Vertical Velocities in Continental Boundary Layer Stratocumulus Clouds

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Why BL Stratocumulus??

- Extensive Coverage
  - Cover ~24% of earth's surface
  - Persist of long time-scales

- Impact on radiation budget
  - High SW albedo compared to land or ocean

Klein and Hartmann 1993

But Why Continental Clouds?

- They do exist
  - Monthly cloud fraction can vary from 10% to 23%
- Impact on pollution & Diurnal Cycle
  - Affect pollutant venting out of BL & Aerosol processing by clouds
- Variety of conditions
  - Useful to evaluate LES models and GCM parameterizations

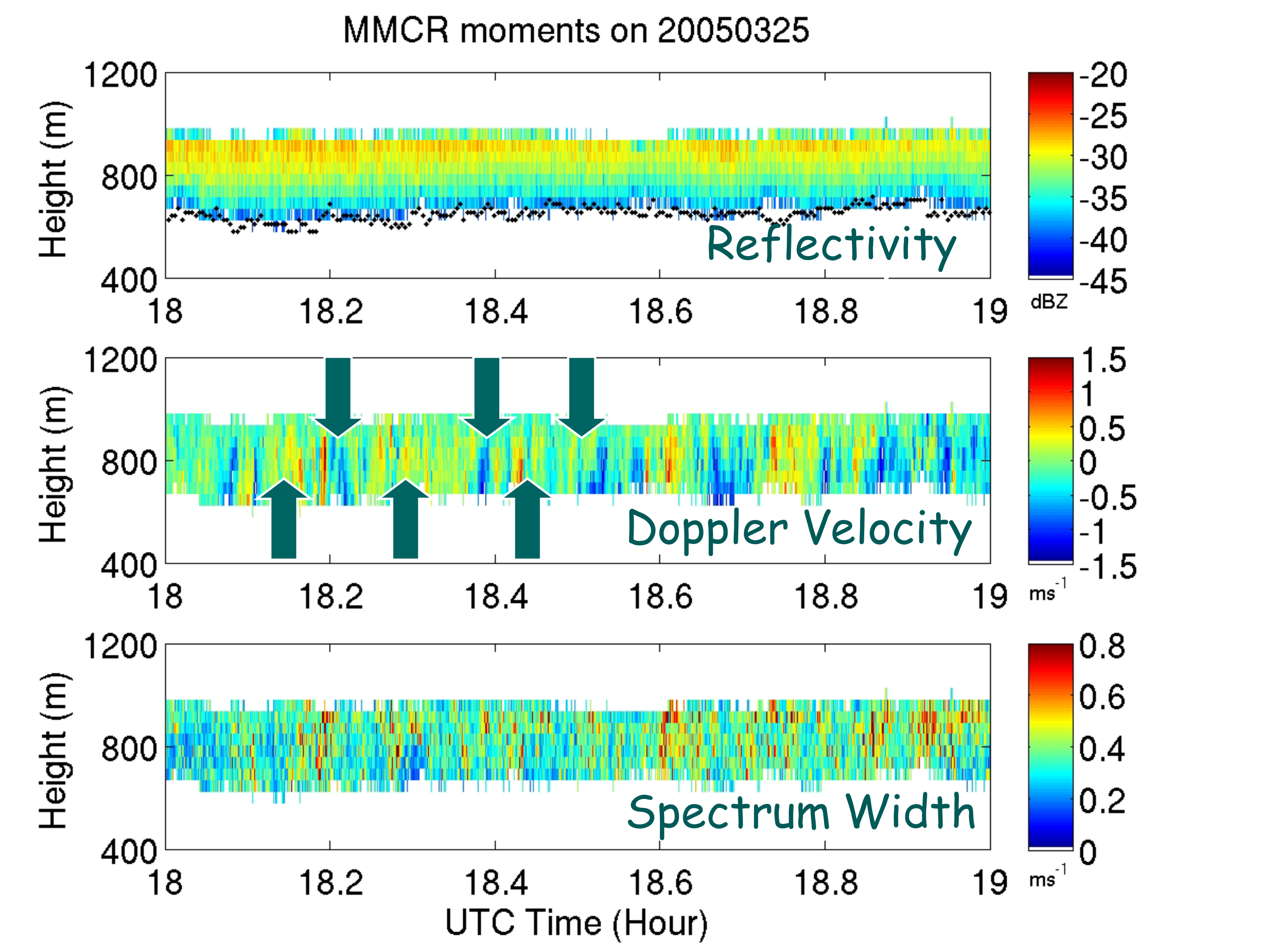
Slingo et al. 2004; Kollias et al. (2007)

Need of Vertical Velocity (w)

- LES model inter-comparisons and evaluations are based on simulated w pdf.
- Variance, Skewness, updraft fraction etc. are used in GCM Scu parameterizations.
- Correct simulation of strong updrafts/downdrafts in microphysical models

