TES NH_3 and CO observations and model simulations: their correlations and implications

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(1) Understanding TES NH_3 and CO retrievals and the proper way to compare TES data to GEOS-Chem model simulations.

(2) Examine and compare TES and model NH_3 and CO global / seasonal observations.

(3) NH_3 and CO regional /seasonal correlations and the enhancement ratios of NH_3:CO.

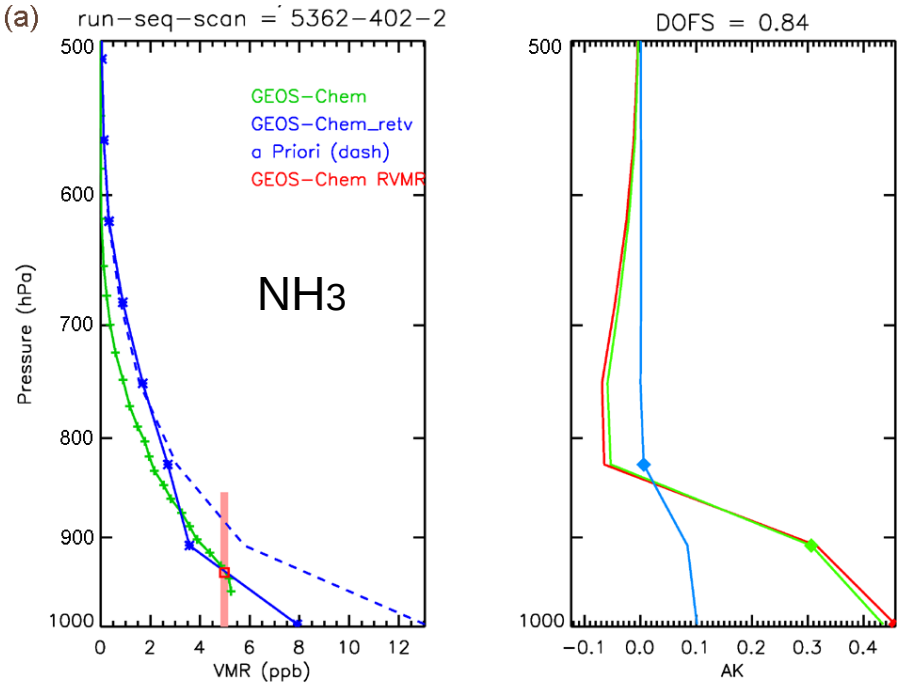
(4) Discussions.

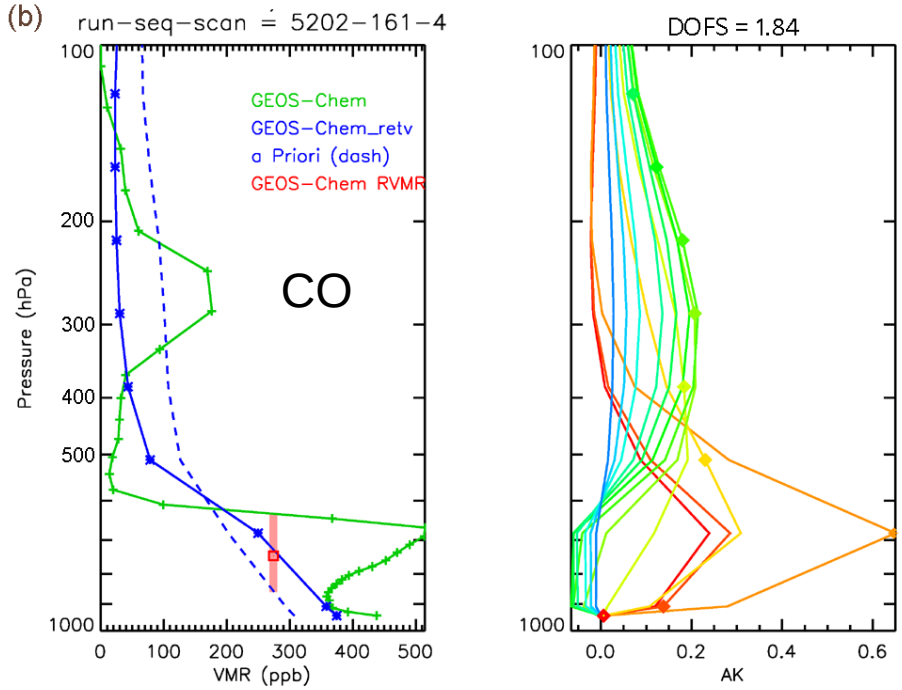
TES NH_3 Retrieval

- Optimal estimate (all retrieval characteristic data provided).
- The init/aP are determined by BT.
- Representative VMR (RVMR).

TES – Model Comparisons

- Spatial / time sampling Mod data.
- Derive “retrieved” model profiles using TES Xa and AK.
- Calculate Mod NH_3 and CO RVMR.





Sources of NH_3 vs. Sources of CO

NH3:

Biomass burning / Forest fires
Fossil fuel combustion
Livestock wastes
Fertilizer Application/production

CO:

Biomass burning / Forest fires
Fossil / Bio-Fuels
CH_4/Hydrocarbon oxidation
(uniform background)

Atmospheric Chemistry and Transport

NH_3:

$$2NH_3 + H_2SO_4 \Longrightarrow (NH_4)_2SO_4$$

$$NH_3 + HNO_3 \Longleftrightarrow NH_4NO_3$$

Secondary fine aerosol particles

Sinks: dry/wet deposition; bi-directional fluxes.

