

Innovation in Rainfall Measurement for Tropical Hydrology :

From Satellite to Mobile Phone Networks

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IRD/GET, Toulouse, Francia

In collaboration with

Fr Cazenave (LTHE/IRD)

Fr Zougmore (LAME/ Univ Ouagadougou)

And the Megha-Tropiques Sc team.



www.ore-hybam.org

HYBAM
6 th Meeting
26-30 de Octobre de 2015

MONITORING RAINFALL

¿Como medir la lluvia y su reparticion temporal i espacial?



Redes de pluviometros



Historical records

Radar meteorologico



~ since 1945
Polarimetry since late
90s

Satelites



Since late 70s (InfraRed)
Since late 90s for
Microwave + radar

Redes de telecomunicacion
comercial



NOW !!

MONITORING RAINFALL

¿Como medir la lluvia y su reparticion temporal i espacial?



The big challenge :
Rainfall variability !

At climatological scales :existing
networks ~OK

For monitoring very fast
occurring phenomena like urban
floods or mountain areas fast
floods : small time and space
scales needed.



MONITORING RAINFALL

¿Como medir la lluvia y su reparticion temporal i espacial?



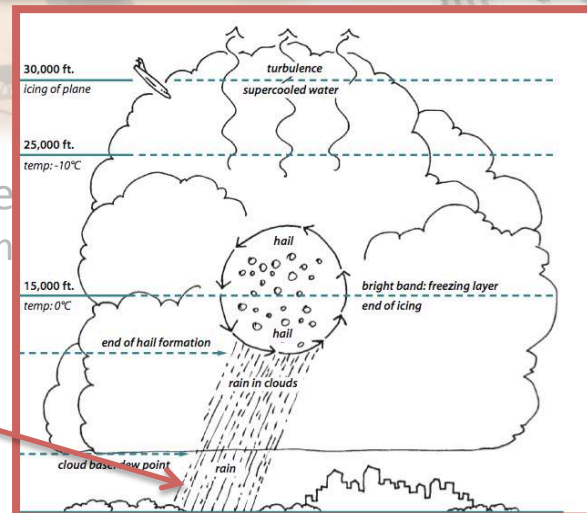
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floods : small time and space
scales needed.

✓ Sampling (space and time) is
a big issue in rainfall
monitoring

✓ Also, the precision of the
estimation – linked to how
direct rainfall measurement
is.



Rec

Desde centurias

Wanted
Rainfall

~ since
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MONITORING RAINFALL

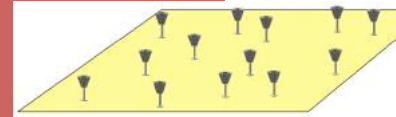
¿Como medir la lluvia y su reparticion temporal i espacial?



Redes de pluviometros



- ✓ Very direct measurement
- Sampling limited by network density
- Some zones not accessible
- Real time transmission not always possible



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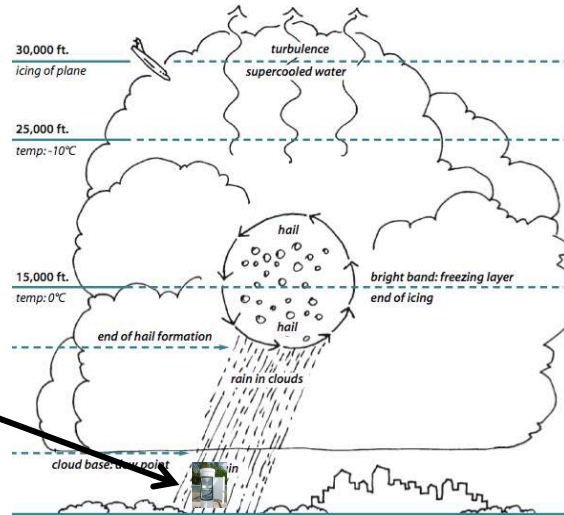
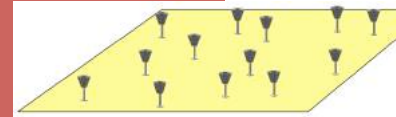
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Direct measure of Rain rate R mm/h, or rain accumulation, With a bucket.

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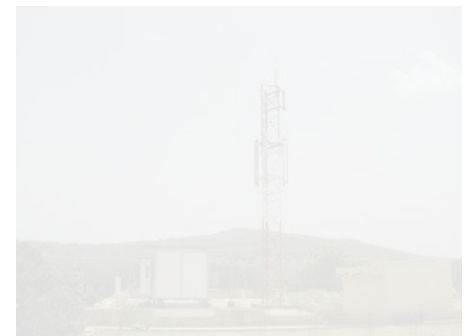
- ✓ Excellent sampling (5 minutes – 1 km)
 - ✓ Real Time maps / large coverage
 - ✓ Many information on Rain Systems, interesting for weather prediction
- Indirect Measurement
 - EXPENSIVE !

Satelites



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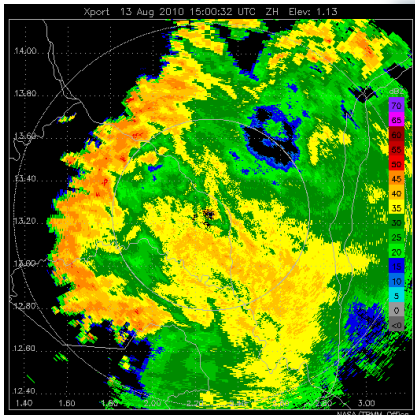
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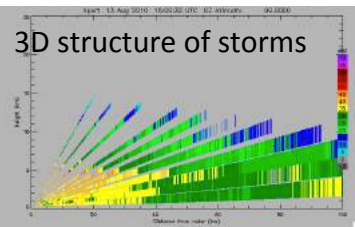
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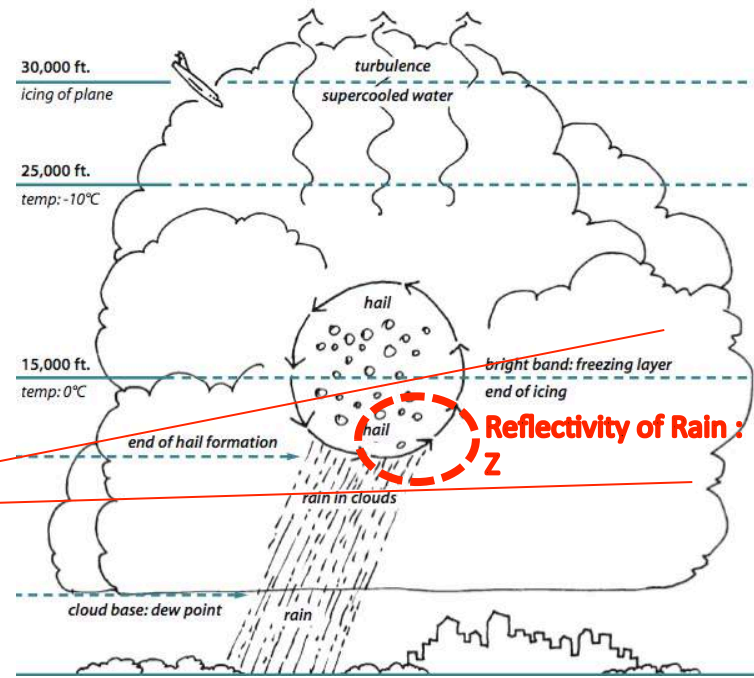
Radar meteorologico



