The Global N_2O Model Intercomparison Project (NMIP)

– Overview, Status and the First Results

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and

NMIP Participants

- The Global N2O Budget: A Joint Activity between GCP and INI

- **NMIP**: The Global N_2O Model Intercomparison Project

GCP-INI Global N_2O budget

The Scientific Committee

Co-Chairs:

Hanqin Tian (USA) and **Rona Thompson** (Norway)

Members:

Pep Canadell (Australia) – Global Carbon Project (GCP), **Wilfried Winiwarter** (Austria) – International Nitrogen Initiative (INI), **Almut Arneth** (Germany), **Parv Suntharalingam** (UK), **Eric Davison** (USA), **Michael Prather** (USA), **Luiz Martinelli** (Brazil), **Pete Raymonds** (USA), **Pierre Regnier** (Belgium), **Philippe Ciais** (France), **Robert Jackson** (USA), **Greet Maenhout and Adrian Leip** (Italy), **Carolien Kroeze** (The Netherlands), **Feng Zhou** (China)

Toward a regular update of major greenhouse gases

- Annual update of the global C budget (since 2007)
- The global CH_4 budget published on (12/12/2016)
- What is next? The global N_2O budget

Overarching Goals of GCP-INI Joint Activity

- Establish an improved global N_2O budget and distinguish anthropogenic perturbations from natural sources of N_2O (updates ca. every 2 years)

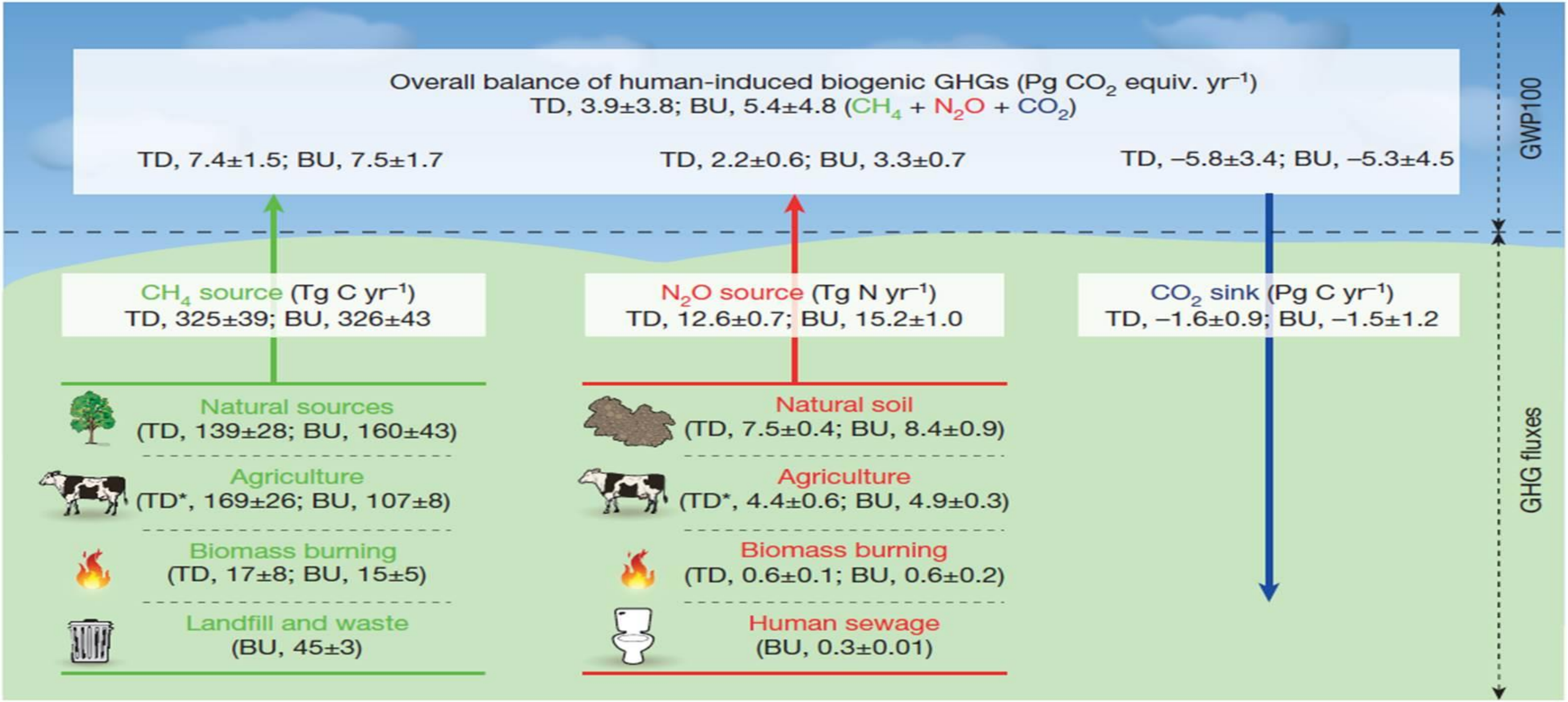
- Resolve emissions at seasonal to annual scales and examine inter-annual variability and long-term trends

- First budget paper: global N_2O budget for the last 3.5 decades (1980 – 2016), which also meets the needs for decadal averages required by major climate assessments (e.g. IPCC)

The first global N_2O budget:

Target Date: **2018**

Toward a Full Budget Assessment of Greenhouse Gases (CO_2, CH_4 and N_2O)



Source: Tian et al. 2016 *Nature*

Global N_2O Budget Components and Leaders

Top-down assessment
Atmospheric observations & modeling
(Lead: R. Thompson; Michael Prather)

Terrestrial biosphere modeling
Emissions from agricultural and natural soils
(Lead: Hanqin Tian)

Inventory-based estimates
Emissions from agriculture, industry, waste, and fuel & biomass combustion
(Lead: Greet Maenhout)

Inland water system models and observations
Emissions from rivers, reservoirs, and lakes
(Lead: Pete Raymond & Pierre Regnier)

Ocean biogeochemistry models and observations
Fluxes in the coastal and open ocean
(Lead: Parv Suntharalingam)

Integration and Uncertainty
(Lead: H. Tian and R. Thompson)

- The Global N2O Budget: A Joint Activity between GCP and INI
- **NMIP**: The Global N_2O Model Intercomparison Project

