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Global budgets of nitrous oxide under GCP/INI, the contribution of the global N_2O intercomparison project (NMIP), and refinements to regionally assess diverse drivers, fluxes, and impacts (RECCAP-2)

Wilfried Winiwarter, Pep Canadell, Rona Thompson, Hanqin Tian

Climate change, reactive nitrogen, food security and sustainable agriculture
Garmisch-Partenkirchen, April 15-16, 2019

Overview

- The Global Carbon Project and N_2O
- The global N_2O intercomparison project (NMIP)
- Regional refinements (RECCAP-2)

The Global Carbon Project

GCP-INI Global N_2O budget

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)

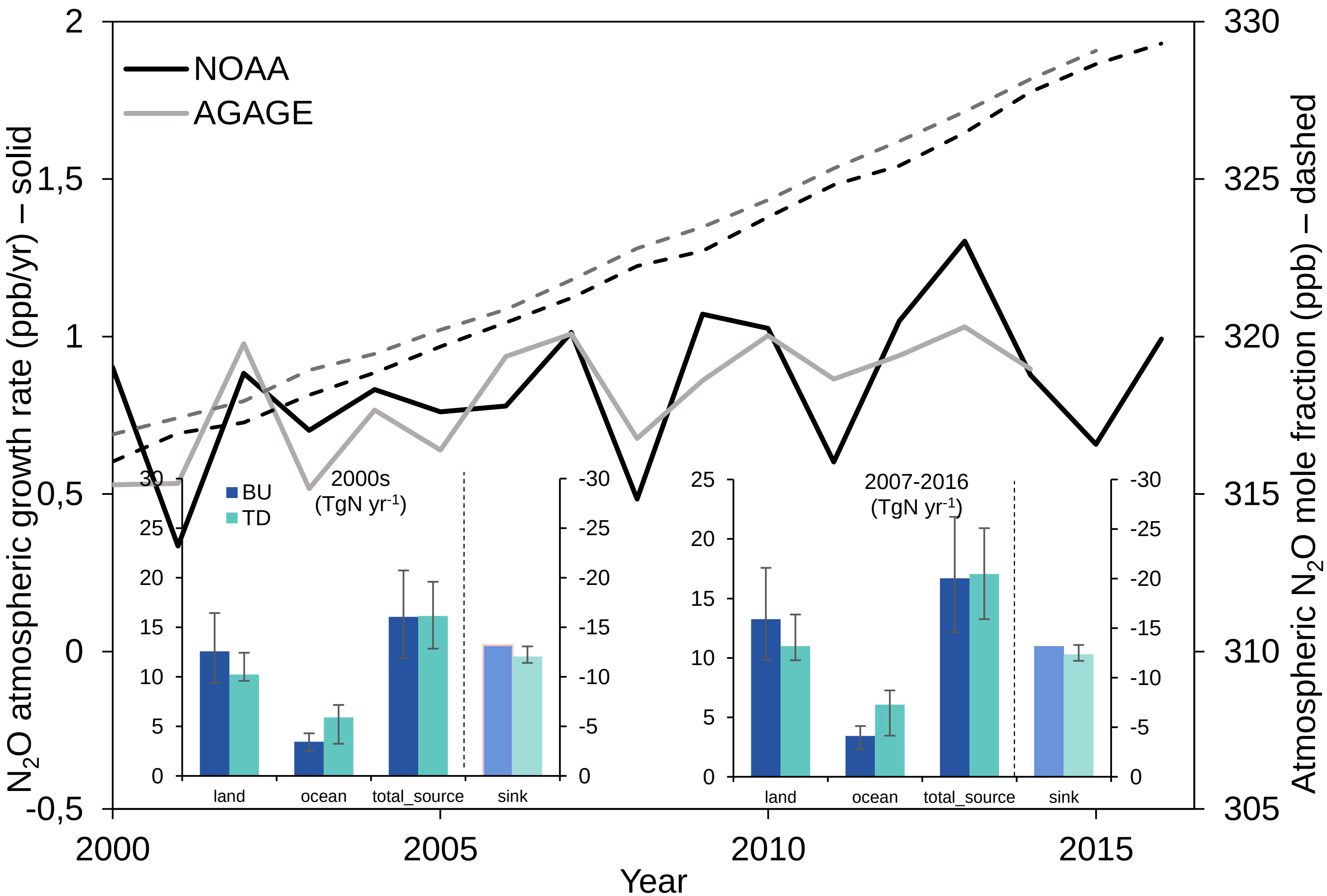
Ocean biogeochemistry models and observations
Fluxes in the coastal and open ocean
(Lead: Pierre Regnier, Parv Suntharalingam)

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

Inverse modelling

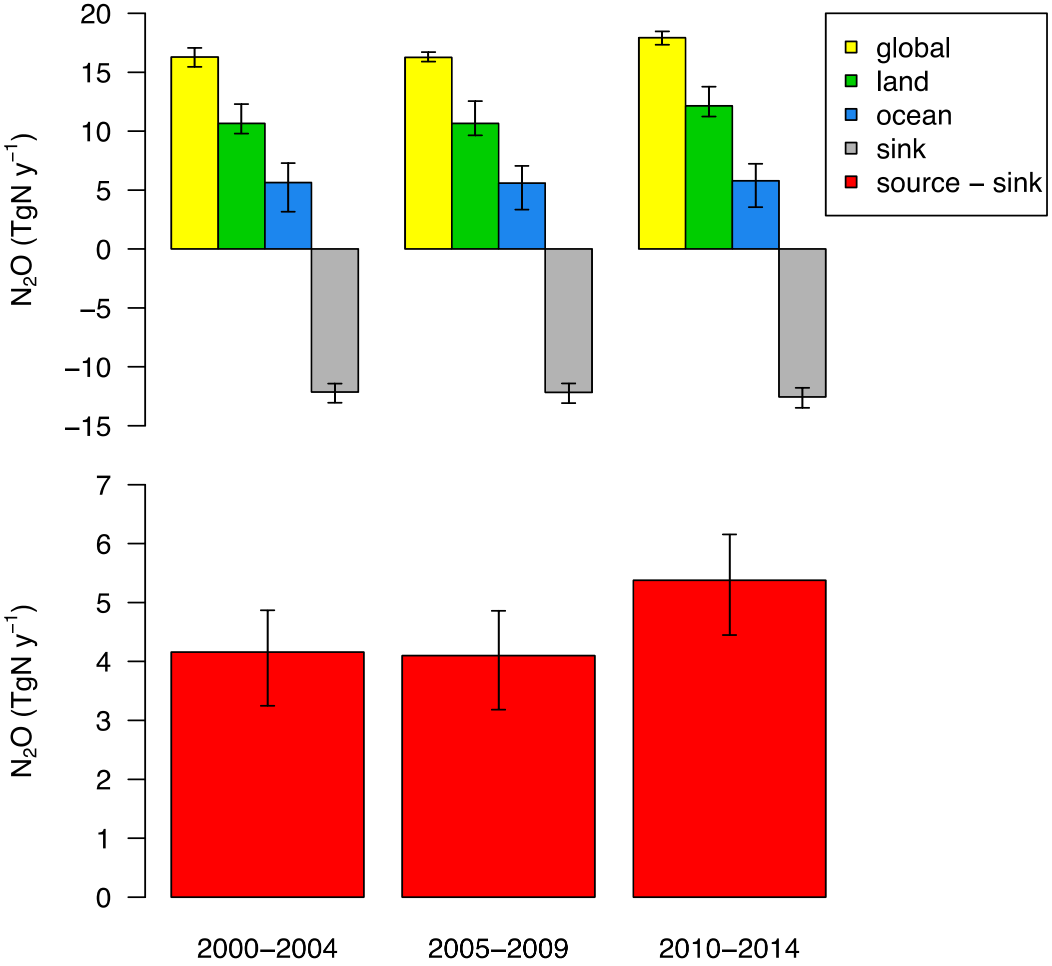
(slides by Rona Thompson)