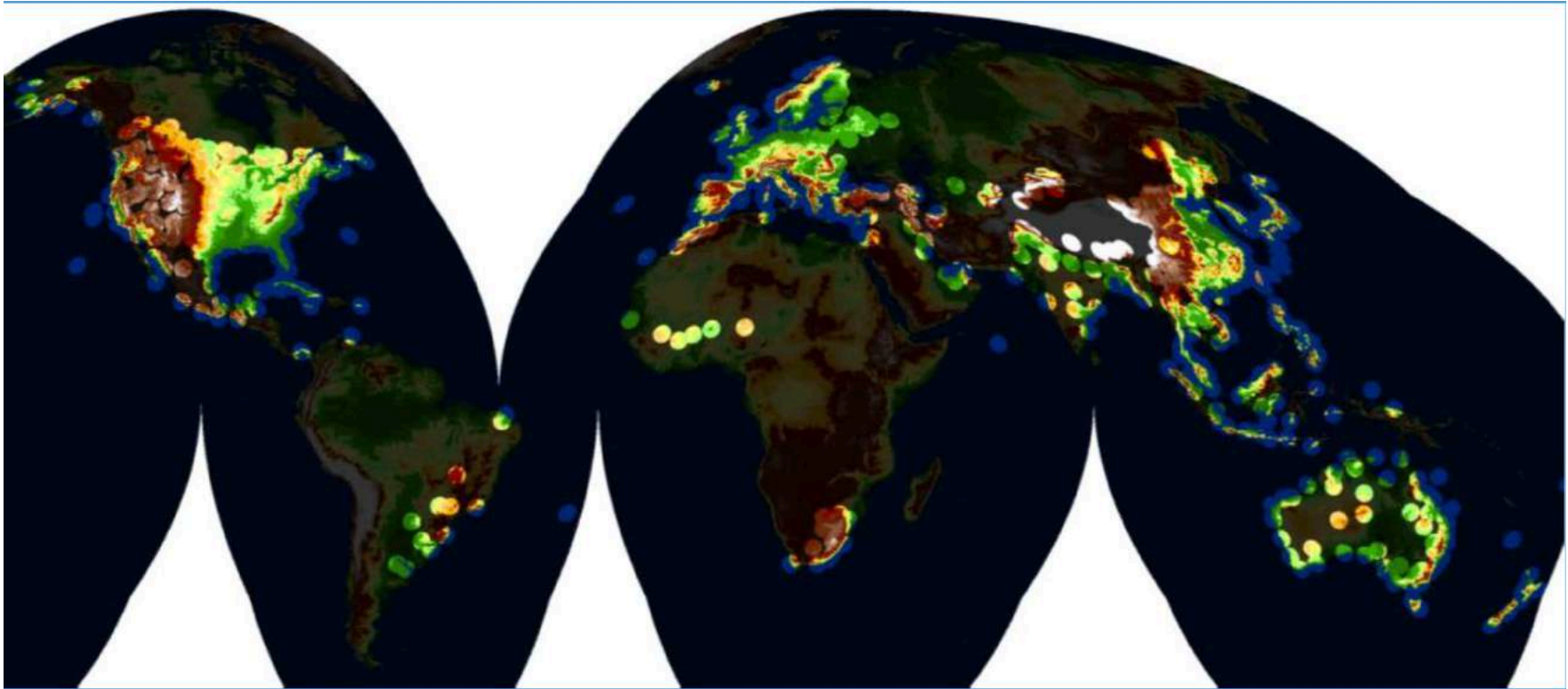
High Resolution Rain Map



3D structure of storms



✓ In many tropical countries ; no radar coverage !



World Map of Weather Radar coverage

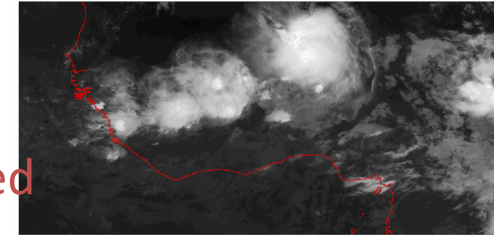
(Heistermann et al., 2012)

MONITORING RAINFALL

¿Como medir la lluvia y su reparticion temporal i espacial?

Geostationary (GOES) Infra Red info

- ✓ Global coverage
- ✓ Excellent sampling (< 1h – 5 km)
- ✓ Real Time - Freely available
- VERY Indirect Measurement (cloud top)



Radar meteorologico

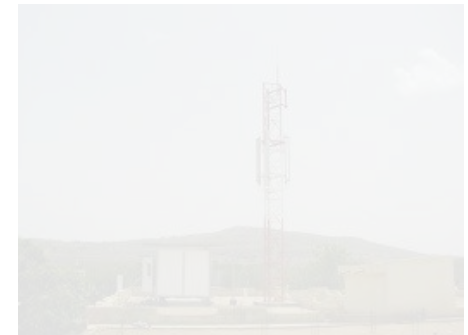


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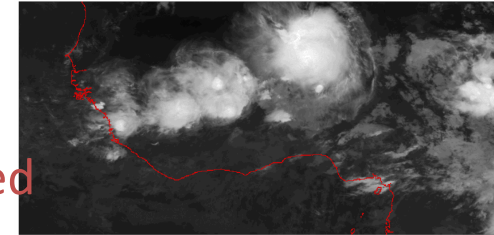
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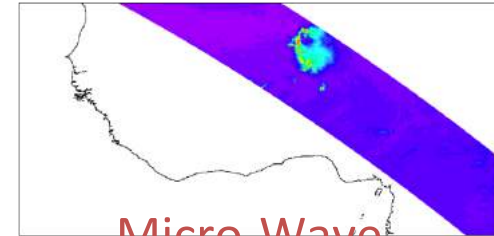


Infra-red



Radar meteorologico

Satellites



Micro-Wave

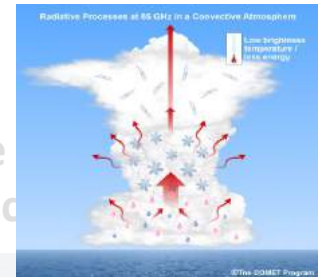
Orbiting – Microwave Information (TRMM / Megha-Tropiques / GPM core GPM constellation)

- ✓ Indirect (precipitating ice)
- ✓ Near Real Time - Freely available
- Insuffisant sampling



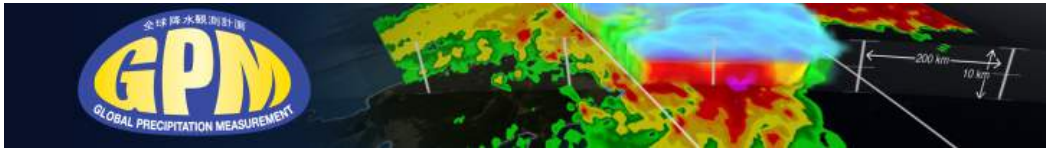
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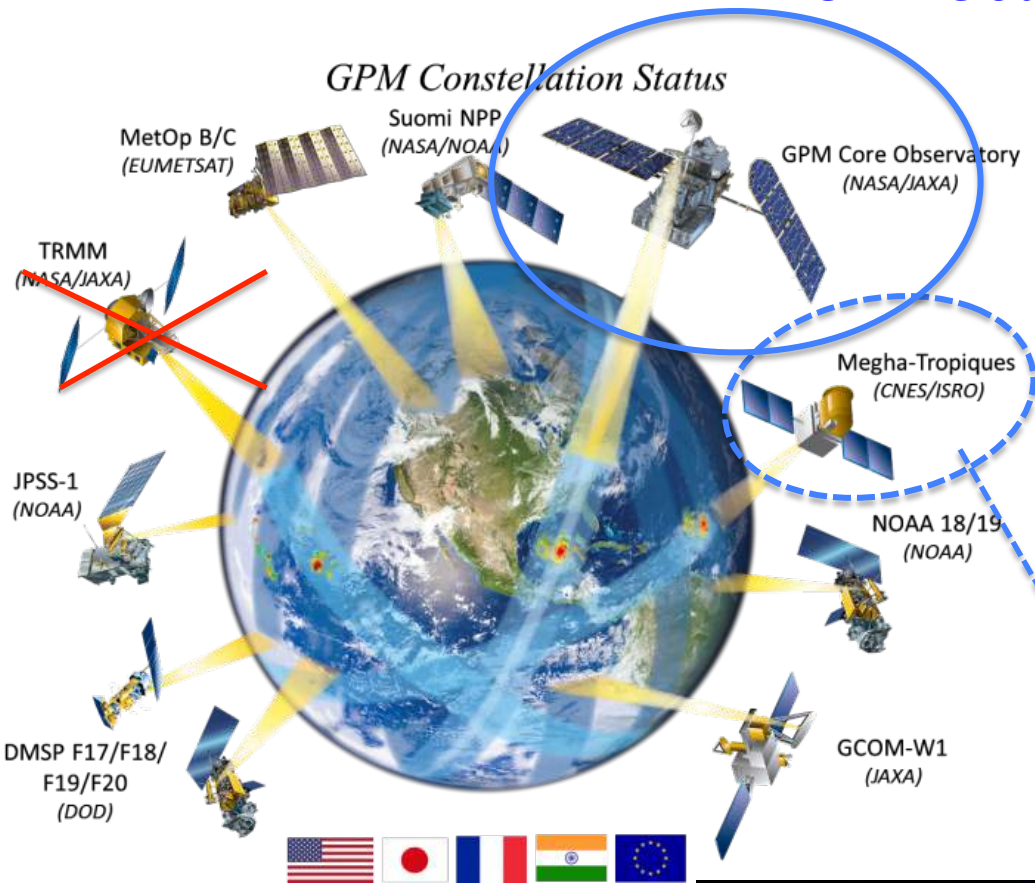


