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]
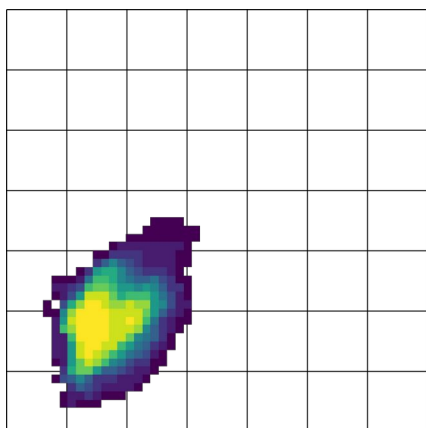
Contact: Jenna.Ritvanen@fmi.fi

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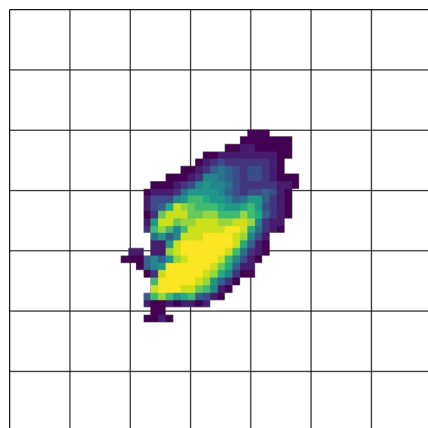[2]University of Helsinki, INAR, Helsinki, Finland
[3]MeteoSwiss, Locarno-Monti, Switzerland

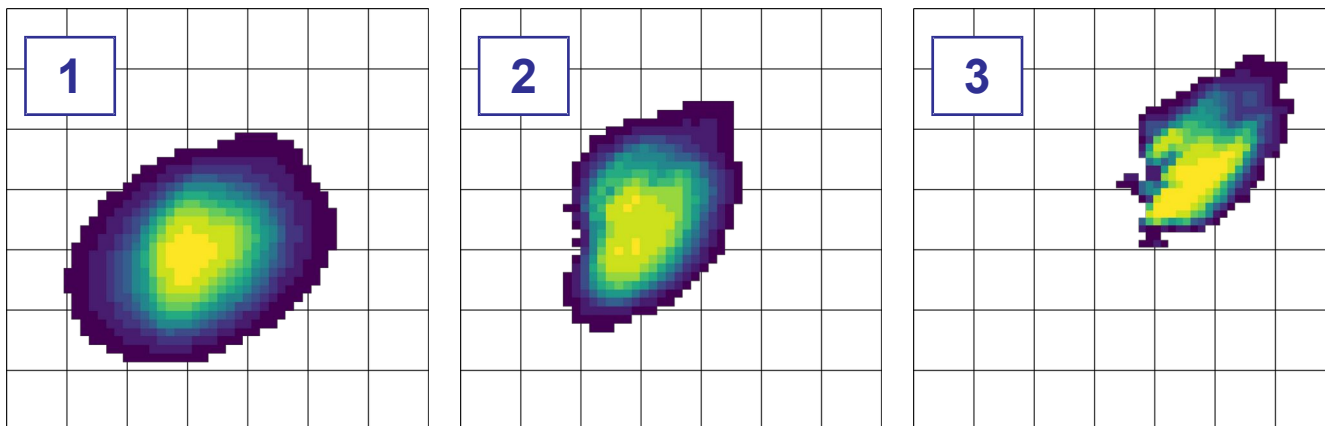# How to evaluate grid-based nowcasting models in convective rainfall?

**Observation at t**   **Observation at t + T**

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

1

2

3

- 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
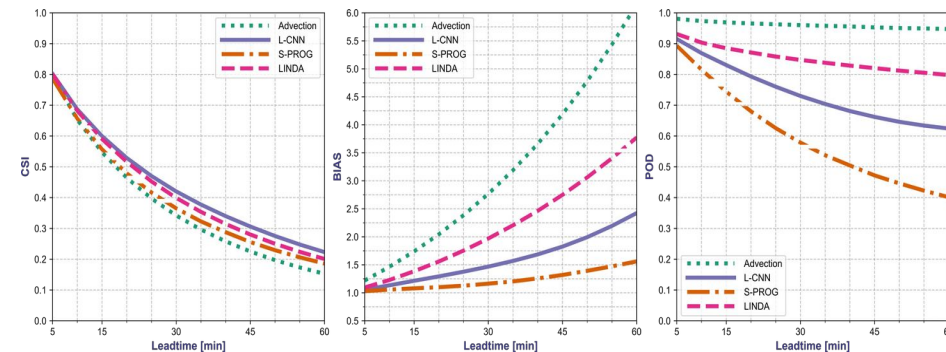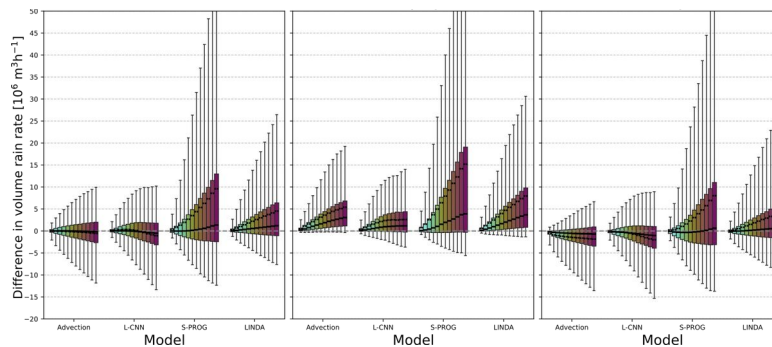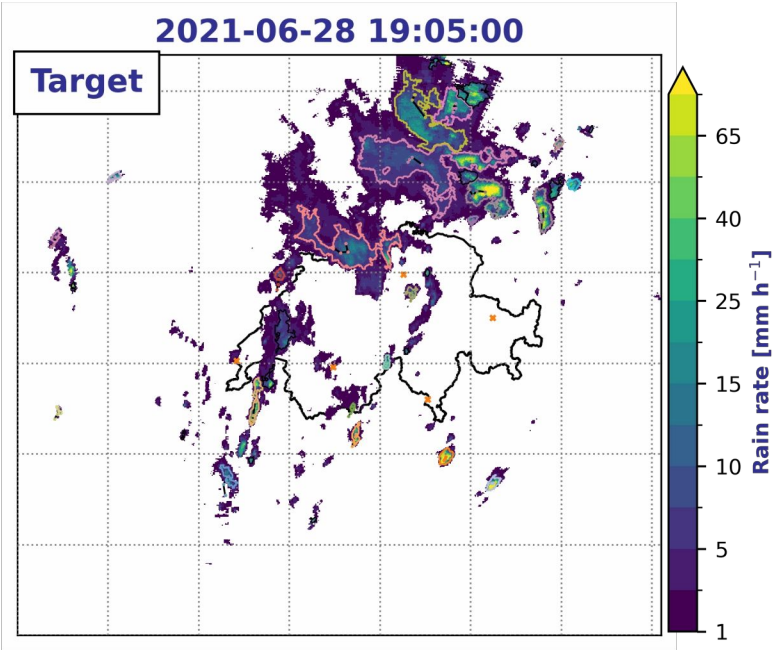
Cell tracking approach

