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Modeling nitrogen deposition: Seasonal variation of dry deposition velocities on various land-use types in Switzerland

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Oxidized and reduced nitrogen compounds in the air

primary compounds

NO_x *(NO_2 + NO)* **NH_3**







chemical transformation

secondary compounds

gas-phase **O_3, HNO_3, ...**

aerosol phase **NH_4NO_3, ..**

dry and wet deposition

(oxidized and reduced N)

Impacts

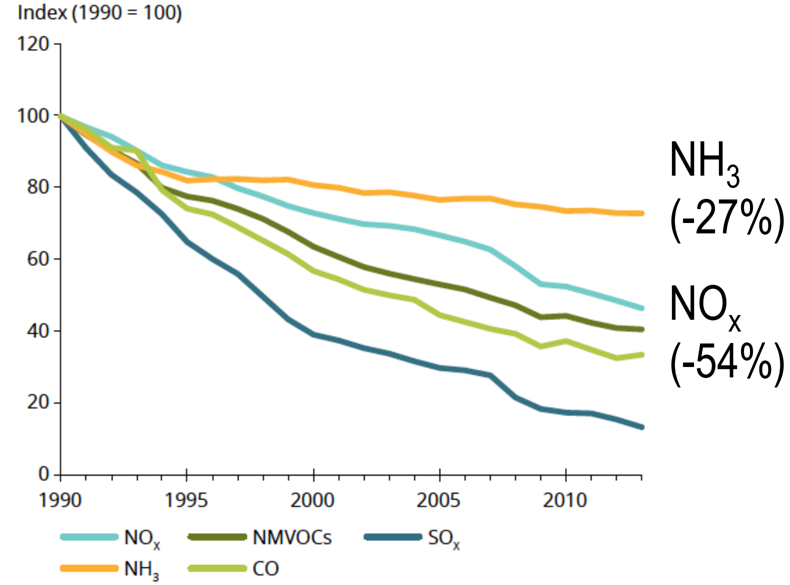
acidification, eutrophication,
toxicity to plants,
loss of plant diversity

Background

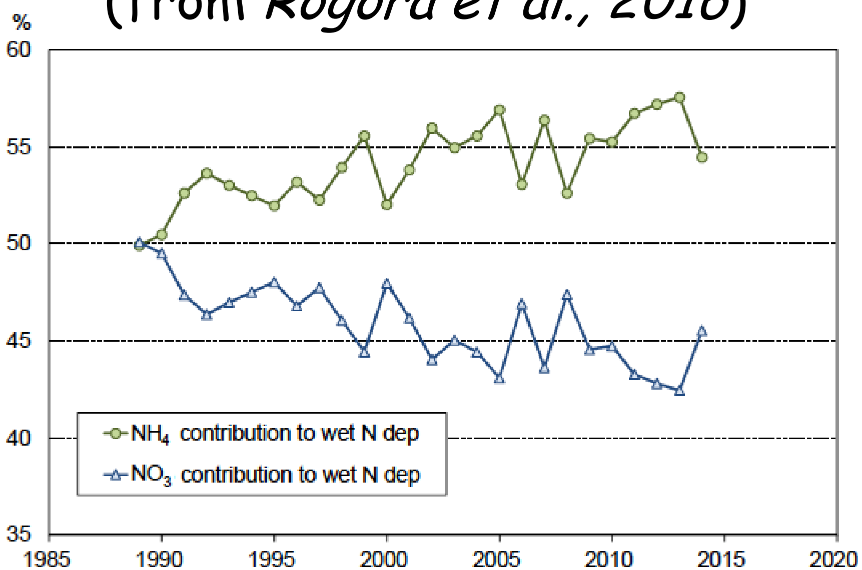
•significant decrease in NO_x emissions in Europe over the past decades, further decrease expected according to the revised Gothenburg Protocol

•the decrease in NH_3 emissions is slower, no significant change is expected in near future

Change in EU-28 emissions 1990-2013 *(EEA, 2015)*



South of Alps
(from *Rogora et al., 2016*)



consequently the contribution of reduced nitrogen to deposition has been increasing

