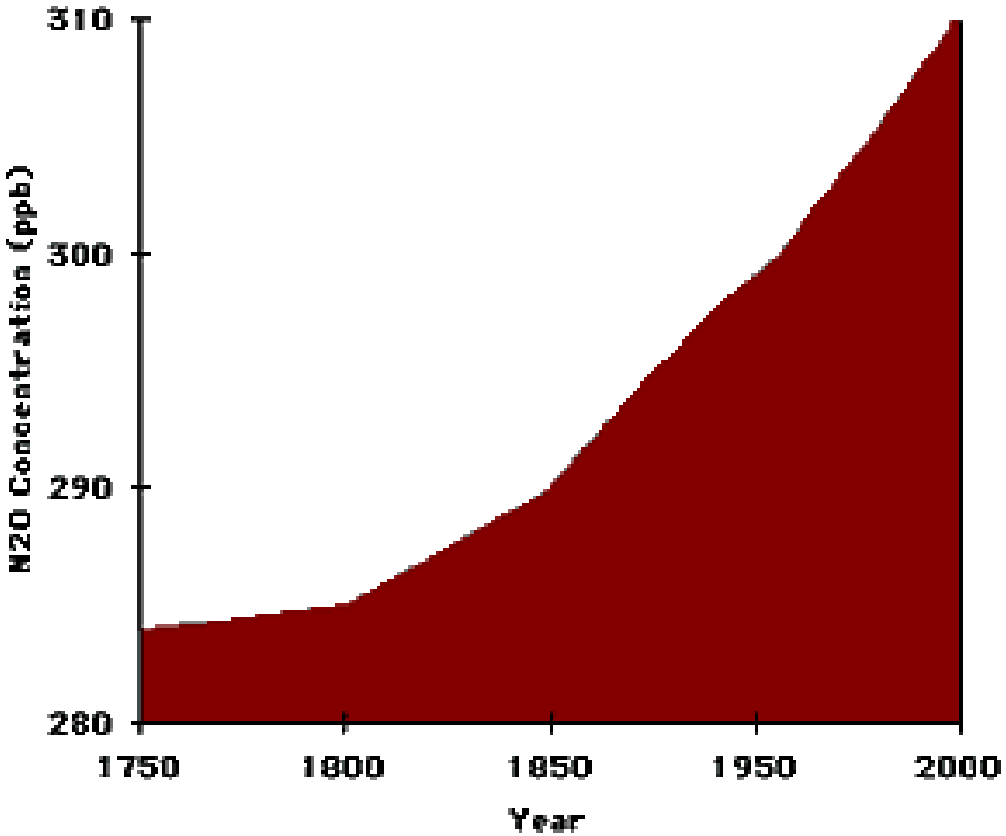
Sampling Methods

Aircraft Top Down

- Large foot print (> 10 km2)
- Brief periods of time sampled
- Expensive

Global Top Down

source – sink = • atmos



- atmospheric concentration is well quantified
- Well established chemistry
- Cannot distinguish sources

Modeling Methods

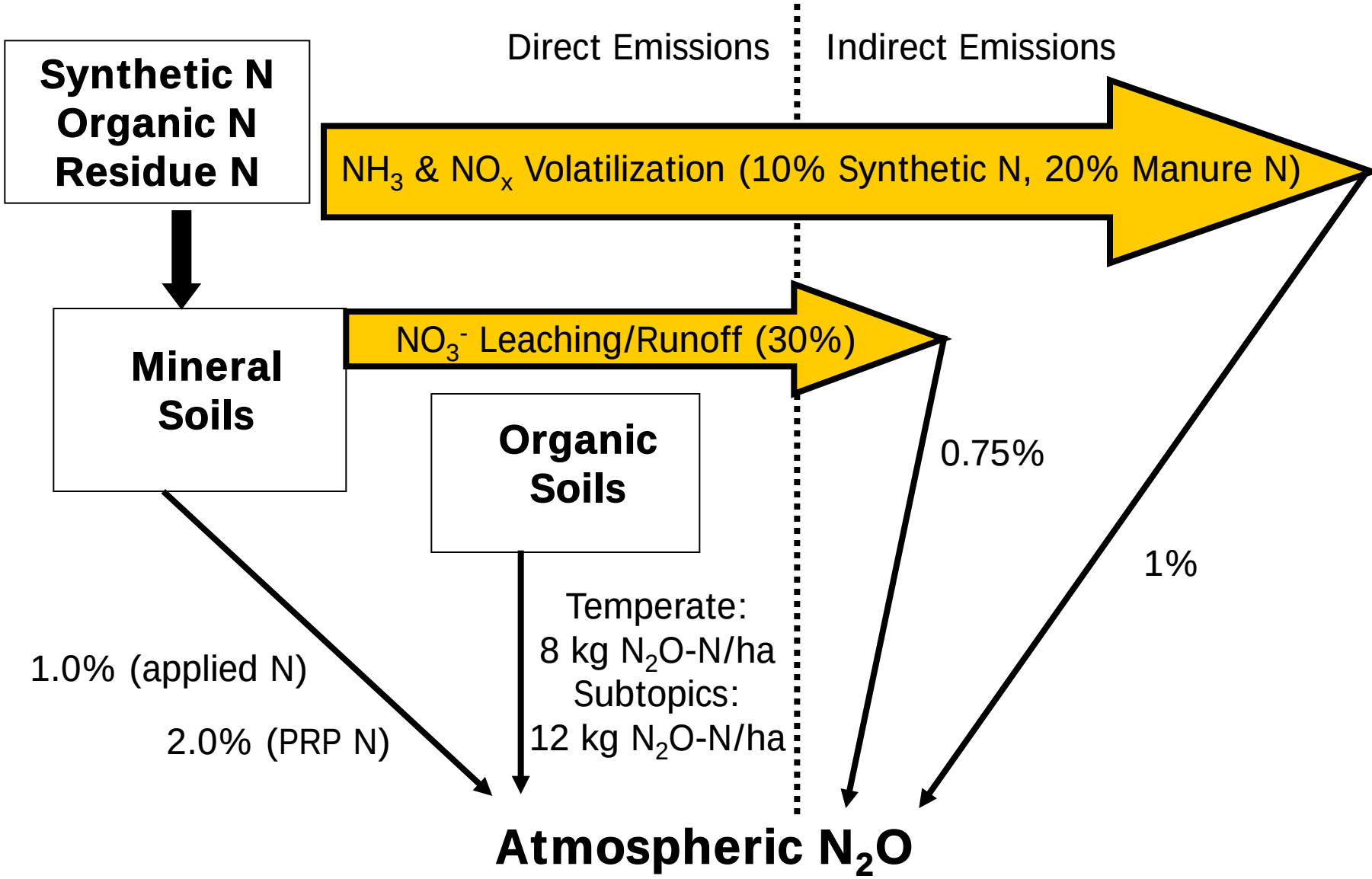
Empirical:

- Simple regression eqns.
- Easy computations
- High transparency
- e.g. default IPCC emission factors

Process Based:

- Simulate mechanisms
- Complex algorithms
- Low transparency
- e.g. DAYCENT, DNDC

IPCC METHODOLOGY FOR N_2O



DAYCENT Ecosystem Model

History:

- CENTURY was developed in the 1970's to simulate changes in SOM, NPP, etc. in response to changes in land management, climate etc.
- DAYCENT is the daily time step version of CENTURY
- arose from the need to simulate trace gas (N_2O, NOx, CH_4) fluxes

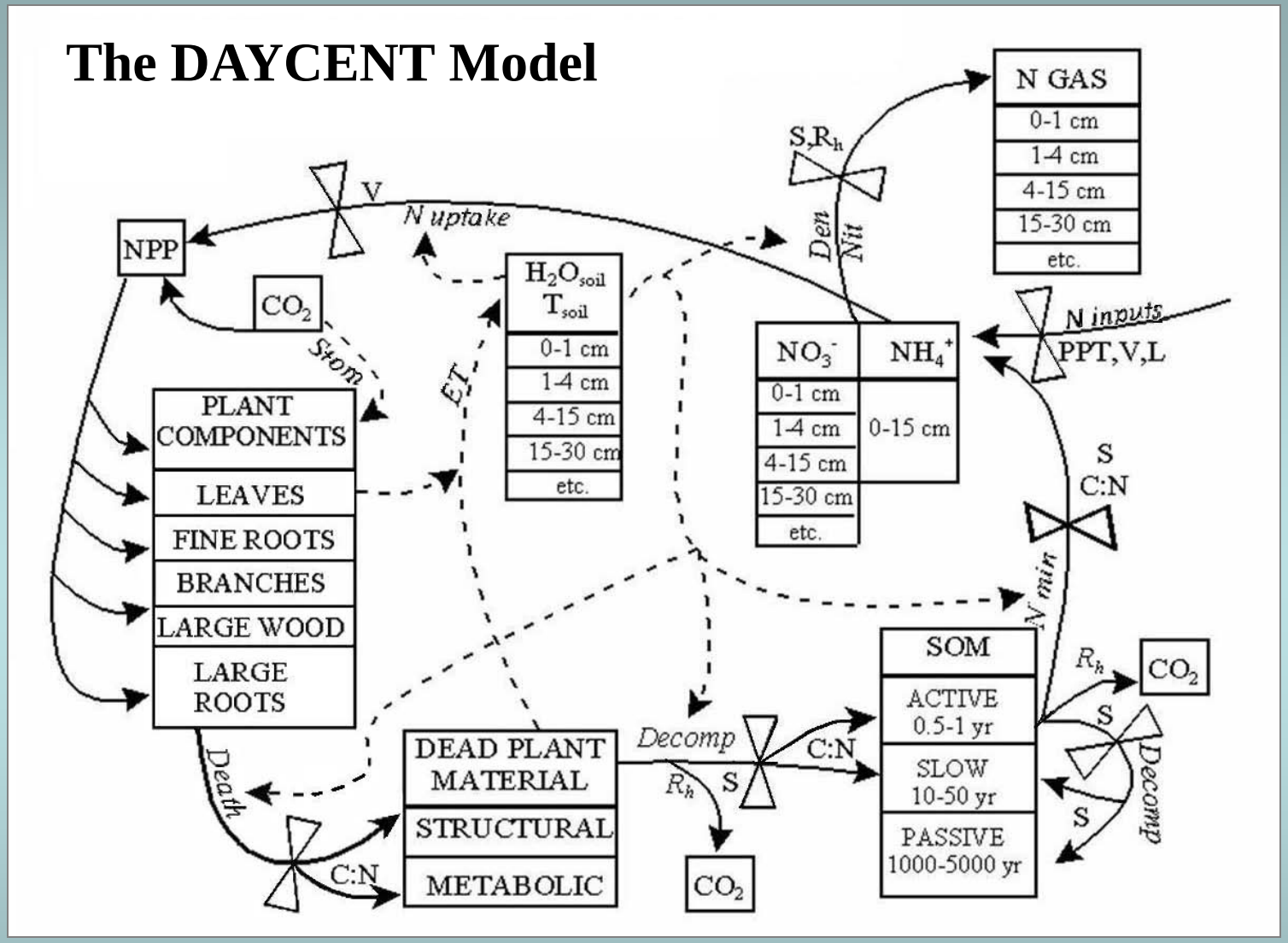
Key Features:

- Intermediate complexity
- Easy to acquire inputs
- Ability to simulate disturbance/mgmt events

Some limitations:

- Non-spatial
- NH_4 considered immobile
- Microbial diversity is discounted

The DAYCENT Model



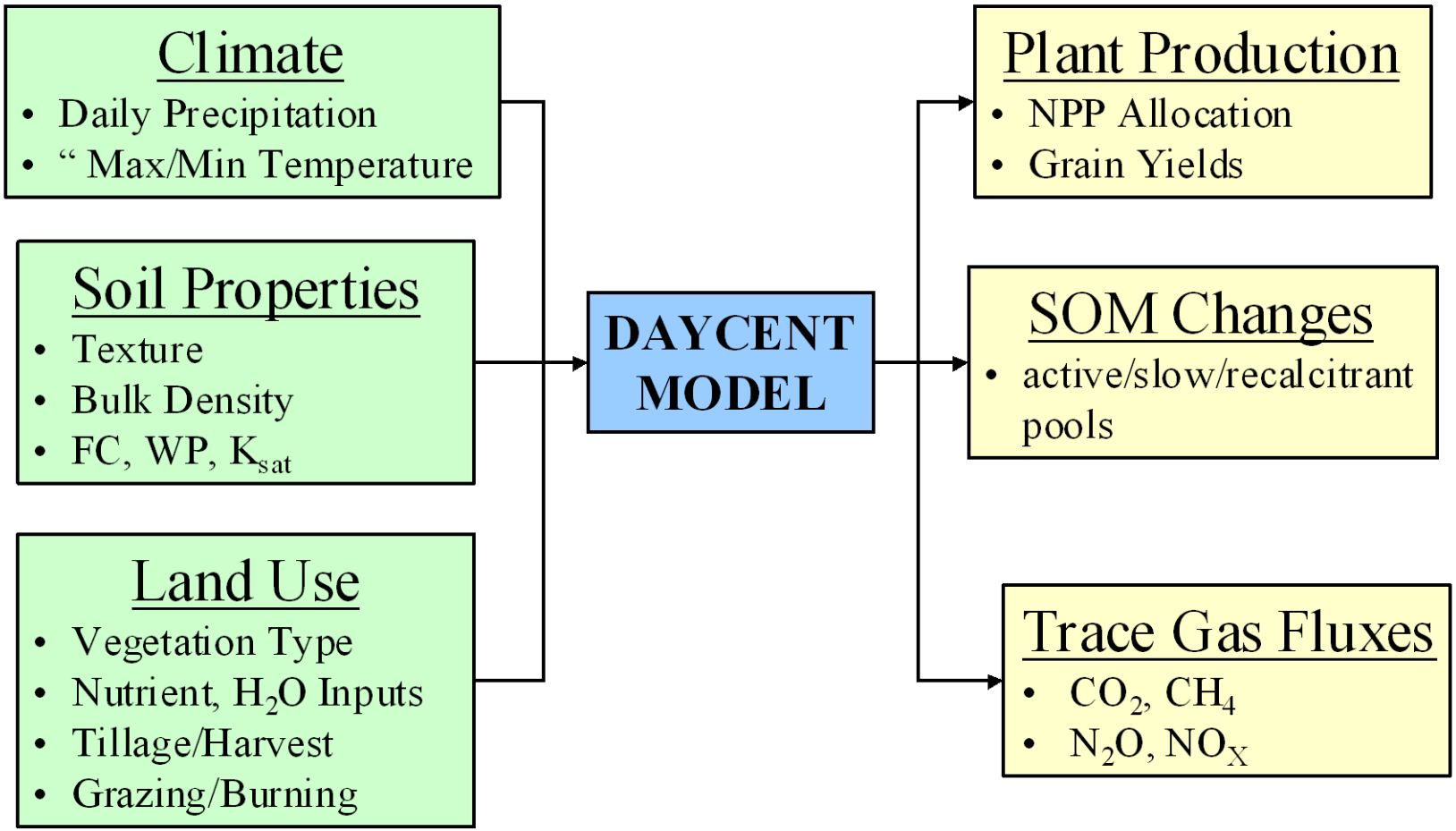
→ = C, N flows
- - → = Feedbacks, information flow
⋈ = Control on process
H_2O_{soil} = Soil water content
T_{soil} = Soil temperature
S = Soil texture

C:N = Carbon:Nitrogen ratio of material
V = Vegetation type
SOM = Soil Organic Matter
L = Land use
R_h = Heterotrophic respiration

N GAS = N_2O, NO_X, N_2
Processes designated by *italics*
Stom = Stomatal conductance
Death = Plant component death
Decomp = Decomposition
N inputs = N Fixation, N deposition, N fertilization

Nit = Nitrification
Den = Denitrification
N min = N mineralization
ET = Evapotranspiration

DAYCENT: Primary Inputs/Outputs



Measurements vs. models

Measurements:

- Truth
- Space/time resolution issues
- State variables used to infer fluxes
- Disturbance can be a problem

Models:

- Complete coverage
- Simplification of reality

Uncertainty

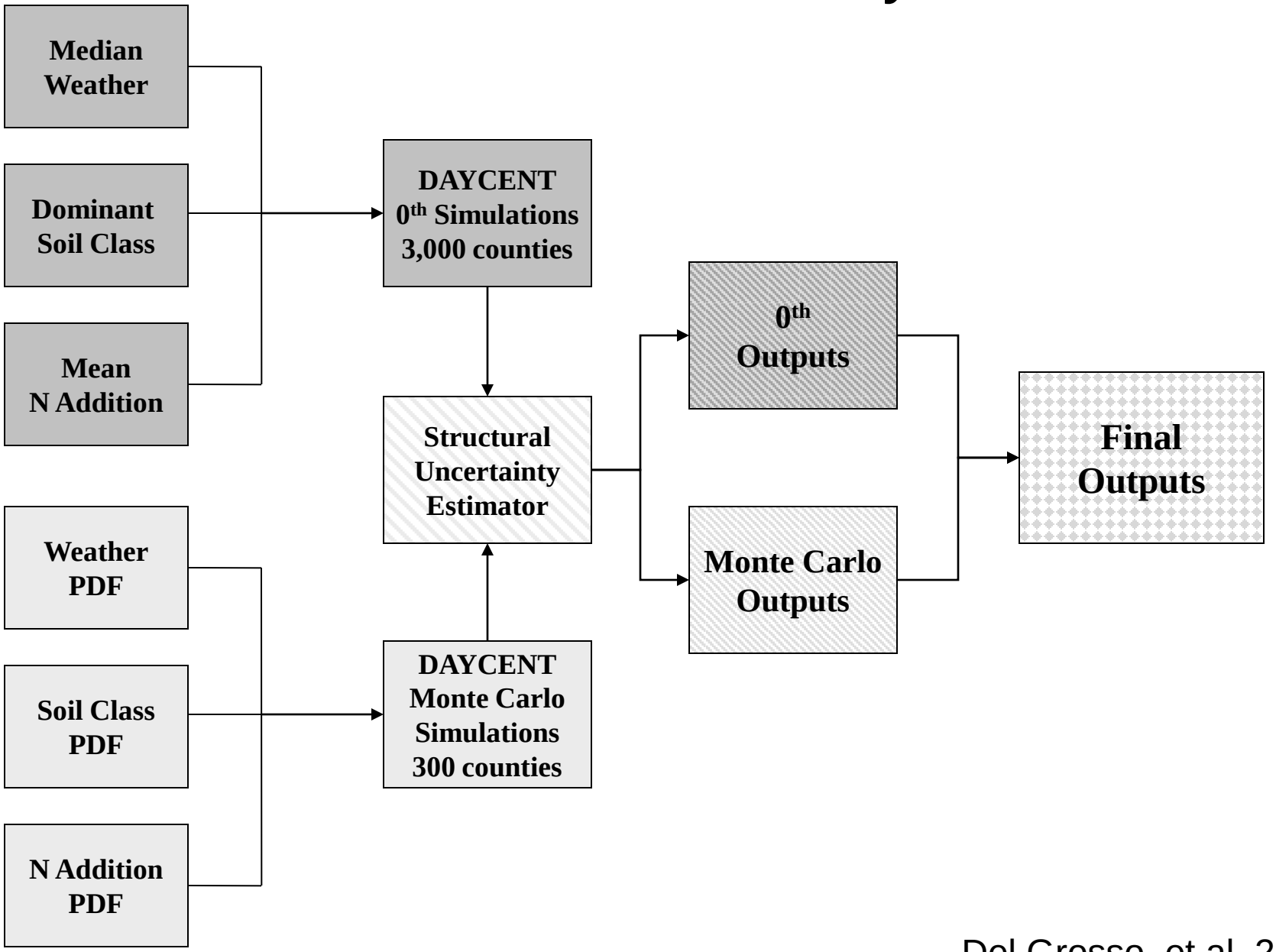
Measurements:

- P-values
- Sampling intensity
- ANOVA

Models:

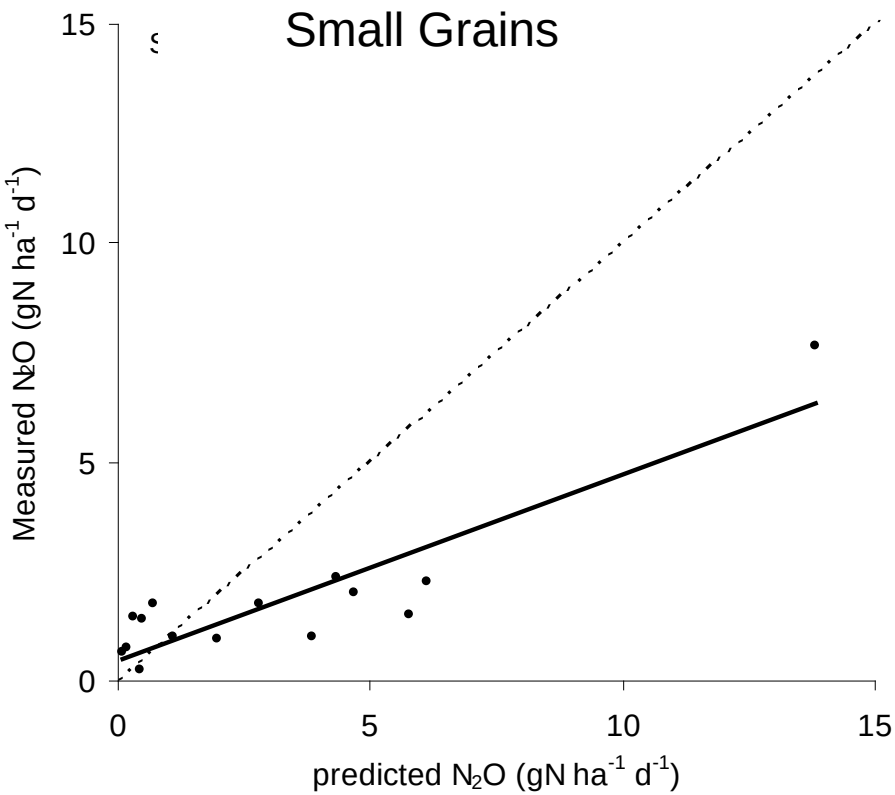
- Monte Carlo approach
- Model input and model structure uncertainty

