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

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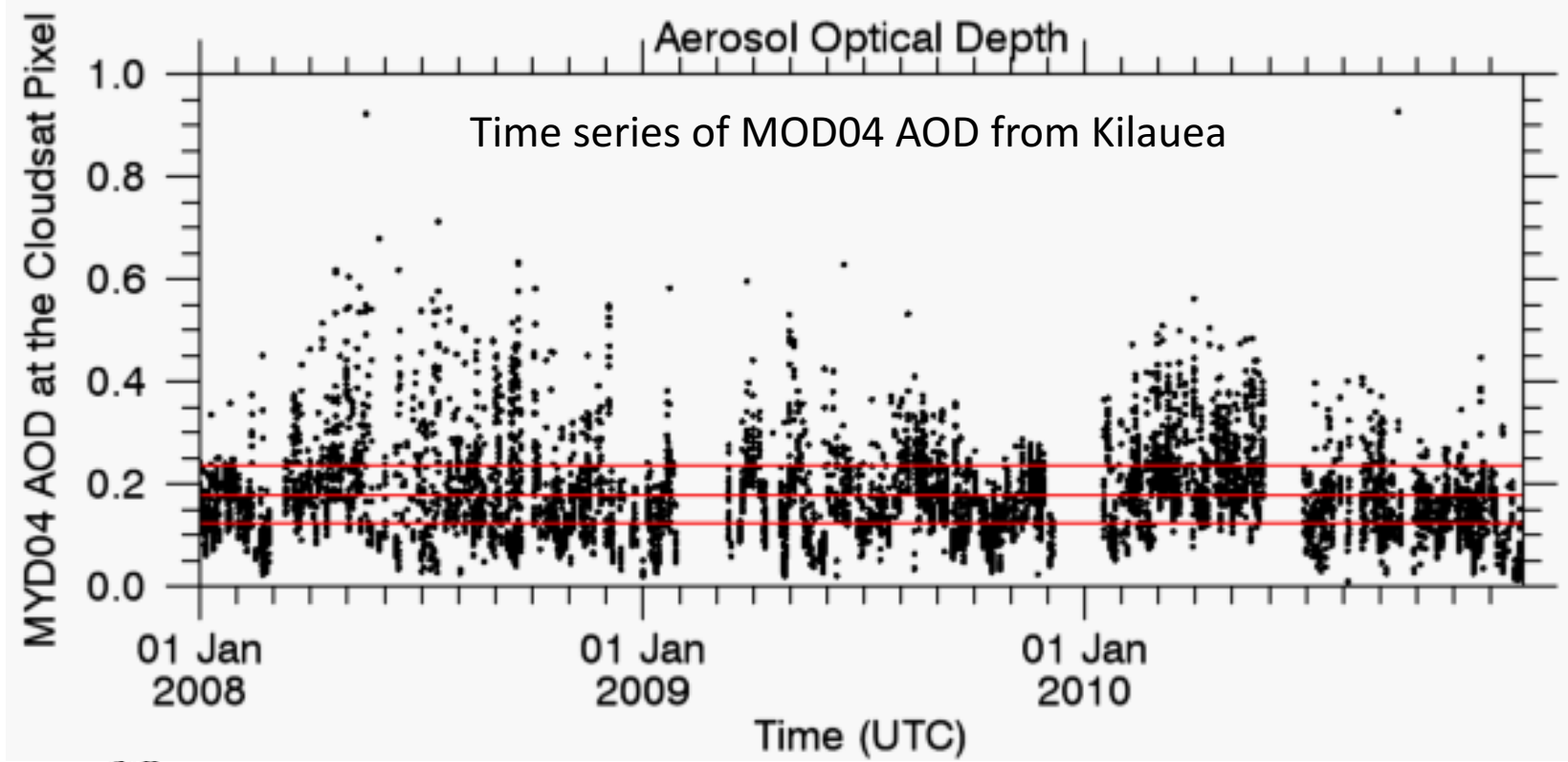
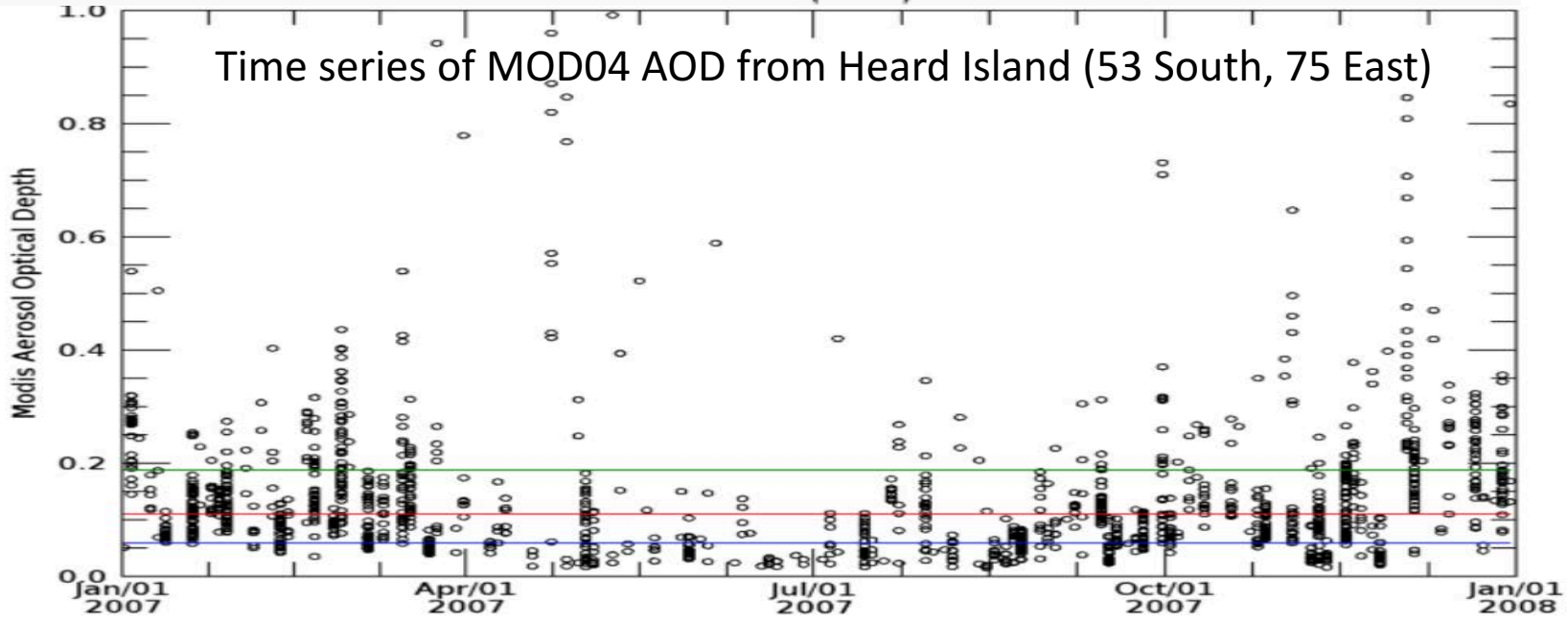
Active marine volcanoes often emit varying amounts of SO2 into the MBL over periods of many years. Example: Kilauea

