Synthesizing satellite- and surface-based air quality observations during the 2018 Kilauea eruption

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HAQAST

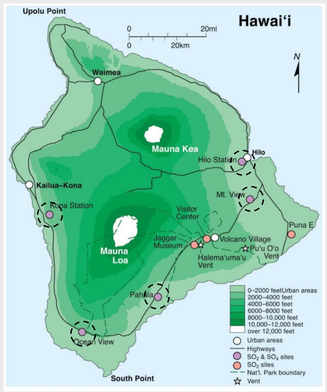
Introduction

Background

- Kilauea Volcano (Big Island, Hawaii)
  - Major SO_2 source in past decades [1]
  - May 3, 2018: new eruption begins
  - Aug 4, 2018: decrease of activity
- Some signs of eruption end in July, but was not recognized at the time [USGS]
- Vog typical for Big Island western coast, with increased impact during 2018 eruption
- Data available but needs to be synthesized

Research Questions

- What was the spatial and temporal pattern of volcano-impacted air quality on the Big Island?
  - Sulfur dioxide
  - Particulate matter
- Could public satellite and sensor network data have helped track the eruption activity?

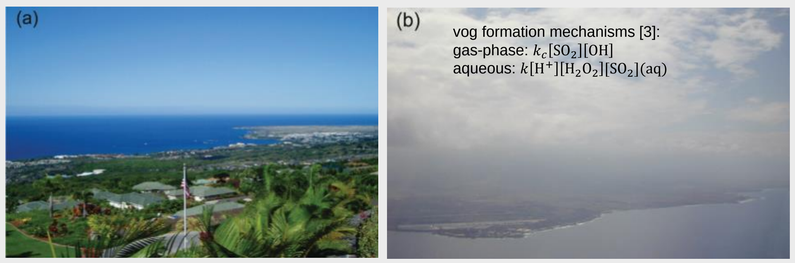


Big Island surface monitoring sites and elevation map. Source [2]

Stakeholder Input

- Value to public to conveniently combine and present available data
- Some concerns with satellite data
  - Cloud cover handling; SO_2 height assumption; row anomaly (for OMI)
  - Consistency with measured lava effusion rate
  - Consistency with the USGS, ground-based emission estimates

Volcanic Air Quality



Clear (*left*) versus voggy (*right*) day on the Kona coast. Source [2]

- $PM_{2.5}$ from sulfate conversion; also, laze [4] and biomass burning activity
- Vog mediated by wind-driven dispersion patterns [5]

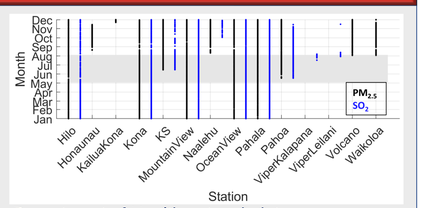
Datasets Investigated

Hawaii Department of Health
- 14 stations
- Variable coverage $PM_{2.5}$, SO_2
- 5-, 15-, or 60-min averages

PurpleAir network (commercial)
- 44 stations, $PM_{2.5}$ and met
- 80 s averages

Satellite (OMI and OMPS)
- SO_2 column using consistent retrieval algorithm [6]

Mobile monitoring (Princeton)
- Multi-species campaign Aug. 5 to 20

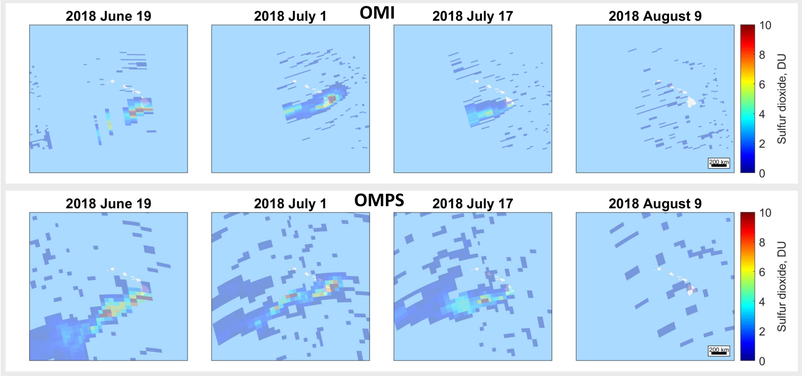


Department of Health network data coverage

Satellite summary

Instrument	Satellite	Operational date	Pixel size
Ozone Monitoring Instrument (OMI)	NASA Aura	2004-10-01 to present	13 km x 24 km
Ozone Mapping Profiler Suite (OMPS)	Suomi NPP	2012-01-26 to present	50 km x 50 km

