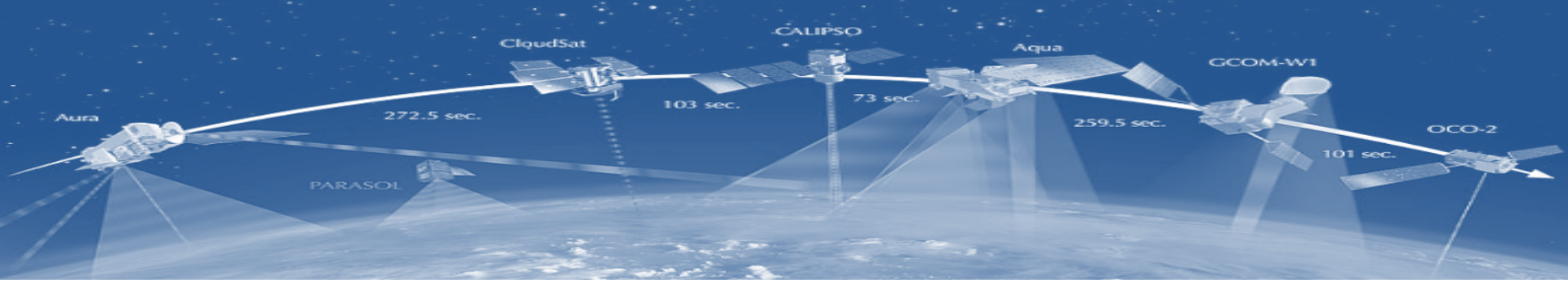

Deriving top-down NO_x and SO_2 emissions simultaneously using OMI observations and GEOS-Chem adjoint

Zhen Qu[1,*], Daven K. Henze[1],
Jun Wang[2], Xiaoguang Xu[2], Yi Wang[2], Wei Wang[3],
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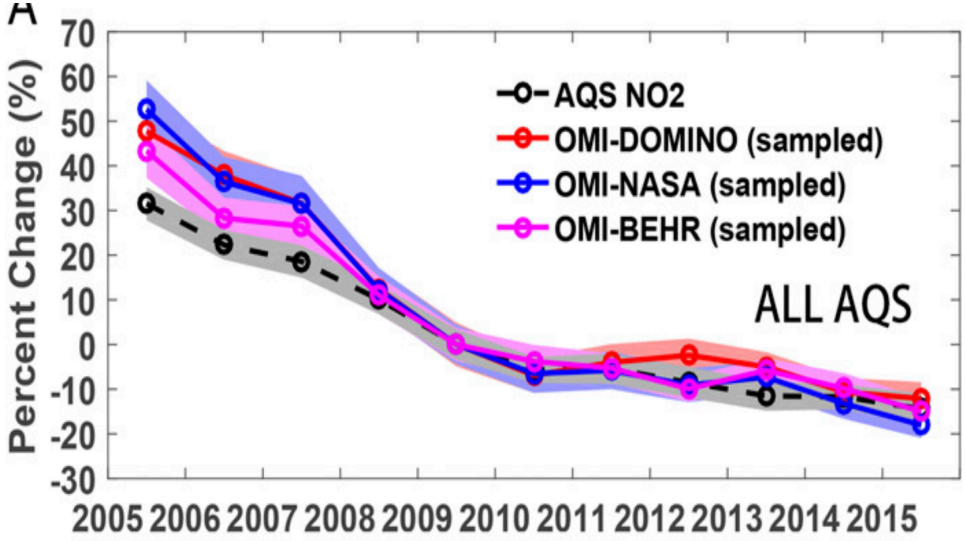
May 22nd, 2018, GEOS-Chem Asia Meeting (GCA1)

[1]University of Colorado Boulder, [2]University of Iowa, [3]China National Environmental Monitoring Center, [4]University of Maryland, [5]Royal Belgian Institute for Space Aeronomy

University of Colorado **Boulder**

Satellite observations provide timely update of pollutant emissions and concentrations

NO_2 column density for US



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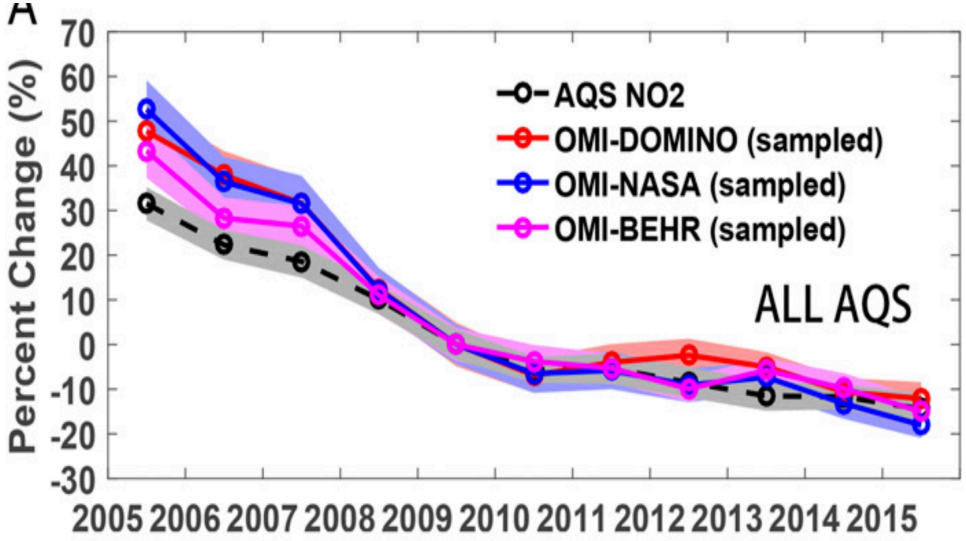

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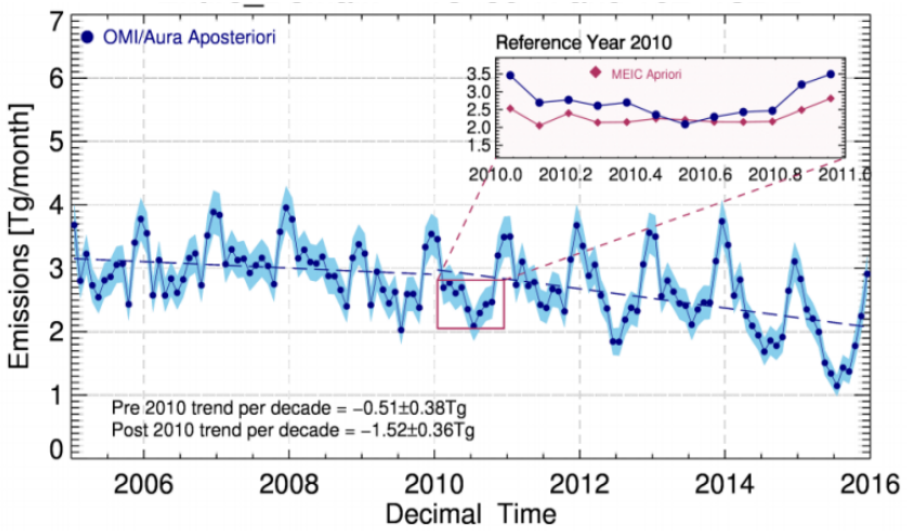
Top-down SO_2 emissions for China



