Karlsruhe Institute of Technology

Modelling nutrient transport and greenhouse gas emissions in managed arable soils with a fully coupled hydrology-biogeochemical modelling system at catchment scale

Department of biogeochemical processes

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LandscapeDNDC team

Philipp Kraft, Lutz Breuer
University of Giessen, Germany
CMF team

Motivation

- N-fertilization in arable systems
- Reactive nitrogen pathways
  - N_2O / NO emissions
  - NH_3 volatilization
  - NO_3 leaching
- N redistribution in the landscape
  - Indirect N_2O emissions
  - Feedback to plant growth

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Coupling biosphere – hydrosphere

- Establish coupled biosphere – hydrosphere simulation system
  - CMF (Catchment modelling framework)
  - LandscapeDNDC (regional scale biogeochemistry model)

- Coupling of regional models
  - Building a landscape scale biogeochemical model
  - Use of coupling tools (parallel computing tools)
  - Easy to add other regional models,

    → Atmospheric chemistry (WRF-Chem, EMEP)

Haas et al., 2013, Landscape Ecology

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Coupled system dynamics

- Virtual experiment to demonstrate coupled dynamics
  - 20 x 20 grid cell squared domain of 100 x 100 m
  - Soil properties & agr. management from existing site
  - Observations on yield, N_2O and NO emissions
  - Soil layer of 1.5 m depth
  - No ground water interaction
  - Different slope angles, soil types, precipitation schemes

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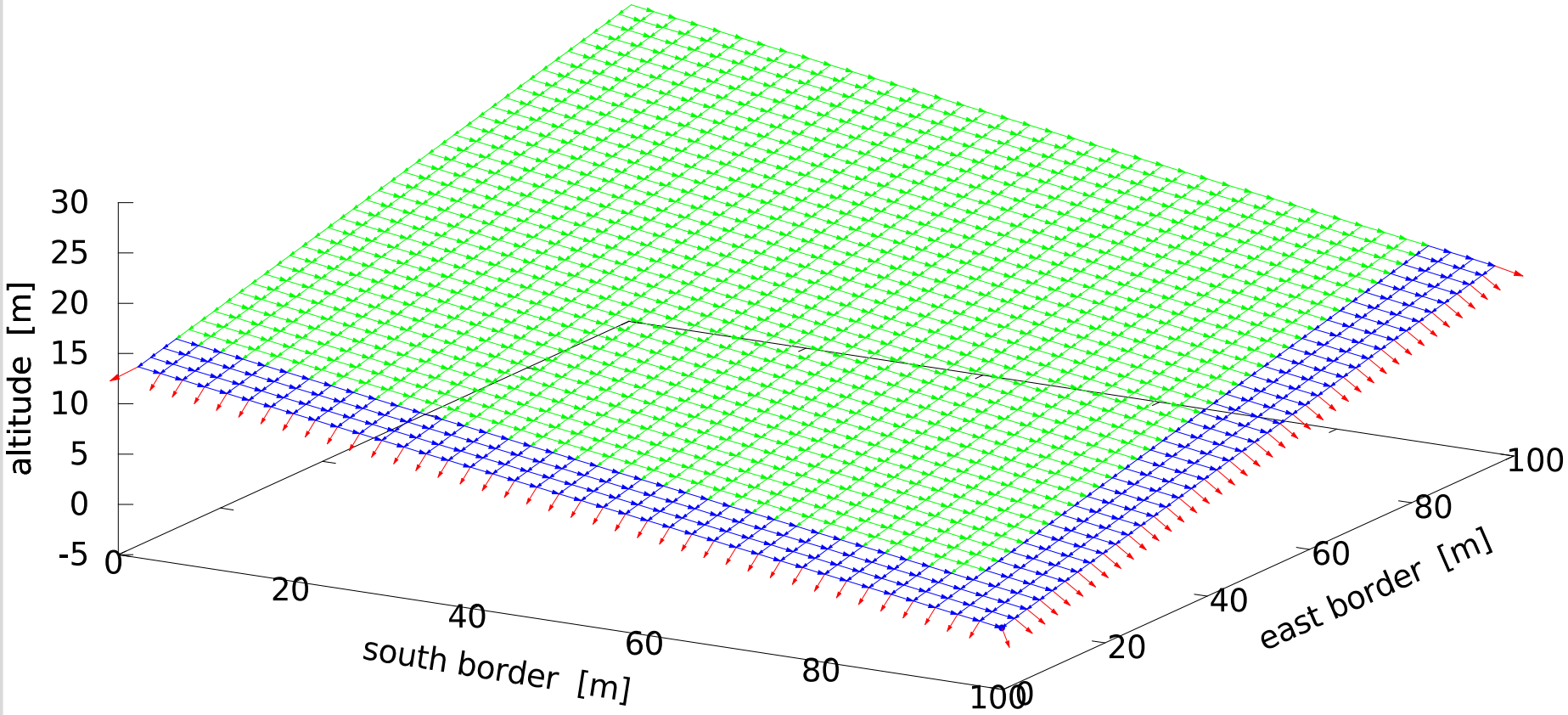
Coupled system dynamics

- Virtual experiment to demonstrate coupled dynamics



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Coupled system dynamics

- Agricultural Management
  - Site data: INRA observation site Grignon (France)
  - 6 year crop rotation: 2003 - 2008
  - 4 year spin up (2003 – 2006)
  - Compare crop yields & trace gas emissions with observations
  - Estimate NO_3 leaching into the stream

