EGU, 30 April, 2014

The Scaling of Uncertainty in Precipitation Measurements

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Outline

Question:

How do uncertainties in precipitation data change with space/time scale ?

→ How does precipitation change with scale?

→ What is uncertainty?

→ How does uncertainty change with scale?

Answers to these questions are critical for down/up scaling, etc.

This is a difficult problem

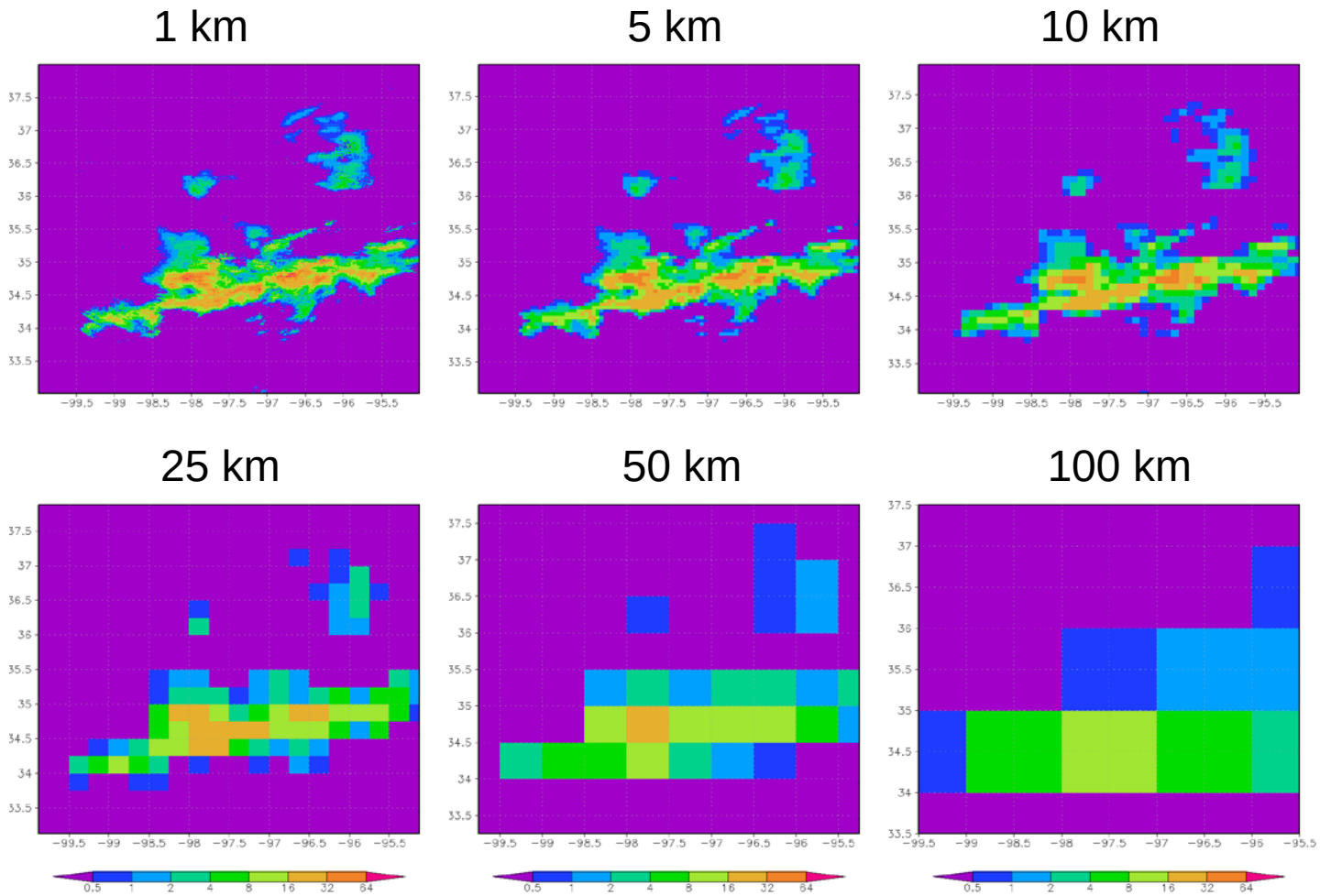
1. Non-Gaussian variable
2. Intermittency
3. Non-simple scaling

