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Spatial analysis of hydraulic conductivity for slope deposits at catchment scale in Northern Tuscany, Italy

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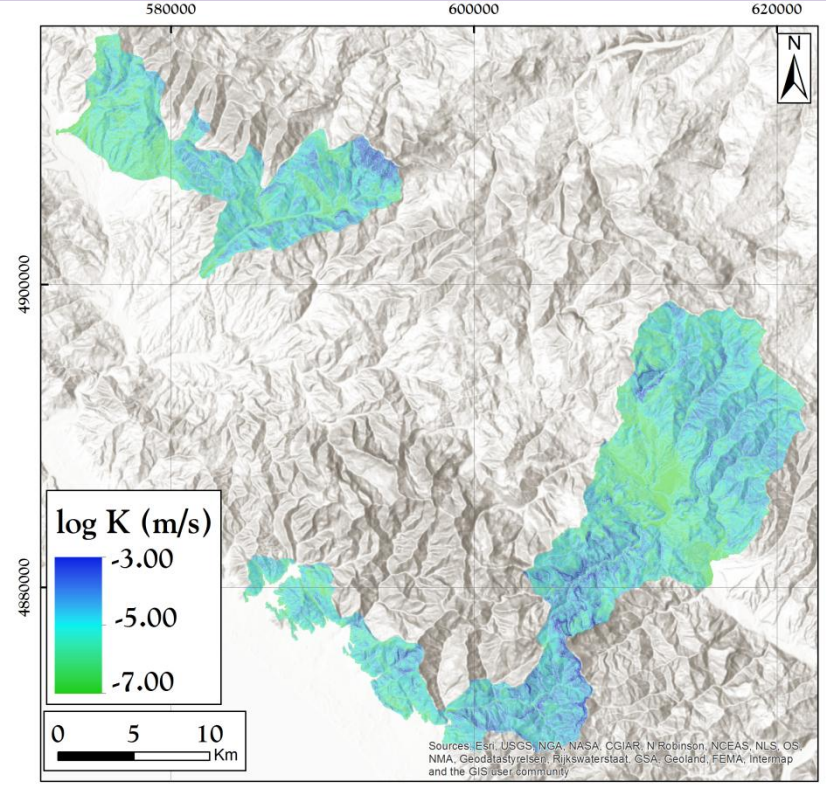
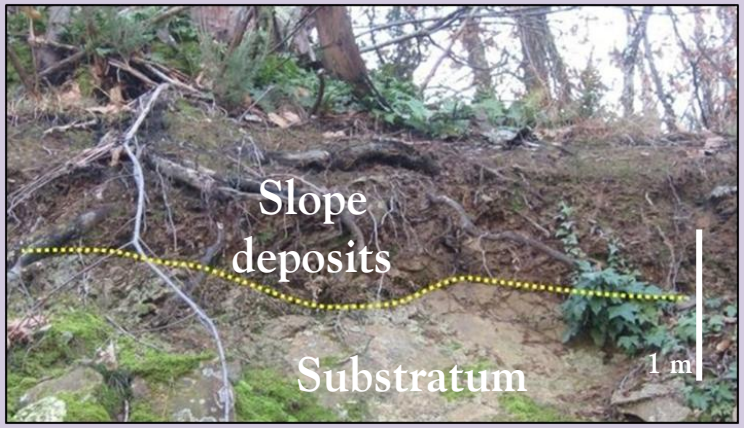
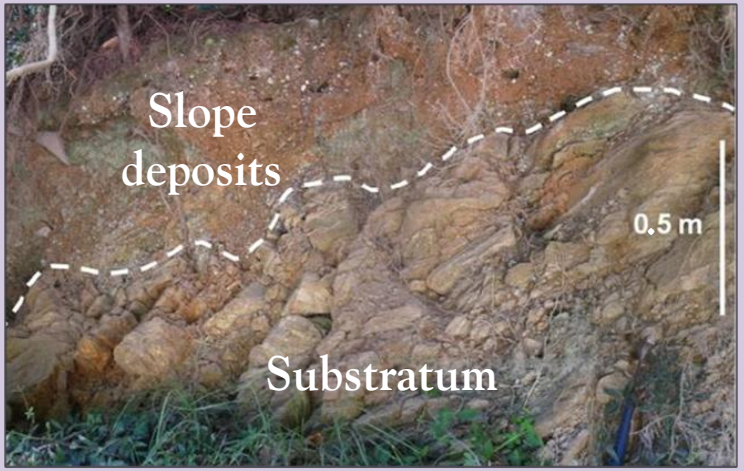
Agreement between Geomatica lab, *LaMMA* and *IMT Mines Alès*

Analysis of **site-variability** and **spatial distribution** at **catchment scale** of hydraulic conductivity of slope deposits (SD)





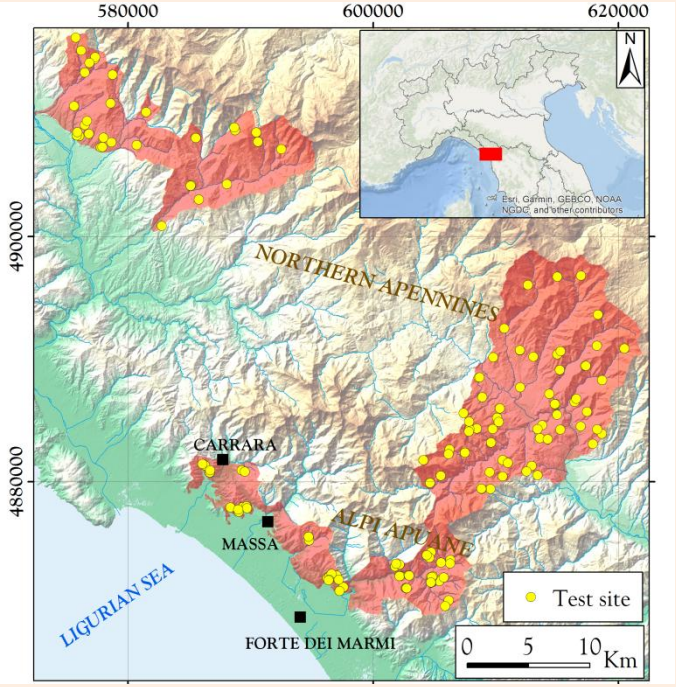


Slope deposits are **unconsolidated** (Quaternary) **soils** that unconformably cover the geological substratum

Spatial analysis of hydraulic conductivity for slope deposits at catchment scale in Northern Tuscany, Italy - Michele Pio Papasidero (michele.papasidero@unisi.it)

UNIVERSITÀ DI SIENA 1240 · DSFTA · CONSORZIO LaMMA · IMT Mines Alès École Mines-Télécom

Study area is represented by **2** regions (**420 km²**) in Northern Tuscany (Italy)