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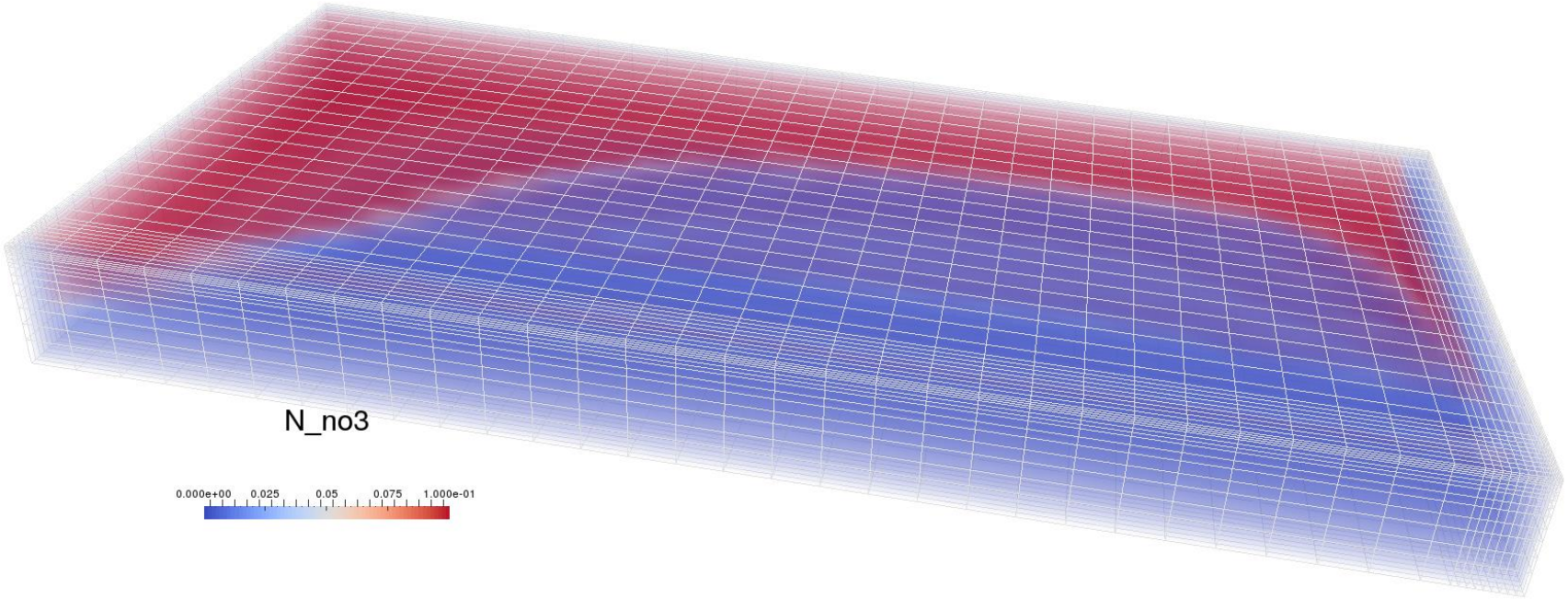
Coupled system dynamics

- Nutrient redistribution and associated trace gas emissions
  - Nitrate redistribution due to transport



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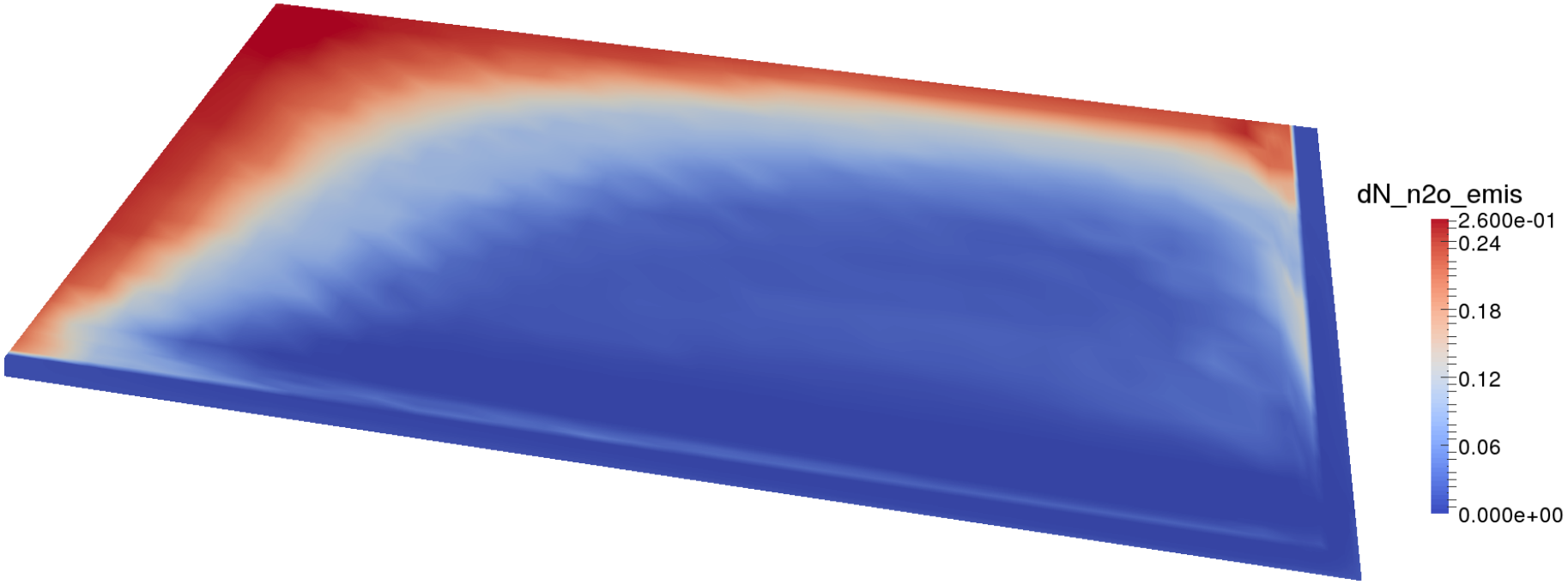
Coupled system dynamics

