What are celestial bodies made of?

Remote Sensing of celestial rocks:

Prediction of the chemical structure from spectral analysis

The team

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RESEARCH QUESTION

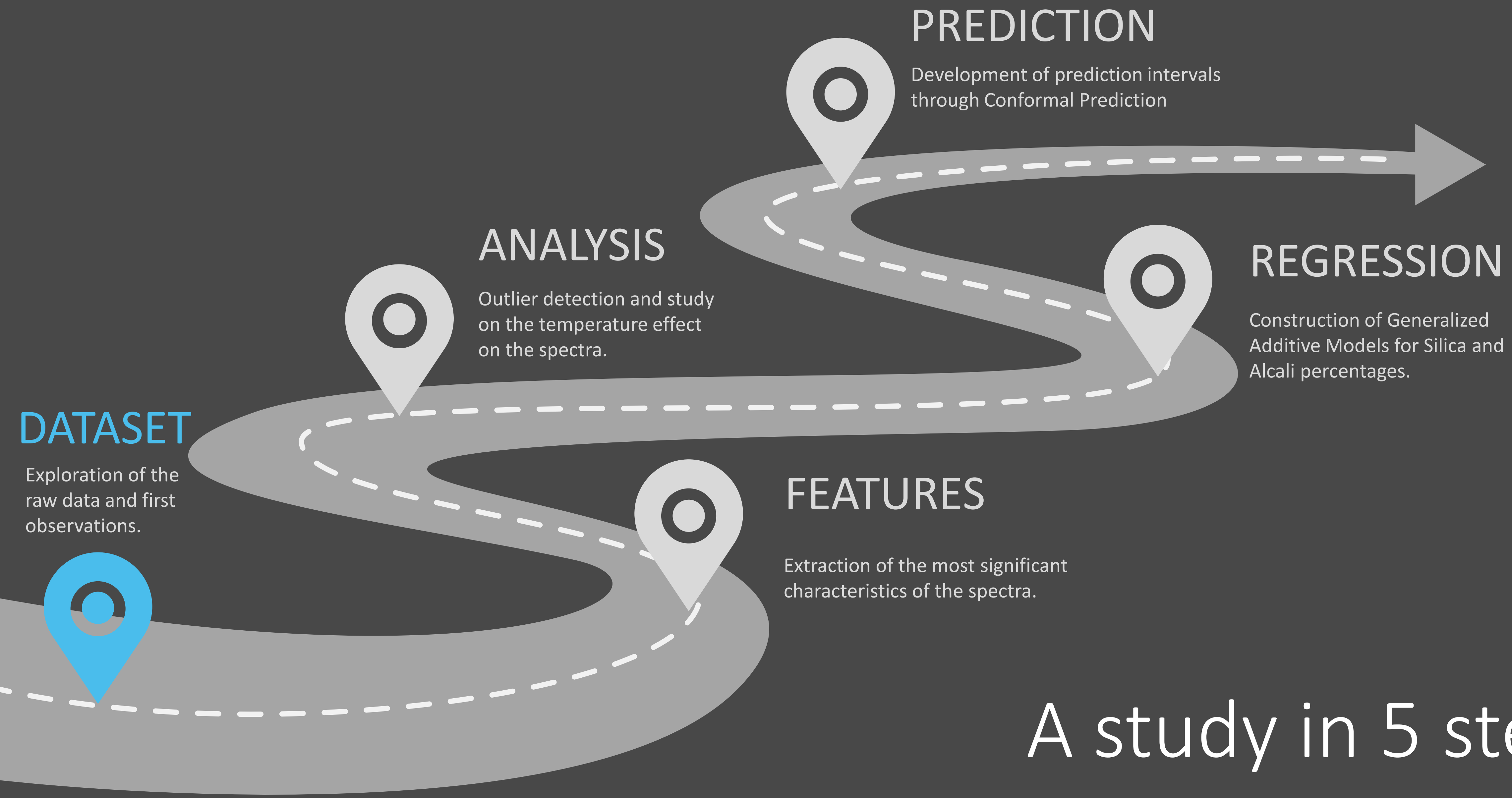
Aim of the study:

Understand, through remote sensing, the composition of celestial rocky bodies’ surface which are not physically reachable.

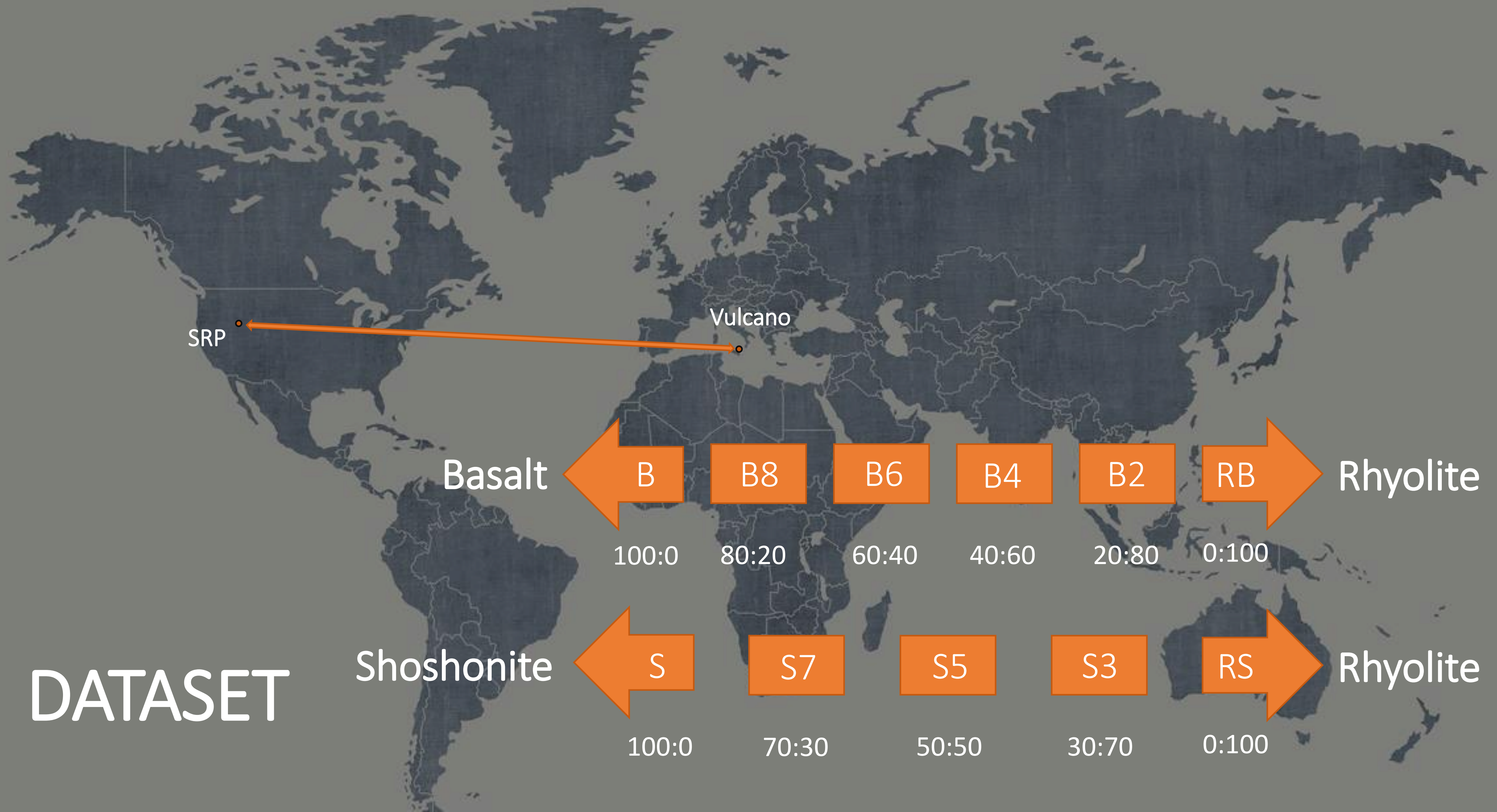
Why not using EMISSIVITY and REFLECTANCE of those bodies at different wavelengths?

The idea is to use data collected on Earth to understand the relationship between chemical compositions of rocks and spectral properties. Thanks to such relationship we aim to build a prediction model to detect the compositions of celestial bodies.

