Comparison of inversions with inventories of CO2, CH4 and N2O fluxes

Open Access Earth System Science Data Discussions

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https://essd.copernicus.org/preprints/essd-2021-235/

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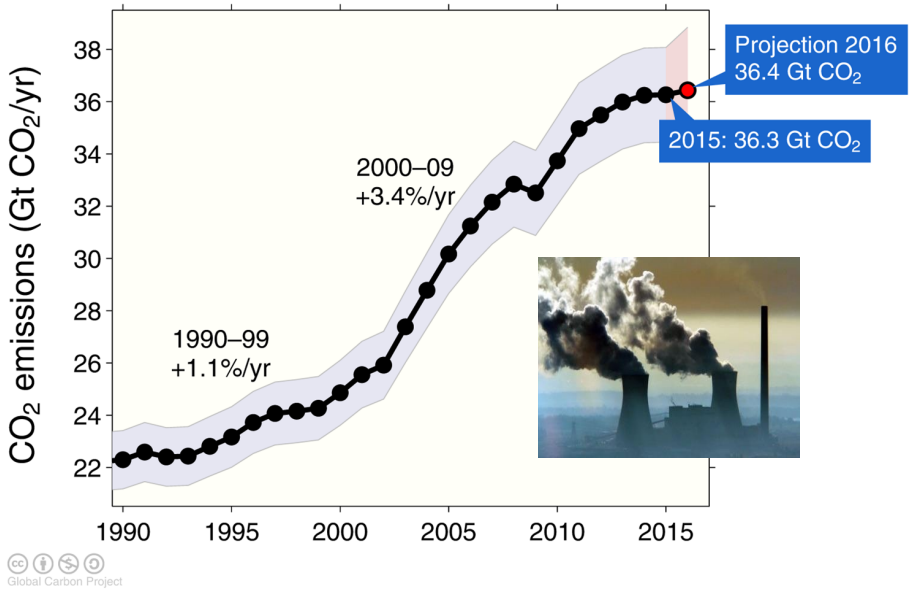
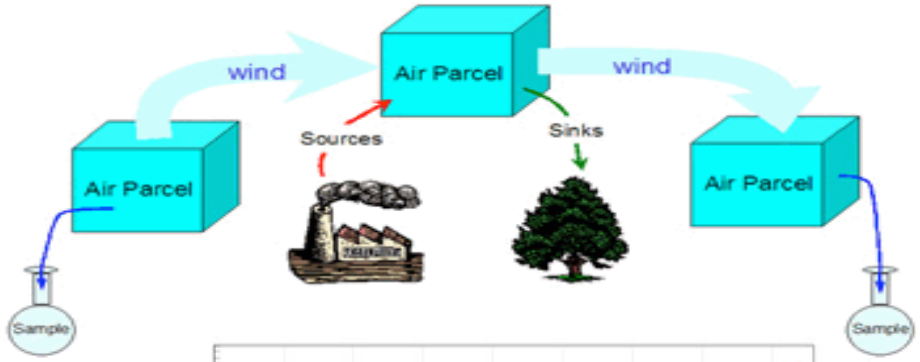
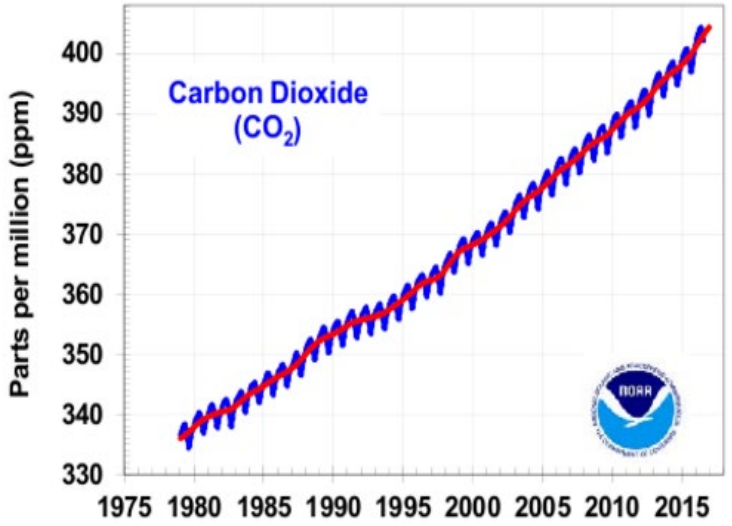
Bottom-up and top-down

CO2 emissions and sinks:
by bottom-up inventories : activity data + emission factors, biomass C and soil C stock change

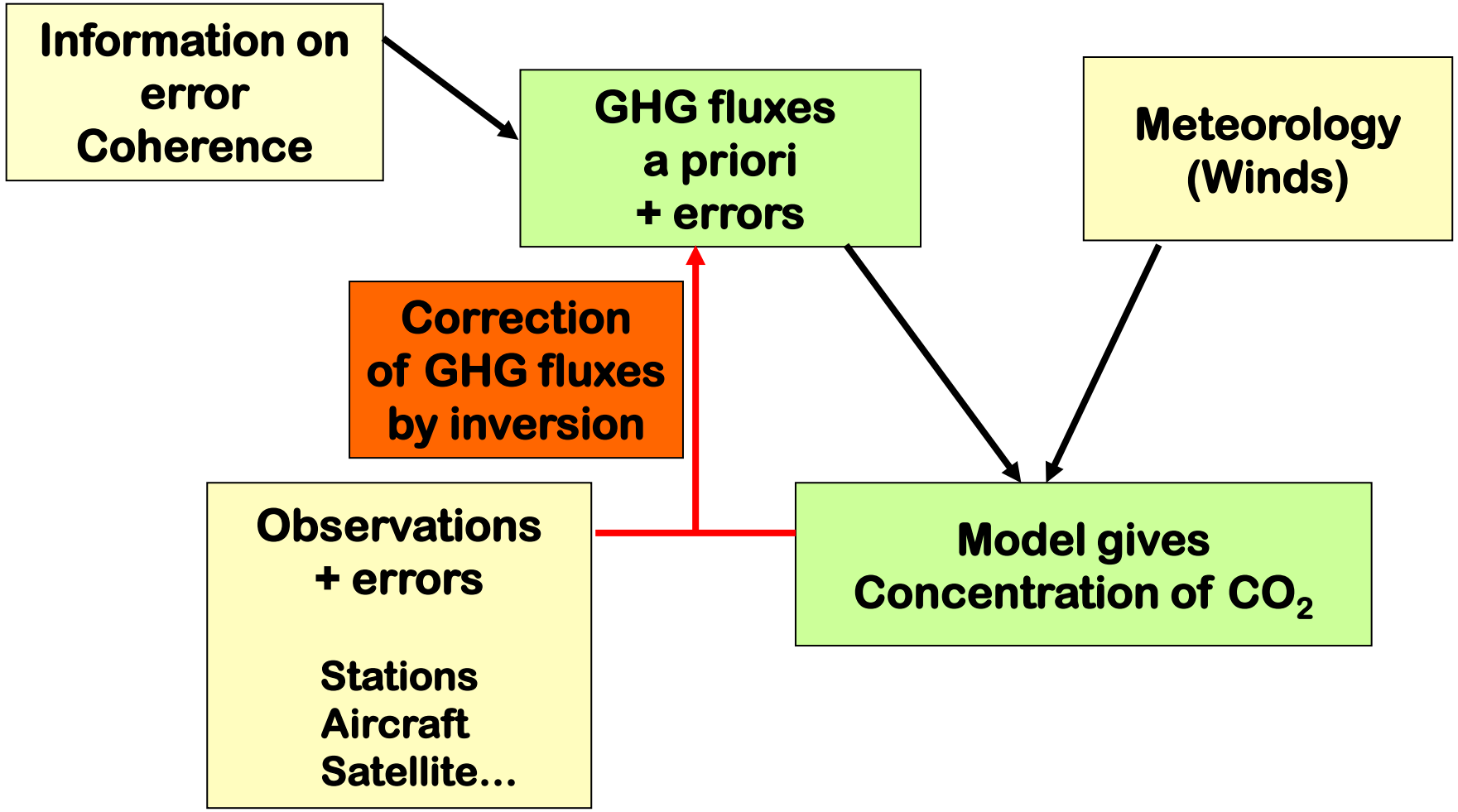


CO2 sinks : prior fossil emissions from inventories, concentration measurements and transport models

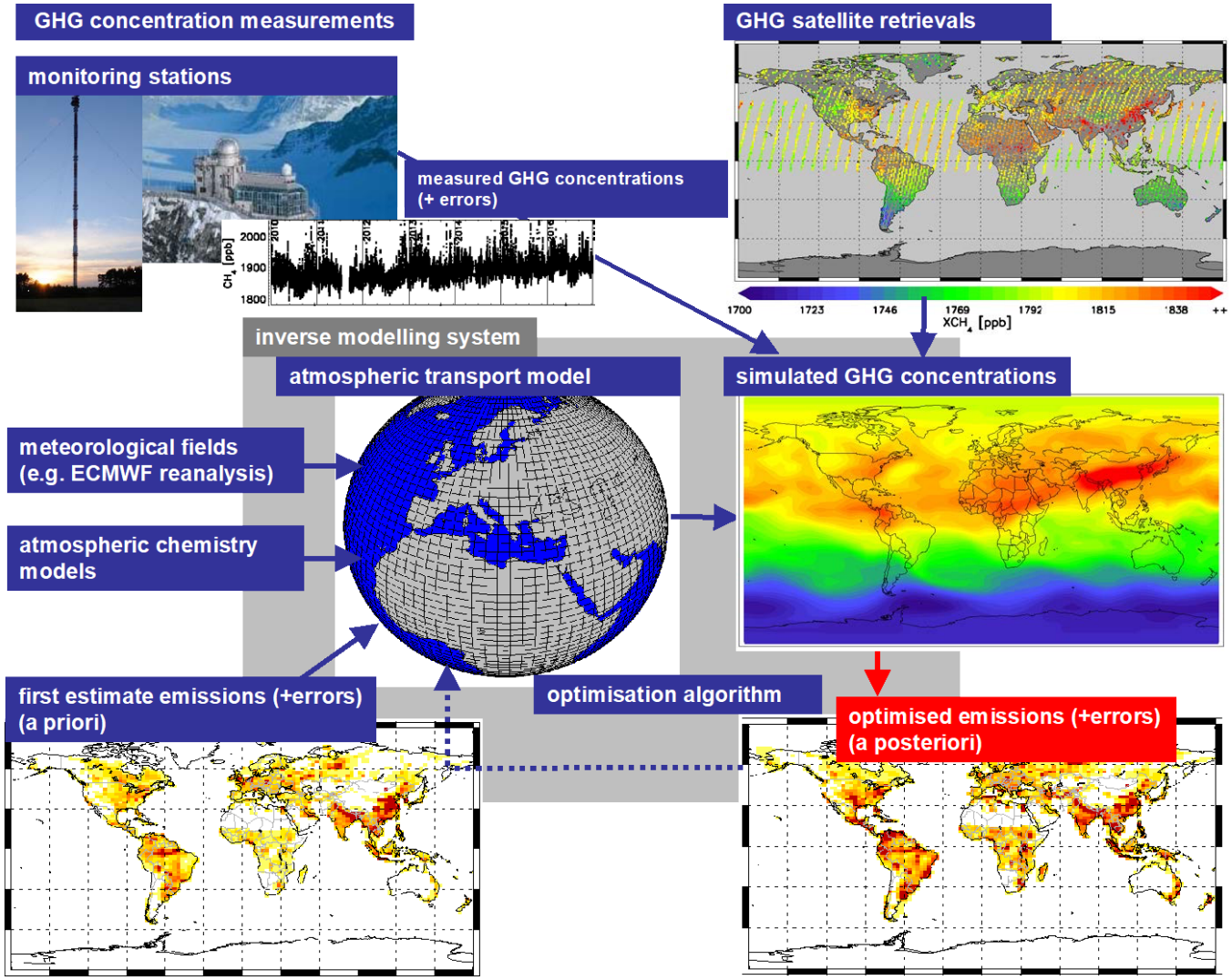




Inversions


Information on error Coherence
GHG fluxes a priori + errors
Meteorology (Winds)
Correction of GHG fluxes by inversion
Observations + errors
Stations
Aircraft
Satellite…
Model gives Concentration of CO_2

Inversions


GHG concentration measurements
monitoring stations
measured GHG concentrations
(+ errors)
GHG satellite retrievals
1700
1723
1746
1769
1792
1815
1838
XCH4 [ppb]
inverse modelling system
atmospheric transport model
meteorological fields
(e.g. ECMWF reanalysis)
atmospheric chemistry
models
simulated GHG concentrations
first estimate emissions (+errors)
(a priori)
optimisation algorithm
optimised emissions (+errors)
(a posteriori)

Global Inversions used in this study

CO2 : 6 in-situ inversions up to 2019
Same prescribed fossil fuel emissions ; only the land flux is optimized
Period 1979-2019
Available but not used :
[2009 -] GOSAT satellite inversions
[2015 -] = OCO2 satellite inversions

CH4 : 17 inversions up to 2017
Separation of sectors in priors in most of them
2000-2017 = 9 in-situ inversions & 2 combined inversions
2009-2017 = 8 satellite inversions (GOSAT)

N2O : 2 inversions up to 2017
2000-2017 = 3 in situ inversions

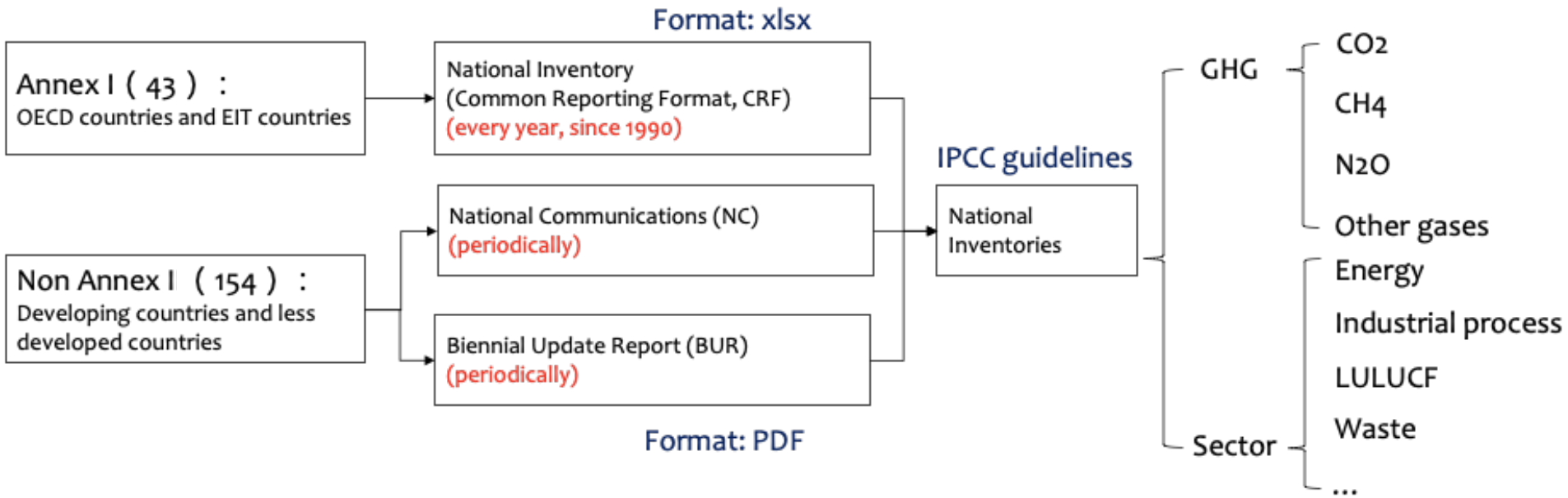
Data from Global carbon project publications

