Deutscher Wetterdienst
Wetter und Klima aus einer Hand

SINFONY

Development of a probabilistic precipitation-nowcasting approach at DWD

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Operational DWD preciptation-nowcasting

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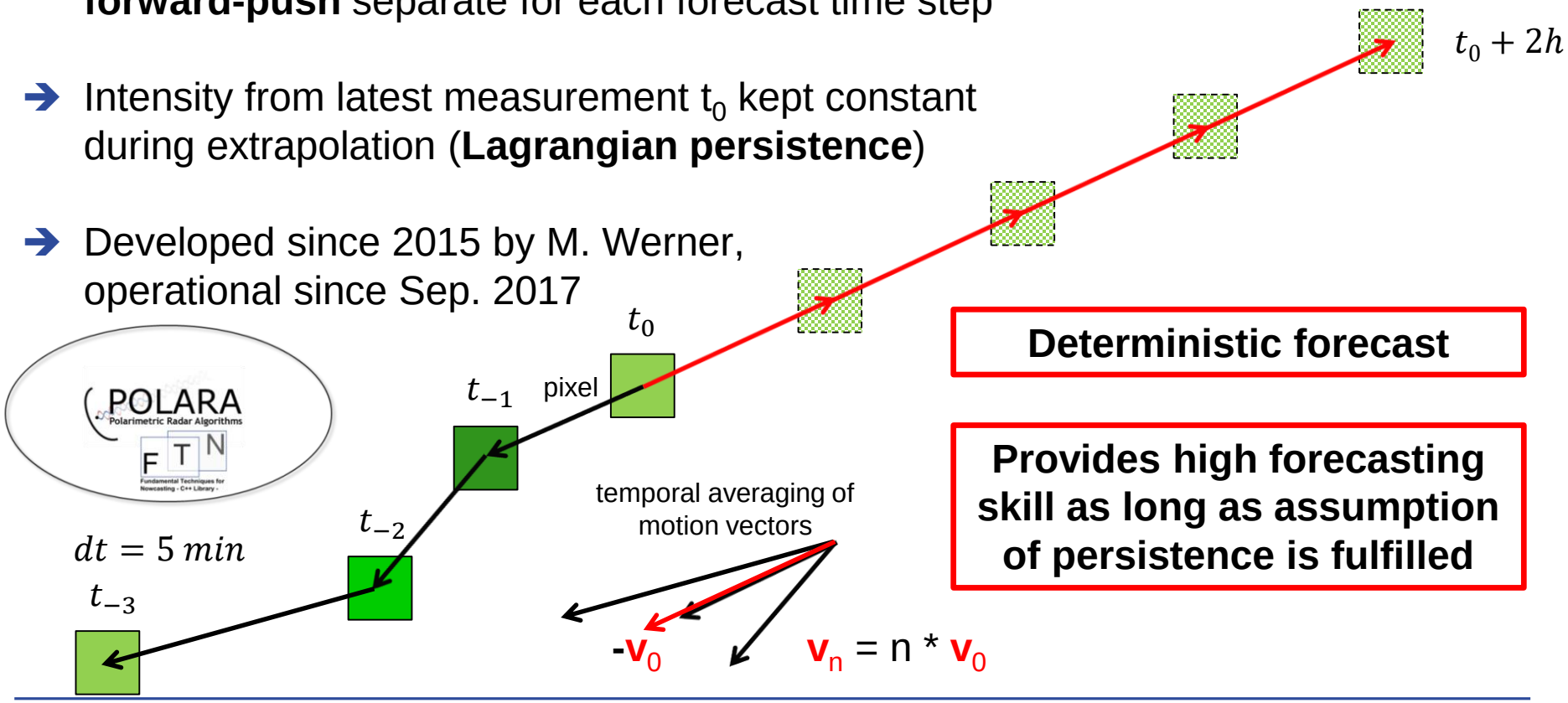
- Estimate displacement vector field („motion vectors“) of latest radar composites (900x900 pixel, 1km/5min resolution) using **optical-flow** technique (TV-L1 scheme)
- Extrapolate position of pixel from history of latest motion vectors by **forward-push** separate for each forecast time step
- Intensity from latest measurement t_0 kept constant during extrapolation (**Lagrangian persistence**)
- Developed since 2015 by M. Werner, operational since Sep. 2017



