Modeling ammonia volatilization in CLM: global emissions and atmospheric impacts

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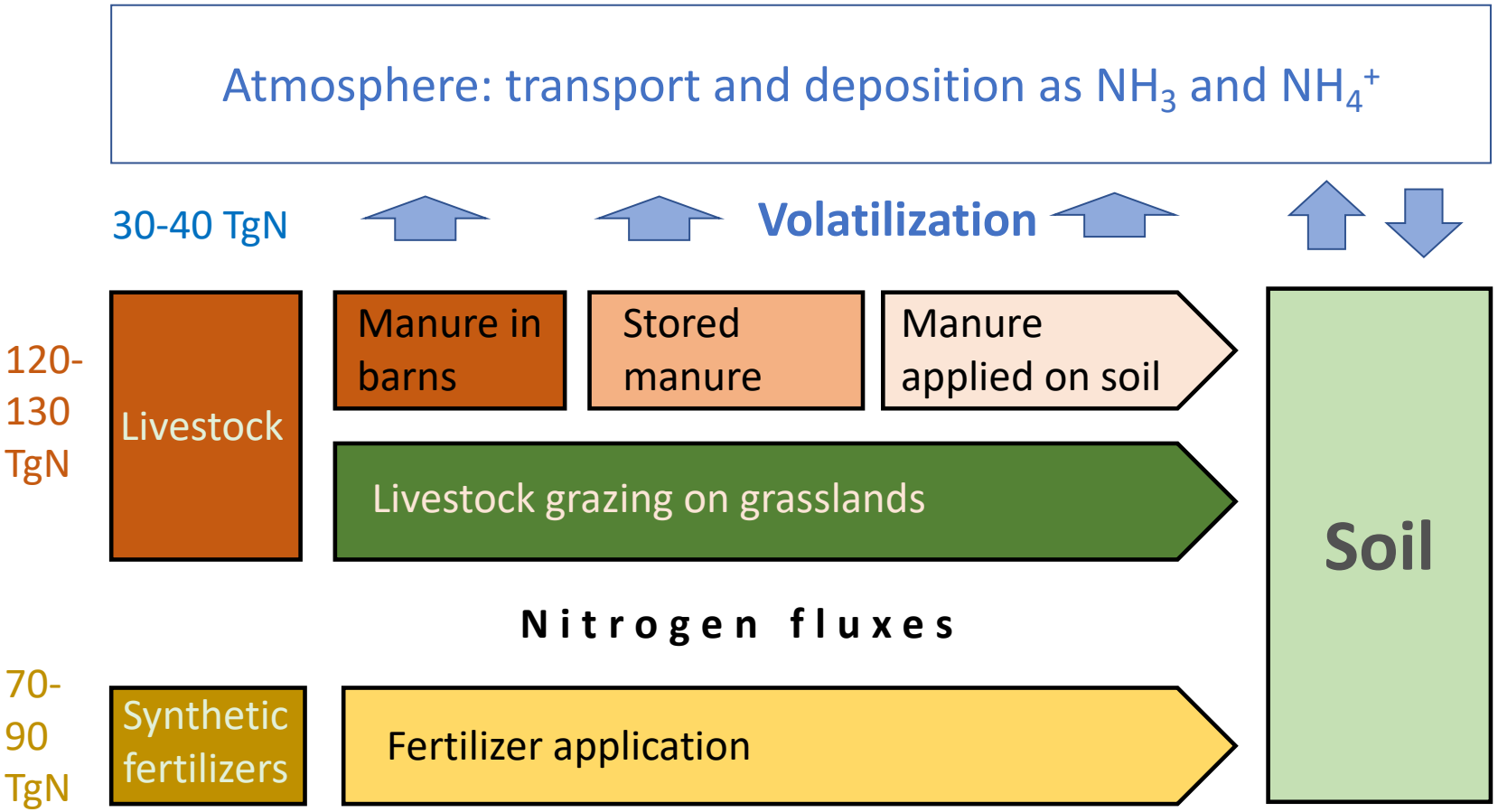
Introduction



Presentation outline

- The FAN v.2 mechanistic model for agricultural ammonia emissions
- Comparison of present-day NH3 from FAN and in existing inventories
- Evaluation of CAM atmospheric simulations using FAN and other inventories
- Climate sensitivity of NH3 volatilization

The Flow of Agricultural Nitrogen (FAN) process model

N fertilization from CLM crop model

Fertilizer types from International Fertilizer Association

Manure N production from FAO datasets

CLM

FAN

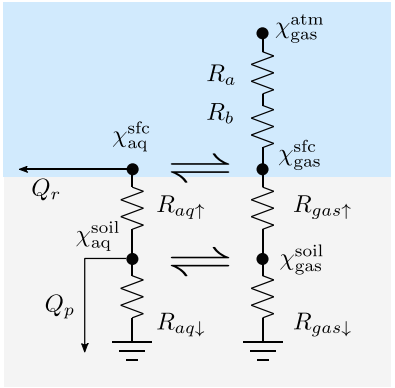
Ammonia emissions across the agricultural sector:

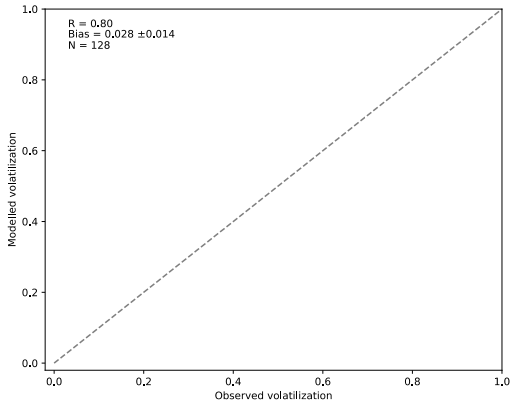
Manure spreading

Manure storage & handling

Grazing

Fertilizer use: urea, nitrate, others





CAM

atmospheric transport

partitioning between NH3 (gas) and NH4+ (aerosol)

nitrate formation

wet and dry deposition

N runoff

N remaining in soil

Coupled CAM/CLM simulations for 2010-2015

FAN: FAN NH3 + HTAP2 for other species
- CLM5, 30 min coupling step

EDGAR: EDGAR 4.3.2 emissions for 2010
- global inventory for 2010
- monthly time profiles for temperate regions

