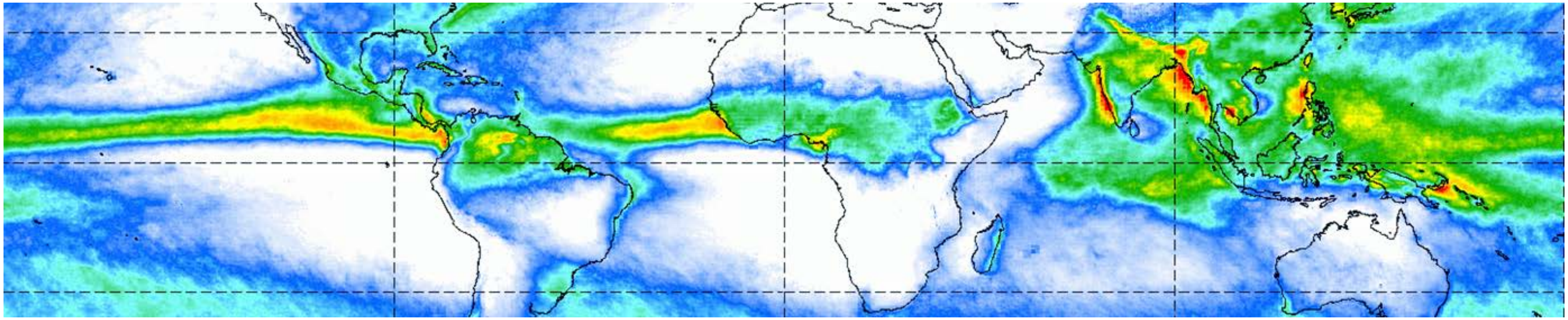
Long term monitoring of tropical precipitation

linking the SSM/I era to the GPM era towards post-EPS times



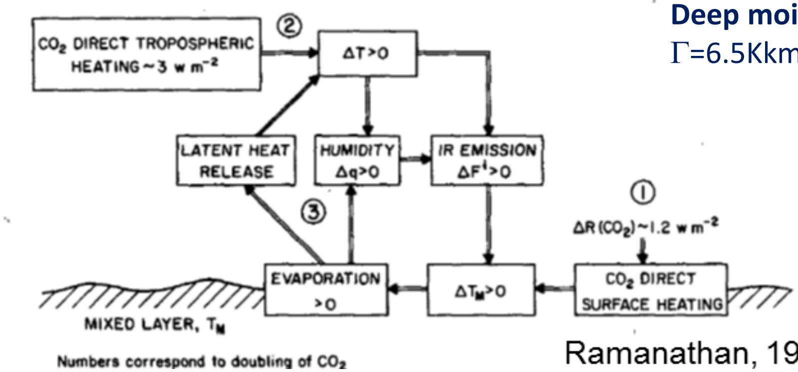
Rainfall multi year average for July from TRMM 3B43

Rémy Roca, (remy.roca@legos.obs-mip.fr)

Philippe Chambon, Nicolas Taburet and Nicolas Viltard

The Global Radiative Convective Equilibrium (RCE)

Theoretical expectation to an increased CO2 concentration



Ramanathan, 1981

Deep moist convection
Γ=6.5Kkm^{-1}

Surface temperature of the globe

TABLE 5. Change of equilibrium temperature of the earth's surface corresponding to various changes of CO_2 content of the atmosphere.

Change of CO_2 content (ppm)	Fixed absolute humidity: Average cloudiness	Fixed absolute humidity: Clear	Fixed relative humidity: Average cloudiness	Fixed relative humidity: Clear
300 → 150	−1.25	−1.30	−2.28	−2.80
300 → 600	+1.33	+1.36	+2.36	2.92

Manabe and Wetherald, 1967

Global « warming » (verified)

Atmospheric humidity

RH=cte hence q increase with T

$$\frac{d\ln e_s}{dT} = \frac{L_{c,s}}{R_V T^2}$$

Précipitable water increases at the 7 %K^{-1} rate via the Clausius-Clapeyron law

Clear sky radiative cooling increase $\Delta R_{net,atm,clear}$ at ~2-3 %K^{-1} (Stephens and Ellis, 2008)

Global « moistening » (~verified)

Global precipitation

Atmospheric budget

$\Delta R_{net,atm} \sim \Delta R_{net,clear} = \Delta S + L_{c,s}\Delta P$

P increase at ~2-3%K^{-1}

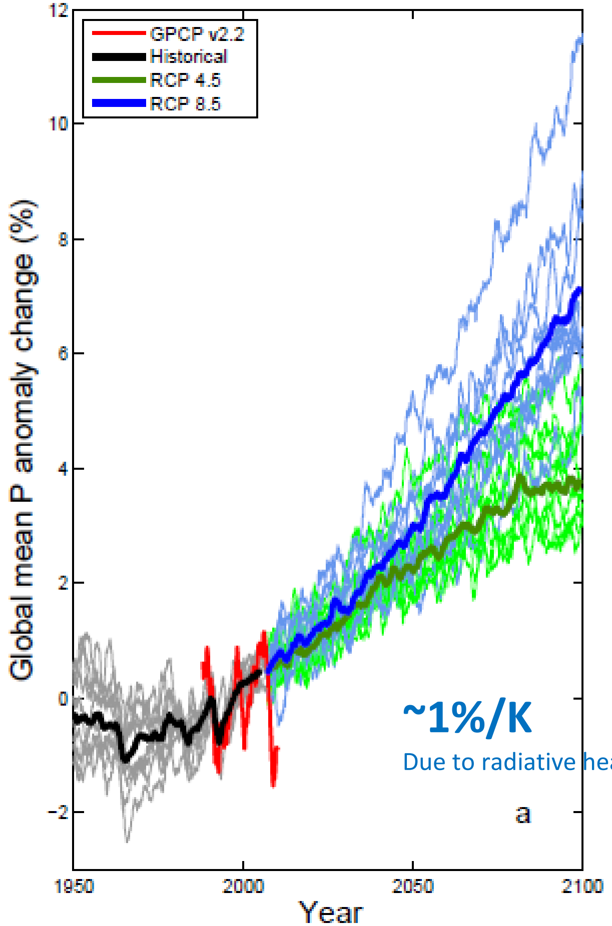
Global « raining » (about to be verified)

Expectation to an increased CO_2 concentration

Transient responses from climate models

Mean

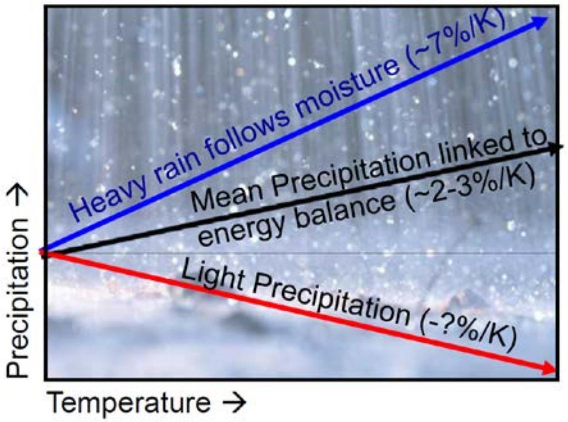
Allan et al., Survey of Geophysics, 2013



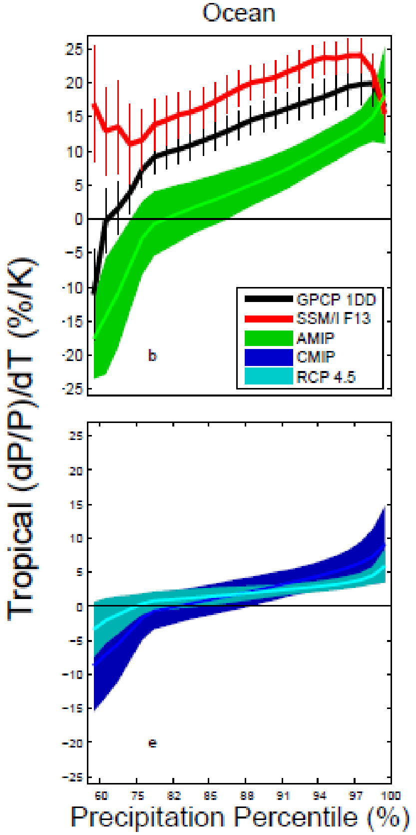
~1%/K

Due to radiative heating of the atmosphere

Distribution



Courtesy Allan, 2013



Allan et al., Survey of Geophysics, 2013

Good understanding from theory and models of mean precipitation evolution under CC
Weak support from the observational data record of precipitation (data? nat var?)
Large uncertainty on the evolution of the **distribution** of rainfall

