Geostatistical modelling of soil property maps for Europe

Gerard Heuvelink, Wim de Vries, Hans Kros and Gert Jan Reinds

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Why geostatistical modelling of soil property maps?

- NitroEurope project involves UQ/UA of ecosystem models at the European scale
- Soil properties treated as uncertain model input
- Therefore probability distributions of soil properties needed for the entire EU
- These probability distributions must take spatial correlation into account because this has a large impact on the uncertainty in aggregated (upscaled) model outputs (e.g. average emission in EU)
- Such probabilistic models are not available for Europe: must derive ourselves within the NitroEurope project

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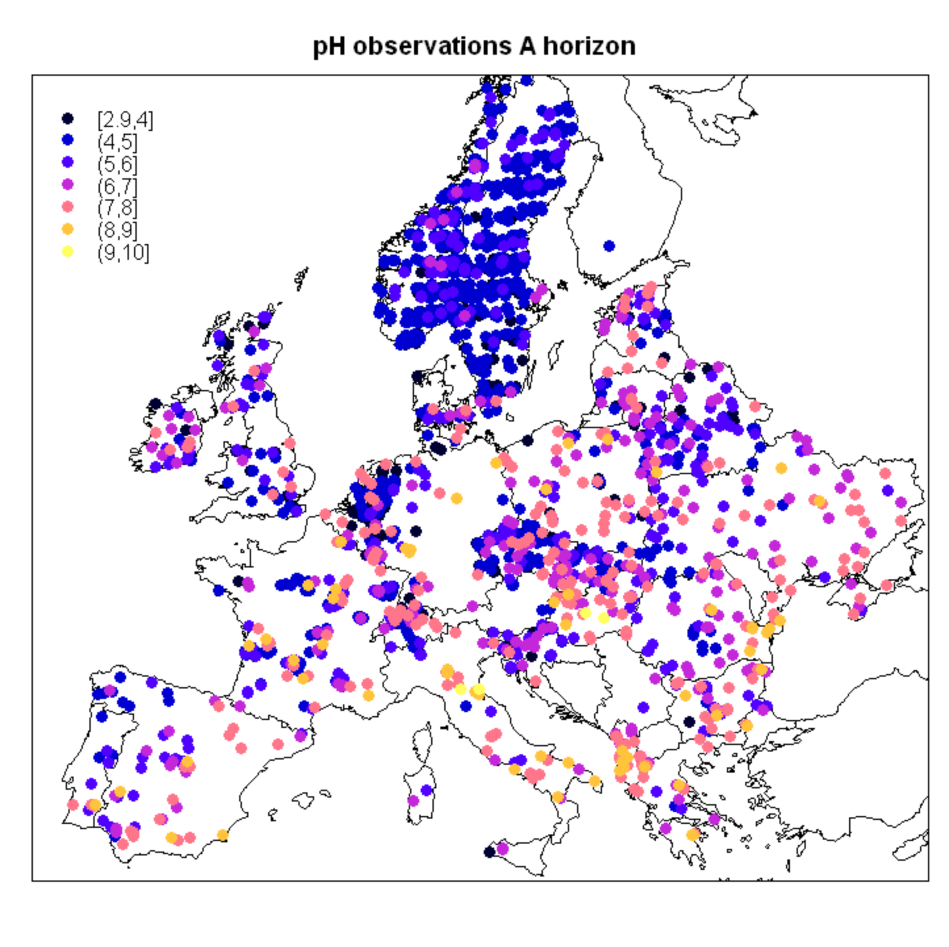
Target soil properties, source data, and covariates

- Seven soil properties (pH, OC, total N, BulkD, clay, sand, thickness) for three horizons (A, B, C): 21 variables in total
- Georeferenced observations from three databases: WISE, SPADE and EFSDB. In total about 3,100 locations
- Categorical maps of land cover, environmental zones and soil type provide additional information



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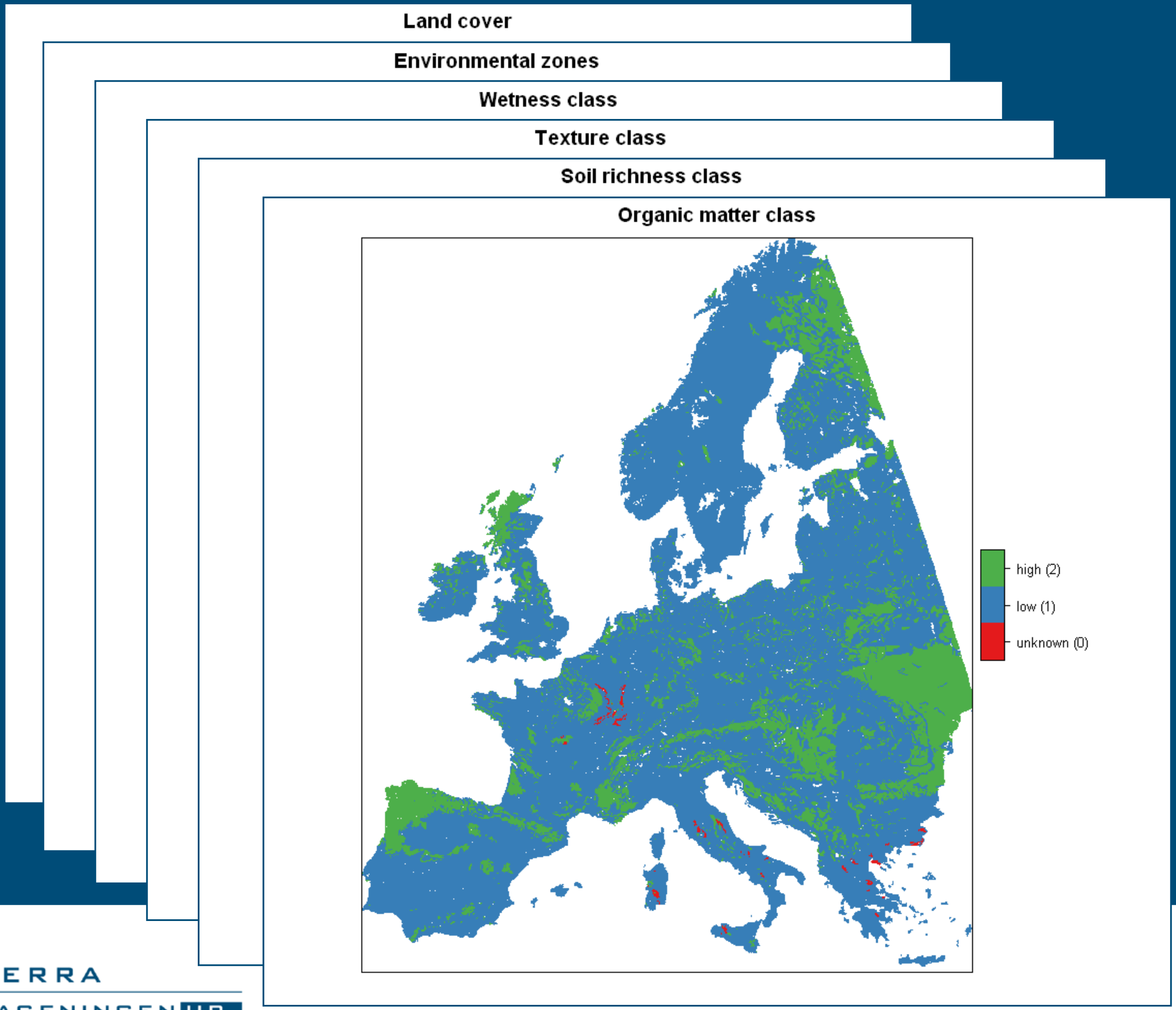
Geostatistical model and approach

$$Z_i(x) = \mu_i(x) + \sigma_i(x) \cdot \varepsilon_i(x) \qquad i = 1,\ldots,21$$

- μ_i and σ_i are constant within strata defined by the categorical maps, with values derived from the point observations contained in each stratum
- Estimation errors in μ_i and σ_i ignored
- OC and Total N log-transformed prior to geostatistical modelling
- Stochastic residuals ε_i are assumed second-order stationary with zero mean and unit variance, possibly cross- and spatially correlated
- Leads to a straightforward 'simple cokriging' model

