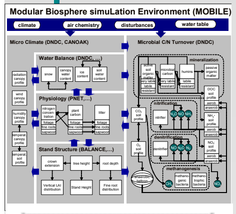
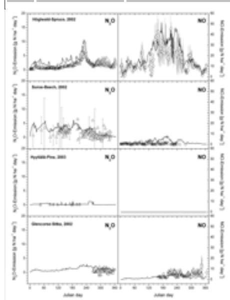
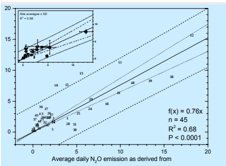
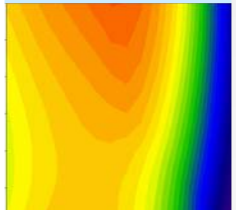
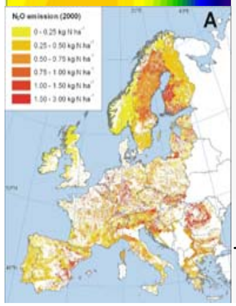


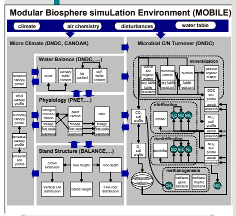



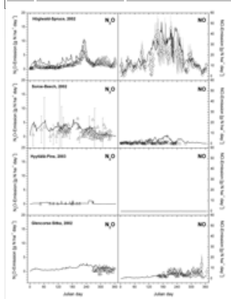

**Klaus Butterbach-Bahl**

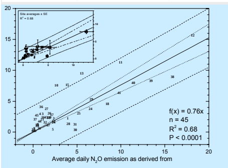
Forschungszentrum Karlsruhe
Institute for Meteorology and Climate Research (IMK-IFU)
Germany

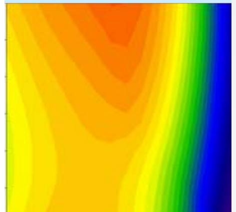
# NitroEurope - Component 3

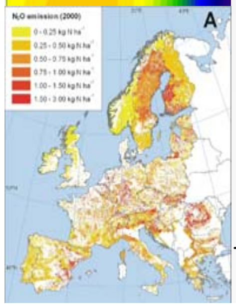
# The application of plot-scale models to interpret N and GHG exchange processes









## Complexity of biosphere-atmosphere GHG exchange

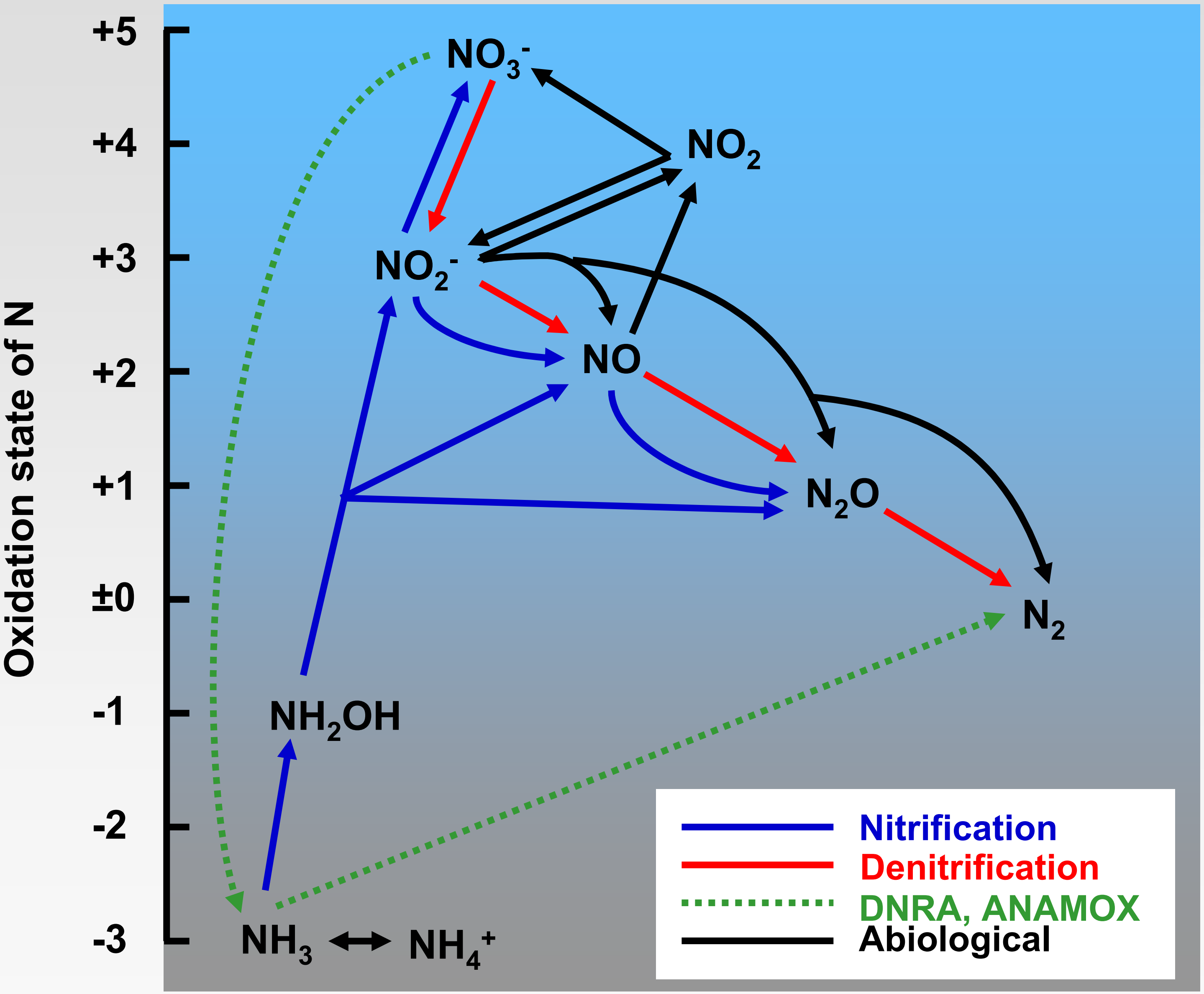
NitroEurope IP

- Biosphere-Atmosphere exchange processes are driven by interacting physico-chemical and biological processes, e.g.:
  - Energy transfer, water fluxes, redox potential,
  - C and N assimilation mainly by plants and microbes,
  - C and N dissimilation (e.g. microbial mineralisation),
  - Interacting oxidation-reduction processes, substrate displacement, diffusion etc.

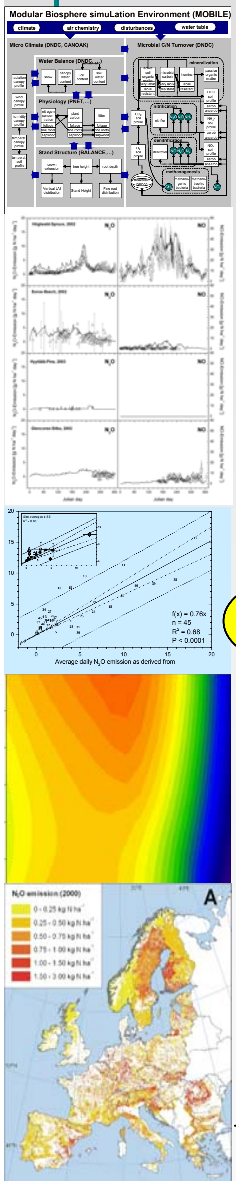
- Processes are occuring on different temporal and spatial scales (e.g. rhizosphere processes versus landscape processes).

- Biosphere-Atmosphere exchange processes are bi-directional (also with regard to gaseous N compounds).

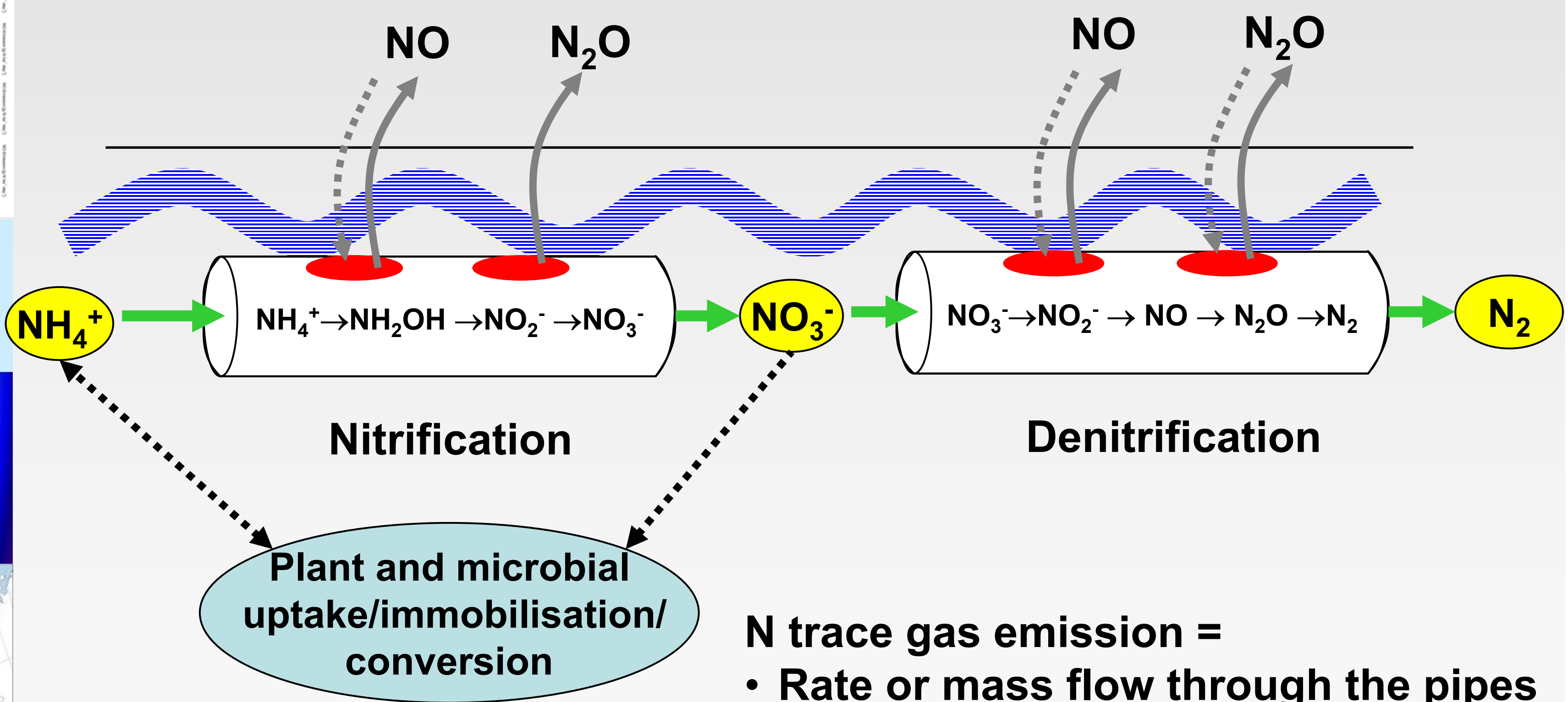
# Complexity of inorganic N reactions



# Rational for the development of plot models




- System understanding
- Identification of key processes driving CN turnover and coupled biosphere-atmosphere exchange
- Generalisation/ simplification



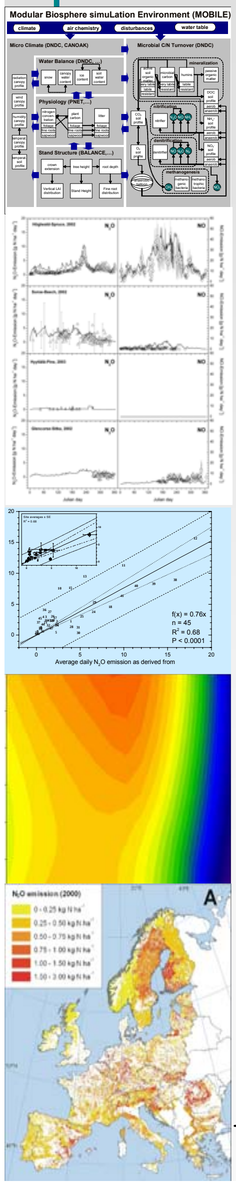

**N trace gas emission =**

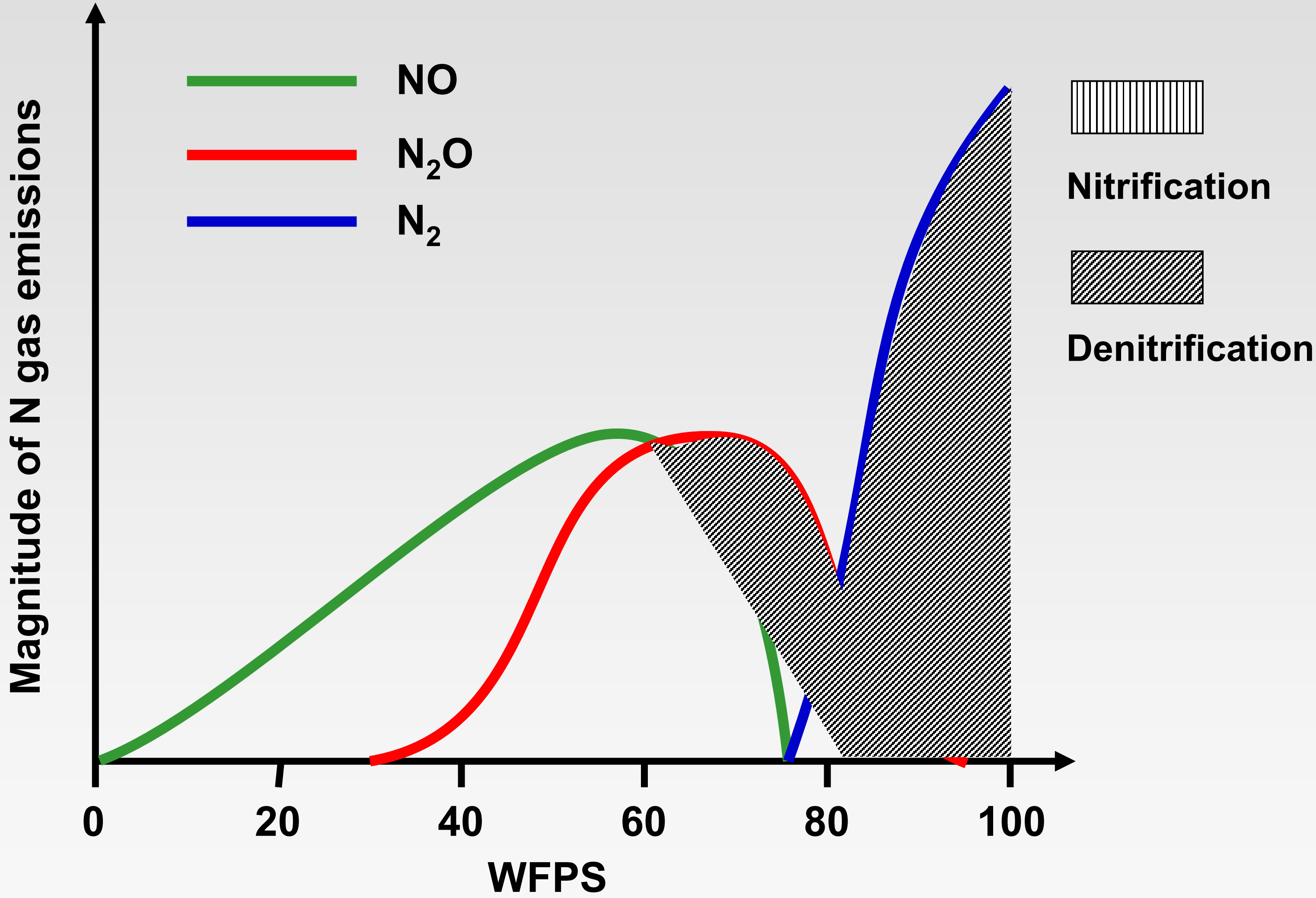
- **Rate or mass flow through the pipes**
- **Leaks through holes**

Davidson et al., 1993, 2000

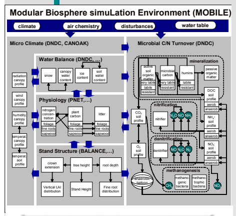
NitroEurope IP

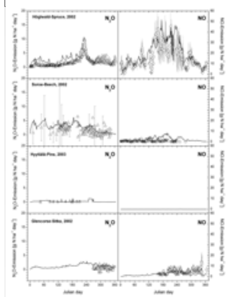
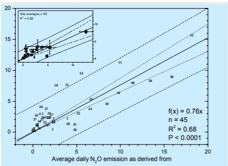
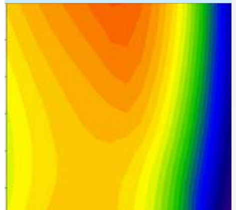
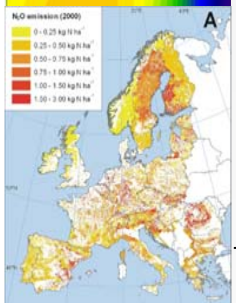
# Effect of soil moisture on N gas emissions

