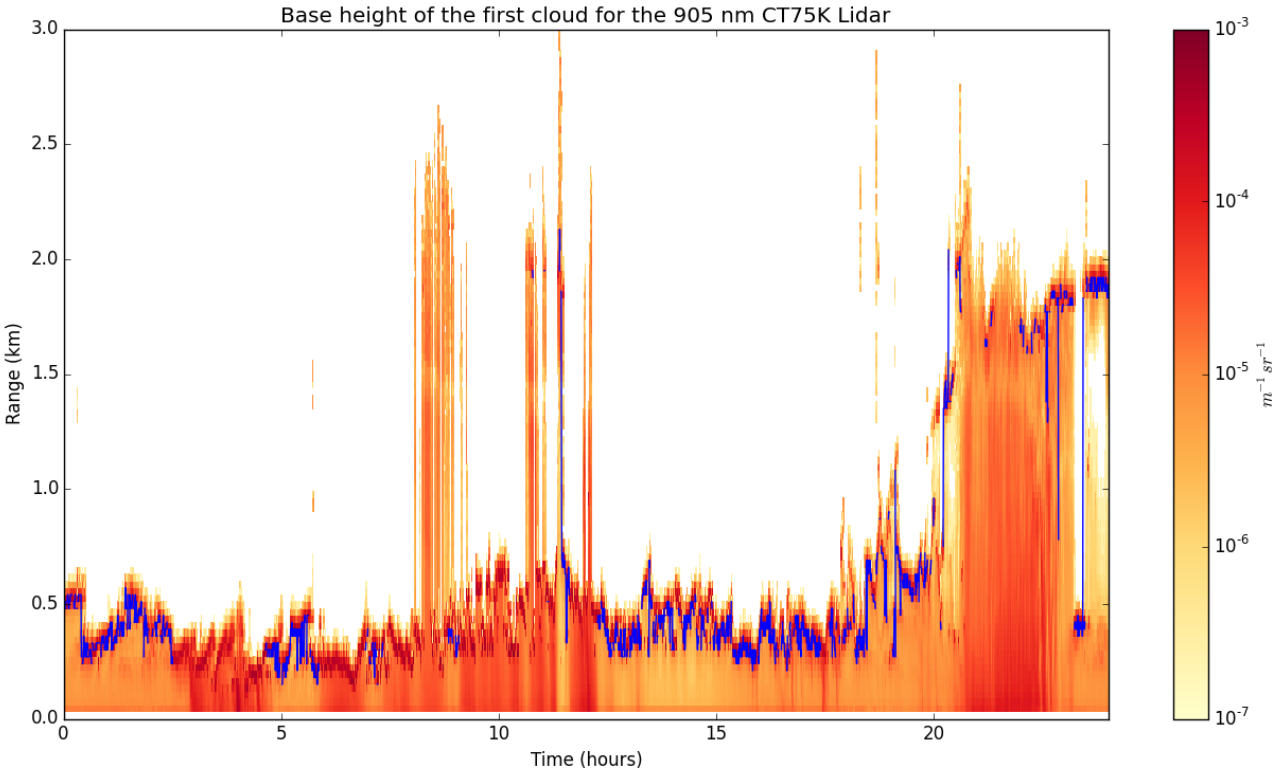
Summer internship 2015 report

Over the course of this internship I have used data from the Chilbolton Observatory to investigate the distribution of clouds and whether this distribution is altered by the concentration of aerosol. Using data collected from the 905 nm CT75K lidar ceilometer, I calculated the cloud base height (CBH) by finding the maximum change in the signal strength and filtering out values where the signal falls below a threshold.