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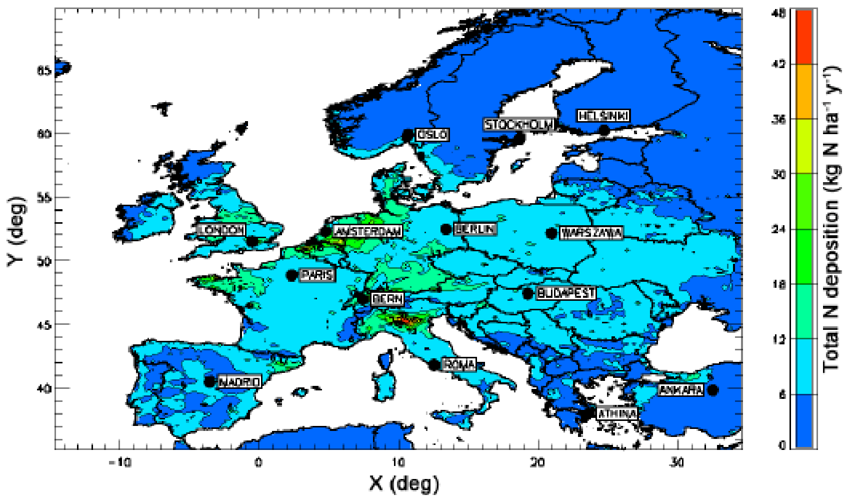
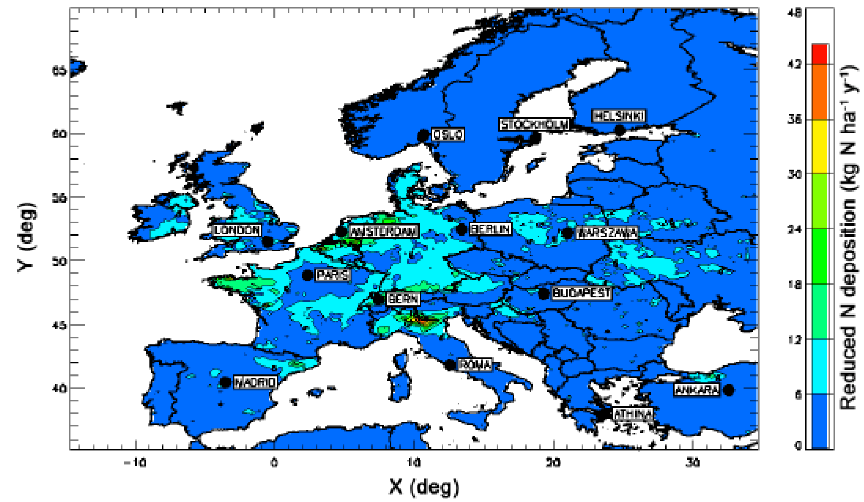
Modeled N deposition in 2006 *(Aksoyoglu et al., ACP, 2014)*

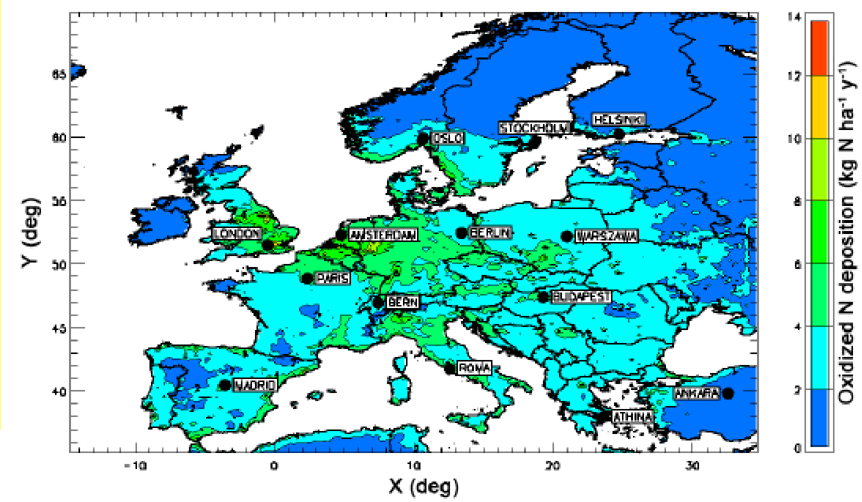
total N deposition 48



reduced N deposition 48



oxidized N deposition 14



deposition of reduced N compounds (NH_3, NH_4^+) is higher than the deposition of oxidized N compounds (HNO_3, NO_3^-)

decrease in N deposition between 1990-2005 was mainly due to a decrease in oxidized N deposition

Project for the Federal Office of Environment

estimation of the dry deposition velocity of N compounds on land-use types found in Switzerland from the study *of Aksoyoglu et al., ACP, (2014)*

CAMx *(v5.40)* 14 layers

WRF 31 layers

0.250° x 0.125° coarse domain

0.083° x 0.042° fine domain

CB05 gas-phase mechanism

SOAP, ISORROPIA

TNO/MACC anthropogenic emissions

PSI biogenic emission model

simulations for 2006

Zhang (2003) dry deposition model

for a given species, particle size and grid cell

- CAMx determines a deposition velocity for each land-use type in that grid cell
- then linearly combines them according to the fractional distribution of land-use classes

using the deposition output in the nested domain, we calculated land-use specific dry deposition velocity of oxidized and reduced N compounds in Switzerland

$$V_d = 1/(r_a + r_b + r_c)$$

$$r_c = \frac{1}{\frac{1-W_{st}}{r_{st}+r_m} + \frac{1}{r_{cut}} + \frac{1}{r_{ac}+r_{gs}}}$$

