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Supplement of

Spatial and temporal evolution of future atmospheric reactive nitrogen deposition in China under different climate change mitigation strategies

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Supplement

Text

$$MB = \frac{1}{n}\sum_{i=1}^{n}(S_i - O_i) \quad \text{(S1)}$$

$$ME = \frac{1}{n}\sum_{i=1}^{n}|S_i - O_i| \quad \text{(S2)}$$

where S and O are the monthly meteorological variables from model simulation and observation, respectively; i means the individual month.

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Table S4 Simulated outflow fluxes of OXN from EC for Cases where emissions are maintained at 2010s levels as well as Cases where emissions change to 2060s levels. Relative changes (%) are calculated by comparing Cases with 2060s emission levels to Cases with 2010s emission levels**,** then dividing the difference by the 2010s emission levels. The unit for outflow fluxes is kg N s^{-1}.

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Figure S1 The model domain and defined key regions. The black box represents the WRF domain, and the green box represents the CMAQ domain. Western and Eastern China (WC and EC) are divided by 110°E.The red boxes represent the northern China (NC, 30–45°N, 110–125°E) and southern China (SC, 20–30°N, 110–125°E), respectively. The blue boxes represent the regions of Beijing-Tianjin-Hebei (BTH), Yangtze River Delta (YRD, 20–30°N, 110–125°E), and Pearl River Delta (PRD), respectively.

Figure S2 Annual average emissions of NOx, NH_3, PM_{25}, NMVOC, and SO_2 for 2010s and 2060s for emission scenarios of "Baseline", "Current-goal", and "Neutral-goal".

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Figure S4 Spatial distribution of Nr deposition fluxes in 2060s under "Neutral-goal" scenario.

Figure S5 Annual average changes in near-surface concentrations of NO_2 (a), O_3 (b), HNO_3 (c) and DDEP_OXN (d) attributed to a 20% reduction of emissions in NC for 2010s and 2060s under different emission scenarios.

Table S1 Major physical options for WRF v3.9.1.

Physical Option	Setup
Cloud Microphysics	Lin scheme[a]
Long-wave Radiation	RRTMG scheme[b]
Short-wave Radiation	Goddard scheme[c]
Planetary Boundary Layer	YSU scheme[d]
Cumulus	G3 scheme[e]
Land Surface	Noah-MP scheme[f]
Urban Canopy	UCM scheme[g]
Sea Surface Temperature Update	On
Analysis Nudging	Temperature, water vapor mixing and wind (in and above PBL)

[a]Lin scheme: A sophisticated microphysics scheme to predict different forms of water phase substance developed by Lin et al. (1983). The scheme has considered ice, snow and graupel processes, suitable for real-data high-resolution simulations.

[b]RRTMG scheme: A new version of Rapid Radiative Transfer Model (RRTM) scheme developed by Iacono et al. (2008), which included the Monte Carlo Independent Column Approximation (MCICA) method of random cloud overlap.

[c]Goddard scheme: Two-stream multi-band scheme with ozone from climatology and cloud effects developed by Chou and Suarez (1994).

[d]YSU scheme: Yonsei University scheme developed by Hong et al. (2006), which explicit entrainment layer and parabolic K profile in unstable mixed layer based on the Non-local-K scheme.

[e]G3 scheme: Grell 3D scheme, which is an improved version of the Grell-Devenyi (GD) ensemble scheme (Goodarzi et al. 2019). It could be used on high resolution when considering subsidence spreading.

[f]Noah-MP scheme: Noah multi-physics Land Surface Model scheme. It contains a separate vegetation canopy defined by a canopy top and bottom with leaf physical and radiometric properties used in a two-stream canopy radiation transfer scheme that includes shading. Horizontal and vertical vegetation density can be prescribed or predicted using prognostic photosynthesis and dynamic vegetation models that allocate carbon to vegetation (leaf, stem, wood and root) and soil carbon pools (fast and slow) (Niu et al. 2011).

[g]UCM scheme: Urban Canopy Models scheme. It considers 3-category surface effects for roofs, walls, and streets when calculate the exchange of energy and kinetic energy between the surface and the atmosphere (Chen et al. 2011).

Table S2 Spatial correlation (R) between the emission change and the deposition change from 2010s to 2060s under different emission scenarios.

