China University of Geosciences, Wuhan

Studying geochemical element relationship by considering frequency and spatial information

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Jian Wang, Renguang Zuo

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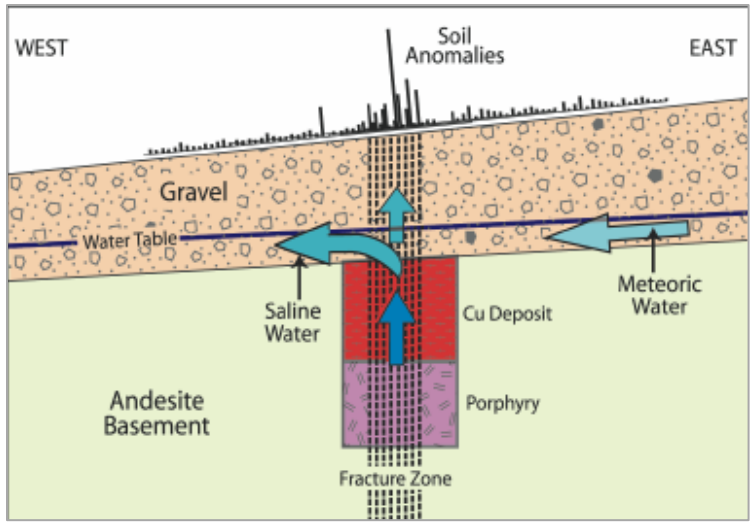
Background and Motivation

(1) Elements with similar mobility under certain environment tend to group together, thus exhibit similar distribution patterns

- Subsurface and surface conditions are different
- Comprehensive reflection of primary and secondary processes (Rollinson, 1993)



(Leybourne and Cameron, 2007)

- Cu, Mo, As, Se, Re were found to be indicative of underlying mineralization
- Paragenetic elements for porphyry copper deposits: Cu, Au, Ag, Mo, Pb, Zn, etc.

Background and Motivation

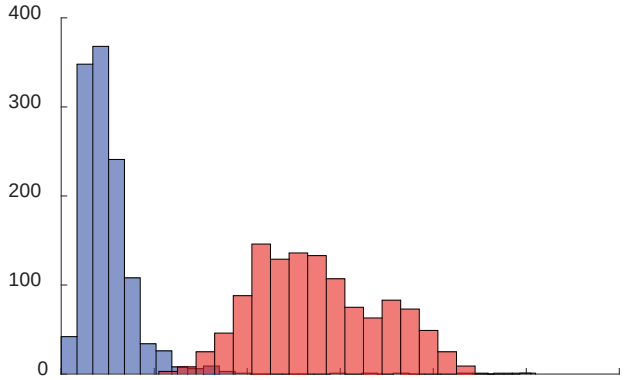
(2) Difference of distribution patterns for elements should reflect difference of involved processes

- How to measure similarity/dissimilarity of elements

(3) Commonly used numerical methods

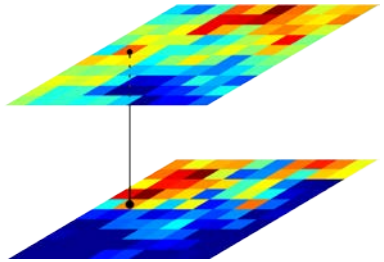
- Principal component analysis and its variants (e.g. Caritat and Grunsky, 2013)
- Factor analysis (e.g. Zibret and Sajn, 2010; Shiva and Atkin, 2004)
- Cluster analysis (e.g. Nude et al., 2012)

Comparing frequency and spatial characteristics



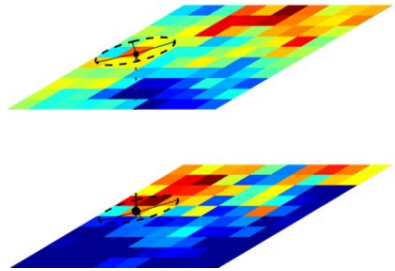
(1) Frequency distribution

Global measure of dissimilarity



(2) Spatial correspondence

1. Secondary dispersion
2. background; etc.



(3) Spatial pattern

Dispersion/accumulation mechanism; etc.

