Exploiting polarimetric radar observations to improve the ICON-D2 2-moment microphyiscs

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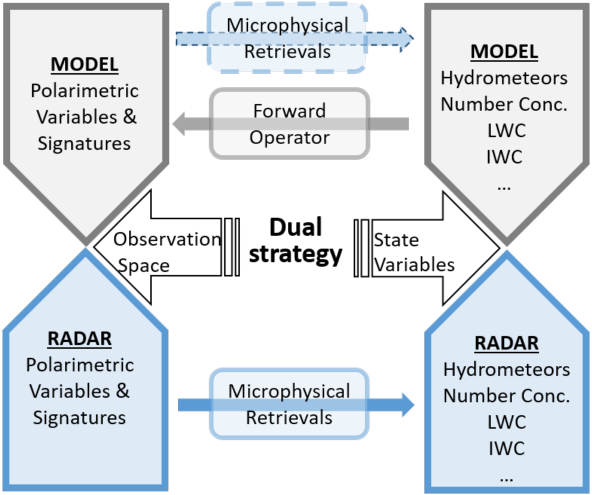
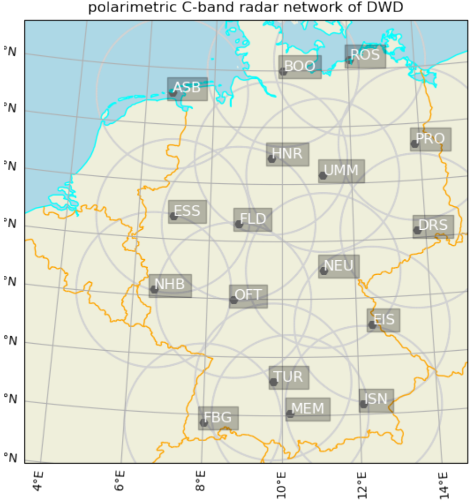
Validate NWP and pol. forward operator (FO) with polarimetric radars

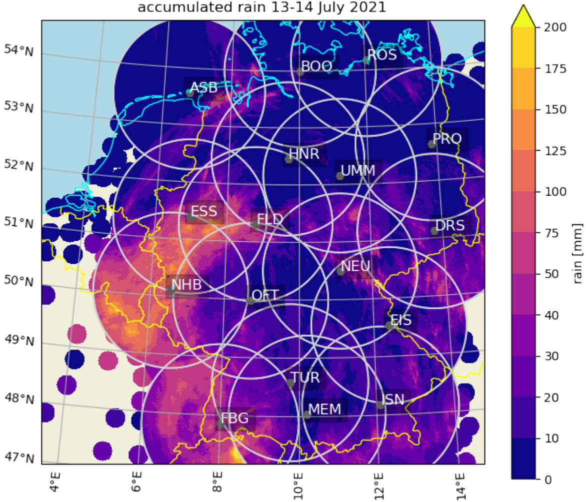


Validate ICON-D2 and FO EMVORADO with C-band radars



Validate ICON-D2 and FO EMVORADO with C-band radars (July ’21 flood)

Ahr near Altenahr



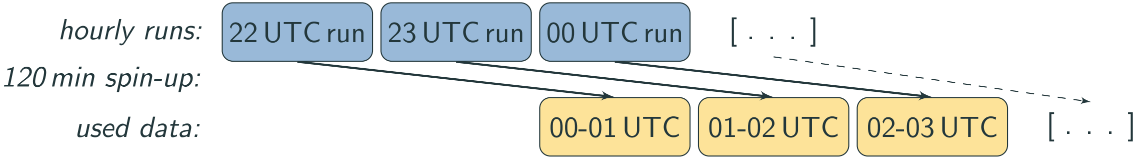
RADOLAN RW

ICON-D2

- with 2-moment microphysics (MP; Seifert and Beheng, 2005)
- with 6 hydrometeor (HM) classes (Rn, Sn, Gr, Ha, Ic, Cw)
- versions: 2022 spring (RUC 0.0; Trömel et al., 2023); 2024 summer (RUC 1.0);
  2024/25 winter (RUC 2.0)

