Inter-comparison of carbonyl sulfide (COS) TransCom part II: Evaluation of the optimized fluxes using ground-based, aircraft, and FTIR data

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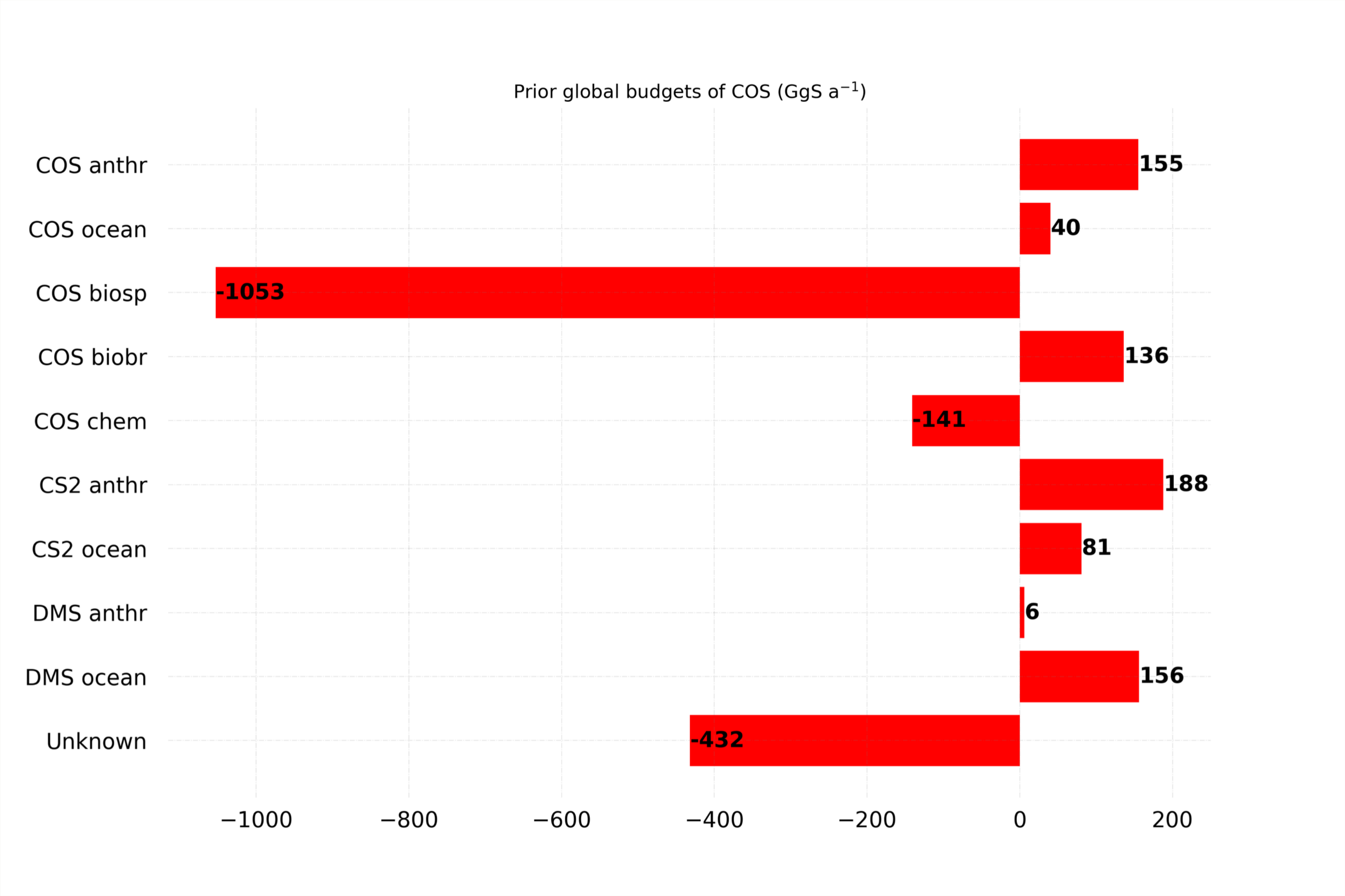
Motivations

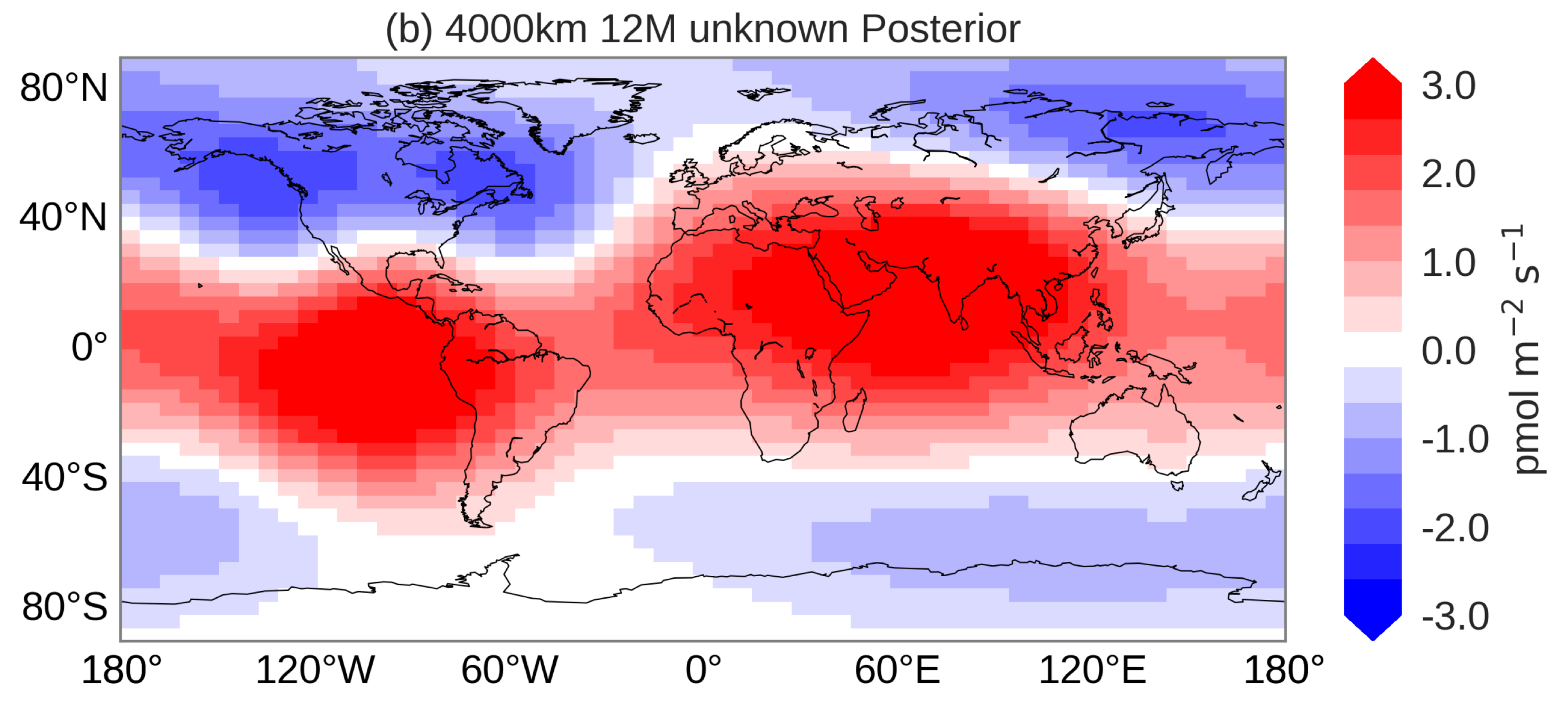
- COS is important trace gas with 500 ppt in the atmosphere
  - *contribute to sulfur aerosols in stratosphere*
  - *absorbed by plants and useful for tracking* CO_2

- However, the sources and sinks of COS is unresolved.
  - Comparison of recent COS inversions with control scenario
  - Comparison amongst different transport models
  - Validation with different data platforms:
    - NOAA surface network: 15 sites
    - NOAA airborne
    - HIPPO: Pacific
    - ATOM: Pacific and Atlantic
    - FTIR: 7 sites

Global COS budget: Prior



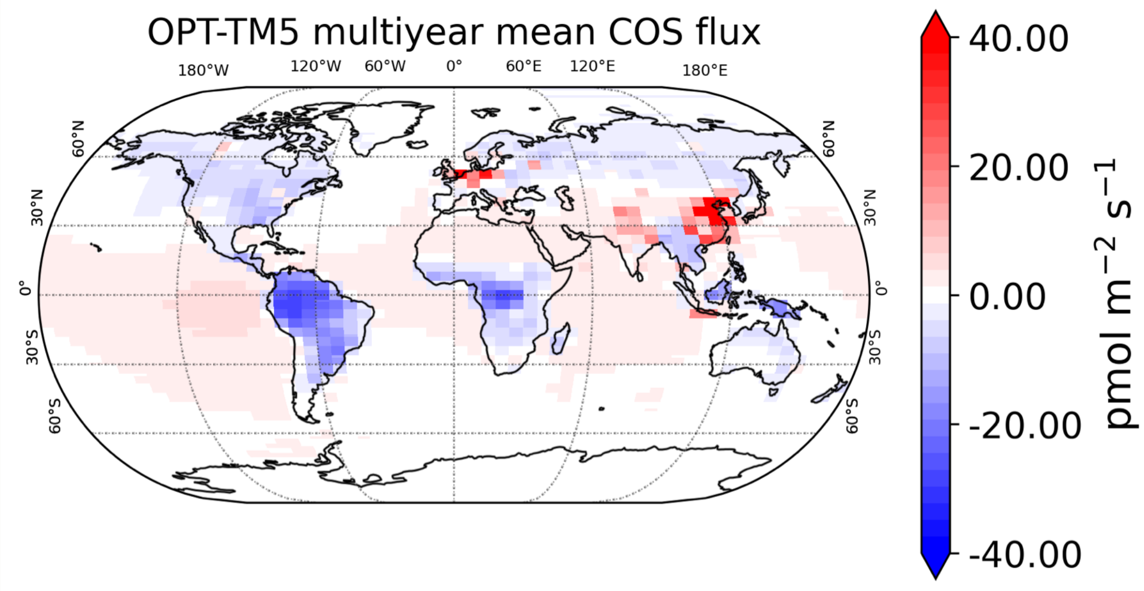
Global COS budget optimization based on TM5-4DVAR



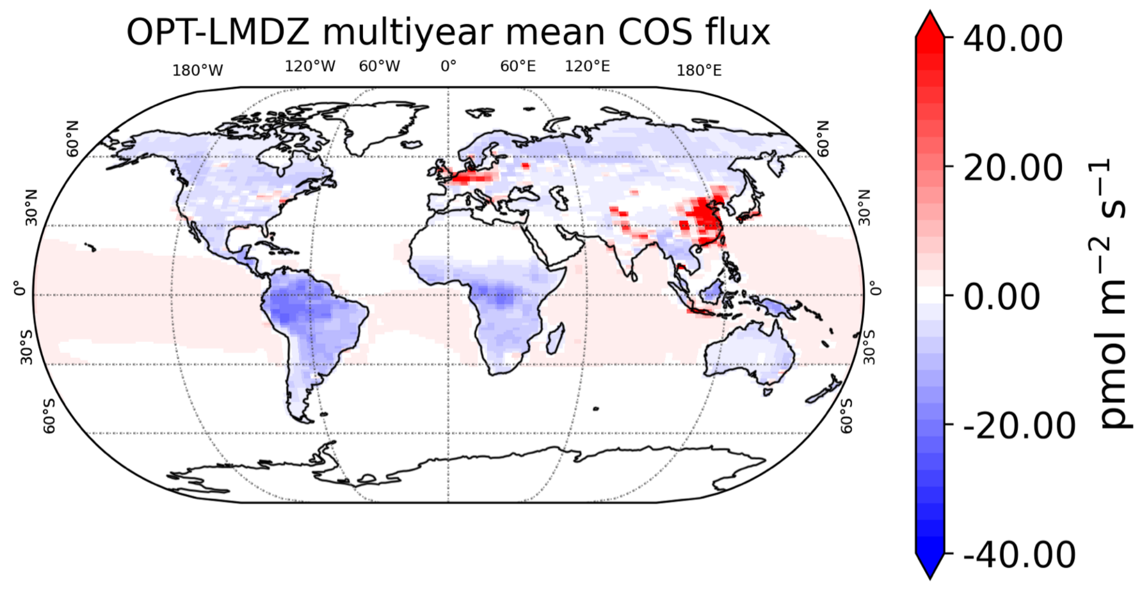
Optimizing the so called "missing" emissions globally 432 GgS a^{-1} (Ma et al., 2021)