Compilation and harmonisation of National Inventories

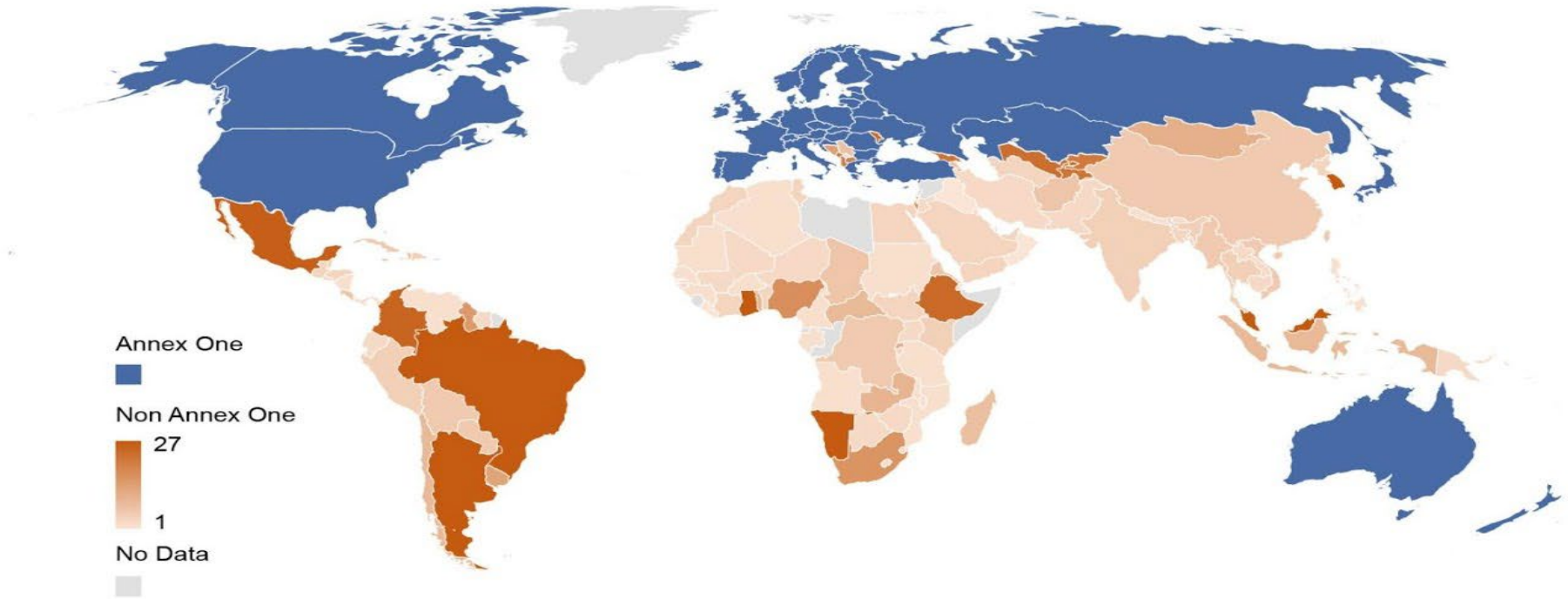
Submitting national inventories periodically to UNFCCC - commitment of the parties

「All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall:(a)Develop, periodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties……」

Format: xlsx



Number of updates of National Inventories



Numbers of years covered by national inventories reports (NC+BUR) in each non-Annex I country

National inventories submitted to UNFCCC (Non Annex I) July 2021

National Communications (NC) & Biennial Update Report (BUR)

National Communications (Total: 396)

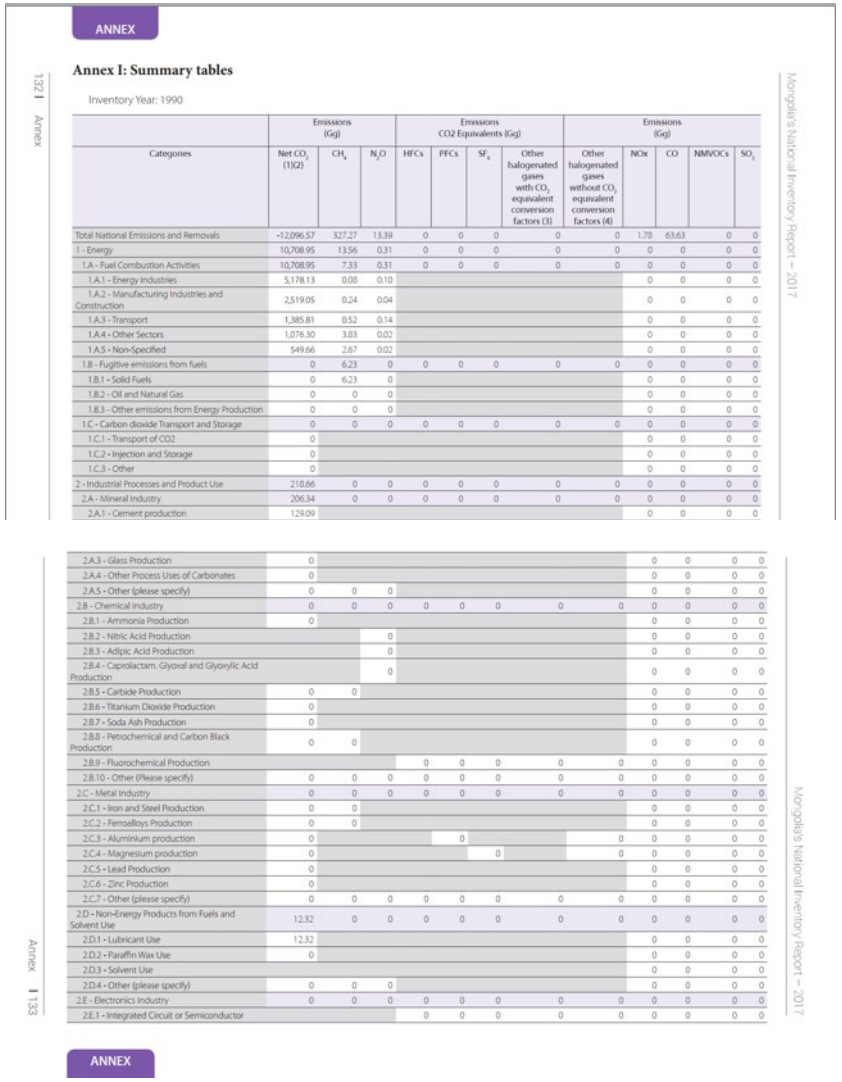
NC cycle	Total	Recent submissions
NC1	154	Equatorial Guinea, 25 October 2019 South Sudan, 19 August 2019 Somalia, 19 January 2019
NC2	143	Andorra, 11 March 2021 Timor-Leste, 17 November 2020 Oman (Sultanate of), 23 December 2019
NC3	85	Vanuatu, 22 March 2021 Malawi, 10 February 2021 Bhutan, 3 February 2021
NC4	11	Brazil, 31 December 2020 Ghana, 3 August 2020 Armenia, 17 May 2020
NC5	2	Mexico, 6 December 2012 Uruguay, 31 December 2019
NC6	1	Mexico, 28 November 2018

Biennial Update Report (Total: 113)

BUR cycle	Total	Recent submissions
BUR1	63	Zambia, 7 December 2020 Cuba, 23 November 2020 Honduras, 19 November 2020
BUR2	32	Panama, 27 March 2021 Morocco, 31 December 2019 Costa Rica, 23 December 2019
BUR3	13	India, 20 February 2021 Malaysia, 31 December 2020 Thailand, 25 December 2020
BUR4	5	Andorra, 11 March 2021 Namibia, 18 February 2021 Chile,18 January 2021

Harmonization and consistency checks (Non Annex I)

Mongolia_BUR1.pdf, P132-139



ANNEX

Annex I: Summary tables

Inventory Year: 1990

Categories	Emissions (Gg) Net CO_2 (1)(2)	CH_4	N_2O	Emissions CO_2 Equivalents (Gg) HFCs	PFCs	SF_6	Other halogenated gases with CO_2 equivalent conversion factors (3)	Other halogenated gases without CO_2 equivalent conversion factors (4)	Emissions (Gg) NOx	CO	NMVOCs	SO_2
Total National Emissions and Removals	-12,096.57	327.27	13.39	0	0	0	0	0	1.78	63.63	0	0
1 - Energy	10,708.95	13.56	0.31	0	0	0	0	0	0	0	0	0
1.A - Fuel Combustion Activities	10,708.95	7.33	0.31	0	0	0	0	0	0	0	0	0
1.A.1 - Energy Industries	5,178.13	0.08	0.10						0	0	0	0
1.A.2 - Manufacturing Industries and Construction	2,519.05	0.24	0.04						0	0	0	0
1.A.3 - Transport	1,385.81	0.52	0.14						0	0	0	0
1.A.4 - Other Sectors	1,076.30	3.83	0.02						0	0	0	0
1.A.5 - Non-Specified	549.66	2.67	0.02						0	0	0	0
1.B - Fugitive emissions from fuels	0	6.23	0	0	0	0	0	0	0	0	0	0
1.B.1 - Solid Fuels	0	6.23	0						0	0	0	0
1.B.2 - Oil and Natural Gas	0	0	0						0	0	0	0
1.B.3 - Other emissions from Energy Production	0	0	0						0	0	0	0
1.C - Carbon dioxide Transport and Storage	0	0	0	0	0	0	0	0	0	0	0	0
1.C.1 - Transport of CO2	0								0	0	0	0
1.C.2 - Injection and Storage	0								0	0	0	0
1.C.3 - Other	0								0	0	0	0
2 - Industrial Processes and Product Use	218.66	0	0	0	0	0	0	0	0	0	0	0
2.A - Mineral Industry	206.34	0	0	0	0	0	0	0	0	0	0	0
2.A.1 - Cement production	129.09								0	0	0	0
2.A.3 - Glass Production	0								0	0	0	0
2.A.4 - Other Process Uses of Carbonates	0								0	0	0	0
2.A.5 - Other (please specify)	0	0	0						0	0	0	0
2.B - Chemical Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.B.1 - Ammonia Production	0								0	0	0	0
2.B.2 - Nitric Acid Production			0						0	0	0	0
2.B.3 - Adipic Acid Production			0						0	0	0	0
2.B.4 - Caprolactam, Glyoxal and Glyoxylic Acid Production			0						0	0	0	0
2.B.5 - Carbide Production	0	0							0	0	0	0
2.B.6 - Titanium Dioxide Production	0								0	0	0	0
2.B.7 - Soda Ash Production	0								0	0	0	0
2.B.8 - Petrochemical and Carbon Black Production	0	0							0	0	0	0
2.B.9 - Fluorochemical Production				0	0	0	0	0	0	0	0	0
2.B.10 - Other (Please specify)	0	0	0	0	0	0	0	0	0	0	0	0
2.C - Metal Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.C.1 - Iron and Steel Production	0	0							0	0	0	0
2.C.2 - Ferroalloys Production	0	0							0	0	0	0
2.C.3 - Aluminium production	0				0		0	0	0	0	0	0
2.C.4 - Magnesium production	0					0	0	0	0	0	0	0
2.C.5 - Lead Production	0								0	0	0	0
2.C.6 - Zinc Production	0								0	0	0	0
2.C.7 - Other (please specify)	0	0	0	0	0	0	0	0	0	0	0	0
2.D - Non-Energy Products from Fuels and Solvent Use	12.32	0	0	0	0	0	0	0	0	0	0	0
2.D.1 - Lubricant Use	12.32								0	0	0	0
2.D.2 - Paraffin Wax Use	0								0	0	0	0
2.D.3 - Solvent Use									0	0	0	0
2.D.4 - Other (please specify)	0	0	0						0	0	0	0
2.E - Electronics Industry	0	0	0	0	0	0	0	0	0	0	0	0
2.E.1 - Integrated Circuit or Semiconductor				0	0	0	0	0	0	0	0	0

Mongolia's National Inventory Report – 2017

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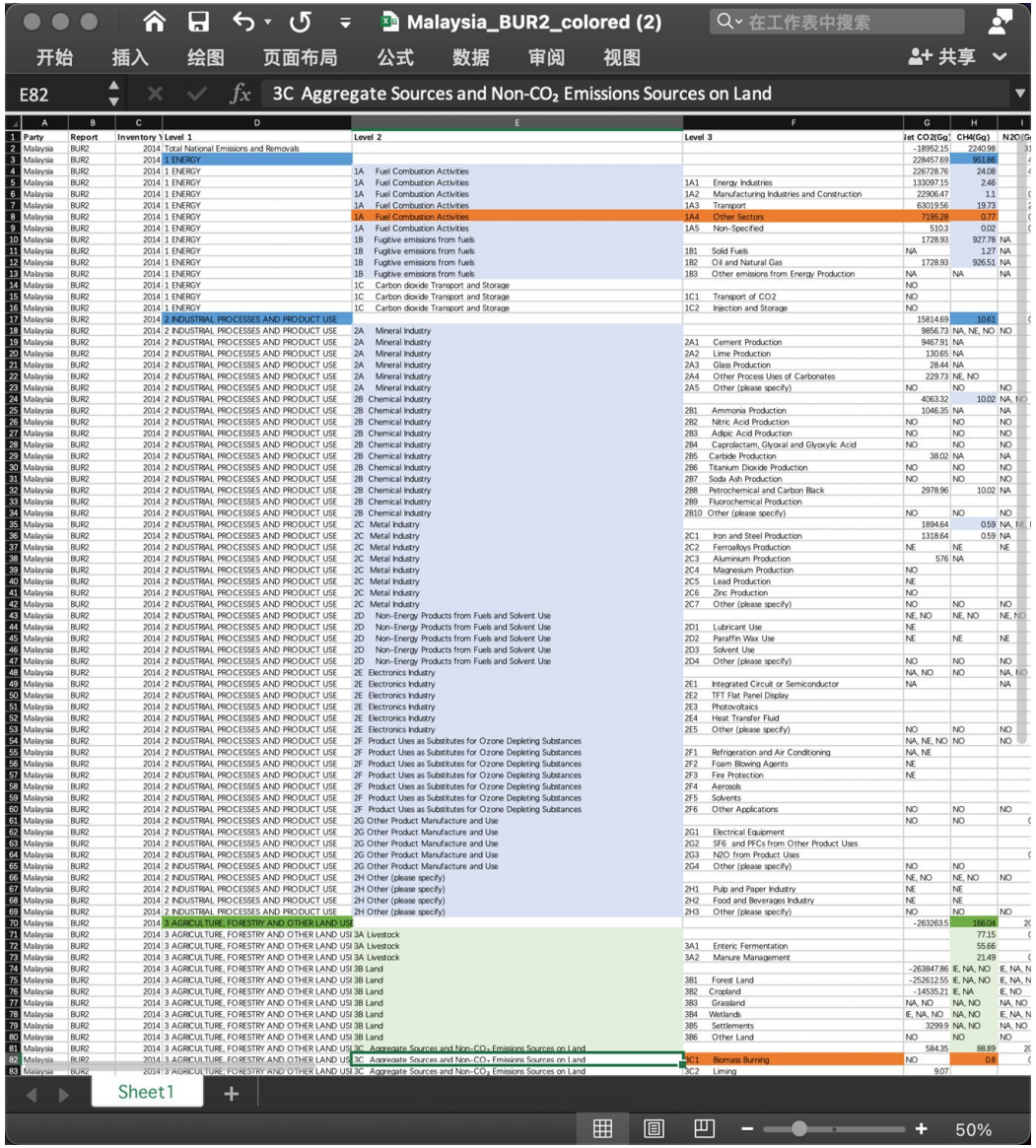
Mongolia's National Inventory Report – 2017

ANNEX



Malaysia_BUR2_colored (2)