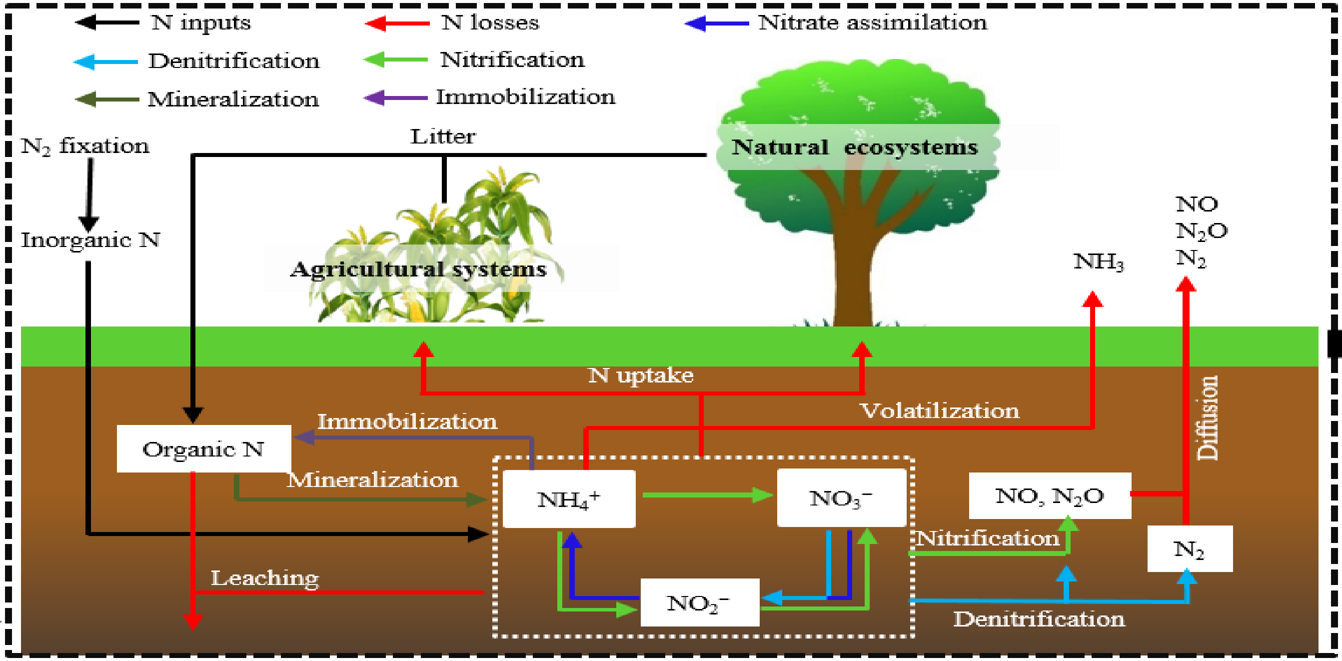
Framework of N_2O Model Intercomparison Project (NMIP)

Model input data

- Climate (Temperature, precipitation, radiation, etc.)
- CO_2 concentration
- N deposition
- N fertilizer use
- Manure N use
- Irrigation
- Land cover and land use
- Soil texture
- topography (elevation, slope, aspect, etc.)

Model calibration & evaluation

- Field observations
- Statistical extrapolation
- Inversion models



Participating Models: CLM-CN, DLEM, LM3V-N, O-CN, LPJ-GUESS, ORCHIDEE, ORCHIDEE-CNP, TRIPLEX-GHG, VISIT

Objective 1
Unravel the major controlling processes of N_2O fluxes and the uncertainties from model structure and parameters

Objective 2
Quantify spatial and temporal patterns of global/regional N_2O fluxes, and attribute the relative contributions of multiple environmental factors

Objective 3
Provide a bench-marking estimate of global and regional N_2O budgets through synthesizing multi-source data

NMIP benchmarks for model performance and data evaluation

Objectives of NMIP

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Participating models

Model	Contact	Affiliation	Citation
CLM-CN	Eri Saikawa	Emory University, USA	Saikawa et al. (2013)
DLEM	Hanqin Tian	Auburn University	Tian et al. (2015) Xu et al. (2017)
LM3V-N	Stefan Gerber	University of Florida	Huang and Gerber (2015)
LPX	Sebastian Lienert	University of Bern	Kelly et al. (2014)
LPJ-GUESS	Stefan Olin/ Almut Arneth	Lund University, Sweden/KIM, Dept. Atmospheric Environmental Research, Germany	Olin et al. (2015); Xu-Ri and Prentice (2008)
O-CN	Sönke Zaehle	Max Planck Institute for Biogeochemistry	Zaehle et al. (2011)
ORCHIDEE	Nicolas Vuichard	IPSL – LSCE, France	Vuichard et al. (in prep)
ORCHIDEE-CNP	Jinfeng Chang/ Daniel Goll	IPSL – LSCE, France	Goll et al., 2017
TRIPLEX-GHG	Changhui Peng	University of Quebec at Montreal, Canada	Zhu et al. (2014); Zhang et al. (2017)
VISIT	Akihiko Ito	National Institute for Environmental Studies, Japan	Inatomi et al. (2010); Ito and Inatomi (2012)

Table 3. Model characteristics in simulating major N cycling processes

	CLM-CN	DLEM	LM3V-N	LPJ -GUESS	O-CN	ORCHIDEE	ORCHIDEE-CNP	TRIPLEX-GHG	VISIT
Open N cycle [1]	yes	yes	yes	yes	yes	yes	yes	yes	yes
C-N coupling	yes	yes	yes	yes	yes	yes	yes	yes	yes
N pools[2]	(13, 3, 4)	(6, 6, 8)	(6, 4, 3)	(5, 6, 11)	(9, 6, 9)	(9, 6, 9)	(9, 6, 9)	(3, 9, 4)	(4, 1, 4)
Demand and supply-driven Plant N uptake	yes	yes	yes	yes	yes	yes	yes	yes	yes
N allocation[3]	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
Nitrification	*f*(T, SWC)	*f*(T, SWC, C_{NH4})	*f*(T, SWC, C_{NH4})	*f*(T, C_{NH4})	*f*(T, SWC, pH, C_{NH4})	*f*(T, SWC, pH C_{NH4})	*f*(T, SWC, pH, C_{NH4})	*f*(pH, C_{NH4}, T, SWC)	*f*(T, SWC, pH, C_{NH4})
Denitrification	*f*(T, SWC, C_{NO3})	*f*(T, clay, Rh, C_{NO3})	*f*(T_{soil}, Rh, SWC, C_{NH4}, C_{NO3}	*f*(T, C_{NO3})	*f*(T, SWC, pH, R_{mb}, C_{NO3})	*f*(T, SWC, pH, denitrifier, C_{NO3})	*f*(T, SWC, pH, R_{mb}, C_{NO3})	*f*(DOC, C_{NO3}, pH, T_{soil})	*f*(SWC, Rh, C_{NO3})
Mineralization, immobilization	*f*(C:N)	*f*(C:N)	*f*(C_{NO3}, C_{NH4})	*f*(C:N)	*f*(C:N)	*f*(C:N)	*f*(C:N)	*f*(C:N)	*f*(C:N)
N leaching	*f*(runoff)	*f*(runoff)	*f*(runoff)	*f*(runoff)	*f*(runoff, clay)	*f*(runoff)	*f*(runoff)	*f*(runoff)	*f*(runoff)
NH_3 volatilization	*f*(C_{NH4})	*f*(pH, T, SWC, C_{NH4})	*f*(pH, T, SWC, C_{NH4})	*f*(pH, C_{NH4})	*f*(pH, C_{NH4})	*f*(pH,C_{NH4})	*f*(pH,C_{NH4})	*f*(pH, C_{NH4})	*f*(pH, T, SWC, C_{NH4})
Plant N turnover[4]	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
N resorption	*f*(C:N)	*f*(C:N)	fixed	Crop: dynamic, the rest: fixed	fixed	*f*(Nleaf)	fixed	*f*(C:N)	fixed
N fixation	*f*(NPP)	Fixed	*f*(C_{NH4}, C_{NO3}, light, plant demand)	*f*(ET)	*f*(C_{cost}, C_{root})	*f*(ET)	*f*(NPP)	*f*(biomass)	*f*(ET)
N fertilizer use	no	yes	yes	yes	yes	yes	yes	yes	yes
Manure N use	no	yes	yes	yes	no	yes	yes	no	yes
N deposition	yes	yes	yes	yes	yes	yes	yes	yes	yes