Optimized Fluxes

Inverse Model	TM5-4DVAR	LMDZ
Tracers	COS, CS2 and DMS	COS and CO2
Hori. Res	6x4	1.875x3.75
Vert. Res	25	39
Prior sources	Anthropogenic	Anthropogenic
	Ocean	Ocean
	biomass burning	biomass burning
		CO2 flux
Prior sinks	Sib4 biosphere flux	ORCHIDEE biosphere flux
	OH oxidation	OH oxidation
	Stratosphere photolysis	
Data assimilation	COS measurement at 14 NOAA stations	COS measurement at 15 NOAA stations
		CO2 NOAA surface network
Period	2010-2018	2008-2019

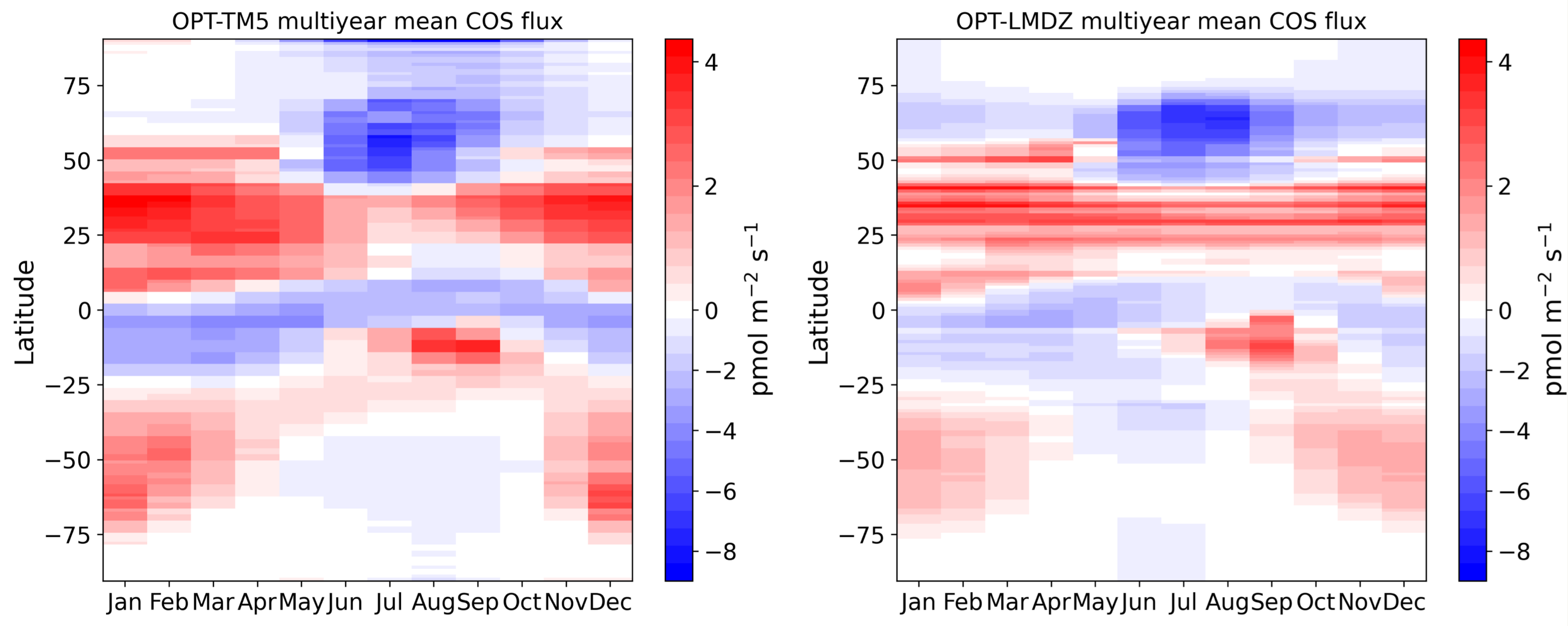

OPT-TM5 multiyear mean COS flux

(Ma et al., 2021)


OPT-LMDZ multiyear mean COS flux

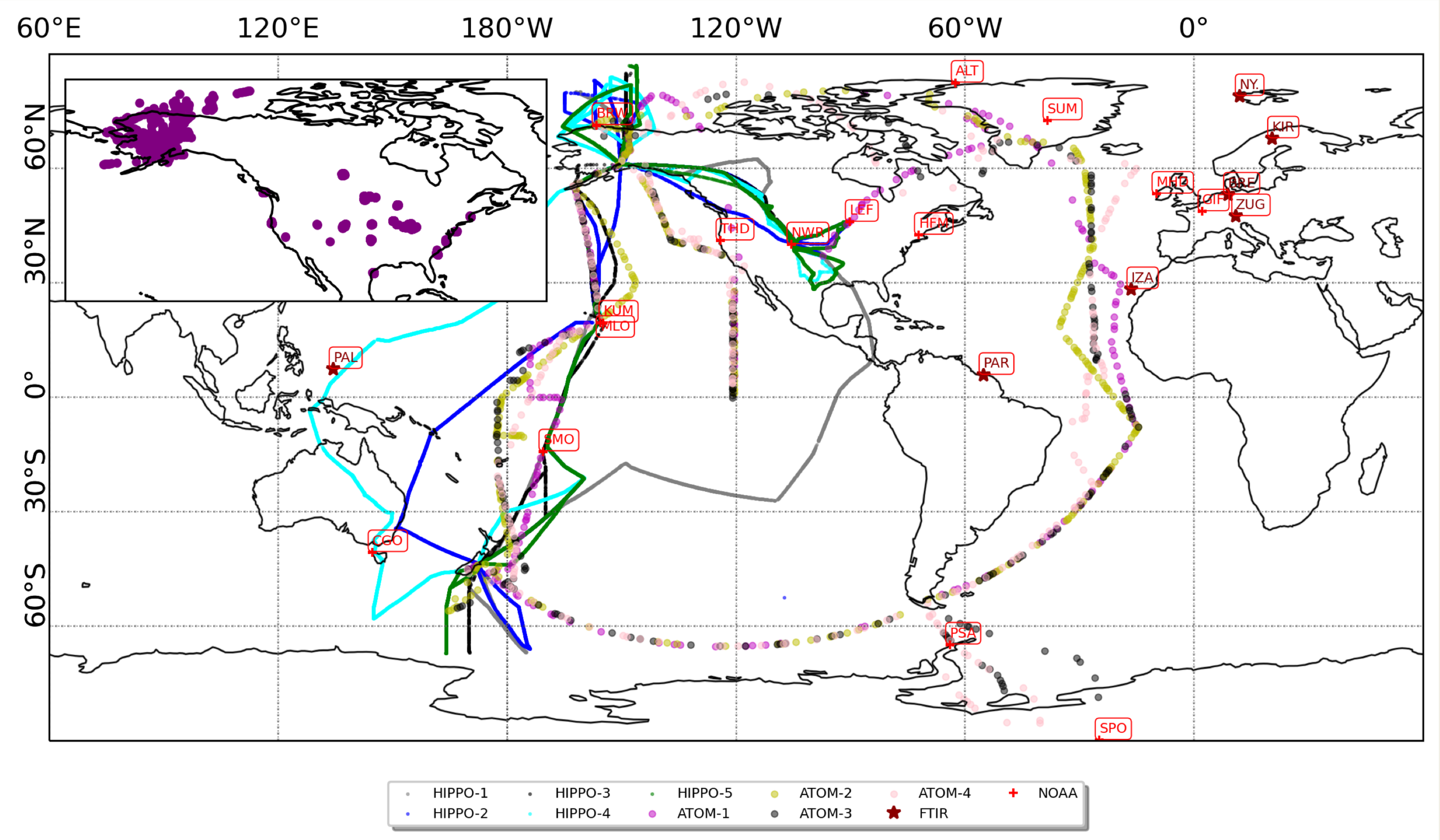
(Remaud et al., 2022)

Optimized fluxes: seasonal and latitude



TM5-flux shows stronger seasonal cycle.

Data platform locations



Model info and model groups

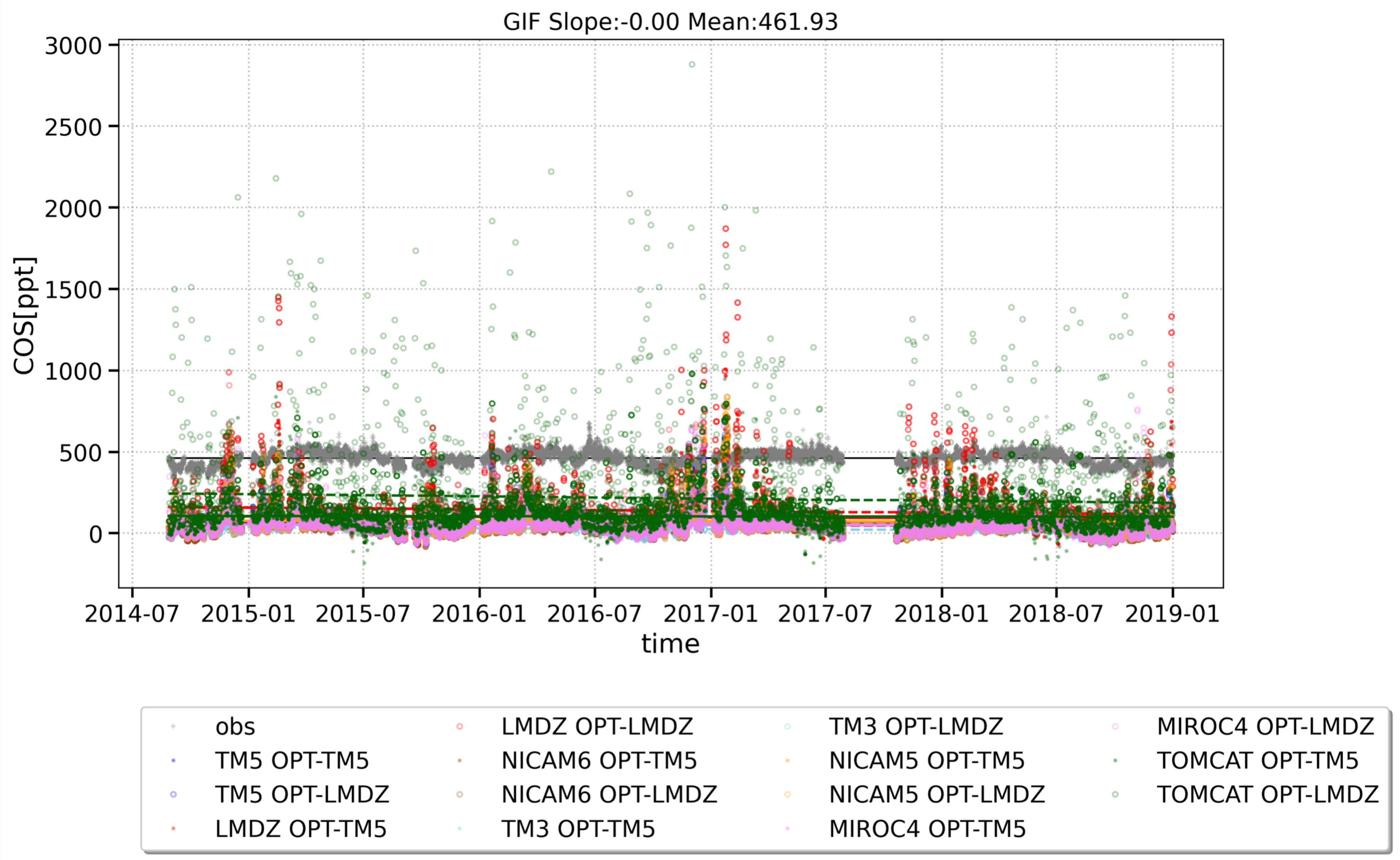
Transport model	Model group	Meteorology	Horizontal resolutions (latitudexlongitude)	Vertical resolutions	Reference
LMDz	weak mixing	Nudging towards horizontal winds from ERA-5	1.875º×3.75º	39η	Remaud et al. (2018)
TM5	strong mixing	Nudging towards horizontal winds from ERA-Interim	2ºx2º	25η	Krol et al. (2005)
TM3	strong mixing	Nudging towards horizontal winds from ERA-Interim	4ºx5º	19η	Heimann et al. (2003)
TOMCAT	strong mixing	Forced with the surface pressure, vorticity, divergence from ERA-Interim	2.8ºx2.8º	60η (surface to ~60 km)	Chipperfield (2006)
MIROC4	weak mixing	Nudging towards horizontal winds and temperature from JRA-55	T42 spectral truncation (~ 2.81º × 2.81º)	67η	Patra et al. (2018)
NICAM5	weak mixing	Nudging towards horizontal winds from JRA-55	2.5° x 2.5° (~223 km)	40η	Niwa et al., (2017)
NICAM6	weak mixing	Nudging towards horizontal winds from JRA-55	1° x 1° (~112 km)	40η	Niwa et al., (2017)