1. Cell tracking
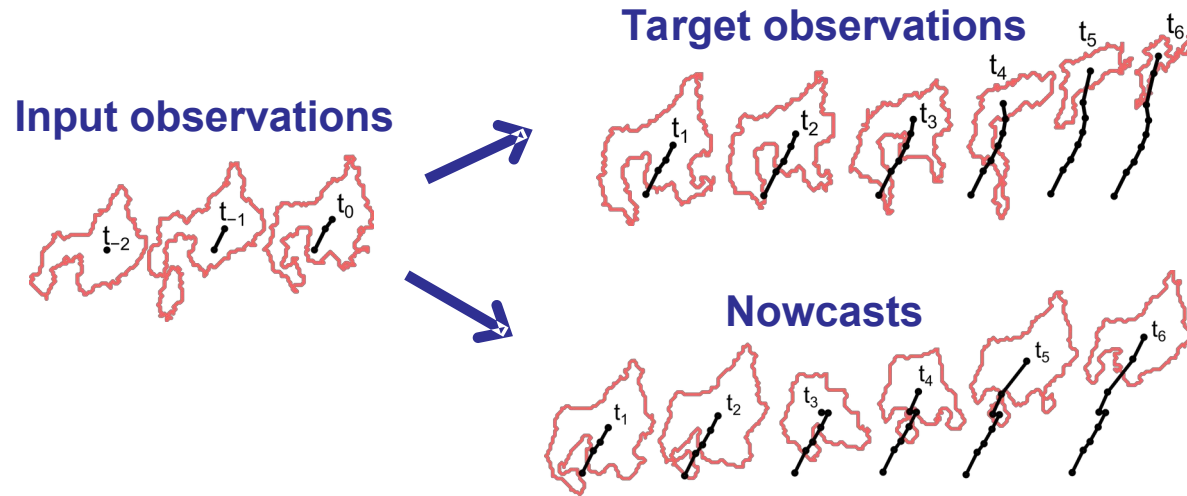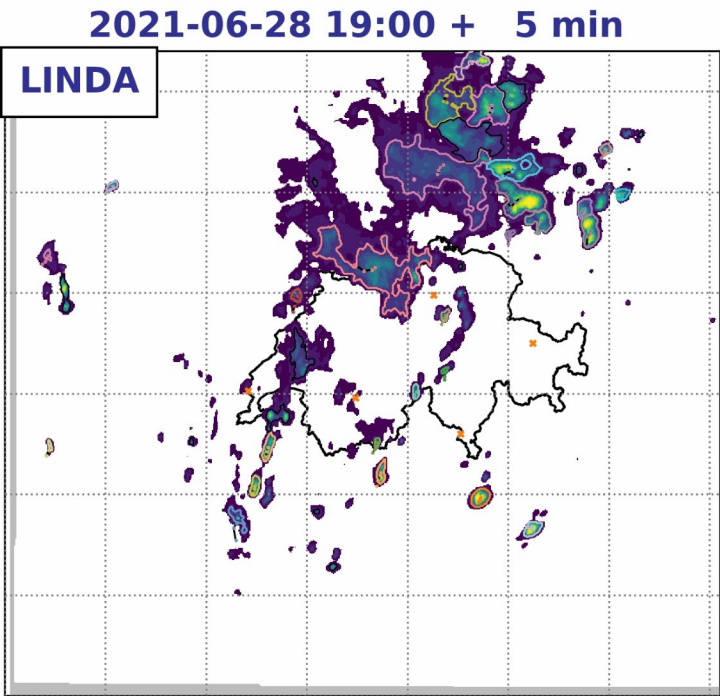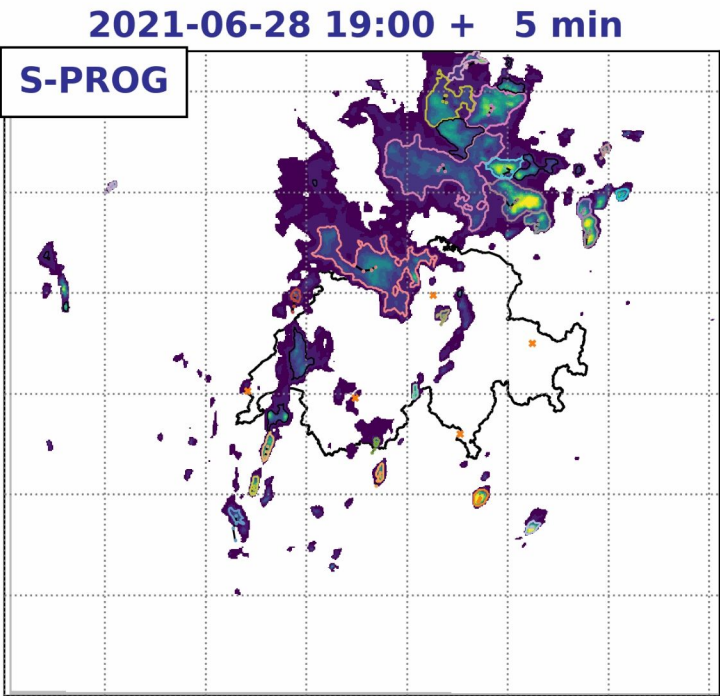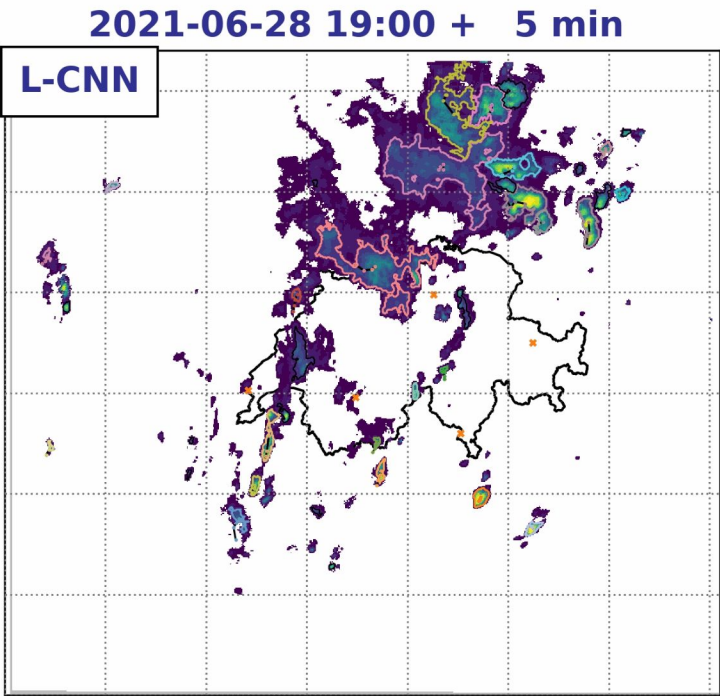
2. Feature extraction
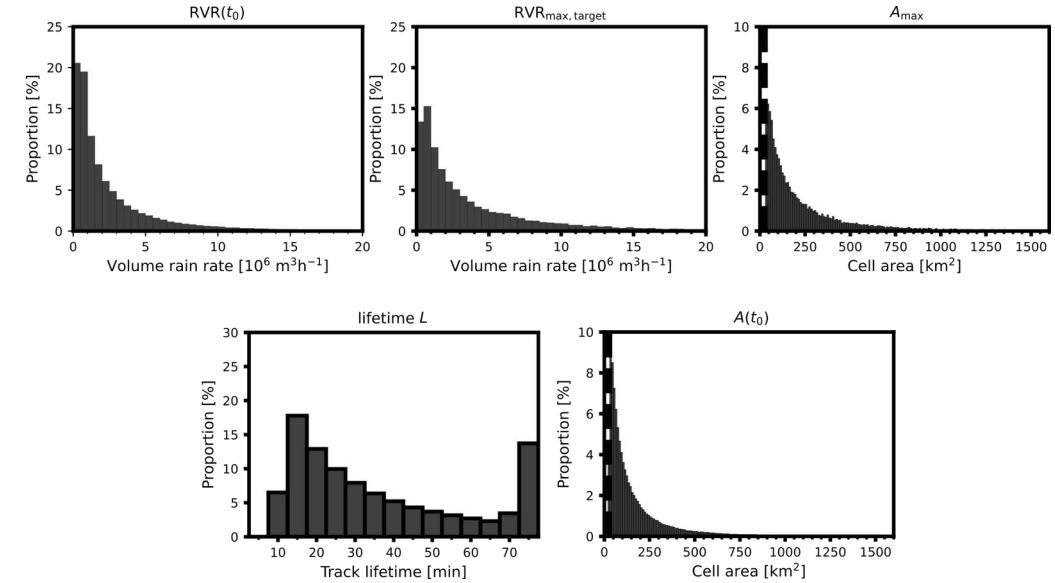
3. Error & metrics calculation

