Session 3: Soils and Geologic Networks

Soil Acidification in China: Will PM control undermine the efforts?

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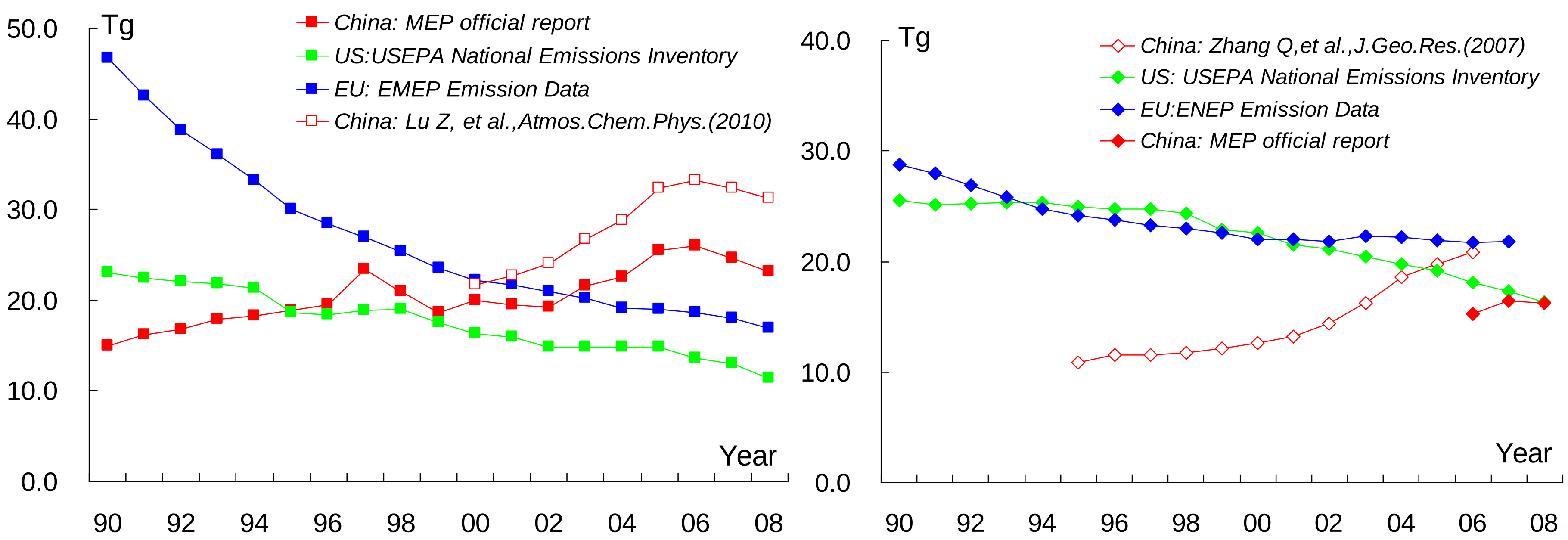
Chinese soil acidification and emission trends

- Acidification in China is generally attributed to intensive coal combustion and high emissions of acid precursors.
- Parts of southern and southwestern China have the highest observed acidity of precipitation in the world, with continuously worsening conditions in recent years.