Optimized fluxes information

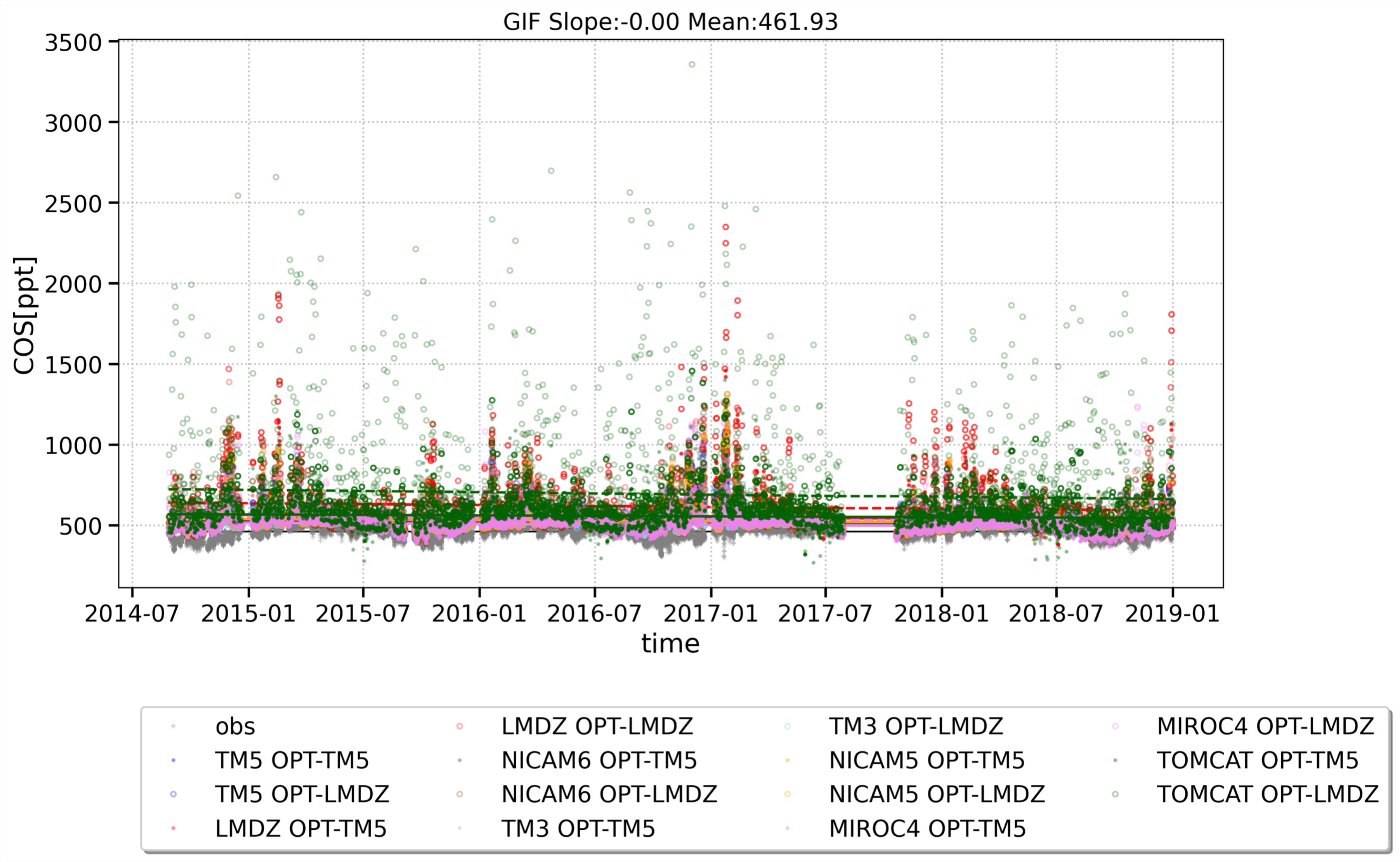
Model	TM5-4DVAR	LMDZ-4DVAR
Resolution	1x1	1x1
Reference	Ma et al., 2021	Remaud et al., 2022
Period	Total flux (OPT-TM5)	Total flux (OPT-LMDZ)
2010	42.6	15.1
2011	9.0	11.1
2012	67.8	14.9
2013	-13.8	-6.8
2014	62.1	12.1
2015	23.2	36.6
2016	65.3	-26.8
2017	-46.2	-7.3
2018	-18.7	-8.1
Average	21.25	4.54

GgS a^{-1}

Correct the COS mixing ratio: before

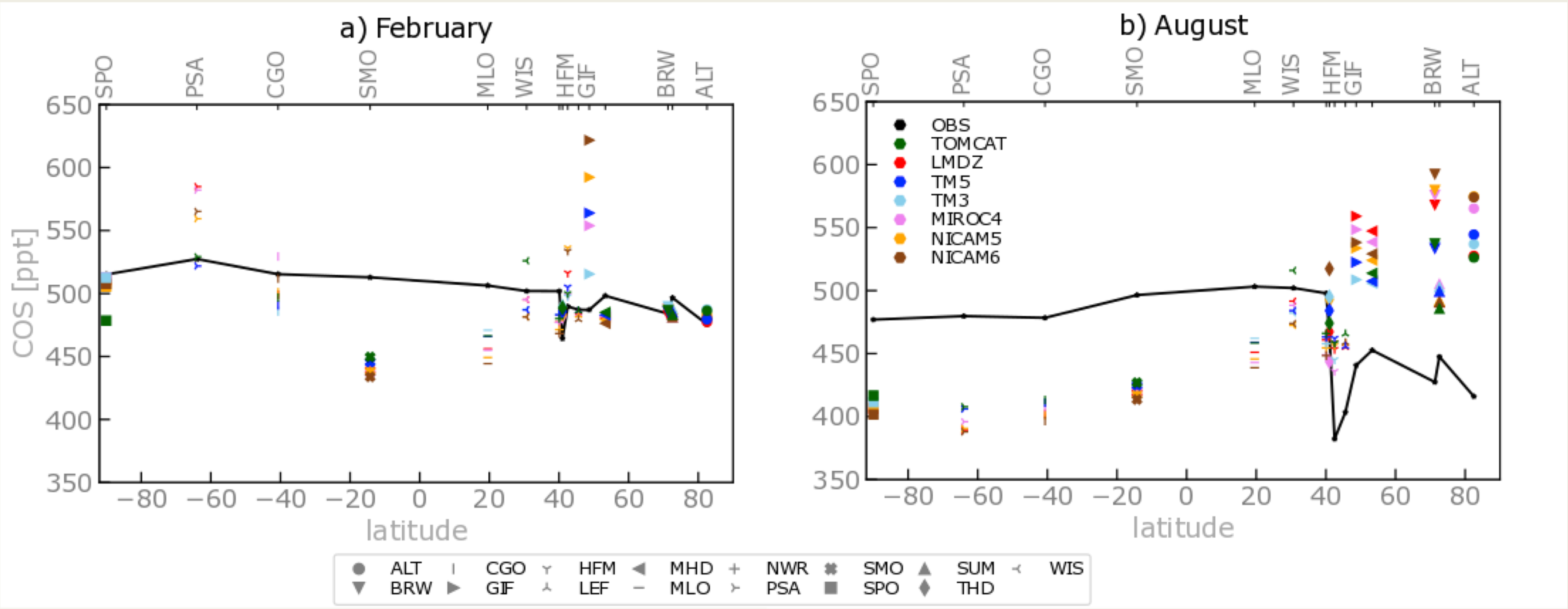


Correct the COS mixing ratio: after



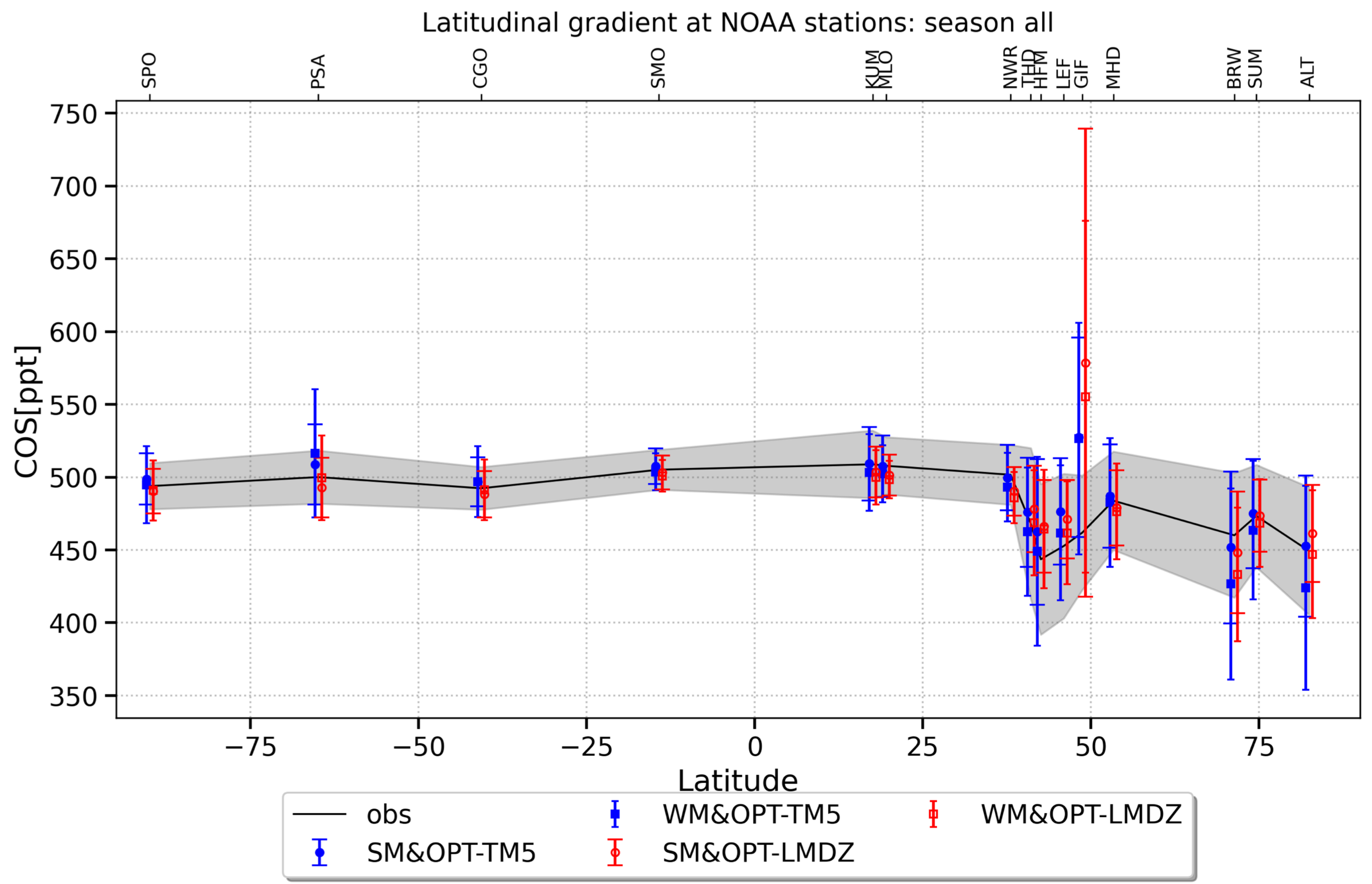
NOAA surface stations: control case

Name	Transported fluxes	Source-sink balance	ATMS
Ctl	Anthropogenic+Biomass burning+Ocean+ biosphere SiB4	-37GgS a^{-1}	all



