Ground Flash Fraction Retrieval Algorithm

GLM Science Meeting
Huntsville, AL
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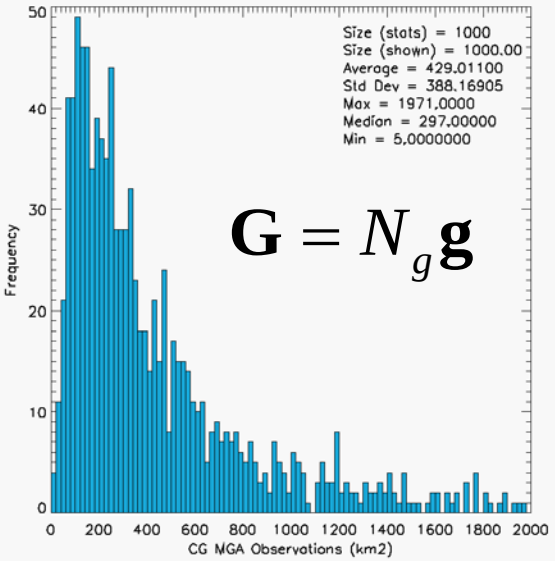
Dr. William Koshak, NASA-Marshall Space Flight Center
Dr. Richard Solakiewicz, Chicago State University

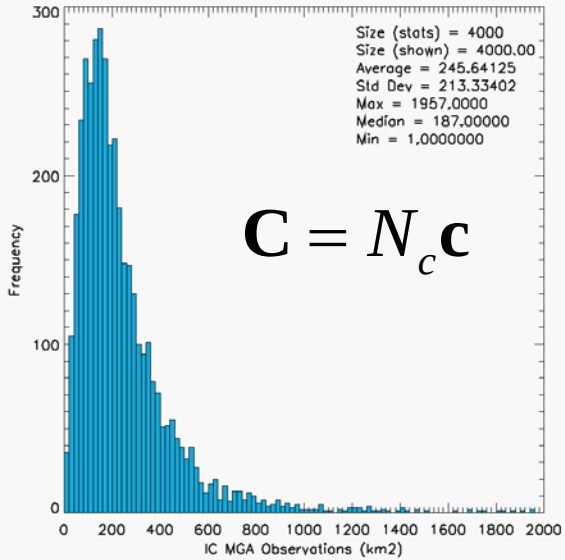
Summary of Main Advances

- **Mathematical Advances to Analytic Perturbation Method**
  - Derived closed form solution for ground flash fraction … no numerical scanning of H function.
  - Derived explicit analytic forms for the perturbation vectors.
  - Derived a way to determine flash type of specific flashes.
- **APM Error Analysis Completed Via Simulations**
- **DEMO Completed**
- **Journal Paper Completed & Ready for Submission (JTECH)**

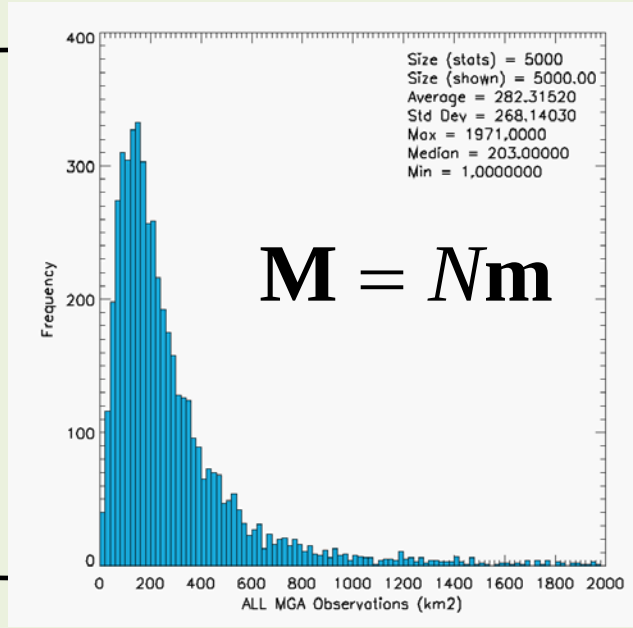


$$\mathbf{G} = N_g \mathbf{g}$$

MIX



$$\mathbf{C} = N_c \mathbf{c}$$



$$\mathbf{M} = N\mathbf{m}$$

Instrument Observes *N* MGAs.

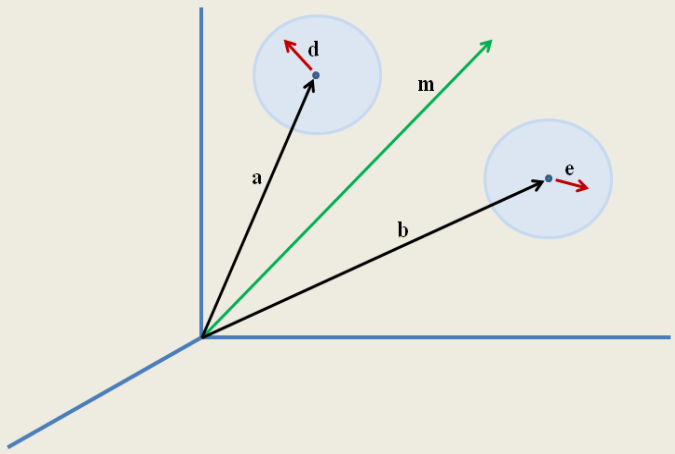
Invert this Distribution to Find Ground Flash Fraction α

$$\mathbf{M} = \mathbf{G} + \mathbf{C}$$

$$\mathbf{m} = \alpha \mathbf{g} + (1-\alpha)\mathbf{c}$$

$$\alpha = N_g / N$$

APM SOLUTION PROCESS

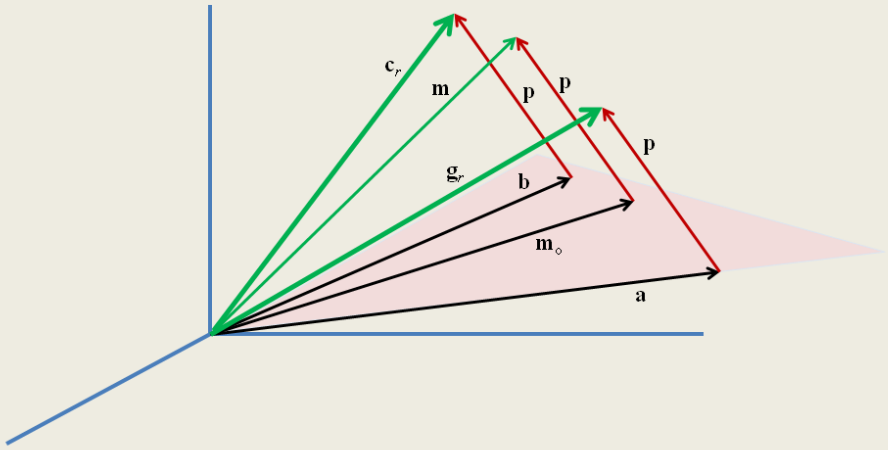


Geometry of the APM depicted in 3-space. Climate vectors are (**a**, **b**) which are perturbed by (**d**, **e**) so that the estimates **g** ≈ **a** + **d**, **c** ≈ **b** + **e** are made.

Minimize: $H = \alpha_r \mathbf{d}^2 + (1-\alpha_r)\mathbf{e}^2$

Subject to: $\mathbf{m} = \alpha_r \mathbf{g}_r + (1-\alpha_r)\mathbf{c}_r$

→ Results in perturbation: $\mathbf{p} = \mathbf{m} - \alpha_r \mathbf{a} - (1-\alpha_r)\mathbf{b}$



The effect of the perturbation is to create a hyperplane out of $(\mathbf{g}_r, \mathbf{c}_r)$ that contains the (fixed) mixture density **m**. The geometry is depicted in 3-space.

$$\mathbf{m} = \alpha \mathbf{g} + (1-\alpha)\mathbf{c} \qquad \text{(truth)}$$

$$\mathbf{m} = \alpha_r \mathbf{g}_r + (1-\alpha_r)\mathbf{c}_r \qquad \text{(model)}$$

APM SOLUTION SUMMARY

PERTURBATION GIVES:

$$\alpha_r = \frac{(\mathbf{m}-\mathbf{b})^T(\mathbf{a}-\mathbf{b})}{(\mathbf{a}-\mathbf{b})^2}$$

$$\mathbf{g}_r = \mathbf{m} + (1-\alpha_r)(\mathbf{a}-\mathbf{b})$$

$$\mathbf{c}_r = \mathbf{m} - \alpha_r(\mathbf{a}-\mathbf{b})$$

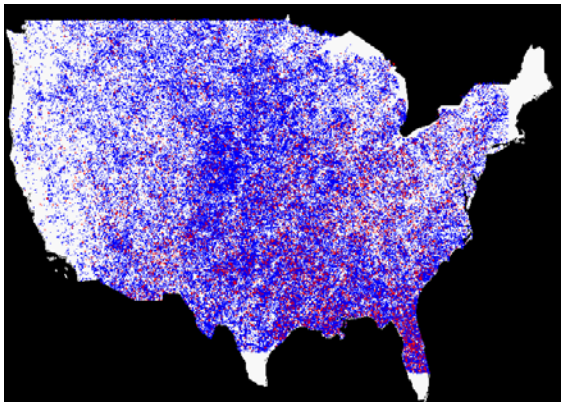
PROBABILITY FLASH, HAVING MGA = x, IS A GROUND FLASH:

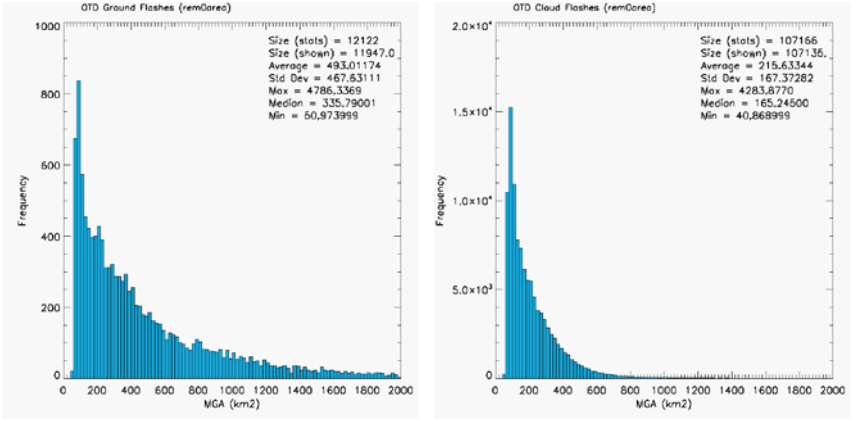
$$P_g(x) = \frac{\alpha_r g_r(x)}{\alpha_r g_r(x) + (1-\alpha_r)c_r(x)}$$

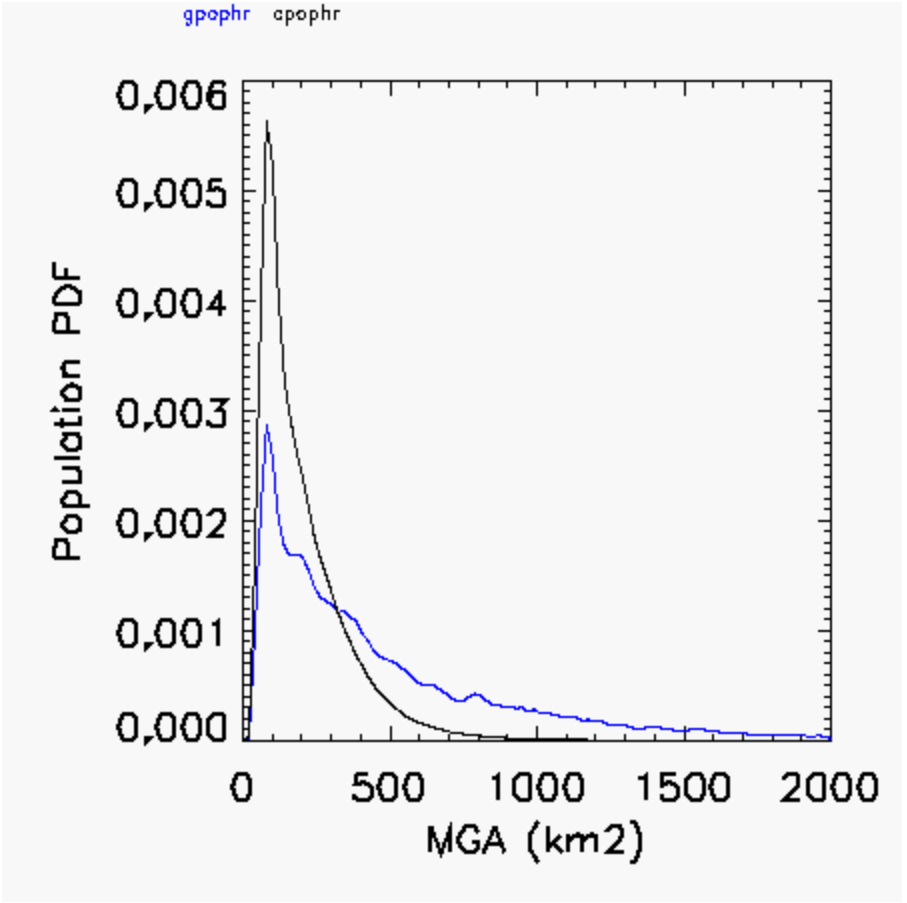
$$P_g(x) > 0.5 \Rightarrow \text{Ground Flash}$$

$$P_g(x) \leq 0.5 \Rightarrow \text{Cloud Flash}$$

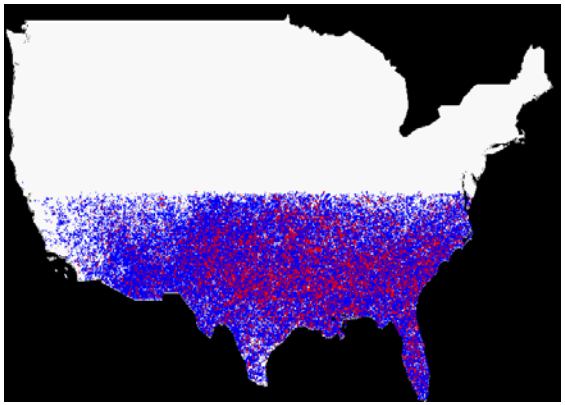
Simulate Population from OTD Data (Flash Type Categorized by NLDN)

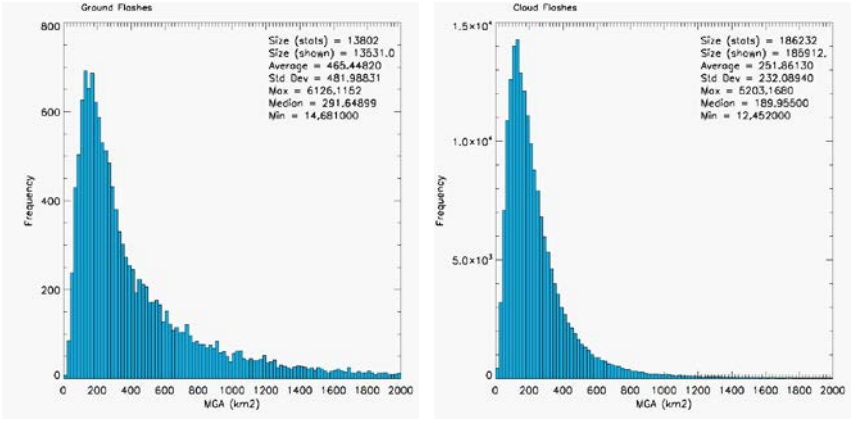


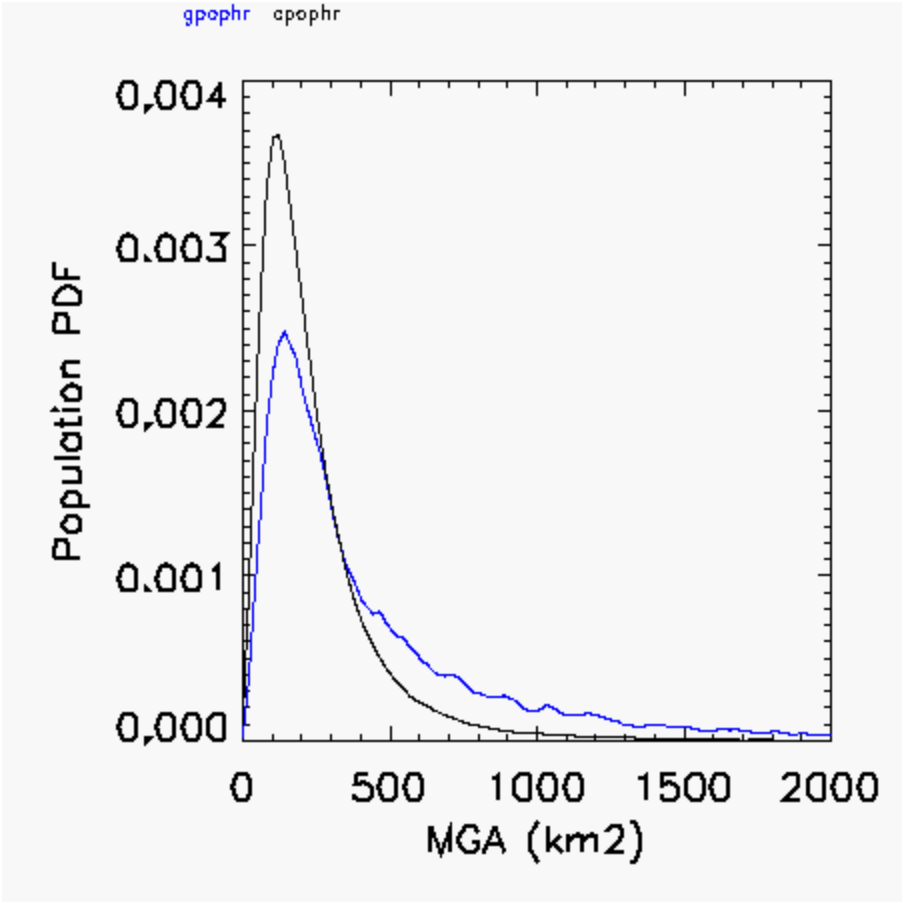




Simulate Population from LIS Data (Flash Type Categorized by NLDN)







Inversion Algorithm Performance Simulator

$\aleph[I[\aleph[S(\mathbf{a}^*, \mathbf{b}^*)]]]$

S = IDL smoothing operator.

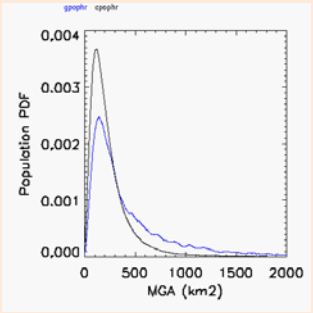
I = IDL interpolating operator.

$\aleph$ = Normalize.

$\mathbf{a}^*$ = OTD or LIS climatology of $\mathbf{g}$.

$\mathbf{b}^*$ = OTD or LIS climatology of $\mathbf{c}$.