- Nutrient redistribution and associated trace gas emissions
  - Nitrous oxide emission strength



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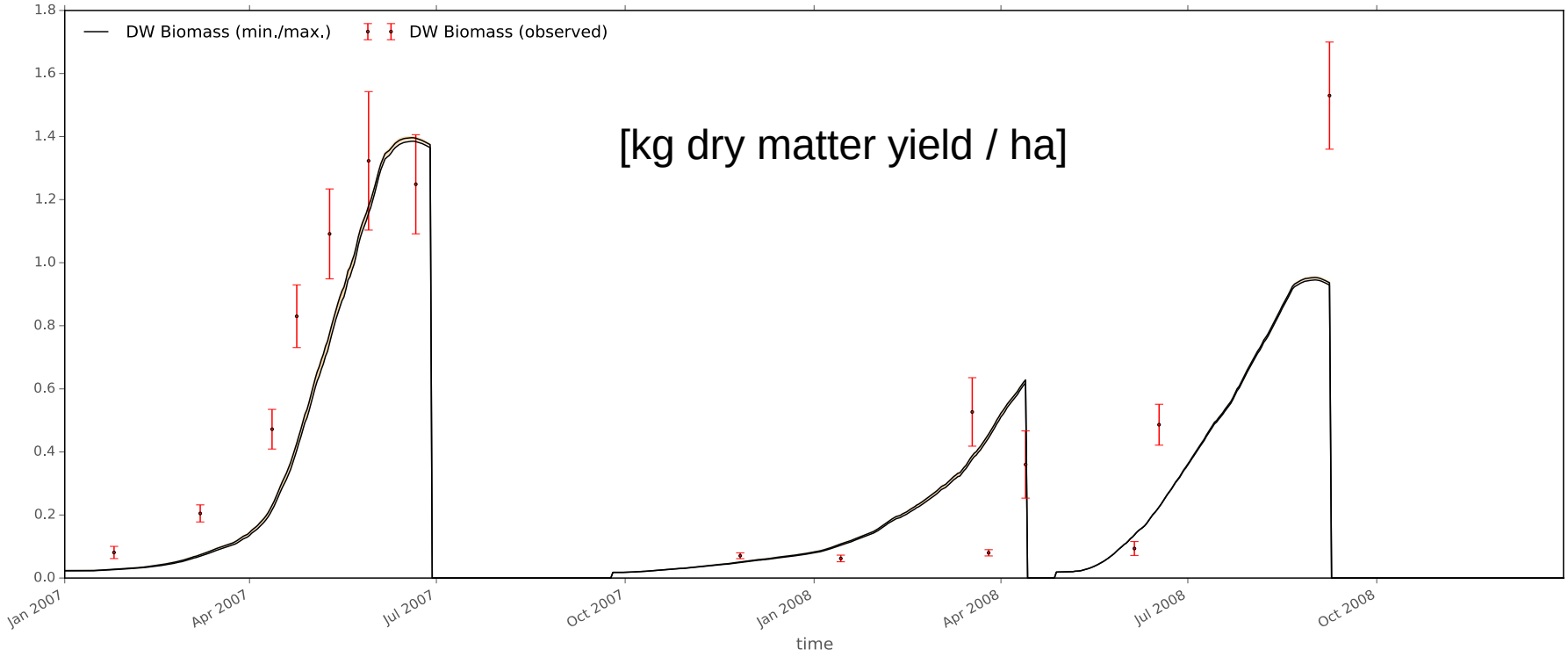
Coupled system dynamics