Atmospheric observations



N_2O budget

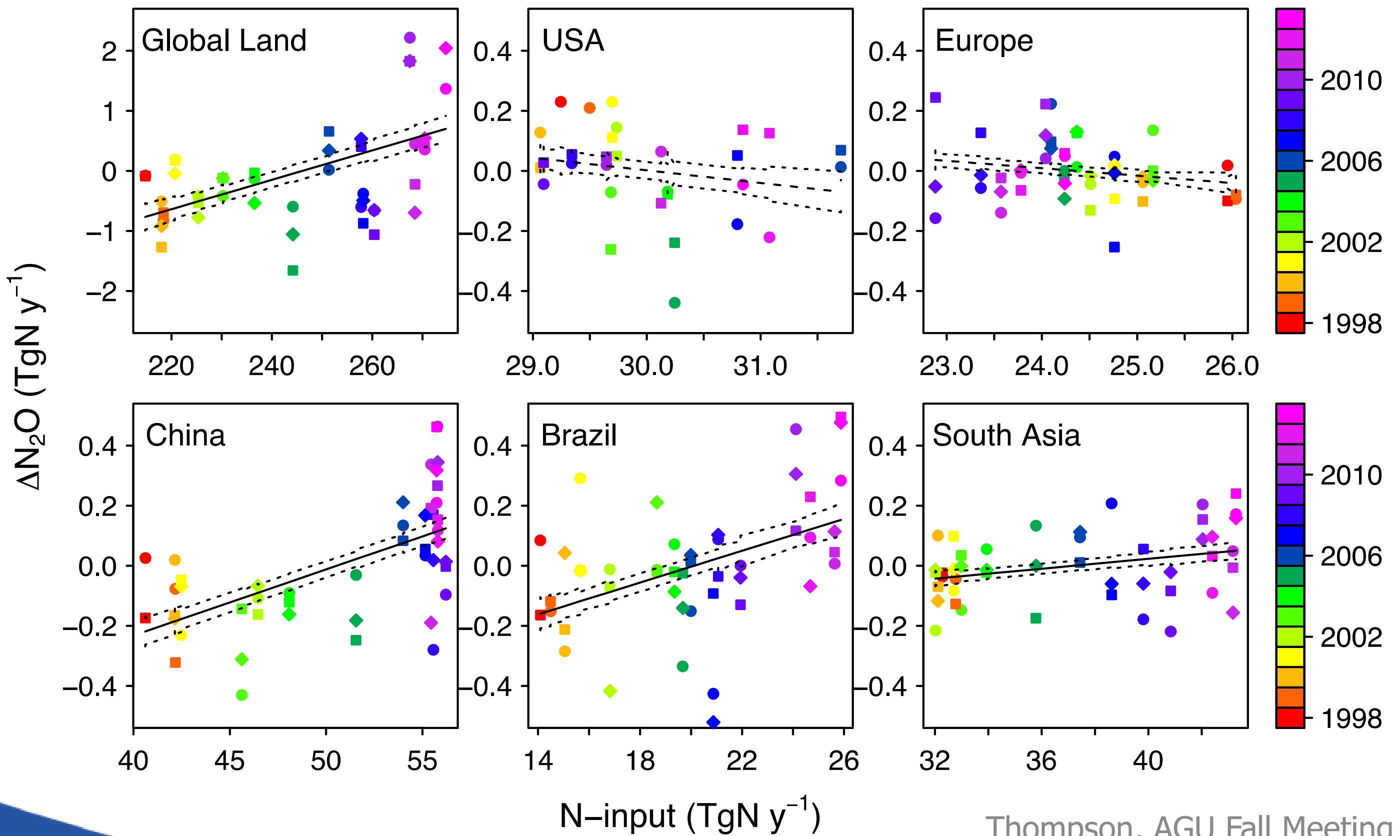
- Global source 17.0 TgN y^{-1}
- Global sink 12.3 TgN y^{-1}
- Global source increased by 1.6 TgN y^{-1} from 2000-2005 to 2010-2015
- 90% of the increase due to emissions from land
- Change in atmospheric abundance increased by 1.3 TgN y^{-1} from 2000-2005 to 2010-2015



Thompson, AGU Fall Meeting, 2018

Estimation of Emission Factors (EF)

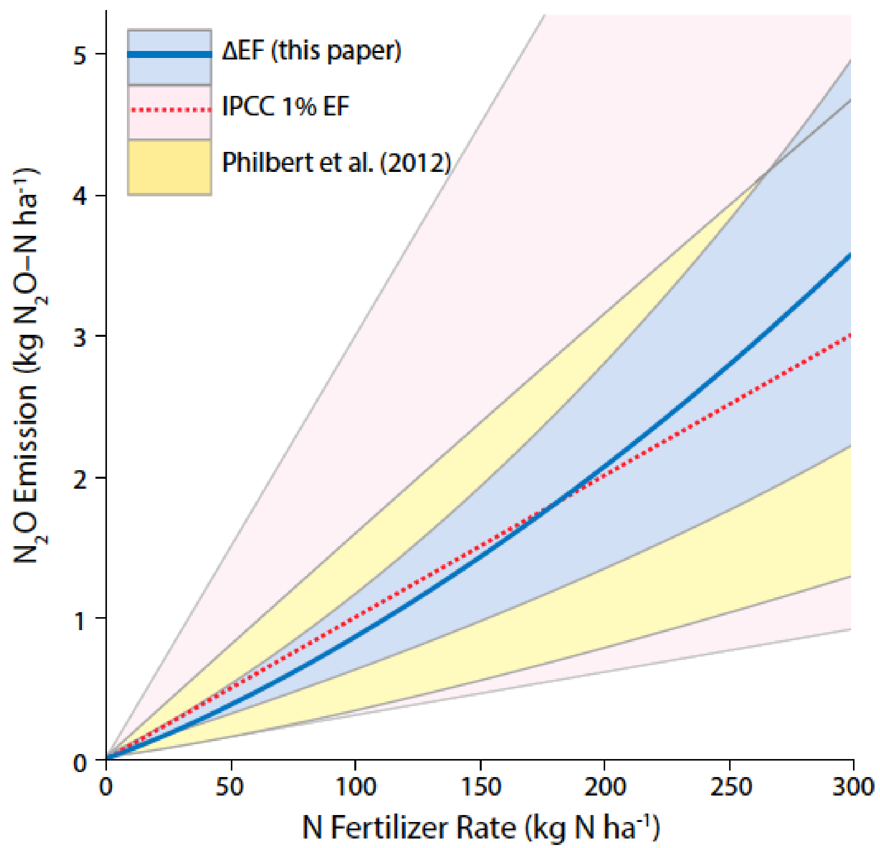
- Regressions N_2O (corrected for non-soil emissions) versus N-input
- Global EF = 2.5 ± 0.6%, China EF = 2.2 ± 0.4% (1.5 ± 0.4%), and Brazil EF = 2.7 ± 0.7%



Thompson, AGU Fall Meeting, 2018

Non-linear response of N_2O?

