



中国大气活性氮排放、沉降及环境效应

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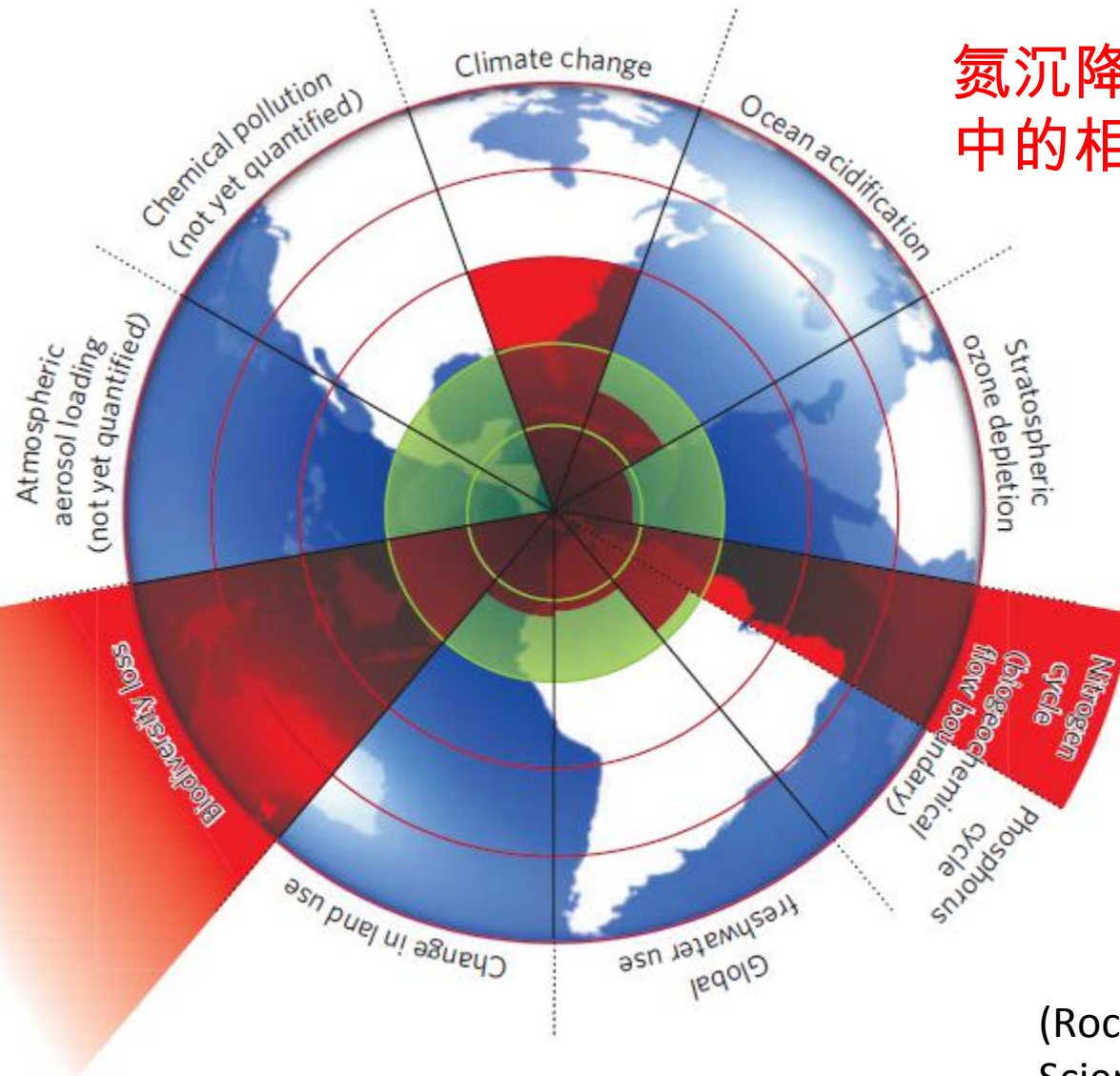
2017.4.05 南京

报告提纲

- 1、研究背景
- 2、我国大气活性氮排放
- 3、我国氮素干湿沉降通量
- 4、氮沉降的生态环境效应
- 5、结论与展望

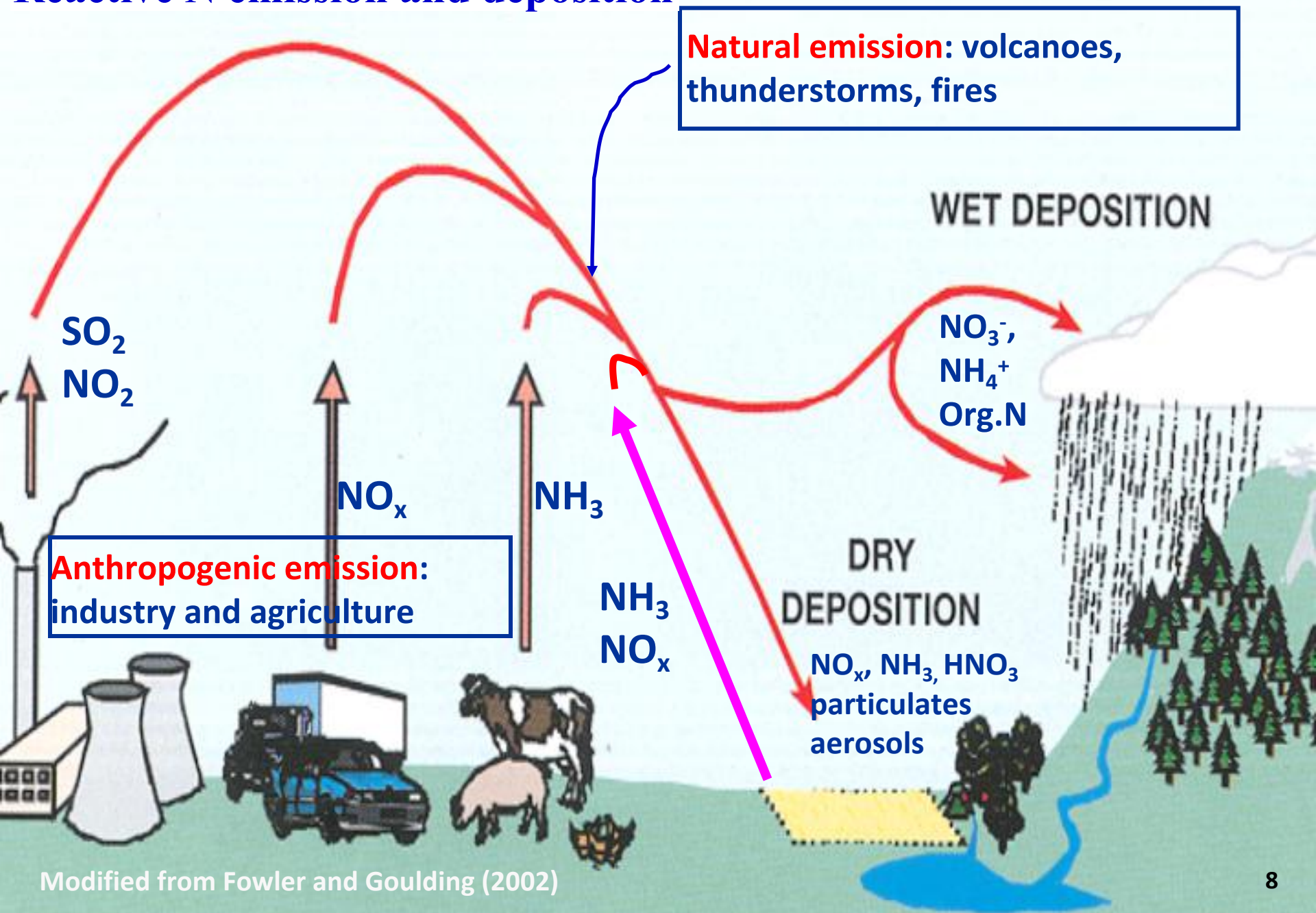
氮素循环、生物多样性下降和气候变化已成为九大系统超出地球环境边界 (planetary boundaries) 的三个

氮沉降则是氮循环研究中的相对薄弱环节



(Rockstroem et al., 2009.
Science 461:471-475)

Reactive N emission and deposition



Global hotspots of atmospheric NO_x pollution

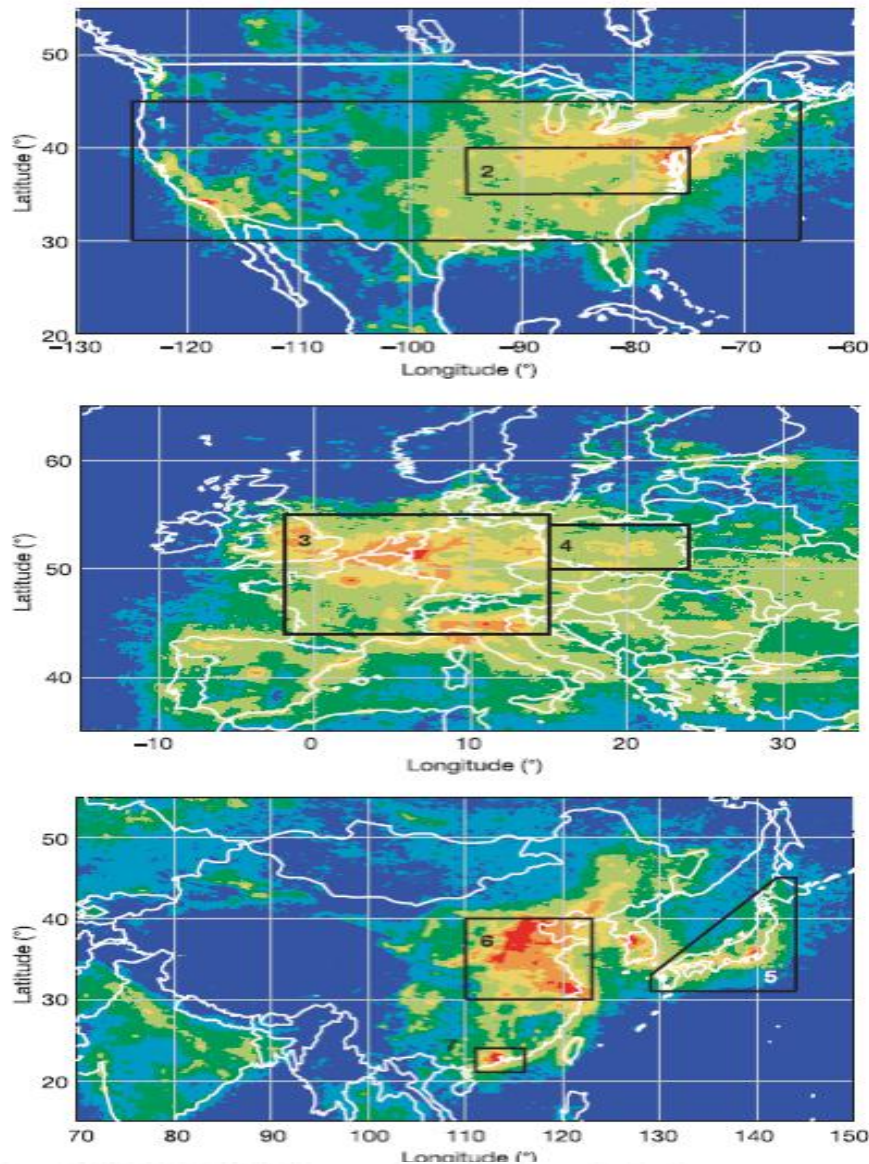
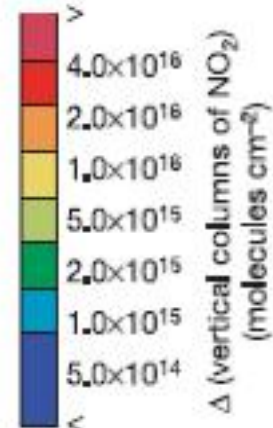


Figure 2 | SCIAMACHY tropospheric NO₂ vertical columns averaged between December 2003 and November 2004 for selected industrial regions. SCIAMACHY measurements are taken close to 10.00 a.m. LT. A



East central China and Hong Kong were the only two regions to show continuous increase in NO₂ conc.!

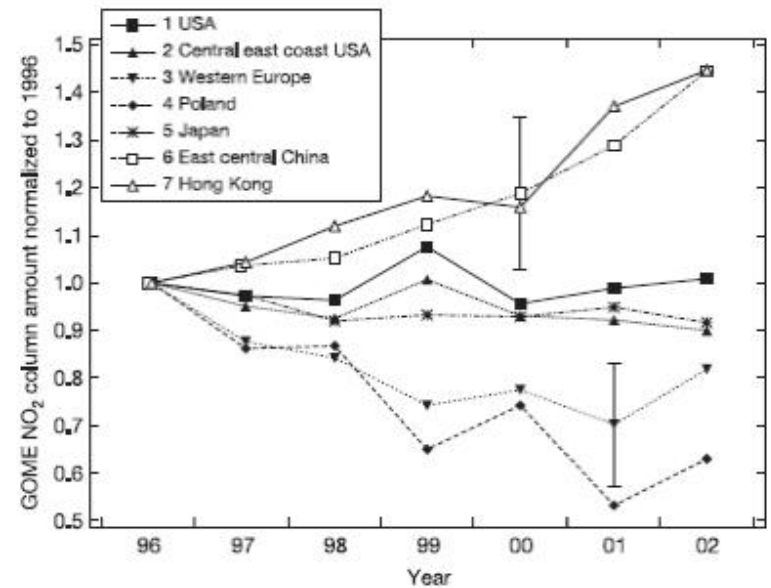
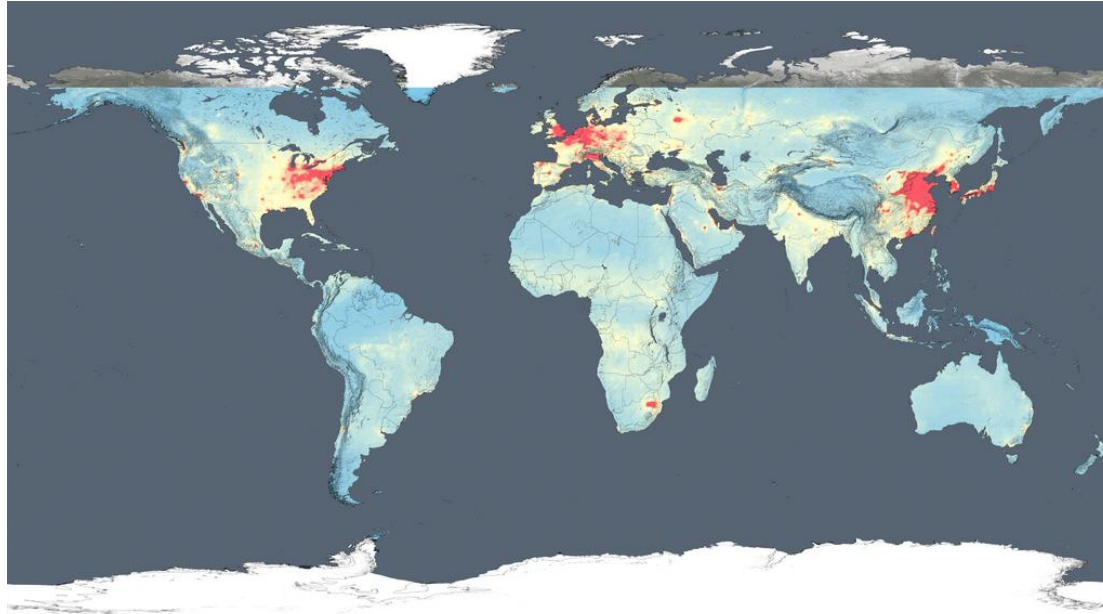


Figure 3 | The temporal evolution of tropospheric NO₂ columns from GOME for selected areas. The mean annual NO₂ column amount normalized to (Richater et al., 2005. Nature 437, 129-132)

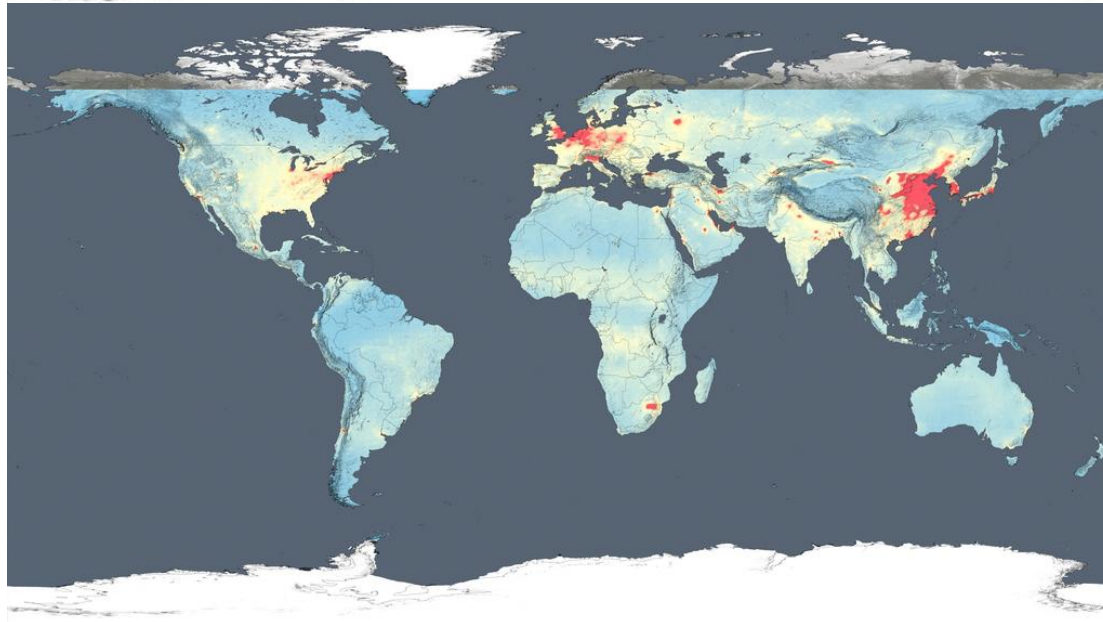
Air pollution map (NO₂) worldwide (2005 vs 2014)

(<http://svs.gsfc.nasa.gov/12094>)