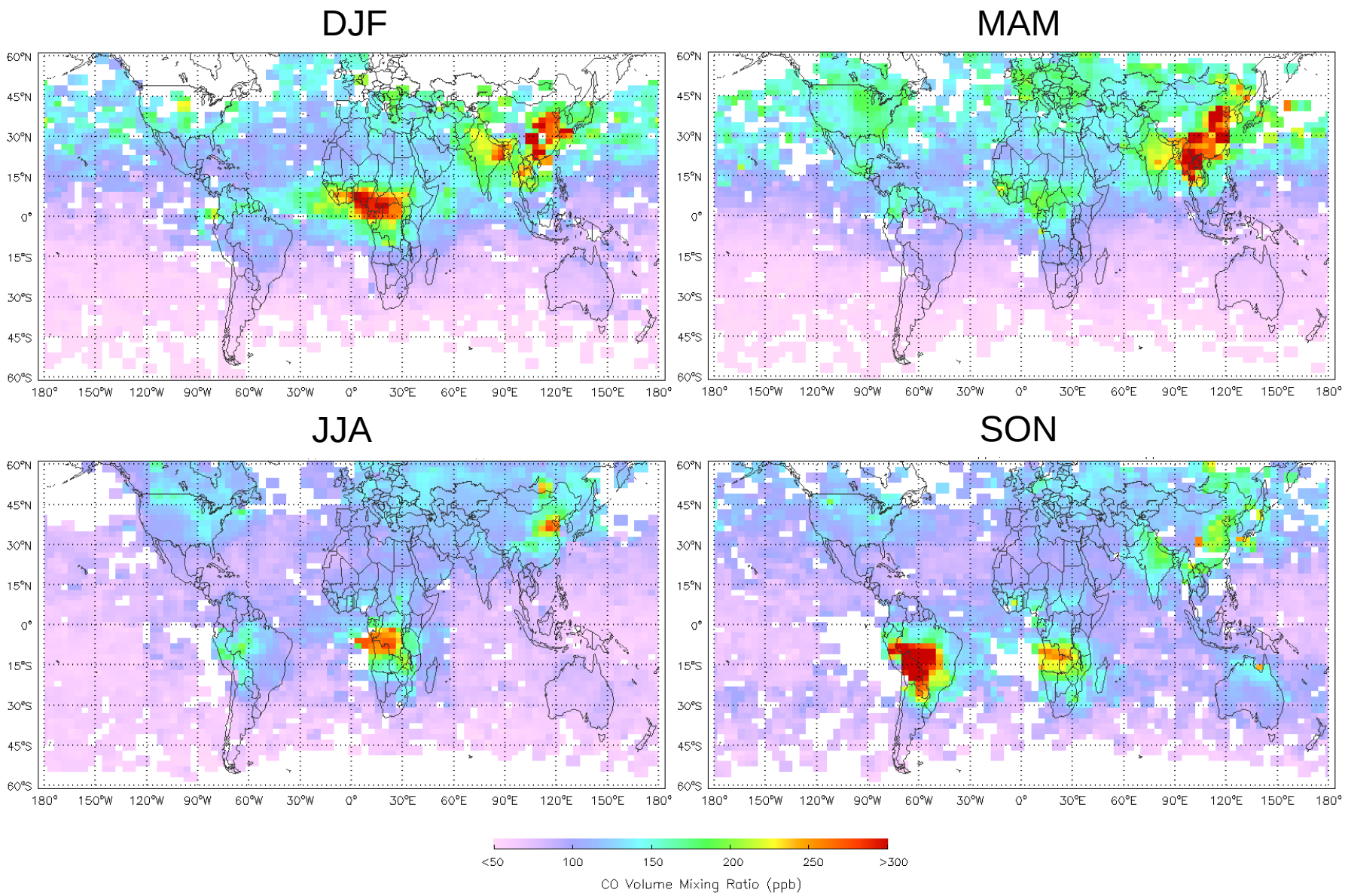
Atmospheric NH_3 lifetime: < hours to a day.

CO:

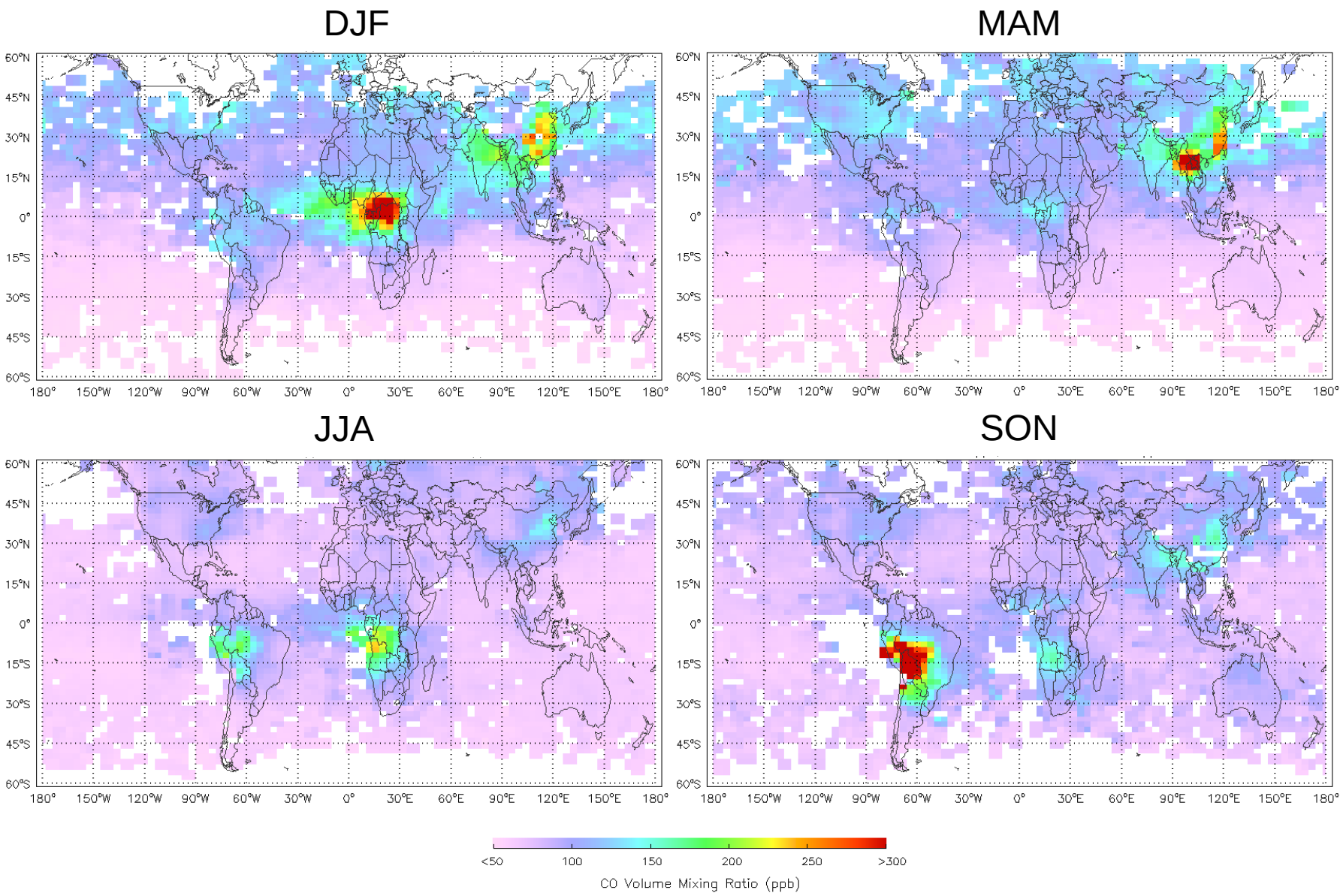
Photochemical oxidation of CO catalyzed by HOx and NOx to produce Ozone, net $CO + 2O_2 \rightarrow CO_2 + O_3$

