Using Mobile Communication Microwave Links for Rainfall Detection

LAFHAZAV Steering Group Meeting INES Ruhengeri

26-05-2023

Extreme Rainfall Impacts

Intense rainfall causes increased losses due to flash floods, landslides and soil erosion

In turn taking a huge toll on:

- Lives
- Livelihoods (crops and cattle, business)
- Infrastructure (roads, utility network, cities)
- Economy: Cost of e.g. 2007 floods alone in Rwanda was $22 million (0,6% of GDP)
- Agriculture: crop damage and soil loss for future generations

Rwanda Losing Over Rwf 37billion Every Season Due to Soil Erosion – Study

Staff Writer August 9, 2022

Rwanda: How Soil Erosion is Posing a Threat on Food Security

africanews. NEWS

Rwanda: Families grieve, count cost after floods, landslides kill 130

Documents And Publications

Author(s): Tsinda, Aime; Kind, Christian; Hess, Janto S. et al

Estimating damage costs of flooding on small- and medium-sized enterprises in Kigali, Rwanda

Source: Jàmbá Journal of Disaster Risk Studies

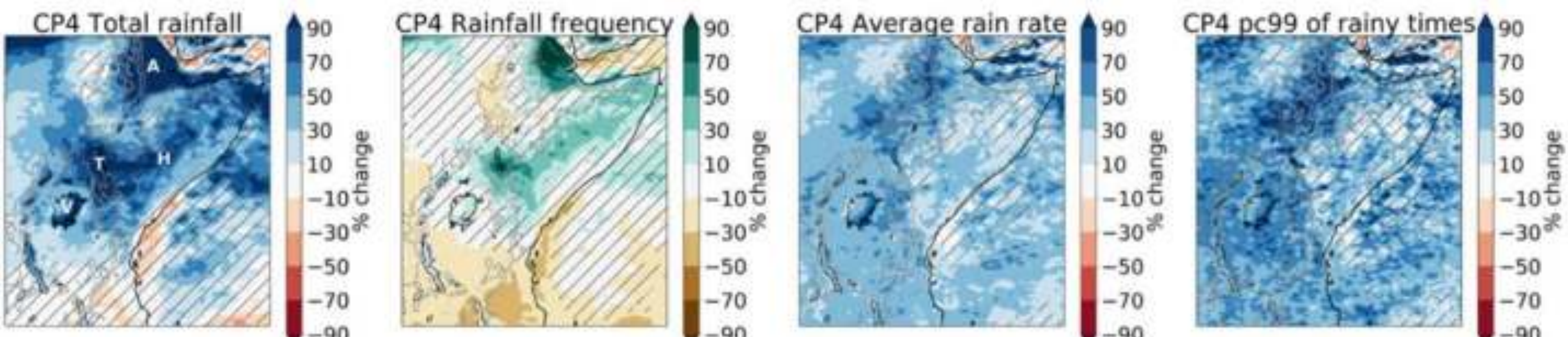
Extreme Rainfall Impacts

Impact of extremes expected to increase over next decades due to climate change

- The future economic costs of climate change are very uncertain. However, aggregate models indicate that the additional net economic costs (on top of existing climate variability) could be equivalent to a loss of almost 1% of GDP each year[1] by 2030 in Rwanda, though this excludes the future effects of floods and other extremes. This estimate is therefore considered a potential lower bound.
- In the longer-term, after 2050, the economic costs of climate change in Africa are expected to rise, potentially very significantly. However, the aggregate models report that global stabilisation scenarios towards a 2°C target could avoid the most severe social and economic consequences of these longer-term changes. This emphasises the need for global mitigation, as well as local adaptation.

There are a number of urgent priorities for building adaptive capacity in Rwanda that should be fast-tracked, notably in relation to meteorological and hydrological data collection, monitoring and forecasting (as these underpin future prediction and analysis), early warning systems, as well as information provision, monitoring (indicators) networks and focal points. The early priorities also include increasing the knowledge base, education and training and strengthening existing programmes.

Stockholm Environment Institute



Finney et al 2020

Need for Better Rainfall Monitoring

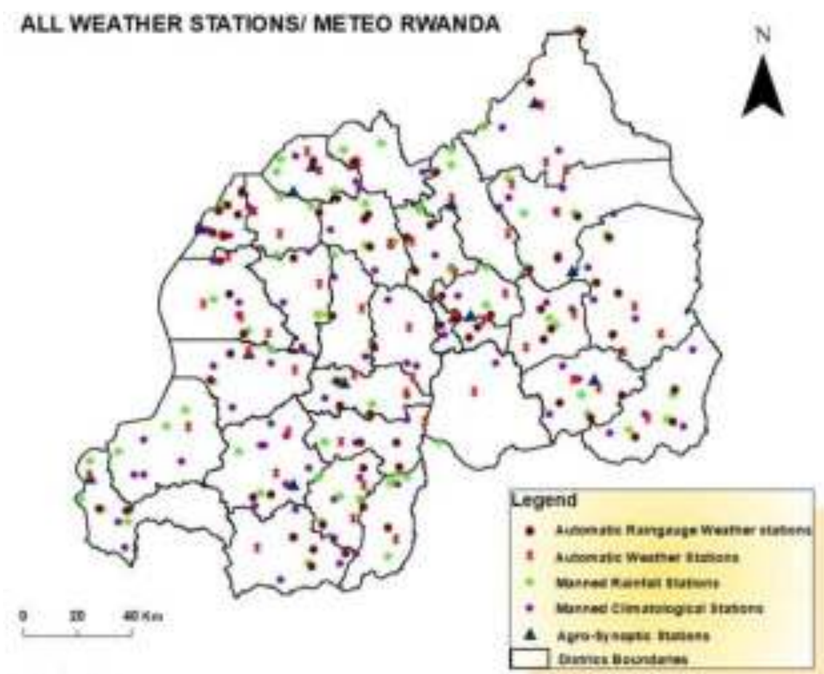
Rainfall can be measured with rain gauges, radar and satellite

GHENT UNIVERSITY

Need for Better Rainfall Monitoring

Rainfall can be measured with **rain gauges**, radar and satellite

- 180 automatic (AWS) and 180 manual stations in Rwanda
- Accurate measurements.
- Can be in real-time (AWS).
- Up to 10 minute sampling frequency for AWS.
- Fairly cheap to buy.

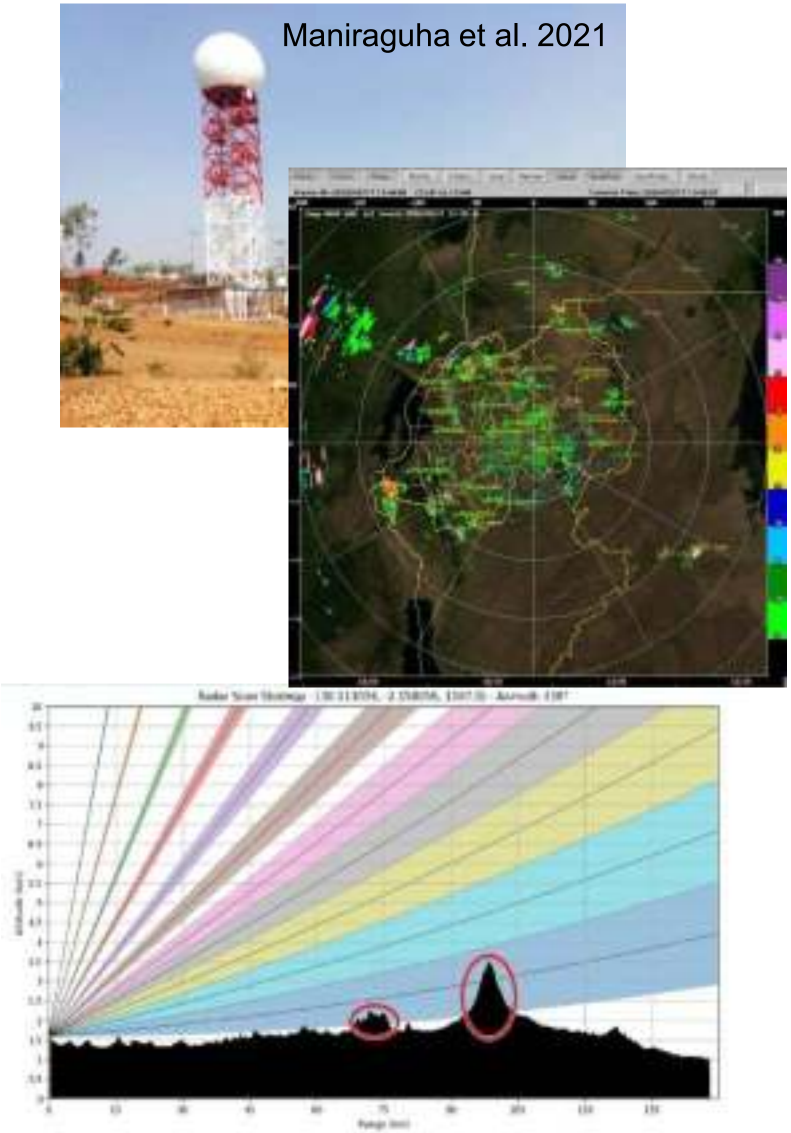


Meteo Rwanda

- Still lots of storms missed due to sparse point measurements.
- Expensive to maintain the quality of the network due to required site visits to remote stations.
- Many stations are manual with only daily reporting.