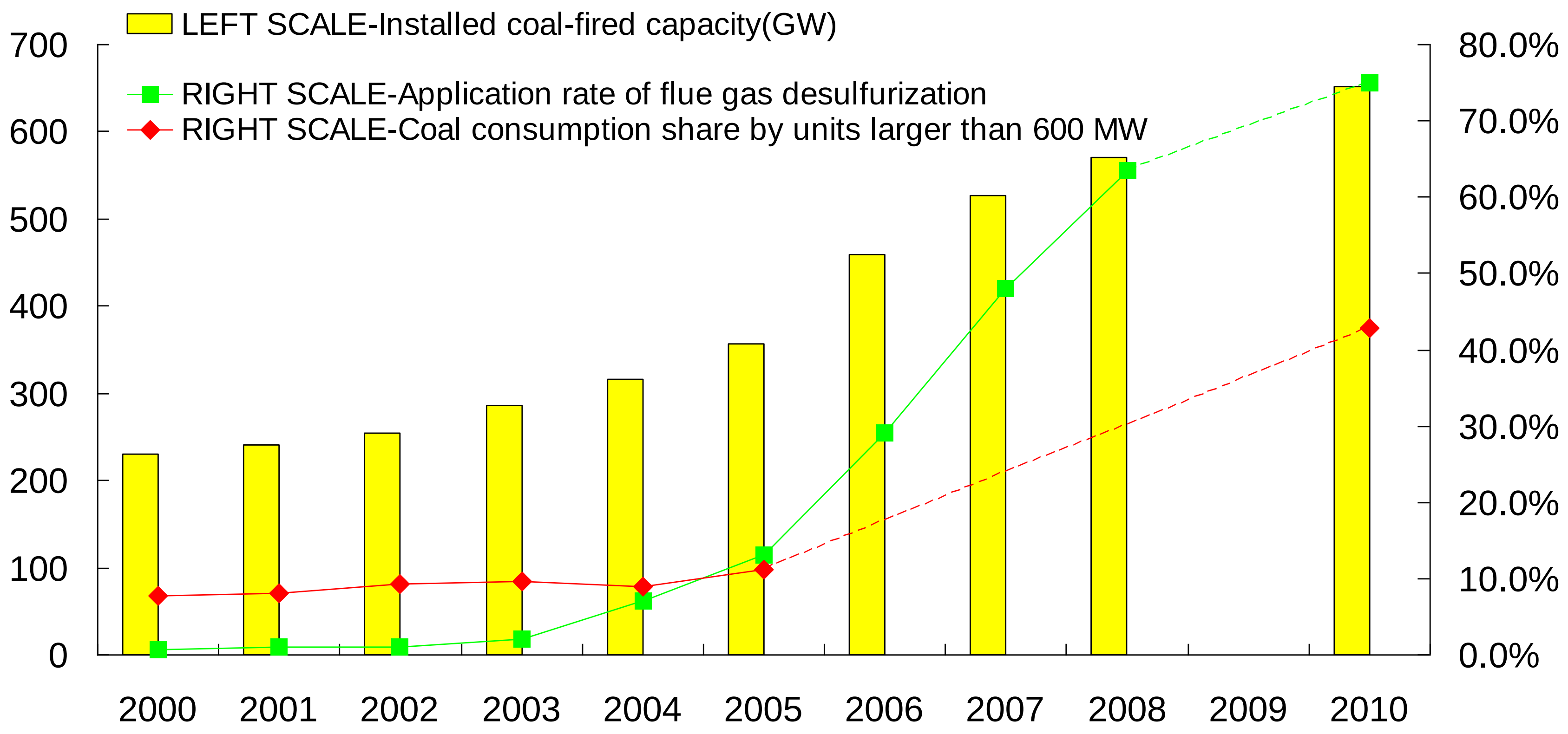


Historical trends of SO_2 (left) and NOx (right) emissions

Chinese emission control policies

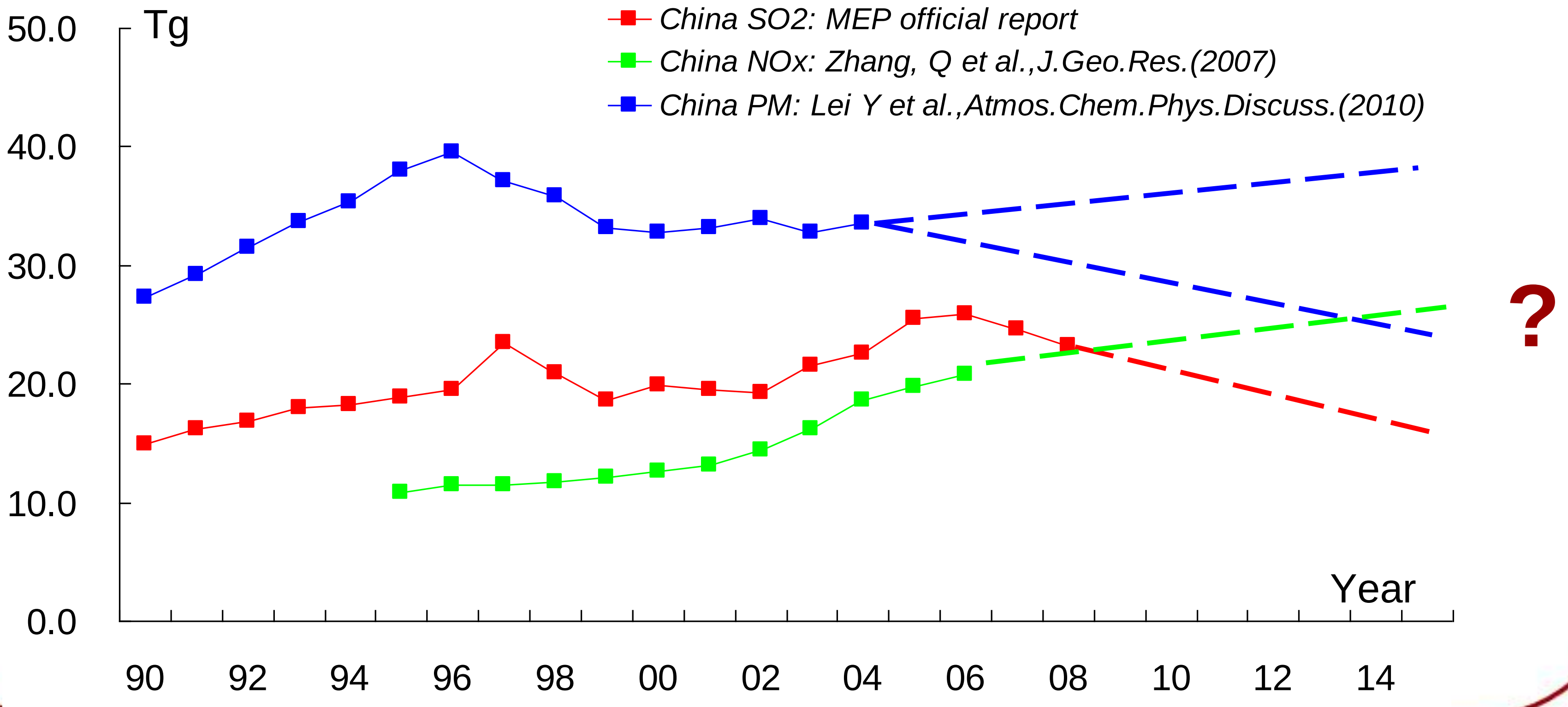
National policy: energy saving and emission reduction

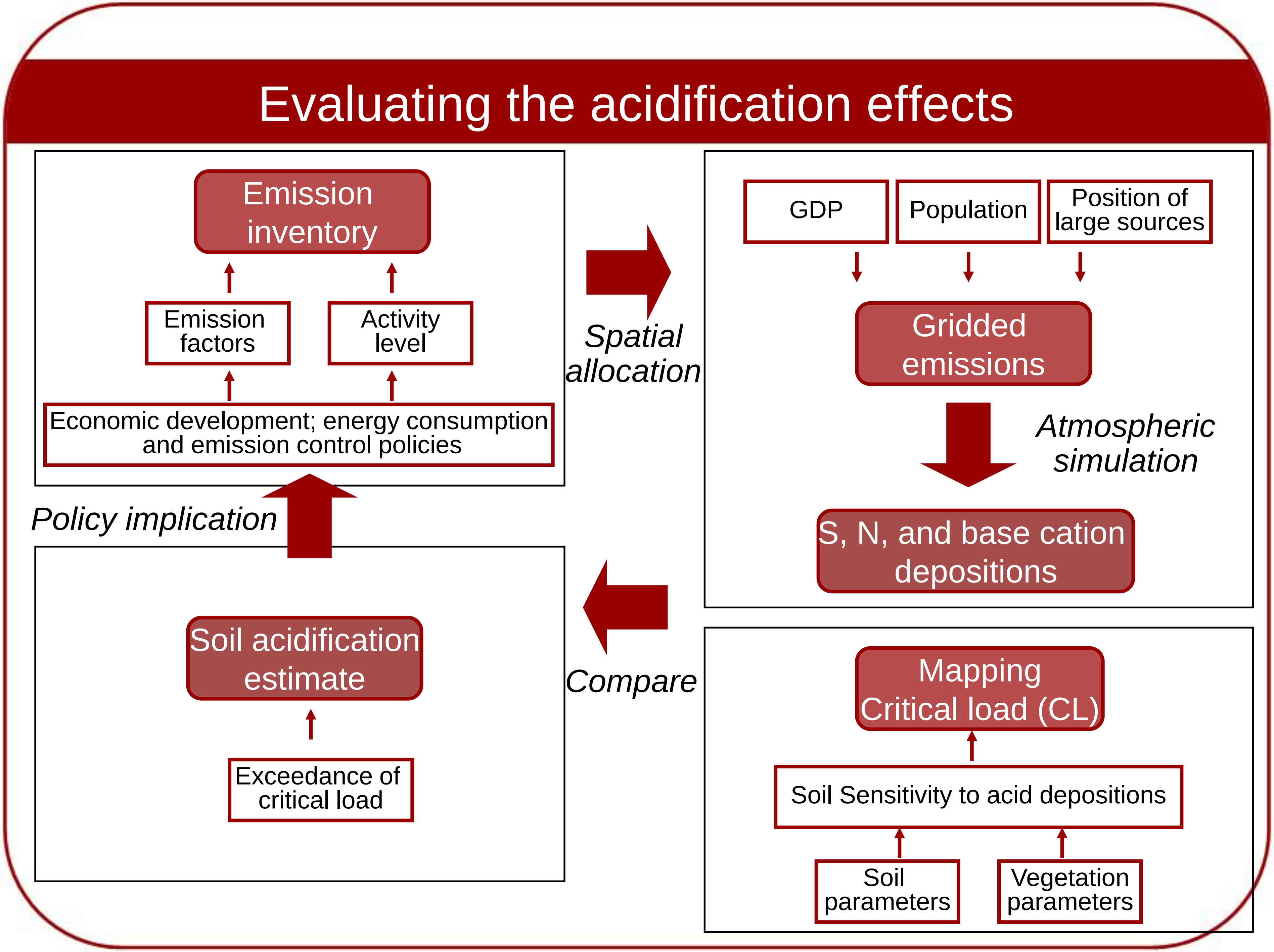
- Shutting down small/inefficient units: 70GW during 2005-2010
- FGD (flue gas desulfurization) application after 2005; SCR (selective catalyst reduction) application after 2010;
- Application of stringent emission regulations for on-road vehicles and cement production



