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Cell tracking -based evaluation of nowcasting model skill for reproducing growth and decay of convective rainfall

Jenna Ritvanen[1,2] , S. Pulkkinen[1], D. Moisseev[2,1], D. Nerini[3]

Contact: Jenna.Ritvanen@fmi.fi

[1]Finnish Meteorological Institute (FMI), Space and Earth Observation Center, Helsinki, Finland
[2]University of Helsinki, INAR, Helsinki, Finland
[3]MeteoSwiss, Locarno-Monti, Switzerland

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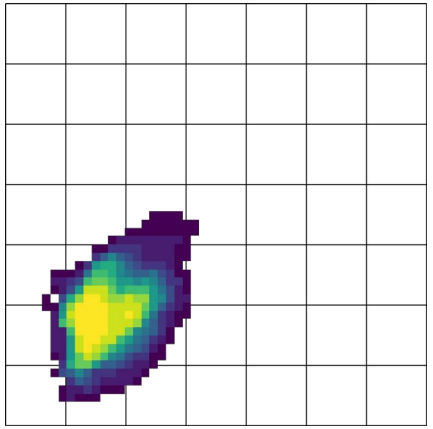
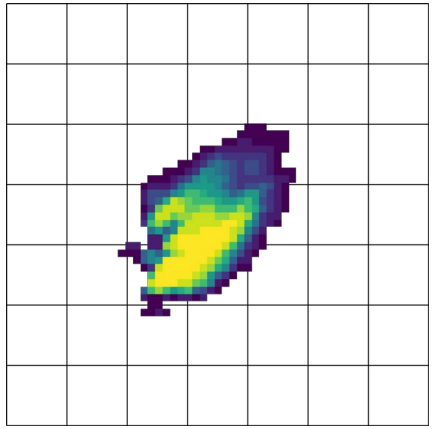
jenna.ritvanen@fmi.fi

How to evaluate grid-based nowcasting models in convective rainfall?

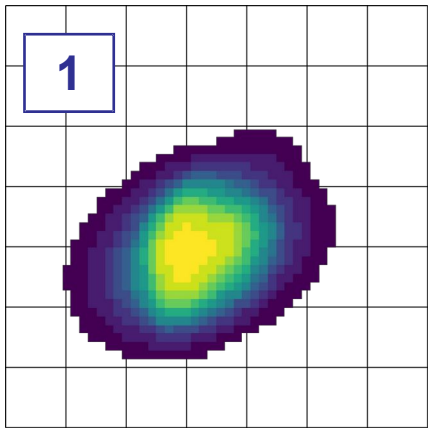
Observation at *t*

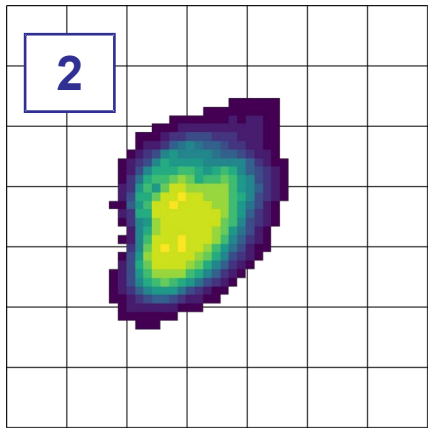


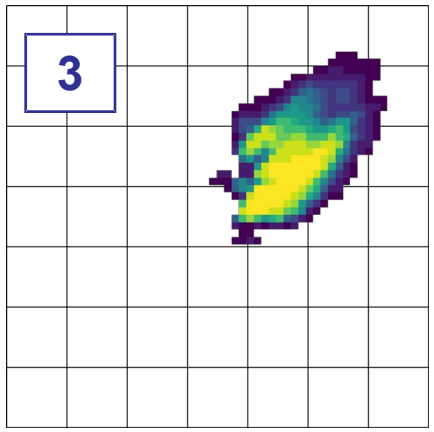
Observation at *t* + T



Nowcasts at *t* + T: which is best?





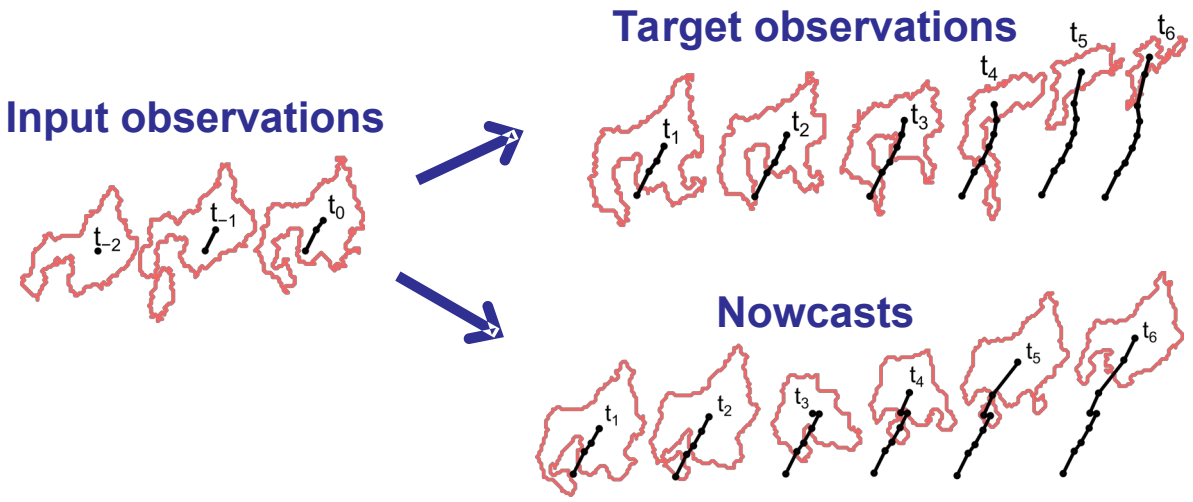


- Pixel-by-pixel metrics (e.g. CSI, FSS)
  - sensitive to location error due to small scale of convective rainfall
  - small values and differences between models at high rainrate thresholds
- Cell / object-based methods (e.g. SAL)
  - focus on various aspects of the nowcast
  - usually averaged over entire nowcast fields, which loses the impact of invidual rain cells
- Cell tracking approach
  - focus on various aspects of the nowcast through identified cells
  - verify predicted development with cell track history
  - separate results for different stages of development, e.g. growth and decay

