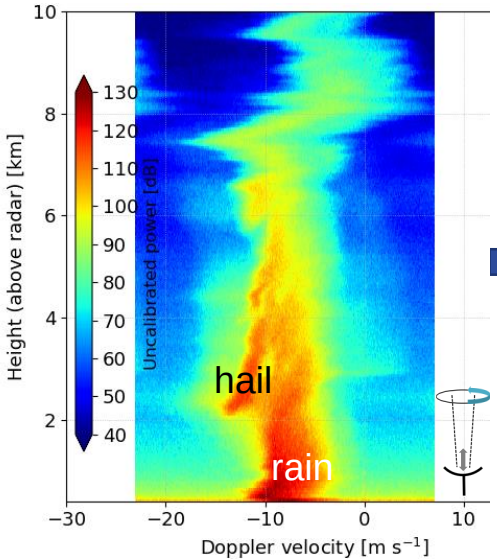
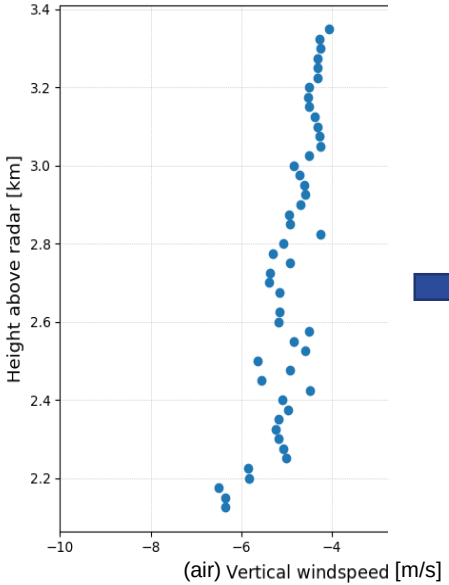
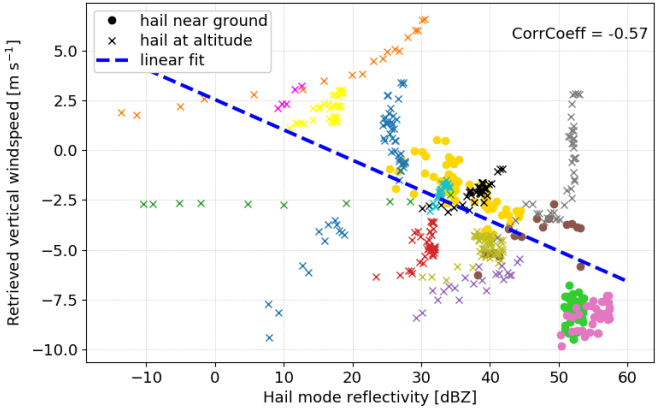


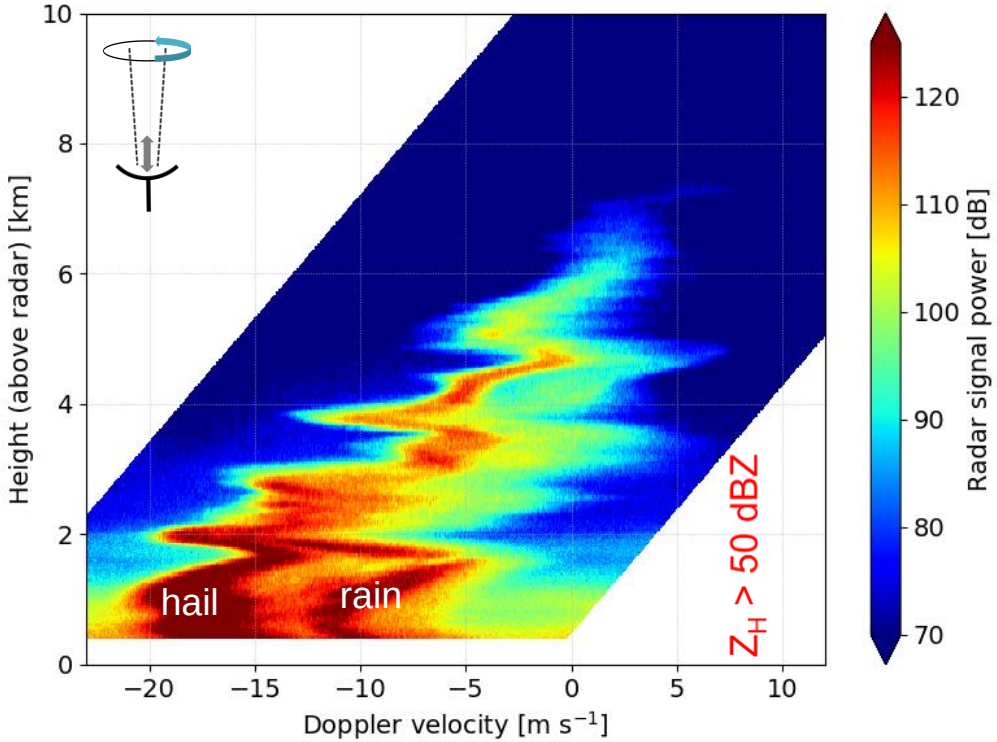




POMODORI – Hail and vertical windspeed

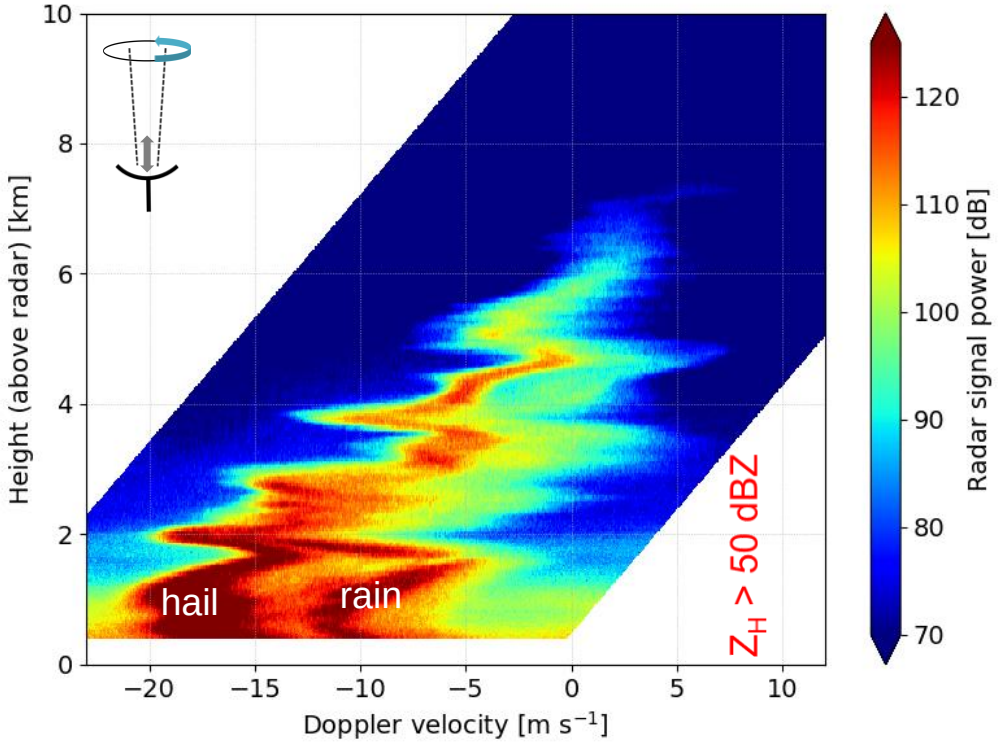
Review

supercell 30 April 2021 MHP

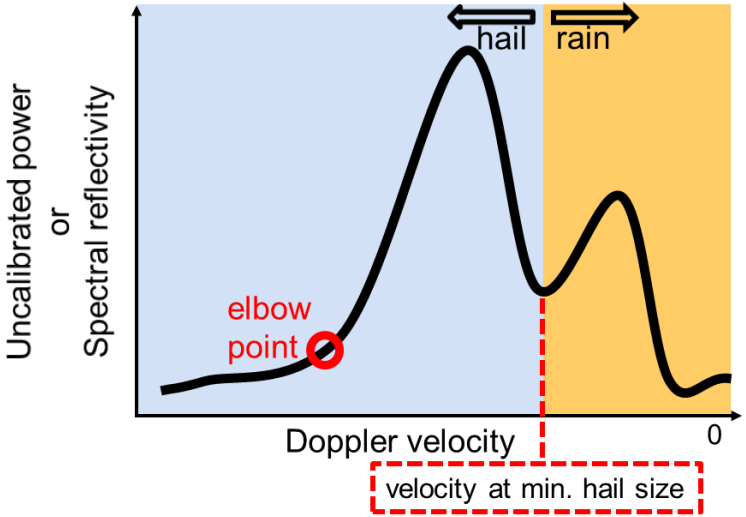


Review

supercell 30 April 2021 MHP



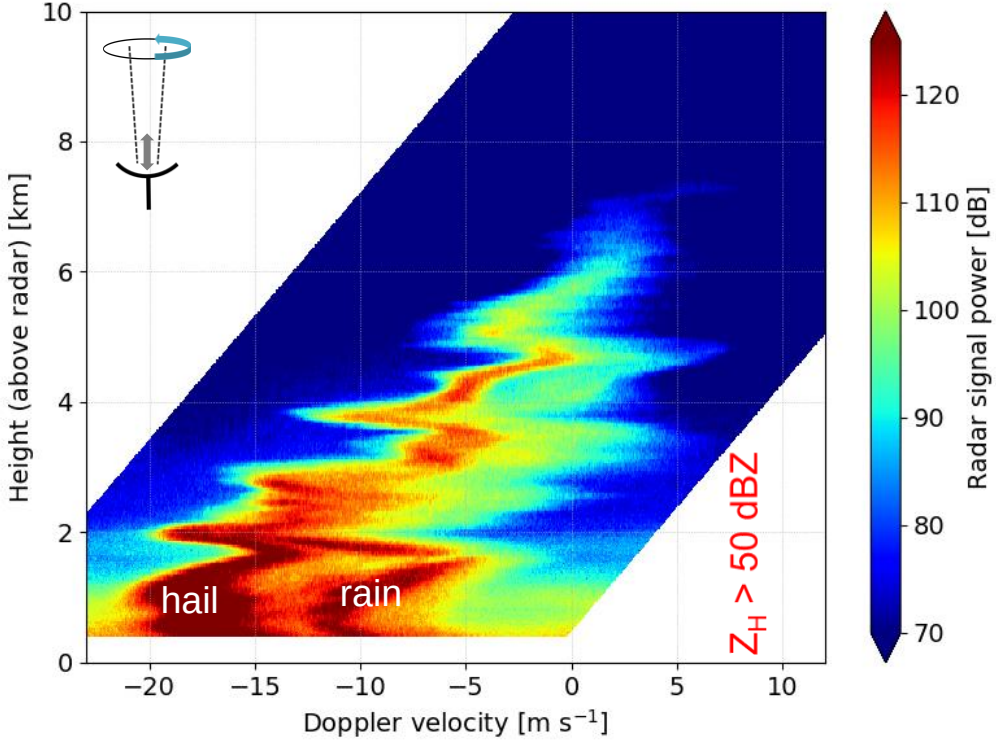
Doppler spectrum for 1 radar range bin:



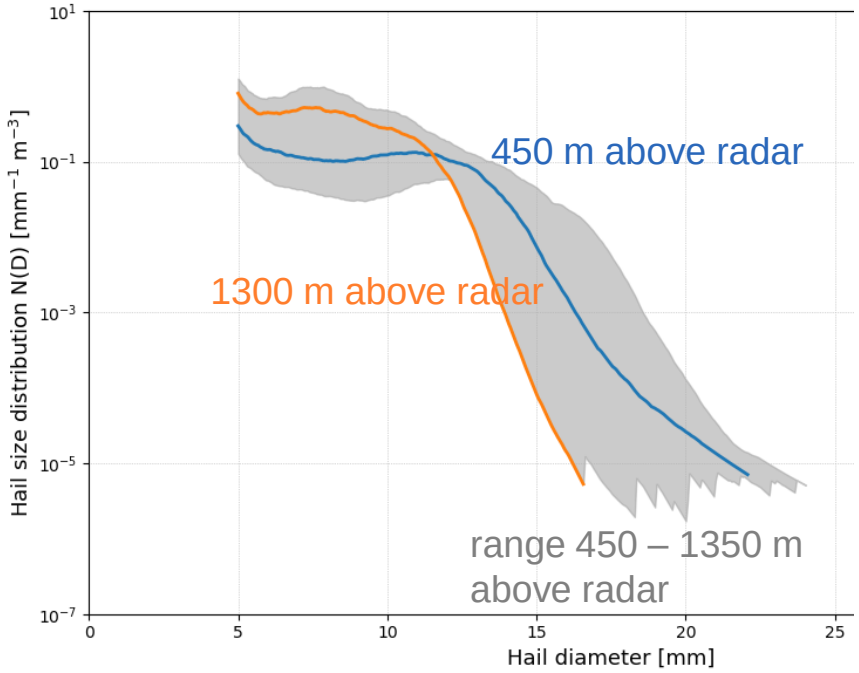
2 main tasks for retrieval of the hail size distribution bin-by-bin:
Doppler velocity → hail size
signal power → hail frequency

Review

supercell 30 April 2021 MHP

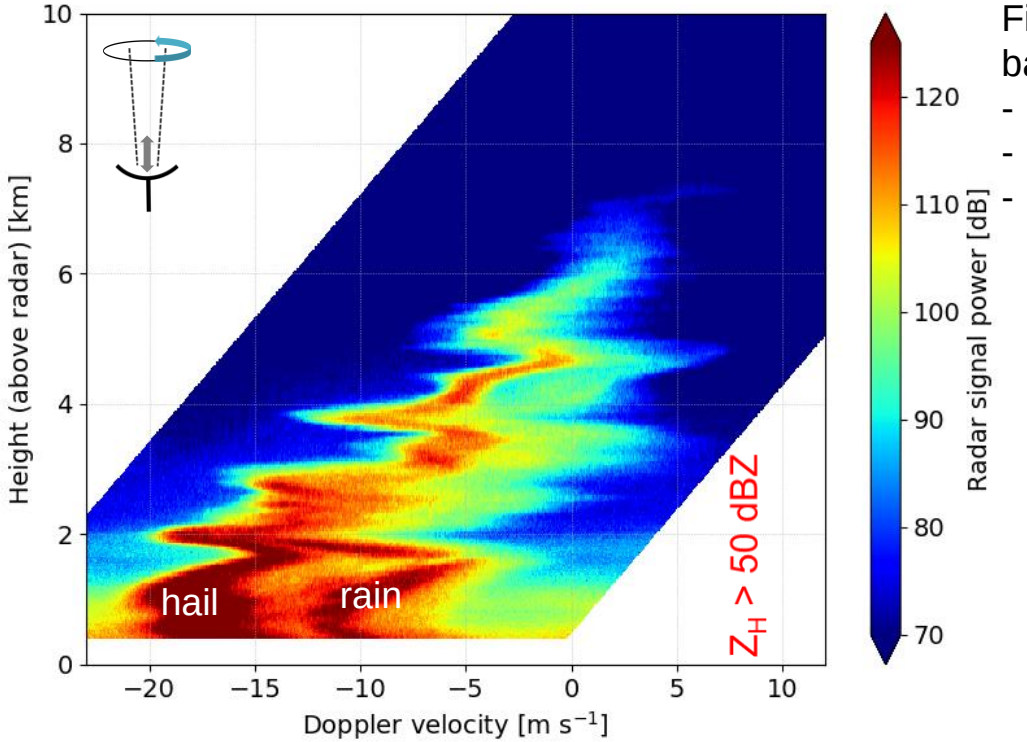


- Retrieved hail size distribution(s)



Hail Doppler spectra

supercell 30 April 2021 MHP



Find hail events near (or directly above) DWD C-band radars spring 2021 – fall 2023:

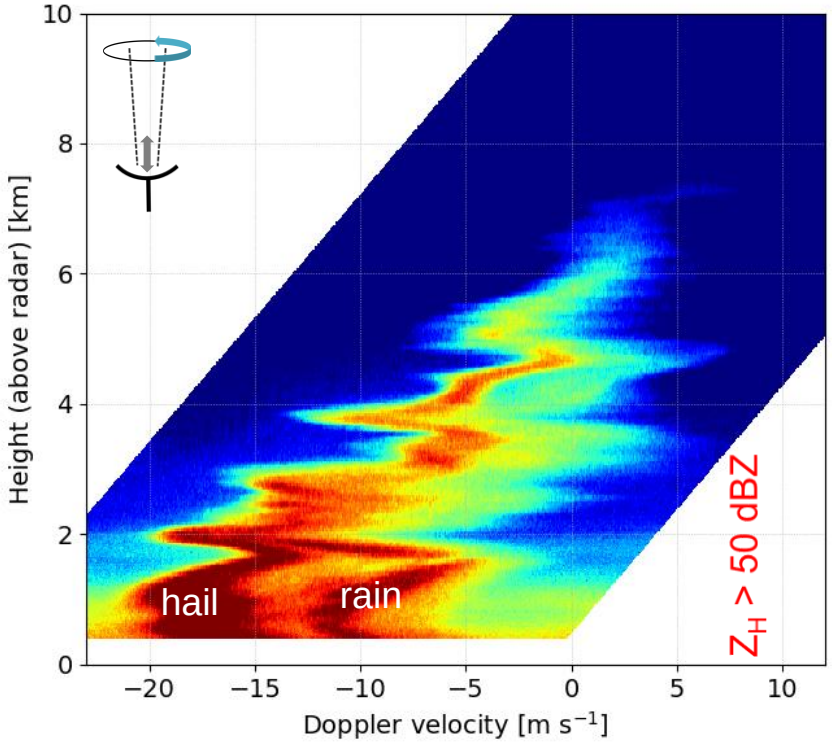
- news reports (TV, online)
- eye witness reports (ESWD)
- radar volumescans over Germany since 2021:

vertically integrated ice (VII) ~ $\int_{h(Temp)} Z_H \, dh$

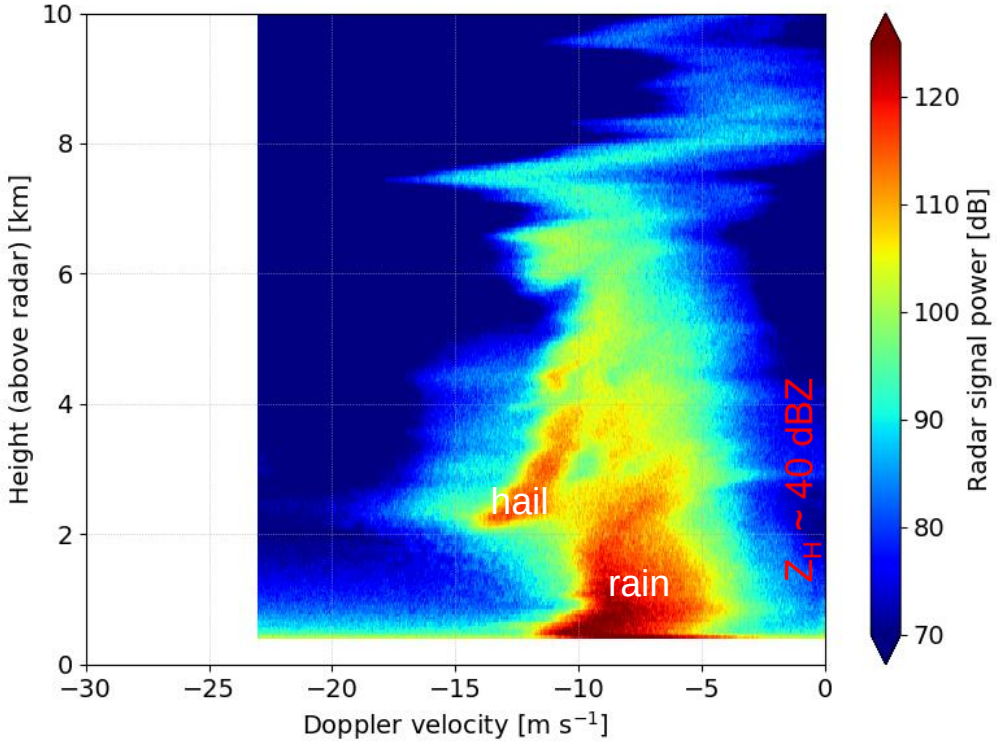
~ 15 hail events
with 'usable' Doppler spectra

