

Rainfall retrieval
from commercial microwave links :
from a validated potential
towards
worldwide operational applications
(?)

Marielle Gosset (IRD/GET) and Hidde Leijnse (KNMI)
And many international collaborators



Introduction and history

- Microwave links can be used to measure rainfall (e.g. Atlas and Ulbrich, 1977; Jameson, 1991)
- Rain rate is nearly linearly related to specific attenuation (around 30 GHz)
- Commercial microwave link networks are abundant and can be used for rainfall monitoring (Messer et al., 2006; Leijnse et al., 2007)
- Technical challenges are:
 - Wet/dry classification
 - Wet antennas
 - Mapping

Open source packages
are available!

- Atlas, D. and C. W. Ulbrich (1977), *J. Appl. Meteorol.*, 16, 1322–1331.
- Jameson, A. R. (1991), *J. Appl. Meteorol.*, 30, 32–54.
- Messer, H. A., A. Zinevich, and P. Alpert (2006), *Science*, 312, 713.
- Leijnse, H., R. Uijlenhoet, and J. N. M. Stricker (2007), *Water Resour. Res.*, 43, W03201.





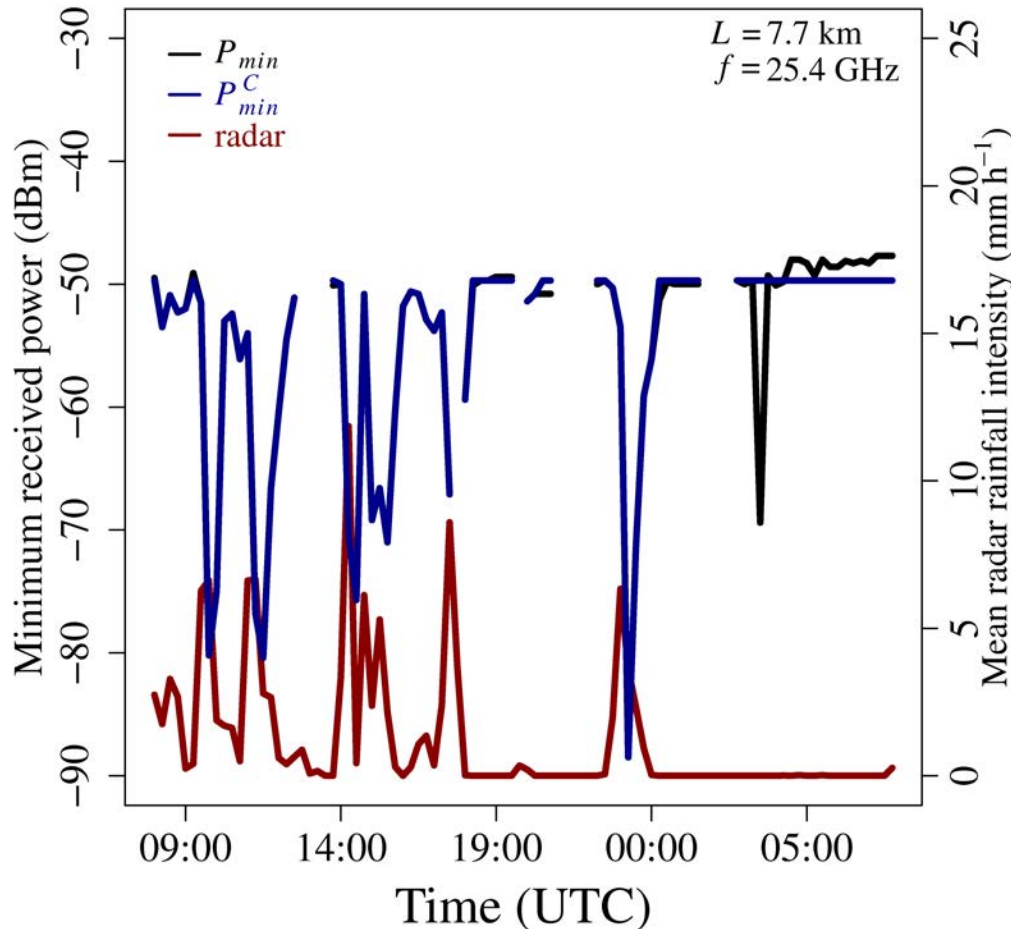
Basic measurement principle

- Microwave links that are used for communication between cellphones can also be used to measure rainfall
- The radio signal is attenuated by raindrops in the path
- The relation between specific attenuation and rainfall intensity is nearly linear, and is nearly independent of the drop size distribution