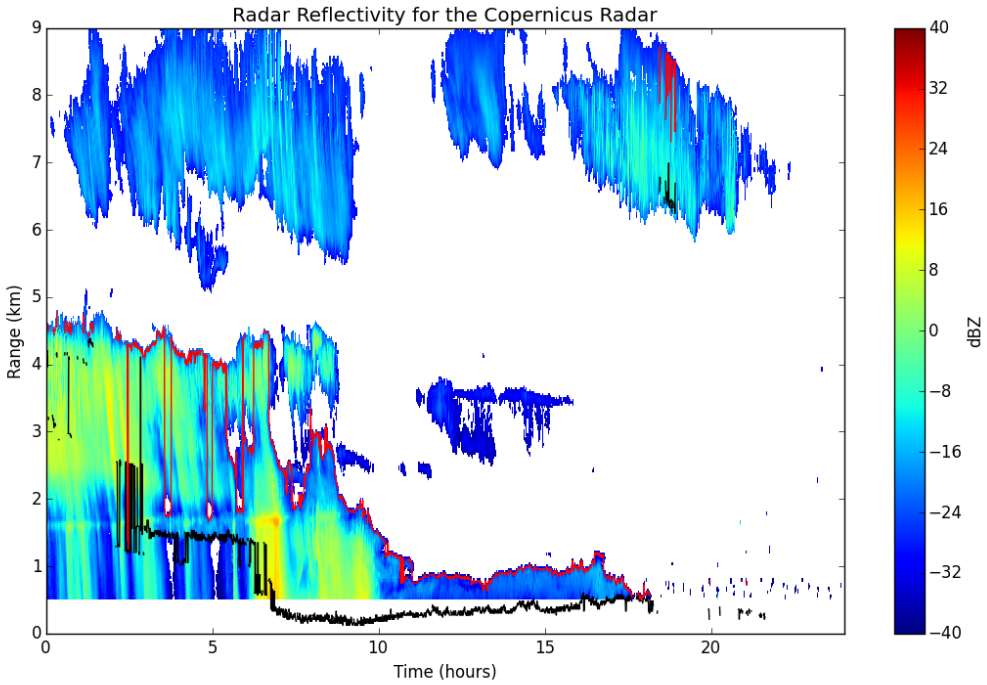
Lidars perform poorly during precipitation events, however these events have a distinctive ‘smear’ profile and can easily be filtered out. I verified the rain filter by comparing the resulting profiles with the rain gauges located at the site.



The Attenuated Backscatter Coefficient with a rain mask applied.

Given that lidar operate within the Infrared and Ultraviolet regions, they are well suited to detecting the base of a cloud. However the signal attenuates rapidly, so lidar are rarely useful for determining the cloud top height. Conversely, radar are sensitive to larger droplets and even light precipitation can cause anomalously low measurements of cloud base height, but the signal does not suffer from the same attenuation problems as the lidar and so is well suited to measuring the cloud top. Used in conjunction these instruments can give a fuller picture of the cloud distribution.

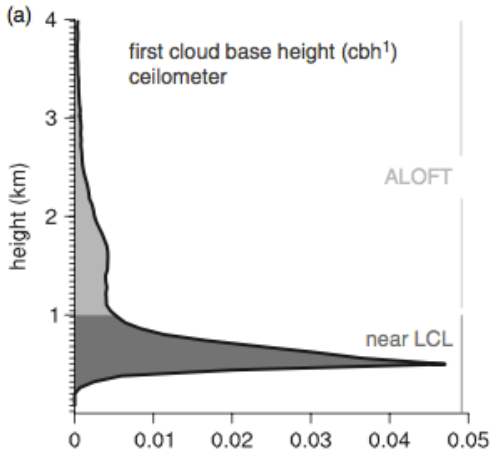
I used data collected by the Copernicus radar to determine the cloud top height (CTH).

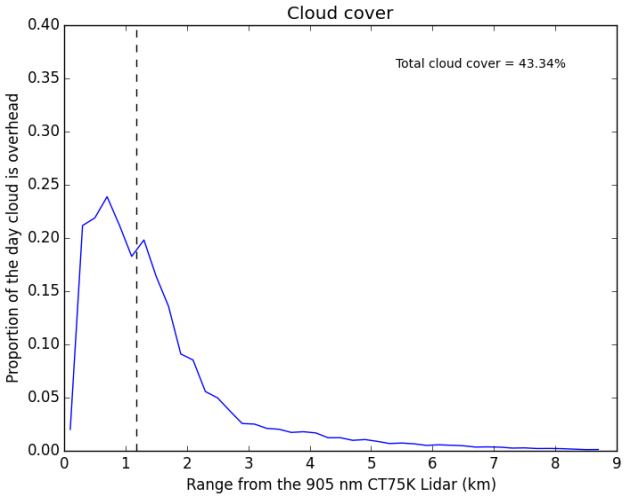


The CBH (black) and CTH (red) overlaid on the radar reflectivity.