Deterministic forecast

Provides high forecasting skill as long as assumption of persistence is fulfilled

Inherent uncertainties in Nowcasting

- **Measurement uncertainties:**
  - Radar: smoothed, indirect picture of precipitation at specific time (5 min interval)
  - Intensity errors and artefacts („clutter“, e.g. by wind turbines)

- **Algorithmic uncertainties:**
  - Generation of composites from sweep data
  - **Optical-flow algorithm**
  - Extrapolation method

- **Displacement uncertainties:**
  - Uncertainty in the propagation of precipitation
  - Stationary motion vector field during the forecast

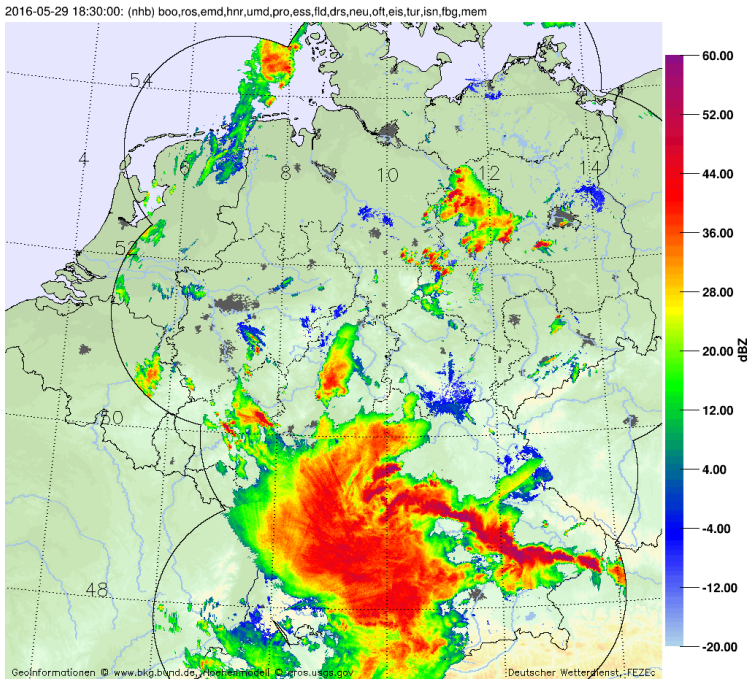
- **Dynamic uncertainties:**
  - Up to now: pure advection of precipitation
  - In real life: **intensification, weakening, new-formation, disappearance**

Algorithmic uncertainty: optical-flow

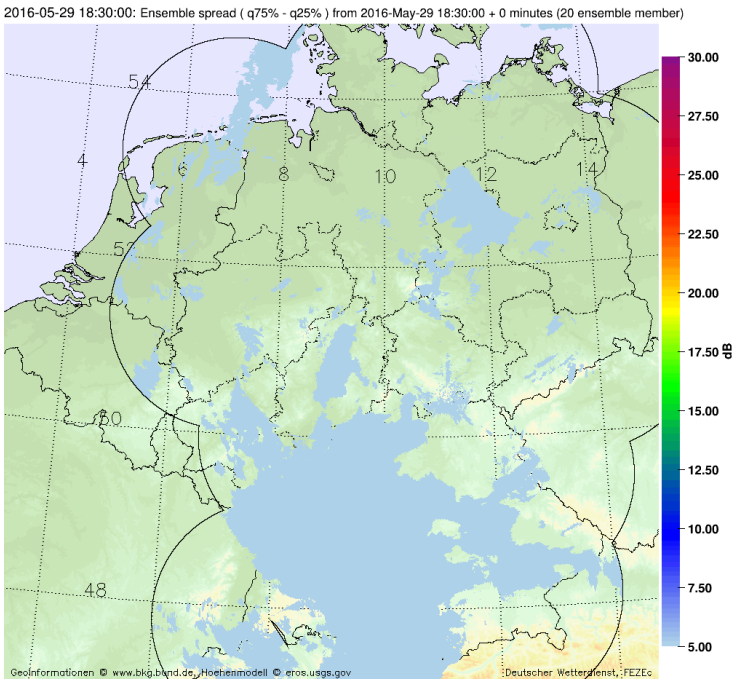
- Several (empirical) tuning parameter in the optical-flow algorithm, e.g.:
  - Weighting of motion of individual pixels in comparison to large-scale motion (determines smoothness of motion field)

