GEOS-Chem Adjoint Inversion of SO_2 Emissions with OMI SO_2 Observations over China

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Background

Sulfur dioxide (SO_2) plays a significant role in the atmosphere. It is oxidized in the atmosphere, leading to aerosol formation and acid deposition. Sulfate aerosols have highly uncertain effect on climate, are deleterious to human health, and degrade visibility. The uncertainties of SO_2 emissions are outstanding questions.

Objectives

- Use OMI SO_2 observations to constrain SO_2 emisssions through GEOS-Chem adjoint model

Data Descriptions

- We use the OMI Level 3 best pixel column SO_2 at 0.25° x0.25° resolution over China. These observations are averaged in 2.0° x2.5° grid boxes at every data assimilation time slot (1 hour) as superobservations. Observation errors for the superobservations are considered as 1.2 D.U. over the square root of the number of pixels averaged.
- The prior anthropogenic SO_2 emissions are scaled from Streets-2001 inventory (Streets et al., 2003) before 2006, and are INTEX-B inventory (Zhang et al., 2009) for 2006 and later years

Observation Opeator

We Developed OMI SO_2 observation operator and validate it through finite difference method. Sensitivities calculated using the adjoint model are compared with sensitivities using centered finite differences (figure 1). All points lie along or near the 1:1 line, demonstrating the correctness and accuracy of OMI SO_2 observation operator.

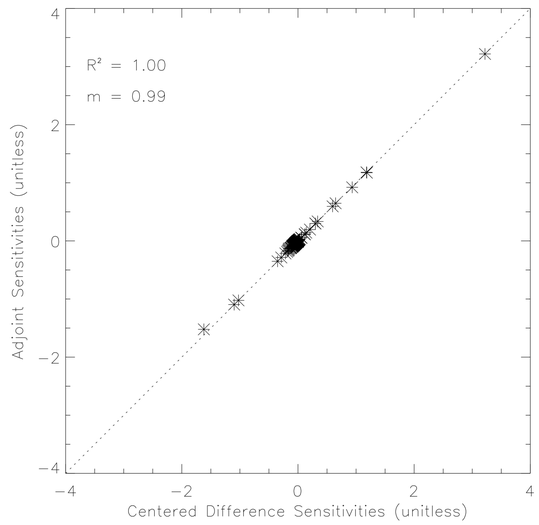

Figure 1: Validation of adjoint model sensitivities via comparison to finite difference results. Shown here are sensitivities of cost function with respect to anthropogenic SO_2 emission scale factors

Inversion Results

Figure 2 shows prior model simulation of column SO_2 are larger than OMI observations in most grid boxes. After inversion, the differences decrease and anthropogenic SO_2 emissions decrease in Sichuan Basin, South China and most grid boxes of North China.