Issues to address

- **Define dissimilarity of these aspects**
  - Method for quantifying distribution patterns
  - Dissimilarity metrics

Frequency distribution

Dissimilarity between *cdfs*

$$d(A,B) = f_{\Delta cdf}\left(F_A(x), F_B(x)\right) \qquad (A, B \text{represent elements})$$

- Different ranges of concentration values

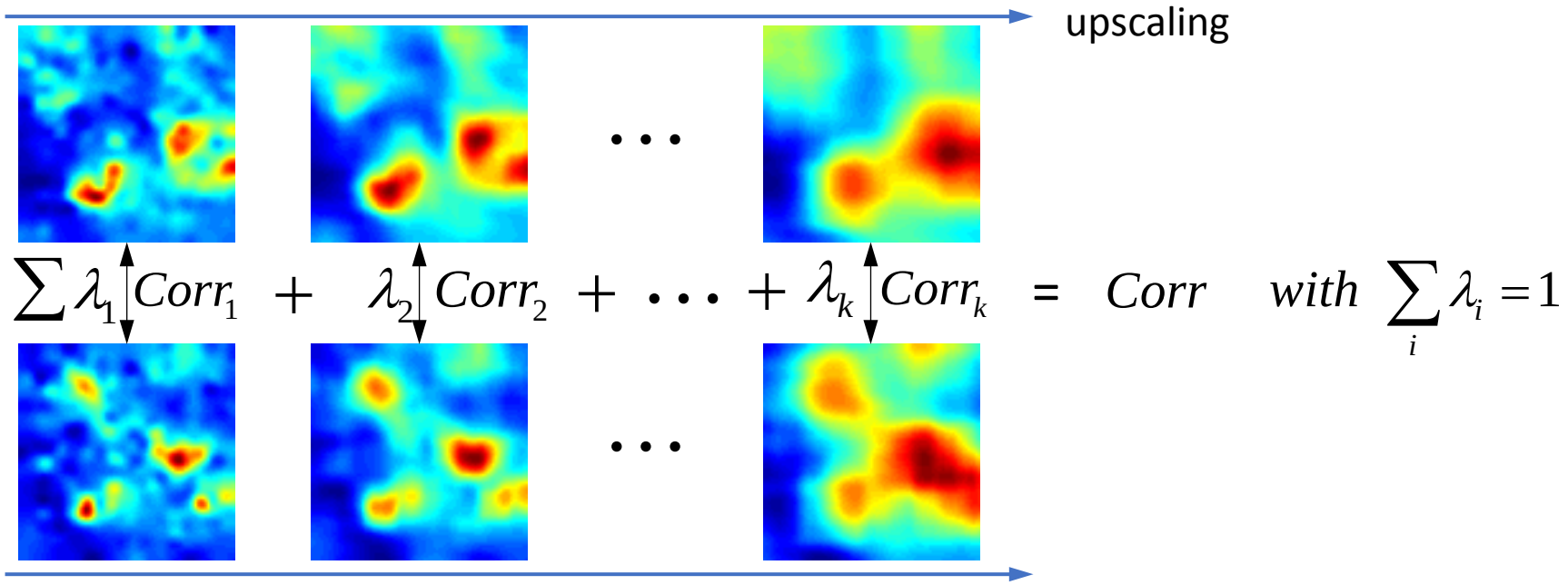
(e.g., Fenwick et al., 2014)

Spatial correspondence

Pixel-by-pixel dissimilarity

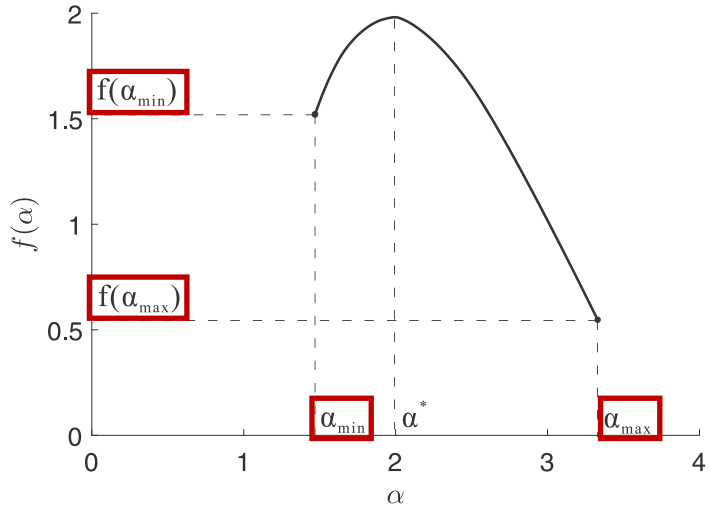
$$d = E\left\{dist\left[c_A(i,j), c_B(i,j)\right]\right\}$$ (i, j denotes spatial location)