$(\mathbf{g}_{poplr}, \mathbf{c}_{poplr})$



CDFs for $\mathbf{g}_{poplr}$ & $\mathbf{c}_{poplr}$

"BURN-IN"
Ng = 40000
Nc = 120000

$\mathbf{x}_B$

$\mathbf{x}_B$ + error

Target Climate Estimate

$(\mathbf{a}, \mathbf{b})$

N = 5000 (MGAs)

$(\mathbf{g}, \mathbf{c})$

$\mathbf{x}$

$\mathbf{m}$

$\mathbf{x}$ + error

$\mathbf{m}' = \mathbf{m} + \text{error}$

(TRUTH)

$$\alpha = \frac{(\mathbf{m}-\mathbf{c})^T(\mathbf{g}-\mathbf{c})}{(\mathbf{g}-\mathbf{c})^2}$$

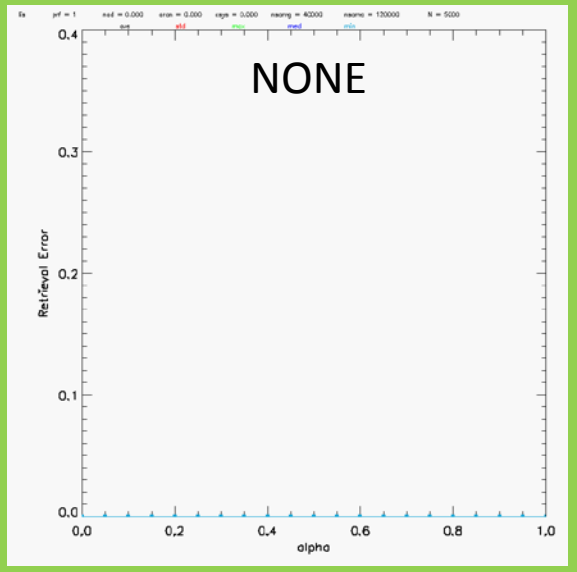
(ERRORS)

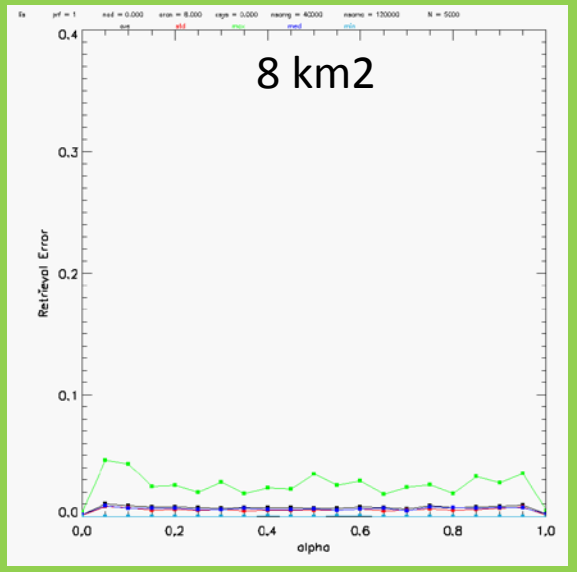
$$\Delta\alpha = \alpha_r - \alpha$$
$$\Delta\mathbf{g} = \mathbf{g}_r - \mathbf{g}$$
$$\Delta\mathbf{c} = \mathbf{c}_r - \mathbf{c}$$

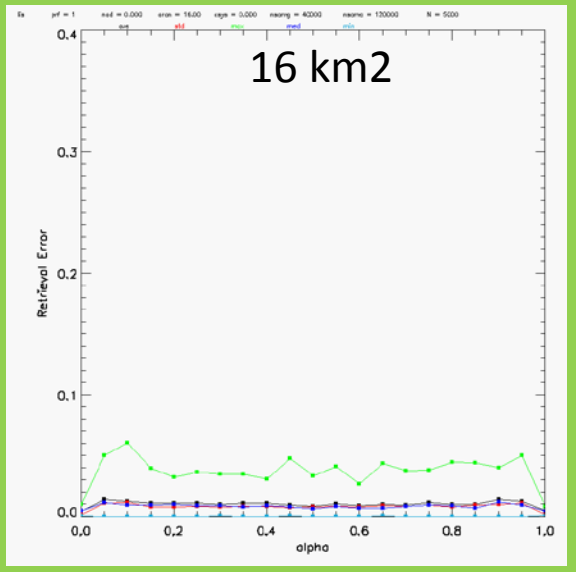
(SOL'N)

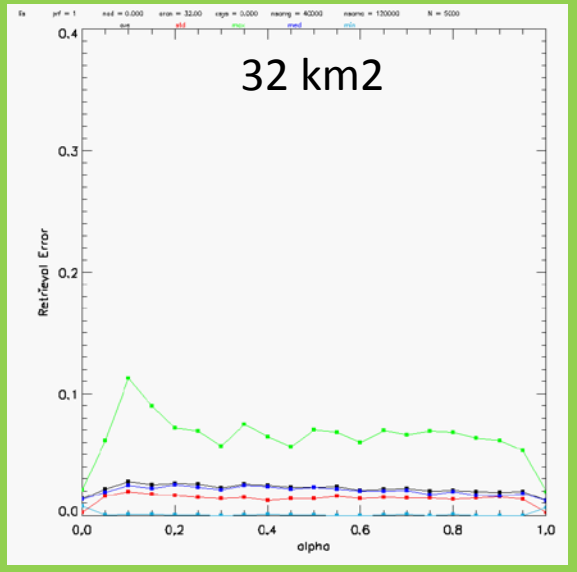
$$\alpha_r = \frac{(\mathbf{m}'-\mathbf{b})^T(\mathbf{a}-\mathbf{b})}{(\mathbf{a}-\mathbf{b})^2}$$
$$\mathbf{g}_r = \mathbf{m}' + (1-\alpha_r)(\mathbf{a}-\mathbf{b})$$
$$\mathbf{c}_r = \mathbf{m}' - \alpha_r(\mathbf{a}-\mathbf{b})$$

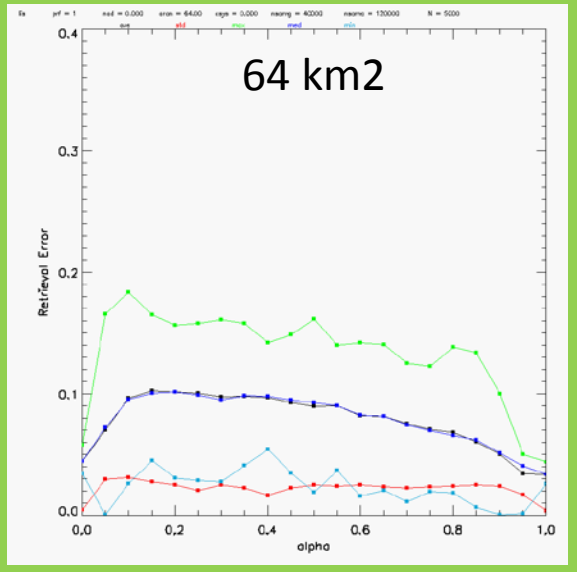
EFFECT OF RANDOM ERROR (a = g, b = c)