	“Baseline”	“Current-goal”	“Neutral-goal”
OXN	0.24	0.32	0.35
RDN	0.67	0.71	0.72

Table S3 Simulated outflow fluxes of OXN from WC to EC for Cases where emissions change to 2060s levels in all regions as well as Cases where emissions in WC are maintained at 2010s levels. Relative changes (%) are calculated by comparing Cases with 2060s emission levels in all regions to Cases with 2010s emission levels in WC, then dividing the difference by the 2010s emission levels in WC. The unit for outflow fluxes is kg N s^{-1}.

	Emissions in WC are maintained at 2010s levels	Emissions change to 2060s levels in all regions	Relative change
"Baseline"	175.49 (Case 7)	193.06 (Case 2)	10%
"Current-goal"	74.62 (Case 6)	54.53 (Case 1)	-27%
"Neutral-goal"	49.31 (Case 8)	12.19 (Case 5)	-75%

Table S4 Simulated outflow fluxes of OXN from EC for Cases where emissions are maintained at 2010s levels as well as Cases where emissions change to 2060s levels. Relative changes (%) are calculated by comparing Cases with 2060s emission levels to Cases with 2010s emission levels, then dividing the difference by the 2010s emission levels. The unit for outflow fluxes is kg N s^{-1}.

	Emissions are at 2010s levels	Emissions are at 2060s levels	Relative change
“Baseline”	178.82 (Case4)	213.38 (Case2)	19%
“Current-goal”	193.70 (Case3)	99.25 (Case1)	-49%
“Neutral-goal”	193.70 (Case3)	20.84 (Case5)	-89%