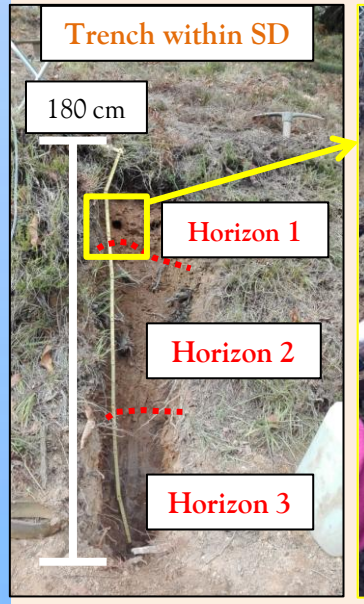


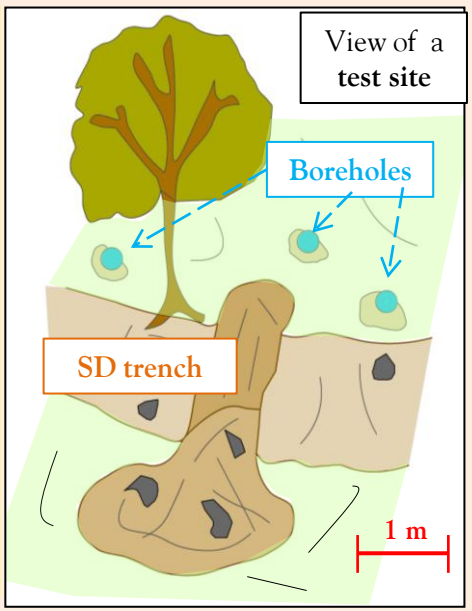
Field survey

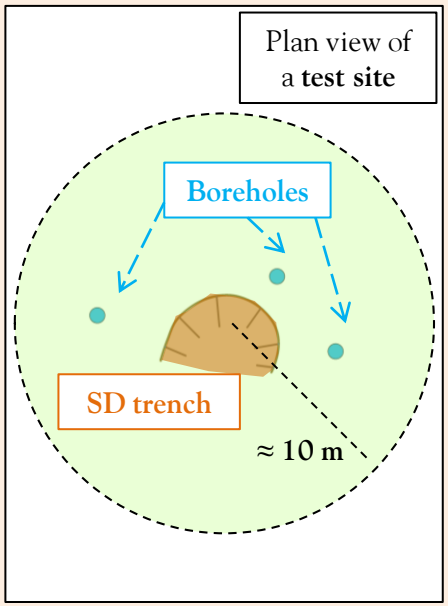
- ✓ **Trench** within SD (depth, texture, structure, soil sampling)
- ✓ **Hydraulic conductivity tests** (Ktests) within 1-5 boreholes close (≤ 10 m) to the trench. Ktests performed by using **constant** and **falling** head permeameters (*LeFranc* tests)

Laboratory

- ✓ Grain size, Atterberg limits, specific gravity of solids, bulk density





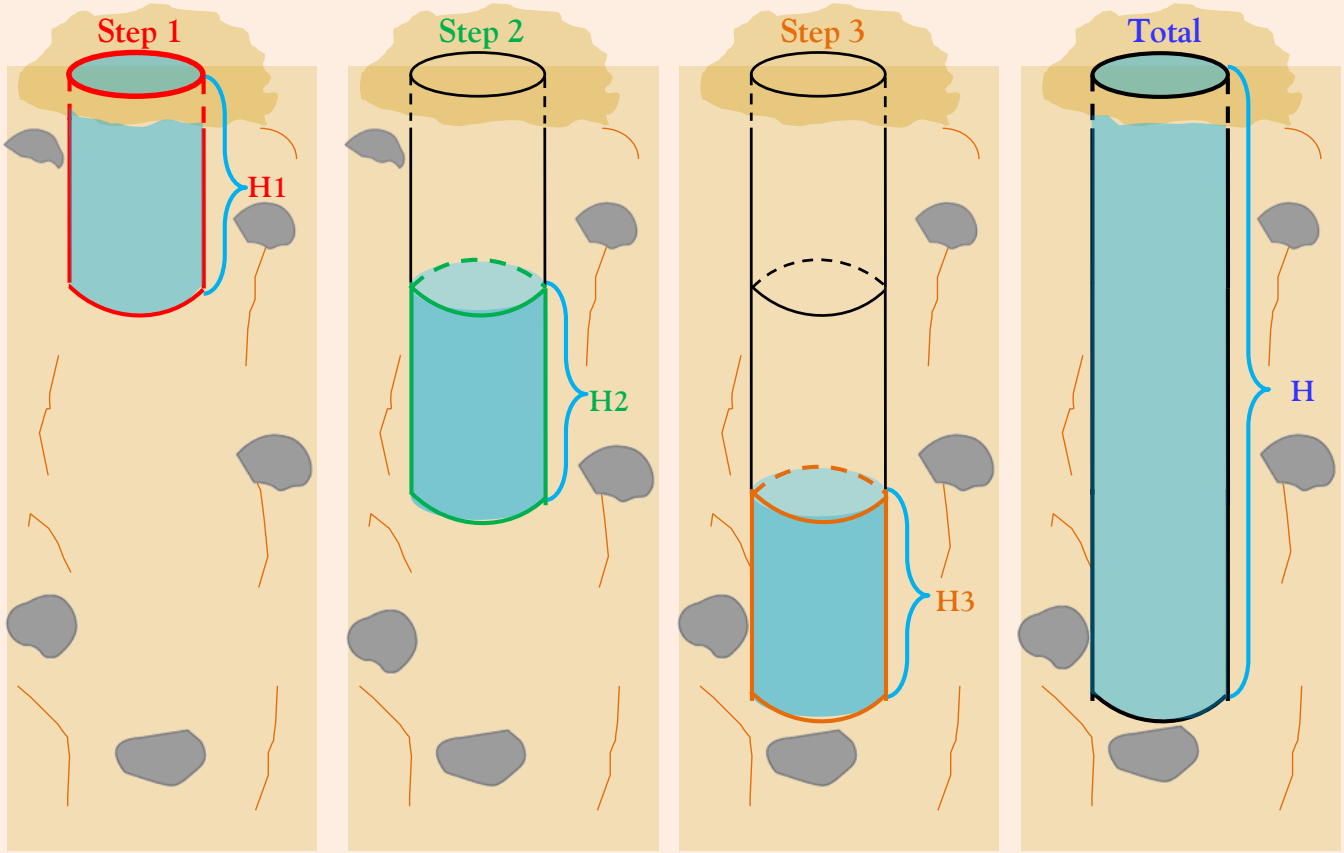


Field survey: Ktests

A total of **720** Ktests for **150** test sites have been performed following this approach:

- **steps of increasing borehole depth** (Step 1, Step 2, Step 3, **Step n**….) in order to evaluate variation of K with depth
- total depth (Total)

