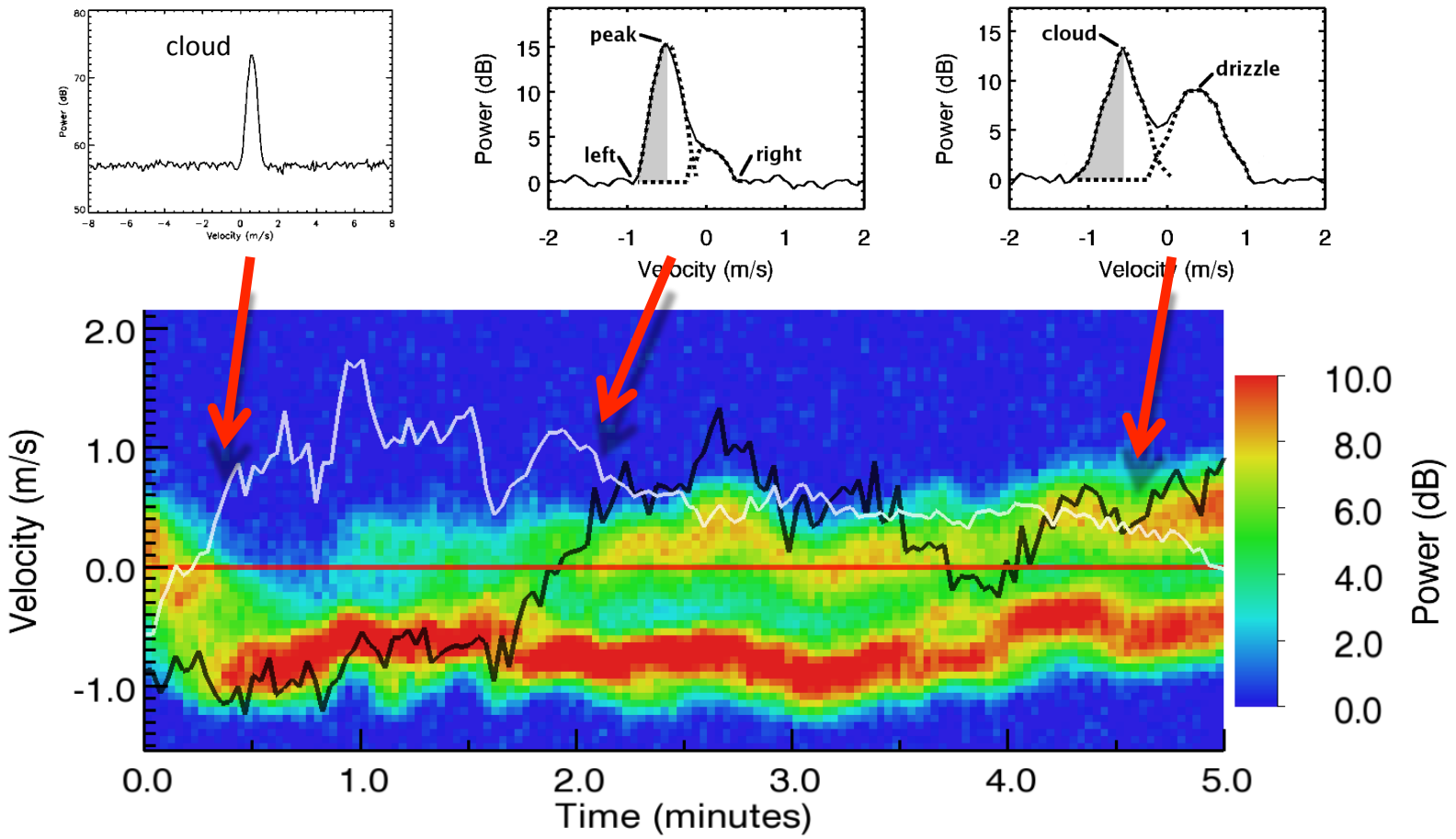
Progress Report on
Cloud and Drizzle Retrievals in the Azores

Edward Luke - BNL
Pavlos Kollias, Wanda Szyrmer - McGill University

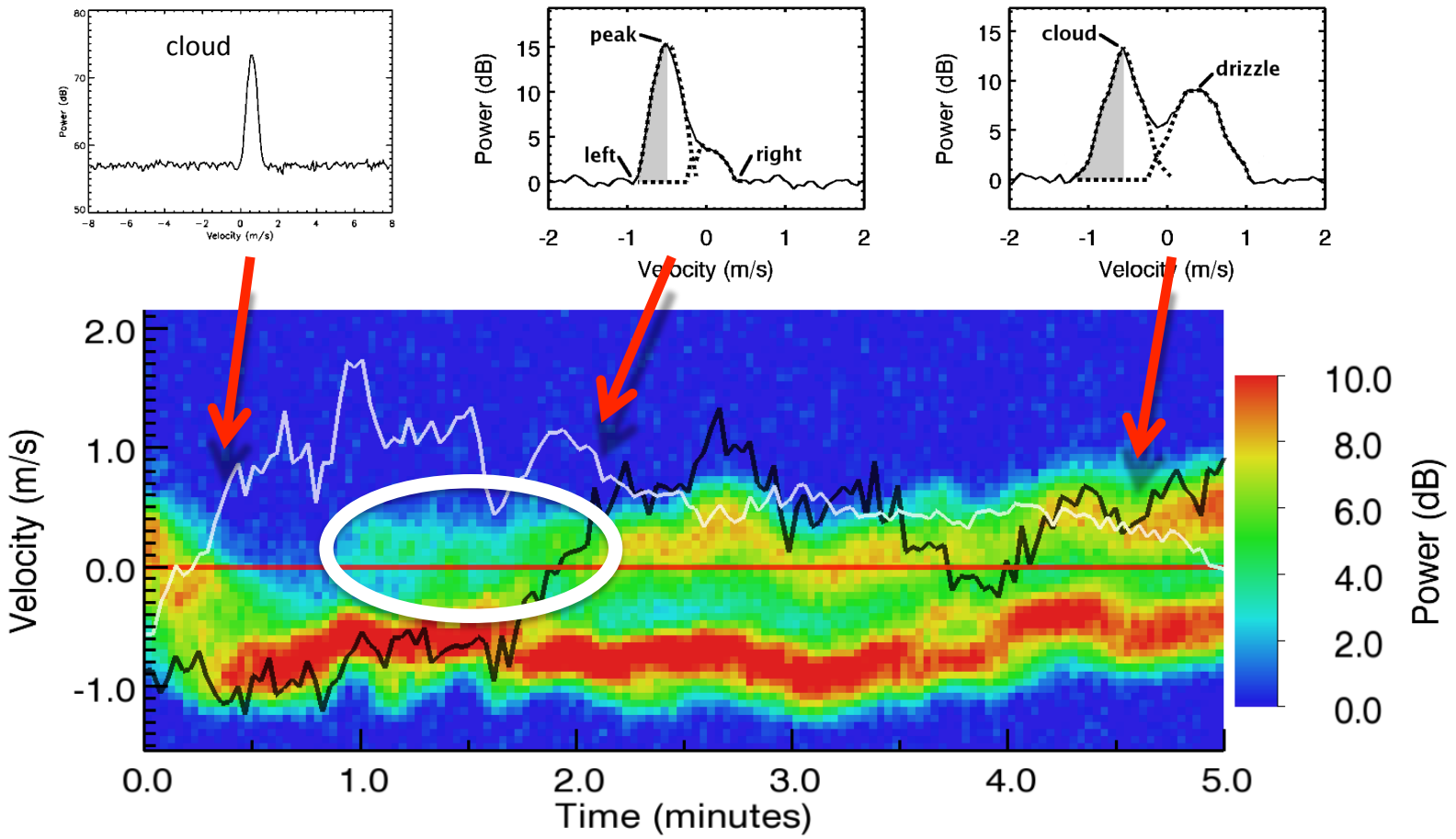
CAP-MBL Breakout Session
2012 ASR Science Team Meeting
March 13, 2012
Arlington, VA

Radar time-spectrogram (color) of lightly drizzling cloud



- Bright red trace is a cloud echo in an updraft, ~0.7m/s.
- Weak drizzle echo begins at 1 min., increasing to near cloud strength.
- Increase in total reflectivity (black) supports microphysical growth.

