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Comparing Satellite Measurements of Volcanic SO_2 Mass from OMI, OMPS, TROPOMI

Abstract

Sulfur dioxide (SO_2) is a major air pollutant that contributes to acid rain and aerosol formation (e.g., sulfates), adversely affects the environment and human health, and explosive volcanic SO_2 emissions can impact climate. The majority of SO_2 emissions are anthropogenic (e.g., fossil fuel burning, metal ore smelting operations), although natural processes such as volcanic eruptions and degassing also play an important role. We will focus on comparing volcanic SO_2 outgassing from a few selected volcanoes using satellite data.

At NASA's Global Sulfur Dioxide Monitoring Home page (https://so2.gsfc.nasa.gov/), we have been posting daily SO_2 maps from 40 volcanic and industrial regions around the world using measurements from three satellite instruments; the Ozone Monitoring Instrument (OMI), the Ozone Monitoring and Profiler Suite (OMPS), and the TROPOspheric Monitoring Instrument (TROPOMI). These instruments in low Earth sun-synchronous polar orbits with 1:30-2:00 pm equator crossing local time provide daily SO_2 maps at different spatial resolutions: 13 x 24 km^2, 50 x 50 km^2 and 5.5 x 3.5 km^2 for OMI, OMPS and TROPOMI respectively. Data from OMI are available since October 2004 (partial coverage since 2008), from OMPS since 2012 and from TROPOMI since 2018. We will present comparative SO_2 mass time-series and statistical analyses of recent eruptions that have data from all the instruments.

SO_2 Algorithms

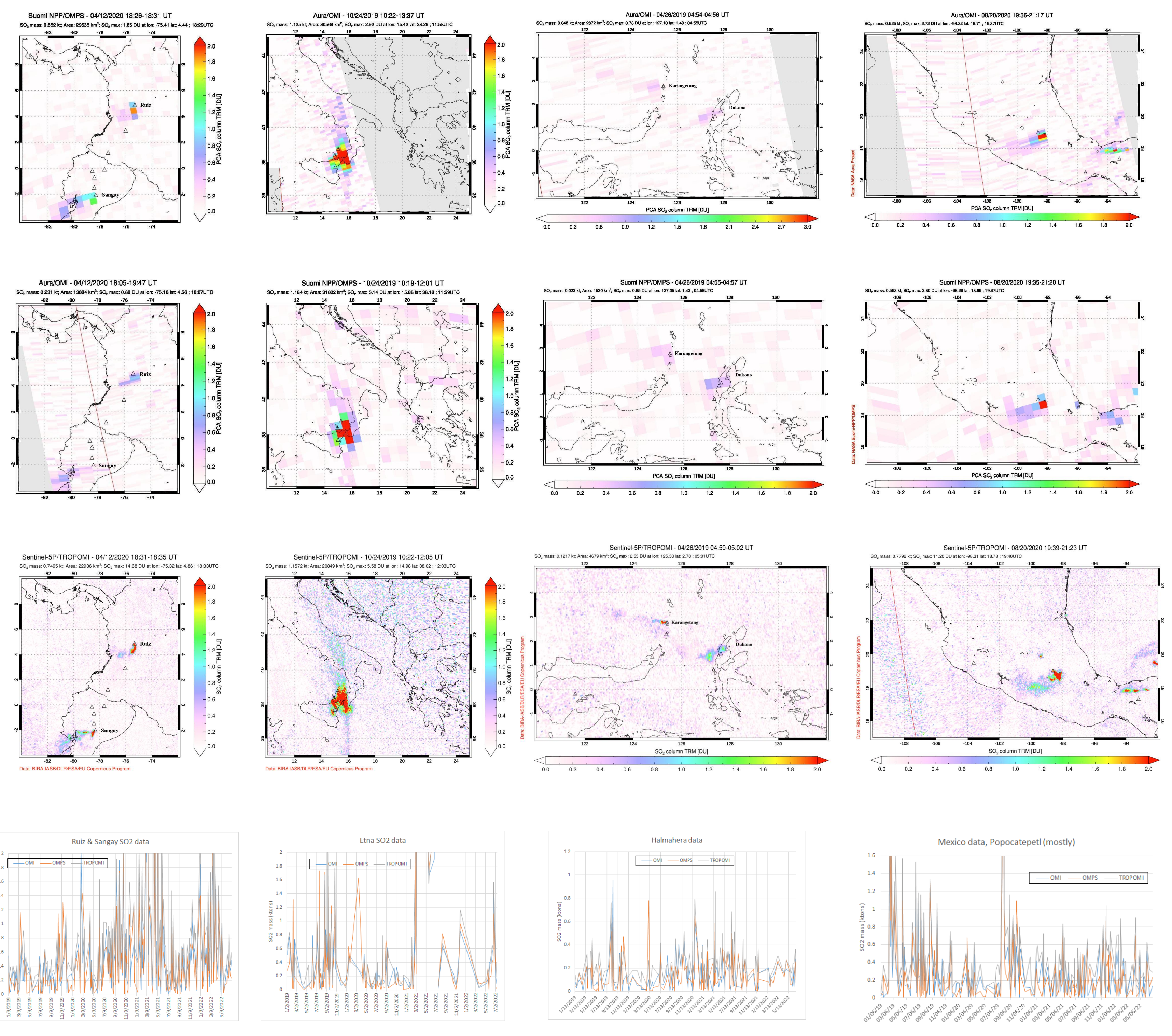
OMI and OMPS use the principal components analysis (PCA) algorithm to retrieve SO_2 mass, while TROPOMI uses the differential optical absorption spectroscopy (DOAS) to compute SO_2 mass.

