High-Resolution Precipitation Product:

Combining C-Band and Local X-Band Radar Data – A Concept for Hamburg

Rain Gain:

International Local Government Conference on Surface Water Flooding

London, GB

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University of Hamburg

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

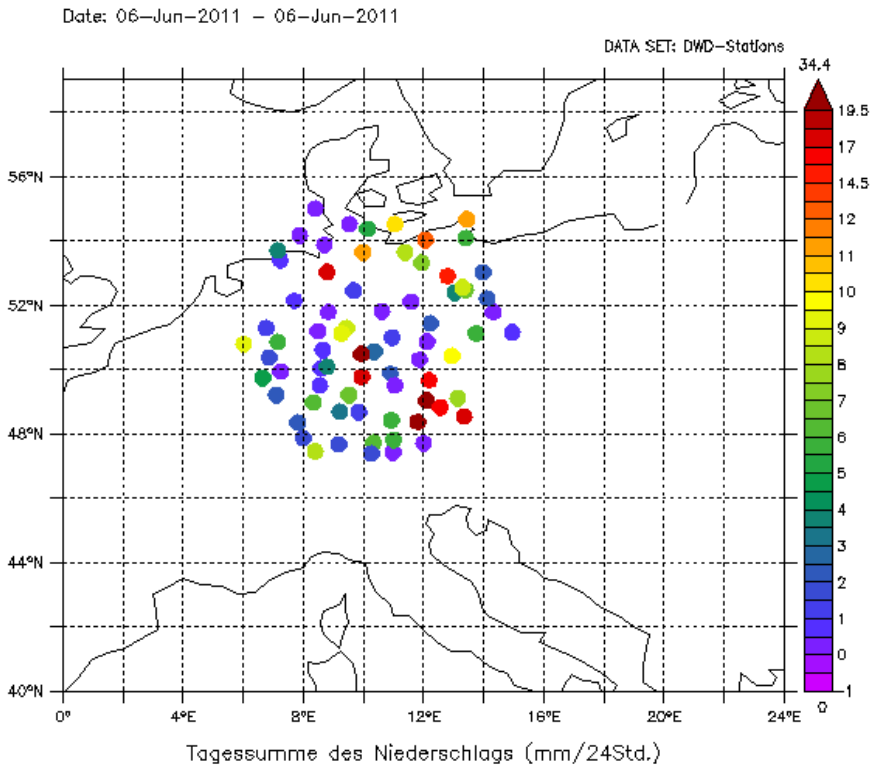
Max-Planck-Institut für Meteorologie

Outline

- **Motivation:**
  - Why do we need precipitation estimates from X-band radar for rainfall-runoff simulation?
- **Single X-band radars:**
  - X-band radars as magnifying glass in urban areas
- **X-band radar network:**
  - What benefits do we get from multiple coverage?
  - Can micro rain radars improve precipitation estimates from X-band radars?
- **Combination** of X-band, C-band and micro rain radars
- Possible **applications** in hydrology (a concept)

Motivation

Rain event June 6th, 2011



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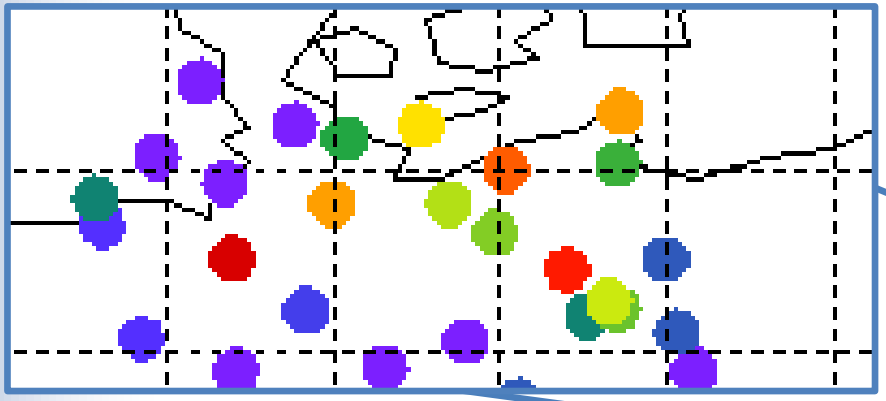

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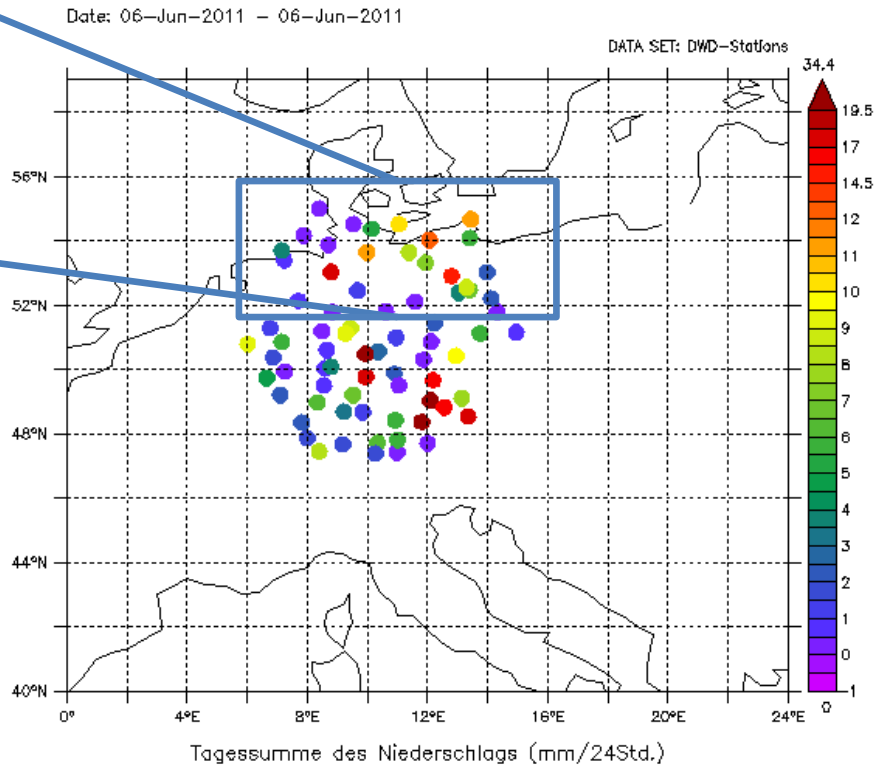

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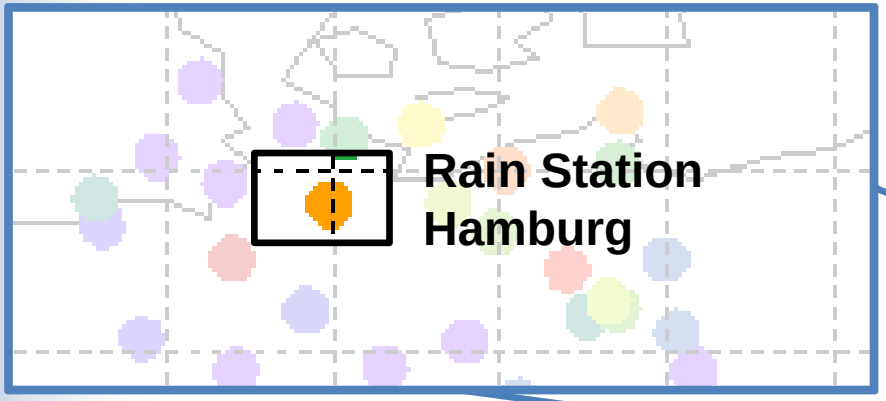

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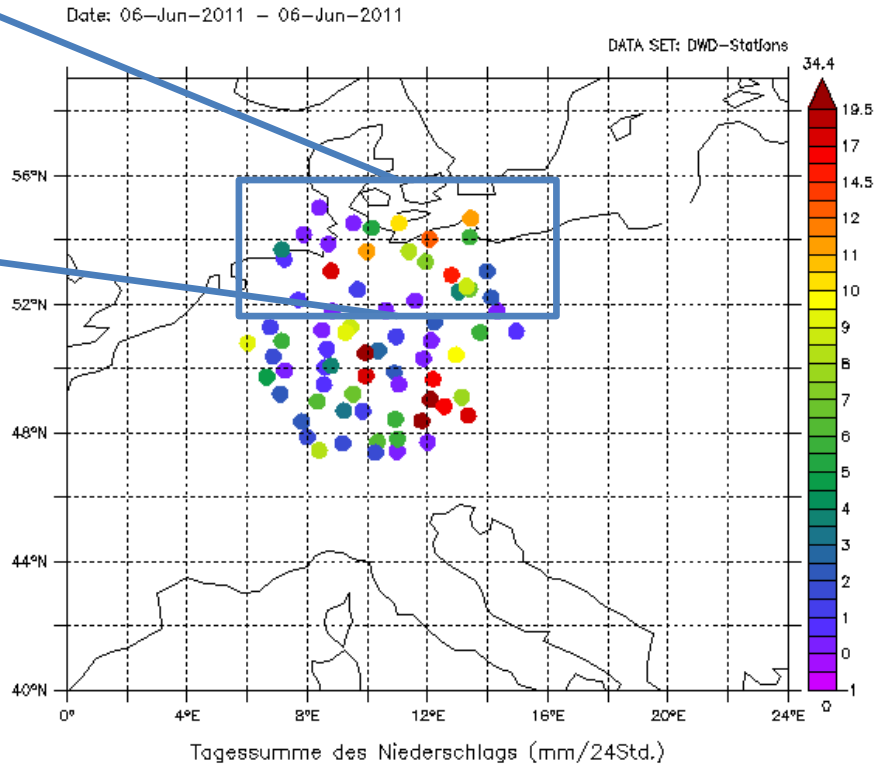
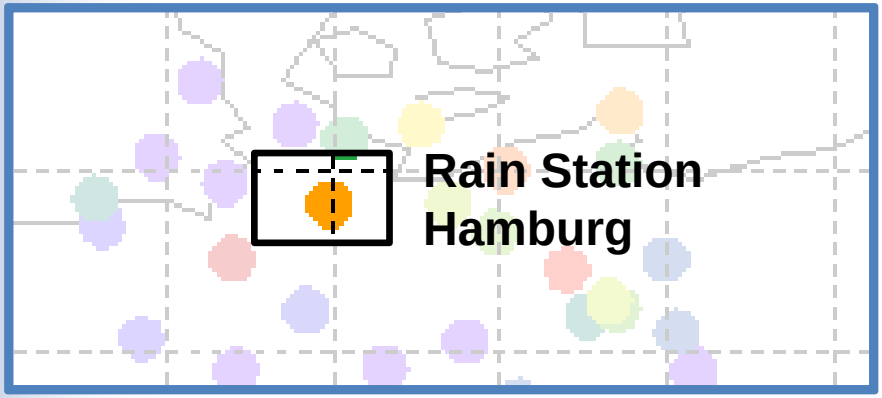


DWD rain station at Hamburg airport:

~11 mm/day

Motivation



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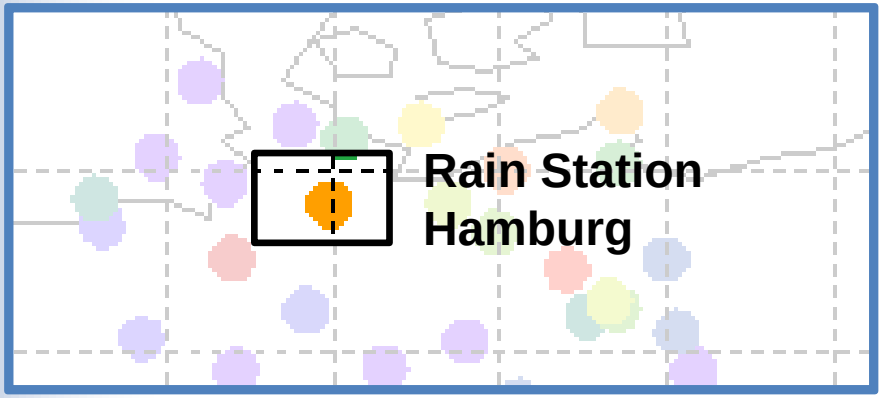
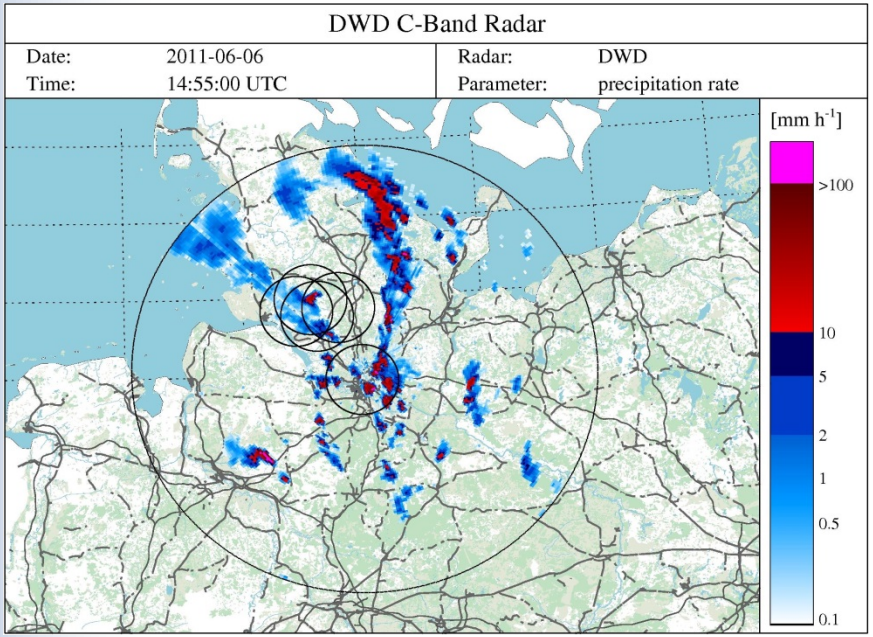
©dapd

Motivation





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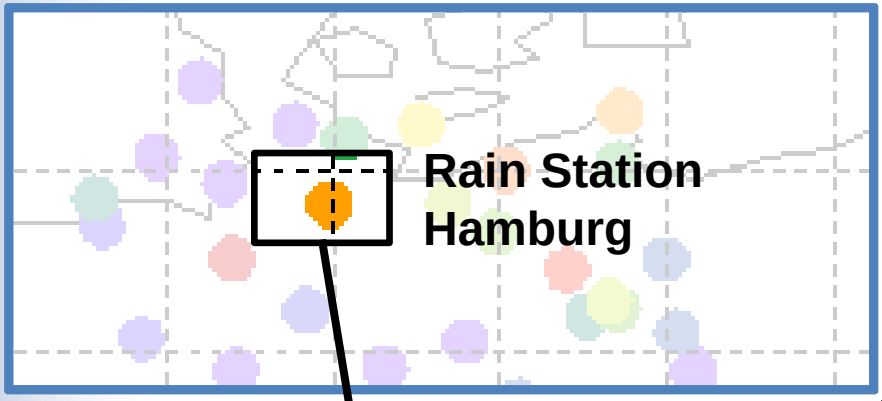

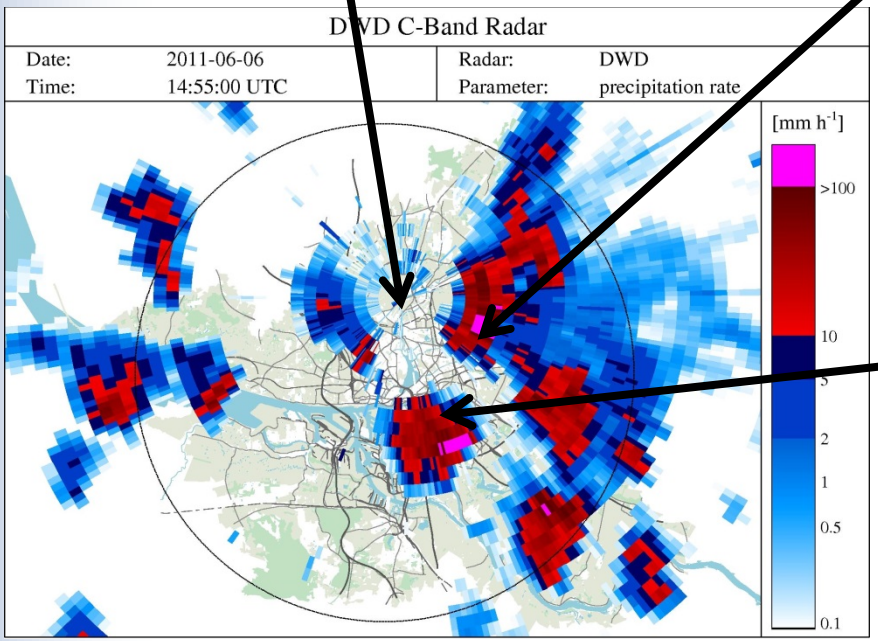

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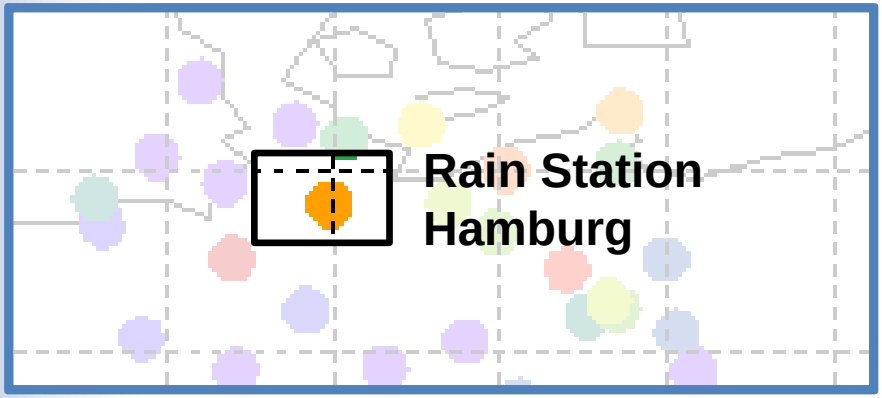
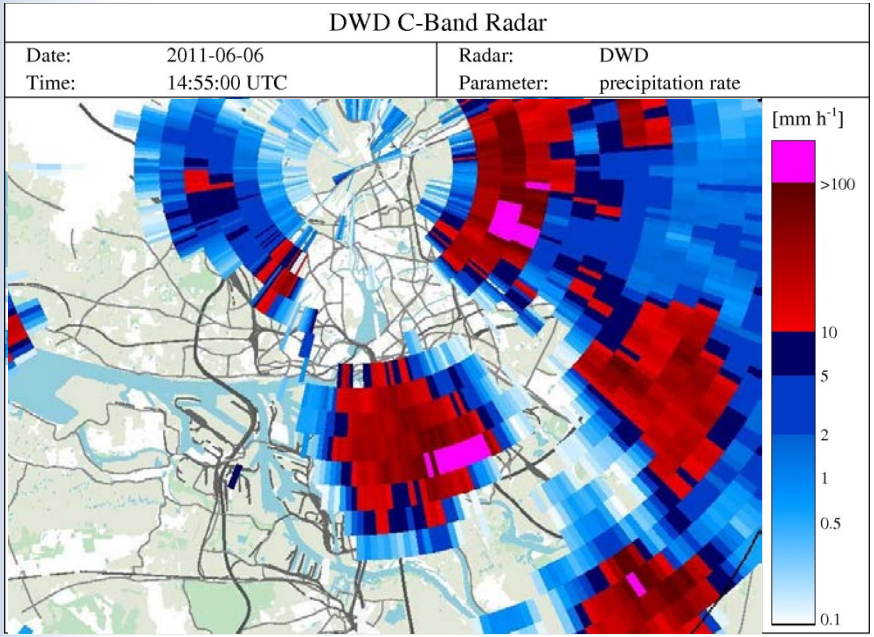




Is 1 km spatial resolution and 5 min temporal resolution sufficient for rainfall-runoff simulation in urban areas?

