# Evaluation of drizzle representation in LES models with bin microphysics

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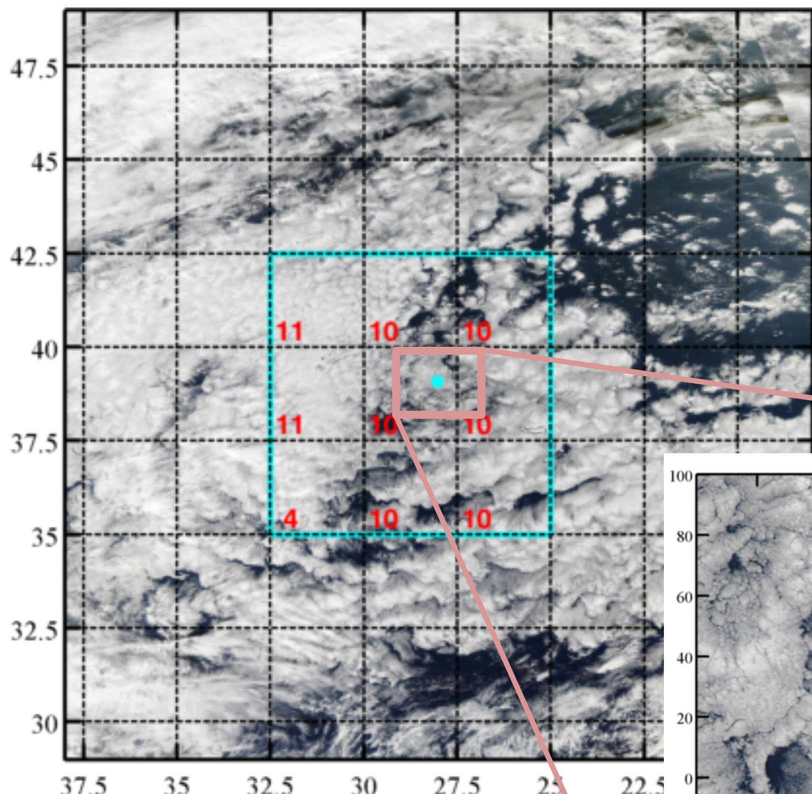
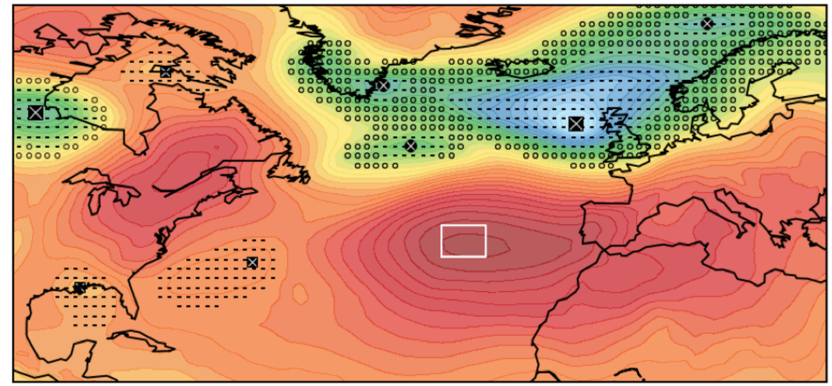
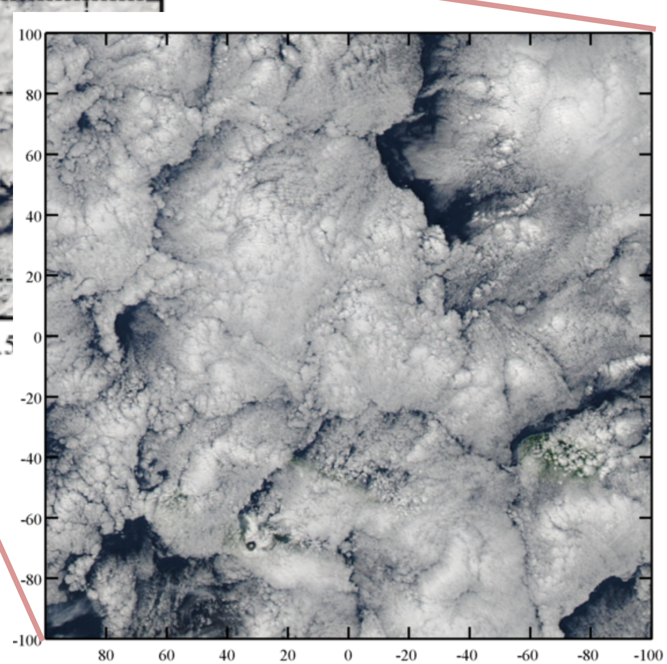
ARM-ASR PI meeting – 5 May 2016