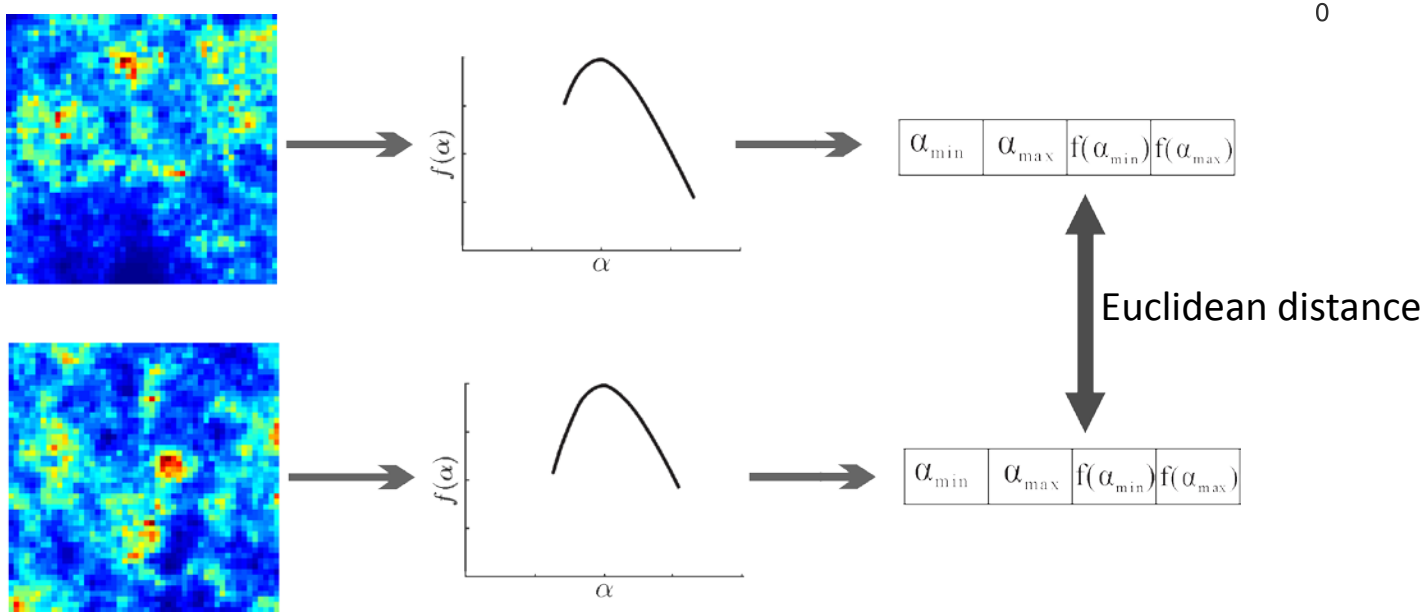
- Correlation coefficient (outliers)
- Euclidean distance
- Mutual information (Maes et al., 1997)
- …



