Conversion of SO2 gas to sulfate aerosols in volcanic plumes from the joint analysis of polar-orbiting POLDER and OMI satellite observations

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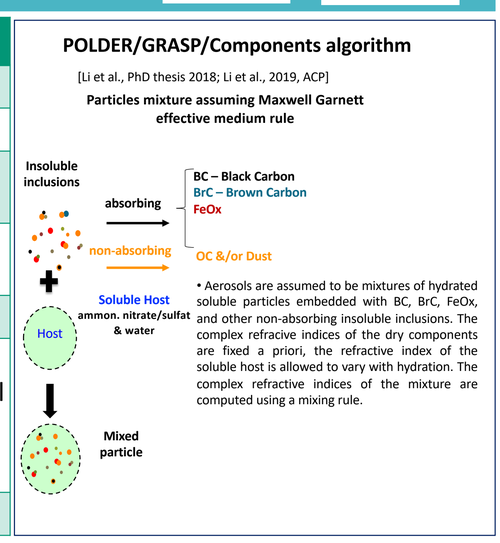
ABSTRACT :

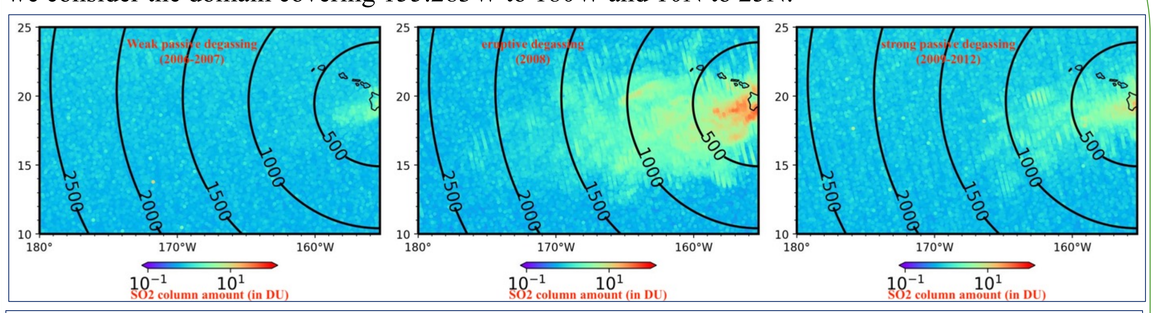
SO_2 emitted from the volcanic emissions converts into secondary sulphate aerosols (SO_4^{2-}) by a series of complex chemical and physical atmospheric processes. There are some publication that report the qualitative detection of volcanic sulphate aerosol using IASI satellite observations (Karagulian et al., JGR 2010, Clarisse et al., 2013) but there is no evidence available for the quantitative detection of volcanic aerosol from the polar orbiting satellite observation so far in our knowledge. In this work, we jointly analyzed the polarimetric satellite observations such as OMI (to constrain sulfur-rich emissions and identify the volcanic plume dispersion) and multi-wavelength, multi-angle and polarization POLDER satellite observation that are specifically sensitive to fine mode particles such as sulphate aerosols (for characterization of aerosols and optical properties) (retrieved using the GRASP algorithm) to further understand the Sulphur cycle and ash presence in the volcanic plume over Kilauea considering it's unique geographical features, meteorological conditions and continues degassing since 1983 (both passive and active) that helps in better understanding of the volcanic aerosols such as sulphate and ash particles and their physio chemical properties.