Basic measurement principle



- A link is assumed to be affected by rain (wet) if nearby links also show a decrease in minimum RSL; RSL is corrected based on this
- Determine reference level based on RSL during dry weather
- Compute mean rainfall intensity from minimum and maximum RSL:
- $R = a [(A - A_{ant})/L]^b$



Data

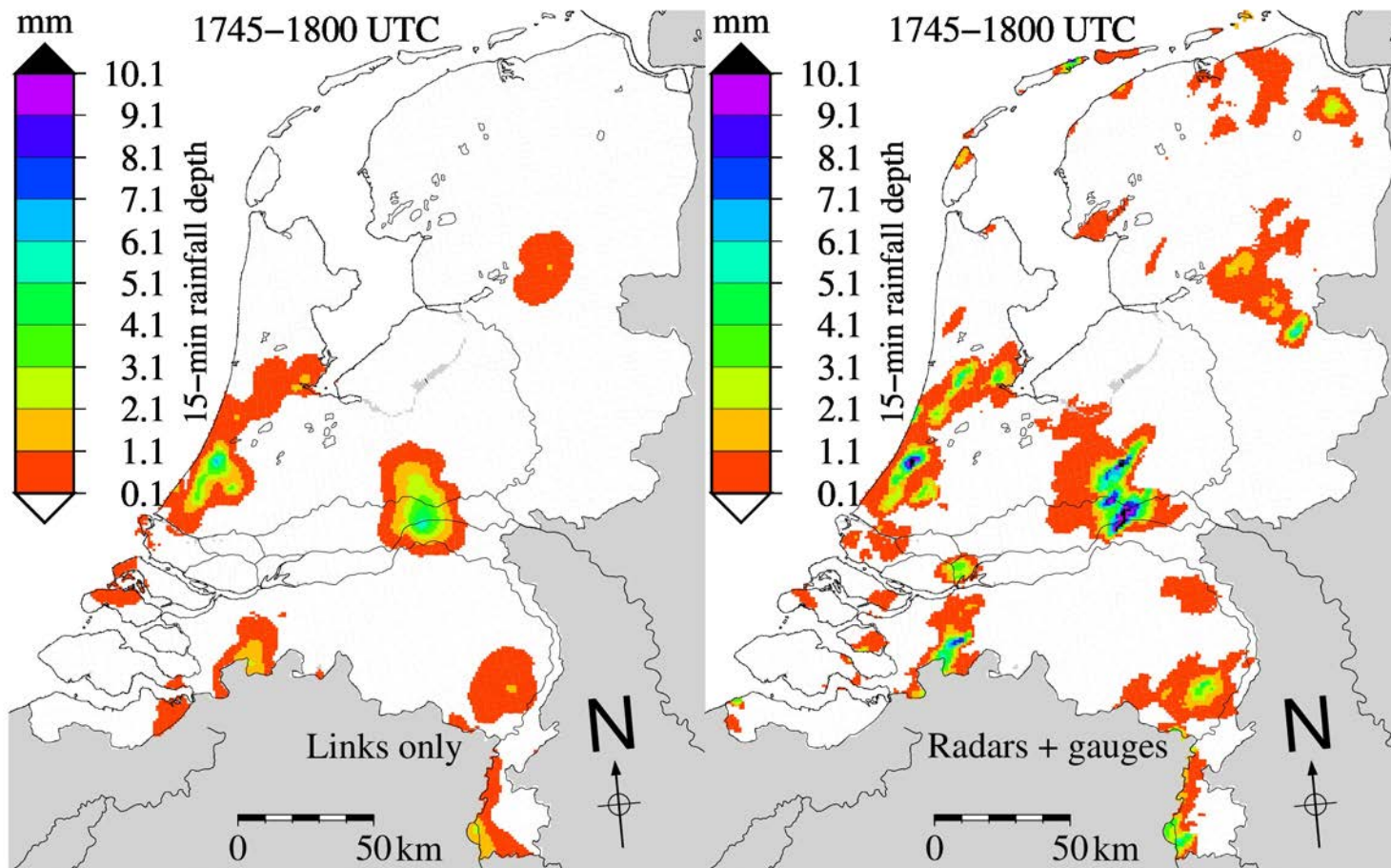


- In NL: ~1900 links
- Minimum and maximum received signal level (RSL) every 15 minutes
- Quantization 1 dB, some links have 0.1 dB
- Average link length: 3-4 km
- Link frequencies: 20-40 GHz (38 GHz most abundant): linear relation and sensitive to rain!
- In NL: Gauge-corrected radar dataset (5 min, 1 km²)



