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Uncertainty Quantification for GPM-era Precipitation Measurements

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Outline

What we learned from TRMM-era measurements --

“The Error Structure”

1. concepts and procedures
2. error composition
3. systematic & random errors

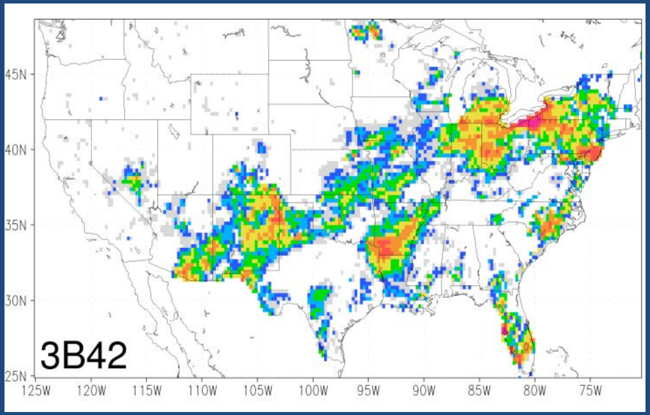
Applications of the Error Structure

4. scaling of errors
5. sources of errors

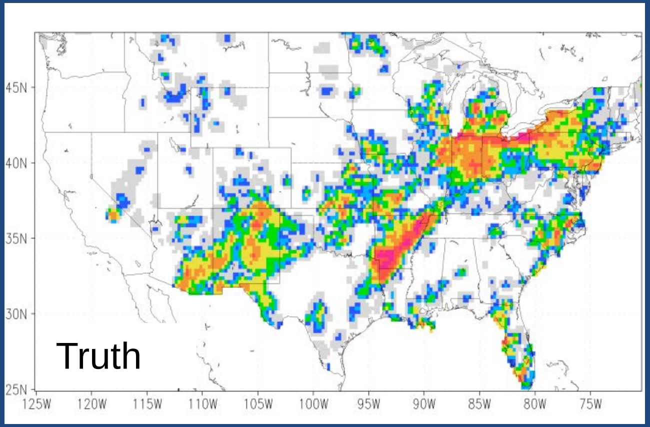
What error structure to expect with GPM-era measurements

Procedure to quantify uncertainty

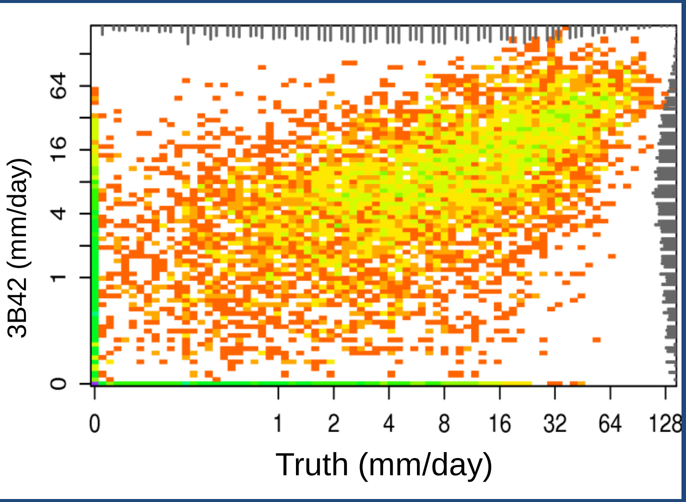
Step 1: Get a reference dataset



It is all uncertain if we know no truth



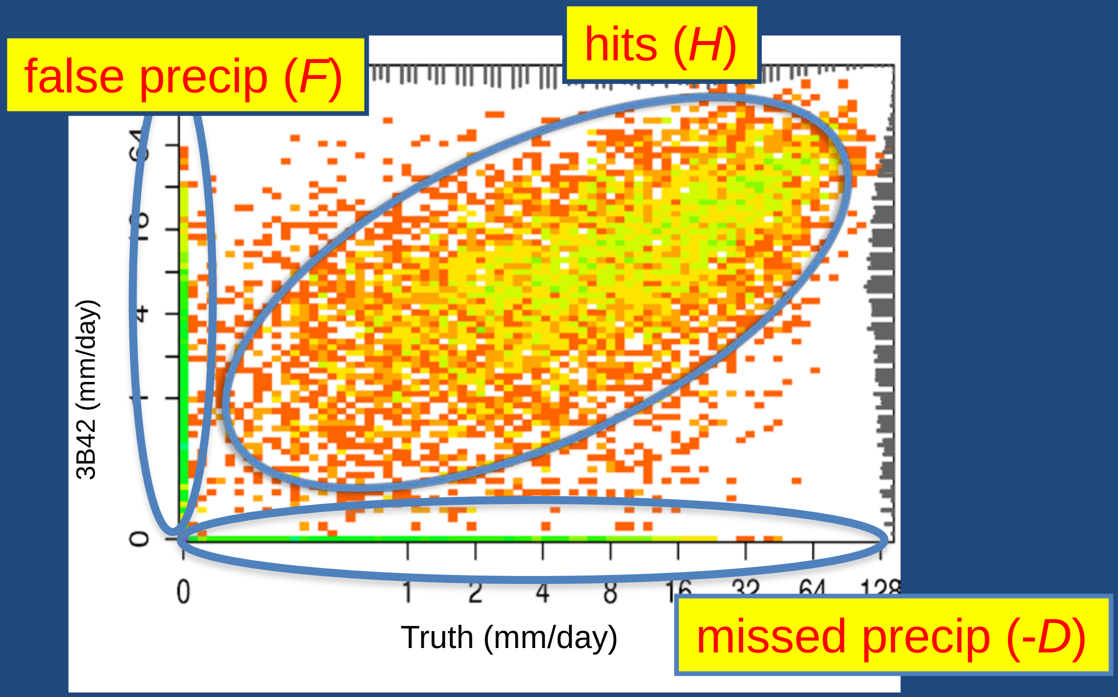
If truth is available …



Measurements can be validated

Procedure to quantify uncertainty

Step 2: Error decomposition (Tian et al., 2009)

