Top-down NH_3 emissions based on IASI observations and GEOS-Chem simulations, 2008-2018

Zhenqi Luo, visiting student, Atmospheric Environment Research Laboratory, Westlake University
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Research Overview

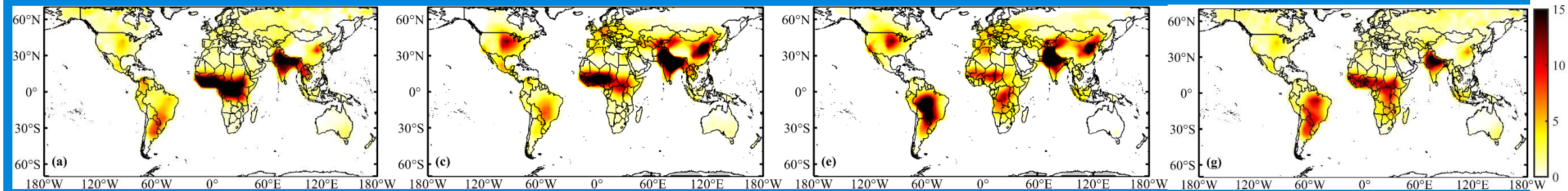
- Observed and Simulated NH_3 Concentrations
- Optimized Emission Fluxes
- Regional Comparison to GEOS-Chem Emissions

NH_3 Seasonal Concentrations

Mean (10^{15} molecules cm^{-2})

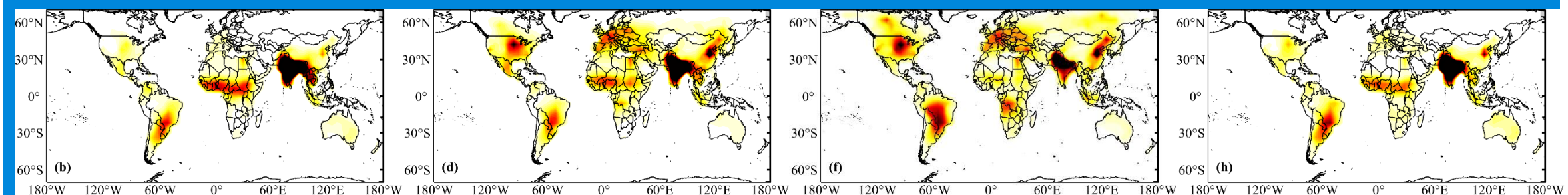
IASI observations

JFM AMJ JAS OND



GEOS-Chem simulations

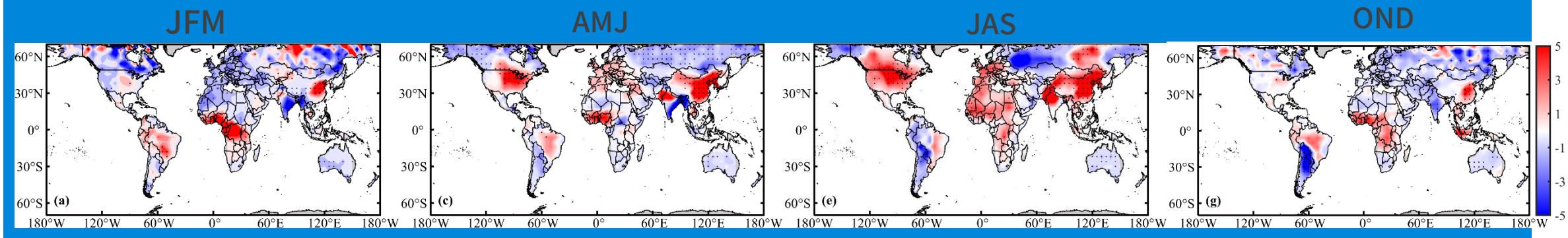
JFM AMJ JAS OND



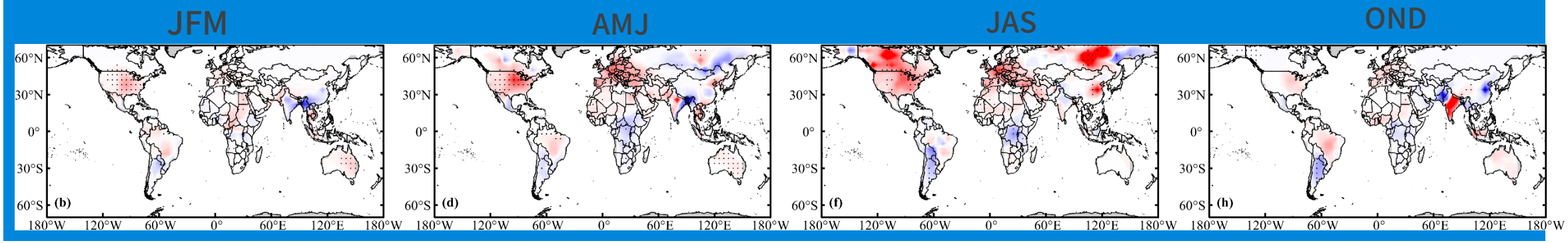
NH_3 Seasonal Concentrations

Trend (10^{-6} Mol m^{-2} yr^{-1})

IASI Observations



GEOS-Chem simulations



Emission Fluxes

Lifetime (τ)

Quasi-equilibrium

Emission fluxes of ammonia are continuous

$$\tau = \frac{M}{F_{out} + L + D}$$

- M: NH_3 mass
- F_{out}: NH_3 mass rate of export
- L: NH_3 mass rate of chemical reaction
- D: NH_3 mass rate of deposition, including the wet deposition and the dry deposition

Ammonia-water equilibrium

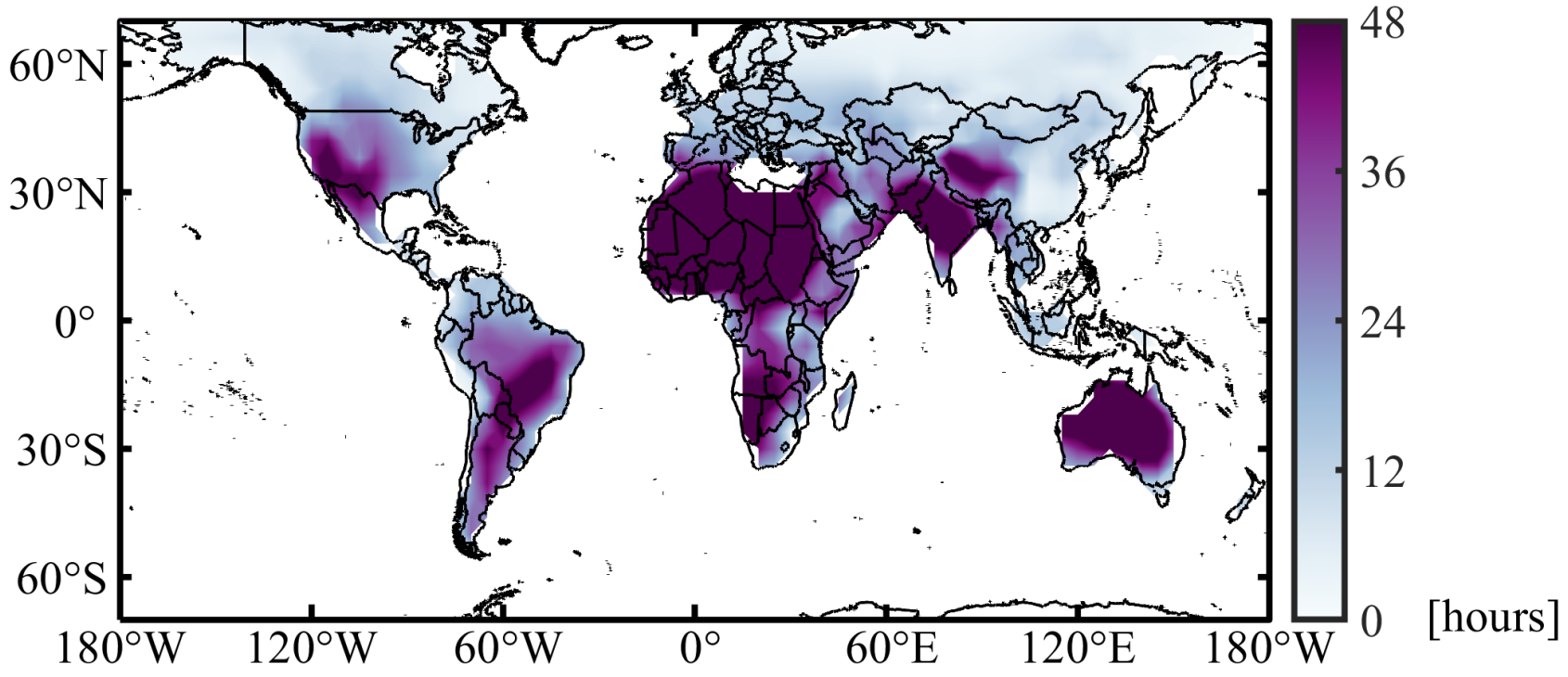
The NH_4^+ concentration ($[NH_4^+]$) is proportional to NH_3 concentration ($[NH_3]$)

$$[NH_4^+] = K \times [NH_3]$$
$$D = D_{NH_3} + D_{NH_4^+}$$

Modeled lifetime

Neglect the NH_3 export (F_{out})

$$\tau_{mod} = \frac{M_{NH_3}}{D_{NH_3} + D_{NH_4^+}}$$



Emission Fluxes

Average Lifetime

Apply one-box model that neglect the NH_3 export and consider the ammonia-water equilibrium.