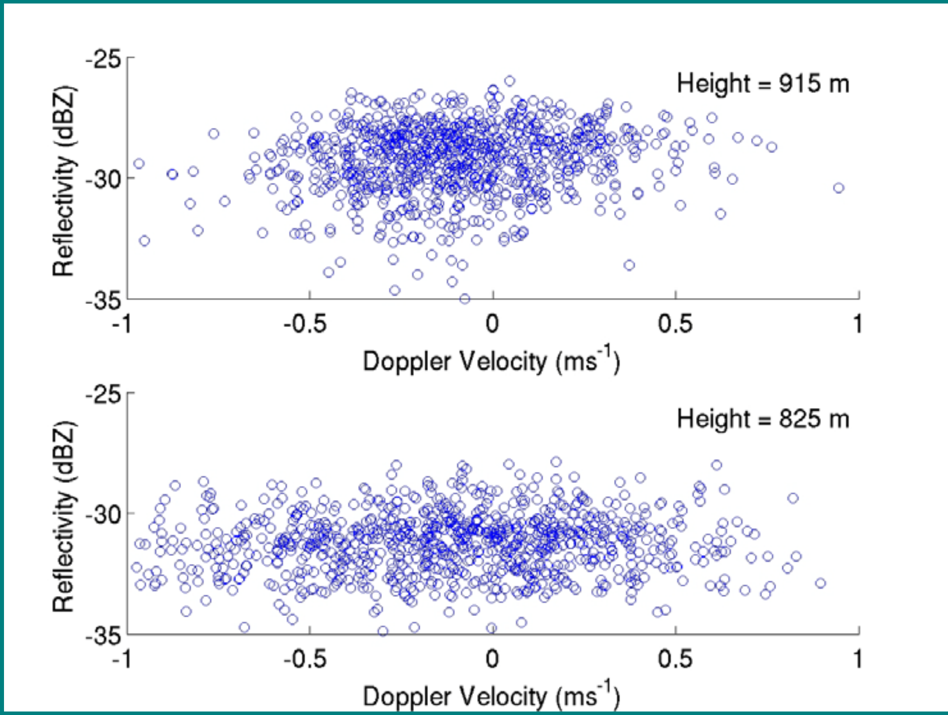
Zhu and Zuidema 2009; Golaz et al. 2005

Vertical Velocity retrieval technique



Vertical Velocity retrieval technique

- Absence of any precipitation size drops. (dBZ<-20)
- Doppler velocity can be used as a surrogate for vertical velocity.



Frisch et al. (1995); Kollias and Albrecht (2000)

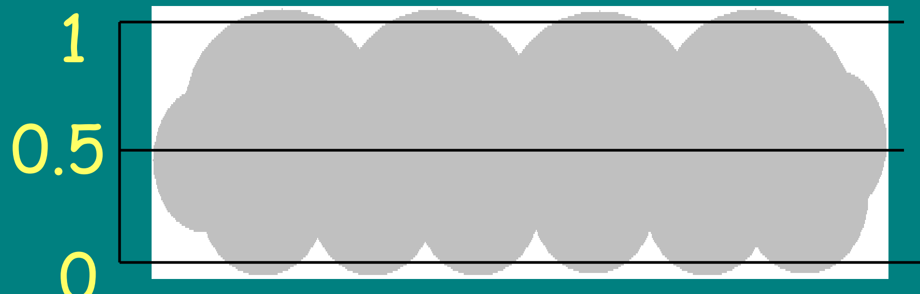
Cases of stratocumulus clouds at SGP site show high variability

Date	Duration (Hour)	LWP (gm^{-2})	Buoyancy Flux (Wm^{-2})	WSpd (ms^{-1})	Cloud Thick (m)
20050219	4	151	-12	7.06	390
20050221	9	113	55	2.67	308
20050323	6	108	68	1.64	240
20050325	10	109	64	5.34	267
20050326	8	106	-2	4.25	222
20060109	9	105	42	7.17	276
20060408	9	164	-6	9.40	356
20060506	6	166	-	4.31	455
20060912	5	162	60	4.52	291
20061021	6	160	51	9.15	301
20070426	5	160	22	6.47	349

