Bottom-up and top-down approaches at the landscape scale over a mixed landscape

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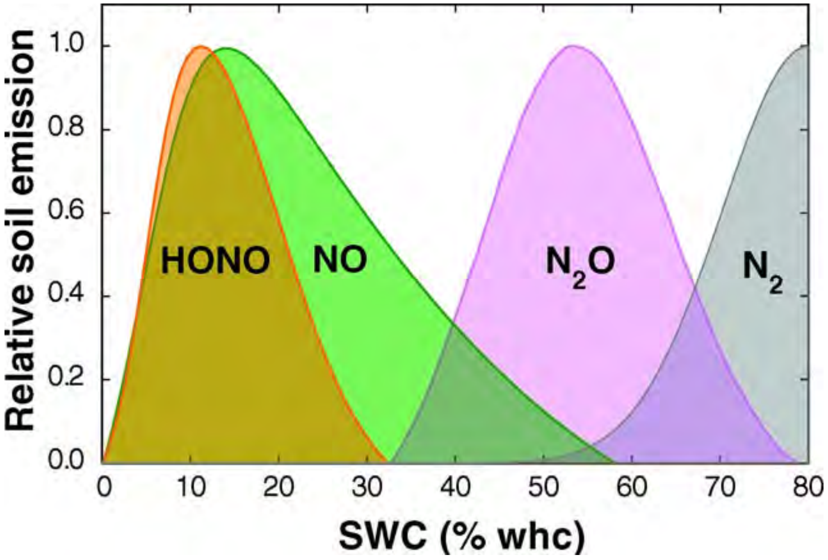
INGOS – **final conference. Utrecht 22-24 September 2015**

Context

- ~80% of anthropogenic N_2O emitted by agriculture
- Main emissions from fertilised agricultural fields.
- Indirect emissions from NO_3^- leaching to freshwater bodies & estuaries

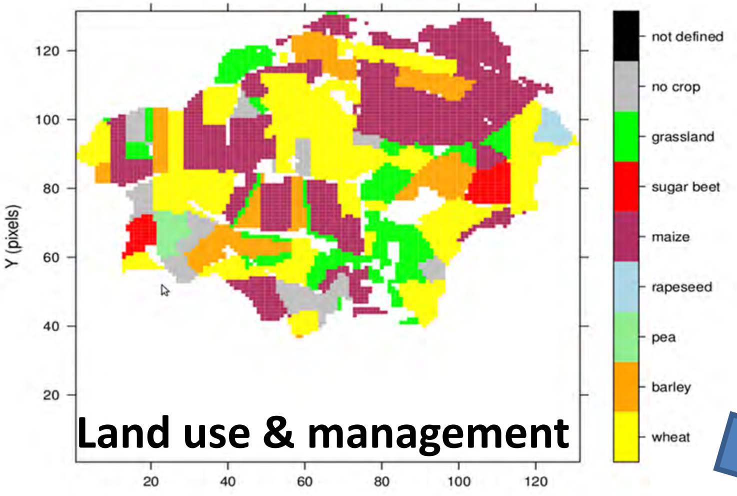
  → **26-37%** of direct emissions (Reay et al., 2012)

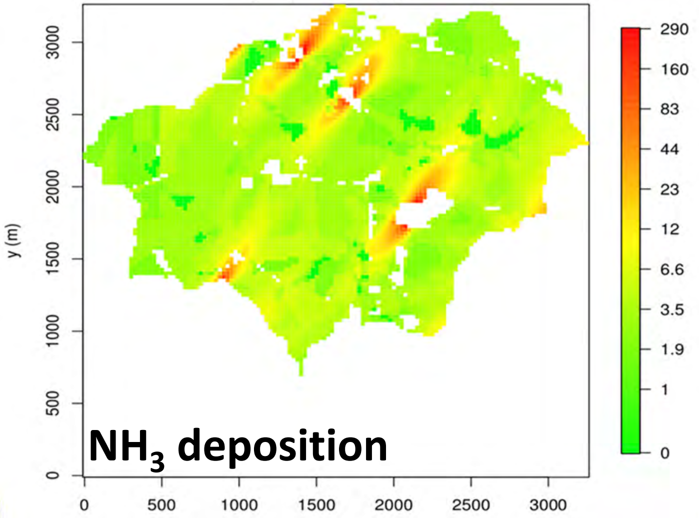
- Great spatial and temporal variability in these emissions
- Measurements difficult and scale dependent
- Uncertainties on emissions
- How will N_2O emission respond to climate change?



Context

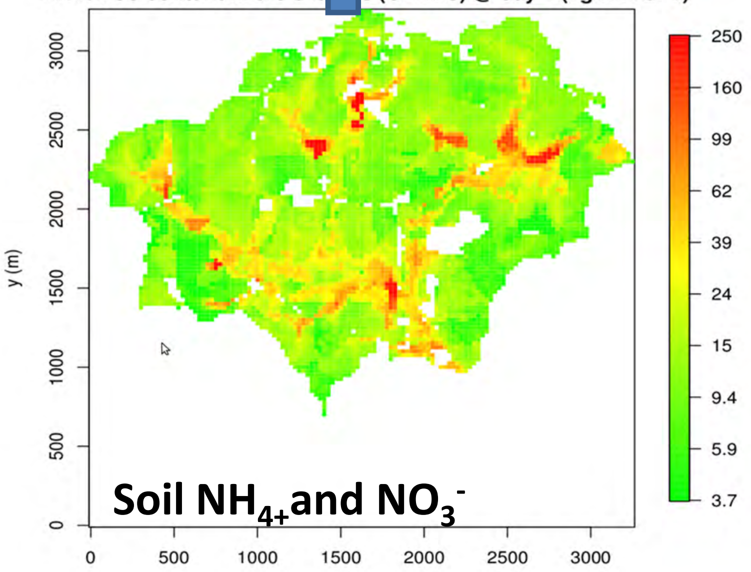
Landscape scale N_2O emissions variability:
an example of the NitroScape model
In Britany (France)