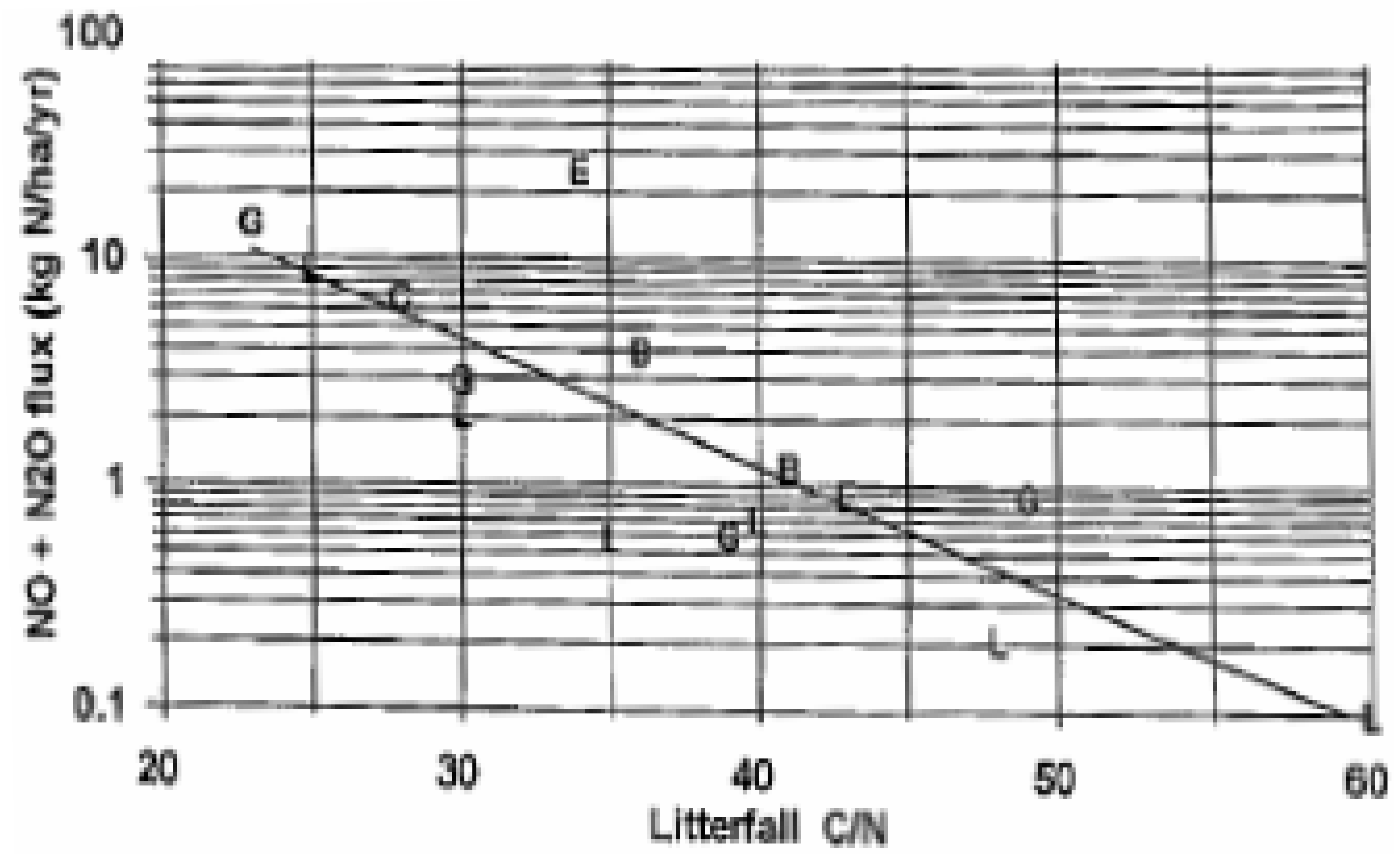




# Using proxis to estimate ecosystem $N_2O$ fluxes

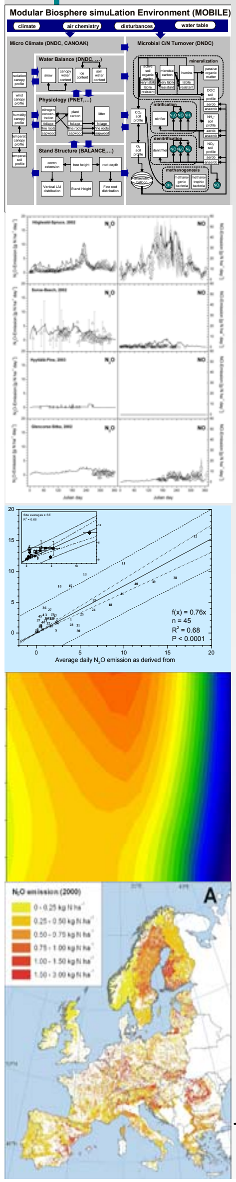


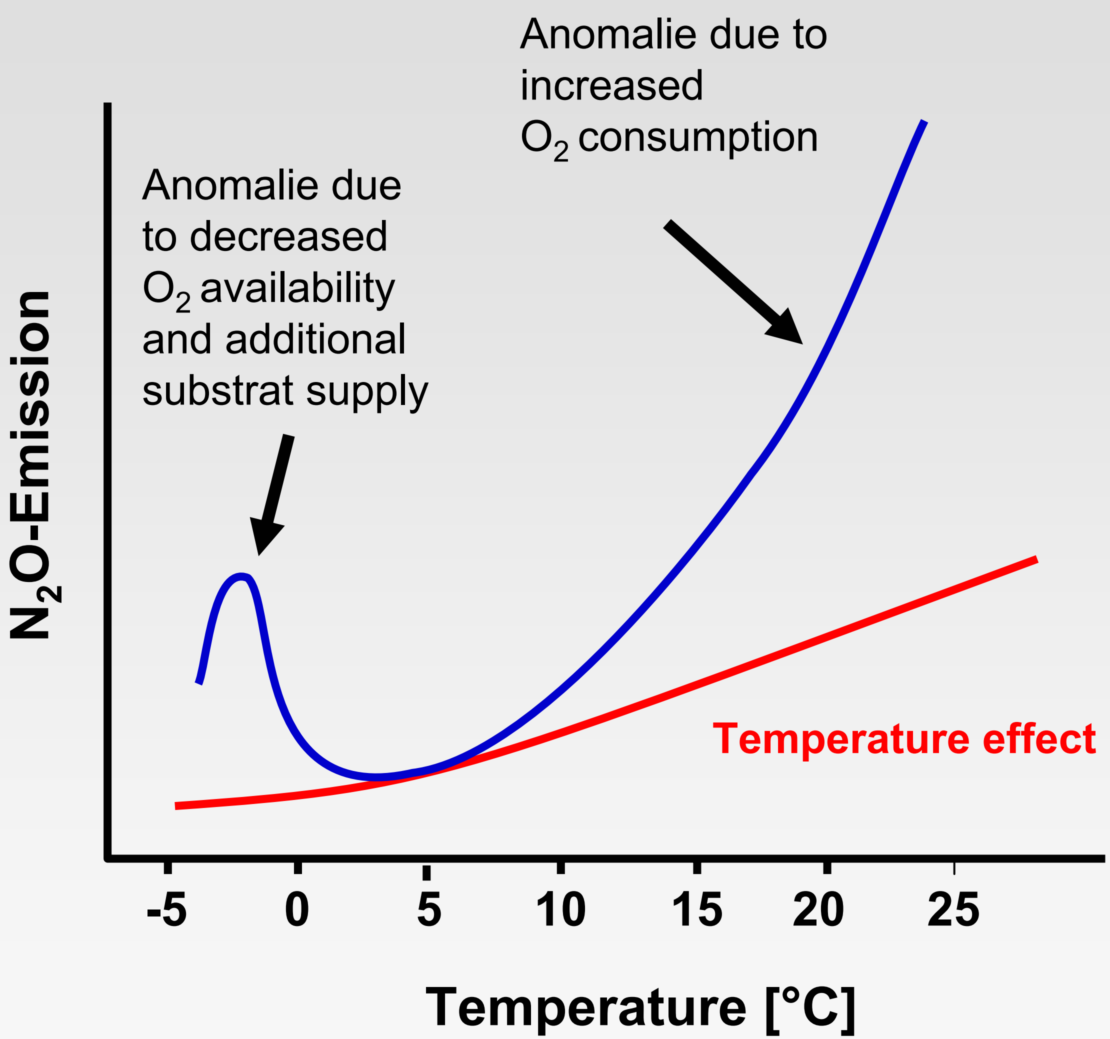


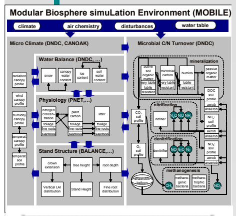

Sum of annual estimates of NO+$N_2$O emissions as a function of litterfall charasteristics.

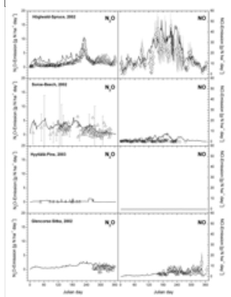
Davidson et al., 2000, BioSciences

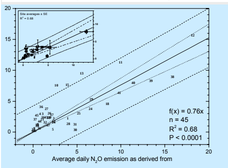


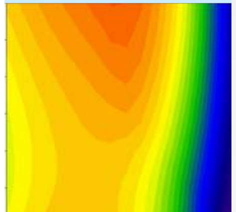
# Soil $N_2O$-emissions and temperature

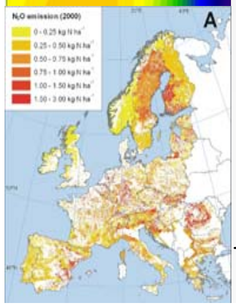


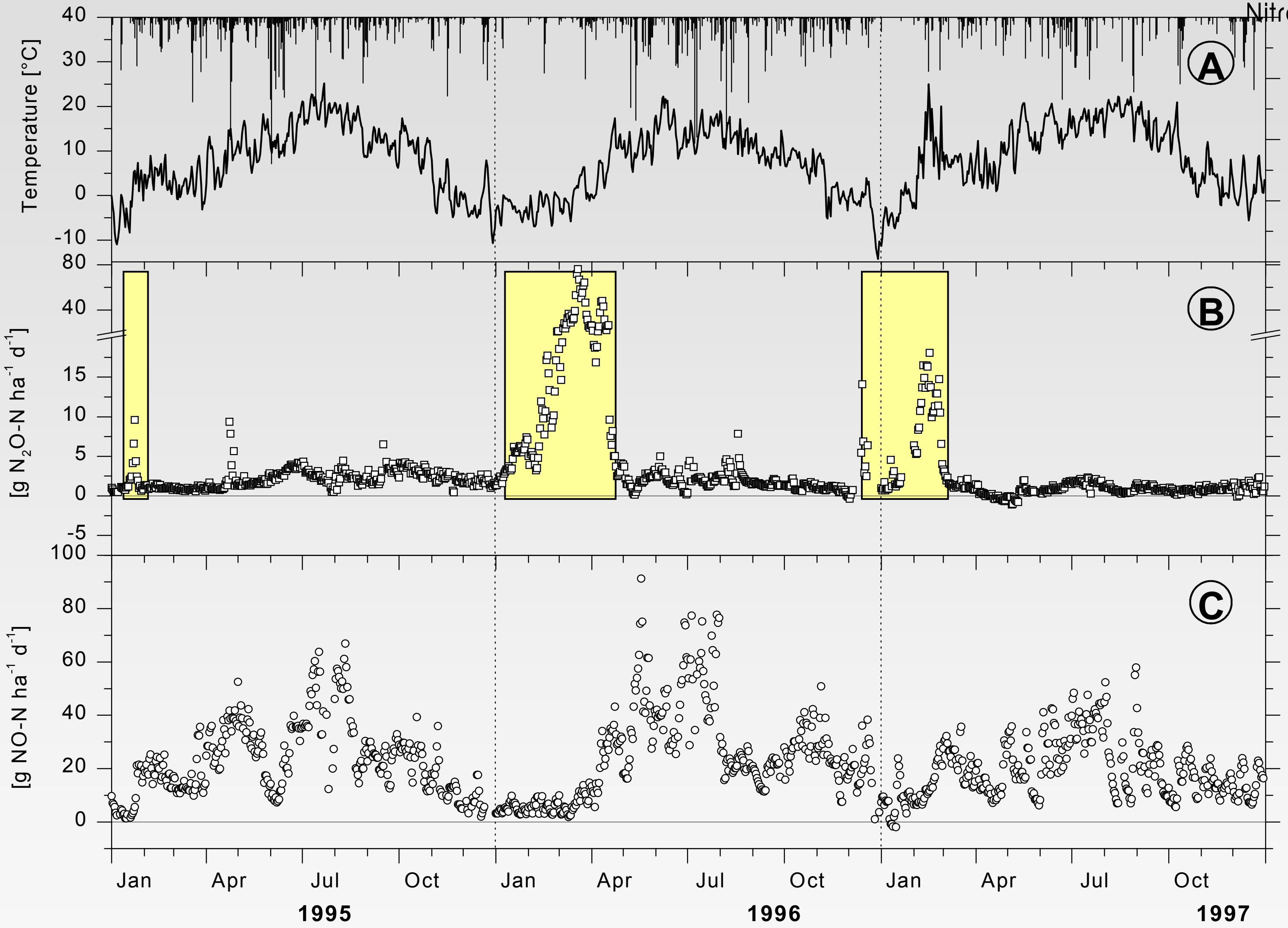




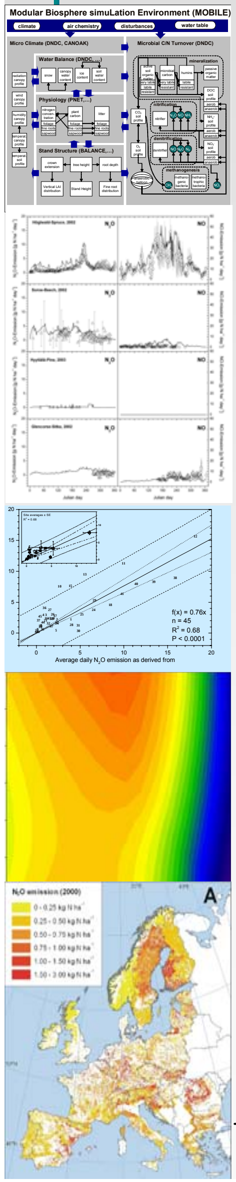


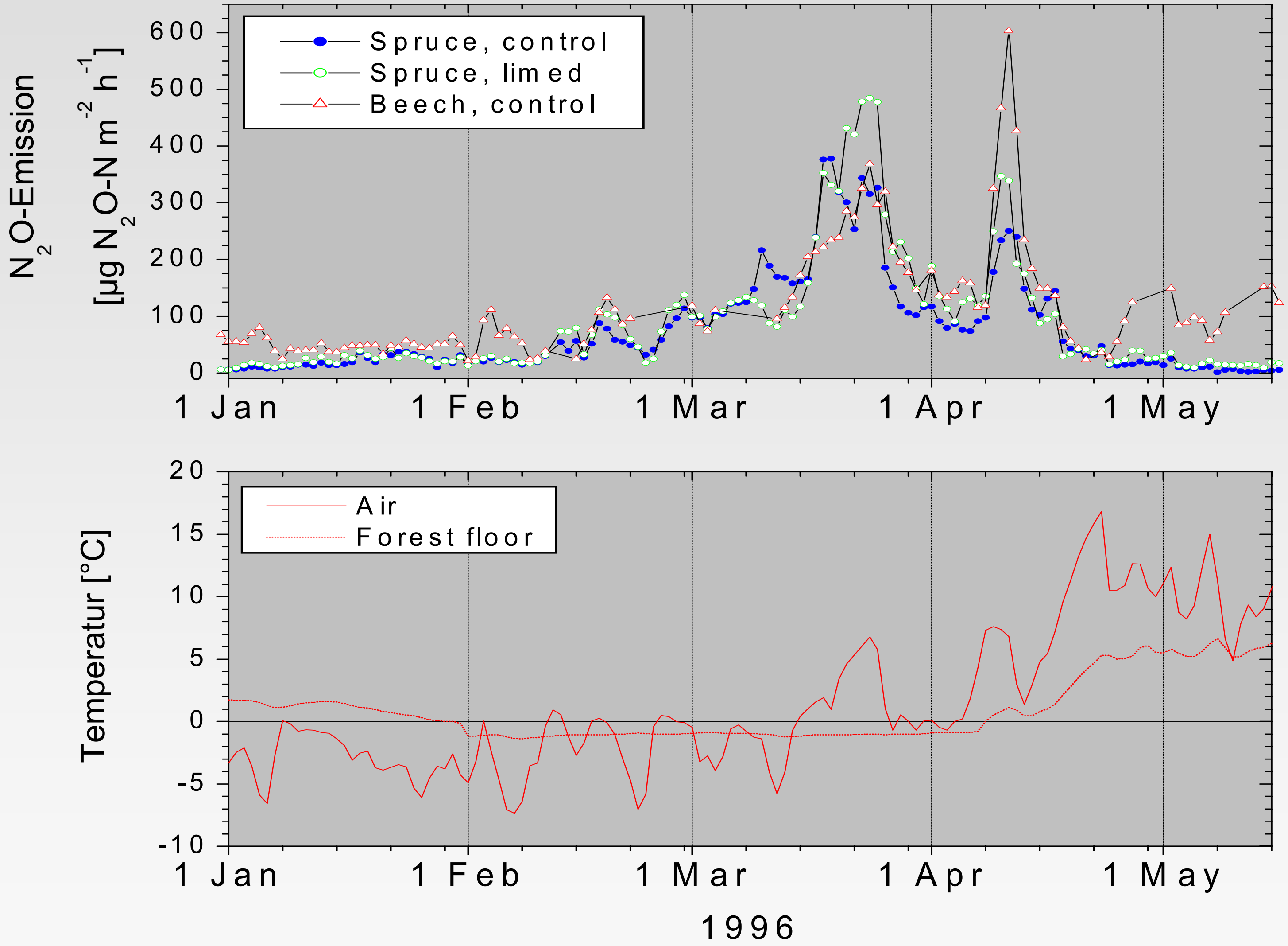




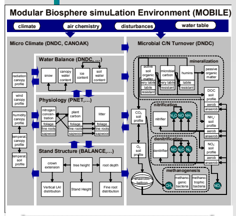


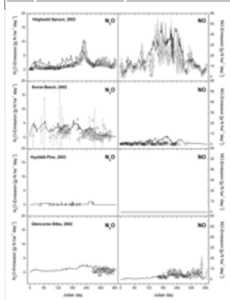
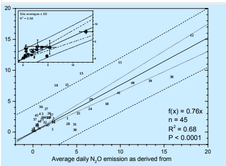
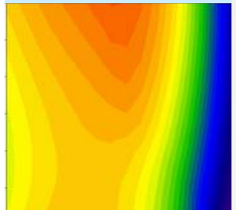
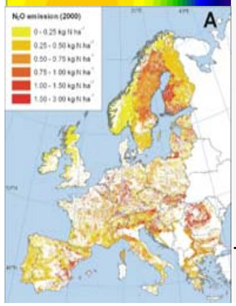

Papen and Butterbach-Bahl, JGR 104, 18487-18503,1999; Butterbach-Bahl et al.,JGR 106, 34155-34166, 2001





Spruce, control
Spruce, limed
Beech, control
$N_2O$-Emission
[µg $N_2O$-N $m^{-2}$ $h^{-1}$]
0
100
200
300
400
500
600
1 Jan
1 Feb
1 Mar
1 Apr
1 May
Air
Forest floor
Temperatur [°C]
-10
-5
0
5
10
15
20
1 Jan
1 Feb
1 Mar
1 Apr
1 May
1996