Need for Better Rainfall Monitoring

Rainfall can be measured with rain gauges, **radar** and satellite

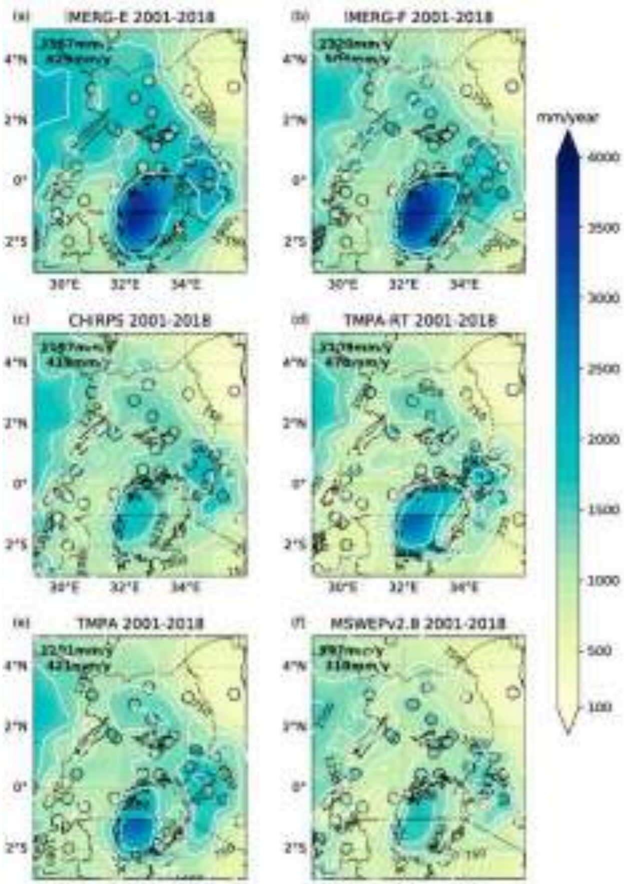


- 1 radar installed in Rwanda, 4 more on the way near each regional airport.
- Reasonably accurate measurements.
- Real-time.
- 5-15 minute sampling frequency.
- Great spatial coverage.

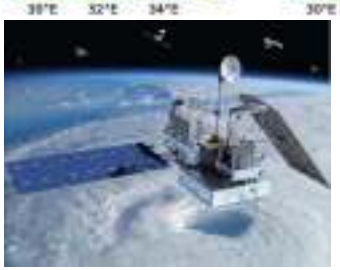
- Expensive to obtain and maintain.
- Signal quality degrades with distance from the radar due to beam broadening and attenuation.
- Frequent blocking of the signal due to mountains and other obstacles.
- Not direct measurement: need for calibration of reflectivity – rainfall relation (sensitive to drop size distribution ~D^6).

Need for Better Rainfall Monitoring

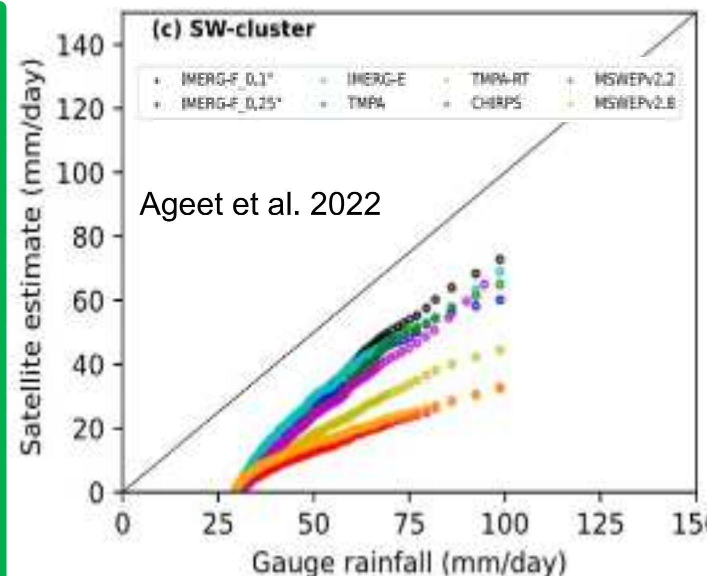
Rainfall can be measured with rain gauges, radar and **satellite**



Ageet et al. 2022



- Several products available.
- Good spatial coverage.
- Up to half-hourly sampling frequency.
- Freely available.



Ageet et al. 2022

- Fairly low accuracy, with wide large spread between different products and generally underestimation of extreme precipitation.
- Fairly low spatial resolution (about 10 km).
- Best quality products often not available in real-time (GPM-final).

Commercial Microwave Links

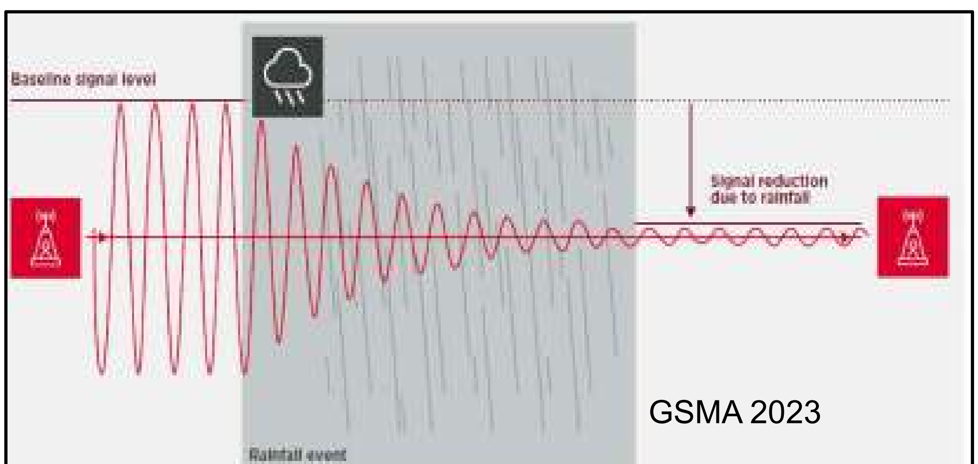
Additional information can be obtained from microwave links from telecommunication

Mobile phone communication:

- Phone ↔ Communication tower: 1-2 GHz: little attenuation.
- **Between communication towers: 10-40 GHz: Significant attenuation from rain.**

$$k = \frac{10log\left[\frac{P_0}{P}\right]}{L} \qquad \bar{R} \approx a\bar{k}^b$$

R=rain rate, k=specific attenuation | a and b = calibration constants | P=power received and P_0=reference power | L=length of the link



GSMA 2023

Commercial Microwave Links

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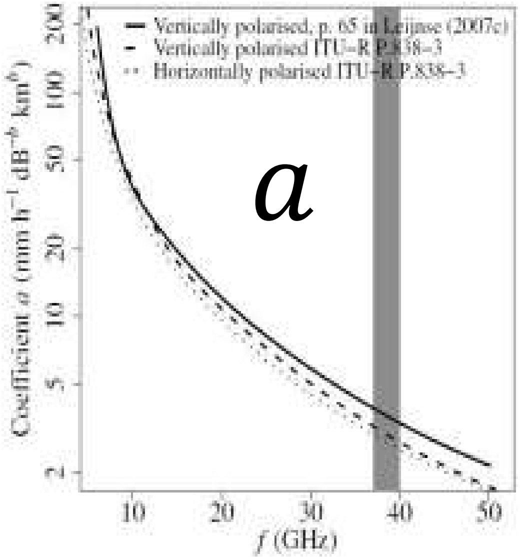
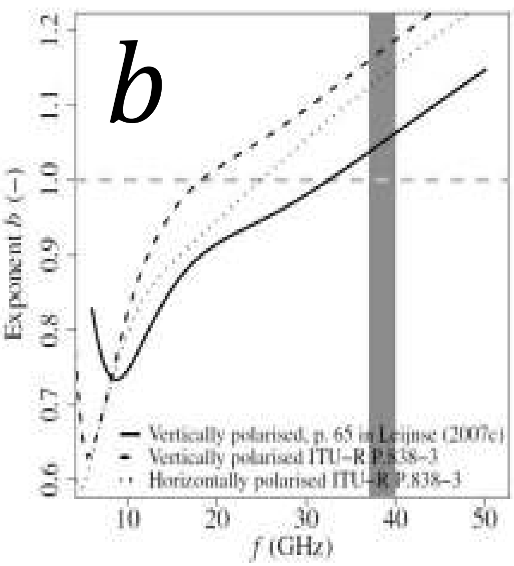
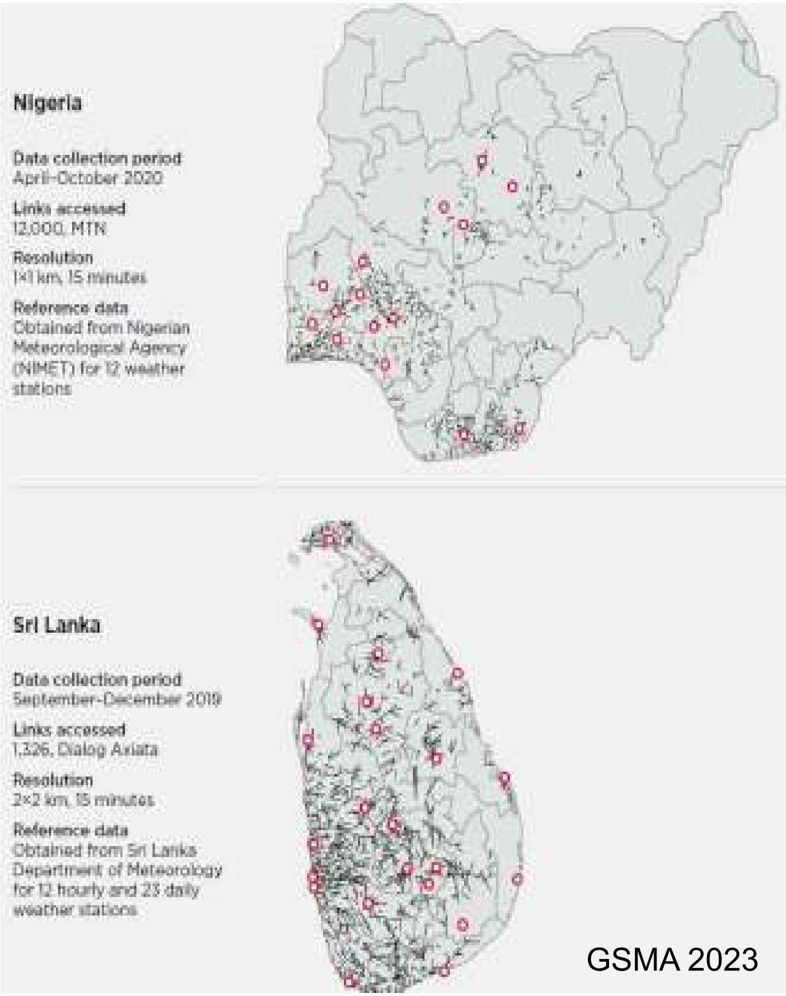