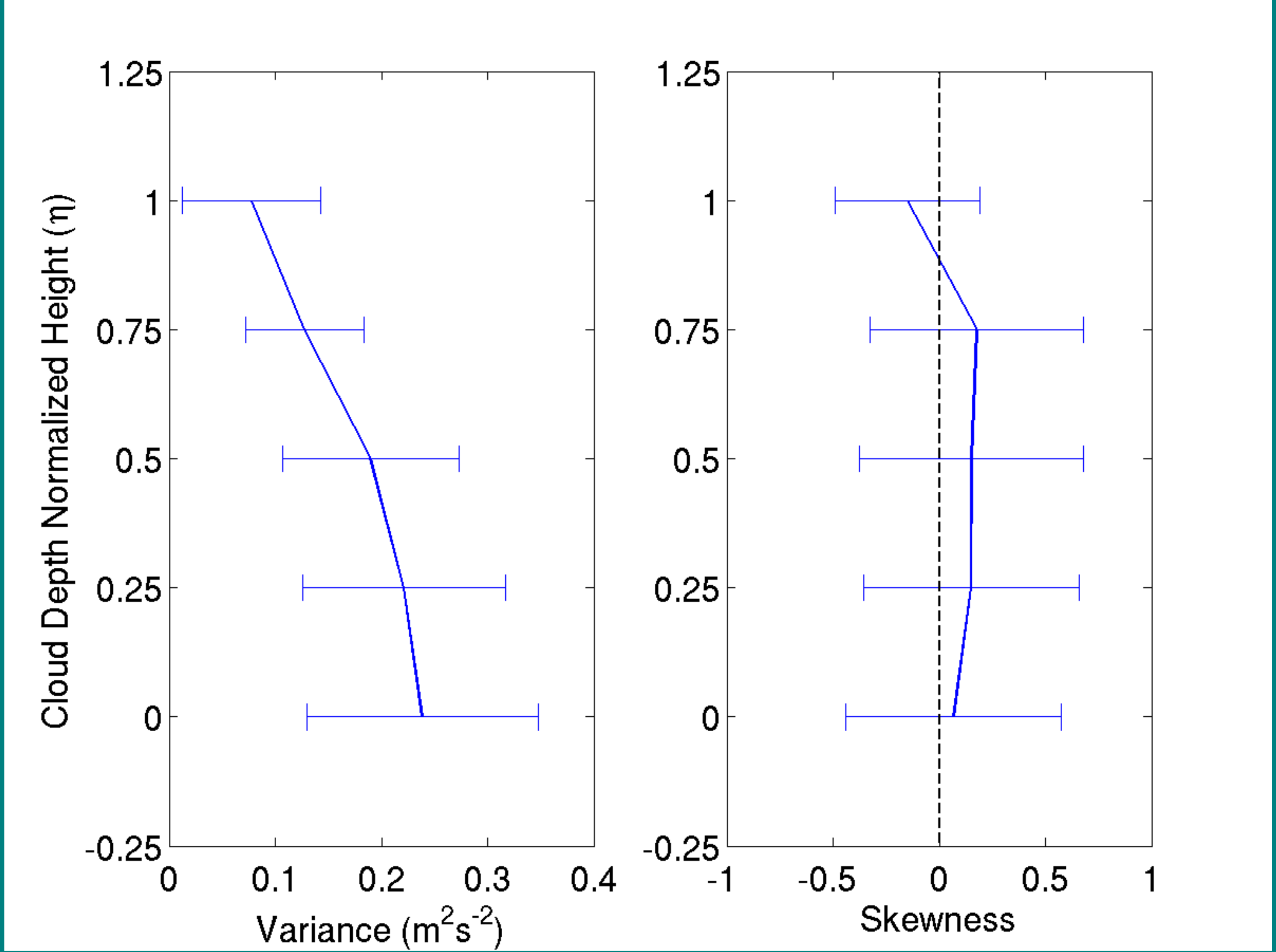
Processing Strategy

- Use high resolution (4 sec; ~45X20 m) MMCR-BL observations.
- Normalize by cloud depth.