Hydrology
Plant uptake
Soil processes

Spatial and tempral
Variability inN_2O emissions



Need for integrated measurements at the landscape scale

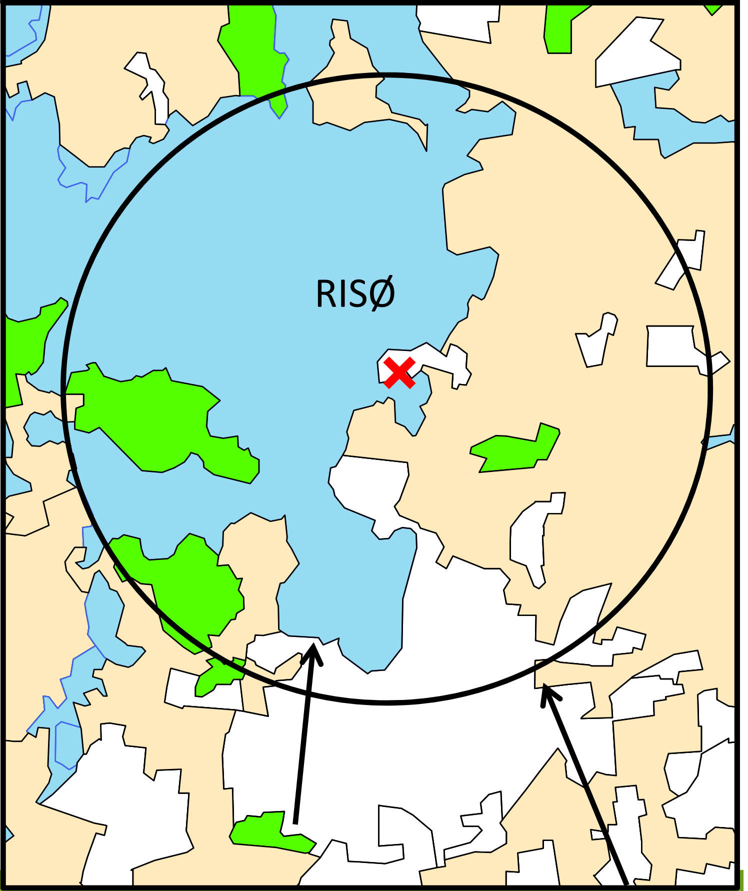
Objectives

- Compare the results of the **bottom-up and top-down** approaches both for the agricultural and the fjord areas
- Evaluate the effect of the scale on bottom-up emissions
- Estimate the **distribution** between direct N_2O emissions and indirect emissions

Study site:

- Tall tower at the DTU Risø Campus (sensor at 96 m high)
- Footprint : 5 km around the tall tower (80 km²)
- **large agriculture area (crops: 18 km²)**
- **inner Roskilde fjord (36 km²)**
- urban area (Roskilde) waste water treatment
- woody areas

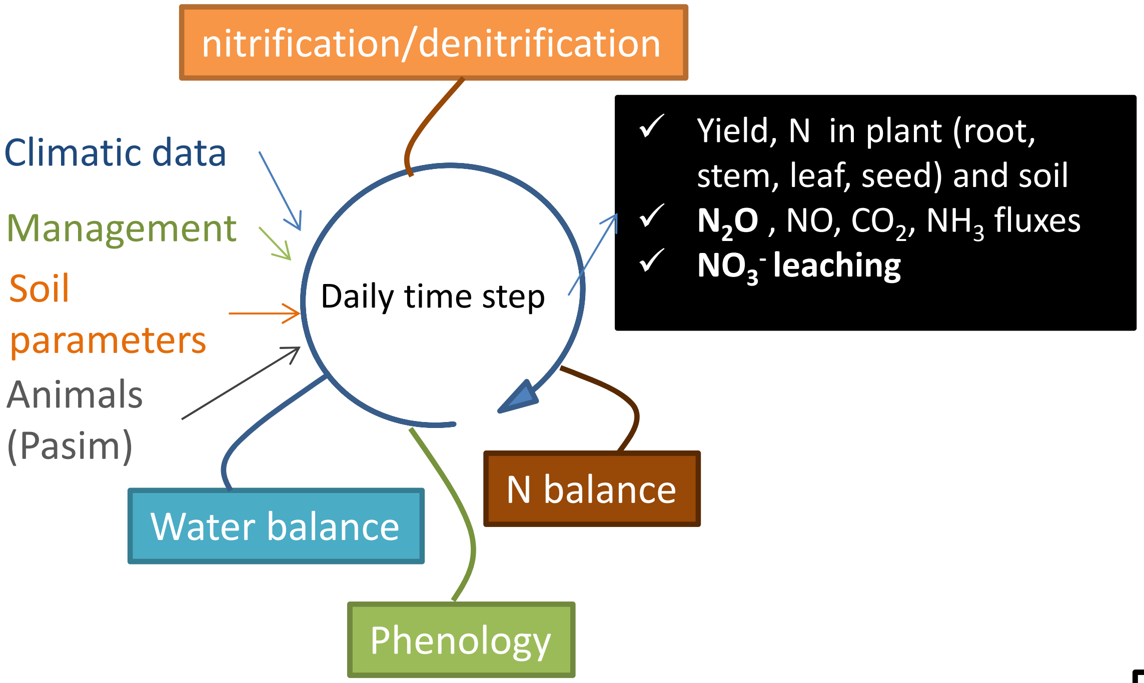
The Roskilde region



Material and methods

❖**Bottom-up emissions from crops and grassland**

- Distribution of crop fields and grasslands in the study site
- CERES-EGC and Pasim crop fields and grasslands models



nitrification/denitrification

Climatic data

Management

Soil parameters

Animals (Pasim)

