

Evaluation of convective cell characteristics in COSMO-CLM

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Motivation

- Deep moist convection (thunderstorms) can cause severe damages due to
 - Heavy precipitation
 - Wind gusts
 - Hail
 - Lightning
- How will deep moist convection change due to climate change?

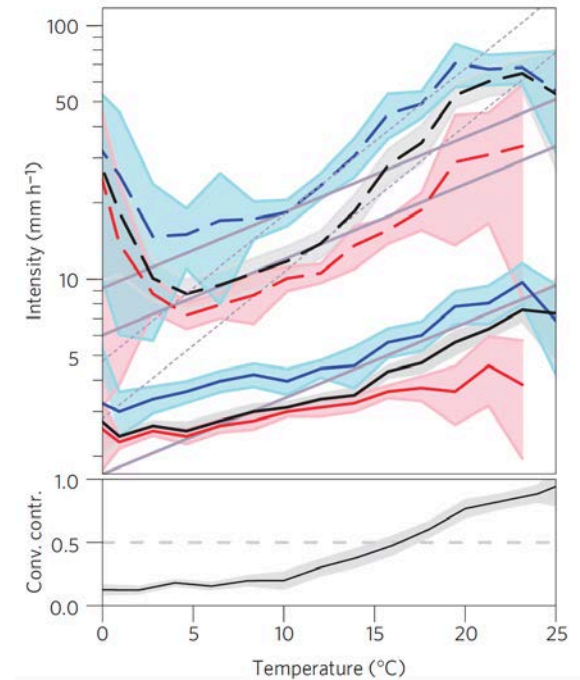


Thunderstorm near Hilter, Niedersachsen [1]



Flash flood in Hesse, on 9.6.2018 [2]

- Intensification of the hydrological cycle with higher temperatures
- Heavy precipitation should be proportional to water holding capacity
- Different scaling relations on sub-daily time scales
 - Many studies show super-clausius-clapeyron scaling (e.g. Knist et al. 2018)
 - Proposed reasons:
 - enhanced updraft strength (due to latent heating)-> enhanced moisture convergence (Lendering et al. 2017)
 - Hourly precipitation extremes increasingly dominated by convective precipitation (Berg et al. 2013)



Temperature scaling of convective (blue), stratiform (red) and total precipitation (black), for the 75th (solid) and 99th (long-dashed) percentiles, Berg et al. 2013

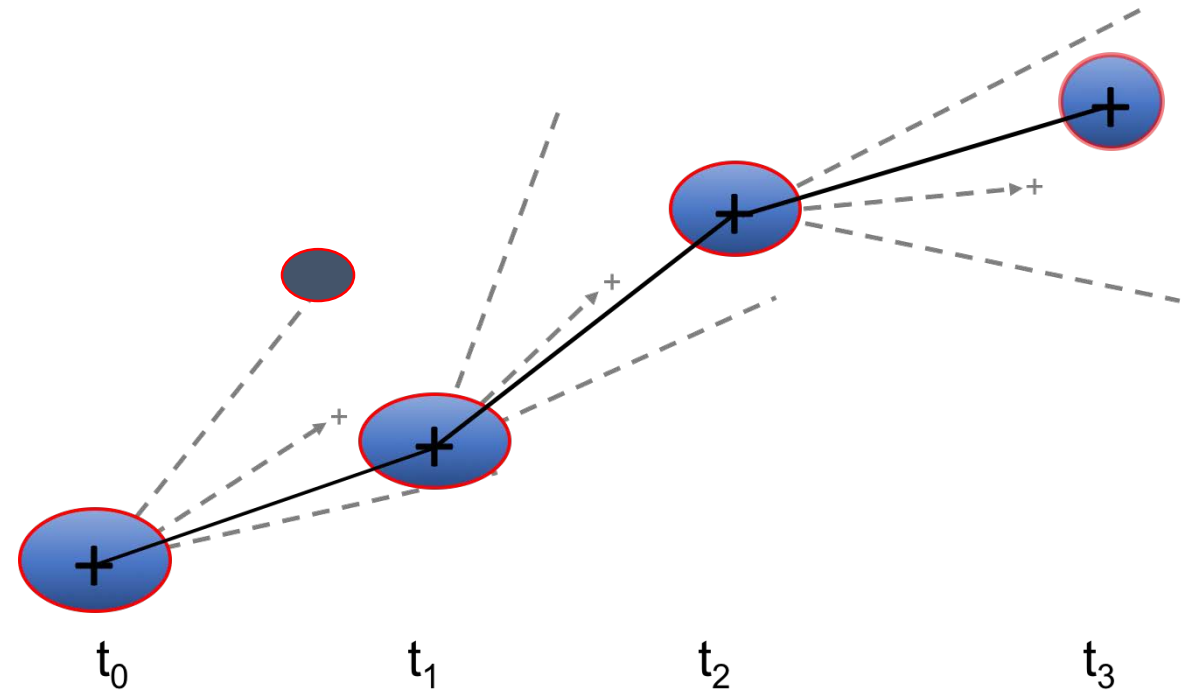
- Understanding of convective cell dynamics necessary
- Convective cell tracking (in radar -and model data)

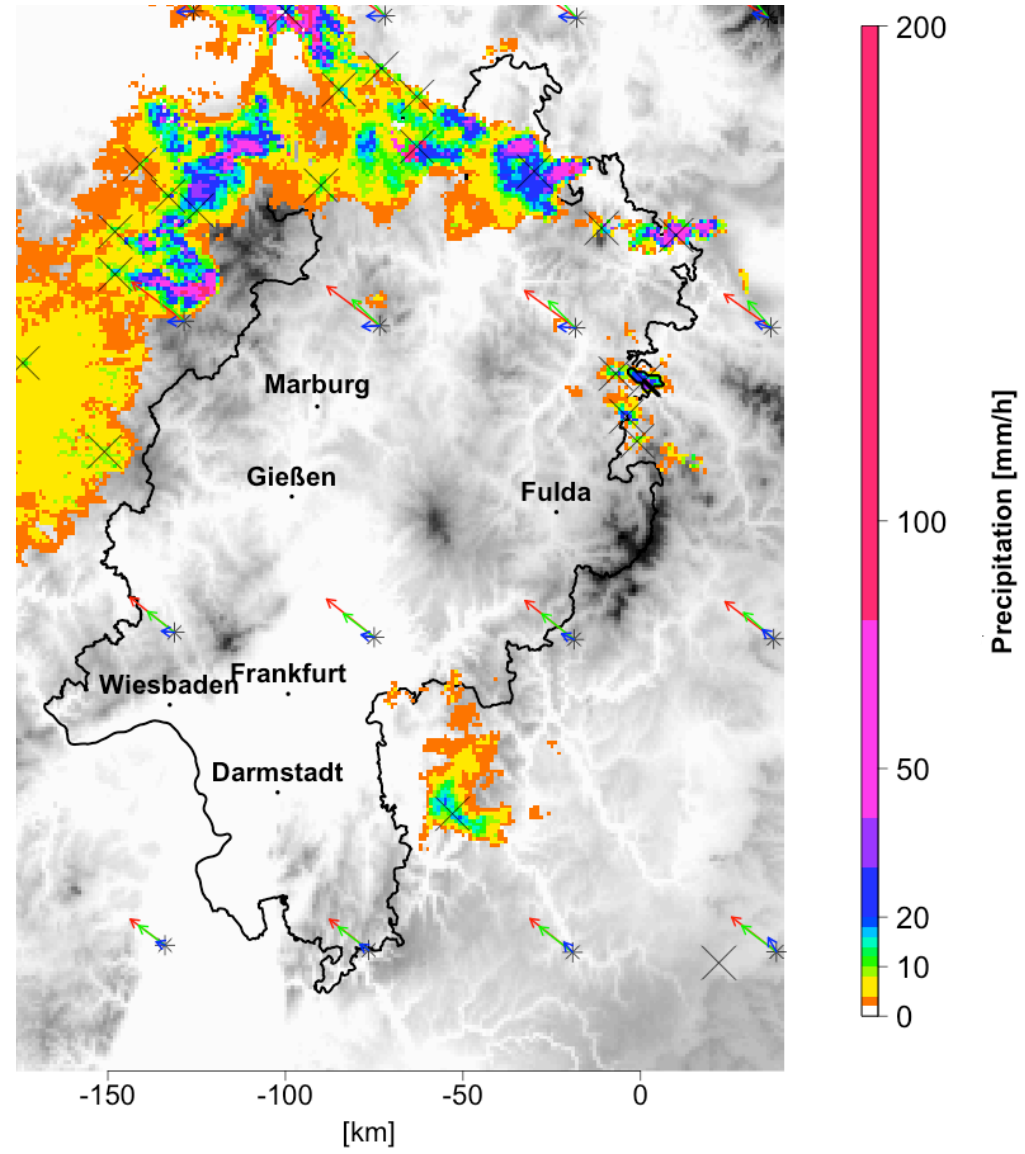
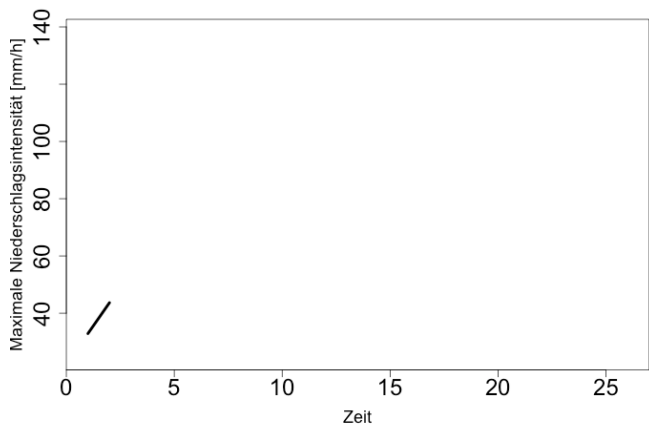
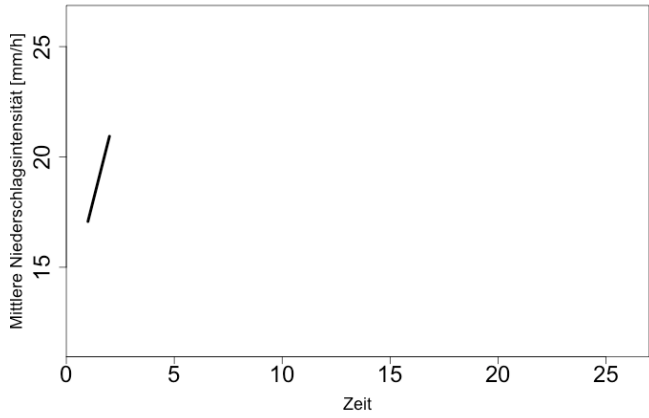
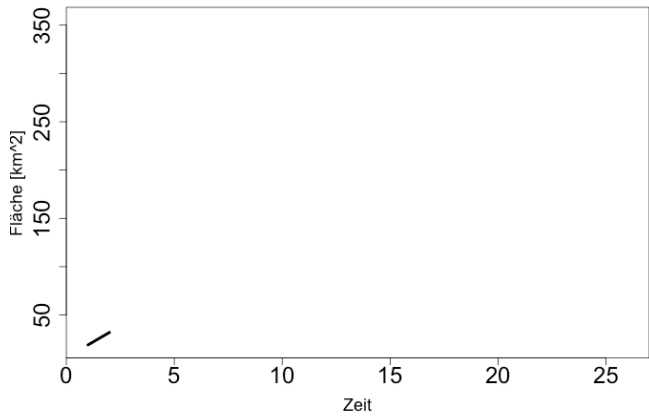
Outline

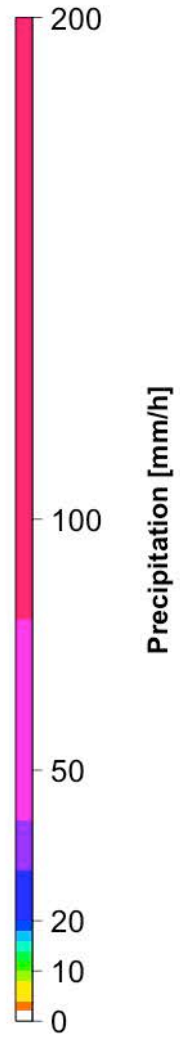
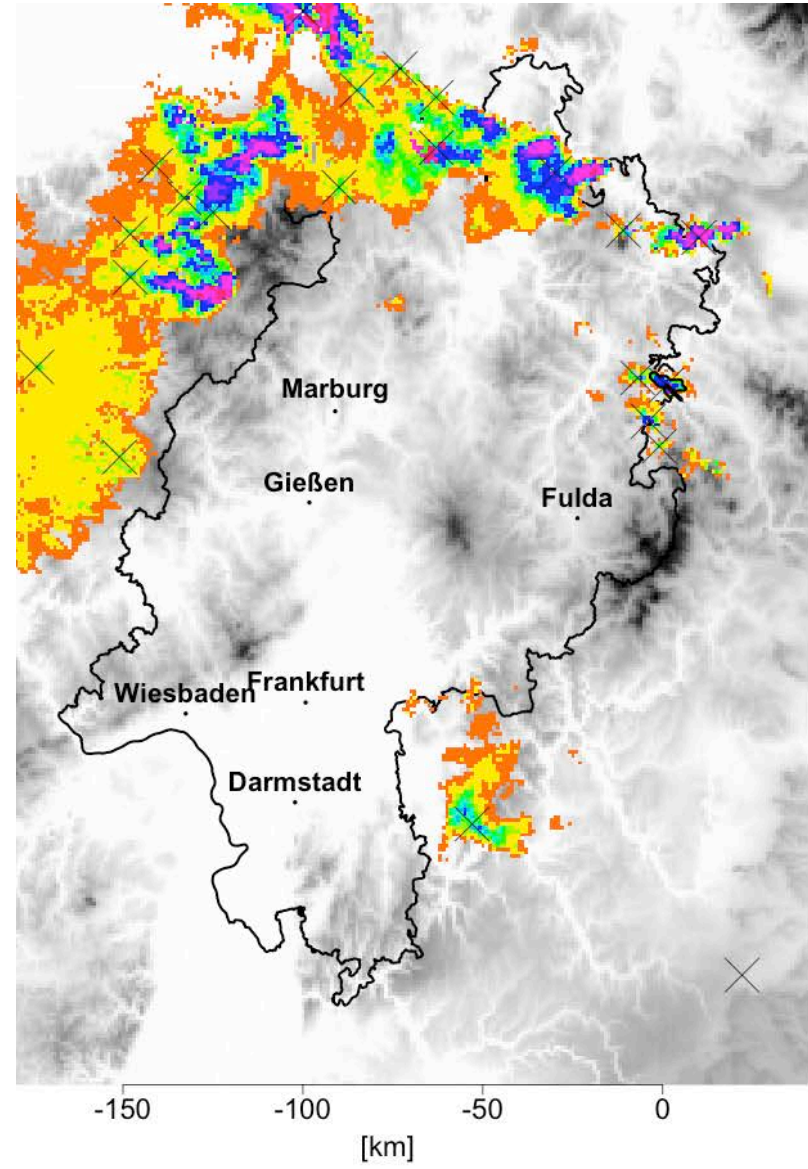
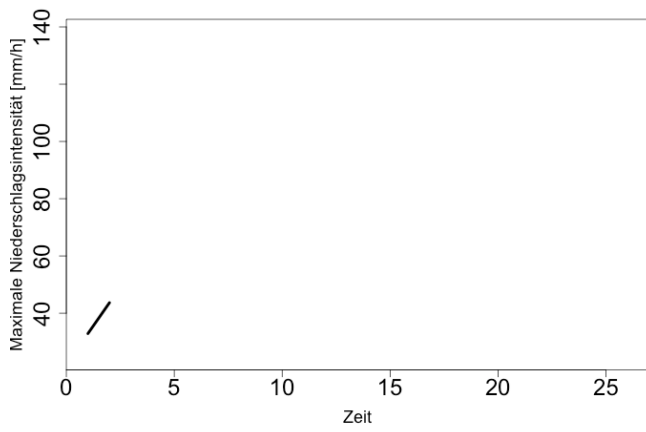
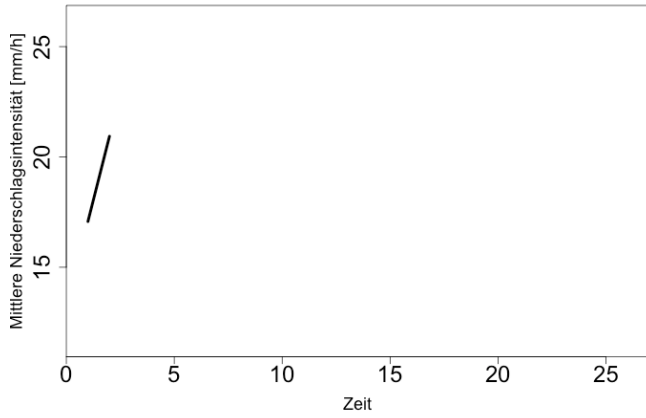
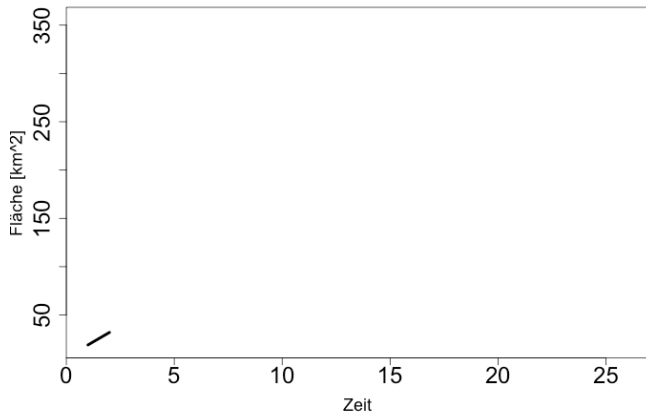
1. Cell Tracking
 1. Method
 2. Results: Climatology of convective cells over Germany
2. Evaluation of COSMO-CLM
3. Temperature scaling of convective cells

