Dynamics and Morphology of Non-precipitating Marine Fair Weather Cumulus Clouds

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Introduction

Boundary layer marine fair weather cumulus clouds play an important role in the earth's radiation budget and are difficult to represent in Global Climate Models (GCMs) due to their small spatial scales and short life spans. The current deployment of the Atmospheric Radiation Measurement (ARM)'s Mobile Facility (AMF) on the island of Graciosa in the Azores gives a unique opportunity to sample these clouds. Nine cases of non-precipitating fair weather cumulus clouds totaling to 114 hours and covering 557 individual cloud elements are analyzed to develop climatology of dynamics and morphology of these clouds. Data from the vertically pointing W-band ARM Cloud Radar (WACR) are used along with that of other instruments. Statistics of cloud fraction and vertical velocity were developed as a function of height normalized by the maximum cloud top height and minimum cloud base height observed during each case.

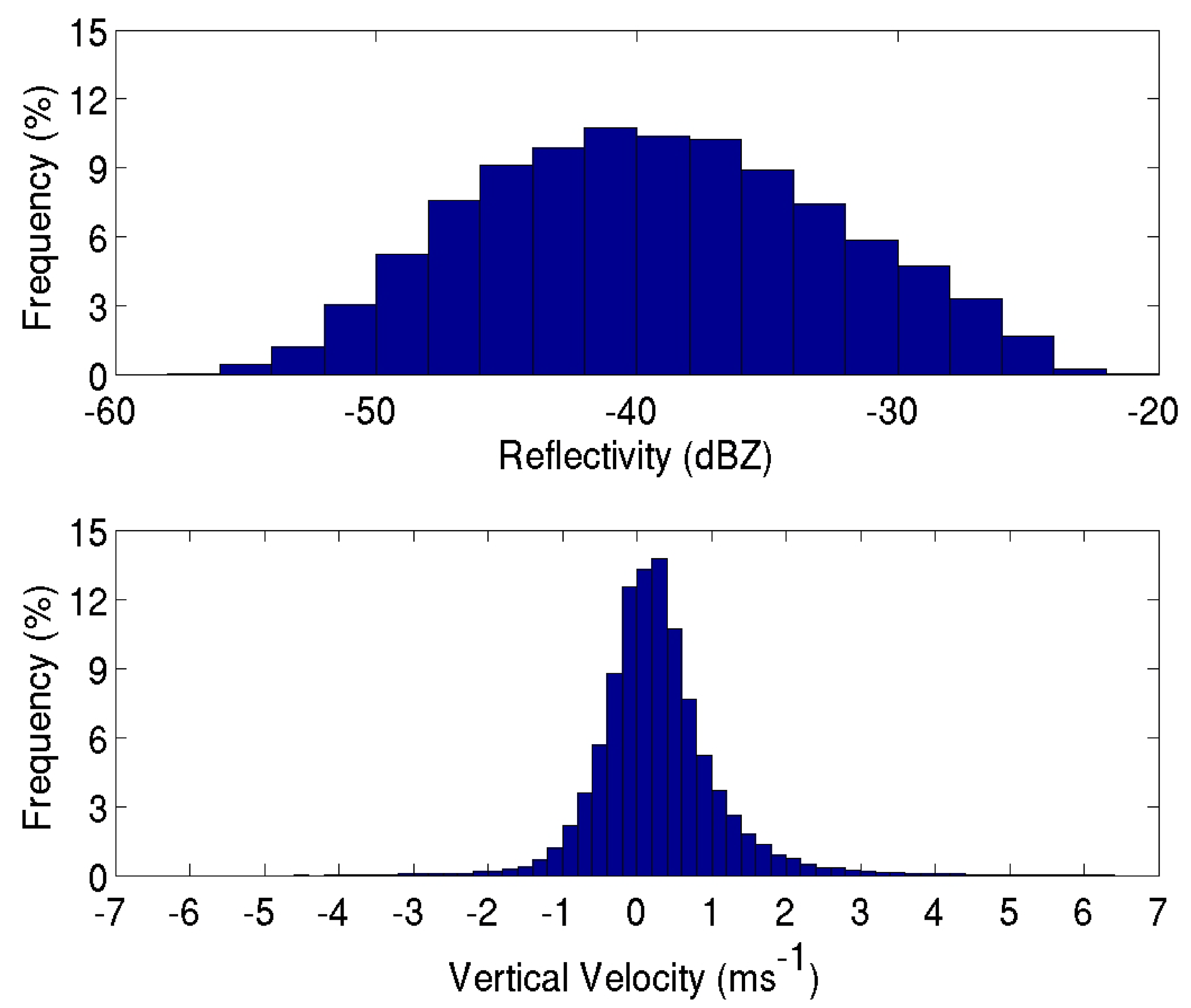

Figure 1: Histogram of reflectivity (top) and vertical velocity (bottom).