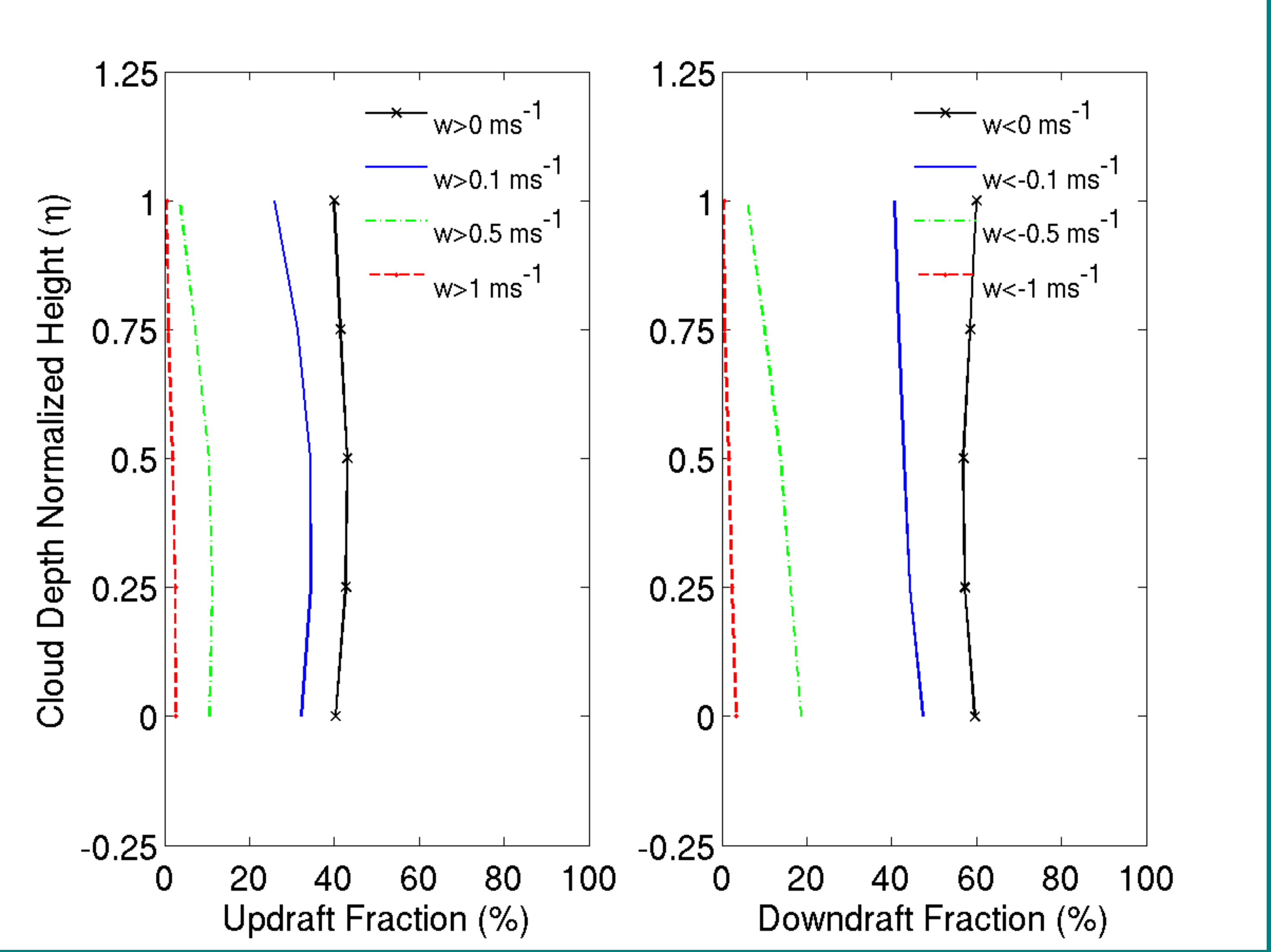
$$\eta = \frac{Z - Z_{base}}{Z_{top} - Z_{base}}$$