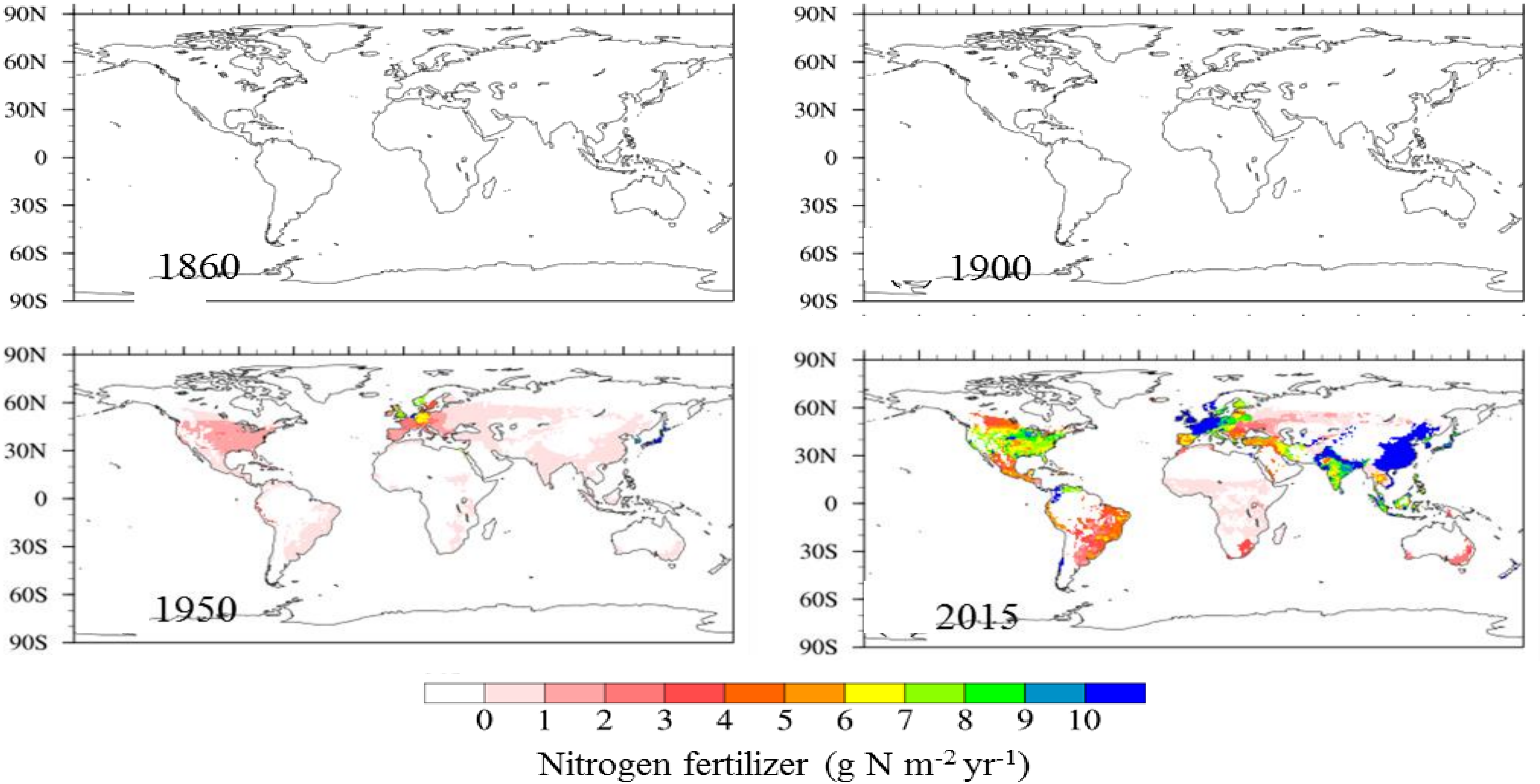
Note: [1] "open" denotes that excess N can be leached from the system; [2]numbers of N pools (vegetation pools, litter pools, soil pools); [3] Dynamic denotes time-varied N allocation ratio to different N pools; [4]turnover time for various vegetation nitrogen pools. T: soil temperature; Clay: soil clay fraction; ET: evapotranspiration; Biomass: vegetation carbon; NPP: net primary production; Nleaf: leaf N concentration; Runoff: soil surface and drainage runoff; Ccost: carbon cost during N_2 fixation; SWC: soil water content; denitrifier: soil denitrifier biomass; Rh: soil heterogeneous respiration.

Tian et al. (2018) BAMS

NMIP Input Data

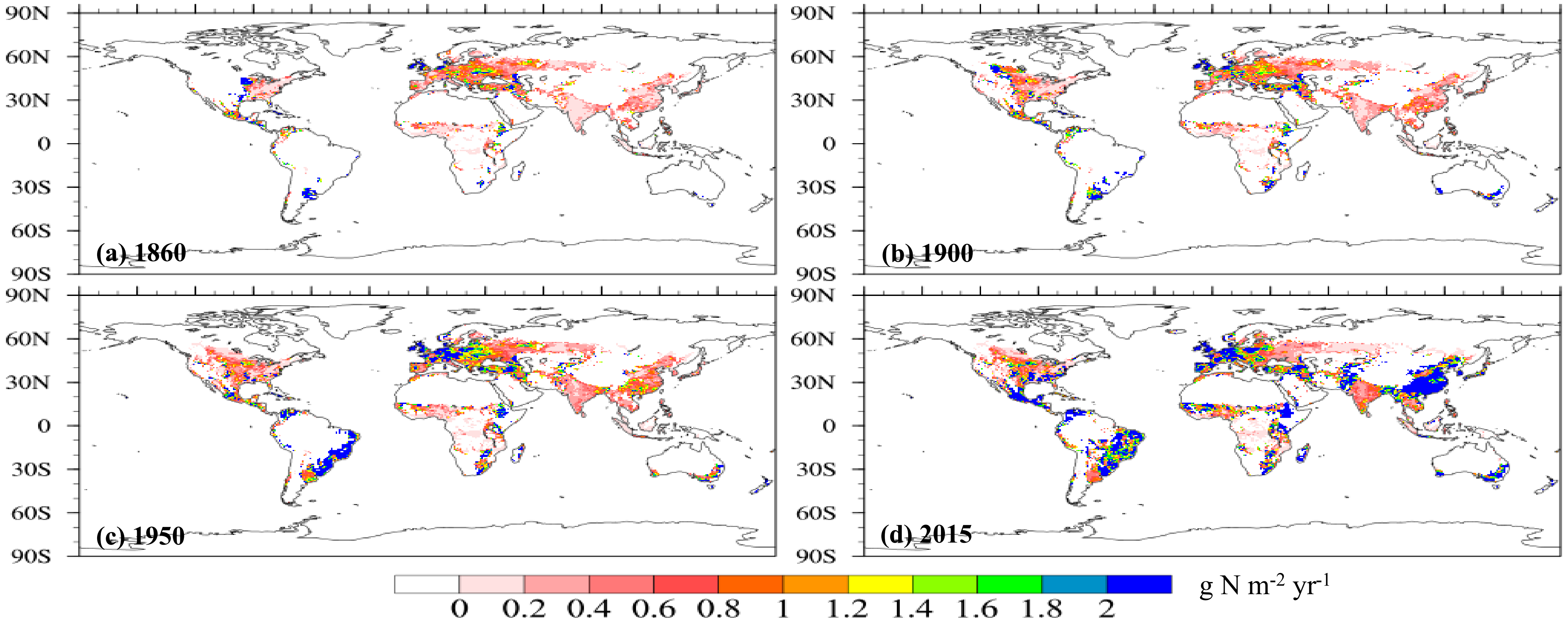
Data name	Period	Temporal resolution	Spatial resolution	Sources	Variables
N deposition	1860-2014	Monthly	0.5°	CCMI	NH_x-N and NO_y-N deposition
N Fertilizer use in cropland	1860-2014	Yearly	0.5°	Lu and Tian (2017)	N fertilizer use rate in cropland
N fertilizer use in pasture	1860-2014	Yearly	0.5°	Xu et al. (in preparation)	
Manure N application in cropland	1860-2014	Yearly	0.5°	Zhang et al. (2017)	
Manure N application in pasture	1860-2014	Yearly	0.5°	Xu et al. (in preparation)	
Manure N deposition in grazing land	1860-2014	Yearly	0.5°	Xu et al. (in preparation)	
Potential vegetation	One time	One time	0.5°	SYNMAP	Fraction of natural vegetation types
Cropland and Pasture	1860-2016	Yearly	0.5°	HYDE 3.2	Cropland and pasture fraction
Climate	1901-2016	6-hourly	0.5°	CRU-NCEP	Incoming longwave / shortwave radiation, air humidity, pressure, precipitation, temperature, and wind speed
CO_2	1860-2016	Monthly	0.5°	NCAR	CO_2 concentration