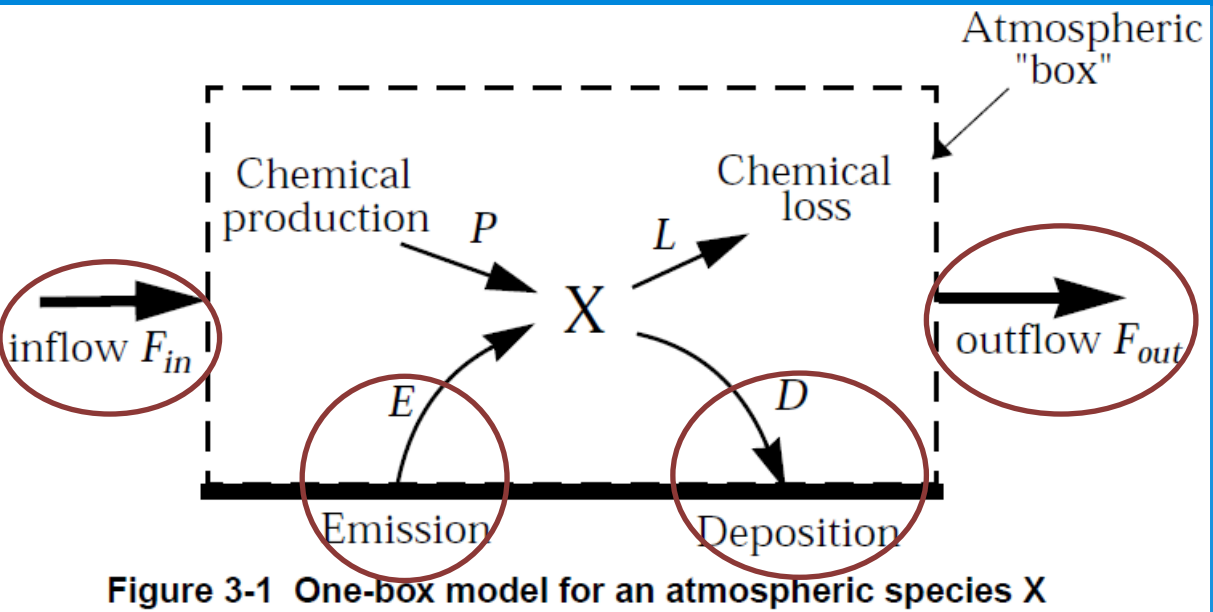


Figure 3-1 One-box model for an atmospheric species X

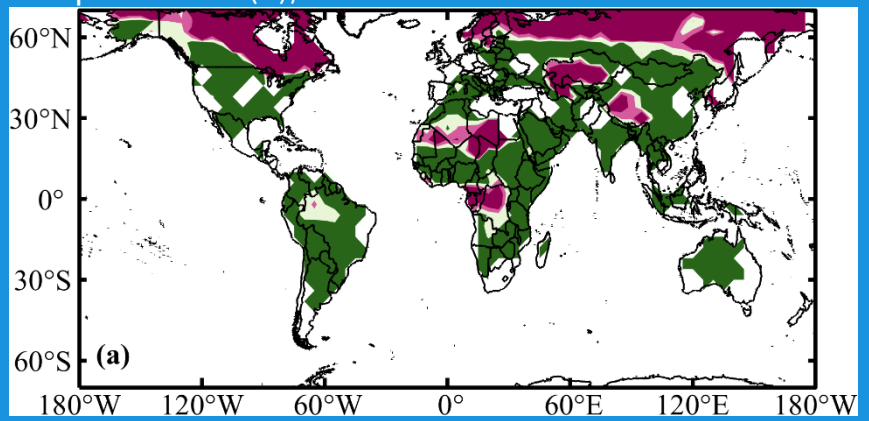
(Jacob, 1999)

Emission Fluxes

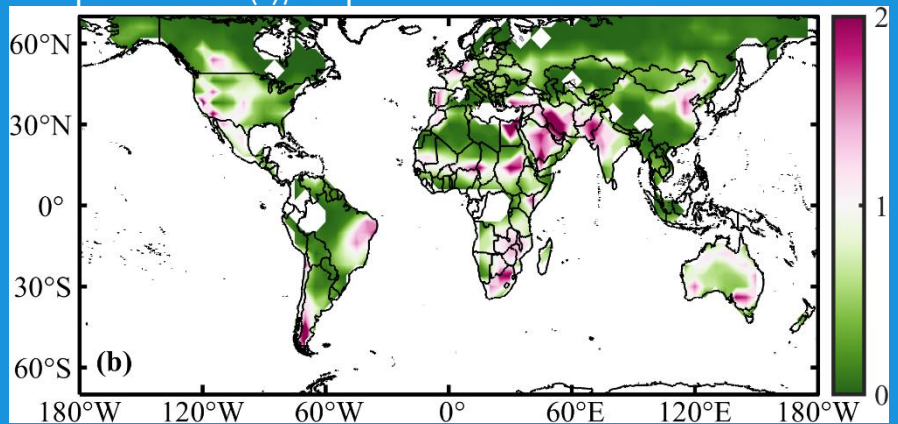
Transportation = $F_{in} - F_{out}$

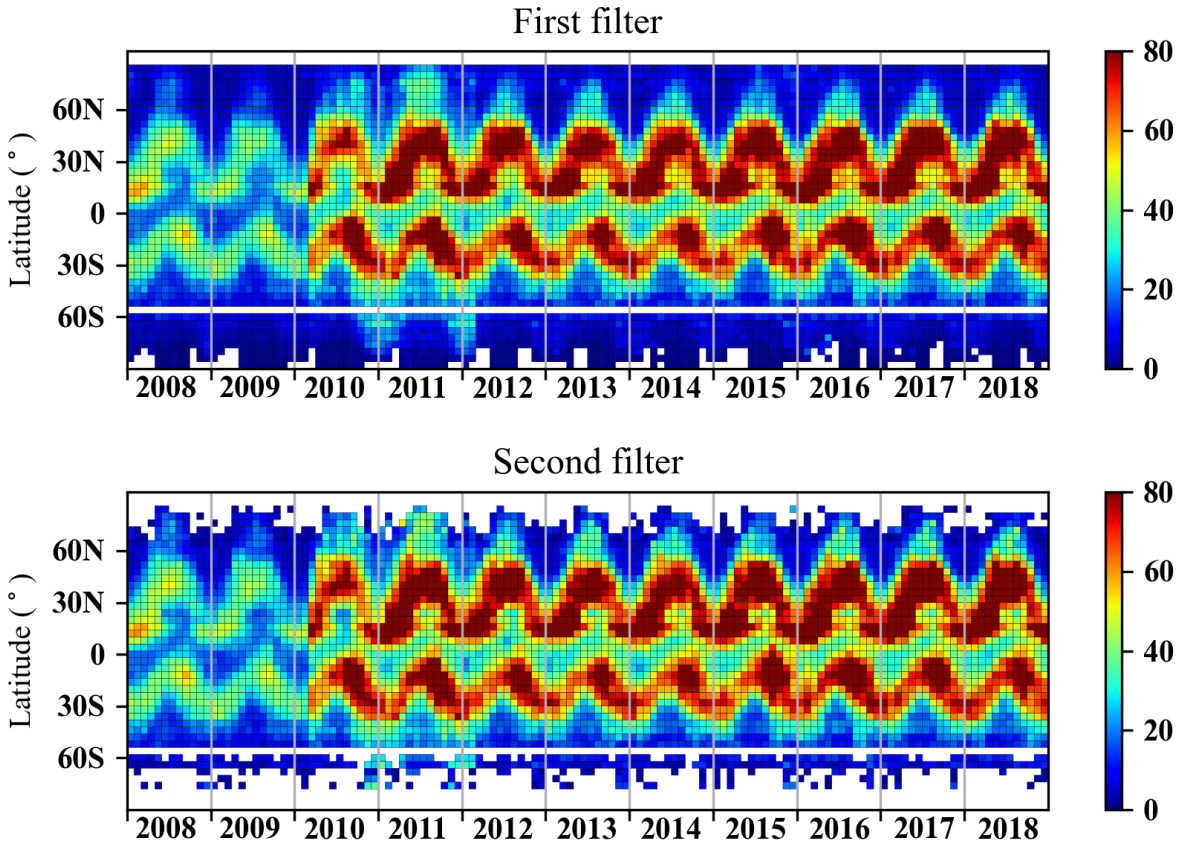
Note Two Situations!