E82 | 3C Aggregate Sources and Non-CO_2 Emissions Sources on Land

	A	B	C	D	E	F	G	H	I
1	Party	Report	Inventory \ Level 1	Level 2	Level 3		Net CO2(Gg)	CH4(Gg)	N2O(G
2	Malaysia	BUR2	2014	Total National Emissions and Removals			-18952.15	2240.98	31
3	Malaysia	BUR2	2014	1 ENERGY			228457.69	951.86	
4	Malaysia	BUR2	2014	1 ENERGY	1A Fuel Combustion Activities		226728.76	24.08	
5	Malaysia	BUR2	2014	1 ENERGY	1A Fuel Combustion Activities	1A1 Energy Industries	133097.15	2.46	
6	Malaysia	BUR2	2014	1 ENERGY	1A Fuel Combustion Activities	1A2 Manufacturing Industries and Construction	22906.47	1.1	
7	Malaysia	BUR2	2014	1 ENERGY	1A Fuel Combustion Activities	1A3 Transport	63019.56	19.73	
8	Malaysia	BUR2	2014	1 ENERGY	1A Fuel Combustion Activities	1A4 Other Sectors	7195.28	0.77	
9	Malaysia	BUR2	2014	1 ENERGY	1A Fuel Combustion Activities	1A5 Non-Specified	510.3	0.02	
10	Malaysia	BUR2	2014	1 ENERGY	1B Fugitive emissions from fuels		1728.93	927.78 NA	
11	Malaysia	BUR2	2014	1 ENERGY	1B Fugitive emissions from fuels	1B1 Solid Fuels	NA	1.27 NA	
12	Malaysia	BUR2	2014	1 ENERGY	1B Fugitive emissions from fuels	1B2 Oil and Natural Gas	1728.93	926.51 NA	
13	Malaysia	BUR2	2014	1 ENERGY	1B Fugitive emissions from fuels	1B3 Other emissions from Energy Production	NA	NA NA	
14	Malaysia	BUR2	2014	1 ENERGY	1C Carbon dioxide Transport and Storage		NO		
15	Malaysia	BUR2	2014	1 ENERGY	1C Carbon dioxide Transport and Storage	1C1 Transport of CO2	NO		
16	Malaysia	BUR2	2014	1 ENERGY	1C Carbon dioxide Transport and Storage	1C2 Injection and Storage	NO		
17	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE			15814.69	10.61	
18	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2A Mineral Industry		9856.73	NA, NE, NO NO	
19	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2A Mineral Industry	2A1 Cement Production	9467.91	NA	
20	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2A Mineral Industry	2A2 Lime Production	130.65	NA	
21	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2A Mineral Industry	2A3 Glass Production	28.44	NA	
22	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2A Mineral Industry	2A4 Other Process Uses of Carbonates	229.73	NE, NO	
23	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2A Mineral Industry	2A5 Other (please specify)	NO	NO	NO
24	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry		4063.32	10.02	NA, NO
25	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry	2B1 Ammonia Production	1046.35	NA	NA
26	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry	2B2 Nitric Acid Production	NO	NO	NO
27	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry	2B3 Adipic Acid Production	NO	NO	NO
28	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry	2B4 Caprolactam, Glyoxal and Glyoxylic Acid	NO	NO	NO
29	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry	2B5 Carbide Production	38.02	NA	NA
30	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry	2B6 Titanium Dioxide Production	NO	NO	NO
31	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry	2B7 Soda Ash Production	NO	NO	NO
32	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry	2B8 Petrochemical and Carbon Black	2978.96	10.02	NA
33	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry	2B9 Fluorochemical Production			
34	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2B Chemical Industry	2B10 Other (please specify)	NO	NO	NO
35	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2C Metal Industry		1894.64	0.59	NA, NE
36	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2C Metal Industry	2C1 Iron and Steel Production	1318.64	0.59	NA
37	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2C Metal Industry	2C2 Ferroalloys Production	NE	NE	NE
38	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2C Metal Industry	2C3 Aluminium Production	576	NA	
39	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2C Metal Industry	2C4 Magnesium Production	NO		
40	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2C Metal Industry	2C5 Lead Production	NE		
41	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2C Metal Industry	2C6 Zinc Production	NO		
42	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2C Metal Industry	2C7 Other (please specify)	NO	NO	NO
43	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2D Non-Energy Products from Fuels and Solvent Use		NE, NO	NE, NO	NE, NO
44	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2D Non-Energy Products from Fuels and Solvent Use	2D1 Lubricant Use	NE		
45	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2D Non-Energy Products from Fuels and Solvent Use	2D2 Paraffin Wax Use	NE	NE	NE
46	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2D Non-Energy Products from Fuels and Solvent Use	2D3 Solvent Use			
47	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2D Non-Energy Products from Fuels and Solvent Use	2D4 Other (please specify)	NO	NO	NO
48	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2E Electronics Industry		NA, NO	NO	NA, NO
49	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2E Electronics Industry	2E1 Integrated Circuit or Semiconductor	NA		NA
50	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2E Electronics Industry	2E2 TFT Flat Panel Display			
51	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2E Electronics Industry	2E3 Photovoltaics			
52	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2E Electronics Industry	2E4 Heat Transfer Fluid			
53	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2E Electronics Industry	2E5 Other (please specify)	NO	NO	NO
54	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2F Product Uses as Substitutes for Ozone Depleting Substances		NA, NE, NO	NO	NO
55	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2F Product Uses as Substitutes for Ozone Depleting Substances	2F1 Refrigeration and Air Conditioning	NA, NE		
56	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2F Product Uses as Substitutes for Ozone Depleting Substances	2F2 Foam Blowing Agents	NE		
57	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2F Product Uses as Substitutes for Ozone Depleting Substances	2F3 Fire Protection	NE		
58	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2F Product Uses as Substitutes for Ozone Depleting Substances	2F4 Aerosols			
59	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2F Product Uses as Substitutes for Ozone Depleting Substances	2F5 Solvents			
60	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2F Product Uses as Substitutes for Ozone Depleting Substances	2F6 Other Applications	NO	NO	NO
61	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2G Other Product Manufacture and Use		NO	NO	
62	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2G Other Product Manufacture and Use	2G1 Electrical Equipment			
63	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2G Other Product Manufacture and Use	2G2 SF6 and PFCs from Other Product Uses			
64	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2G Other Product Manufacture and Use	2G3 N2O from Product Uses			
65	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2G Other Product Manufacture and Use	2G4 Other (please specify)	NO	NO	
66	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2H Other (please specify)		NE, NO	NE, NO	NO
67	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2H Other (please specify)	2H1 Pulp and Paper Industry	NE	NE	
68	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2H Other (please specify)	2H2 Food and Beverages Industry	NE	NE	
69	Malaysia	BUR2	2014	2 INDUSTRIAL PROCESSES AND PRODUCT USE	2H Other (please specify)	2H3 Other (please specify)	NO	NO	NO
70	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE			-263263.5	166.04	2
71	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3A Livestock			77.15	
72	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3A Livestock	3A1 Enteric Fermentation		55.66	
73	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3A Livestock	3A2 Manure Management		21.49	
74	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3B Land		-263847.86	IE, NA, NO	IE, NA, N
75	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3B Land	3B1 Forest Land	-252612.55	IE, NA, NO	IE, NA, N
76	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3B Land	3B2 Cropland	-14535.21	IE, NA	IE, NO
77	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3B Land	3B3 Grassland	NA, NO	NA, NO	NA, NO
78	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3B Land	3B4 Wetlands	IE, NA, NO	NA, NO	IE, NA, N
79	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3B Land	3B5 Settlements	3299.9	NA, NO	NA, NO
80	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3B Land	3B6 Other Land	NO	NO	NO
81	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3C Aggregate Sources and Non-CO_2 Emissions Sources on Land		584.35	88.89	2
82	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3C Aggregate Sources and Non-CO_2 Emissions Sources on Land	3C1 Biomass Burning	NO	0.8	
83	Malaysia	BUR2	2014	3 AGRICULTURE, FORESTRY AND OTHER LAND USE	3C Aggregate Sources and Non-CO_2 Emissions Sources on Land	3C2 Liming	9.07		

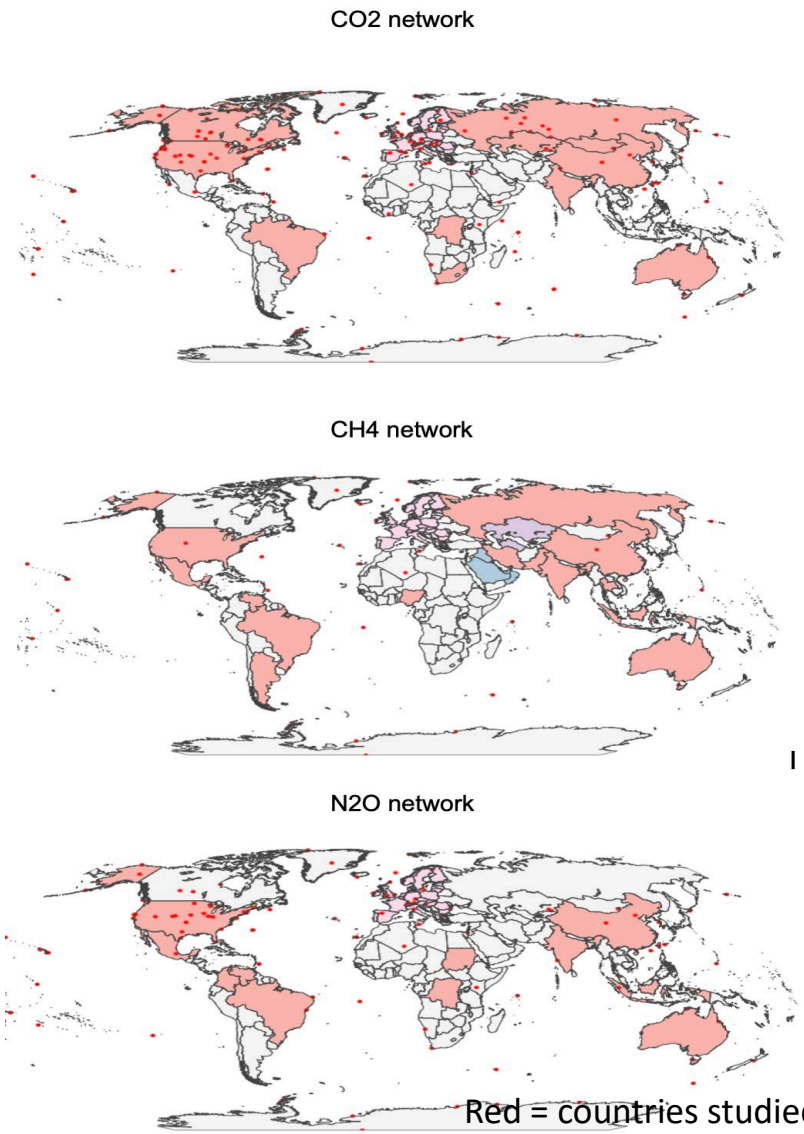
Sheet1

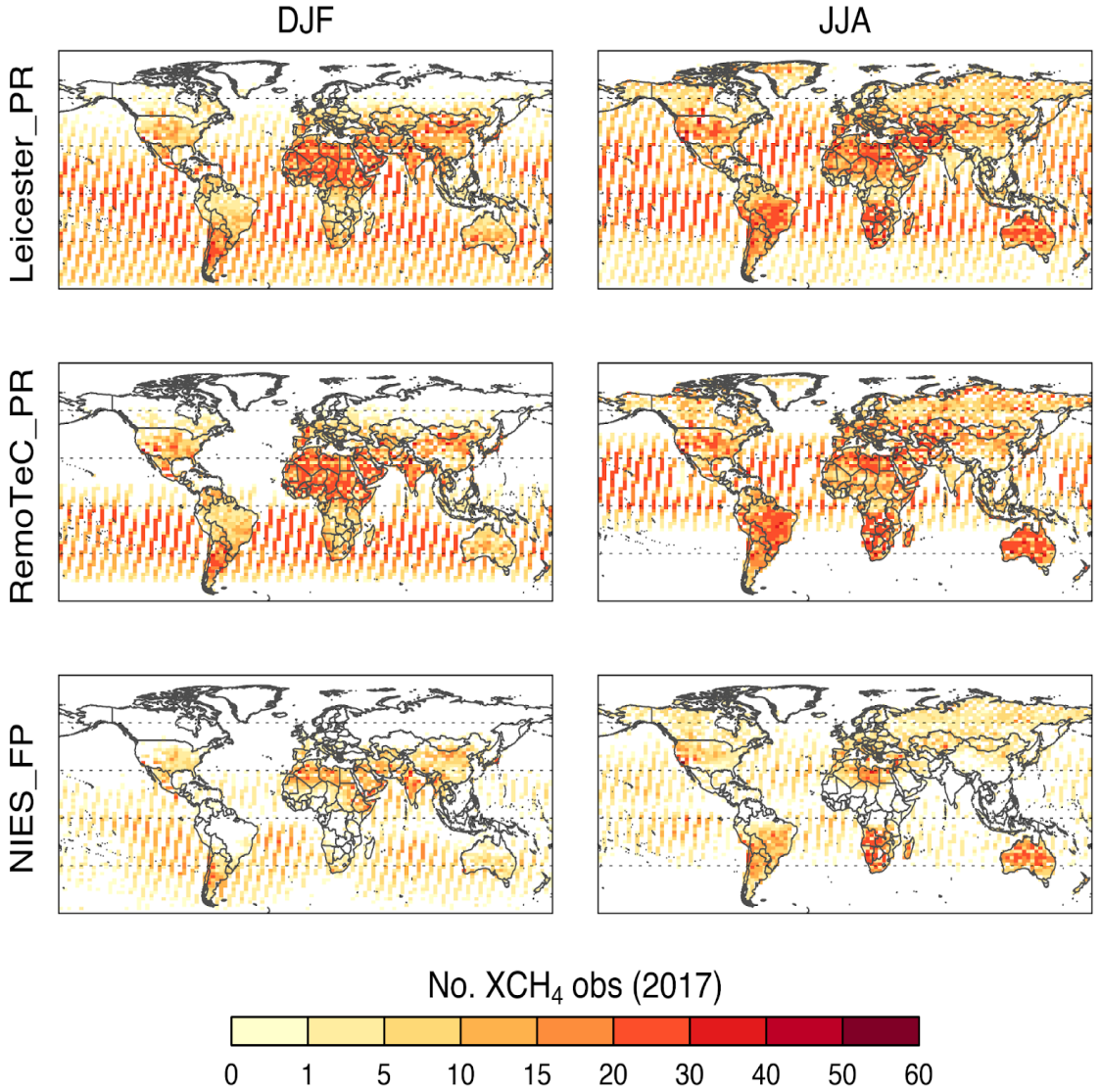
50%

Selected countries (top 12 emitters)

Gas	Sector	Country List
CO_2	Net Land Flux	AUS, BRA, CAN, CHN, COD, EUR, IND, KAZ, MNG, RUS, USA, ZAF
CH_4	Anthropogenic	ARG, AUS, BRA, CHN, EUR, IDN, IND, IRN, MEX, PAK, RUS, USA
	Fossil (including oil, gas, coal)	CHN, EUR, GULF, IDN, IND, IRN, KT, MEX, NGA, RUS, USA, VEN
	Agriculture & waste	ARG, BGD, BRA, CHN, EUR, IDN, IND, MEX, PAK, RUS, THA, USA
N_2O	Anthropogenic	AUS, BRA, CHN, COD, COL, EUR, IDN, IND, MEX, SDN, USA, VEN

Coverage by in-situ networks & (for CH4) by GOSAT soundings





Grouping of sectors from National Inventories to match inversions

Gas	Aggregated sectors in this study	Inversions	Inventories
CO_2	Net Land Flux	Total - Fossil	Net emissions - (Energy + Industrial Processes)
CH_4	Total Anthropogenic	Fossil + Agriculture & Waste + Biomass Burning	Energy + Industrial Processes + Agriculture + Waste + Biomass Burning
	Fossil (including oil, gas, coal)	Fossil	Energy + Industrial Processes - Biofuel Burning*
	Agriculture & Waste	Agriculture & Waste	Agriculture + Waste - Field burning of agricultural residues**
N_2O	Anthropogenic	Total - pre-industrial	Agriculture + Waste direct + anthropogenic

Processing of inversions to make them comparable to inventories

CO_2

$$F_{ant}^{inv\ NEE} = F_{managed\ land}^{inv\ NEE} - F_{tot}^{rivers} - F_{ant}^{crop\ trade} - F_{ant}^{wood\ trade} \Leftrightarrow F_{ant}^{ni}$$

CH_4

Method 1

$$E_{Anth}^{inv} = E_{AgW}^{inv} + E_{FF}^{inv} + E_{BB}^{inv} - E_{wildfires}^{BU} \Leftrightarrow E_{Anth}^{ni}$$

Rely on each inversions solution of anthropogenic sources and remove wildfires

Method 2

$$E_{Anth}^{inv} = E_{AgW}^{inv} + E_{FF}^{inv} + E_{BB}^{inv} - E_{wildfires}^{BU} \Leftrightarrow E_{Anth}^{ni}$$

Remove from inversions median of inversion natural sources for wetlands and rivers

Method 3

$$E_{Ant}^{inv} = E_{tot}^{inv} - E_{Ter}^{BU} - E_{Wet}^{BU} - E_{Fre}^{BU} - E_{Geo}^{BU} - E_{wildfires}^{BU} \Leftrightarrow E_{ant}^{ni}$$

