Precipitation Error Structure and Representation

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"Uncertainty is like happiness – everyone wants it, and everyone has their own idea of what it is."

-- Y. Tian

Outline

1. Precipitation errors are complex

2. Structure of precipitation errors

3. Communication of precipitation error and uncertainty

1. Precipitation errors are complex

-- Physical

* Nonlinearity
* Intermittency
* Non-Gaussian

-- Conceptual

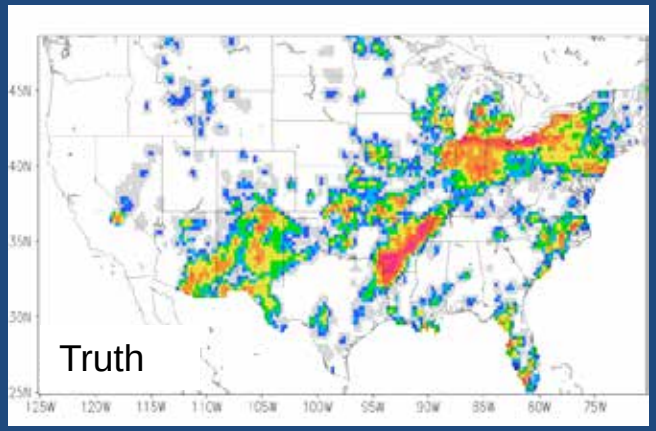
sampling error, retrieval error, systematic error, random error, missed and false error, additive error, multiplicative error, type I error, type II error, signal, noise, …

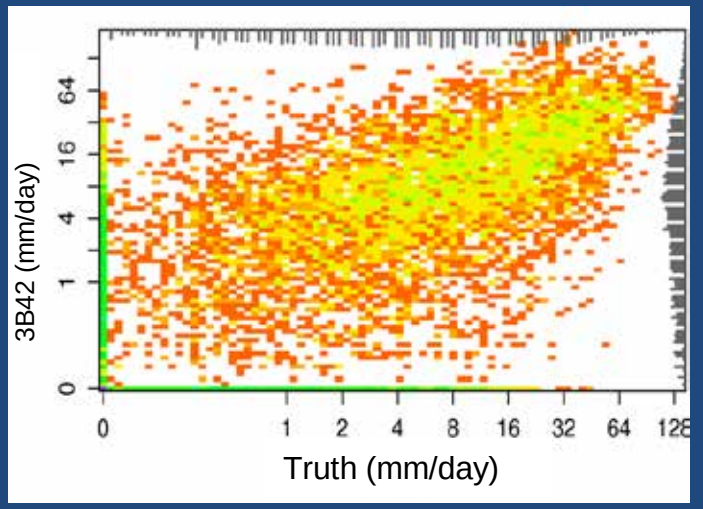
What do they do to uncertainty?