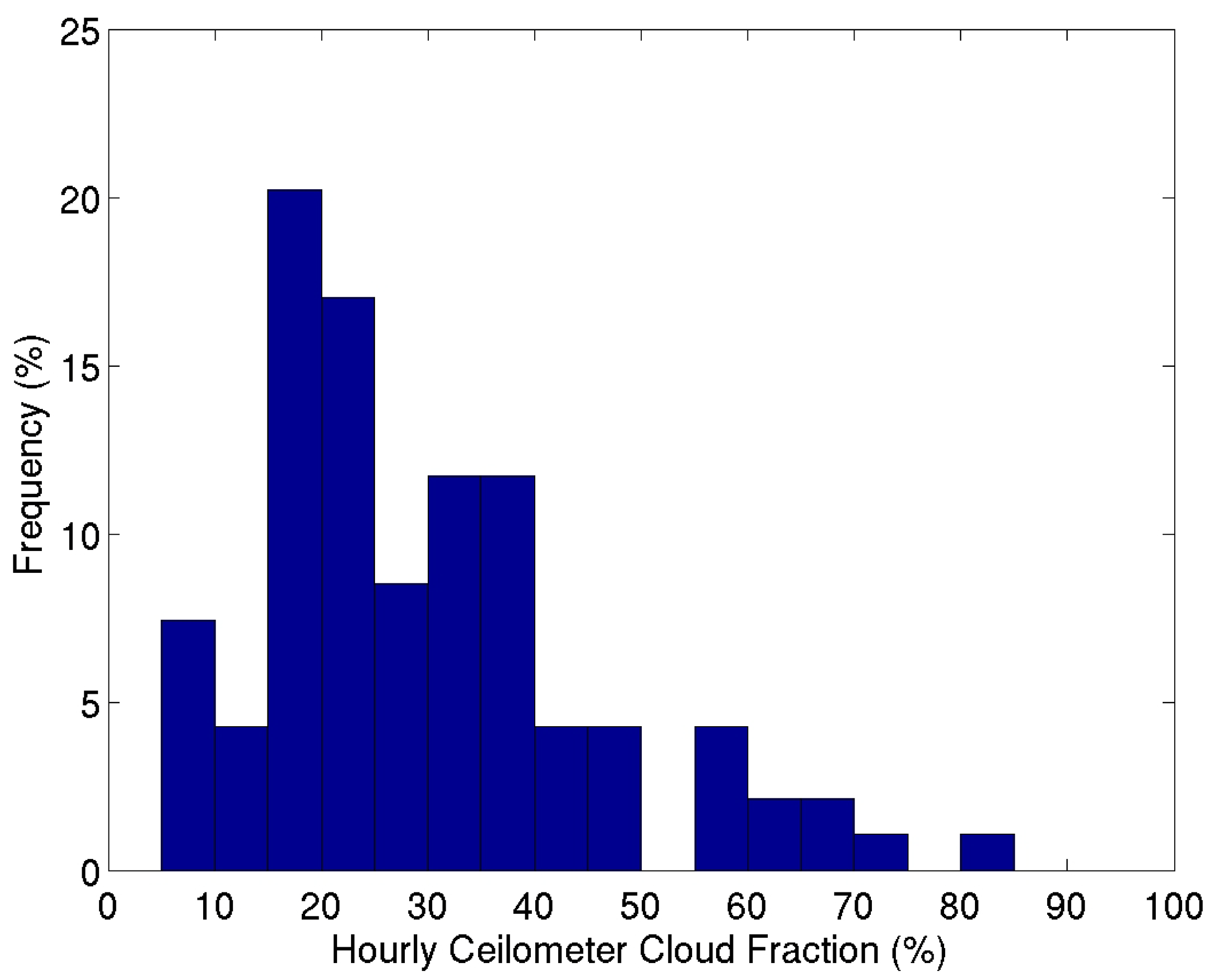

Figure 2: Histogram of ceilometer observed hourly cloud fraction. Hourly cloud fraction was less than 35% over 2/3rd of time.

