Modelling greenhouse gas exchange:

The use of process-based models

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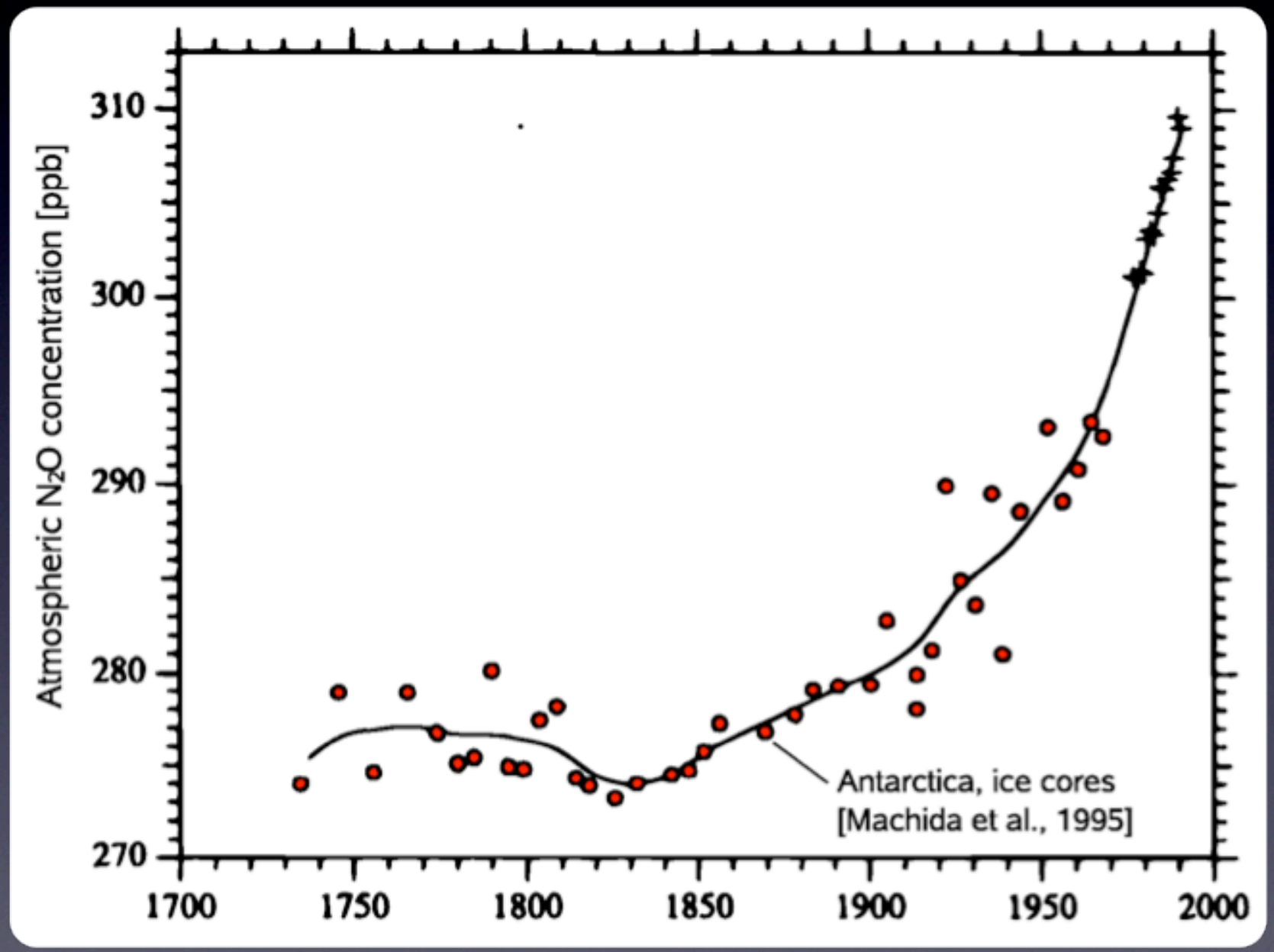
Atmospheric N_2O



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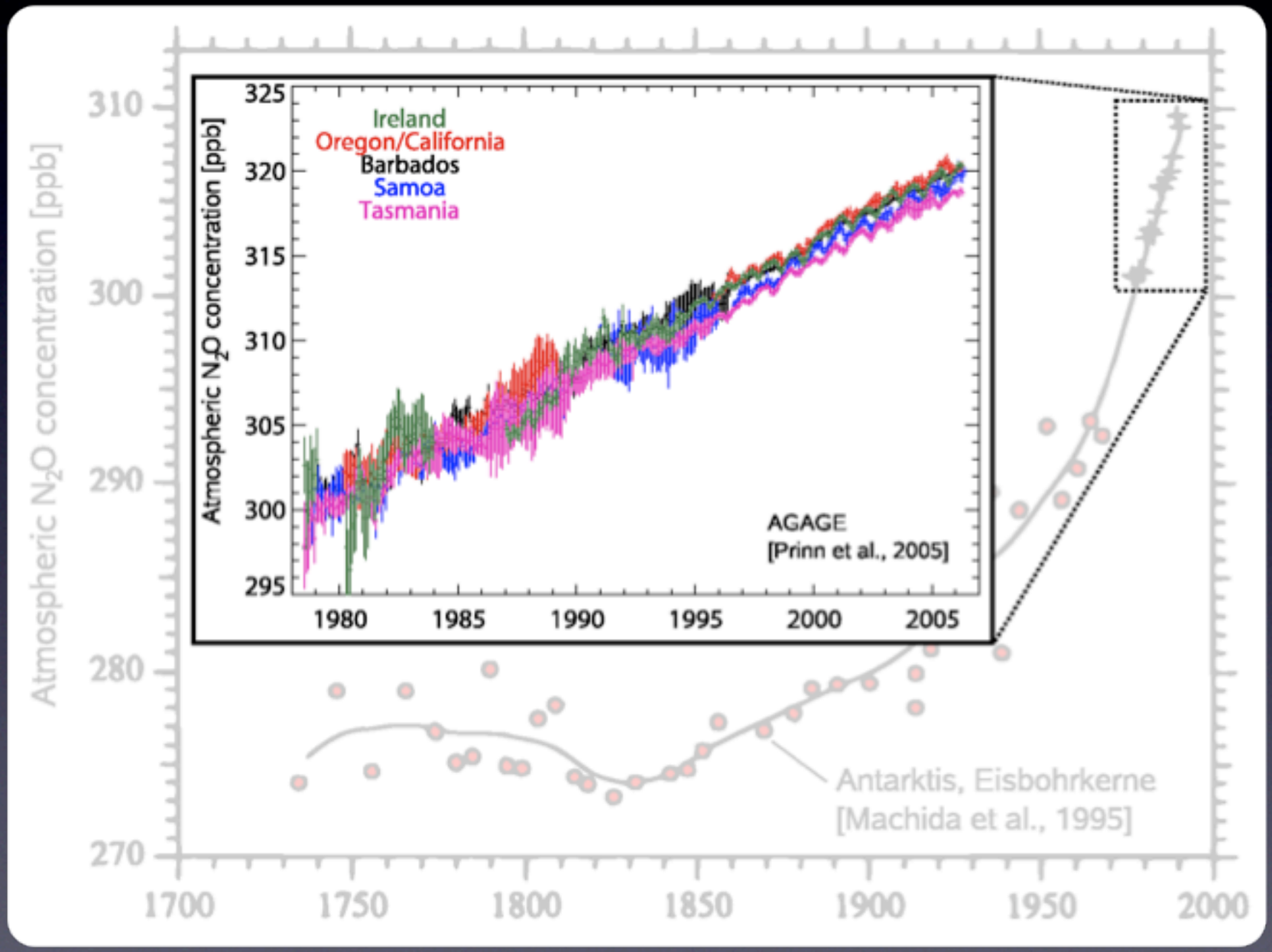

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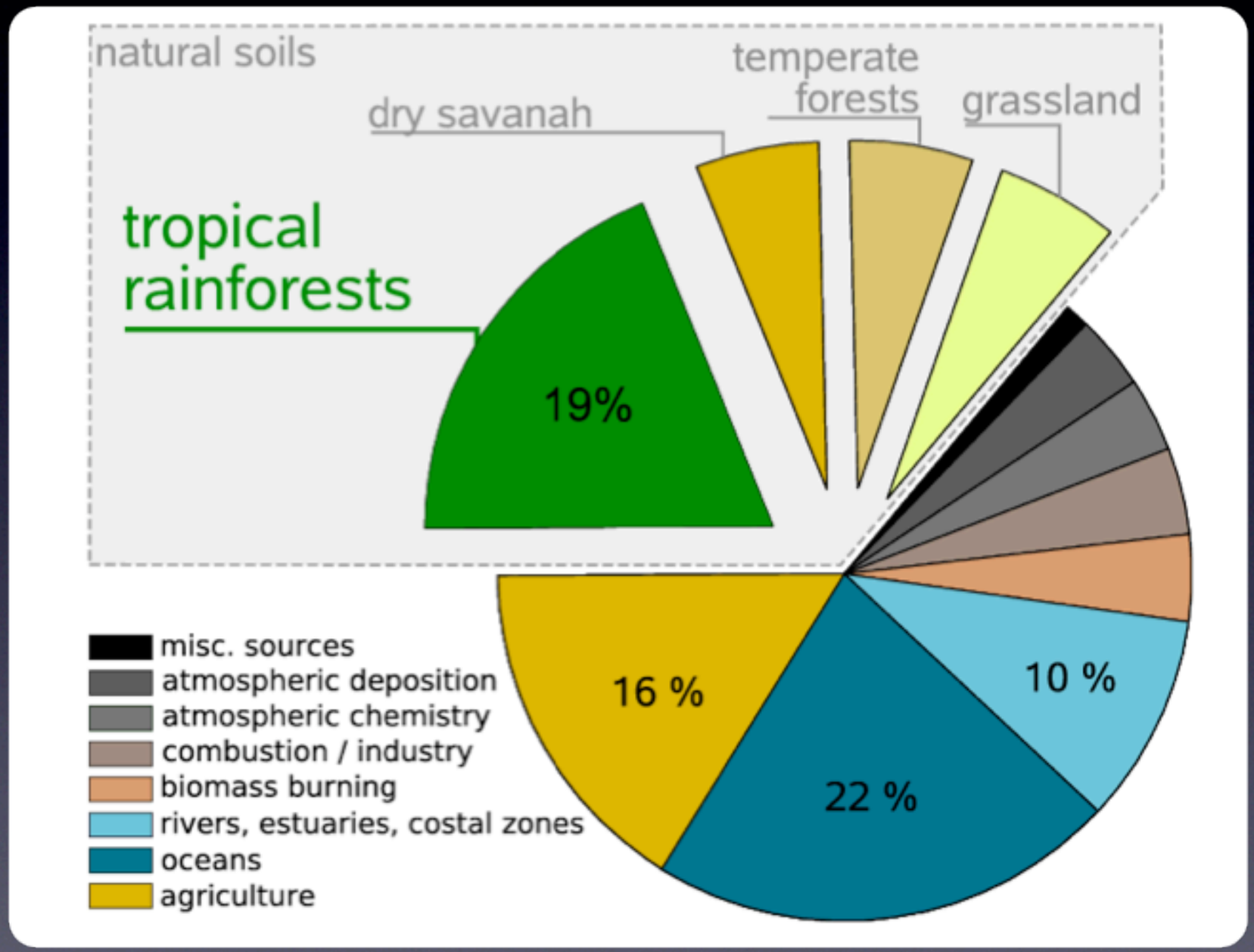
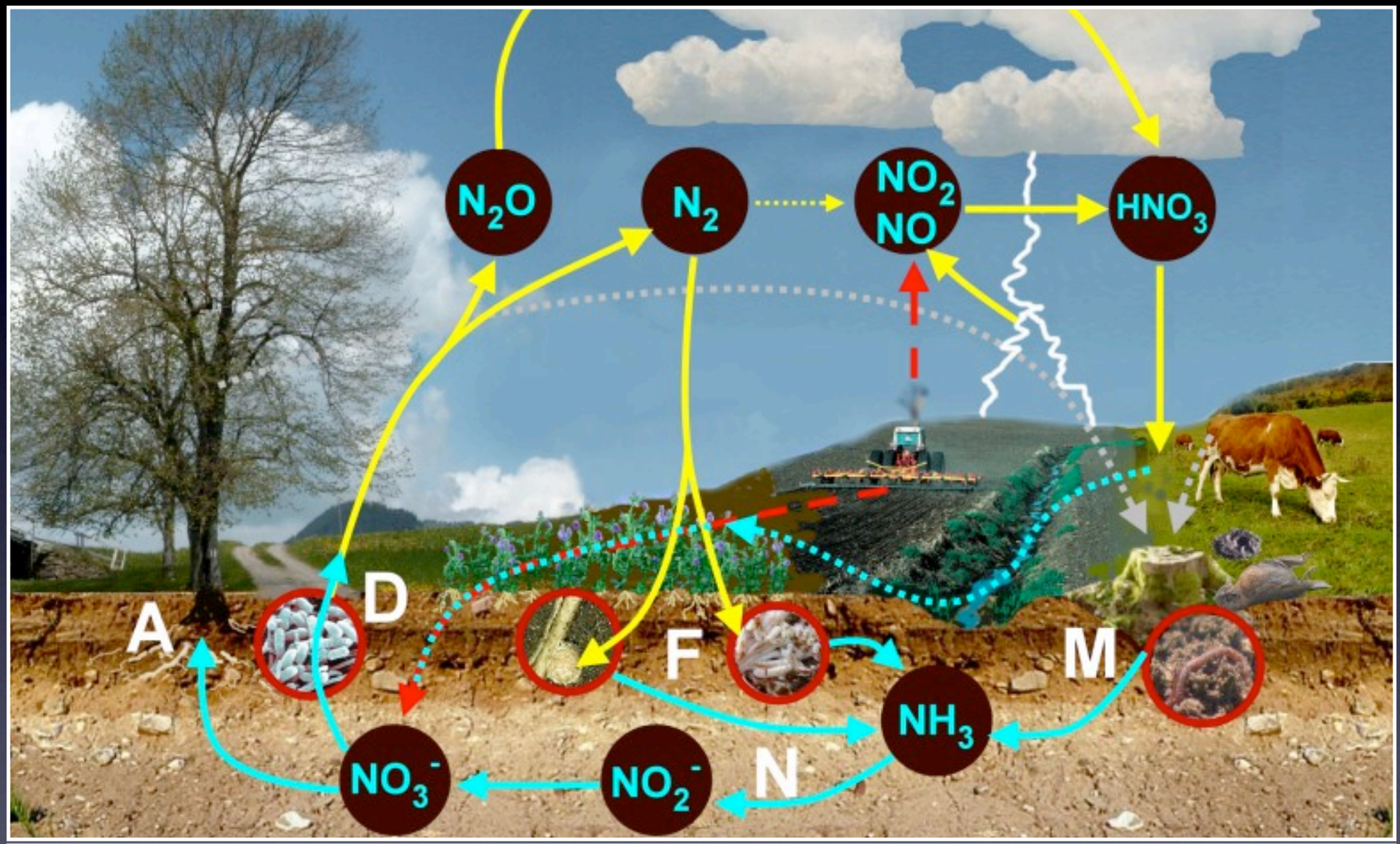


The N-cycle



source: ACCENT network

What are the major controls?

Short-term

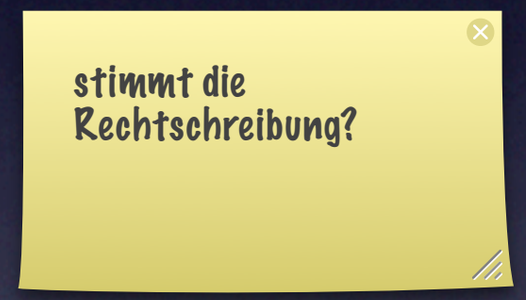
- precipitation
- soil temperature
- (fertilizer)

Mid-term

- soil texture
- substrate
- pH

Common problems

- Complexity of N cycling
- Various scales
- Process-Interaction
- Highly dynamic
- Few high-quality measurements



Modelling N emissions

Models & model applications

Empirical vs. mechanistic

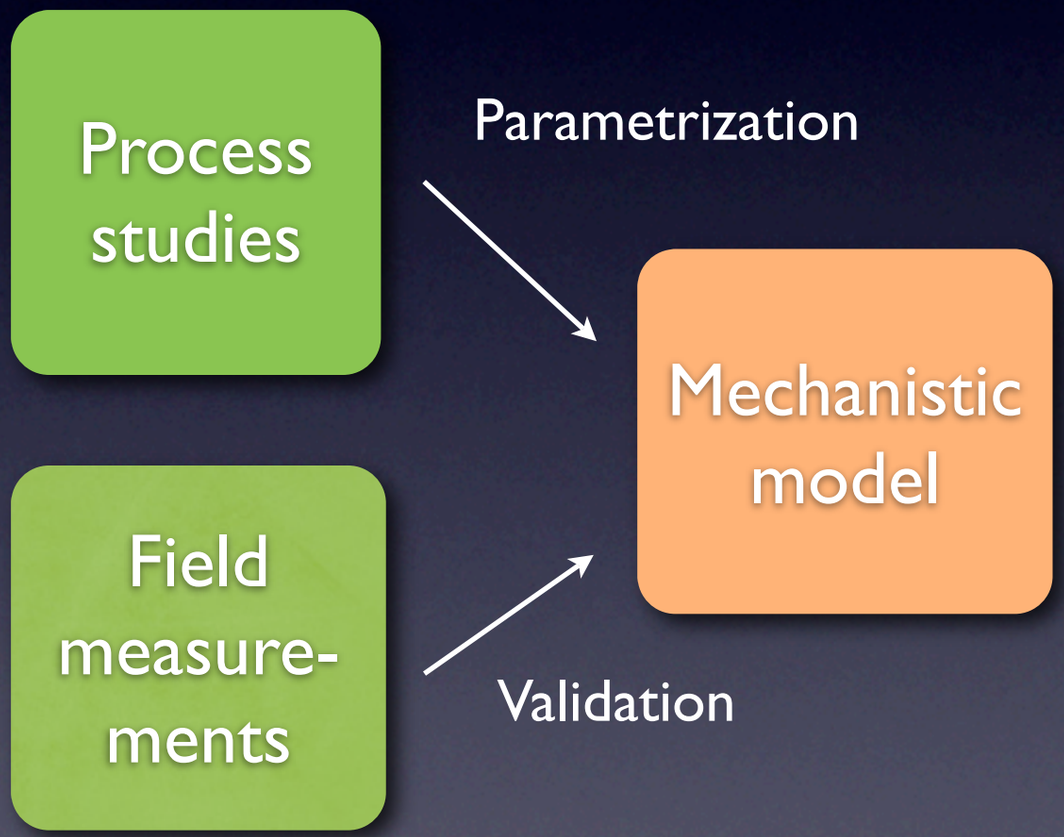
	Empirical	Mechanistic
Advantages	simple accepted by IPCC	feedbacks scenarios continuous the „real thing“
Disadvantages	too simple ? discrete no feedbacks	complex validation data needs