- Transportation > 0, $F_{in} > F_{out}$
- Emissions may be unreliable if the transportation of NH_3 and NH_4^+ are larger than emissions
- Transportation (+)/Emissions:



- Transportation < 0, $F_{in} < F_{out}$
- Emissions may be unreliable if the transportation of NH_3 and NH_4^+ are larger than depositon
- Transportation (-)/Depositions:



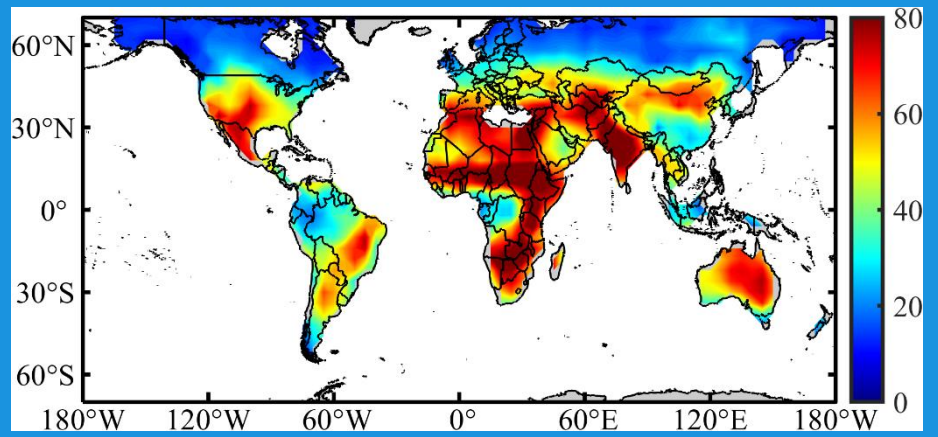


Emission Fluxes

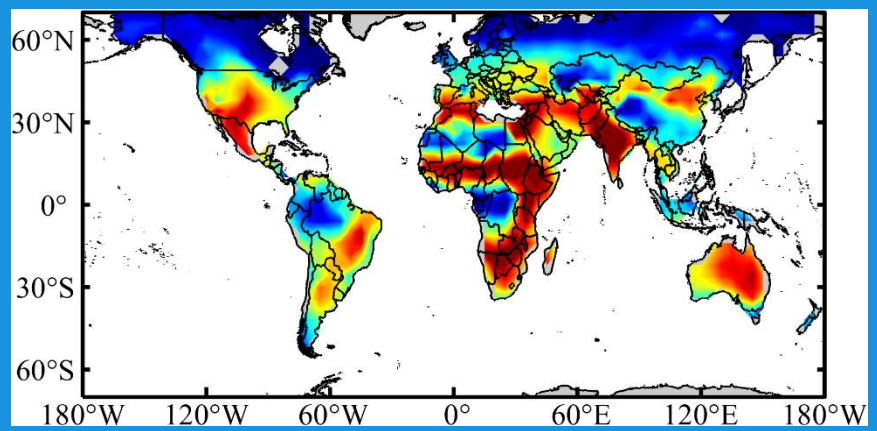
Number of Retrievals

Note Data Validation!

- First filter——based on IASI datasets (Damme et al., 2014)
  - Cloud coverage: [0, 10%]
  - Skin temperature: > 263.15 K
- Average number of retrievals (N grid^{-1} day^{-1})



- Second filter——based on GEOS-Chem output
  - Transportation < Emission



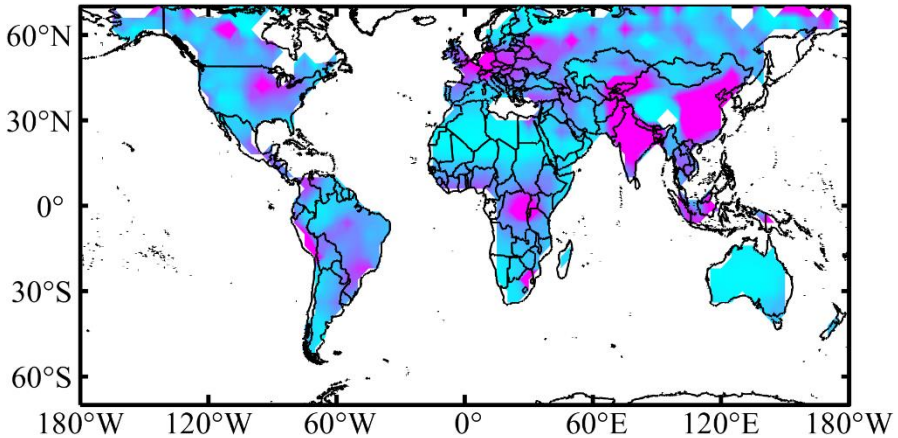
Emission Fluxes ($\hat{E}$)

$$\hat{E} = \frac{\Delta M_{NH_3}}{\tau_{mod}} + E_{mod}$$

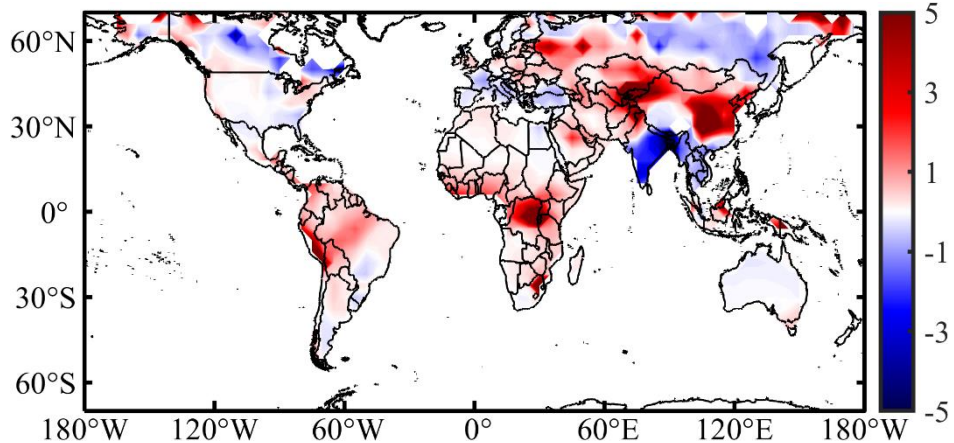
- ΔM_{NH_3}: the NH_3 mass difference between observation and simulation in each atmospheric box
- E_{mod}: GEOS-Chem emission

Mean (10^{-11} kg m^{-2} s^{-1})

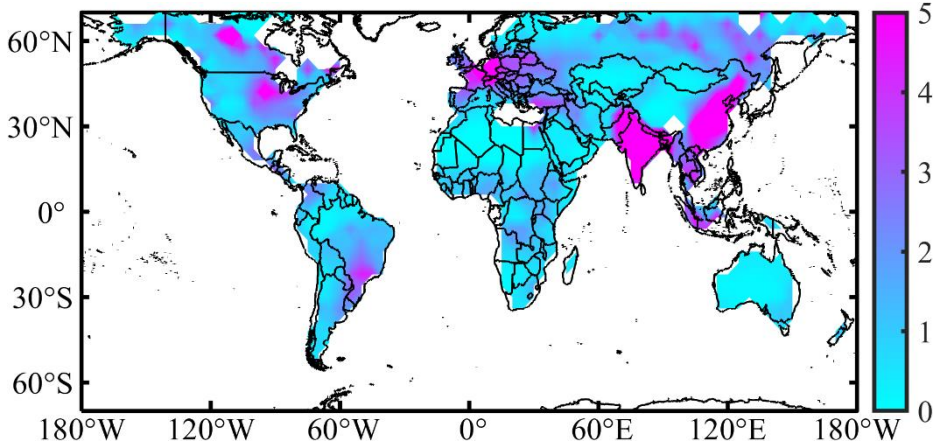
Optimized (N > 30 grid^{-1} day^{-1})



Optimized – GEOS-Chem



GEOS-chem



Emission Fluxes ($\hat{E}$)

