(#694) Monitoring the Hawaii Volcano Plume From Satellite

By John Porter

School of Ocean Earth Science and Technology, University of Hawaii, Honolulu, HI 96822, USA

Volcano Plume Emissions

For more than 20 years, the Hawaii Kilauea volcano has been emitting large concentrations of SO_2 gas into the atmosphere. In the atmosphere the SO_2 gas is converted to acidic aerosols which can adversely affect the human respiratory system and degrade visibility. Typically the volcano plume flows down wind south west of the Big Island of Hawaii with a portion trapped on the lee side of the island. During winter time, as cold fronts approach, south east and south west winds can advect the plume over other islands in the Hawaiian Island chain.

Monitoring the Volcano Plume From Satellite

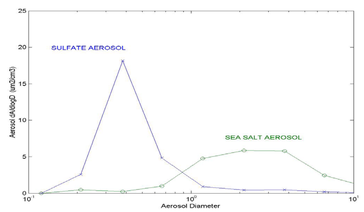
Satellites aerosol retrievals offer one approach to monitor the location and concentration of the volcano plume. The current GEOS satellites offer good temporal coverage (images many times a day) but has poor digitization resolution (8 bits covering dark areas to bright clouds) resulting in poor aerosol retrievals. On the other hand the AVHRR and MODIS satellites offer better digitization resolution and many spectral channels but poor temporal coverage (once or twice a day). The new GOES-R satellites (expected launch in 2015) will offer both good temporal coverage and good digitization resolution along with a set of spectral channels which are well suited to aerosol retrievals. The new GOES-R satellite can provide an ideal platform to monitor the Hawaii volcano plume for real time characterization as well as model initialization.

Aerosol Models to Constrain the Inversion

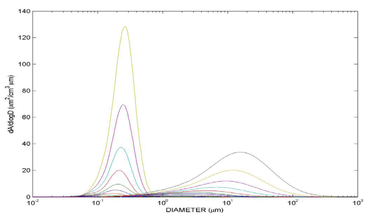
We have used both passive (satellite, and sun photometer) and active (lidar) measurements to study the spatial concentrations and flux rates of volcanic aerosols from the Kilauea volcano plume. In deriving aerosol concentrations from either passive or active approaches some assumptions must be made about the aerosol chemical and hygroscopic properties. This problem requires specific assumptions (or measurements) of the aerosol size distribution and hygroscopic behavior. Some examples of our research efforts related to this problem are shown here.

Aerosol Size Distribution Measurements and Models

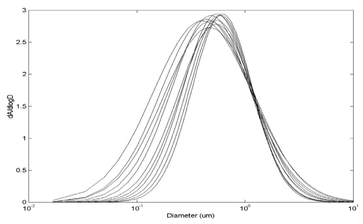
In order to convert optical measurements into mass concentrations one can use Mie theory and knowledge of the aerosol size distribution and its index of refraction. The aerosol size distribution typically depends of the relative amounts of the accumulation mode (~0.2-0.5 μm diameter) and the coarse mode (~1-10 μm diameter). In the case of Hawaii volcano measurements the accumulation mode typically consists of sulfuric acid aerosols with gas phase precursors. In some cases ammonia (from land) can partially neutralize the aerosol to ammonium bi-sulfate or fully neutralize the aerosol to ammonium sulfate. Three examples of aerosol size distributions are shown below for the Hawaii volcano plume. Both the accumulation and coarse modes (typically sea salt for Hawaii) are hygroscopic and retain large amounts of water at ambient relative humidities (Tang, 1980).



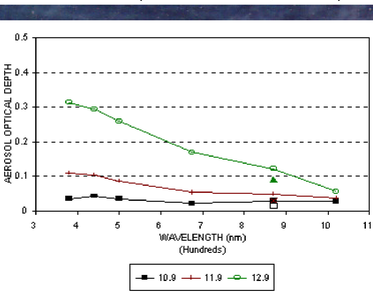
Aerosol size area distribution measured in Kona, Hawaii (Captain Cook, DOH sampling site) with a Moudi Impactor and IC analysis.



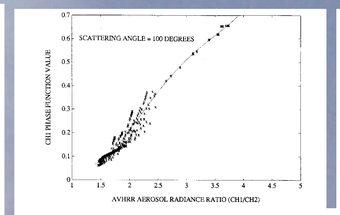
Aerosol size distribution models based on *in situ* aerosol optical size distribution measurements (Porter and Clarke, 1997). Various accumulation and coarse mode concentrations are shown.

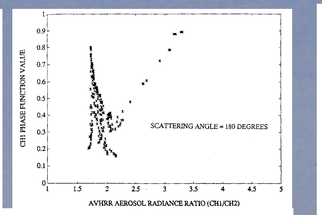


Aerosol size distributions inverted from sun photometer measurements under the Hawaii volcano plume. The range of cases illustrates the uncertainty in the measurements and the inversion (Porter et al., 2002).