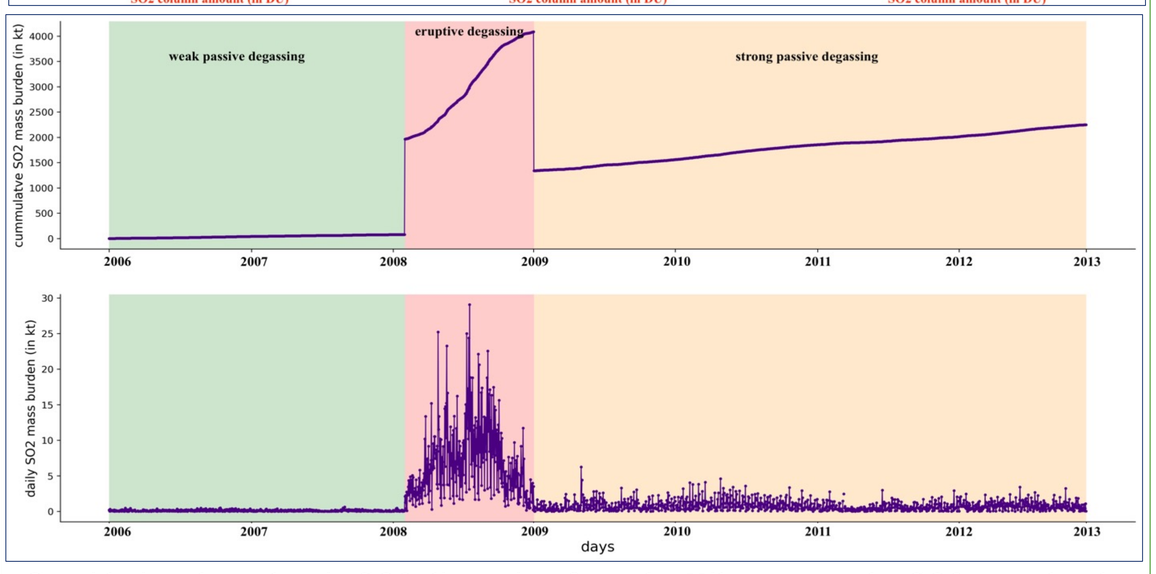
Properties	OMI	POLDER
satellite	Aura	PARASOL
Spectral range	UV	UV-VIS-NIR
Nadir spectral resolution	13 km×24 km	5.3 km×6.2 km
Spectral resolution (nm)	0.42 and 0.63	443-1020
Time of overpass (LT)	13:30	13:33
Parameter	SO2 column amount (in DU)	Standard optical properties and aerosol chemical component classification
Algorithm	PCA	GRASP



1. Classification of volcanic degassing activity over Kilauea based on the SO2 emission from the vent

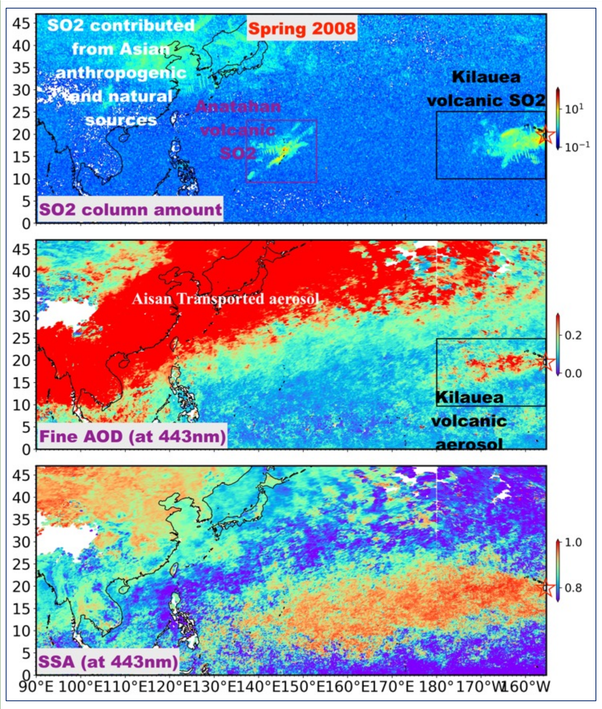
- This study focuses only on volcanic SO_2 emitted from the Kilauea source.
- Days associated with the overpass of stratospheric volcanic SO_2 over the Kilauea region are filtered from the analysis.
- To avoid SO_2 intrusion from other persisting tropospheric eruptions and anthropogenic sources we consider the domain covering 155.283W to 180W and 10N to 25N.

