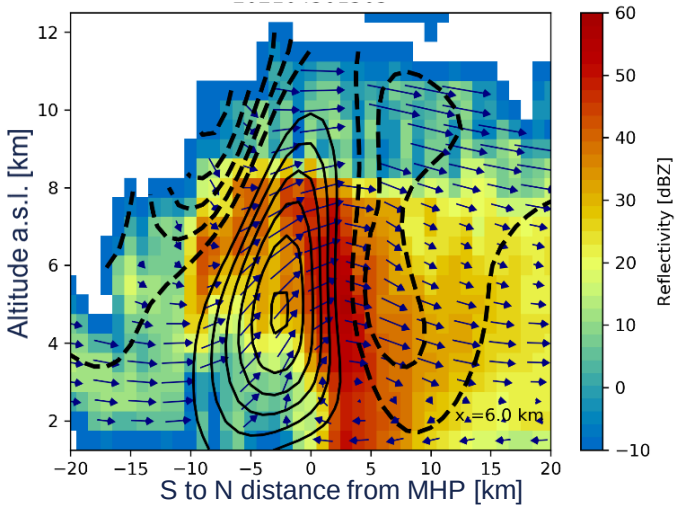
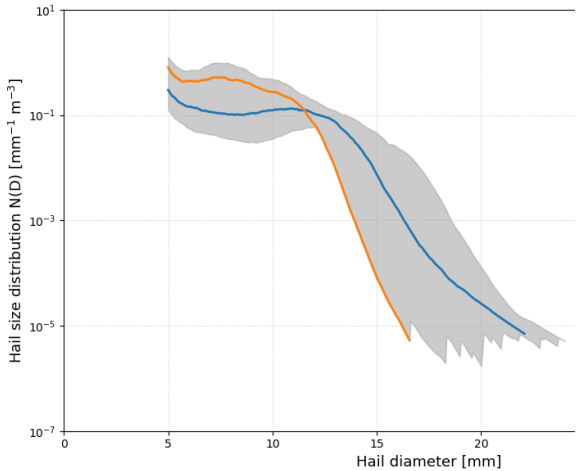


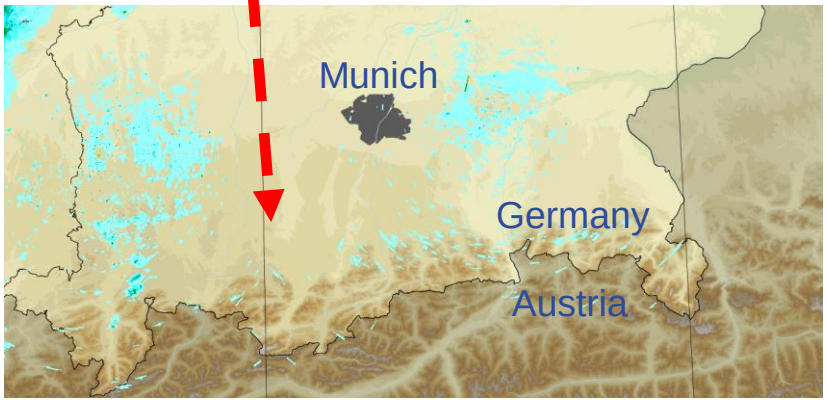


A seamless profile of the precipitation process of mixed-phase clouds employing data from a polarimetric C-band radar, a Micro Rain Radar and disdrometers (HydroColumn) – Supercell multi-Doppler analysis + retrieval of the hail size distribution