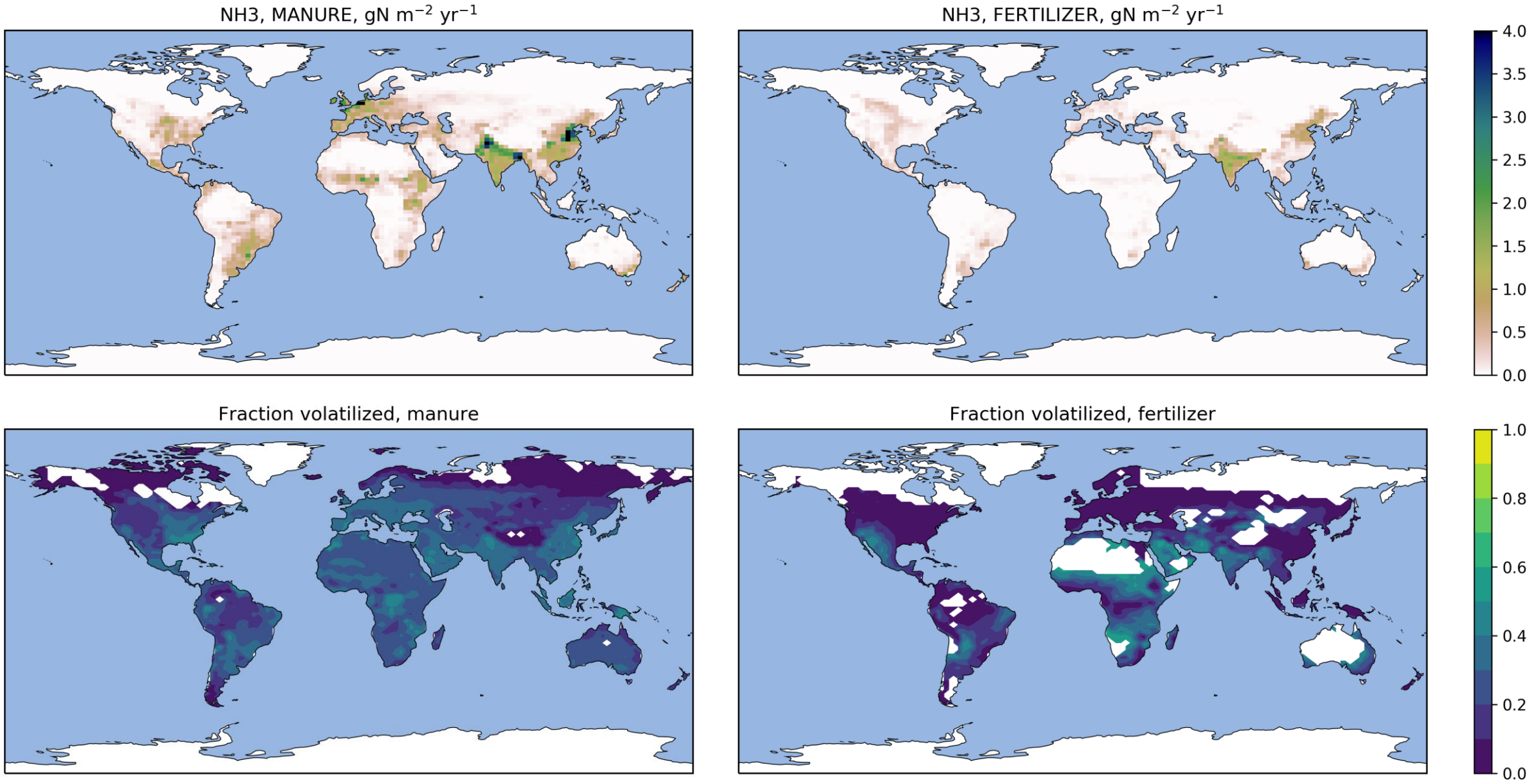
HTAP: HTAP v2.2 emissions for 2010
- mosaic of regional inventories + EDGAR
- monthly time profiles for Europe & N. America

Evaluation with data from atmospheric monitoring networks:

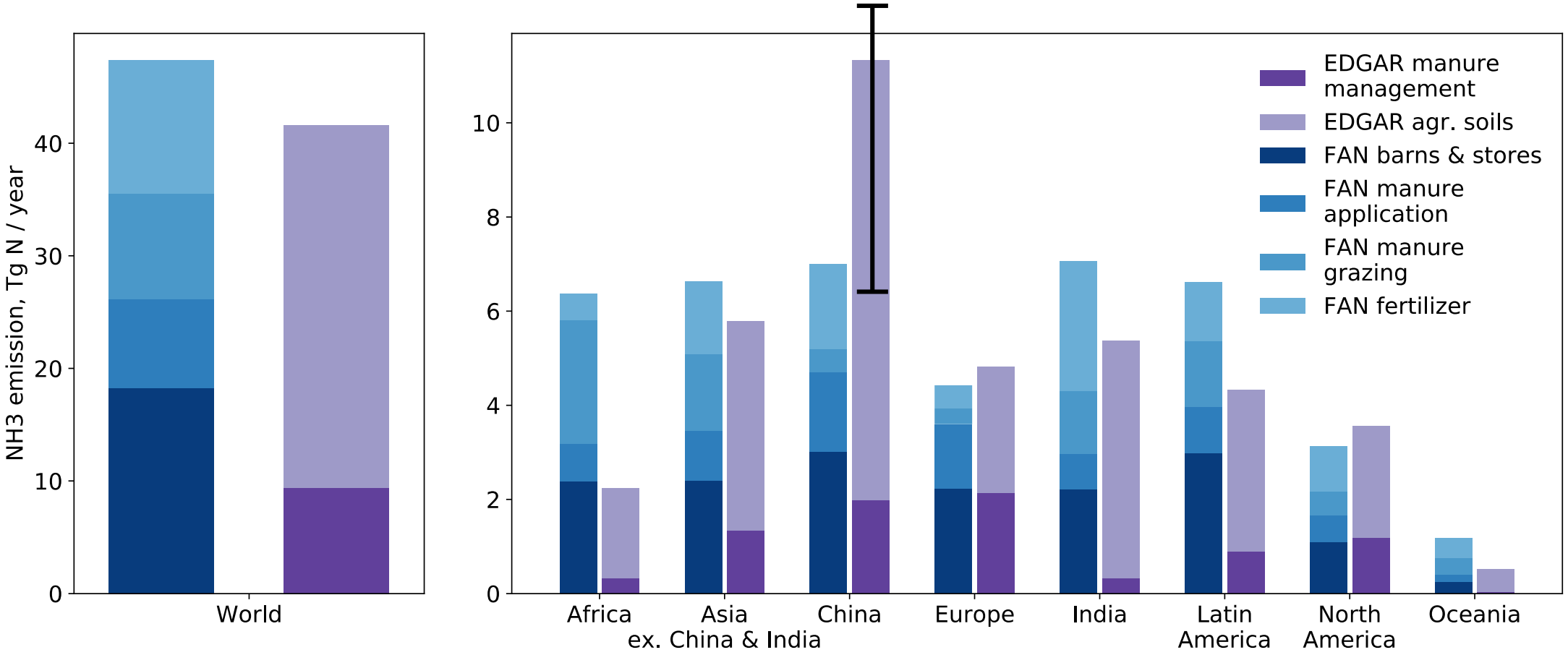
NTN, CASTNET, AMoN (USA)
EMEP (Europe)
EANET (East Asia)
IDAF (Africa)