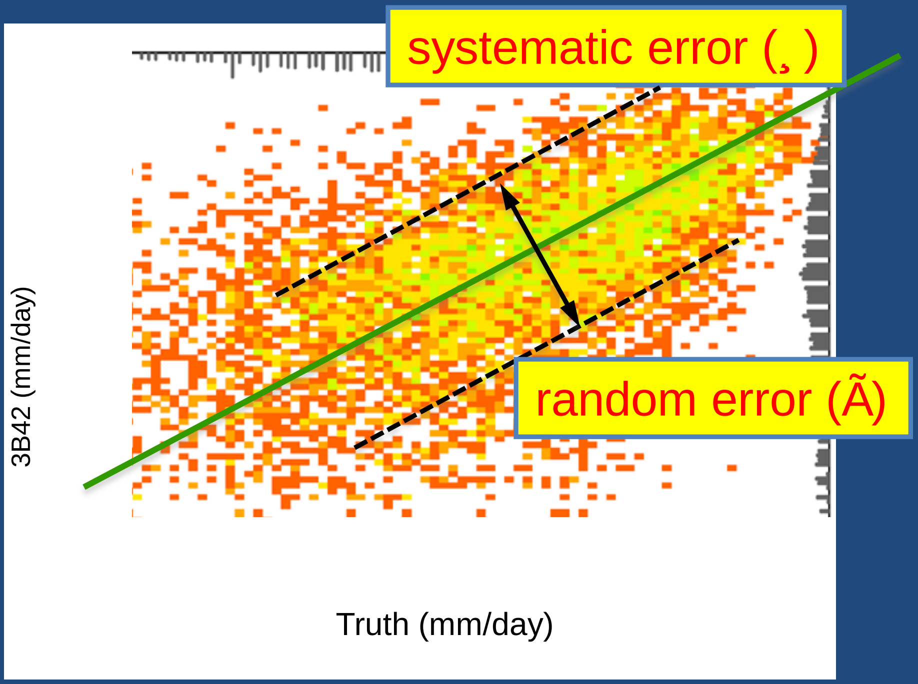


$$\underset{\text{(total error)}}{\boldsymbol{E}} = \underset{\text{(hit error)}}{\boldsymbol{H}} - \underset{\text{(missed)}}{\boldsymbol{D}} + \underset{\text{(false)}}{\boldsymbol{F}}$$

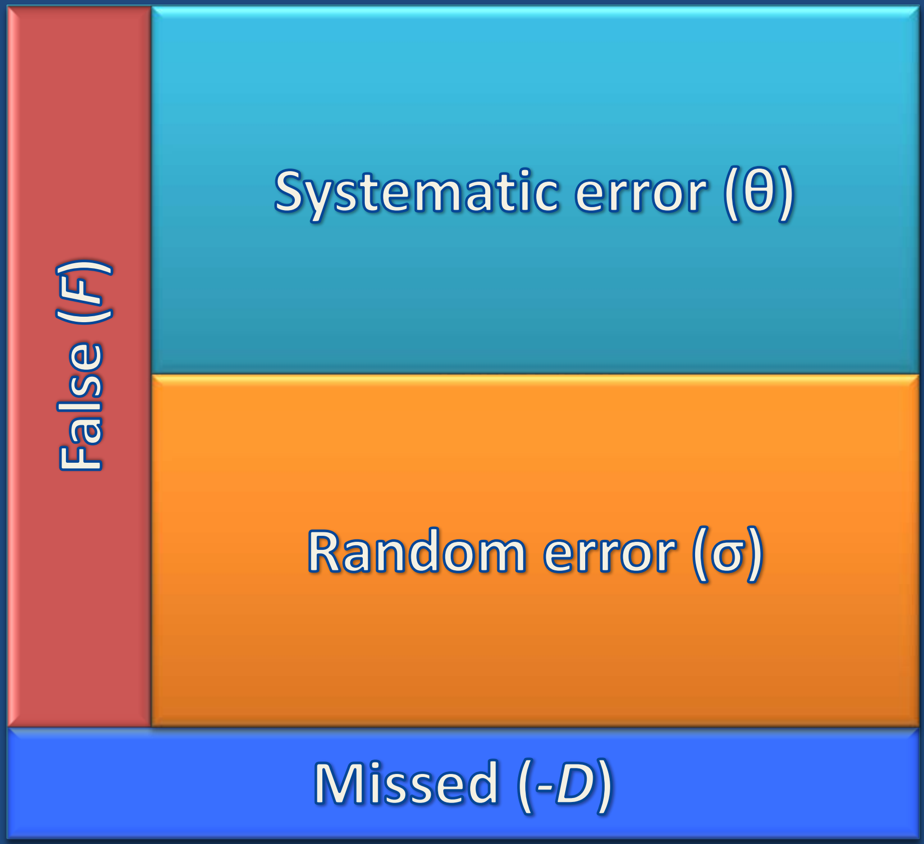
Procedure to quantify uncertainty

Step 3: Separate systematic and random error

$$E = \boxed{H} - D + F$$



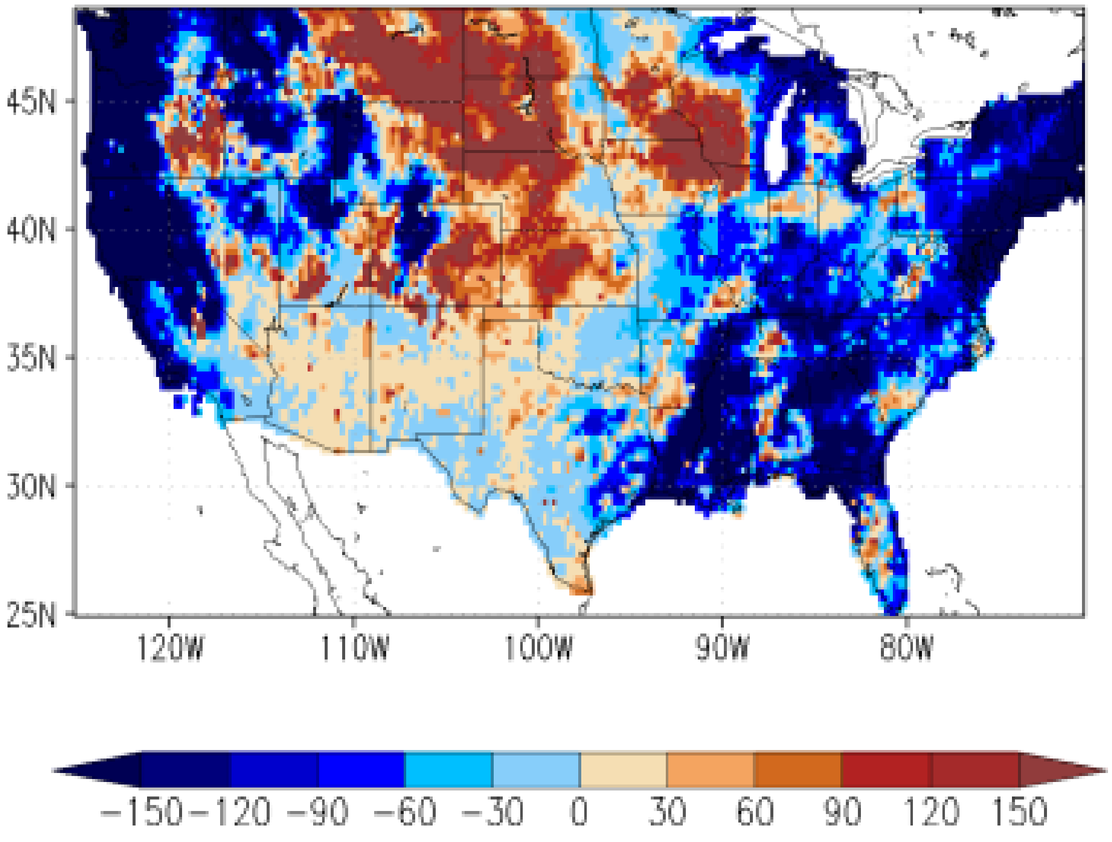
The Error Structure unifies uncertainty definition and quantification