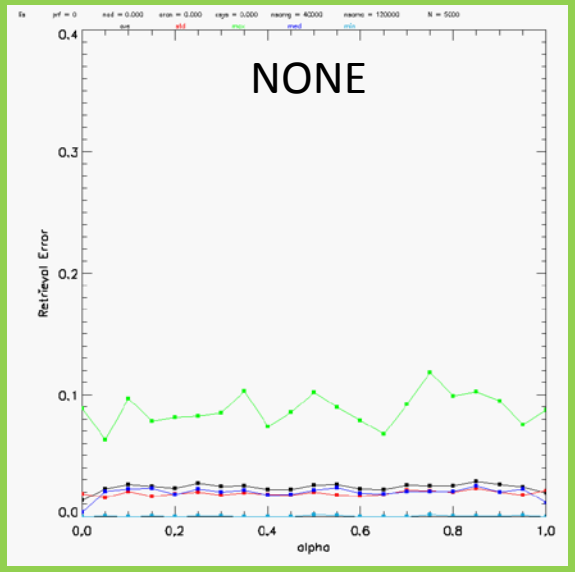


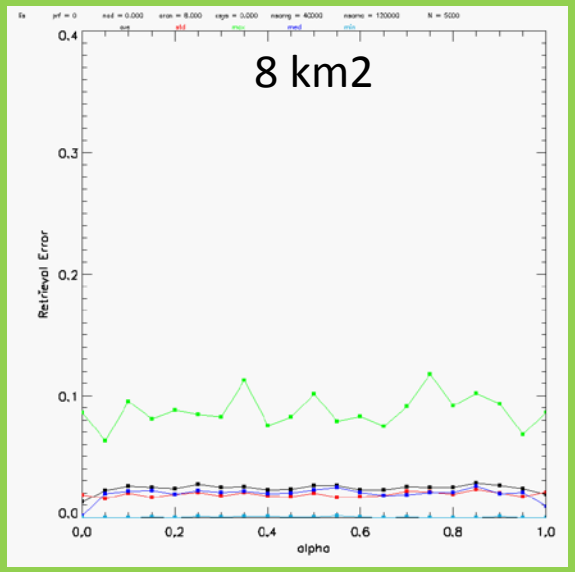


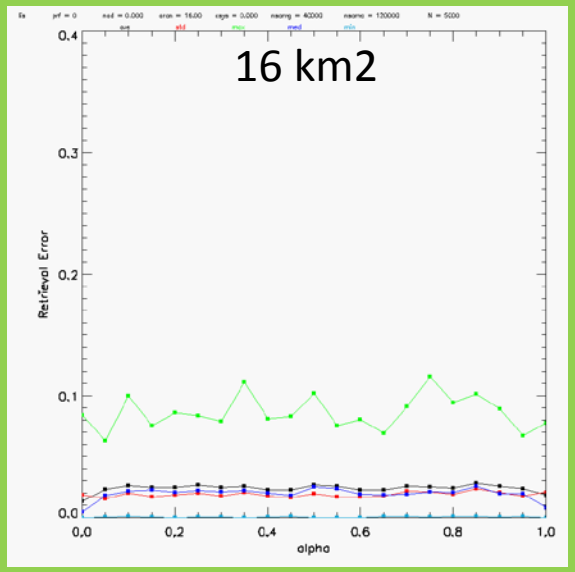


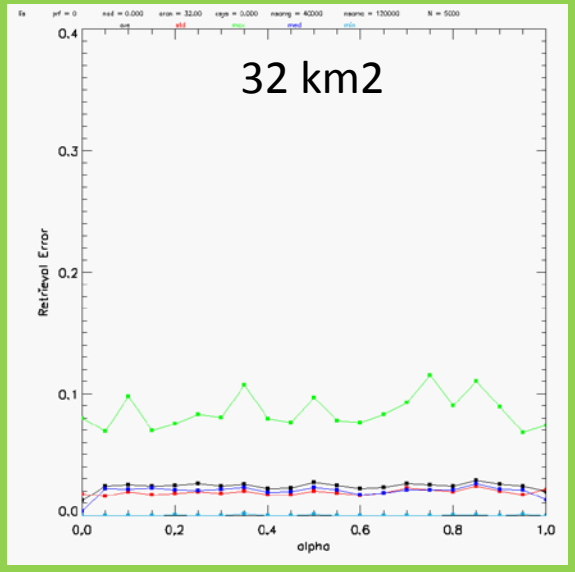


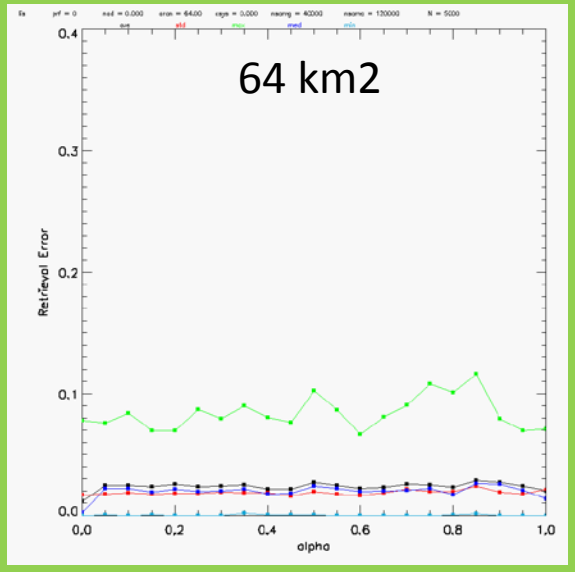
EFFECT OF RANDOM ERROR (**a** and **b** from method)



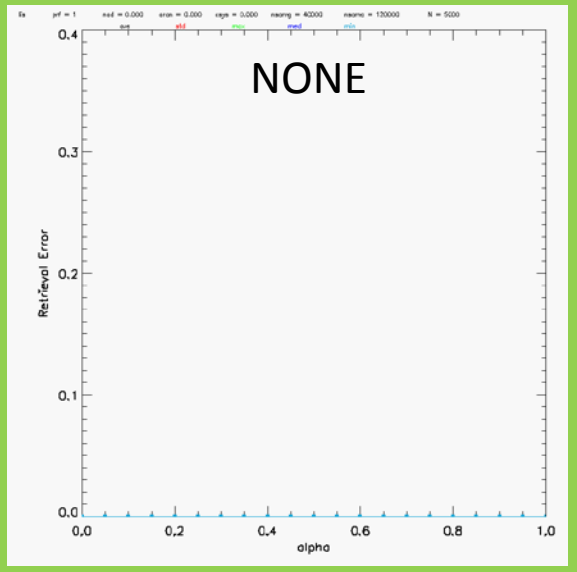


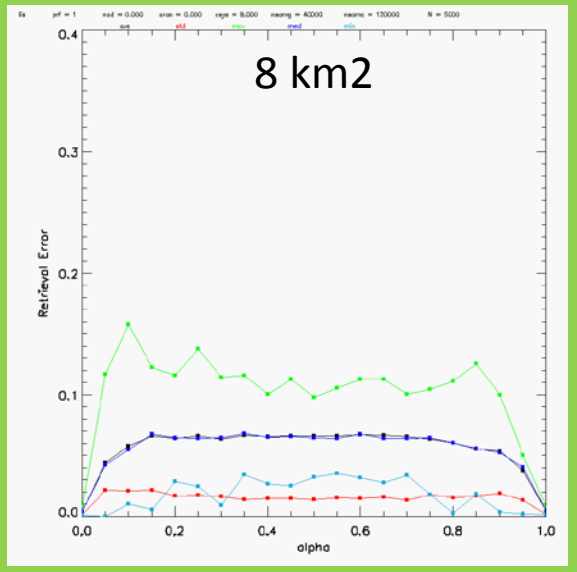


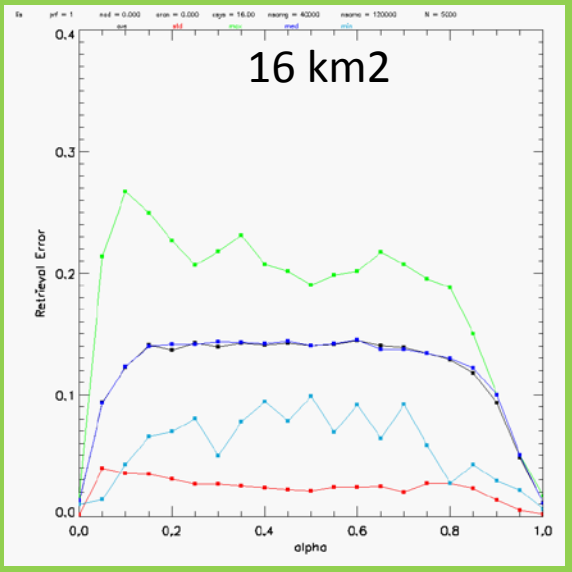


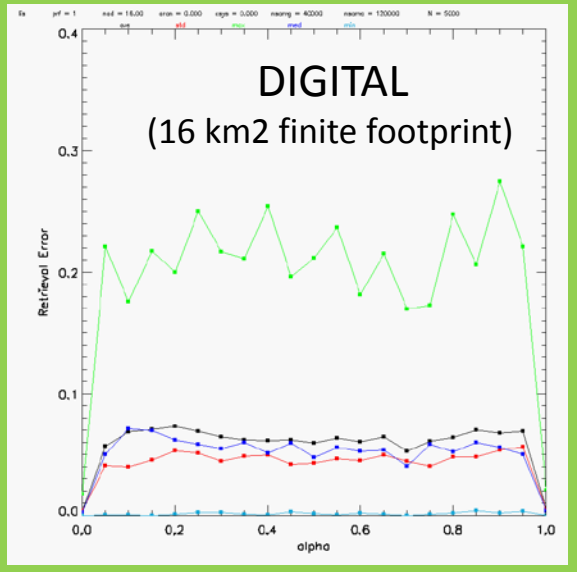


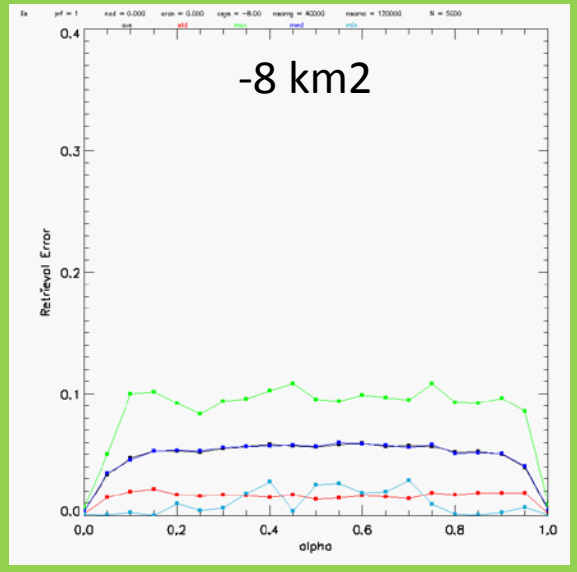
EFFECT OF SYSTEMATIC ERROR (a = g, b = c)