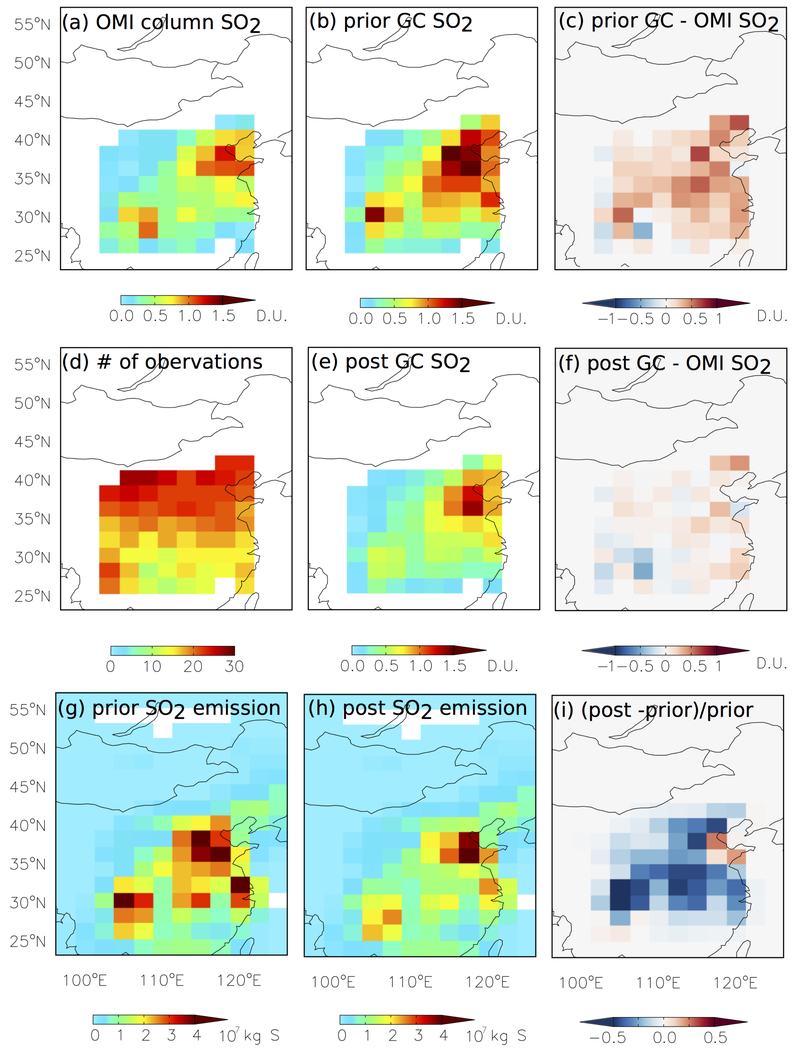

Figure 2: Column SO_2 of OMI (a), prior simulation (b), the difference between prior simulation and OMI (c), posterior simulation (e), and the difference between posterior simulation and OMI. Number of OMI SO_2 observations (d). Prior anthropogenic SO_2 emissions (g). Posterior anthropogenic SO_2 emissions (h). The relative difference of posterior and prior anthropogenic SO_2 emissions (i) in April, 2008

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Validation

Table 1: Design of validation

	Inversion Month	Applying Month
1	April 2005	April 2006
2	January 2006	January 2007
3	April 2008	April 2009

Optimized SO_2 emission scale factors are applied to corresponding month of the next year

When the optimized SO_2 emissions scale factors of corresponding month of last year are applied, the realtive bias and de-biased RMSE of model smiluation of column SO_2 with respect to OMI SO_2 observations decreases significantly in the three case. Correlation coefficient increases in case 2 and 3, but decreases in case 1.

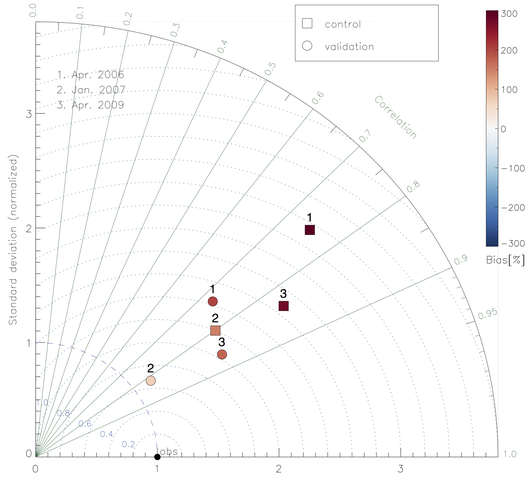

Figure 3: Taylor diagram of column SO_2 for evaluations of using default emission scale factors (square) and optimized emission scale factors of last corresponding month (cycle) when comparing against OMI SO_2

Outlook

The use of OMI SO_2 as constraints for the inversion of SO_2 emissions over China shows that posterior SO_2 emission scale factors can be applied to corresponding month of next year. Based on the promosing reulsts, we plan to assimilate OMI SO_2 and OMI NO_2 sumultanelously, compare model similations of AOD with MODIS AOD. Then we shall use OMI SO_2, OMI NO_2, and MODIS AOD as constraints to inverse SO_2, NO_2, and NH_3 emissions.

Acknowledgements

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References

Streets, D. G. et al., 2003: An inventory of gaseous and primary aerosol emissions in Asia in the year 2000. J. of Geophys. Res., 108, 8809.

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