Uncertainty quantification = $(-D, F, , , \tilde{A})$

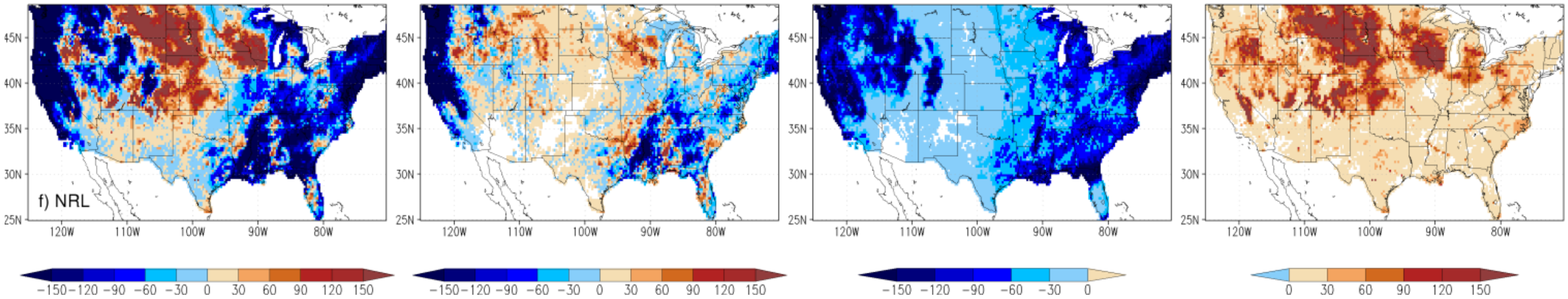
Total Error E

$$E = R - R_{ref}$$



Error Decomposition Scheme

(total error)		(hit error)		(missed)		(false)
E	$=$	H	$-$	D	$+$	F



(Tian et al., 2009)

Error Decomposition, Winter (DJF)

(total error) (hit error) (missed) (false)