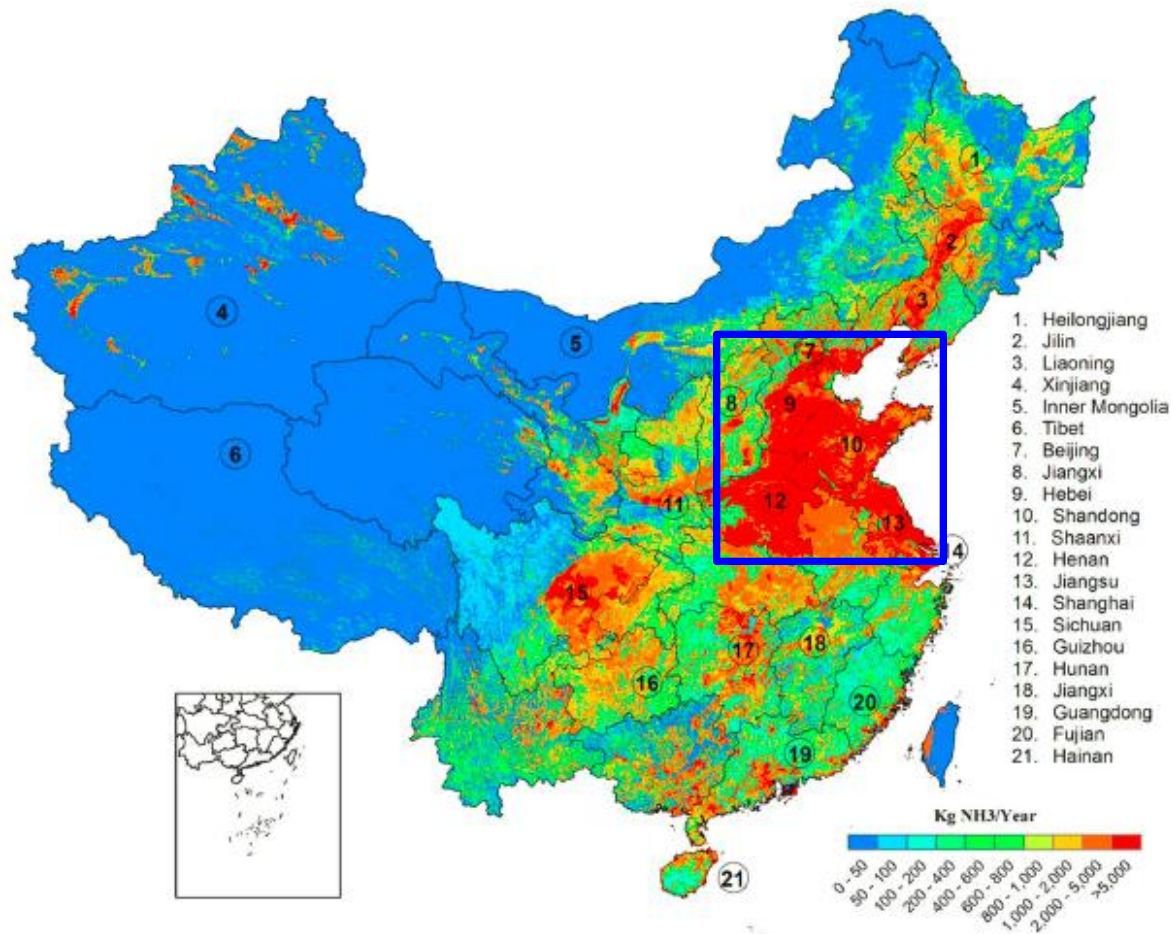
2005



2014



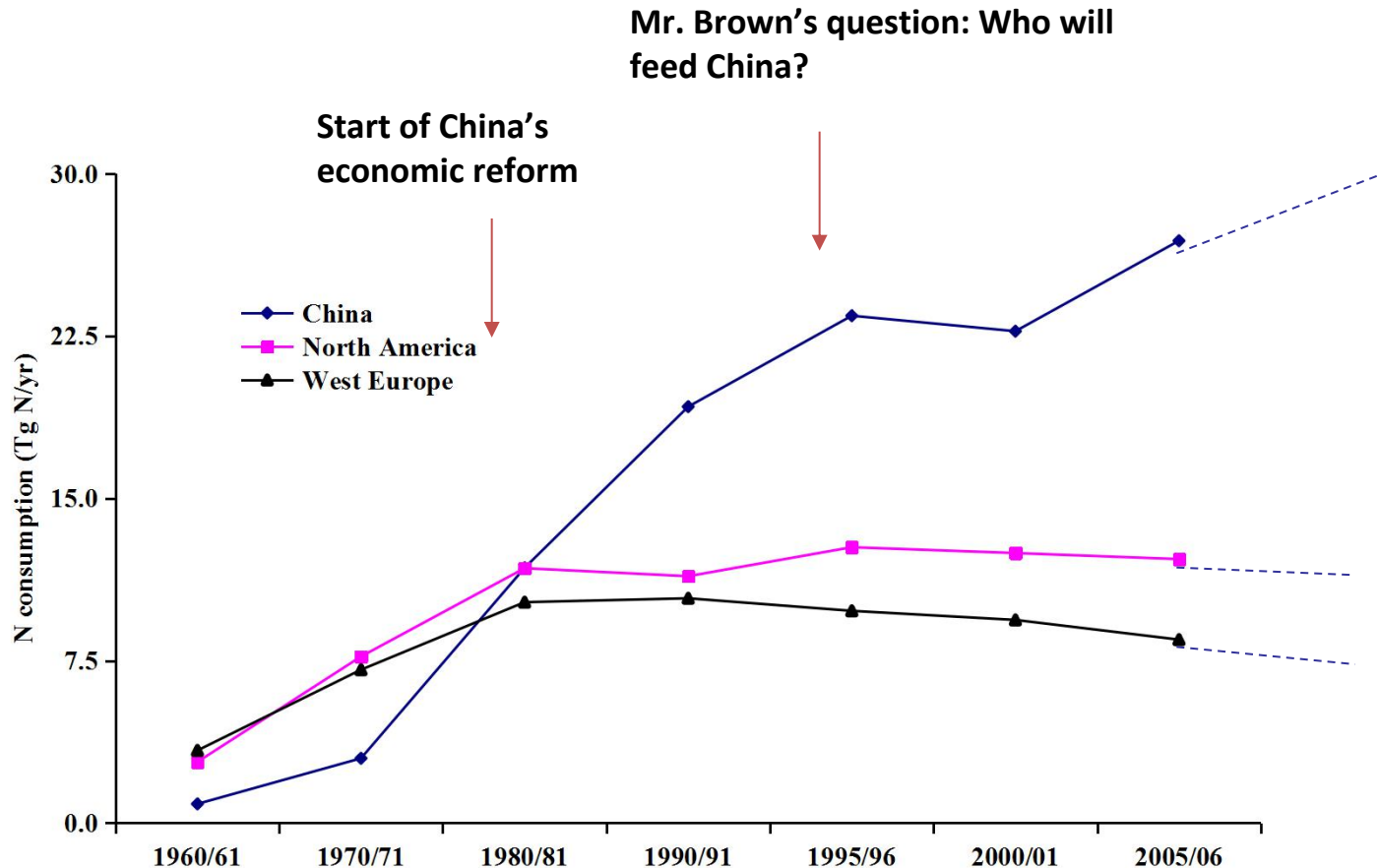
High resolution (1*1 km) inventory of NH₃ emission in 2006 over China



Emissions of both NH₃ and NO_x are very large in the North China Plain!

(Huang et al., 2012. GBC)

Trends of fertilizer N consumption in China, North America and West Europe since 1960s



(<http://www.fertilizer.org/ifa/statistics/indicators/tablen.asp> and
<http://www.fertilizer.org/ifa/statistics/IFADATA/DATA/chn.xls>)

Questions concerned

- **What are the scale and magnitude of atmospheric N deposition in China in relation to Nr emissions?**
- **How does atmospheric N deposition affect agro- and semi-natural ecosystems?**
- **Are there any solutions for lowering reactive N pollution and deposition?**

报告提纲

1、研究背景

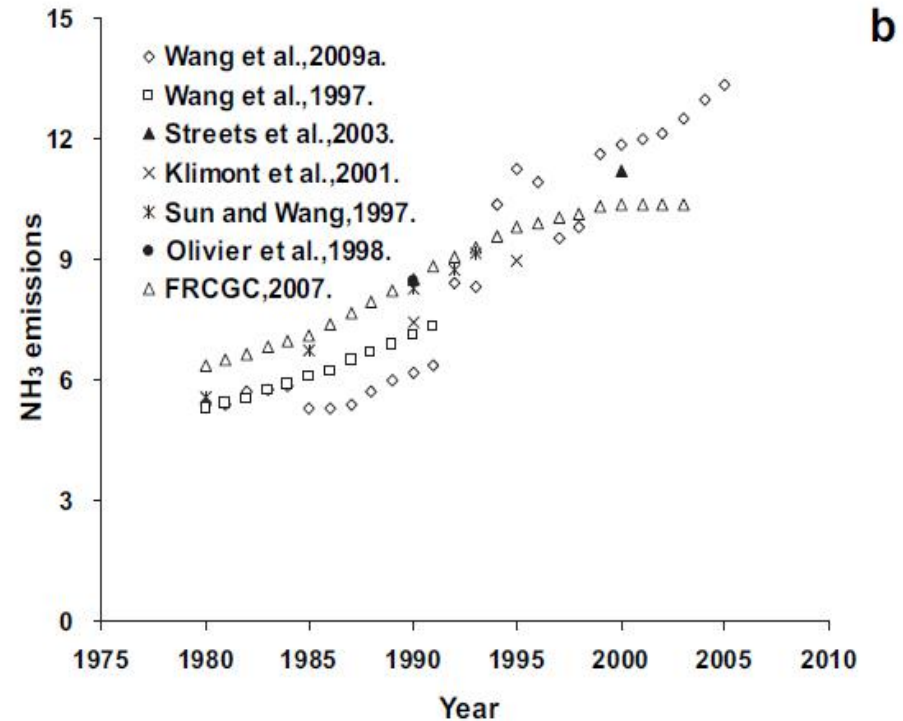
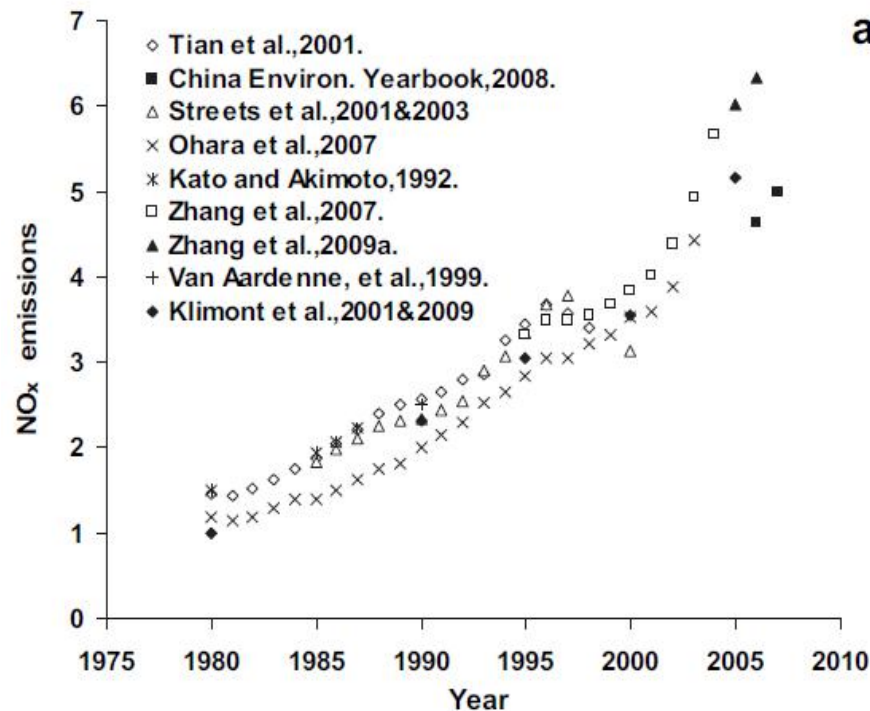
2、我国大气活性氮排放

3、我国氮素干湿沉降通量

4、氮沉降的生态环境效应

5、结论与展望

Trends of reactive N emissions in China since 1980 (summarized from various references)

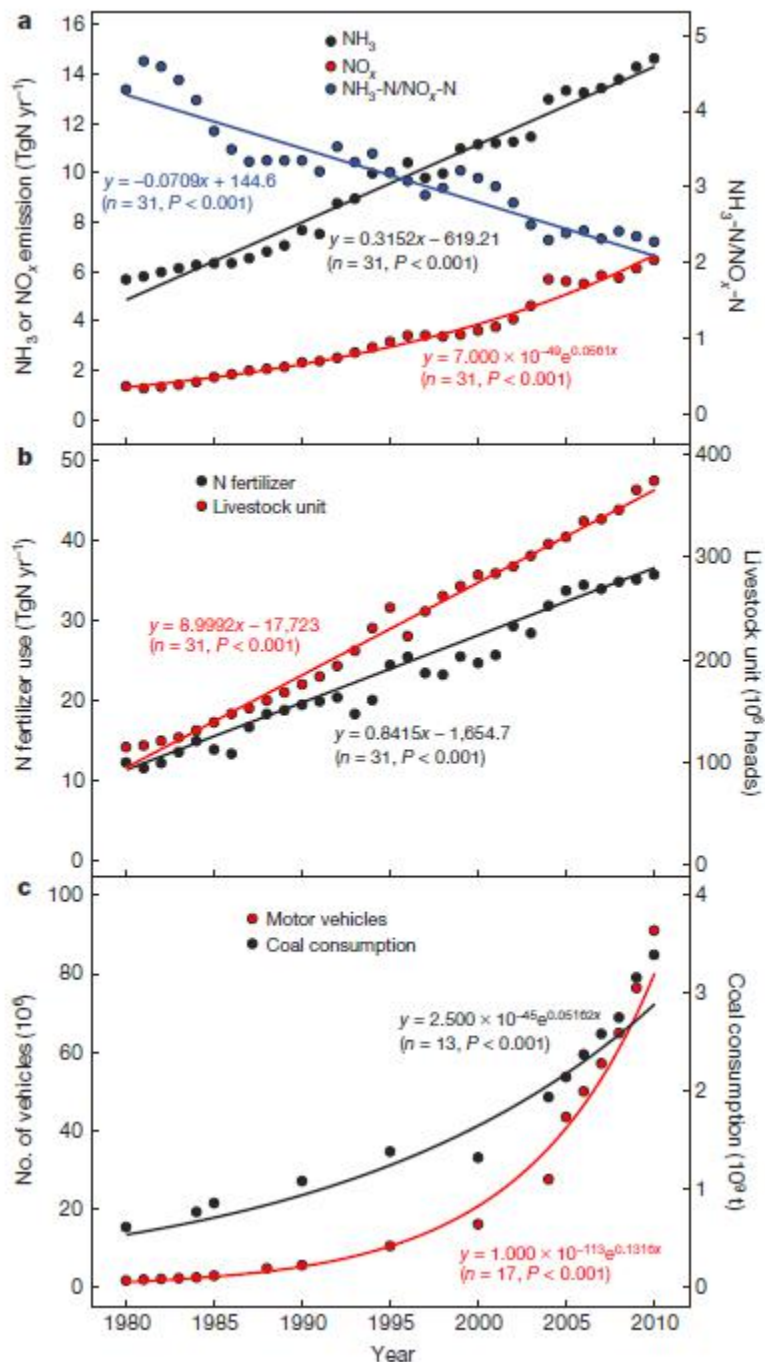


(Liu et al., 2011. Env. Pollut. 159: 2251-64)

我国大气活性氮排放和 铵硝比动态及相关排放 源动态

氨排放线性增长-农业源
排放线性增加；

氮氧化物非线性增长-非
农业源排放加速增长！



总排放

农业源

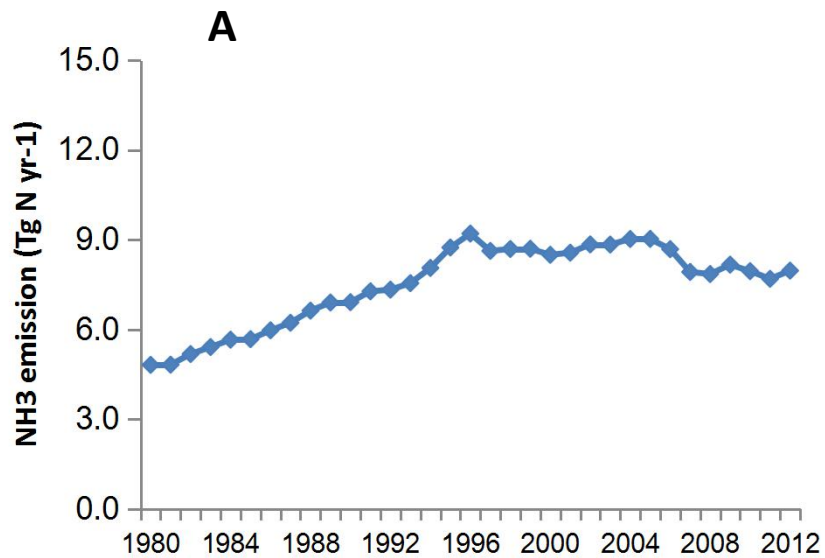
非农业源

NH₃ gap?

Unpublished work

中国氨排放动态比较

(A. 北大宋宇小组 ; B.)



B

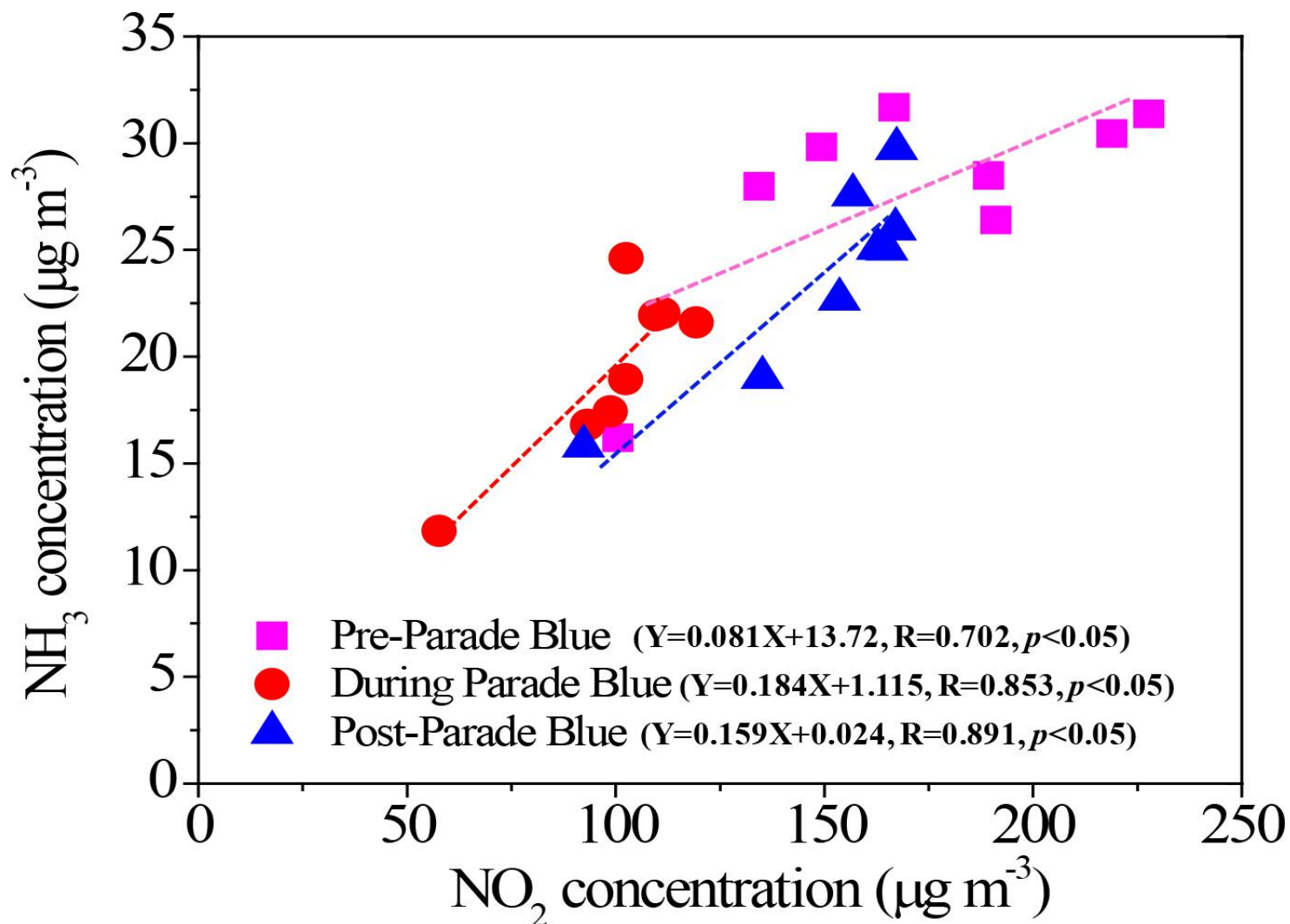
Unpublished work

(Kang et al., 2016. ACP)

