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FOR CHEMISTRY

Improving global SO_2 emission inventories using Sentinel-5P TROPOMI satellite data

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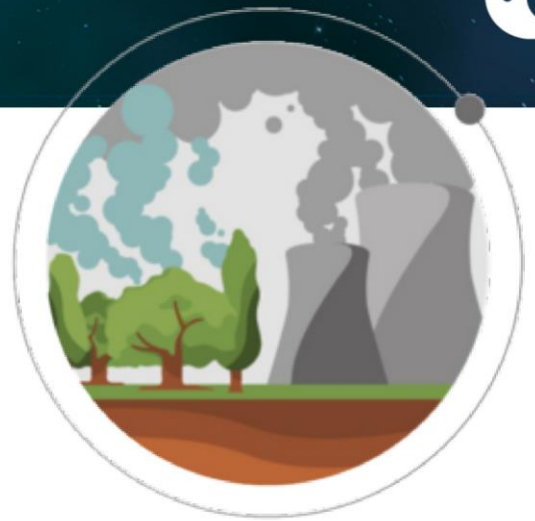
World Emission project

- ESA-funded project which kicked-off in March 2022
- aims to enhance pollutant and greenhouse gas emission inventories using satellite data
- catalog was submitted and is published
  - scan QR code or visit https://www.world-emission.com/
  - updated version will be provided

This study: Identify and quantify anthropogenic SO_2 point sources (ps)

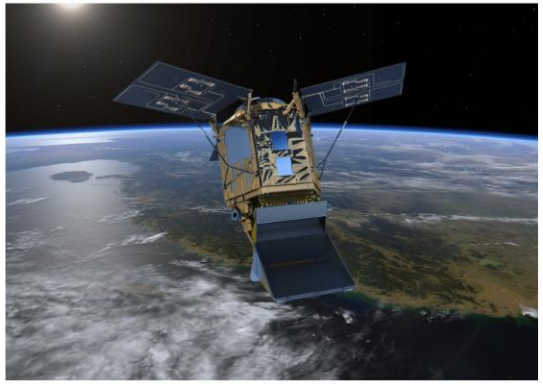


WorldEmission

SO_2 catalog!

Input data

1. TROPOMI COBRA SO_2:
   - data scatter is significantly reduced by a factor of about 2
   - low detection limit allows for finding weak sources
2. ECMWF ERA5 winds:
   - May 2018 - July 2022, global, 0.25° & 1h res.
   - interpolate $\overrightarrow{w}$ (u & v wind components) to 500m
3. Auxiliary databases:
   - for classification: power plants, cities, volcanoes
   - for comparison: EDGAR, Fioletov et al., 2023



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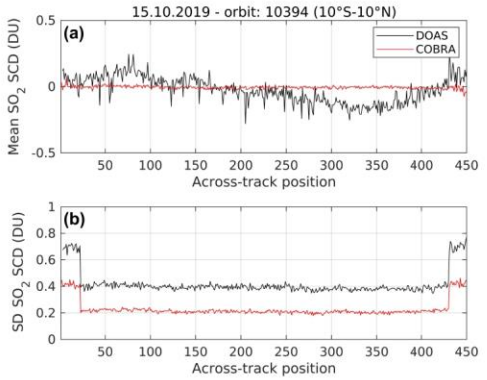