M. Gergely, M. Frech (PI), DWD
(and A. Böhm, F. Seeger, R. Feger at DWD + M. Bell at CSU)

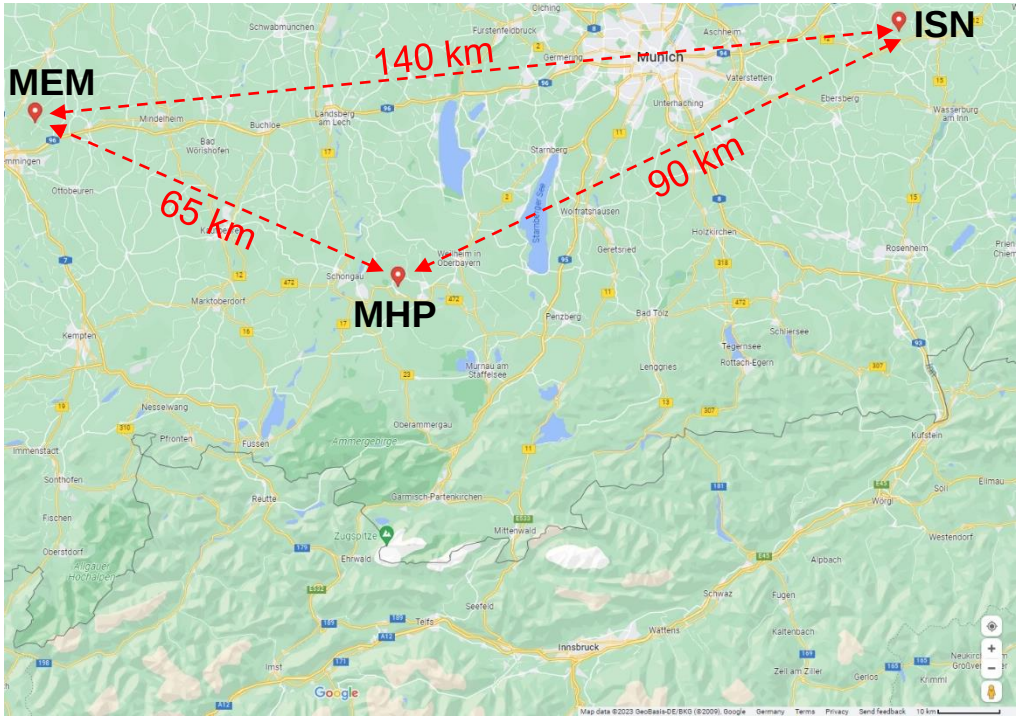
Supercell hailstorm on 30 April 2021

observatory Hohenpeißenberg
+ radar tower



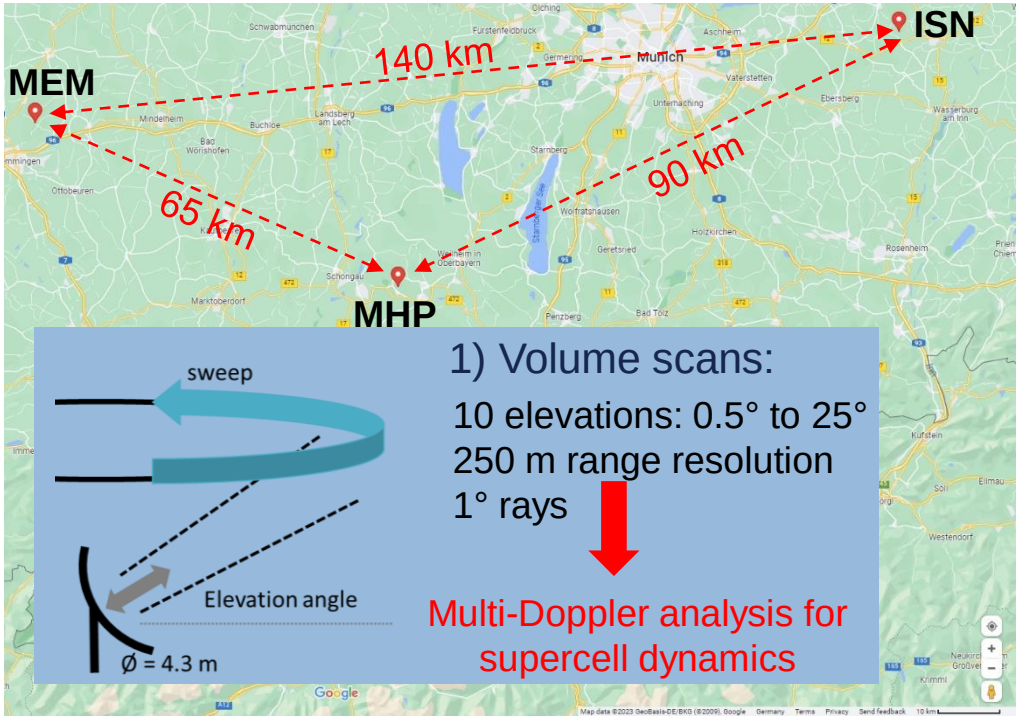
Radar setup

- DWD C-band radars at Memmingen (**MEM**), Isen (**ISN**), and at observatory Hohenpeißenberg (**MHP**)



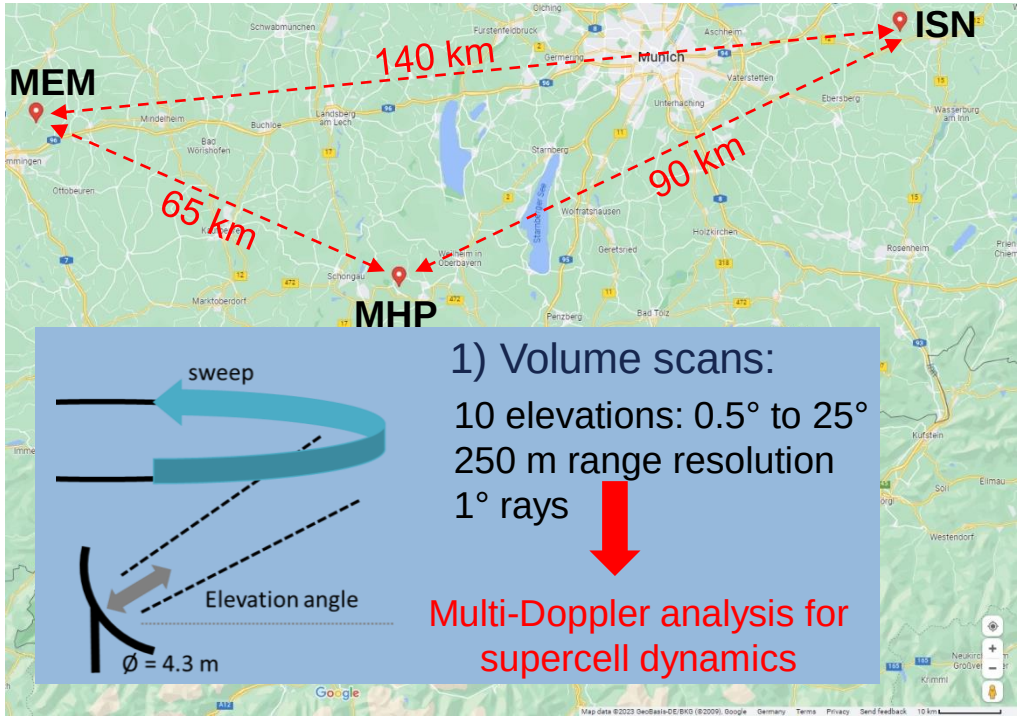
Radar setup

- DWD C-band radars at Memmingen (**MEM**), Isen (**ISN**), and at observatory Hohenpeißenberg (**MHP**)



Radar setup

- DWD C-band radars at Memmingen (**MEM**), Isen (**ISN**), and at observatory Hohenpeißenberg (**MHP**)



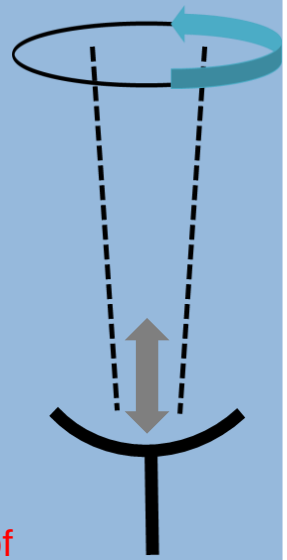
1) Volume scans:

10 elevations: 0.5° to 25°
250 m range resolution
1° rays

Multi-Doppler analysis for supercell dynamics

2) Vertical (birdbath scans) at **MHP**:

~ 15 s birdbath scan:
range sampling = 25 m
PRF = 1000 Hz
integration time ≈ 1 s
FFT for 1024 pulses
Nyquist velocity ≈ 13 m/s
velocity resolution ≈ 2.6 cm/s