城市源NH₃ 排放不容忽视？

Unpublished work

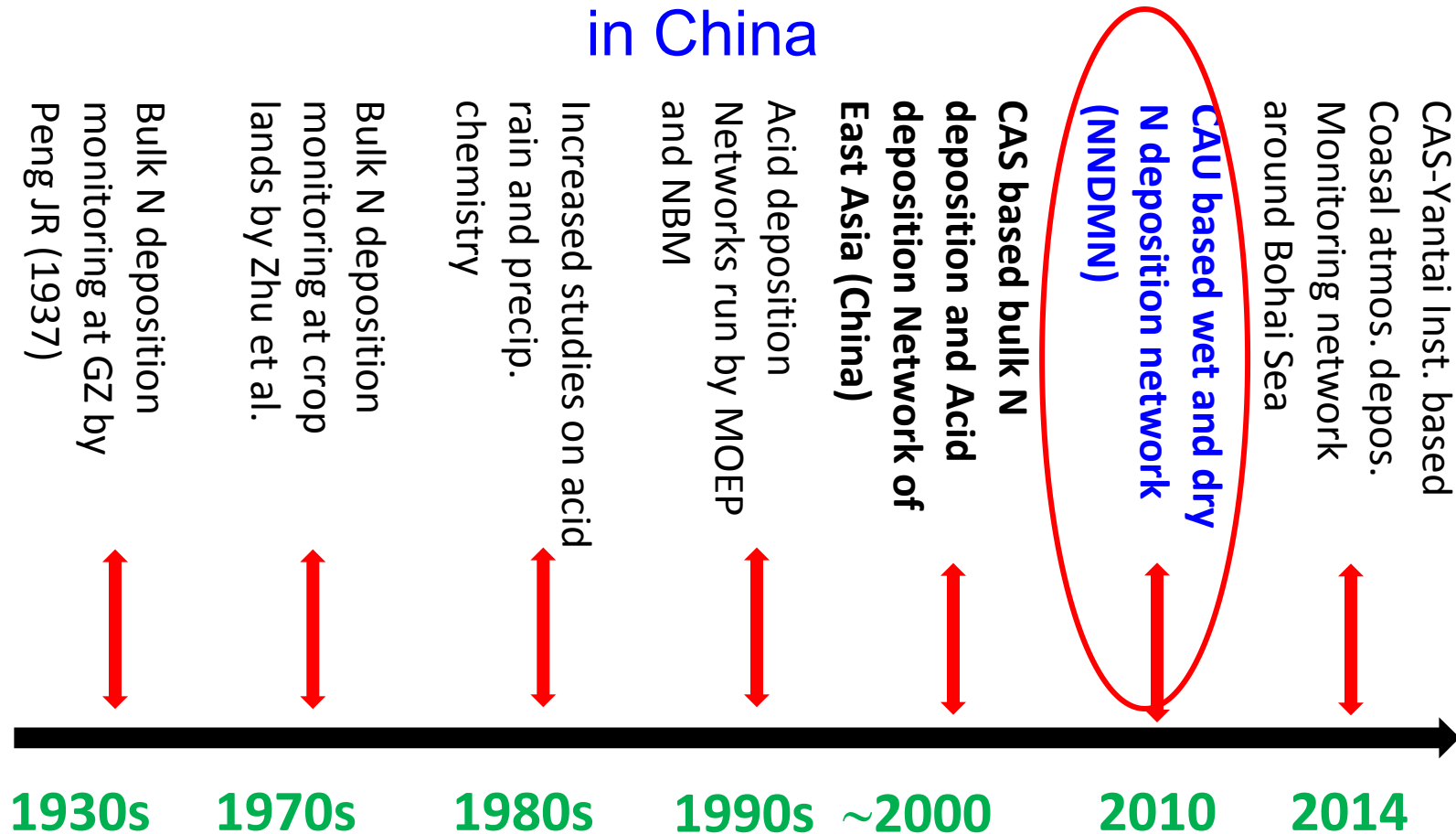
北京五环多点采样结果：NH₃ vs NO₂



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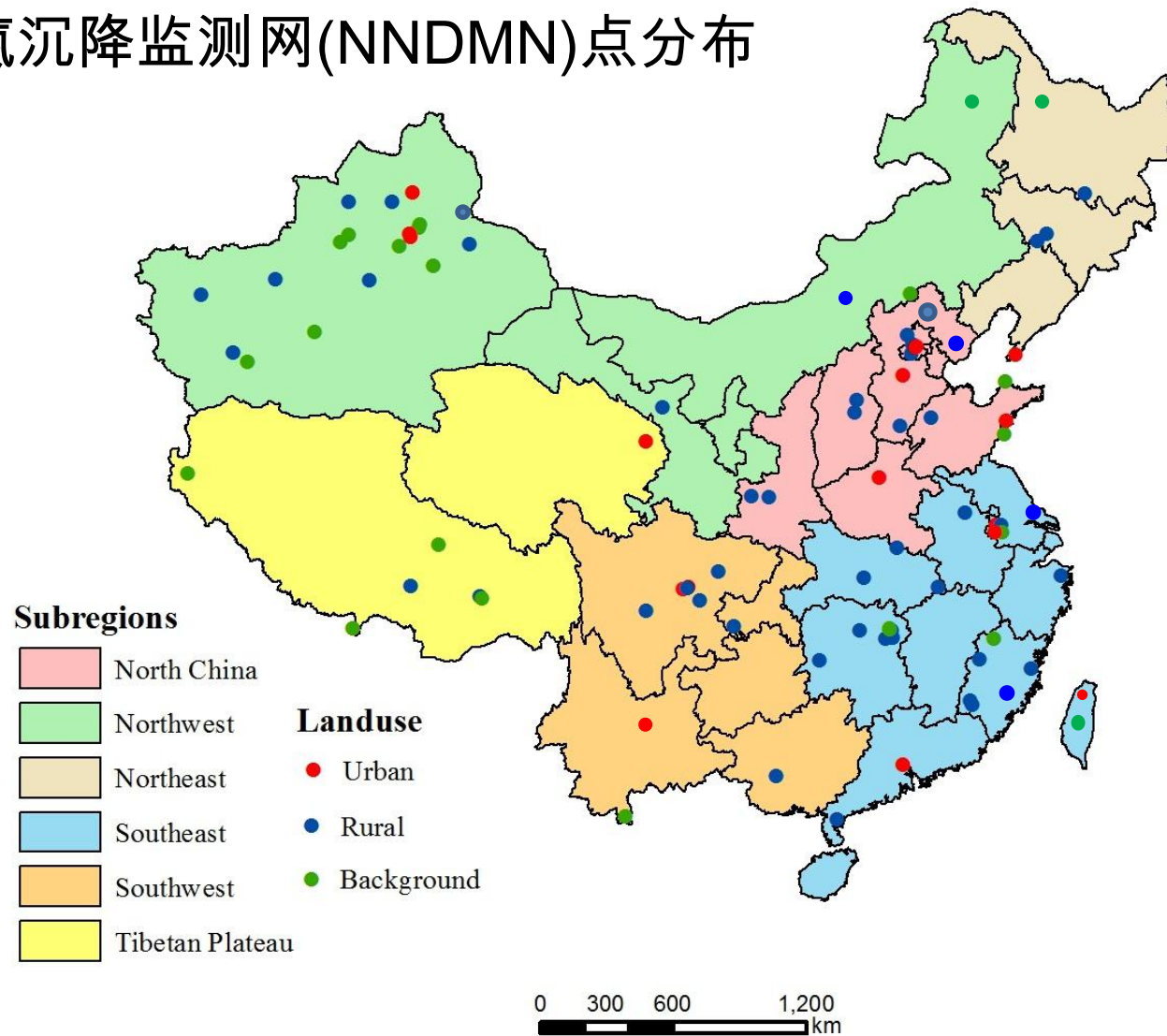
An overview on N deposition monitoring (network) in China



(鲁如坤等, 1979; 朱兆良等, 1992; Zhao et al., 1986; Liu et al., 2011; 陈颖军, 2014; Xu et al., 2015)

Nationwide Nitrogen Deposition Monitoring Network in China (NNDMN)

中国氮沉降监测网(NNDMN)点分布



Wet-only sampler



Rain gauge

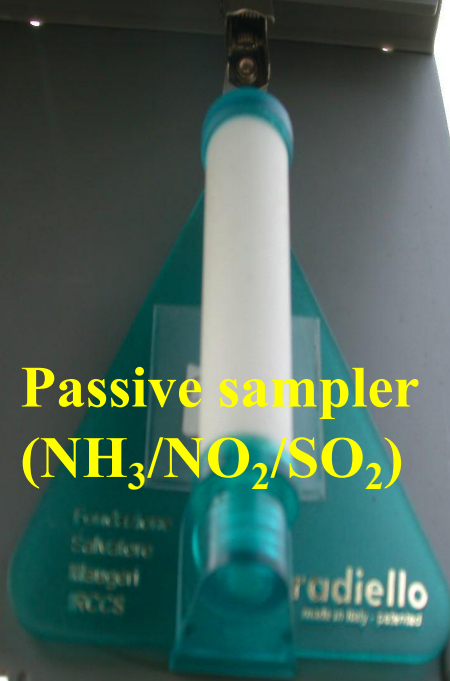


Weather station



Instruments on quantification of N wet and dry deposition

**Passive sampler
($\text{NH}_3/\text{NO}_2/\text{SO}_2$)**



**Particulate sampler
($\text{pNH}_4^+/\text{NO}_3^-/\text{Org.N}$)**

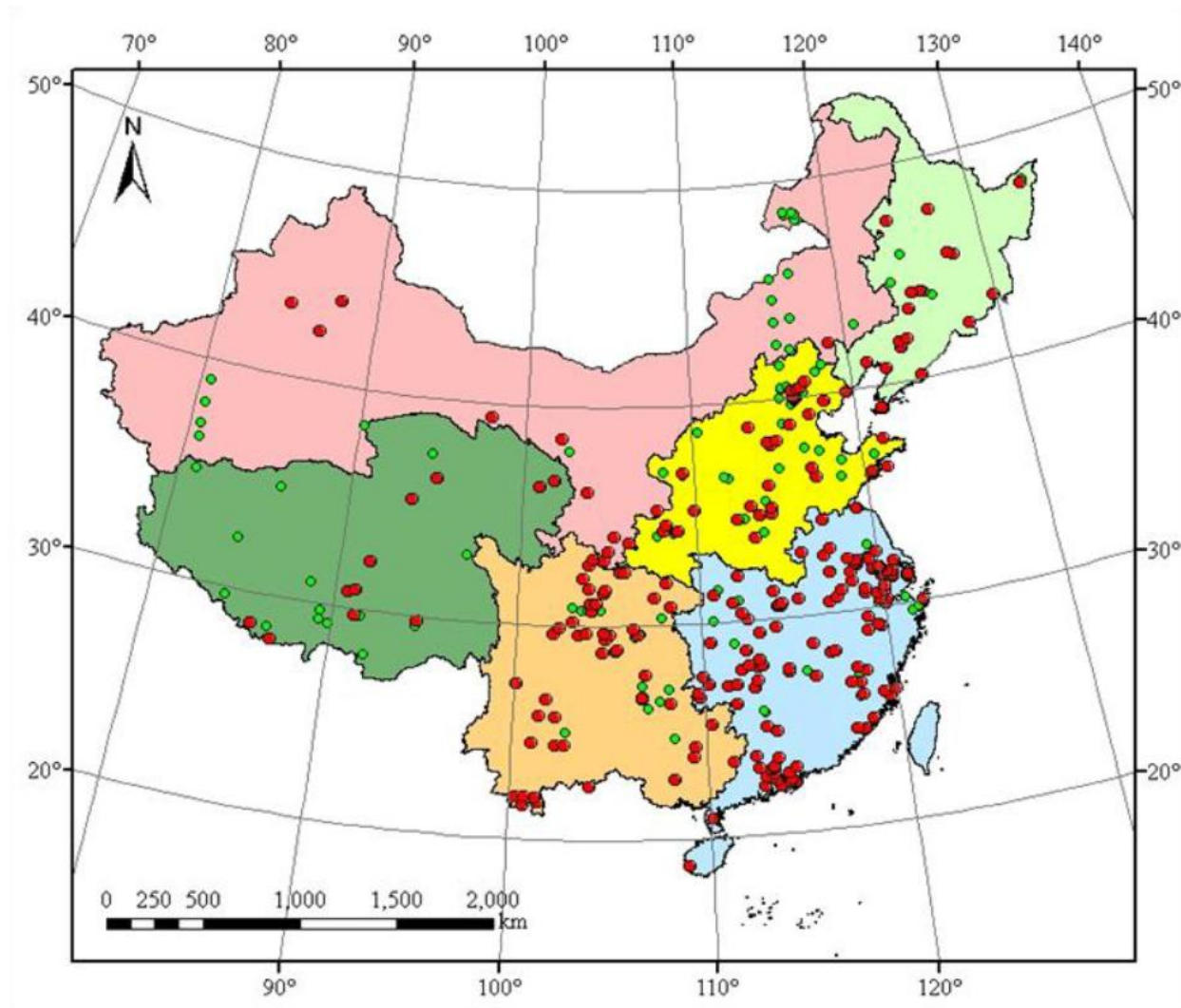


**DELTA system
($\text{NH}_3/\text{HNO}_3/\text{pNH}_4^+/\text{pNO}_3^-$)**



1) Historical N deposition

Distribution of sites reported bulk N deposition (red dots) and foliar N (green dots) in China during 1980 and 2010.



Enhanced nitrogen deposition over China

Xuejun Liu^{1*}, Ying Zhang^{1*}, Wenxuan Han¹, Aohan Tang¹, Jianlin Shen¹, Zhenling Cui¹, Peter Vitousek², Jan Willem Erisman^{3,4}, Keith Goulding⁵, Peter Christie^{1,6}, Andreas Fangmeier⁷ & Fusuo Zhang¹

Trends in bulk N deposition (a), N concentration (b), and ratio of $\text{NH}_4\text{-N}$ to $\text{NO}_3\text{-N}$ (c) in precipitation since 1980

N deposition

1980s: 13.2 kg N/ha/yr

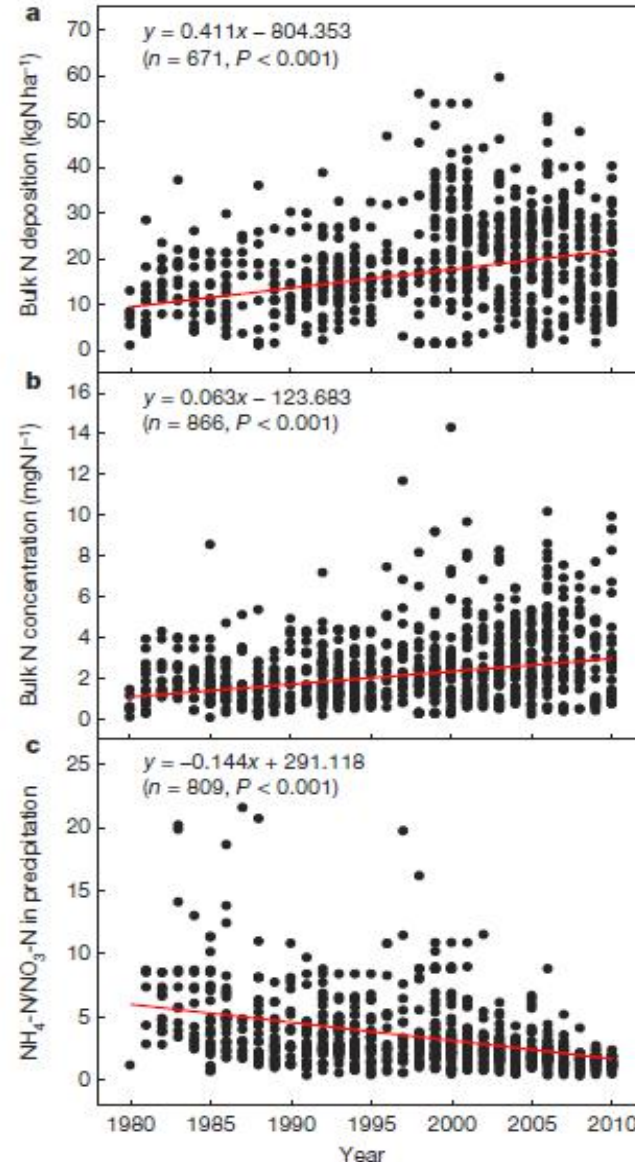
2000s: 21.1 kg N/ha/yr

$\text{NH}_4\text{-N}/\text{NO}_3\text{-N}$

1980s: ~5.0

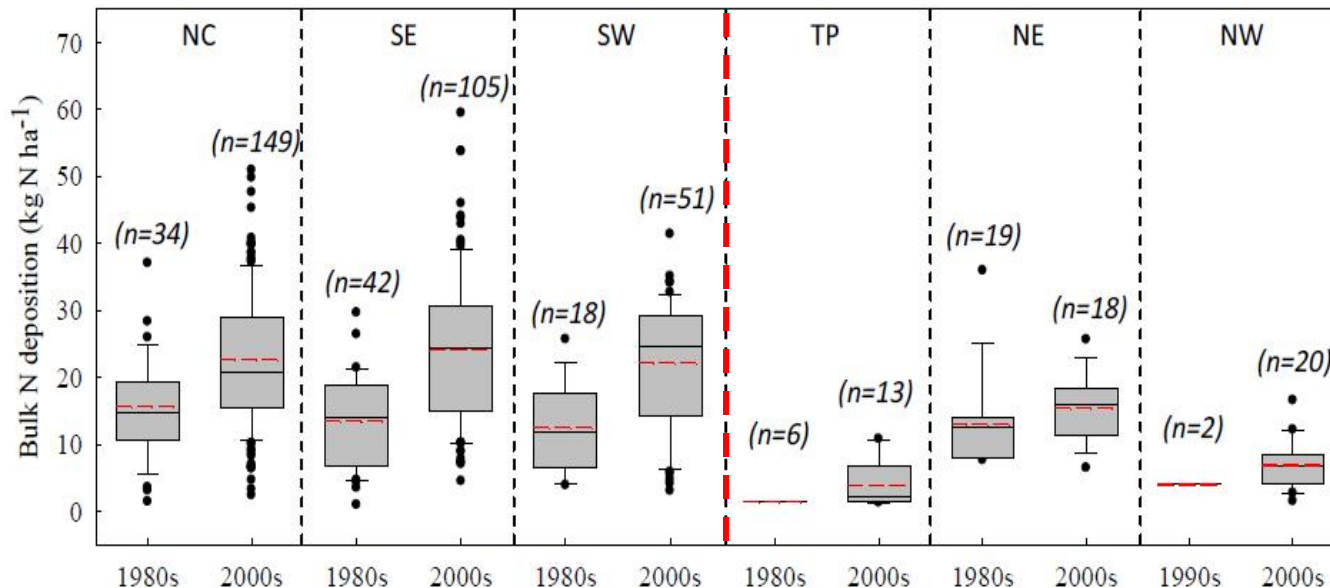
2000s: ~2.0

(Liu et al., 2013. Nature, 494:459-462)



Recent studies by Lu & Tian (2014) and Jia et al. (2014) reported similar increasing trend of N deposition in China.

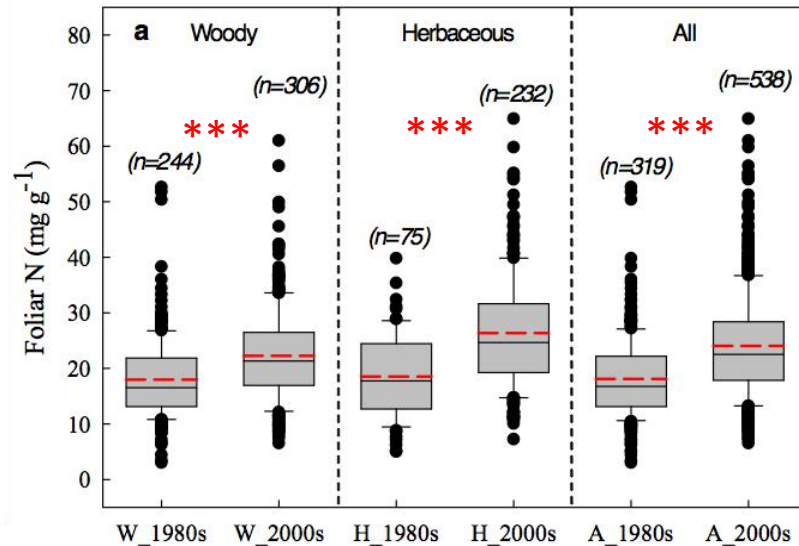
Increased bulk N deposition in different regions of China (2000s vs 1980s)



Rate and increase of N deposition were higher in highly-developed NC, SE and SW regions compared with less developed TP, NE and NW regions.

(Liu et al., 2013. Nature, 494:459-462)

Trends in foliar N in non-agricultural systems (a) and N uptake by rice, wheat and maize in long-term unfertilized croplands (b) during the 1980s and 2000s.



Foliar N concentration

1980s: $18.1 \pm 7.2 \text{ mg/g}$

2000s: $24.0 \pm 9.2 \text{ mg/g}$

Increase: $5.9 \text{ mg/g (+30\%)}$

Crop N from zero-N plots

1980s: $71.1 \text{ kg N ha}^{-1}$

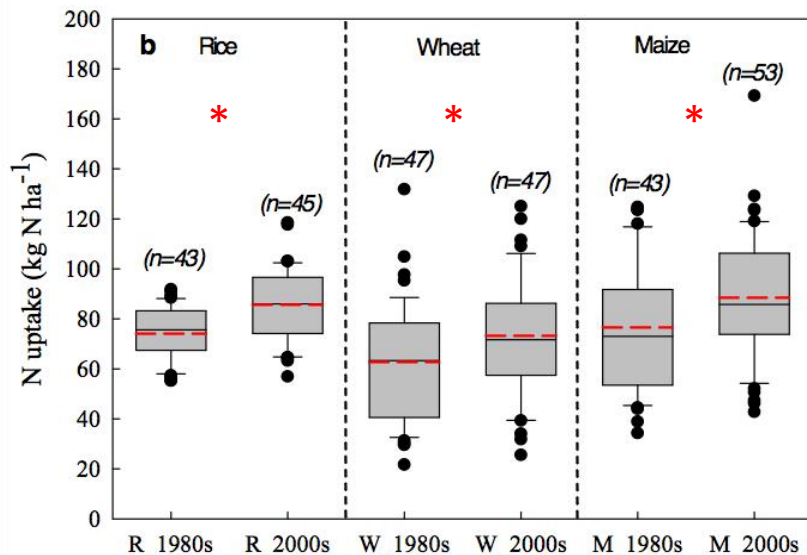
2000s: $82.4 \text{ kg N ha}^{-1}$

Increase: $11.3 \text{ kg N ha}^{-1 (+15\%)}$

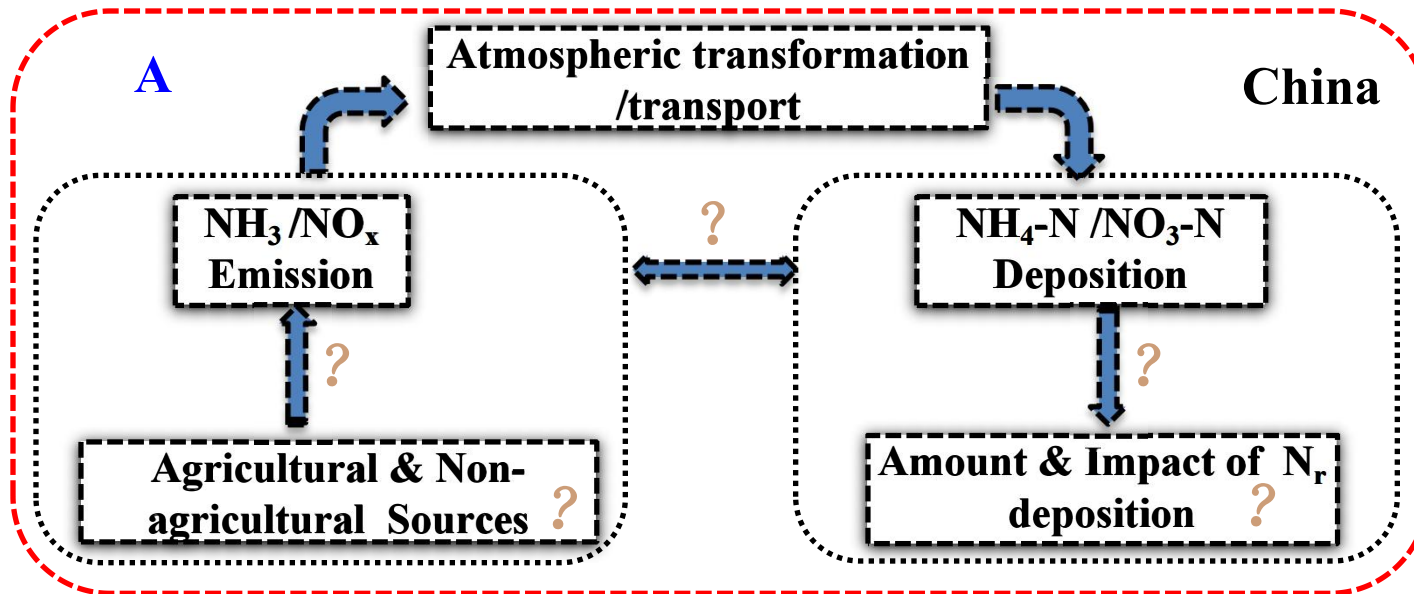
All the evidence clearly shows that N deposition has significantly increased over China since 1980.