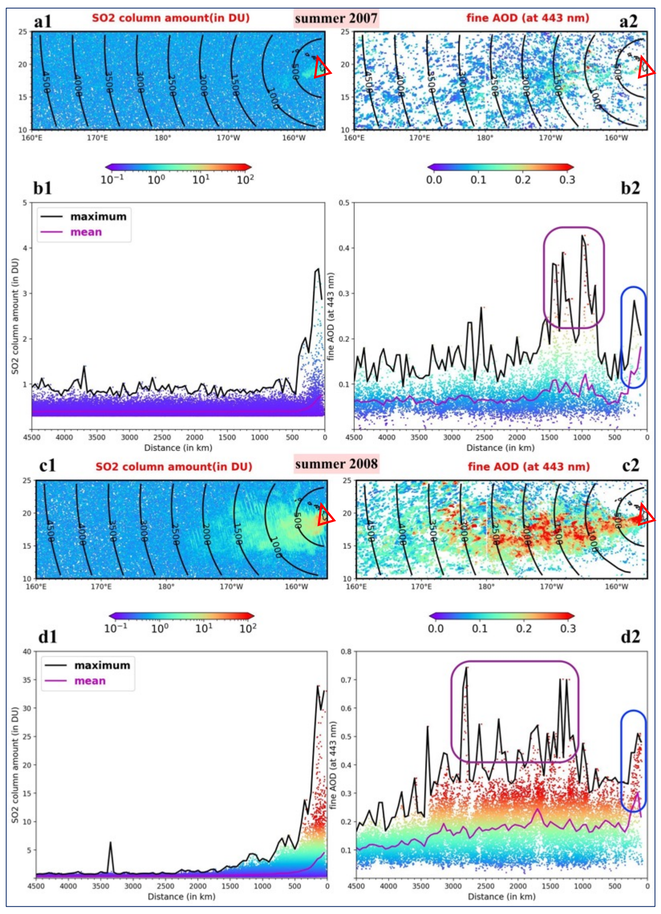




- Considering the volcanic SO2 dispersion from the Kilauea vent the SO2 mass burden and the cumulative SO2 mass has been calculated at the disc of radius **150km**, **1000km**, and **1500km** from the source during weak passive degassing, strong passive degassing, and eruptive degassing period respectively.
- An increase in **SO2 CA** since 2008 Spring indicates the beginning of an explosive eruption over Kilauea which is persistent till the end of the year.

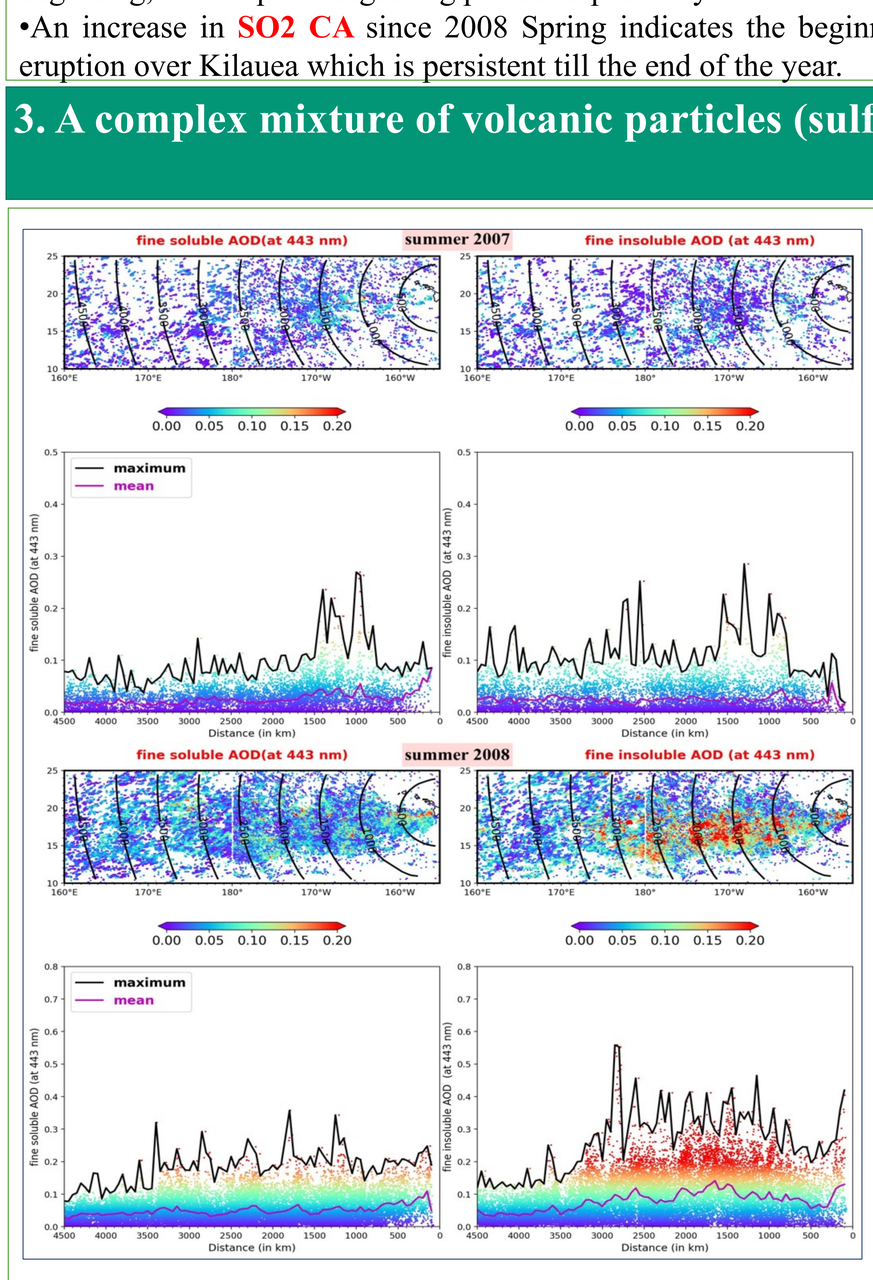
2. Characterization of volcanic and Asian anthropogenic aerosol over Kilauea