C-band vs. X-band

	C-band radar	Single X-band radar
Range	180 km	20 km

C-band vs. X-band

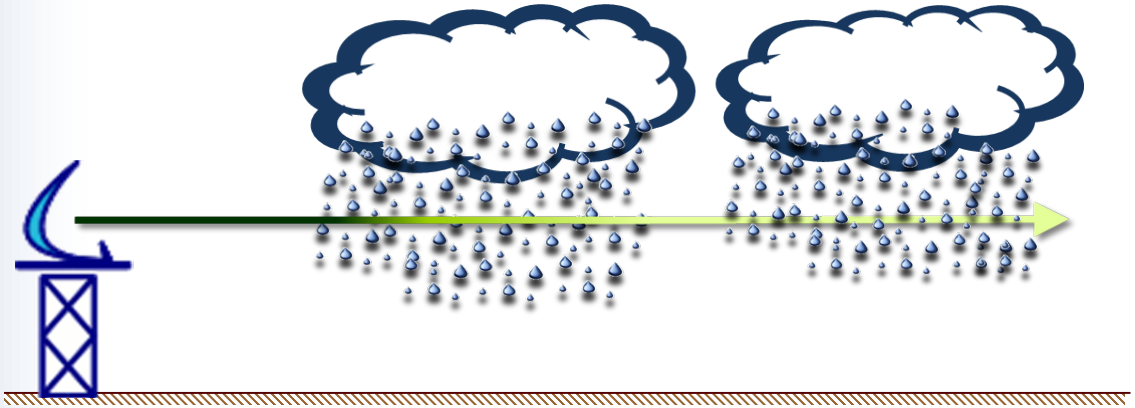
	C-band radar	Single X-band radar
Range	180 km	20 km
Resolution	➢ 1 km in range ➢ 5 min in time ➢ 1° in azimuth	➢ 60 m in range ➢ 30 s in time ➢ 1° in azimuth

C-band vs. X-band

	C-band radar	Single X-band radar
Range	180 km	20 km
Resolution	✗	✓
Costs	➢ > 2.000.000 €	➢ 60.000 € (including PC and tower)

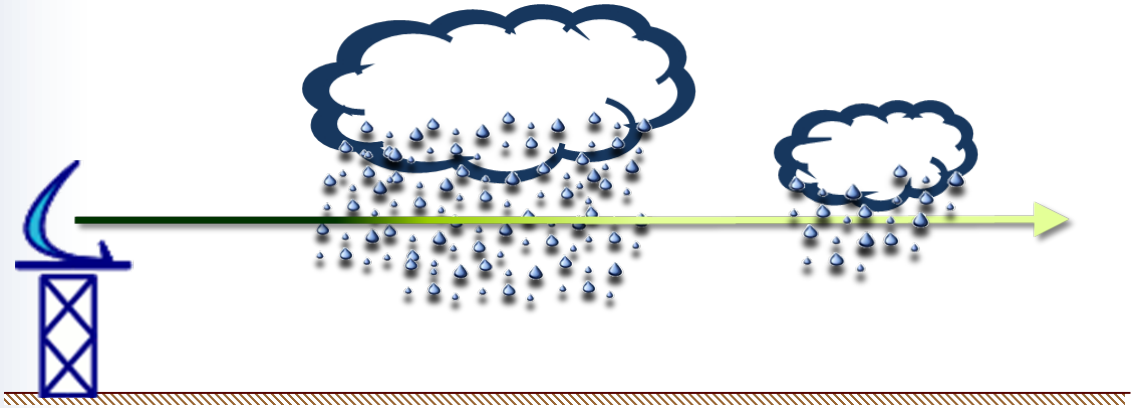
C-band vs. X-band

	C-band radar	Single X-band radar
Range	180 km	20 km
Resolution	✗	✓
Costs	✗	✓
Attenuation	➢ Small effect of attenuation	



C-band vs. X-band

	C-band radar	Single X-band radar
Range	180 km	20 km
Resolution	✗	✓
Costs	✗	✓
Attenuation	➢ Small effect of attenuation	➢ Strongly affected by attenuation

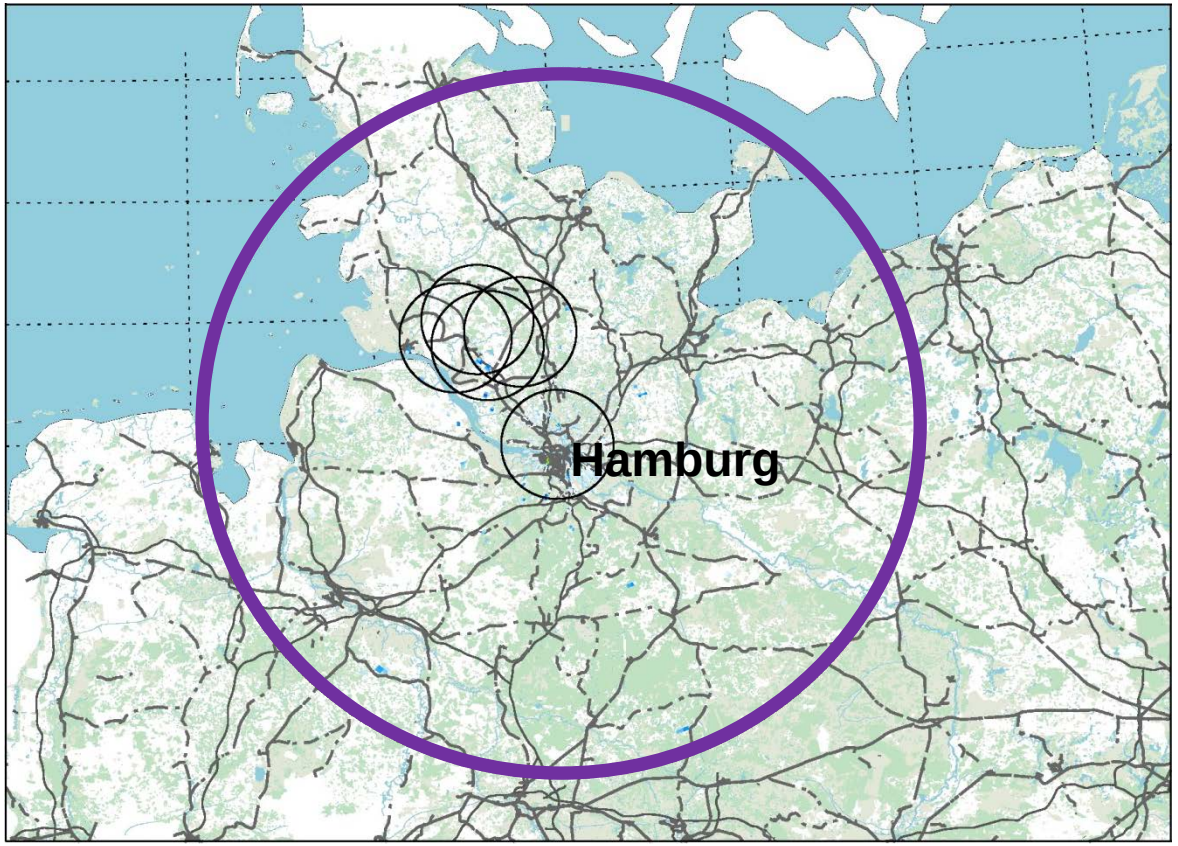


C-band vs. X-band

	C-band radar	Single X-band radar
Range	180 km	20 km
Resolution	✗	✓
Costs	✗	✓
Attenuation	✓	✗
Doppler	✓	✗
Dual-Polarization	✓ ✗	✗

Radar coverage in Northern Germany

- **1 C-band radar (DWD)**
  time resolution: 5 min
  range resolution: 1 km
  azimuth resolution: 1°
  maximum range: 180 km



Radar coverage in Northern Germany

- **1 C-band radar (DWD)**
  time resolution: 5 min
  range resolution: 1 km
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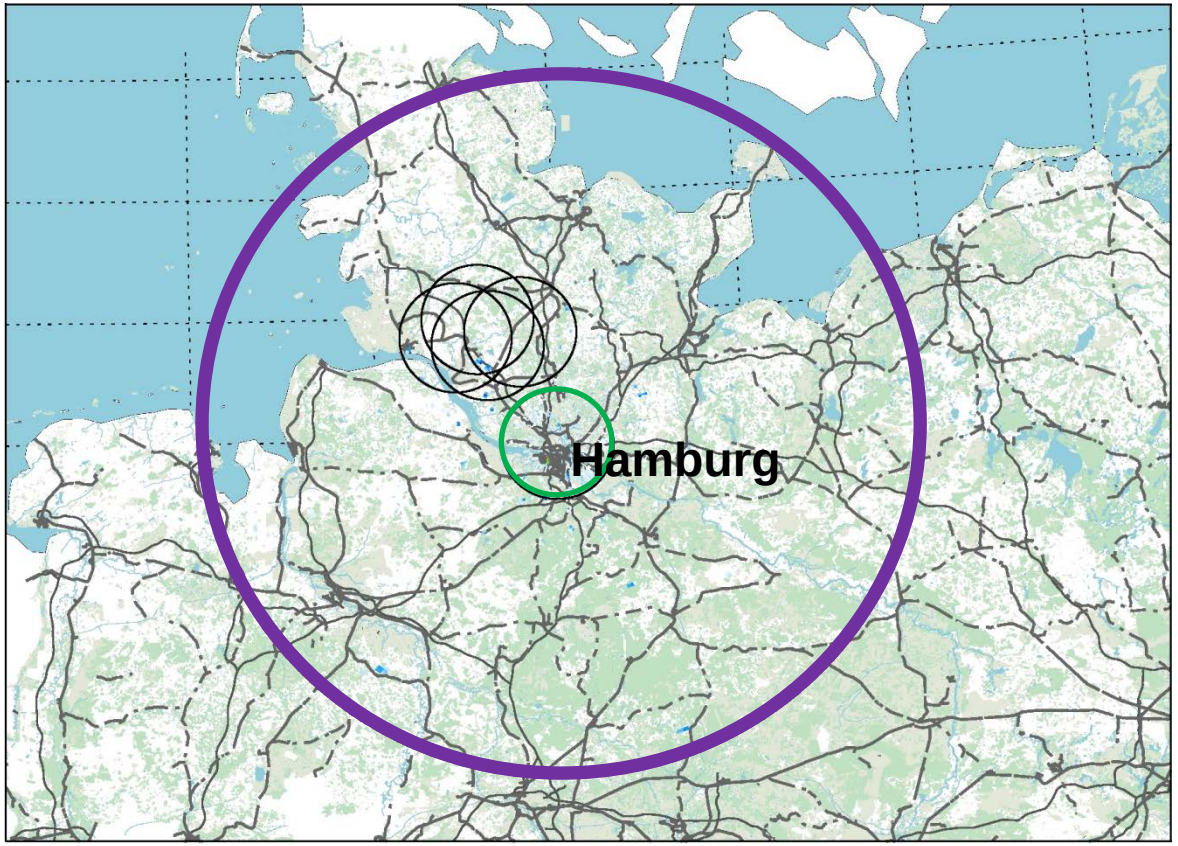
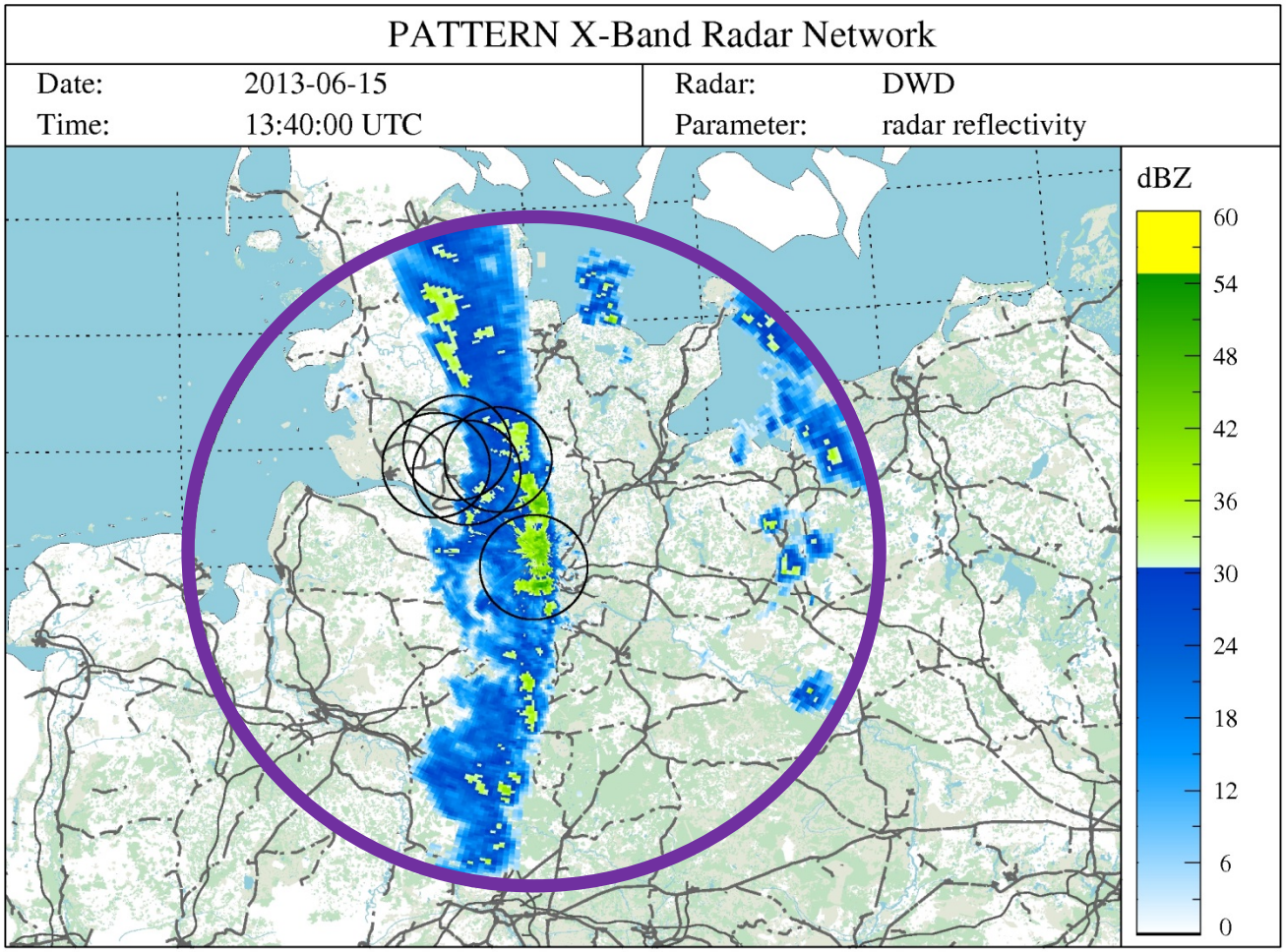
  maximum range: 180 km

- **1 X-band radar (Hamburg)**
  time resolution: 30 s
  range resolution: 60 m
  azimuth resolution: 1°
  maximum range: 20 km



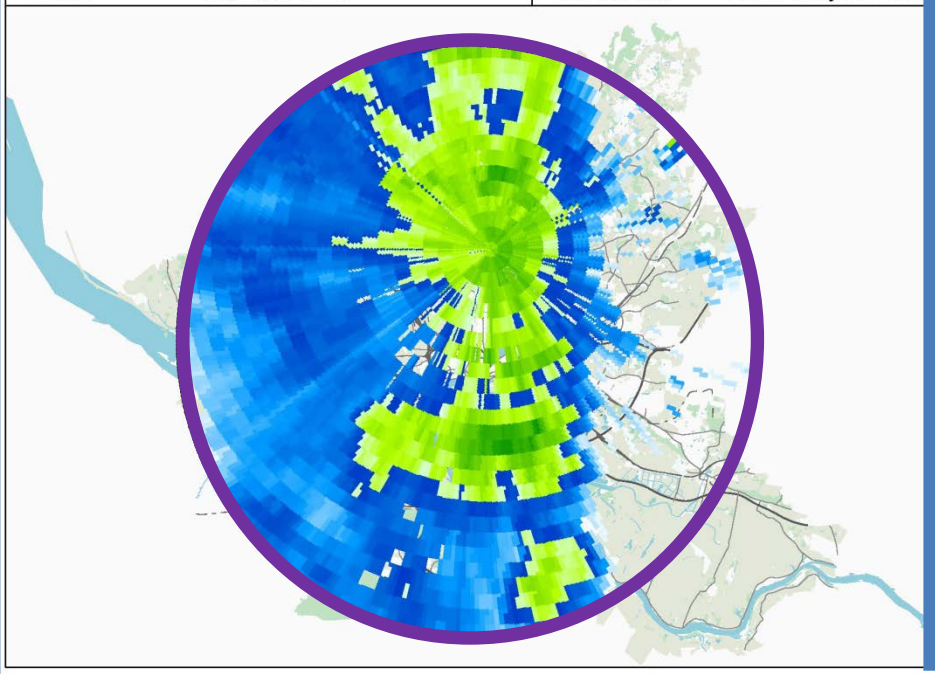
C-Band Radar

- **C-band radar**
  range = 180 km
  resolution = 1 km



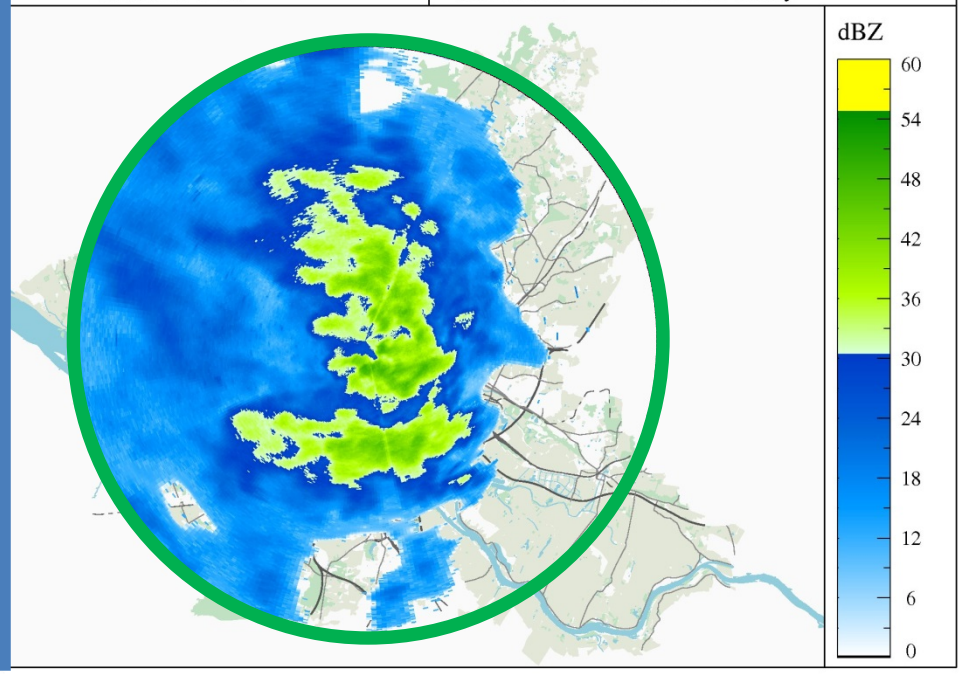
Combination of C-band and single X-band radar