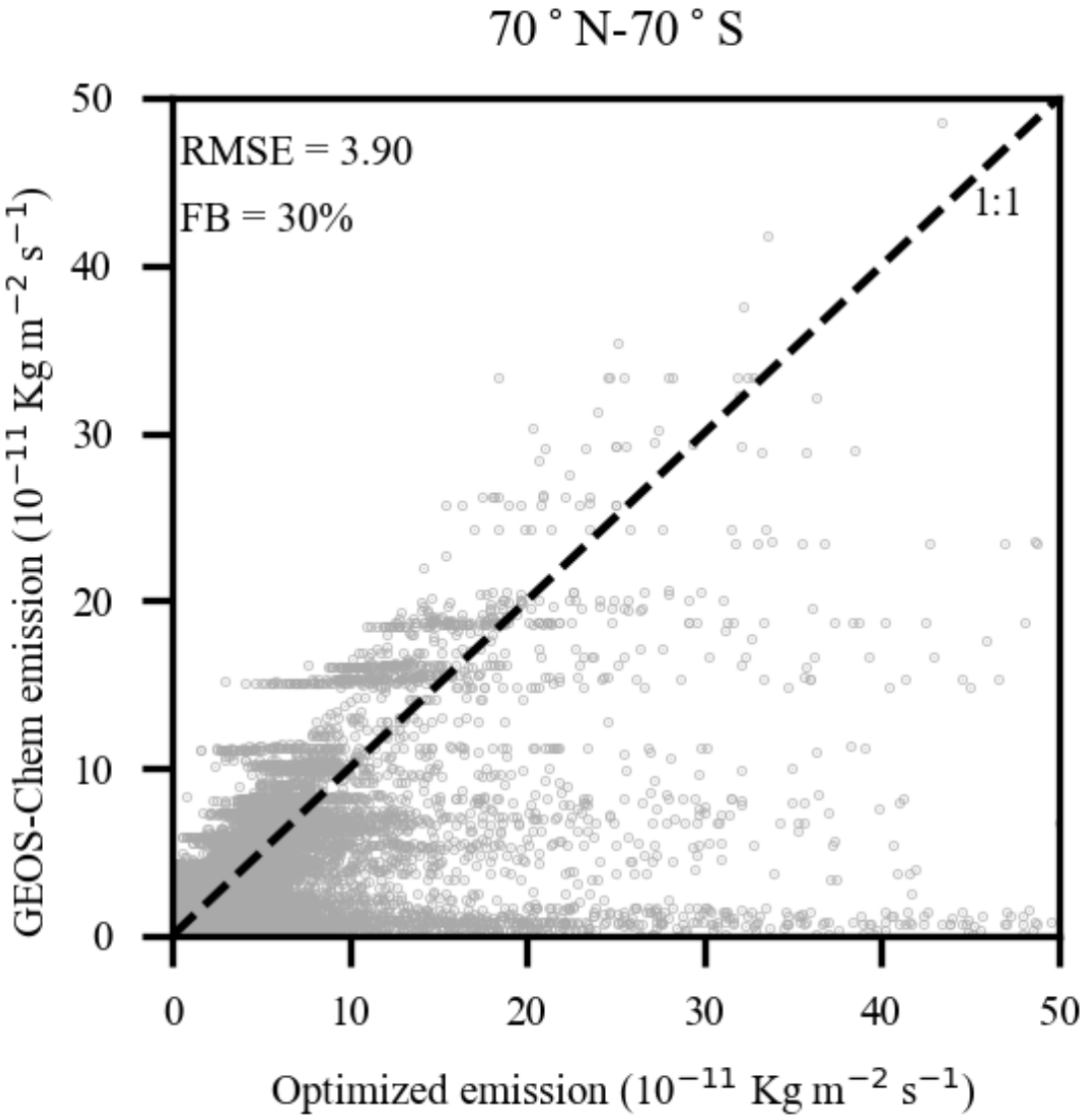
Optimized versus GEOS-Chem

- Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(E_{Opt,i} - E_{Mod,i})^2}$$

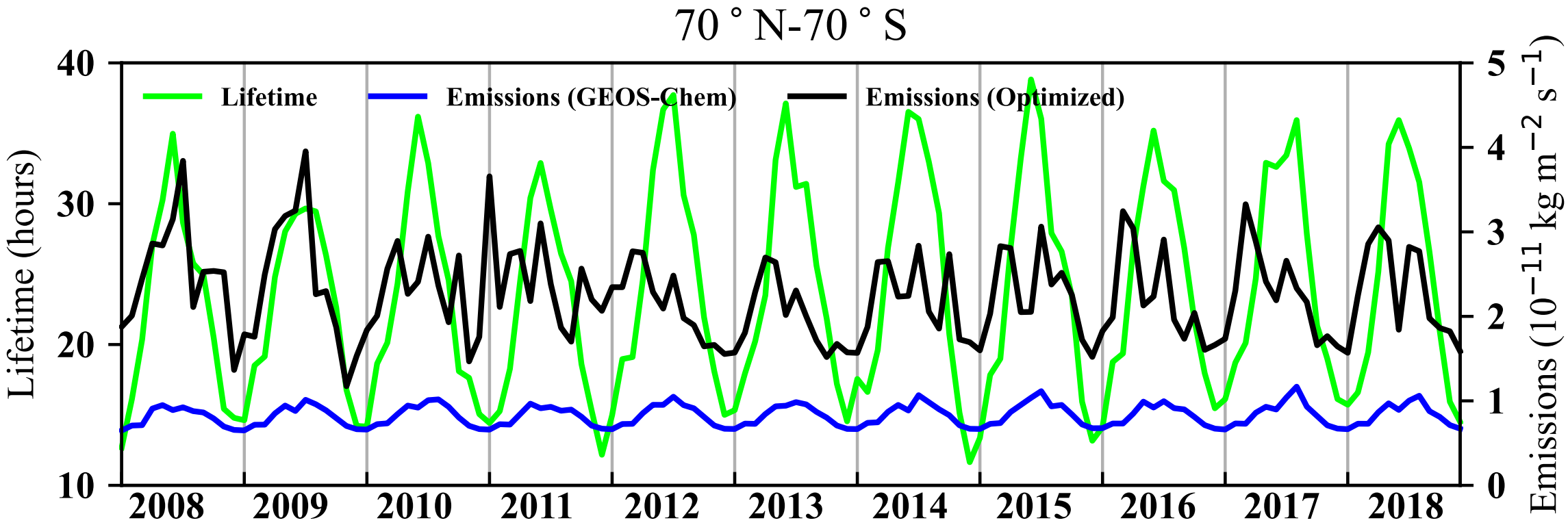
- Fractional Bias (FB)

$$FB = \frac{\sum_i^N (E_{Opt,i} - E_{Mod,i})}{\sum_i^N (E_{Opt,i} + E_{Mod,i})/2} \times 100\%$$



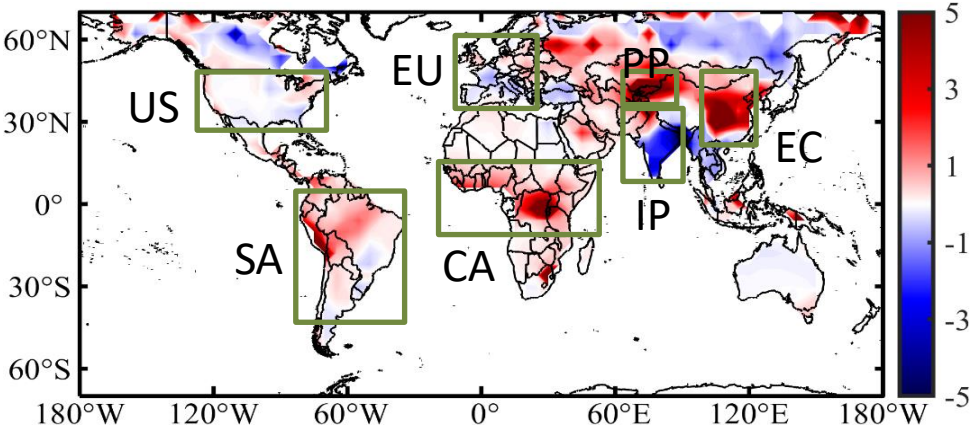
Emission Fluxes ($\hat{E}$)