*, *** denote significant difference at 0.05, 0.001 level.

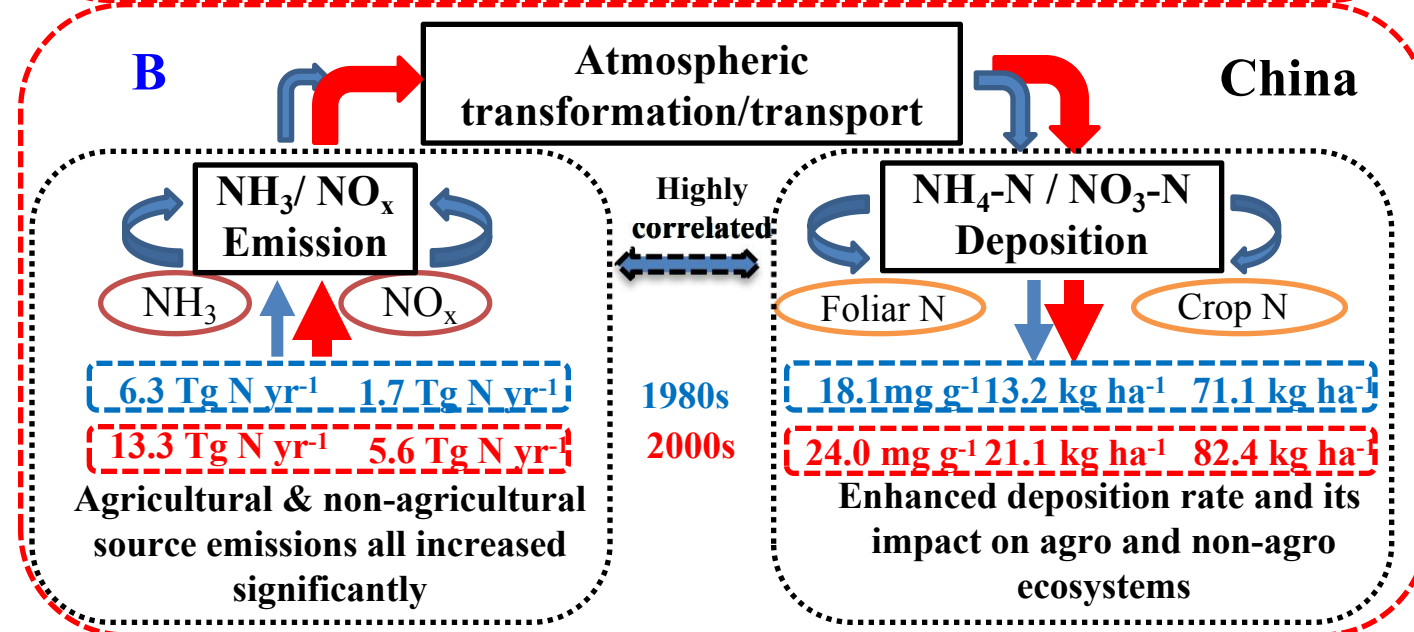
(Liu et al., 2013. Nature, 494:459-462)



Progress on relationship between N_r emission and N deposition



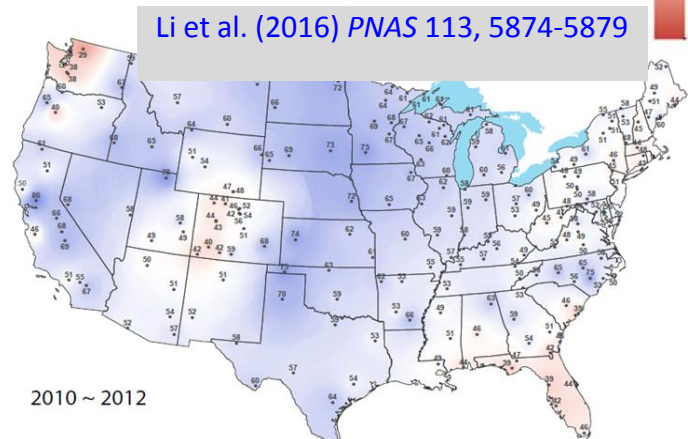
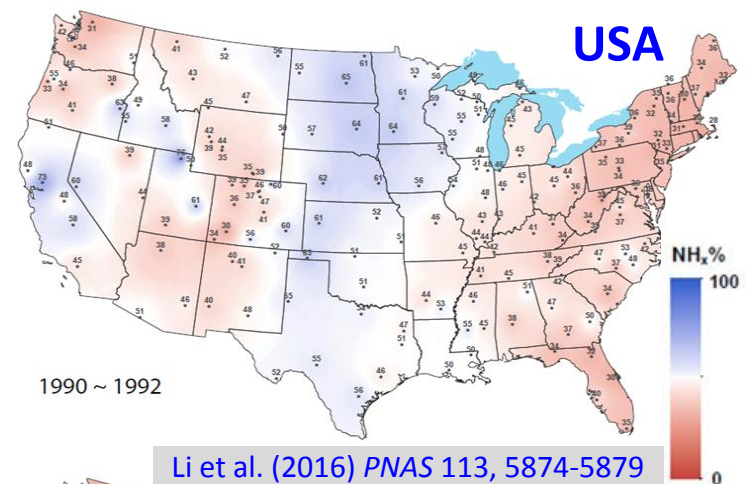
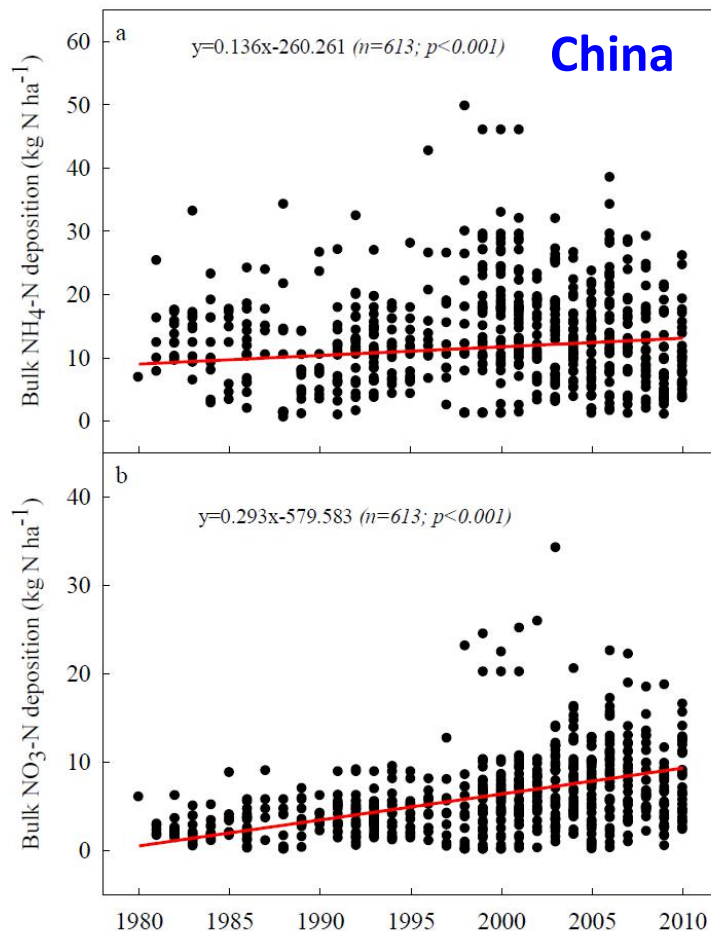
A. Unknown questions for N_r emission, deposition and their interactions



B. Progress in N_r emission, deposition and their impacts on foliar N and crop N uptake from unfertilized soils.

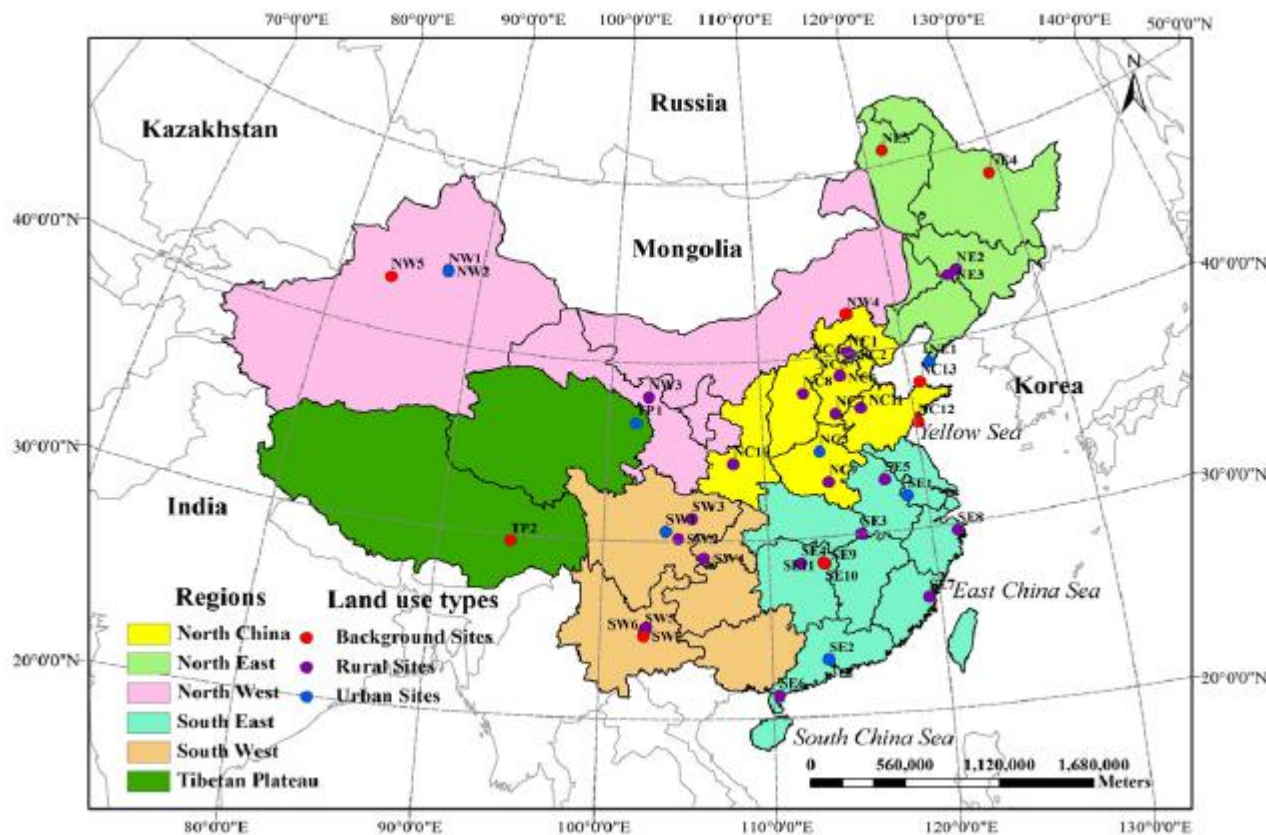
Reduced nitrogen dominated nitrogen deposition in the United States, but its contribution to nitrogen deposition in China decreased

Xuejun Liu^{a,1}, Wen Xu^a, Enzai Du^b, Yuepeng Pan^c, and Keith Goulding^d

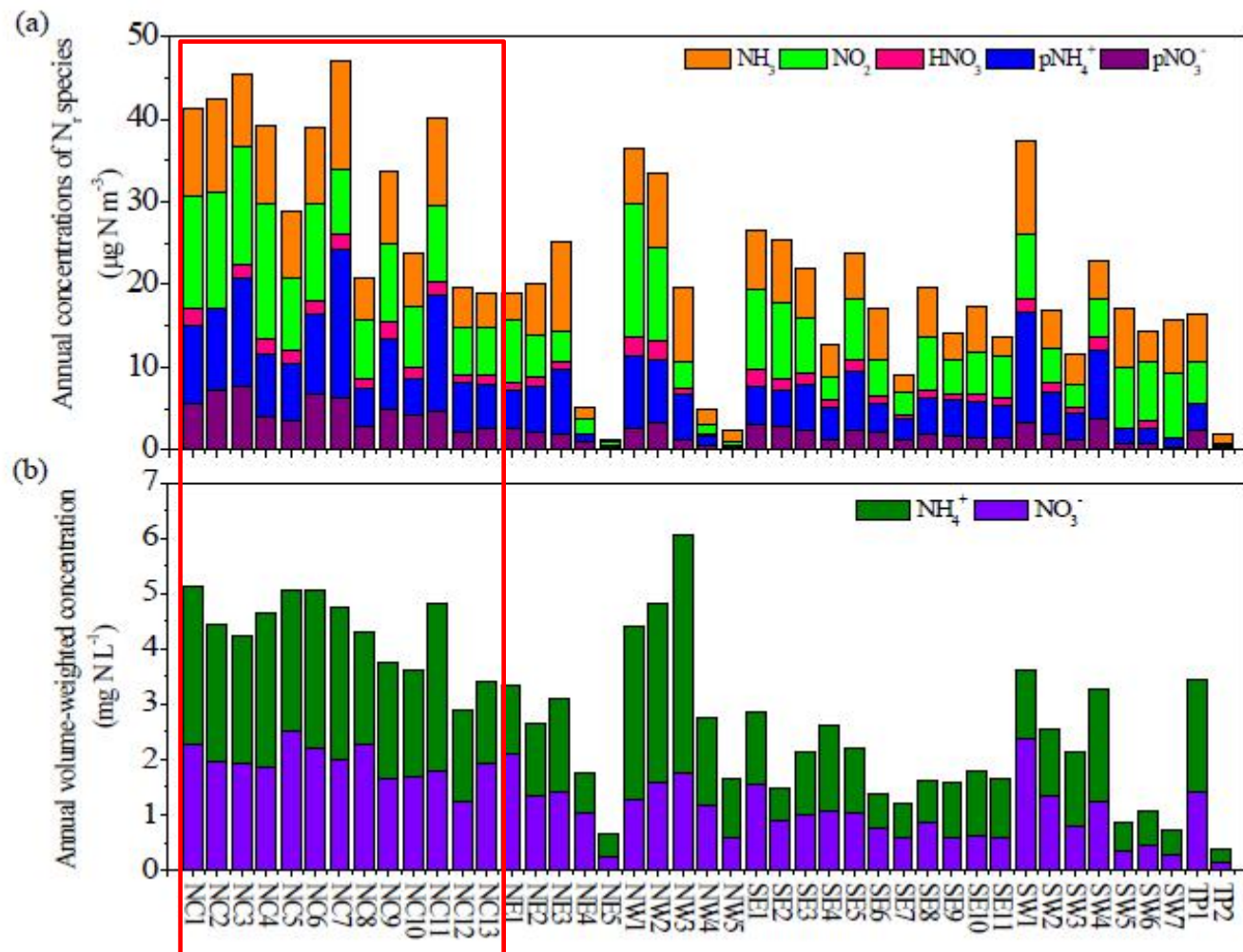


2) Quantification of wet/bulk and dry N deposition

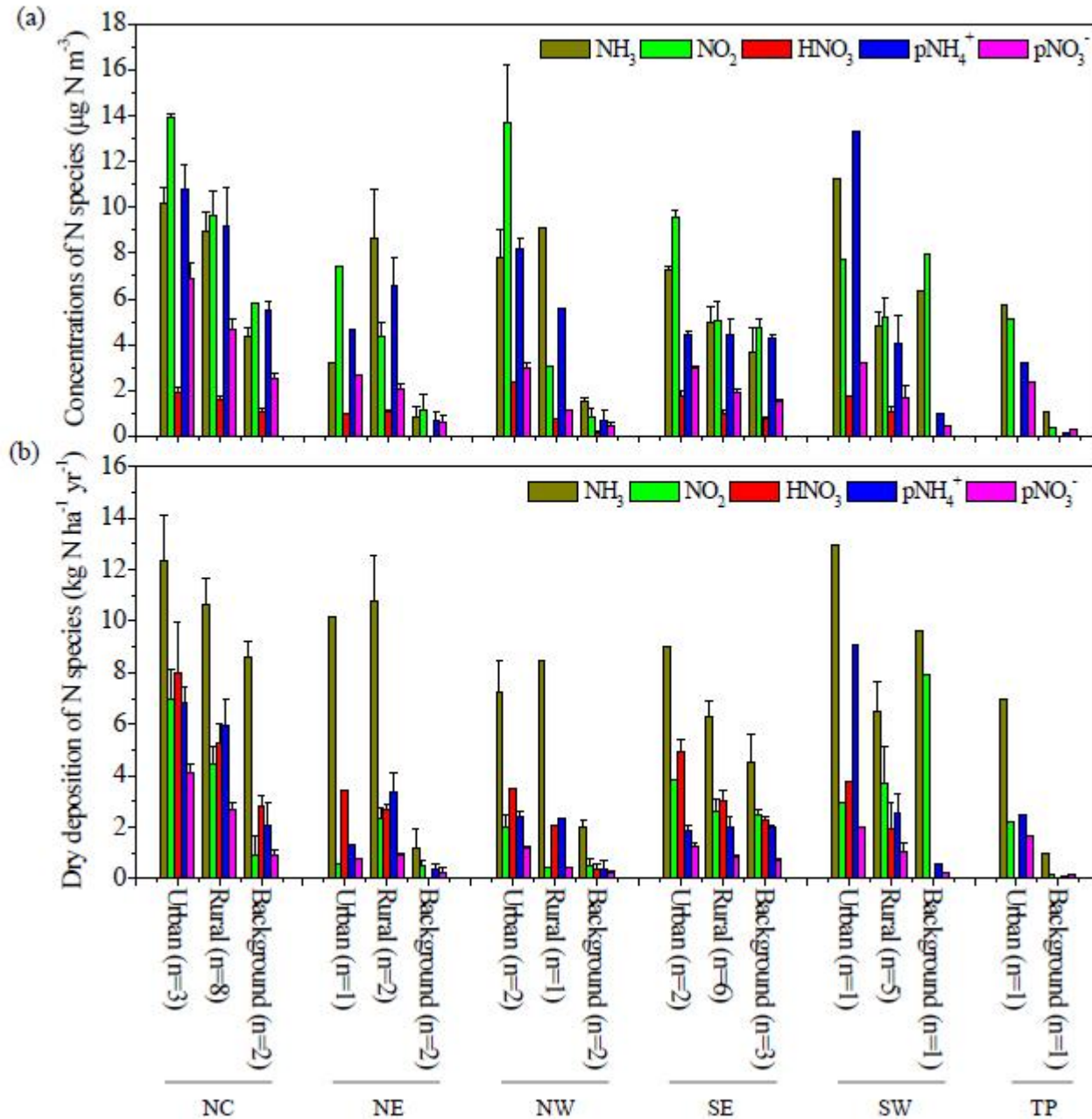
Monitoring N_r concentration and deposition at 43-sites in China during 2010-2014



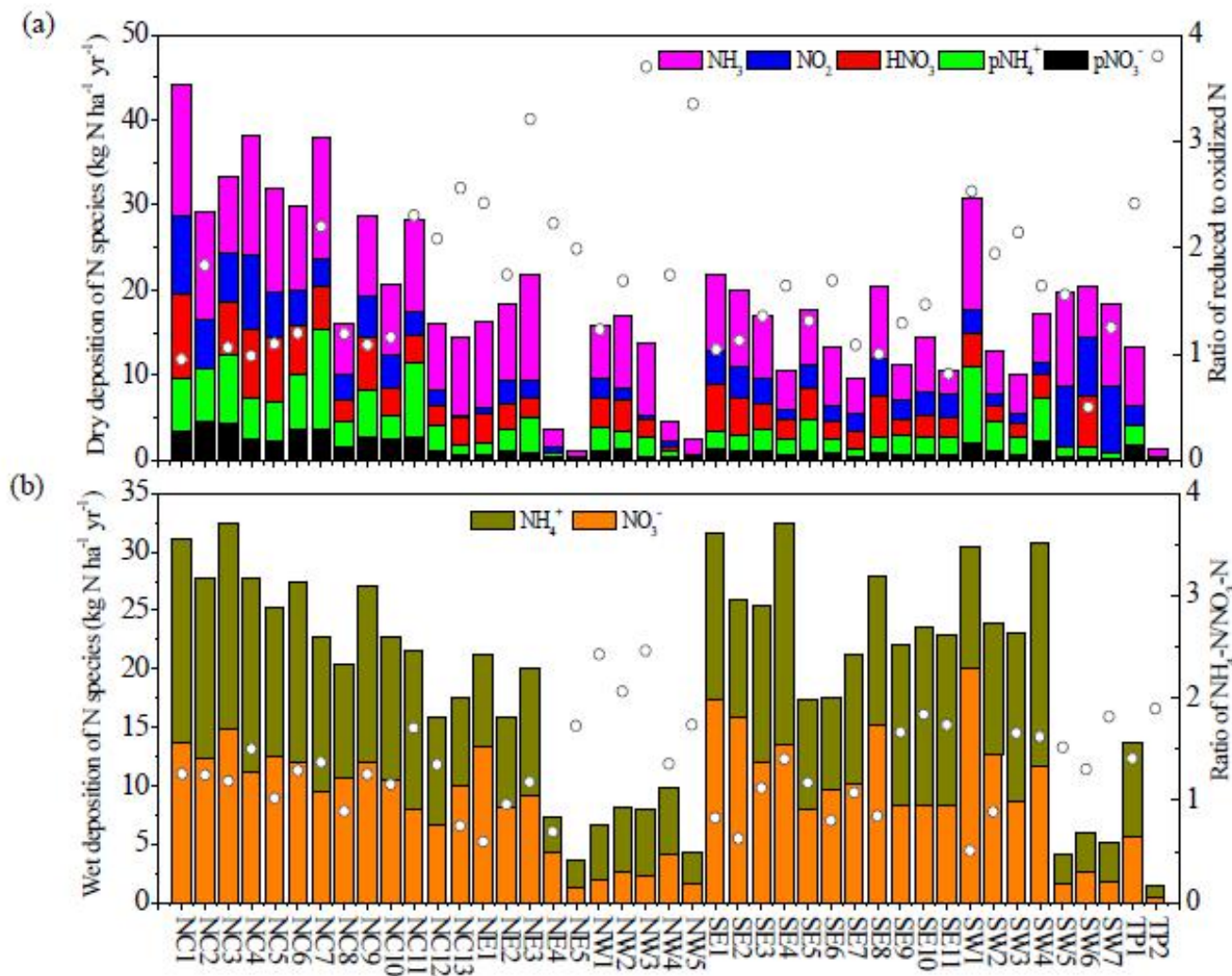
Annual mean concentrations of N_r at 43-sites



