Setting up two-box model for CH_4

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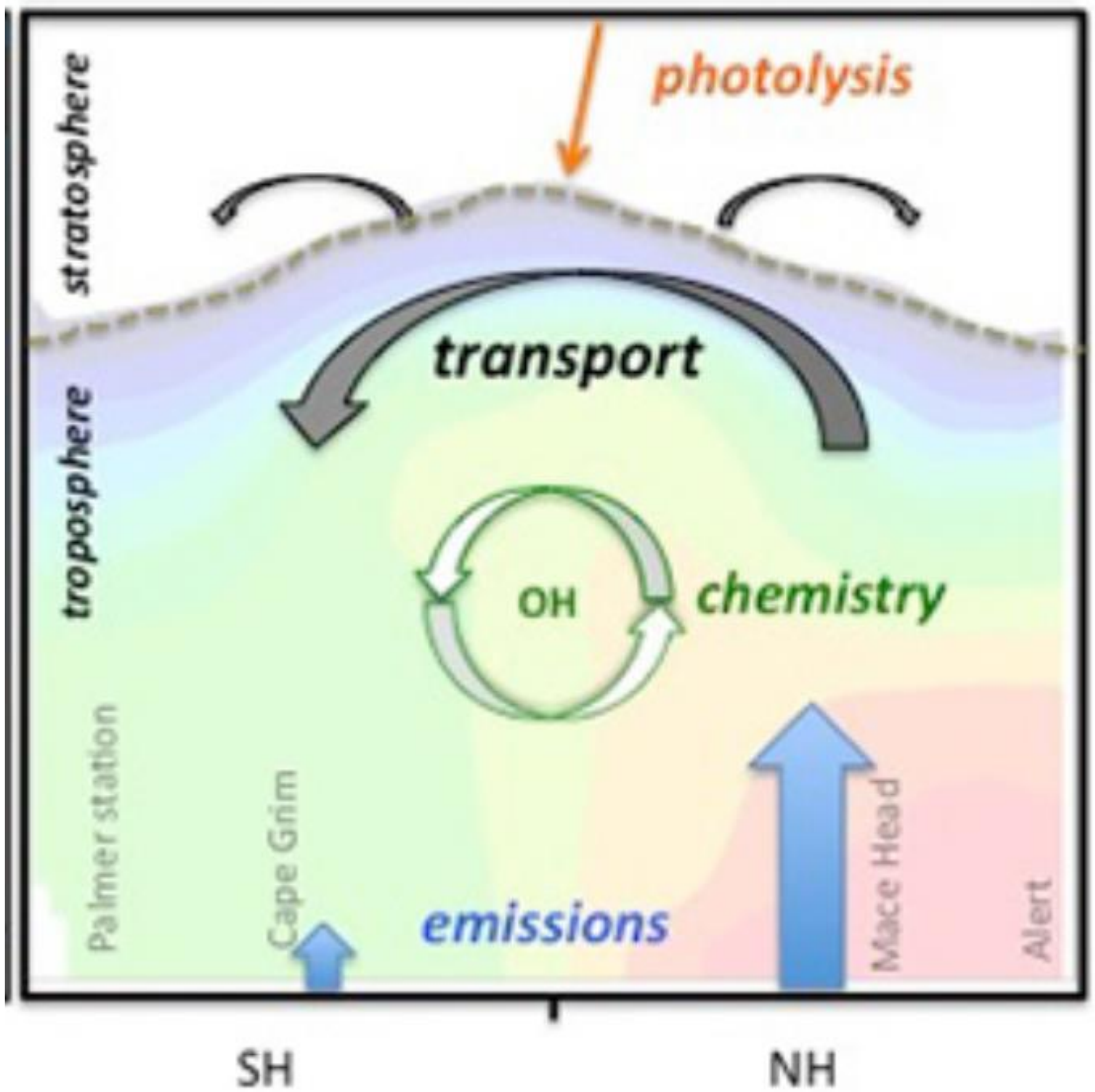
Atmospheric Models: Testing Theory with Reality

