Approaches to characterize the uncertainties related to stochastic simulations

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Kriging vs. Simulation

Kriging

- Generalized least-squares regression algorithms
- Kriging variance is **not a measure of uncertainty**
- An artificially smoothed representation of reality
- **Smoothing is undesirable** when the aim is to outline areas characterized by high or low values

Simulation

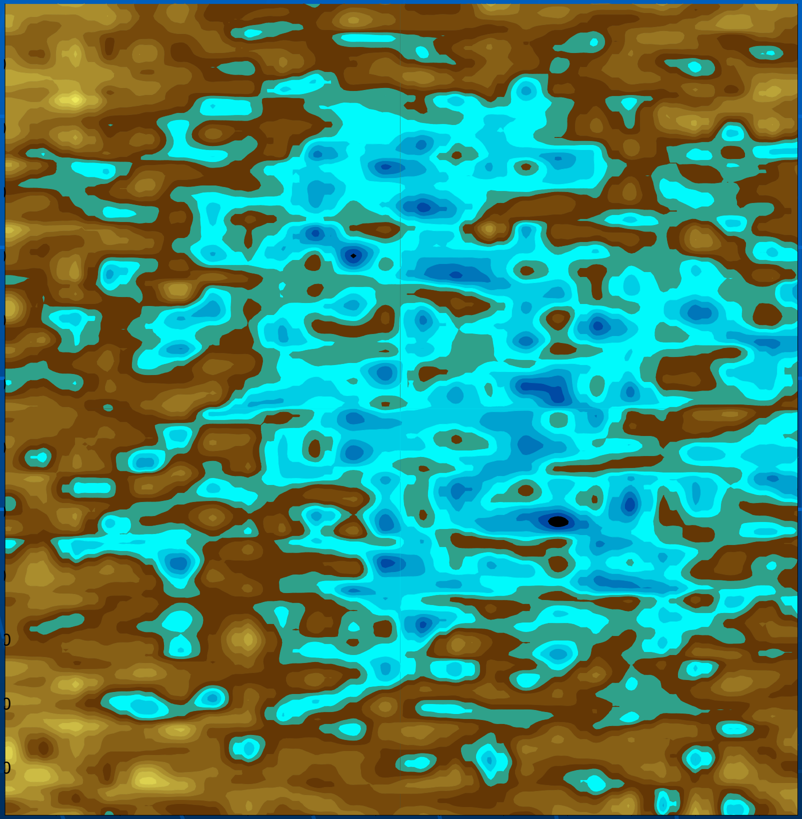
- Reproducing characteristics of the sample distribution
- For **preserving spatial variation** of the studied attribute
- Modeling **local short scale variability**
- Generating equally probable realizations that **allow characterizing uncertainty** of the modeling process

Sequential Gaussian Simulation vs. Sequential Indicator Simulation

SGS	SIS
- Fast and straightforward - Assumes a **parametric distribution** - Maximizes the scattering of extreme values in space **Does not allow significant spatial correlation of extreme values**	- Reproducing **characteristics which are not multigaussian** - Accounting for **class-specific patterns of spatial continuity** - For cases **when extreme values could be better correlated in space** than medium values