V_d : deposition velocity
r_a : aerodynamic resistance
r_b : boundary resistance
r_c : canopy resistance

W_{st} : the fraction of stomatal blocking under wet conditions
r_{cut} : the cuticle resistance
r_{st} : stomatal resistance
r_m : mesophyll resistance
r_{ac} and r_{gs}: ground surface resistance

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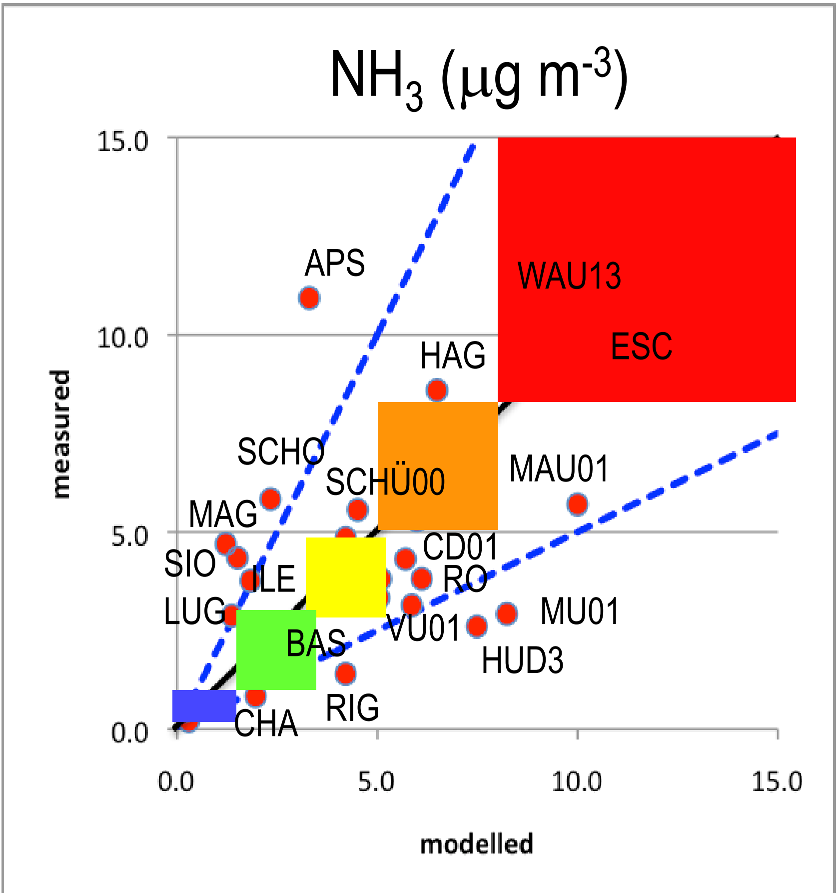
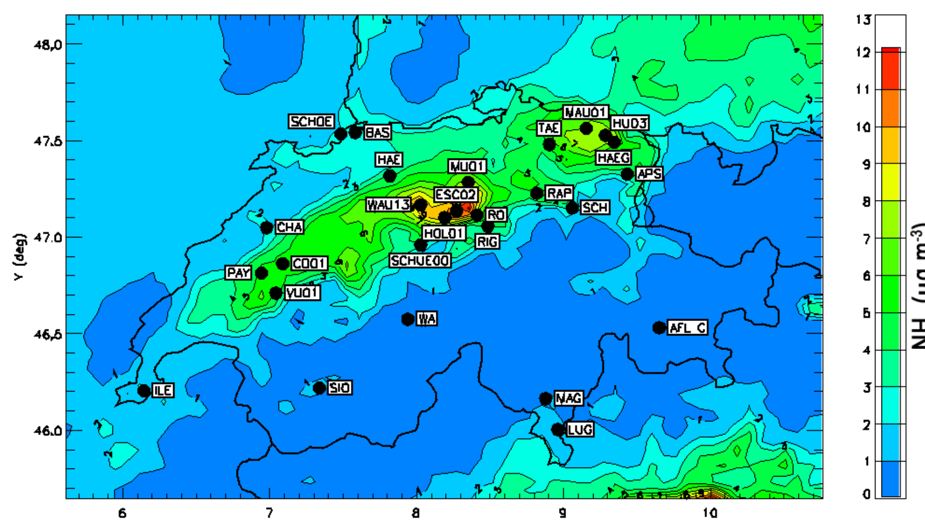
Annual NH_3 concentrations