Hail Doppler spectra

supercell 30 April 2021 MHP



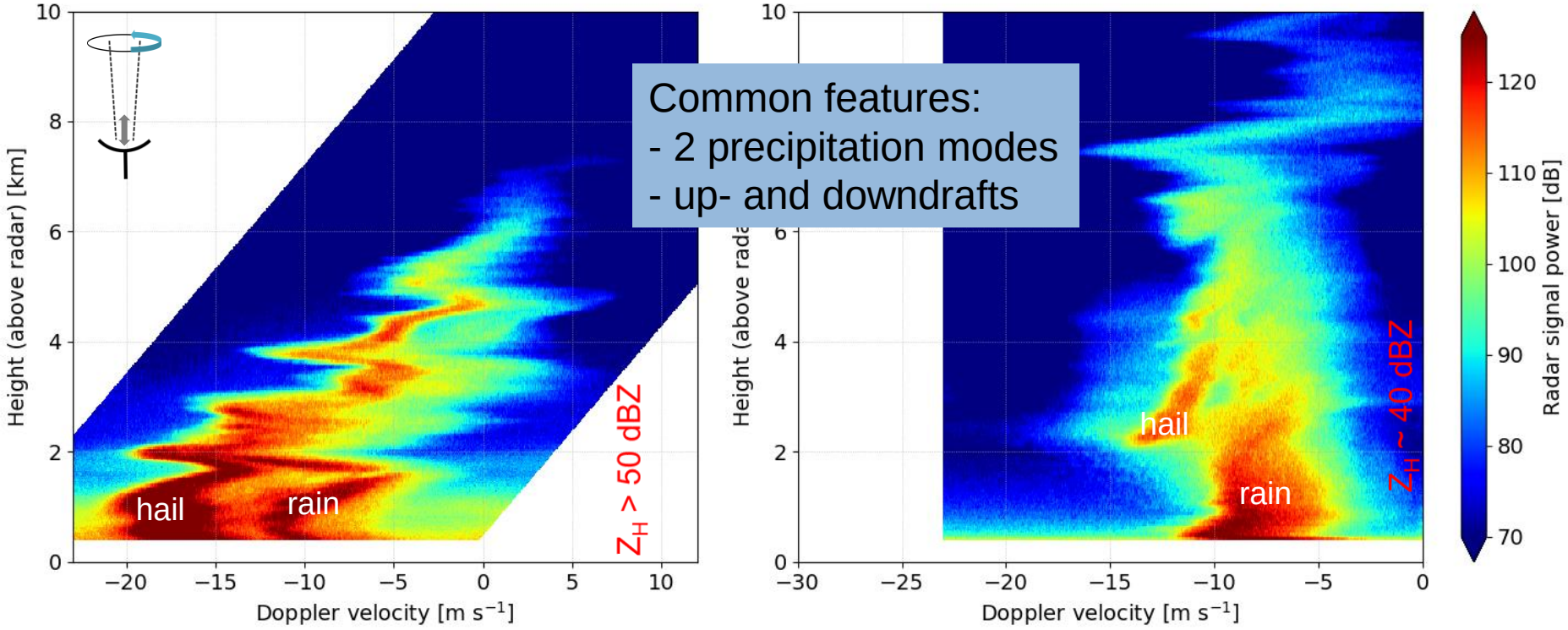
supercell 22 June 2023 FLD



Hail Doppler spectra

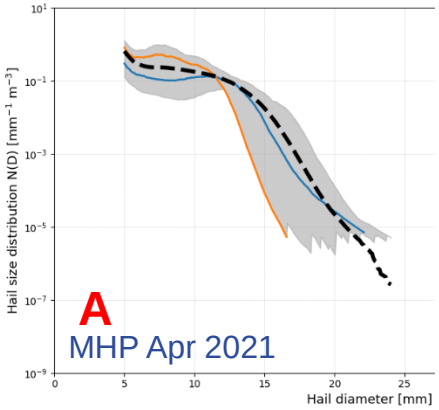
supercell 30 April 2021 MHP

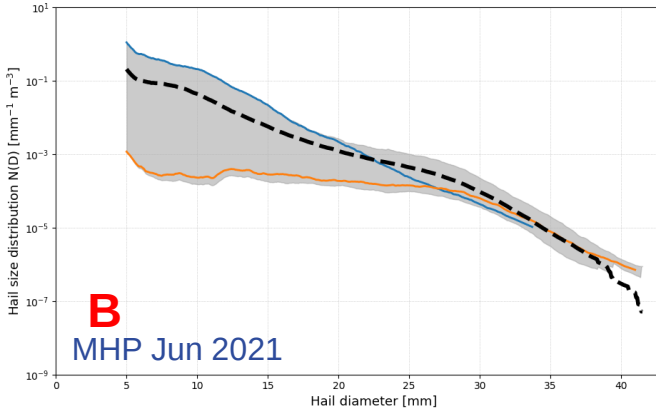
supercell 22 June 2023 FLD

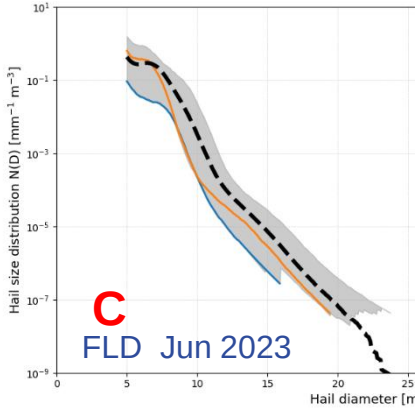


Comparison of HSDs

- Hail size distributions:



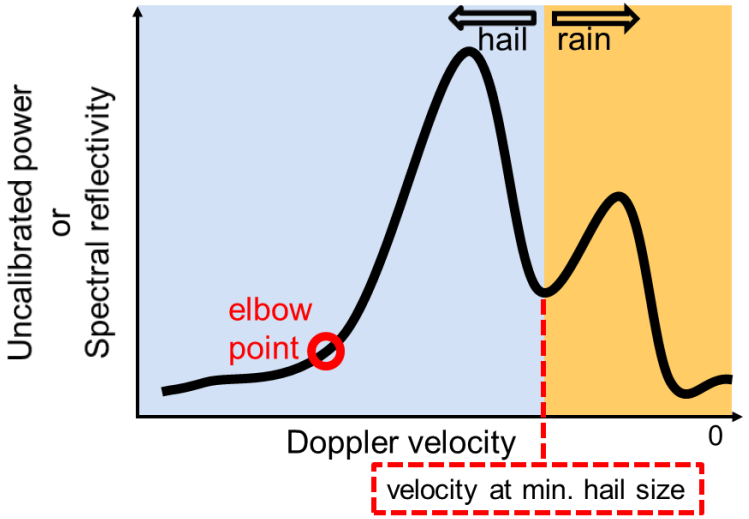




- Hail characteristics:

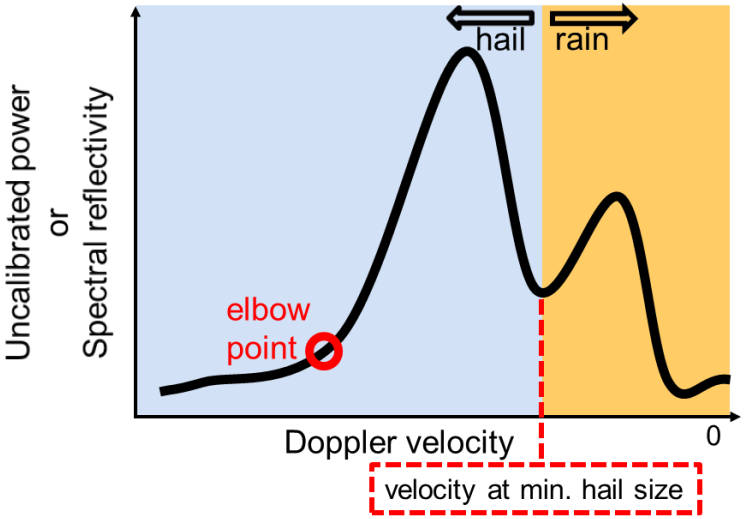
		D_max [mm]	D_mean [mm]	D_meanmass [mm]	Hail rate [mm h^{-1}]	E_kin flux [mW m^{-2}]
A	MHP Apr 2021	24.0	8.7	11.0	13.2	151
B	MHP Jun 2021	41.5	10.7	18.0	5.0	89
C	FLD Jun 2023	23.7	6.5	7.0	1.7	10

Correction for vertical air motion

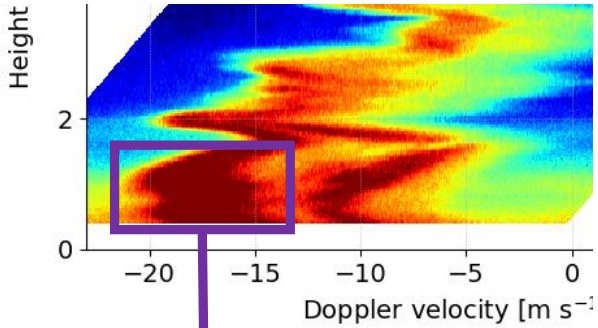


Minimum hail size = D_{min}:
Vertical wind = $v_{DV}(D_{min})$ - $v(D_{min})$,
v_{DV}: radar Doppler velocity
v: terminal fall velocity (v-D relationship)

Correction for vertical air motion



D_{min} = 5 mm?