- Plant growth and trace gas emission validation



1.1.2007 – 31.12.2008

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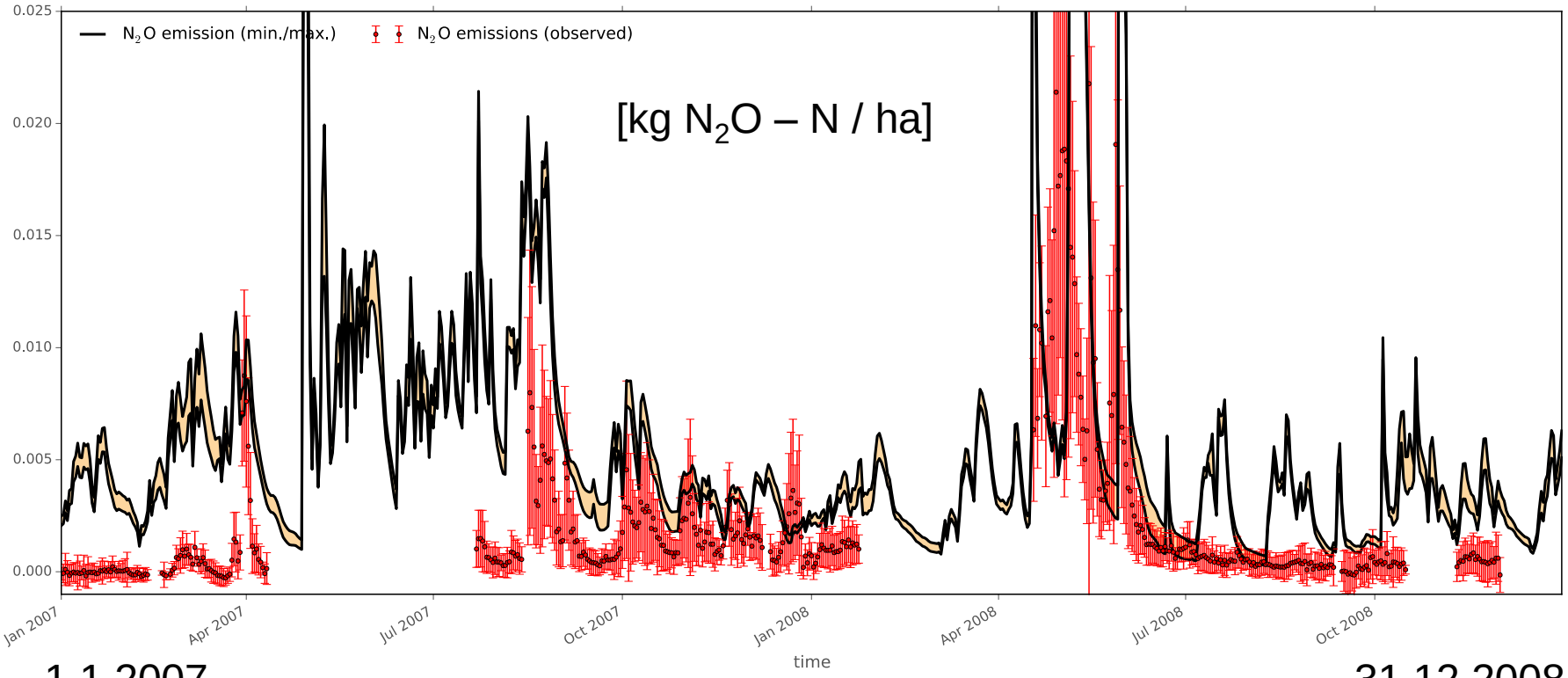
Coupled system dynamics

- Nitrous oxide (N_2O) emission validation



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Coupled system dynamics

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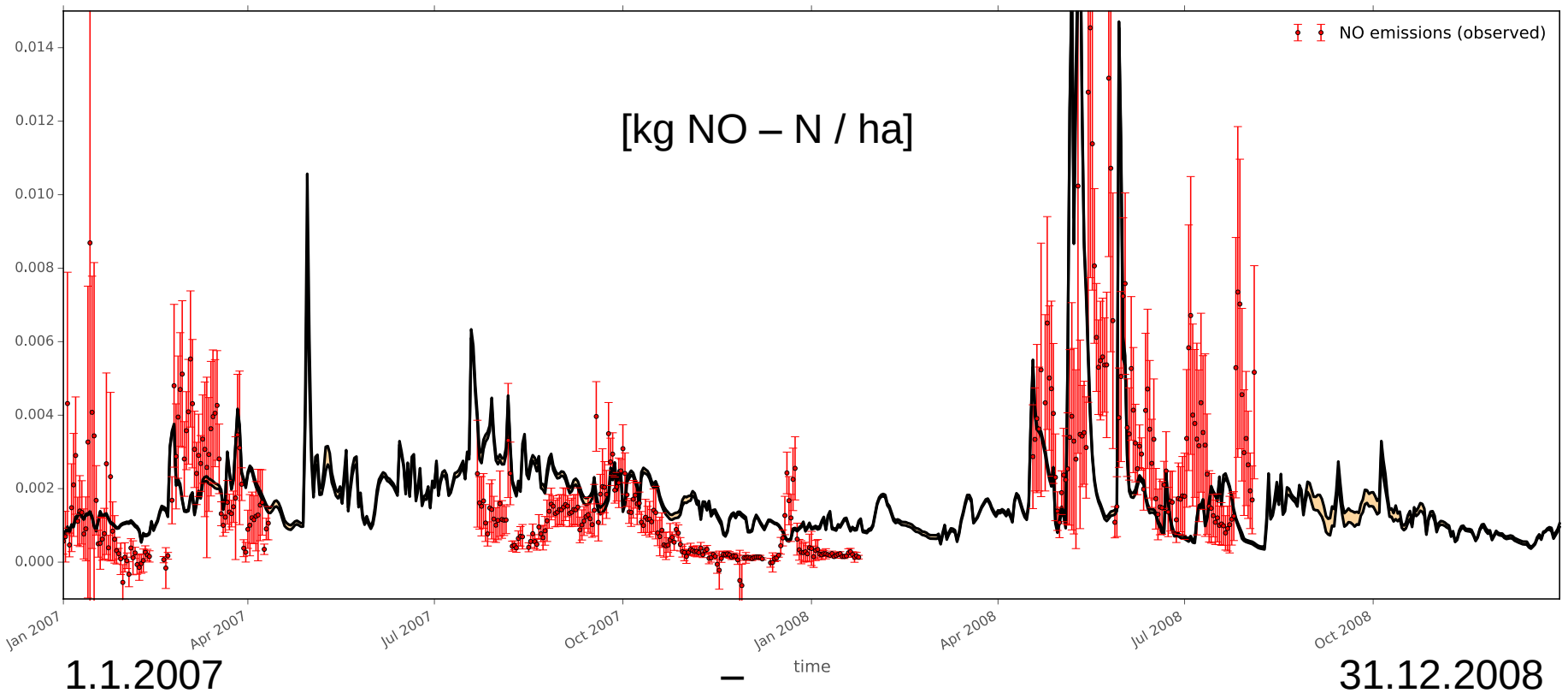

