Radar rainfall experiences from Denmark

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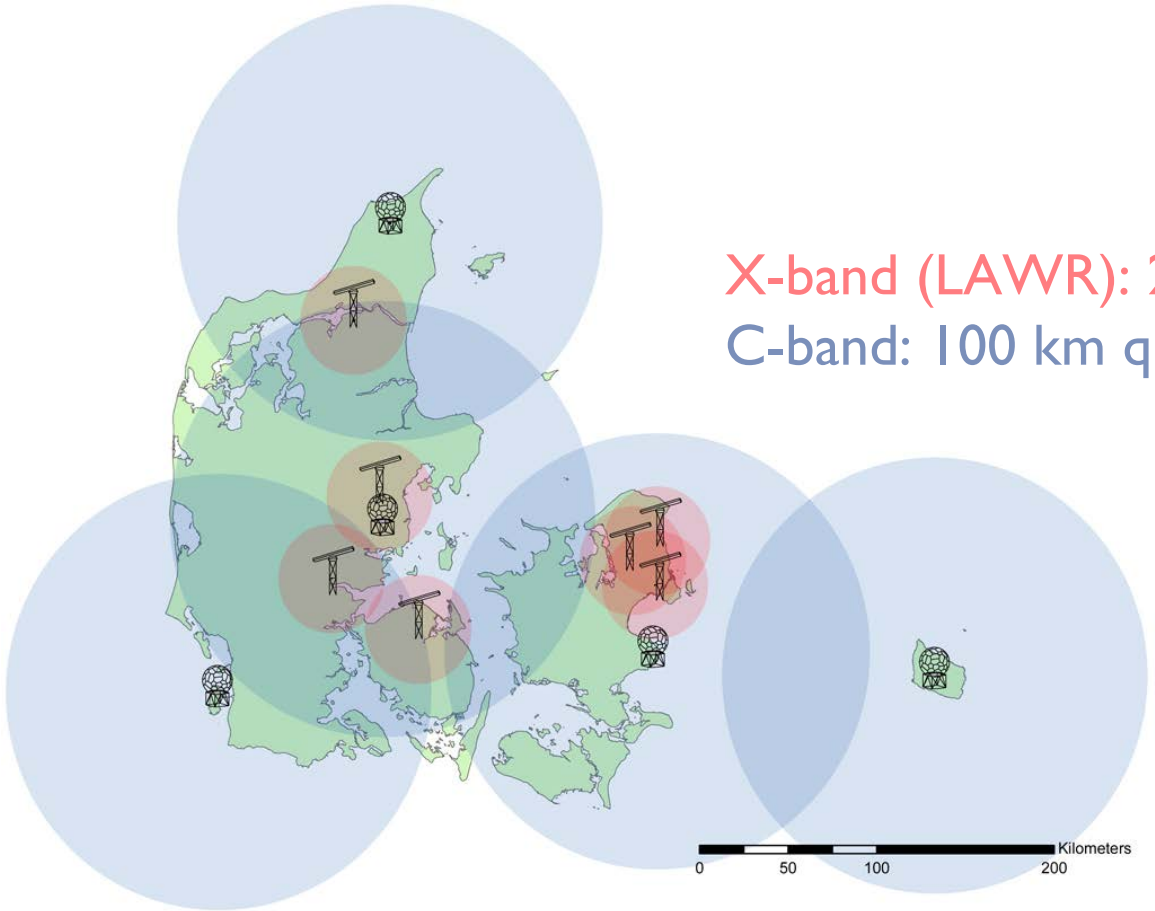
Søren Thorndahl
Associate Professor
Department of Civil Engineering
Aalborg University Denmark

e-mail: st@civil.aau.dk
web: www.rain.civil.aau.dk

Topic 1: X-band and C-band radar calibration: methods and experiences

- calibration of reflectivity, differential reflectivity, differential phase, … single vs. dual polarization
- adjustment to rain gauges: useful? methods? experiences?
- monitoring/maintenance of the radar system (e.g. routine checks of radar parameters & variables)

Weather radar networks in Denmark



X-band (LAWR): 20 km quantitative range

C-band: 100 km quantitative range

Radar types in Denmark

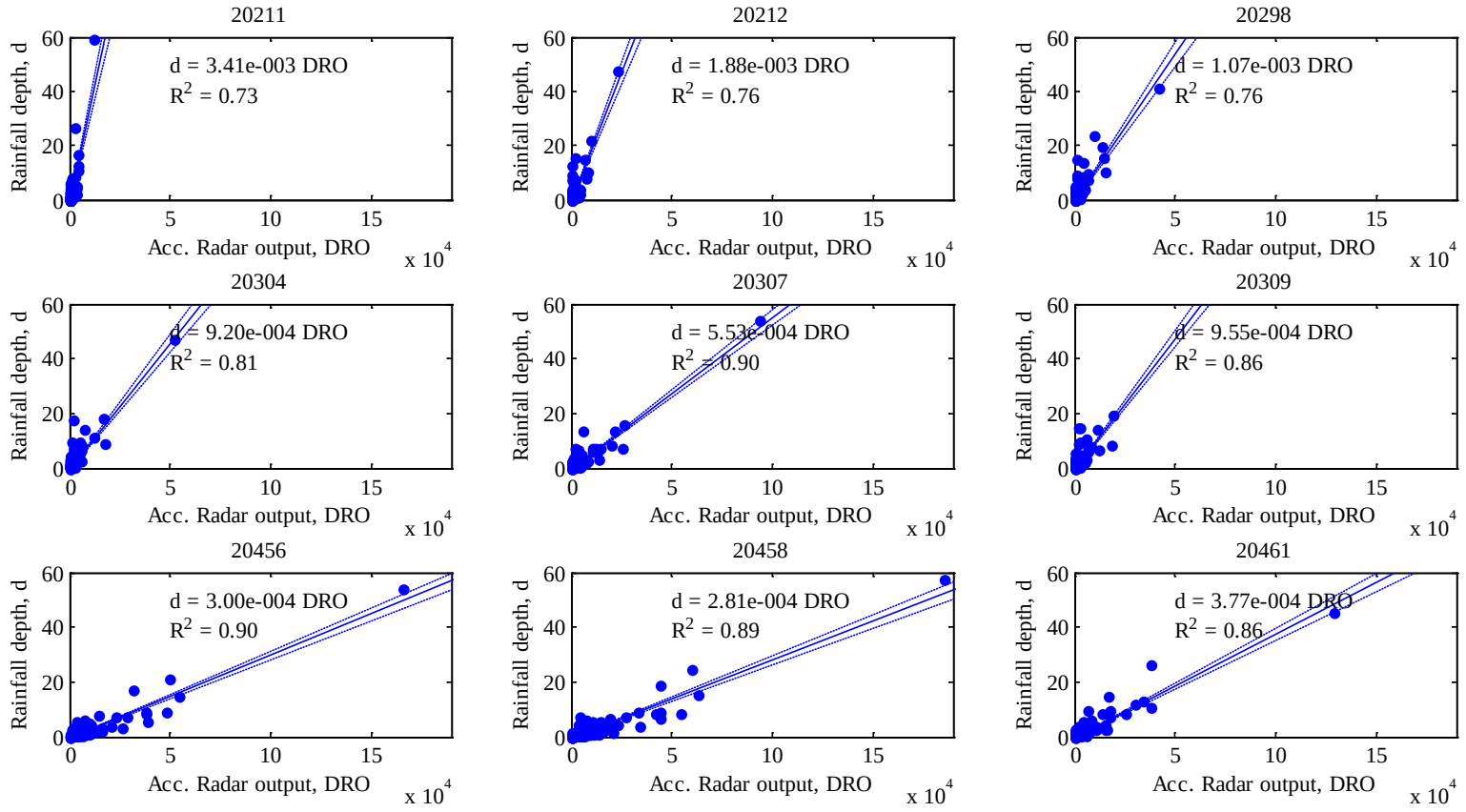
C-band (DMI)

