Quantitative precipitation estimates from satelliteS
-the constellation era-

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Thanks to C Kidd, P Chambon and M Gosset

Background & Context

- Researcher in satellite meteorology
  - Climate, water and energy cycles
  - Developement of sat products and use of them for science.

- Member of various scientific communities:
  - Precipitation Measurements Mission (NASA lead)
  - Megha-Tropiques science & validation groups (French lead)
  - WMO/CGMS International Precipitation Working Group (Chair)

- Rainfall is a tremendously difficult topic and an active research field
  - Ice/water/snow microphysics, atmospheric convection, mesoscale dynamics, thermodynamics, orography, hydrology, extreme events, radar, microwave, physics,…. strong societal demands

I want to share with you a few recent outcome of this research

The messages

- Not a single satellite can do the job, need a constellation of many observing systems

- The state of the art surface rainfall satelliteS products in the tropics are OK at the meteorologically relevant scales

- Promising on going work to adress the hydrologically relevant scales

We are at the beginning of a new era, the constellation era

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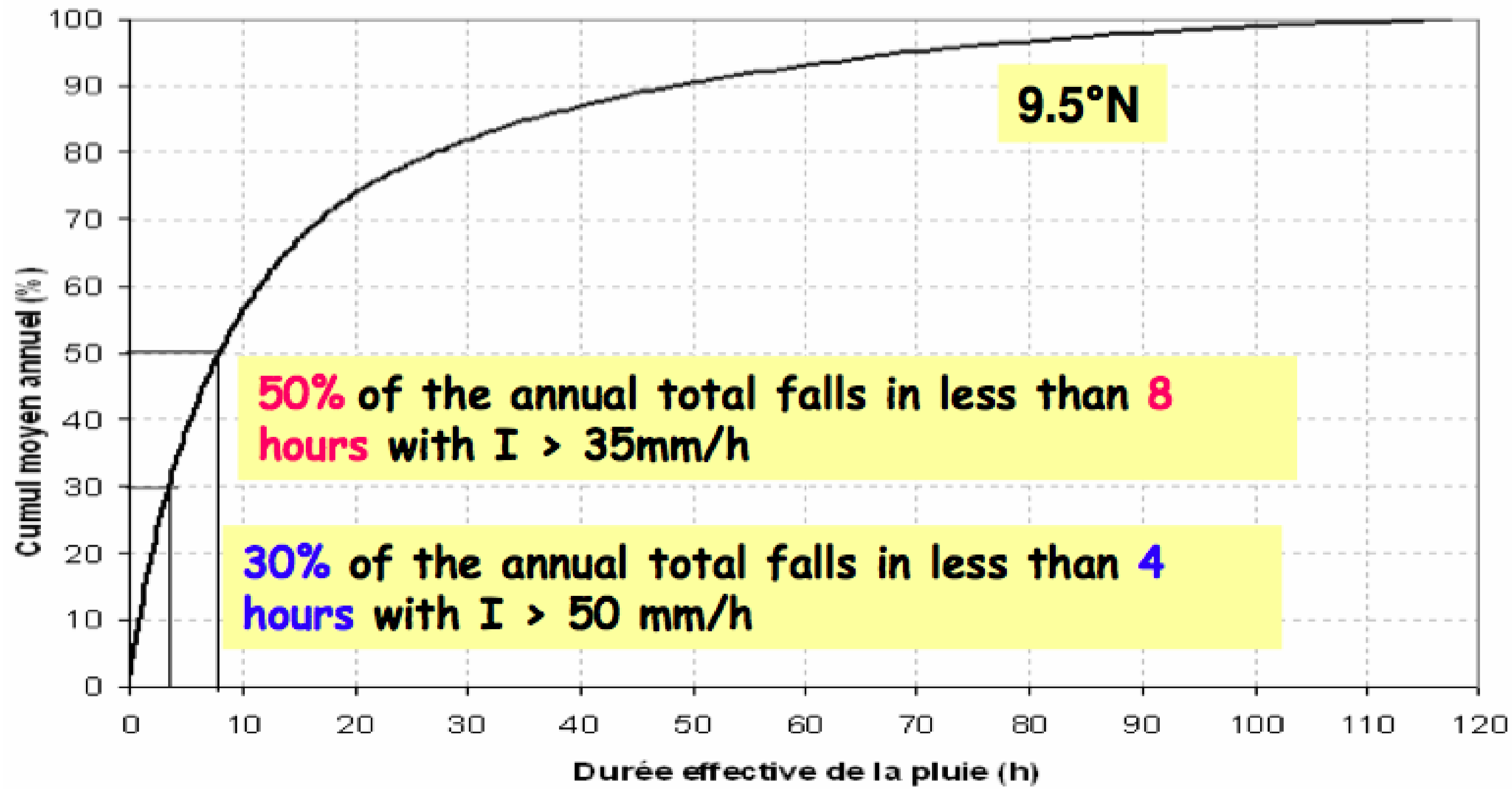
The rainfall…

High time and space variability (1/2)

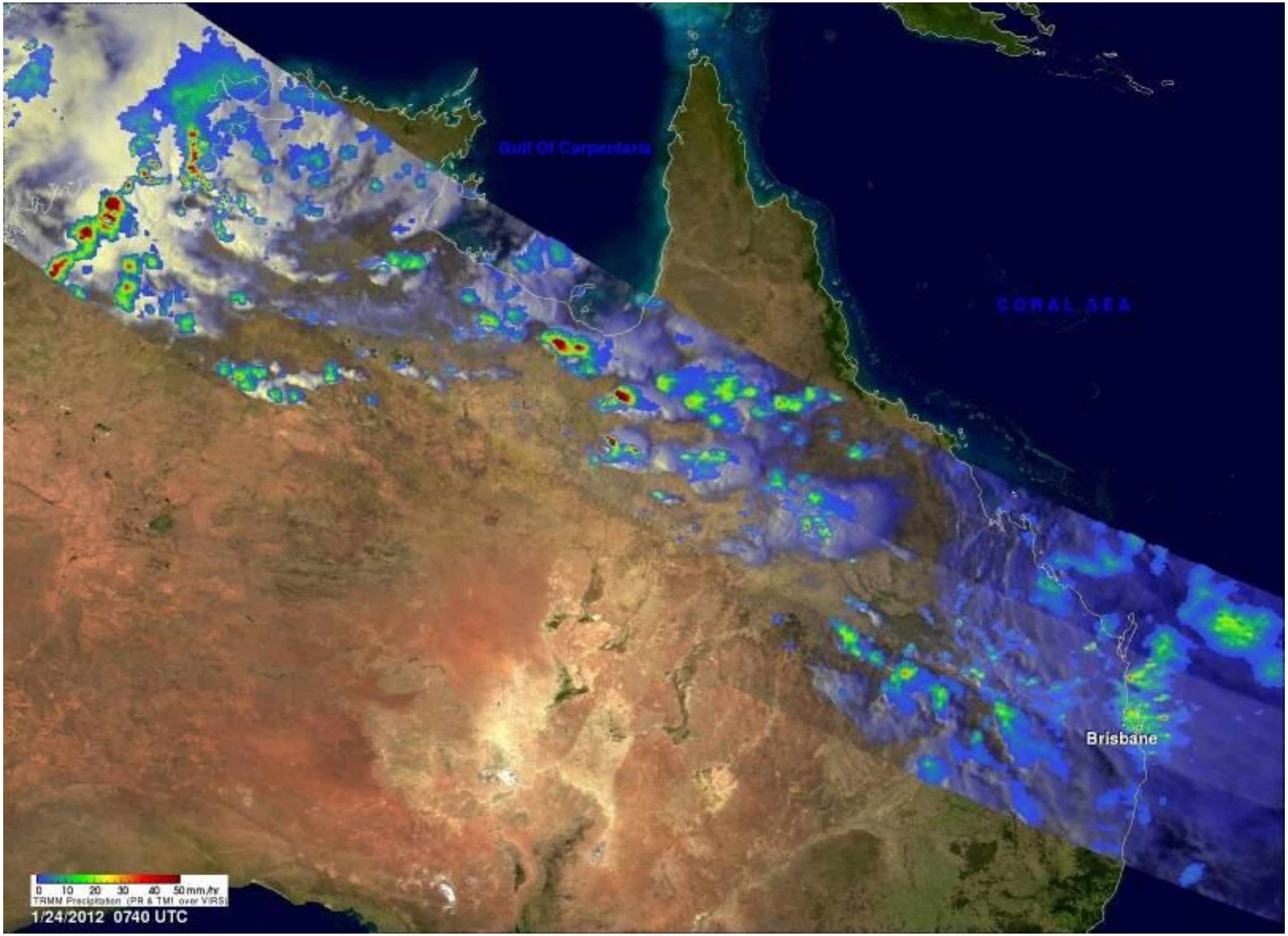
Oueme, Benin



(Courtesy of Th. Lebel, LTHE)

The rainfall…

High time and space variability (2/2)

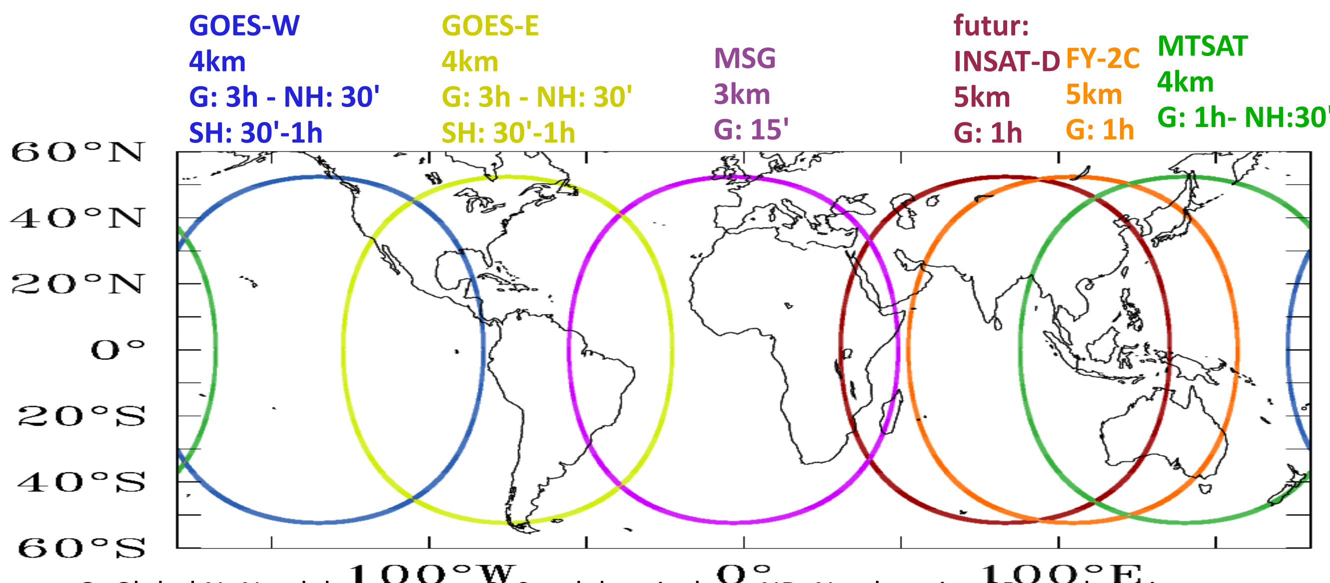


(Courtesy TRMM team)

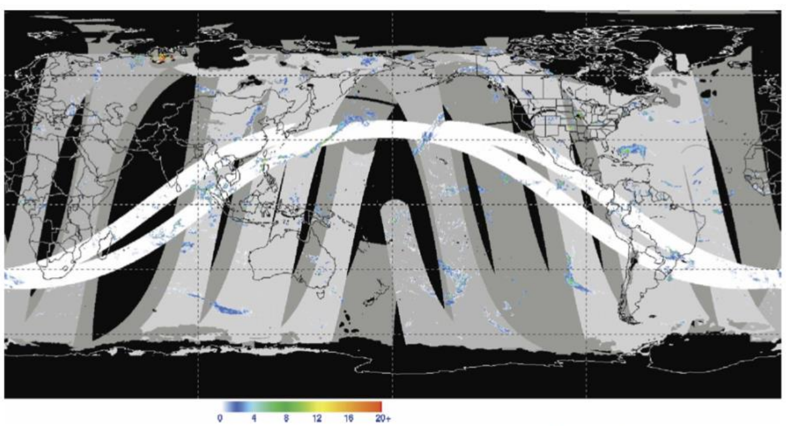
The rainfall…

The solution: merging the IR and the microwave plateforms

Satellites géostationnaires



G=Global N=North hemisphere S=South hemisphere NR=North region SR south region



Satellites défilants

Exemple TMI, SSMI, AMSRE, AMSU-B
(Huffman et al. ,2007)