ϕ = 0.5 m

Measured
D's questionable

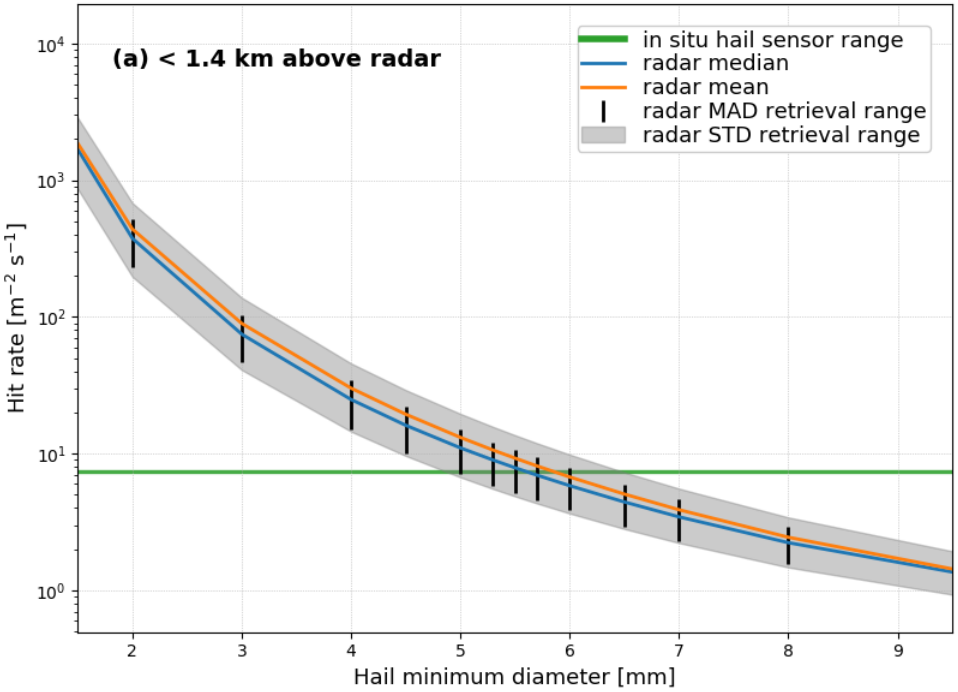
Match times
+ compare

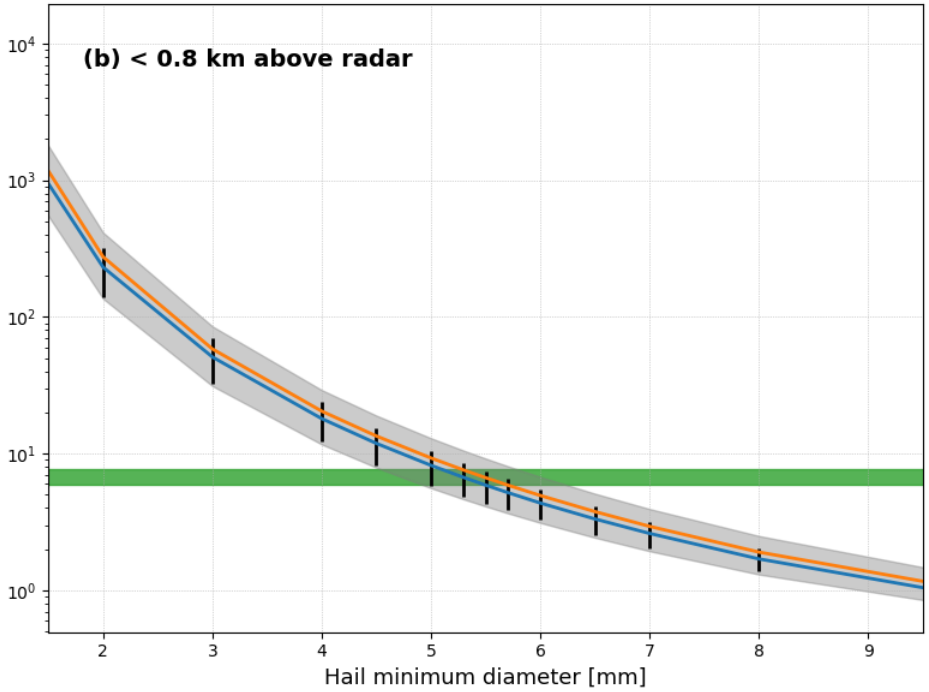
Minimum hail size = D_{min}:
Vertical wind = $v_{DV}(D_{min})$ - $v(D_{min})$,
v_{DV}: radar Doppler velocity
v: terminal fall velocity (v-D relationship)

Find appropriate D_{min} via
hit rate (= hailstone number / m^2 s):
radar-derived vs in situ hail sensor
v(D) from Heymsfield et al. (2018)

Correction for vertical air motion

Only 1 hail event (variability of hail intensity + few in situ hail sensor data)





Correction for vertical air motion

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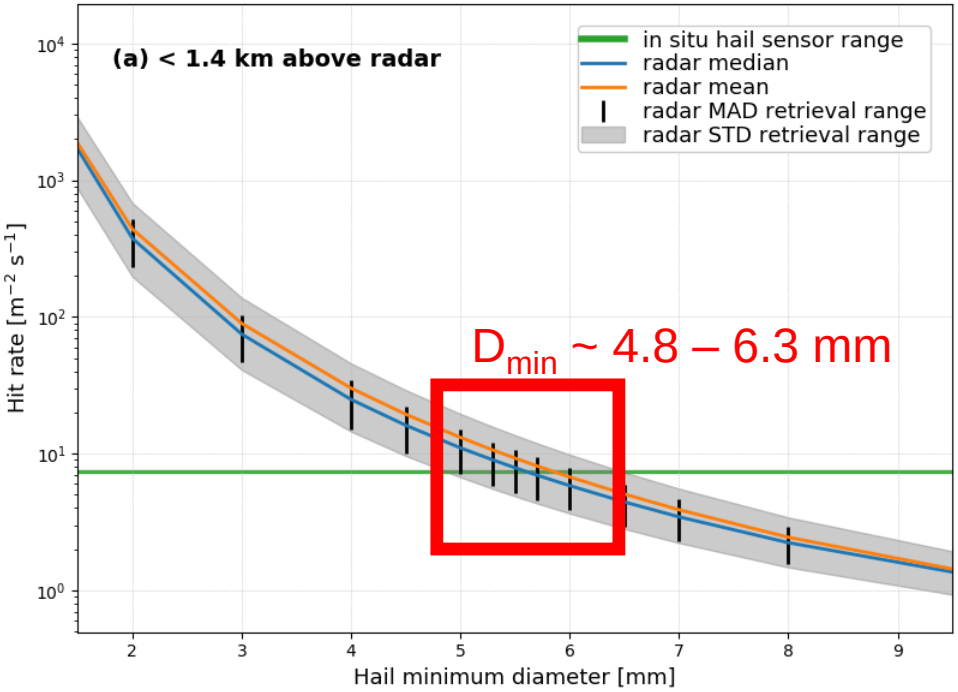
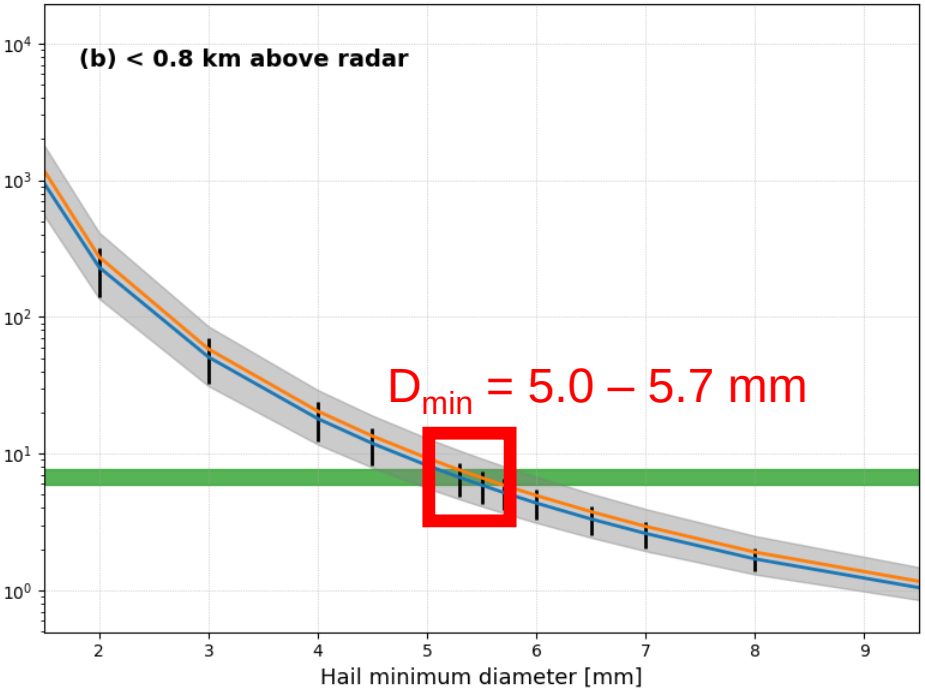
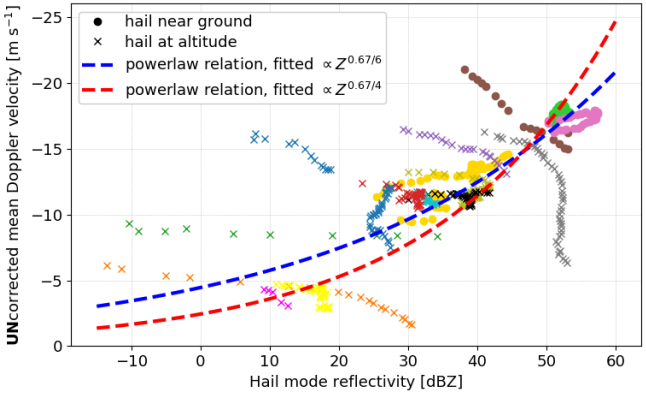
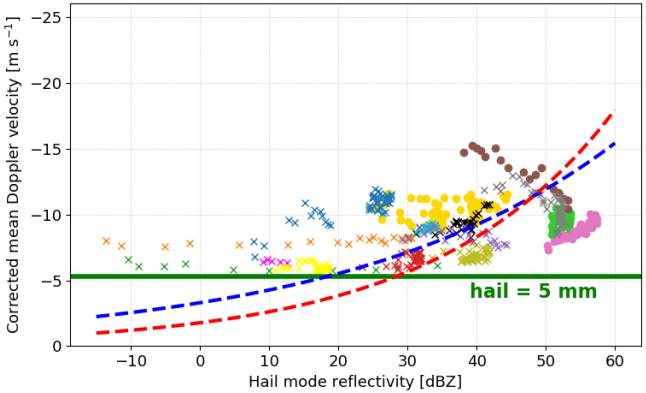