2. Error structure of precipitation measurements

Measurements

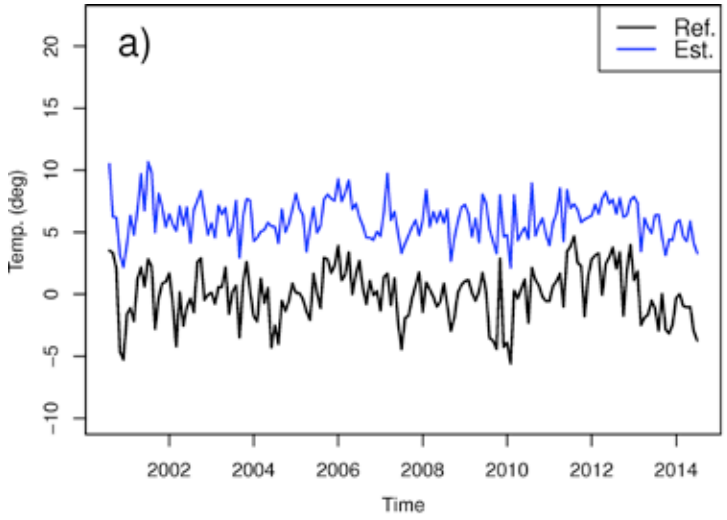
Truth



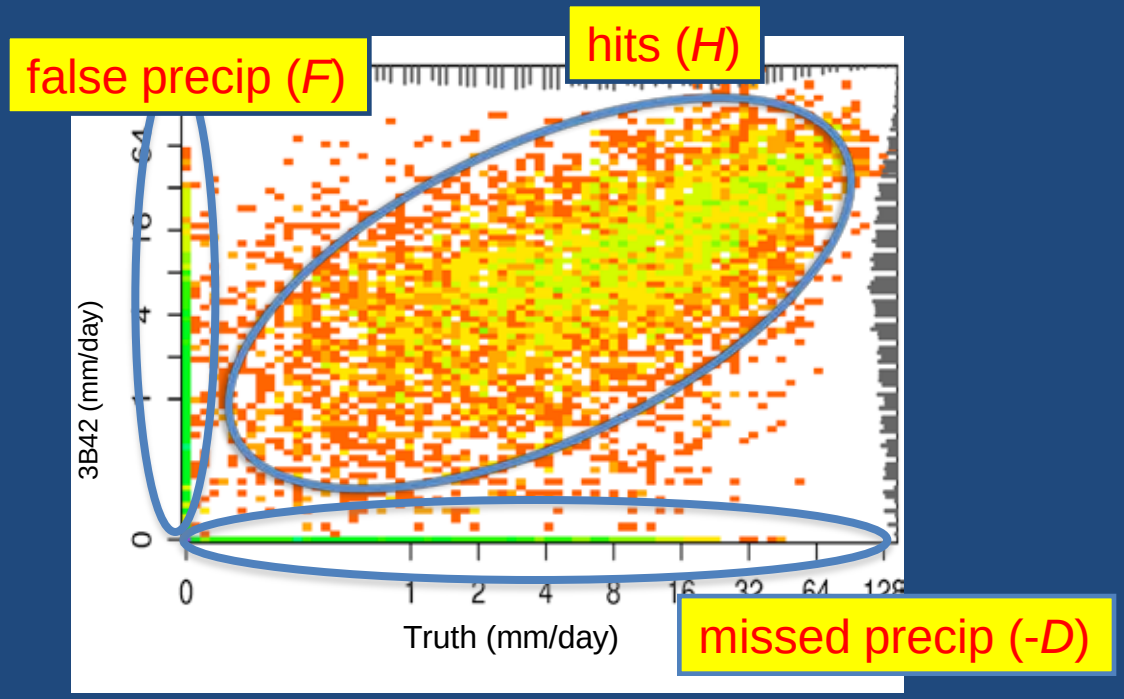


Measurements can be validated

Conventional validation is not enough for error representation



Error comes in three components (Tian et al., 2009)



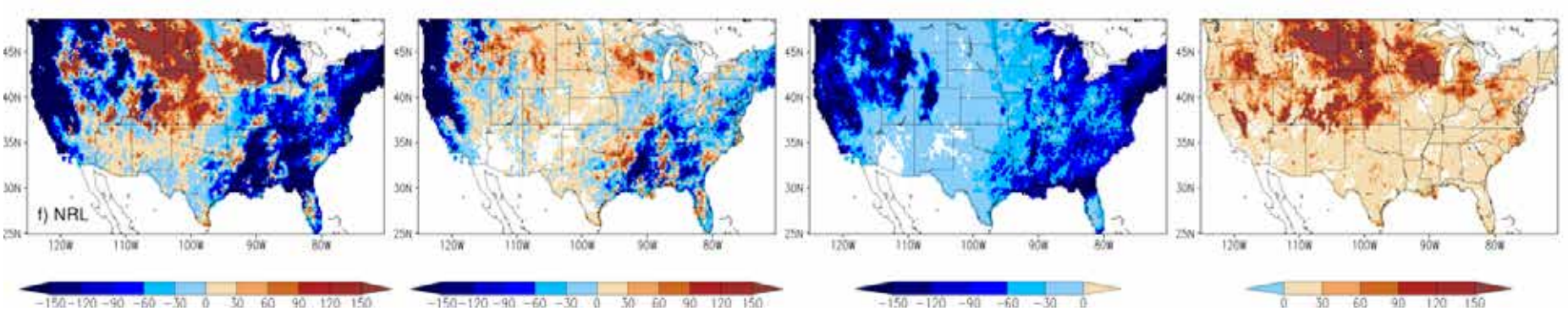
(total error) (hit error) (missed) (false)