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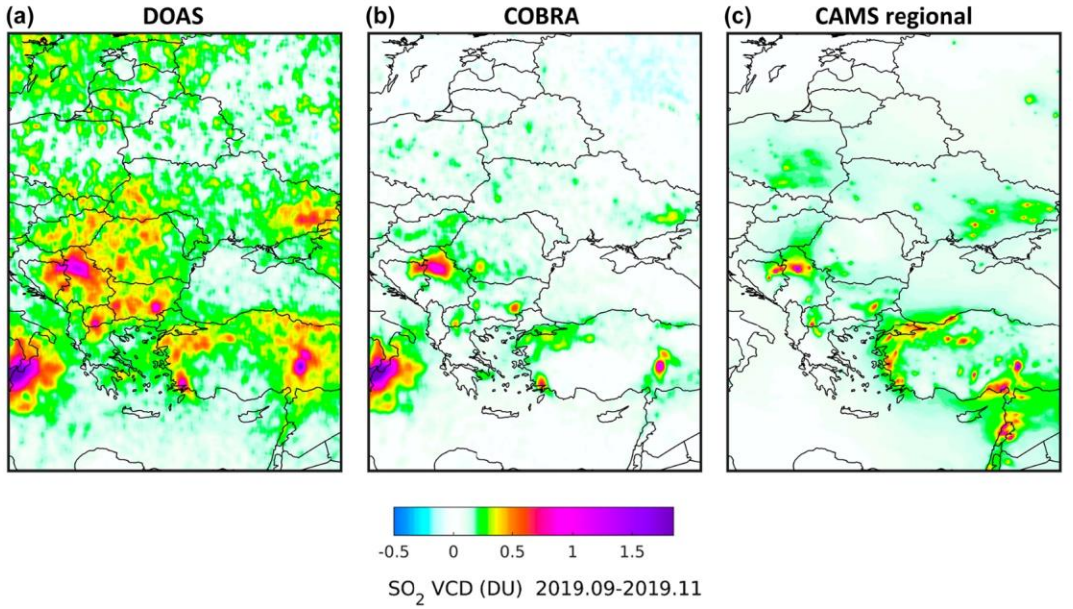

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Advection method

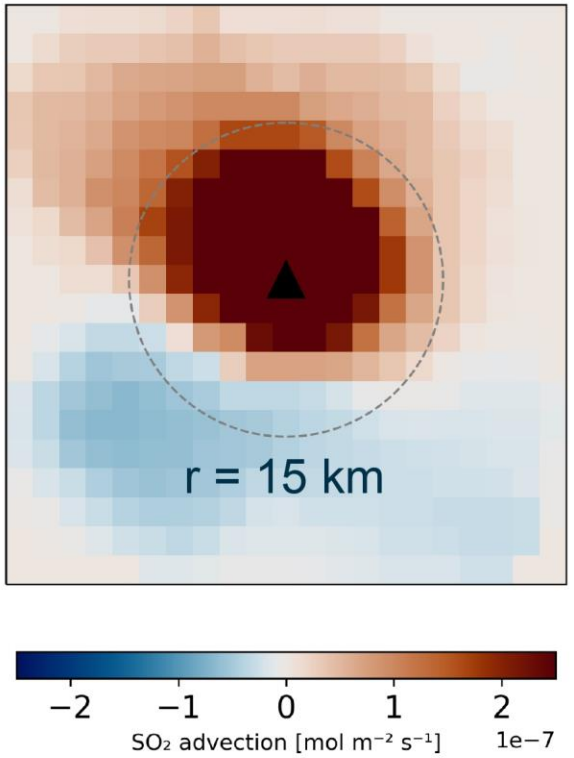
- based on the divergence of the SO_2 flux (Beirle et al., 2019, 2021, 2023):

$$D = \nabla \cdot \vec{F} = E - S$$

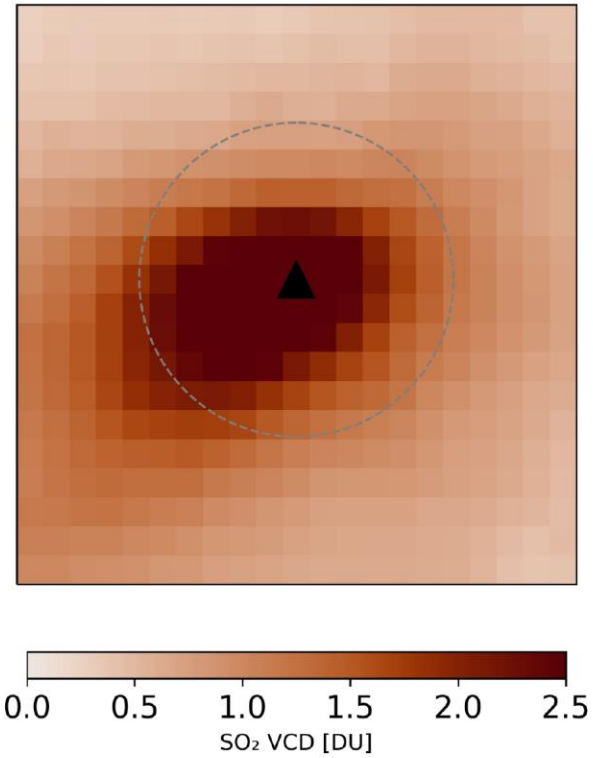
$$D = \nabla \cdot (\vec{w} V) = \vec{w} \cdot \nabla V + V \nabla \cdot \vec{w}$$