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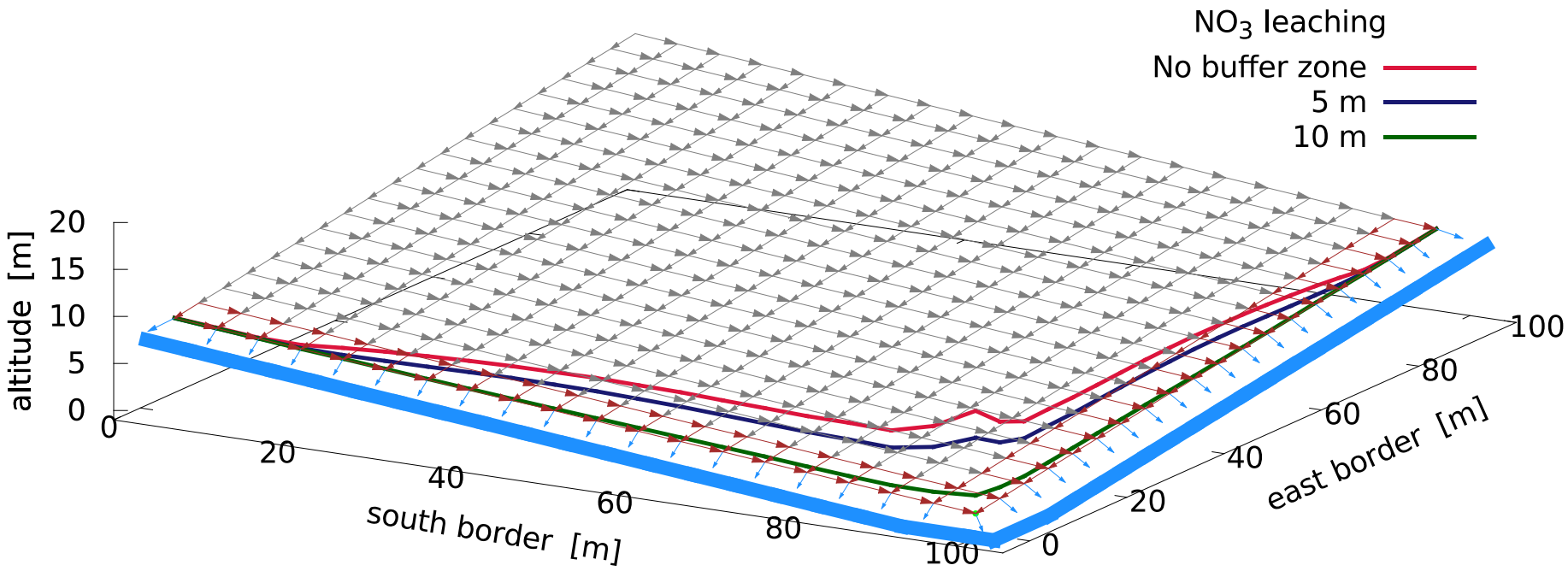
Coupled system dynamics