Build on work by Yuan et al. (2011) and Eguchi et al. (2011)


Aerosol Optical Depth
Time series of MOD04 AOD from Kilauea
MYD04 AOD at the Cloudsat Pixel
1.0
0.8
0.6
0.4
0.2
0.0
01 Jan
2008
01 Jan
2009
01 Jan
2010
Time (UTC)

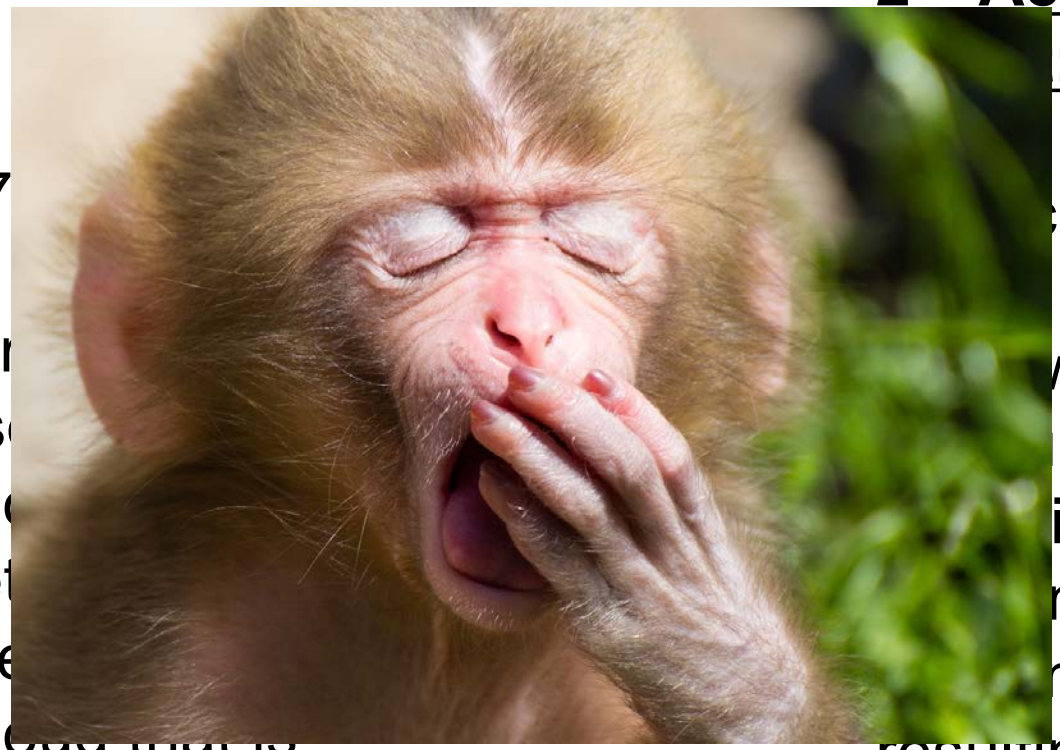

Time series of MOD04 AOD from Heard Island (53 South, 75 East)
Modis Aerosol Optical Depth
0.8
0.6
0.4
0.2
0.0
Jan/01
2007
Apr/01
2007
Jul/01
2007
Oct/01
2007
Jan/01
2008

What we want to know something about….

1st Aerosol Indirect Effect:

Twomey (197

Holding water
fixed, increas
results in a cl
higher droplet
smaller drople
results in a cloud that is
more reflective. The cloud
field then has a higher
albedo.



2nd Aerosol Indirect
:

ht (1989)

womey effect
pts the formation of
itation in clouds
ng in clouds that rain
nd 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

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Along overpasses of the analysis domain over 3 years – **tested for decorrelation of the events from the meteorology**