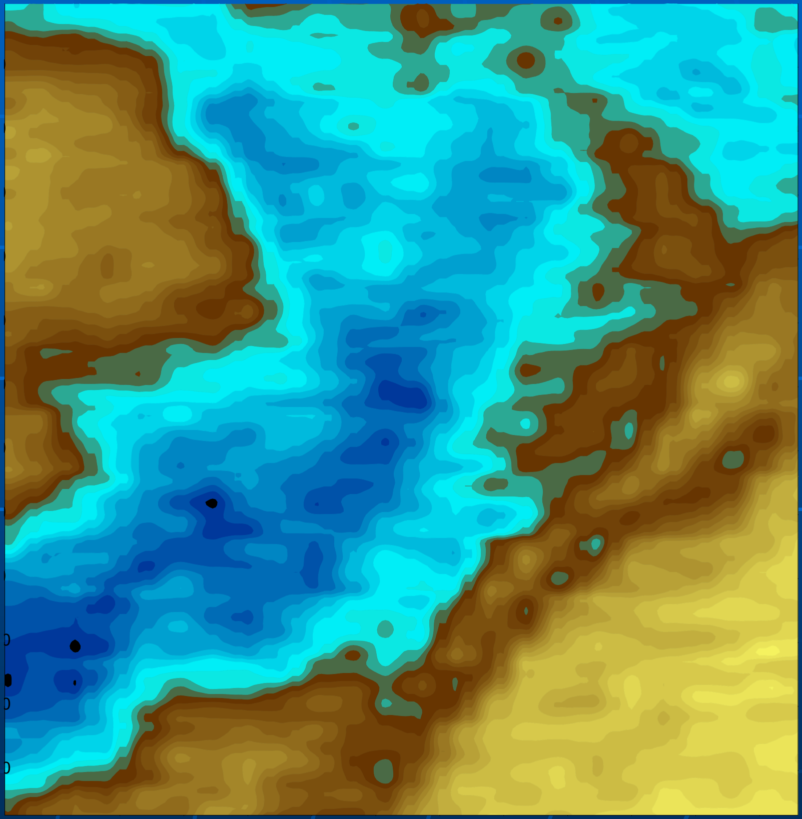
The studied geometries

Slice 1



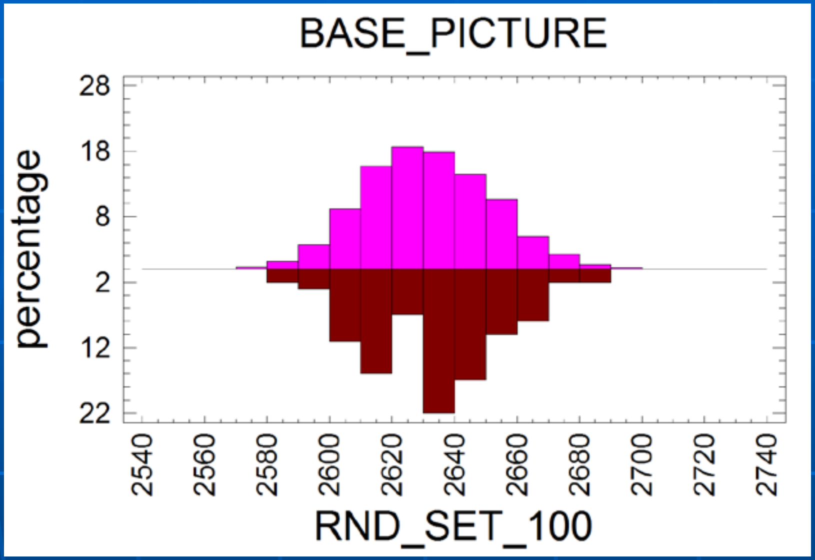
floodplain sediments

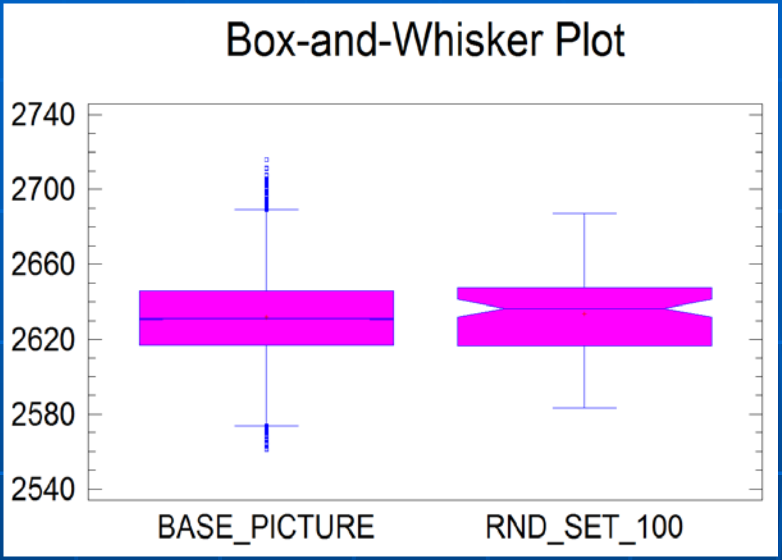
Slice 2

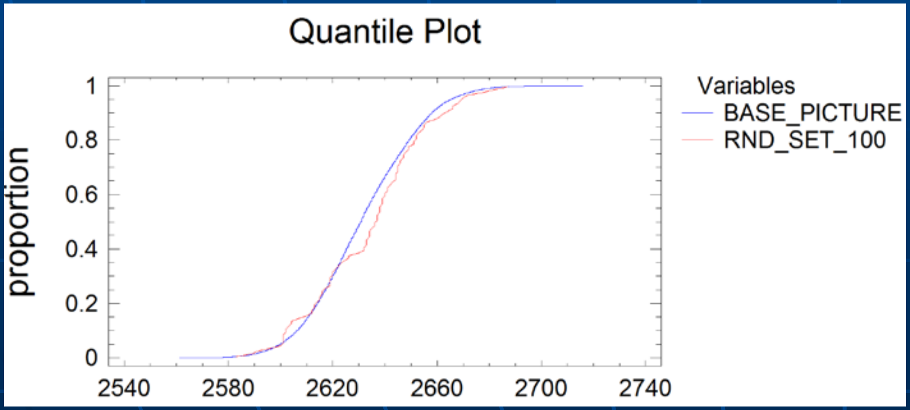


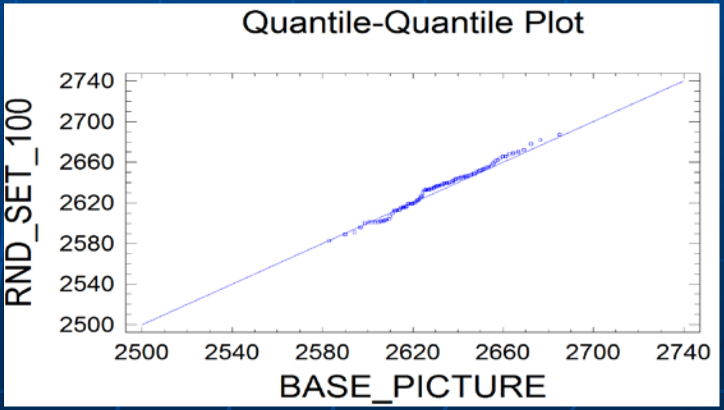
channel mouth bar

Slice1 - Representativity





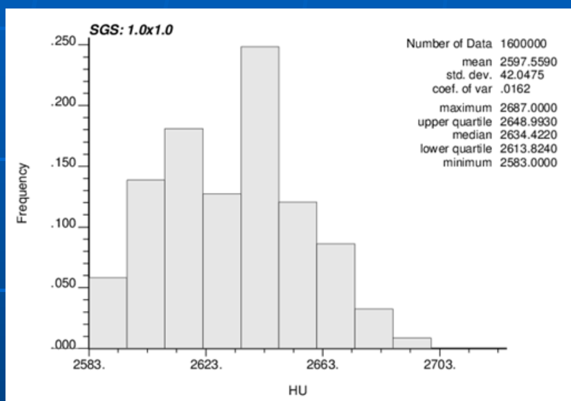




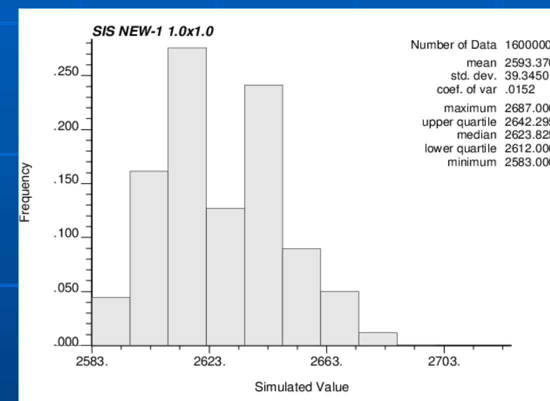
Statistics of Slice1 outputs

- Minimal differences between pooled outputs at different resolutions
- SGS considerably better at reproducing the model distribution