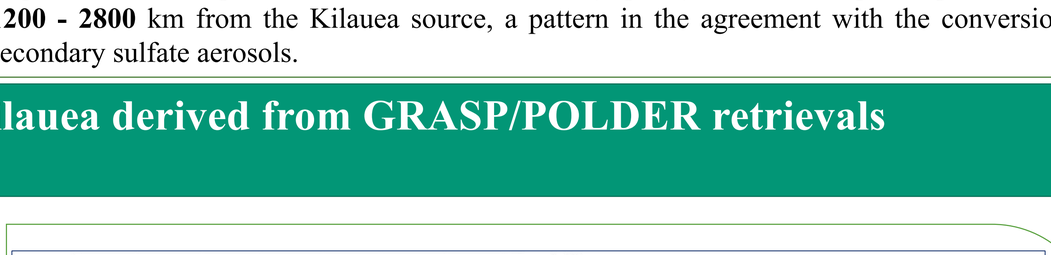
- The collocating pixels of **Fine AOD** and **SSA** from POLDER with **SO_2 CA** indicates the dominance of fine mode volcanic aerosol (more likely sulphate) over Kilauea.
- There is a notable transport of **Asian aerosols** during spring over the island (AOD>0.25, SSA(0.75-0.85)) and it's clearly distinguishable from the **volcanic plume** where the **SSA** is relatively higher (***0.94-1***).
- An SSA pattern (out of background noise) indicates the plume over a **longer distance** from the source than shows the fine AOD.
- In eruptive degassing periods, the SO2 concentration progressively **decreases** (Fig, d1) with plume dispersion while a gradual **increase** in fine AOD (Fig. d2) is observed, peaking at a distance around **1200 - 2800** km from the Kilauea source, a pattern in the agreement with the conversion of SO2 to secondary sulfate aerosols.

3. A complex mixture of volcanic particles (sulfate and ash) from Kilauea derived from GRASP/POLDER retrievals



During the weak passive degassing period there was an excess **fine soluble AOD** has been observed near the source within the plume.

There is a significant **increase** in **fine soluble** and **fine insoluble** AOD. after the beginning of the eruption was detected. This behavior further continued during the strong passive degassing period as well.



- The imaginary RI within the plume during **eruptive and strong passive degassing period** is slightly **higher** than the values for pure ash detected in lab experiments, but RI retrievals at low AOD should be interpreted carefully, the imaginary RI has increasing tendency when lack of sensitivity. The **real RI** is lower then the pure ash – can indicate the presence of sulfates.
- So what really the fine insoluble can be: sulphate coated ash?

Conclusion :

- The joint analysis of gas and particle concentration over Kilauea helps in the unambiguous detection of the volcanic gas and related aerosol over the region.
- The analysis of optical properties over the region indicates a possible opportunity to further verify the presence of sulfate-coated ash over the region.

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