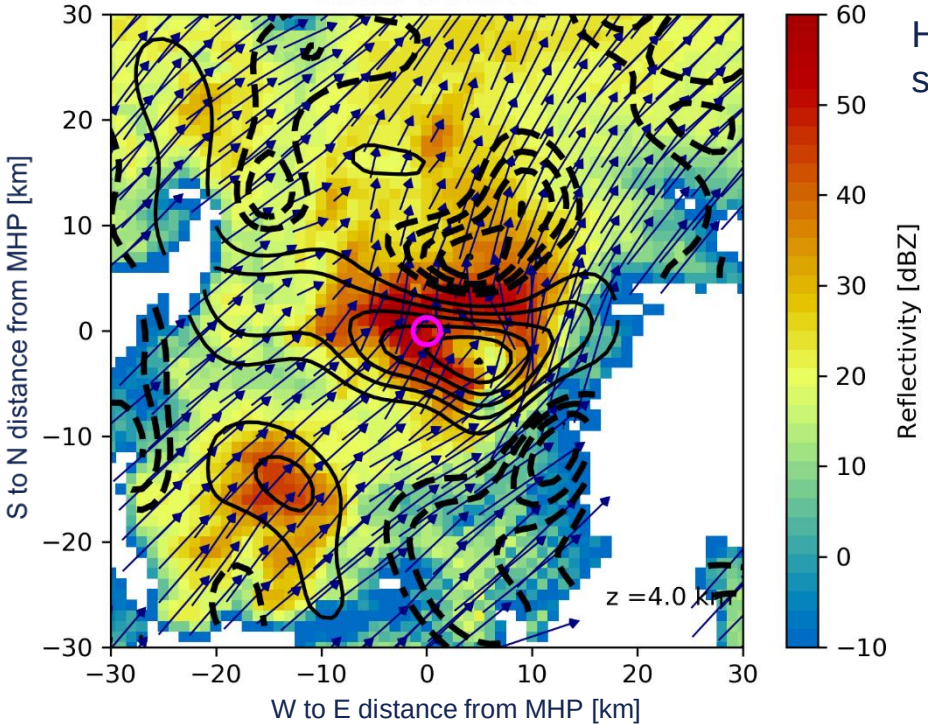


Doppler spectra for retrieval of hail size distribution

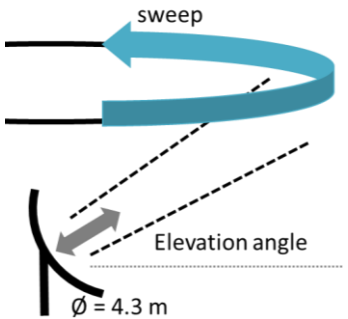
(+ in situ hail sensor 100 m from radar tower)

Triple-Doppler analysis

- SAMURAI software (developed @ CSU) retrieves 3D wind field from multiple Doppler radars

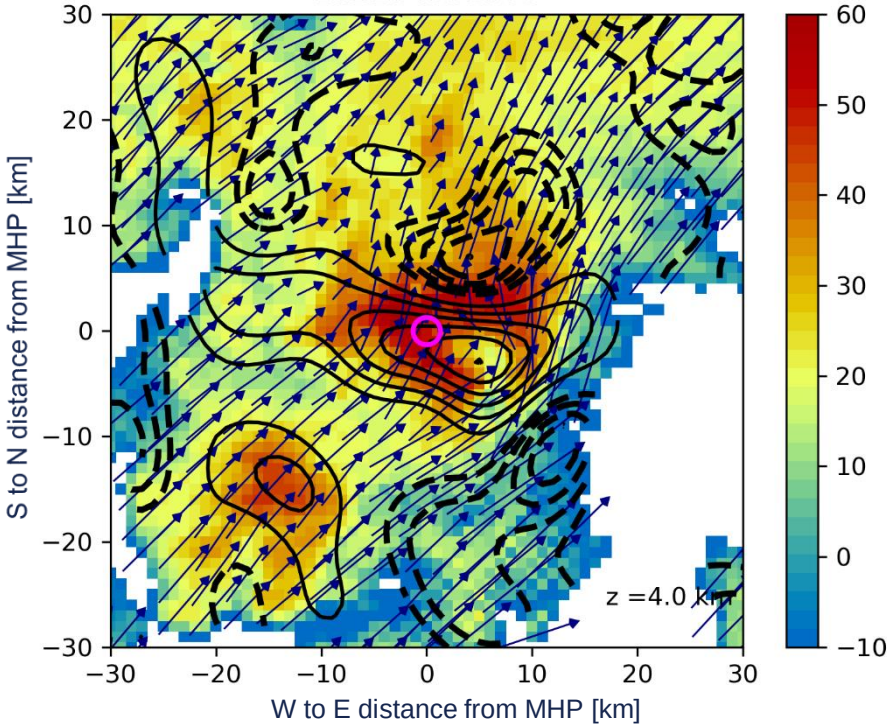


Horizontal cross section at 4 km a.s.l. for radar volume scans at 15:05 to 15:10 UTC (i.e. 17:xy h local time)



Triple-Doppler analysis

- SAMURAI software (developed @ CSU) retrieves 3D wind field from multiple Doppler radars