Borehole diameter **7-10 cm**



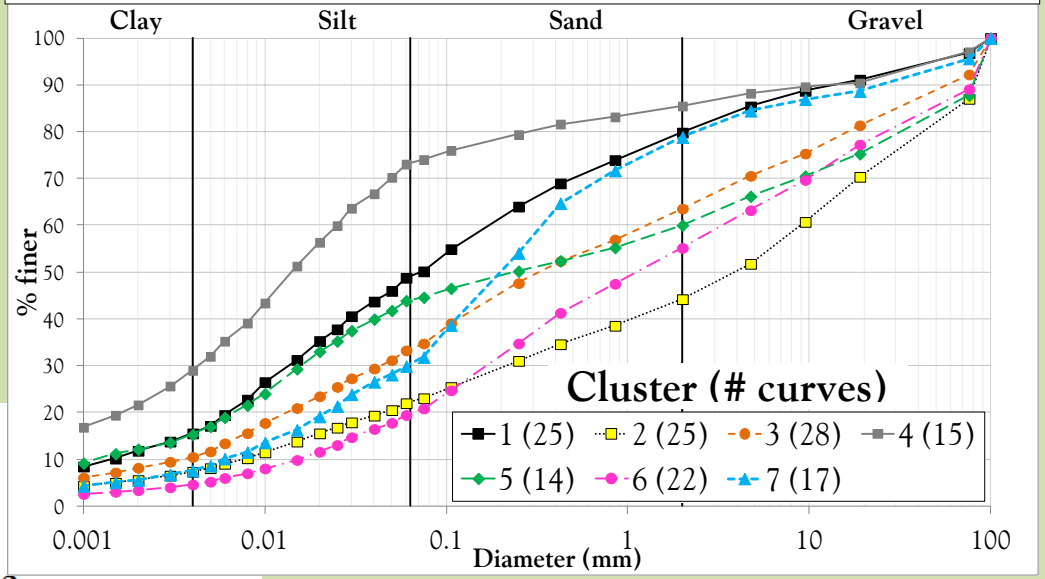
Grain size data – 146 samples

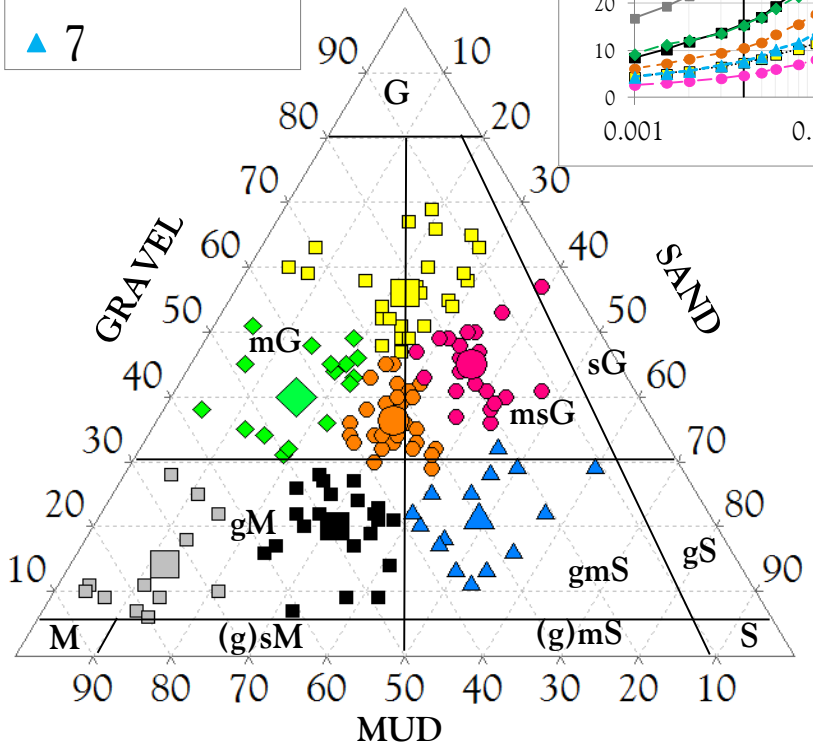
C_u (d_{60} / d_{10})	
Interquartile range	Range
80-630	7-38,000

Clusters

1 2 3 4 5 6 7

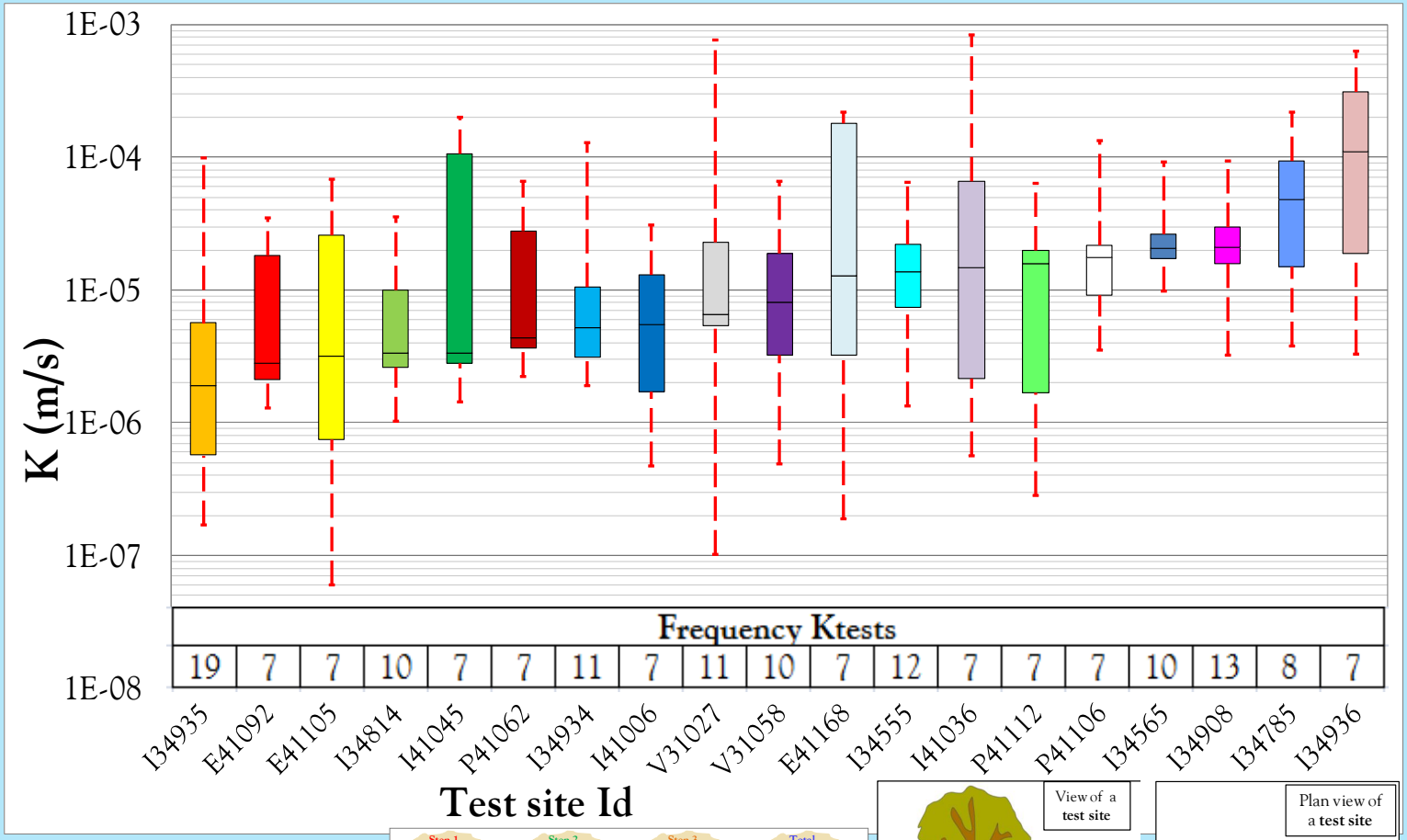
K-means clustering of grain size curves



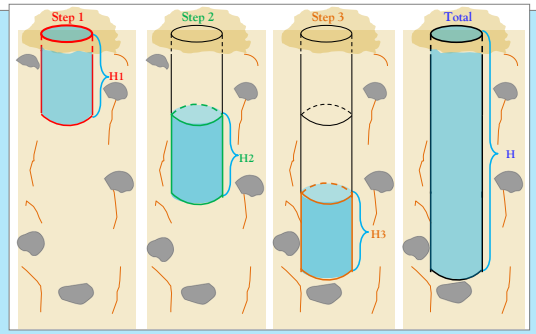


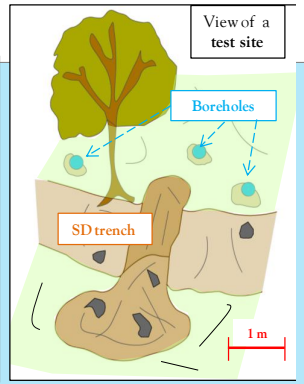
Frequency (%)	Texture Class	Description
34	mG	*muddy Gravel*
30	msG	*muddy sandy Gravel*
24	gM	*gravelly Mud*
12	Others	-

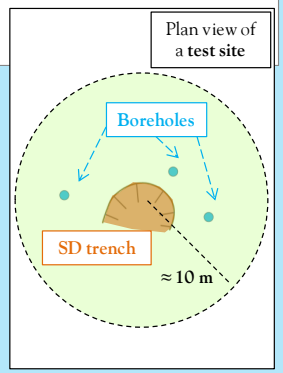
Site variability of hydraulic conductivity