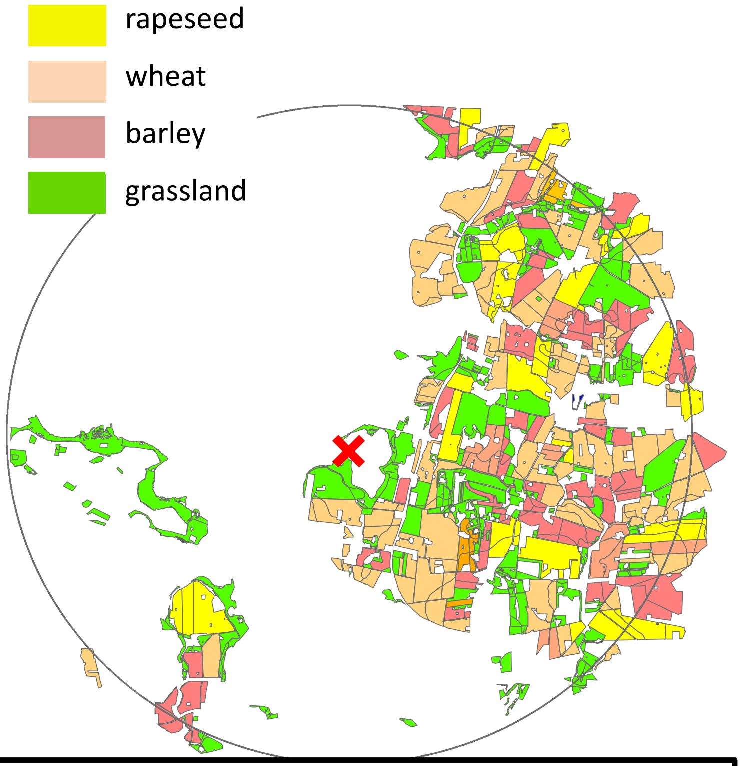
Daily time step

- ✓ Yield, N in plant (root, stem, leaf, seed) and soil
- ✓ **N_2O** , NO, CO_2, NH_3 fluxes
- ✓ **NO_3^- leaching**

Water balance

N balance

Phenology



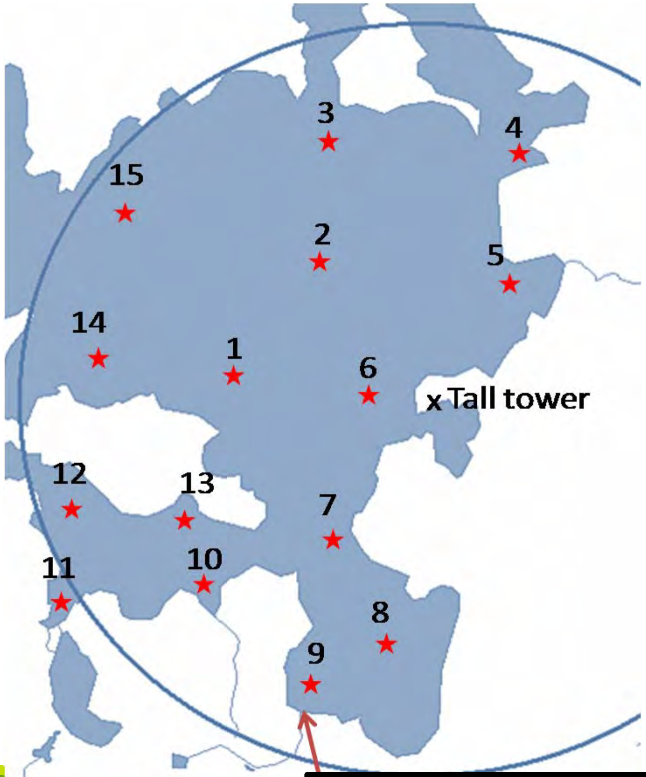
Soils from very sandy to loamy sand
Main rotation rapeseed-wheat-barley
Max application 100-170 kgN ha^{-1} yr^{-1}

CERES (Jones and Kiniry,1986; Gabrielle et al., 2006)
Pasim (Calanca et al. 2007)

Material and methods

❖**Bottom-up emissions from the Roskilde Fjord**

- Mildly salty (10-15), shallow (3m). and recovering from eutrophication
- Measurements of N_2O concentrations in 15 points in May, July and September



Water waste treatment plant

$$F_{N2O} = k_w * ([N_2O]_w - C_e)$$

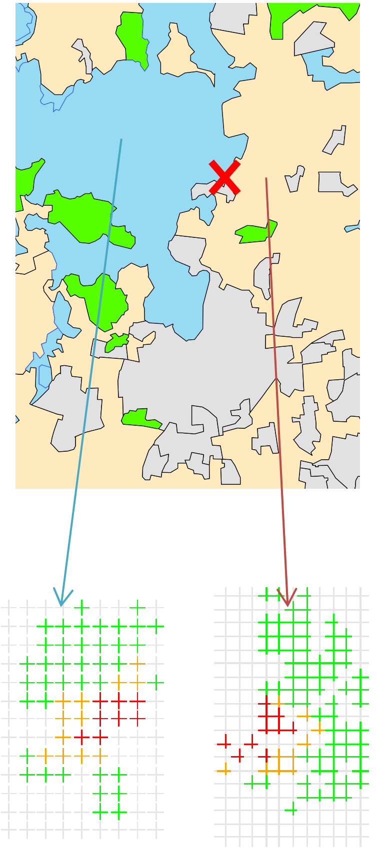
- K_w (m s^{-1}): gas transfer coefficient, f(u,10m)
- C_e (g N_2O-N L^{-1}): equilibrium N_2O concentration in seawater, f(T, salinity, $[N_2O]_{atm}$)