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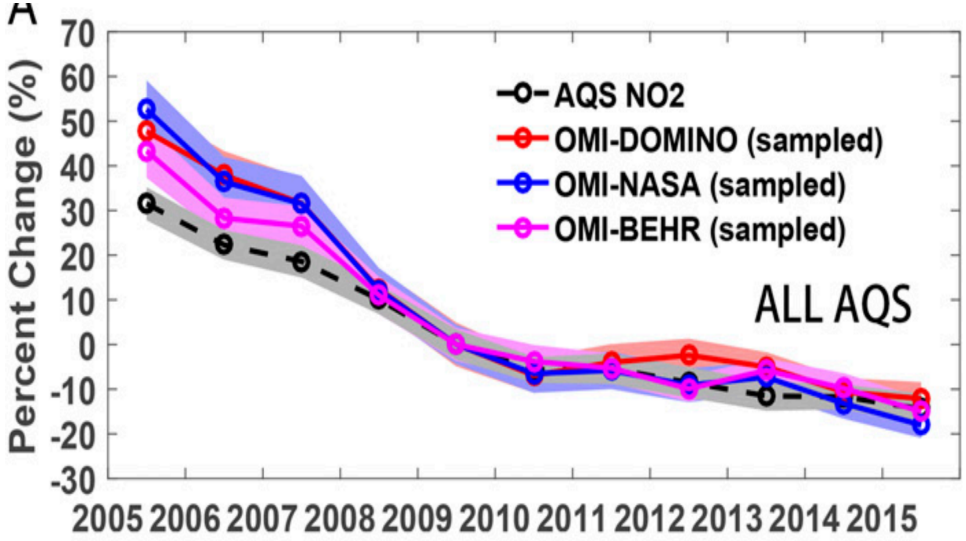

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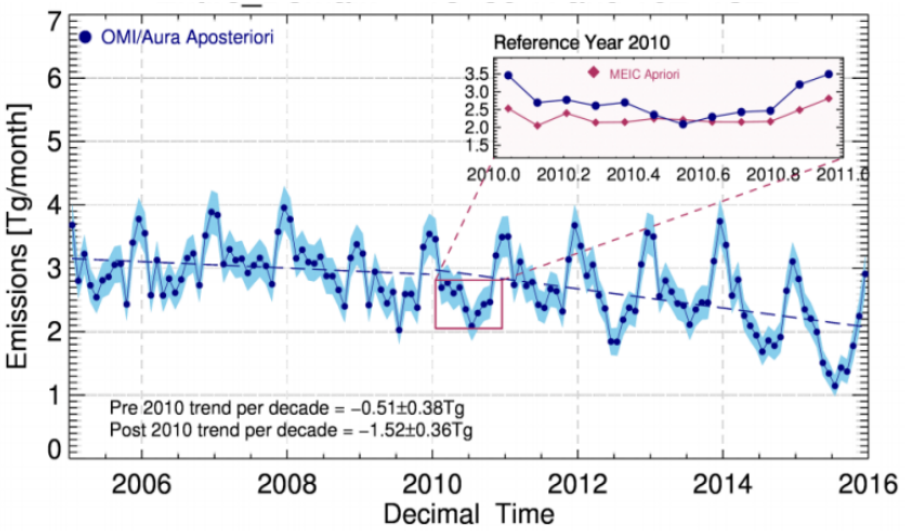

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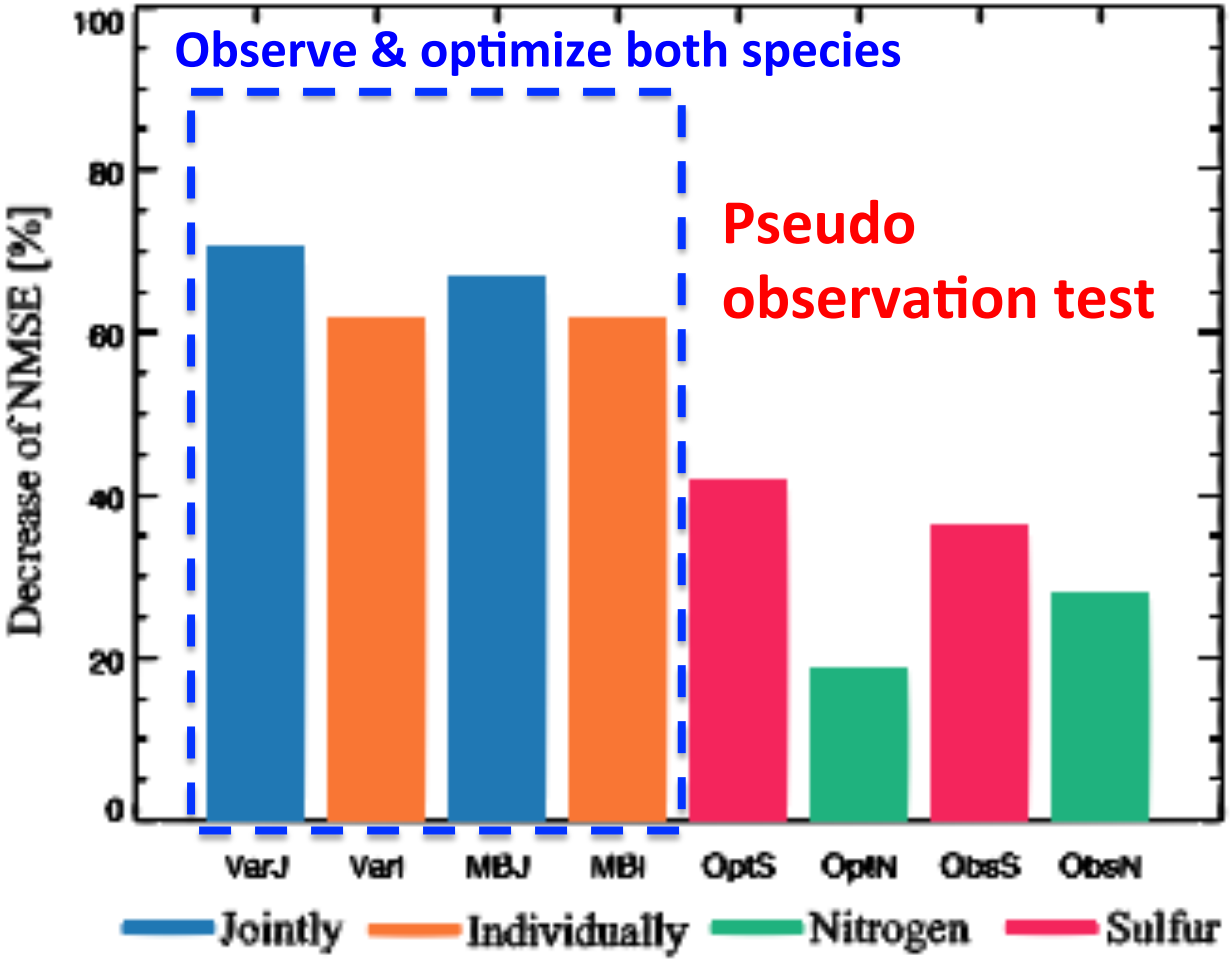
- OMI shows unexpected slow down of NO_2 concentration in US
- SO_2 emissions starts to decrease from 2007 in China.
- Uncertainties: overlooked chemical interactions & retrieval method

Improved performance in emission estimates using multi-species observation and optimization