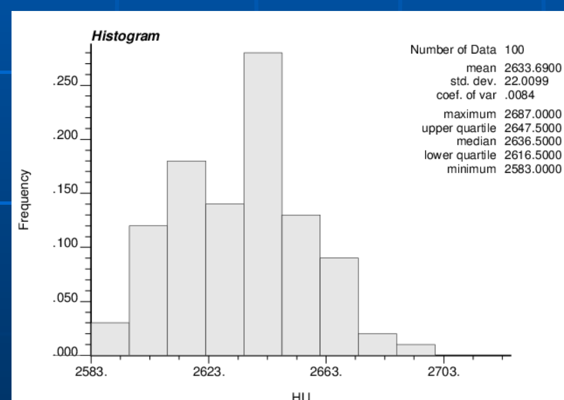
SGS Pooled



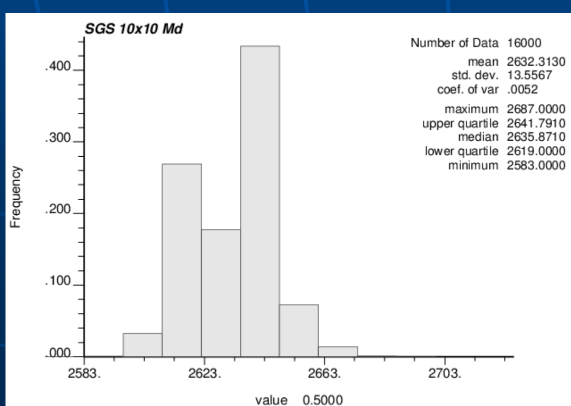
SIS Pooled



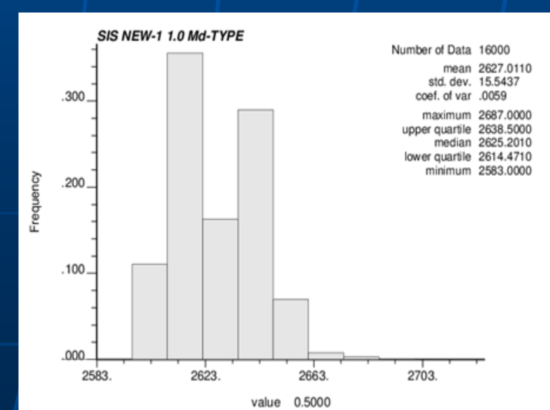
Sample distribution



SGS Median

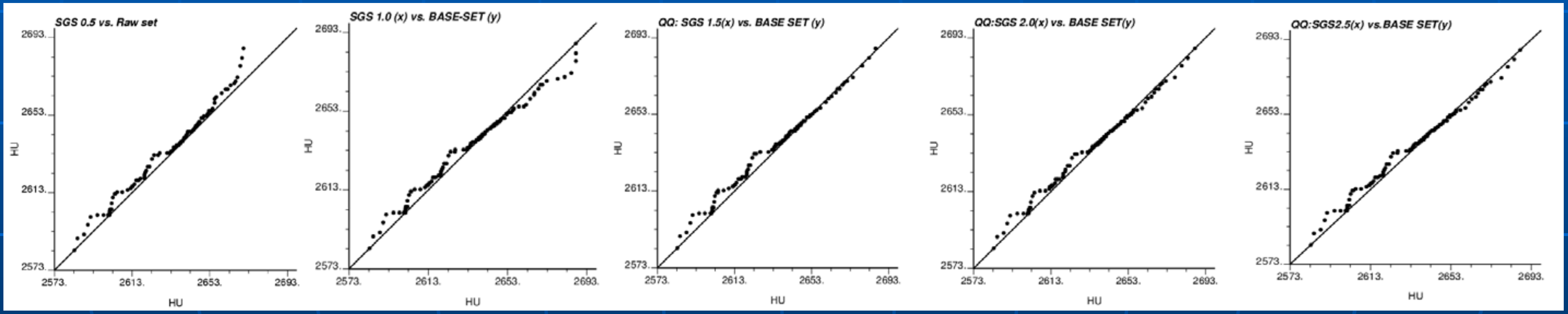


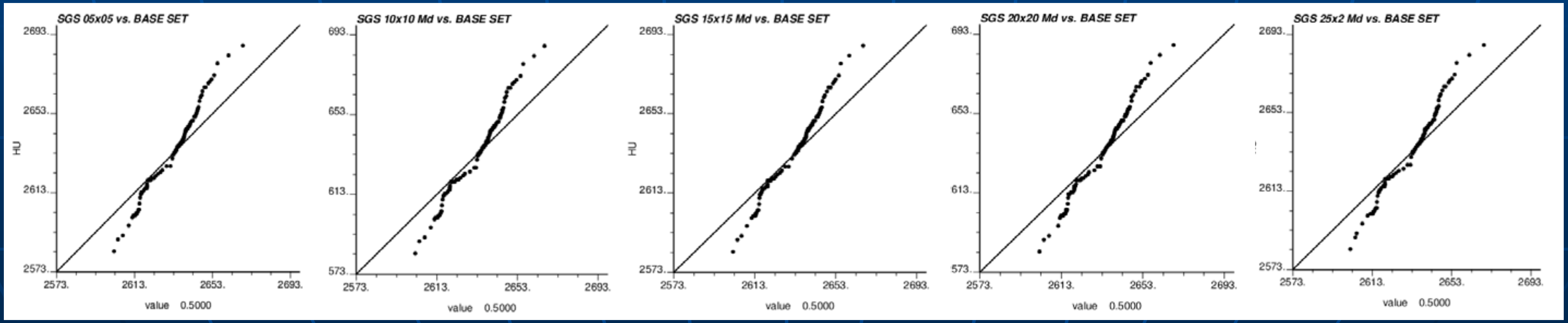
SIS Median



Slice1 SGS QQ plots for pooled realizations and MD estimations

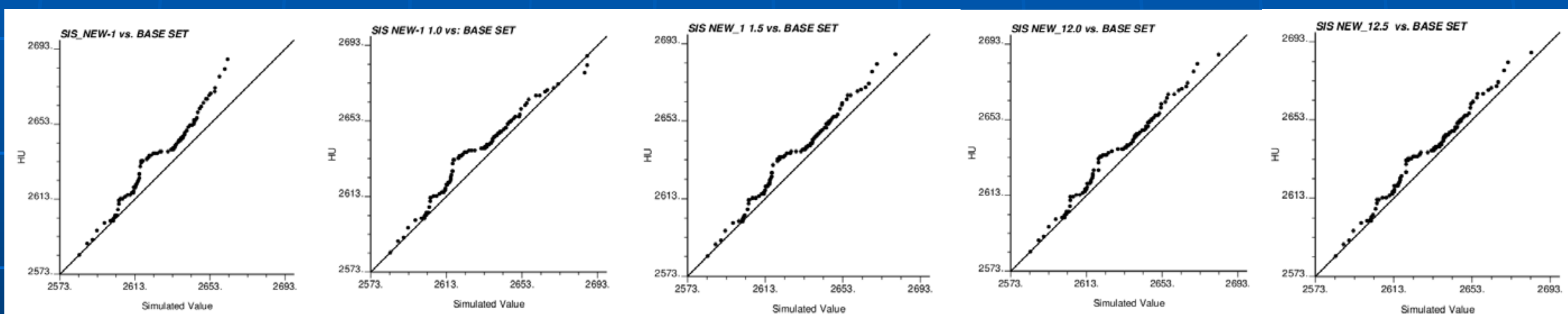
- Better fit of pooled data in the direction of smaller resolutions, but MD type estimates tend to wash this effect away
- Less grid nodes – better reproduction of model distribution

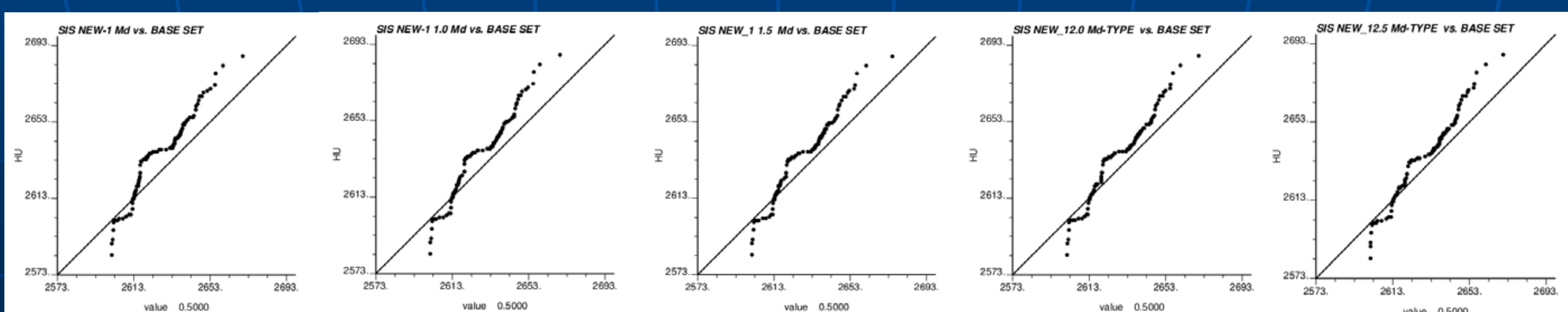




Slice1 SIS QQ plots for pooled realizations and MD estimations

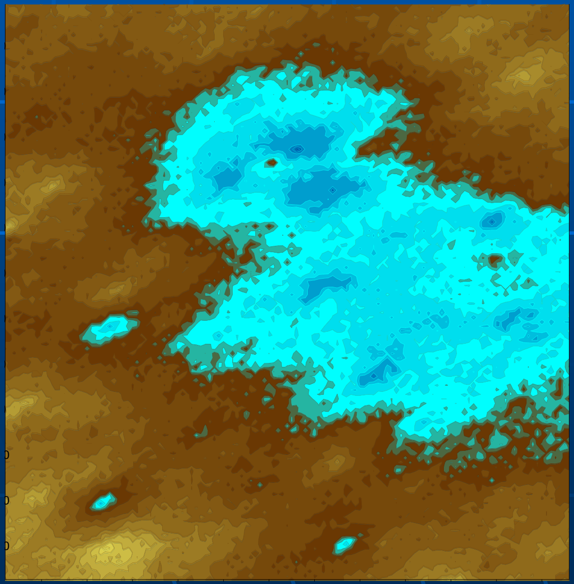
- Reproduction of statistics for pooled realizations improve toward lower grid resolutions, but MD type estimates still hardly follow this
- An overall less accurate fit than in the case of SGS



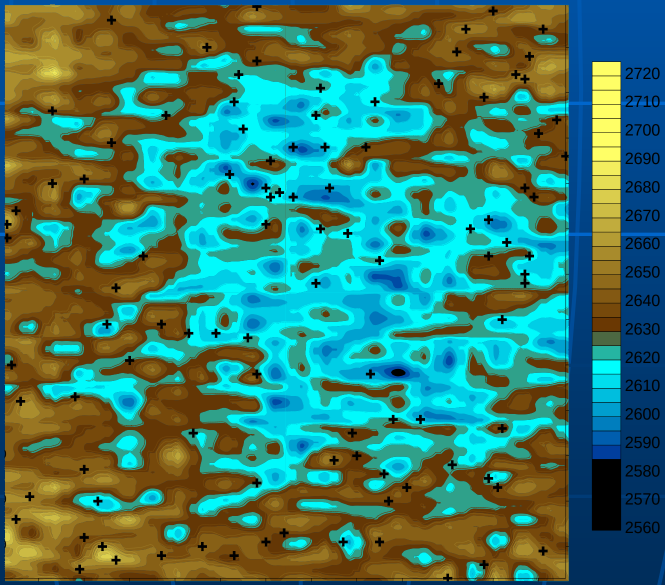


Slice1 MD type visualizations

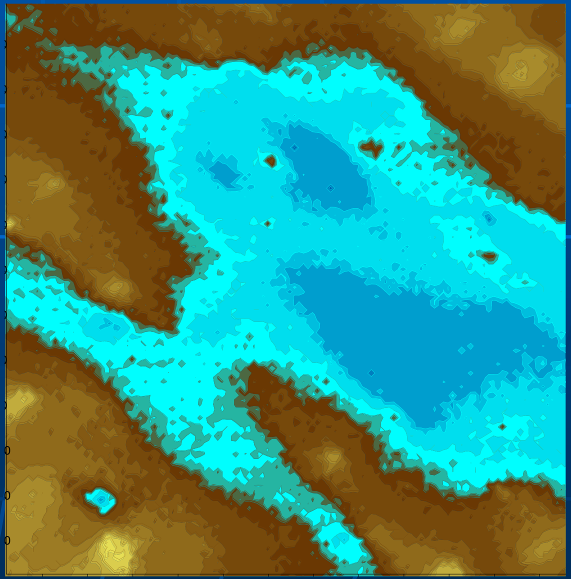
- Both far from reality, but true to what one might expect from the simulation algorithm itself
- SGS maximizes the scattering of extreme values while SIS is more pattern oriented