Results in the Netherlands

31-08-2012



Rain Cell AFRICA

opportunistic use of telecom network
for rain estimation in Africa



Ouagadougou, Burkina Faso
2012-2014

The Rain Cell Africa
team that did the first
quantitative tests in
Africa, in
Ouagadougou :



Doumouni, Gosset et al, 2014 , GRL
; Rainfall Monitoring based on Microwave links from
cellular telecommunication Networks: First Results
from a West African Test Bed. *Geophysical Research
Letters*, 10.1002/2014GL060724

Gosset, M., et al , 2016 BAMS : Improving
Rainfall Measurement in gauge poor regions thanks to
mobile telecommunication networks, Bull. Amer.
Meteor. Soc doi:10.1175/BAMS-D-15-00164.1



Rain Cell AFRICA

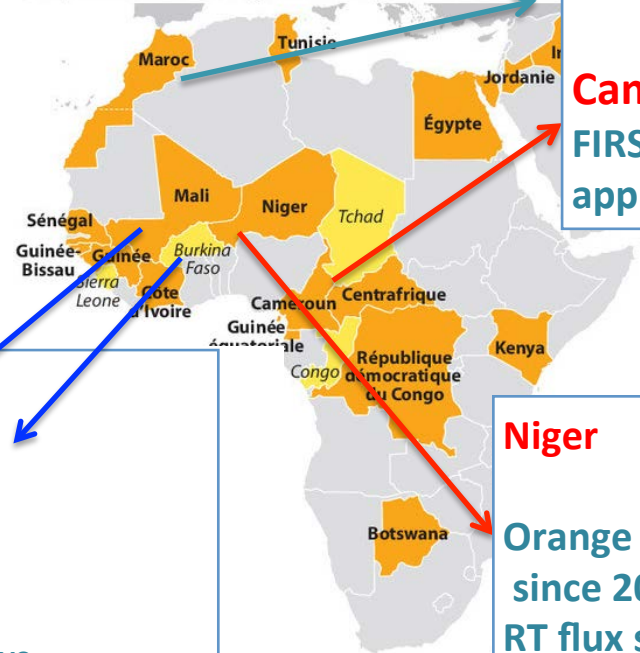
opportunistic use of telecom network
for rain estimation in Africa



Thanks to WB/GFDRR ; KGGF; UNF
Data4SDG, **IRD initiated** several
operational pilots in Africa in
collaboration with Orange **since**
2016



La présence d'Orange en Afrique et au Moyen



Maroc
Cameroun
FIRST Real Time
application !!

Mali
Burkina
RAINCELL APP
For urban flood warning

Met service ; Hydro services
Civil Security services -> formal plan via CREWS

Niger
Orange data available
since 2016
RT flux set up in 2018



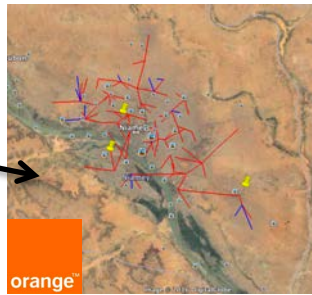
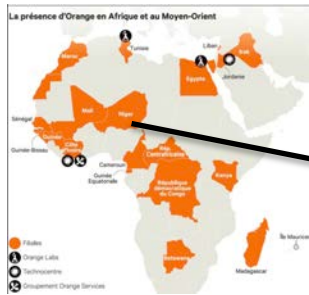
Rain Cell AFRICA