- Monthly timeseries



Regional Comparison

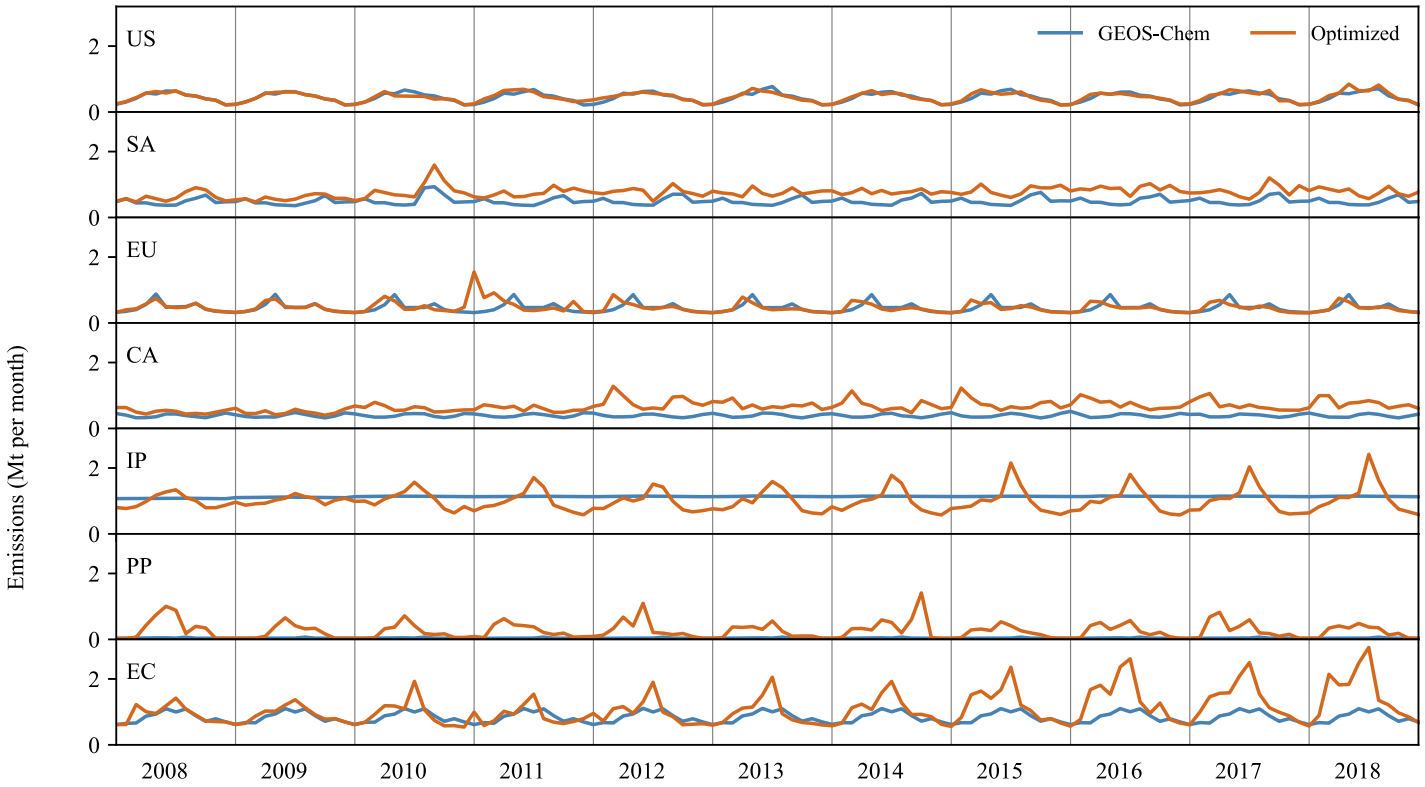
Optimized – GEOS-Chem



7 Regions:

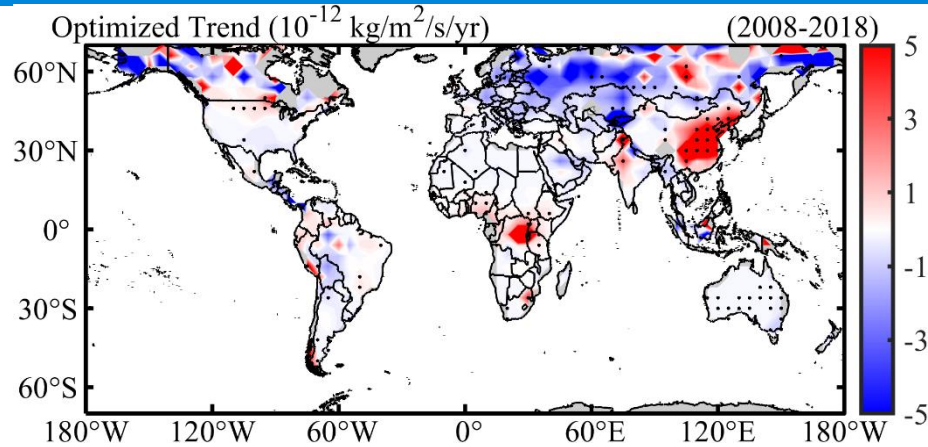
- US: Contiguous United States
- SA: south America
- EU: Europe
- CA: central Africa
- PP: Pamirs Plateau
- IP: India Peninsula
- EC: eastern China

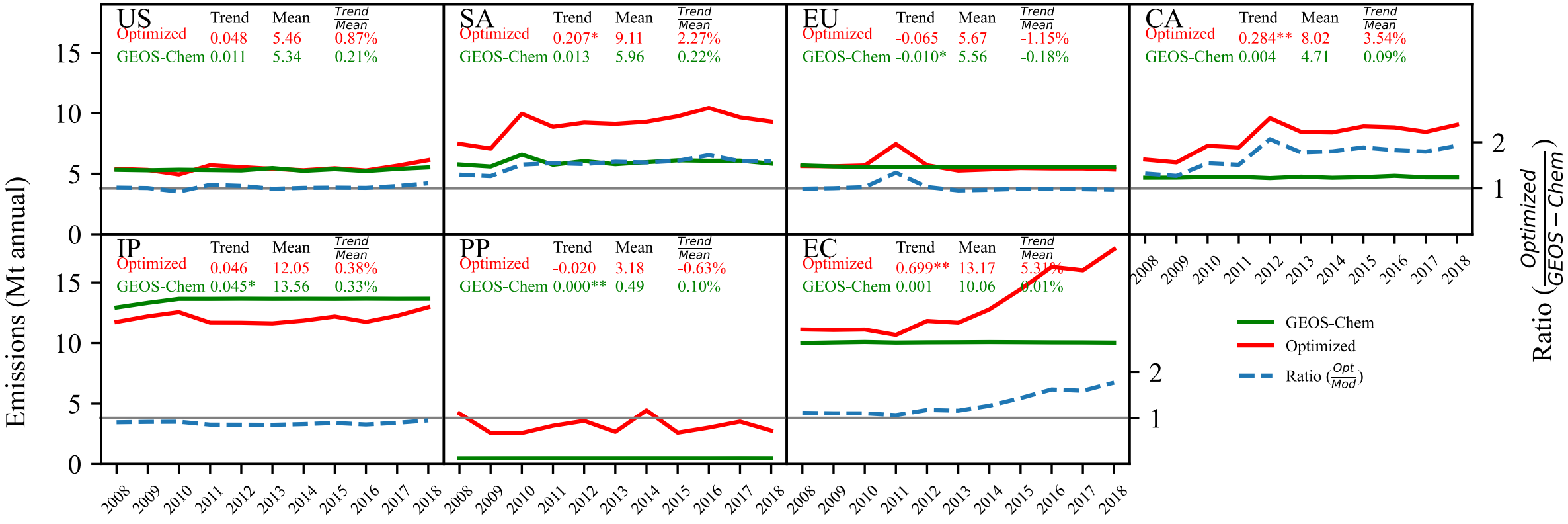
Monthly timeseries (replace the missing value by GEOS-Chem emissions)