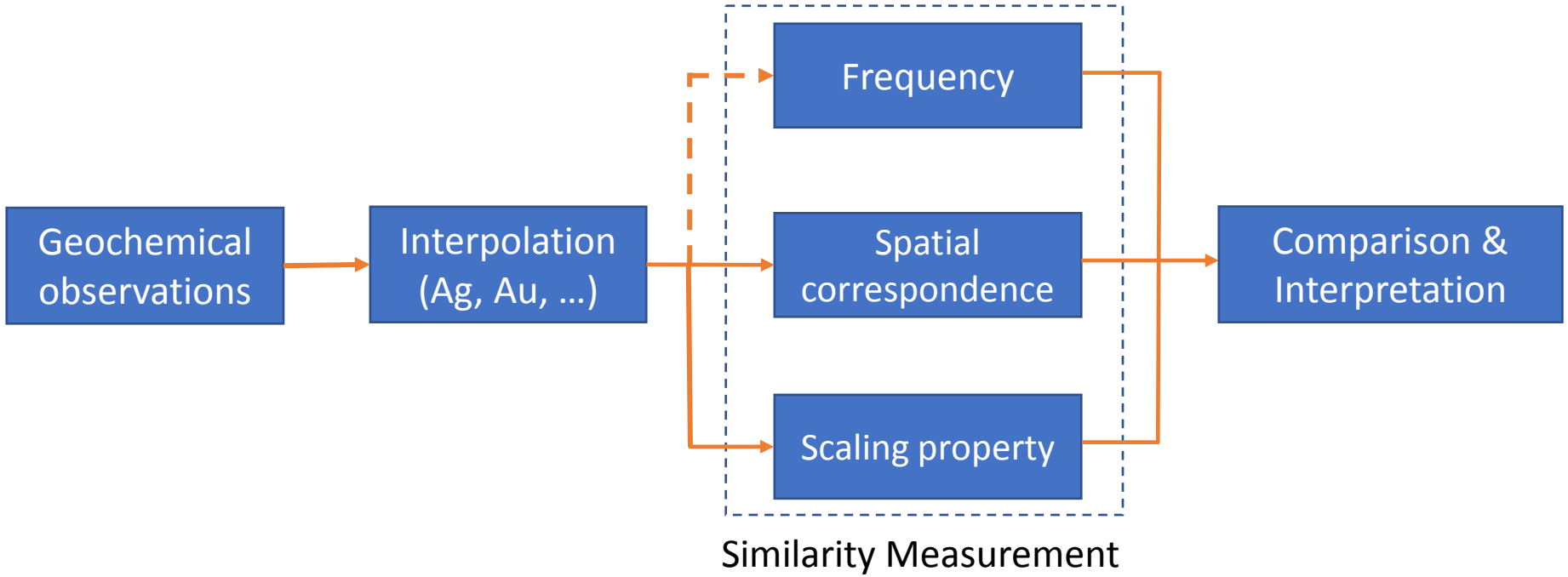
Spatial patterns

- Singularity index measures enrichment/depletion patterns
- Multifractal spectrum
  - — distribution of singularity index
  - — equivalent representation





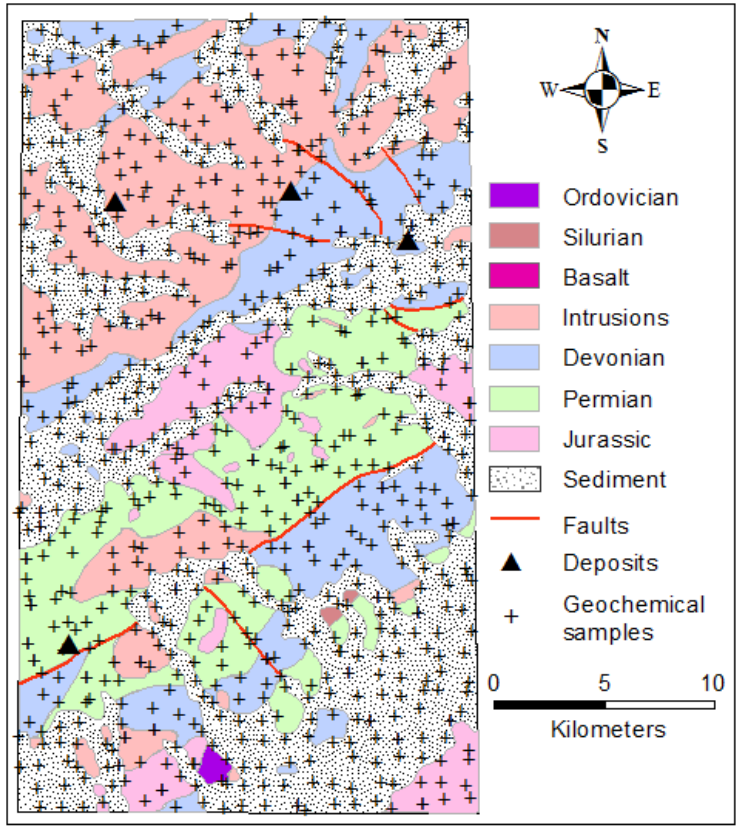
Workflow in practice



- Interpretation should be also based on geological background, and typical mobility of elements at surficial condition
- Further analysis or experiment is needed