Radar time-spectrogram (color) of lightly drizzling cloud



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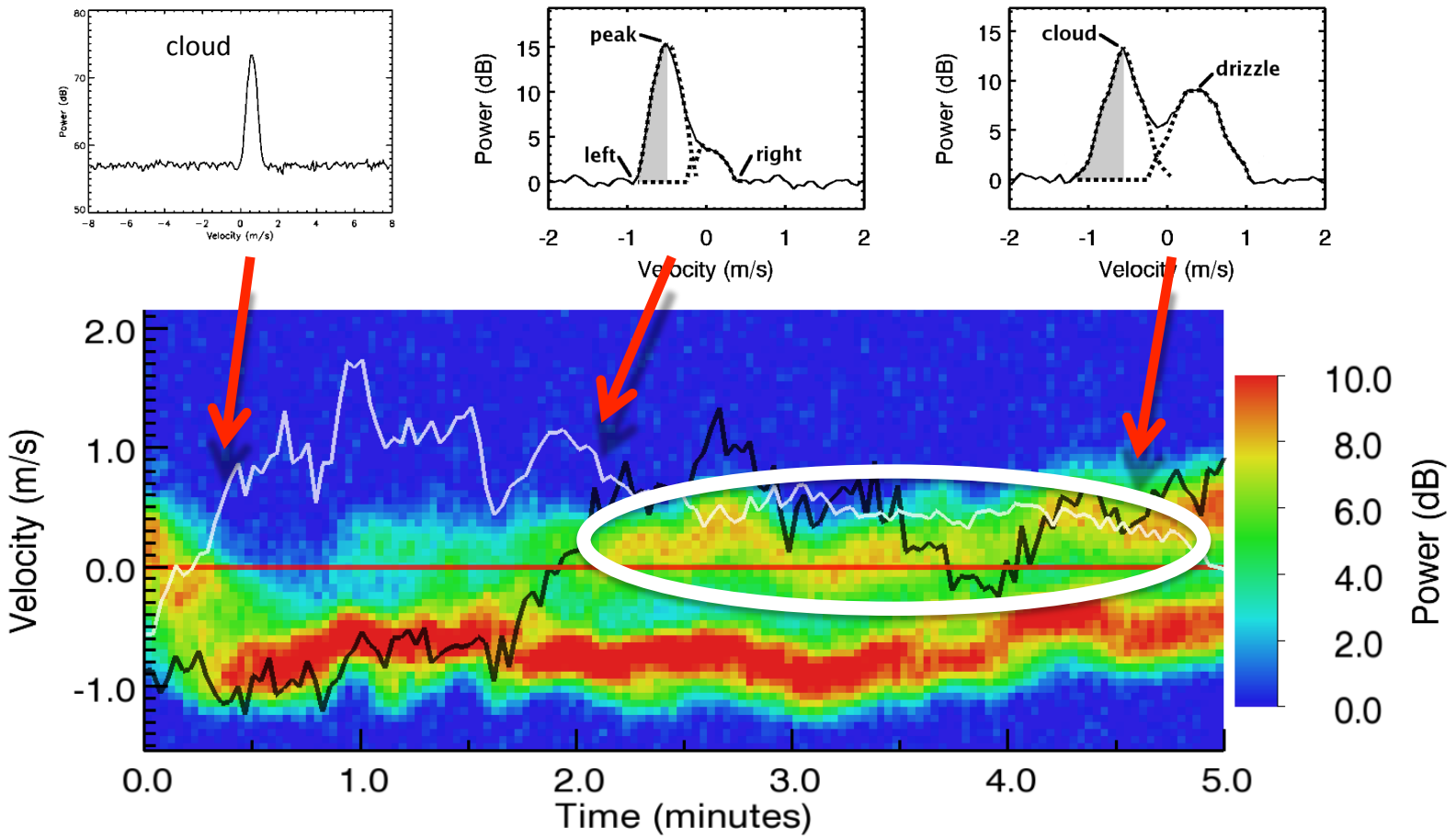

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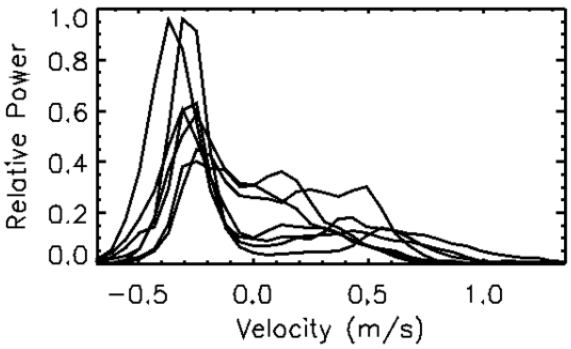
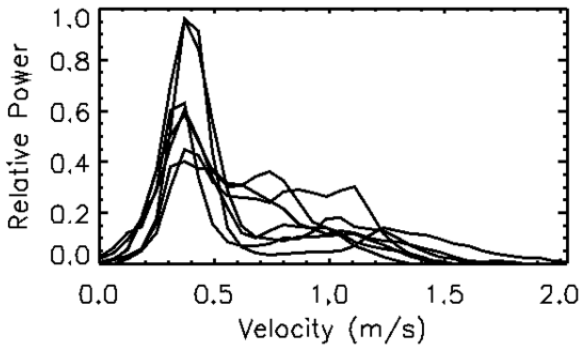
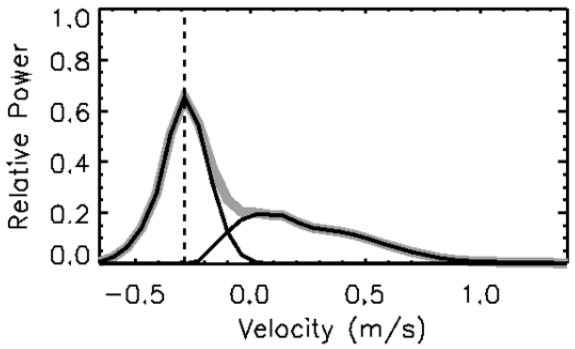
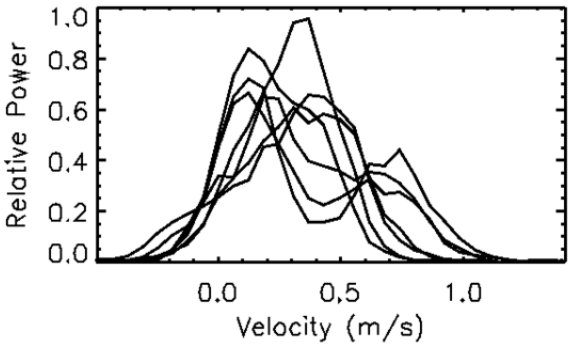
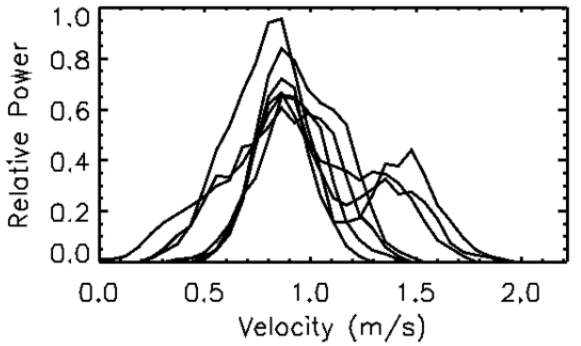
Spectrum alignment, averaging, and decomposition