   (Lovejoy & Mandelbrot, 1985; Gupta & Waymire, 1990)
4. Nonlinear, multiplicative errors (Tian et al., 2014)

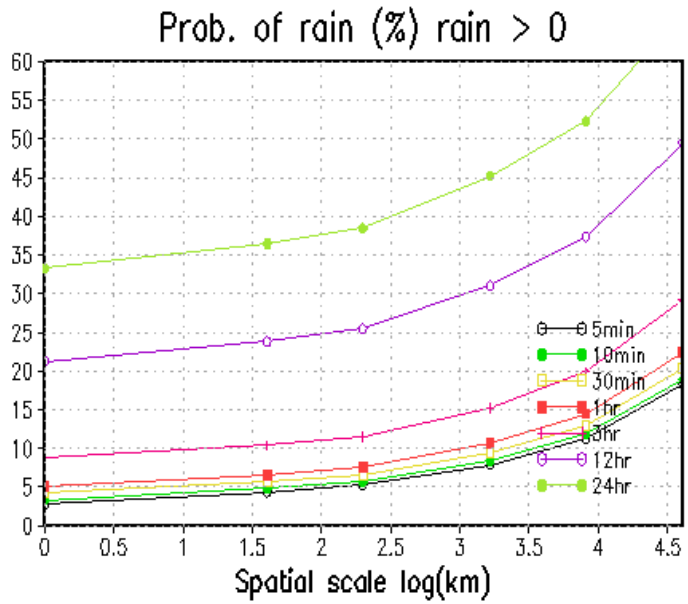
The easy problem

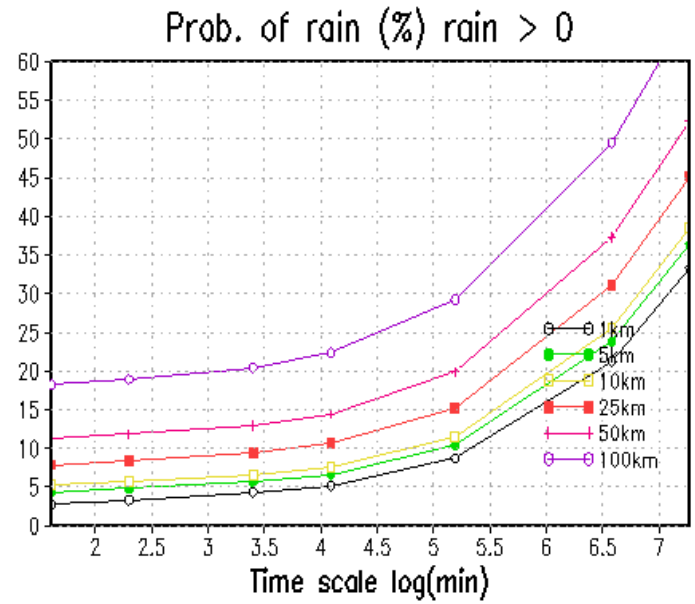
1. Gaussian variable
2. Smooth
3. Trivial scaling
4. Linear, additive error

