Dual-pol C-band radars for analyzing the precipitation type at the ground

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Motivation

Dual-polarization (dual-pol) weather radars enable the estimation of both precipitation quantity and hydrometeor type. This study identifies the optimal precipitation type classification method for Belgium's C-band radar network.

Method 1: BMRC

The Australian Bureau of Meteorology Research Center (*BMRC*) uses 1D-membership functions and a fuzzy logic approach based on [2].

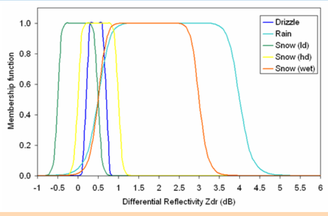
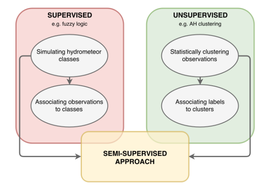


Image from: Bringi, Thurai, Hannesen: Dual-Polarization Weather Radar Handbook: An Overview of Dual-Polarization Weather Radar: Theory and applications, 2nd edition

Method 3: Besic

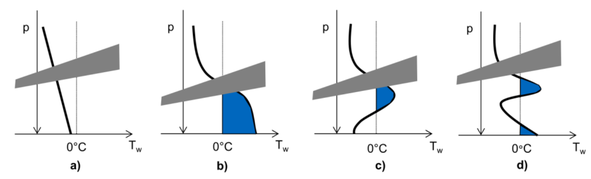
The semi-supervised classification algorithm of *Besic* [4] separates 9 precipitation types. It is used with default C-band centroids in this work.



Scheme of the semi-supervised algorithm. Besic et al., Fig. 1.

Ground transition

The dual-pol methods identify precipitation types at the altitude of the radar beam. The transition towards the ground uses the method of Steinert et al. (2021) [8] with vertical temperature profiles and pressure from RMI's numerical weather prediction model ALARO.



Temperature vertical profiles (black) and melting area (blue) below the radar beam (gray). Steinert et al., Fig. 6.

Method 2: Dolan

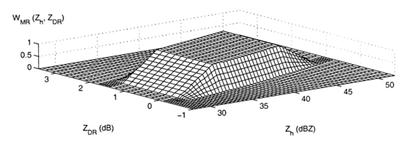
Dolan's method [3] also uses a 1D fuzzy logic classification method for C-band radars.

	Z_h			Z_{dr}			K_{dp}			ρ_{hv}			Temperature		
	m	*a*	*b*	*m*	*a*	*b*	*m*	*a*	*b*	*m*	*a*	*b*	*m*	*a*	*b*
Drizzle	1.75	29	10.0	0.46	0.46	5.0	0.03	0.03	2.0	1.0	0.018	3.0	40.0	41.0	50.0
Rain	39	19	10.0	2.3	2.2	9.0	5.5	5.5	10.0	1.0	0.025	3.0	48.0	51.0	30.0
Ice crystals	−2.8	22.1	20.0	2.9	2.7	10.0	0.08	0.08	6.0	0.98	0.025	3.0	−50.0	50.0	25.0
Aggregates	17.0	18.1	10.0	1.0	1.1	7.0	−0.008	0.3	1.0	0.93	0.07	3.0	−25.0	26.0	15.0
Wet snow	24.0	21.3	10.0	1.3	0.9	10.0	0.25	0.43	6.0	0.74	0.25	10.0	1.0	3.5	5.0
High-density graupel	44.3	10.2	6.0	1.6	1.2	3.0	1.9	1.9	3.0	1.0	0.04	2.0	−2.5	20.0	2.0
Low-density graupel	37.0	9.2	0.8	0.9	0.9	6.0	0.1	0.08	3.0	1.0	0.025	1.0	−50.0	50.0	25.0
Hail	62.3	14.3	10.0	0.14	0.56	8.0	0.6	3.5	6.0	0.97	0.1	3.0	0.0	100.0	5.0
Big drops	57.8	8.5	10.0	4.4	1.9	8.0	3.4	3.3	6.0	0.99	0.03	3.0	48.0	21.0	30.0
Vertical aligned ice	−1.0	25.0	20.0	−0.90	0.9	10.0	−0.75	0.75	30.0	0.975	0.022	3.0	−50.0	50.0	25.0

Parameters of beta-membership functions to separate the 10 different precipitation types. Table A2, Dolan et al. (2013) [3]

Method 4: Wradlib

A 2D membership function approach based on [5], [6] as implemented in the *wradlib* Python library [7].



Two-dimensional weighting function for moderate rain, WMR(Zh, ZDR), over the space Zh, ZDR. Zrnic et al. [6], Fig. 1.