27 stations (FUB, passive samplers)

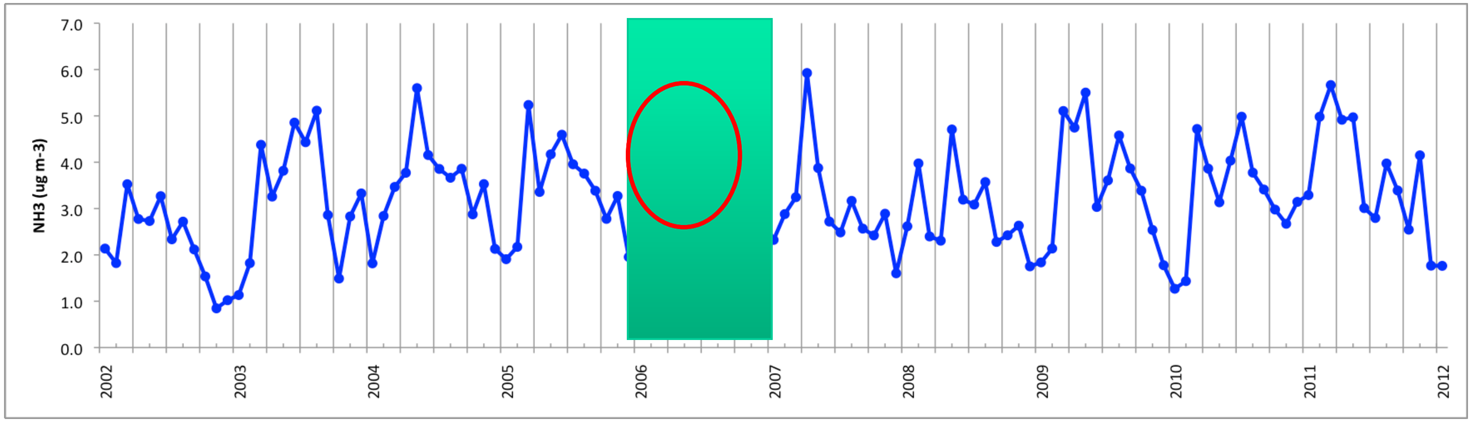
Annual mean NH_3	
< 1 µg m^{-3}	Alps > 1880 m asl.
1 - 3 µg m^{-3}	suburban, urban
3 - 5 µg m^{-3}	crop farming
5 - 8 µg m^{-3}	less intensive farming
> 8 µg m^{-3}	intensive cattle farming

modelled annual mean NH_3

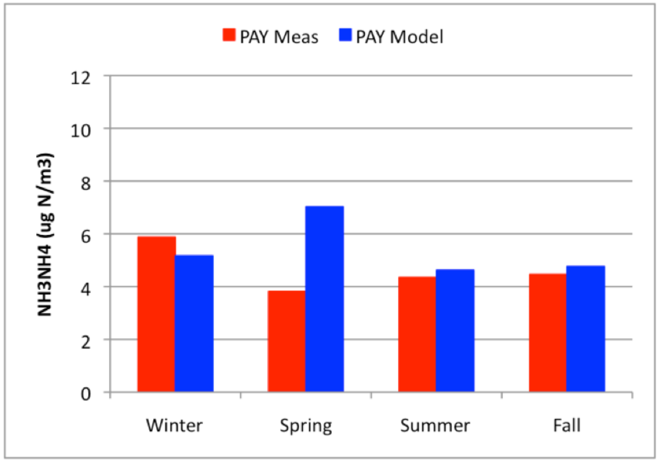


- very good prediction of the highest levels
- good prediction for most of the stations in the Swiss Plateau
- underestimation at southern stations

Seasonal variation of measured NH_3 concentrations at Payerne between 2002-2012 *(from FUB)*



Seasonal variation of NH_3 emissions depends on the meteorological conditions prevailing each year. In Switzerland, the highest values are usually in spring followed by smaller peaks in summer and fall, similar to emissions used in the model.