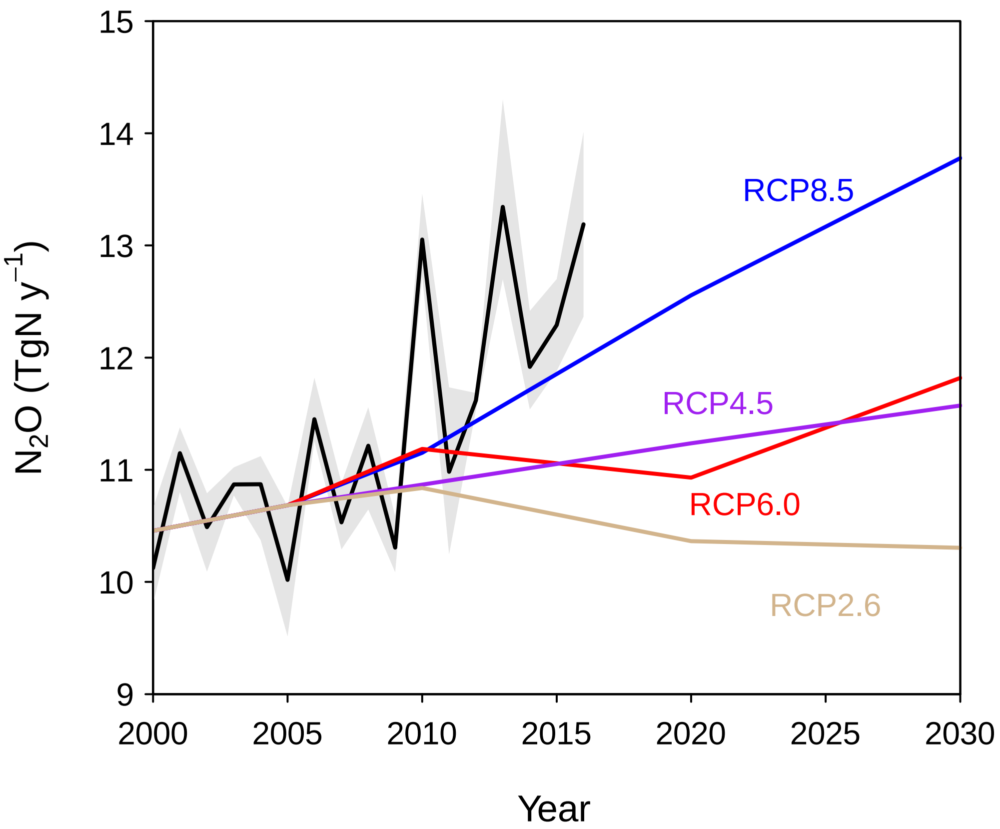
- Based on 78 field studies Shcherbak et al. find quadratic relationship for N_2O response
- Response may be non-linear with high N-fertilizer rates since:
  1. more N-substrate available for nitrification/denitrification
  2. higher yield of N_2O from denitrification when NO_3^- concentration is high
  3. higher N_2O emission when N-availability to microorganisms greater than C-availability



Shcherbak et al., PNAS, 2014

Reality versus RCP scenarios

- Mean of 3 inversions show faster rate of emission increase after 2009 than "business as usual" scenario
- Globally, emissions appear to follow quadratic relationship to N-input

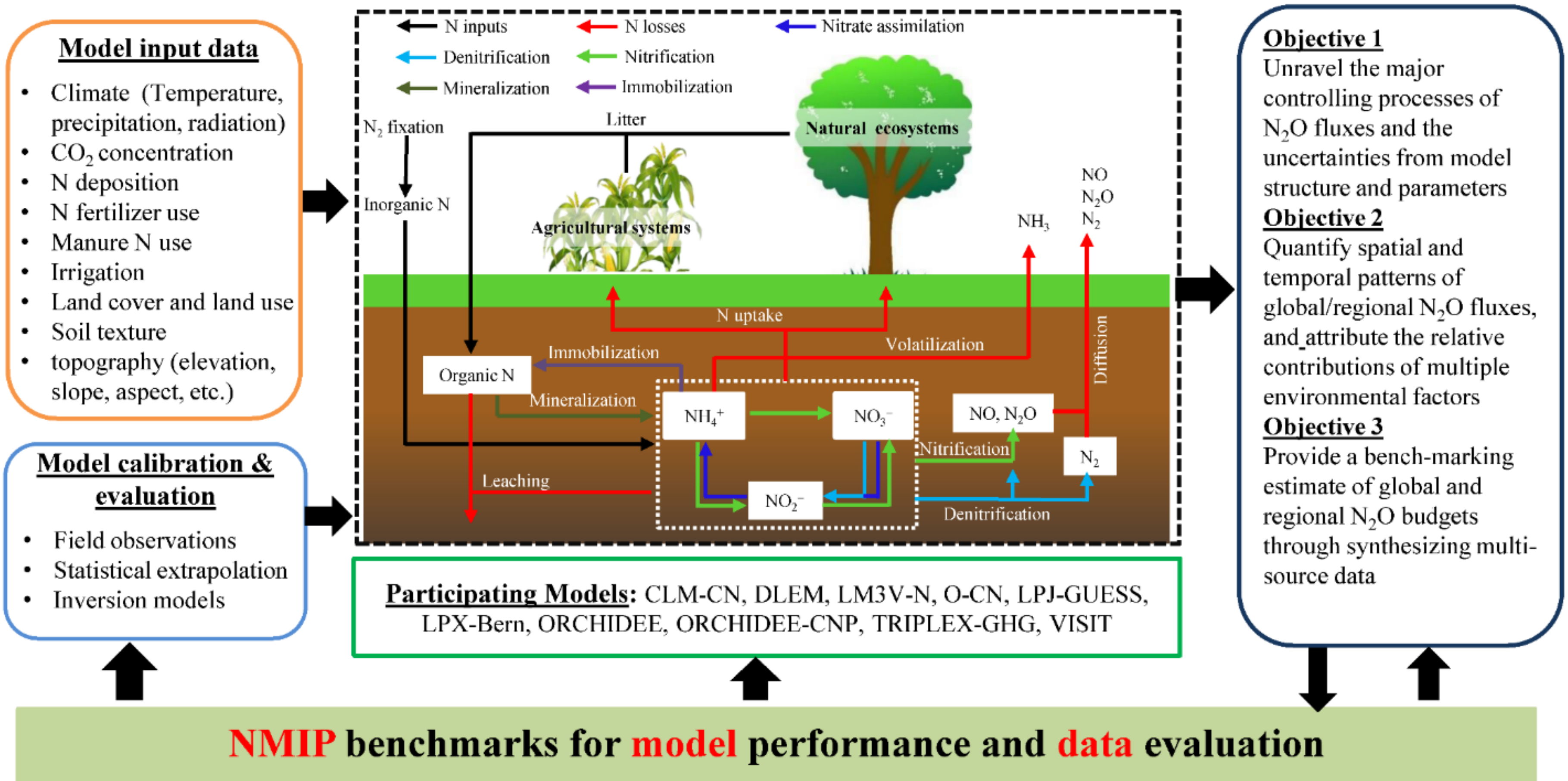


Thompson, AGU Fall Meeting, 2018

NMIP

(slides by Hanqin Tian)

