Correlation between Lightning Density and Precipitation Amount based on high-resolution Radar Measurements

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Motivation

- Many previous studies about thunderstorms are based on measurement data with spatial resolution of 1 km or worse.
- Verification of similar studies with high spatial resolution of 250 m precipitation data, based on X-band radar measurements.
- Do high temporal and spatial resolution provide additional knowledge?

Data Basis

The PATTERN X-Band Radar Network:

- **P**recipitation and **ATT**enuation **E**stimates from a high **R**esolution weather radar **N**etwork of the 4 X-band radars span a area of 60 km x 80 km, northwest of Hamburg, Germany (s. Fig. below)
- large area covered by at least two radars at the border and up to four radars in the center of the network (during the analysis period the western radar was offline)

LINET Lightning Detection Network:

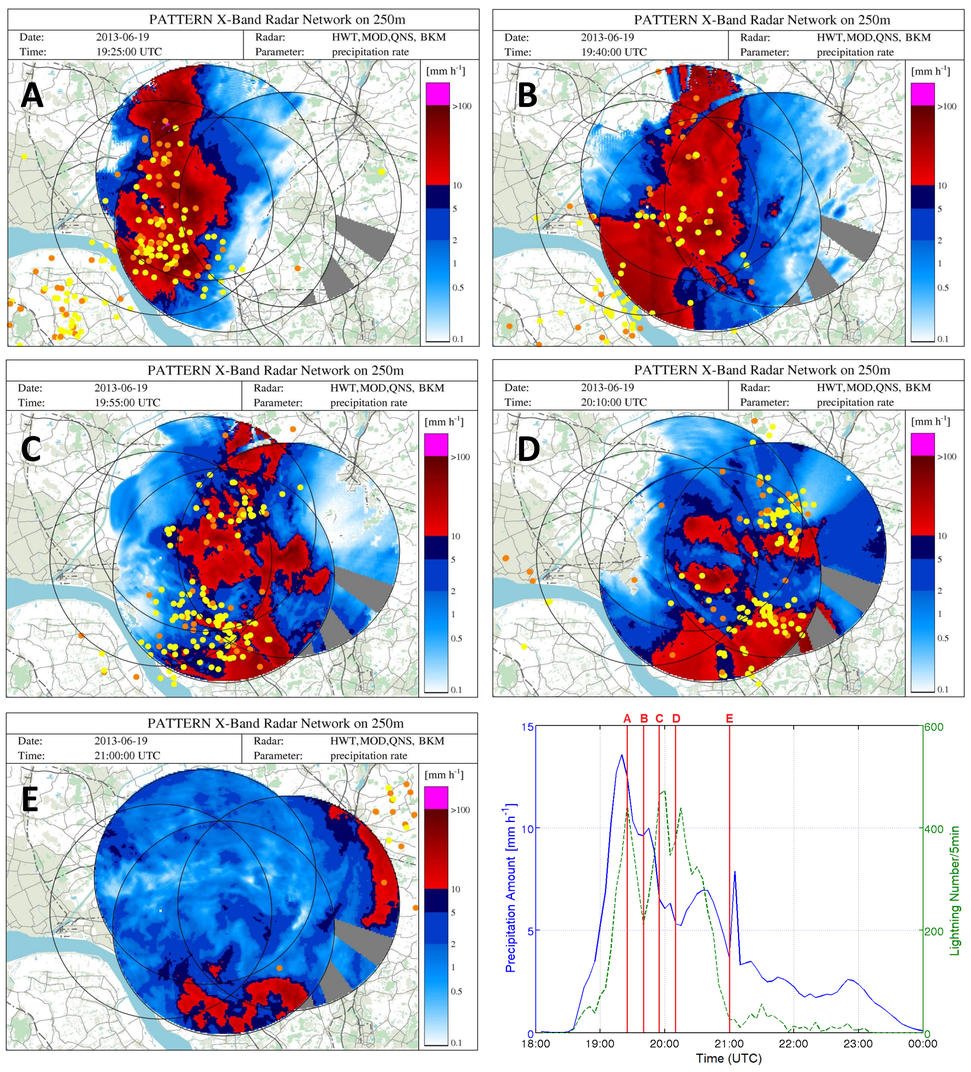
- Lightning data are from the lightning detection system LINET (high-precision lightning detection network) from nowcast GmbH.
- extensive European monitoring network
- Sensors measure in low frequency range electromagnetic radiation that is emitted by lightning.
- lightning distinction between inner-cloud (IC) and cloud-to-ground (CG)

X-Band Radar Network	Specifications
Time Resolution	30 s
Grid Resolution	250 m x 250 m
Longitudinal Range	60 km x 80 km

LINET	Specifications
Time Resolution	1 ms
Position Resolution	10 m
Position Accuracy	≤ 150 m

