Identification of mineralization in geochemistry based on the spatial curvature of log-ratios

C. Rieser, D. Mikšová and P. Filzmoser

Vienna University of Technology

christopher.rieser@tuwien.ac.at and dominika.miksova@tuwien.ac.at

Motivation

Develop tool which allows to:

- Identify important log-ratios for the detection of subcropping mineralizations.
- Identify features related to specific type of mineralization.
- Indicate sampling target - mineralization.

Generalized Additive Models (GAMs)

Generalized Additive Models allow one to model the mean and variance of a random variable $y|x$ dependent on the predictor x in a very flexible way:

$$h(\mathbb{E}(y|x)) = \eta(x) \qquad \mathbb{V}(y|x) = V(\mathbb{E}(y|x))\frac{\psi}{\omega}$$

for a fixed function V depending on the distribution of $y|x$.

Assumptions and fitting:

- The response belongs to the exponential family and the linear predictor η is a sufficiently smooth function.
- We solve the following optimization problem

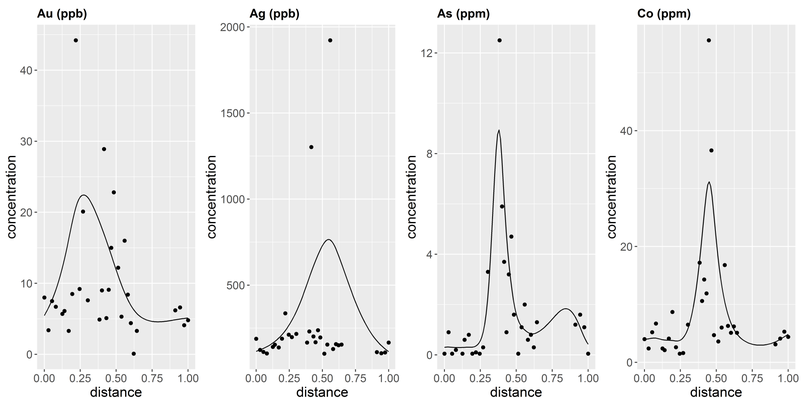
$$\max_{\eta} \sum_{i=1}^{n} \omega_i l(y_i|x_i;\eta) - \lambda \int (\eta''(x))^2 dx,$$

  where λ controls the smoothness of η.

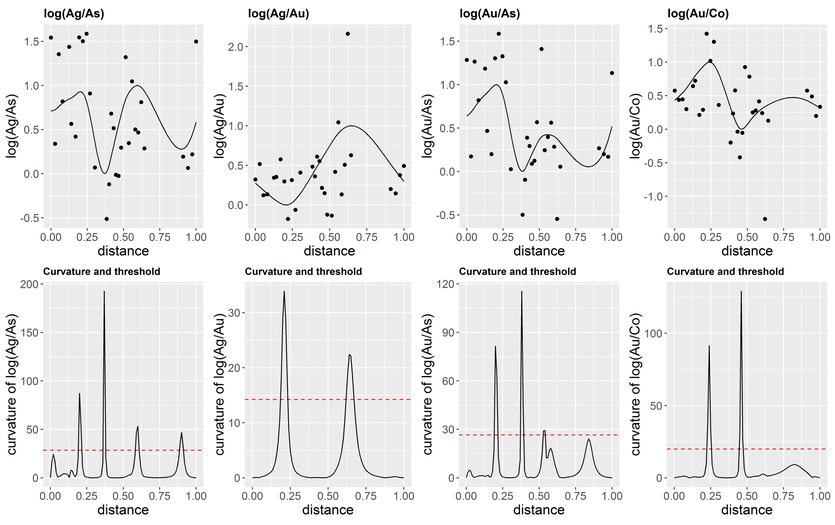
- The weights ω_i can be used up or downweigh outliers; we upweighted outliers.

Juomasuo - Selected GAM fits and log-ratios

- The Juomasuo dataset consists of 64 different elements measured at 30 locations each. Each measurement is comprised of 6 different species respectively organs, e.g. Crowberry, Bilberry, etc respectively leaf, twig, etc.
- We fit Generalized Additive Models to the concentration of elements at certain positions:

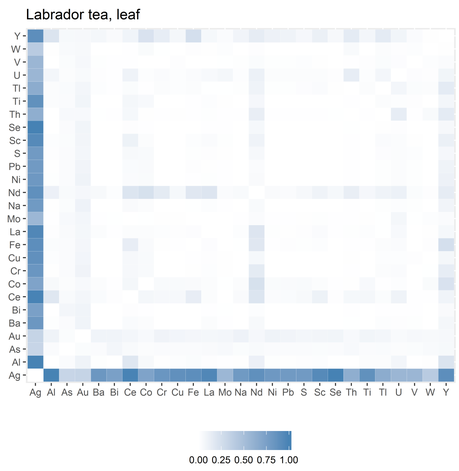


- The curvature can be used to measure a quick behavioural change of log-ratio:



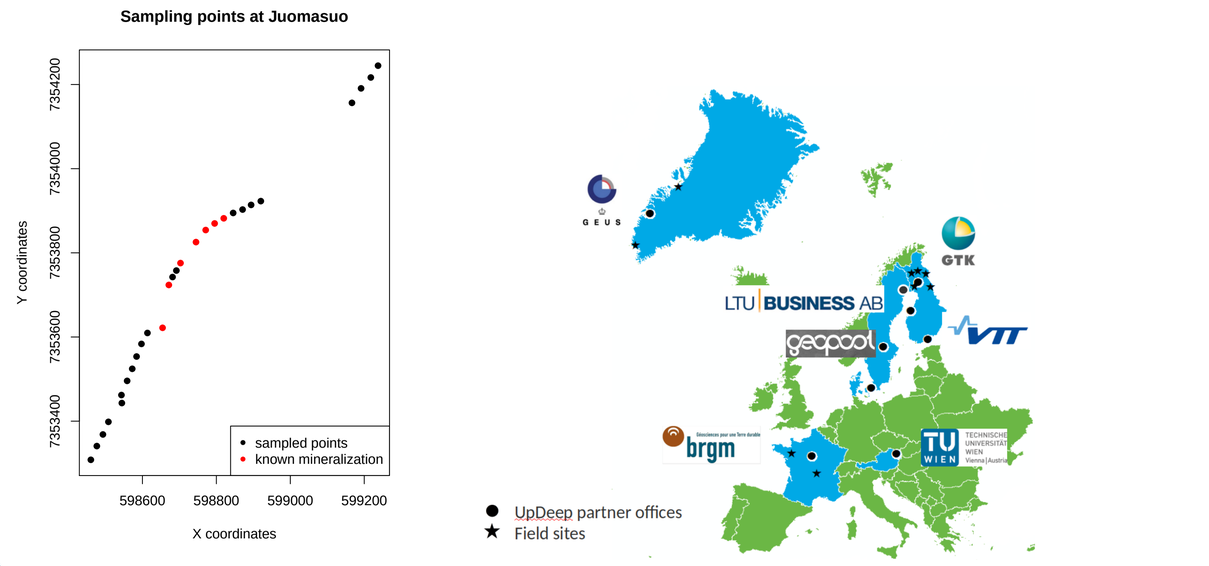
Juomasuo - Heatmaps of the measures

- The ranked log-ratios can be displayed in a heatmap, e.g. for Labrador tea, Silver seems to be a meaningful pathfinder for mineralization:



UpDeep project

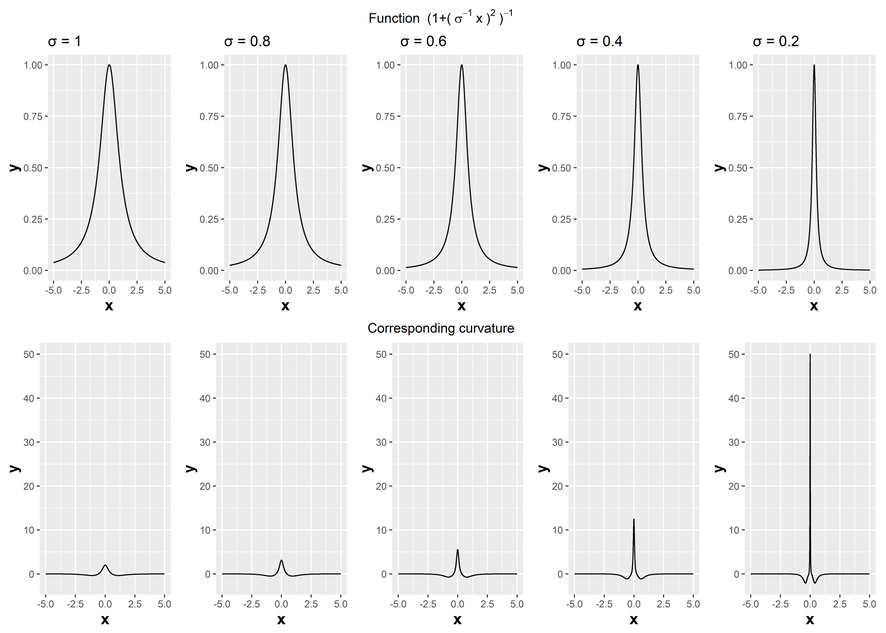
Upscaling deep buried geochemical exploration techniques into European business.
TU Wien is responsible for statistical data analysis.



Detection of interesting log-ratios

With the use of GAMs we construct the log-ratios of all the combinations, which are then ranked from the most interesting to the least interesting by the use of a measure, between zero and one, based on the curvature.

- Geochemically interesting log-ratios have presumably sharp peaks.
- The curvature of a [0, 1] scaled function can be used to measure a sudden change, e.g.:



- Once GAMs are fitted to the concentration of each element the curvature κ of each log-ratio g is calculated:

$$\kappa(x) := \frac{|g''(x)|}{(1 + (g'(x))^2)^{\frac{3}{2}}}$$

- For multiple peaks we use for each pair of elements,

$$\frac{1}{J}\sum_{j=1}^{J} \max_{x \in I_j} (\kappa(x) - \mathcal{T})_+^2$$

  to measure the average deviation of the peaks from a treshold $\mathcal{T}$.
- $\mathcal{T}$ is $\mu + \sigma$, where μ is the mean of κ over the whole range and σ is respectively its variance.
- The intervals I_j mark the intervals for which κ lies above $\mathcal{T}$.

Summary and future work

Summary:

- A statistical tool which can identify meaningful features related to mineralization.
- Based on curvature of log-ratios of chemical elements.
- Developed for the case where sampling was done on (linear) transects.

Future work:

- Extension to the two dimensional predictor case.
- Individual modelling of mean and variance through VGAMs.

References

[1] UltraLIM-project, Ultra low-impact exploration methods in the subarctic (2013–2015). Funded from Tekes Green Mining Programme.

[2] KAVA Reference: 16329, UpDeep, Upscaling deep buried geochemical exploration techniques into European business (2017–2020).

[3] Wood, S. N. (2017). *Generalized Additive Models: An Introduction With R.* Chapman and Gall/CRC, Boca Raton, USA.