Gridded (0.5°×0.5°), Annual N Fertilizer application in cropland



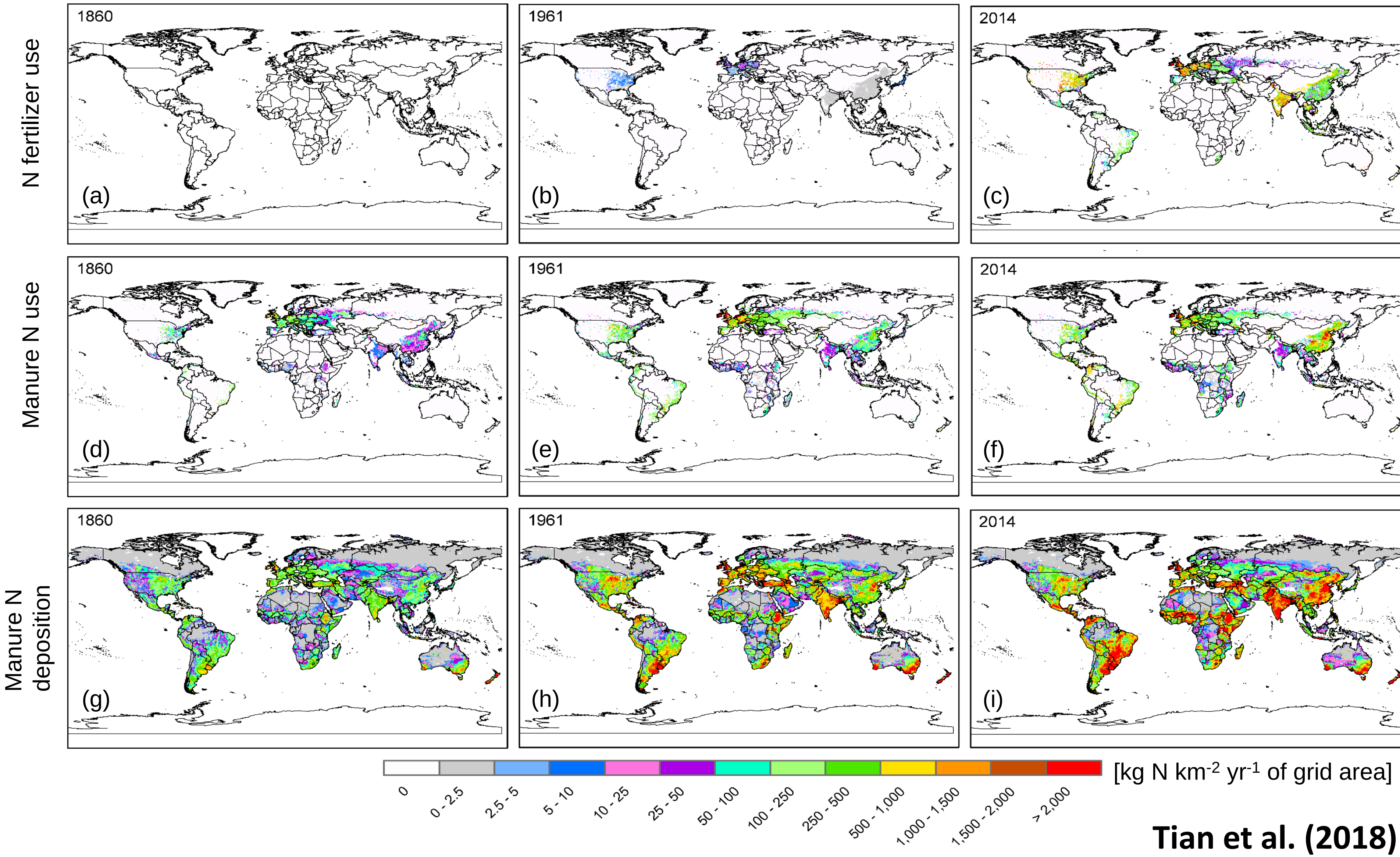
Lu and Tian 2017 ESSD

Gridded (0.5°×0.5°), Annual Manure N application in cropland



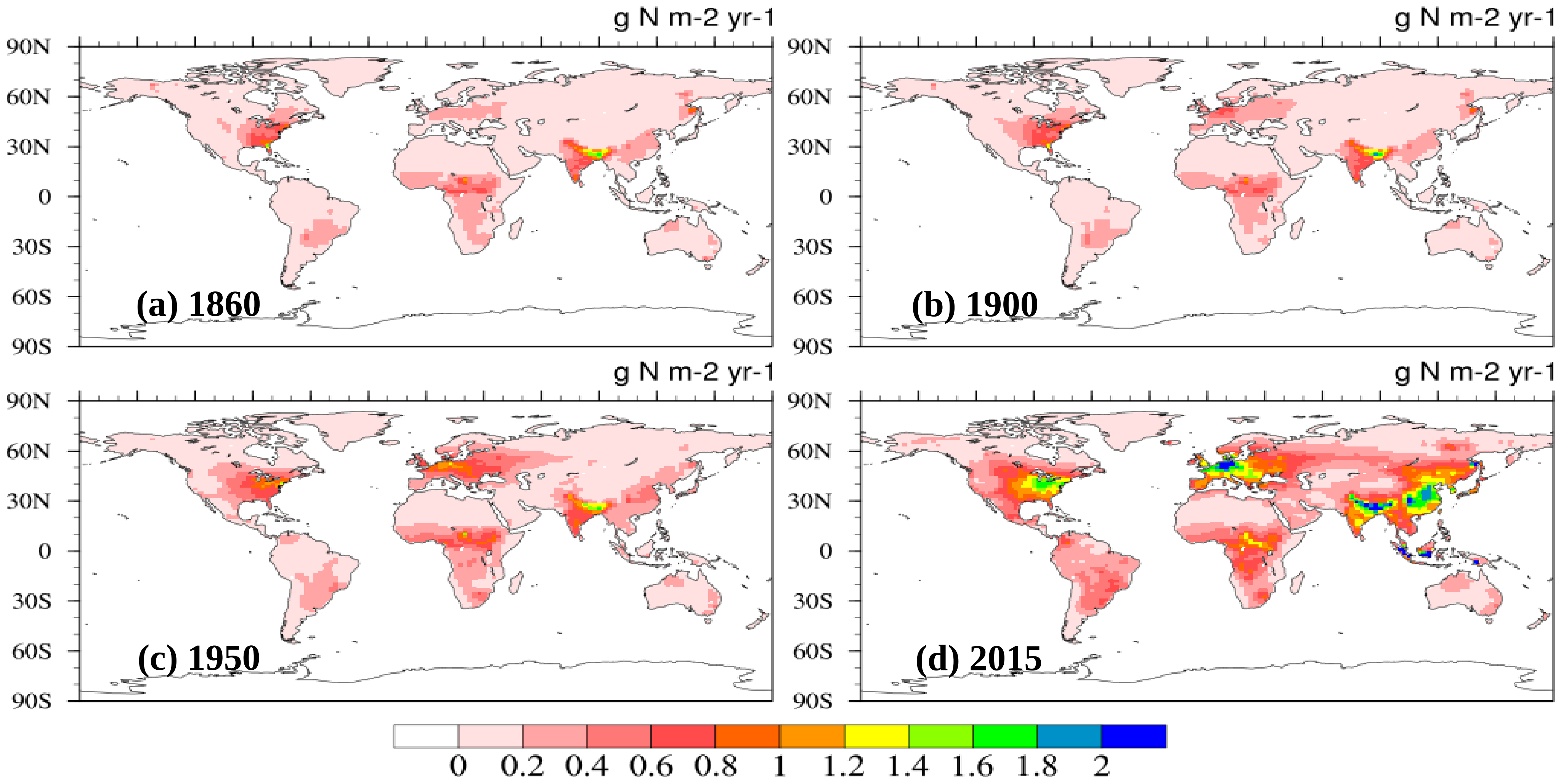
Tian et al. (2018) BAMS

Gridded (0.5°×0.5°), annual N fertilizer use, Manure N use and Manure N deposition in grassland from 1961 to 2014



Tian et al. (2018) BAMS

Gridded (0.5°×0.5°), Monthly Atmospheric Nitrogen deposition



Data is provided by the IGAC/SPARC Chemistry-Climate Model Initiative (CCMI)

http://blogs.reading.ac.uk/ccmi/

Experimental design