Base cation: against acidification

- Base cations (BC: Ca^{2+}, Mg^{2+}, K^{+}, Na^{+})
  - Sources: PM emissions of industrial process e.g., cement and lime production
  - Future trends: controlled due to huge effects on human health
- Multi-pollutant control strategy
  - Research on acidification effect of S, N and PM control simultaneously





Evaluating the acidification effects
Emission inventory
Emission factors
Activity level
Economic development; energy consumption and emission control policies
Spatial allocation
GDP
Population
Position of large sources
Gridded emissions
Atmospheric simulation
S, N, and base cation depositions
Policy implication
Compare
Soil acidification estimate
Exceedance of critical load
Mapping Critical load (CL)
Soil Sensitivity to acid depositions
Soil parameters
Vegetation parameters

Methodology of emission inventory

POINT sources

- **Power plants**: Pulverized; Grate; CFB; Oil and gas plants
- **Cement**: Precalciner; Shaft; Other rotary kilns
- **Iron and steel**: Coke; Sintering; Pig iron; Steel making; casting

AREA sources

- **Industrial boilers**: Grate; CFB; Oil and gas plants
- **Other processes**: Lime; Smelting; Chemical engineering; etc
- **Residential**: Fossil burning; Biomass burning
- **Agriculture (NH_3)**: Livestock; Fertilizer use

MOBILE sources

- **Transportation**: On road vehicles; Non-road sources

Bottom up

$$E_{i,T} = \sum_j E_{i,j} \qquad i\text{, species}$$

$$E_{i,j} = \sum_k E_{i,j,k} \qquad j\text{, regions}$$

$$E_{i,j.k} = \sum_m E_{i,j,k,m} \qquad k\text{, sectors}$$

$$E_{i,j,k,m} = \sum_n AL_{j,k,m,n} \times EF_{i,j,k,m} \times R_{i,j,k,m,n} \times (1-\eta_{i,n})$$

Emission | Activity level | Emission factor | Penetration rate | Removal efficiency

m, fuel types; *n*, emission control types

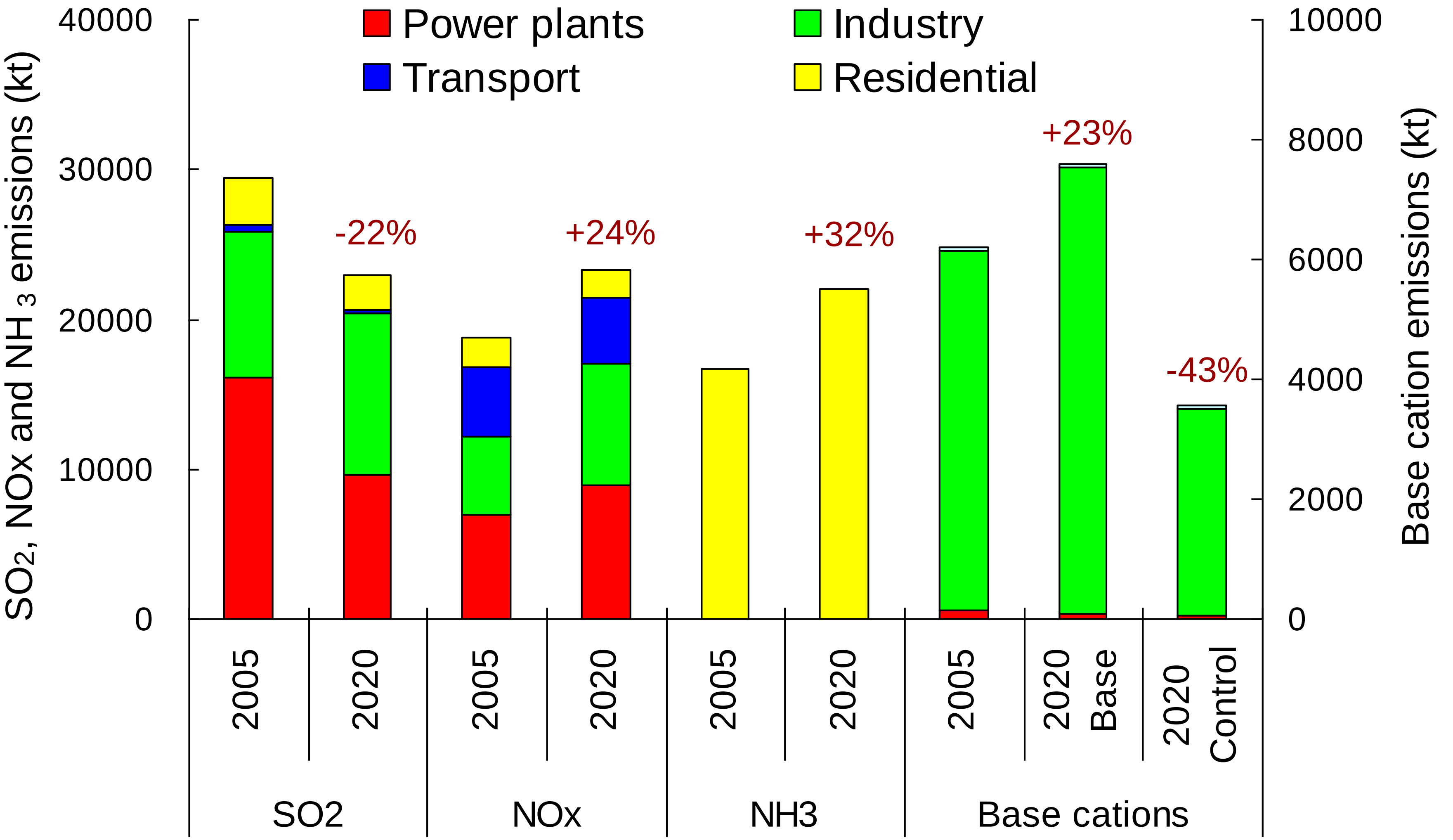
Projections in 2020:

- SO_2/NO_X: Current and upcoming policies
- NH_3: No specific control;
- PM (and there by base cation):
  Two scenarios: BASE and CONTROL

Changes of EF and AL for 2005-2020

	Emission factor				Activity level
	SO_2	NO_X	PM-base	PM-control	
Power plant	-72%	-39%	-72%	-75%	+110%
Cement	-50%	+14%	0%	-82%	+60%
Iron & steel	-80%	0%	0%	-20%	+117%
Other Industry	-15%	0%	0%	-20%	+40% Including: -37% for brick making; -10% for lime production
On-road transport	-80%	-60%	-85%	-85%	+161%
Non-road transport	-80%	-30%	-56%	-56%	+27%
Residential (biofuel)	0%	0%	0%	0%	-20%
Residential (coal)	-15%	0%	0%	-20%	-5%
Biomass open burning	0%	0%	0%	0%	-20%

Emission estimate



Atmospheric simulation

Modelling:

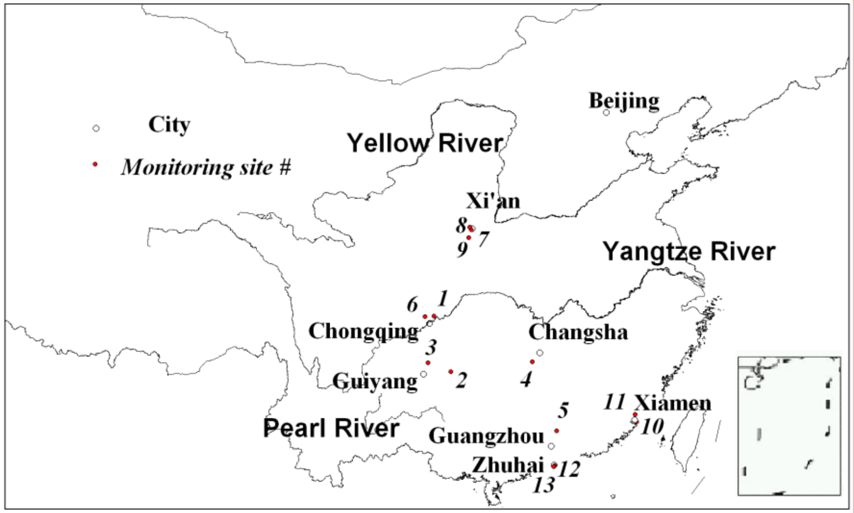
Community Multiscale Air Quality (***CMAQ***) (V4.4)

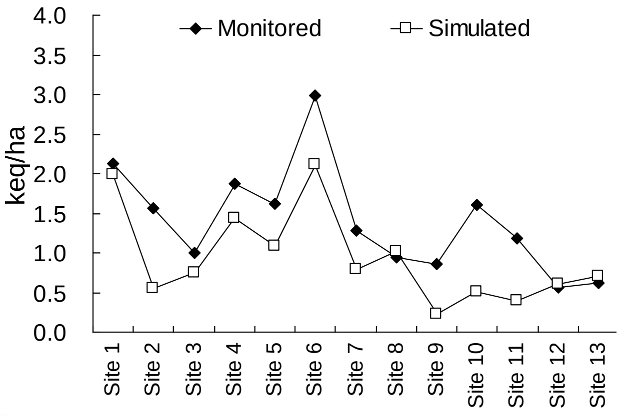
Multi-layer Eulerian model – base cations

Monitored data:

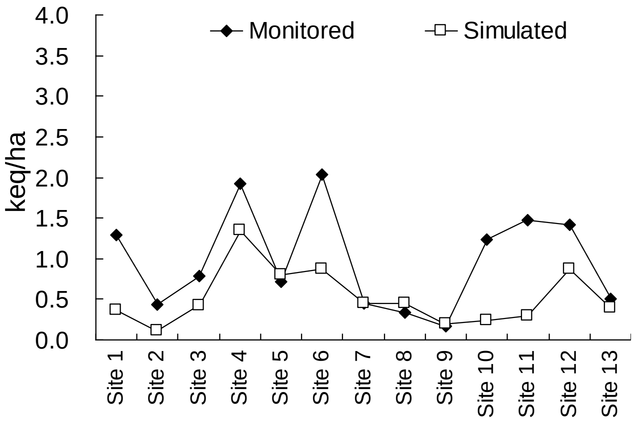
***IMPACTS**: Larssen T, et al., Environ. Sci. Technol. (2006)*