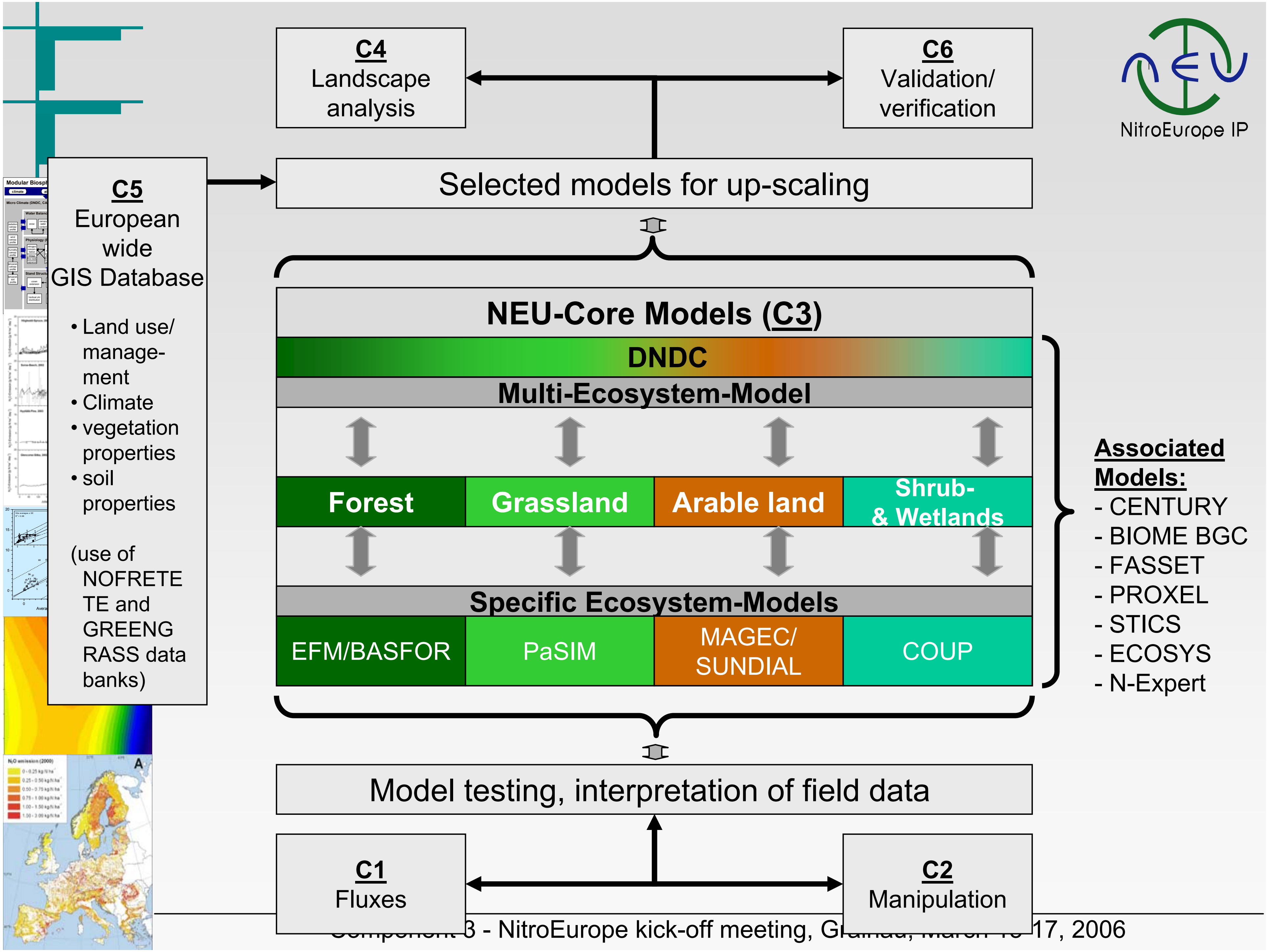

# Rational for the development of plot models

NitroEurope IP

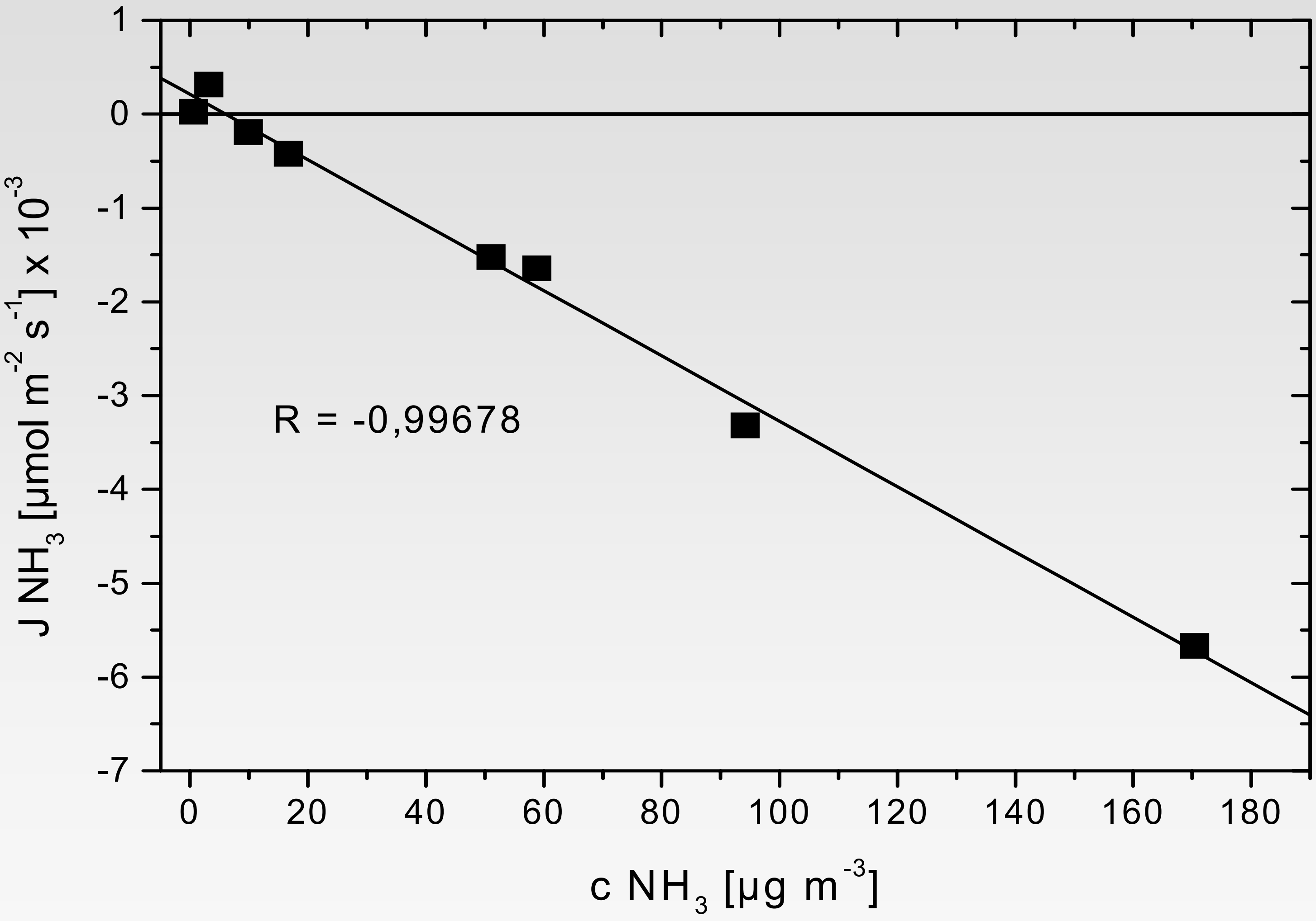
Improvement

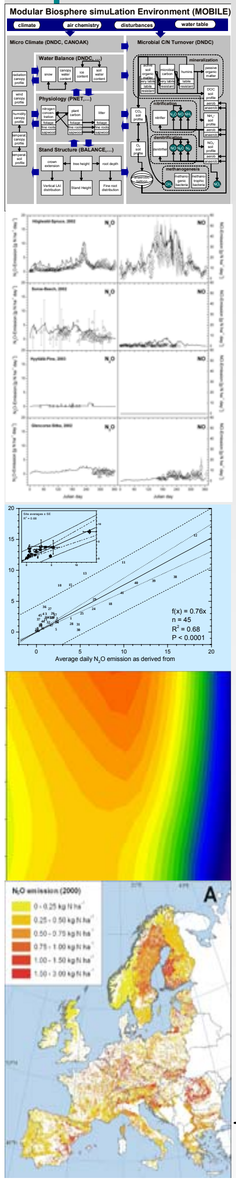
- System understanding
- Identification of key processes driving CN turnover and coupled biosphere-atmosphere exchange
- Generalisation/ simplification

- **Identify uncertainties -►guide/define lab/field work**
- **Extrapolate (gap filling, different sites, retrospective)**
- **Analyse past and predict future developments**
- **Identify/ develop mitigation/adaptation strategies**

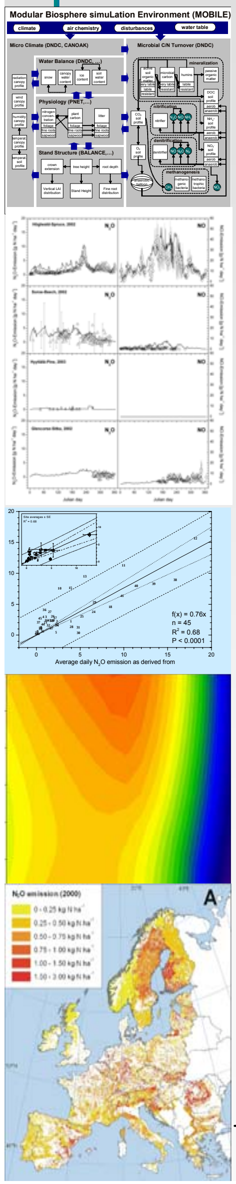

C4
Landscape analysis
C6
Validation/ verification
NitroEurope IP
C5
European wide GIS Database
• Land use/ manage-ment
• Climate
• vegetation properties
• soil properties
(use of NOFRETETE and GREENGRASS data banks)
Selected models for up-scaling
NEU-Core Models (C3)
DNDC
Multi-Ecosystem-Model
Forest
Grassland
Arable land
Shrub- & Wetlands
Specific Ecosystem-Models
EFM/BASFOR
PaSIM
MAGEC/ SUNDIAL
COUP
Associated Models:
- CENTURY
- BIOME BGC
- FASSET
- PROXEL
- STICS
- ECOSYS
- N-Expert
Model testing, interpretation of field data
C1
Fluxes
C2
Manipulation
3 - NitroEurope kick-off meeting, Gr 17, 2006

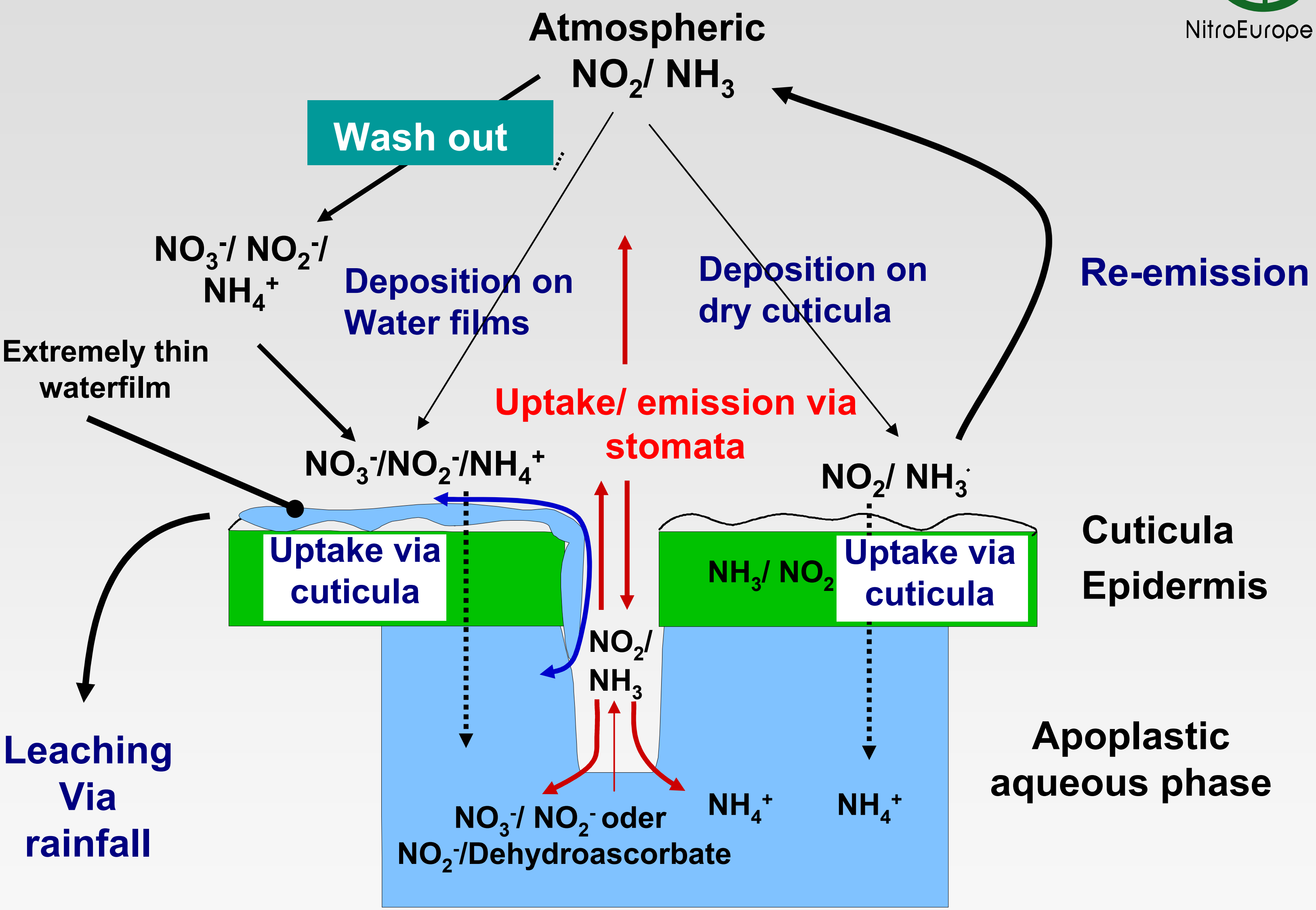
# Bi-directional $NH_3$ flux at the leaf surface



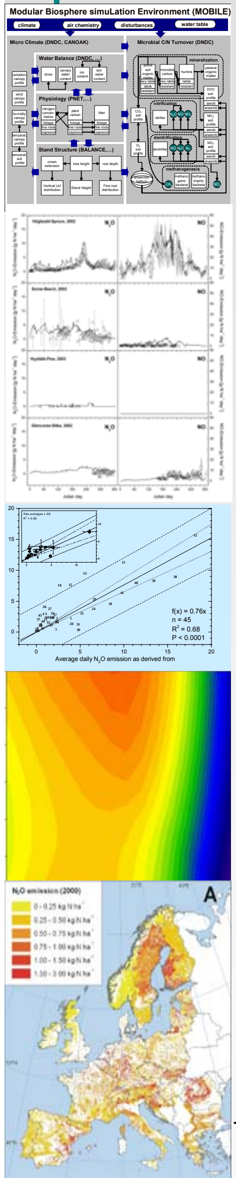



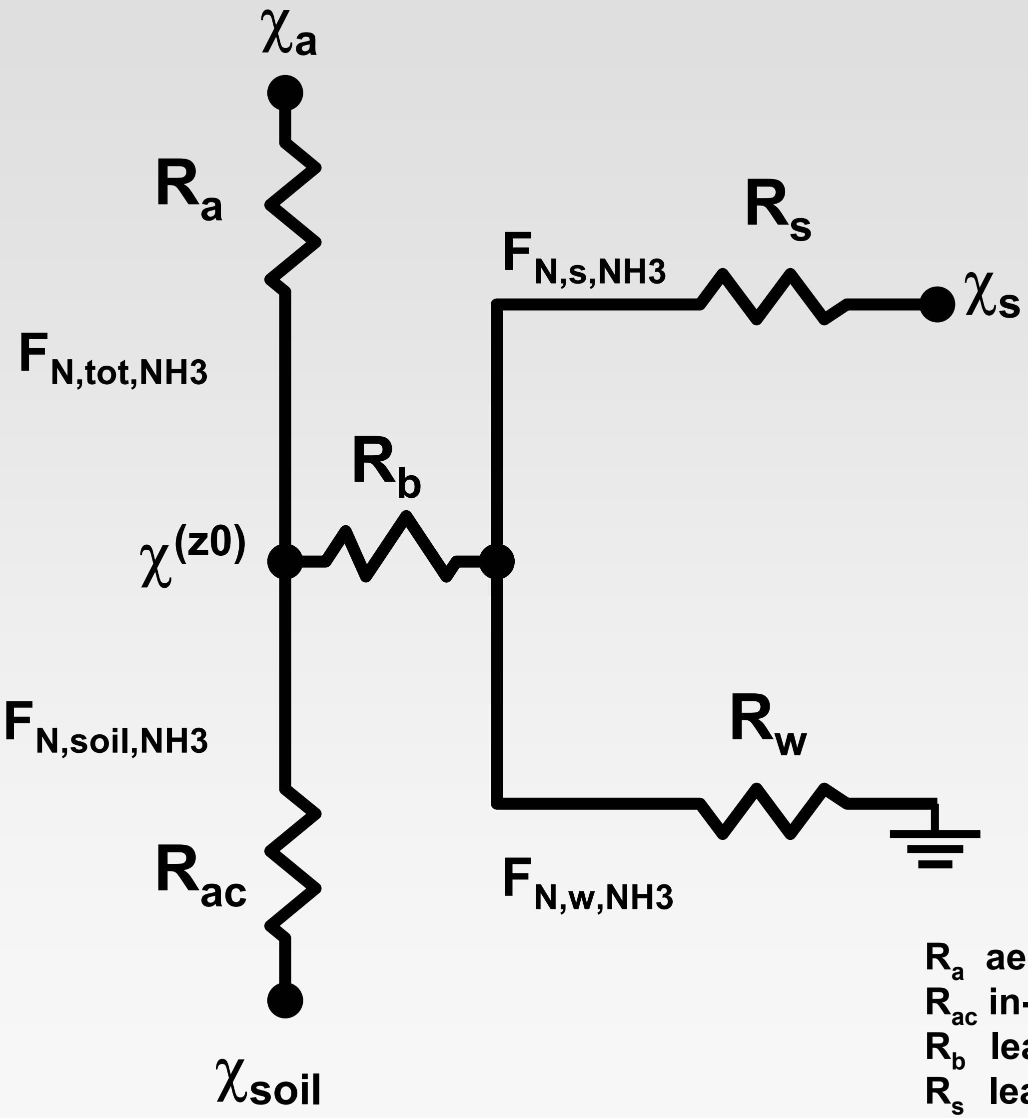
**Gessler, 1999**




Atmospheric $NO_2$/ $NH_3$
Wash out
$NO_3^-$/ $NO_2^-$/ $NH_4^+$
Deposition on Water films
Deposition on dry cuticula
Re-emission
Extremely thin waterfilm
Uptake/ emission via stomata
$NO_3^-$/$NO_2^-$/$NH_4^+$
$NO_2$/ $NH_3$
Cuticula
Epidermis
Uptake via cuticula
$NH_3$/ $NO_2$
Uptake via cuticula
$NO_2$/ $NH_3$
Leaching Via rainfall
Apoplastic aqueous phase
$NO_3^-$/ $NO_2^-$ oder $NO_2^-$/Dehydroascorbate
$NH_4^+$
$NH_4^+$