Remove from inversions median of natural sources from bottom-up estimates

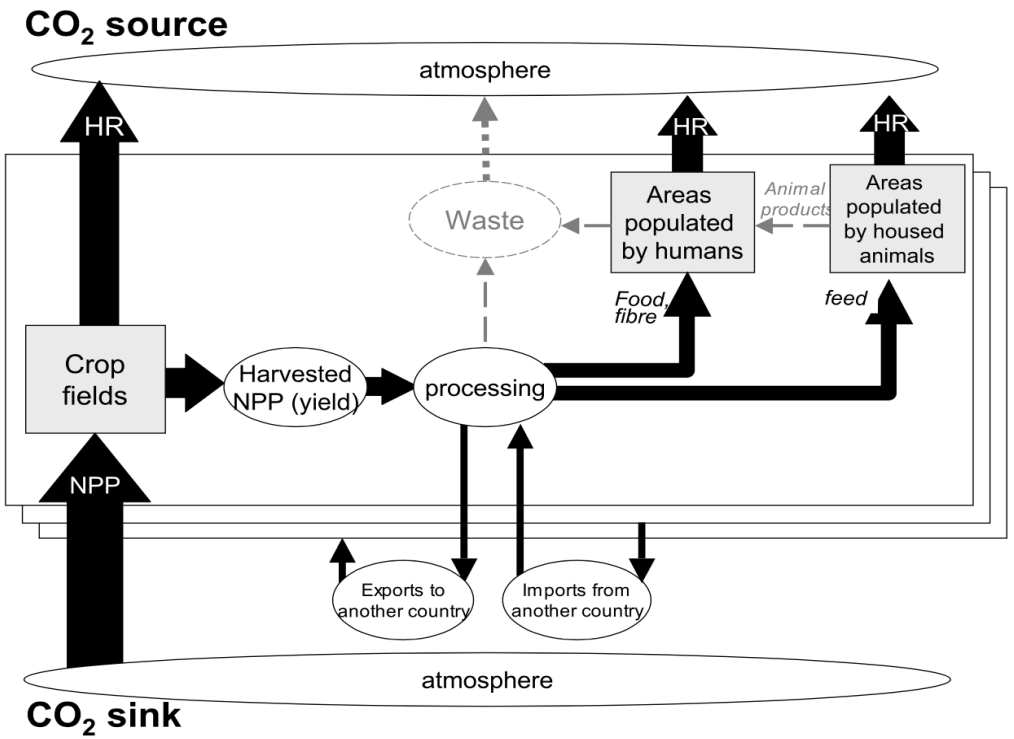
N_2O

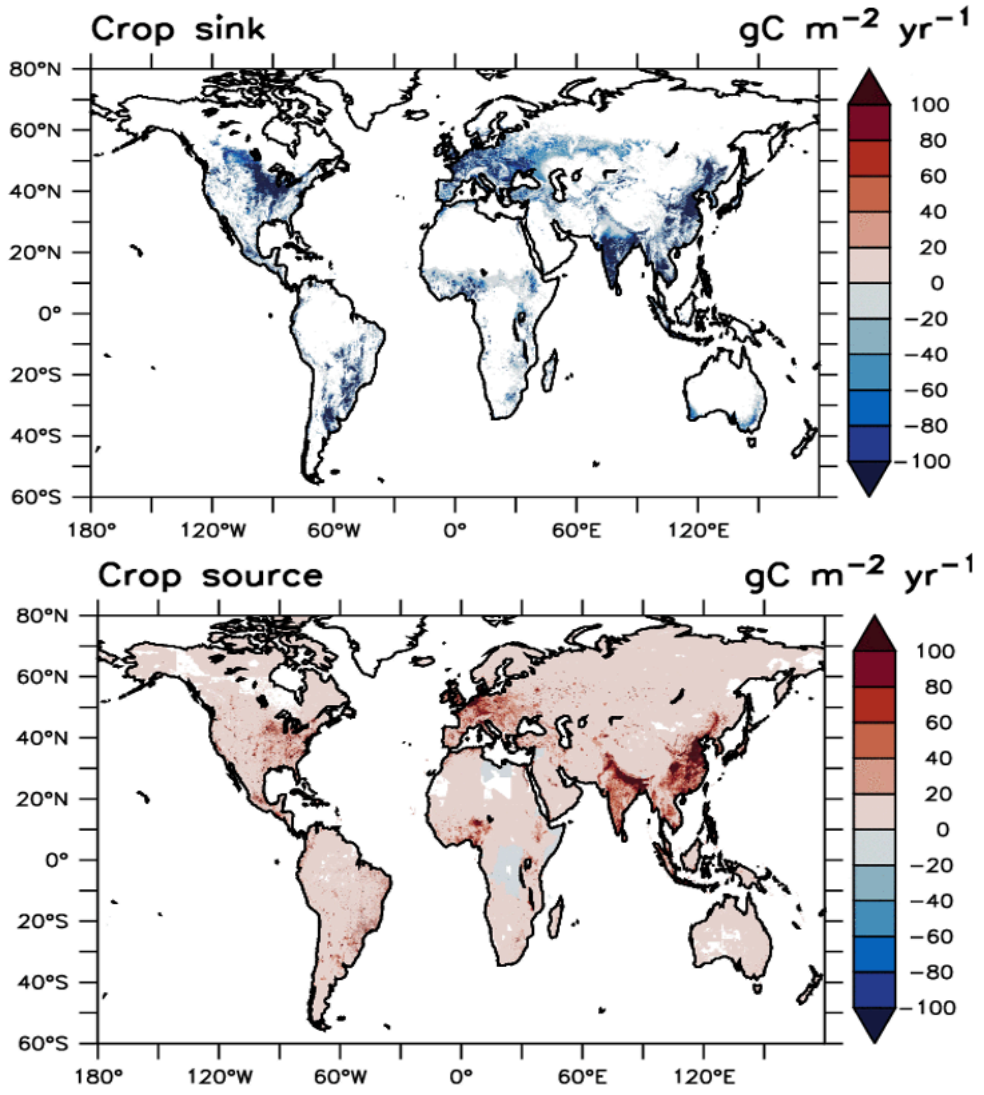
$$E_{ant}^{inv} = E_{managed\ land}^{inv} - E_{nat}^{aq} - E_{wildfires}^{GFED} \Leftrightarrow E_{ant}^{ni}$$

Remove from inversions natural sources from bottom-up estimates

Removing CO2 fluxes that give no stock change and are not surveyed by inventories

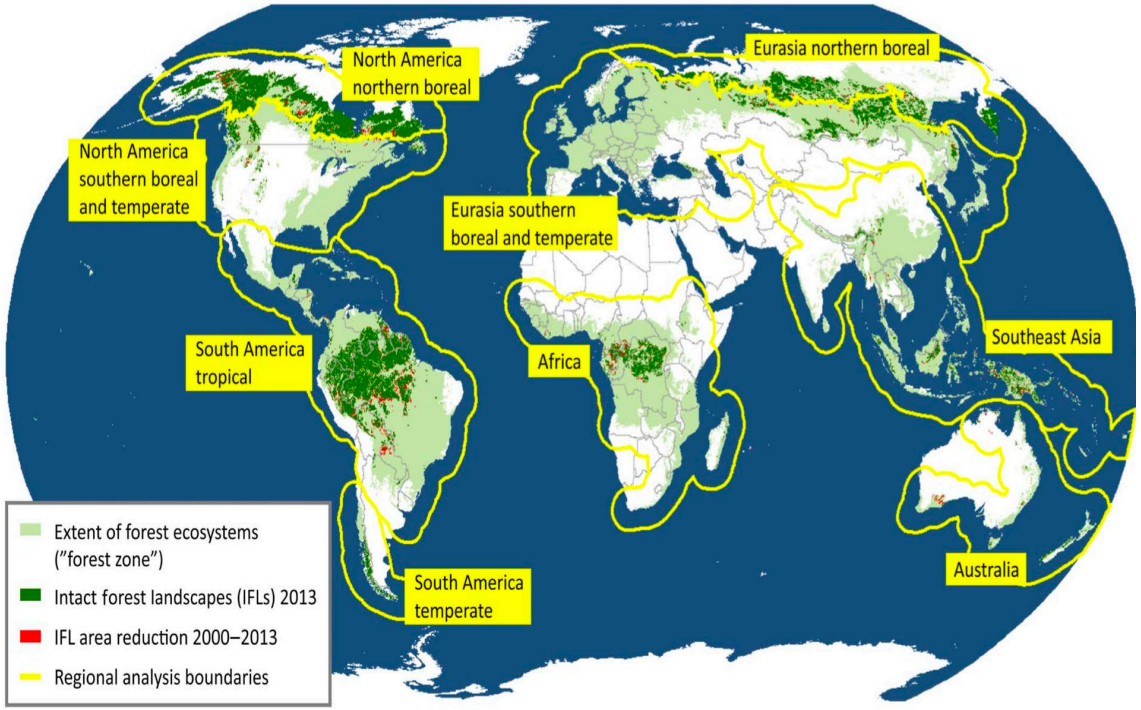
Wood products trade
Crop products trade
Biofuels
Rvers



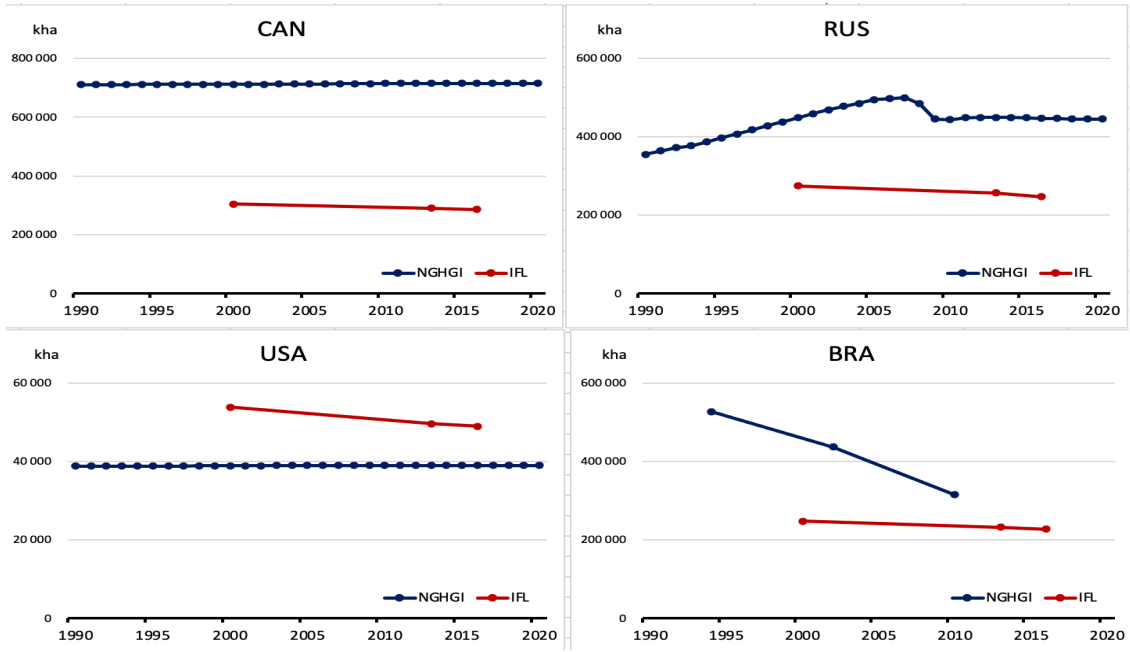


Restricting gridded inversion fluxes to spatially explicit 'intact land' as a proxy of unmanaged

Removal of (spatially explicit) un-managed land using remote sensing data
Potapov et al. for intact forests Landscapes and Chang et al. for natural grasslands

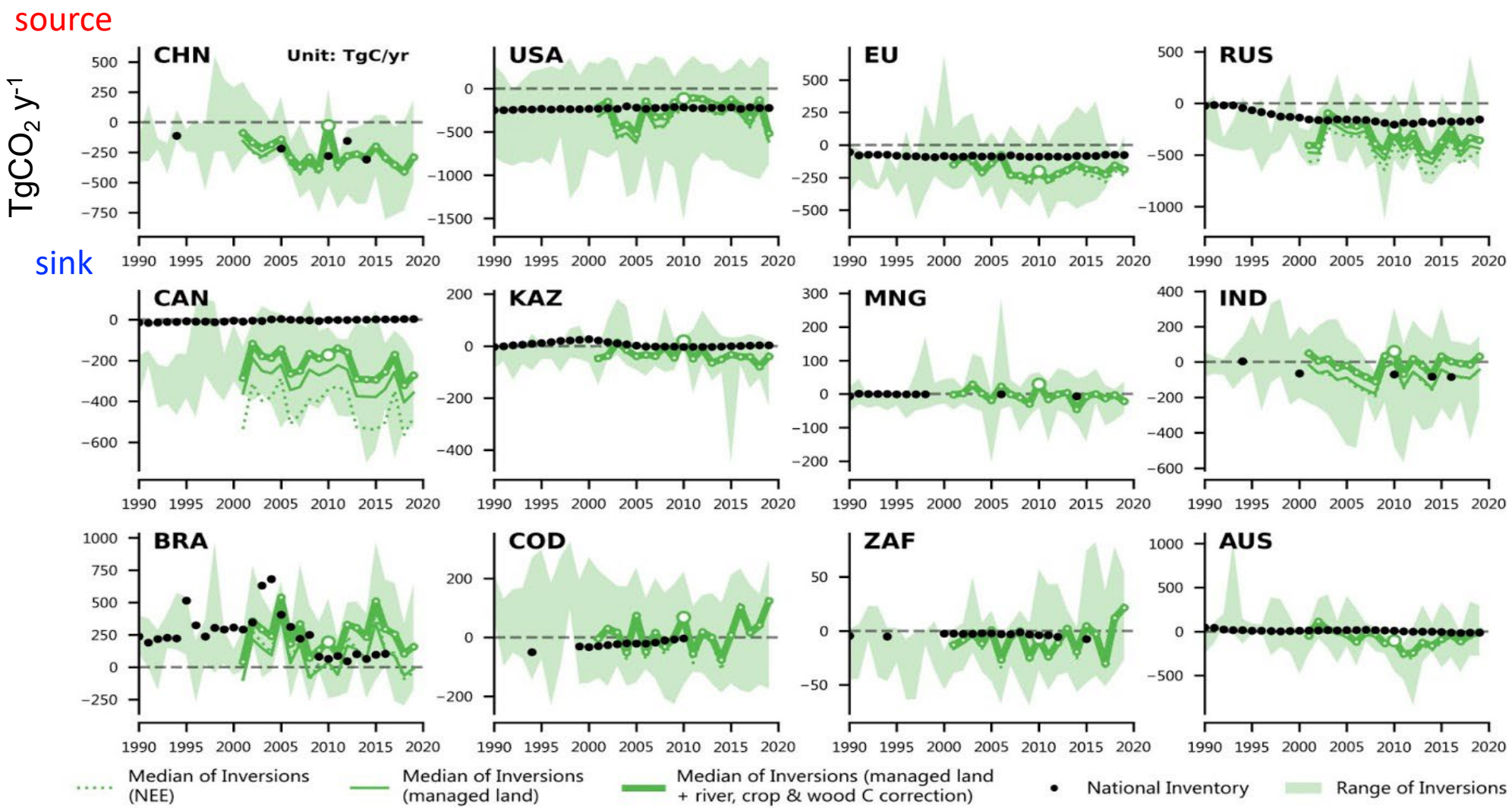


'Intact forest' vs 'Unamanaged'



Note that Ogle et al. 2018 published spatially explicit maps of unmanaged land for Canada, USA, Brazil

CO_2 – LULUCF fluxes (sink = negative values)



CO_2 – LULUCF fluxes : global sum

Global land CO2 sink

	GtC y^{-1}	$GtCO_2$ y^{-1}	ref.	period
NGHGI	**-0.3**	**-1.6**	Grassi et al. 2021	2000-2015
NGHGI UNFCCC data interface + gap filled	**-1.5**	**-5.4**	Grassi et al. 2022	2000-2020
FAOSTAT	**+0.3**	**+1.1**	Grassi et al. 2022	
Inversions (managed land)	**-2.7**	**-9.9**	Deng et al. 2022	2007-2017
Inversion (unmanaged land)	**+0.2**	**+0.7**		

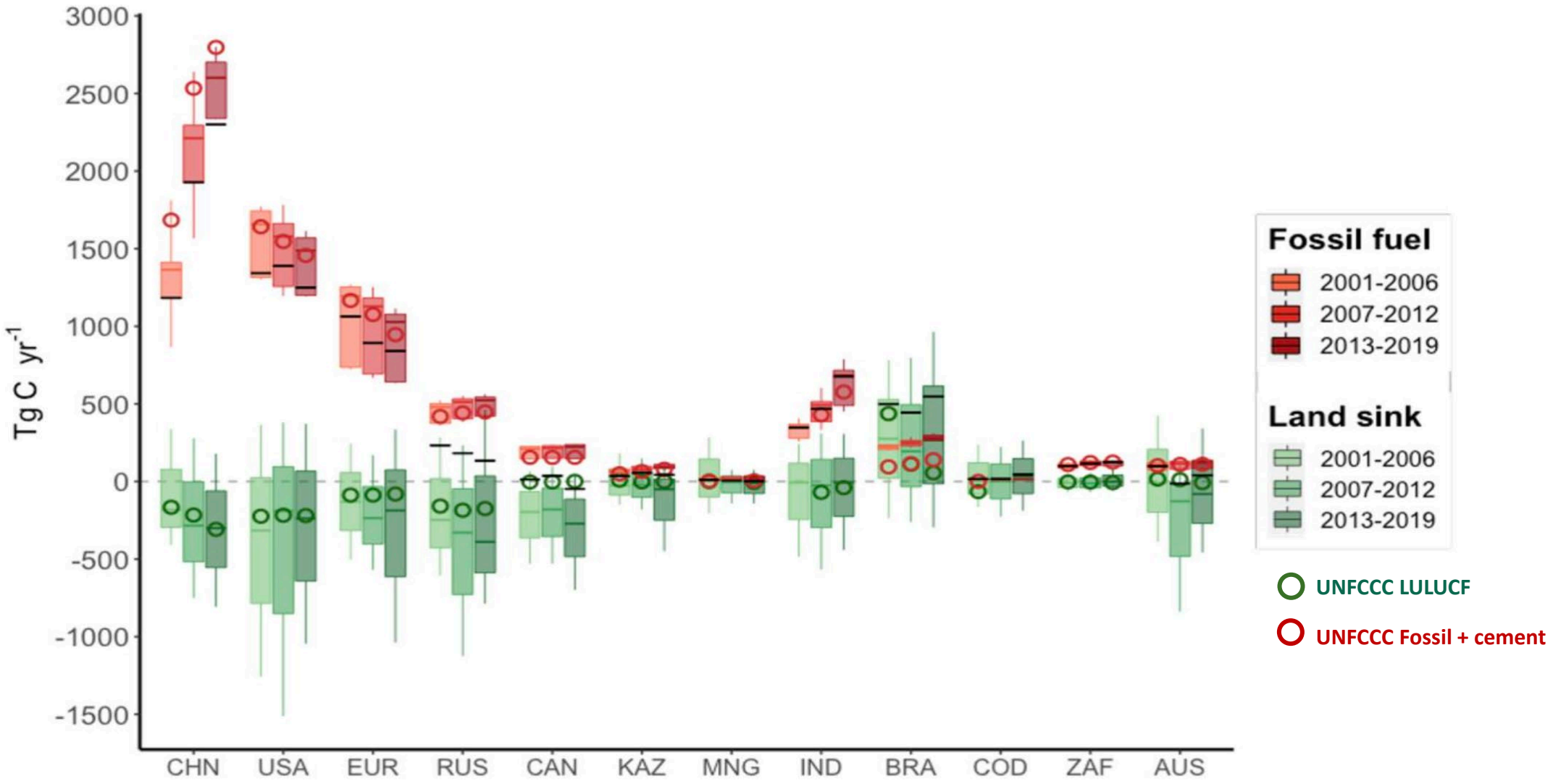
FAO – NGHGI difference :
Due to a much greater forest sink for non-Annex I countries in the NGHGI database than FAOSTAT.