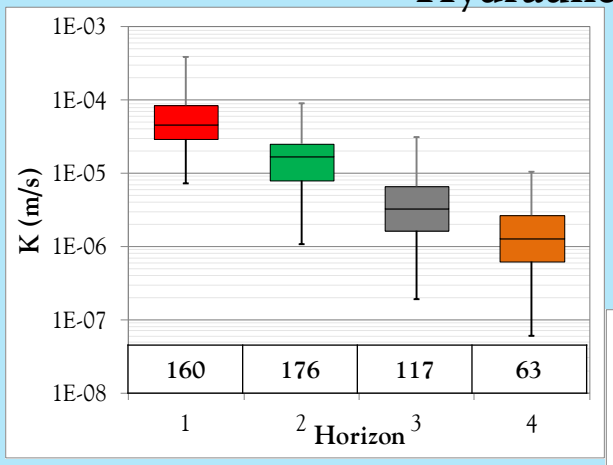
log K (m/s)	
Median of Interquartile range	Median of Range
0.8	1.9

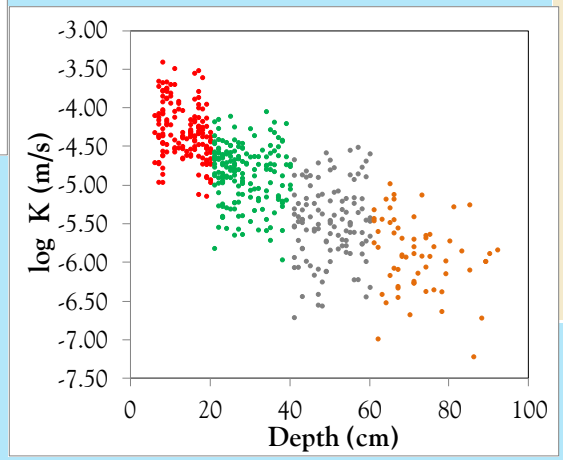


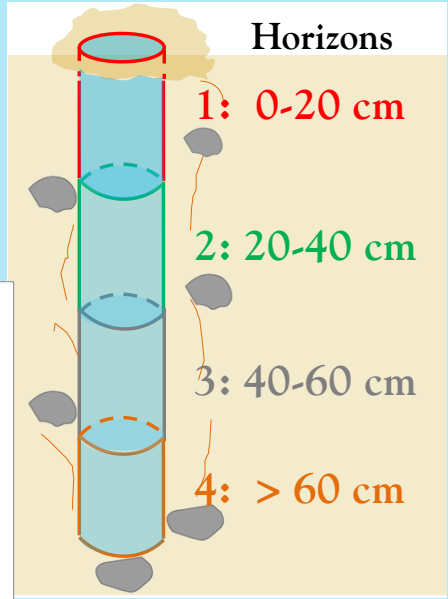




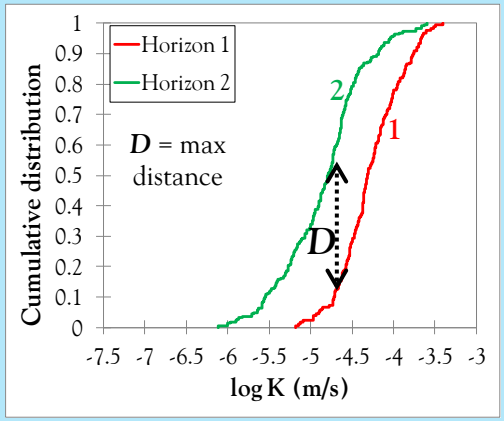
Hydraulic conductivity by horizons

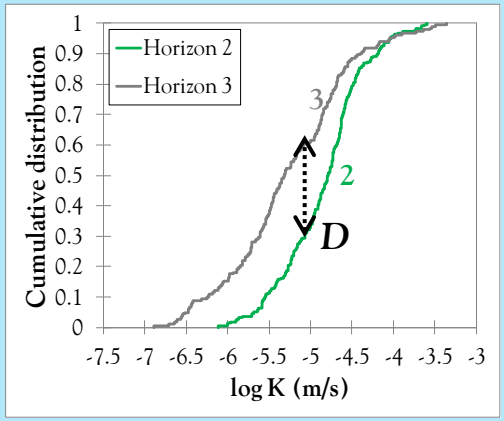


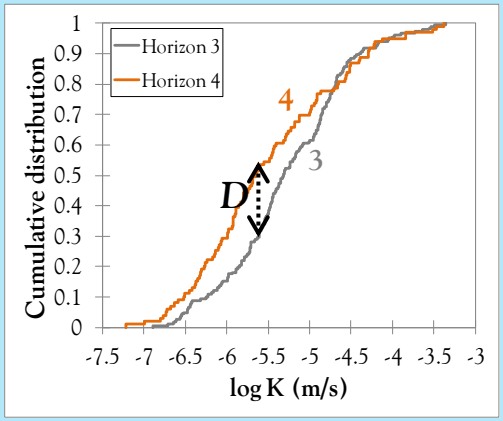




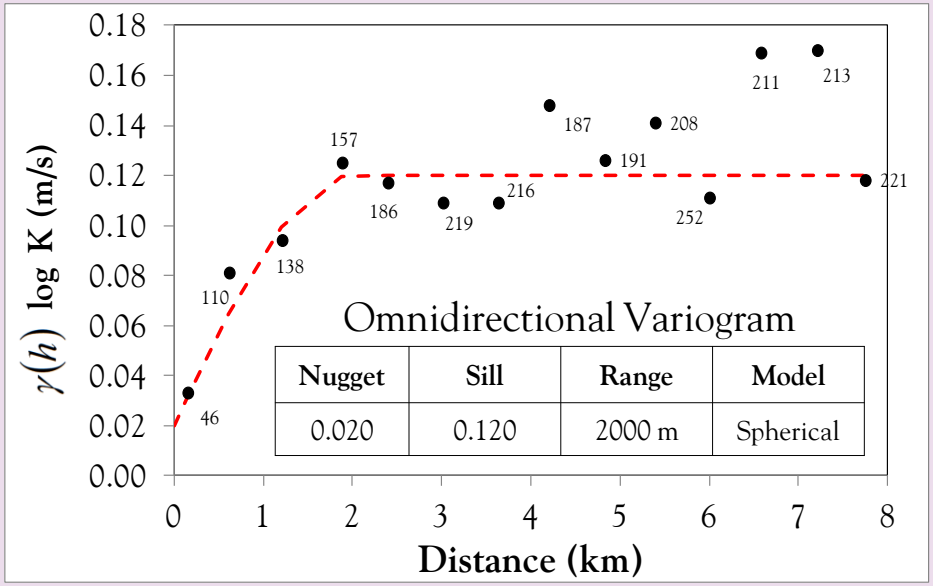
Kolmogorov-Smirnov test: horizons 1, 2, 3 and 4 are **ALL** statistically each other different