# Two-layer resistance model for $NH_3$ exchange

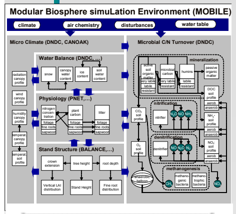


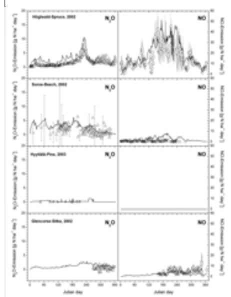


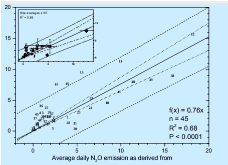

$R_a$ aerodynamic resistance
$R_{ac}$ in-canopy aerodynamic resistance
$R_b$ leaf boundary resistance
$R_s$ leaf stomatal resistance
$R_w$ cuticular resistance

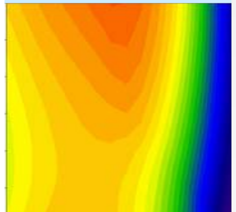
Nemitz et al., 2001

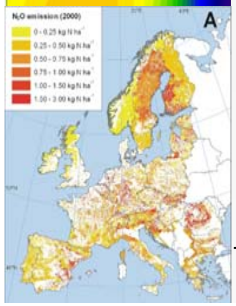
# Linking plant N cycling to stomatal $NH_3$ exchange

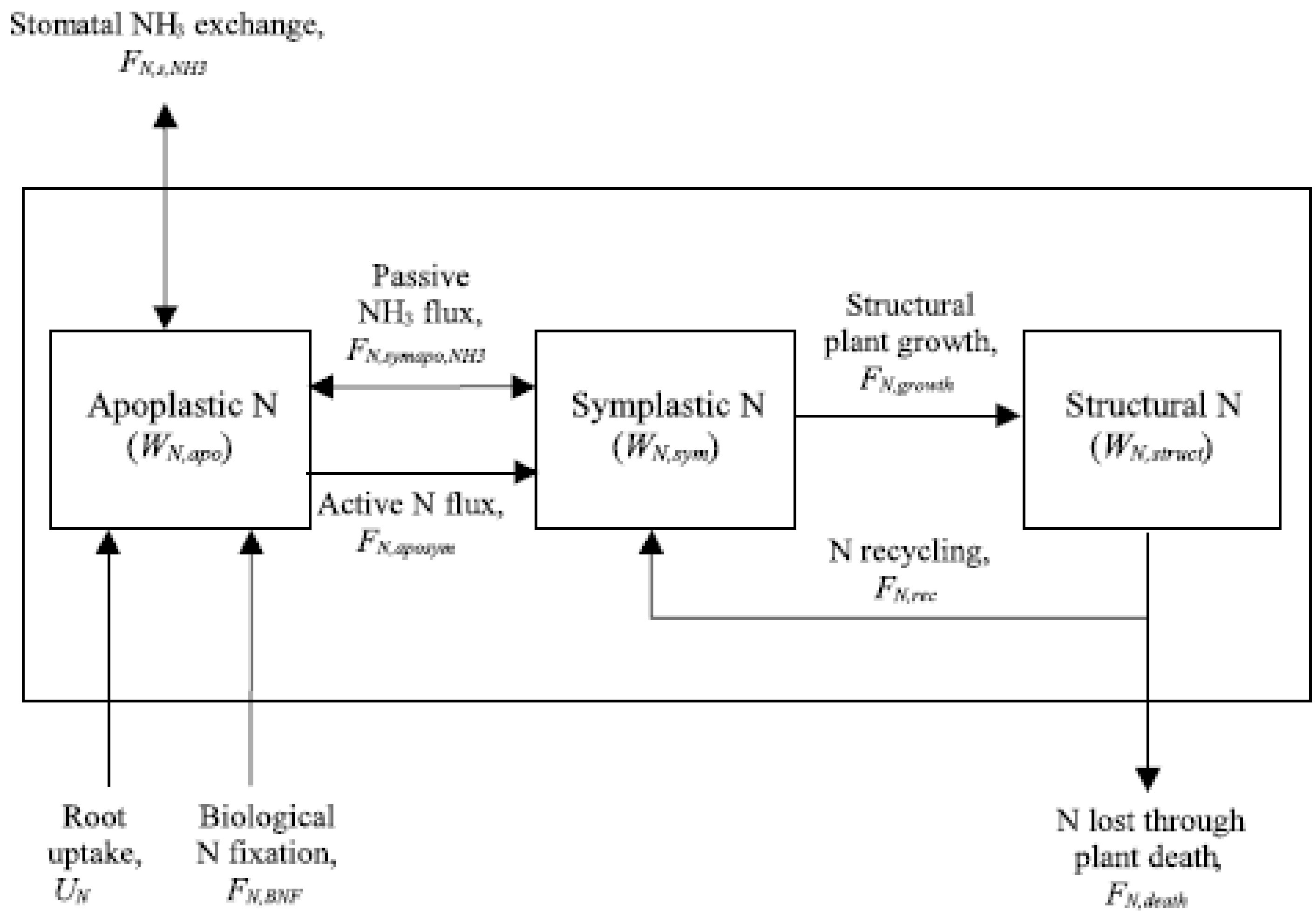




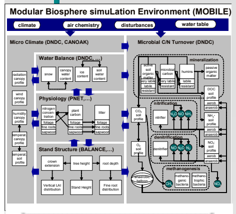


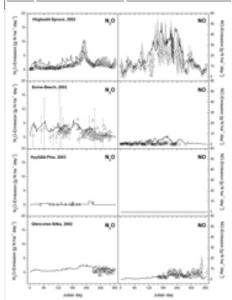


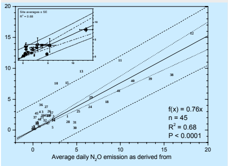


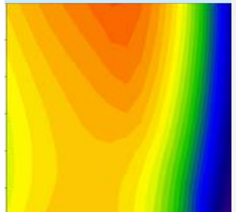

**Riedo et al., 2002**

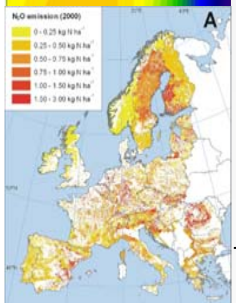
# Simulation of $NH_3$-exchange at a grassland site in Scotland

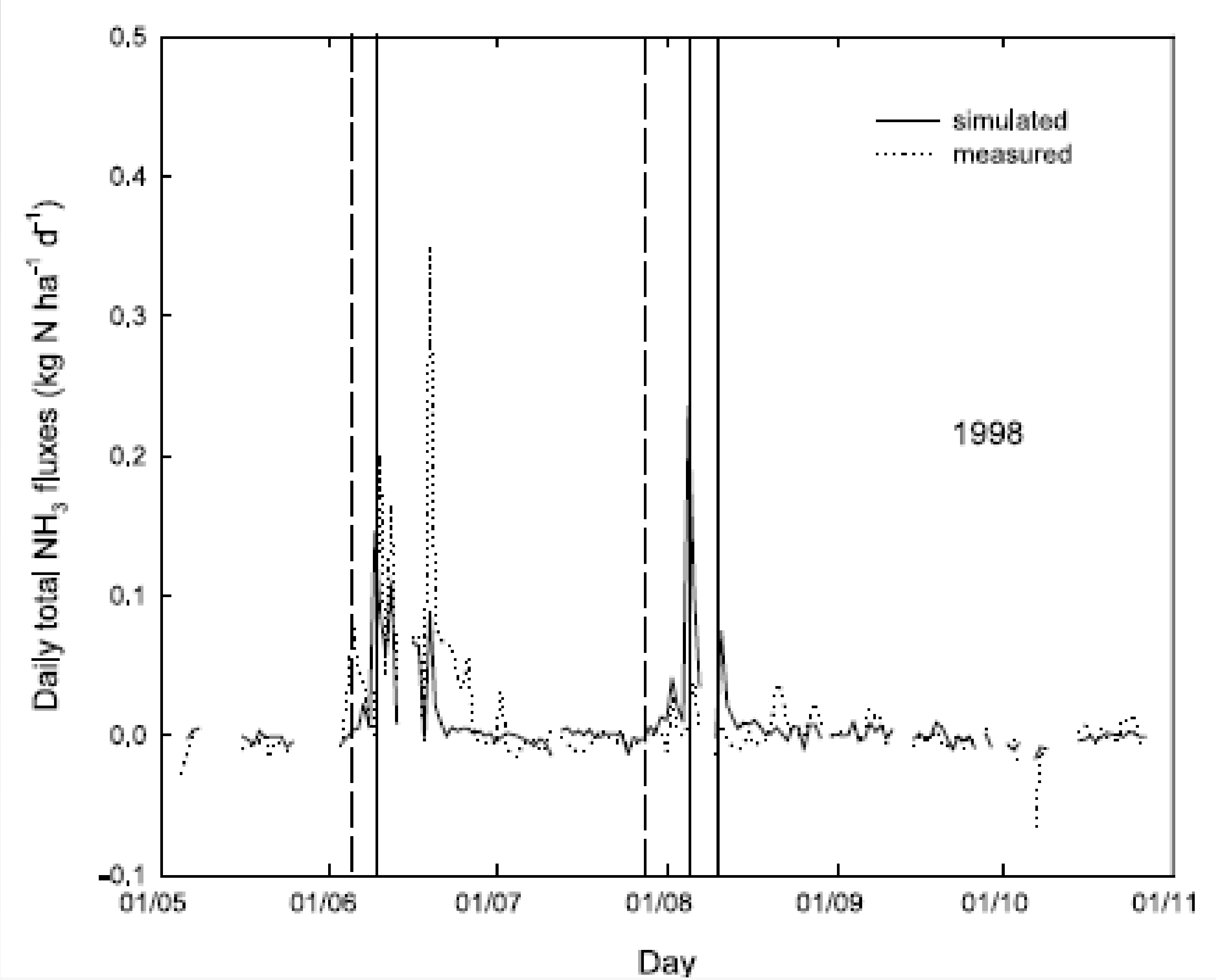








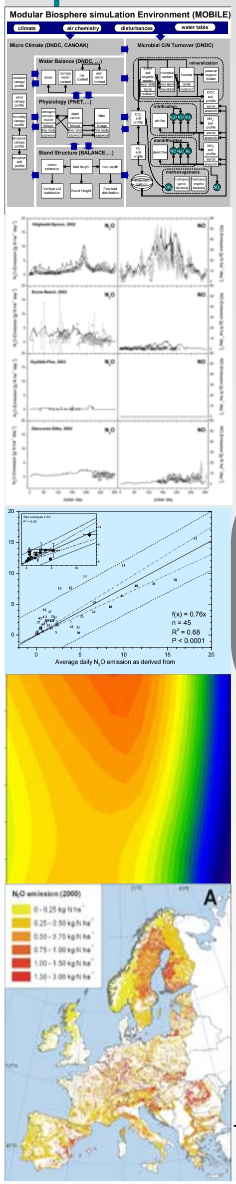


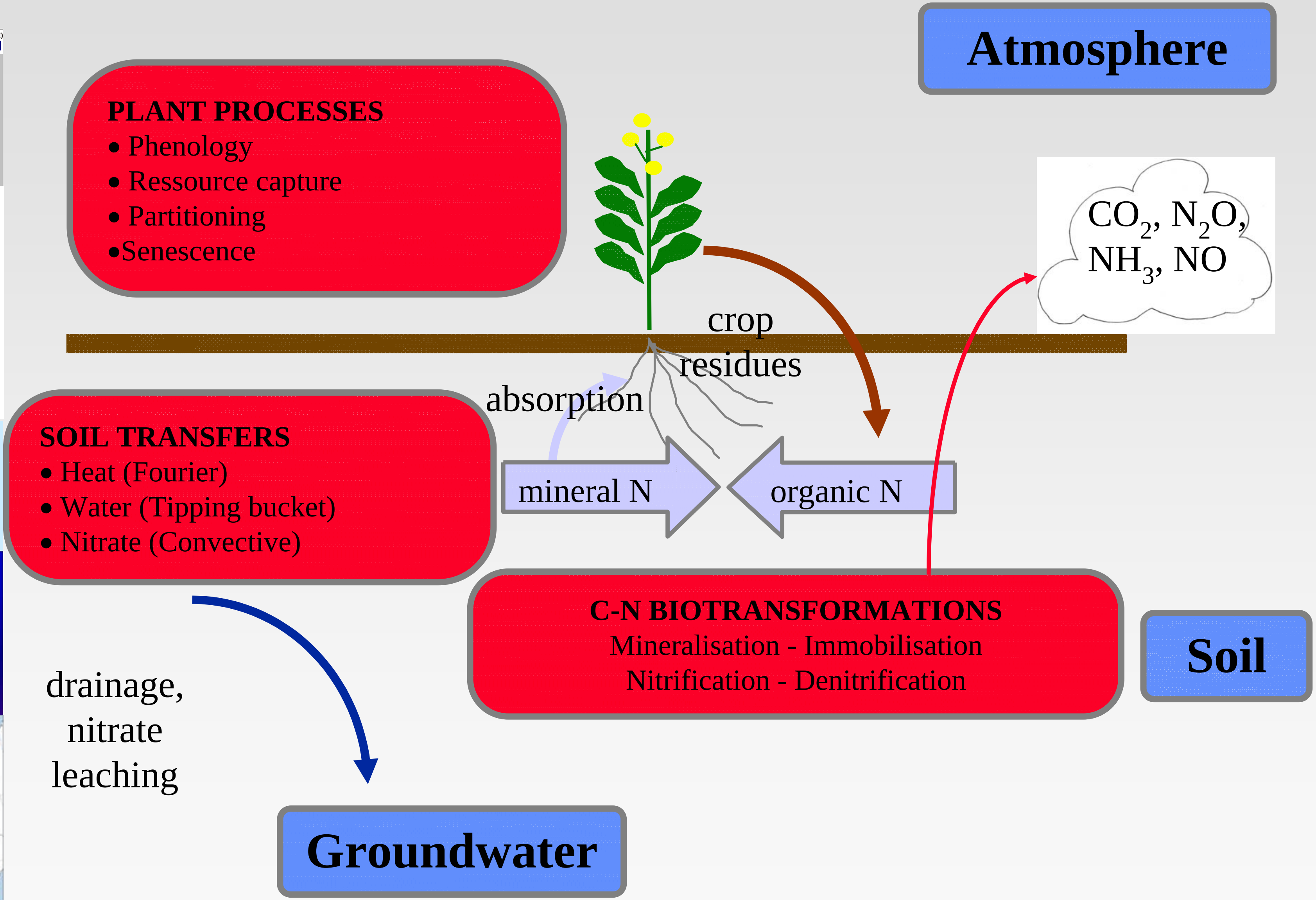

**Riedo et al., 2002**

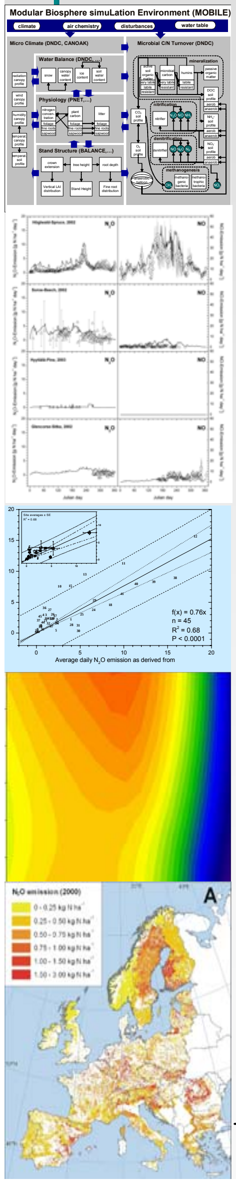
NitroEurope IP

# Simulation of $N_2O$ emissions from arable soils

## Structure of the CERES-EGC model







# Estimation of $N_2O$ production using the NOE algorithm
**(Hénault et al., 2005)**

NitroEurope IP

**Nitrification**

$$N_A = F_W \, F_{NH_4^+} \, F_T$$

**Denitrification**

$$D_A = D_P \, F_{NO_3^-} \, F_W F_T$$

$N_A$, $D_A$ = actual nitrification and denitrification activity

**►$N_2O$ emissions are a fixed fraction of $N_A$ and $D_A$**

Response functions for substrate, water and temperature

$$F_N = \frac{[NO_3^-]}{Km + [NO_3^-]}$$

$$F_W = 0, \, WFPS < 0.62$$

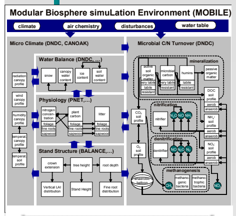
(Grundmann & Rolston, 1987; Hénault & Germon, 2000)

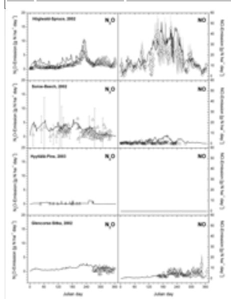
$$F_W = \left( \frac{WFPS - 0.62}{0.38} \right)^{1.74}, WFPS \geq 0.62$$