Radar–hail (cor)relations

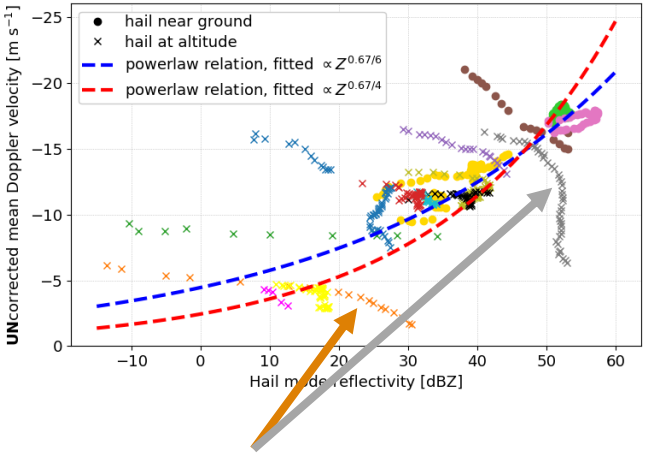
4x hail at ground
11x hail at altitude

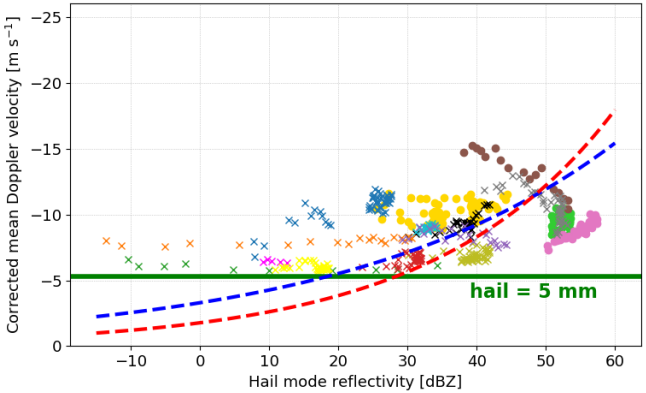




Radar–hail (cor)relations

4x hail at ground
11x hail at altitude

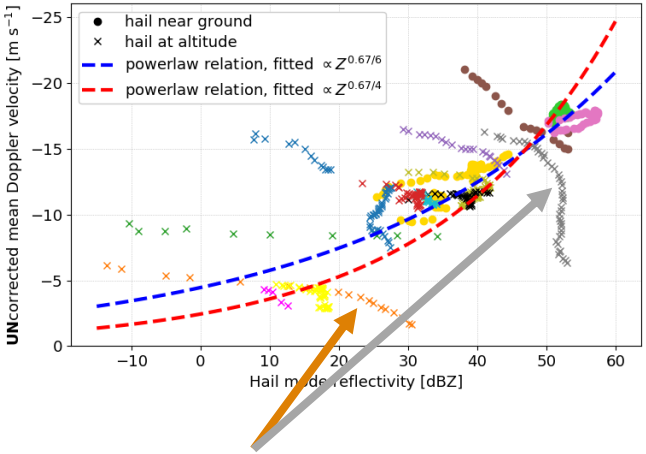


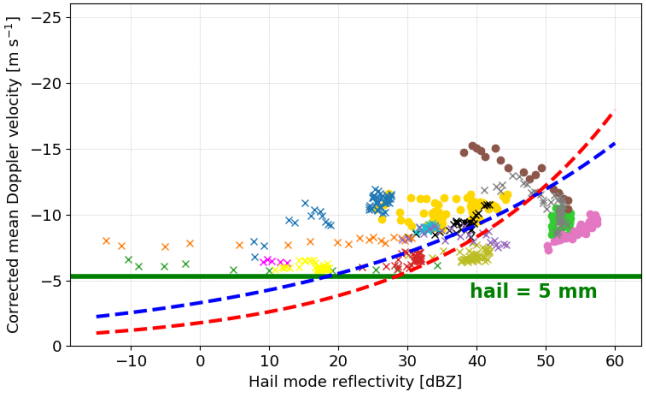


Artifacts due to vertical wind profile,
can be mitigated by correction

Radar–hail (cor)relations

4x hail at ground
11x hail at altitude





Artifacts due to vertical wind profile, can be mitigated by correction

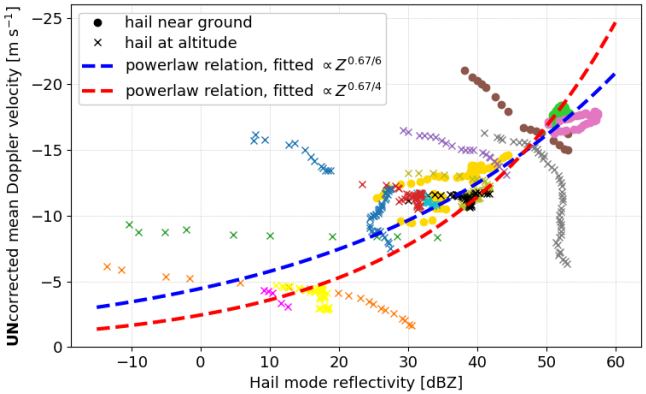
$v(D) = a * D^{0.67}$ (Heymsfield et al., 2018)
$\sigma_b \sim D^6, D^4$

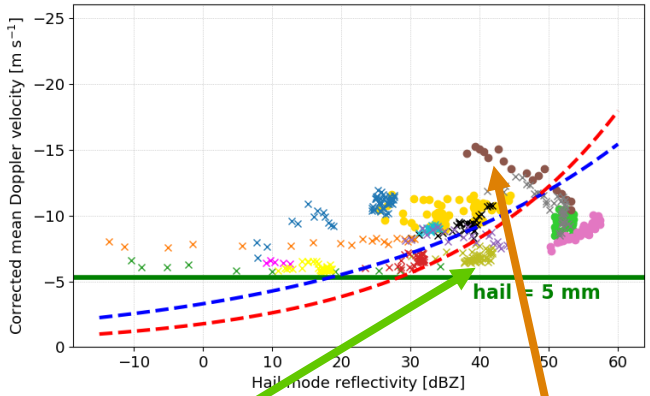
v–Z relationship

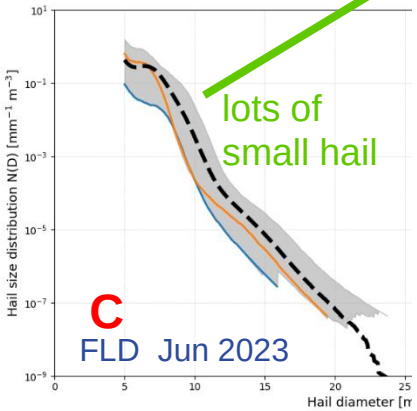
$v(D), m(D), \sigma_b(D)$

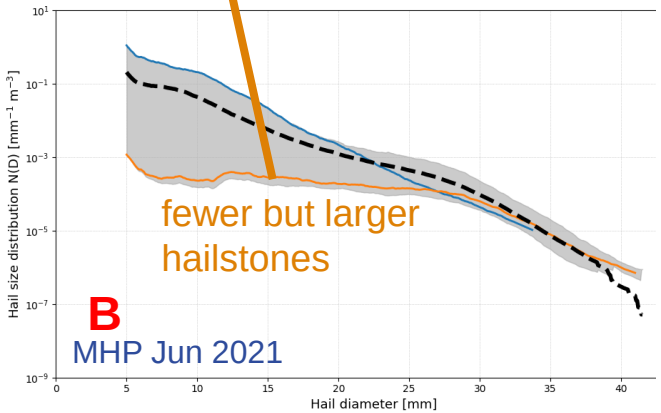
typical hail size, number, kinetic energy
BUT non-unique