- Nitrate leaching



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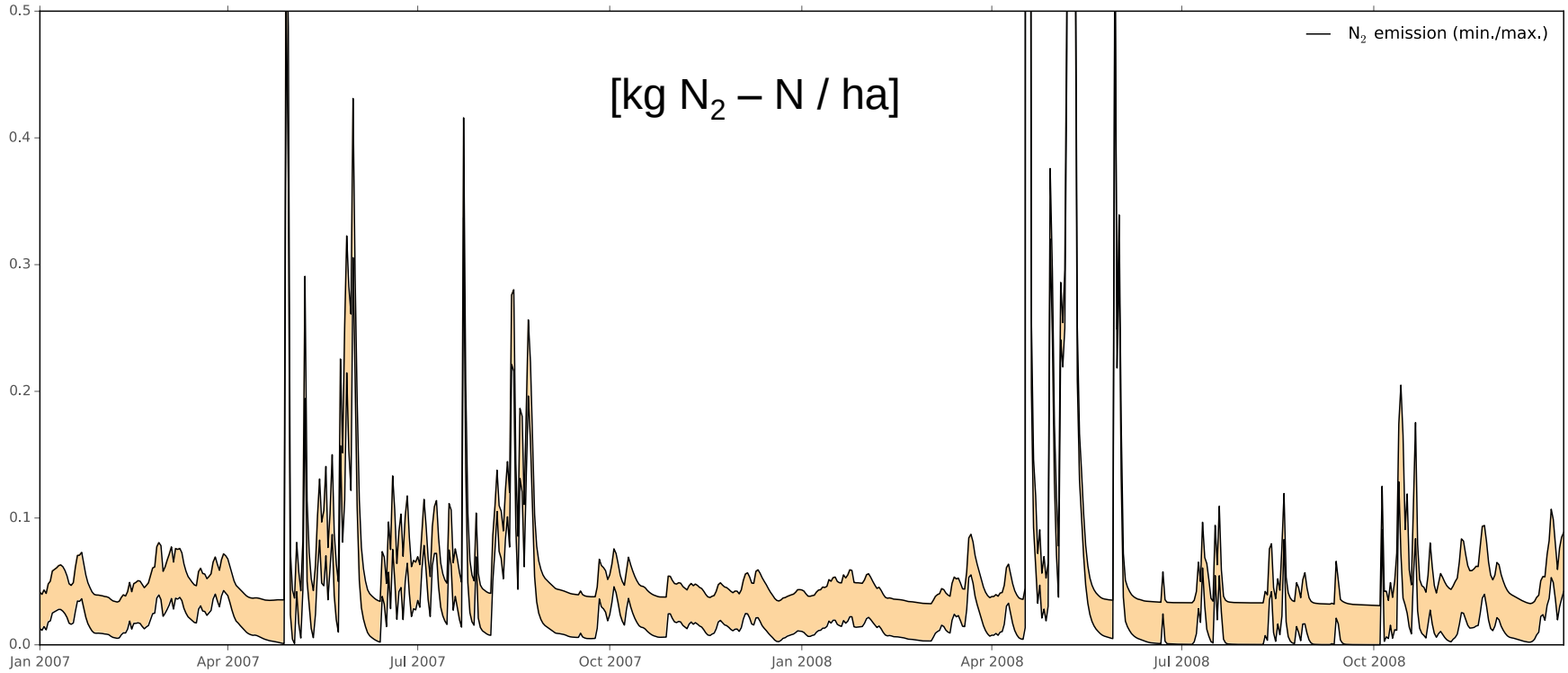
Coupled system dynamics

- N_2 emission
  - Variability resulting from different denitrification regimes



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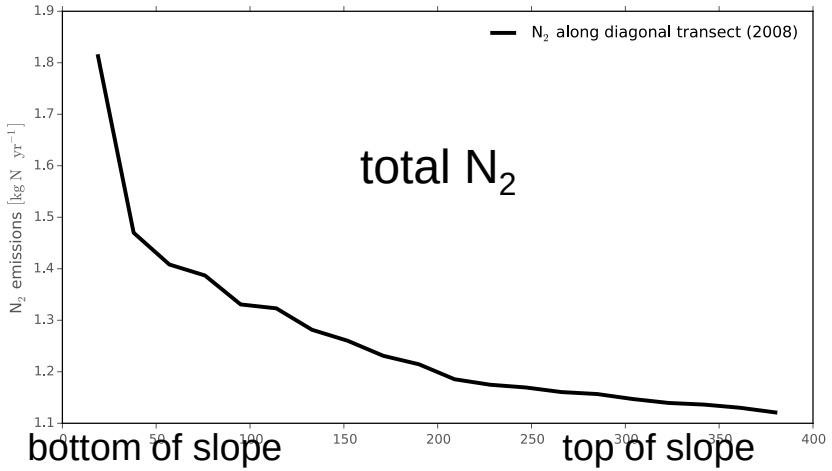
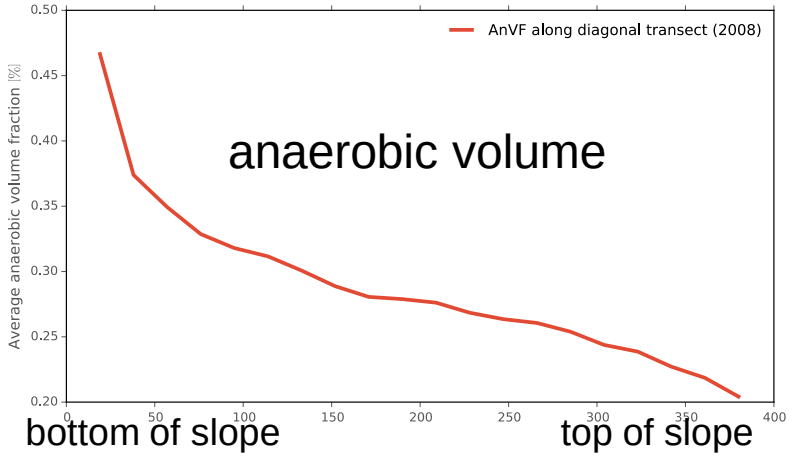
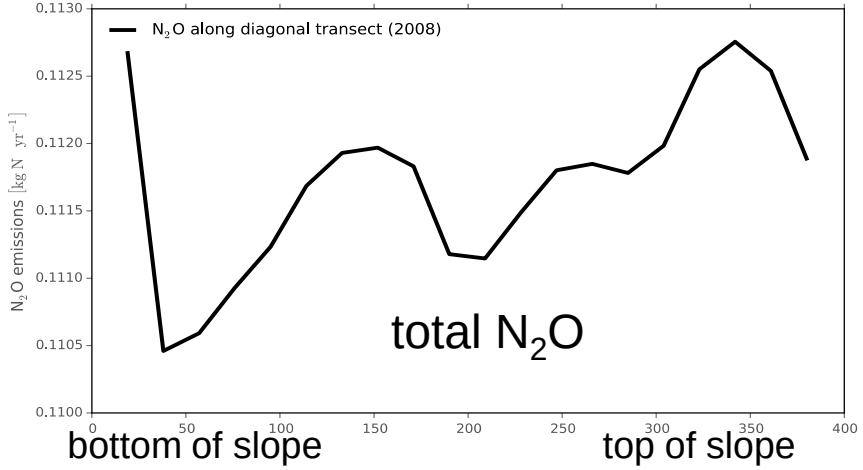
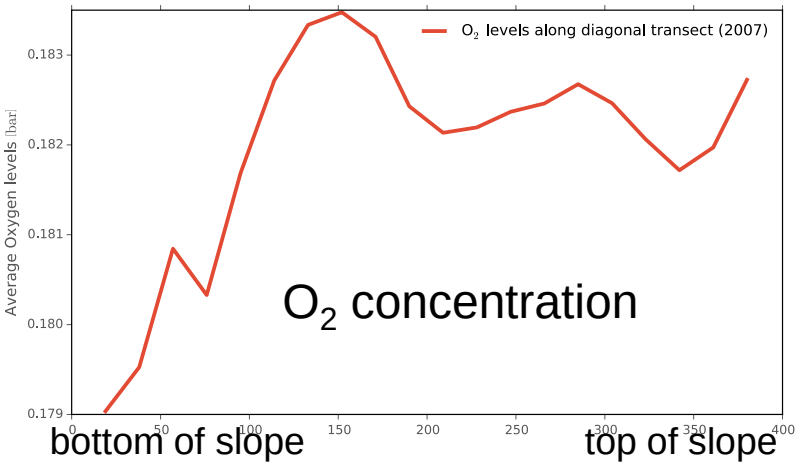
Coupled system dynamics