Inversions – NGHGI difference :
Due to a smaller forest sink for Annex I and for some non-Annex-1 countries in the NGHGI database than inversions / indirectly confirmed by the upward revision of the sink in non Annex 1 countries from Grassi et al. 2022

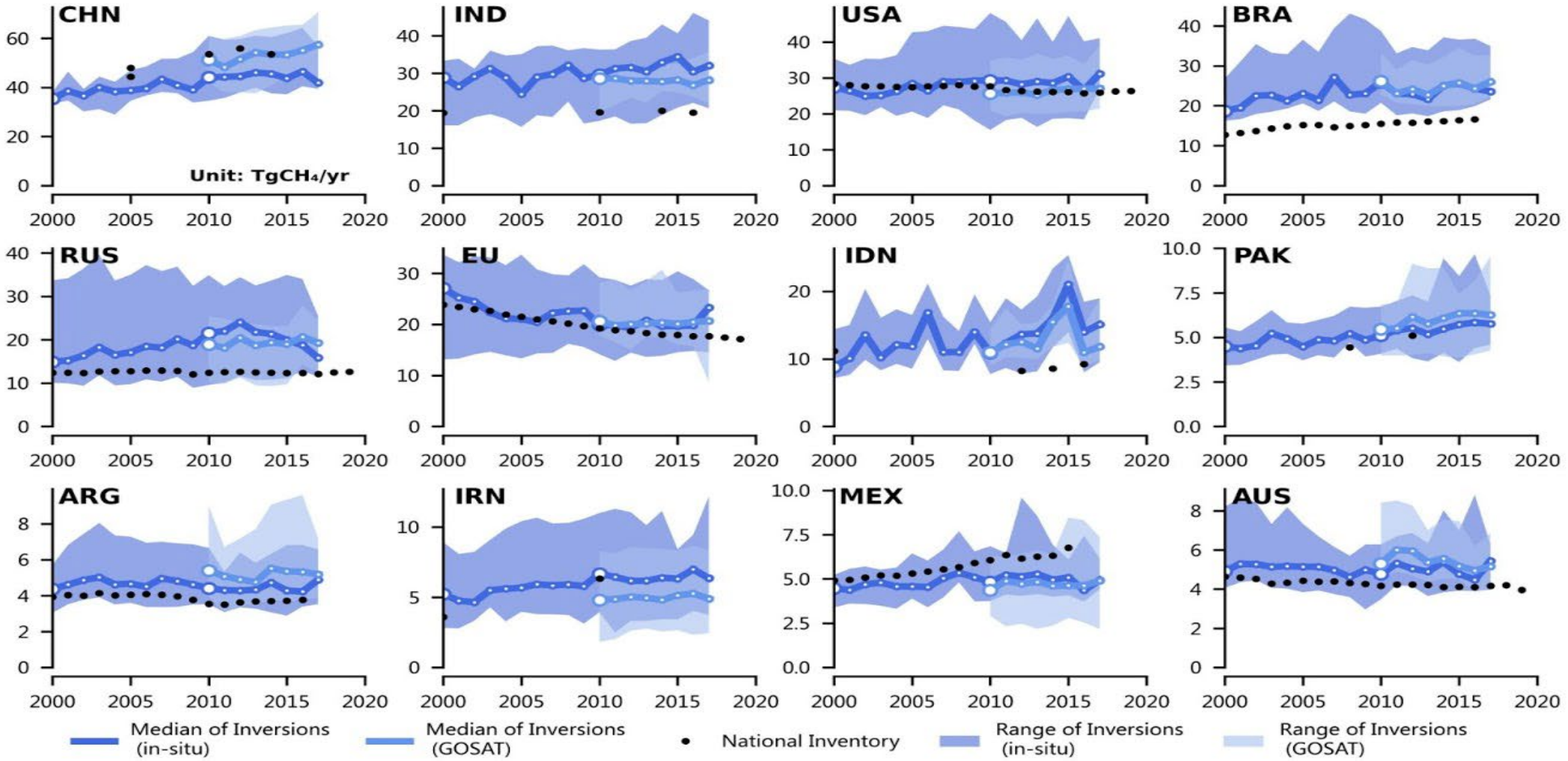
Even with the latest NGHGI data compilation, inversions find a 80% larger CO_2 sink in managed land than inventories

Although unmanaged land area is globally a source, it is a sink in Canada (+40% more than managed land) and Russia (+16%)

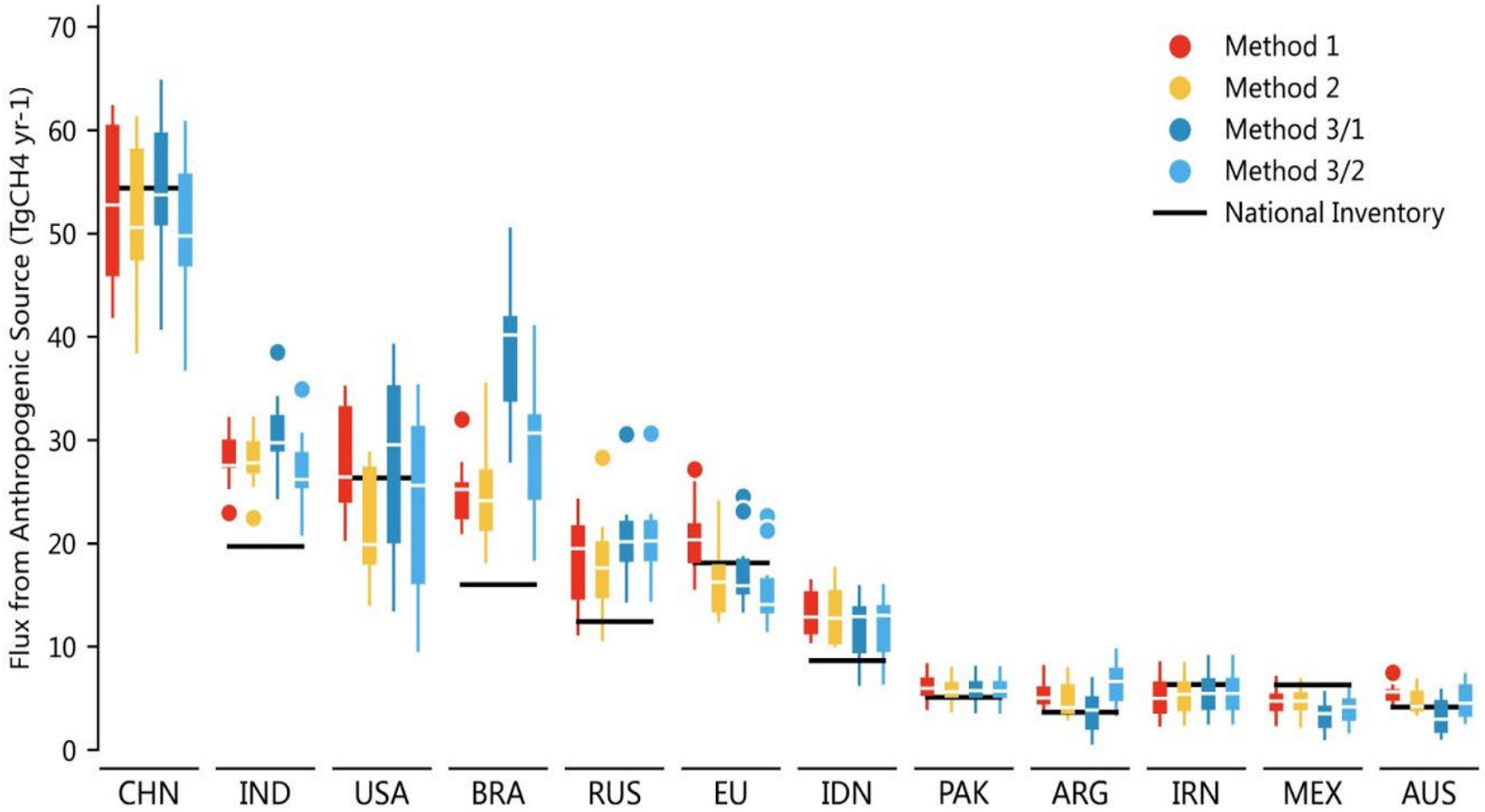
Summary CO2 Emissions and sinks from Top fossil CO2 Emitters



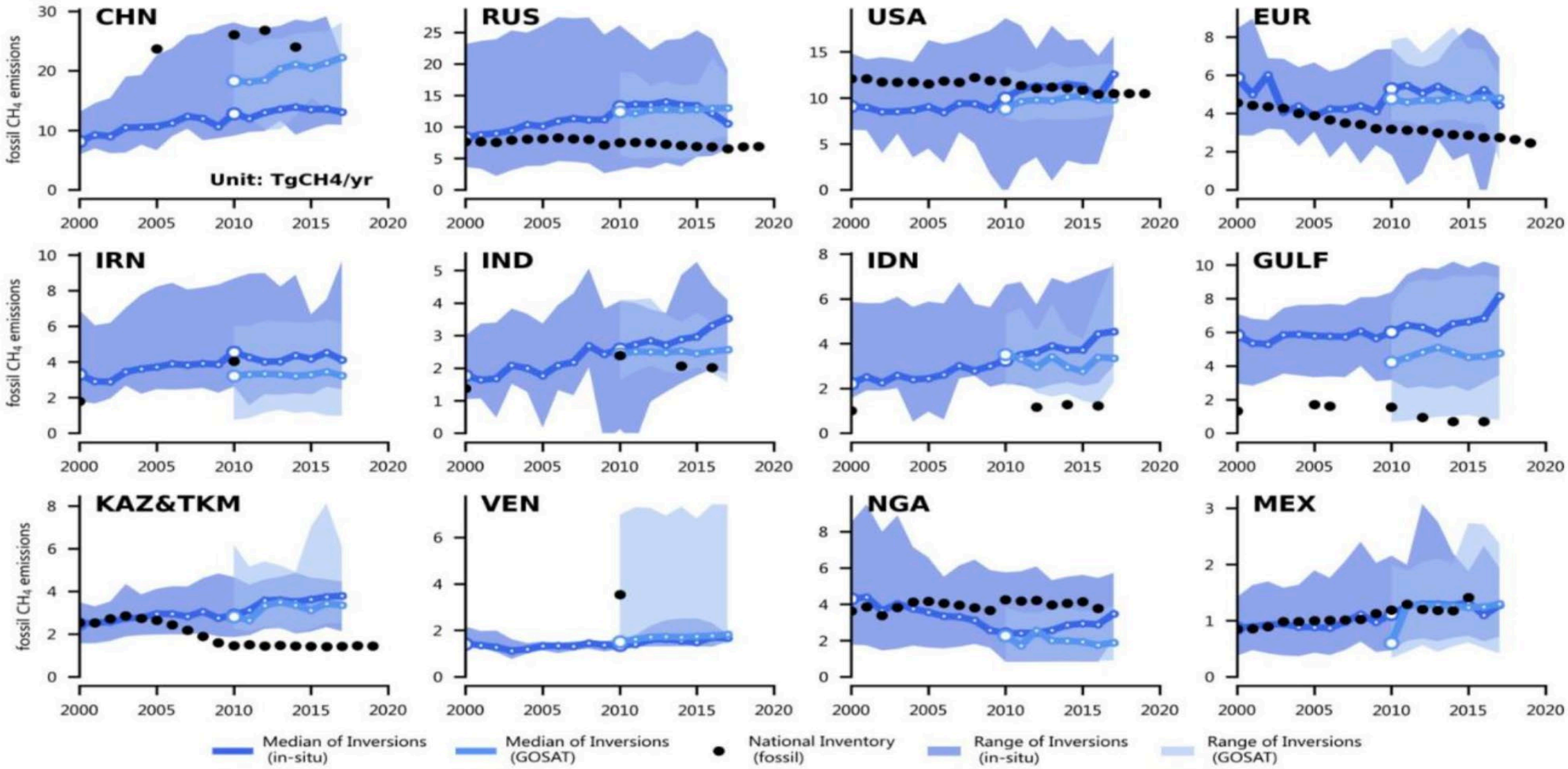
CH_4 – total anthropogenic emission (in-situ and GOSAT inversions)



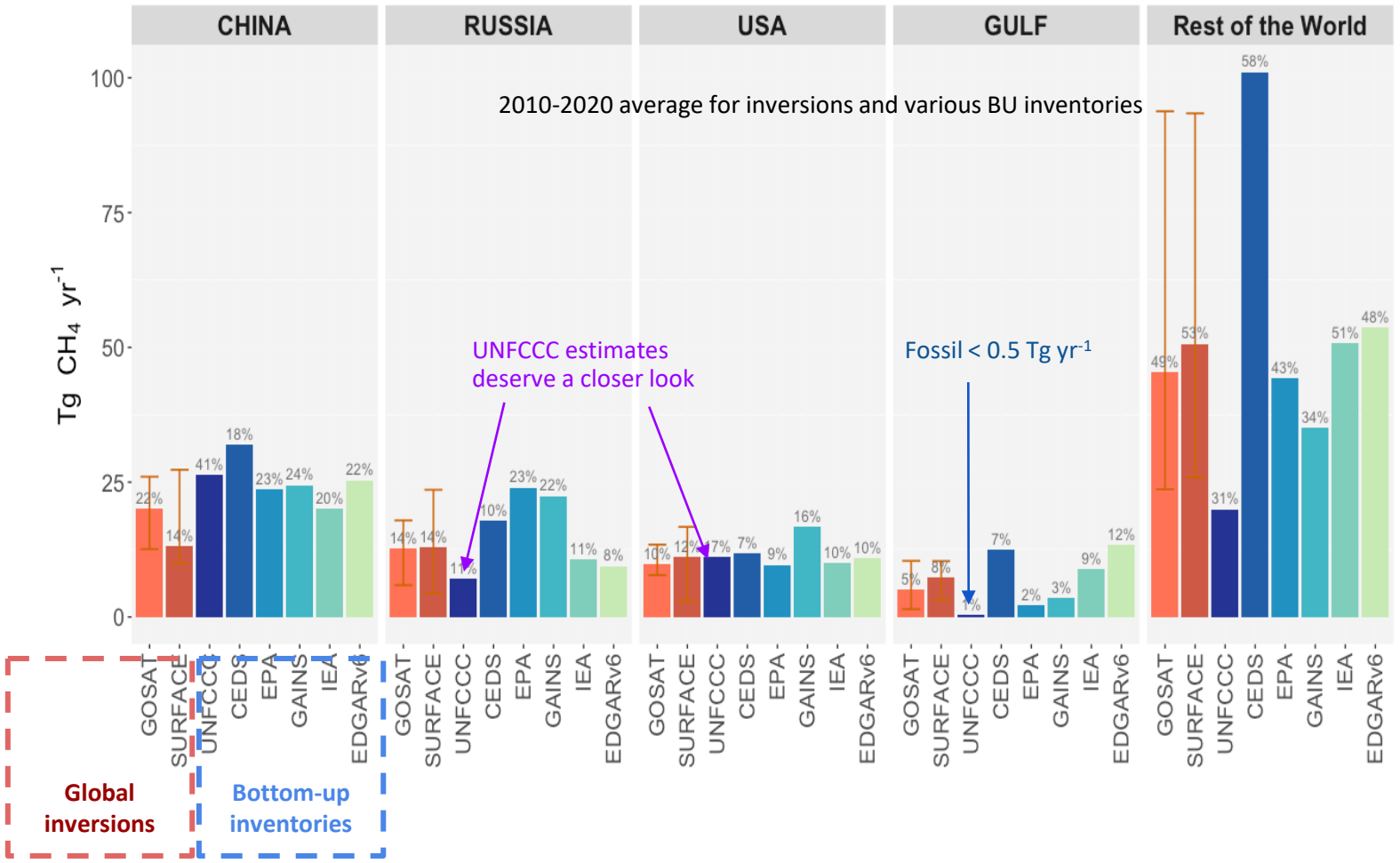
Robustness of inversions anthropogenic CH4 emissions to the choice of a separation method for natural sources



CH_4 – Fossil emissions (in-situ & GOSAT inversions)