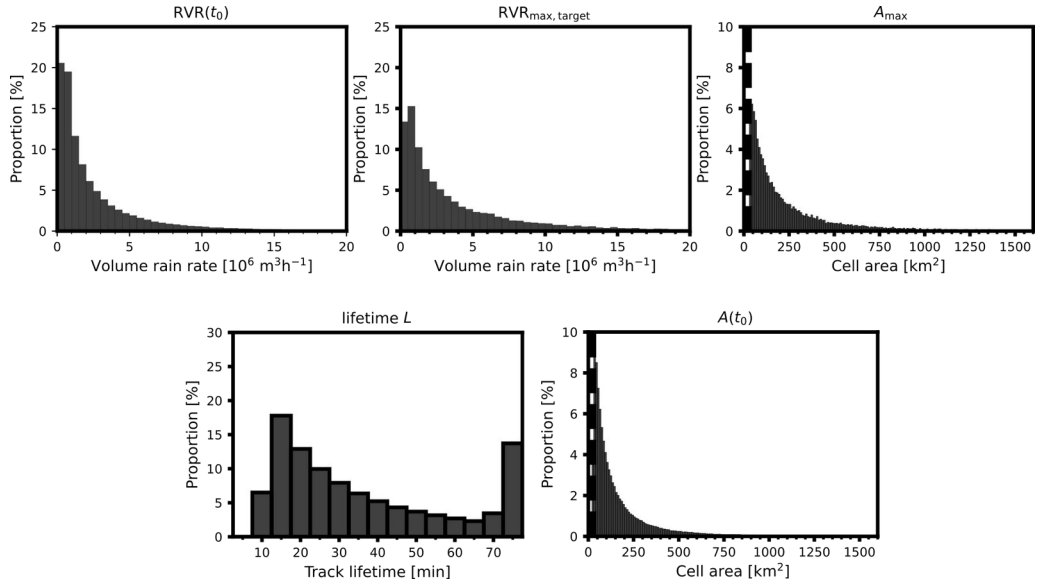
jenna.ritvanen@fmi.fi

Cell tracking approach

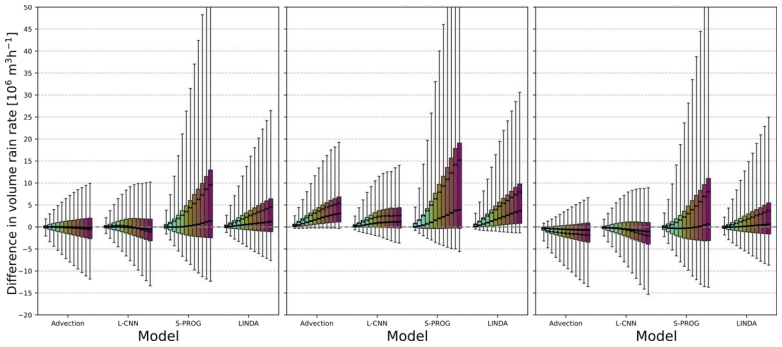
1. Cell tracking

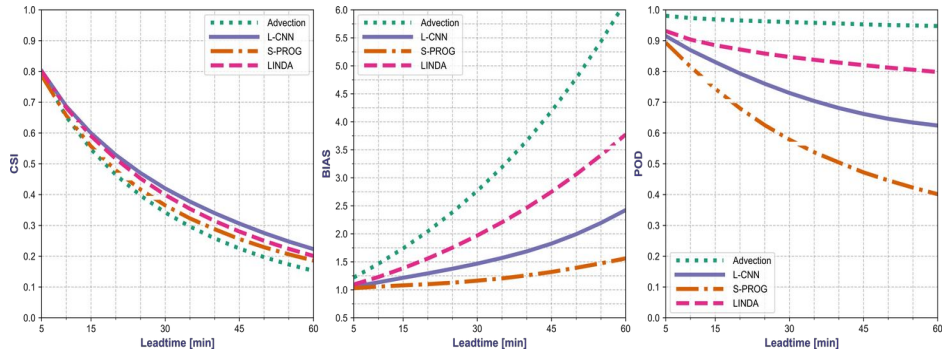


2. Feature extraction

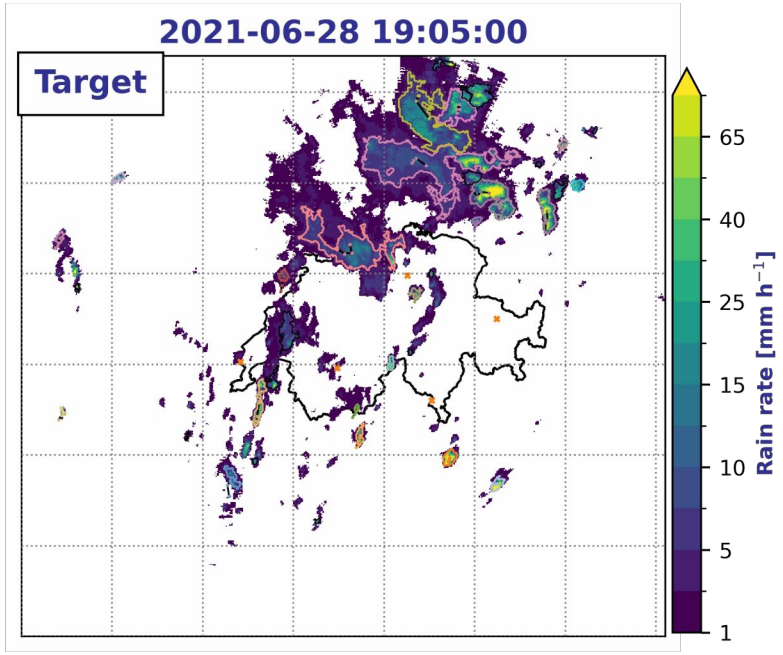


3. Error & metrics calculation

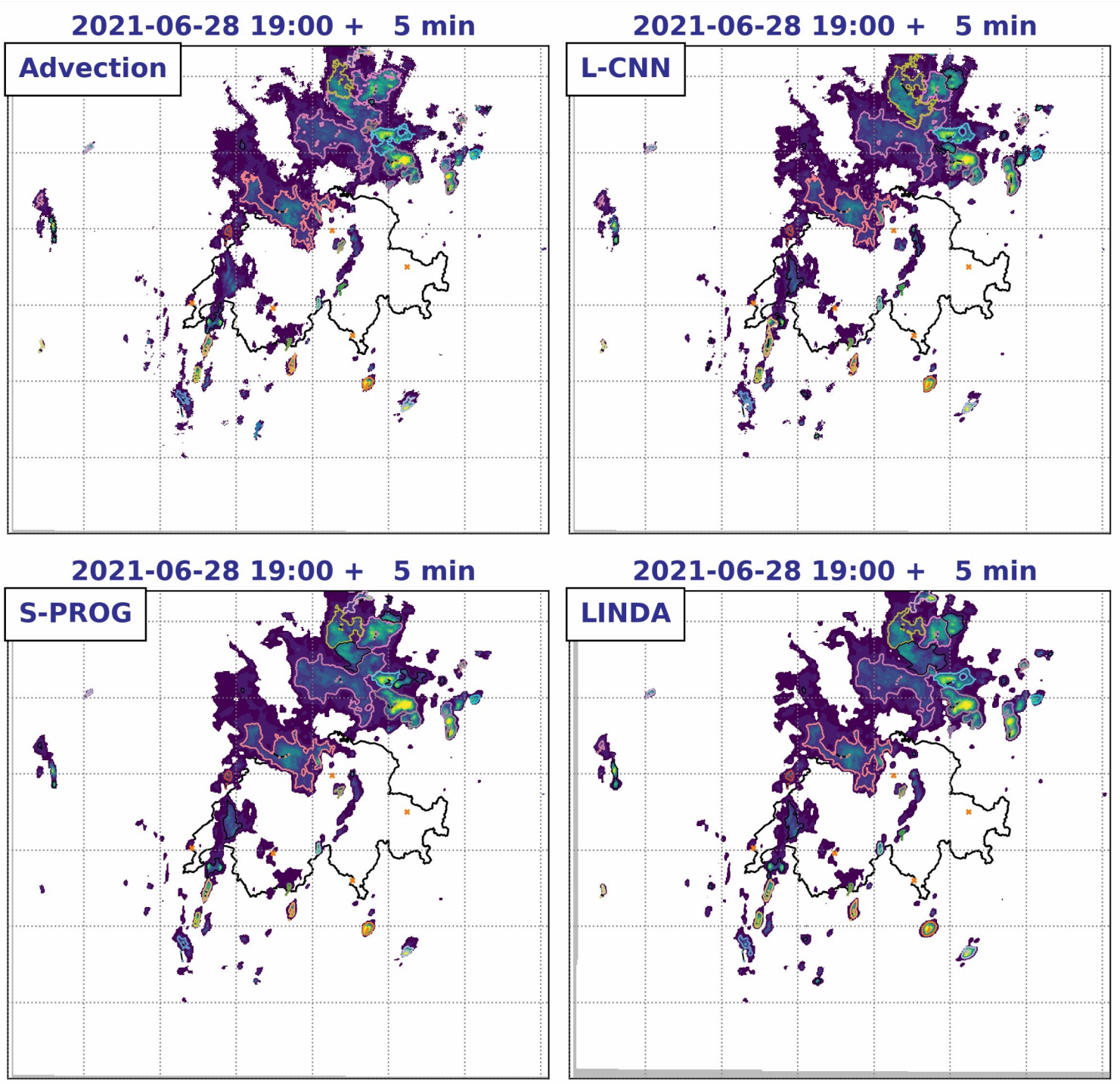




Cells in nowcasts display qualities of the models, e.g. blurring



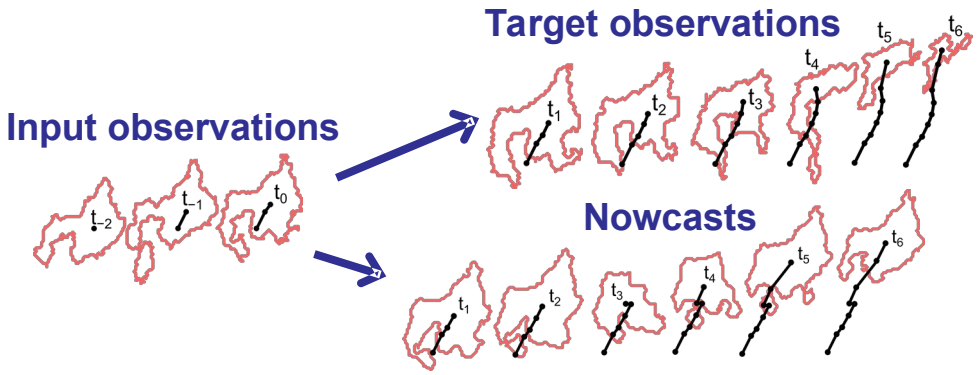
	Advection	S-PROG	LINDA	L-CNN
Rainfall motion	optical flow			
Rainfall development	–	AR(2)	ARI(1,1)	U-Net
References	Pulkkinen et al. GMD 2019	Seed JAMC 2006, Pulkkinen et al. GMD 2019	Pulkkinen et al. JTECH 2021, Pulkkinen et al. GMD 2019	Ritvanen et al. J-STARS 2023