A study in 5 steps

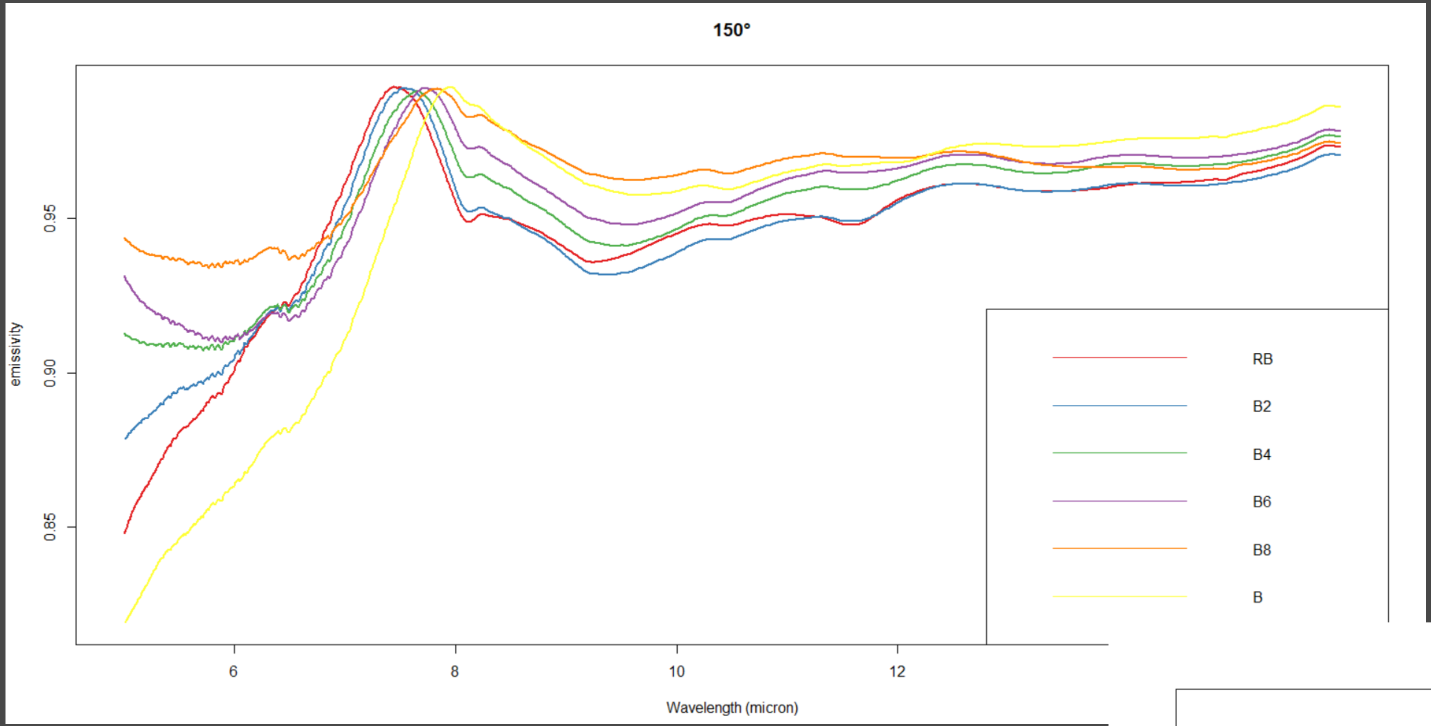


DATASET



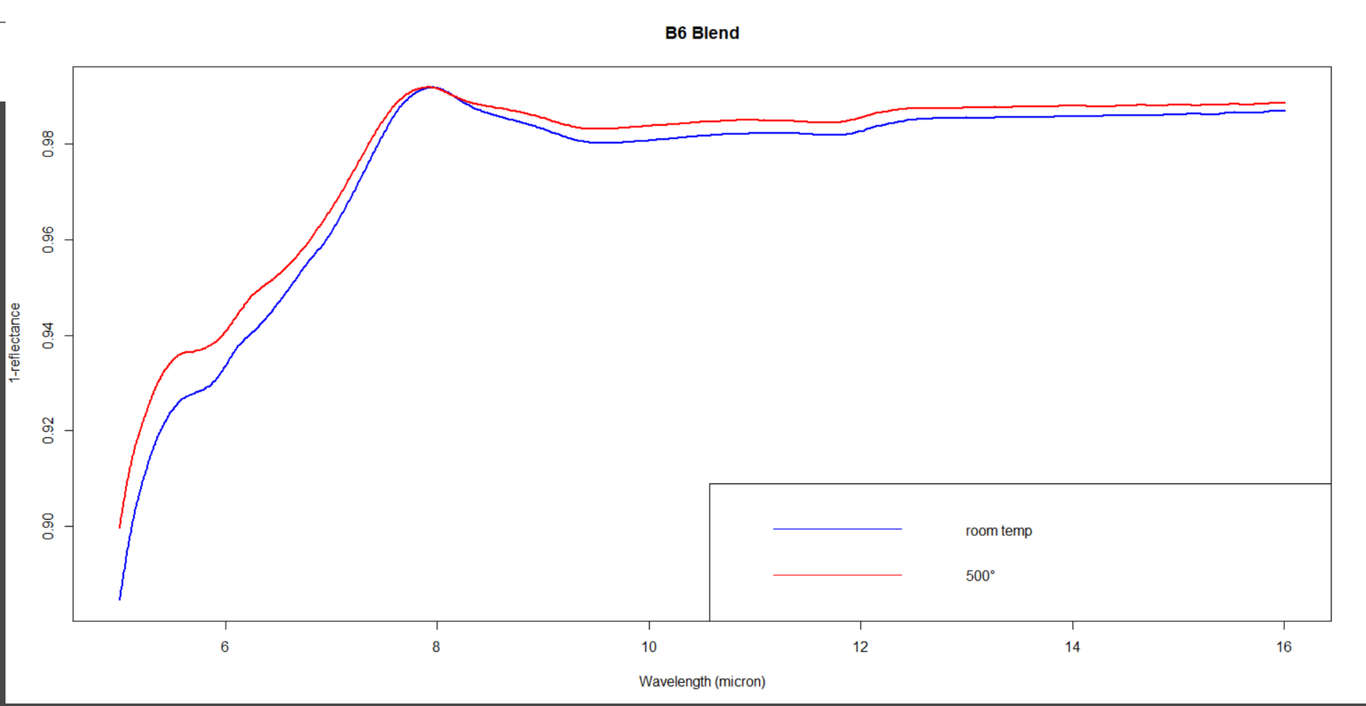
SRP
Vulcano
Basalt
B
B8
B6
B4
B2
RB
Rhyolite
100:0
80:20
60:40
40:60
20:80
0:100
Shoshonite
S
S7
S5
S3
RS
Rhyolite
100:0
70:30
50:50
30:70
0:100

Some examples of spectra



Emissivity for the SRP rocks @ 150°

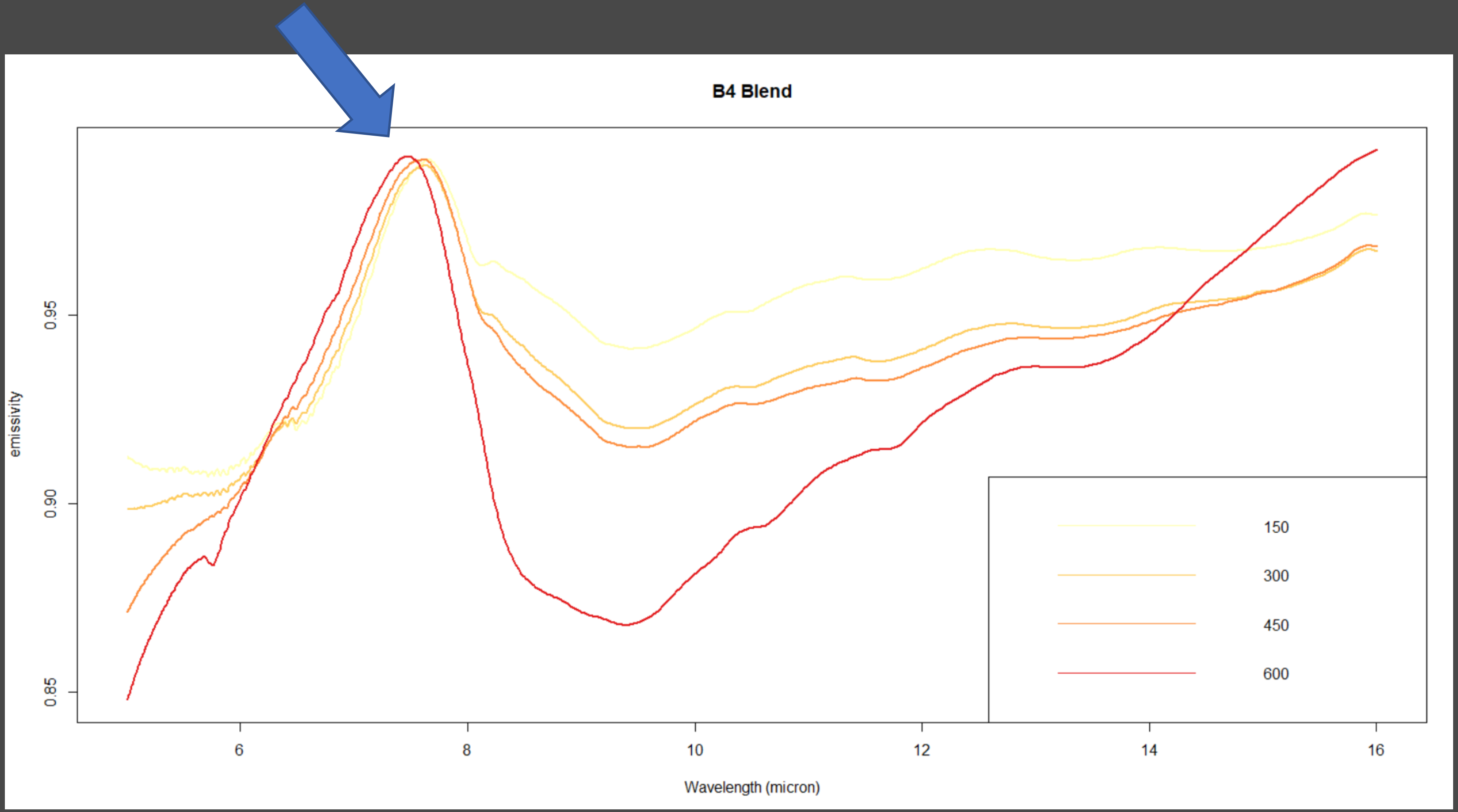
Reflectance for the B6 blend at two different temperatures



