A computational Cultural Transmission model of Bronze Age burial rites in Central, Northern and North-western Europe

Observations on spatial and cultural distance

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Evolution of
Cultural Complexity III
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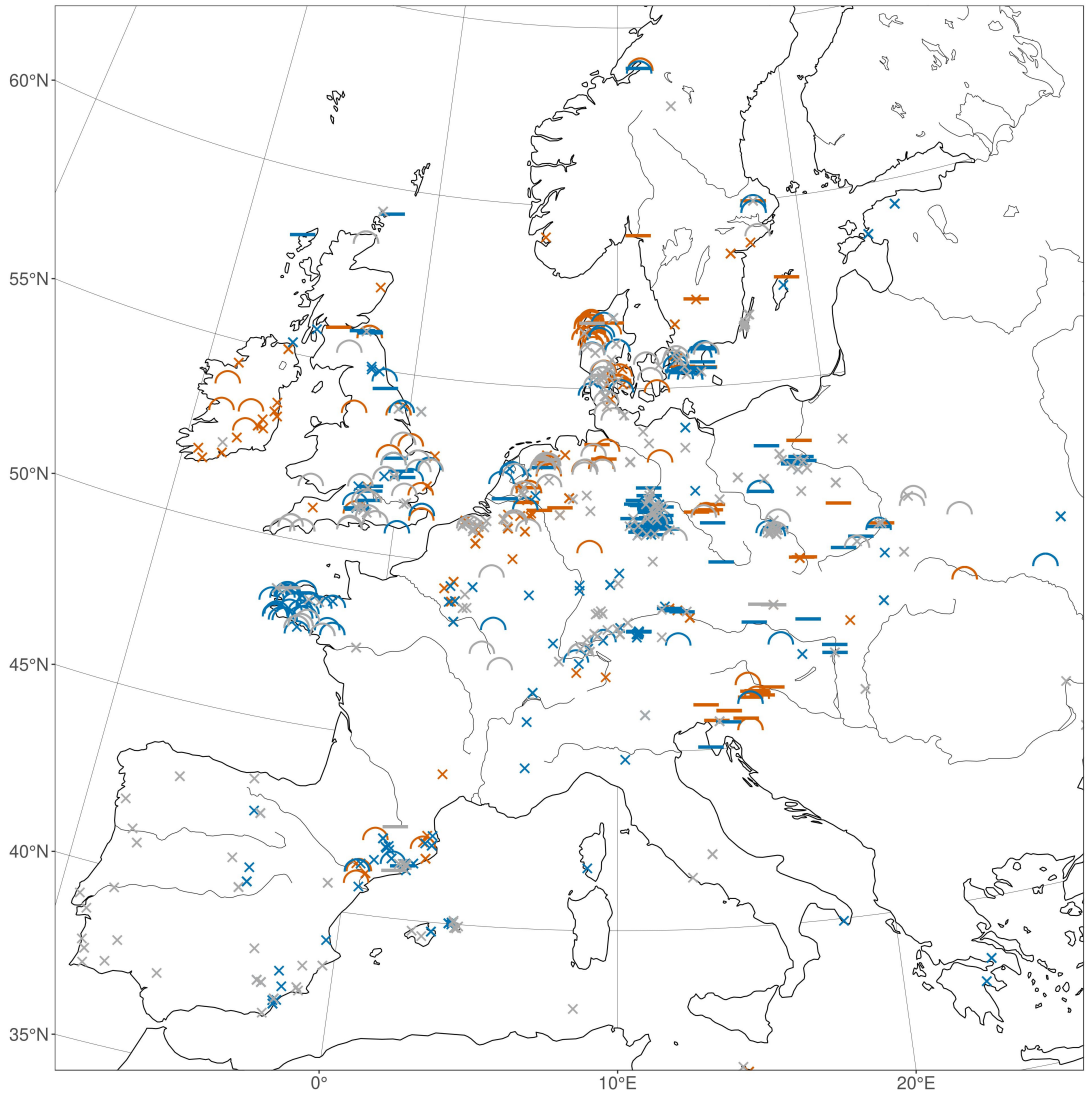
Introduction

Data

Radon-B: Database for European ^{14}C dates for the Bronze and Early Iron Age

Radiocarbon dating is one of the most important absolute dating methods: One date equals a **fuzzy point in space and time with context information**



Metainformation for dates from graves: **burial type** & **burial construction**

Heterogeneous information density in space and time

Figure 1: Radon-B ^{14}C dates of graves 2200-800 calBC (Albers Equal Area Conic).