Linking methods, bridging scales

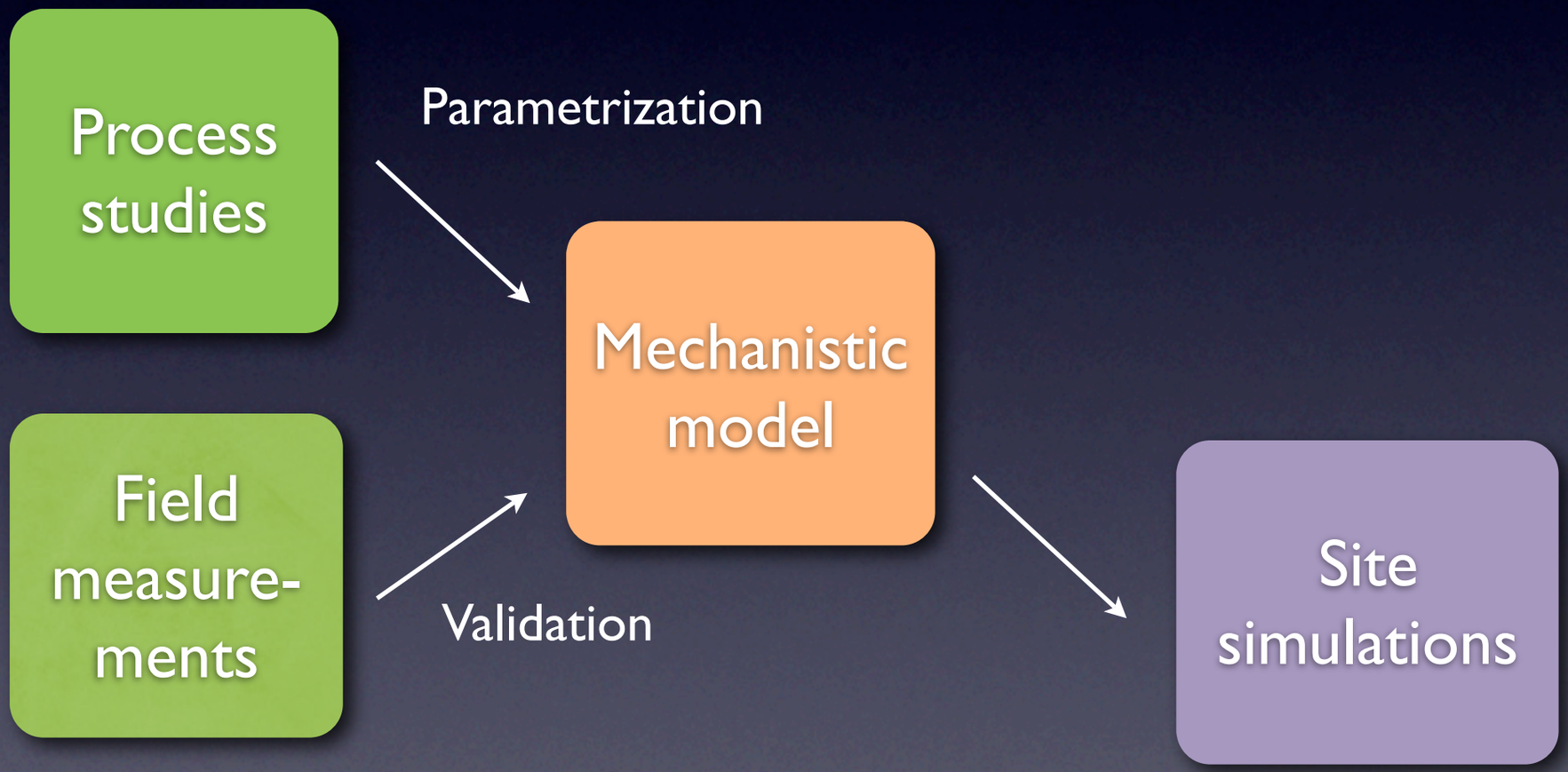
Process studies

Field measure-ments

Linking methods, bridging scales



Linking methods, bridging scales



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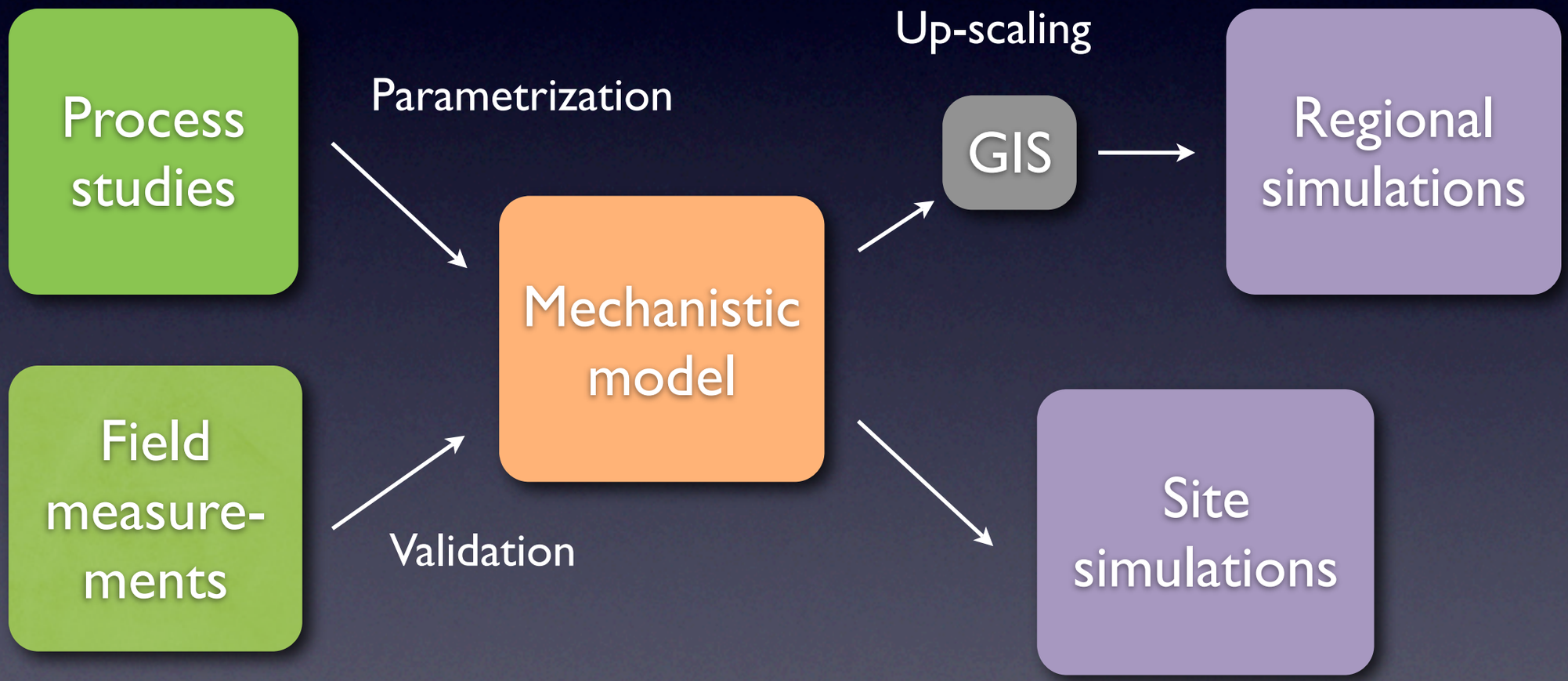
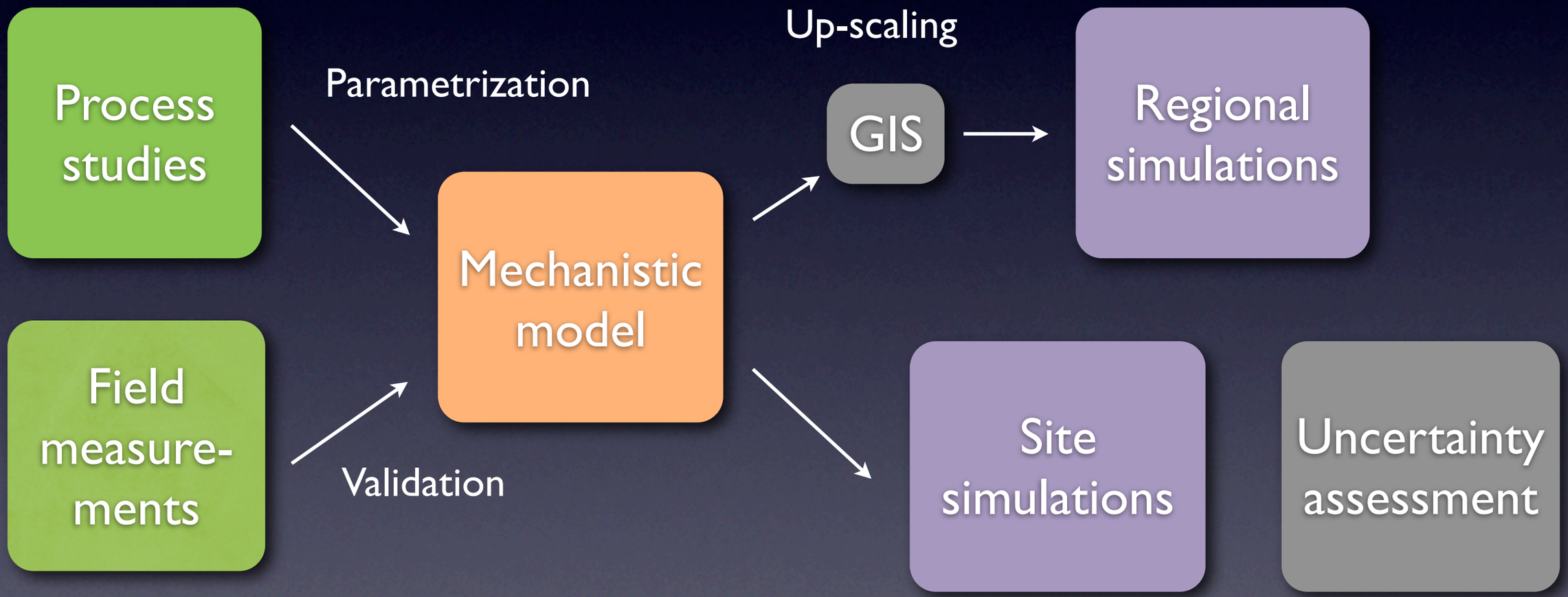


Linking methods, bridging scales



Mechanistic, biogeochemical models

CENTURY

CENTURY 

DayCENT 

http://www.nrel.colostate.edu/projects/century/

Mechanistic, biogeochemical models

CENTURY

CENTURY

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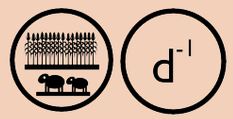
DNDC

DNDC



PnET-N-DNDC (ForestDNDC)

http://www.dndc.sr.unh.edu/

Mechanistic, biogeochemical models

CENTURY

CENTURY

DayCENT

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DNDC

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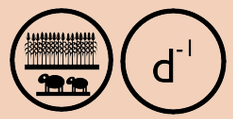


PnET-N-DNDC (ForestDNDC)

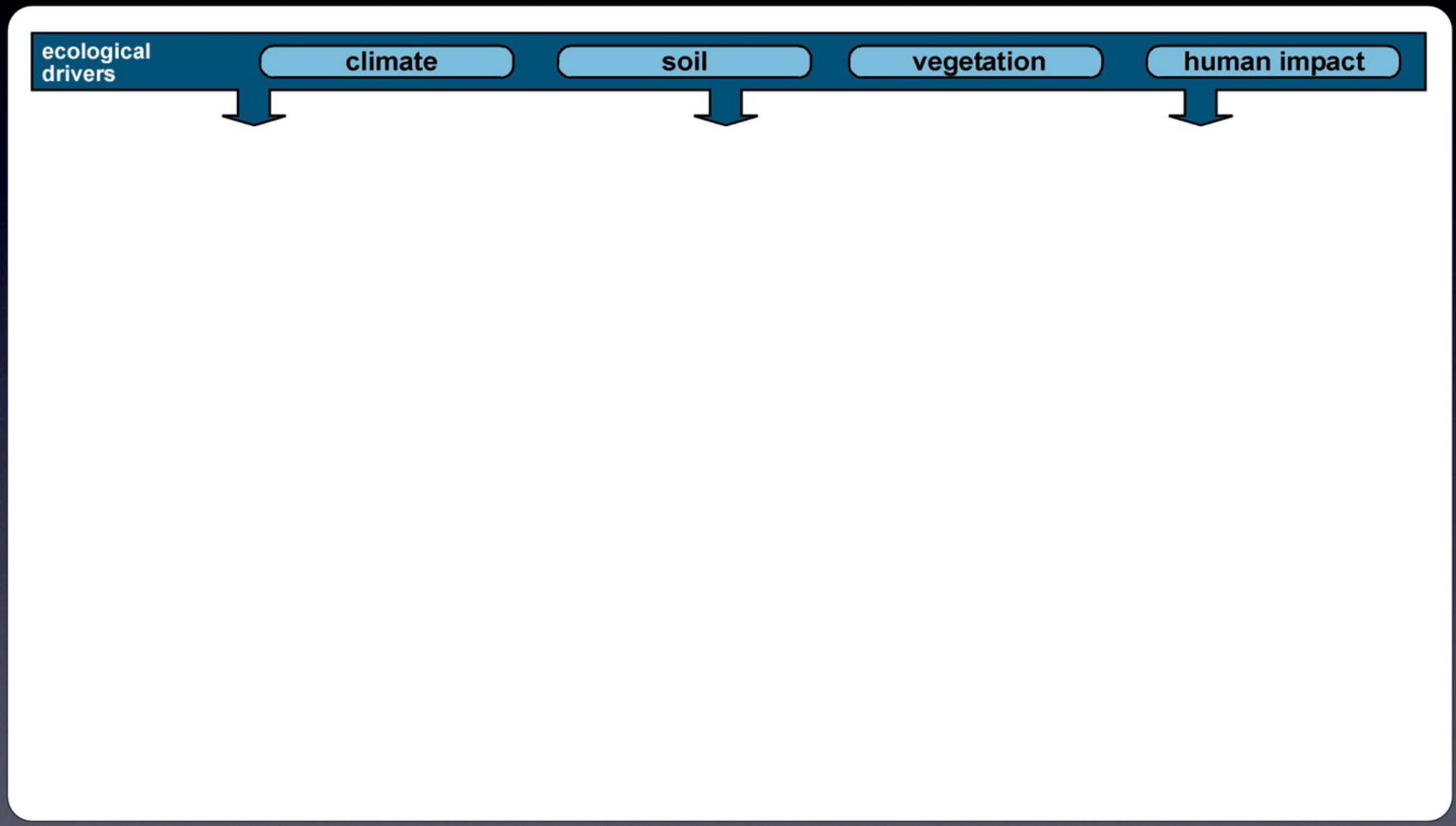
http://www.dndc.sr.unh.edu/

MOBILE framework

MOBILE

http://svn.gap.fzk.de/

The DNDC model(s)



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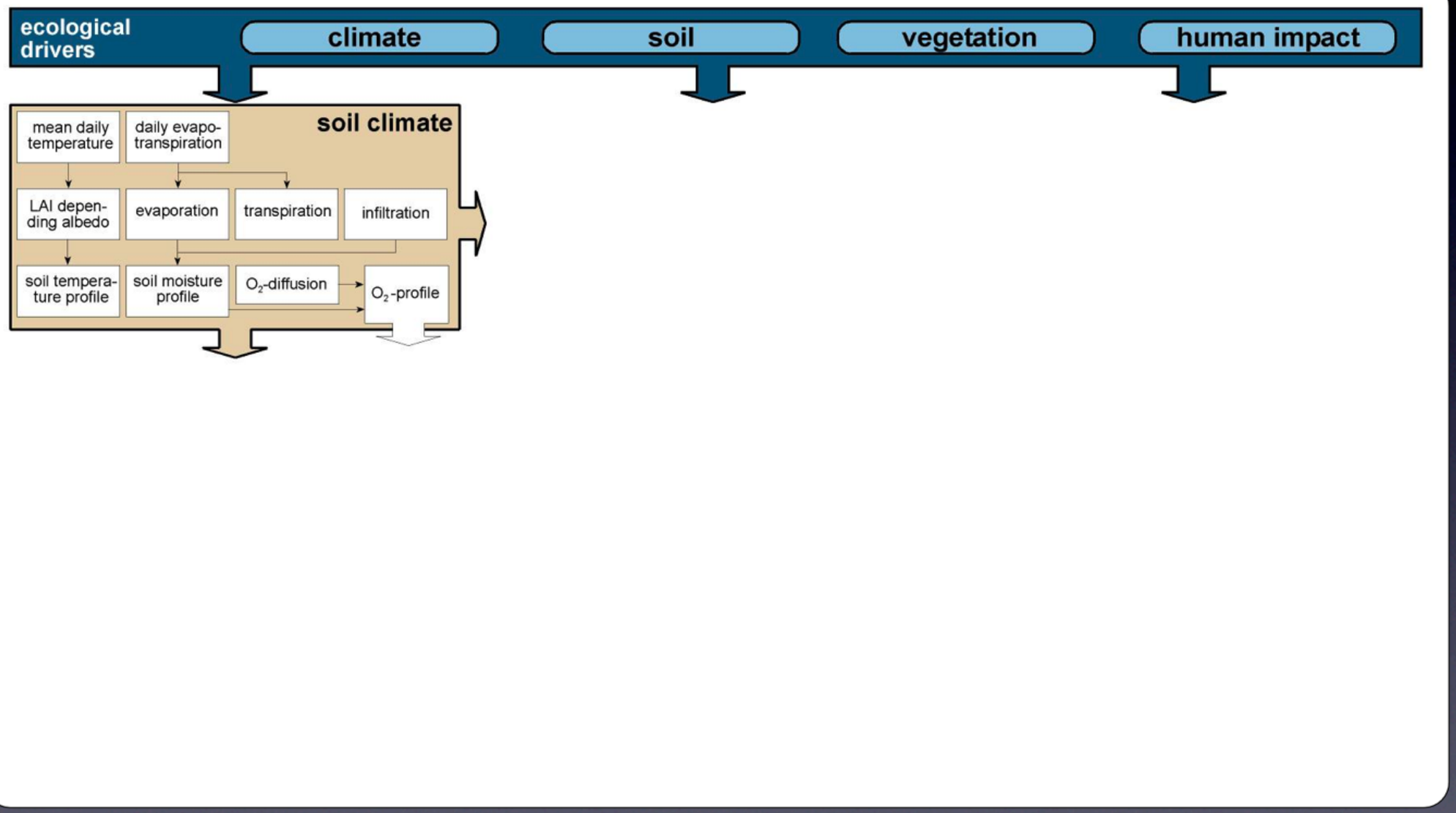

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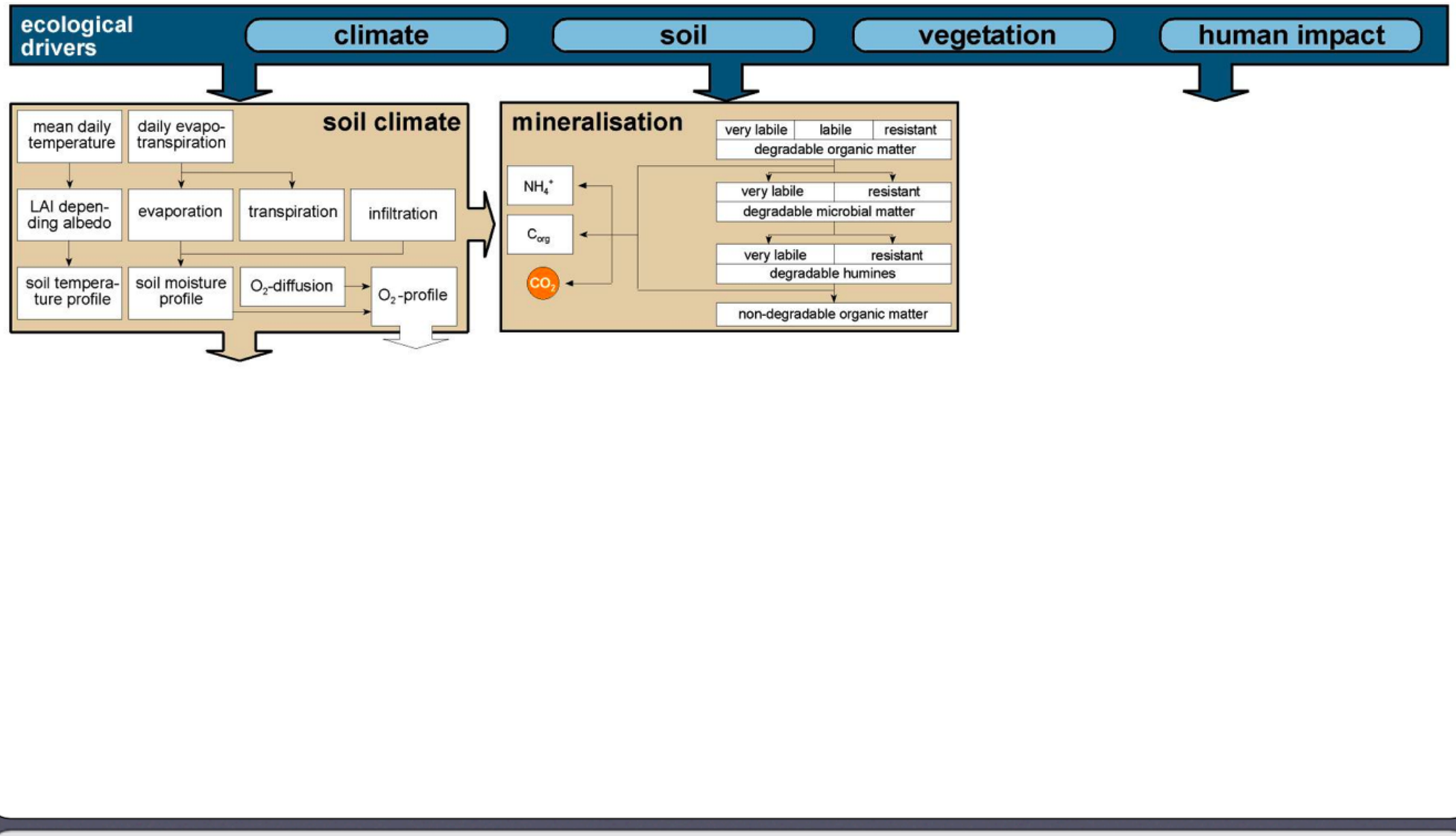