opportunistic use of telcom network for rain estimation in Africa



Example : Niger, Niamey

Revisiting the 2017 August 21st storm that lead to intense flooding in Niger



Orange network data in Niamey : 80 links

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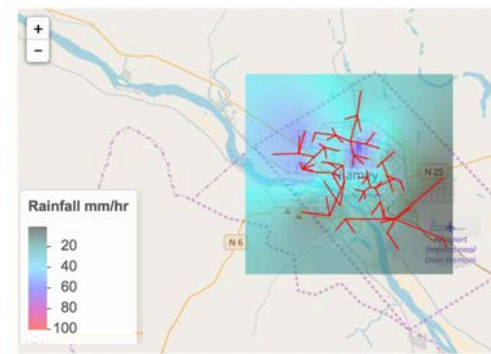
####
NE IP:10.1.3.6
Site : MPR_SITE33
ports: 3:1 direction: DIR_022
Direction: DIR_022
TIMEDATE    MinTSL    AvgTSL    MaxTSL    MinRSL    AvgRSL    MaxRSL
08/04/2016 00:00:00    17    17    17    -40    -40    -39
08/04/2016 00:15:00    17    17    17    -41    -40    -39
08/04/2016 00:30:00    17    17    17    -43    -39    -39
08/04/2016 00:45:00    17    17    17    -40    -40    -36
08/04/2016 01:00:00    17    17    17    -40    -40    -39
08/04/2016 01:15:00    17    17    17    -40    -40    -39
08/04/2016 01:30:00    17    17    17    -40    -40    -39
08/04/2016 01:45:00    17    17    17    -40    -40    -39

```



21/08/2018 4:15 am
Strong cells over Niamey

Raincell Niamey 2016/17
Microwave Link Network Interpolation

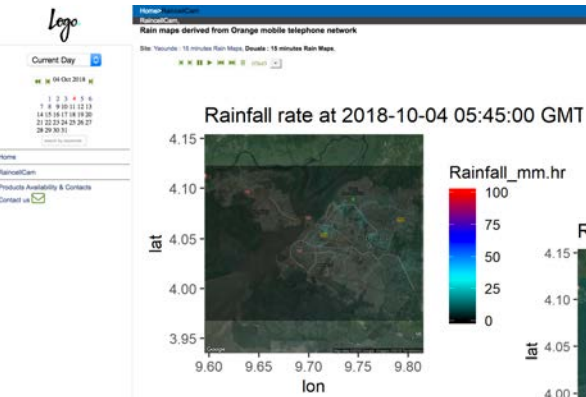


Rainfall estimation
And rainfall maps over
city every 15 minutes

