Monitoring Volcanic Eruptions by OMI/OMPS, ASTER, and MERRA-2

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Introduction

Volcanic lava flows and/or the gas eruptions are the most common characteristics that can be remotely monitored with satellite technology in the global perspective and on different timescales. Atmospheric Sulfur Dioxide (SO_2) is a toxic colorless gas which might cause irritation/burns on skins and eyes or even death in high concentration. As one of the most abundant gases from volcanic eruptions apart from atmospheric common gases Carbon Dioxide and water vapor, SO_2 can be directly detected by space-based sensors on satellites (Ref. 1).

Kilauea Volcano, on the Big Island of Hawaii in the USA, is considered to be one of the world's most active volcanoes. This presentation will demonstrate the Kilauea long-lasting 2018 May-July eruptions with remote sensing measurements from the Ozone Monitoring Instrument (OMI) on NASA's EOS-Aura satellite, the Ozone Mapping Profiler Suite (OMPS) Nadir Mapper (NM) on the Suomi National Polar-Orbiting Partnership (Suomi-NPP or S-NPP), the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) aboard NASA's EOS-Terra satellite, as well as NASA's second Modern-Era Retrospective analysis for Research and Applications (MERRA-2).

Data

- The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) archives and supports over a thousand data collections in the Focus Areas of Atmospheric Composition, Water & Energy Cycles, and Climate Variability. The archived SO_2 data sets starts from the Nimbus-7 TOMS in 1978, till OMI from 2004 and OMPS on both the S-NPP from 2012 and into the future JPSS missions. In addition to the standard OMI and OMPS standard SO_2 products, SO_2 products created under the charter of the Making Earth System Data Records for Use in Research Environments (MEaSUREs) project, are also archived at GES DISC, through which NASA enacts to expand understanding the Earth system using consistent data records.
- The Land Processes Distributed Active Archive Center (LP DAAC) provides land data products and operates as a partnership with the U.S. Geological Survey (USGS). The LP DAAC has been archiving the satellite imagery from ASTER/EOS-Terra, a high spatial resolution (15 meters) and 14 band multispectral instrument. The ASTER imagery is one of the land products contributing to the application for monitoring hot spots and land terrain changes caused by volcanic eruption events.
- MERRA-2 is NASA's atmospheric reanalysis, using an upgraded version of Goddard Earth Observing System Model, version 5 (GEOS-5) data assimilation system. MERRA-2 includes improved aerosol and wind vector data reanalysis compared with its predecessor MERRA, in both instantaneous and time-averaged collections.

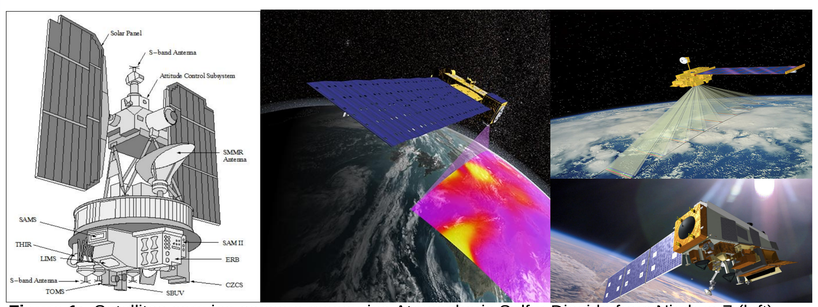

Figure 1: Satellites carrying sensors measuring Atmospheric Sulfur Dioxide from Nimbus-7 (left), EOS-Aura (middle), EOS-Terra (top right) and JPSS-1 (bottom right)

Acknowledgment: The authors acknowledge NASA for the Atmospheric Sulfur Dioxide products. Acknowledgment also goes to TOMS, OMI and OMPS L2 Science Teams for the science algorithms.

Application Use Case

Data from both OMI and OMPS sensors becomes available on a very timely basis, and imagery can be created quickly to assess SO_2 plume propagation and extent, figure 2(a) and figure 2(b). Compared to atmospheric SO_2 data corresponding to the Ambae volcanic eruption in Vanuatu a month earlier in figure 2(c) with the same map size as figure 2(a) and 2(b), Kilauea's gas plume may look relatively small. However, it is the infrastructure and population density that ultimately weigh in when assessing immediate socio-economic impacts. These figures demonstrate the potential of satellite algorithms to be applied to the emissions from volcanoes with different eruptive characteristics, thus allowing scientists to globally monitor, in almost real time, the evolution and transport of SO_2 plumes from volcanoes around the world.