polarimetric Forward Operator EMVORADO

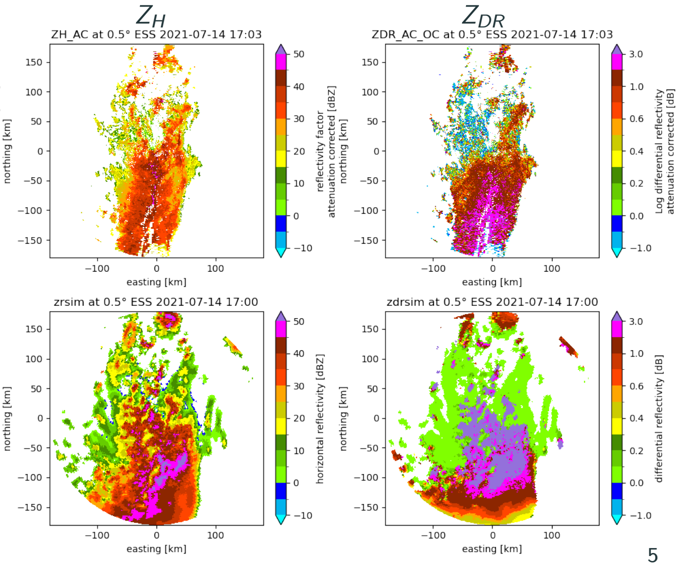
- providing synthetic polarimetric radar observations
- based on bulk-scattering lookup tables
- melting scheme (MS) for simulating mixed-phased characteristics



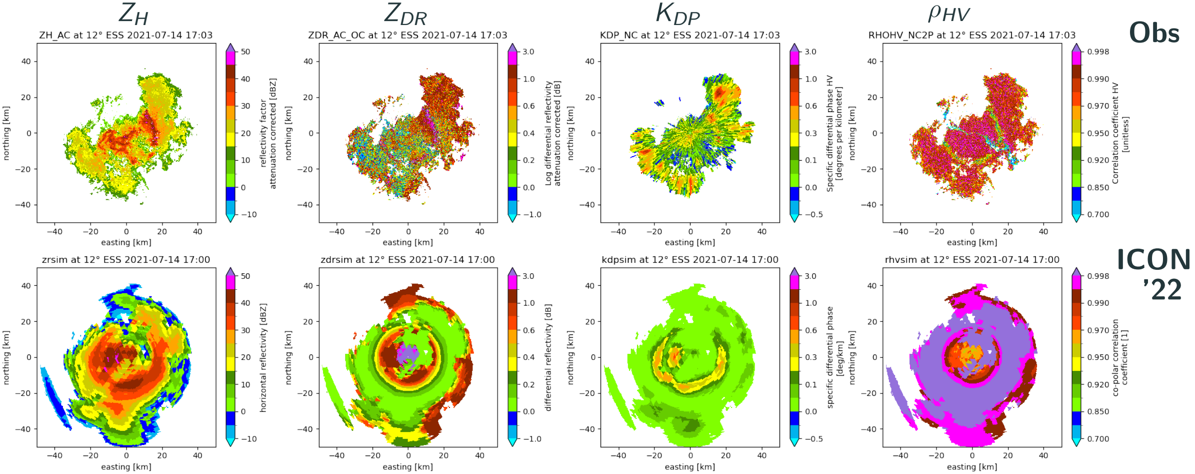
PPIs (0.5°) for ESS on 14-07-2021 17 UTC