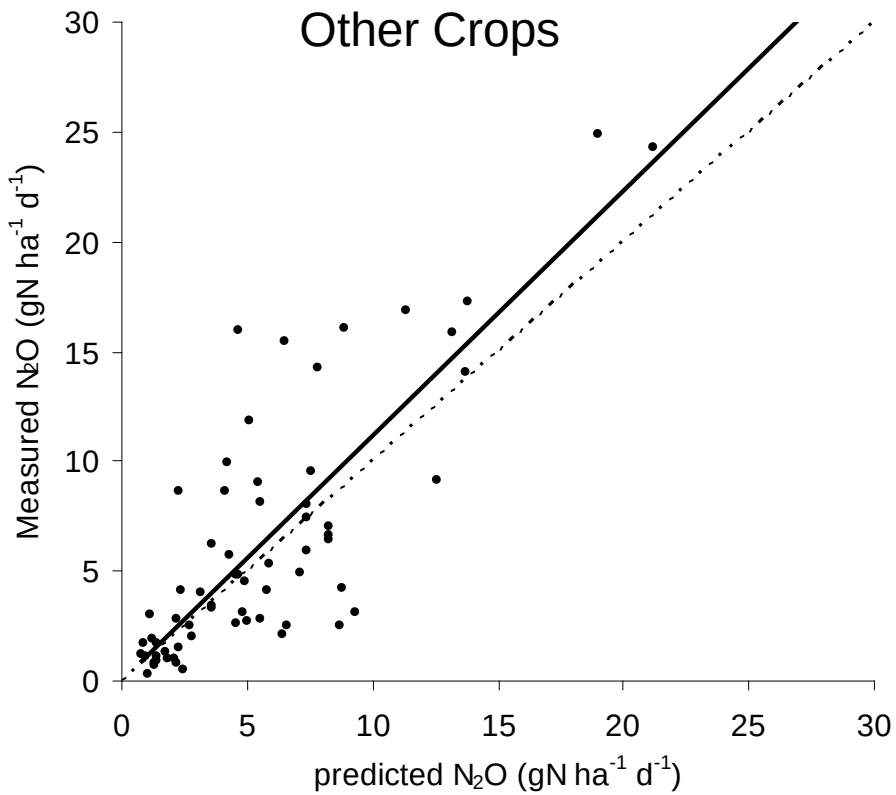
Overall Uncertainty



Del Grosso et al. 2010

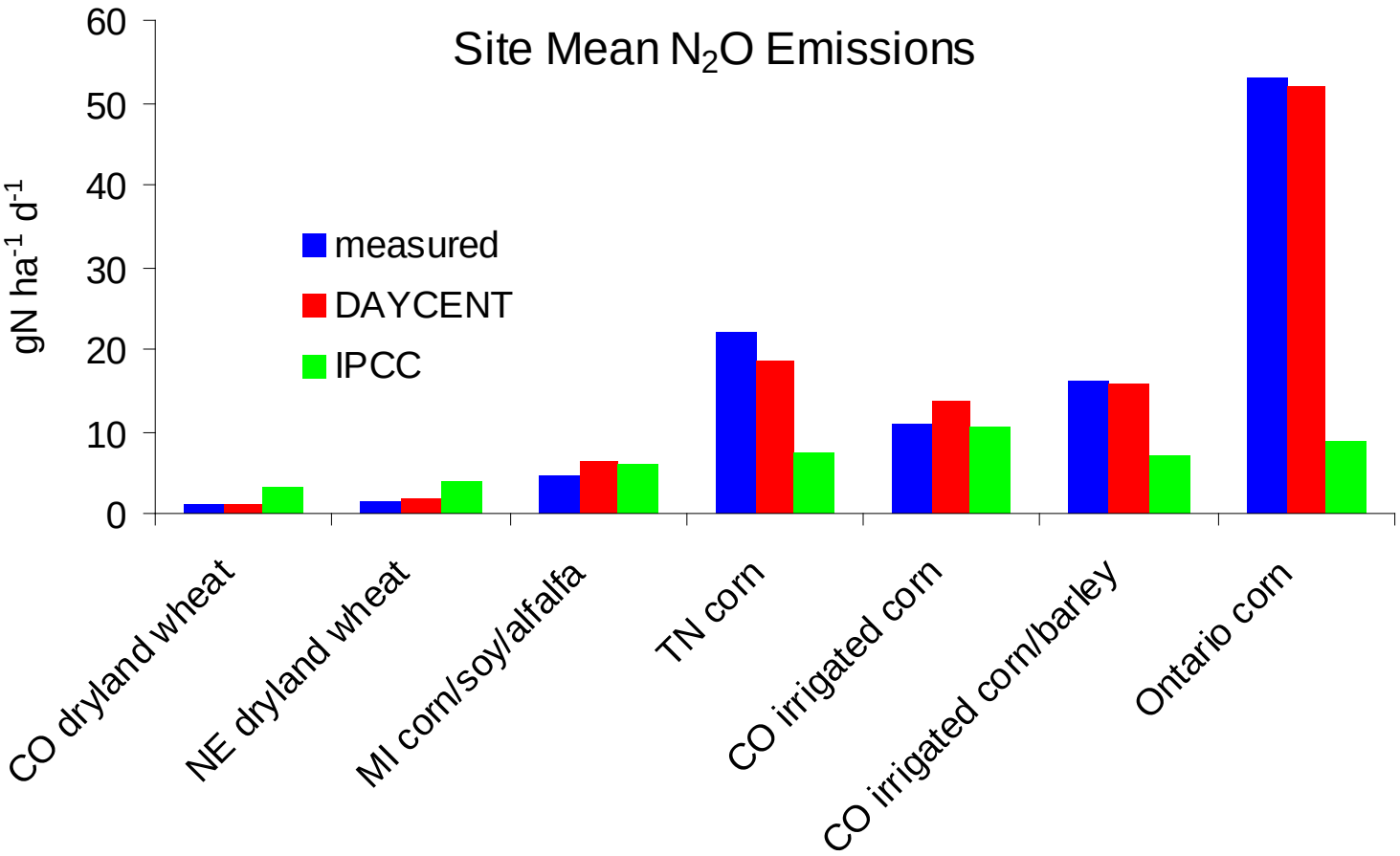
Model Structural Uncertainty



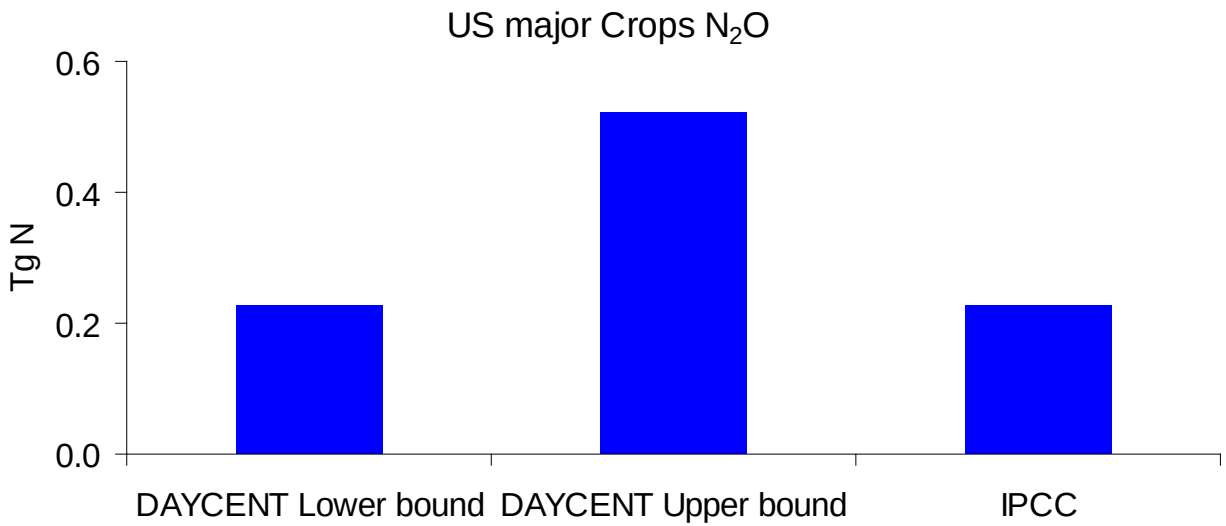


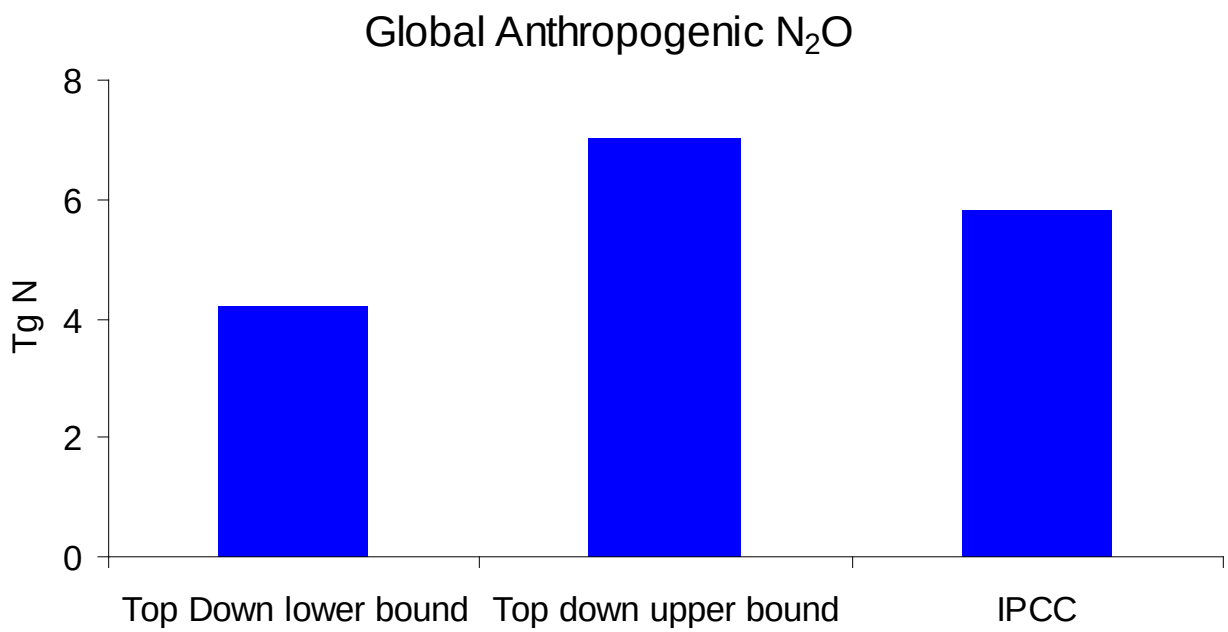