Radar–hail (cor)relations

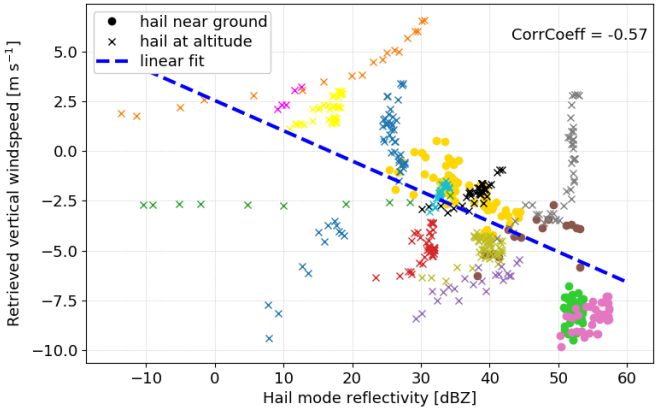


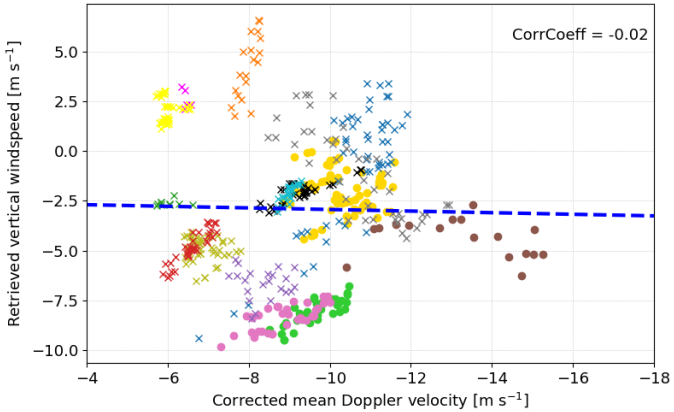


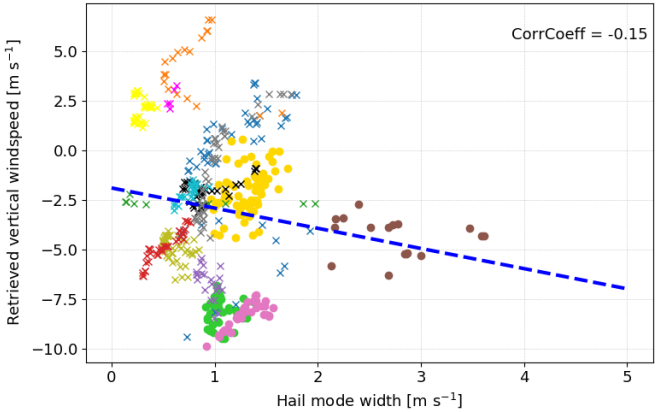




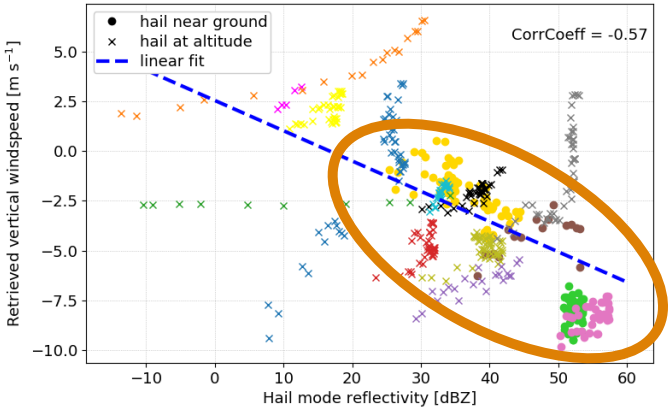
Radar–hail (cor)relations

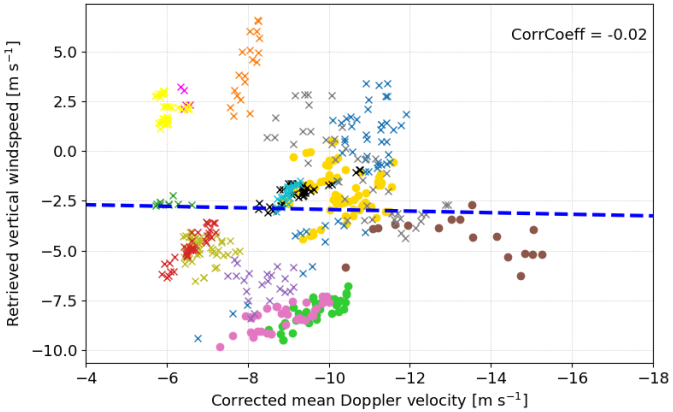


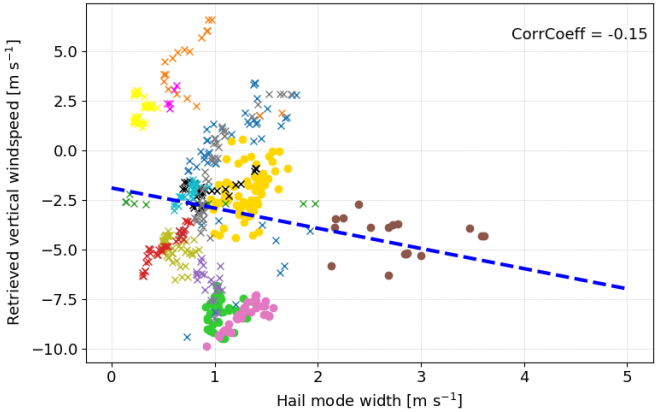




Radar–hail (cor)relations

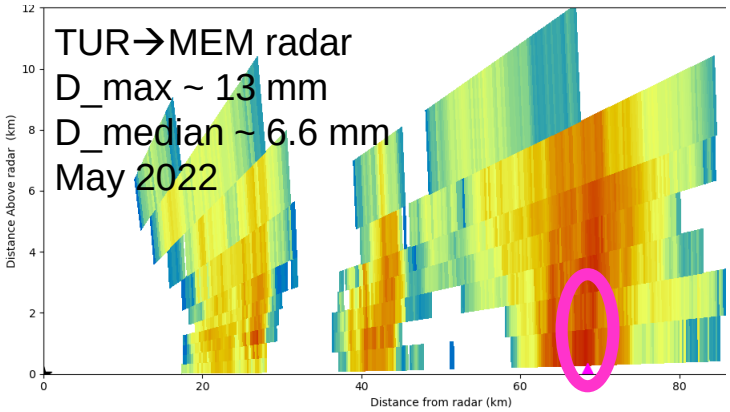


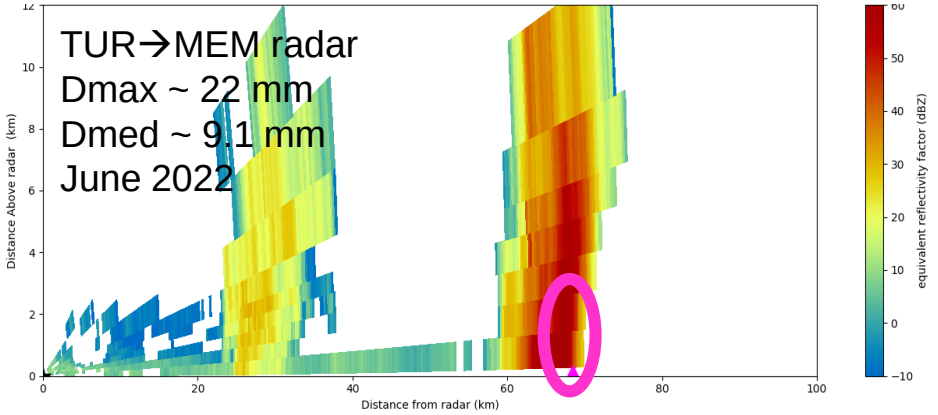


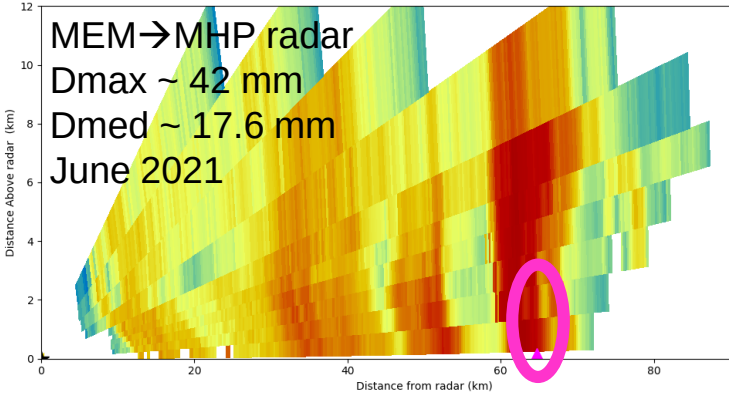


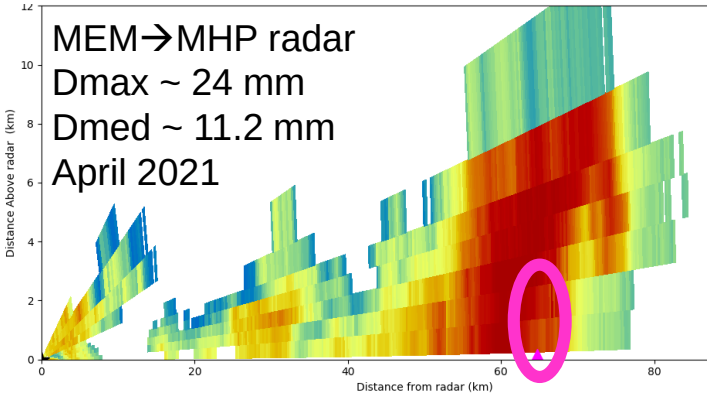
- Hail near ground falls in downdraft (not in updraft)
- Generally: **stronger downdraft for higher hail reflectivity**
  (not necessarily for larger maximum hail size)