Annual mean conc. of N_r based on landuse types and regions



Dry and wet deposition of N_r at 43-sites in China



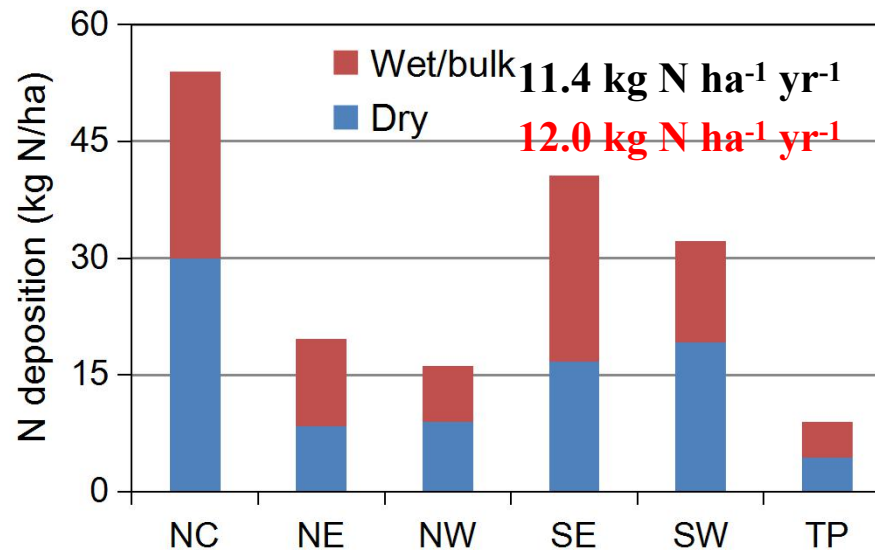
Average:

Dry: 20.0 kg N/ha

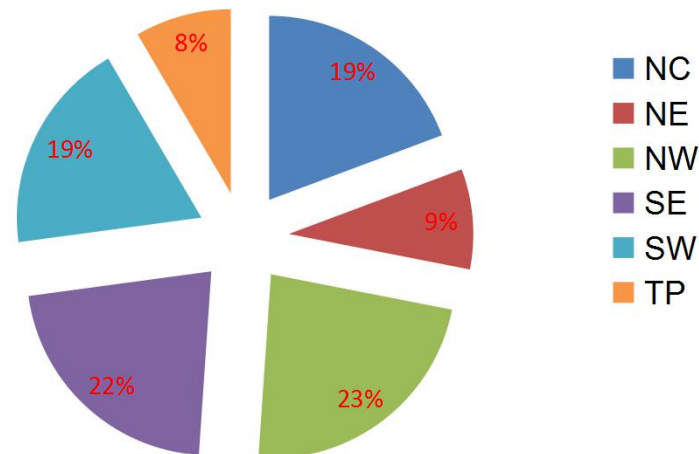
Wet: 19.9 kg N/ha

Total: 39.9 kg N/ha

Total N deposition in different regions of China



Total N deposition:
22.4 Tg N yr⁻¹

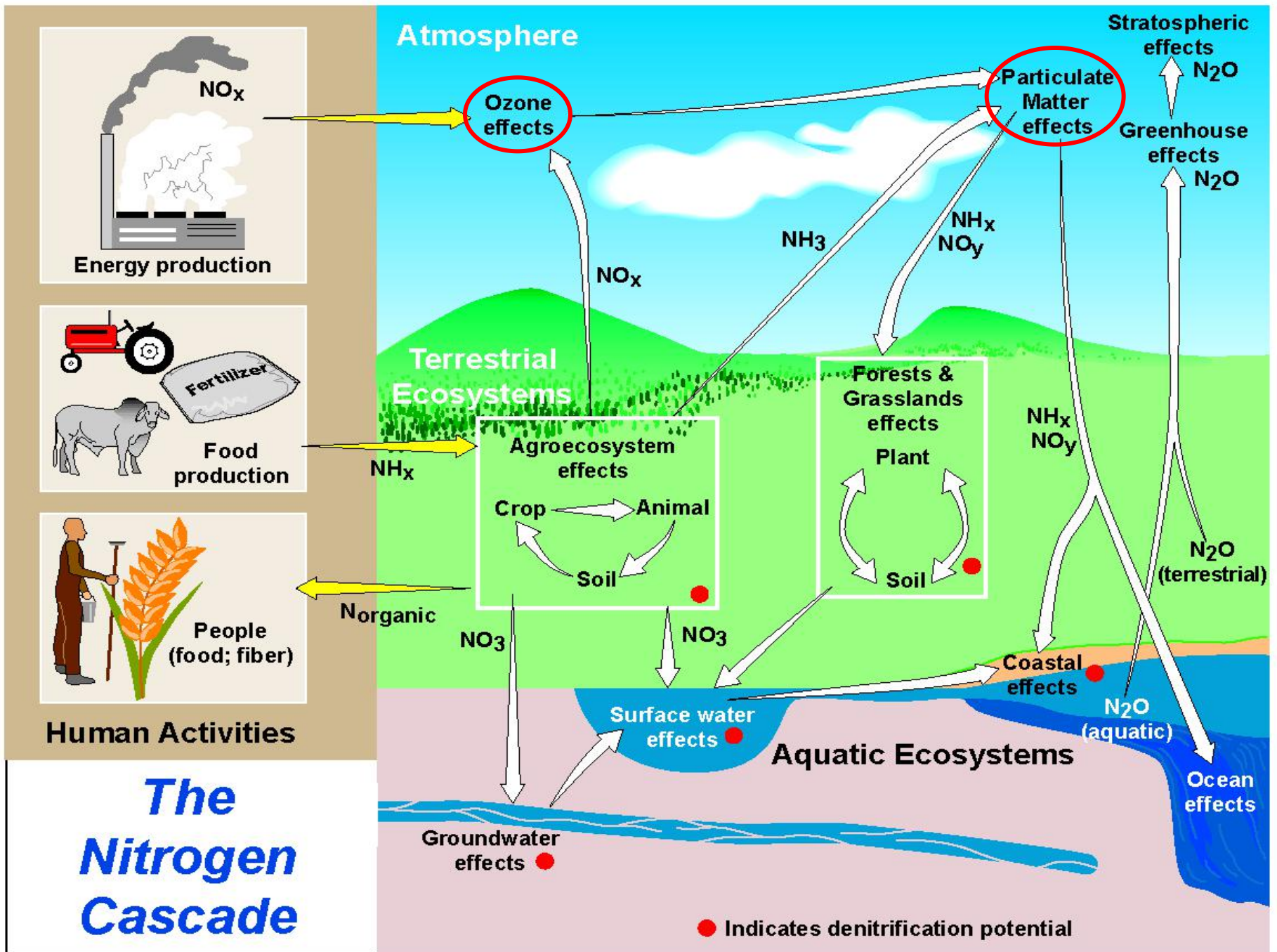


沉降模型结果表明中国氮素干湿沉降总量为16.4 Tg N yr⁻¹ (Zhao et al., 2017. AE)

(Based on Xu et al., 2015. ACP, 15: 12345-12360)

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- 5、结论与展望



1. Environmental nutrient to croplands

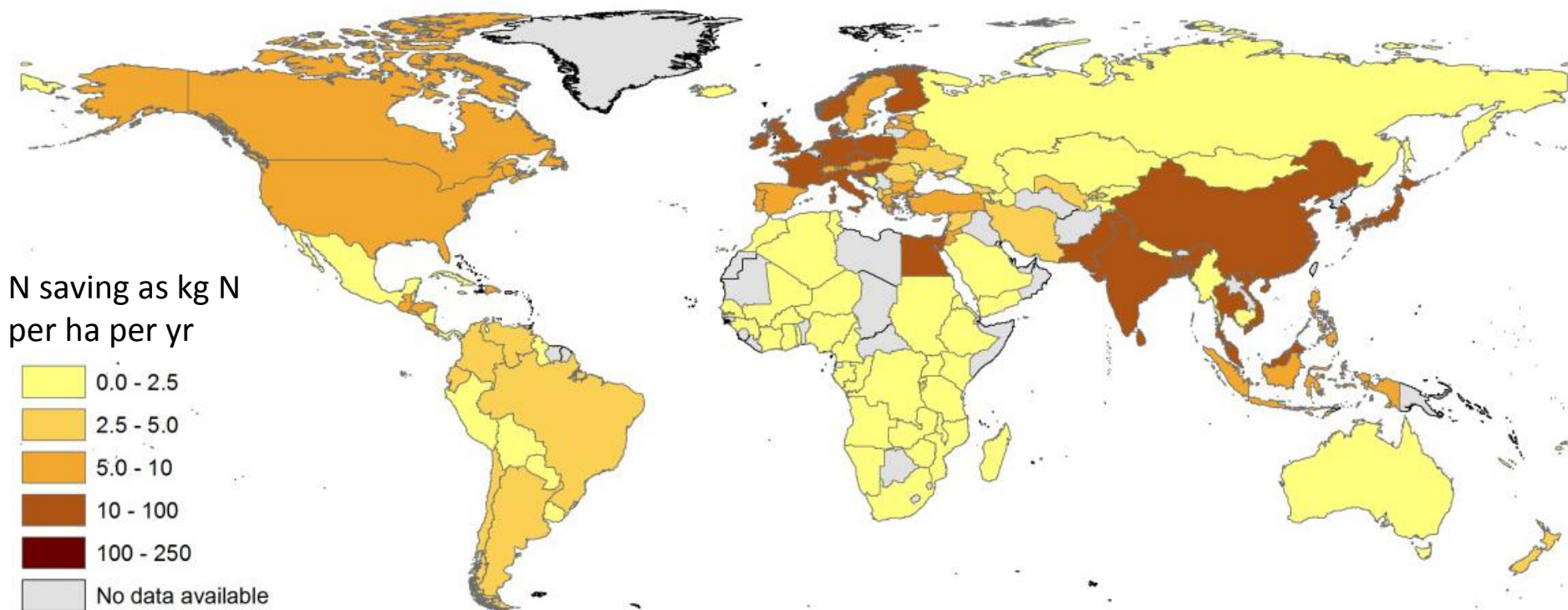
Atmospheric N deposition is a major
environmental nutrient source to croplands

Unpublished work

Historic change of environmental nutrient to croplands

“20:20 for 2020” program

20% better NUE: saving 20 Mt N per yr by 2020



Benefits expressed here as equivalent N saving / ha per year
from the Full-chain NutUE target

China (and India) can make larger contribution!

(Sutton et al., 2013)

2. Soil acidification



Significant Acidification in Major Chinese Croplands

J. H. Guo, *et al.*

Science **327**, 1008 (2010);

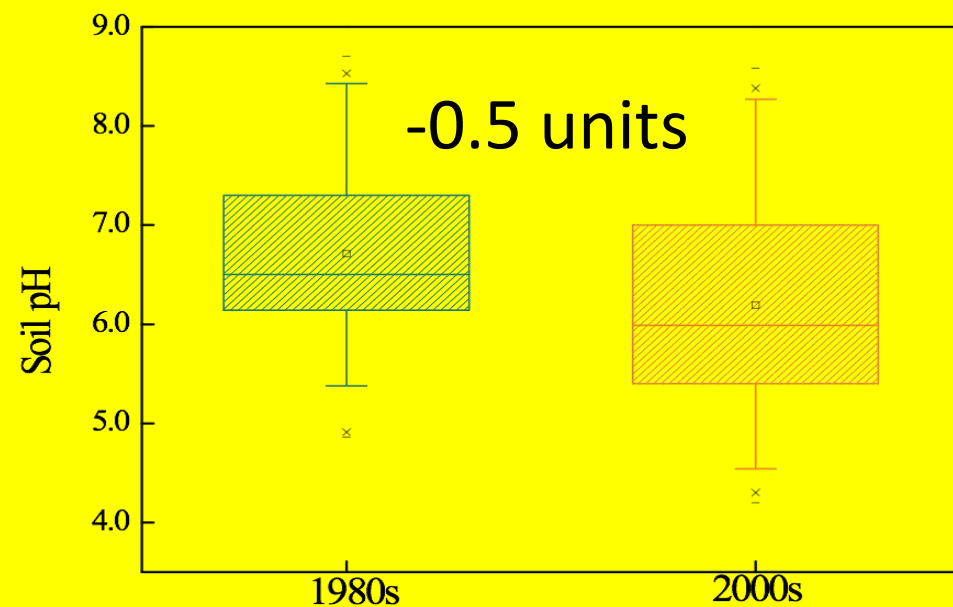
DOI: 10.1126/science.1182570

Soil pH was decreased by 0.5 units due to overuse of N fertilizers and elevated N deposition.

Homepage

Research Highlights

REPORTS



Significant Acidification in Major Chinese Croplands

J. H. Guo,^{1*} X. J. Liu,^{1*} Y. Zhang,¹ J. L. Shen,¹ W. X. Han,¹ W. F. Zhang,¹ P. Christie,^{1,2} K. W. T. Goulding,³ P. M. Vitousek,⁴ F. S. Zhang^{1†}

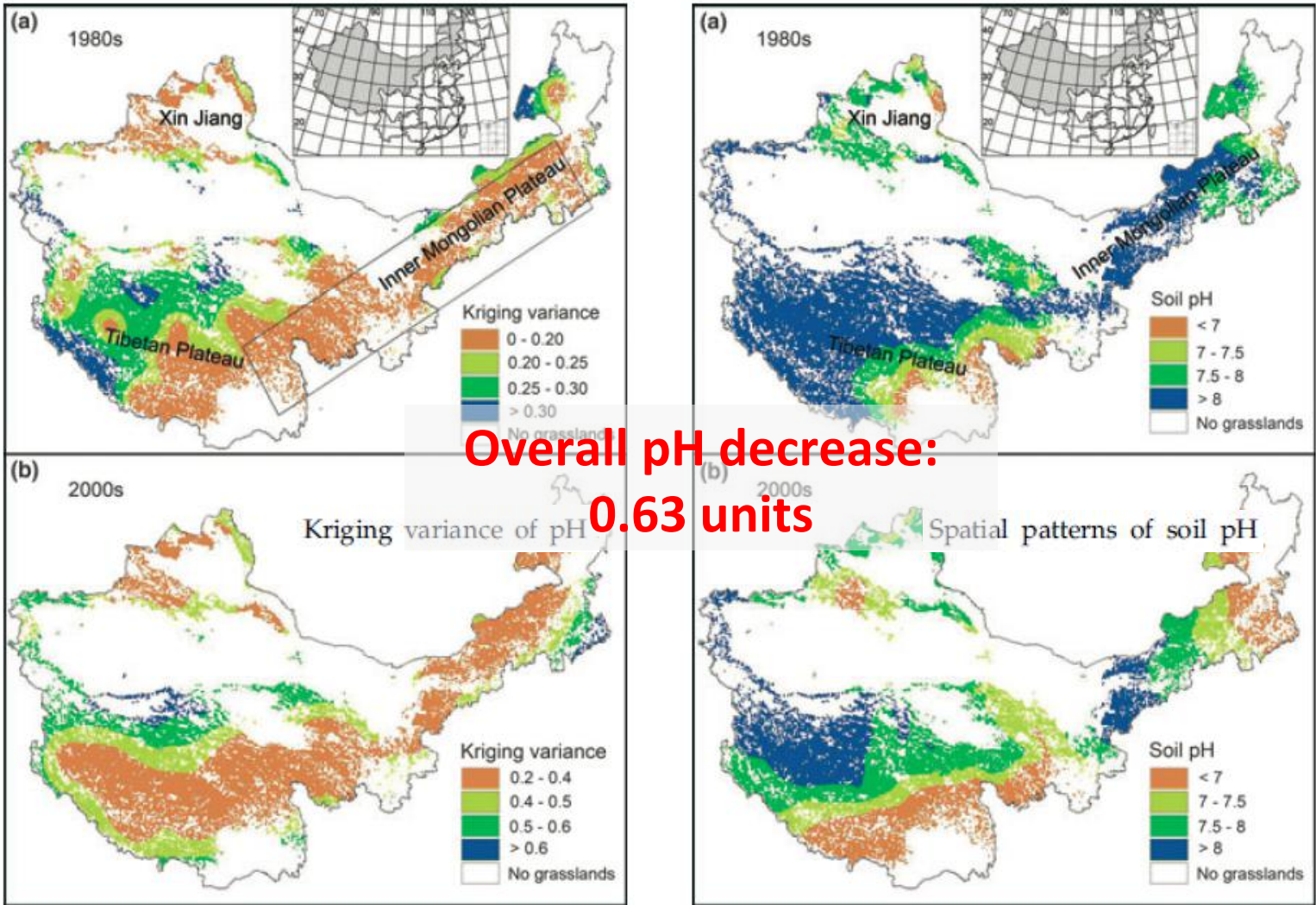
Soil acidification is a major problem in soils of intensive Chinese agricultural systems. We used two nationwide surveys, paired comparisons in numerous individual sites, and several long-term monitoring-field data sets to evaluate changes in soil acidity. Soil pH declined significantly ($P < 0.001$) from the 1980s to the 2000s in the major Chinese crop-production areas. Processes related to nitrogen cycling released 20 to 221 kilomoles of hydrogen ion (H^+) per hectare per year, and base cations uptake contributed a further 15 to 20 kilomoles of H^+ per hectare per year to soil acidification in four widespread cropping systems. In comparison, acid deposition (0.4 to 2.0 kilomoles of H^+ per hectare per year) made a small contribution to the acidification of agricultural soils across China.



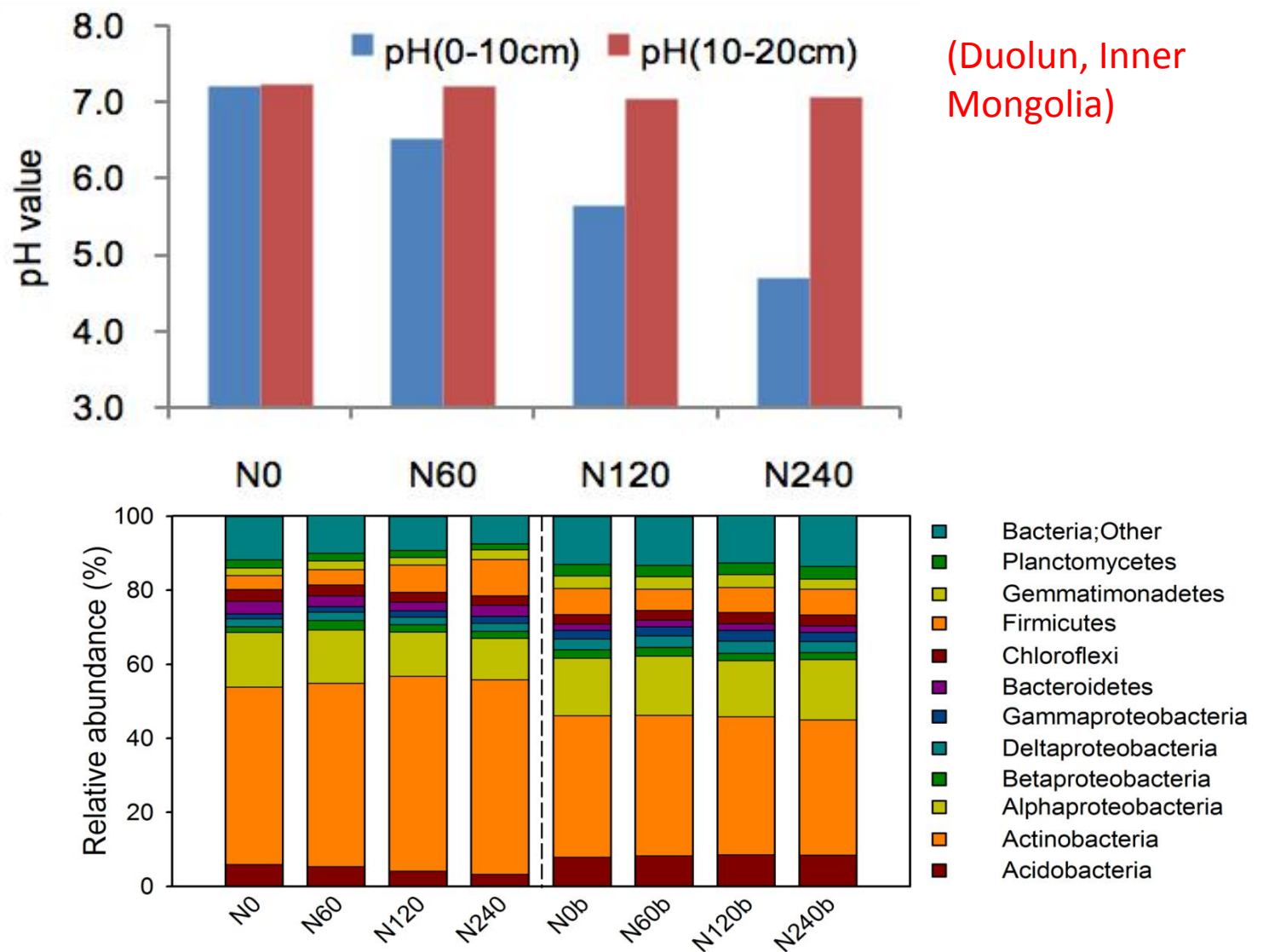
ANNOUNCING
nature

Significant soil acidification across northern China's grasslands during 1980s–2000s