C-Band



range = 180 km
resolution = 1 km

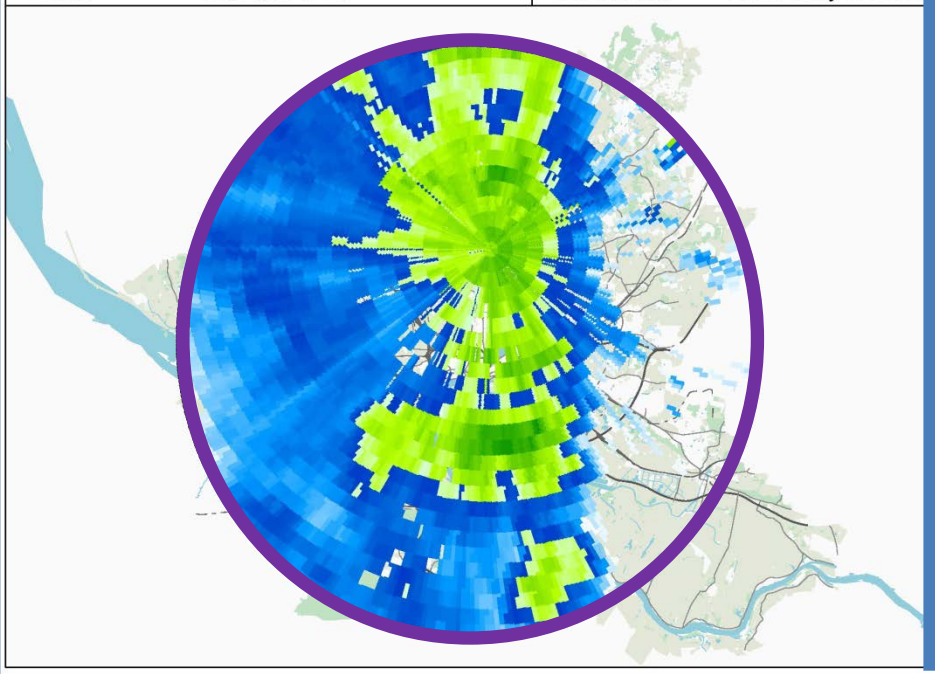
X-Band



range = 20 km
resolution = 60 m

Combination of C-band and single X-band radar

C-Band



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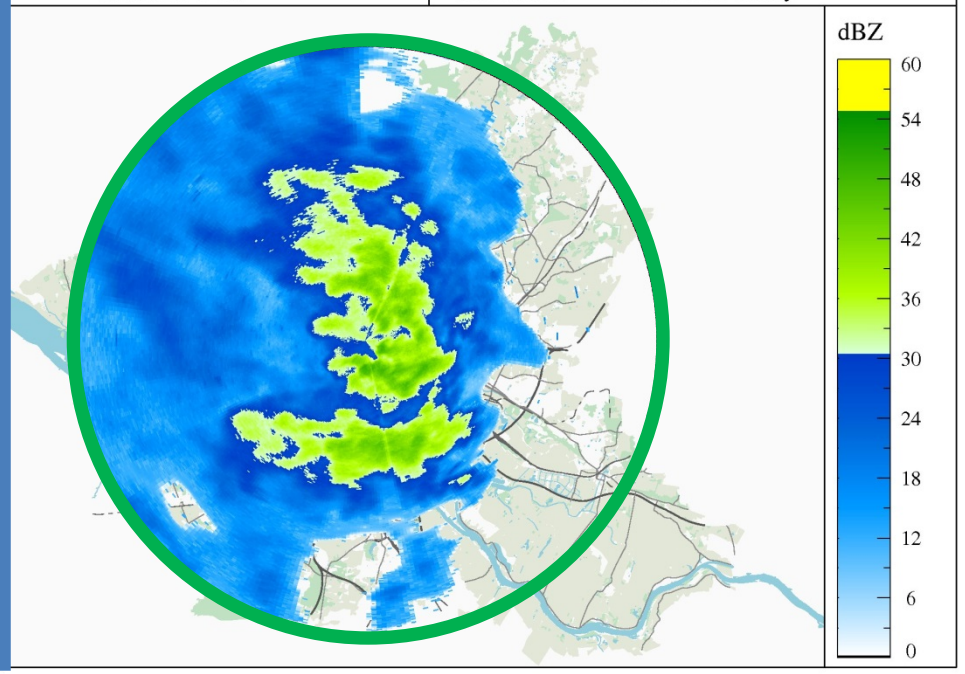
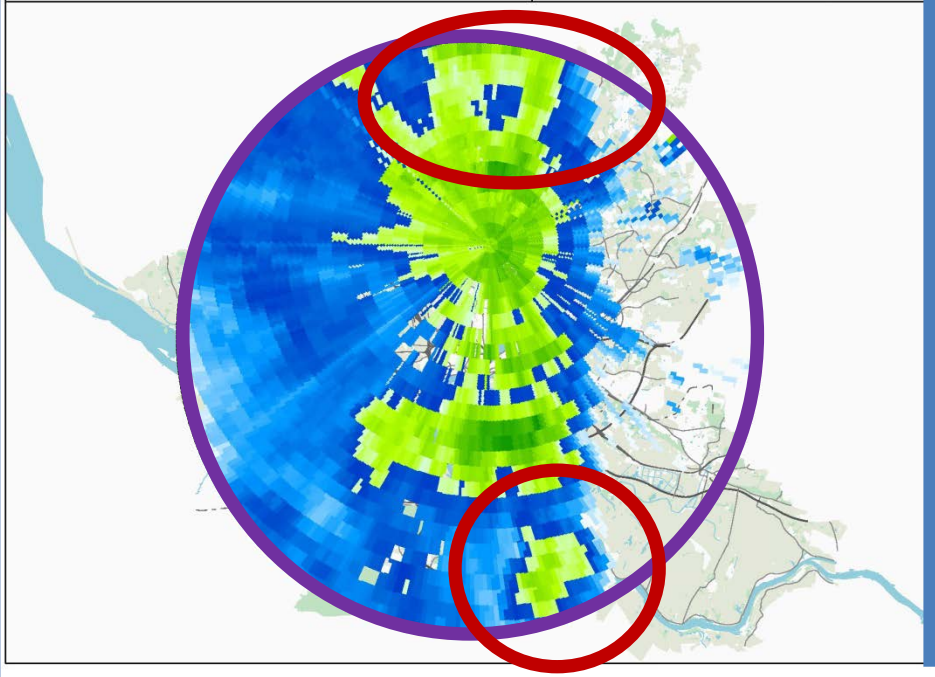


- Good agreement in spatial structure with higher resolution

Combination of C-band and single X-band radar

C-Band



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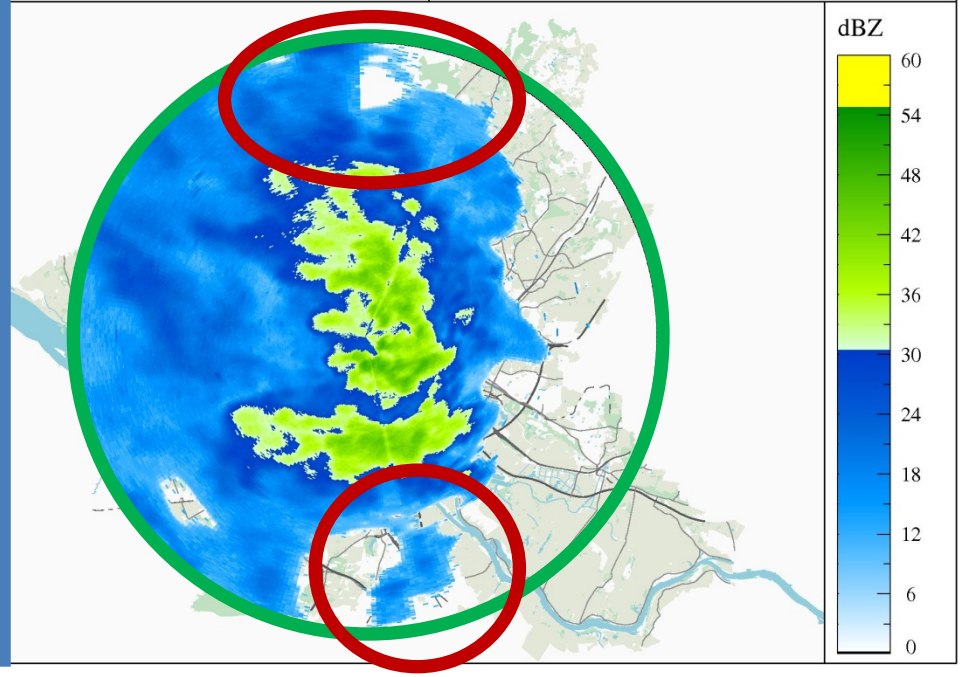
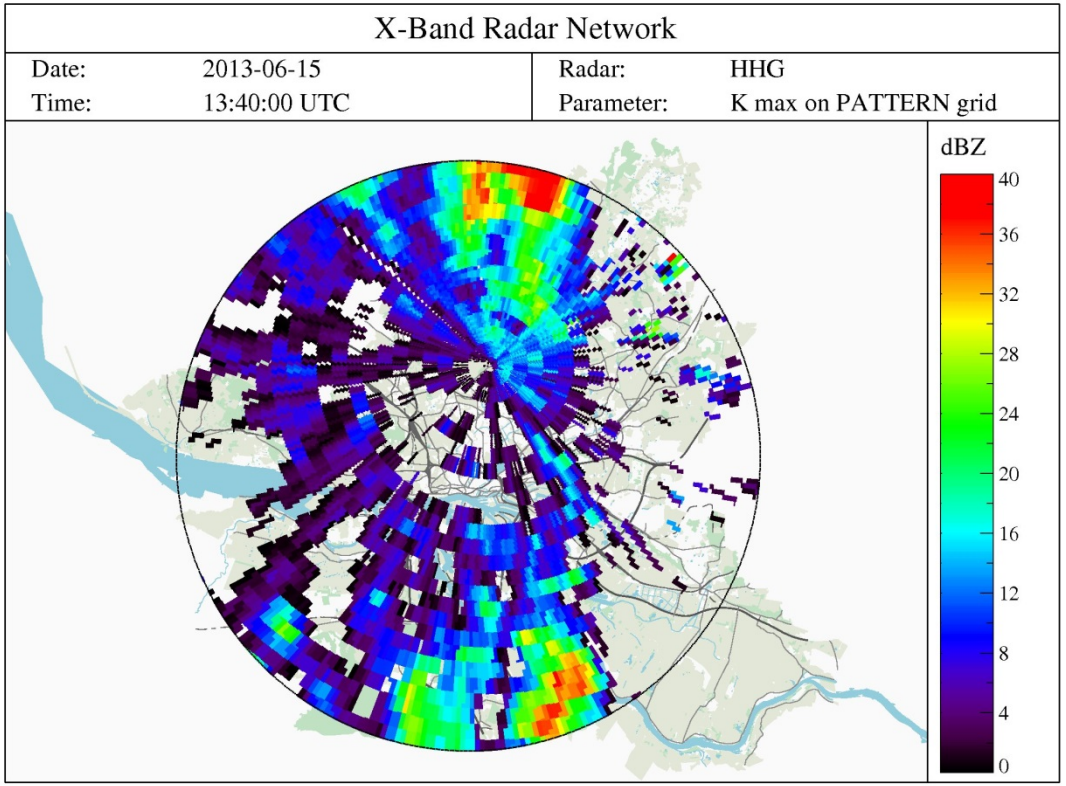


- X-band radar highly attenuated by liquid water

Combination of C-band and single X-band radar

Using the ratio of reflectivities of C- and X-band radars for attenuation correction:

$$K_{max} = 10\log\left(\frac{Z_{C-band}}{Z_{X-band}}\right)$$



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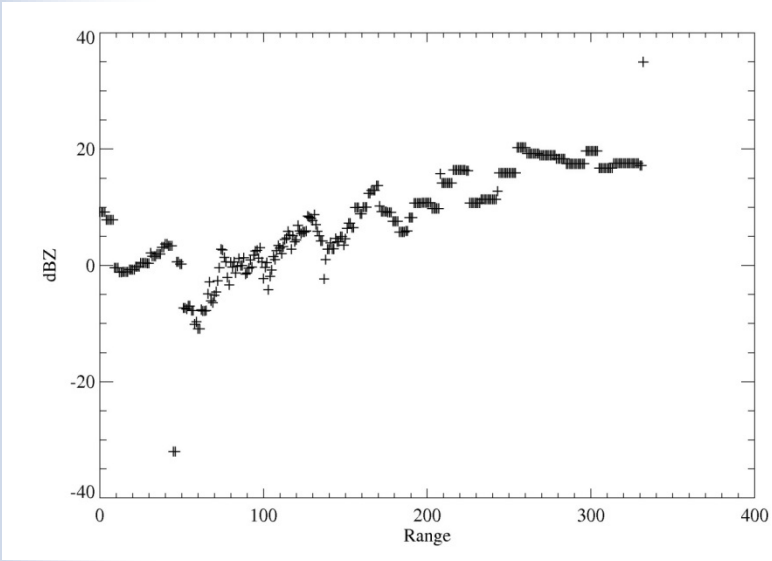

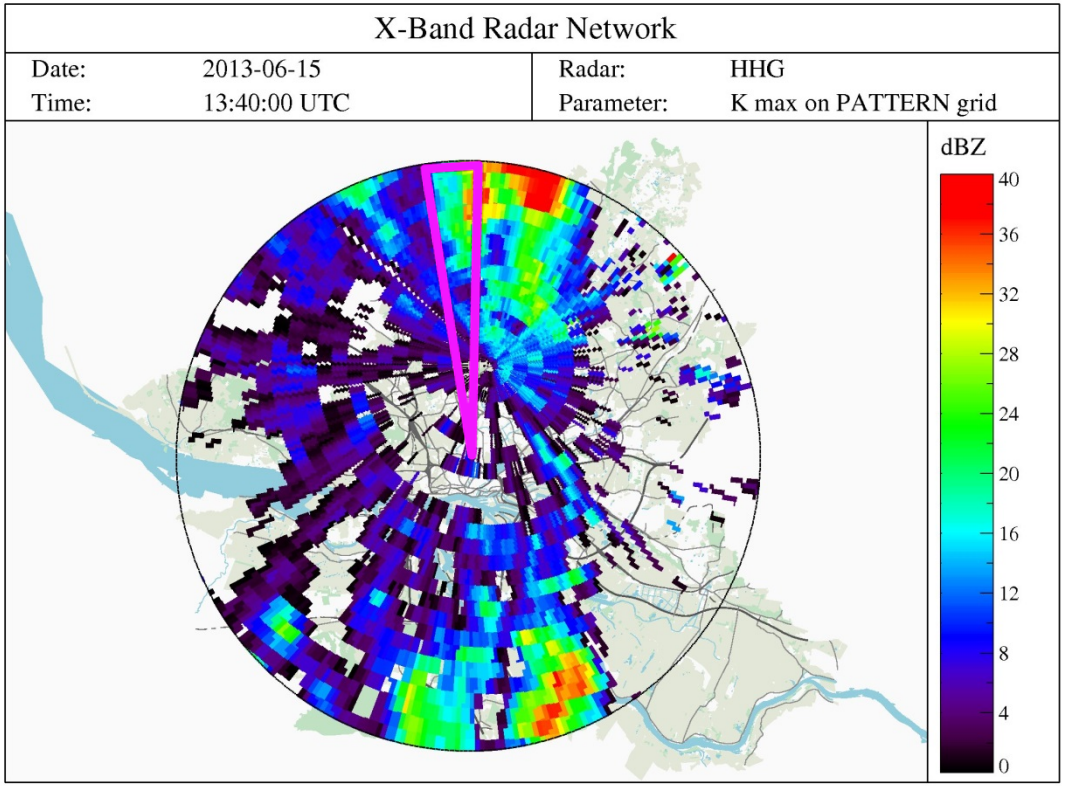

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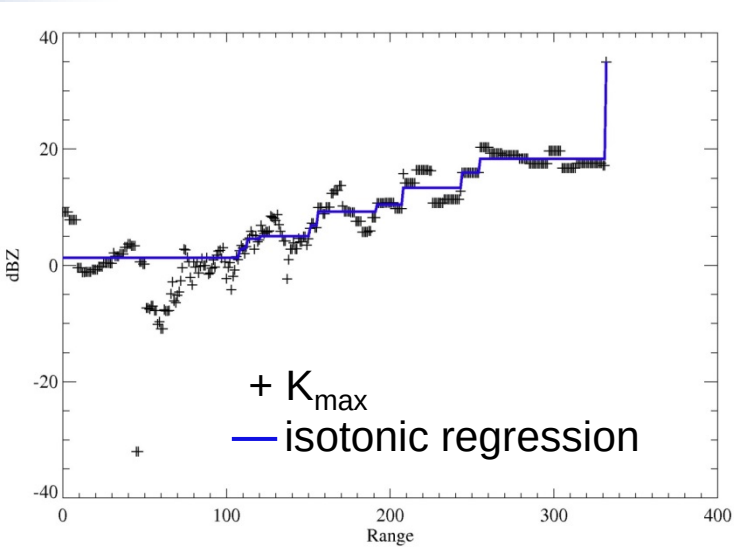

