Investigating the influence of volcanic sulfate aerosol on cloud properties using MODIS data along A-Train tracks

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Active marine volcanoes often emit varying amounts of SO2 into the MBL over periods of many years. Example: Kilauea

Build on work by Yuan et al. (2011) and Eguchi et al. (2011)
Time series of MOD04 AOD from Kilauea

Time series of MOD04 AOD from Heard Island (53 South, 75 East)
1st Aerosol Indirect Effect:

Twomey (1974)

Holding water content fixed, increased CCN results in a cloud with a higher droplet number and smaller droplets. This results in a cloud that is more reflective. The cloud field then has a higher albedo.

2nd Aerosol Indirect Effect:

Albrecht (1989)

The Twomey effect interrupts the formation of precipitation in clouds resulting in clouds that rain less and live longer, resulting ultimately in higher cloud fraction and higher albedo.
Our thinking (Mace and Abernathy, 2016, GRL):

Look at the data within the plume and use the natural variability of the volcanic AOD.

Take advantage of the cloudsat radar and calipso lidar to characterize cloud boundaries, we examined the statistics of

- MYD AOD
- L1B radiances (1km)
- 250 m cloud fraction (recorded in MYD35 Cloud Mask)
- Microwave (AMSR) Wind Speed
- CloudSat Z
- Calipso Cloud top

Along overpasses of the analysis domain over 3 years – tested for decorrelation of the events from the meteorology.
Note 2 distinct cloud populations – shallow (not seen by CloudSat) and deeper (precipitating)

Kilauea has more range in AOD than Ambrym-Vanuatu
Tabular Results:

Shallow Mode Clouds: Those not observed by CloudSat (precipitation not yet developed)
Deep Mode Clouds: Those that were observed by CloudSat (usually precipitating)

We see systematic changes from Quartile 1 to 4:
• Overall cloud fraction increases
• MODIS-only clouds decrease
• Shallow mode clouds increase
• Deep mode clouds don’t change in coverage
From Q1 to Q4:

Deep clouds get deeper

MODIS/CALIPSO clouds get deeper
From low to high aerosol the 0.55 um reflectance increases. Similar increase in near IR.
Now – control for 250 m cloud fraction

We find that the reflectance in sub overcast pixels is nearly insensitive to AOD - nearly entirely explained by 250 m cloud fraction until the pixel is overcast.
Summary:

Partially cloudy 1km domains show increasing coverage fraction with AOD.

Evidence for 1st AID can be identified in the overcast 1km pixels but not in the partially cloudy pixels.

We also find a distinct deepening of the clouds with increasing AOD.

No increase in Z in the deeper clouds. Suggests that the polluted clouds deepened just enough to overcome the inhibition of the autoconversion process.
Future:
- Expand to other island volcanoes that offer unique opportunity to learn about A-C-P interaction
- Develop trajectory approach to track the volcanic plumes (especially important in mid latitudes)
- Use CloudSat, Calipso, MODIS, VIIRS, to examine sensitivity of precipitation processes in downstream clouds.
- Virtual Volcanoes???

Photo Credit: CSIRO Marine National Facility