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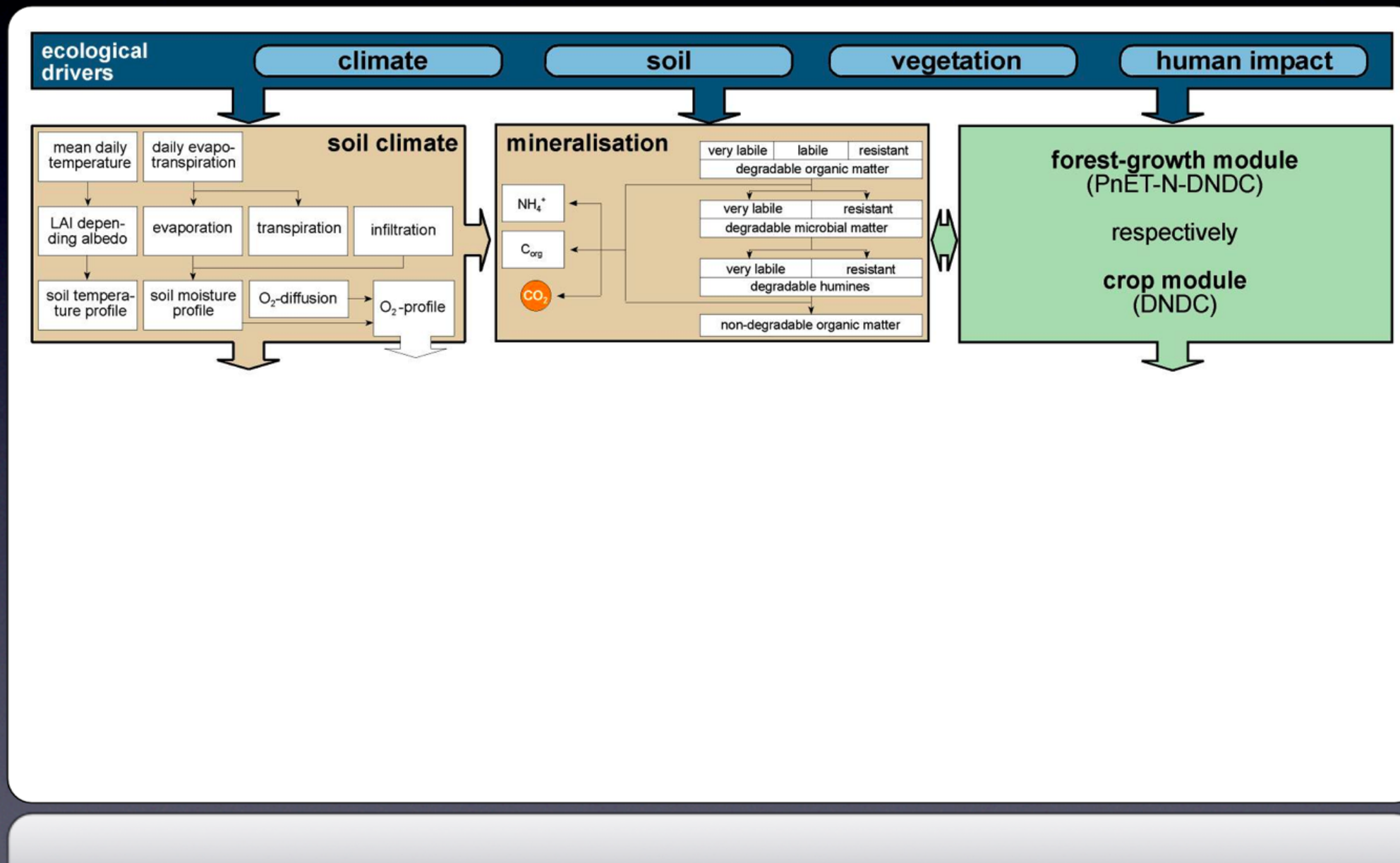

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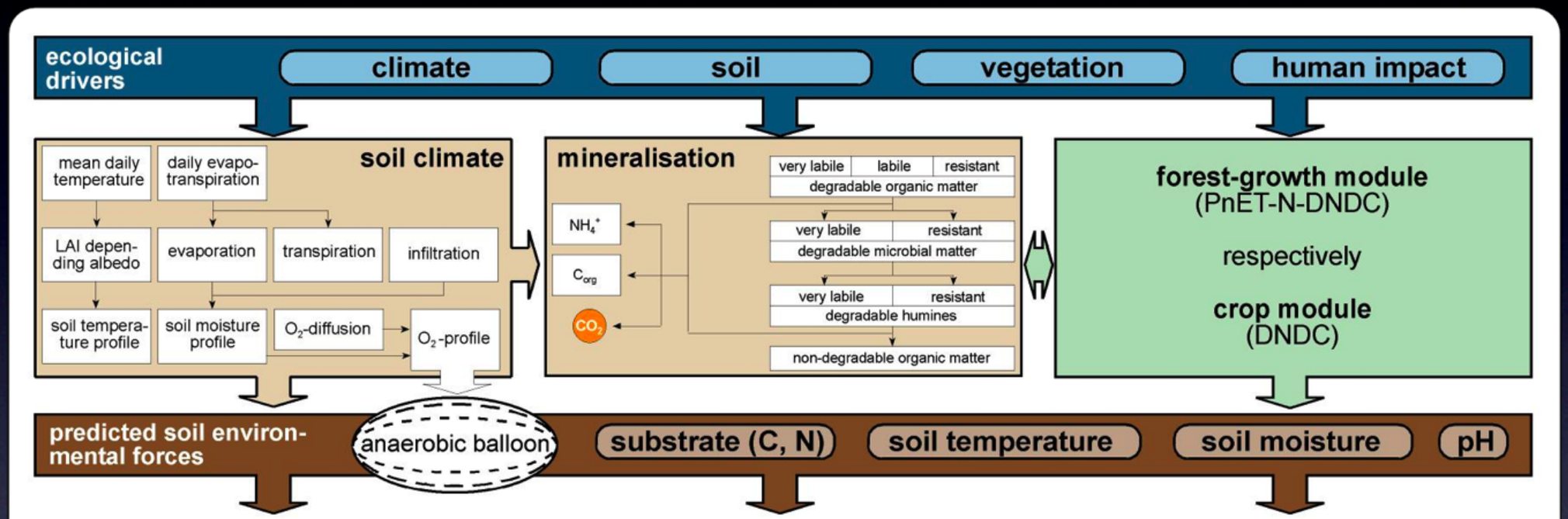

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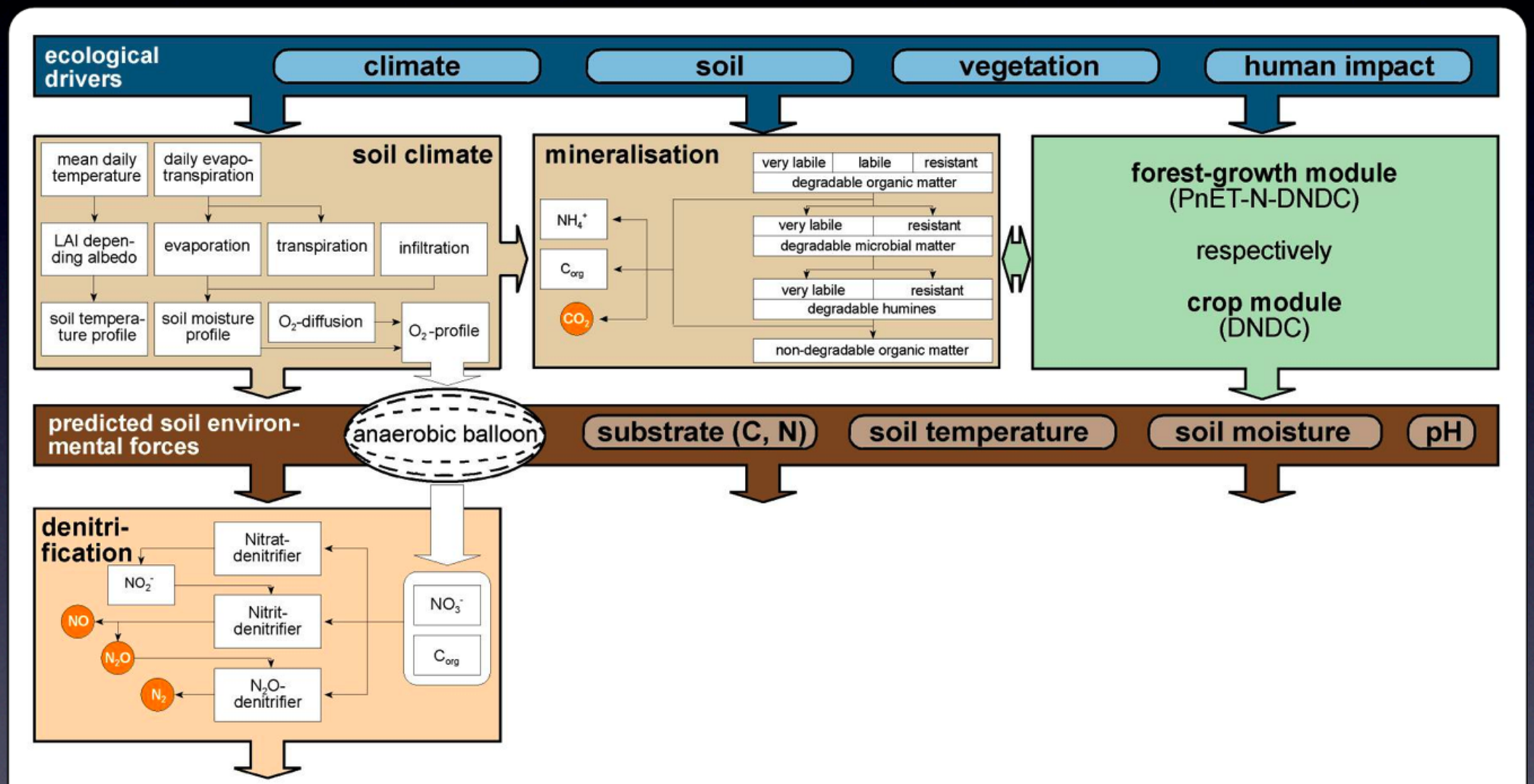

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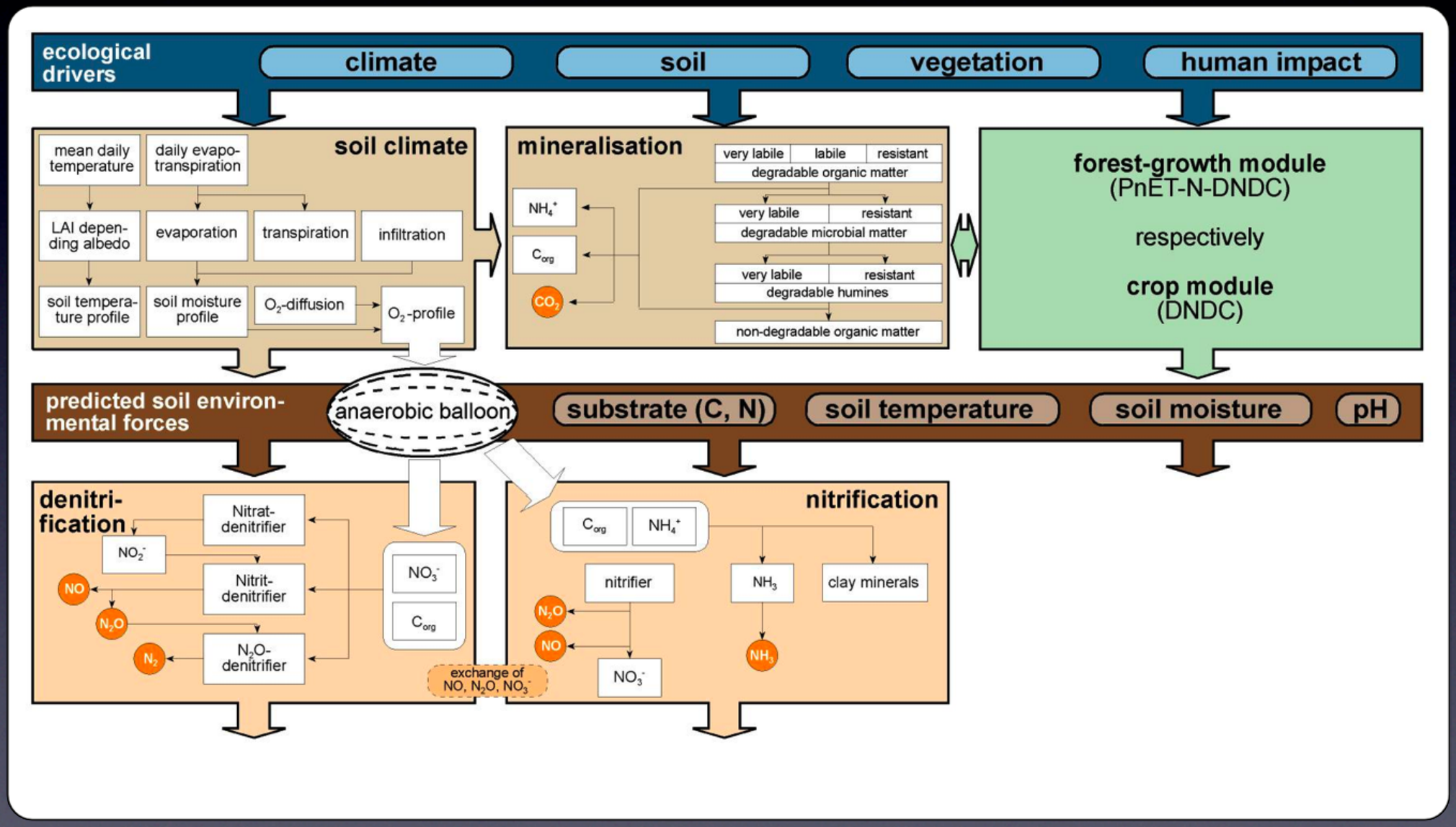

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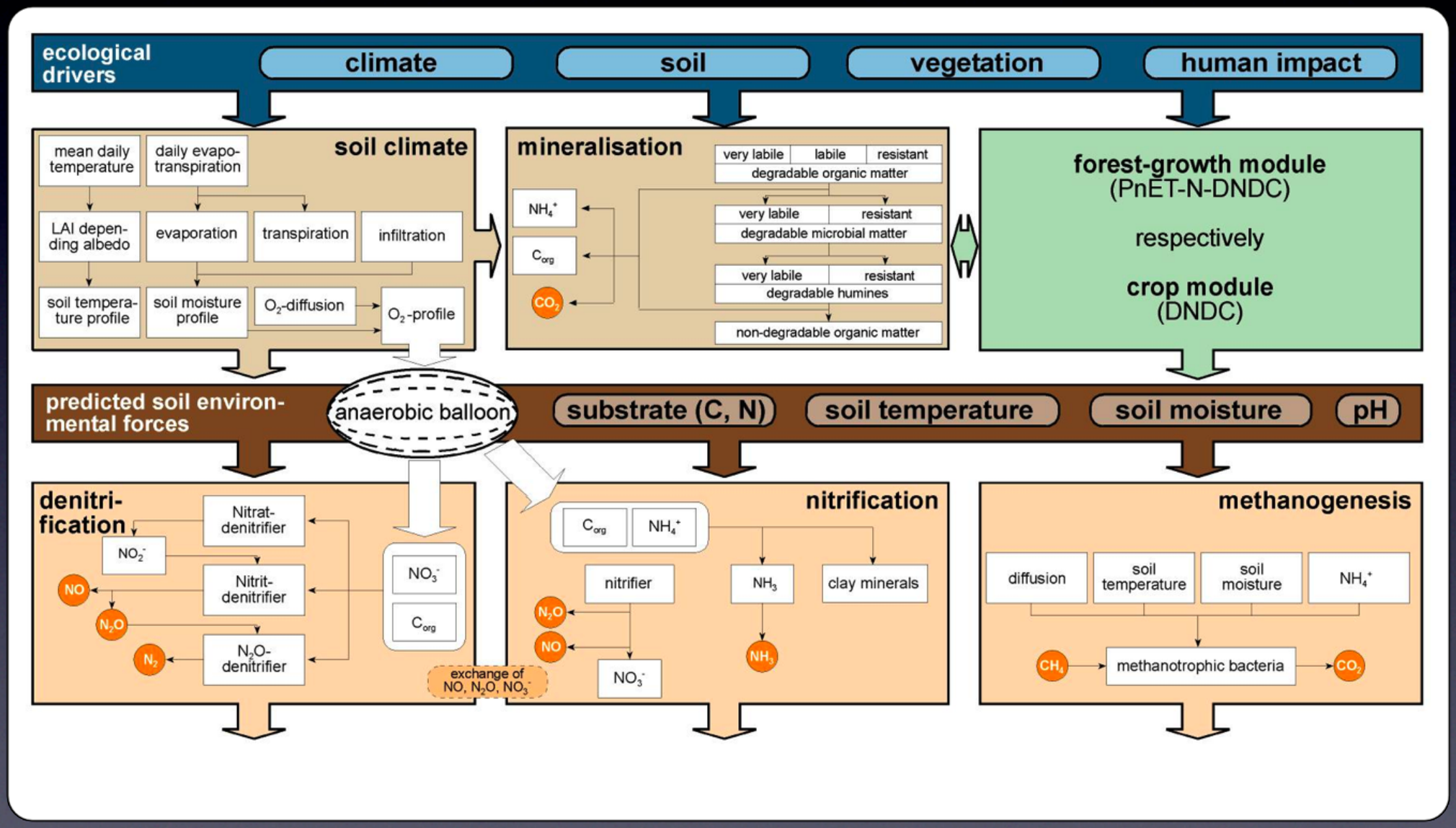

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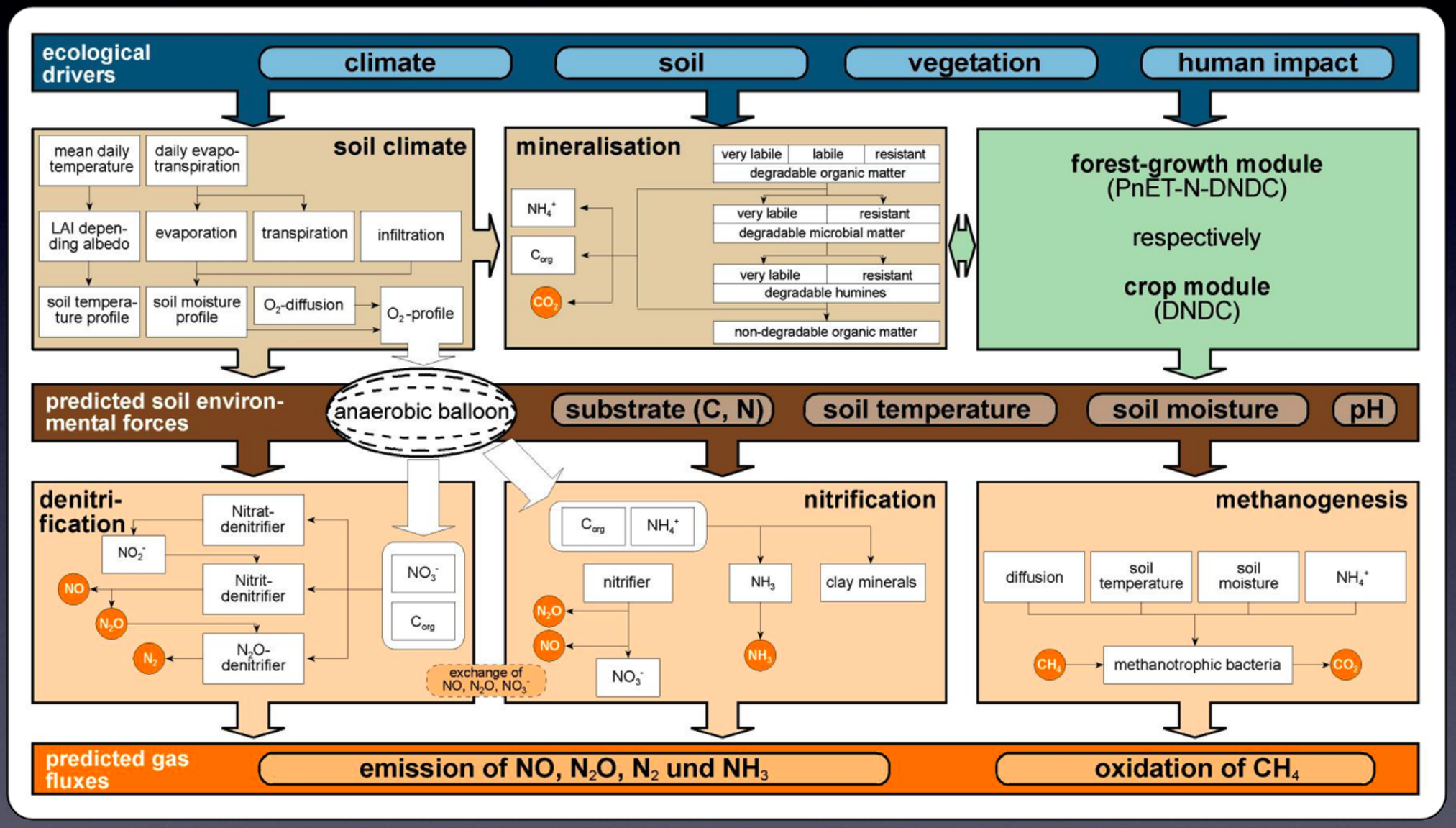
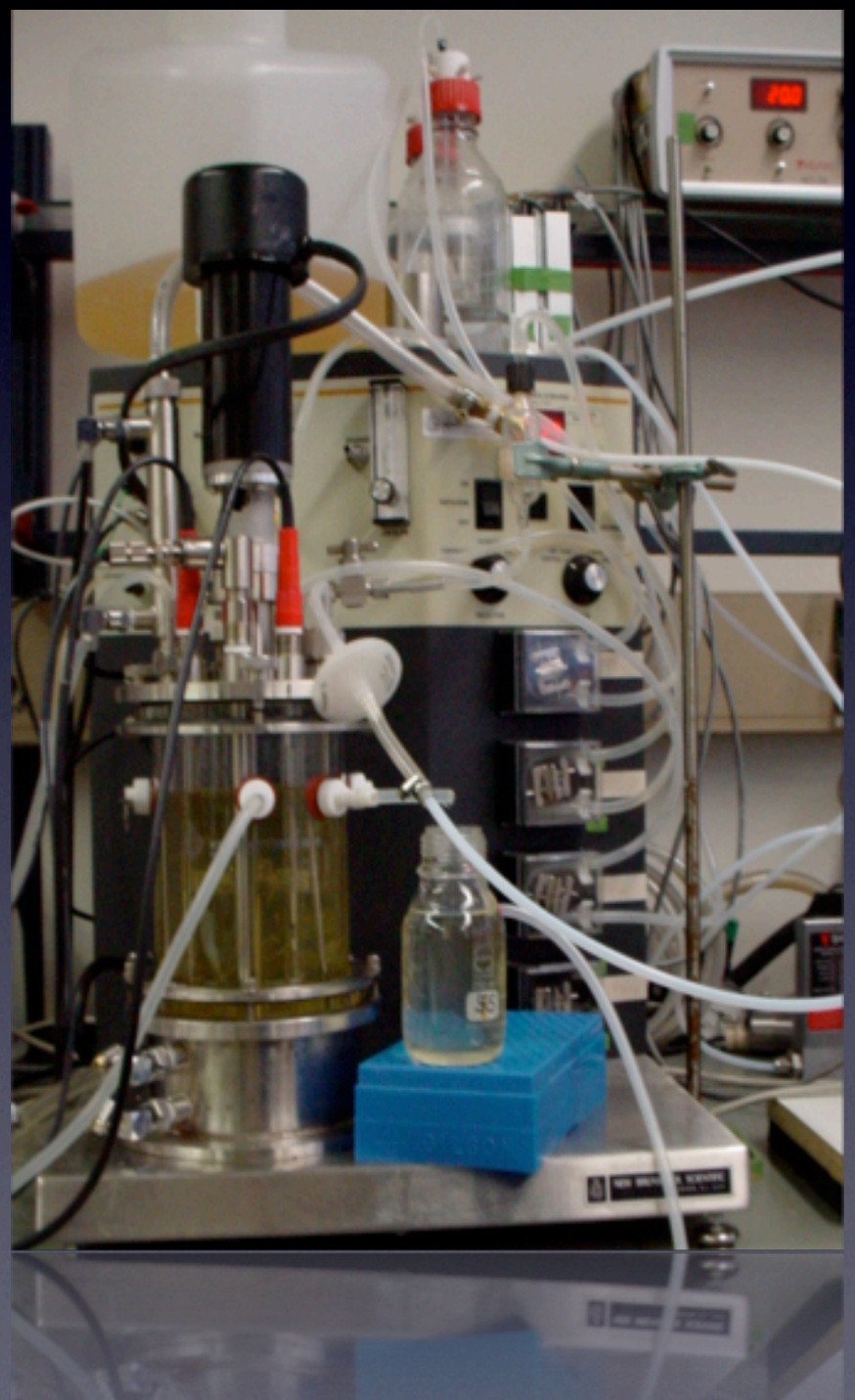