X-band, LAWR (DHI)

Radar types in Denmark

Bandwidth	C-band	X-band (LAWR)
Range	240 km	60 km
Quantitative range	75-100 km	20 km
Spatial resolution	2000 x 2000 m	500 x 500 m
Temporal resolution	10 min (snapshot)	1 or 5 min (averaged)
Horizontal beam width	1°	1°
Vertical beam width	1°	10°
Scanning strategy	Multiple layers	Continuous in one layer
Owner/developer	DMI	DHI

Calibration – Aalborg Weather radar (X-band, LAWR) regression approach



Accumulated values per event, July – December 2008

$$i_g = \beta(r) \cdot DRO_{n,m}$$

Calibration – Aalborg Weather radar (X-band, LAWR) regression approach

- Ratios between rain gauges (i_g) and the dimensionless radar output (DRO) are found using the linear regression:

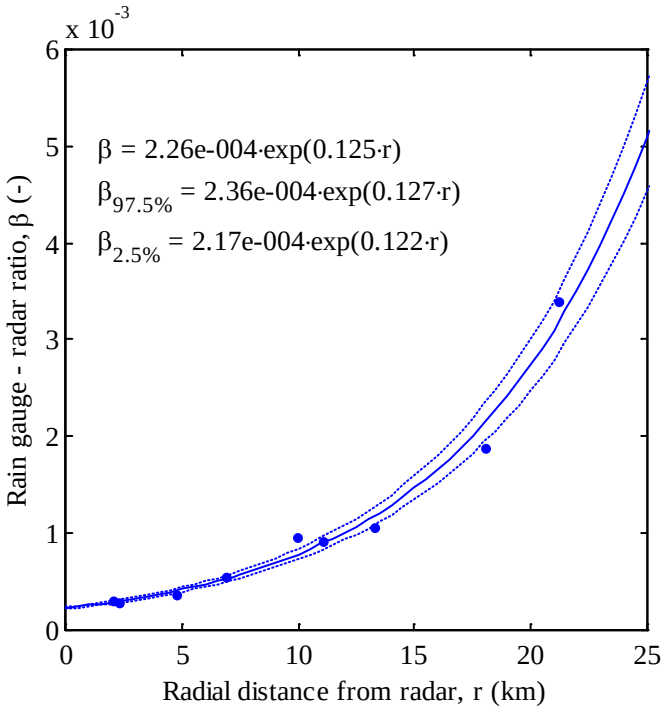
$$i_g = \beta(r) \cdot DRO_{n,m}$$

- Ratios as a function of the radial distance from the radar is fitted to an exponential function:

$$\beta(r) = c_1 \cdot \exp(c_2 \cdot r)$$

- The rain intensity can the be calculated everywhere within the radar range:

$$i_{n,m} = c_1 \cdot \exp(c_2 \cdot r) \cdot DRO_{n,m}$$



- Based on 6 months of data, July – December 2008
- Does not change if based on shorter periods (e.g. monthly data)

- From Thorndahl and Rasmussen (2012)

Other LAWR approaches

The double exponential method: asuming an exponential relation between the dimensionless radar output (DRO) and rain intensity

Dynamical calibration: – real time adjustment against rain gauges (might be more data assimilation than calibration)

Concept of dynamic calibration

- using data from the last 5-15 min. dynamical local β-values are calculated

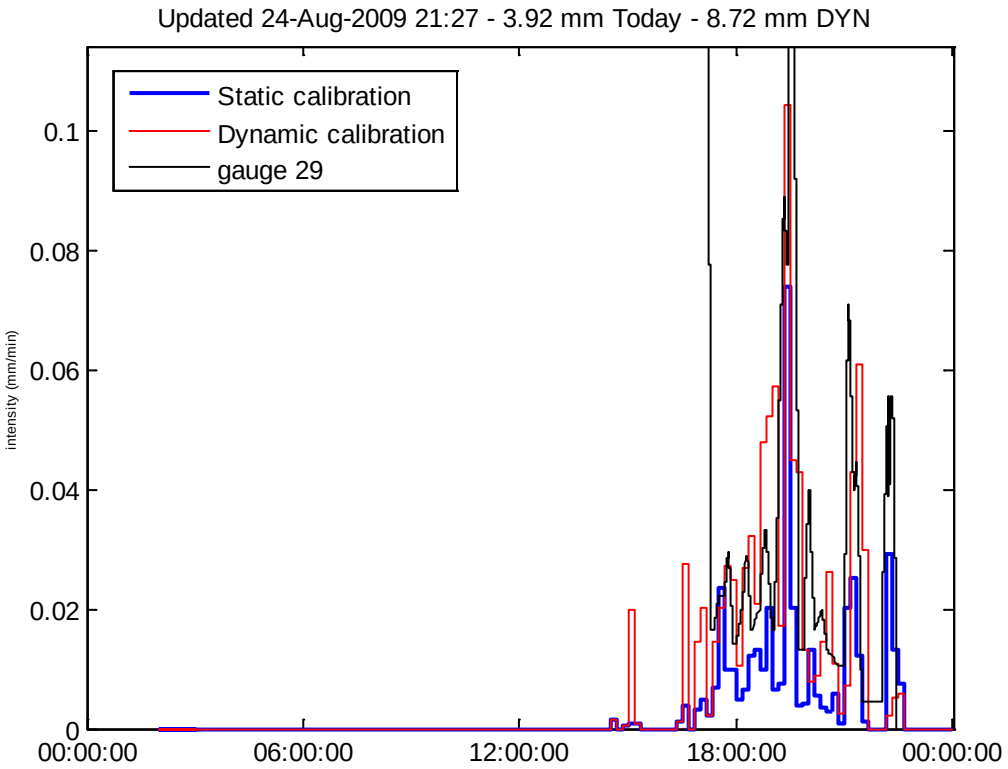
$$\beta_{dyn,j} = \frac{\sum i_{gauge,j}}{\frac{\sum DRO}{\beta_{stat}(r)}}$$

- a global β_{dyn} are calculated by simple averaging or by some weighting between the different local values, eg.:

$$\beta_{dyn} = \frac{\sum_{j=1}^{J} \beta_{dyn,j}}{J}$$

- Rain intensities within the range of the radar can then be estimated:

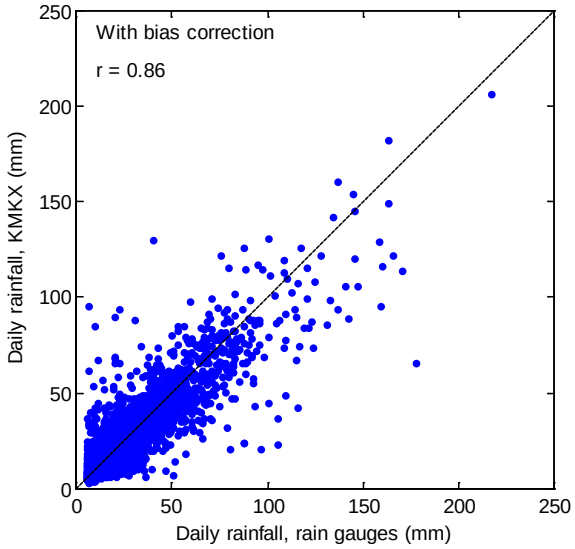
$$i_{radar} = DRO \cdot \beta_{dyn} \cdot \beta_{stat}(r)$$



Calibration of C-band

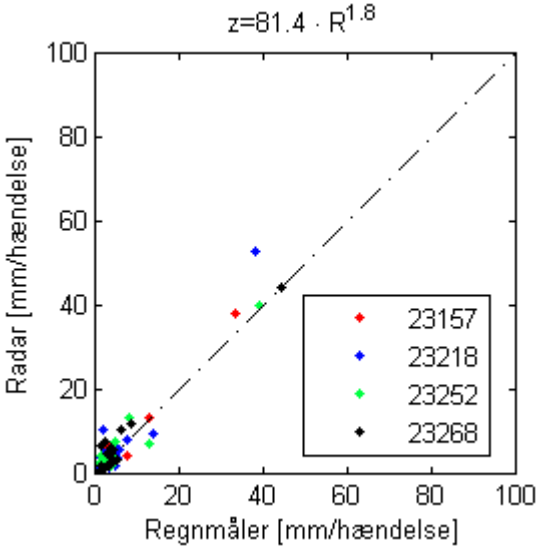
Standard Marshall-Palmer:
e.g. A=200, B=1.6

On historical series:
- Daily bias correction



Or by **fitting the Marshall-Palmer A and B**

- minimizing the absolute error between radar and rain gauges



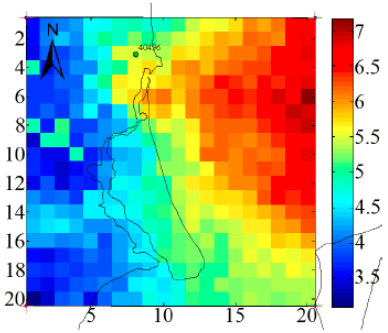
Ensample generator

$$\Phi_{t,i} = R_t + \delta_{t,i}$$

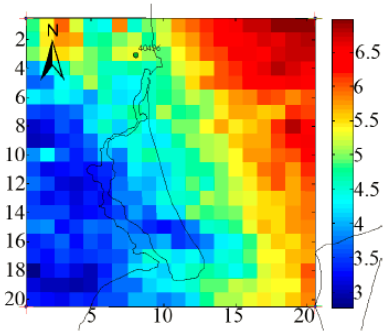
Symbol	Unit	Description
Φ	$mm\ hr^{-1}$	Resulting precipitation field (probabilistic)
R	$mm\ hr^{-1}$	Orginal unperturbed radar precipitation field (deterministic)
δ	$mm\ hr^{-1}$	Perturbation field (stochastic)

- Using ideas from Germann et al., 2009
- Based on a derived co-variance matrix

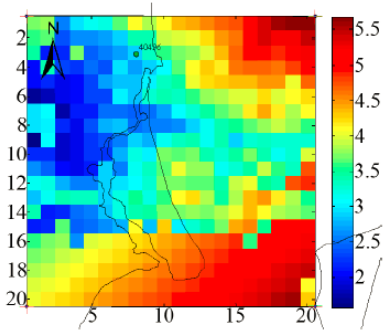
David G. Jensen (2012, draft)



(b) Ensemble member 2 time step 1

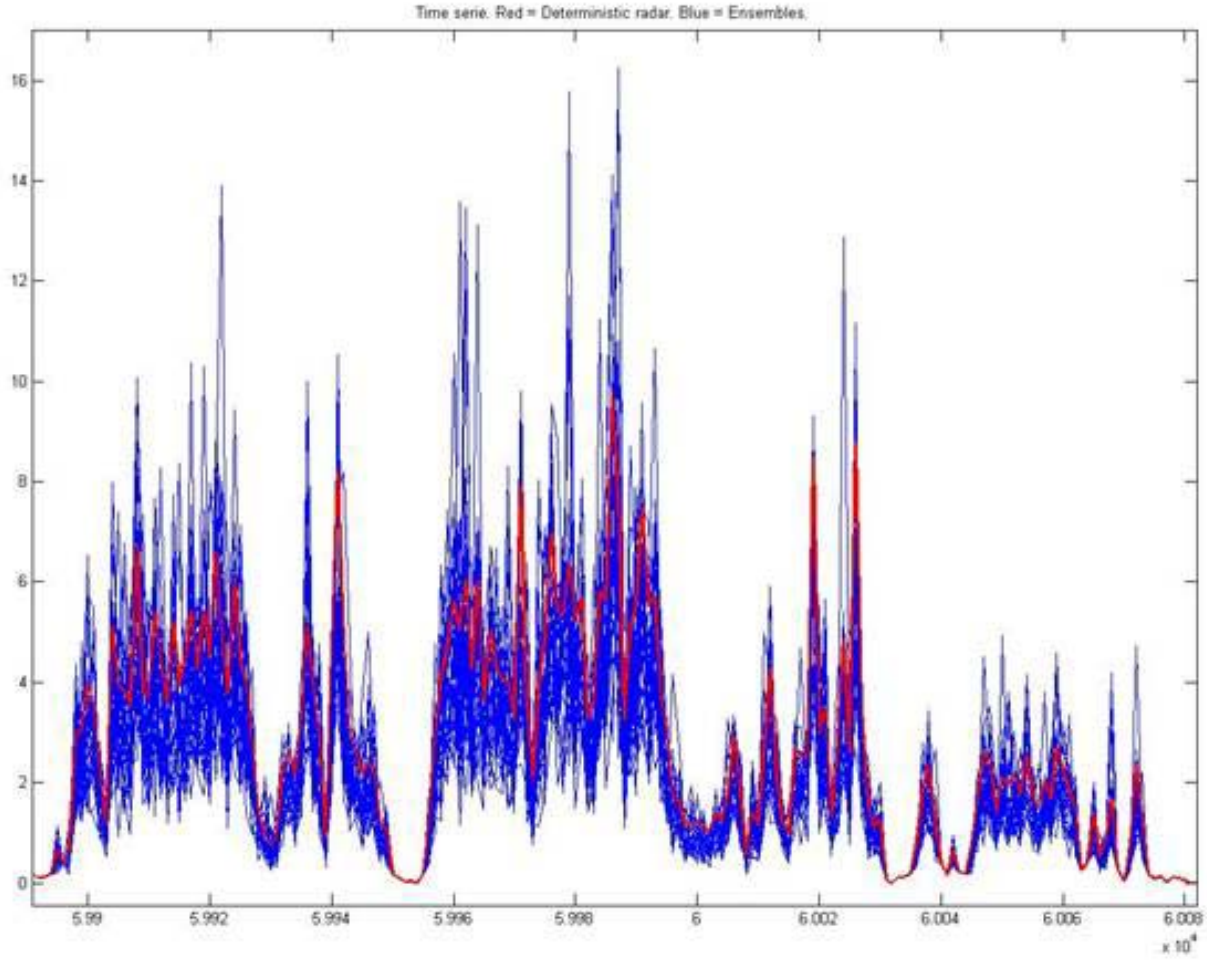


(d) Ensemble member 2 time step 2



(f) Ensemble member 2 time step 3

Ensample generator



Topic 2: X-band versus C-band performance : experiences

2.1 limitations/differences of X-band and C-band radars in rain rate estimation performance: influence of attenuation, clutter, maximum effective range, detection capability, stability, …