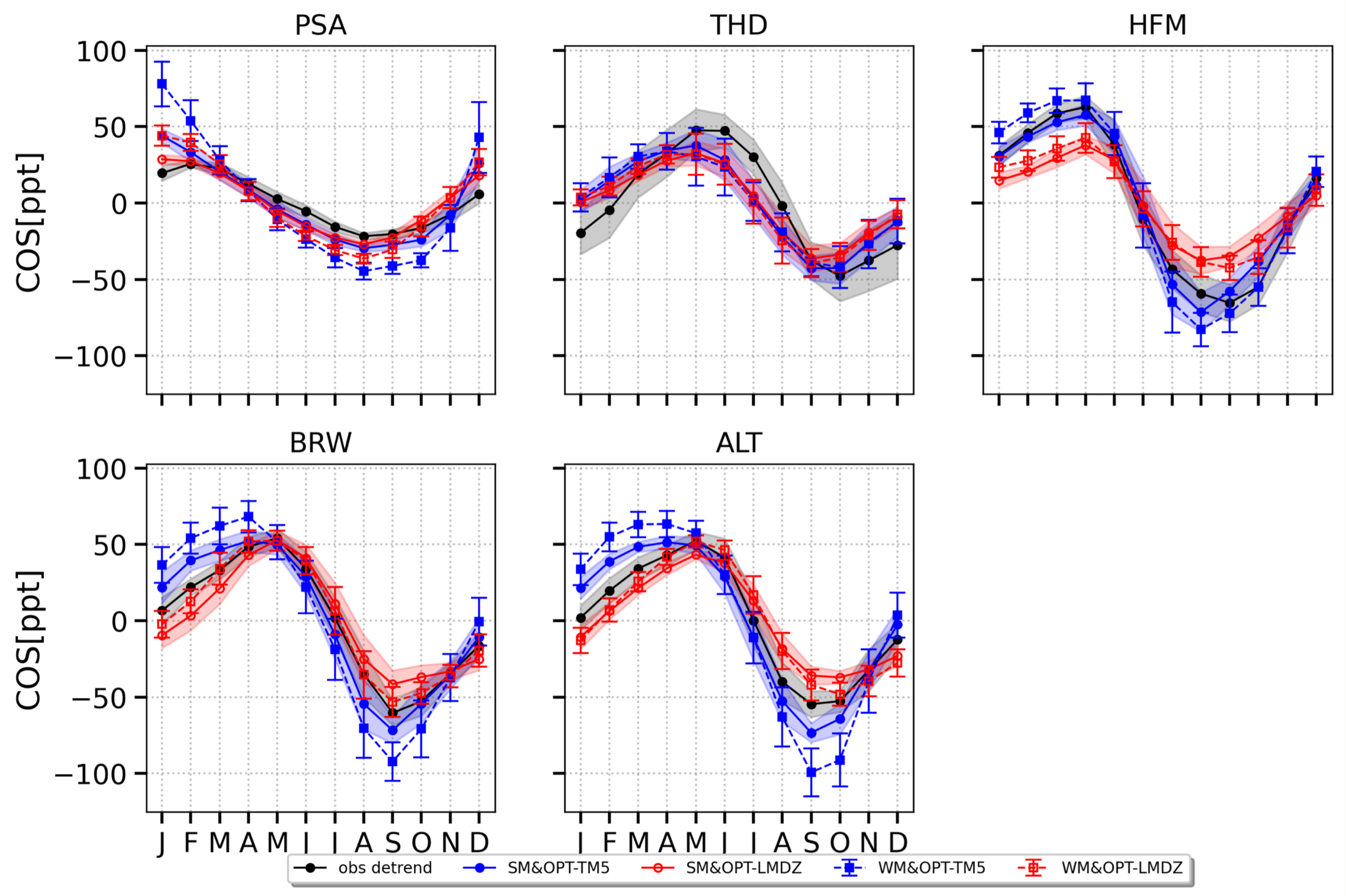
Remaud et al., 2022, under review.

NOAA surface stations: optimized fluxes



- In SH, all the models are close to NOAA observations.
- GIF, is an exception, because it is not assimilated in inversions.
- In NH, strong mixing models work better.

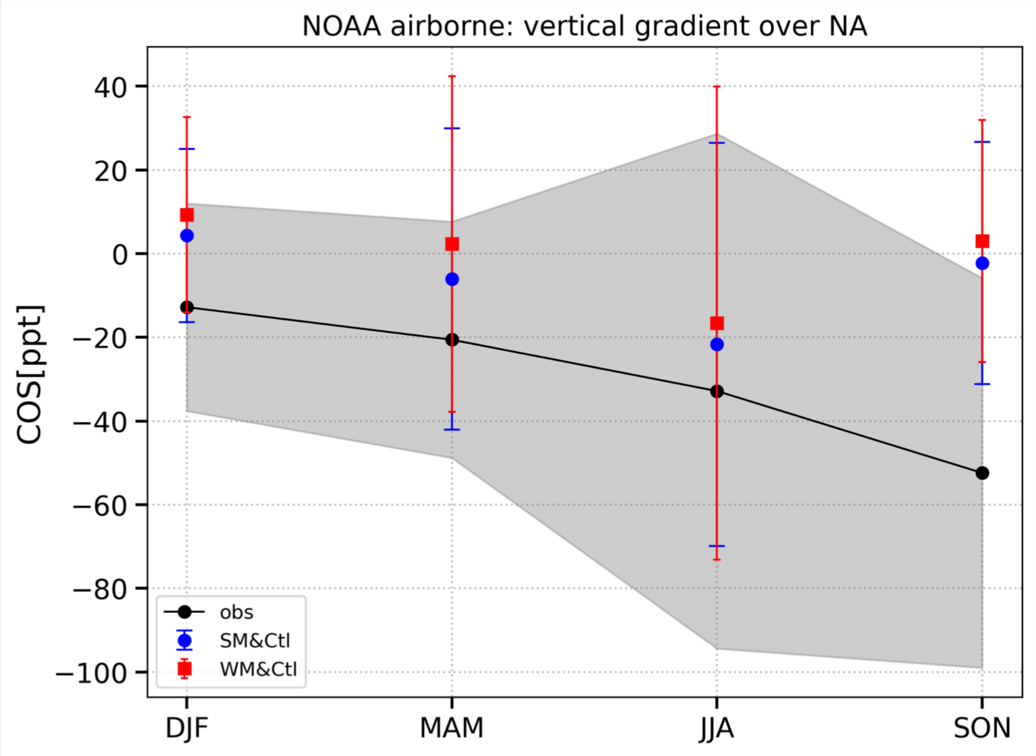
NOAA surface stations: seasonal cycle

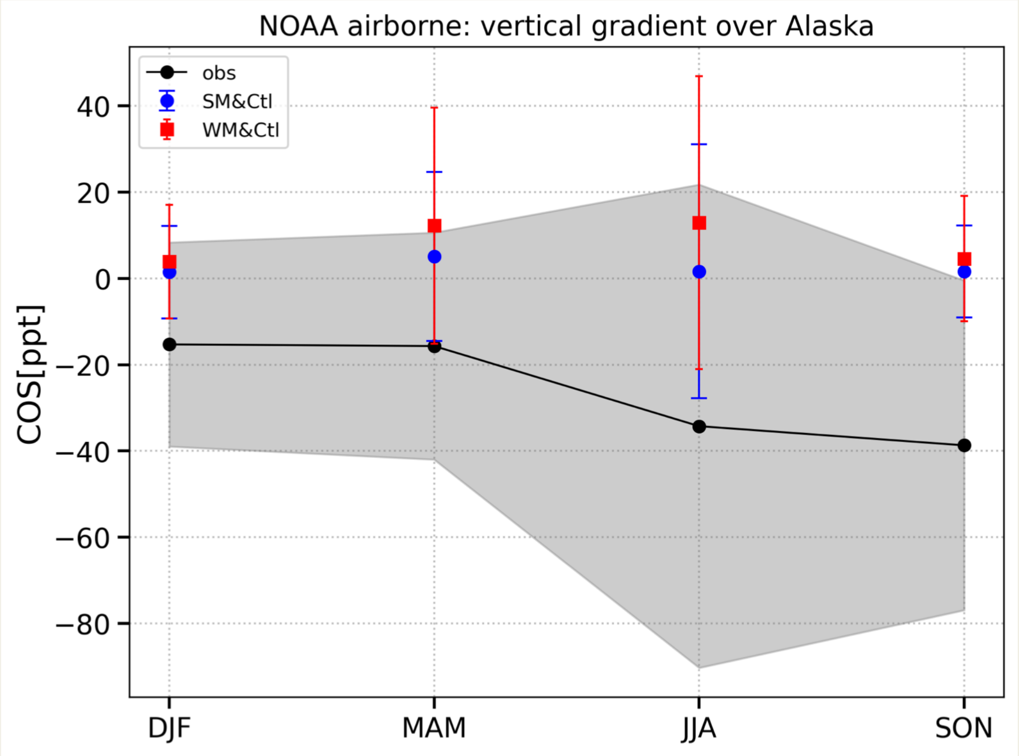


- Selected stations showing large deviations from observed seasonal cycle.
- Weak-mixing group transporting TM5-flux shows larger seasonal cycle, at PSA, BRW, ALT.

Decomposed by standard software CCGVU.

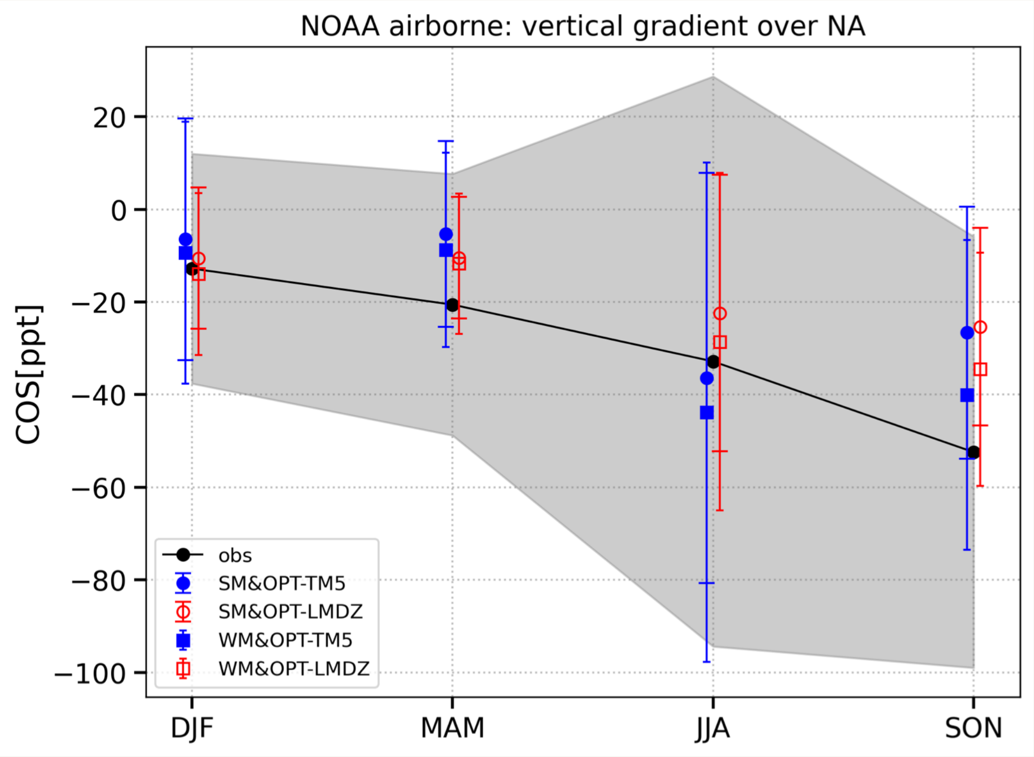
NOAA airborne platform: control scenario

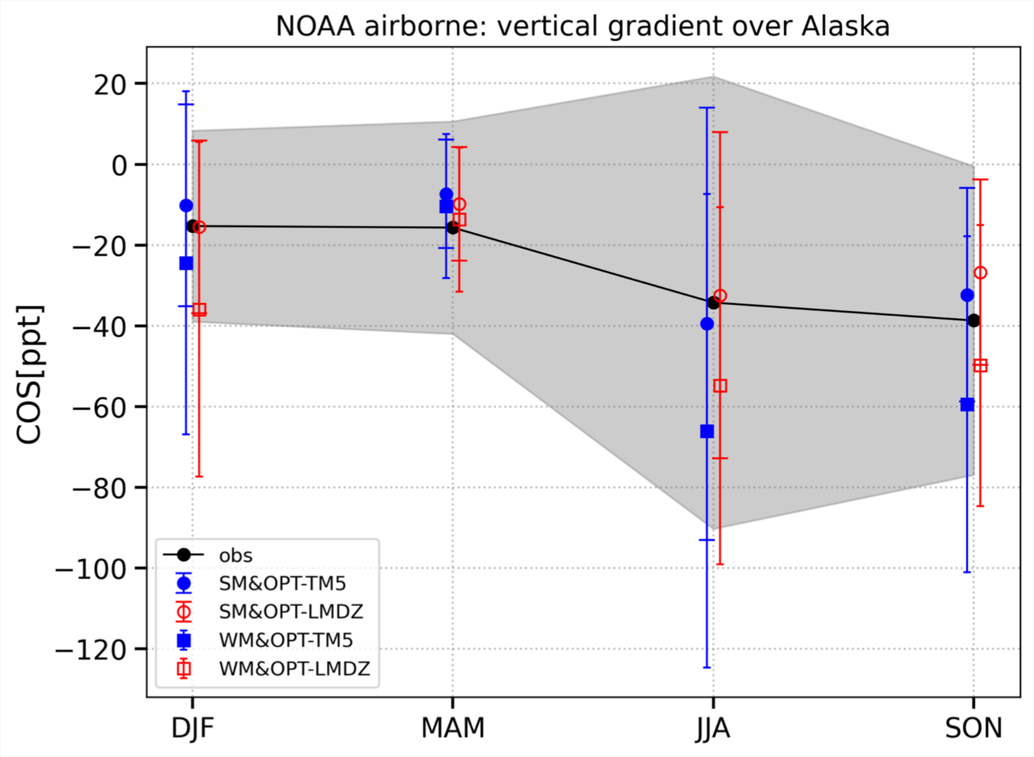




Vertical gradient between 1 km and 4 km in the atmosphere.
The control scenario is off from observed vertical gradient.