SGS



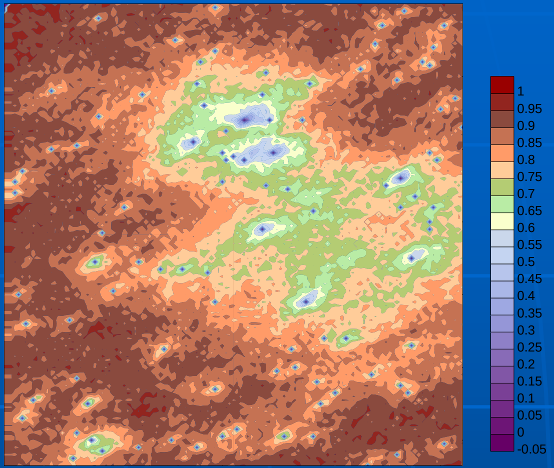
Original image



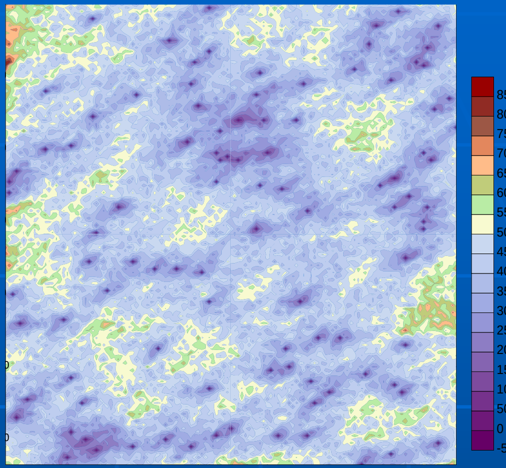
SIS

Uncertainty of the SGS estimations

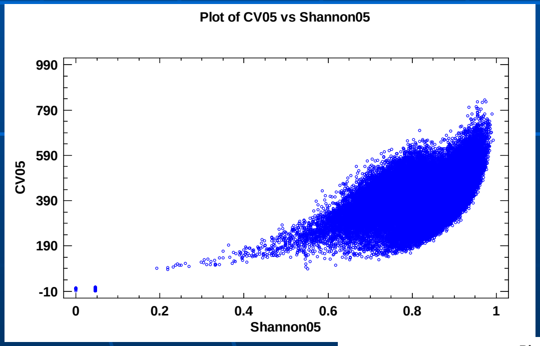
- Higher entropies dominate over the area
- CV confirm the entropies everywhere - entropy is a stricter measure of uncertainty than CV
- Entropy and CV vary together
- Lower resolutions yield less stable estimates

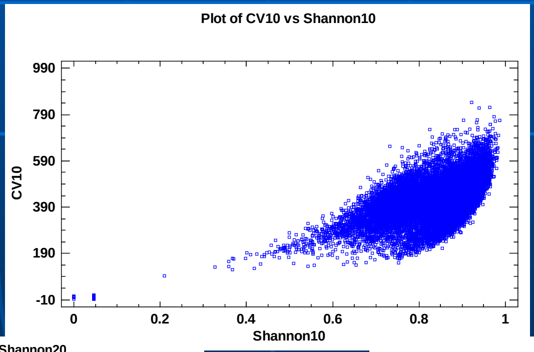


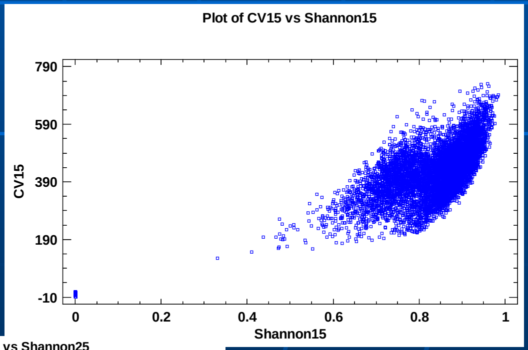
Entropy

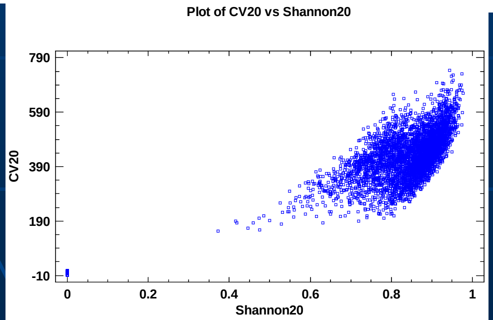


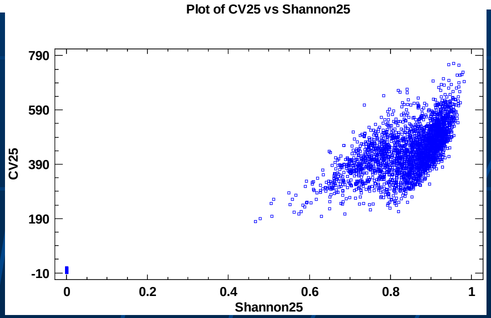
Conditional Variance





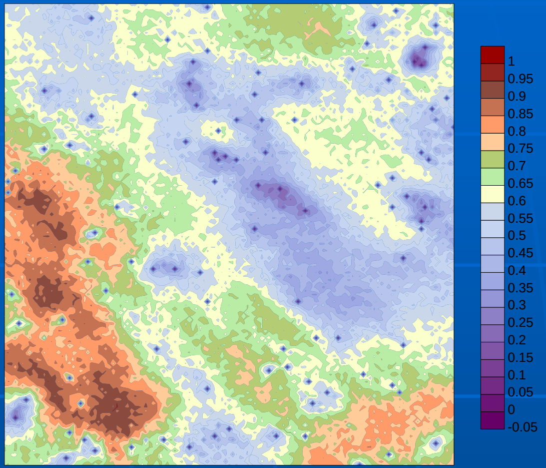




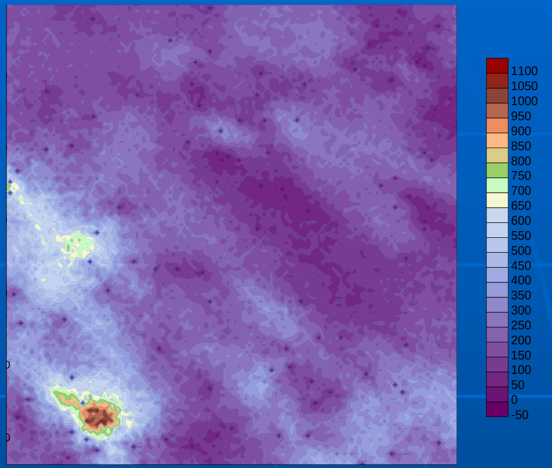


Uncertainty of the SIS estimations

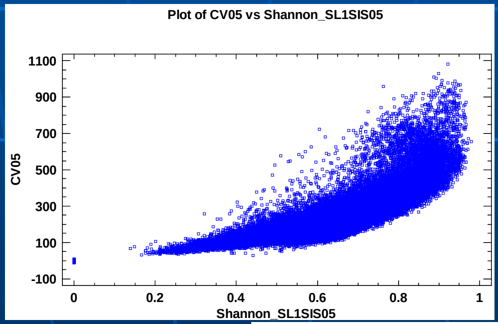
- Lower entropies – SIS estimates are more stable than SGS
- Also lower conditional variances dominate
- SIS entropies are less sensitive to grid resolution
- The width of the entropy interval changes less with grid resolution than in the case of SGS