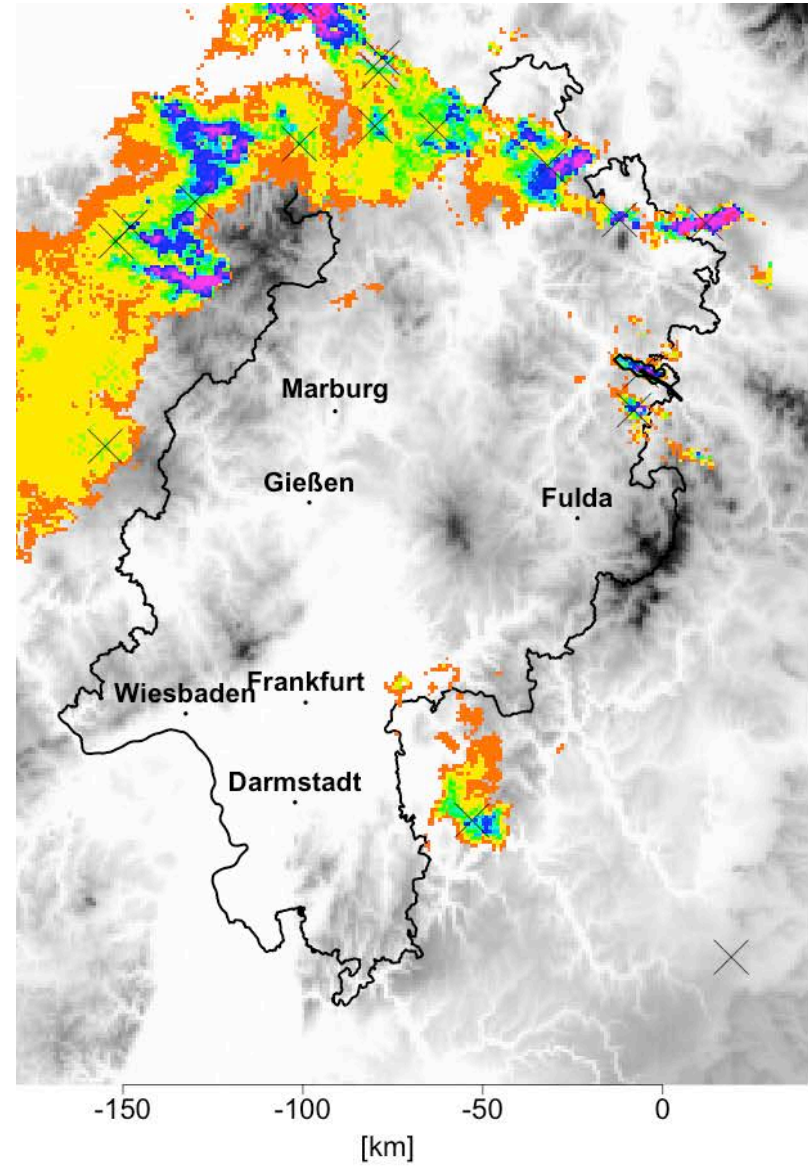
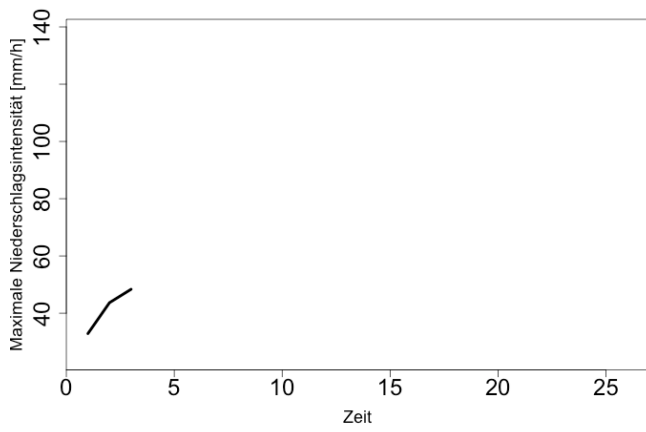
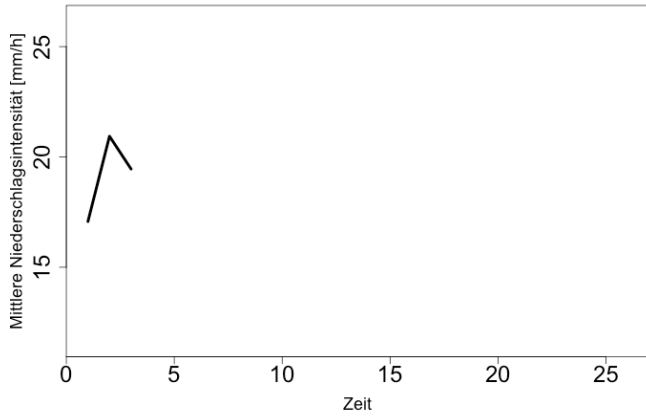
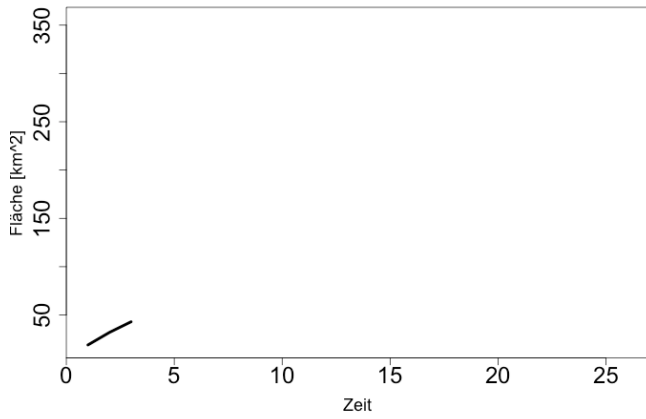
Tracking algorithm

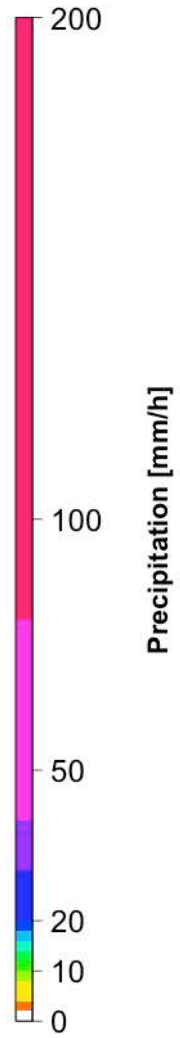
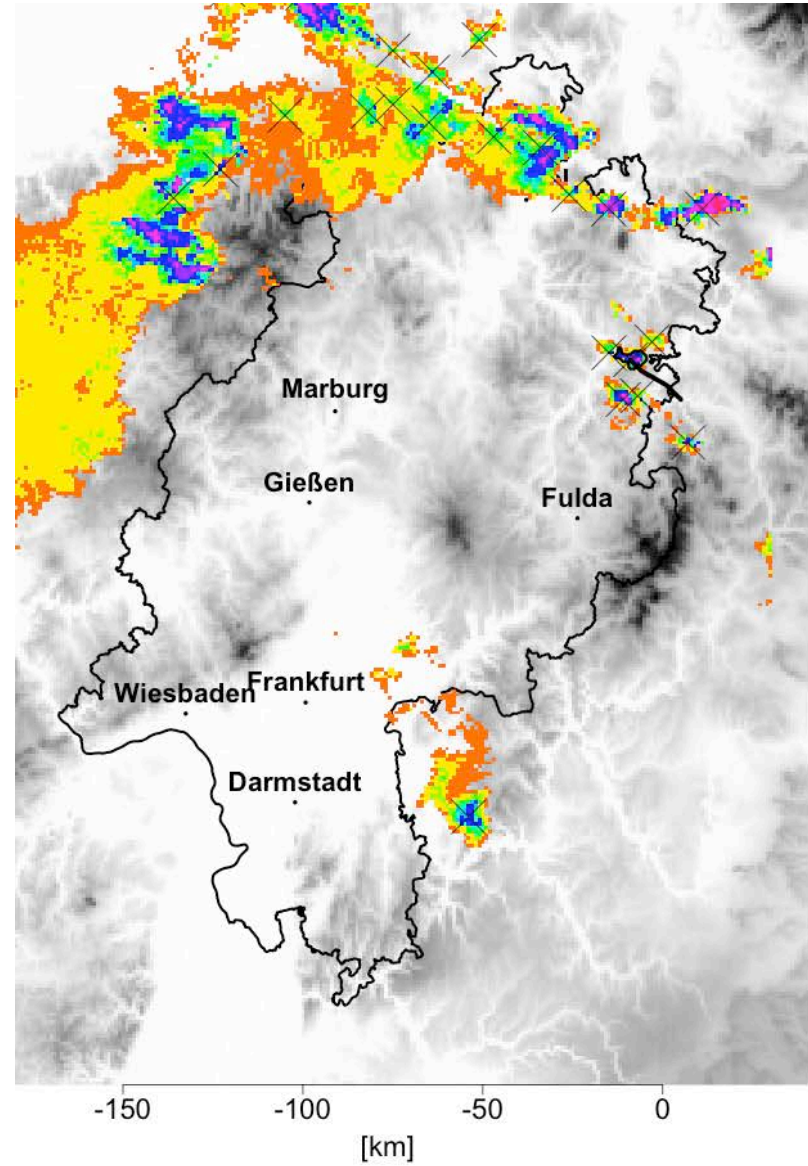
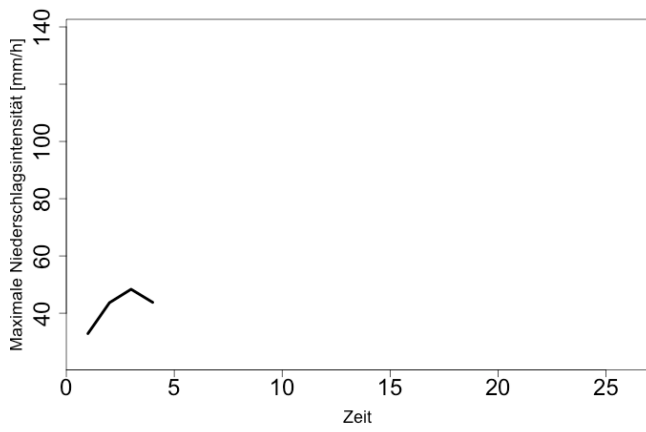
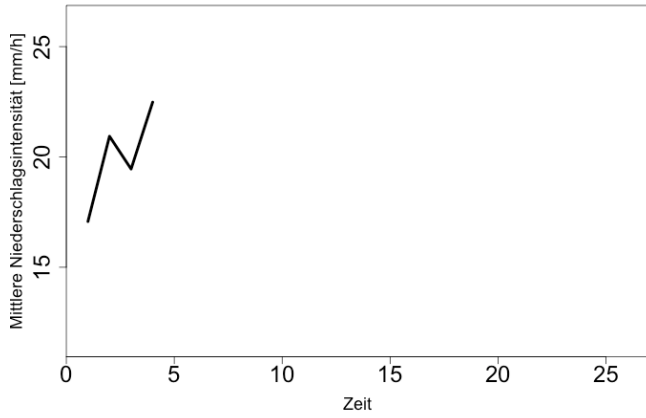
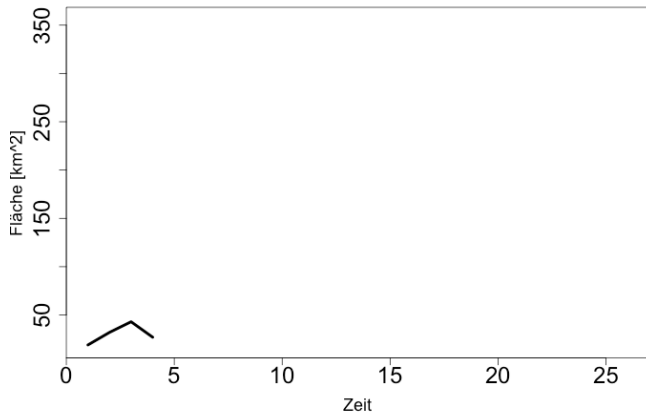
- Detection of cells as contiguous areas above threshold (8.12 mm/h)
 - Calculation of cell area, mean intensity, maximum intensity
- Estimation of position at subsequent time step from wind data (reanalysis or model)

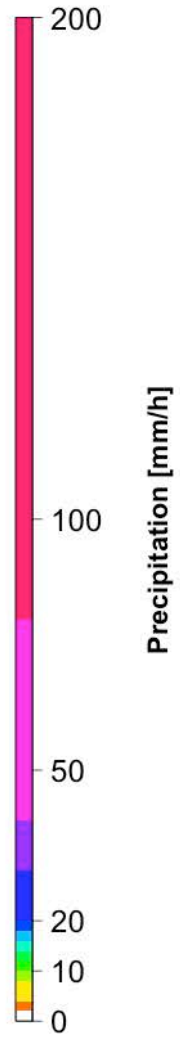
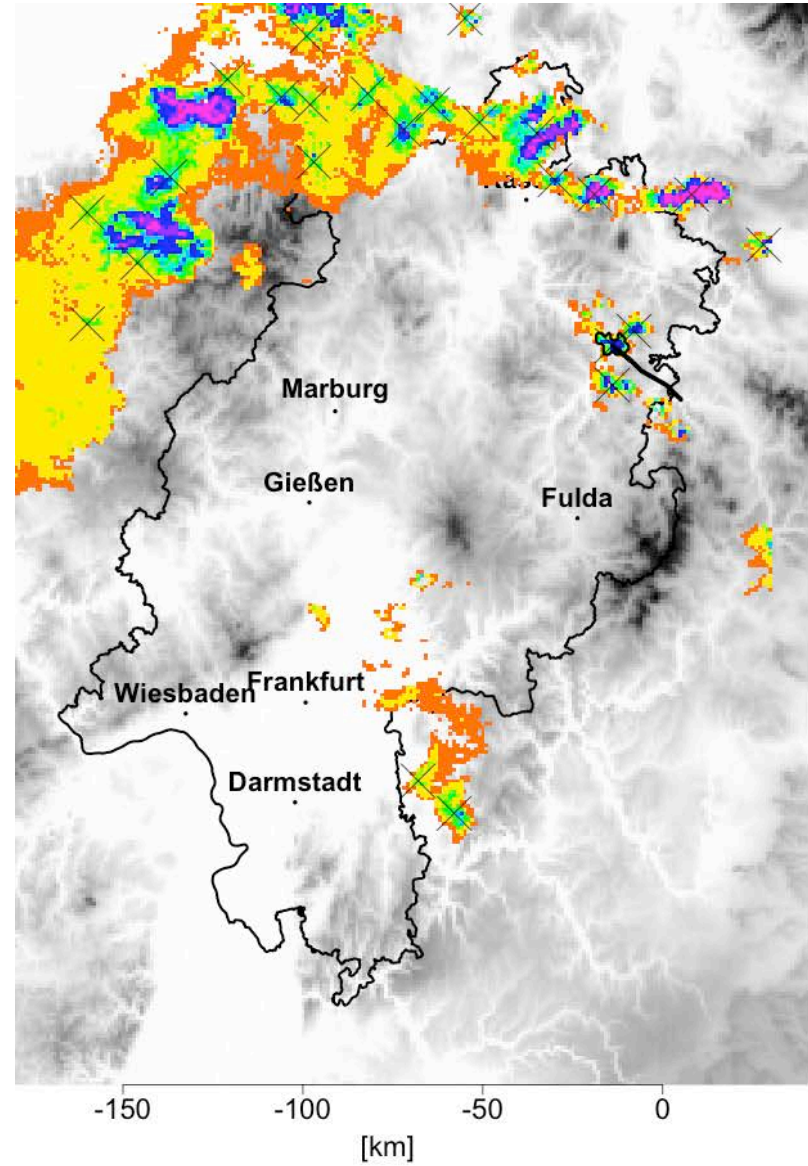
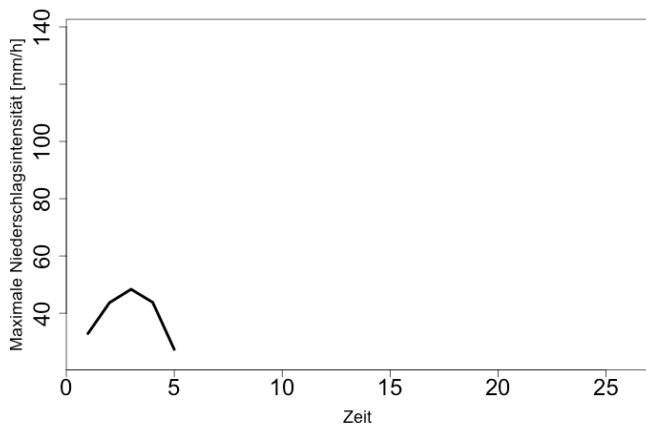
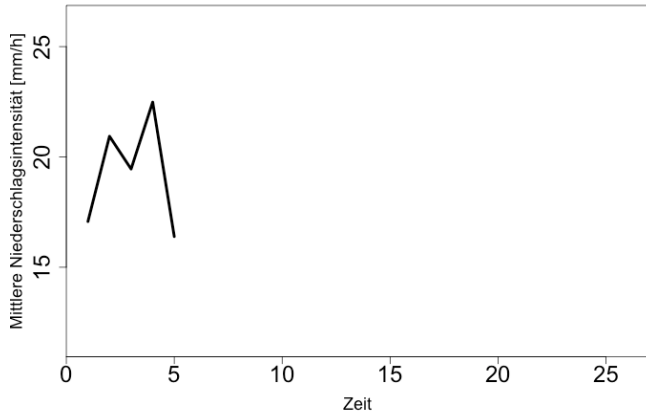
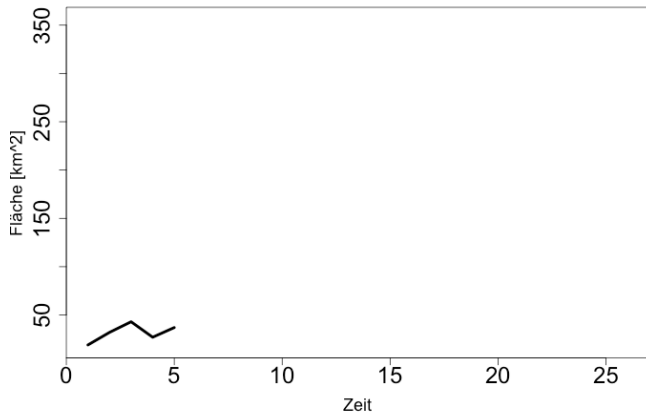


