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Radar rainfall estimation and nowcasting

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Ruben Imhoff

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Meet the presenters

Pieter Hazenberg PhD

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Senior Advisor/Researcher

Topics:

- Remote sensing
- Hydrological extremes
- Distributed modelling using HPCs

Xiaohan Li PhD

Deltares

Junior Advisor/Researcher

Topics:

- Radar rainfall estimation
- Urban flooding applications

Ruben Imhoff

Deltares / Wageningen UR

PhD Candidate

Topics:

- Radar rainfall nowcasting
- Hydrological predictability

(Mentimeter) Let’s Chat!

Join the mentimeter and let’s chat!

Tell us anything, who are you? Where are you from? Which organization are you from? Why are you interested in this break out session?

It does not has to be radar-related ☺.

What is the first thing that comes to mind when you think about the weather radar?

Intro

Radar rainfall

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Weather Rainfall Estimation

From reflectivity to rainfall rate

(Mentimeter) Do you have access to real-time radar rainfall data?

- A) No
- B) Yes, through our met office
- C) Yes, through a third party
- D) Yes, we have a radar locally
- E) Yes, we have multiple sources

(Mentimeter) What types of **Radar** data do you have access for?

- A) Raw radar reflectivity
- B) Processed radar reflexivity
- C) Rainfall rate of high resolution (e.g. <15min)
- D) Rainfall accumulation of low resolution (e.g. > 1hr)
- E) Bias corrected rainfall products
- D) Rainfall nowcast (deterministic / probabilistic)
- F) Others: ___

(Mentimeter) How satisfied are you with the data you get?

- A) Very unsatisfied
- B) Somewhat unsatisfied
- C) Neither satisfied nor unsatisfied
- D) somewhat satisfied
- E) Very satisfied

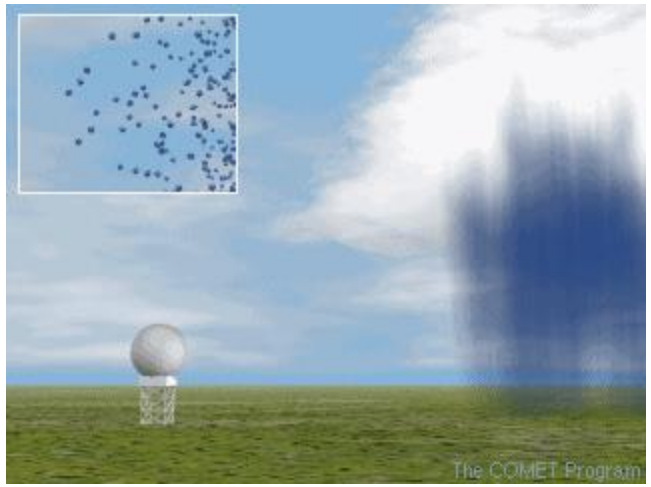
(Mentimeter) If not, why?

- Open question

The weather radar

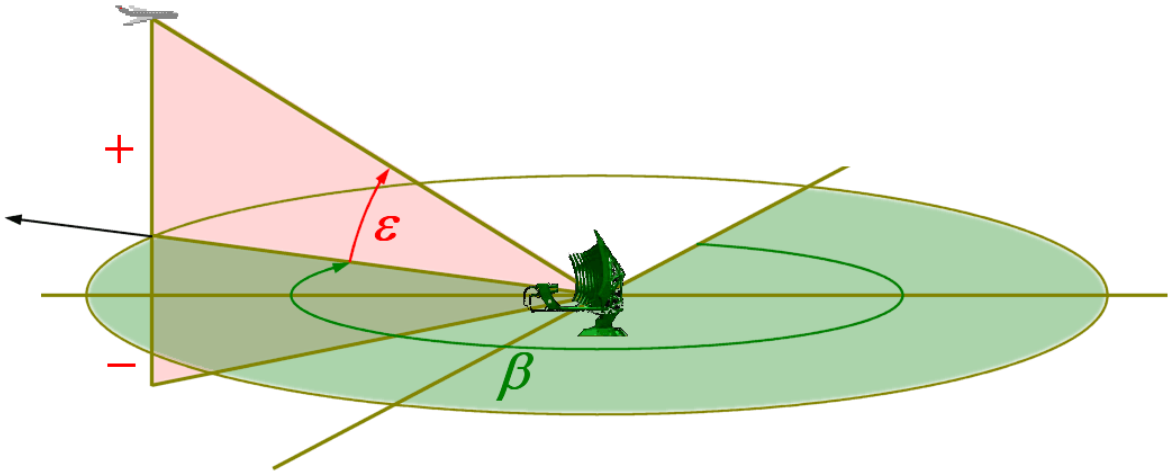
KNMI radar at Herwijnen, Netherlands

The weather radar



KNMI radar at Herwijnen, Netherlands

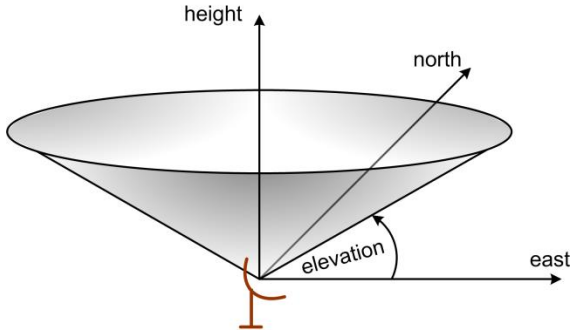
Looking under the radome

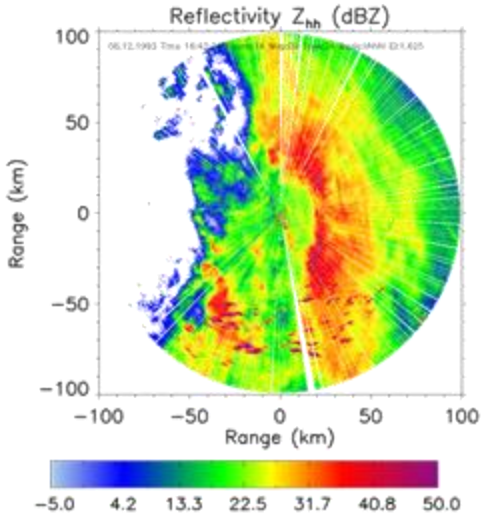


Turns around 360 degrees

Operational characteristics

PPI (plan-position indicator):





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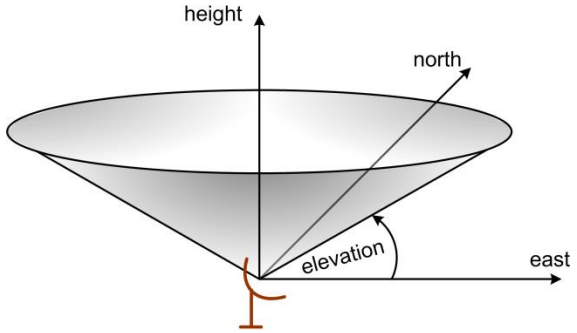

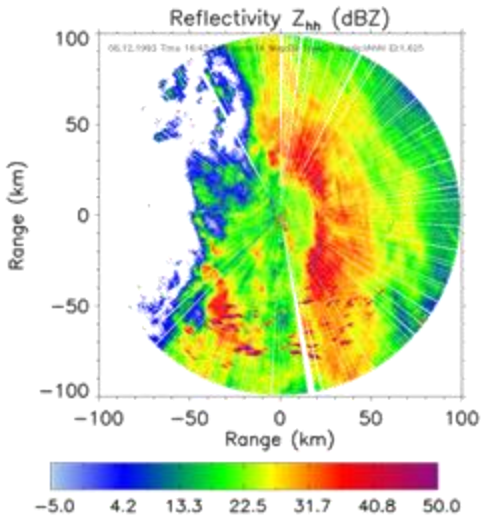

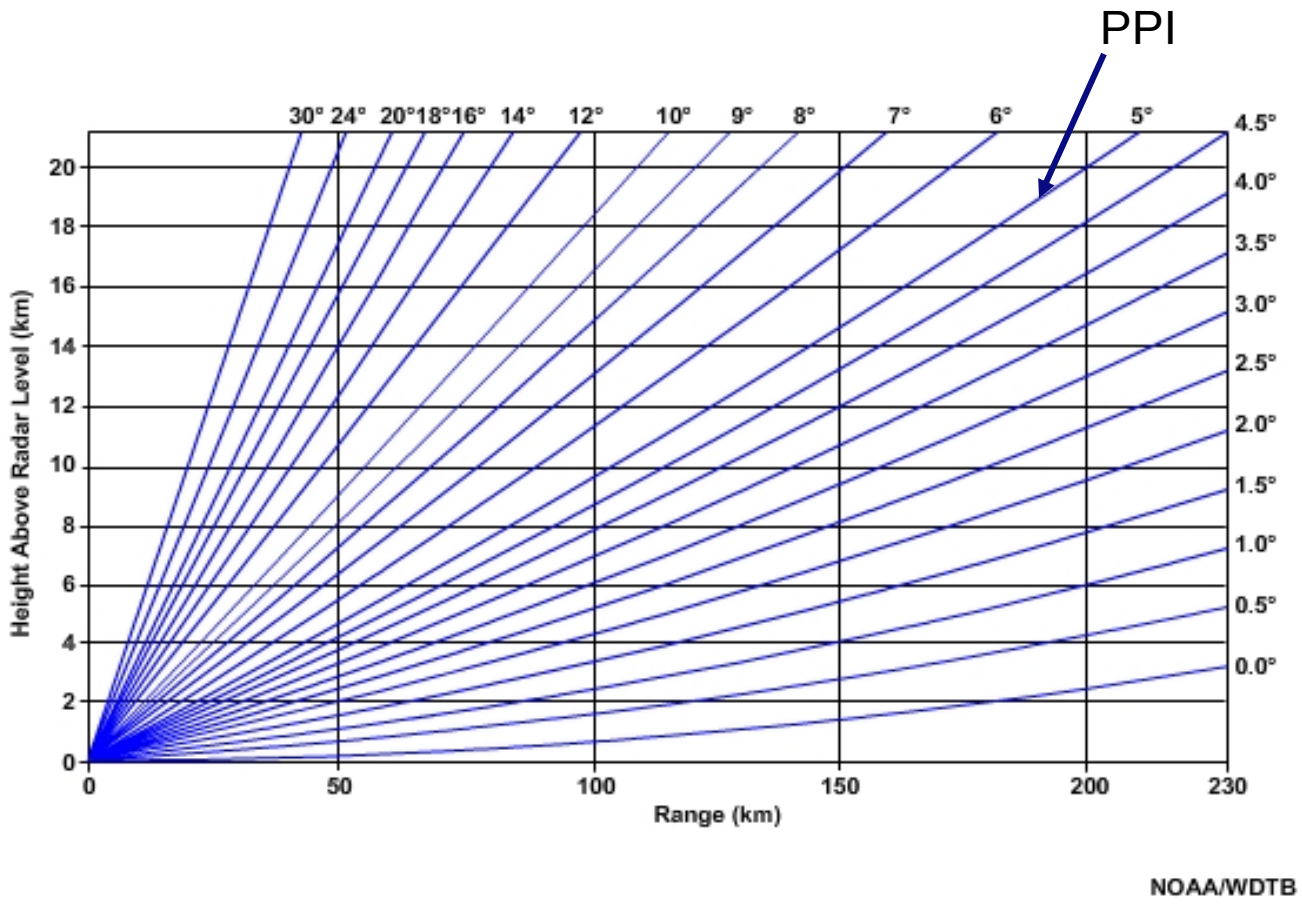

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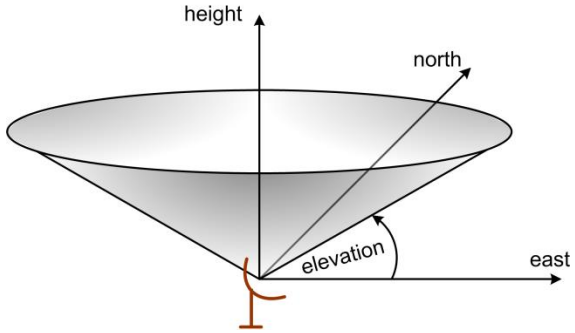
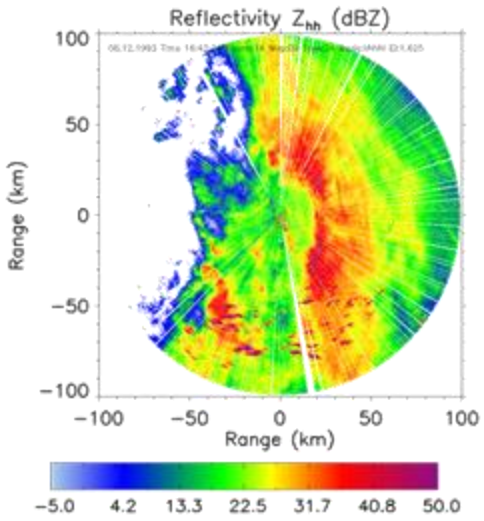
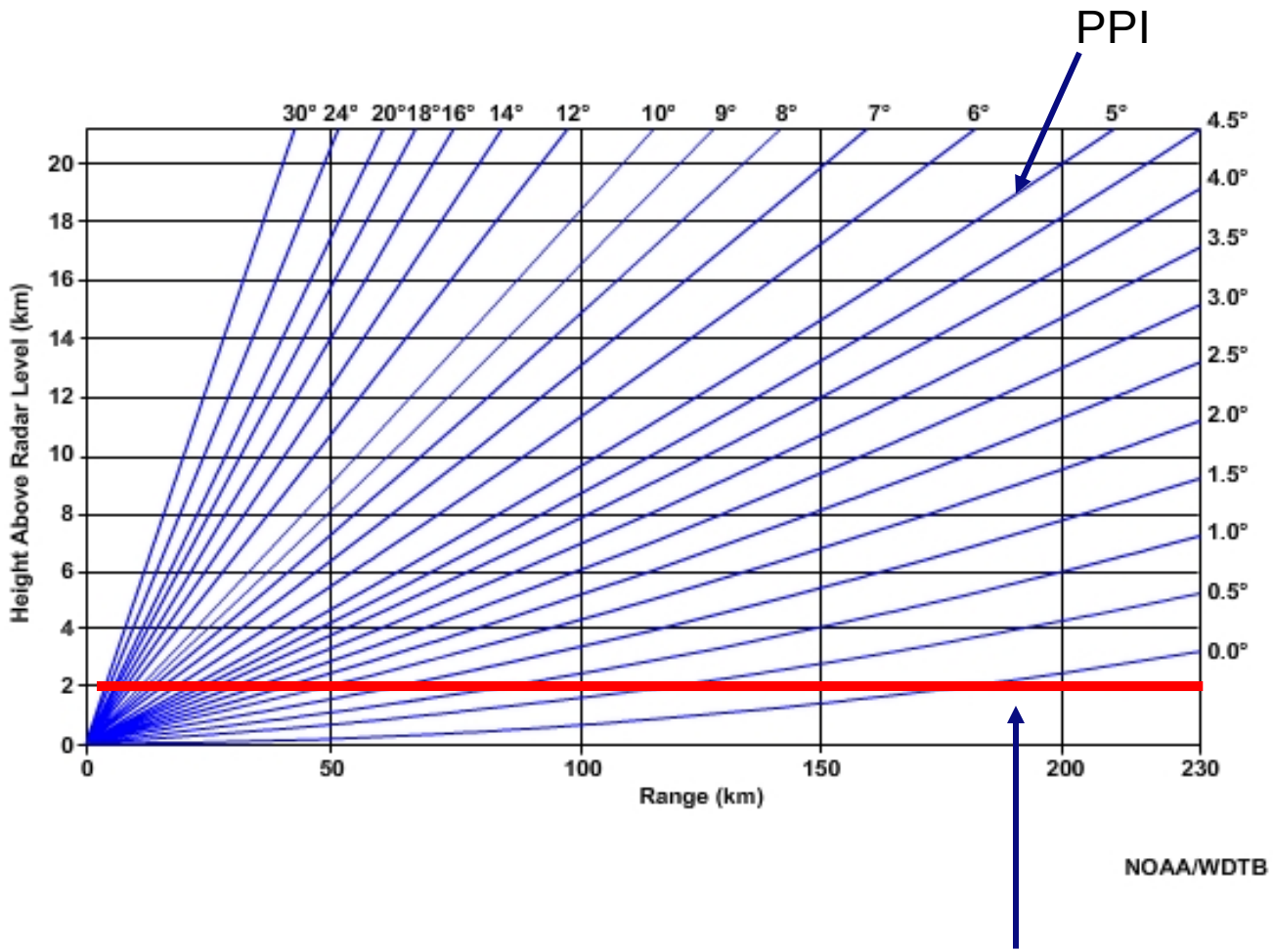
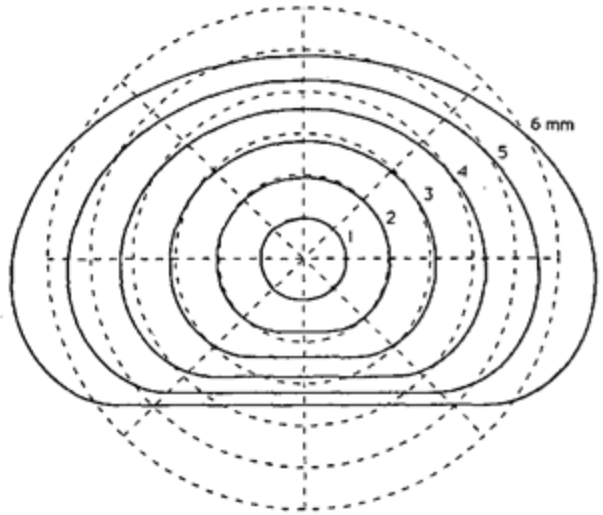