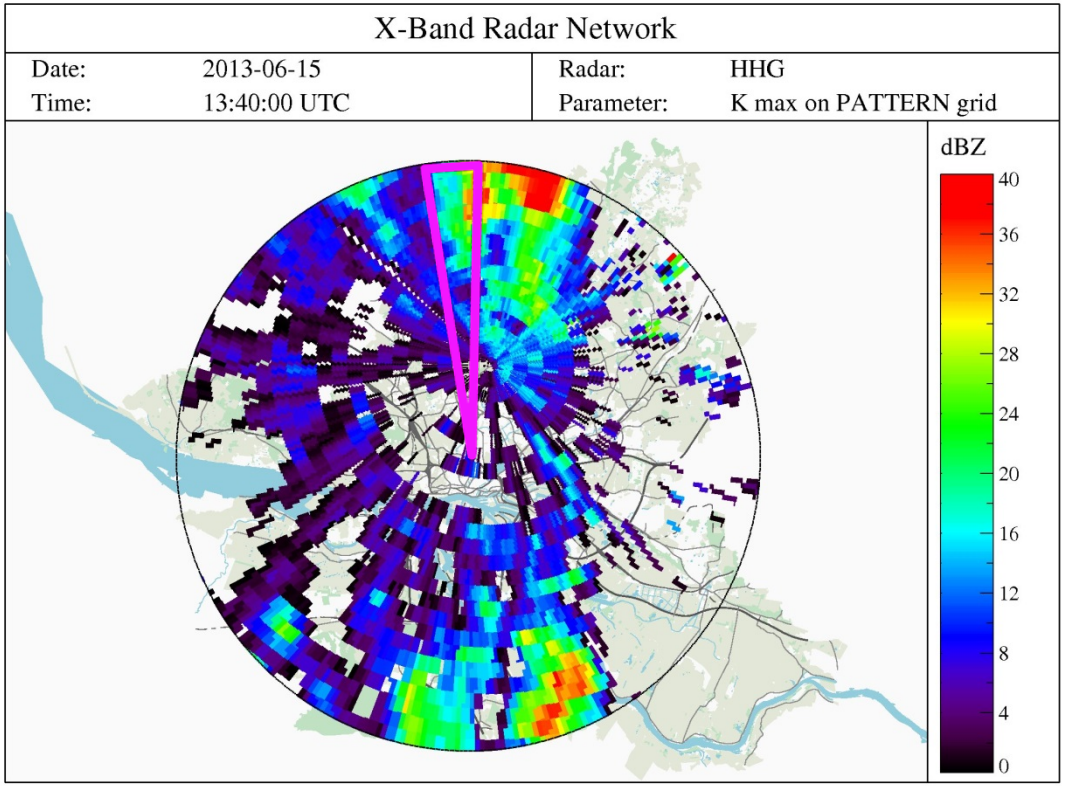

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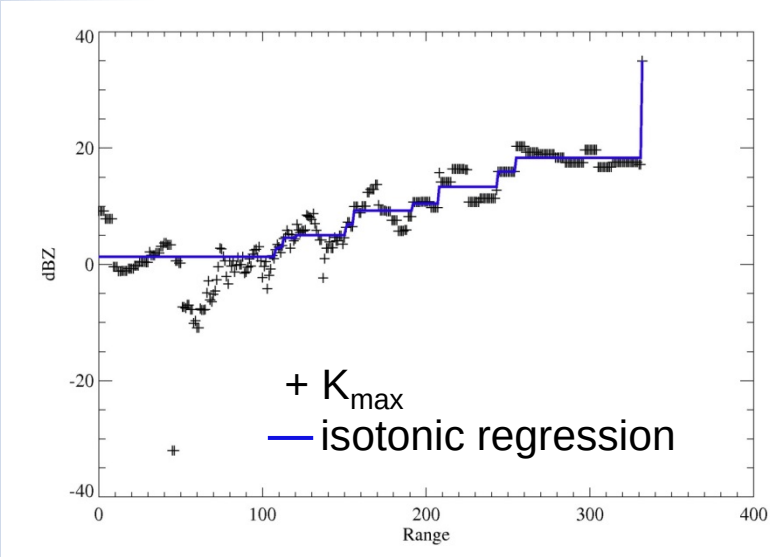

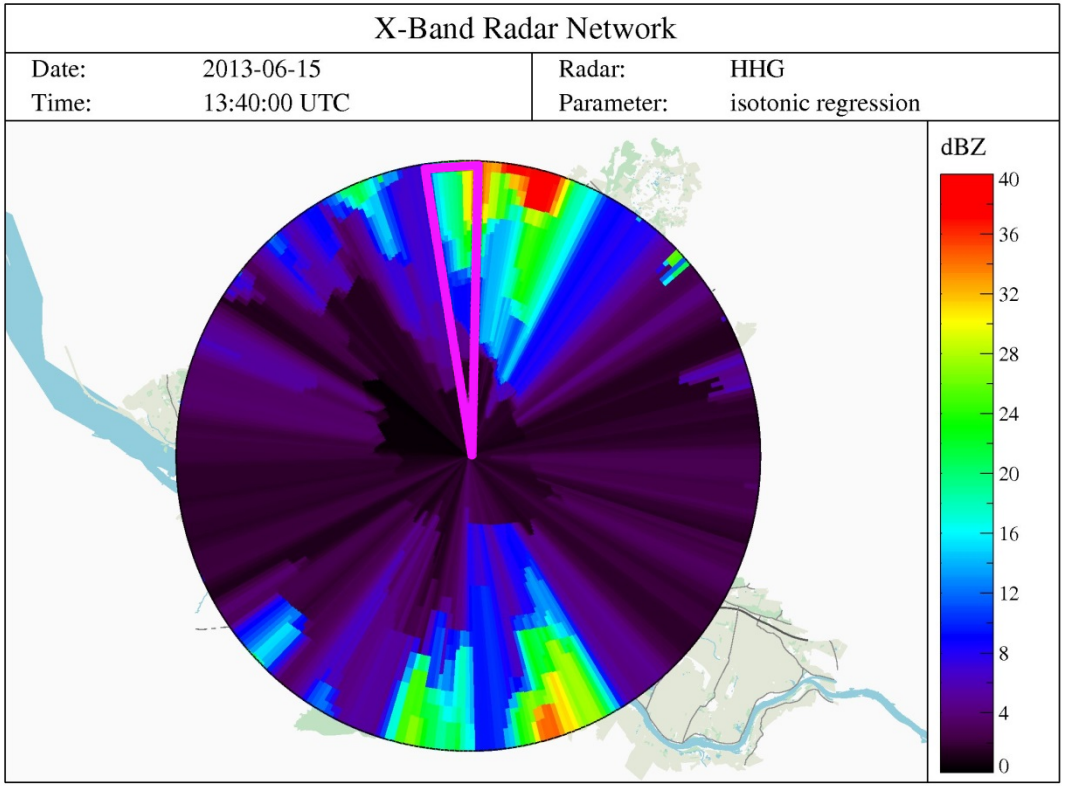

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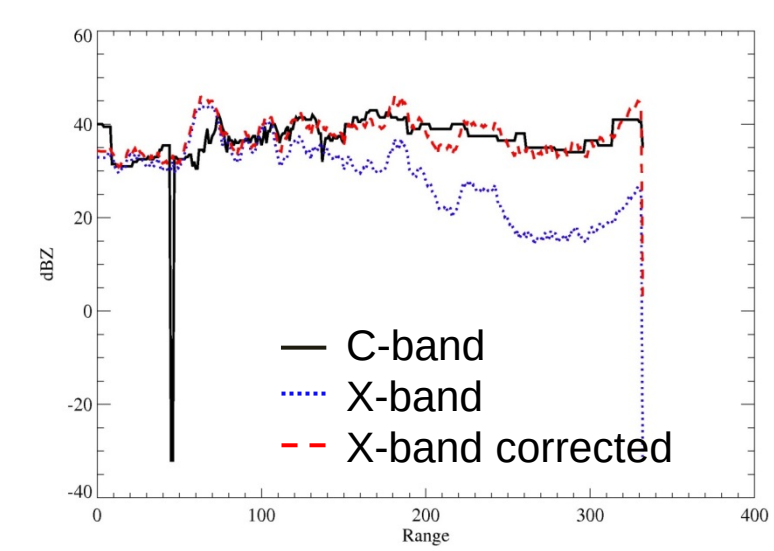

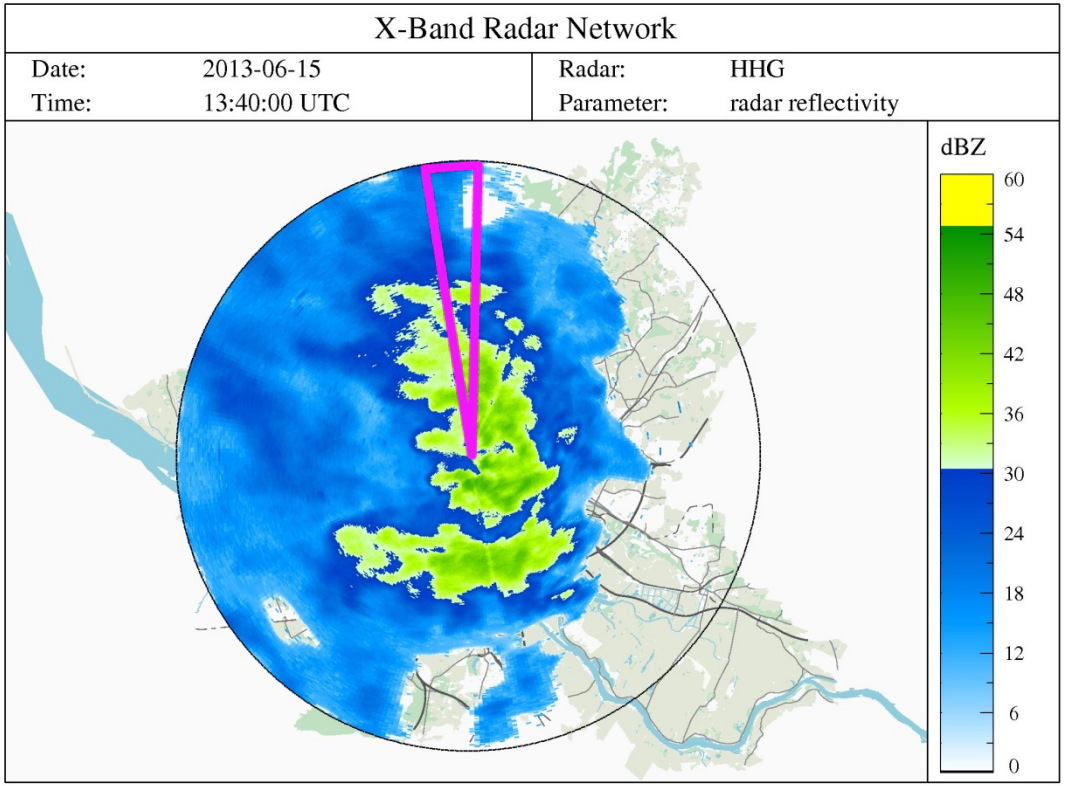

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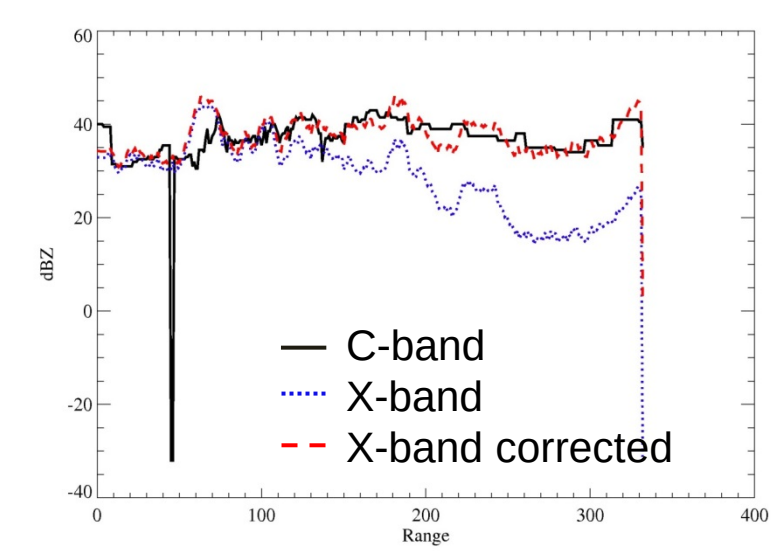
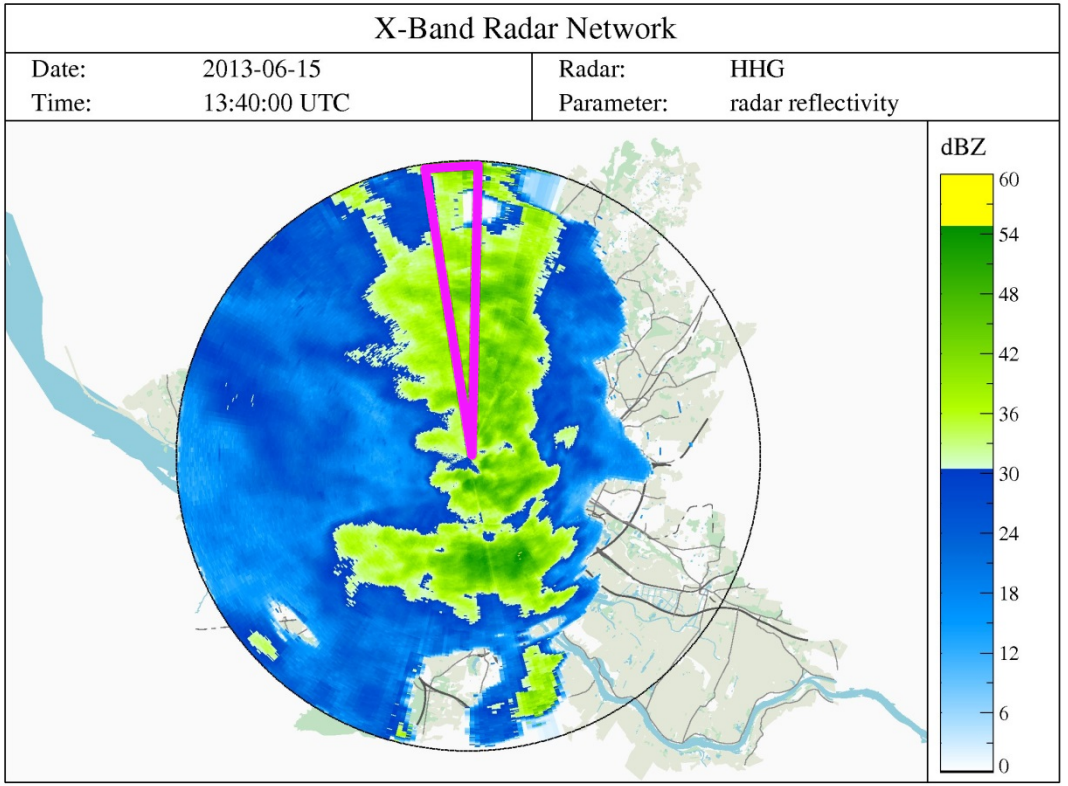
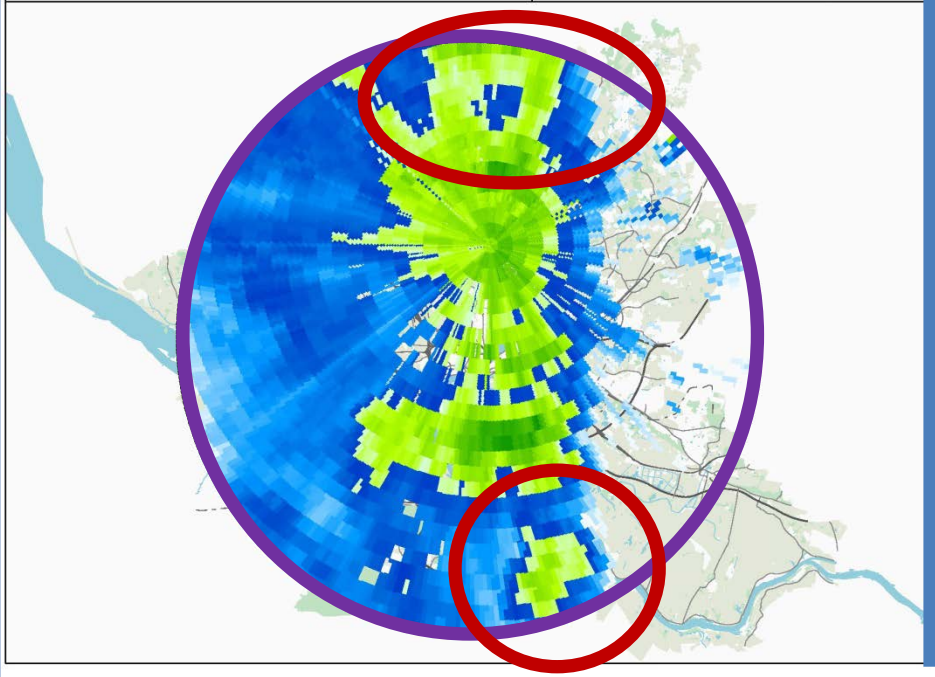