Six categorical maps available for stratification



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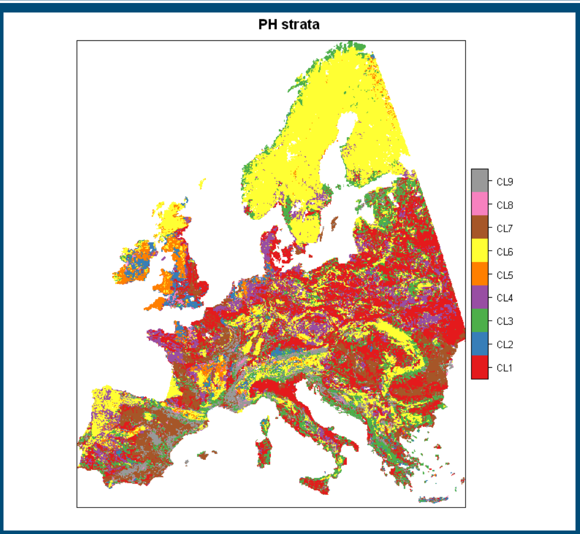
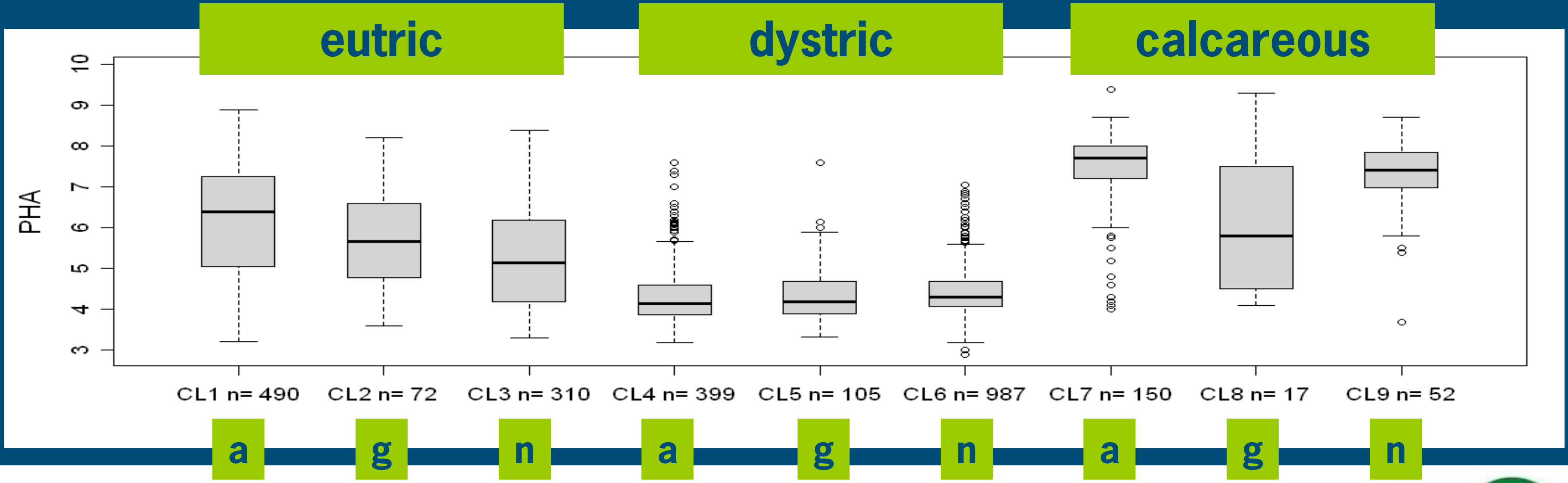
Stratification, example pH of A horizon

- Only soil richness and land cover maps used for stratification
- Overlay gives 3x3=9 strata
- Boxplots show meaningful differences between strata, but also large within-stratum variability





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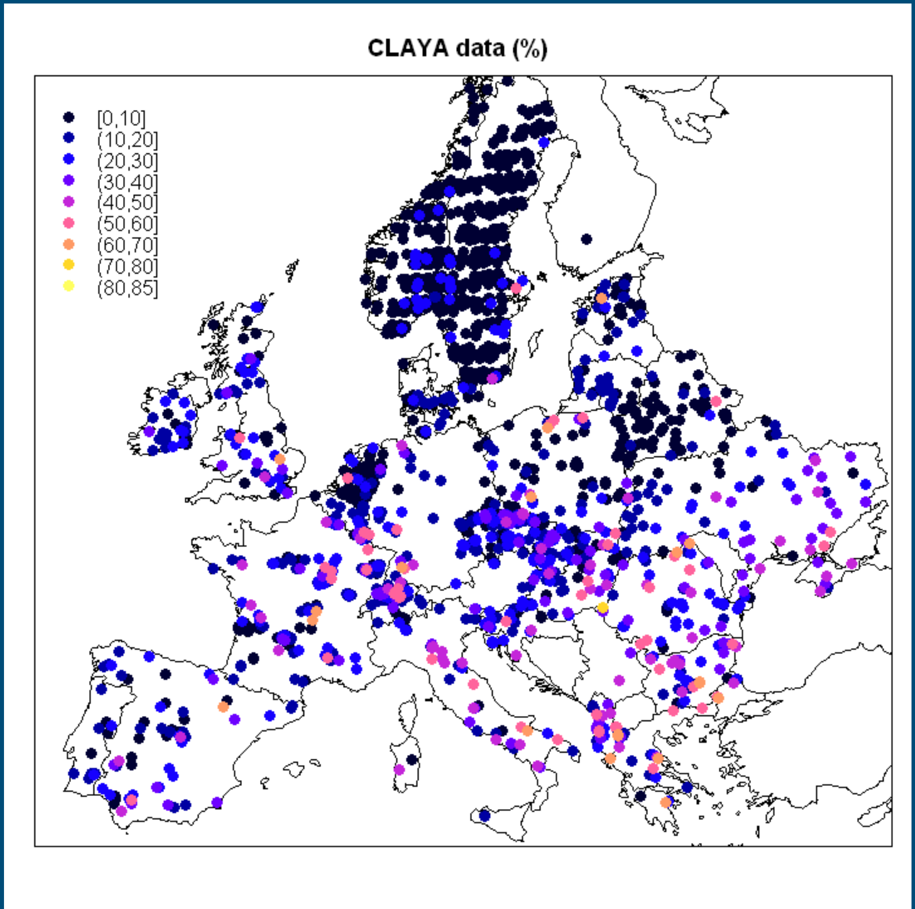
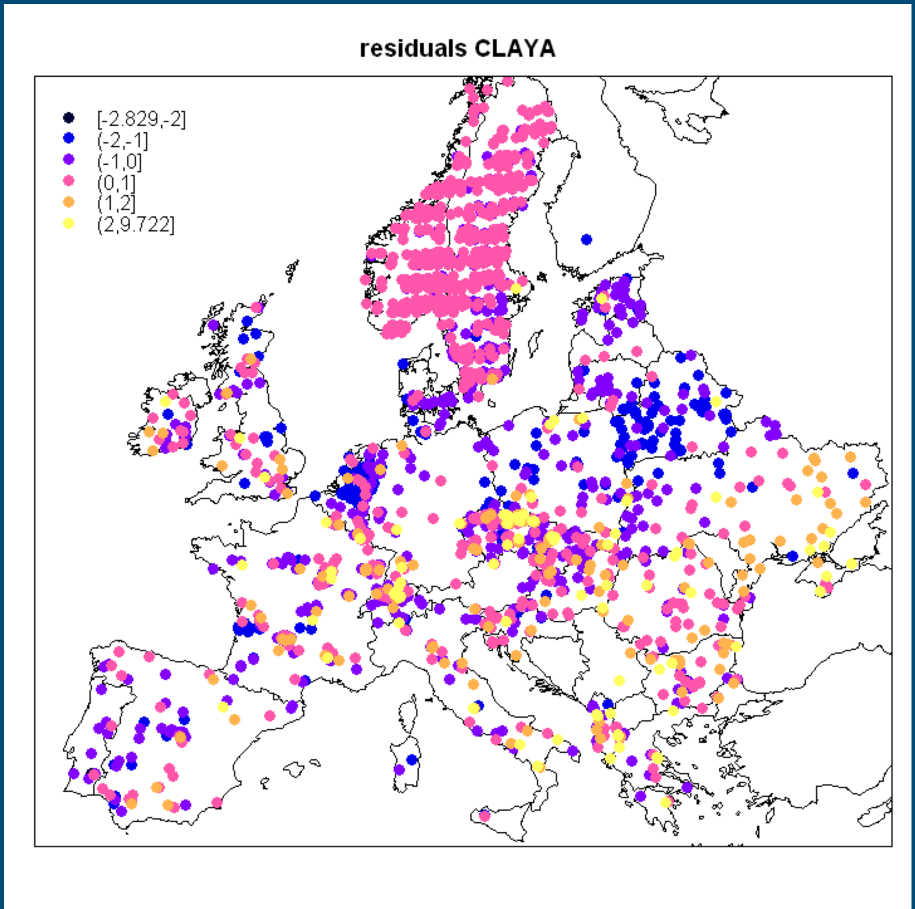
Observations pH of A horizon, before and after standardisation using μ and σ