Research Area and Regions

Divide and Conquer: Separation into eight **artificial regions** within the area of the highest data density

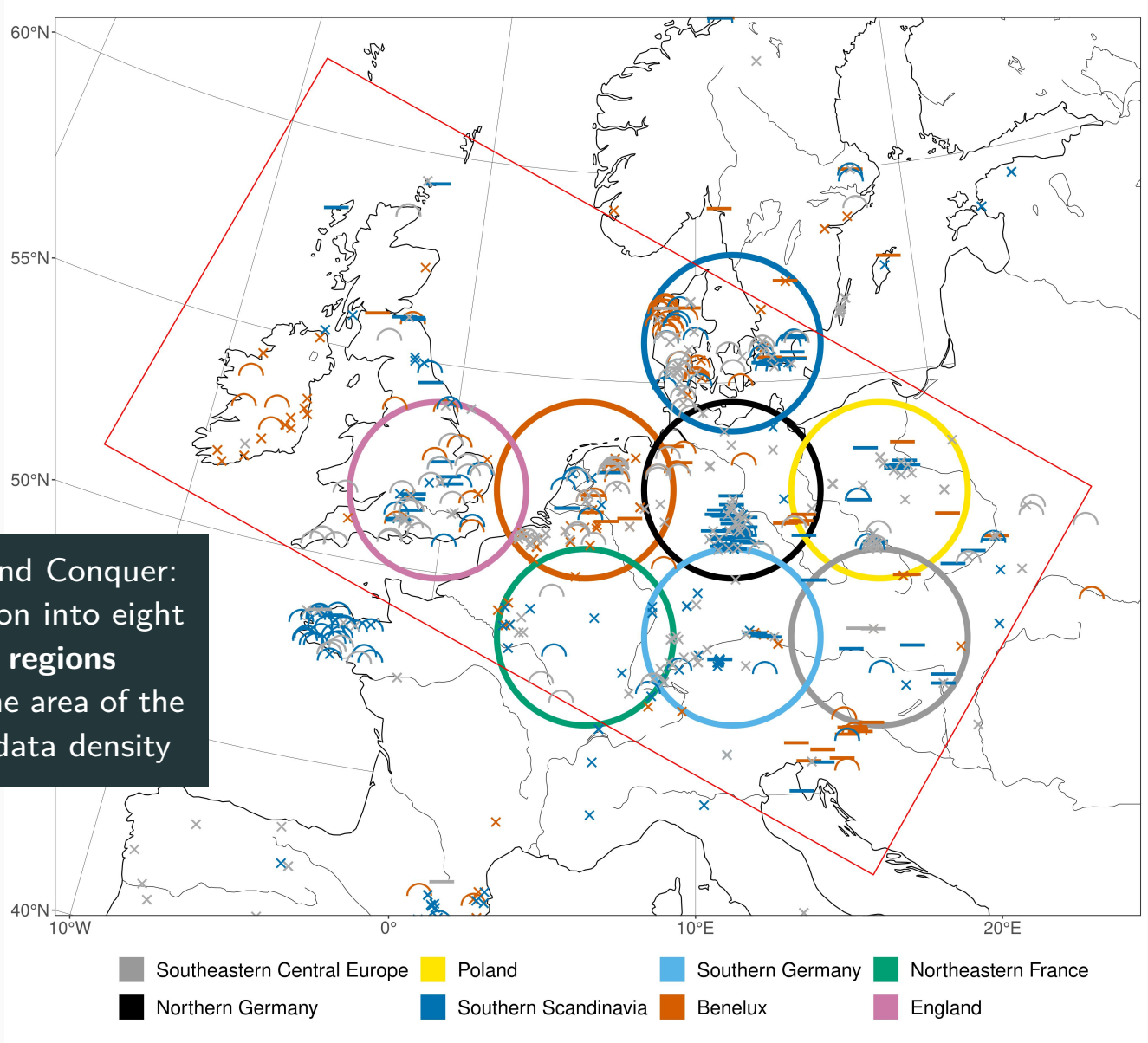


Figure 2: Artificial Regions: 400km distance, 240km radius, >= 70 dates.