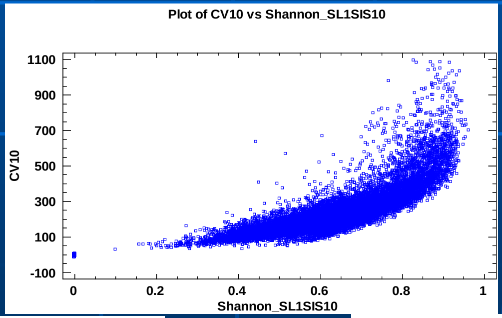


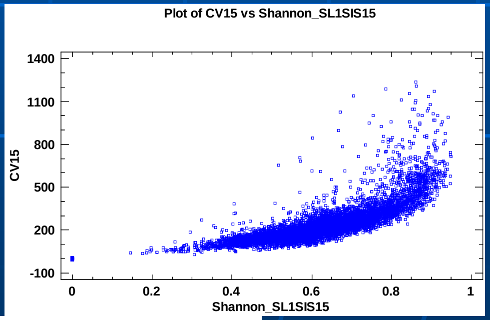
Entropy

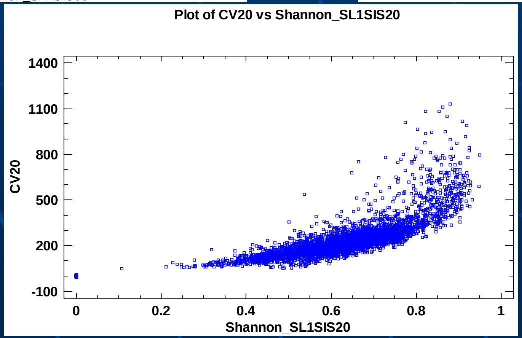


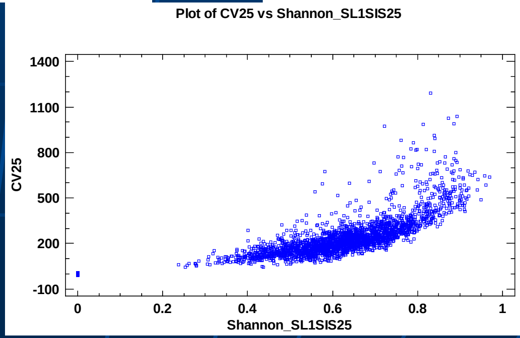
Conditional Variance



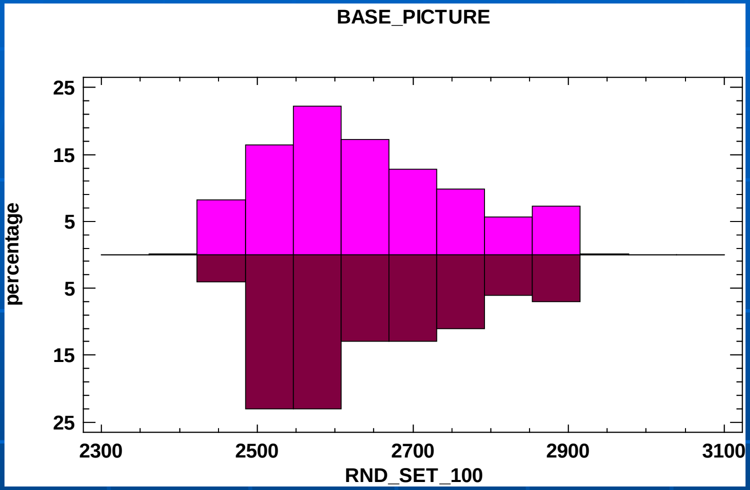


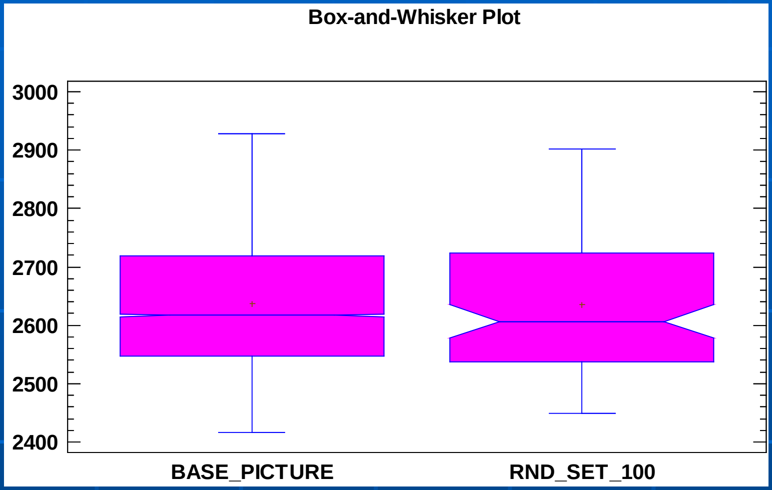


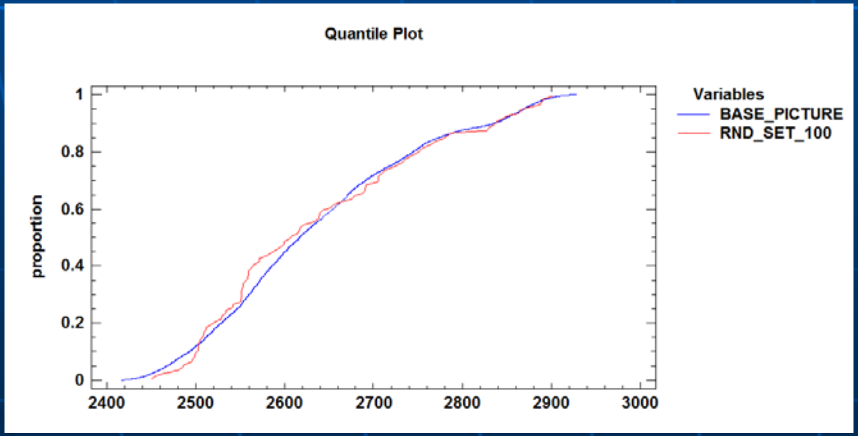


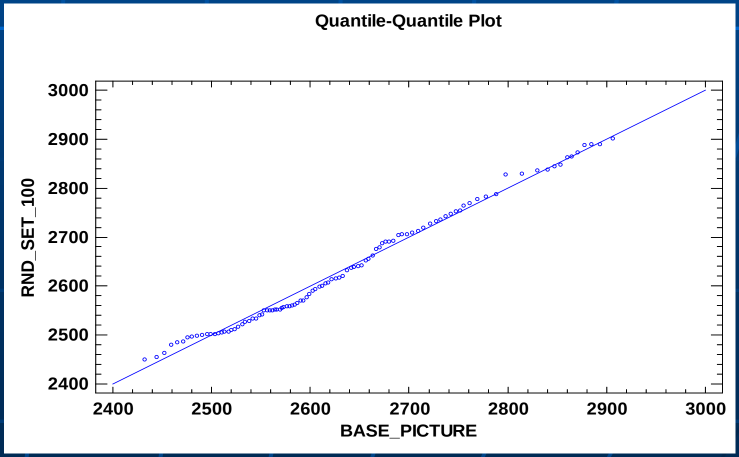


Slice2 - Representativity





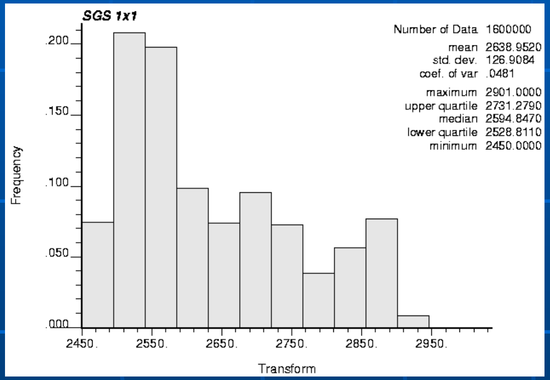




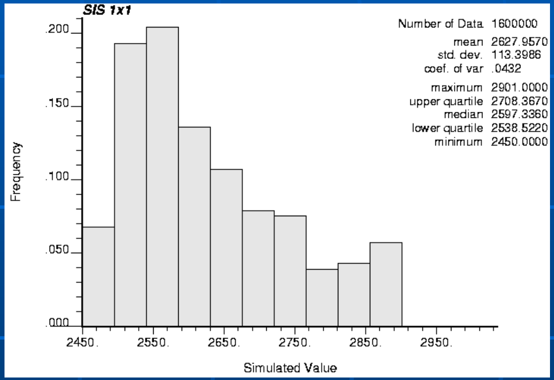
Statistics of Slice2 outputs

- SGS honors model distribution better than SIS
- MD type estimates less far from model distribution than in case of Slice1