$$E = H - D + F$$

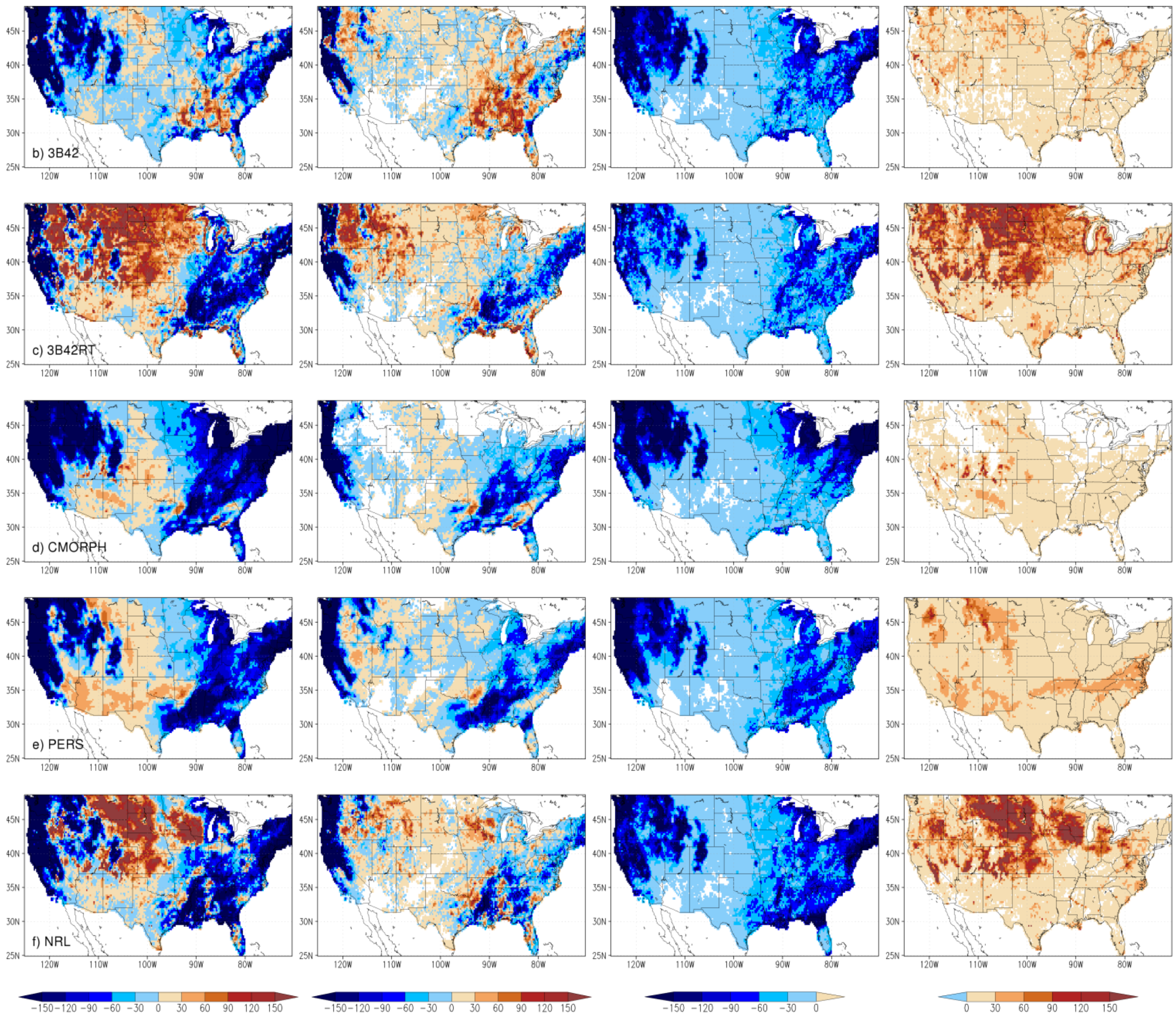
3B42

3B42RT

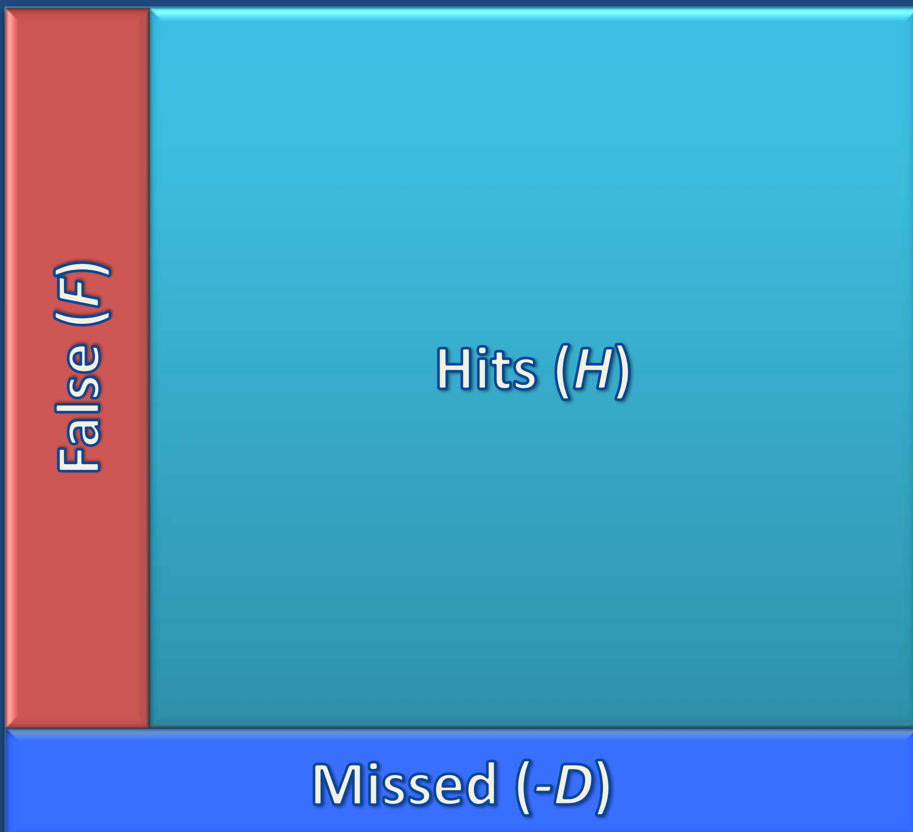
CMORH

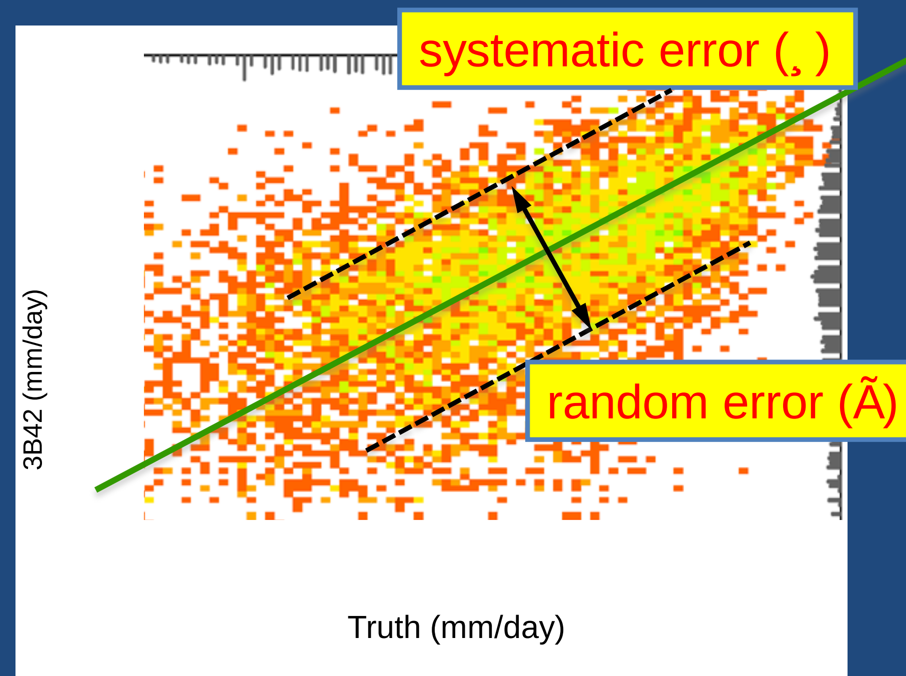
PERS’N

NRL



Determining the Error Structure – next step, hits error

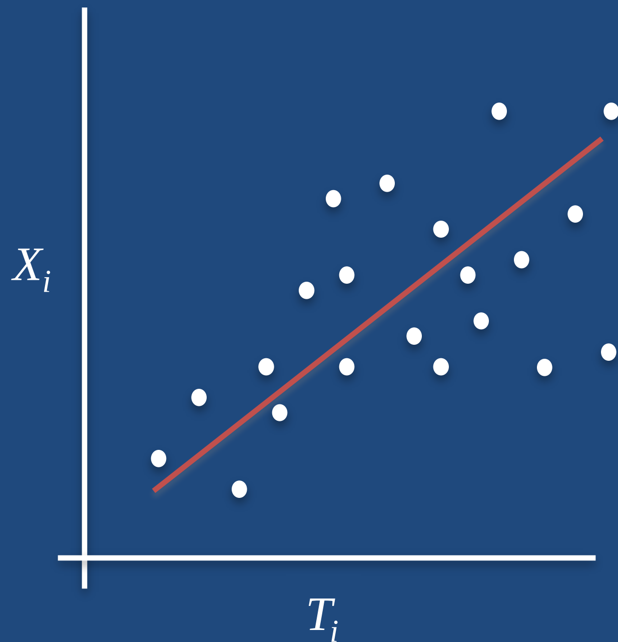




Hit error (H) is multiplicative
(Tian et al., 2014)