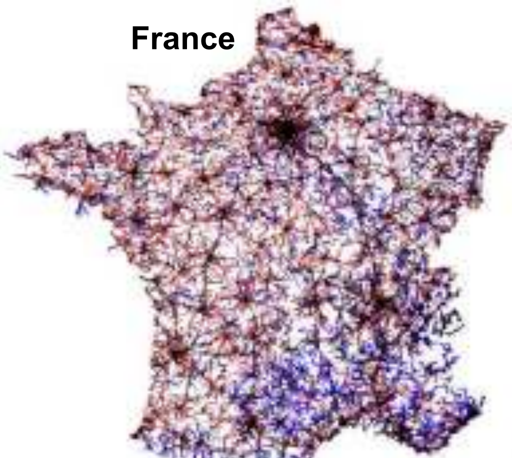


$$\bar{R} \approx a\bar{k}^{b}$$

Overeem et al. 2016

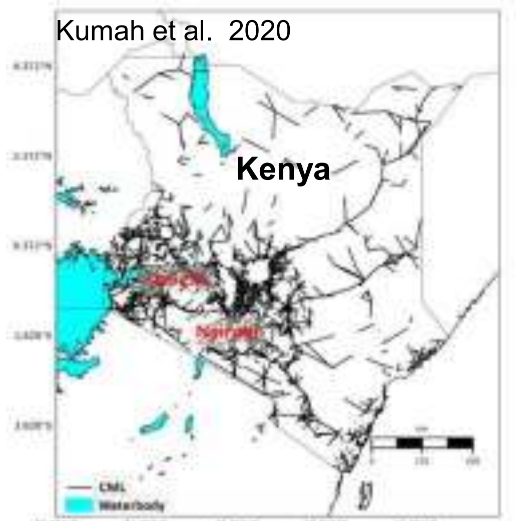


GSMA 2023



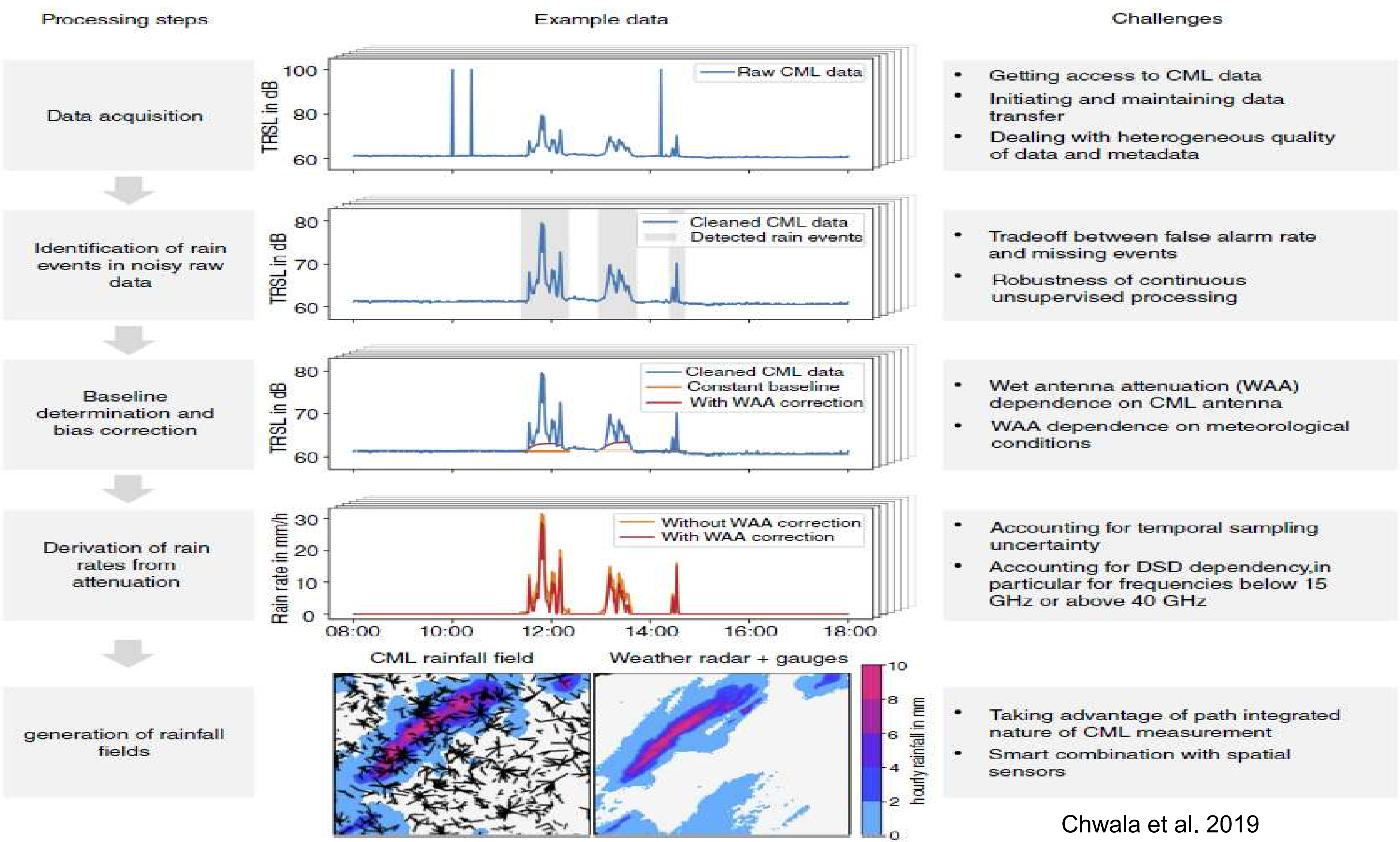
Chwala et al. 2019

Kumah et al. 2020



Commercial Microwave Links

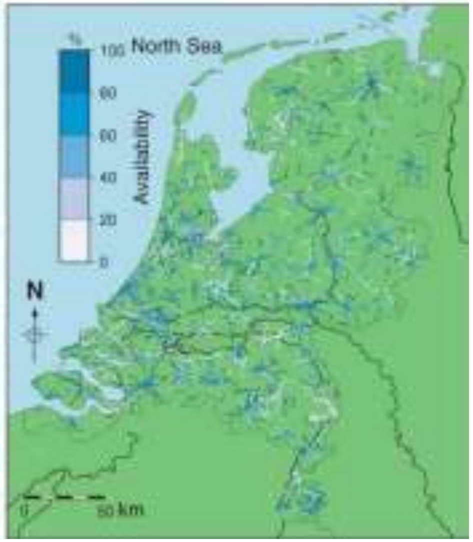
Data is available from the network management systems from telecom operators



Chwala et al. 2019

Commercial Microwave Links

Rainfall can be measured with rain gauges, radar and satellite **and microwave links**