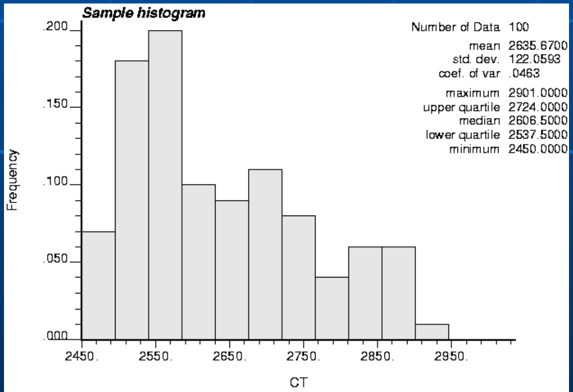
SGS Pooled



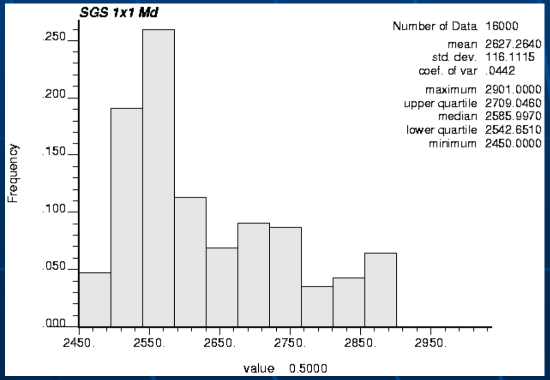
SIS Pooled



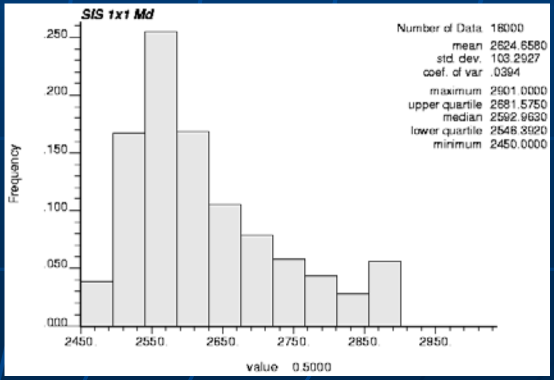
Sample distribution



SGS Median

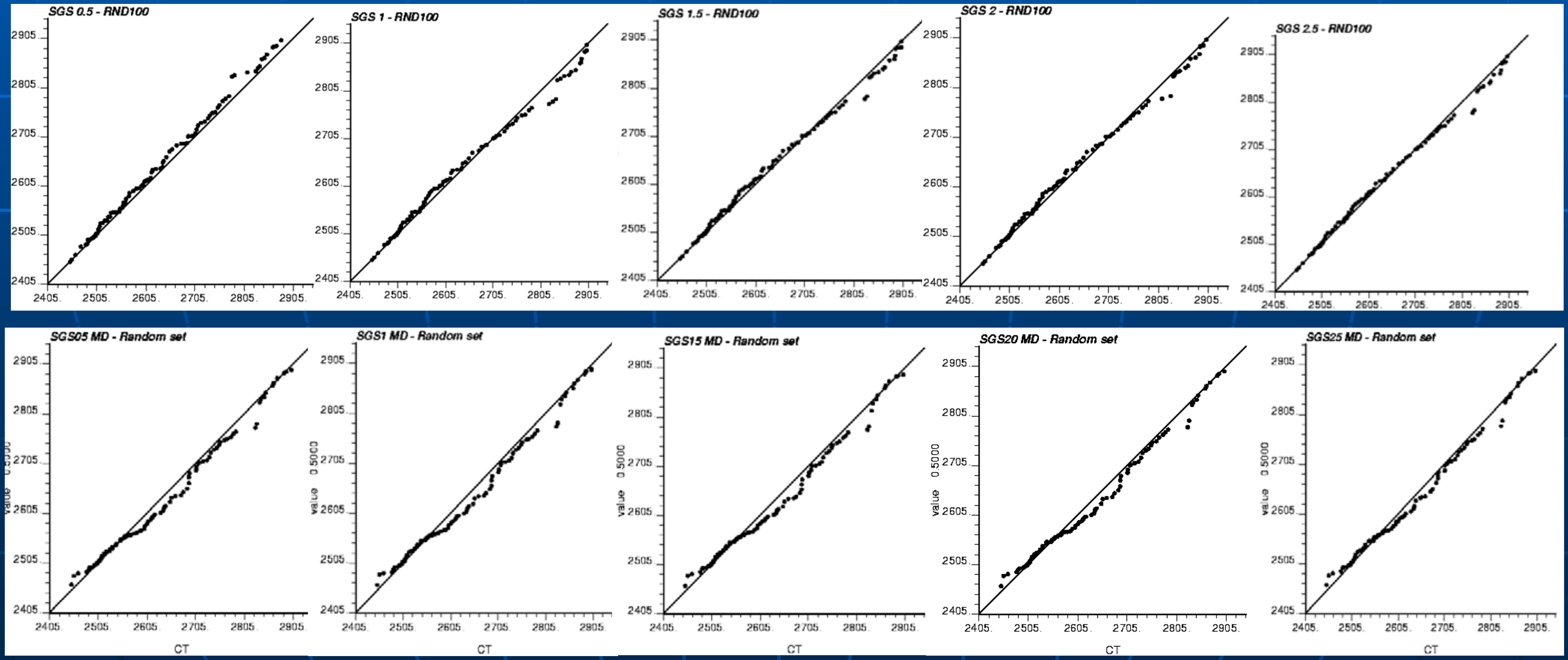


SIS Median



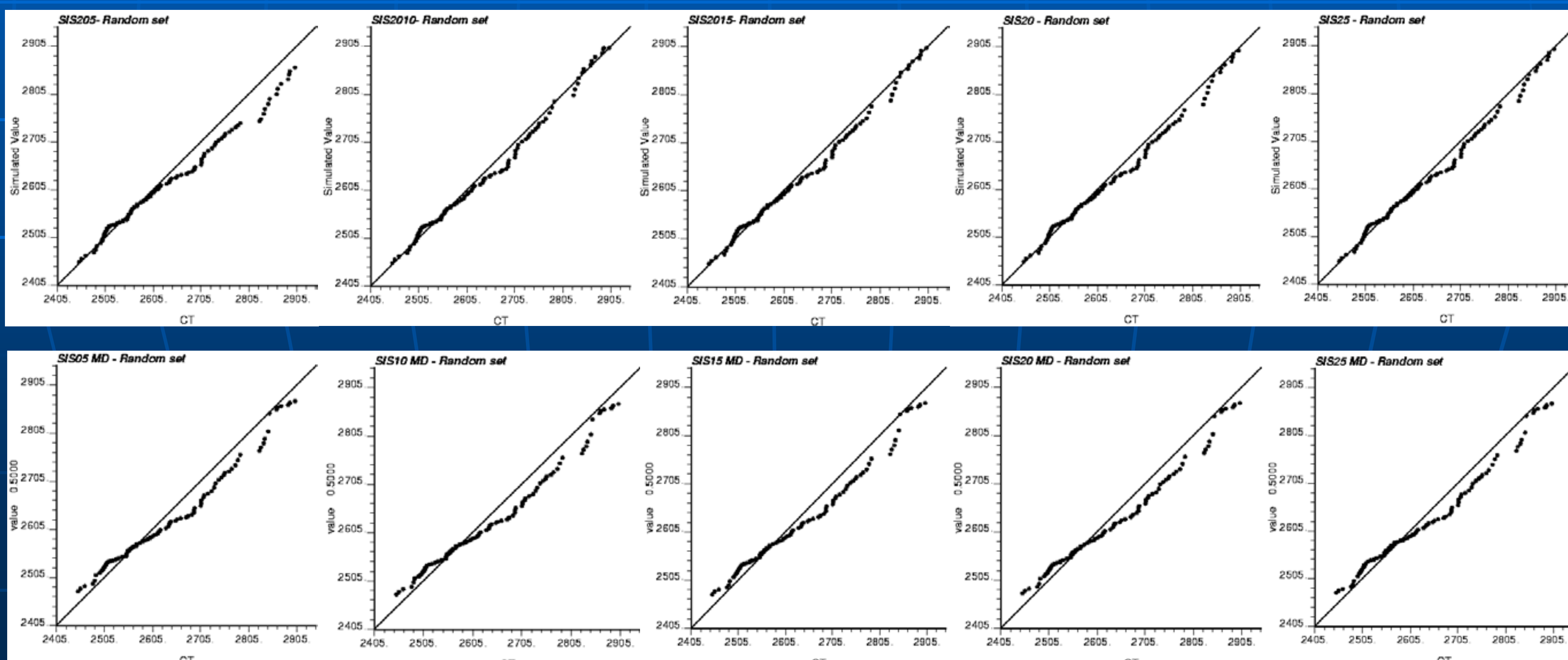
Slice2 SGS QQ plots for pooled realizations and MD estimations