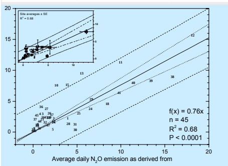
$$F_T = \exp^{\left( \frac{(t-11)\ln(89) - 9\ln(2.1)}{10} \right)}, \, t < 11°C$$

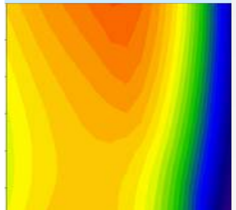
(Hénault et al., 2001)

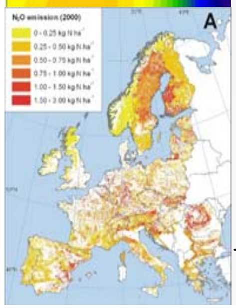
$$F_T = \exp\left( \frac{(t-20)\ln(2.1)}{10} \right), t \geq 11°C$$





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## Potential problems and uncertainties:

Response functions may be seasonal variabel

- Potential denitrification rate,
- Temperature response,

e.g. due to changes in microbial biomass and speicies composition

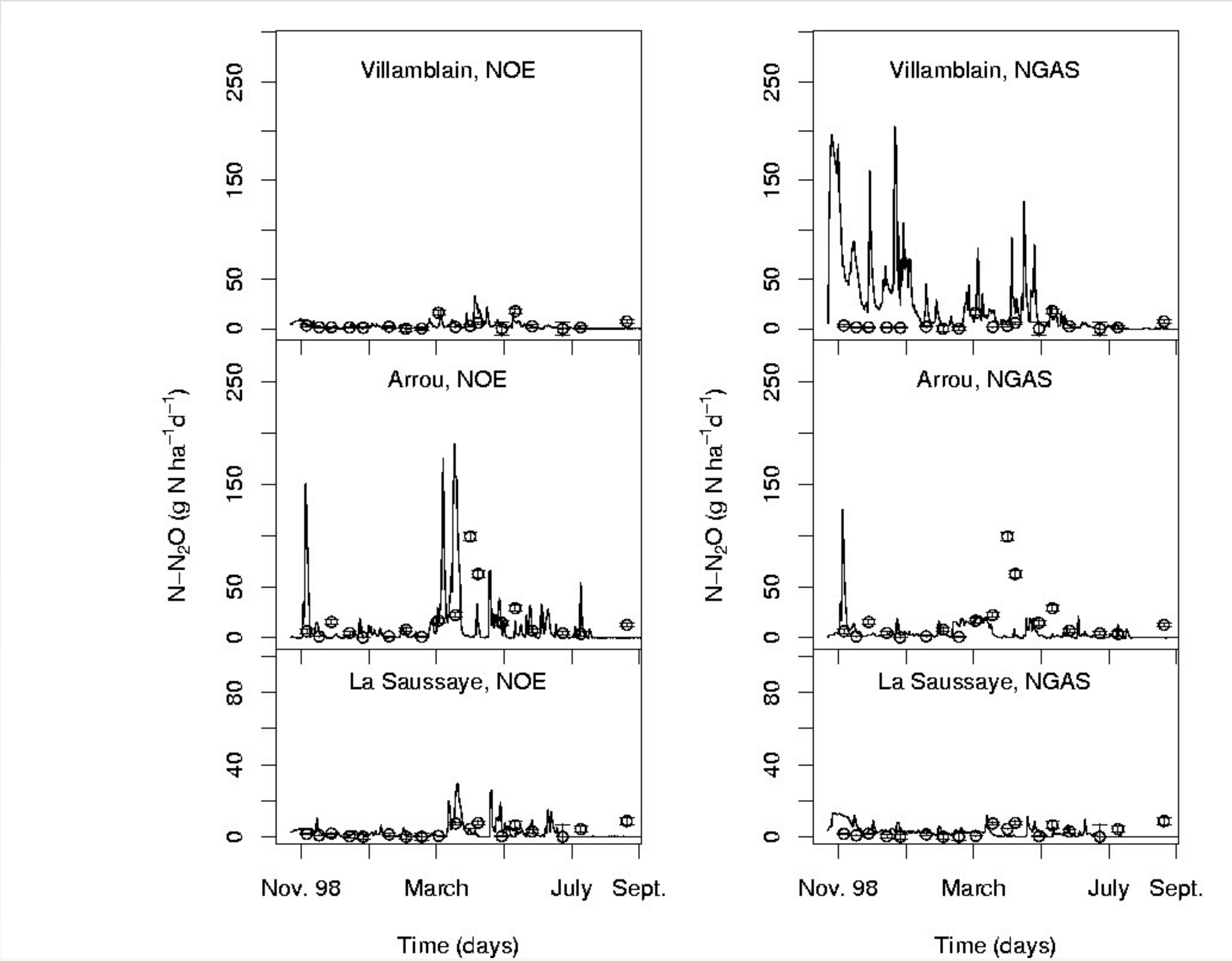
- Response functions may vary with type of ecosystem or soil,

- Dynamic production and consumption of $N_2O$ in the soil cannot be simulated.

However, coupled to a plant-soil model such as CERES-EGC observed patterns and site variability of $N_2O$-emissions have succesfully been simulated

# Evaluation of CERES-EGC

--- Simulated
o Observed



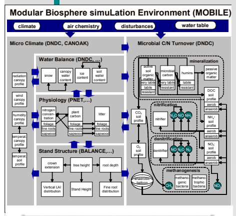

Haplic calcisol

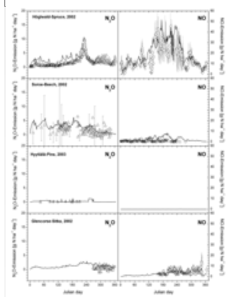
Redoxic luvisol

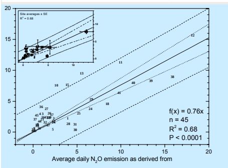
Haplic luvisol

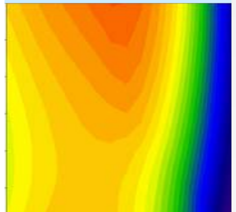
**Simulation by CERES with two different $N_2O$ emission modules**

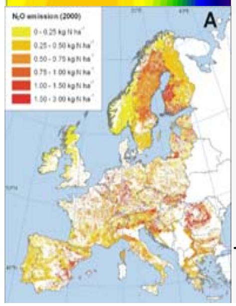
Gabrielle, Laville, et al., Nutr. Cycling Agroecosys. (in the press)

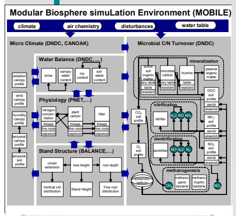


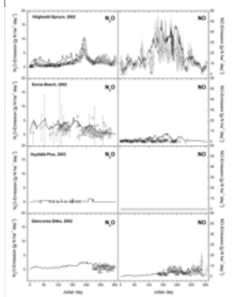



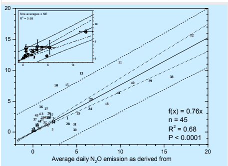


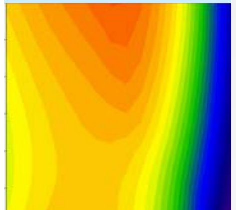


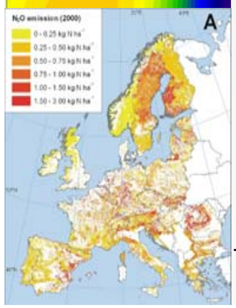


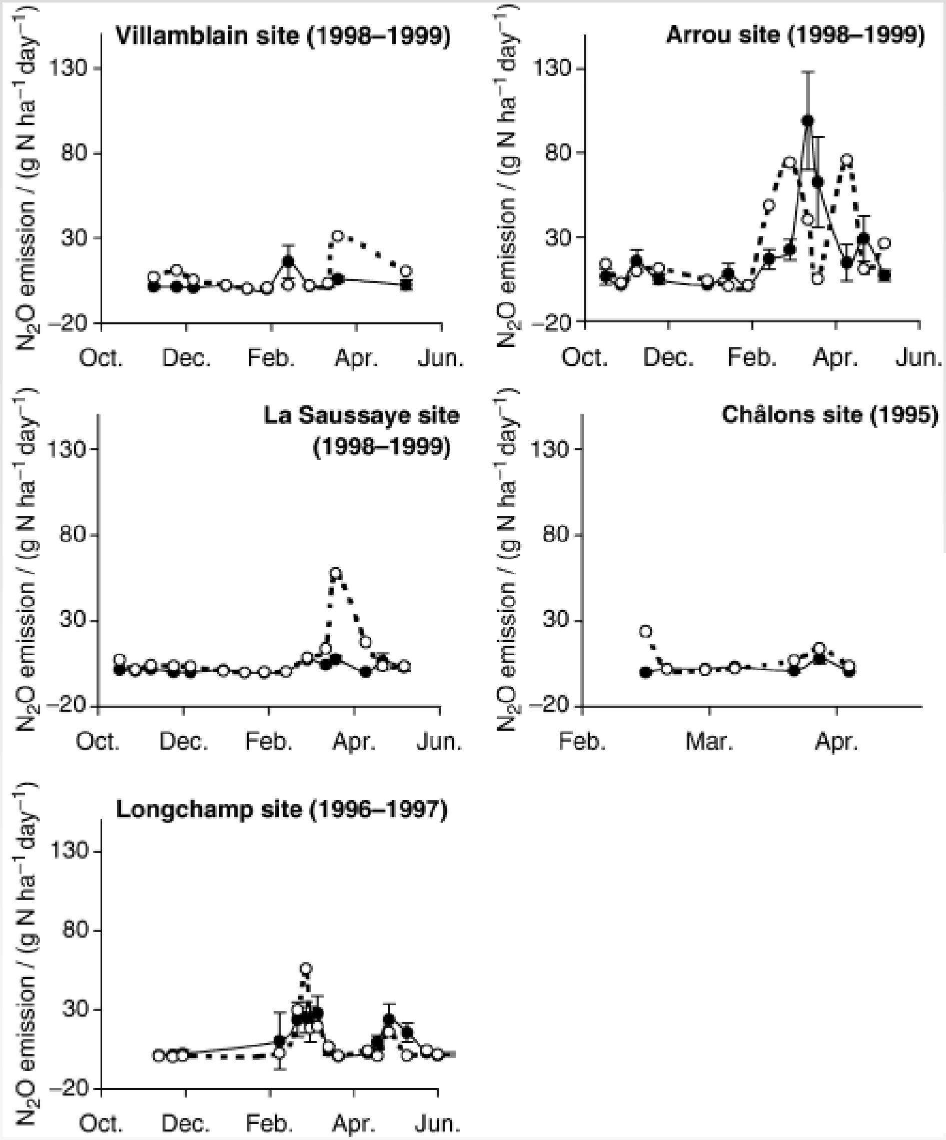


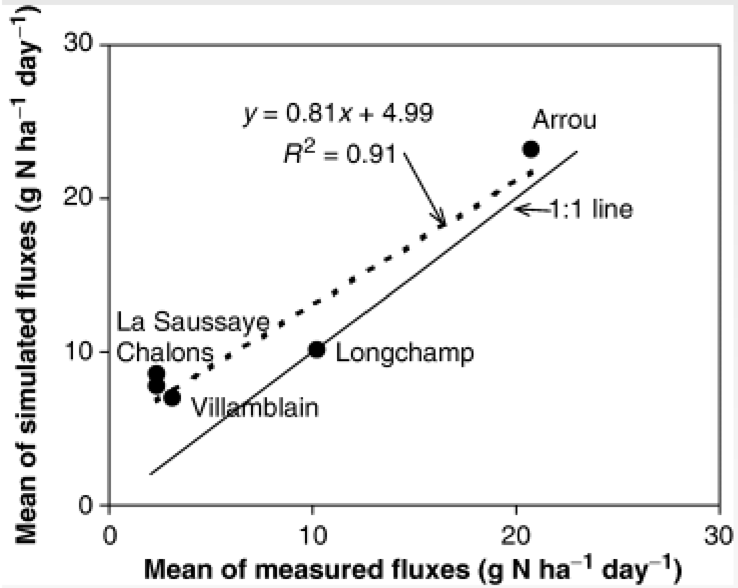







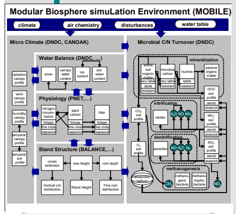


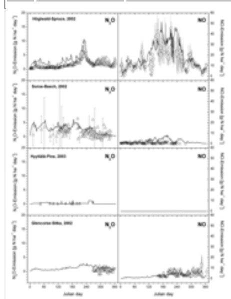


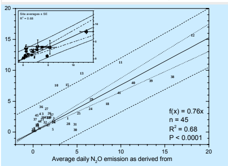



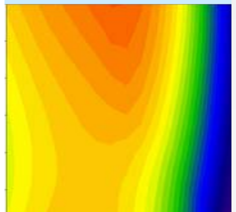

Hénault et al., 2005, Global Change Biol., 111, 115-127

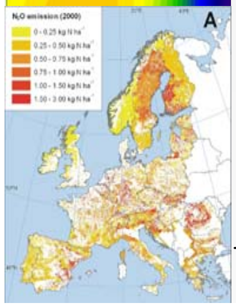
# Component 3: Plotscale Modeling – Objectives (1/2)







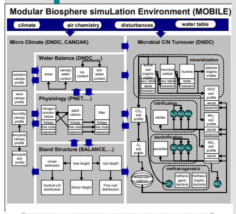

## Objective 3.1 (-►A3.1, Marcel van Oijen, NERC)

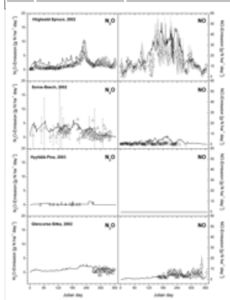
To conduct a priori ***assessment of the uncertainty of selected existing biogeochemical models*** which serve as NEU core models (PaSIM, BASFOR-EFM, CERES-EGC, MAGEC, SUNDIAL, DNDC, CoupModel) and development of a) ***recommendations for model improvements*** and b) ***protocols to address uncertainty*** coming from parameters, driving variables or model structure.

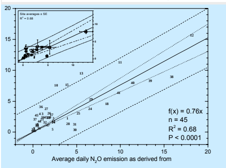
## Objective 3.2 (-►A3.2, Klaus Butterbach-Bahl, FZK)

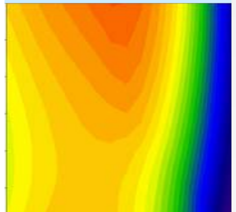
To ***improve the NEU core models*** to aid a comprehensive understanding of the processes that are controlling the biosphere-atmosphere exchange of trace gases and to enable predictions of effects of changes in climate, land use and land management on gas exchange of C and N compounds.

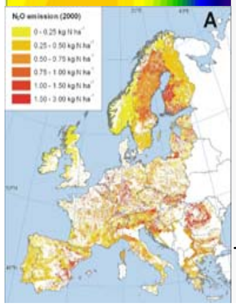
# Component 3: Plotscale Modeling – Objectives (2/2)







## Objective 3.3 (-►A3.3, Pierluigi Calanca/JürgFuhrer, FAL-CH)

To ***simulate and interpret fluxes at NEU measuring sites*** in order to identify and assess the forces driving the biosphere-atmosphere exchange of C and N trace gases.

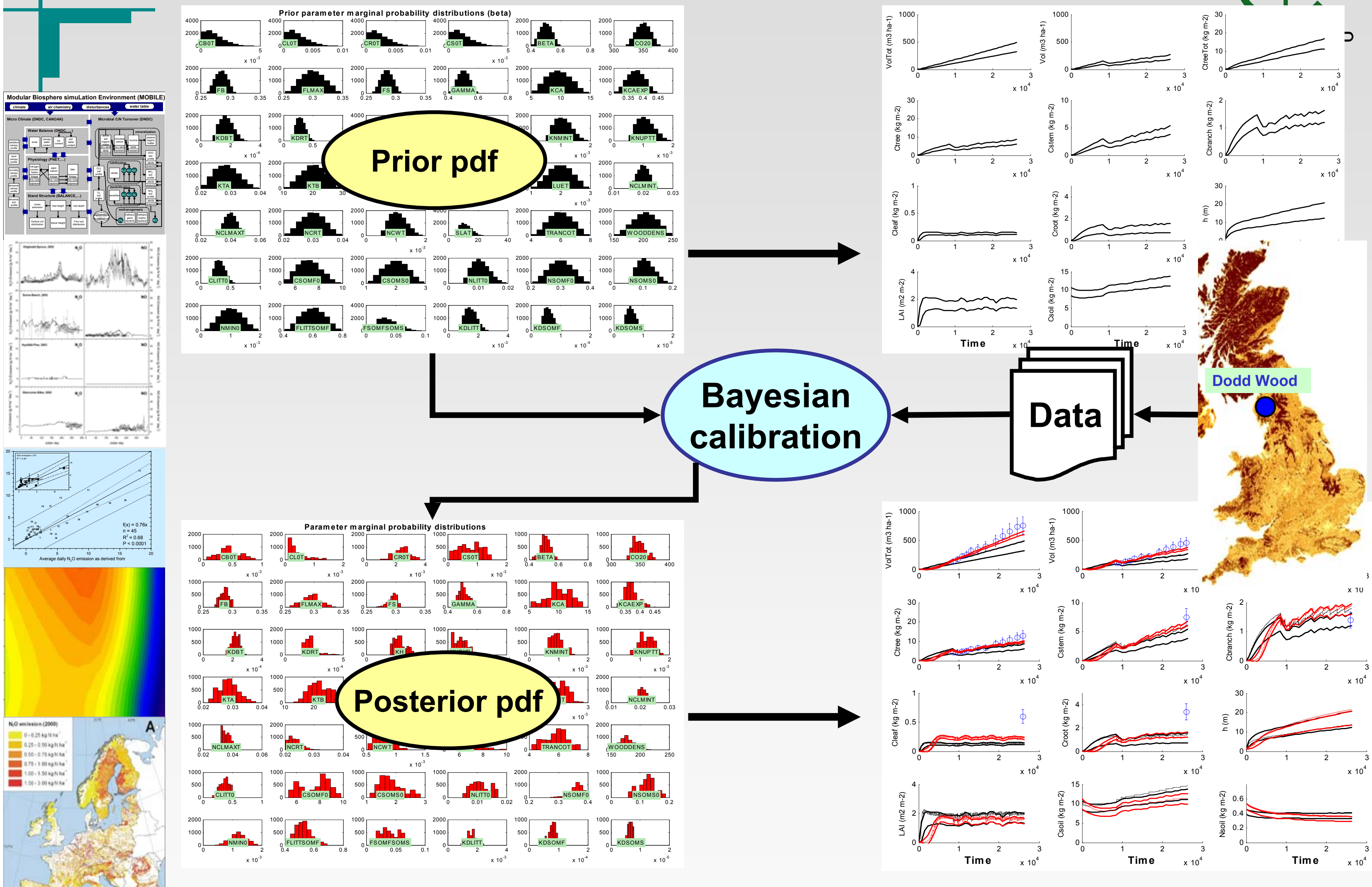
## Objective 3.4 (-►A3.3, Pierluigi Calanca/JürgFuhrer, FAL-CH)

To provide ***means for gap filling*** in the observational record and for estimating fluxes associated with processes that cannot, or are only sporadically, determined experimentally.