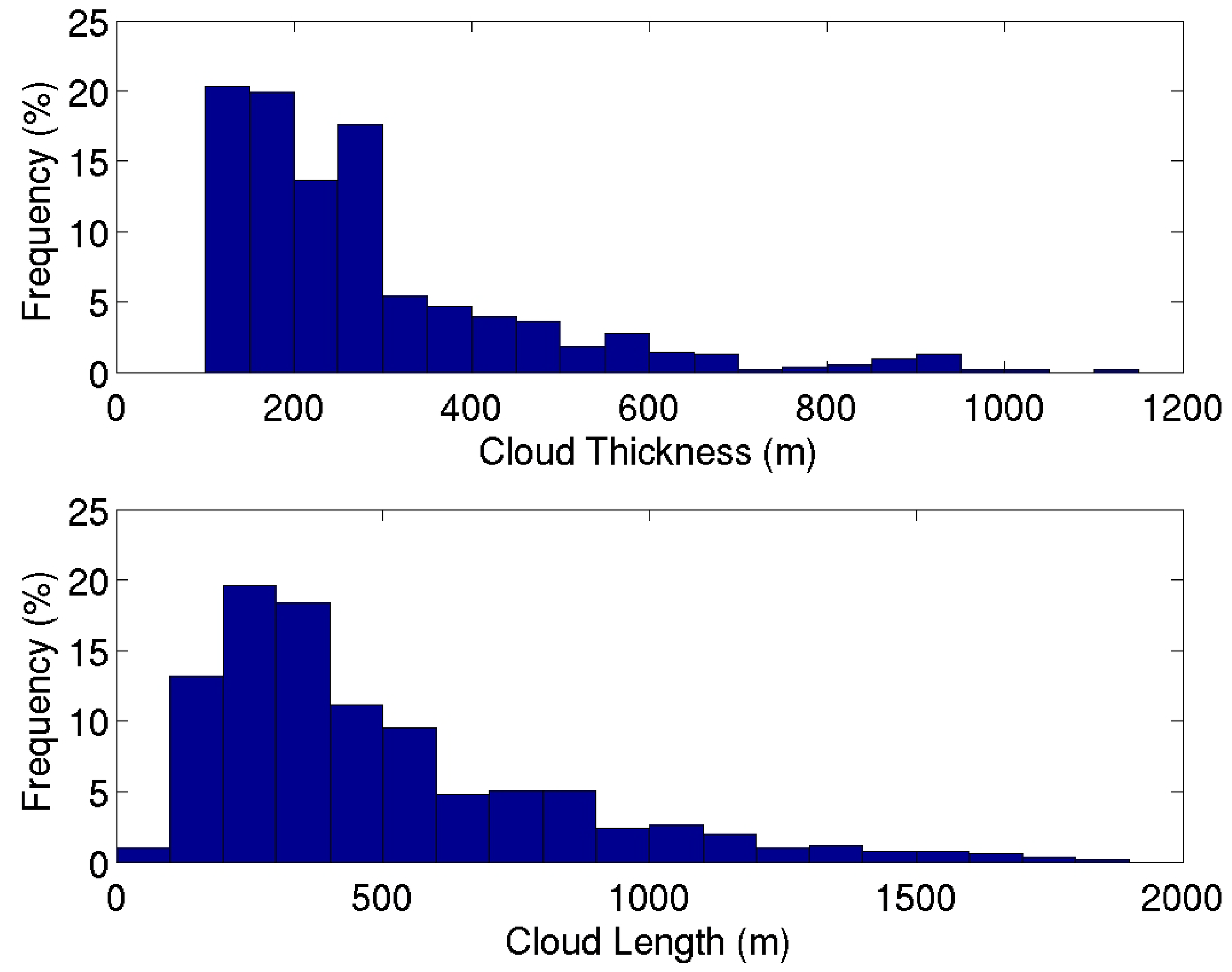

Figure 3: Frequency distribution of cloud thickness (top) and cloud chord length (bottom) from 557 cloud elements. About 40% of clouds have thickness less than 200 m, while a third of clouds have chords smaller than 300 m.

