Radar-based ensemble nowcasting: predictability analysis

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Abstract

Conventionally, radar-based nowcasting methods have been conducted by shifting or extrapolating the most recent estimated precipitation field along the estimated motion field to lead times up to 3 hr. However, such methods assume that these fields do not evolve during the lead-time period. A more recent nowcasting approach is the short-term ensemble prediction system known as STEPS. STEPS aims to filter small spatial scales of rain as they have an expected short life-time compared to large spatial scales. Besides, it perturbs the precipitation field during extrapolation so that the prediction uncertainties related to the evolution of precipitation is considered, resulting in an ensemble nowcast. In this work, the configuration, implementation, and performance of STEPS are studied for its radar-based ensemble nowcasting application in Germany. Attention is given to the spatial localization (i.e., the adjustment of parameters that control the spatio-temporal evolution of precipitation in large domains). For such purpose, the capability of STEPS is analyzed using multiple rain events collected by the German radar network. Preliminary analysis regarding the spatial scale filtering of STEPS (without perturbation) shows an improvement against conventional extrapolation of 20 to 30 % on the critical success index starting at lead times of 30 min at a rainfall threshold of 0.1 mm hr^{-1}. In terms of the spatial structure, STEPS (without perturbation) provides a consistent nowcast for lead times up to 3 hr. Although small spatial structures are filtered, the spatial structure at scales of 32 km or larger is maintained. The skill of a probabilistic nowcast (STEPS with perturbation) was also analyzed. It is shown that for the probability of exceeding the 5.0 mm hr^{-1} threshold, the predictability of the nowcast is compromised for lead times on the order of 1 hr. However, the capability of identifying rain and non-rain areas is still valuable: the hit rates are still larger than the false alarm rates. Our preliminary results highlight aspects needed in the configuration of STEPS such as the evolution model and the perturbation model. In this manner, this study can serve as a basis for an improved nowcasting system in Germany and as a reference for forecasters to understand the characteristics of the examined nowcast system.

RealPEP

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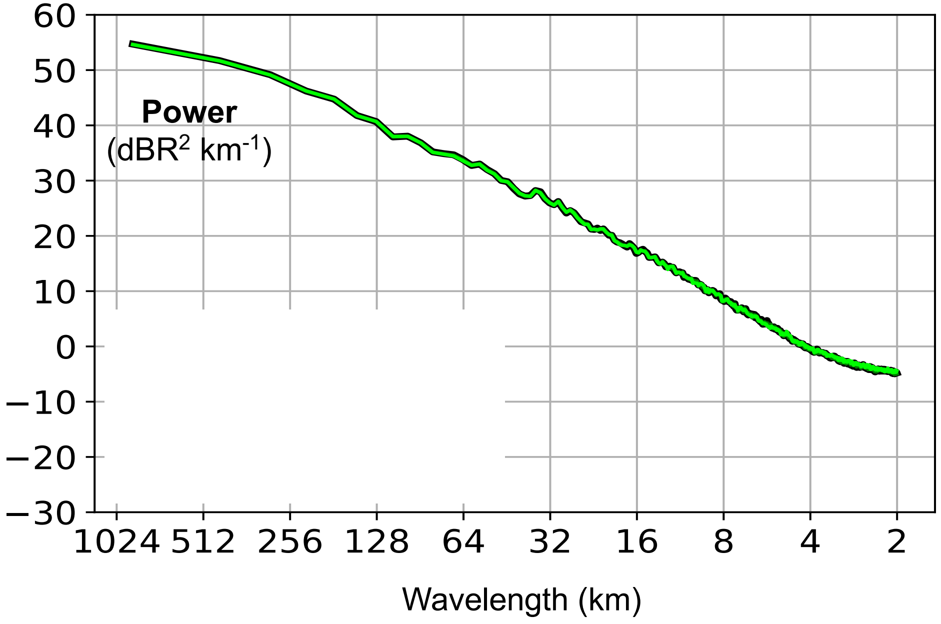
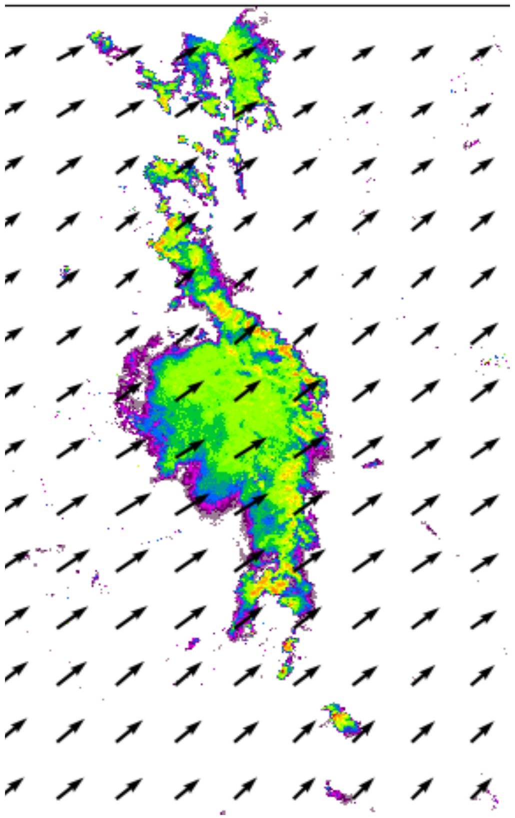
Motivation

How to improve advection-based prediction of precipitation?

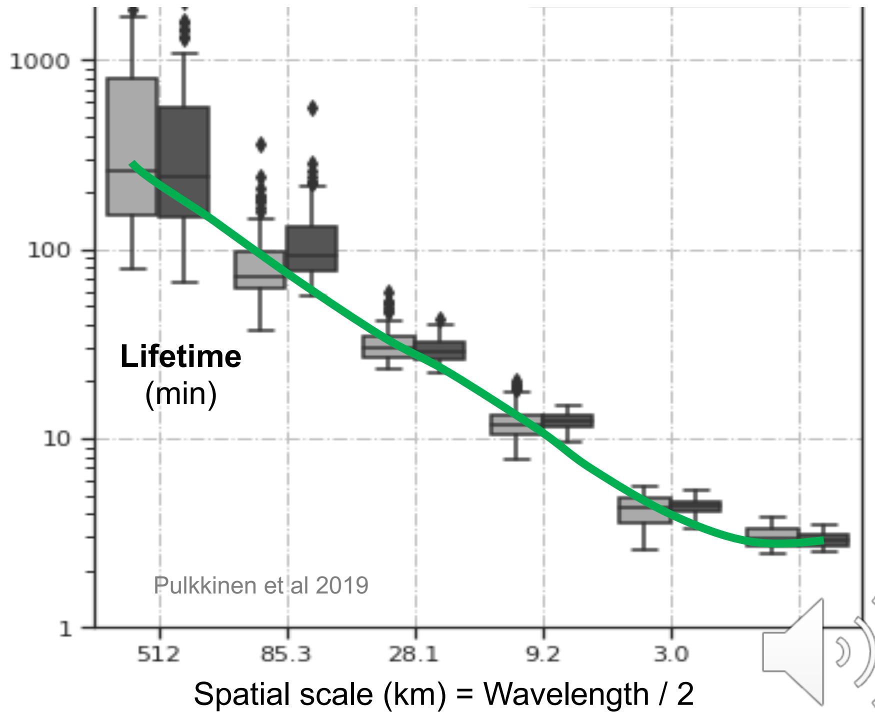
Scaling behavior of rain (Seed 2003) – SPROG approach