***EANET**:* http://www.eanet.cc/product/datarep/

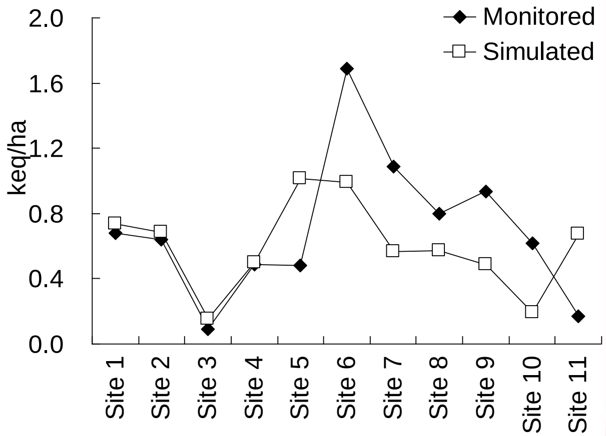




Wet S depositions

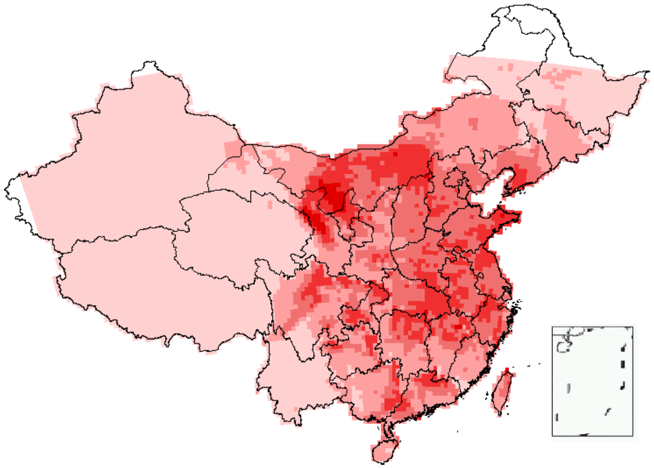


Wet N depositions

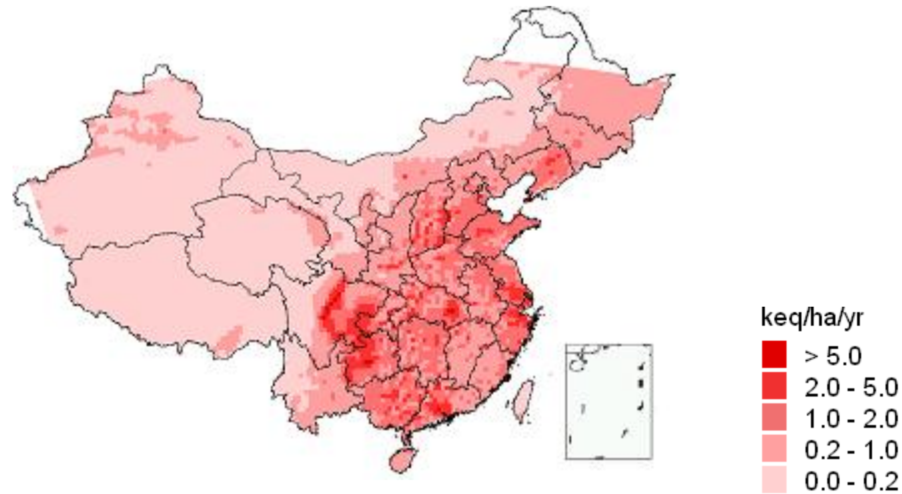


Wet BC depositions

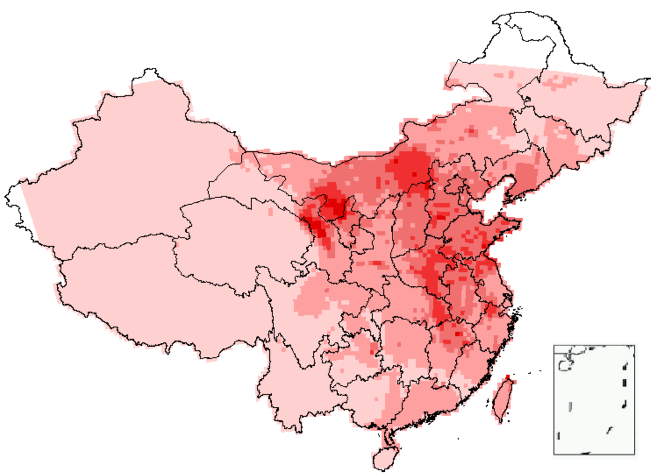
Simulated depositions of S and N



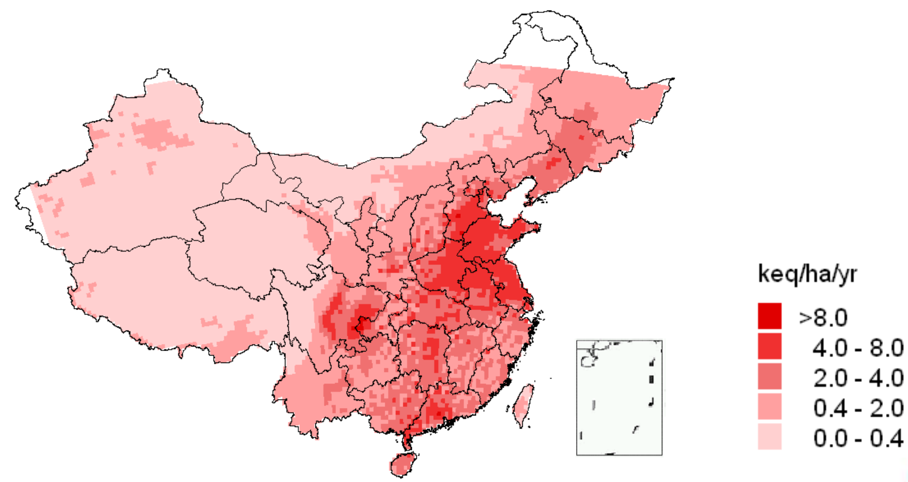
2005 S



2020 S

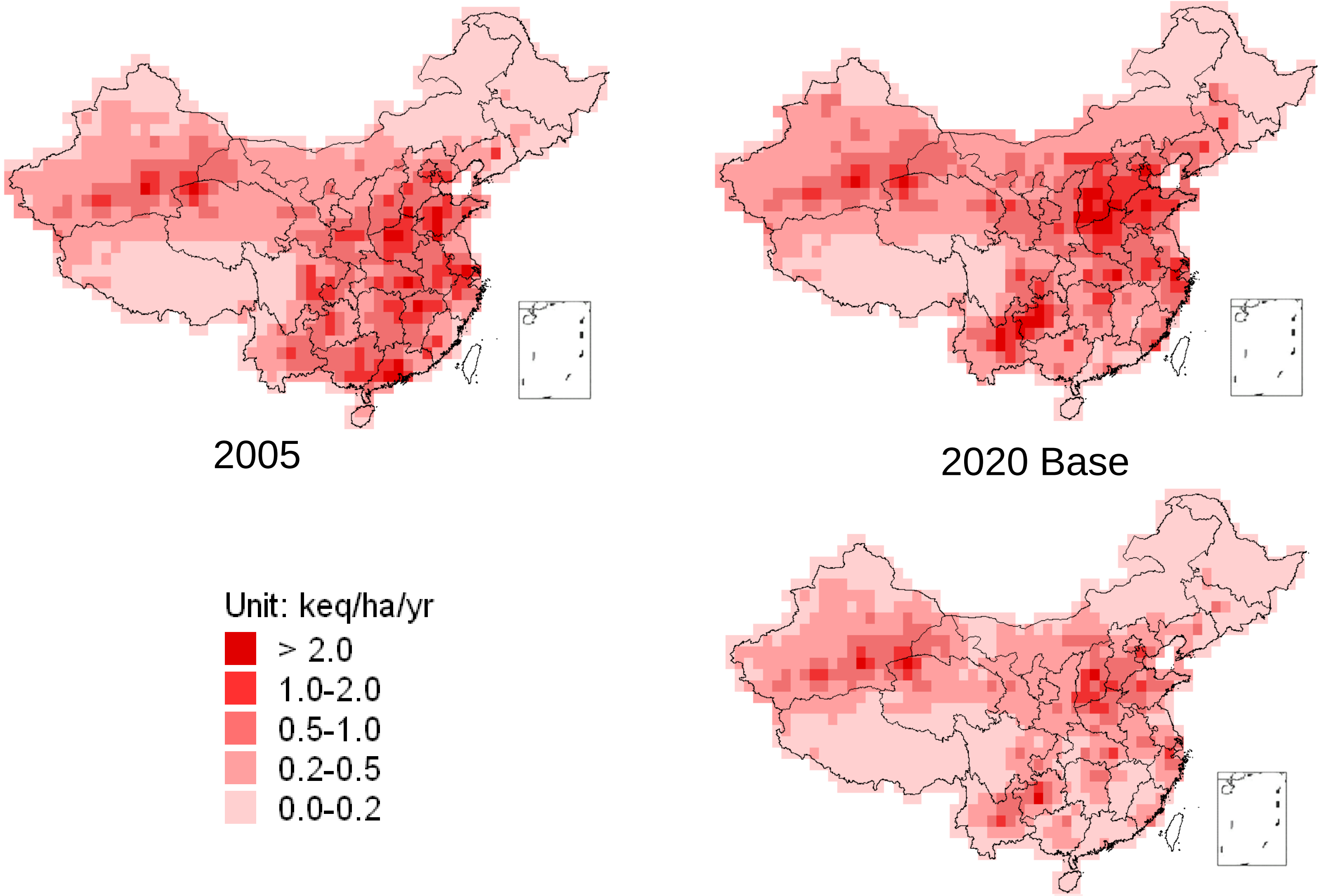


2005 N



2020 N

Simulated depositions of base cations



The extended critical load function

- The deposition of pollutants below which harmful ecological effects do not occur.