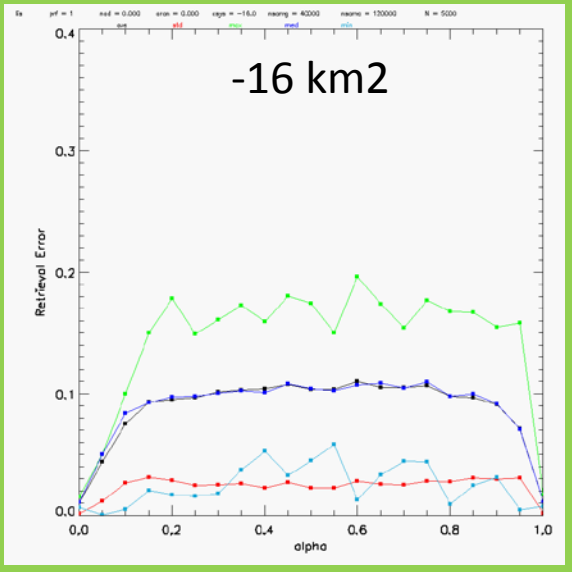




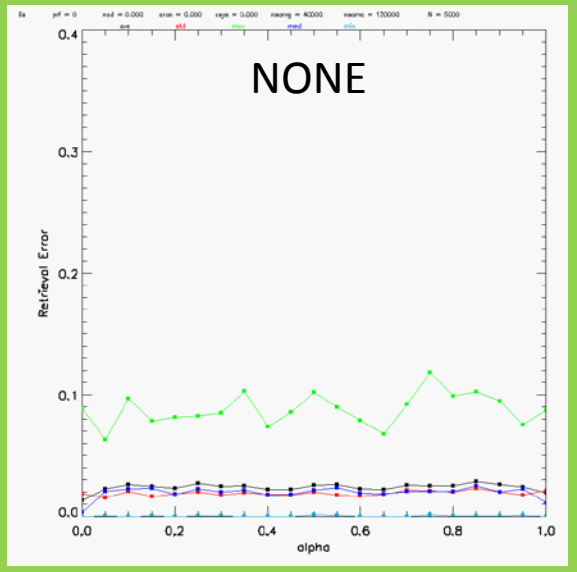


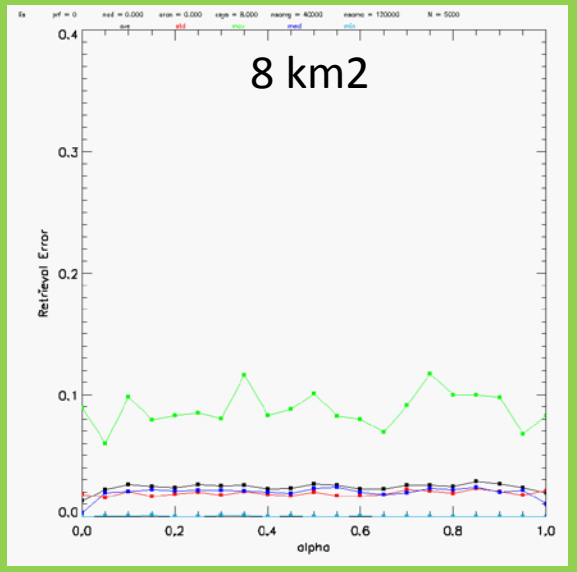


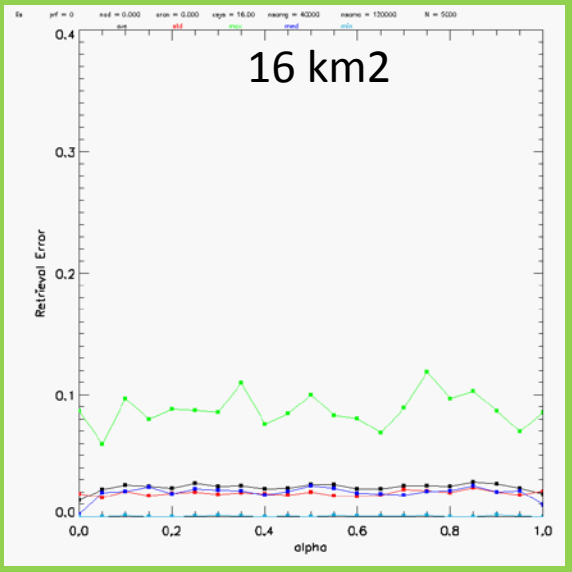


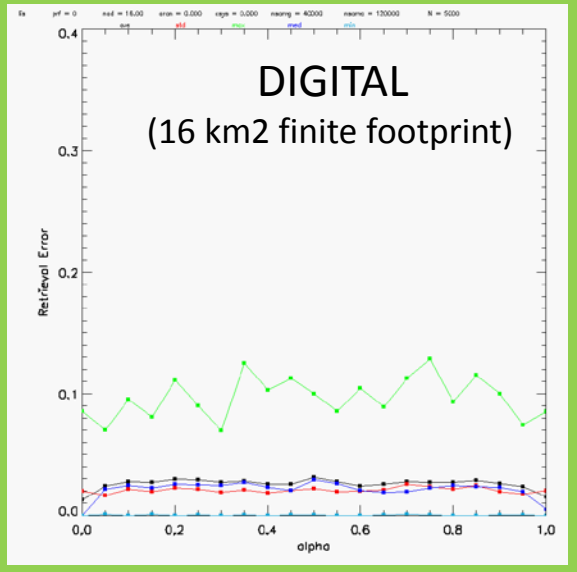


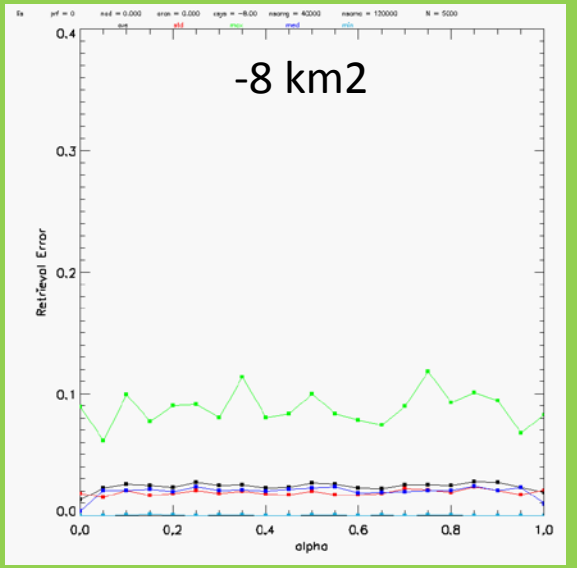
EFFECT OF SYSTEMATIC ERROR (**a** and **b** from method)