Here mainly NH4 wet deposition

Simulated NH3 emissions for 2010-2015

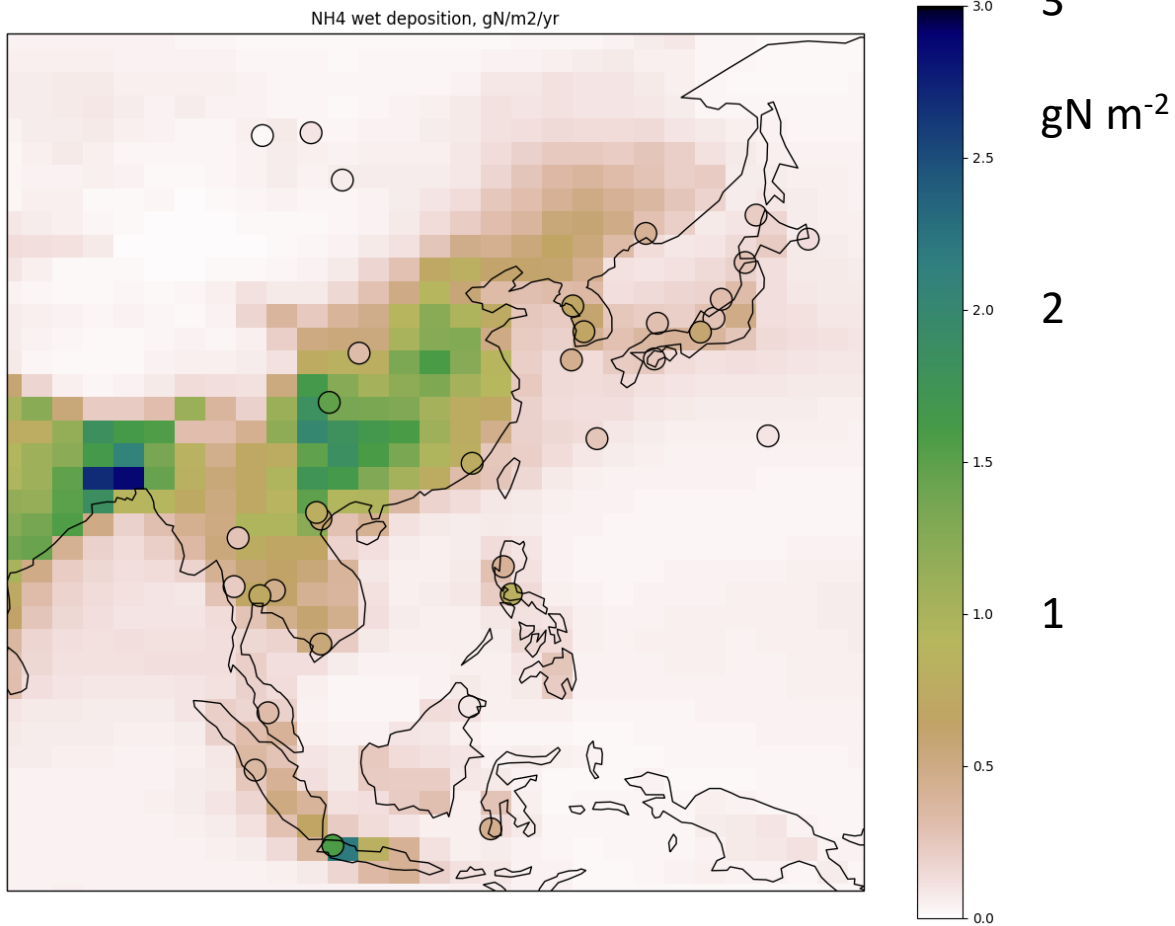


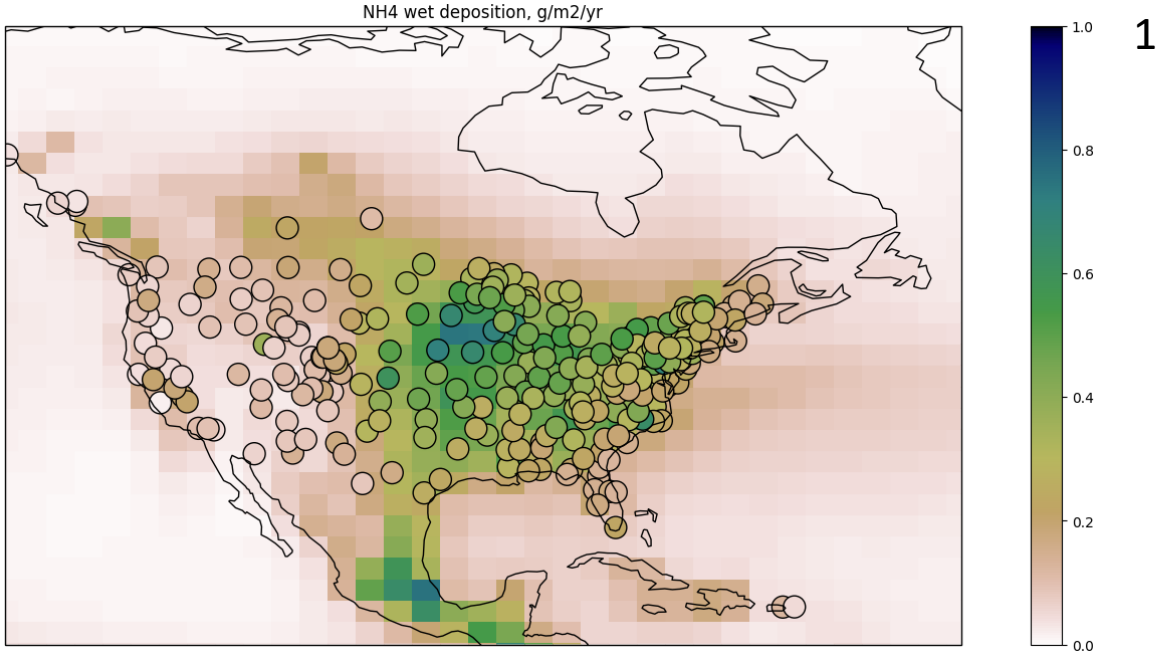
FANv2 compared to EDGAR 4.3.2

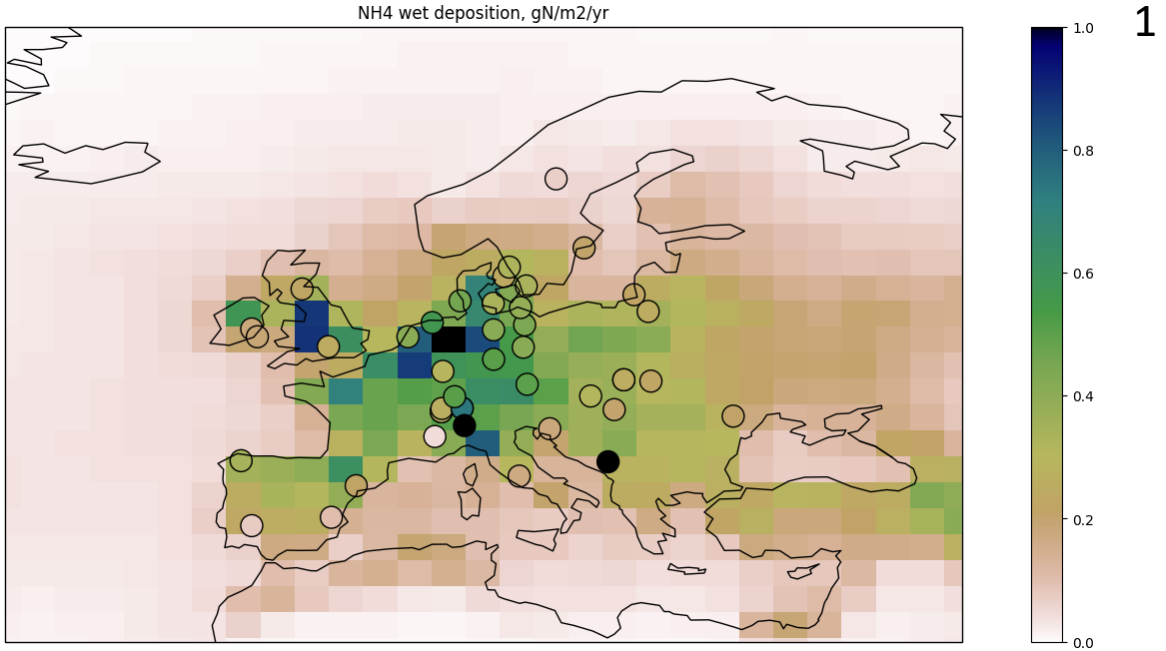


Average NH_4^+ wet depositions from FAN

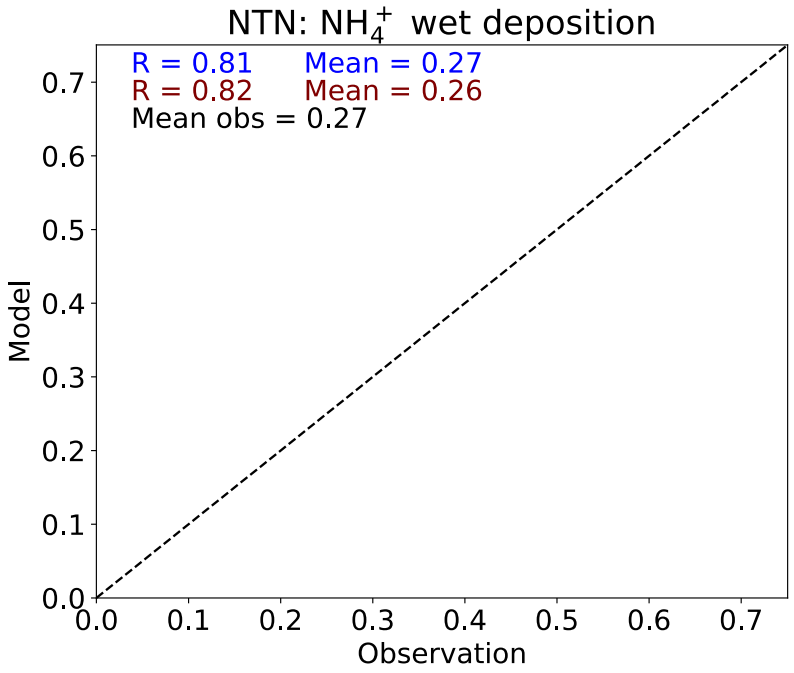
6-year means, model + obs from EANET, NTN, EMEP