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

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Target

Rain rate [mm h^{-1}]

	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

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Advection

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L-CNN

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S-PROG

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LINDA
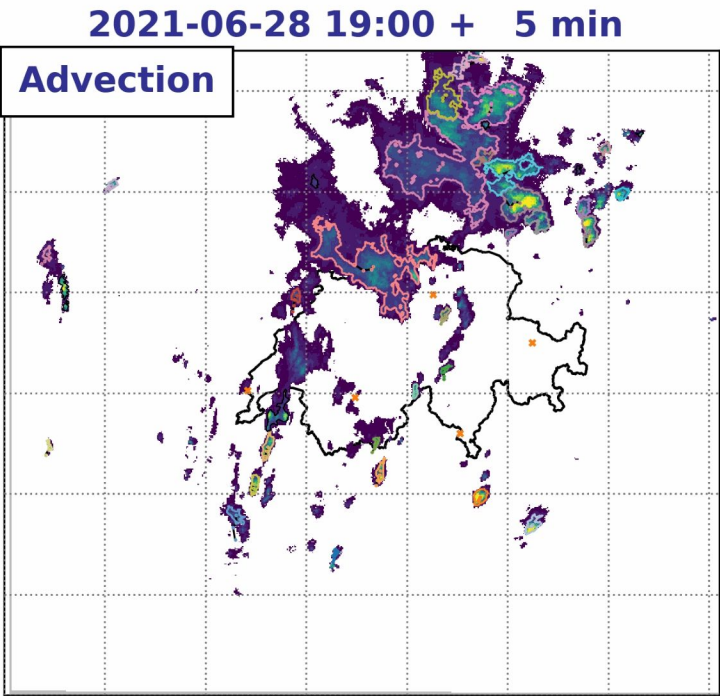
Research questions the cell tracking can answer

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

Input observations

Target observations

Nowcasts

Cell feature values

- Area
- Mean rain rate
- Volume rain rate

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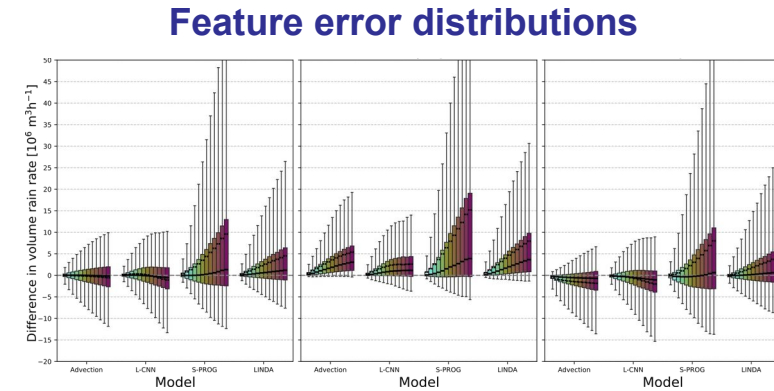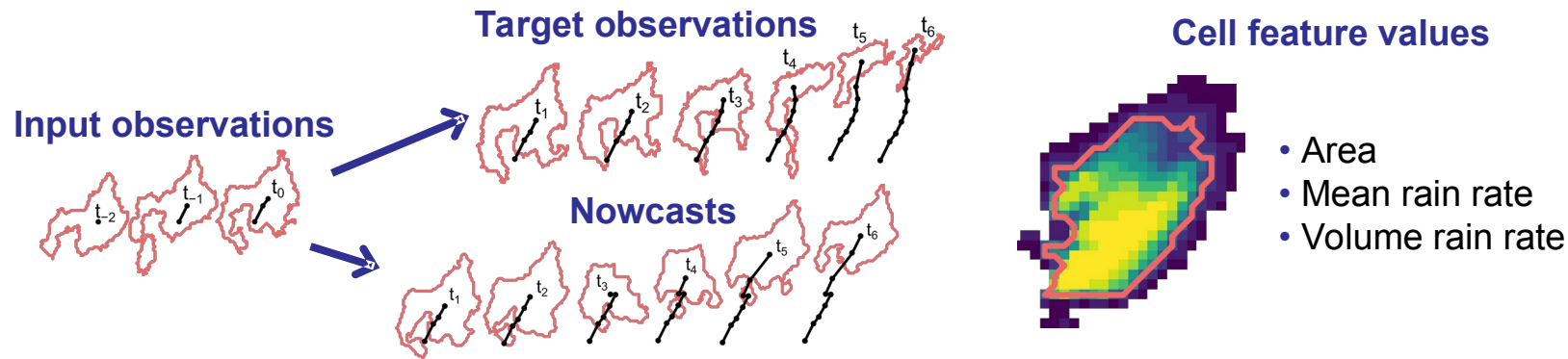
2. How accurately do the models reproduce the existence of cell tracks?

Input observations

Target observations
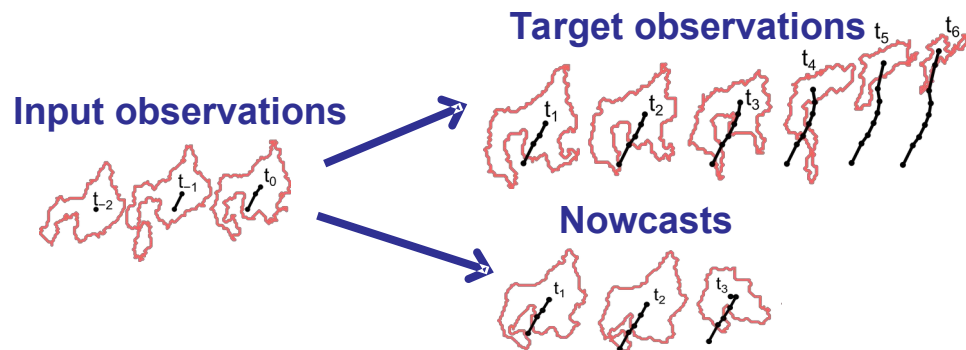
Nowcasts

Metrics describing cell track existence
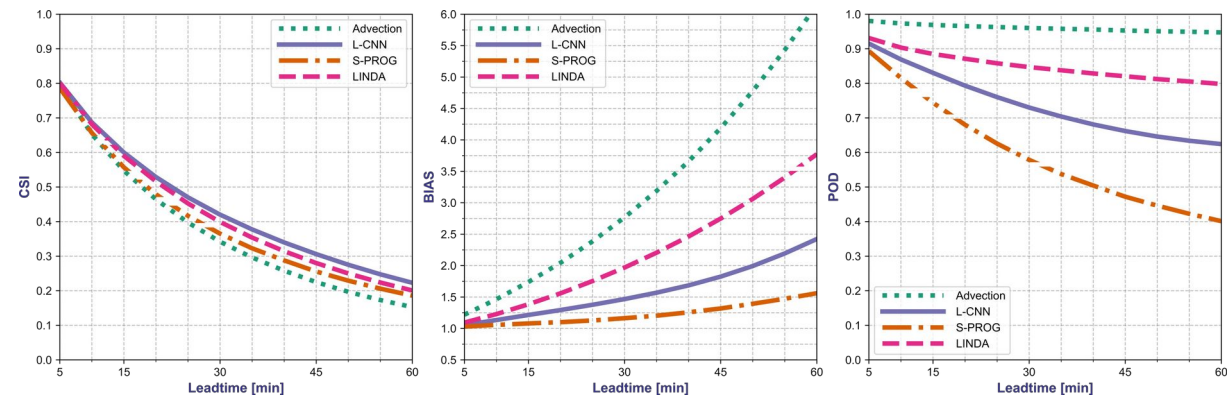
Definition of decaying and growing cell tracks