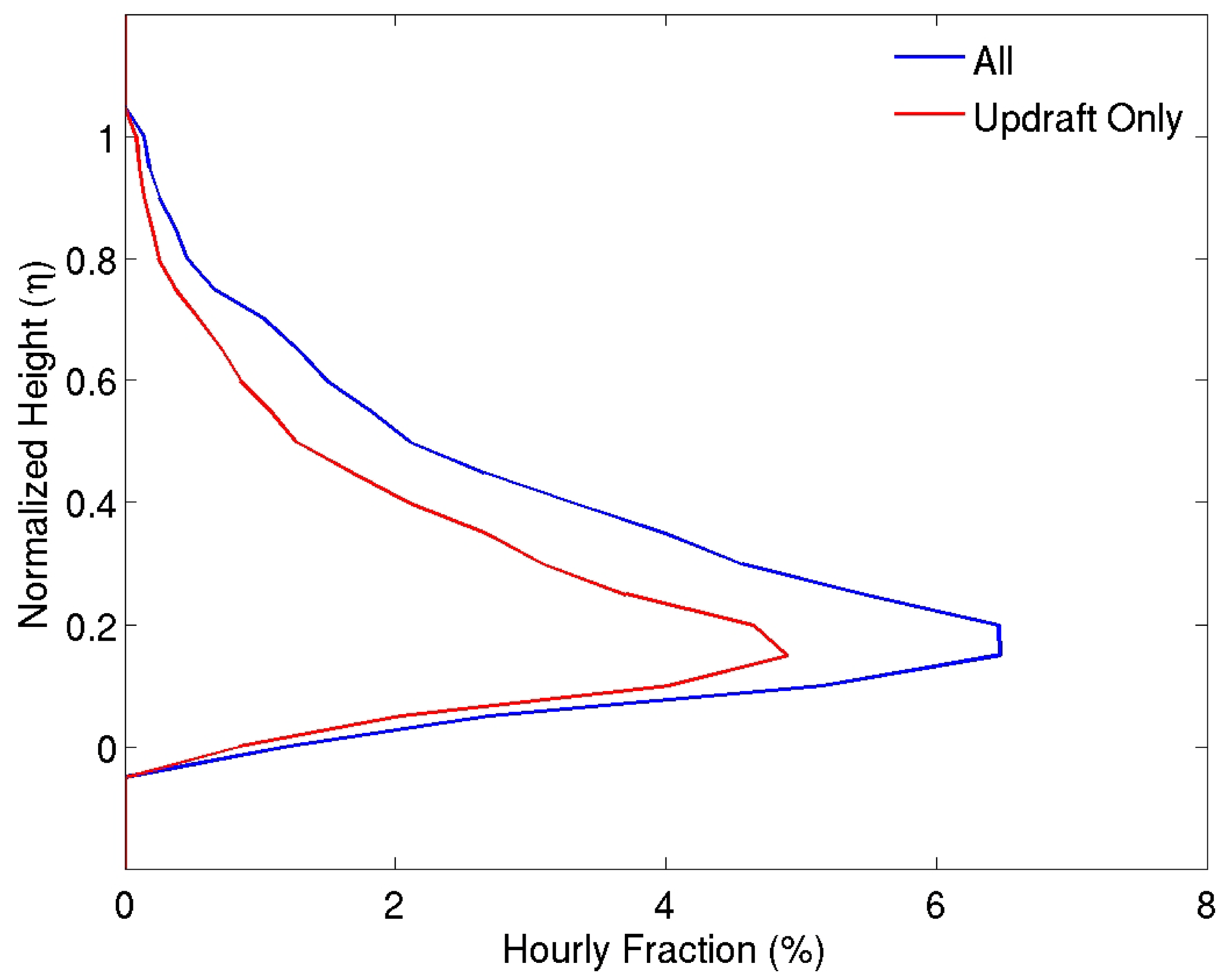

Figure 4: Vertical profile of hourly averaged cloud fraction from all in-cloud and updraft only samples.