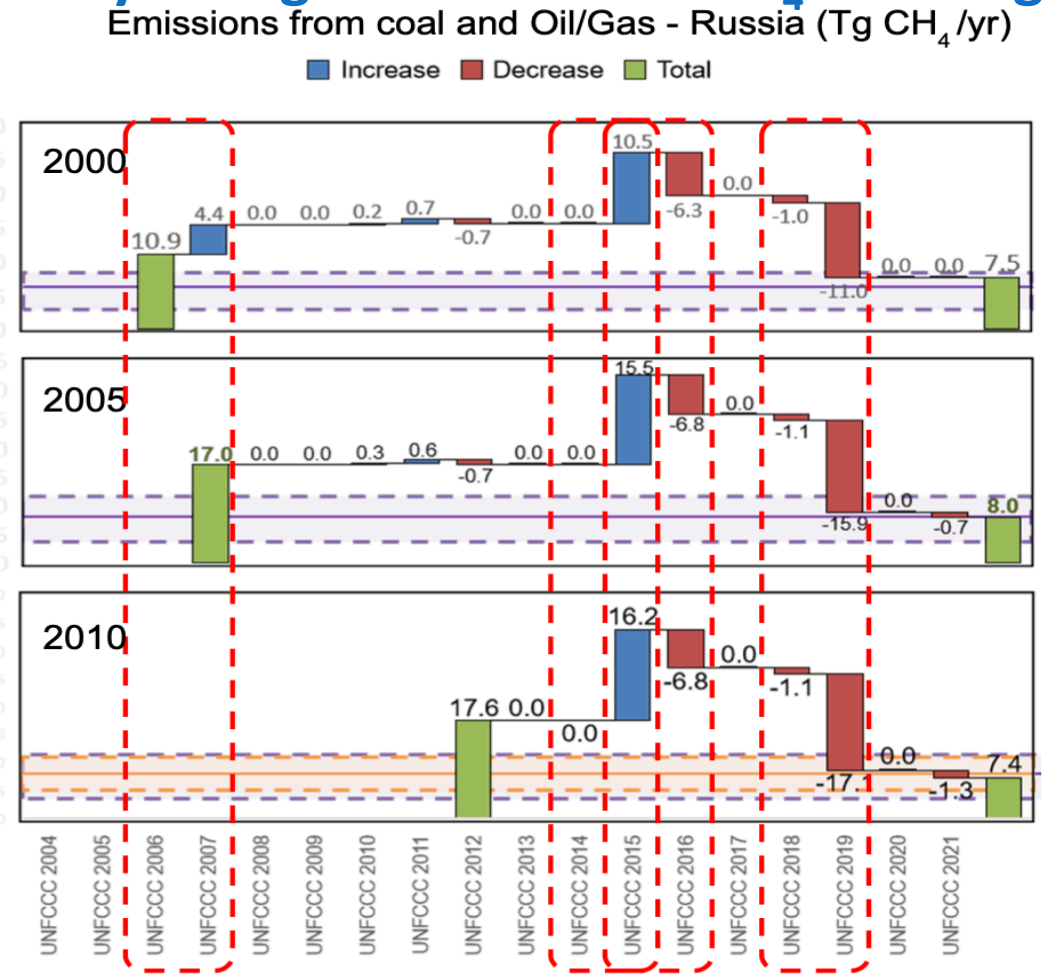


Inventories from countries in the Middle East (Gulf) and rest of the underestimate fossil CH4 emissions



Different versions of UNFCCC reported emissions have larger variability than inversions uncertainty

Key changes from Russia CH_4 oil and gas emissions

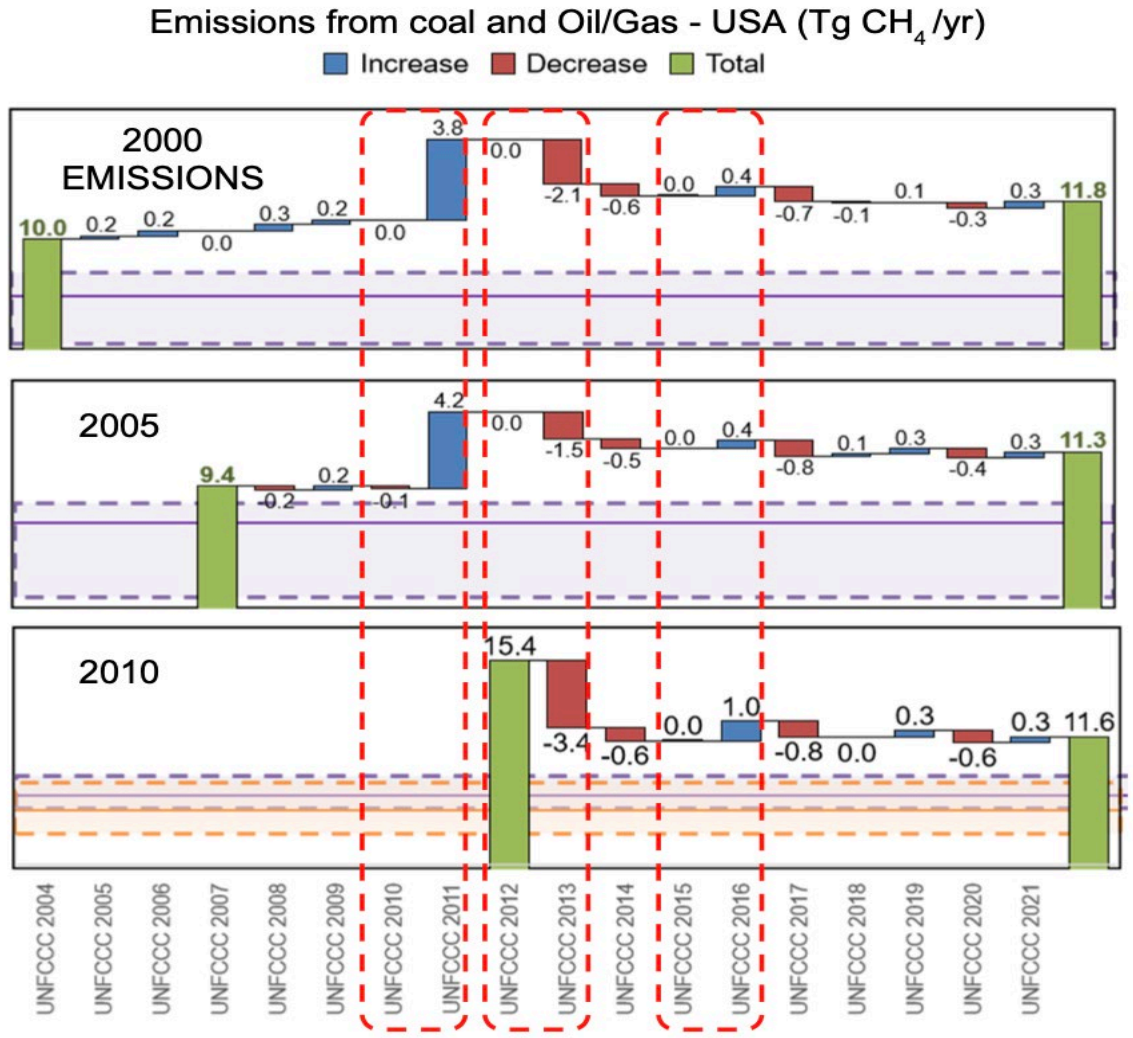


Changing points	Change type	Change of	Details
2007	increase	Methodology + Emfacs	Inclusion of new sources - oil and gas exploration and distribution, venting/flaring; Updation of several emfacs
2015	increase	Methodology	Change in calculation for oil emissions, massive change in emfacs
2016	decrease	Emfac	change in emfac for NG production - massive decrease
2019	decrease	Emfac	change in emfacs for oil systems - probably looks like correction

Superimposing the inversion data can tell if the changes going towards right direction
(**shaded region - Purple: SURFACE | Orange: GOSAT inversions**).

Different versions of UNFCCC reported emissions have larger variability than inversions uncertainty

Key changes from USA CH_4 oil and gas emissions

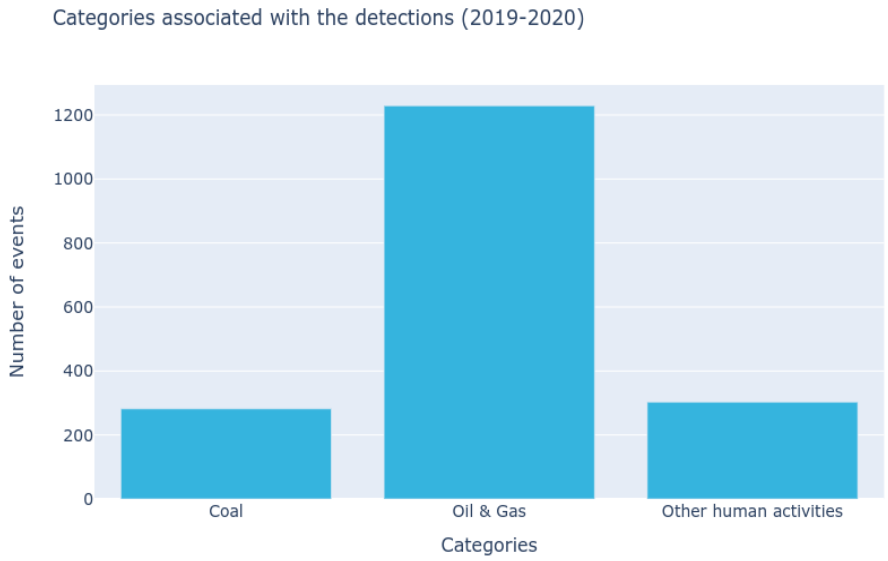


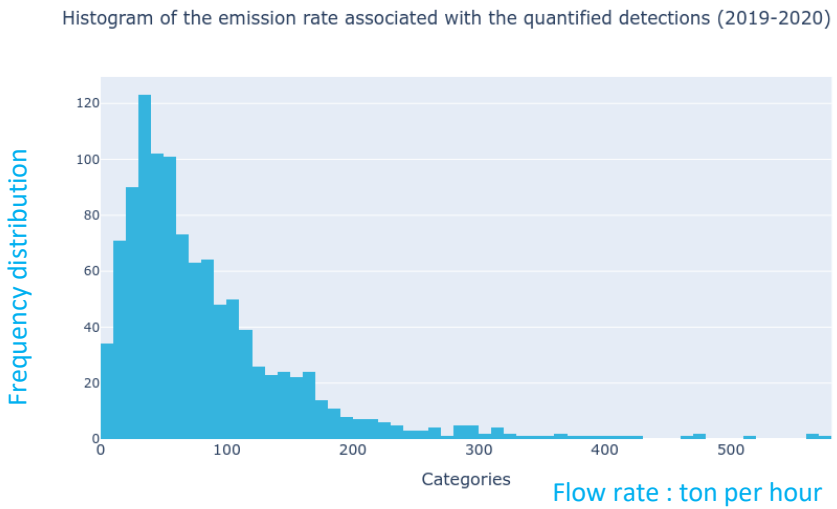
Changing points	Change type	Change of	Details
2011	Increased w.r.t. previous	Emfac	Change in implied emfacs for gas production/processing, (nearly 2.4 times)
2013	Decreased w.r.t previous	Methodology + Activity data	• Input data for calculating emissions from "liquids unloading" were updated from a survey conducted by API/ANGA (API/ANGA 2012). • Activity data on well counts was updated using DI Desktop data.
2016	Increased w.r.t. previous	Activity data + Methodology	• Updated activity factors for fugitives, pumps and controllers • Using the GHGRP data, the EPA developed new technology-specific activity data and emission factors for pneumatic controllers.

Superimposing the inversion data can tell if the changes going towards right direction
(**shaded region - Purple: SURFACE | Orange: GOSAT inversions**).

CH_4 – Resolving discrepancies using ultra emitters TROPOMI inversion

(assuming they are seen in the total emissions by global inversions but may be missed by inventories)





KAYRROS
ENLIGHTENING ENERGY

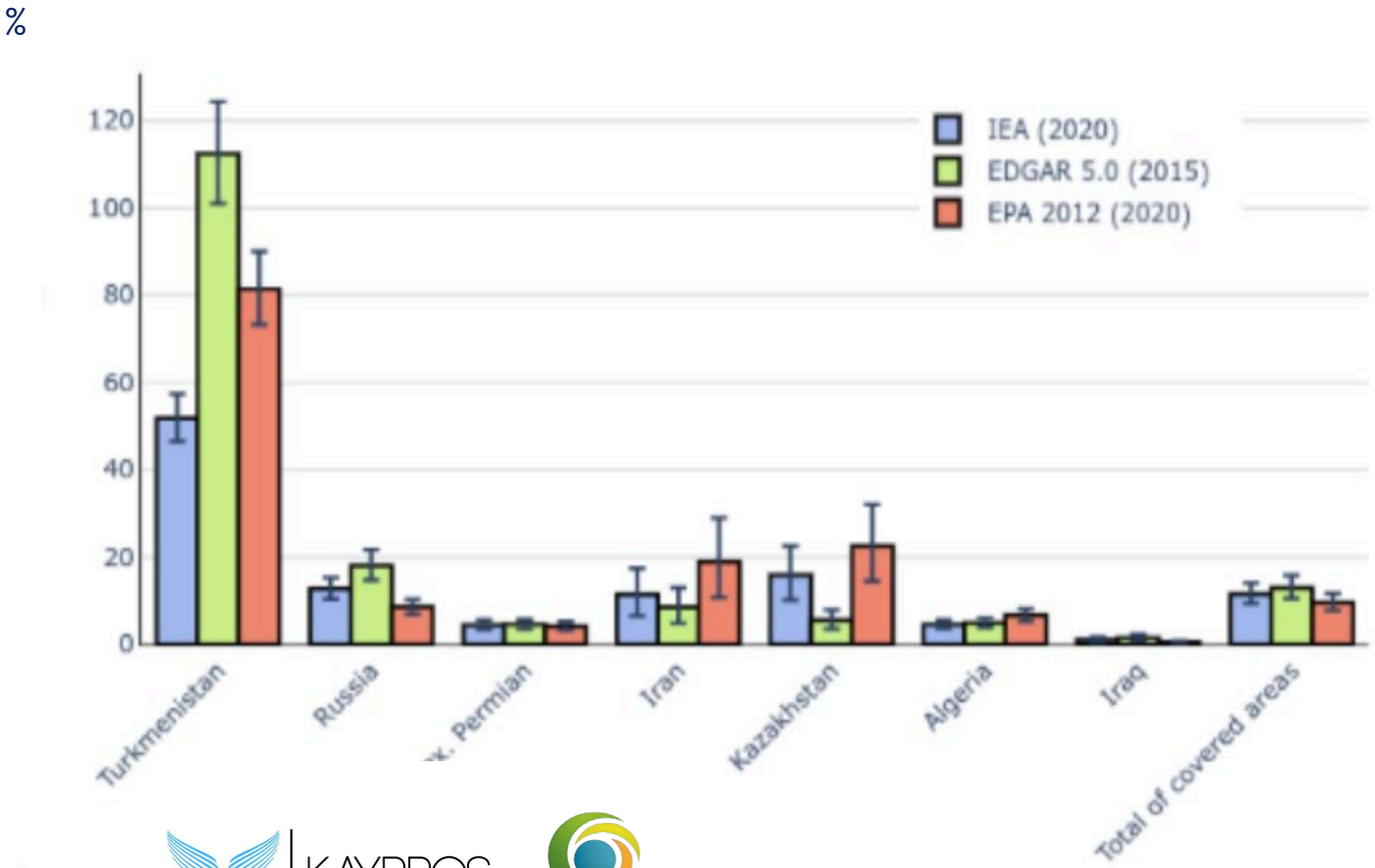
LSCE

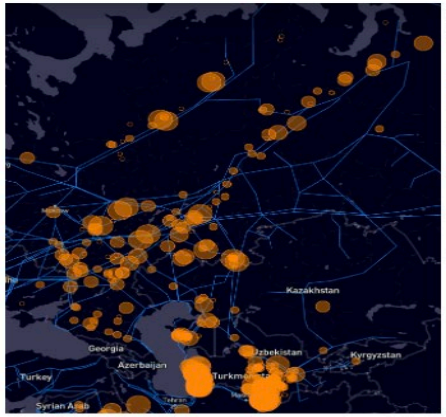
CH_4 – Resolving discrepancies using ultra emitters TROPOMI inversion (> 20 tCH4 per h)

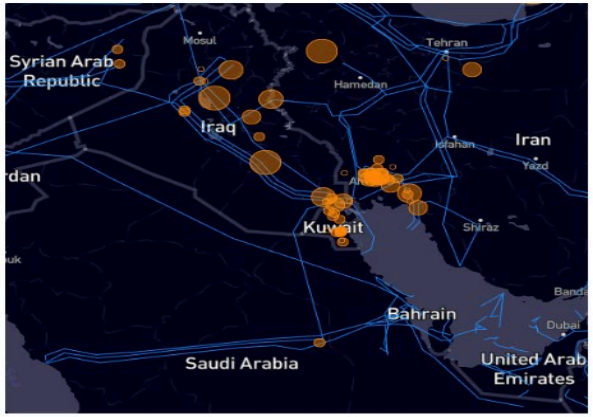
(assuming they are seen in the total emissions by global inversions but may be missed by inventories)