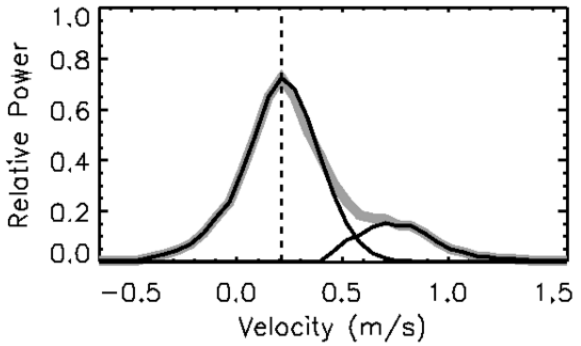


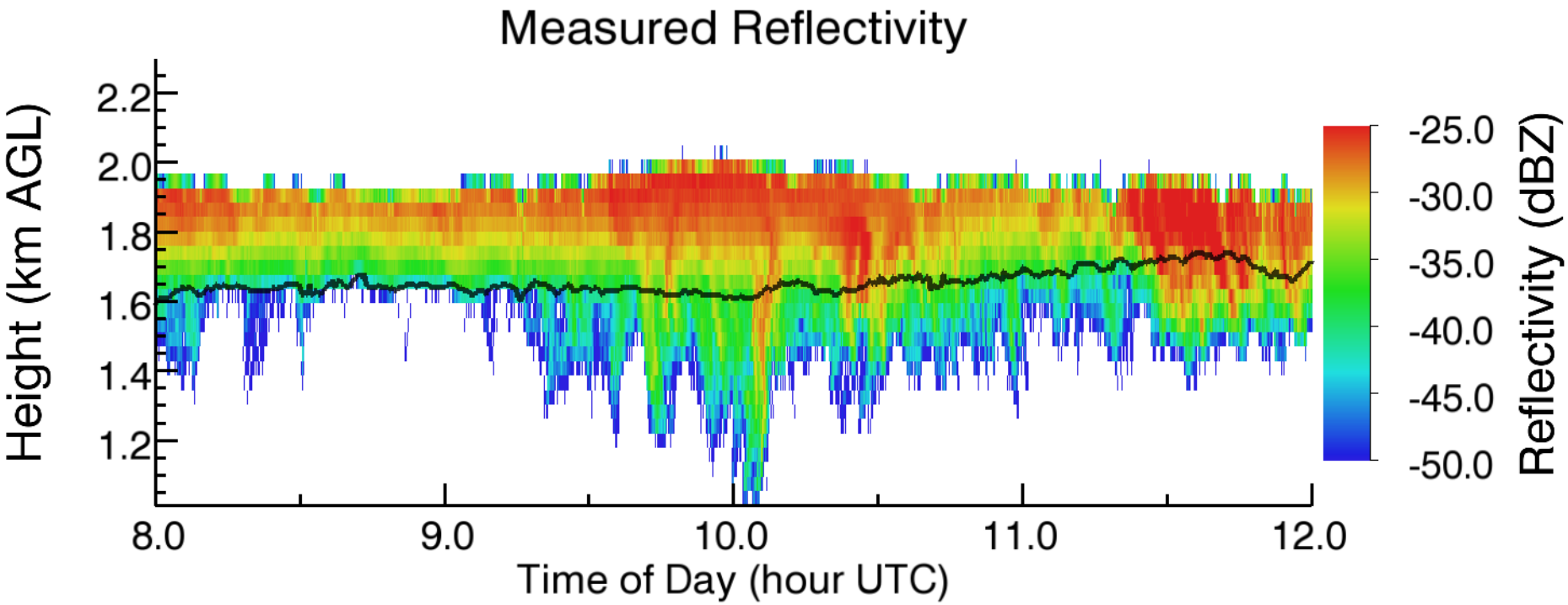




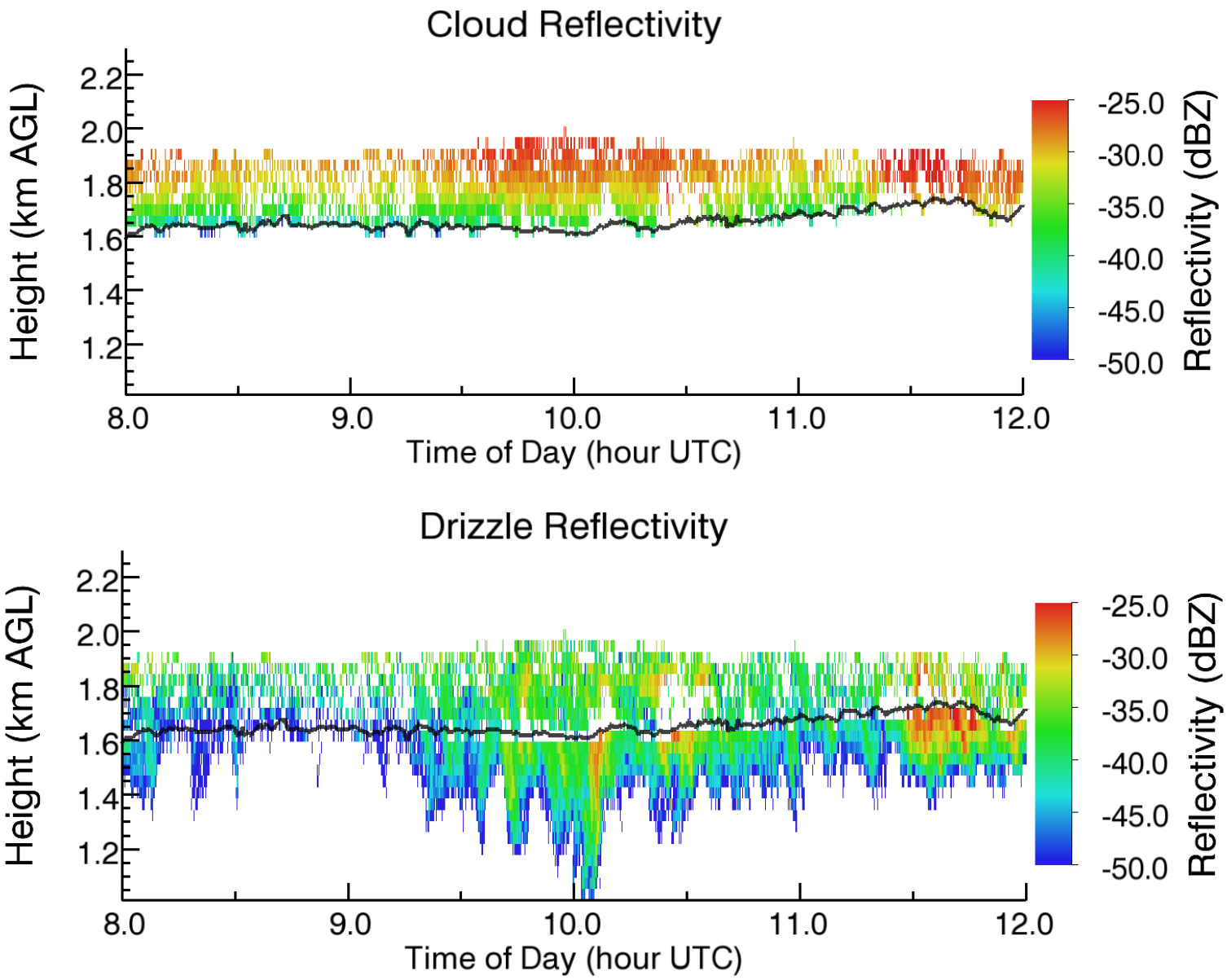




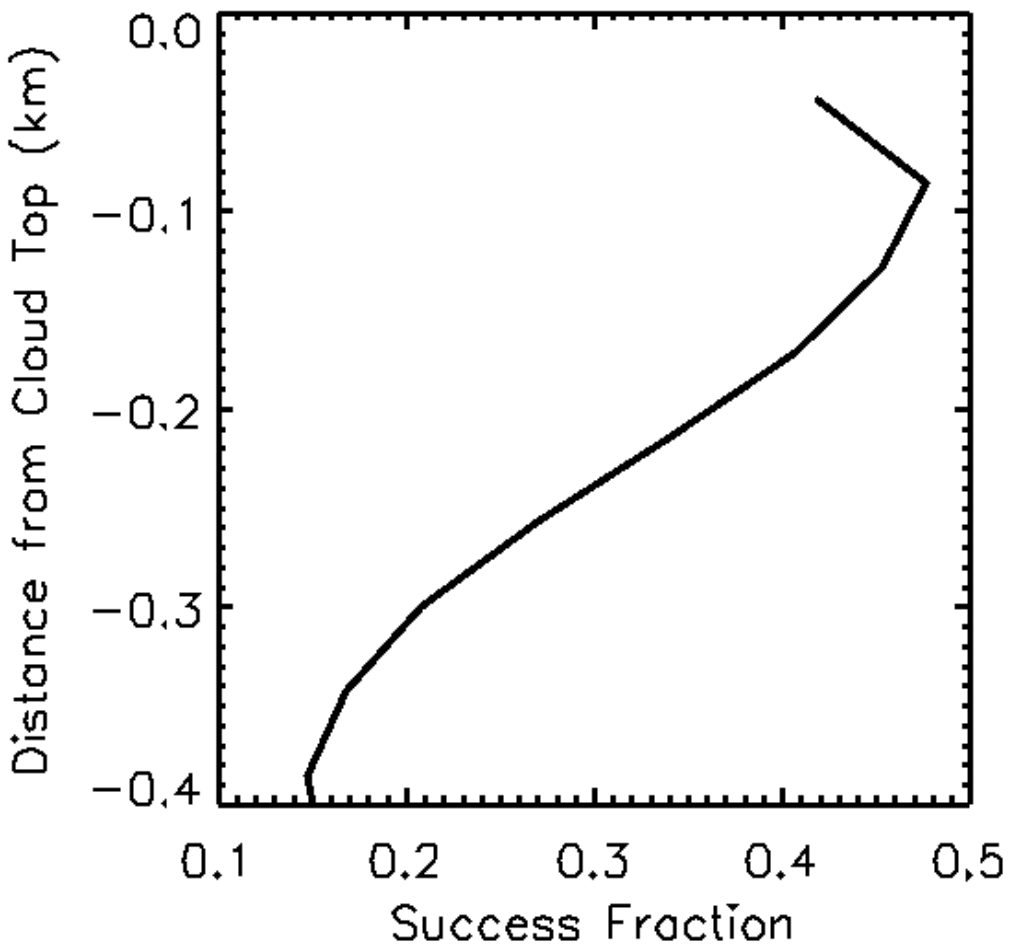



Measured Reflectivity
Height (km AGL)
2.2
2.0
1.8
1.6
1.4
1.2
8.0
9.0
10.0
11.0
12.0
Time of Day (hour UTC)
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
Reflectivity (dBZ)