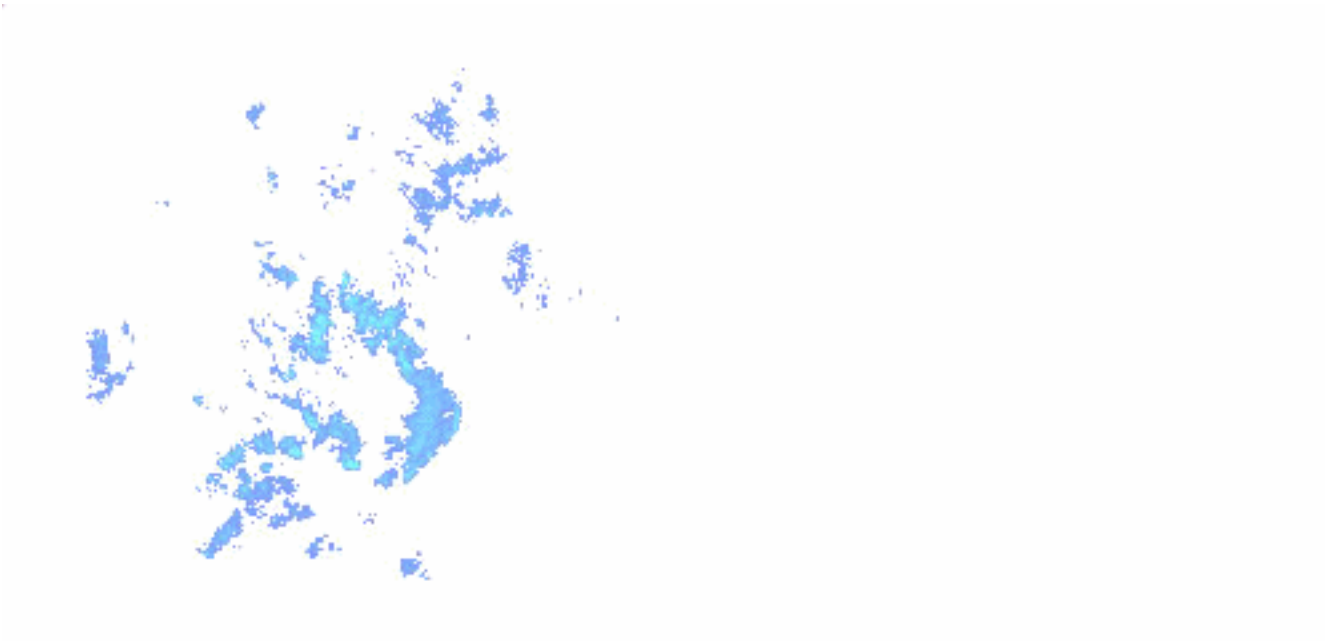
2.2 accuracy estimation of rain rate estimation (e.g. taking rain gauge observations as reference?) methods? typical results?

X-band (LAWR) vs. C-band in nowcasting

Using CO-TREC to extrapolate radar images

C-band, leadtime:
Lead time: 0-2 hours
Range (240 km)

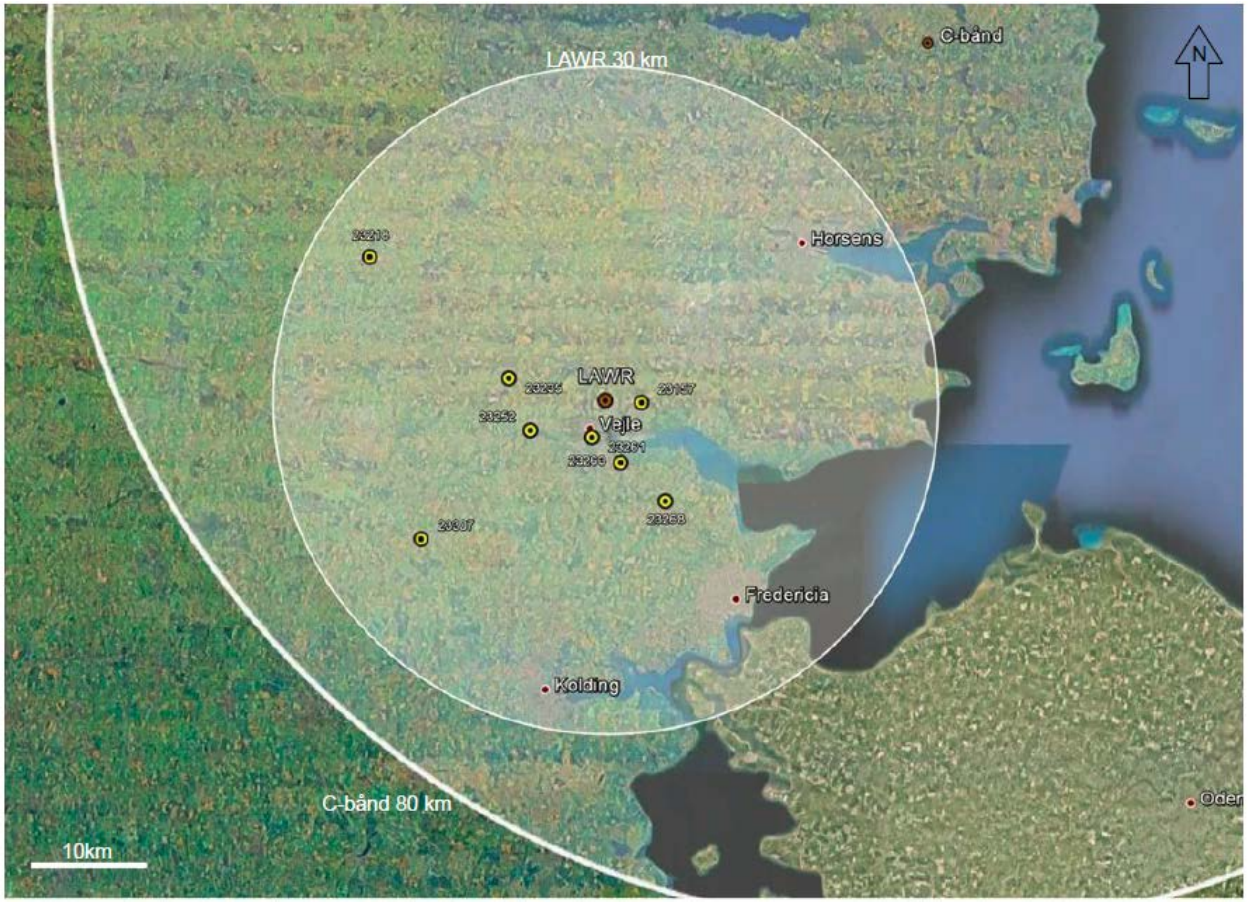
X-band (LAWR),
Lead time : 0-30 min.
Range(60 km)