- only consider the first term (flux changes caused by local SO_2 emissions)
- method yields sources/sinks on a map

Sample advection map



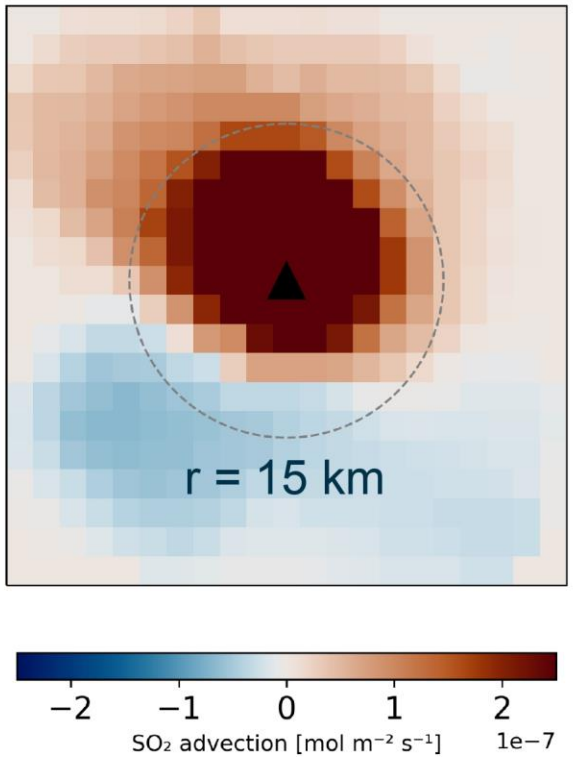
Sample VCD map



Core algorithm (workflow)

1. creation of advection dataset
   - consists of several steps, e.g.:
     - data filtering
     - AMF correction
     - calculation of advection: $A = \vec{w} \cdot \nabla V$
     - topographic correction
     - calculation of temporal means
2. identification of point sources
   - fully automated iterative procedure searching for local maxima
3. quantification of point sources
   - spatial integration of the advection map around potential source
4. selection of significant point sources

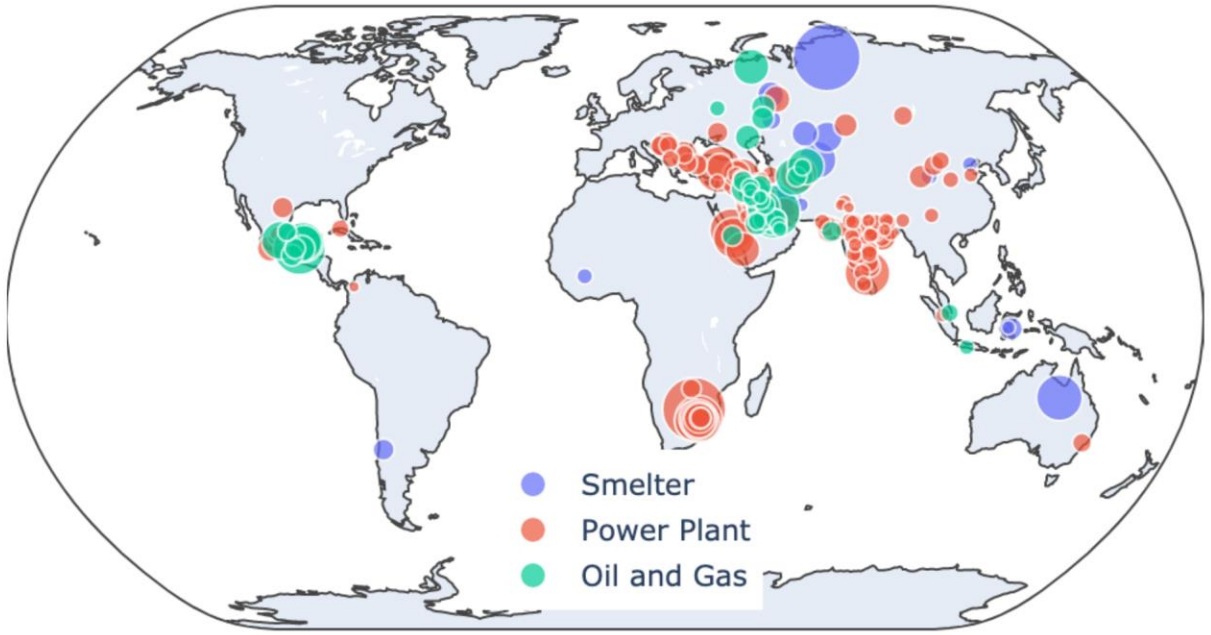
Advection map (Matimba, SA)