Bange et al. (2001), Weiss and Price (1980)

Material and methods

- **Top-down measurements with eddy covariance**
  - Tall tower with anemometer and inlet tube at 96 m
  - N_2O Los Gatos analyser for eddy covariance
  - Short lag time insured by large pump (Ibrom et al. *in prep*)

- **Top-down and bottom-up flux estimations**
  - Selection of rasters where bottom-up emissions are computed
  - Rasters outside the modelling domain are considered emitting an average flux
  - Source attribution calculated with the Kormann and Meixner (2001) footprint model
  - Comparison of daily averages



Raster of the Roskilde fjord

Raster of the agricultural area

Results – modelled terrestrial emissions

❖ **Bottom-up CERES and PASIM emissions**

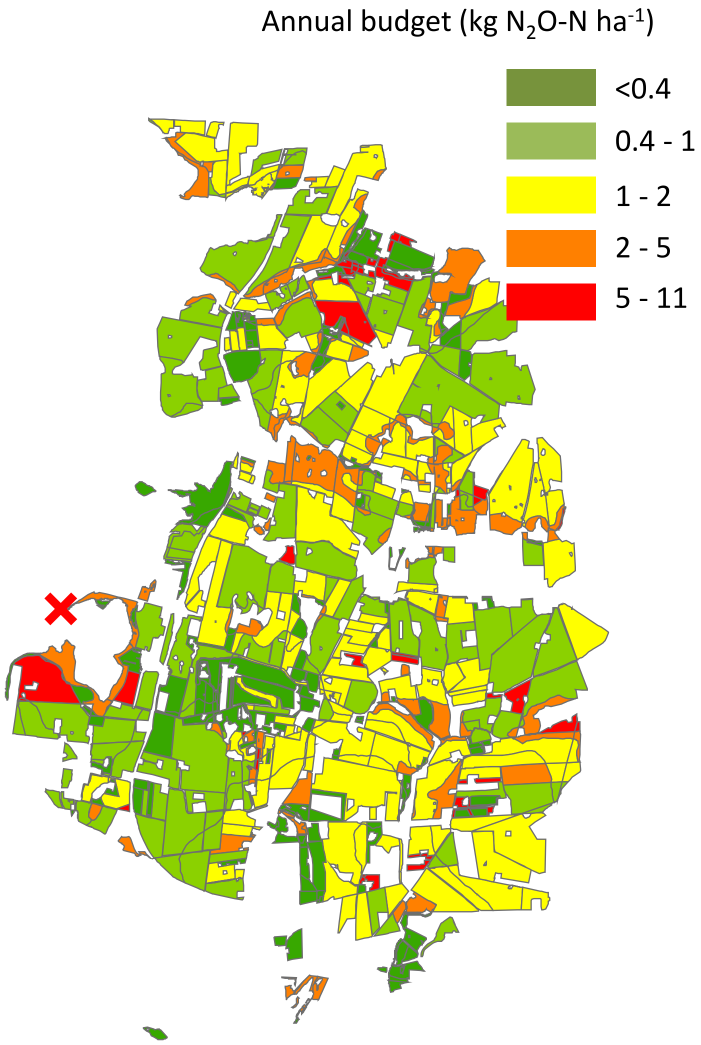
- Annual fluxes : from 1 to 10 kg N_2O-N ha^{-1} year^{-1}

→ Fertilizers inputs : 0 to 300 kg N ha^{-1} yr^{-1}

- Temporal variations between CERES and PASIM

→ Dates of fertilization, harvest, cuttings

	Crop Fields
Area (km²)	18
N-Fertilisers (tons)	135
2013 N_2O emissions (kg N_2O-N yr^{-1})	**1100 (IPCC)** **690 (CERES-EGC)**
Emission factors N_2O/N-fertiliser	**IPCC : 1%** **Sjælland: 0.8%** **CERES-EGC: 0.6%**
NO_3-N leaching	18 tons