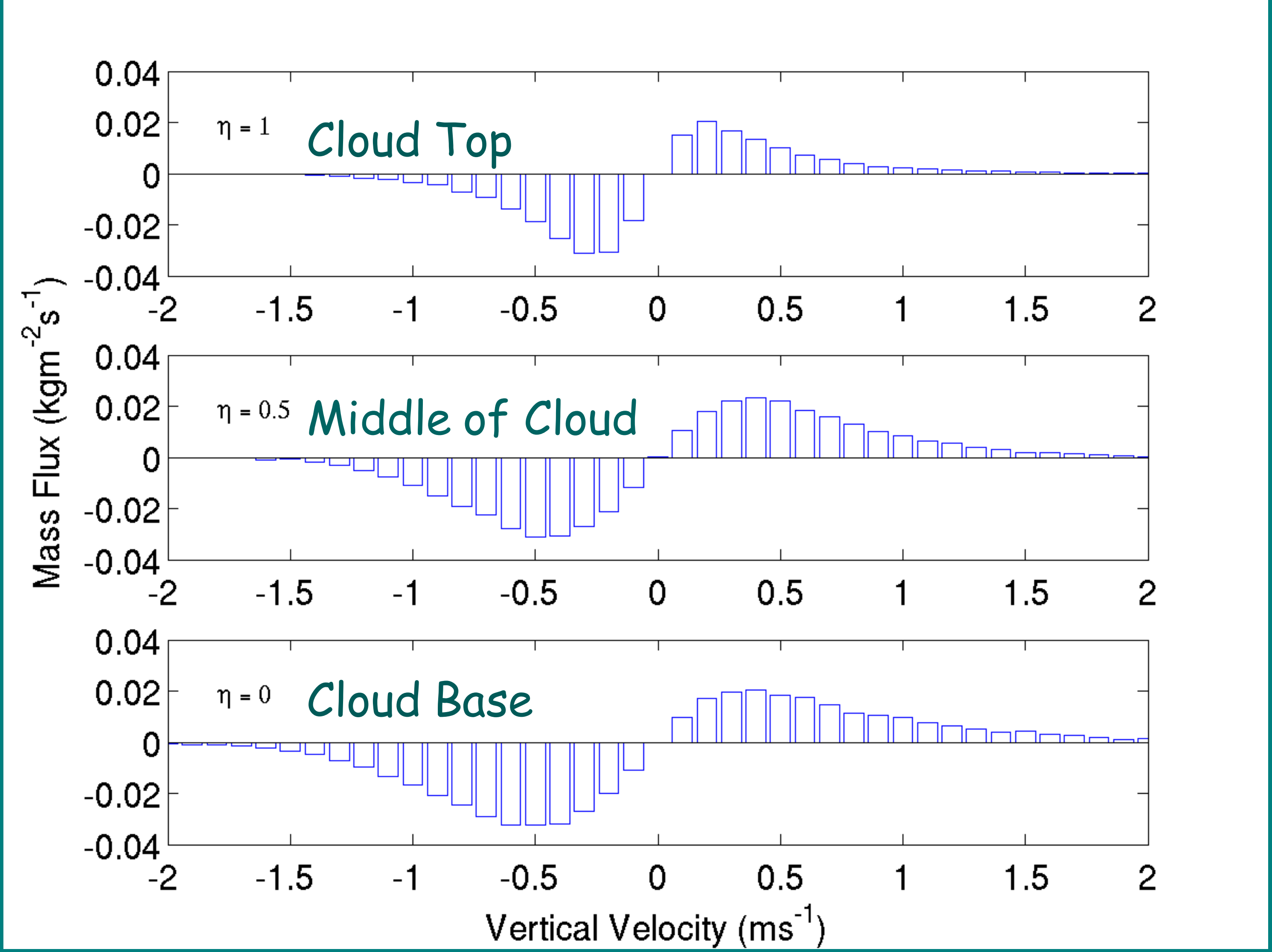
- Calculate vertical velocity variance, skewness, updraft fraction etc. for 30 min periods. (~141 periods)
- Divide the half hour periods using some criteria and study changes in the parameters.



- Decrease in variance with increase in height.
- Positive skewness in the cloud layer except at cloud top.



- Number of updrafts decrease with increase in height
- Number of downdrafts increase with decrease in height



Mass Flux $$F = \sigma \times (w - \overline{w})$$

σ = Velocity Fraction of w

w = Vertical Velocity

Classification Criteria

- Surface Buoyancy Flux
  - Clouds are surface forced
- Percent of BL occupied by the cloud
  - Radar sampling issues
- In-cloud vertical velocity variance
  - Impact on collision-coalescence process
- In-cloud vertical velocity skewness
  - Dependence on aerosol activation