- Example: Nowcast with 20 ensemble member, forecast up to +2h, 5 min time step

Init: 29.05.16 18:30 UTC

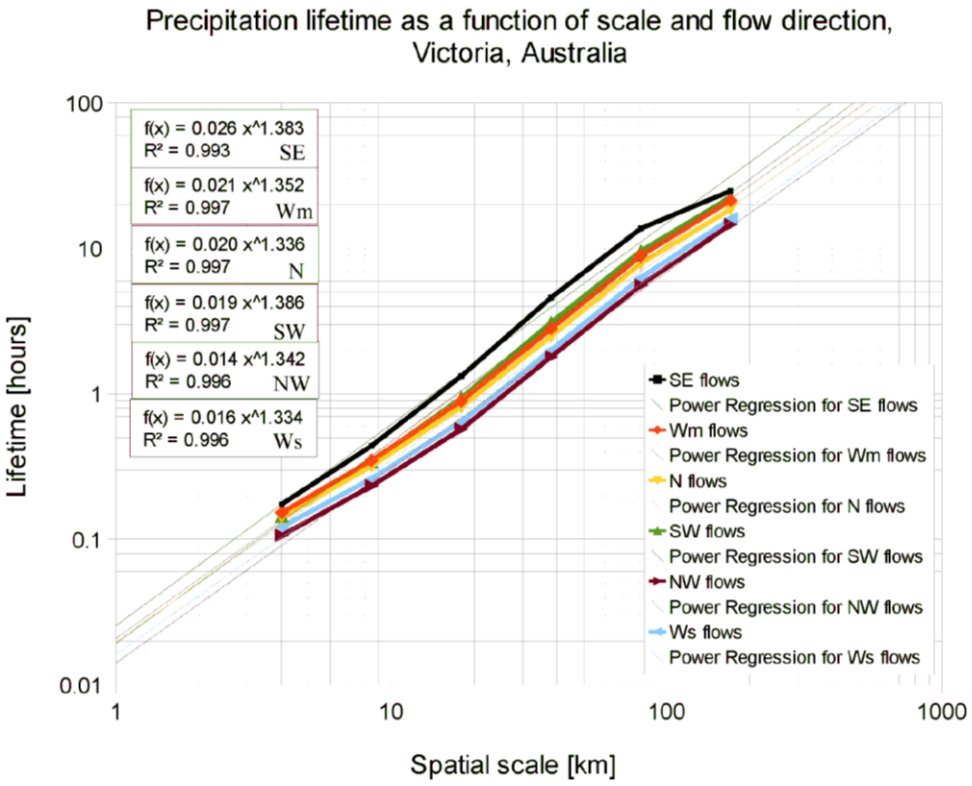


Spread: 75-25 percentile (IQR)



Dynamic uncertainty

- Up to now: pure advection of precipitation
- But large (or even largest) source of uncertainty!



Foresti & Seed, Hydrol. Earth Syst. Sci., 2014

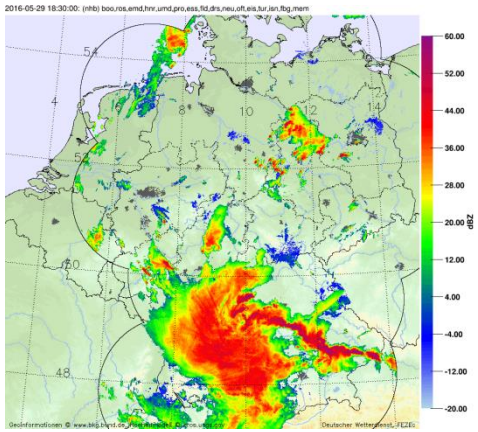
lifetime = f(scale) [**dynamic scaling**]

predictability = f(lifetime) = f(scale)