NMIP - Global and regional N_2O model Inter-comparison Project-Framework

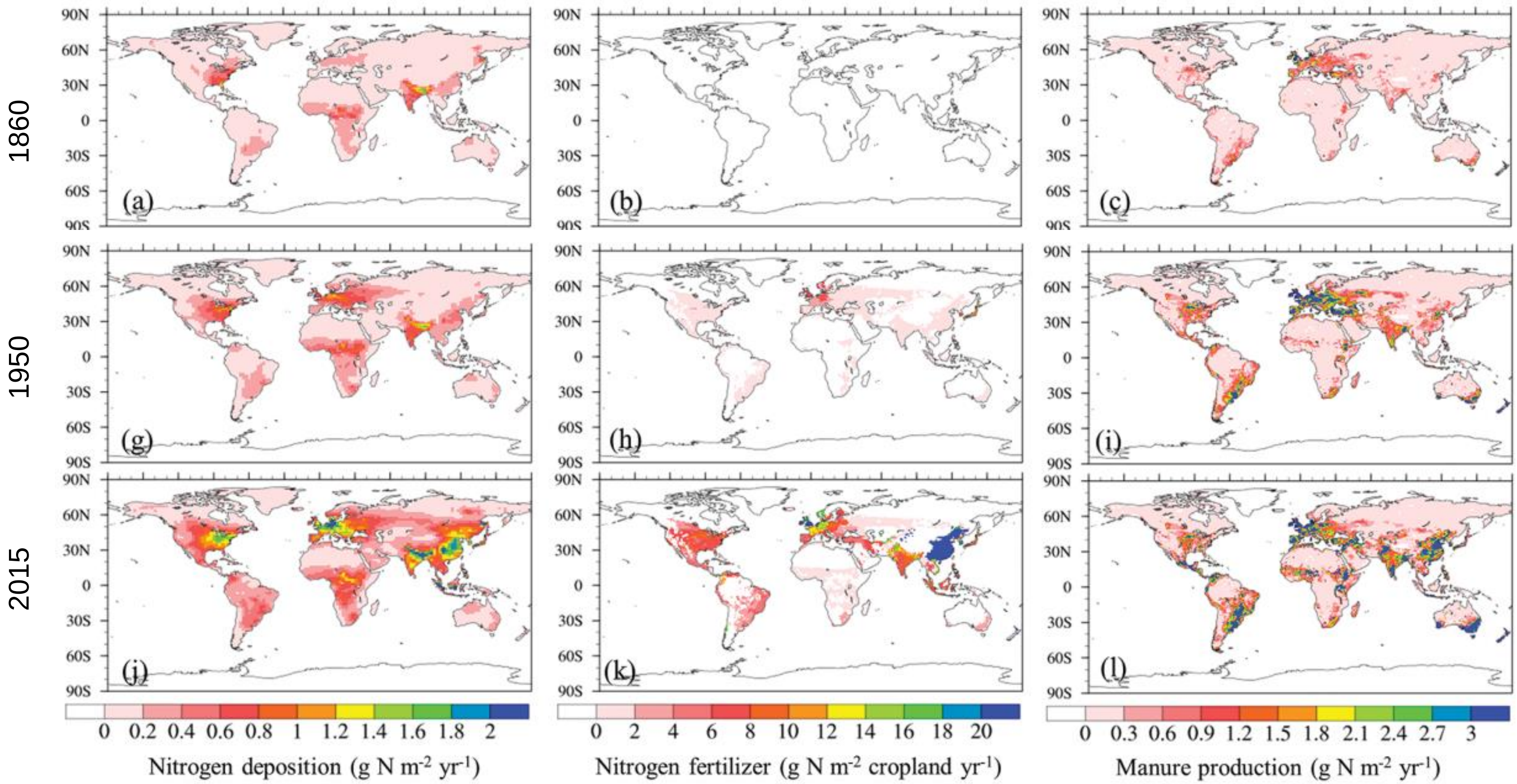


Tian et al., 2018 BAMS

Participating models

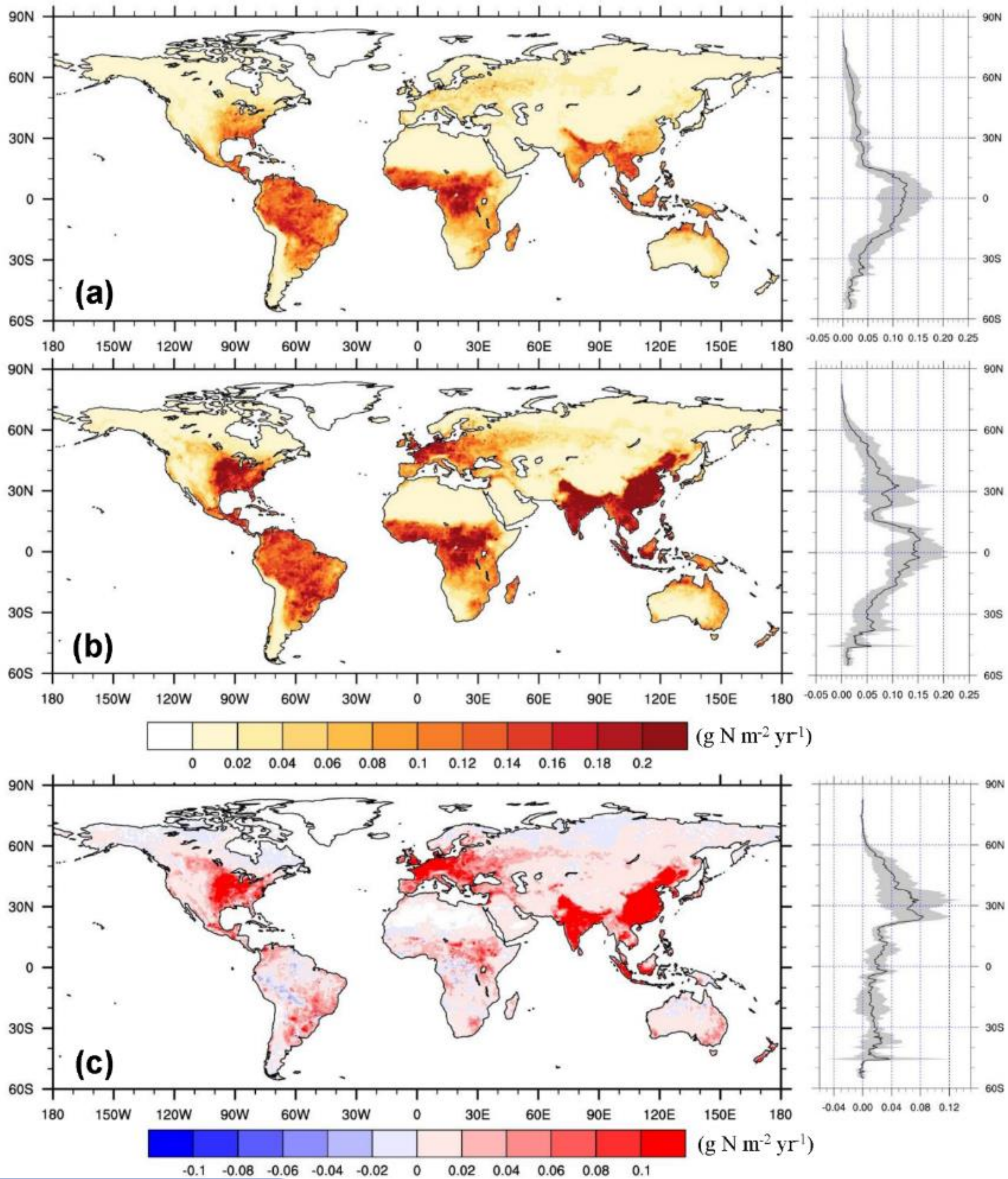
Model	Contact	Affiliation	Citation
CLM-CN	Eri Saikawa	Emory University, USA	Saikawa et al. (2013)
DLEM	Hanqin Tian	Auburn University	Tian et al. (2015) Xu et al. (2017)
LM3V-N	Stefan Gerber	University of Florida	Huang and Gerber (2015)
LPX	Sebastian Lienert	University of Bern	Kelly et al. (2014)
LPJ-GUESS	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)

Gridded (0.5º×0.5º), annual N fertilizer use, Manure N use and Manure N deposition in grassland from 1860 to 2015