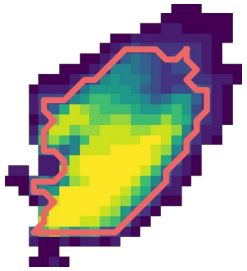
jenna.ritvanen@fmi.fi

Research questions the cell tracking can answer

1. How accurately the models predict the development of various cell features, e.g. area or mean rain rate?

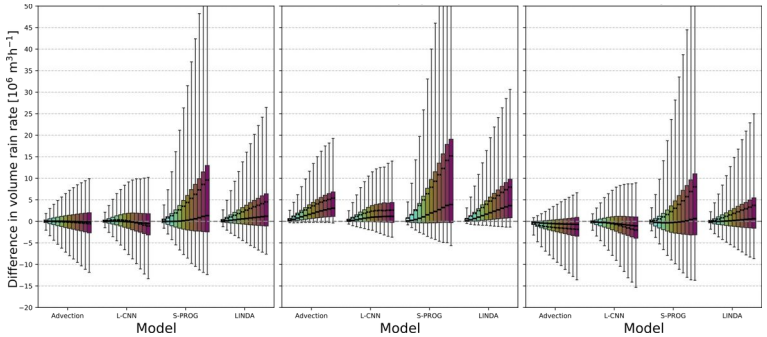


Cell feature values

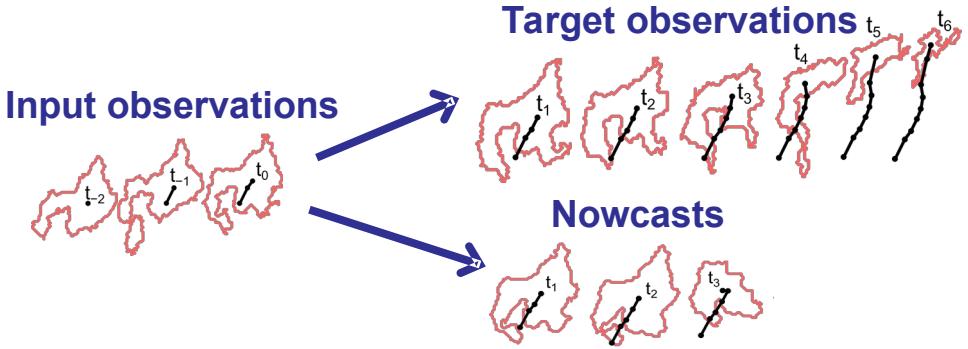


- Area
- Mean rain rate
- Volume rain rate