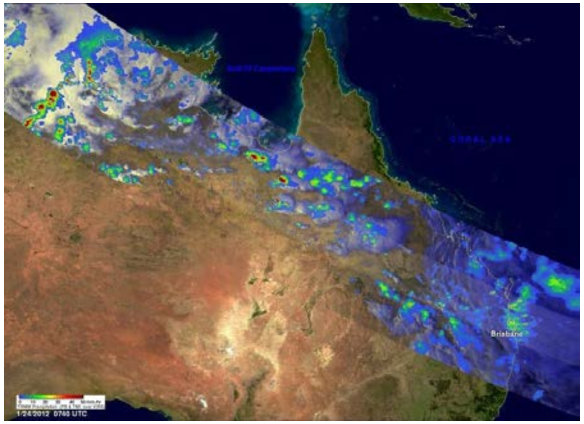
Outline of the presentation

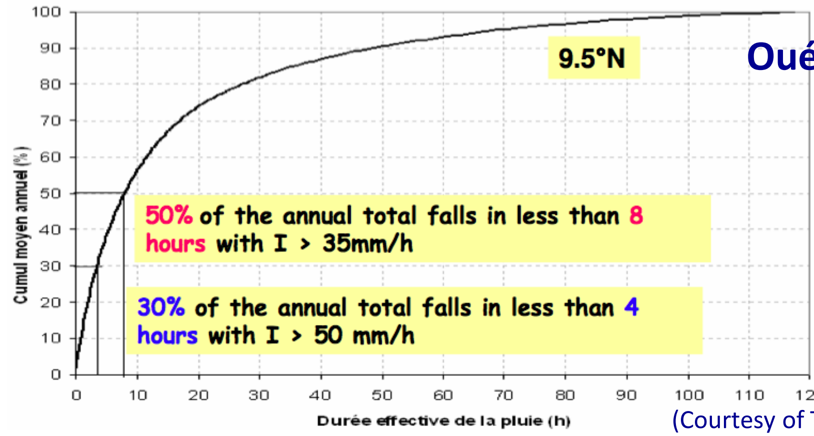
- **Precipitation and climate change**
- **Quantitative precipitation estimate from satellite**
- **Usage of QPE product for climate trends analysis**
- **Conclusions and Perspectives**

Quantitative Precipitation Estimate from space

Basics

High time and space variability





Ouémé, Benin

(Courtesy of Th. Lebel, LTHE)

Rainfall is a tremendously difficult topic and a very active research field:

- Cloud Ice/water/snow microphysics,
- Atmospheric convection,
- Mesoscale dynamics, thermodynamics,
- Hydrology, extreme events,
- Radar, microwave physics
- Strong societal demands
- Progressing fast

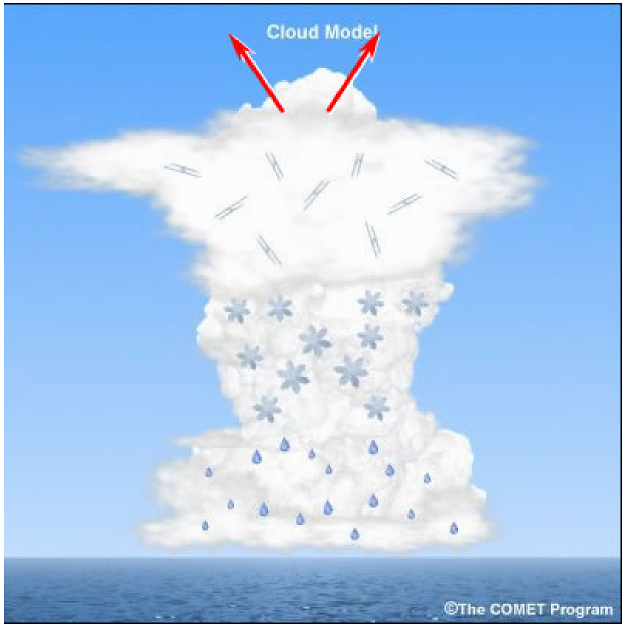
Are we measuring the rain ? No, the cloud !

INDIRECT surface precipitation estimation via the cloud physical properties

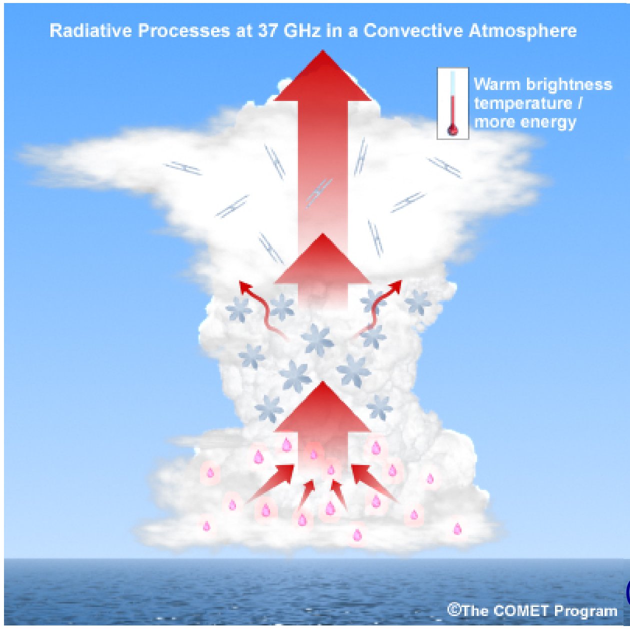
Infrared

Micro-wave

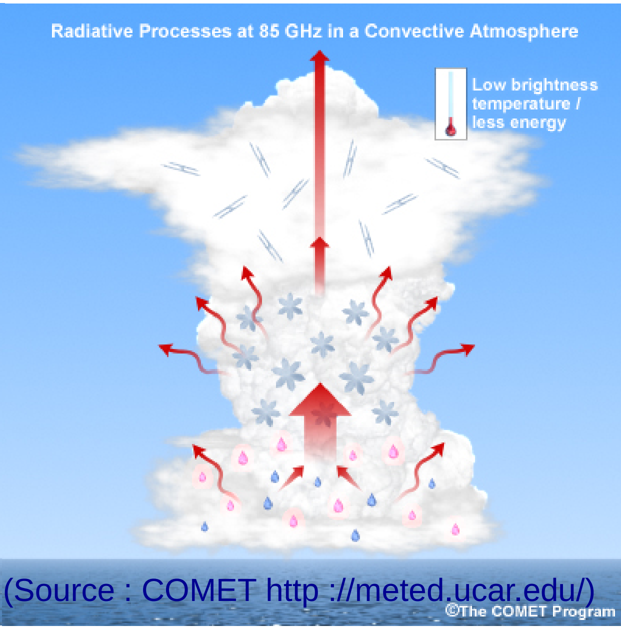
Emission/absorption **Scattering**



IR between 10 et 12 µm



Lower frequency
Below 60 GHz



(Source : COMET http ://meted.ucar.edu/)

Higher frequency
Above 60 GHz

The difficulty lies in establishing a QUANTITATIVE link bewteen the column water and the rainfall at the surface

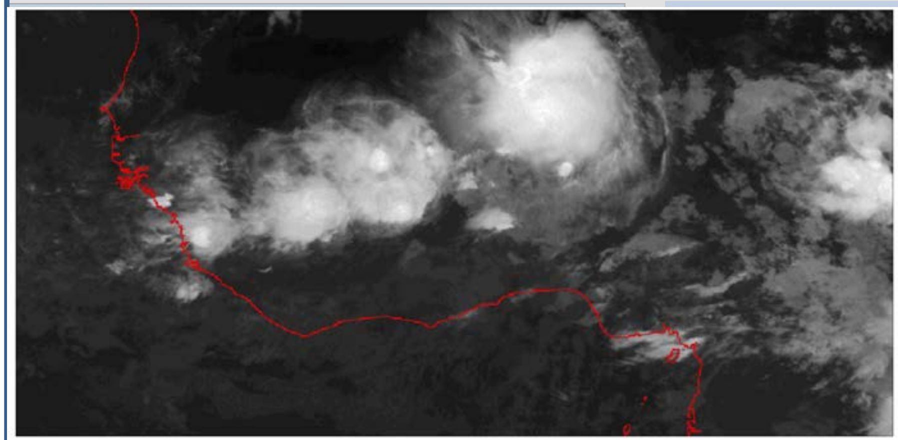
Are we measuring the rain ? No, the cloud !

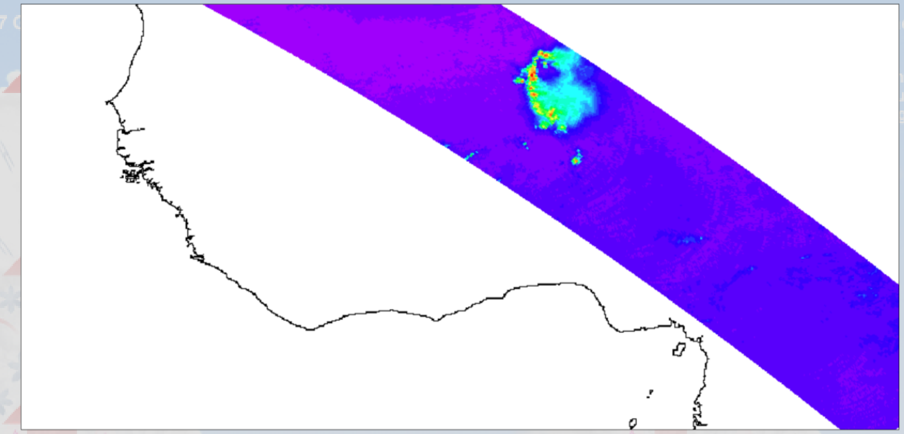
INDIRECT surface precipitation estimation via the cloud physical properties

Infrared **Micro-wave**

Emission/absorption

Scattering





(Source : COMET http ://meted.ucar.edu/)