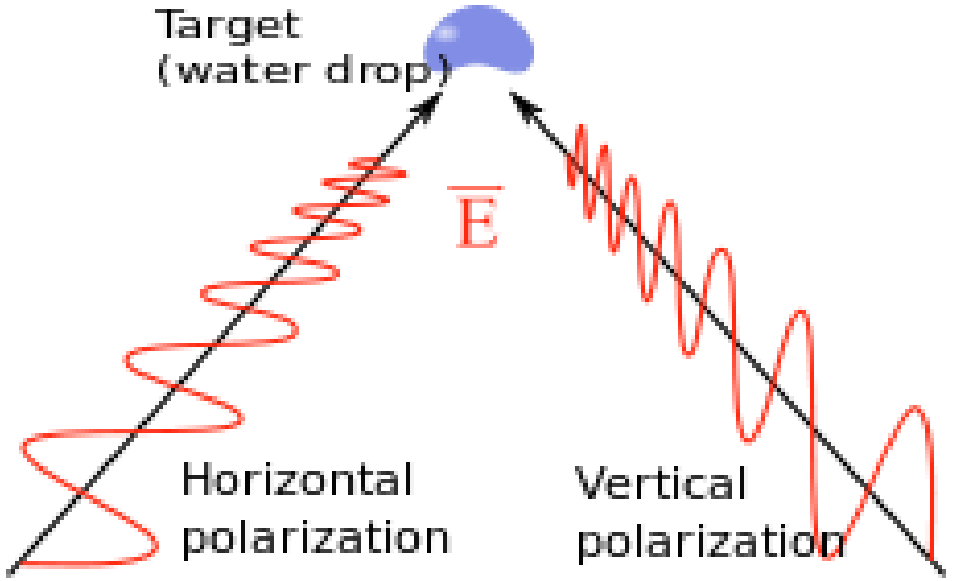




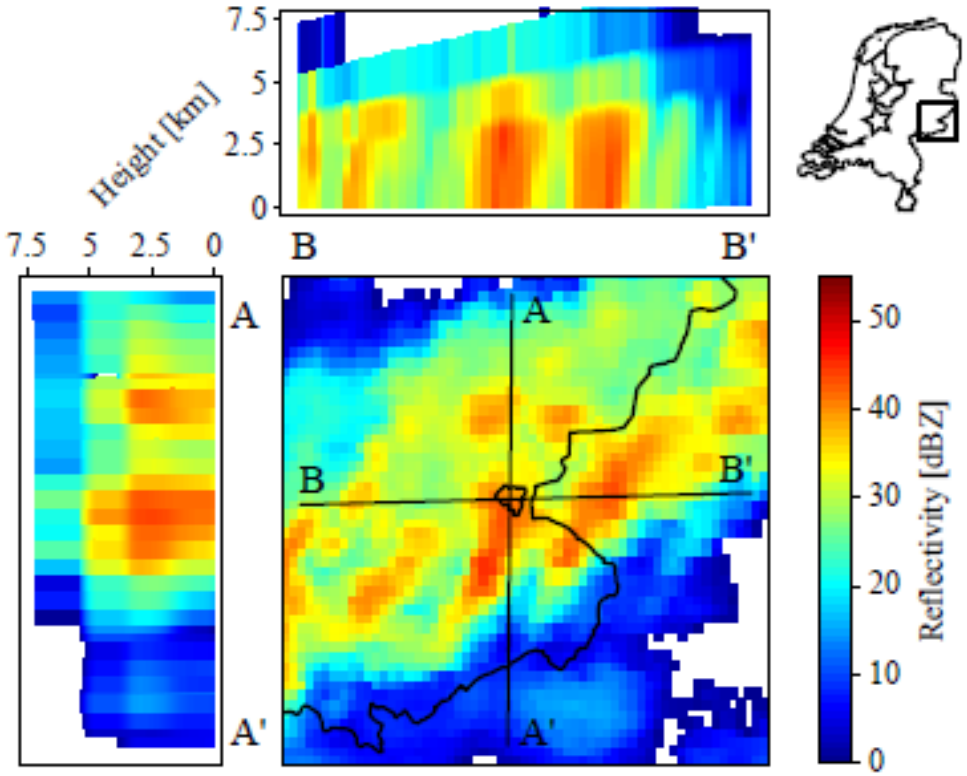
Radar polarization



(Beard et al., 1986)



Volumetric measurement to rainfall



- Returned signal to radar or Radar reflectivity: Z
- Rainfall rate R
- One interested in: $R = f(Z)$

- Classically: $Z = AR^b$
- Coefficients A and b depend on precipitation type.

Non-meteorological targets complicate measurements and QPE quality

Weather radars do not discriminate. Even though the focus is on measuring precipitation, they also receive a return from airborne insects, birds, bats, airplanes, buildings and mountains

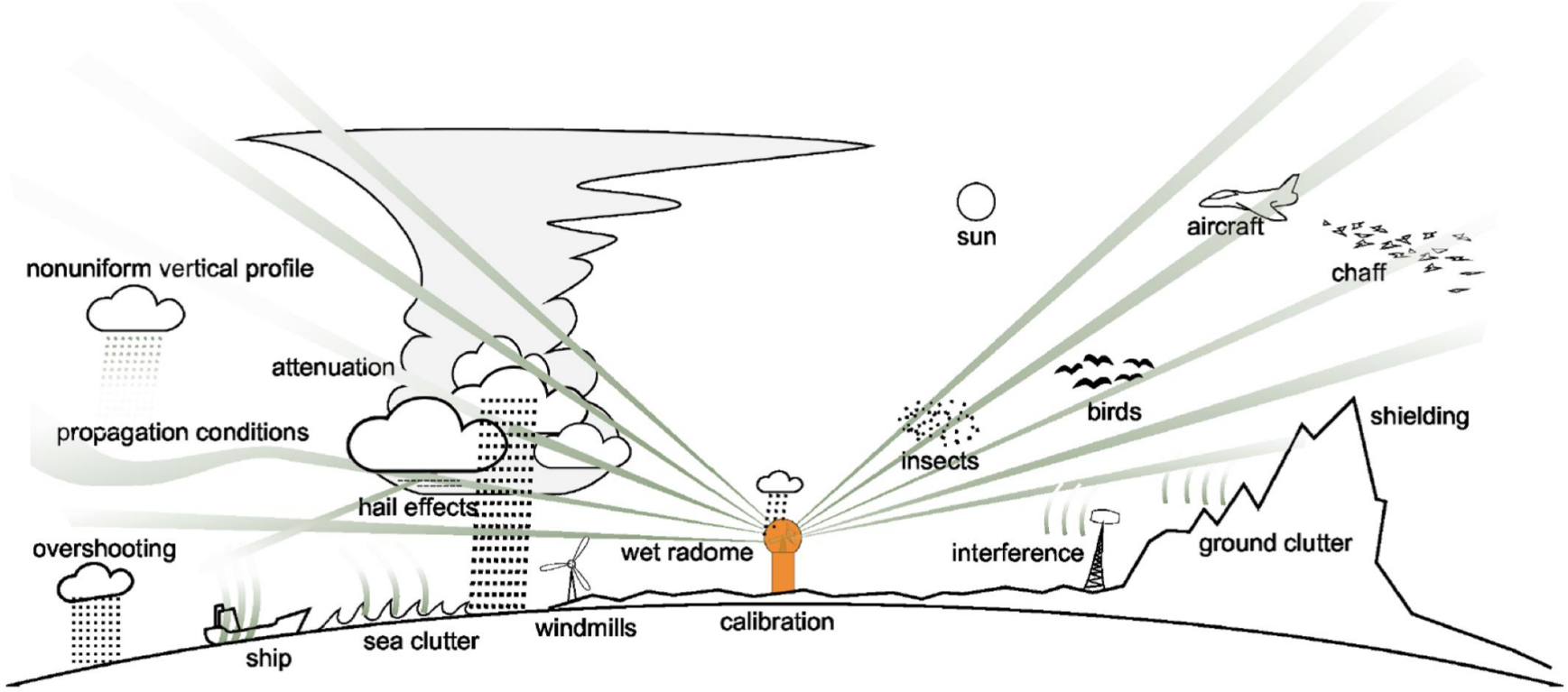
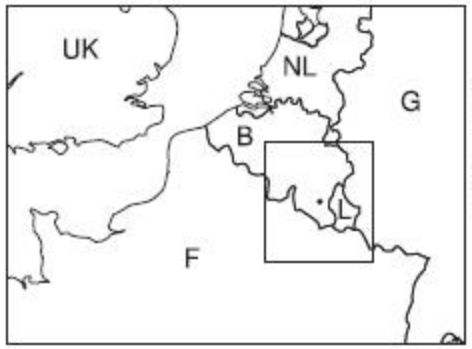
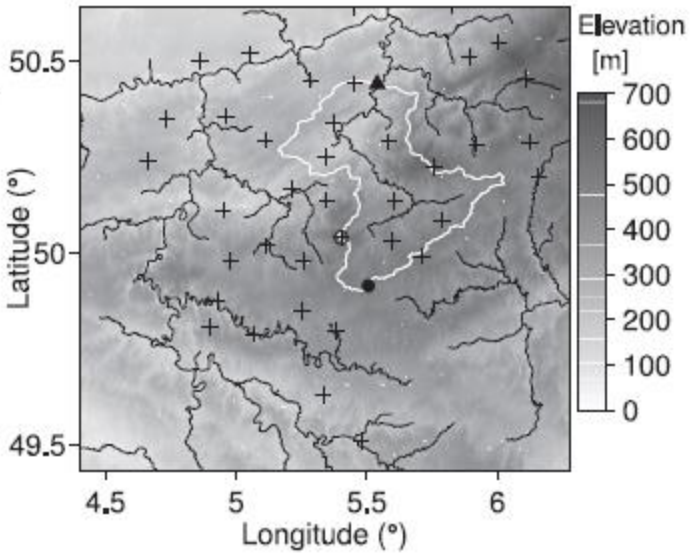
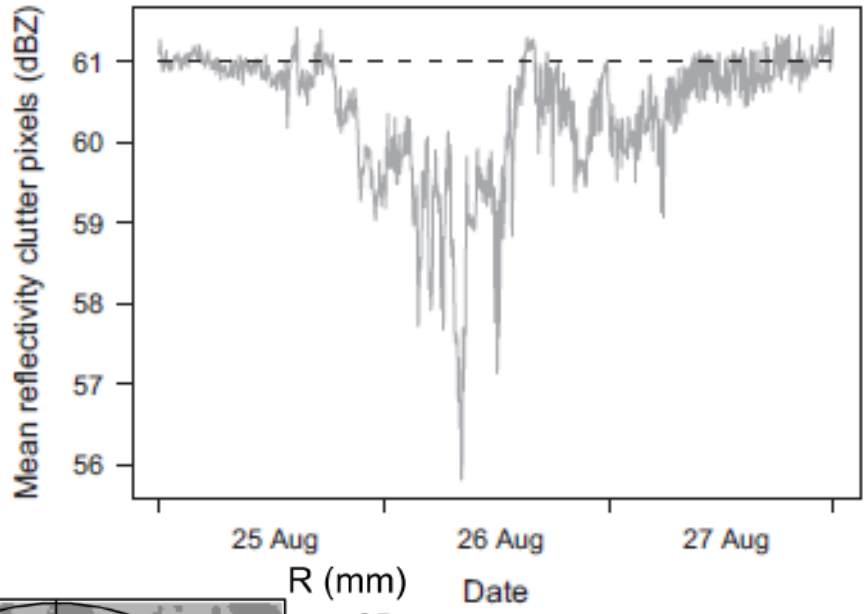


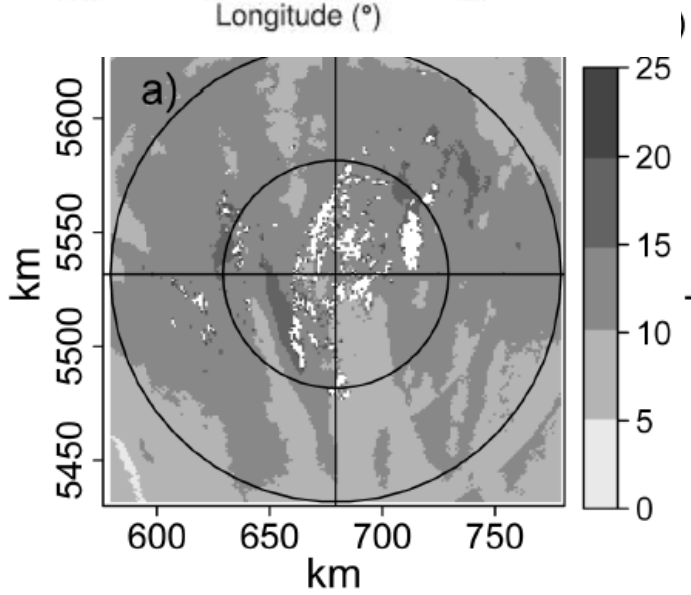
Figure 1: Phenomena Affecting Radar Data Quality (Holleman et al. 2006).