DATASET

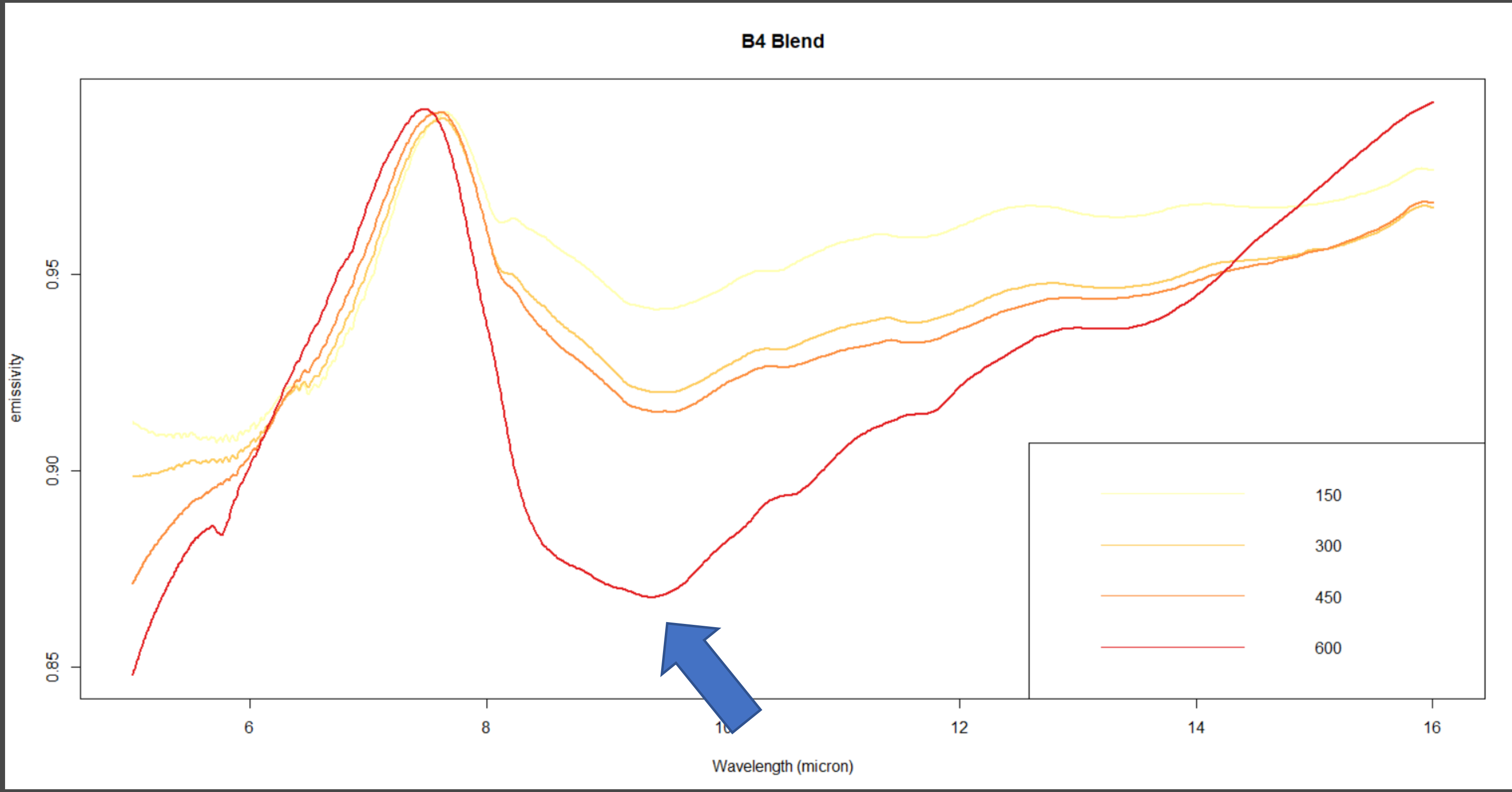
A study in 5 steps

FEATURES



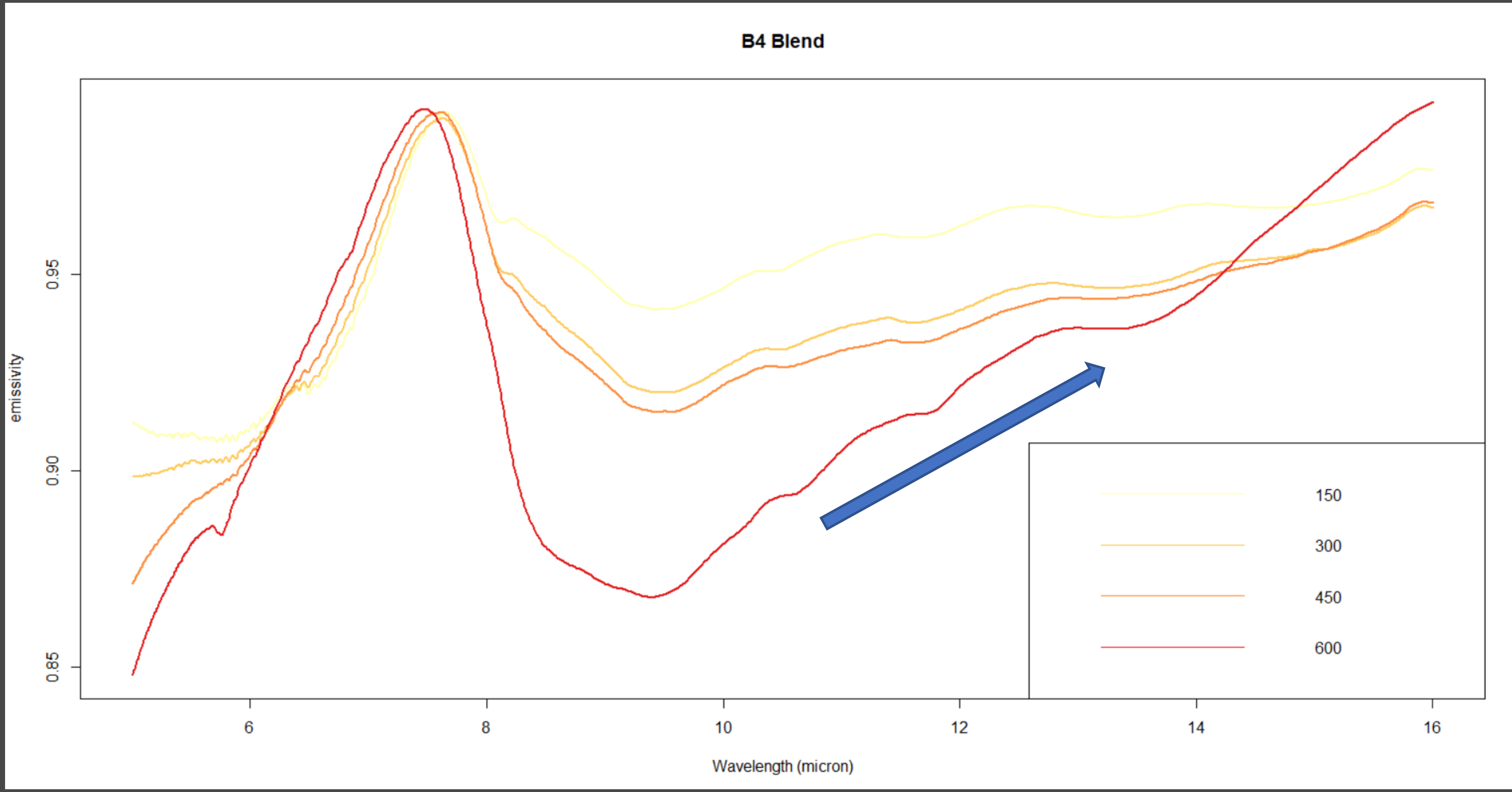
- Christiansen feature

FEATURES



- Christiansen feature
- Transparency feature

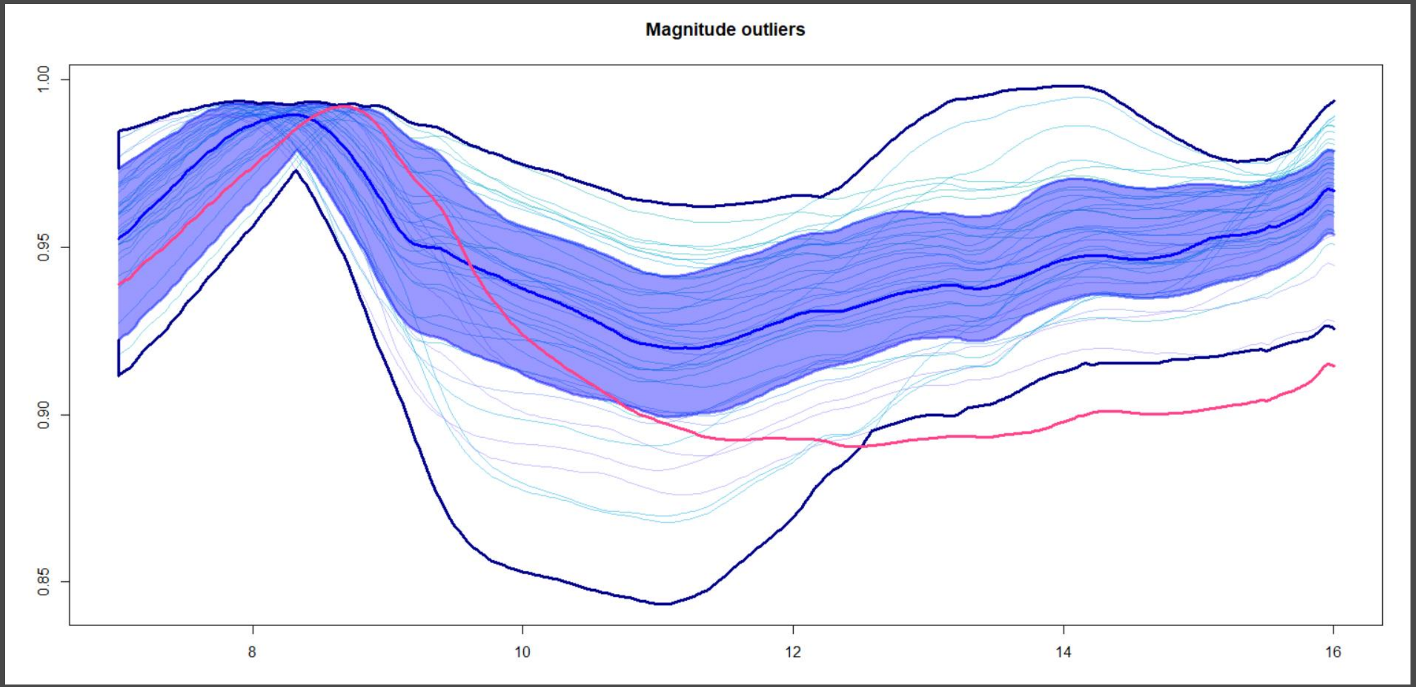
FEATURES



- Christiansen feature