Development – Absolute Numbers

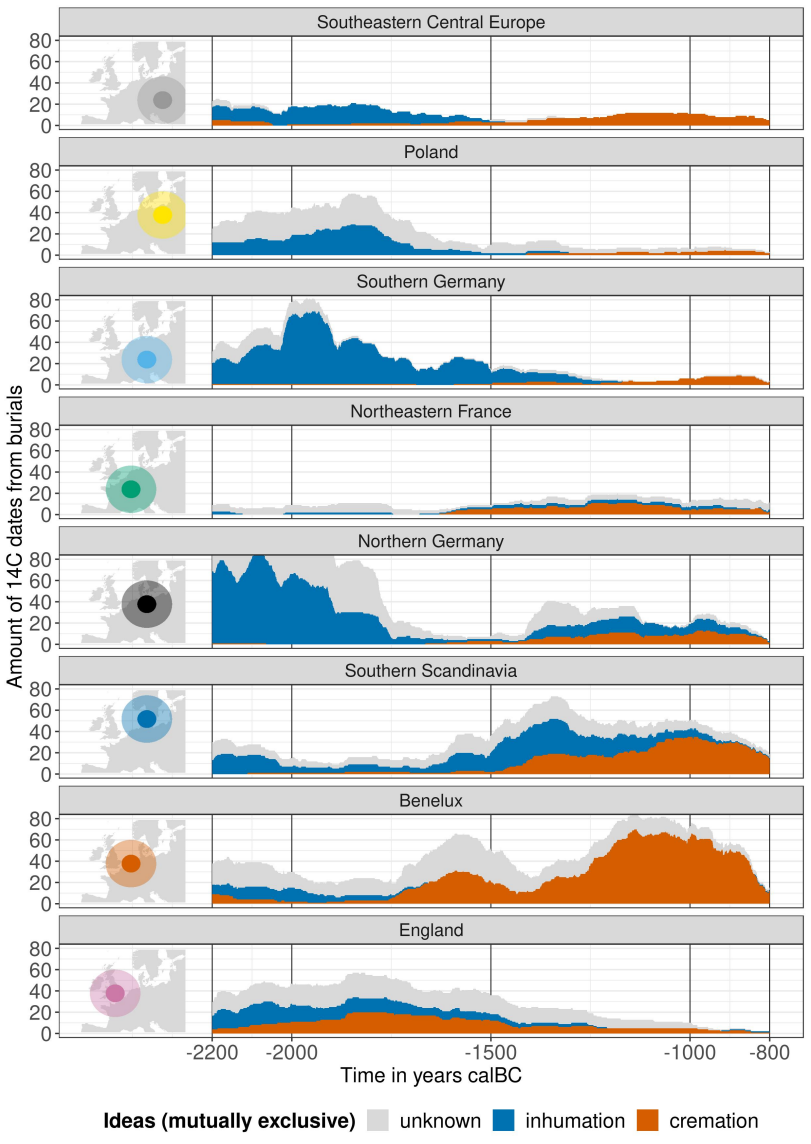


Figure 3: burial type development: Sum of ^{14}C dates whose 2σ range cover the respective year.