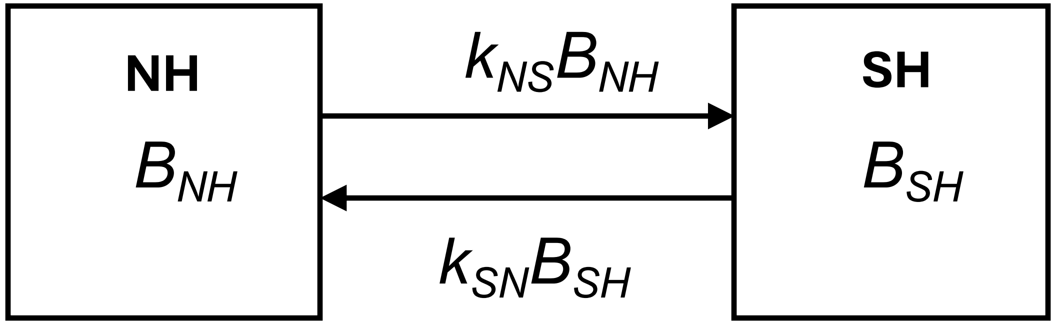
- ✓ Understand processes
- ✓ Interpret observations

Processes
- Emissions
- Transport
- Chemistry



Setting Up the Box Model Framework

Predicting atmospheric mixing ratio of CH_4



$$k = \frac{1}{\tau_{IH}}$$

Interhemispheric Exchange time ($\tau_{IH} \sim 1yr$)

Mass balance equations:

$$\frac{dB_{NH}}{dt} = \sum S_{NH} - \sum L_{NH} + k_{SN} B_{SH}$$

$$\frac{dB_{SH}}{dt} = \sum S_{SH} - \sum L_{SH} + k_{NS} B_{NH}$$

Sources (S) :Anthropogenic Sources

Bottom-up emission inventories:

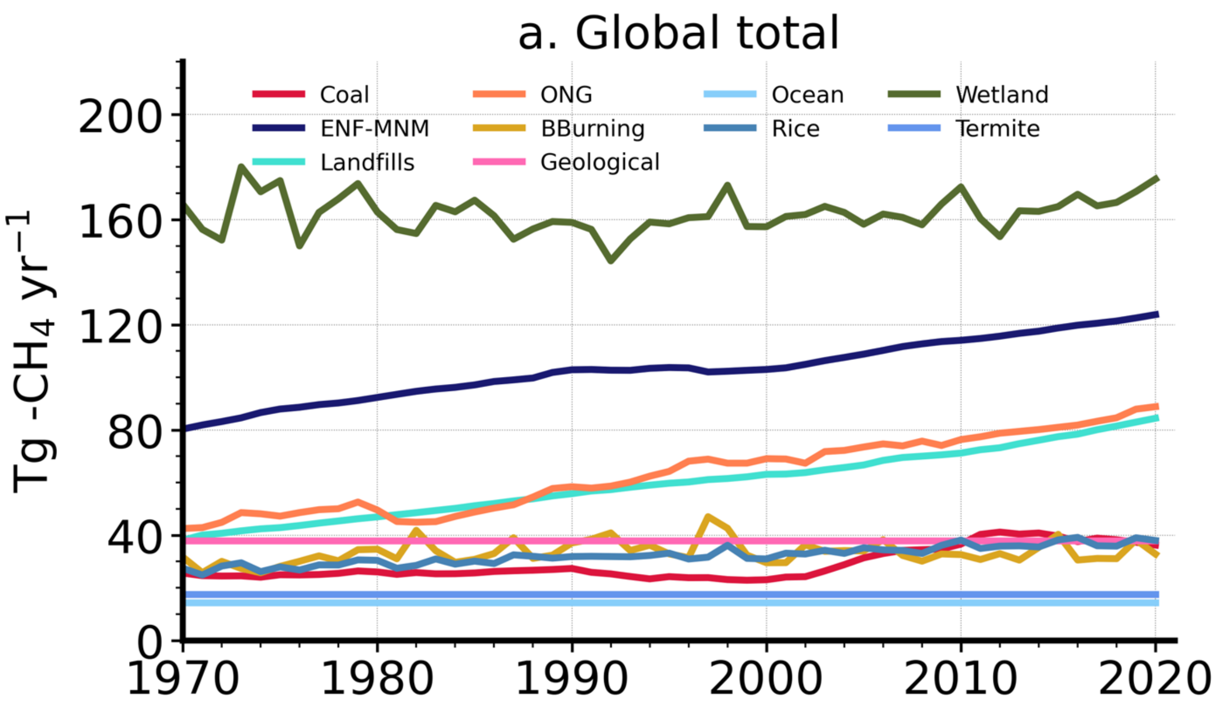
Activity x Emission factor

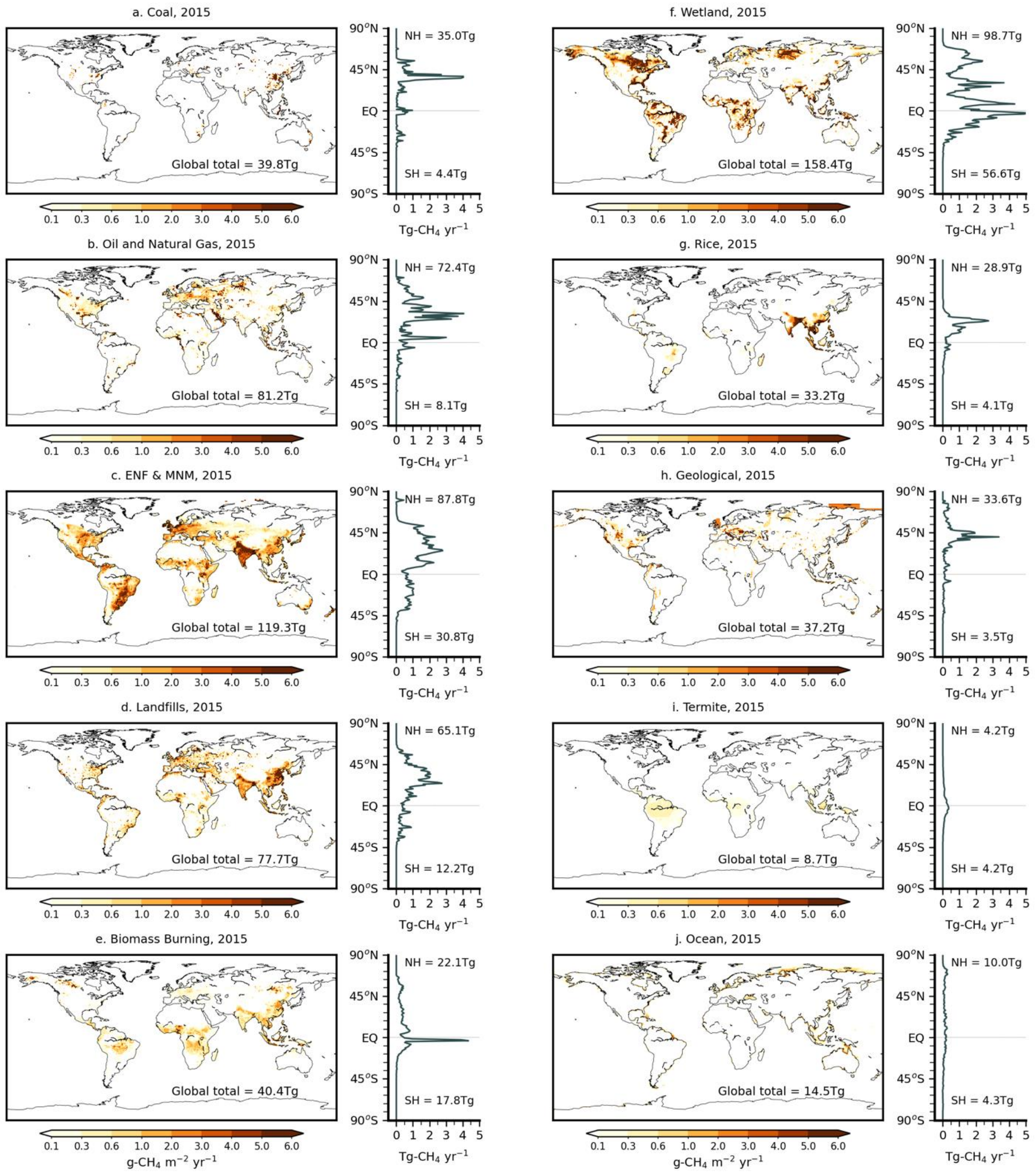
BU models and inventories	Contribution	Time period (resolution)	Gridded	References
CEDS (country-based)	fossil fuels, agriculture and waste, biofuel	1970–2019 (yearly)	no	Hoesly et al. (2018)
CEDS (gridded)[a]	fossil fuels, agriculture and waste, biofuel	1970–2020 (monthly)	$0.5 \times 0.5°$	Hoesly et al. (2018), O'Rourke et al. (2021)
EDGARv6	fossil fuels, agriculture and waste, biofuel	1990–2018[b] (yearly, monthly for some sectors)	$0.1 \times 0.1°$	Oreggioni et al. (2021), Crippa et al. (2021)
EDGARv7	fossil fuels, agriculture and waste, biofuel	1990–2021 (yearly)	$0.1 \times 0.1°$	Crippa et al. (2023)
IIASA GAINS v4.0	fossil fuels, agriculture and waste, biofuel	1990–2020 (yearly)	$0.5 \times 0.5°$	Höglund-Isaksson et al. (2020)
USEPA	fossil fuels, agriculture and waste, biofuel, biomass burning	1990–2030 (10-year interval, interpolated to yearly)	no	USEPA (2019)
FAO-CH_4	agriculture, biomass burning	1961–2020 1990–2020 (yearly)	no	Federici et al. (2015), Tubiello et al. (2013), Tubiello (2019)
FINNv2.5	biomass burning	2002–2020 (daily)	1 km resolution	Wiedinmyer et al. (2023)
GFASv1.3	biomass burning	2003–2020 (daily)	$0.1 \times 0.1°$	Kaiser et al. (2012)
GFEDv4.1s	biomass burning	1997–2020 (monthly)	$0.25 \times 0.25°$	Giglio et al. (2013), van der Werf et al. (2017)
QFEDv2.5	biomass burning	2000–2020 (daily)	$0.1 \times 0.1°$	Darmenov and da Silva (2015)