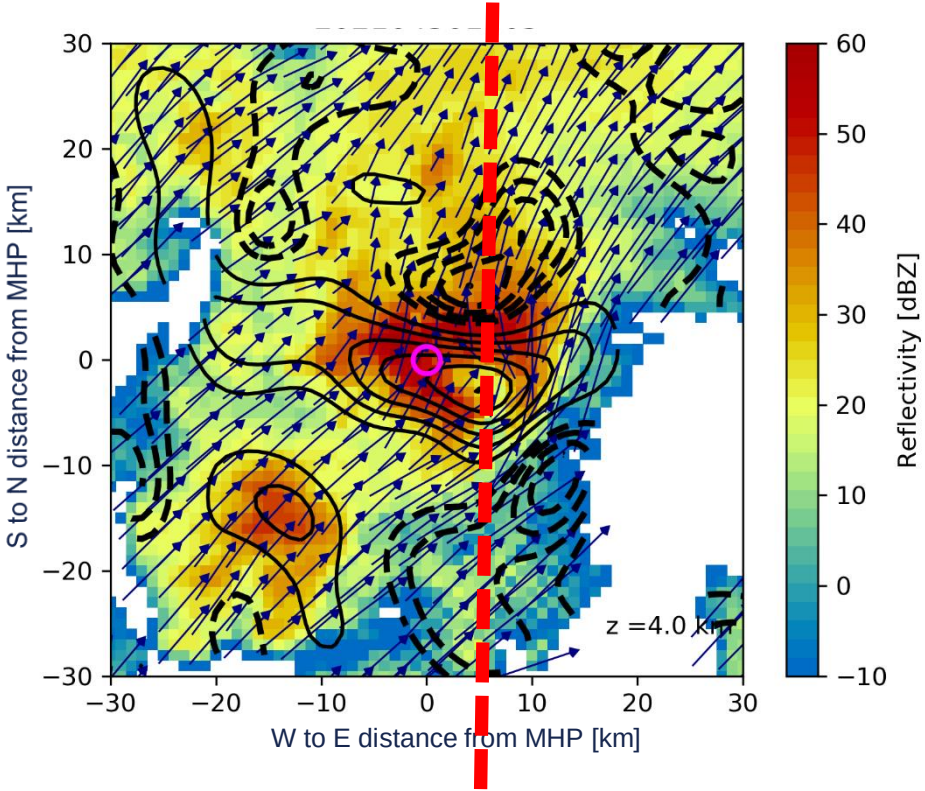


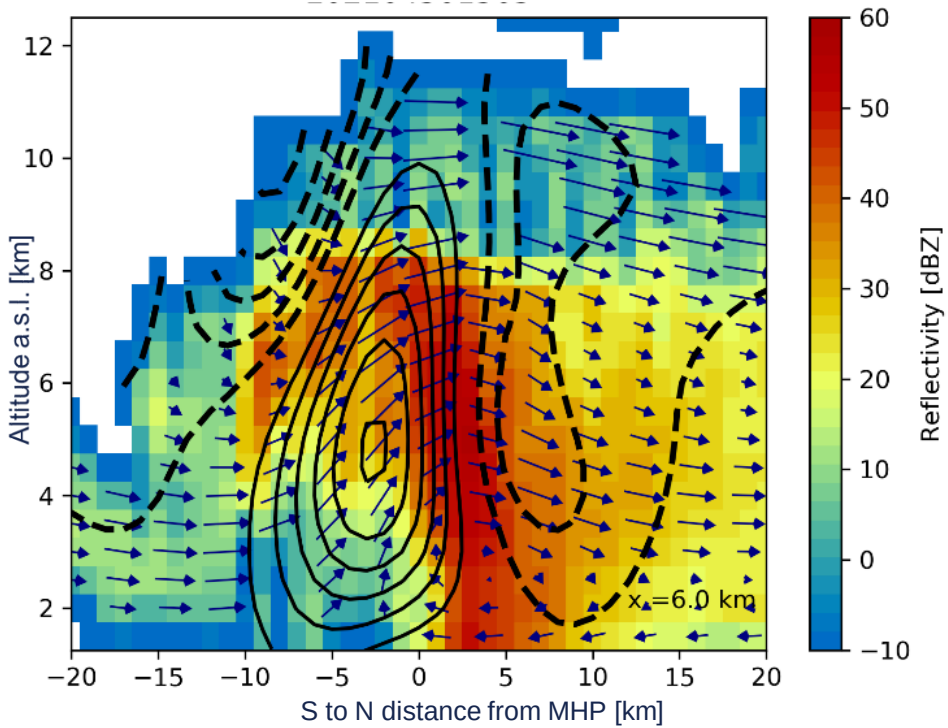
Horizontal cross section at 4 km a.s.l. for radar volume scans at 15:05 to 15:10 UTC (i.e. 17:xy h local time)

- hail at observatory, i.e. at MHP radar
- atmospheric flow from SW, supercell moves W to E, mesocyclone rotation not visible at this height
- updraft speeds > 10 m/s (at this timestep) in low-reflectivity BWER
- downdrafts stronger than 4 m/s in FFD region to NE
- secondary cell ~ 15 km to SW of main cell (merges 1h later) → no well-developed RFD

Triple-Doppler analysis

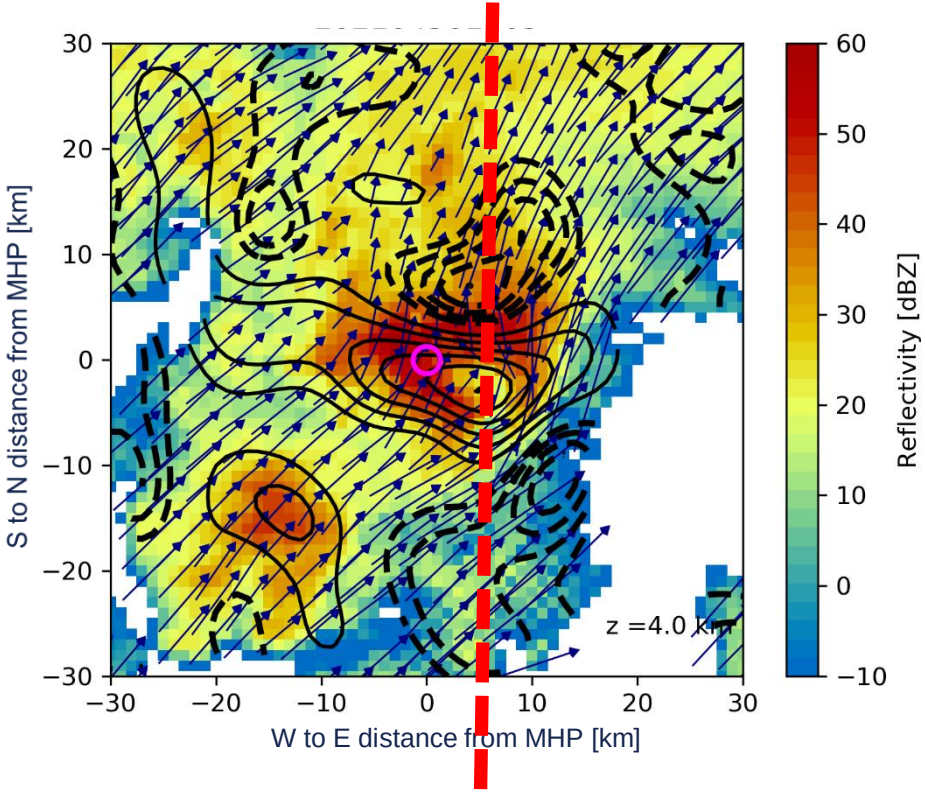
- SAMURAI software (developed @ CSU) retrieves 3D wind field from multiple Doppler radars