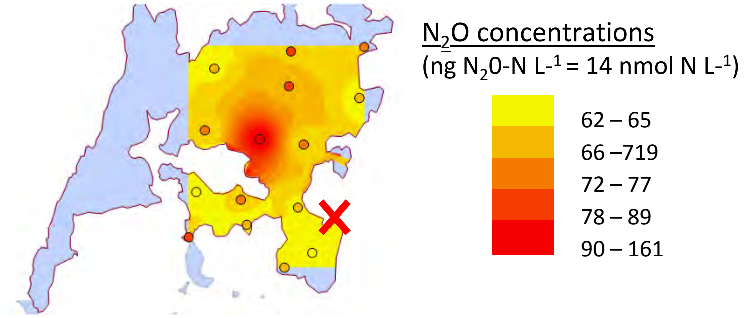


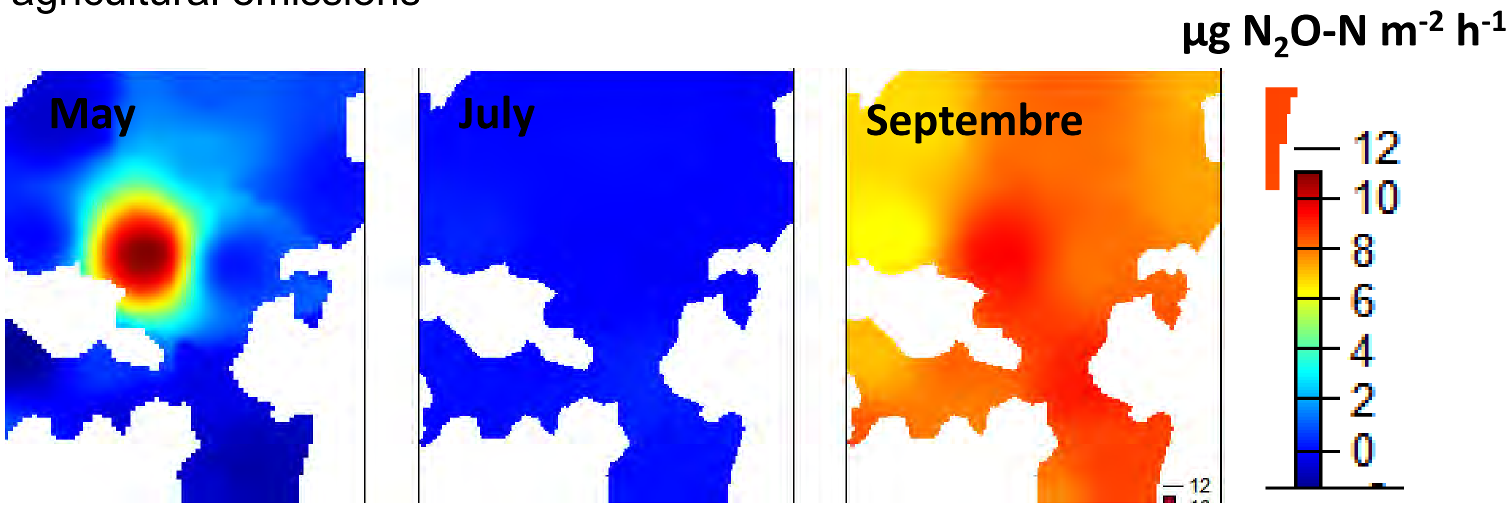
Results – Estimated Fjord emissions

❖ **Bottom-up N_2O fluxes from water sampling**

- Low concentrations (< 0.24 µg N_2O-N L^{-1})
- Estimated fluxes can be positive or negative
- Fluxes in July are lesser than those in May and Septembre
- Highest N_2O fluxes comparable to lower agricultural emissions