Volume scan: Z_H

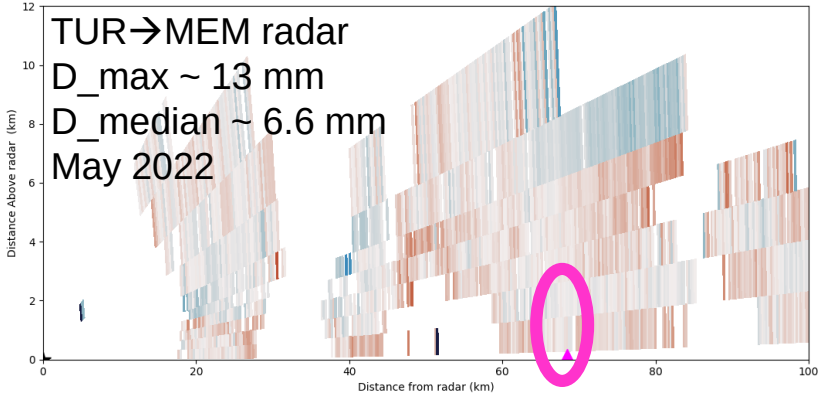


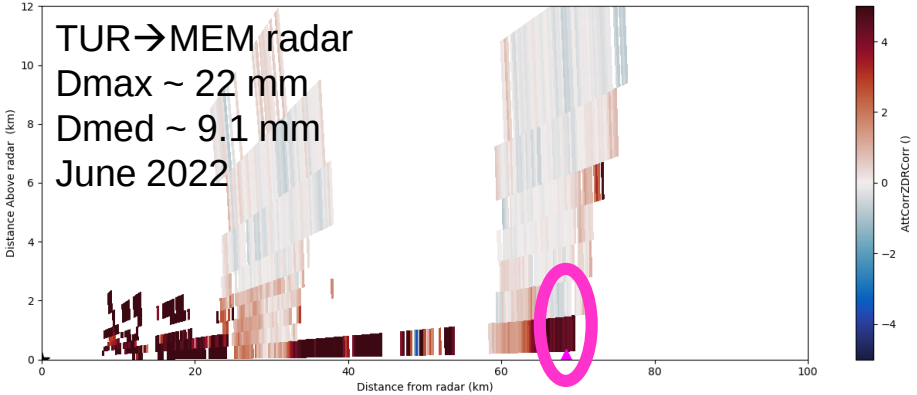


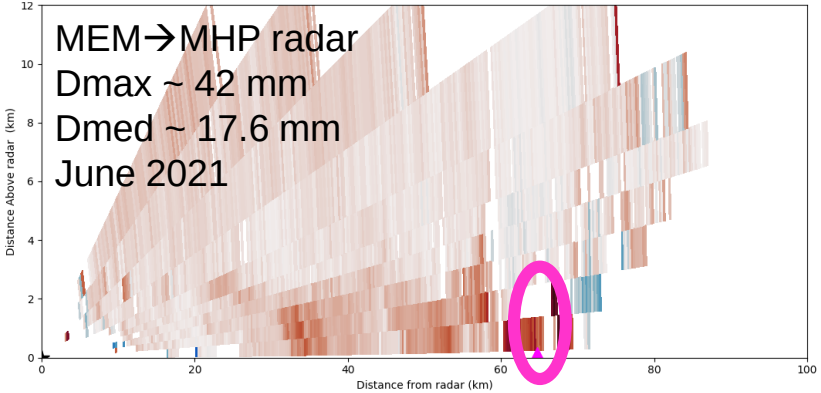


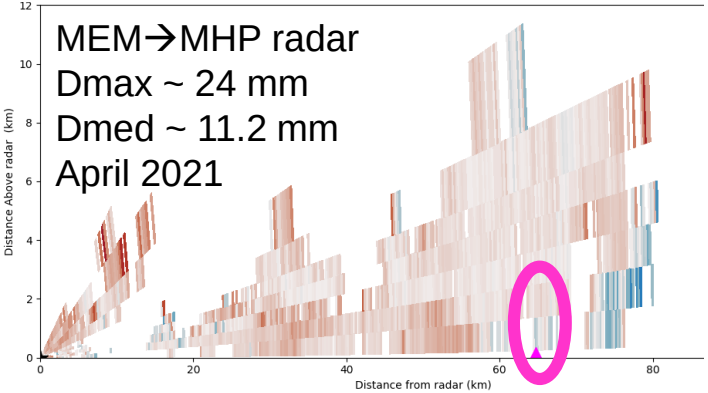


Volume scan: ZDR

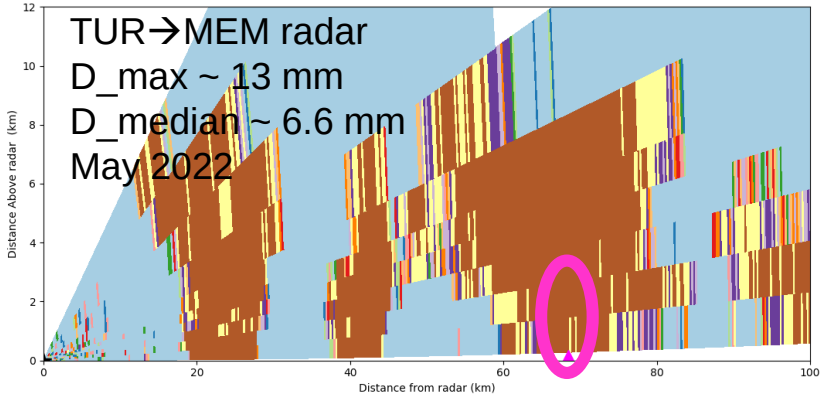


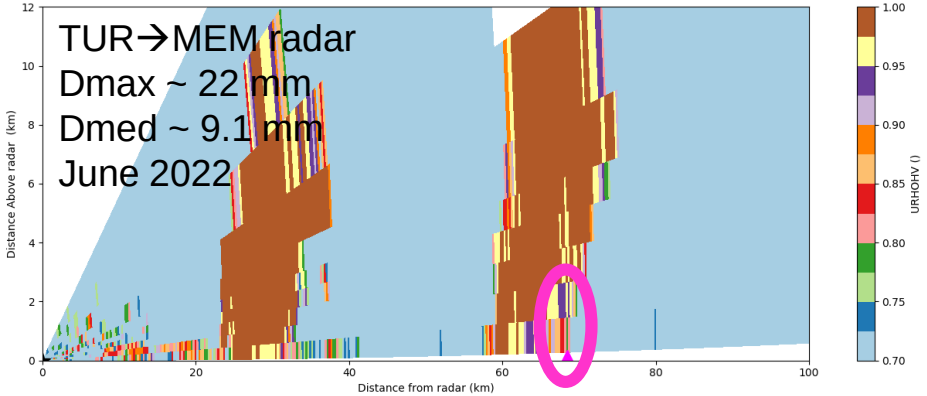


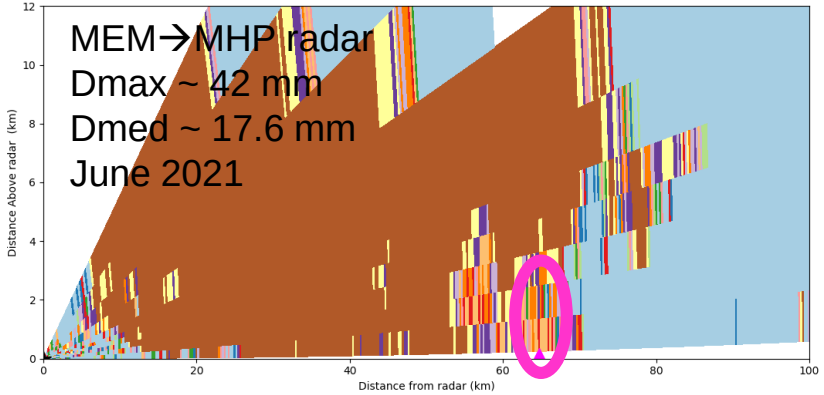


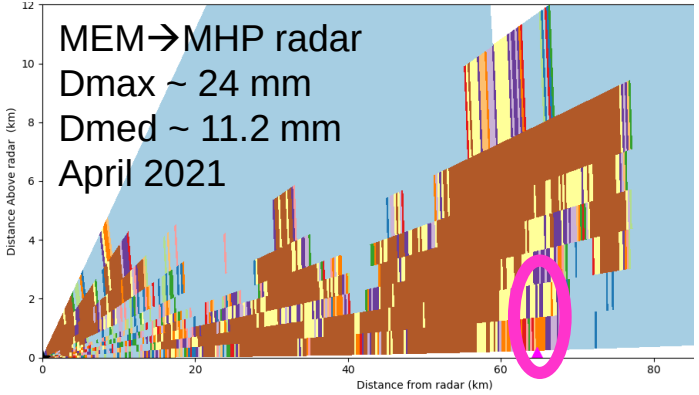


Volume scan: RHOHV





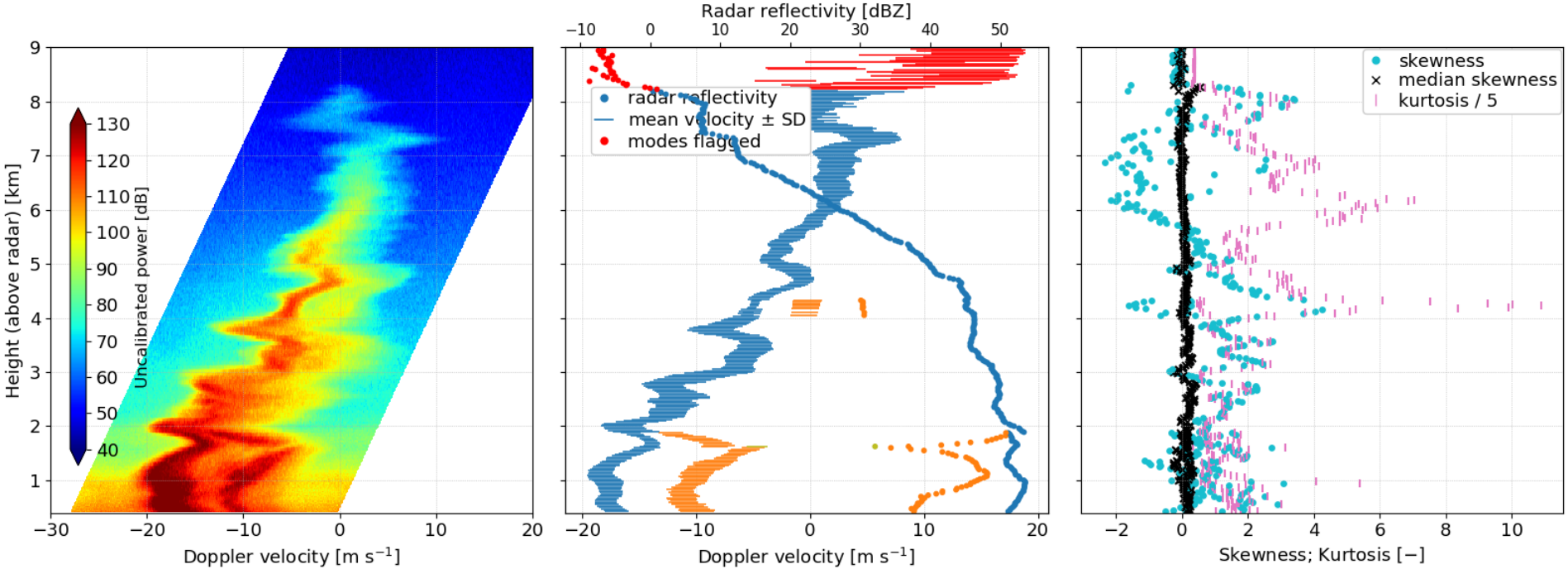




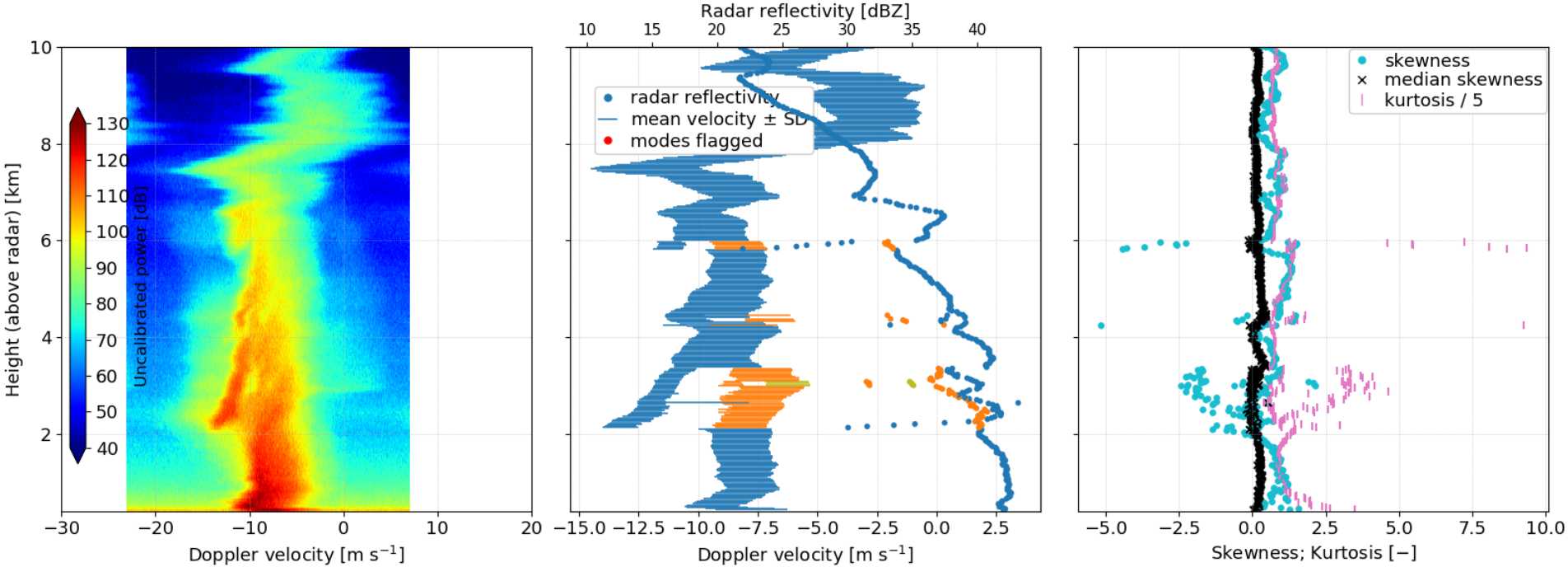
Summary

- Typical hail fall velocity v_h(Z) in m/s, uncorrected and corrected for vertical wind:
  Z_linear = $10^{0.1*dBZ}$
  (–) v_h(Z) = 4.45 $Z\_linear^{0.67/6}$
  (–) v_h(Z) = 2.44 $Z\_linear^{0.67/4}$
  (–) v_h(Z) = 3.30 $Z\_linear^{0.67/6}$
  (–) v_h(Z) = 1.77 $Z\_linear^{0.67/4}$
- Typical hail fall velocity v_h(width) with width = standard deviation of hail mode:
  (–) v_h(width) = 8.04 + 3.84*width
  (–) v_h(width) = 6.15 + 2.83*width
- Vertical (air motion) wind speed v_air(dBZ) in m/s in hail region:
  (–) v_air(dBZ) = 2.55 – 0.15*dBZ
- Can we resolve non-uniqueness with polarimetry (→ RHOHV)?

Extra: postprocessing

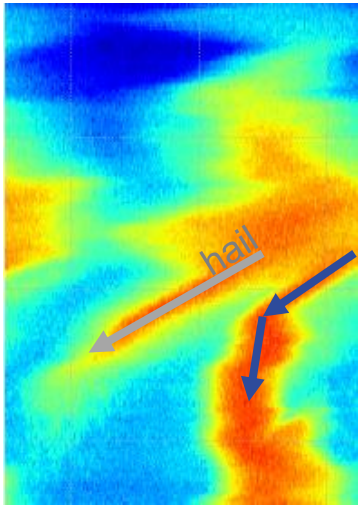


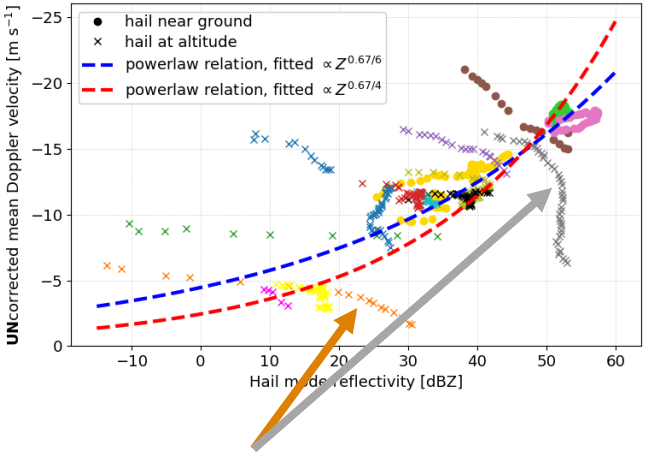
Extra: postprocessing

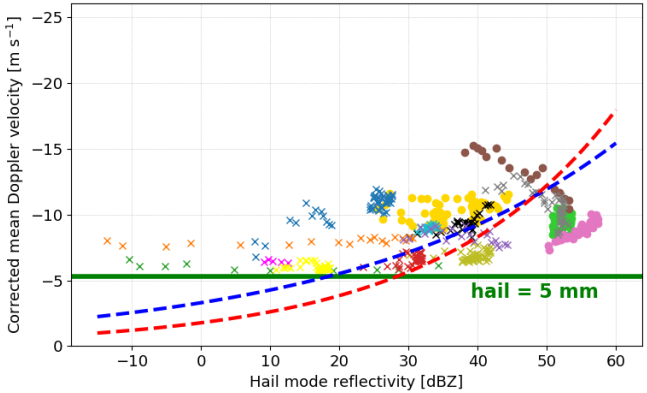


Extra: Radar–hail (cor)relations

4x hail at ground
11x hail at altitude

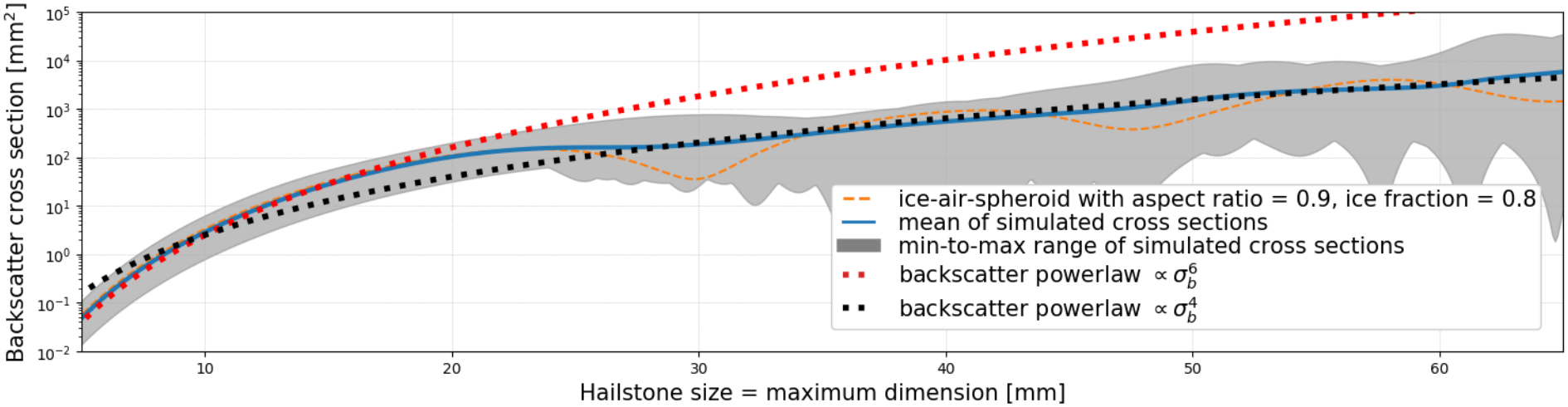




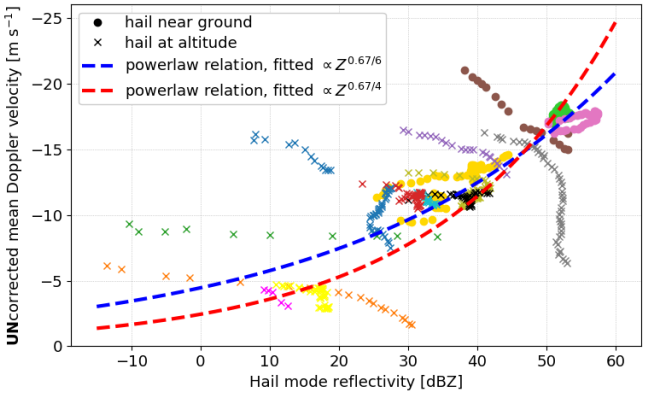


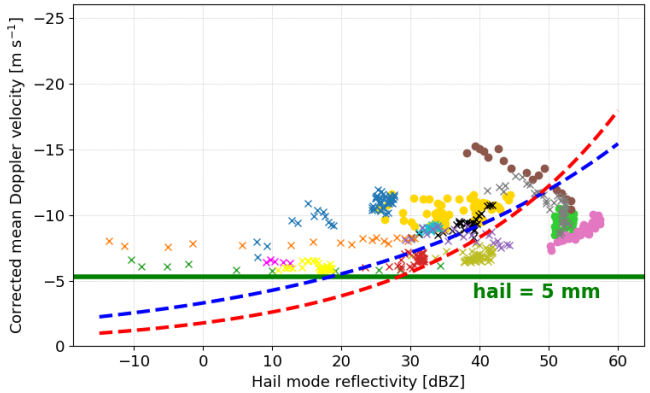
Artifacts due to vertical wind profile,
can be mitigated by correction

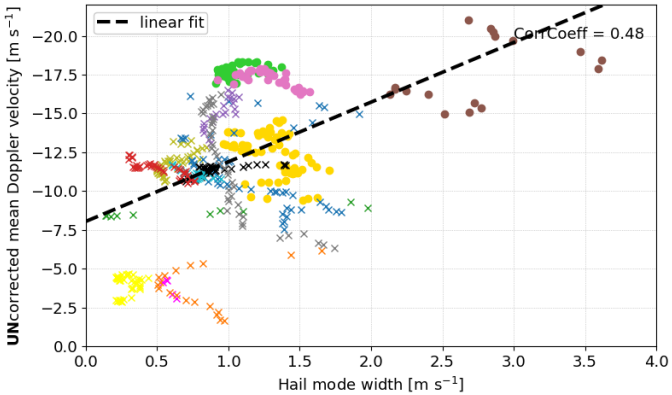
Extra: backscatter power law

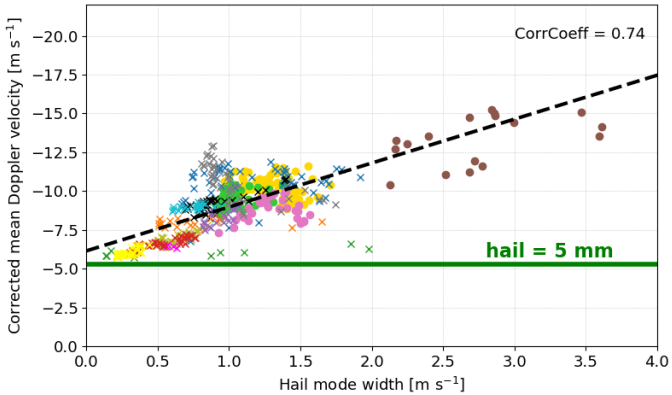


Radar–hail (cor)relations









Extra: Width vs. reflectivity