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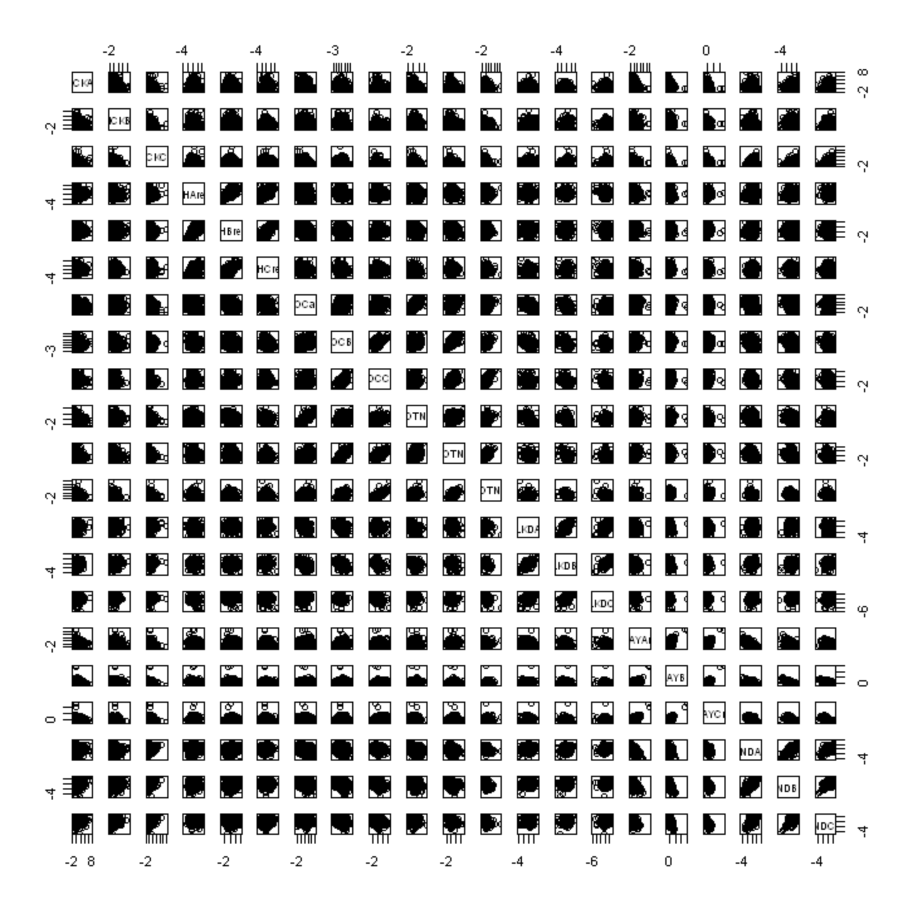
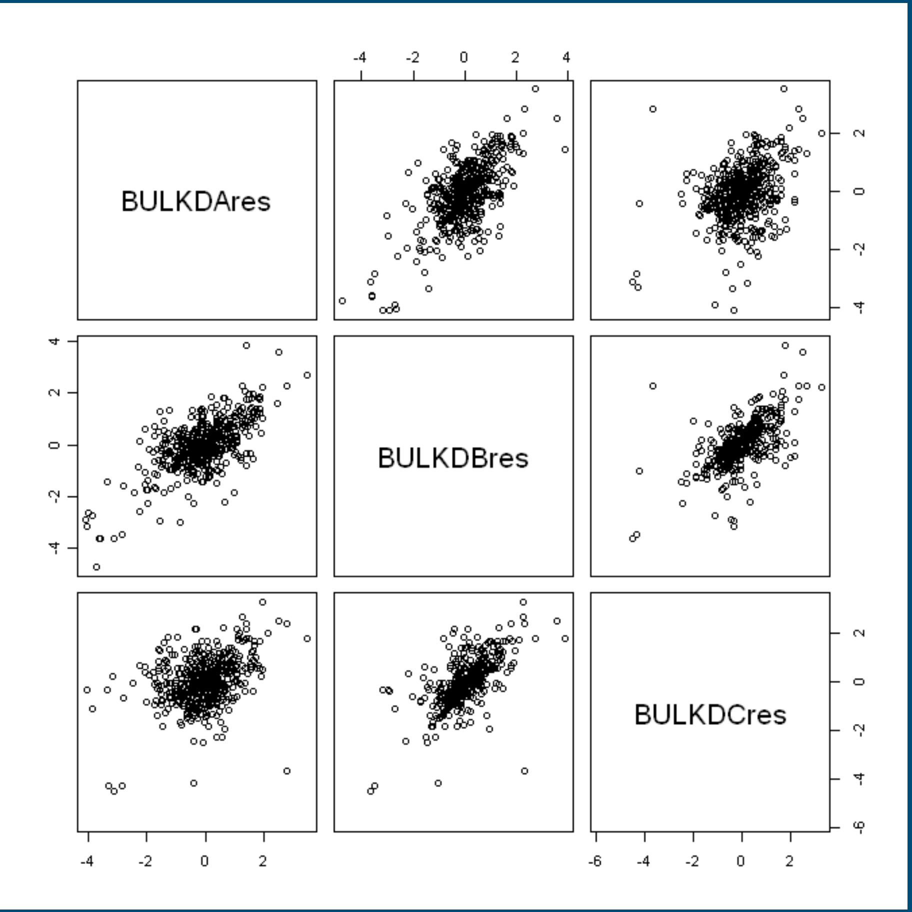
Residuals strongly correlated between horizons