Process studies

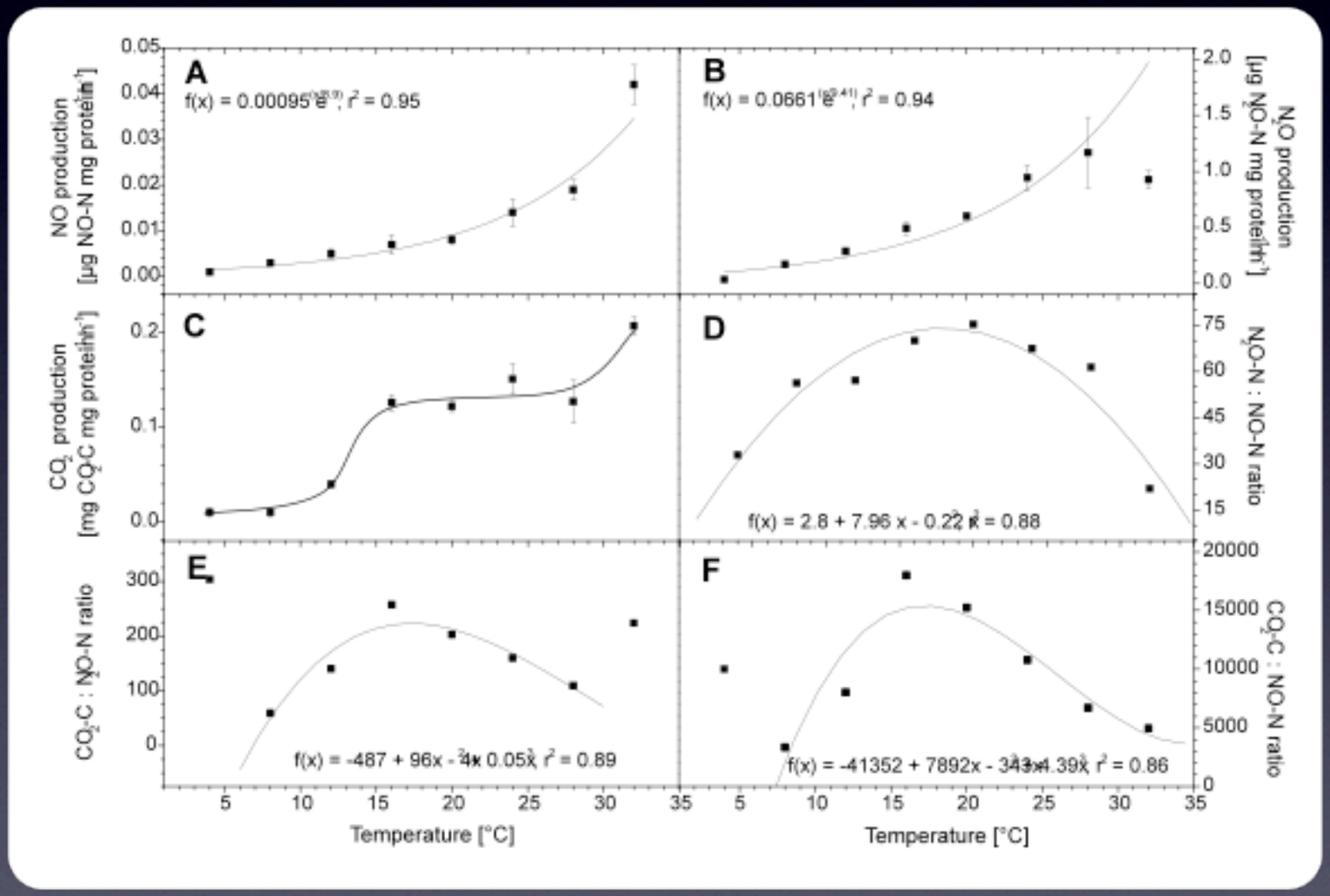
Measuring the „real thing“

Fermenter studies



source:
Kesik et al. (2006)
J. Appl. Microbiol.

Fermenter studies

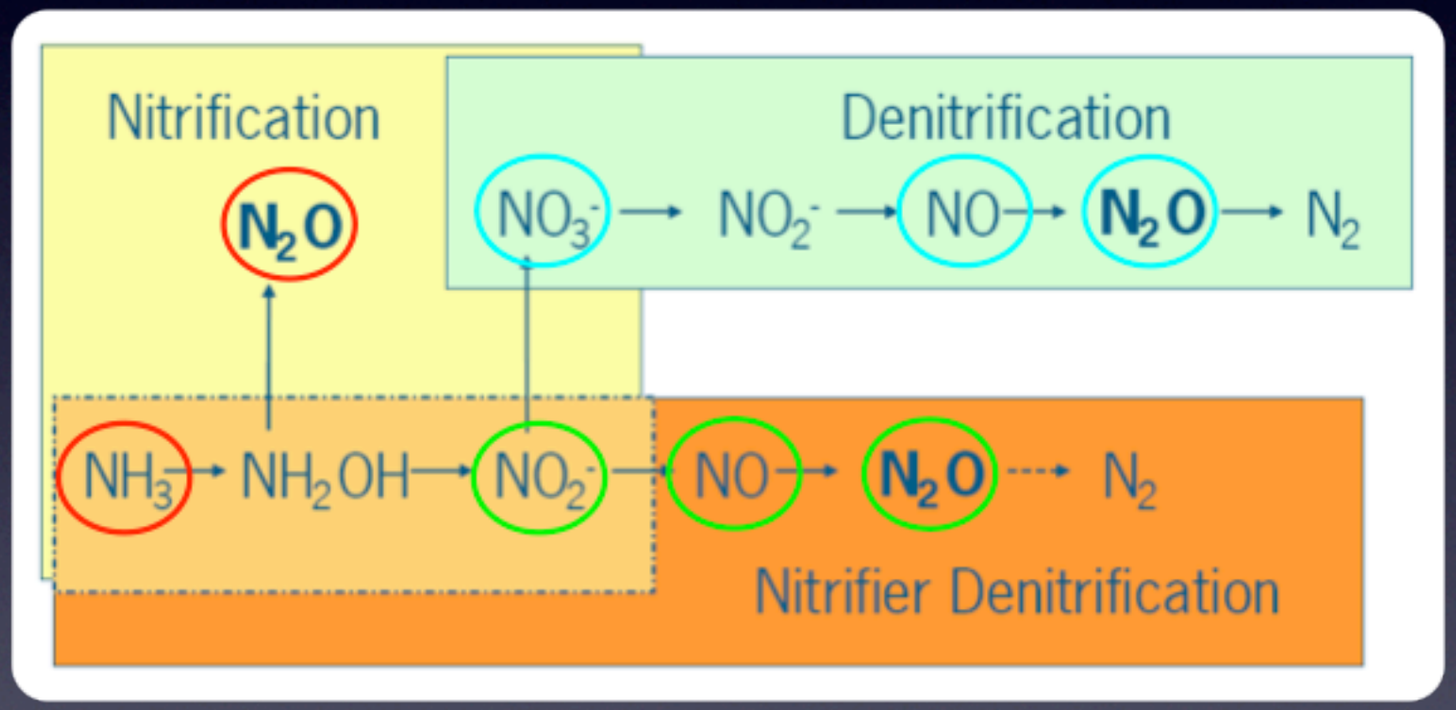


source:
Kesik et al. (2006)
J. Appl. Microbiol.

Isotope labeling

source:
Dannenmann et al.
(2006) Plant Soil

Isotope labeling



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(2006) Plant Soil

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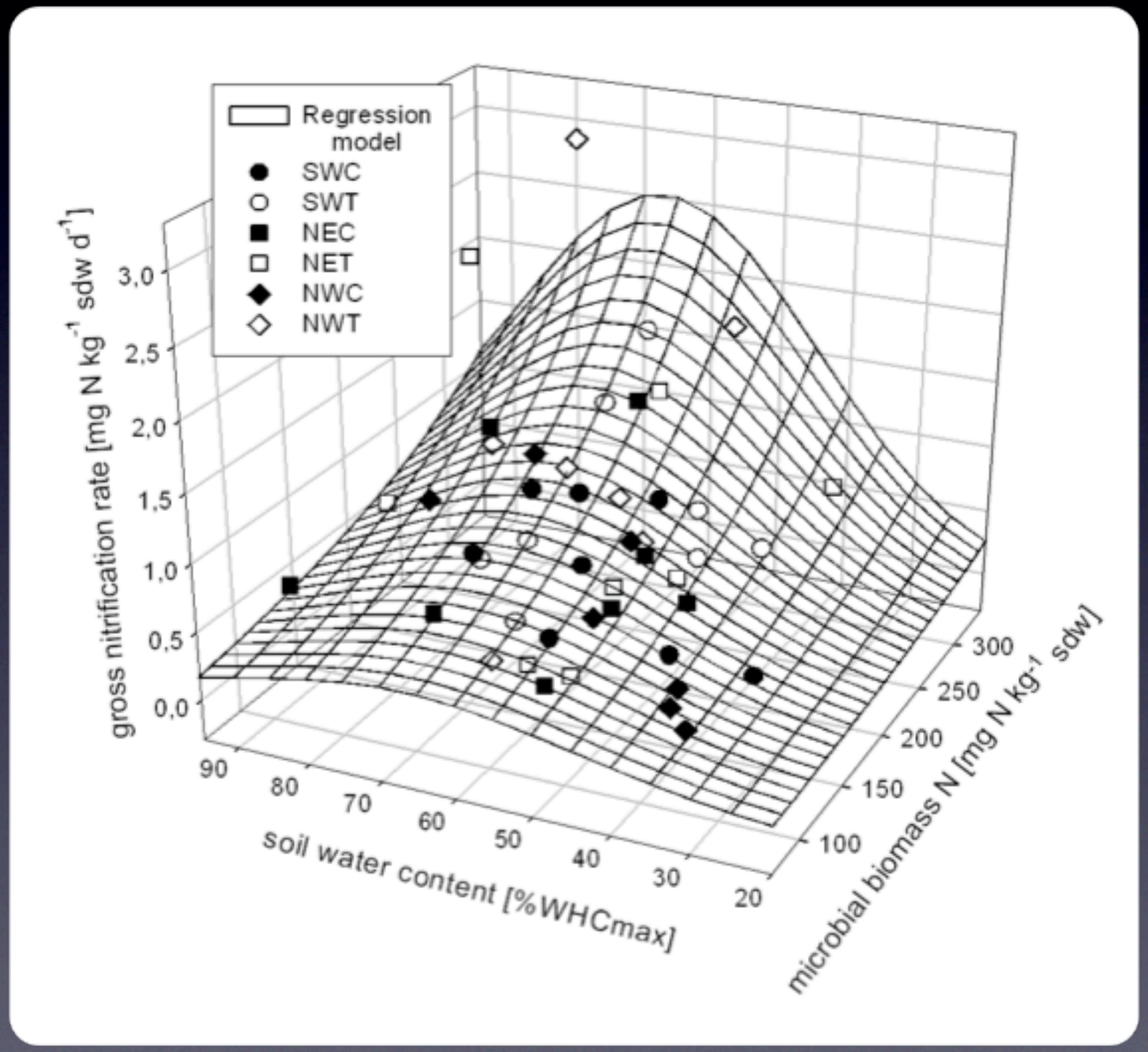

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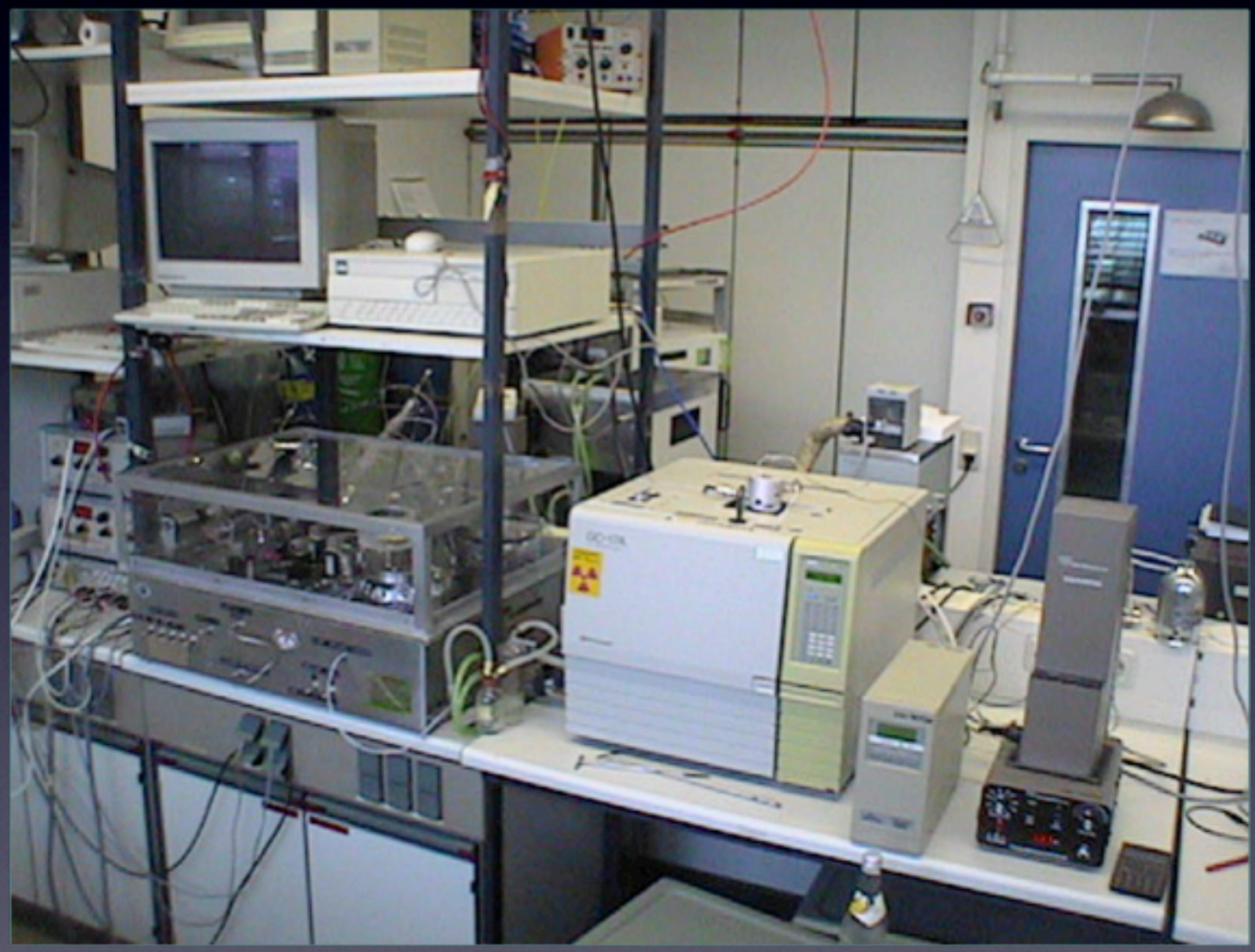
N_2 measurements



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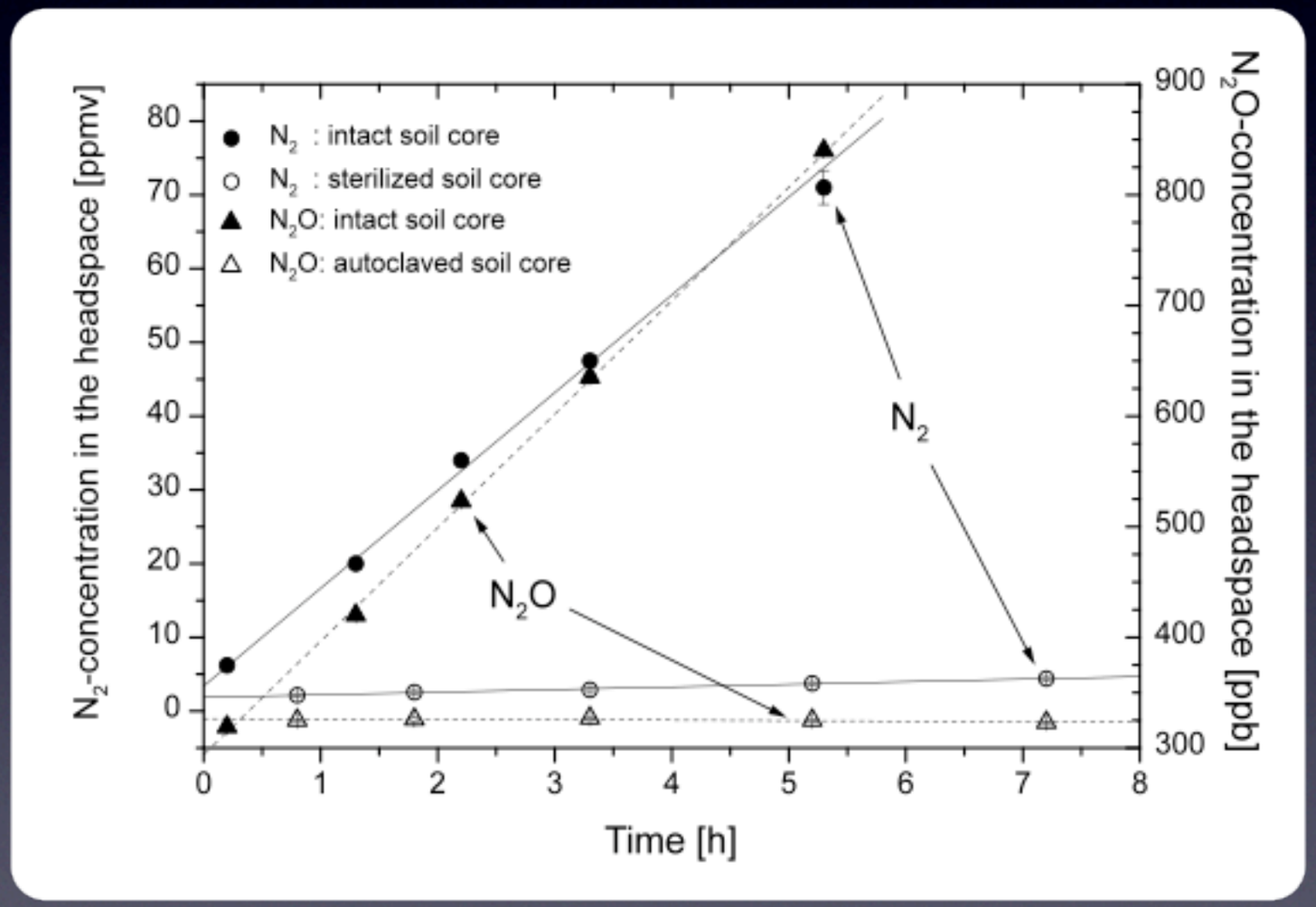