IR between 10 et 12 µm

Lower frequency
Below 60 GHz

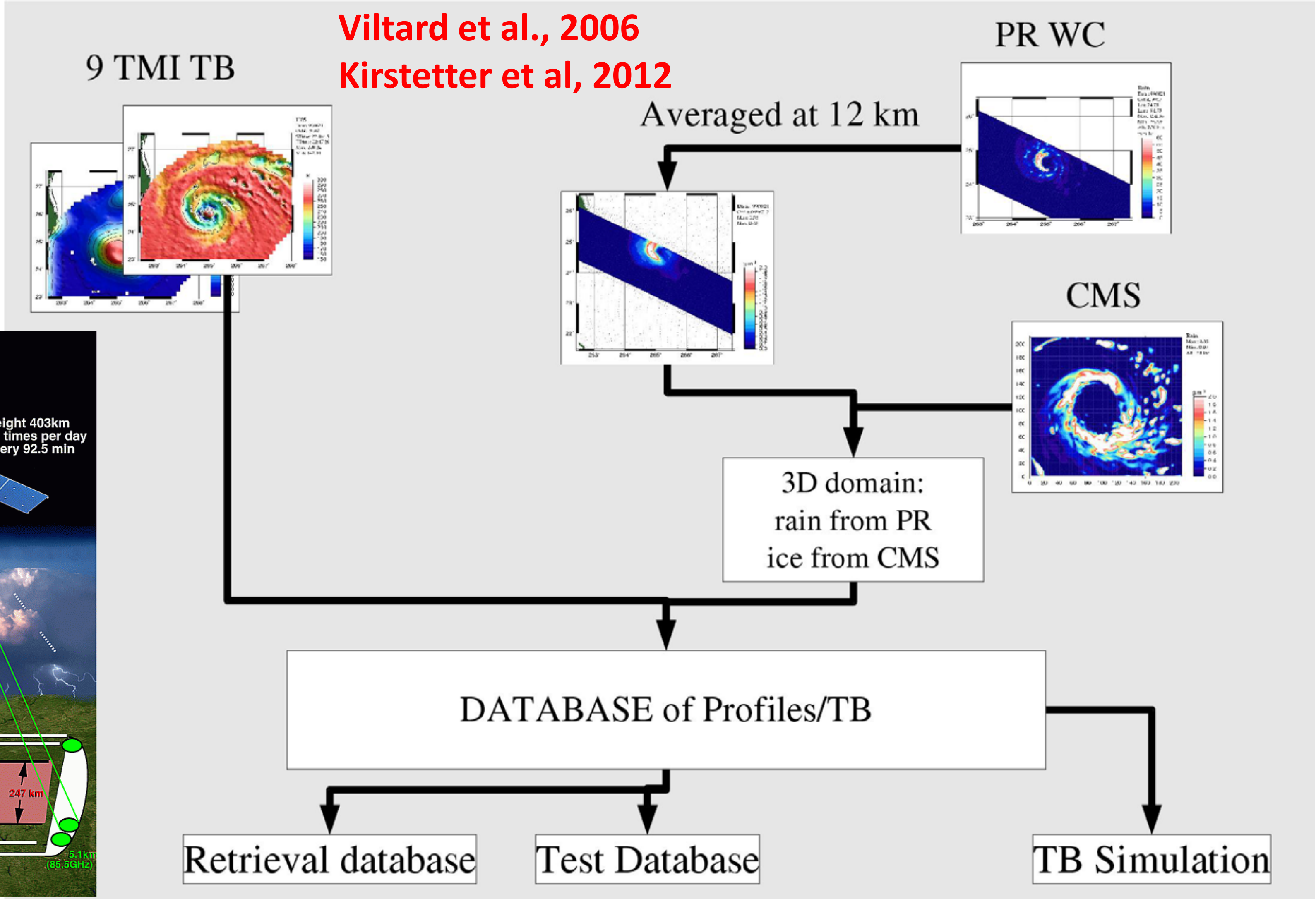
Higher frequency
Above 60 GHz

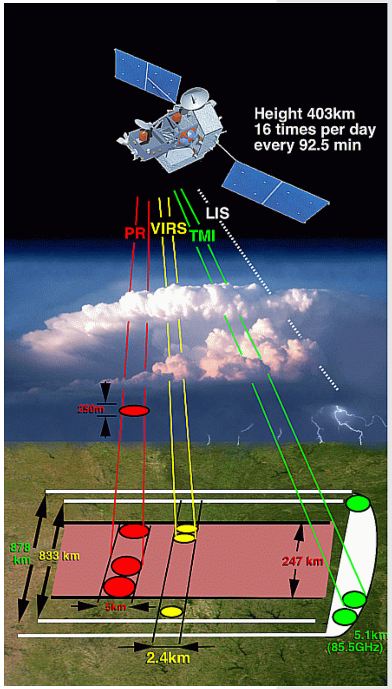
The difficulty lies in establishing a QUANTITATIVE link bewteen the column water and the rainfall at the surface

A method to transform MW observations in Rain Rate

Making use of the TRMM radar in the database the BRAIN algo

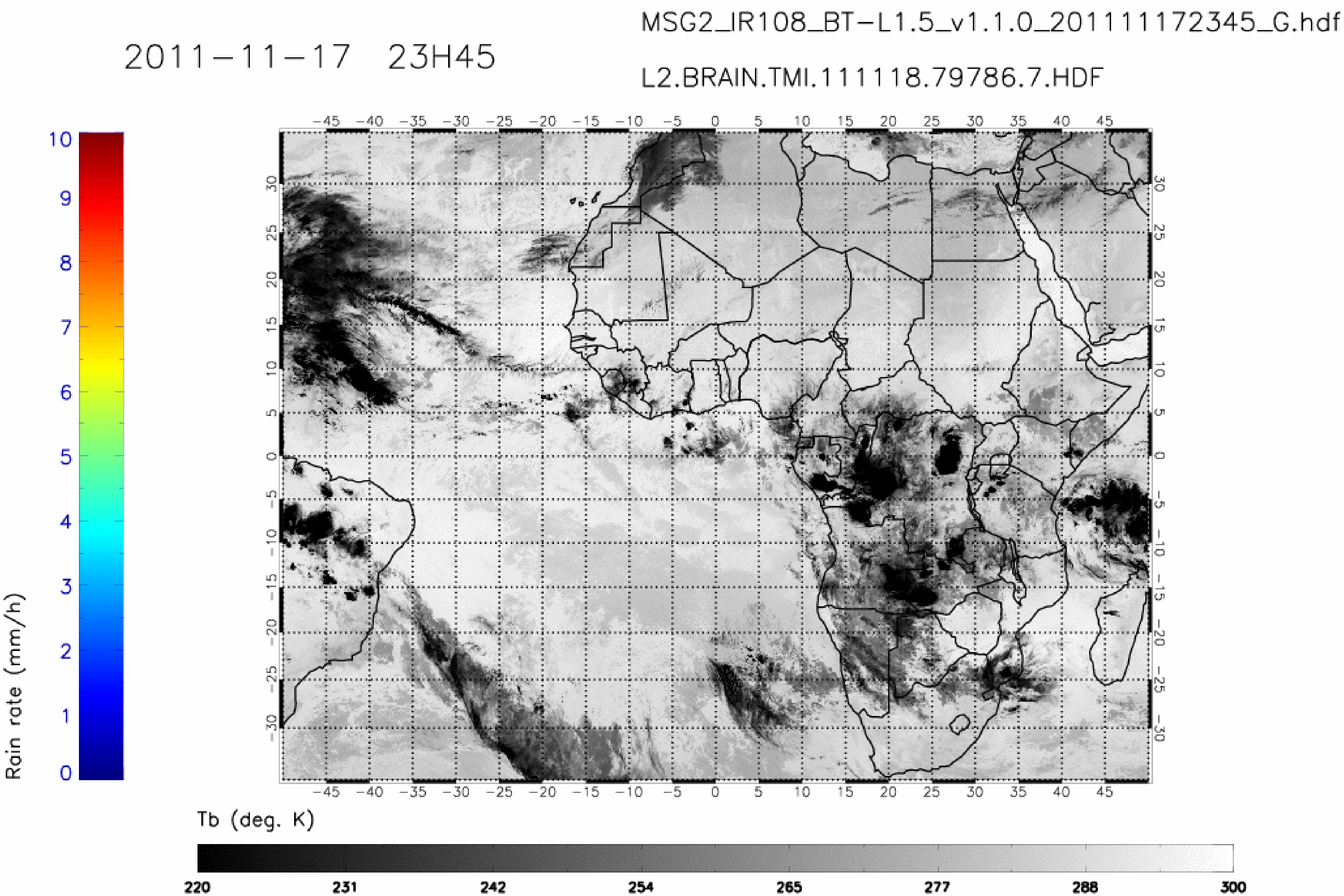
The BRAIN retrieval for INSTANTANEOUS estimates of surface rainfall





Merging the cloud and the rainfall information

Accumulated rainfall using geostationnary imagery



(Animation: J. Aublanc)