Figure S1

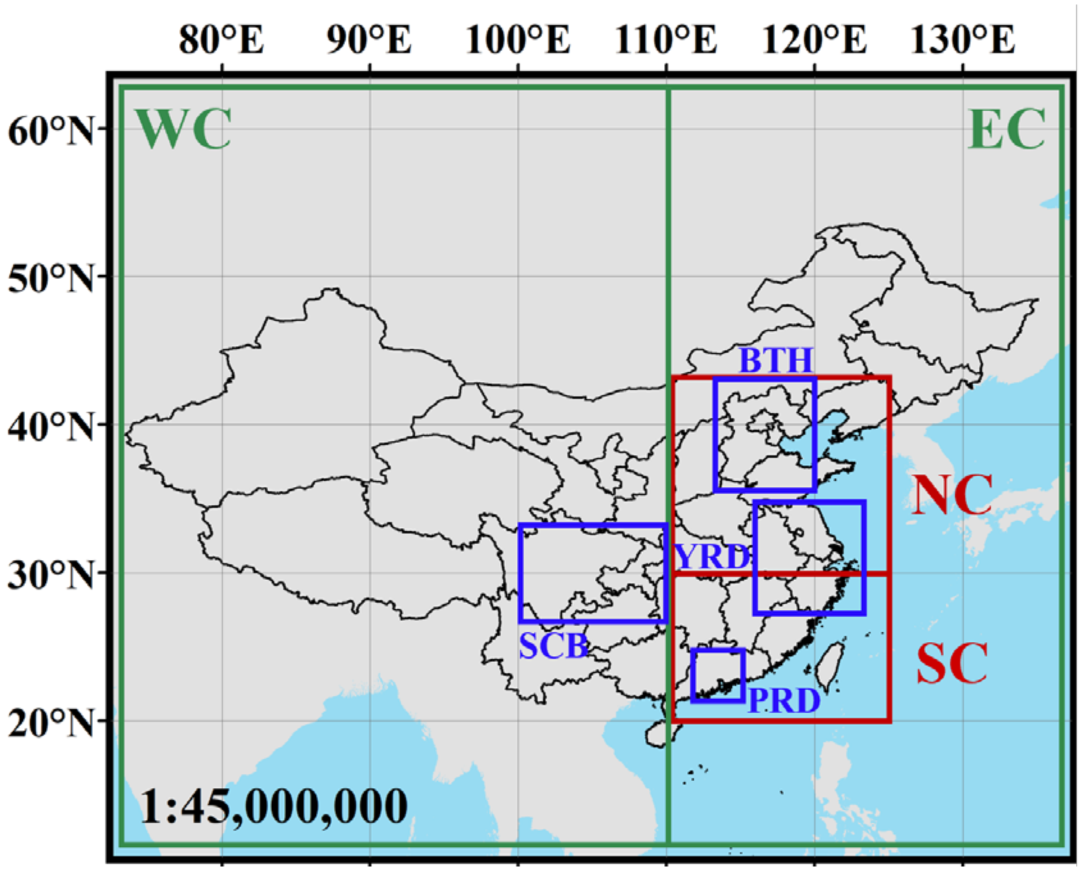
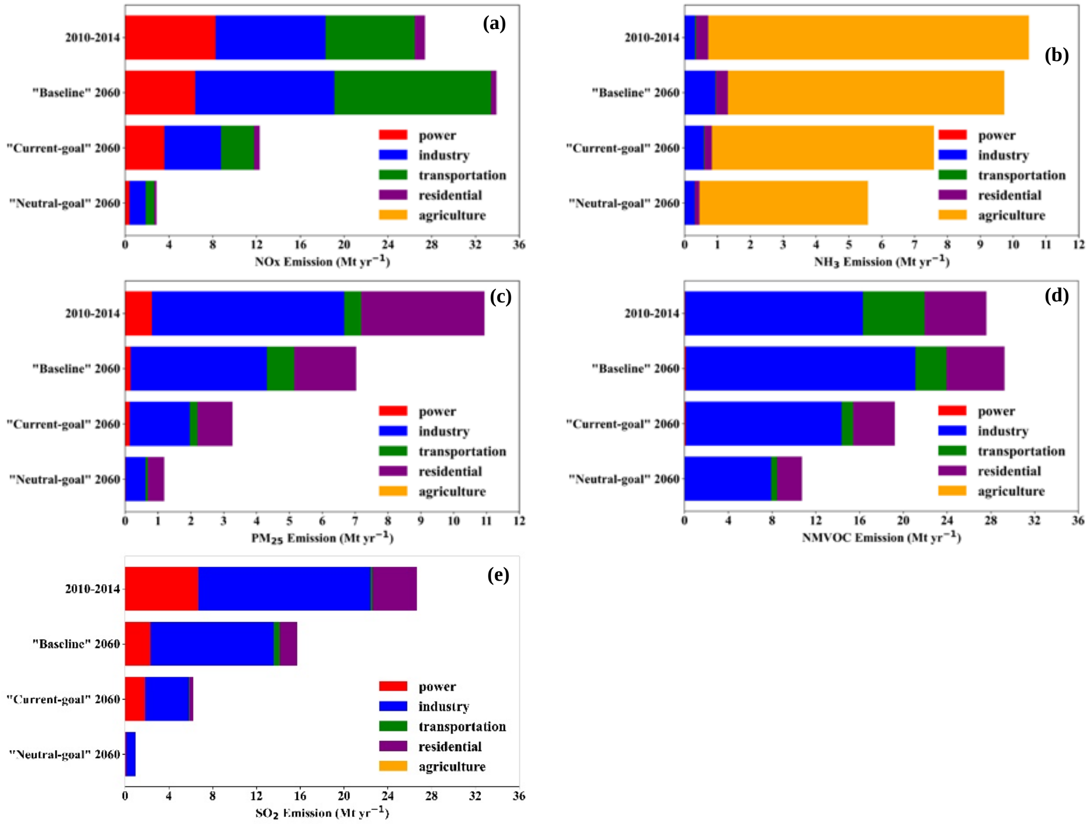
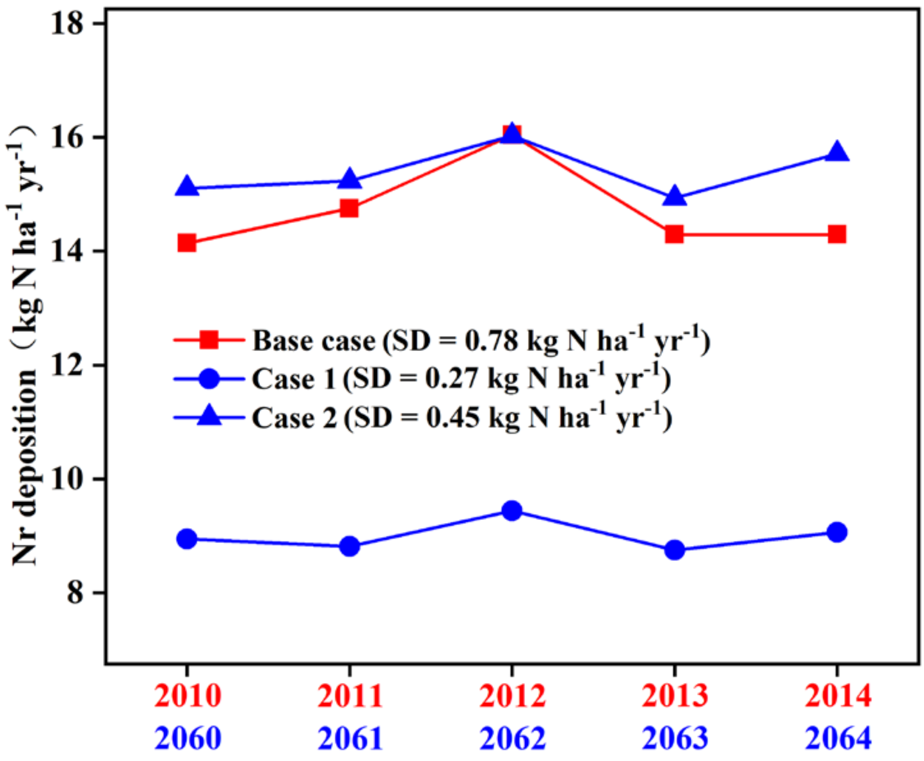