Del Grosso et al. 2010

At plot level, process based models usually perform better than simple models

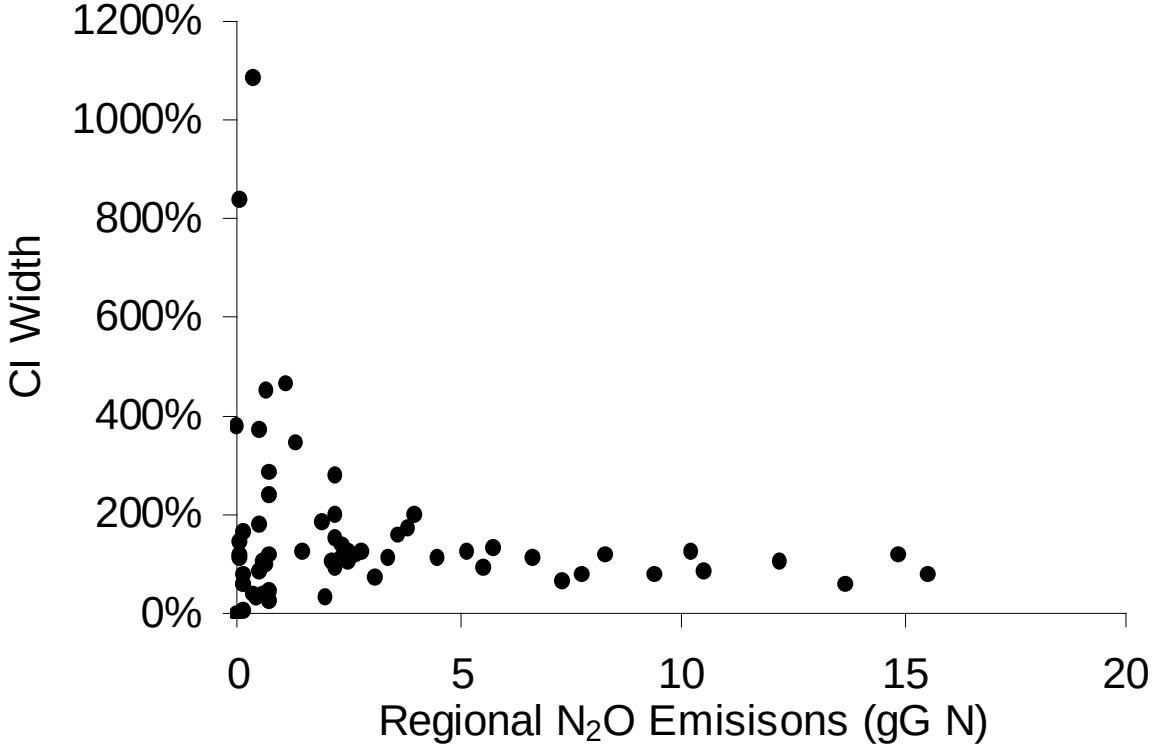


As scale increases, simple models become more reliable





as scale decreases, CIs get wider