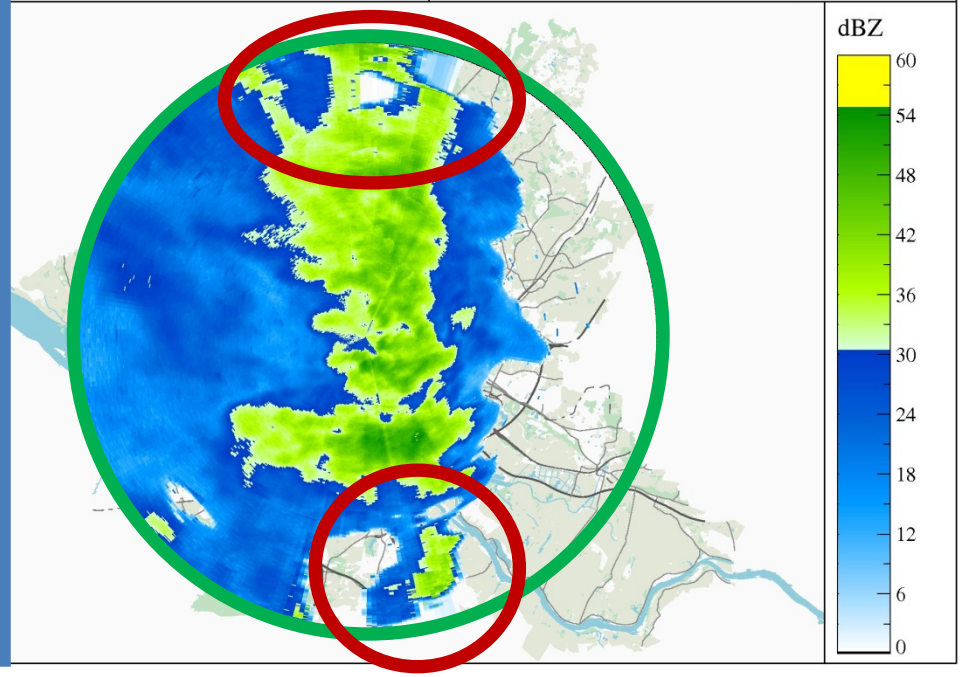
Combination of C-band and single X-band radar

C-Band



- Good agreement in spatial structure with higher resolution

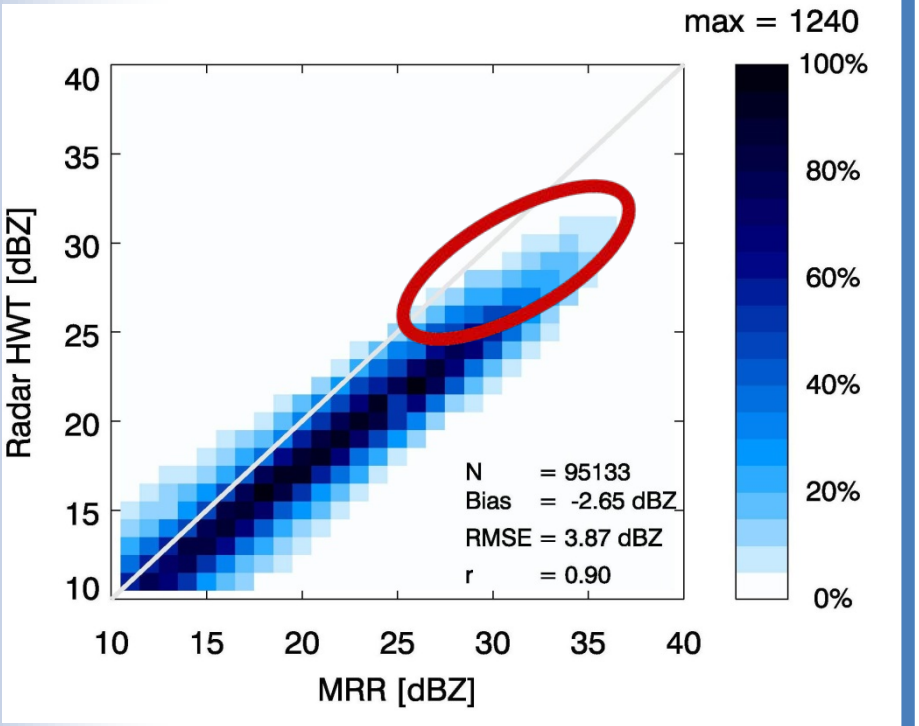
X-Band



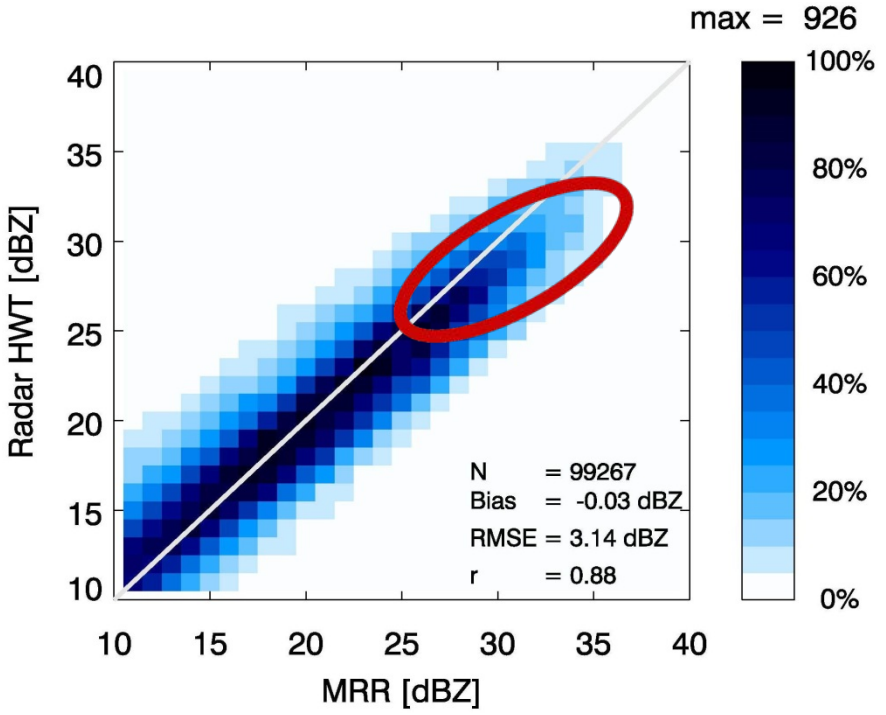
- Slight underestimation of attenuation
- Stable even at high attenuation

Combination of C-band and single X-band radar

uncorrected



corrected



- Reduction of bias (-2.65 dBZ → -0.03 dBZ)
- Reduction of RMSE (3.87 dBZ → 3.14 dBZ)
- Slight decline in correlation (0.90 → 0.88)

Summary I

- X-band radars can serve as **magnifying glass** in urban areas

Summary I

- X-band radars can serve as **magnifying glass** in urban areas

Can a network of high-resolution X-band radars improve precipitation estimates?

C-band vs. X-band

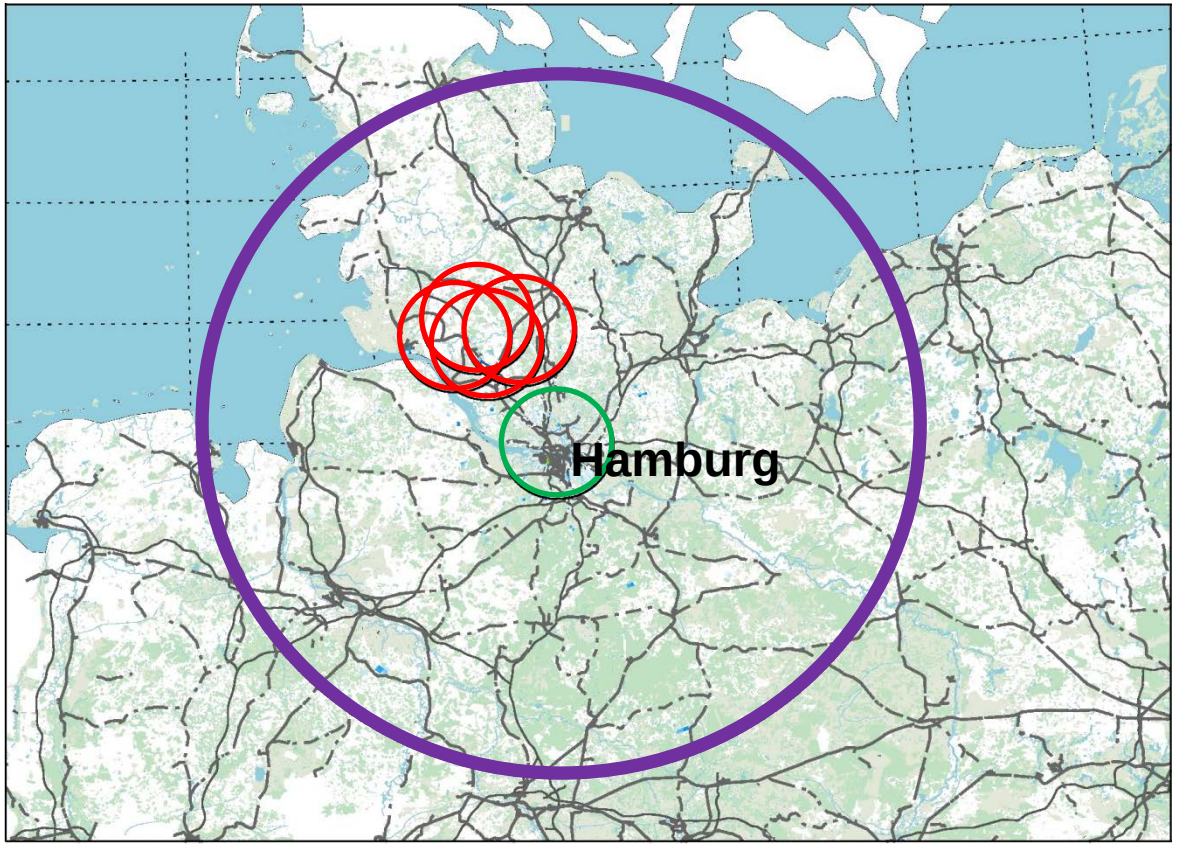
	C-band radar	Single X-band radar	X-band radar network of 4 radars
Range	180 km	20 km	60 km x 80 km
Resolution	✗	✓	➢ 250 m in range ➢ 30 s in time
Costs	✗	✓	➢ < 300.000 €
Attenuation	✓	✗	➢ multiple coverage allows for correction
Doppler	✓	✗	✗
Dual-Polarization	✓ ✗	✗	✗

Radar coverage in Northern Germany

- **1 C-band radar (DWD)**
  time resolution: 5 min
  range resolution: 1 km
  azimuth resolution: 1°
  maximum range: 180 km

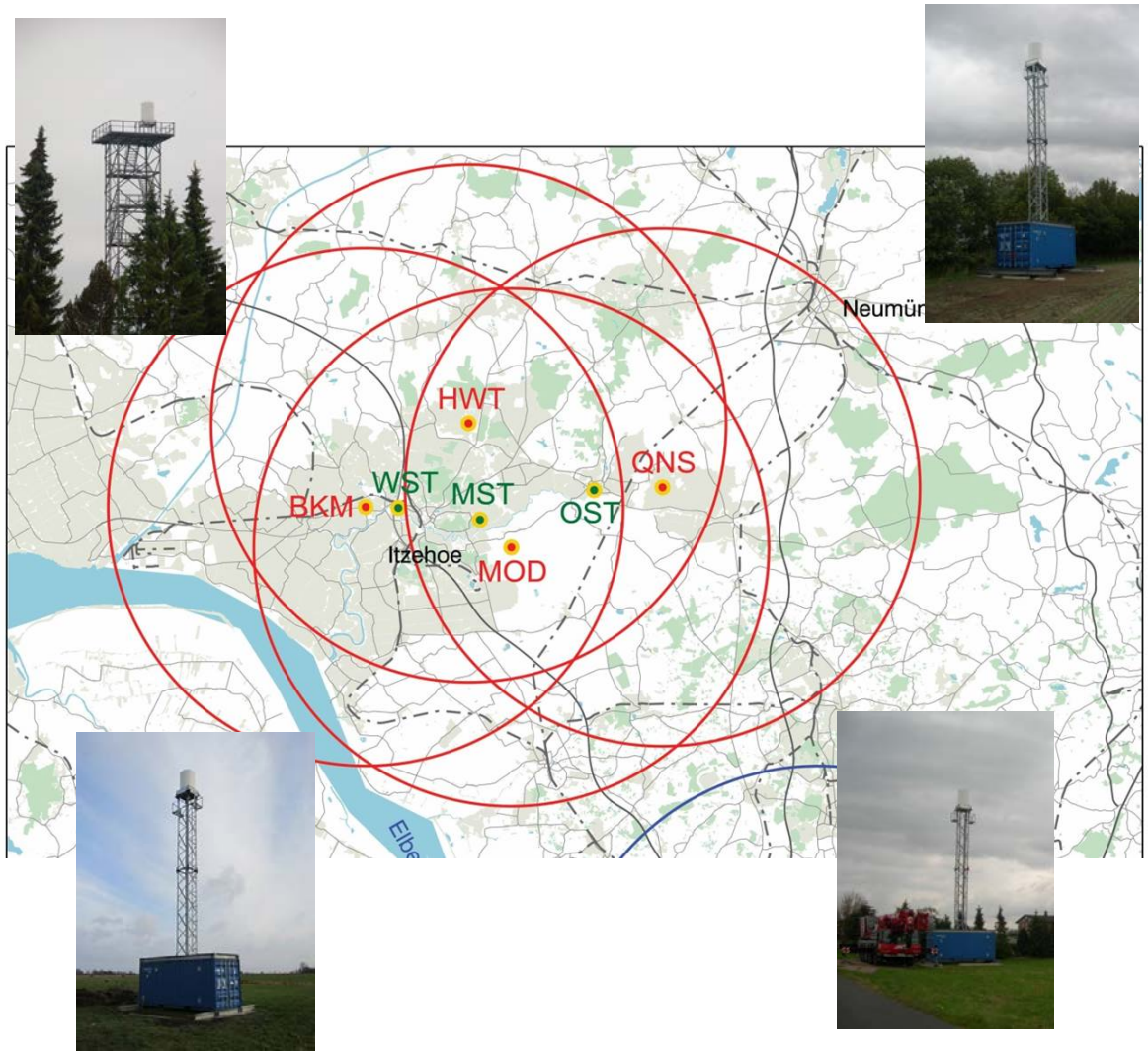
- **1 X-band radar (Hamburg)**
  time resolution: 30 s
  range resolution: 60 m
  azimuth resolution: 1°
  maximum range: 20 km

- **4 X-band radars (PATTERN)**
  time resolution: 30 s
  range resolution: 60 m
  azimuth resolution: 1°
  maximum range: 20 km



Design of the radar network

- **4 X-band radars**
  time resolution: 30 s
  range resolution: 60 m
  azimuth resolution: 1°
  maximum range: 20 km

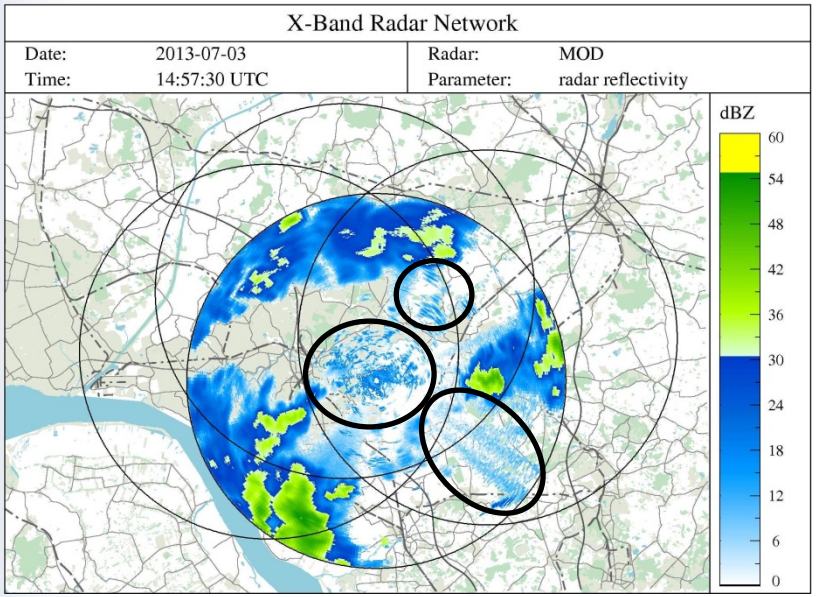


Design of the radar network

- **4 X-band radars**
  - time resolution: 30 s
  - range resolution: 60 m
  - azimuth resolution: 1°
  - maximum range: 20 km
- **4 MRRs**
  - time resolution: 10 s
  - height resolution: 35 m
  - height levels: 31
- **3 reference stations**
  - i) MRRs:
    - time resolution: 10 s
    - height resolution: 35 m
    - height levels: 31
  - ii) gauges:
    - time resolution: 1 min
    - intensity resolution: 0.1 mm

X-band radar network: Clutter detection

Example: Reflectivity field of X-band radar MOD, July 3rd, 2013



- Disturbances due to houses, trees, moving objects, other emitters, etc.