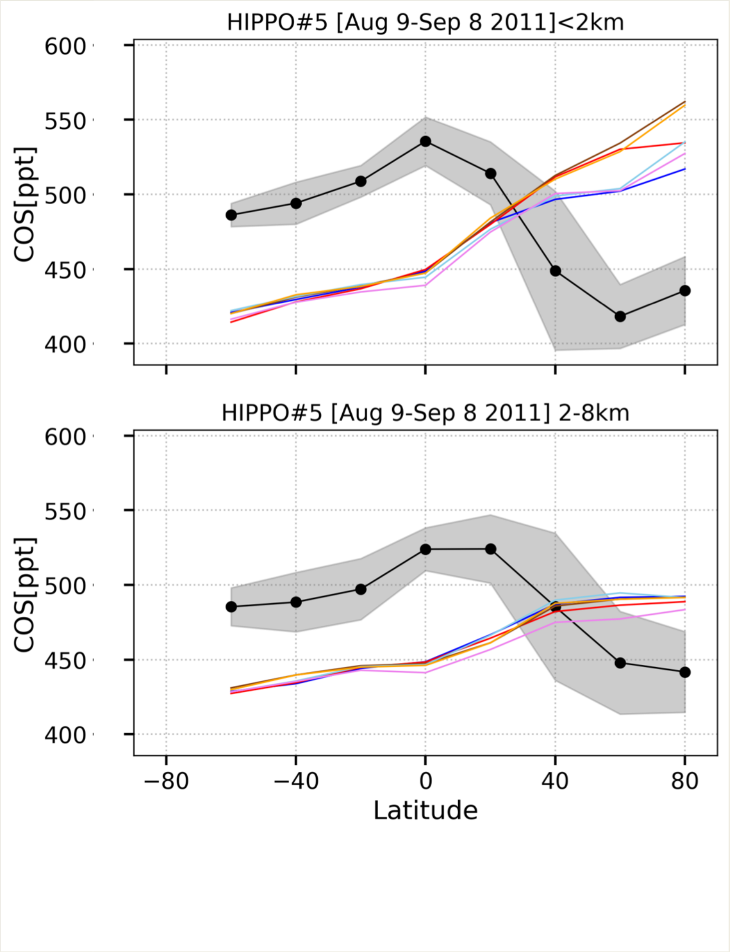
NOAA airborne platform: optimized scenario

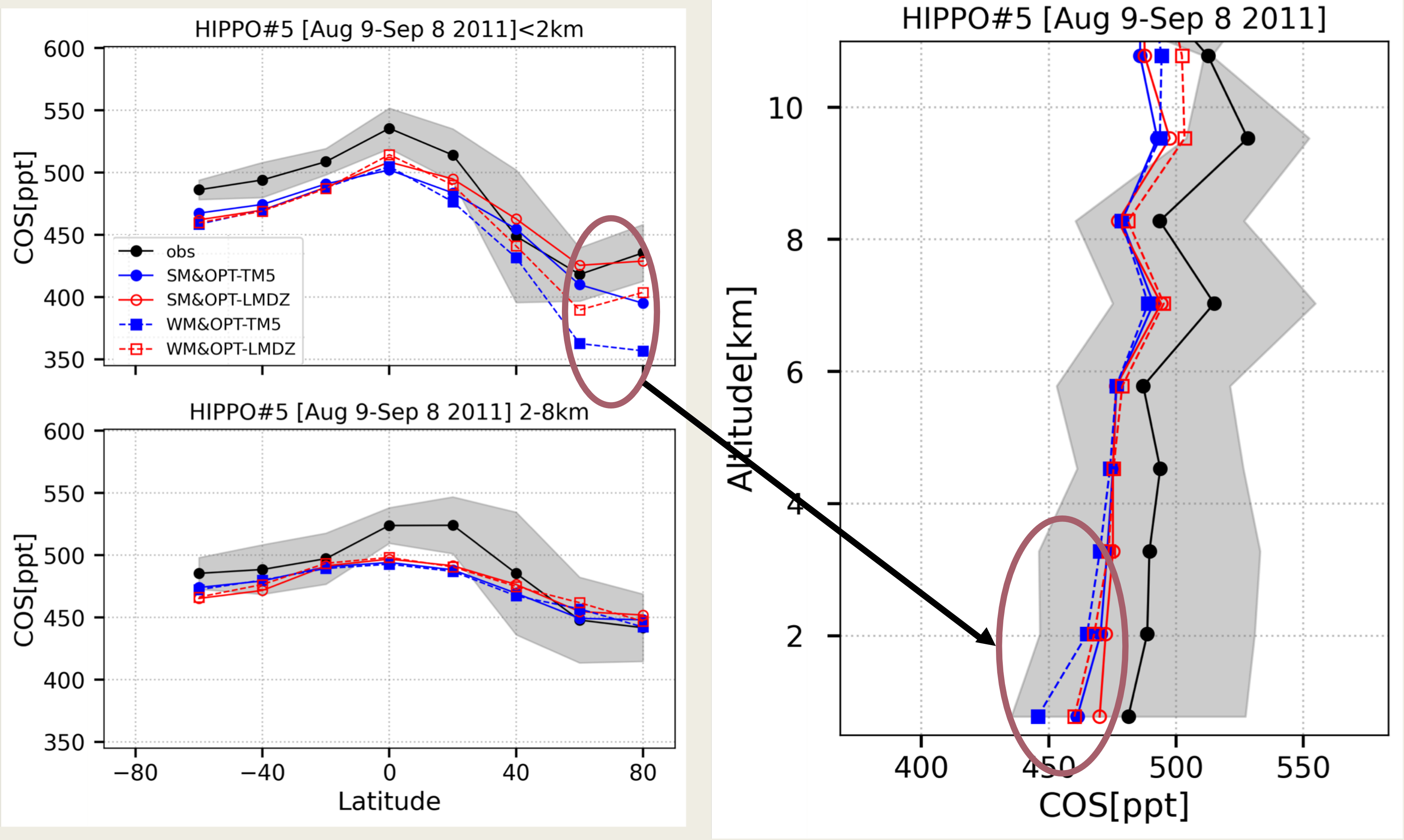




The optimized fluxes improve the vertical gradient.
In SON, over North America, weak-mixing models are better
However over Alaska, strong-mixing models are better.

HIPPO: control vs optimized fluxes

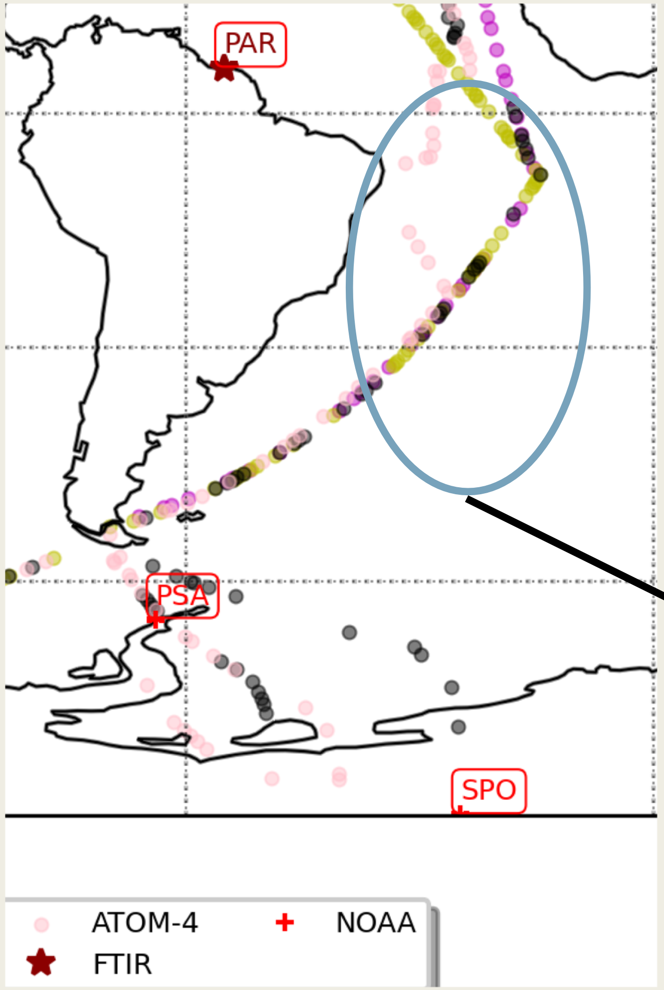


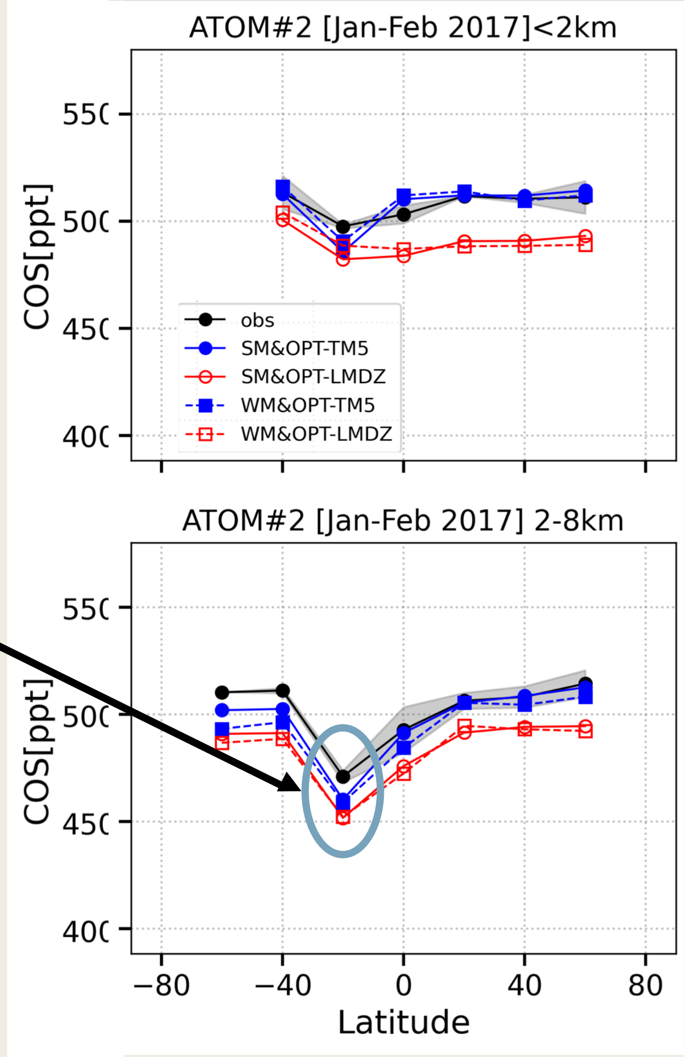


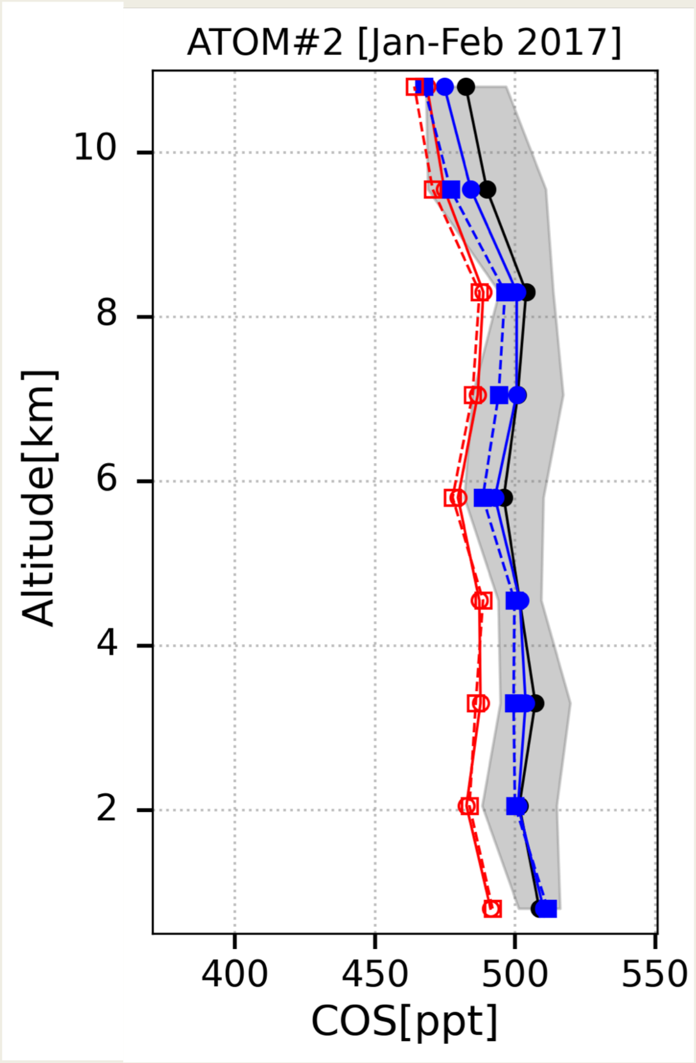
Control case Failed

- OPT cases consistent with data, lower in tropics.
- HIPPO#5 indicates COS drawdown in boundary layer.