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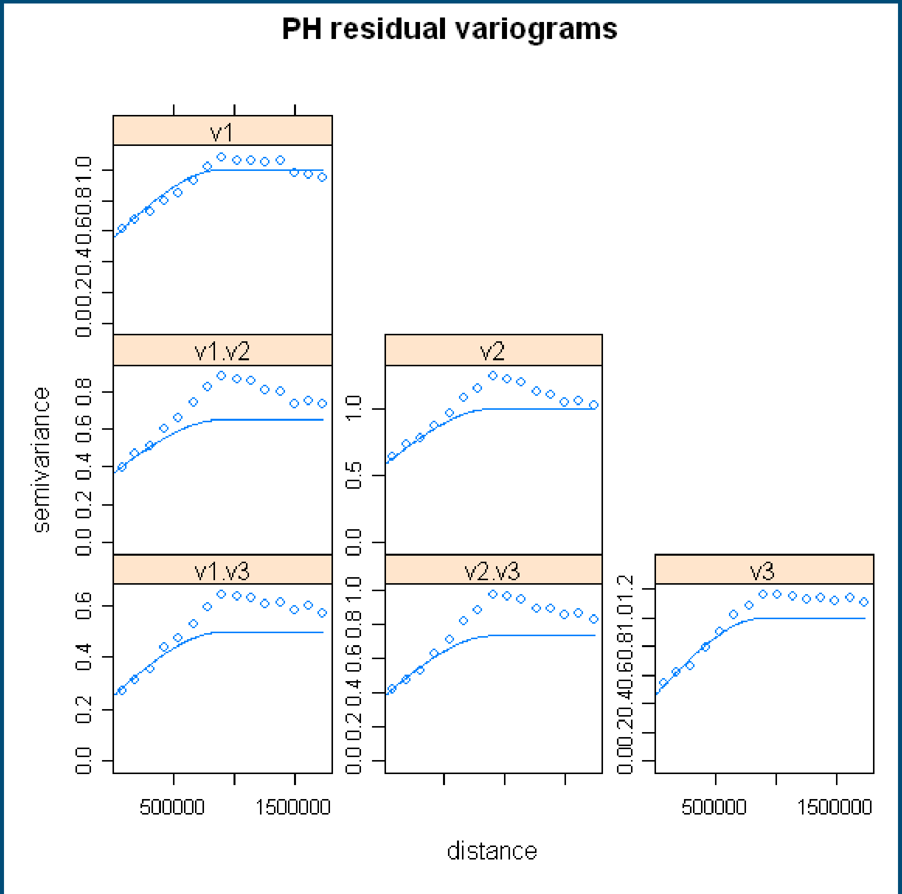
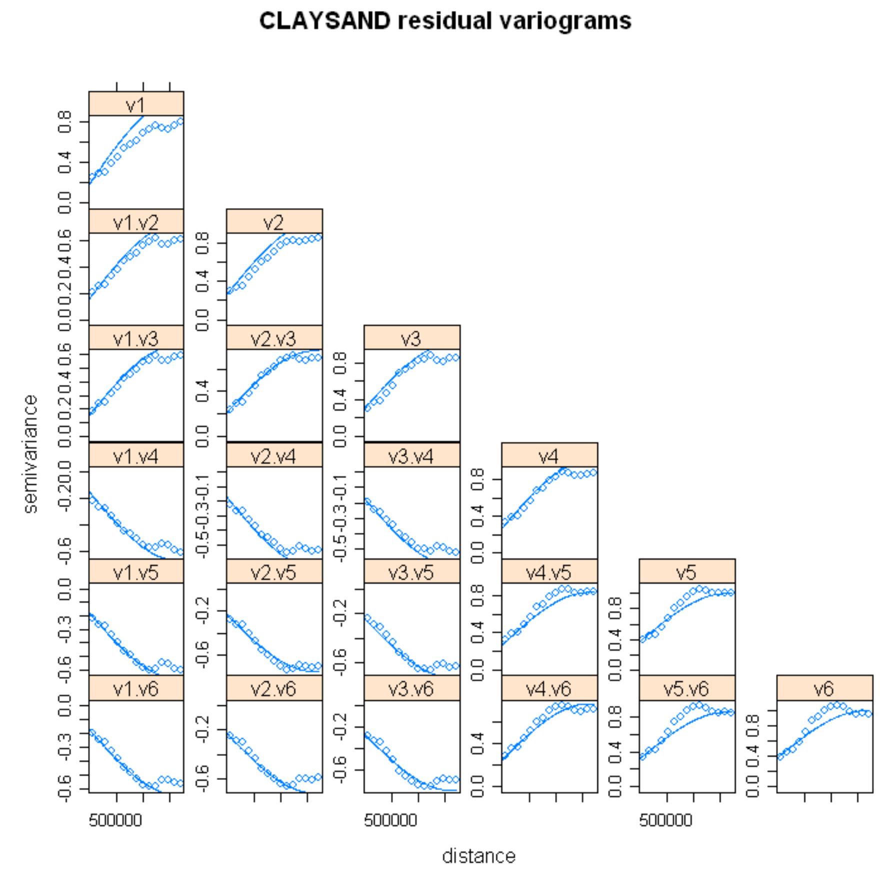
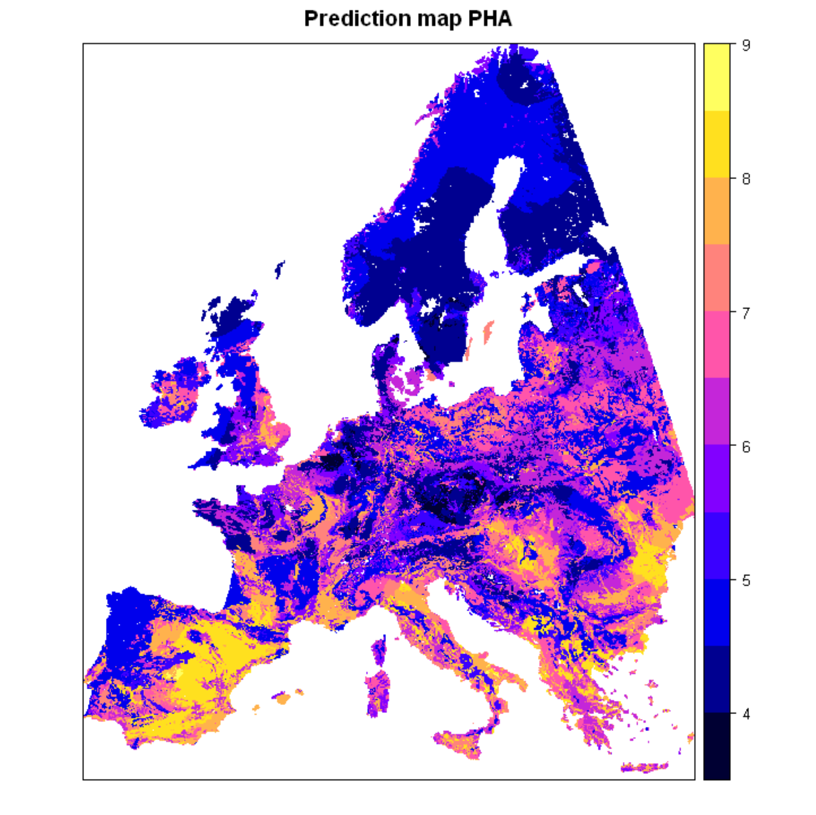
Residuals also spatially correlated, some are spatially cross-correlated with other residuals