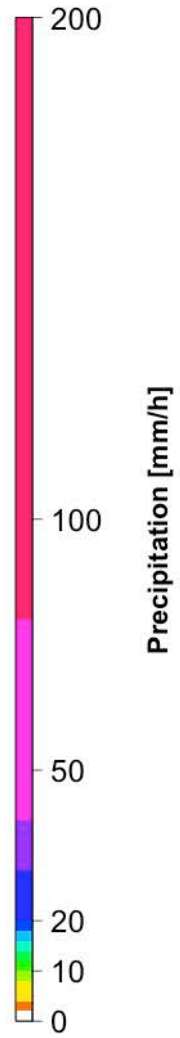
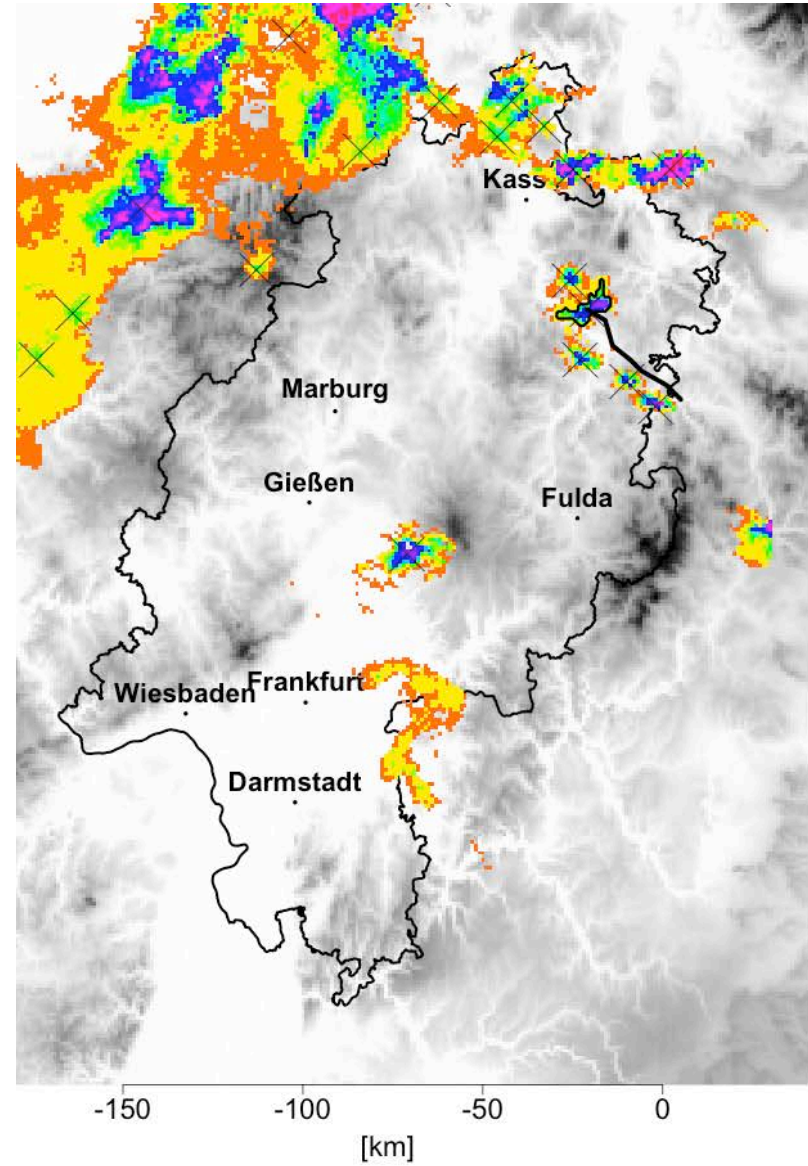
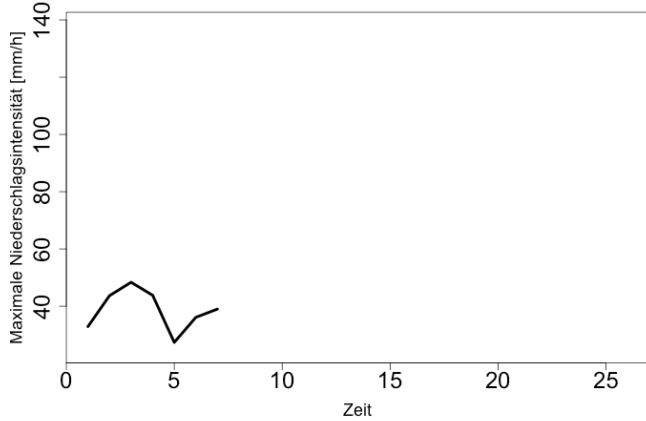
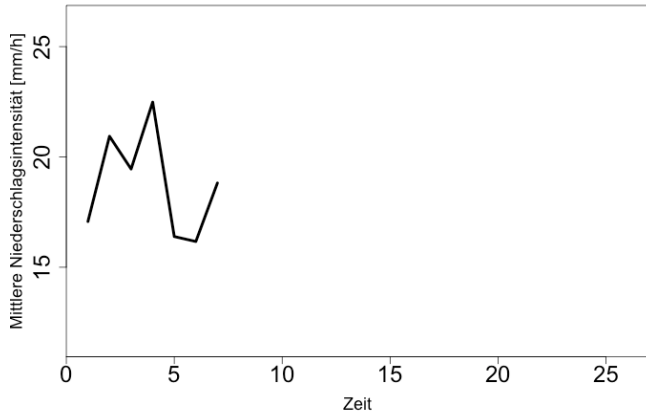
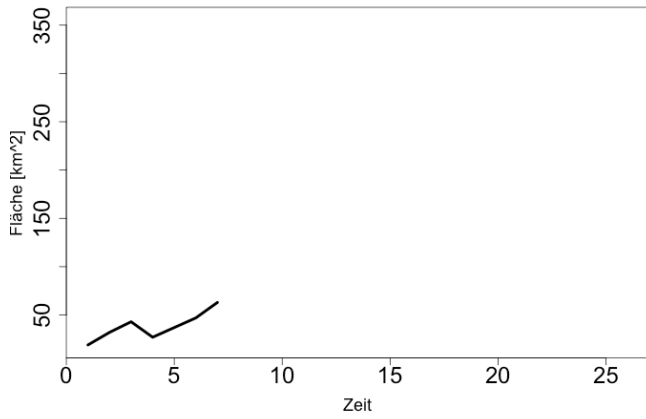


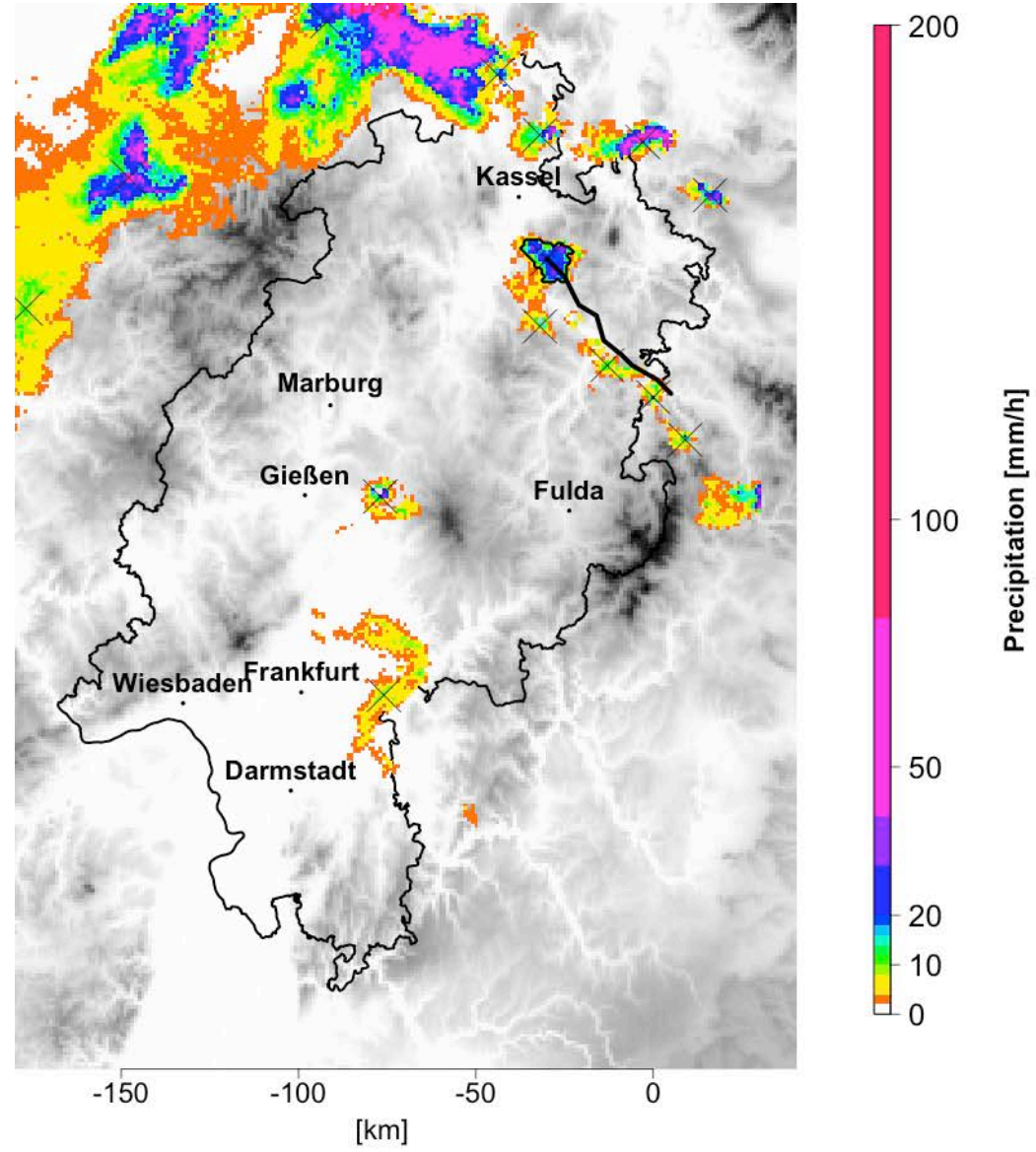
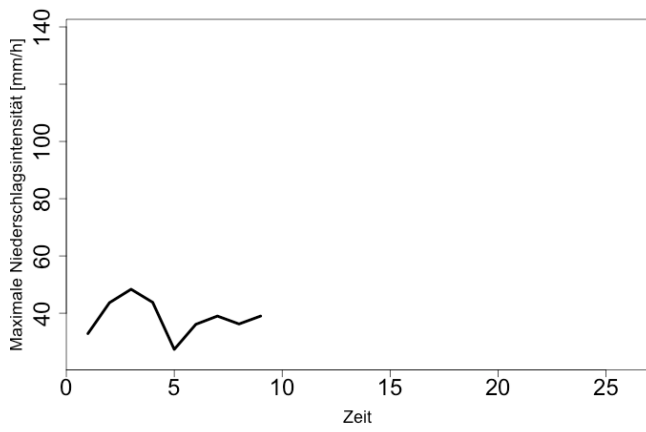
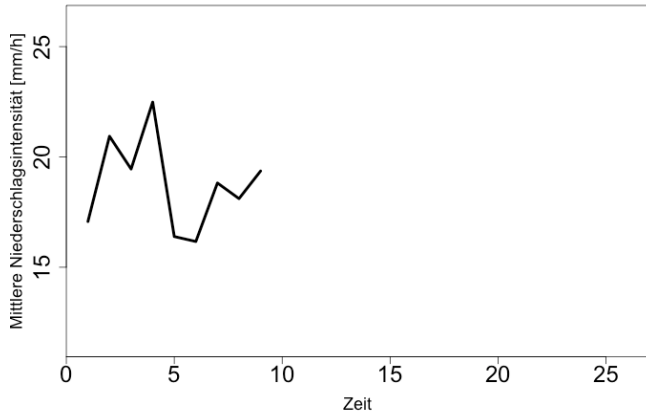
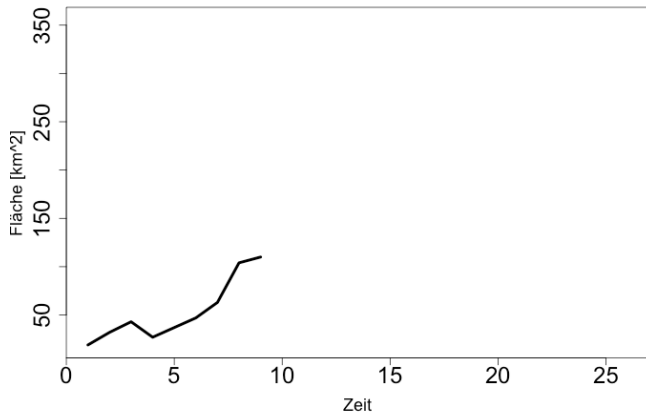


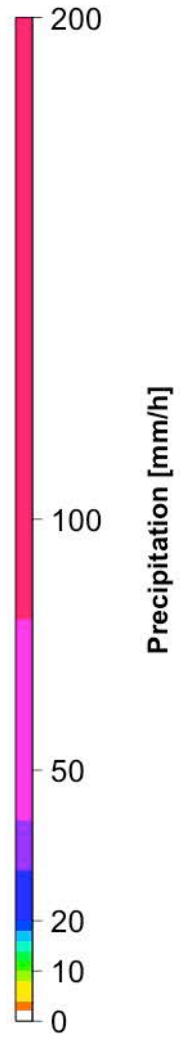
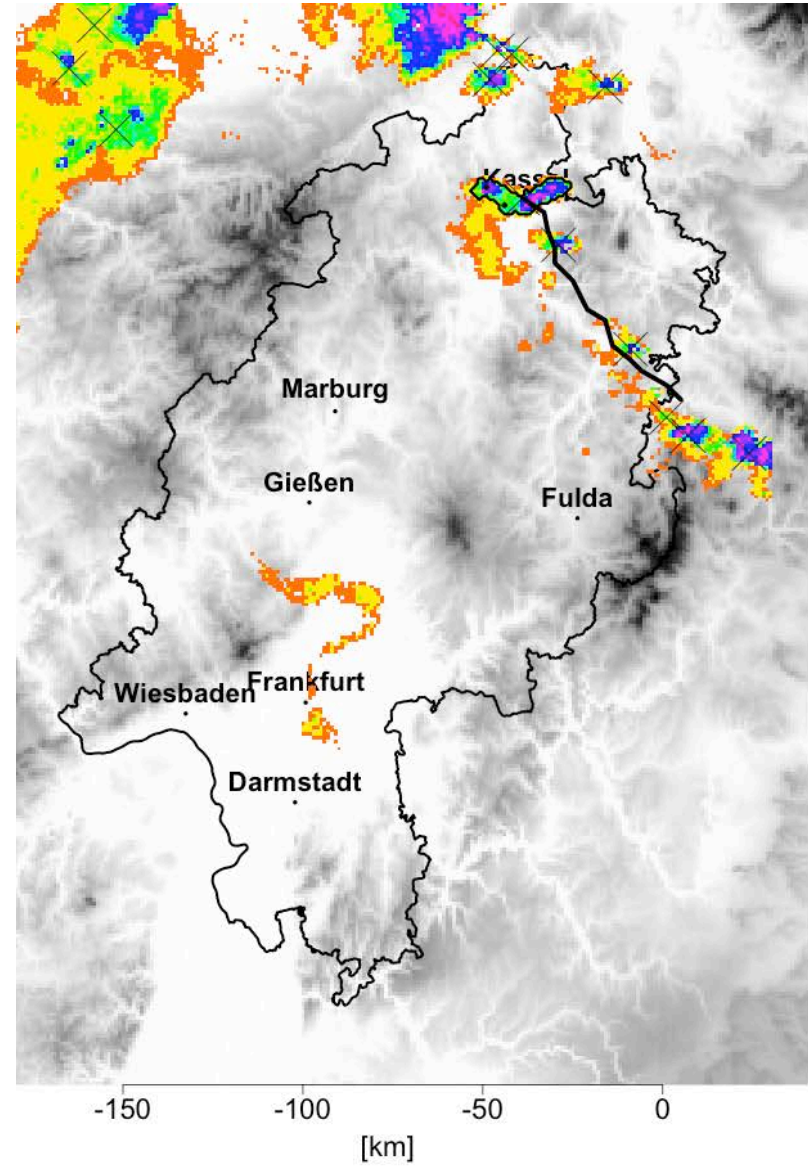
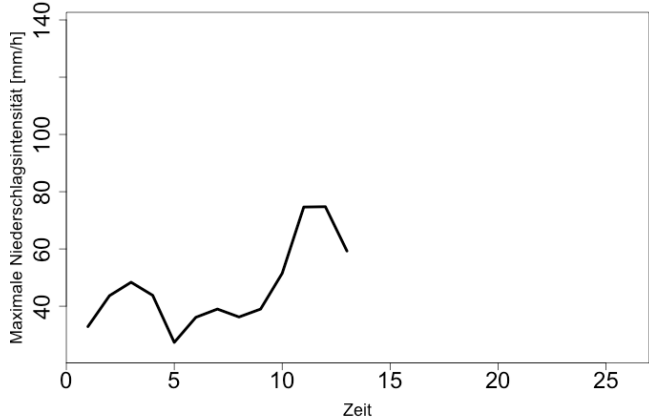
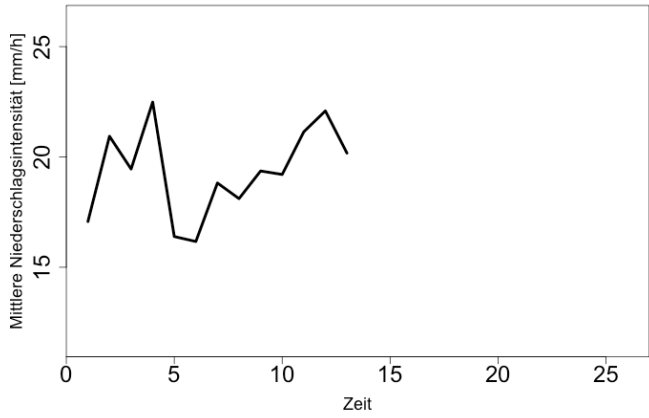
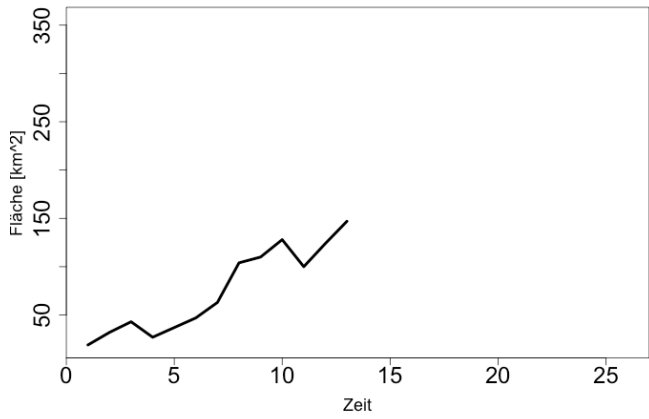