- We classify the cell tracks as either **decaying** or **growing**
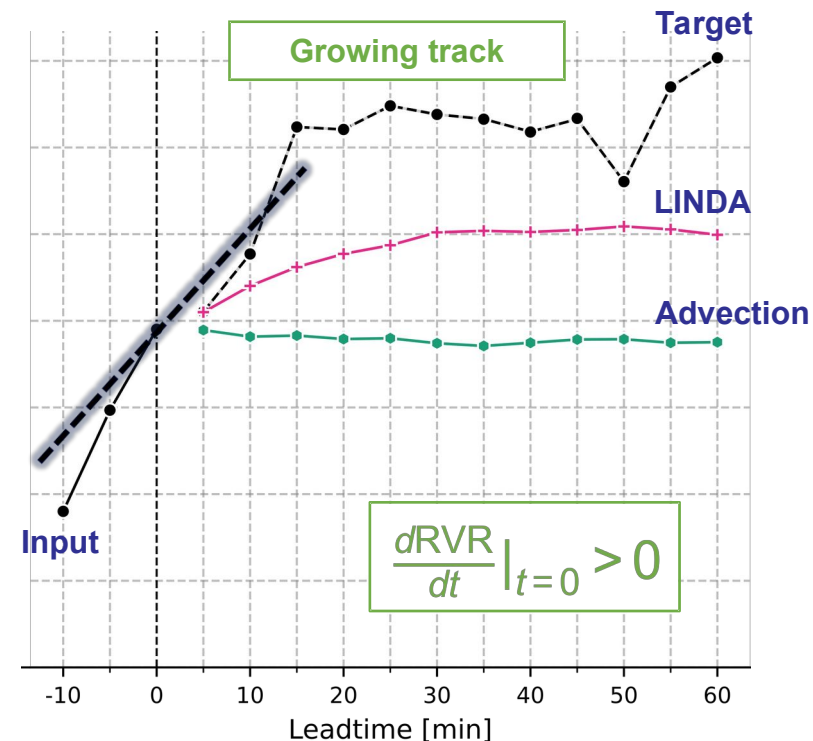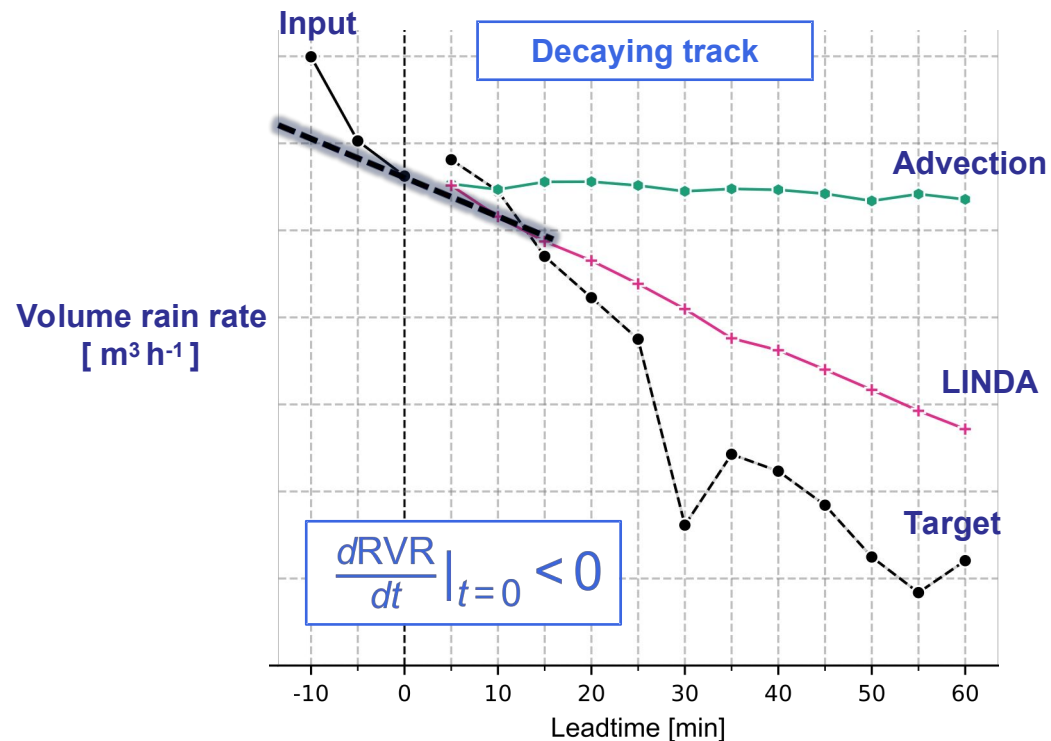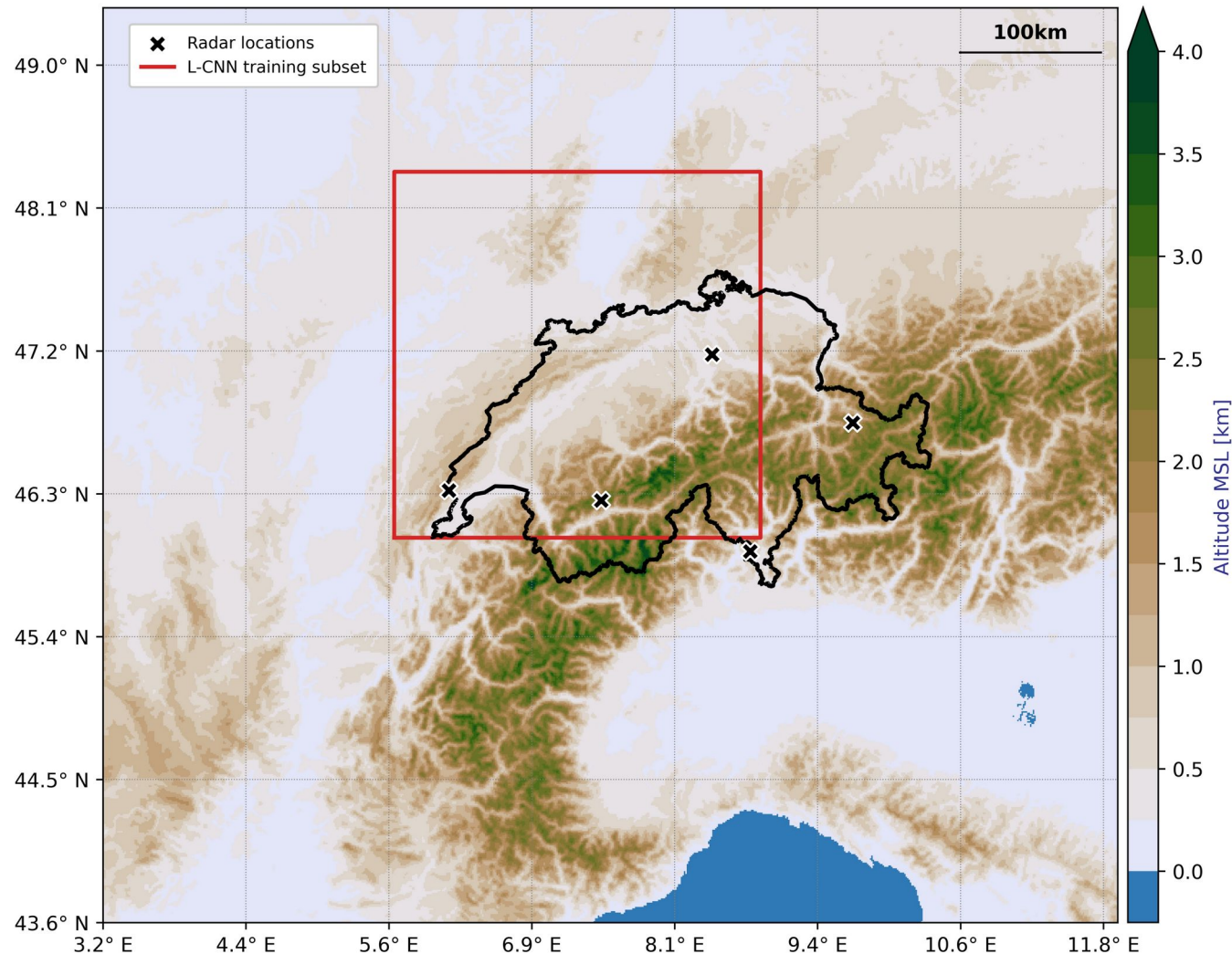 **at the time when the nowcast is created** in both the observations and nowcast