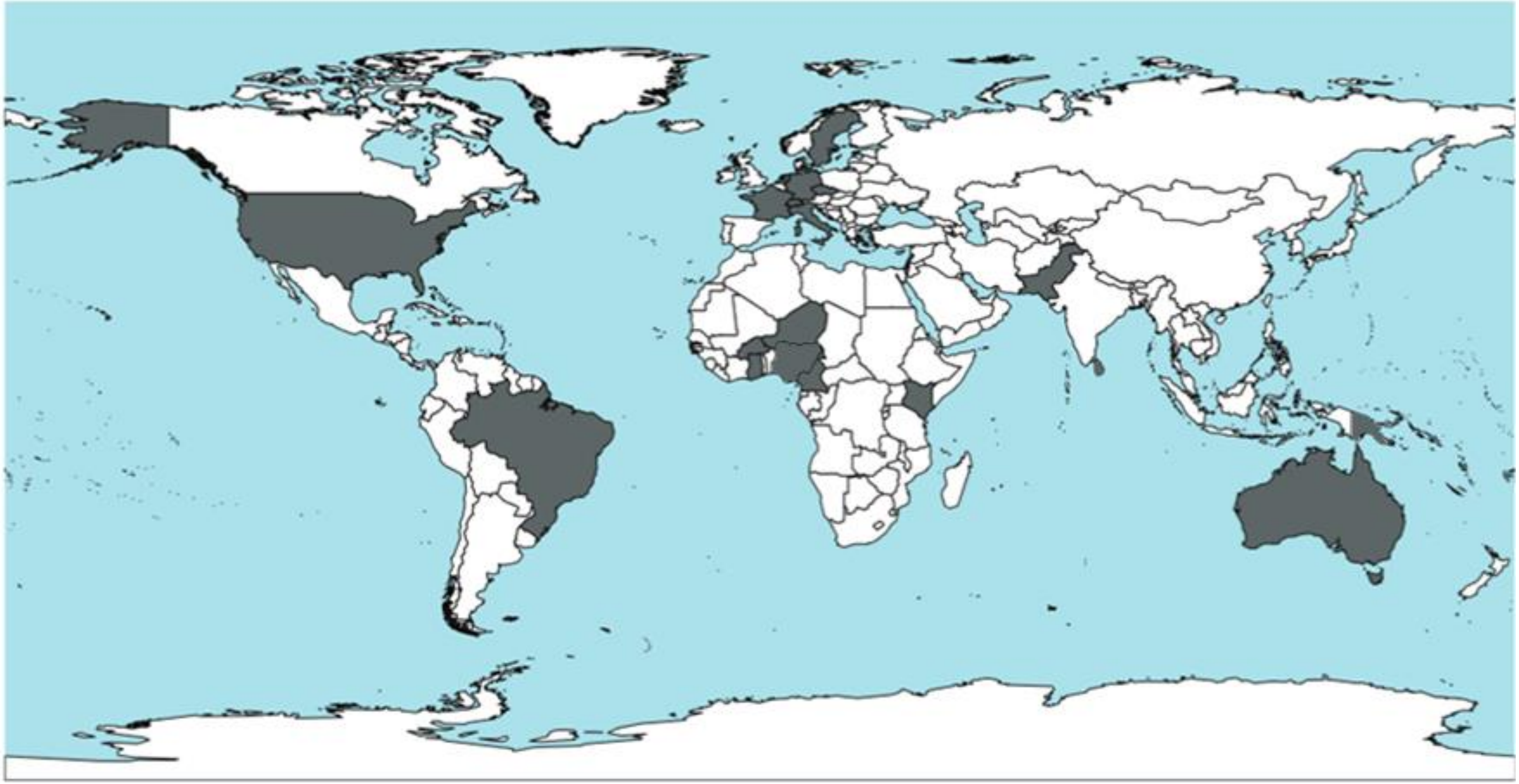
Uijlenhoet et al. 2018

- Real-time.
- 15 min sampling frequency.
- Great spatial coverage.
- No blocking (direct line of sight).
- Cheap (infrastructure available).
- More accurate retrieval than radar due to linear rain rate – attenuation relation.

- Data access not always straightforward (negotiation telecom operators).
- Transmitting power sometimes variable (automatic transmit power control).
- Microwave absorption due to fog or water vapour can contaminate signal (as with radar).
- CML increasingly replaced by fiber-optic cables.

Commercial Microwave Links

CML for rainfall monitoring now applied in an increasing number of countries



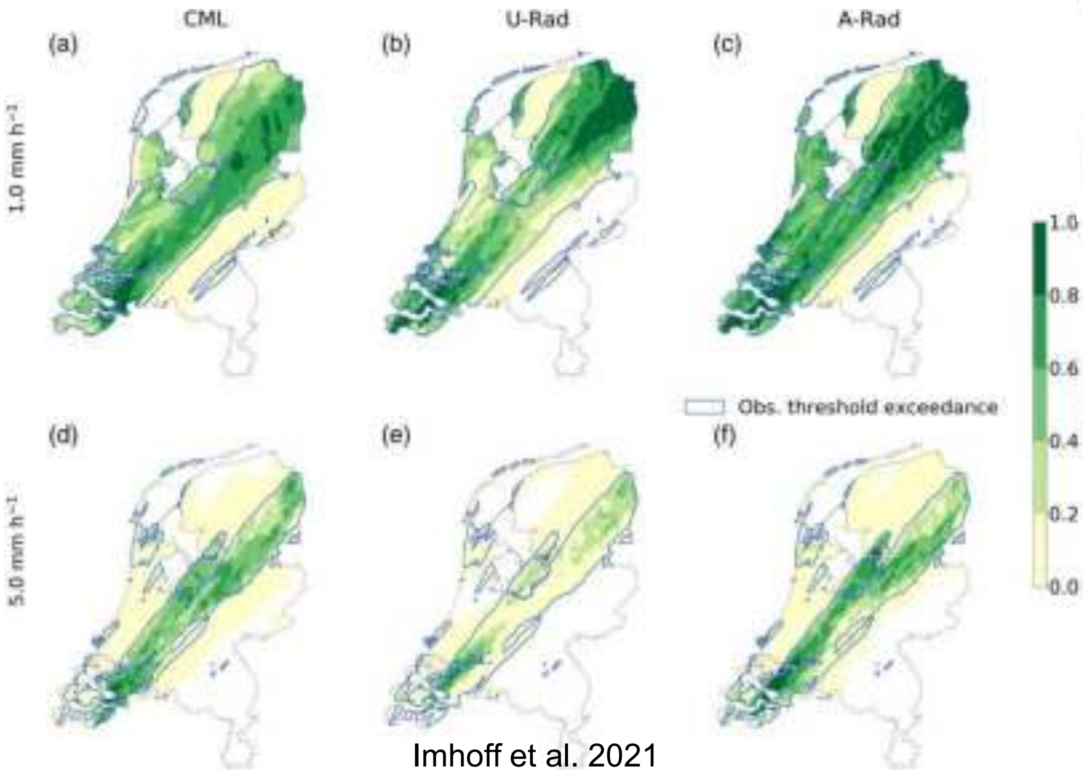
Uijlenhoet et al. 2018

Example: Netherlands

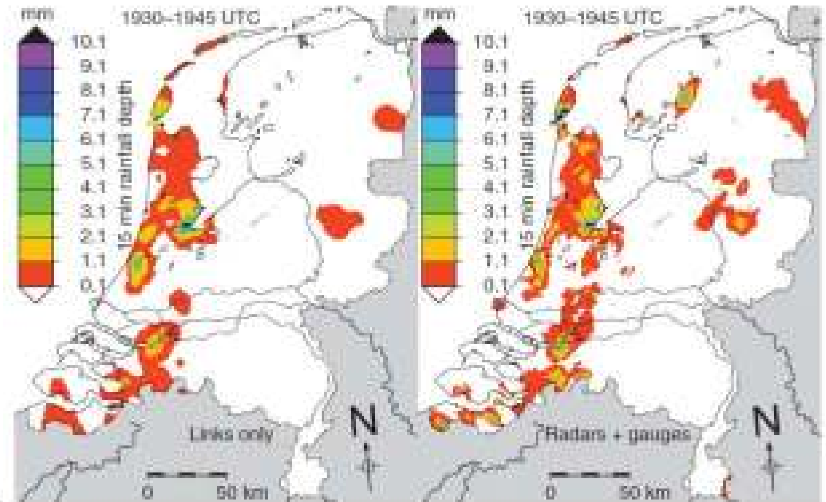
Pioneering project about 10 years ago: currently climatology of several years of thousands of links from T-Mobile

Country-wide rainfall maps from cellular communication networks

Aart Overeem[a,b,1], Hidde Leijnse[b], and Remko Uijlenhoet[a]