Atmospheric CO lifetime: days to months.

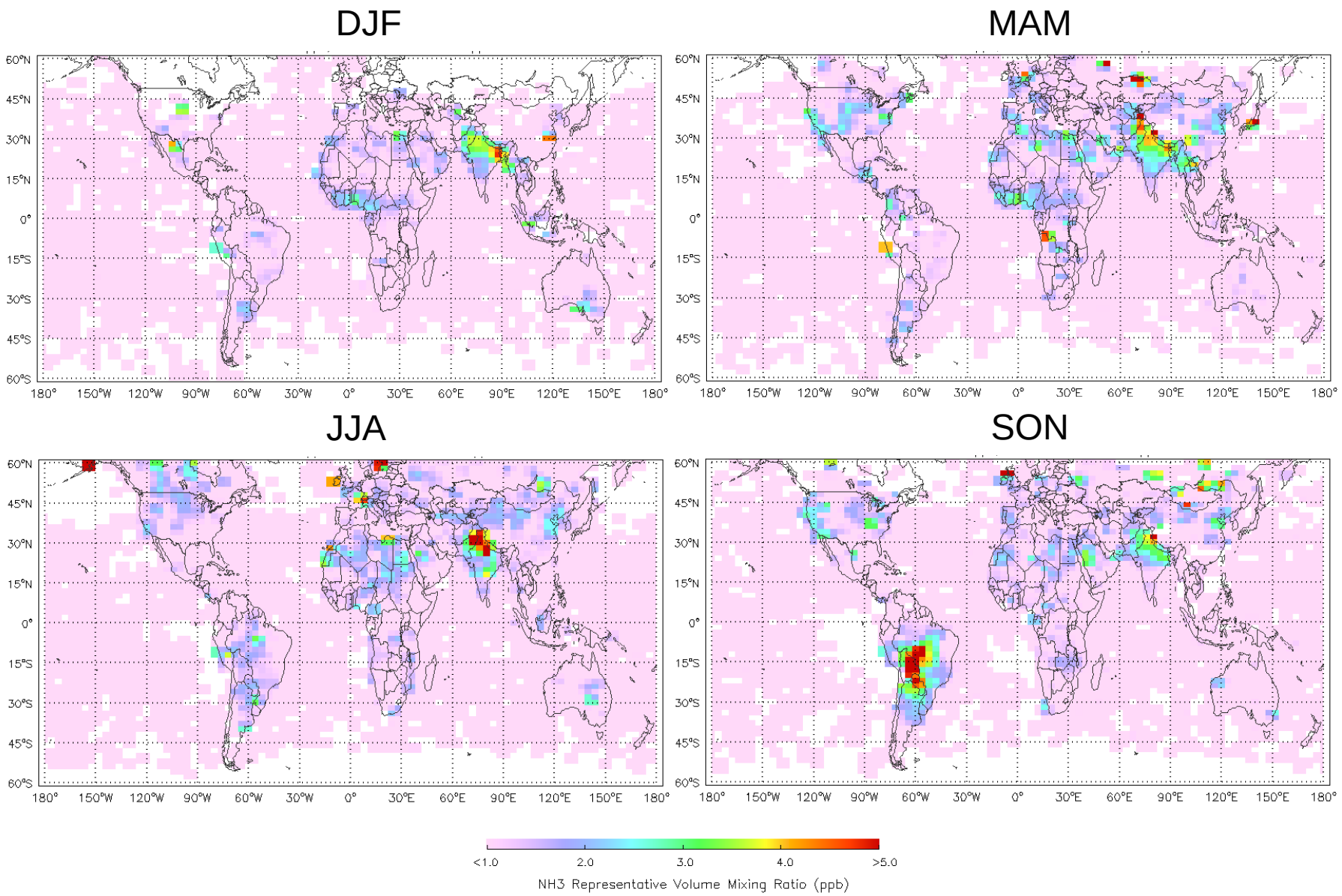
TES CO Observations (RVMR) 2007



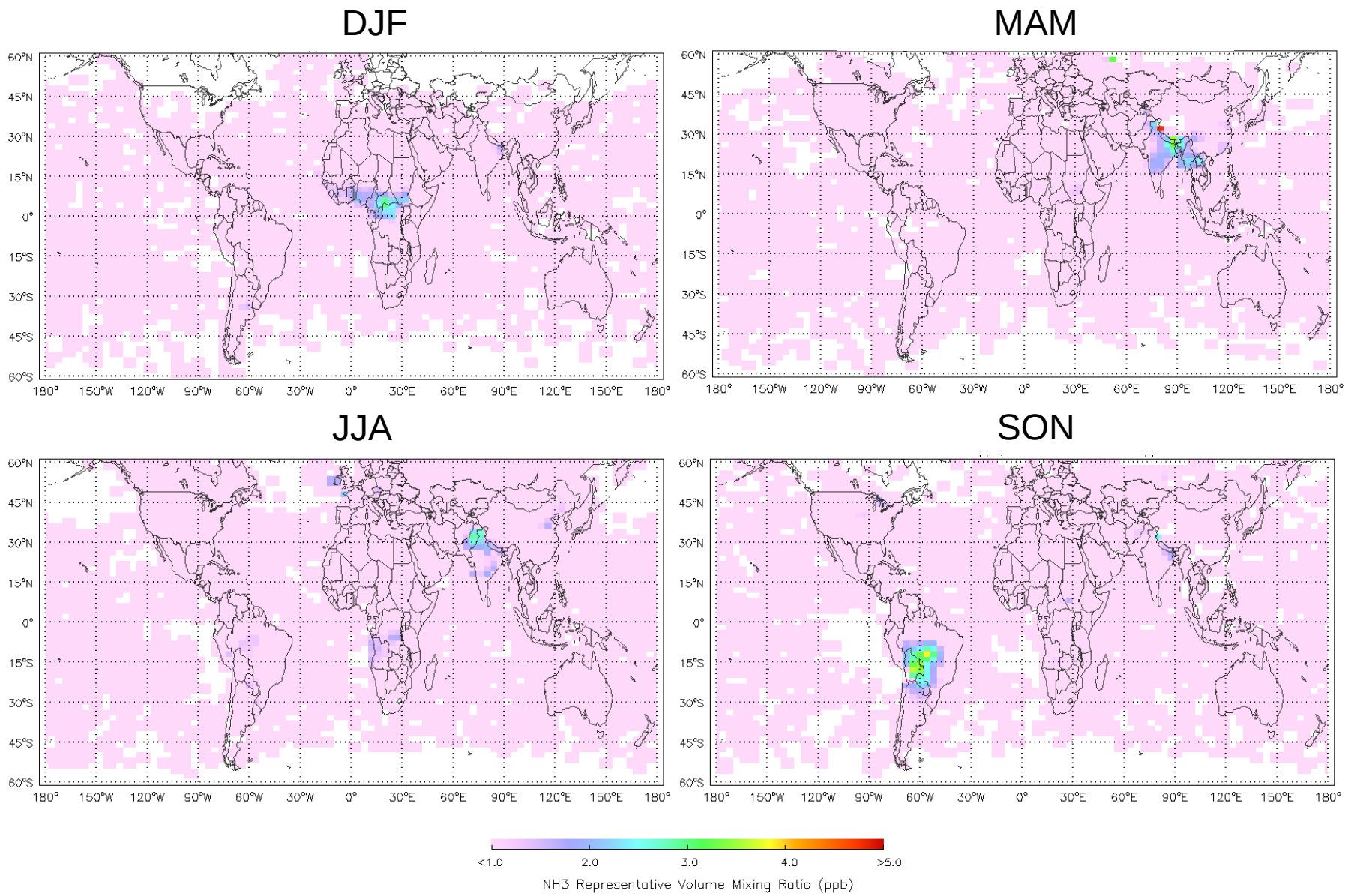