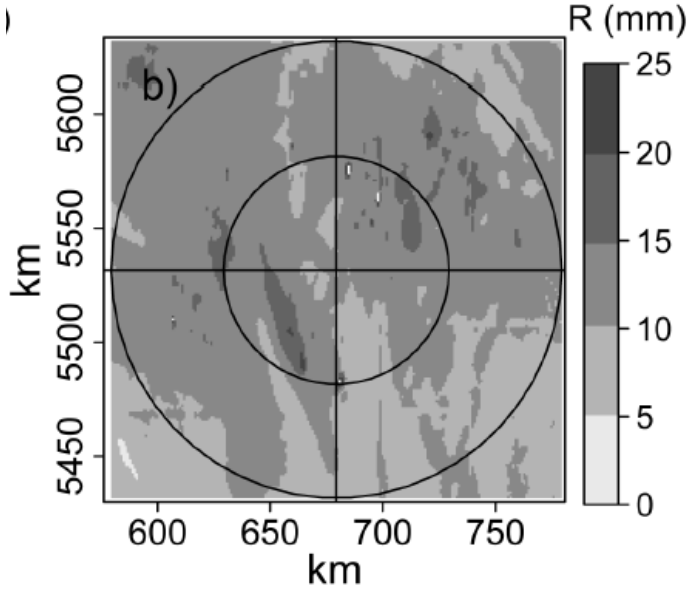
Correcting for measurement errors











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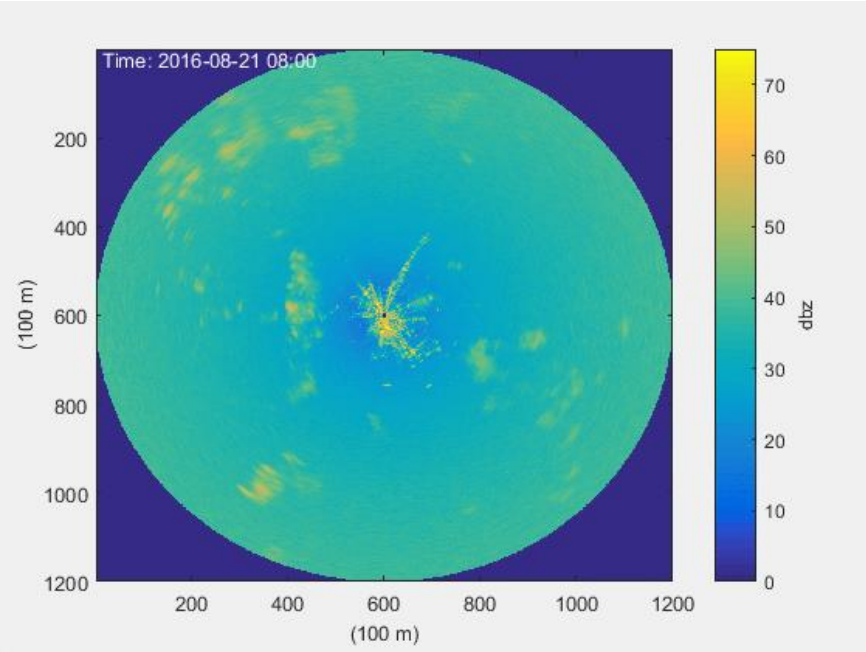
Quantitative precipitation estimations (QPEs)

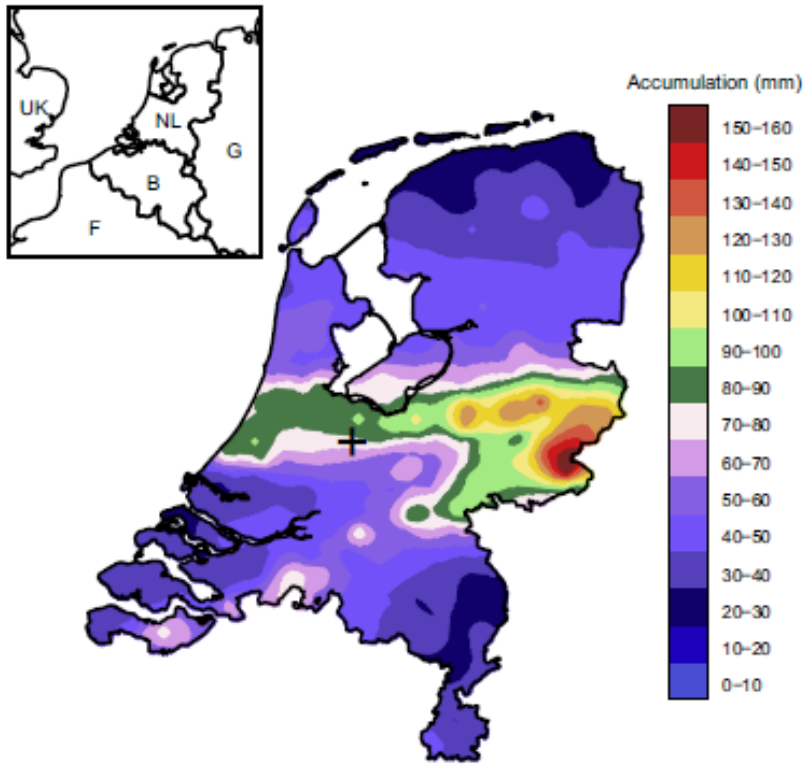


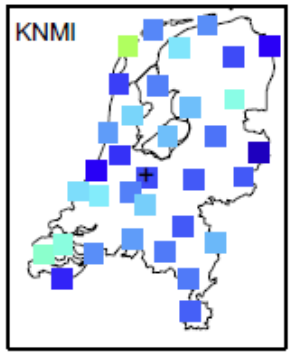
Signal processing
- Noise removal
- Clutter removal
- Interference filtering

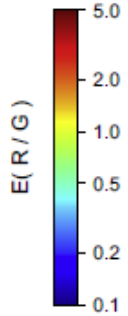
Corrections
- Beam blockage correction
- VPR correction
- Hydrometer classification

Rainfall rate estimation
- Choose variables
- Choose Drop Size Distribution (DSD)

Compose
- Multiple radars
- Multiple products







Impact of weather radar reflectivity correction on extreme hydrological events

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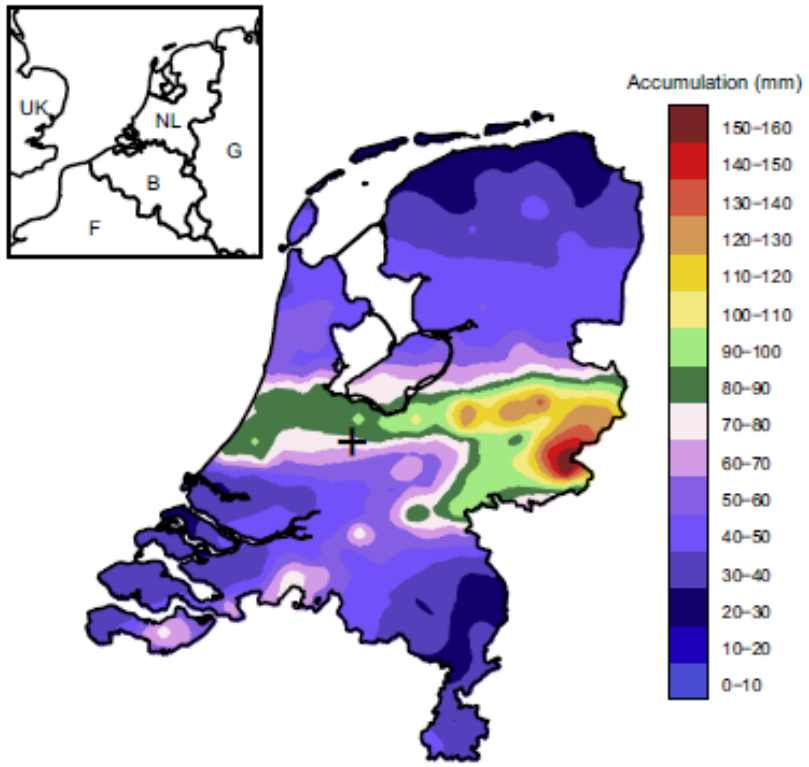
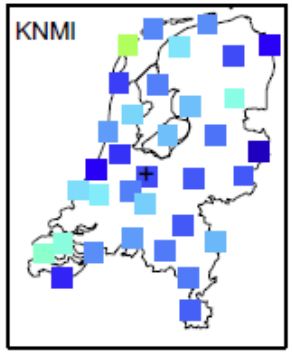
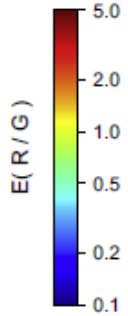

UK
NL
G
B
F
Accumulation (mm)
150–160
140–150
130–140
120–130
110–120
100–110
90–100
80–90
70–80
60–70
50–60
40–50
30–40
20–30
10–20
0–10


KNMI


E(R / G)
5.0
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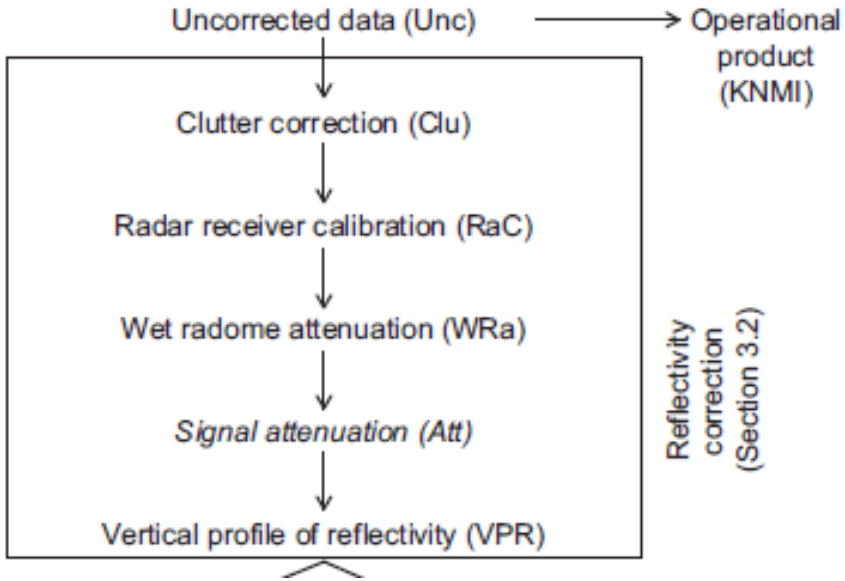
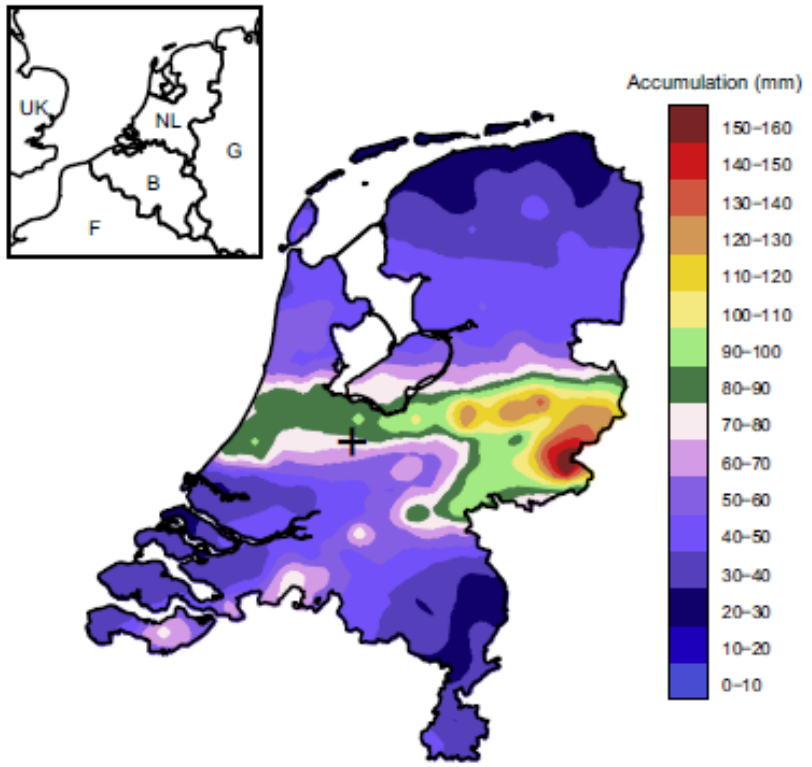