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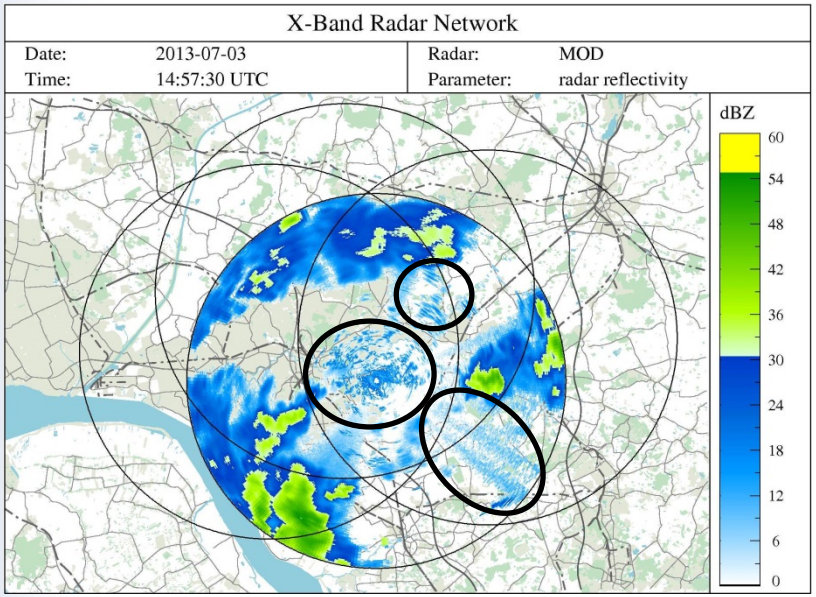

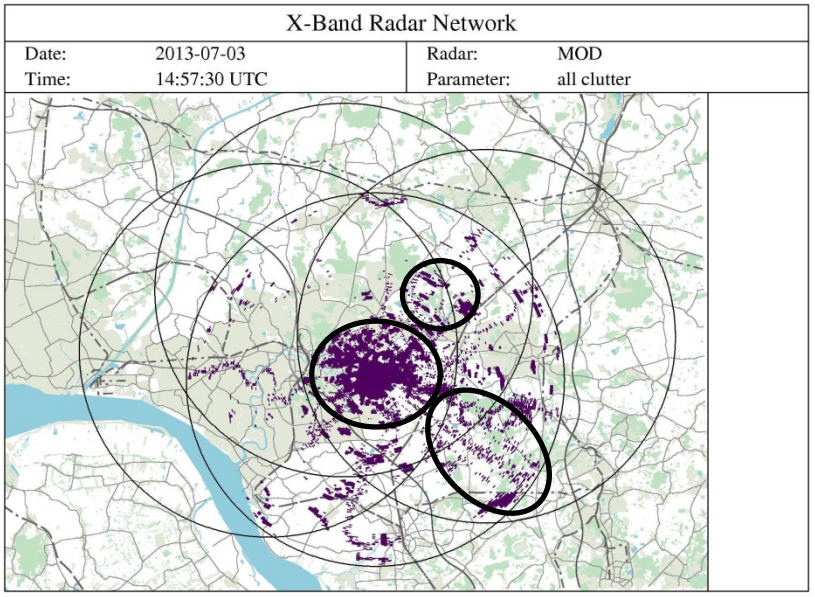

- Disturbances due to houses, trees, moving objects, other emitters, etc.
- Clutter filters for single radars do not detect all disturbances

X-band radar network: Clutter detection

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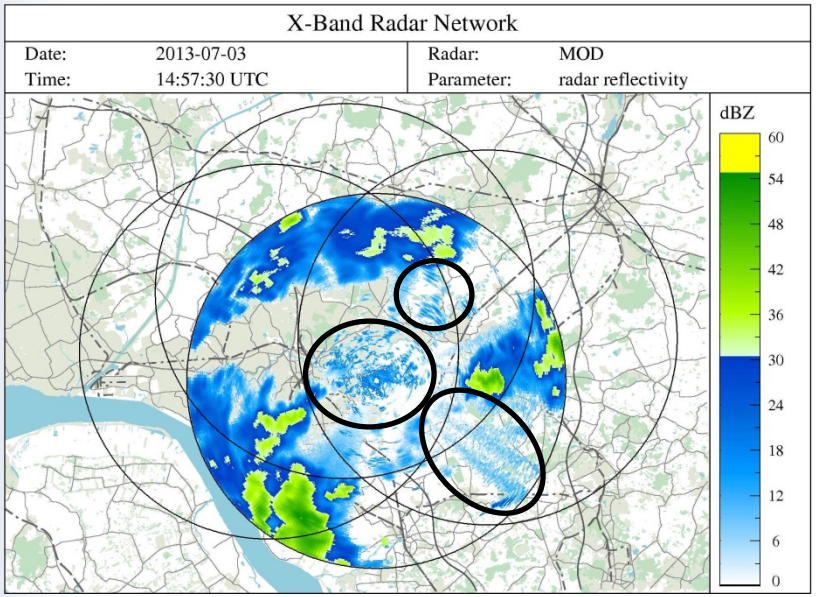
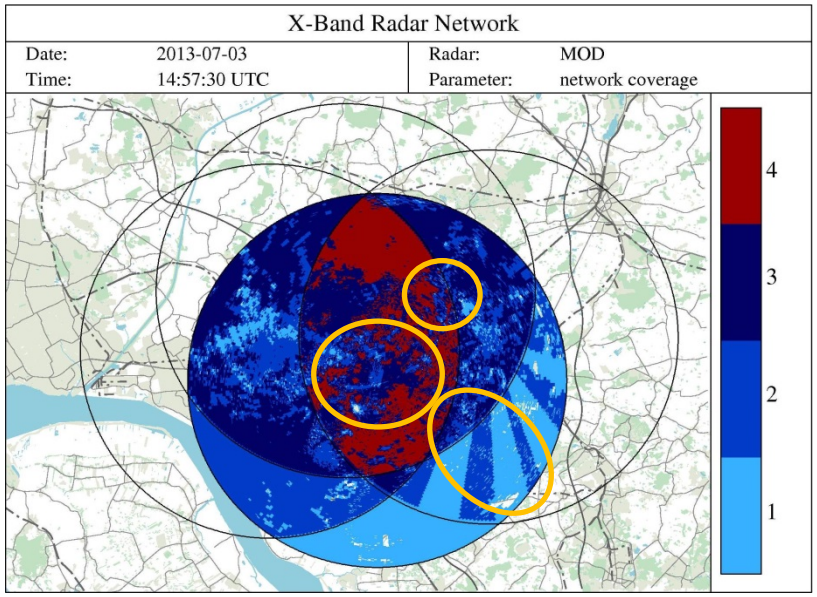
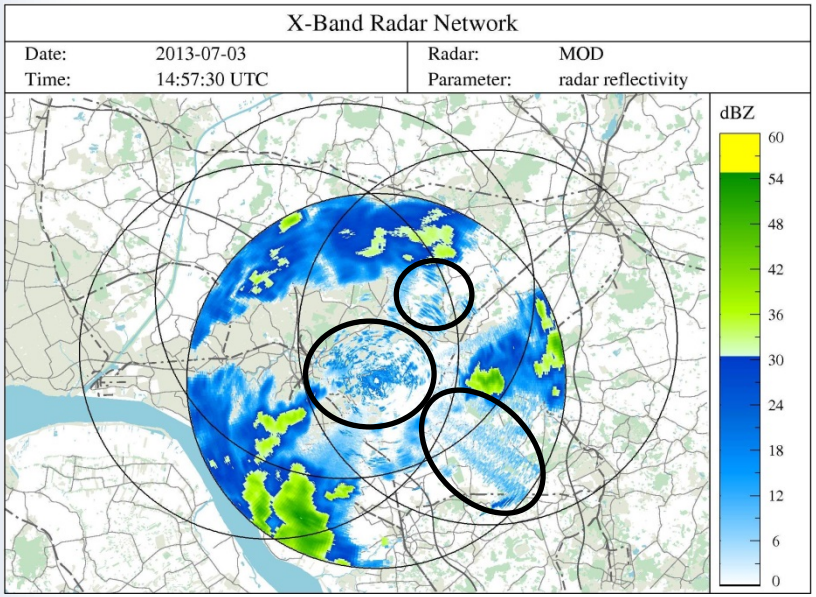


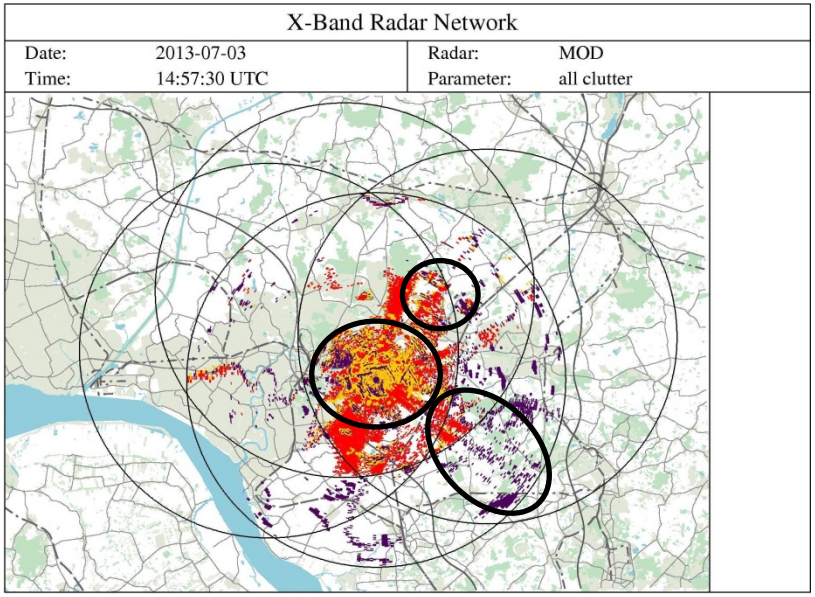


- Disturbances due to houses, trees, moving objects, other emitters, etc.
- Clutter filters for single radars do not detect all disturbances
- Multiple coverage within the network area

X-band radar network: Clutter detection

Example: Reflectivity field of X-band radar MOD, July 3rd, 2013





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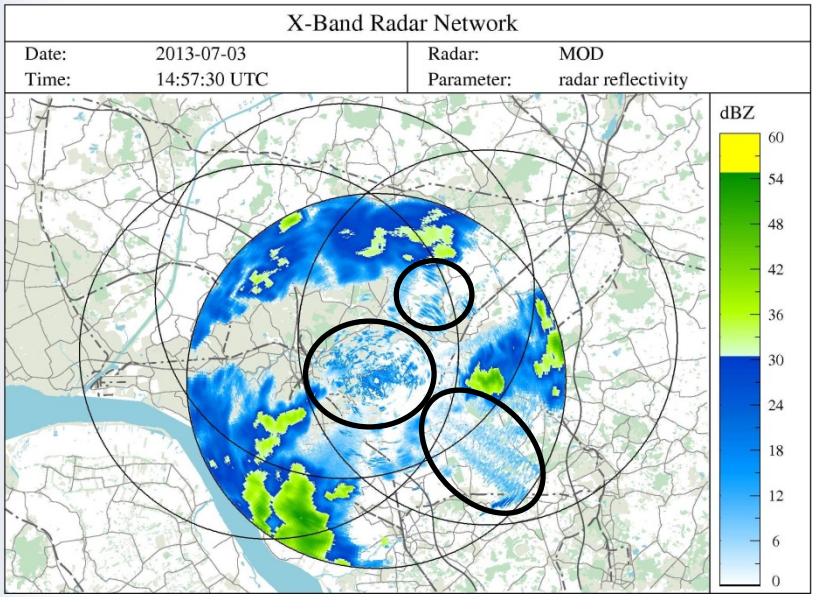

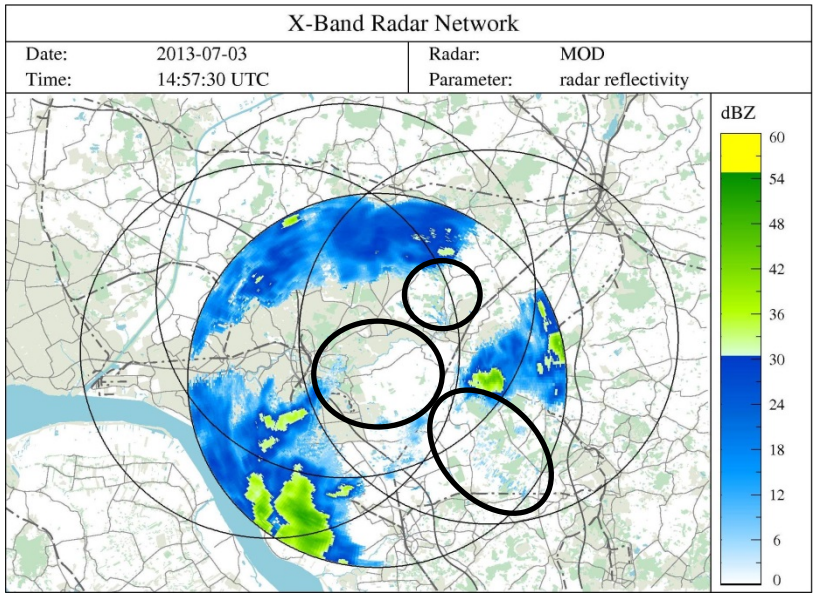

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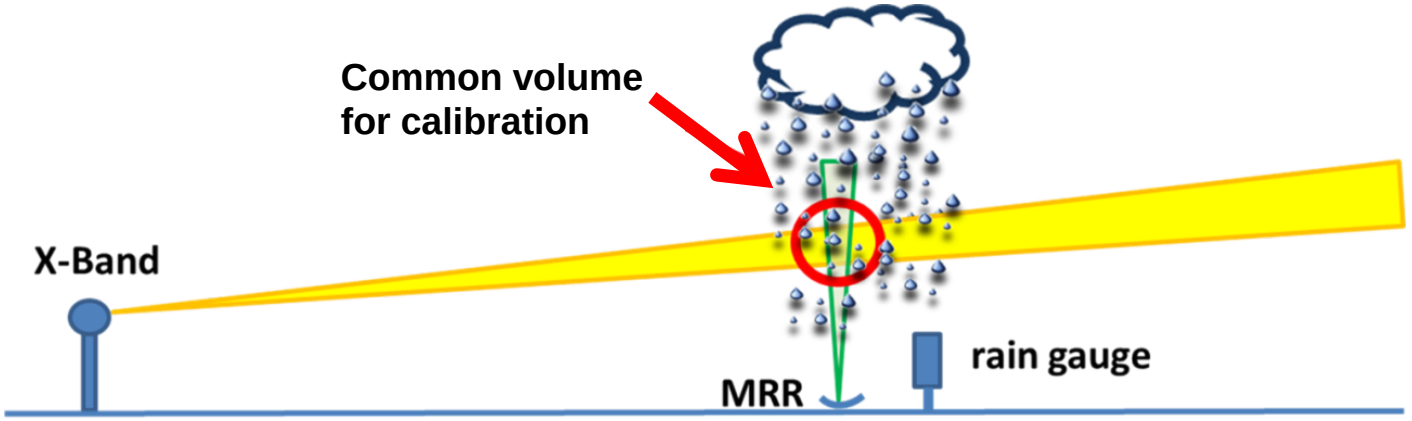
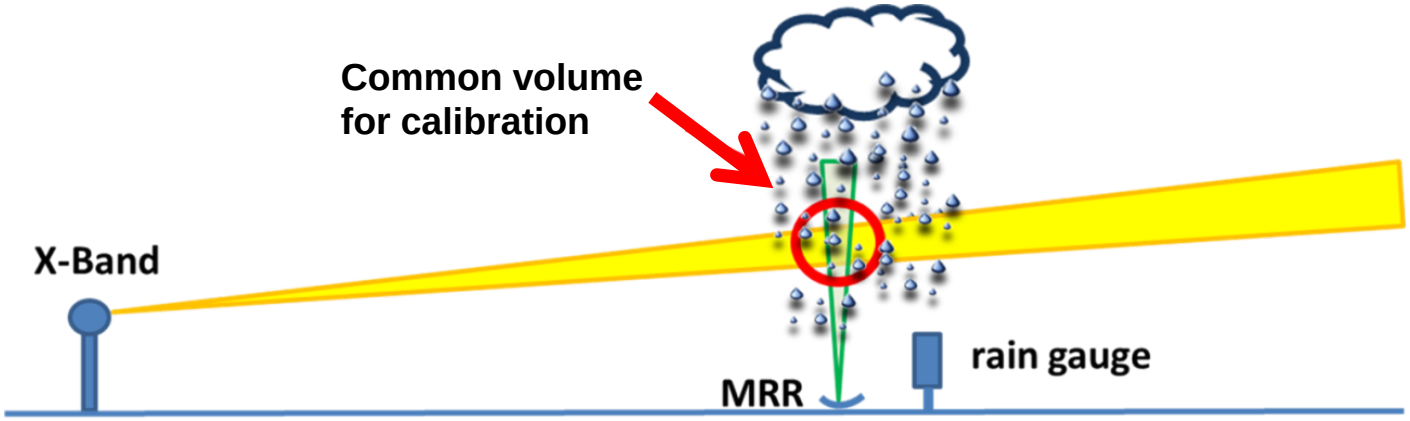
X-band radar network: Calibration



Calibrating X-band radar with MRRs has several advantages:

- Common intersecting volume
- MRR measurements for each 30 s reflectivity field of the X-band radar
- Using the actual measured quantity „reflectivity“ instead of estimated rain rate

X-band radar network: Calibration



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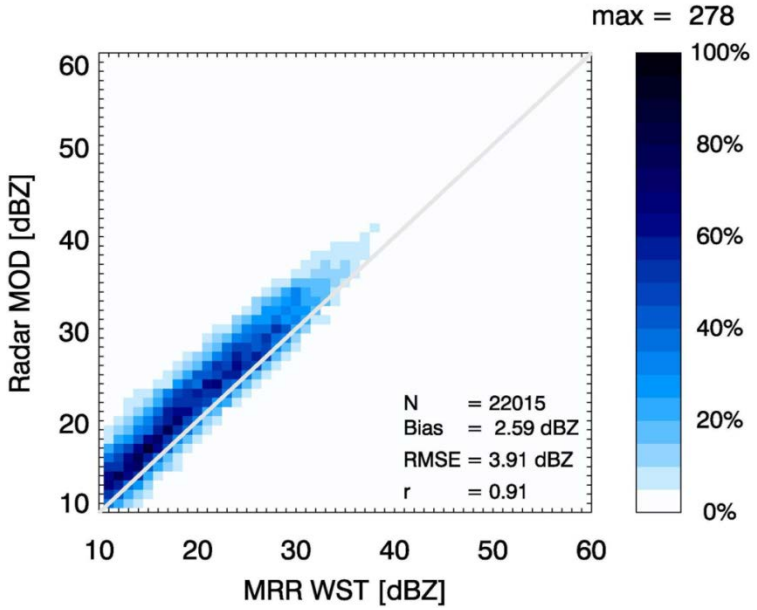
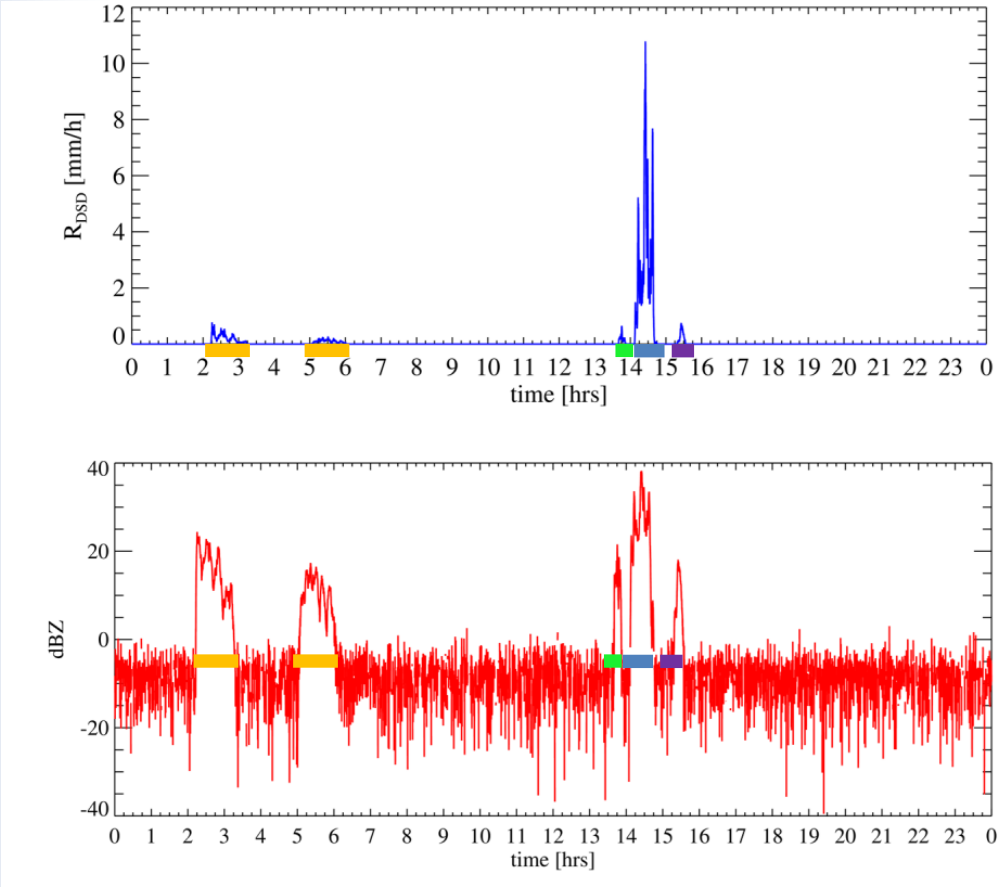
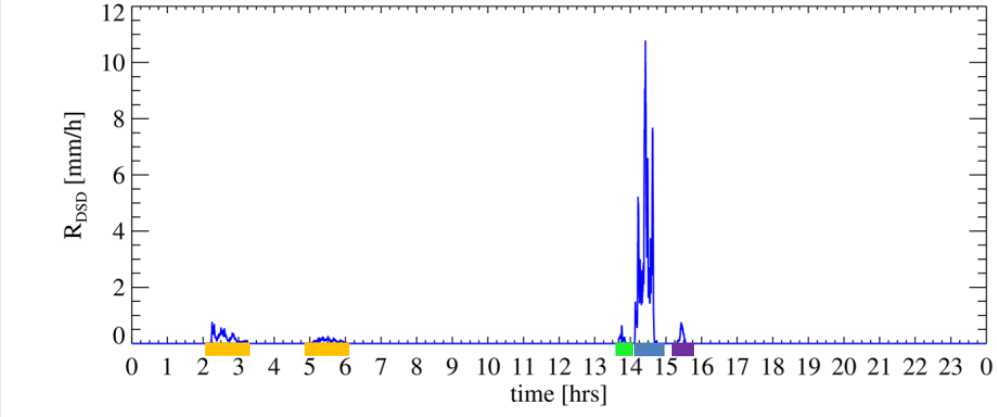