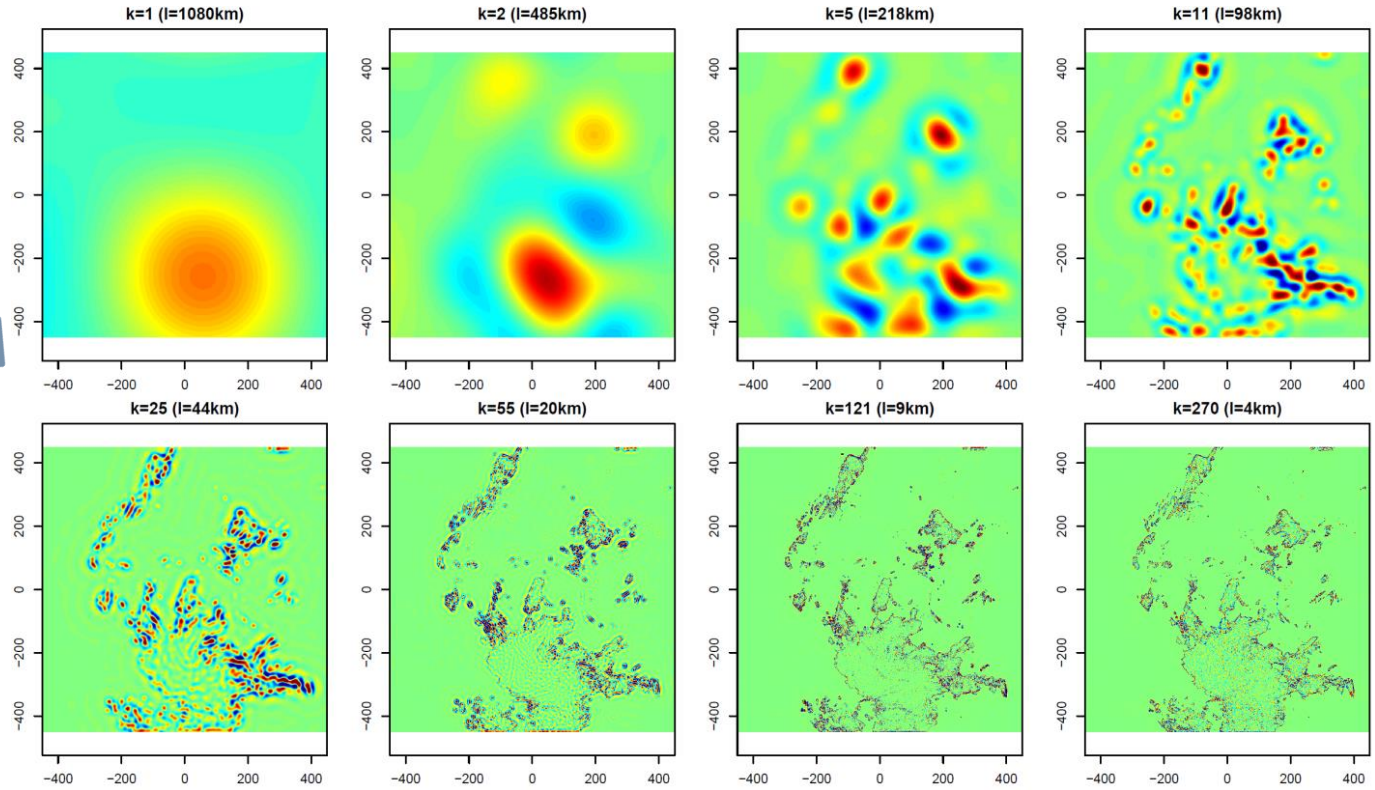
predictability => scale-dependent!

- **STEPS**-approach (Short-Term Ensemble Prediction System)
- Developed at BoM (Seed, 2003) and UKMO (Bowler et al., 2006)