Precipitation:
Almost all statistical properties change with scale

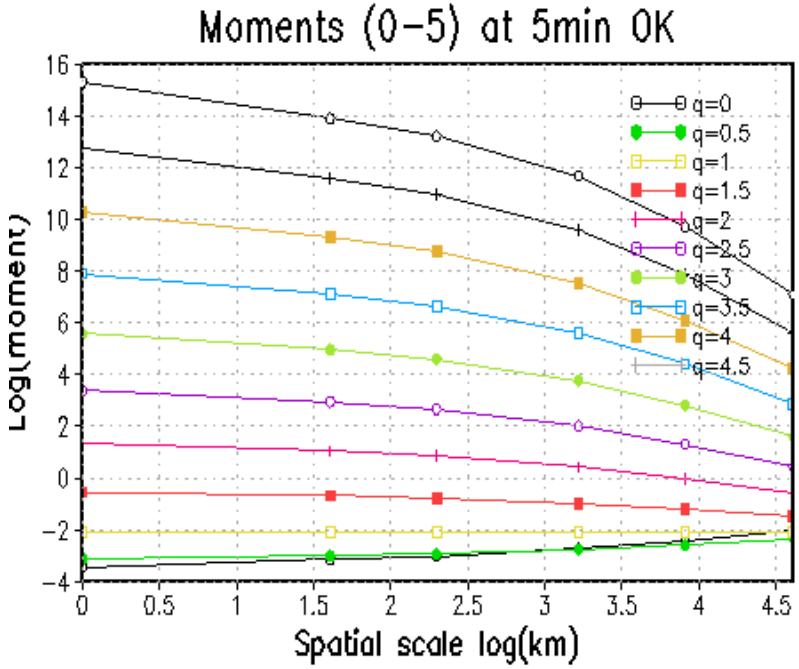


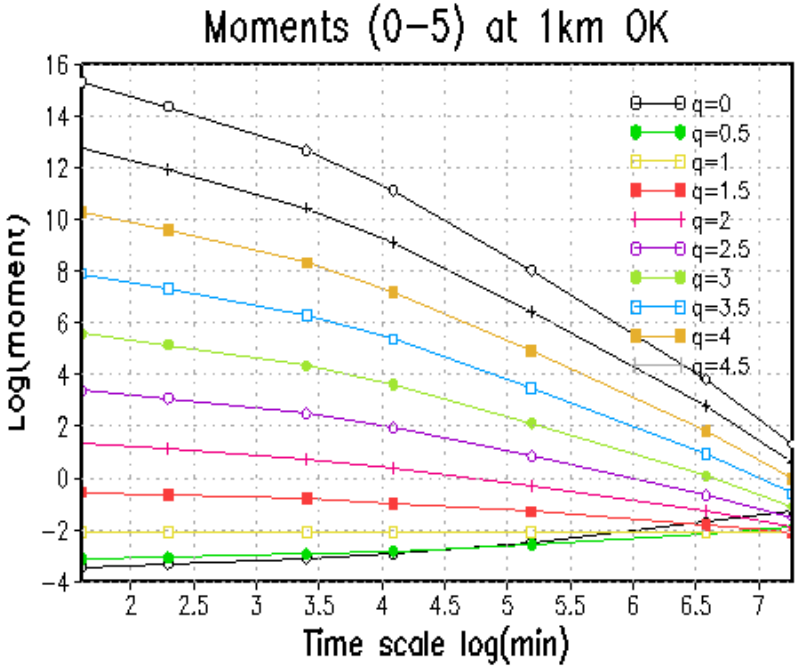
Precipitation:
Probability of rain changes with scale