## Objective 3.5 (-►A3.4, Pete Smith, UNIABDN)

To ***develop site-specific GHG mitigation strategies for selected landuses*** across Europe by analysing how past, current and future land use and land management changes in agriculture and forestry or the drainage of wetlands has and will affect the carbon and nitrogen balances and biosphere-atmosphere exchange.

# Component 3: A3.1 – Uncertainty analysis



# Component 3: A3.1 – Uncertainty analysis

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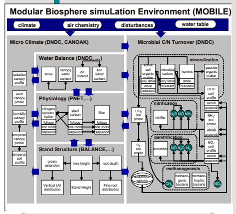
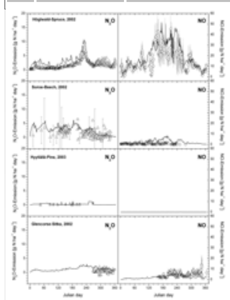
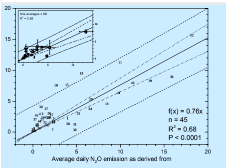
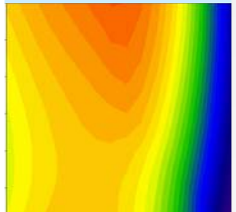
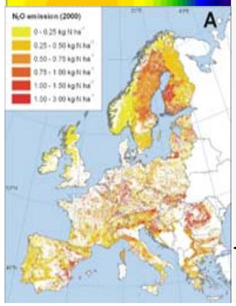







Development of protocol for adressing uncertainty in parameters and driving variables:

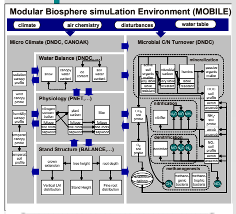
- methods for quantifying input uncertainty,
- methods for calculating output uncertainty from given input uncertainty,
- method for updating input uncertainty when new data come in.

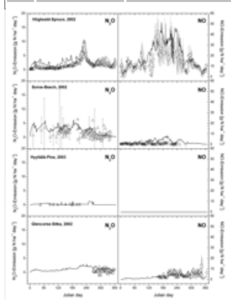
► Identification of the parameters, driving variables and model components that contribute most to the output uncertainty of the different models.

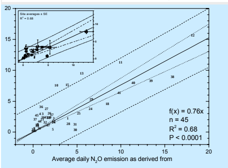
► subsequent model improvement. Re-iteration.

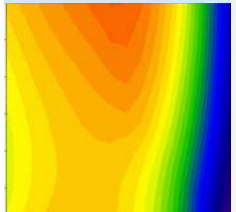
**Goal: faster, more robust, easier to calibrate & quantify uncertainty**

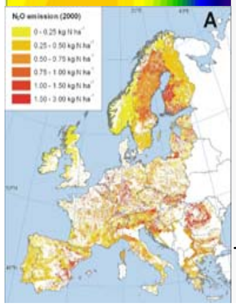
# Component 3: A3.2 – Model development





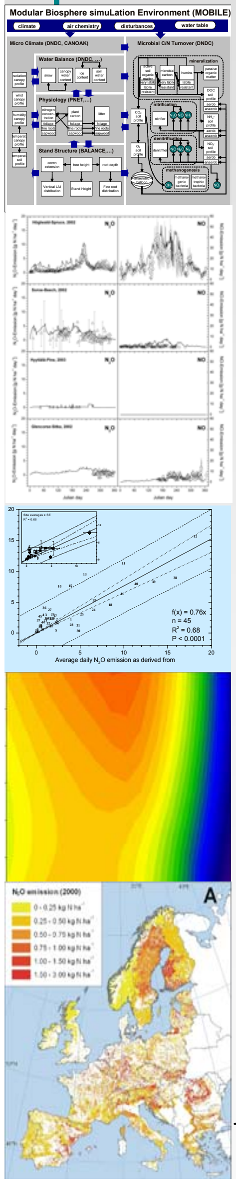



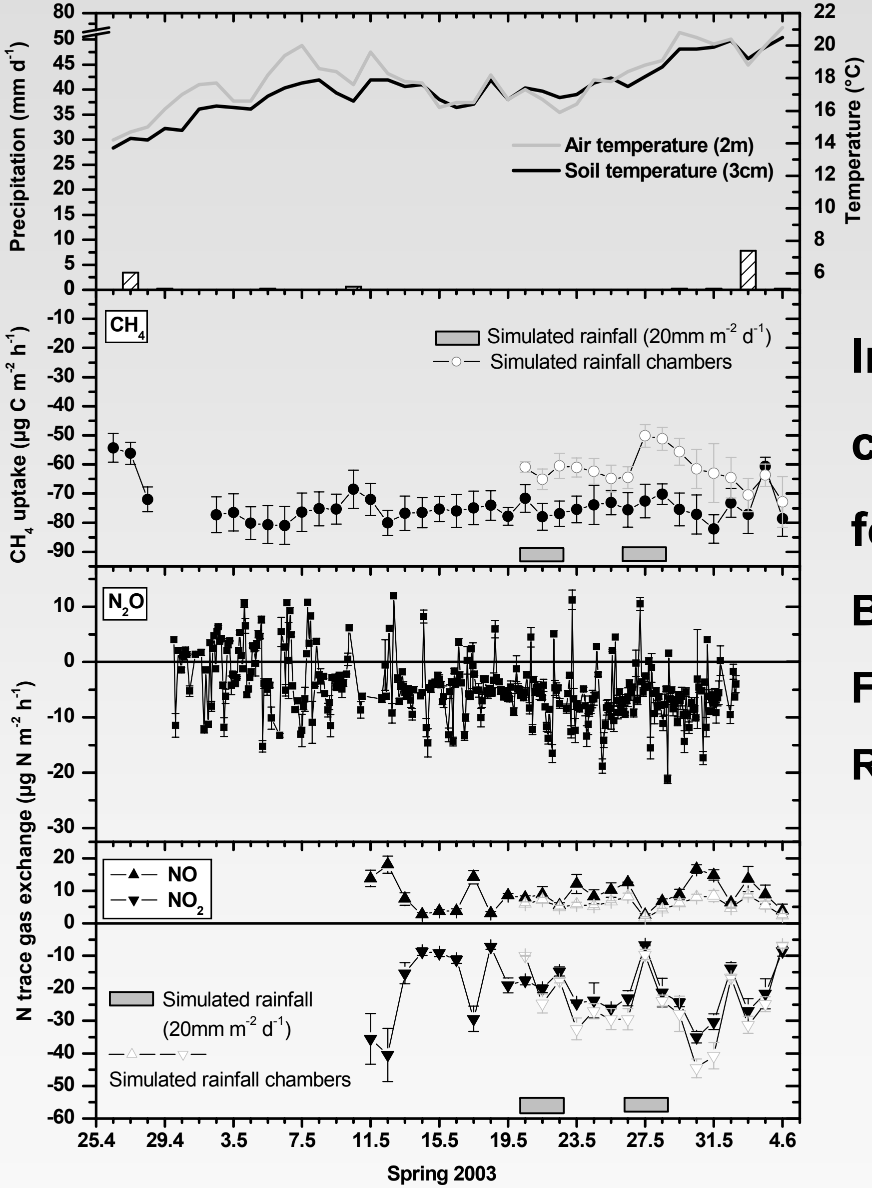



Model developments will be based on previous identified uncerAinties and on the outcome of UC-assessment within A3.1, and may focus on:

- biotic processes (e.g. mineralization, nitrification, denitrification)
- abiotic soil processes (water movement, gas diffusion)
- plant growth/ physiology
- interactions with management (e.g. gazing, manure spreading, irrigation, drainage) and their effects on N- and C-trace gas exchange
- GHG exchange for sites with drained organic soils

# Component 3: A3.2 – Model development






**Increasing evidence that soils can act as significant sinks for atmospheric $N_2O$, e.g.:**

**Butterbach-Bahl et al., 1998**

**Flechard et al., 2005**

**Rosenkranz et al., 2006**

**Rosenkranz et al., Biogeosciences, 2006**

# Component 3: A3.2 – Model development

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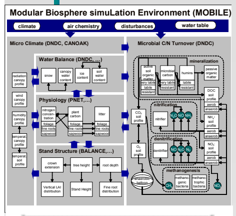
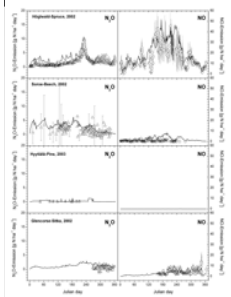
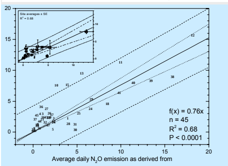
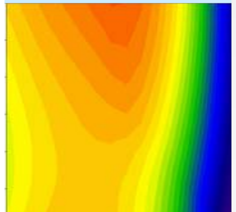
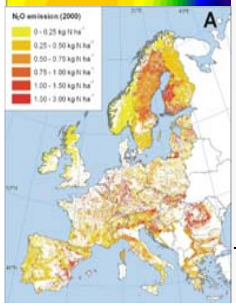








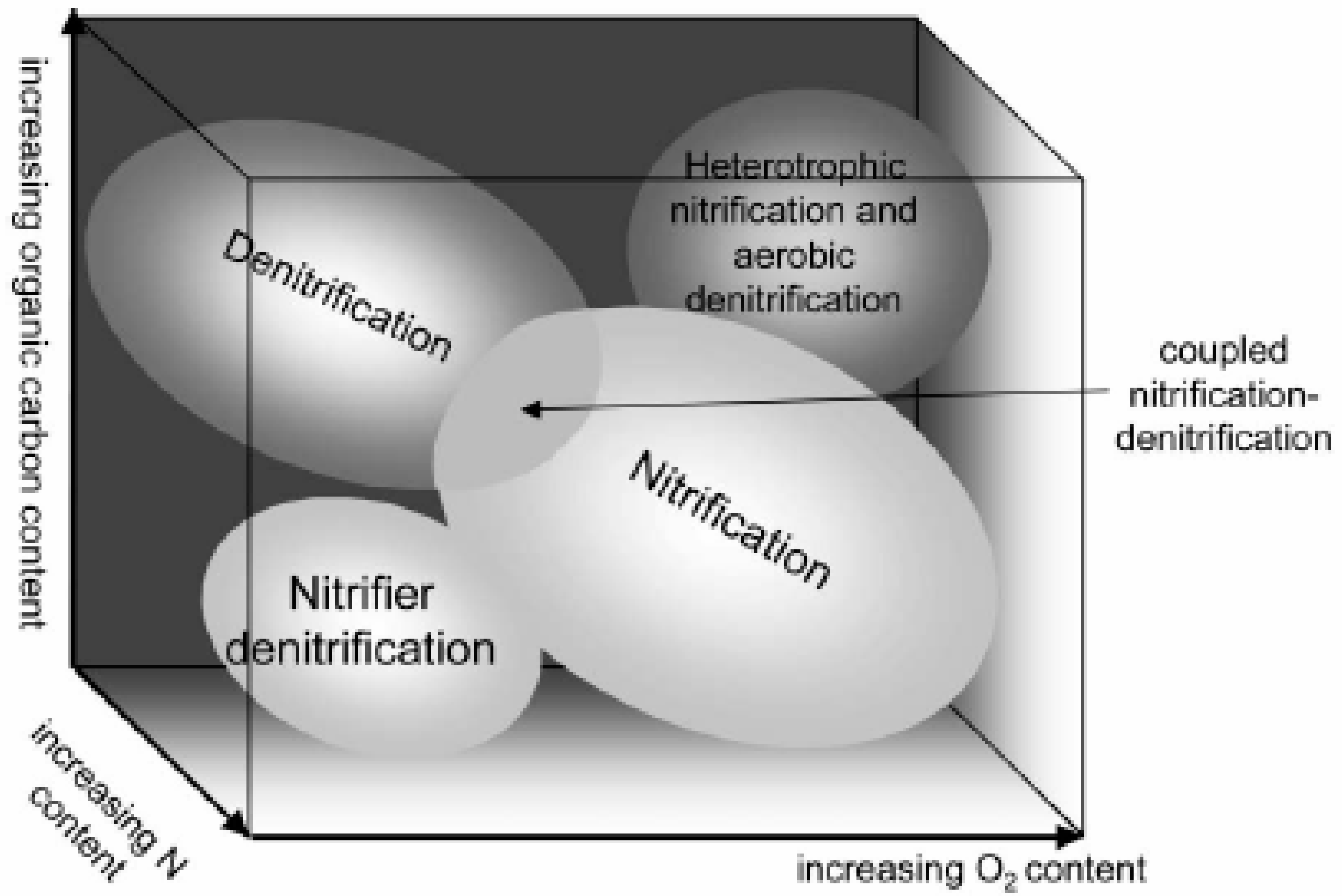
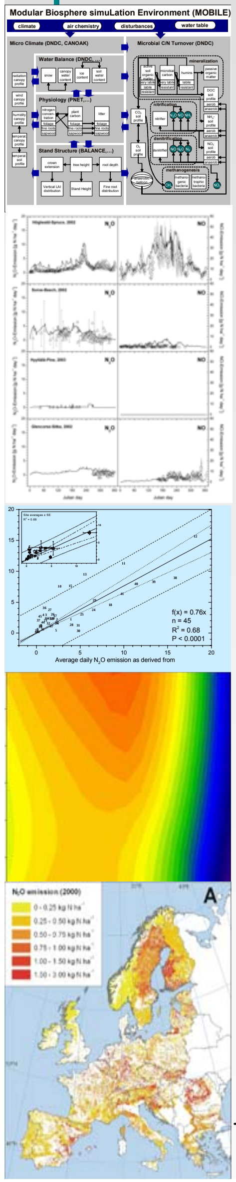
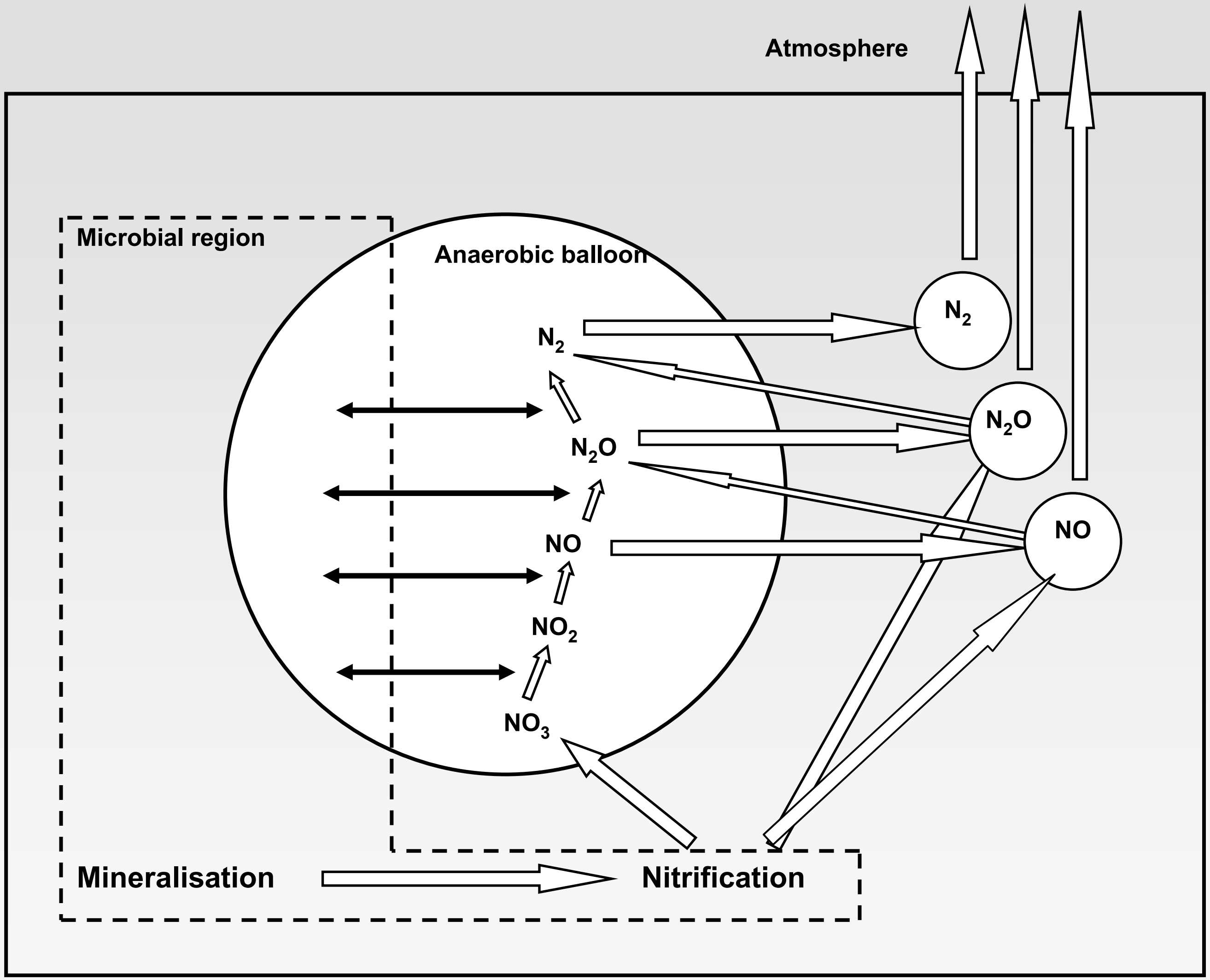



Fig. 6. Possible ecological niche for the nitrification pathway nitrifier denitrification in fertilized soils.