VarJ: 4D-Var jointly
VarS: Sum of two individual 4D-Var
MBJ: Mass balance jointly
MBS: Sum of two individual mass balance
OptS: Optimize SO_2 emissions
OptN: Optimize NO_x emissions
ObsS: Observe SO_2 column
ObsN: Observe NO_2 column

- Better performance of joint 4D-Var (by 8.7%) and mass balance (by 5.1%) than single species inversion

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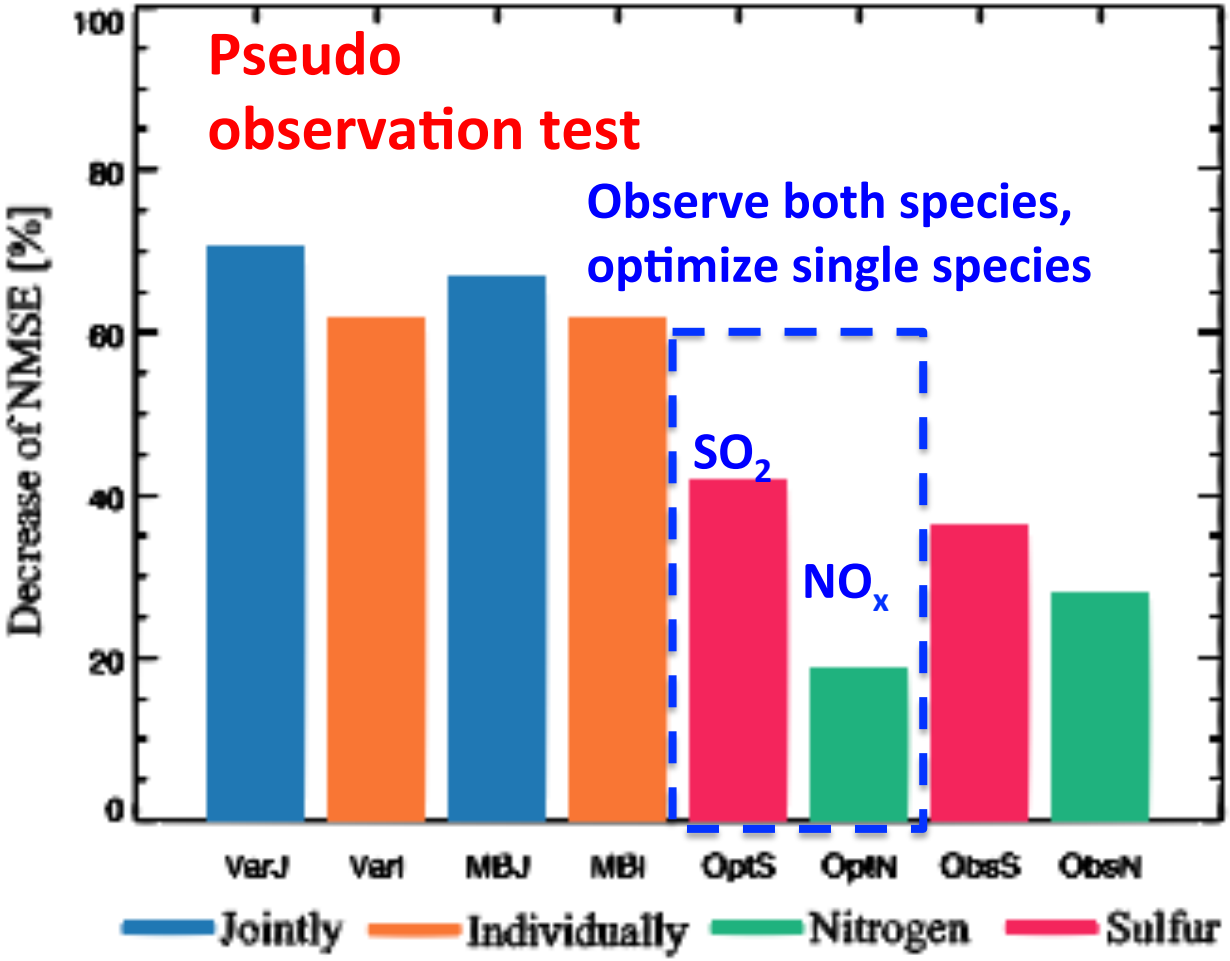

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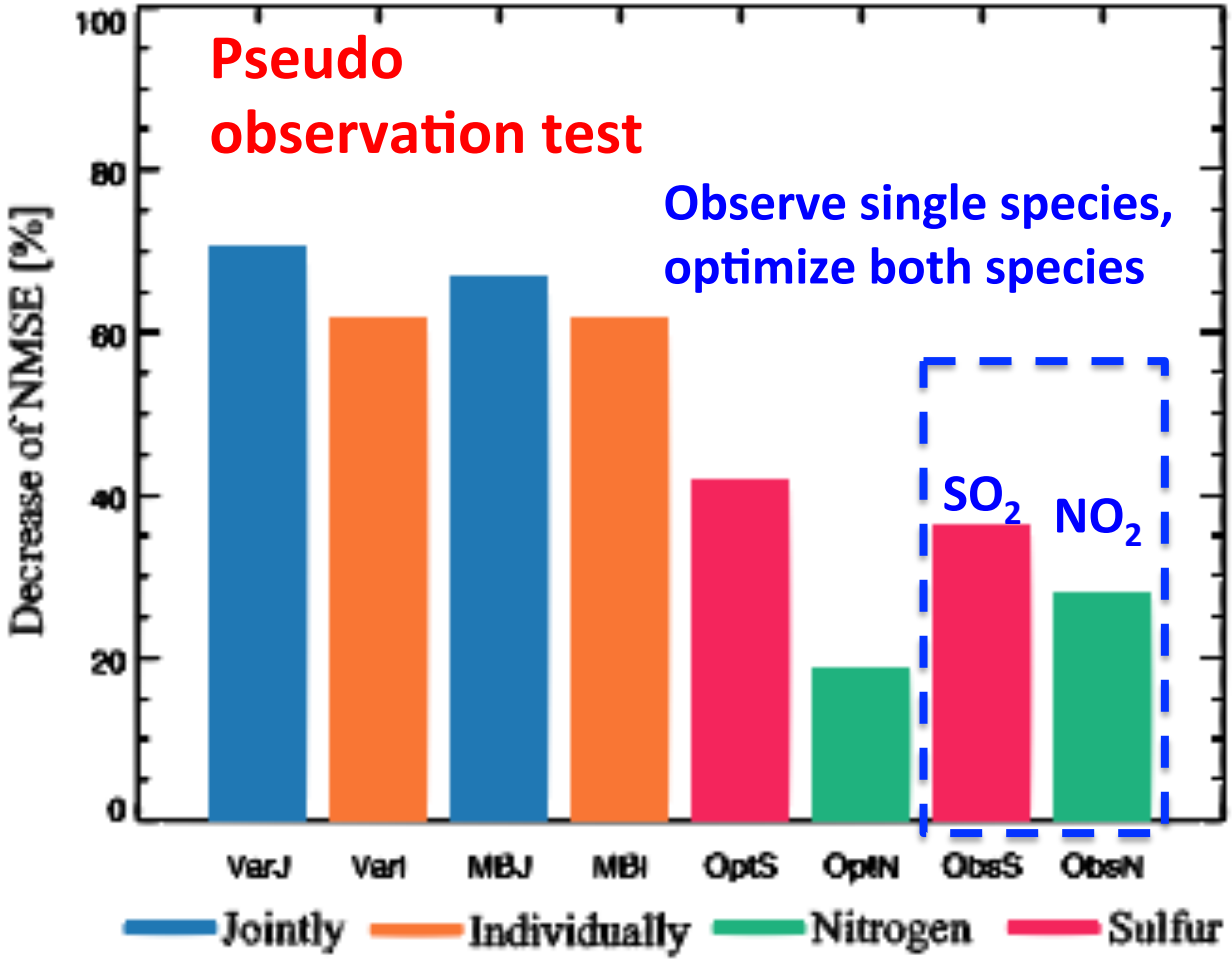