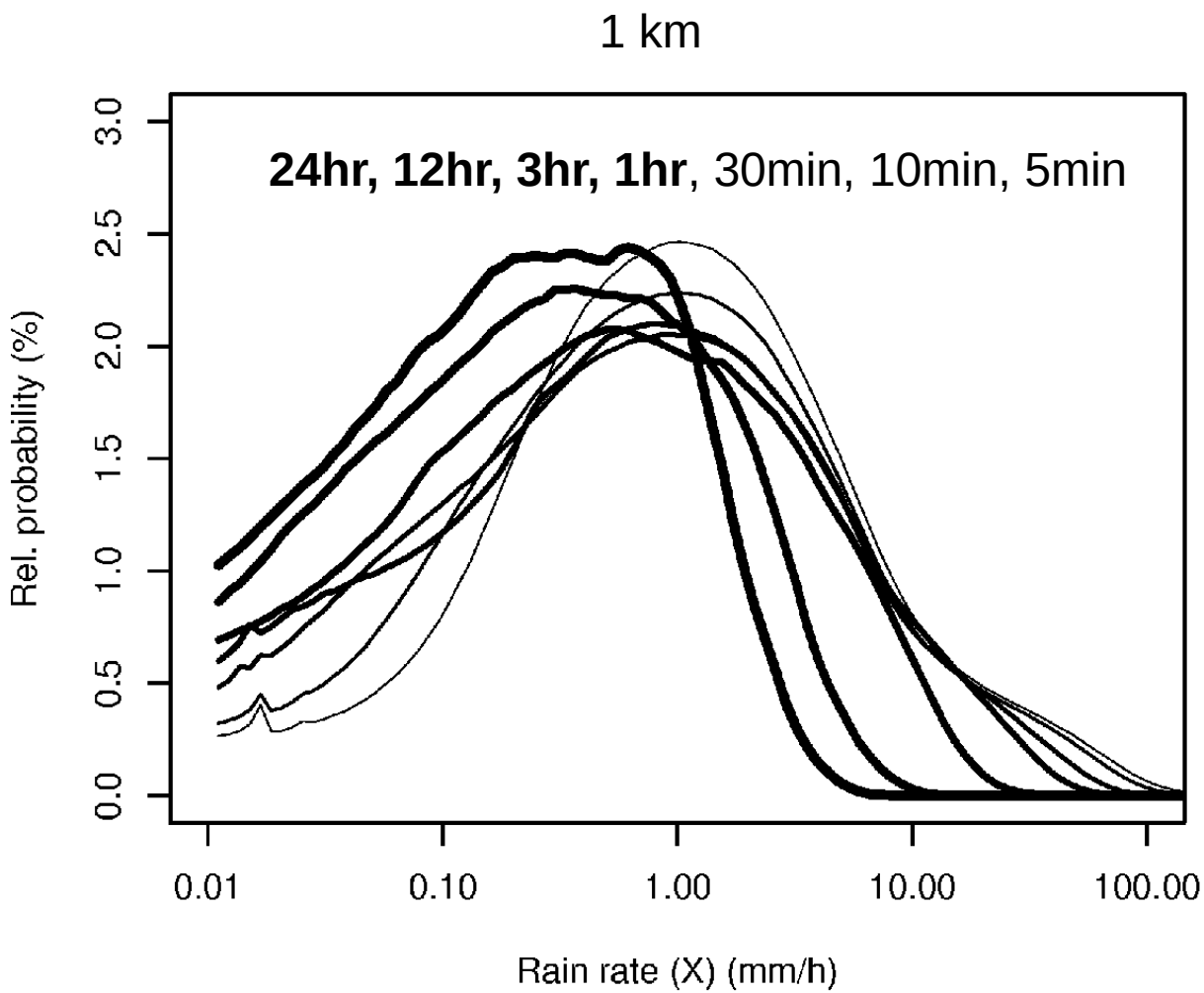


Precipitation:
Most statistical moments change with scale

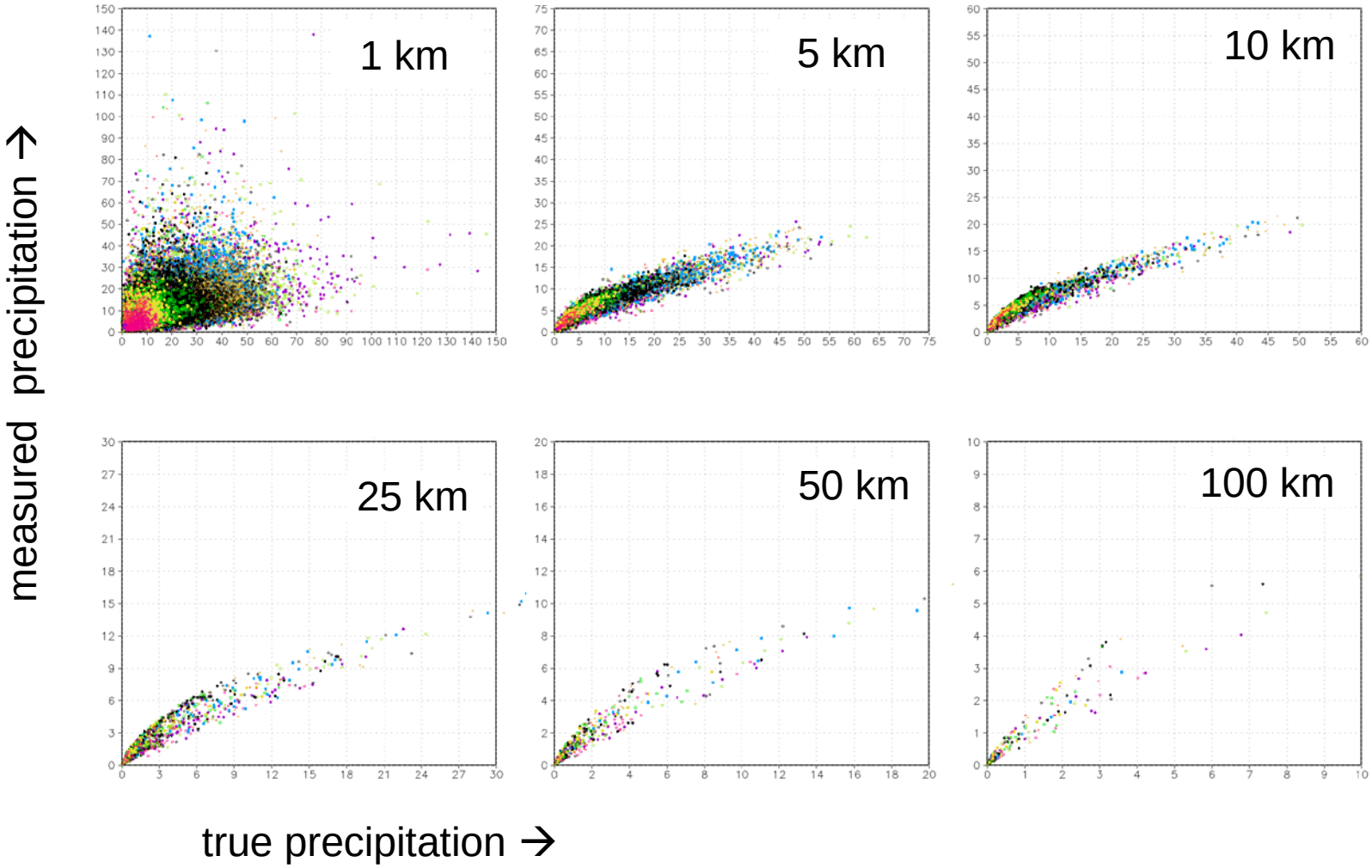




Precipitation:
Probability distributions change with scale