Ultra emitters as a fraction of national inventories

Lauvaux et al. in press



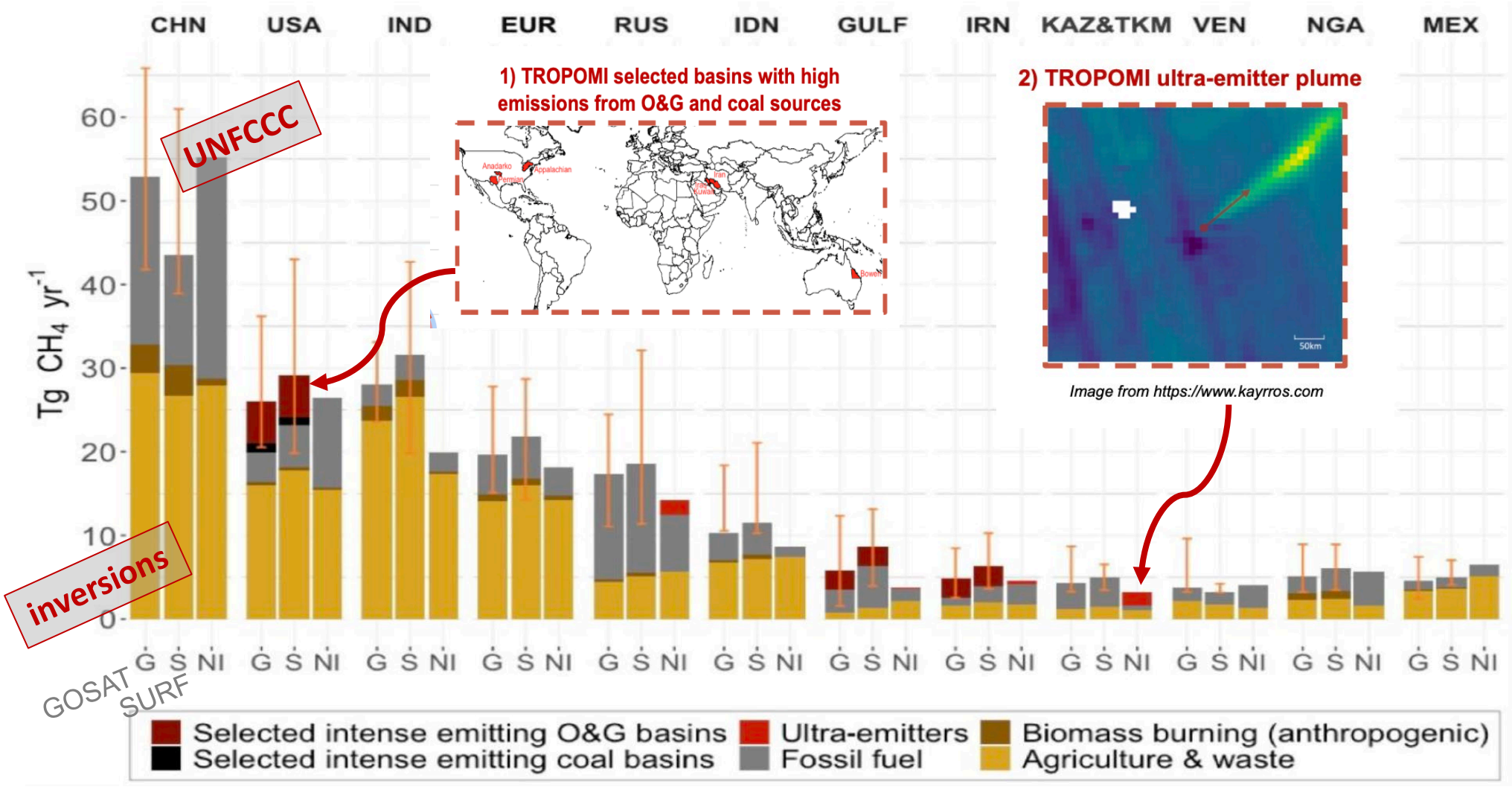




KAYRROS ENLIGHTENING ENERGY

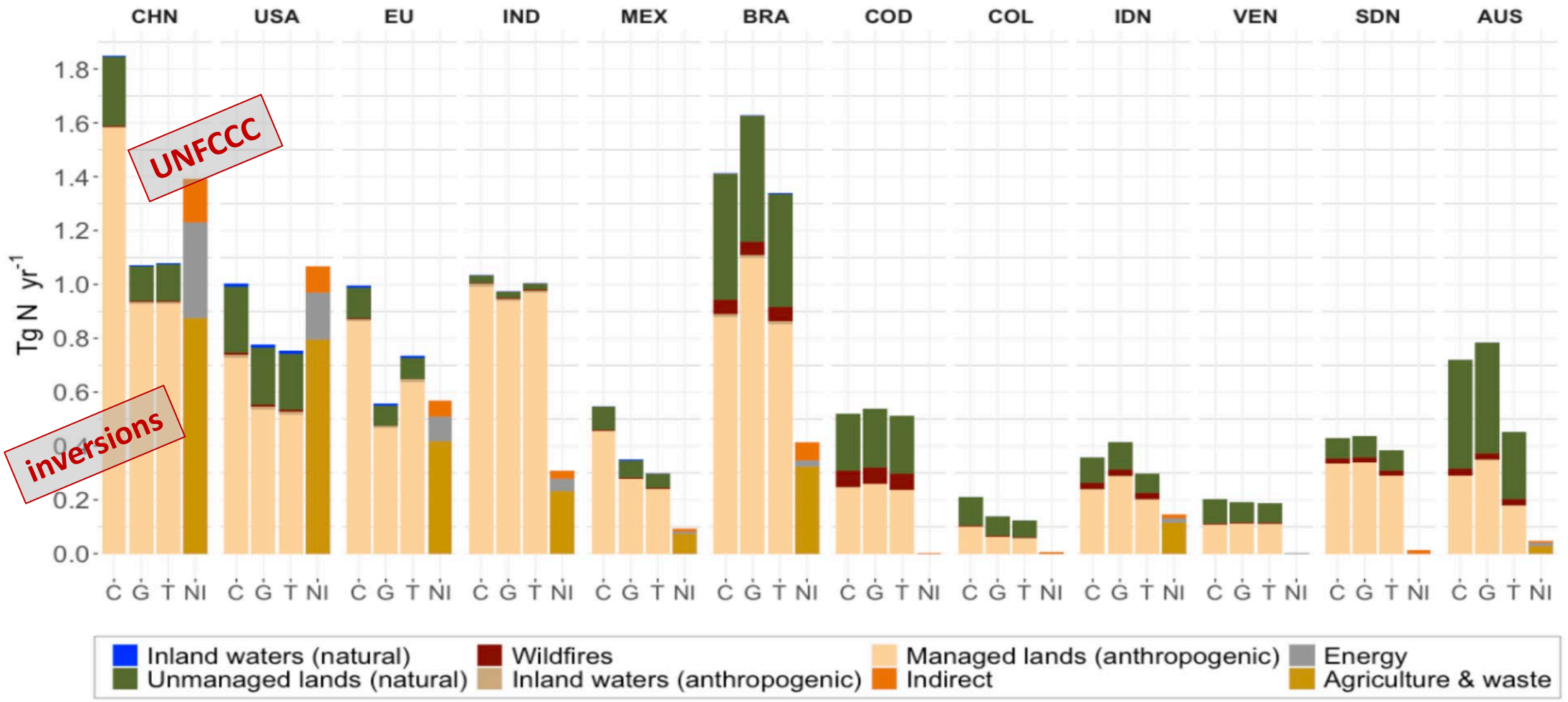
LSCE

Summary of CH4 anthropogenic inversions (last 5 years)



Ultra emitters assumed not captured by UNFCCC inventories / basins emissions assumed as part of inversions fossil emissions

Summary N2O anthropogenic emissions (last 5 years)

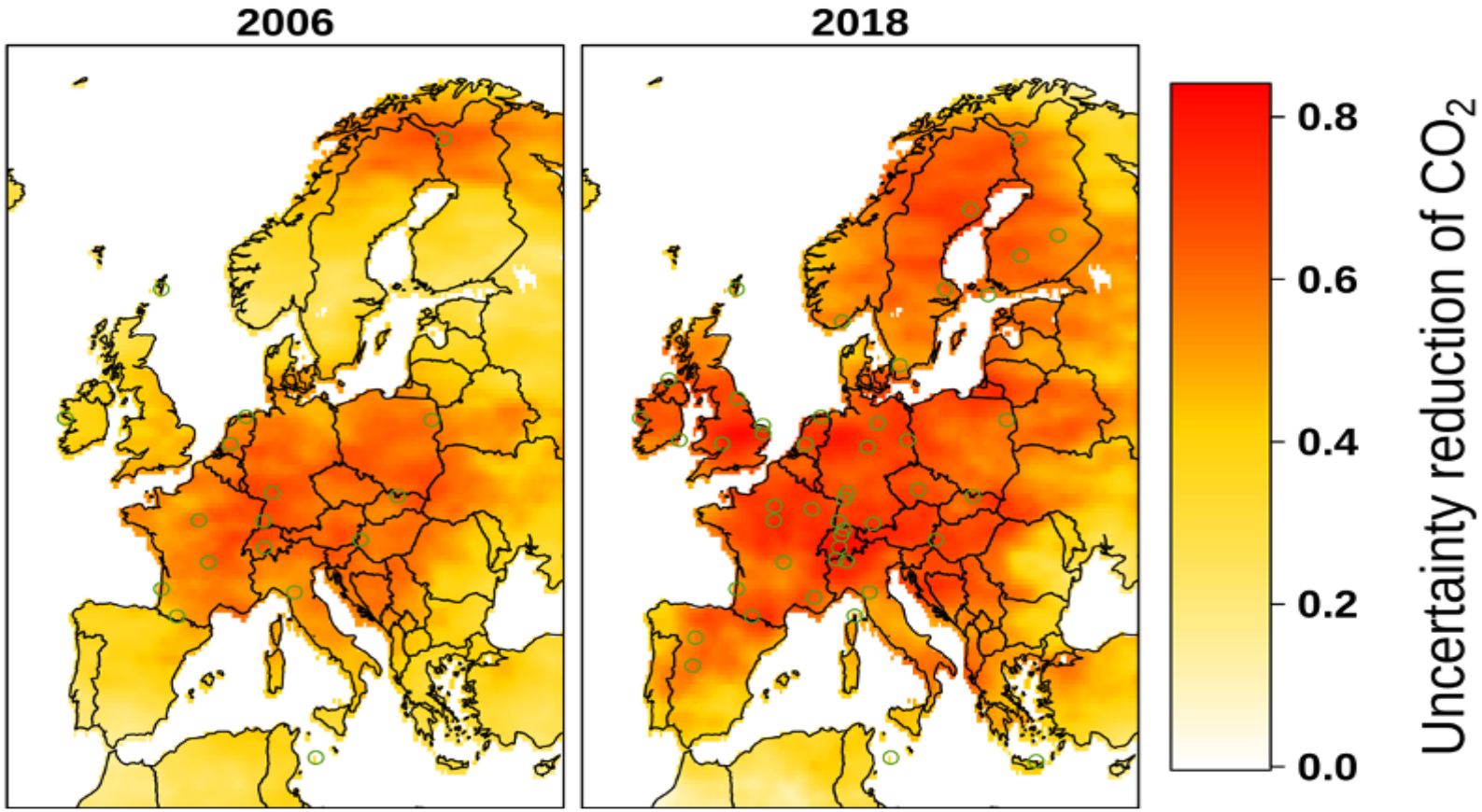


- Note the overlooked importance of natural emissions (including fires in BRA and IDN) in tropical countries

Conclusions

- Importance of sampling inversions over managed lands
- Need to correct CO_2 inversions for lateral fluxes
- Most northern countries under-estimate LULUCF carbon sinks
- UNFCCC fossil CH_4 emissions lower than inversions for key O&G extraction countries
- N_2O emissions < inversions in EU, India, DRC, Australia
- Perspectives
  - Regional higher resolution inversions
  - Lack of in-situ data in many countries
  - Assimilate satellite XCO2 concentration data
  - ✓ Inversions using GOSAT and OCO-2 data
  - ✓ Complete global CH4 inversions by ultra emitters and basins-scale regional inversions
  - Criteria to benchmark inversions (cross-validation)
  - Weighed ensembles
  - Analysis of inversions sources of uncertainties

Can we hope to beat the proble with data ?



CarboScopeRegional uncertainty reduction maps computed as $1-(\sigma_{post} / \sigma_{prior})$ *for 2006 and 2018 using a Monte Carlo approach*

Thank you for your attention

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National inventories submitted to UNFCCC (Annex I)

Common Reporting Format (CRF)

「At its eighth session, the Conference of the Parties requested the secretariat to publish on its web site the **annual inventory submissions** consisting of the national inventory report (NIR) and common reporting format (CRF) of all Parties included in Annex I to the Convention. The NIRs contain detailed descriptive and numerical information and the **CRF tables contain all greenhouse gas (GHG) emissions and removals, implied** **and a**

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A1 | TABLE 1 SECTORAL REPORT FOR ENERGY

TABLE 1 SECTORAL REPORT FOR ENERGY
(Sheet 1 of 2)

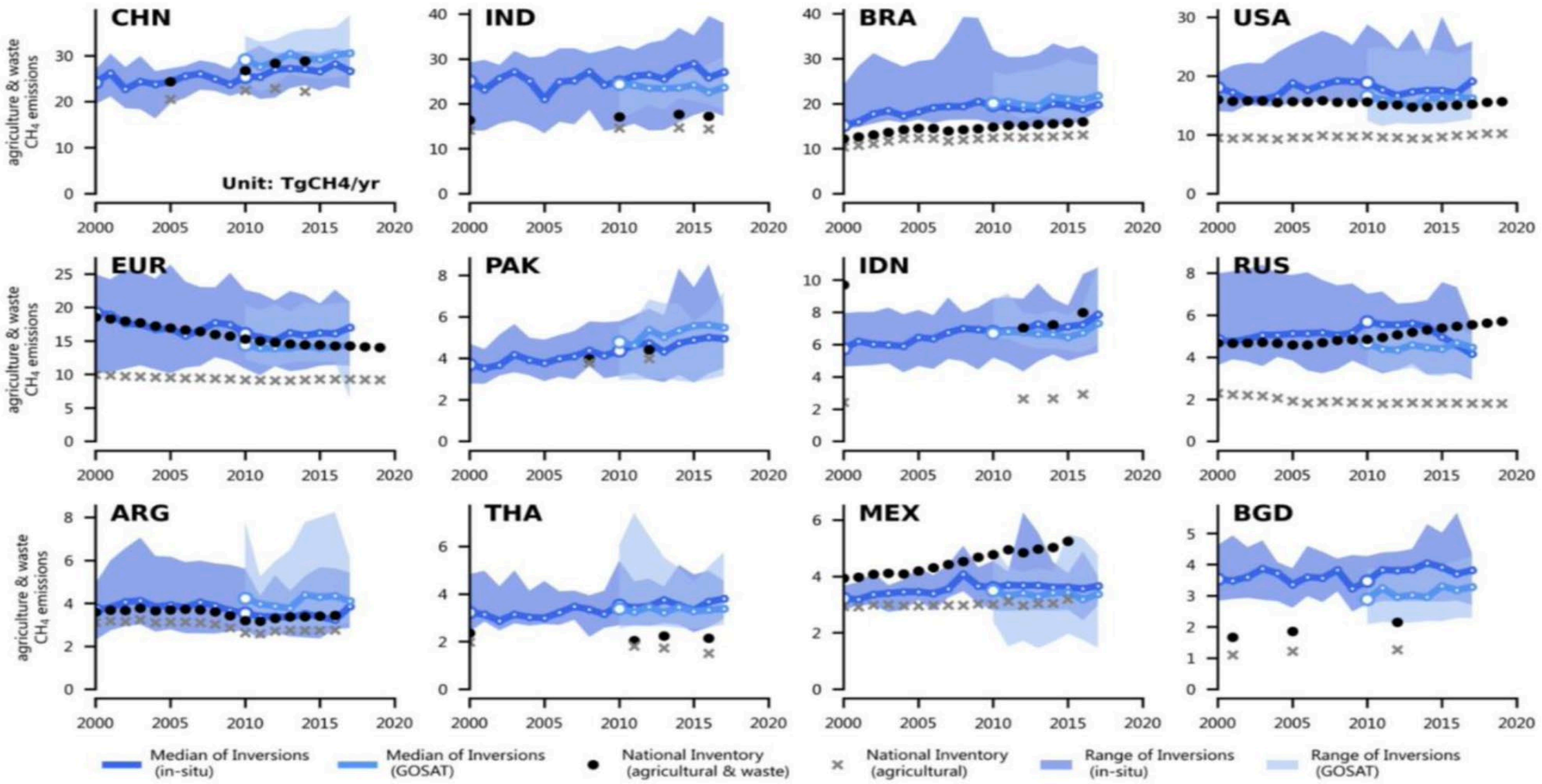
Inventory 2018
Submission 2020 v1
AUSTRALIA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_2
	(kt)						
Total Energy	393408.22	1562.20	10.43	2693.12	2261.93	783.95	636.13
A. Fuel combustion activities (sectoral approach)	376140.74	77.92	10.18	2689.12	2238.96	539.18	636.13
1. Energy industries	212312.80	25.12	3.00	1188.60	248.63	76.39	542.83
a. Public electricity and heat production	181906.70	23.91	2.23	670.89	97.64	13.01	525.64
b. Petroleum refining	3075.20	0.05	0.01	19.77	2.55	0.05	5.75
c. Manufacture of solid fuels and other energy industries	27330.90	1.15	0.76	497.94	148.44	63.34	11.44
2. Manufacturing industries and construction	40222.09	2.37	1.47	751.13	241.30	100.46	57.69
a. Iron and steel	1548.21	0.03	0.02	17.54	2.78	0.27	7.39
b. Non-ferrous metals	12259.23	0.21	0.13	76.91	12.89	1.30	22.82
c. Chemicals	6842.07	0.22	0.08	50.09	16.03	9.86	3.89
d. Pulp, paper and print	998.31	0.21	0.14	7.90	5.71	0.51	1.33
e. Food processing, beverages and tobacco	2523.25	0.84	0.54	23.43	23.36	1.67	3.00
f. Non-metallic minerals	4928.92	0.29	0.05	74.77	23.08	15.10	7.98
g. Other (*please specify*)	11122.10	0.57	0.51	500.49	157.45	71.74	11.30
3. Transport	98973.04	14.33	4.91	302.48	1083.14	239.32	24.33
a. Domestic aviation	9000.09	0.04	0.06	30.37	19.96	1.99	1.06
b. Road transportation	83980.68	9.13	3.29	174.60	780.52	189.94	16.90
c. Railways	3564.91	0.20	1.53	77.98	10.29	3.62	2.91
d. Domestic navigation	1593.73	4.81	0.03	16.40	267.20	43.05	3.45
e. Other transportation	833.64	0.15	0.00	3.13	5.17	0.72	0.01