Observation

ICON-D2 ’22

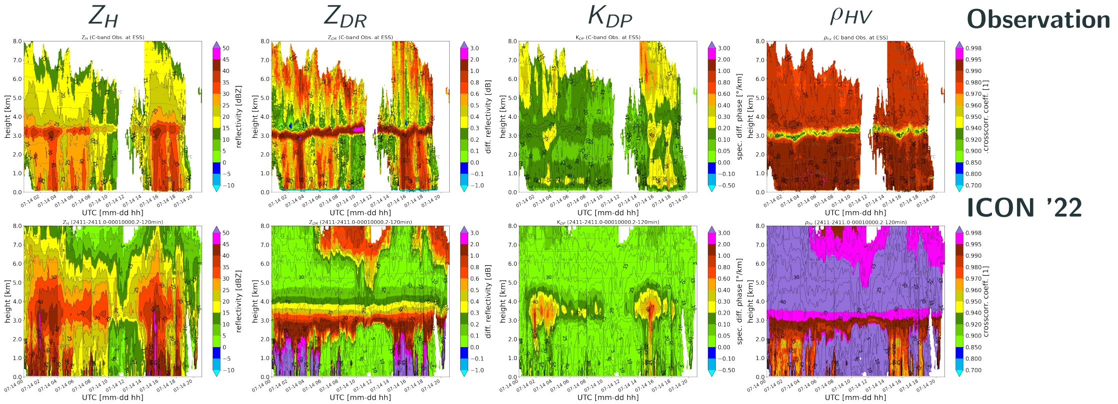


PPIs (12°) for ESS on 14-07-2021 17 UTC



→ very pronounced melting layer (ML)

QVPs (12°) for ESS on 14-07-2021 00:00-21:00



→ no sharp ML detectable

→ too high Z_{DR} values below ML

→ too strong K_{DP}-signal in ML

→ ρ_{HV}-overestimation

Refinments in EMVORADO's melting scheme

! polarimetric signatures in the heights above the melting layer are too strong

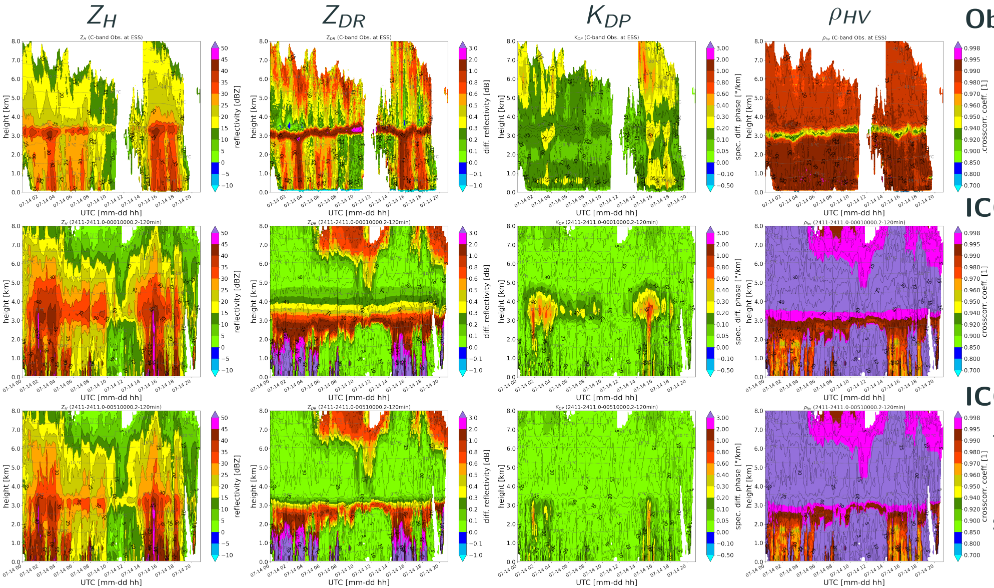
! EMVORADO assumes a melted fraction (f_{melt}) of frozen HM's in the heights above $0°C$, where $f_{melt} = 0$ at $-10°C$ increases linearly to $f_{melt} = 0.2$ at $0°C$

new melting scheme: dynamical wet-growth in $[-10°C, 0°C]$

→ only mixed-phased HM's **if** liquid water is present

→ Gr, Ha has only a melted fraction **if** mean diameter large enough (around 10 mm)