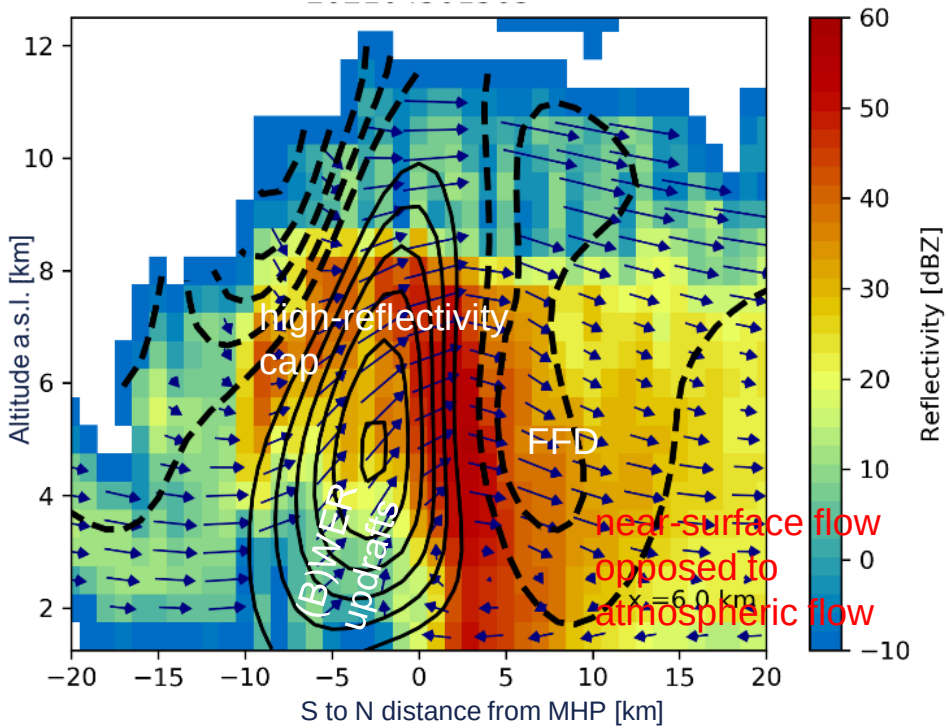




Triple-Doppler analysis

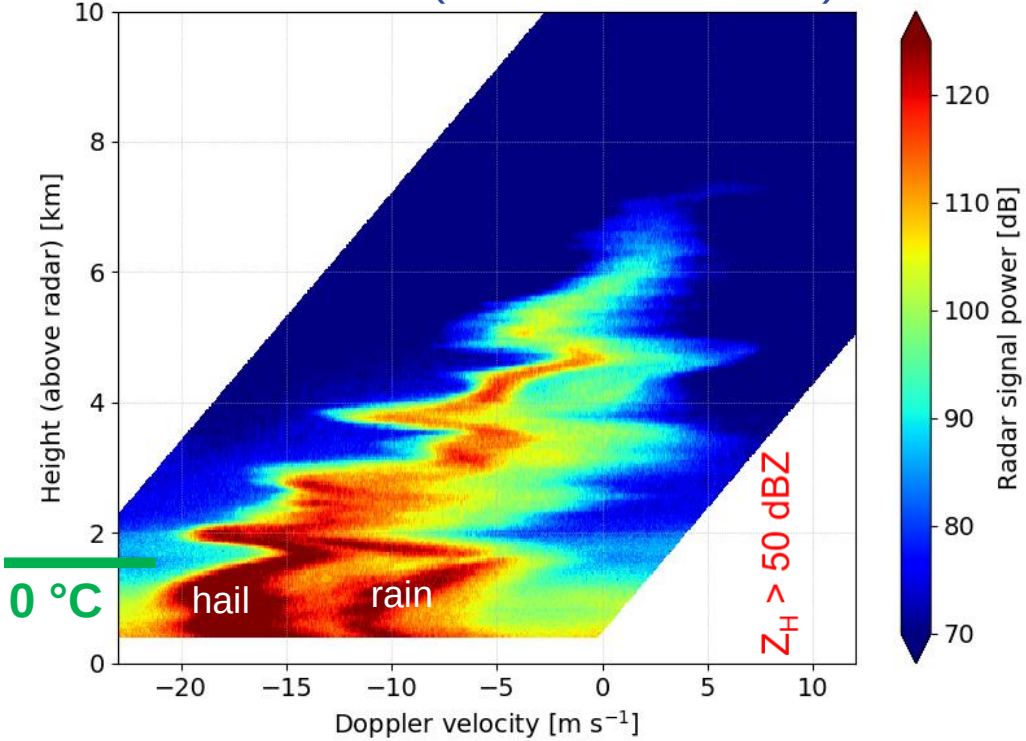
- SAMURAI software (developed @ CSU) retrieves 3D wind field from multiple Doppler radars

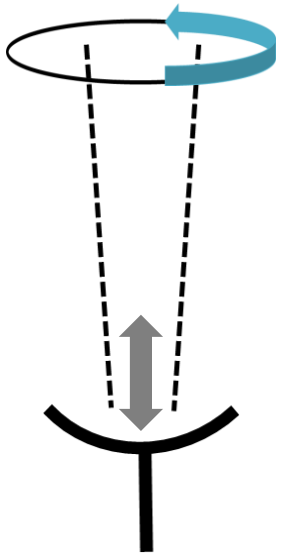




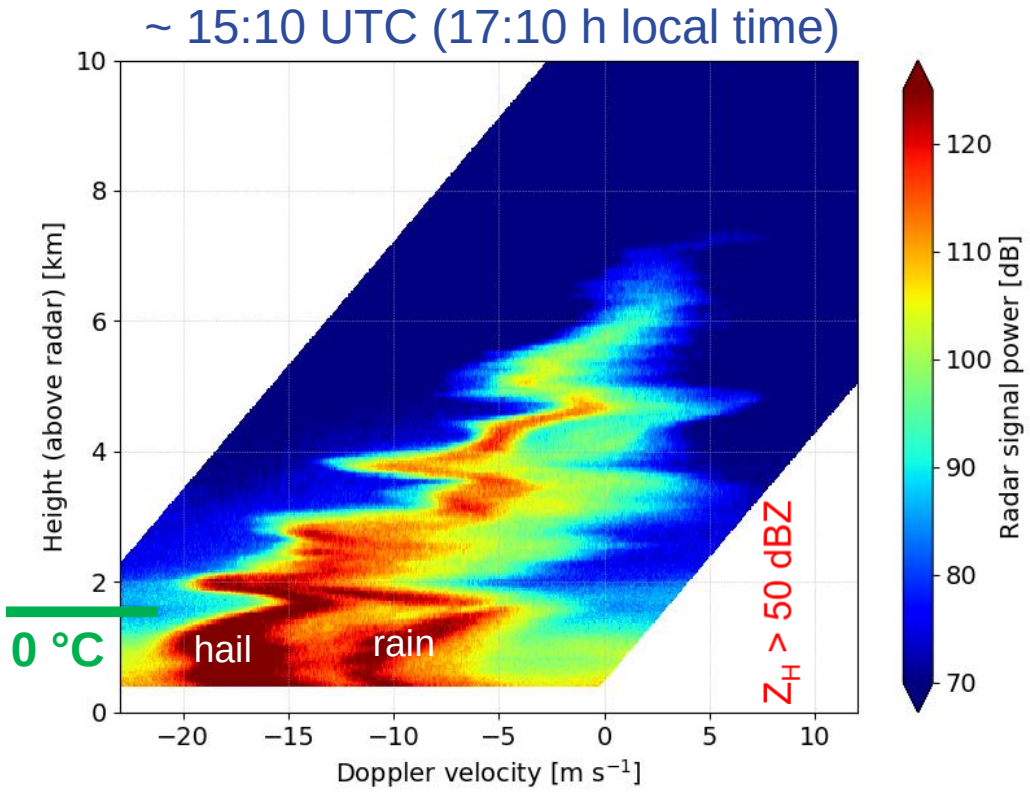
MHP Doppler spectra

~ 15:10 UTC (17:10 h local time)