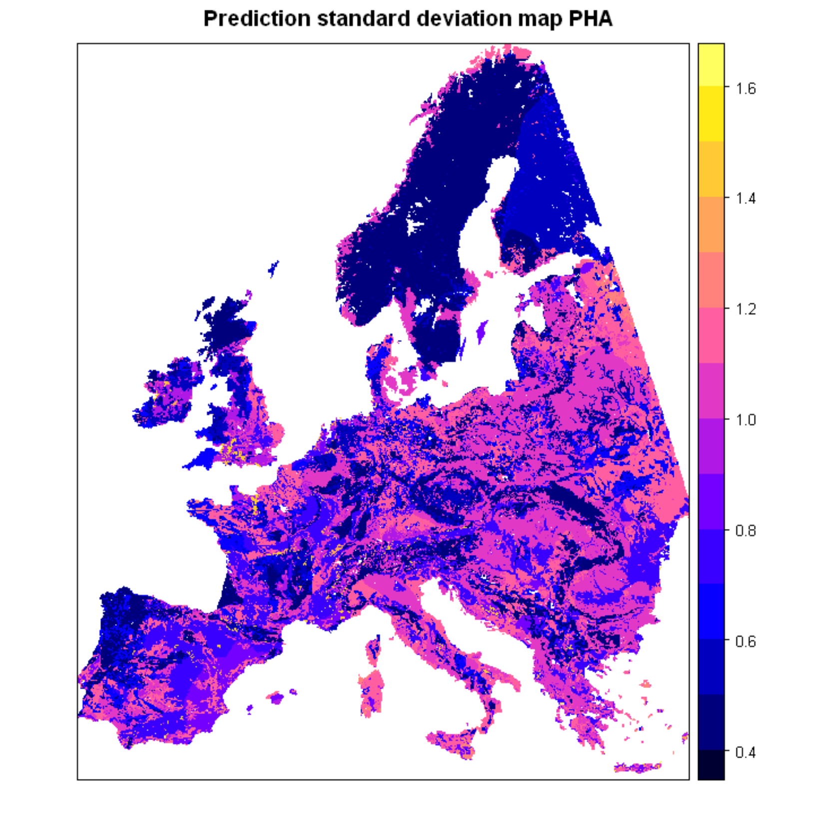


Kriging result, pH example

prediction pH horizon A



prediction st.dev. pH horizon A



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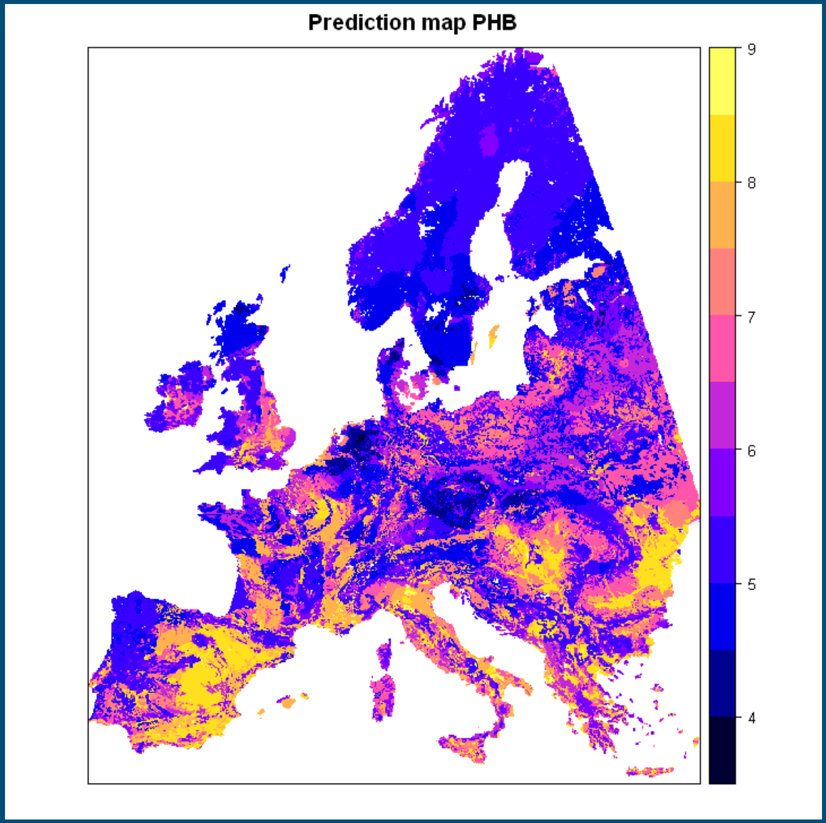
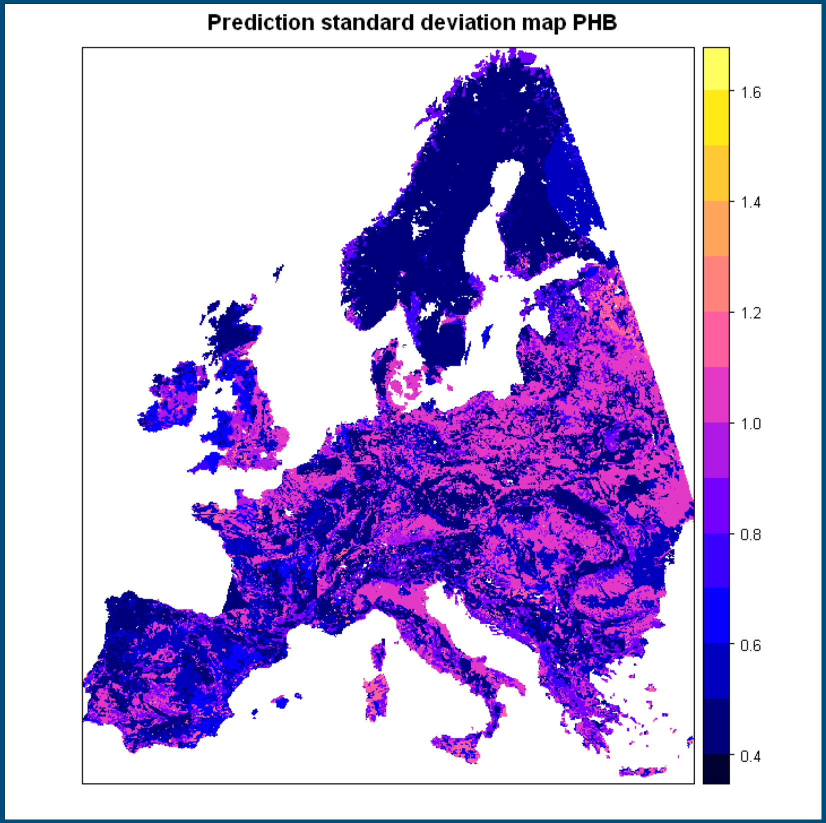
Kriging result, pH example

prediction pH horizon B



prediction st.dev. pH horizon B



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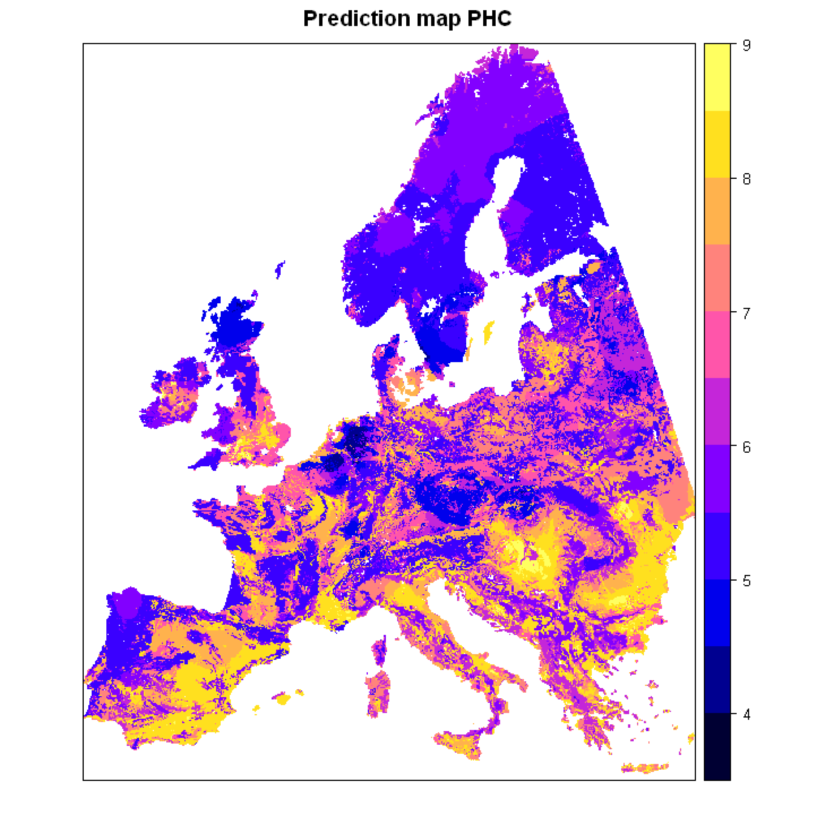
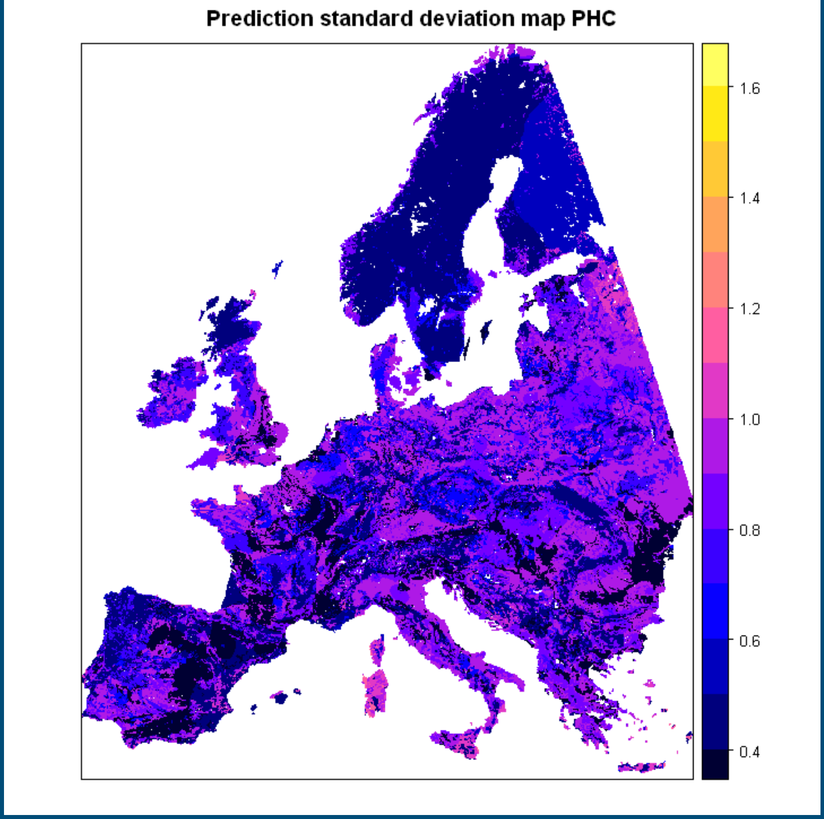
Kriging result, pH example