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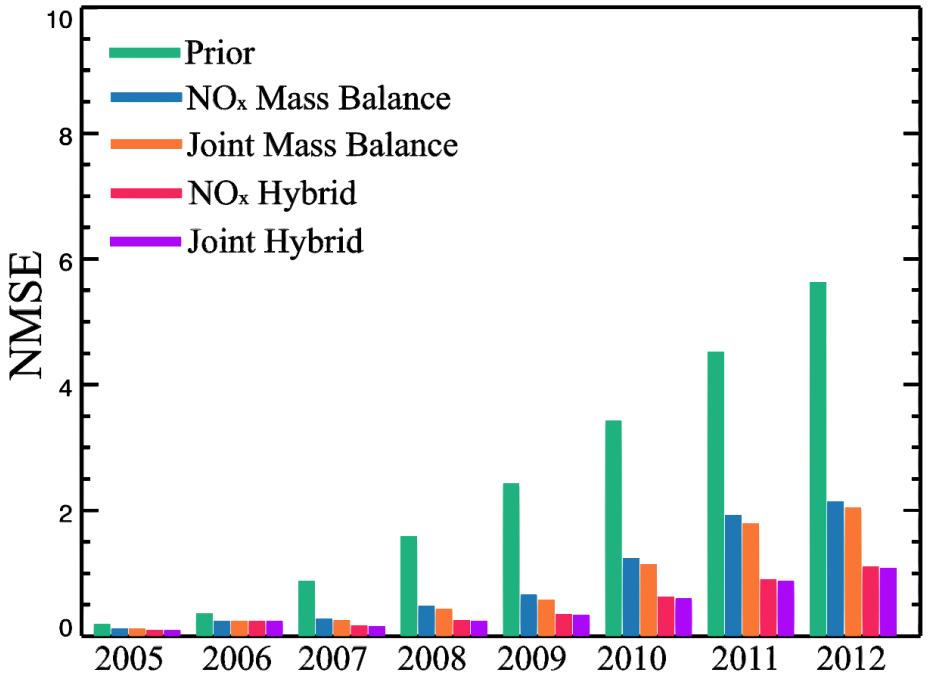
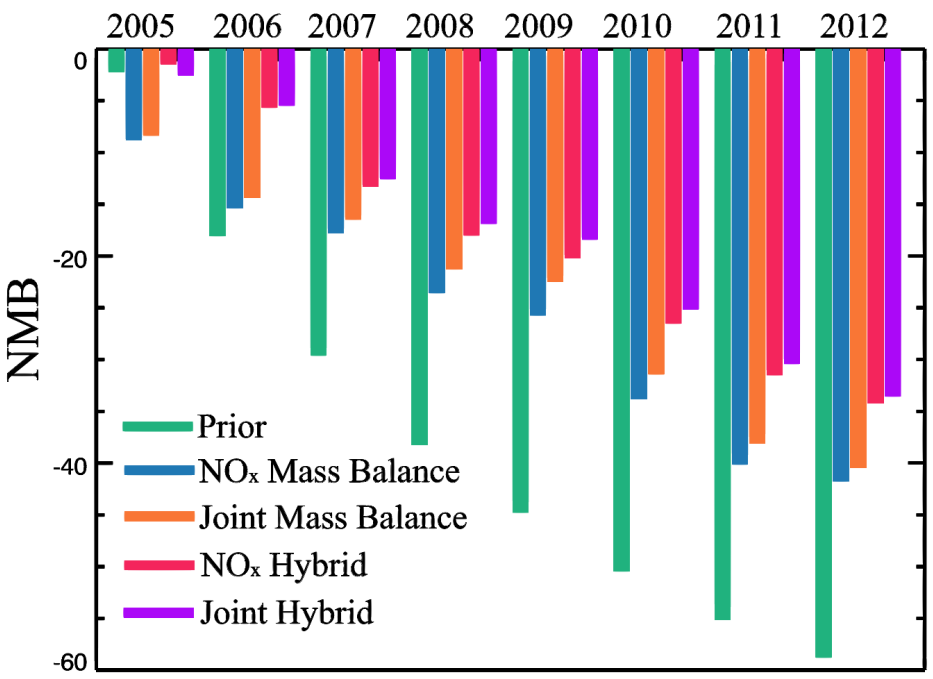
- Largest decrease of NMSE if observe and optimize both species at the same time

Generally reduced error and bias in hybrid joint posterior NO_x

Setup (2005-2012):

- **True emissions:** 10% annual growth rate
- **Prior emissions:** 2010 true emissions x random noises x 0.5, for all years





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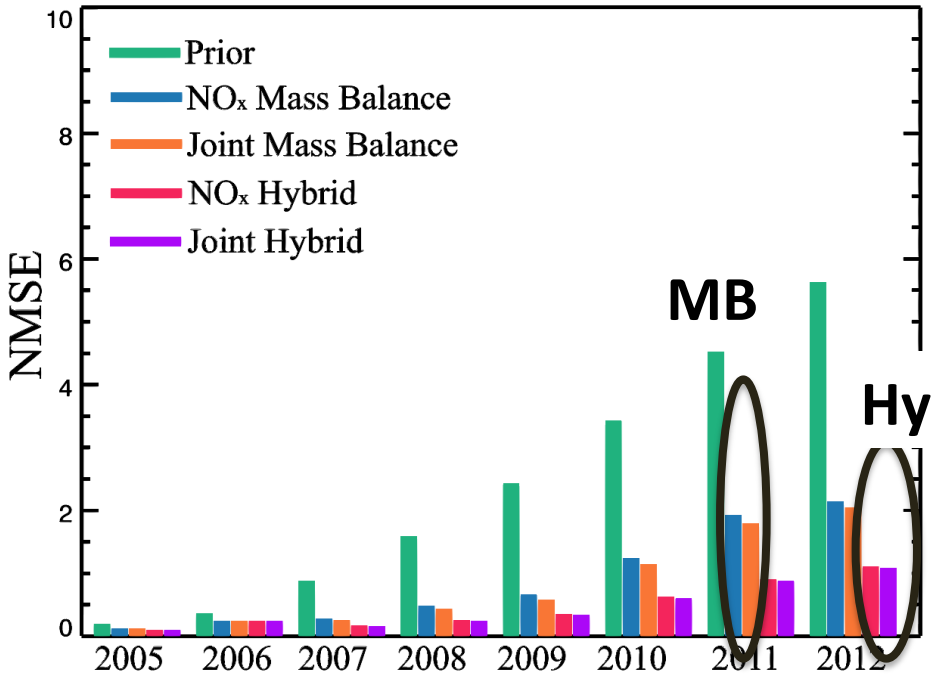