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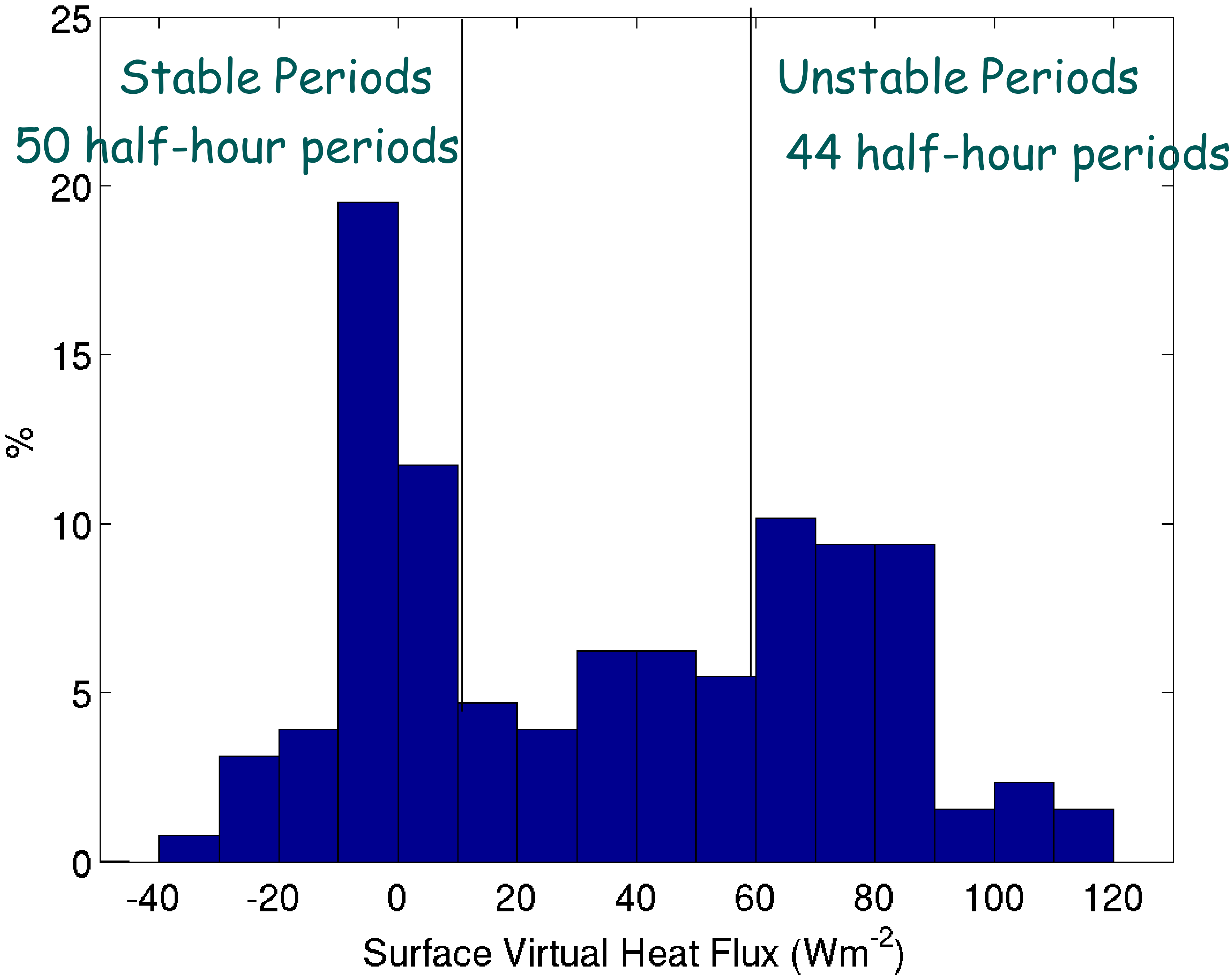