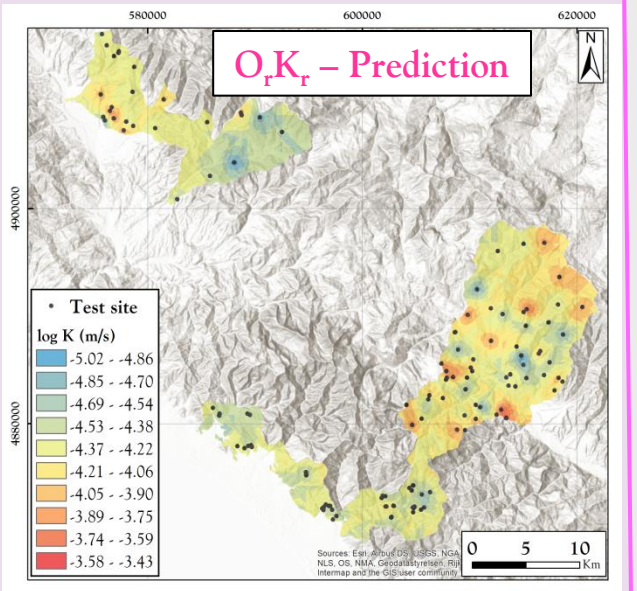


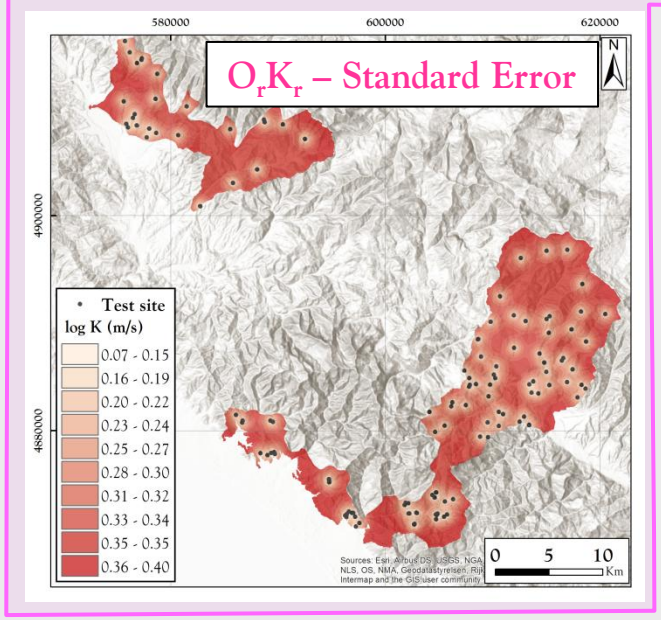
Horizon 1 (0-20 cm) – Ordinary Kriging (O_rK_r) and Inverse Distance Weighting (Idw)



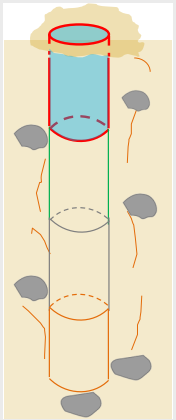
Omnidirectional Variogram

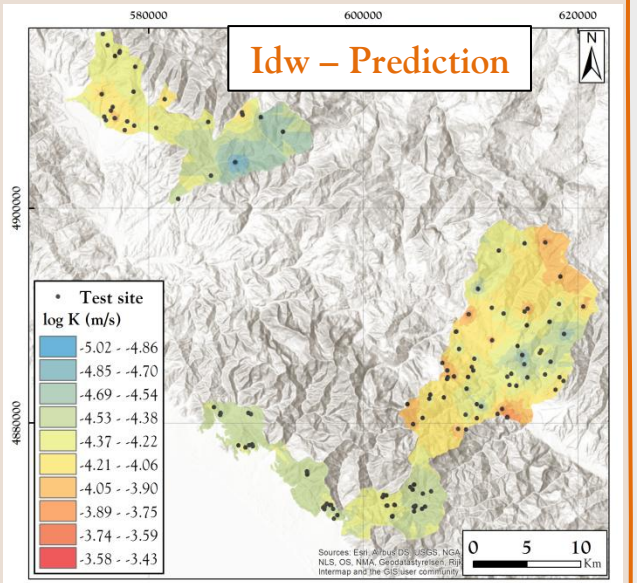
Nugget	Sill	Range	Model
0.020	0.120	2000 m	Spherical





Power	1
Range	2000 m



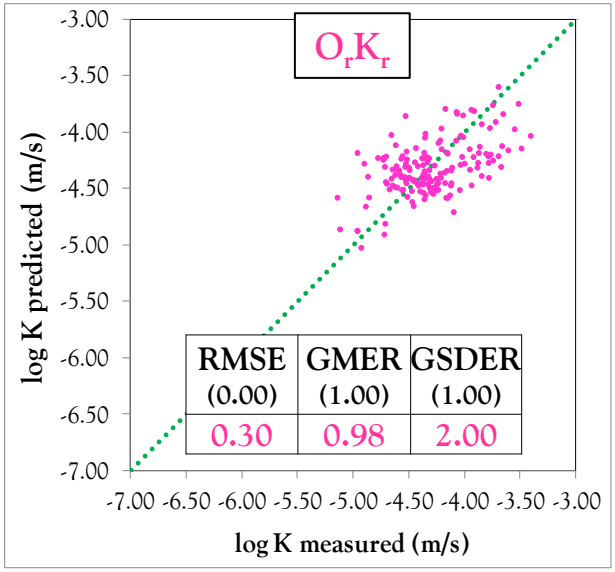


Horizon 1 (0-20 cm) – Ordinary Kriging (O_rK_r) and Inverse Distance Weighting (Idw)

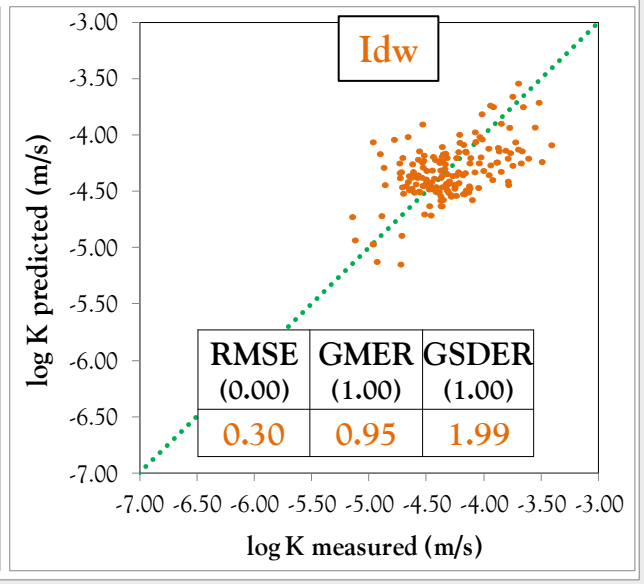
Cross-validation

Procedure

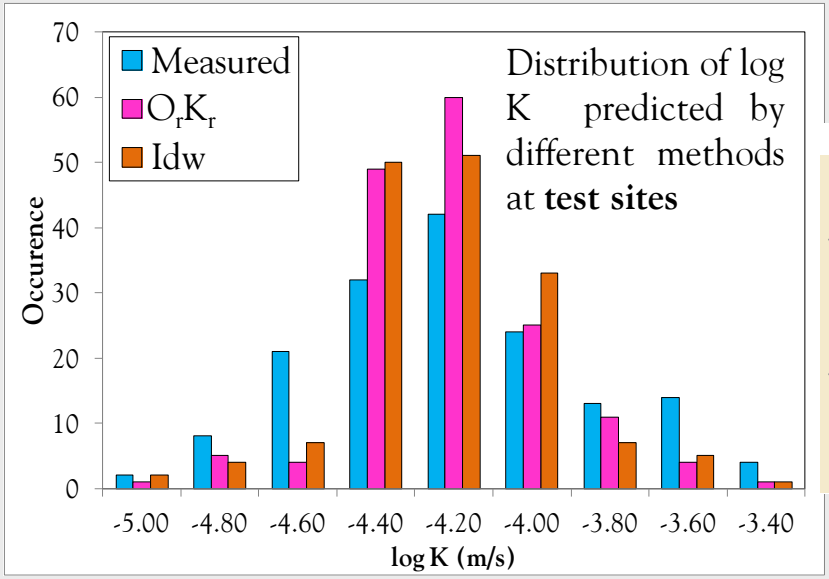
1. **Remove** the **first** point in the dataset, then use the **remaining** (n-1) points to **predict** the value at the **location** of the **removed** point.
2. **Repeat** step 1 for **whole** dataset, and calculate the statistics.

