The error model of the TAPEER rainfall estimation product

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Introduction: Within the frame of the Megha-Tropiques and GPM missions, a new algorithm, TAPEER (Tropical Amount of Precipitation with an Estimate of ERrors) has been developed. It makes use of both microwave imagers and microwave sounders data to estimate 1°/1day accumulated rainfall and its associated uncertainty overt the Tropical belt.
A first subset of the observing system (SSMI, TMI, SSMIS, AMSR2, SAPHIR), noted constellation 1, is considered over a 3°x3°x1day training volume to derive a local rain/no rain threshold IR temperature (UAGPI technique, Xu et al. 1999). BRAIN Level 2 rain rates derived from a second subset of the observing system (SSMI, TMI, SSMIS, AMSR2), noted constellation 2, are used to compute a local mean conditional rain rate **<Rcond>** over a larger training volume (5°x5°x5days). Daily rain accumulations are then computed at a 1°/1day scale by applying the local mean conditional rain rate to the cold fraction **Frac** computed with the full sample of geostationary data :

$$R = \langle Rcond \rangle \times Frac \times 24h$$

The error budget is composed of calibration errors, the algorithmic uncertainty from the merging of IR and microwave data and the uncertainty arising from the sampling limitations of the observing system :

$$S^2 = S^2_{calibration} + S^2_{algo} + S^2_{sampling}$$

Roca et al. (2010) developed a method for the computation of the sampling uncertainty and Chambon et al. (2012) showed that it significantly exceeds the calibration term.

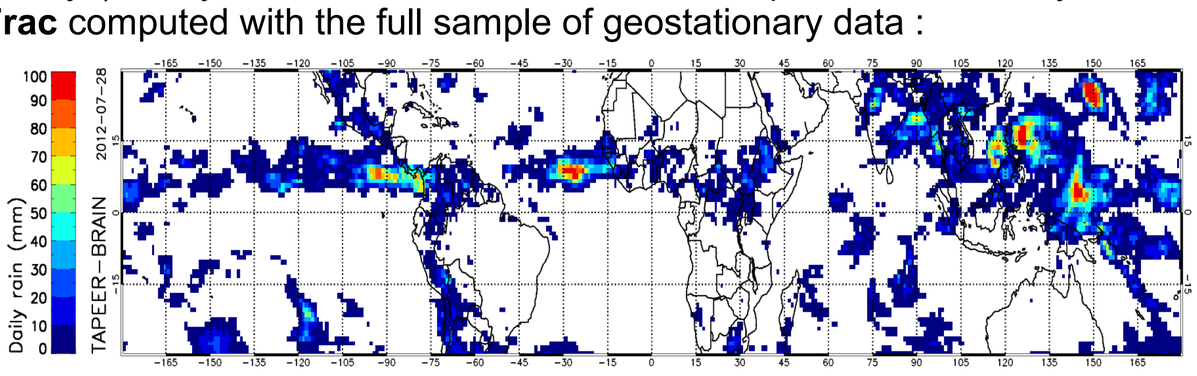


Fig.1: Example of TAPEER daily rain accumulation for 2012-07-28

The algorithmic error results from the propagation of the variance on the determination of <Rcond> and the threshold temperature :

$$S^2_{algo} = \langle R_{cond} \rangle^2 S^2_{Frac} + Frac^2 S^2_{\langle Rcond \rangle} + 2 \langle R_{cond} \rangle Frac \times cov(\langle R_{cond} \rangle, Frac)$$

The cold fraction variance depends on the number $Nobs_{detection}$ of imager and sounder pixels used in constellation 1 to determine the threshold temperature and <Rcond> variance depends on the number $Nobs_{Rcond}$ of imager pixels used in constellation 2.

- The cold fraction variance is determined using Monte Carlo data denial experiments in which we draw subsamples of the MW data available for a 2012 reference constellation.

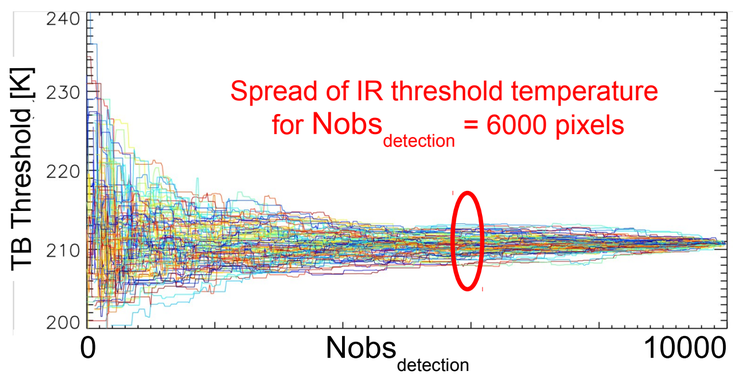


Fig.2: Rain / no rain IR threshold temperature as a function of $Nobs_{detection}$. Each line represents a realisation of the successive integration of MW data.

The propagated variances are then fitted as a function of the daily rain accumulation for various ranges of the number $Nobs_{Rcond}$ of pixels.