Tian et al. (2018) BAMS

The NMIP Project - global results

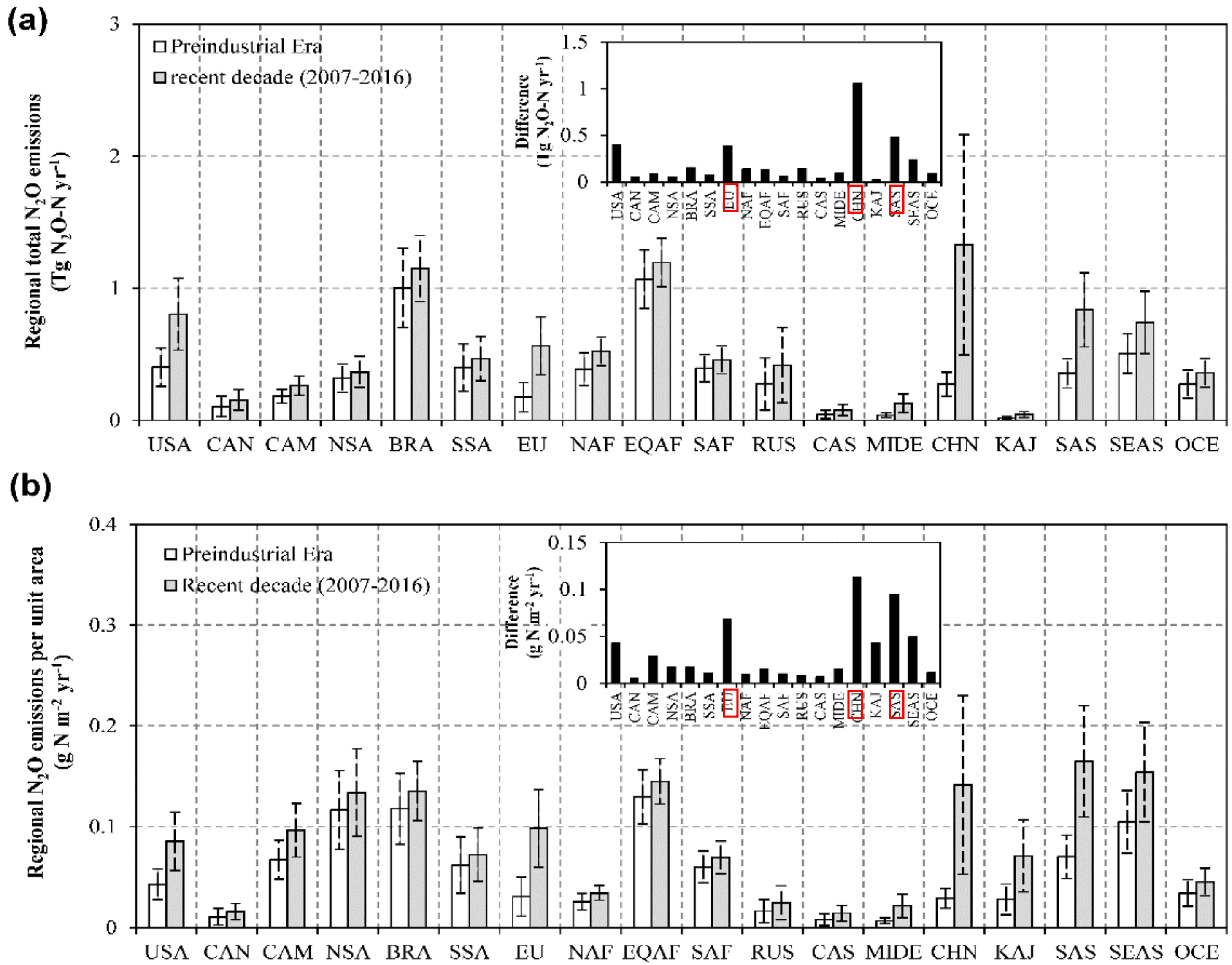


In the preindustrial era, N_2O emissions along a latitudinal gradient (Figure 2a) showed a single peak in the tropics (23.5 °N – 23.5 °S in this study), which contributed 69% to the global total soil N_2O emissions. In the recent decade, N_2O emissions displays two peaks, one in the tropics and the other in the temperate region of the Northern Hemisphere (Figure 2b).

The model-ensemble mean showed that the most significant increases occurred in the mid-latitudes of the Northern Hemisphere. (Figure 2c)

Tian et al., 2018 GCB

The NMIP Project - regional results

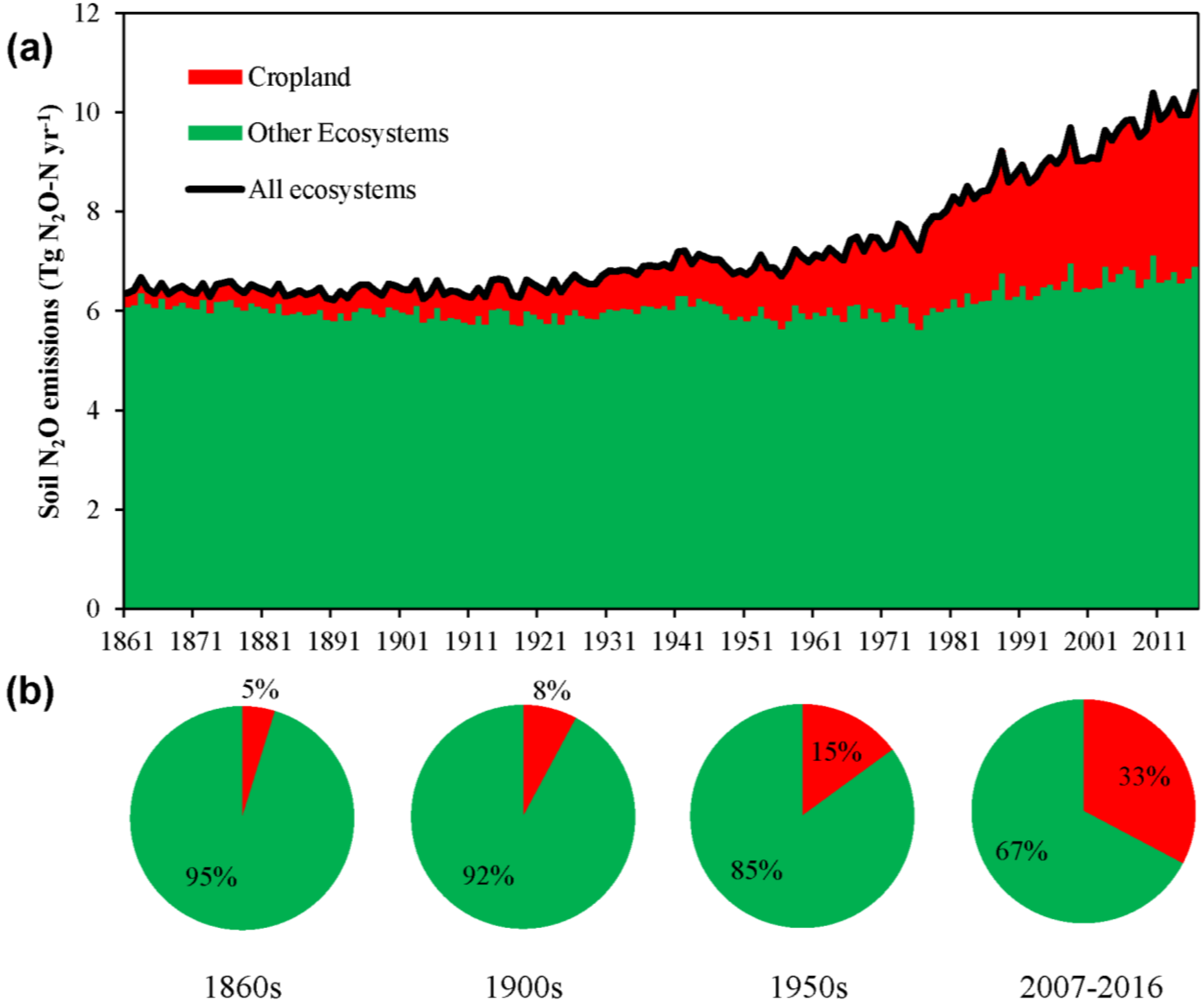


CHN, SAS, and EU were the three regions showing the fastest increases in N_2O emission density.