- N dynamics / characteristics along the domain diagonal









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Coupled system dynamics

- Results
- 2007
  - Fertilizer 110.0 kg N (Wheat)
  - NO3: 5.057 kg NO_3 – N / ha
  - N2O: 2.310 kg N_2O – N / ha
  - N2: 14.447 kg N_2 – N / ha
- 2008
  - Fertilizer 180.0 kg N (Silage Maize)
  - NO3: 4.884 kg NO_3 – N / ha
  - N2O: 2.234 kg N_2O – N / ha
  - N2: 24.338 kg kg N_2 – N / ha

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Coupled system dynamics

- Real catchment application (SinoGerman Collaboration Project)
  - Yanting Research Station Catchment, approx. 1 km^2

    Sichuan province, China
  - Double cropping system
  - Upland Maize – wheat & lowland paddy rice – wheat rotations
  - Discharge observations 2000 – 2014
  - Nitrate measurements in discharge
  - Management data
  - Yield, trace gas emissions, NH_4 and NO_3 concentrations

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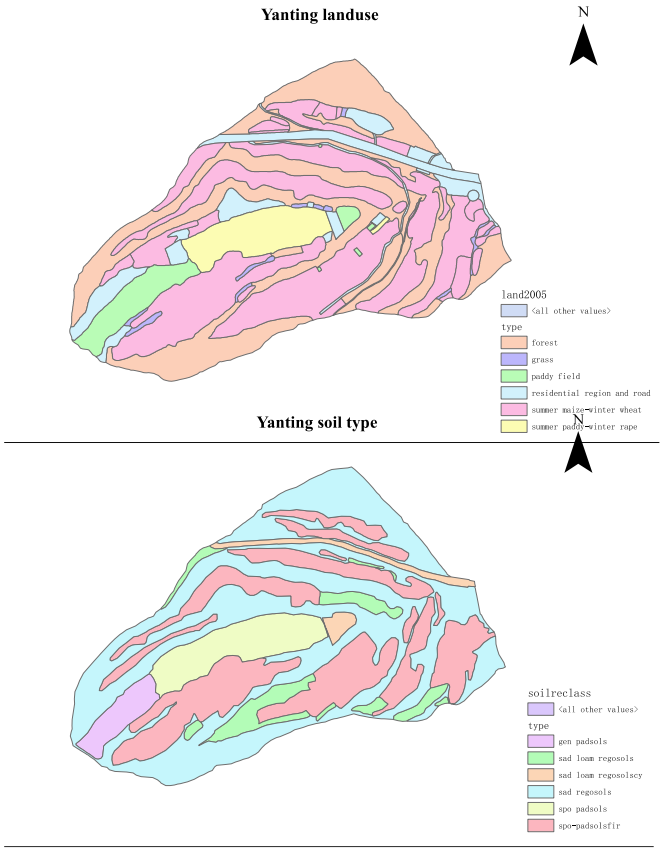
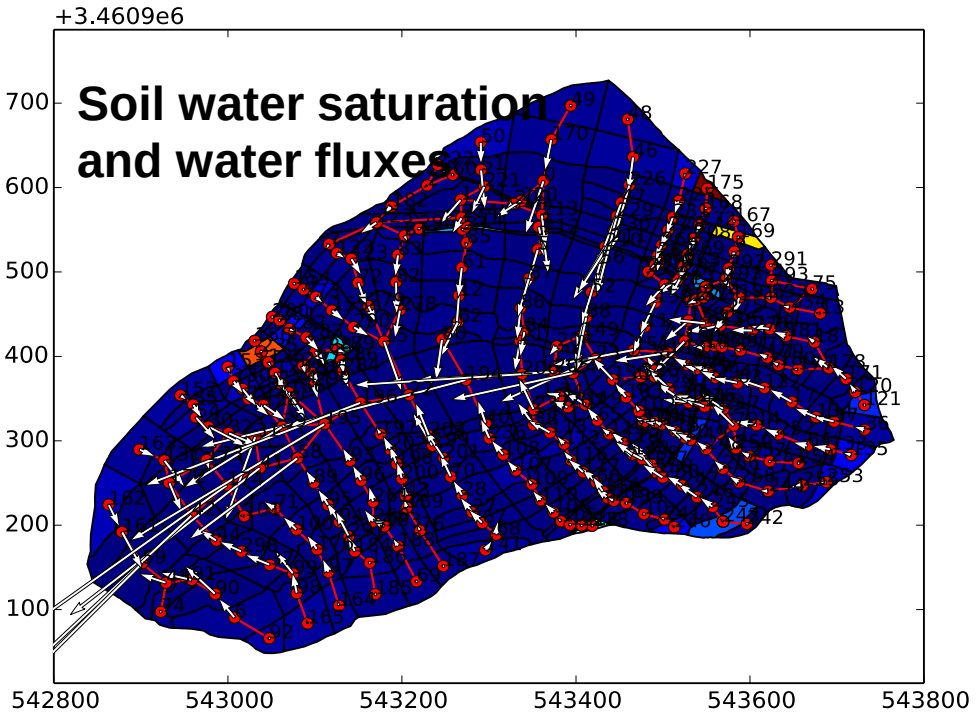
Coupled system dynamics

