GEOS-Chem Adjoint Inversion of $\text{SO}_2$ and $\text{NO}_x$ Emissions with Multi-sensor (OMPS, OMI, and VIIRS) Data over China

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Satellite view of SO\textsubscript{2} and NO\textsubscript{2} and forecasts

Tropospheric NO\textsubscript{2} [10\textsuperscript{15} molec/cm\textsuperscript{2}] over China

(Georgoulias et al., 2018)

SO\textsubscript{2} forecasts

(a) Slant column SO\textsubscript{2} forecast

(b) Surface SO\textsubscript{2} forecast

(Wang et al., 2016)
Data and Method

Inverse Modeling

- Satellite vs. model
- GEOS-Chem adjoint
- Inverse theory

Model $SO_2$, $NO_2$

Simulation

Emission sources

Inconsistency (cost function)

Adjust emission

Validated with

Validation

- NASA OMI $SO_2$, $NO_2$

- Validation with in situ observations

Downscale emissions
GEOS-Chem Simulation, and forecasts

Validated with

VIIRS nighttime light

NASA OMI $SO_2$, $NO_2$
SO₂ and NOₓ emissions (October 2013)

Prior (MIX, 2010)

SO₂
1166 Gg S/mon

NOₓ
714 Gg N/mon

Posterior

SO₂
748 Gg S/mon

NOₓ
672 Gg N/mon

(Posterior – Prior) / Prior

SO₂
-35.8%

NOₓ
-5.8%
Comparisons of OMPS based SO$_2$ and NO$_2$ with OMI
Downscale posterior SO$_2$ emissions

- Assuming the spatial distribution of prior emission at a resolution of 0.25°x0.3125° is correct, but systematic bias exist.

- Posterior 2°x2.5° emission is downscaled according to the spatial distribution of prior emission at a resolution of 0.25°x0.3125°

\[
E_{f,i}^{\text{post}} = E_{c}^{\text{post}} \times \frac{E_{f,i}^{\text{prior}}}{\sum_i E_{f,i}^{\text{prior}}}
\]
Validation with in situ SO$_2$ observations

- Bias decreases from 38 µg/m$^3$ to -3 µg/m$^3$

- Root mean square error decreases from 60 µg/m$^3$ to 25 µg/m$^3$

- Standard deviation decreases from 63 µg/m$^3$ to 20 µg/m$^3$, which is more consistent with observation (18 µg/m$^3$)
Downscale posterior NO\textsubscript{x} emissions

\[ E_{f,i}^{\text{post}} = E_{c}^{\text{post}} \times \frac{E_{f,i}^{\text{prior}}}{\sum_i E_{f,i}^{\text{prior}}} \]

TROPOMI NO\textsubscript{2} VS VIIRS nighttime light

NO\textsubscript{2} VS nighttime light

\begin{align*}
R &= 0.66 \ (p < 0.01) \\
N &= 311843 \\
y &= 0.07x + 0.15
\end{align*}
Validation with in situ NO\(_2\) observations

- Linear correlation coefficient increases from 0.46 (prior) to 0.61 (MIX emission downscale) and 0.58 (nightlight emission downscale)

- Root mean square error decreases from 12 µg/m\(^3\) (prior) to 10 µg/m\(^3\) (MIX emission downscale) and 11 µg/m\(^3\) (nightlight emission downscale)
Apply top-down emissions to next month for forecast

**SO₂**

Bias: 44 μg/m³
RMSE: 78 μg/m³

**NO₂**

Bias: -7 μg/m³
RMSE: 37 μg/m³
All the three future GEO satellite will provide hourly retrievals of SO$_2$ and NO$_2$, which will facilitate optimization of SO$_2$ and NO$_x$ emissions at high temporal resolution.
Conclusions and acknowledgement

• Both posterior SO$_2$ and NO$_x$ emissions constrained by OMPS retrievals are smaller than MIX prior emissions in October 2013, respectively.

• Posterior simulation of SO$_2$ and NO$_2$ vertical column densities are in better agreement with OMI retrievals than prior simulation.

• Coarse resolution posterior emissions are downscaled to simulate surface SO$_2$ and NO$_2$ at fine resolution and show better result when validating against in situ observation.

• Posterior emissions are applied to next month to improve air quality forecast.

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