Most of this uncertainty is due to model structure

Del Grosso et al. in press

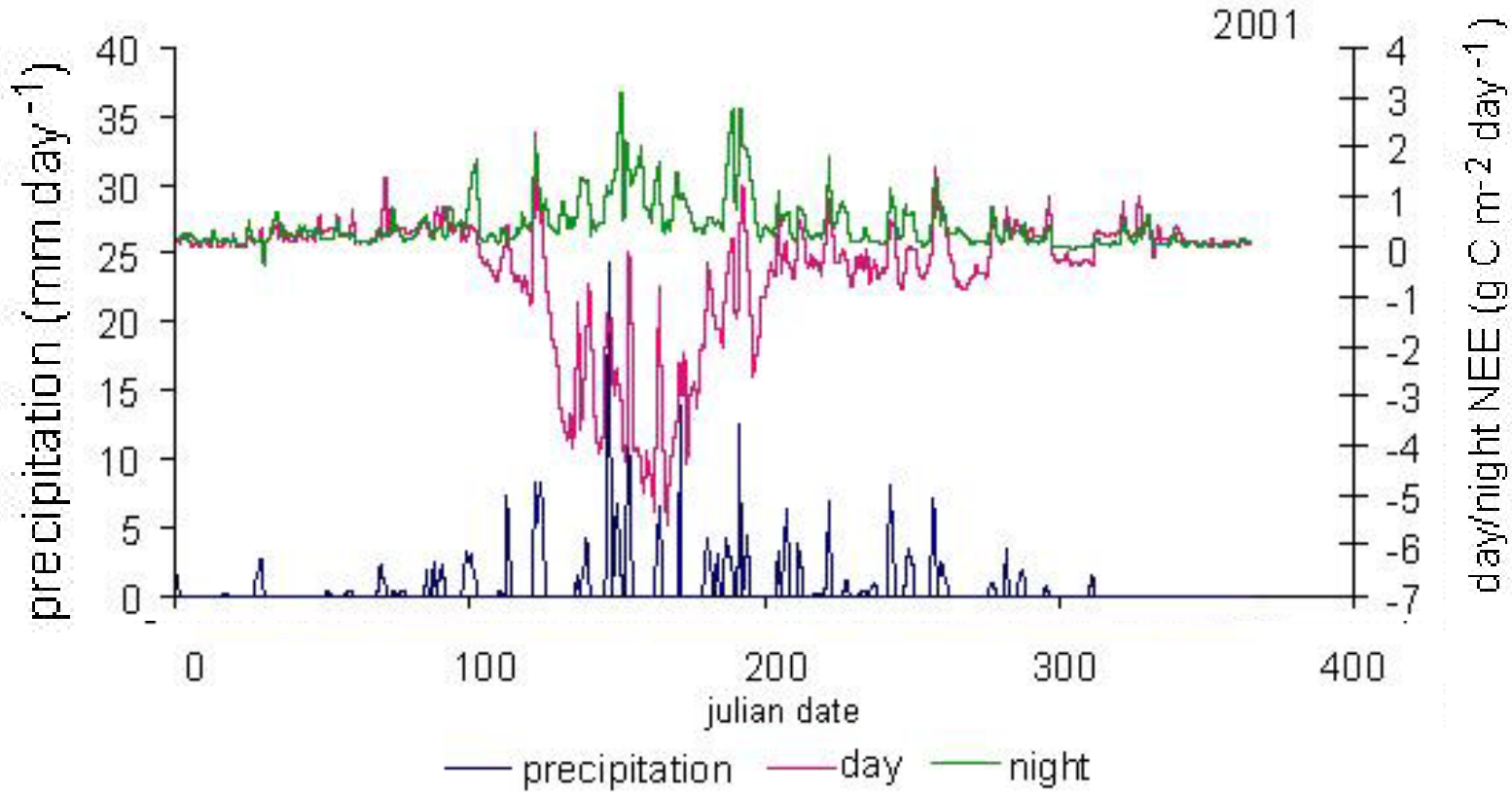
Land Use and Climate Change Impacts?

Convert corn ethanol to switch grass – Soil GHG (N2O + • Soil C)