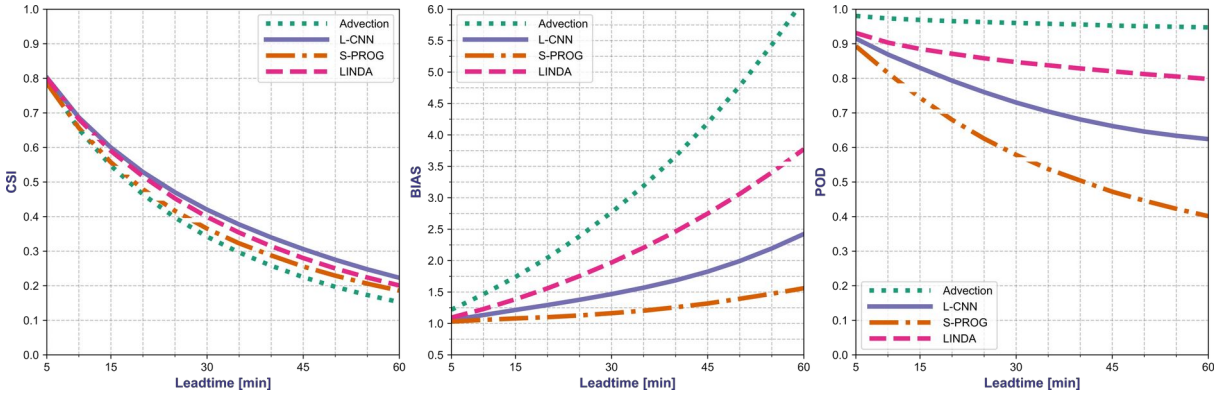
Feature error distributions



2. How accurately do the models reproduce the existence of cell tracks?

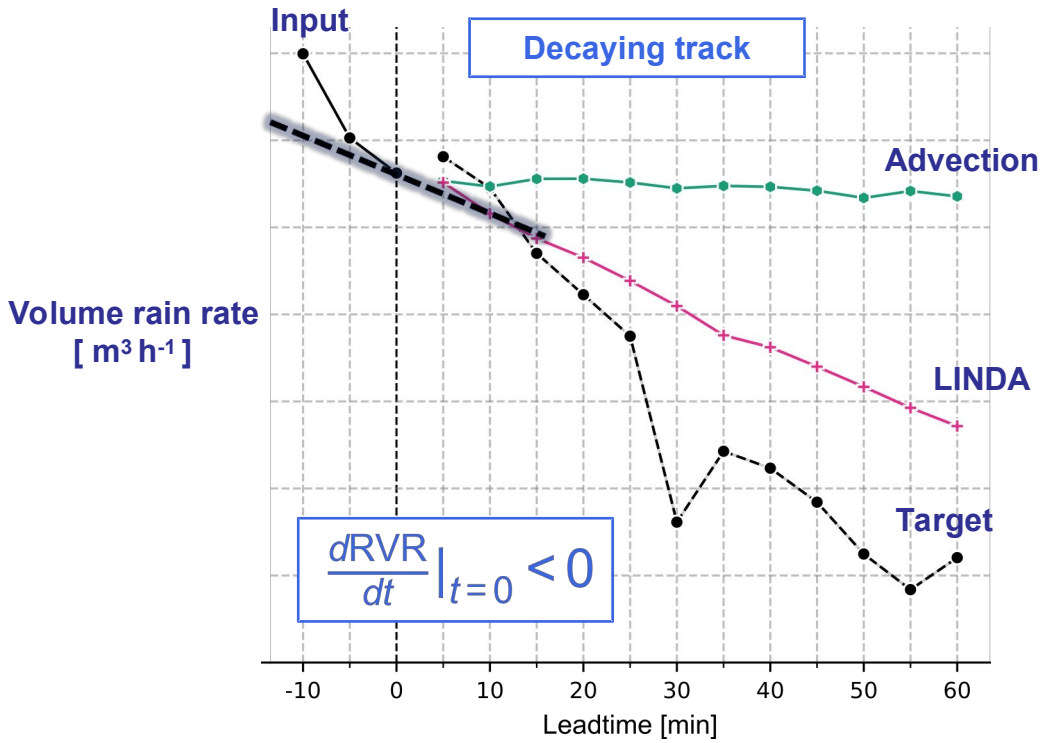


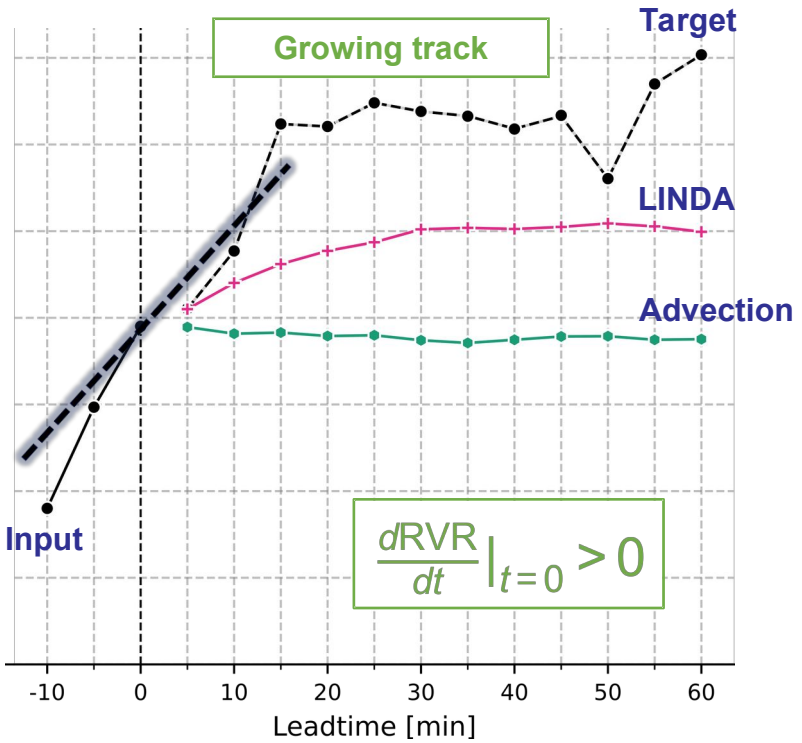
Metrics describing cell track existence



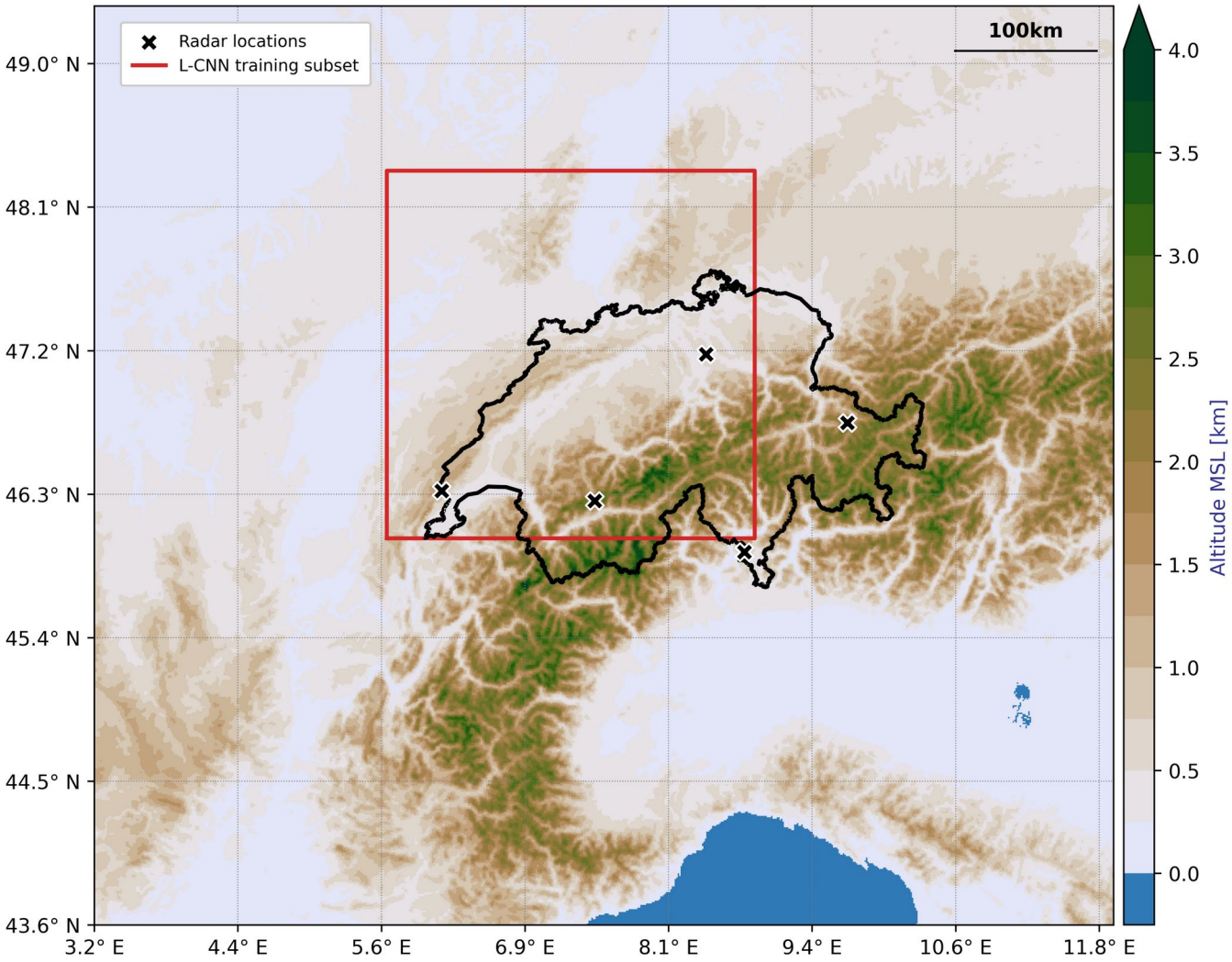
Definition of decaying and growing cell tracks