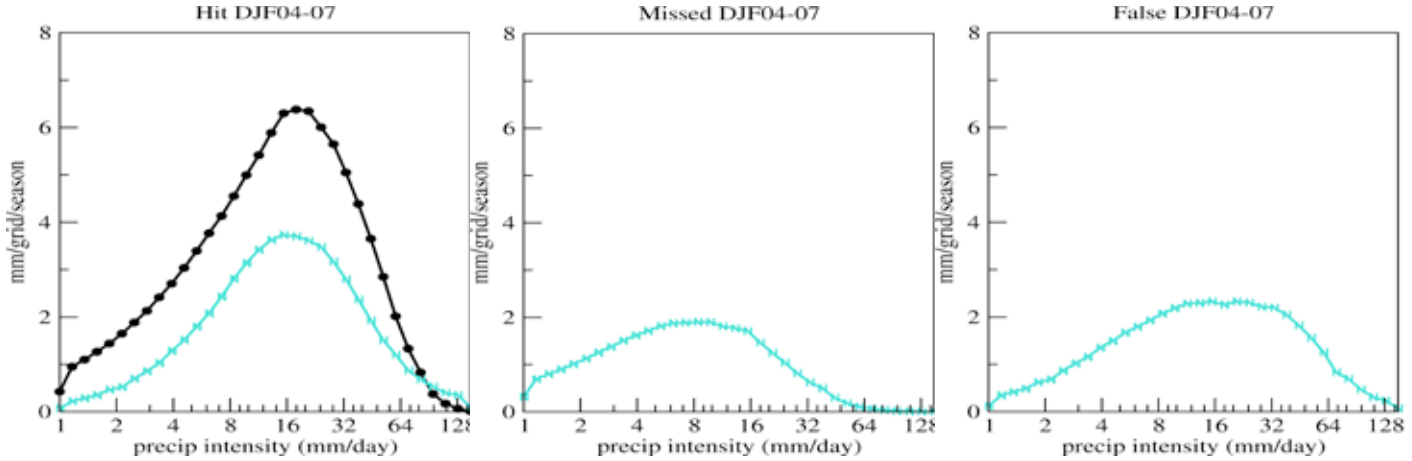
$$E = H - D + F$$

New Error Decomposition Scheme

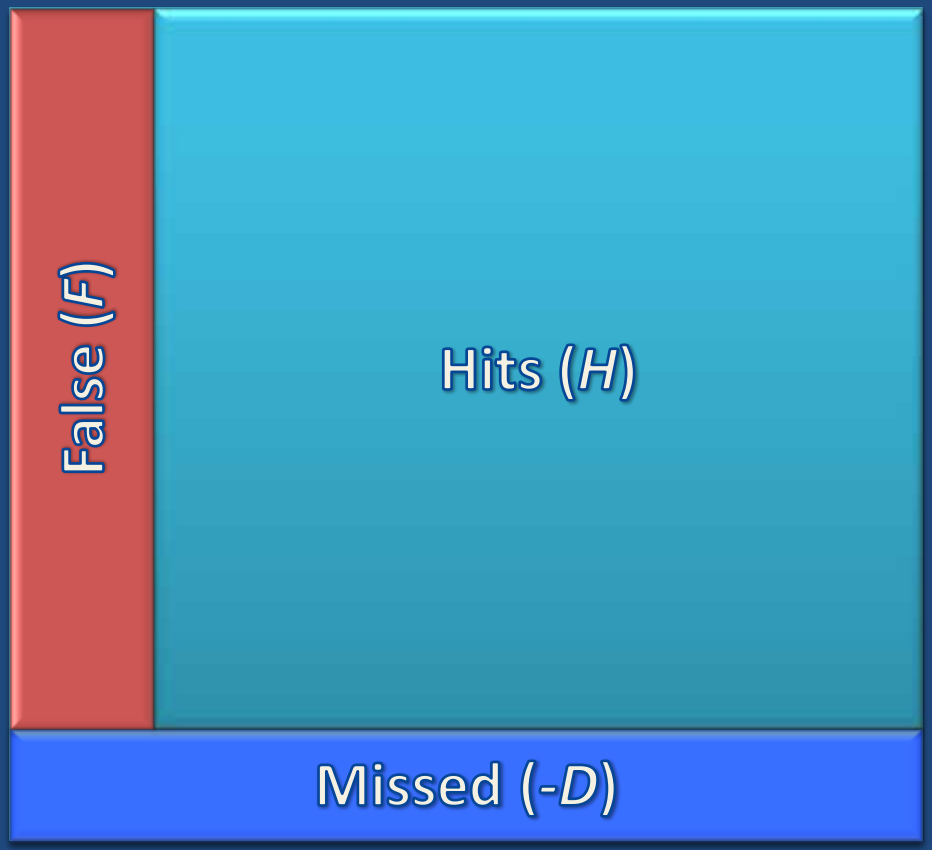
(total error) (hit bias) (missed) (false)