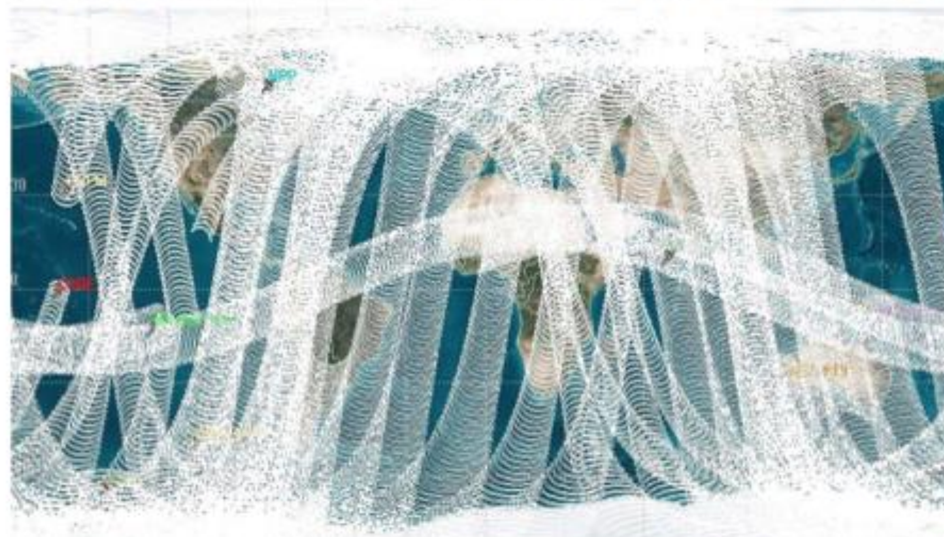
From a single mission to a constellation approach

Merging MW LEO and IR GEO for precipitation

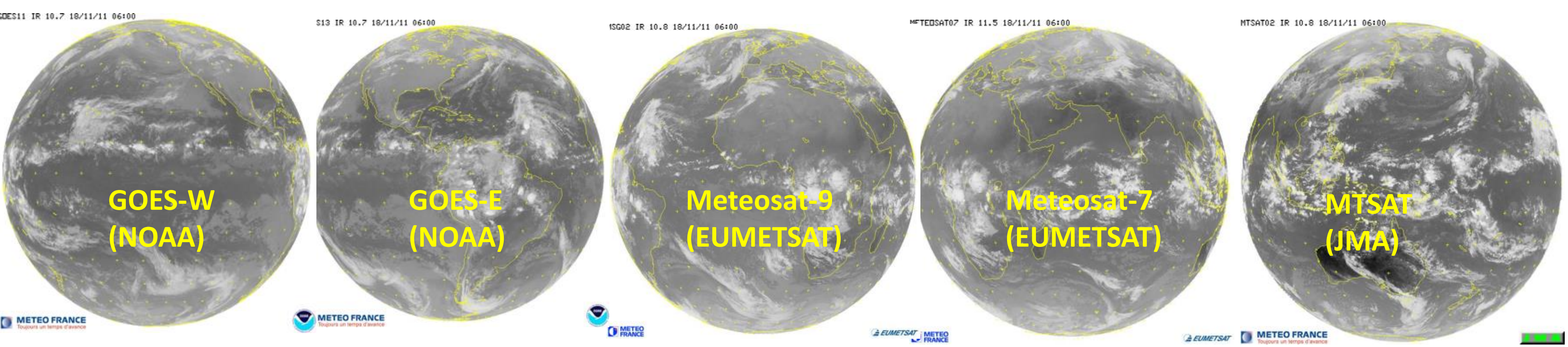
The GPM constellation comprises dedicated and operational satellites:

GPM Core, F18, F19, GCOM-W
Megha-Tropiques, NASA-1
Partner-1 (NPOESS-1)
Partner-2 (EGPM, NPOESS-2)

GPM Core + 7 Constellation 3-Hour Coverage



(Courtesy A. Hou)

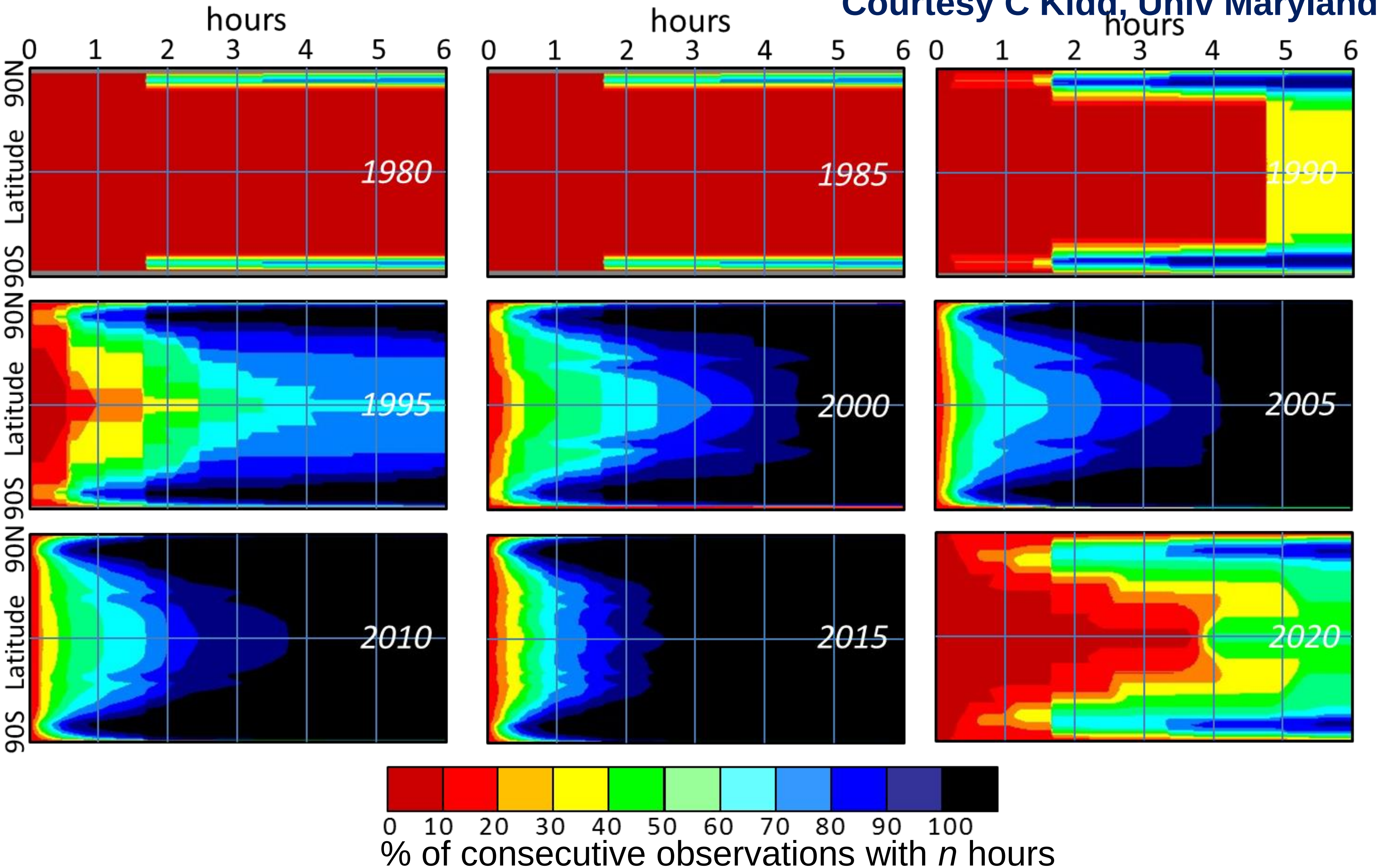


Canal IR Thermique ; 18 nov 2011 06h00 UTC (Source : www.meteo.satmos.fr)

The GPM constellation in the historical context

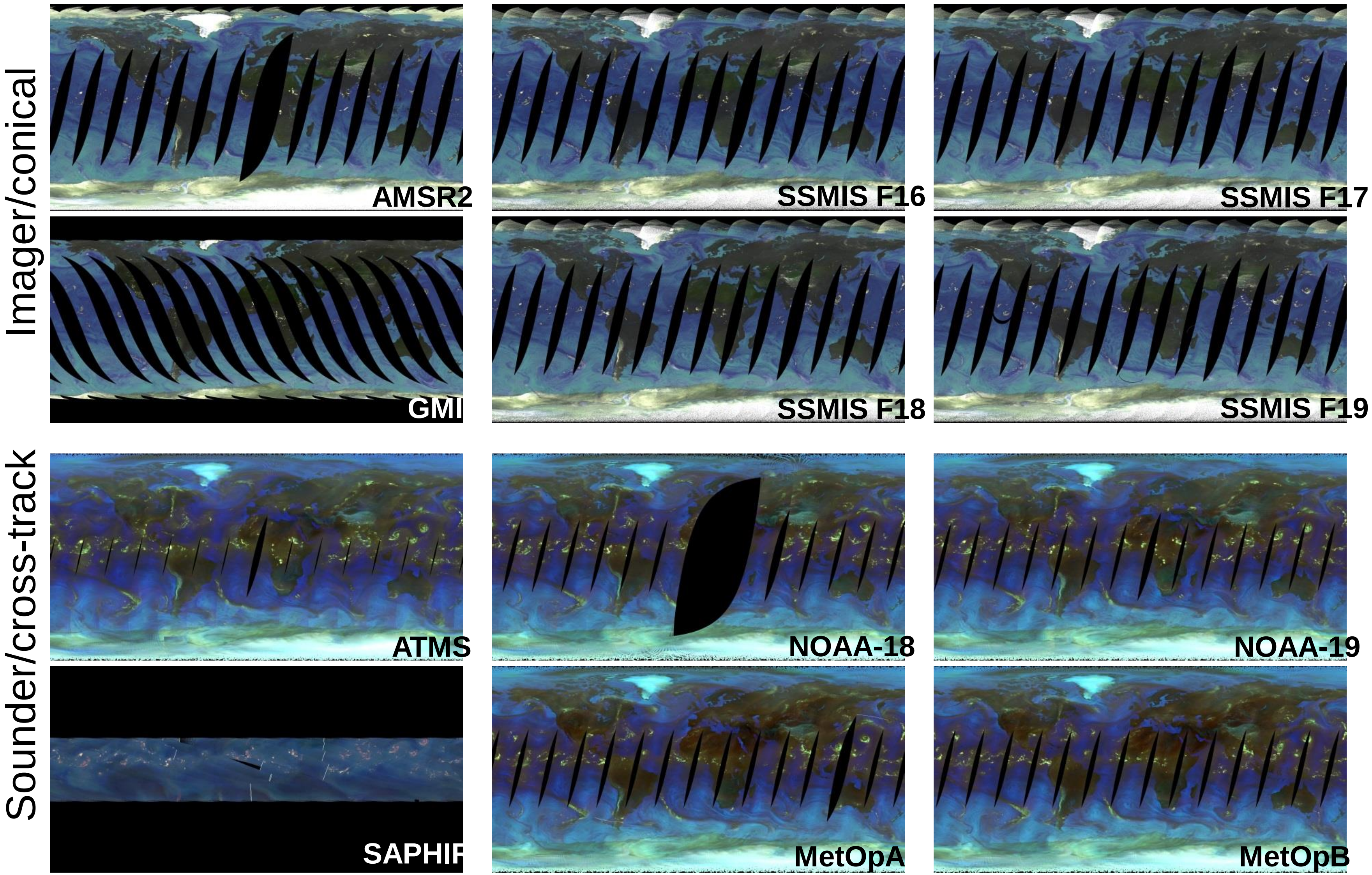
US/EU/Japan/Indian PMW radiometers

Courtesy C Kidd, Univ Maryland



The GPM constellation now !