- The classification is based on the derivative of volume rain rate at t_0
  (RVR; integrated rain rate over the cell area)

Input

Decaying track

Advection

Volume rain rate
[$m^3 h^{-1}$]

LINDA

Target

$$\frac{dRVR}{dt}\big|_{t=0} < 0$$

-10   0   10   20   30   40   50   60
Leadtime [min]

Target

Growing track

LINDA

Advection

Input

$$\frac{dRVR}{dt}\big|_{t=0} > 0$$

-10   0   10   20   30   40   50   60
Leadtime [min]

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

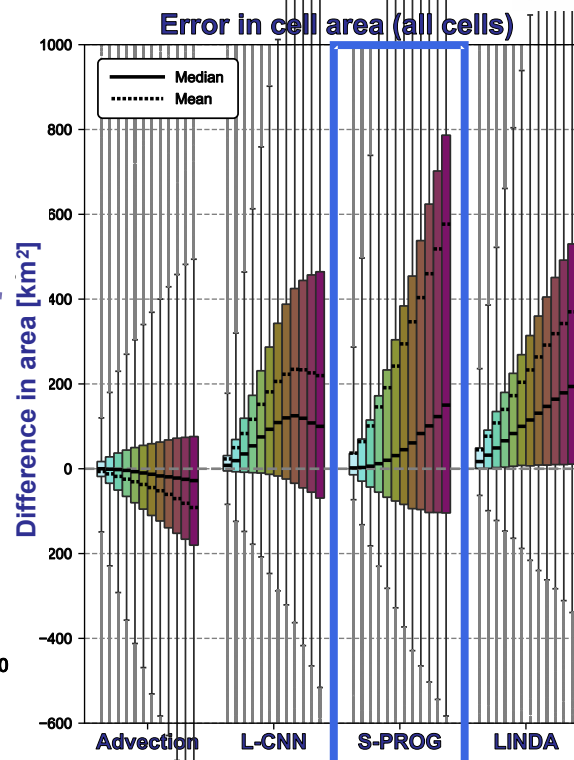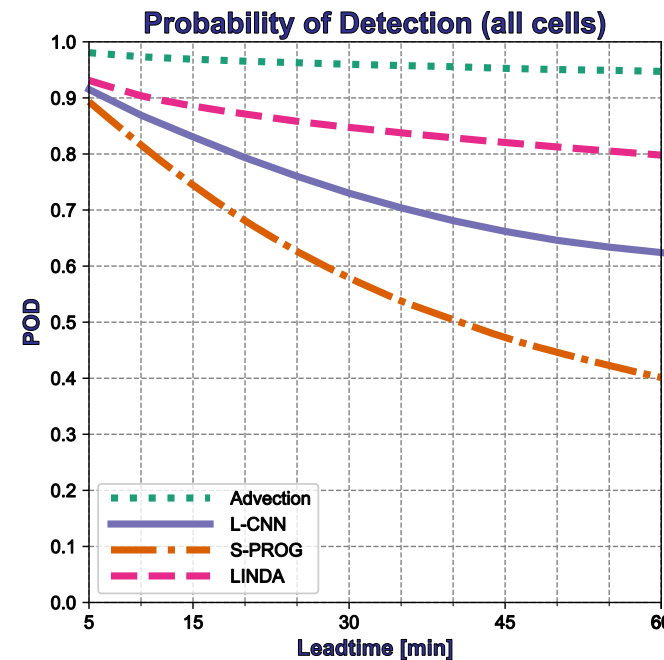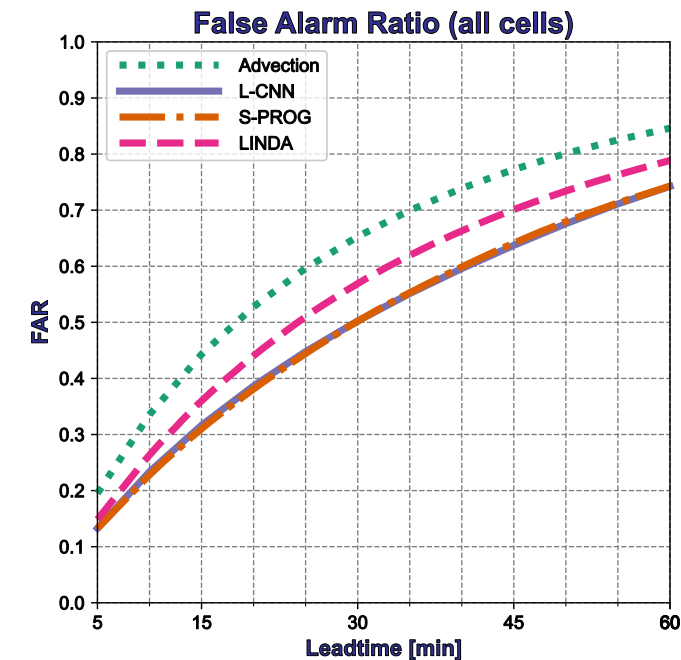 - Data corrected for ground & non-met clutter, radar visibility & VPR, and adjusted for rain gauge bias

  - 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

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

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S-PROG

False Alarm Ratio (all cells)

Probability of Detection (all cells)

Error in cell area (all cells)