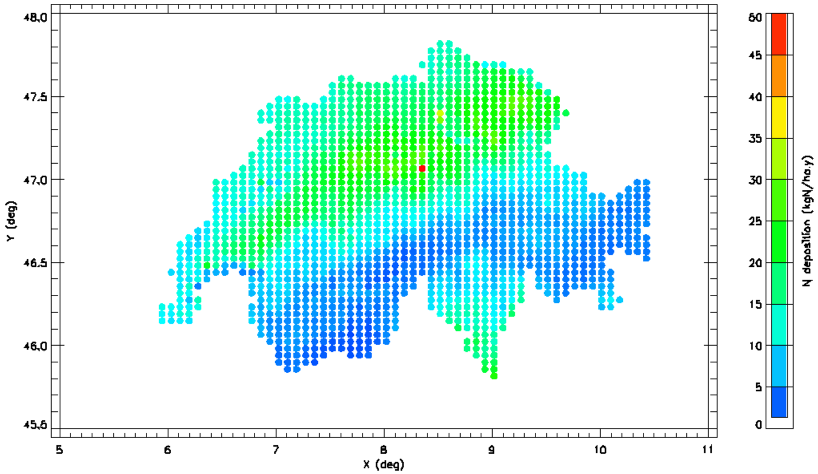


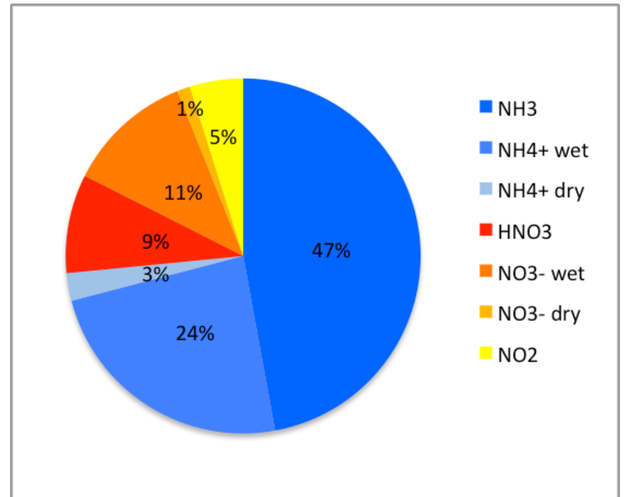
In 2006, however, spring peak was smaller than in summer

leading to overestimation of total ammonia (NH_3+NH_4^+) in spring 2006 by the model

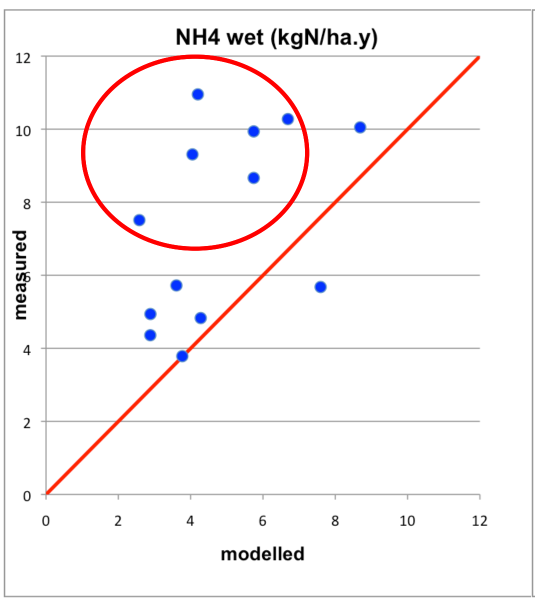
Modeled annual N deposition in Switzerland (2006)