MicroWave +IR
Satellites
Are necessary for
quantitative
estimation of rainfall

Good News : GPM/MT



GPM : Global Precipitation Measurement

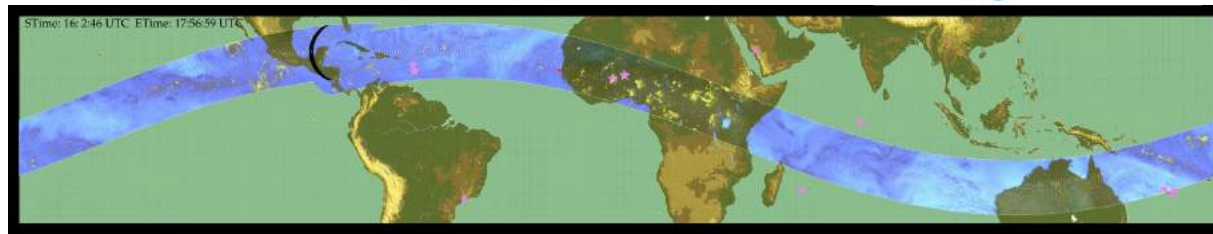


The GPM era:

- More MW information -> new products (I-merg ; TAPEER) with better accuracy
- Megha-Tropiques (MT) Improved sampling in the Tropics



A constellation of **micro-wave** Satellite
+ GPM RADAR !



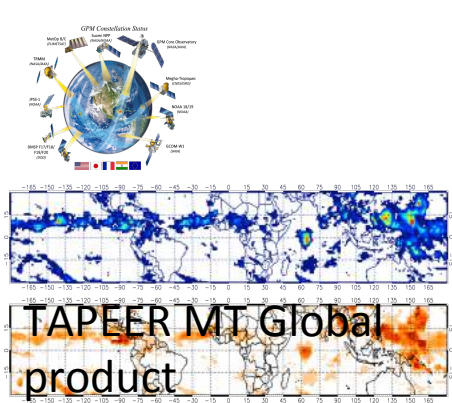
SOME CONCLUSIONS REGARDING LATEST SATELLITE PRODUCTS

Thanks to the GPM/MT era

Great improvements in satellite Rainfall Products that combine Geostationary and MicroWave information

- TRMM TMPA products
- MT TAPEER
- GPM I-MERG
- PERSIANN ; CMORPH ; GSMAP ..

many use in hydrology/climate studies etc...



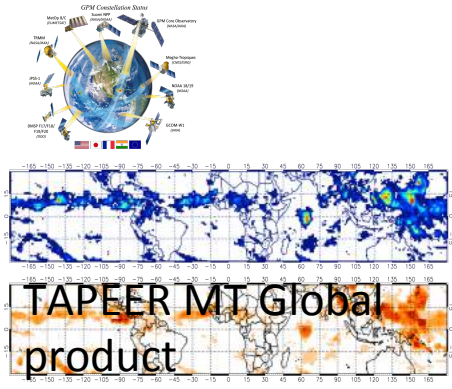
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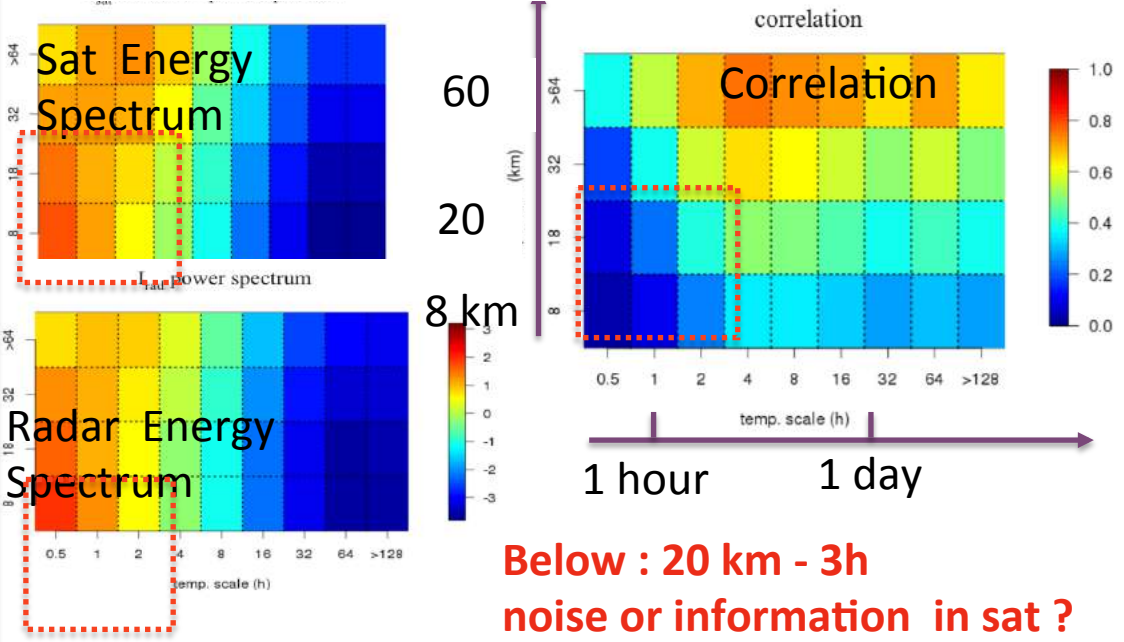
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Wavelet comparison of Radar and Satellite Rain maps



**Below : 20 km - 3h
noise or information in sat ?**

HOWEVER
For very fine scale (less than 3 h ; less than 30 km) and for Real Time, still too many uncertainty/biases