Observation Nowcast model

Comparison of C-band and X-band (LAWR) performance in Vejle Denmark

Nielsen and Rasmussen (2011) (In Danish)



Accumulated precipitation

Periode 3: 1. juli – 30. september

	Regnmåler		Vejle LAWR		Virring C-bånd	
	Svk nr	[mm]	Lin. Reg. [mm]	2exp[mm]	MPfit [mm]	BIASfit [mm]
Kalibrering	23 157	**270,4**	294,3	311,8	281,5	260,5
	23 218	**328,0**	133,2	16,2	309,9	293,0
	23 252	**300,6**	187,0	122,6	302,9	291,6
	23 268	**288,0**	170,8	81,9	278,6	255,5
	RMSE [mm]		127,6	208,0	**11,7**	24,8
	APF [%]		36,7	60,3	**3,4**	7,2
Validering	23 235	**288,8**	172,4	97,5	319,1	305,4
	23 261	**286,6**	252,5	261,7	289,3	269,7
	23 263	**264,4**	~~2,5~~	~~1,6~~	~~232,2~~	~~217,3~~
	23 307	**319,8**	166,5	30,7	342,4	324,4
	RMSE [mm]		112,9	200,7	21,9	**13,9**
	APF [%]		33,4	55,1	6,2	**4,4**

Tabel 12: Akkumuleret nedbør for de tre data perioder med fremhævning af laveste RMSE og APF. I beregningen af RMSE og APF for valideringsregnmålerne måler nr: 23263 ikke anvendt, da LAWR radaren har store problemer med at estimere nedbøren for denne måler. Radar og kalibreringsmetode med den laveste RMSE og APF er understreget.

Quality measure (R2)

R2 related to the bisector (f)

$$R^2 \equiv 1 - \frac{SS_{err}}{SS_{tot}}$$

$$SS_{err} = \sum_i (Radar_{Est(i)} - f_{(i)})^2$$

$$SS_{tot} = \sum_i \left(Radar_{Est(i)} - \overline{Radar_{Est}}\right)^2$$

- If the radar estimates deviate more from the bisector than the estimates deviate from the mean of the estimates R2 becomes negative
- In this case the mean of the radar estimates fits the rain gauge observations better than the individual radar estimates

3 hour accumulations

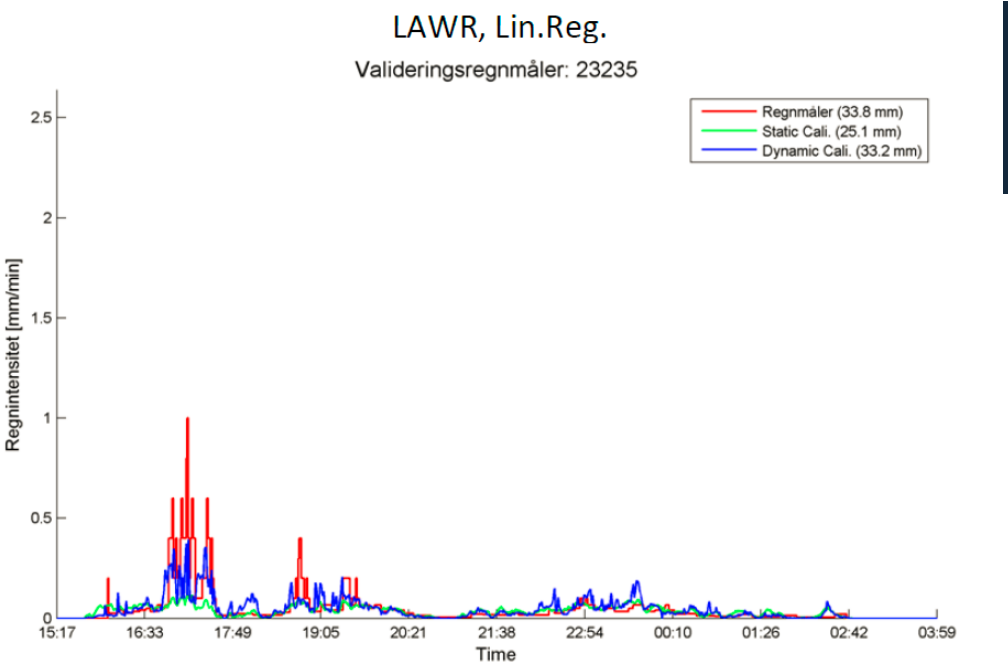
Periode 3: 1. juli – 30. september

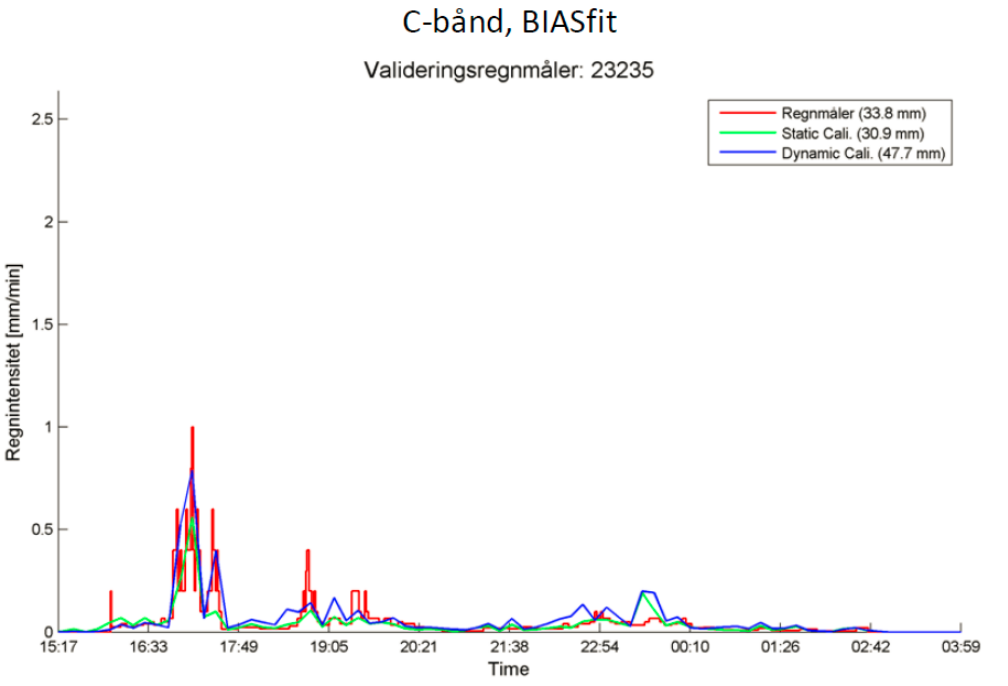
		Vejle LAWR				Virring C-bånd			
		Lin. Reg.		2exp		MPfit		BIASfit	
	Svk nr	Statisk R^2	Dyn R^2	Statisk R^2	Dyn R^2	Statisk R^2	Dyn R^2	Statisk R^2	Dyn R^2
Kalibrering /Justering	23 157	0,436	0,670	0,486	0,653	0,651	**0,680**	0,606	0,417
	23 218	-0,851	-1,92	-38,4	-15,2	0,382	**0,685**	0,441	0,582
	23 252	-0,379	0,741	-2,71	0,500	0,593	**0,897**	0,454	0,851
	23 268	-1,120	0,110	-6,8	-1,14	0,417	**0,893**	0,507	0,867
Validering	23 235	-0,465	**0,639**	-4,27	-0,133	0,604	0,584	0,546	0,464
	23 261	0,088	0,751	0,276	**0,824**	0,619	0,642	0,601	0,491
	23 263	-6110	-2940	-2260	-585	-0,131	**0,253**	-0,171	0,176
	23 307	-1,65	-1,74	-17,4	-10,2	0,526	**0,732**	0,561	0,619