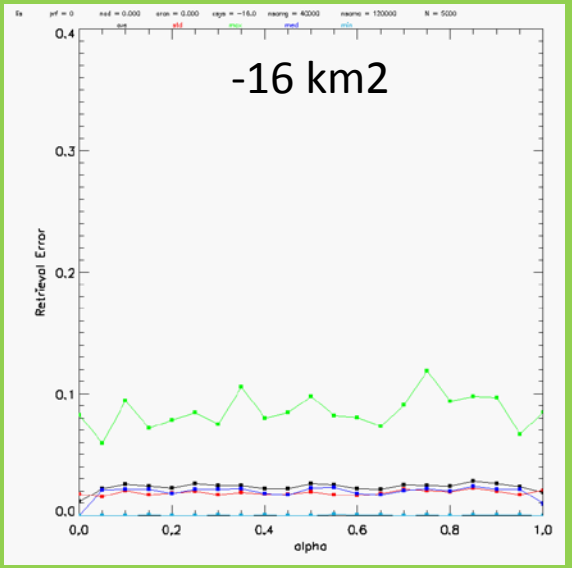




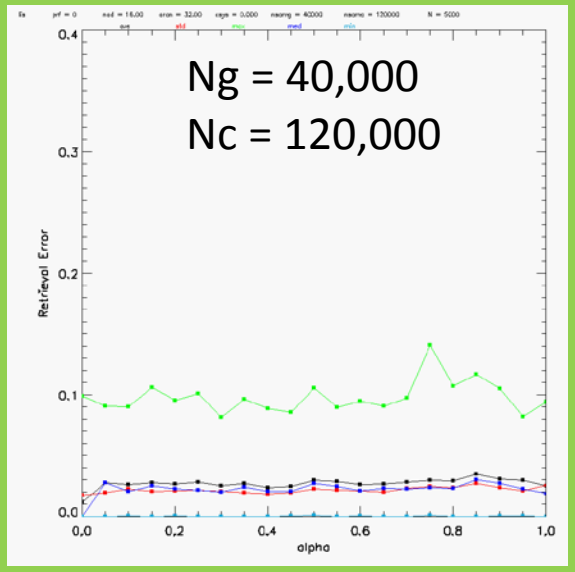


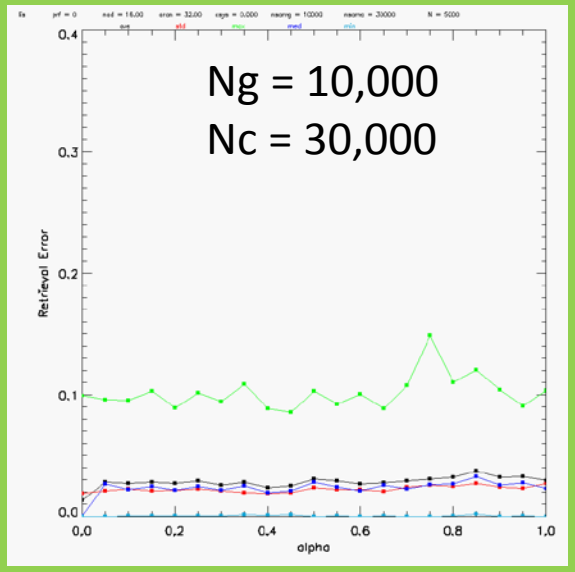


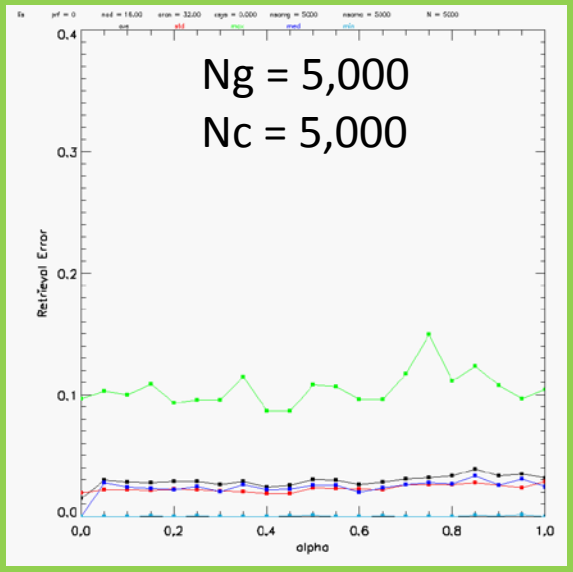


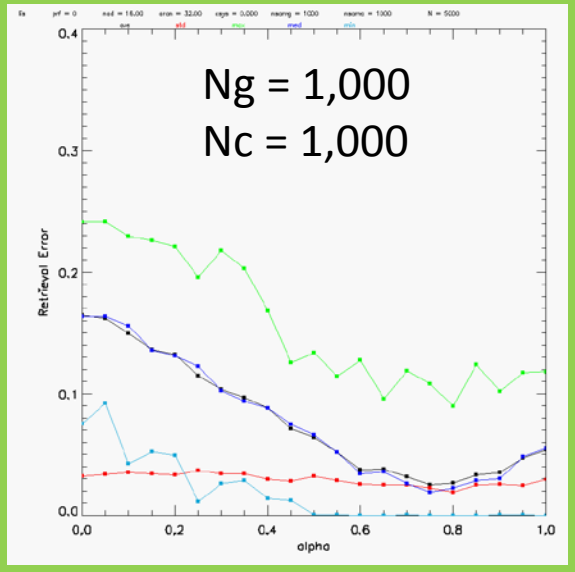


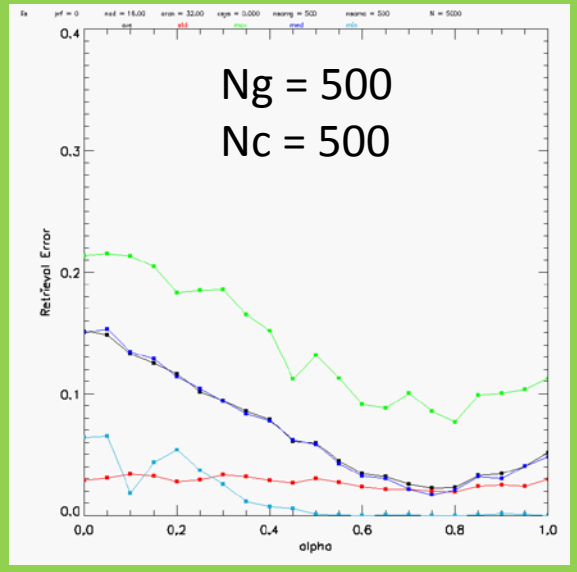
EFFECT OF CLIMATOLOGY SAMPLE SIZE

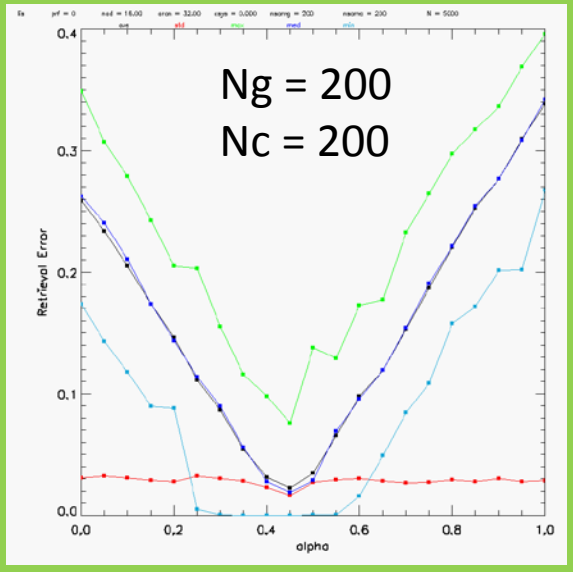




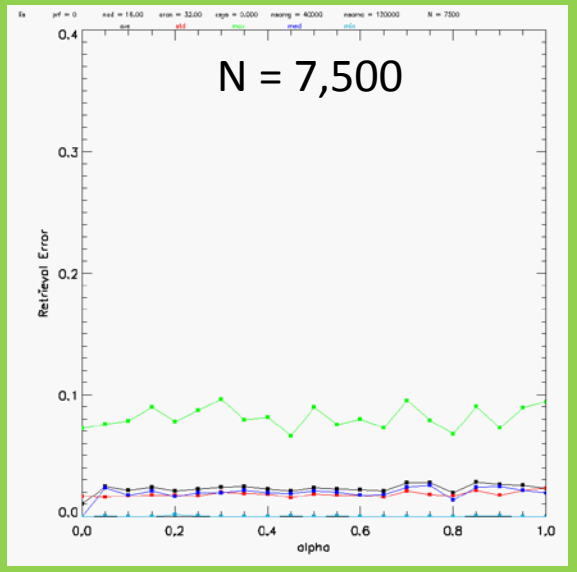


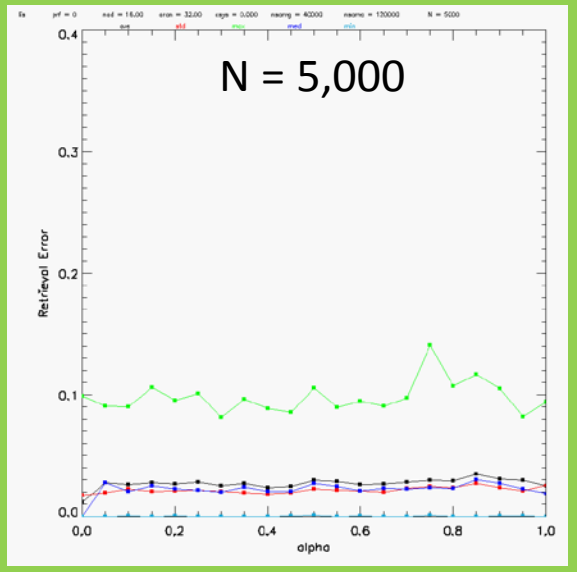


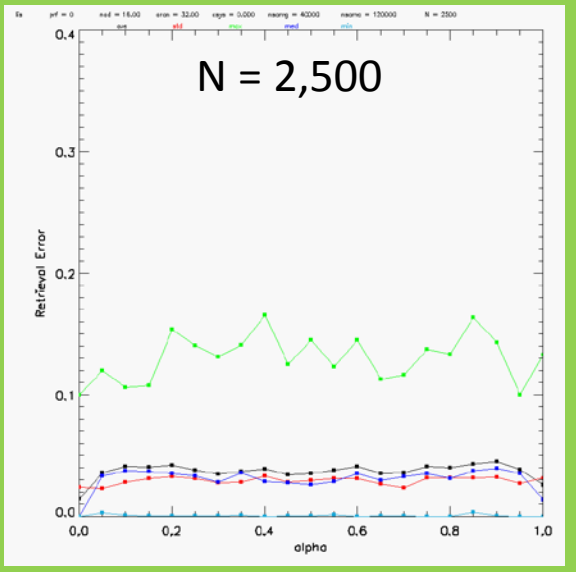


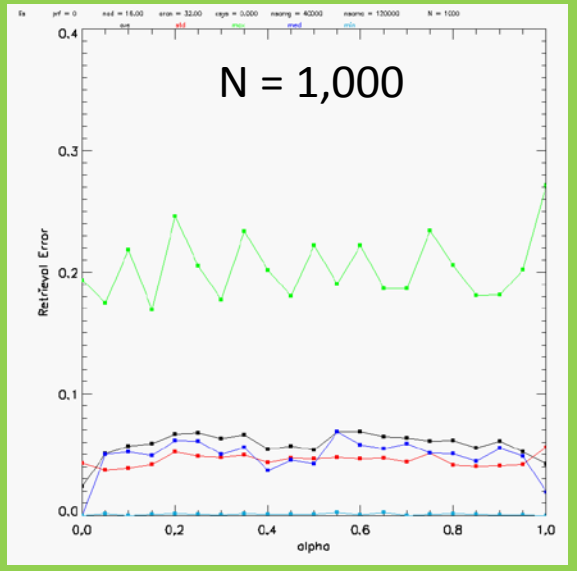


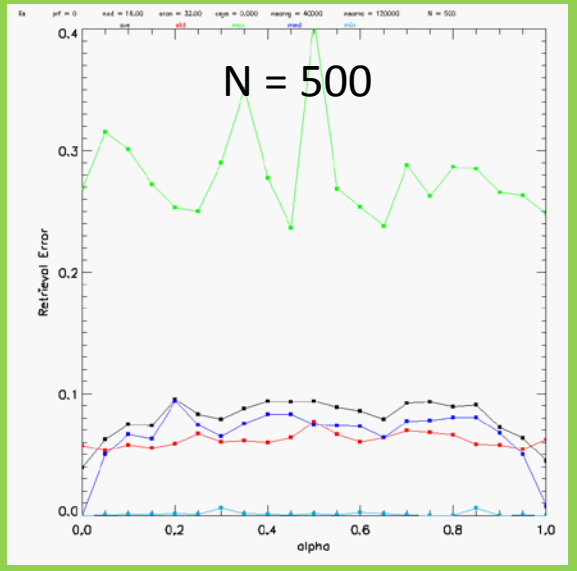
EFFECT OF OBSERVATION SAMPLE SIZE *N*











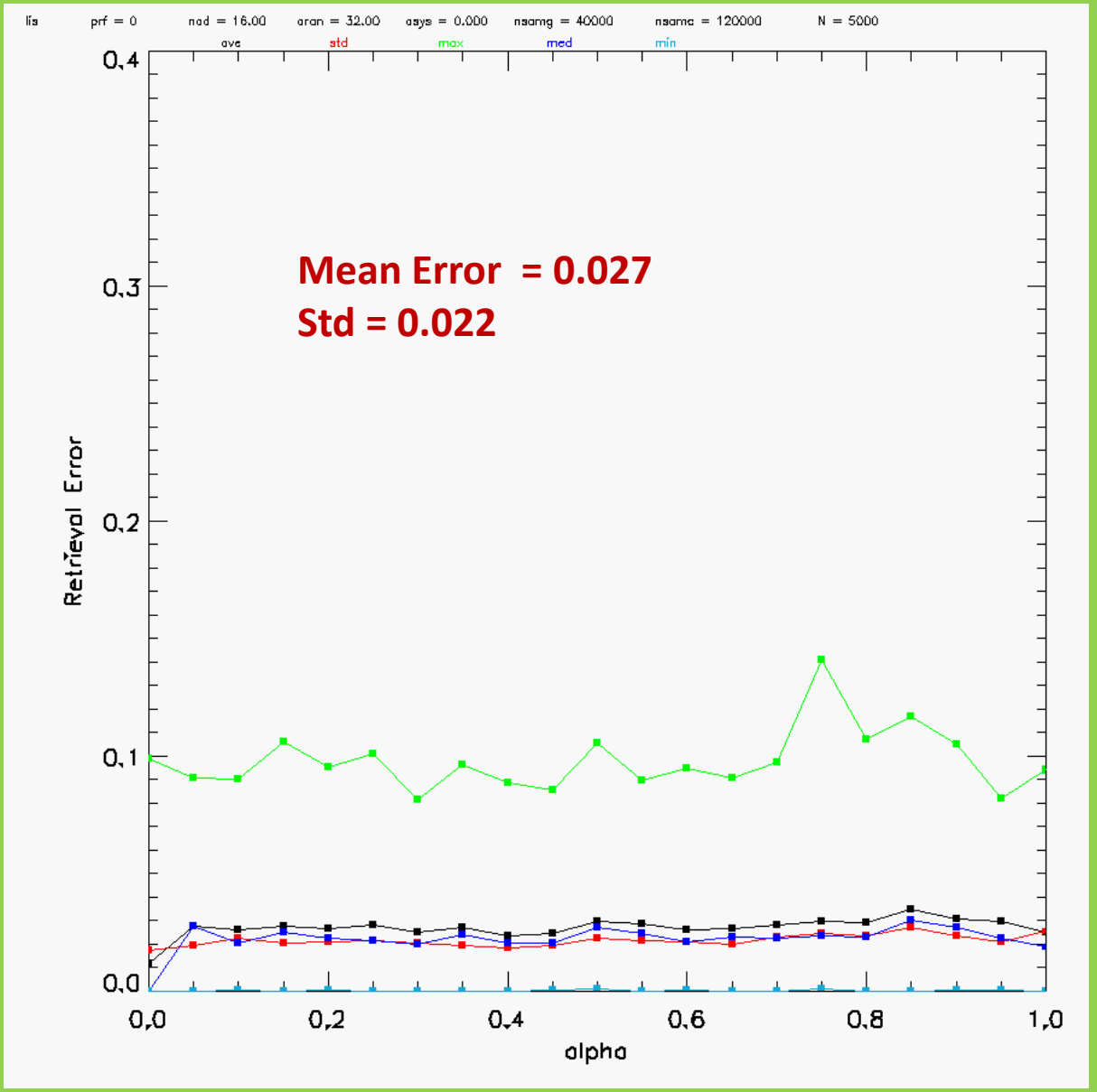
NOMINAL (LIS data)