- We classify the cell tracks as either **decaying** or **growing** **at the time when the nowcast is created** in both the observations and nowcast
- The classification is based on the derivative of volume rain rate at t_0 (RVR; integrated rain rate over the cell area)





Dataset used in this study

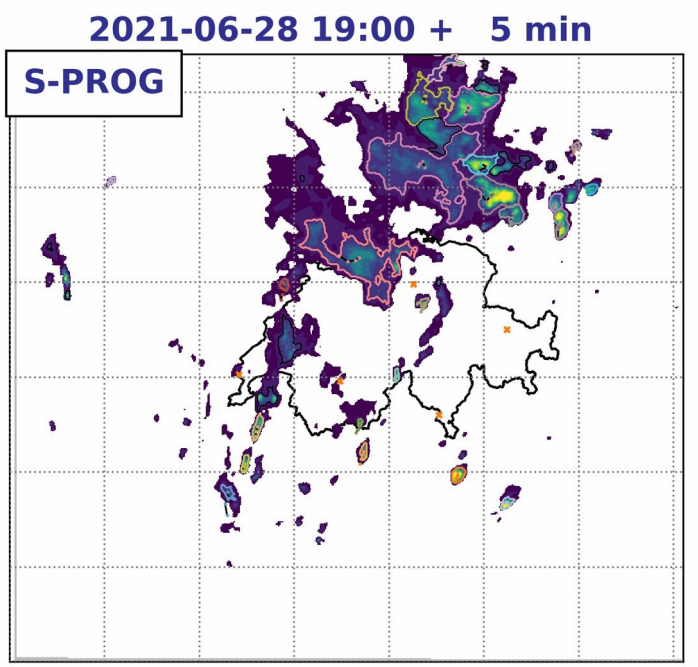


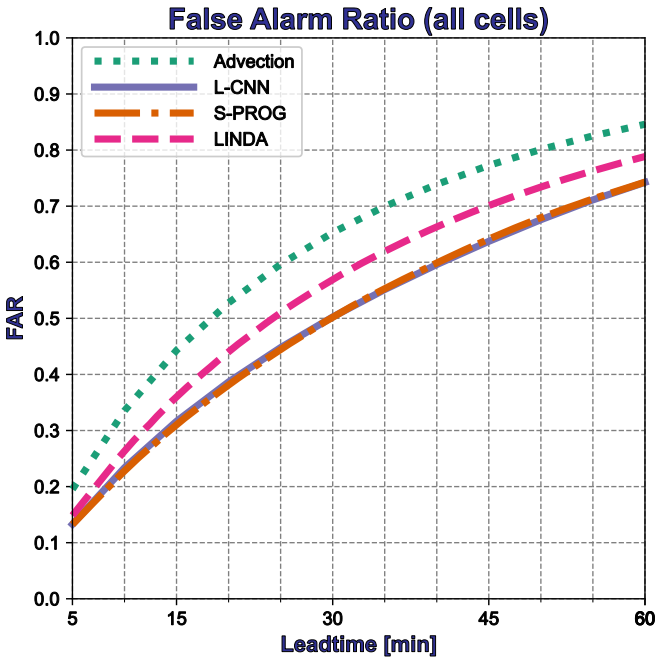
- Data selected from the Swiss radar network from May–Sep 2021–2023
- A single-pol rainfall product with 5-min time & 1 km spatial resolution
  - Data corrected for ground & non-met clutter, radar visibility & VPR, and adjusted for rain gauge bias
  - For cell identification, rainfall rate transformed to reflectivity with $Z = 316R^{1.5}$
- Cells identified & tracked with the open source pysteps T-DaTing module
  - Cell identification threshold 35 dBZ (4.6 mm/h)
  - Test dataset has 156k cell tracks