Space





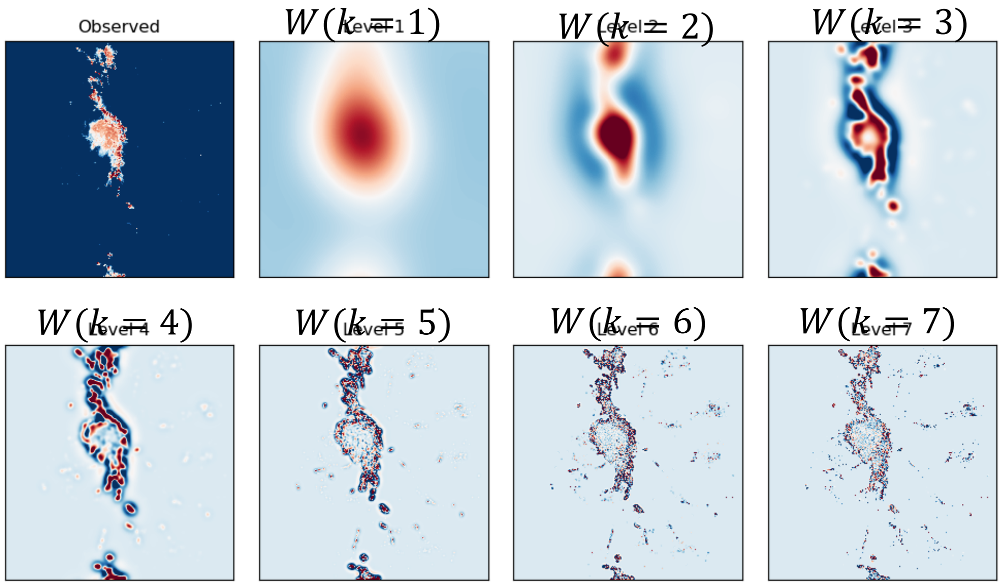
Time



The AR(p) parameters control the rate of evolution at each cascade level consistent with the expected lifetime

Spatial decomposition

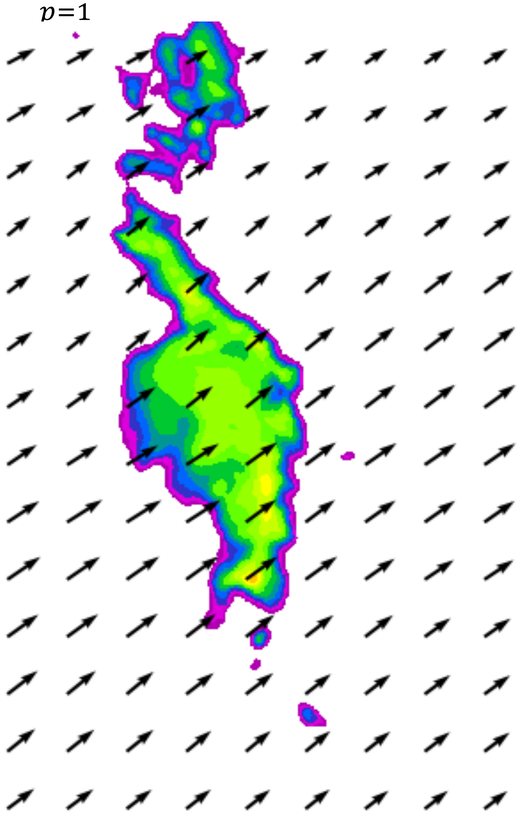
$$\mathrm{R}(x,y) = \mu + \sum_{k=1}^{n} \sigma(k) W(k,x,y)$$



$$= \mu + \sum_{k=1}^{n} ($$

Temporal evolution

$$W(t,k) = \sum_{p=1}^{2} \varphi^{p}(k) W(t-p,k) + \varphi^{0}(k)\varepsilon(t,k)$$