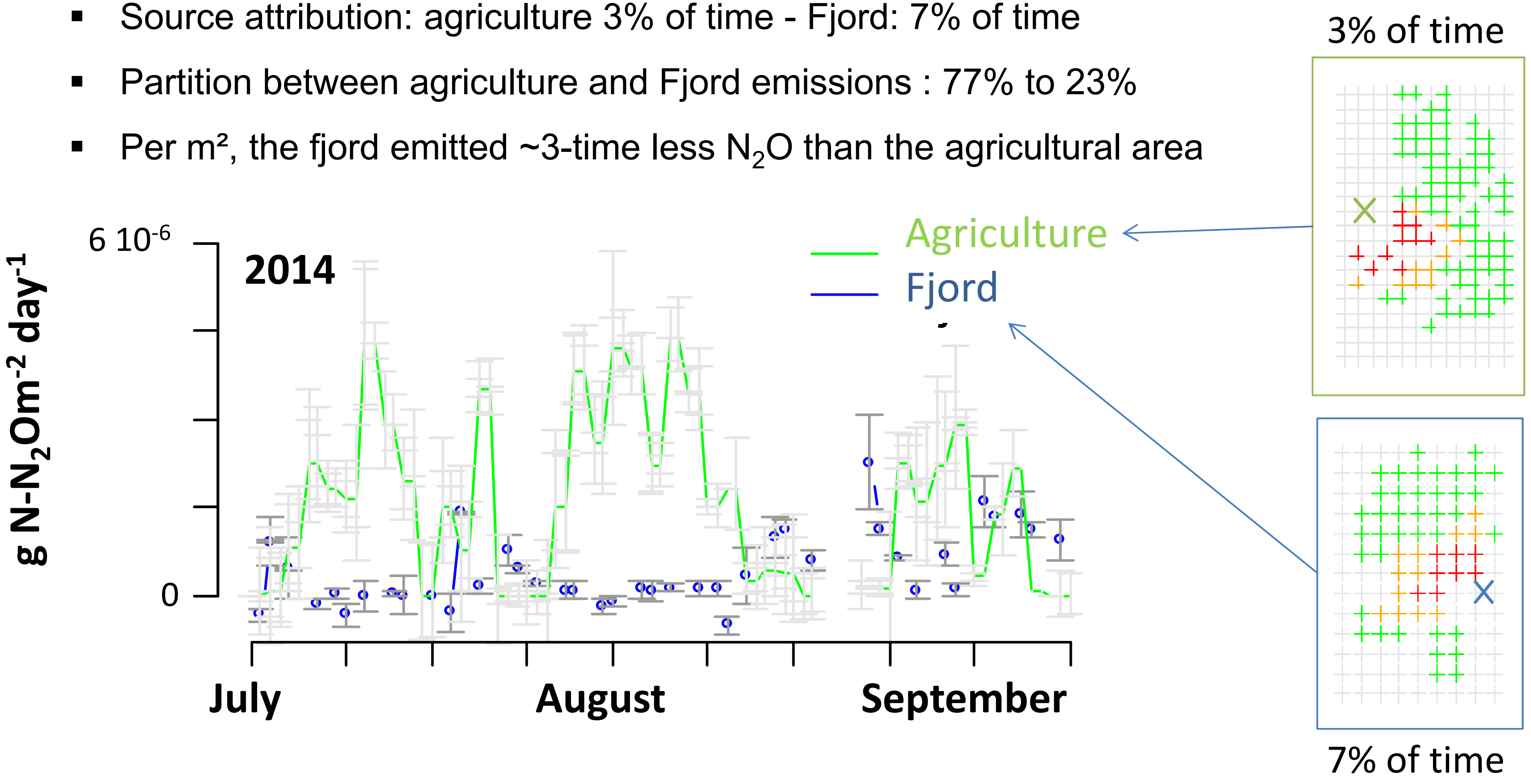
May concentrations





Results – Top-down emissions

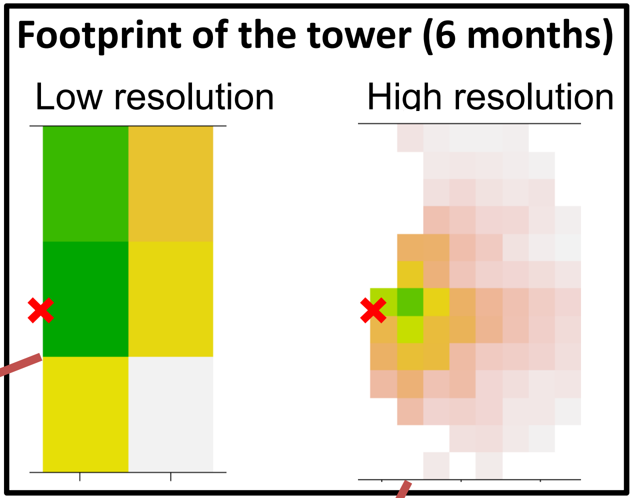
- **Eddy covariance N_2O fluxes in Fjord and Agricultural area**
  - Source attribution: agriculture 3% of time - Fjord: 7% of time
  - Partition between agriculture and Fjord emissions : 77% to 23%
  - Per m², the fjord emitted ~3-time less N_2O than the agricultural area



Comparison top-down and bottom up

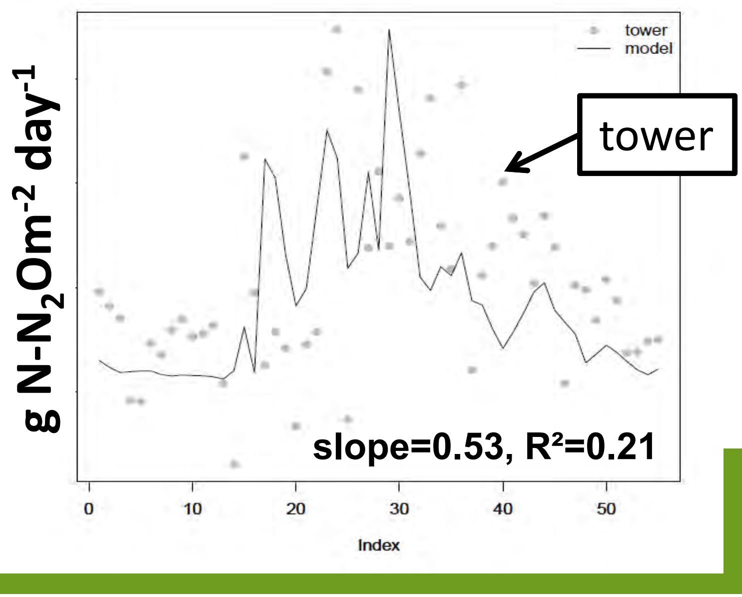
❖ **Agricultural sources: two aggregation scales**

- Footprint weighed fluxes
- Good seasonality in both approaches
- Higher resolution gives less variability
- Better agreement with lower resolution
- Peaks not well reproduce



Footprint of the tower (6 months)