Retrievals of cloud and drizzle reflectivity

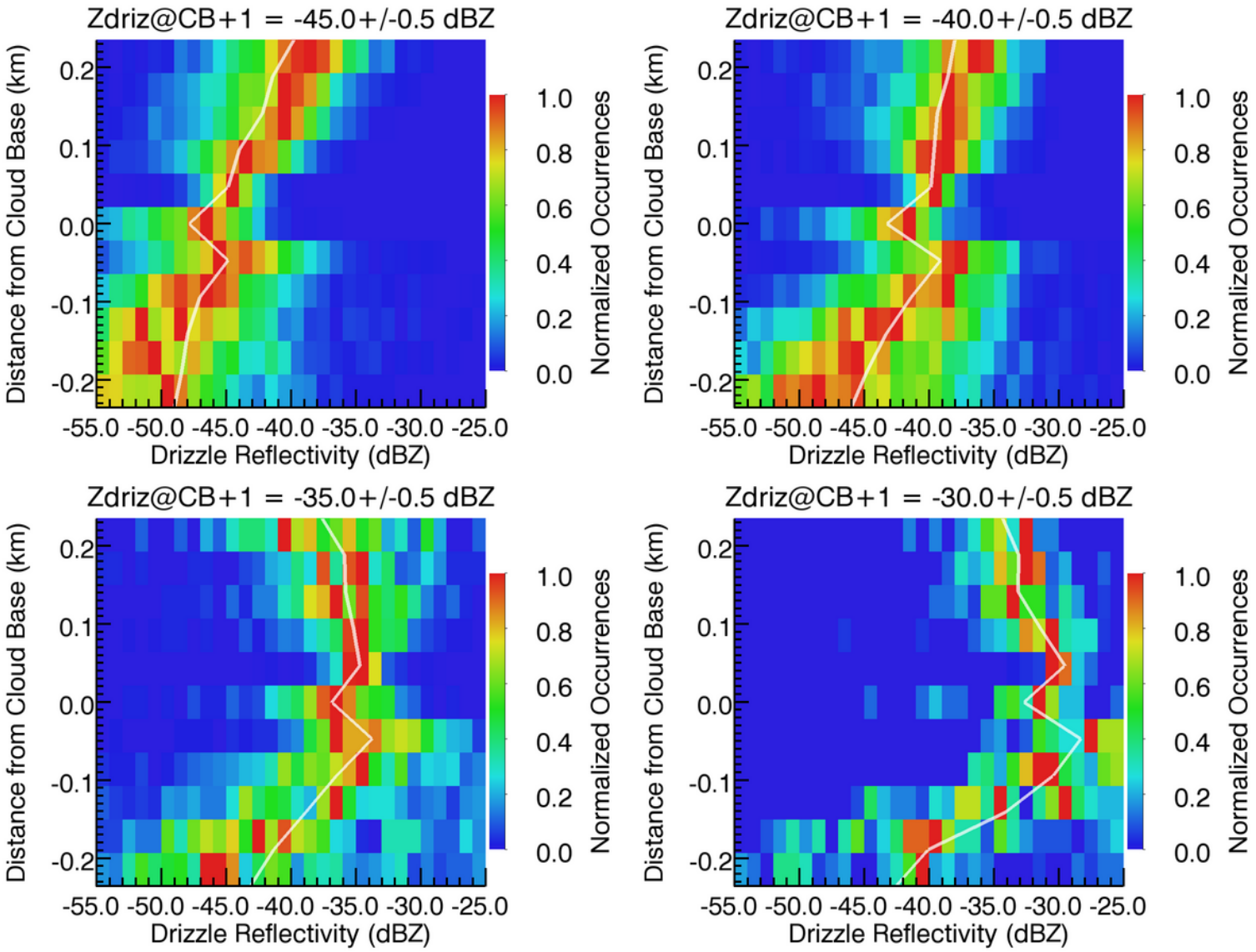


Retrieval success fraction

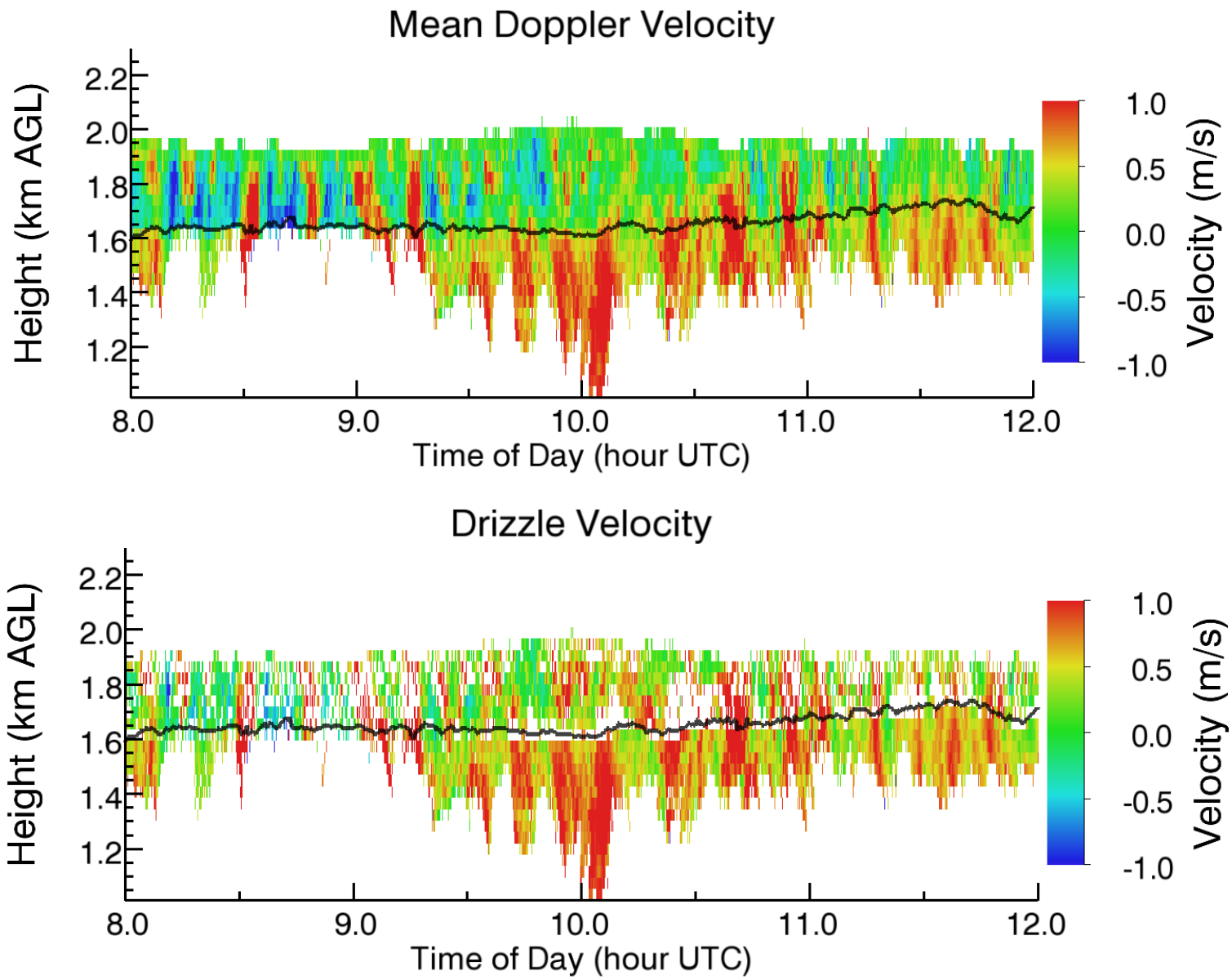


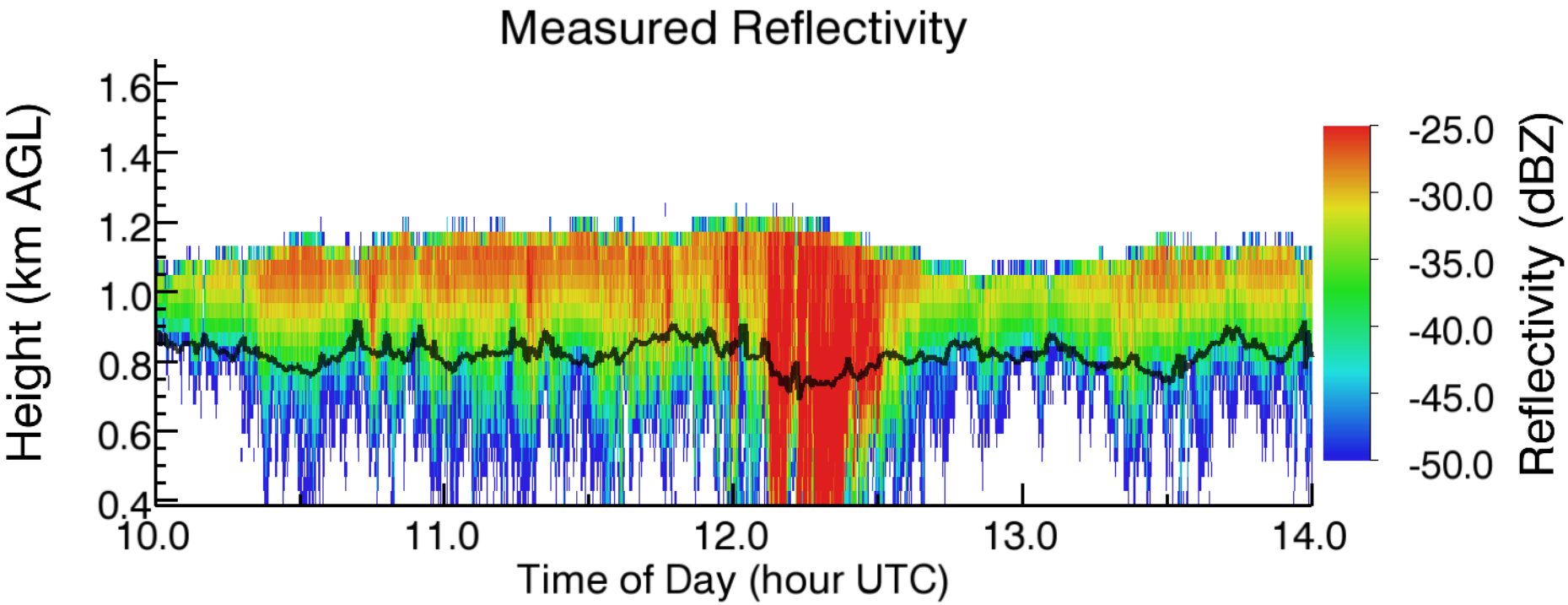
approaches 0.5 near cloud top

Drizzle reflectivity profiles above/below cloud base for four different cloud reflectivity ranges