Validation

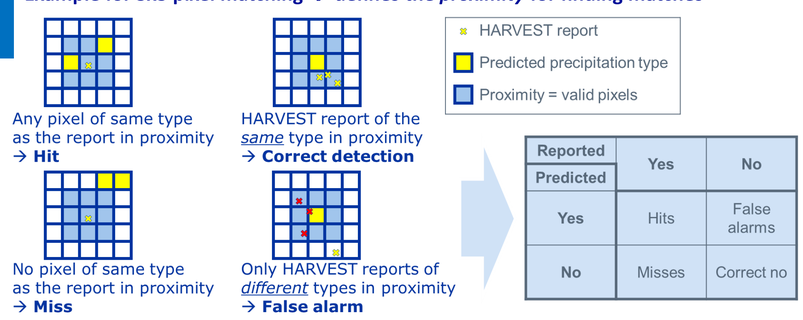
Benchmark: INCA-BE

The INCA-BE deterministic nowcasting system [1] includes an analysis of 5 precipitation types at the ground, provided on a 1km grid.

Ground truth: HARVEST reports

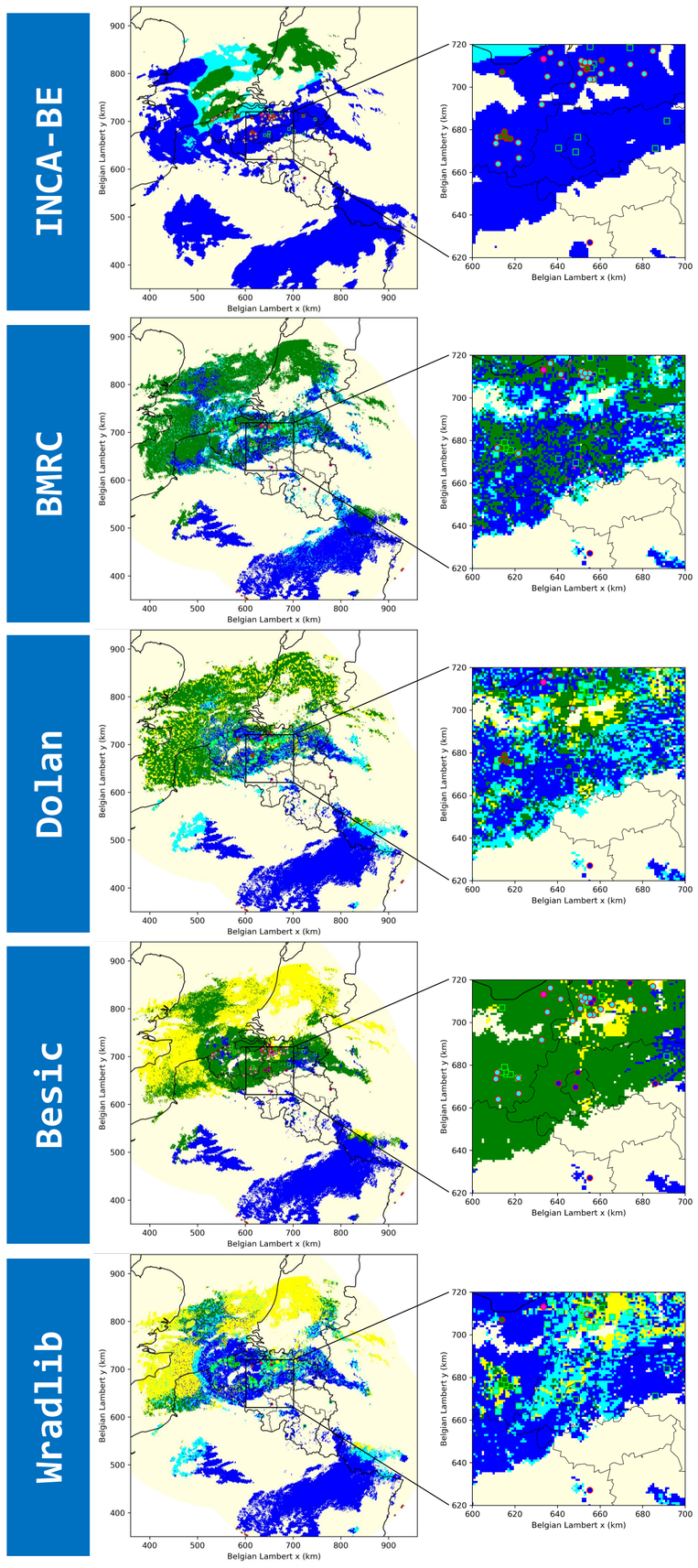
Weather reports are received from users via the RMI app. The raw reports are checked for plausibility, clustered in space (1km) and time (5min) to reduce ambiguity, and matched to the 1km dual-pol precipitation type grids.