Regional Comparison

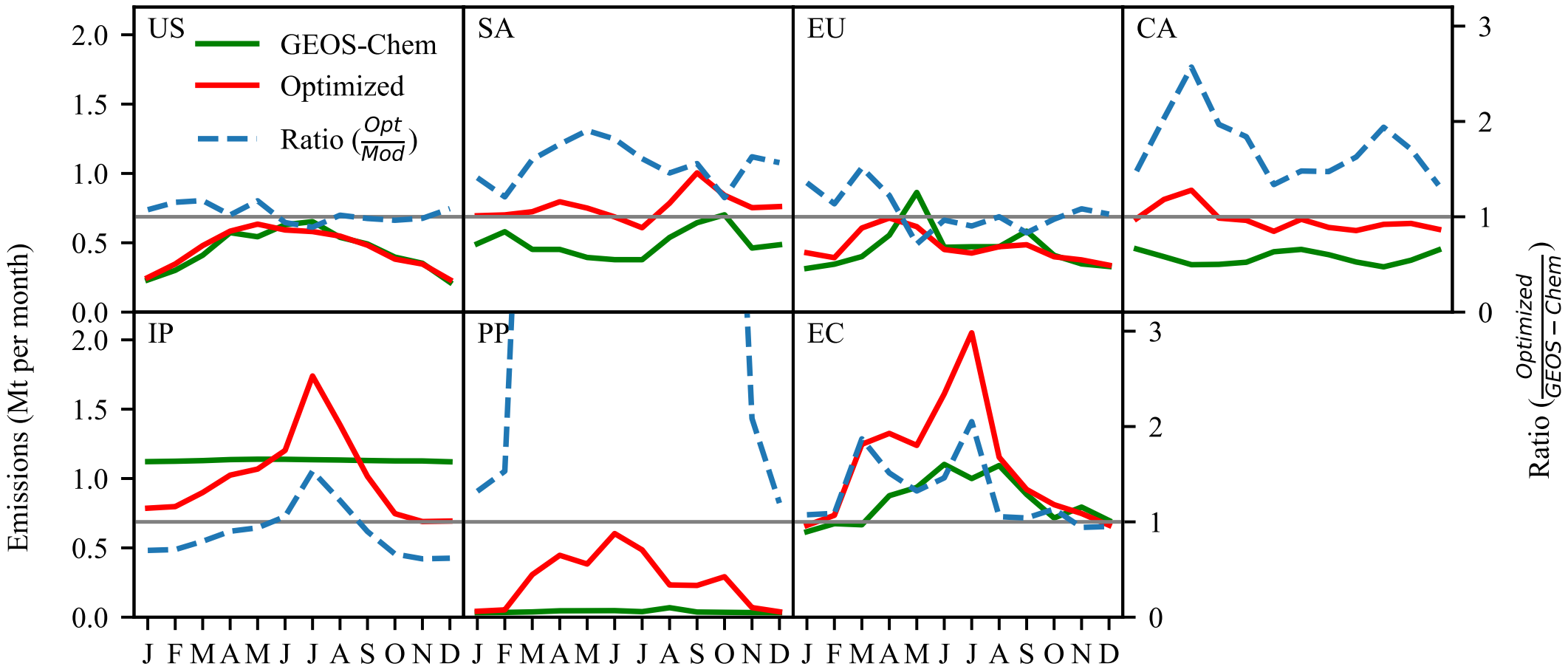
- Annual timeseries





Regional Comparison

Monthly variation

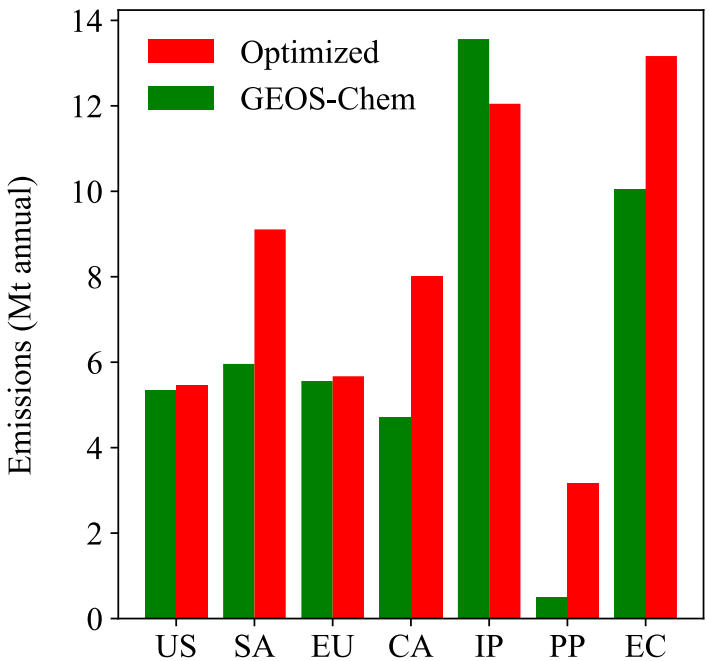


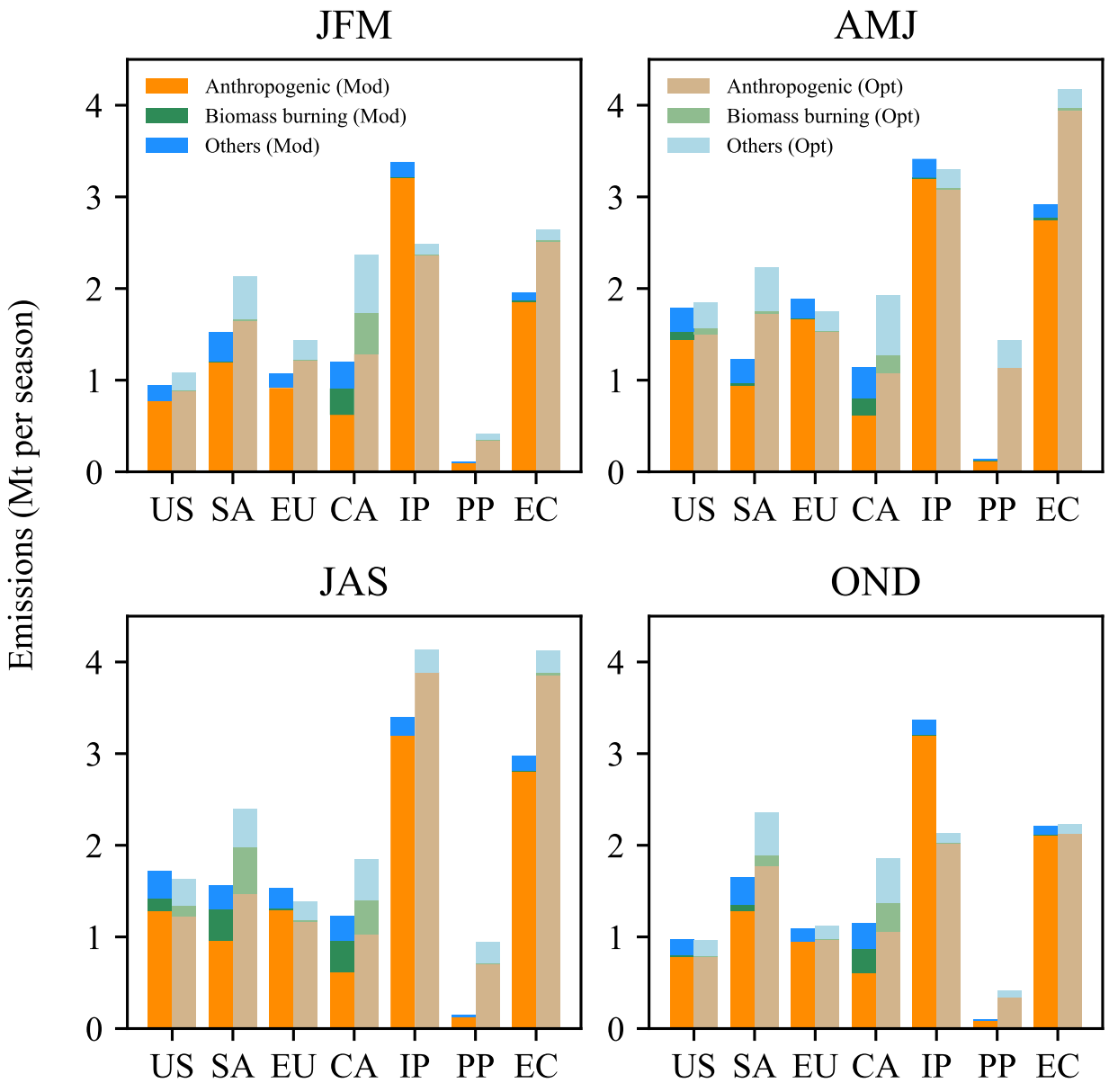
Regional Comparison

Proportions of emission sectors

From GEOS-Chem (monthly) :