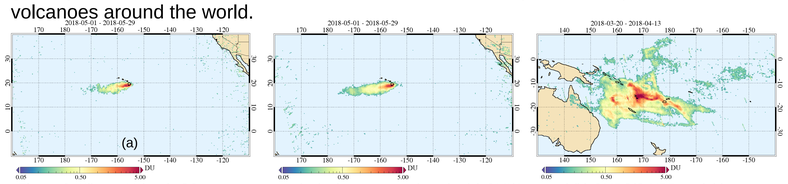

Figure 2: Kilauea Volcanic SO_2 measurements in the lower troposphere by (a) OMI/Aura and (b) OMPS/S-NPP, *variable ColumnAmountSO2_TRL*, for the period of May 1st to May 29th, 2018. Ambae volcano plume (c), from OMPS/S-NPP is shown for comparison. The end dates in the titles reflect the end time of the last granule used in the averaging.

ASTER imagery in figure 3 reveals great details such as the locations and sizes of hotspots as well as the lava flows taking place on the islands caused by lava erupting from the fissures in Kilauea's East Rift Zone. Figure 3(a) is the Thermal Infrared (TIR) image from 10:43 pm HST on May 14th, which is 8:43 Zulu time on May 15th. In this nighttime thermal image (bands 10-12-14), hot lava is evident in the Kilauea crater as well as emerging from Pu'u 'O'o. The white hotspot to the right of the image is one of the fissures that has opened up near Leilani Estates (not pictured). Figure 3(b) is the Visible and Near Infrared (VNIR) image (Bands 3-2-1) showing all three locations of interest (Kilauea, Pu'u 'O'o, and Leilani estates) at 10:54 am HST. Newer lava is black and older lava shows as shades of grey.

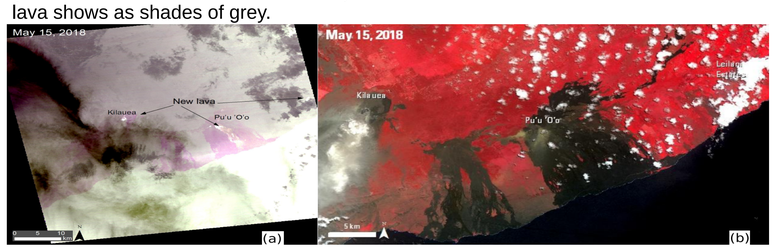

Figure 3: ASTER high spatial resolution TIR and NVIR images captured Kilauea volcanic lava, new fissures, as well as the direction of gas plume drift, on May 15th, 2018 (Courtesy of Lindsey Harriman of USGS). These data are available from the Land Processes Distributed Active Archive Center (LPDAAC) in Sioux Falls, South Dakota.

A very interesting feature in figure 3(a) is the volcanic gas plume (in black color) blowing toward the northwest direction, indicating the SO_2 gas dispersed inward onto the Hawaii Island as well as other main islands in Hawaii, thus could likely endanger the residents and visitors on the islands.

Figure 4 shows the sequence of OMPS/S-NPP images that captured the increases of SO_2 column amount in the planetary boundary layer (PBL) from May 15th to 17th, 2018 in Hawaii islands. The NASA Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA-2) hourly wind field diagnostics products, also curated at GES DISC, confirms the change of wind vectors during this time period, illustrated in figure 5.

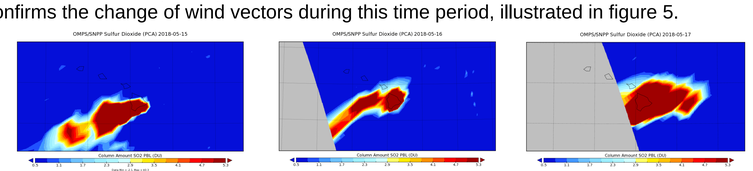

Figure 4: PBL SO_2 column amount by OMPS/SNPP increases over the islands of Hawaii from May 15th to 17th, 2018

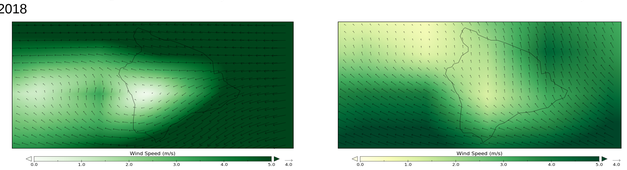

Figure 5: MERRA-2 Wind field (850hpa) comparison at 08:30UTC on May 15th and at 00:30UTC on May 17th, 2018.

Data Availability

OMI and OMPS Sulfur Dioxide products are available at https://disc.gsfc.nasa.gov. ASTER are available from the Land Processes Distributed Active Archive Center (LPDAAC) in Sioux Falls, South Dakota.