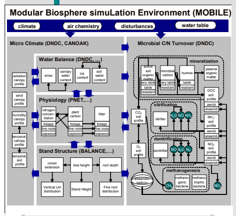
**Wrage et al., 2001, Soil Biol. Biochem.**

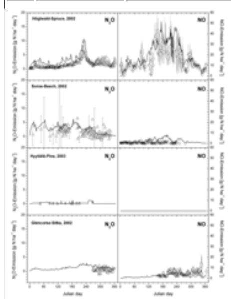
# Component 3: A3.2 – Model development

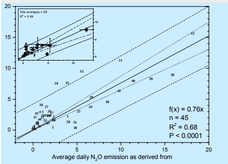


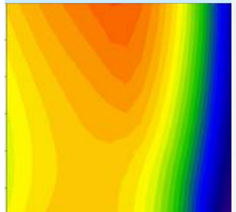


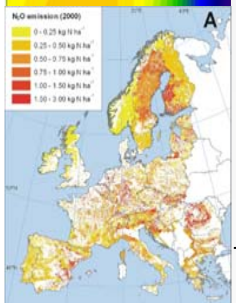
# Component 3: A3.2 – Model development



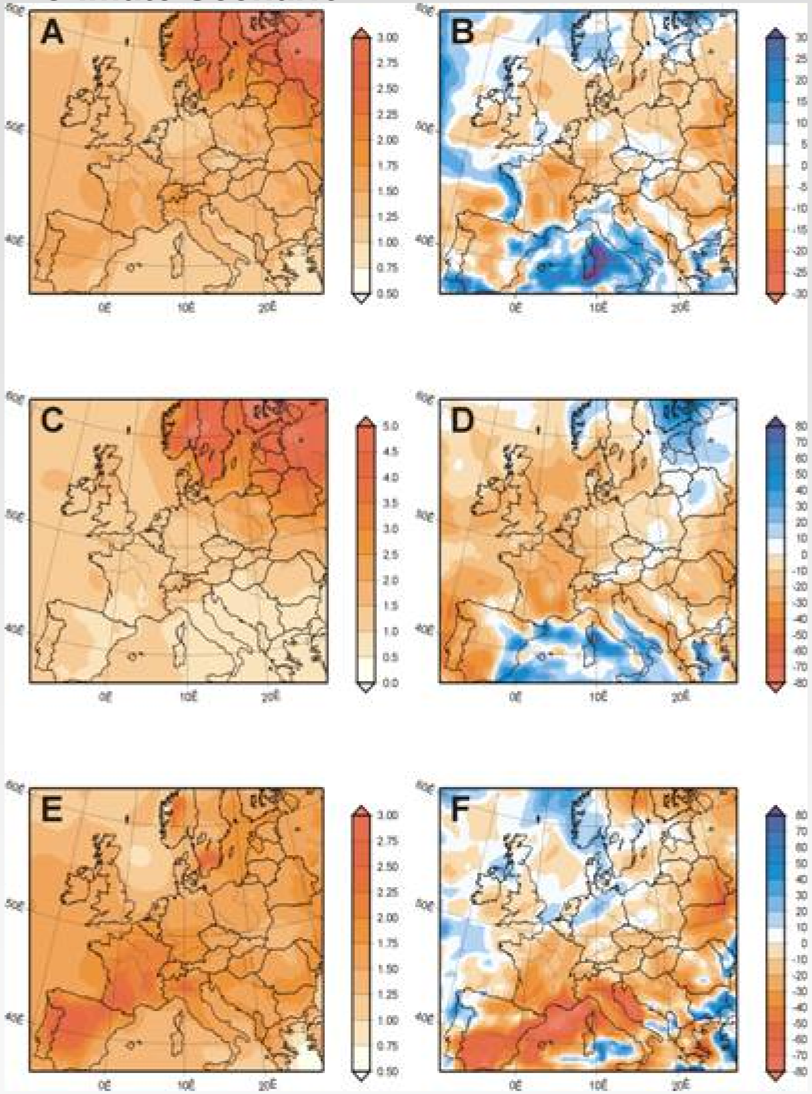





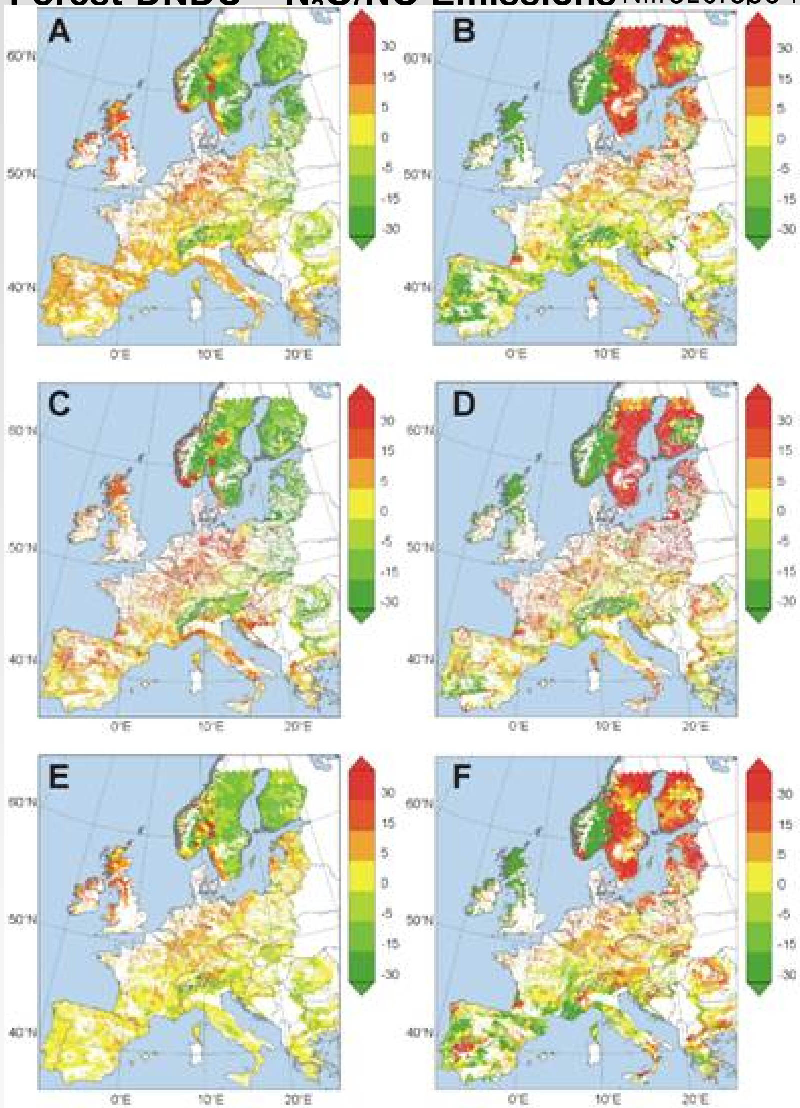






## Climate Scenario

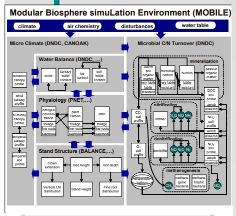


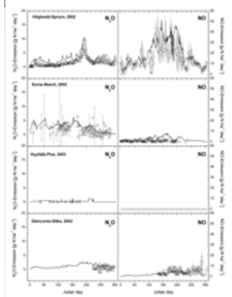

## Forest-DNDC – $N_2O$/NO Emissions

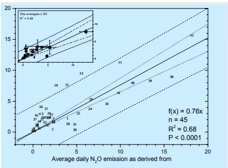


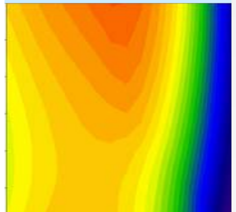

**Kesik et al., 2006, JGR - Biogeosciences**

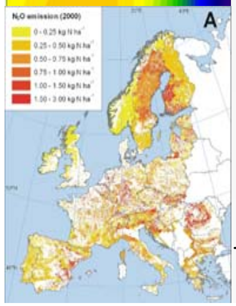
# Component 3: A3.2 – Model development

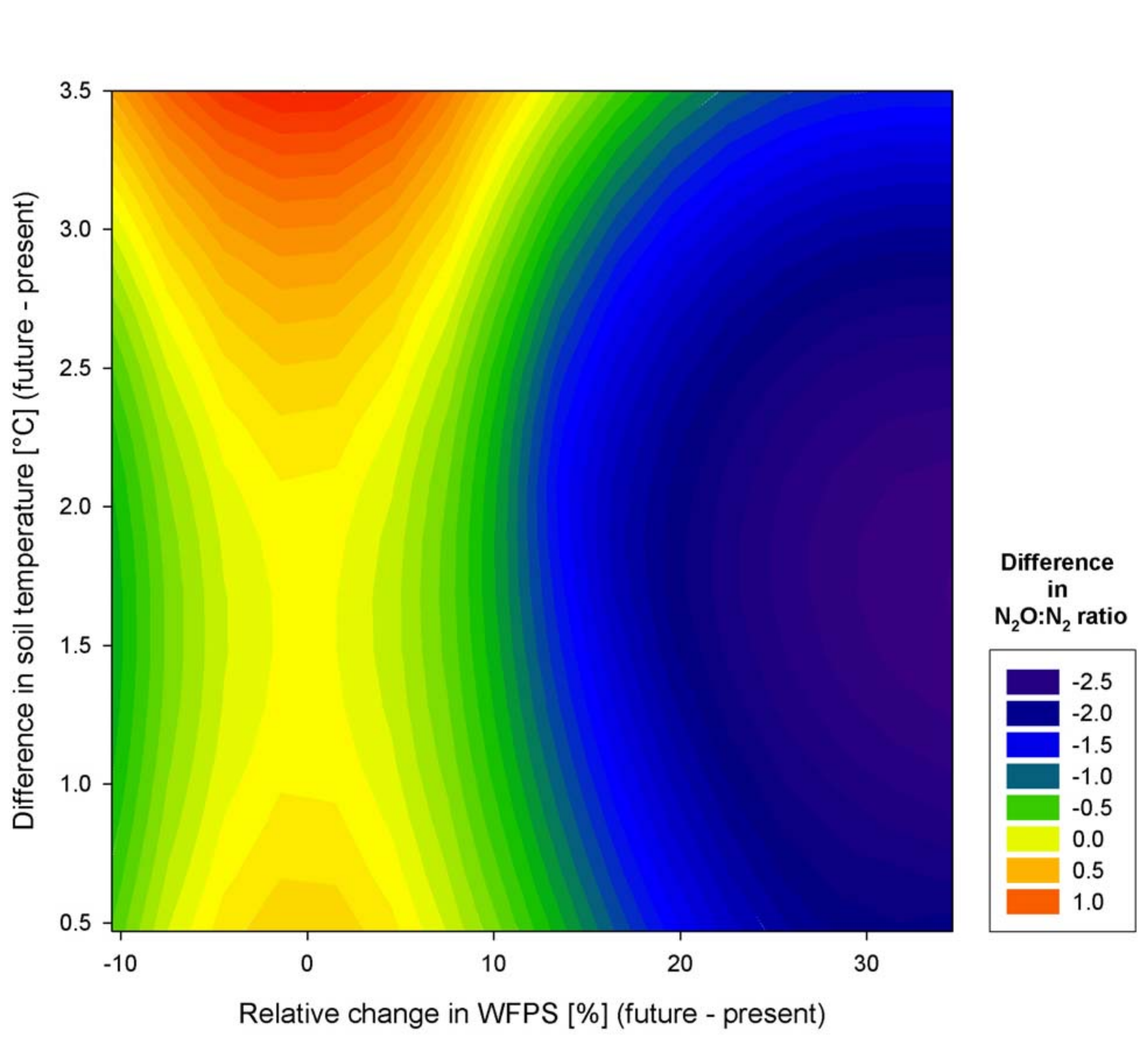











**Kesik et al., 2006, JGR - Biogeosciences**

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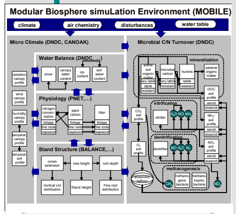
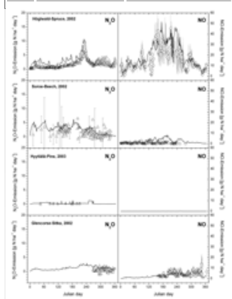
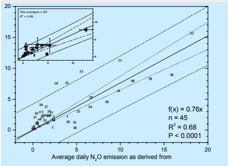
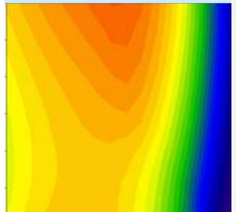
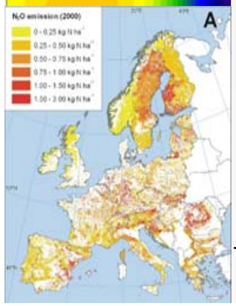
# Component 3: A3.3 – Simulation and interpretation

**Required input**

**Climate**
- Rainfall
- Temperature
- Radiation
- N deposition (Dry/Wet)
- $CO_2$

**Soil**
- Type
- Texture
- pH
- density
- SOC

**Vegetation**
- Type
- Biomass
- Structural parameters

**Land Managem.**
- Fertilization (organic-miner.)
- Drainage
- Rotation
- Irrigation

**Models**

**NEU-Core Models (C3)**

**Multi-Ecosystem-Model – DNDC**

**Output** (daily or subdaily)

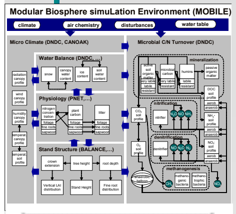
**Atmosphere**
$N_2O$
$NO/NO_2$
$NH_3$
$CO_2$
$CH_4$

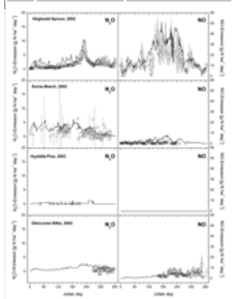
**Biosphere**
Biomass increm./part.
C/N uptake
C/N turnover
Storage

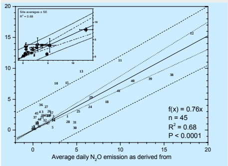
**Pedosphere**
C/N pool sizes
Soil moisture

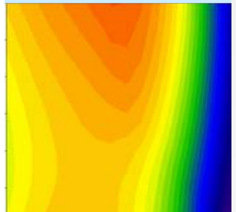
**Hydrosphere**
Leaching
$NO_3$-concentr.

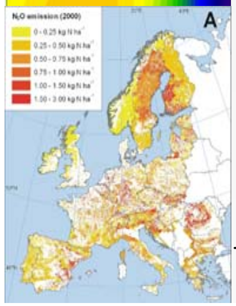
# Component 3: A3.3 – Simulation and interpretation

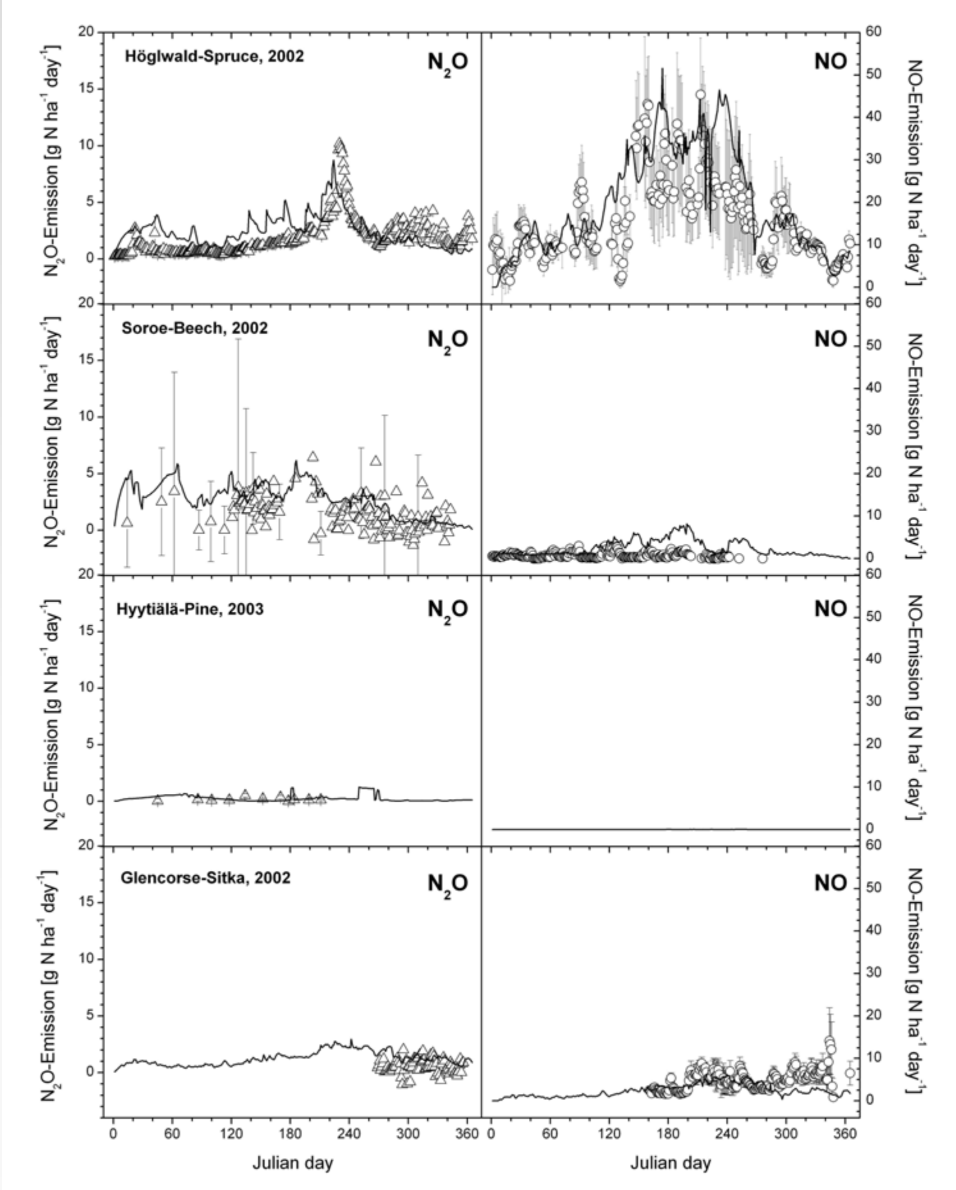


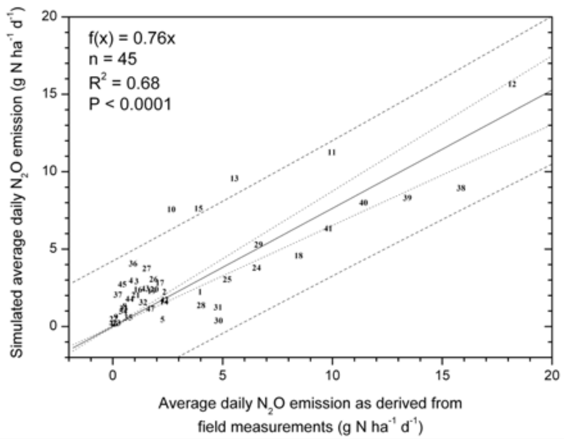






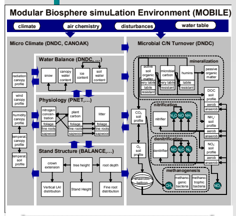



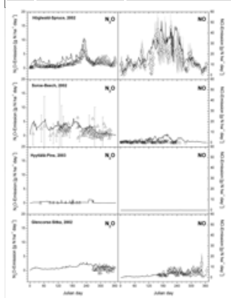

- Definition of protocols
- Identification of gaps
- Identification of quality problems
- Interpretation of results
- Recommendation of additional measurements