Additive error model

$$X_i = a + bT_i + \varepsilon$$

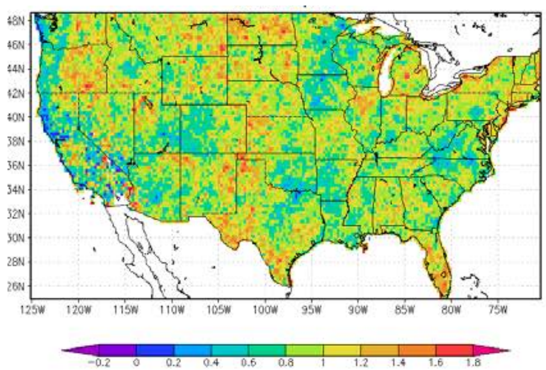
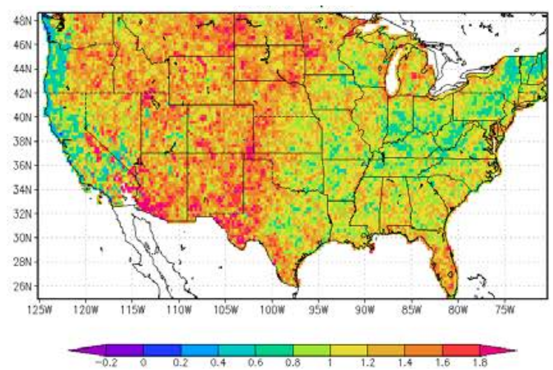
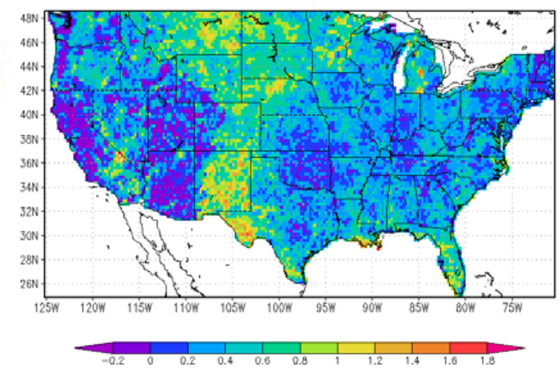
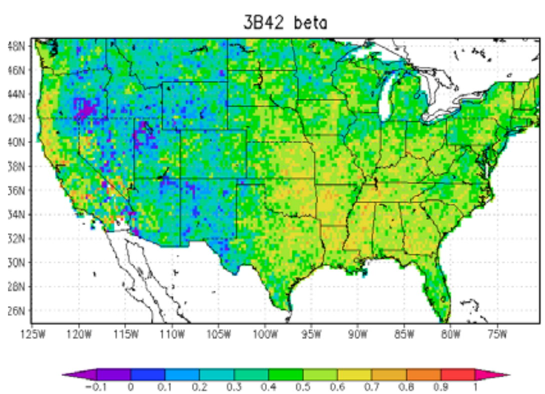
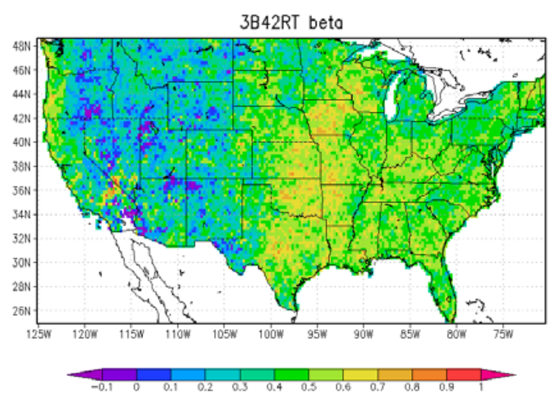
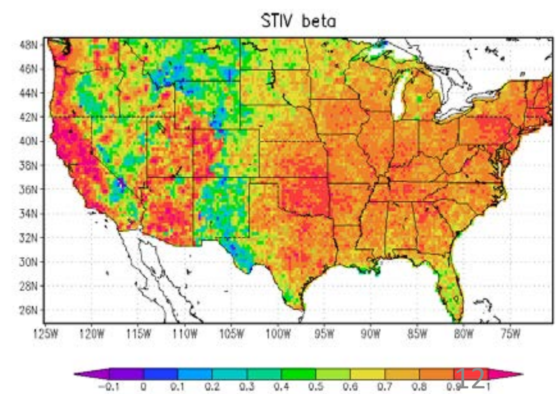


Two parameters quantify systematic error

$$X_i = \boxed{a\,T_i^{\beta}}\,e^{\varepsilon} \qquad \boxed{\sigma} = stdev(\varepsilon)$$

systematic error

±: scale error (ideal: 1)
²: shape error (ideal: 1)

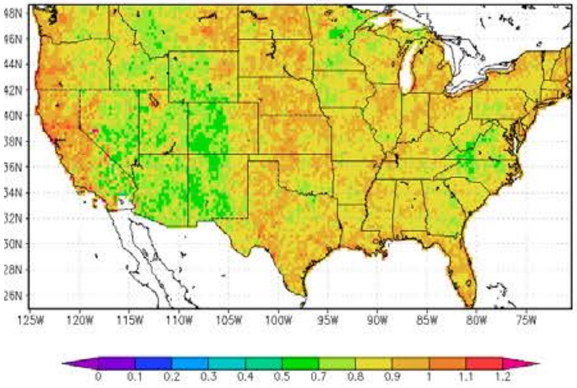
	TMPA 3B42	TMPA 3B42RT	NOAA Radar
ln(±)			
2			

One parameter quantifies random error

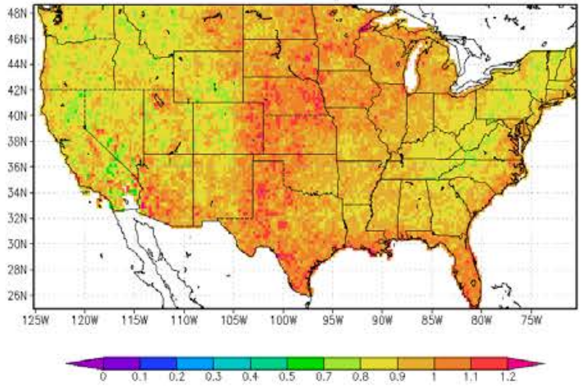
$$X_i = a\,T_i^{\beta}\,e^{\varepsilon} \qquad \boxed{\sigma} = stdev(\varepsilon)$$