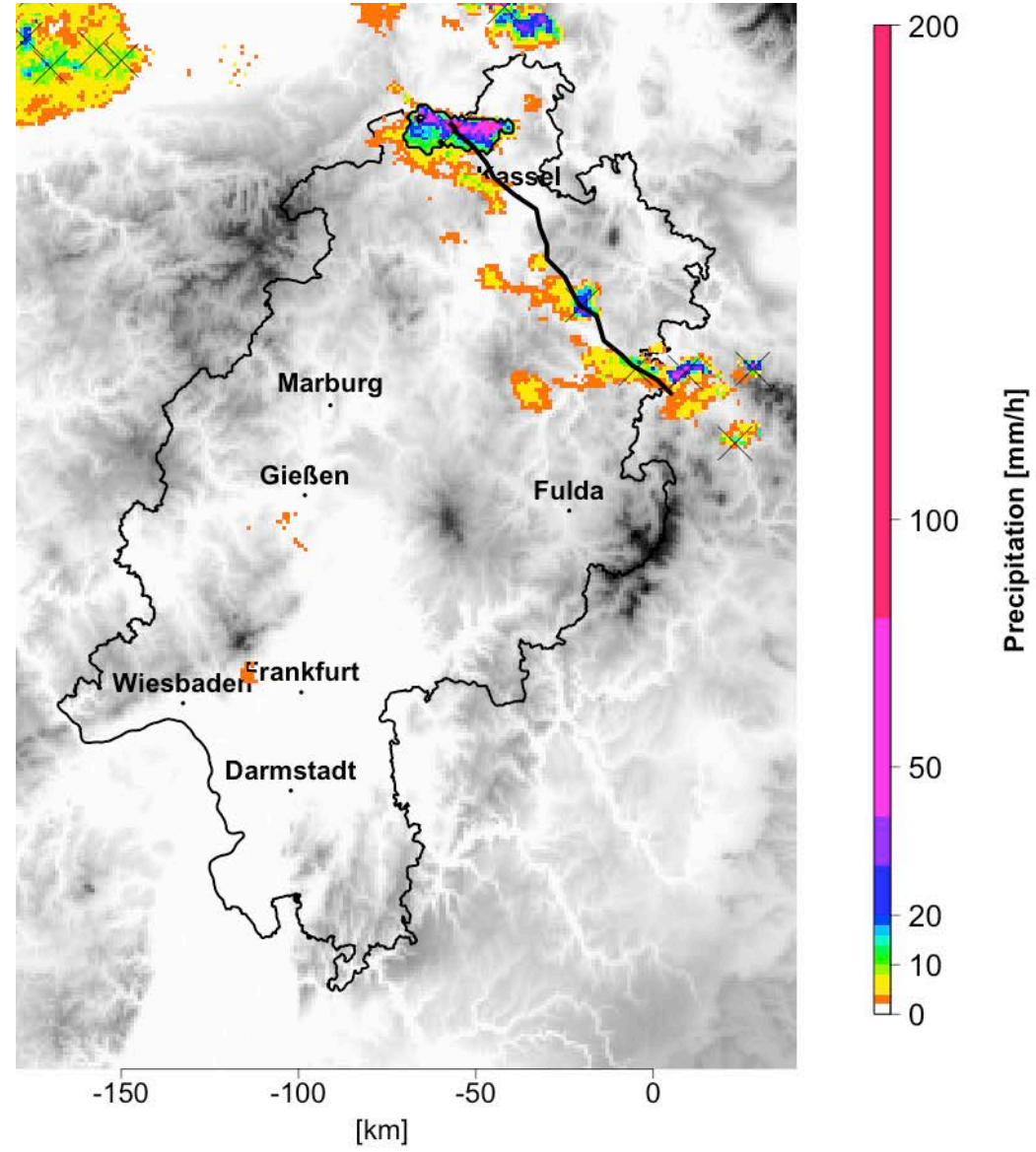
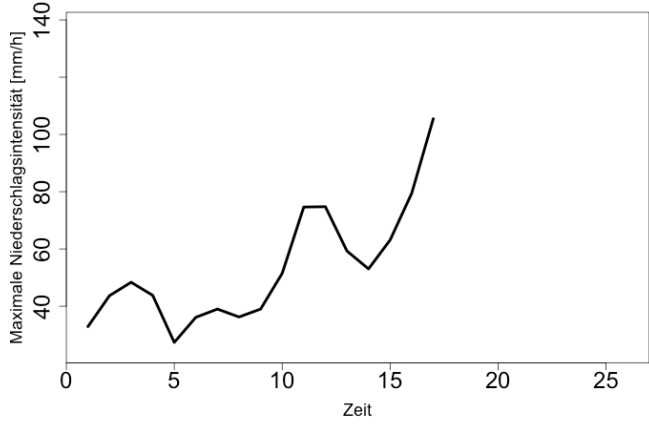
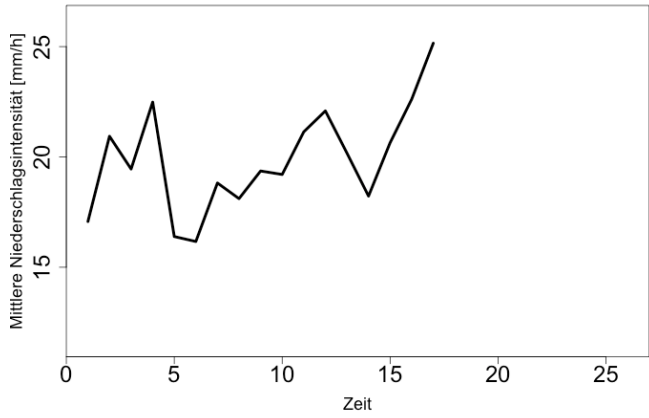
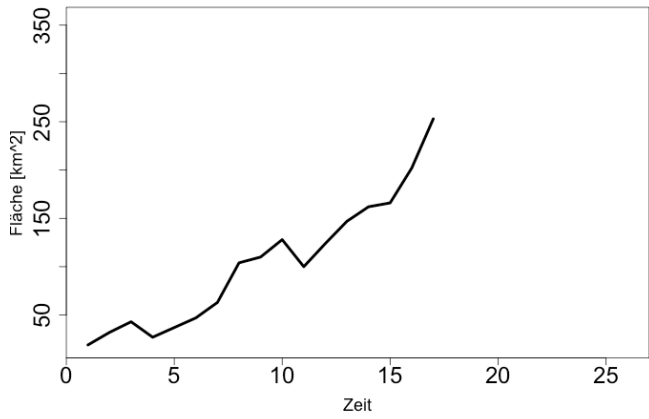


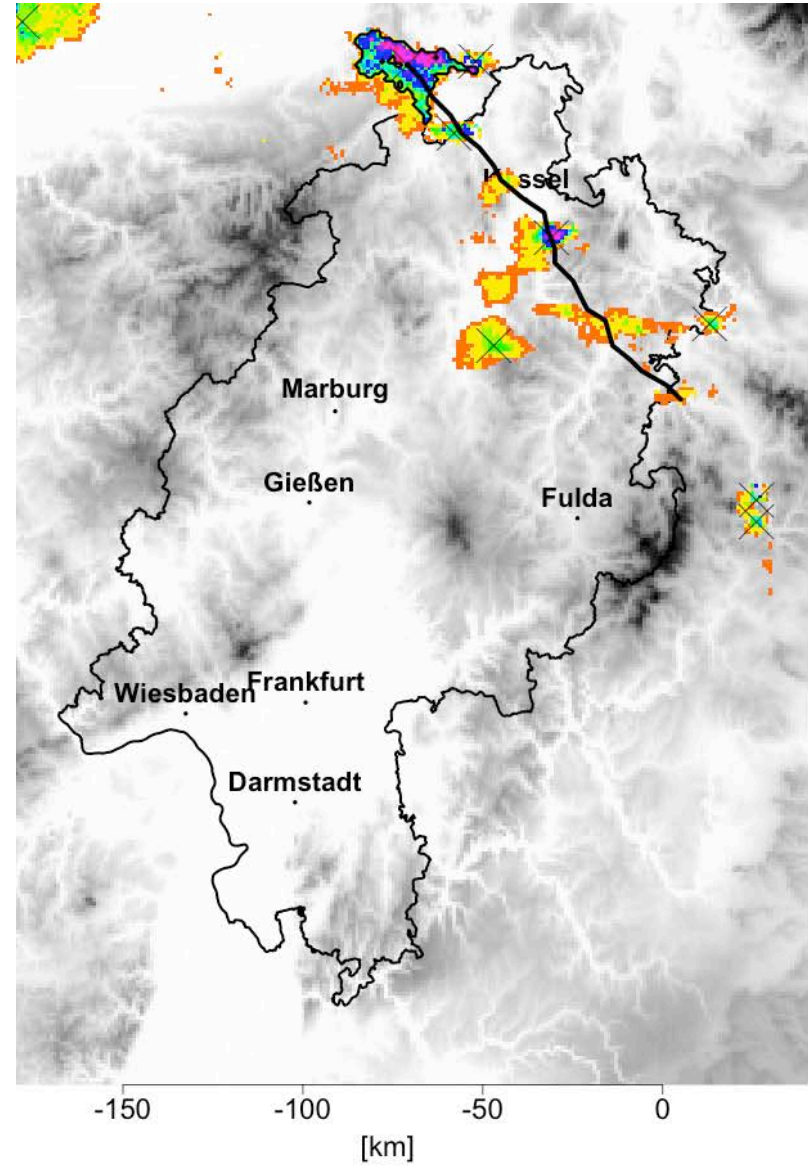
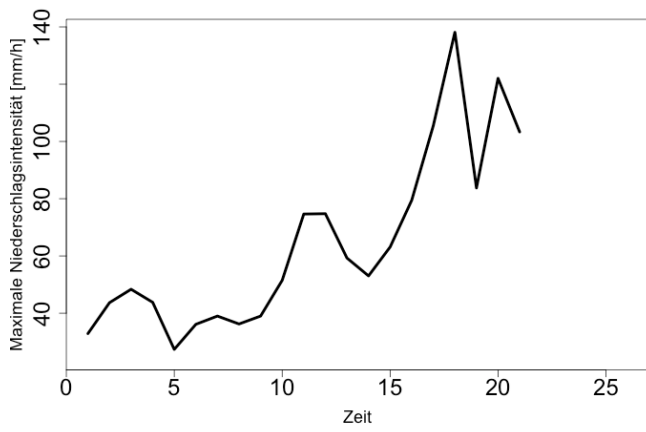
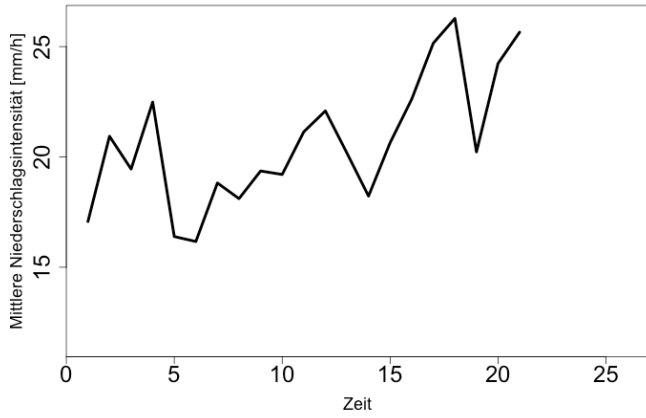
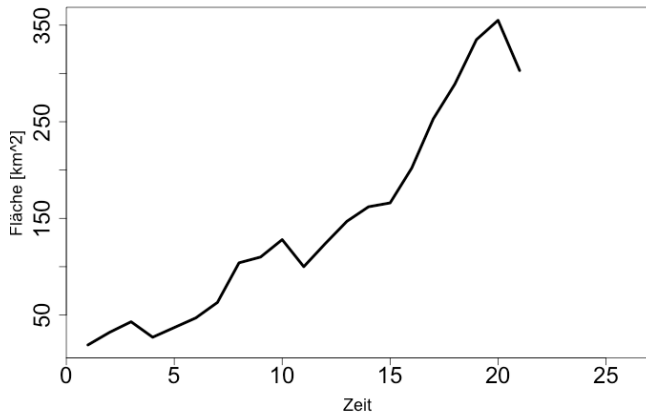


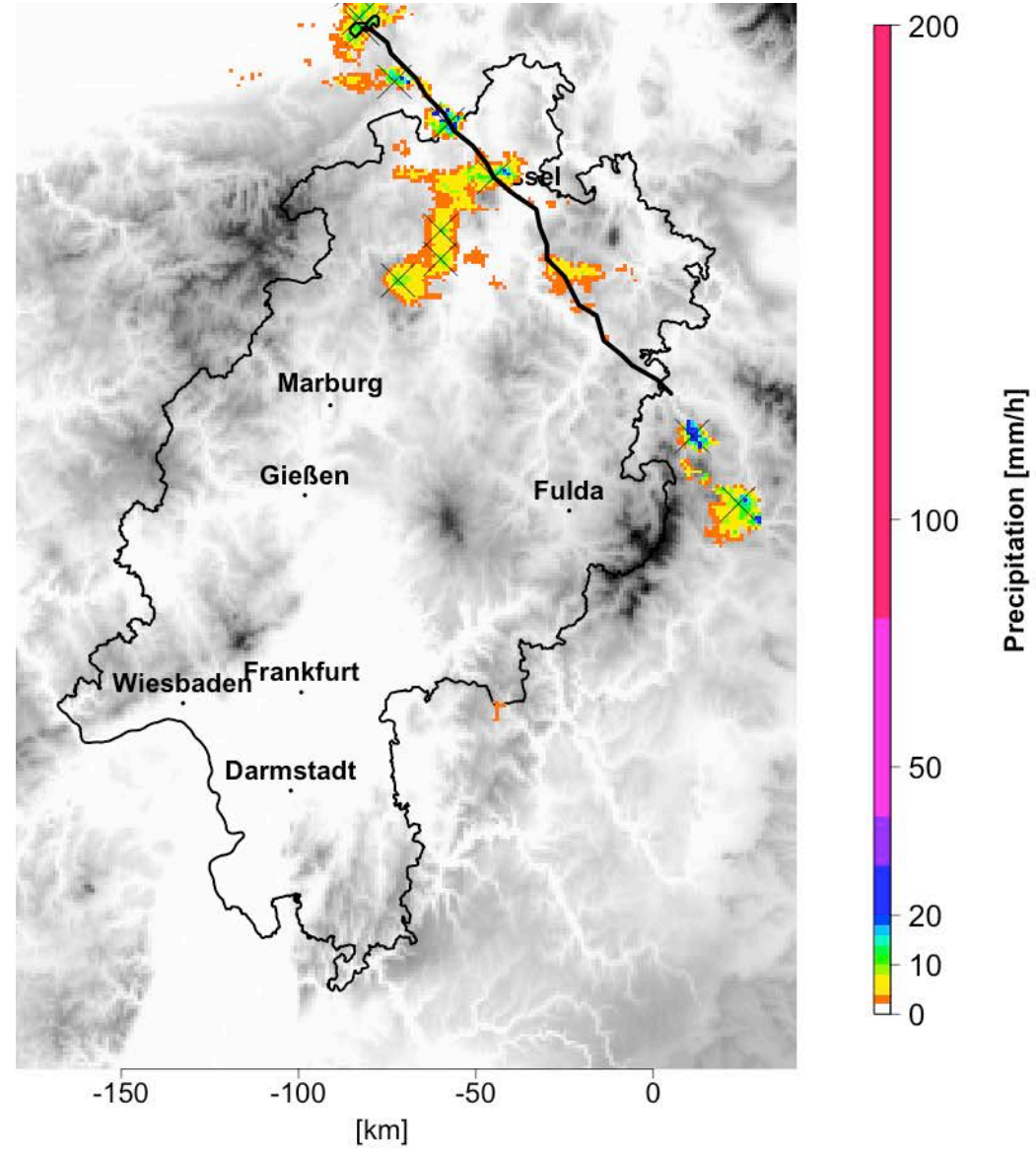
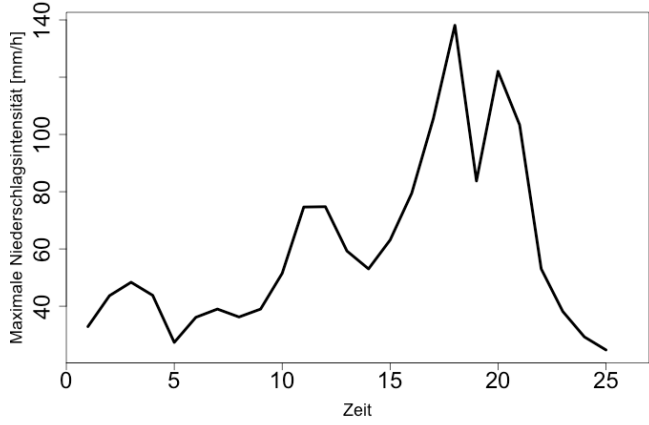
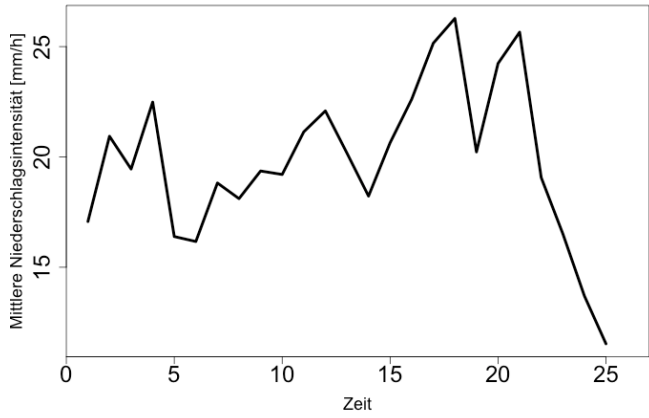
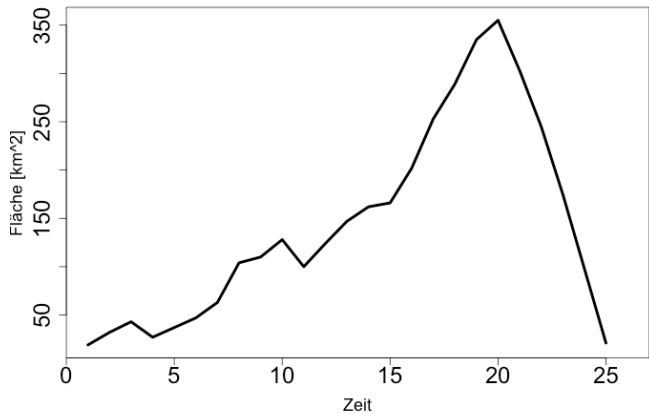