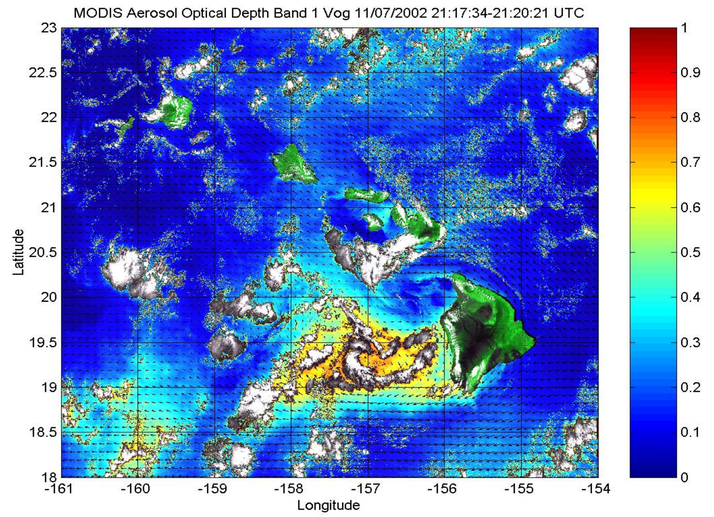


Three consecutive days of aerosol optical depth measurements collected from the monthly Hawaii Ocean Time Series (HOTS) 100 km north of Oahu. Measurements range from pure sea salt to volcanic vog (volcanic smog).

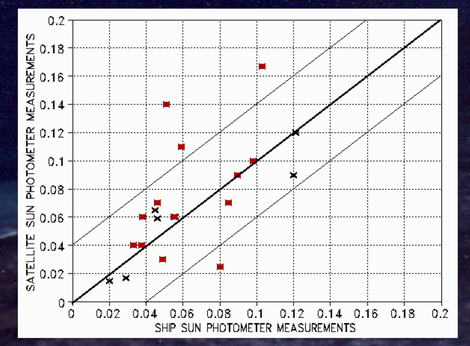


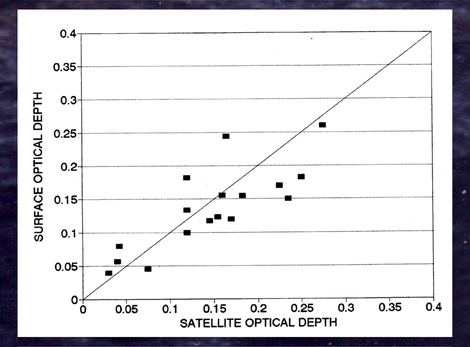


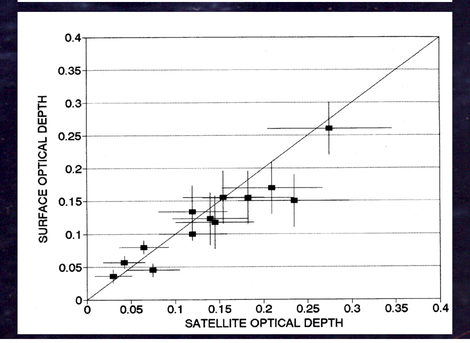
Various scattering angles can occur depending on sun-satellite geometry. The figures above show the aerosol phase function versus the ratio of modeled single scatter satellite aerosol radiance ~(670/780). At scattering angles of 100 degrees a curve fit is possible while at 180 degrees the relationship is multivalued and a relationship is not possible. Clearly certain scattering angles create problems. This illustrates potential problems which are not always evident when best fit lookup tables are used to address the inversion problem.



Aerosol optical depths derived from MODIS satellite image (250 m resolution) using our algorithm. Surface reflections are derived from interpolated AVN and RSM wind fields. 900 mb winds are shown as arrows. This image shows a case with lighter trade wind conditions and more variable island wind conditions.







Comparison of aerosol optical depths from satellite (using our inversion algorithm) and ground based measurements

Top (HOT ship cruises, SeaWifs satellite data)

Middle (Big Island and Christmas Island, AVHRR satellite data)

Bottom (Oahu, AVHRR satellite data)

Conclusion

Deriving quantitative aerosol optical depths near Hawaii has several challenges:

1) The aerosol types include clean marine sea salt aerosols, volcanic smog, Asian dust, and Asian pollution,
2) Aerosol hygroscopic humidity effects change aerosol properties,
3) The complex orography and wind fields requires meso-scale weather models rather than synoptic scale models in order to accurately model the surface bi-directional reflection function,
4) Our studies suggest that even the best meso-scale model simulations still make mistakes in surface wind speed and direction. We argue the better observations are needed for better model initialization,
5) The presence of overlaying aerosol layers presents challenges to our best algorithms.