Radiative Effect of Recent Changes in $PM_{2.5}$ Pollution over China and local and Remote Climate Impacts

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Introduction

- $PM_{2.5}$ is fine particulate matter with a diameter of 2.5 μm or less, which can come from both natural and **anthropogenic** sources.
- The Chinese government issued a series of emission control policies, led to a large reduction in aerosol emissions over China in recent years.
- Two major components of $PM_{2.5}$ and major contributors to aerosol radiative forcing: **Black Carbon (BC)** – absorb solar radiation
  Sulphate – scatter solar radiation

Emissions

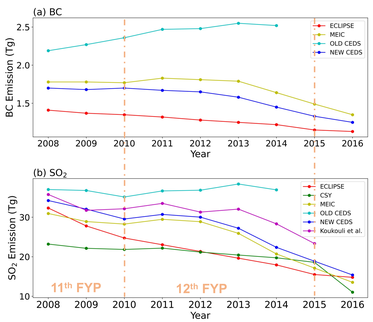


Figure 1. Trends of (a) BC and (b) SO_2 emissions (units: Tg) in China between 2008 and 2016 from different inventories.

- **ECLIPSE**
- Community Emissions Data System (**CEDS**) used in Coupled Model Intercomparison Project Phase 6 (CMIP6), CEDS_new and CEDS_old.
- Multi-resolution Emission Inventory (**MEIC**), v1.3
- China Statistical Yearbook (**CSY**), 2009- 2017, linked to Five-Year Plan (FYP)

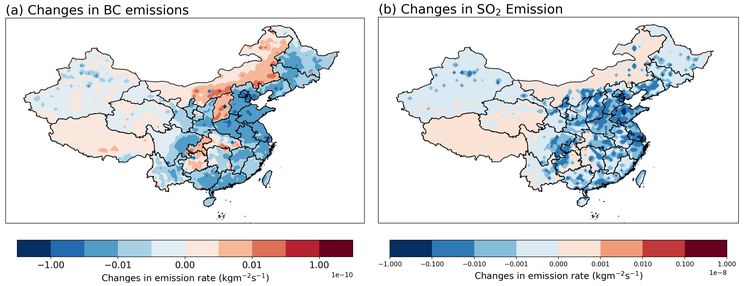
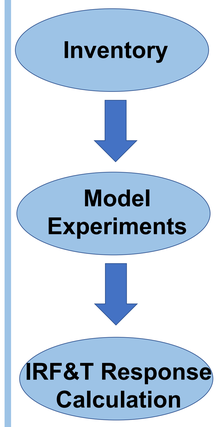


Figure 2. Changes in the emission rate (units: $kgm^{-2}s^{-1}$) of (a) BC and (b) SO_2 over China in ECLIPSE inventory between 2008 and 2016.

- ECLIPSE inventory provides good estimates of the aerosol emissions in China during 2008 and 2016.
- Changes in SO_2 emission (17.53 Tg) is extremely larger than changes in BC emission (0.38 Tg) over China between 2008 and 2016.
- Largest aerosols reduction over Eastern China.

Data & Methods



- Evaluating the Climate and Air Quality Impacts of Short-lived pollutants (**ECLIPSE**), v6b

United Kingdom Earth System Model (UKESM), v1

Anthropogenic Aerosol Emissions				
Experiment	**All**	**BC**	**SO_2**	**Meteorology**
EXP08	2008	2008	2008	2012 -2014
EXP16	2016	2016	2016	
EXP16ChinaBC	2008	2016 only over China	2008	
EXP16ChinaSO_2	2008	2008	2016 only over China	

Table 1: Detail of the model experiments conducted in this study with information on the anthropogenic pollutant emissions used in each experiment.