 # Observations:
N = 5000

 # in Climate Sampling:
Ng = 40,000
Nc = 120,000

Instr. Measurement Error:
Random = ±32 km2
Systematic = 16 km2 digital

gpop mean = 465.4 km2
cpop mean = 251.9 km2
difference = 213.5 km2



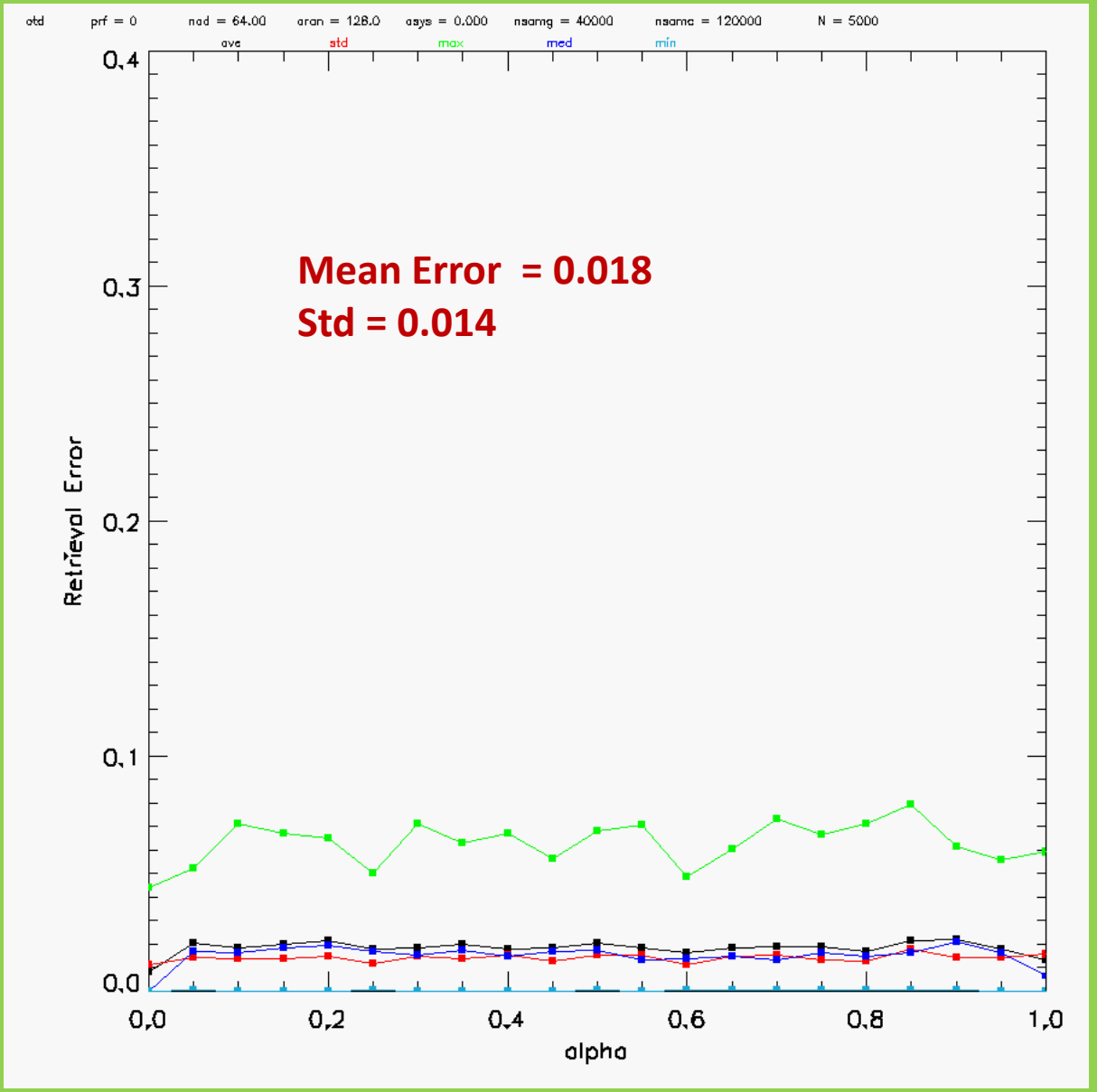
NOMINAL (OTD data)

 # Observations:
N = 5000

 # in Climate Sampling:
Ng = 40,000
Nc = 120,000

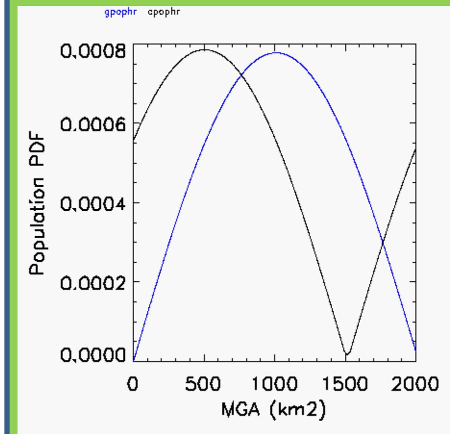
Instr. Measurement Error:
Random = ±128 km2
Systematic = 64 km2 digital

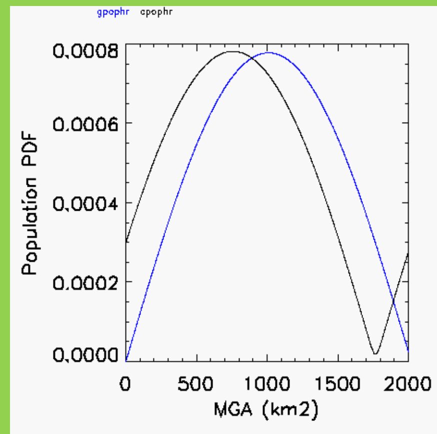
gpop mean = 493.0 km2
cpop mean = 215.6 km2
difference = 277.4 km2

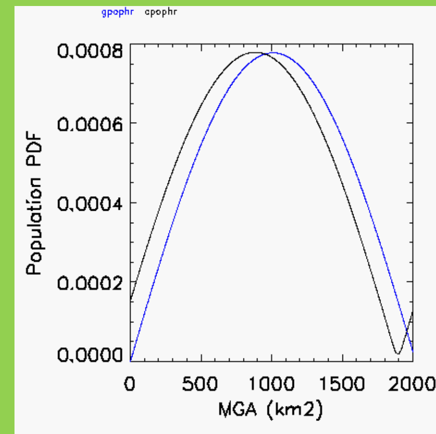


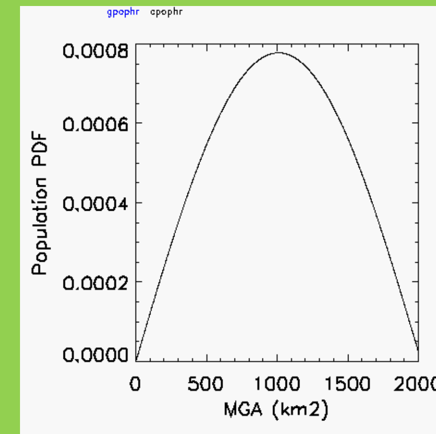
CAN HANDLE ARBITRARY DISTRIBUTIONS

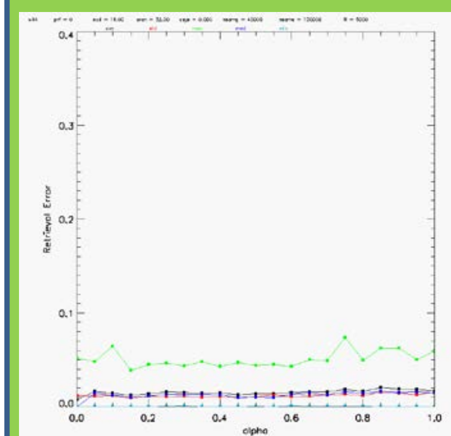
(AS USUAL, CG & IC DISTRIBUTIONS NEED TO BE DISTINCT)