Imhoff et al. 2021



Overeem et al. 2013

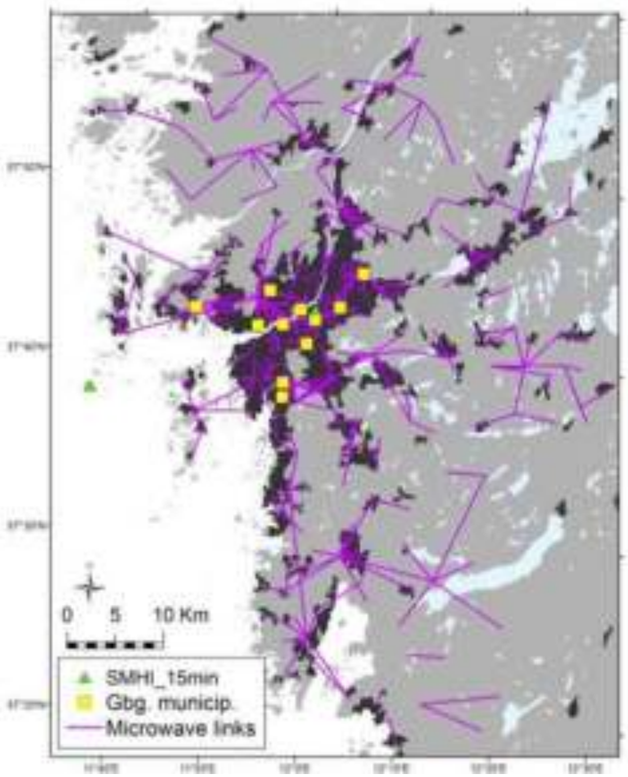
Example: Sweden

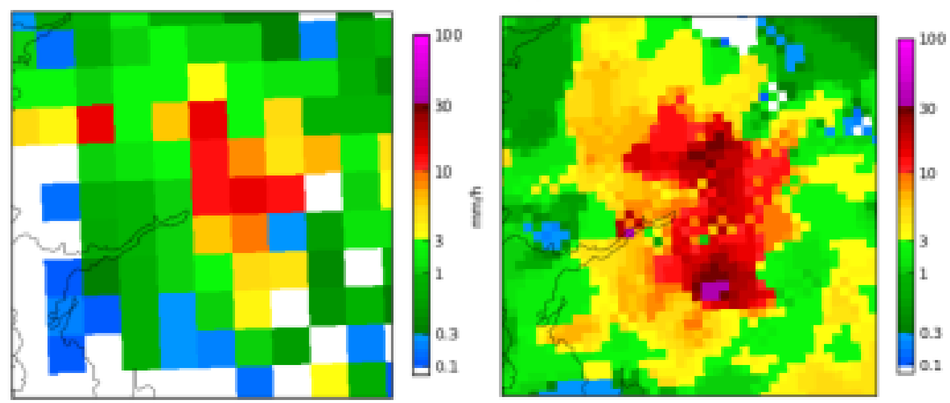
First country with operational real-time CML rainfall monitoring system (Ericsson Hi3G)

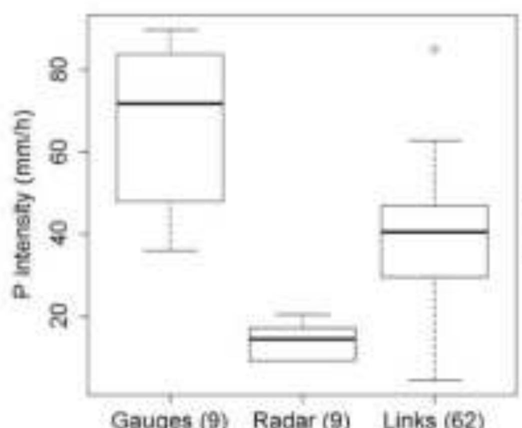
Microwave Links Improve Operational Rainfall Monitoring in Gothenburg, Sweden

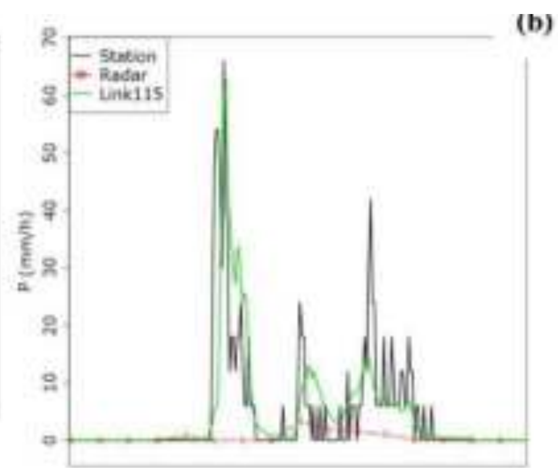
Andersson J.C.M.[1,*], Berg P.[1], Hansryd J.[2], Jacobsson A.[2], Olsson J.[1] And Wallin J.[1]
[1] Swedish Meteorological and Hydrological Institute (SMHI), 601 76 Norrköping, Sweden
[2] Ericsson AB, Lindholmspiren 11, 417 56 Göteborg, Sweden
*corresponding author: Jafet C.M. Andersson

Very high-resolution urban rainfall monitoring for real-time drainage modelling in Gothenburg









Andersson et al. 2017

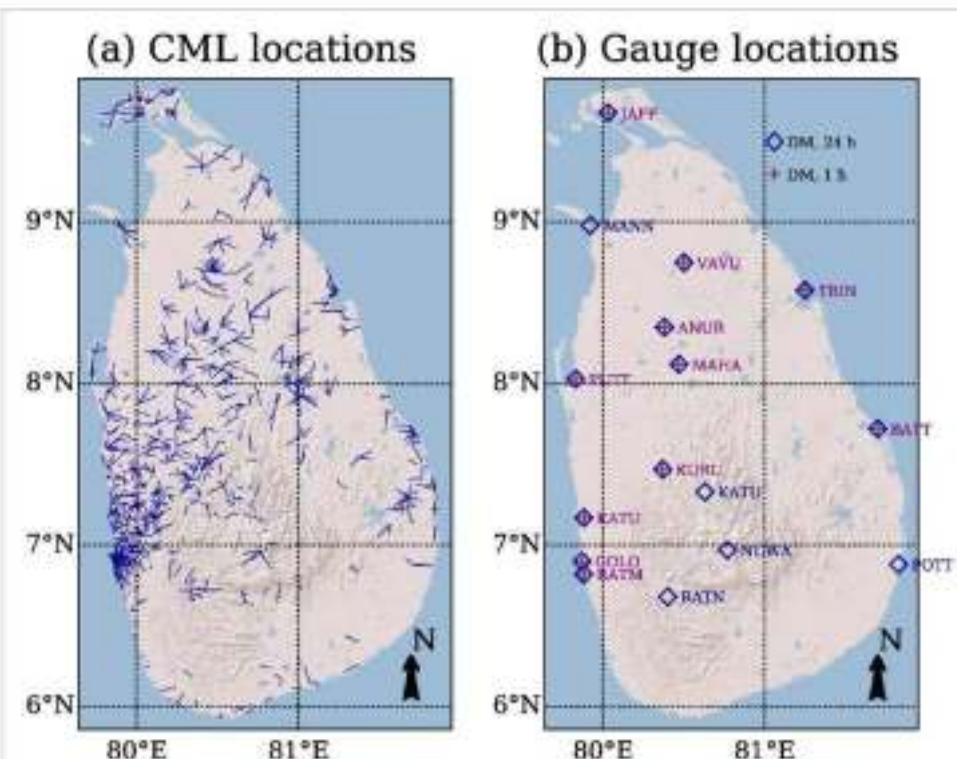
Example: Sri Lanka

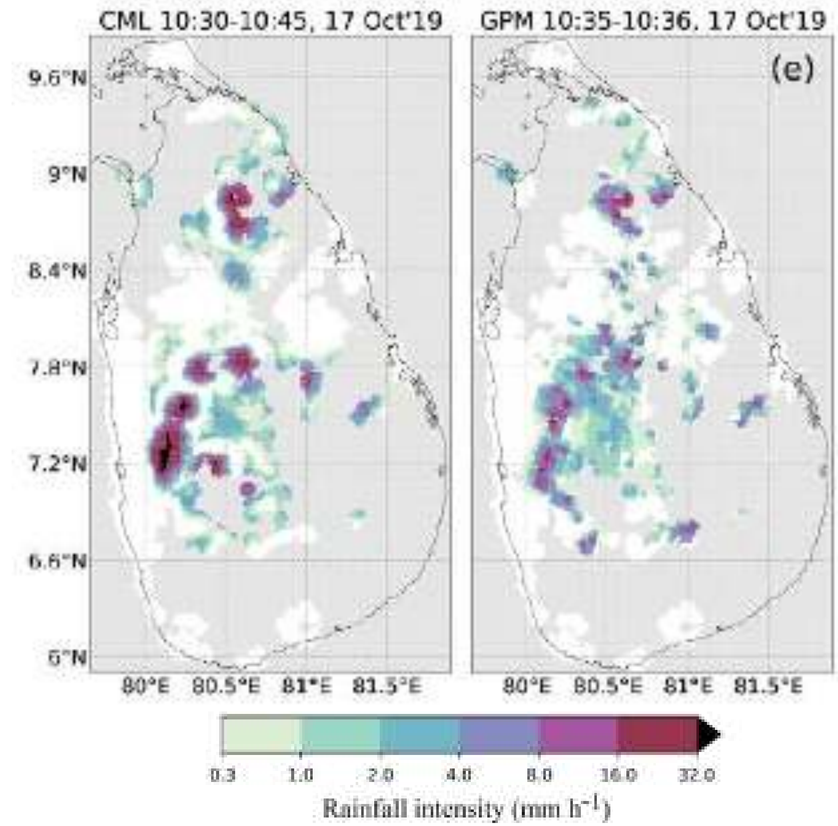
1140 links compared to rain gauge and satellite data (Dialog Sri Lanka via GSMA)