YUANHE YANG*†‡, CHENGJUN JI*, WENHONG MA§, SHIFENG WANG‡, SHAOPENG WANG*, WENXUAN HAN¶, ANWAR MOHAMMAT||, DAVID ROBINSON‡ and PETE SMITH‡



Continuous N addition led to significant soil acidification and substantial changes in microorganism communities



(Zeng et al., 2016. SBB)

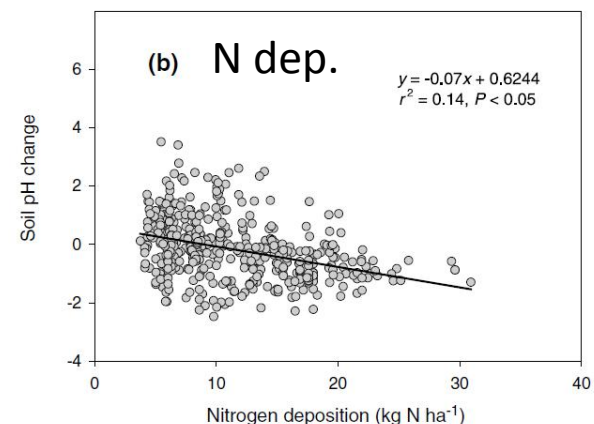
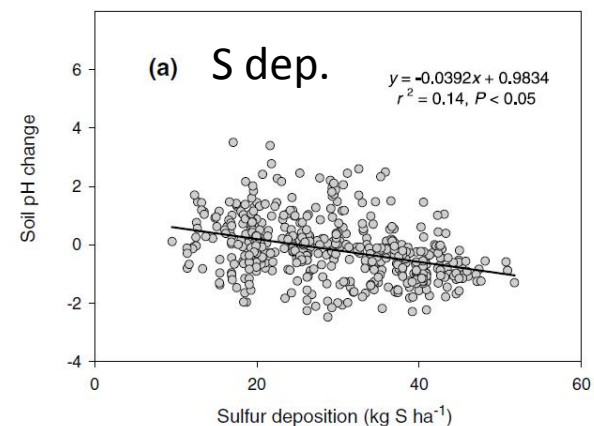
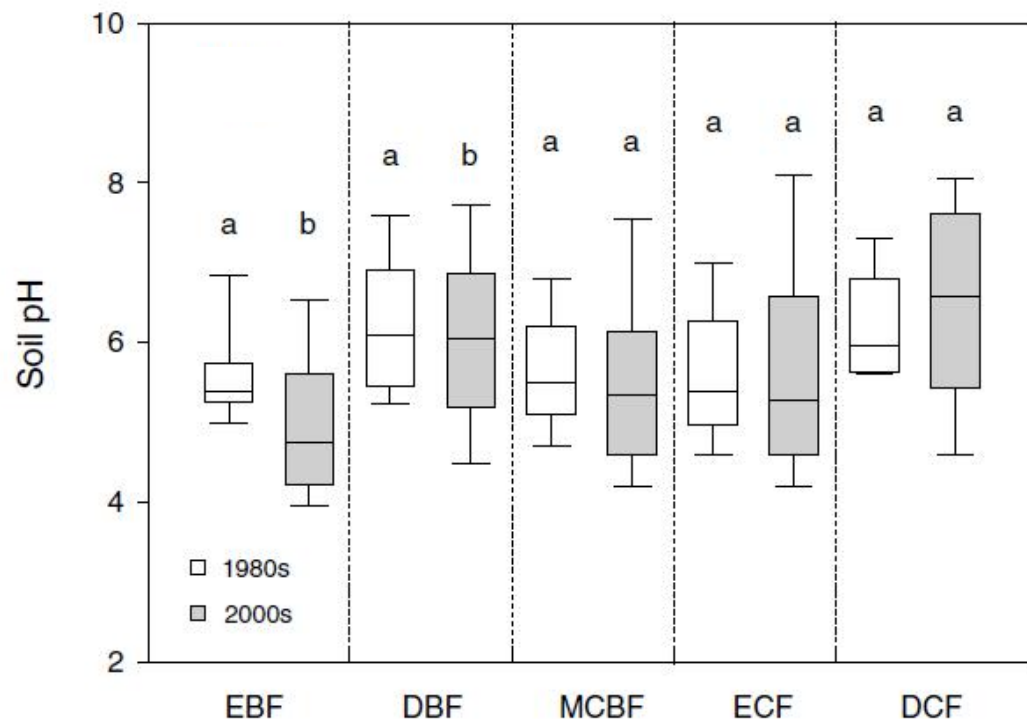
RESEARCH LETTER

10.1002/2014GL062575

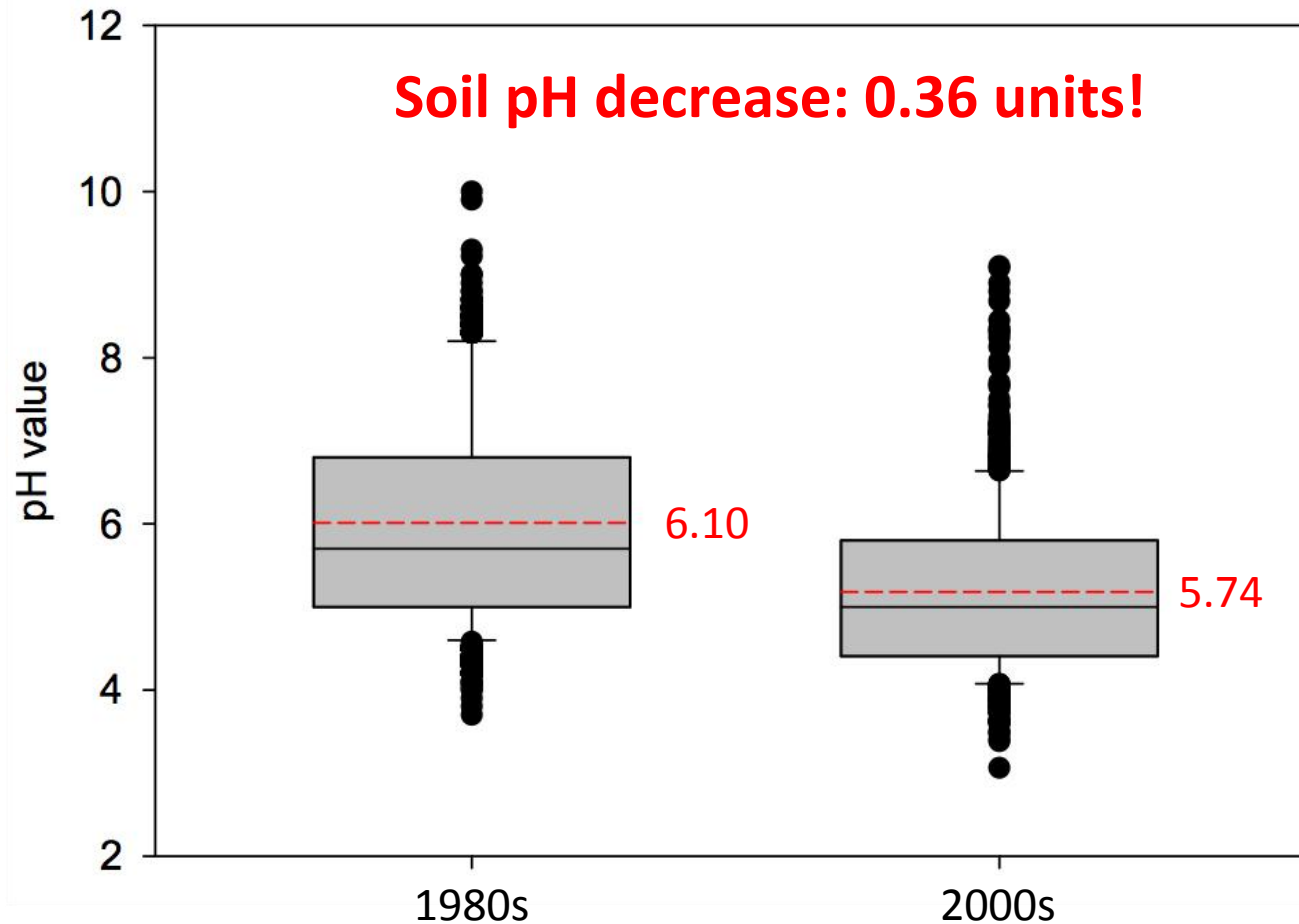
Key Points:

- Long-term changes of topsoil pH in forest ecosystems were explored

Long-term changes in soil pH across major forest ecosystems in China

Yuanhe Yang¹, Pin Li², Honglin He³, Xia Zhao¹, Arindam Datta⁴, Wenhong Ma⁵, Ying Zhang⁶, Xuejun Liu⁷, Wenxuan Han⁷, Maxwell C. Wilson⁸, and Jingyun Fang^{1,2}


Forest soil acidification in China



Atmospheric
deposition
contributes to
84% of H^+
production

Number of data: 1679

3919

(Zhu et al., 2016. AE)

3. Eutrophication



中华人民共和国中央人民政府

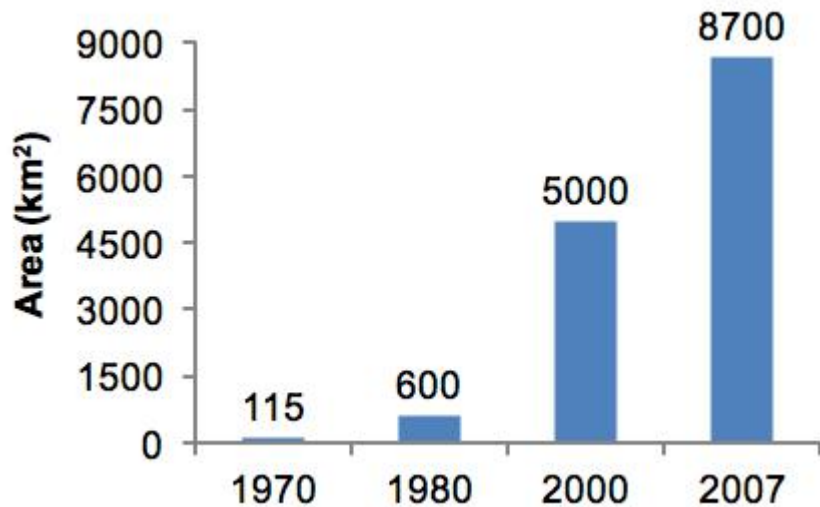
The Central People's Government of the People's Republic of China



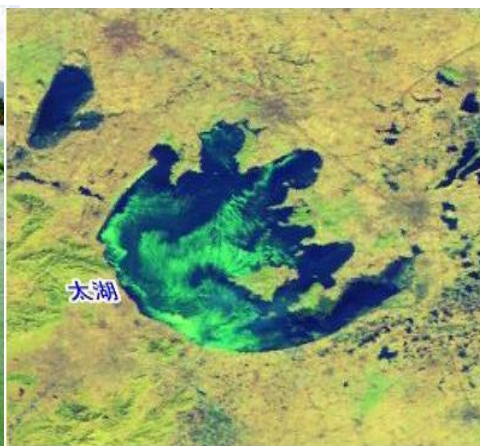
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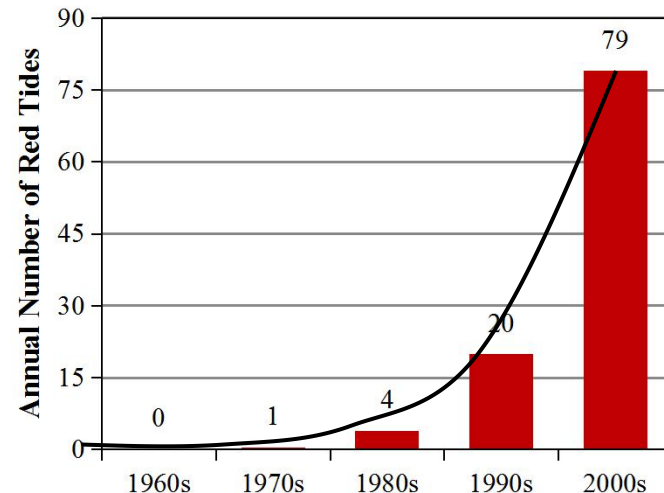
China's eutrophied lake area has increased from 135 (1970) to 8700 km² (2007).



(Jin, 2009)



太湖蓝藻监测图像 2007年11月21日11时02分(北京时间)



(the State Oceanic Administration, 2009)

(Science 2009, 1014-1015)

POLICYFORUM

ECOLOGY

Controlling Eutrophication: Nitrogen and Phosphorus

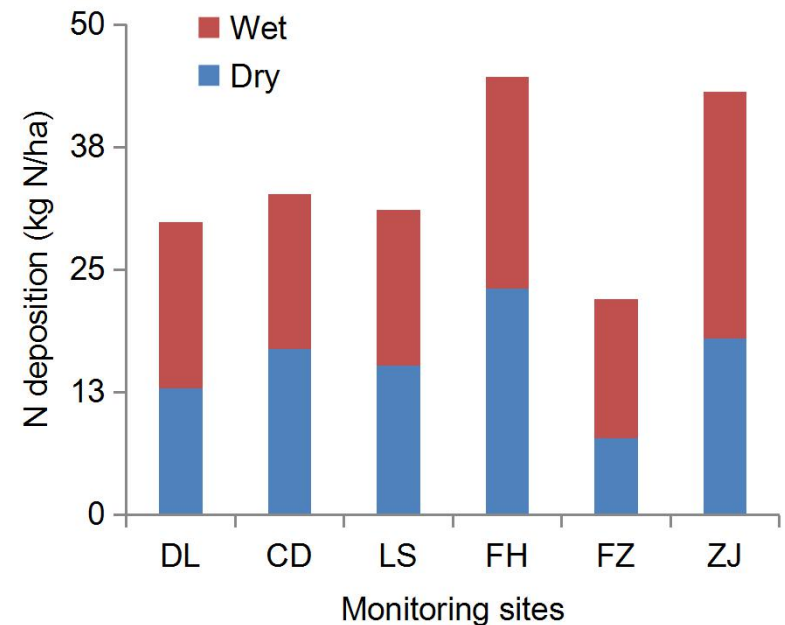
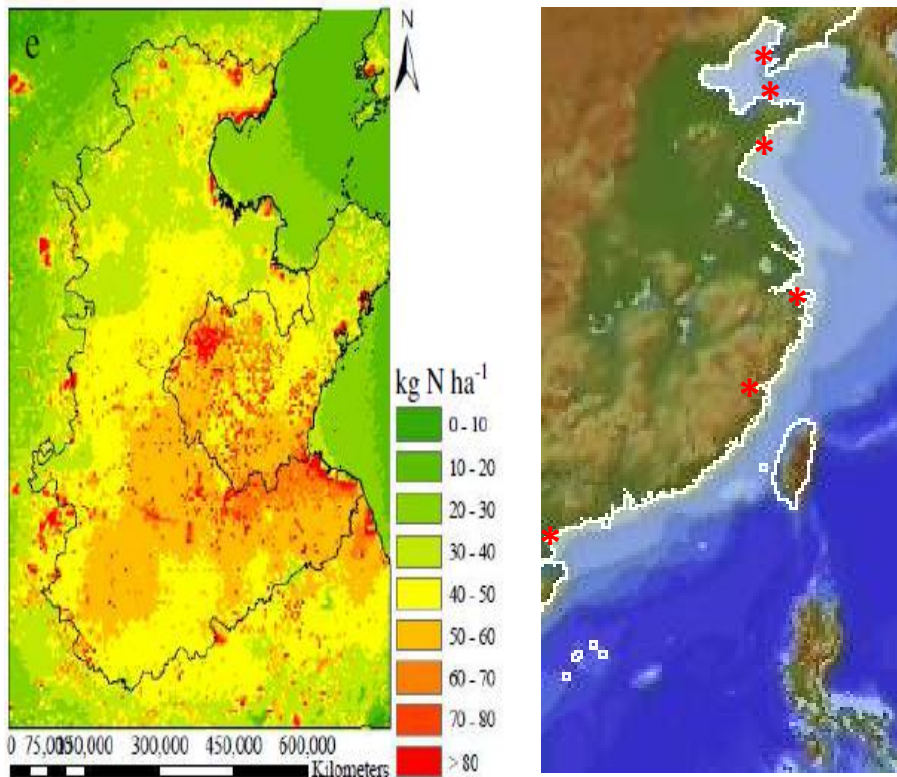
Daniel J. Conley,^{1*} Hans W. Paerl,² Robert W. Howarth,³ Donald F. Boesch,⁴ Sybil P. Seitzinger,⁵ Karl E. Havens,⁶ Christiane Lancelot,⁷ Gene E. Likens⁸



N deposition to coastal seas of China

Total N deposition to Bohai Sea:
22 kg N ha⁻¹ yr⁻¹

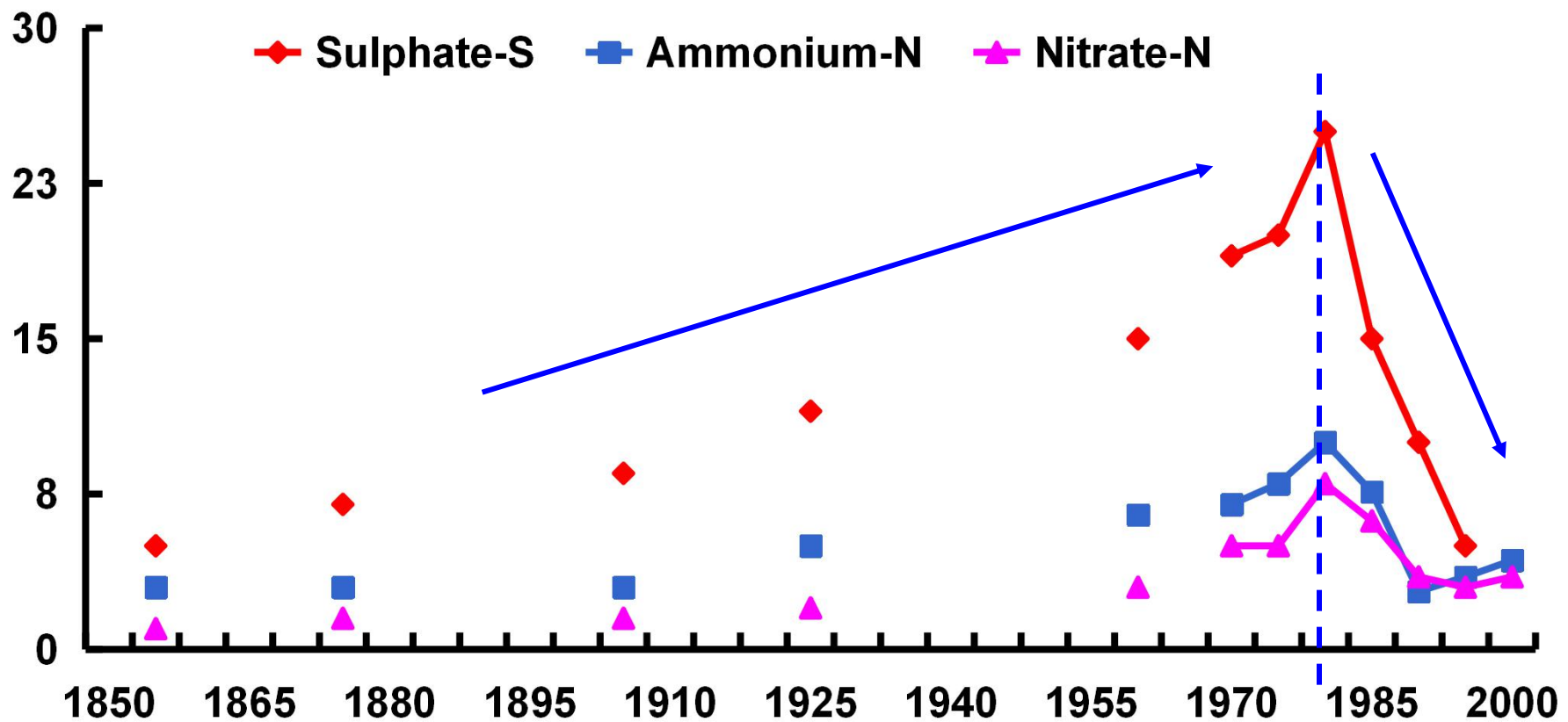
Annual N deposition in coastal
zone: 34 kg N ha⁻¹



Assuming half of coastal N deposition rate (~17 kg N/ha) into Bohai, Yellow, East China and South China Seas (3×10^6 km²), total N deposition input can amount to 5.1 Tg N per year to the 4 marine ecosystems surrounding China.