prediction pH horizon C



prediction st.dev. pH horizon C



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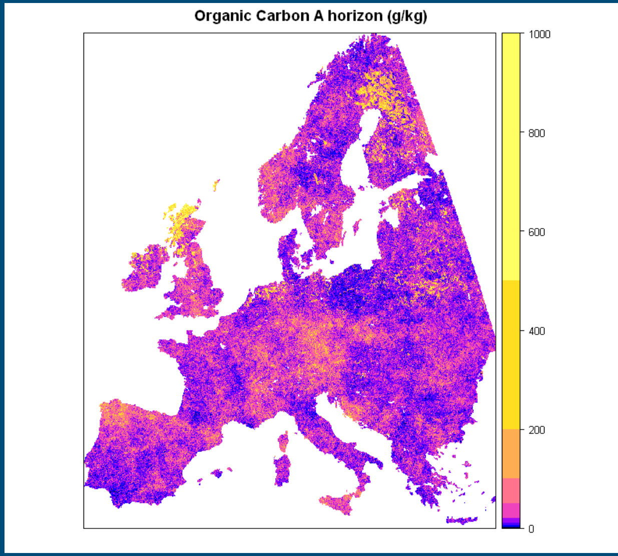
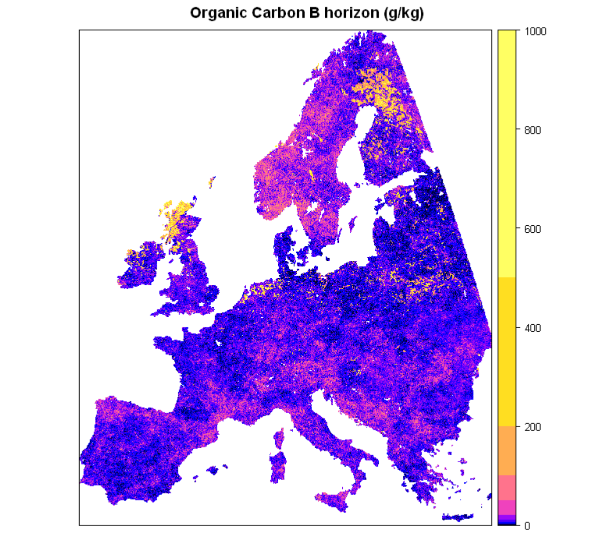
Stochastic simulations, OC example

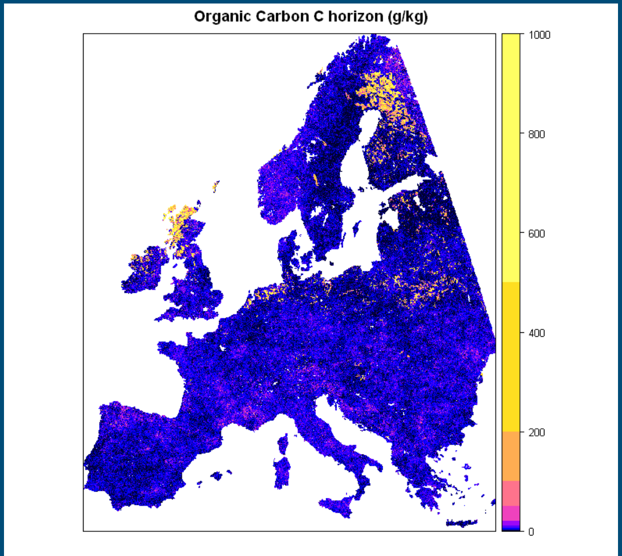
A horizon



B horizon



C horizon



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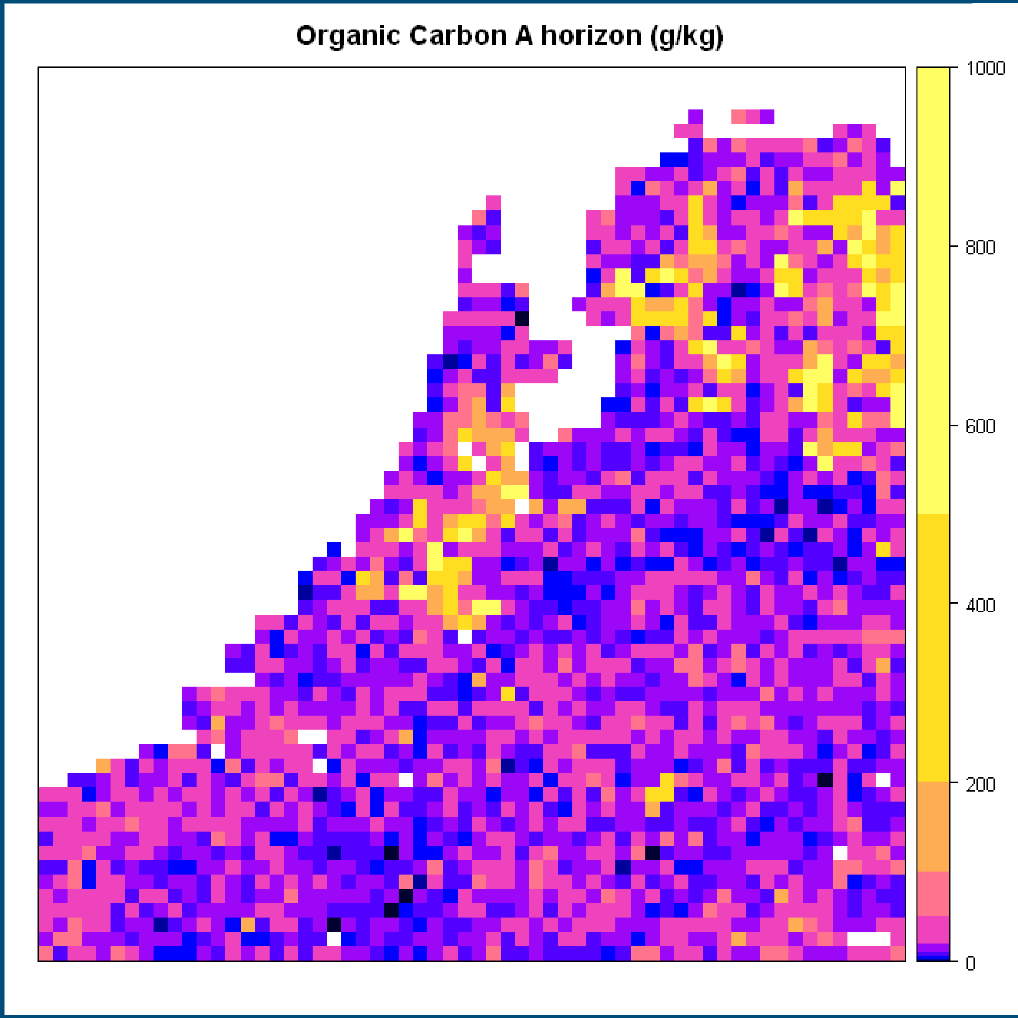
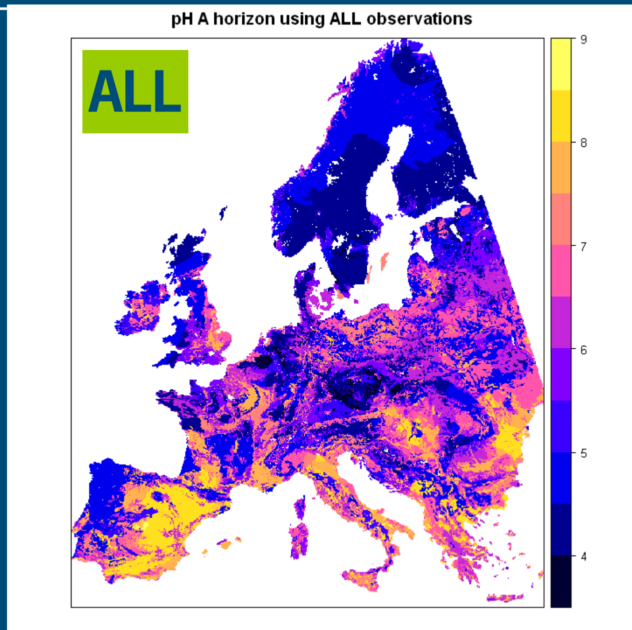
Substantial uncertainty obvious when zooming in