- IRF Calculation

$$F_{tot} = F_{SW} + F_{LW}$$

$$F_{net} = F_{down} - F_{up}$$

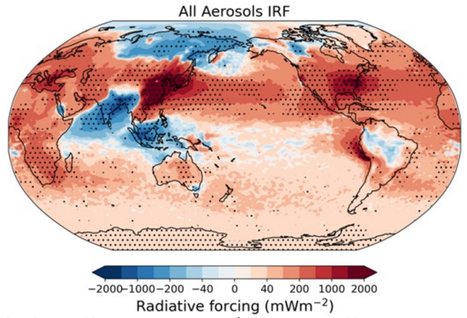
$$IRF = F_{net\_dirty} - F_{net_{clean}}$$

$$Dif f_{IRF} = EXP - EXP08$$

- Temperature Response Calculation

  BC & Sulphate IRF × regional temperature response coefficients at different latitude bands

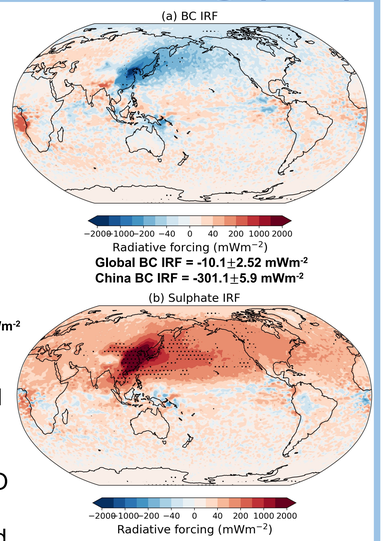
Instantaneous radiative Forcing (IRF)



Global Aerosol IRF = 120.0±5.06 mWm-2 **China Aerosol IRF = 866.9±164.4 mWm-2**

Figure 3. Changes in the global all-sky aerosol mean SW IRF (units: mWm^{-2}) between EXP16 and EXP08. Stippling denotes regions where the changes are significant ($p \leq 0.05$)

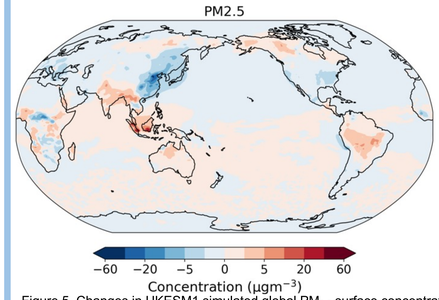
- China's SO_2 and BC changes domain aerosol IRF changes locally over China (85%) between 2008 and 2016.
- This proportion is more pronounced over NPO (97%).
- Arctic aerosol IRF changes are mainly caused by local or other remote aerosol sources, but not China.



Global BC IRF = -10.1±2.52 mWm-2
China BC IRF = -301.1±5.9 mWm-2
Global sulphate IRF = 77.1±4.18 mWm-2
China sulphate IRF = 1031.6±73.1 mWm-2

Figure 4. Changes in the all-sky SW IRF due to China (a) BC and (b) SO_2 emissions (units: mWm^{-2}).

Concentration



China had the largest reduction in $PM_{2.5}$ concentration between 2008 and 2016, which is mainly caused by the reduction in sulphate (49.04%) and Organic Carbon (OC) (41.25%).

Figure 5. Changes in UKESM1 simulated global $PM_{2.5}$ surface concentration (units: μgm^{-3}) between 2008 and 2016.

Temperature Response

NH Latitude Bands	BC	Sulphate
60° - 90°	-2.45±0.47	8.68±0.49
28° - 60°	-7.78±0.52	59.64±3.77
0 - 28°	-0.12±0.33	9.34±0.43

Table 2: Temperature response of Changes in all-sky China BC and SO_2 SW IRF (units: mK) for each latitude bands in North Hemisphere (Shindell and Faluvegi (2009)).

- The temperature responses are opposite due to China's BC and SO_2 emission changes.
- Mid-latitudes experienced the greatest warming, while high-latitudes and low-latitudes experienced much smaller warming.

Conclusion

- $PM_{2.5}$ (both BC and SO_2) emissions over China decreased significantly between 2008 and 2016.
- Reduction in $PM_{2.5}$ over China has larger local RF, but is also important for remote climate changes, especially the NPO.
- Mid-latitudes had the largest temperature response.

References

- Shindell, D. and Faluvegi, G.: Climate response to regional radiative forcing during the twentieth century, Nat Geosci, 2, 294–300, https://doi.org/10.1038/ngeo473, 2009.

Acknowledgements

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