- Total
  - Biomass burning
  - Anthropogenic
  - Others





Regional Comparison

Optimized versus GEOS-Chem

Optimize < GEOS-Chem

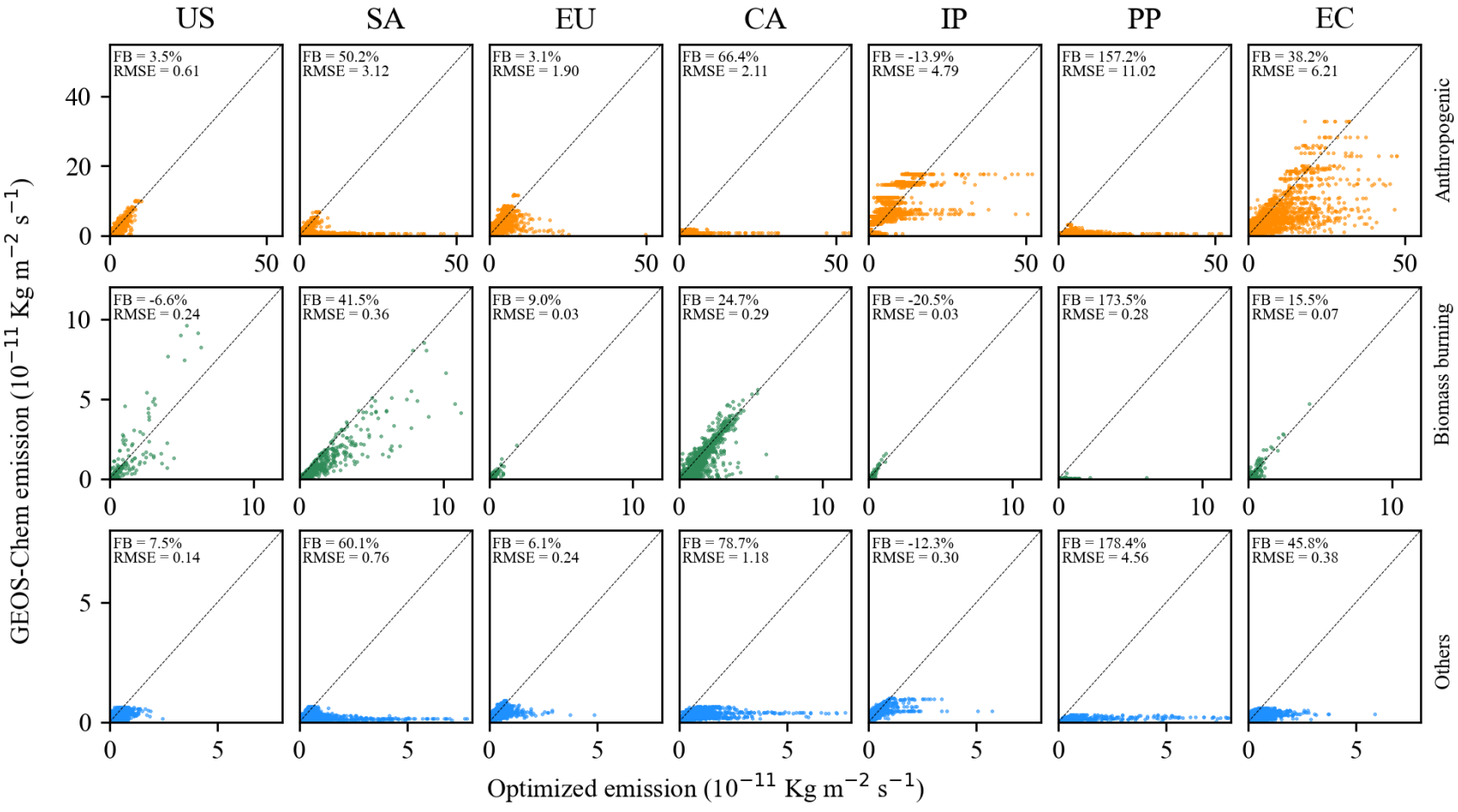
- IP

Optimize > GEOS-Chem

- SA
- CA
- PP
- EC

Optimize ≈ GEOS-Chem

- US
- EU

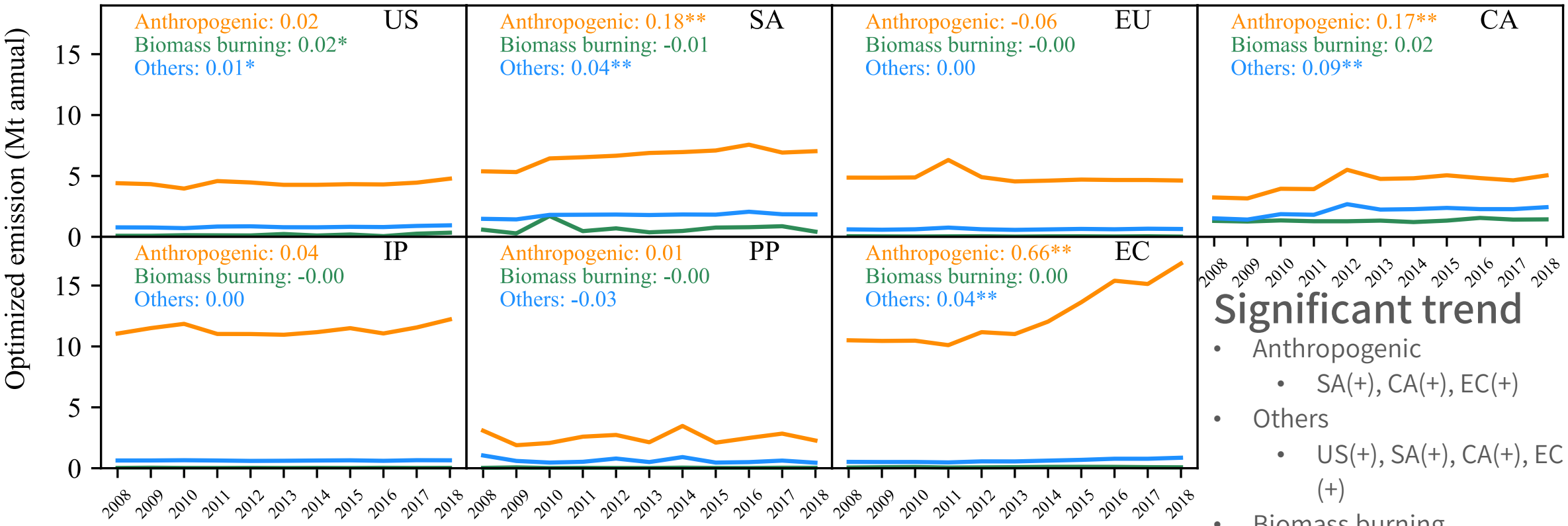


Regional Comparison

Optimized emission trends

Significant confidence levels

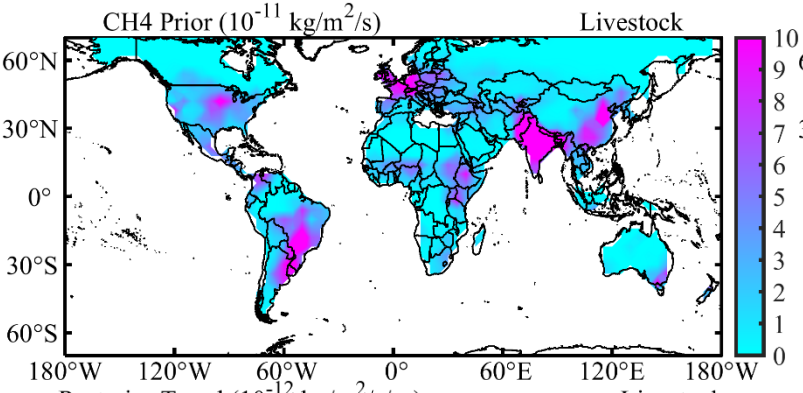
- >95%: *
- >99%: **

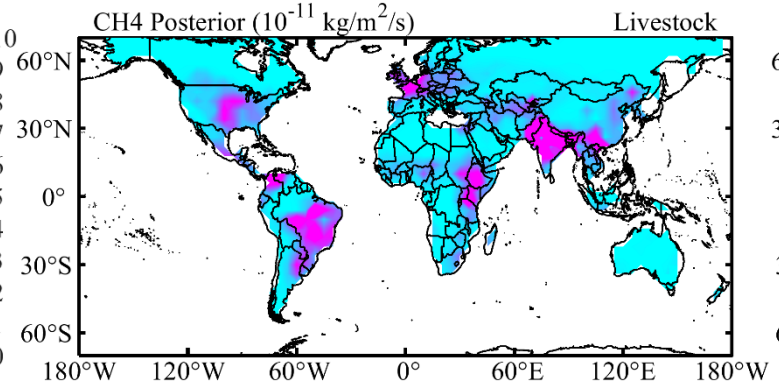


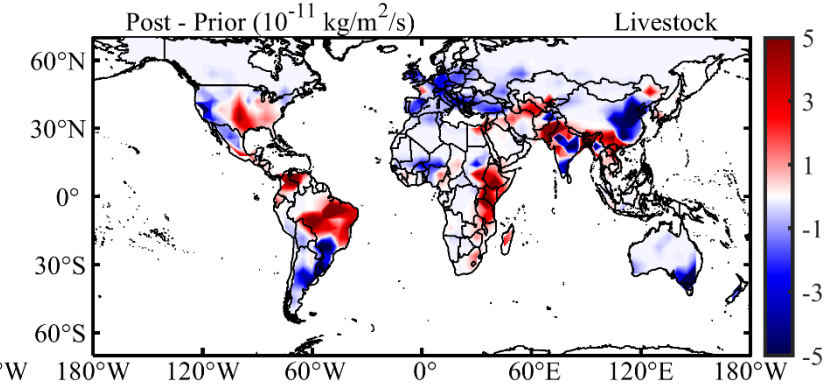
Significant trend

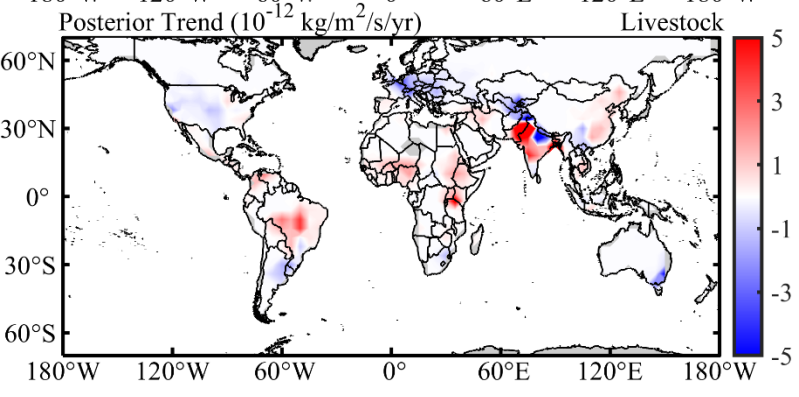
- Anthropogenic
  - SA(+), CA(+), EC(+)
- Others
  - US(+), SA(+), CA(+), EC(+)
- Biomass burning
  - US(+)