ATOM#2: optimized fluxes



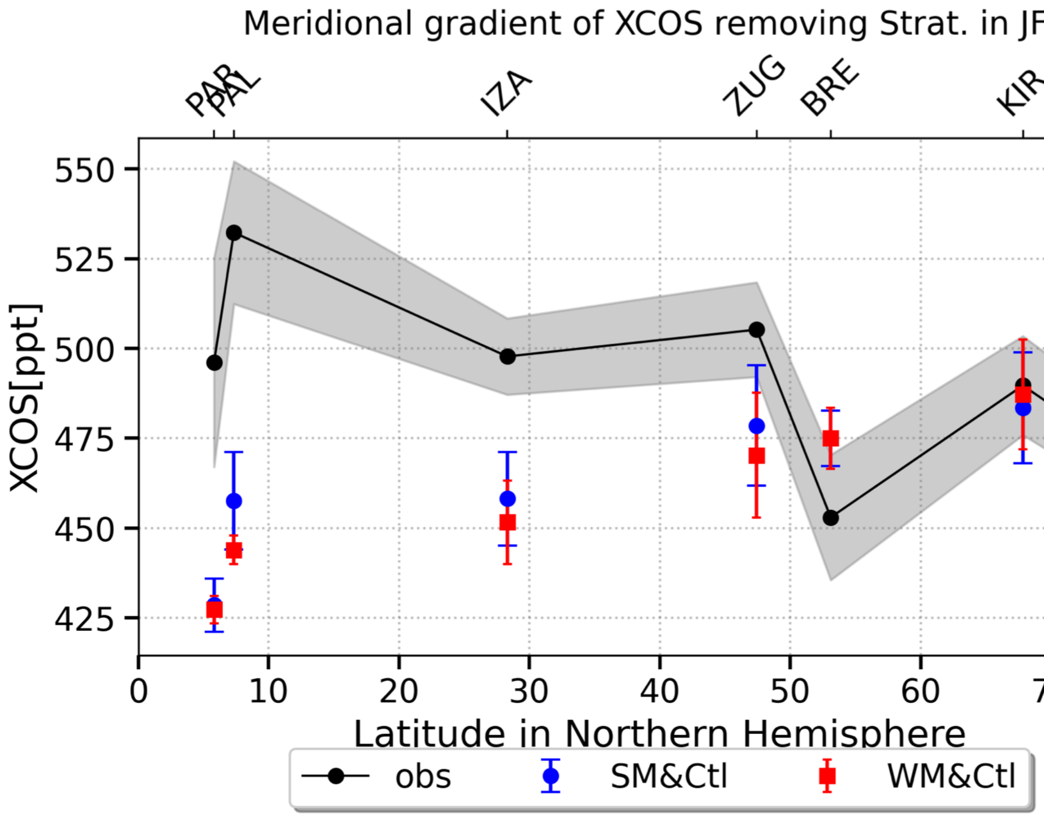


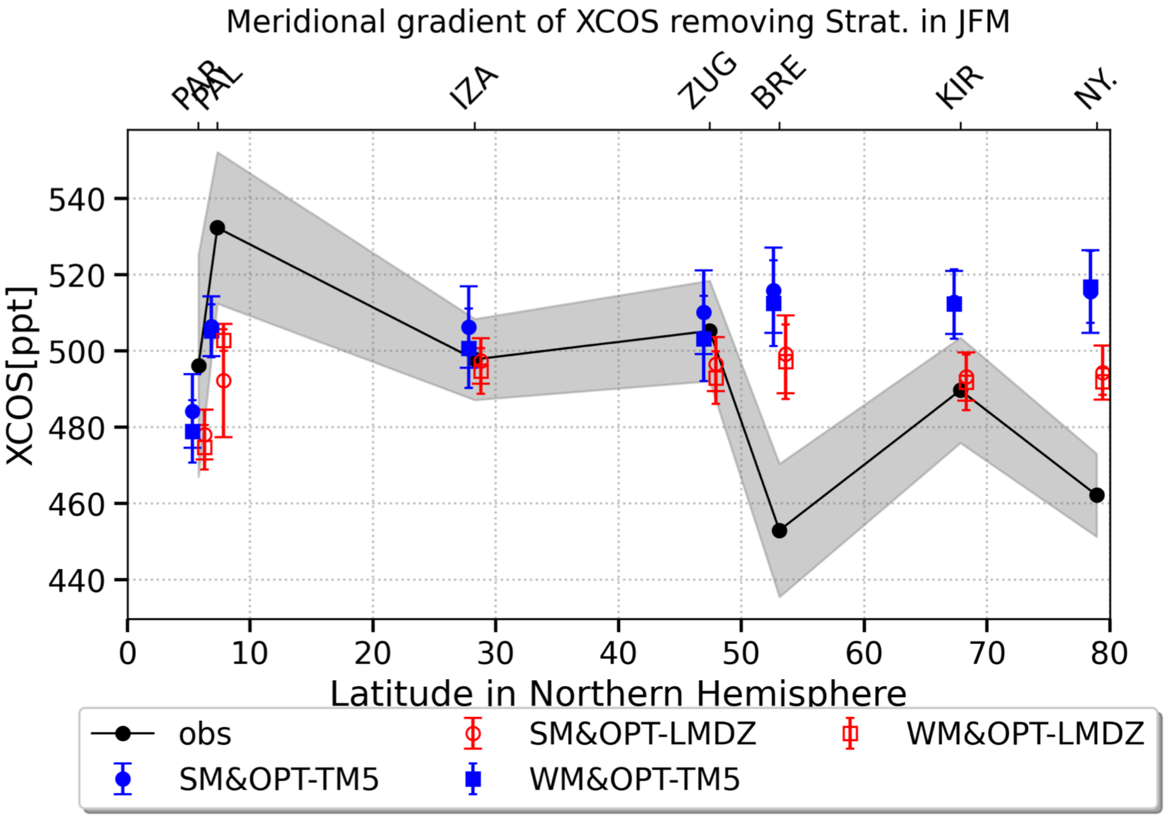


ATOM#2 track near Amazonia

Amazon drawdown effect captured in free troposphere.

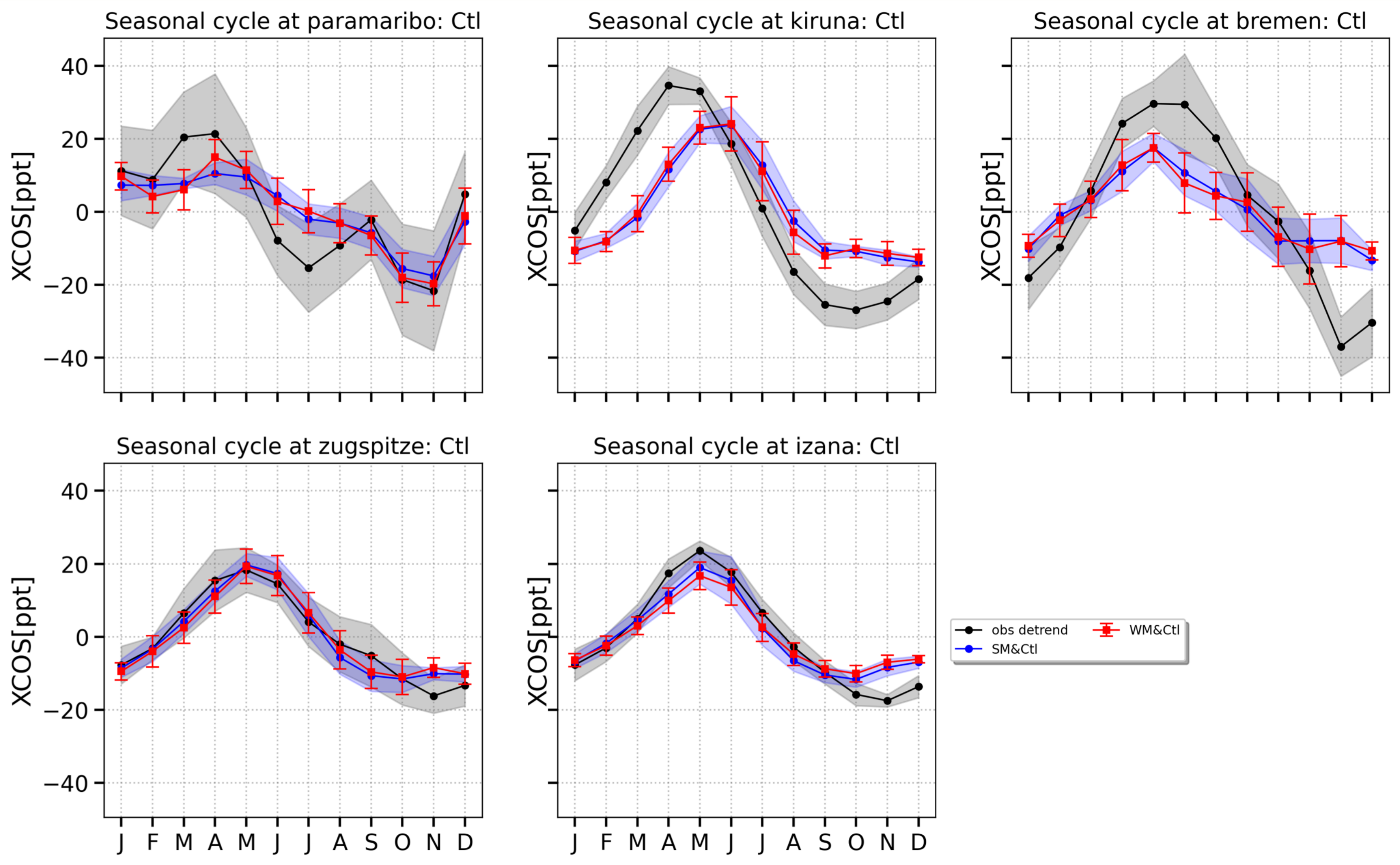
FTIR XCOS latitude distribution: control vs optimized cases