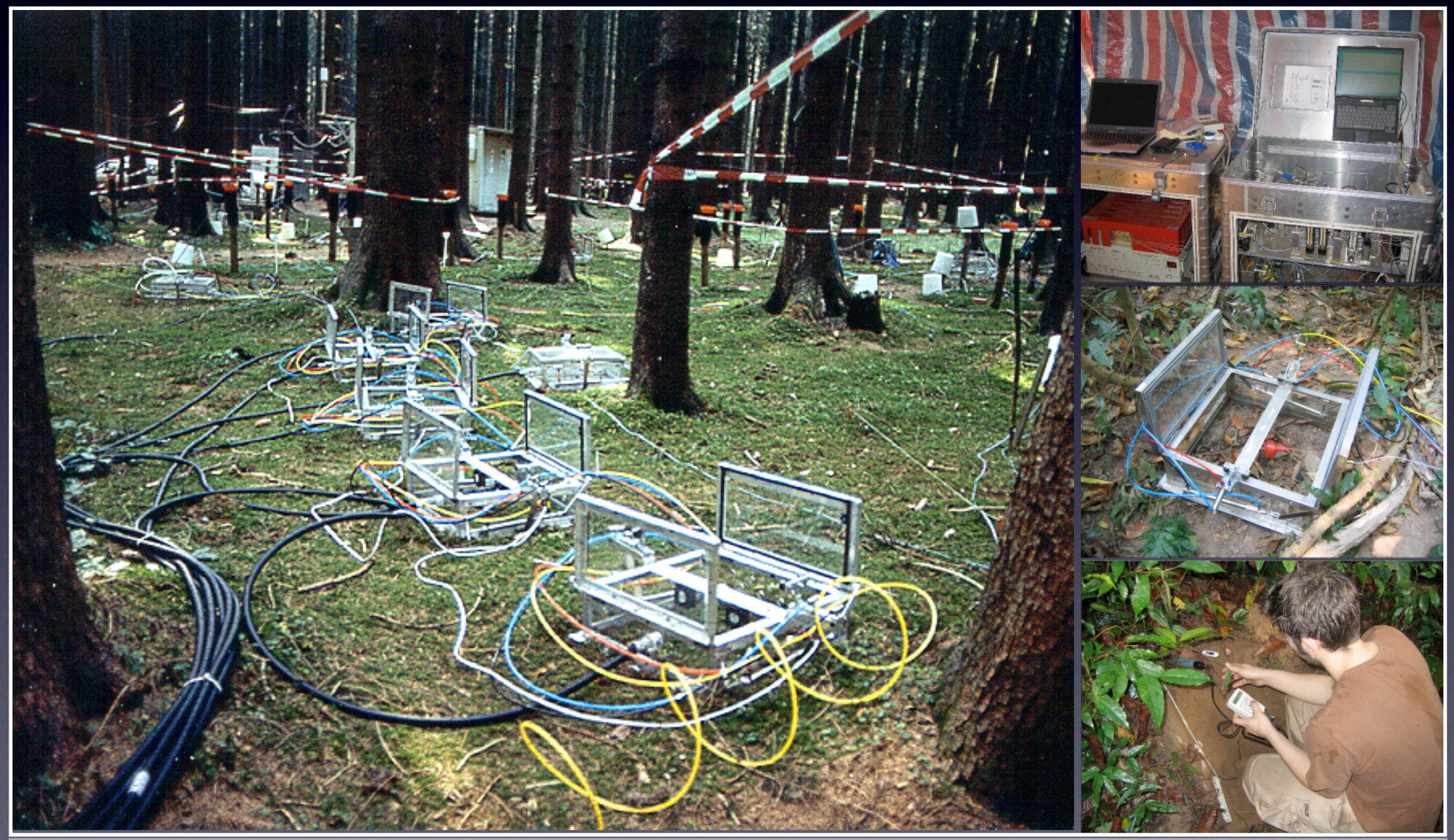
Field measurement

Measuring the soil-atmosphere exchange and controlling factors

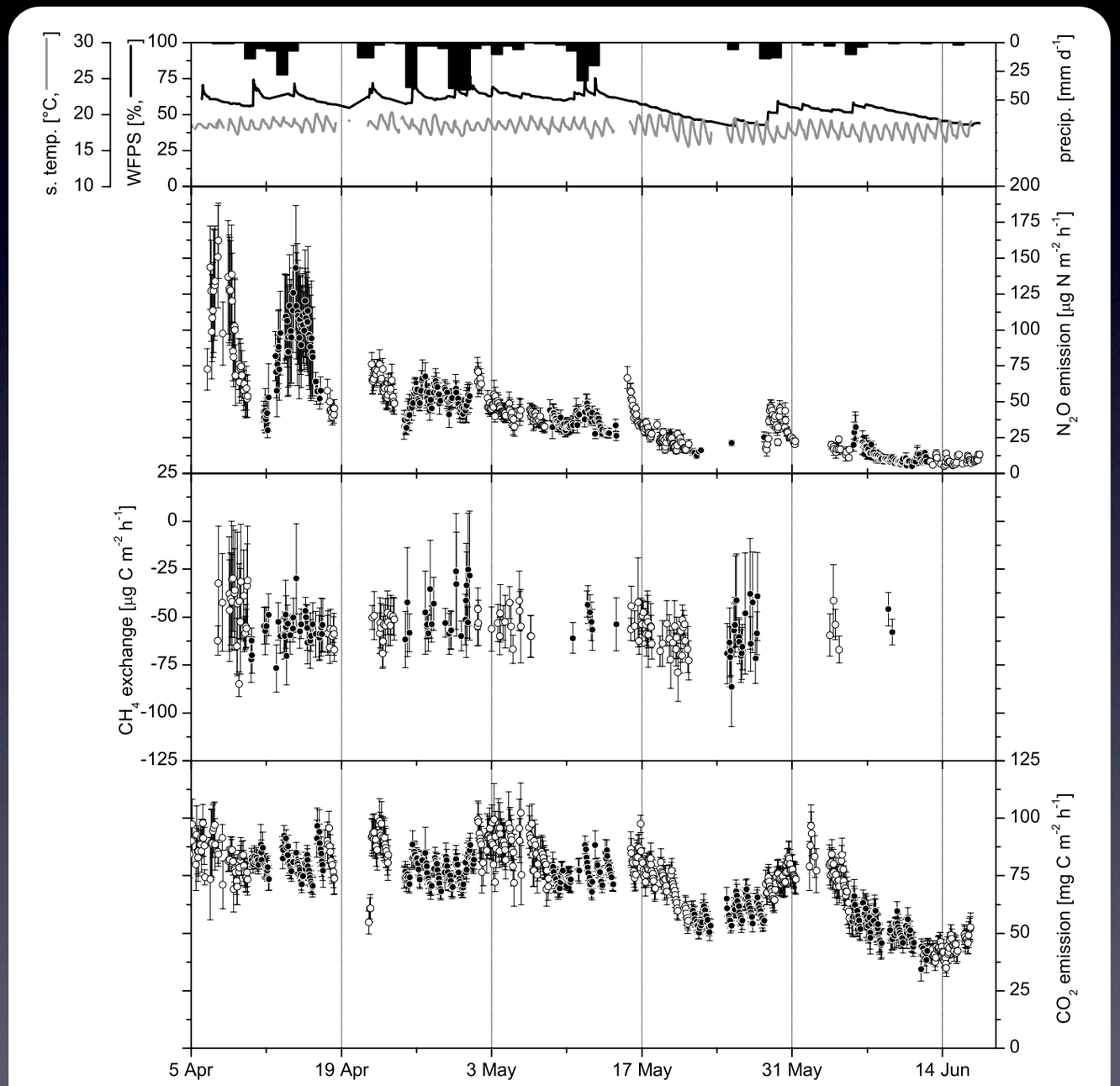
Measured variables

- N_2O, NO, CH_4, CO_2
  (sub-daily res., multiple chambers; n > 4)
- local weather
- soil climate
- soil properties (substrate, physicochemical)

High-resolution measurements



Fluxes + environ. factors



Sub-daily measurements,
Kakamega forest, 2004

source:
Werner et al. (2007)
JGR

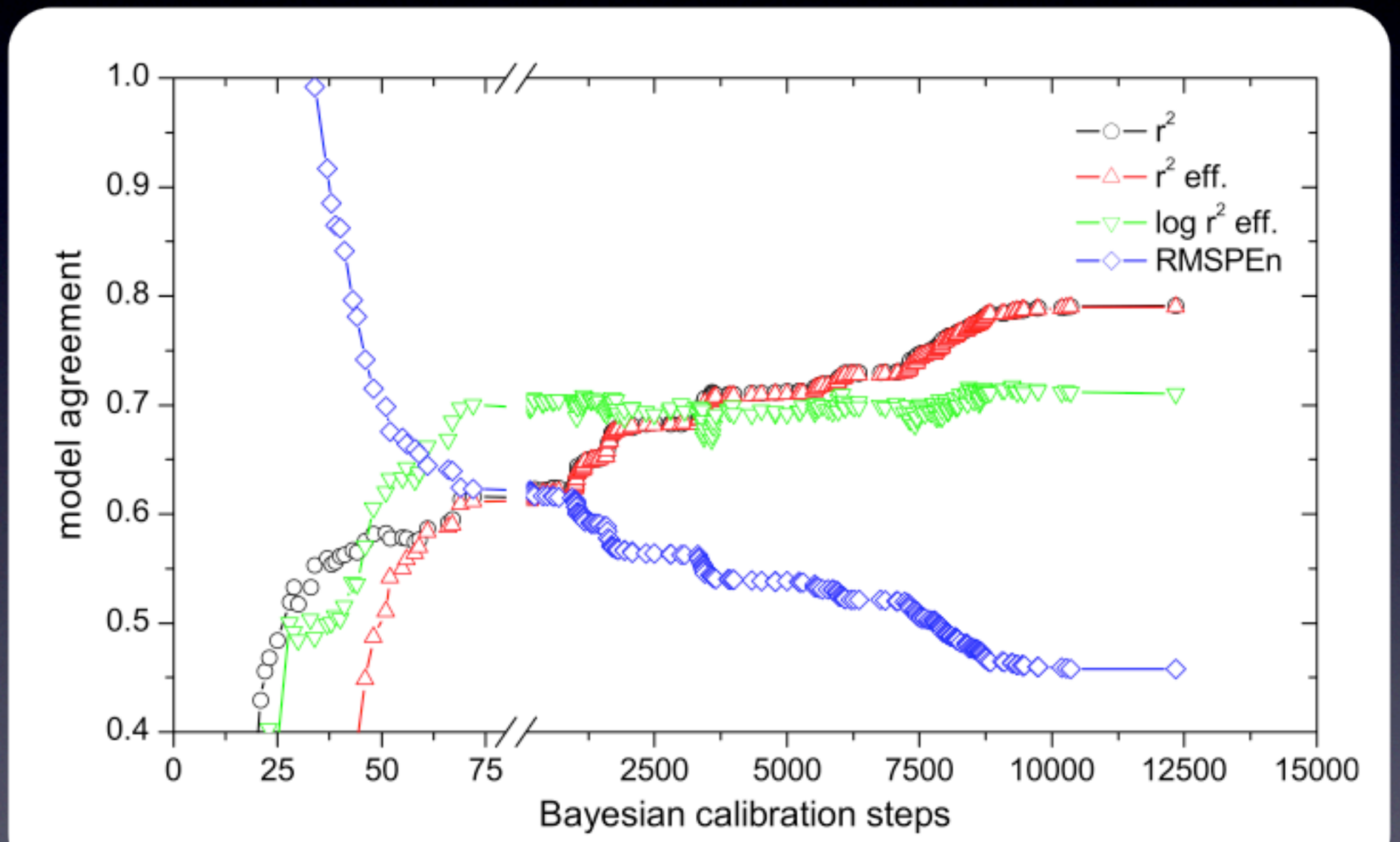
Model development

Implementation, Calibration, Validation

Calibration techniques

Developer	„expert knowledge“, visuall tuning
Optimization	Find best fit (objectively)
Bayesian Calibration	Find best fit (objectively) + the uncertainty

Validation & calibration



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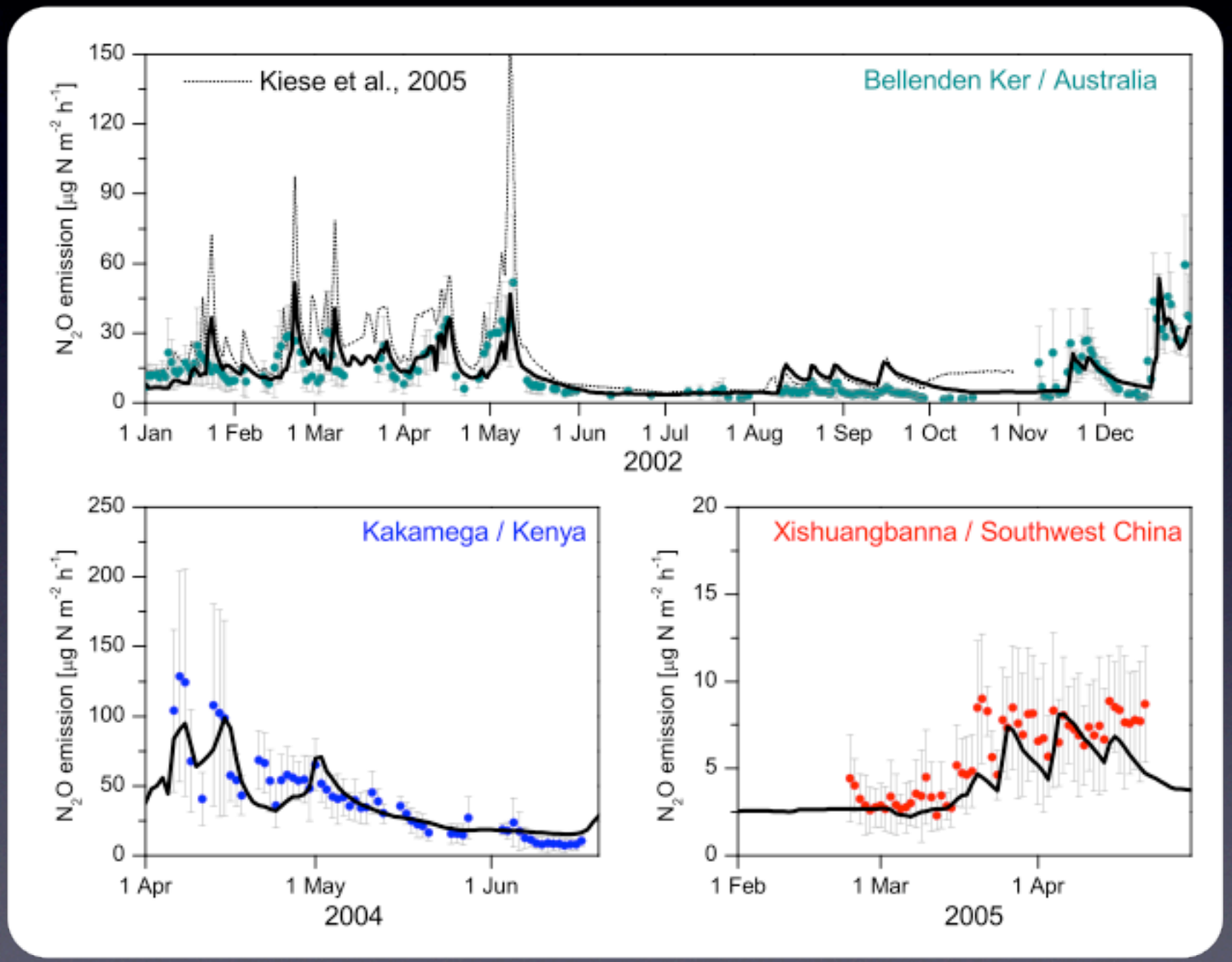
Validation & calibration



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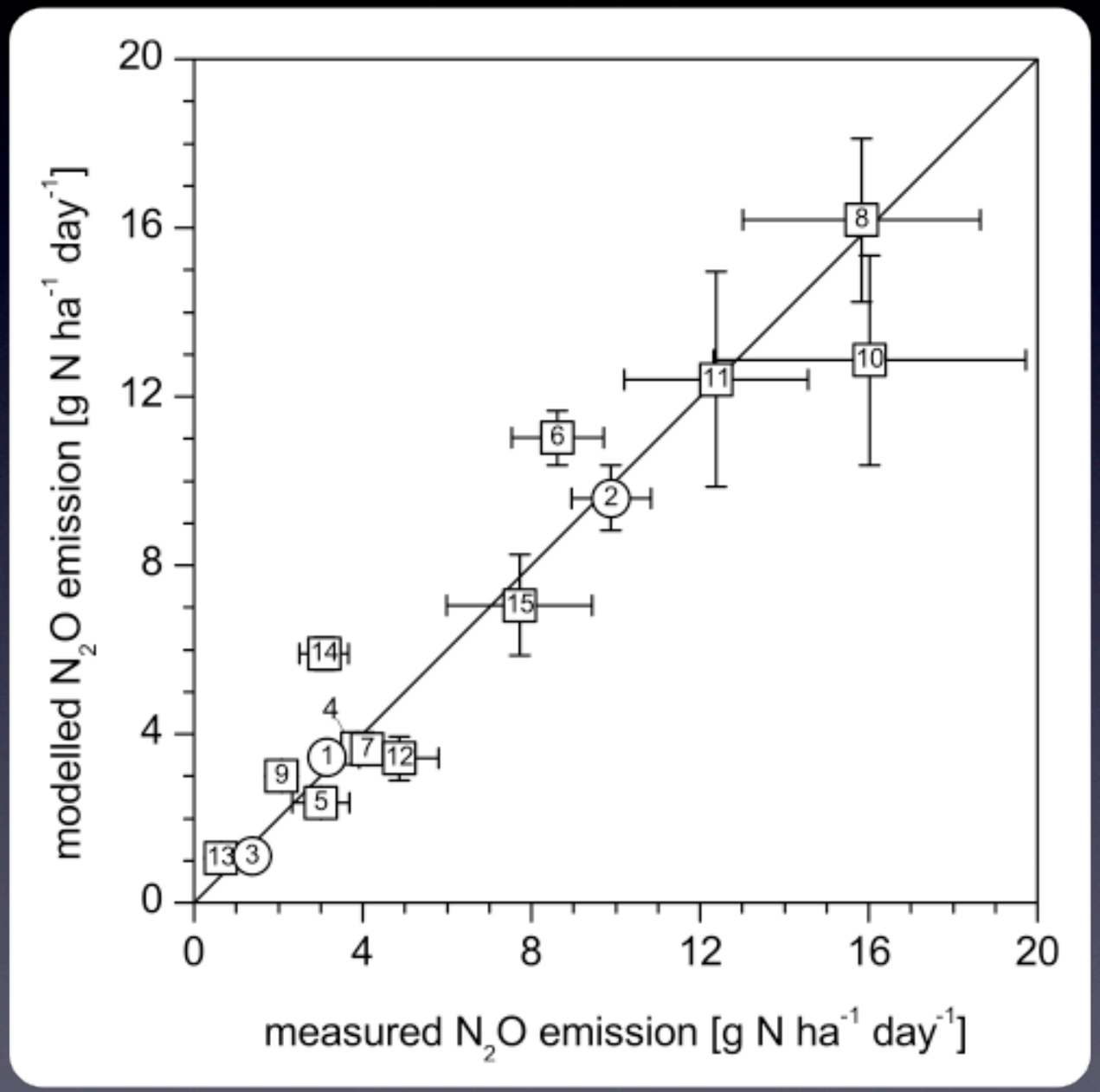


source:
Werner et al.
(2007) GBC

Model applications

Example applications of the DNDC models

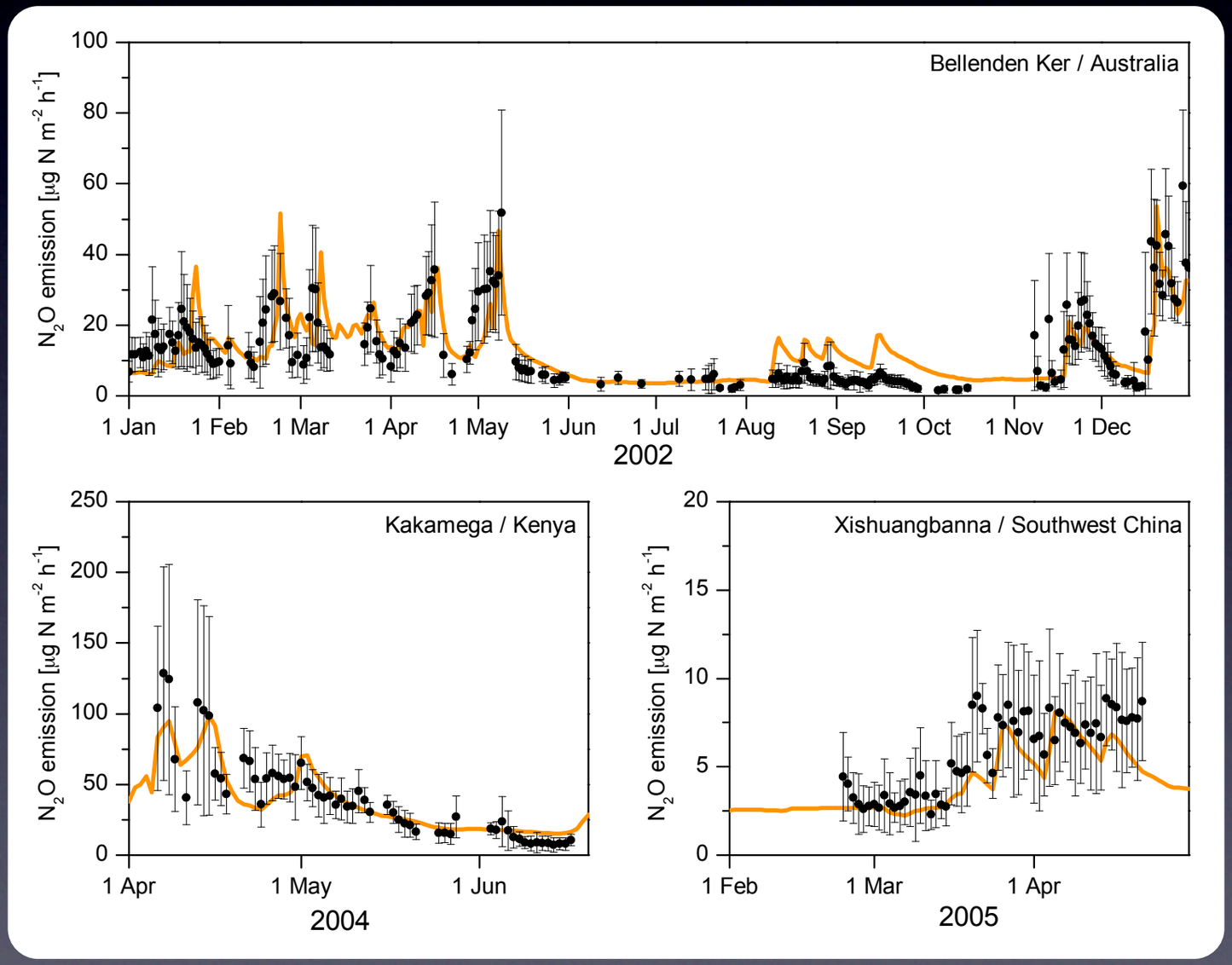
Data requirements (DNDC family)

	required	optional
climate	daily precip., temperature	radiation, N deposition
soil	texture, SOC, pH, BD,	gravel
vegetation	species, age	biomass, DBH
management		fertilizer, timing, etc.