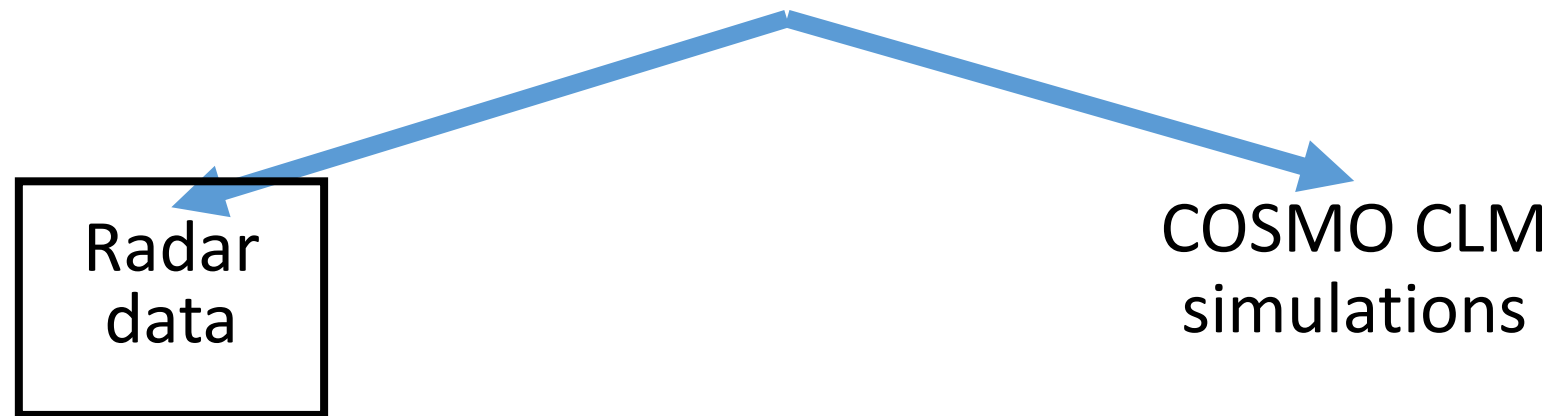






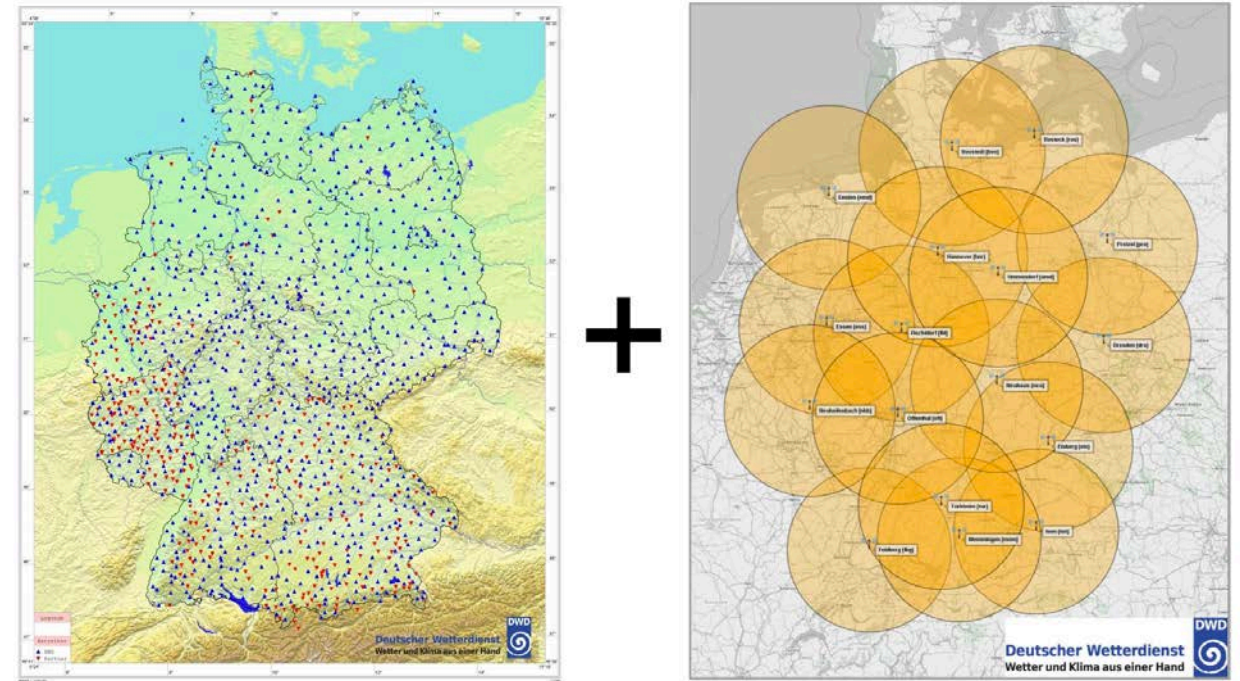


Tracking algorithm



Radar Data

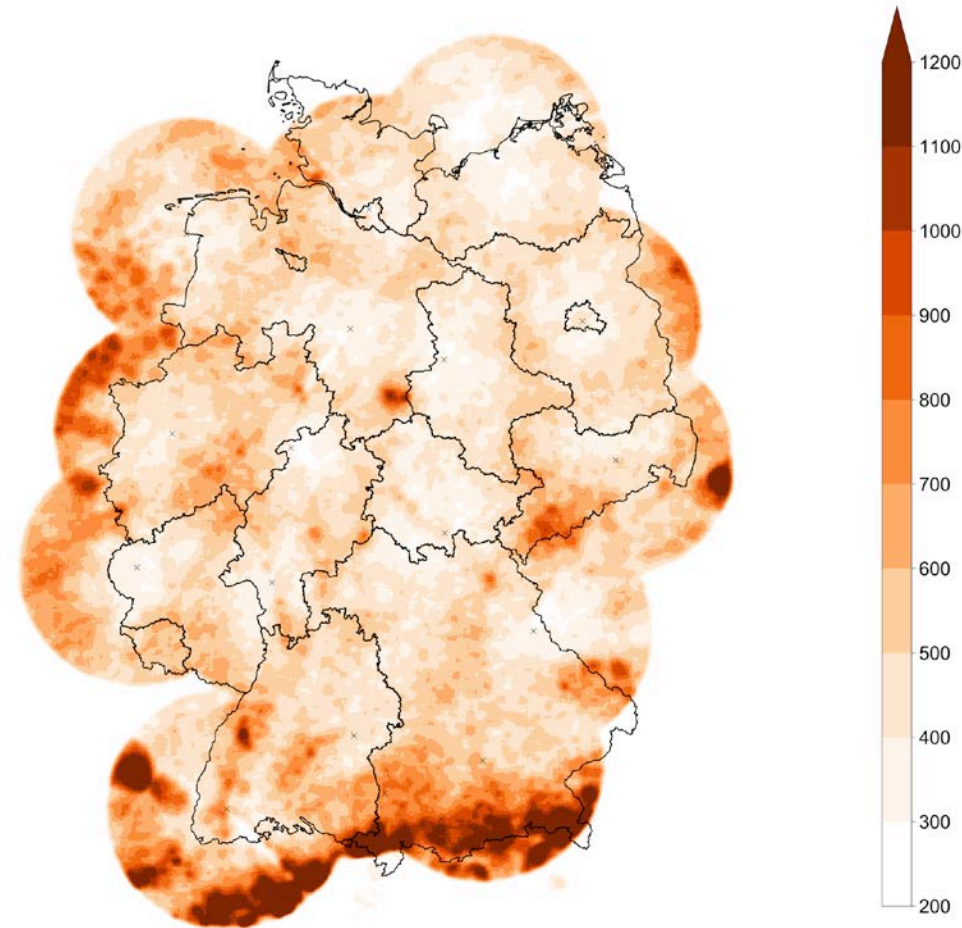
- 16 years of quality checked radar data
- Adjusted to rain gauge measurement
- Spatial resolution: 1 km * 1 km
- Temporal resolution: 5 min



Locations of gauge station (left) and C-band radars used to generate the precipitation data set. [2]

Spatial distribution of convective cells

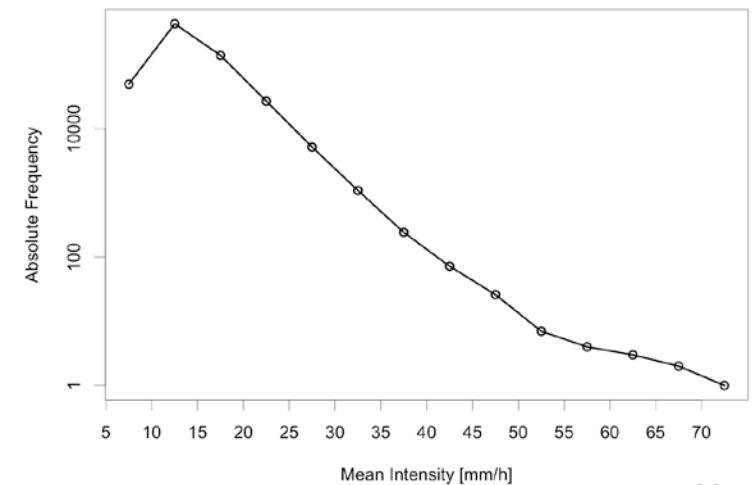
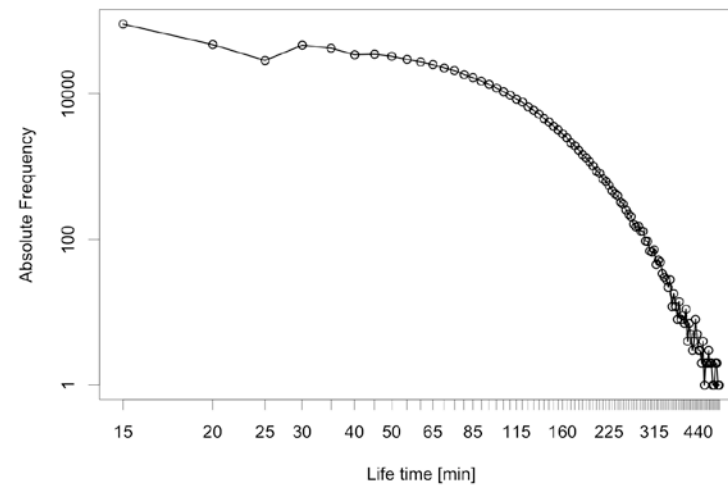
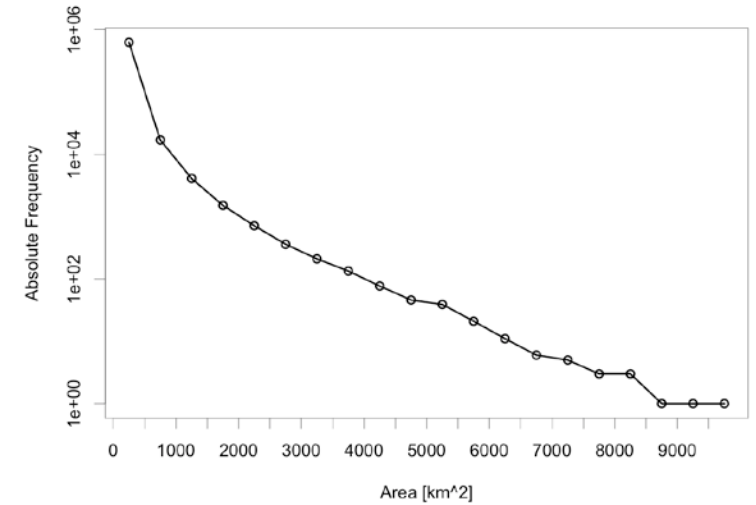
- Maximum activity over the alps
- High activity over low mountain ranges (especially Harz, Black Forrest, Erzgebirge)
- Minima around radar locations



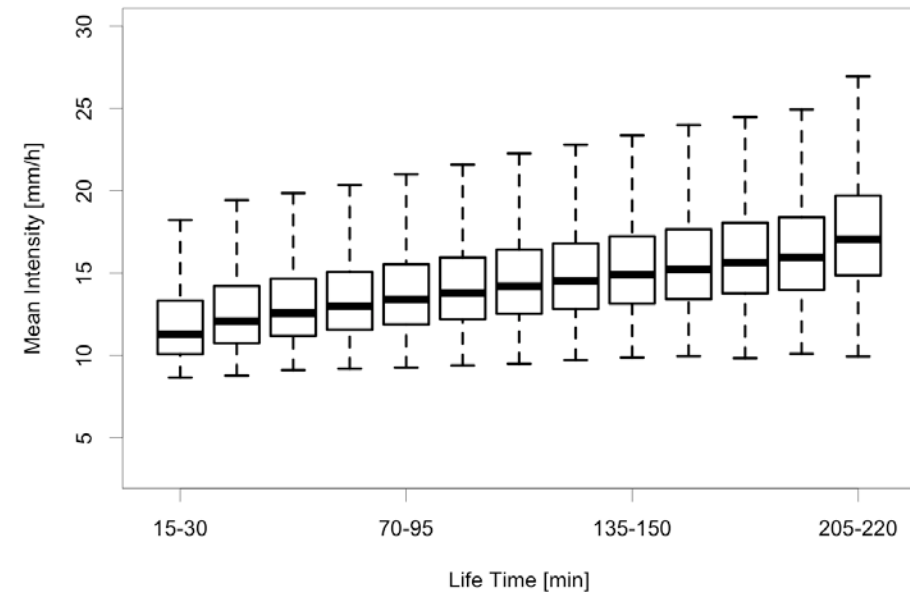
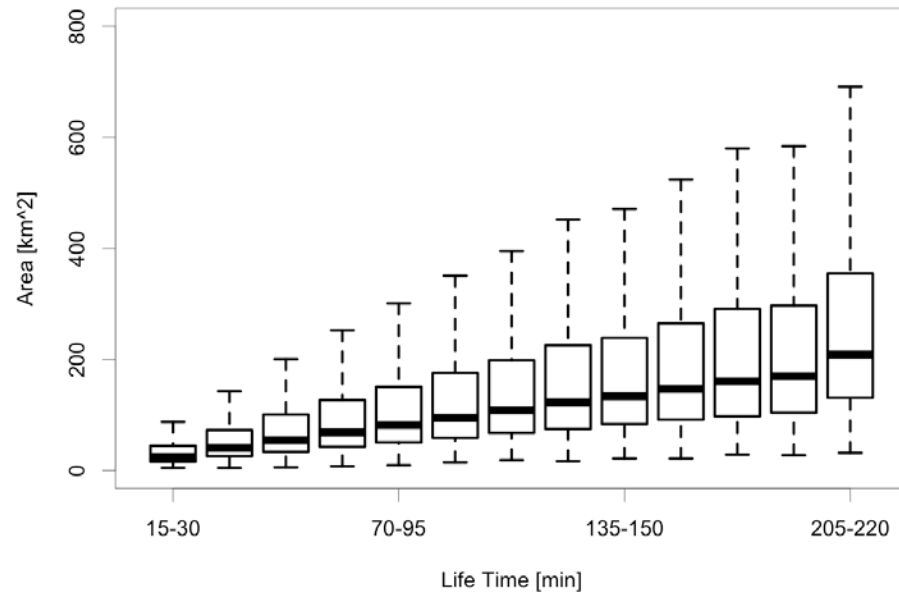
Number of convective cells in 2001-2015 with an area > 35 km² and life time > 10 min

Characteristics of convective cells

- Short living cells are more frequent

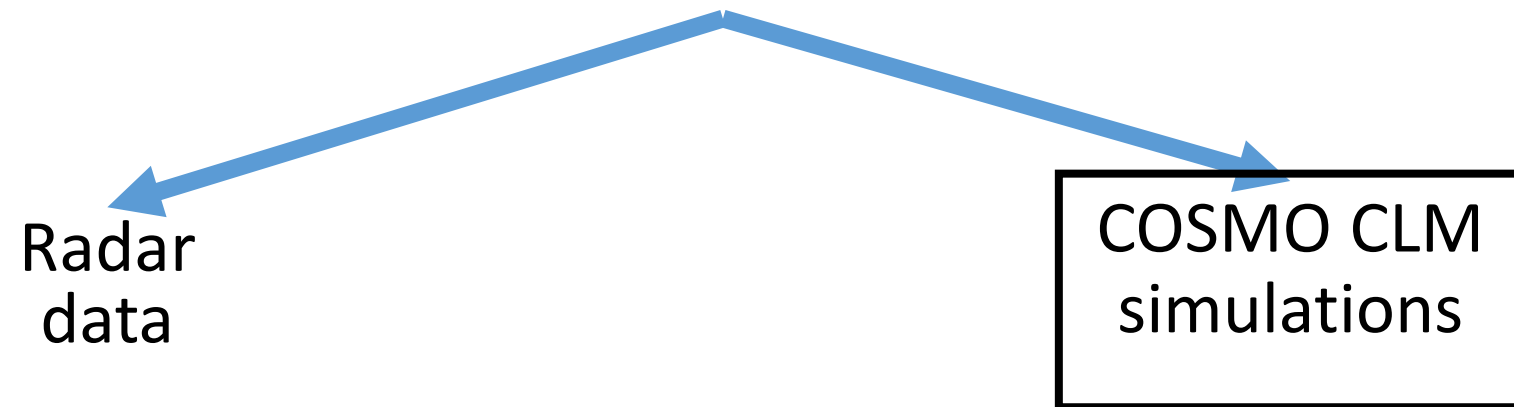


Characteristics of convective cells



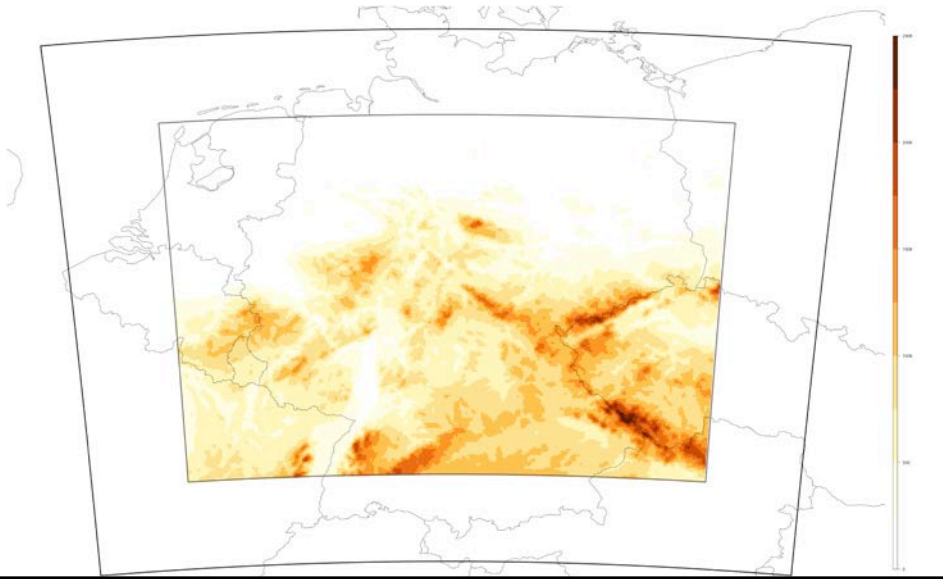
- Maximum area and mean intensity increase with lifetime

Tracking algorithm

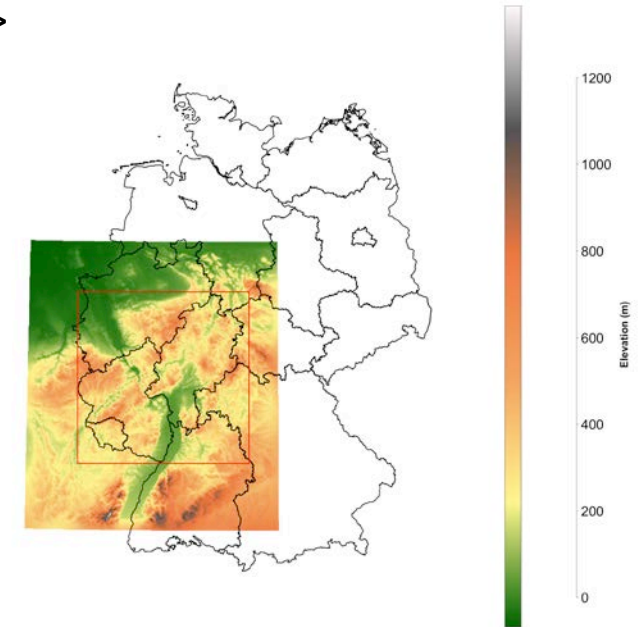


COSMO-CLM simulations

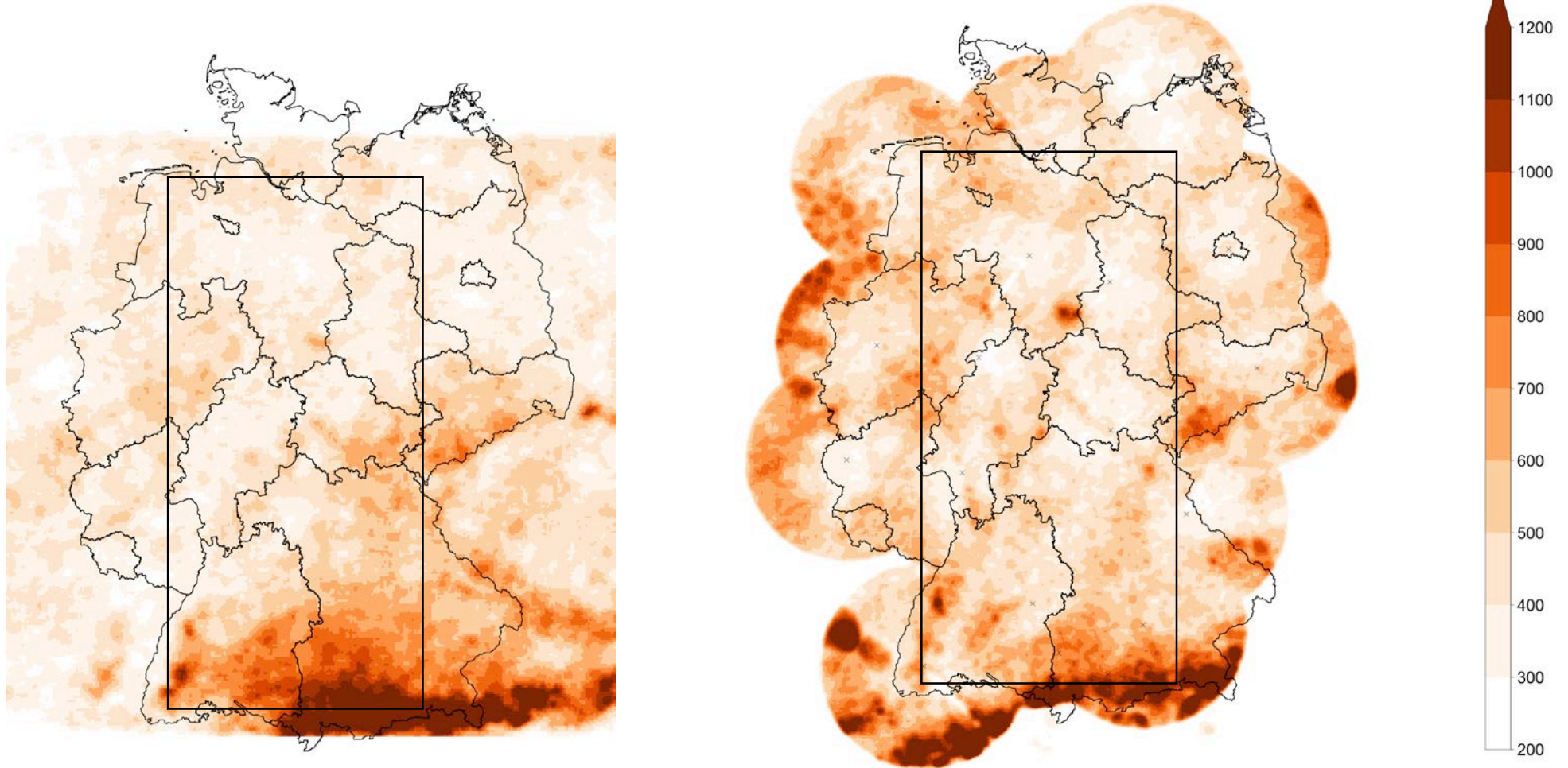
- Continuous Simulation 1982-2015
- Grid mesh size: ca. 2.8 km
- 1-moment microphysics with graupel
- Nesting strategy:
 - ERA-INTERIM -> 0.22° COSMO-> 0.025° COSMO