4. Air pollution control effects

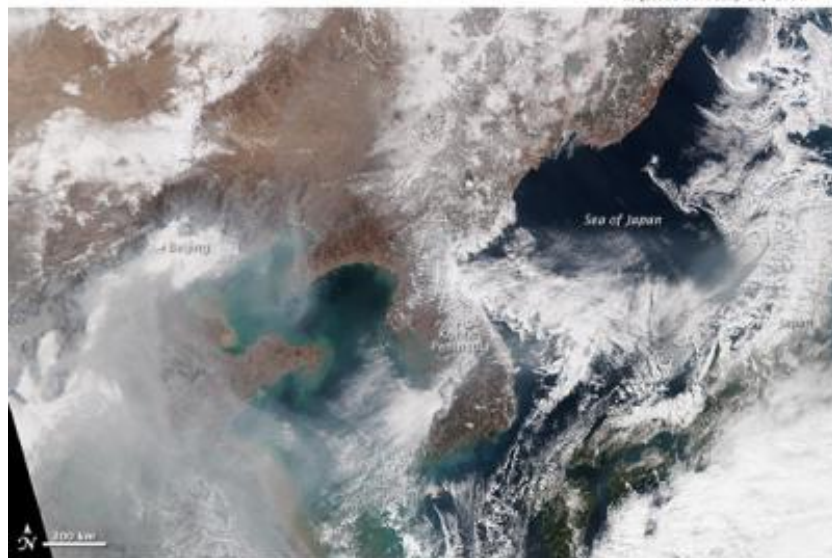
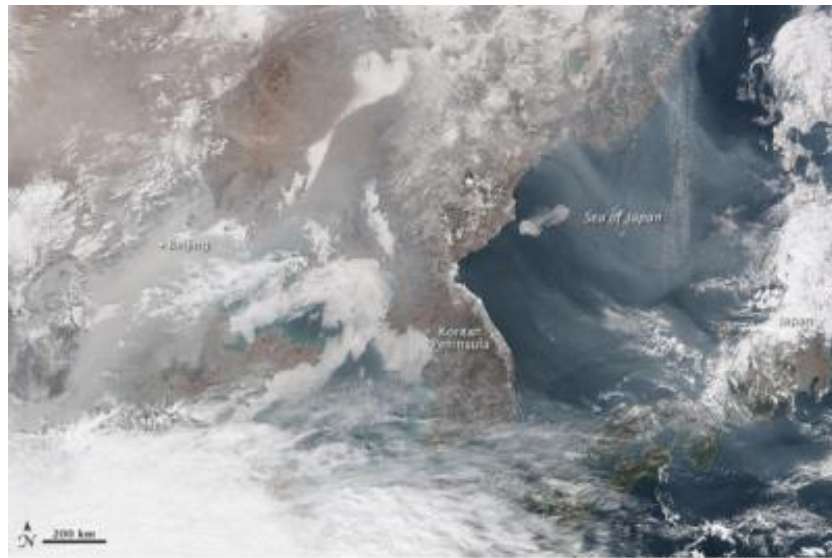
Wet deposition at Rothamsted UK, 1853-2000



由于硫沉降的大幅下降，目前英国多数农田小麦需要施用硫肥来保持产量。

(From Goulding et al., 2005)

Beijing Smog



CAU west campus, Feb. 26th, 2014

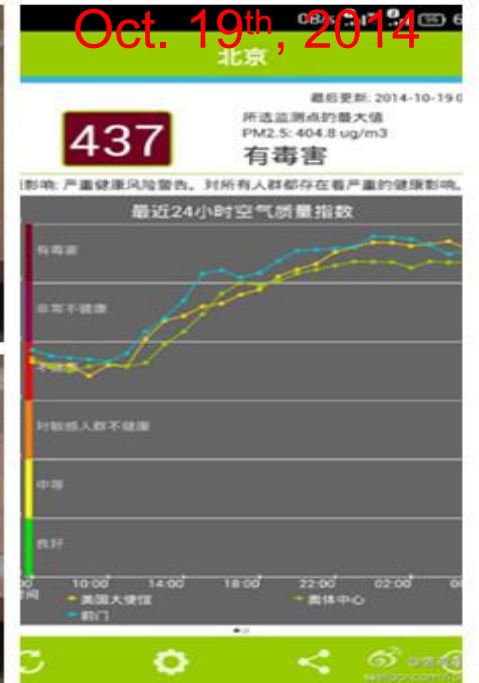
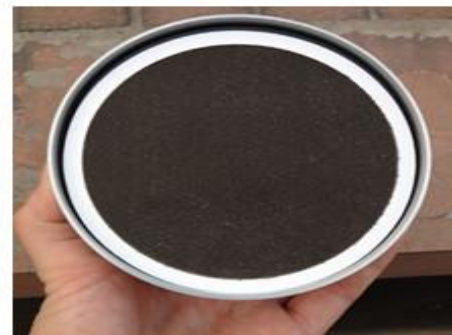
PM2.5

406 $\mu\text{g}/\text{m}^3$



PM10

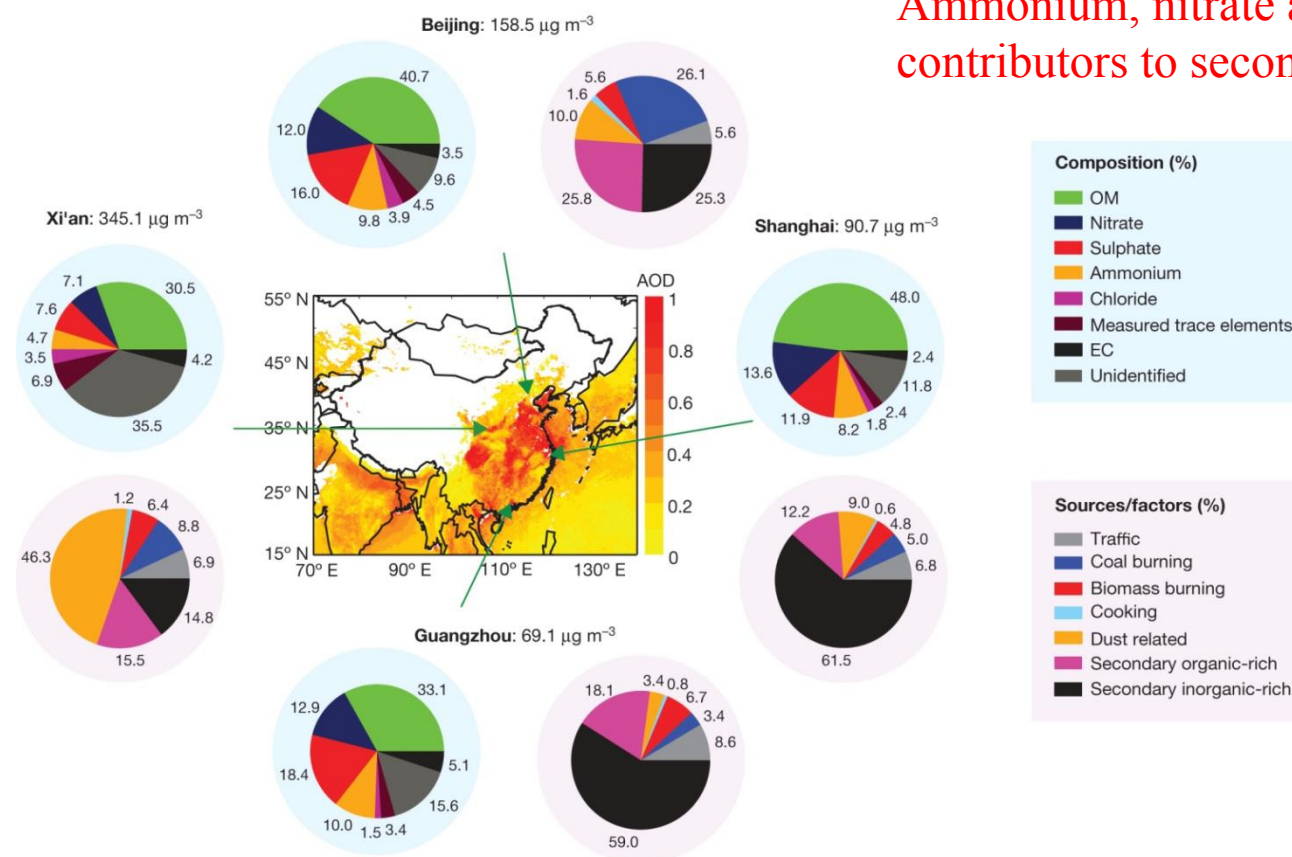
770 $\mu\text{g}/\text{m}^3$



High secondary aerosol contribution to particulate pollution during haze events in China

Ru-Jin Huang^{1,2*}, Yanlin Zhang^{3,4}, Carlo Bozzetti¹, Kin-Fai Ho⁵, Jun-Ji Cao², Yongming Han², Kaspar R. Daellenbach¹, Jay G. Slowik¹, Stephen M. Platt¹, Francesco Canonaco¹, Peter Zotter¹, Robert Wolf¹, Simone M. Pieber¹, Emily A. Brunns¹, Monica Crippa^{1†}, Giancarlo Ciarelli¹, Andrea Piazzalunga⁶, Margit Schwikowski^{3,4}, Gülcin Abbaszade⁷, Jürgen Schnelle-Kreis⁷, Ralf Zimmermann^{7,8}, Zhisheng An², Sönke Szidat³, Urs Baltensperger¹, Imad El Haddad^{1*} & André S. H. Prévôt¹

Ammonium, nitrate and sulphate are major contributors to secondary aerosols!



N_r contribution to $\text{PM}_{2.5}$:

Beijing/SH/GZ: 22-23%

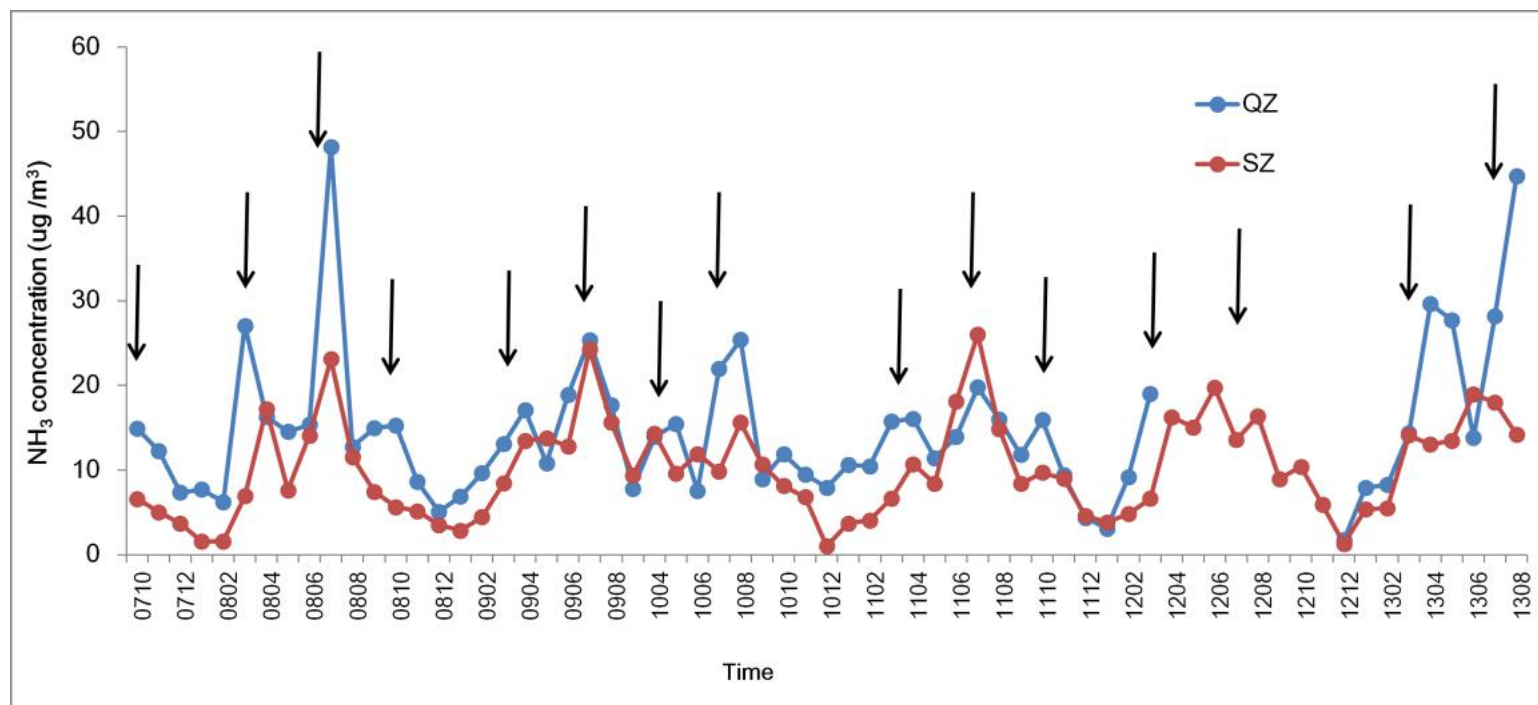
Xi'an: 12%

N_r +sulphate contribution:

Beijing/SH/GZ: 34-41%

Xi'an: 19.4%

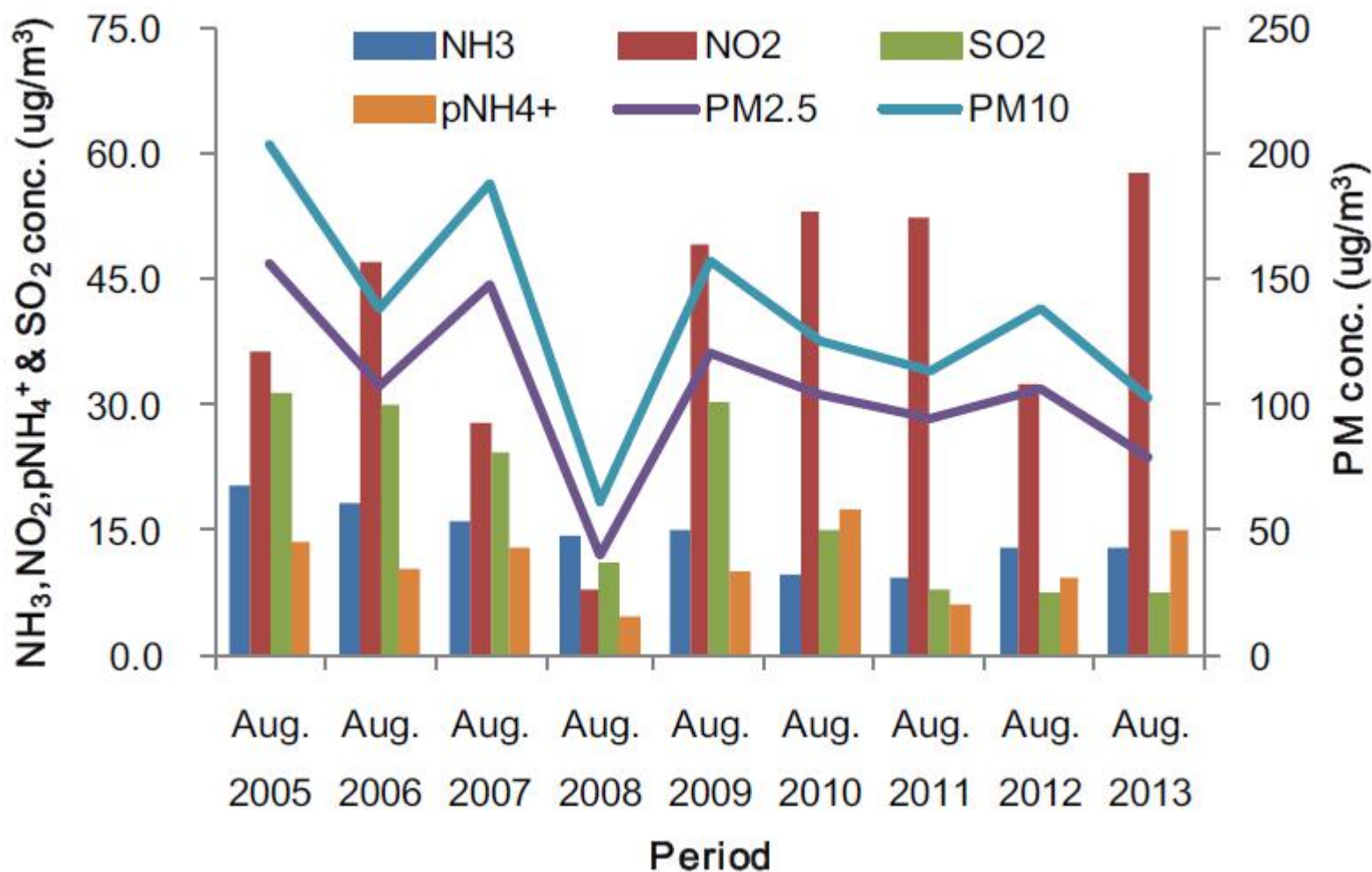
华北农田区域大气氨浓度动态及其与氮肥使用关系 (2007.10-2013.08)



QZ: 河北曲周 (典型农田) ; SZ: 北京上庄 (郊区 , 局部农田)

(刘学军, 2014. 国家基金结题报告)

北京2005-2013年8月大气中NH₃, NO₂, SO₂, 颗粒态铵离子及PM_{2.5}和PM₁₀浓度动态变化 (注: 2008年8月为北京奥运期间)



(刘学军, 2014. 国家基金结题报告)

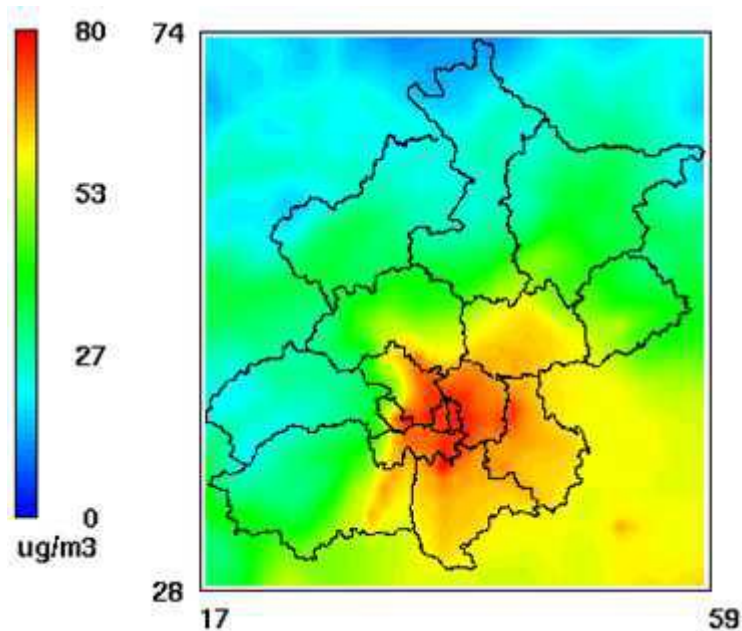
APEC blue effects

Combined air pollutant reducing actions in north China:

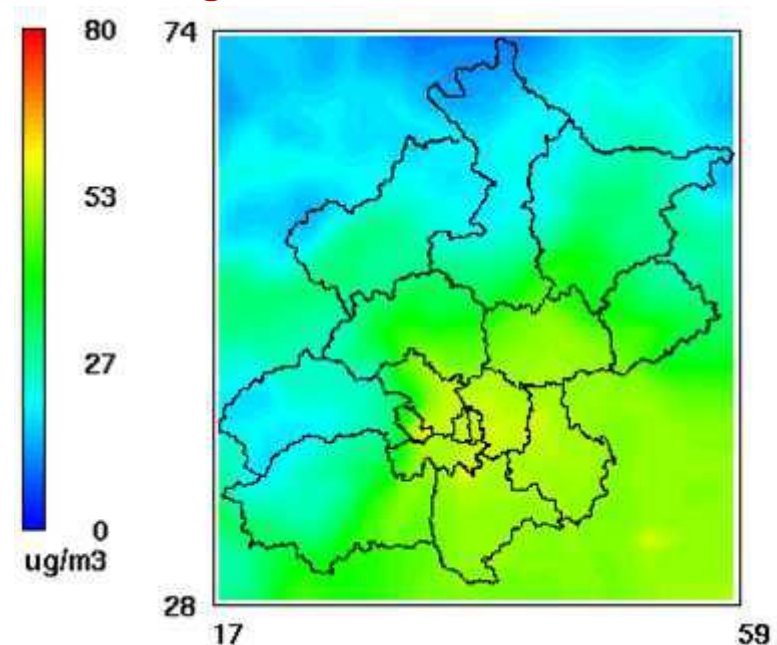
1. Restricted vehicle Nos. on road
2. Strict dust control
3. Close of heavy polluted factories ...