Uncorrected data (Unc)
Operational product (KNMI)
Clutter correction (Clu)
Radar receiver calibration (RaC)
Wet radome attenuation (WRa)
Signal attenuation (Att)
Vertical profile of reflectivity (VPR)
Reflectivity correction (Section 3.2)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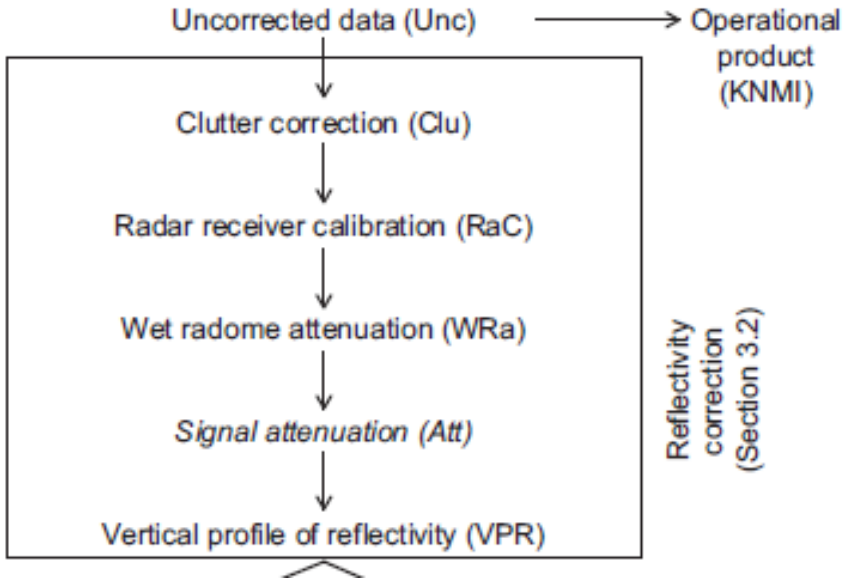
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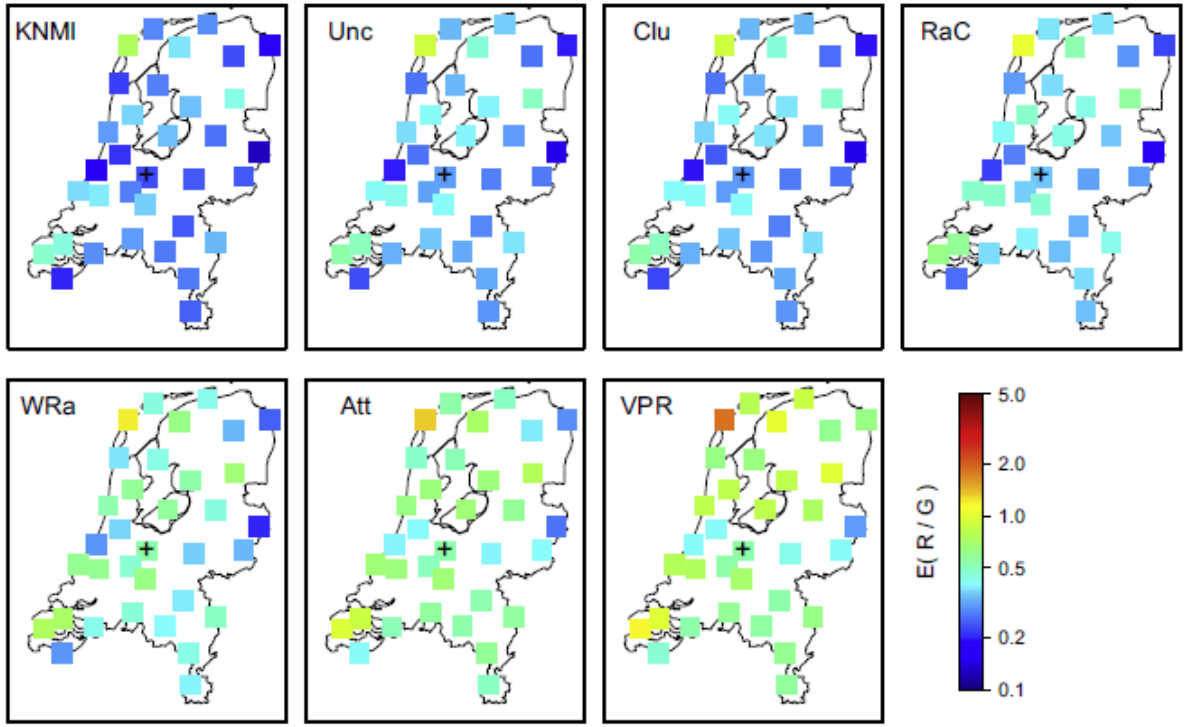
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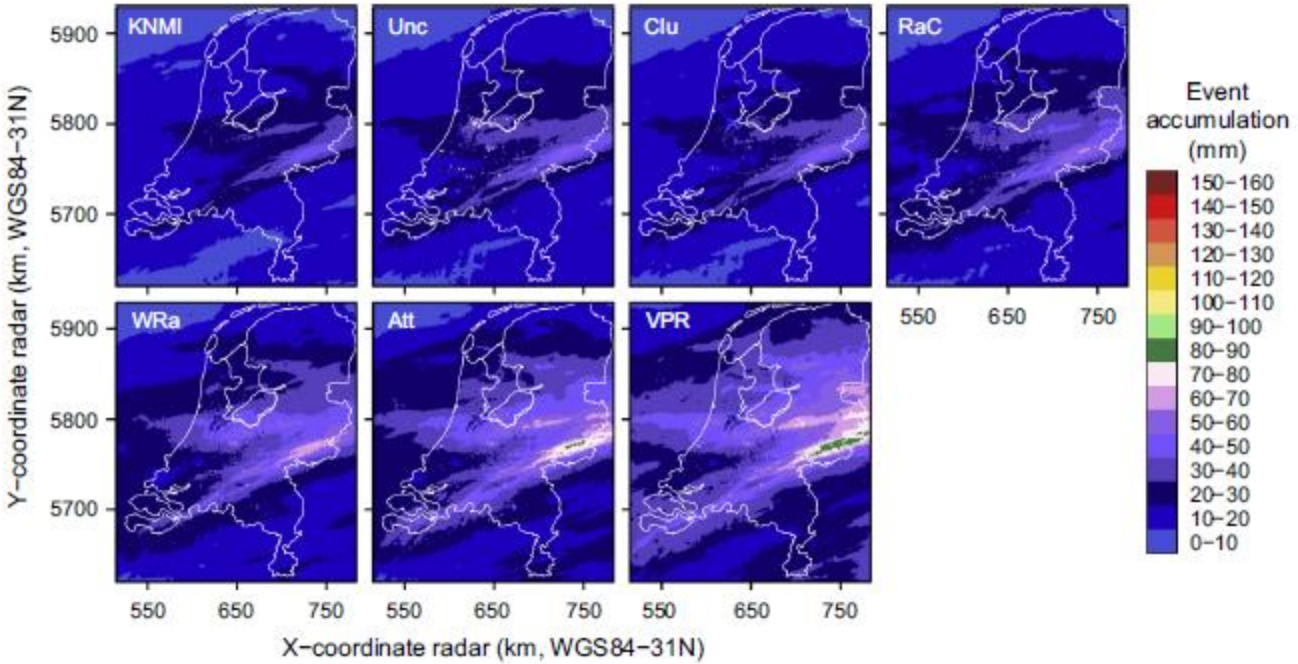
KNMI
Unc
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750
Y−coordinate radar (km, WGS84−31N)
X−coordinate radar (km, WGS84−31N)
Event accumulation (mm)
150–160
140–150
130–140
120–130
110–120
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90–100
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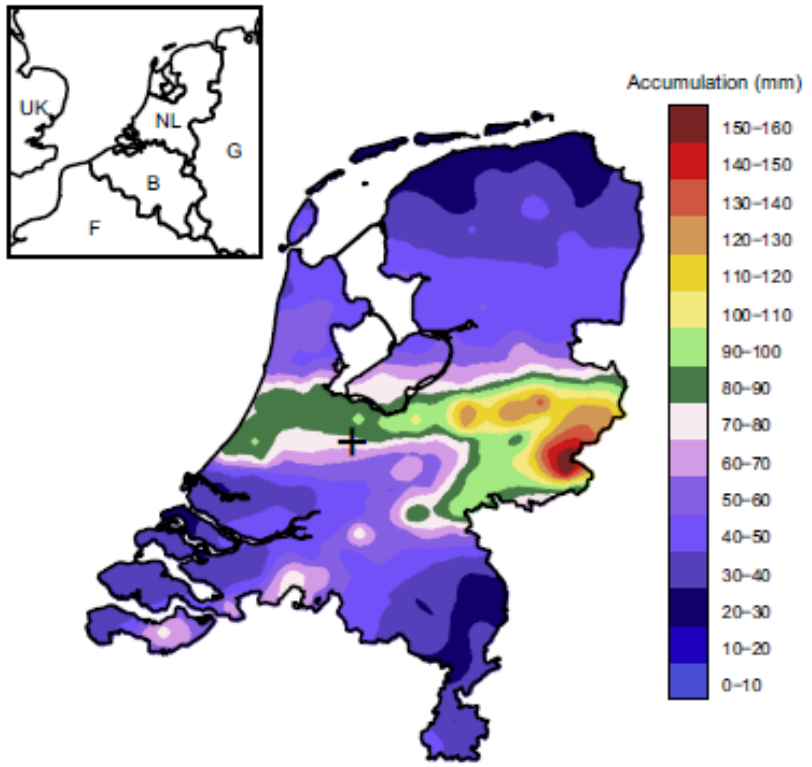
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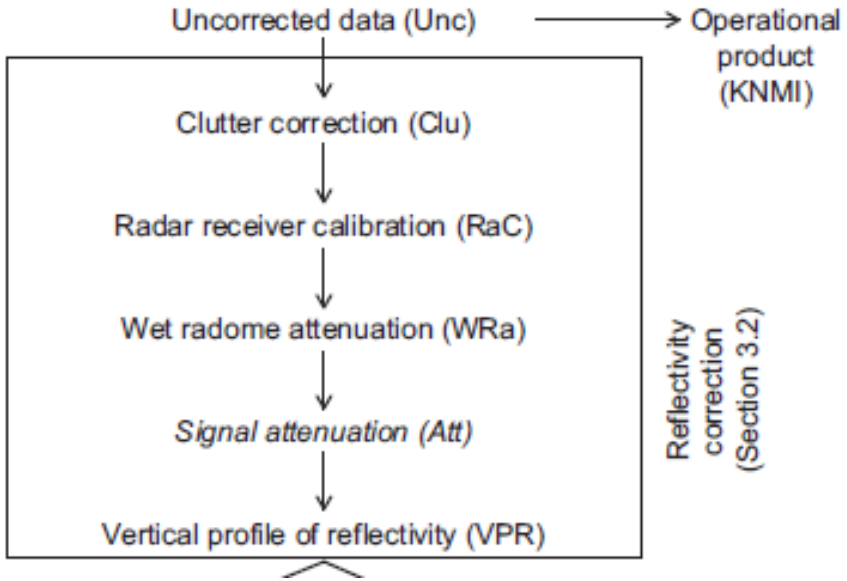
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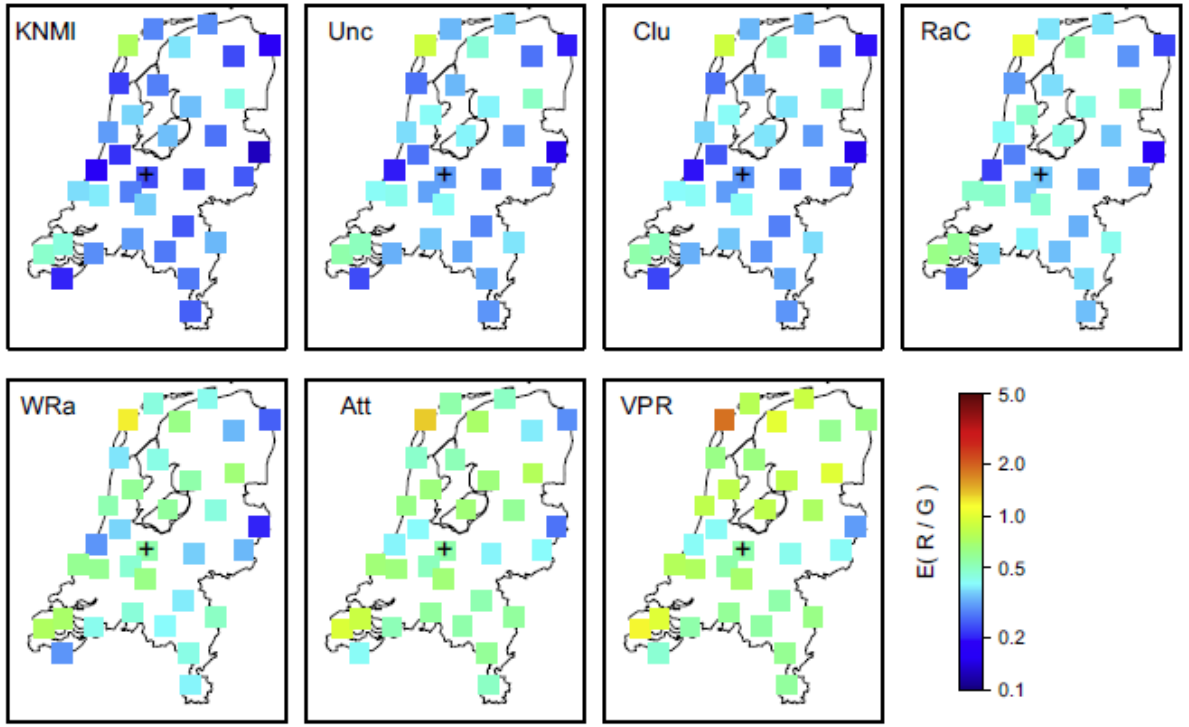
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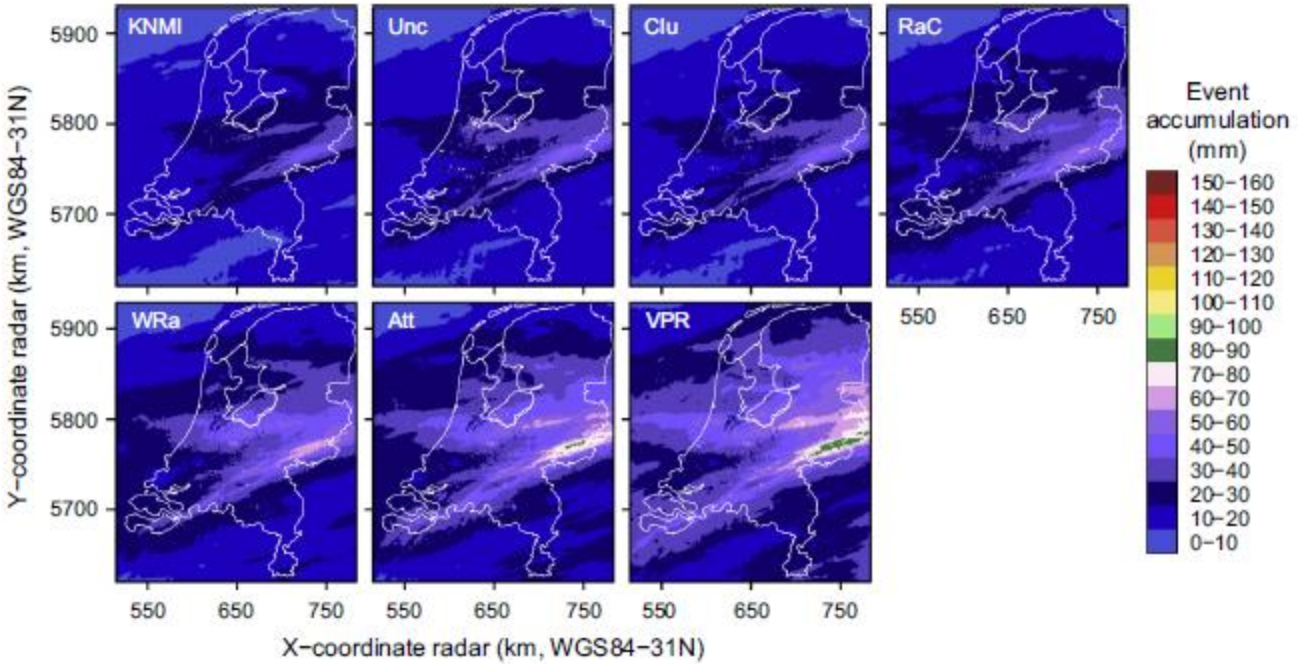
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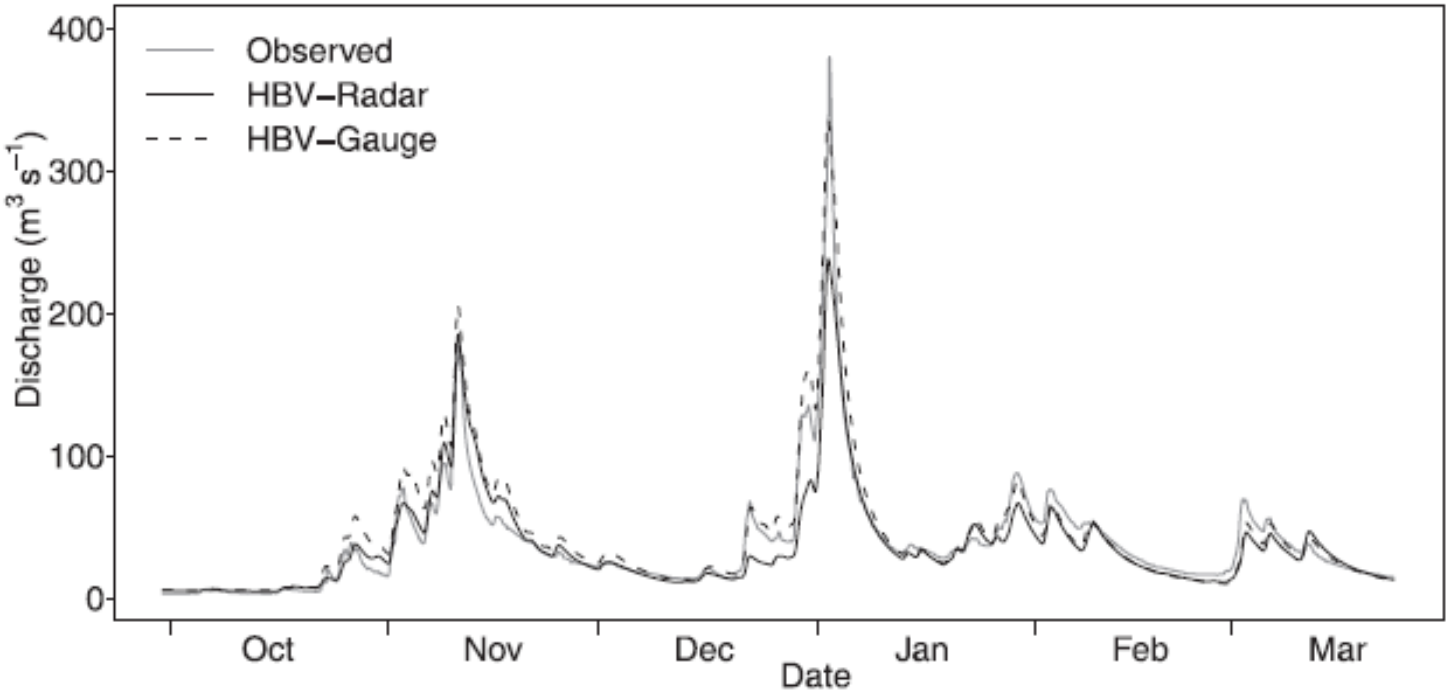
Weather radar QPE for operational usage

2 options:

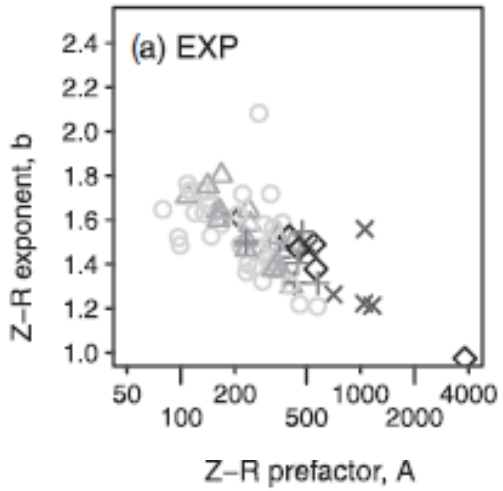
1. Apply as is and accept potential error



Weather radar QPE for operational usage

2 options:

1. Apply as is and accept potential error
2. Further correct using surface observations
    1. Bias correction
    2. Improving Z-R relations
    3. Gridded interpolation (co-kriging)



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Weather radar QPE for operational usage

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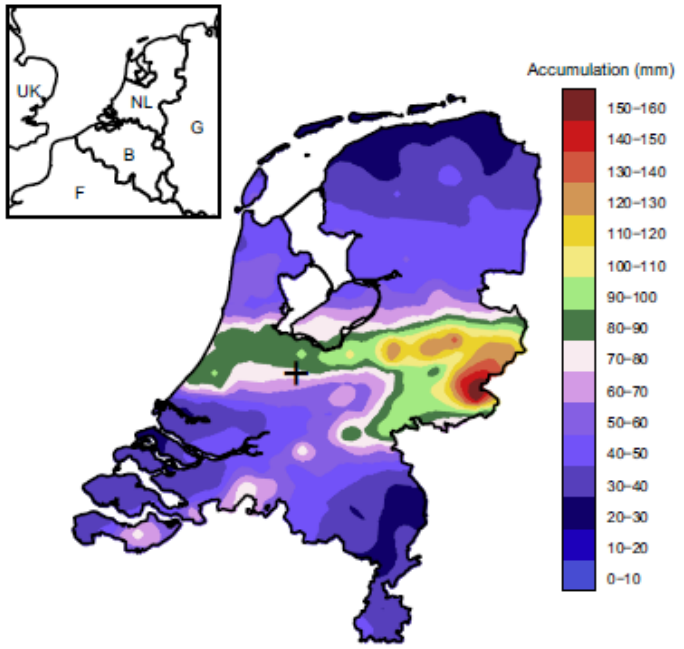

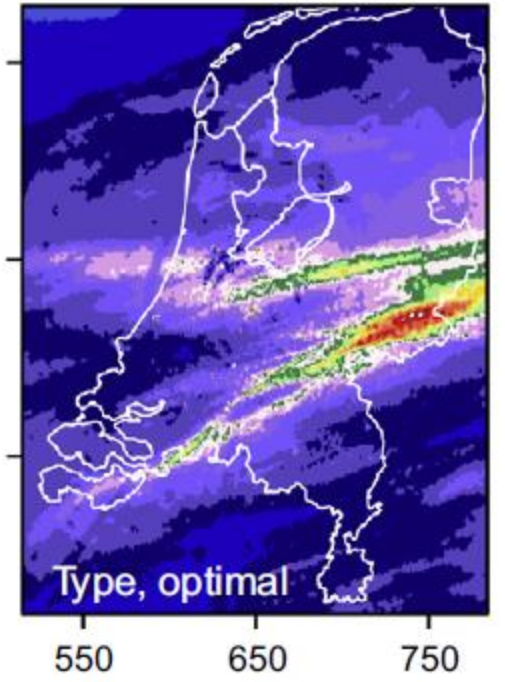

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Radar Rainfall Post-processing

Derive the product for your application

(Mentimeter) Which type of application would you like to use radar for?