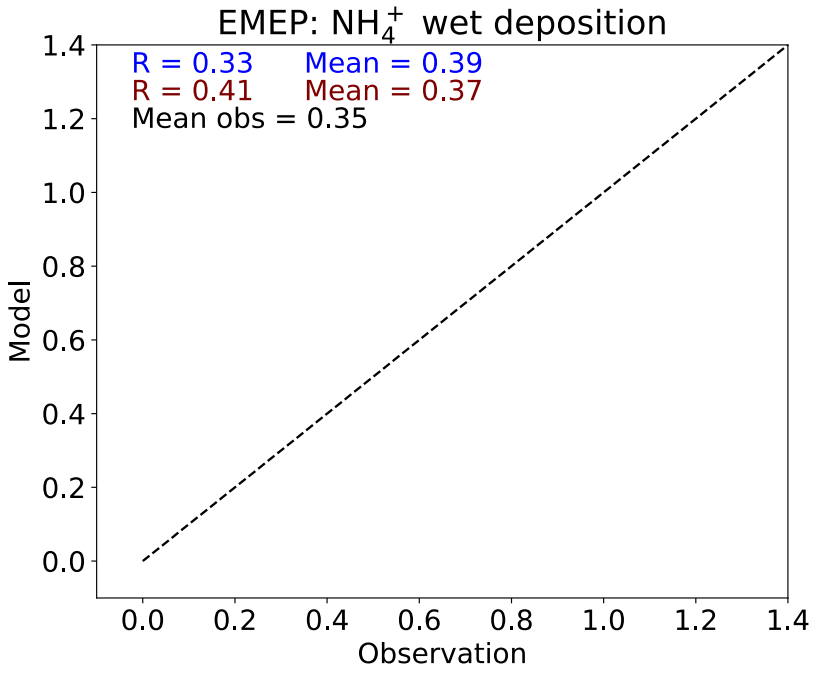


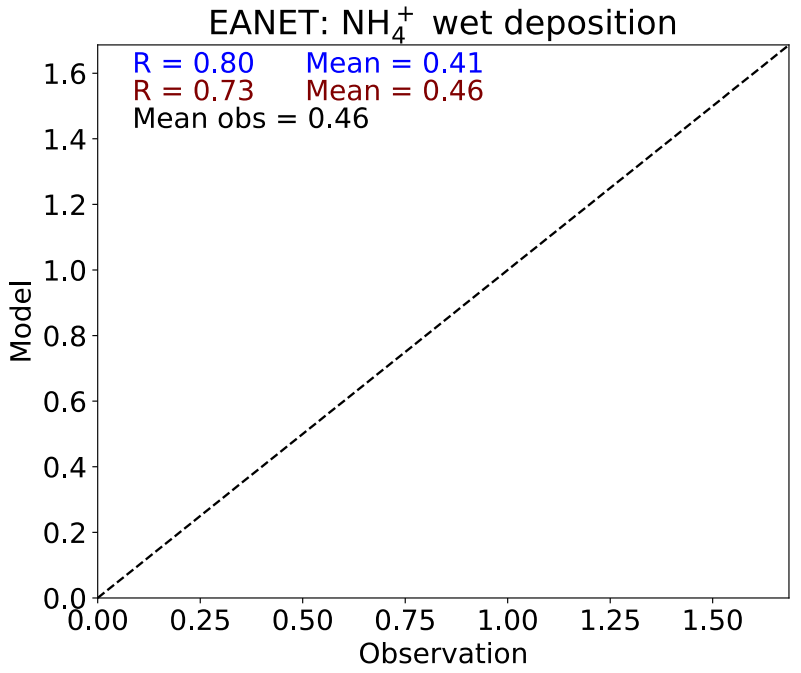




2010-2015 average NH4 wet depositions from FAN, HTAP







FAN HTAP

Comparison against INDAAF: NH3, NH4, wet dep