Before APEC summit



During APEC summit



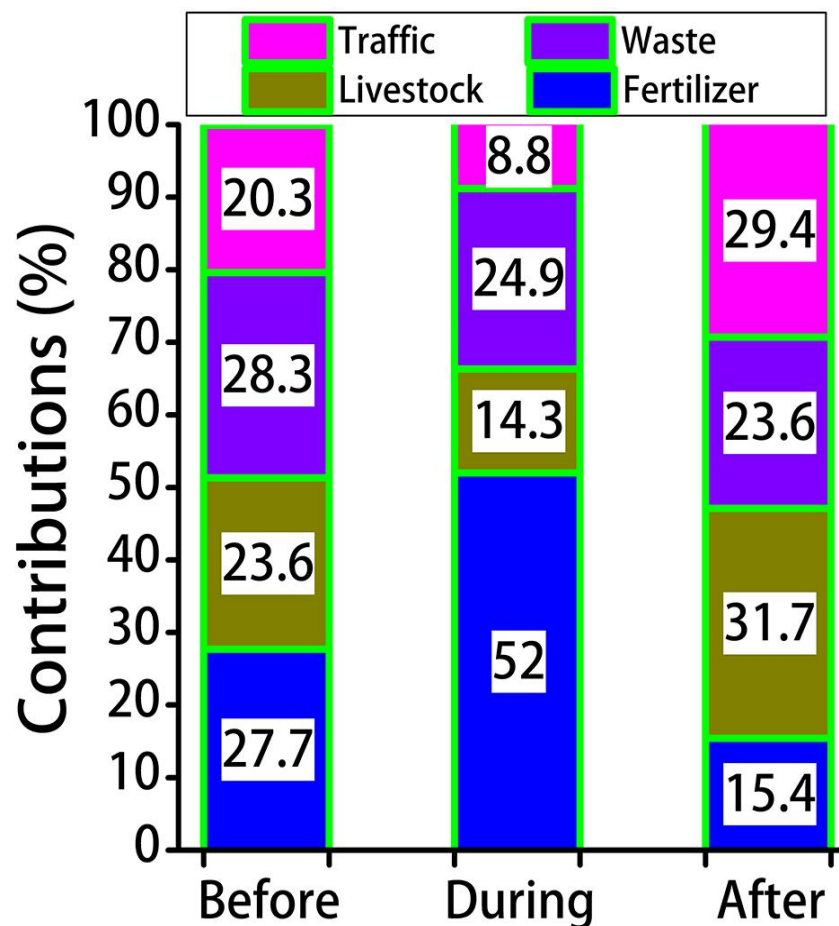
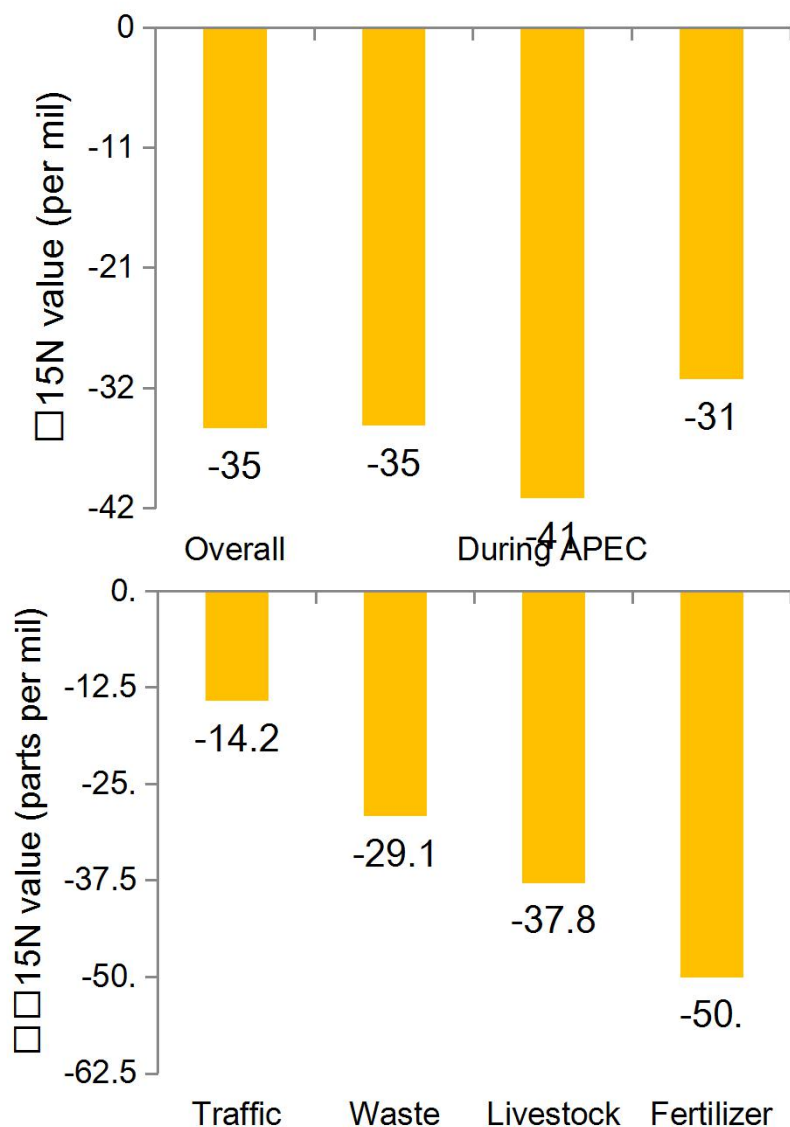
(Hao Jimin, 2014)

Change of PM_{2.5} levels and parts of components in PM_{2.5} at CAU, Beijing

Unpublished work

**Sustainable pollution control measures are key to improved
air quality and lower N and S deposition!**

Source apportionment of atmospheric NH_3 before, during, and after the 2014 APEC summit in Beijing



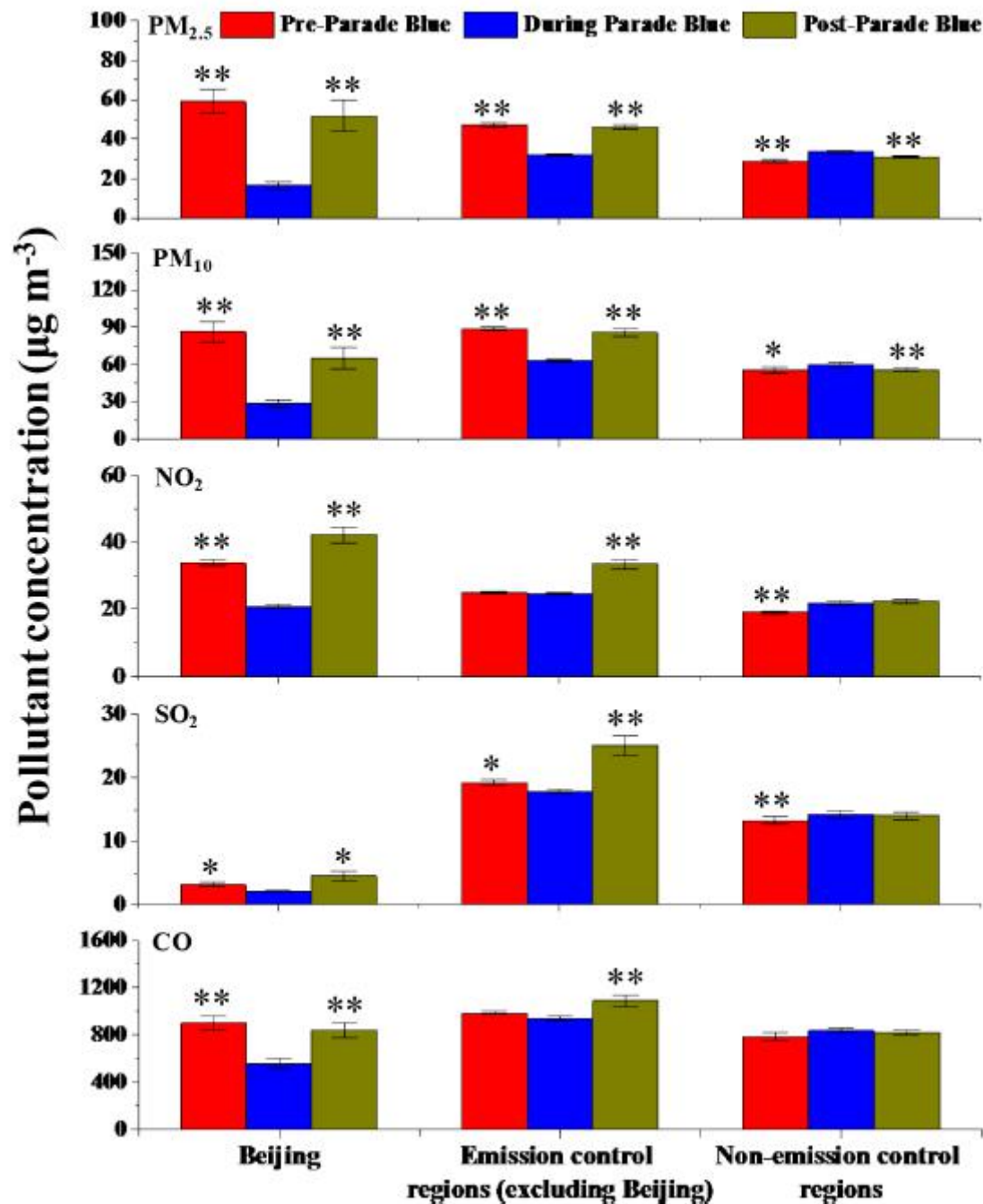
(Chang et al., 2016. ACP 16: 11635-47)

Air quality greatly improved in Beijing and surrounding areas during the Parade blue period (21 Aug.-3 Sep. 2015)

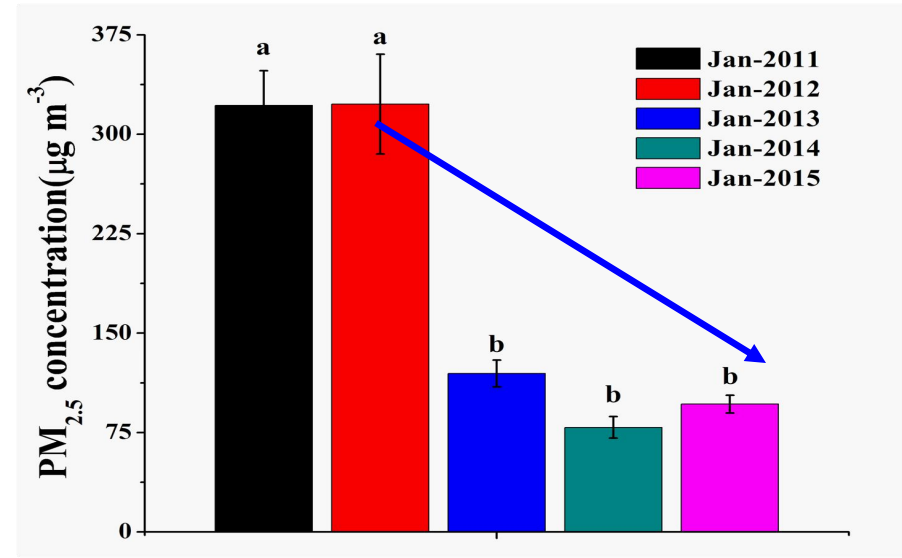
北京阅兵蓝



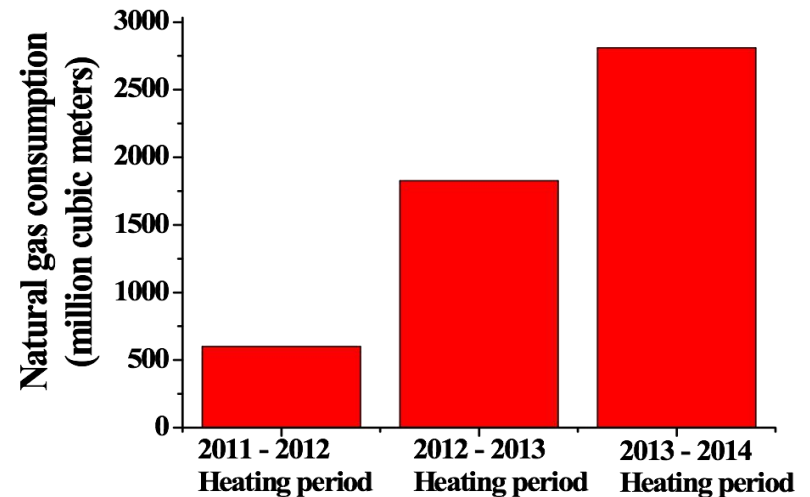
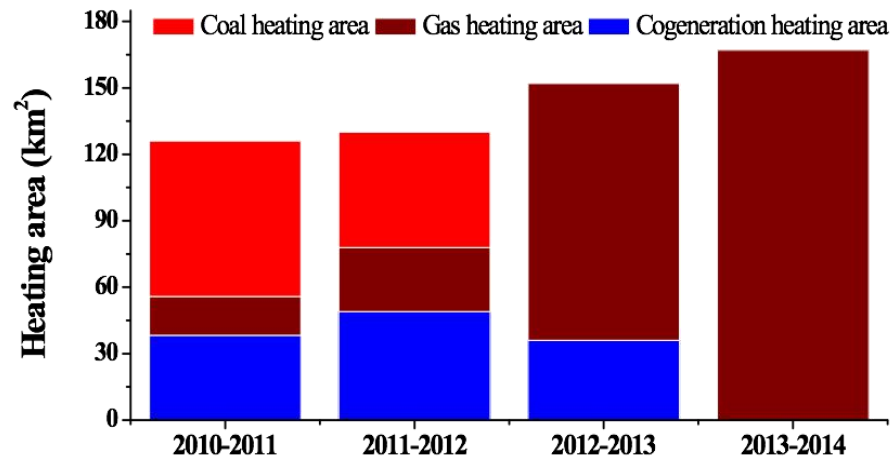
(Xu et al., 2017. ACP, 17: 31-46)



A successful example at Urumqi: Shift of coal to natural gas for heating



N dry deposition decreased from 26 kg N ha⁻¹ (2012) to 16 kg N ha⁻¹ (2015).



(Song et al., 2015. EST 49: 2066-2072)

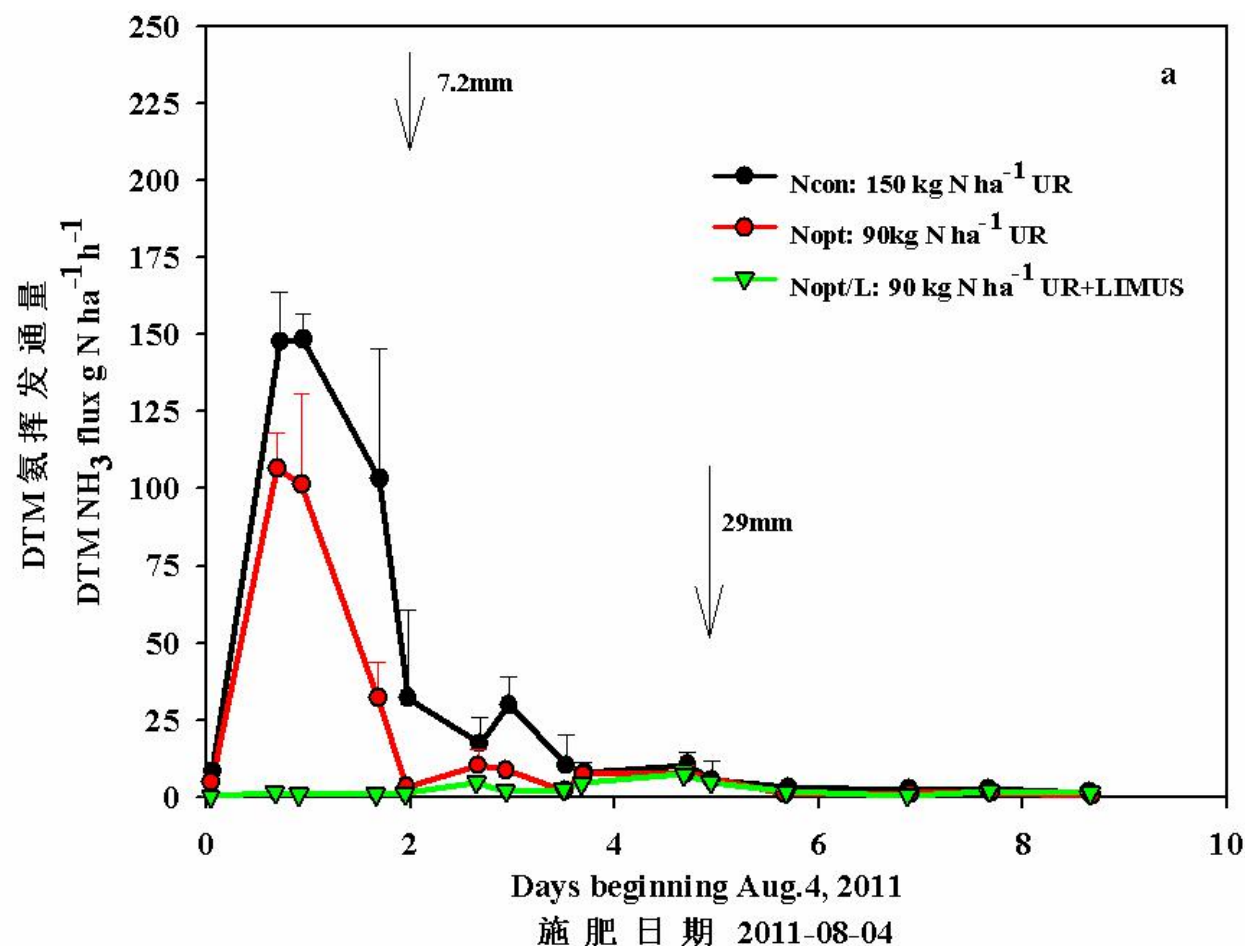
Potential to reduce NH₃ loss in croplands: Effects of urease inhibitor Limus in maize (Quzhou, Hebei, 2012-2013)

Treatment	QZ 2012			QZ 2013		
	Grain yield (t DM /ha)	NH ₃ loss (kg N/ha)	RE _N (%)	Grain yield (t DM /ha)	NH ₃ loss (kg N/ha)	RE _N (%)
N0	4.5a	--	--	7.5a	n.d.	--
Ncon	10.1b	55 c	40a	9.9b	108 d	31a
Nopt	9.0b	42 b	53ab	10.0b	85 c	50ab
Nopt/L-2	9.6b	4 a	70cd	10.1b	30 b	61b
N_{80%}opt/L-2	10.0b	4 a	76d	9.8b	31 b	58b
N_{80%}opt/L-1	9.5b	5 a	60bc	9.8b	17 a	49ab

尿素NH₃挥发占总施氮量20-57%，添加LIMUS可减少65-90%氨挥发损失。

(Li et al., 2015. FCR; Li et al., 2017. Sci. Rep.)

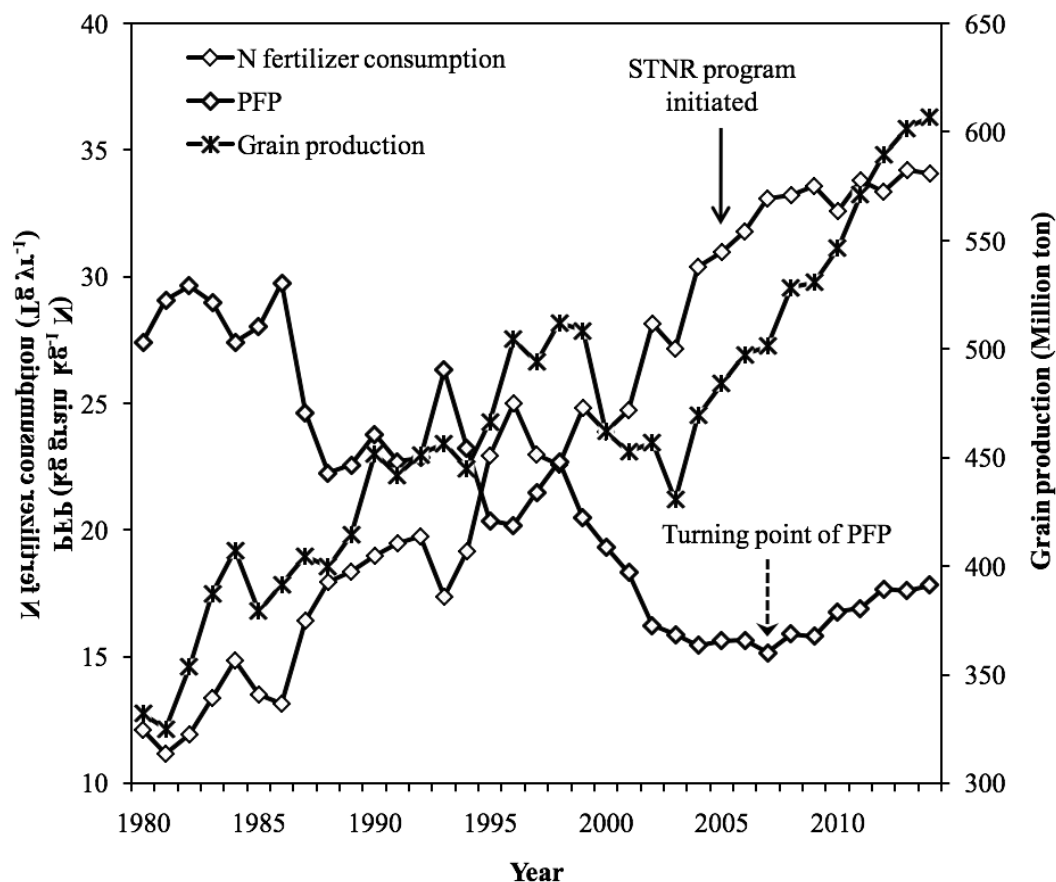
脲酶抑制剂Limus可以通过抑制尿素水解显著降低 农田NH₃挥发损失！



(Li et al., 2015. FCR)

Evidence for a Historic Change Occurring in China

Xuejun Liu,^{*,†} Peter Vitousek,[‡] Yunhua Chang,[§] Weifeng Zhang,[†] Pamela Matson,^{||} and Fusuo Zhang[†]



中国养分利用, 粮食安全与环境保护已处于一个历史性转折点!

(Liu et al., 2016. EST)

结论与展望

1. 我国大气氮沉降自上世纪80年代以来显著增加，尤其以华北平原等中东部地区增长显著，已成为我国农田和自然生态系统环境养分的重要来源；
2. 有证据表明氮沉降等环境养分增加已对土壤酸化、农业面源污染和大气污染等环境问题产生重要影响；
3. 将来需要进一步加强氮沉降等环境养分对陆地和水生生态系统等影响的综合研究。

致 谢

科研项目: 国家自然科学基金、国家973项目、中科院百人计划、教育部新世纪人才项目、中德合作项目等的支持

合作伙伴: Fangmeier, Vitousek, Goulding, Fowler, Collett, Erisman及许多国内同行

研究生: 张颖, 何春娥, 沈健林, 宋玲, 李凯辉, 骆晓声, 许稳, 常运华, 李欠欠, 温章, 鲁丽, 朱齐超, 张洋洋等

Thank you for your attention!
Questions / Comments?