- The fits for SGS are reasonably good for the pooled realizations with small differences between resolutions
- MD type estimates are more sensitive to change of grid resolution then pooled realizations (lower heterogeneity)



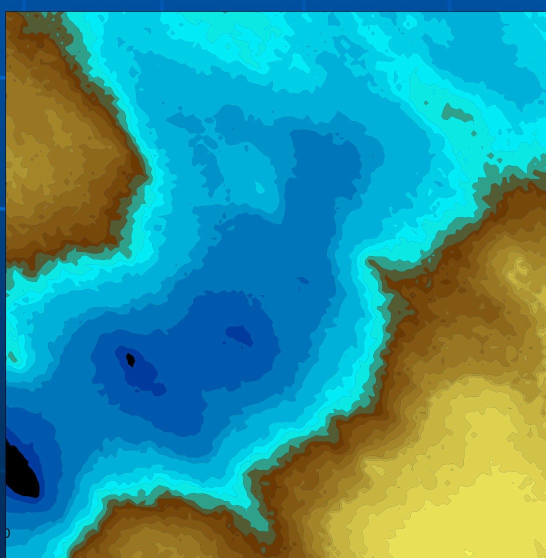
Slice2 SIS QQ plots for pooled realizations and MD estimations

- Compared to SGS, the fits for SIS a less accurate
- For SIS grid resolution also matters at the level of pooled realizations
- The fit for MD type estimates is not that accurate compared to the pooled realizations

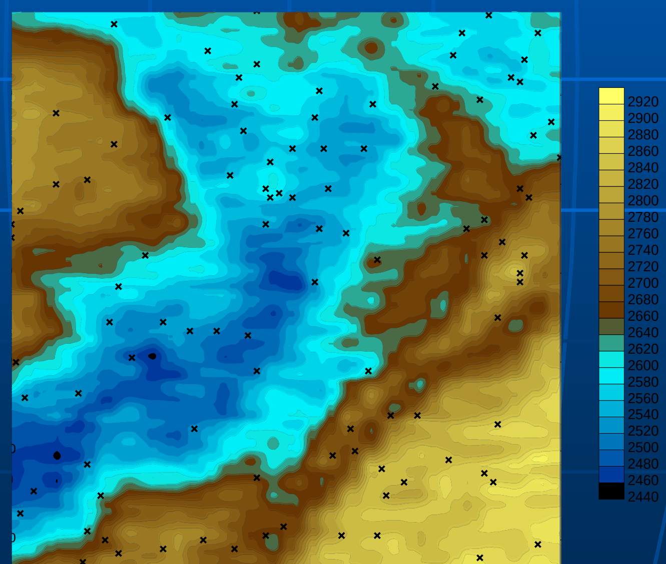


Slice2 MD type visualizations

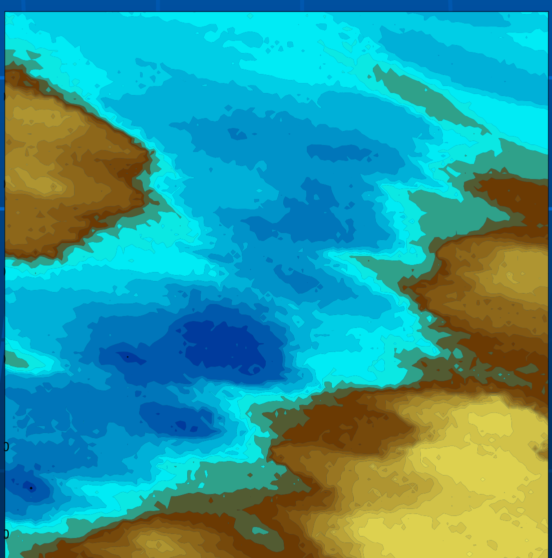
- Better representativity of sample data set results in a more reliable spatial prediction
- Better reproduction of inner heterogeneities with SIS



SGS



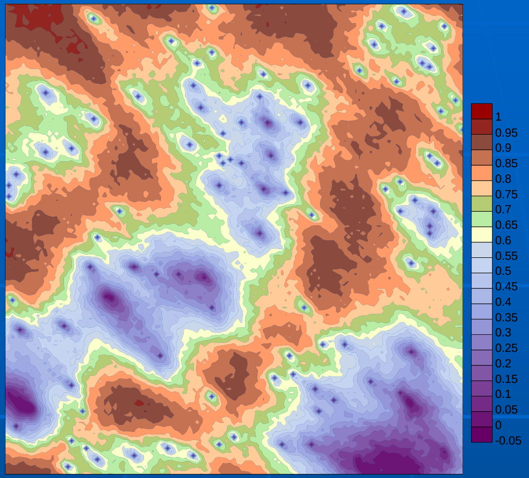
Original image



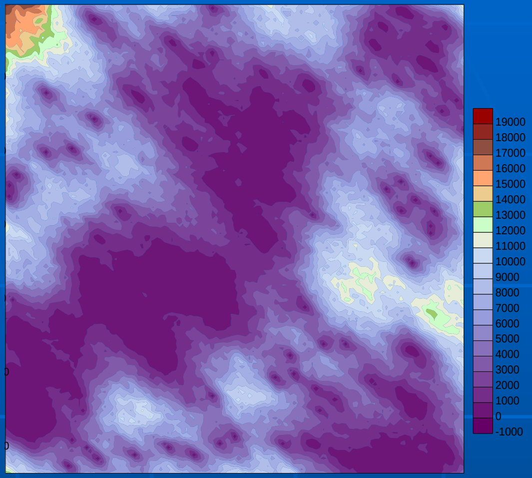
SIS

Uncertainty of the SGS estimations

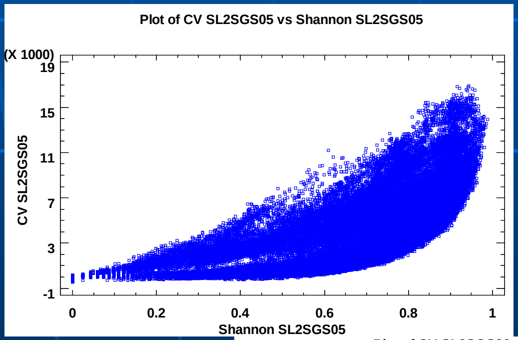
- Stable estimates around data locations
- More areas with higher uncertainties than in case of SIS
- CV confirm entropies