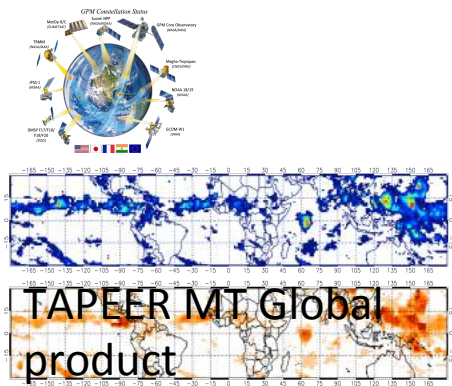
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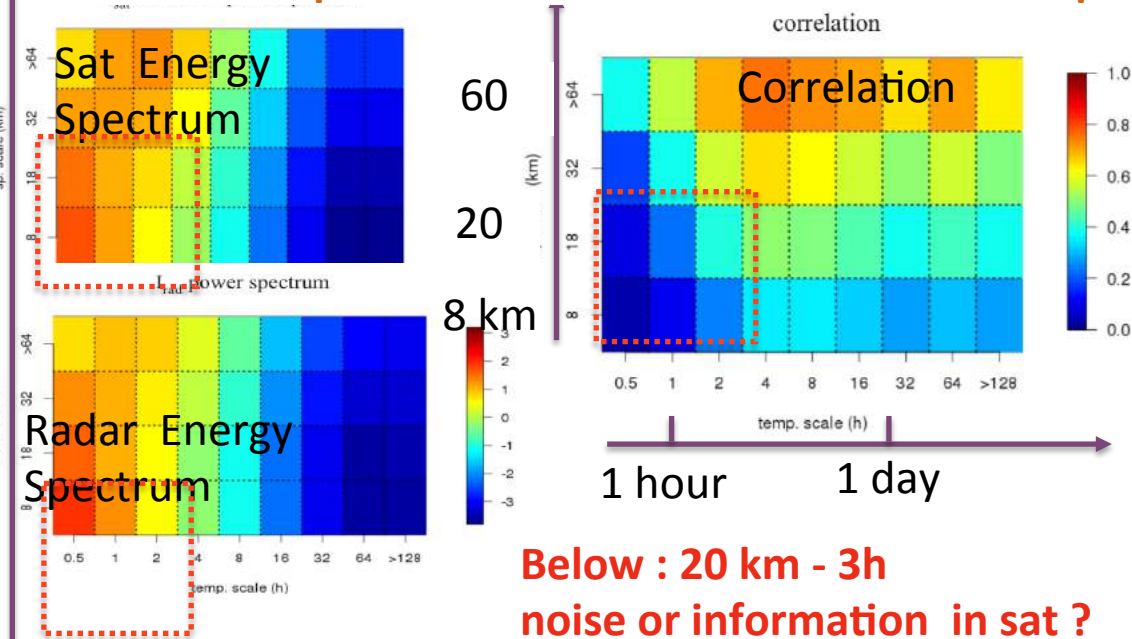
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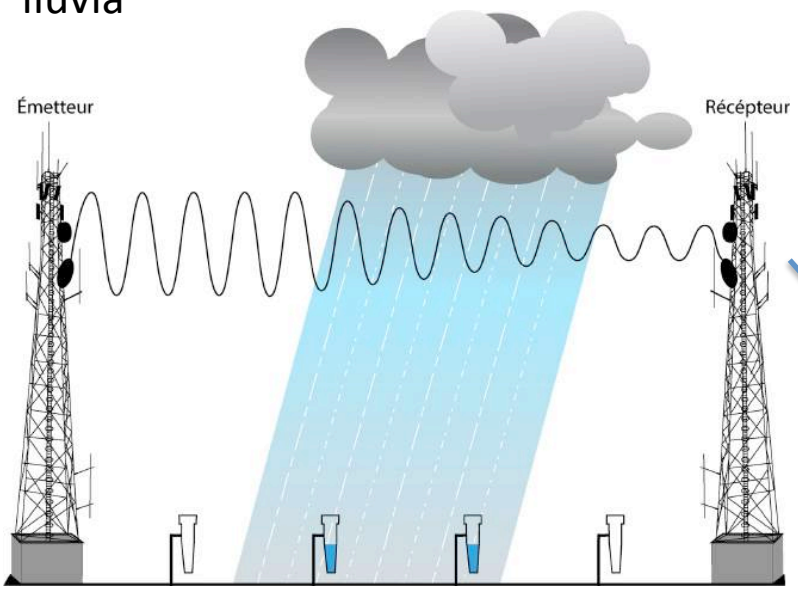


NEXT :
Rain Measurement based on cellular phone networks can be a great complement

Rainfall measurement from cellular phone networks microwave links : First quantitative tests in Africa and potential for tropical hydrology

M. Gosset (IRD/GET, Toulouse)
F. Zougmoré, A. Doumounia, (LAME/Un Ouagadougou)
F. Cazenave (IRD/LTHE)
M. Kacou (LAPA, Abidjan)
M. Sawadogo (Telecel B Faso)
Meteo-Burkina Team

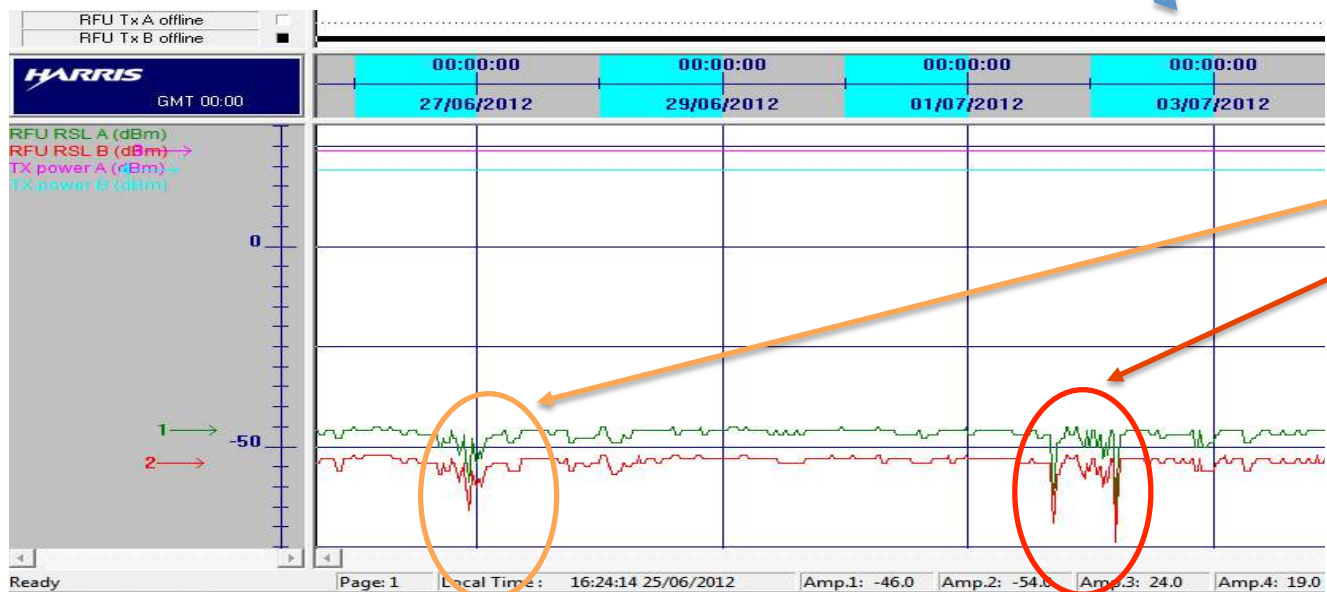
La onda electromagnetica sufre durante su viaje entre las dos antenas una atenuacion de su potencia a causa de la lluvia



Principle :

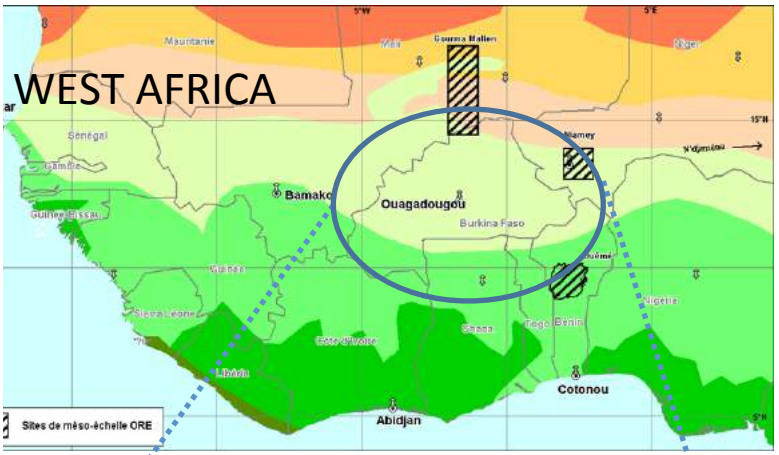
Rainfall attenuates the microwave signal between telecom towers.

If fluctuations are recorded :
-> Rainfall can be estimated !!!!



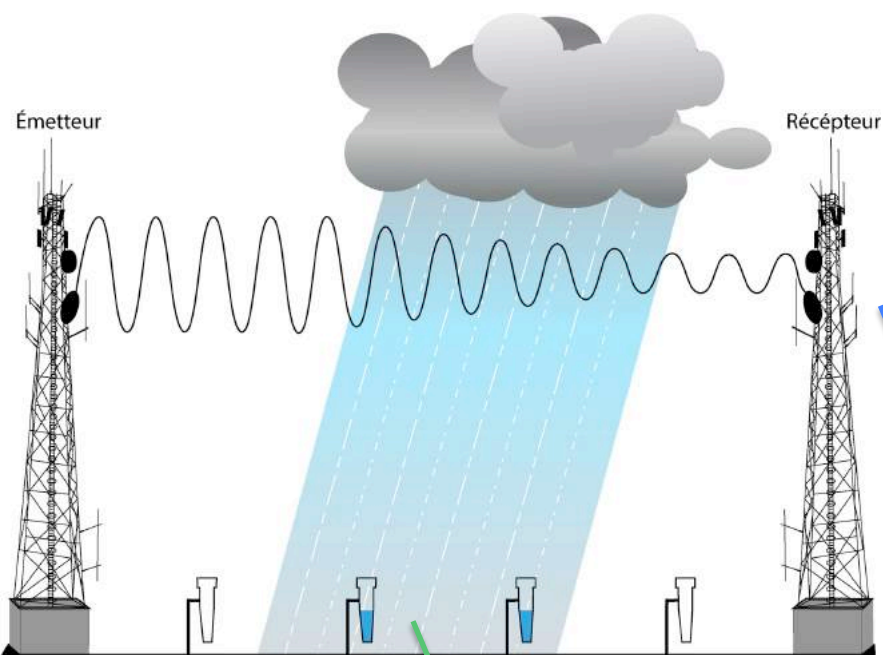
Typical Rainfall signature
In reception data record from telecom operator