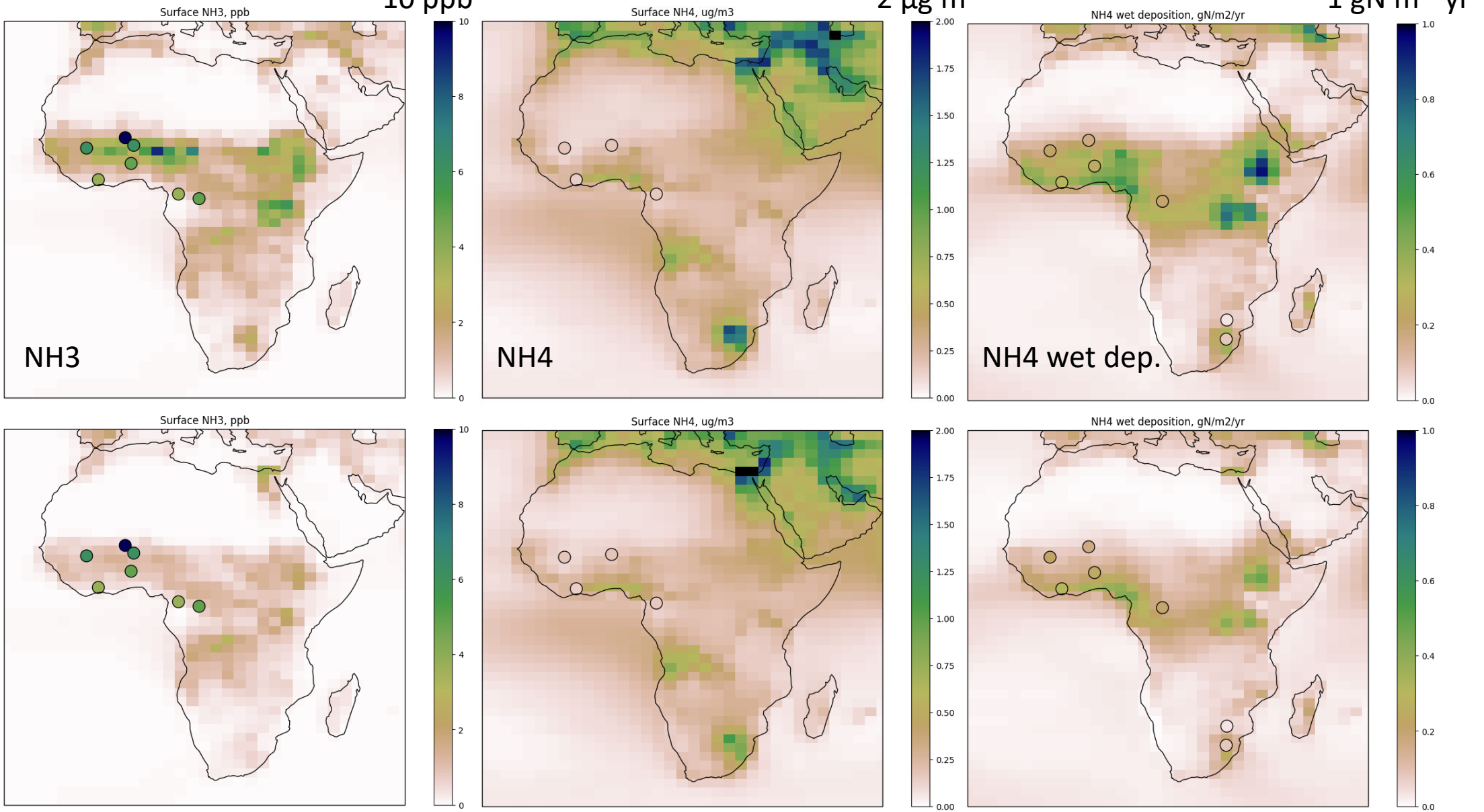
FAN

HTAP

10 ppb

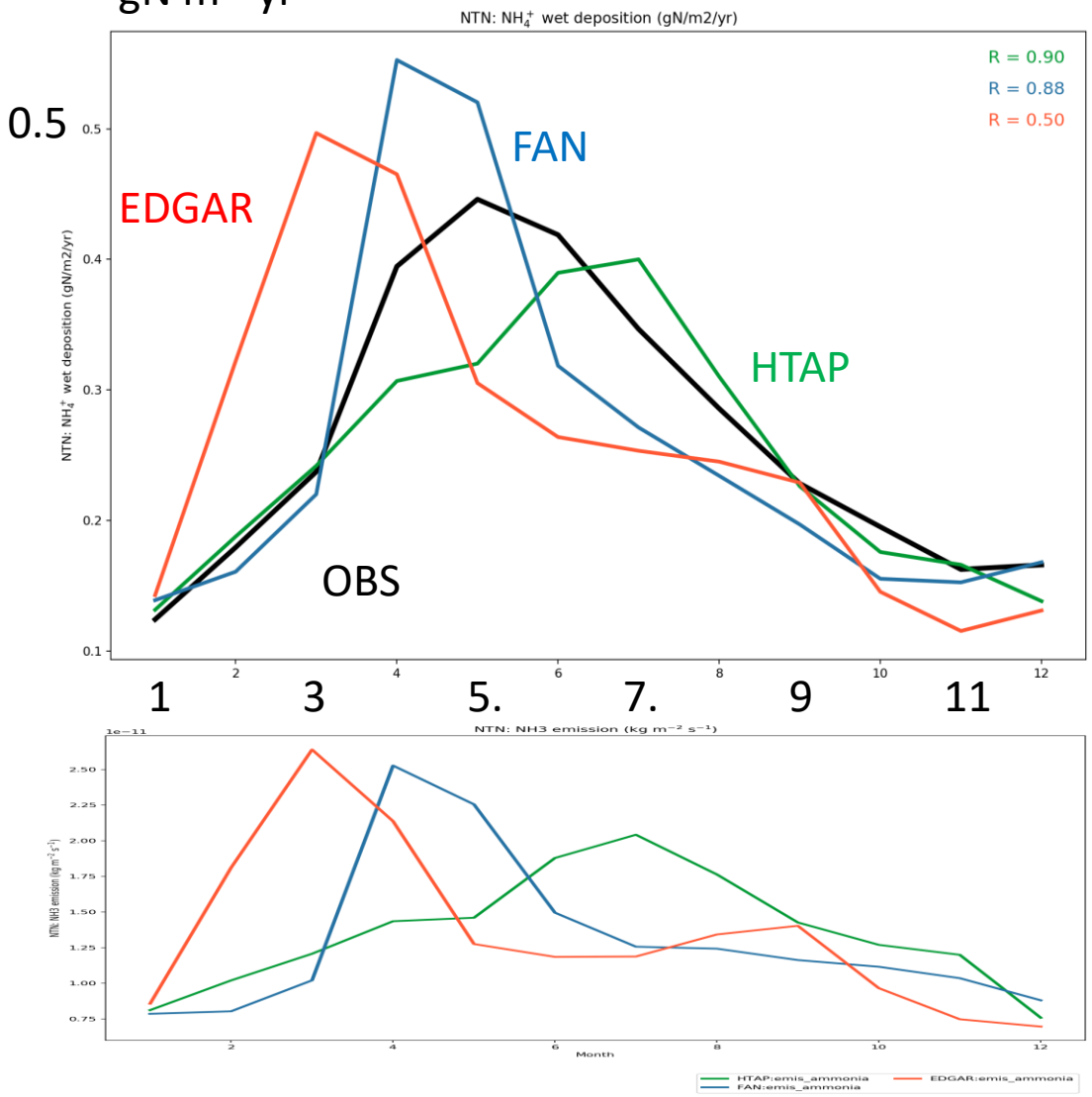
2 µg m^{-3}

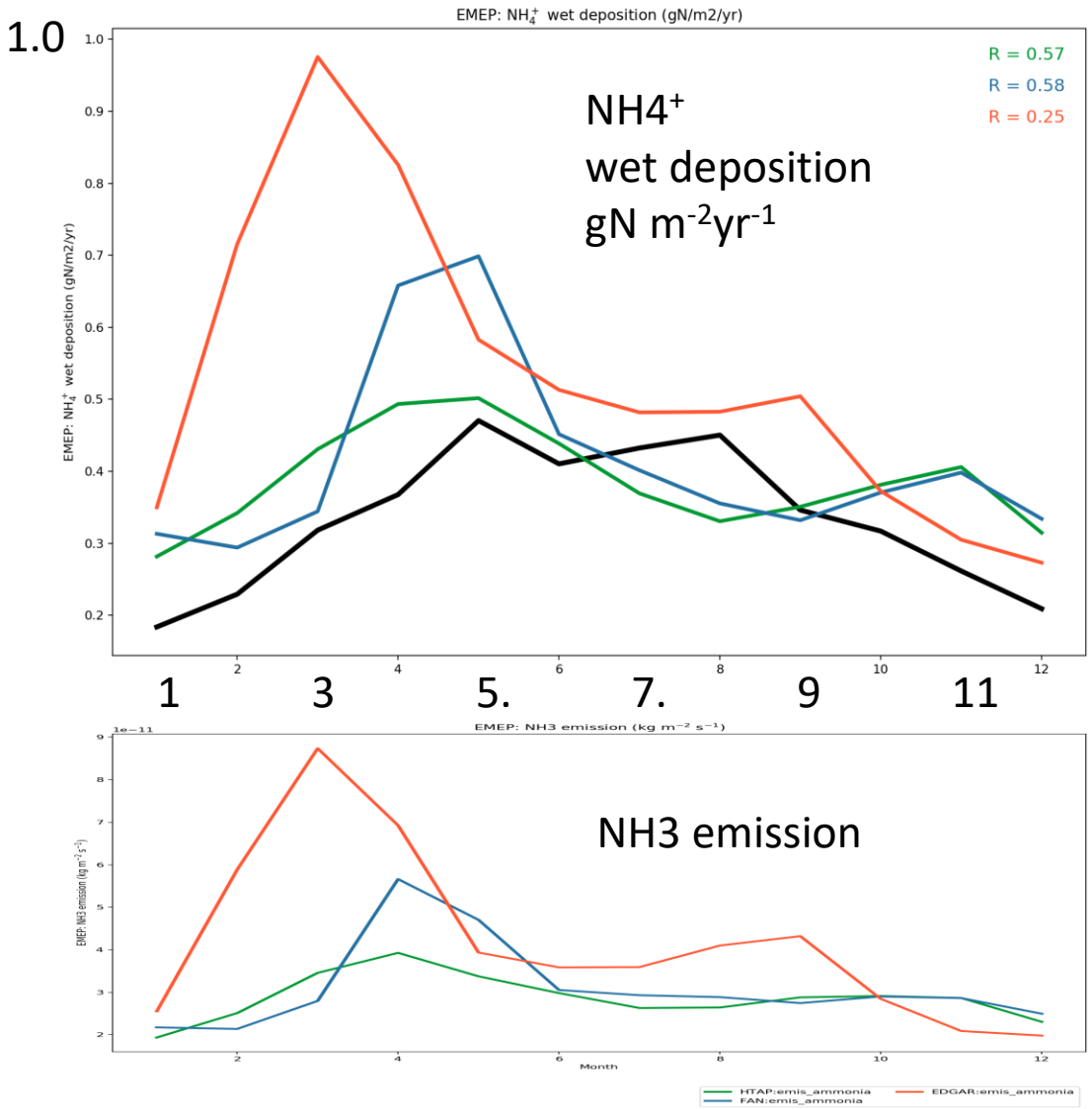
1 gN m^{-2} yr^{-1}



Monthly profiles, NH4 wet dep: US, Europe

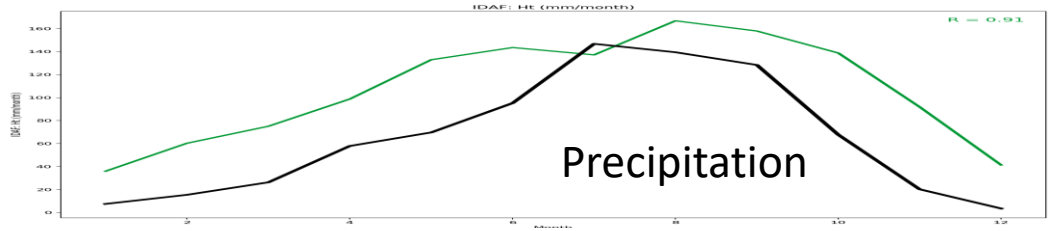