# Case study: 2009-11-22



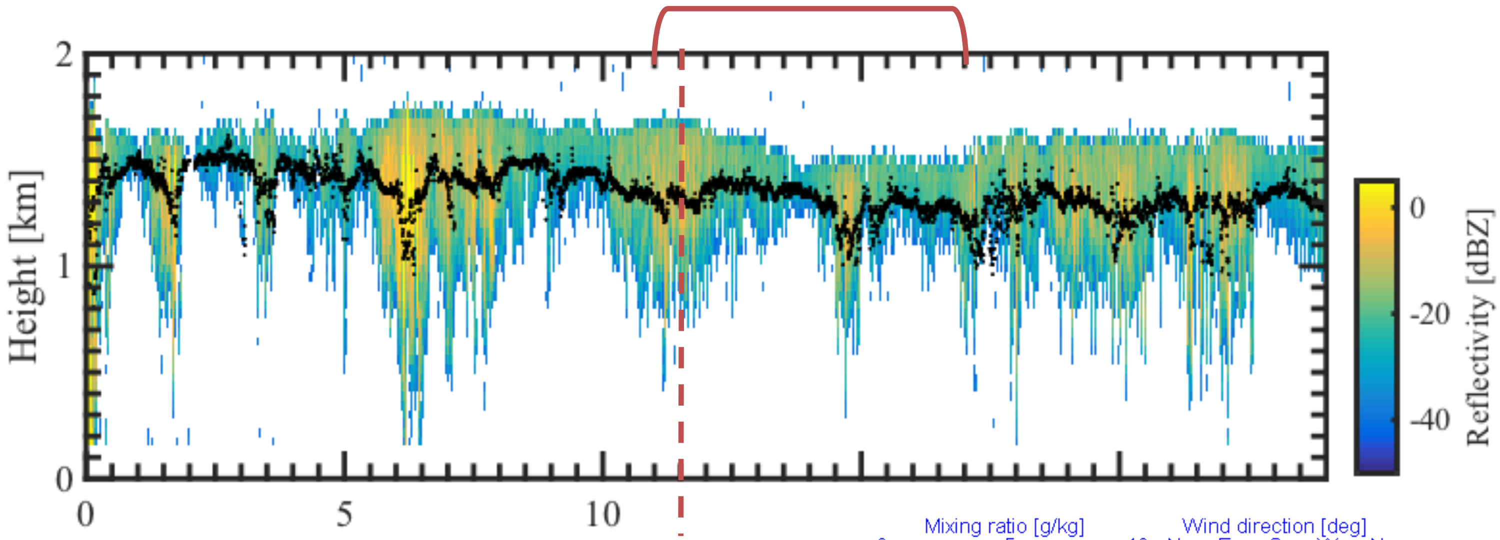



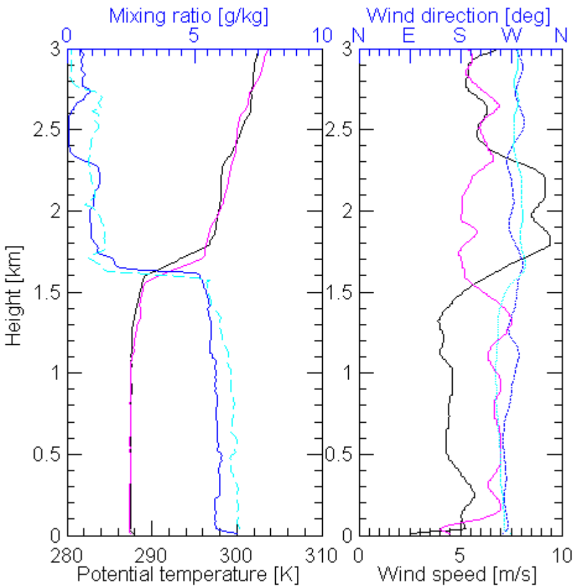
Storm influence from reanalysis



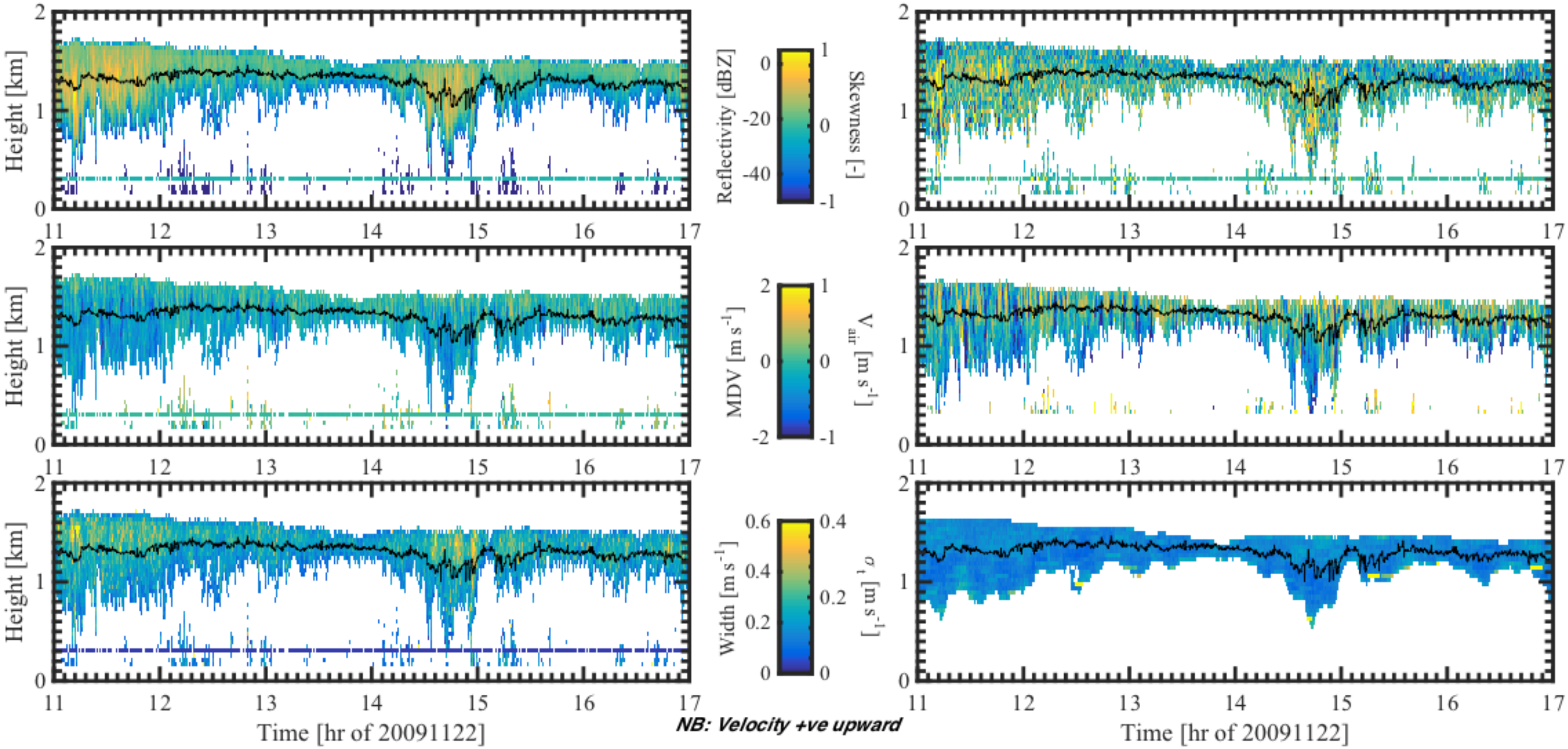

MODIS image from AQUA overpasses

# Case study: 2009-11-22



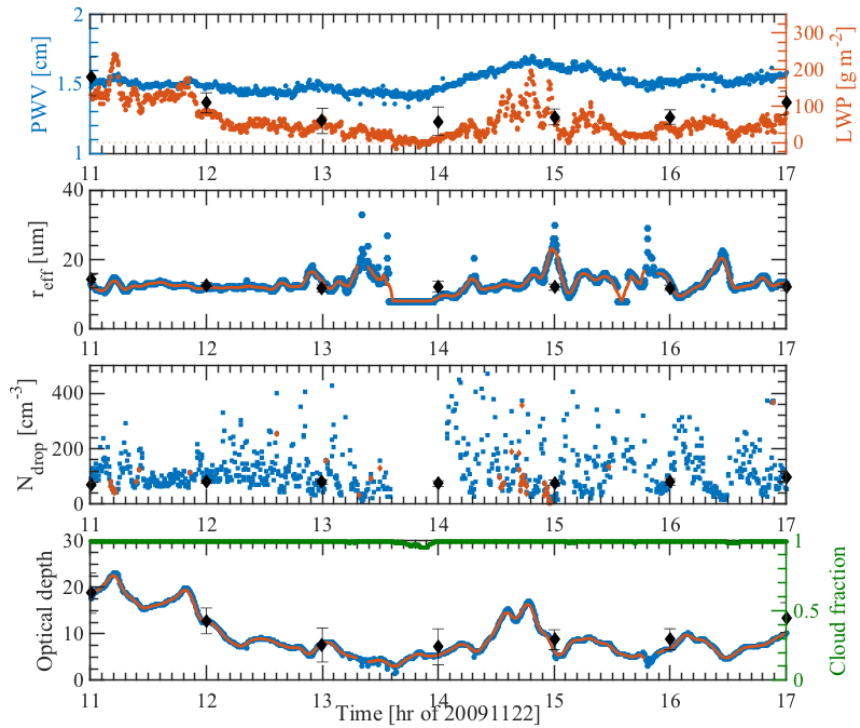



# Case study: 2009-11-22



# Motivation

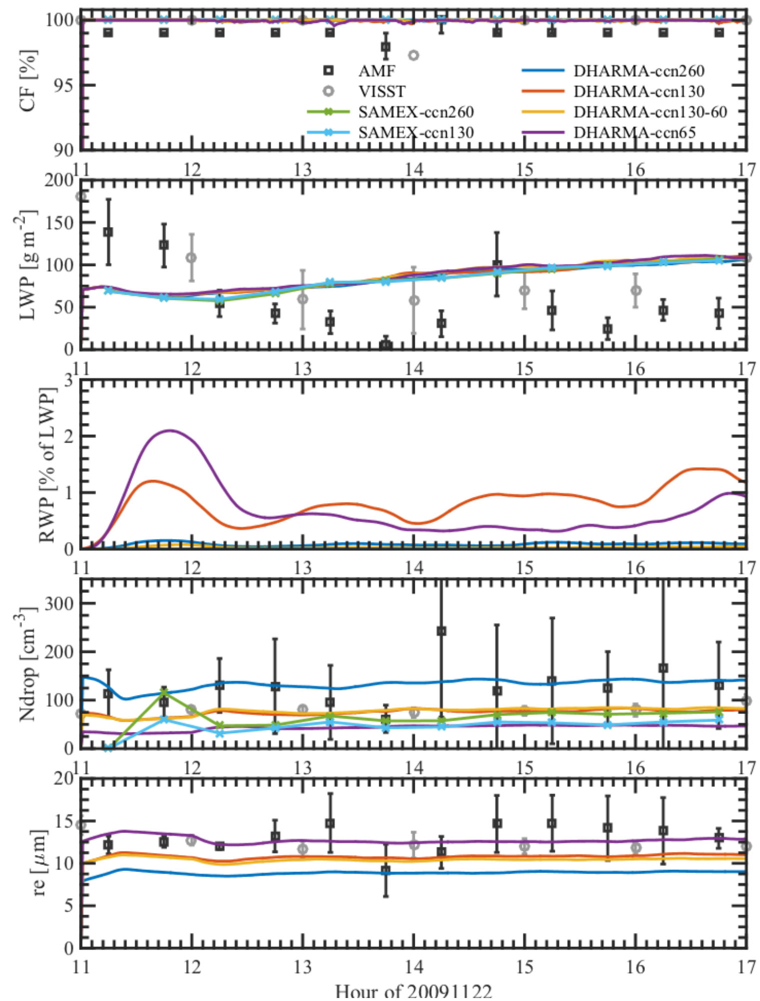
1. Found no "easy" constraint of LES drizzle formation owing to large spread in observed variables over very wide range of *(all?)* spatiotemporal scales
   - Drizzle strongly dependent on LWP (among other parameters)
   - No clear approach to reproduce observed frequencies (of LWP or other parameters) in LES
   - No clear approach (yet in hand) to robustly evaluate single LES case study with observations variably sampled over wide and multivariate parameter space