Study area

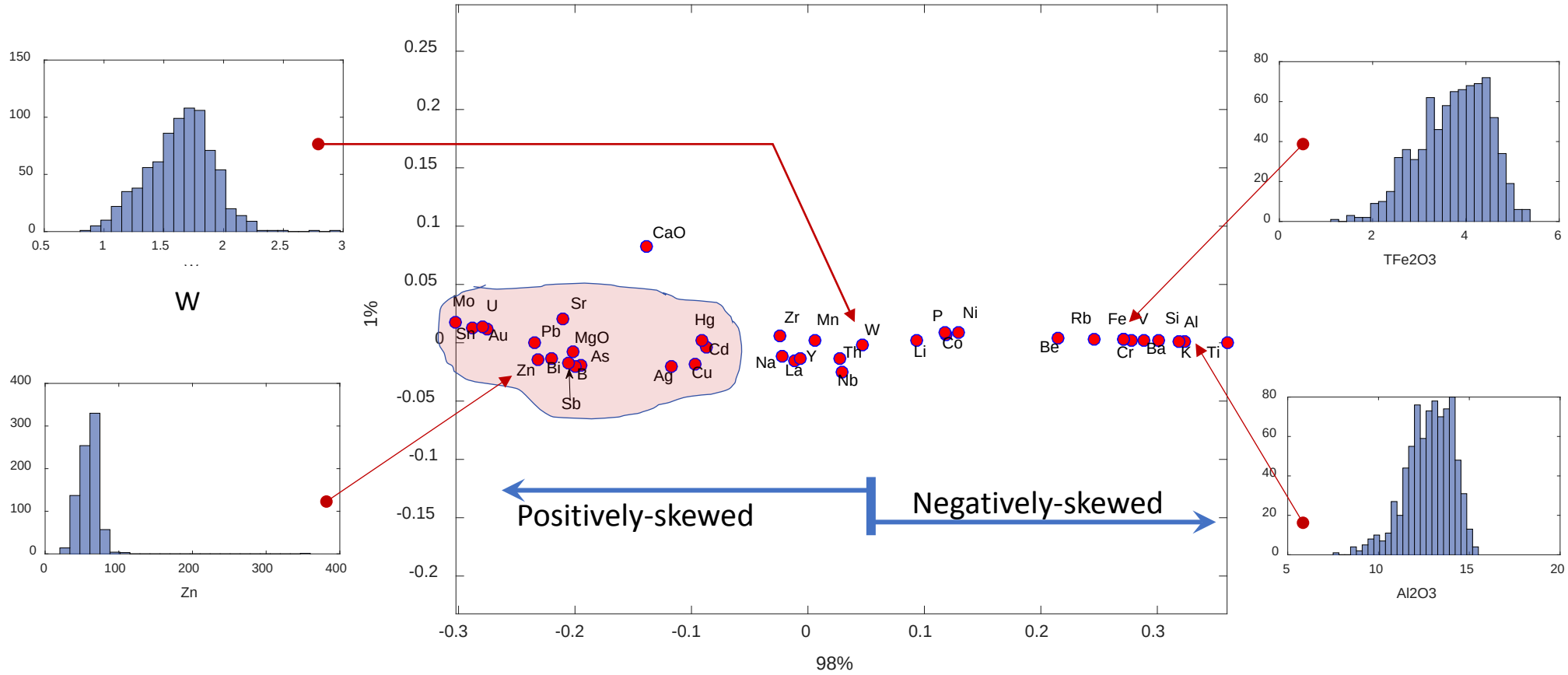
- 800 geochemical soil samples
- cover about 664 km^2
- 39 elements analyzed
- known hydrothermal mineralization (Ag, Au, Pb, Zn , Cu, As, Cd)



(modified from Liu, 2011)