80°E
90°E
100°E
110°E
120°E
130°E
60°N
50°N
40°N
30°N
20°N
WC
EC
BTH
NC
YRD
SCB
SC
PRD
1:45,000,000

Figure S2



(a)
2010-2014
"Baseline" 2060
"Current-goal" 2060
"Neutral-goal" 2060
power
industry
transportation
residential
agriculture
0 4 8 12 16 20 24 28 32 36
NOx Emission (Mt yr^{-1})
(b)
2010-2014
"Baseline" 2060
"Current-goal" 2060
"Neutral-goal" 2060
power
industry
transportation
residential
agriculture
0 1 2 3 4 5 6 7 8 9 10 11 12
NH_3 Emission (Mt yr^{-1})
(c)
2010-2014
"Baseline" 2060
"Current-goal" 2060
"Neutral-goal" 2060
power
industry
transportation
residential
agriculture
0 1 2 3 4 5 6 7 8 9 10 11 12
PM_{25} Emission (Mt yr^{-1})
(d)
2010-2014
"Baseline" 2060
"Current-goal" 2060
"Neutral-goal" 2060
power
industry
transportation
residential
agriculture
0 4 8 12 16 20 24 28 32 36
NMVOC Emission (Mt yr^{-1})
(e)
2010-2014
"Baseline" 2060
"Current-goal" 2060
"Neutral-goal" 2060
power
industry
transportation
residential
agriculture
0 4 8 12 16 20 24 28 32 36
SO_2 Emission (Mt yr^{-1})

Figure S3



Nr deposition （kg N ha-1 yr-1）
18
16
14
12
10
8
Base case (SD = 0.78 kg N ha-1 yr-1)
Case 1 (SD = 0.27 kg N ha-1 yr-1)
Case 2 (SD = 0.45 kg N ha-1 yr-1)
2010
2060
2011
2061
2012
2062
2013
2063
2014
2064