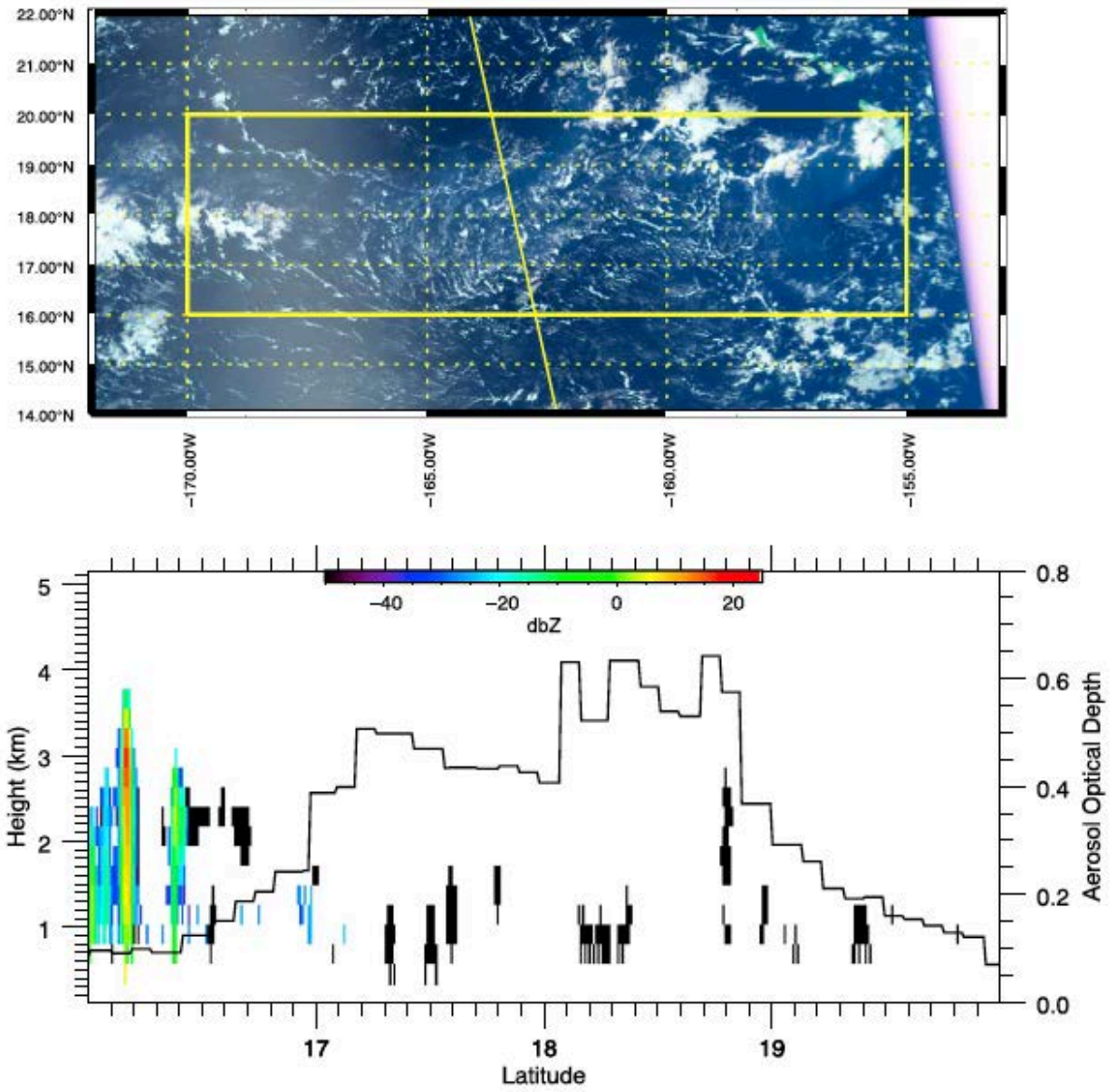


Figure 1. Example MODIS three-color visible image collected on 21 September 2008. The solid yellow box shows the analysis domain we use. The thin solid line shows the ascending node of CloudSat. (b) Data from the CloudSat CPR (dBZ > − 30) and cloud boundaries from the Cloud-Aerosol Lidar And Infrared Pathfinder Satellite Observations (CALIPSO) lidar (indicated by dBZ = −40 when below the sensitivity of CloudSat) are shown plotted with MYD04 aerosol optical depth. This image shows an aerosol plume that is clearly visible in the Moderate Resolution Imaging Spectroradiometer (MODIS) image and represented by elevated τ_A.

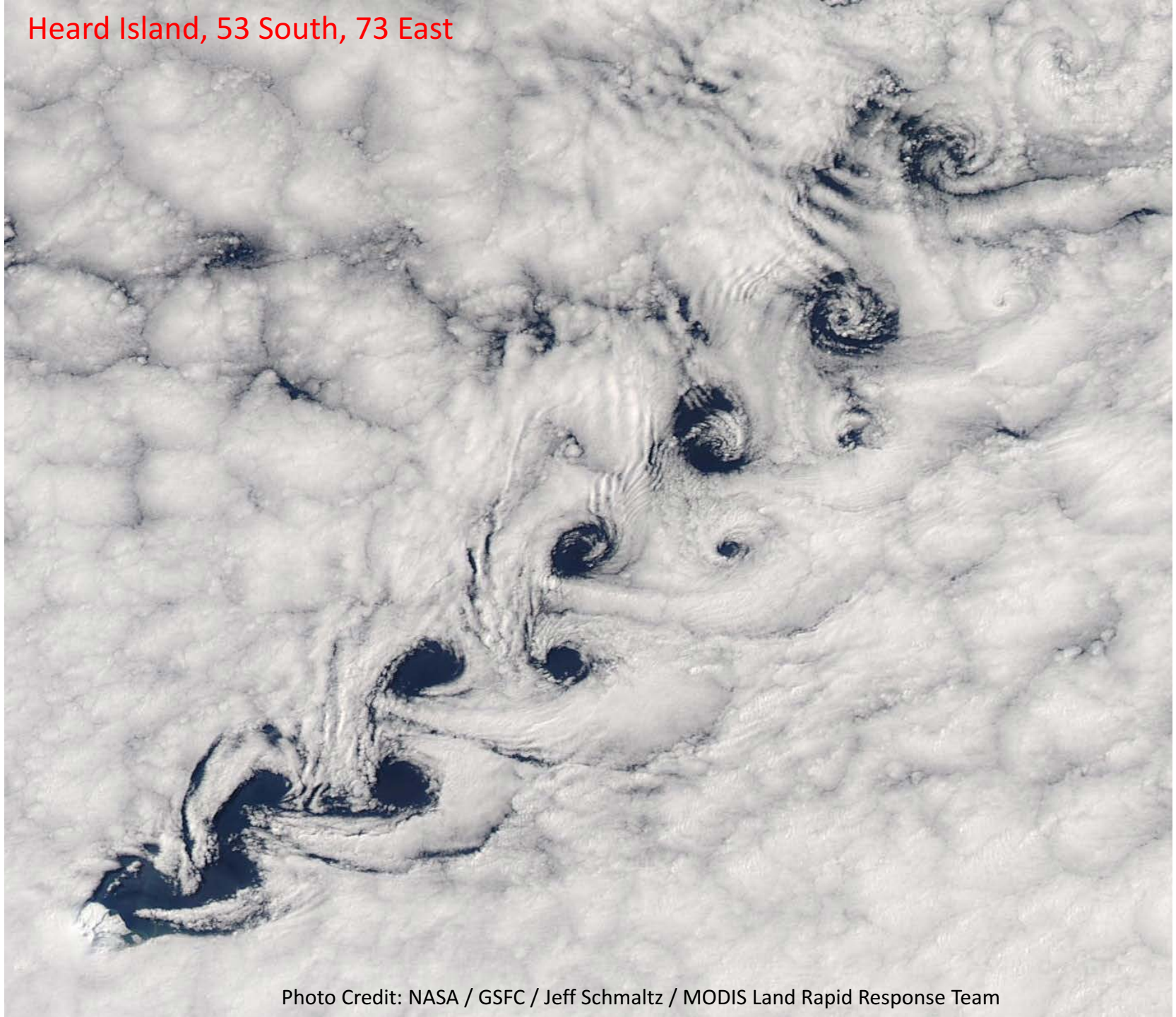
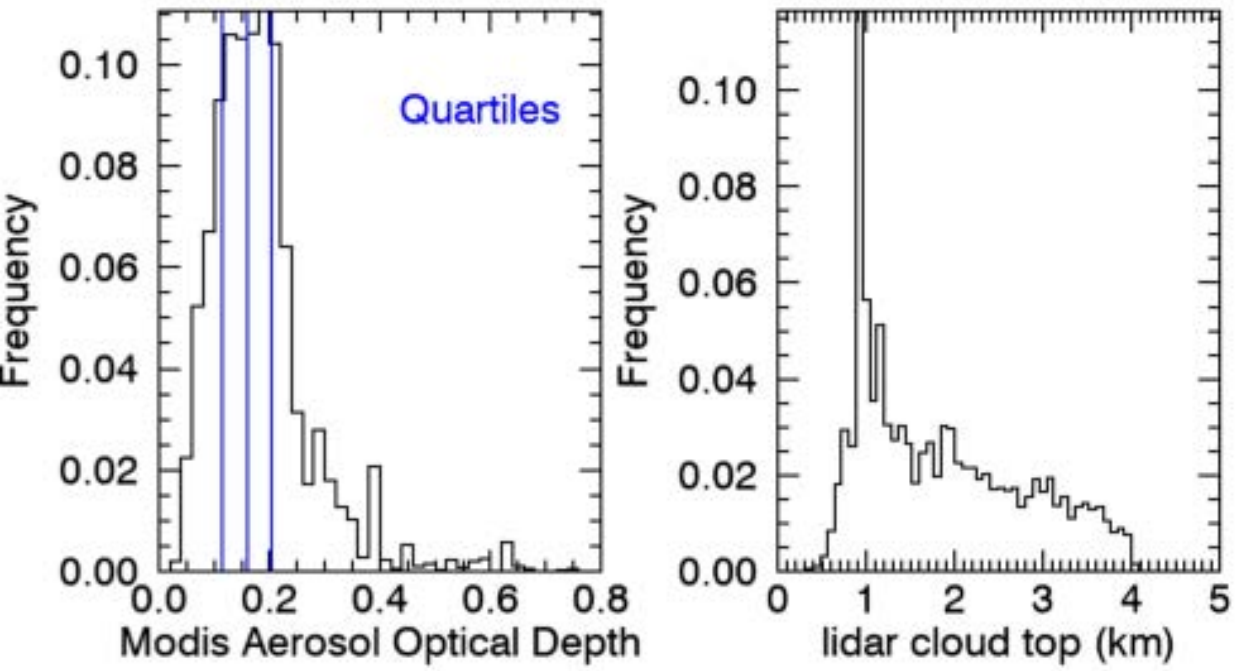
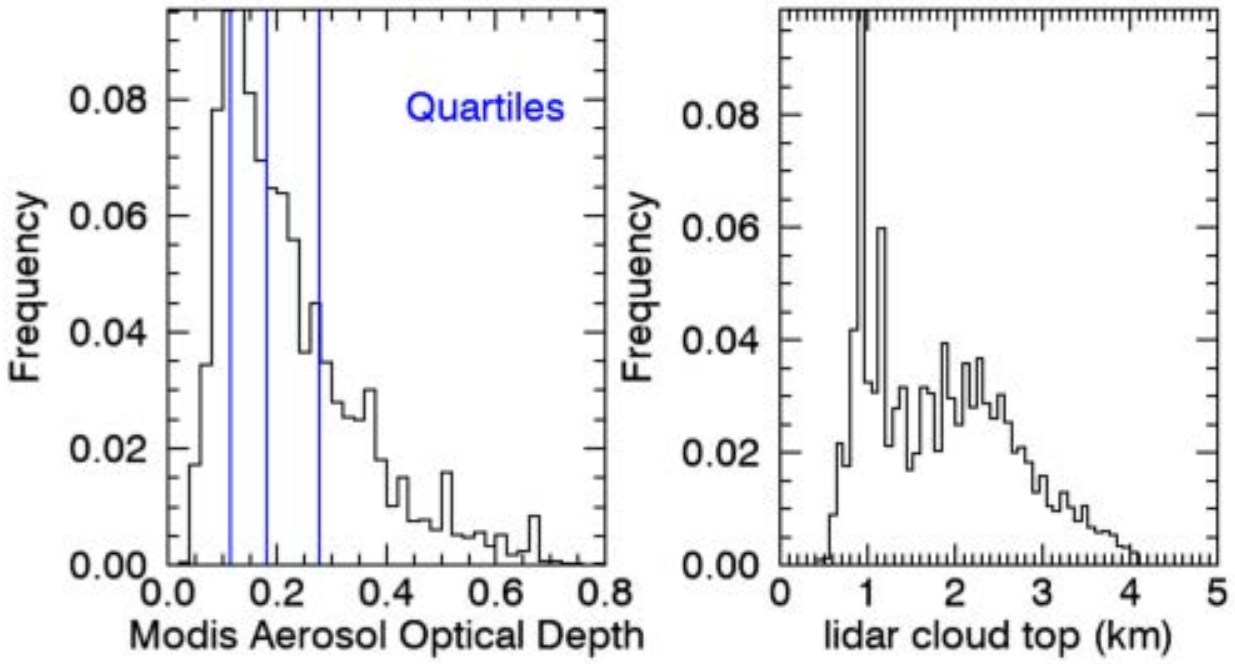