Dynamic uncertainty
Scale separation



$$\mathrm{dBZ}(x,y) = \sum_{i=0}^{N} X(i,x,y)$$



for t_0, t_{-1}, t_{-2}, t_{-3}, …

$$X(i,x,y) \rightarrow X(t,i,x,y)$$

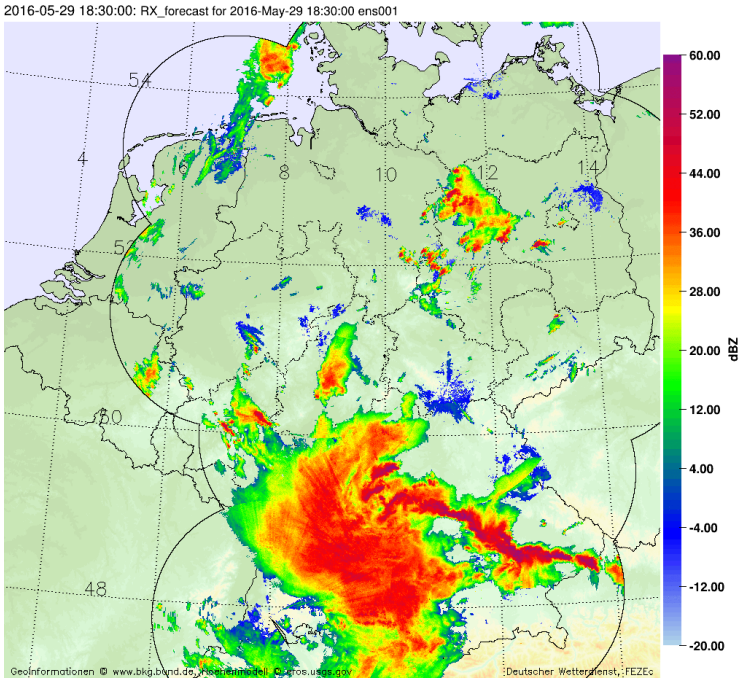
Intensity cascade

Dynamic uncertainty
Extrapolation of intensity + Perturbation

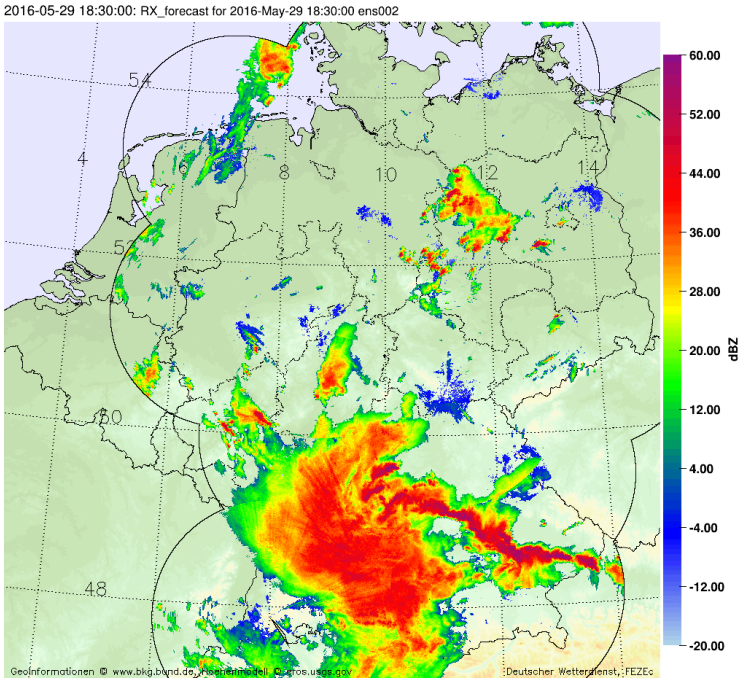
- Auto-regressive extrapolation for each scale superimposed by correlated noise (large scale = strong memory; small scale = weak memory)
- stochastic perturbations in areas far from observed precipitation are suppressed
- Accumulation over all scales and advection => final forecast field for each step

Nowcast : 18:30 UTC – 20:30 UTC

Ensemble Member 1



Ensemble Member 2



Dynamic uncertainty
Extrapolation of intensity + Perturbation

➔ Example: Nowcast with 20 ensemble member, forecast up to +2h, 5 min time step

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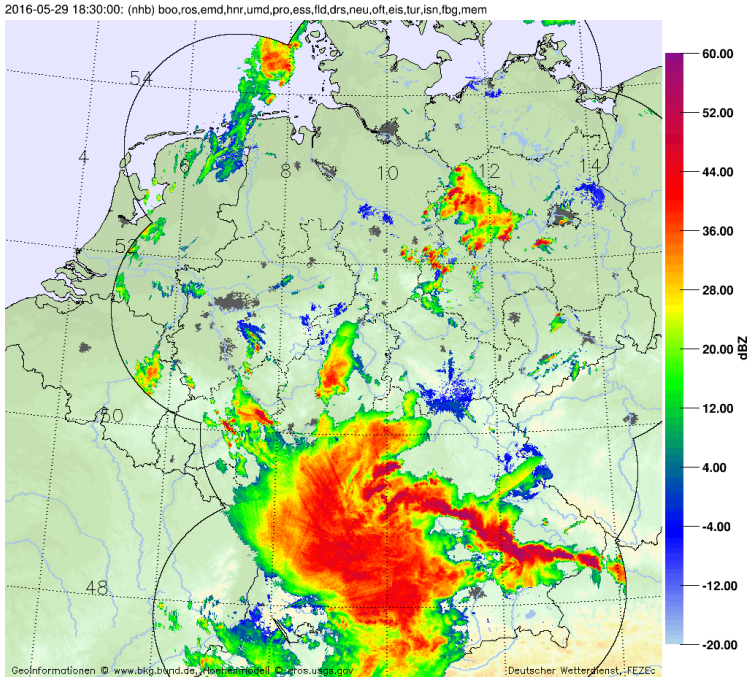