$$E = H - D + F$$

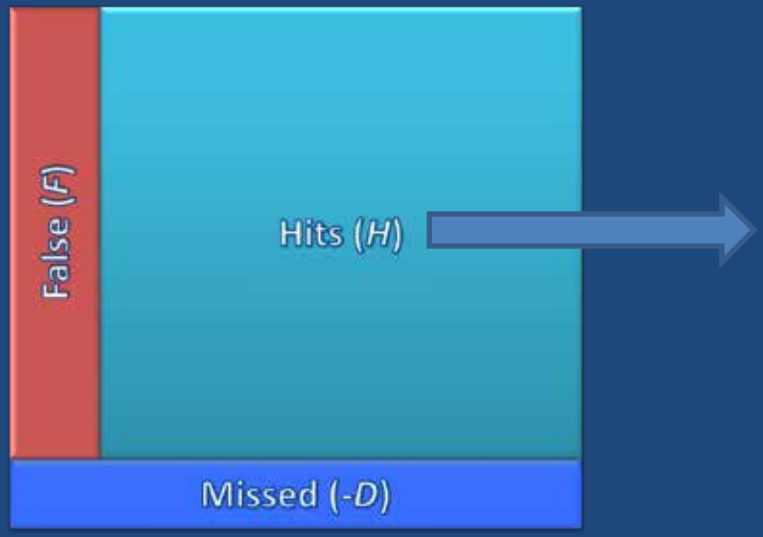


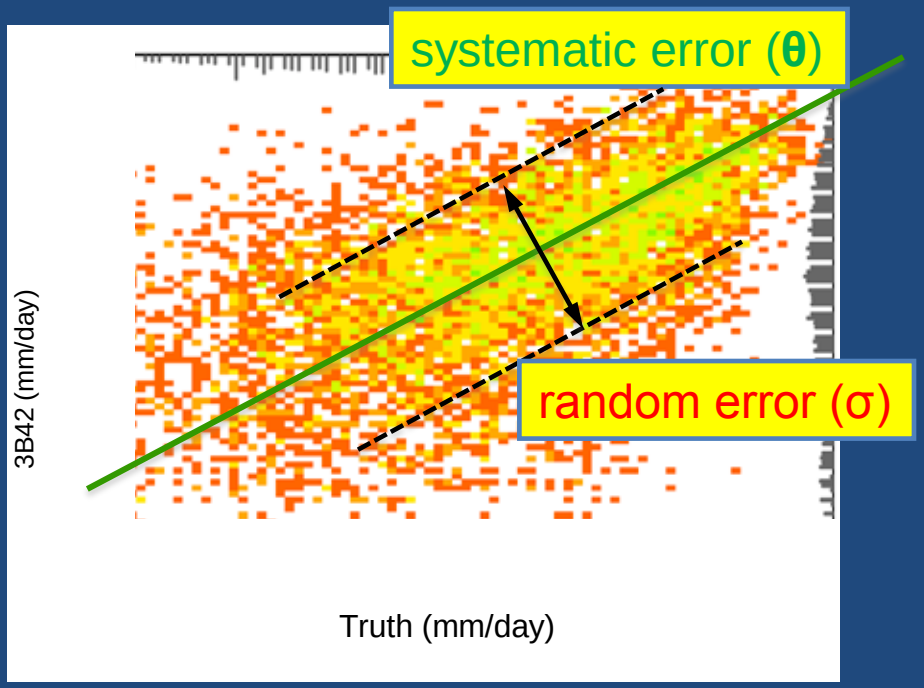


Precipitation error comes in three components



Each error component can be separated into systematic and random error





Epistemology of uncertainty

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systematic error | random error