Site simulations

Modelling site properties and fluxes

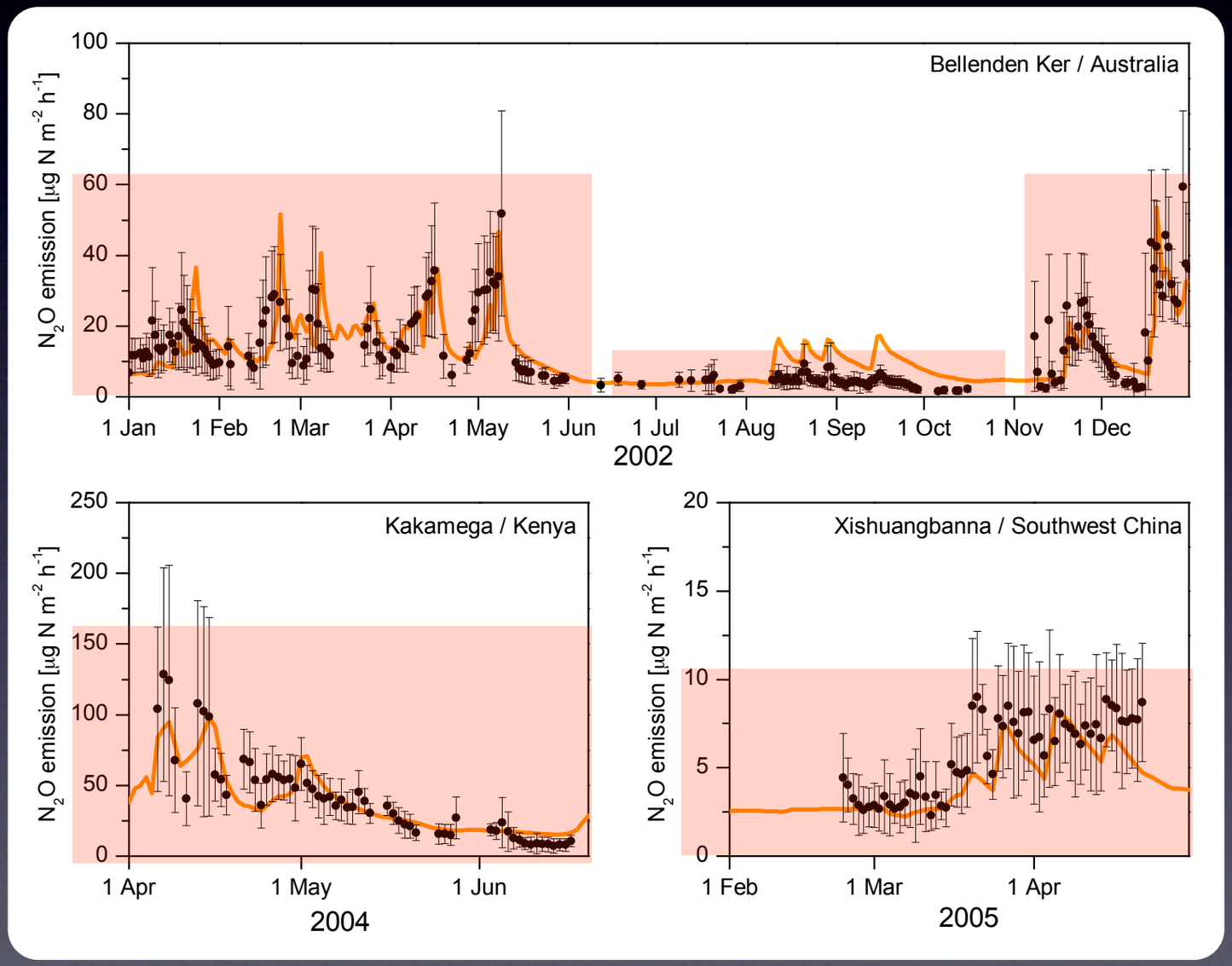
The „base emission“



sandy soils
low substrate

source:
Werner et al.
(2007) GBC

The „base emission“



sandy soils
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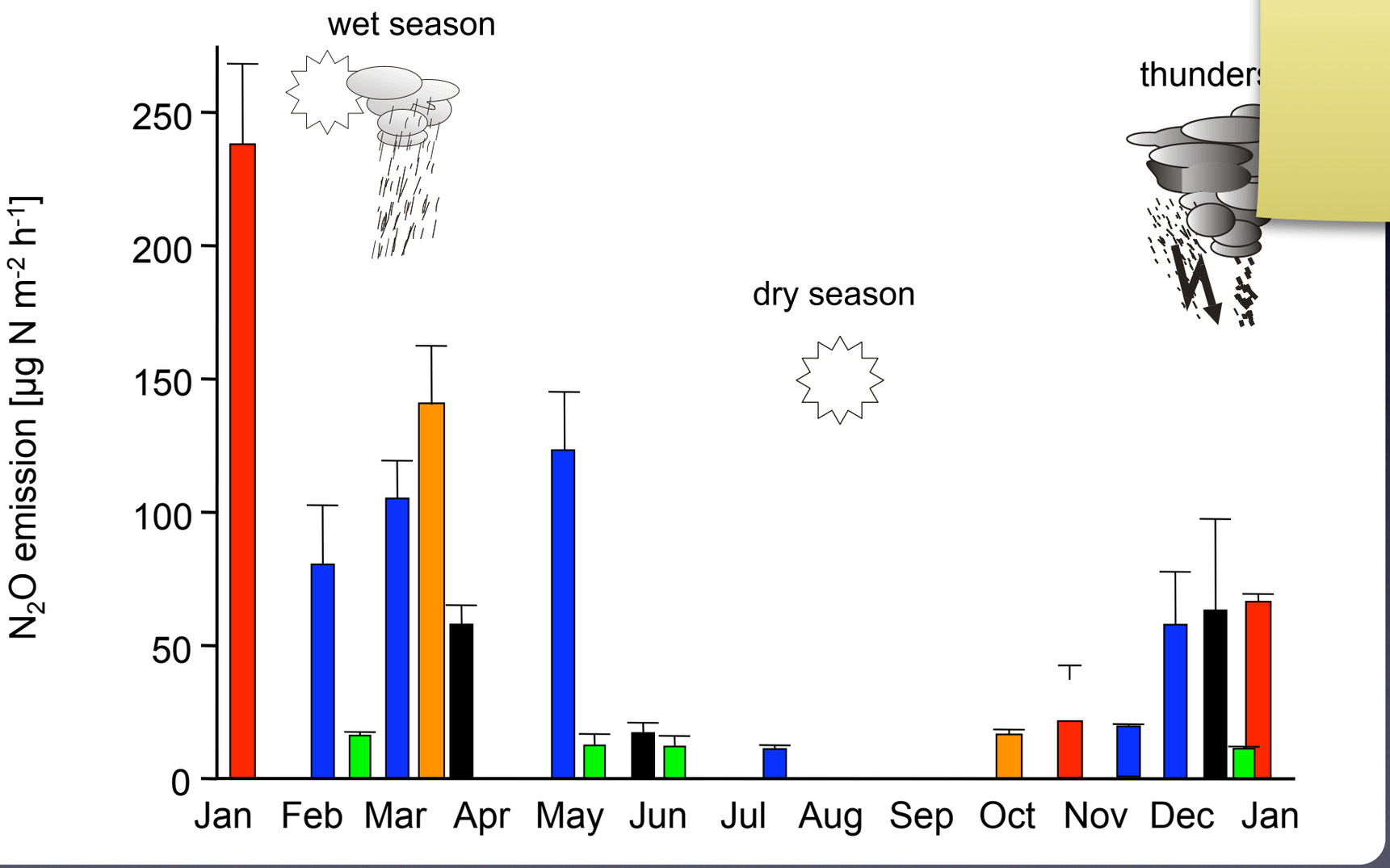
Werner et al.
(2007) GBC

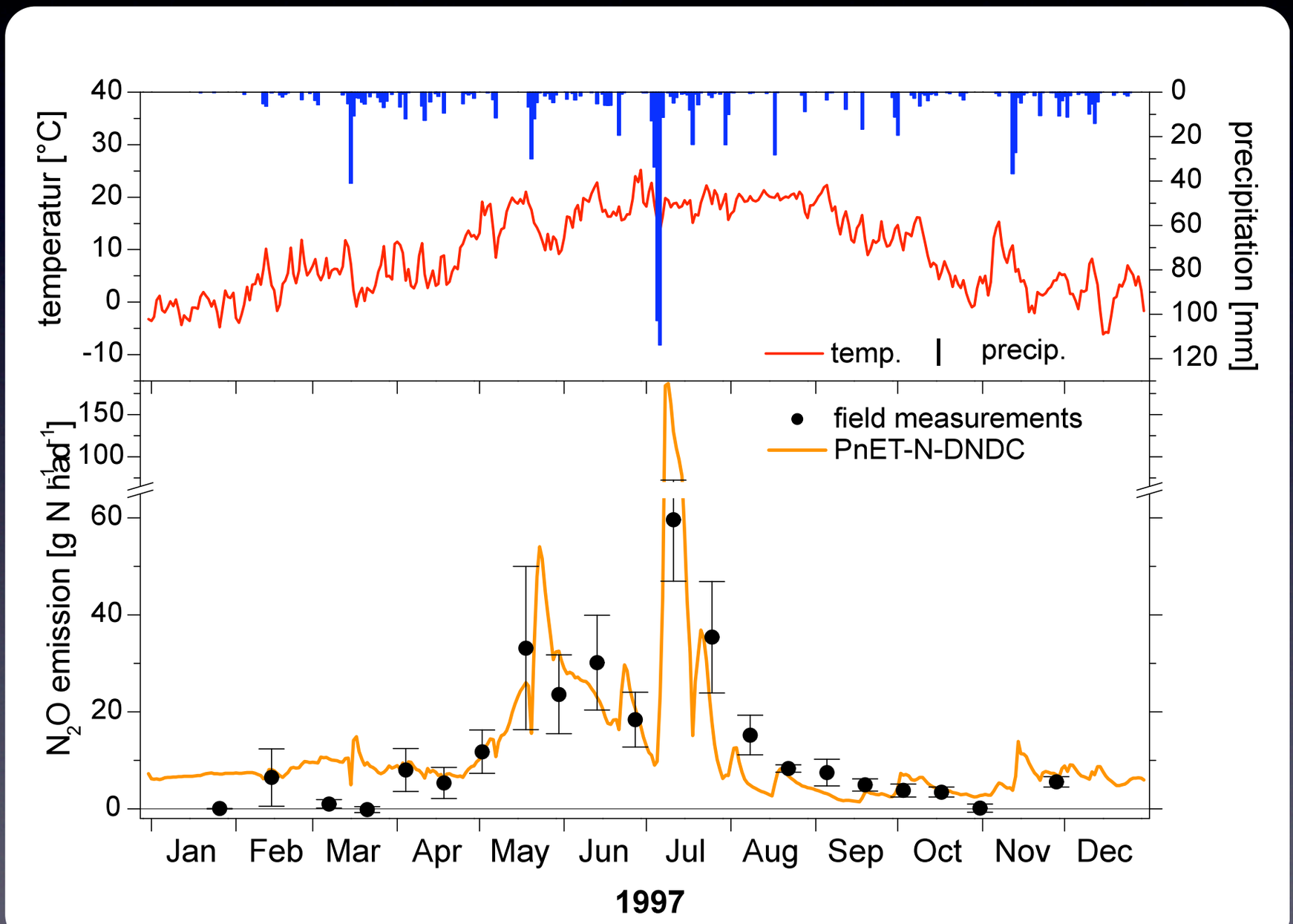
Seasonal dynamics

Quelle ?



data:
Kiese et al.
(2003) GBC

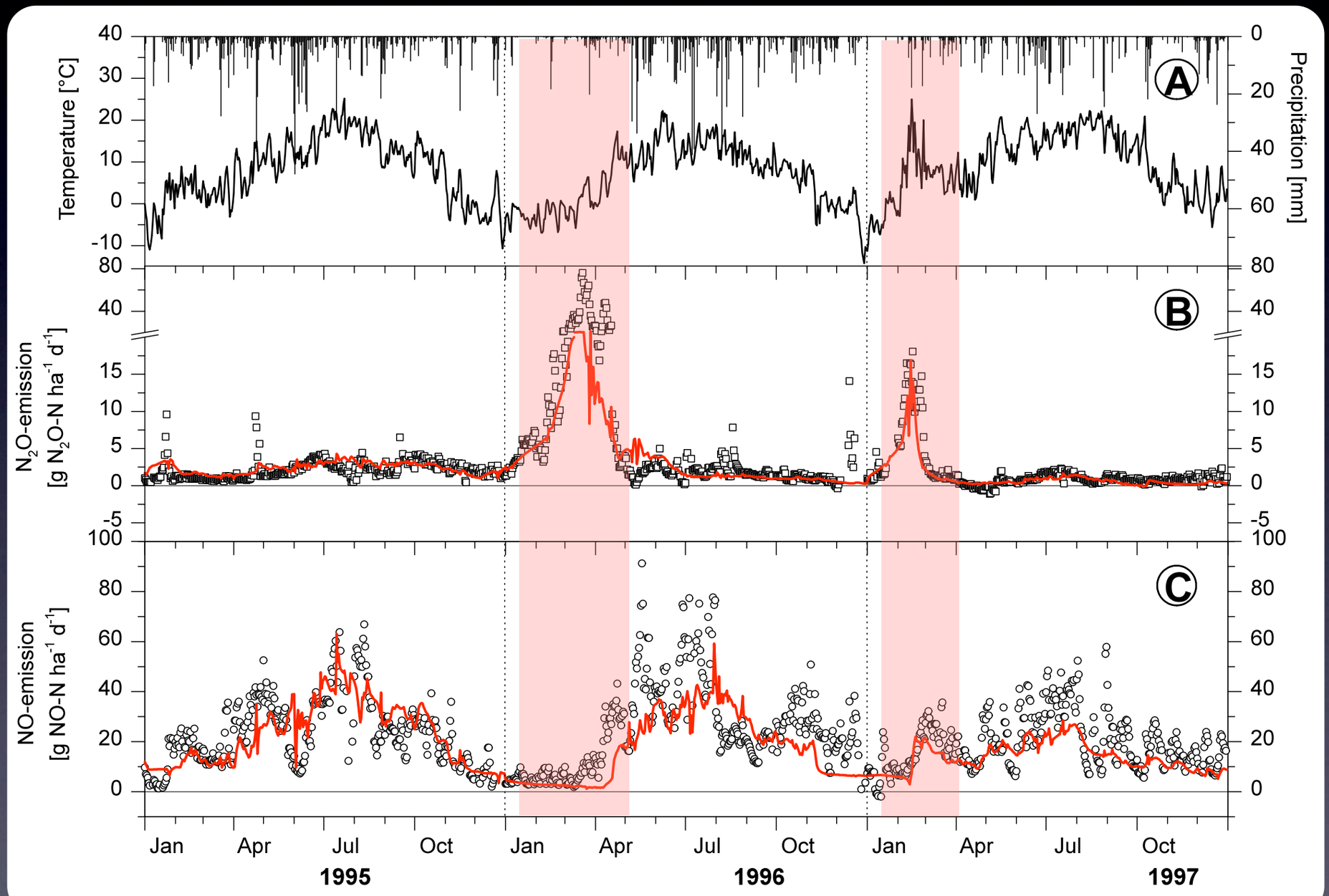
Weather dynamics



Schottenwald, Austria

data: Zechmeister-Boltenstern & Meger (1997)

Freeze-thaw events



source: Papen & Butterbach-Bahl (1999) JGR

Lessons for future measurements?

- Where should we measure next?
- What else to measure?
- How frequent should we measure?
- ...