Example for 3x3 pixel matching → defines the *proximity* for finding matches



Example: 10/02/2025 1500UTC

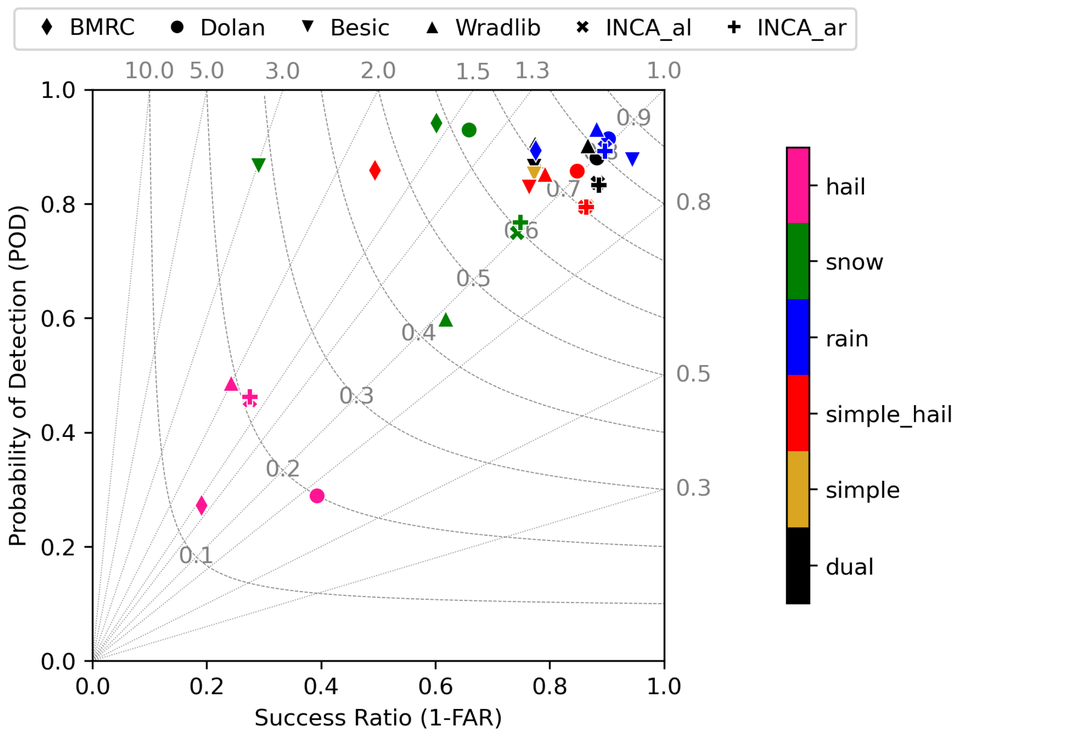
Statistic and Scores



The validation dataset consists of 160 cases from 2024/25 in which at least two different precipitation types were reported. A case is defined as a 20-minute time period. Only independent cases are included in the validation, meaning a minimum inter-case interval of six hours, corresponding to the ALARO update cycle.
The example on the left illustrates a winter precipitation mix over Belgium. The first column with the full domain and a zoomed-in view in the second column. HARVEST reports are shown as colored symbols whose color indicates the precipitation type, and with green edges for hits and red edges for misses.

The table with scores for the validation mode that distinguishes liquid, mixed, frozen precipitation, and hail.
Dolan yields the best scores overall, as also shown in the performance diagram. The diagram summarizes results for all six validation modes (see legend).

Method	*POD*	*FAR*	CSI_{pix}
BMRC	0.86	0.51	0.46
Dolan	0.86	0.15	0.74
Besic	0.83	0.24	0.66
Wradlib	0.85	0.21	0.70
INCA-BE_al	0.79	0.14	0.70
INCA-BE_ar	0.79	0.14	0.71



Acknowledgements

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References

[1] INCA-BE technical report: https://zenodo.org/record/5798952
[2] Keenan et al. (2003): Aust. Met. Mag. Hydrometeor 52 (2003) 23-31
[3] Dolan et al. (2013): doi: 10.1175/JAMC-D-12-0275.1
[4] Besic et al. (2016): doi: 10.5194/amt-9-4425-2016
[5] Straka et al. (2000): doi: 10.1175/1520-0450(2000)039<1341:BHCAQU>2.0.CO;2
[6] Zrnic et al. (2001): doi: 10.1175/1520-0426(2001)018<0892:TAPFAC>2.0.CO;2
[7] Wradlib hydrometeor classification: https://docs.wradlib.org/en/latest/notebooks/classify/2d_hmc.html
[8] Steinert et al. (2021): doi: 10.1175/WAF-D-20-0232.1