Comparison of frequency distribution

Multidimensional scaling (MDS) plot of dissimilarity matrix

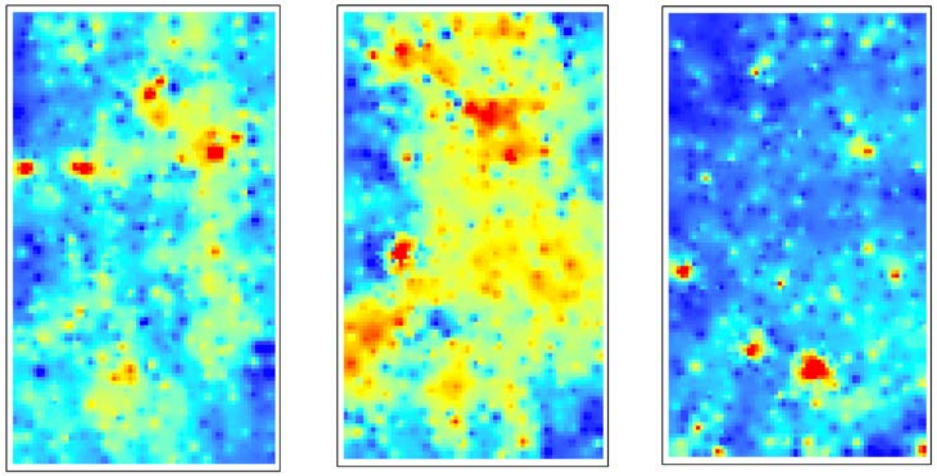


- Hydrothermal elements showed positively-skewed distribution and grouped together, which is consistent with prior knowledge from geological background