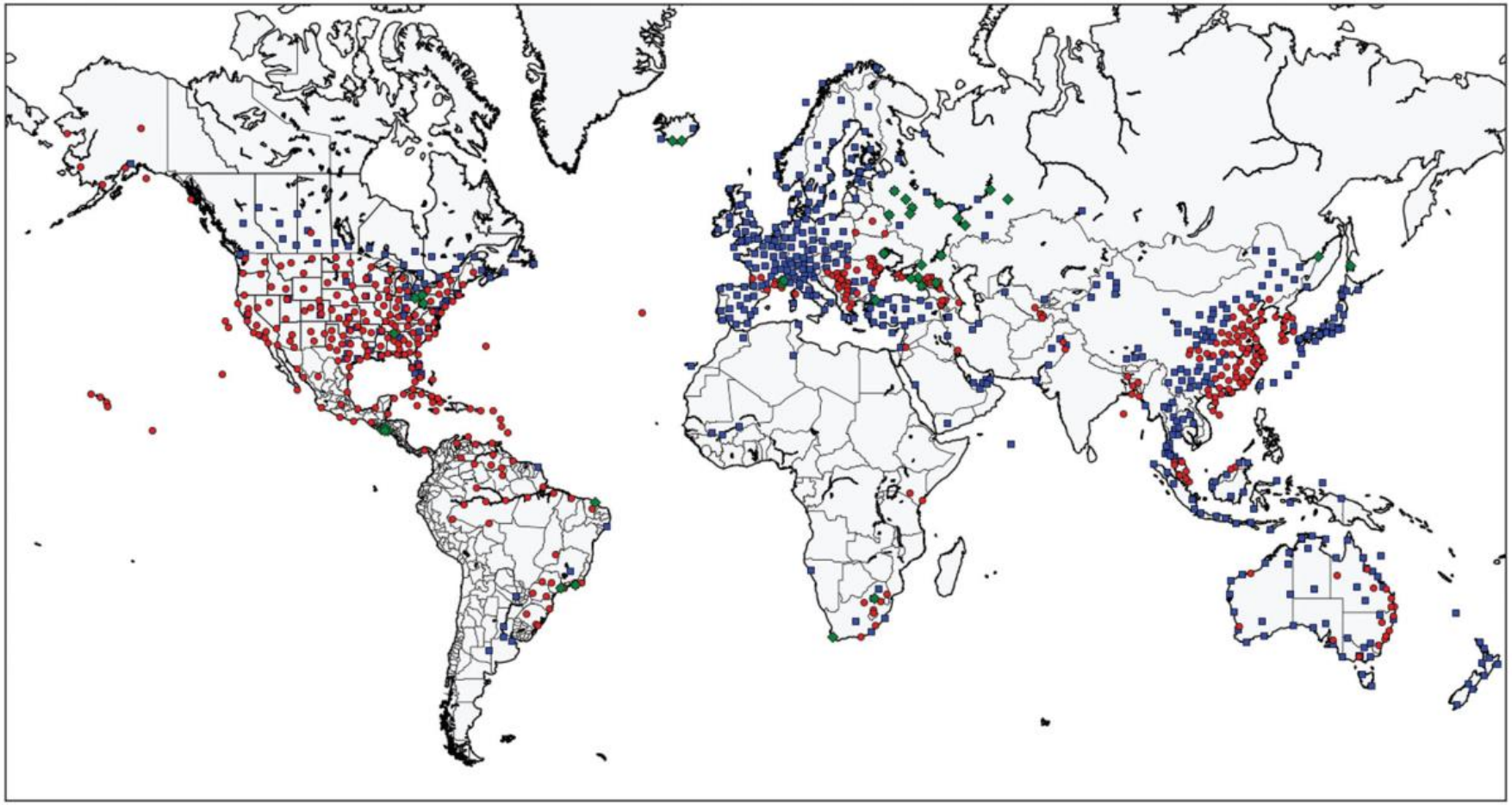
Open question:

Think of:
Coastal, river, urban
flood forecasting, real-time control, etc

(Mentimeter) Which types of weather radars are used in your data?

- A) S-band
- B) C-band
- C) X-band
- D) A combination of above
- E) I don’t know

Weather radars around the world



Distribution of **C-**, **S-**, and **X-**band radars from the current WMO radar database plus additions (Saltikoff et al., 2016).

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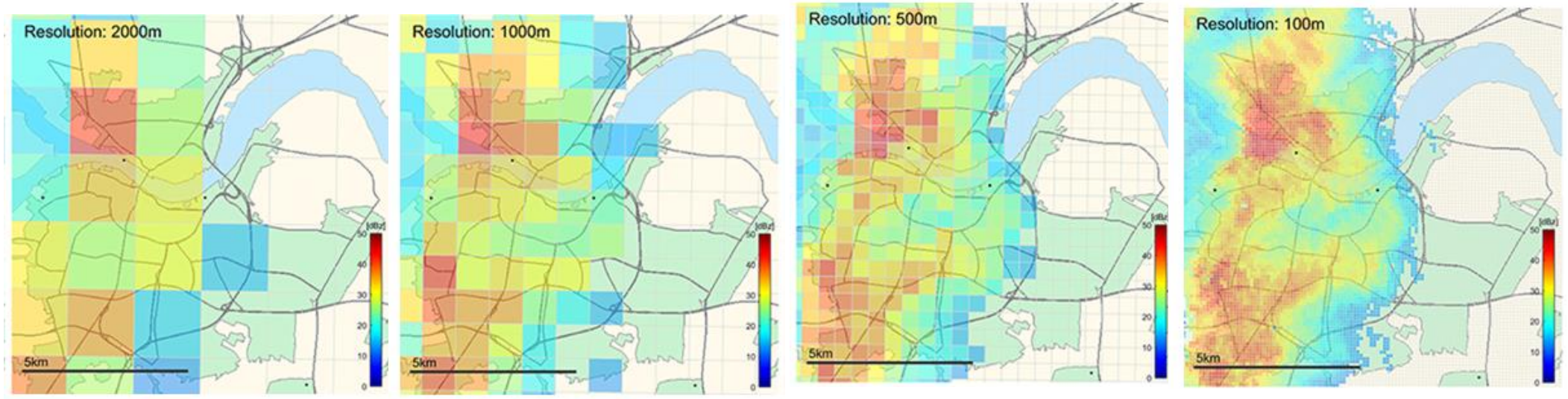
(Mentimeter) Which is the most important to your application?

A) Quantitative precipitation estimation
B) Spatial patterns
C) Temporal resolution
D) Spatial resolution
E) Real-time availability
F) Others:___
G) All of above

Radar observation resolutions

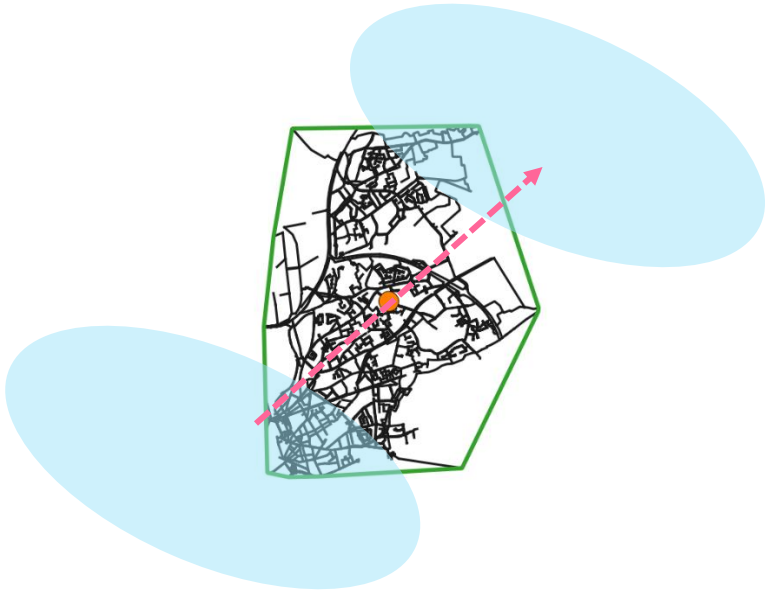
	S-band	C-band	X-band
Frequency	2700–2900 MHz	5600-5650 MHz	9300-9500 MHz
Spatial resolution	1000–4000 m	250–2000 m	100–1000 m
Temporal resolution	10–15 min	5–10 min	1-5 min
Maximum range	100–200 km	100–130 km	30–60 km



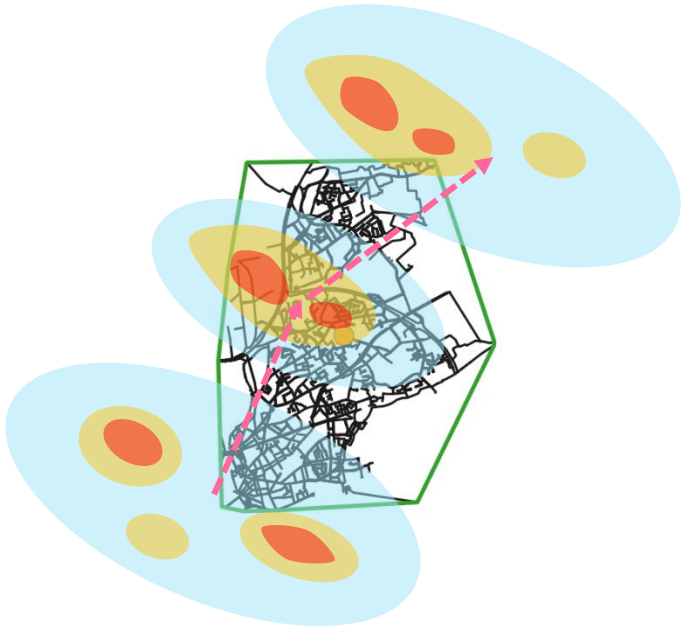
(Thorndahl et al., 2017)

Fine-scale rainfall activities

Large scale

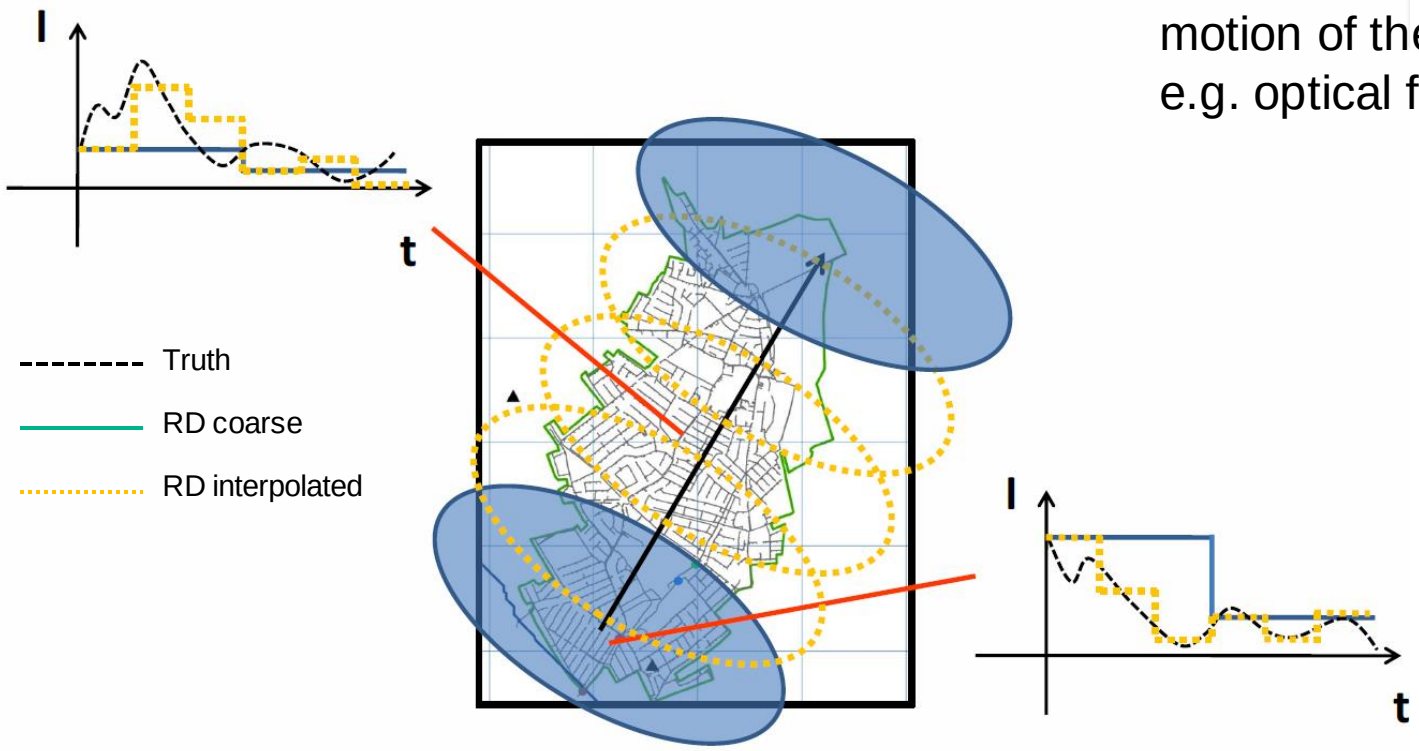


Fine scale



Particularly important for small basins, e.g. urban

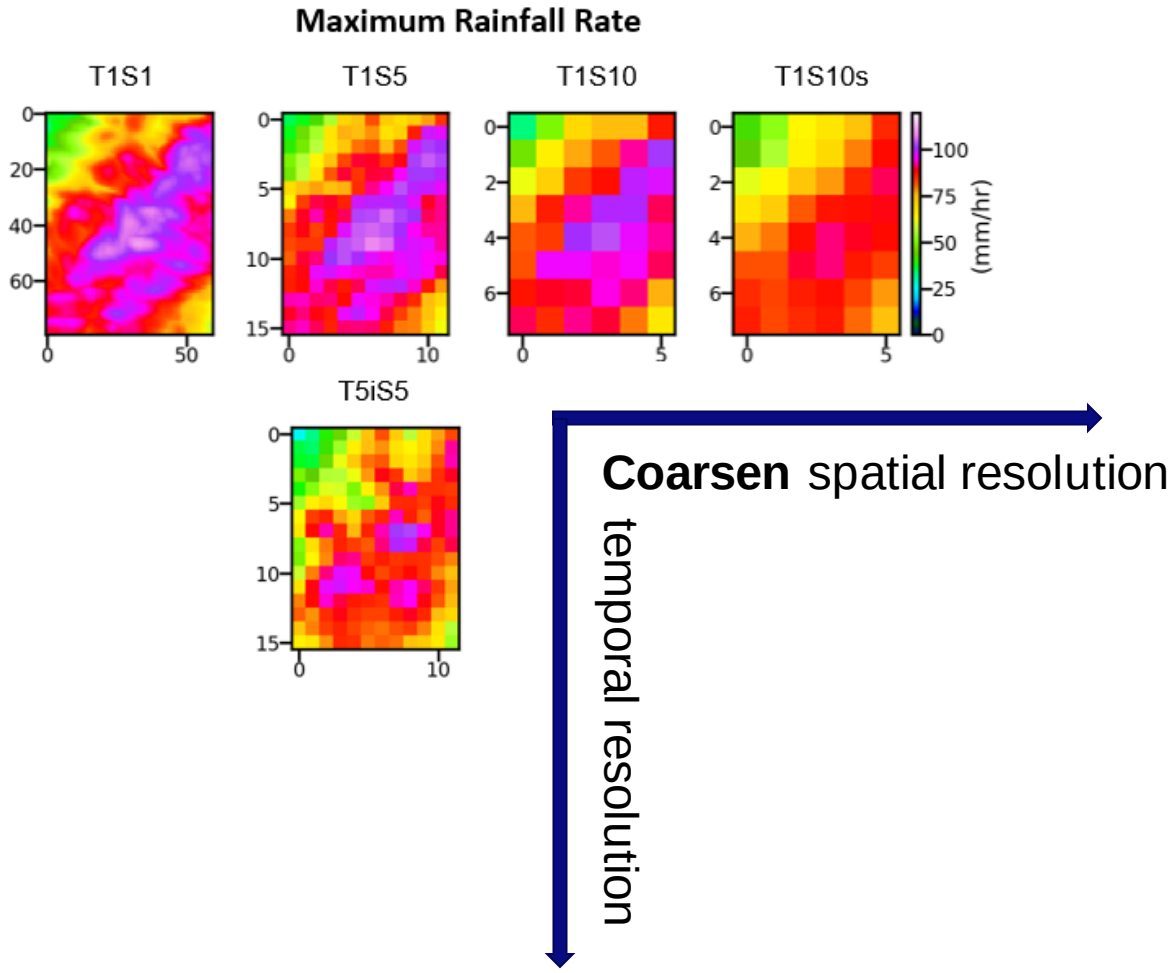
Rainfall interpolation



Based on tracking the motion of the rainfall field, e.g. optical flow method

(Wang, et al. 2015)