gN m^{-2} yr^{-1}

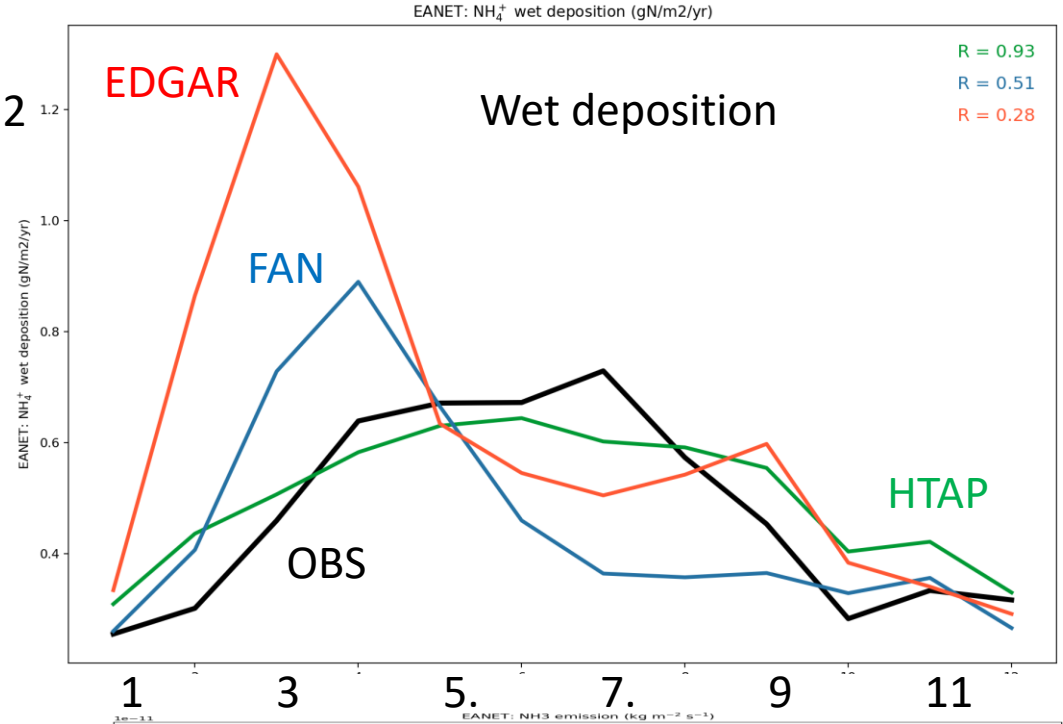


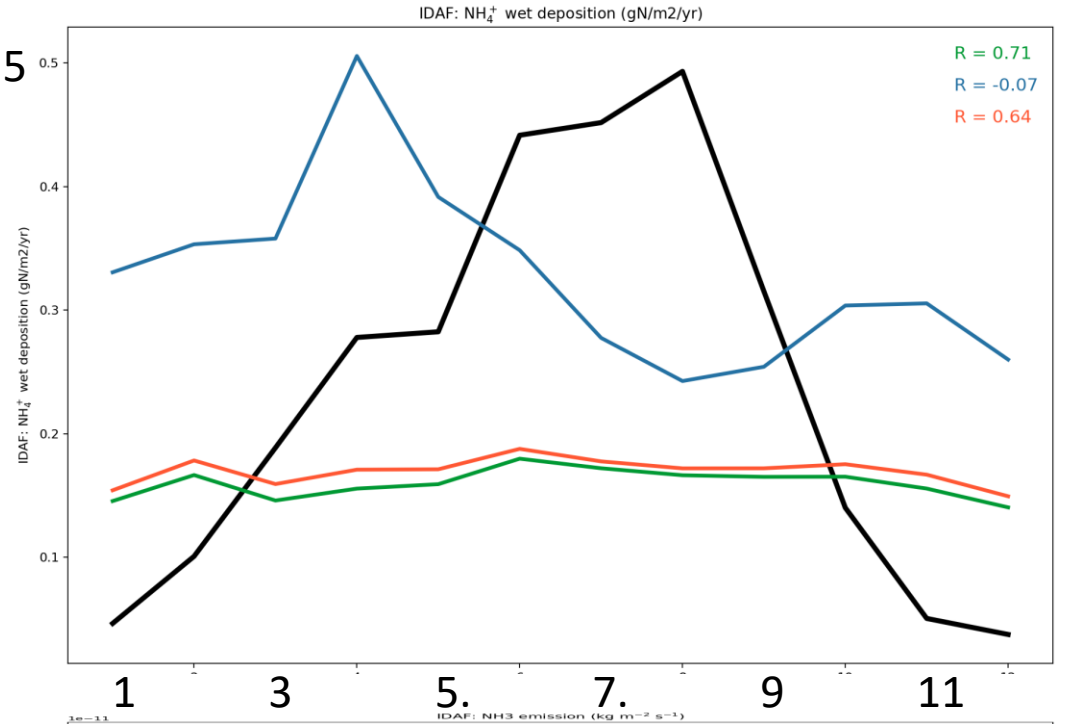


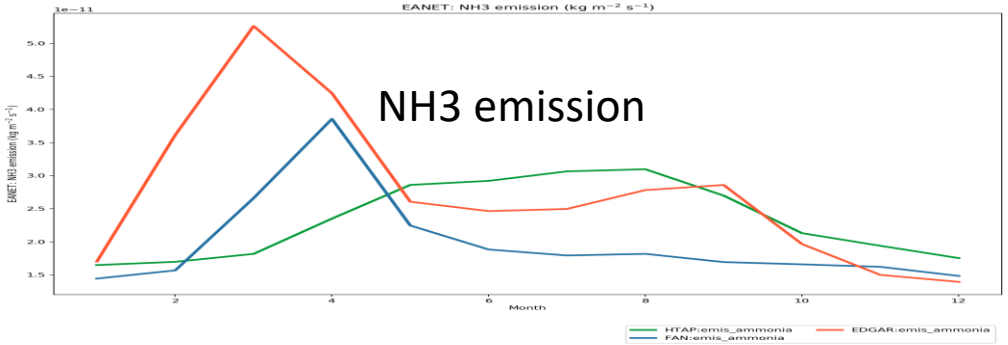
China and East Asia

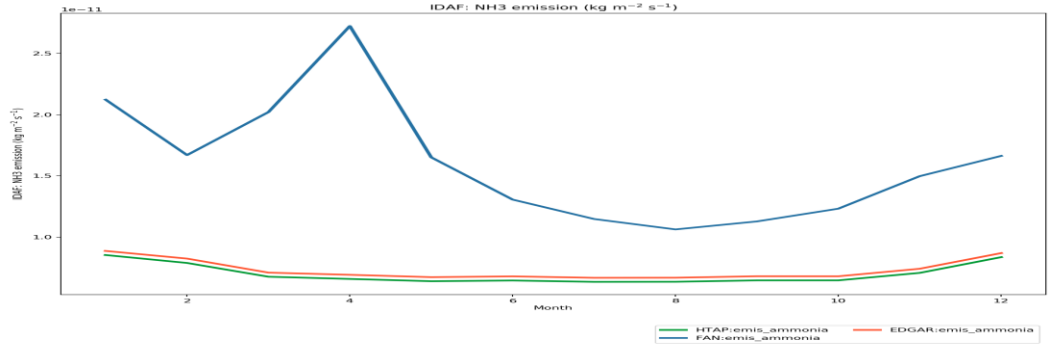