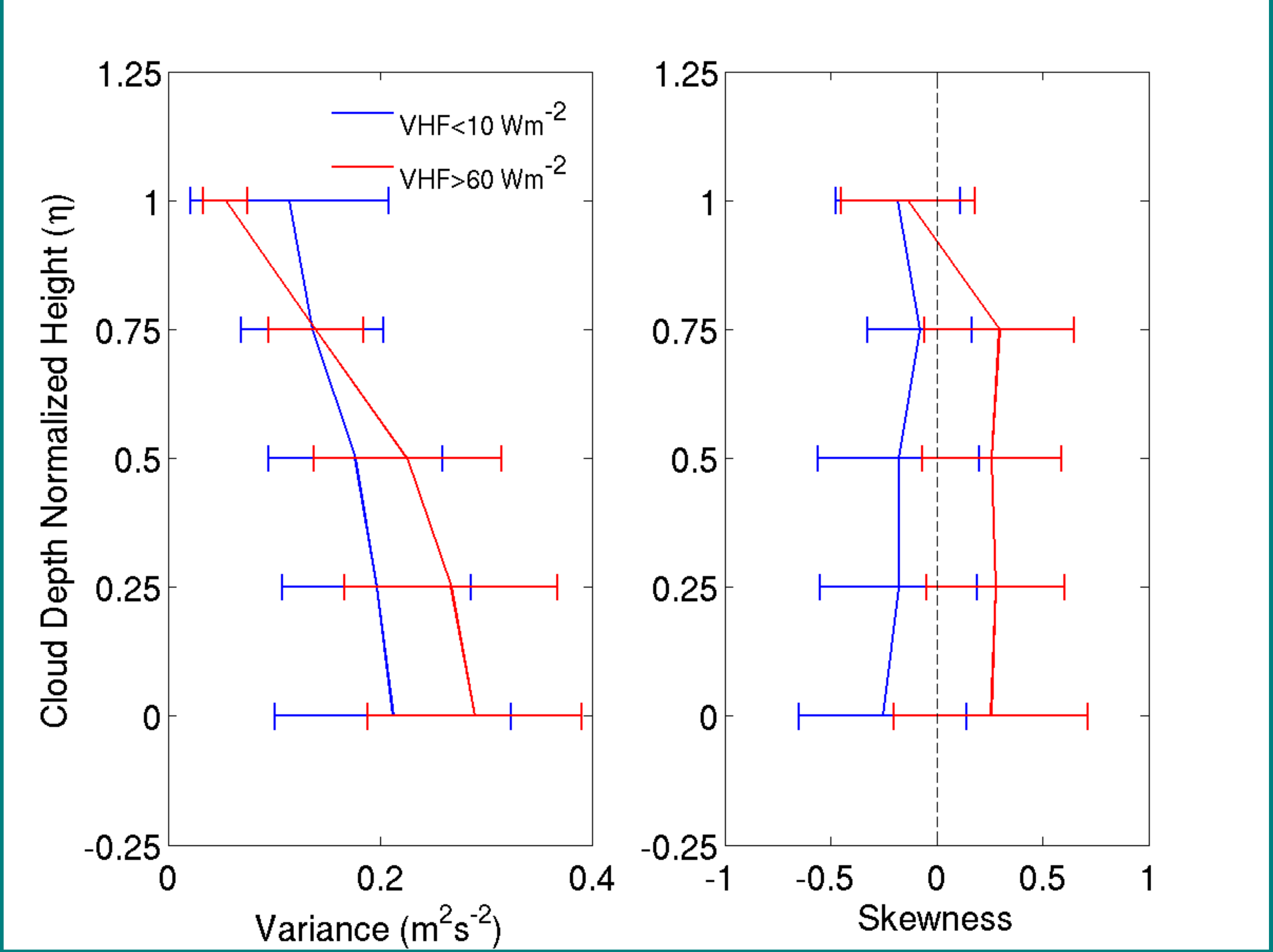
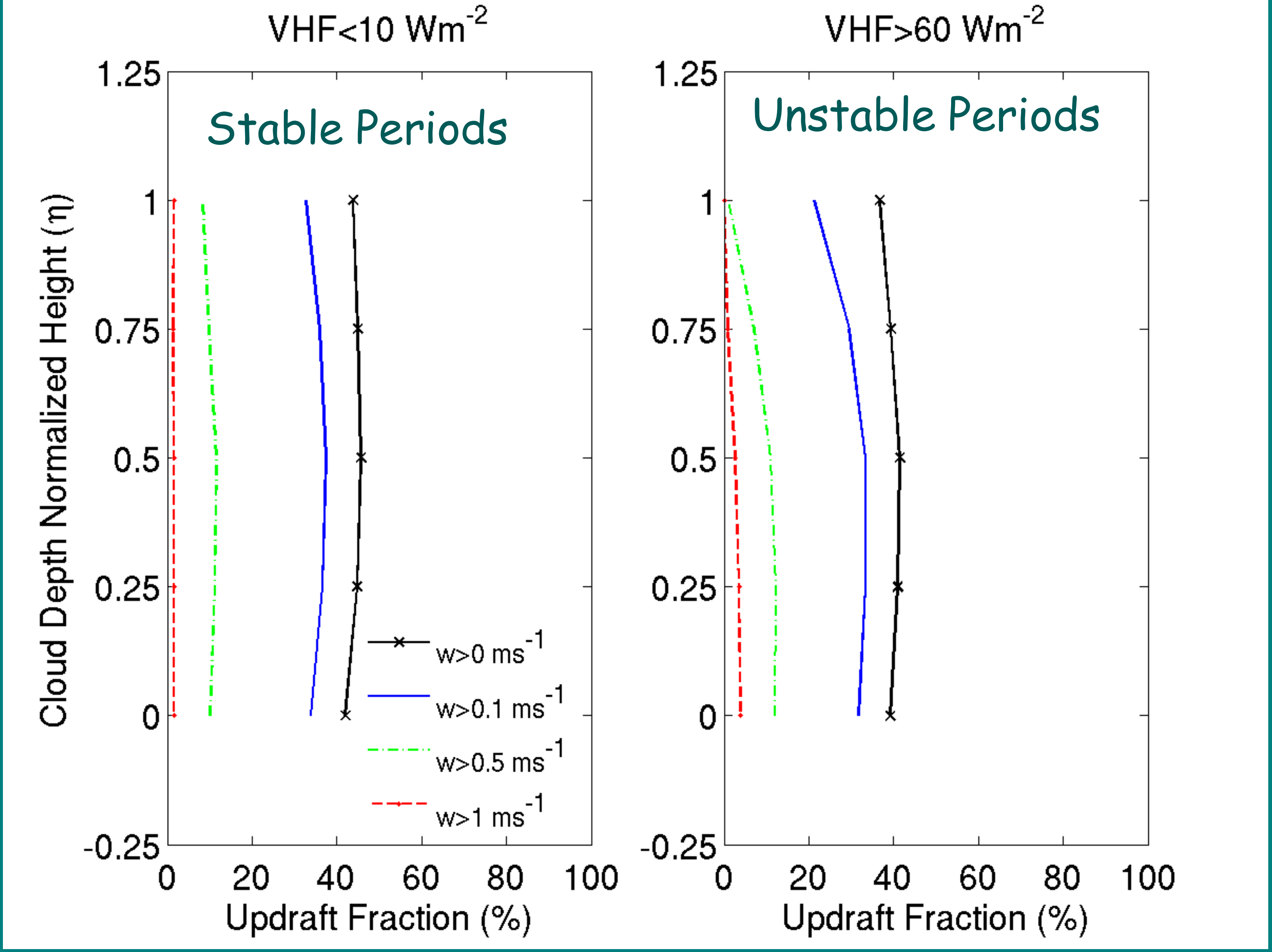