Thunderstorm – Statistical Description

The Event – June 19th, 2013



Time sequences of mean precipitation amount and cloud-ground lightning density

- main activity: 18:00 – 21:00 UTC
- highest lightning density: 20:00 UTC 473 lightning strikes in 5 min
- highest precipitation amount: 19:15 UTC with 14 mm h^{-1}
- correlation coefficient of 0.79

19:25 UTC (A)

- the storm reached its maximum intensity within a short time after entering the PATTERN area
- at the beginning, there was a high consistency of heavy rainfall greater than 10 mm h^{-1} and lightning distribution

19:40 UTC (B)

- strong rain band moved eastward
- lightning amount decreased, was still in the high rainfall activity

19:55 UTC (C)

- in the further course the rain band started dissolving
- lightning amount rose again
- lightning were separated into two groups, no longer in the same area as heavy rain

20:10 UTC (D)

- both lightning groups were shifted eastward
- rain band weakened further and dissolved into smaller precipitation cells

21:00 UTC (E)

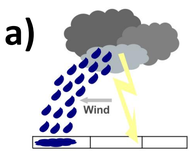
- thunderstorm moved to the northeast until it was outside of the PATTERN area
- the active thunderstorm cell was followed by a spatially extended, weaker precipitation (≤ 10 mm h^{-1})

Data Mapping

Form pairs of values from CG lightning and precipitation data.

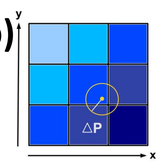
Falsification of values by pairing through:

a) drifting of precipitation due to wind
b) blur of the lightning position in the edge of the grid



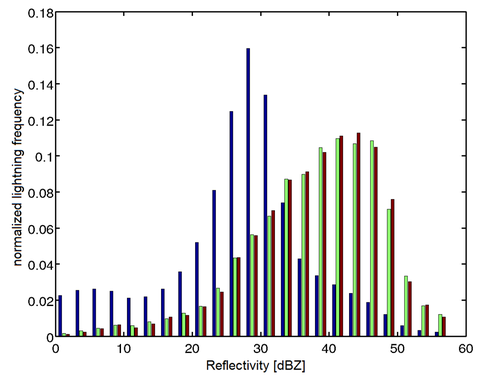
Two methods of pairing values:

1) each flash assign the corresponding precipitation from the cell of its origin coordinates (direct mapping)
2) considering the adjacent cells, each flash fits into the cell of the highest precipitation value (9-cell mapping)



Distribution	N	μ [dBZ]	σ [dBZ]	dBZ_{max} [dBZ]
direct mapping (green)	7445	9.66	37.68	41.25 ± 1.25
9-cell mapping (red)	7283	9.46	37.81	43.37 ± 1.25
total precip. (blue)	17292508	10.63	26.83	28.75 ± 1.25

- left skewed distribution at occurrence of flashes (green and red)
- no significant differences between the two mapping methods
- total rainfall distribution (blue) almost symmetrical shape



➢ **distributions (green and red) are specific for lightning**
➢ **lightning appeared more frequently in heavy rain**

Spatial and Temporal Correlation

Relationship between CG lightning from the entire PATTERN area and the:

a) total rainfall from the PATTERN area

- large number of lightning strikes (> 100/5 min) at precipitation rates greater than 5 mm h^{-1}
- little rainfall (< 5 mm h^{-1}) has low to no lightning activity (< 100/5 min)
- correlation coefficient of 0.79

➢ **no statement regarding the spatial context**

b) precipitation from the cells in direct mapping

- wider spread
- correlation coefficient of 0.15

➢ **lightning and precipitation are not spatially related**

➢ **high lightning activity requires high rainfall activity**

Investigation of the temporal shift of both maxima with spatial and temporal moving averaging intervals:

- negative time shift: lightning field associated with past precipitation field
- positive time shift: lightning field assigned to future precipitation field
- for large average intervals (> 10 min; > 10 km x 10 km) similar results as for the whole area (r ≈ 0.79)
- as the storm is not constant over time function no. 1, no. 2 and no. 3 are unsuitable

➢ **the larger the spatial averaging interval and averaging times (coarse resolution), the greater the correlation coefficient**

➢ the highest correlated to precipitation fields **lightning fields are 6.5 to 8 min prior to the rain fields**

Color	Fct.	avg. Area	avg. Time	r_{max}	$\Delta t(r_{max})$
orange	8	1 km x 1 km	5 min	0.23	+7, +7.5
red	7	2.5 km x 2.5 km	5 min	0.37	+7, +7.5
purple	6	5 km x 5 km	5 min	0.46	+6.5
dark blue	5	5 km x 5 km	10 min	0.50	+7
light blue	3	5 km x 5 km	60 min	0.63	+1, +1.5
light green	**4**	**10 km x 10 km**	**5 min**	**0.59**	**+8**
dark green	2	20 km x 20 km	5 min	0.79	+12.5
black	1	20 km x 20 km	60 min	0.90	+4

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PATTERN

nowcast