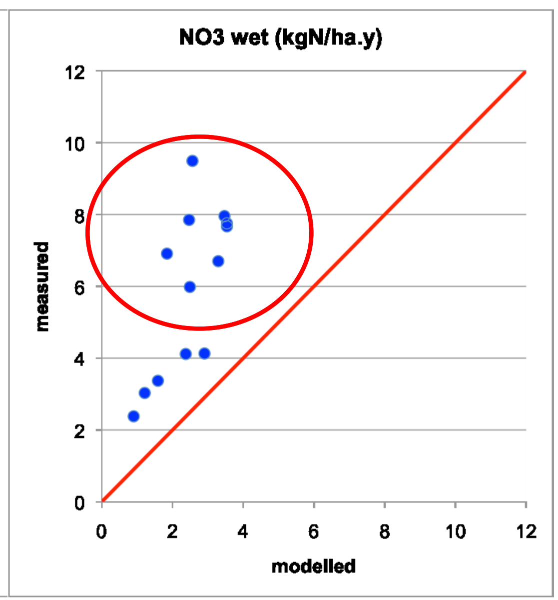
average 12.2 kg N ha^{-1} a^{-1}





reduced N: 74% | oxidized N: 26%



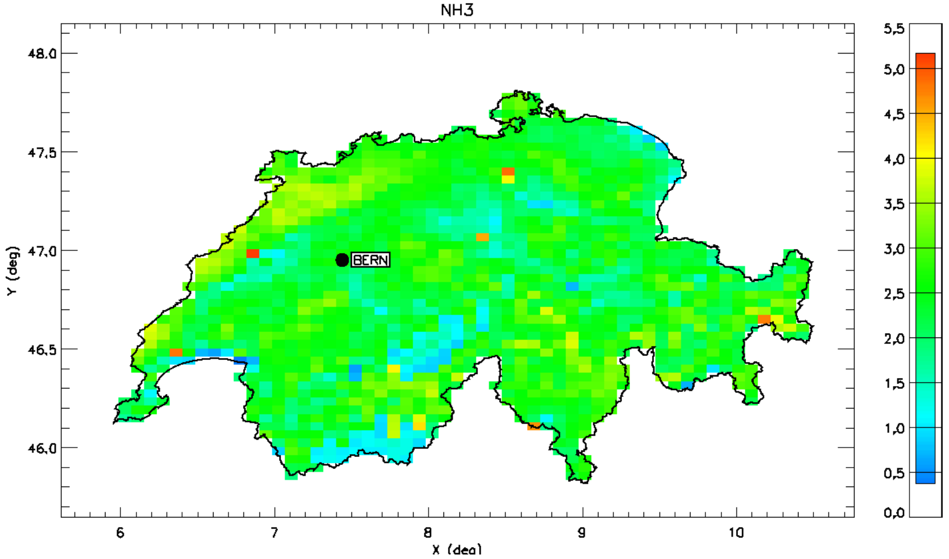


underestimation of wet deposition especially at southern sites

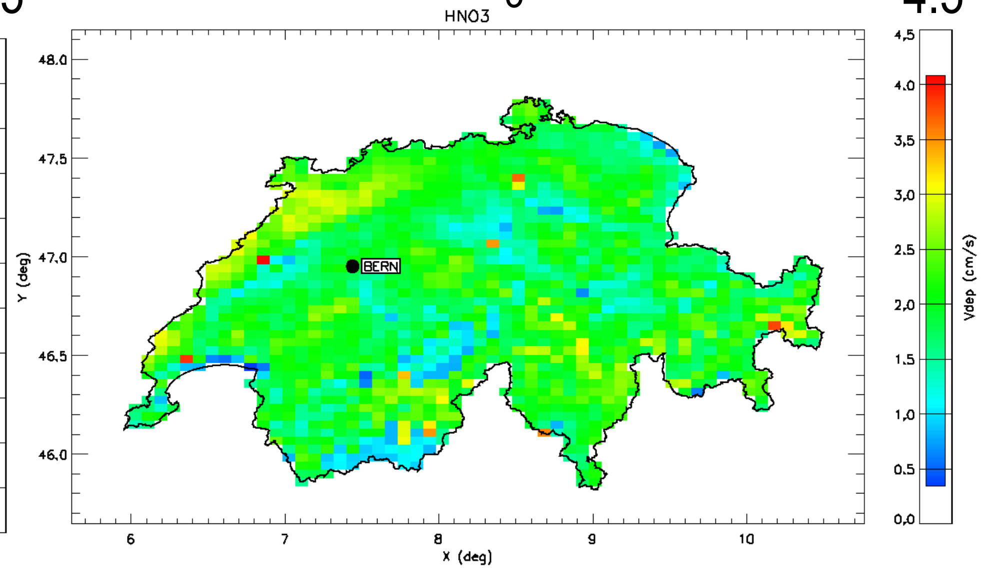
Annual dry deposition velocity *(cm s^{-1})*