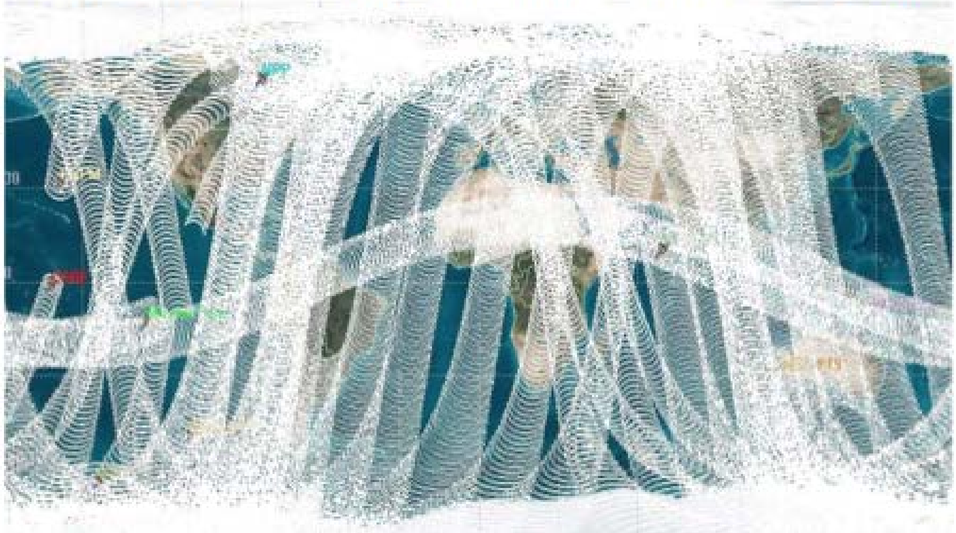
From a single mission to a constellation approach

The Global Precipitation Measurement Mission

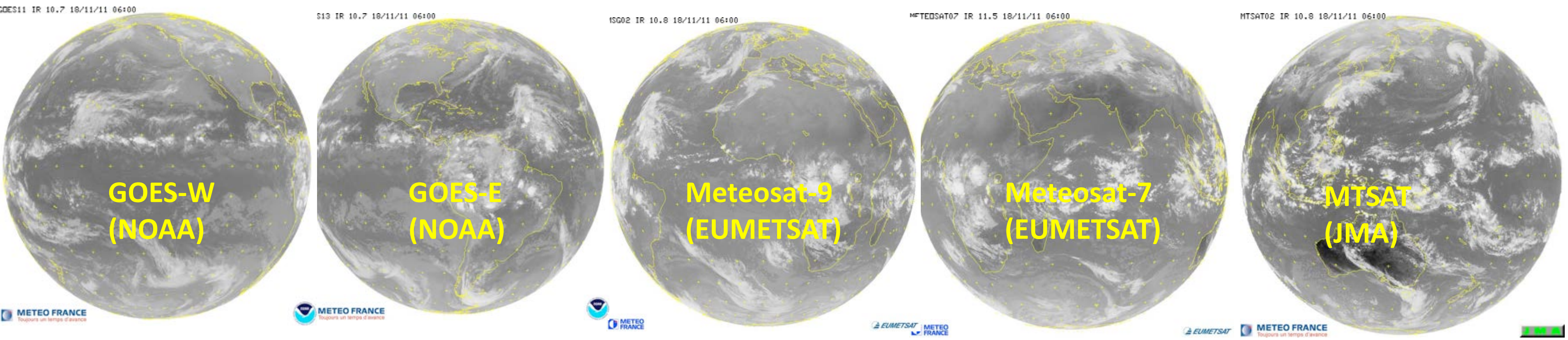
The GPM constellation comprises dedicated and operational satellites:

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



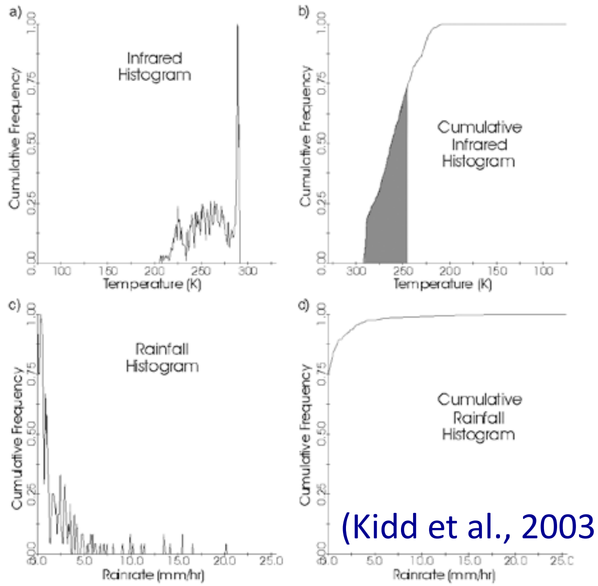
(Courtesy A. Hou)



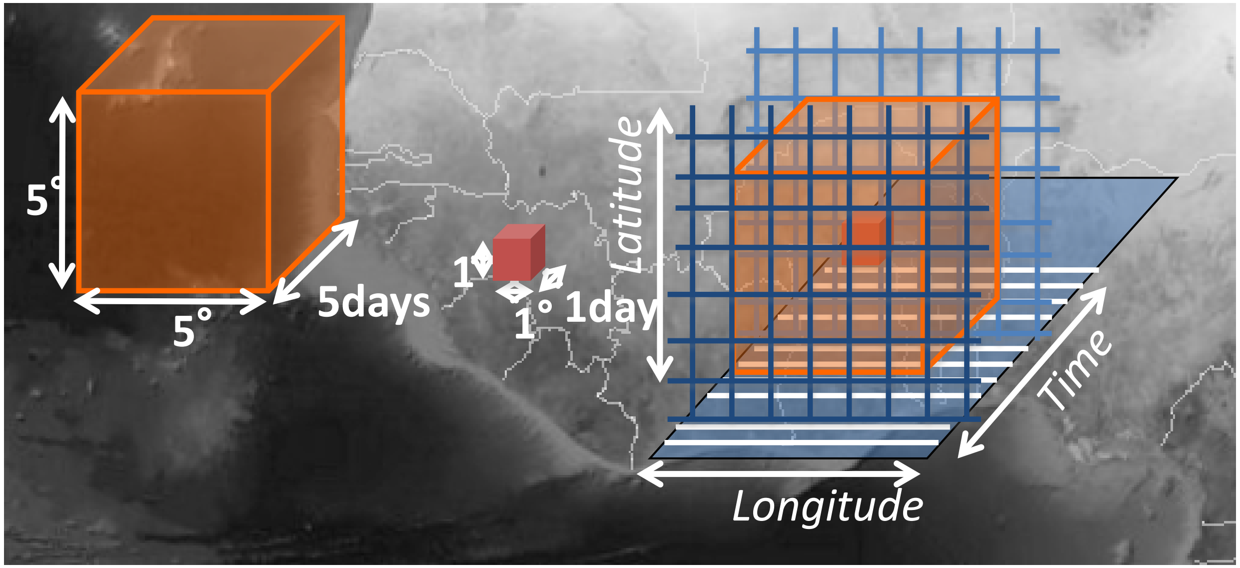
Canal IR Thermique ; 18 nov 2011 06h00 UTC (Source : www.meteo.satmos.fr)

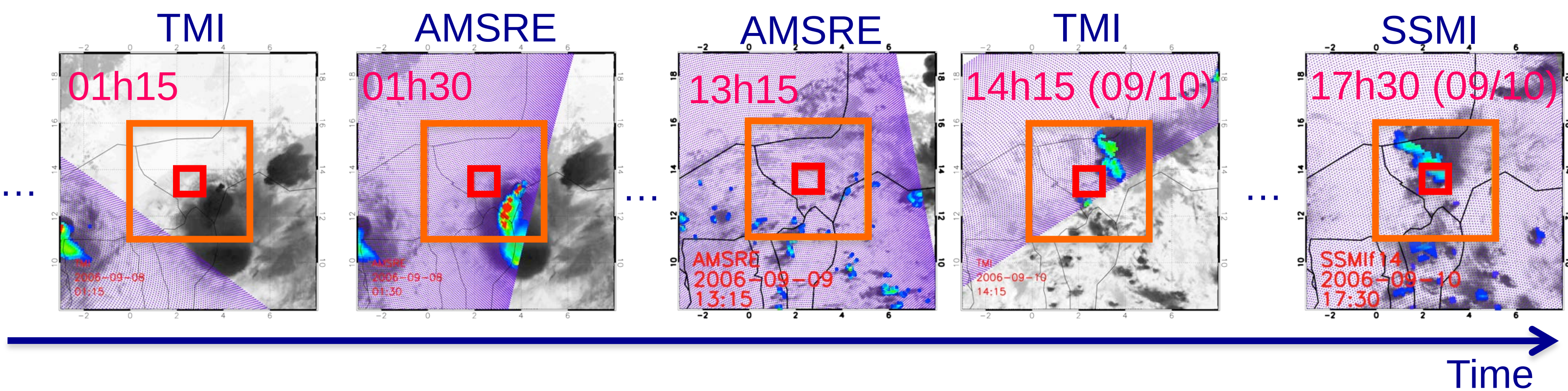
Merging microwave data from LEO and IR data from GEO

The Universally adjusted GP Index approach



(Kidd et al., 2003)