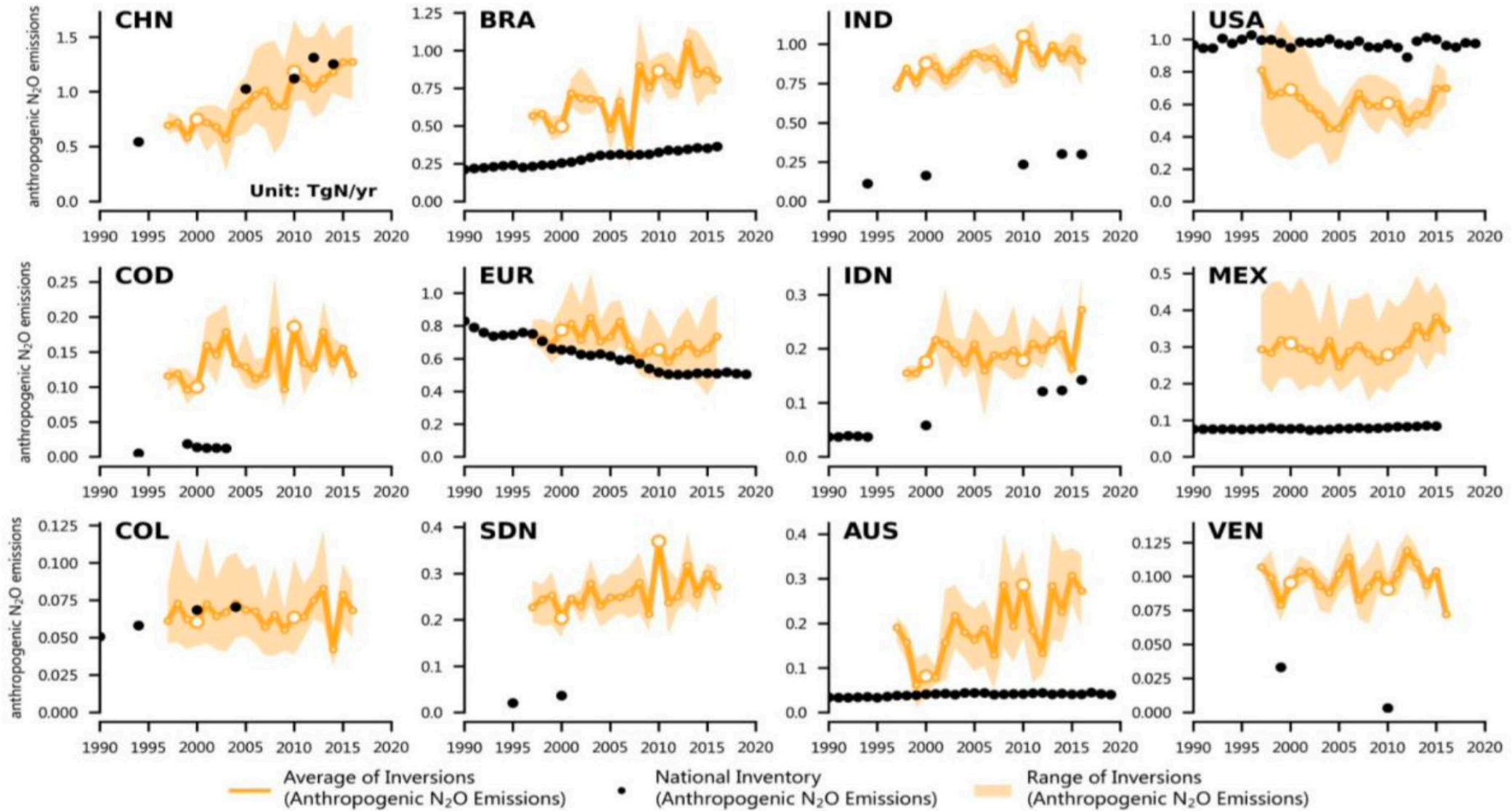
Index sheet | Table1s1 | Table1s2 | Table1.A(a)s1 | Table1.A(a)s2 | Table1.A(a)s3 | Table1.A(a)s4 | Table1.A(b)

125%

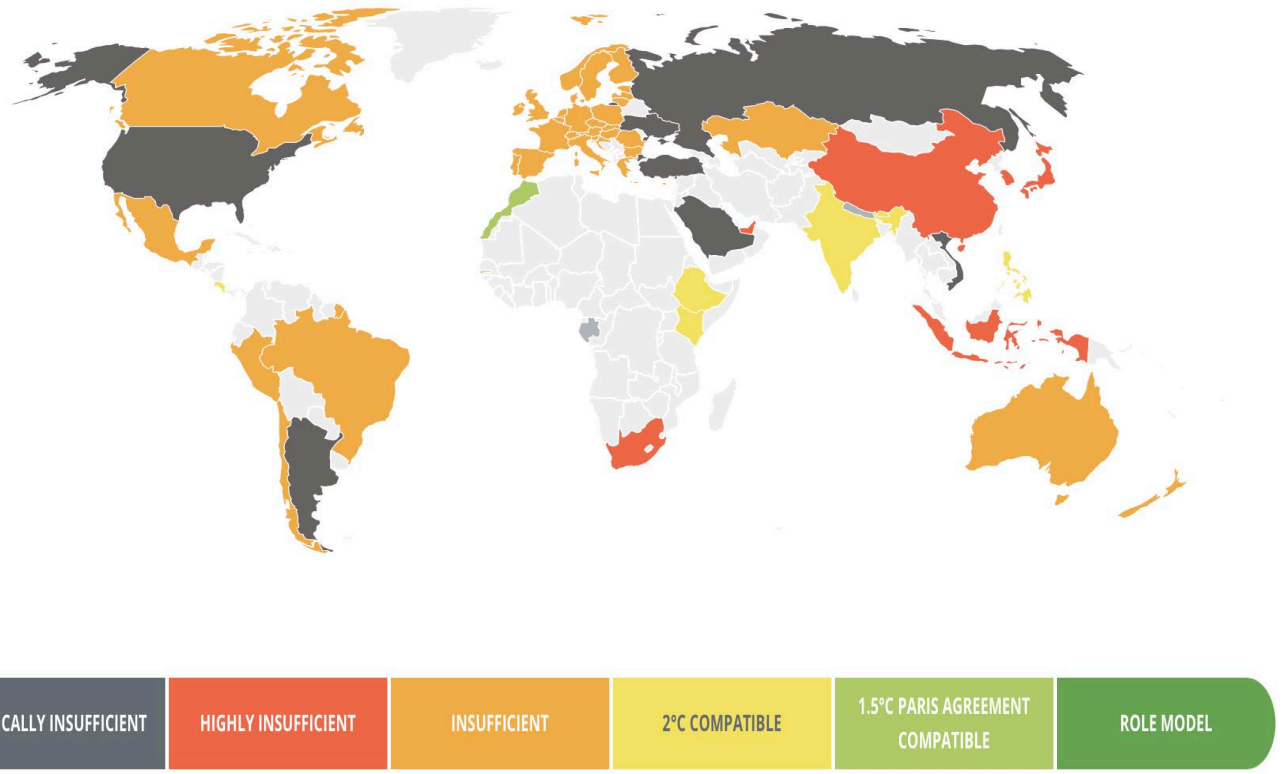
CH_4 – Agricultural and waste emissions (in-situ & GOSAT inversions)

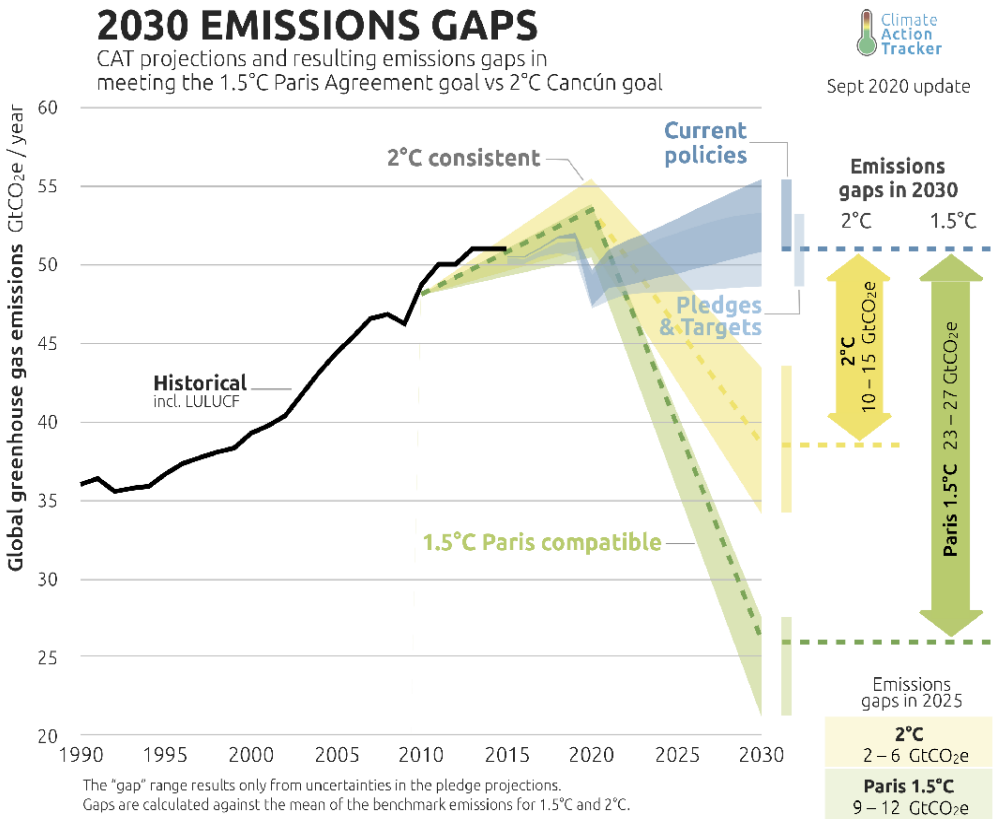


N_2O – anthropogenic emissions

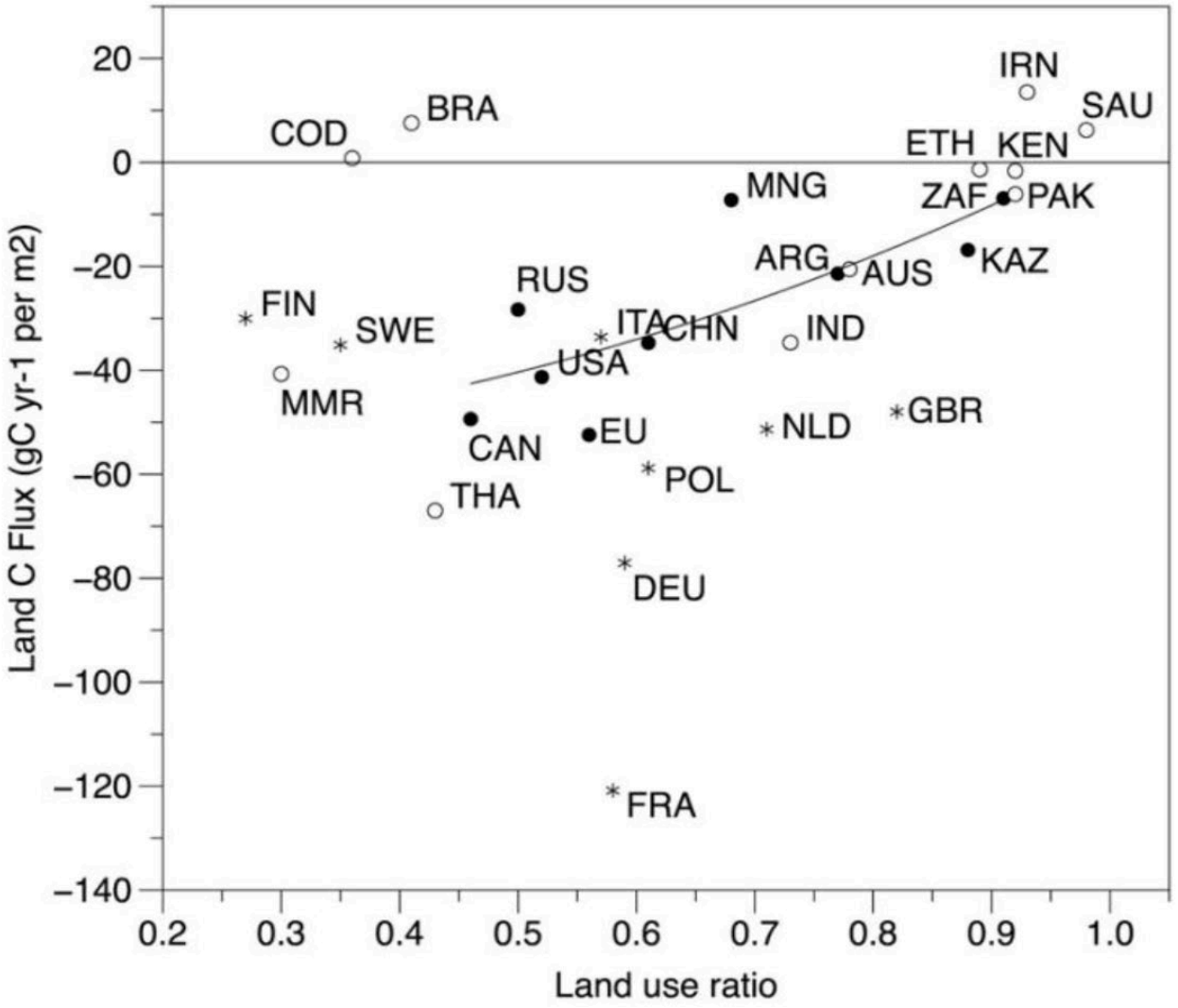


Current policies lead to a 3°C warming

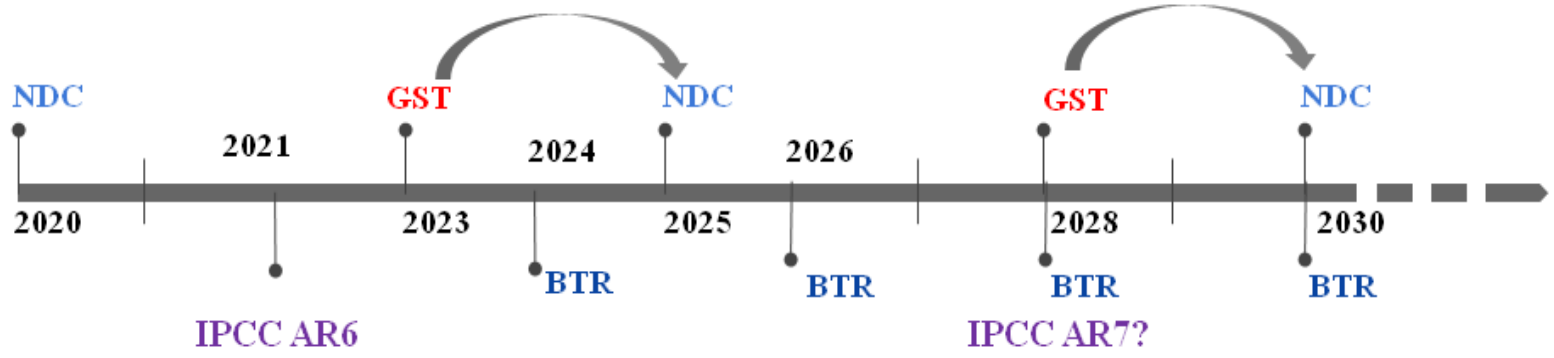




LULUCF CO2 sinks decreases with increasing land use ratio in temperate countries



Global stock take in 2023



NDC: Focus on Mitigation, Adaptation on voluntary basis (every 5 years)
GST: assess the collective progress against long term targets (every 5 years)
BTR: GHG inventories - Track progress of NDC implementation (mitigation and financial support)
IPCC AR: Assessment Reports about knowledge on climate change, its causes, potential impacts and response options

Perugini et al. 2021

- The GST shall include information about **mitigation and adaptation processes**, and the **means of implementation and support**, based on the best available science and the equity concept.
- The process should inform Parties whether the **cumulated efforts** of all the Parties is in track with the "well-below 2°C" trajectory, thus providing indication on how to enhance and update their actions at national level and through cooperation.
- The outputs of the GST should, thus, provide indication of opportunities and challenges for **enhancing action and support**.
- The process needs to be **transparent**, in the light of **equity and best available science** and it is strictly Party driven, although external experts are invited to participate to support the process.