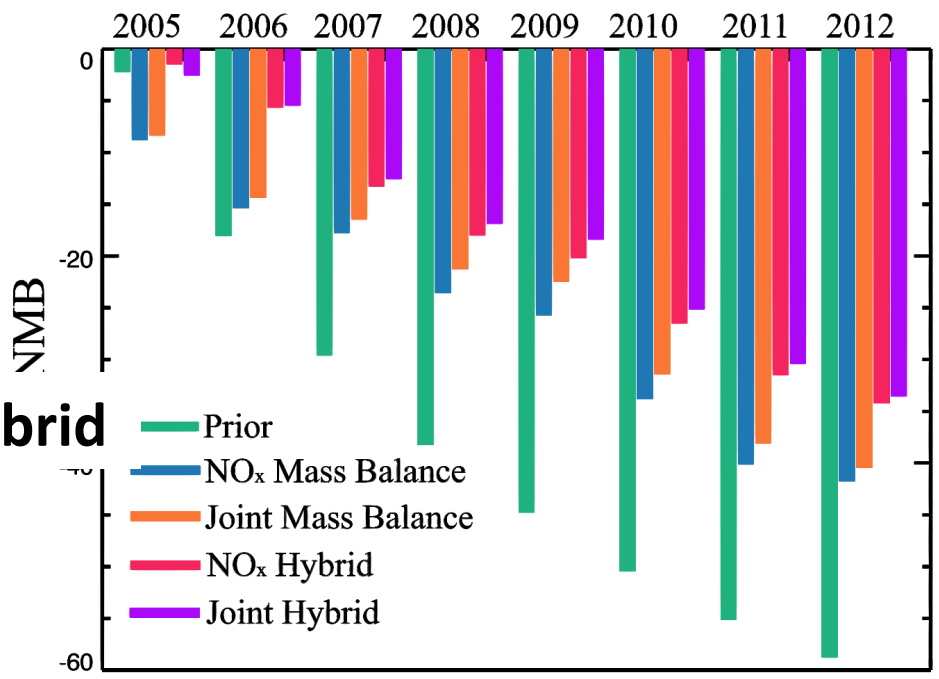

- Hybrid approach reduce error (bias) by 17-53% (17-83%) compared to MB for NO_x, except for 2006

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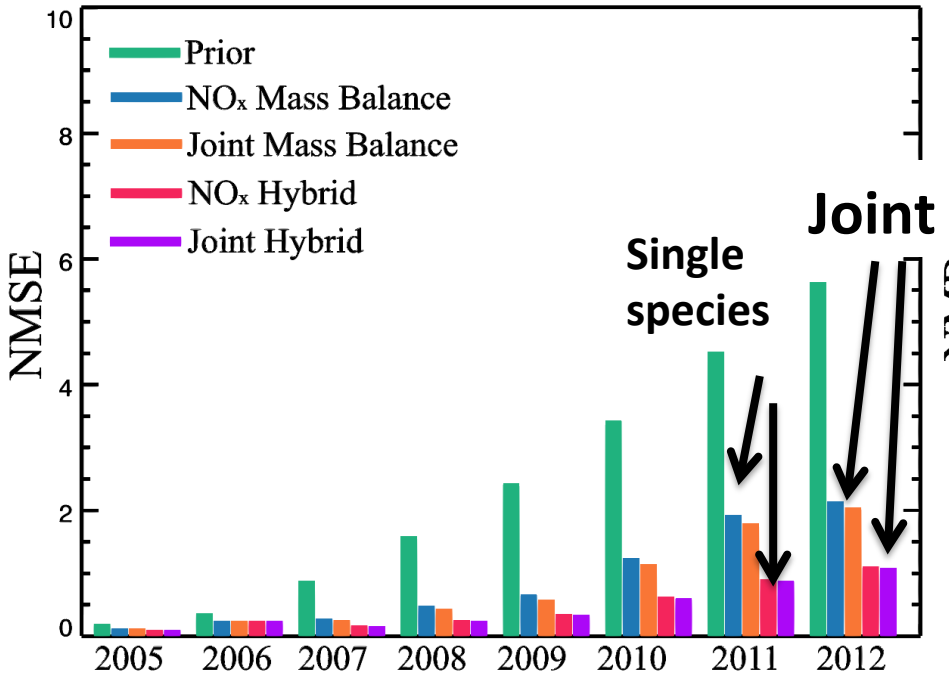

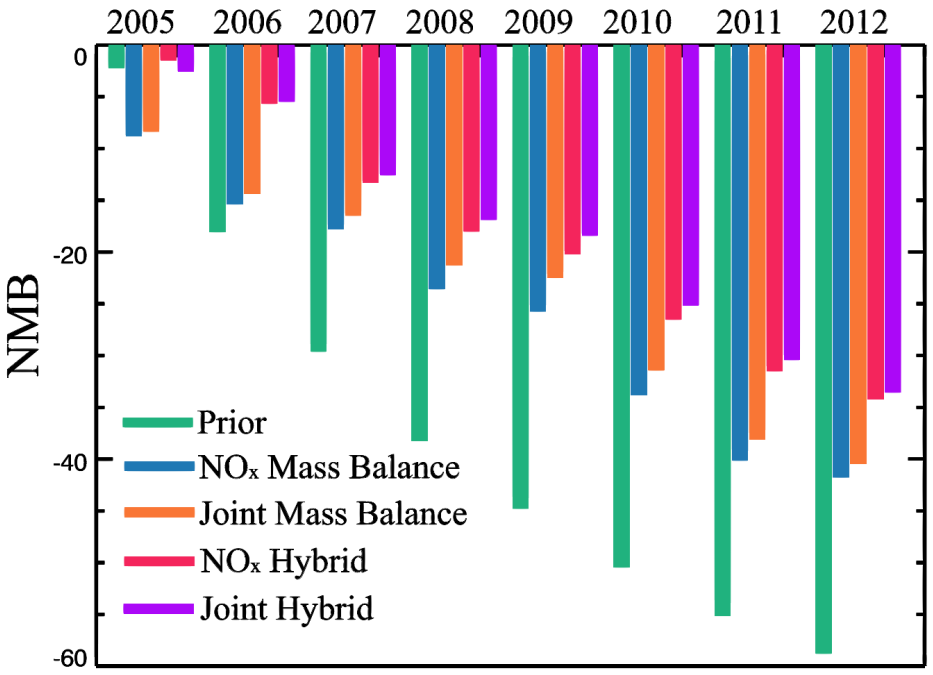

- Hybrid approach reduce error (bias) by 17-53% (17-83%) compared to MB for NO_x, except for 2006
- Joint inversion reduce error (bias) by by 0-12% (3-13%) compared to single species inversion for NO_x

Generally reduced error and bias in hybrid joint posterior SO_2

Setup (2005-2012):