Cascade Decomposition and Spatial Filtering – STEPS Nowcast

1. Motion field → 2. Decomposition and AR filtering → 3. Perturbation → 4. Post-processing

2. Decomposition and AR filtering: Parameters: control the spatial structure and temporal evolution

3. Perturbation: Generation of ensemble members

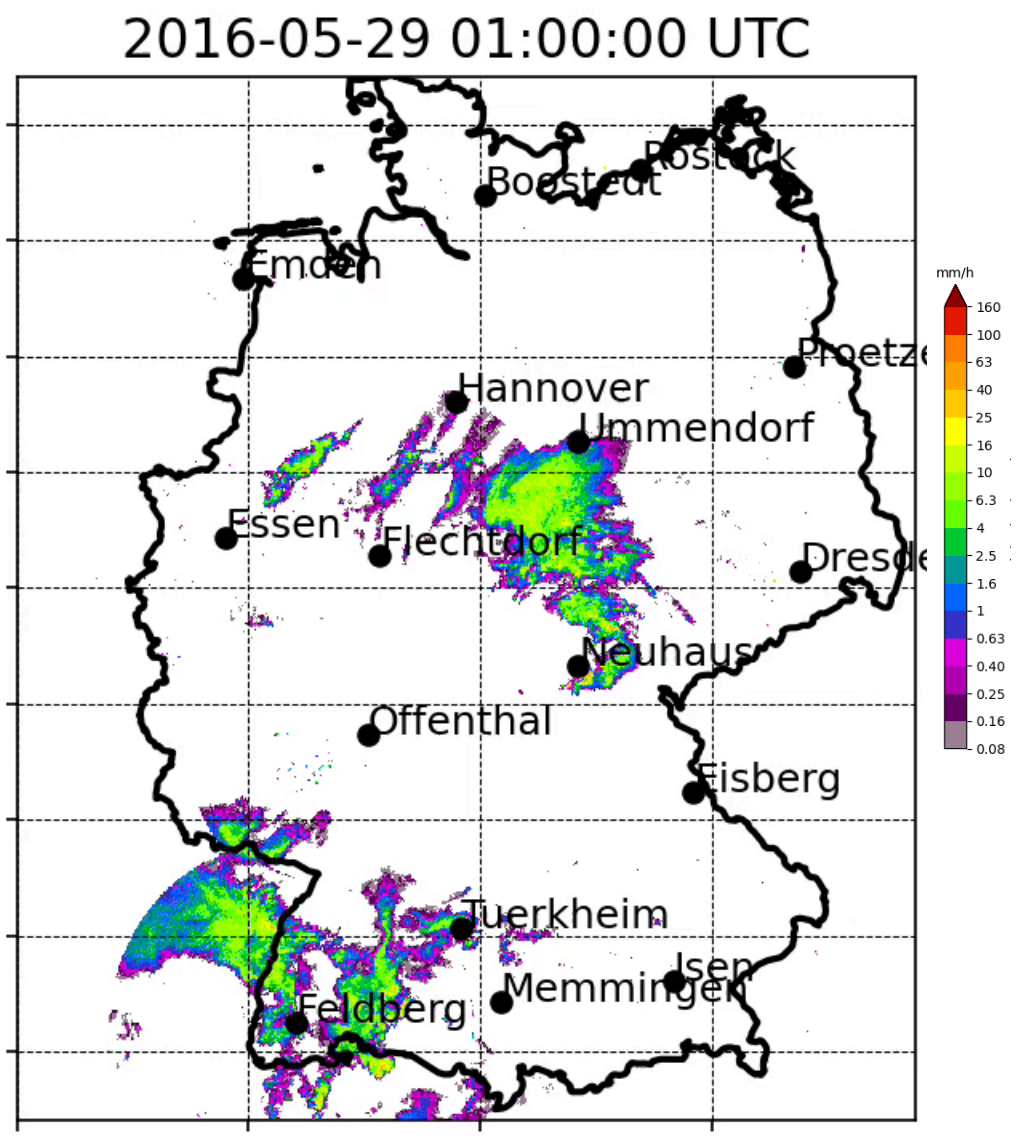
4. Post-processing: Parameters: control statistical properties of predicted precipitation

SPROG nowcasting (Seed 2003)

STEPS nowcasting (Bowler et al 2006)

[*]Pulkkinen, S., D. Nerini, A. Perez Hortal, C. Velasco-Forero, U. Germann, A. Seed, and L. Foresti, 2019: **pySTEPS**: an open-source Python library for probabilistic precipitation nowcasting (v1.0). *Geosci. Model Dev.*, **12 (10)**, 4185–4219, doi:10.5194/gmd-12-4185-2019

Precipitation events collected by the DWD C-band radar network



Parameters:

- AR-order (memory) – 1 or 2
- Scale Levels (resolution) – 3, 6, or 12
- Post-processing (statistical properties)
  - ➢Mean
  - ➢Cumulative distribution function (CDF)

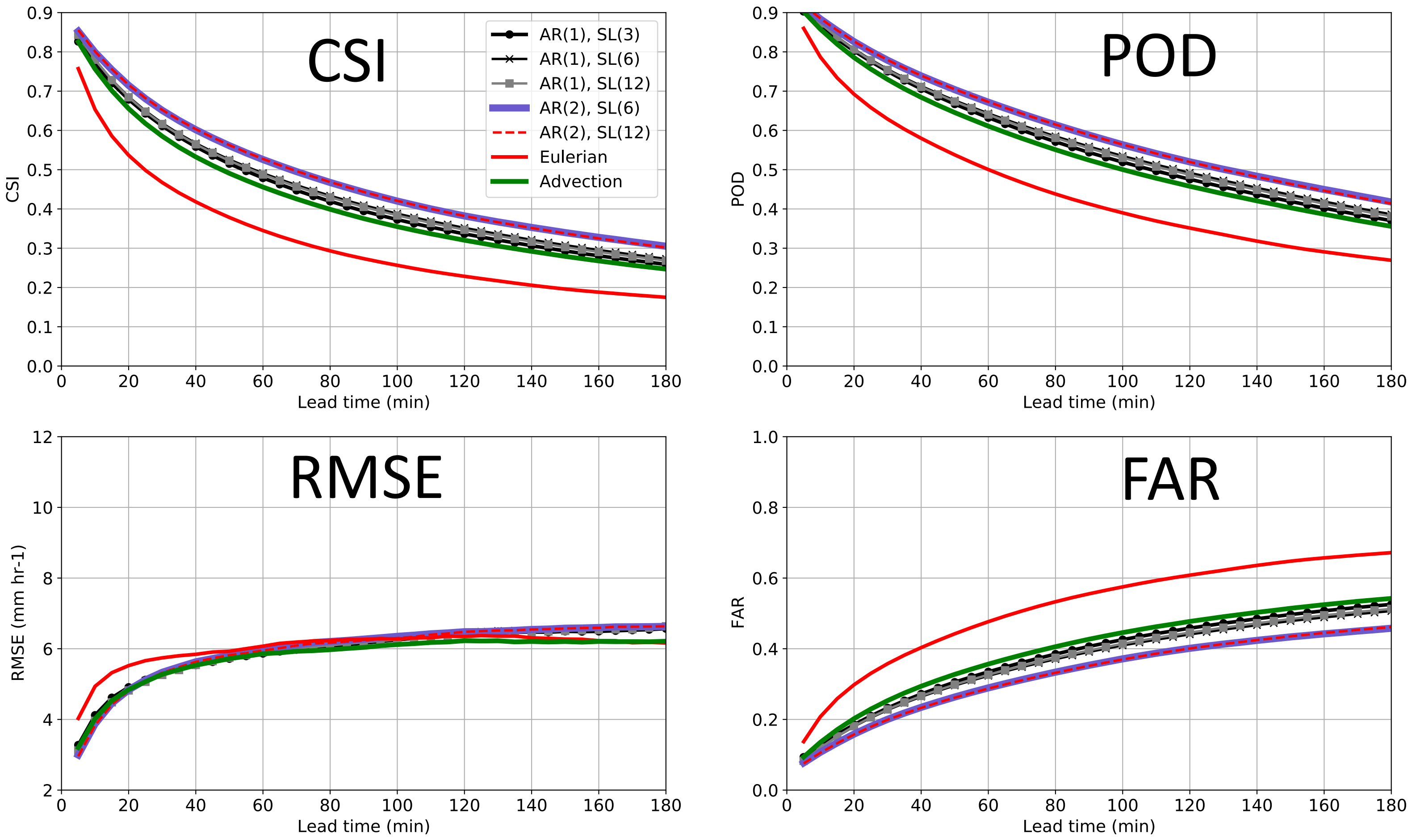
Performance:

- Rainfall rate thresholds (light-heavy)

The predictability properties of precipitation allow the formulation of an improved nowcasting approach

Parameters at $R_{th} = 0.1\ mm\ h^{-1}$:

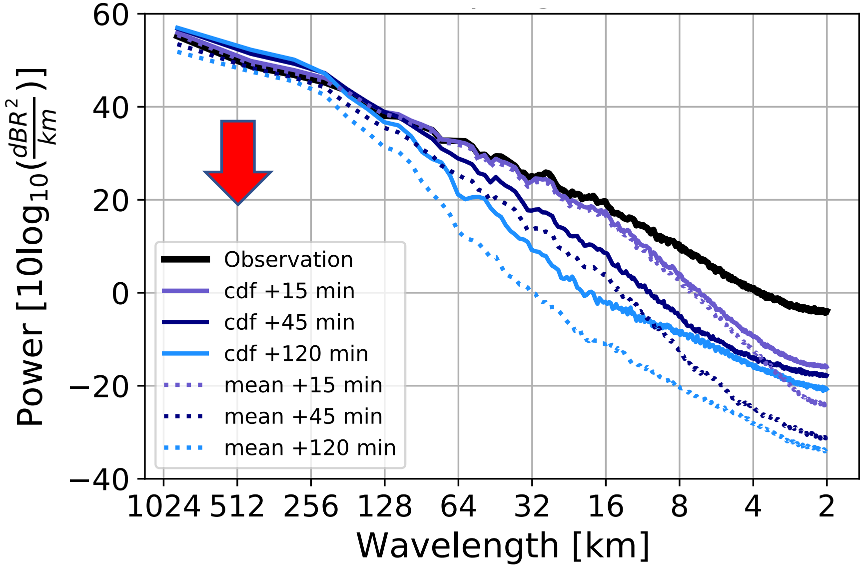
- AR order and
- Number of decomposition levels

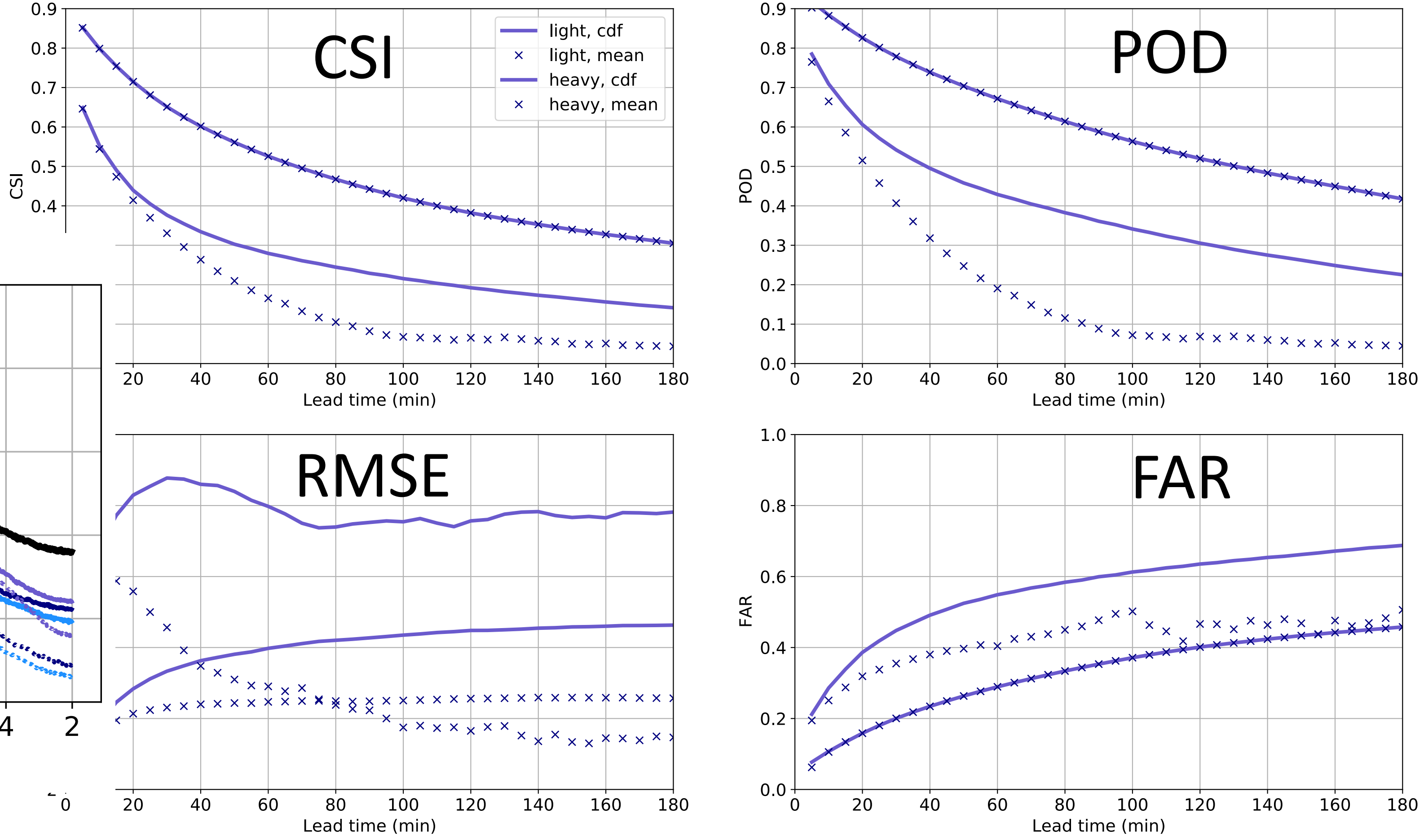


The selection of the post-processing plays a roll on the nowcasting skill

Parameters at R_{th} = 0.1 mm h^{-1} and 5.0 mm h^{-1} : AR(2) and SL(6)