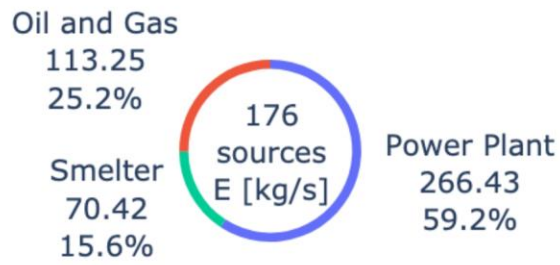
Catalog

- 176 significant point sources globally
- catalog does not include volcanoes and area sources
- plenty of additional info about the source is provided, e.g.:
  - uncertainty
  - significant months
  - nearby power plants & cities
  - annual emissions
  - source type
  - source name

Global ps catalog



Number of ps



Emissions of ps

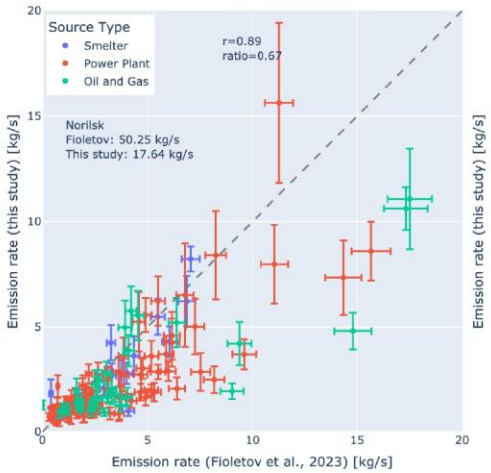
Comparison with EDGAR and Fioletov et al., 2023

- overall good agreement is found

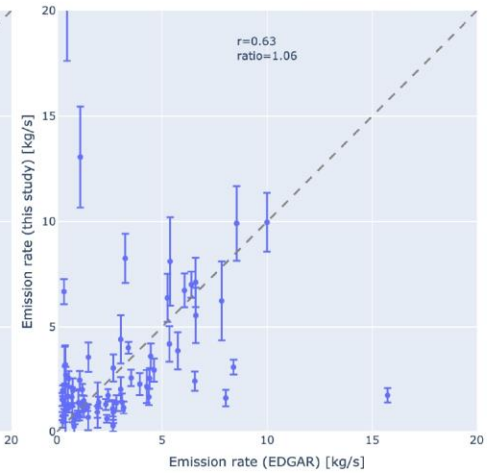
1. comparison with Fioletov et al., 2023:
   - our emissions are on average 33% lower
   - different methodology but discrepancy has to be further investigated

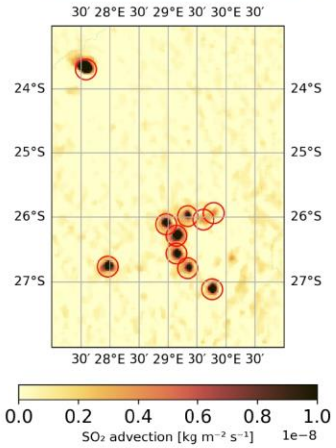
2. comparison with EDGAR:
   - our emissions are on average 6% higher
   - comparison is quite limited:
     A. only eight months overlap in 2018
     B. EDGAR doesn't include many sources
     C. EDGAR shows SO_2 emissions where TROPOMI sees none