Figure S4

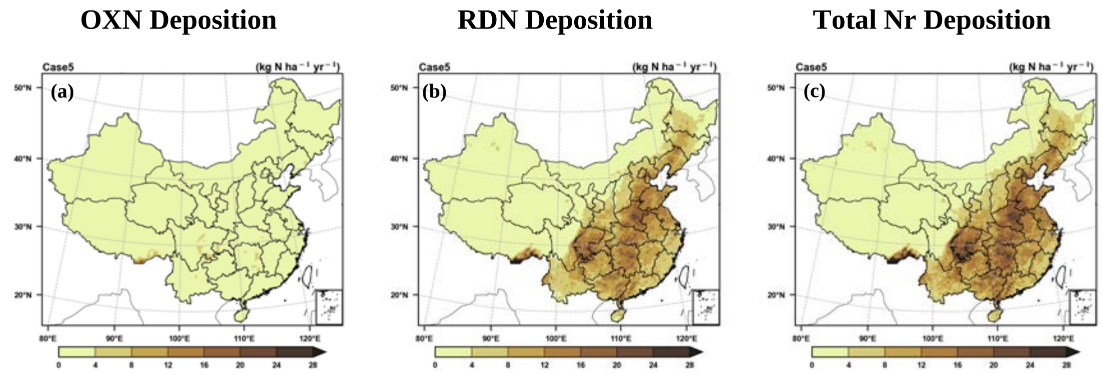
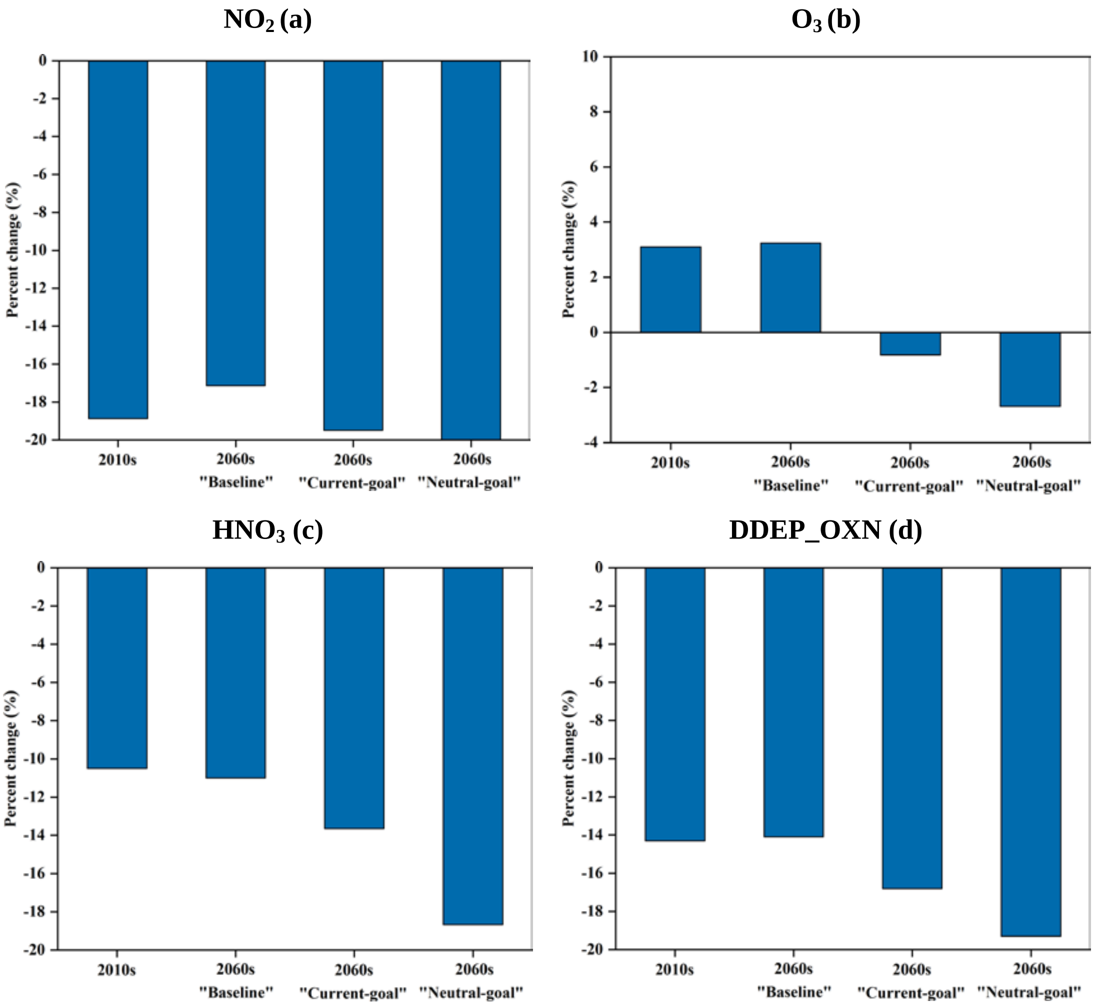

OXN Deposition
RDN Deposition
Total Nr Deposition
Case5
(kg N ha⁻¹ yr⁻¹)
(a)
(b)
(c)
50°N
40°N
30°N
20°N
80°E
90°E
100°E
110°E
120°E
0
4
8
12
16
20
24
28

Figure S5


NO2 (a)
O3 (b)
HNO3 (c)
DDEP_OXN (d)
Percent change (%)
2010s
2060s "Baseline"
2060s "Current-goal"
2060s "Neutral-goal"

Supporting References

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