Tian et al., 2018 GCB

The NMIP Project-biome-level results

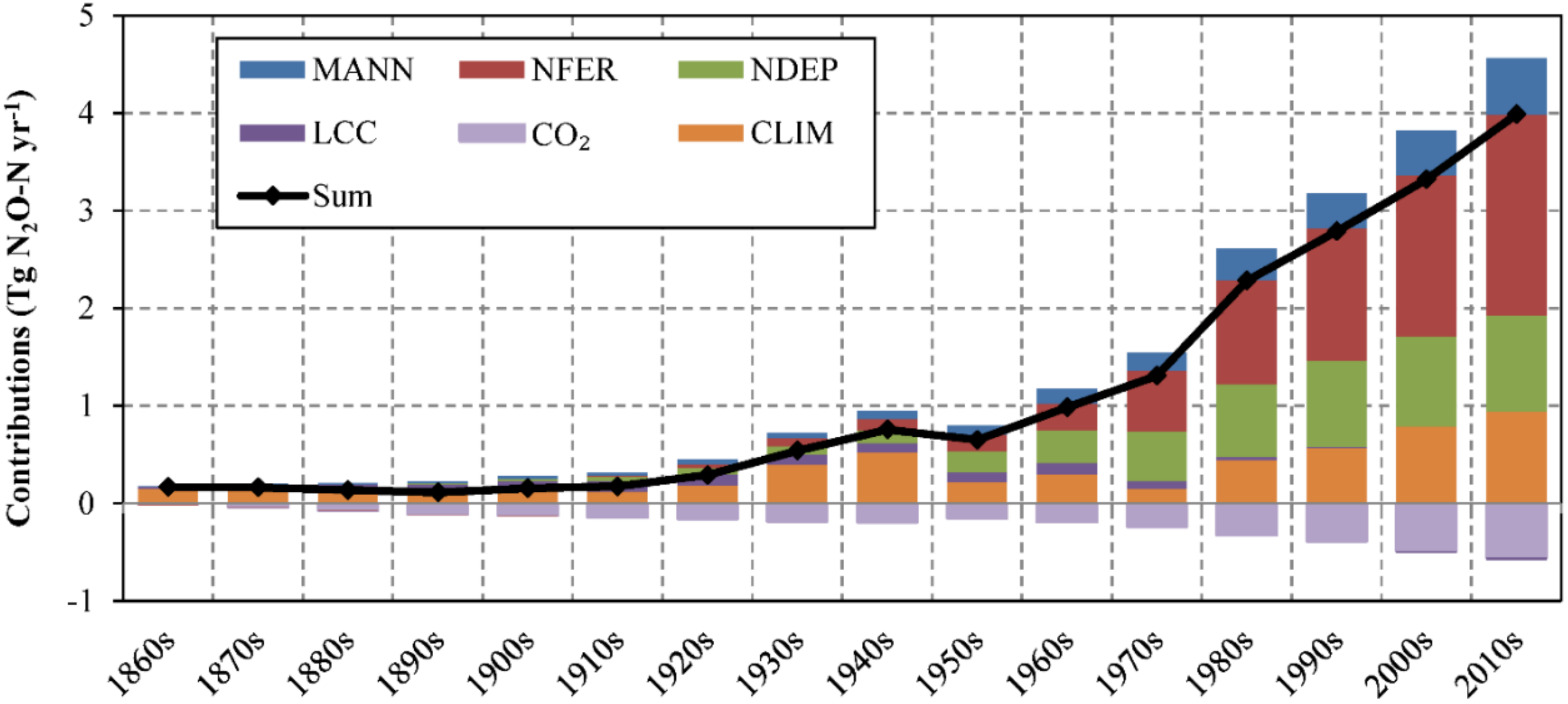
Global cropland soil N_2O emissions increased by 3.0 ± 1.1 Tg N_2O-N yr^{-1} (~11 times) from the pre-industrial period to the recent decade, contributing the majority (82%) to the increased global soil N_2O emissions.



Tian et al., 2018 GCB

The NMIP Project-factorial contributions

Manure and N fertilizer addition (MANN and NFER), N deposition (NDEP) and climate change (CLIM) were found to increase soil N_2O emissions. Rising CO_2 concentration reduced global soil N_2O emissions with its effect increasing through time.
Model ensemble results showed that LCC (land cover change) effects on emissions were close to neutral (-0.0 ± 0.5 Tg N_2O-N yr^{-1} in the recent decade).



Tian et al., 2018 GCB

Remaining challenges for GCP/INI global N_2O budget

Three different approaches

Inversion – land surface modelling – inventories

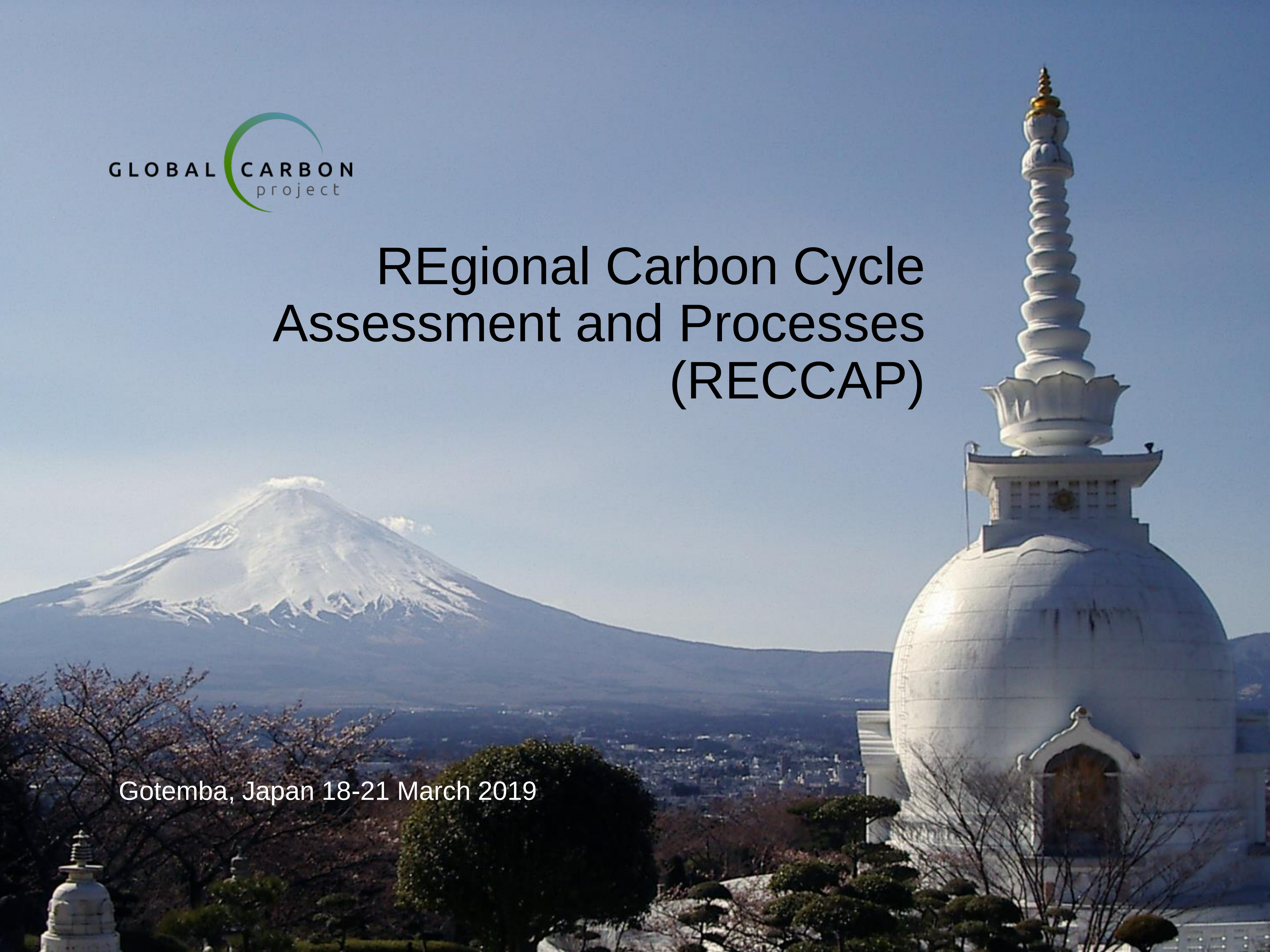
- Different purposes, nomenclatures and system boundaries
- Agreements most easily on trends