Source (S): Wetland Emissions: Process-based Models

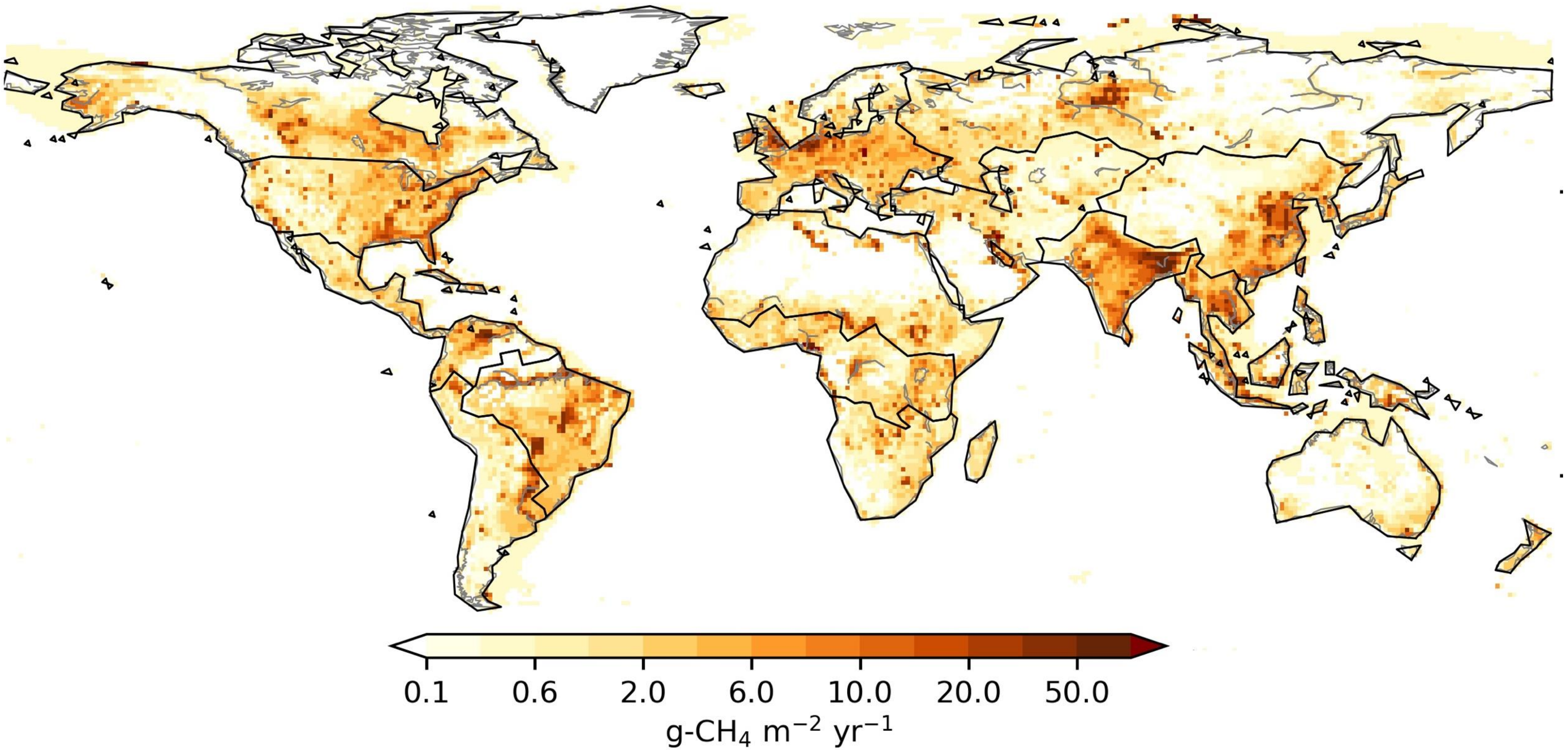
Model	Institution	Prognostic		Diagnostic		References
		CRU	GSWP3-W5E5	CRU	GSWP3-W5E5	
$CH_4MOD_{wetland}$	Institute of Atmospheric Physics, CAS	n	n	y	y	Li et al. (2010)
CLASSIC	Environment and Climate Change Canada	y	y*	y	y*	Arora et al. (2018); Melton and Arora (2016)
DLEM	Boston College	y	y	y	y	Tian et al. (2015, 2023)
ELM-ECA	Lawrence Berkeley National Laboratory	y	y	y	y	Riley et al. (2011)
ISAM	University of Illinois, Urbana-Champaign	y	y	y	y	Shu et al. (2020) Xu et al. (2021)
JSBACH	MPI	y	y	y	y	Kleinen et al. (2020, 2021, 2023)
JULES	UKMO	y	y	y	y	Gedney et al. (2019)
LPJ-GUESS	Lund University	n	n	y	y	McGuire et al. (2012)
LPJ-MPI	MPI	y	y	y	y	Kleinen et al. (2012)
LPJ-WSL	NASA GSFC	y	y	y	y	Zhang et al. (2016b)
LPX-Bern	University of Bern	y	y	y	y	Spahni et al. (2011), Stocker et al. (2014)
ORCHIDEE	LSCE	y	y	y	y	Ringeval et al. (2011)
SDGVM	University of Birmingham/University of Sheffield	y	y	y	y	Beerling and Woodward (2001), Hopcroft et al. (2011, 2020)
TEM-MDM	Purdue University	n	n	y	y	Zhuang et al. (2004)
TRIPLEX-GHG	UQAM	n	n	y	y	Zhu et al. (2014, 2015)
VISIT	NIES	y	y	y	y	Ito and Inatomi (2012)