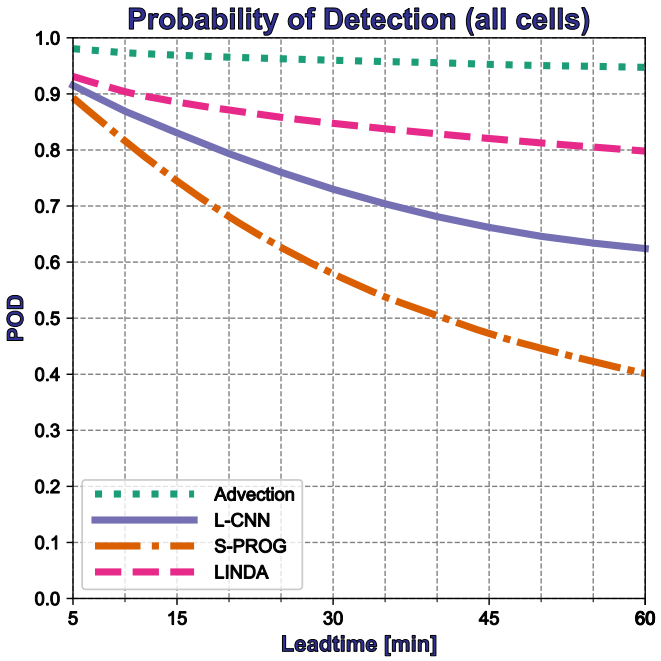
jenna.ritvanen@fmi.fi

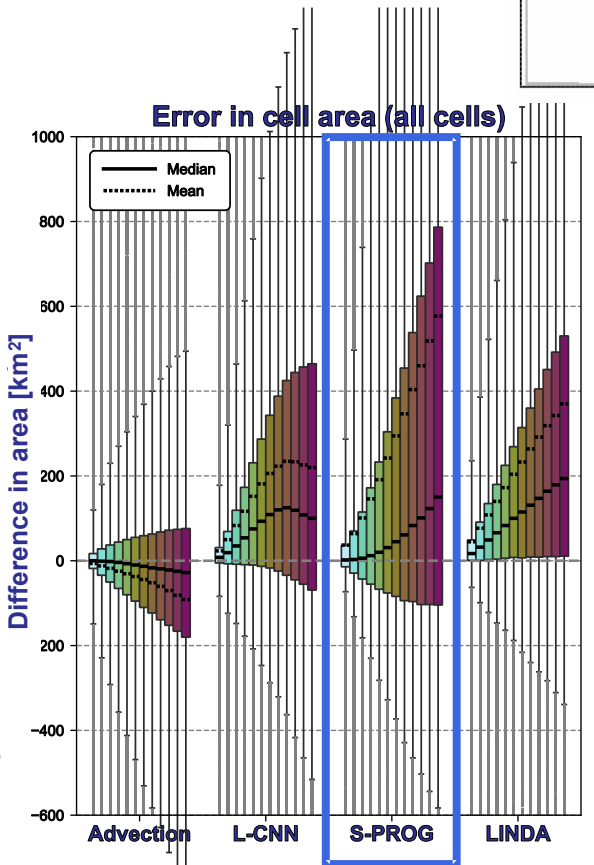
S-PROG underestimates amount of cells & overestimates cell size

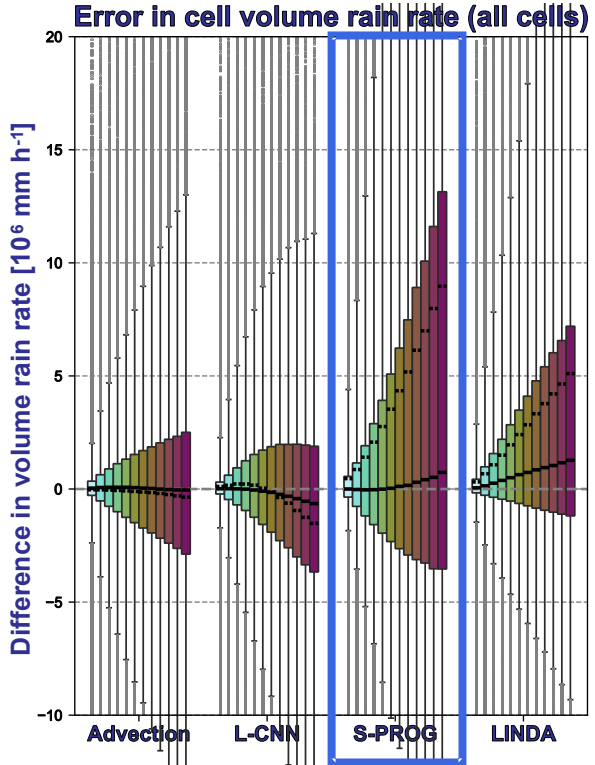
- In S-PROG the cells merge as leadtime increases, which causes a drop in the number of cell tracks
- Blurring leads to spreading medium-intensity areas, which leads to overestimation of cell area and cell volume rain rate