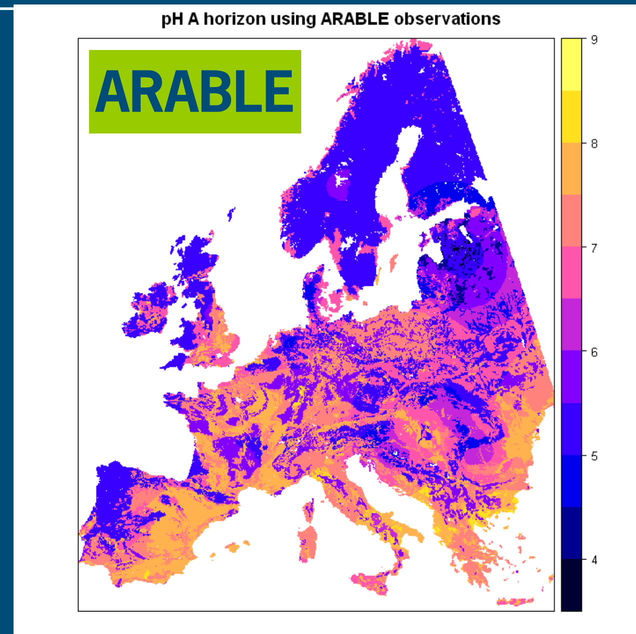


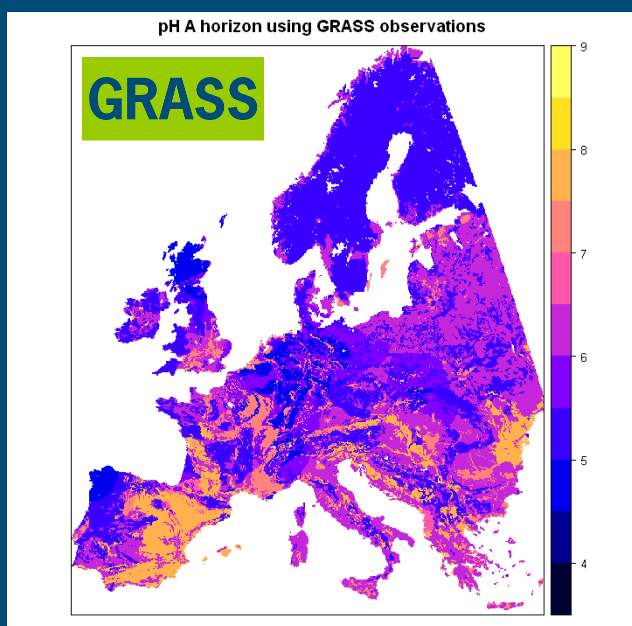
Separate modelling per landuse type

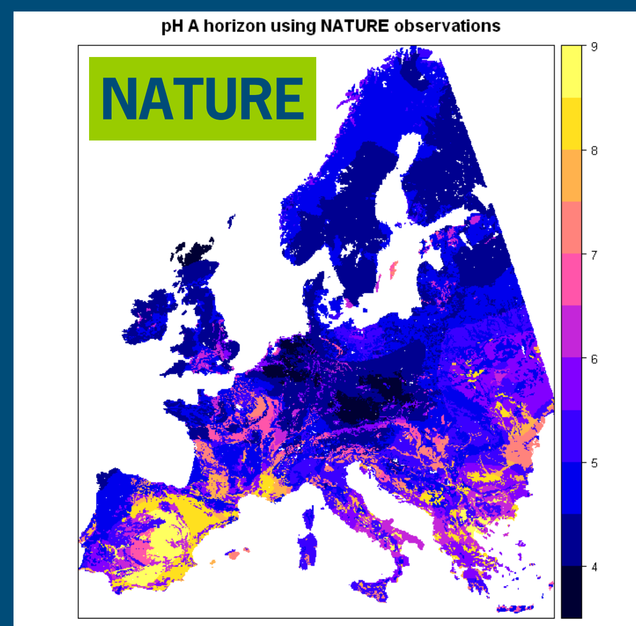
- We used the landuse map as a covariate, but this map is not error-free
- Therefore there will be observation and prediction locations for which the mapped landuse is different from the 'true' landuse: wrong allocation increases uncertainty and may give nonsense
- Conditioning to true landuse can be done by redoing the analysis three times: each time using only observations from locations with a specific landuse
- Resulting maps are only valid for locations that have the same landuse