- Transparency feature
- First derivative

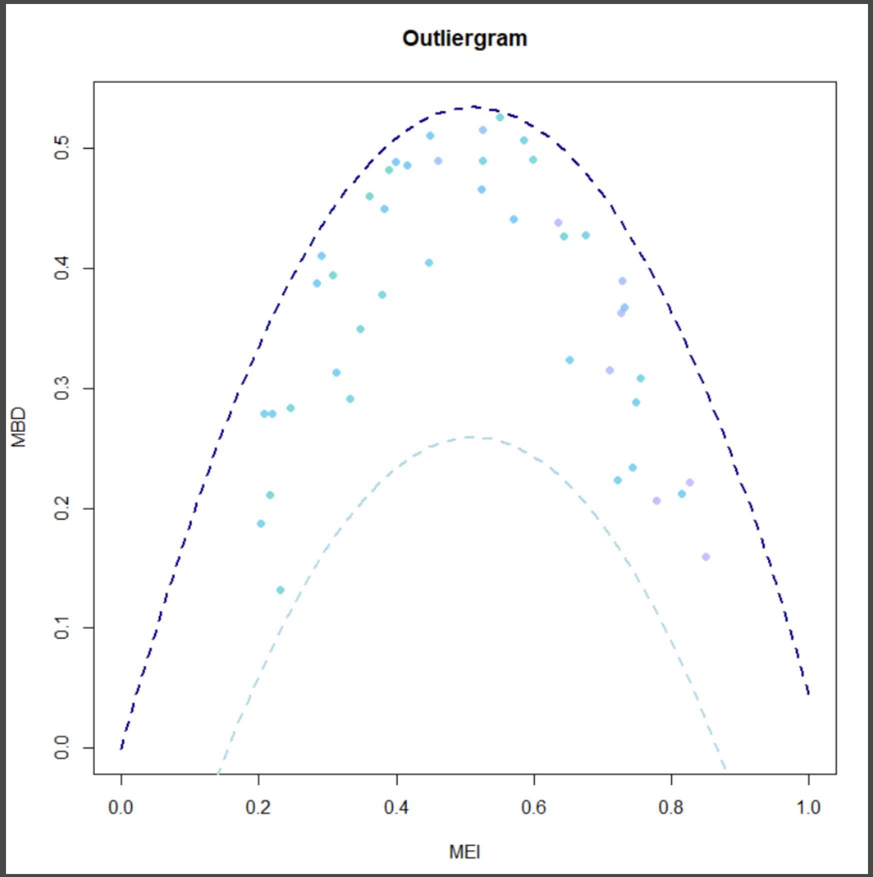
A study in 5 steps

ANALYSIS

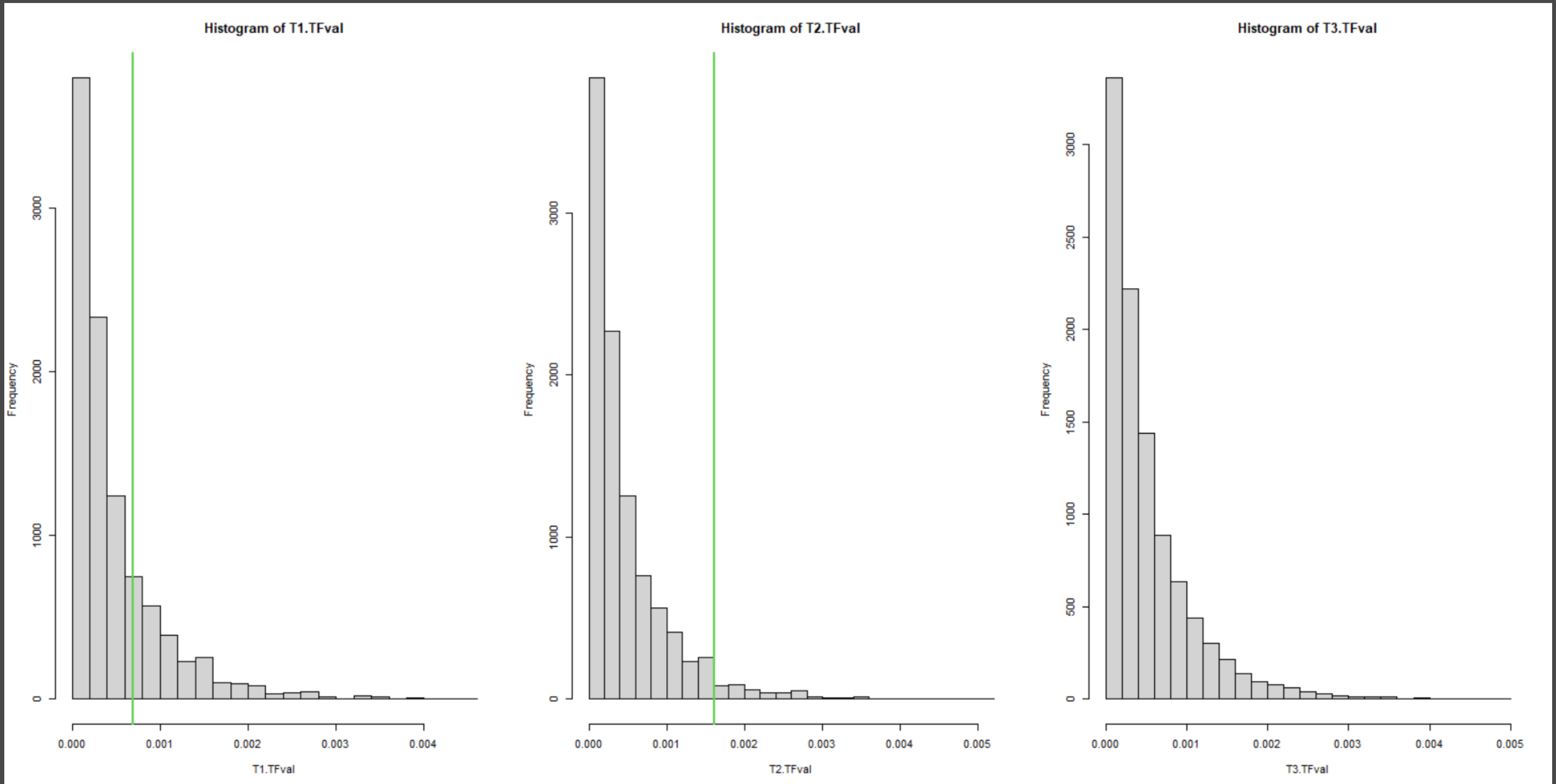


Functional boxplot and outliergram

The sample B600 collected in SRP at temperature 600°C looks suspicious. But is it?