First quantitative test bed in Africa Ouagadougou 2012 ->

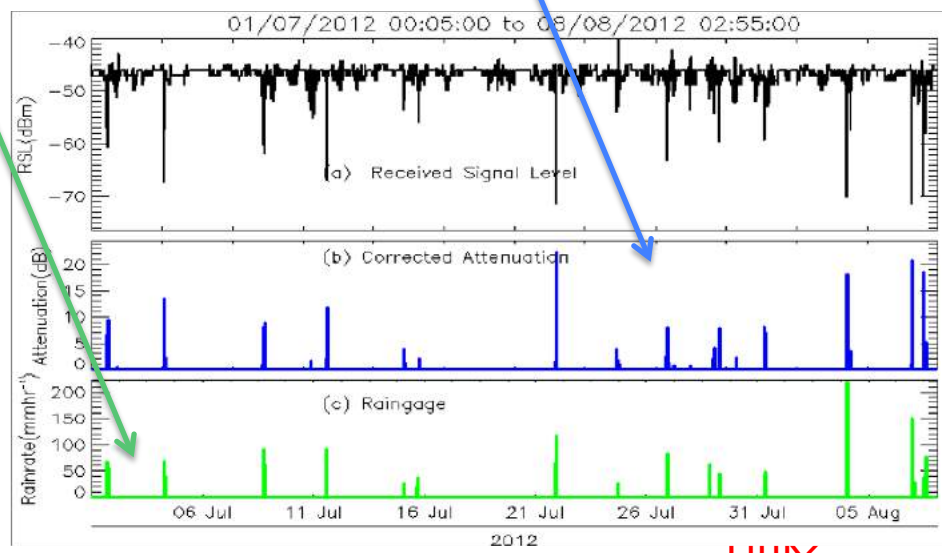


Comparison of
Telecom Link based
Rain Estimation
with Radar and
gauges





Excellent agreement between attenuation peaks and rainfall event recorded by gauge



Raw signal from telecom link

Link Attenuation due to rain

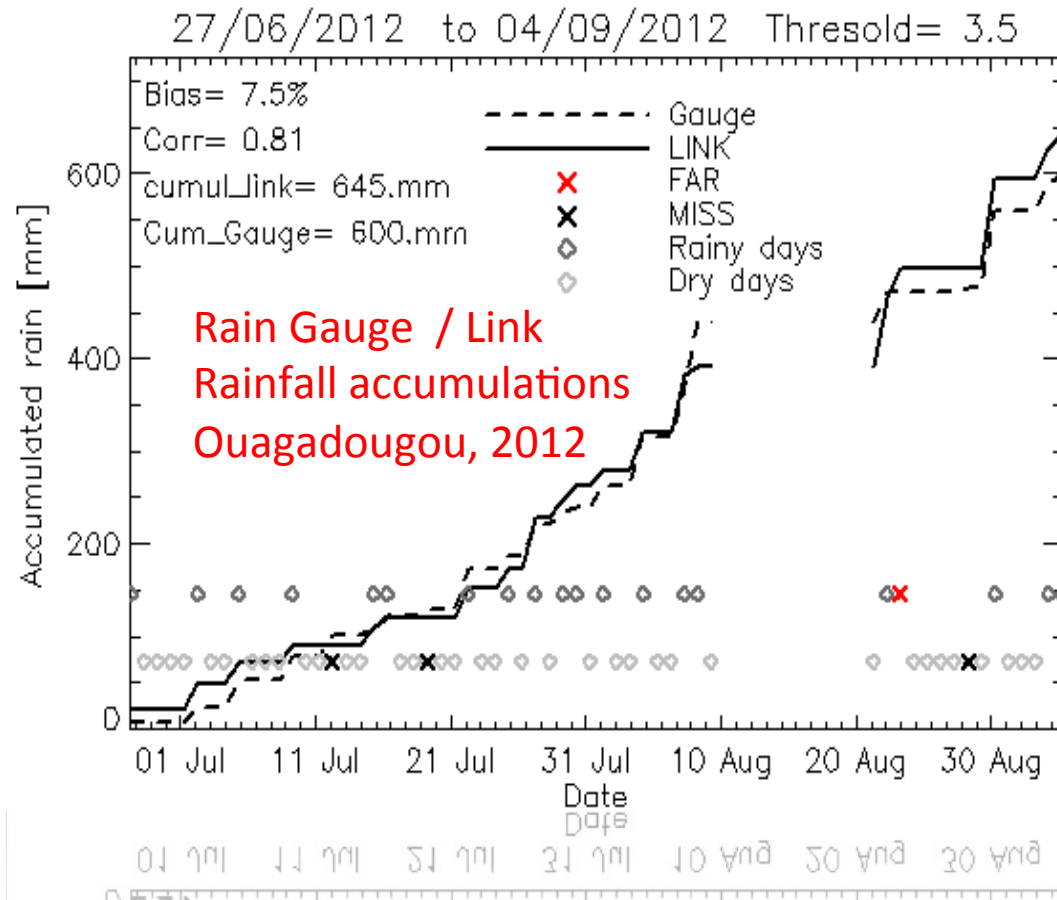
Rain Measurement by gauge

: (a) Received minus Transmitted Raw Microwave Signal level. (b) path attenuation due to rain. (c) rain rate time series from the gauge situated below the link.

➤ Daily rainfall detection and quantification



- Excellent agreement with the rain gauge (correlation 0.8 for the whole season)
- Probability of detection = 95 % !
- Better or as good as satellite rainfall products !
- Very Low overall bias
- But rRMSE ~ 40%



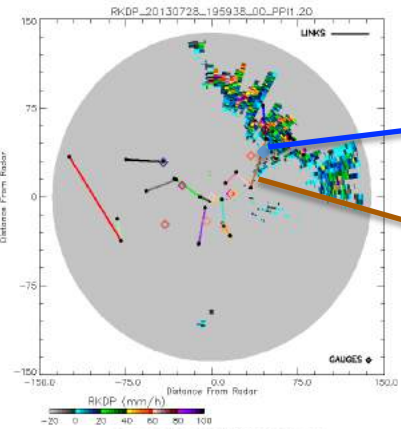
Doumounia et al, 2014 , GRL

Doumounia, A, M Gosset, F Cazenave, M Kacou and F Zougmore, 2014 ; Rainfall Monitoring based on Microwave links from cellular telecommunication Networks: First Results from a West African Test Bed. *Geophysical Research Letters*, 10.1002/2014GL060724

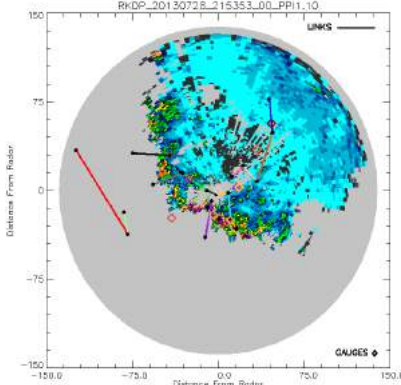
2013 several links

5 minutes time step evolution

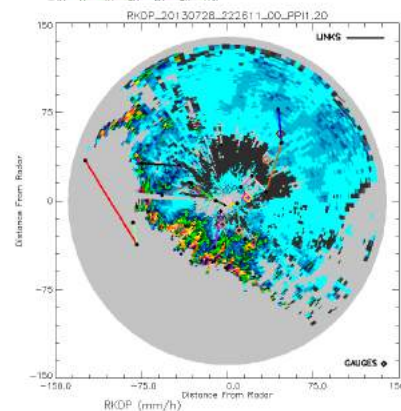
Link vs Radar :