Error in cell volume rain rate (all cells)
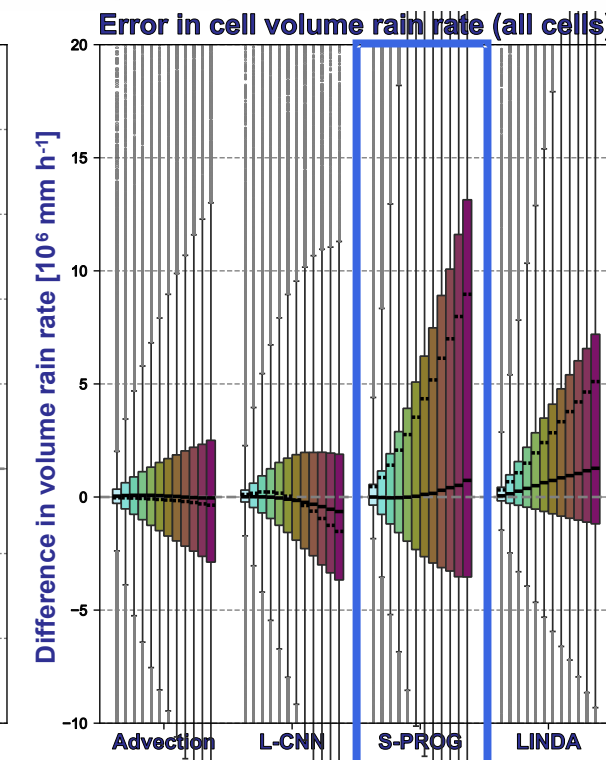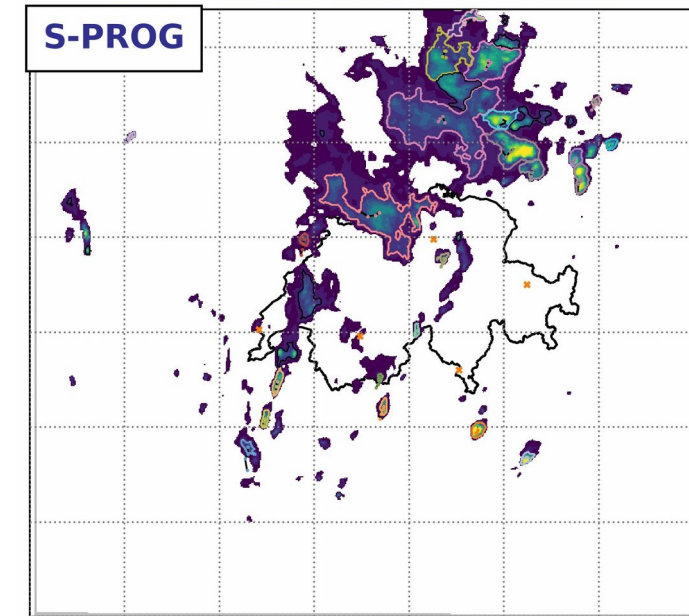
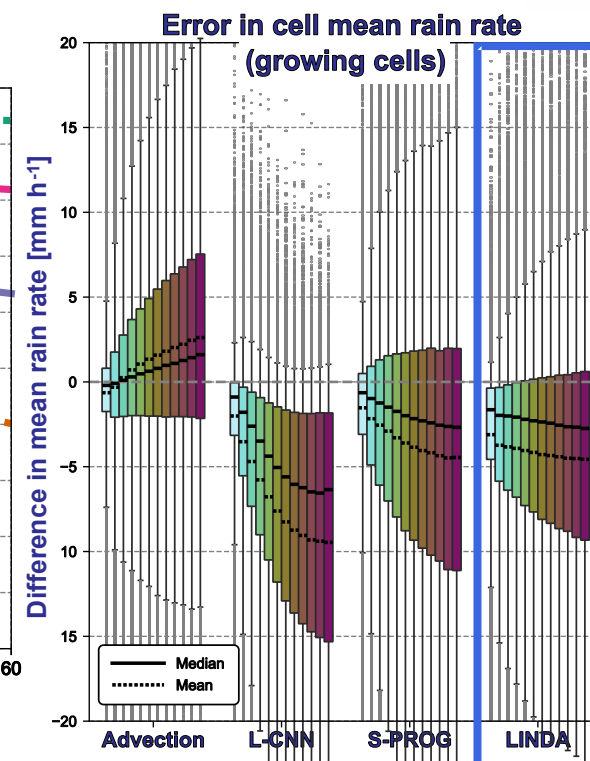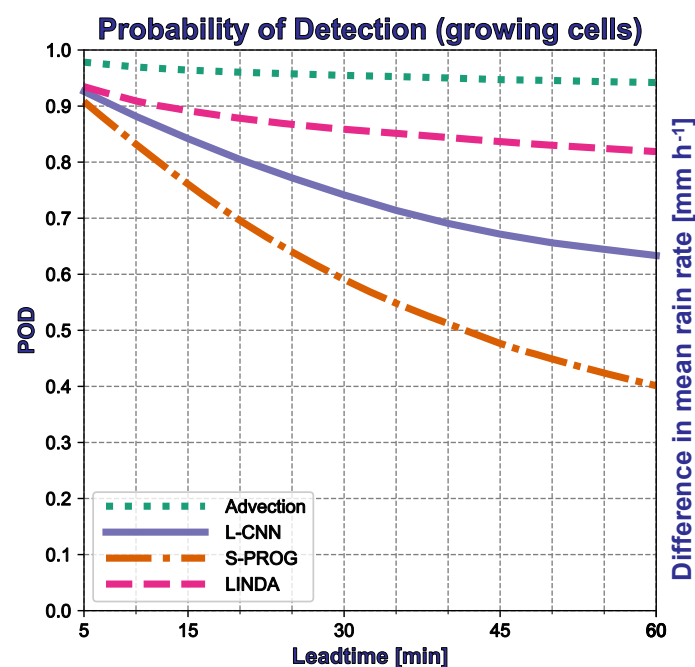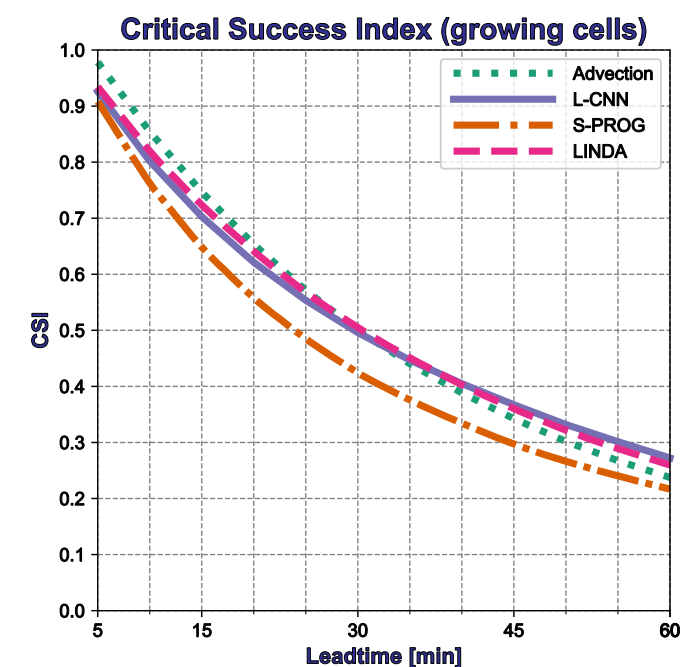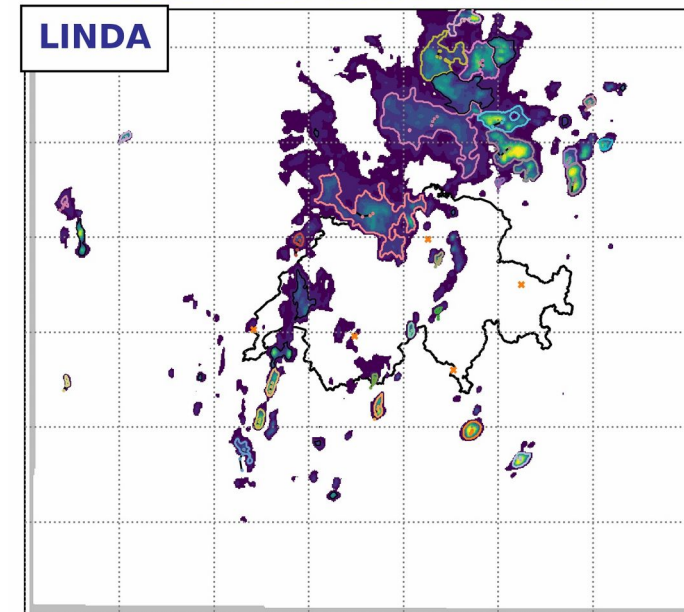# LINDA is best for nowcasting growing cells