ANALYSIS

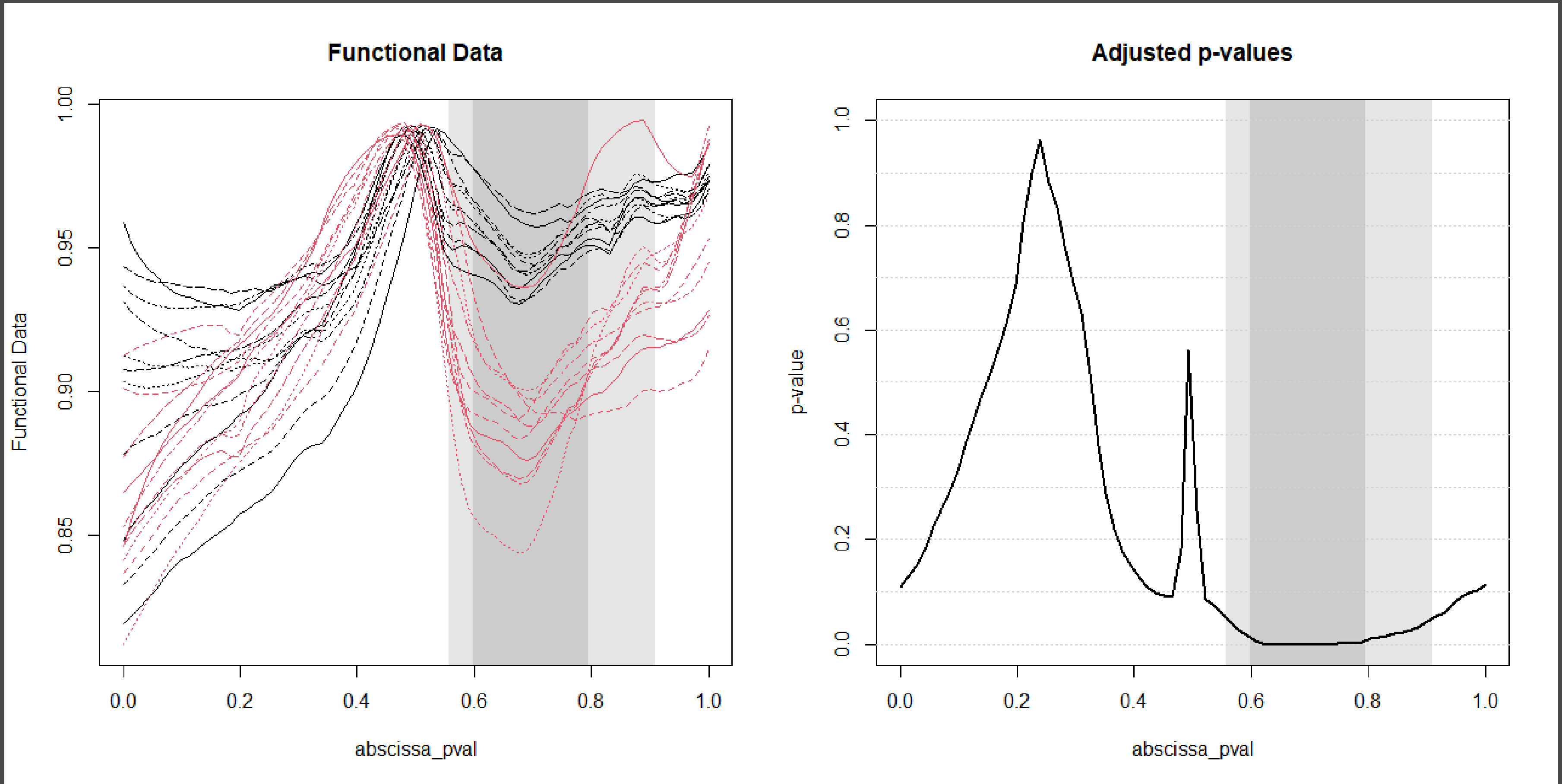


Temperature effect

Multivariate approach:

- Mean
- Median
- L^2 norm of the differences between quartiles

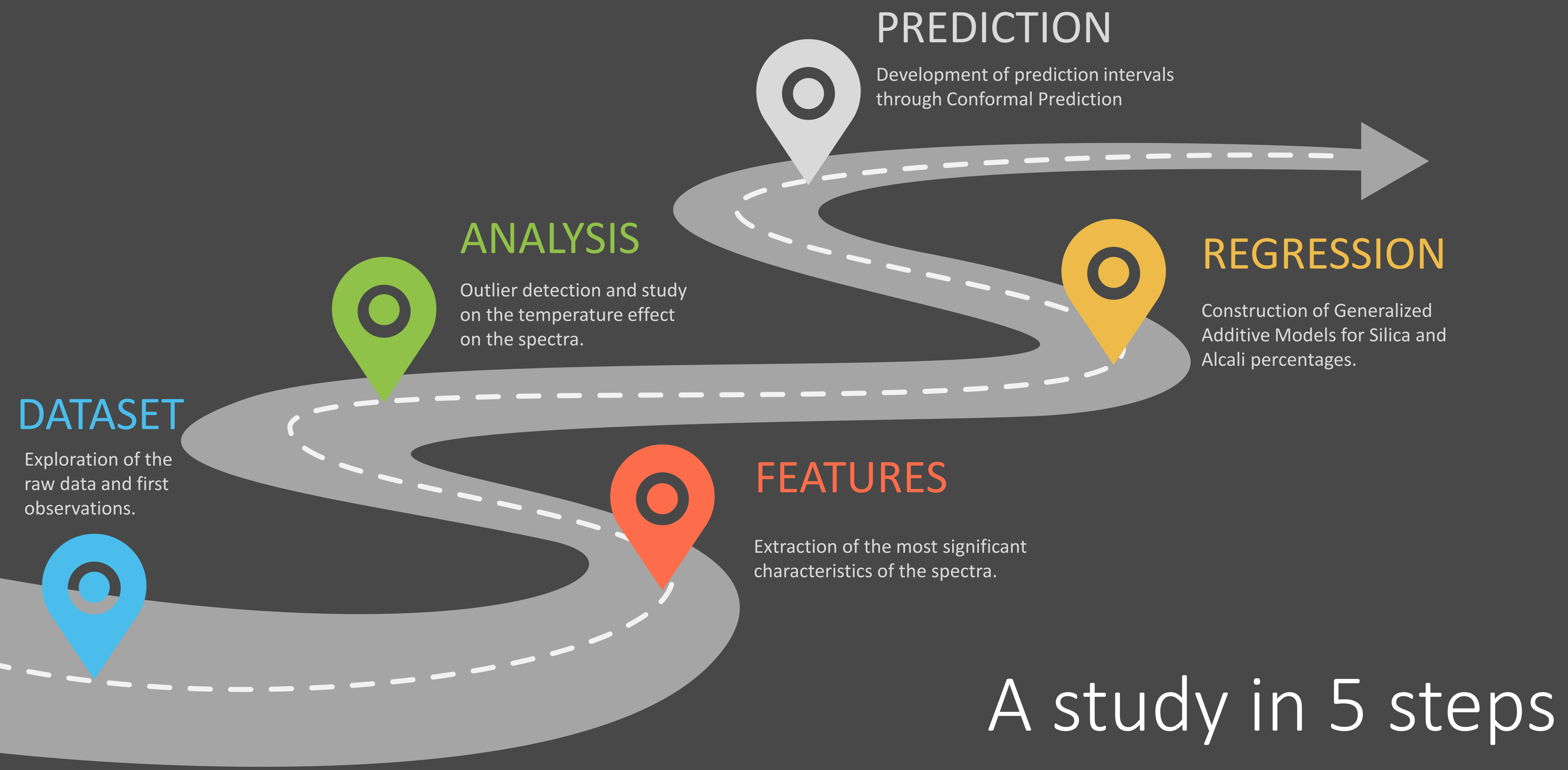
ANALYSIS



Temperature effect

Functional approach:

Highlights which intervals in the curves makes the groups different from each other