N_2O source attribution table

IPCC AR5	Inventory approach (GAINS)	Land surface modelling
Fossil fuel combustion and industrial processes	Energy - conversion	----
	Energy - industry	----
	Energy - transport	----
	Energy - domestic	----
	Nitric acid plants	----
	Adipic acid plants	----
	Caprolactam plants	----
	N2O use	----
Agriculture	Manure management	----
	Soil: Inorganic fertilizer and crop residues	grassland and arable land
	Soil: organic fertilizer	
	Grazing	pasture
	Indirect - Atmos.Depo	emissions appear in grassland, pasture, forests, natural vegetation
	Indirect - leaching	emissions appear in lakes, rivers, sea shelves
	Histosols	emissions appear in grassland and arable land
	Composting	----
Human excreta	Wastewater	----
Biomass and biofuel burning	Included when used as energy source. Not covered: forest/savannah burning	----
Atmospheric deposition on land	"indirect" only cover agricultural N	emissions appear in grassland, pasture, forests, natural vegetation
Atmospheric deposition on ocean	"indirect" only cover agricultural N	emissions appear in oceans
Surface sink	----	----
Rivers, estuaries, coastal zones	"indirect" only cover agricultural N	emissions appear in lakes, rivers, sea shelves
Soils under natural vegetation	----	natural vegetation
Oceans	----	oceans
Lightning	----	----
Atmospheric chemistry	----	----

Upcoming: RECCAP-2

(slides by Pep Canadell)


GLOBAL CARBON project
REgional Carbon Cycle Assessment and Processes (RECCAP)
Gotemba, Japan 18-21 March 2019

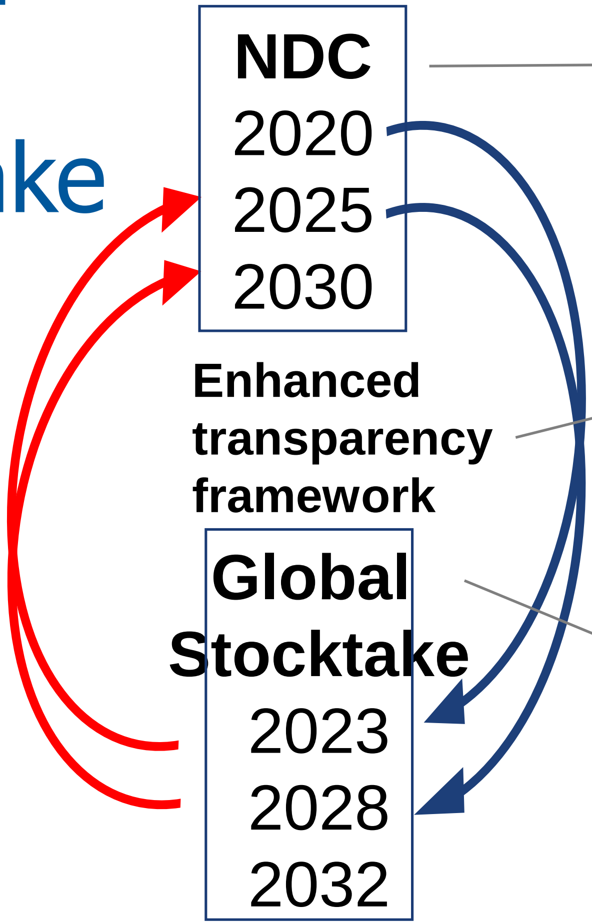
REgional Carbon Cycle Assessment and Processes-2

- to quantify anthropogenic greenhouse gas emissions,
- to develop robust observation-based estimates of changes in carbon storage and greenhouse gas emissions and sinks by the oceans and terrestrial ecosystems,
- to gain science-based evidence of the response of marine and terrestrial regional GHG budgets to climate change and direct anthropogenic drivers.

… includes NMIP-2

Paris Agreement

”The Ambition” cycle & Global Stocktake



Submit new (2025)
or update (2030)
9-12 months before
Communicated individual efforts

Reported individual efforts

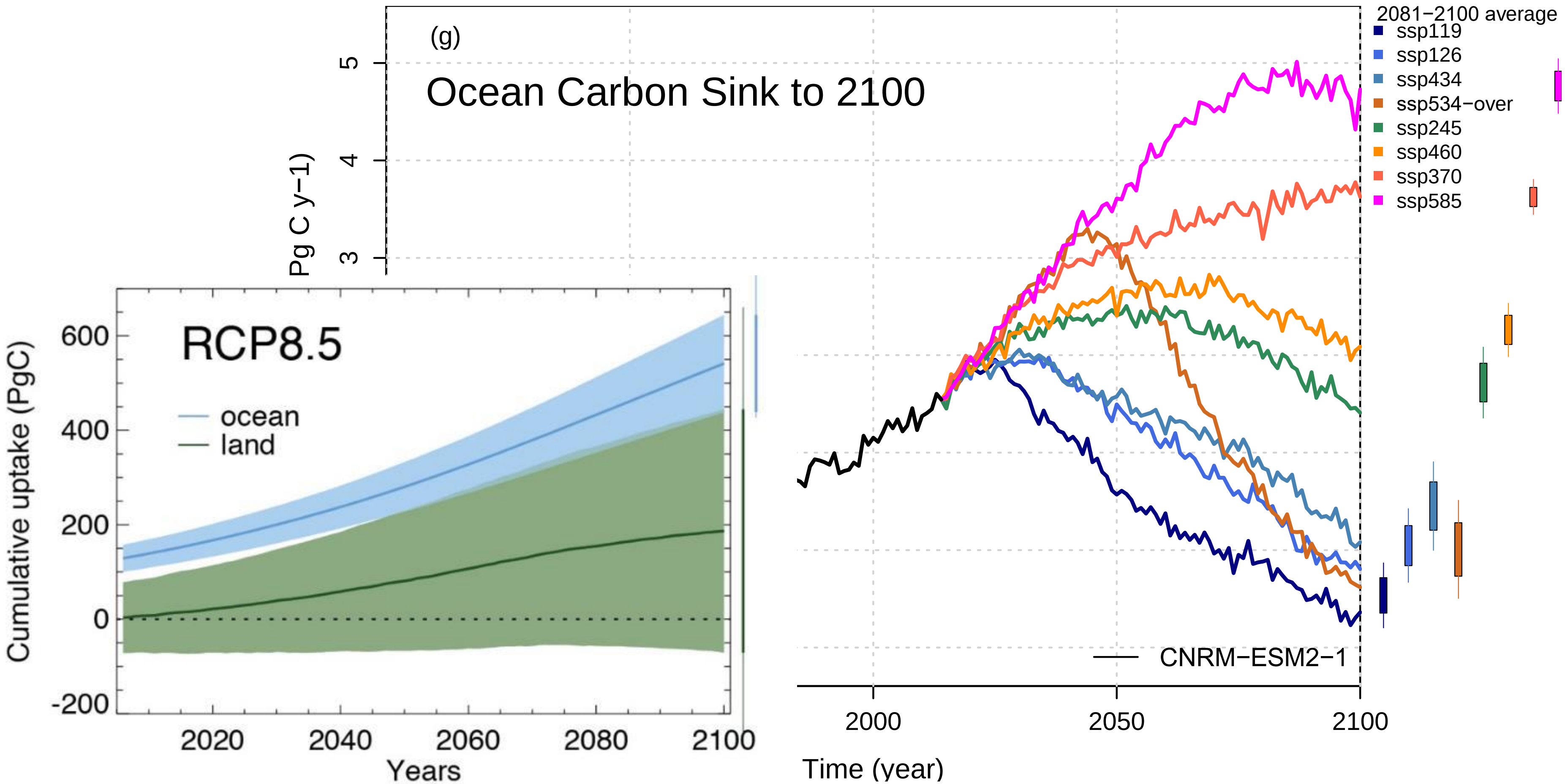
Collective progress towards purpose and long-term global goals

- Where are we?
  Where we want to go?
  How to get there?