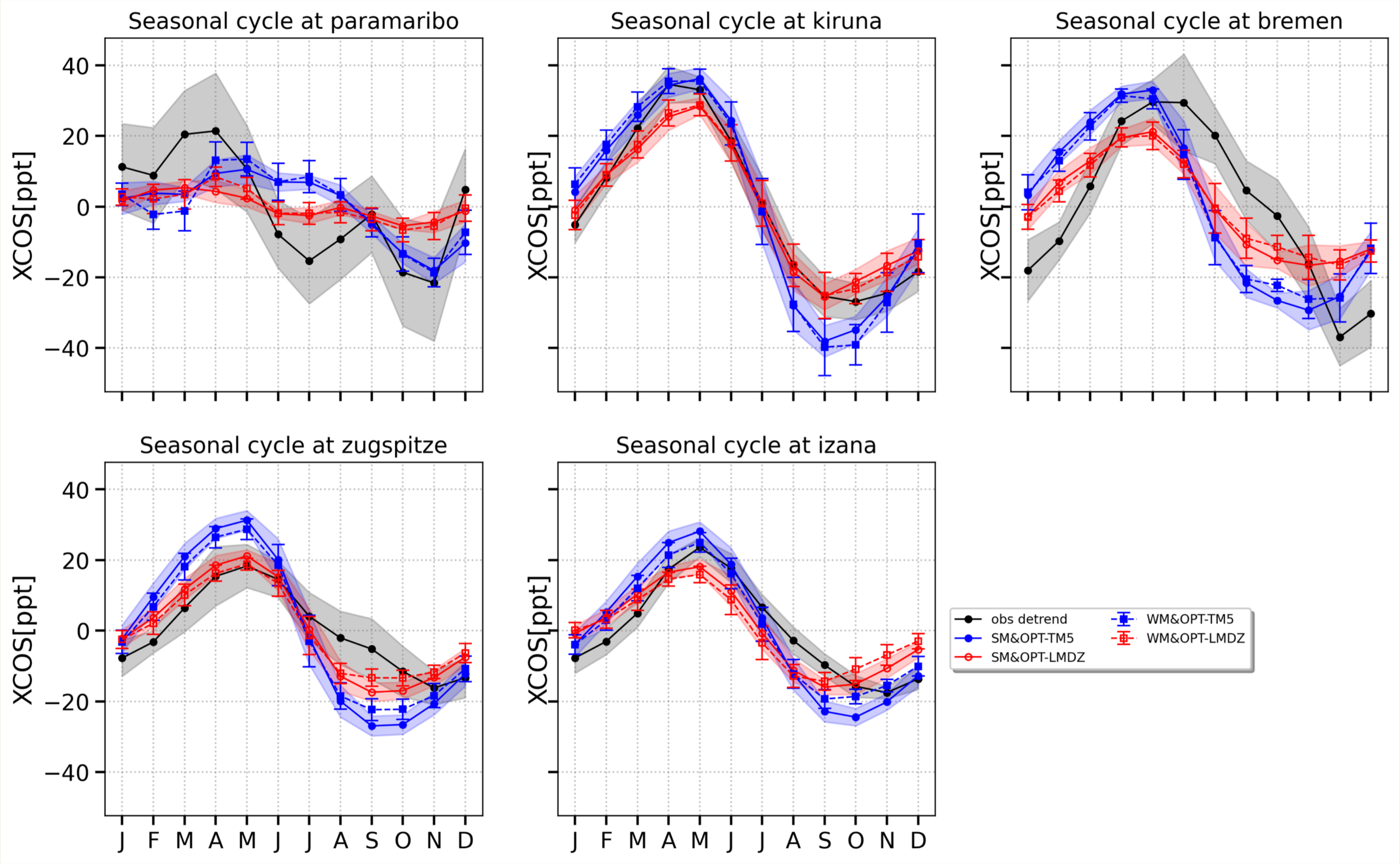
- Control: the models are quite off from the observed XCOS. Stratosphere is removed.
- Optimized: the models are improved but still failed to show the latitudinal distributions.

FTIR XCOS seasonal cycle: control case



- Paramaribo: missing data in years
- Kiruna: observed later than models
- Bremen, Zugspitze and Izana: seasonal maximum and minimum close to observed.

FTIR XCOS seasonal cycle: optimized case



- Paramaribo: missing data in years
- Kiruna, Zugspitze and Izana : models are similar with observed seasonality.
- Bremen: observed is 1-2 months later than models
- Flux is more dominant than model difference in XCOS

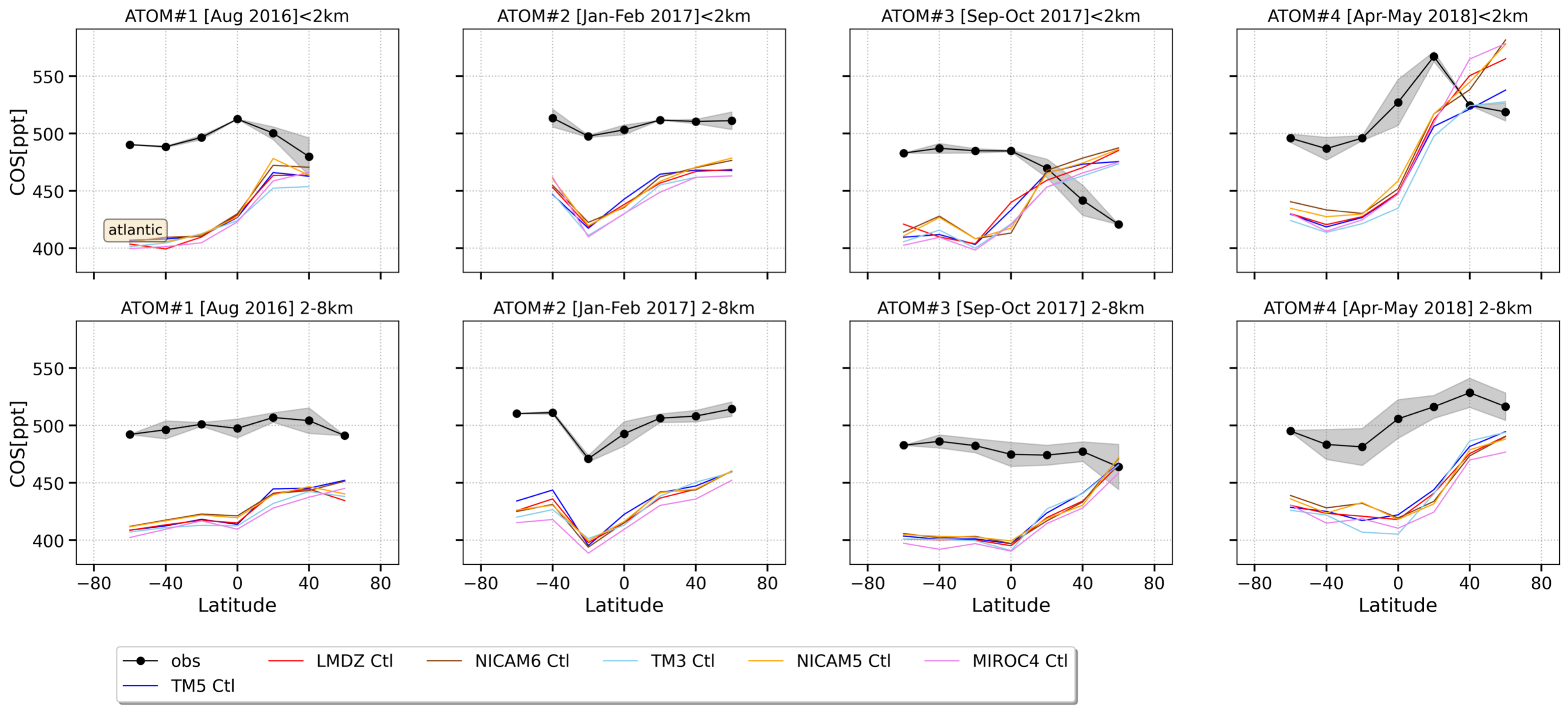
Conclusions and Recommendations

- The TM5 and LMDZ optimized fluxes show close spatial distribution.
- The optimized fluxes improved the simulations over control scenario, and well match the aircraft data HIPPO and ATOM.
- HIPPO and ATOM comparisons are generally good, also indicate the COS drawdown effect from NH continent over Pacific and from Amazonia over Atlantic ocean.
- FTIR XCOS failed due to lack of data assimilation in troposphere and a few sites in NH.
- COS Data assimilation can be further enhanced in future.

Thank you for your attention!

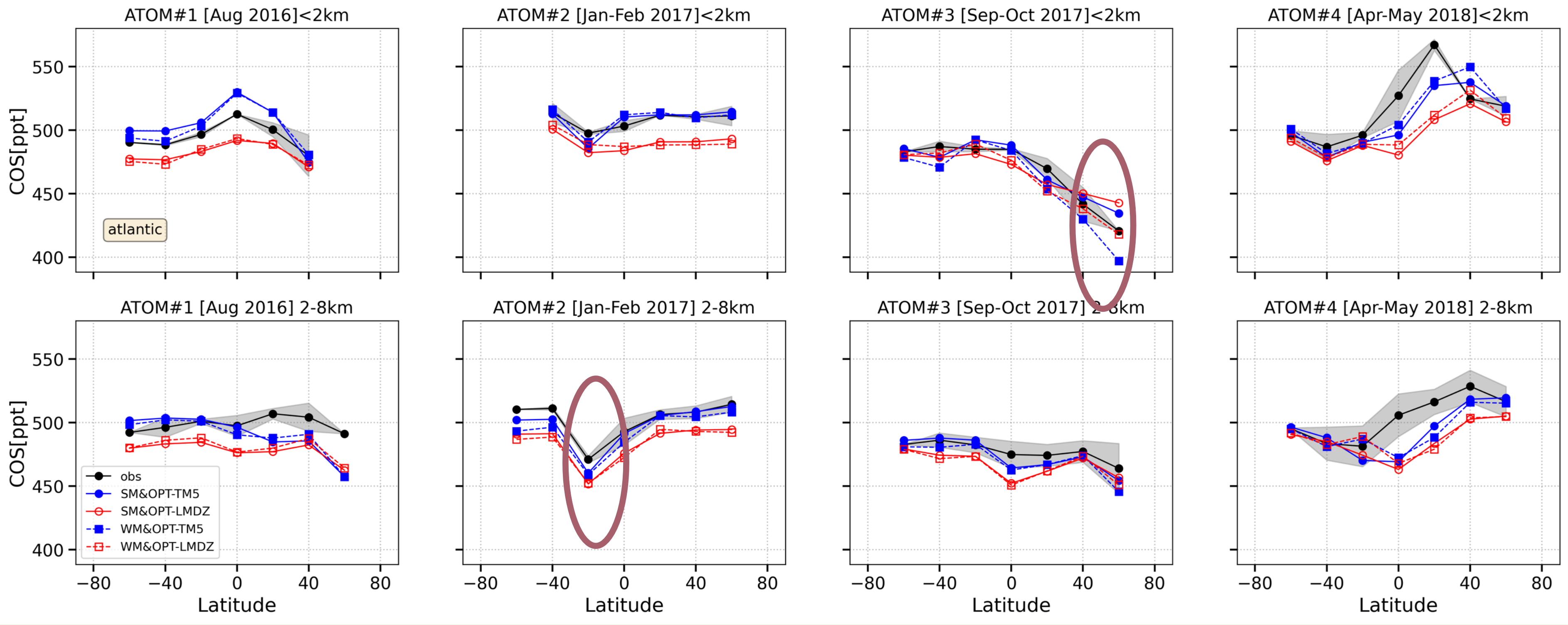
- Welcome questions!

ATOM latitudinal distribution: control scenario



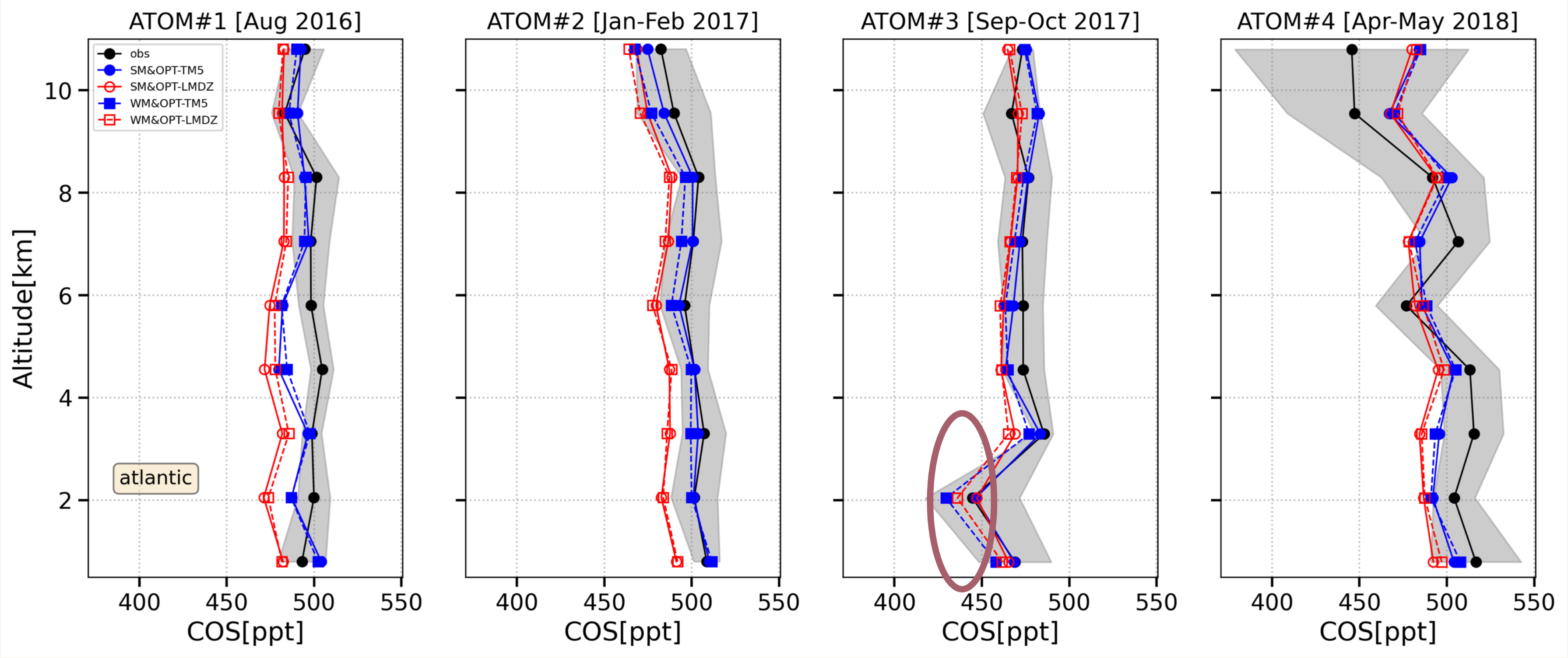
Atlantic ocean: control scenario failed due to too low COS mixing ratios.