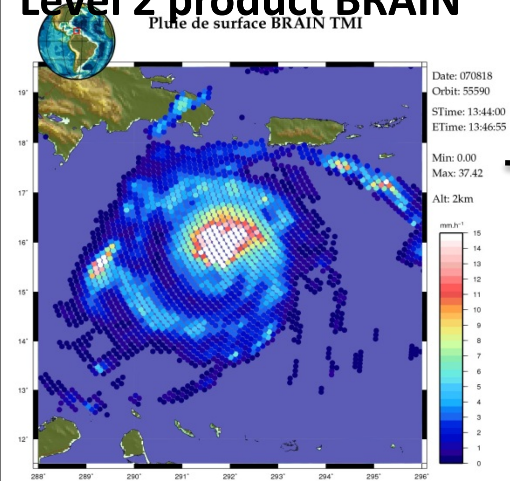


The TAPEER algorithm

Tropical Amount of Precipitation with an Estimate of ERrors

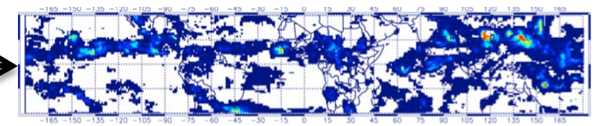
- Adaptation of the UAGPI technique (Xu et al., 1999)
- Rain rates from PMW through the BRAIN algorithm (Viltard et al., 2006)

Level 2 product BRAIN



IR images time series

IR/MW COMBINATION



Accumulated rain 1°x1° / 1 day

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 measurements occurence

The error budget of the satellite estimates

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

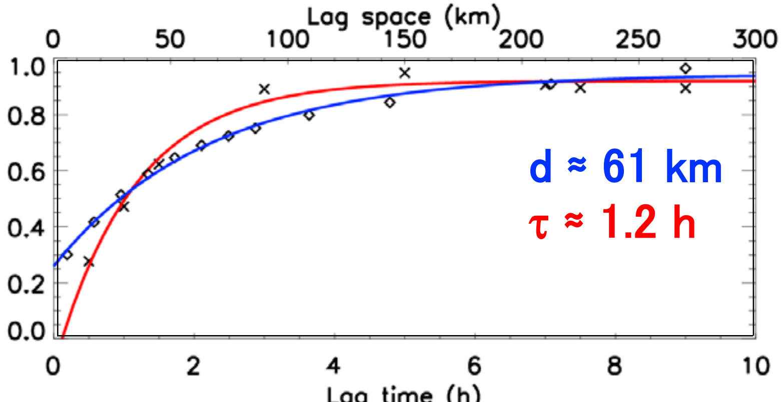
N_{ind}: Number of independent samples

Computation of N_{ind} : variogram analysis

In space : A/d^2 independent samples

In time : T/τ independent

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

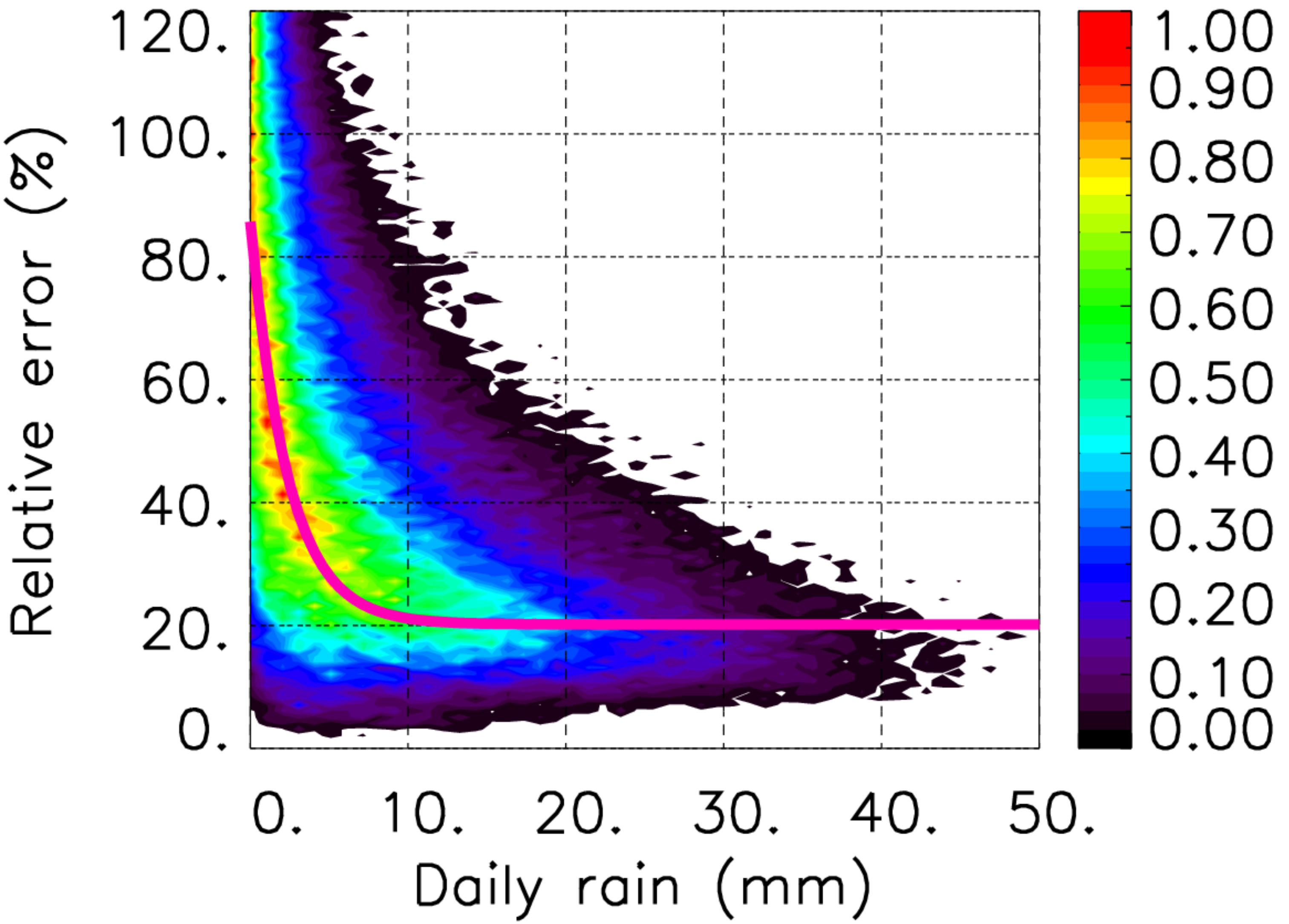


Ex : [12°N – 17°N ; 3°W – 3°E]

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: 1 sigma value

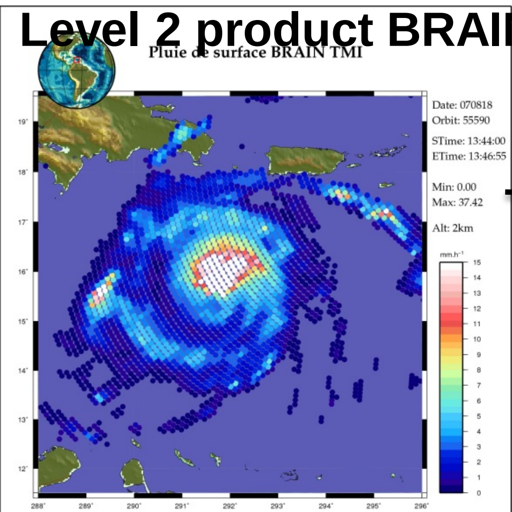


The TAPEER algorithm

Tropical Amount of Precipitation with an Estimate of ERrors

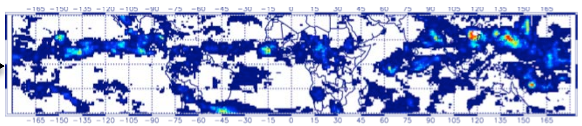
- Adaptation of the UAGPI technique (Xu et al., 1999)
- Rain rates from PMW through the BRAIN algorithm (Viltard et al., 2006)