Precipitation errors:
Almost all statistical properties change with scale too

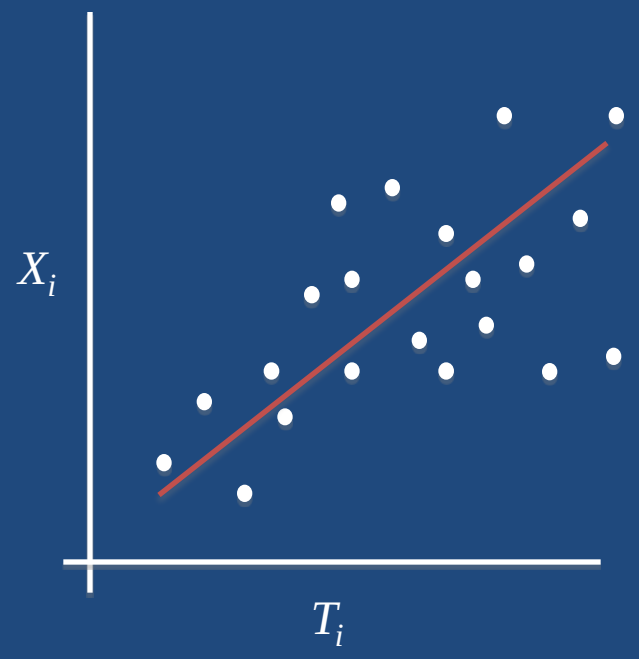


Precipitation errors are multiplicative

(Tian et al., 2013)