The PCA technique[1] is a data-driven approach and uses a set of principal components (PCs) extracted directly from satellite radiance data in the spectral fitting. It benefits from the fact that the PCs that account for the most spectral variance have characteristics associated with various geophysical processes (e.g., O_3 absorption, rotational Raman scattering) or measurement details (e.g., wavelength shift, variation in dark current). This allows these various interferences in SO_2 retrievals to be minimized without extensive forward calculation or explicit instrument characterization, leading to an efficient implementation with relatively small biases and noise in the retrieved SO_2 data.

The DOAS technique[2] performs spectral fitting using multiple fitting windows to cope with the large range of atmospheric SO_2 columns encountered. It is followed by a slant column background correction scheme to reduce possible biases or across-track-dependent artifacts in the data. The SO_2 vertical column data are determined by applying air mass factors calculated for a set of a priori profiles accounting for parameters influencing the retrieval sensitivity to SO_2.

([1]Li, C., Krotkov, N.A., Carn, S., *et al.*, (2017), *Atmos. Meas. Tech.*, **10**, 445-458, DOI: 10.5194/amt-10-445-2017.
[2]Theys, N., *et al.*, (2017),, *Atmos. Meas. Tech.*, **10**, 119-153, DOI: 10.5194/amt-10-119-2017.)

These are sample images of the regions presented in this poster. OMI SO_2 mass is shown in the top row, OMPS SO_2 mass in the middle row and TROPOMI SO_2 mass in the bottom row. From left to right the regions are Colombia & Ecuador (Nevada del Ruiz & Sangay), Sicily (Etna), Halmahera (Dukono & Karangetang), Mexico (Popocatepetl & El Chichon). The last row are time series of all three satellite SO_2 mass amounts. This poster is only concerned with smaller amounts of SO_2 so that the spikes in the time series images will not be discussed much here. Generally, the values aren't the same but time series of the three satellites follow the same up and down trend.