spatial variation

NH$_3$ 5.5

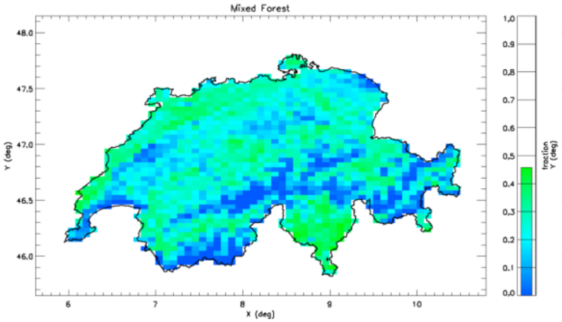


HNO$_3$ 4.5

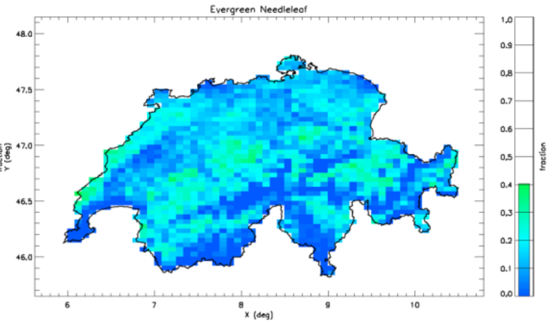


Fractional distribution of land-use types in grid cells

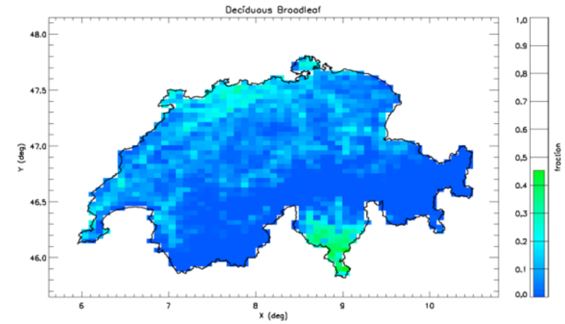
mixed forest



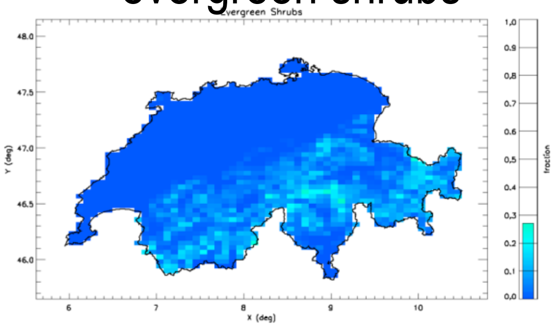
evergreen needleleaf



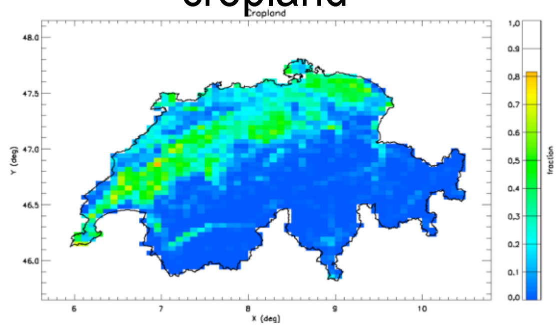
deciduous broadleaf



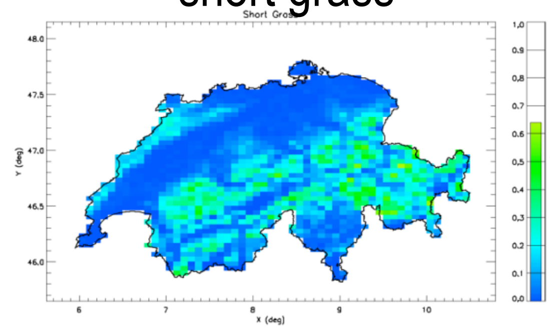
evergreen shrubs



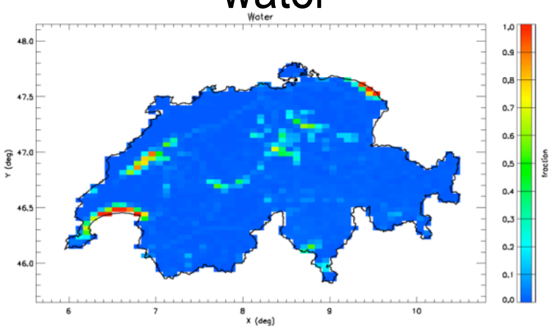
cropland



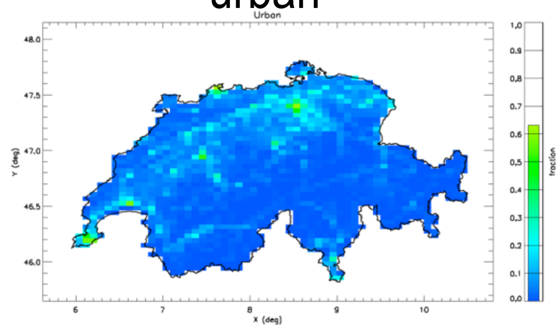
short grass



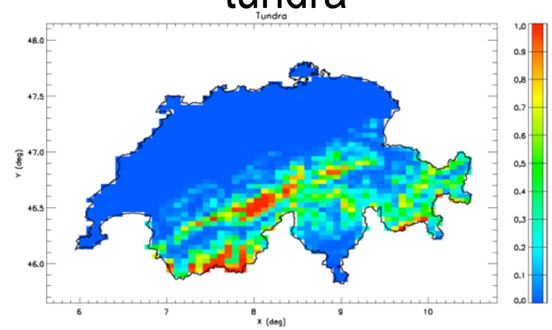
water



urban



tundra



Land-use specific annual dry deposition velocity *(cm s^{-1})*

land-use type	HNO_3	literature values for HNO_3*	NH_3	literature values for NH_3*
water	0.8	0.8	0.9	0.5 - 0.9
evergreen needleleaf	2.7	1.8 – 2.7	3.5	0.5 - 3.3
deciduous broadleaf	3.0	0.9 - 1.5	3.8	0.3 – 2.2
evergreen shrubs	3.4		4.6	
short grass	1.4	1.1 - 1.7	1.7	0.2 – 2.0
cropland	1.3	0.8 – 1.5	1.6	0.2 - 7.1
urban	2.4	1.5	3.0	0.1 - 1.1
tundra	1.1	1.5 - 1.6	1.3	
mixed forests	1.9	1.0 – 3.2	2.5	0.4 - 3.0