- Prob. Matching – Mean
- Prob. Matching – CDF

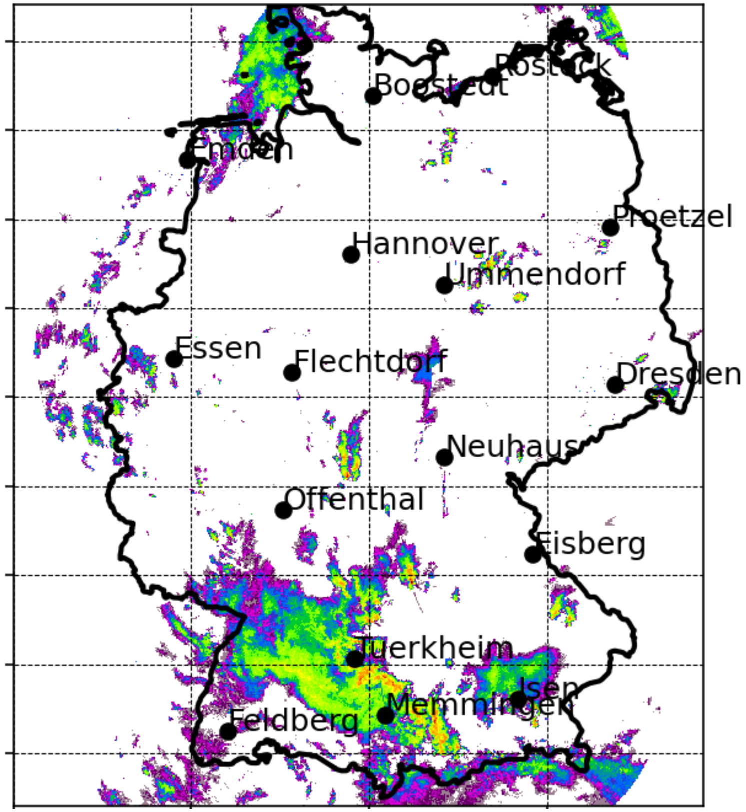




Different realizations to consider uncertainties (growth-decay) are obtained by perturbing the AR process

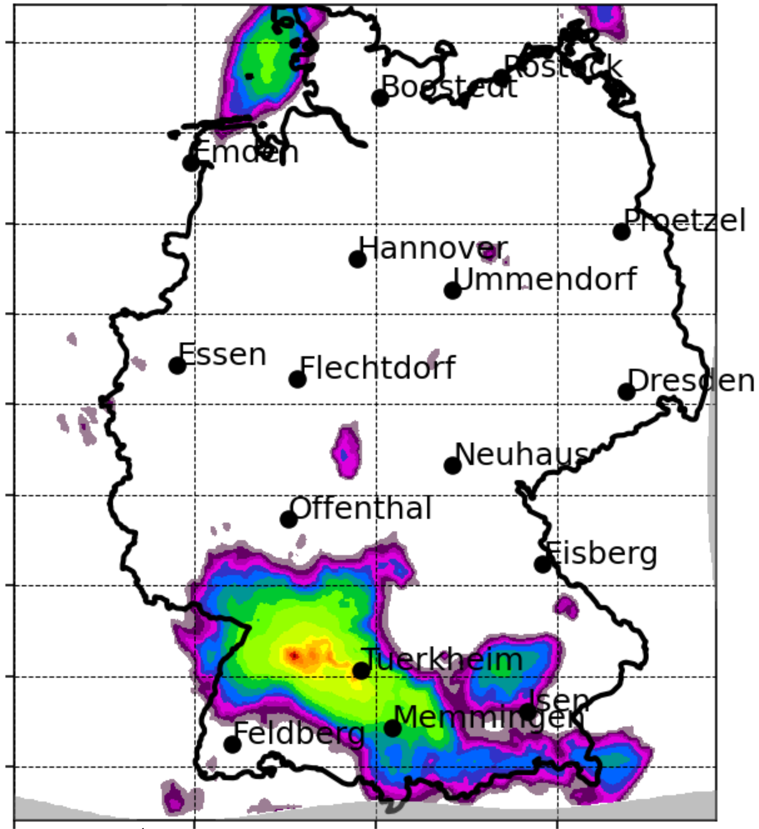
Observation

2016-05-29 16:00:00 UTC



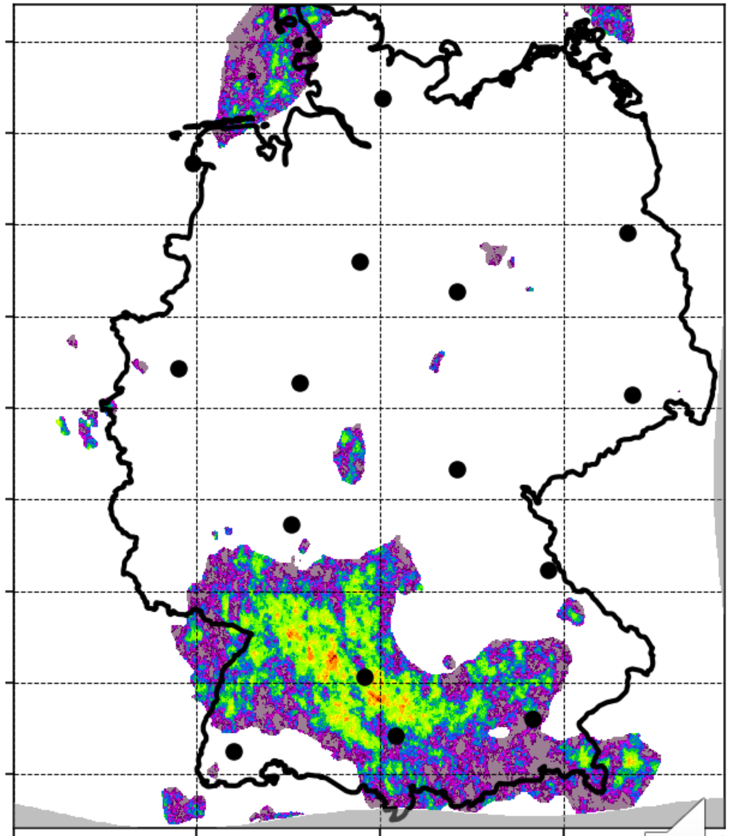
Prediction (1 h)