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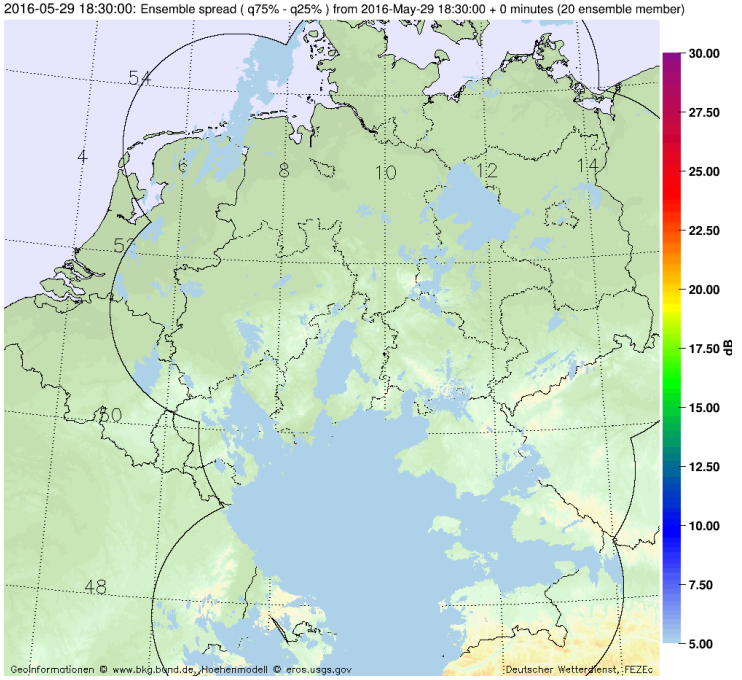
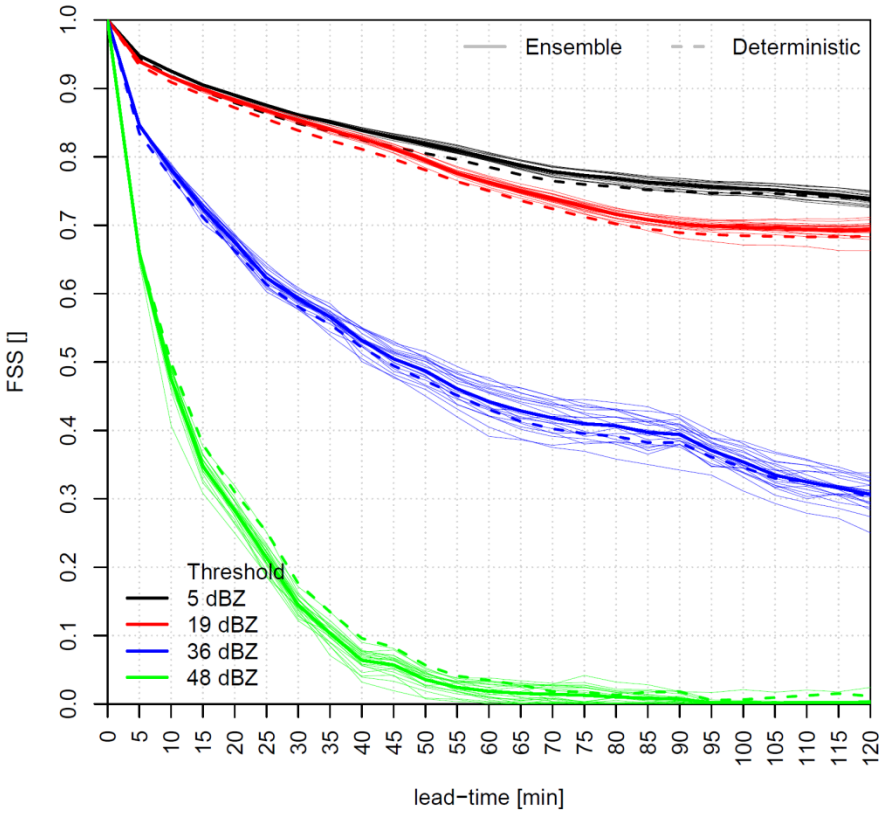