pH maps A horizon, conditional to true landuse

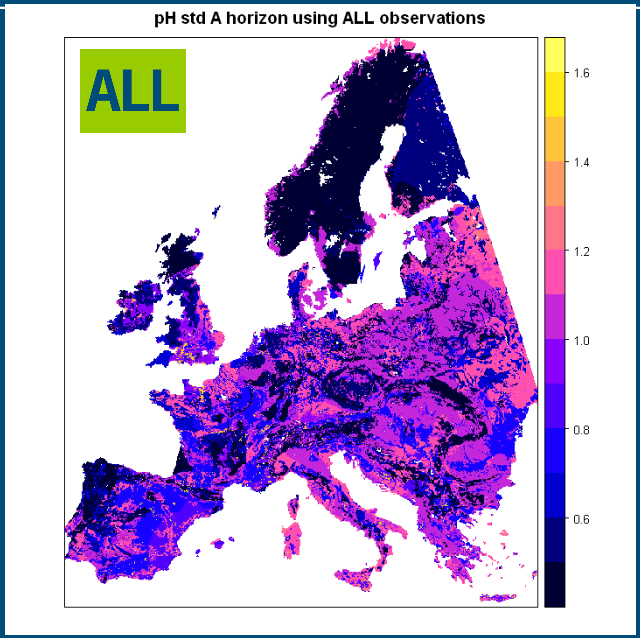


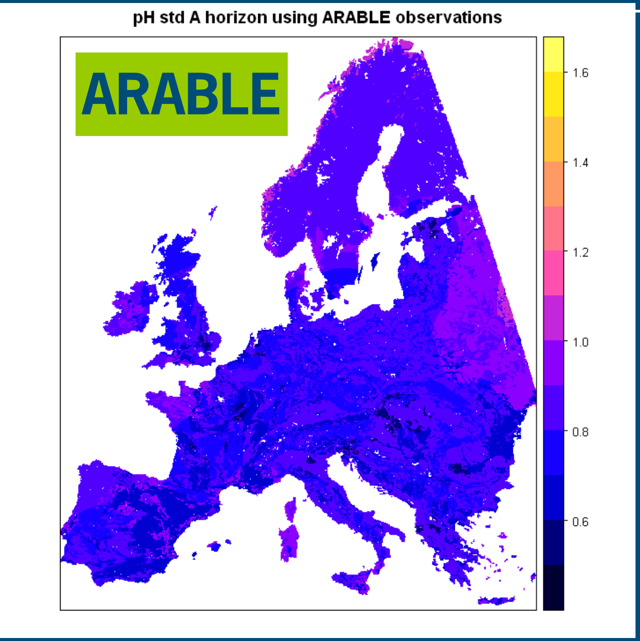


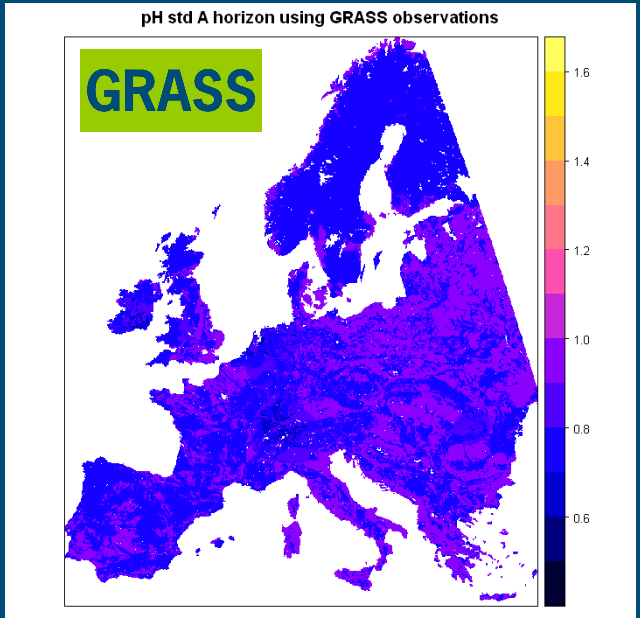


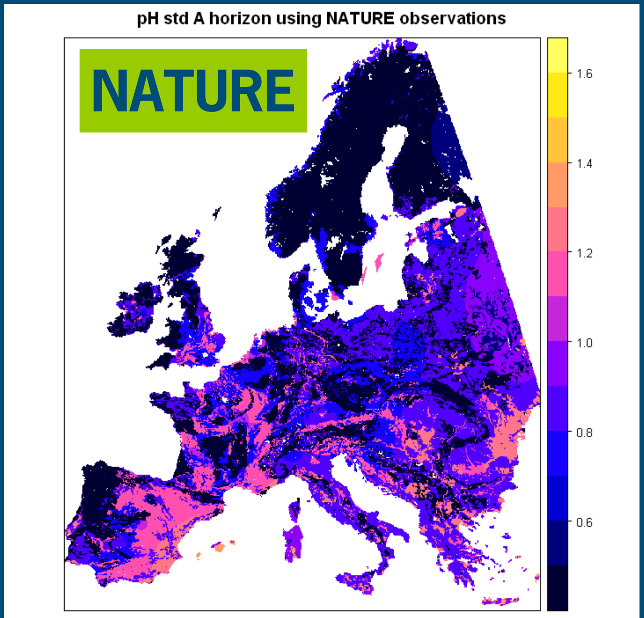


Corresponding pH standard deviation maps

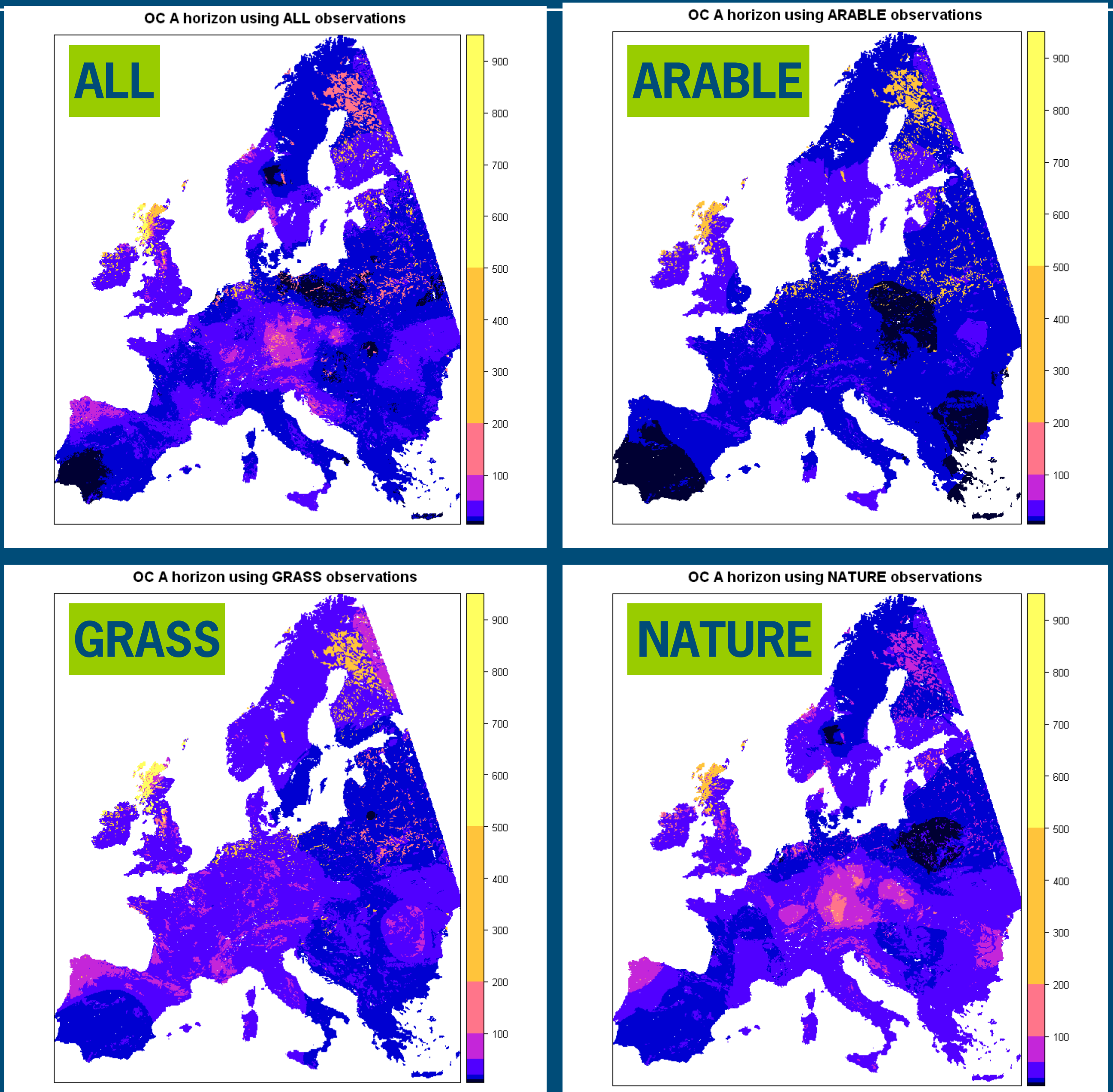








OC maps A horizon, conditional to true landuse



Conclusions

- A straightforward geostatistical approach yields maps of soil properties for Europe that overall appear realistic
- Associated uncertainties are large, not surprising given the small dataset (<1 observation per 44 km^2), coarse maps of covariates and large spatial variation at ‘short’ distances
- Uncertainty can be reduced by using more data: in fact these exist (e.g. national databases), but:
  - rarely freely available, if for free no easy download but licenses
  - may not store all soil properties
  - may lack georeferencing (e.g. SPADE2)
  - will cause harmonization problems
- Conditioning to ‘true’ landuse makes a difference, but uncertainties remain large
- Next step (before the end of NEU): analyse how these uncertainties propagate through ecosystem models!

Thank you





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