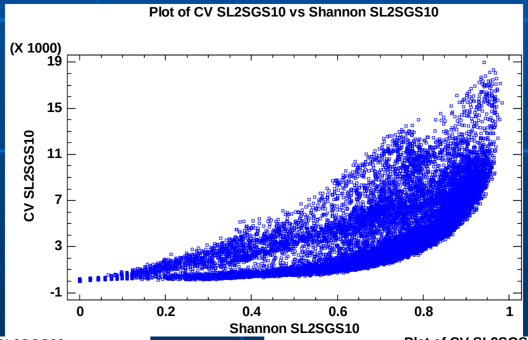


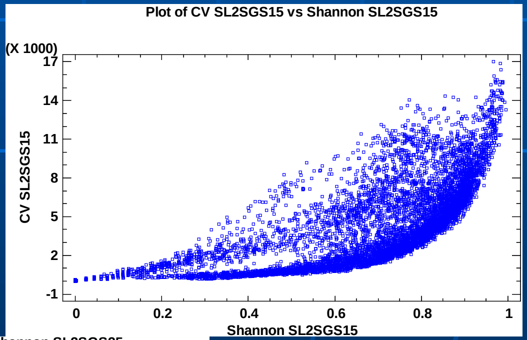
Entropy

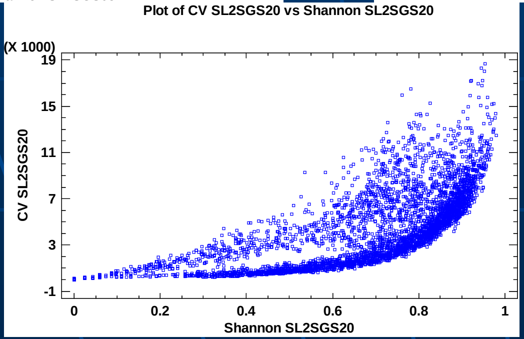


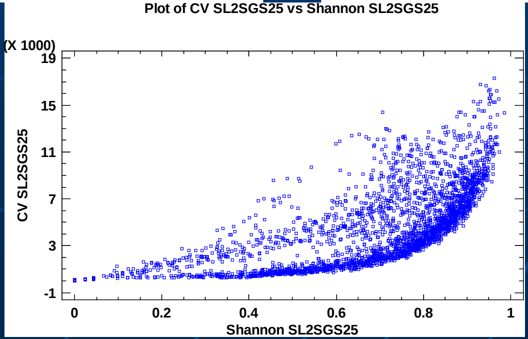
Conditional Variance







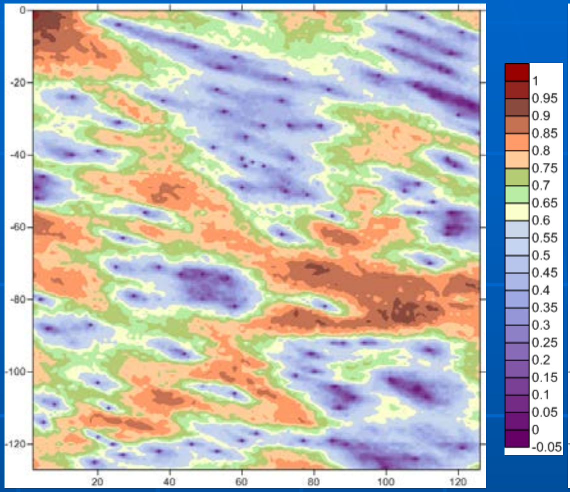


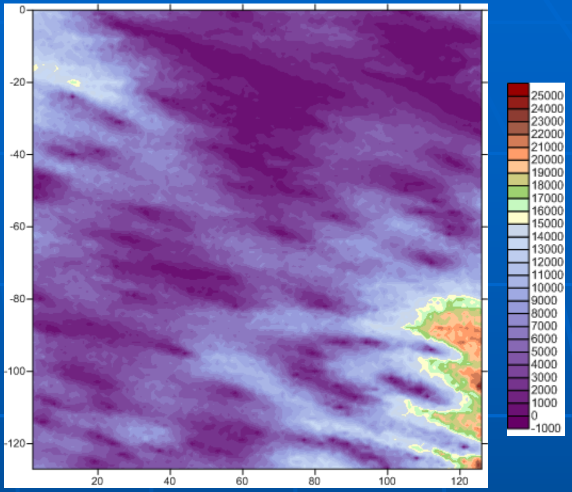


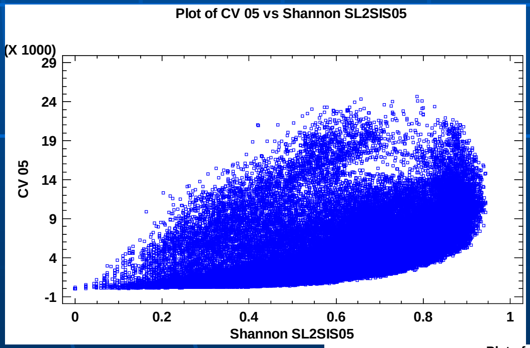
Uncertainty of the SIS estimations

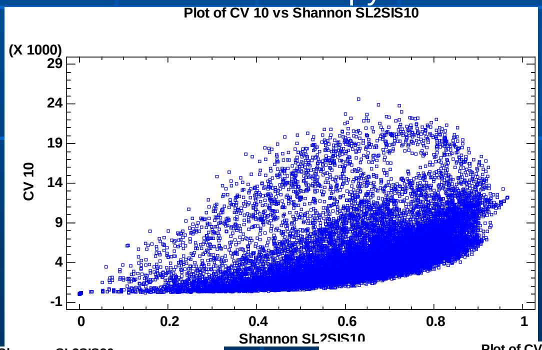
- Better connectivity of areas characterized by low uncertainties
- Lower entropies and

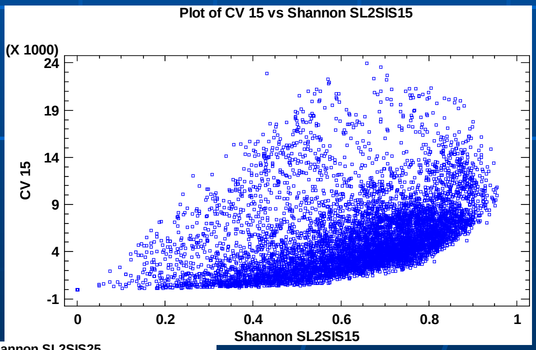
  conditional variances

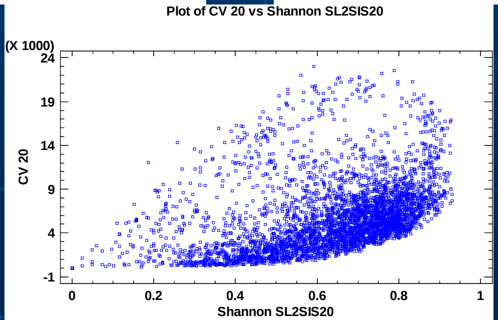

Entropy

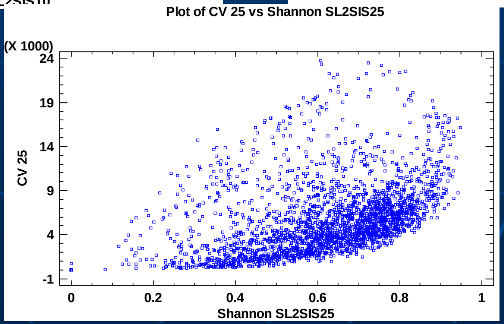

Conditional Variance











Overview

	SGS	SIS
Reproduction of the model distribution in highly heterogenous case	✓	✗
Reflecting high heterogeneities in space	✓	✗
Uncertainties related to high heterogeneities	✗	✓
Reproducing the model distribution in the low heterogeneity case	✓	✗
Reflecting low heterogeneities in space	✗	✓
Uncertainties related to low heterogeneities	✗	✓
Effect of grid resolution on reproducing heterogeneities	✗	✗

Summary

- Building a model that actually suits the data
- The measures of uncertainty are characteristic of the model, the simulation and its outputs rather than the studied process itself
- Statistics of pooled realizations match the model distribution better than the estimates derived from them
- However, estimates are inevitable for spatial assessment and for dinamic simulations