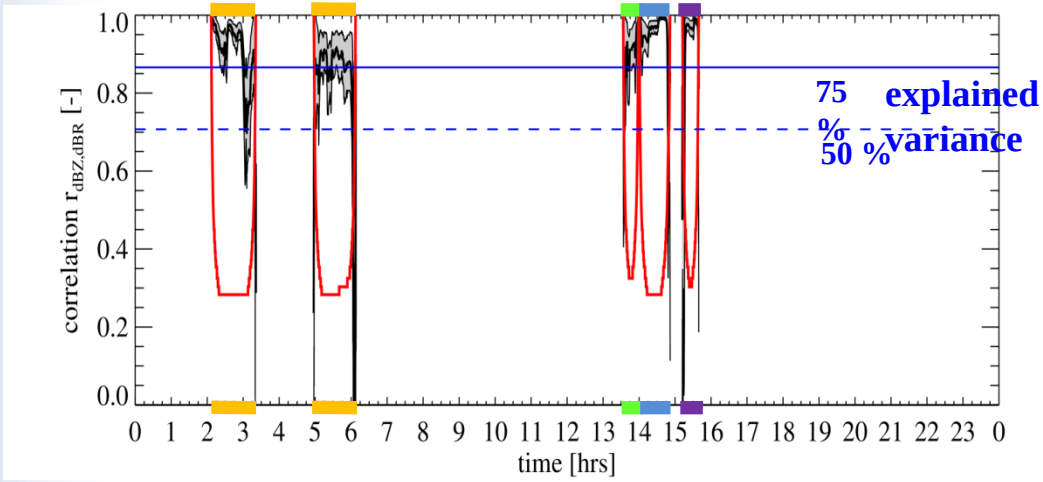
X-band radar network: Z-R-relation



- MRRs measure reflectivity Z **and** rain rate R
- Direct determination of Z-R relation is possible

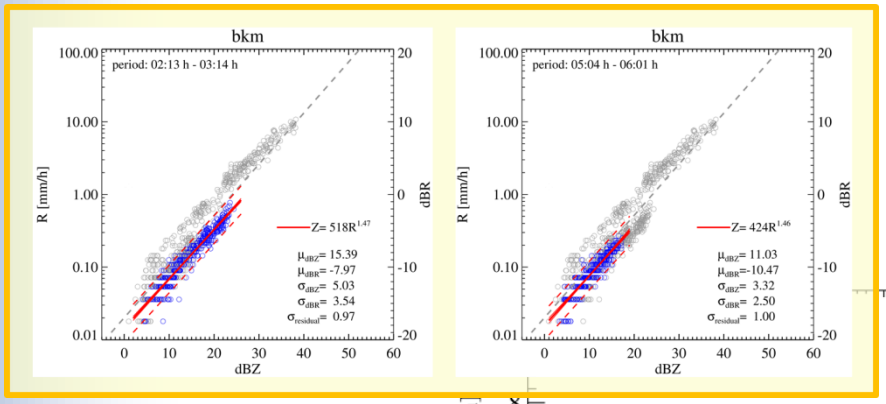
X-band radar network: Z-R-relation

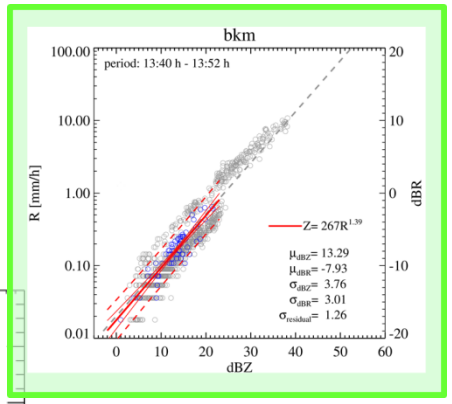


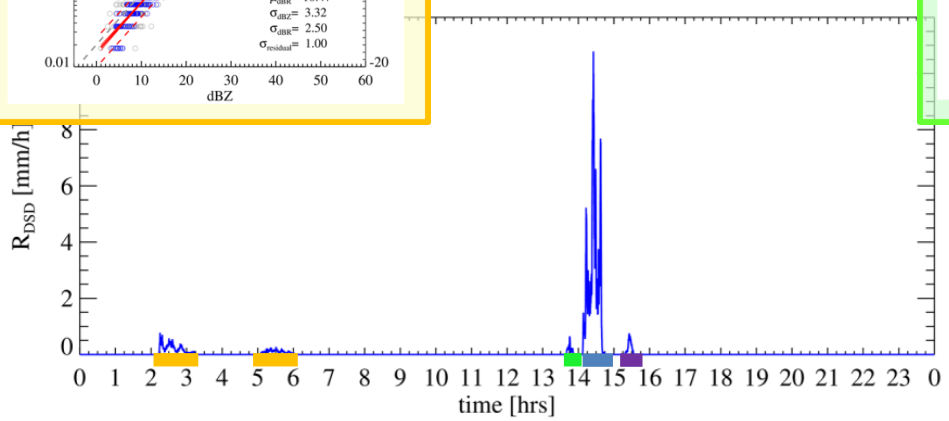


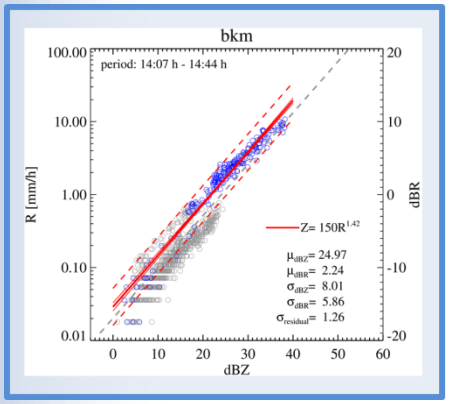
- MRRs measure reflectivity Z **and** rain rate R
- Direct determination of Z-R relation is possible
- Drop in the correlation of Z and R is a good indicator for new Z-R relation
- **Orange** periods are characterized by light rain
- **Green** period represents a kind of transition between light rain and shower
- **Blue** period characterizes the intense shower event
- followed by light shower (**violet** period)

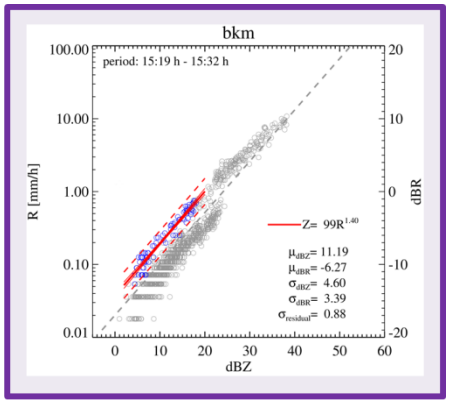
X-band radar network: Z-R-relation











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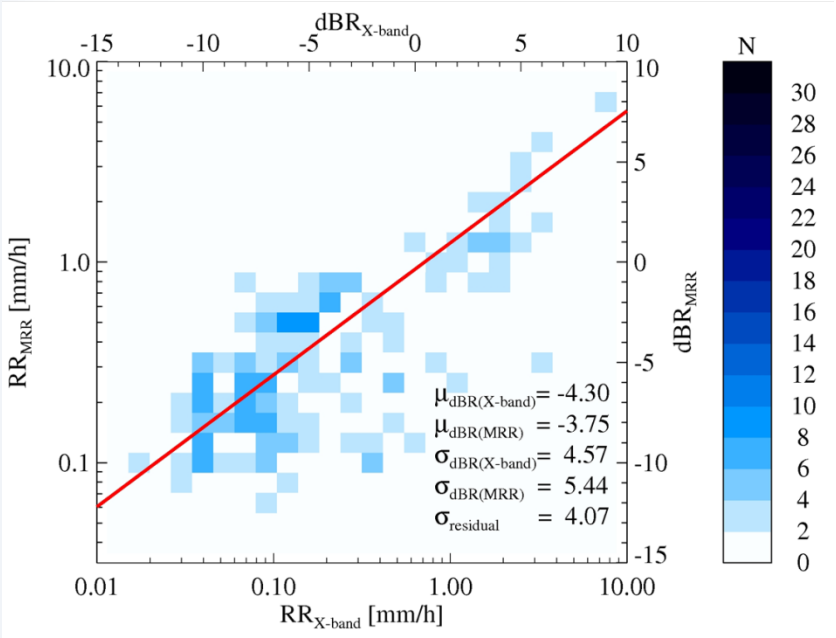
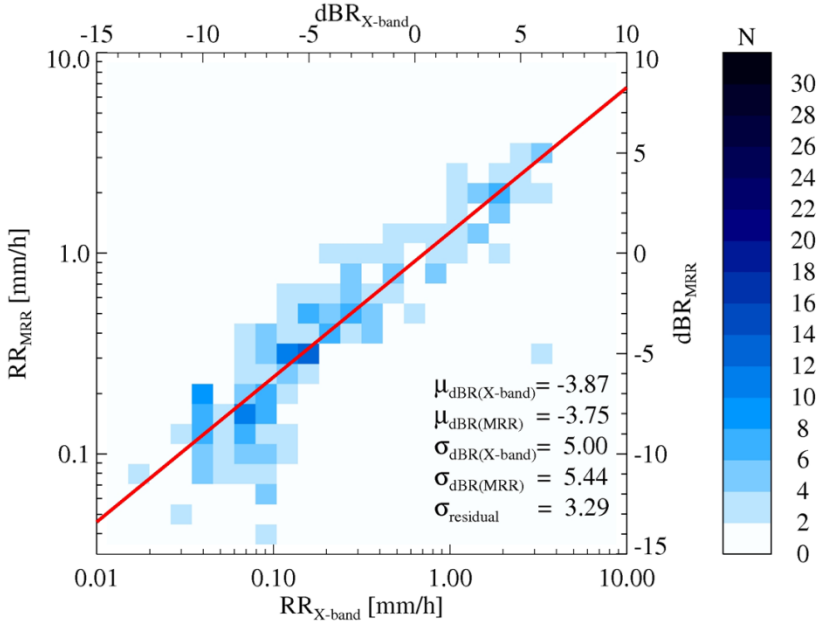
X-band radar network: Z-R-relation

Climatological



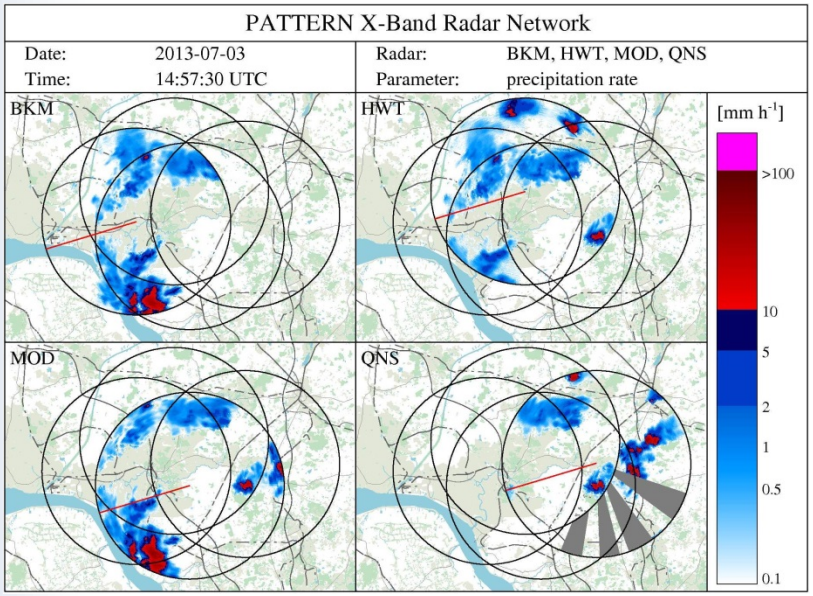
Variable



- Variable Z-R relation leads to better agreement of rain rate derived by MRR and X-band radar
- Standard deviation is reduced by 20 %.

X-band radar network: Composite

Example: Precipitation field of July 3rd, 2013



- Precipitation estimates for the network radars

X-band radar network: Composite

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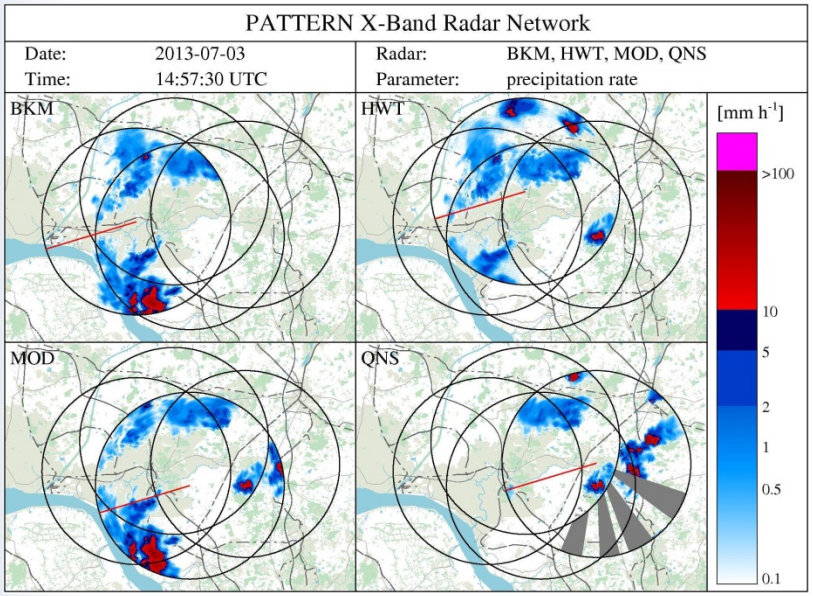

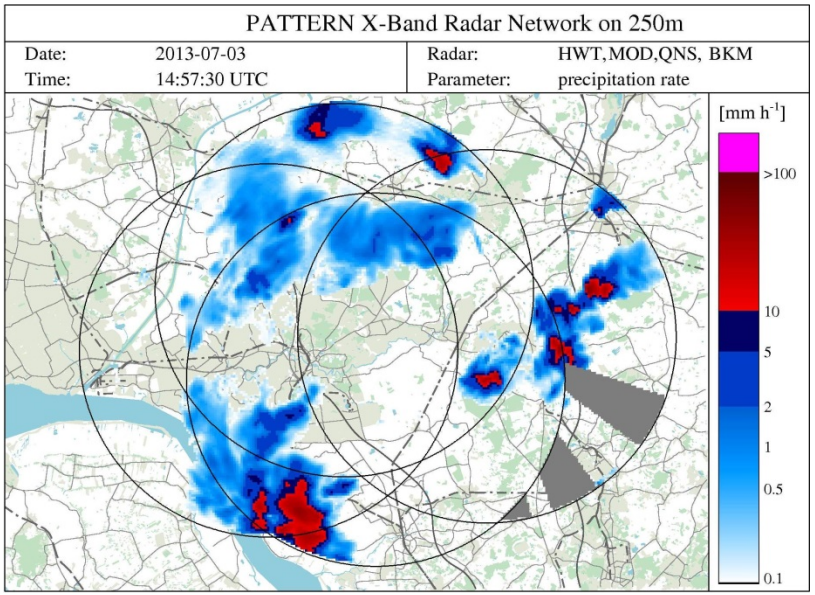

- Precipitation estimates for the network radars
- Composite of all four network radars on a 250 m grid

X-band radar network: Composite

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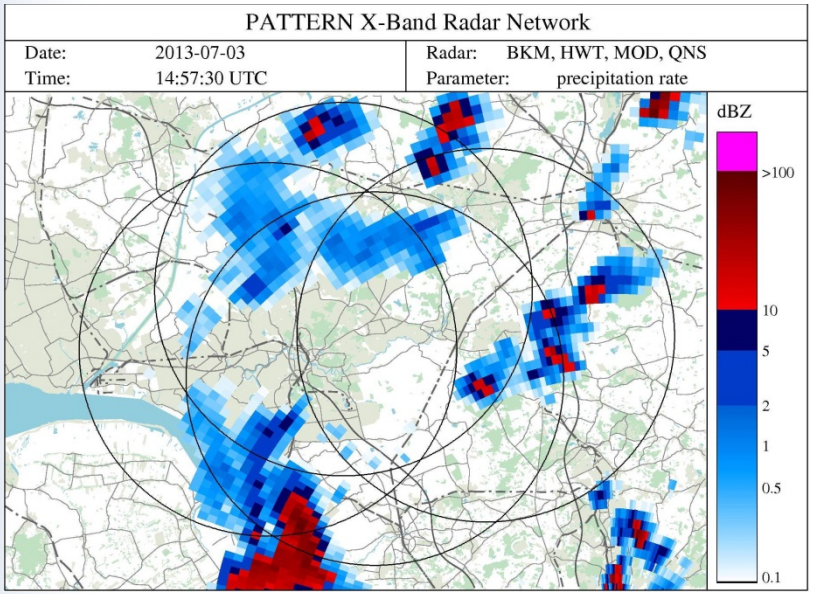