Descending overpasses: 21 August 2015



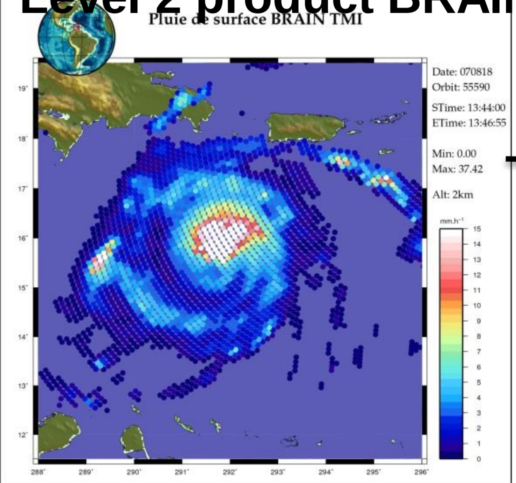
Courtesy C Kidd, Univ Maryland

A framework of IR-MW rainfall estimation

Tropical Amount of Precipitation with an Estimate of ERrors

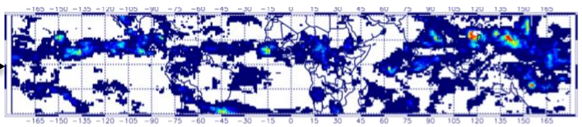
- Adaptation of the UAGPI technique (Xu et al., 1999)
- Rain rates from PMW through the BRAIN algorithm (Viltard et al., 2006)
- All operating LEO satellites with MW imagers

Level 2 product BRAIN

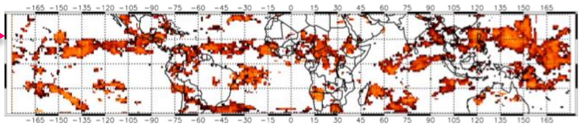


IR images time series

IR/MW COMBINATION

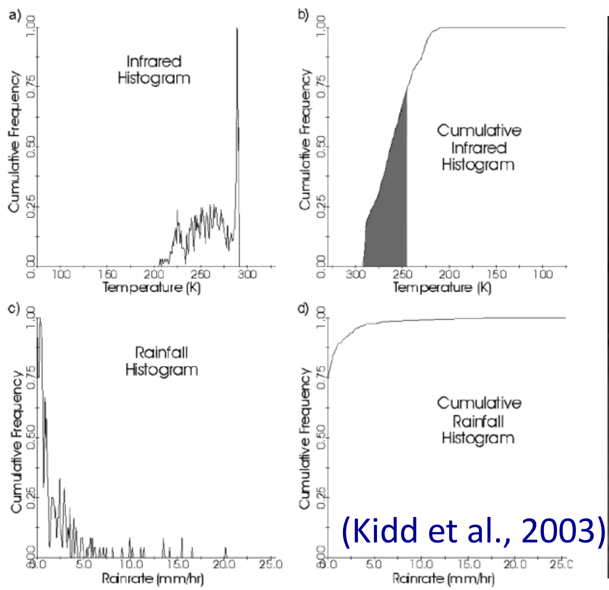


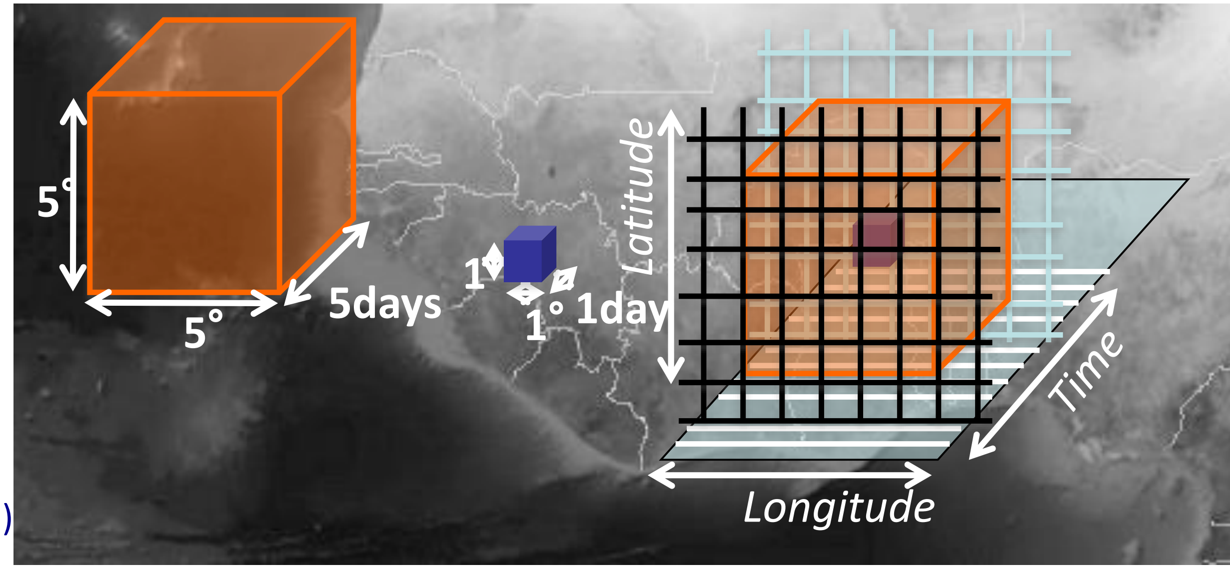
ERROR COMPUTATION

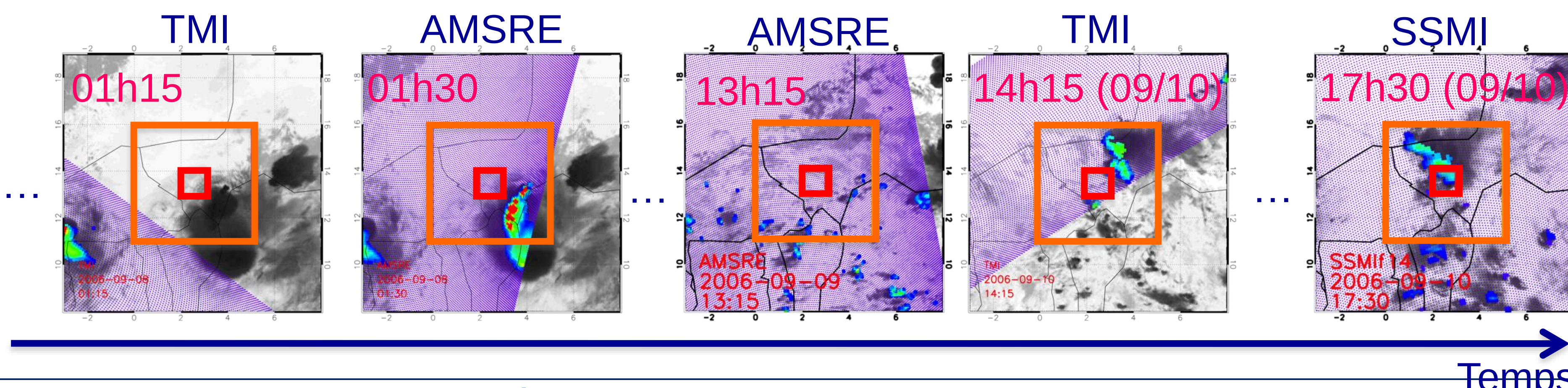


Accumulated rain and error at 1°x1° / 1 day

The Universally adjusted GP Index approach
Merging Level -2 MW and IR from GEO







Rainfall estimation with two constellations

Rationale for the TAPEER (UAGPI) at 1°/1 day

Accumulated Rainfall (in mm)= $\overline{R_{cond}}$ (in mm/day) x Fraction (in

1. training over a volume to obtain $\overline{R_{cond}}$ using MW instantaneous rain rates estima
2. training over a volume to obtain $BTIR_{threshold}$ using - MW instantaneous rain mas
   - IR imagery

3. use $BTIR_{threshold}$ to obtain Fraction of the actual day using the IR imagery

Step 1 relies on the L2 retrieval of rainrates estimation (bias, etc…)
Step 2 relies on the L2 detection (sensitivity, definition, etc..)
Both steps depends (differently) on the training dataset volume and its representativity

Each step requires to identify
the relevant L2 products
and the adequate training volume

Rainfall estimation with two constellations

Mitigating the loss of MADRAS in the Level-4 product

Accumulated Rainfall (in mm)= $\overline{R_{cond}}$ (in mm/day) x Fraction (in

STEP1: Constellation for $\overline{R_{cond}}$

BRAIN Estimation on TMI, AMSR2, SSMI F15, SSMIS F16,F17,F18

5° x 5 days optimized for estimating the mean with as many point as possible

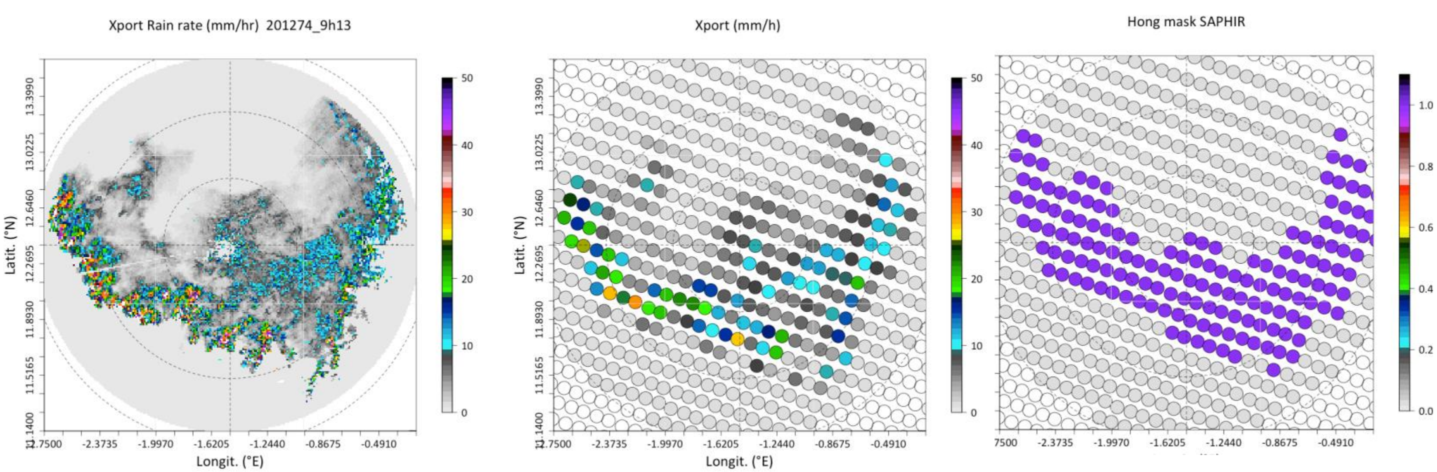
STEP2: Constellation for Frac

BRAIN Detection on TMI, AMSR2, SSMI F15, SSMIS F16,F17,F18

Hong detection on SAPHIR

3°x1 day optimized for representativity of the BTIR threshold with daily update

SAPHIR 183 GHz
« Hong et al» Mask
Available as part of the SAPHIR UTH retrieval
(Brogniez et al., 20



Courtesy M. Alcoba

The error budget of the satellite estimates

The error budget

$$E^2 \approx E^2_{Calibration} + E^2_{Algorithm} + E^2_{Sampling}$$

Calibration / inter-calibration of instruments

Instantaneous rain product errors + Multiple data merging method errors

Space/time occurence measurements

The error budget of the satellite estimates

The error budget

$$E^2 \approx E^2_{Calibration} + E^2_{Algorithm} + E^2_{Sampling}$$

Can be neglected
in the present framework

Roca et al., 2010

Taburet et al., 2015
in preparation

A framework of IR-MW rainfall estimation

A simple sampling error model

Uncertainty on the mean of a sampled random variable

over a surface A and period T :