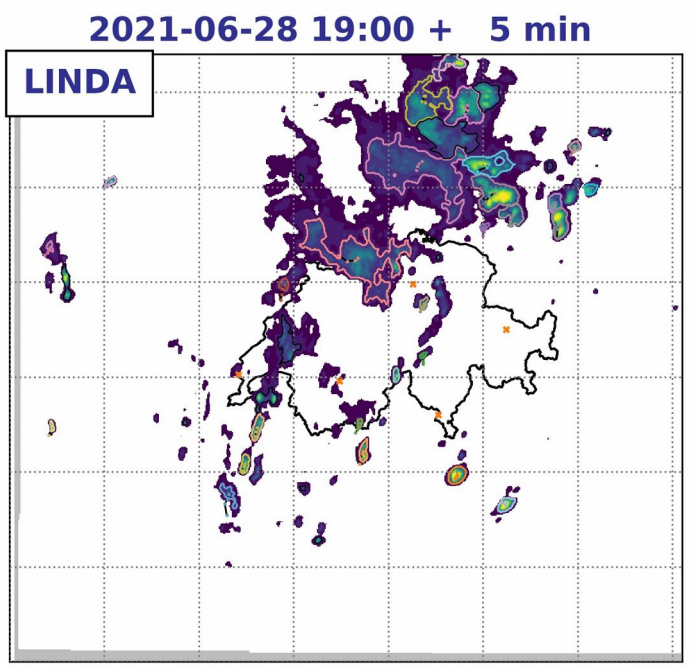


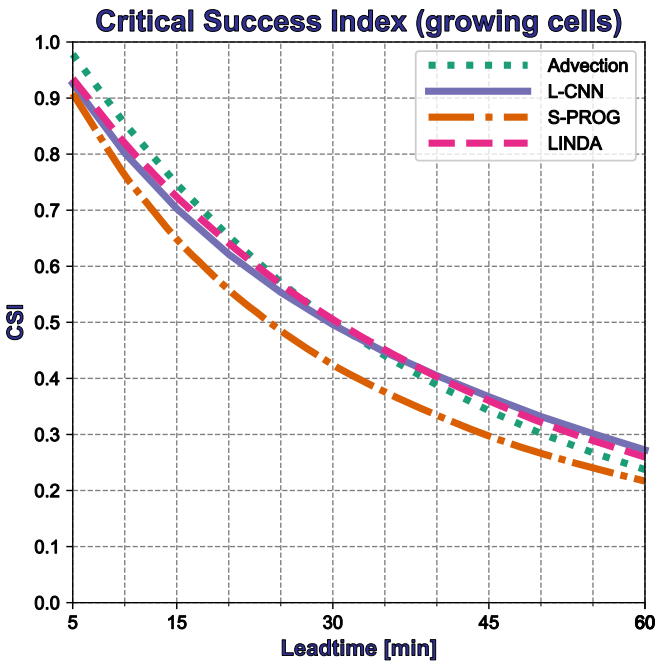


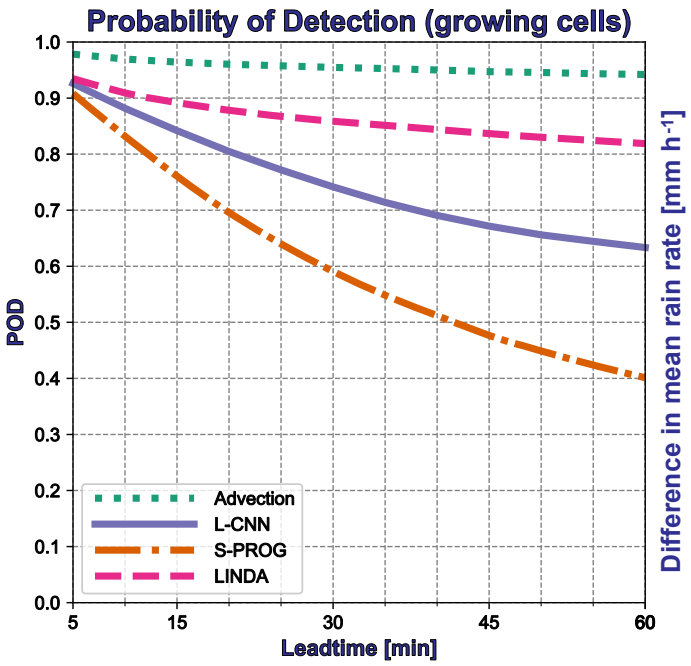
jenna.ritvanen@fmi.fi

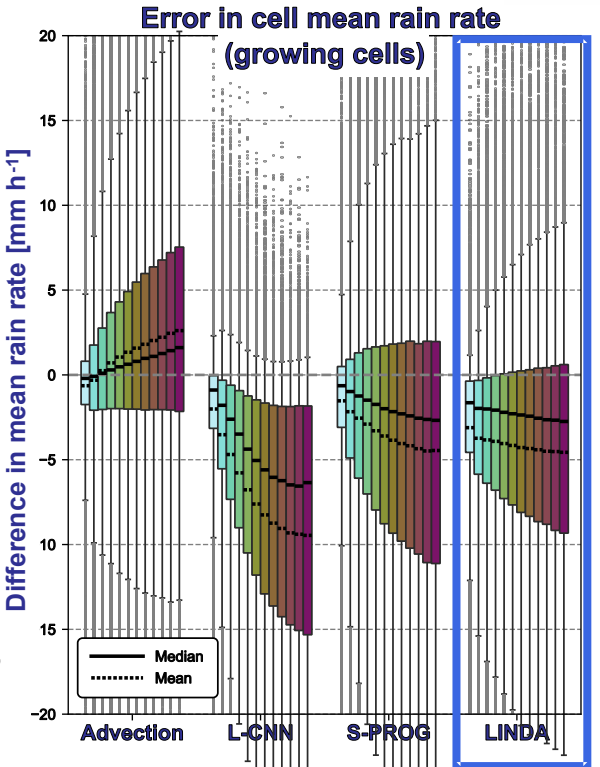
LINDA is best for nowcasting growing cells

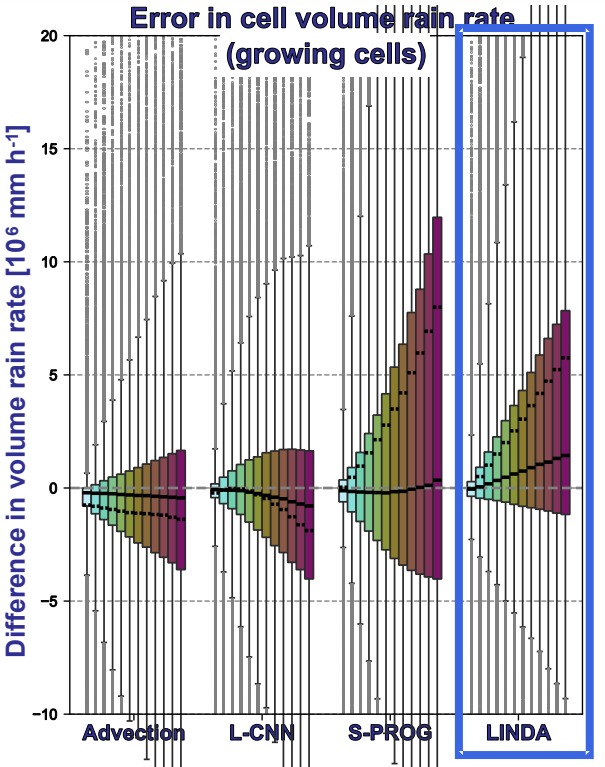
- LINDA predicts the existence of growing cell tracks best among the models
- Increased growth leads to smallest underestimation of mean rain rate, but also to overestimated volume rain rate