Photo Credit: NASA / GSFC / Jeff Schmaltz / MODIS Land Rapid Response Team

Ambrym-Vanuatu AOD and cloud top PDF



Kilauea AOD and cloud top PDF



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)

Table 1. Occurrence Frequencies of Various Cloud Types[a] Kilauea

	Total Cloud Fraction	Observed Only by MODIS[c]	Shallow-Mode Clouds	Deep-Mode Clouds
Overall[b]	0.33	3,938	16,014 (0.45)	13,684
Quartile 1	0.30 ←	1,273 ←	3,285 (0.25) ←	3,152 ←
Quartile 2	0.33	1,256	3,697 (0.32)	3,402
Quartile 3	0.34	780	3,974 (0.45)	3,828
Quartile 4	0.35 ←	629 ←	5,058 (0.65) ←	3,302 ←

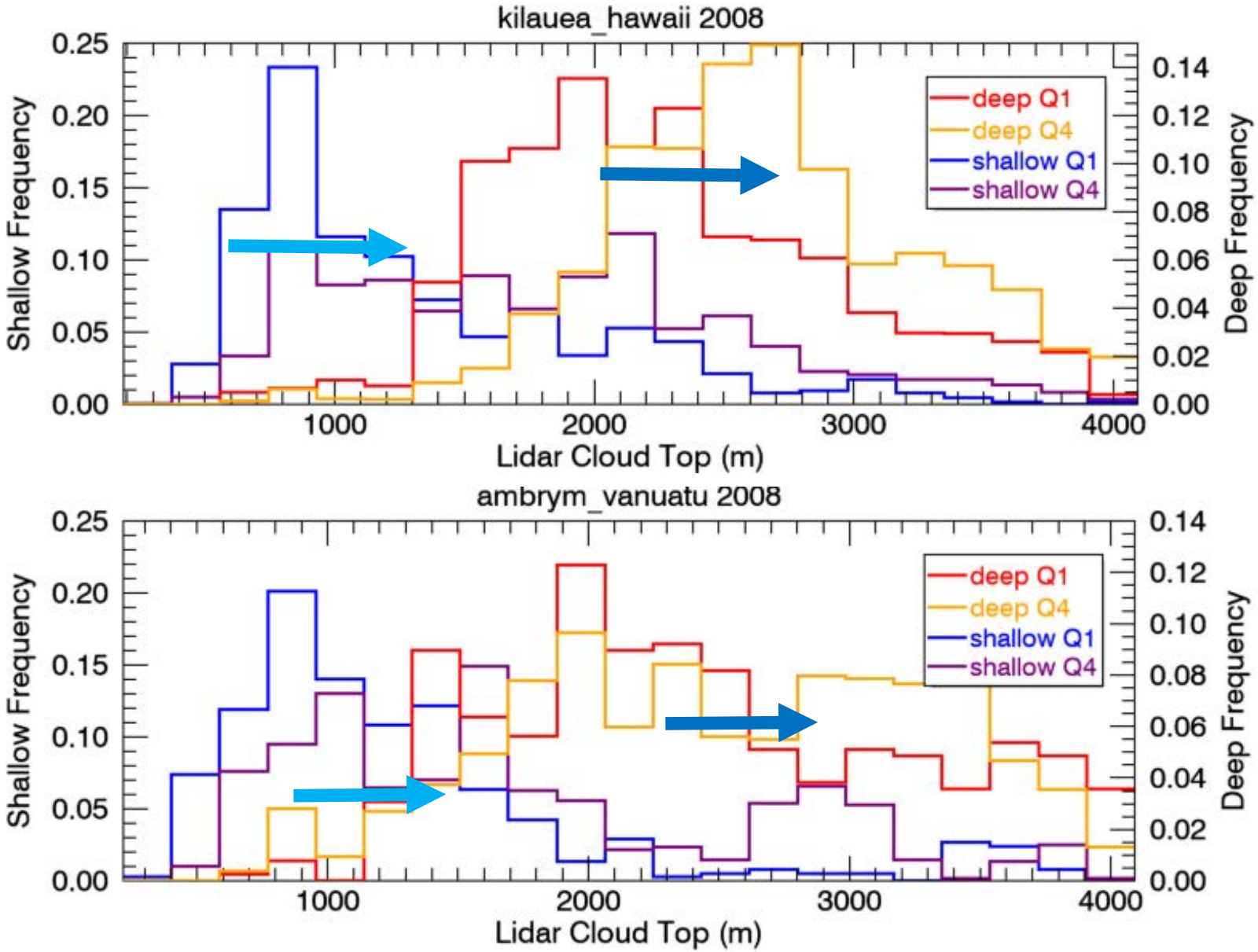
We see systematic changes from Quartile 1 to 4:

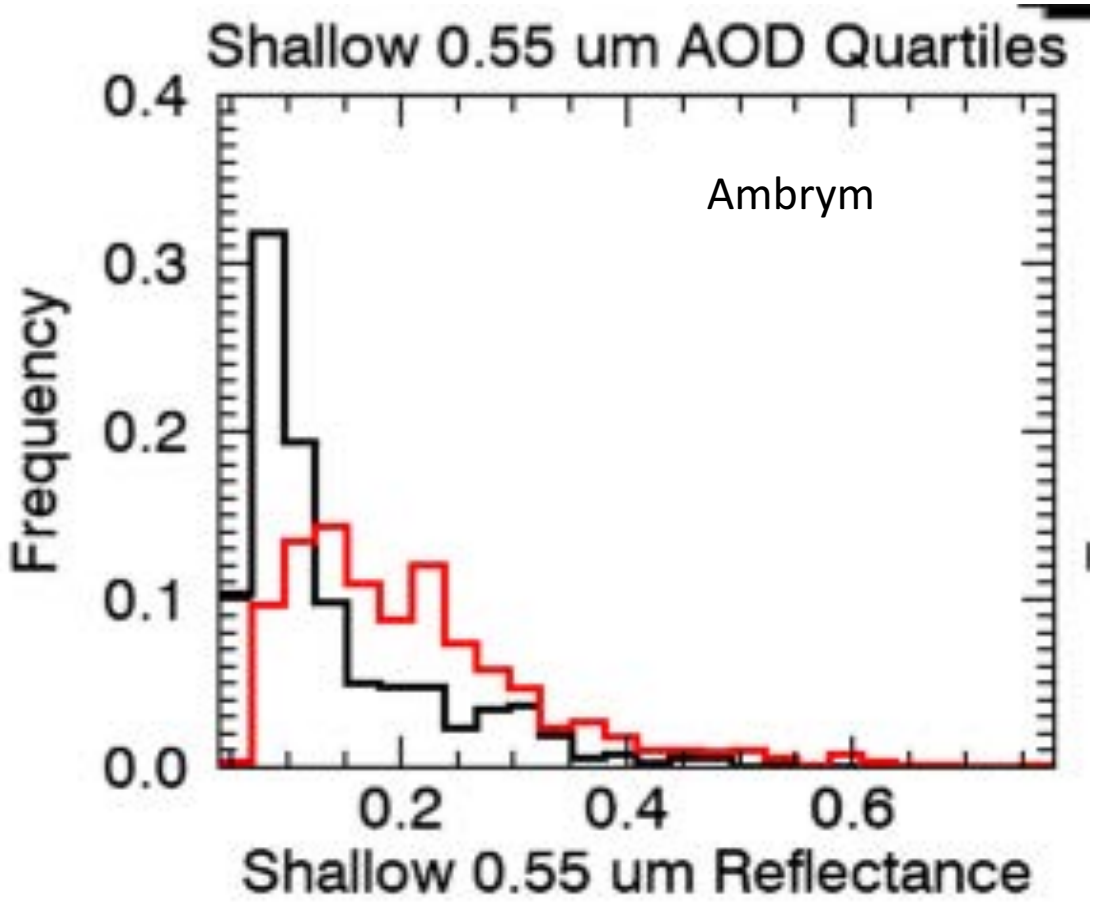
- Overall cloud fraction increases
- MODIS-only clouds decrease
- Shallow mode clouds increase
- Deep mode clouds don’t change in coverage

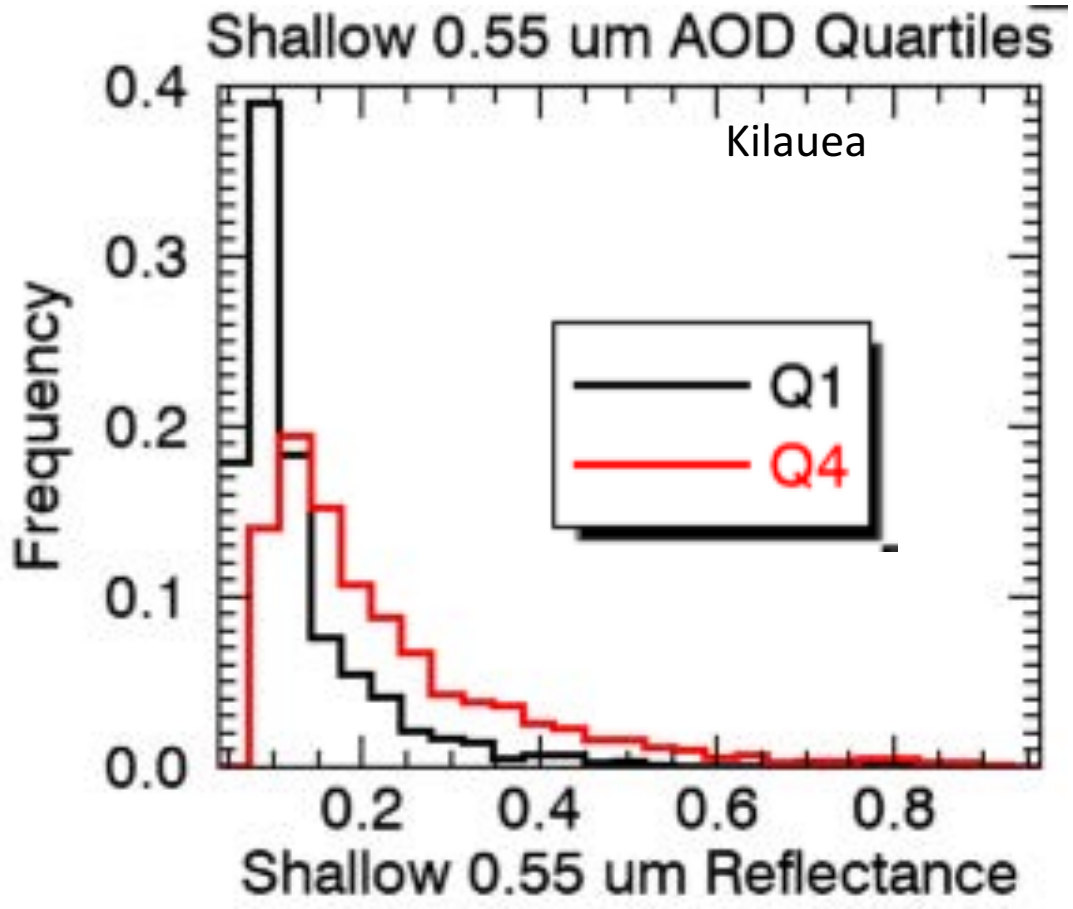
From Q1 to Q4:

Deep clouds get deeper

MODIS/CALIPSO clouds get deeper



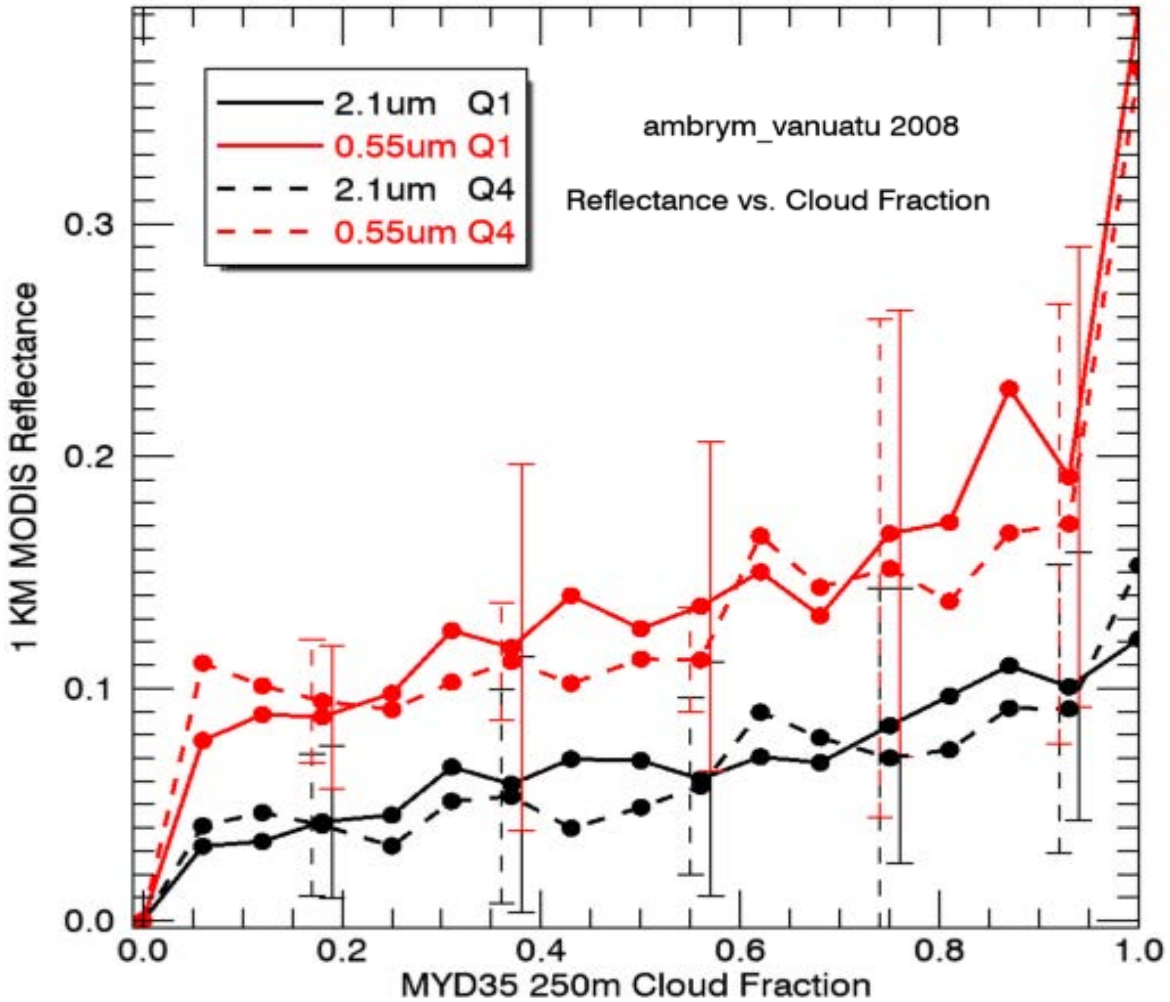


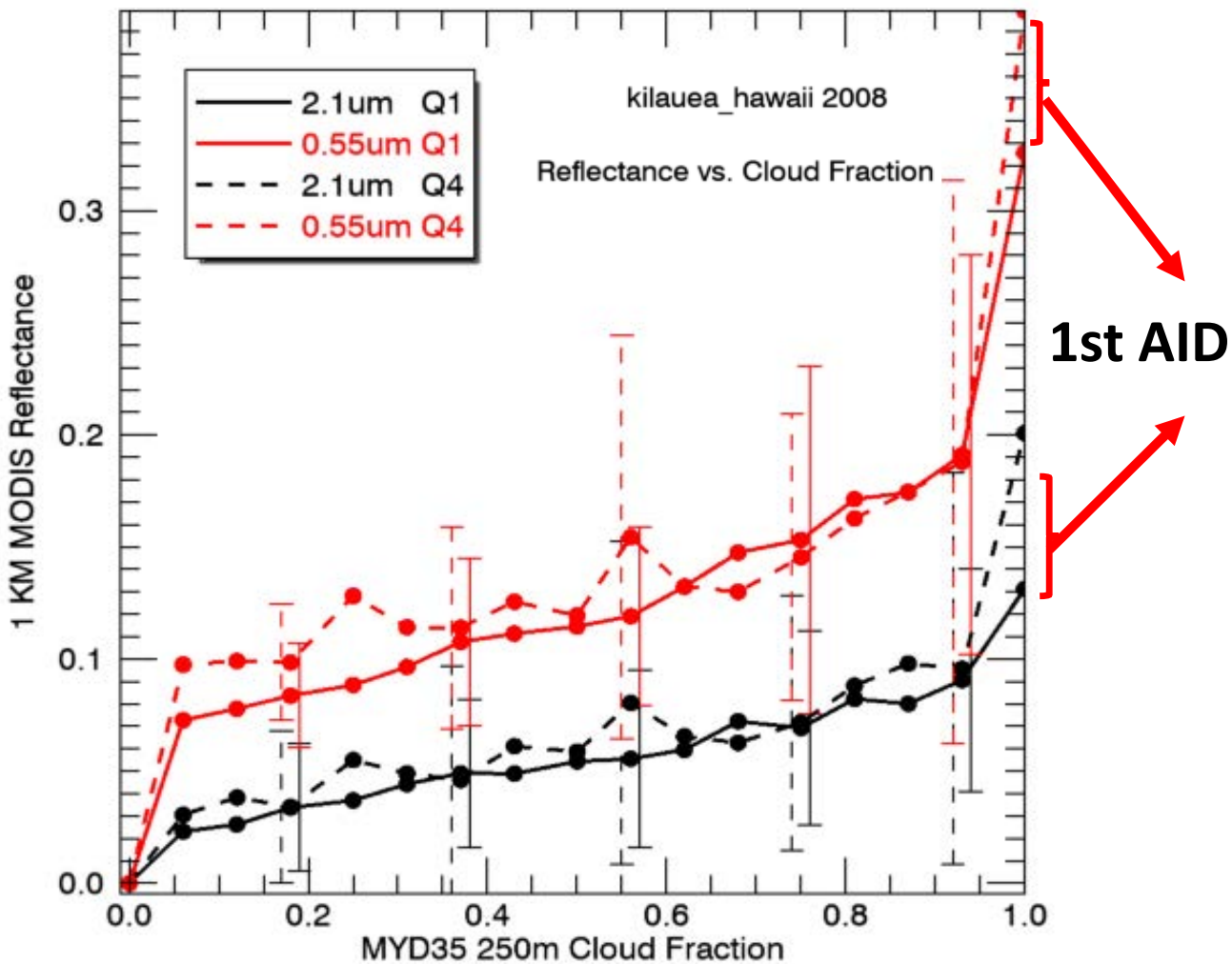


From low to high aerosol the 0.55 um reflectance increases. Similar increase in near IR.

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





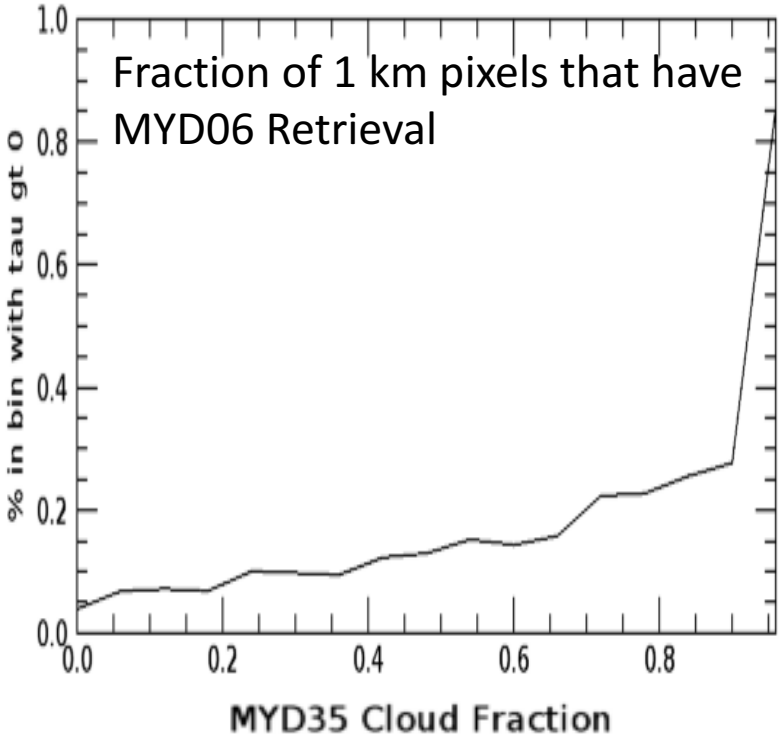
Summary:

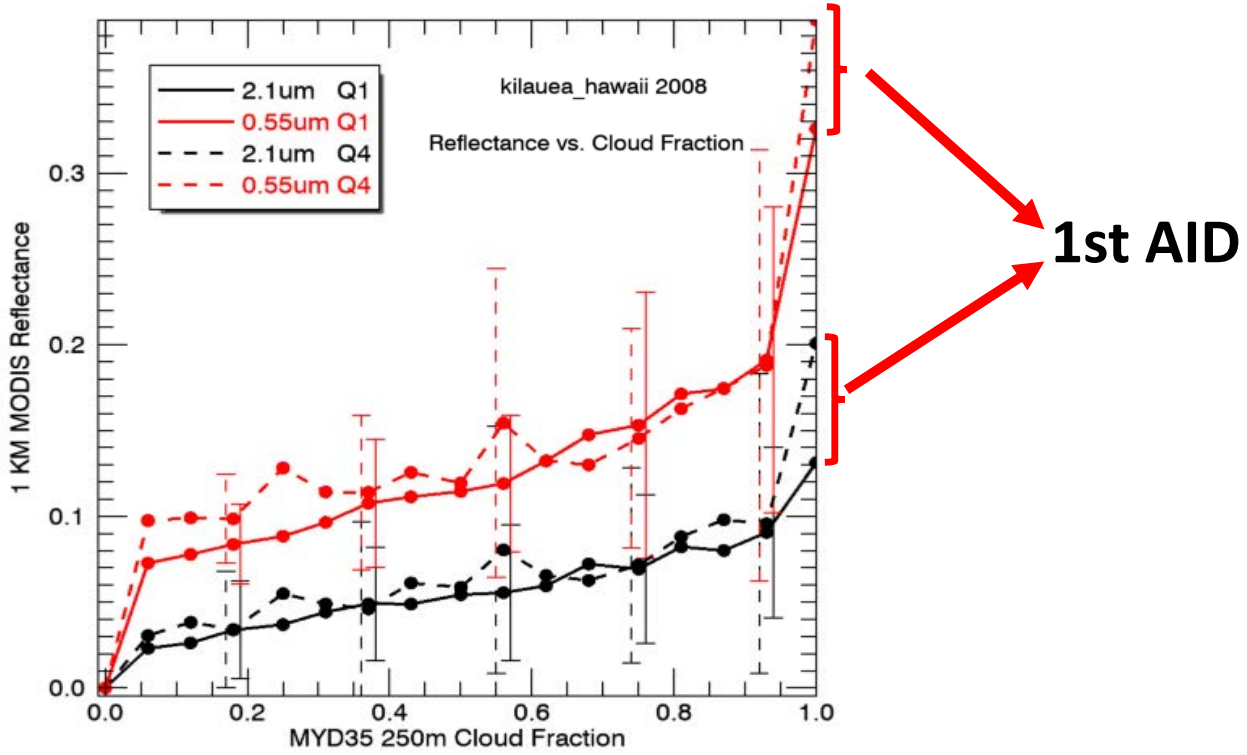
Partially cloudy 1km domains show increasing coverage fraction with AOD.