➔ Spread is largest at edges of precipitation field and in convective regions
➔ Small-scale isolated structures disappear rather fast

Dynamic uncertainty
Event verification – global perspective

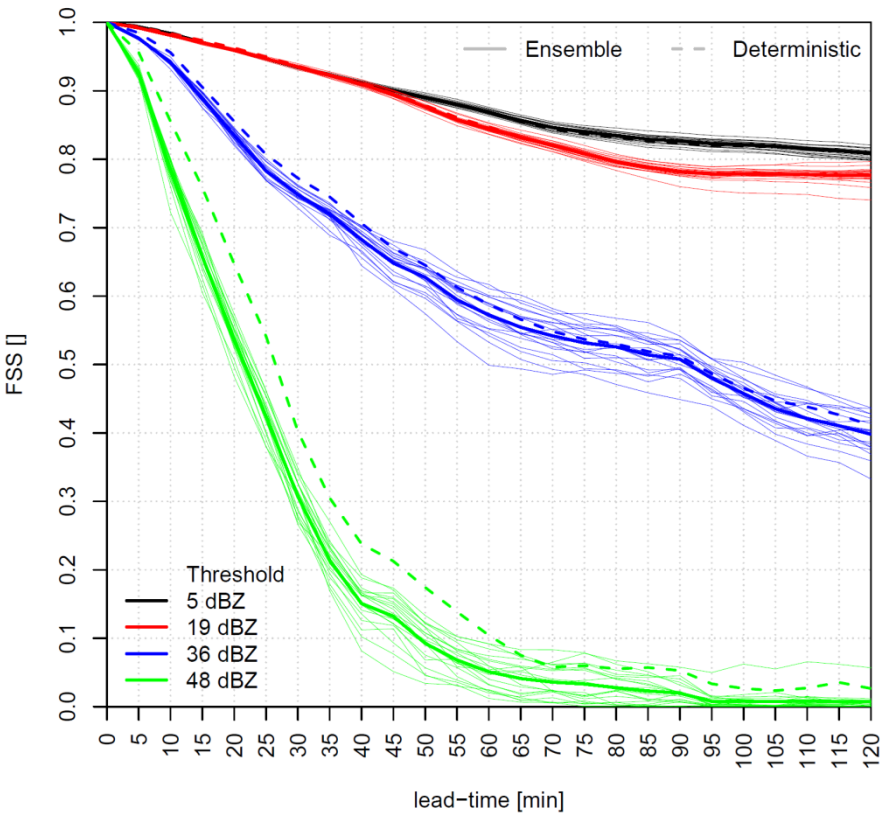
➔ For only one init time: 29.05.2016 18:30 UTC

Box = 1 km



no skill ← 0 ≤ FSS ≤ 1 → perfekt

Box = 11 km



➔ Ensemble skill comparable with deterministic setting (except for high intensities)