Additive error model

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



Two parameters quantify systematic error

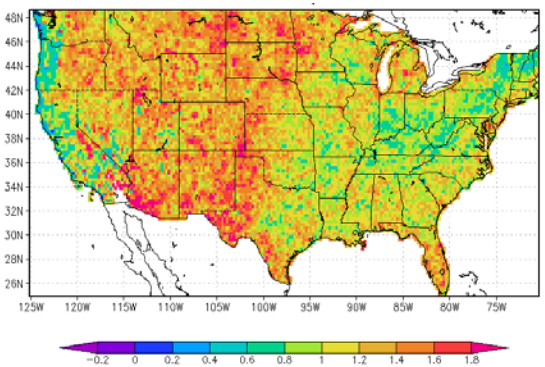
$$X_i = a\,T_i^{\beta}\,e^{\varepsilon} \qquad \sigma = stdev(\varepsilon)$$

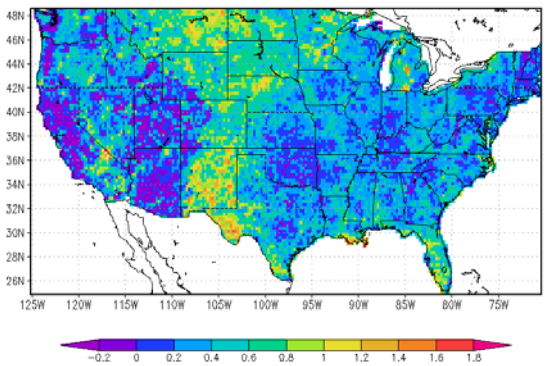
systematic error

±: scale error (ideal: 1)
^{2} : shape error (ideal: 1)

TRMM Data **NOAA Radar**

ln(±)





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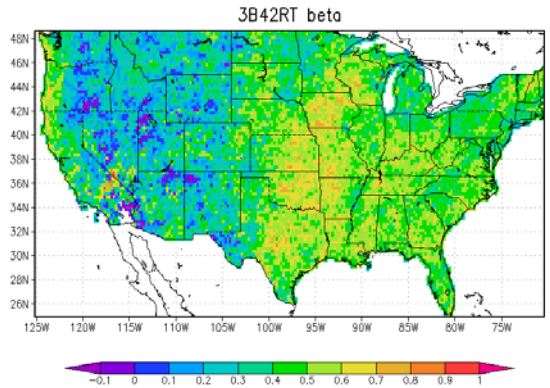
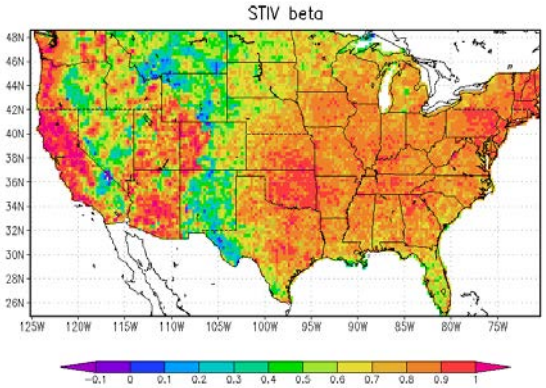


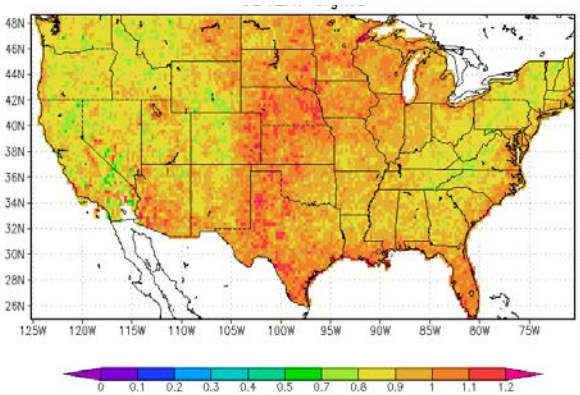


One parameter quantifies random error

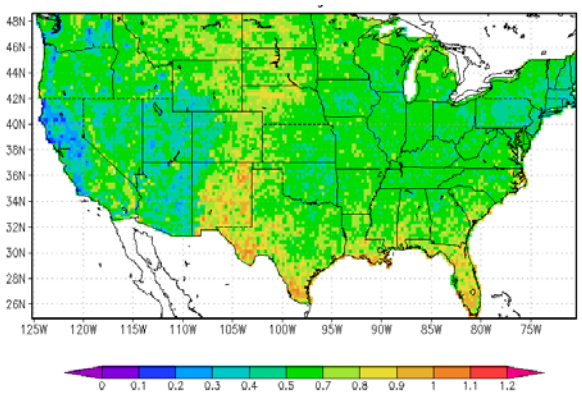
$$X_i = a\,T_i^{\beta}\,e^{\varepsilon} \qquad \sigma = stdev(\varepsilon)$$