GEOS-Chem CO (RVMR) 2007



TES NH_3 Observations (RVMR) 2007

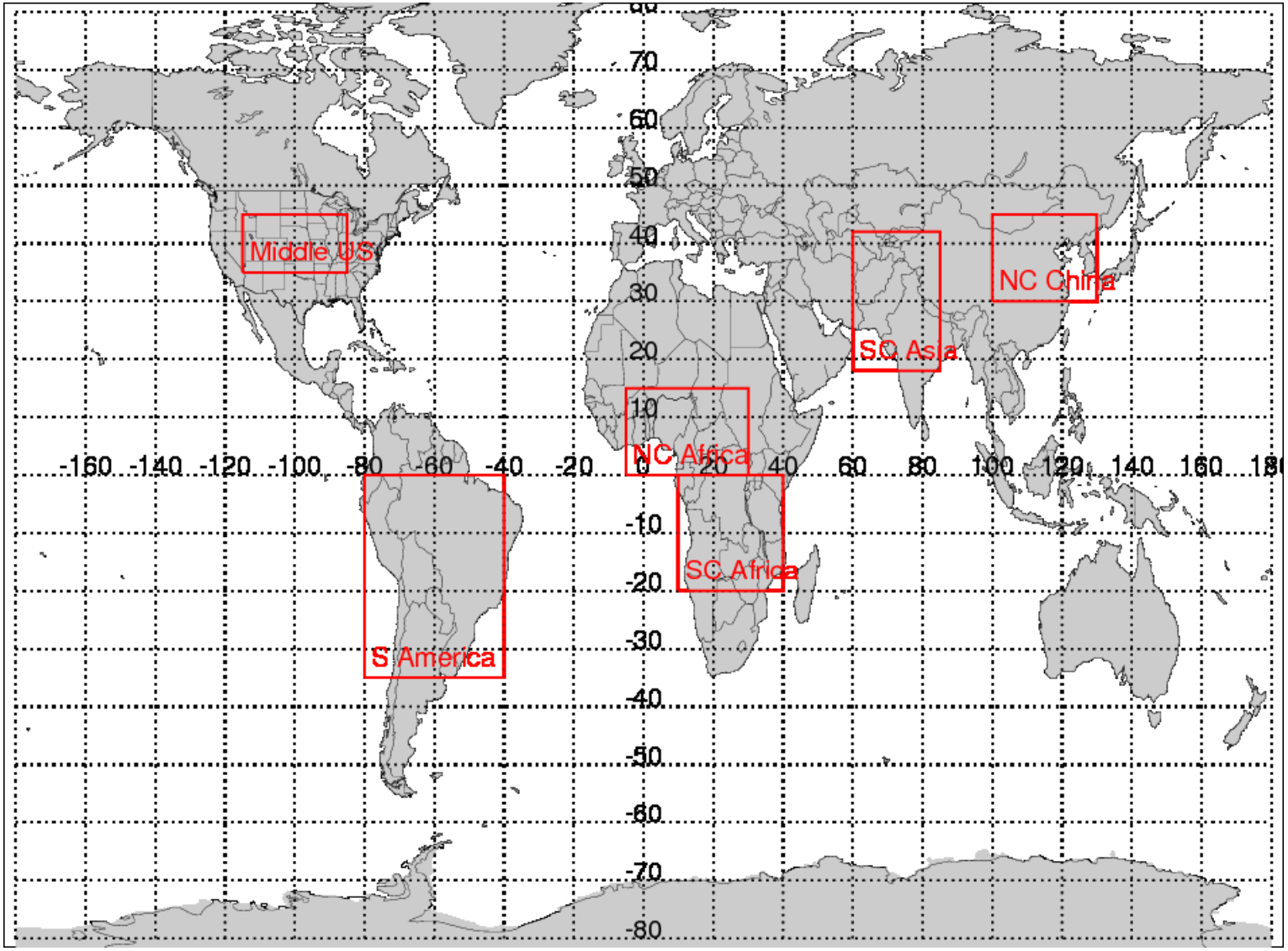


GEOS-Chem NH_3 (RVMR) 2007