Example : Real time rainfall maps in Cameroun

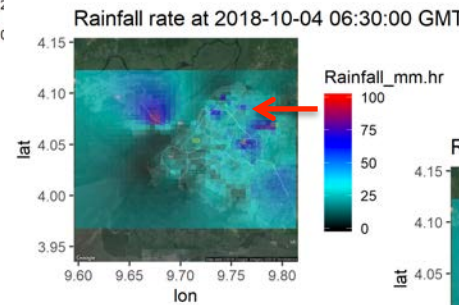
A flux of raw data at 15 minute time step (min/max/mean) is provided to an external FTP server.

Based on Orange SAM Network Monitoring System (script written by Orange tech team)

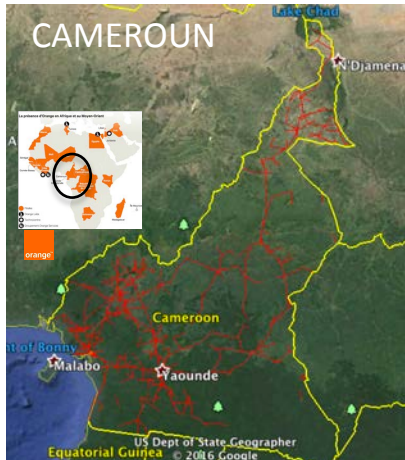


Rainfall starts at 6:15

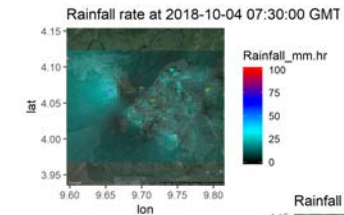
Oct 4rth morning in Douala
A convective shower developed from 06:15 and receded at 7:45



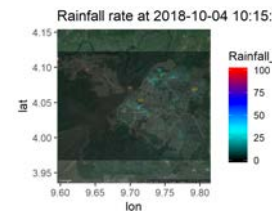
Strong rain at 6:30
In N sector of town



Dense network over Douala

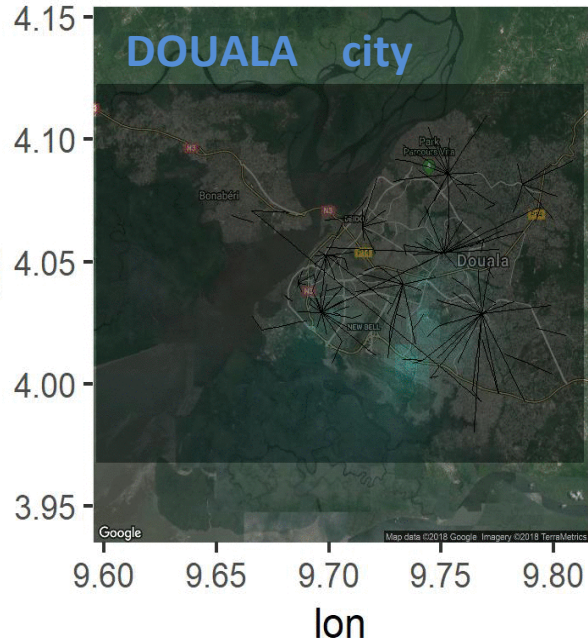


7:30 Rainfall recedes

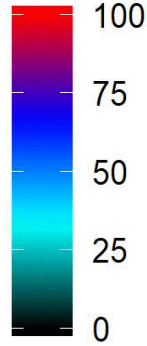


Real time rainfall maps

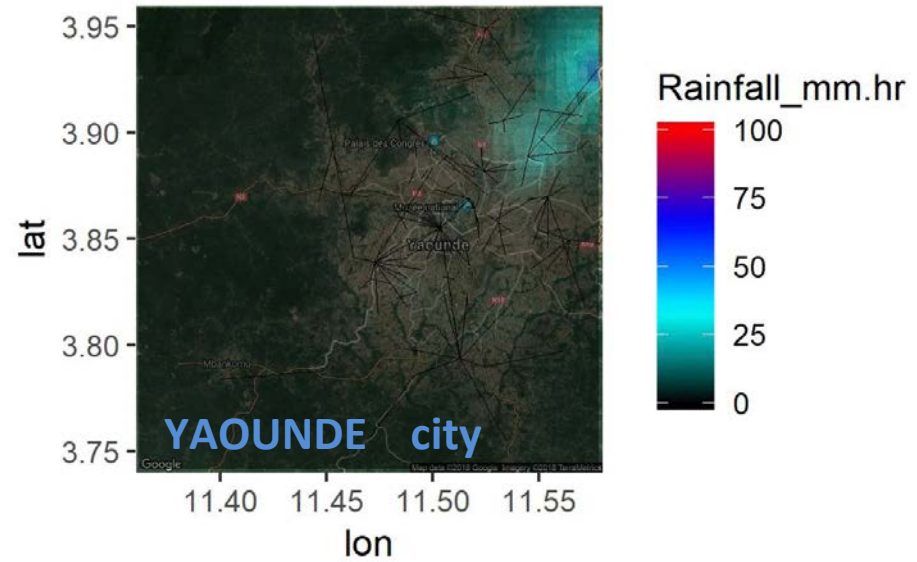
Rainfall rate at 2018-09-27 21:00:00 GMT



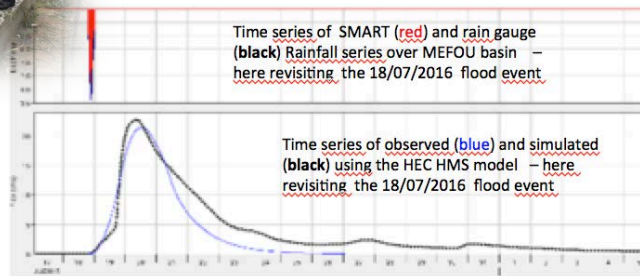
Rainfall_mm.hr



Rainfall rate at 2018-09-27 16:00:00 GMT



Validation & hydrological applications with local partners



CML rainfall estimate – Scientific/technical Proof of concept

10 years research – Validation of QPF - Mature concept

- Uncertainties understood
- Applications for QPE/QPF – Hydrological Applications tested.