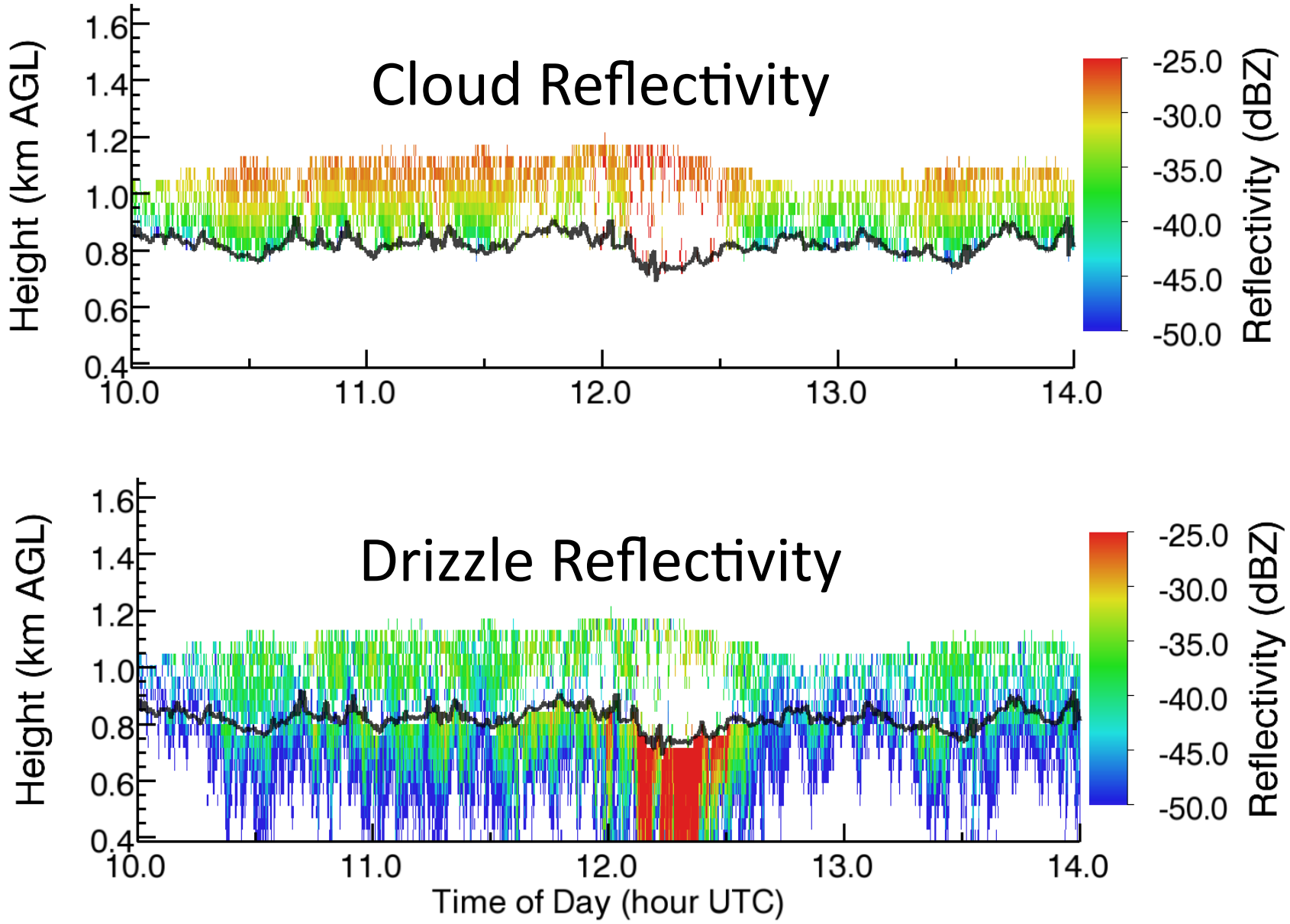


Mean Doppler velocity and retrieved drizzle velocity




Measured Reflectivity
Height (km AGL)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
10.0
11.0
12.0
13.0
14.0
Time of Day (hour UTC)
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
Reflectivity (dBZ)