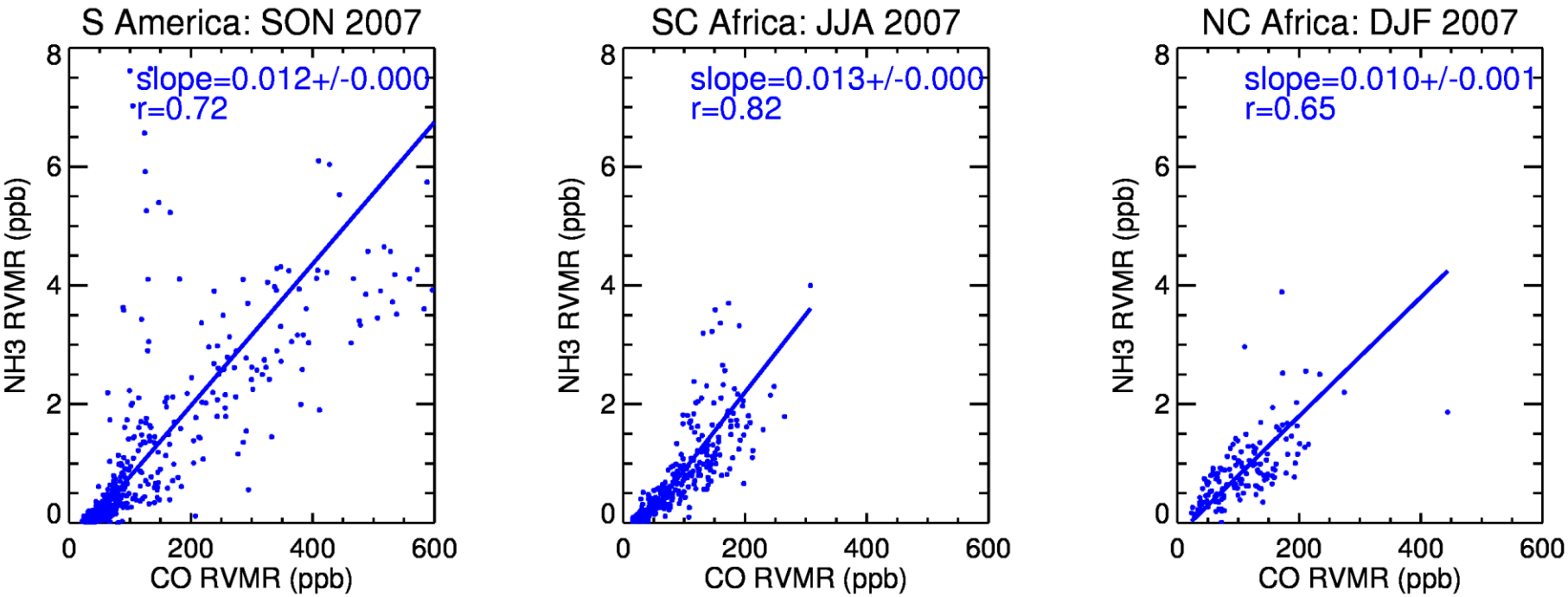


Selected regions to examine NH_3 and CO correlations and to derive the enhancement ratios of NH_3 relative to CO (NH_3:CO)