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

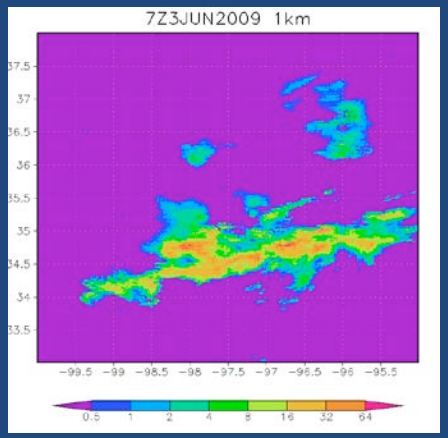
TRMM Data

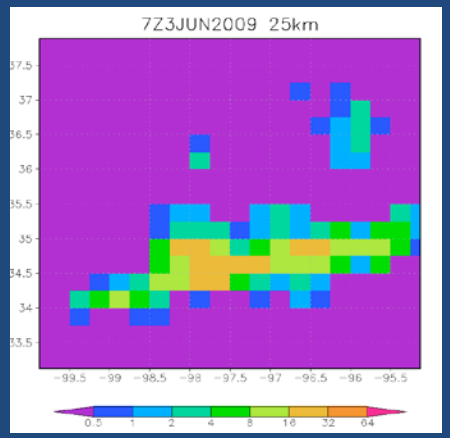


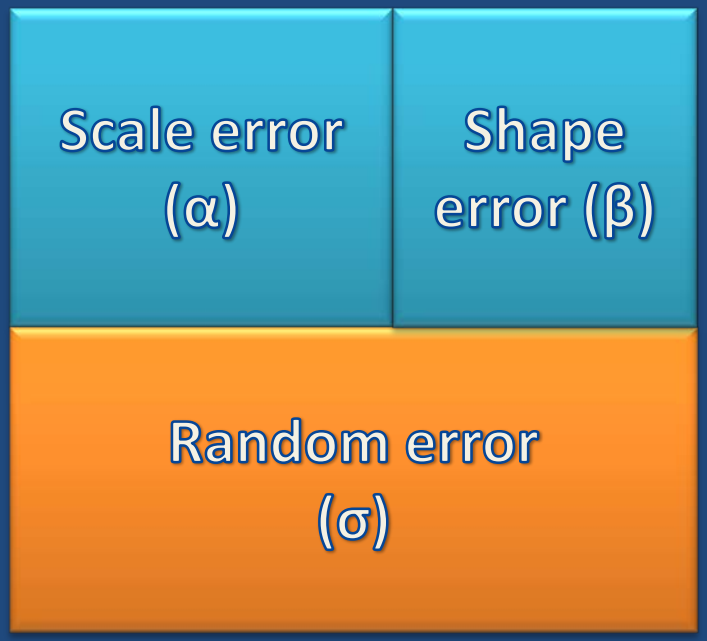
NOAA Radar

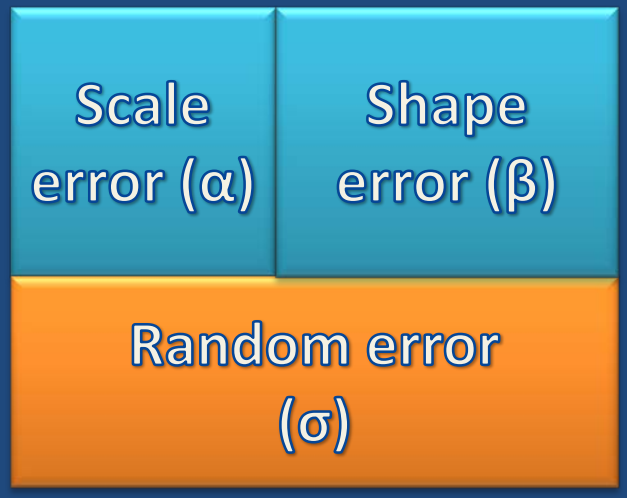


Scaling of uncertainty: how errors change with space/time scales









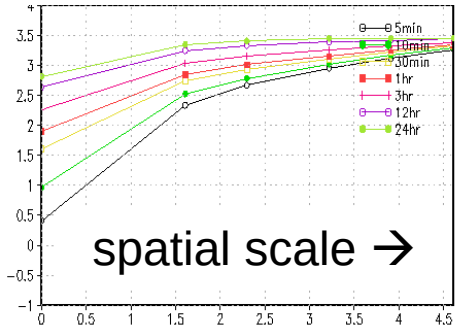
How systematic and random errors vary with space/time scales

$$X_i = \alpha T^{\beta}{}_i e^{\varepsilon}$$

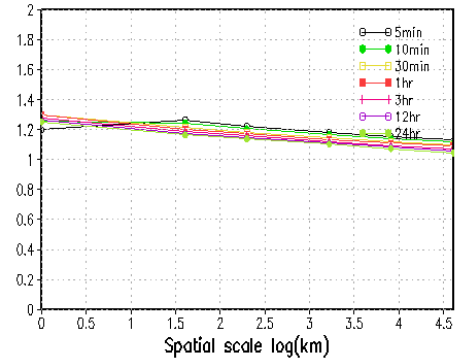
$$\sigma = stdev(\varepsilon)$$

Systematic errors (α, β)

scale error ln(±)

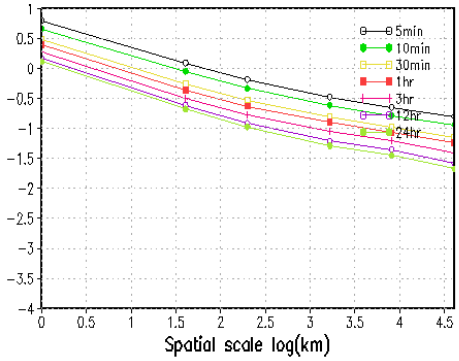


shape error (²)

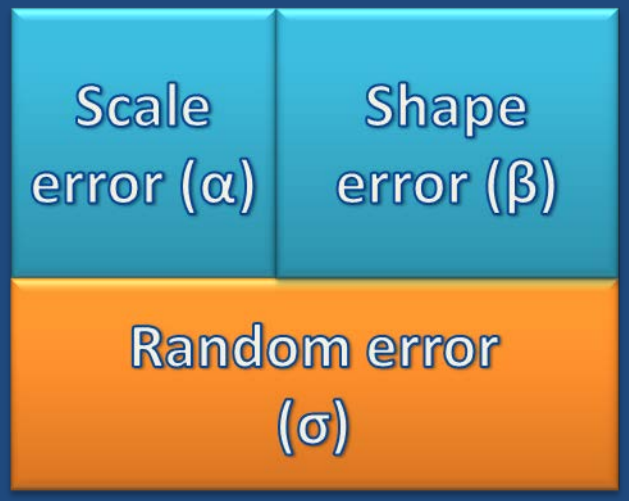


Random errors σ

random error (Ã)



Summary



Scaling of precipitation uncertainty

= scaling of (systematic + random) errors

= scaling of (α, β, and σ)

Low resolution → high resolution

scale error α → decrease

shape error β → ~constant

random error σ → increase

Conversion between systematic and random errors:

Low resolution ←→ high resolution

scale error ←→ random error

References

Lovejoy, S., and B. B. Mandelbrot (1985), Fractal properties of rain, and a fractal model, Tellus A, 37A(3), 209–232, doi:10.1111/j.1600-0870.1985.tb00423.x.

Gupta, V. K., and E. Waymire (1990), Multiscaling properties of spatial rainfall and river flow distributions, Journal of Geophysical Research: Atmospheres, 95(D3), 1999–2009, doi:10.1029/JD095iD03p01999.

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