PREDICTION
Development of prediction intervals through Conformal Prediction
ANALYSIS
Outlier detection and study on the temperature effect on the spectra.
REGRESSION
Construction of Generalized Additive Models for Silica and Alcali percentages.
DATASET
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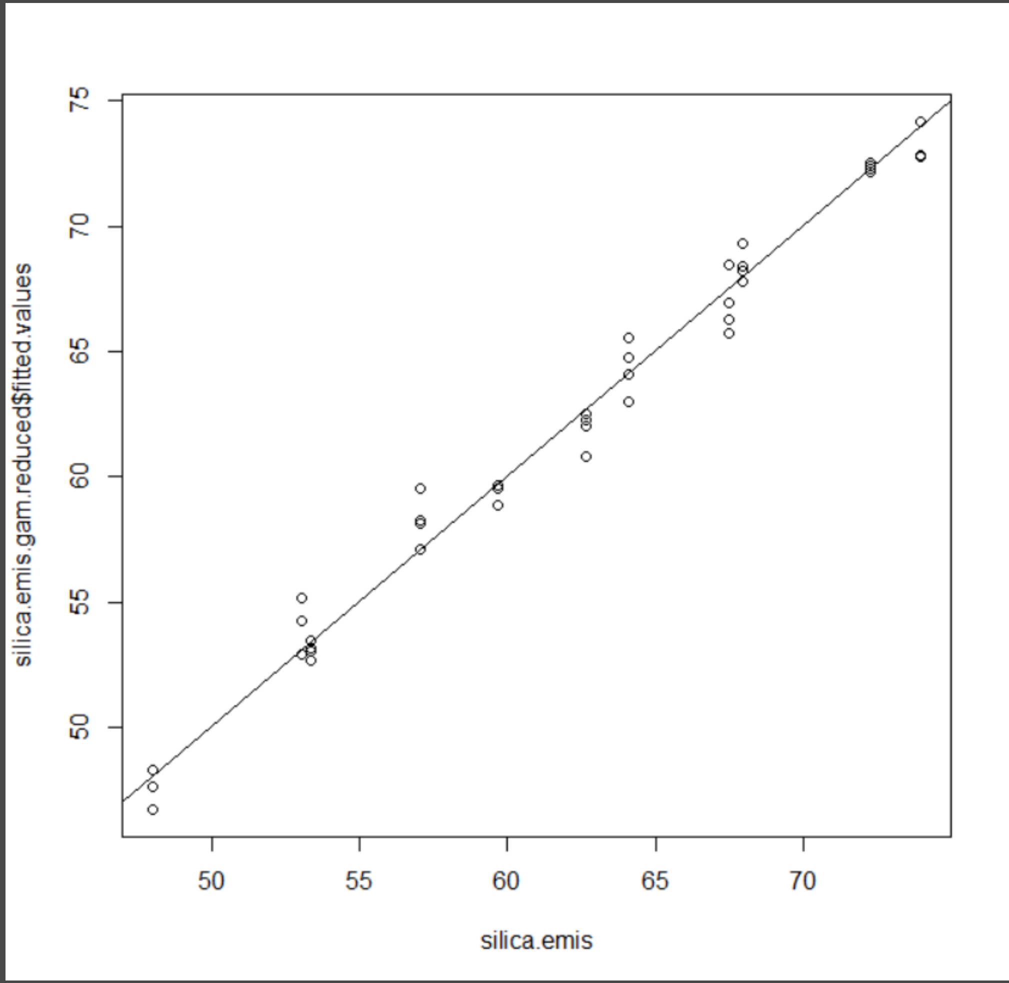
Generalized Additive Models REGRESSION

	Emissivity	**Reflectance**
$\mathbf{SiO_2}$	$CF + s(CFval) + s(TF) + s(TFval)$ $R_{adj} = 0.977$ $\quad$ $Deviance\ expl = 0.988$	$s(CF) + s(TFval)$ $R_{adj} = 0.995$ $\quad$ $Deviance\ expl = 0.996$
$\mathbf{Na_2O + K_2O}$	$CF + s(CFval) + s(TF) + s(TFval)$ $R_{adj} = 0.835$ $\quad$ $Deviance\ expl = 0.924$	$s(CF\ ) + s(TFval)$ $R_{adj} = 0.945$ $\quad$ $Deviance\ expl = 0.979$

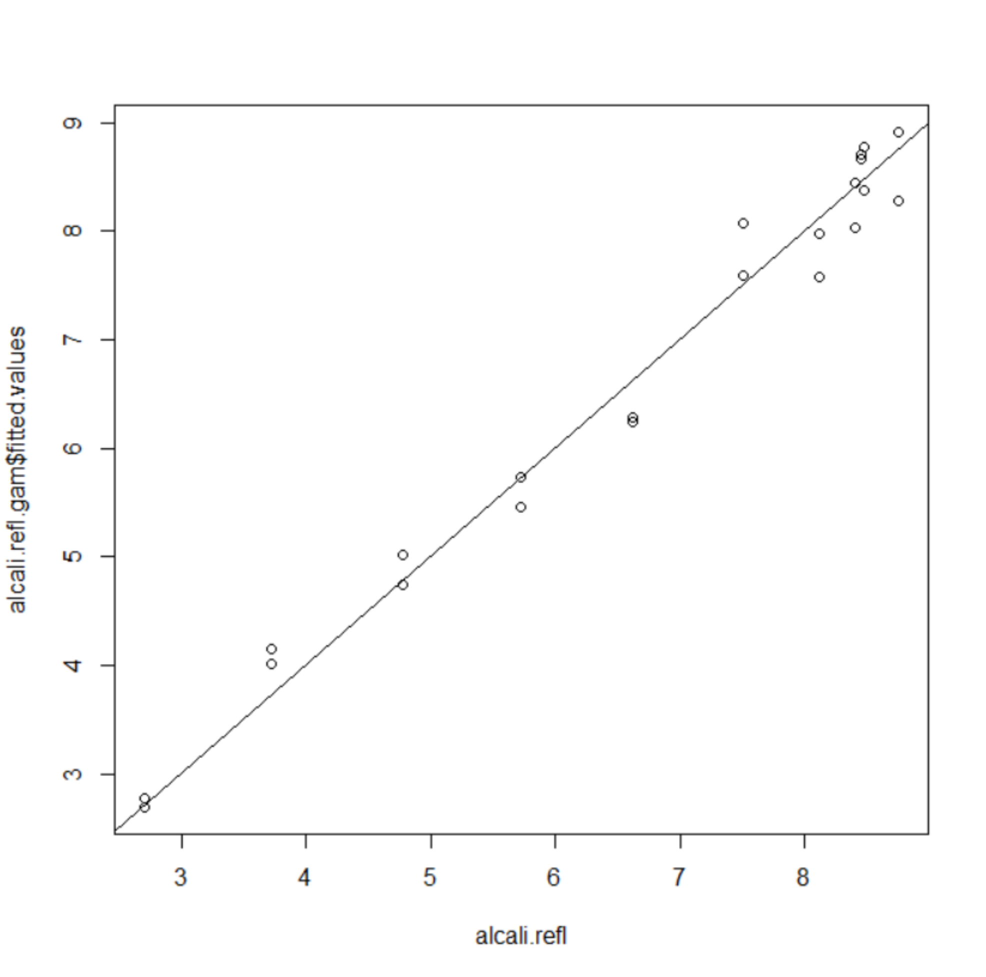
CF = Christiansen feature, TF = Transparency feature

True values vs fitted values

REGRESSION

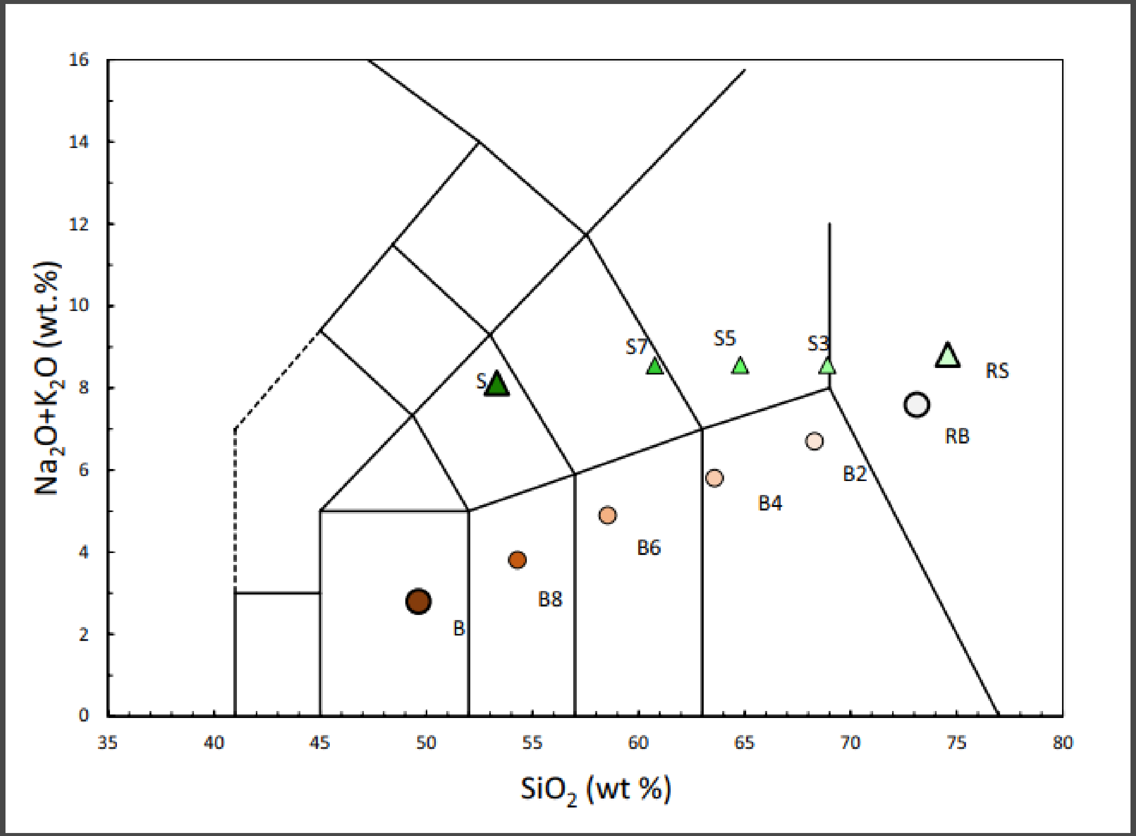


SILICA: Real values vs fitted values by the GAM (at each temperature)