Tabel 13: R^2 for 3 timers akkumuleret nedbør fordelt på periode, radarer, kalibrerings og justeringsmetode. Fremhævet er de højeste R^2 værdier for hver SVK-regnmåler.

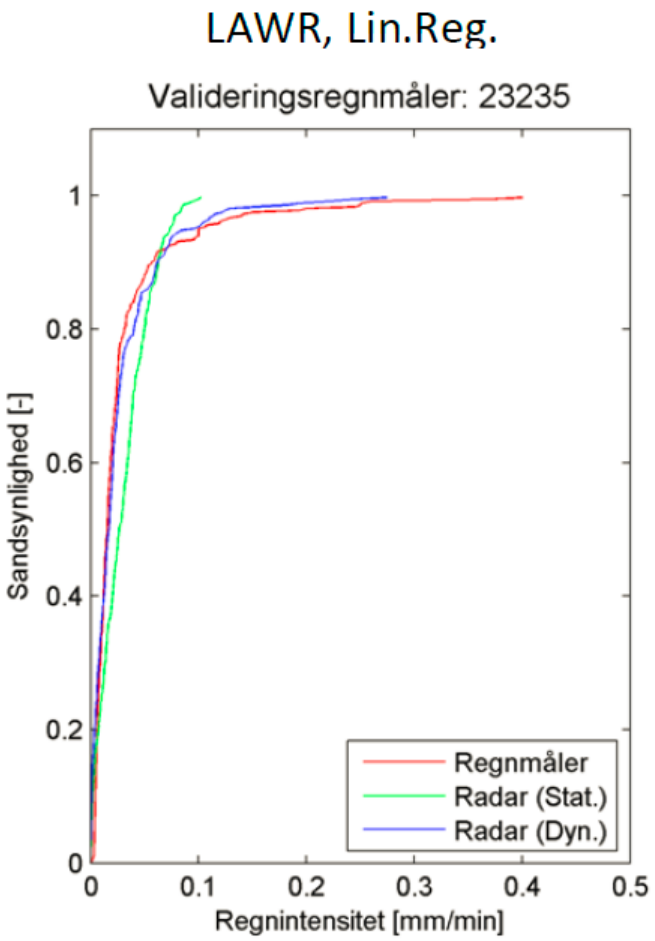
Time series comparisons

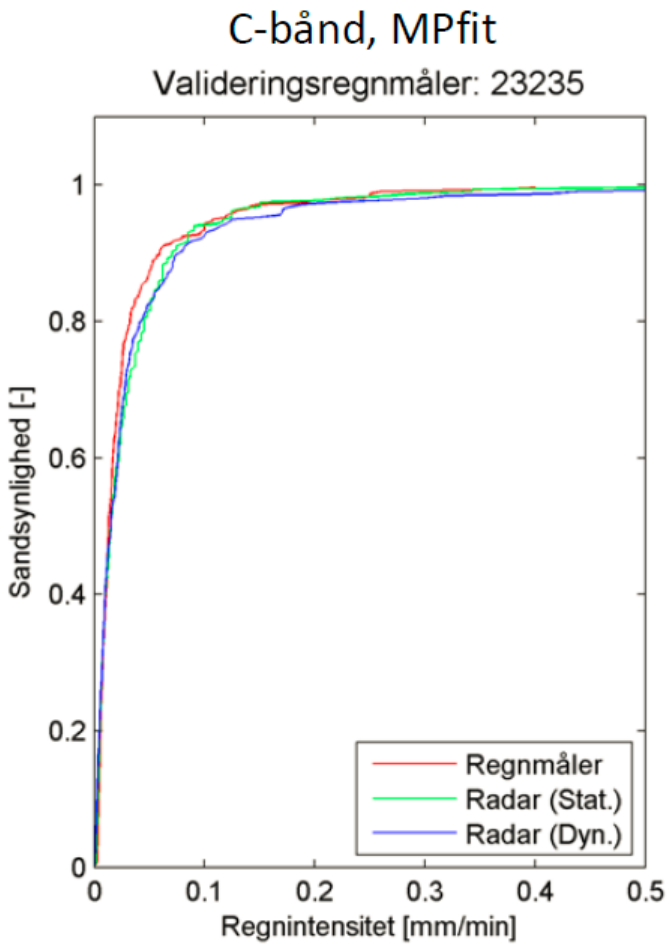
- LAWR underpredicts peaks in static calibration
- If dynamic calibration is used the performance is somewhat better
- Good performance using C-band despite the calibration method





Cumulative distribution functions of rainfall intensities





Conclusions

- The C-band radar performs with satisfactory results
- Despite different calibration methods the X-band, LAWR cannot measure rain with intensities more than 6 mm/h (0.1 mm/min)
- The C-band radar is able to produce a distribution of rainfall intensities which is in the same order of magnitude as the rain gauges estimates.
- The X-band has no estimated rainfall intensities in the upper tail of the distribution
- It is possible to improve radar rainfall estimates on both C- and X-band radars introducing dynamical calibration (continuous adjustment against rain gauges)
- For the X-band LAWR radars, a new processing algorithm based on new receiver measurements has been proposed by DHI and is tested over the spring and summer 2012

New soultions – test site

The owners of the LAWR radars in Denmark have jointed together to analyse radar rainfall over the spring/summer 2012, in order to compare the old processing algorithm with the new proposed by DHI

Test site with:

- 1 x C-bands radar
- 2 x LAWR radars + a parallel processing unit
- 4 x Laser Disdrometers