deterministic | stochastic

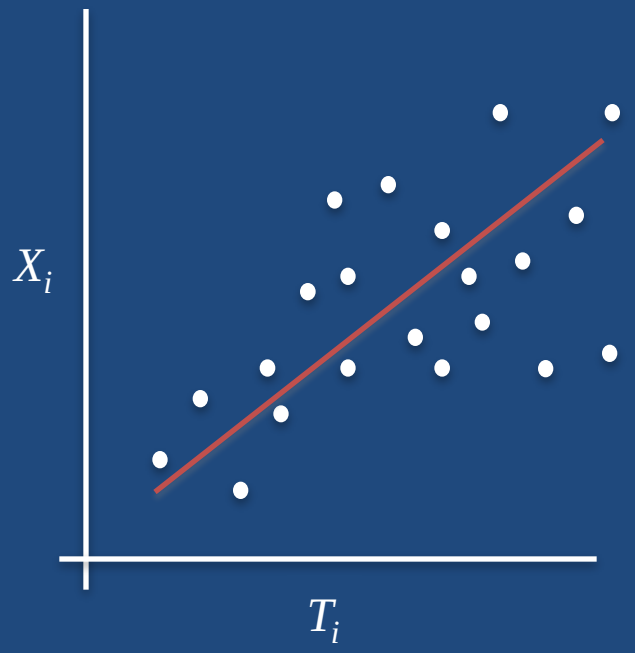
knowledge | ignorance

certainty | uncertainty

An error model is needed to separate systematic and random errors

Linear, additive error model

$$X_i = a + bT_i + e$$



Two parameters quantify systematic error

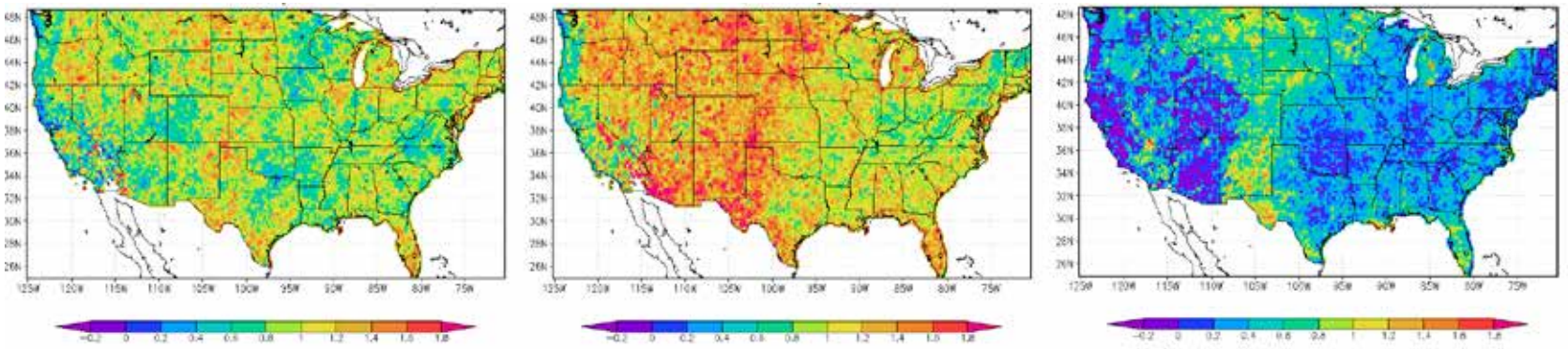
$$X_i = a\,T_i^{\beta}\,e^{\varepsilon} \qquad \sigma = stdev(\varepsilon)$$