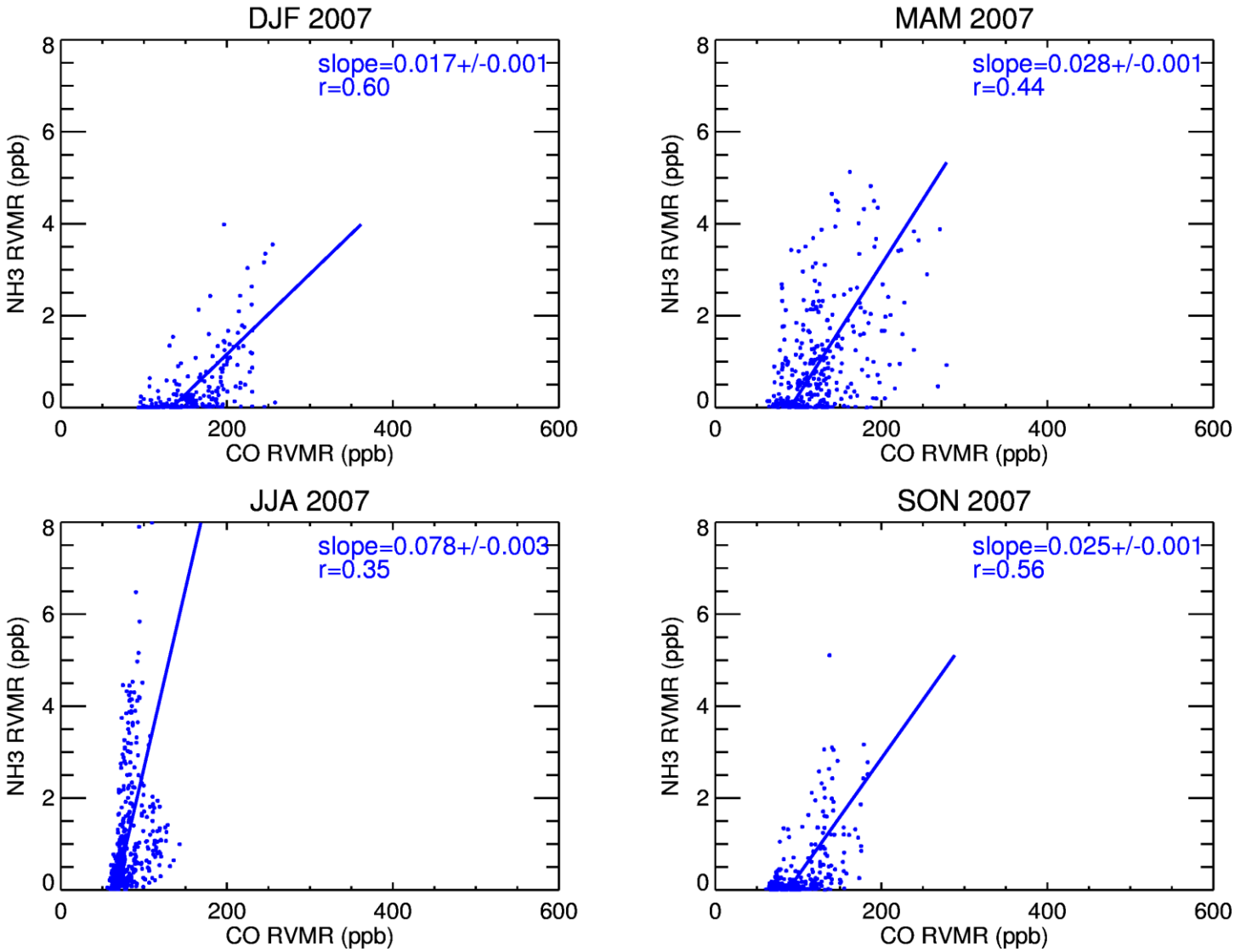
(Fires, mixtures of agriculture, industrial, and dense population regions, megacities)



GEOS-Chem fire-only simulations: NH_3 vs CO

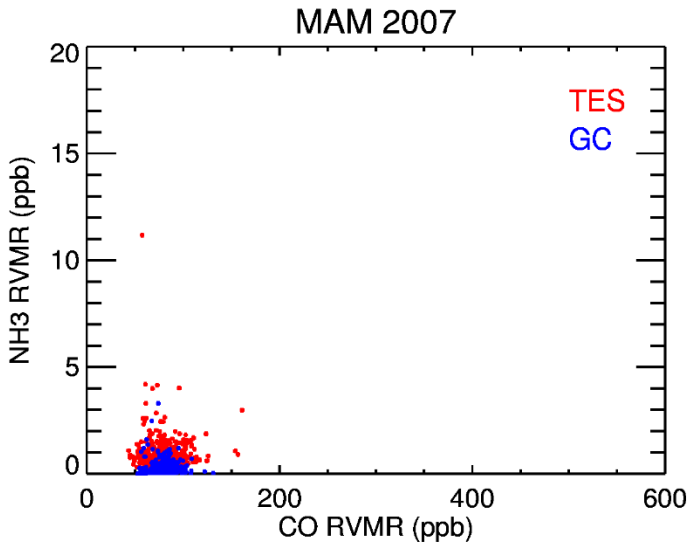


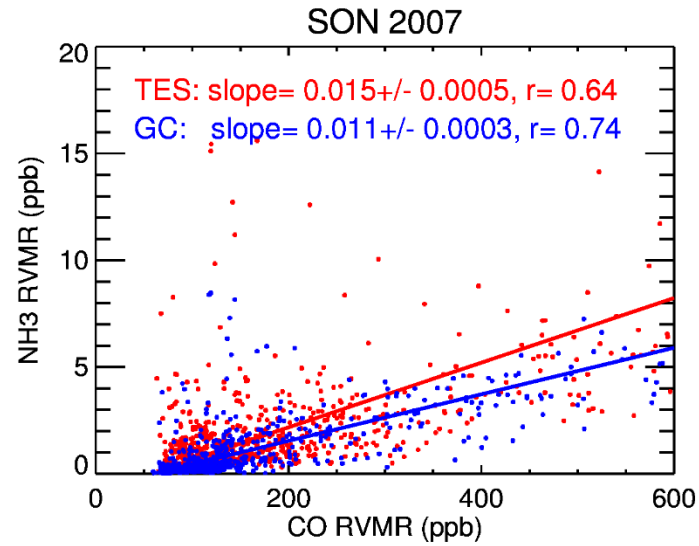
GEOS-Chem simulations for SC Asia: NH_3 vs CO



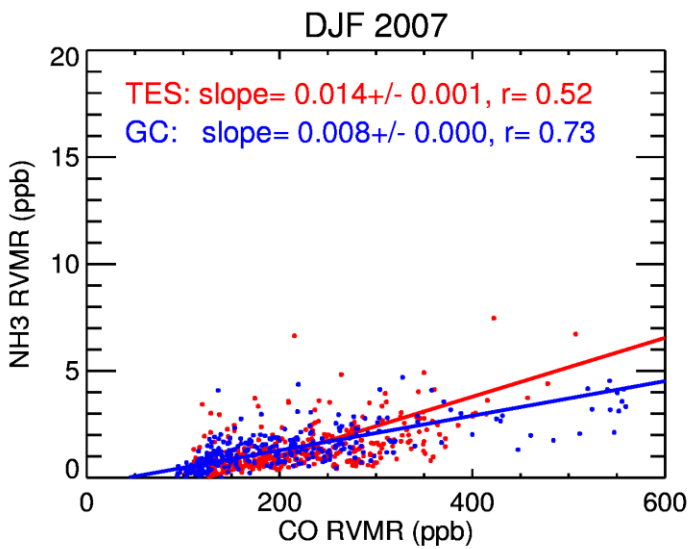
TES and GEOS-Chem in fire regions : NH_3 vs CO