- 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

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LINDA

Critical Success Index (growing cells)

Probability of Detection (growing cells)

Error in cell mean rain rate (growing cells)

Error in cell volume rain rate (growing cells)
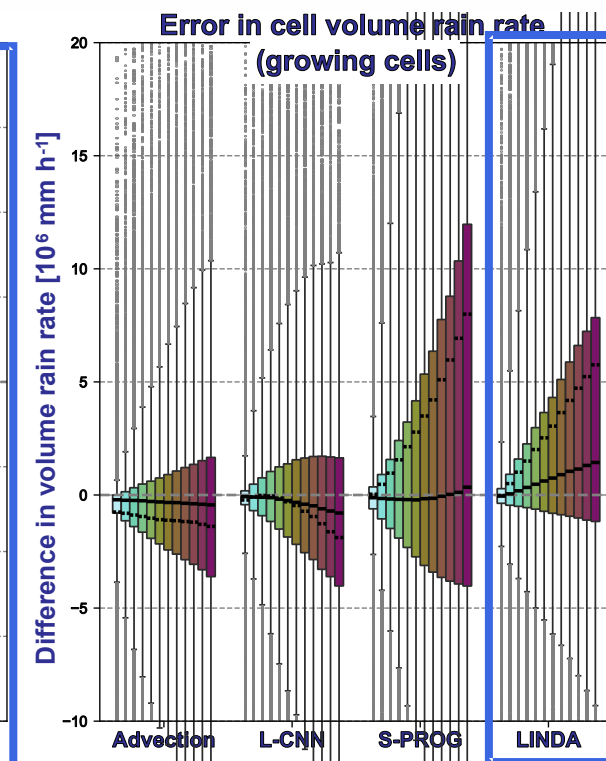
L-CNN is best at nowcasting cell volume rain rate

- 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
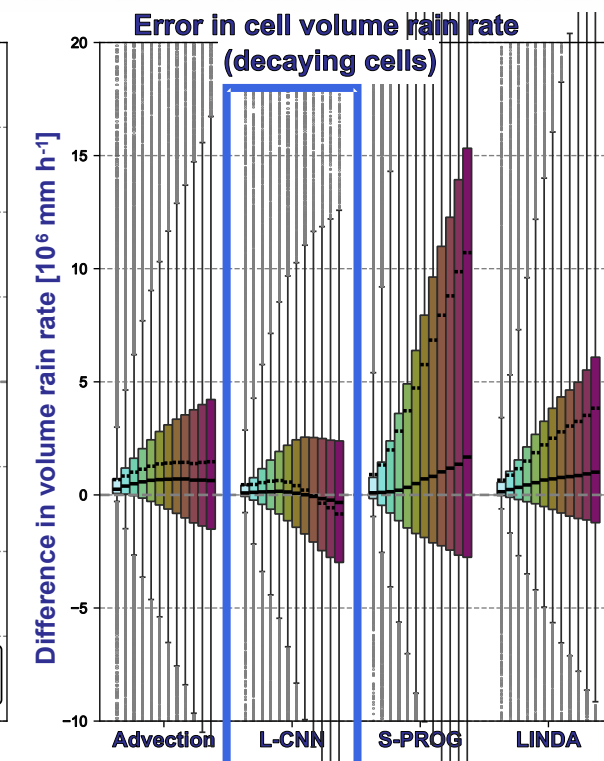
Cell tracking for evaluating nowcasts in convective rainfall

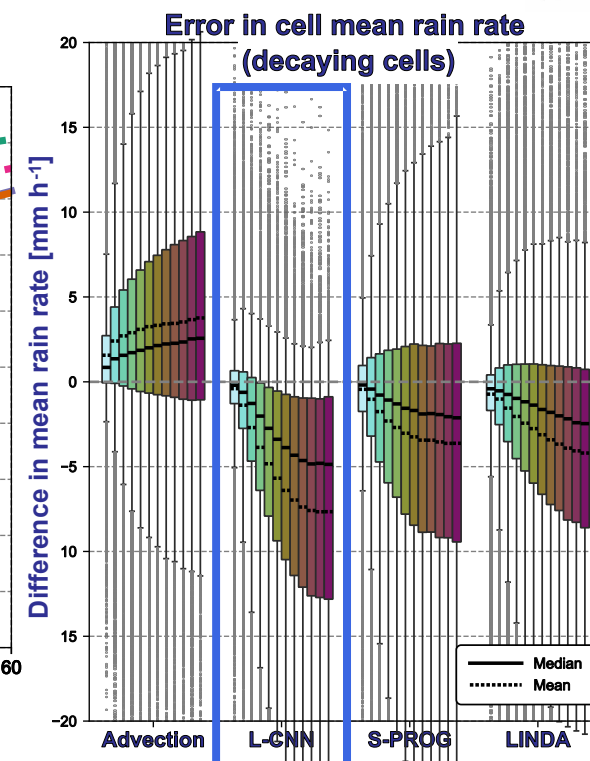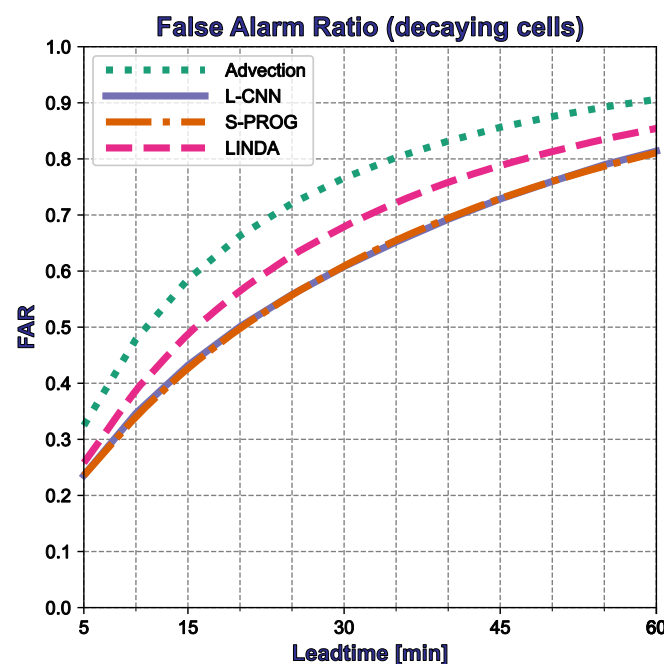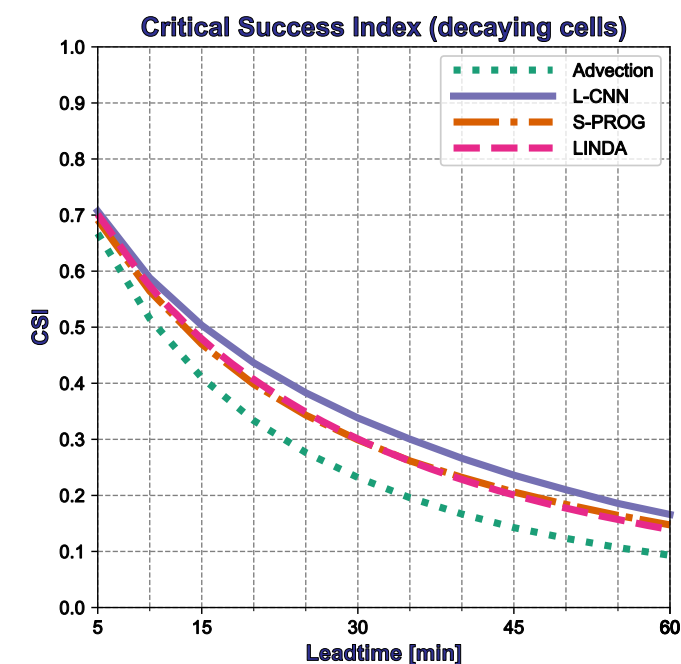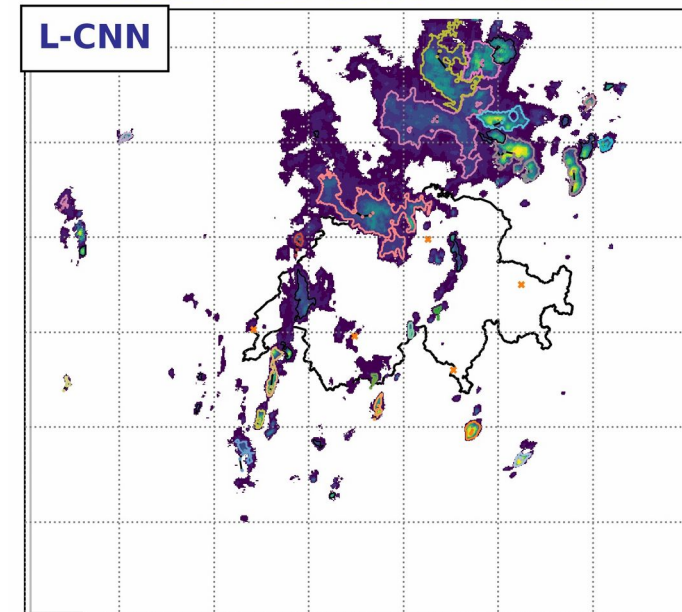- Allows focus on various aspects of the nowcasts of convective rain cells, e.g. location, shape, intensity, total predicted rainfall, lifetime