MHP Doppler spectra



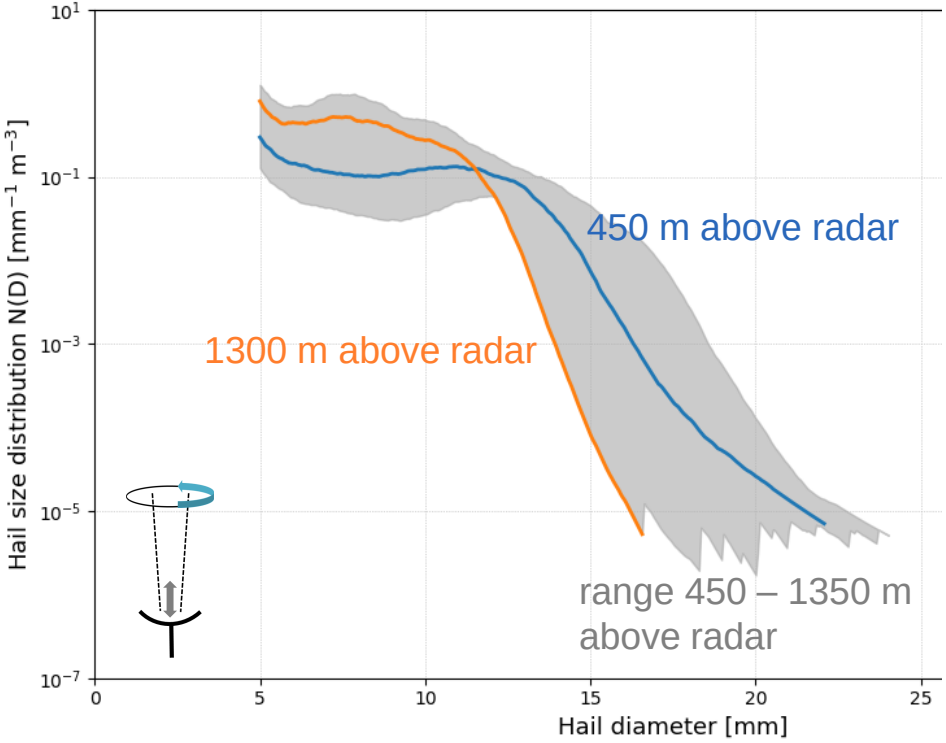
2 main tasks for retrieval of the hail size distribution bin-by-bin:
Doppler velocity → hail size
signal power → hail frequency

(some) specific challenges:

- convert uncalibrated power to Z_H
- separate hail from rain mode
- identify height range with hail
- correct for vertical air motion
- find truncation point at fast velocity
- pick appropriate v-D relationship
- hailstone scattering properties
- scale hail frequency distribution

Hail size distribution

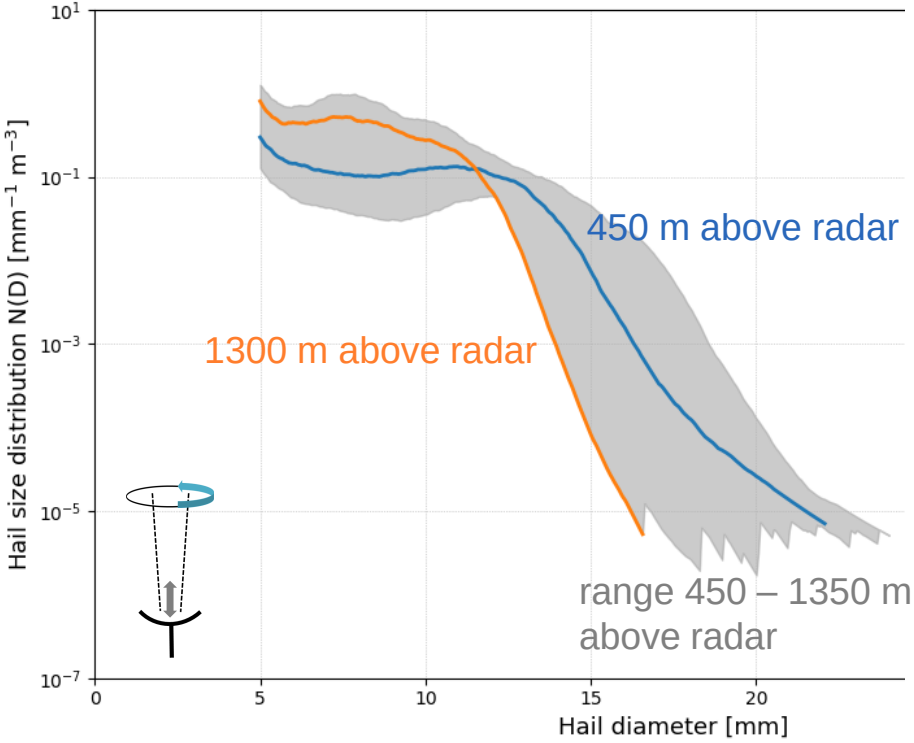
- Retrieved hail size distribution

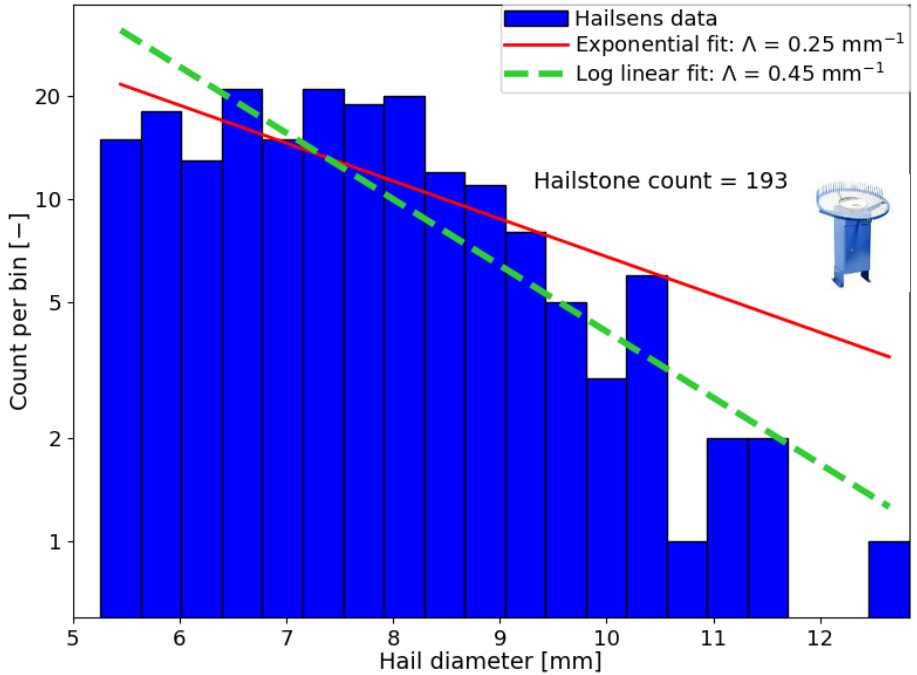


- Plateau for small hailstones
- Maximum hail diameter of 17 to 24 mm

Hail size distribution

- Retrieved hail size distribution





Hail size distribution

- **Mean of characteristic properties** of hail size distribution for full hail height range of 450 – 1350 m