$$S^2_{Sampling} = \frac{\sigma_X^2}{N_{ind}}$$

σ_X: standard deviation of the samples (X) used to build the rain accumulation

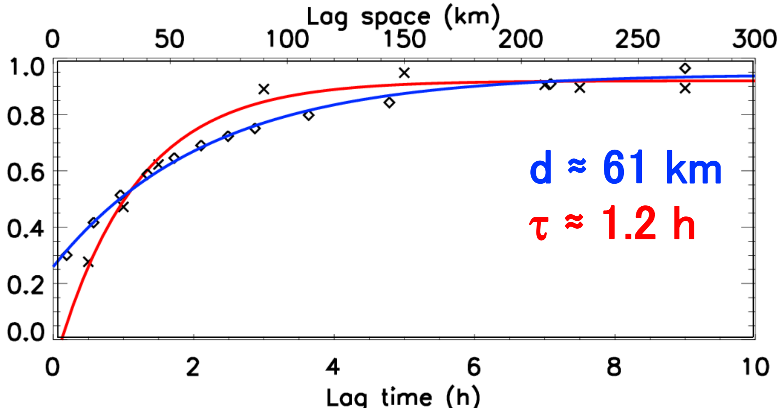
N_{ind}: Number of independent samples

Computation of N_{ind} : variogram analysis

In space : A/d^2 independent samples

In time : T/τ independent

$$N_{ind} = \frac{A}{d^2} \frac{T}{\tau}$$

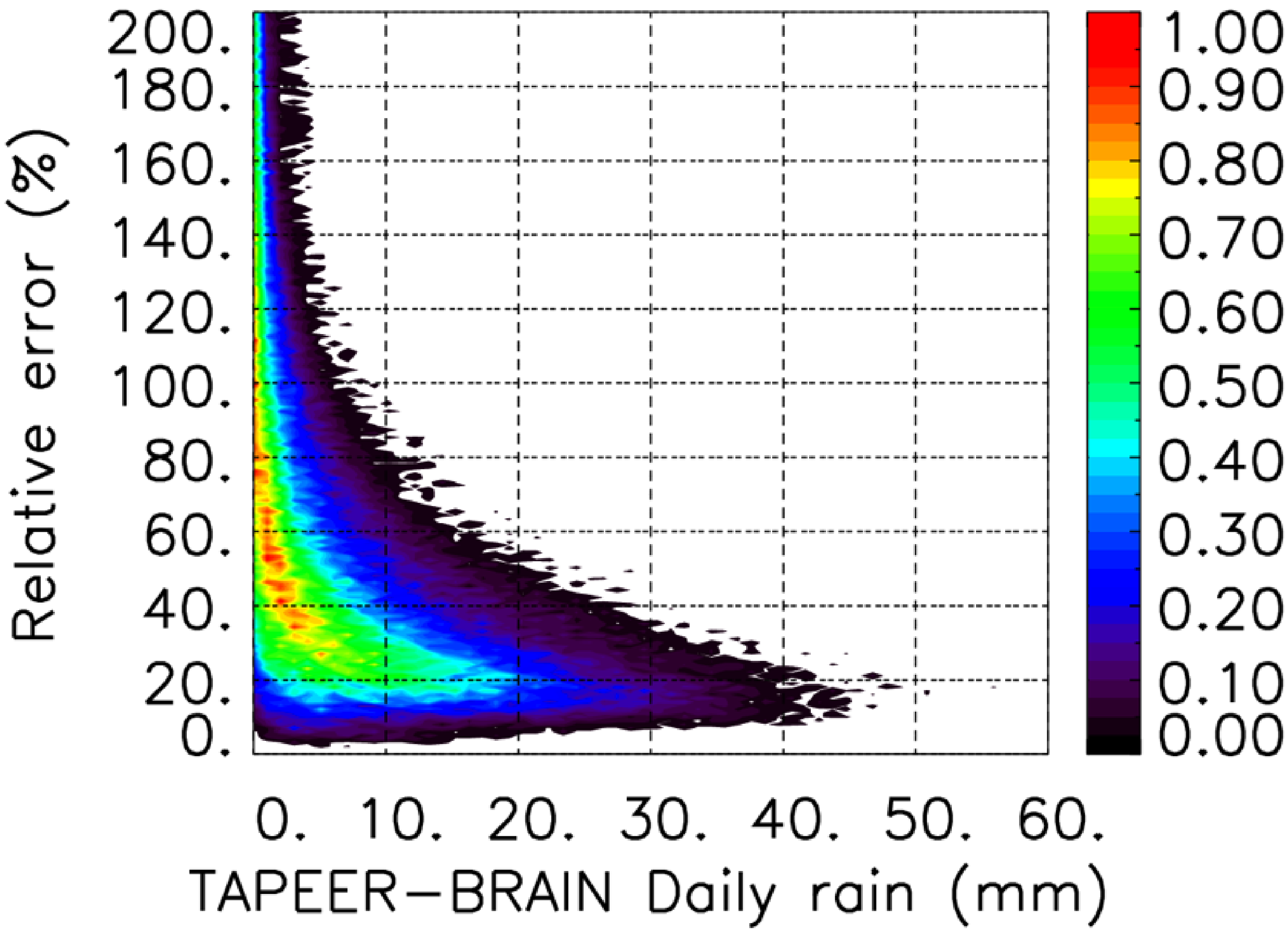


Ex : [12°N – 17°N ; 3°W – 3°E]

Estimation of the autocorrelation between the samples contributing to the rain accumulation

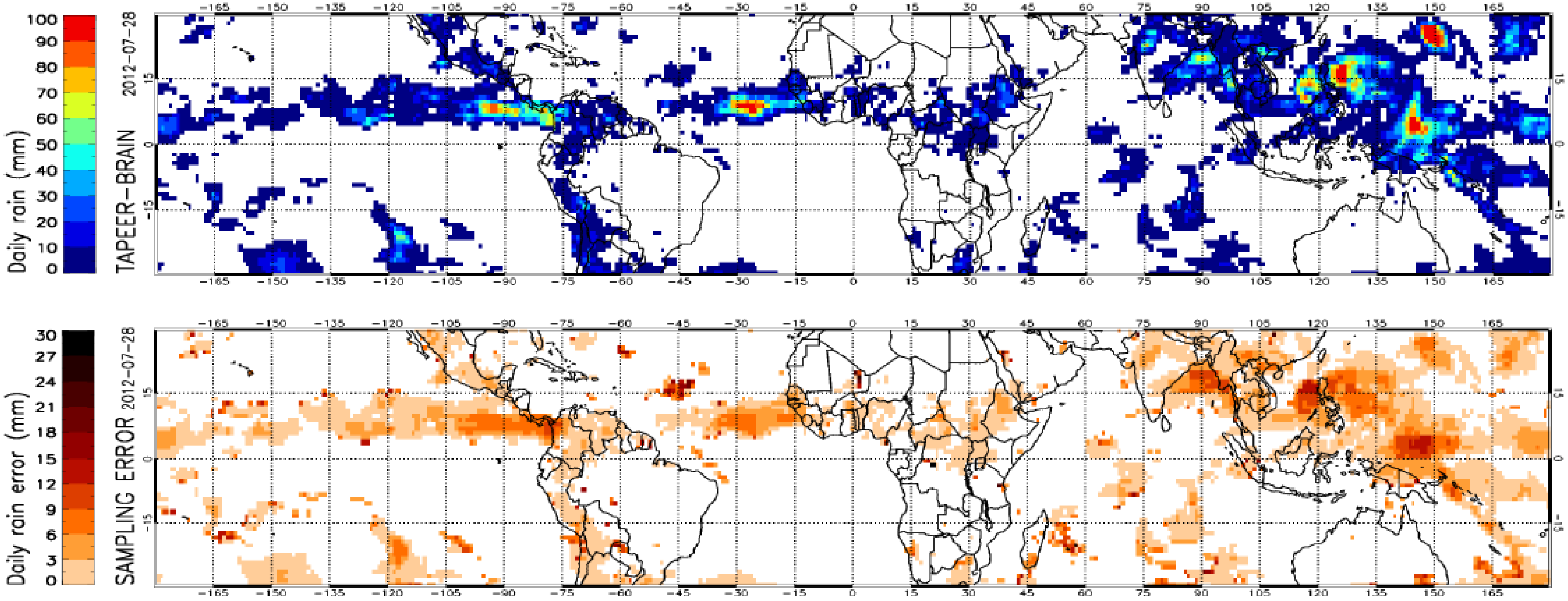
The error budget of the satellite estimates

The magnitude of the sampling error



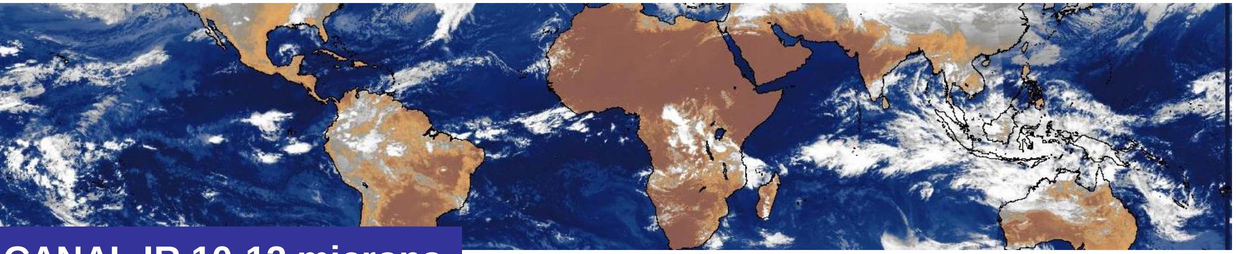
An example of the resulting product

The TAPEER algorithm 28 July 2012

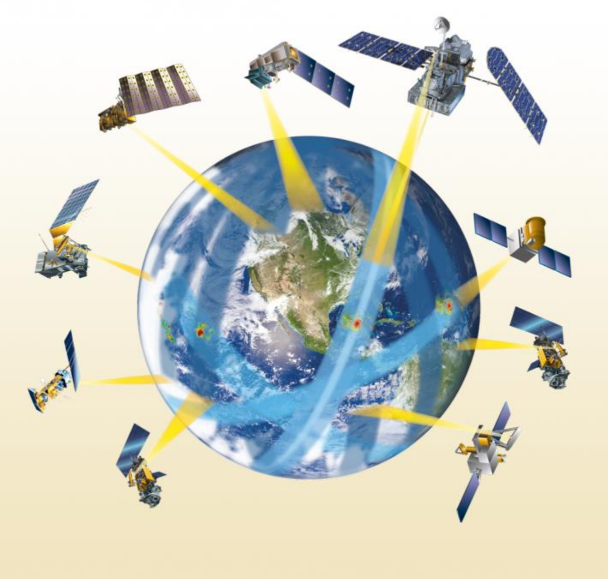


Not a single satellite can do the job, need a constellation of many observing systems

- Combination of multiple microwaves imagers instantaneous estimates with the IR data from GEO to cope with the high space/time variability of the rainfall
- The sampling of the constellation is very godd right now!
- QPE: accumulation AND uncertainty



CANAL IR 10-12 microns



The messages

- Not a single satellite can do the job, need a constellation of many observing systems

- The state of the art surface rainfall satelliteS products in the tropics are OK at the meteorologically relevant scales

- Promising on going work to adress the hydrologically relevant scales

We are at the beginning of a new era, the constellation era

The state of the art surface rainfall satelliteS products in the tropics are OK at the meteorologically relevant scales

- How to evaluate/validate the products
  - Data and methodology depends upon scales

- Some results using the existing products
  - Good points and limitations

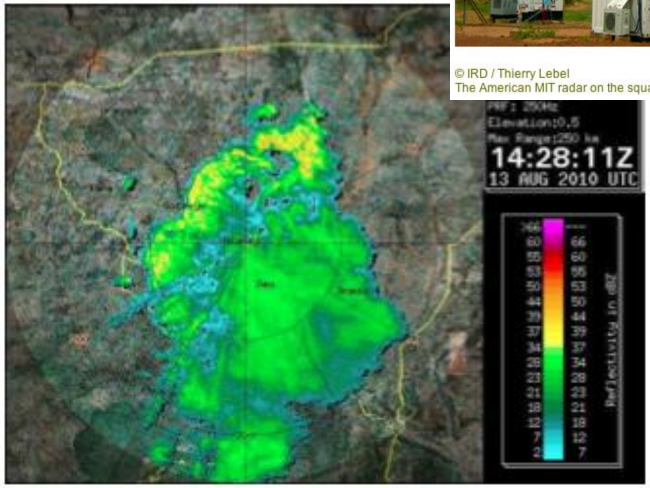
How to evaluate the satellite estimations of precipitation ?

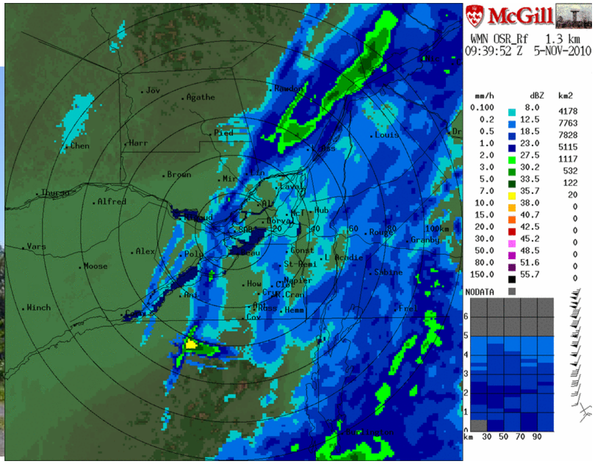
The conventional means to measure rainfall

- **PLUVIOMETERS, aka GAUGES**
- **RADARS**

© IRD / Thierry Lebel
The American MIT radar on the square degree site at Niamey, Niger.