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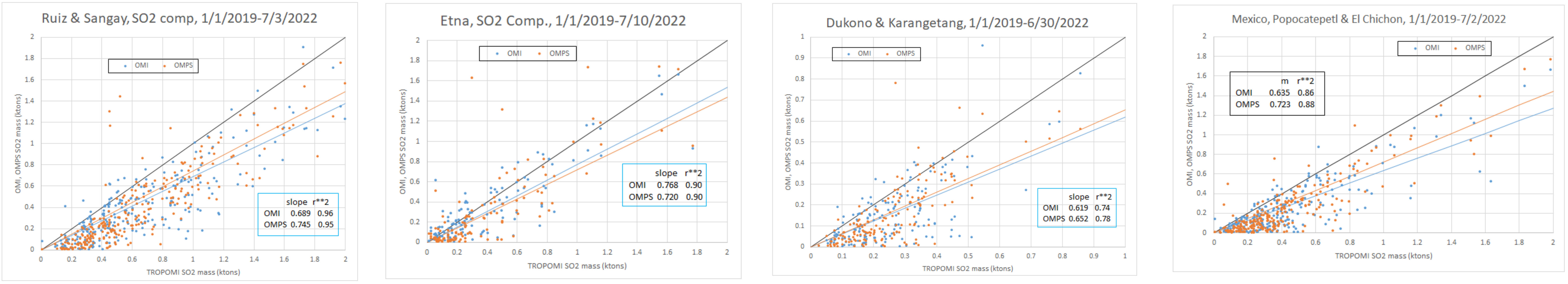
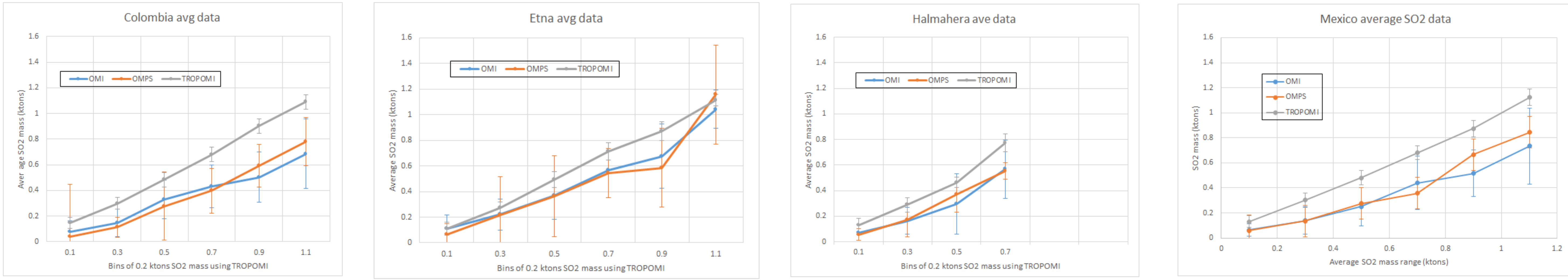
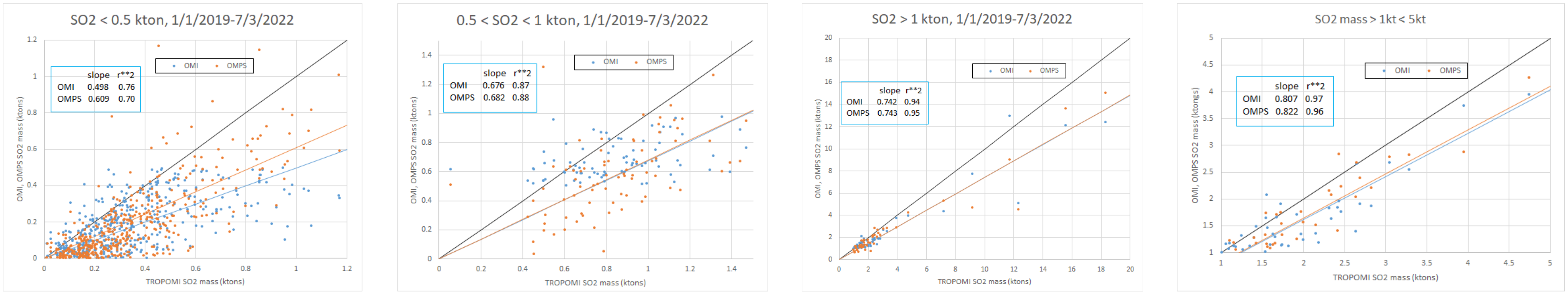
Scatter plots: We used TROPOMI as the reference value (x-axis) The OMI and OMPS use the same retrieval algorithm, so those data are compared to the TROPOMI algorithm. Generally, the OMI and OMPS SO_2 mass values are correlated with TROPOMI. Linear regression analysis suggestions that OMI/OMPS are about 30% smaller than TROPOMI.





We tried to separate the SO_2 mass data by season and year, but there was no change in the relative values of OMI and OMPS SO_2 mass compared to TROPOMI SO_2 mass. The above row of images show an average over range increments of 0.2 TROPOMI SO_2 mass. These plots show the average difference between OMI & OMPS SO_2 mass and TROPOMI SO_2 mass.



Scatter plots by SO_2 mass values. We compared the OMI and OMPS SO_2 mass values by range (0-0.5, 0.5-1., 1-5 and > 1). The 0-0.5 range is about 40-50% less than the TROPOMI SO_2 mass. The 0.5-1 SO_2 mass range is only about 35% less than the TROPOMI values. The >1 SO2 mass has better agreement, only about 25% less than the values of TROPOMI SO_2 mass. The 1-5 SO_2 mass comparison is the best. The OMI and OMPS values are only about 20% less than the TROPOMI SO_2 mass values.

Results and Discussion

Here we compared OMI and OMPS SO_2 mass amount to TROPOMI mass amount over a three and a half year period (1/1/2019-7/3/2022). OMI and OMPS use similar algorithms to compute the SO_2 mass which is different from how TROPOMI computes SO_2 mass. We looked at four sites. Two that were over land (Colombia/Ecuador and Mexico) and two that were over islands (Sicily and Halmahera in the Pacific Ocean). These sites have SO_2 outgassing on a regular occasion and an occasional larger eruption. We focused on the outgassing data. We limited the dataset to days when all three satellites had data and similar coverage over the volcanoes. We eliminated days when the OMI row anomaly might be an issue. The data do not show a significant difference between the land only sites and over islands.

The time series data showed generally correlated values for each satellite. Using SO_2 data < 1 kton, generally, the OMI and OMPS SO_2 mass was about 35-50% lower than the TROPOMI SO_2 mass measurements. We tried separating the data by year and season and site, but there was not much difference in the OMI and OMPS SO_2 data compared to the TROPOMI data.

We did find that OMI & OMPS data > 1 kton was slightly closer in value to the TROPOMI data (only 25% less). And SO_2 values between 1-5 ktons were about 80% of the TROPOMI SO_2 mass values.

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