The aerosol data was sourced from the AERONET programme, which uses sun photometers to determine the Aerosol Optical Thickness (AOT). Because of the need for clear skies to accurately calculate AOT, the CBH distribution for days where there is both aerosol and lidar data is different from the underlying CBH distribution.

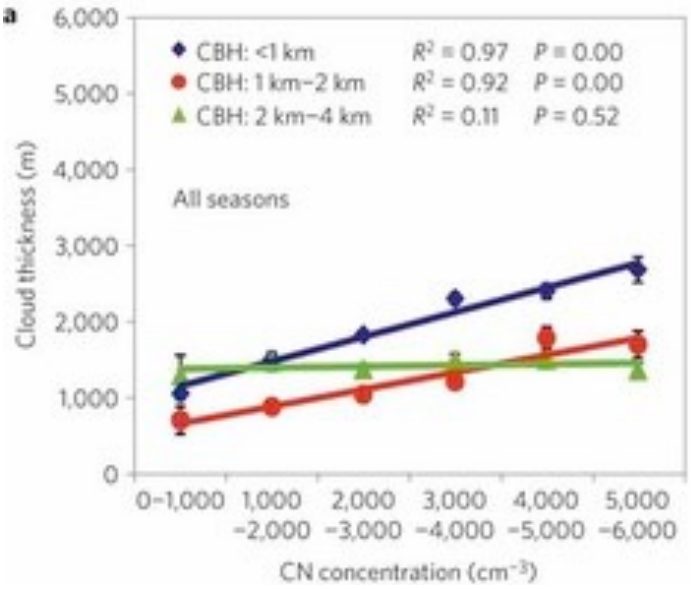
Nuijens (*Q. J. R. Meteorol. Soc.* 140: 2364 – 2374, October 2014 A DOI:10.1002/qj. 2307) examines the distribution of CBH in Barbados and finds that the majority of cloud (about two thirds) forms below 1 km. Running a similar analysis on 8 years of data I find that cloud bases over Chilbolton are less concentrated around the boundary layer, with 42 % lying below 1km.