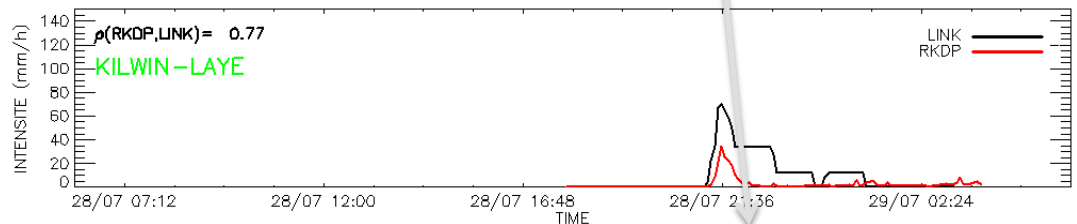
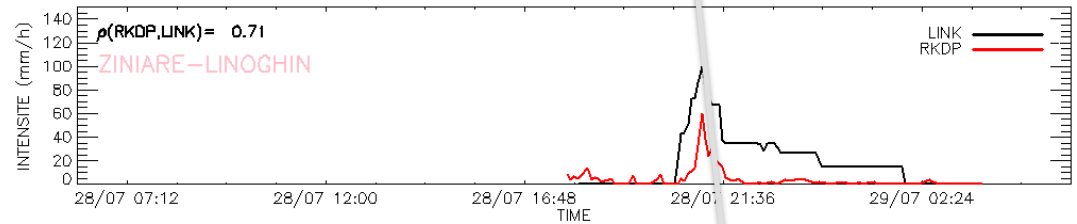
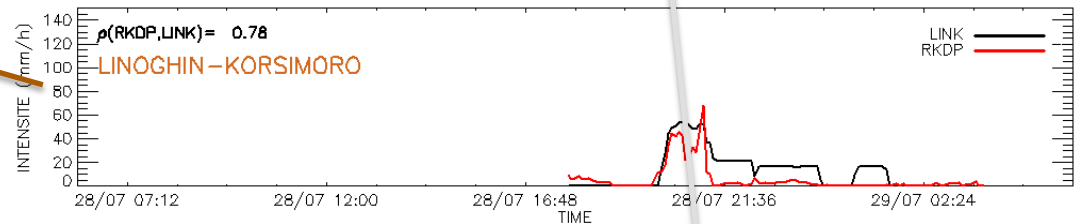
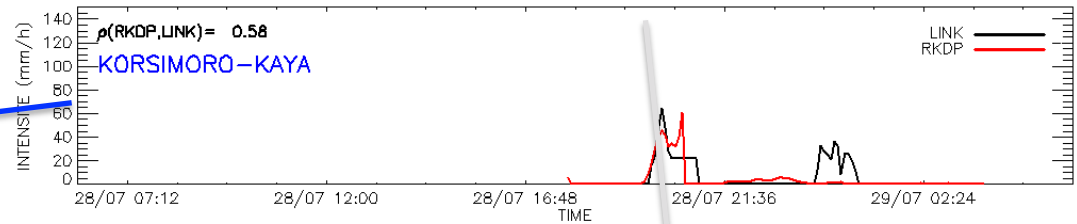
- From 1 sec sampling



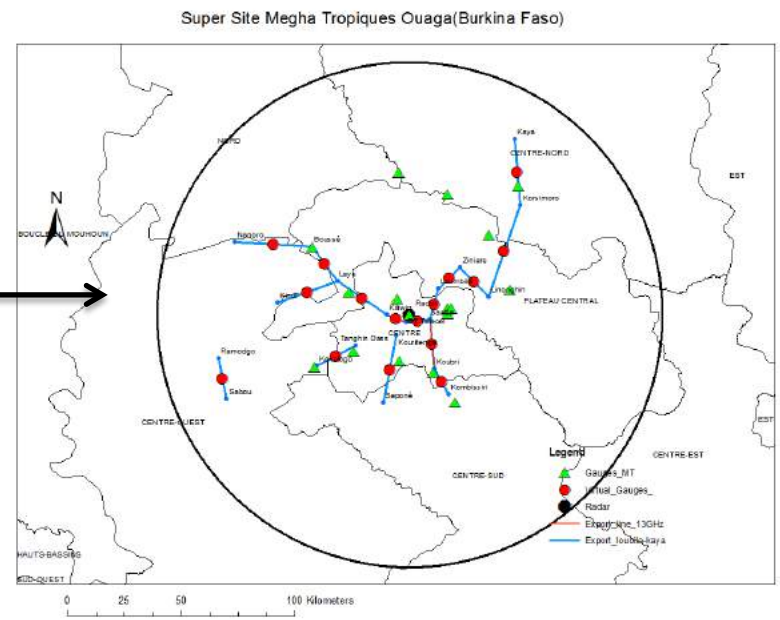
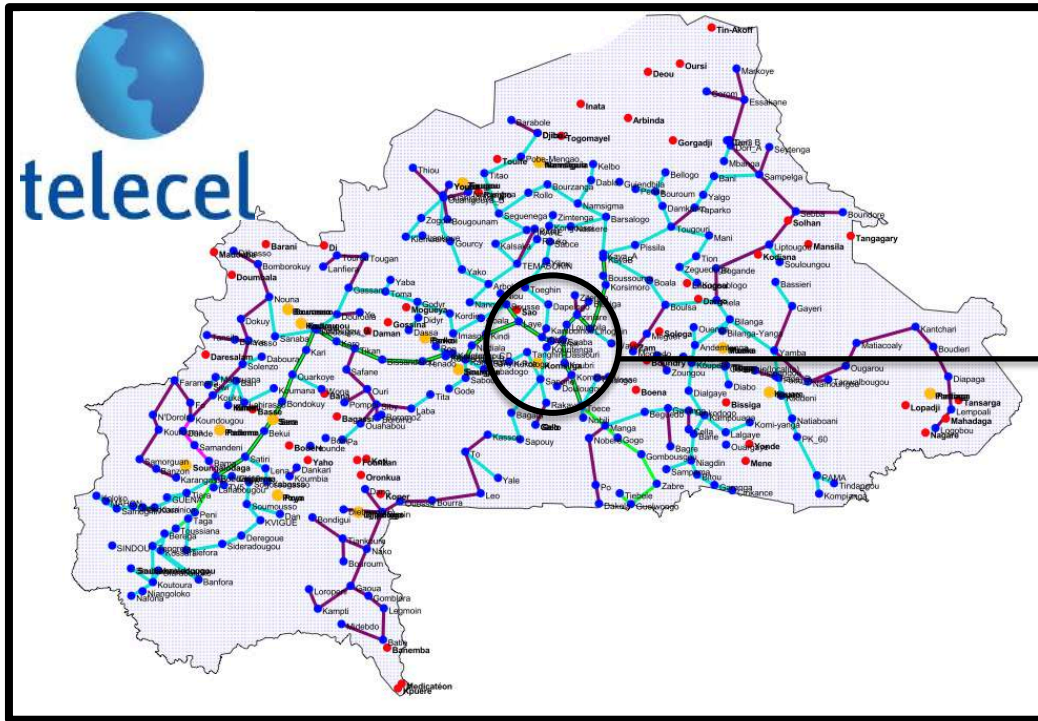
- $R2 > 0.7$
- But quantitative uncertainty at the 5 min time step.
- Error bar needed



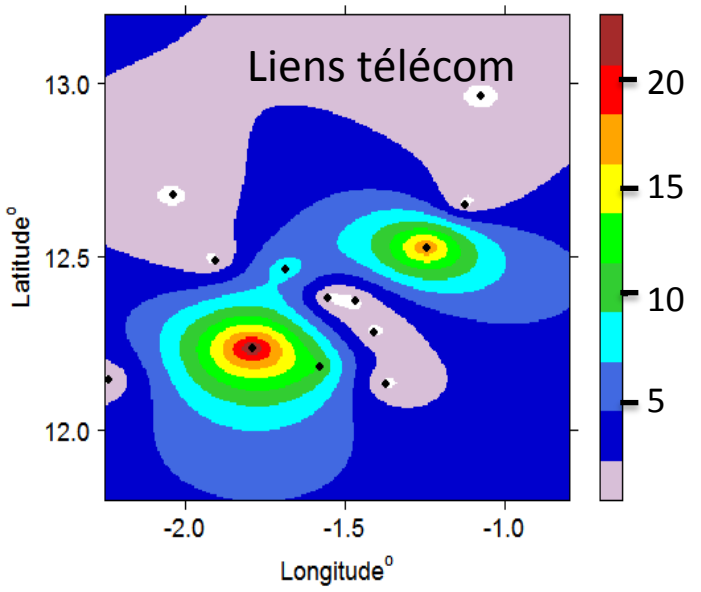
- Westwards propagation of the system well spotted by the MW-link network (as by the gauge network)



- High temporal sampling (< 5 min)
- Diurnal cycle studies / hydrol / GV etc...