Example of rainfall interpolation



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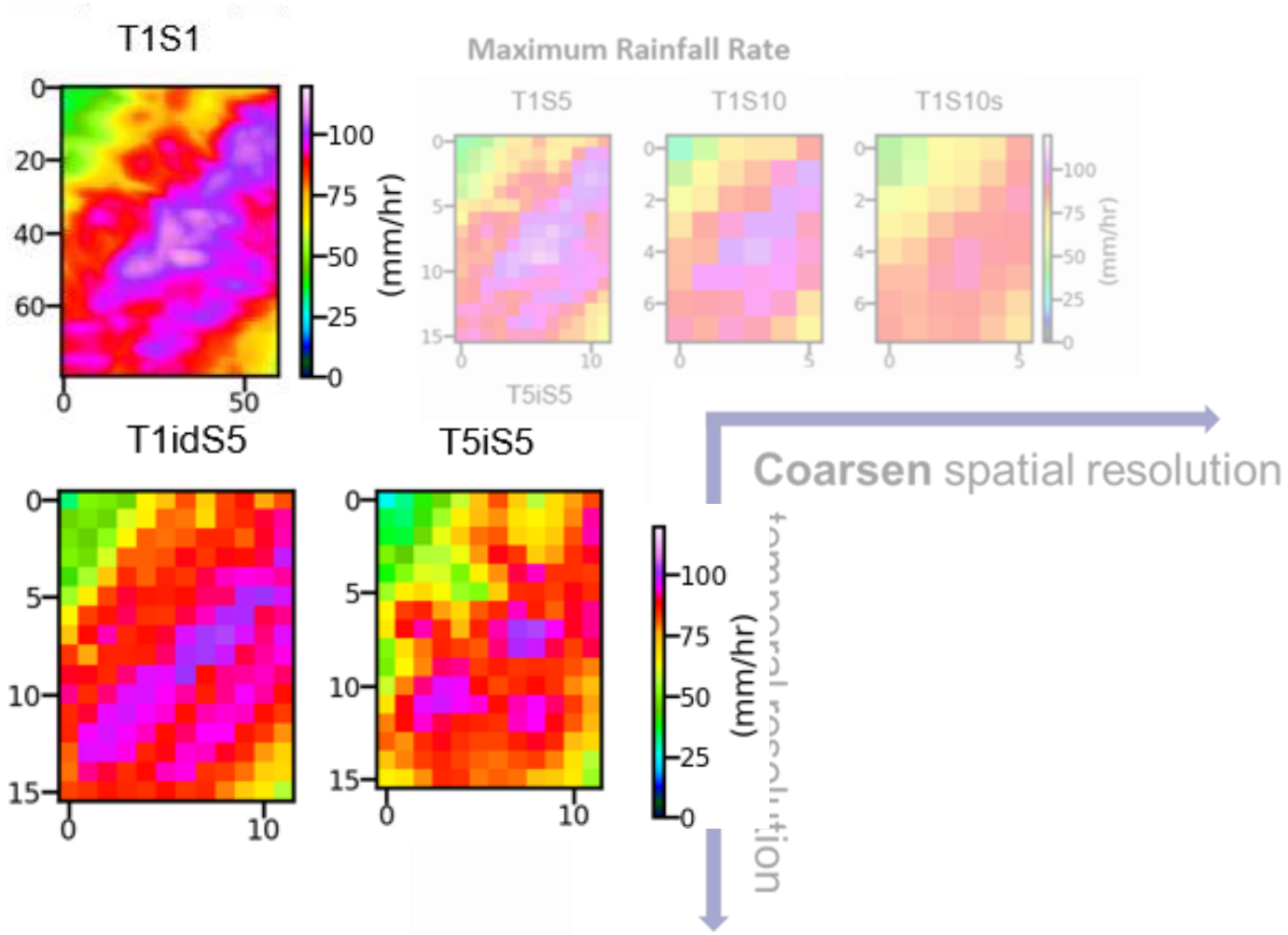
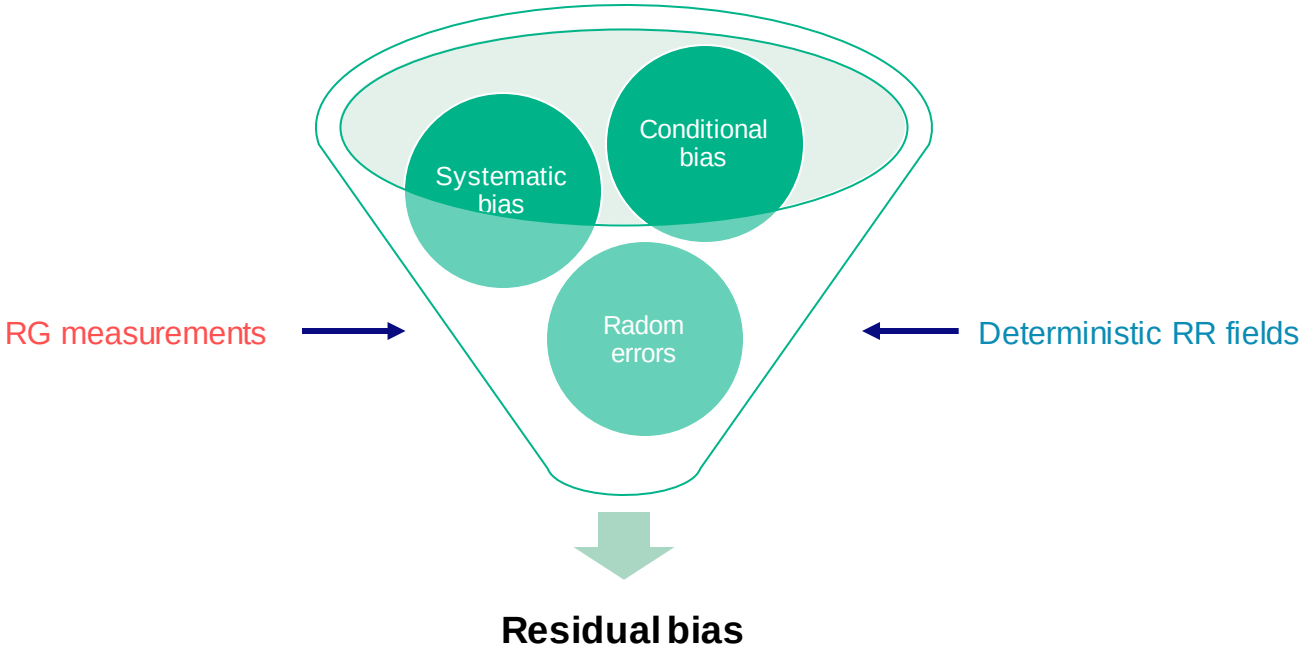
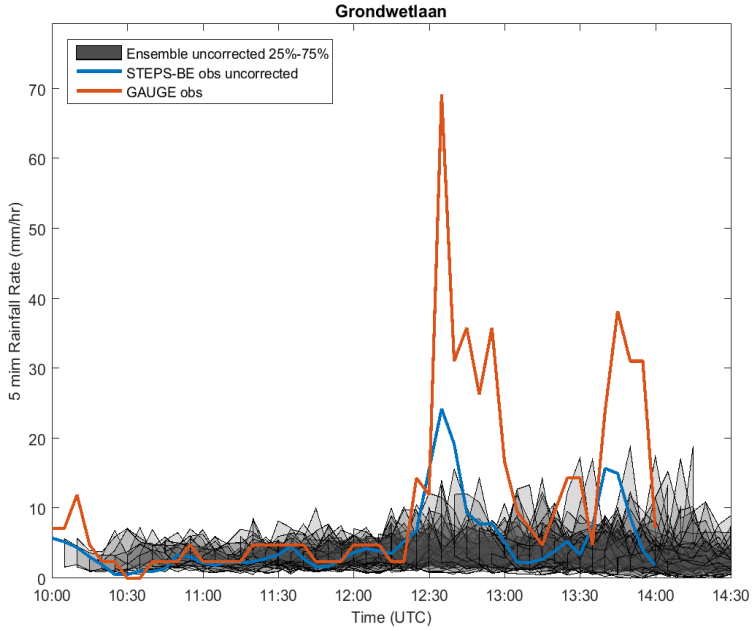
Example of rainfall interpolation



Residual bias in radar observations





(an example in Belgium)

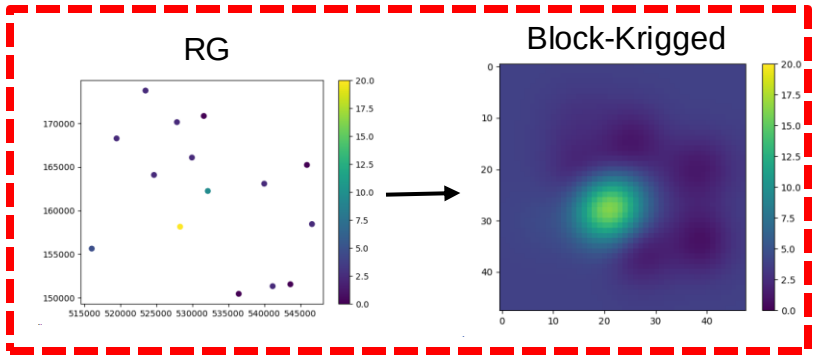
Effect of bias in radar observation will propagate into radar nowcasts

Radar - RainGauge Merging

Merging techniques: (near real time):

Category	Methods	Description
Simple error computing-based	Mean Field Bias	global mean field applied across the domain
Geostatistical-based	Block Kriging Kriging with External Drift	local mean field inferred from rain gauge/radar data
Bayesian-based	Bayesian Merging (Todini, 2001); Singularity-Bayesian Merging (Wang et al., 2015)	co-variance of estimation errors from radar and rain gauges

Singularity-Sensitive Bayesian Merging



1. Block kriging

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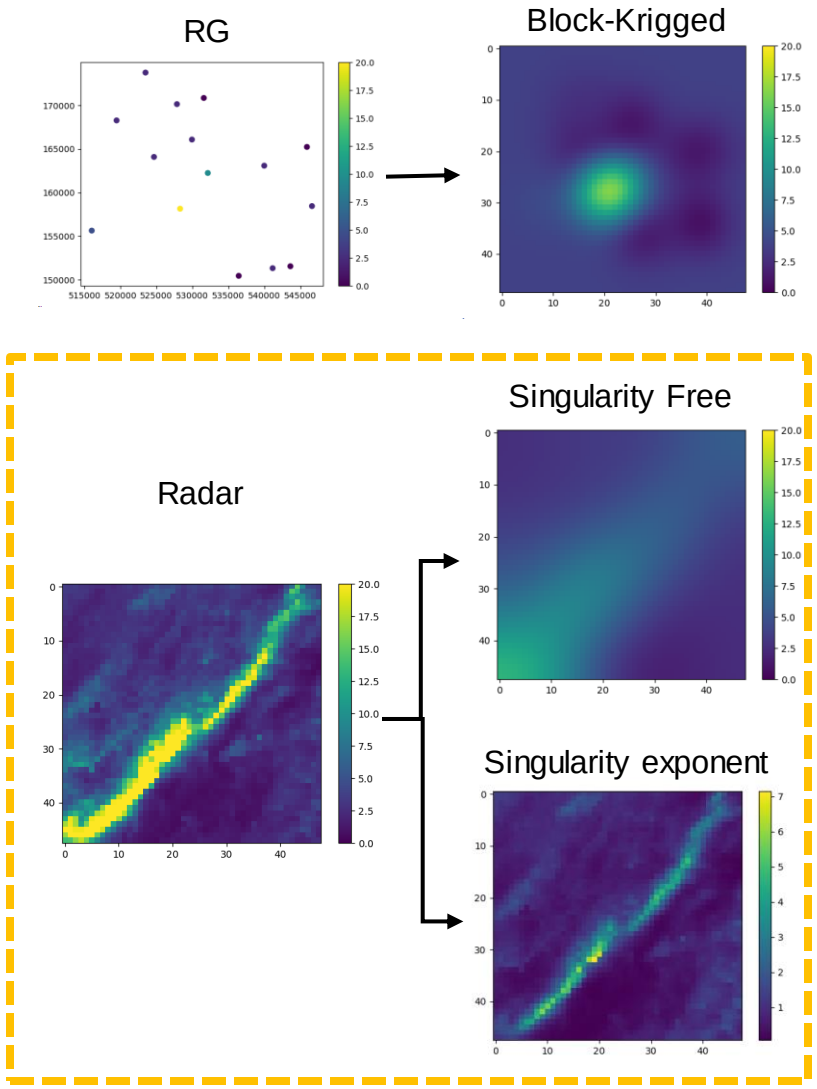
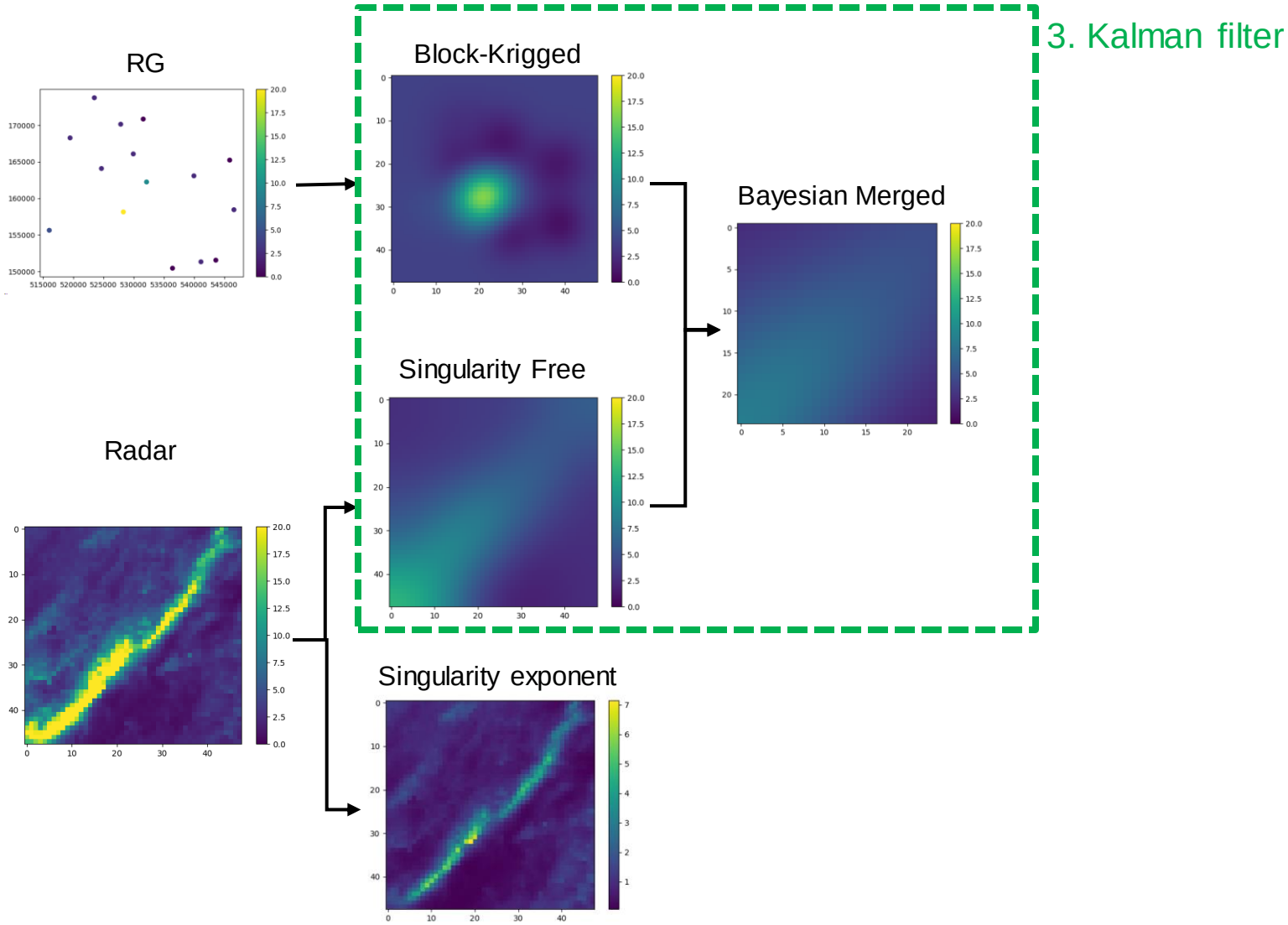
Singularity-Sensitive Bayesian Merging