- Steady-Status Mass Balance (SSMB)

$$CL_{\max}(S) = BC_D + BC_W - BC_U - ANC_{L,crit}$$

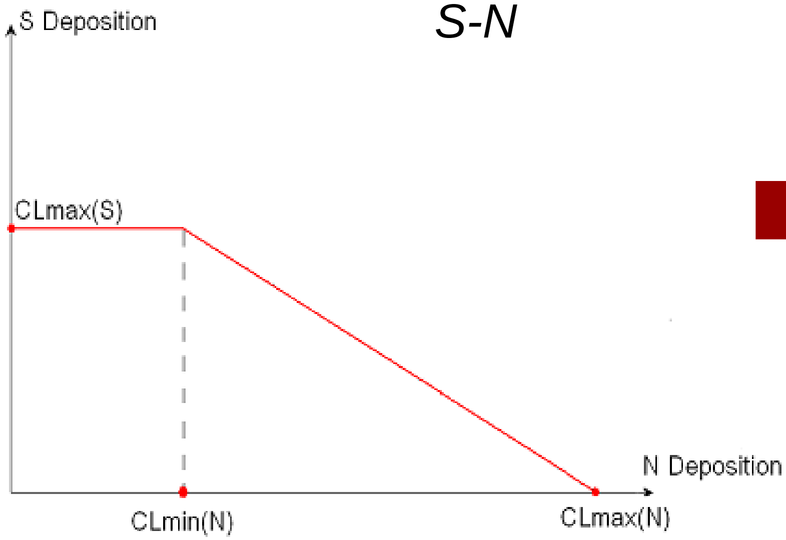
$$CL_{\min}(N) = N_I + N_U;\ CL_{\max}(N) = N_I + N_U + \frac{CL_{\max}(S)}{1 - f_{DE}}$$

$$CL(S)_{\text{limit}} = BC_W - BC_U - ANC_{L,crit}$$

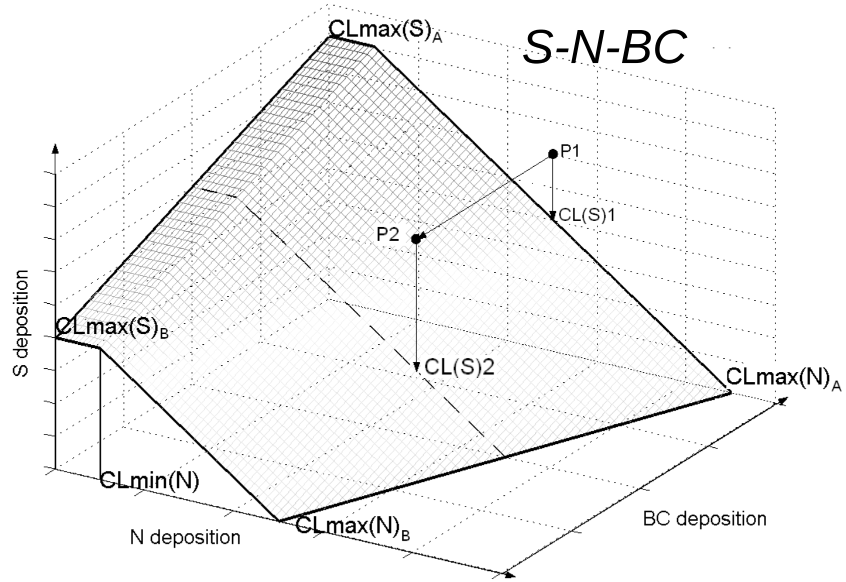
$$S_D \le CL(S) = \begin{cases} BC_D + CL(S)_{\text{limit}} & (N_D \le CL_{\min}(N)) \\ BC_D + CL(S)_{\text{limit}} - (1 - f_{DE}) \times (N_D - CL_{\min}(N)) & (N_D > CL_{\min}(N)) \end{cases}$$