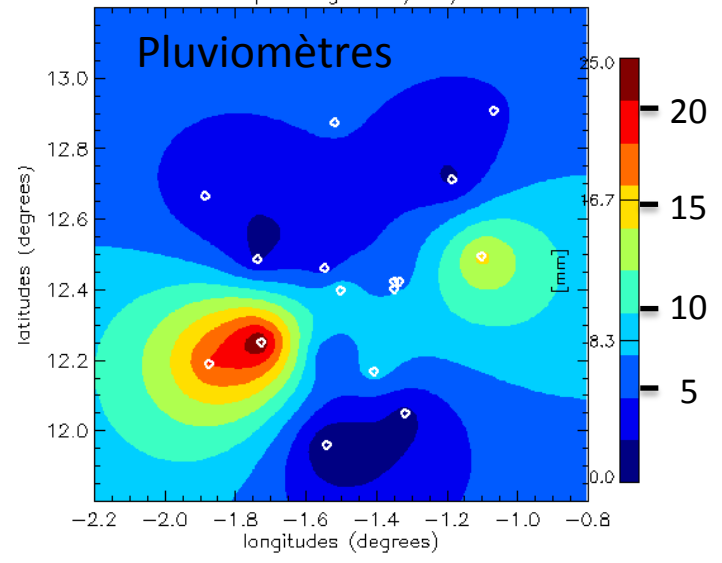


MWL precip estimation : 17 / 07 / 2013

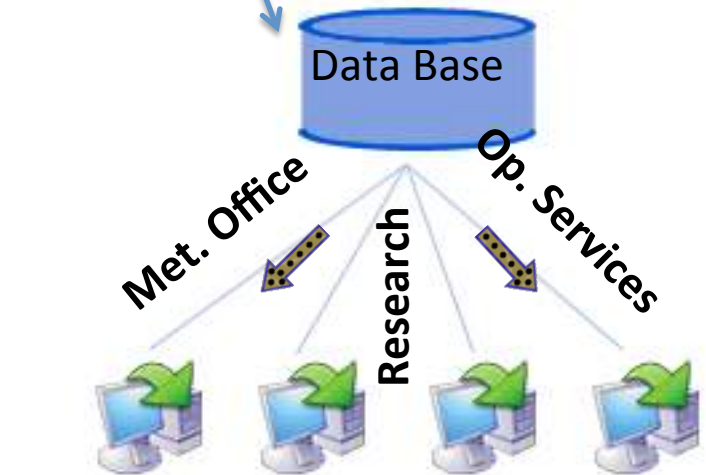
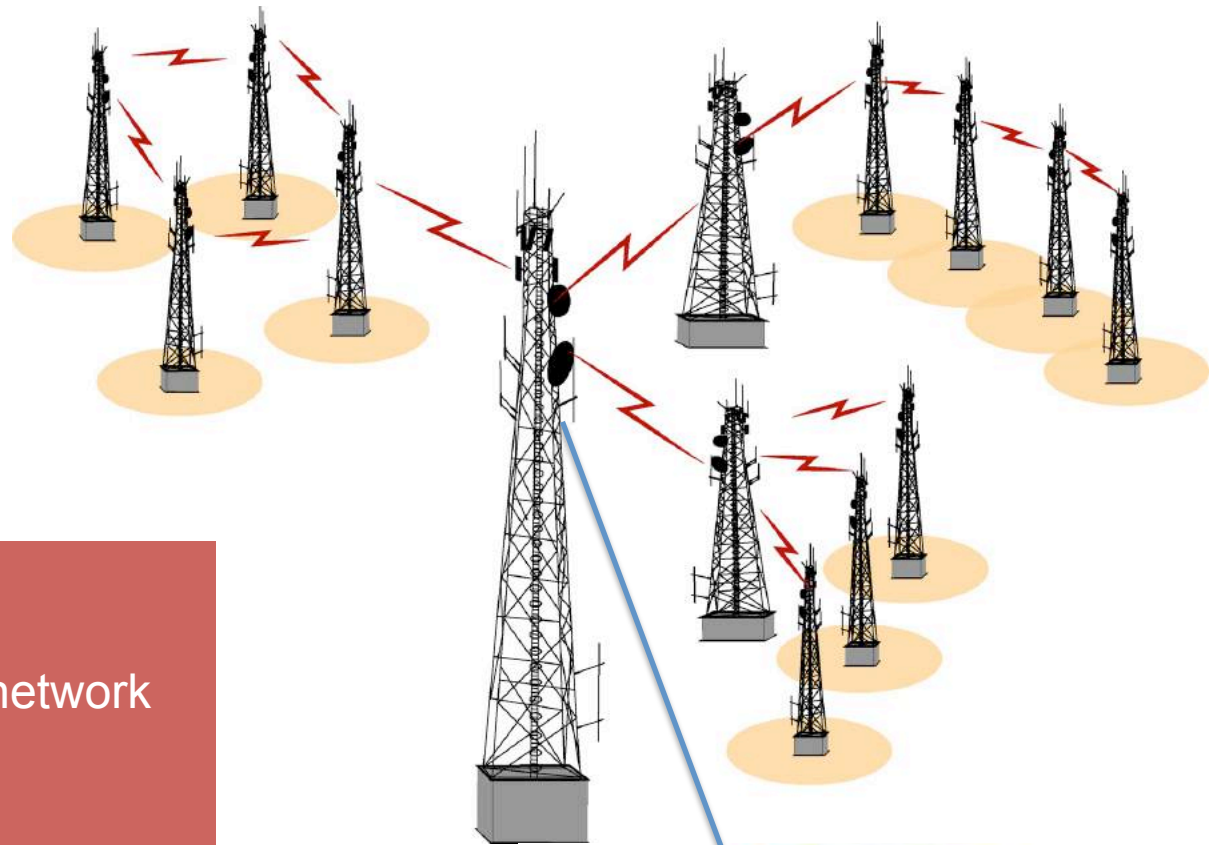
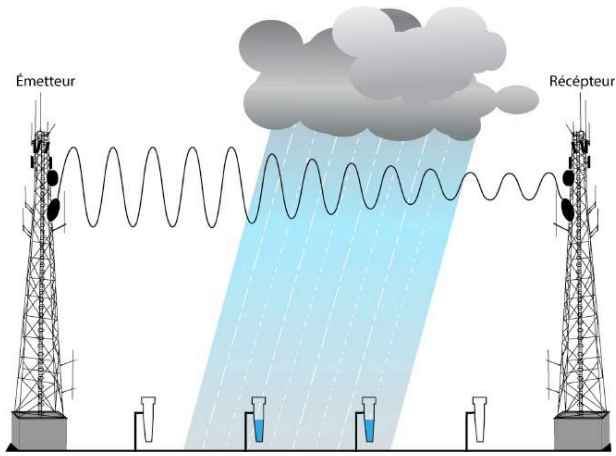


Several links
+
interpolation
MAP !