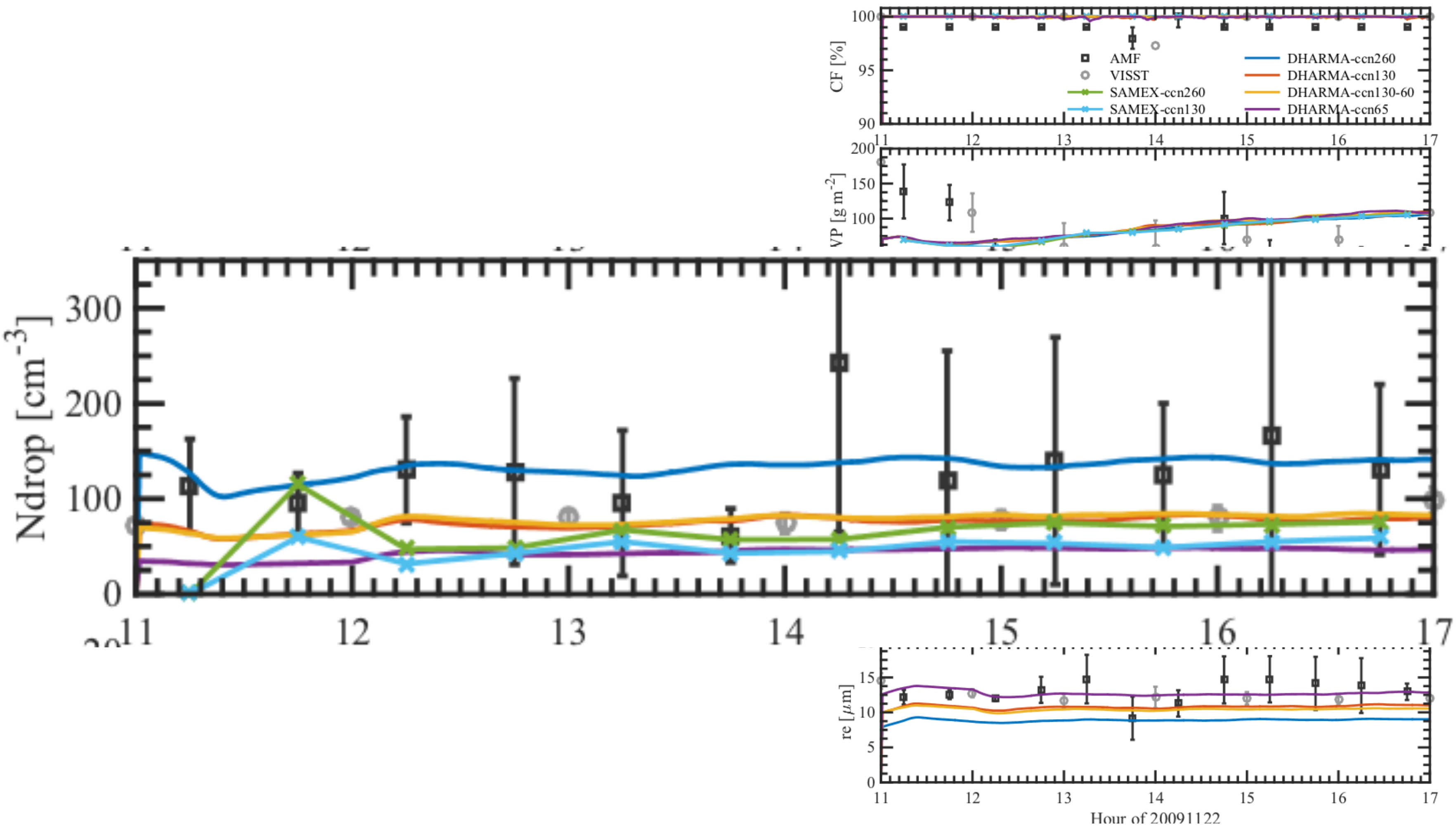

*Time series from ground instruments (MWR, MFRSR, TSI)*
*Black symbols from VISST (courtesy of Kirk Ayers / NASA Langley)*

# Motivation

2. Found motivation to work harder owing to large differences in the number of drops produced by two LES for a given CCN *[due to differences in vertical velocity variance for same cloud-top entrainment!]*
   - Drizzle strongly dependent on the number of drops
   - Updated SAM dynamics agree closely with DHARMA, but observational verification required
   - No clear approach yet in hand to well constrain the LES vertical velocity variance

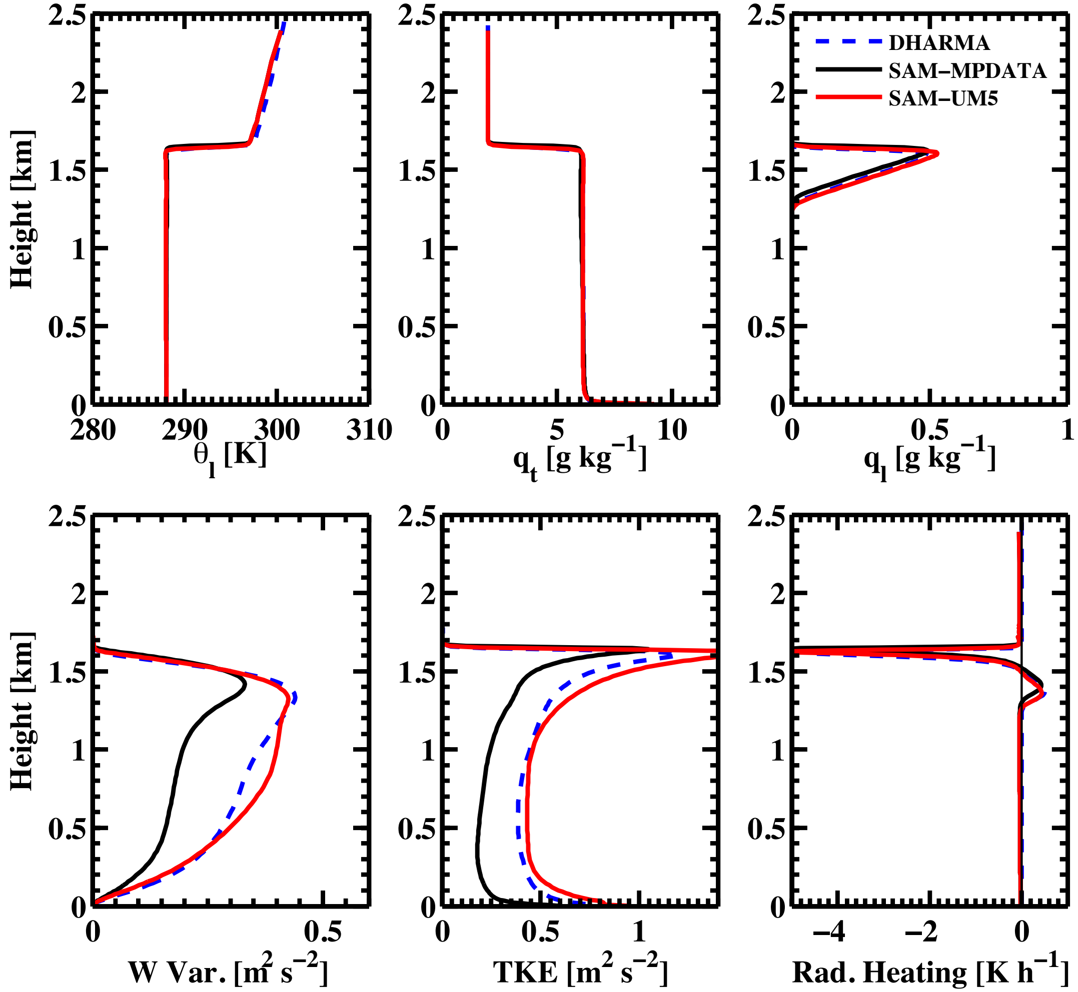


# Motivation



AMF
VISST
SAMEX-ccn260
SAMEX-ccn130
DHARMA-ccn260
DHARMA-ccn130
DHARMA-ccn130-60
DHARMA-ccn65
CF [%]
Ndrop [cm$^{-3}$]
re [$\mu$m]
Hour of 20091122

# Differences in the dynamics



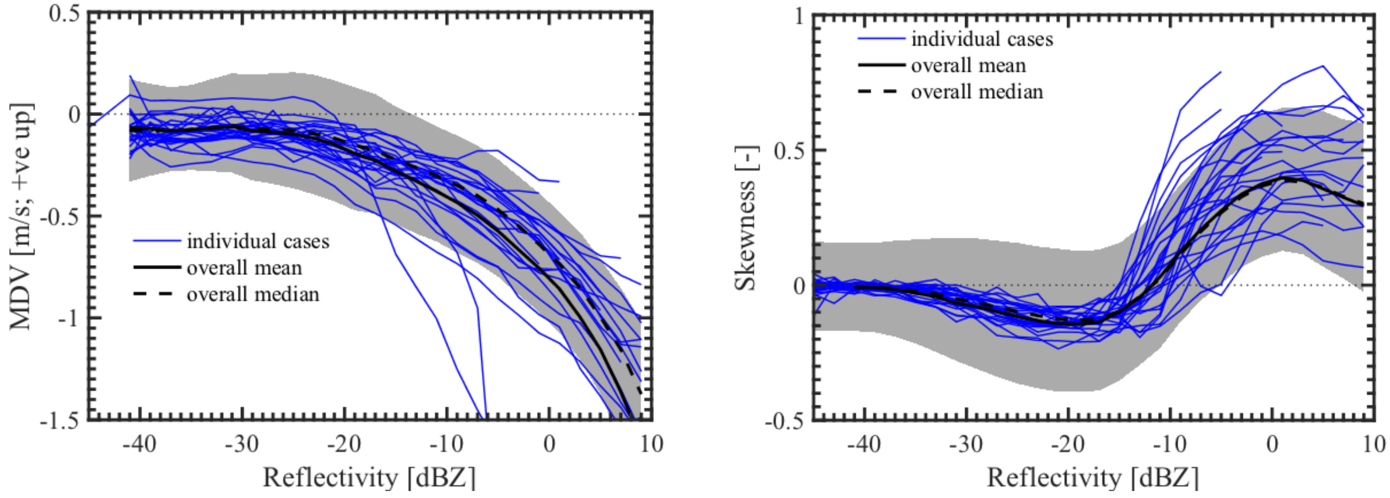
# Two LES models with bin microphysics

- idealized initial sounding (11Z), fixed subsidence profile and SST, periodic boundaries, fixed/similarity surface fluxes, nudged horizontal winds, diagnostic ammonium bisulfate aerosol PSD [Clarke et al. 1974]

| DHARMA | SAMEX |
|---|---|
| finite-difference dynamics scheme [Stevens et al. 2002] | finite-difference dynamics scheme [Khairoutdinov and Kogan 2003] |
| dynamic Smagorinsky sub-grid scale scheme [Kirkpatrick et al. 2006] | prognostic TKE sub-grid scale scheme [Deardorff 1980] |
| one-moment bin scheme | one-moment bin scheme |
| piecewise parabolic diffusional growth scheme [Colella and Woodward 1984] | semi-Lagrangian diffusional growth scheme [Kogan 1991] |
| 3$^{rd}$-order advection scheme | 2nd-order advection scheme |
| implicit collision-coalescence conserves N and M [Jacobson et al. 1994] | explicit scheme of Berry and Reinhardt [1974] |
| Hall [1980] or Böhm [1999] collision kernel | Hall [1980] collision kernel |
| Beard and Ochs [1984, 1995] or coalescence efficiency = 1 | coalescence efficiency = 1 |