Spin-up

Climate: 1901-1920
CO_2: 1860
Nitrogen deposition: 1860
Nitrogen fertilizer: 1860
Manure: 1860
Land use: 1860

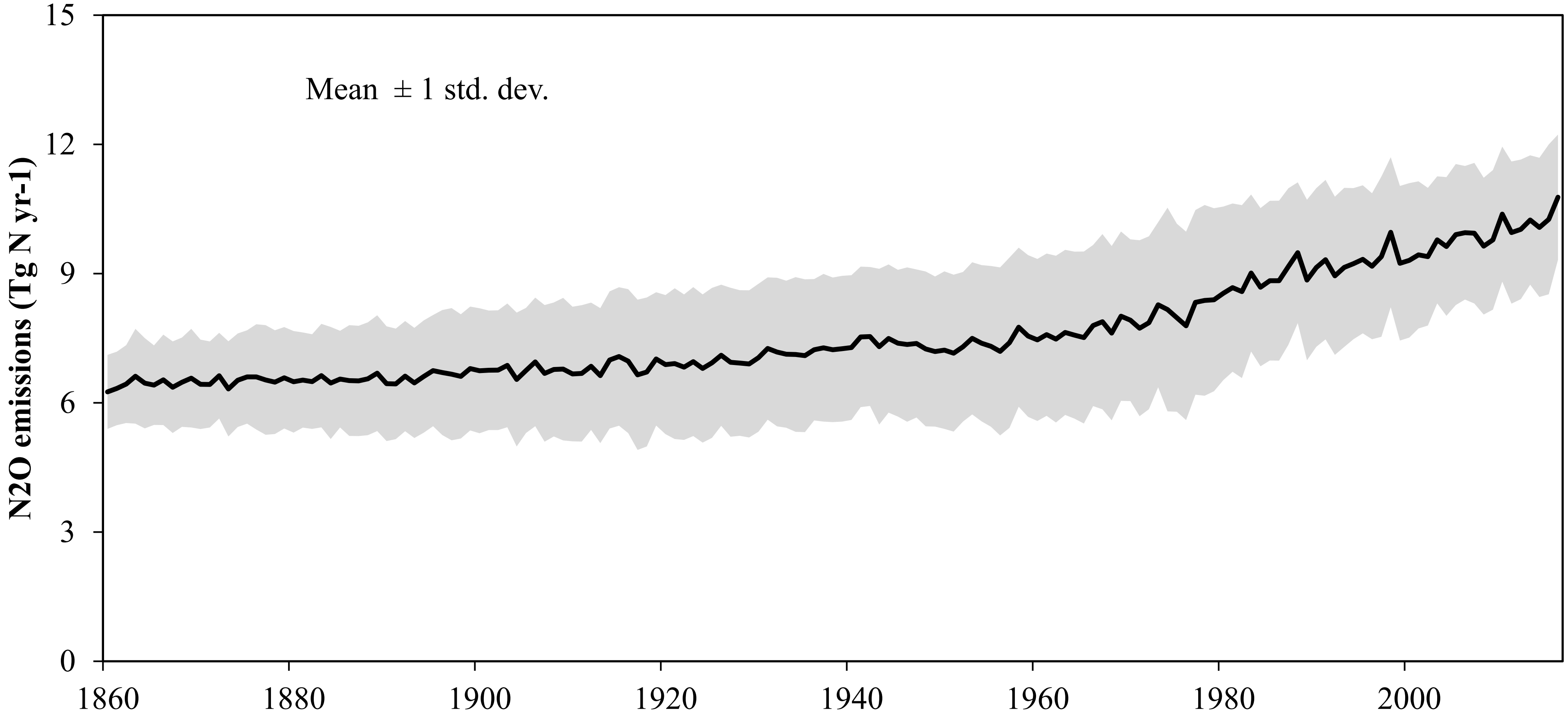
Equilibrium state

Experimental design (1860-2016)

	Climate	CO_2	LCLUC	Ndep	Nfer	ManureN
S0	1901-1920 average	1860	1860	1860	1860	1860
S1	1901-2016	1860-2016	1860-2016	1860-2016	1860-2016	1860-2016
S2	1901-2016	1860-2016	1860-2016	1860-2016	1860-2016	1860
S3	1901-2016	1860-2016	1860-2016	1860-2016	1860	1860
S4	1901-2016	1860-2016	1860-2016	1860	1860	1860
S5	1901-2016	1860-2016	1860	1860	1860	1860
S6	1901-2016	1860	1860	1860	1860	1860