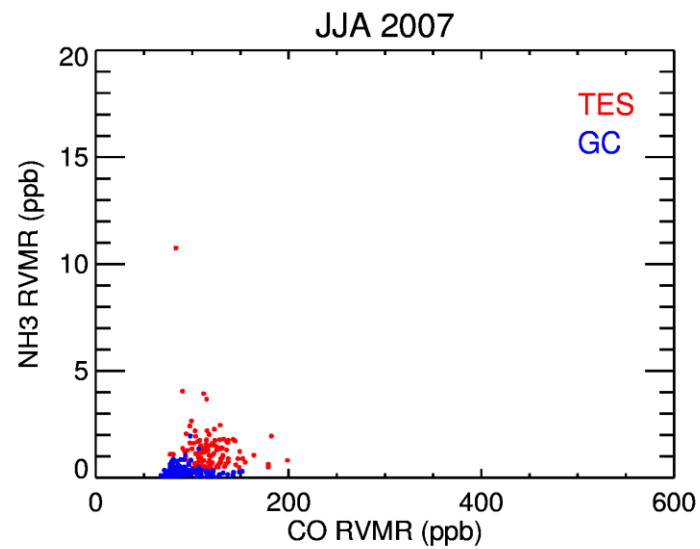
S America



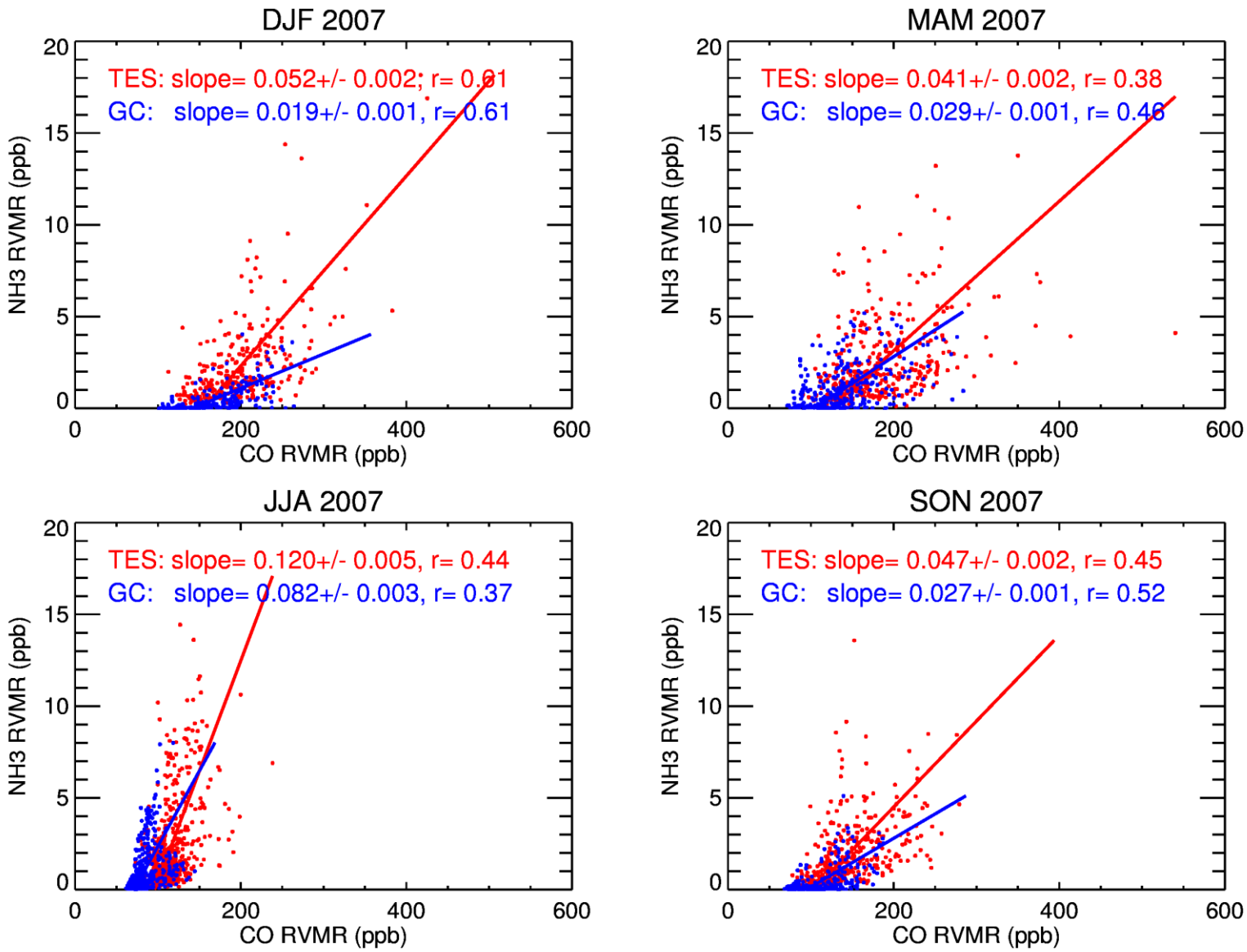


NC Africa





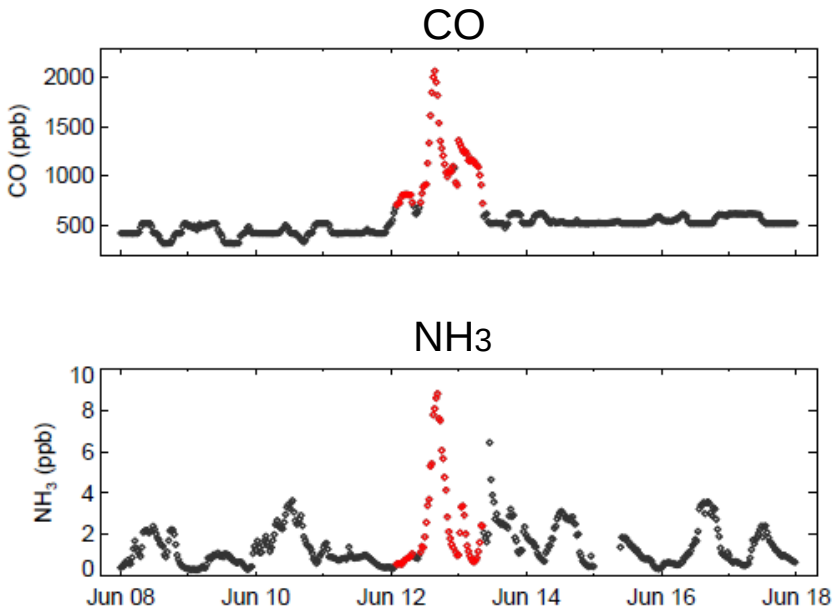
TES and GEOS-Chem in SC Asia: NH_3 vs CO



Anthropogenic NH_3:CO

Fire NH_3:CO

Region	Season	TES		GC		Class
		Slope	Corr Coef	Slope	Corr Coef	
SC Asia	DJF	0.052±0.002	0.61	0.019±0.001	0.61	High NH_3
	MAM	0.041 ±0.002	0.38	0.029±0.001	0.46	High NH_3
	JJA	0.120 ±0.005	0.44	0.082 ±0.003	0.37	High NH_3
	SON	0.047±0.002	0.45	0.027±0.001	0.52	High NH_3
NC China	DJF					
	MAM	0.015±0.001	0.24	0.017±0.002	0.14	High NH_3
	JJA	0.018±0.001	0.09	0.032 ±0.001	0.45	High NH_3
	SON	0.038±0.001	0.12	0.026±0.002	0.44	High NH_3
Mid US	DJF					
	MAM					
	JJA	0.049±0.002	0.28	0.041 ±0.002	0.34	High NH_3
	SON	0.082±0.009	0.12	0.048±0.004	0.55	High NH_3
Average		**0.051±0.003**		**0.036±0.002**		**High NH_3**
S America	DJF					
	MAM					
	JJA					
	SON	0.015±0.000	0.64	0.011±0.000	0.74	BB
SC Africa	DJF					
	MAM					
	JJA	0.013±0.001	0.11	0.014±0.001	0.62	BB
	SON	0.011±0.001	0.19	0.016±0.001	0.70	BB
NC Africa	DJF	0.014±0.001	0.52	0.008±0.000	0.73	BB
	MAM	0.023±0.001	0.38	0.017±0.001	0.37	BB
	JJA					
	SON					
Average		**0.015±0.001**		**0.013±0.001**		**BB**



CO and NH3 enhancement in fire plumes.

Near surface measurements of CO and NH_3 from Duke Forest, during fires in Jun 08 – 18, 2008 in Washington, Hyde and Tyrrell counties of NC. Red symbols represent data taken during the fire plume. NH3:CO = 0.007.

Akagi S. K et al., Emission factors for open and domestic biomass burning for use in atmospheric models, ***Atmos. Chem. Phys.*** 11, 4039-4072, 2011.

Table 1. Emission factors ($g\,kg^{-1}$) for species emitted from different types of biomass burning[a].