20160529 1700 UTC

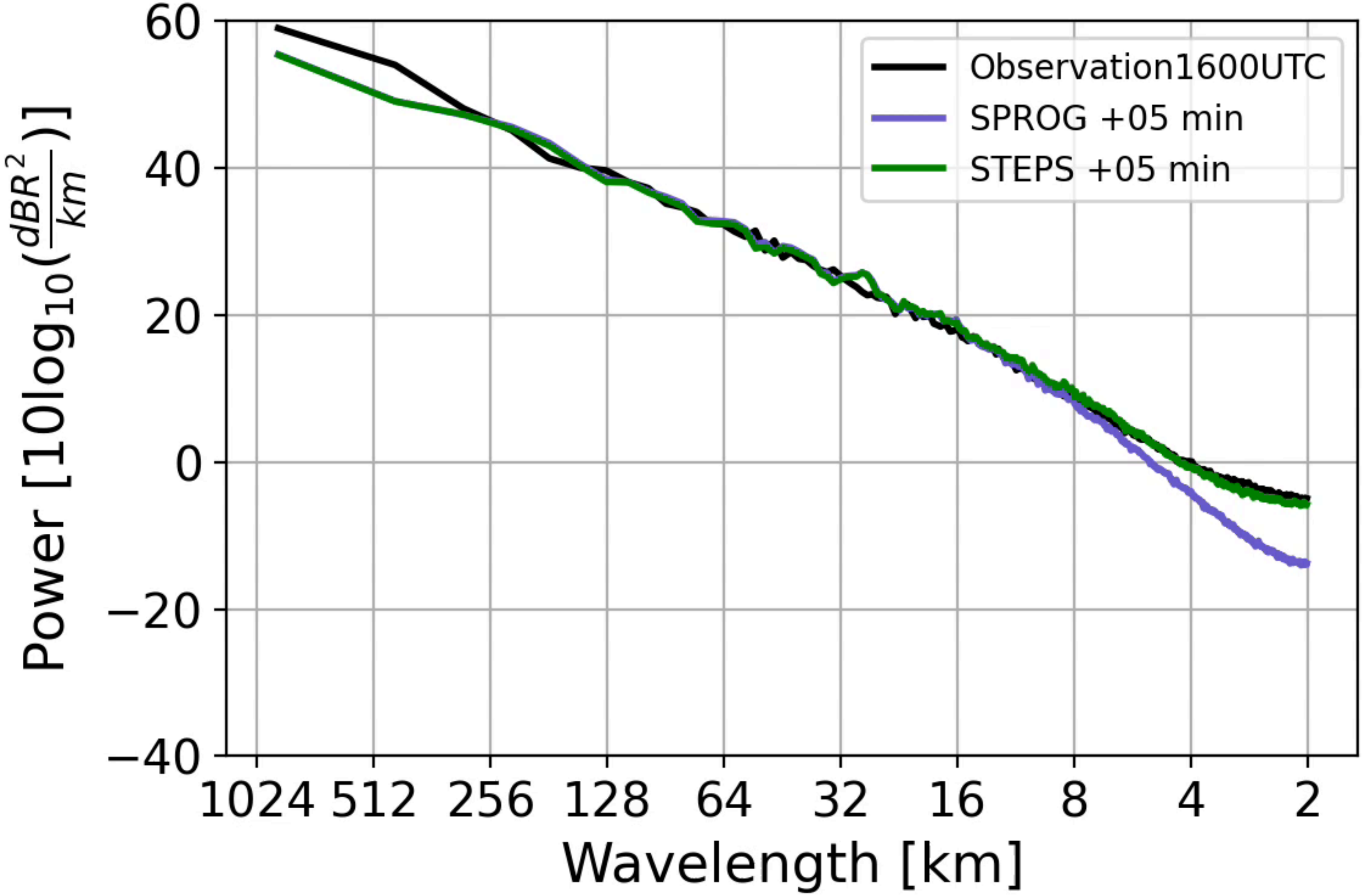


Prediction (1 h)