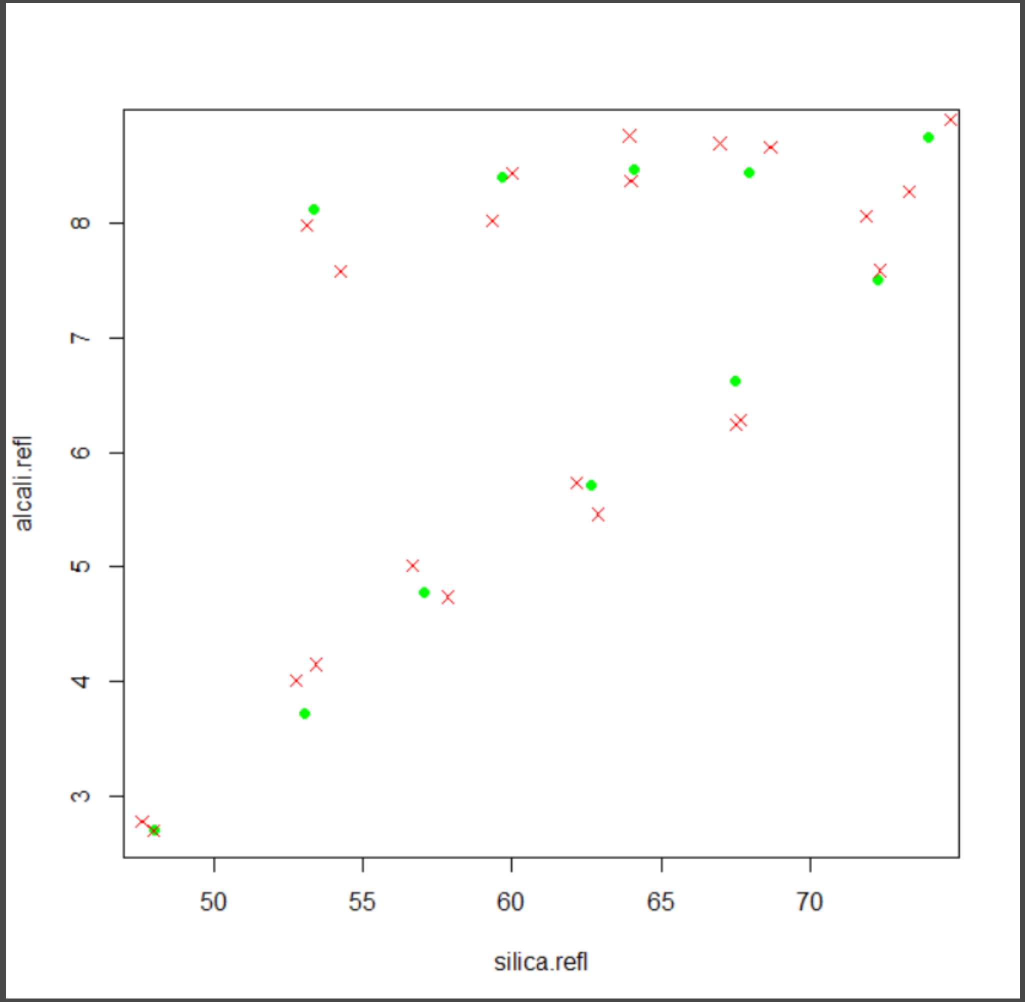
ALCALI: Real values vs fitted values by the GAM (at each temperature)

TAS diagram



A very important tool for classification of minerals based on their chemical composition

REGRESSION

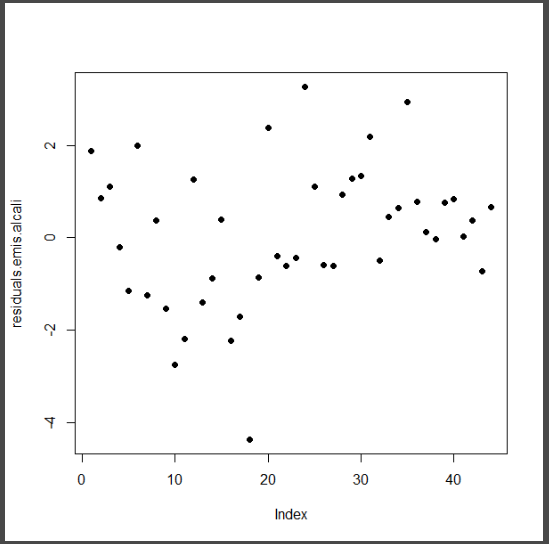


Green dots correspond to real position of our samples, while red crosses are our estimates for each temperature