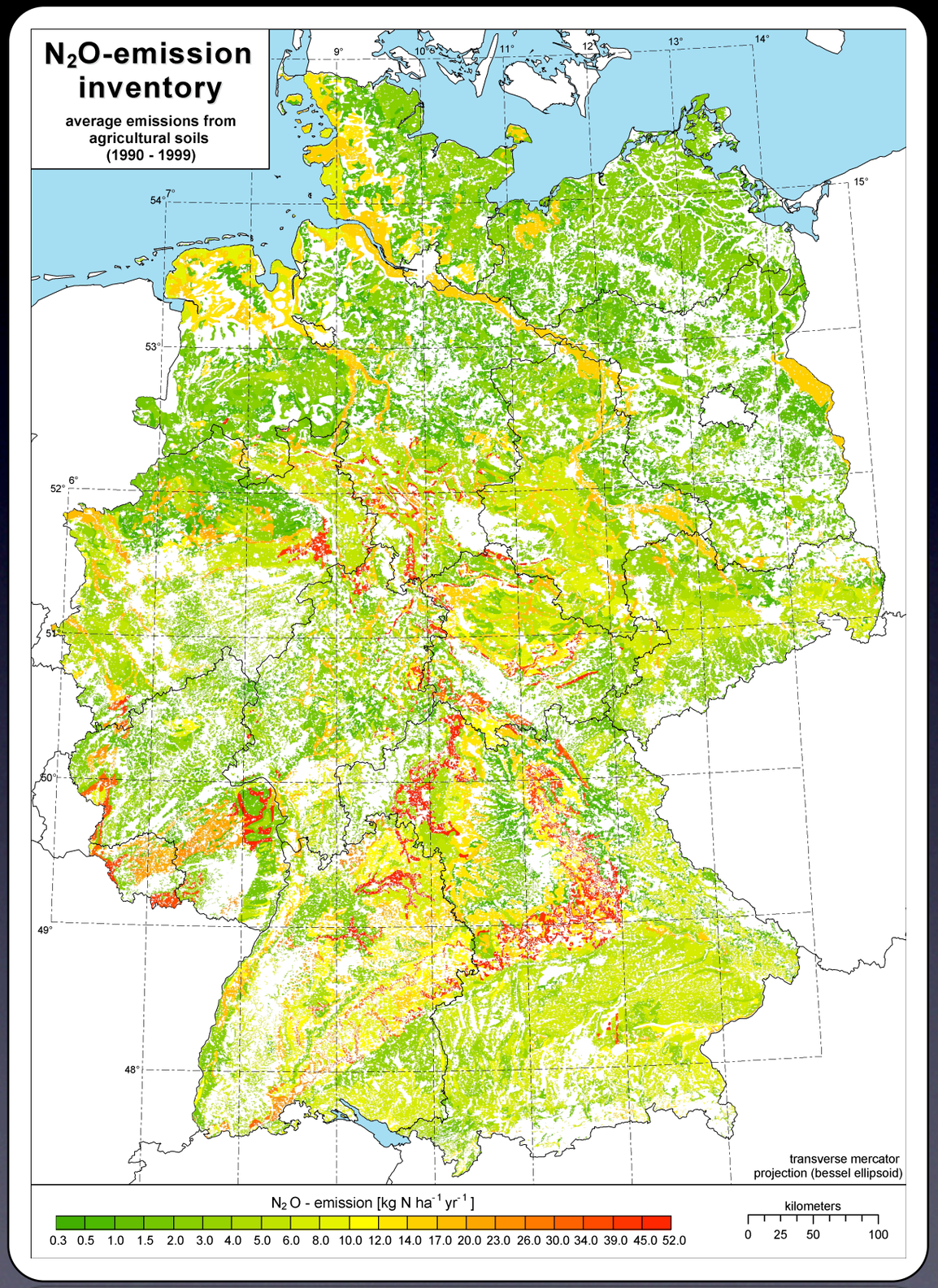
Emission inventories

From regional to global scales

Example 1

National scale inventory
N_2O emissions of forest soils of Germany

source:
Butterbach-Bahl & Werner (2003)
UBA FE20012257



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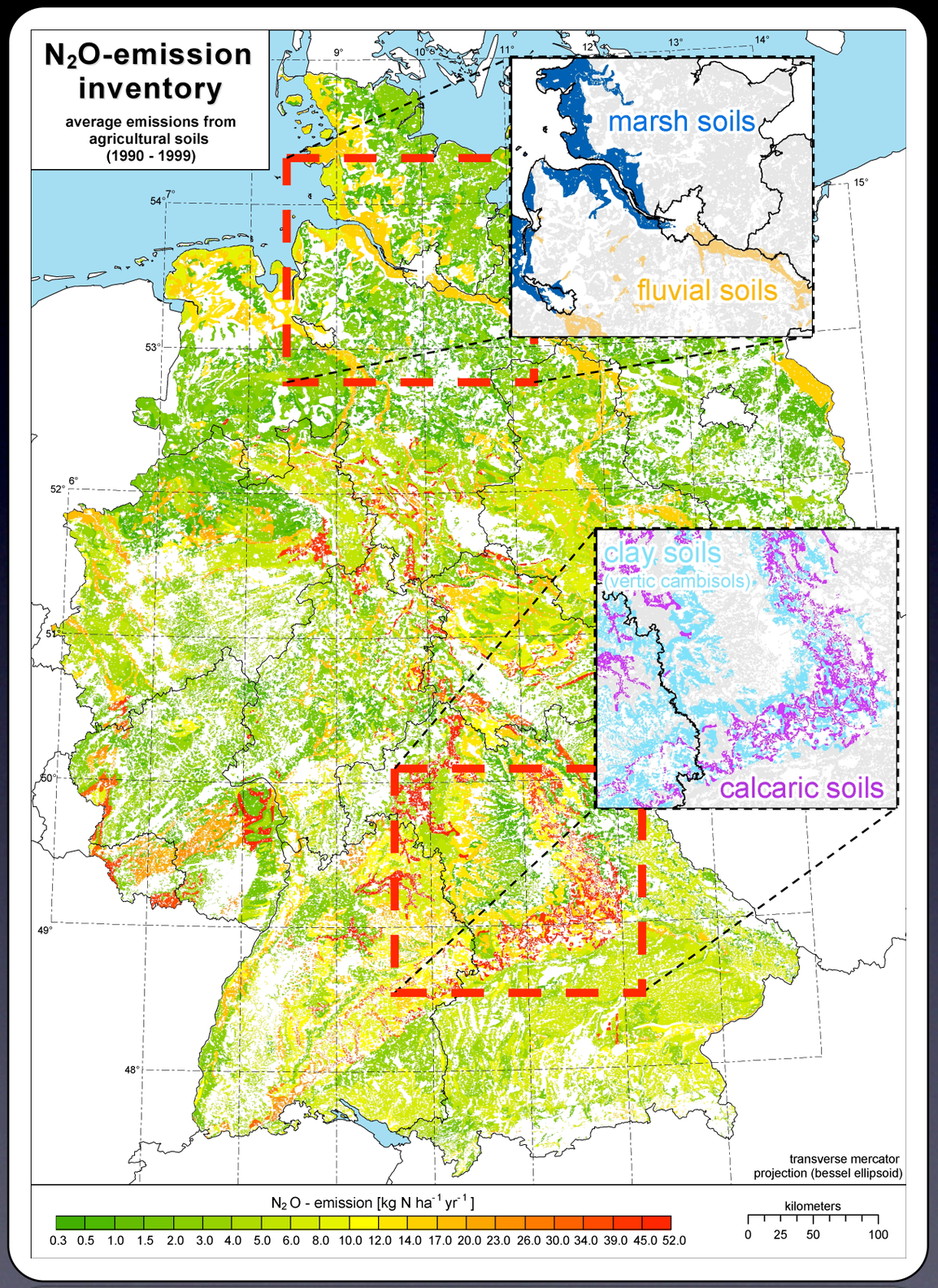
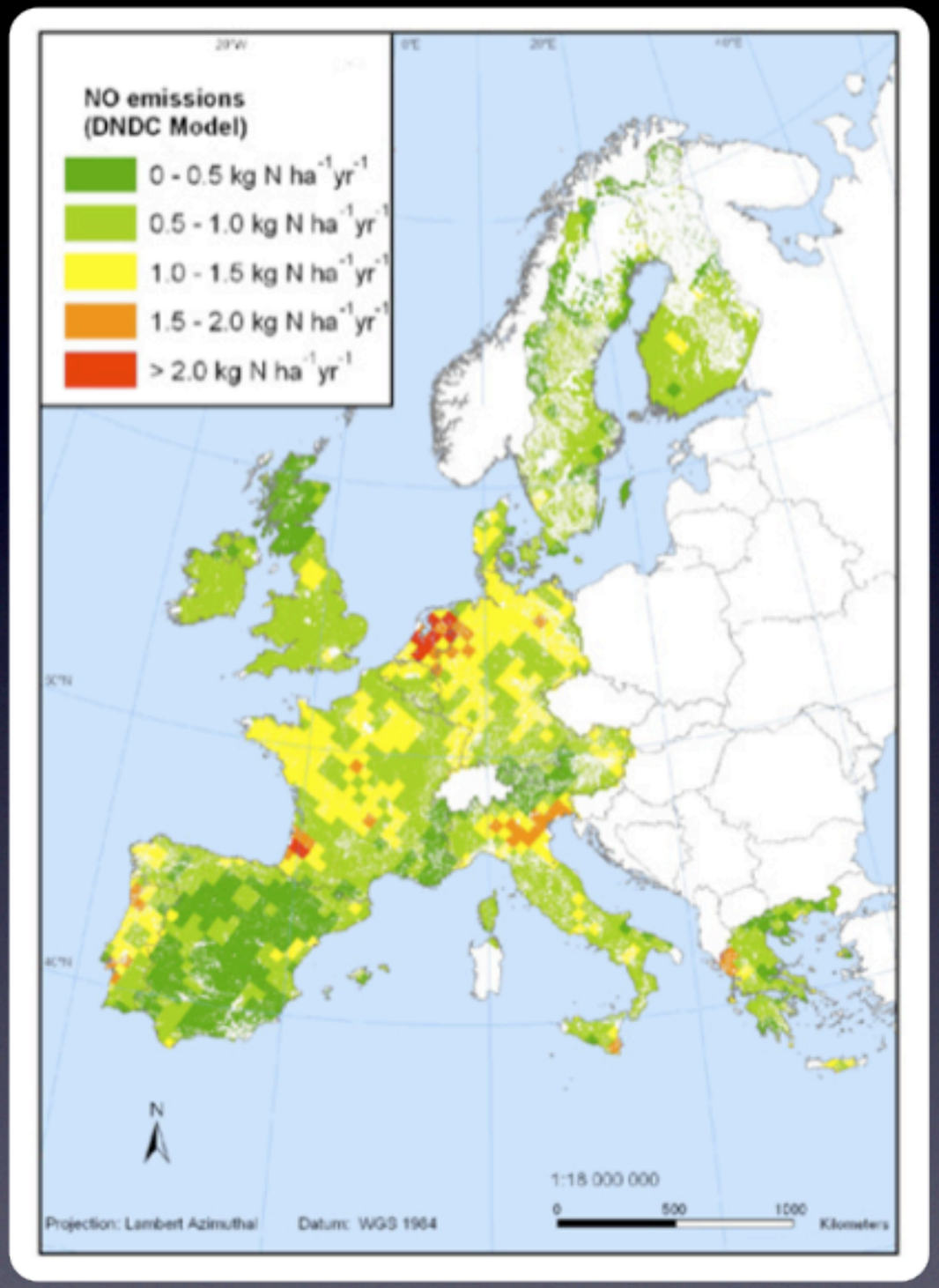


Example II

Continental scale
NO emissions from arable soils
of Europe

source:
Butterbach-Bahl et al. (2008)
Atmos. Environ.



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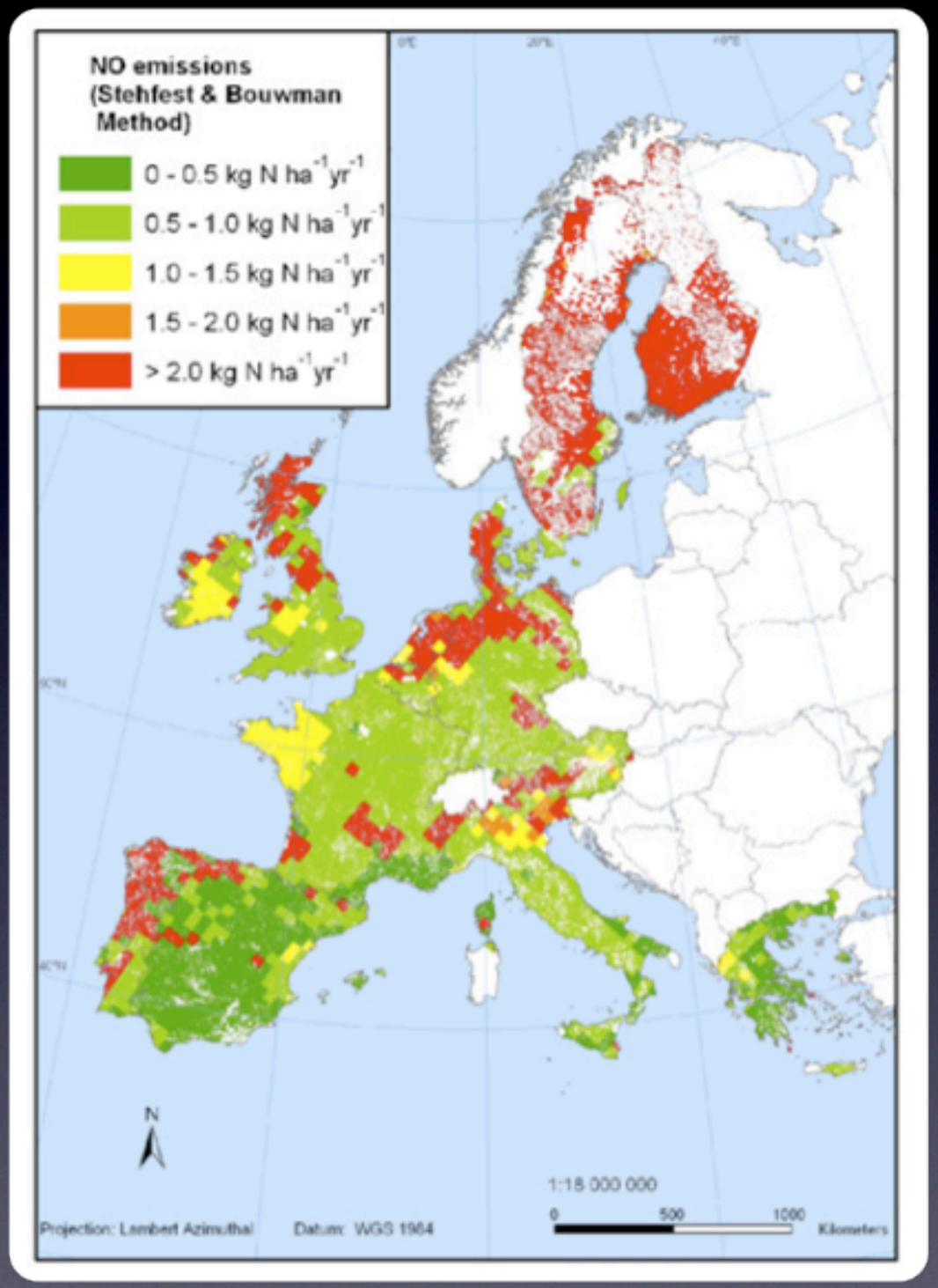
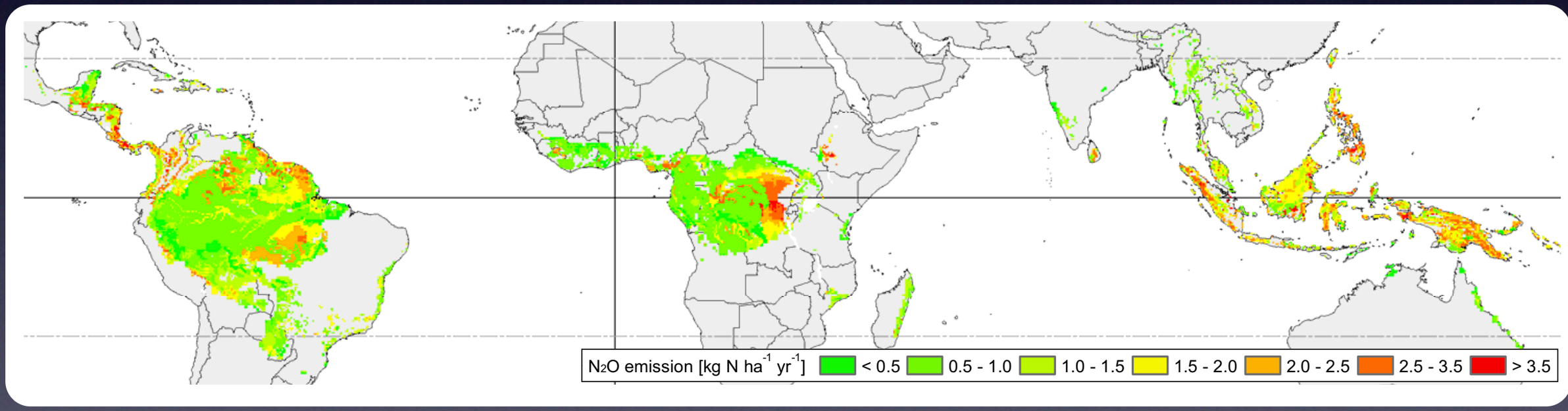


Example III

Global scale
N_2O emissions from tropical
rainforest soils world-wide

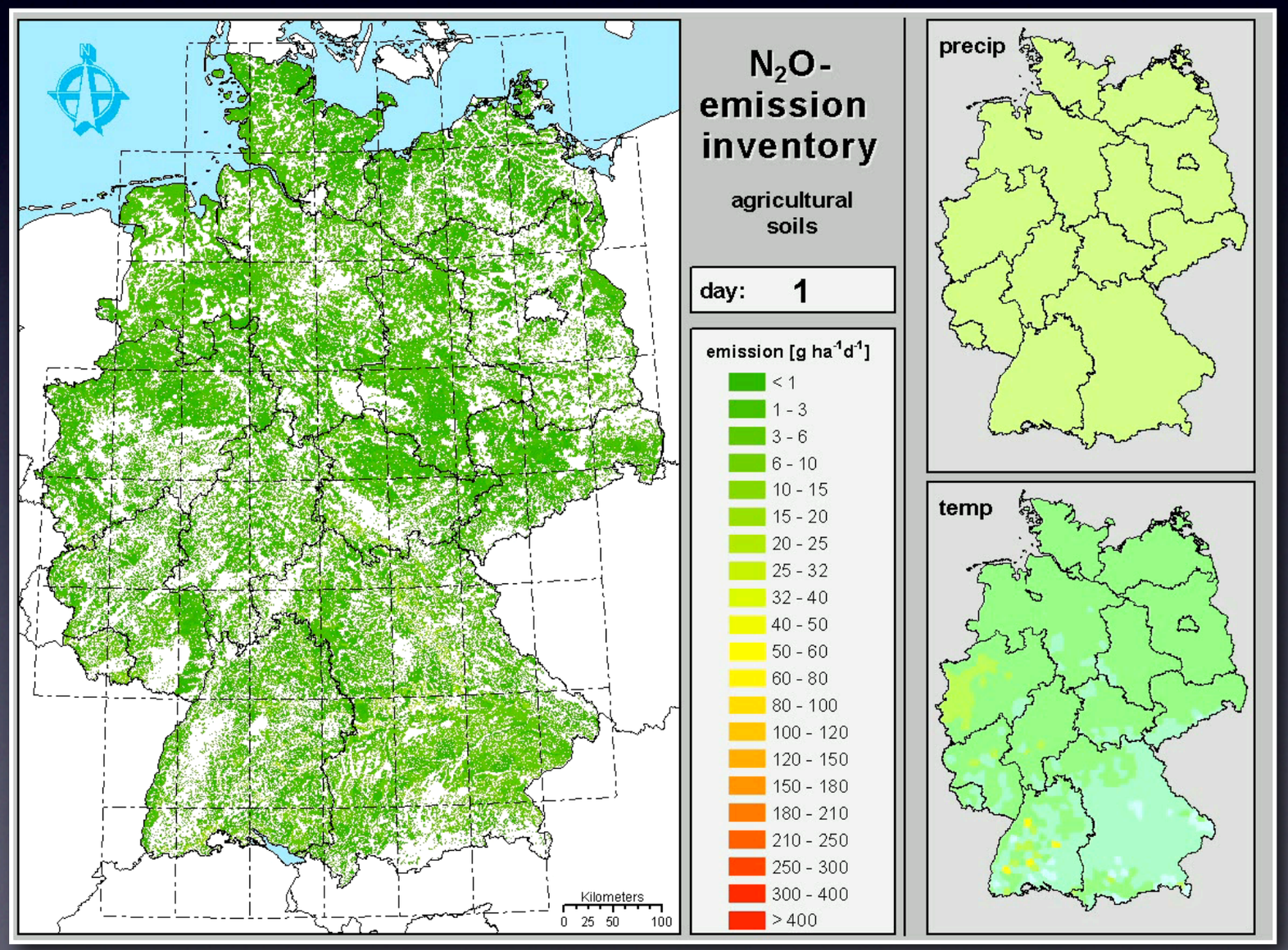


source: Werner et al. (2007) GBC

Regional emission dynamics

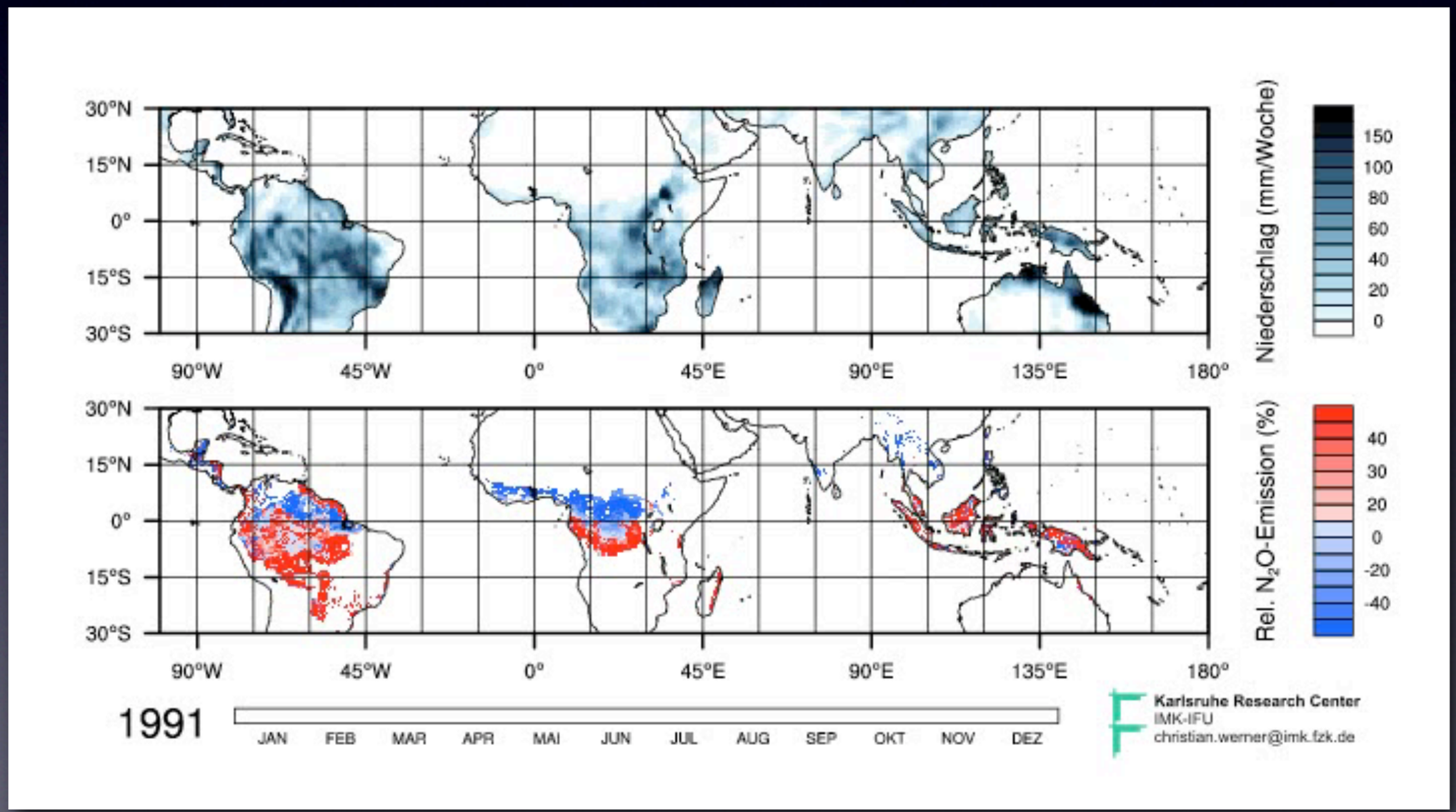
Inventories change!