Level 2 product BRAIN

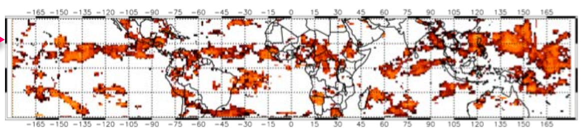


IR images time series

IR/MW COMBINATION

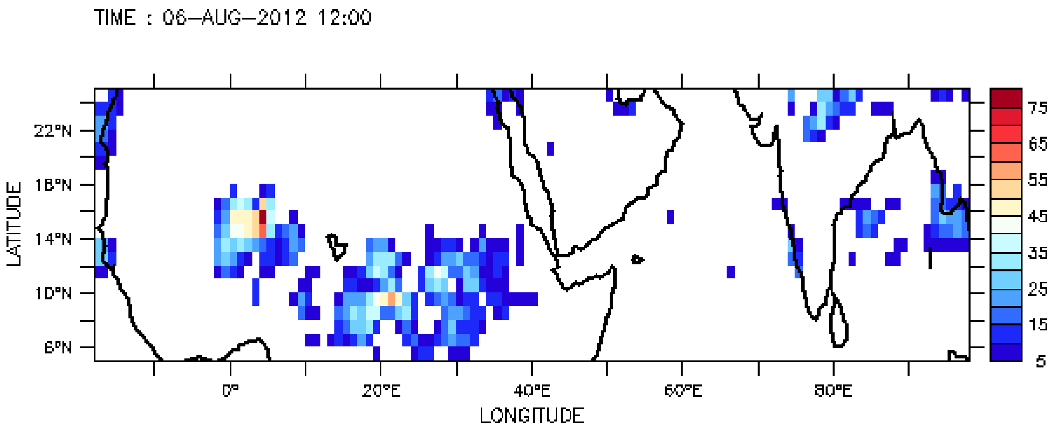


ERROR COMPUTATION

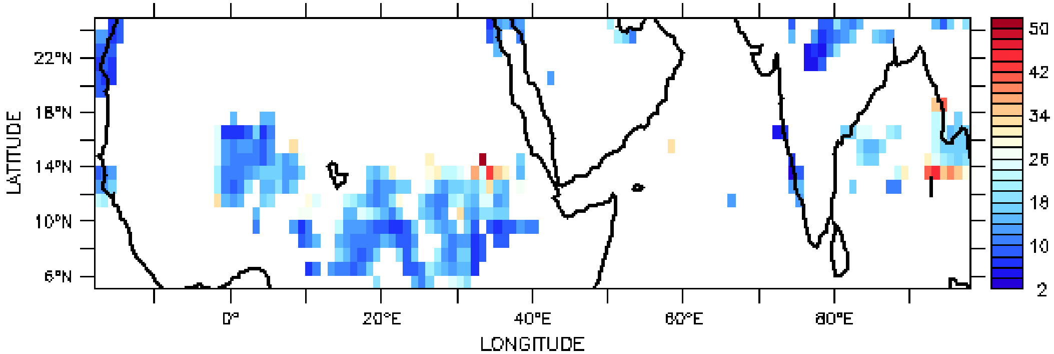


Accumulated rain and error at 1°x1° / 1 day

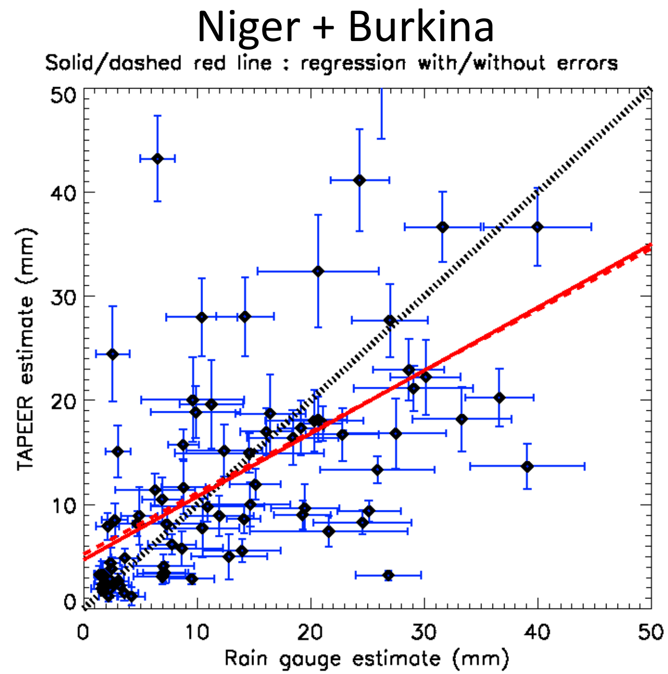
An example from the Megha-Tropiques french team



Precipitation TAPR v1.0 (mm/day)



Relative Error (%)



Statistics :

Slope : 0.606 sigma : 0.087
Ordinate at origin : 4.700 sigma : 1.489
Instrinsic scatter deviation : 7.53064 sigma : 0.81791
Correlation : 0.690 sigma : 0.086
Correlation no errors : 0.619
Slope no errors : 0.587

Site	R^2	R^2_{sqrt}	RMSD (mm/d)	Biais (%)	Biaisc (%)	FAR (%)	MR (%)
Niger	**0.5**	**0.6**	**7**	**0**	**0**	**19**	**29**
Burkina	**0.7**	**0.8**	**6**	-8	-8	**6**	**13**

Outline of the presentation

- **Precipitation and climate change**
- **Quantitative precipitation estimate from satellite**
- **Usage of QPE product for climate trends analysis**
- **Conclusions and Perspectives**

Quantitative Precipitation Estimate from space

For climate related issues

FCDR MW imagers
FCDR IR imagers from GEO

GPCP venue:
-6AM/PM microwave only
-constant diurnal bias
-> for climate

TMPA venue:
-all platforms
-time varying inputs
-> for process

Our venue:
-all platforms
-time varying inputs
-elaborated error model
-> for climate
& process

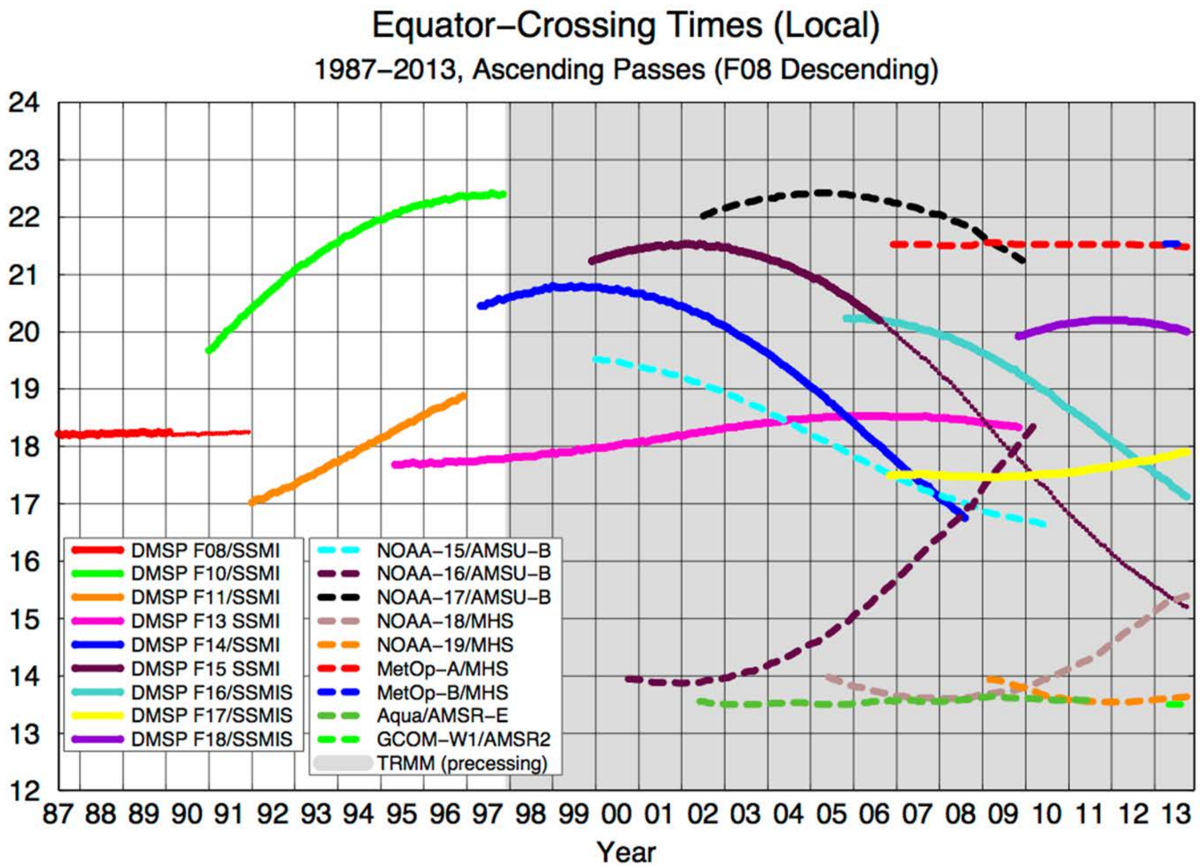


Image by Eric Nelkin (SSAI), 23 October 2013, NASA/Goddard Space Flight Center, Greenbelt, MD.

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

Rely on GSCICS effort — Preliminary results next — We have one model

Climate trends using uncertainty information

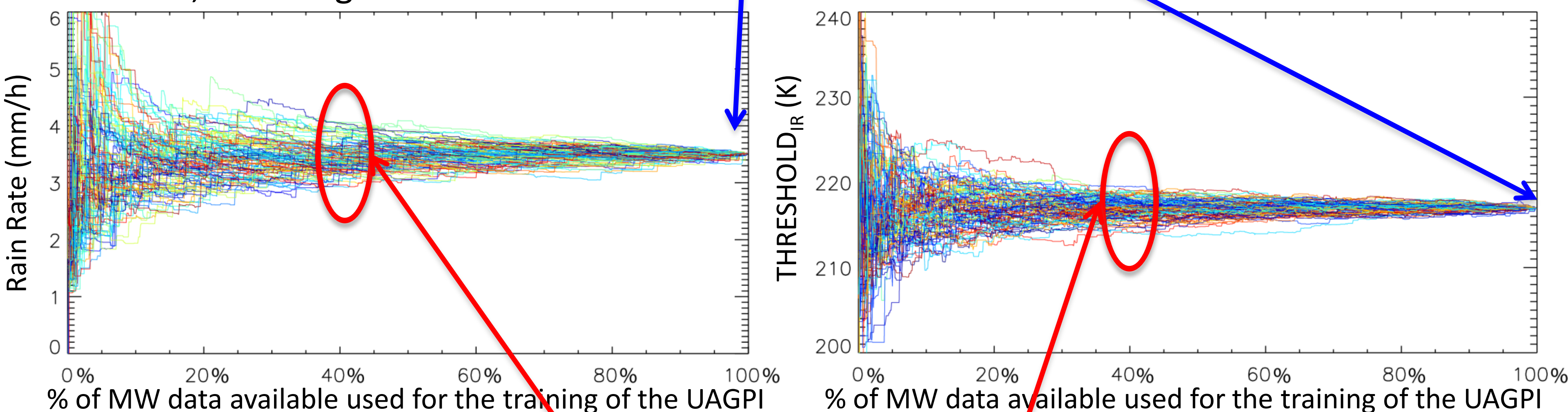
Error model depending on the amount of availabe MW observations