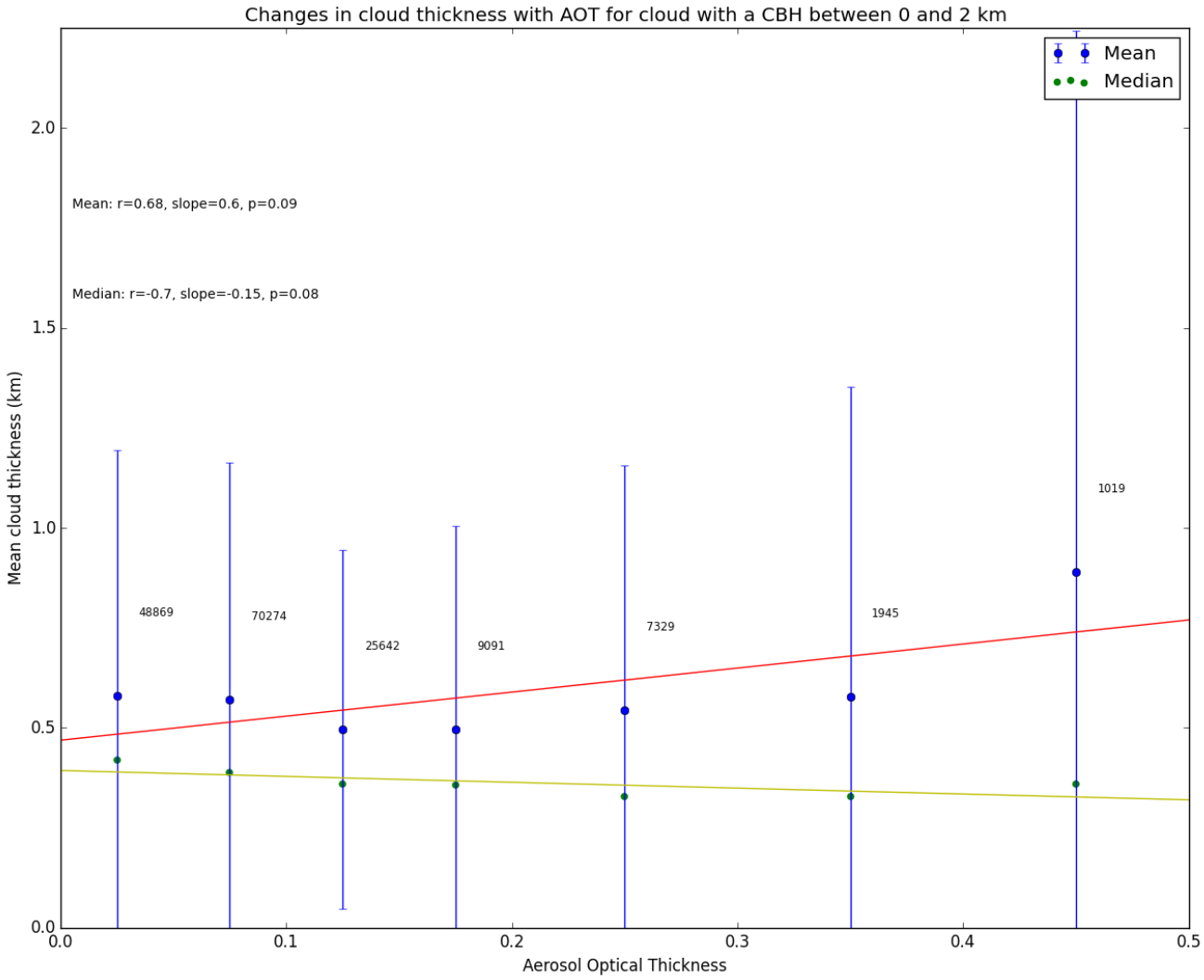


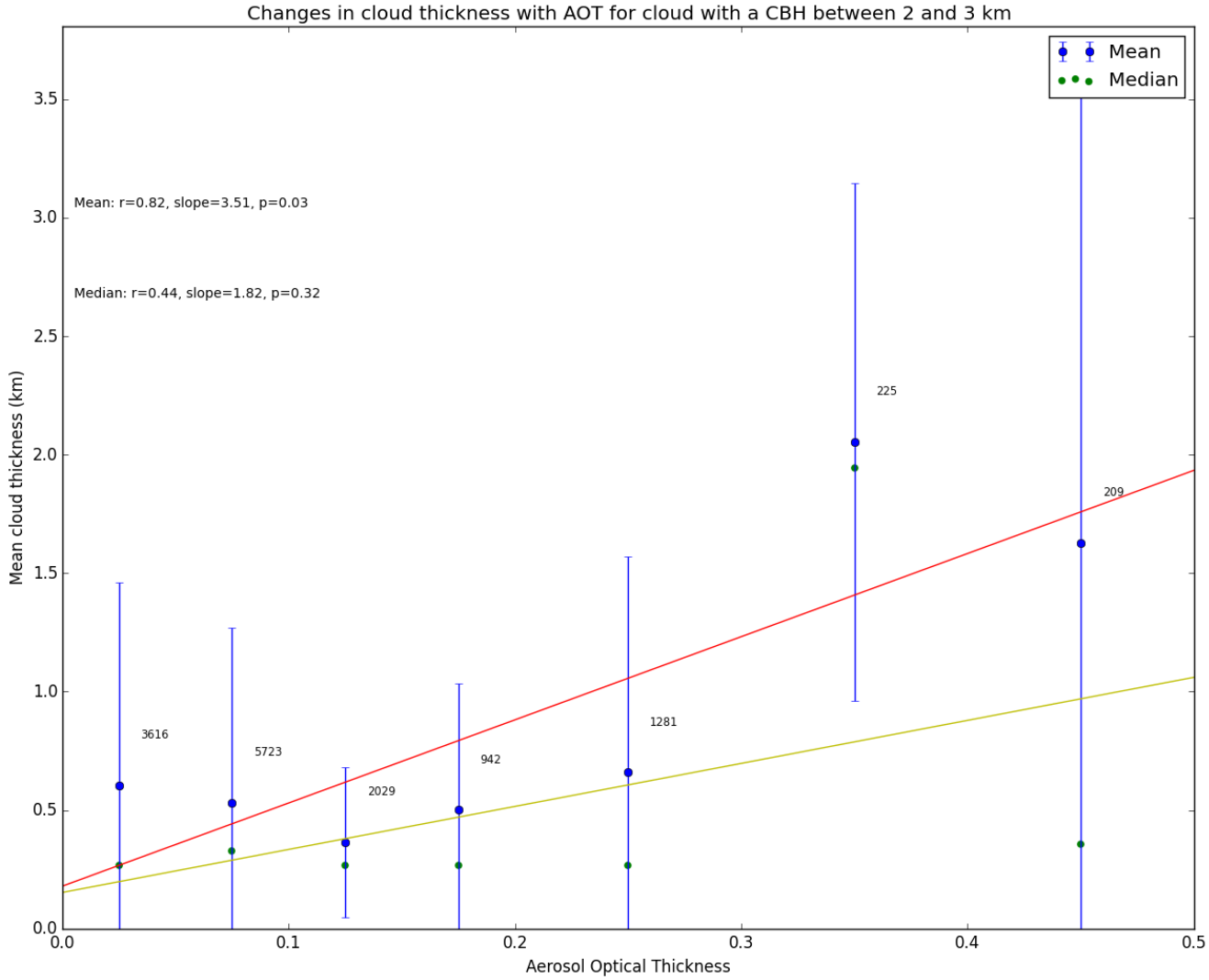
Li *et al* (*Nature Geoscience, Vol* 4 , December 2011, DOI: 10.1038/ngeo1313) explores the relationship between aerosol concentration and the vertical development of cloud. They find that there is a positive correlation between cloud thickness and aerosol for clouds with a low base, however this effect disappears for clouds with a