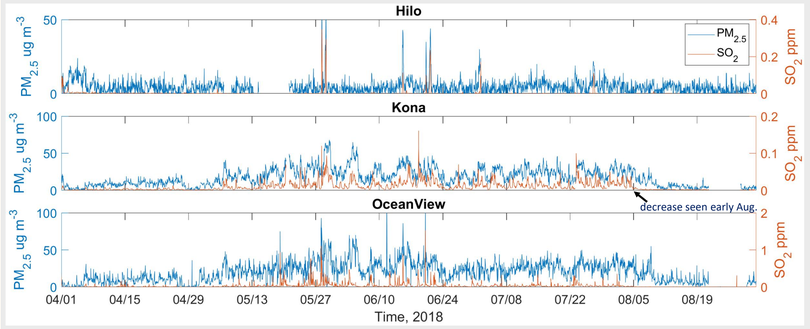
Satellite Examples



SO_2 plume as observed from space, driven by trade wind conditions

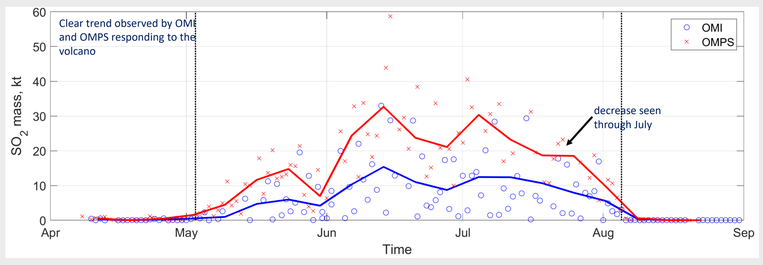
Spatial and Temporal Trends

DEPARTMENT OF HEALTH NETWORK



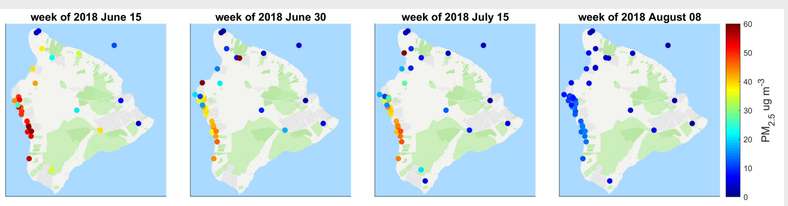
Air quality at three stations through early Dec. 2018; volcanic signal seen May to early August

OMI AND OMPS



SO_2 mass evolution from both satellites (circles: individual days; lines: 7-day mean); product from https://so2.gsfc.nasa.gov/index.html

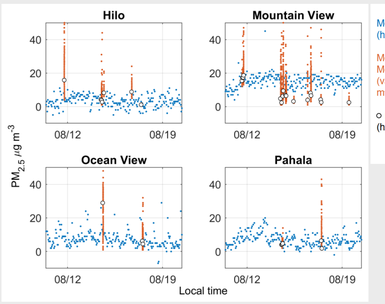
PURPLE AIR NETWORK

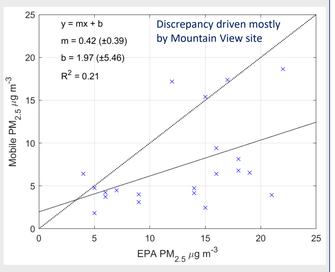


7-day mean $PM_{2.5}$ readings (primarily on the Kona coast). 3 weeks during eruption, 1 afterwards

Comparison

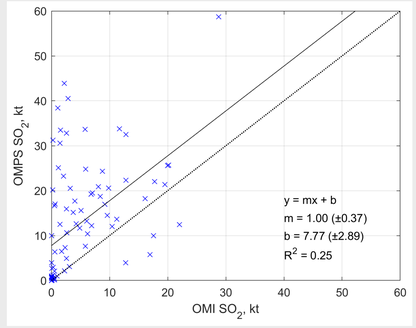
DEPARTMENT OF HEALTH VS. MOBILE MONITORING





Comparison to DustTrak instrument (where driven within 10 km of monitoring station)

SATELLITE COMPARISON



- Most OMPS readings above 1:1 line; through trends consistent for both
- Results used lower tropospheric (3 km center altitude) profile
  - OMI: PBL assumption 4.3x higher
  - OMPS: PBL assumption 3.2x higher
- Number of quality controlled results (April through August)
  - 131 results for OMI, 104 for OMPS
  - 90 for both

Conclusions and Implications

Main results

- Clear start, evolution, and end to eruption seen in all four observational datasets; satellite measures spatially integrated emissions while surface monitors directly applicable to air quality
- Satellite SO_2 retrievals tracked slowdown in July (especially OMPS) unlike the surface networks; in retrospect, had value as sign of slowing volcano activity
- Air quality significantly impacted during May-July; afterwards, conditions cleaner than normal
- 7-day mean OMPS SO_2 consistently higher than from OMI

Future work

- Model SO_2 dispersion patterns with STILT and estimate daily SO_2 emissions

Bibliography

(1) Carn, S.A., V.E. Fioletov, C.A. McLinden, C. Li, N.A. Krotkov, A decade of global volcanic SO_2 emissions measured from space, *Sci. Rep.*, 2017
(2) Businger, S., R. Huff, A. Pattantyus, K. Horton, A.J. Sutton, T. Elias, T. Cherubini, Observing and Forecasting Vog Dispersion from Kīlauea Volcano, Hawaii, *Bull. Am. Meteorol. Soc.*, 2015
(3) Pattantyus, A.K., S. Businger, S.G. Howell, Review of sulfur dioxide to sulfate aerosol chemistry at Kīlauea Volcano, Hawai'i, *Atmos. Environ.*, 2018
(4) Edmonds, M., T.M. Gerlach, The airborne lava–seawater interaction plume at Kīlauea Volcano, Hawai'i, *Earth Planet. Sci. Lett.*, 2006
(5) Hollingshead, A.T., S. Businger, R. Draxler, J. Porter, D. Stevens, Dispersion Modelling of the Kilauea Plume, Bound.-Layer Meteorol., 2003
(6) Li, Can, J. Joiner, N.A. Krotkov, P.K. Bhartia, A fast and sensitive new satellite SO_2 retrieval algorithm based on principal component analysis: Application to the ozone monitoring instrument, *Geophys. Res. Lett.*, 2013

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