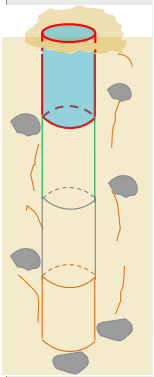


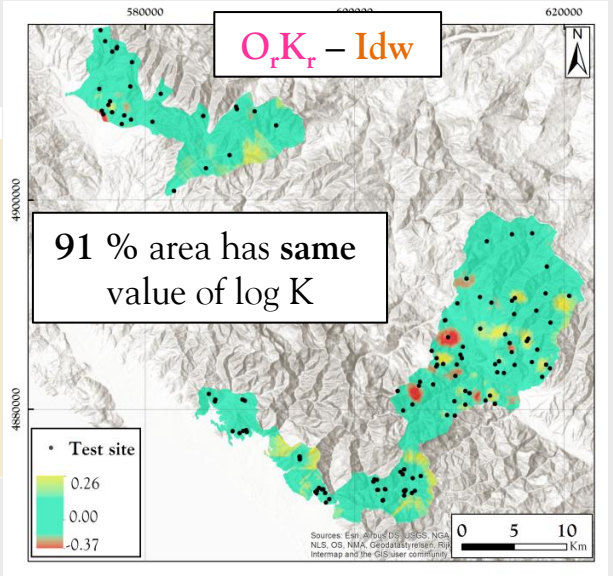
RMSE (0.00)	GMER (1.00)	GSDER (1.00)
0.30	0.98	2.00



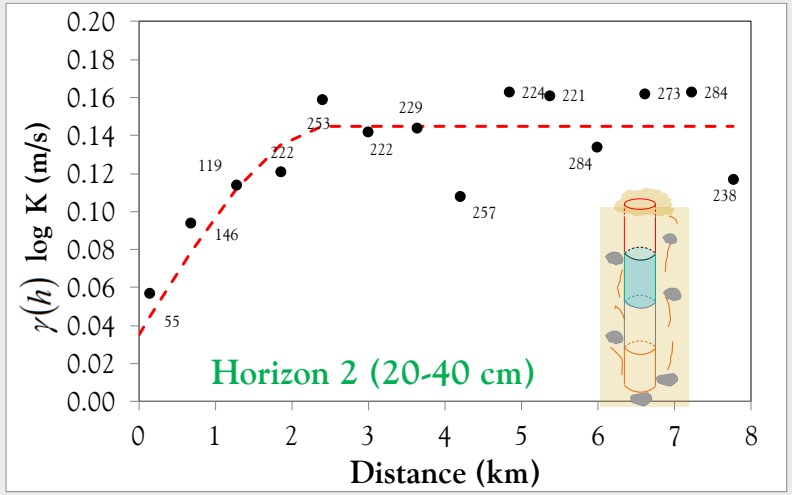
RMSE (0.00)	GMER (1.00)	GSDER (1.00)
0.30	0.95	1.99



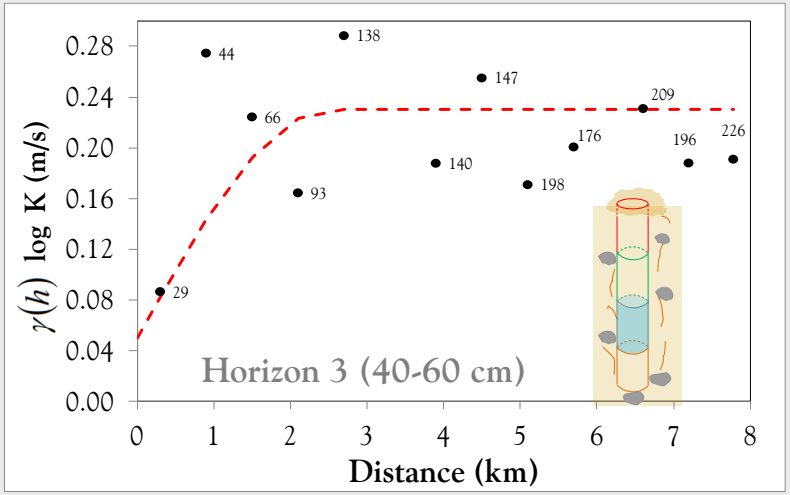


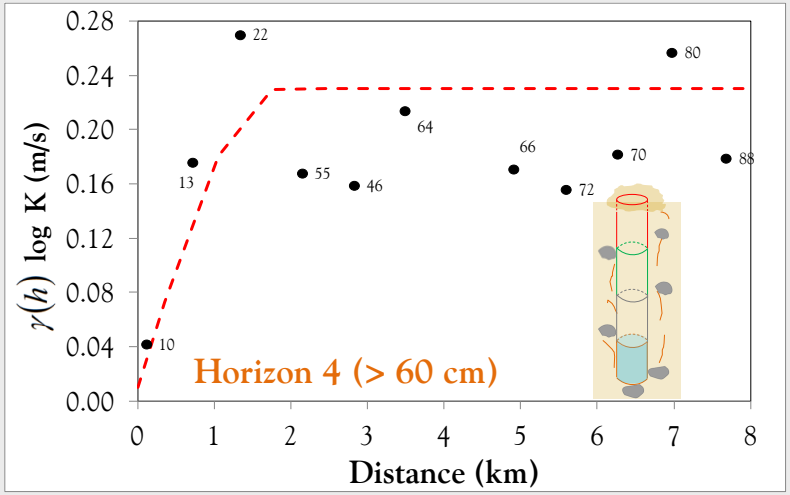


Horizon 2, 3, 4 – Omnidirectional Variograms



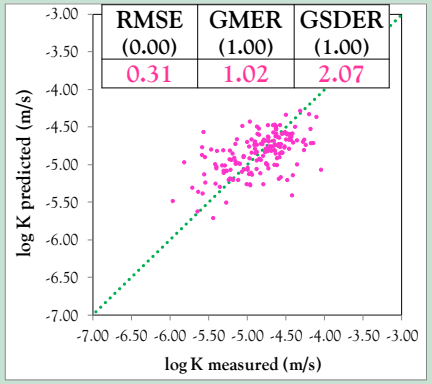
Horizon	Nugget	Sill	Range	Model
2	0.035	0.145	2500 m	Spherical
3	0.050	0.230	2500 m	Spherical
4	0.010	0.230	1800 m	Spherical

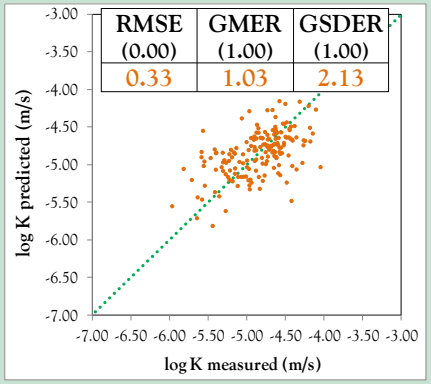


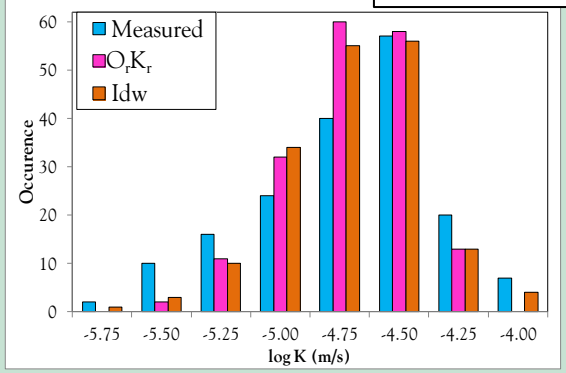


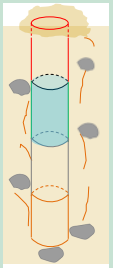
Horizon 2, 3, 4 – Cross-validations

Horizon 2 (20-40 cm)