Random error $\tilde{A}$: (ideal: 0)

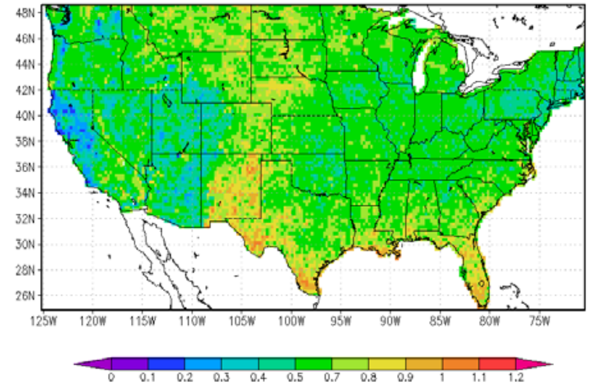
TMPA 3B42



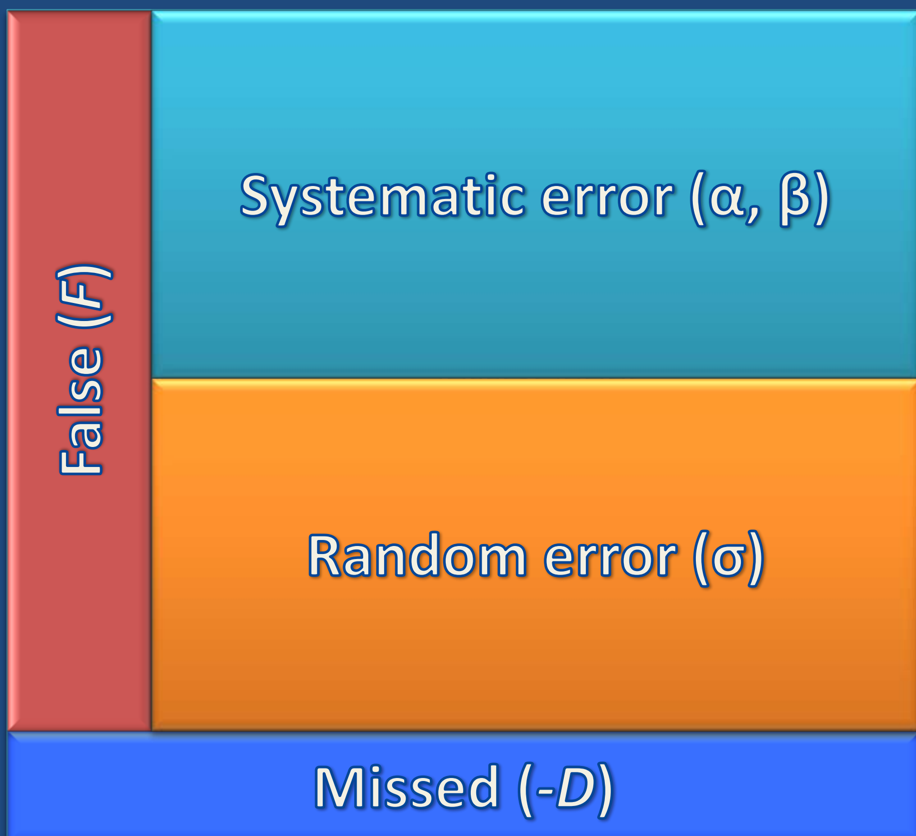
TMPA 3B42RT



NOAA Radar

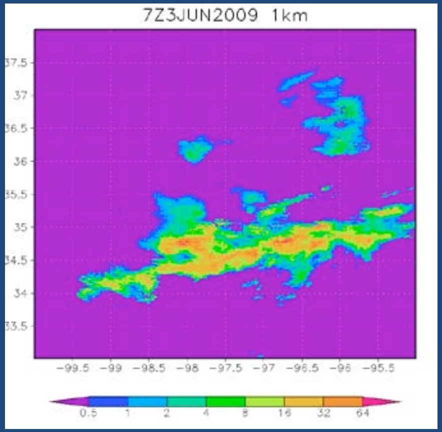


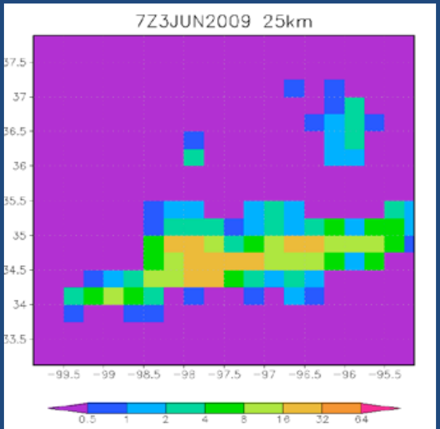
Procedure of uncertainty quantification – 3 steps to the Error Structure



Uncertainty quantification = $(-D, F, \pm, {}^{2}, \tilde{A})$

Scaling of errors: how Error Structure changes with space/time scales





False (*F*)

Systematic error (α, β)

Random error (σ)

Missed (-*D*)

False (*F*)

Systematic error (α,β)

Random error (σ)

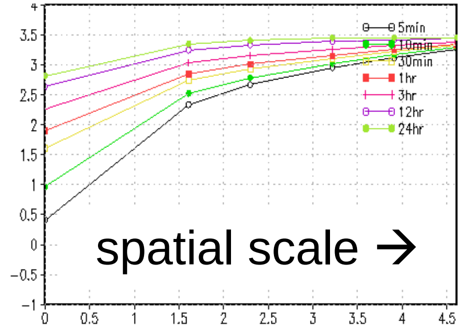
Missed (-*D*)

How systematic and random errors vary with space/time scales

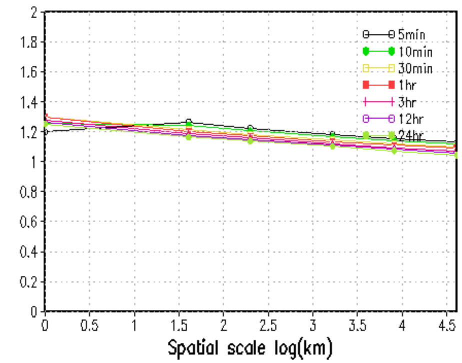
$$\boxed{\begin{aligned} X_i &= \alpha T^{\beta}{}_i \, e^{\varepsilon} \\ \sigma &= stdev(\varepsilon) \end{aligned}}$$