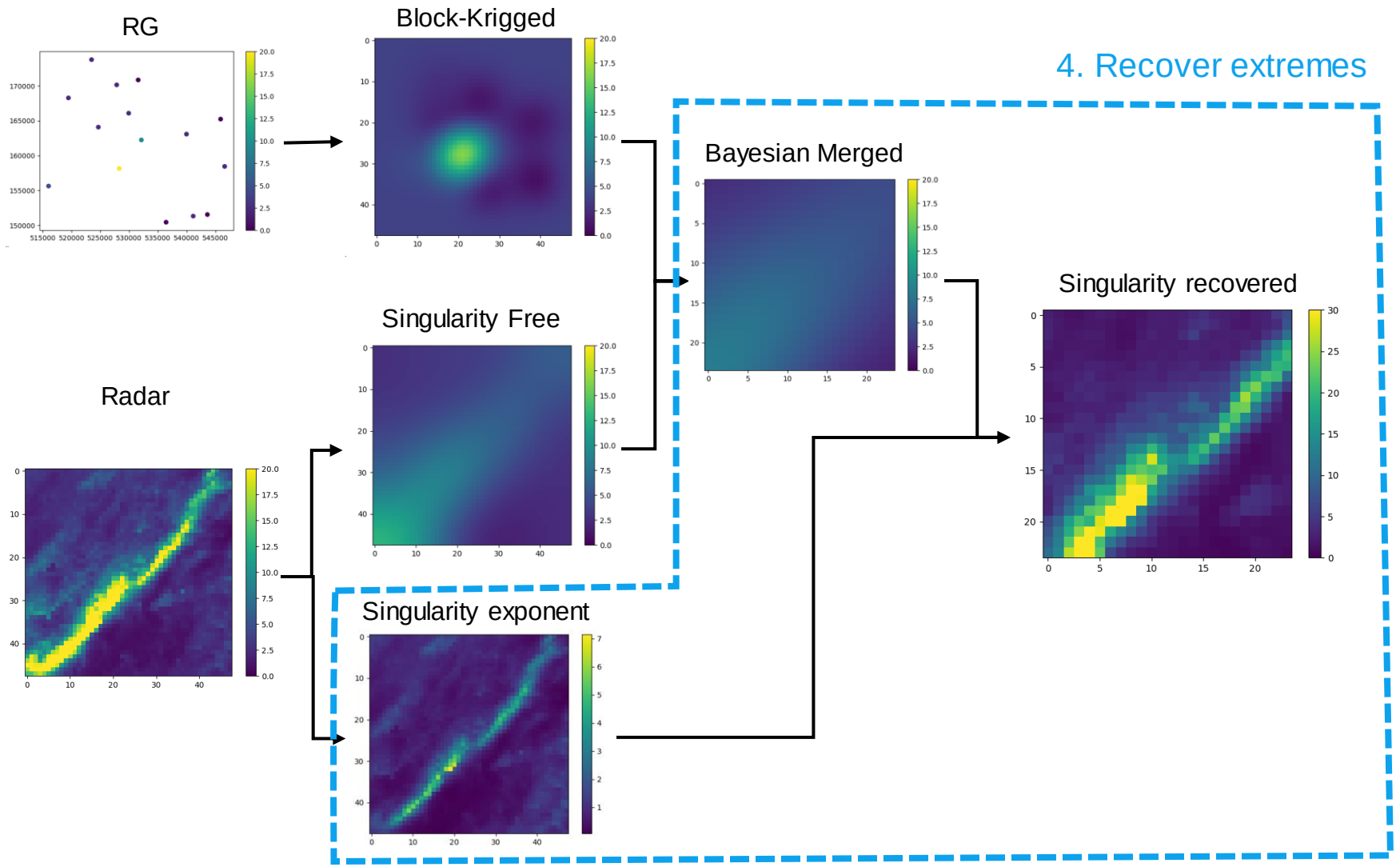
2. Singularity analysis

Singularity-Sensitive Bayesian Merging

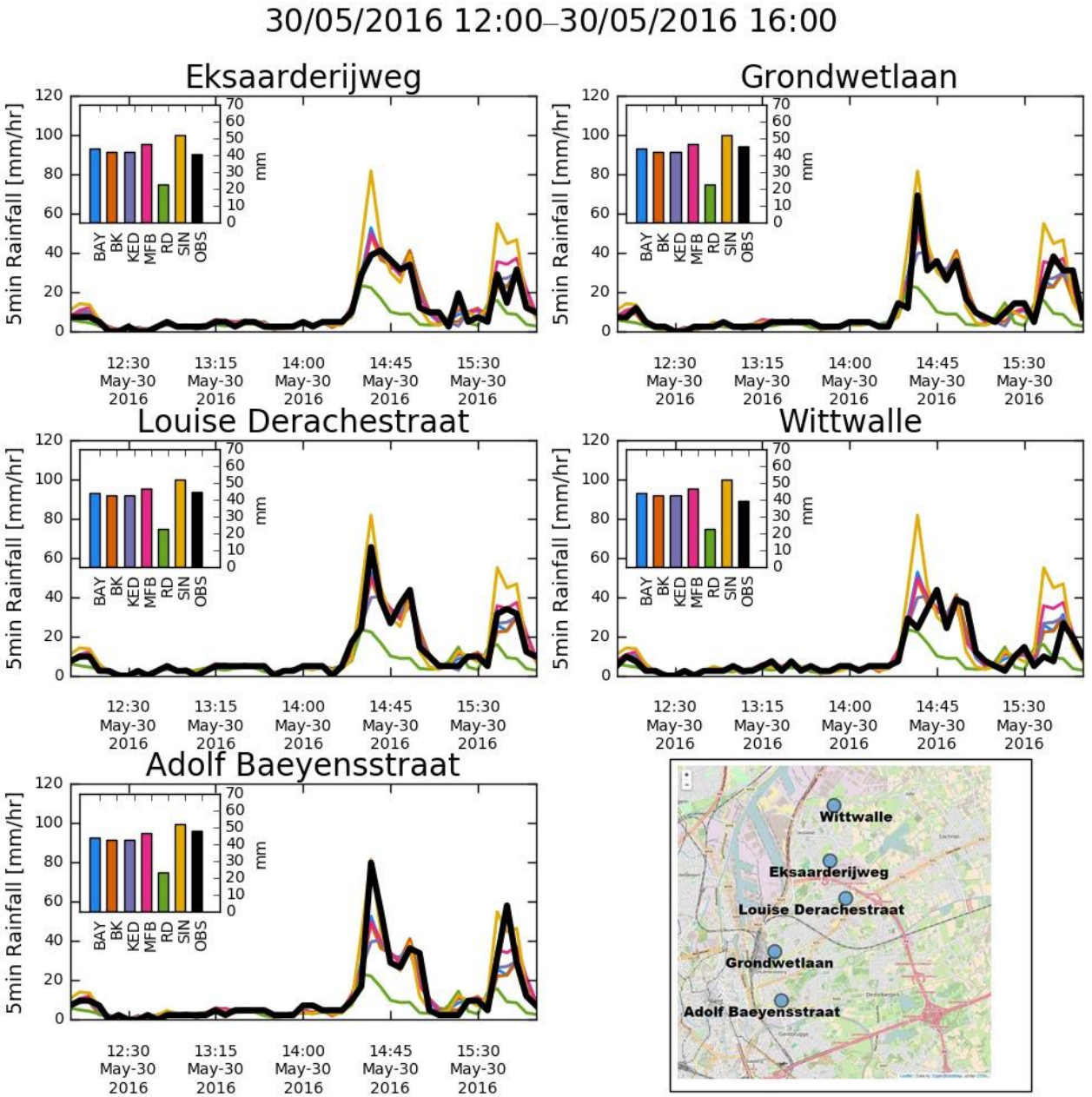


(Wang et al., 2015)

Singularity-Sensitive Bayesian Merging



Merging Evaluation



Corrected radar data is following rain gauges
And is almost twice as high as the uncorrected radar data!

(Plurisk, 2017)

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Nowcasting

Towards short-term operational rainfall forecasts

Which sources of information do you already use for rainfall forecasting?

Think of:

- Numerical weather prediction models
- Seasonal rainfall predictions
- Nowcasting of rainfall
- Satellite based information
- Etc.

Open question (get a cloud of words or so)

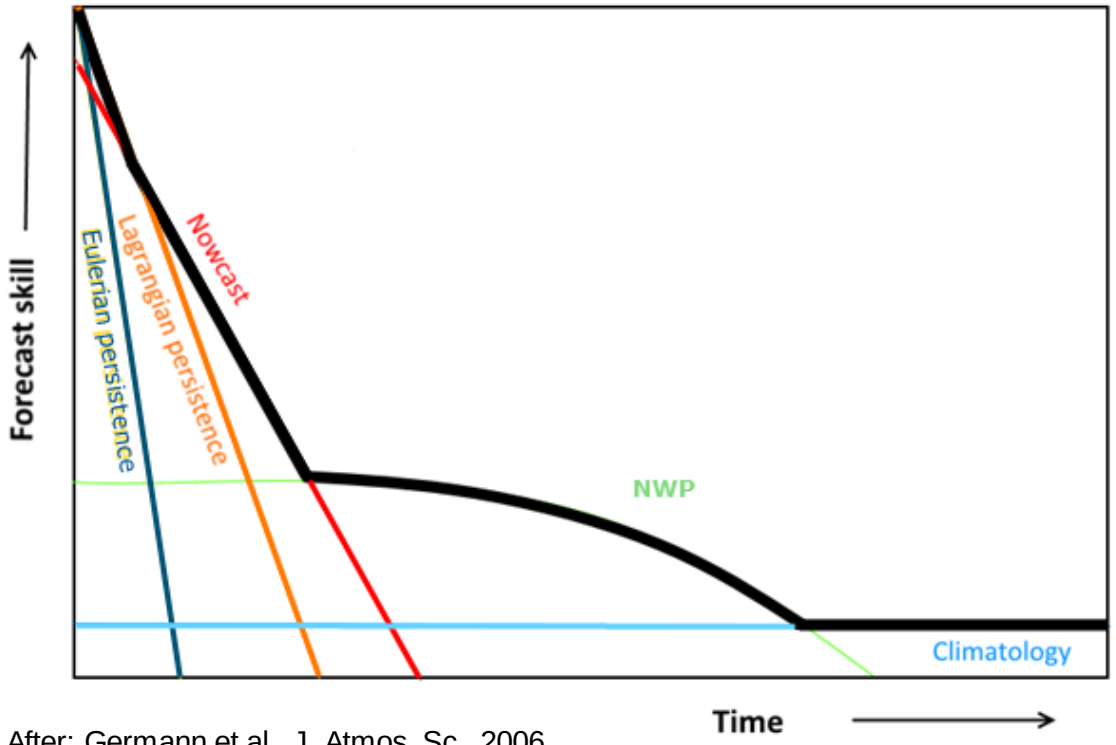
How many hours/days/weeks in advance should the end-user of your operational system have rainfall forecasts for timely actions?

- A) <1 hour in advance
- B) 1 – 6 hours in advance
- C) 6 - 48 hours in advance
- D) 1 week in advance
- E) > 1 week in advance

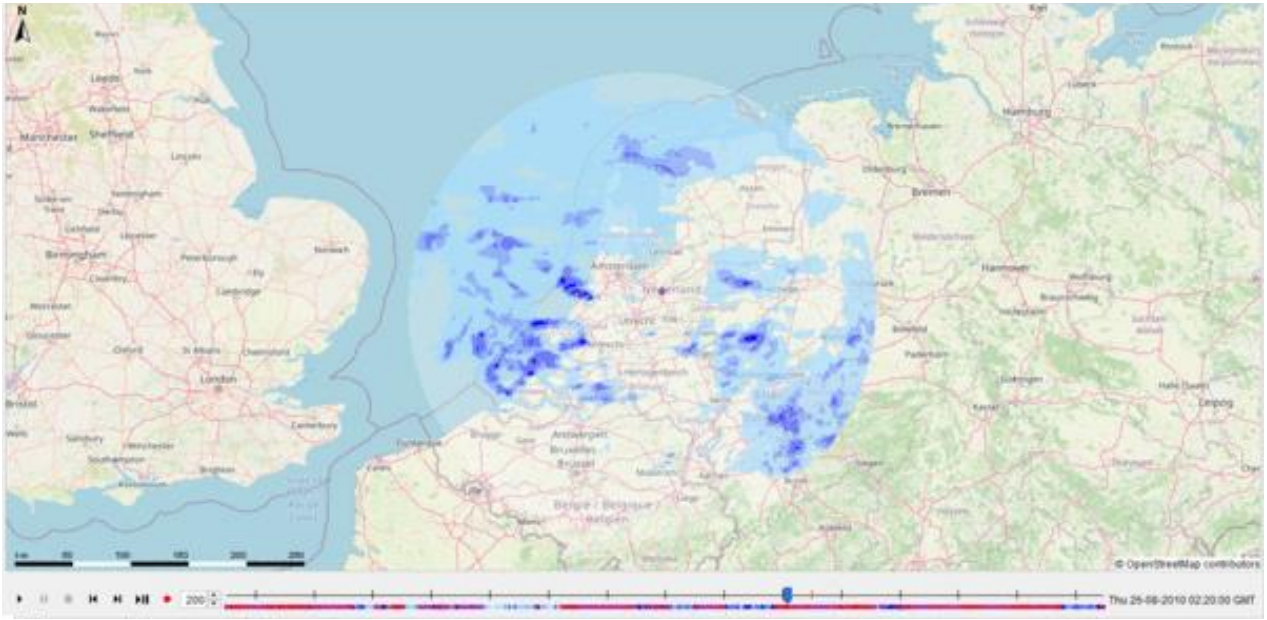
Do you have access to (radar) rainfall nowcasts?

- A) No
- B) Yes, through our met office
- C) Yes, through a third party
- D) Yes, we run a nowcasting method locally
- E) Yes, we have multiple sources

When can radar rainfall nowcasting be of interest to you?



After: Germann et al., J. Atmos. Sc., 2006



- A short introduction to nowcasting was given during the pitch: “Evaluation of radar rainfall nowcasting techniques for operational water management". Slides will be posted online later.

Steps towards operational nowcasting in Delft-FEWS
1. What do you need? Where do I start?