Spatial Maps





Total CH_4 emissions



Total Loss

$$\text{Loss due to OH} = k_{CH_4+OH} \times [OH] \times B$$

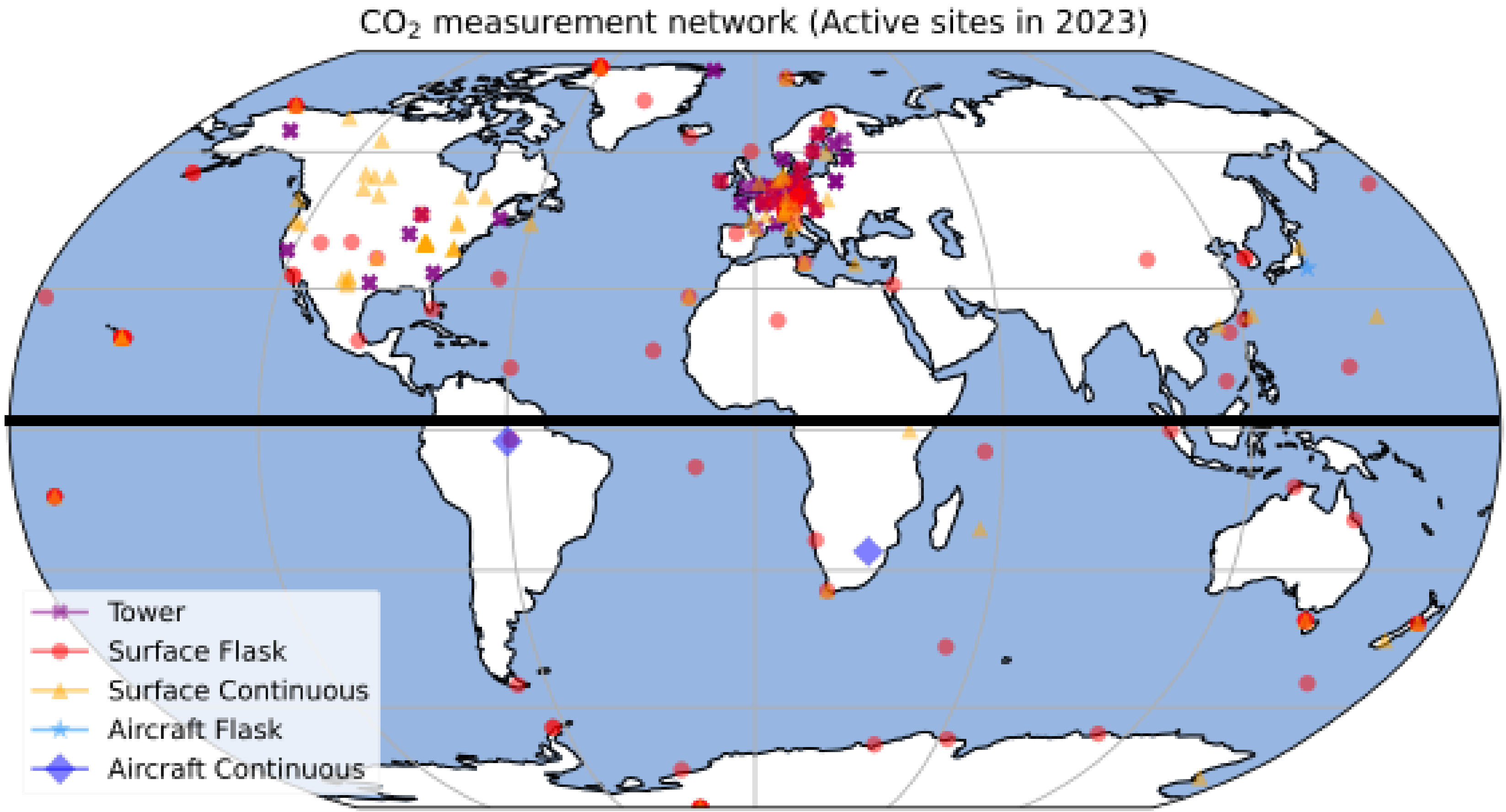
Global average [OH] = 1 x 10^6 molec/cm^3

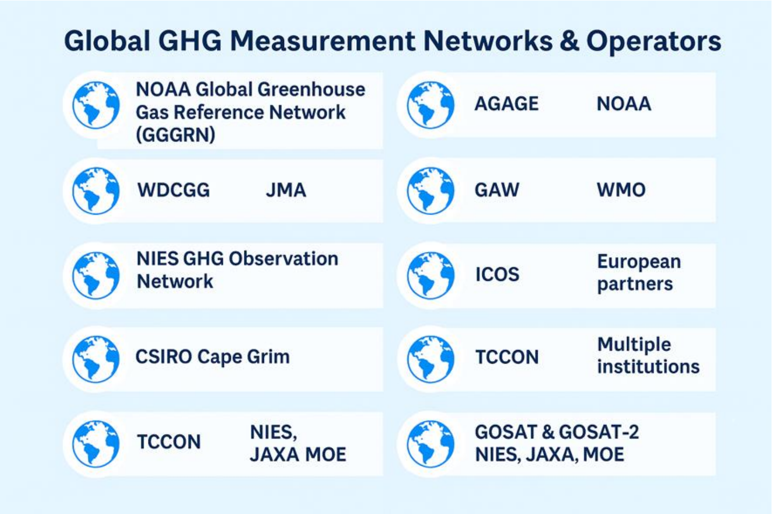
Reaction rate (k_{CH_4+OH})= 3.4 x 10^{-15} cm^3/molec/s

1 ppb = 2.78 $TgCH_4$

$\mathrm{B} = \mathrm{Burden} = \mathrm{Mixing\ Ratios\ (ppb)}$ x 2.78 Tg/ppb

Aggregate observations in two hemispheric bands for comparisons





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Exercise

Mass balance equations:

$$\frac{dB_{NH}}{dt} = \sum \cancel{S_{NH}} - \sum L_{NH} + k_{SN}\, B_{SH}$$

$$\frac{dB_{SH}}{dt} = \sum \cancel{S_{SH}} - \sum L_{SH} + k_{NS}\, B_{NH}$$

How Will Atmospheric CH_4 Respond if Emissions Are Stopped?

(Understanding the impact of policy actions)

- What will be the atmospheric lifetime of CH_4 in this scenario?
- How will the CH_4 burden change over time?