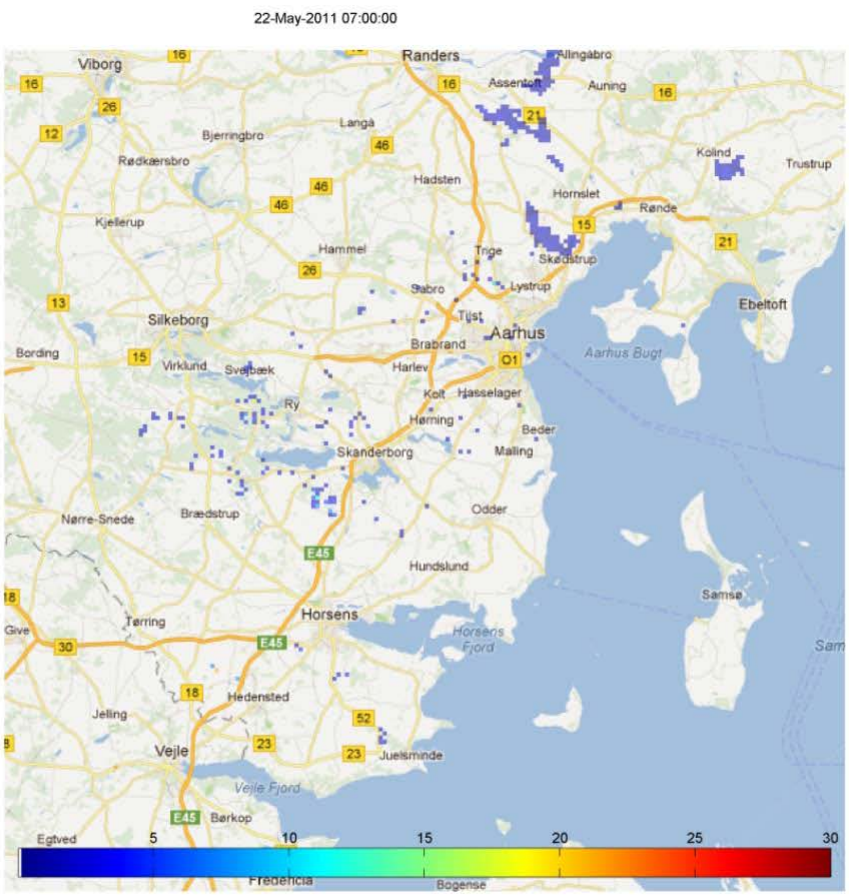
Topic 3: Integration of X-band, C-band and rain gauge measurements : methods and experiences

methods to merge different rainfall products from different sources (X-band, C-band and rain gauges) to come to a most reliable fine-scale rainfall estimate for urban drainage applications

3.1 mosaicking radars of different wavelengths, with focus on nesting Xpol in Cpol