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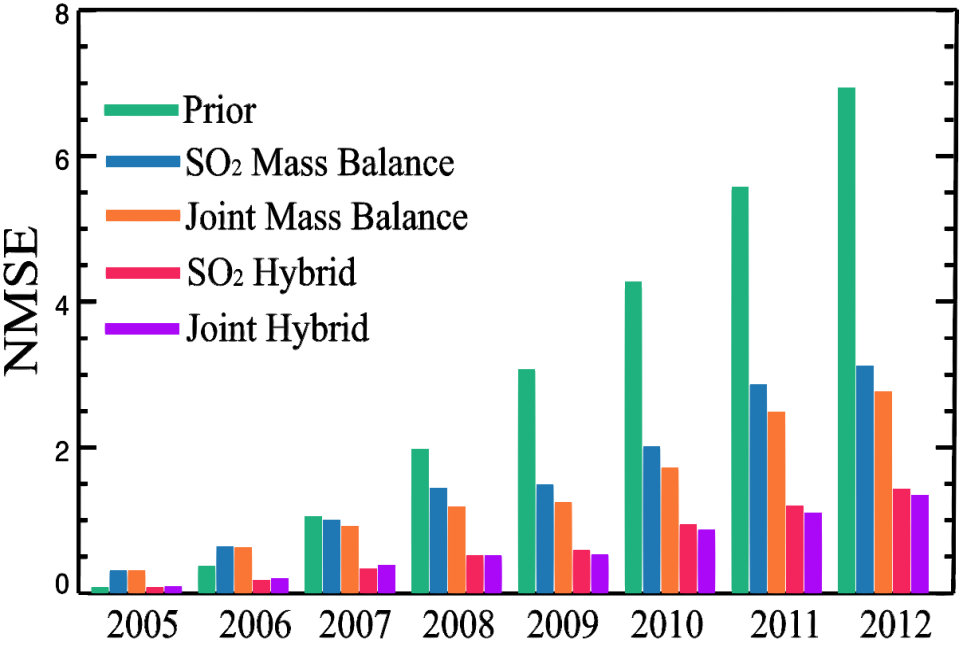
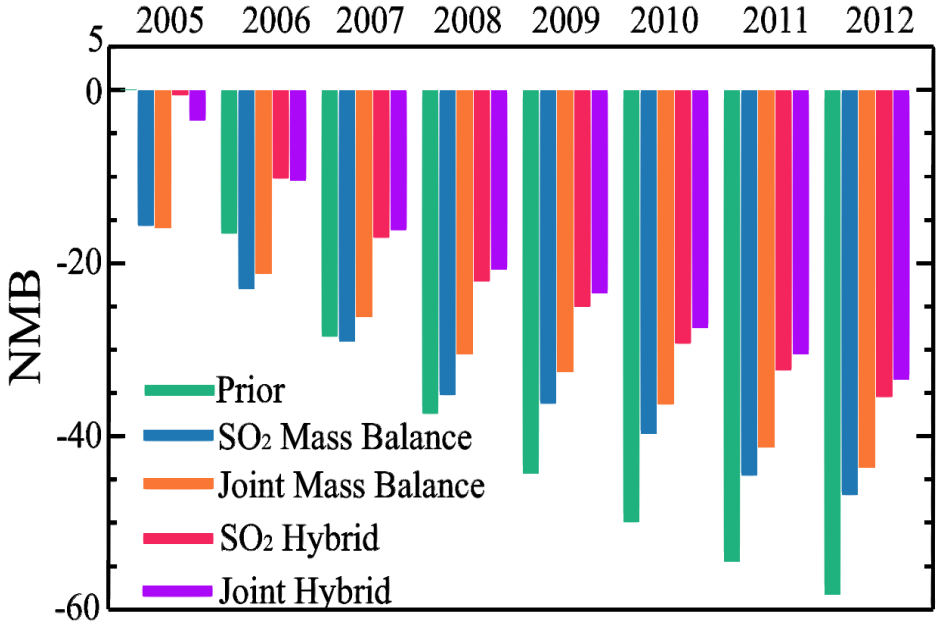
- **Prior emissions:** 2010 true emissions x random noises x 0.5, for all years





- Hybrid approach reduce error (bias) by 50-74% (23-96%) compared to MB for SO_2
- Joint inversion reduce error (bias) by by 3-18% (7-13%) compared to single species inversion for SO_2, except for 2005

Different magnitude and changing directions of NO_2 and SO_2 SCD from different retrieval products

- NO_2 NASA standard product is 50% smaller than DOMINO retrievals in densely populated and industrial regions.
- Posterior NO_x emissions are more robust in Yangtze River Delta, Xinjiang, Ningxia, and Inner Mongolia.

(Qu et al., JGR, 2017)

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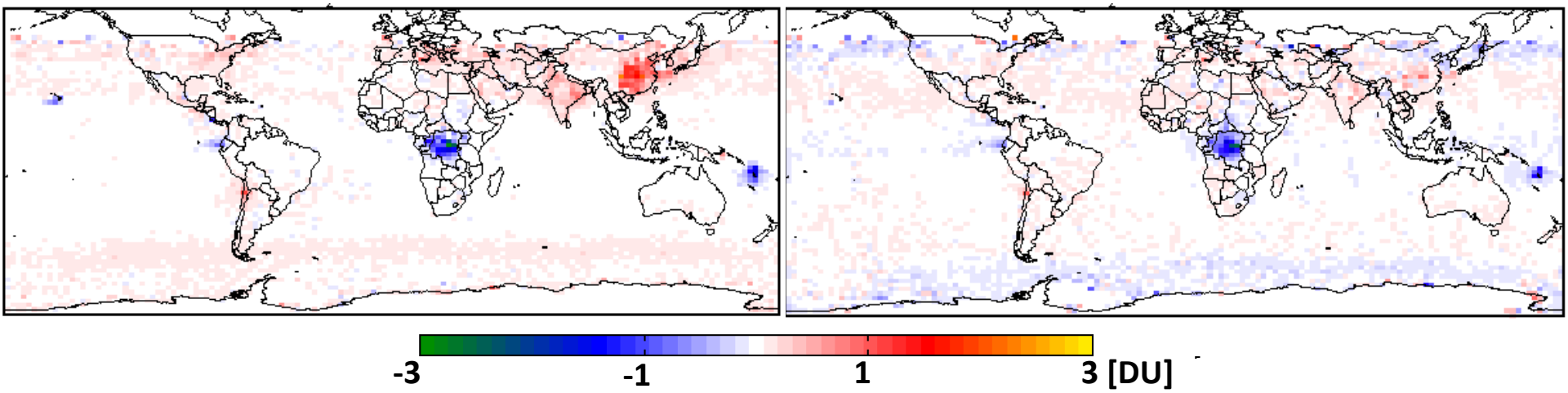
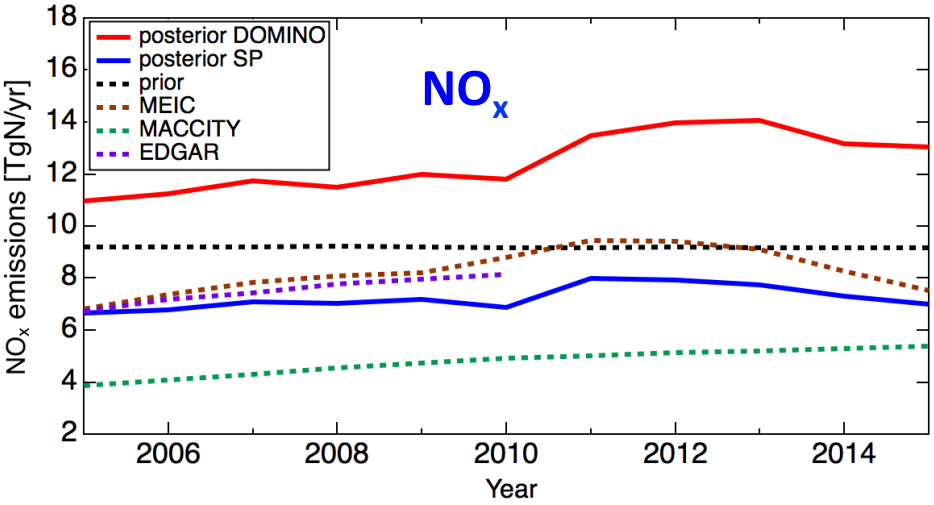
SO_2 SCD, GC – OMI, Jan 2010