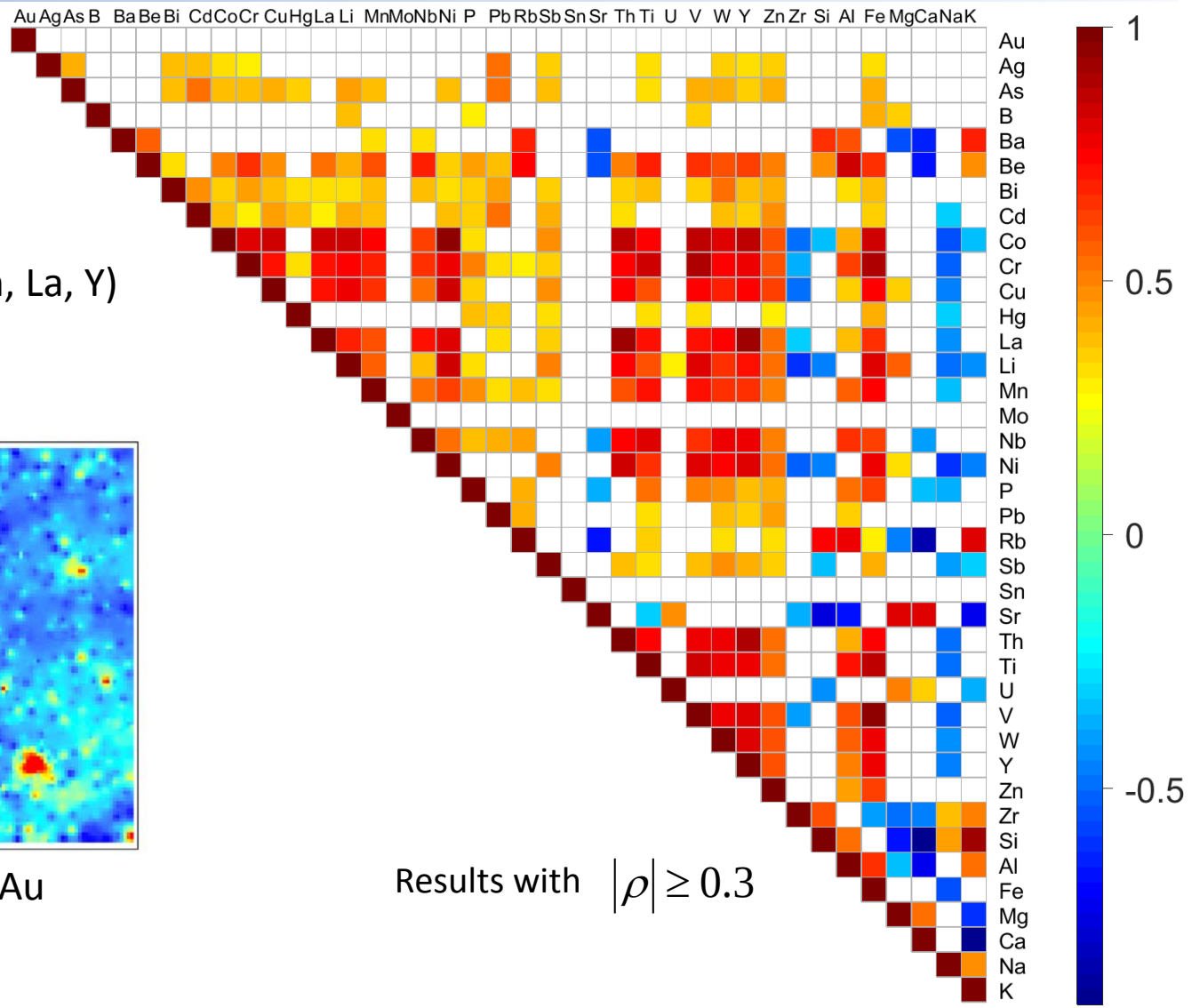
Spatial correlation among elements

Grouped elements:

- Pb, As, **Ag**, Cd
- (Cu, **Zn**, Fe, Mn, Co, Ni), Cr, V, Ti, W, (Th, La, Y)
- (**Au**), (Sn)