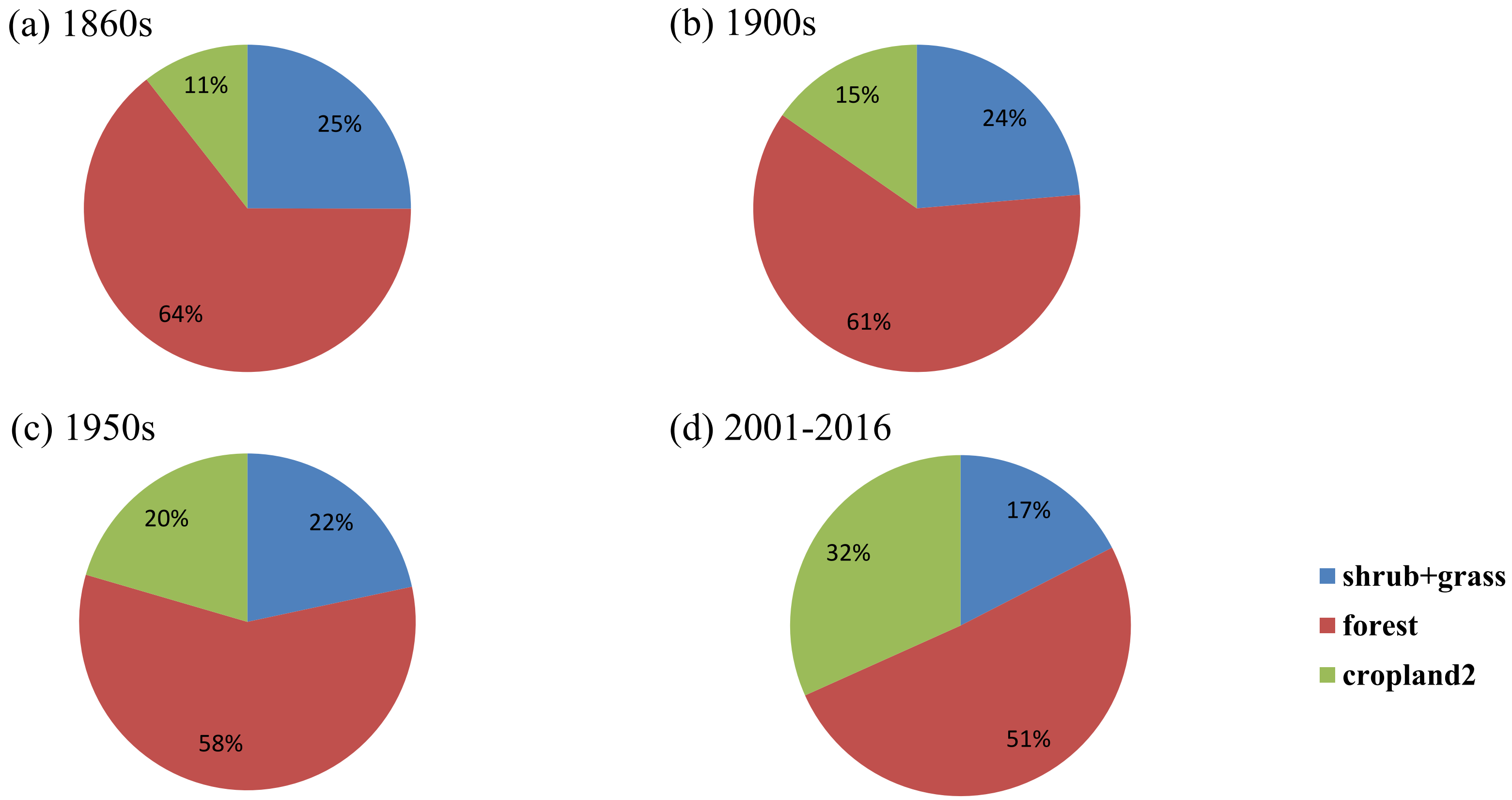
The First Results

Ensemble Mean of Global N_2O emissions during 1860-2016



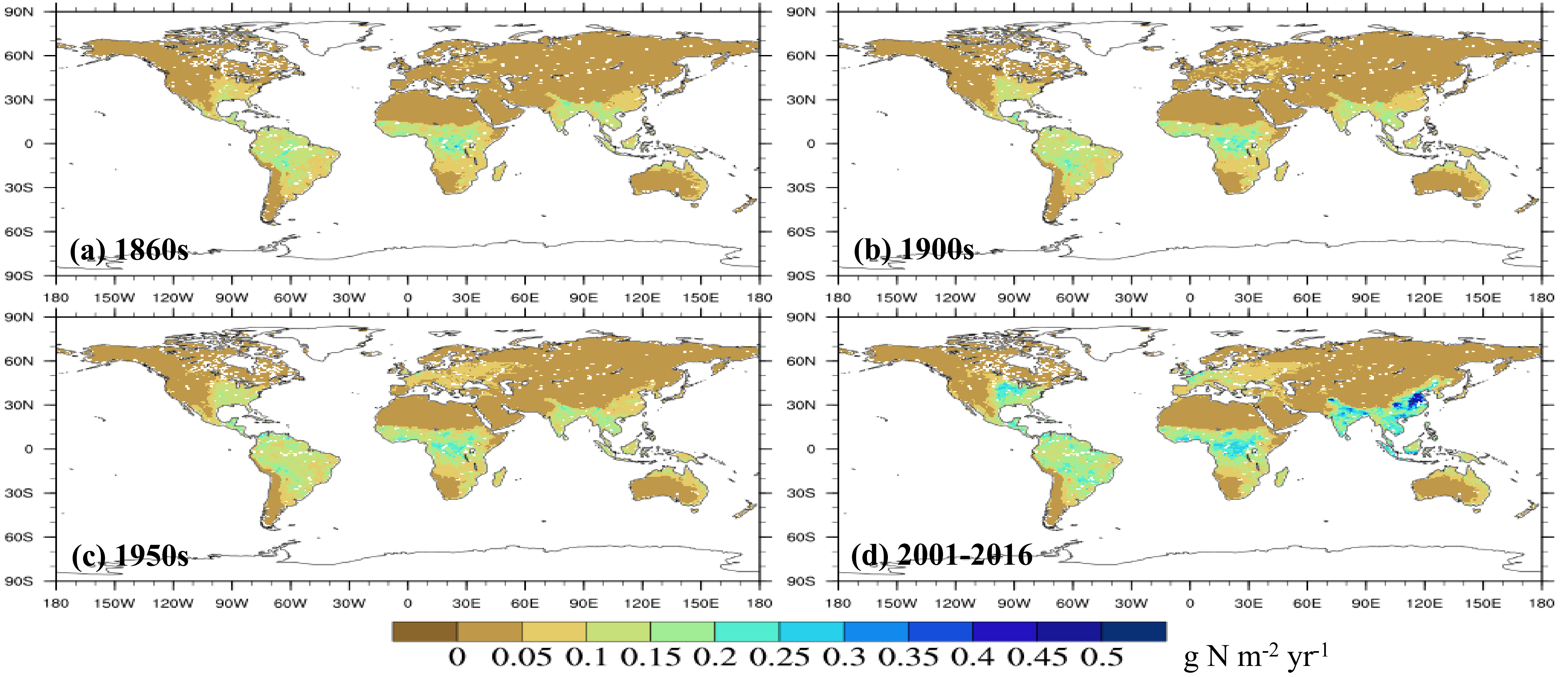
Model ensemble based on the “best estimates” of 6 models
(S1 for DLEM, ORCHIDEE-CNP, and TRIPLEX; S2 for LPX, OCN, and VISIT)

