Response to reviewer2:

We thank reviewer 2 for his valuable review and the positive feedback of the manuscript. Below, we provide a point-to-point response to the comments and list the related changes made to the manuscript. The original review comments are shown in italic blue font, our responses are in regular black font, and new text added to the revised paper is indicated in red.

1. *The divergence method seems to sacrifice the temporal resolution to give a high spatial resolution. This paper calculate a 5-year averaged SO2 emissions. Is the 5-year dataset necessary to get the high spatial resolution. Will the long-period dataset introduce errors to the result?*

We update the analysis with both annual and five-year averaged results. Specifically, the Section 4.2 and 4.3 are based on annual results. And Section 4.4 and 4.5 are based on both annual and five-year averaged results. In addition, we also detect more point sources and added this in Section 4.5.

Long-term averaging results reduces noises, allowing the sharpening algorithm to better detect small but stable emitters. And long-term averaging results also provide more precise source locations. Short-term results enable the analysis of temporal variability, including emission changes and possible commissioning or shutdowns events. And short-term results better distinguish the small point sources located near large ones.

Here we show the most related content we added in Section 4.5:

We find some new operating SO_2 point sources using both annual and five-year averaged SO_2 emission inventories. These emissions are absent in the Indian power plant database and are also not identified by the top-down SO_2 catalogue MSAQSO_2L4. These new point sources include not only coal-based power plants, but also cement factories, crude oil production facilities, a chemical fertilizer factory, and copper, steel, and aluminum industries. Table 2 provides the list and locations of these sources. Many newly detected sources are small and located close to known large point sources, but their weaker signals are distinguishable in our inventory. The annual emission inventory better distinguishes small point sources located near large ones, whereas the long-term averaged inventory provides more precise source locations. Most operating point sources show persistent SO_2 emission signal over five years. However, Rashtriya Chemicals Fertilizers (RCF) complex involving a sulphuric acid plant located in Trombay, Maharashtra is detected only for the year 2021. RCF reported that sulphur consumption in the financial year March 2021-March 2022 was 2.7 times higher than in 2020-2021 (https://www.rcfltd.com/public/storage/investers/1669721755.pdf, last access 20 Feb, 2026), indicating substantially higher potential SO_2 emissions in 2021.This indicates that applying the sharpening algorithm to short-term emission results enables the analysis of temporal variability, including emission changes and possible commissioning or shutdown events. In contrast, the Phil Coal

Beneficiation and Sponge Iron Cluster is only detected in the five-year averaged inventory, but not in any individual annual result. This is because long-term averaging results reduces noises, allowing the sharpening algorithm to better detect small but stable emitters.

2. *The final result is based on the TROPOMI SO2 column dataset between December 2018 to November 2023. But the description for the determination of the spreading kernel in the manuscript is based on data from December 2022 to November 2023 and validation with the CAMS model is based on the experiment from December 2019 to November 2020. Could you explain the reason of this time inconsistency.*

Based on the reviewer's concerns, we add the short-term (annual) results (mainly focus on December 2022-November 2023 in the manuscript), which is corresponding to the derived spreading kernel.

For model evaluation, it is sufficient that the input emissions and simulation outputs correspond to the same time period. Therefore, we selected a year with readily accessible data (December 2019-November 2020). The choice of year does not affect the real-case analysis or the overall conclusions of the study.

3. *The noise level appears many time in the manuscript. And SO2 emissions sharpened only above the noise level. How does it calculated or given?*

We add this text about the noise level and detection threshold in Section S6 in supplementary file:

The noise levels for one-year annual emissions and five-year averaged emissions are different. To quantify the noise, we selected a clean ocean region without SO_2 emissions (5°–18° N, 85°–90° E). The emission signal within this region was treated as noise. For the annual emissions, the frequency distribution of the noise in the selected clean region approximates a normal distribution with a standard deviation of $\sigma = 0.125$ Gg yr^{-1}. To avoid inflating the noise level, we define the noise threshold as three times σ (3σ), corresponding to 0.37 Gg yr^{-1} per grid cell. In our case, the sharpening procedure increases the signal in the central grid cell by approximately a factor of 28. Therefore, the detection threshold for the annual sharpened emission map is 10 Gg $year^{-1}$.For the five-year averaged emissions, σ is 0.06 Gg yr^{-1}, yielding a 3σ noise level of 0.17 Gg $year^{-1}$. The sharpening leads to an enhancement factor of approximately 20, resulting in a detection threshold of 3.4 Gg $year^{-1}$ for the five-year averaged emissions.

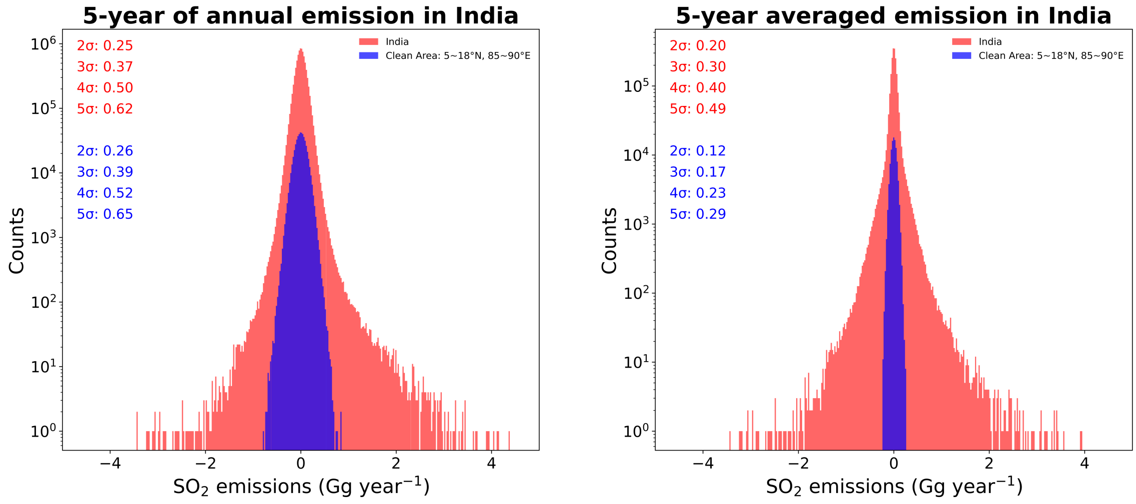

Figure S4. Histogram of the frequency of SO_2 emissions. The red bars represent the frequency of SO_2 emissions within the simulation domain. The blue bars denote the frequency of SO_2 emissions (or the noise) in the selected clean oceanic region (latitude: 5°N-18°N; longitude: 85°E- 90°E). The left panel is derived from the annual emissions, and the right panel is derived from the five-year averaged emissions.

4. *The deconvolution method update the emissions iteratively. How many iterations does require normally? Will it affect the computational efficiency? This information could be stated in the paper if this is a issue.*

It is a stepwise procedure in which each step involves only a sharpening of a single grid cell. The iterative procedure terminates when the remaining signal falls below a user-defined noise level. Therefore, the number of steps (called 'iterations' by us) equals the number of detected point-sources. It is, therefore, by definition, faster (i.e. less steps) than any deconvolution algorithm. We have re-written our Method section and made it more clear now.

Line 70: change "time and computational efficient" to "time- and computational efficient"

Revised

Line 96: change "horizonal" to "horizontal"

Revised

Line 185: change "e" to "ε"

Refined