BCD: base cation deposition
BCW: weathering rate of BC
BCU: vegetation uptake of BC
ANCL,crit: critical leaching of alkalinity
NI: N immobilization rate
NU: vegetation uptake of N
fde: denitrification rate

S-N

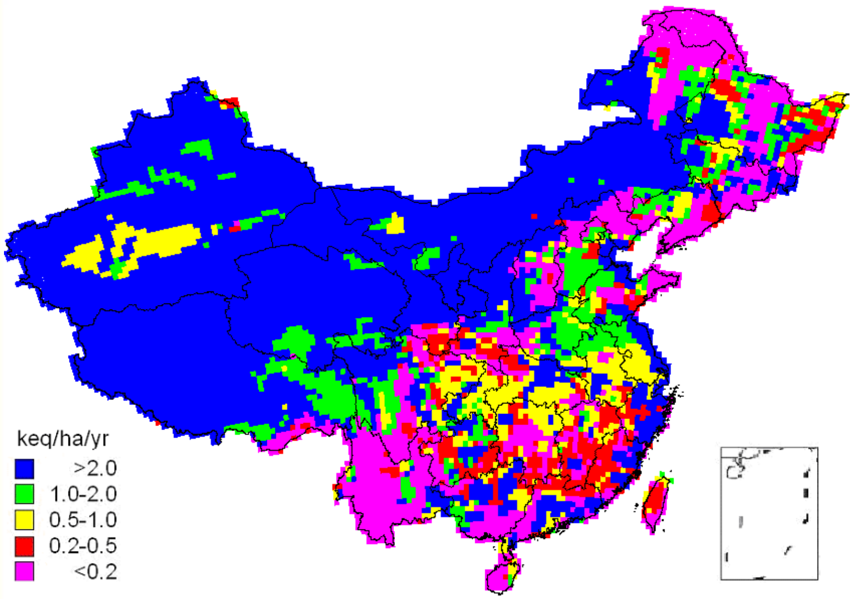


S-N-BC

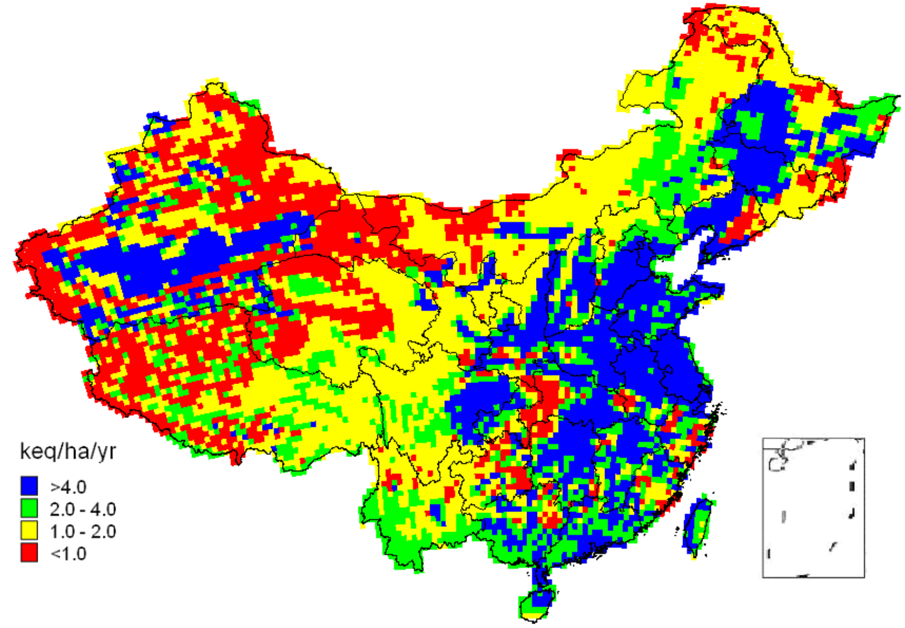


Zhao Y, et al., Environ. Sci. Technol. (2007)

Chinese critical load maps (36×36 km)