- 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/
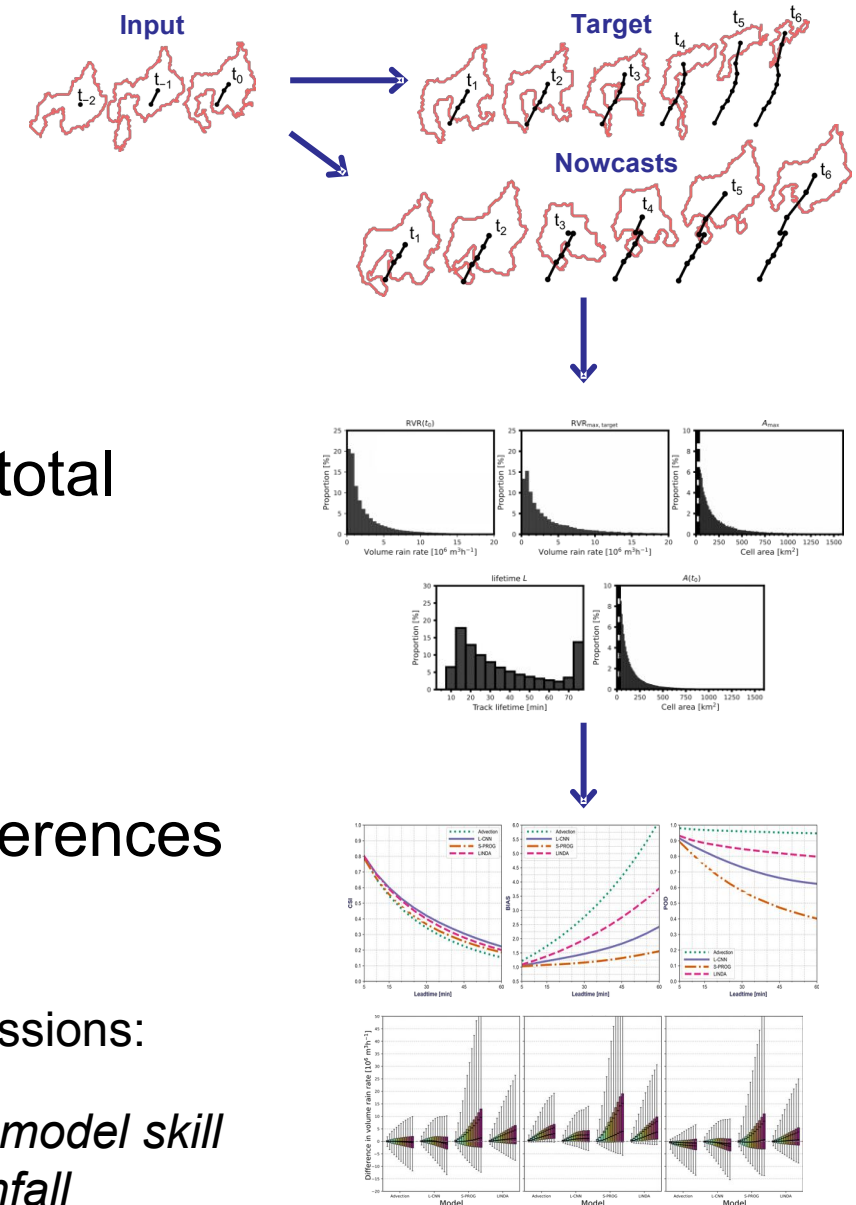
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Hering, A. M., Morel, C., Galli, G., Senesi, S., Ambrosetti, P., and Boscacci, M.: Nowcasting thunderstorms in the Alpine region using a radar based adaptive thresholding scheme, in: Proc. Third European Conf. on Radar Meteorology, Visby, Sweden, 2004.

Pulkkinen, S., Nerini, D., Pérez Hortal, A. A., Velasco-Forero, C., Seed, A., Germann, U., and Foresti, L.: Pysteps: An Open-Source Python Library for Probabilistic Precipitation Nowcasting (v1.0), Geosci. Model Dev., 2019, 4185–4219, https://doi.org/10/ghmfhd, 2019.

Pulkkinen, S., Chandrasekar, V., and Niemi, T.: Lagrangian Integro-Difference Equation Model for Precipitation Nowcasting, Journal of Atmospheric and Oceanic Technology, 38, 2125–2145, https://doi.org/10.1175/JTECH-D-21-0013.1, 2021.

Ritvanen, J., Harnist, B., Aldana, M., Mäkinen, T., and Pulkkinen, S.: Advection-Free Convolutional Neural Network for Convective Rainfall Nowcasting, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 16, 1654–1667, https://doi.org/10.1109/JSTARS.2023.3238016, 2023.

Seed, A. W.: A Dynamic and Spatial Scaling Approach to Advection Forecasting, Journal of Applied Meteorology and Climatology, 42, 381–388, https://doi.org/10/brsrnc, 2003.