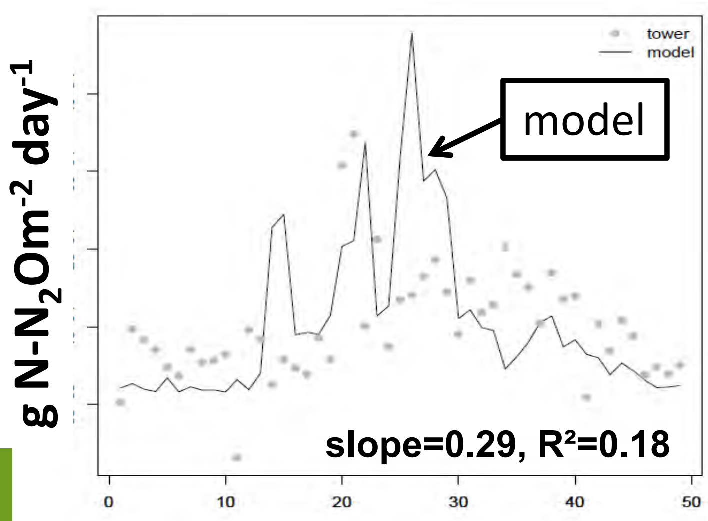
Low resolution



tower

slope=0.53, R²=0.21

High resolution



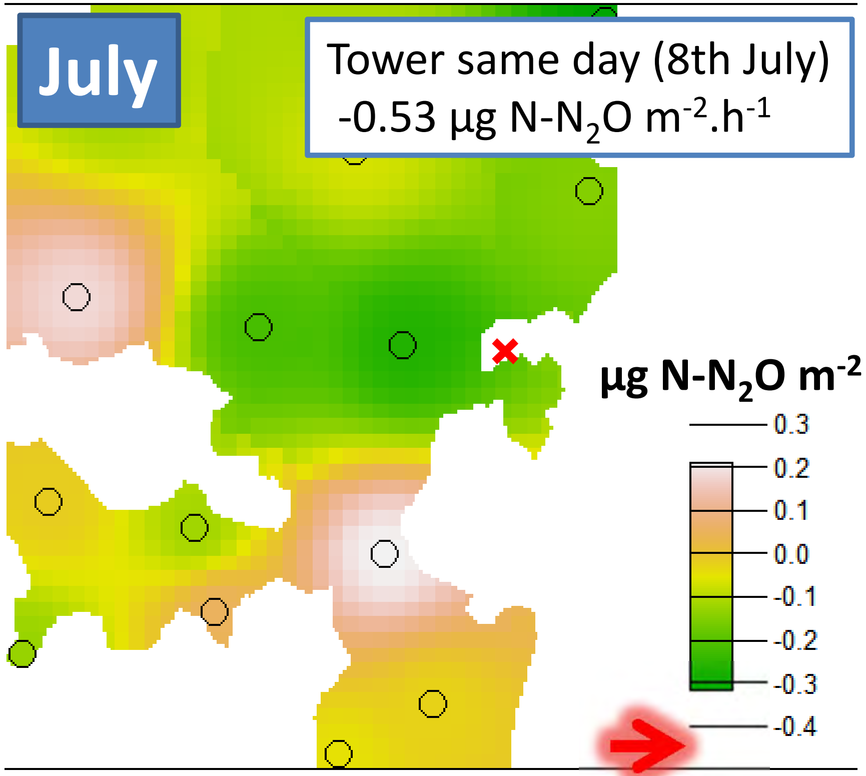
model

slope=0.29, R²=0.18

Comparison top-down and bottom up

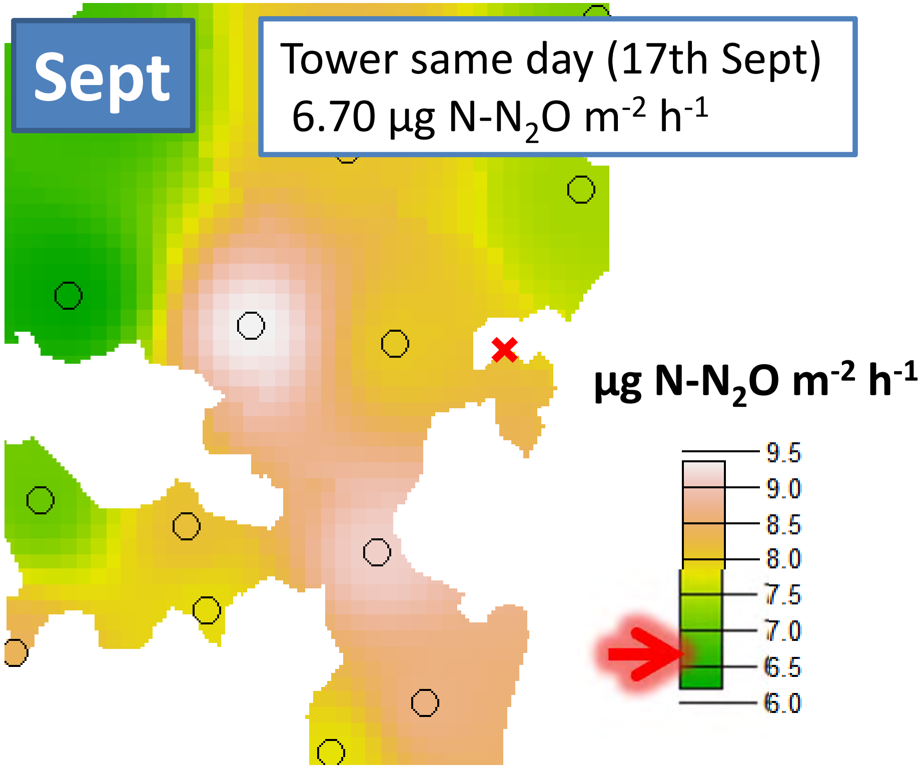
❖ **Fjord: daily comparison**

- Less data, but consistent
- Sign and order of magnitude in good agreement



July

Tower same day (8th July)
-0.53 µg $N\text{-}N_2O\ m^{-2}.h^{-1}$



Sept

Tower same day (17th Sept)
6.70 µg $N\text{-}N_2O\ m^{-2}\ h^{-1}$

Summary

- ✓ Bottom-up N_2O emissions
  - ✓ Agricultural emissions lower than IPCC by 40% (~0.6 emission factor)
  - ✓ Fjord emissions temporally variable (factor of 10 changes)
  - ✓ Deposition flux observed in the Fjord
  - ✓ Higher Fjord emissions similar to lower Agricultural emissions

- ✓ Top-Down N_2O emissions with Eddy covariance at 96 m height
  - ✓ Demonstrated as a method for regional N_2O flux (Andreas Ibrom)
  - ✓ Emissions from Agriculture 3 times larger than from the Fjord

- ✓ Comparison between top-down and bottom up
  - ✓ Footprint approach useful. No clear conclusions from scale evaluations
  - ✓ Comparable seasonality and order of magnitude between methods
  - ✓ Peaks not well reproduced (timing and soil characteristics?)

Limitations and perspectives

- ✓ Limitations
  - Time x Spatial correlation of tower data
    - Limited representativeness (3%-7% time in median)
    - How to evaluate the potential bias (link the with bottom-up ?)
  - Crop models not linked to hydrological models (no horizontal transfer)
  - N_2O flux measurements still required at local scale for emissions models

- ✓ Perspectives
  - Link eddy covariance with calibrated N_2O emissions models?
  - Test this methods at the landscape scale for other tall (or smaller) towers in Europe.
  - Use landscape models to better constraint water and soil nitrogen (Landscape-DNDC or integrative NitroScape)