Plan A: Nowcasts are issued by met office or a third party

Plan B: Run nowcasts locally:

1. Radar data	Reflectivity fields (2D or 3D)
	Rainfall fields (2D – end product) – Easiest start!
	Vertically integrated liquid contents (in combination with reflectivity or rainfall fields)
2. Nowcasting algorithm	Which nowcasting algorithm do you want to use? → Cross-correlation based or similar (most used), centroid tracking, analogue based, machine learning based, etc.
	Open source options: pySTEPS (Python - modular framework consisting of e.g. S-PROG, STEPS and ANVIL), Rainymotion (Python), TITAN (L-Rose C++ package)

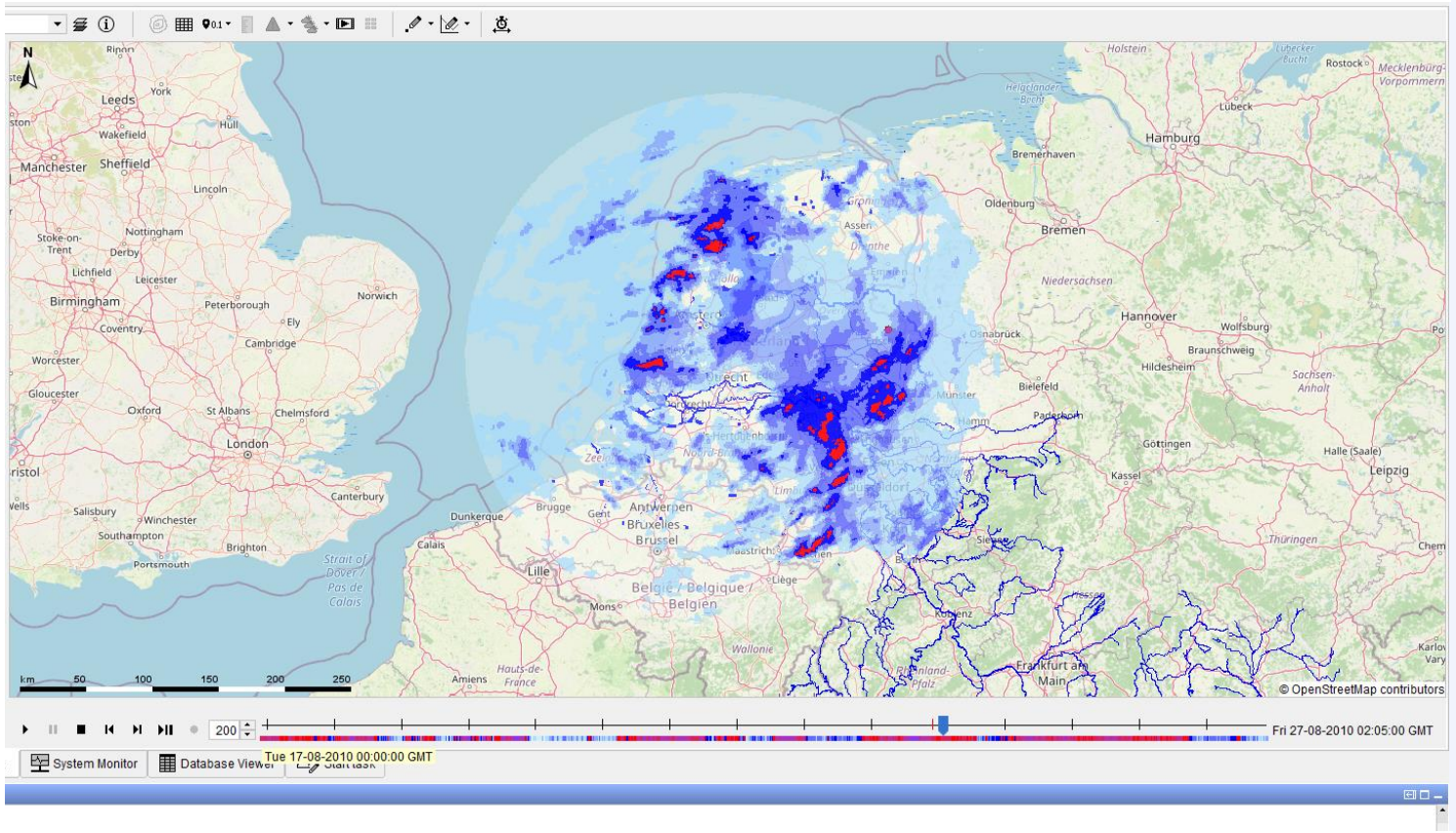
Steps towards operational nowcasting in Delft-FEWS

2. Import the nowcast results in Delft-FEWS

Nowcast results from external source

Nowcasts run locally, but outside Delft-FEWS

Nowcasts run with a general adapter run of Delft-FEWS



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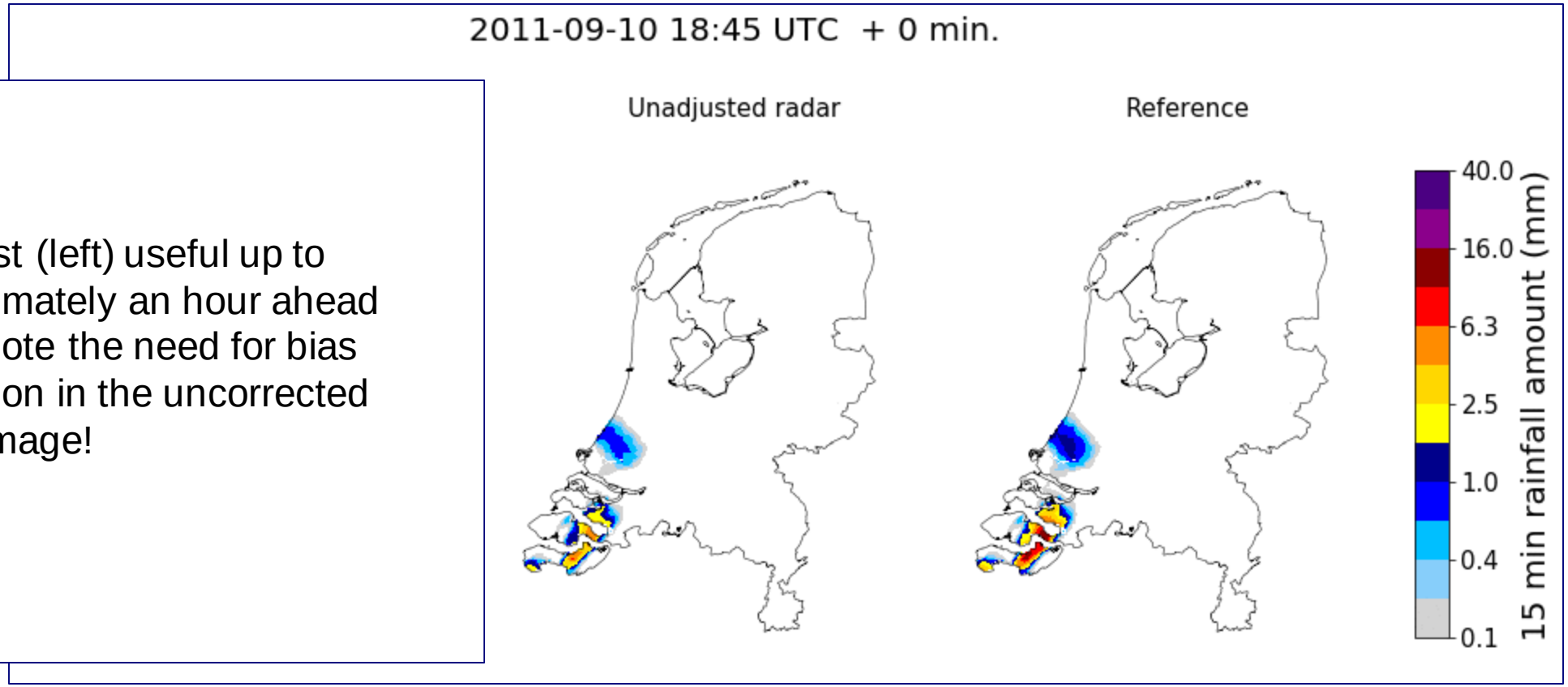
Steps towards operational nowcasting in Delft-FEWS

2. Import the nowcast results in Delft-FEWS

Nowcast (left) useful up to approximately an hour ahead here. Note the need for bias correction in the uncorrected radar image!



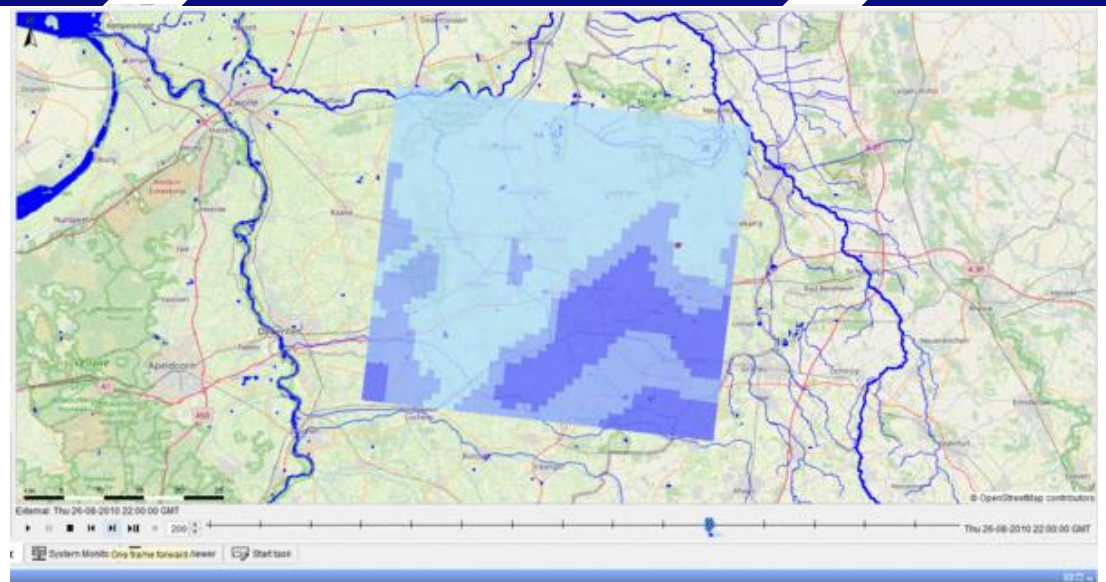
Steps towards operational nowcasting in Delft-FEWS
3. Use the rainfall forecasts for hydrological predictions

An example for the Regge catchment (water authority Vechtstromen) in the Netherlands

Imported nowcasts

Preprocess data for catchment (e.g. bias correction, clip and get catchment average)

Run model, here WALRUS



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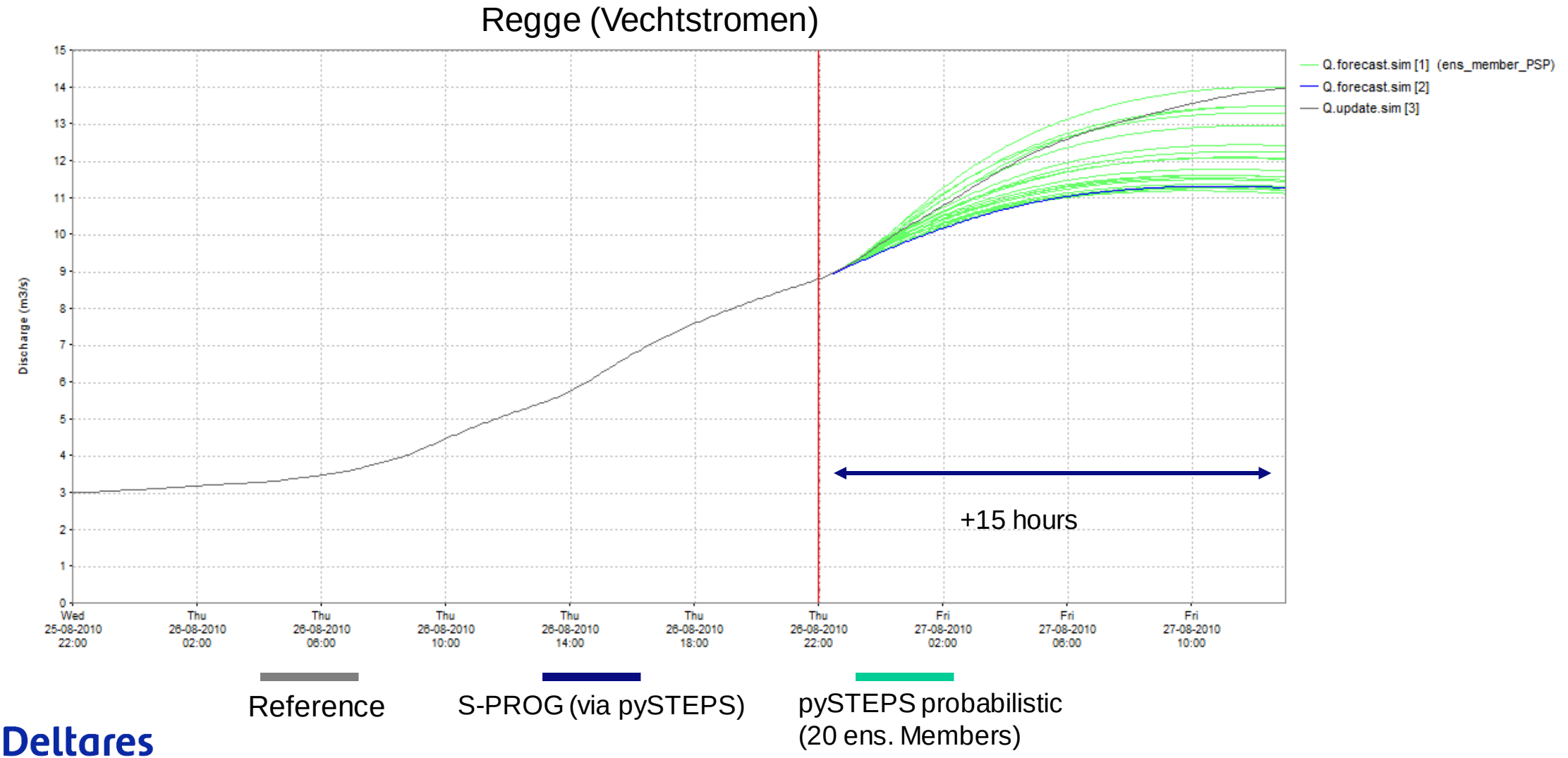
Steps towards operational nowcasting in Delft-FEWS

3. Use the rainfall forecasts for hydrological predictions



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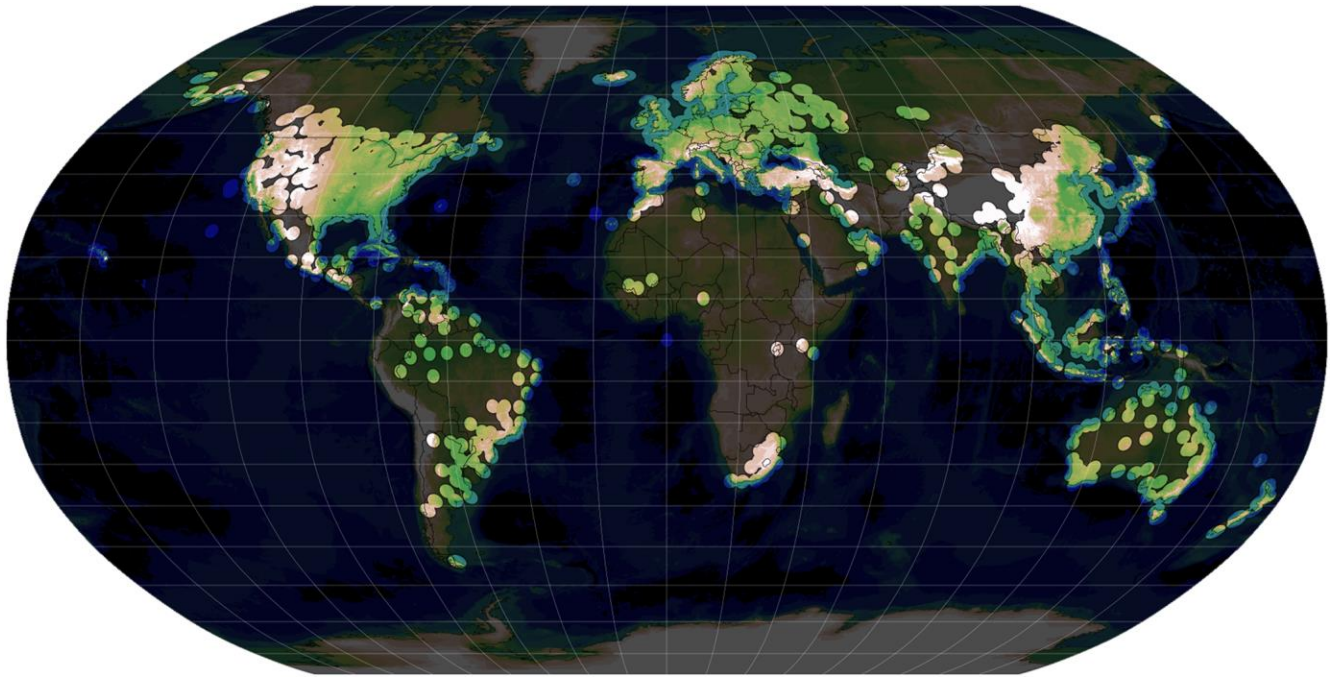
Other rainfall estimates:
What other QPE sources would you like to use for nowcasting?

- Open question again.

- Think of:
  - Satellite data
  - Personal weather stations
  - Commercial microwave links

Global radar coverage



Saltikoff et al., 2019, BAMS

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Wrap up

We would like to hear more from you!

enabling delta life

What makes a radar based operational system successful to your opinion?

Open question

What are the main challenges (you had/would have) to achieve so?

Open question

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