$RAIN_{UAGPI}$ = <Rain rate> . $ColdFrac_{IR}$. Δt   from the training data volume 5° x5° x 5 days

Sensitivity is estimated through an **ensemble of data denial experiments**

Results with all MW data available used

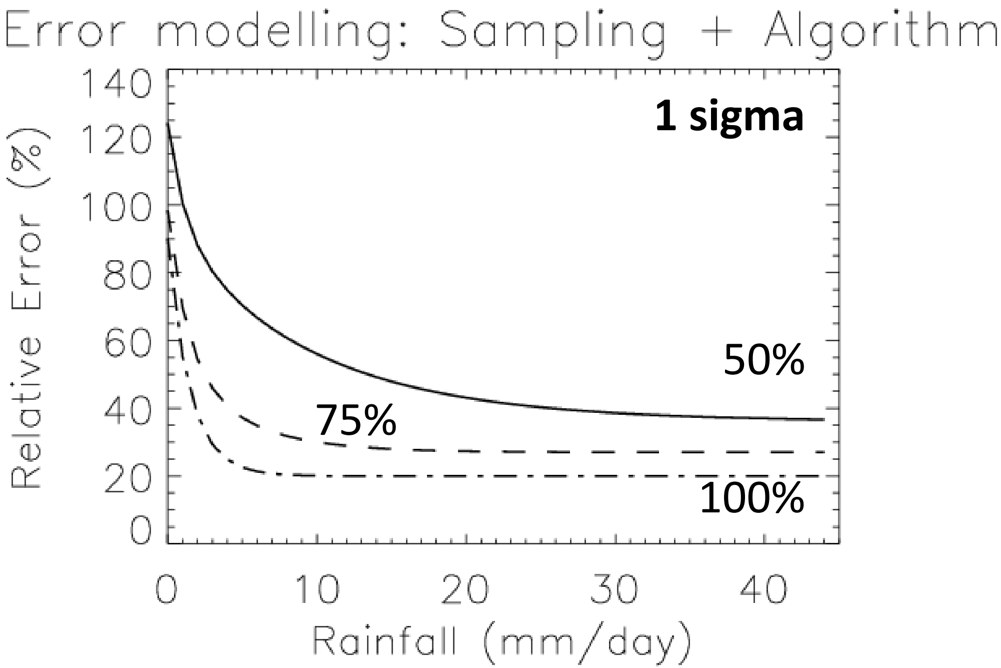
12.5°N,2°E 7 Aug 2012



Spread of the ensemble with 60% of all MW data available denied

Climate trends using uncertainty information

Idealized time-varying error model



Scenario 1: constant in time

$$E^2 \approx E^2_{Sampling}$$

Scenario 2: time varying

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

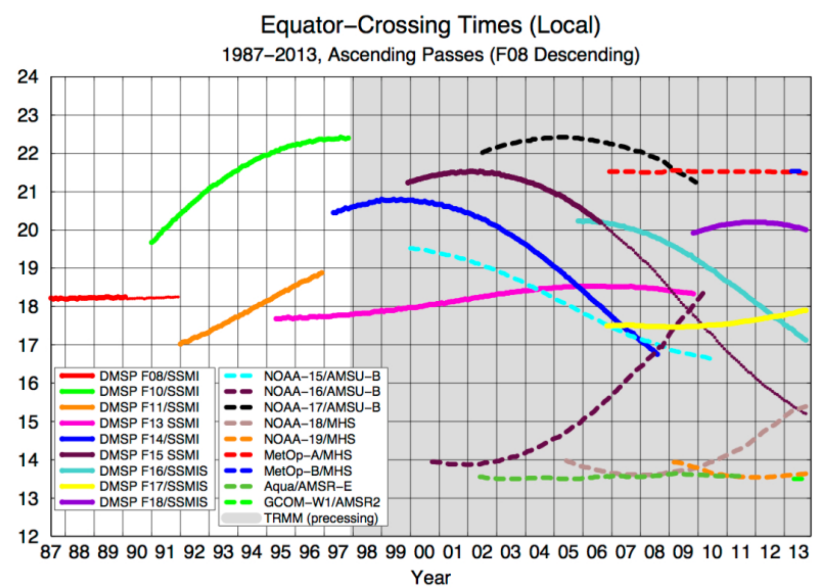
Time varying inputs

Assuming :

-50% of the constellation for 1998-2002

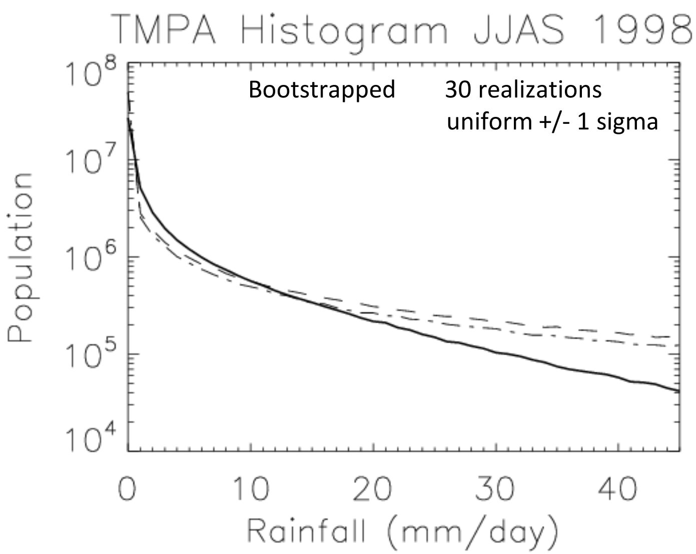
-75% of the constellation for 2003-2007

-100% of the constellation for 2008-2012



Climate trends using uncertainty information

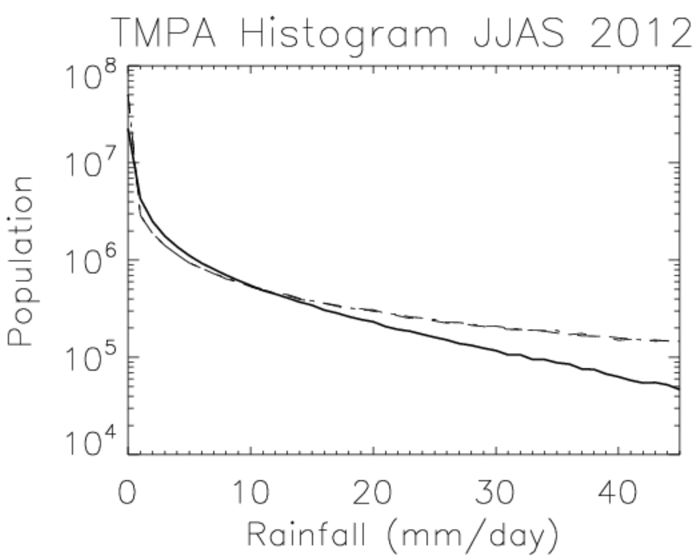
Results for the tropical band 30°S-30°N based on the TMPA product

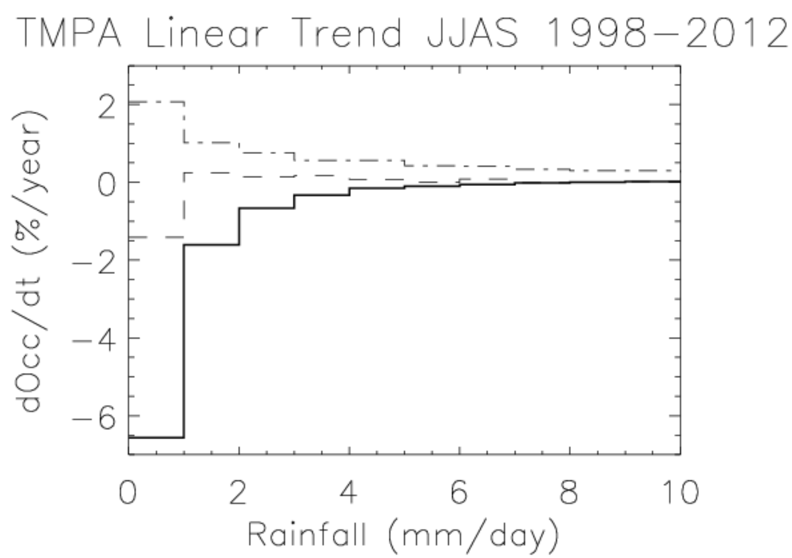


No uncertainty:

Scenario 1 (time cte):

Scenario 2 (time varying):