	D_{min} [mm]	Dmax [mm]	# density [1/m3]	Hit rate [1/(s m2)]	W [g/m3]	Ekin [J/m3]	Hail rate [mm/h]	E_flux [W/m2]	Dmean [mm]	Dmedian [mm]	Dmassmean [mm]	DEmean [mm]	E(DEmean) [J]	E(Dmax) [J]
bin retrieval	5.0	20.94	1.78	13.14	0.42	0.02	13.2	0.15	8.67	11.22	10.96	11.67	0.02	0.28
exp. fit in log	5.0	20.94	3.88	23.93	0.36	0.01	8.98	0.07	6.49	7.31	7.91	8.98	0.01	0.28
exp. fit in lin	5.0	20.94	1.79	13.62	0.59	0.03	21.27	0.35	8.82	12.8	12.73	14.23	0.06	0.28
gamma fit	5.0	20.94	1.82	13.86	0.61	0.03	22.37	0.38	9.18	14.5	14.01	15.58	0.09	0.28

Hail size distribution

- **Mean of characteristic properties** of hail size distribution for full hail height range of 450 – 1350 m

	D_{min} [mm]	Dmax [mm]	# density [1/m3]	Hit rate [1/(s m2)]	W [g/m3]	Ekin [J/m3]	Hail rate [mm/h]	E_flux [W/m2]	Dmean [mm]	Dmedian [mm]	Dmassmean [mm]	DEmean [mm]	E(DEmean) [J]	E(Dmax) [J]
bin retrieval	5.0	20.94	1.78	13.14	0.42	0.0	13.2	0.15	8.67	11.22	10.96	11.67	0.02	0.28
exp. fit in log	5.0	20.94	3.88	23.93	0.36	0.01	8.98	0.07	6.49	7.31	7.91	8.98	0.01	0.28
exp. fit in lin	5.0	20.94	1.79	13.62	0.59	0.03	21.27	0.35	8.82	12.8	12.73	14.23	0.06	0.28
gamma fit	5.0	20.94	1.82	13.86	0.61	0.03	22.37	0.38	9.18	14.5	14.01	15.58	0.09	0.28

Hail size distribution

- **Mean of characteristic properties** of hail size distribution for full hail height range of 450 – 1350 m

	D_{min} [mm]	Dmax [mm]	# density [1/m3]	Hit rate [1/(s m2)]	W [g/m3]	Ekin [J/m3]	Hail rate [mm/h]	E_flux [W/m2]	Dmean [mm]	Dmedian [mm]	Dmassmean [mm]	DEmean [mm]	E(DEmean) [J]	E(Dmax) [J]
bin retrieval	5.0	20.94	1.78	13.14	0.42	0.02	13.2	0.15	8.67	11.22	10.96	11.67	0.02	0.28
exp. fit in log	5.0	20.94	3.88	23.93	0.36	0.01	8.98	0.07	6.49	7.31	7.91	8.98	0.01	0.28
exp. fit in lin	5.0	20.94	1.79	13.62	0.59	0.03	21.27	0.35	8.82	12.8	12.73	14.23	0.06	0.28
gamma fit	5.0	20.94	1.82	13.86	0.61	0.03	22.37	0.38	9.18	14.5	14.01	15.58	0.09	0.28

- **Relative difference** (i.e. bias) of fits vs. bin retrieval

	D_{min}	Dmax	# density	Hit rate	W	Ekin	Hail rate	E_flux	Dmean	Dmedian	Dmassmean	DEmean	E(DEmean)	E(Dmax)
bias exp. log [%]	0.0	0.0	106.8	71.9	-19.2	-47.0	-35.0	-55.9	-24.9	-34.6	-27.7	-23.1	-68.0	0.0
bias exp. lin [%]	0.0	0.0	-2.1	-0.3	32.6	84.2	54.4	124.0	1.7	15.3	17.0	22.9	202.8	0.0
bias gamma [%]	0.0	0.0	1.6	4.9	46.3	105.4	71.6	149.7	5.7	28.2	27.2	32.8	256.3	0.0

Hail size distribution

- **Mean of characteristic properties** of hail size distribution for full hail height range of 450 – 1350 m

	D_{min} [mm]	Dmax [mm]	# density [1/m3]	Hit rate [1/(s m2)]	W [g/m3]	Ekin [J/m3]	Hail rate [mm/h]	E_flux [W/m2]	Dmean [mm]	Dmedian [mm]	Dmassmean [mm]	DEmean [mm]	E(DEmean) [J]	E(Dmax) [J]
bin retrieval	5.0	20.94	1.78	13.14	0.42	0.02	13.2	0.15	8.67	11.22	10.96	11.67	0.02	0.28
exp. fit in log	5.0	20.94	3.88	23.93	0.36	0.01	8.98	0.07	6.49	7.31	7.91	8.98	0.01	0.28
exp. fit in lin	5.0	20.94	1.79	13.62	0.59	0.03	21.27	0.35	8.82	12.8	12.73	14.23	0.06	0.28
gamma fit	5.0	20.94	1.82	13.86	0.61	0.03	22.37	0.38	9.18	14.5	14.01	15.58	0.09	0.28

- **Relative difference** (i.e. bias) of fits vs. bin retrieval

	D_{min}	Dmax	# density	Hit rate	W	Ekin	Hail rate	E_flux	Dmean	Dmedian	Dmassmean	DEmean	E(DEmean)	E(Dmax)
bias exp. log [%]	0.0	0.0	106.8	71.9	-19.2	-47.0	-35.0	-55.9	-24.9	-34.6	-27.7	-23.1	-68.0	0.0
bias exp. lin [%]	0.0	0.0	-2.1	-0.3	32.6	84.2	54.4	124.0	1.7	15.3	17.0	22.9	202.8	0.0
bias gamma [%]	0.0	0.0	1.6	4.9	46.3	105.4	71.6	149.7	5.7	28.2	27.2	32.8	256.3	0.0

Questions? Comments?