QVPs (12°) for ESS on 14-07-2021 00:00-21:00 with new MS in EMVORADO



Observation

ICON '22

ICON '22, new MS

finer ML

improved above ML

still: too high Z_{DR} below ML

Refinments in ICON's microphysics

below the ML: Z_H and Z_{DR} streaks are too strong and to frequent

- ! graupel is too large and too long surviving
- ! raindrops are too often too big

changes microphysics:

2024 summer (RUC 1.0)

$\rightarrow$ graupel: - reduce the collision efficiency
- increase the terminal velocity
- limit formation to T $> -3\,°C$

$\rightarrow$ snow: - reduce the terminal velocity
- reduce the sticking efficiency

Refinments in ICON's microphysics

below the ML: Z_H and Z_{DR} streaks are too strong and to frequent

- ! graupel is too large and too long surviving
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changes microphysics:

2024 summer (RUC 1.0)

→ graupel: - reduce the collision efficiency
- increase the terminal velocity
- limit formation to $T > -3\,^\circ C$

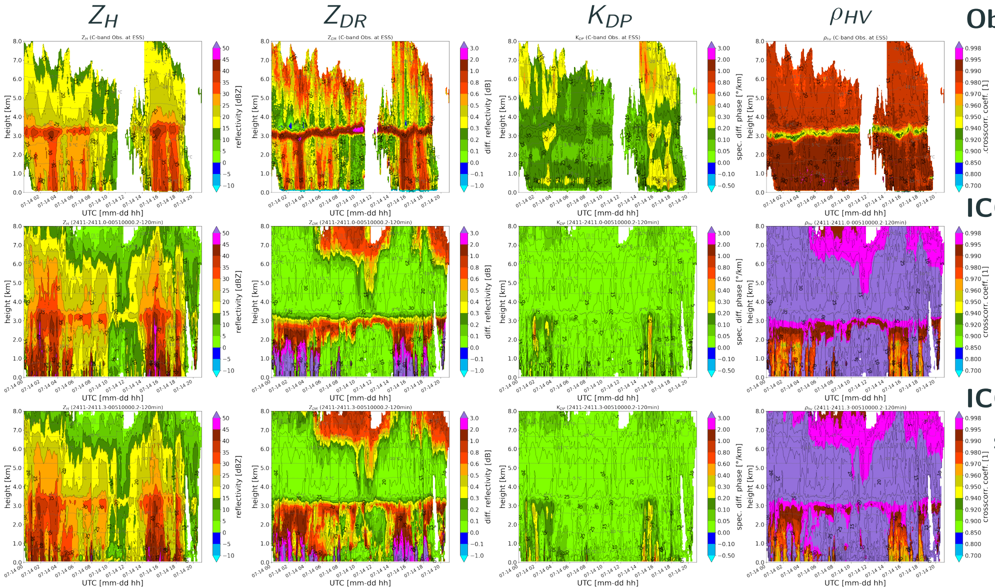
→ snow: - reduce the terminal velocity
- reduce the sticking efficiency

2024/25 winter (RUC 2.0)

→ graupel/hail: - shedding for HM's $> 9\,mm$ (rain release)