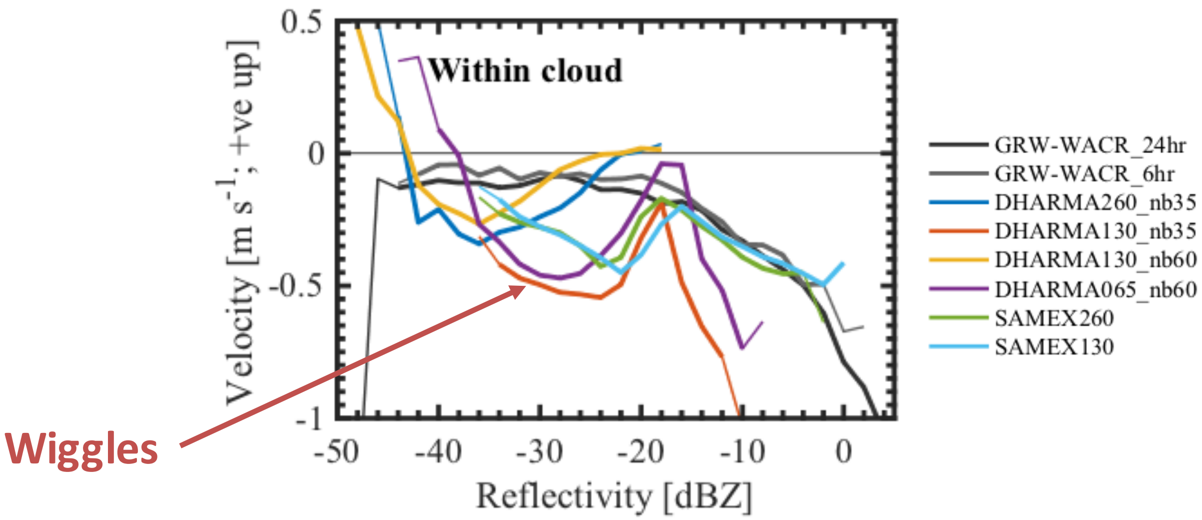
# Approach

- Observed drizzle moments and spectral properties exhibit robust relationships: do LES reproduce these?

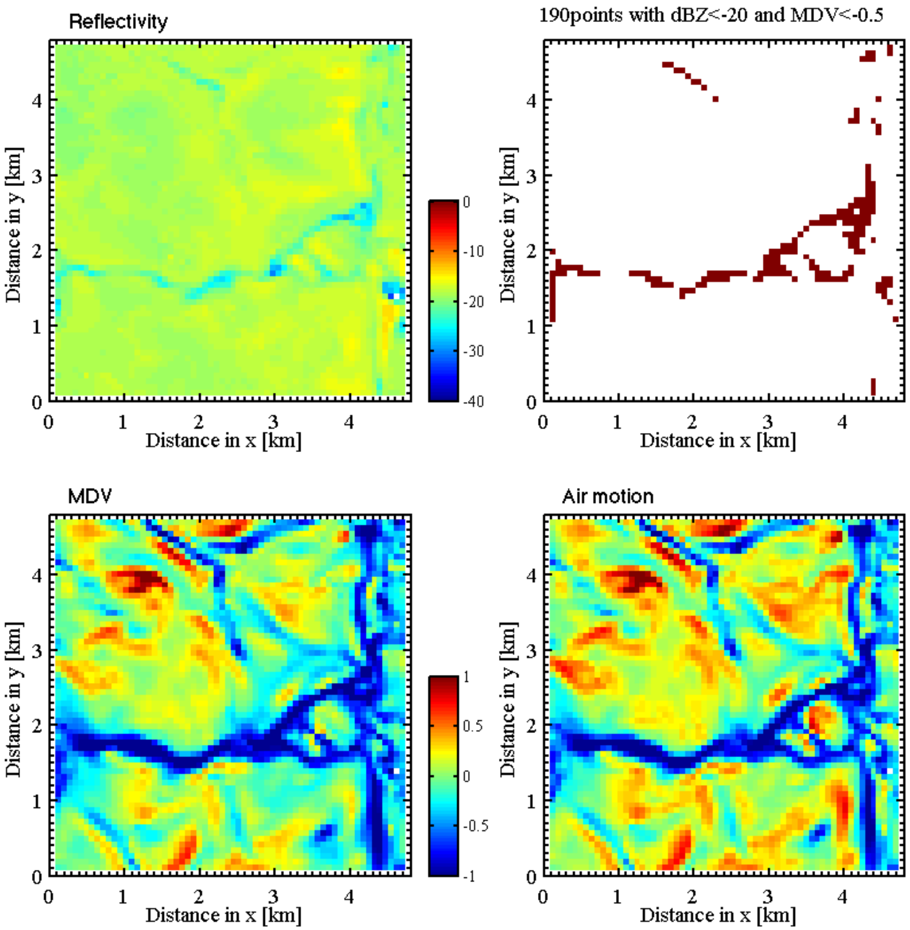



→ Use the McGill radar Doppler spectra simulator to emulate radar spectra and moments from results of both LES models