Retrievals of cloud and drizzle reflectivity



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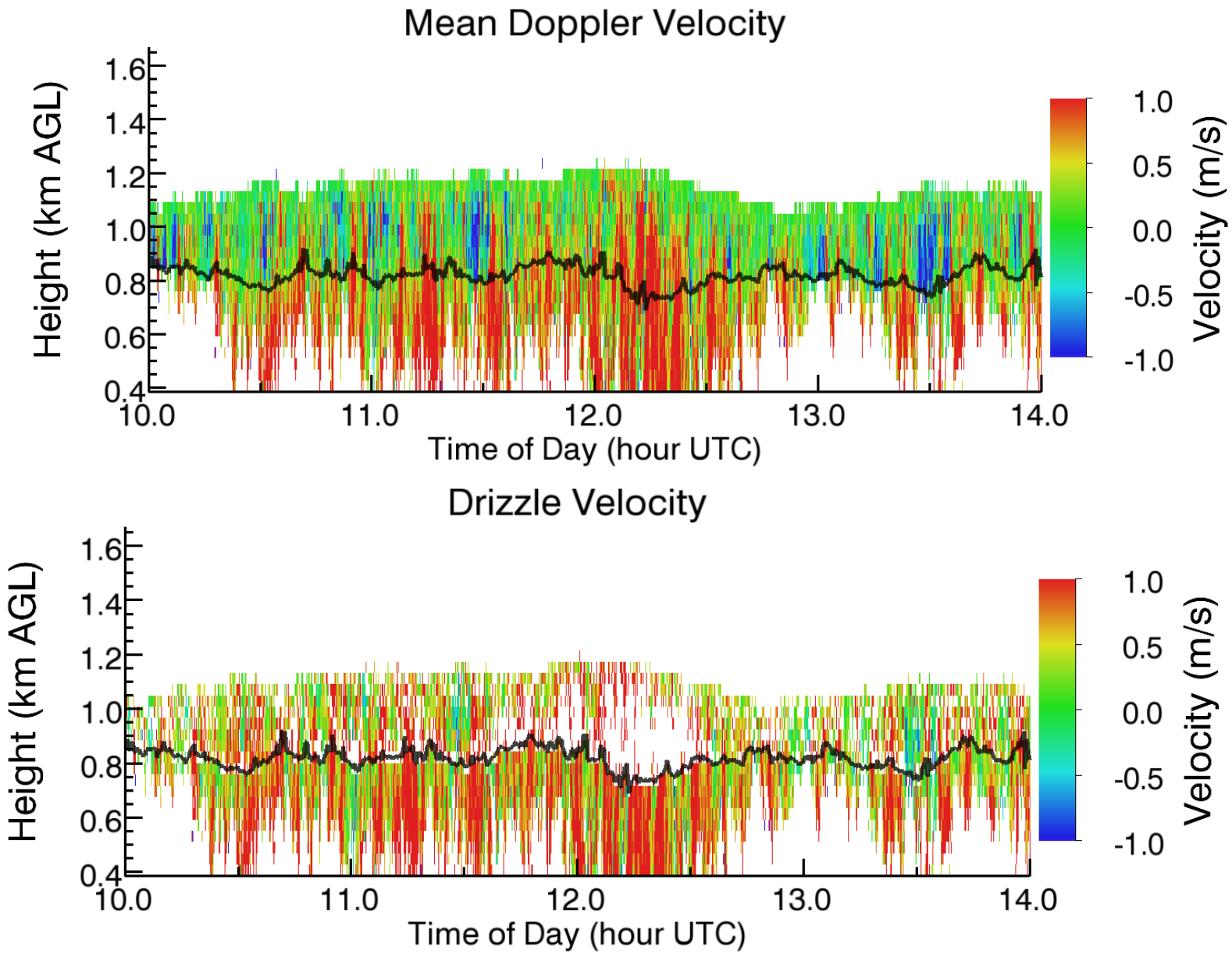

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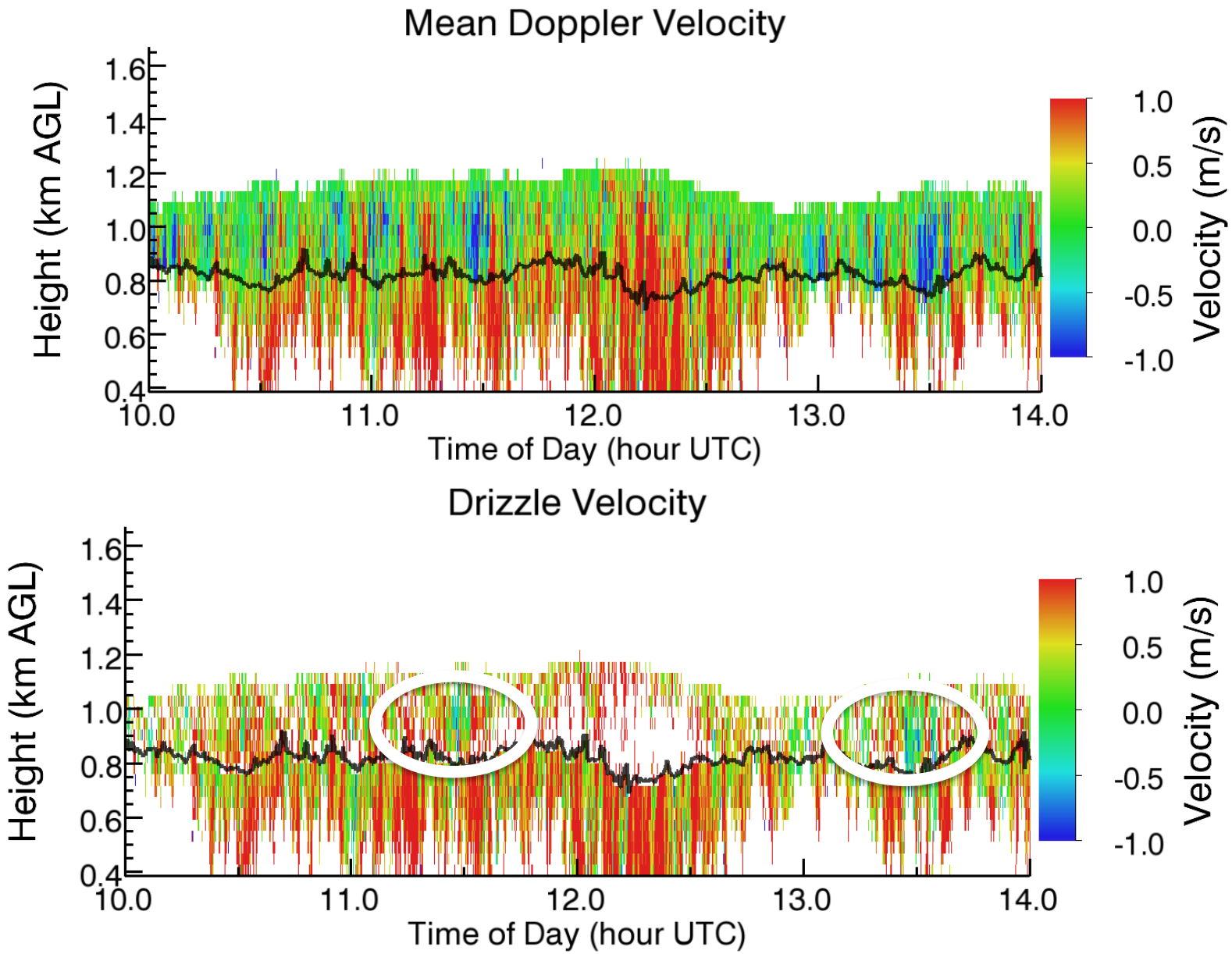
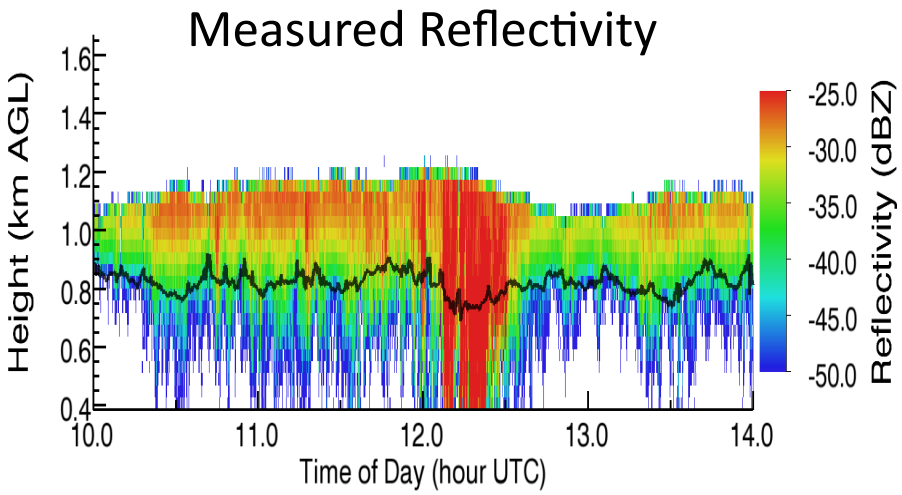
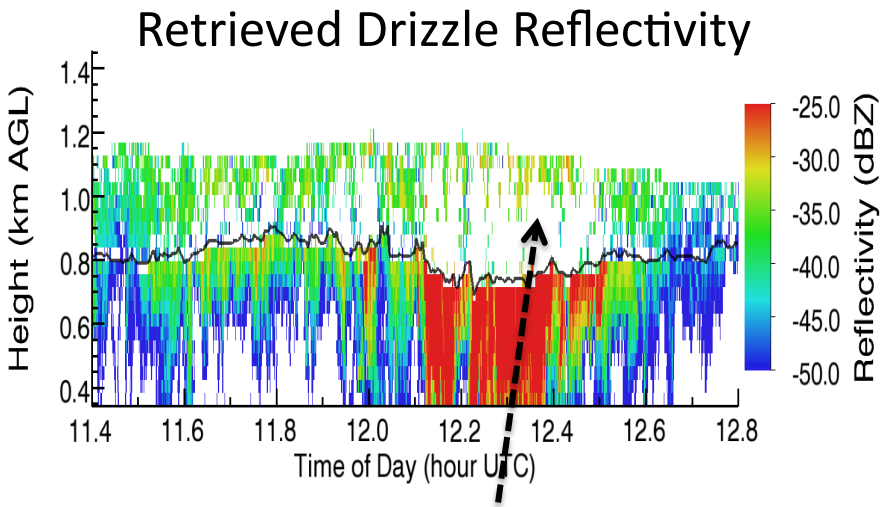
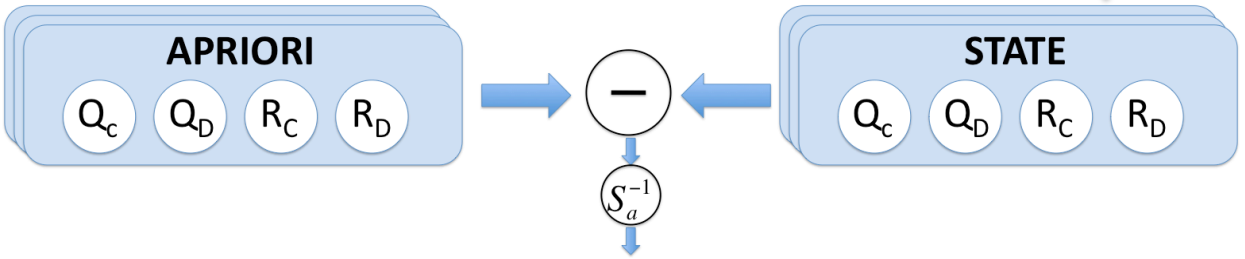