Radar du MIT
à Niamey, Niger





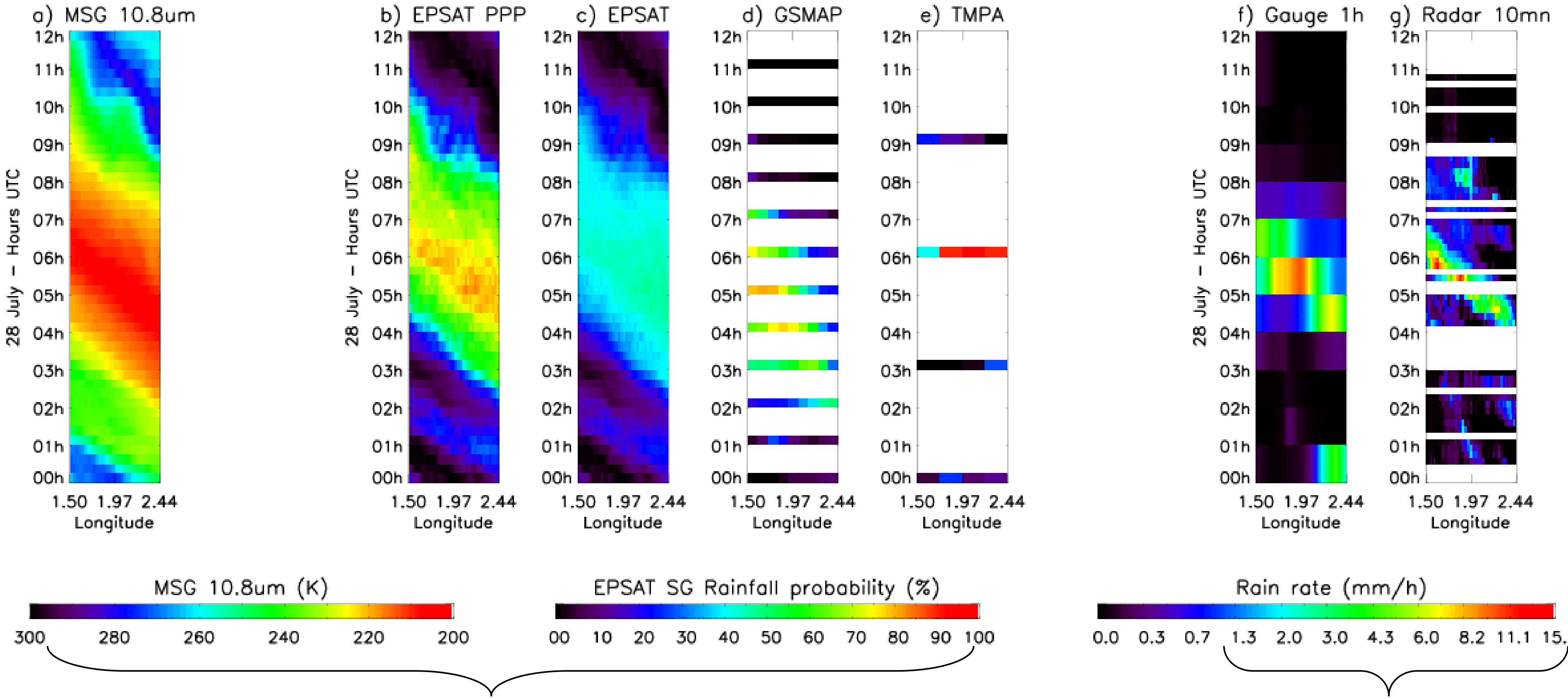
Radar de McGill à Montréal, Canada

Validation of précipitations estimations

Conceptual difficulty

AMMA data

Oume Vallée, Bénin 28 July 2006; Surface rain rate



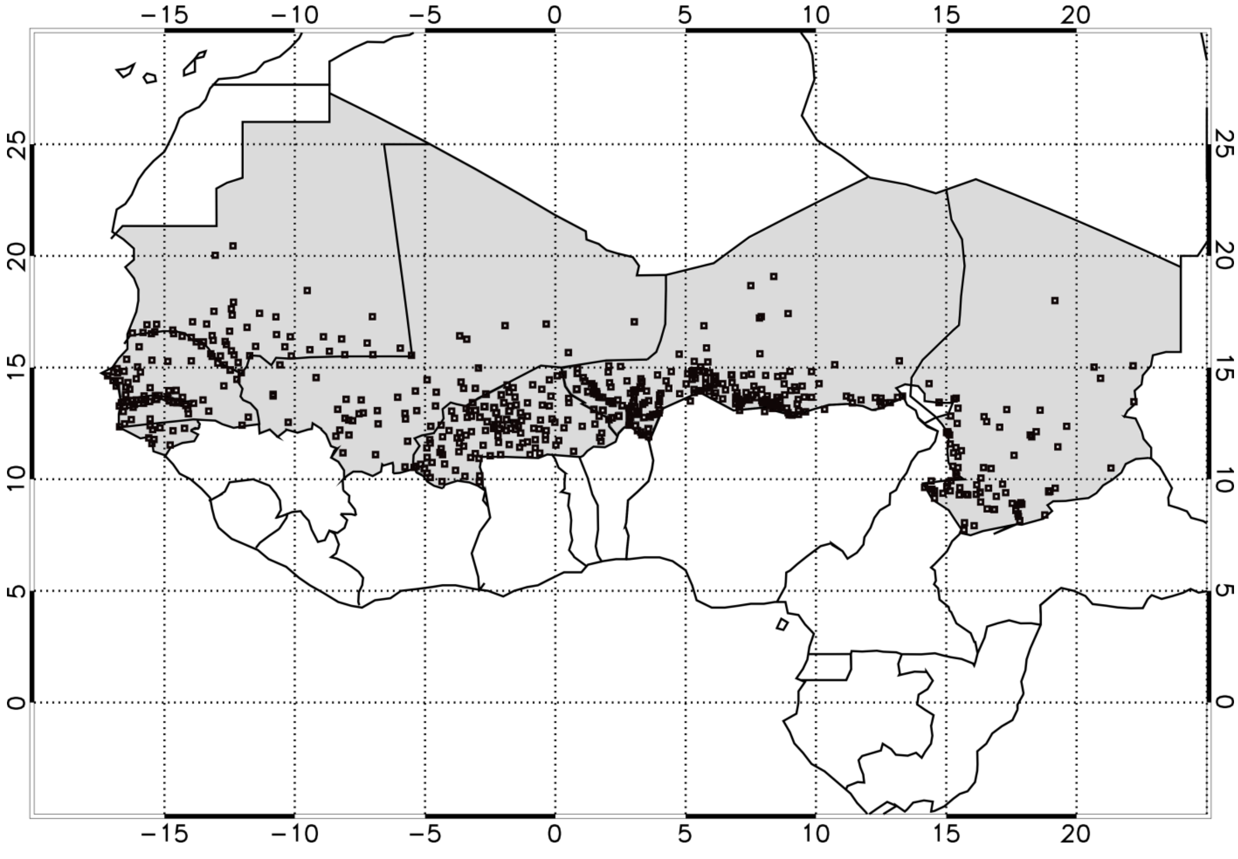
Atmospheric perspective

Surface perspective

Need dedicated methodological efforts !

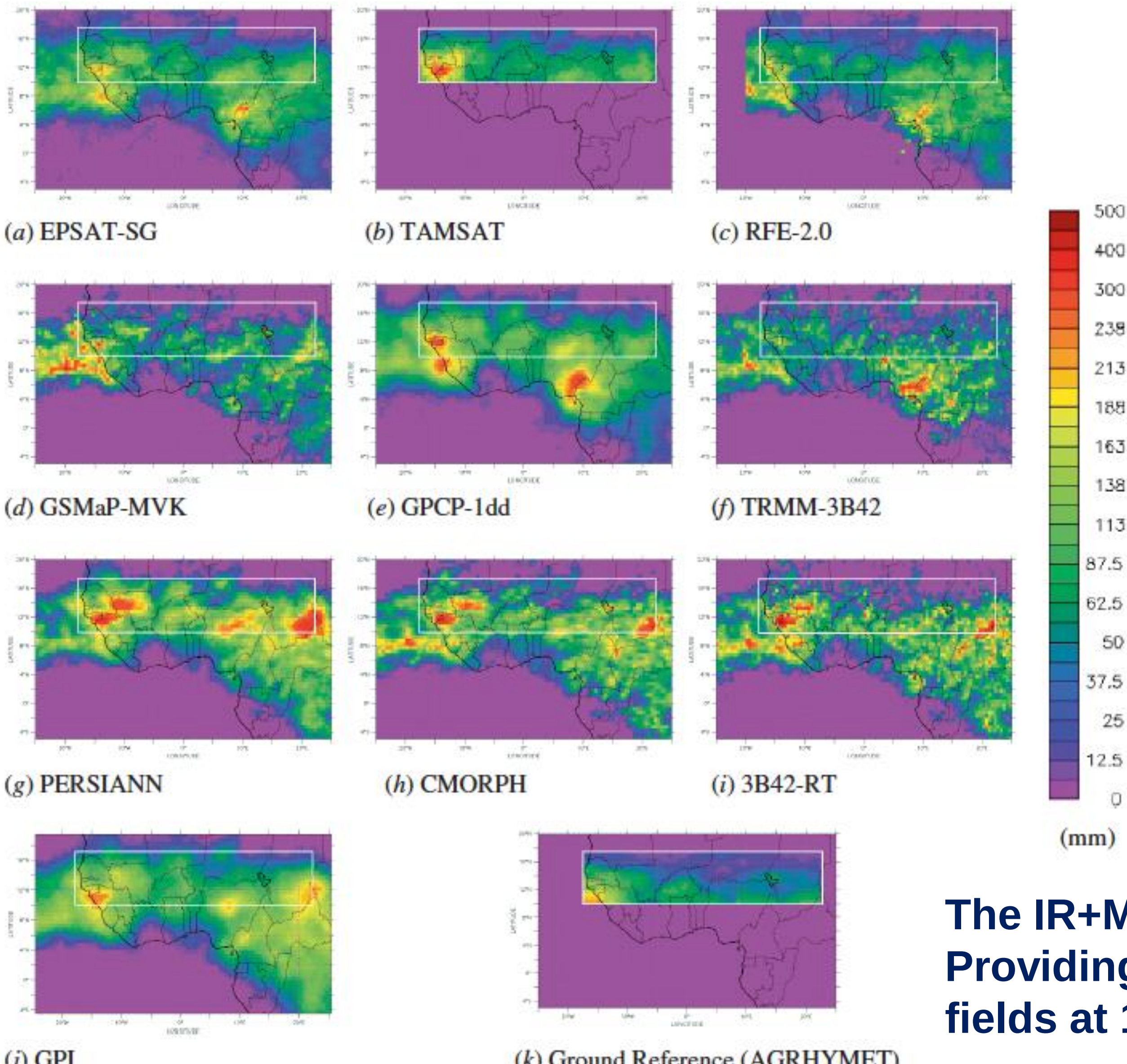
West Africa
The 10 days scales (1/2)

The network of gauges



Réseau CILSS – cumul à 10 jours, 570 pluviomètres
(Comité Inter-états de Lutte contre la Sécheresse au Sahel)

West Africa
The 10 days scales (2/2)

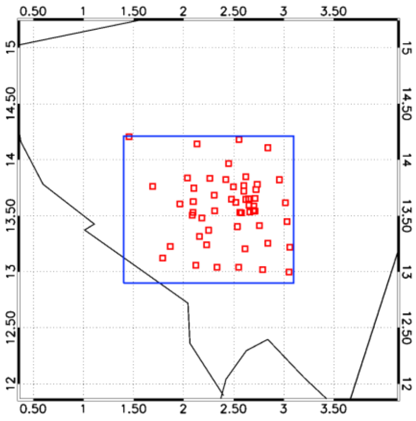


(Jobard et al., 2011)

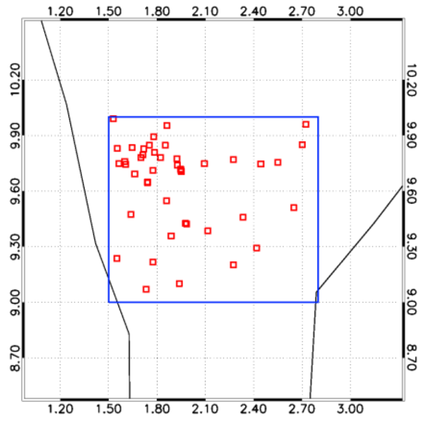
The IR+MW products are Providing useful accumulated fields at 10 days

West Africa
The 1-day scales: the need of an error model !