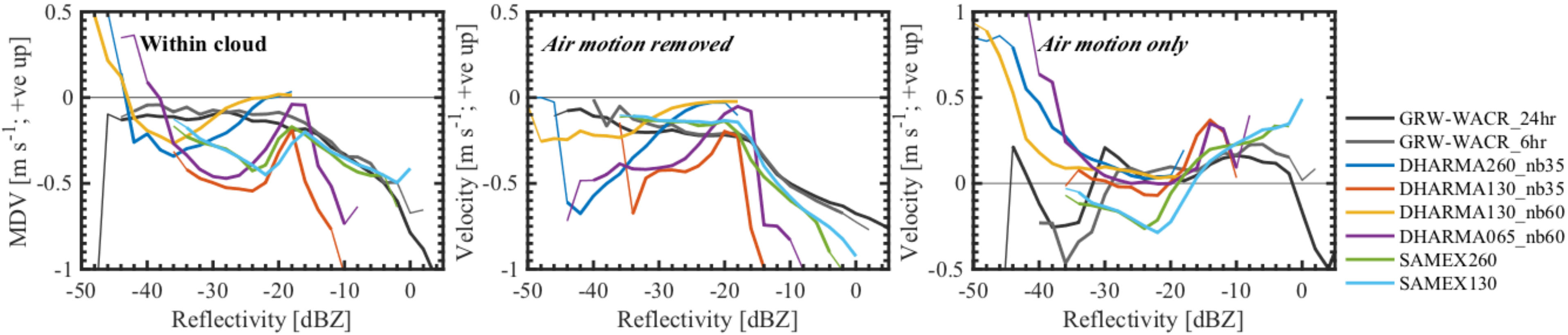
# Z–MDV relationship



# Z, MDV, W near CT

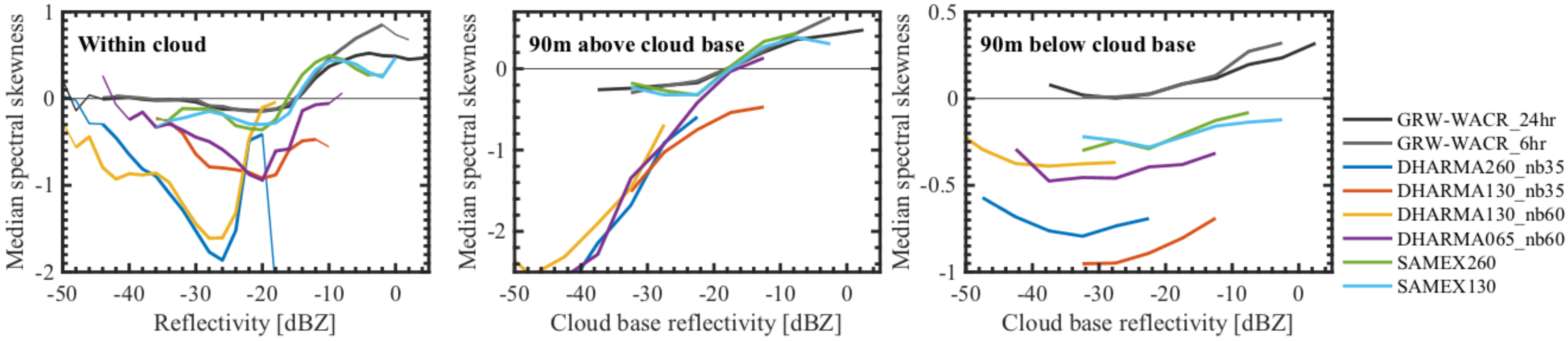


# Z–MDV relationship

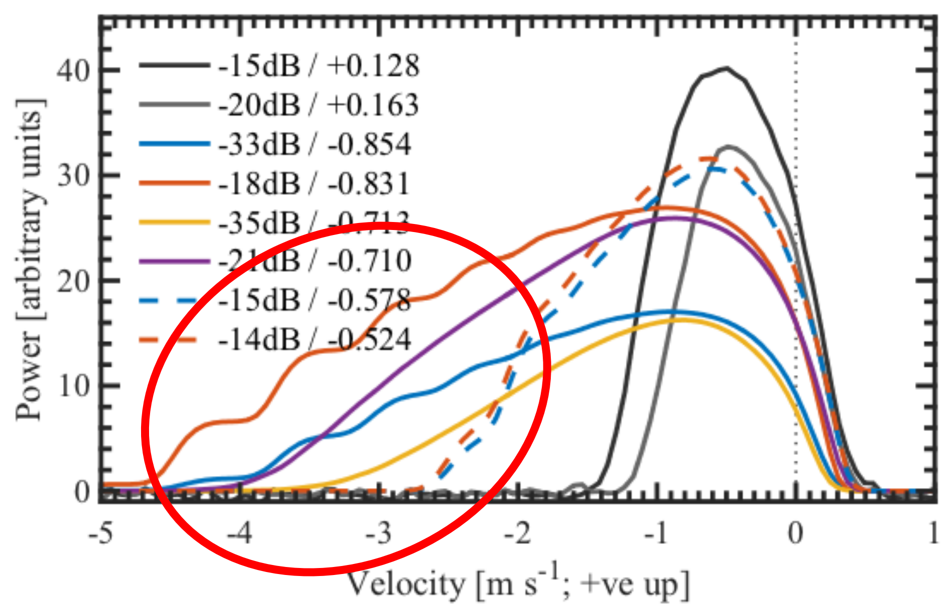



Wiggles in Z-MDV space appear to be caused by limitations in LES representation of cloud-top dynamics: strong LES downdrafts near cloud top are not observed, presumably owing to limitations of LES dynamics here

# Z–Skewness relationship

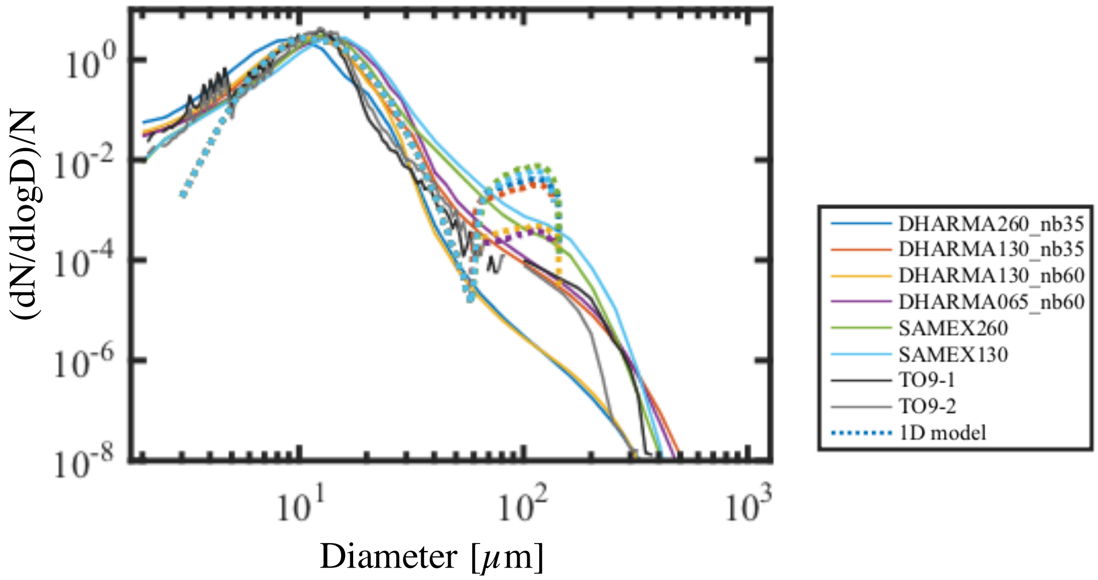



Most pronounced: excessively negative spectral skewness in LES everywhere (DHARMA) or below cloud base (SAMEX)



# Further look

- Forward simulations from a 1D model and in situ observations are consistent with a sharp decrease in N(D) at largest D more closer to SAMEX
- Motivation for follow-on study with DHARMA and McGill in 1D framework (DSDs realistic enough)