- Consistent underestimate of volcanic SO_2 due to missing sources
- Inconsistent magnitude and signs of model-observation differences in mid latitude in NH, possibly caused by different cloud product and surface reflectivity

Discrepancies in different retrieval products can propagate into top-down emissions

Emissions in China



(natural source from GEOS-Chem)

- Posterior NO_x emissions from NASA SP is smaller than that from DOMINO by 39-46%

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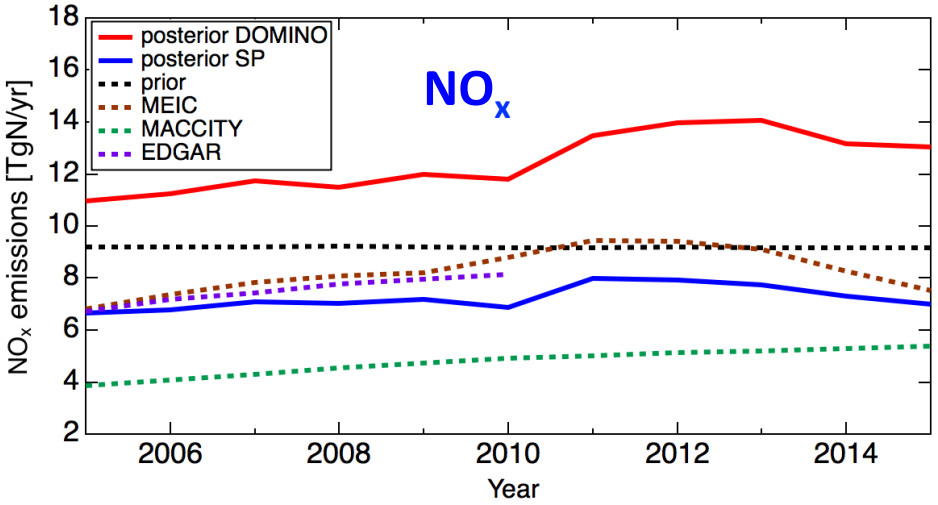
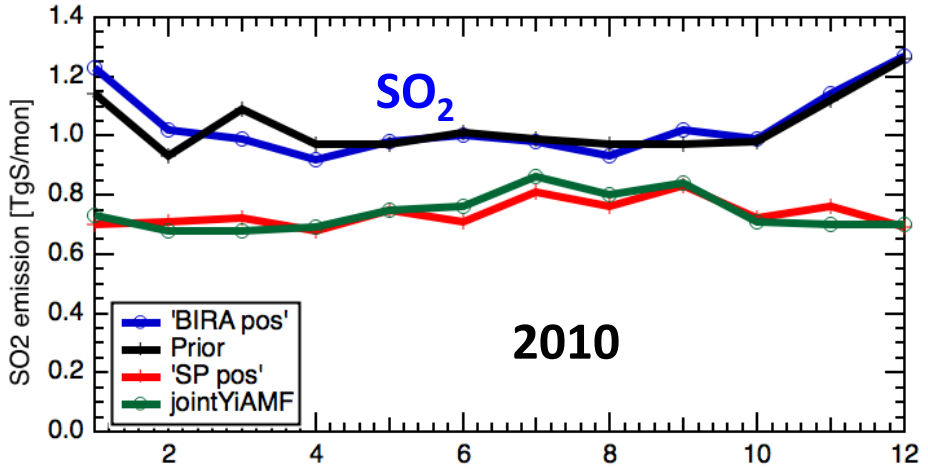


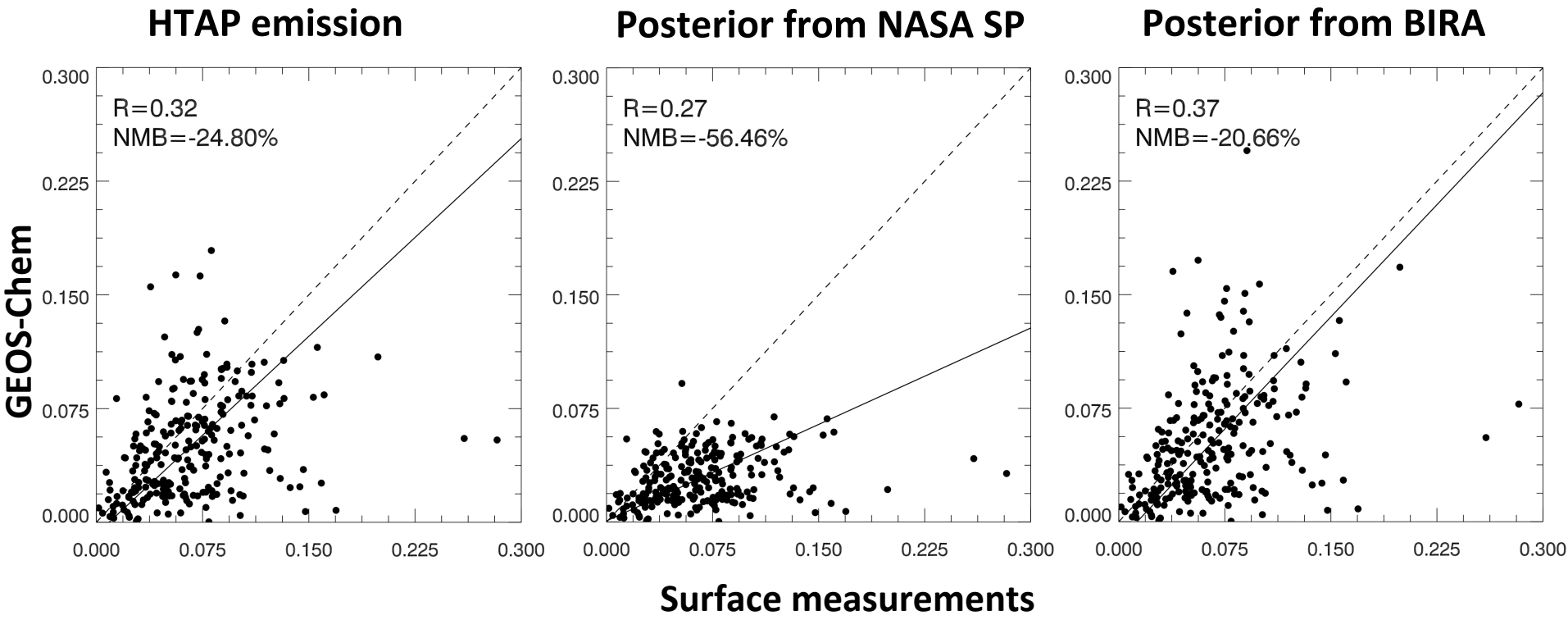


(natural source from GEOS-Chem)

- Posterior NO_x emissions from NASA SP is smaller than that from DOMINO by 39-46%
- China's posterior SO_2 emission from NASA SP is 17-46% smaller than top-down estimates from BIRA product.