Rain map Gauge : 17/07/2013



Towards Real Time High Resolution rain Maps : cities / Basins / Country

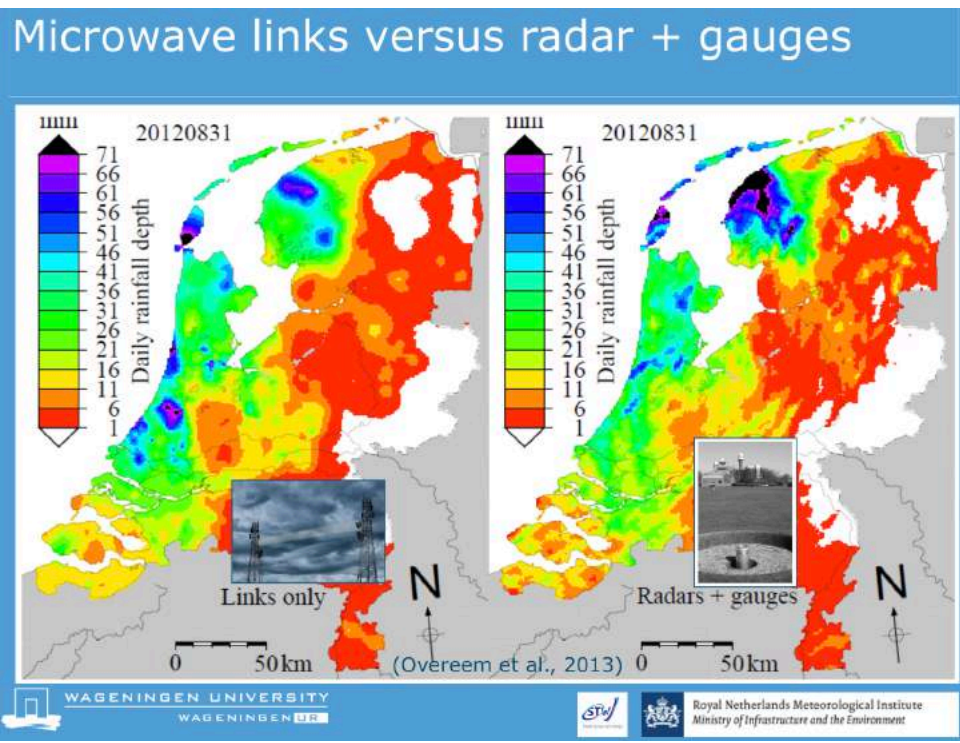
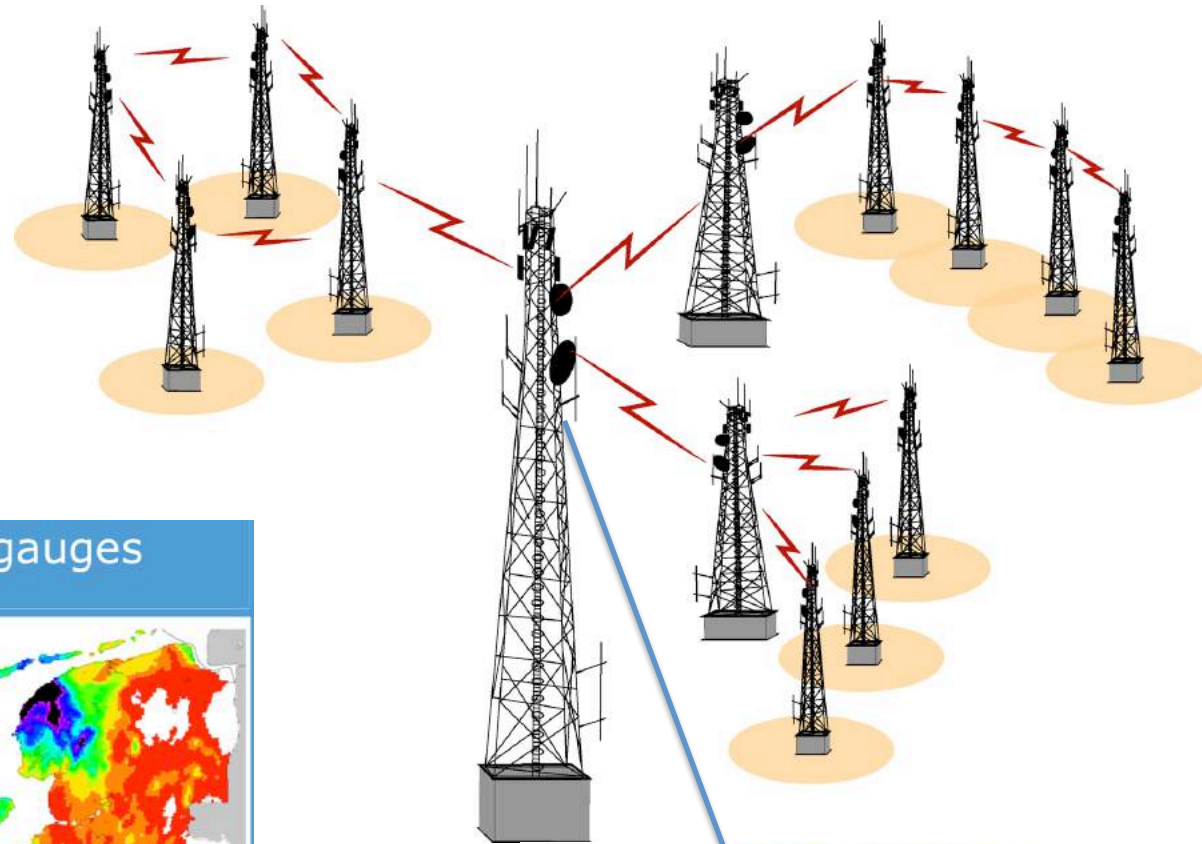
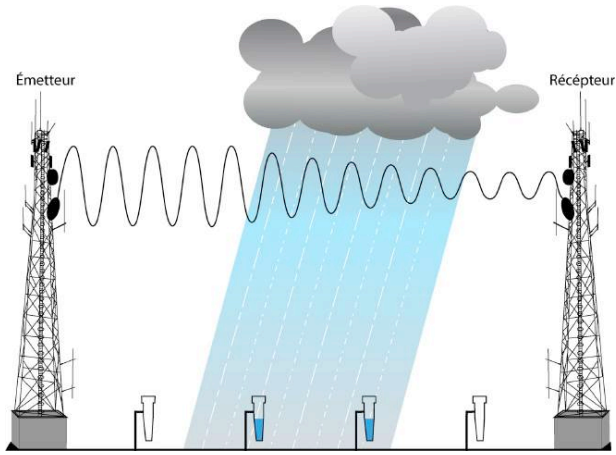


If we have access to the information on the whole network in RT.

→ REAL TIME RAIN MAPS !!

→ For many potential applications
Flood alert etc..

Towards Real Time High Resolution rain Maps : cities / Basins / Country



Exemple from Netherland Weather Services

CONCLUSION

- Great Potential of Mwlink for Rainfall estimation in the Tropics
- Complementary with existing (Gauge / Satellite info)
- Hydrological /flood warning / Crop / Met/Climatology applications
- **LOW COST** because dense network already exists !!!
- **Partnership with Telecom operators to be constructed**

Ventajas:

- Buena cobertura espacial
- Posible acceso a los datos en tiempo casi real
- Mantenimiento efectuado por la operadora de telefonía
- Ningun sobrecoste para la operadora

Let's try in Peru
and South America !!
Amazonia / Andes

Simulacro de
INUNDACION

DIA: 17 DE OCTUBRE
HORA: 18 PM

¡Prepárate y
Participa!



Latest info :

<http://www.ird.fr/climat/recherches-sur-le-changement-climatique/projet-rain-cell-africa/>

More info :

Doumounia et al, 2014 , GRL

Doumounia, A, M Gosset, F Cazenave, M Kacou and F Zougmore, 2014 ; 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 et al, 2015 , BAMS

Gosset, M., H. Kunstmann, F. Zougmore, F. Cazenave, H. Leijnse, R. Uijlenhoet, C. Chwala, F. Keis, A. Doumounia, B. Boubacar, M. Kacou, P. Alpert, H. Messer, J. Rieckermann, and J. Hoedjes, 2015: Improving Rainfall Measurement in gauge poor regions thanks to mobile telecommunication networks, *Bull. Amer. Meteor. Soc* doi:10.1175/BAMS-D-15-00164.1



Ouagadougou 03/2015

90 participants – 18 pays

SCIENCES
ET
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High-tech

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aux antennes

The Washington Post

toward making cell
of weather observati

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relais se transforment en
pluviomètres

The Guardian

ca: Mobile Phones Take Over Rainfall Monitoring in
ca

ad: Africa • Business • Climate • Environment • ICT

ULTURE, with...
gs, etc.: rainfall monitoring is vital in many ar...
ation networks remain insufficient. This is not...
mobile telephones, which cover 90 p...
signal distur... Besides trans...
of the Rain Cell Africa...
with a reliability rate of 95 per cent...
published in the *Geophysical Research Lett...*

Gracias por su
atencion !!

Trophée recherche publique
Environnement Climat 2015