Dynamic uncertainty
Event verification – local perspective

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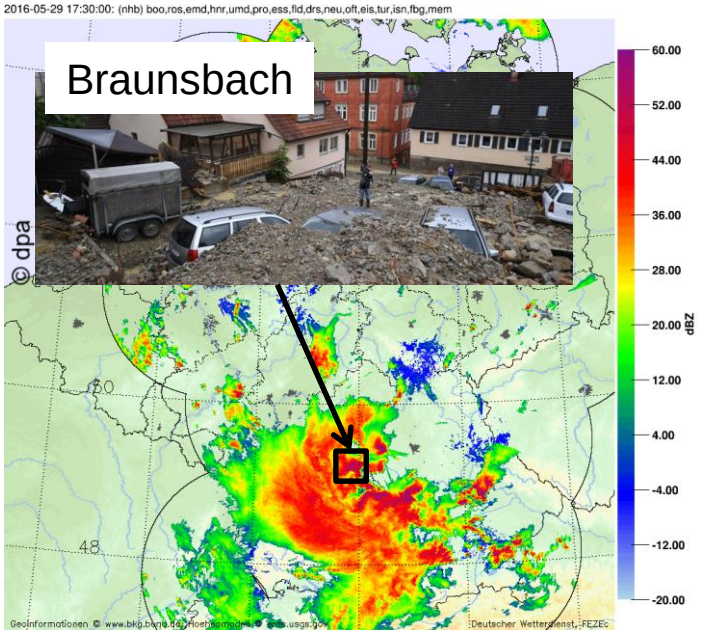
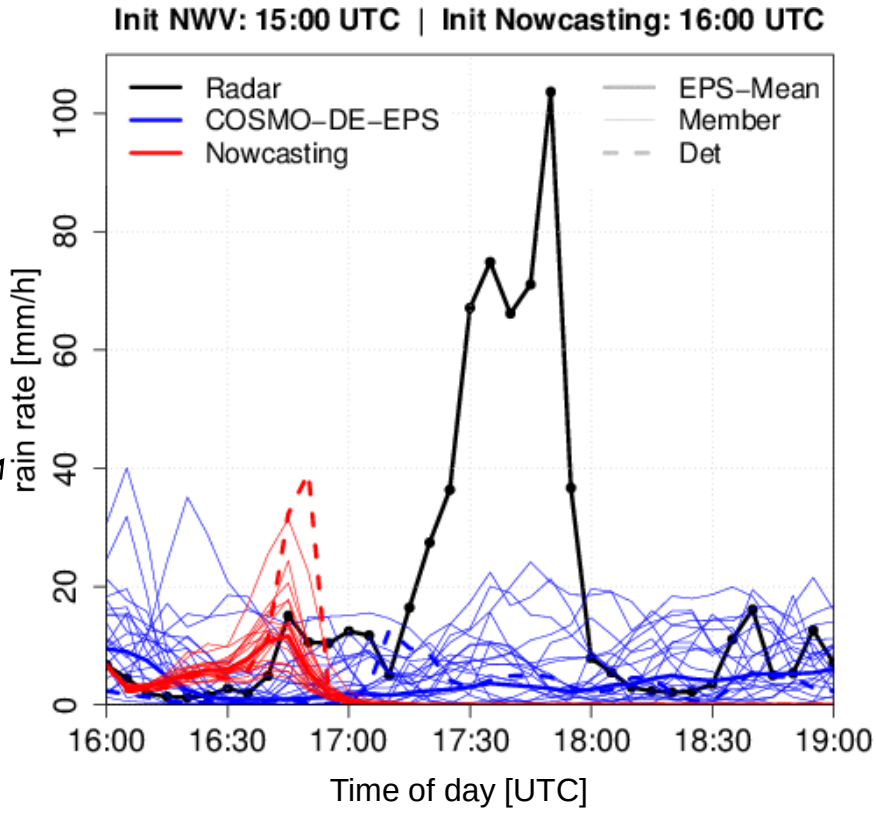
- Synoptic-scale precipitation and embedded convection from the east
- Beginning of a 2 week phase of weather type „Low Central-Europe“ associated with several heavy precipitation events in Germany

29.05.16 17:30 UTC



Langenburg-Atzenrod: 105 mm/24h (17-18 UTC: ~ 50 mm)



- Standard Z-R relationship: $Z = 200R^{1.6}$
- Mean over 5x5 grid boxes = 25 km²

Summary and Outlook

➔ Generation of an area-based Nowcasting-Ensemble by:

- Variation of parameters in optical-flow algorithm (**algorithmic uncertainty**)
- Scale-dependent auto-regressive intensity extrapolation superimposed by correlated perturbations (STEPS-approach, **dynamic uncertainty**)

➔ Work in progress:

- Combined Ensemble with different sources of uncertainty
- Tuning and Spread/Skill verification for longer period (May/June 2016)

➔ Future aspects:

- Localized estimation of cell-lifetime (presently they disappear to fast)
- Incorporate cell-properties from KONRAD3D
- Use environmental conditions (e.g. DLS) from NWV