Percent contribution of Major biomes to N_2O emissions

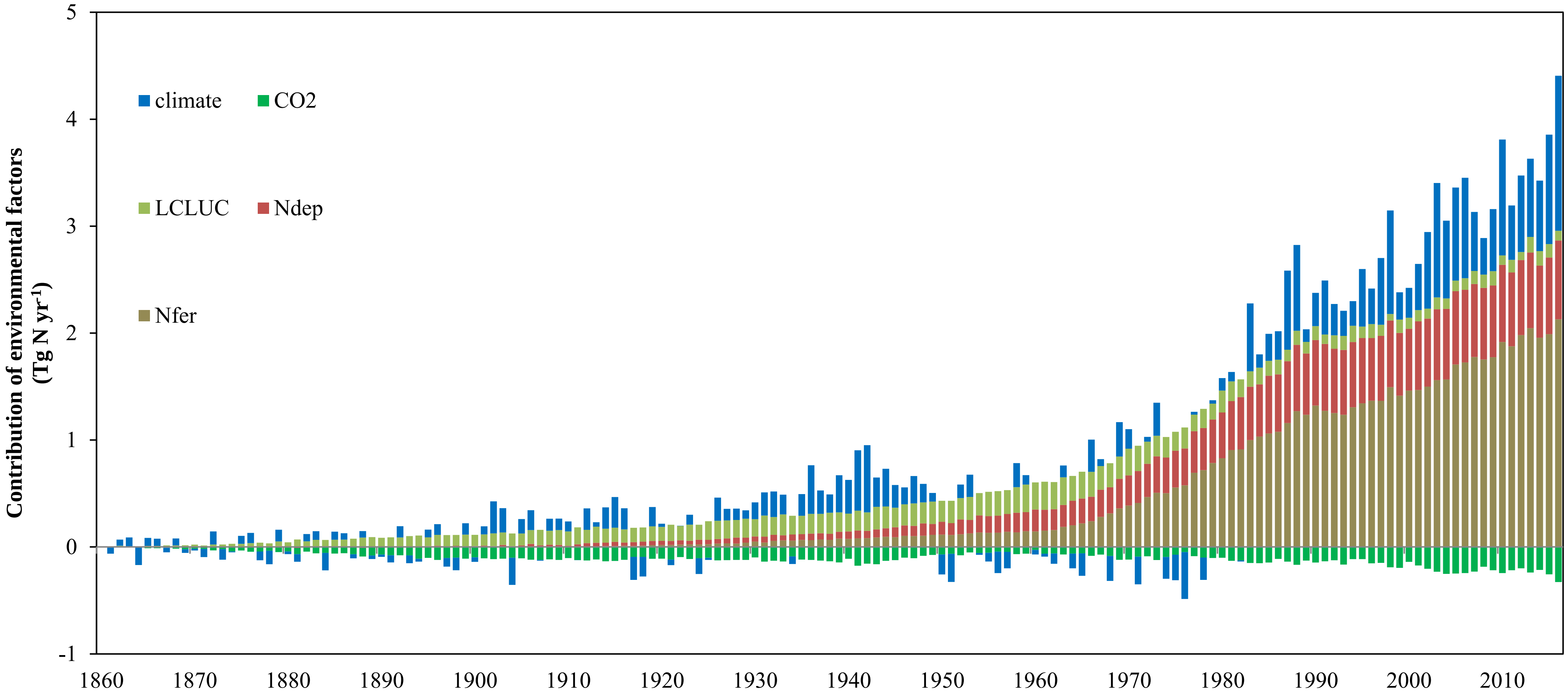


1. **Forests make the largest contribution (51% ~ 64%) to global N_2O emissions throughout the entire period.**
2. **The percentage of N_2O emissions from cropland increased from 11% to 32%.**

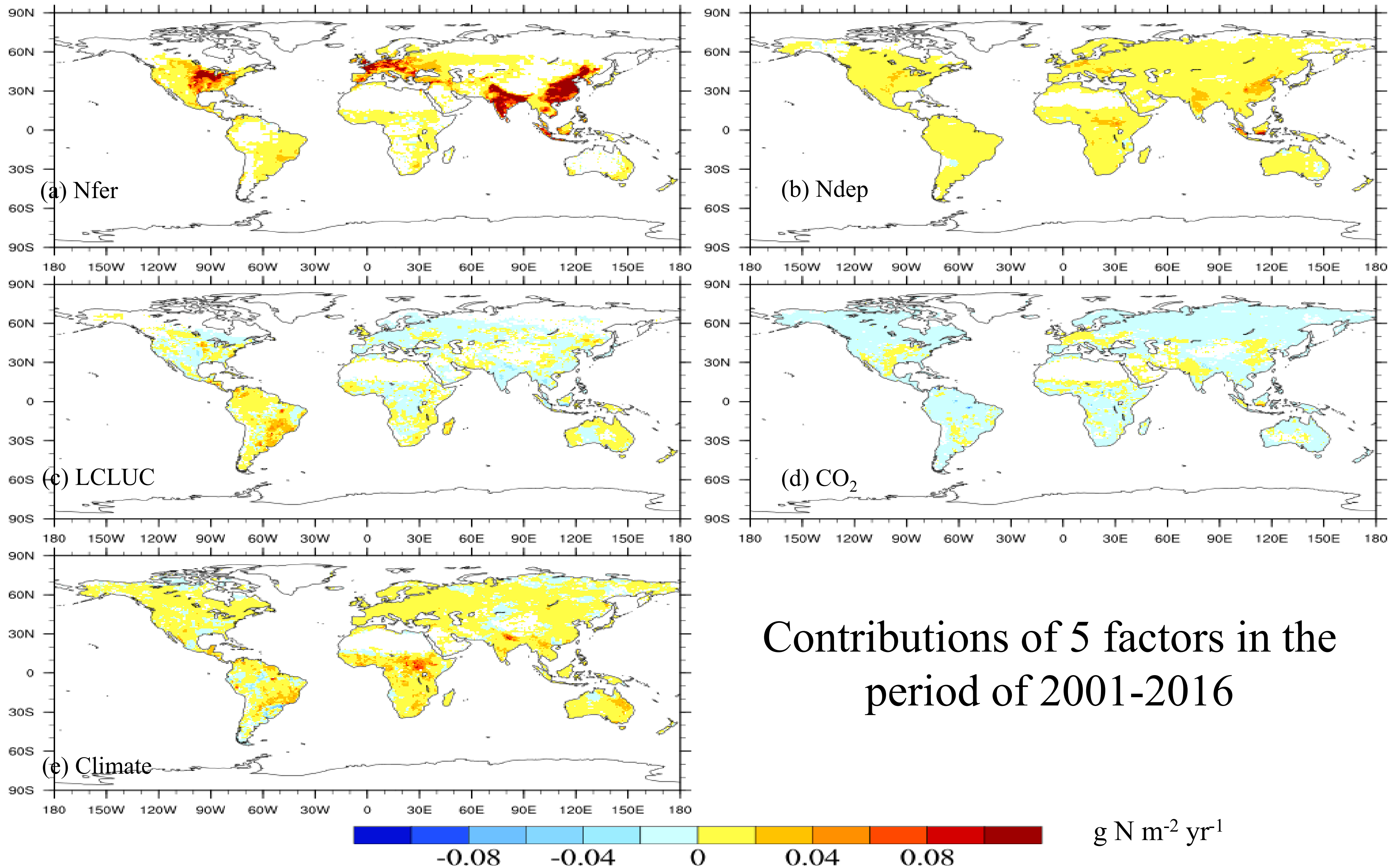
Model ensemble estimated global N_2O emissions



Model ensemble estimated contribution of environmental factors to net change in N_2O emission