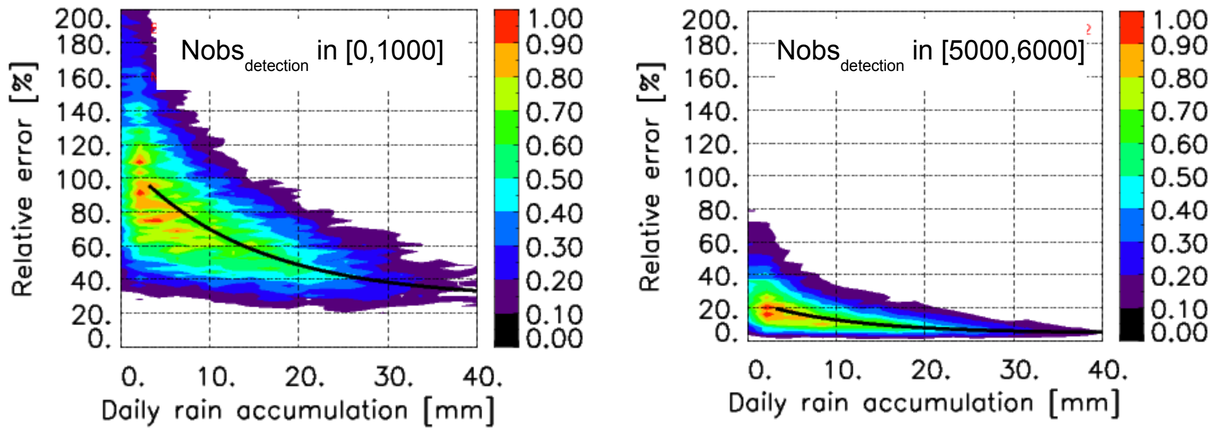


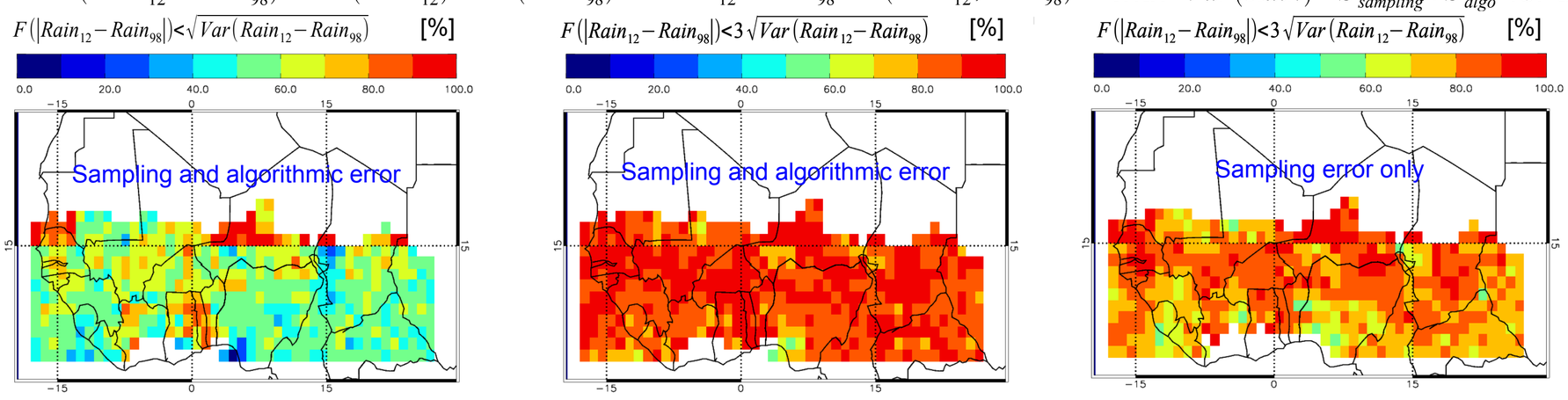
Fig.3: $\langle R_{cond} \rangle S_{Frac}$ uncertainty term and their exponential fits as a function of the daily precipitation for 2 bins of $Nobs_{detection}$.

- The mean conditionnal rain rate variance is given by the uncertainty on the mean estimation from $Nobs_{Rcond}$ pixels : $S_{\overline{Rcond}} = \sigma_{Rcond} / \sqrt{Nobs_{Rcond}}$
- We computed the cross term using cross covariance calculation and found it to be negligible compared to the first two terms. Therefore the algorithmic error is modeled as follows:

$$S^2_{algo} = [Fit(\overline{Rcond}\, S_{Frac})]^2 + Frac^2 \sigma^2_{Rcond} / Nobs_{Rcond}$$

Application to rain estimates using 2012 and 98-like MW constellations: We calculated the rain accumulation over West Africa with our 2012 reference MW constellation and with a 1998 like degraded MW constellation (2 SSMIS instruments and TMI). We computed the sampling errors as well as the algorithmic errors using our model. In order to determine the TAPEER grid points where our error model explains the 2012 and 1998 accumulation differences we computed the variance of those differences :

$$Var(Rain_{12} - Rain_{98}) = Var(Rain_{12}) + Var(Rain_{98}) - 2\, Rain_{12} \times Rain_{98}\, cov(Rain_{12}, Rain_{98})$$ with $Var(Rain) = S^2_{sampling} + S^2_{algo}$ for the 2012 and 98like estimates.



Accounting for the algorithmic uncertainties in addition to the sampling error, allows us to significantly improve the agreement between TAPEER rainfall estimations obtained from various constellations.

Fig.4: Percentage of days over 3 months where the $Rain_{12}$-$Rain_{98}$ difference is explained by the error model
Left : 1 time the sampling and algorithmic error Center : 3 times the sampling and algorithmic error Right : 3 times the sampling error

Conclusions : We developed a model for algorithmic uncertainties arising from the UAGPI method and combined it with the sampling error model. We applied our model to a 98-like constellation and showed it explains the Rain estimates differences with those obtained with a 2012 constellation.

References:
Chambon et al, 2012, Q. J. R. Meteorol. Soc.
Roca et al., 2010, J. Appl. Meteorol.and Climatol., 49(4), 715-731
Xu et al., 1999, J. Appl. Meteorol., 38(5), 569-579

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