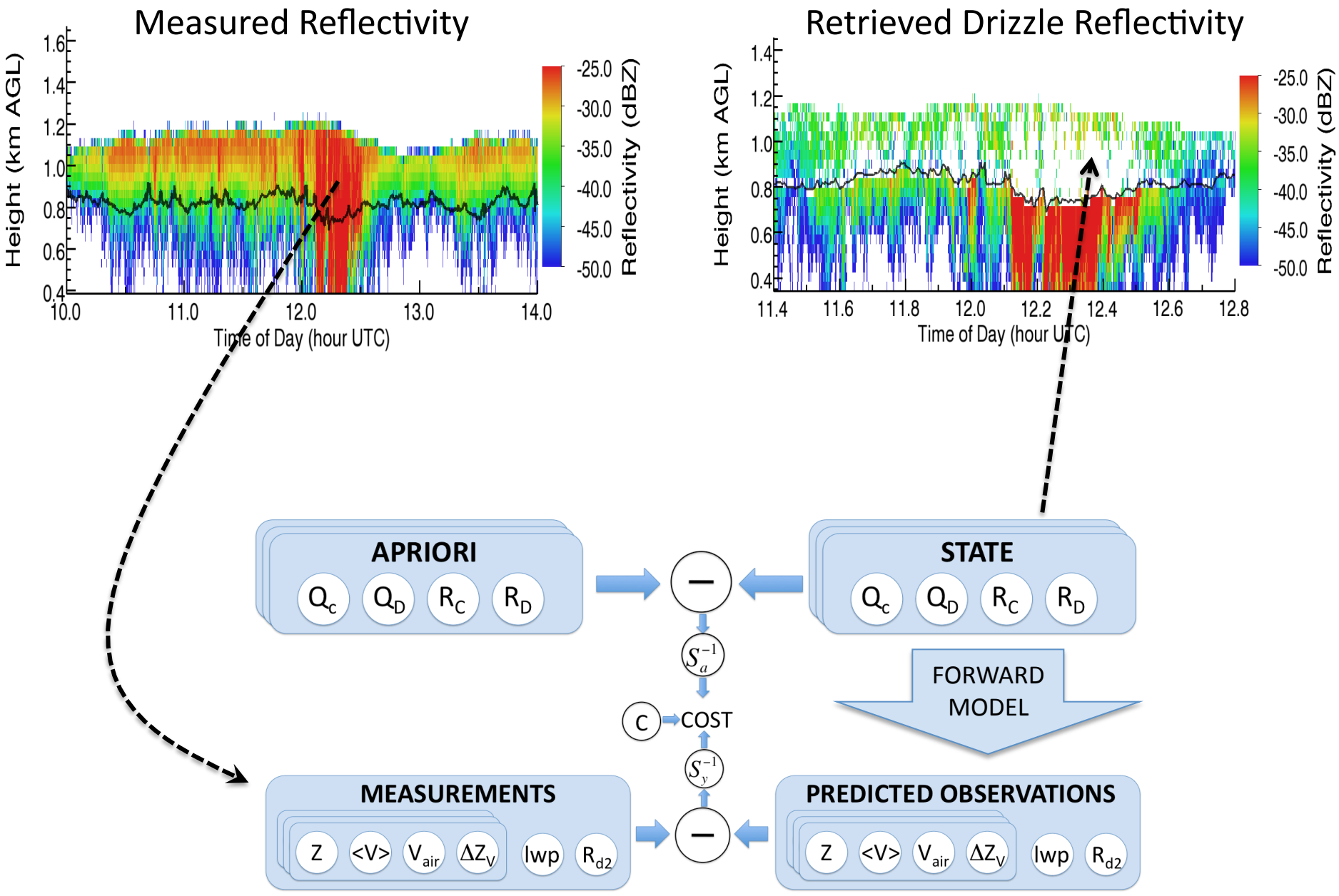
Optimal estimation based retrievals







Optimal estimation based retrievals



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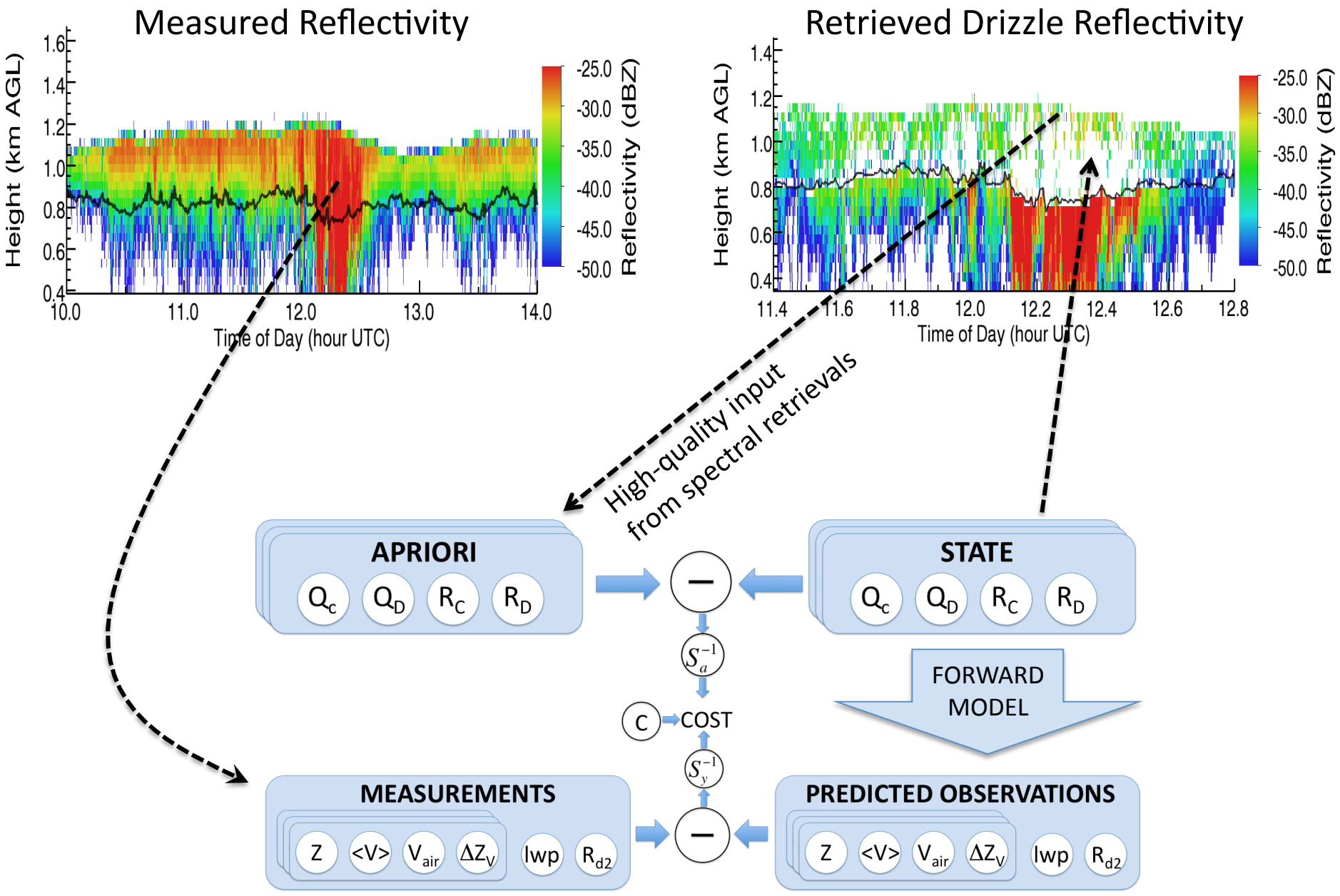

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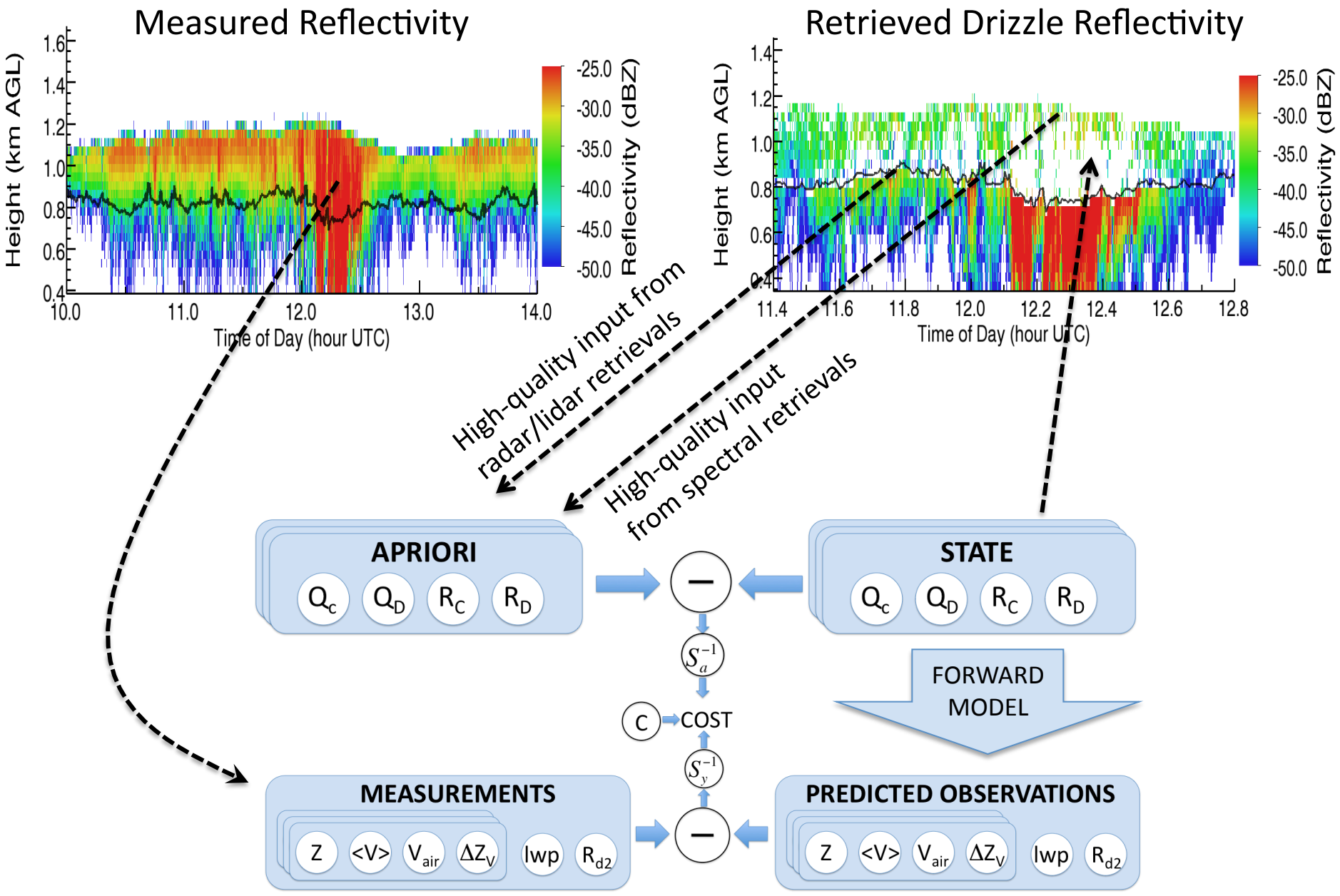

SUMMARY: **We are working to close the remaining gaps in the conditions for which we can perform combined cloud/drizzle retrievals, in effect, maximizing the domain covered by the middle column below. We are integrating our recent techniques, and more established ones, into an optimal estimation framework driven by a powerful forward model of cloud processes, to produce a unified best estimate of physical quantities with robust tools for estimating uncertainty.**