→ graupel: - limited generation from rain-rimed snow/ice via bulk-density check

QVPs (12°) for ESS on 14-07-2021 00:00-21:00 with new MP in ICON



Observation

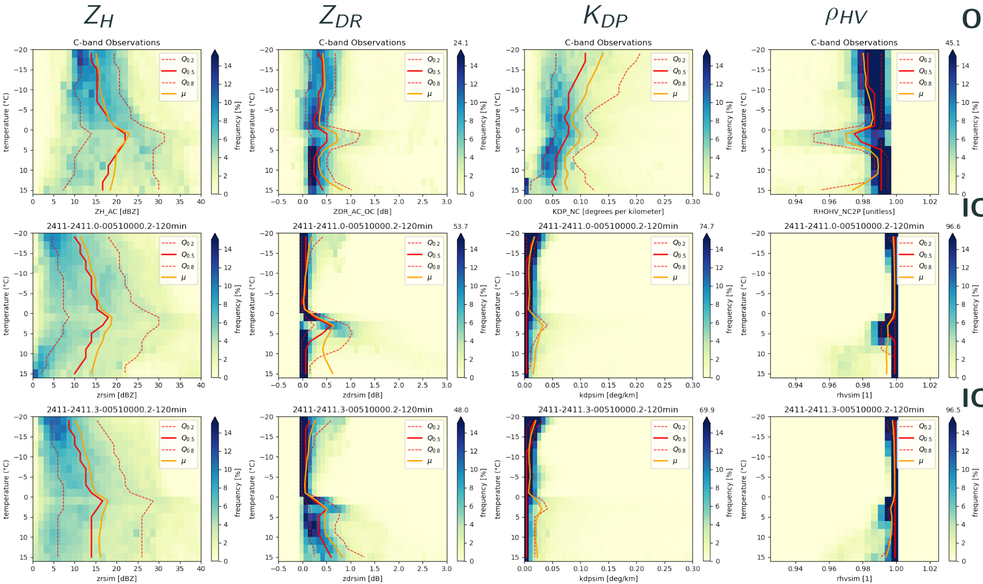
ICON '22, new MS

ICON '24/25

streak reduction in Z_H and Z_{DR}

more realistic Z_{DR} below ML

CFTDs (12°) for all radars and 13-07-2021 – 14-07-2021



Observation

ICON '22, new MS

low Z_H near surface

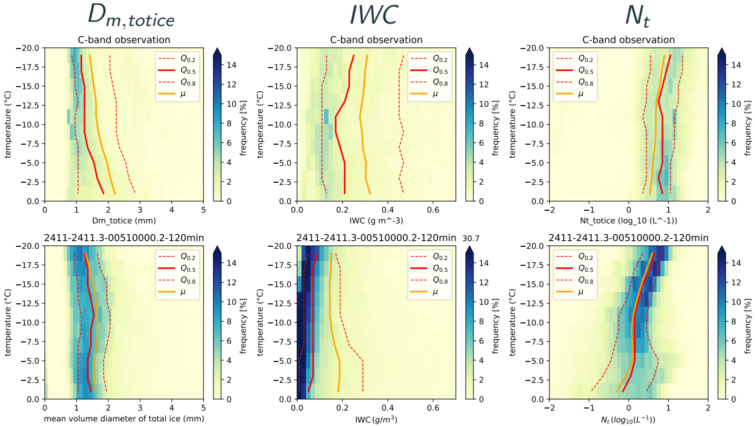
unrealistic Z_{DR} distribution

ICON '24/25

more representative Z_H distribution

more realistic Z_{DR} distribution

CFTDs(12°, ALL) on 13-07-2021 – 14-07-2021 of ice microphysical retrievals



Observation

$D_{m,totice} = D_{m,totice}(Z_h, K_{DP})$

$IWC(Z_{DR} < 0.4dB) = IWC(Z_h, K_{DP})$

$IWC(Z_{DR} \geq 0.4dB) = IWC(Z_{DR}, K_{DP})$

$N_t = N_t(Z_H, IWC)$ (Carlin et al., 2021)