- Two dense rain gauge networks of the AMMA Catch program
- A network in Ouagadougou



Niamey, Niger
1.7° x 1.3°
54 gauges



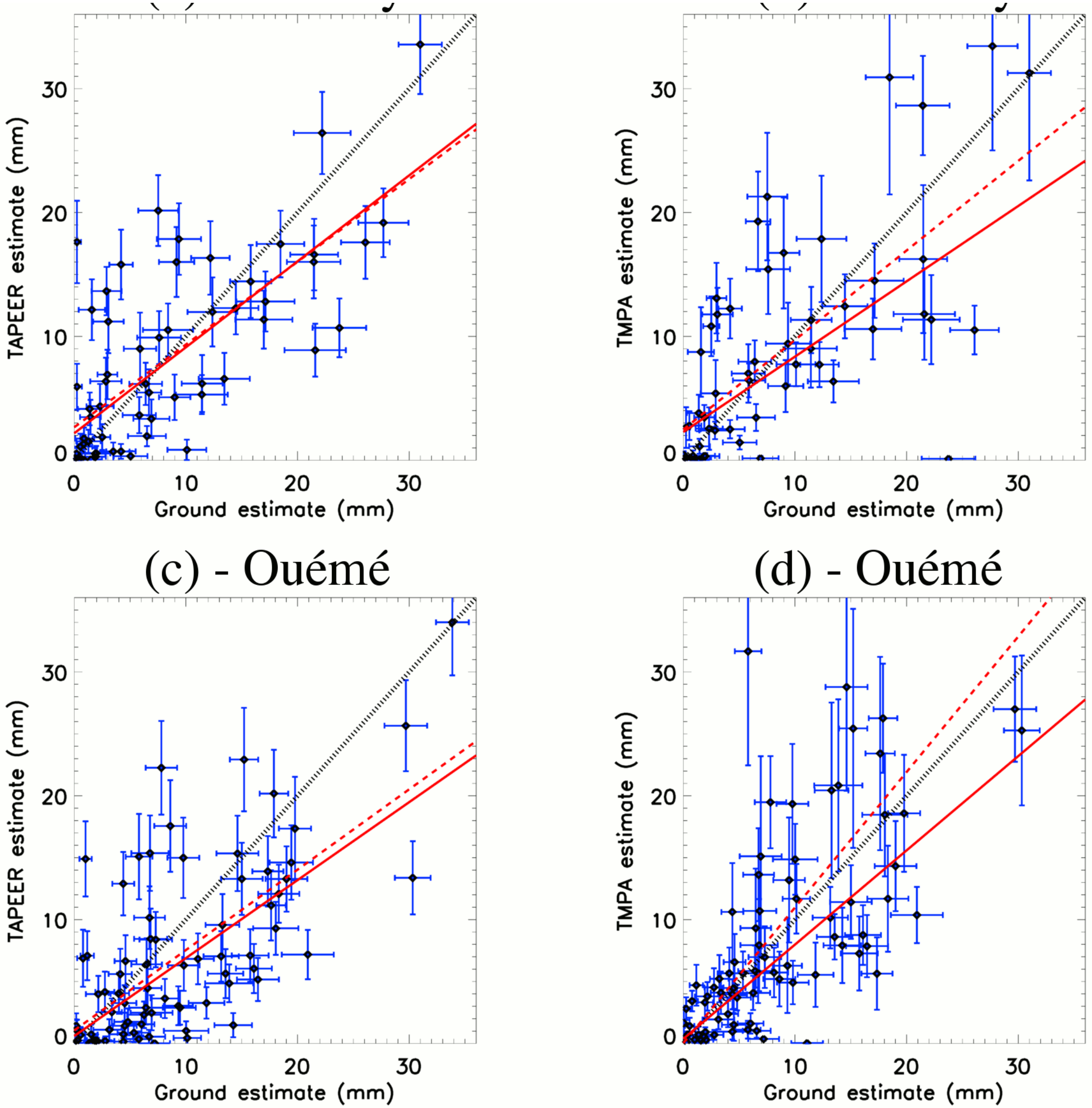
Ouémé, Bénin
1.5° x 1.0°
49 gauges

- Block kriging technique applied to provide
  areal estimates + variance of estimation

Ground reference also has an uncertainty !