Seasonal N_2O emissions of Germany

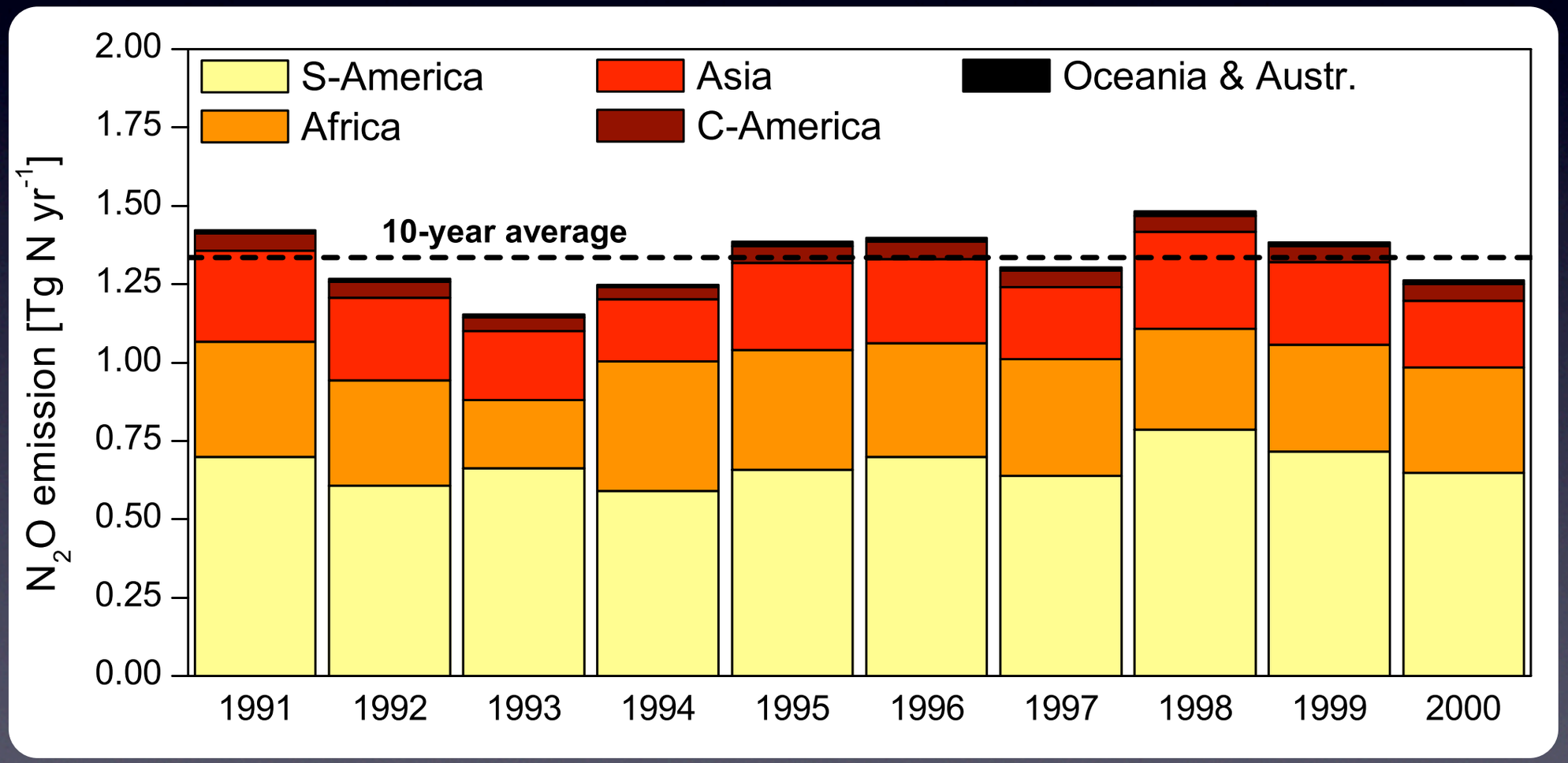


arable land
1995

Seasonality of N_2O emissions in the tropics



Annual variability at continental scales



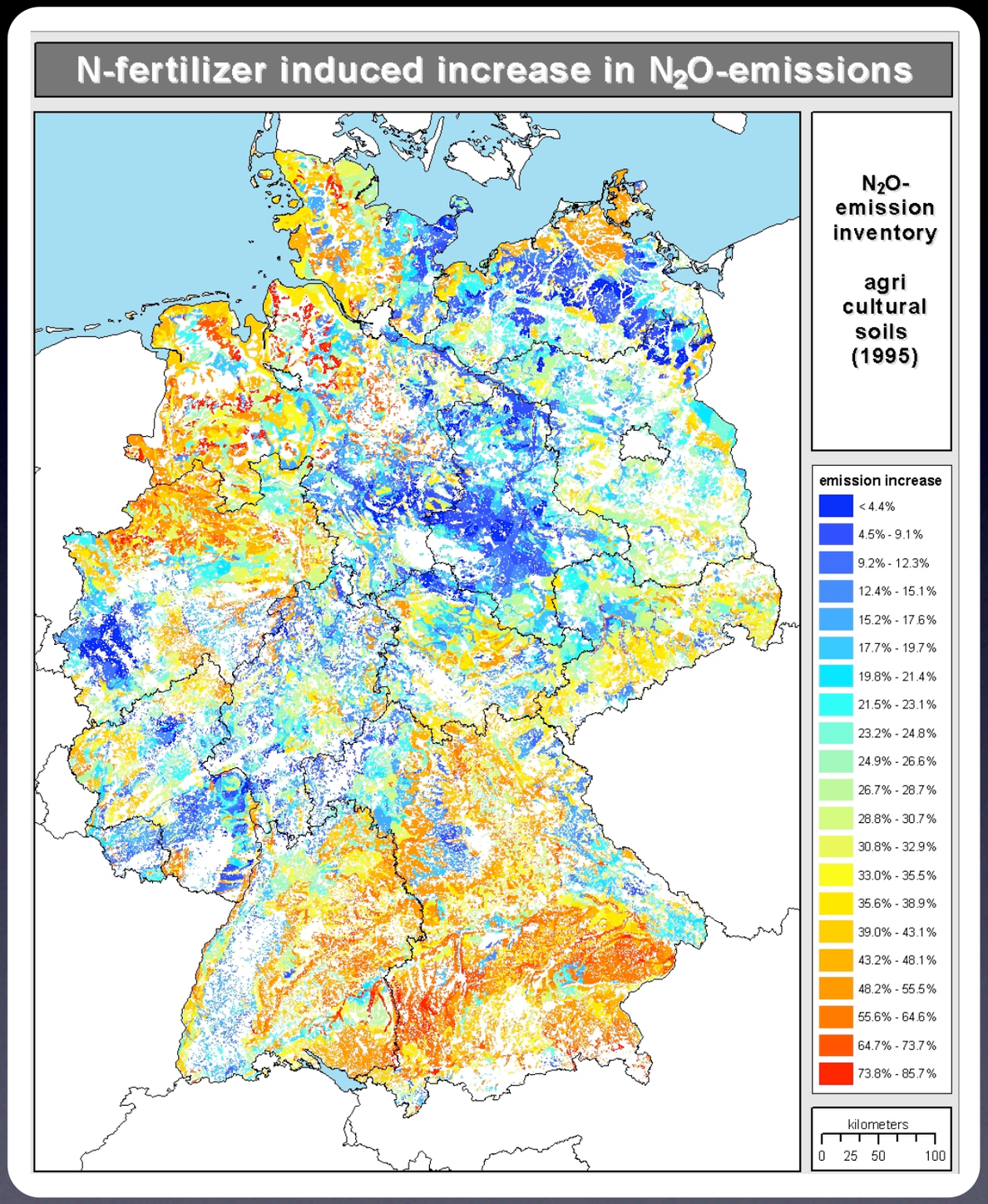
source: Werner et al. (2007) GBC

Simulating scenarios and future trends

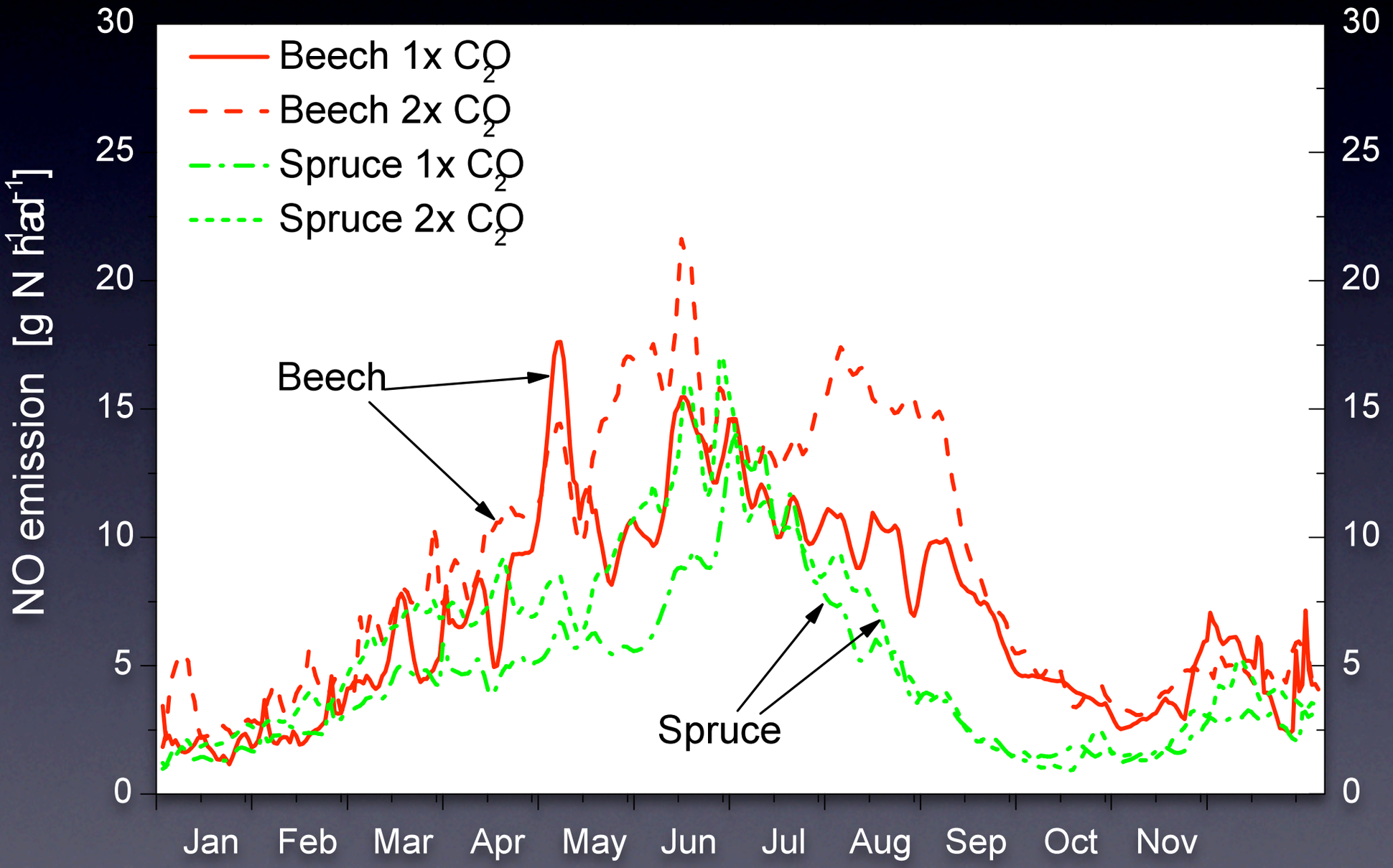
No-fertilizer scenario

Comparisson of regular and non-fertilized management on N_2O emissions

source:
Butterbach-Bahl & Werner (2003)
UBA FE20012257



Effect of 2xCO_2

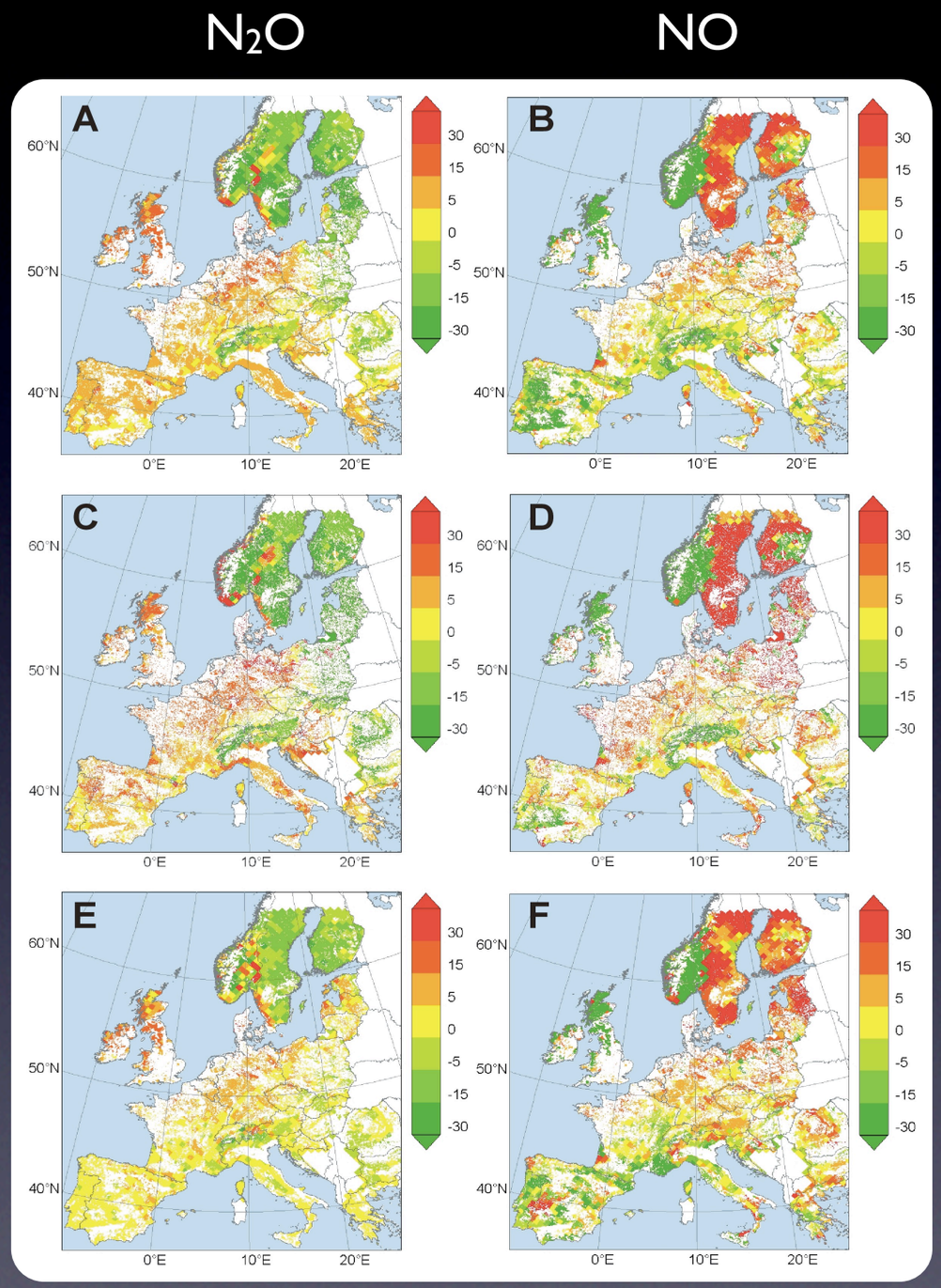


source: Butterbach-Bahl et al. (2000) in: Non-CO_2 Greenhouse gases, Kluwer

Future climate predictions

Changes of N_2O/ NO emissions in future climates

source:
Kesik et al. (2006)
JGR - Biogeosciences



Coupled modelling

Integration of biogeochemical models into larger model frameworks

Common problems

- monolithik model structure
- duplicate functions in models
- continous data exchange
- temporal synchronization
- computational demand

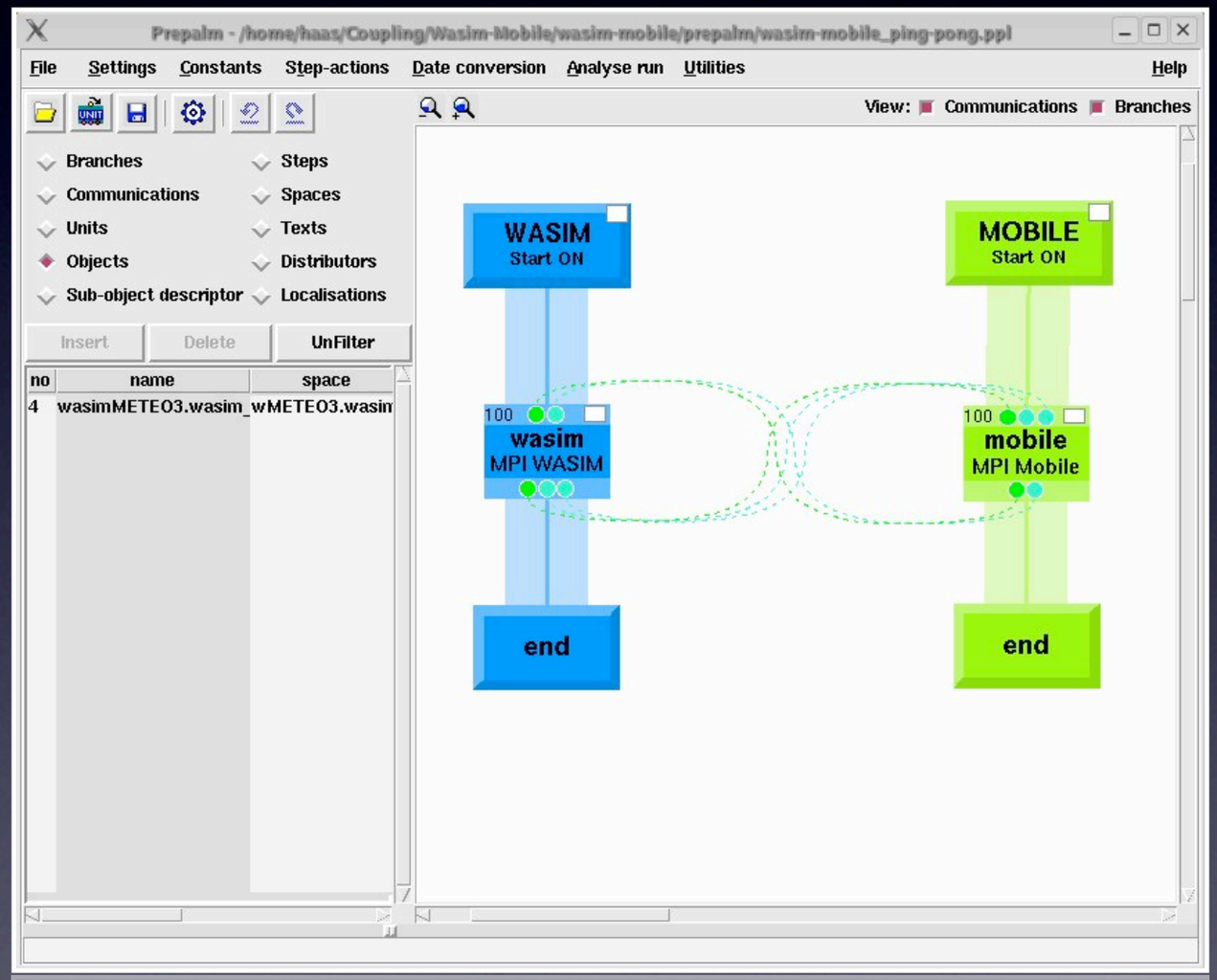
MOBILE

- functional sub-models, e.g.: (physicsDNDC, plantgrowthDNDC, soilchemistryDNDC, ...)
- free combination of different sub-modules
- flexible time stepping
- code cleanup !

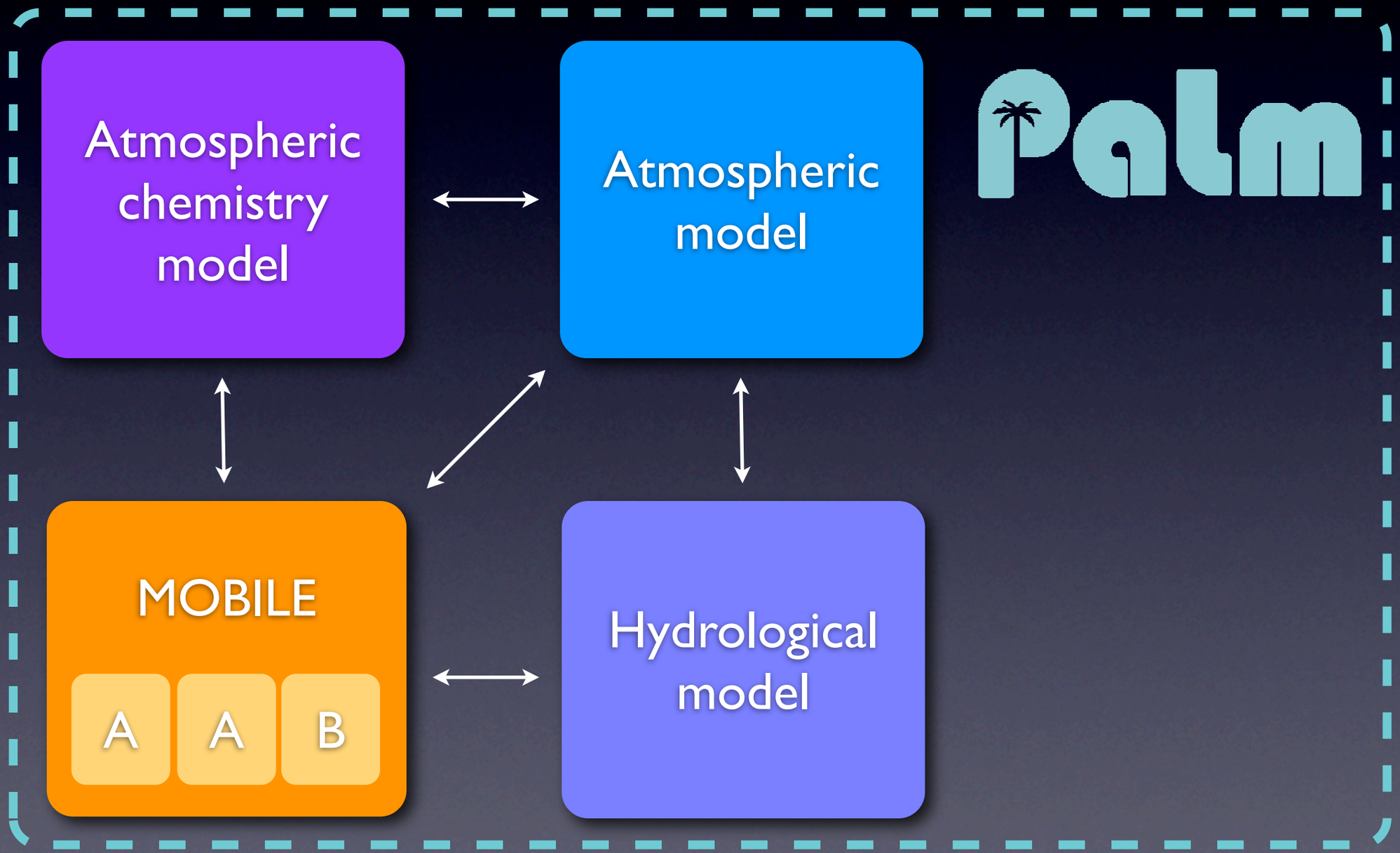
Dynamic coupling

Palm

- run models in parallel
- flexible data exchange
- fast & free



The future (?)


Atmospheric chemistry model
Atmospheric model
PALM
MOBILE
A
A
B
Hydrological model