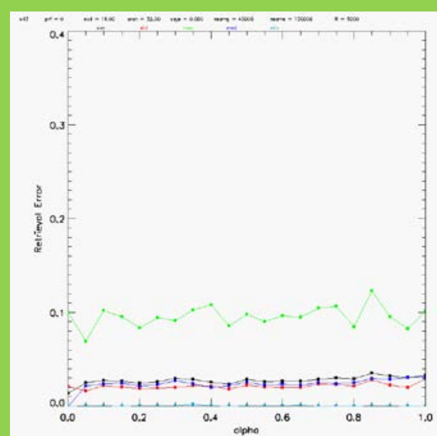


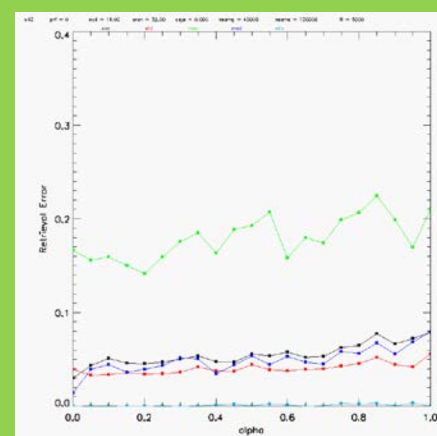


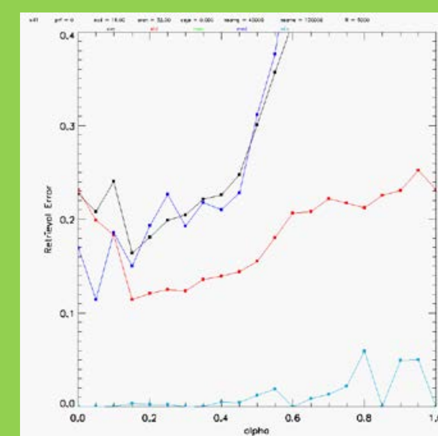




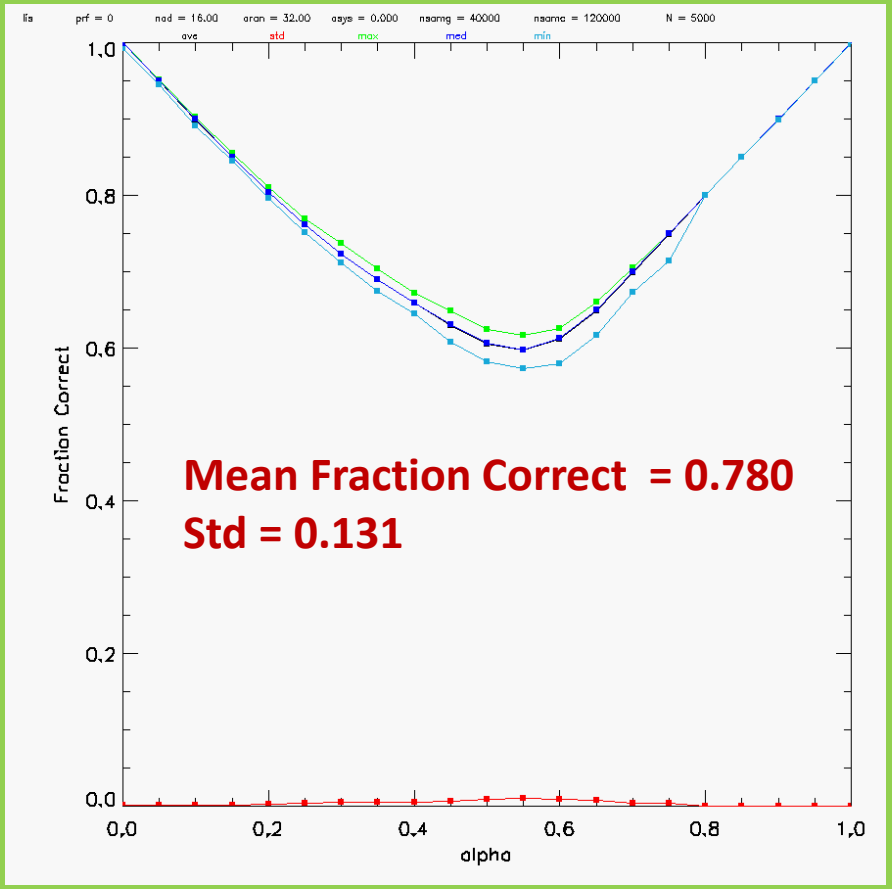




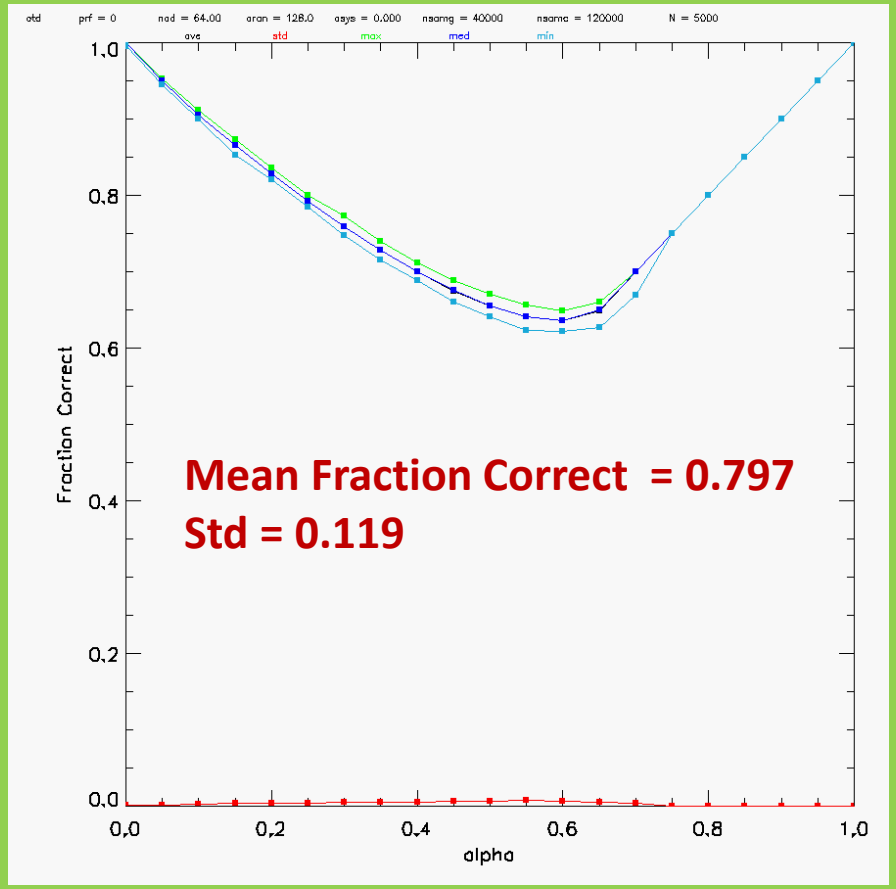




PERFORMANCE OF SPECIFIC FLASH TYPING

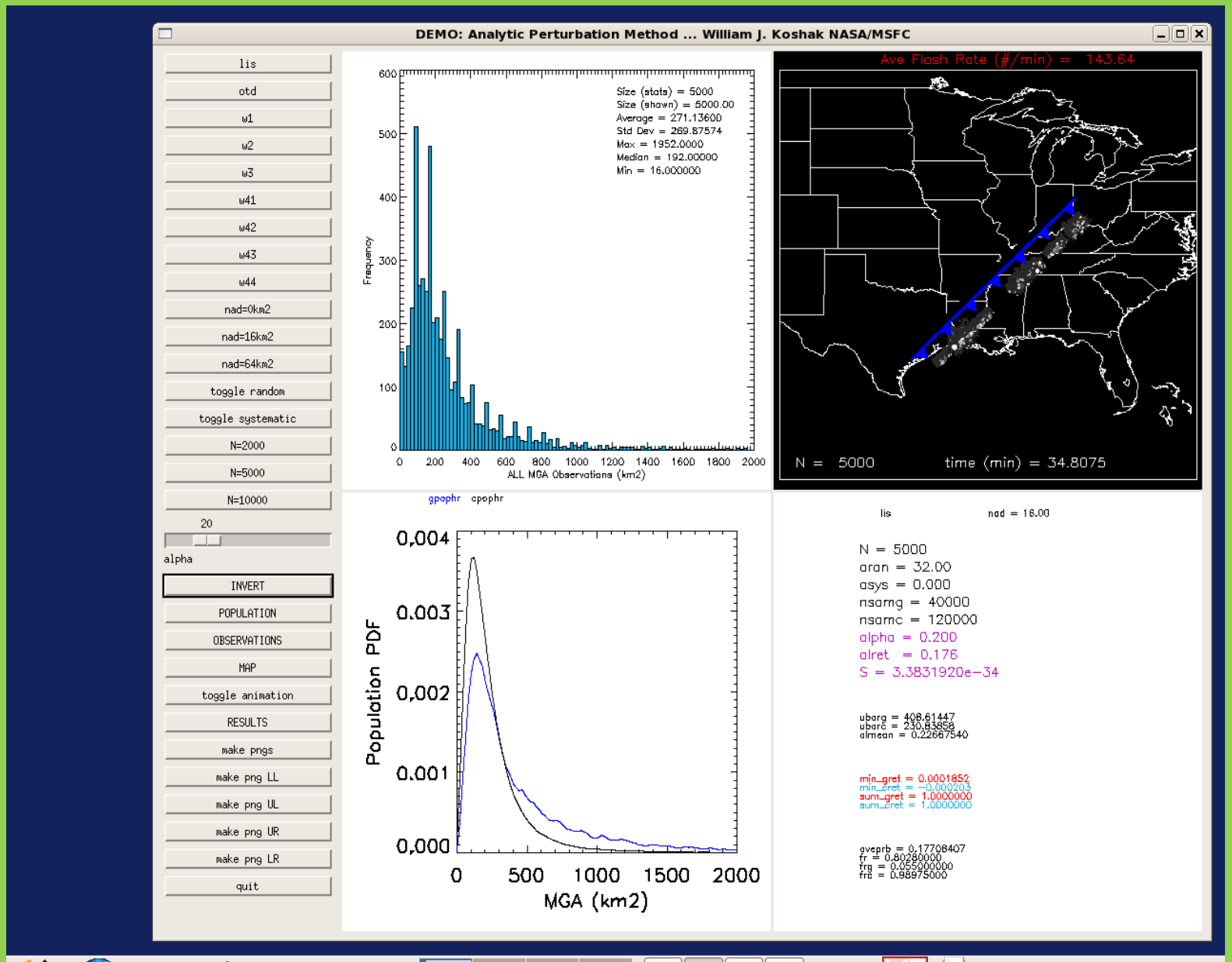


LIS data



OTD data

FUNCTIONAL DEMO NOW EXISTS



Thank You