unfertilized

fertilized

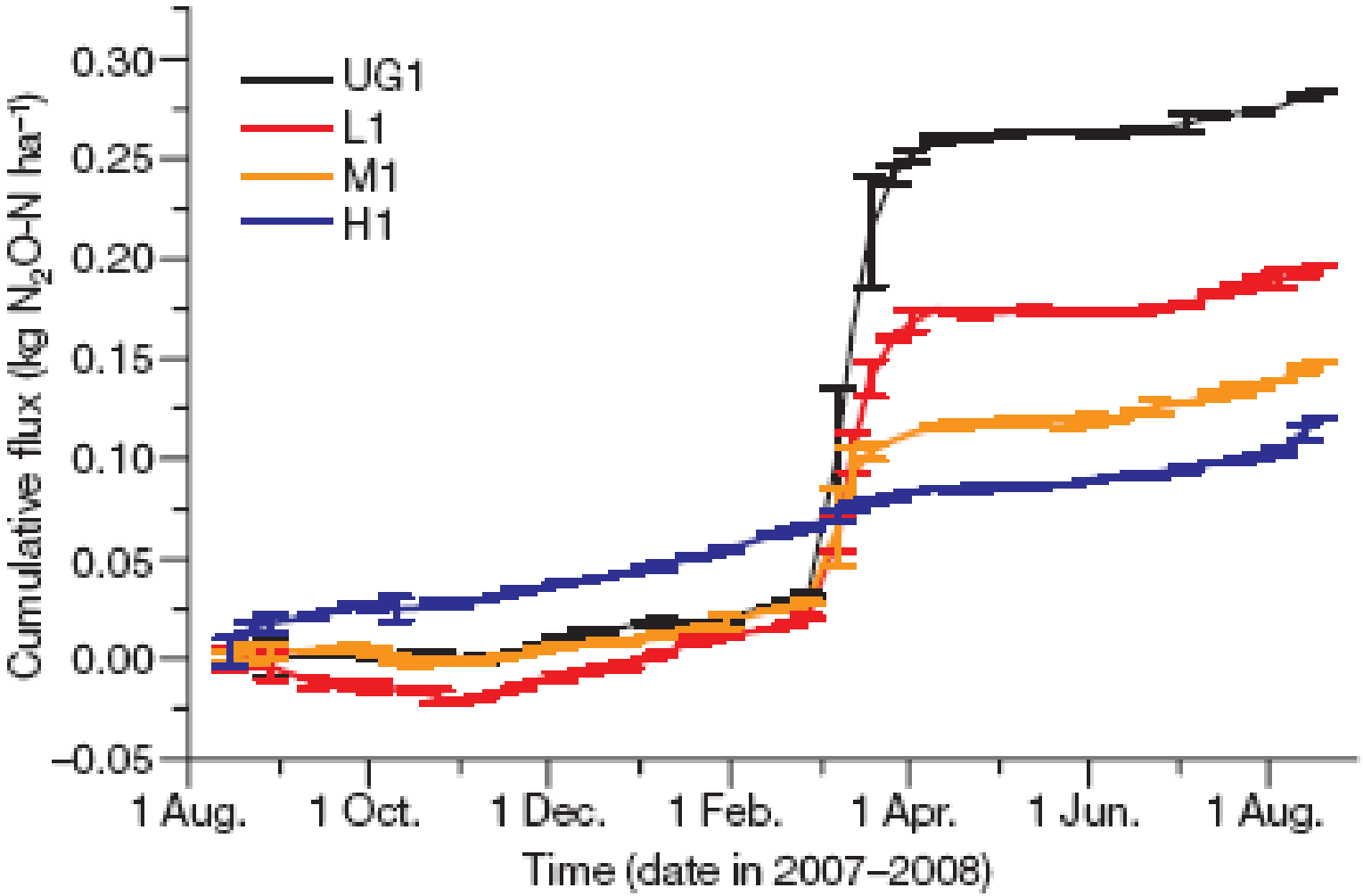
Bowen Ratio Tower Net Ecosystem Exchange Short Grass Steppe



How can we improve?

- Hot Spots and hot Moments
- Compare Different Methods
- Better resolved and more complete model input and testing data are needed

Majority of annual emissions can occur in 1 month



Wolf, *et al. Nature* 464, 881–884 (2010)

Model results diverge for vectors that are not often measured

Embarras River Watershed , Illinois

Flux	Observed	SWAT	DAYCENT	DRAINMOD -N II	EPIC	DNDC82a	DNDC82h
Corn yield (kg C ha^{-1})	4230	4250	4370	4510	4150	3910	3710
Soybean yield (kg C ha^{-1})	1400	1440	1500	1460	1420	1400	1390
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
• soil N storage (kg N ha^{-1})		-22	5.5	-7	-2	19	15
N balance (kg N ha^{-1})*		-32	13	-1	-2	20	15

A National Soil Inventory Network

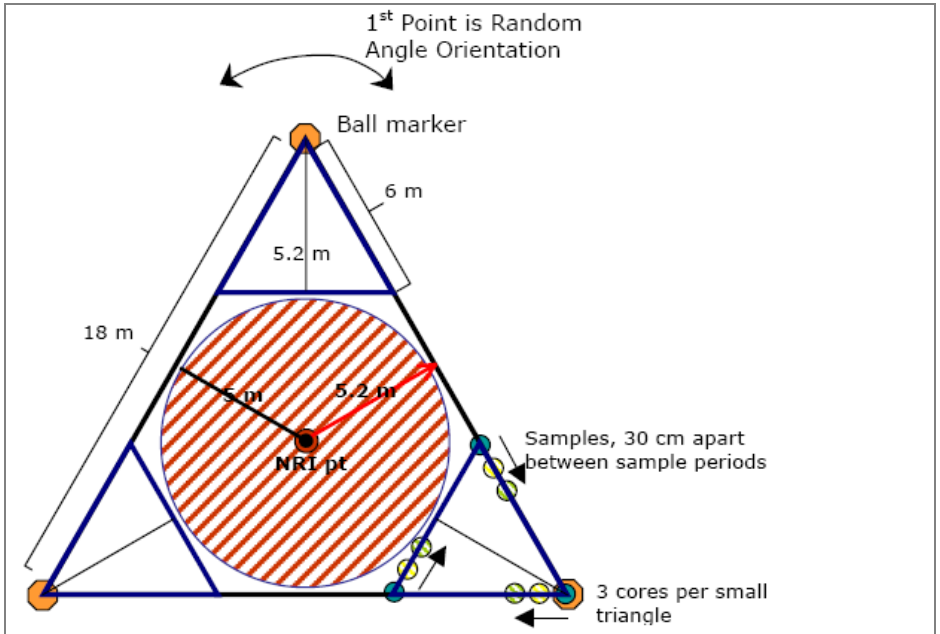


Figure 4. Layout of a monitoring site in proximity to a NRI point location.

- Prototype network under development with USDA/NRCS-NRI
- Proposed build-out to 5000-10,000 locations, with 1000-2000 locations per year

Conclusions

- No perfect method to quantify soil SOM cycling
- As scale increases, different methods tend to converge
- Largest uncertainties are for vectors that are rarely measured
- Convergence of methods that rely in different assumptions increases confidence
- Need complete C and N balance data