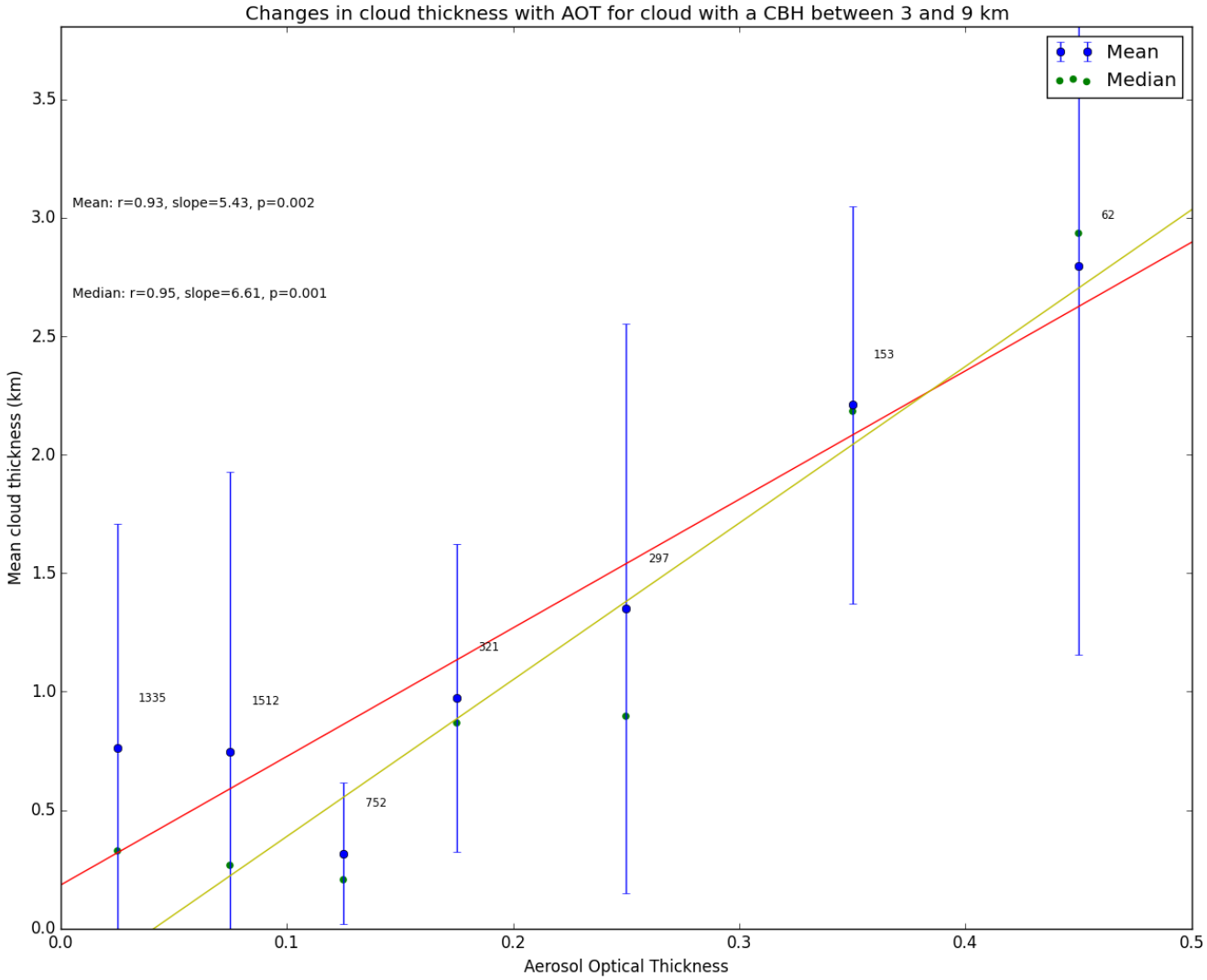
base above 2 km. This effect is attributed to an “aerosol-induced invigoration of upward winds.” As the aerosol concentration increases the radius of water droplets will decrease, allowing more water to freeze and providing additional latent heating to augment the convective parcel buoyancy.



Using AOT as a proxy for concentration nuclei, I attempted to replicate this finding. The numbers next to each bin corresponds to the number of data points within that bin. Concentrating on the median cloud thickness, I found that there was no significant correlation for clouds with a CBH below 2km or between 2km and 3km. However for clouds above 3km there is a very strong correlation, although this may be an error due to the small number of data points that have both an AOT above 0.4 and a CBH above 3km. If these findings bear out when the number of points analysed is increased, they would appear to contradict Li’s findings.


Changes in cloud thickness with AOT for cloud with a CBH between 0 and 2 km
Mean
Median
Mean: r=0.68, slope=0.6, p=0.09
Median: r=-0.7, slope=-0.15, p=0.08
48869
70274
25642
9091
7329
1945
1019
Mean cloud thickness (km)
Aerosol Optical Thickness
0.0
0.5
1.0
1.5
2.0
0.1
0.2
0.3
0.4


Changes in cloud thickness with AOT for cloud with a CBH between 2 and 3 km
Mean
Median
Mean: r=0.82, slope=3.51, p=0.03
Median: r=0.44, slope=1.82, p=0.32
3616
5723
2029
942
1281
225
209
Mean cloud thickness (km)
Aerosol Optical Thickness
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0.1
0.2
0.3
0.4


Changes in cloud thickness with AOT for cloud with a CBH between 3 and 9 km
Mean
Median
Mean: r=0.93, slope=5.43, p=0.002
Median: r=0.95, slope=6.61, p=0.001
1335
1512
752
321
297
153
62
Mean cloud thickness (km)
Aerosol Optical Thickness
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0.0
0.1
0.2
0.3
0.4
0.5