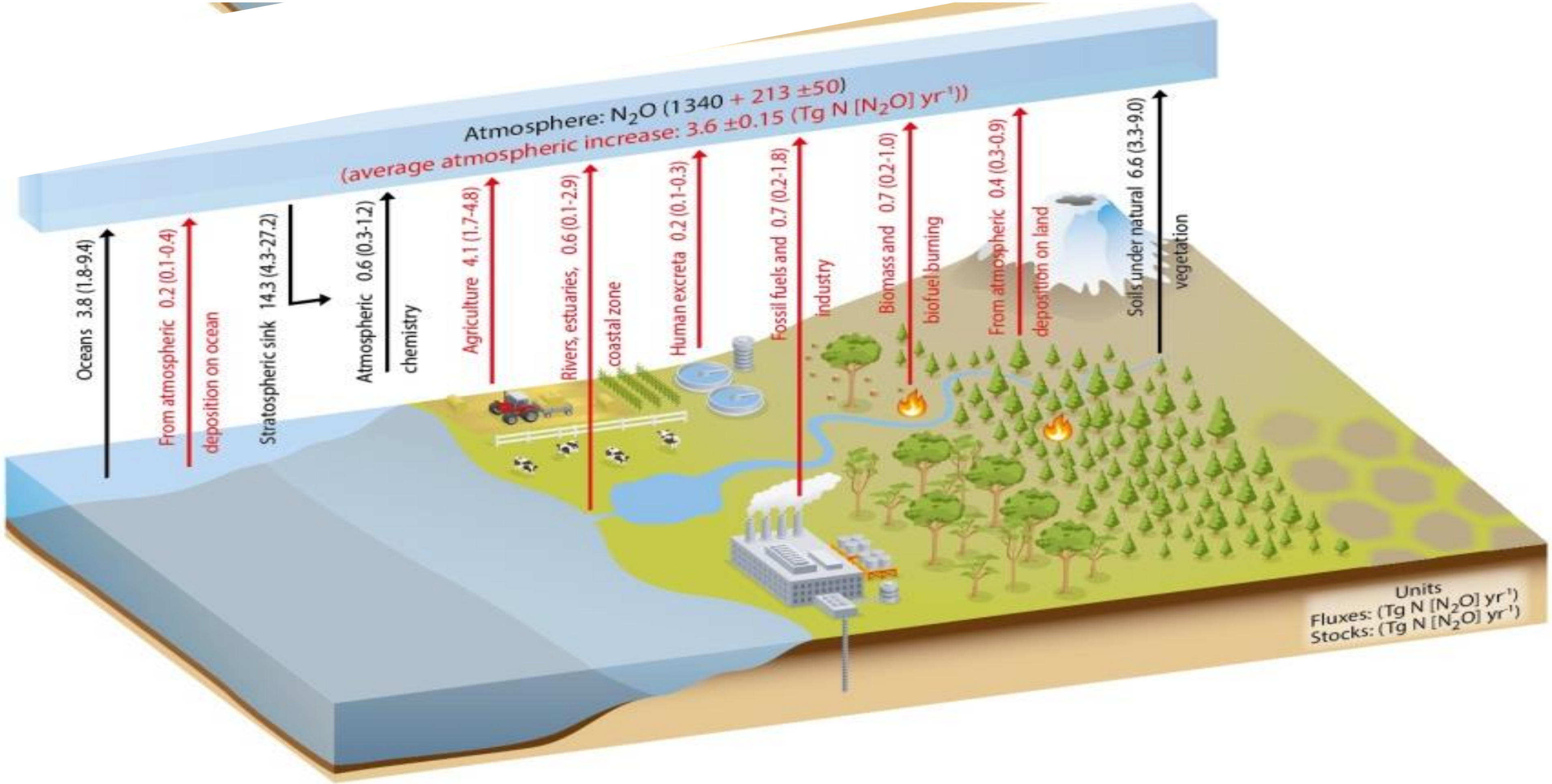


Model ensemble estimated N_2O Emissions by Driving Forces



Contributions of 5 factors in the period of 2001-2016

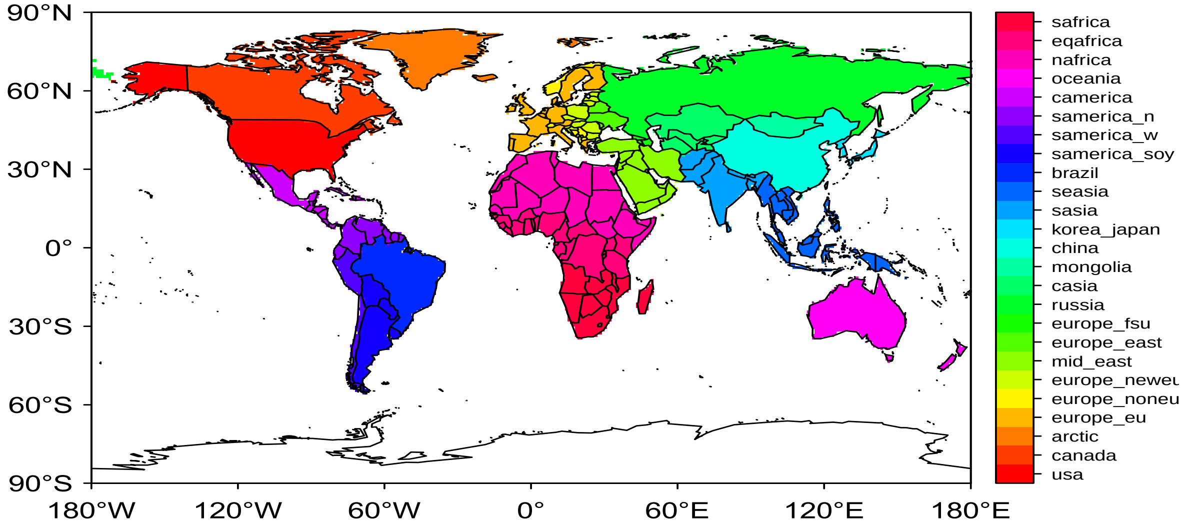
The global N2O budget: Components

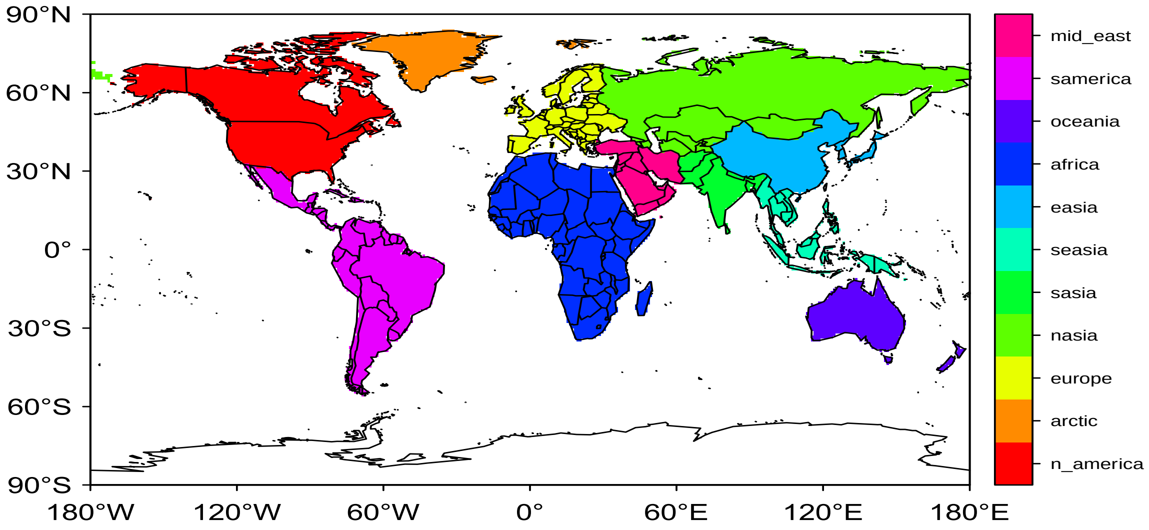


Source: IPCC AR5

Regionalization

Propose small adjustment to RECCAP regions…





Mask with smaller sub-continental regions following country borders, large countries (USA, Canada, China, Brazil) separated – allows flexibility for more detailed studies

Same mask but aggregating some regions together: 10 (sub)-continental regions (excl. Arctic and Antarctic) similar to RECCAP

Expected Products:

- Pre-industrial period (1860/s) for grid-level and PFT-level output,
- annual time step for grid-level output during 1861-2016, and
- monthly time step for biome-level output during 1980-2016.

The first global N_2O budget:

Target Date: **2018**

Invitation to attend/contribute to the AGU Session:

Global and Regional Nitrous Oxide Budget: Data, Models and Uncertainty

Conveners:

Hanqin Tian, Auburn University, USA;

Rona Thompson, Norwegian Institute for Air Research, Norway,

Josep Canadell, CSIRO Ocean and Atmosphere, Australia

Wilfried Winiwarter, IIASA

AGU 100 ADVANCING EARTH AND SPACE SCIENCE

FALL MEETING

Washington, D.C. | 10–14 Dec 2018

Acknowledgements

GLOBAL CARBON PROJECT

International Nitrogen Initiative

All NMIP Participants

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