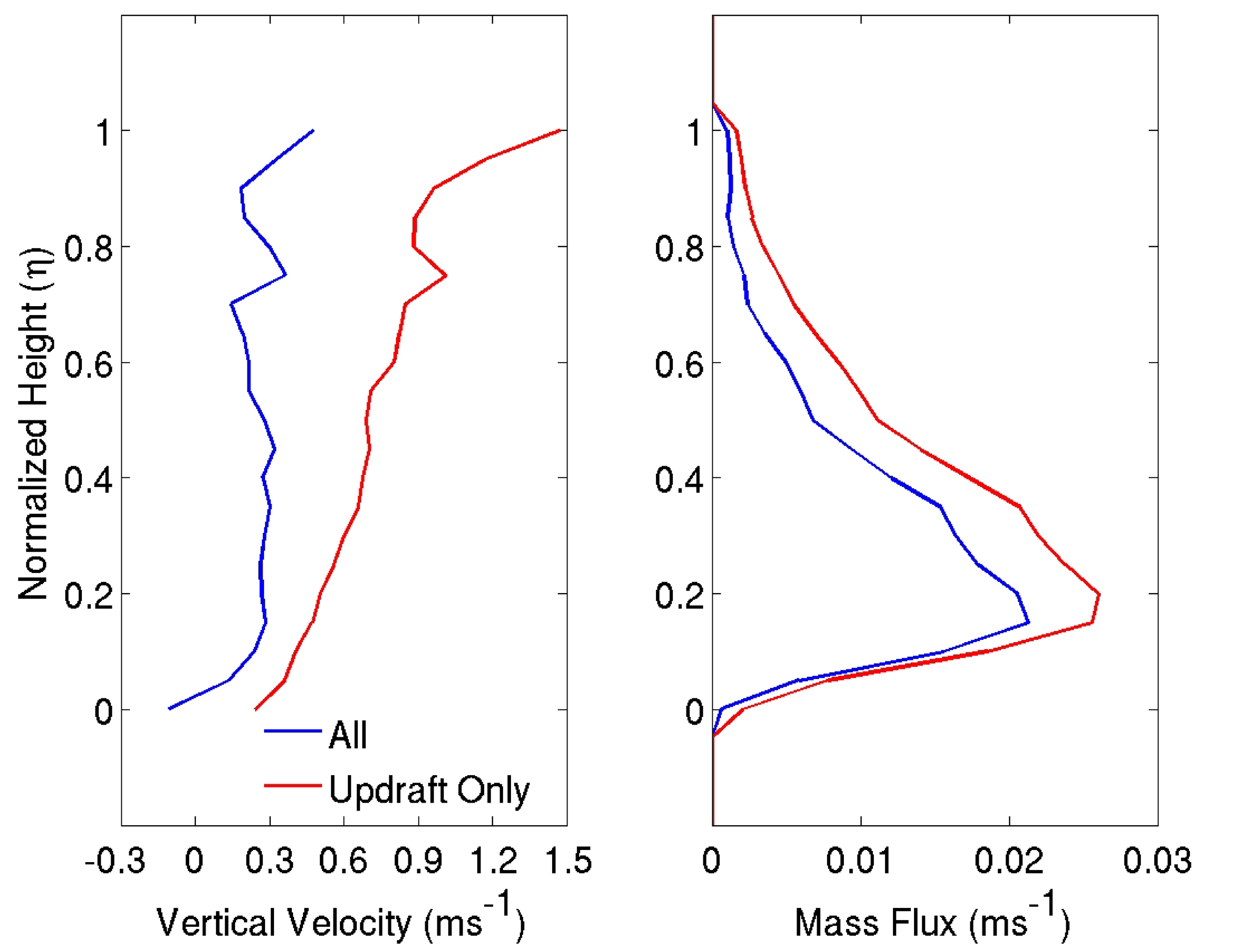

Figure 5: Hourly mean vertical velocity and mean hourly mass-flux from all in-cloud and updraft only samples.

Summary

Nine cases of marine fair weather cumulus clouds totaling to 114 hours and consisting of 557 individual cloud elements are analyzed to understand the dynamics and morphology of these clouds. The cloud averaged vertical velocity was almost a constant ~0.3 m/s in the entire cloud layer. Although the mean ceilometer observed hourly cloud fraction was ~25%, the mean cloud base fraction was ~7%. The averaged hourly updraft mass-flux near cloud base was 0.025 m/s and decreased rapidly from the cloud base until the middle of the cloud with a slower decrease above that. The vertically averaged mass-flux contribution of thin clouds to the total hourly mass-flux was about 1/10th of that contributed by thick clouds, highlighting the relatively major contribution of the thick clouds in the mass-flux budget. Future work will focus on understanding the role of these clouds in the radiation budget.