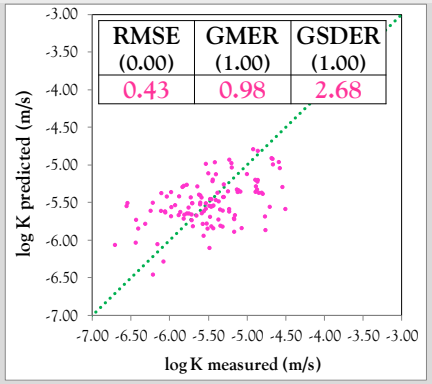


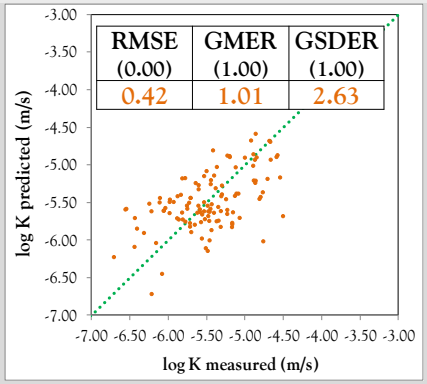


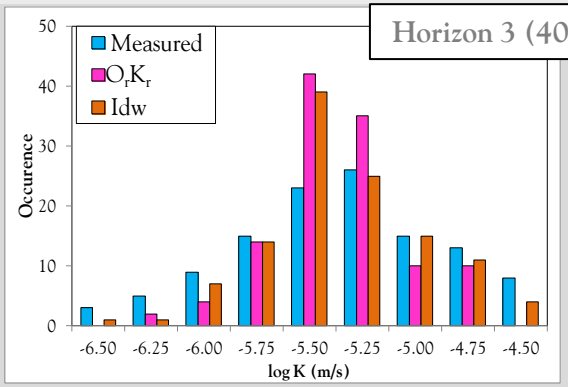


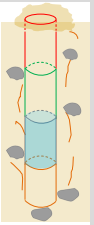


Horizon 3 (40-60 cm)

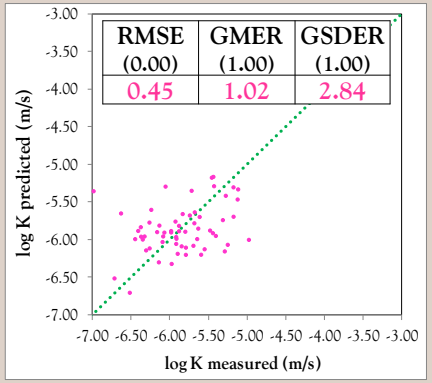


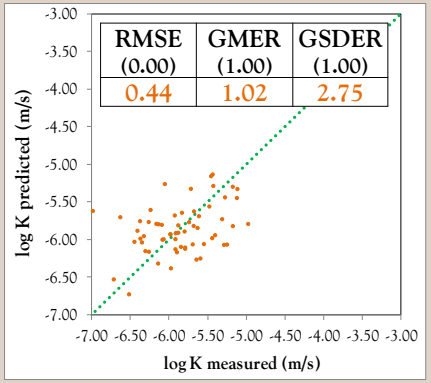


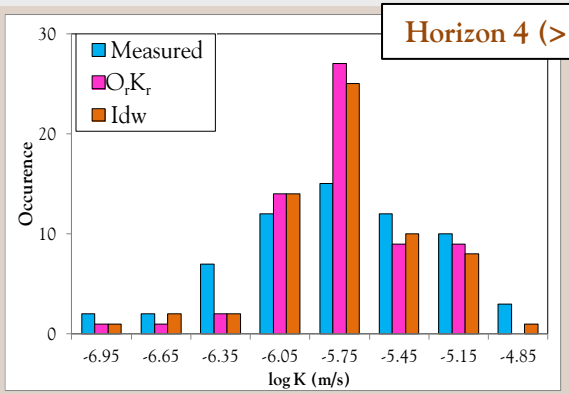


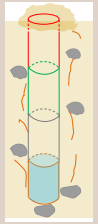


Horizon 4 (> 60 cm)