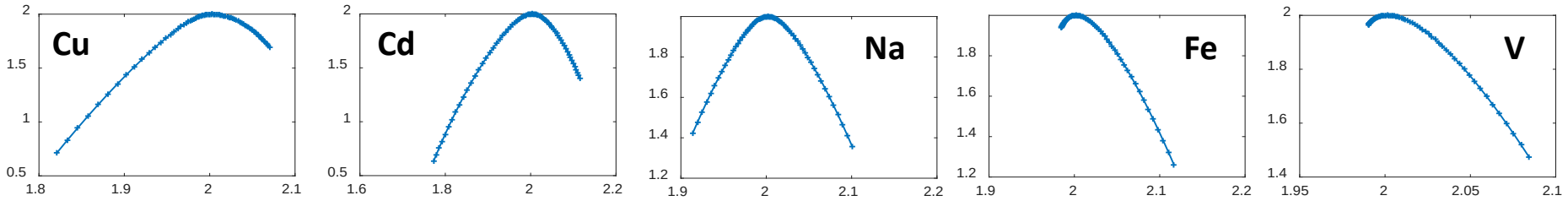


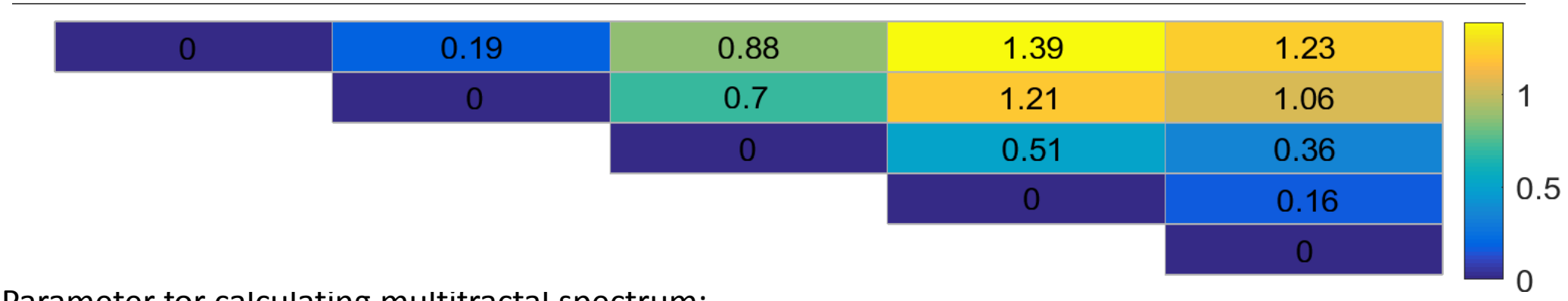
Ag Zn Au



Results with $|\rho| \geq 0.3$

Distance between multifractal spectrum



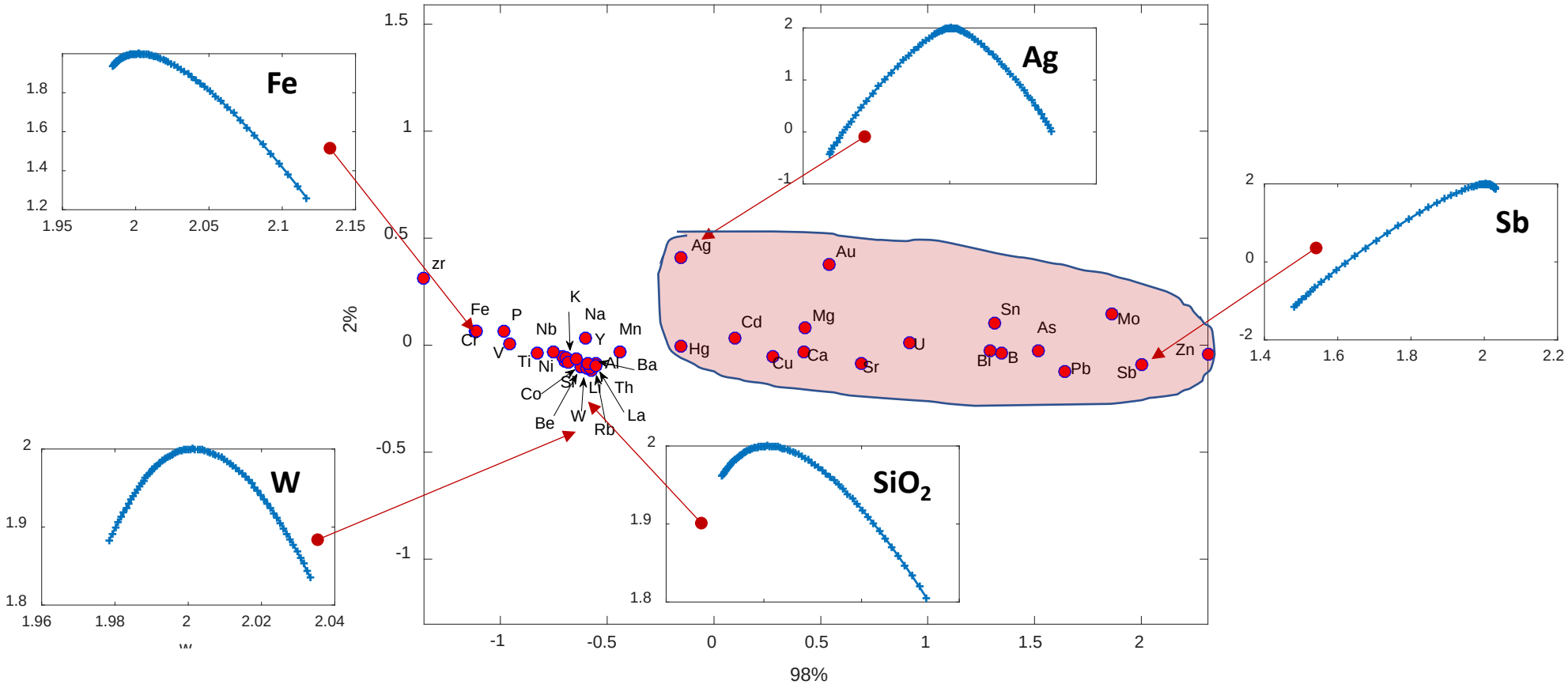


Parameter for calculating multifractal spectrum:

- q: from -10 to 10 by step of 0.5
- Method: box-count

Comparison of spatial patterns

MDS plot of dissimilarity matrix



Discussion and Conclusion

- Secondary dispersion impose obvious influence on their migration and distribution
  - most of hydrothermal elements group together in frequency distribution
  - they show wide variation in spatial correlation
  - left-deviated multifractal spectra, but with distinct degrees
- **Cu, Zn**:
  - mobile under surficial environment (oxidation, acid)
  - Separation due to different mobility: (Pb vs. Zn); (Ag vs. Cu)
  - spatially correlated with Fe, Mn oxides (transport and accumulation carrier?)
  - Zn shows stronger enrichment pattern
- **Pb, As, Ag, Cd**:
  - limited solubility and mobility under surficial environment
  - enrichment patterns vary for these elements
- **Au, Sn**:
  - mainly related with residual minerals
- Different tools that reveal different characteristics of distribution patterns can be combined together to dig out some interesting information

Future work

- Find geological and geochemical evidence to check the information obtained above
- Incorporate other kinds of properties
  - Anisotropy characteristic
  - Spatial autocorrelation
  - …

Thank you!