- 80 day with high convective activity 2001-2016
- Grid mesh size: ca. 1 km
- No shallow convection
- 2-moment microphysics
- Nesting strategy:
 - ERA-INTERIM -> 0.22° COSMO-> 0.01° COSMO



Spatial distribution of convective cells in 2.8 km simulations



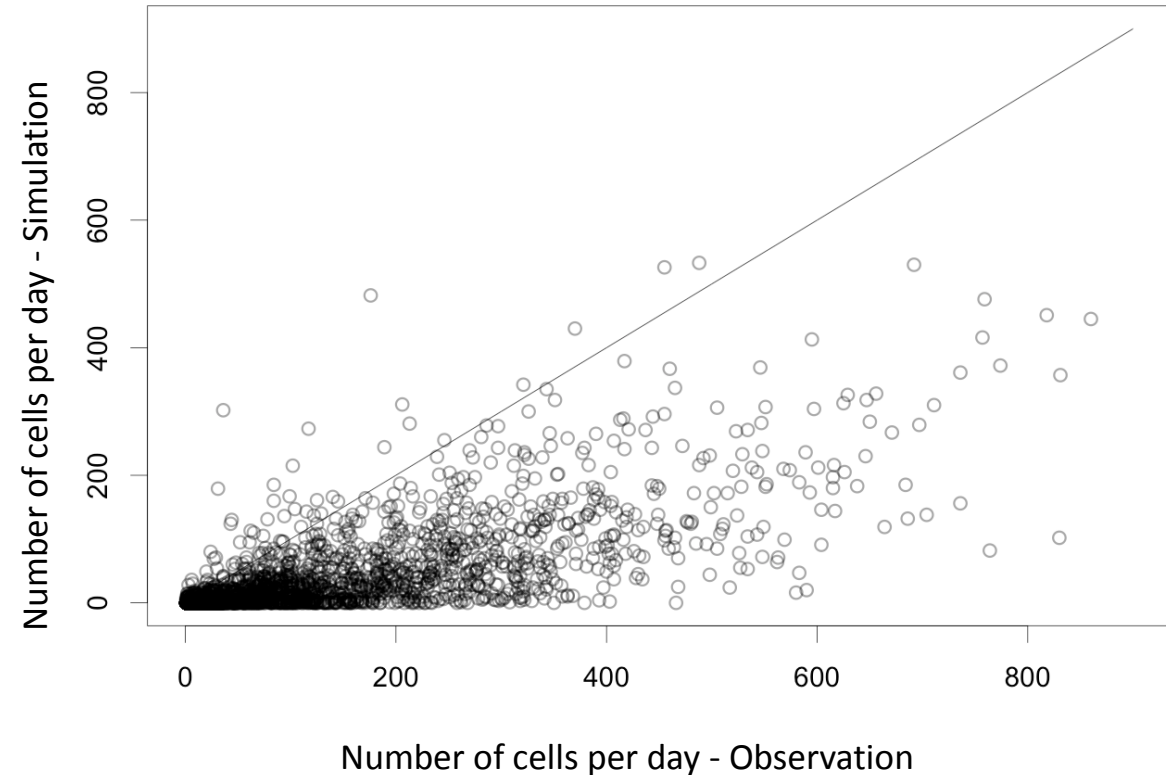
Number of convective cells in 2001-2015 with an area $>35 \text{ km}^2$ and life time $>10 \text{ min}$

Overall convective activity

Total number of convective cells

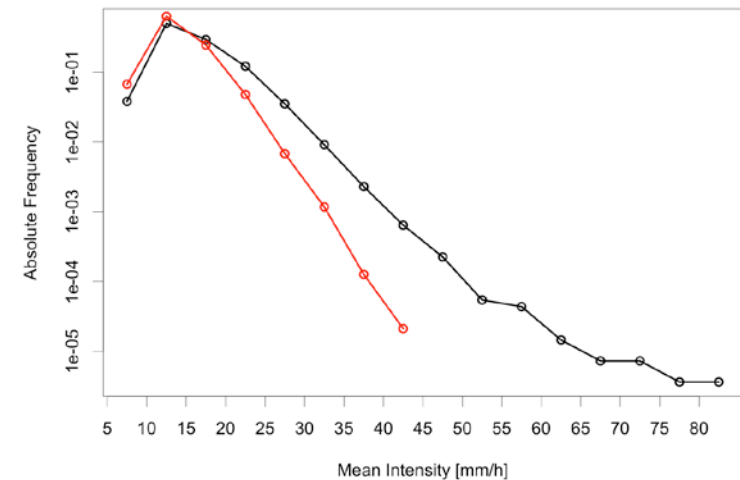
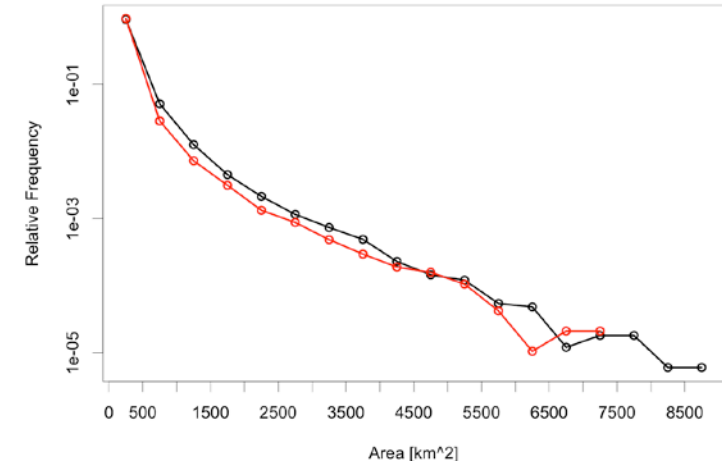
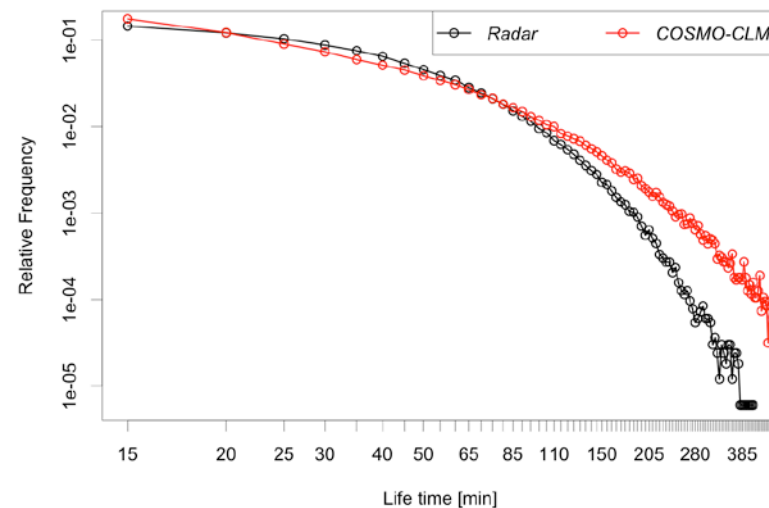
Radar: 165624

COSMO-CLM (2.8 km): 94867

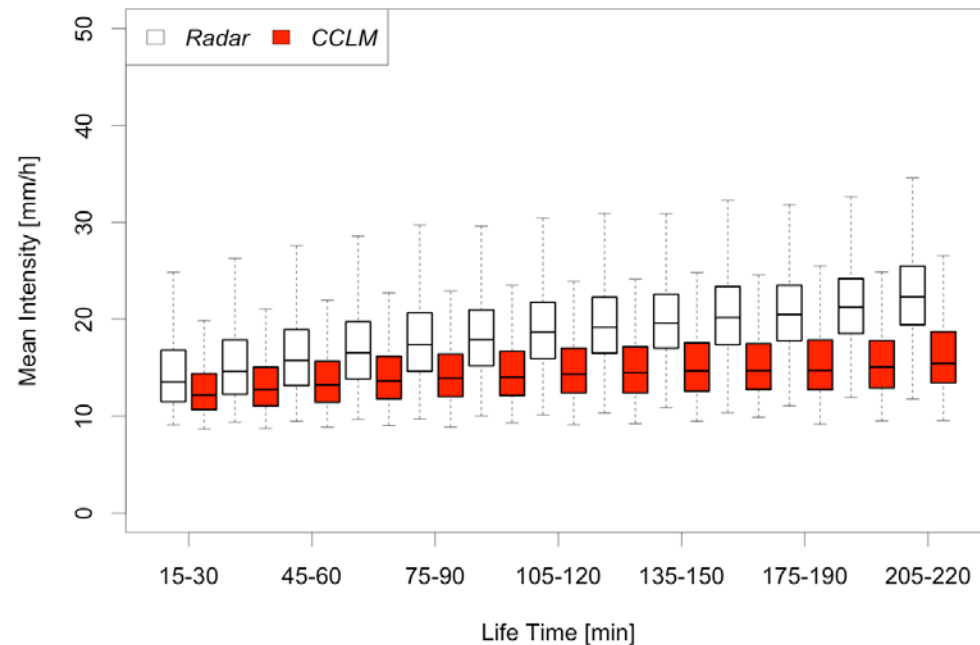


Characteristics of convective cells

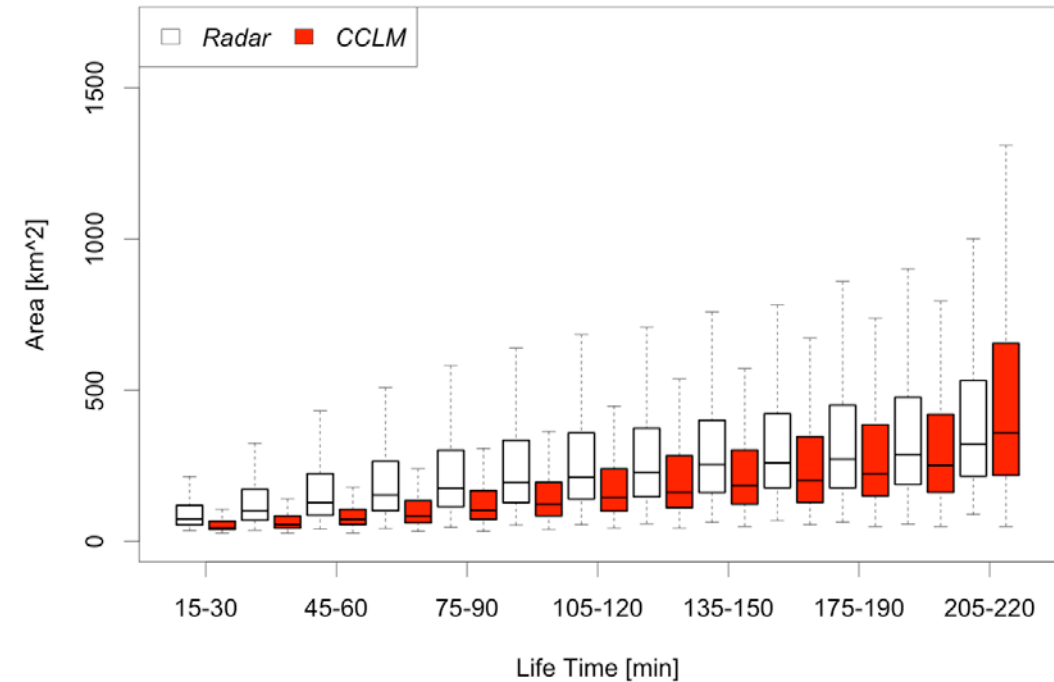
- Maximum area well represented
- too many long living cells
- high precipitation intensities heavily underestimated



Characteristics of convective cells

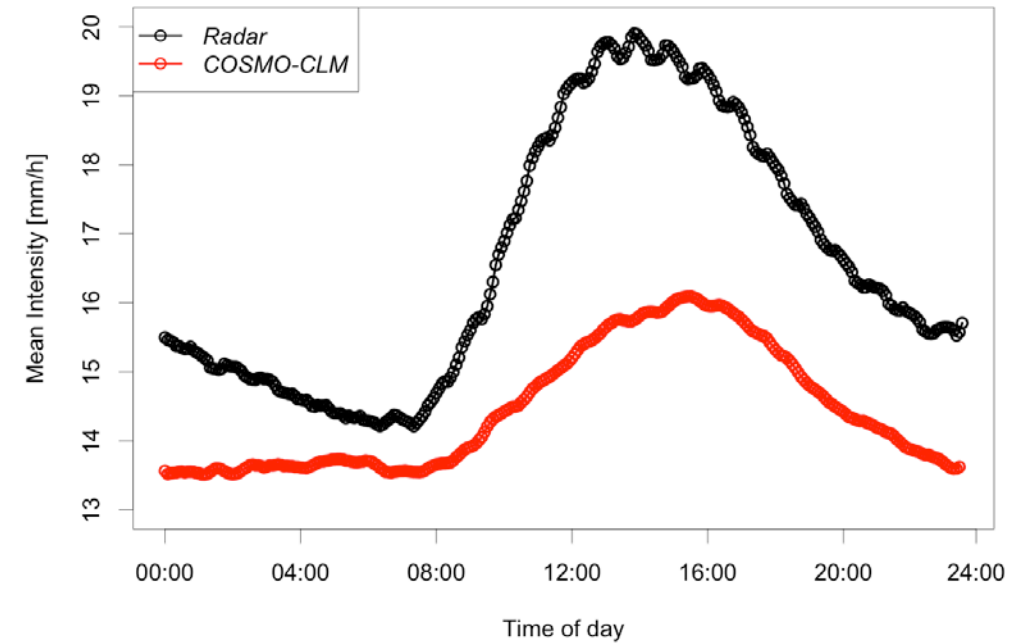
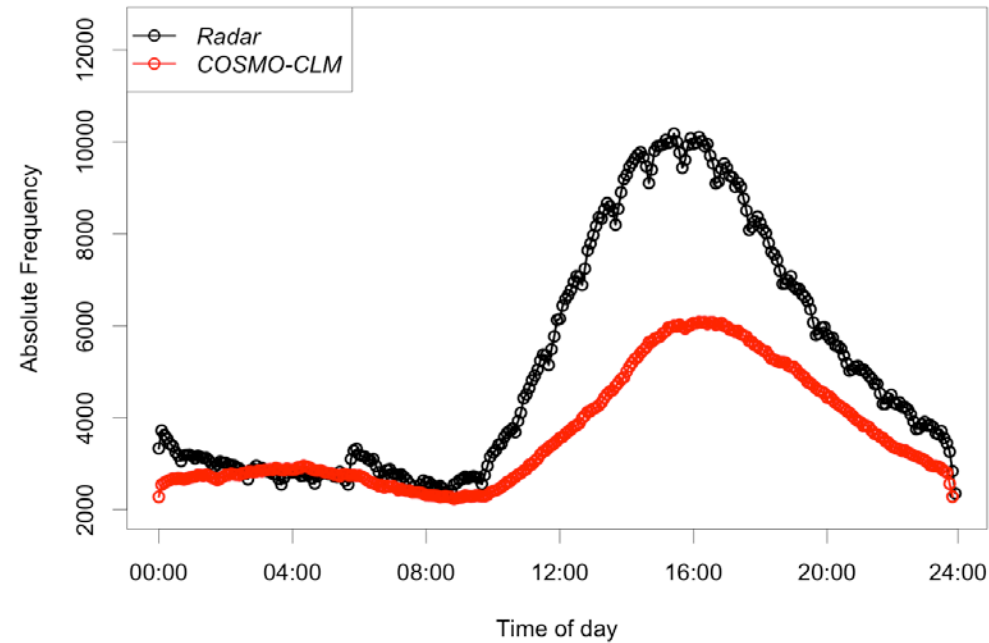


- Underestimation of cell mean intensity increases with cell lifetime



- Short living cell are too small
- Underestimation revoked for longer lasting cells