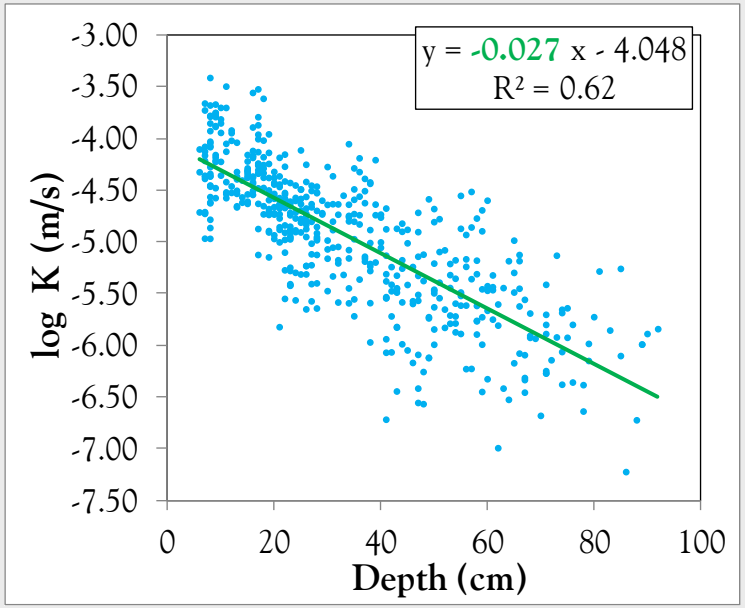


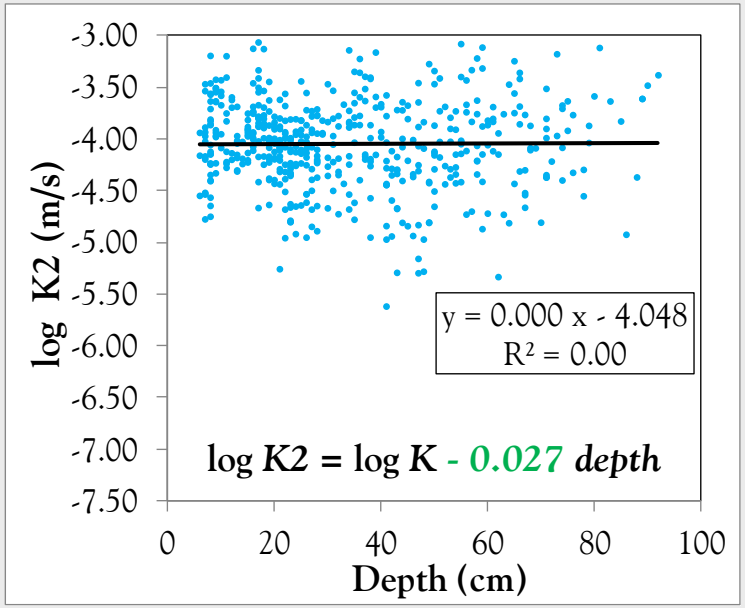




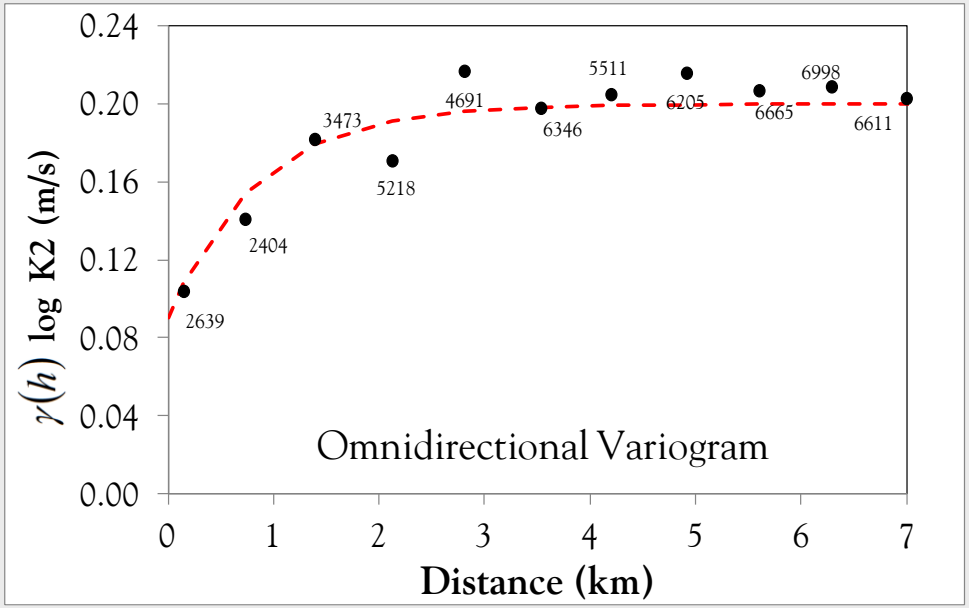


All Ktests – Detrend analysis

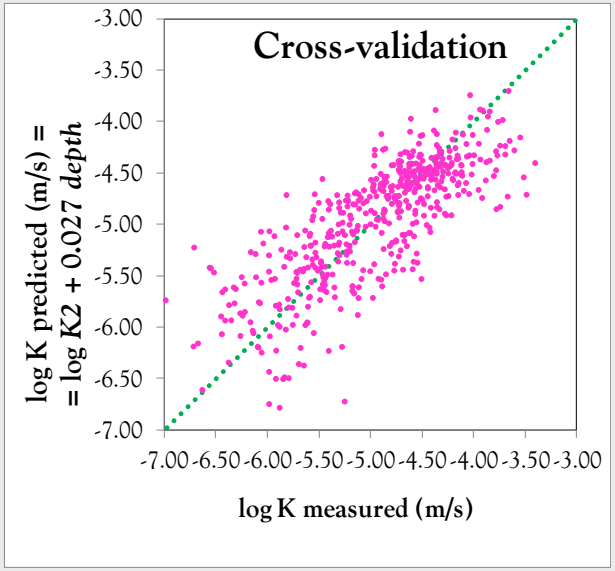




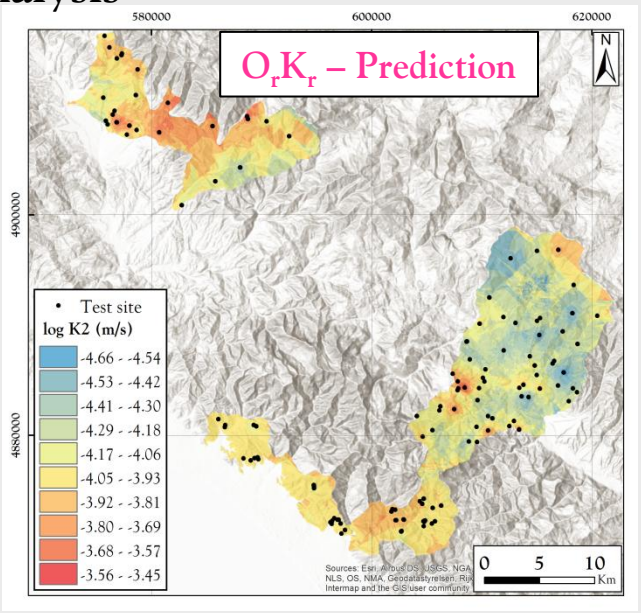
Parameter	log *K2*
Nugget	0.09
Sill	0.20
Range	2500 m
Model	Exponential

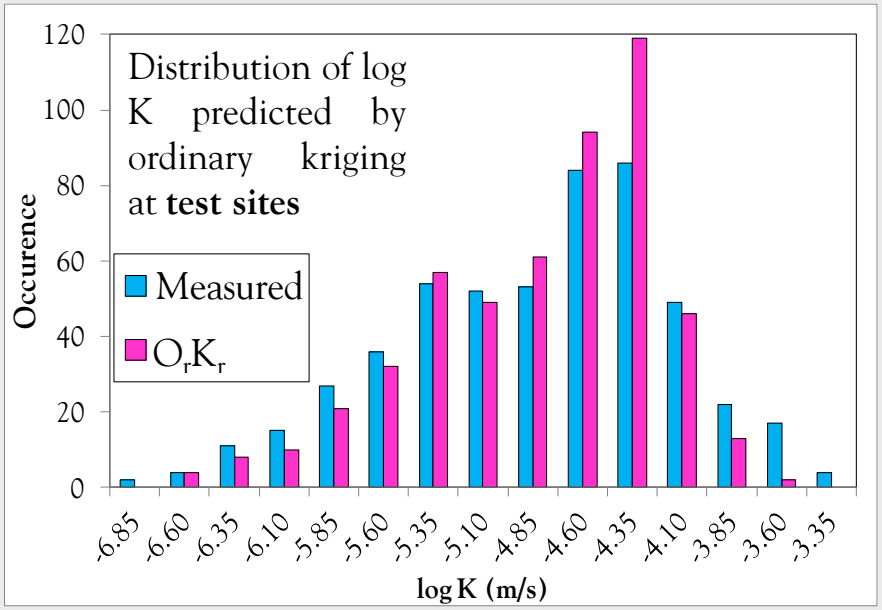


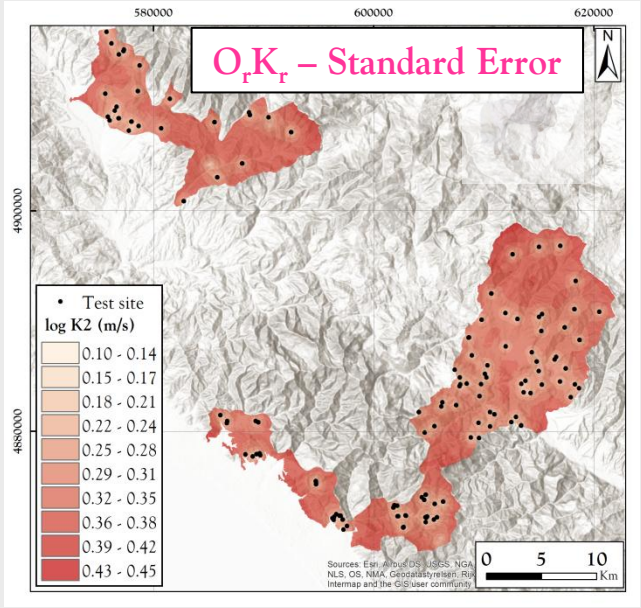
All Ktests – Detrend analysis



Error	log K (m/s)
RMSE (0.00)	0.42
GMER (1.00)	1.01
GSDER (1.00)	2.62







- ✓ **Texture classes** of slope deposits are mostly muddy gravel (***mG***), muddy sandy gravel (***msG***) and gravelly mud (**gM**). The interquartile range of C_U is ≈ 80-600
- ✓ **Site variability** (both location and depth) of log K in term of **interquartile range** and **range** is respectively **0.8** and **1.9**
- ✓ **Negative** trend of log K with **depth** and **different** distribution of log K among **horizons**
- ✓ **Geostatistical methods** are implemented to obtain continuous maps of log K:
  - ❑ **Horizons** approach: **Ordinary Kriging** and **Inverse Distance Weighting** provide maps each other **similar** of log K for the corresponding horizons
  - ❑ **Detrend** approach: linear regression allows to **mitigate** the effect of **depth** and **Ordinary Kriging** analyzes the spatial features
- ✓ Follow up
  - ❑ **Implementing more** methods to obtain continuous maps of log K (**Empirical Bayesian Kriging**, etc..) and/or use **pedotransfer function** (**already** developed by multilinear regression analysis)
  - ❑ Integrating the role of different geological **substratum** and/or **texture classes** in the spatial analysis of log K