systematic error

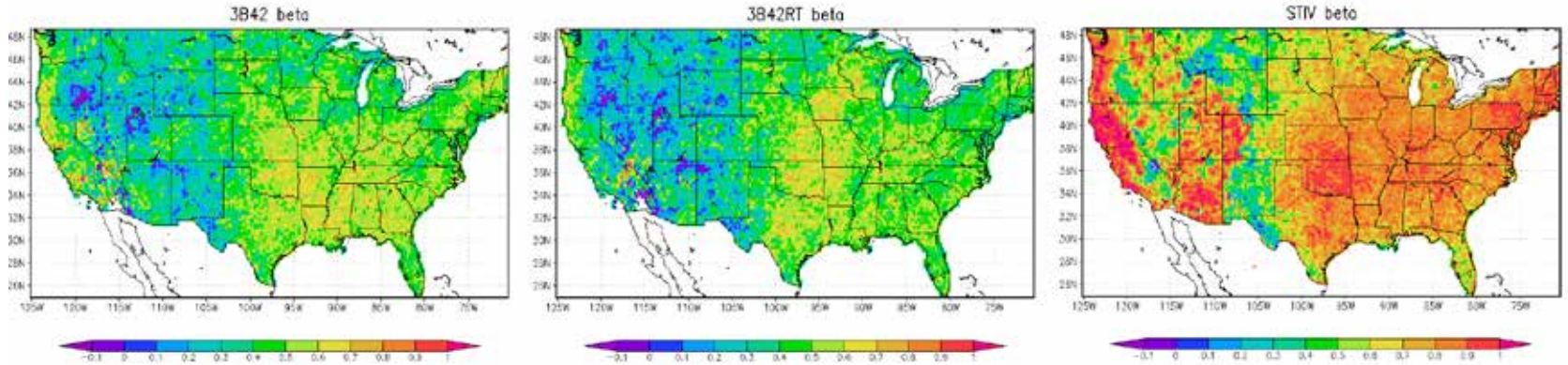
α: scale error (ideal: 1)
β: shape error (ideal: 1)

TMPA 3B42 | **TMPA 3B42RT** | **NOAA Radar**

ln(α)



β

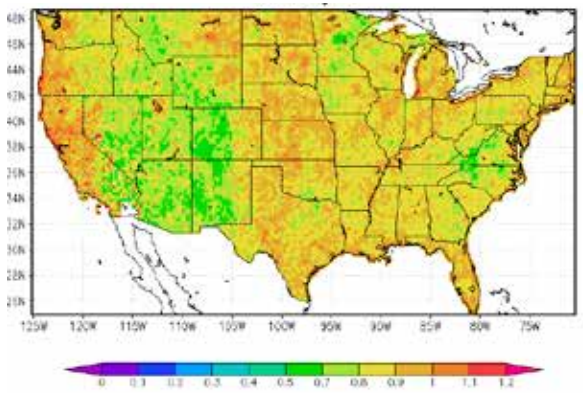


One parameter quantifies random error

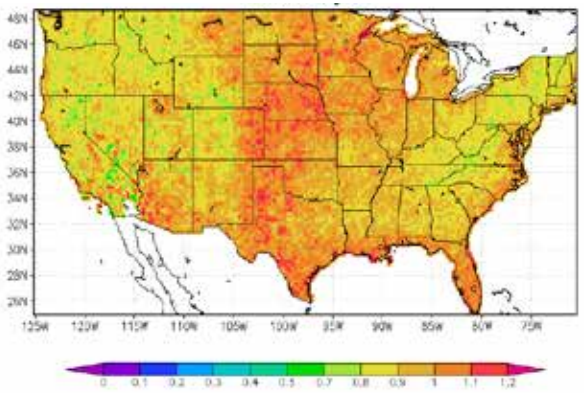
$$X_i = a\,T_i^{\beta}\,e^{\varepsilon} \qquad \sigma = stdev(\varepsilon)$$

Random error σ: (ideal: 0)