Inform updating NDCs in a nationally determined manner (progression clause)

5 years cycle

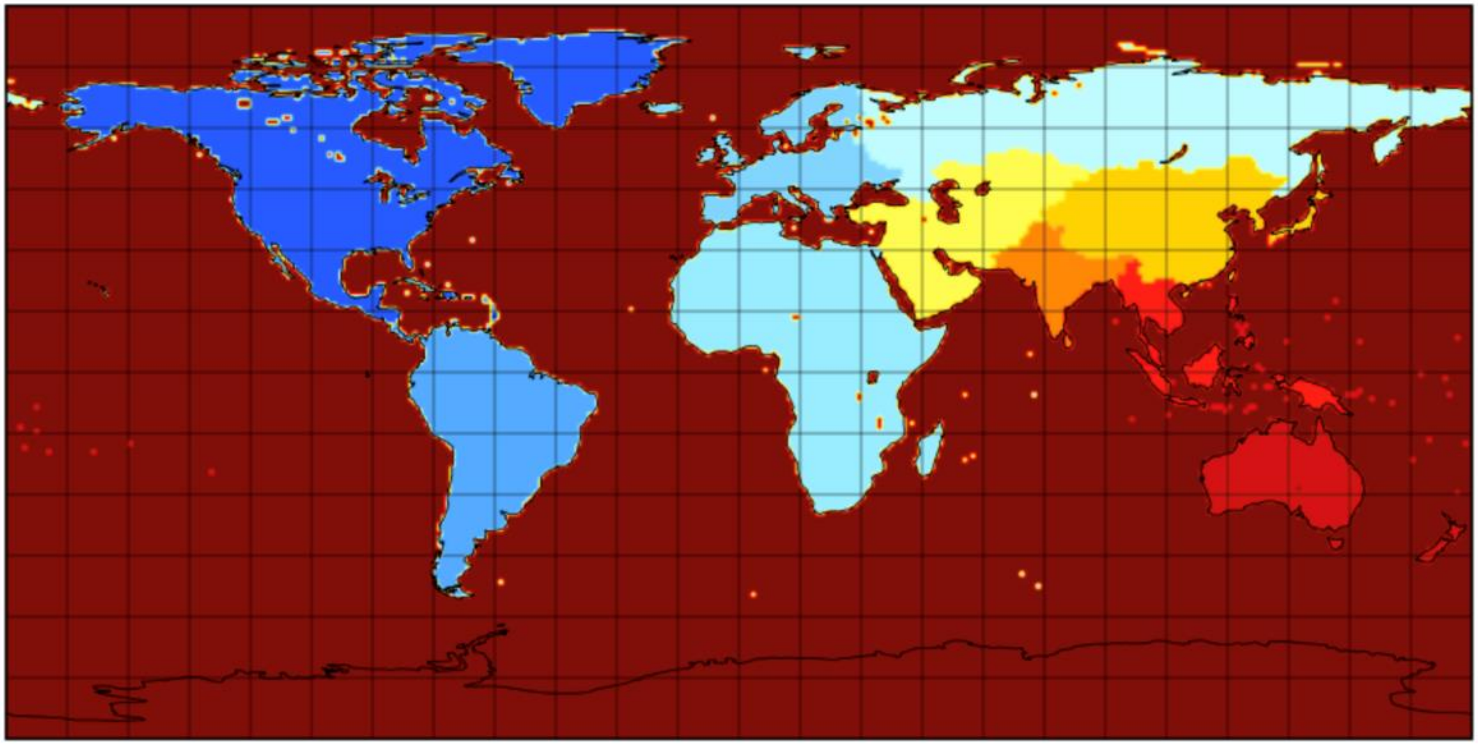
Future Component



Chris Jones, Roland Séférian ppt presentation

The 3-GHG Budgets

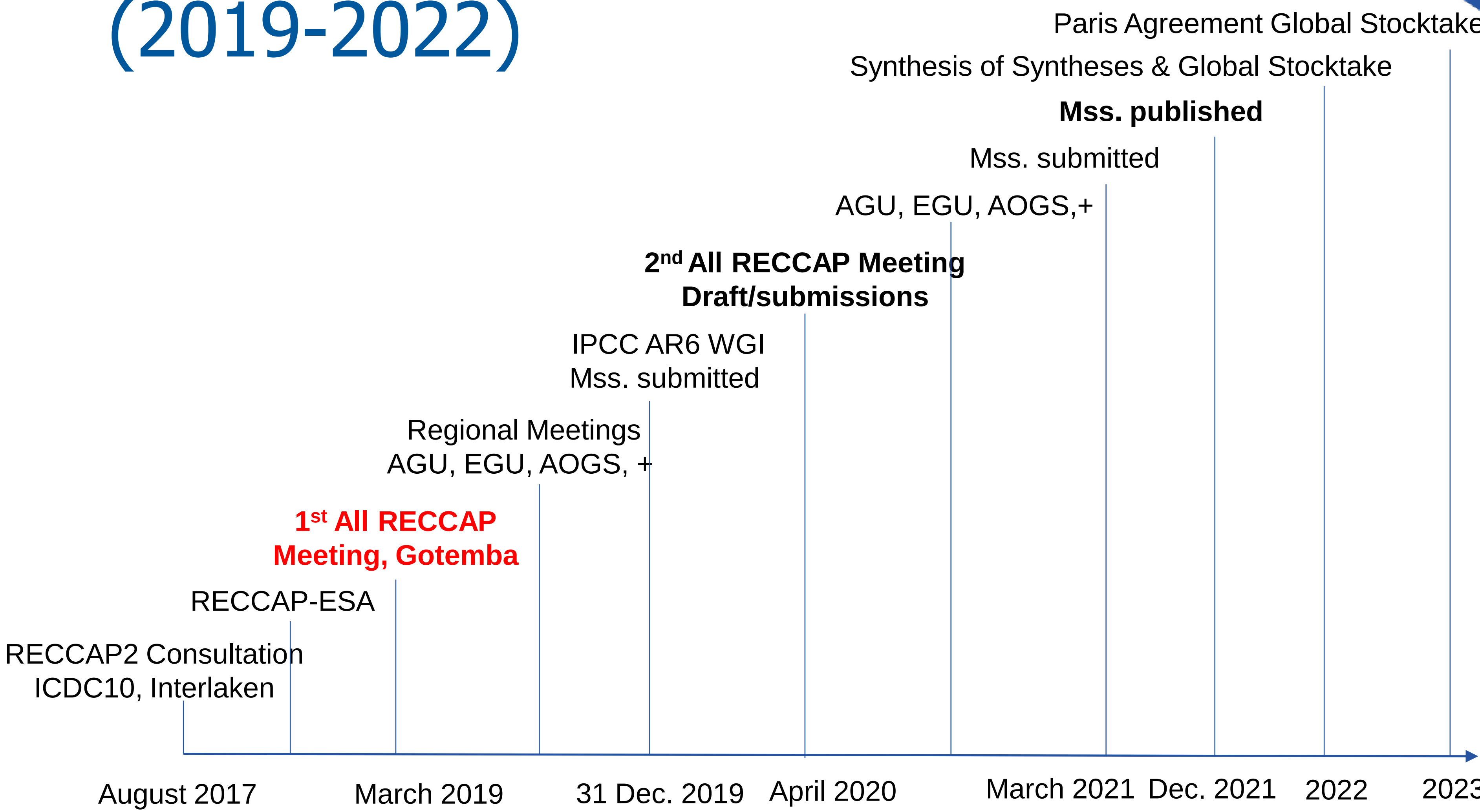
Trends
Variability
Processes



Land

L1	Africa	L6	South America
L2	Australia	L7	East Asia
L3	Europe	L8	Southeast Asia
L4	North America	L9	South Asia
L5	Russia	L10	Western Asia

Timetable RECCAP2 (2019-2022)



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More information:

http://www.globalcarbonproject.org/