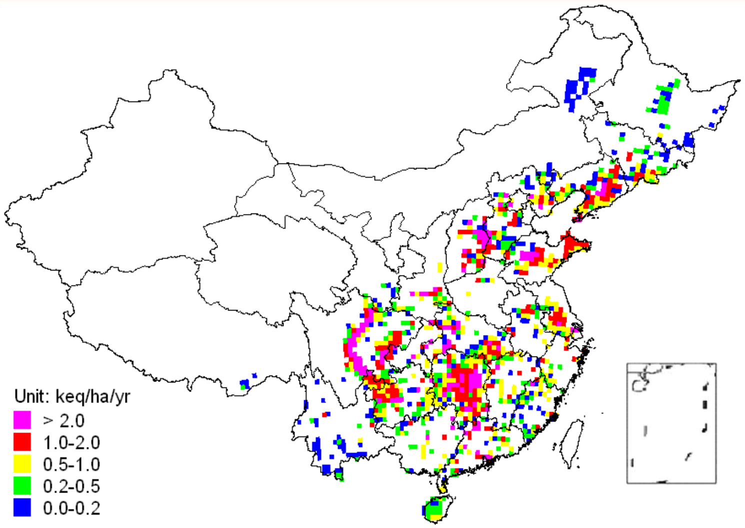


$CL_{max}(S)$

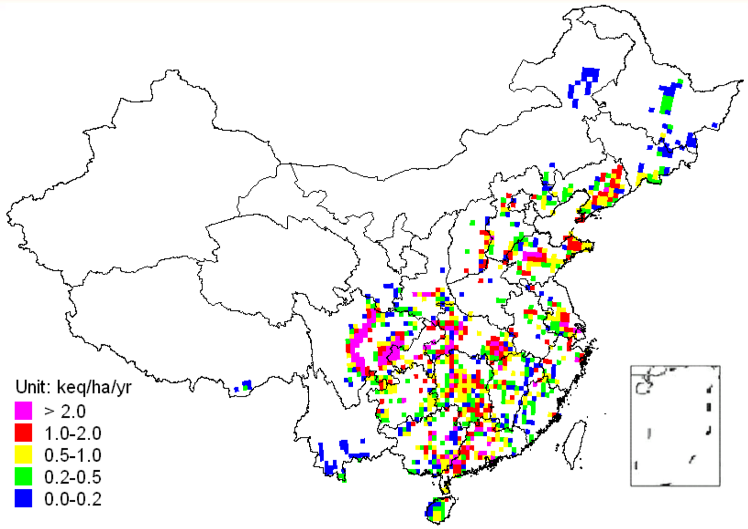


CL (N):
minimum of $CL_{max}(N)$ ***and*** $CL_{nut}(N)$

Exceedance of critical load

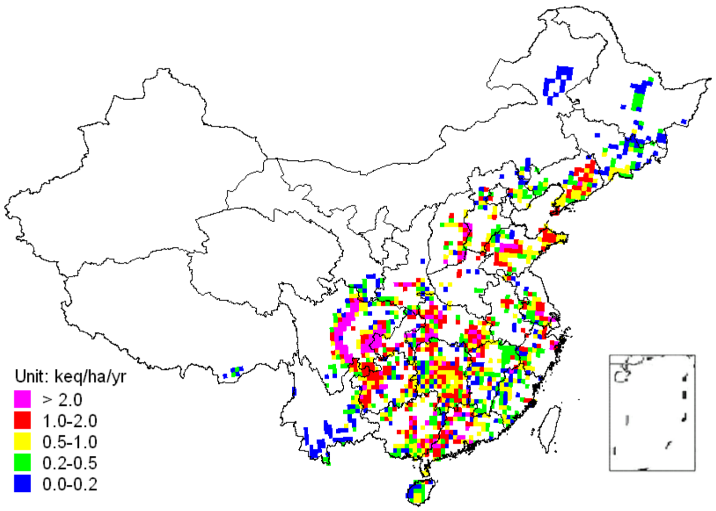


2005



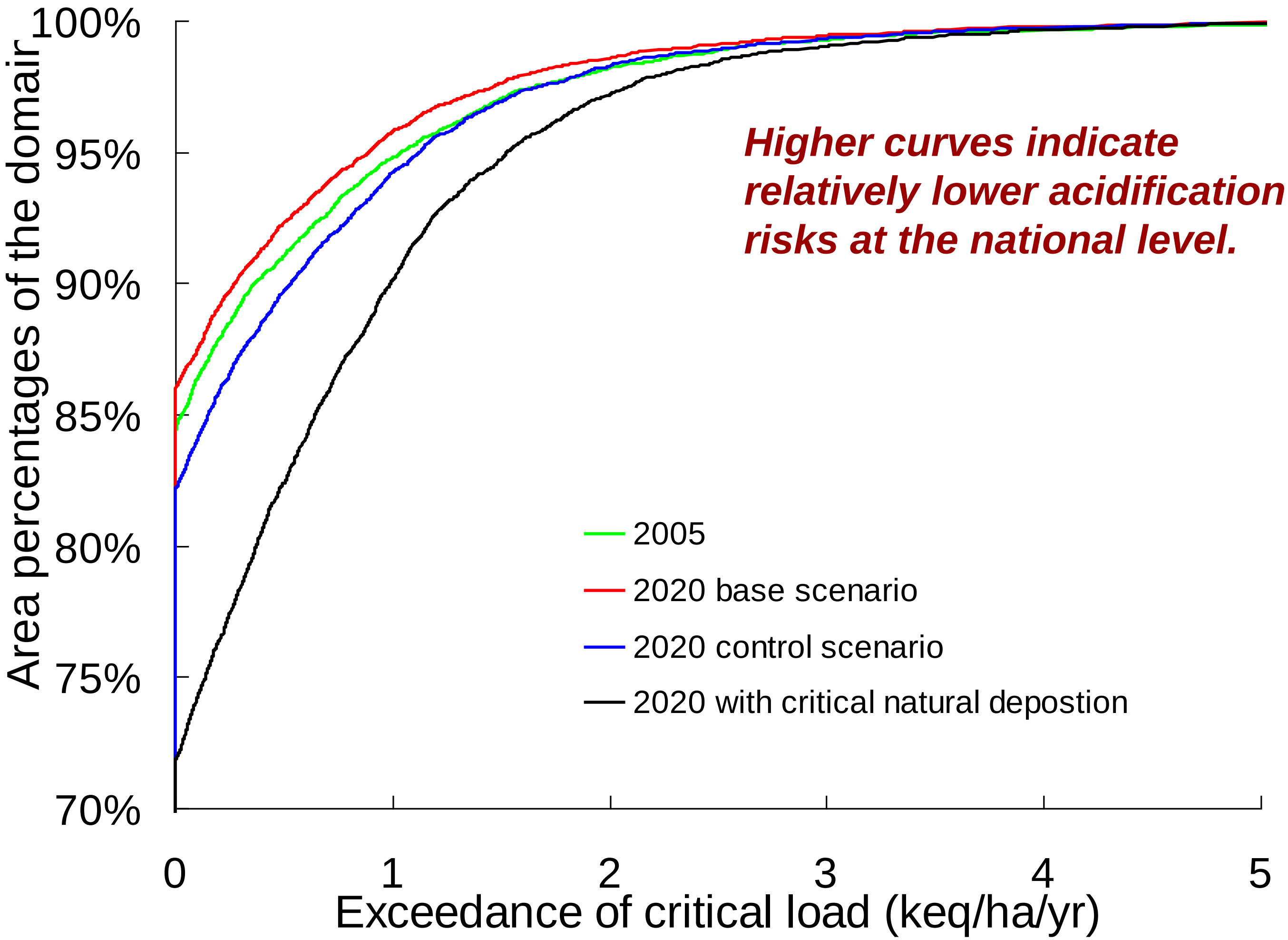
2020 Base

	Exceedance of critical loads	
	Million tons of S	Area percentage
2005	2.2	15.6%
2020 base	1.8	14.1%
2020 control	2.4	17.9%



2020 Control

Cumulate distribution of exceedance



Unwanted side effects of the control of primary PM and thus BCs, may wholly counteract the benefits to regional acidification of reduced emissions of acid precursors.

Conclusion remarks

- China's current program of emission controls is unlikely to achieve its longstanding goal of reduced acidification.
- In accord with the simulation, long-term monitoring found correlation of an increasing trend of precipitation acidity with a decrease in concentrations of airborne PM at many sites across China, and that correlation cannot be explained by changes in natural sources.
- Ongoing PM control efforts must be continued because of the benefits of reduced aerosol pollution and avoided associated damages to public health. Policy-makers may have little choice but to pursue even more stringent SO_2 and NOx controls in the future.

Thank You !

For More Information

Zhao Y, et al., Environ. Sci. Technol. (2007)

Zhao Y, et al., Environ. Sci. Technol. (2009)

Zhao Y, et al., Environ. Sci. Technol. Submitted in 2010

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Formation and harms of acidification