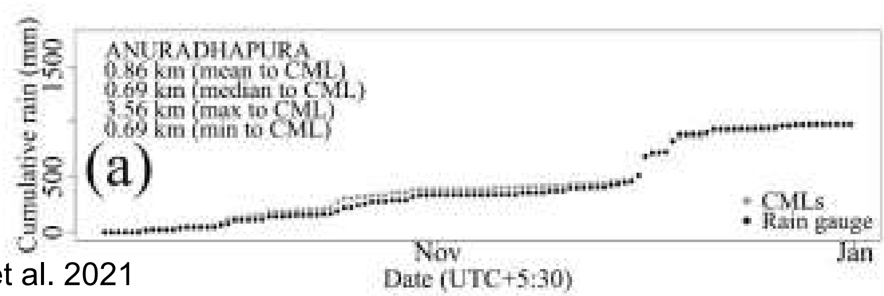
Tropical rainfall monitoring with commercial microwave links in Sri Lanka

Aart Overeem[1,2], Hidde Leijnse[1,2], Thomas C van Leth[1], Linda Bogerd[1,2], Jan Priebe[3], Daniele Tricarico[3], Arjan Droste[1] and Remko Uijlenhoet[2,4]

[1] R&D Observations and Data Technology, Royal Netherlands Meteorological Institute (KNMI), Utrechtseweg 297, 3731 GA De Bilt, The Netherlands
[2] Hydrology and Quantitative Water Management Group, Wageningen University & Research, Wageningen, The Netherlands
[3] AgriTech/Mobile for Development, GSM Association (GSMA), London, United Kingdom
[4] Department of Water Management, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands







Overeem et al. 2021

Example: Burkina Faso

CML data acquisition system in place since 2017 between Telecel Faso and LA.ME university of Ouagadougou: Direct access to CML IP addresses using SNMP protocol

Article

Towards Innovative Solutions for Monitoring Precipitation in Poorly Instrumented Regions: Real-Time System for Collecting Power Levels of Microwave Links of Mobile Phone Operators for Rainfall Quantification in Burkina Faso

Moumouni Djibo [1,2], Wend Yam Serge Boris Ouedraogo [1], Ali Doumounia [1,3], Serge Roland Sanou [1,4], Moumouni Sawadogo [1], Idrissa Guira [5], Nicolas Kone [6], Christian Chwala [2,7], Harald Kunstmann [2,7] and François Zougmoré [1,a]

1. Laboratoire de Matériaux et Environnement (LA.M.E), Université Joseph KI-ZERBO (UJKZ), Ouagadougou 03 BP 7021, Burkina Faso
2. Institute of Geography, University of Augsburg, 86159 Augsburg, Germany
3. Institut Des Sciences (IDS), Ouagadougou 01 BP 1757, Burkina Faso
4. Autorité de Régulation des Communications Electroniques des Postes (ARCEP), Ouagadougou 01 BP 6437, Burkina Faso
5. Telecel Faso SA, Ouagadougou 08 BP 11059, Burkina Faso
6. Institut de l'Environnement et de Recherches Agricoles (INERA/CNRST), Ouagadougou 03 BP 7047, Burkina Faso

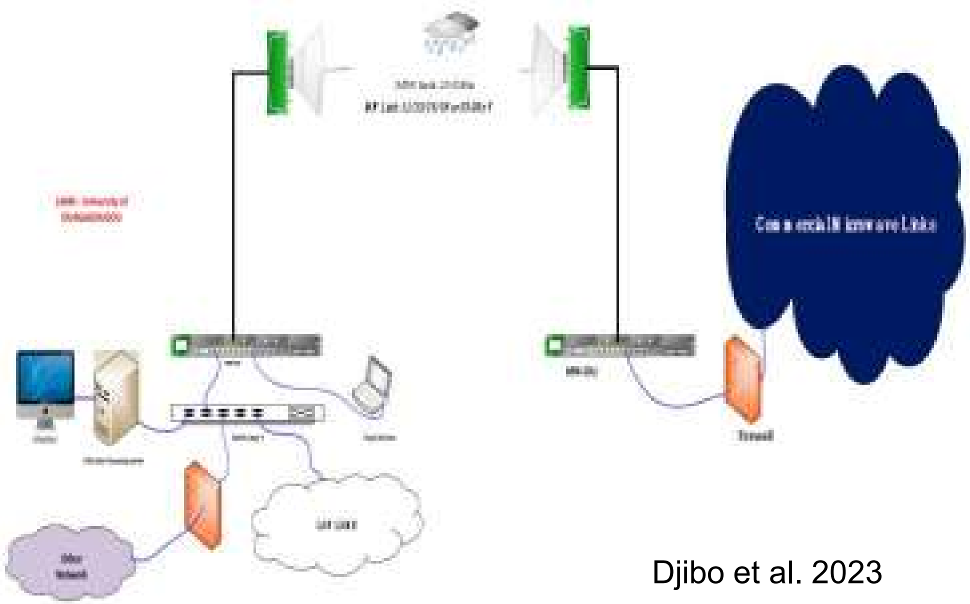


Figure 1. Schematic of Telecel Faso's CML power data acquisition system.

Djibo et al. 2023

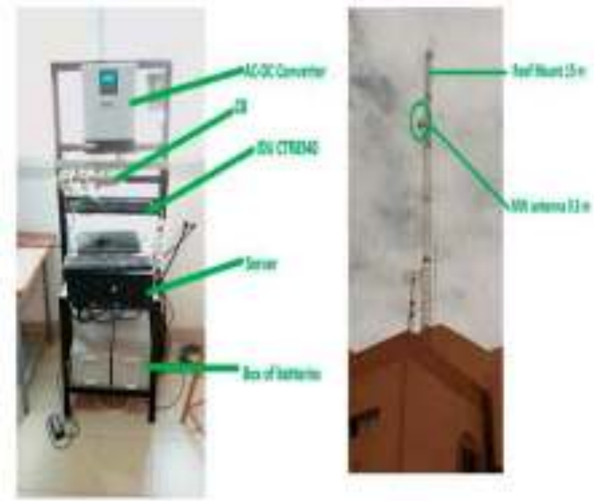


Figure 3. Acquisition system installed at the LA.M.E.

Example: Kenya

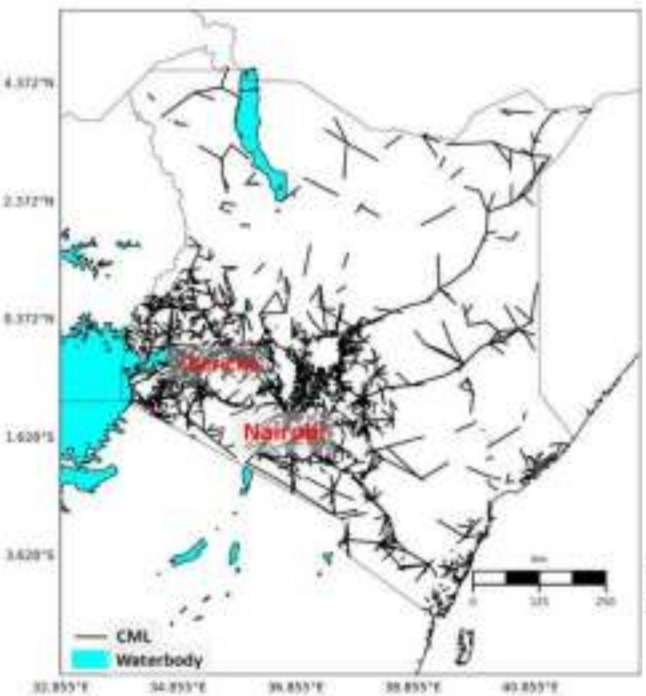
Merge information from satellite, rain gauges and CML using machine learning

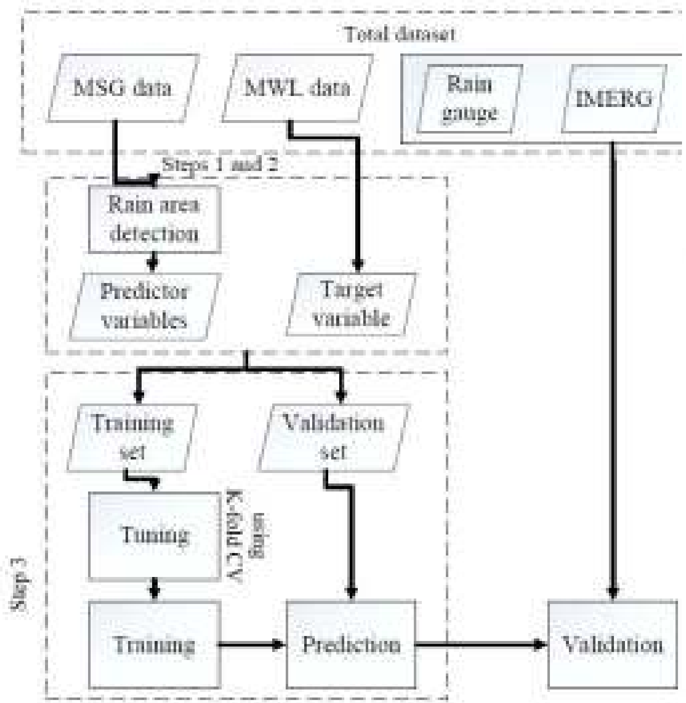
Combining MWL and MSG SEVIRI Satellite Signals for Rainfall Detection and Estimation