Radar Doppler spectrum parameters	Cloud only ($\chi \to \infty$)	Cloud and Drizzle ($100 > \chi > 0.01$)	Drizzle only ($\chi \to 0$)
Z (Reflectivity)	$f\,(N_c,\ r_{o,c},\ \sigma_{x,c})$	$(1+\chi)\cdot f\,(N_d,\ r_o,\ \sigma_{x,d})$	$f\,(N_d,\ r_{o,d},\ \sigma_{x,d})$
V_D (Mean Doppler velocity)	w_{air}	$w_{air} + f(r_o,\ \sigma_x)/(1+\chi)$	$w_{air} + f\,(r_{o,d},\ \sigma_{x,d})$
σ_D (Spectrum Width)	$f\,(\varepsilon)$	$f\,(\varepsilon) + f\,(\chi,\ r_{o,d},\ \sigma_{x,d})$	$f\,(\varepsilon) + f\,(r_{o,d},\ \sigma_{x,d})$
s_D (Skewness)	$f\,(\varepsilon,\ r_{o,c},\ \sigma_{x,c}) \cong f\,(\varepsilon)$	$f\,(\varepsilon,\ \chi,\ r_{o,d},\ \sigma_{x,d})$	$f\,(\varepsilon,\ r_{o,d},\ \sigma_{x,d})$
k_D (Kurtosis)	$f\,(\varepsilon,\ r_{o,c},\ \sigma_{x,c}) \cong f\,(\varepsilon)$	$f\,(\varepsilon,\ \chi,\ r_{o,d},\ \sigma_{x,d})$	$f\,(\varepsilon,\ r_{o,d},\ \sigma_{x,d})$