Comparison with Fioletov

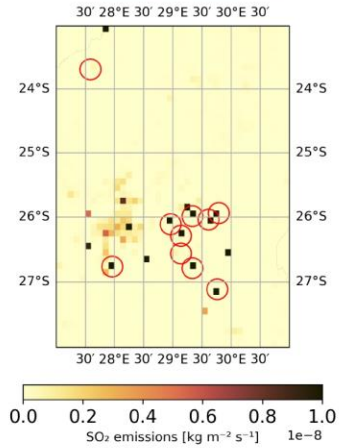


Comparison with EDGAR





Advection map (SA)

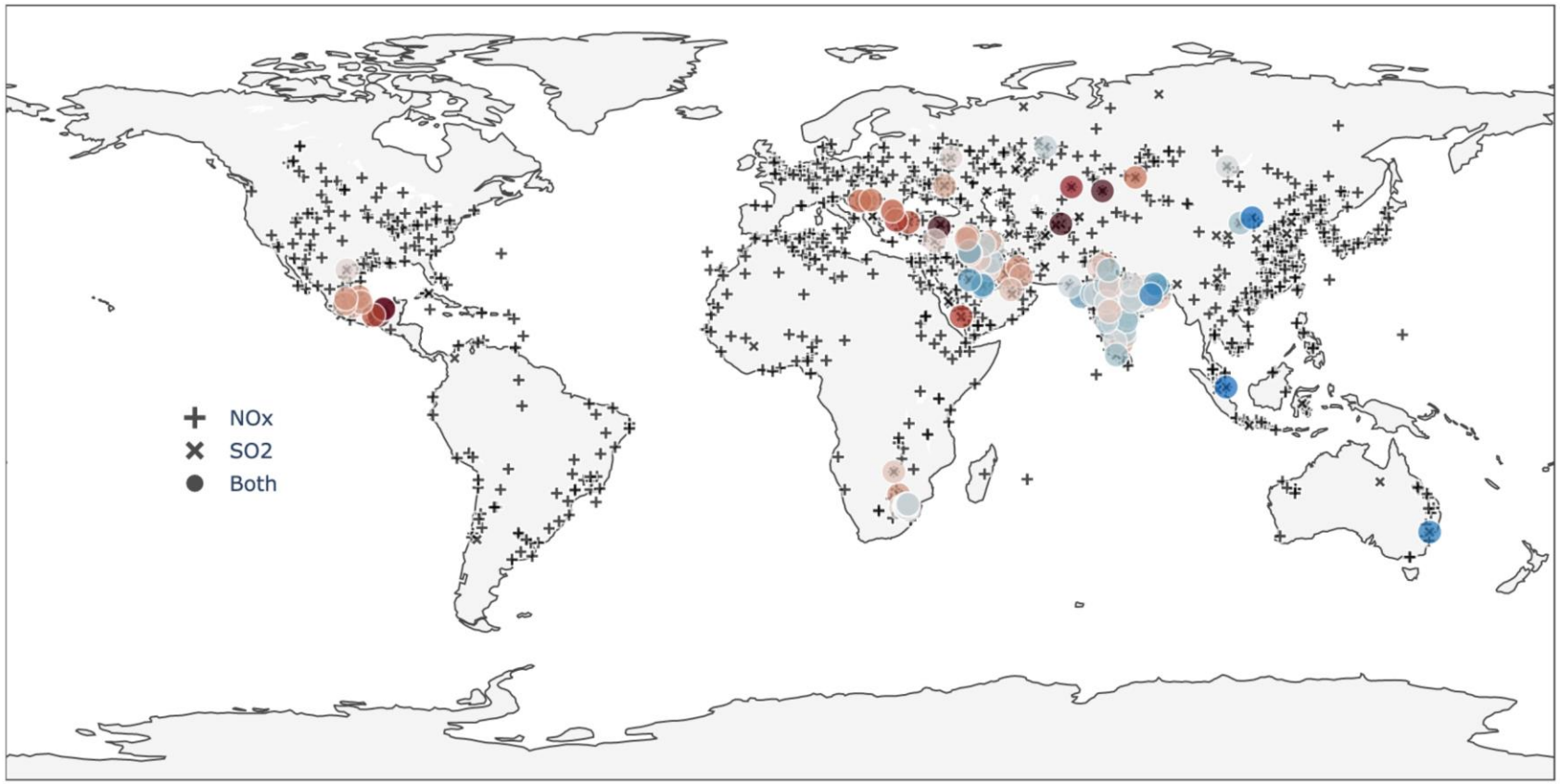


EDGAR emission map (SA)