Systematic errors (α, β)

scale error ln(±)

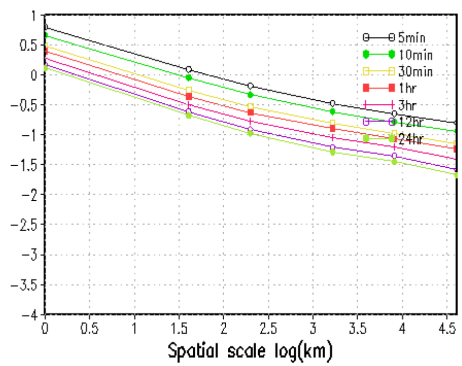


shape error (²)

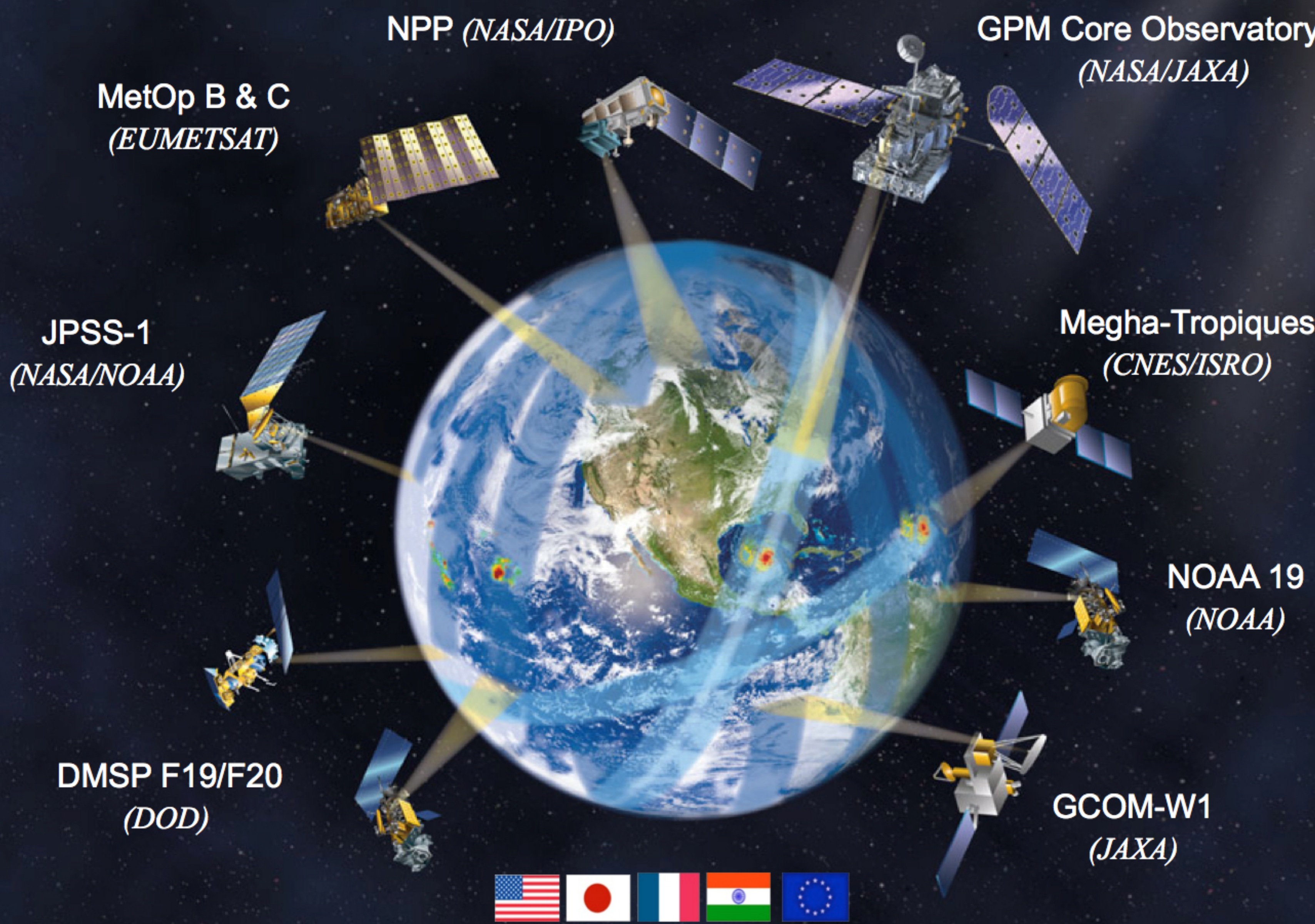


Random errors σ

random error (Ã)