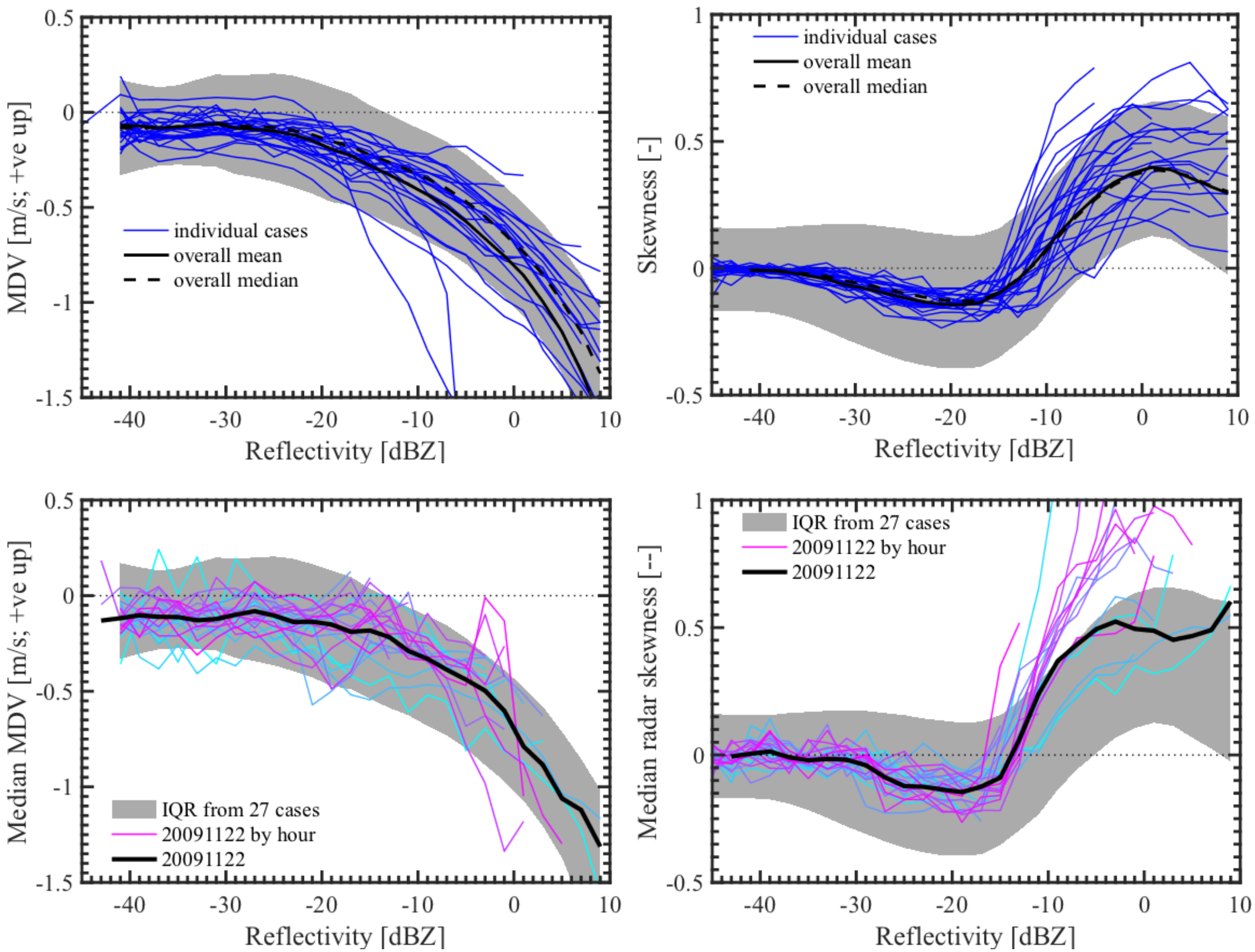


# Ultimate goals

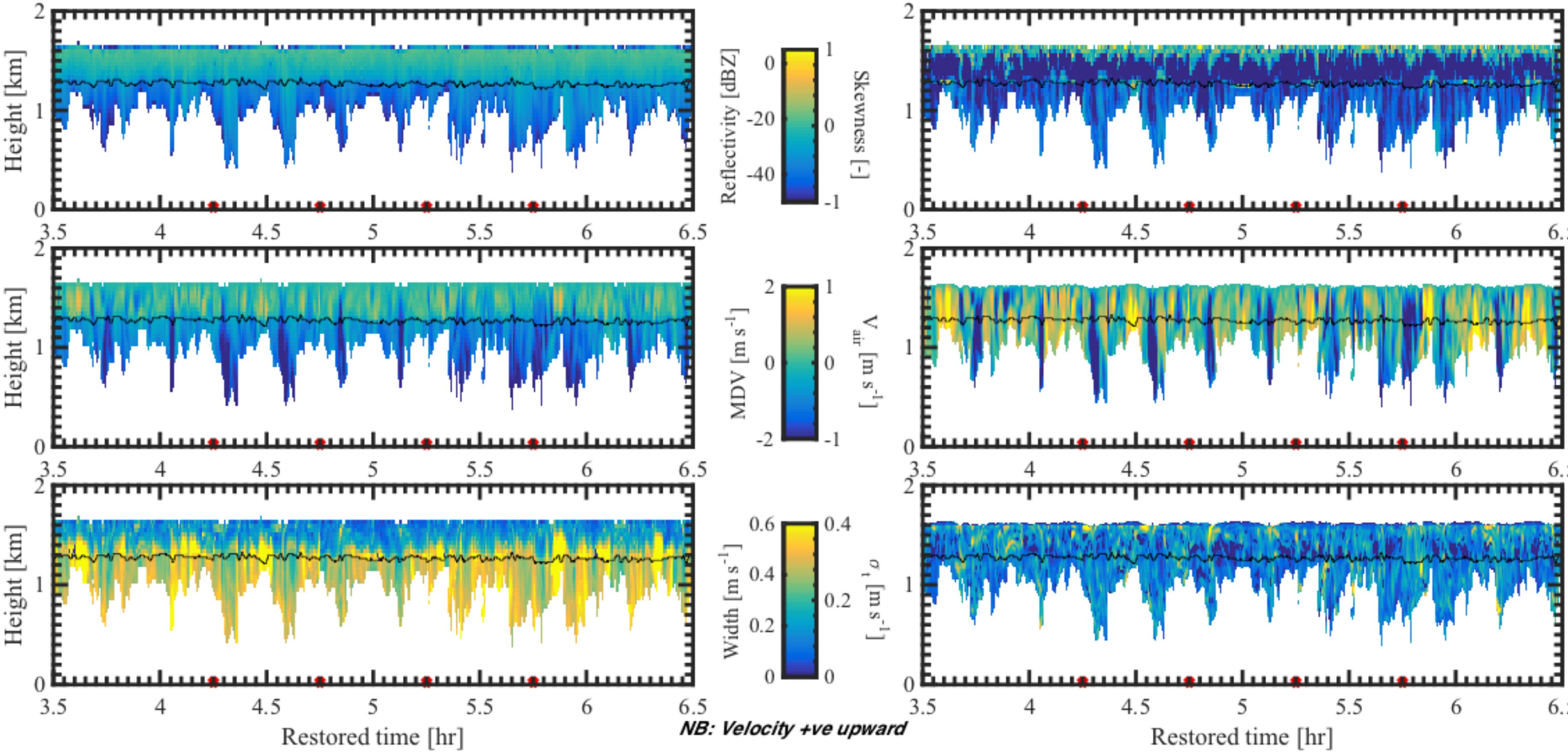
- Improve ability of LES with bin microphysics to faithfully represent radar observables without sacrifice to performance (analogous to three-moment CRM schemes)
- Use radar observables to do the “hard” constraint of LES drizzle formation