ATOM latitudinal distribution: optimized scenario



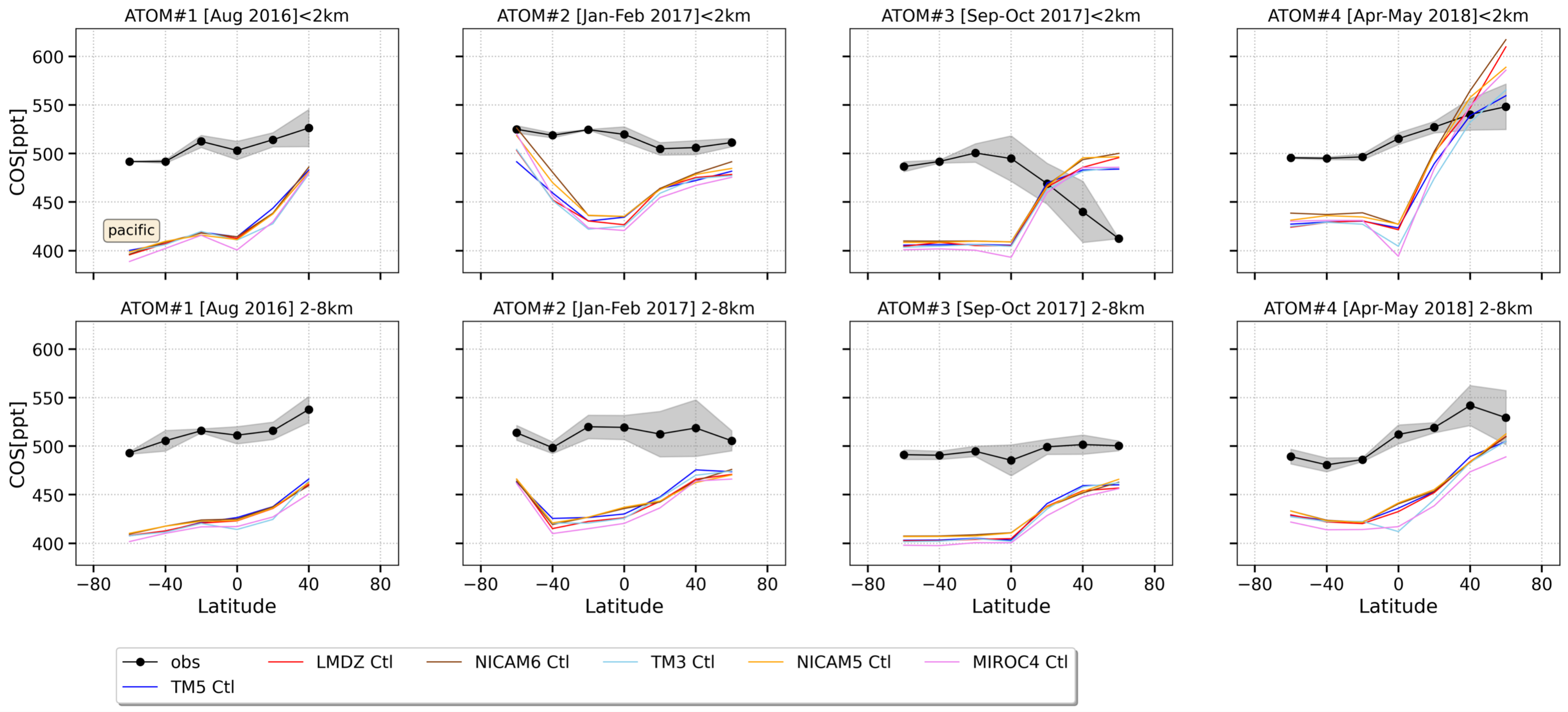
Atlantic ocean: ATOM#2 catches Amazon drawdown effect in 0-40S. ATOM#3 catches NH continental drawdown effect in boundary layer. OPT-TM5 is better than OPT-LMDZ.

ATOM vertical distribution: optimized scenario



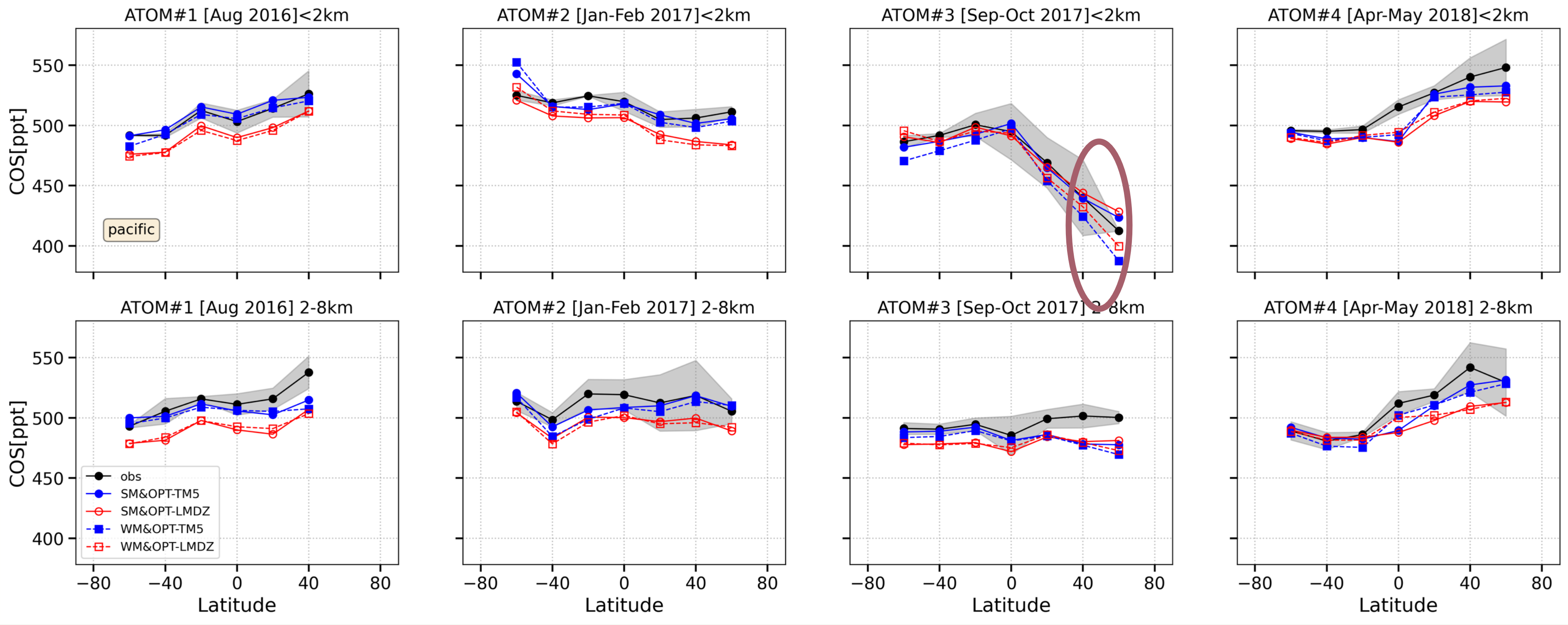
Atlantic ocean: OPT-TM5 is better than OPT-LMDZ also vertically. ATOM#3 shows a drawdown below 2km, in boundary layer.

ATOM latitudinal distribution: control scenario



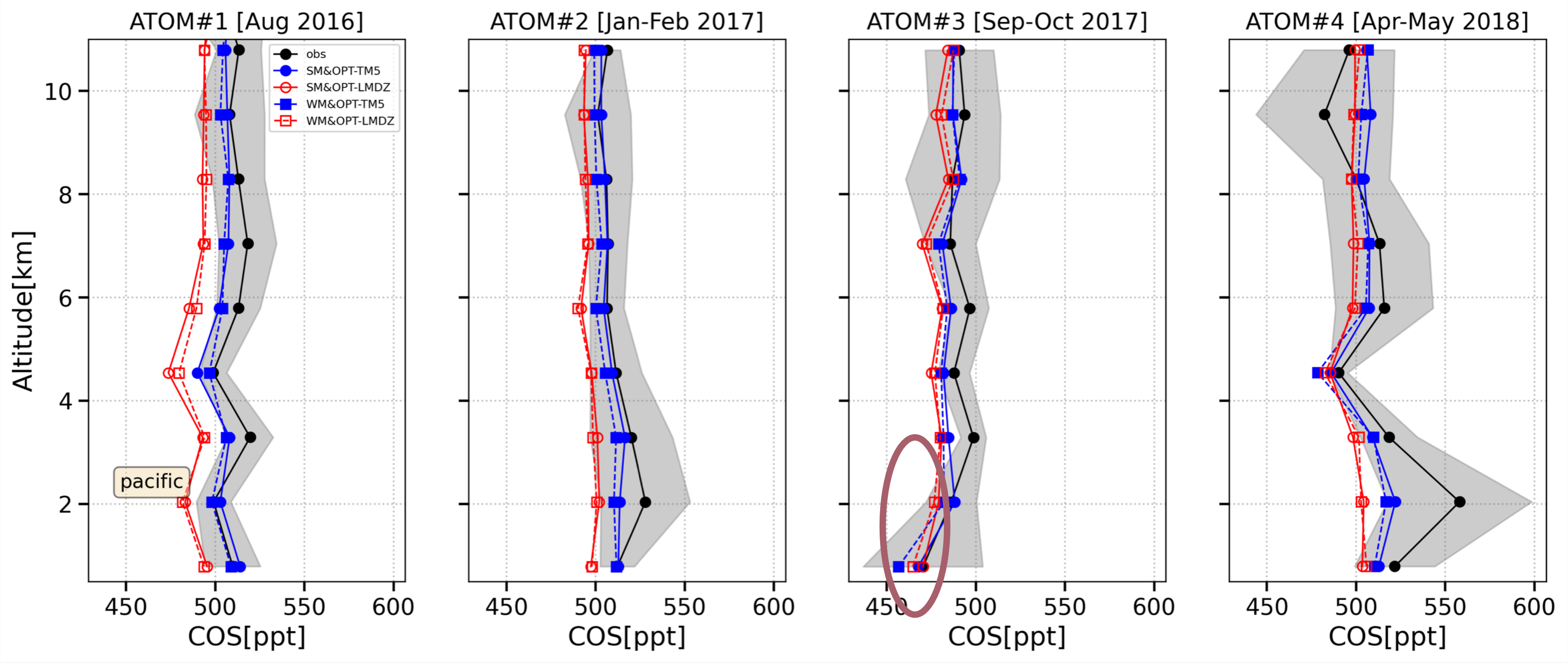
Pacific ocean: control scenario failed due to too low COS mixing ratios.

ATOM latitudinal distribution: optimized scenario



Pacific: OPT-LMDZ flux leads to lower COS than OPT-TM5. Also COS drawdown in NH along ATOM#3.

ATOM vertical distribution: optimized scenario



Pacific: OPT-LMDZ flux leads to lower COS than OPT-TM5 on vertical scale. Also COS drawdown in NH along ATOM#3.