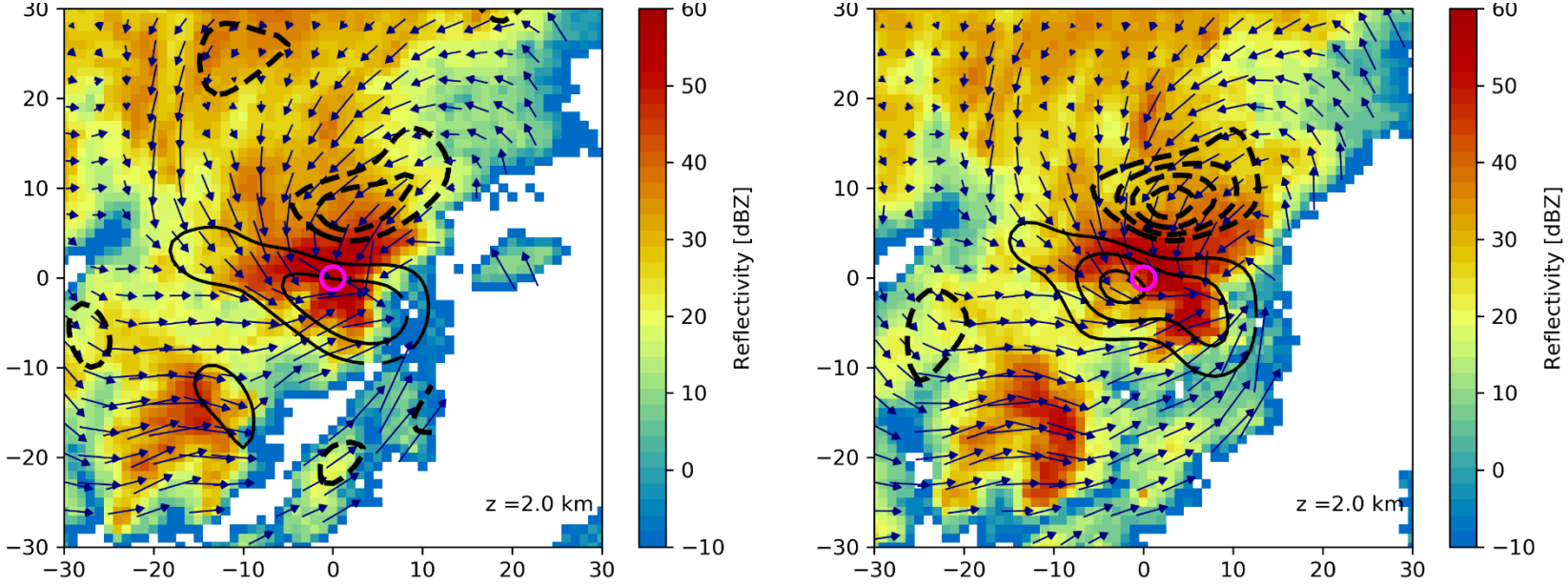
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

DWD

Thank you

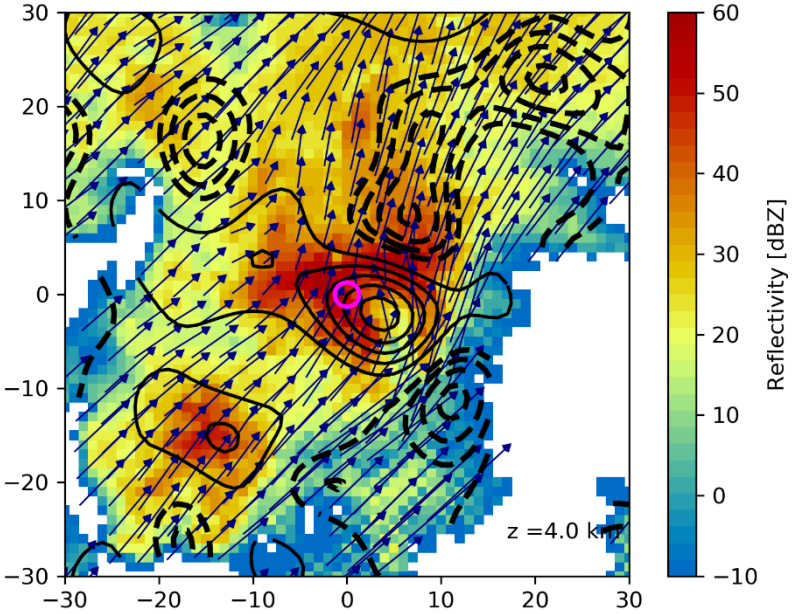
Extra slides

- Triple-Doppler analysis horizontal cross sections at 2 km a.s.l.

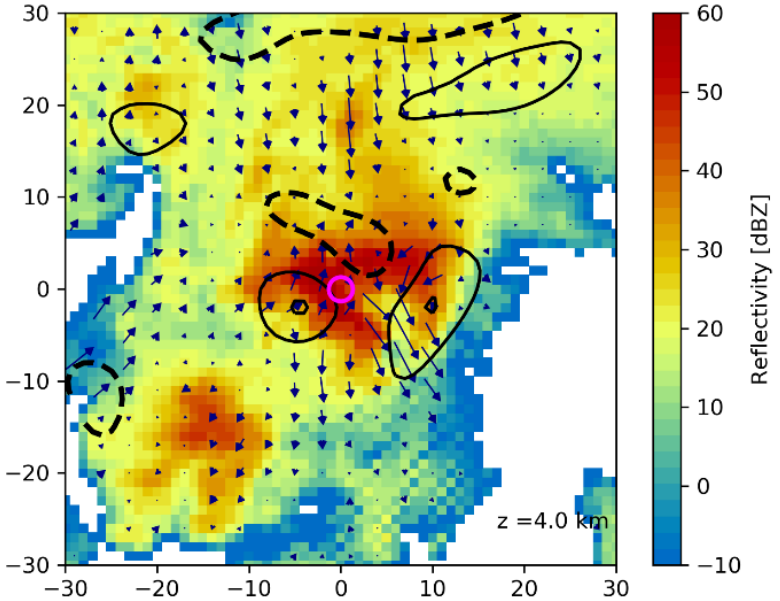


Triple-Doppler vs. dual-Doppler analysis

- Differences most pronounced close to MHP radar and around storm core

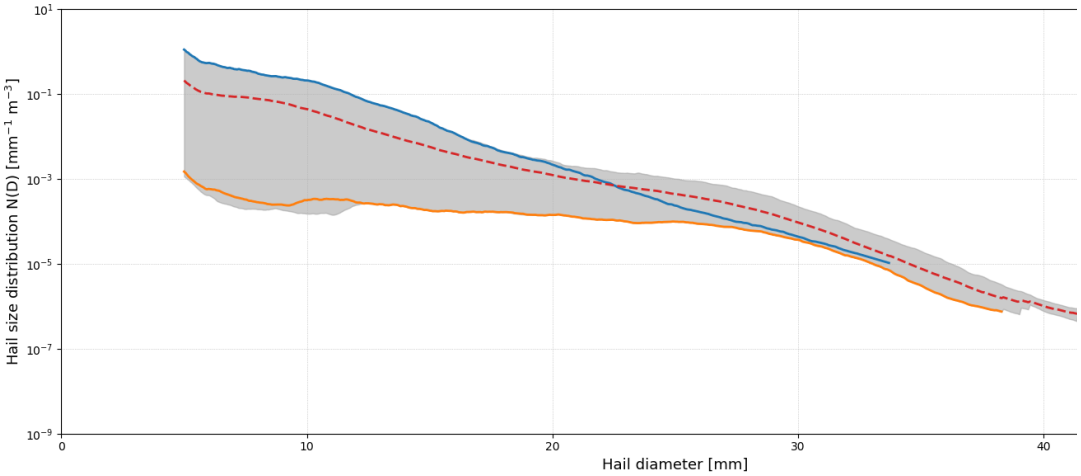


Differences triple – dual Doppler analysis



Extra hail size distributions

- **MHP 29 June 2021**



- **FLD 22 June 2023**