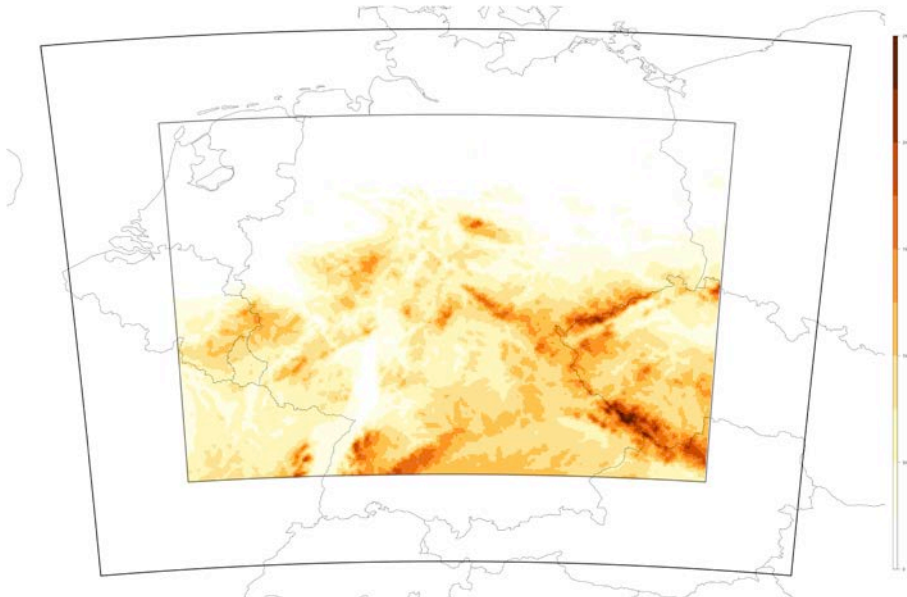
Daily cycle



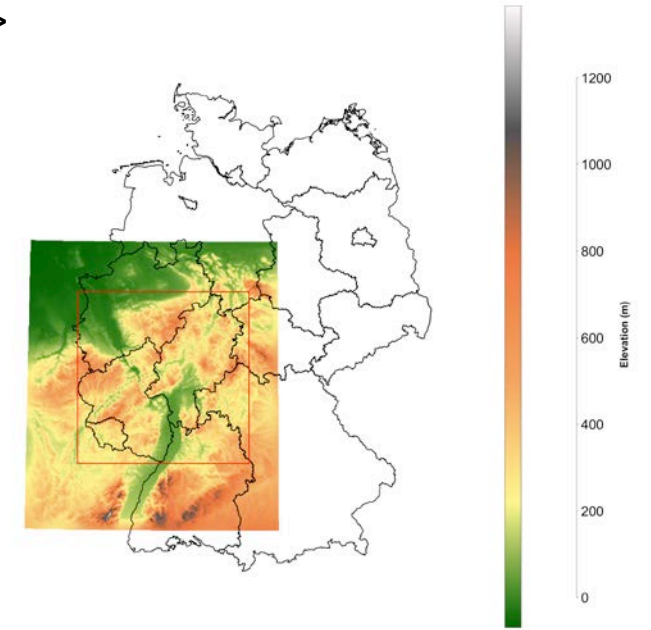
- Afternoon peak in total number of cells and mean intensity underestimated

COSMO-CLM simulations

- Continuous Simulation 1982-2015
- Grid mesh size: ca. 2.8 km
- 1-moment microphysics with graupel
- Nesting strategy:
 - ERA-INTERIM -> 0.22° COSMO-> 0.025° COSMO

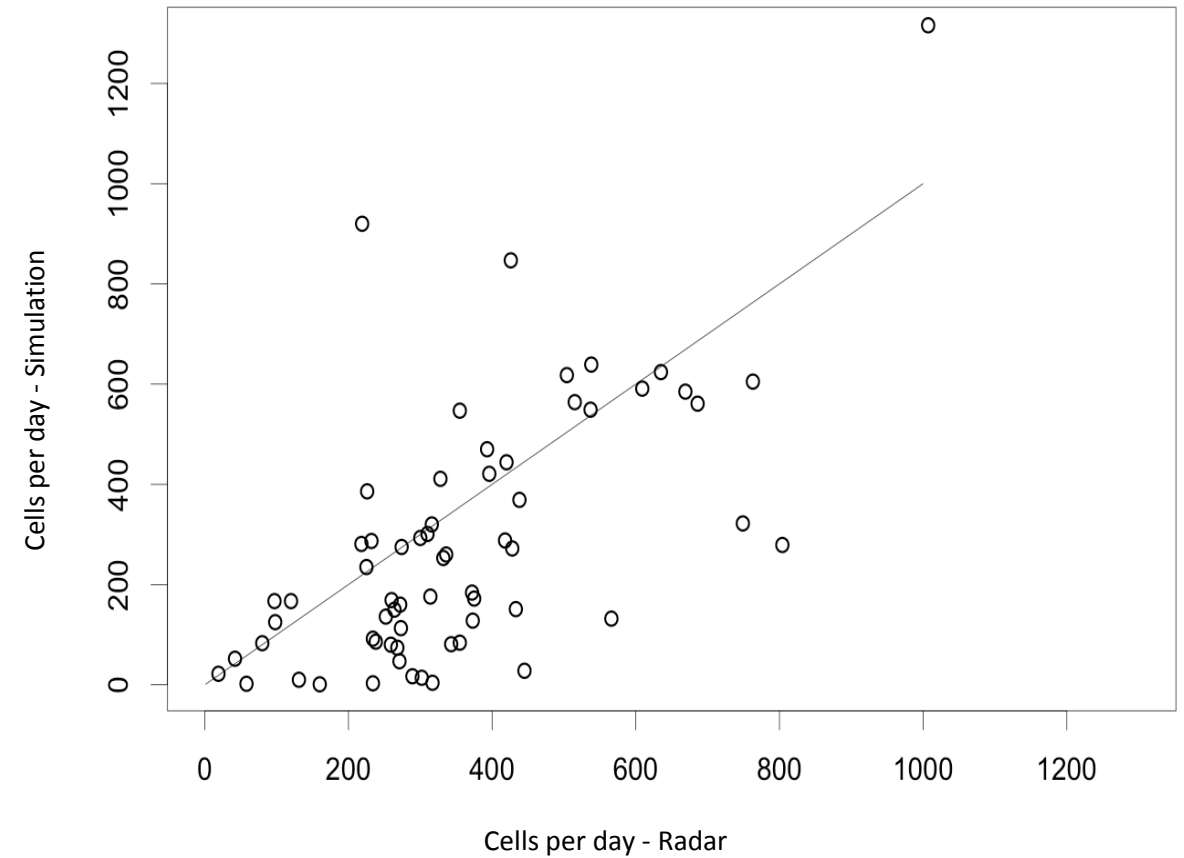


- 80 day with high convective activity 2001-2016
- Grid mesh size: ca. 1 km
- No shallow convection
- 2-moment microphysics
- Nesting strategy:
 - ERA-INTERIM -> 0.22° COSMO-> 0.01° COSMO



Overall convective activity

- Total number of convective cells
 - Radar: 22720
 - CCLM(1 km): 18043



Overall convective activity

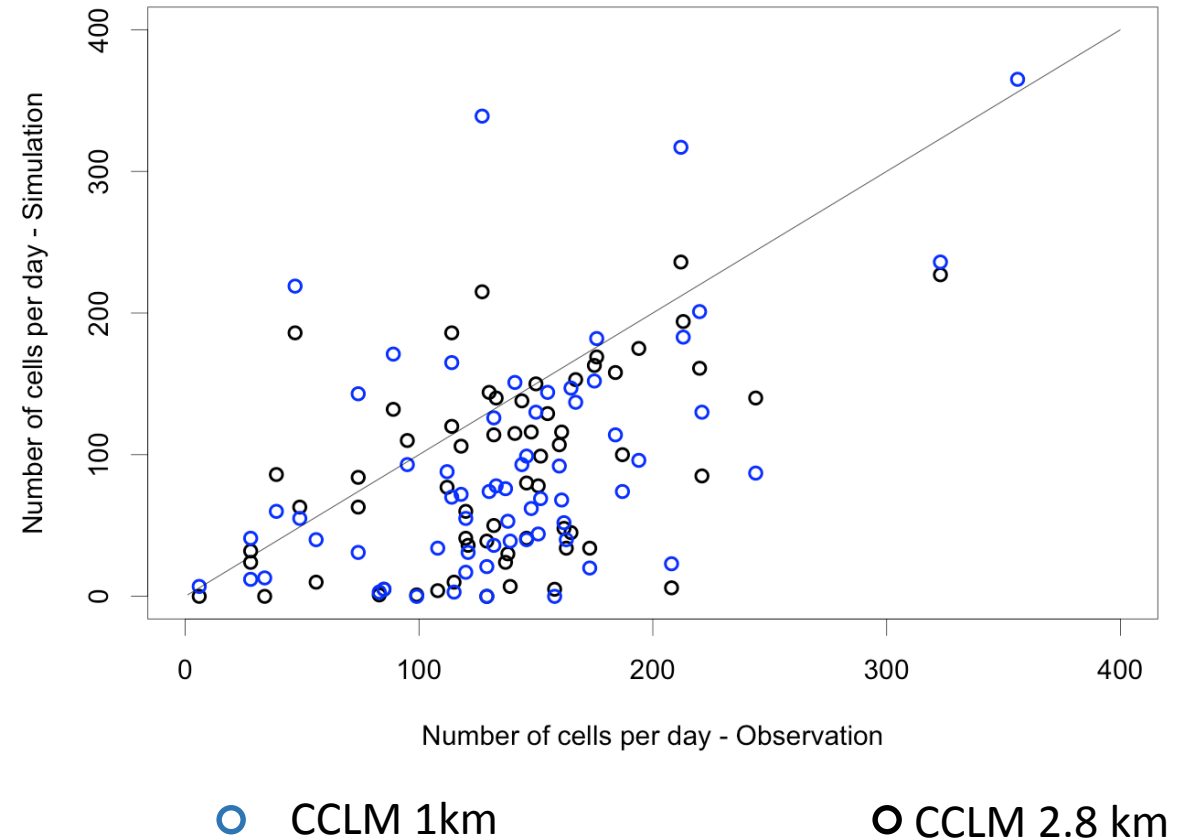
Total number of convective cells (>35 km²)

Radar: 8809

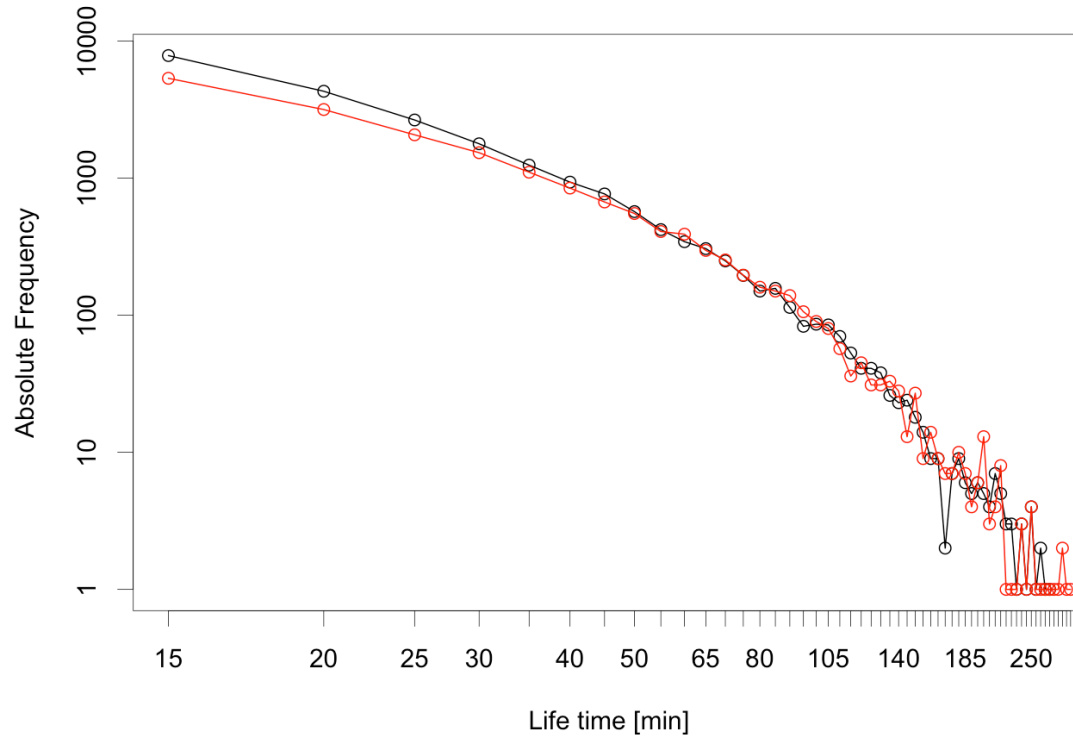
CCLM(1 km): 5927

CCLM (2.8 km): 5818

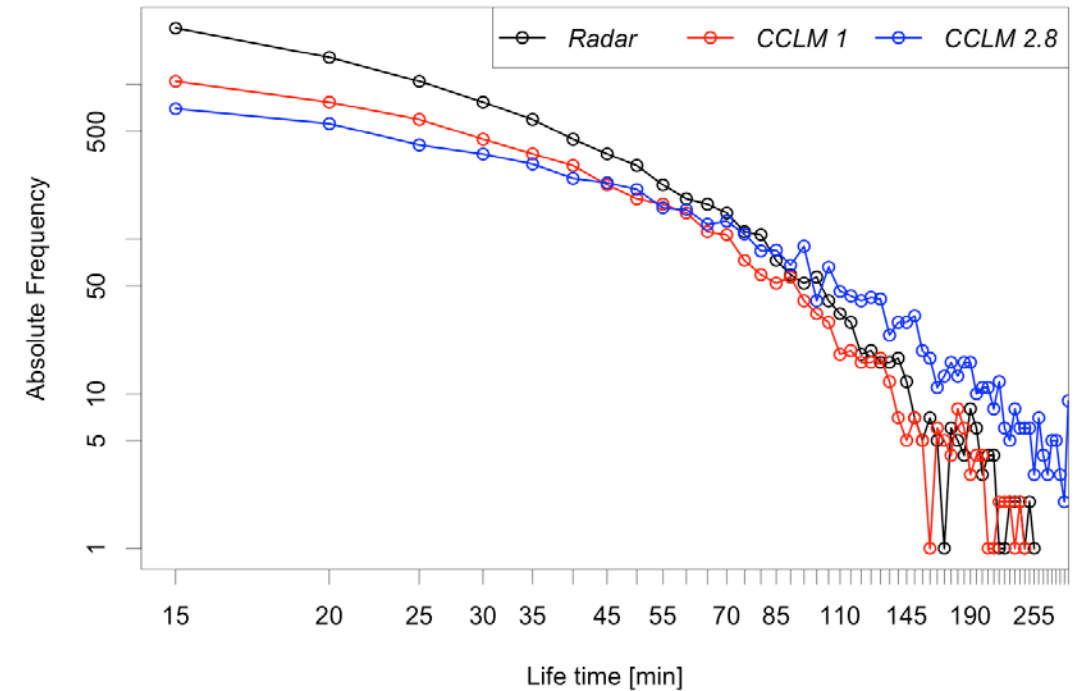
	1km	2.8km
RMSE	78.3	85.9
COR	0.6	0.52



Characteristics of convective cells

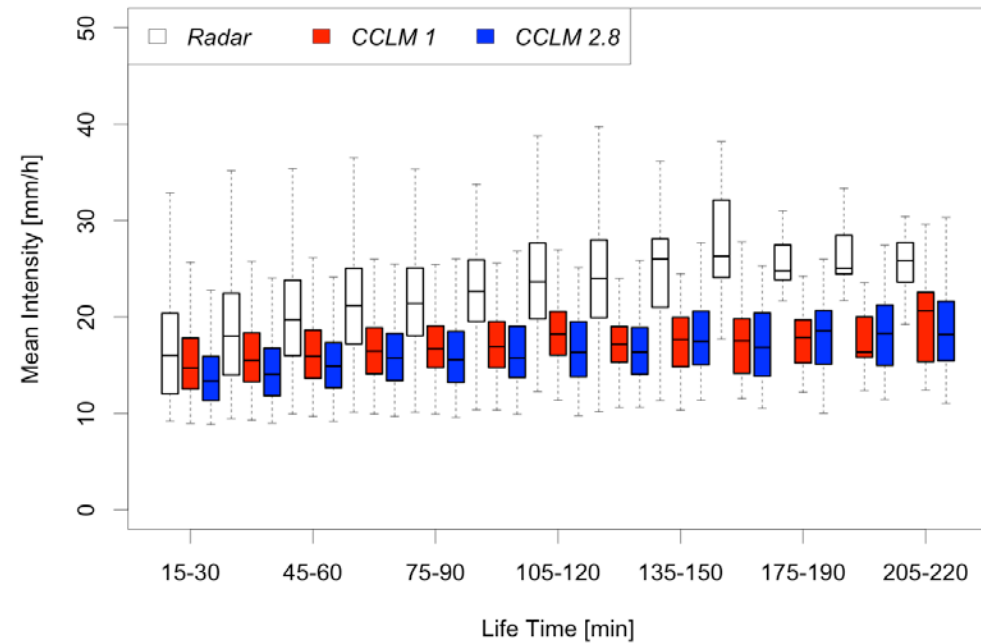
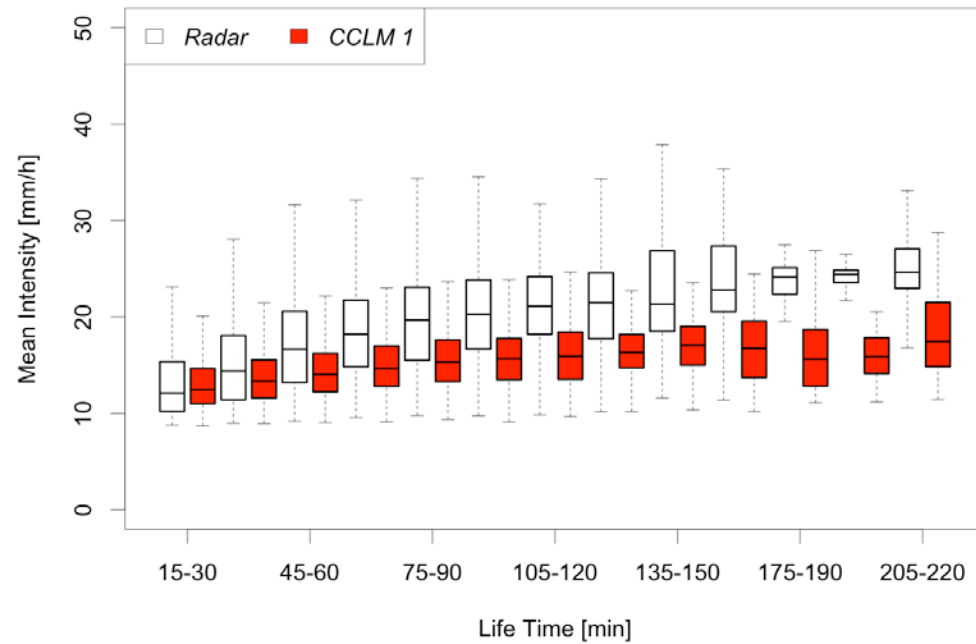