West Africa



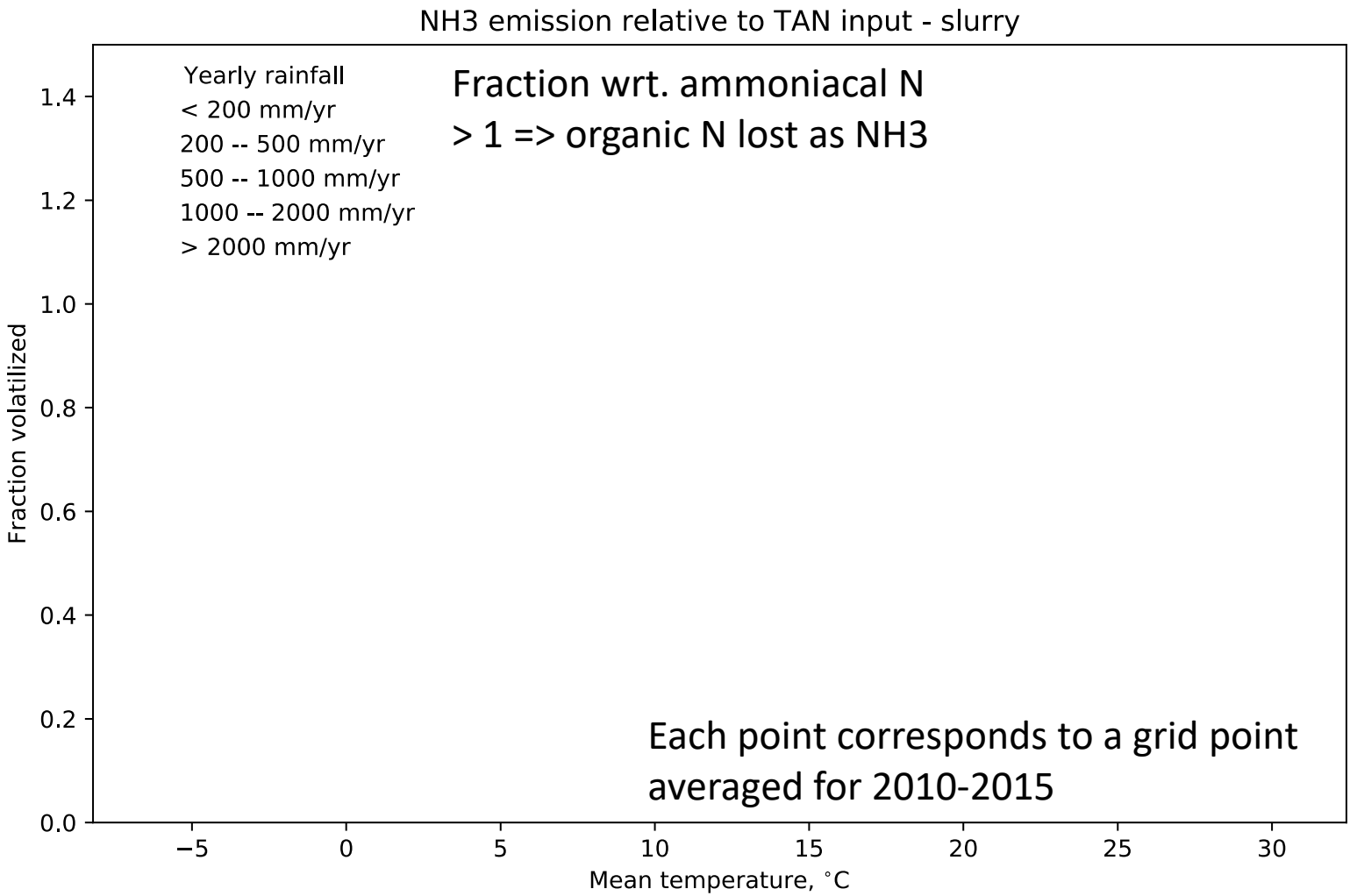








Sensitivity to yearly mean temperature & precip



4-7 % increase in emission
per 1 ℃ increase in yearly mean temperature

Literature for manure slurries:

2 % $℃^{-1}$
Hafner et al. (2018), empirical model

3-7 % $℃^{-1}$
Sutton et al. (2013) based on several sources

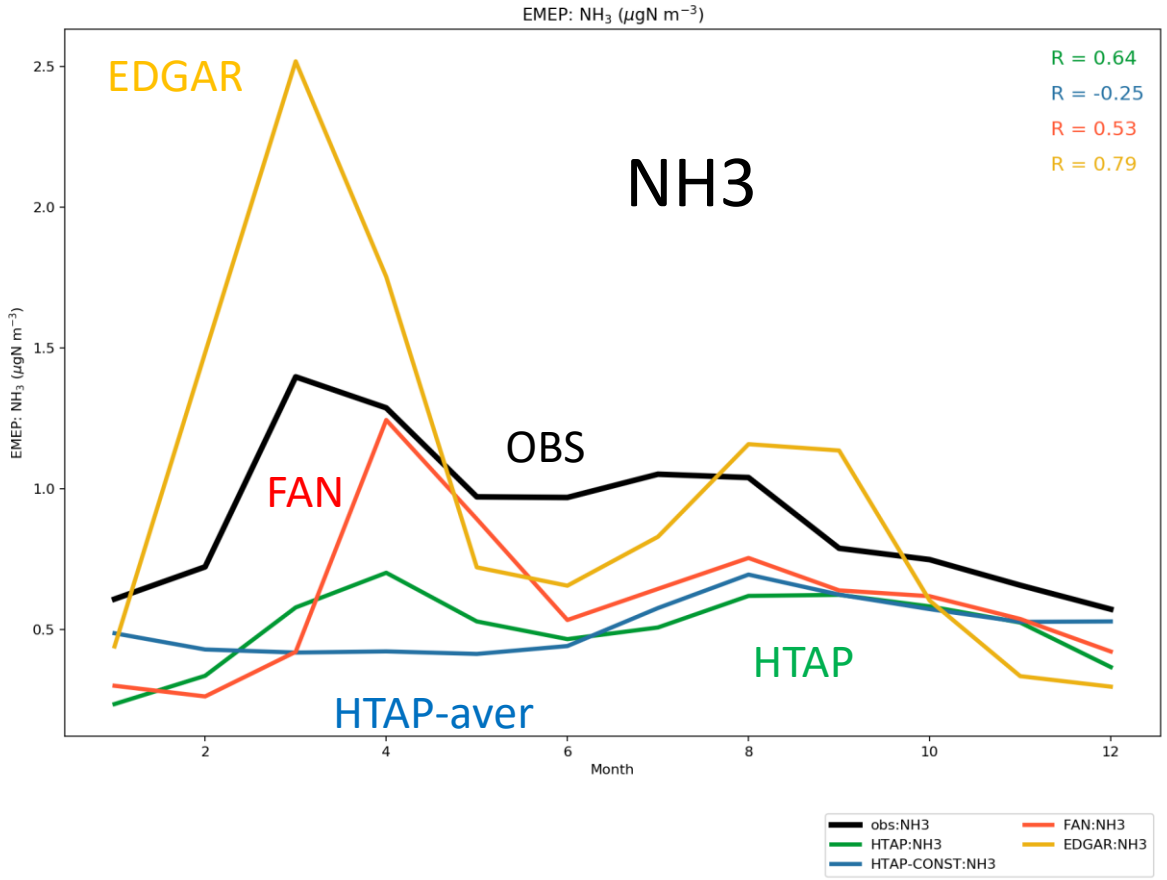
Both much less than 12-15 %
predicted from chemical equilibrium between NH3 (g) and NH4/NH3 (aq)

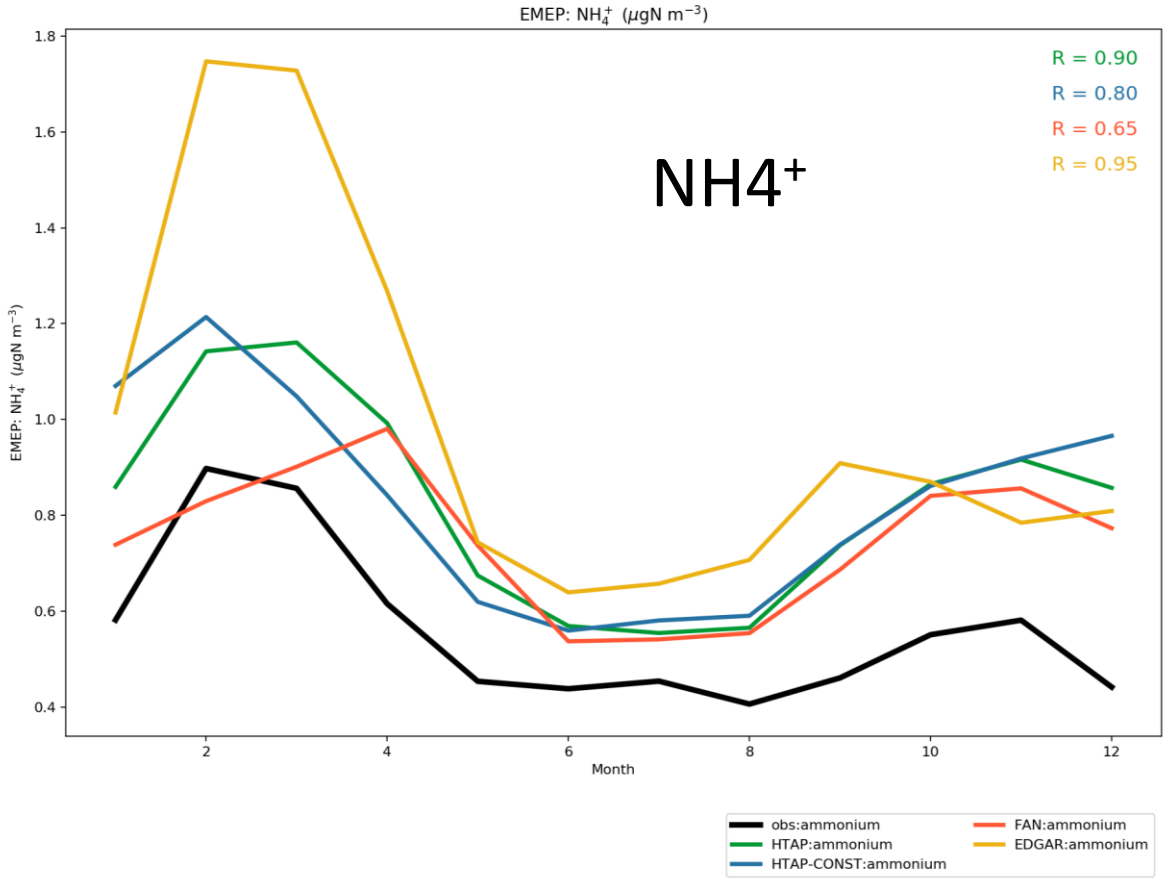
Conclusions

- No need to compromise CAM simulations when replacing tradational inventories with FAN emissions
- FAN consistent with regional inventories for Europe and North America but predicts larger emissions for data-sparse regions (Africa, Latin America, India)
- NH3 emissions sensitive to temperature, but probably less than predicted from Henry's law and chemical equilibrium between NH3 and NH4+ in soil

Thank you!

Temporal profiles: NH3 gas, NH4+ aerosol





NH3 in atmosphere