	Tropical Forest	Savanna	Crop Residue	Pasture Maintenance	Boreal Forest	Temperate Forest	Extratropical Forest[b]
Carbon Dioxide (CO_2)	1643 (58)	1686 (38)	1585 (100)	1548 (142)	1489 (121)	1637 (71)	1509 (98)
Carbon Monoxide (CO)	93 (27)	63 (17)	102 (33)	135 (38)	127 (45)	89 (32)	122 (44)
Methane (CH_4)	5.07 (1.98)	1.94 (0.85)	5.82 (3.56)	8.71 (4.97)	5.96 (3.14)	3.92 (2.39)	5.68 (3.24)
Acetylene (C_2H_2)	0.44 (0.35)	0.24 (0.10)	0.27 (0.08)	0.21 (0.29)	0.18 (0.10)	0.29 (0.10)	0.19 (0.090)
Ethylene (C_2H_4)	1.06 (0.37)	0.82 (0.35)	1.46 (0.59)	1.28 (0.71)	1.42 (0.43)	1.12 (0.35)	1.38 (0.42)
Ethane (C_2H_6)	0.71 (0.28)	0.66 (0.41)	0.91 (0.49)	0.95 (0.43)	1.79 (1.14)	1.12 (0.67)	1.70 (1.05)
……							
Ammonia (NH_3)	1.33 (1.21)	0.52 (0.35)	2.17 (1.27)	1.47 (1.29)	2.72 (2.32)	0.78 (0.82)	2.46 (2.35)

The average TES NH_3:CO ratio in TES data from the biomass burning cases lies within the range of NH_3:CO values from different biomass burning types recently reported by Akagi et al., (2011)

0.014 (tropical forest)
0.008 (savanna)
0.026 (crop residue)
0.011 (pasture maintenance)
0.021 (boreal forest)
0.009 (temperate forest)
0.020 (extra tropical forest)

0.013 (temperate forest, Paton-Walsh et al., 2014)
0.008 (tropical savanna fires, Smith et al., 2014)

Discussions

- The science value of deriving multiple species products from satellite IR observations.
- Remote sensing retrieved profile ≠ the truth. Data users need to be educated.
- Applications of TES new species products (CO_2, NH_3, HCOOH, CH_3OH, PAN, OCS, …).
  - Emission sources (distribution and variability).
  - Study of secondary pollutants.
  - Atmospheric chemistry in models.