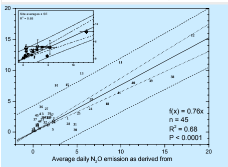


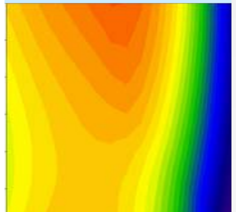
# Component 3: A3.4 – GHG mitigation strategies

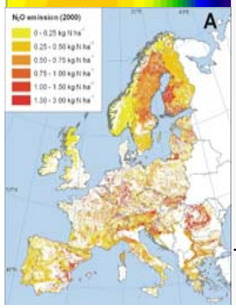
NitroEurope IP





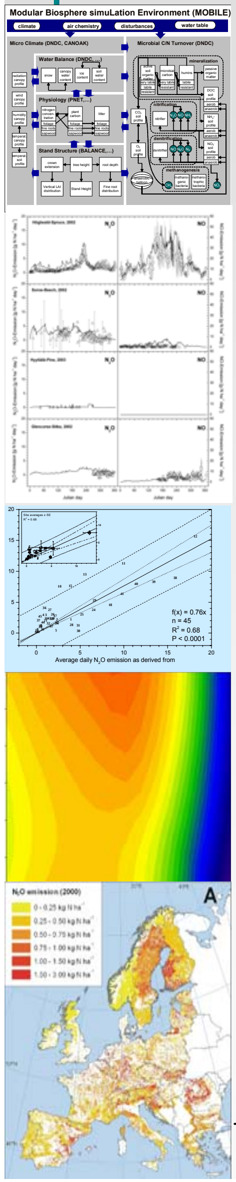



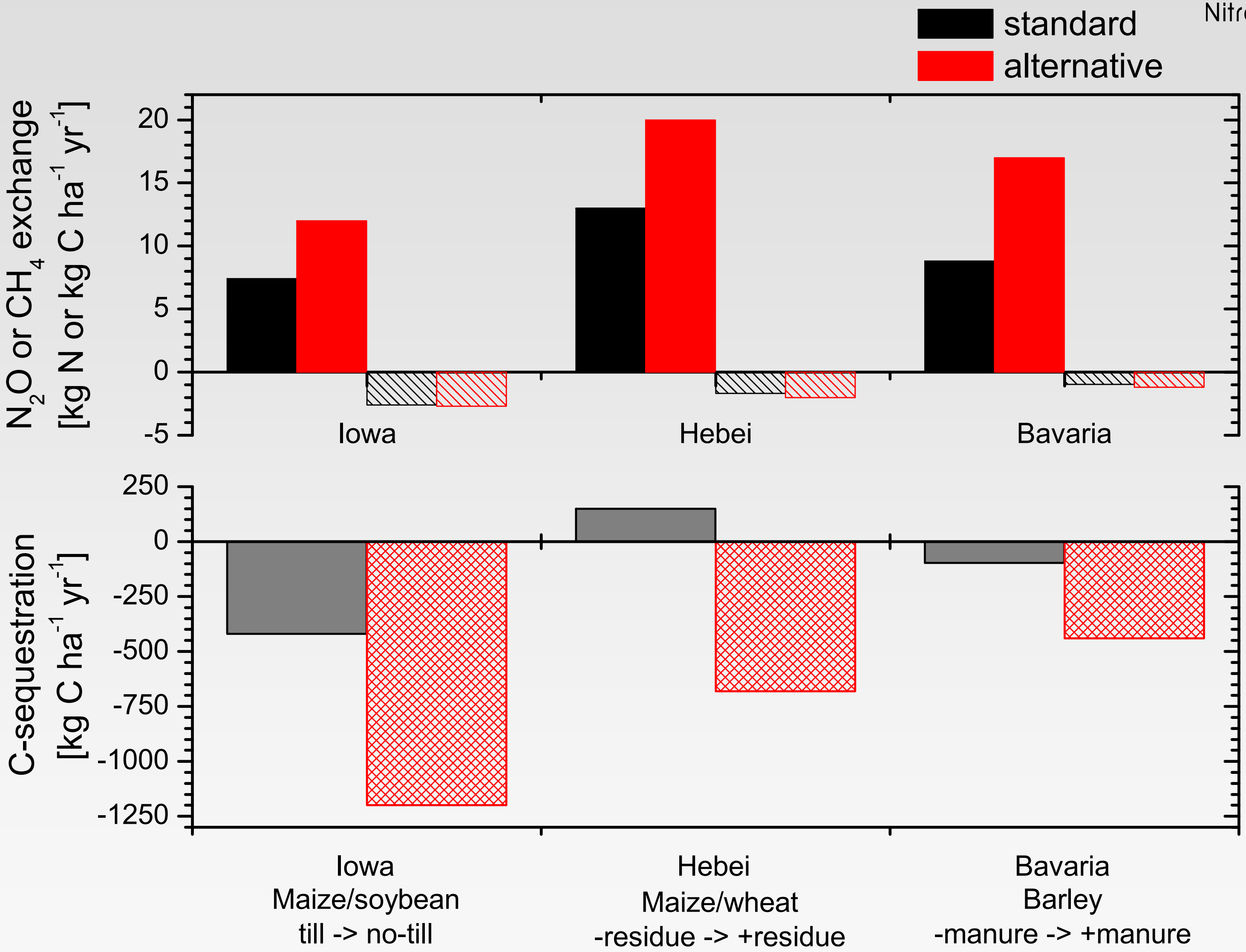


Identification of mitigation strategies for selected C1 and C2 sites by quantifying effects of land management, atmospheric composition and climate change on net GHG exchange.

- Past and present landuse changes and GHG exchange
- Feedback of climate and atmospheric composition change on GHG exchange
- Feedback of agricultural practices (e.g. changes in manure spreading) on GHG-exchange
- How will EU policy changes affect GHG emissions?
- Feedback of increased C storage on non-$CO_2$ emissions

# Component 3: A3.4 – GHG mitigation strategies

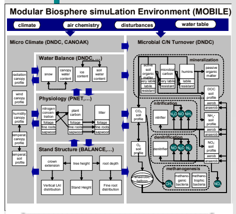


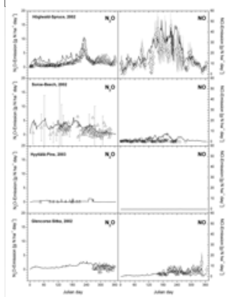


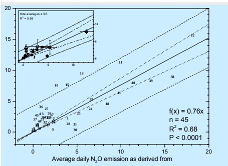

**Li et al., Climatic Change, 2005**

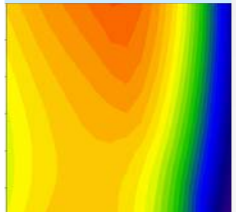
# Component 3: A3.4 – GHG mitigation strategies

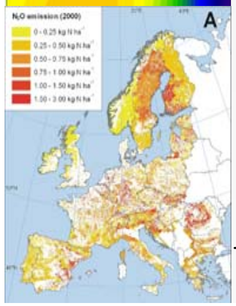
NitroEurope IP

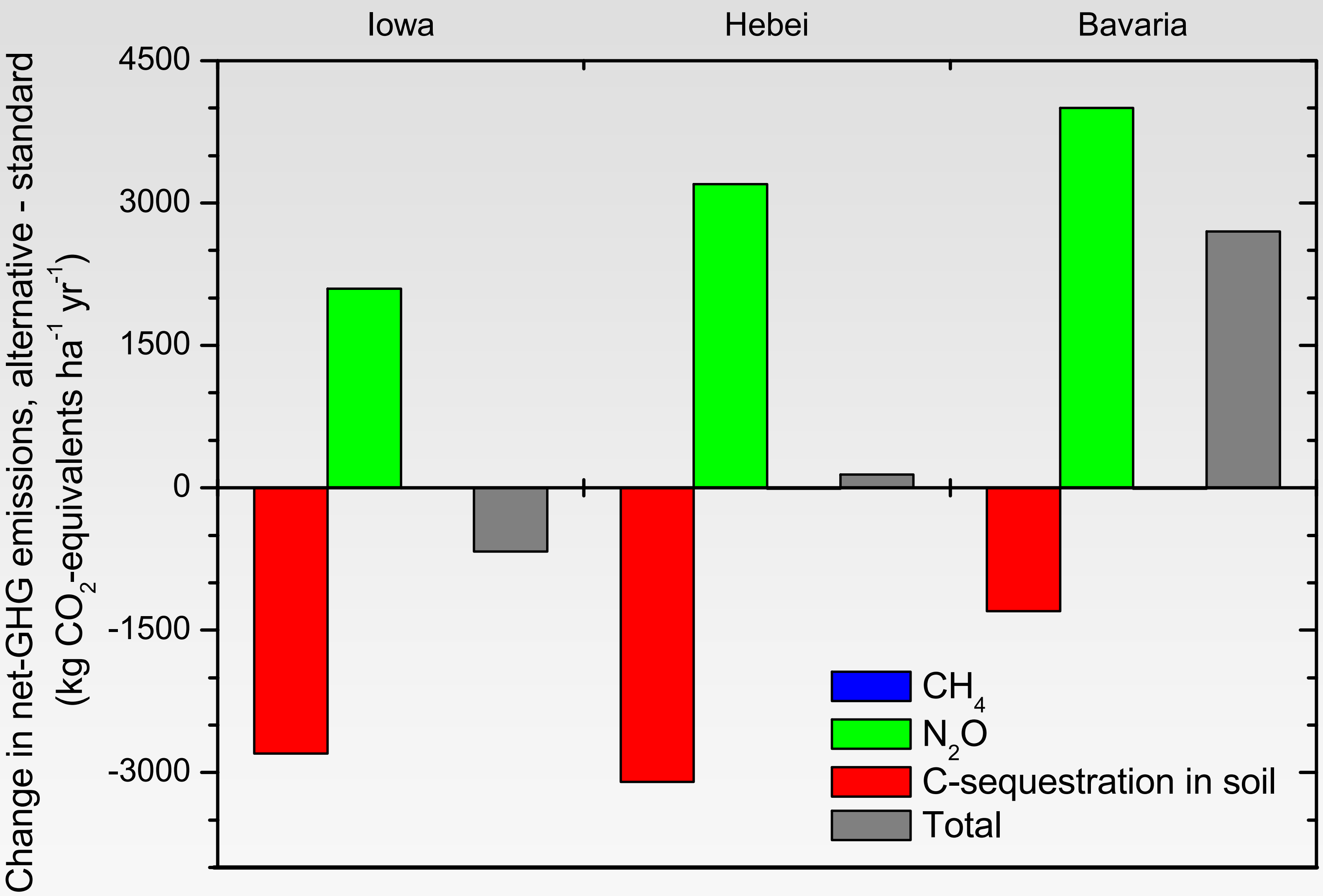








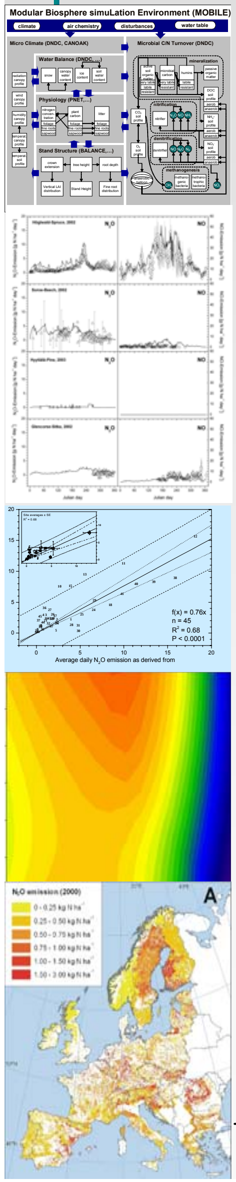




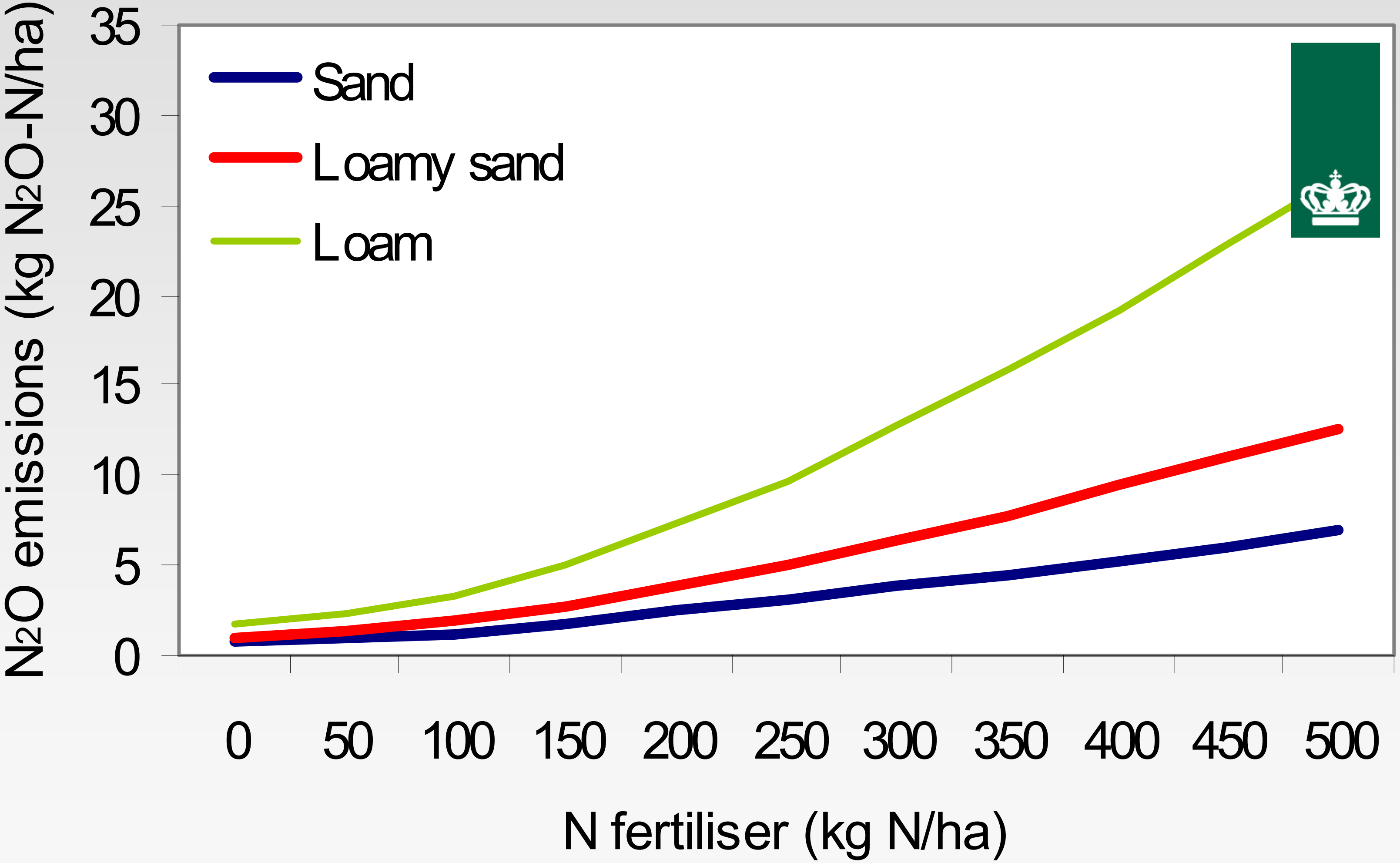

**Li et al., Climatic Change, 2005**

## Component 3: A3.4 – GHG mitigation strategies

NitroEurope IP



### Simulated $N_2O$ emissions from grazed grassland

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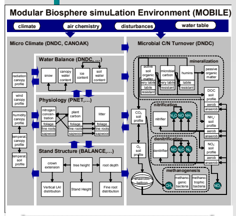
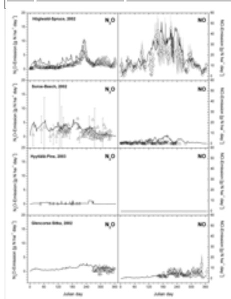
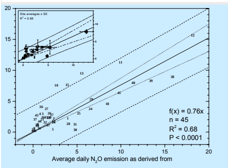
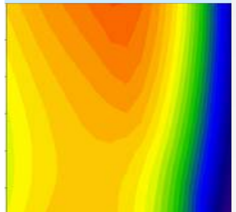
Danish Institute of Agricultural Sciences

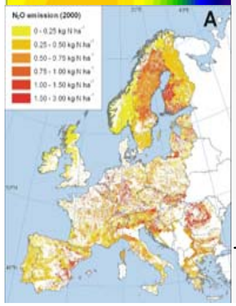
FASSET model –Chatskikh et al. (2005)







# Component 3: Conclusions

- Lots of experiences from previous projects (e.g. GREENGRASS; NOFRETETE)
- Strong links to other IP´s (e.g. CarboEurope, SEAMLESS)
- Plot modeling in NitroEurope does not only focus on $N_2O$, but also on the other GHG ($CO_2$, $CH_4$) as well as on the exchange of reactive N species (NO, $NO_2$, $NH_3$)
- Coupled CN models are a pre-requisite
- Improve and make models more robust to get applied in C4-C6

**Further C3 related sessions:**

***Tuesday (9:00-12:00):*** Room C. Current status and uncertainties in plot scale models for Nr and GHG.

***Tuesday (16:00-18:00):*** Room A: Common Measurement Protocols in relation to model needs.

***Wednesday (10:00-11:30):*** Room D. Application of plot scale models and scenarios

***Thursday (8:30-10:30):*** WG7. Uncertainty assessment in data and modelling