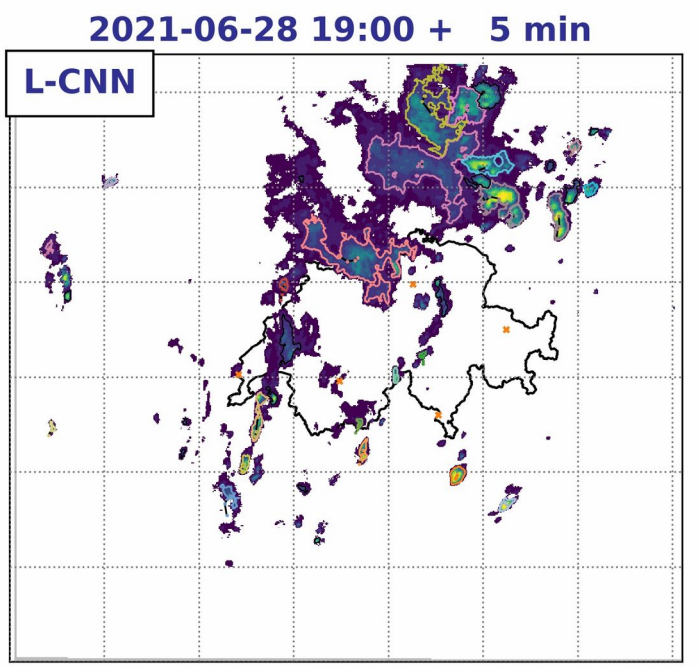


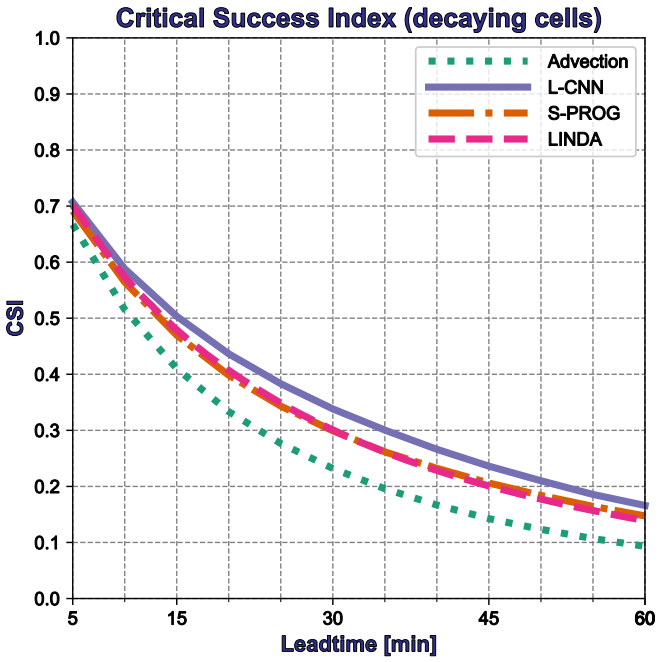


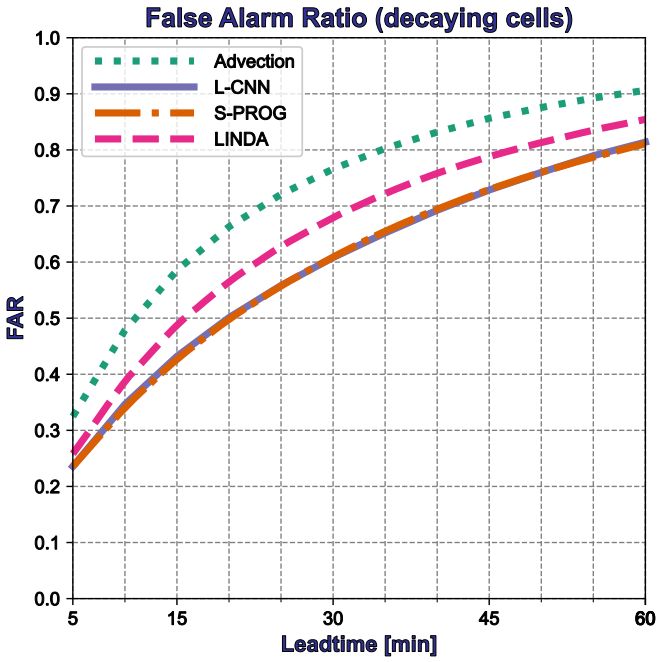
jenna.ritvanen@fmi.fi

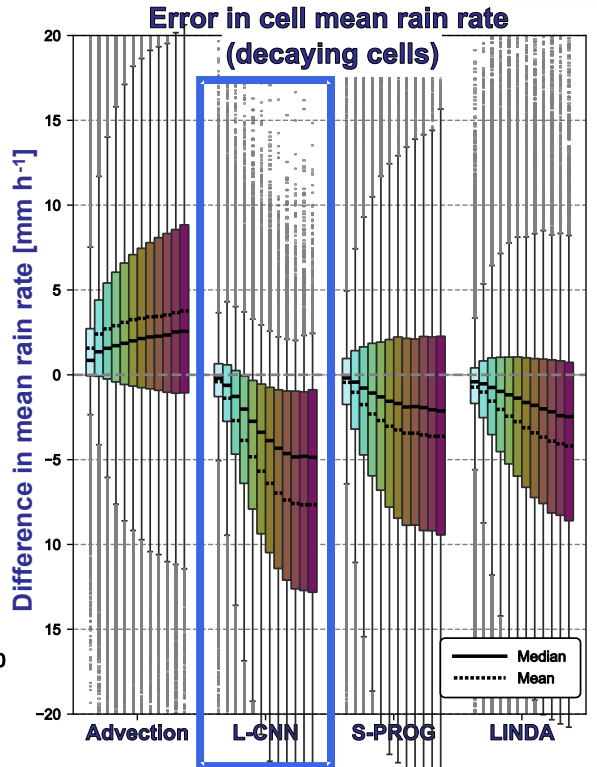
L-CNN is best at nowcasting cell volume rain rate

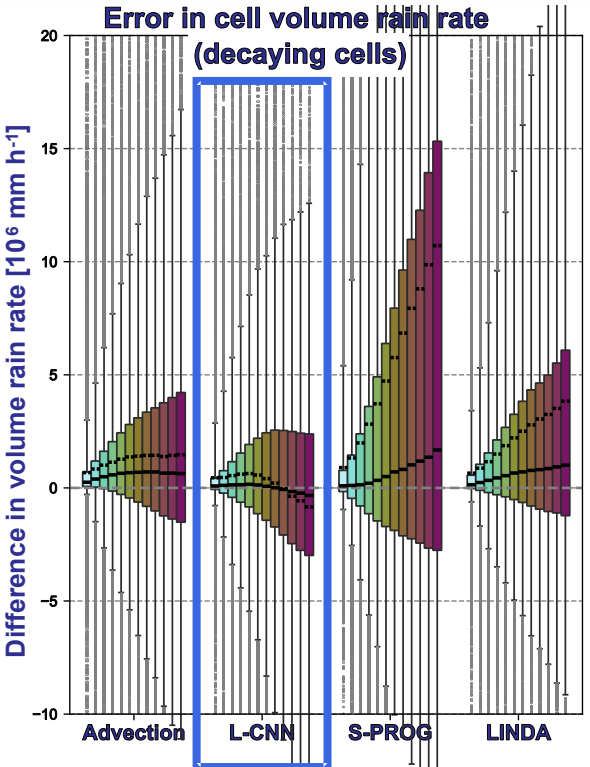
- L-CNN reproduces decaying cells better than LINDA
- Local decay in L-CNN leads to largest underestimation of mean rain rate, but most accurate volume rain rate



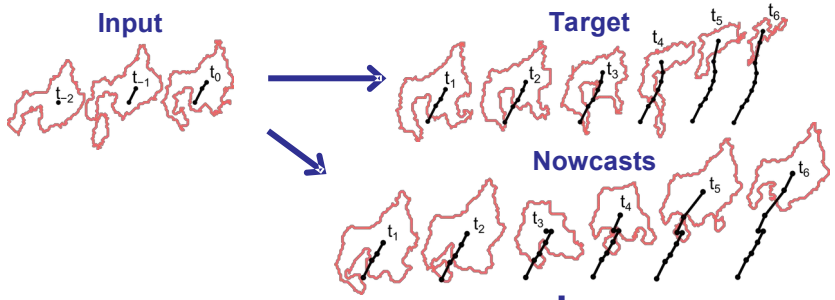




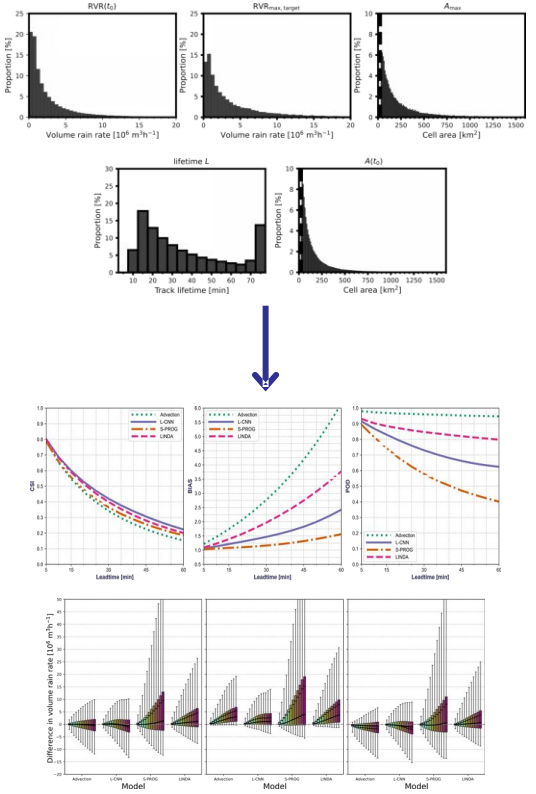




Cell tracking for evaluating nowcasts in convective rainfall



- Allows focus on various aspects of the nowcasts of convective rain cells, e.g. location, shape, intensity, total predicted rainfall, lifetime
- Allows separating results based on cell track history, e.g. stage of cell development
- Aids in model development by quantifying visible differences between models, e.g. in blurring



Manuscript in Geoscientific Model Development Discussions:
Ritvanen, J., Pulkkinen S., Moisseev D., and Nerini, D.:
Cell tracking -based framework for assessing nowcasting model skill in reproducing growth and decay of convective rainfall
https://gmd.copernicus.org/preprints/gmd-2024-99/

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