- OMI
- OMI 1-orbital Level-2 (L2), daily level-2 gridded (L2G) and level-3 (L3) SO_2 products (October 1st, 2004 and ongoing). The current version 3 products also applies the NASA GSFC PCA trace gas algorithm (Ref. 2)
- NASA GES-DISC Interactive Online Visualization and Analysis Infrastructure(Giovanni) is a Web application used to visualize, analyze and access Earth science data in a extremely convenient manor. Figure 6 shows a Giovanni example of the Kilauea SO_2 expansion over the period of May 1st to June 5th, 2018.

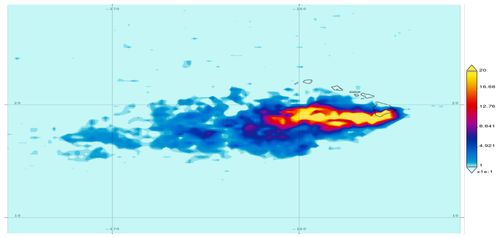

Figure 6: Time Averaged Map of SO_2 column amount in Planetary boundary layer in Hawaii over May 1st to June 5th, 2018

- OMPS
- OMPS/S-NPP NM 1-orbit L2 SO_2 product retrieved by the NASA GSFC Principal Component Analysis (PCA) trace gas algorithm. This algorithm applied improved PCA technique under the Making Earth Science Data Records for Use in Research Environments (MEaSUREs) (Ref. 3)

UUI Search for Kilauea:
https://disc.gsfc.nasa.gov/datasets?keywords=OMPS_NPP_NMSO2_PCA_L2&start=2018-05-01&end=2018-05-21&bbox=-170.739,7.383,-142.614,32.695&page=1
UUI search for Ambae:
https://disc.gsfc.nasa.gov/datasets?keywords=OMPS_NPP_NMSO2_PCA_L2&start=2018-03-20&end=2018-04-12&bbox=141.57,-32.344,177.429,8.438&page=1

- OMPS/S-NPP NM 1-orbit L2 SO_2 product retrieved by a direct vertical column fitting (DVCF) algorithm (Ref. 4).

- ASTER
- The TIR image was created using Bands 10, 11, and 12, from Terra ASTER Expedited L1B Registered Radiance at the Sensor data.

Original granule:
https://e4ftl01.cr.usgs.gov/ASTT/AST_L1BE.003/2018.05.15/AST_L1BE_00305152018084357_20180515040613_2169.hdf

- The VNIR image was created using Bands 3, 2, and 1, from Terra ASTER Level 1 Precision Terrain Corrected Registered At-Sensor Radiance data.

Original granules:
https://e4ftl01.cr.usgs.gov/ASTT/AST_L1T.003/2018.05.15/AST_L1T_00305152018205454_20180516143016_18160.hdf
https://e4ftl01.cr.usgs.gov/ASTT/AST_L1T.003/2018.05.15/AST_L1T_00305152018205502_20180516143026_18304.hdf

Summary

- The data potential at GES DISC and LP DAAC to monitor volcanic sources of SO_2 and the influence of wind fields on the gas plume spread was demonstrated with the 2018 May-July Kilauea Volcano eruptions.
- Data Availability are shown in great details in this presentation.
- Giovanni is a convenient tool to demonstrate volcanic plume development and expansion with time series and averaged distributions.

References

1. Symonds, R.B., Rose, W.I., Bluth, G.J.S., Gerlach, T.M., 1994: Volcanic-gas studies: methods, results and applications, Rev. Mineral., 30, 1–66.
2. OMI Algorithm Theoretical Basis Document (Volume IV) OMI Trace Gas Algorithms (https://docserver.gesdisc.eosdis.nasa.gov/repository/Mission/OMI/3.3_ScienceDataProductDocumentation/3.3.4_ProductGenerationAlgorithm/ATBD-OMI-04.pdf)
3. MEaSUREs README Document for OMPS_NPP_NMSO2_PCA_L2 OMPS NPP Nadir Mapper SO2 Level 2 Product Based on PCA Algorithm (https://docserver.gesdisc.eosdis.nasa.gov/public/project/MEaSUREs/Krotkov/README.OMPS_NPP_NMSO2_PCA_L2.pdf)
4. README Document for Suomi-NPP OMPS NM Sulfur Dioxide (SO2) L2 Product (https://snpp-omps.gesdisc.eosdis.nasa.gov/data/SNPP_OMPS_Level2/OMPS_NPP_NMSO2_L2.2/doc/README.OMPS_NPP_NMSO2_L2.2.pdf)