- Open Source codes for data collection/processing/rain mapping exist

Recent review : Uijlenhoet R, Overeem A, Leijnse H. Opportunistic remote sensing of rainfall using microwave links from cellular communication networks. *WIRES Water* 2018, 5: null. doi: 10.1002/wat2.1289



DATA SHARING ISSUE

Archived data for R&D and Proof of concept – worldwide

- Many examples In Europe and Israel for ~10 years
- telecel Faso provided archived data in 2012-2014 for first validation study in Africa
- Orange is involved in 4 pilot sites in Sub Saharian Africa



Real time data flux provided by operator (on a good will basis)

- Cameroun
- Niger (currently in test)



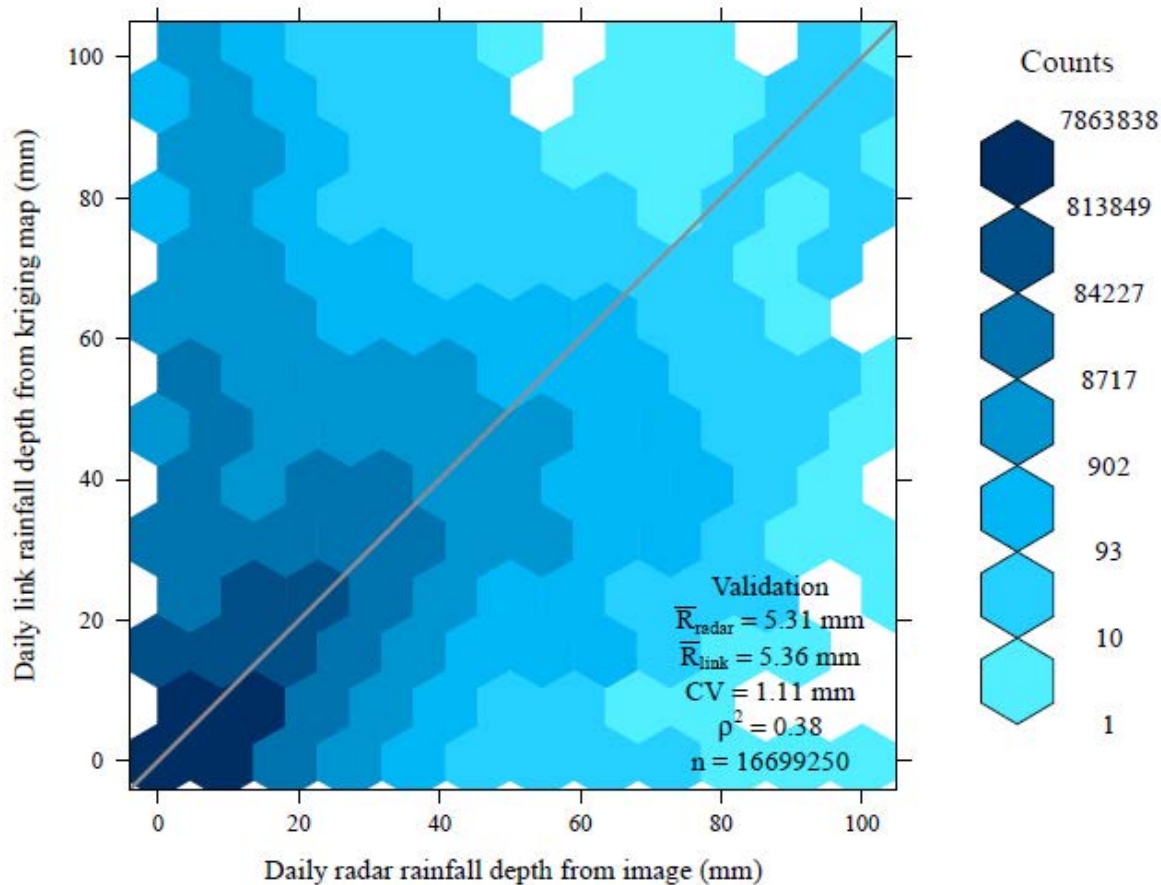
Commitment for RT flux beyond pilot ?

- Sustainable PPP model to be developed
- will to participate to own country civil protection motivates current involvement (Cameroun; Niger ; Mali ; Burkina Faso) – but how sustainable ?
- Mutual interest model to be built
 - Image greening ?
 - Shared benefit in future HyMet services to private users ?
 - Other ?

Additional material



Results in the Netherlands



- Daily rainfall
- 1086 days
- Independent of calibration
- Bias close to 0
- Correlation > 0.6