GPM Constellation of Satellites



Errors can be traced back to Level-2 retrievals

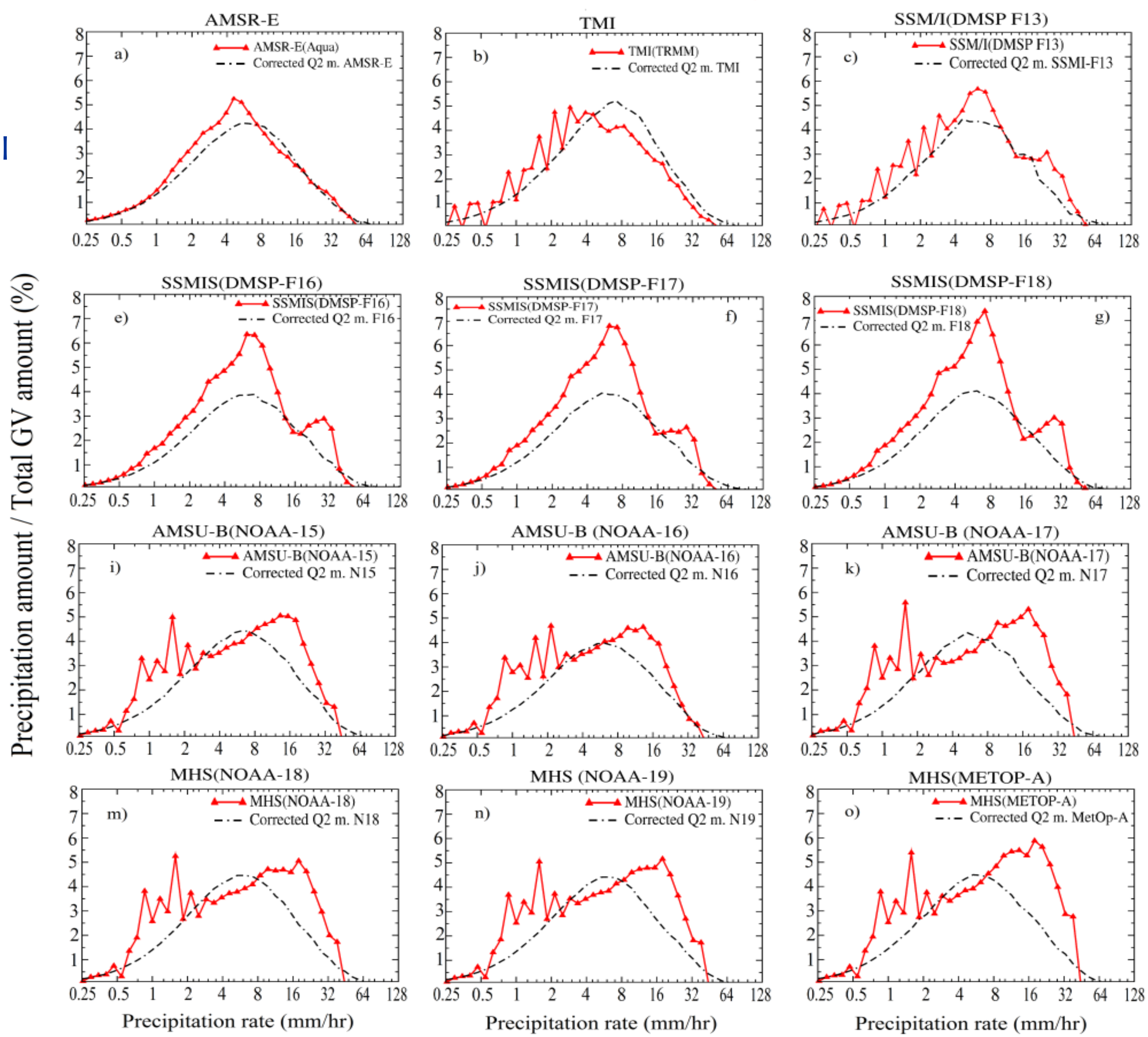
(Tang, Tian & Lin, 2013; Poster #Z42 today)

AMSR-E/TMI/SSMI

SSMIS

AMSU-B

MHS

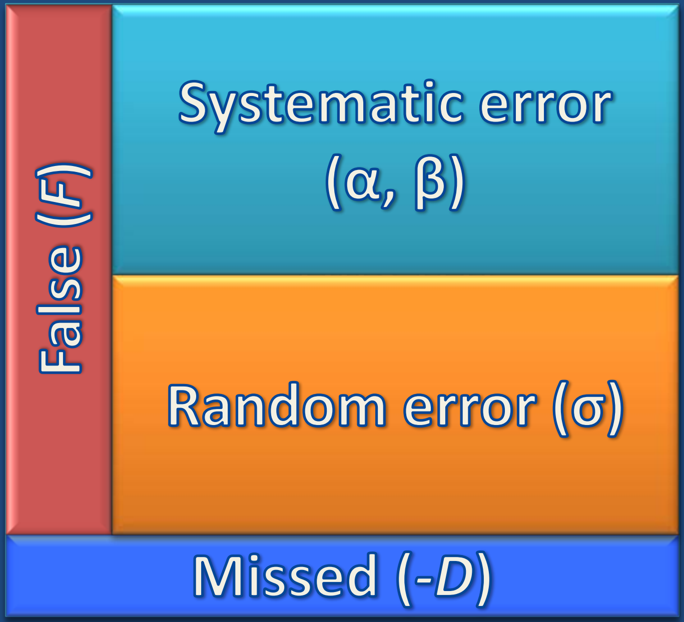


Summary

What we learned from TRMM-era measurements:

The Error Structure and procedures to determine it

1. concepts and procedures
2. error composition
3. separation of systematic
   & random errors

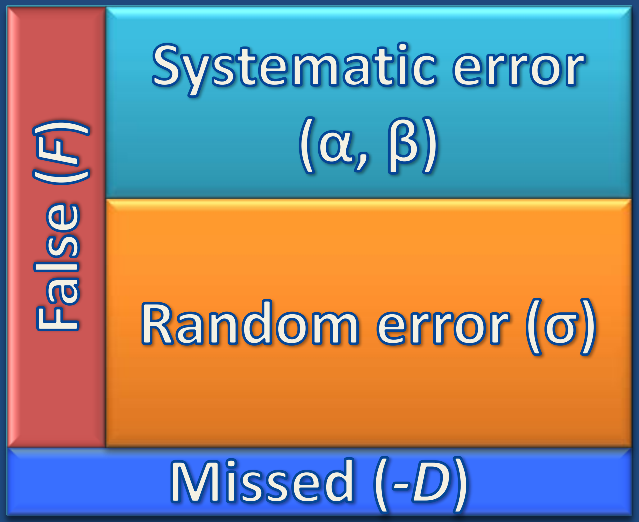


4. scaling of errors
5. sources of errors

Summary

What uncertainty do we expect from GPM-era measurements

1. Missed precipitation (-D): reduced
2. False precipitation (F): reduced
3. systematic errors (α, β): slight to moderate improvement
4. random errors (σ): ~same, but higher at higher resolution



References

Tang, L, Y. Tian, and X. Lin, 2014: Validation of precipitation retrievals from satellite-based passive microwave sensors, J. Geophys. Res., 119, doi:10.1002/2013JD020933.

Tian, Y., C. Peters-Lidard, J. Eylander, R. Joyce, G. Huffman, R. Adler, K.-L. Hsu, F. J. Turk, M. Garcia, and J. Zeng (2009), Component analysis of errors in satellite-based precipitation estimates, J. Geophys. Res., 114, D24101, doi:10.1029/2009JD011949.

Tian, Y., G. Huffman, R. Adler, L. Tang, M. Sapiano, V. Maggioni, and H. Wu, 2014: Modeling errors in daily precipitation measurements: additive or multiplicative? Geophys. Rev. Lett., 40, doi:10.1002/grl.50320.