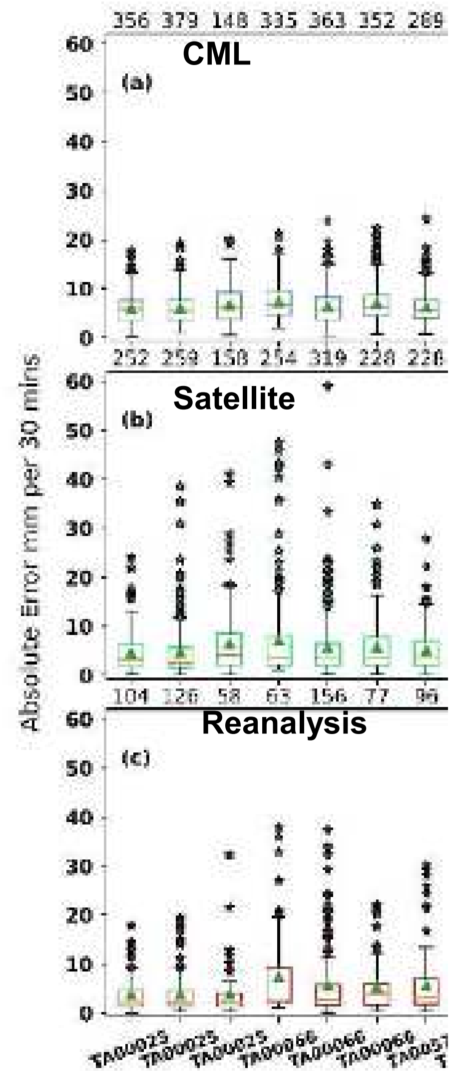
Kingsley K. Kumah [1,*], Joost C. B. Hoedjes [1], Noam David [2], Ben H. P. Maathuis [1], H. Oliver Gao [3] and Bob Z. Su [1]

1 Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, 7500 AE Enschede, The Netherlands; j.c.b.hoedjes@utwente.nl (J.C.B.H.); b.h.p.maathuis@utwente.nl (B.H.P.M.); z.su@utwente.nl (B.Z.S.)
2 AtmosCell, Tel Aviv, Israel; noam@atmoscell.com
3 The School of Civil and Environmental Engineering, Cornell University, Ithaca, NY 14853, USA; hg55@cornell.edu

Kumah et al. 2020







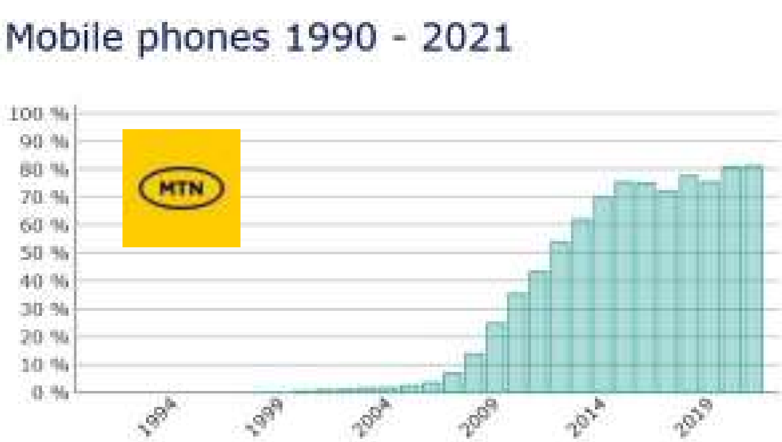
Why Rwanda?

Rwanda is particularly well-suited to implement CML rainfall monitoring

Figure 1. Map of Rwandan cell phone towers, January 2008. The median area cove each tower is roughly 70km^2.

Blumenstock 20

- Large variability in rainfall: often very extreme during rainy season with significant impacts.
- Large population density, increasingly living in cities (urban flooding).
- Widespread usage of mobile phones with dense network of communication towers (1200 operated by MTN).
- Polarimetric radar in Bugesera (and more to come) and automatic rain gauges to validate technique.
- Particular added value to calibrate radars and for gap-filling in data sparse regions (mountain valleys).



Preliminary Proposed Research Plan – short term

Initially: obtain funding from Flemish Interuniversity Council for Ph.D. student INES

Projects 2003-2021		
Type	Budget (€)	Number
Total	*1.404.626*	*13*
TEAM	633.947	3
SI	770.679	10

Scholarships 2003-2020		
Type	Budget (€)	Number
Total	*4.256.765*	*427*
Ph.D.		
Subtotal	*977.625*	*7*
ICP Ph.D.	110.175	1
VLADOC	867.450	6
Short term		
Subtotal	*552.748*	*337*
ITP	188.268	32
KOI	76.472	36
REI	280.583	268
Other scholarships	7.425	1
Study		
Subtotal	*2.726.392*	*83*
ICP	2.726.392	83

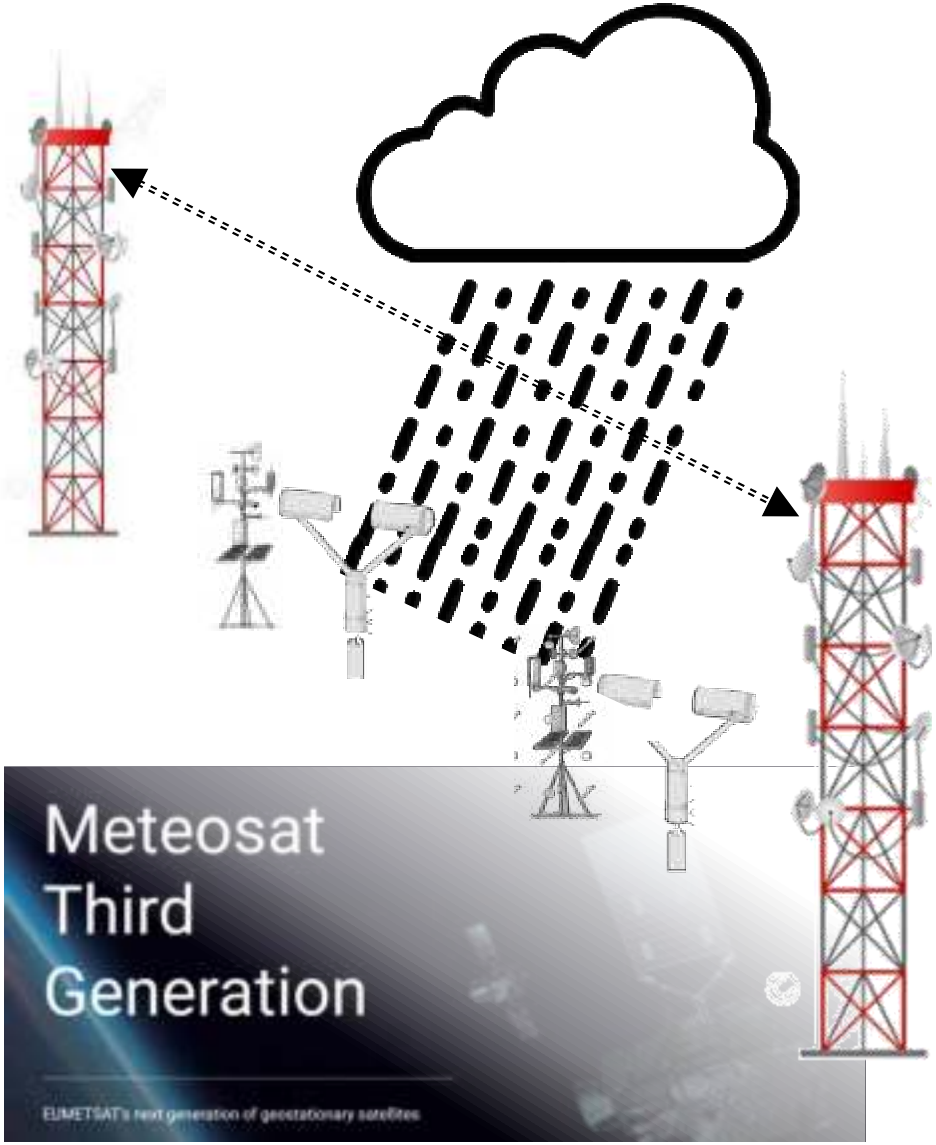
- **VLIRUOS supports partnerships** between Flemish universities and partner countries, searching for answers to global and local challenges.
- Together with **Rwanda partner university (INES Ruhegneri), Meteo-Rwanda and MTN** we will apply for a **TEAM-project**, sponsoring **two PhDs**.
- 2 years at home institution and 2 years at Ghent University (in close contact with **experts on CML** in Netherlands and other Belgian partners).
- **Deadline for proposal**: end of this year (2023).
- Similar project is being negotiated with partners in Uganda.