Evaluation with in-situ measurement show better consistency of posterior concentration in China but worse in US

Surface SO_2 concentration in China (Jan 2010) [ug/m^3]



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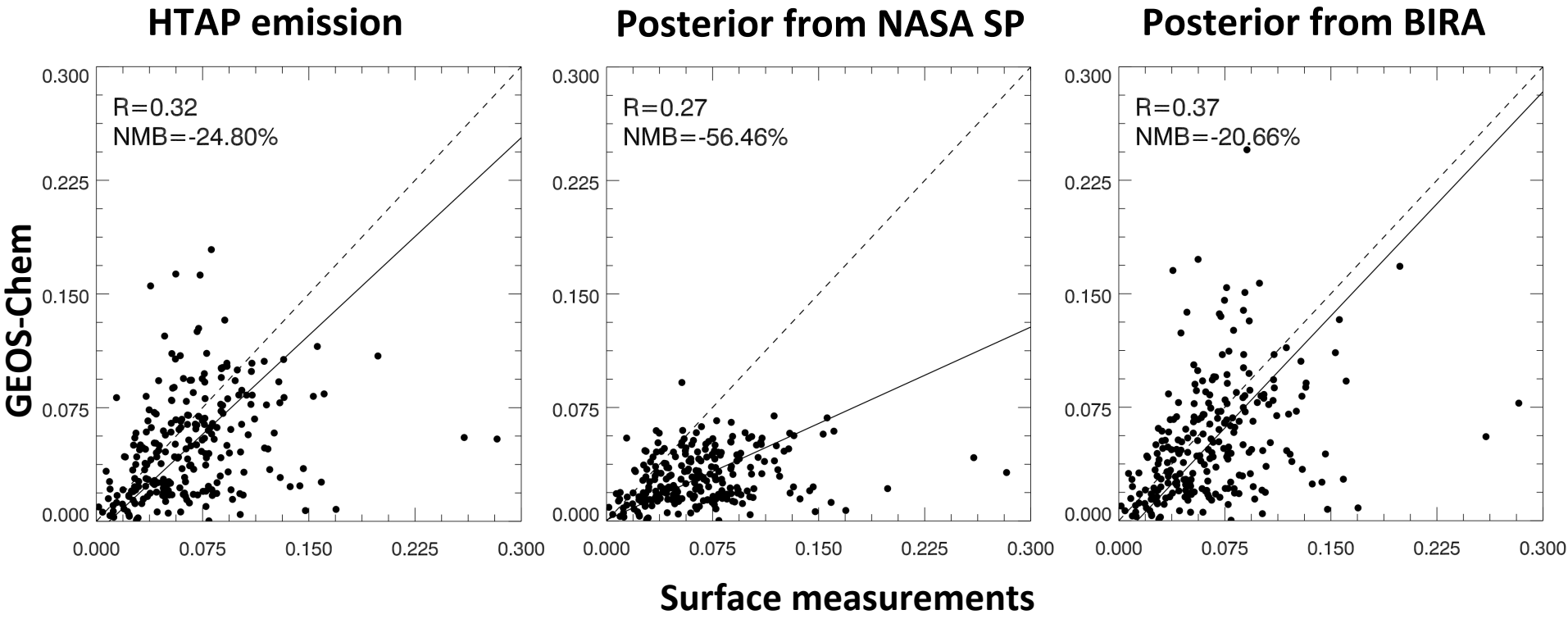
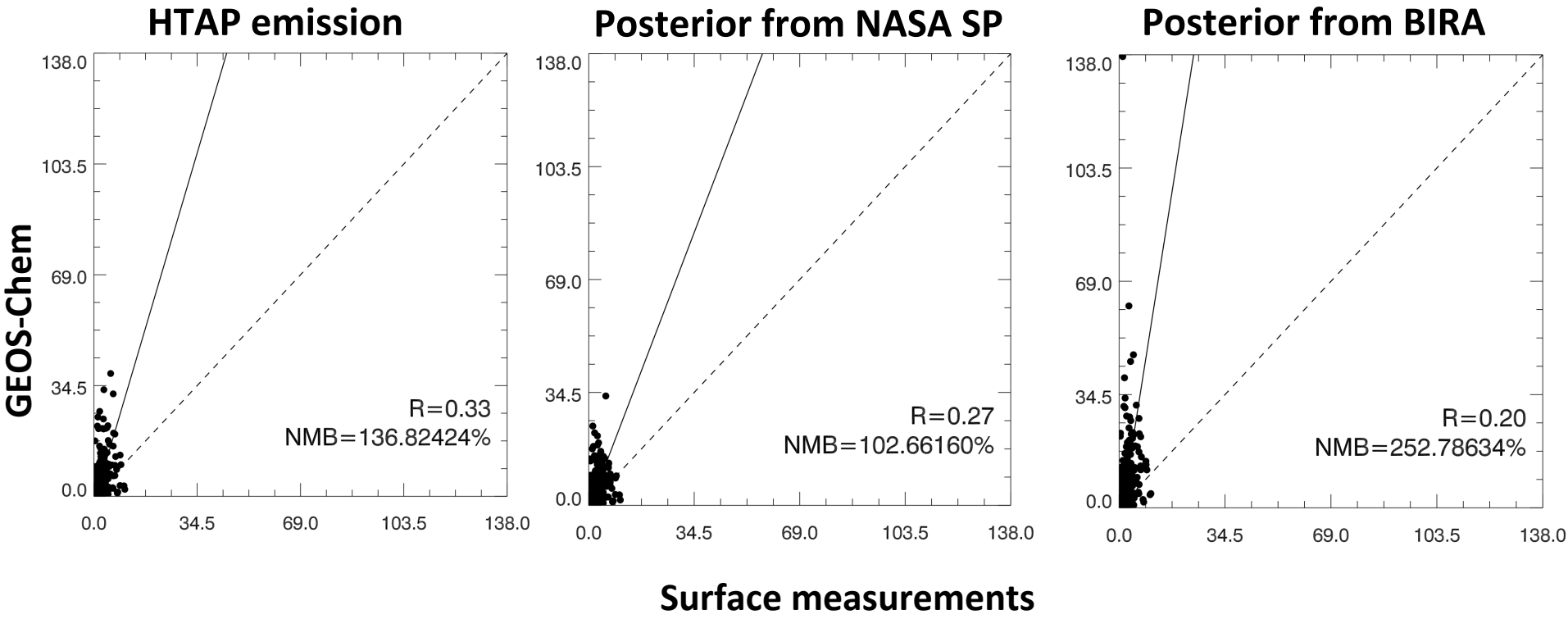


- Posterior surface SO_2 concentration constrained by BIRA product reduce bias and improve correlation while SP posterior degrade the performance in China.

Evaluation with in-situ measurement show better consistency of posterior concentration in China but worse in US

Surface SO_2 concentration in US [ppbv]



- Posterior surface SO_2 concentration in US has worse correlation
- SP posterior has reduced bias compared to AQS measurements

Summary

- Reduced posterior emission error when assimilating NO_2 and SO_2 to optimize NO_x and SO_2 emissions simultaneously
- Different NO_2 and SO_2 retrievals lead to ~ 50% discrepancies in posterior emissions
- Differences in SO_2 retrievals are possibly related to different cloud product and meteorology
- Improved consistency in posterior simulation of SO_2 concentration with surface measurements in China, but no obvious improvements in US

OMI SO2 SCD from different products, Jan 2010