SO_2/NO_x

- information about used fuel and applied filtering measures can be inferred
- SO_2 to NO_x mass ratio:
  - range: 0.8 to 66.2
  - mean: 6.2

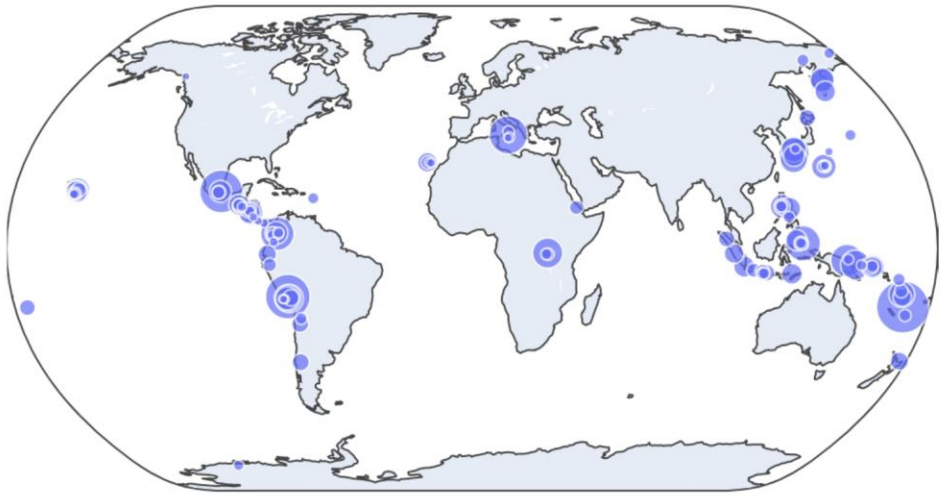
Comparison of SO_2 sources with matches in NO_x catalog

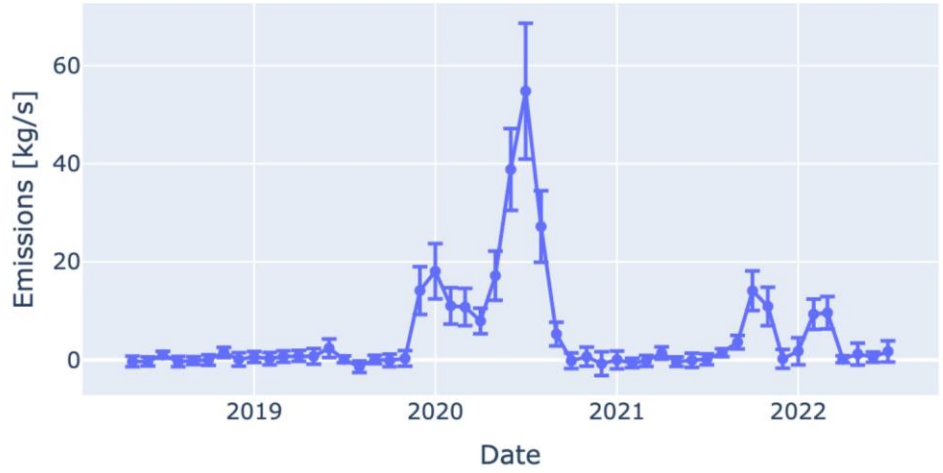


Volcanoes

- 121 volcanic signals have been detected (out of 710 total ps or area source candidates)
- in principle the algorithm can identify and quantify volcanic sources, however there are several problems, e.g.:
  - potential saturation in SO_2 fitting window
  - assumed plume height possibly wrong
    - wrong wind fields
    - unsuited AMF
  - temporal variability of emissions
- a more extensive algorithm is needed

Volcanic signals globally





Nishinoshima time series (Japan)

Conclusions

- 176 anthropogenic point sources detected globally
- catalog is made available by World Emission project and will be updated
- validation shows good agreement with independent emission estimates
  - differences will be investigated further
- comparison with NO_x catalog provides information on fuel type and filtering
- detailed global volcanic emission inventory would require much more work
- potential for (upcoming) geostationary satellites