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.



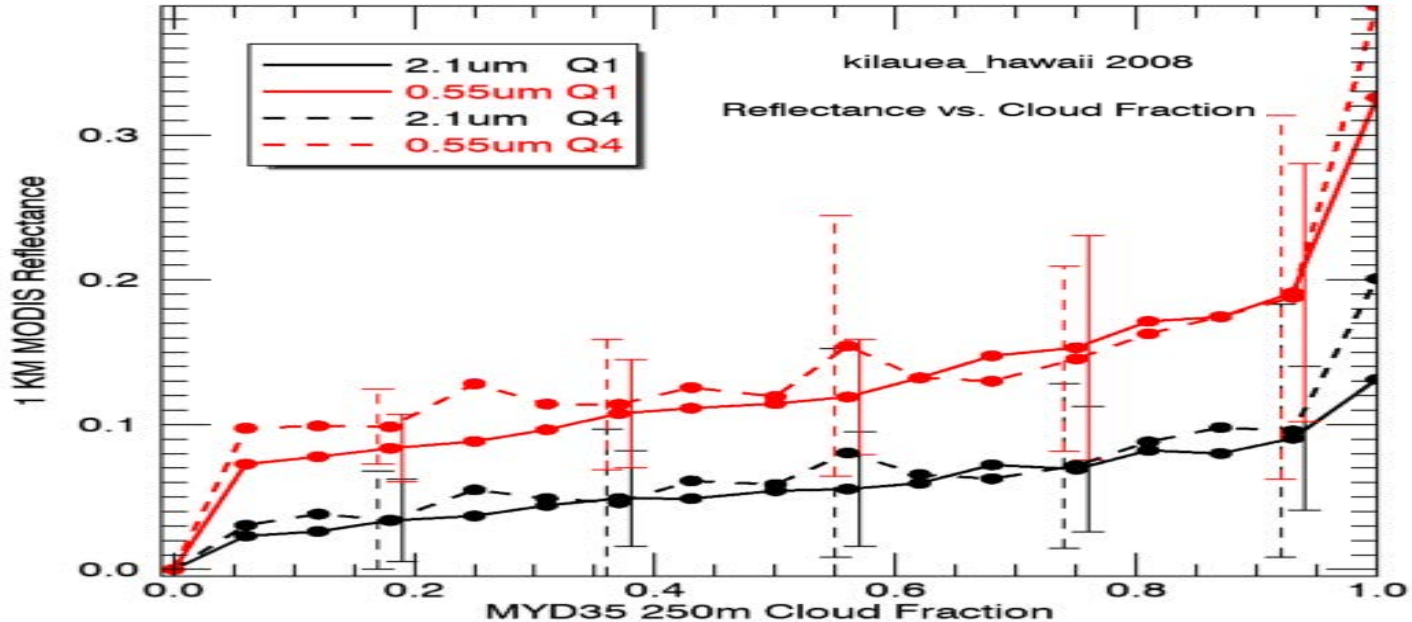


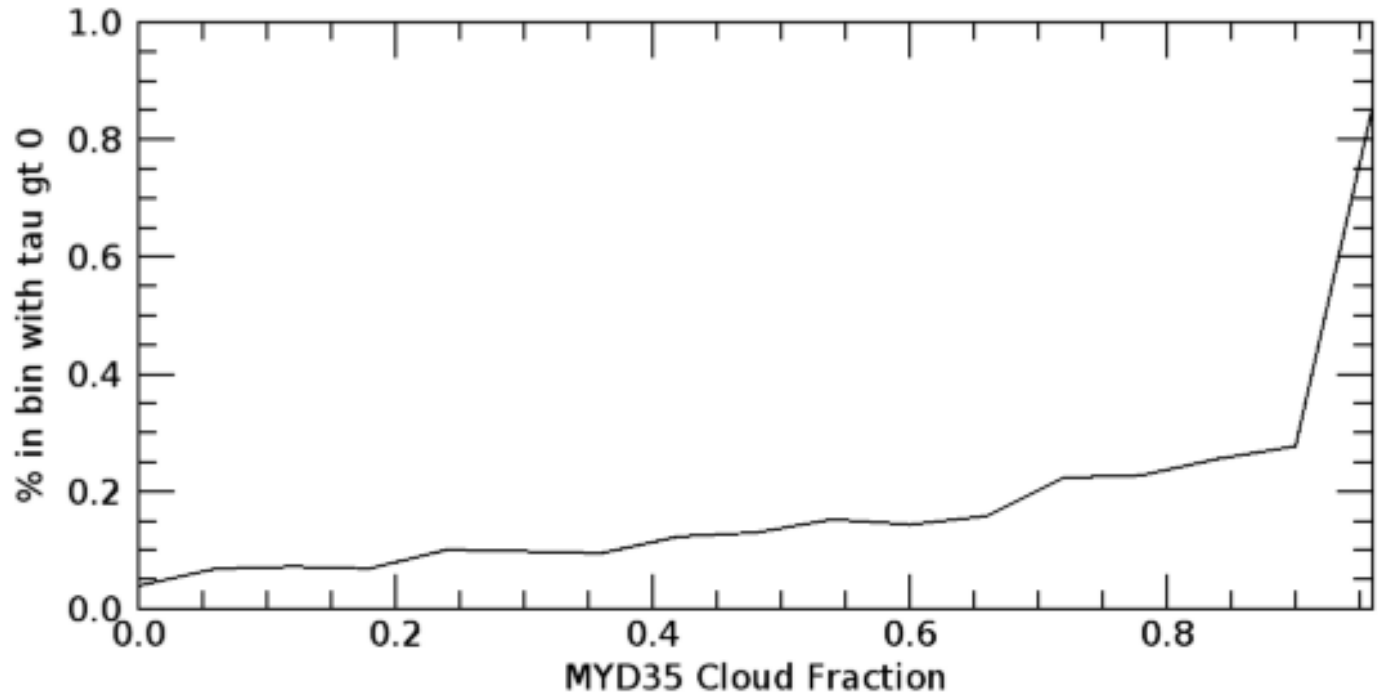
Future:

- 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


Heard Island, 53 South, 73 East
Photo Credit: CSIRO Marine National Facility


2.1um Q1
0.55um Q1
2.1um Q4
0.55um Q4
kilauea_hawaii 2008
Reflectance vs. Cloud Fraction
1 KM MODIS Reflectance
MYD35 250m Cloud Fraction
0.0
0.1
0.2
0.3
0.4
0.6
0.8
1.0


% in bin with tau gt 0
MYD35 Cloud Fraction
0.0
0.2
0.4
0.6
0.8
1.0