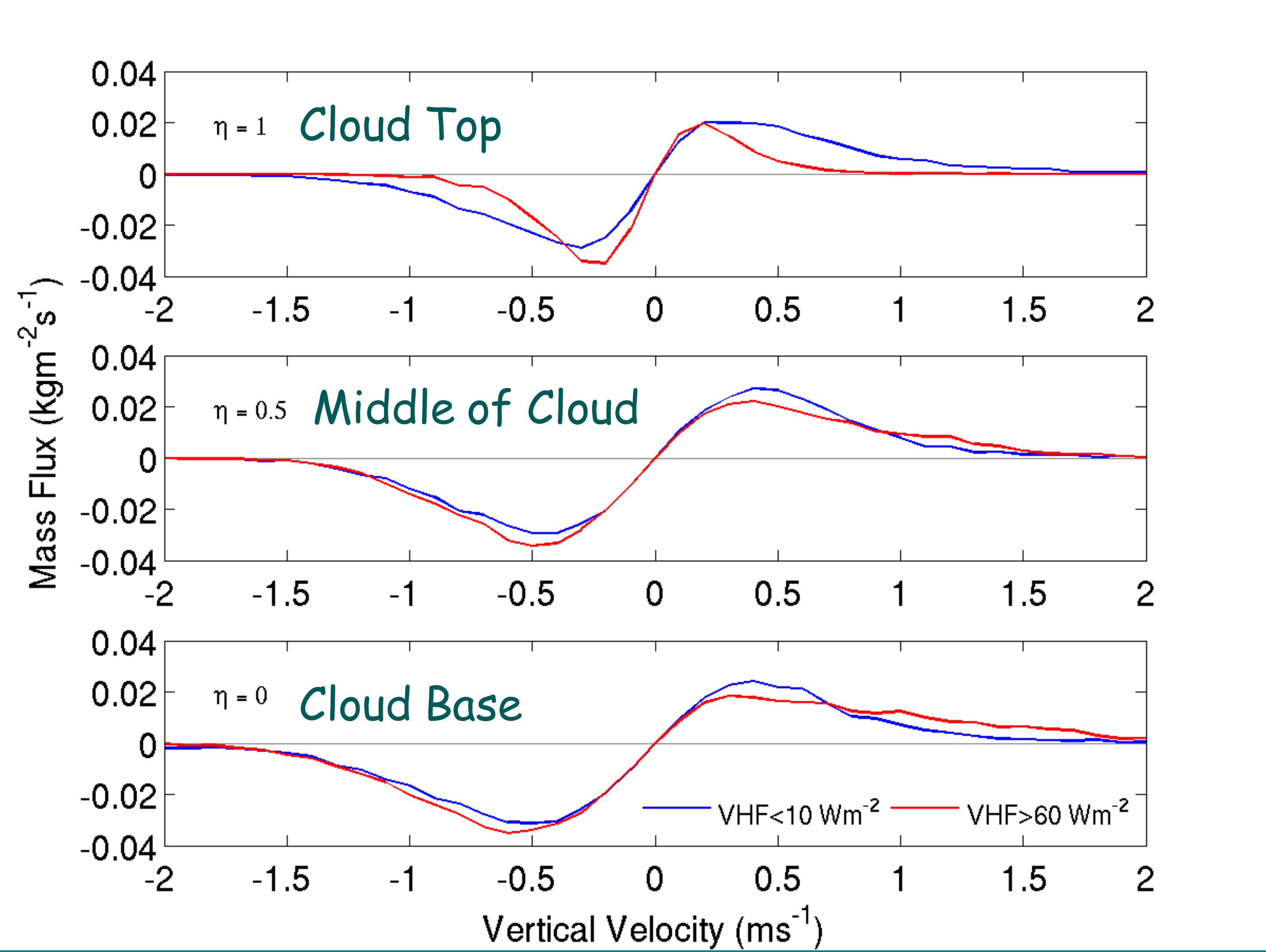
Stable Periods
50 half-hour periods
Unstable Periods
44 half-hour periods
%
25
20
15
10
5
0
-40
-20
0
20
40
60
80
100
120
Surface Virtual Heat Flux (Wm-2)



- Comparatively more variance near cloud top in stable periods.
- Skewness near cloud top is negative in both scenarios.



- Almost constant updraft fraction in stable periods.
- More updrafts near cloud top in stable periods compared to unstable periods.



- Longer tail of updraft mass-flux as compared to downdraft mass-flux.
- Higher mass-flux near cloud top in stable periods as compared to unstable cases.

Summary

- Use cloud radar to study in-cloud vertical velocity structure.
- Updrafts get weaker, while downdrafts get stronger with height.
- Higher updraft mass-flux near cloud top during stable periods compared to unstable periods.