- Underestimation of short living cells



- CCLM1 fits better

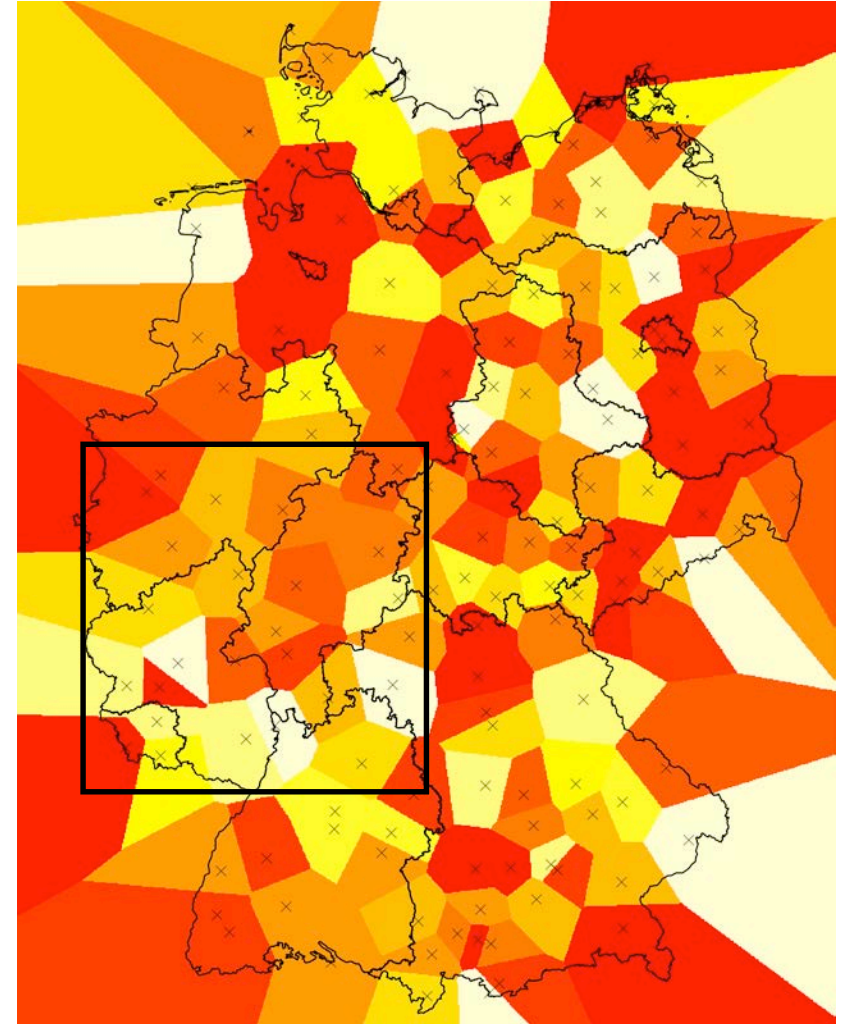
Characteristics of convective cells

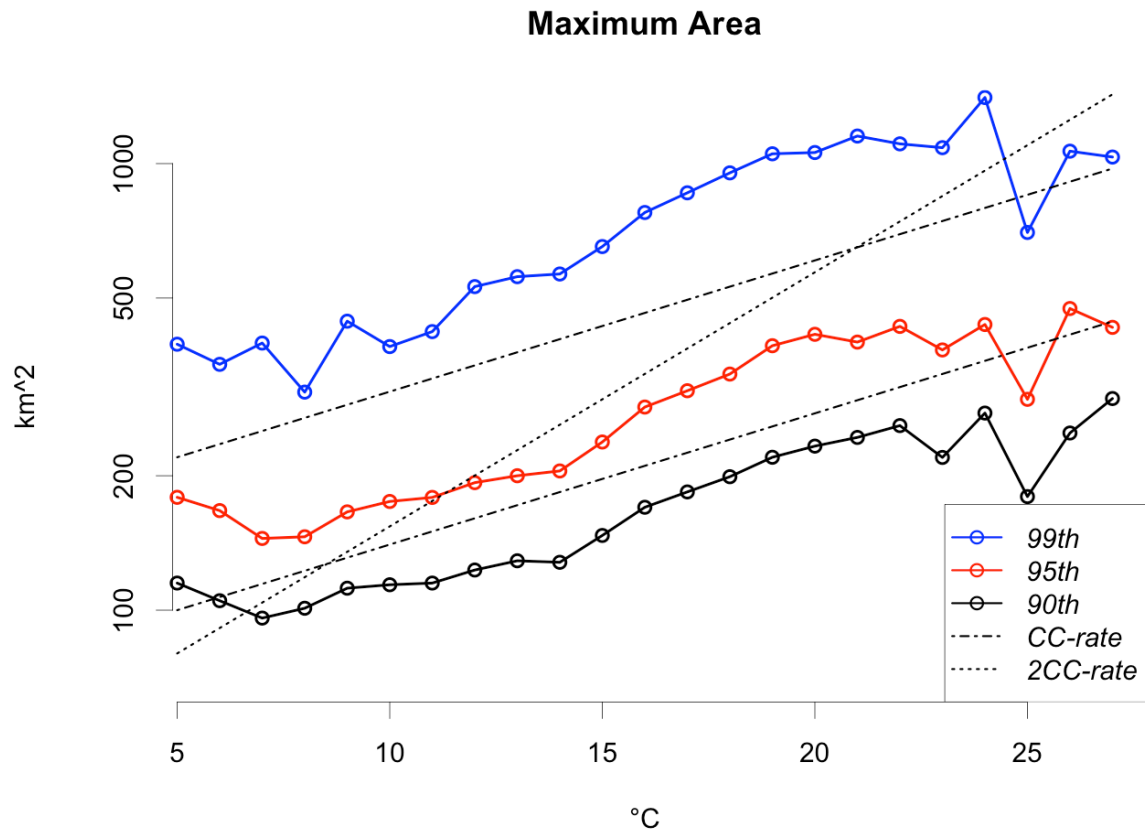


- Underestimation of mean intensity in CCLM 1 comparable to CCLM 2.8

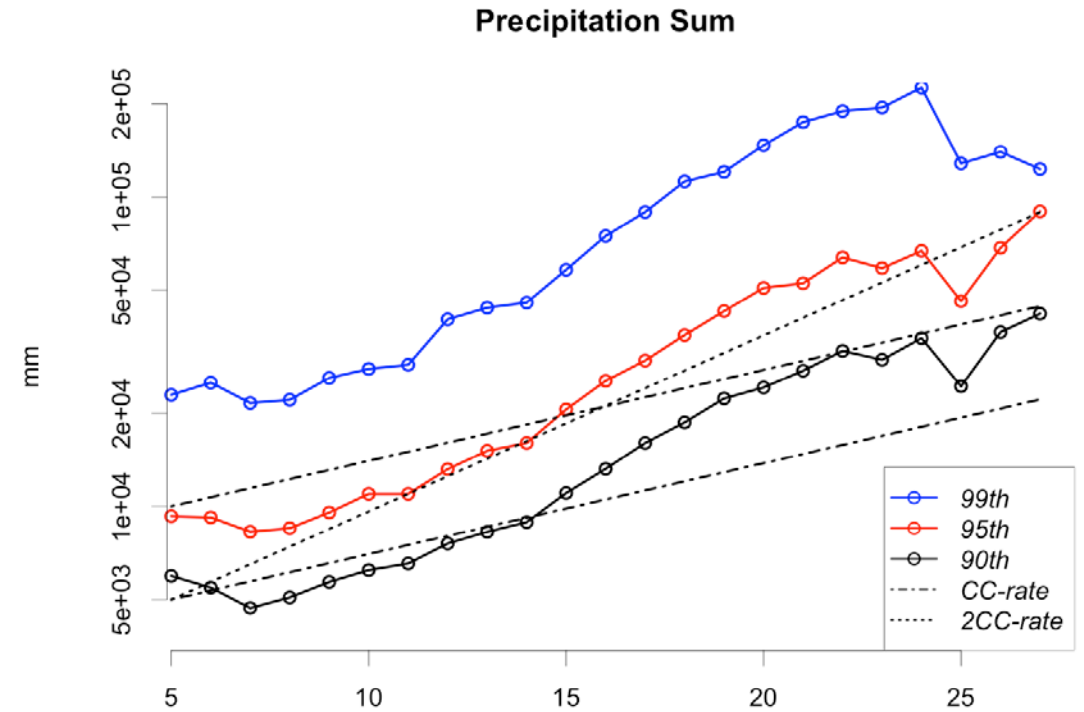
Temperature scaling of convective cells

- Temperature data: 157 DWD climate stations
- Each cell is assigned the daily mean temperature of closest station at origin



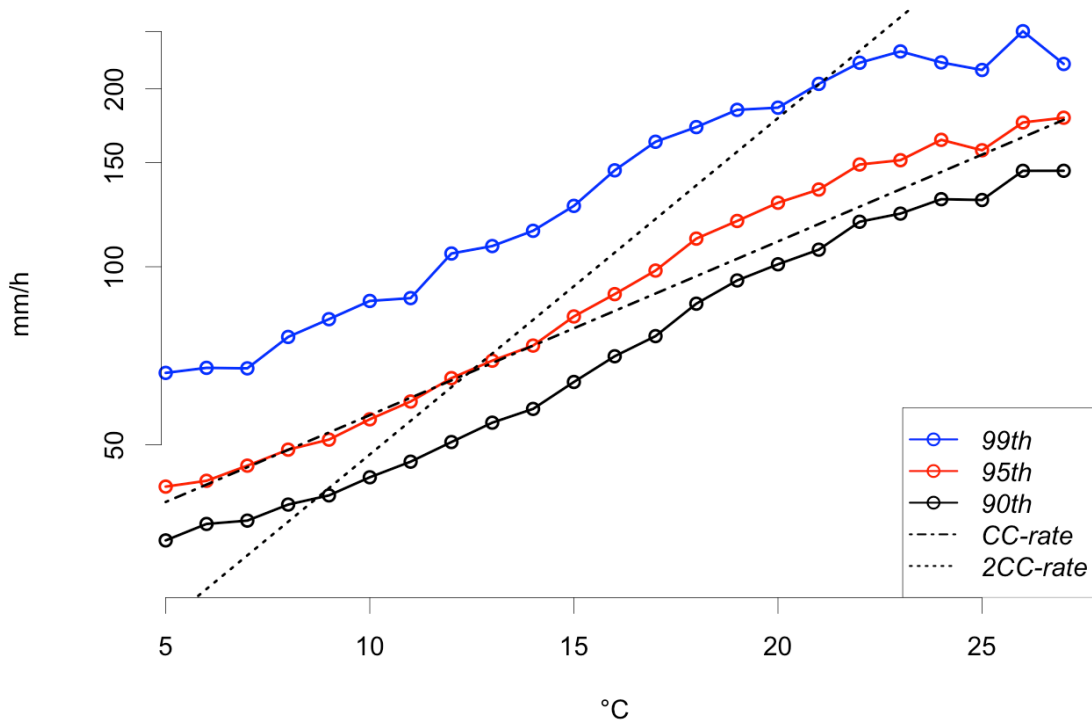


- Cell area scales close to the CC-rate at low temperatures



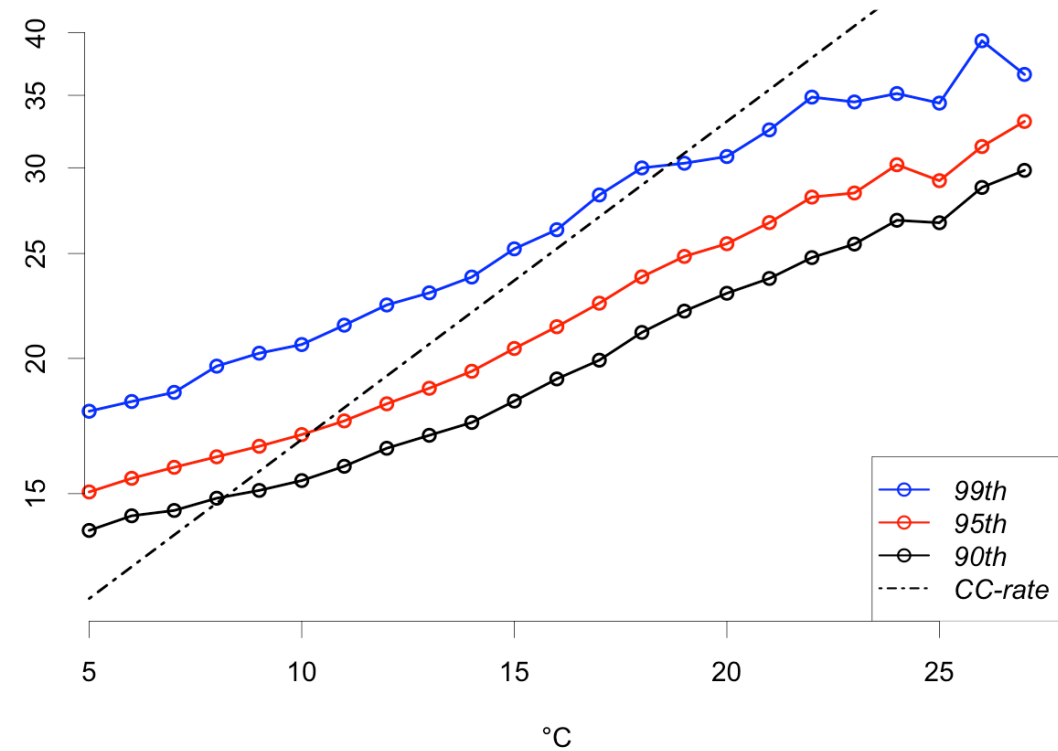
- Precipitation sum shows CC-scaling at low temperature ranges and 2*CC scaling between 15°C and 23 °C

Maximum Intensity



- Maximum intensity scales at rates close to CC

Mean Intensity



- Mean intensity scales at rates < CC

Summary

Evaluation of CCLM simulations:

- Model is capable to represent lifetime and area of convective cells realistically
- Afternoon Peak of convective activity is underestimated
- Precipitation intensity of convective cells are underestimated
- Using higher resolution and more sophisticated microphysics shows slight improvements

Temperature scaling of cell characteristics:

- Observations show a super-CC scaling of cell area and precipitation sum
- Further analysis necessary

Thank you for your attention!

References

Figures:

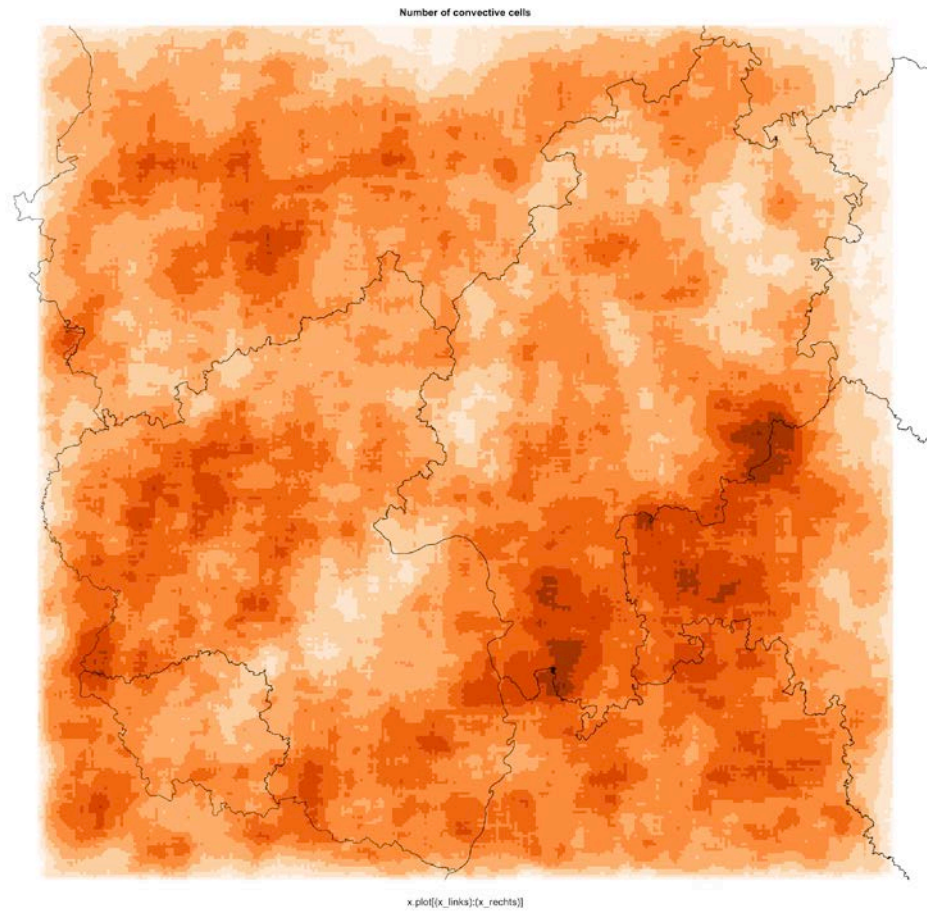
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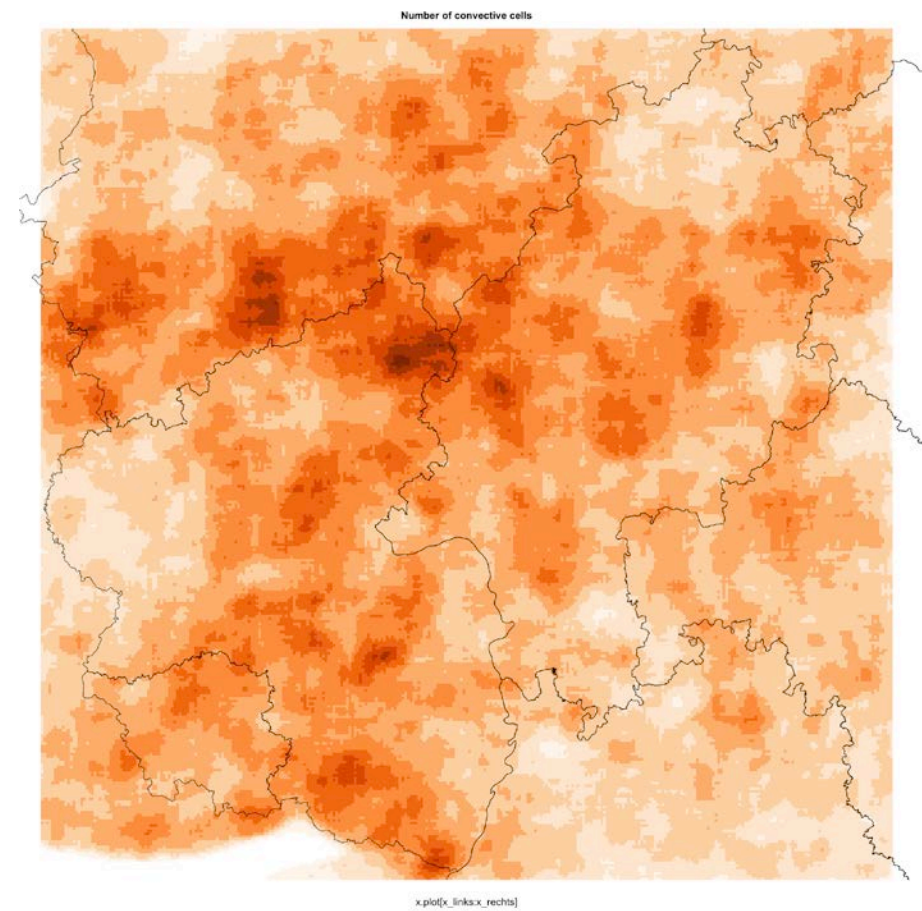
[3] ©Deutscher Wetterdienst, Abteilung Hydrometeorologie,
https://www.dwd.de/DE/leistungen/radolan/radarniederschlagsprodukte/radolankurzbeschreibung_pdf.pdf;jsessionid=062355FC67AE927CC4C147E3455BC21F.live21063?__blob=publicationFile&v=6

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Simulation



Radar