Outline of the presentation

- **Precipitation and climate change**
- **Quantitative precipitation estimate from satellite**
- **Usage of QPE product for climate trends analysis**
- **Conclusions and Perspectives**

Conclusions and perspectives

Summary

Important scientific questions on the long term evolution of the rainfall

Not only the spatial average but also the distribution is needed

1°/1 day resolution

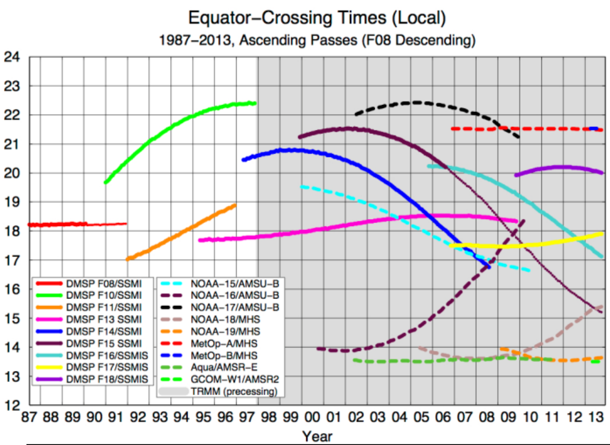
Rainfall estimation from space is a difficult task

Progress have paved the way for the MW+IR merging approach

Climate oriented products are yet to benefit from the MW constellation thinking

A framework is being developped to account for time varying data inputs thanks to uncertainty /error modelling

The MW constellation is evolving and will evolve in the futur



MWI on post-eps

Conclusions and perspectives

NASA/Goddard Space Flight Center Scientific Visualization Studio

Thank You !

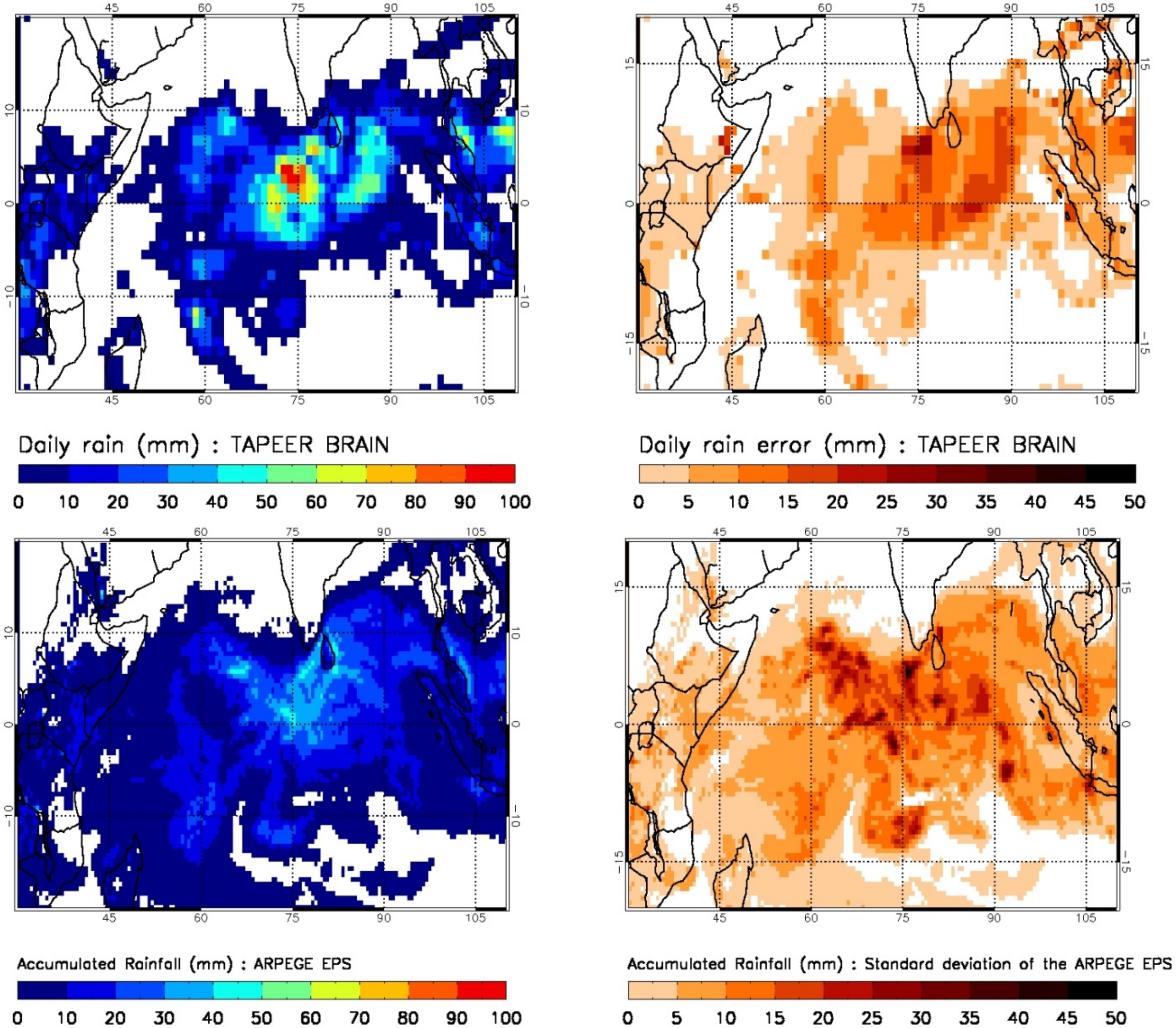
Preliminary studies using the errors

Validation of Meteo-France Ensemble Prediction System

CINDY DYNAMO campaign

TAPEER (no Madras)

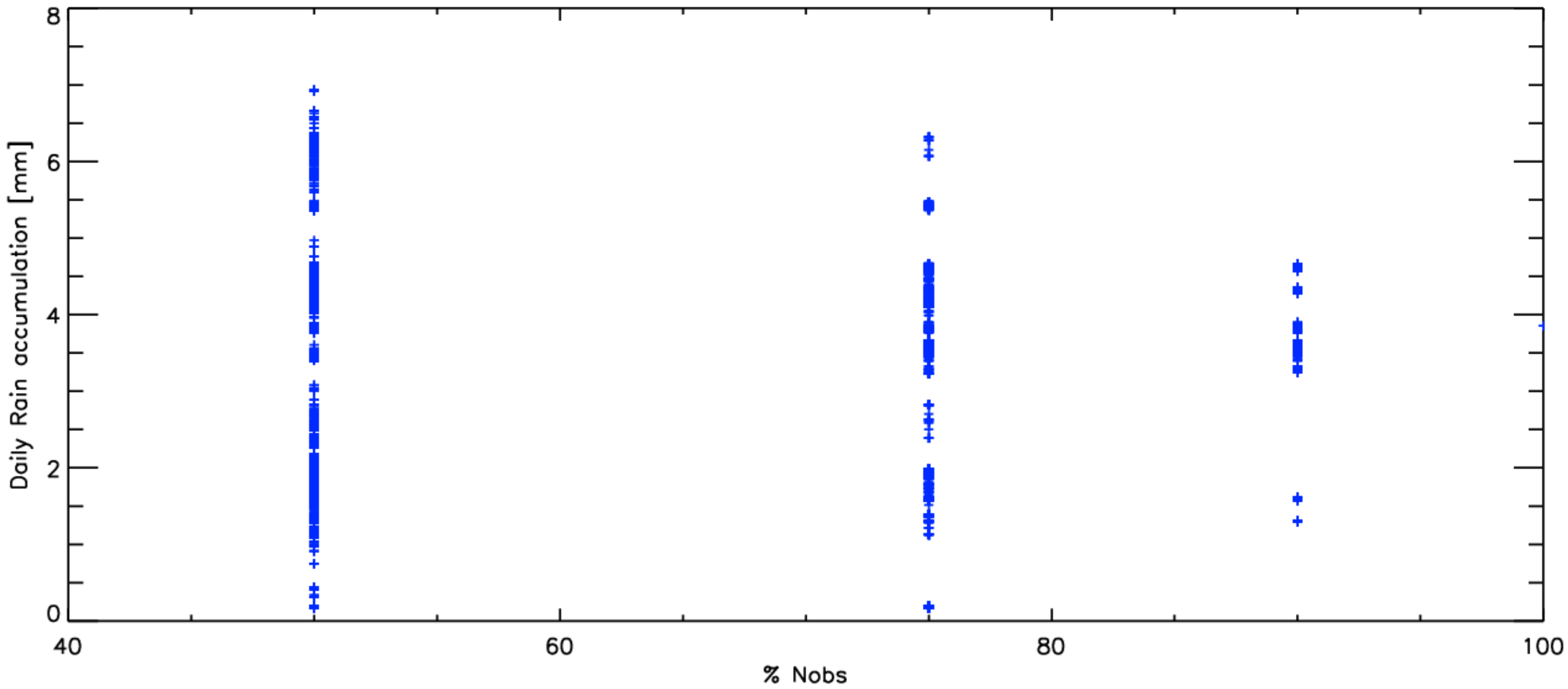
From 2011/11/23 06h, to 2011/11/24 06h



Modelling of the errors in the UAGPI

Error model depending on the amount of availabe MW observations

La valeur de référence est 3.85 mm



Pour 50 % : 3676 points, 75% : 3613 points et 90 % : 5460 points