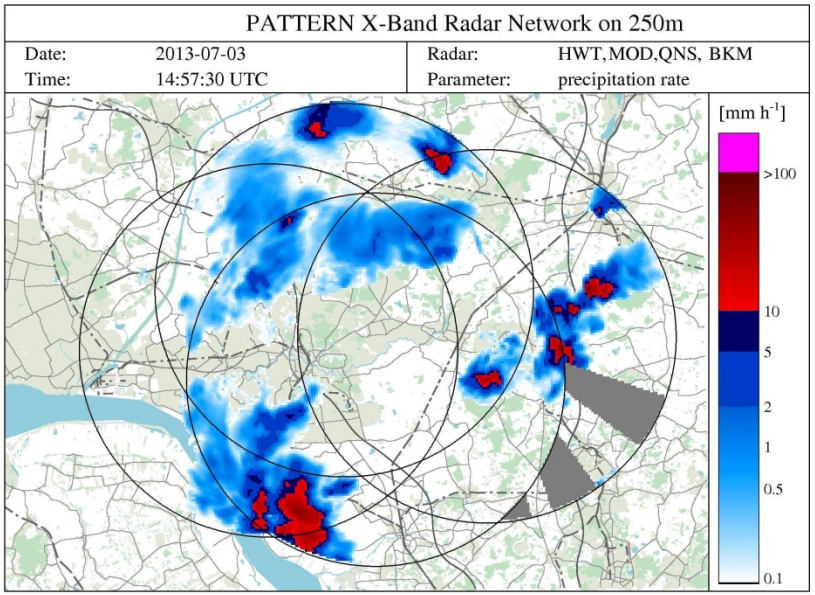

- Precipitation estimates for the network radars
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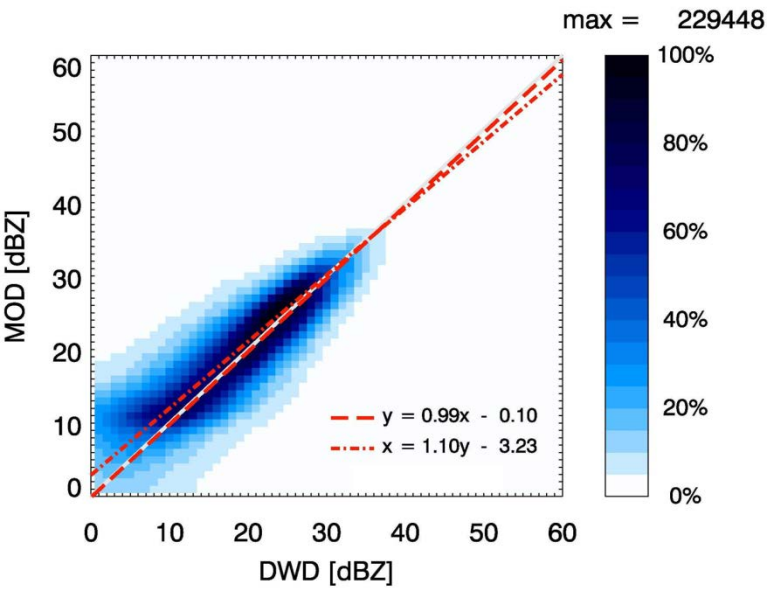
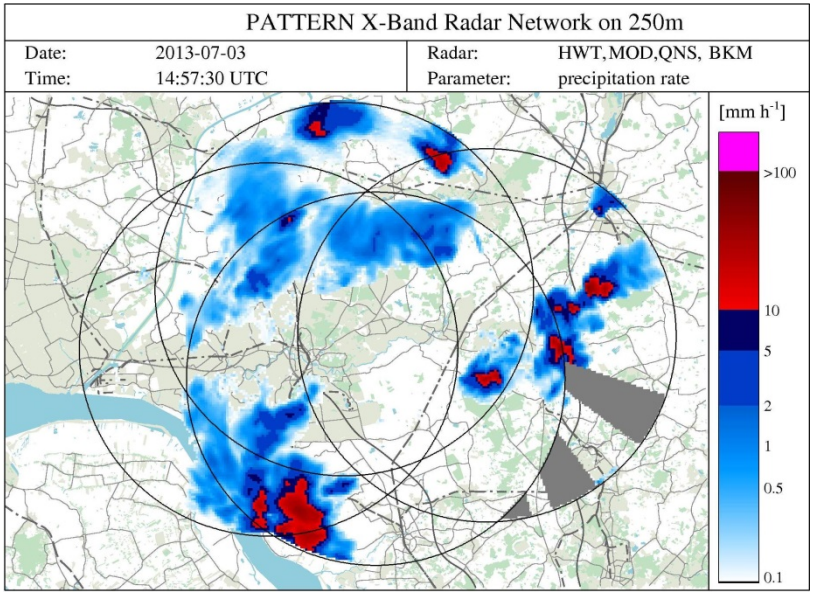
- Good agreement between X-band radar network and C-band radar

X-band radar network: Composite





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X-band radar network: Combined product

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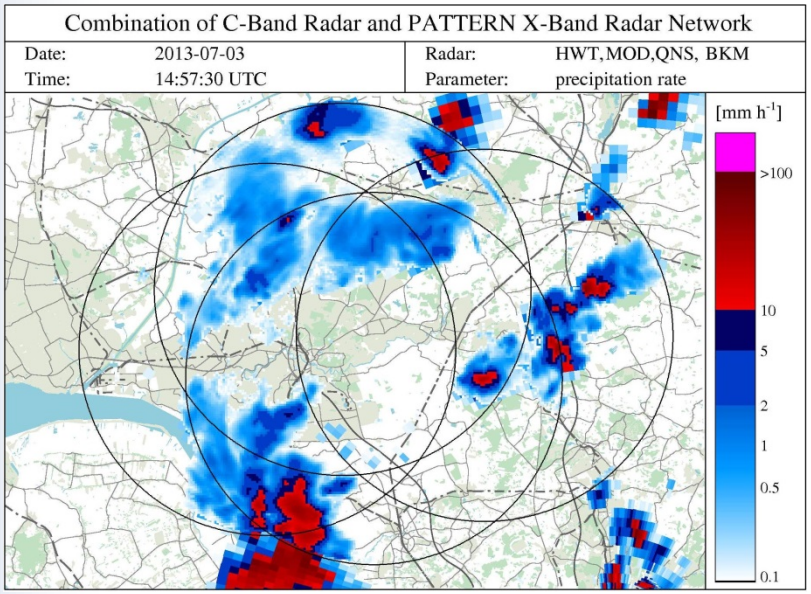

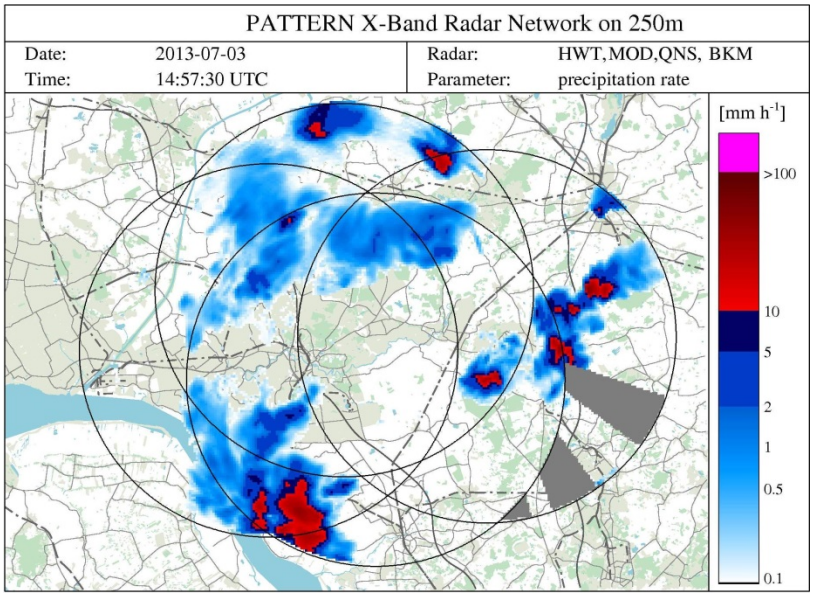

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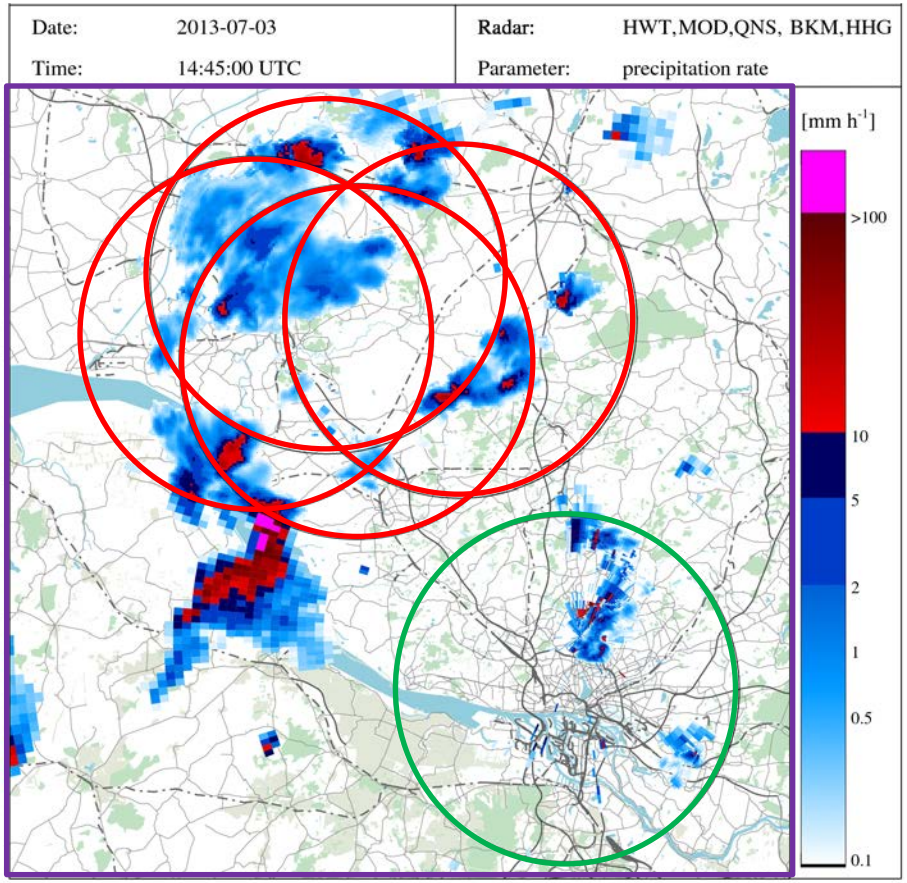
- Combing C-band radar and composite of X-band radar network

X-band radar network: Combined product



C-band radar

- Range resolution: 1 km
- Time resolution: 5 min
- Maximum range: 180 km

Composite of X-band radar network

- Range resolution: 250 m
- Time resolution: 30 s
- Covered area: 60x80 km^2

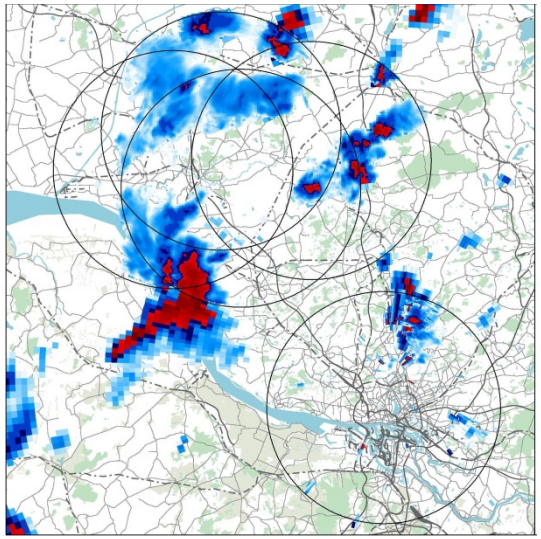
X-band radar Hamburg

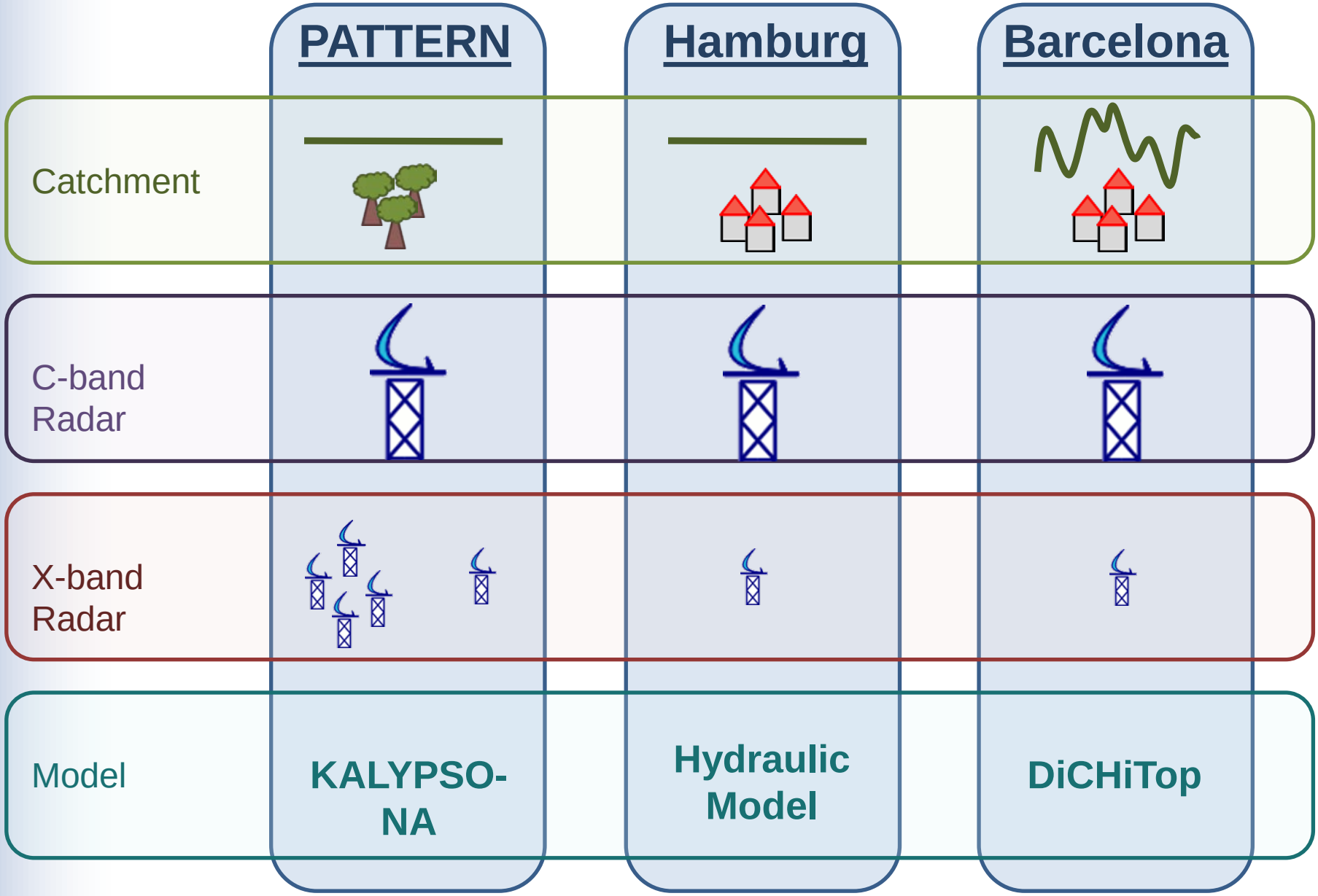
- Range resolution: 60 m
- Time resolution: 30 s
- Maximum range: 20 km

Summary II

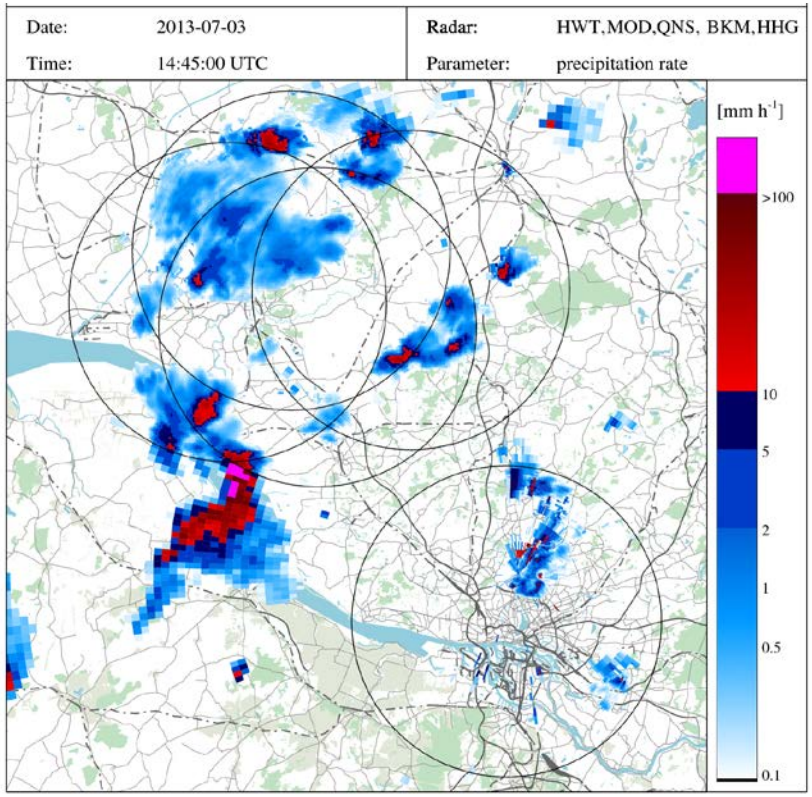
- X-band radars can serve as **magnifying glass** in urban areas

- The precipitation product of C-band, X-band and micro rain radars combines advantages of all three systems:
  - **Long-range and accurate** reflectivity measurements from C-band radars
  - **High-resolution** reflectivity measurements from X-band radars
  - **Direct determination of Z-R-relations** from MRRs




PATTERN
Hamburg
Barcelona
Catchment
C-band Radar
X-band Radar
Model
KALYPSO-NA
Hydraulic Model
DiCHiTop

Thanks for your attention!



Questions?

http://pattern.zmaw.de

Contact:
katharina.lengfeld@zmaw.de

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

PATTERN

Max-Planck-Institut für Meteorologie