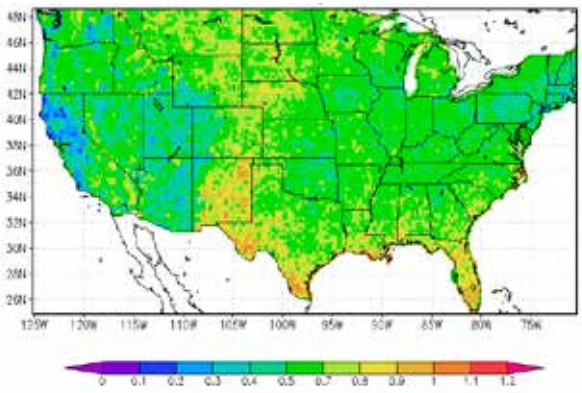
TMPA 3B42



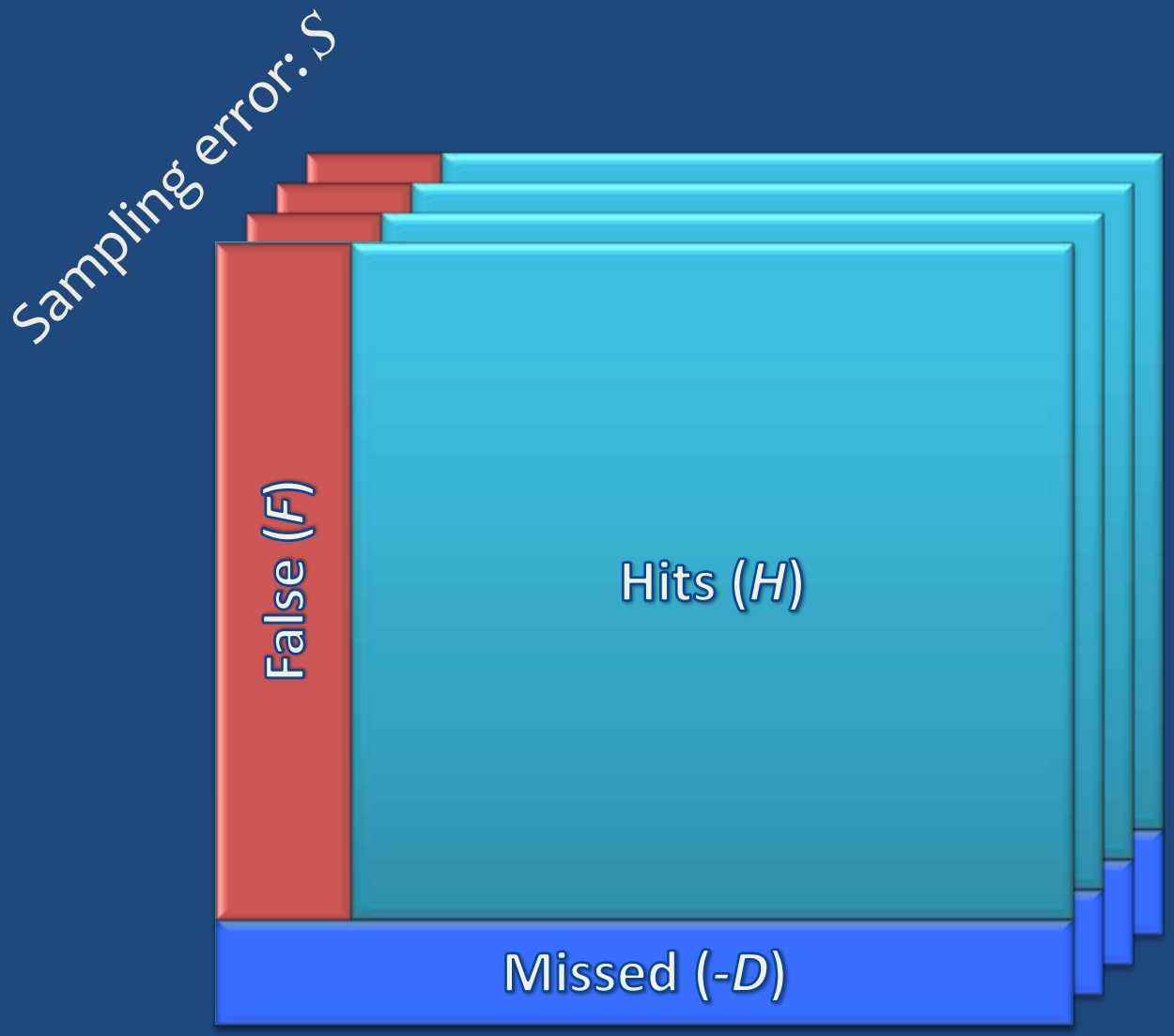
TMPA 3B42RT



NOAA Radar



Sampling error comes in when going from instantaneous to averages



Retrieval error: quantification = ($-D$, F, H)