CH4 Livestock Emission Fluxes

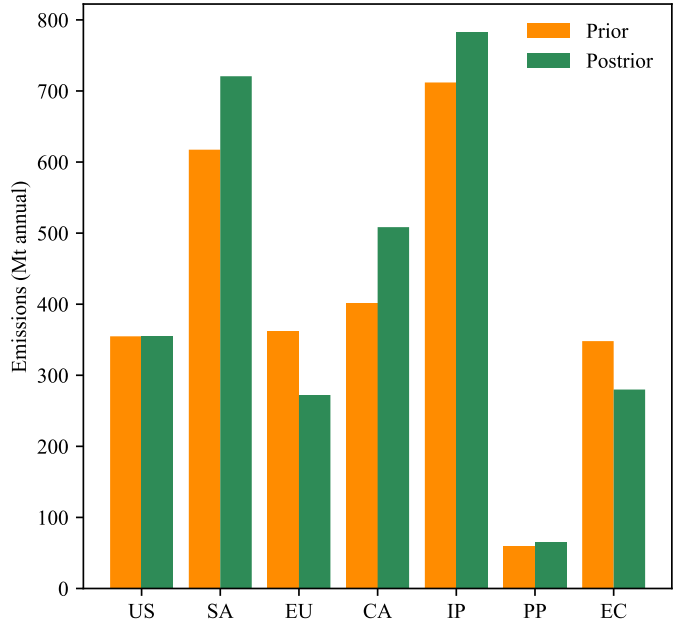






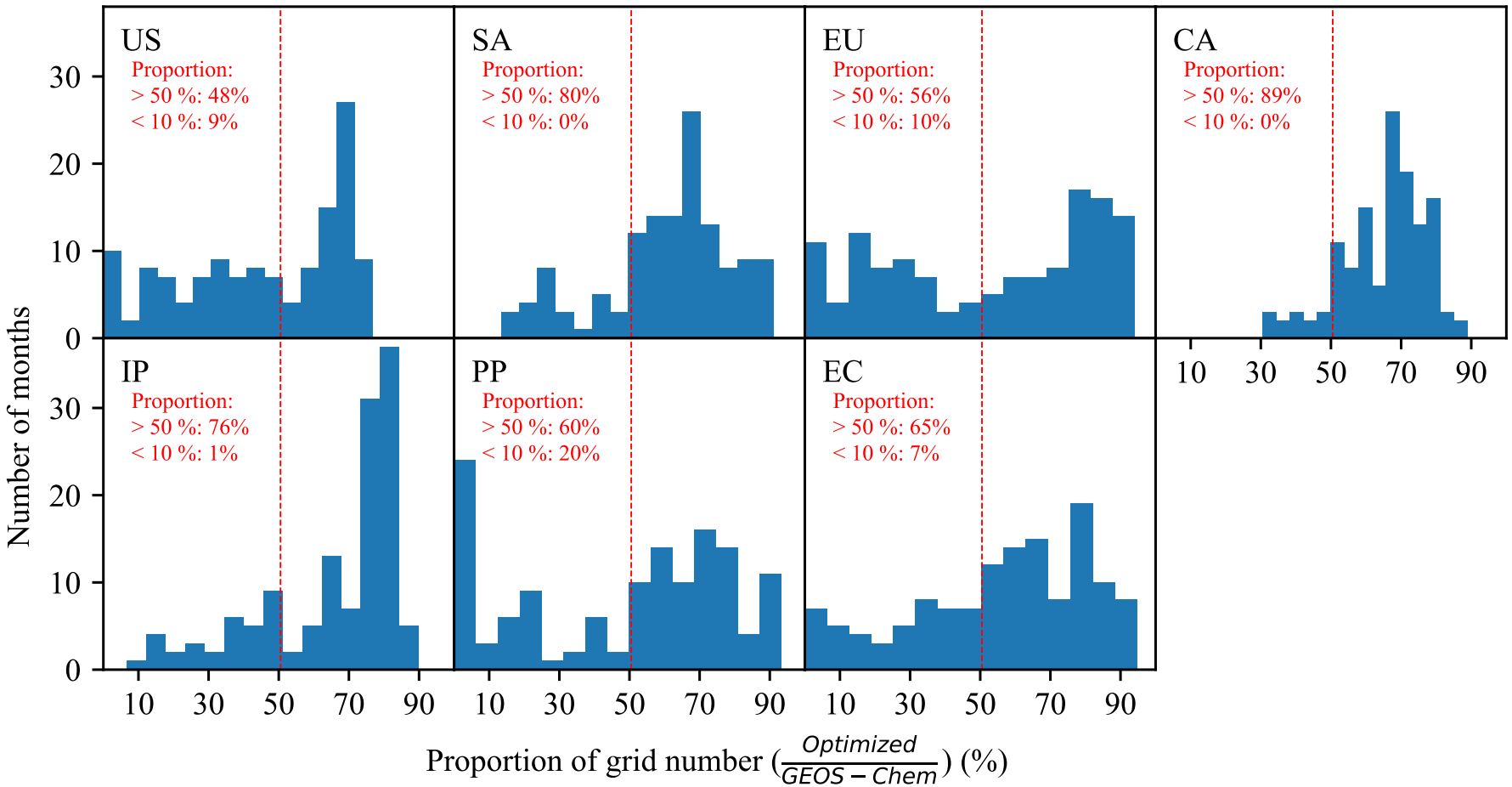


	Mean (Mt)	Trend (Mt/yr)	Relative trend (%)
US	355	-1.11	-0.14
SA	721	5.05	0.46
EU	272	-2.67	-0.24
CA	508	8.02	0.86
IP	783	10.68	0.71
PP	66	-1.65	-1.15
EC	280	1.37	0.49



Regional Comparison

Optimized grid number proportion

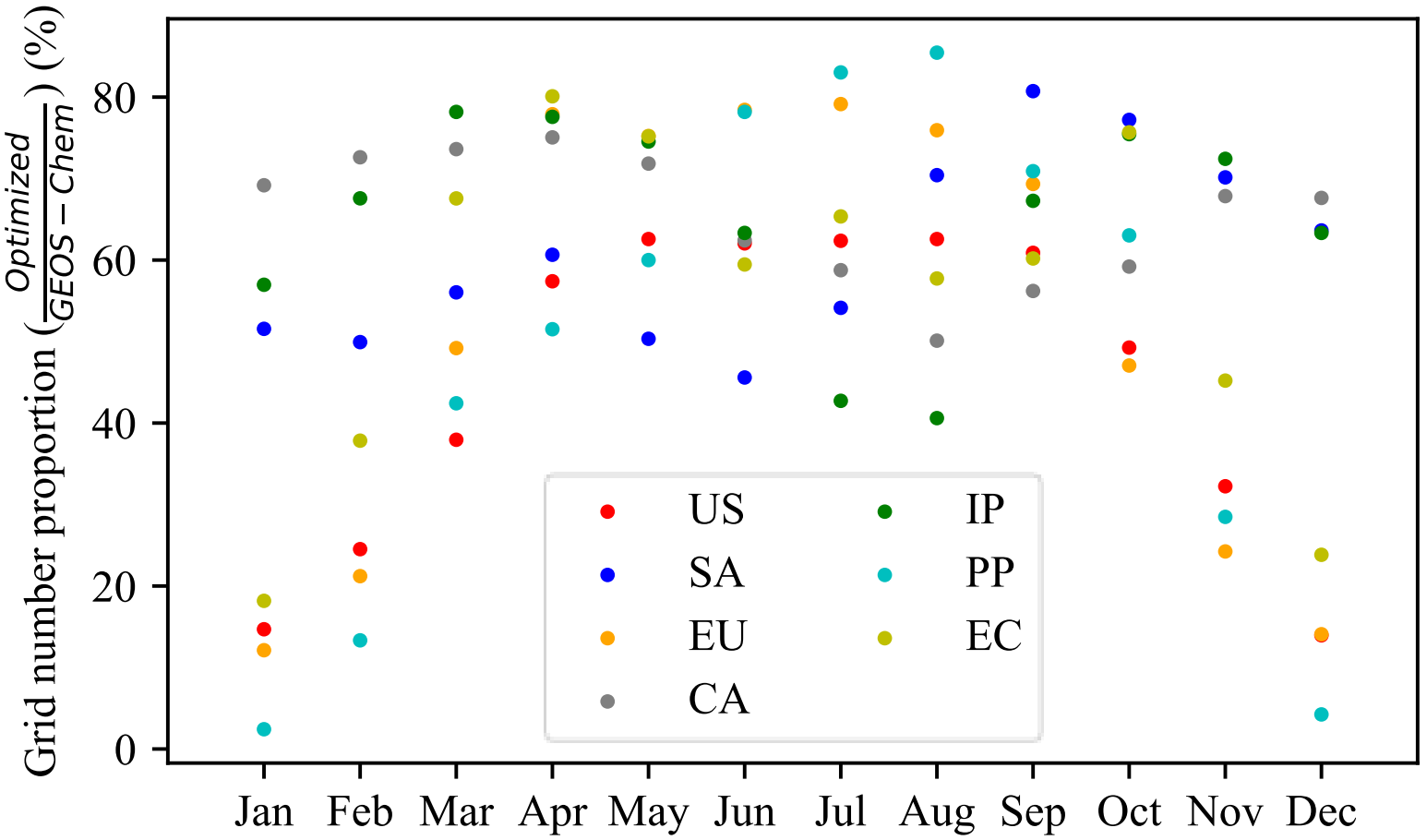


Data quantity

- Good:
  - SA, CA, IP
- Not bad:
  - US, EC, EU
- Bad:
  - PP

Regional Comparison

■ Optimized grid number proportion



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Reference

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THANK YOU!

luozhenqi@westlake.edu.cn 18 Shilongshan Rd.,Cloud Town, Xihu District, Hangzhou,Zhejiang Province, China, 310024