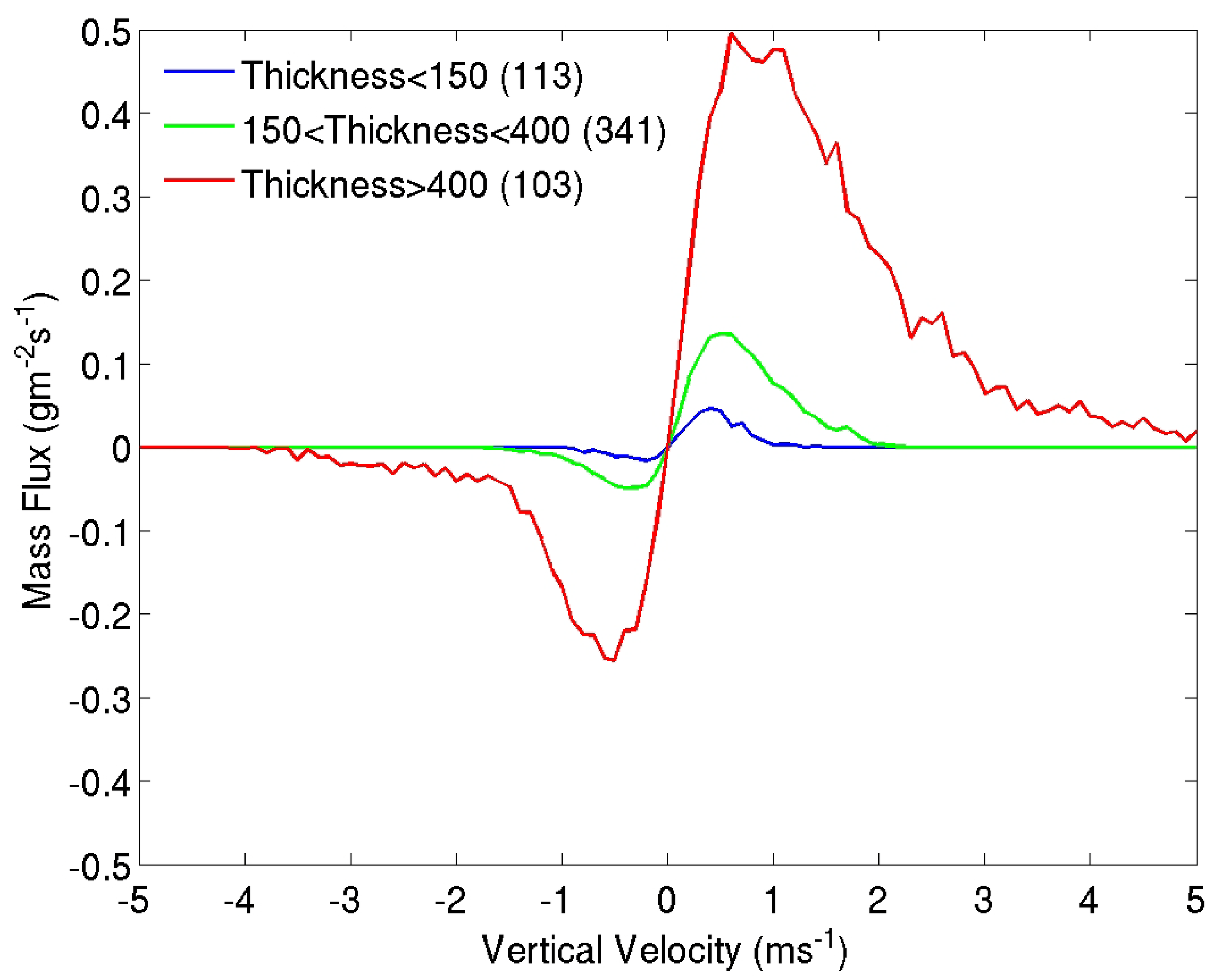

Figure 6: Vertically averaged mass-flux contribution of clouds to the hourly mass-flux as a function of vertical velocity for different cloud thickness. The numbers in parentheses correspond to the number of clouds in each category.

References:

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