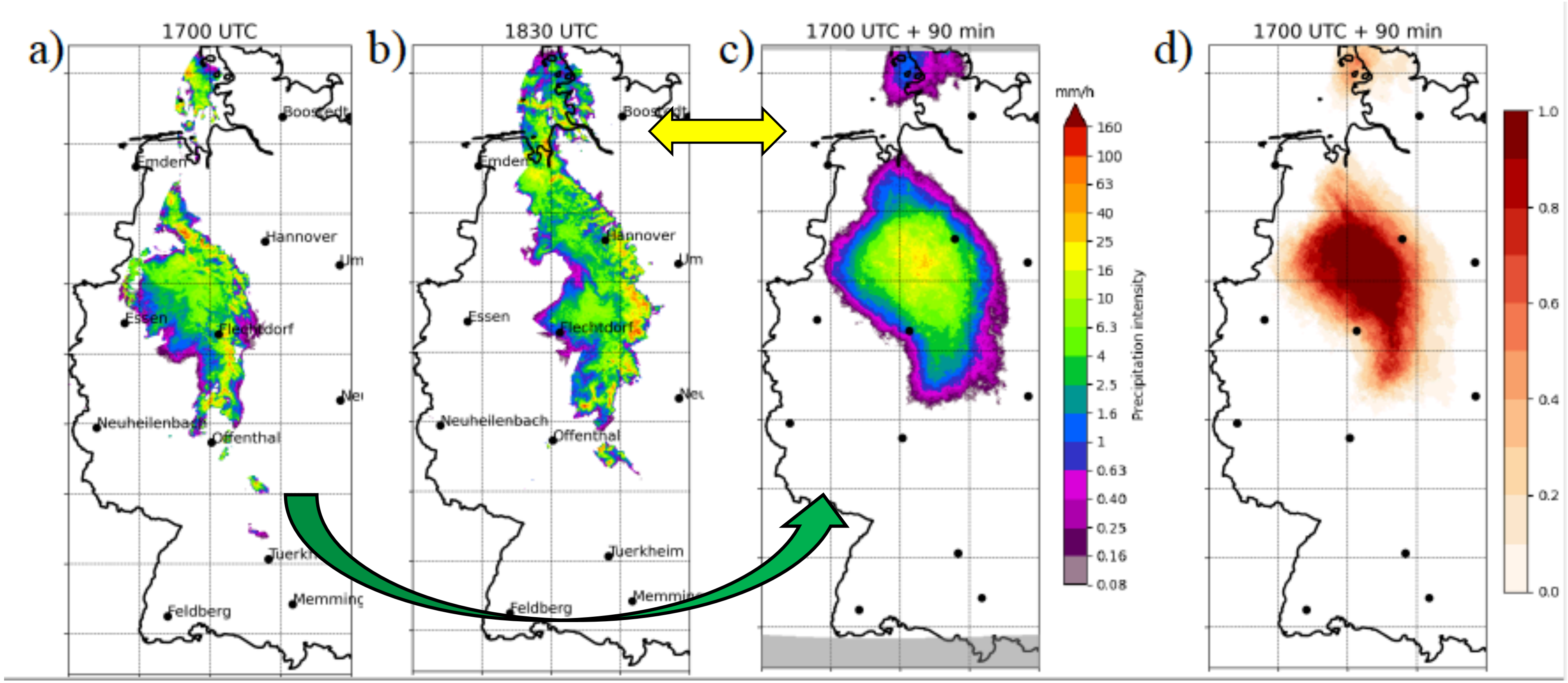
20160529 1700 UTC



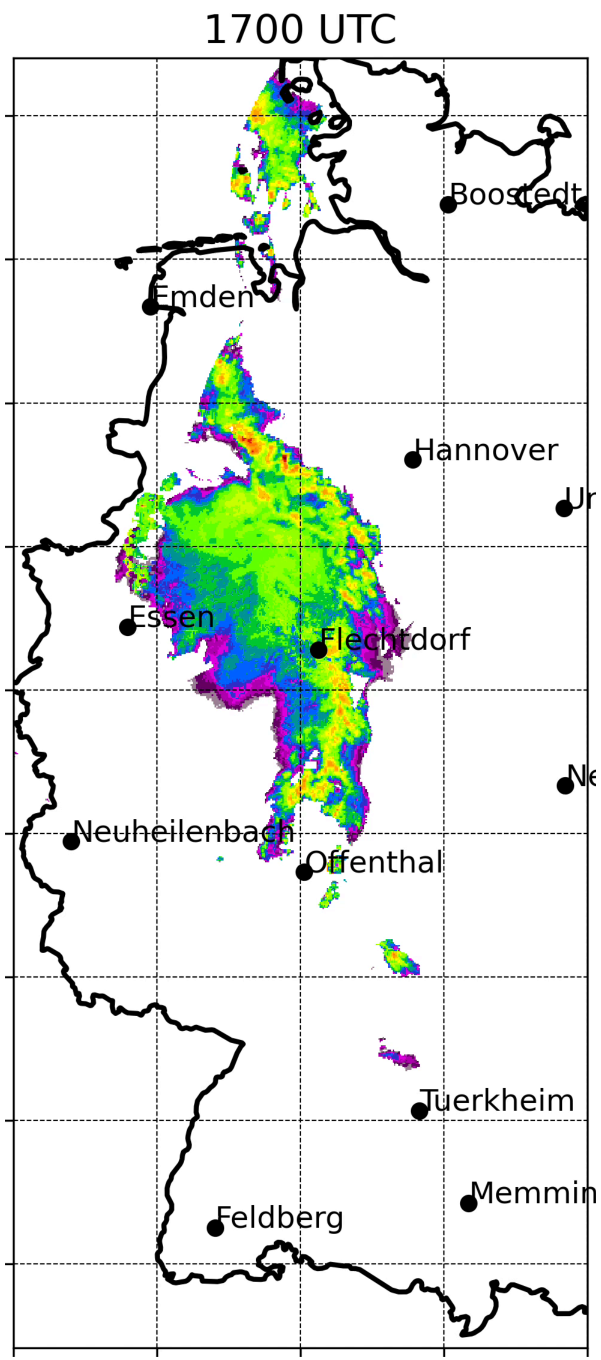
Now a prediction captures the spatial variability at small scales

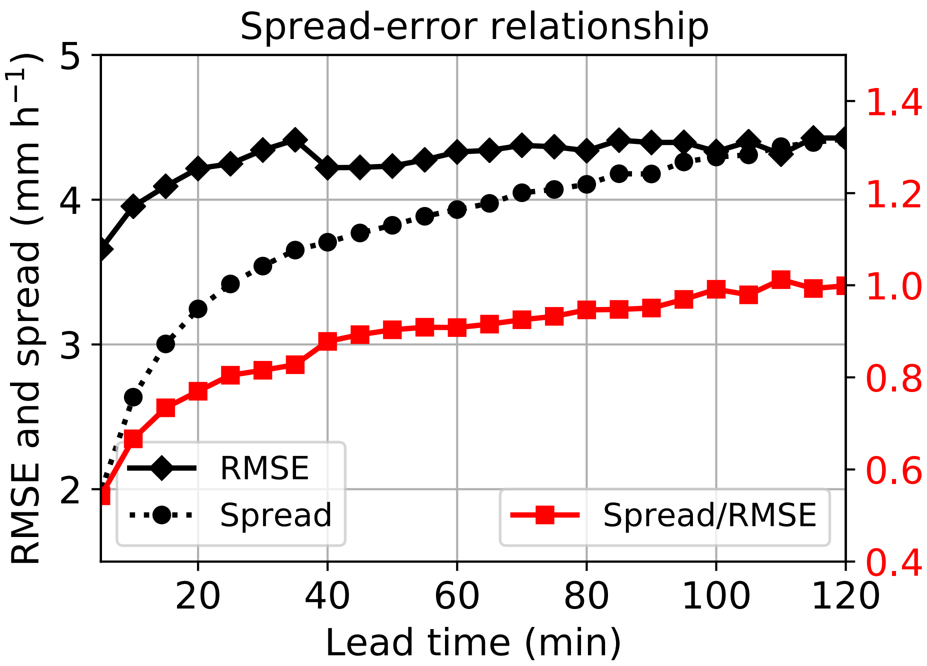


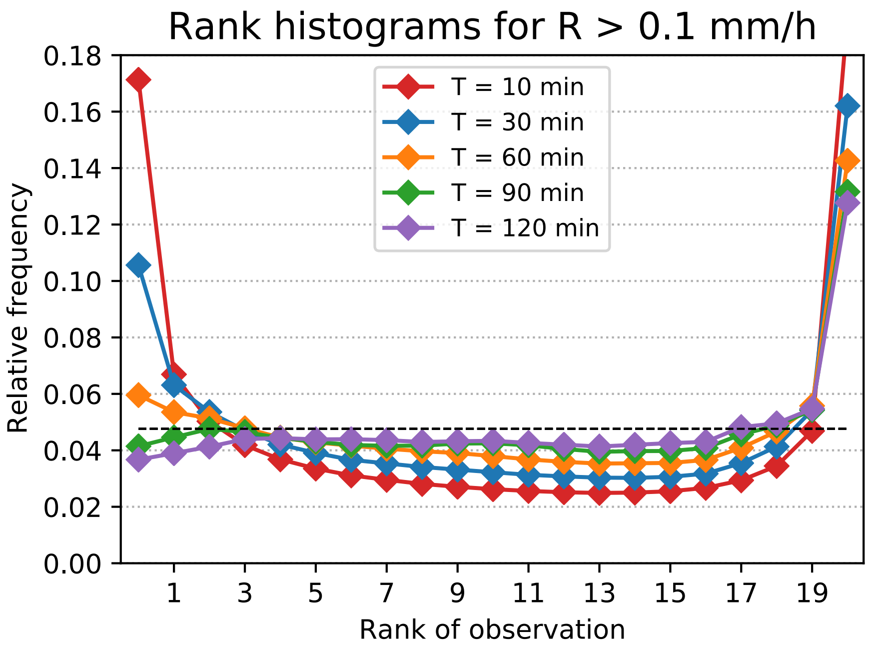
A prediction example of 20 members (90 min lead time)