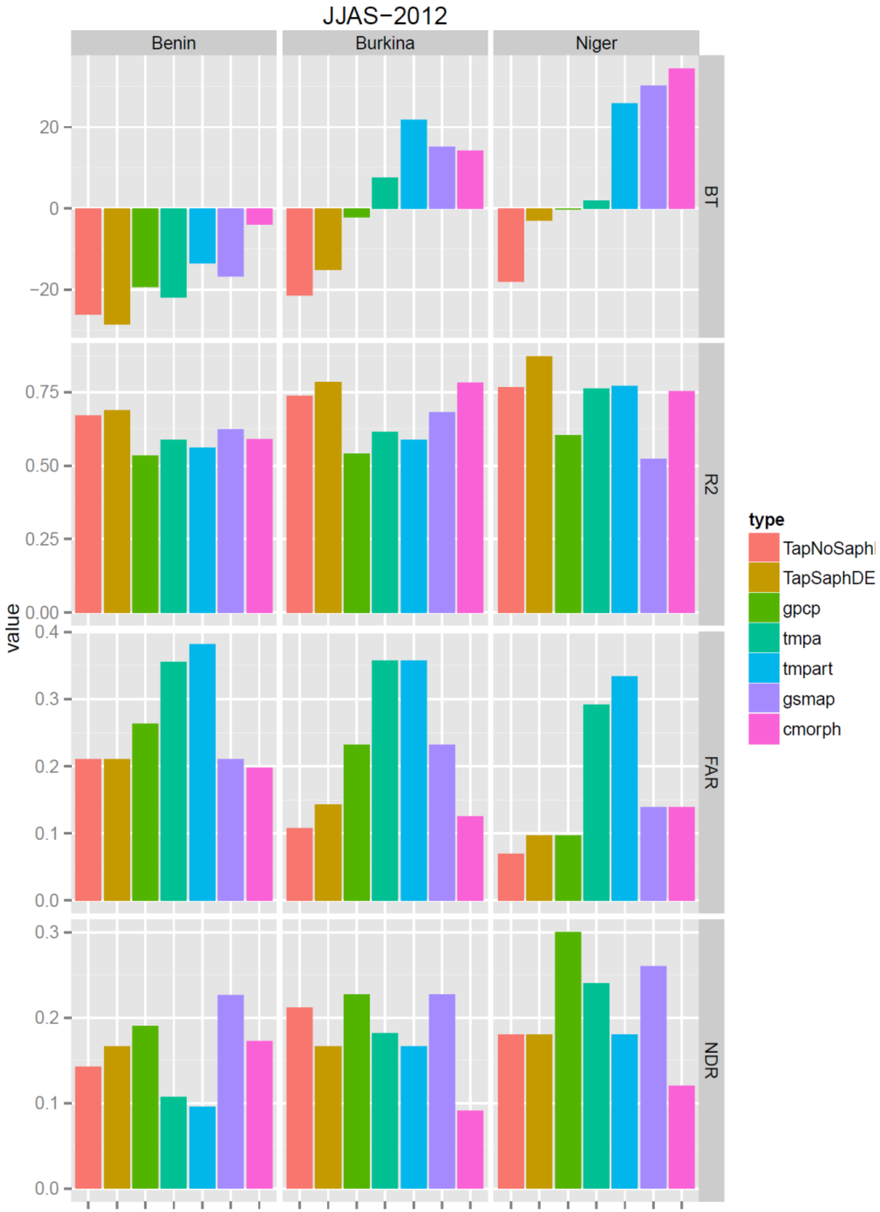
Validation

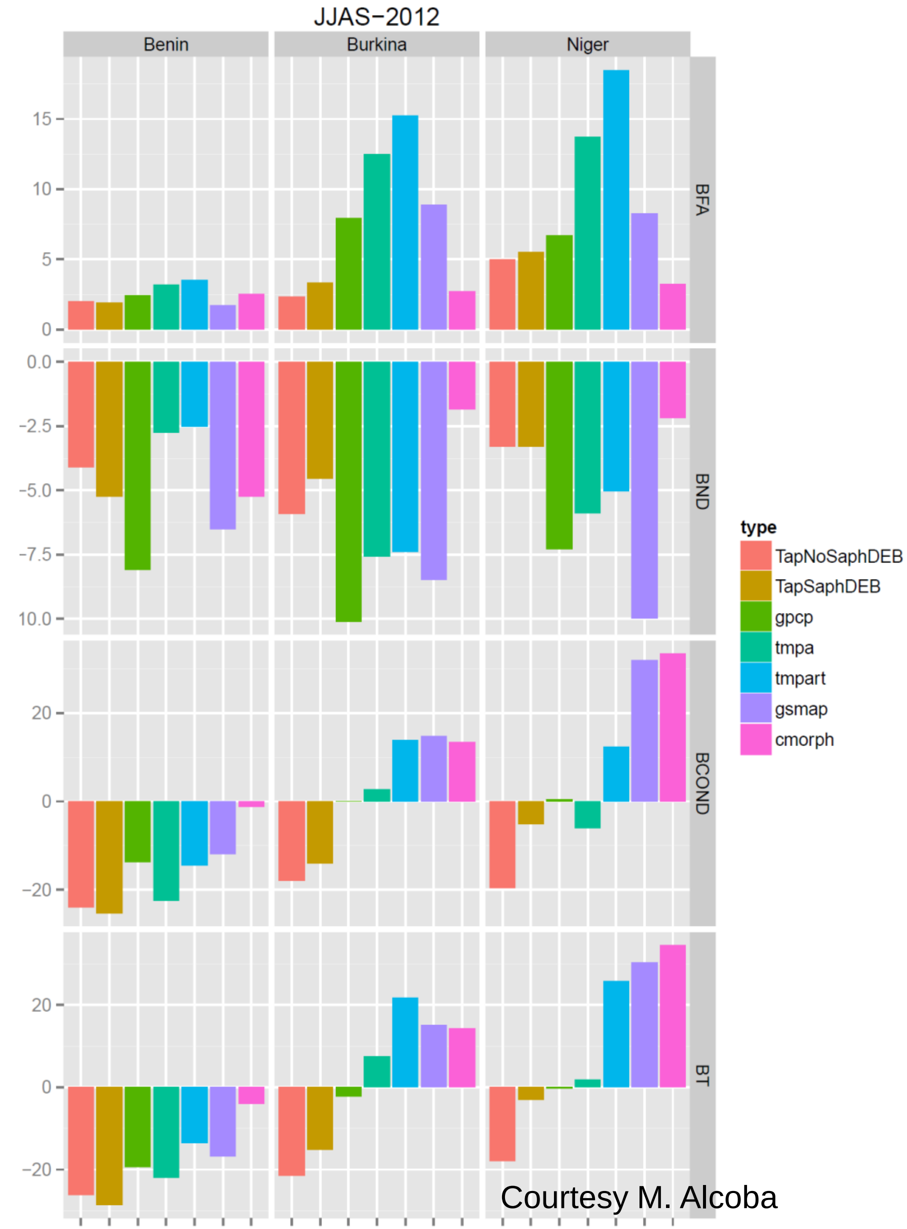
1°/1day over the 2006 season



Bulk statistics over West Africa

Comparison to rain gauges network at 1° daily resolution

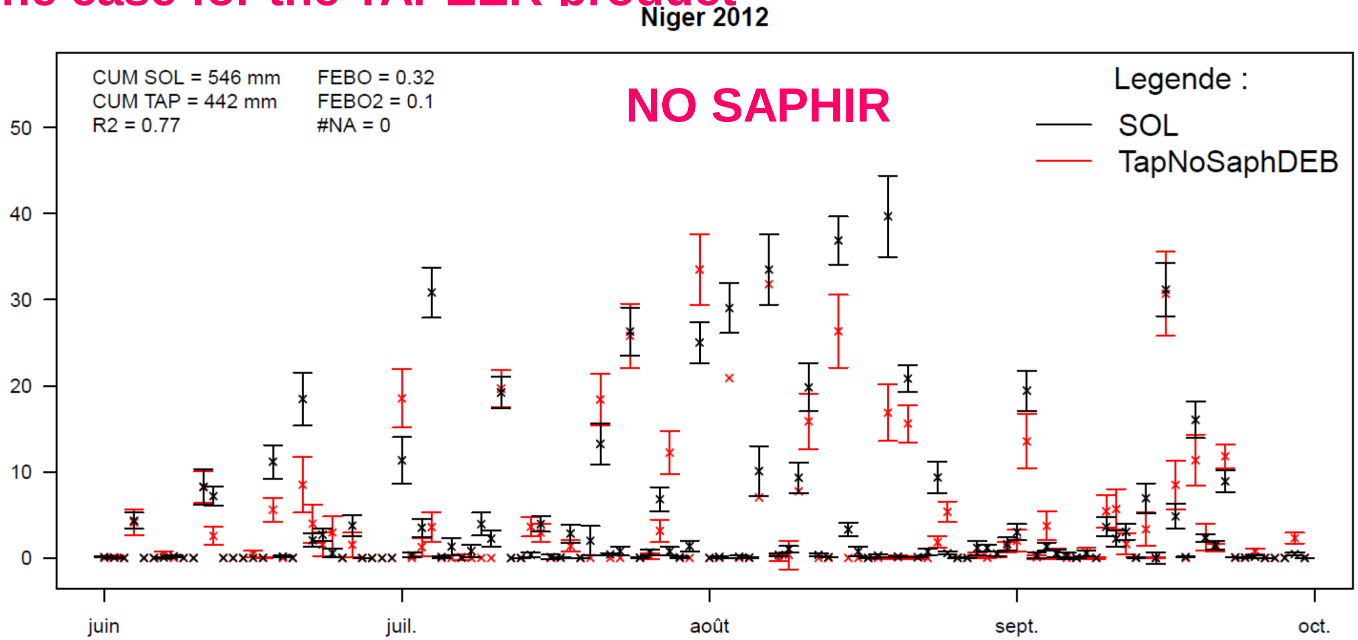


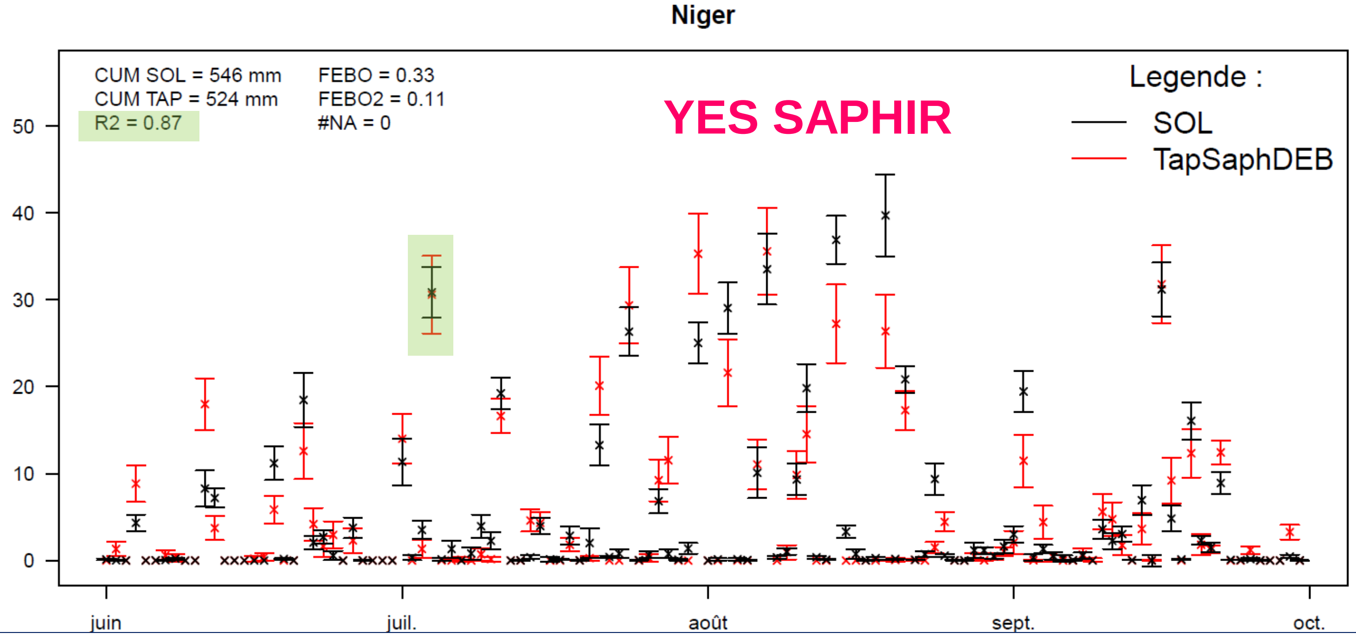


Courtesy M. Alcoba

The impact of the Megha-Tropiques mission on rainfall estimation

The case for the TAPEER product





Courtesy M. Alcoba

The state of the art surface rainfall satelliteS products in the tropics are OK at the meteorologically relevant scales

- At the 10 days and 1 day-1° scale the new generation of merged products has reached a level of quality similar to the rain gauges network

- Error modelling is progressing and is a very active research topic.

The messages

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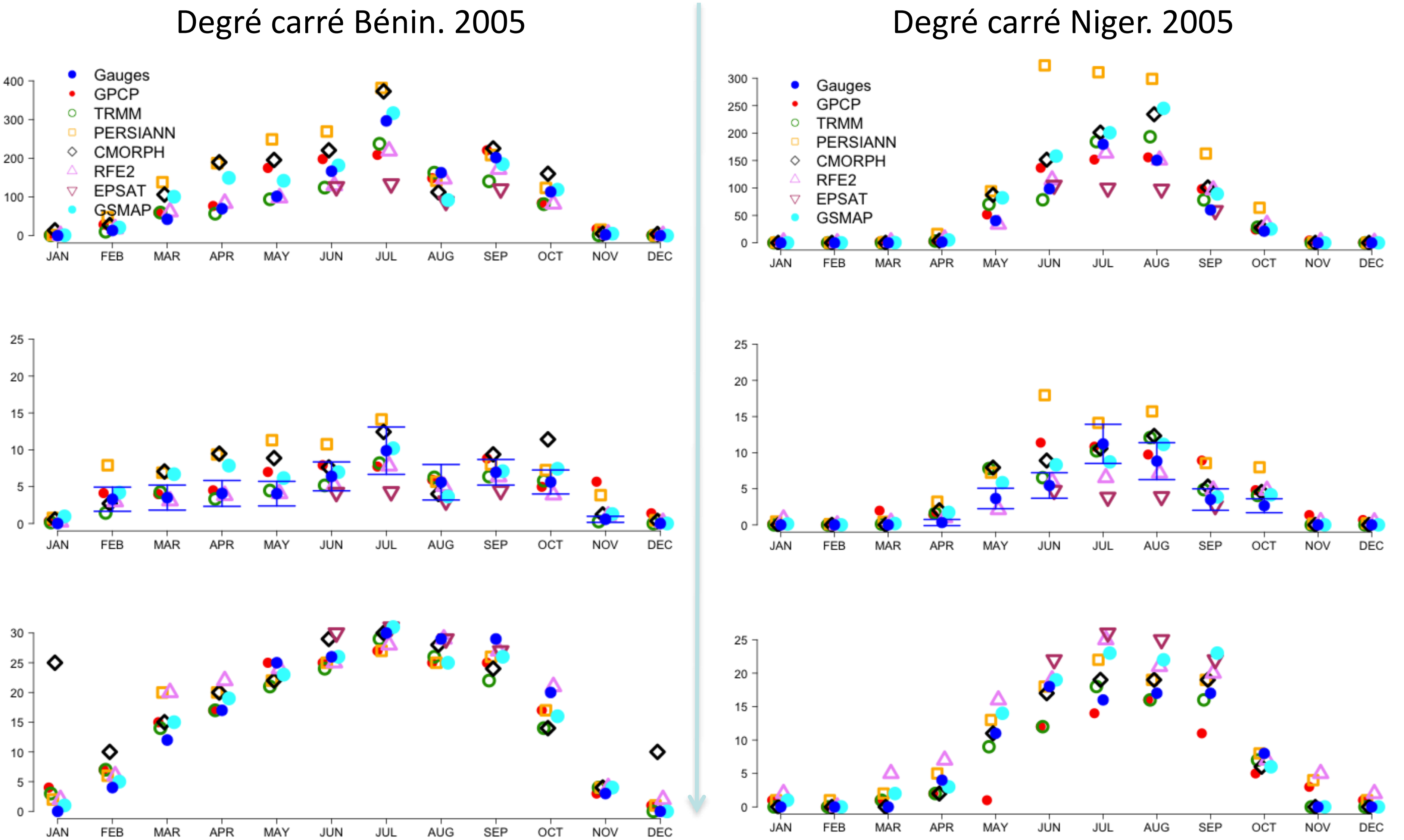
We are at the beginning of a new era, the constellation era

Evaluation with a hydrological perspective

The seasonal cycle

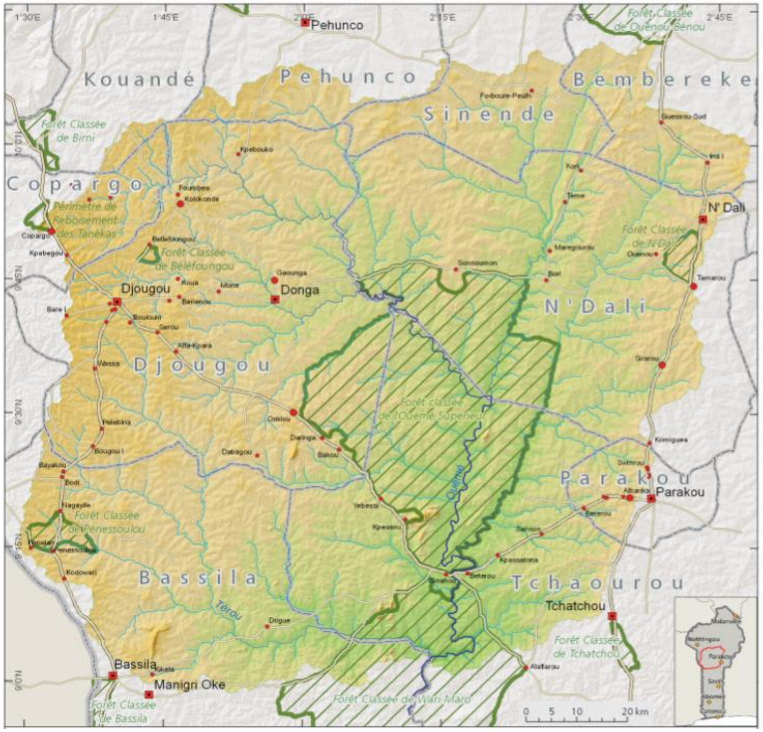


Cumul mensuel (mm, haut) / Moyenne journalière (mm, milieu) / Nombre de jours pluvieux (bas)

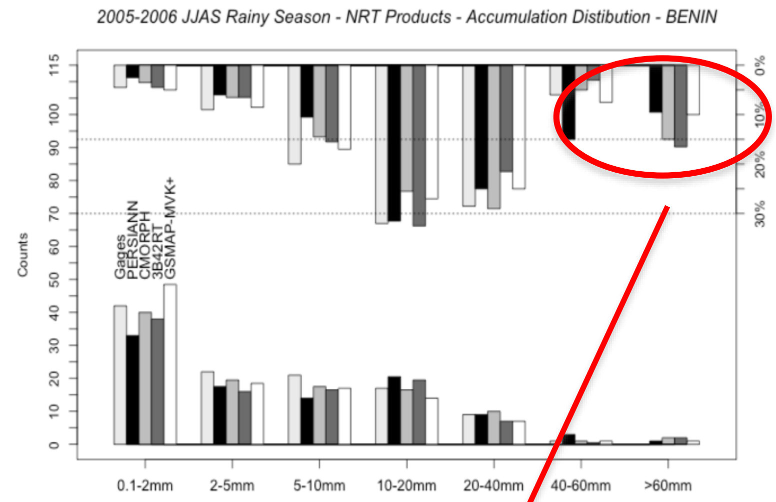
Gosset et al, 2013

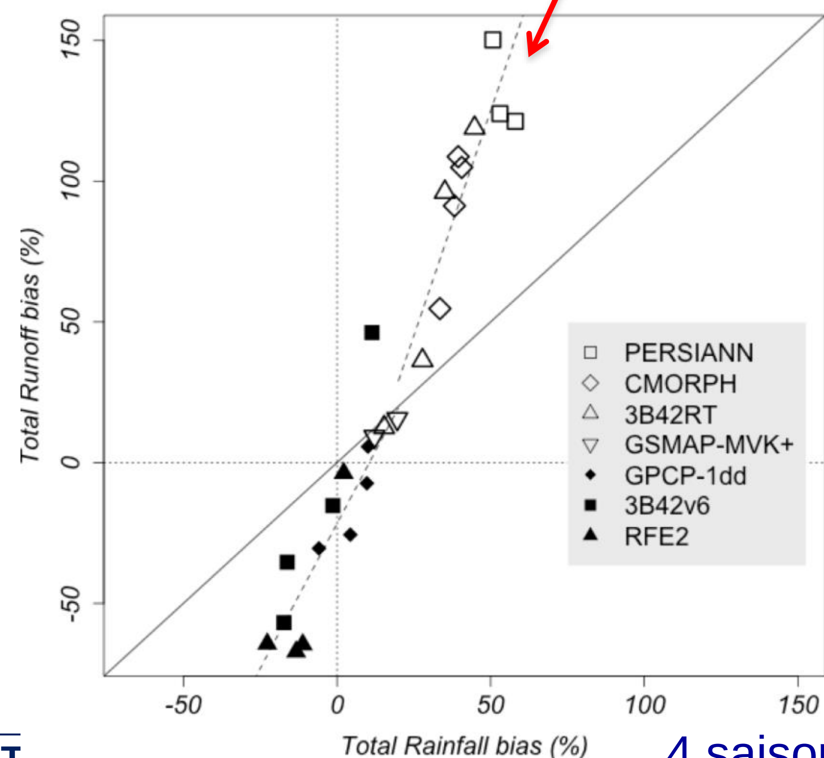
Integrated validation

Validation hydro: example in Bénin



Gosset et al, 2013





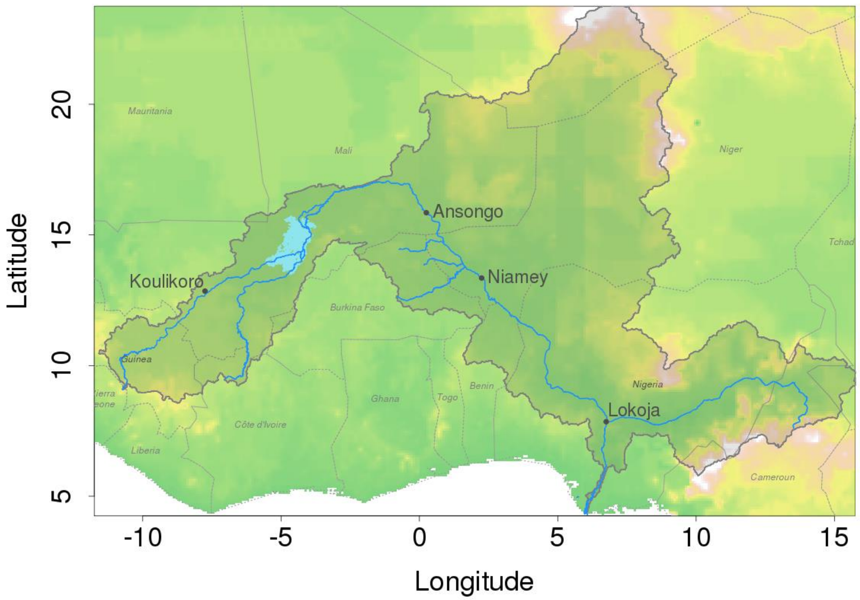
Modelling of the river flow
(modèle GR4J)