Error representation boils down to quantifying 3+1 components

Error type		Systematic	Random
Retrieval error	Hit error	$H=f(\alpha, \beta)$	σ_H
	Missed	$-D$	σ_D
	False	F	σ_F
Sampling error		$g(H, -D, F)$	σ_S

3. Communication of precipitation error and uncertainty

-- Validation ≠ error representation

Retrieval errors:

-- Errors in precipitation come in components (H, -D, F)

-- Each component has systematic and random errors

-- Random errors define uncertainty

-- Be explicit on error models used/assumed

Sampling errors:

-- Estimating mean from discrete samples

-- One more source of random errors

3. Communication of precipitation error and uncertainty

Questions for future studies:

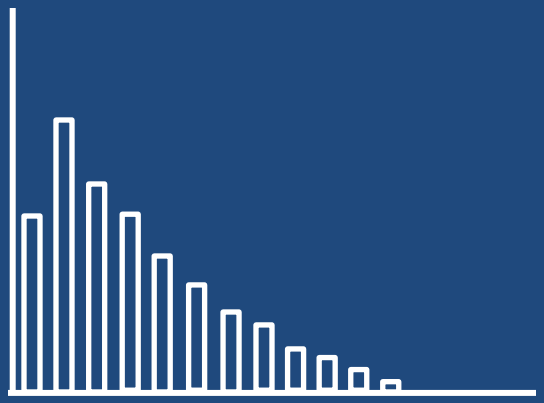
-- How to use the error structure for data assimilation/fusion?

-- How detailed does error information have to be?

Can we simplify our message?

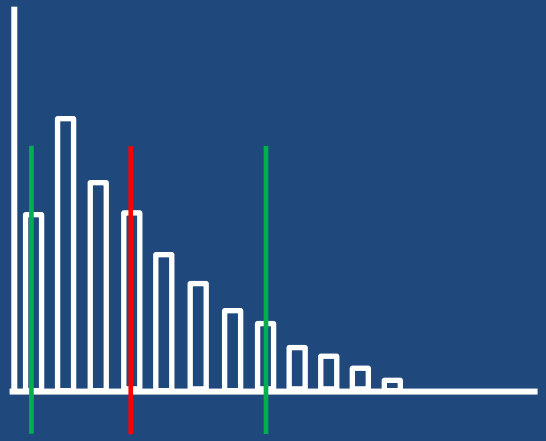
Error components			Selected references
Errors in precipitation	Sampling error		Laughlin (1981), Huffman (1997), Bell & Kundu (1996, 2000, 2003), Bell et al. (2001), Steiner et al. (2003), Nijssen & Lettenmaier (2004)
	Retrieval error	Systematic error	Arkin & Xie (1994), Smith et al. (1998), Adler et al. (2001), McCollum et al. (2002), McCollum & Ferraro (2003), Gottschalck et al. (2005), Hossain and Anagnostou (2006), Ebert et al. (2007), Tian et al. (2007), Tian & Peters-Lidard (2007), Lin & Hou (2008), Villarini et al. (2009), Sapiano & Arkin (2009), Tian et al. (2009, 2010), Tang et al. (2014)
		Random error	Villarini et al. (2009), Tian & Peters-Lidard (2010), Tian et al. (2013), Maggioni et al. (2014)

Two schemes for random error representation

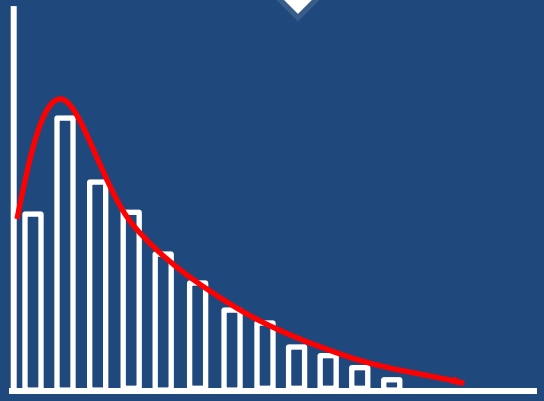


Non-parametric

Mean, median, percentiles, etc.



Parametric modeling



Error PDF with parameters (α, β, σ, etc...)