Thanks for your attention

View of the agricultural area and the Roskilde fjord from the tall tower

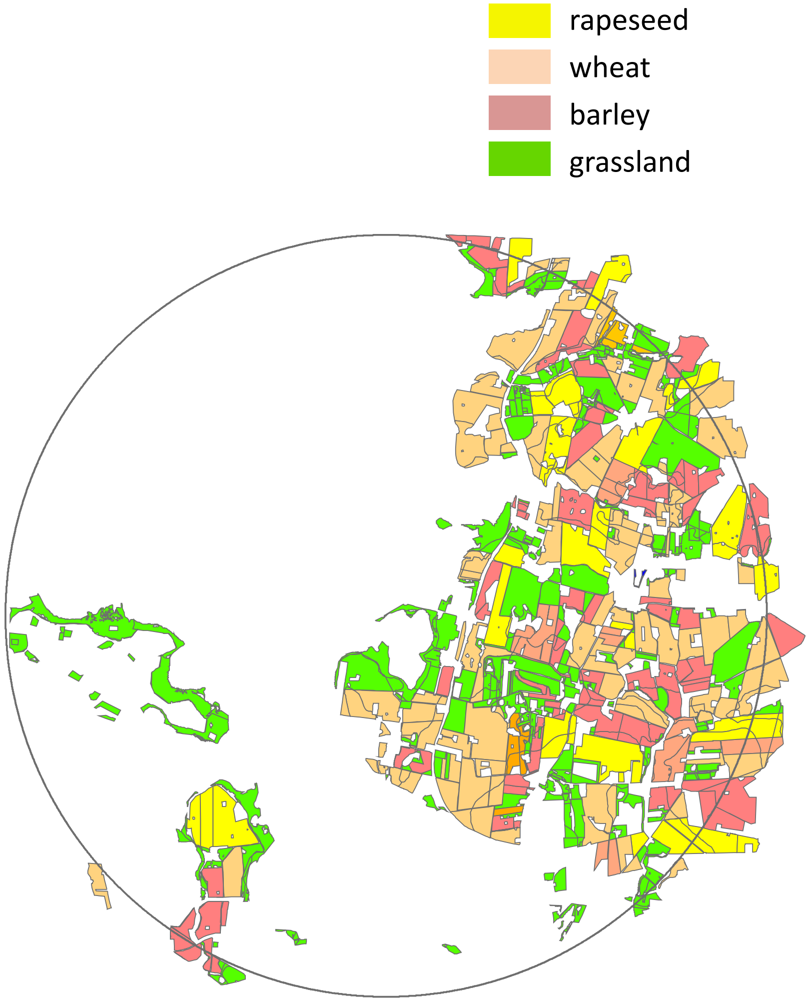
Courteously from Ebba Dellwik, DTU

Crop modelling with CERES

Overview of the agricultural area

- Distribution of the crop and soil types
  - Main rotation: rapeseed / wheat / barley (data from NaturErhvervstyrelsen)
  - Soils from very sandy to loamy sand (data from Danish soil database)

→ Maximal authorized fertilization for each crop/soil: 100-170 kgN ha^{-1} yr^{-1}
(223 tons N over the study site)



Crop modelling with CERES

Results in 2014

- **N_2O emissions**: **0.93±0.86** kg N_2O-N ha^{-1} yr^{-1}

- Distribution of the N_2O emissions
  - Factor 30 between the crop fields
  - Average ratio N_2O/fertilisation: 0.8
  - Soil type n°5 emits more than the others

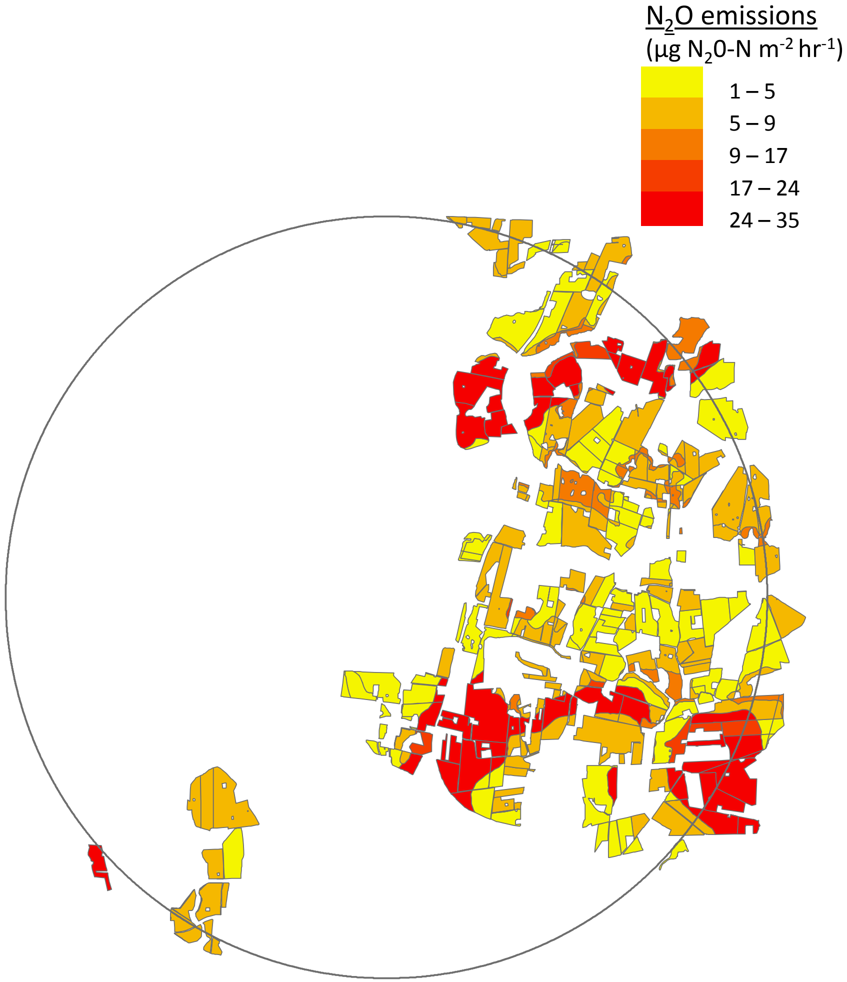
  → data check

- Comparison with IPCC calculations

  → 0.98 kg N_2O-N ha^{-1} yr^{-1}

  (Emission Factor for Sjælland: 0.8 (Chirinda et al. 2010))

  → Good agreement between IPCC calculations and CERES-EGC modelling



Crop modelling and tower measurements

Results in 2014

- Extraction of values from the EC and CERES datasets
  - From July to September 2014
- EC dataset
  - Points between 500-5000m from the tall tower
  - Eastern points
  - Daily mean
- CERES dataset
  - Daily mean of all the crop fields