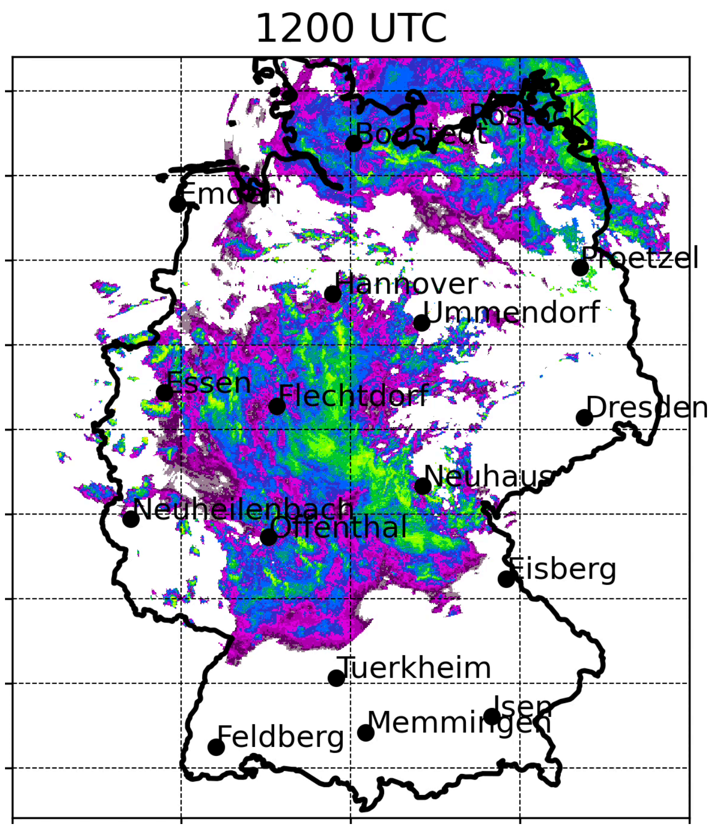
Convective precipitation: the ensemble members are not dispersive enough (underestimate uncertainty)

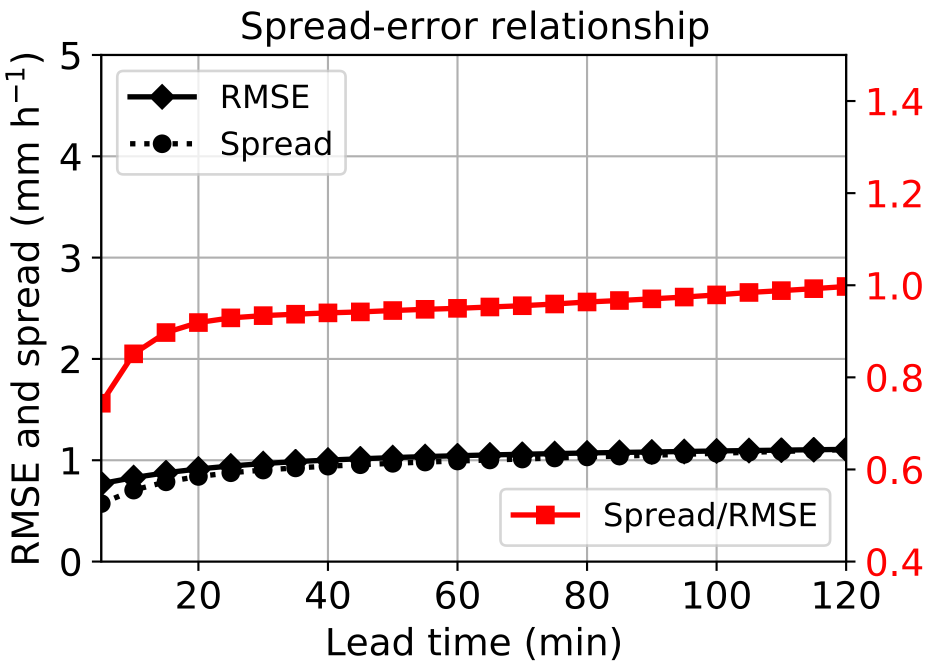


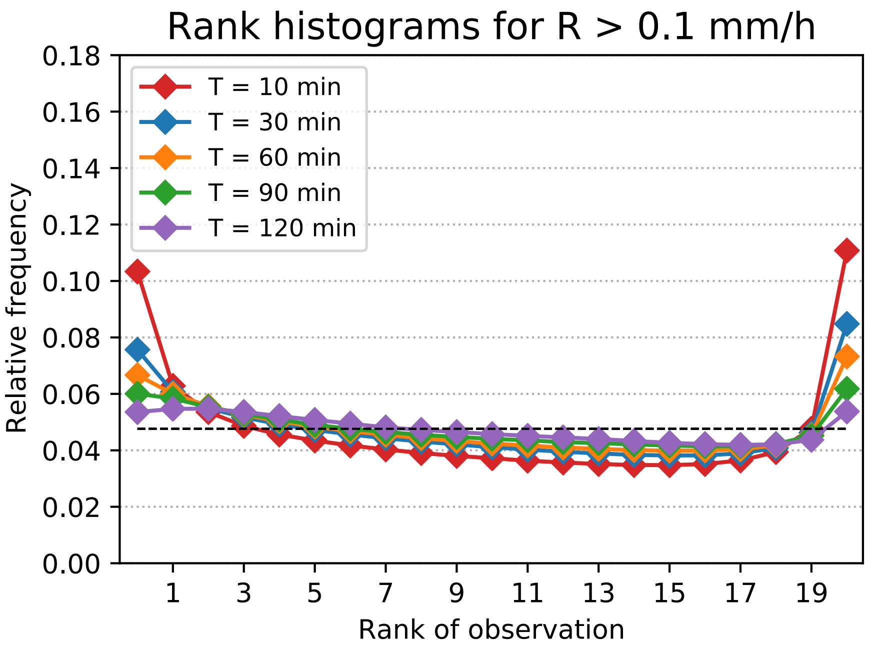




Moderate precipitation: the ensemble members seem to be dispersive enough







Conclusions

1. The configuration of STEPS parameters related to the AR process, spatial decomposition, and post-processing allows for improved nowcasting skills.

2. Ensemble members shown an equiprobable realization in light and moderate precipitation but not dispersive enough in heavy precipitation.

3. Fast and reliable radar-based nowcasting approach for the generation of ensemble members reliable up to ~2 hr.

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RealPEP website: https://www2.meteo.uni-bonn.de/realpep/doku.php