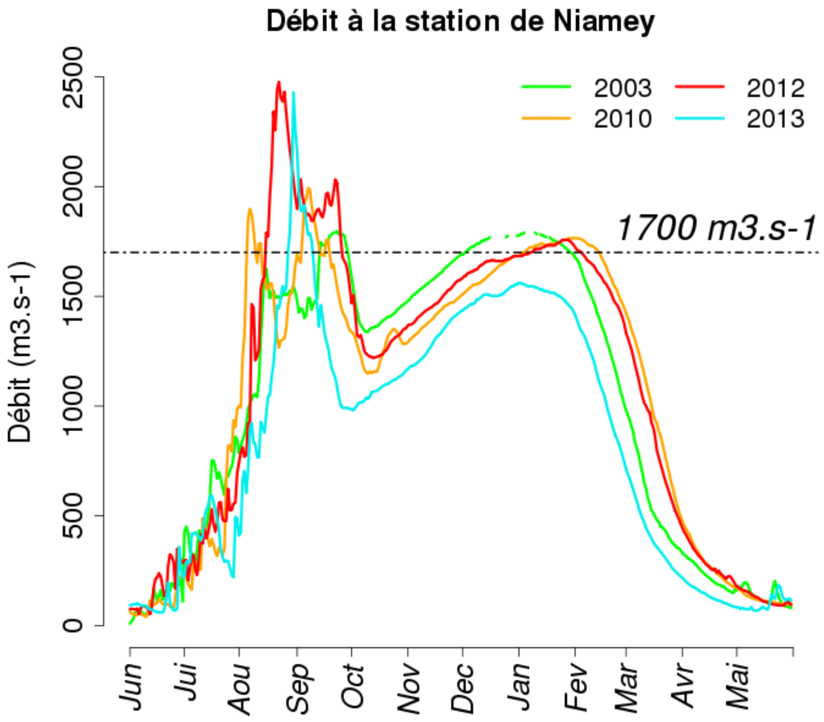
Propagation of the rainfall issue on the river flow
High rain rates-> unrealistic flow
Large interannual flow

4 saisons

Hydrological application

The case of the Niger basin and the red flood in Niamey in 2012





Courtesy C. Cassé and M Gosset

Hydrological application

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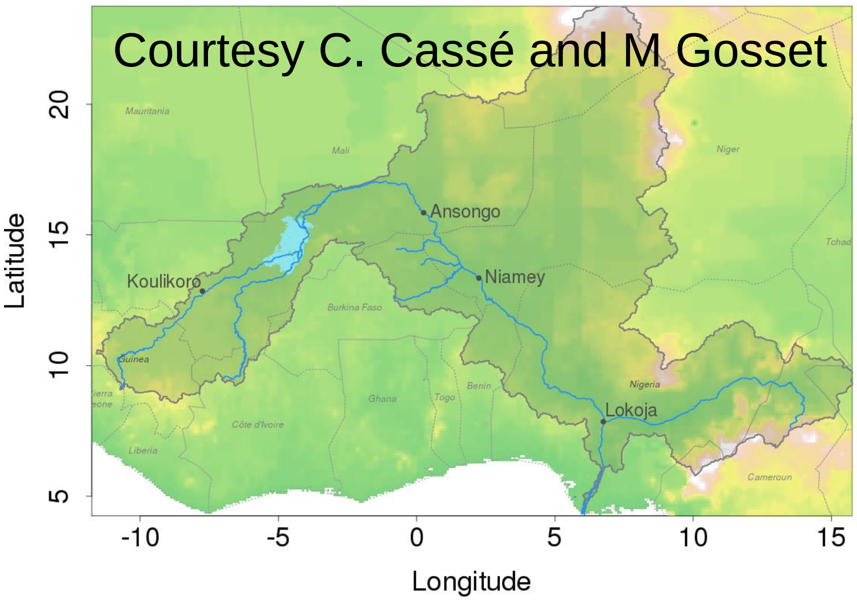
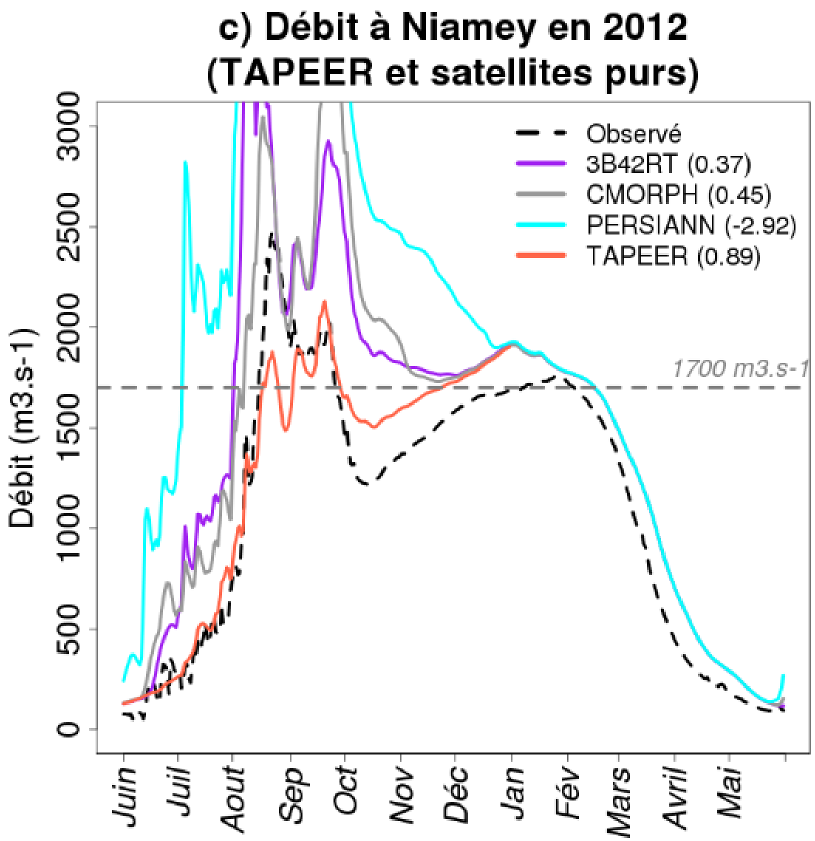


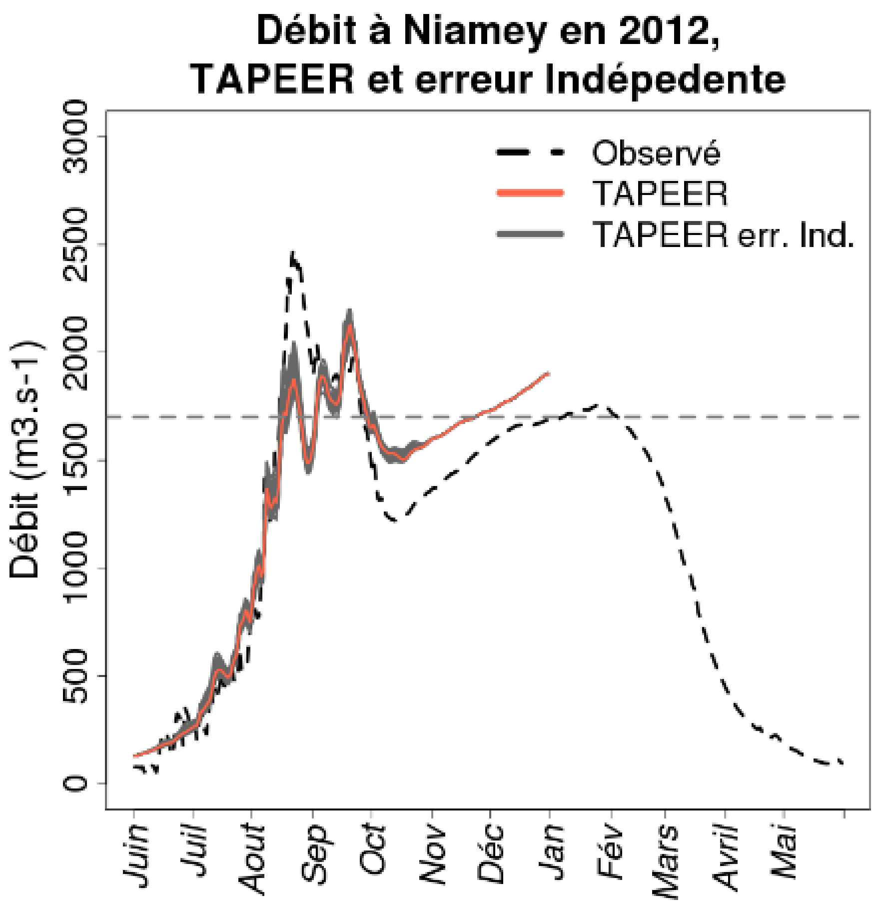
Hydrological model+ sat products

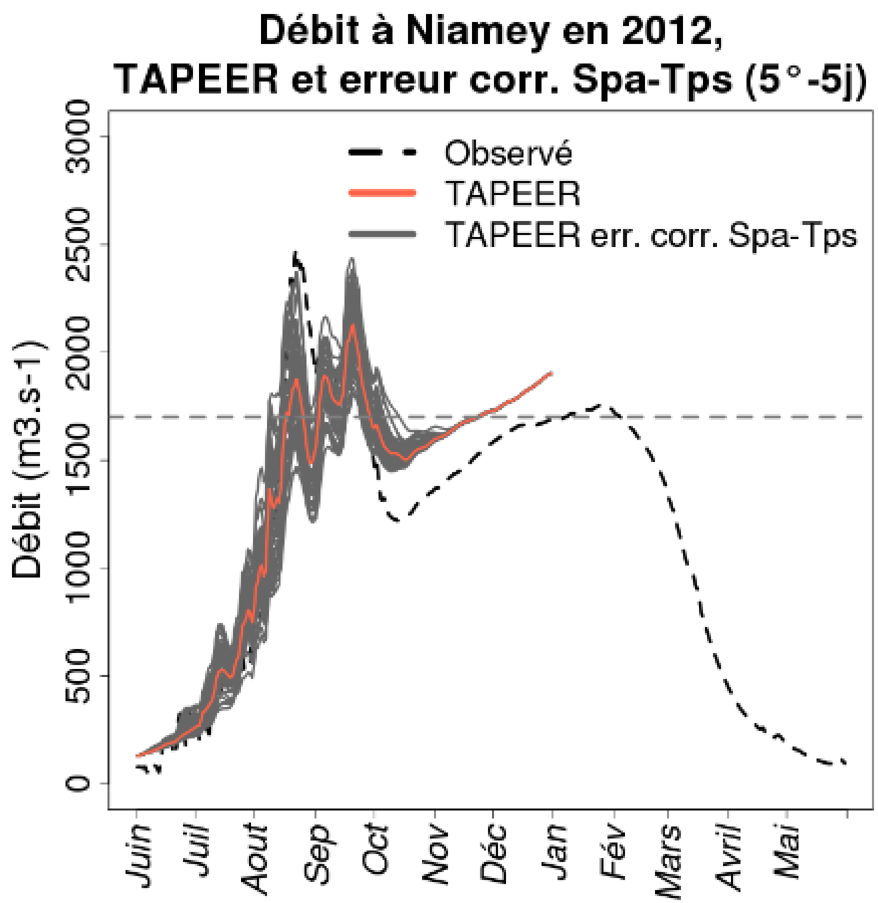


Weak score for RT products (biais)
Better for TAPEER (no bias)

Hydrological application

Ensemble modelling using the error bar from the TAPEER products





Assumptions about the error bars spatial and temporal distribution are key
To generate the proper ensemble of hydrological simulations

Courtesy C. Cassé and M Gosset

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The IPWG

The best way to go further !

- From CGMS and the World Meteorological Organization (WMO)

- focuses the scientific community on operational and research satellite-based quantitative precipitation measurement issues and challenges.

- In parallel of the workshop, we run training sessions to help students, researchers and operational persons to get acquainted with the newest satellite rainfall products

http://www.isac.cnr.it/~ipwg

Open bi-annual meetings

IPWG-7 Tsukuba

Hosted by JAXA

17-20 November 2014

125 participants,
- from over 20 countries
- 49 oral presentations
- 57 poster presentations
- 28 attendees for the lectures

Next meeting in Bologna, Italy hosted by CNR
3-7 October 2016
You are welcome to participate !


Thank You !
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Some useful references

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