- Real catchment application (SinoGerman Collaboration Project)





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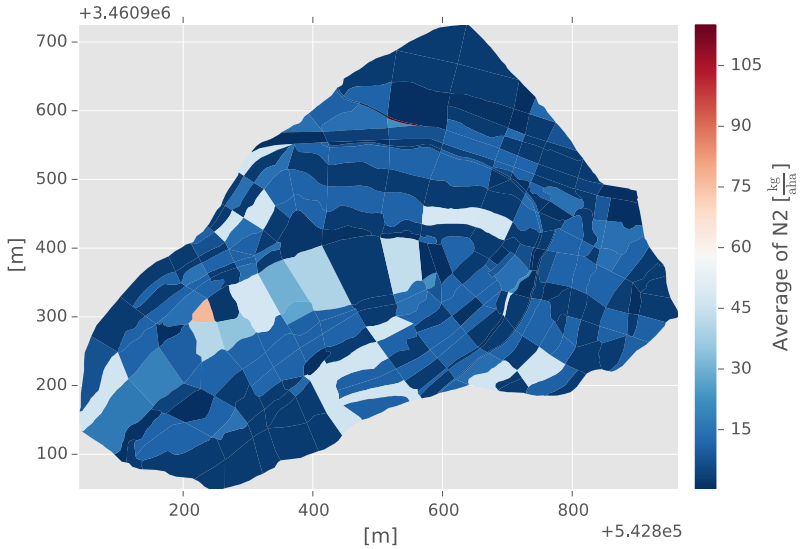
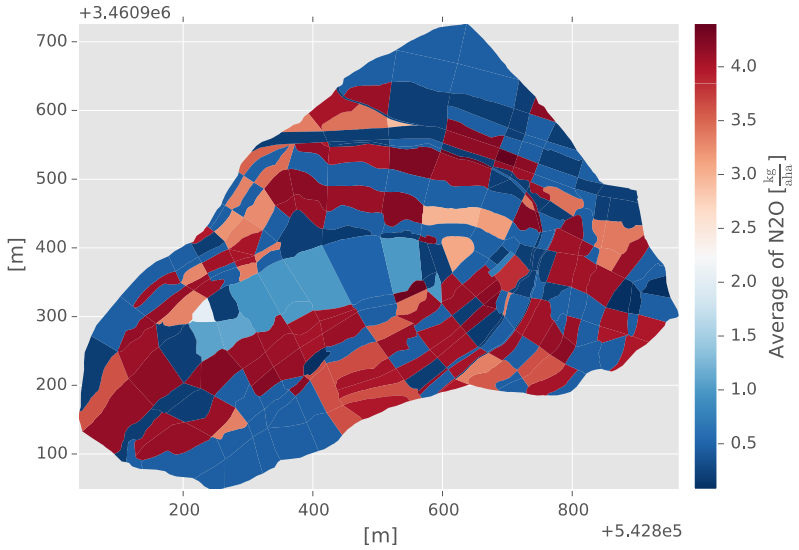
Coupled C & N cycling in a catchment

Yanting Research Station, Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu, Sichuan province, China
Foto: Google Maps





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Outlook

- Calibration of the hydrology with catchment discharge observations
- Identification of missing water sources and sinks

- Validate coupled simulations
  - Catchment scale N balance over 15 years
  - Yield observations
  - NO_3 observation in outlet water
  - N_2O emissions (Eddy Covariance, automatic chamber systems)

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Outlook

- Validate coupled system

- Looking for collaboration & validation datasets

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Thank you

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