Rwanda is a partner country with potential for VLIR-UOS. From 2003 to 2021 VLIR-UOS spent over € 5.3 million in cooperation with Rwanda, including 7 ongoing departmental projects. A new project dealing with a 'International & Digital Midwifery Workplace learning Network' started in 2018. More projects are expected to be selected during the coming years.

vliruos SHARING MINDS, CHANGING LIVES

Preliminary Proposed Research Plan – mid term

Ph.D. research will focus on implementation, calibration and improvement of CML



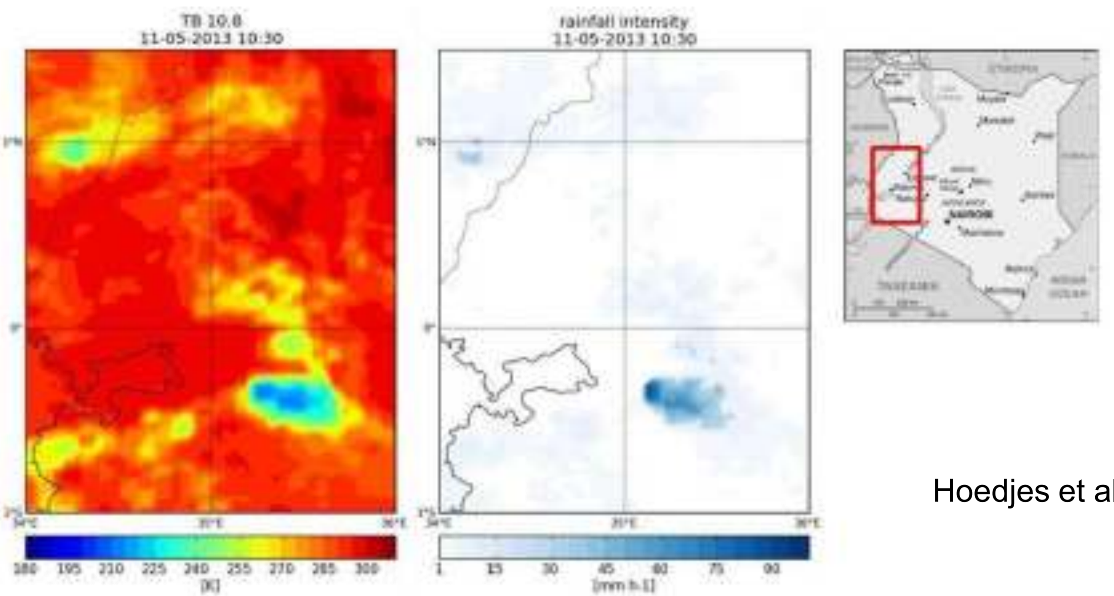
- Set up **calibration stations** (disdrometer, weather sation and rain gauges) for a few CMLs in **Ruhengeri.**
- Set up **calibration stations** near **Kigali polarimetric radar** as well within line of sight of a few CMLs.
- **Rainfall mapping,** combining CML, radar and satellite for whole of Rwanda for one rainy season.
- Use rainfall data as input for **landslide** model for Ruhengeri and **flash flood** model in Kigali.
- **Evaluate** rainfall maps.
- Great **multi-stakeholder partnership** academia, private sector and government

Preliminary Proposed Research Plan – long term

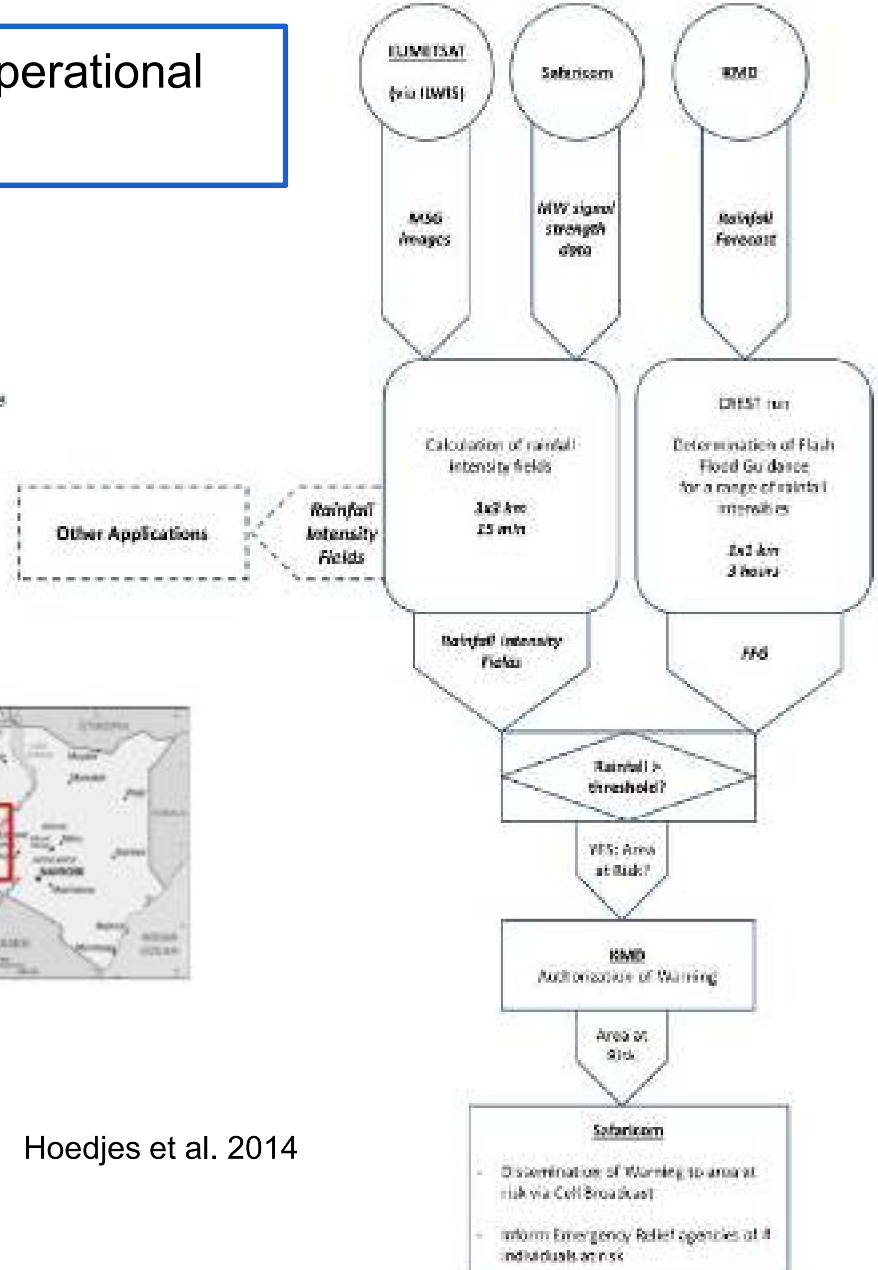
Integrate commercial microwave links in operational early-warning system for flash floods

A Conceptual Flash Flood Early Warning System for Africa, Based on Terrestrial Microwave Links and Flash Flood Guidance

Joost C. B. Hoedjes [1,*], André Kooiman [2], Ben H. P. Maathuis [3], Mohammed Y. Said [1], Robert Becht [3], Agnes Limo [4], Mark Mumo [4], Joseph Nduhiu-Mathenge [4], Ayub Shaka [5] and Bob Su [3]



Hoedjes et al. 2014



CML for rainfall monitoring has the support from GSMA and WMO

Key messages and recommendations

MNOs

Wireless backhaul, specifically CMLs, is an untapped opportunity for rainfall observation.

Rainfall data can be provided from wireless backhaul using open-source software for data access and rainfall retrieval.

MNOs can benefit from CML rainfall services by monetising the data, entering new sectors and improving corporate social responsibility.

Flood early warnings are considered the most viable entry point for CML rainfall data services due to the added value of CML data and high ROI.

Climate service providers

CML rainfall data provides a unique source of quantitative precipitation estimates with an extensive coverage area, high spatiotemporal resolution and real-time availability.

Accessibility is the main barrier to using CML rainfall observations and can be improved through the development and/or vetting of software to access

Donors

Future funding is urged to focus on the operationalisation and commercialisation of CML rainfall data sources, namely:

Optimising rainfall retrieval algorithms to provide consistent results across CML networks and climatological zones.

Researching the integration of rainfall data from CMLs and geostationary satellites to provide a hybrid data source.

Supporting the identification and development of software to facilitate real-time access to CML data.

Supporting projects that use CML rainfall data to develop services with maximum potential for impact, such as rainfall nowcasting and flood early warnings.

Supporting initiatives to explore how public, private and academic organisations can collaborate to develop and provide commercially sustainable CML services.

Conclusion

- Commercial Microwave Links are increasingly used to monitor rainfall.
- Promising for tropical, mountainous regions with sparse measurements.
- We would like to seek VLIR-funding for 2 Ph.D. students to work on this topic, in close collaboration with INES, MTN, Meteo Rwanda, Ghent University (and other partners in the Netherlands and Belgium). Strong background in mathematics, physics or statistics required.
- Goal is to have an operational system for rainfall monitoring in real-time at the end of the project.
- Software, raw data and expertise is expected to remain in Rwanda.
- Benefits for all partners at low cost. Long-term commercial/operational applications with large return on investment.
- Deadline for research proposal end 2023.

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Conclusion

- Commercial Microwave Links are increasingly used to monitor rainfall.
- Promising for tropical, mountainous regions with sparse measurements.
- We would like to seek VLIR-funding for 2 Ph.D. students to work on this topic, in close collaboration with INES, MTN, Meteo Rwanda, Ghent University (and other partners in the Netherlands and Belgium). Strong background in mathematics, physics or statistics required.
- Goal is to have an operational system for rainfall monitoring in real-time at the end of the project.
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Thank you. We look forward to collaborating
with INES Ruhengeri, MTN and Meteo Rwanda