* from Schrader and Brümmer (2014), Jia et al., (2016), Seitler et al., (2015)
literature values are based on measurements and models at various times of the day, season and region

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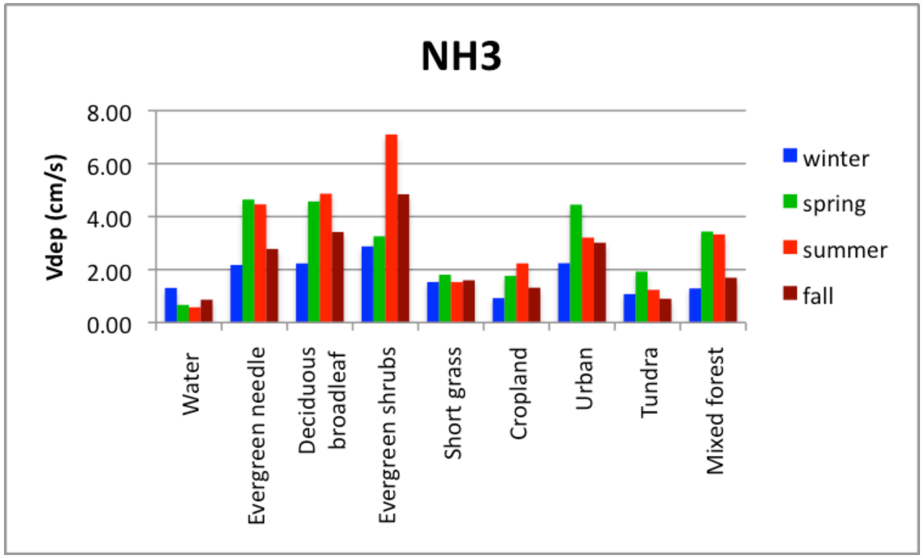
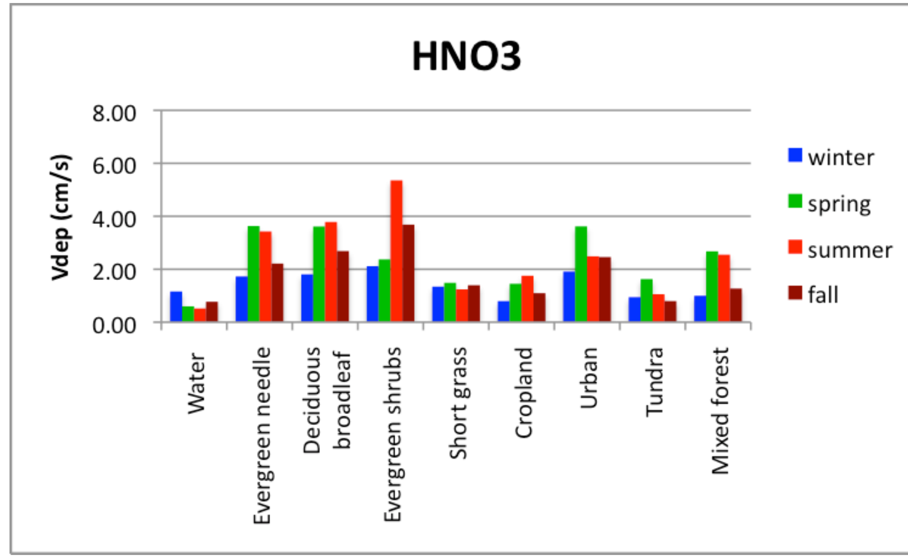
Seasonal variation of dry deposition velocity

(cm s^{-1})





Deposition velocities vary seasonally, highest values over vegetation were predicted in spring and summer, lowest in winter

V_d over evergreen shrubs in summer

for NH_3 : 7.1 cm s^{-1}

for HNO_3 : 5.4 cm s^{-1}

Summary

- although annual ammonia (NH_3) concentrations could be captured quite well, modeling seasonal variation is more difficult due to different temporal variation of emissions depending on meteorological conditions
- modeled N deposition in 2006 (12.2 kg N $ha^{-1}a^{-1}$) was dominated by deposition of reduced nitrogen (NH_3, NH_4^+) compounds (74%) in Switzerland
- the largest contribution to N deposition comes from dry deposition of ammonia (47%)
- the highest annual dry deposition velocities for NH_3 and HNO_3 were predicted over evergreen shrubs, followed by evergreen needleleaf and deciduous broadleaf forests
- deposition velocities over vegetation vary seasonally with highest values in spring and summer, lowest in winter

Thank you

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