# Approach

- Observed drizzle moments and spectral properties exhibit

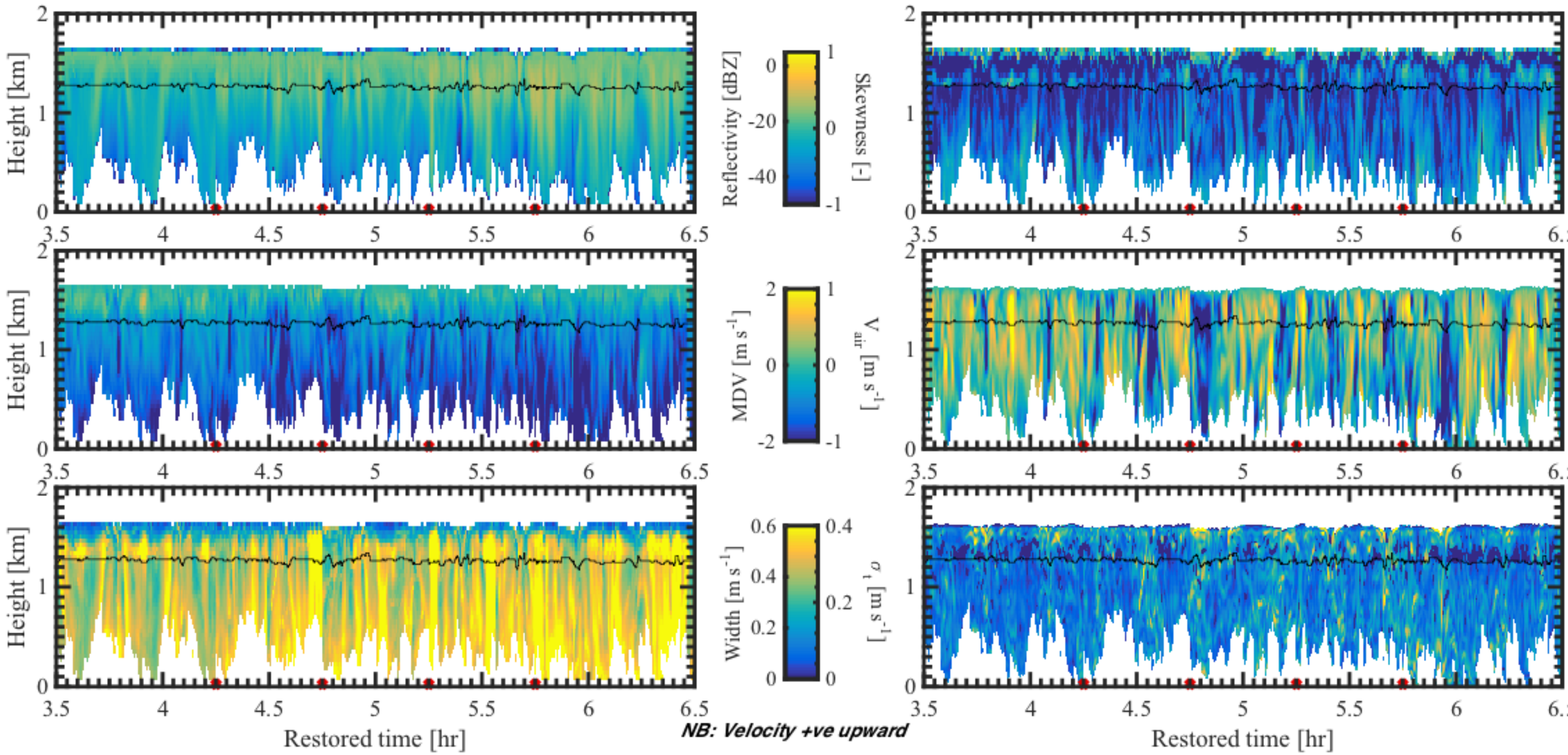


# DHARMA – 260cc

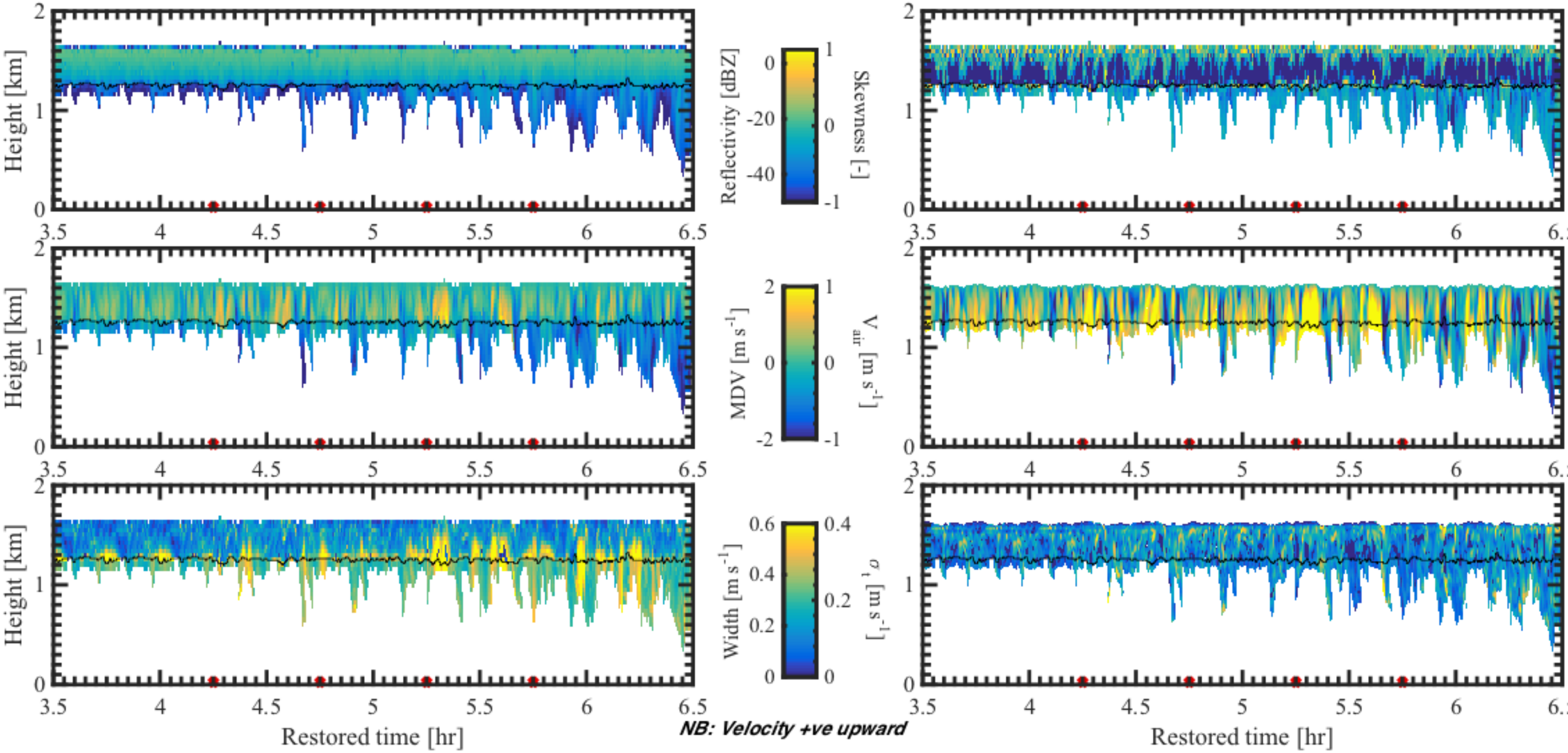



*NB: Velocity +ve upward*

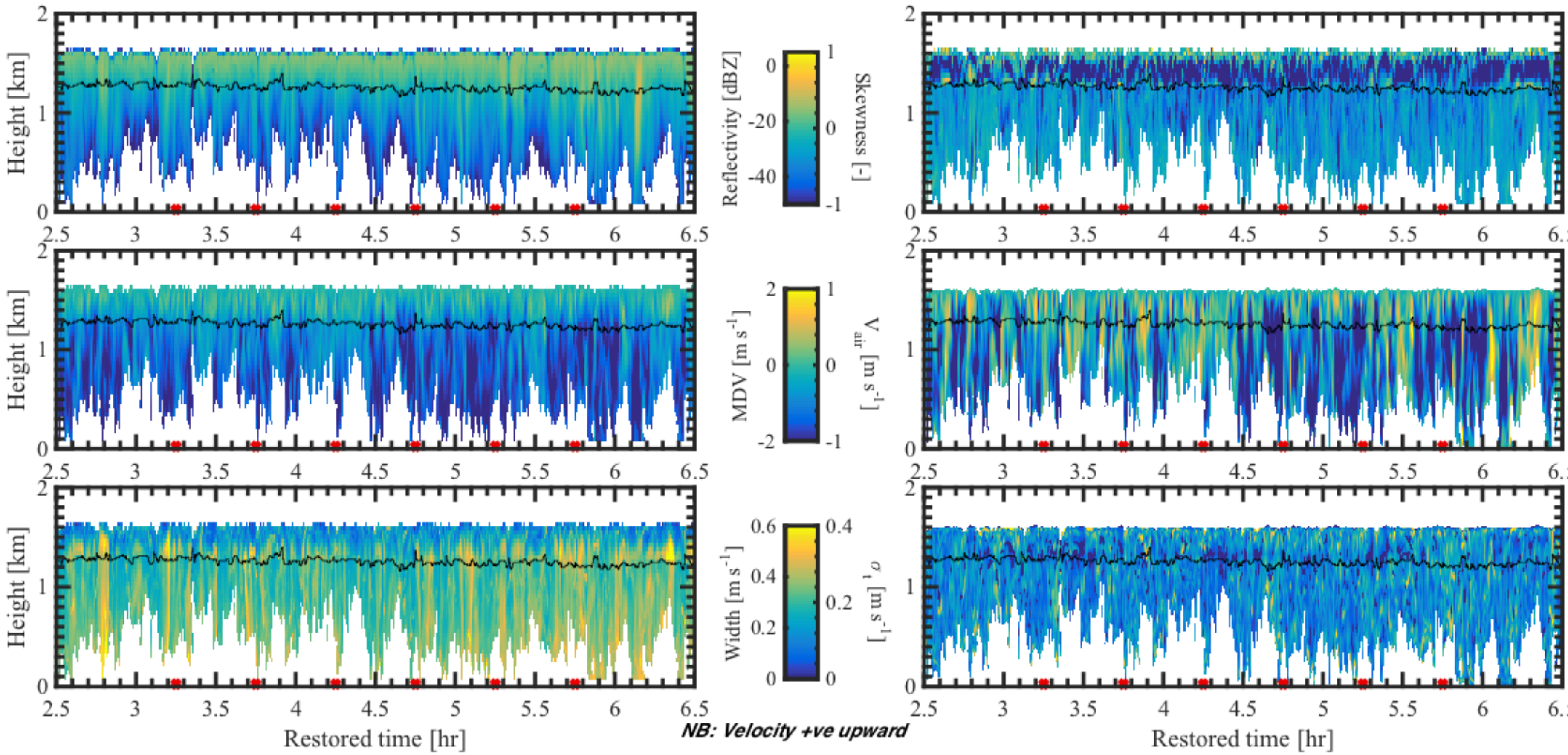
# DHARMA – 130cc



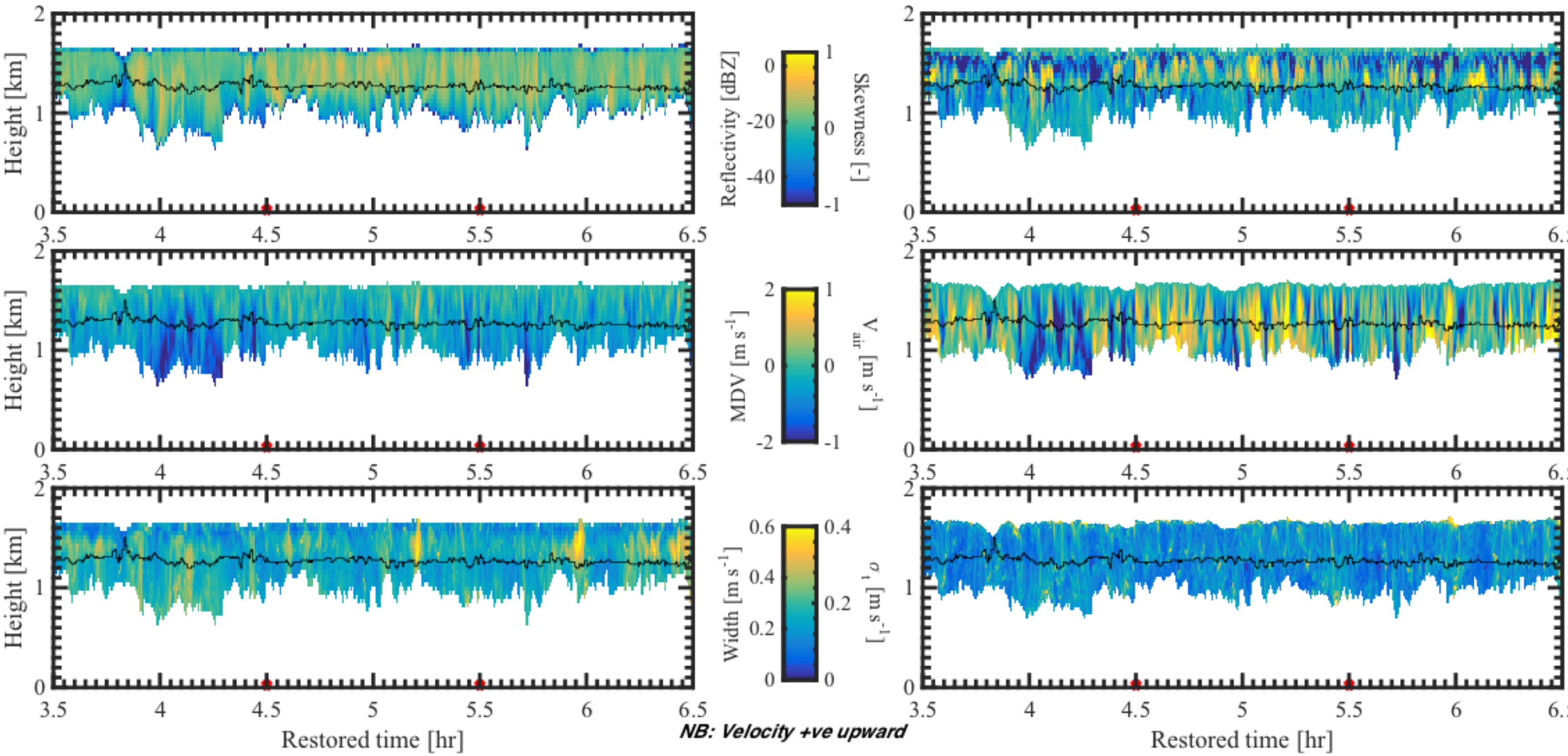
# DHARMA – 130cc – 60 bins



# DHARMA – 65cc – 60 bins

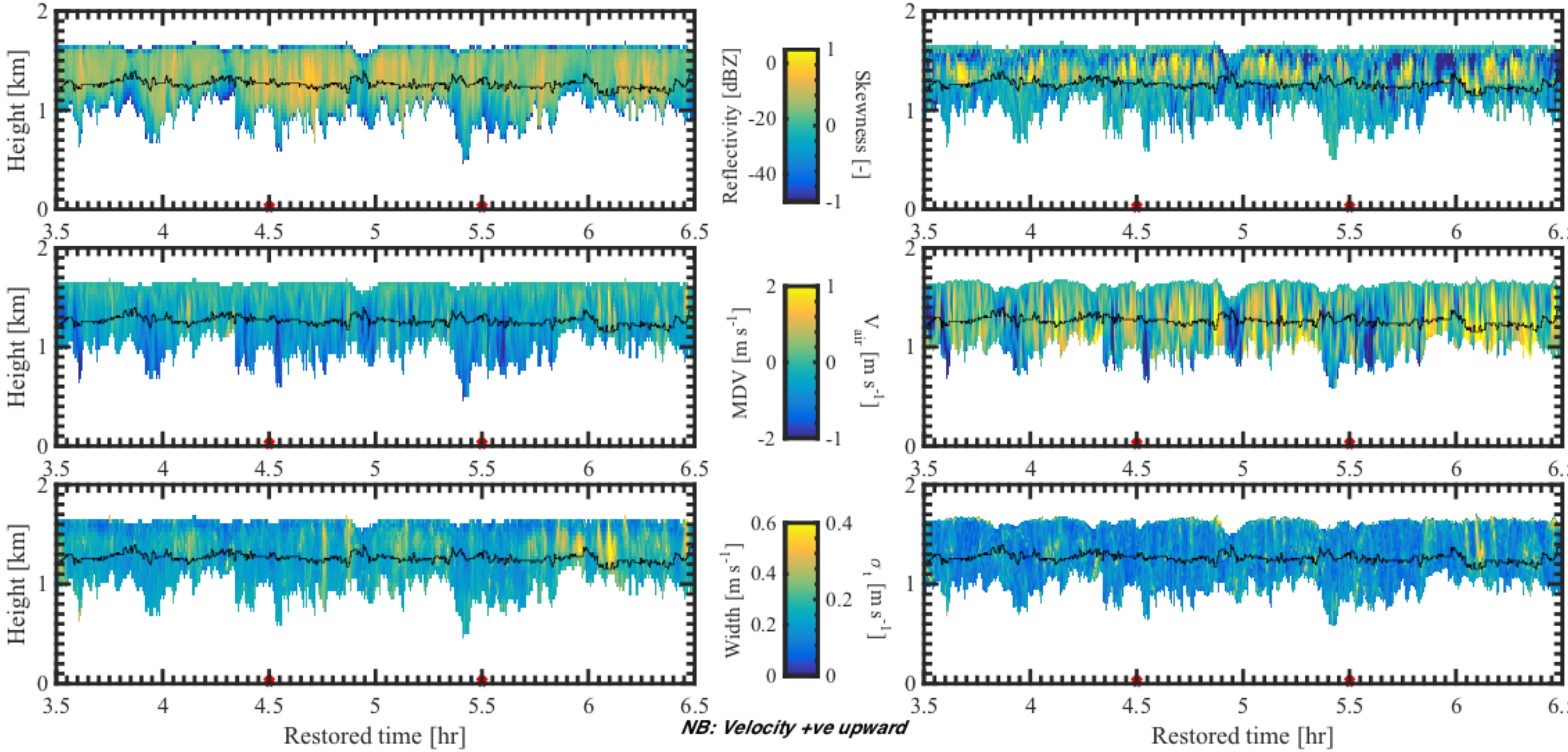


# SAMEX – 260cc

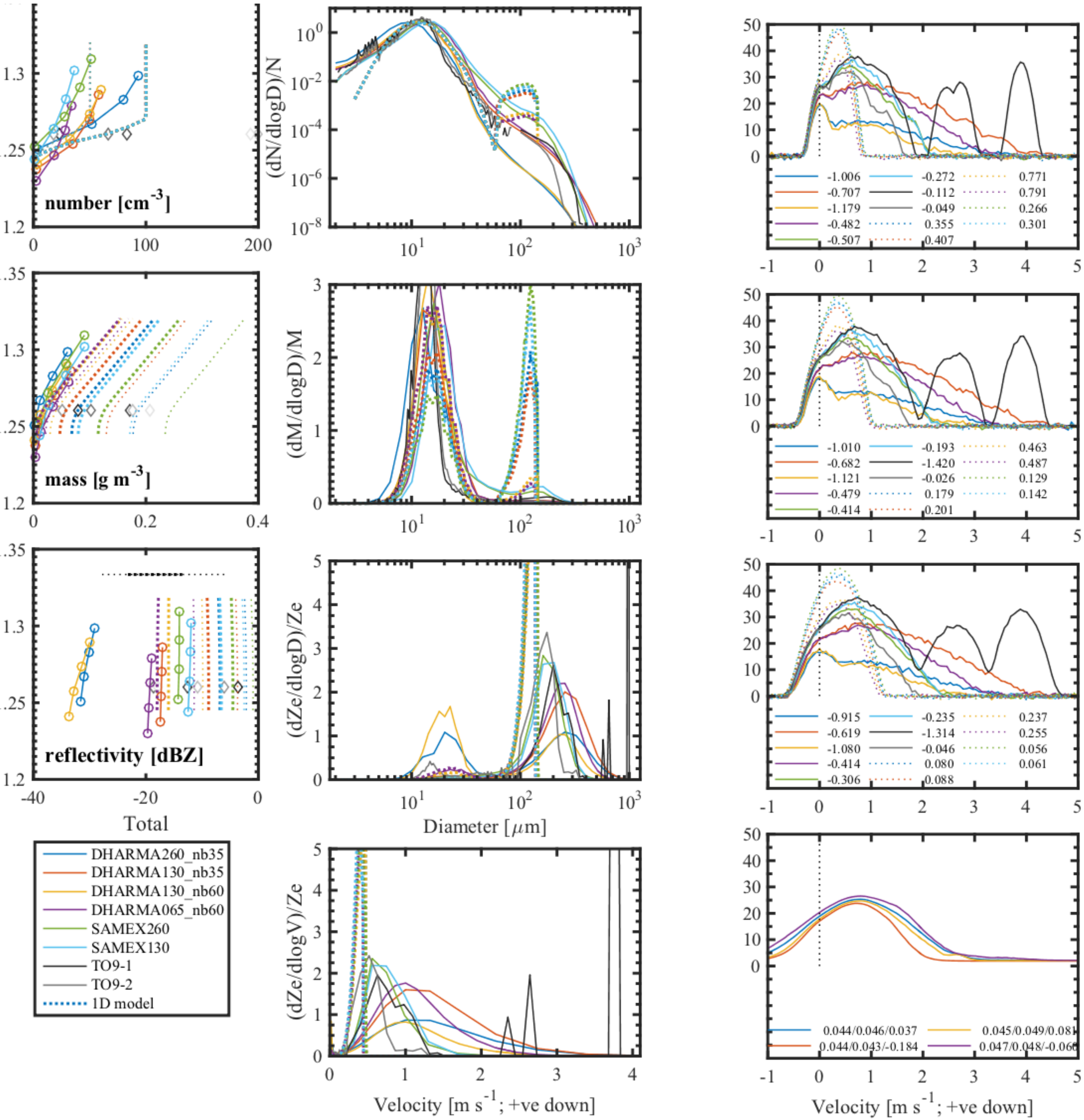


Height [km]
Reflectivity [dBZ]
Skewness [-]
MDV [m s-1]
Vair [m s-1]
Width [m s-1]
σt [m s-1]
Restored time [hr]
NB: Velocity +ve upward

# SAMEX – 130cc



Height [km]
Reflectivity [dBZ]
Skewness [-]
MDV [m s^-1]
V_air [m s^-1]
Width [m s^-1]
σ_t [m s^-1]
Restored time [hr]
NB: Velocity +ve upward


number [cm-3]
mass [g m-3]
reflectivity [dBZ]
Total
(dN/dlogD)/N
(dM/dlogD)/M
(dZe/dlogD)/Ze
Diameter [μm]
(dZe/dlogV)/Ze
Velocity [m s-1; +ve down]
DHARMA260_nb35
DHARMA130_nb35
DHARMA130_nb60
DHARMA065_nb60
SAMEX260
SAMEX130
TO9-1
TO9-2
1D model
-1.006 -0.272 0.771
-0.707 -0.112 0.791
-1.179 -0.049 0.266
-0.482 0.355 0.301
-0.507 0.407
-1.010 -0.193 0.463
-0.682 -1.420 0.487
-1.121 -0.026 0.129
-0.479 0.179 0.142
-0.414 0.201
-0.915 -0.235 0.237
-0.619 -1.314 0.255
-1.080 -0.046 0.056
-0.414 0.080 0.061
-0.306 0.088
0.044/0.046/0.037 0.045/0.049/0.081
0.044/0.043/-0.184 0.047/0.048/-0.066