ICON ’24/25

frozen HM’s combined

→ modeled diameters not too big

→ IWC distribution thinner

→ ’S’-shape maybe too pronounced

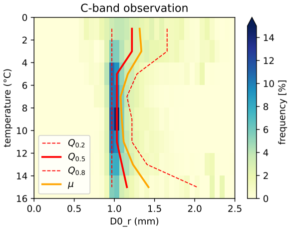
CFTDs(12°, ALL) on 13-07-2021 – 14-07-2021 for rain drops

mean vol. diameter

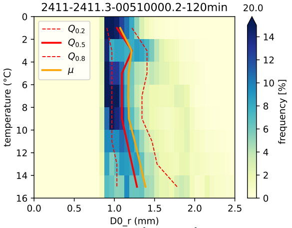
$$D_{0,rain} = D_{0,rain}(Z_{DR}) \geq 0.8\,\text{mm}$$

(Bringi et al., 2009)

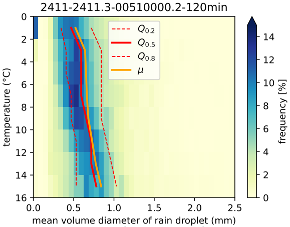
Observation



ICON ’24/25



$D_{0,rain}(Z_{DR})$



$D_{0,rain}(q_r, qn_r)$

$\leftarrow$ inconsistent $\rightarrow$

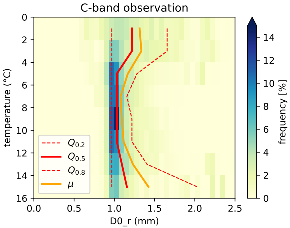
CFTDs(12°, ALL) on 13-07-2021 – 14-07-2021 for rain drops + graupel

mean vol. diameter

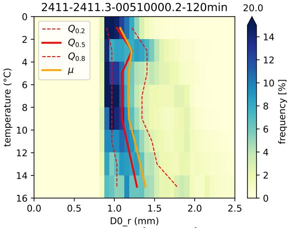
$$D_{0,rain} = D_{0,rain}(Z_{DR})$$
$$\geq 0.8\,\text{mm}$$

(Bringi et al., 2009)

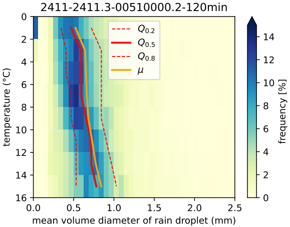
Observation



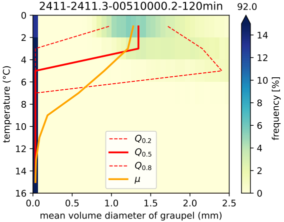
ICON '24/25



$D_{0,rain}(Z_{DR})$



$D_{0,rain}(q_r, qn_r)$

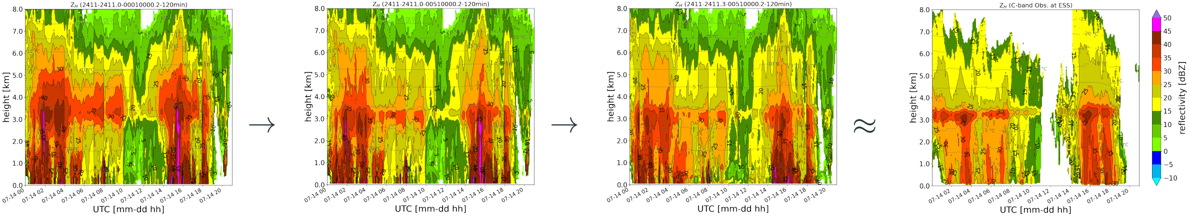


$D_{0,graupel}(q_g, qn_g)$

← inconsistent →

→ retrieval is convoluted by graupel

Summary: Converging ICON-D2/EMVORADO to radar observations



EMVORADO:

dynamical melting scheme

→ decrease of pol. signal

for mixed phase HM's

ICON-D2:

microphysical changes

→ reduction of

graupel sizes

Converging is never finished:

! differences for retrievals

! convective situations behaves differently

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