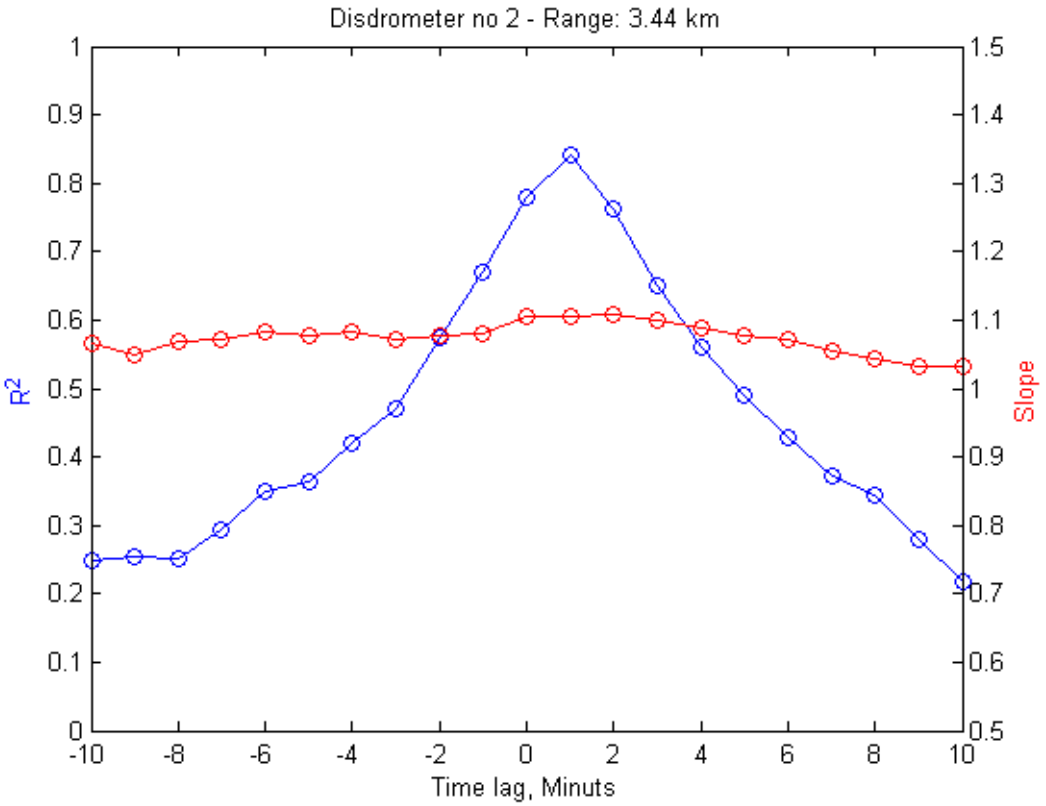
3.2 radar - rain gauge merging

10 min resolution – C-band data

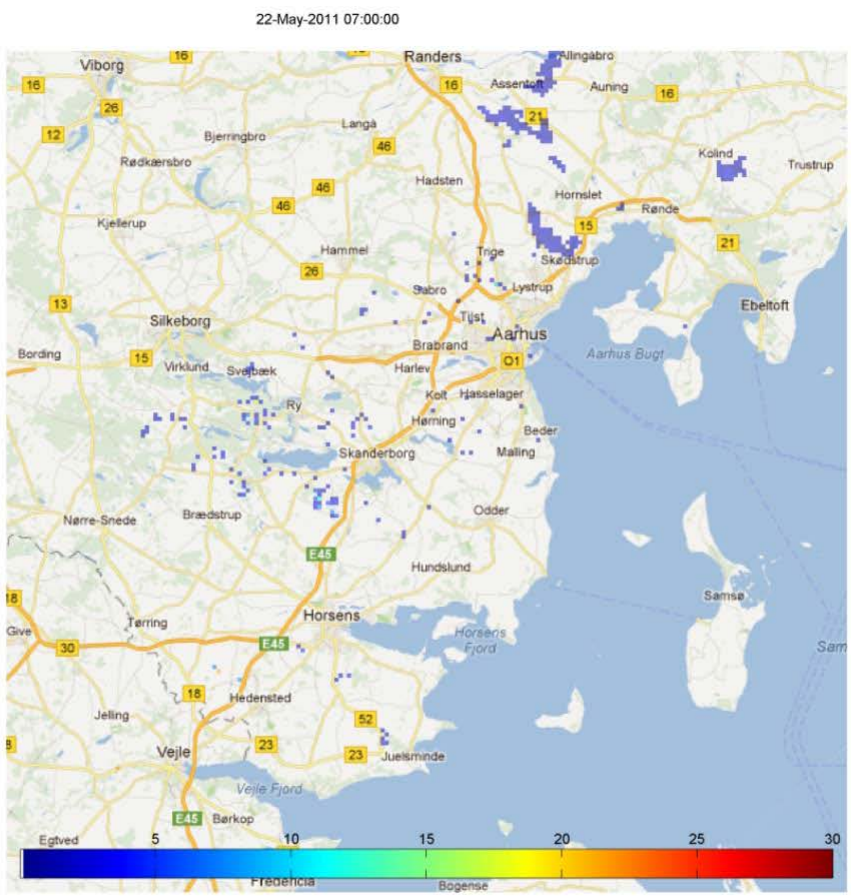


10 min resolution – C-band data

Correlation coeffecient - Radar vs. distromenter

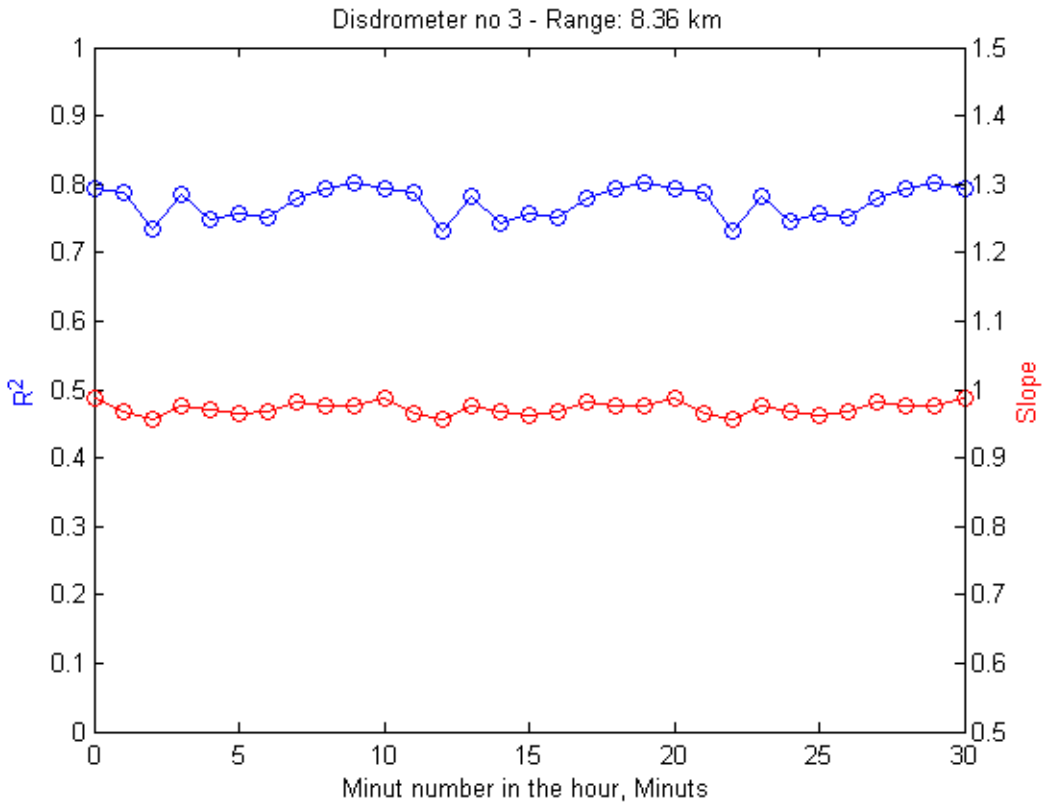


1 min. resolution
- Forecaster used to interpolate between 10 min. time steps

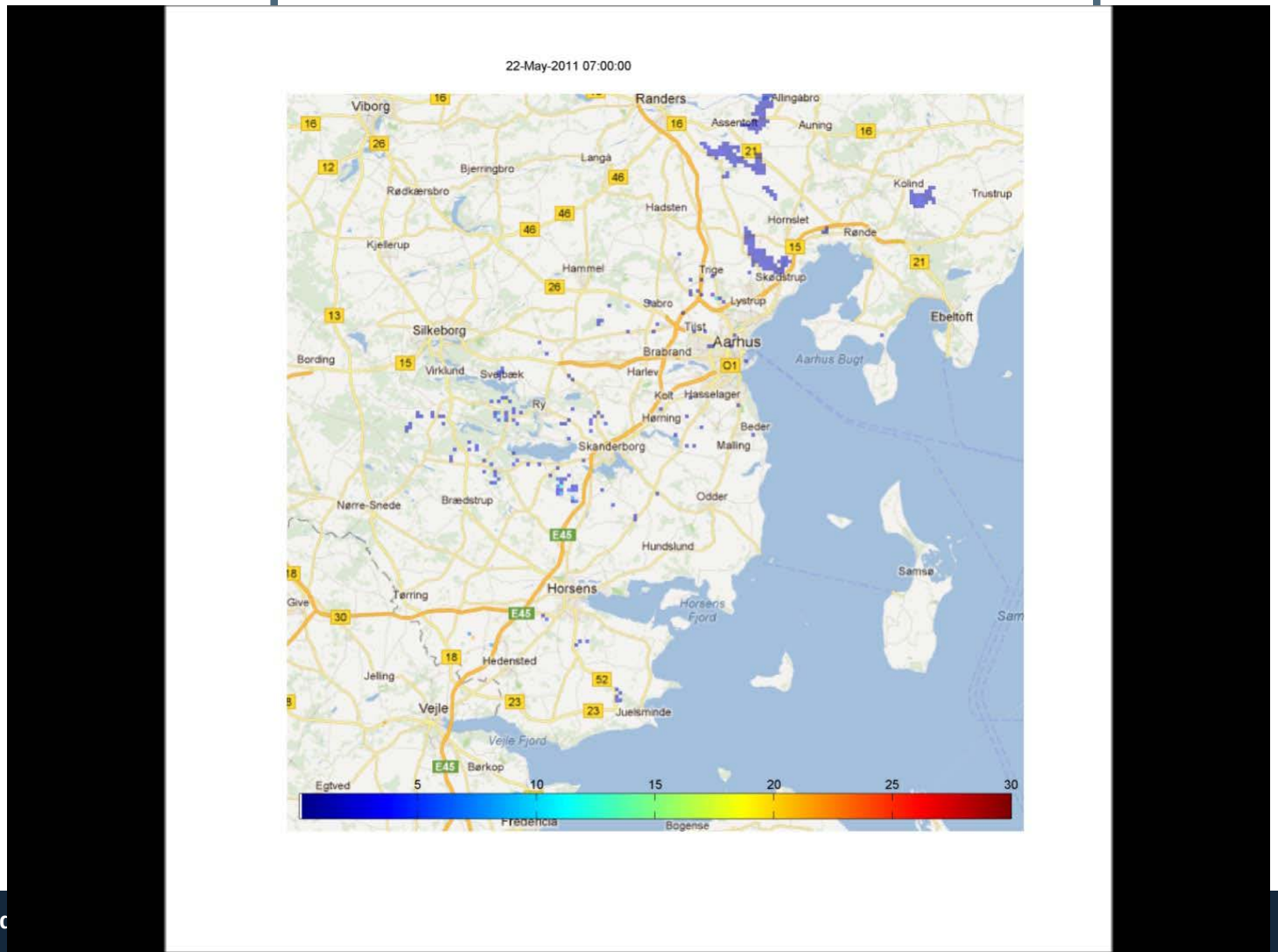


1 min. resolution
- Forecaster used to interpolate between 10 min. time steps

Correlation coeffecient - Radar vs. distromenter



1 min. resolution
- Linear interpolation between 10 min. time step



Topic 4: Fine-scale rainfall estimation : recommendations and guidelines

here we will formulate general conclusions, based on the outcomes from the discussions on topics 1, 2 and 3. I will prepare an outline with main recommendations during the workshop, to be agreed on at the end of the workshop, which will be used as starting basis to write a guidelines publication after the workshop.