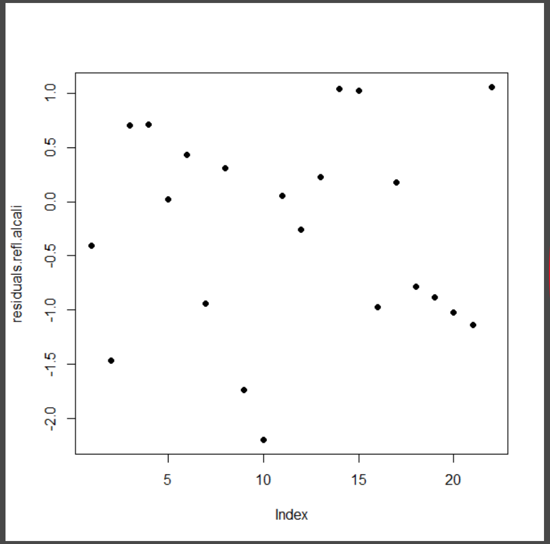
Leave-one-out cross validation

REGRESSION

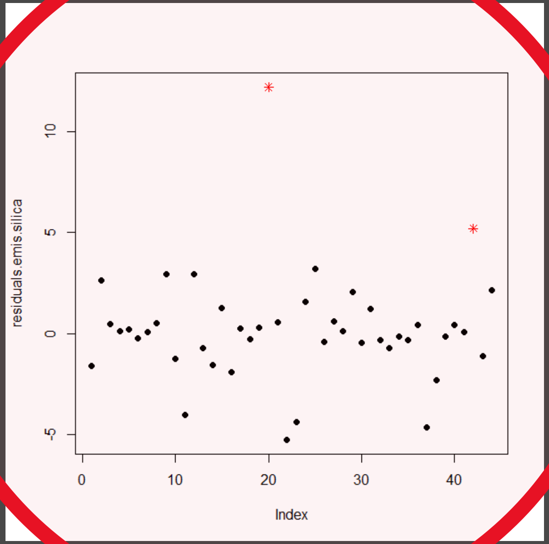
Alcali from emissivity



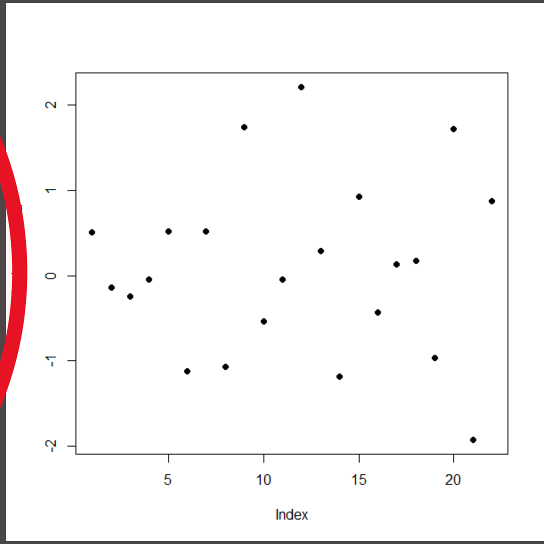
Alcali from reflectance



SIlica from emissivity



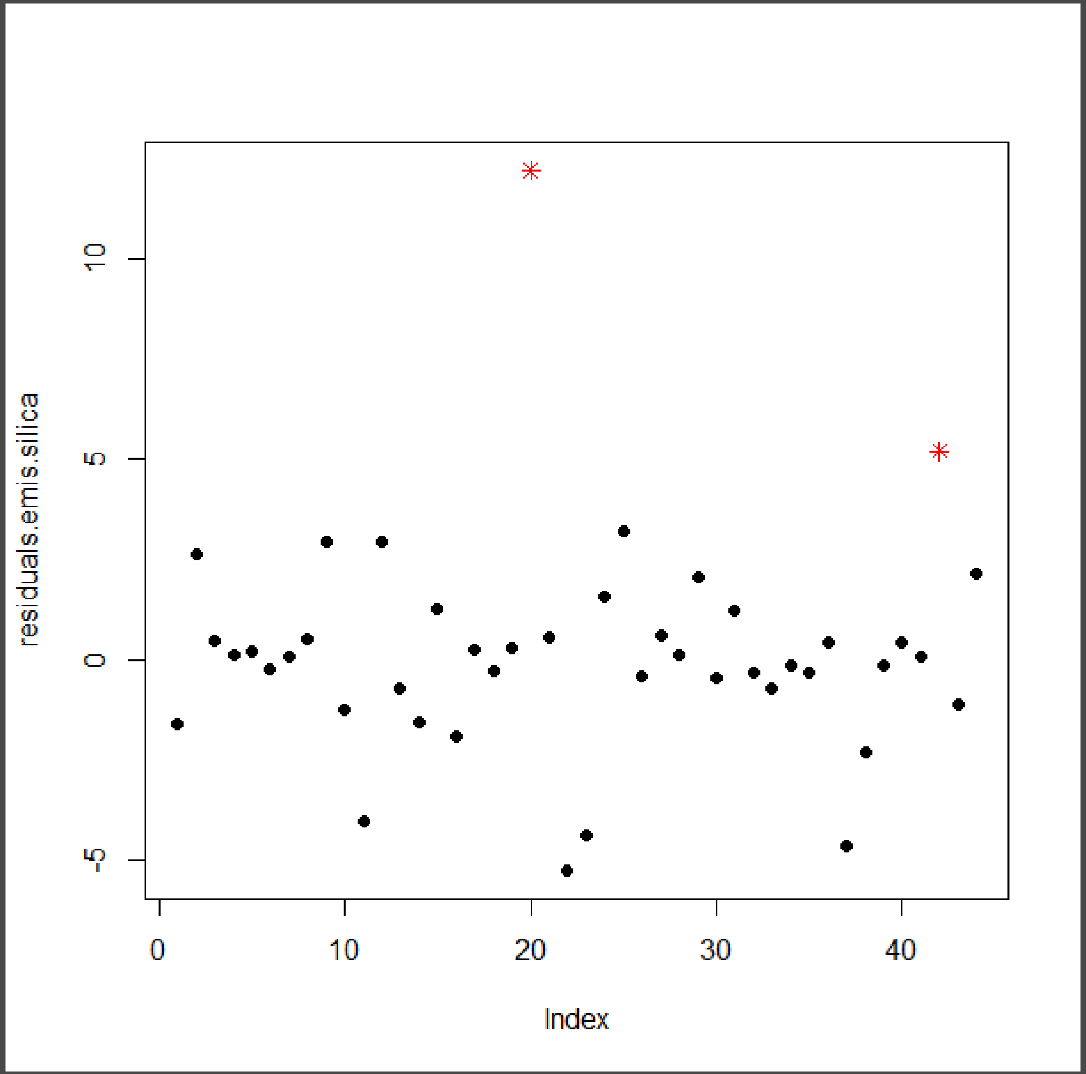
SIlica from reflectance



Leave-one-out cross validation

REGRESSION

Silica from emissivity, are we overfitting?

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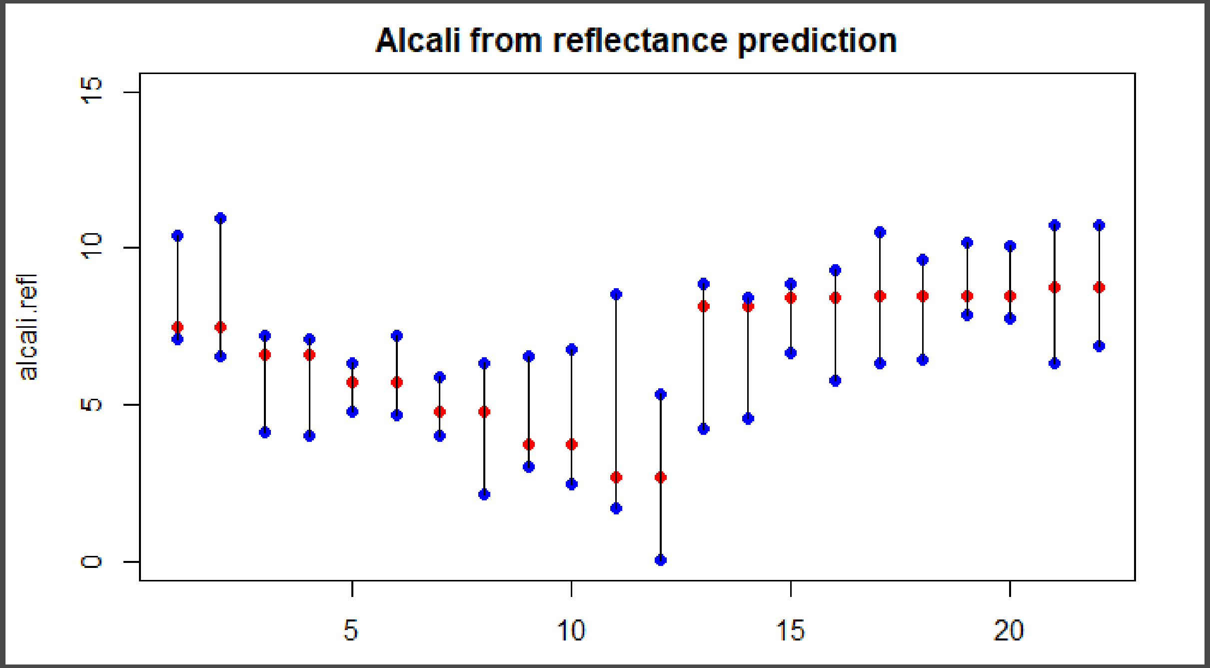
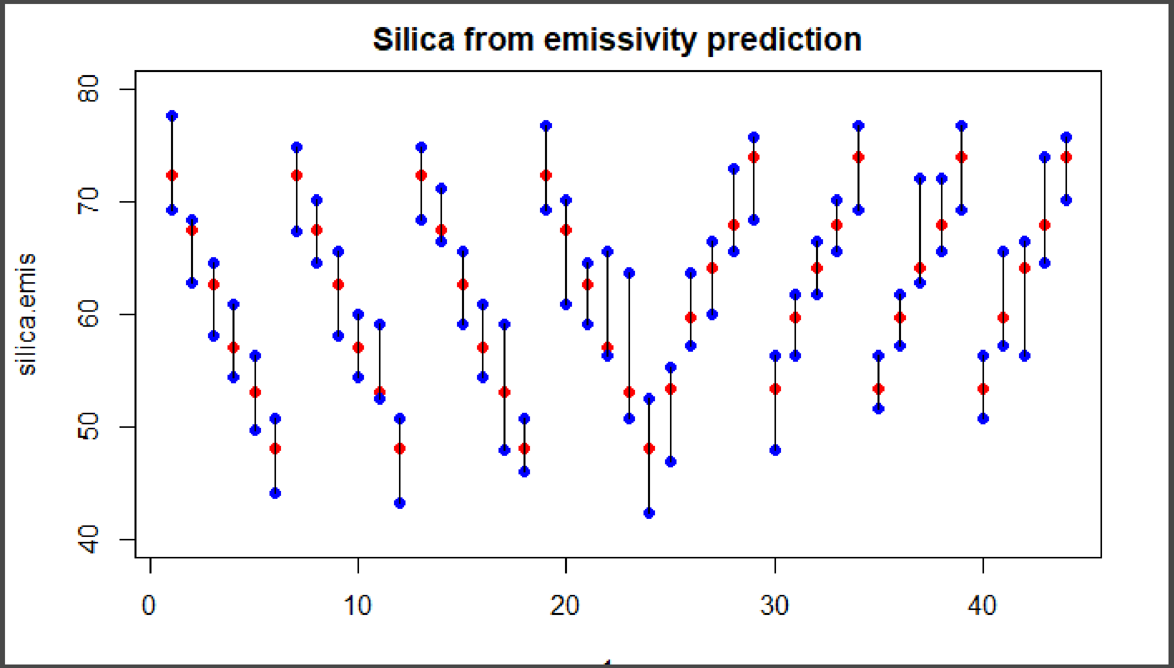
CONFORMAL PREDICTION





Not only pointwise prediction -> 0.95% prediction intervals.
True values (red dots) are always contained in the intervals.

DID WE REACH OUR GOAL?

- Q: Can we obtain informations about the chemical composition of rocky celestial bodies throught remote sensing?
- A: Yes, emissivity and reflectance curves contain very significant indicators for this kind of tasks.
- Q: Is it worth to invest in this field of research?
- A: Of course yes, both because of the importance of this study and because the results we obtained are promising.
- Q: How could the results be improved?
- A: Because of the scarcity of data, we could not use all informative features we identified. For future studies a larger amount of data would be required.

References

Vetere F. P., Bisolfati M., Pisello A., Maturilli A., Morgavi D., Pauselli C., iezzi G., Lustrino M. & Perugini D. «*Retrieving magma composition from TIR spectra: implications for terrestrial planets investigrations*» (2019).

Cooper B.L., Salisbury W., Killen R.M. & Potter A.E. «*Midinfrared spectral features of rocks and their powders*» (2002).

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