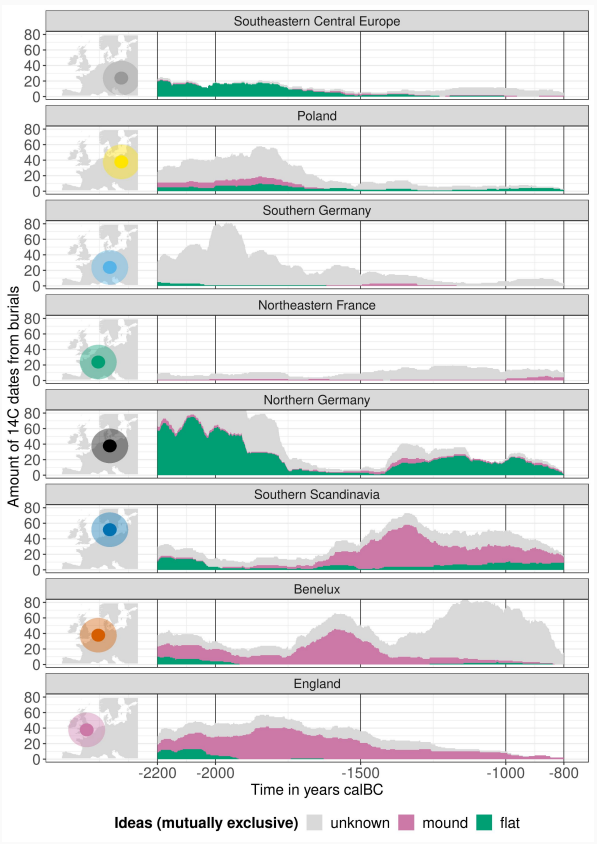


Figure 4: burial construction

Data structure transformation: Individual ^{14}C dates to region wise **time series** of burial rite **presence**

Development – Proportions

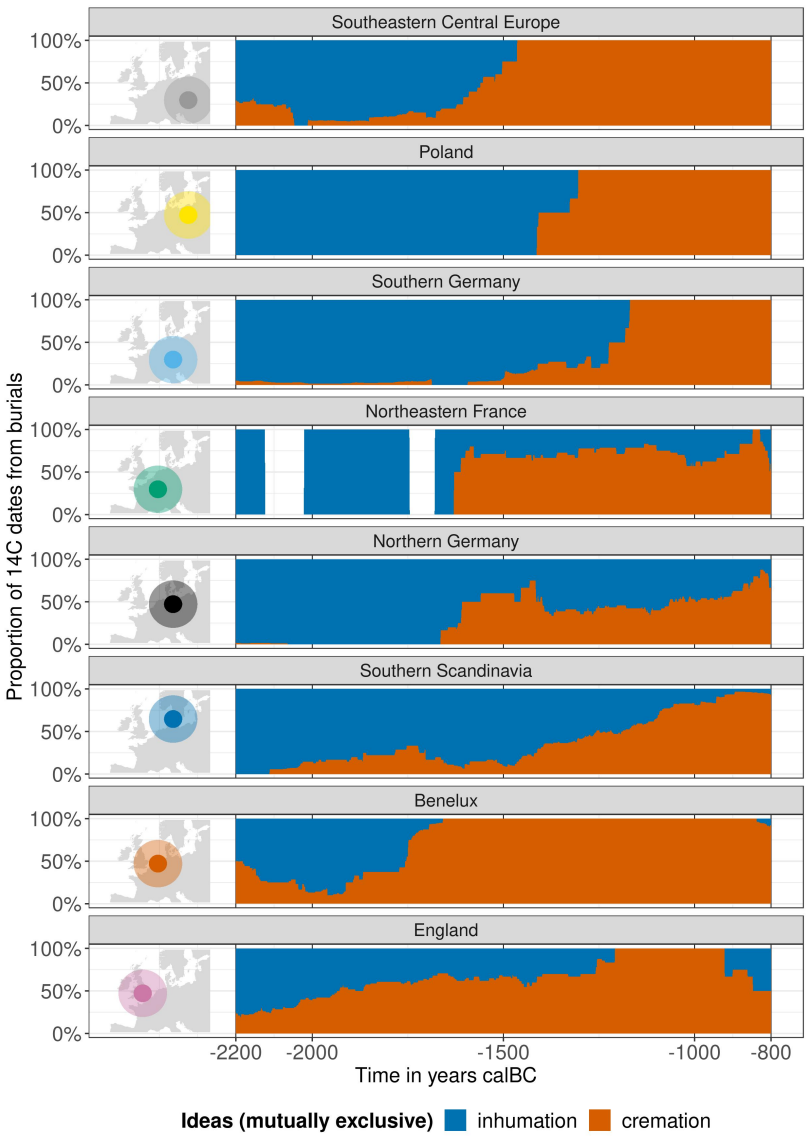


Figure 5: burial type development: Year wise proportions of dates. *unknown* is filtered out.

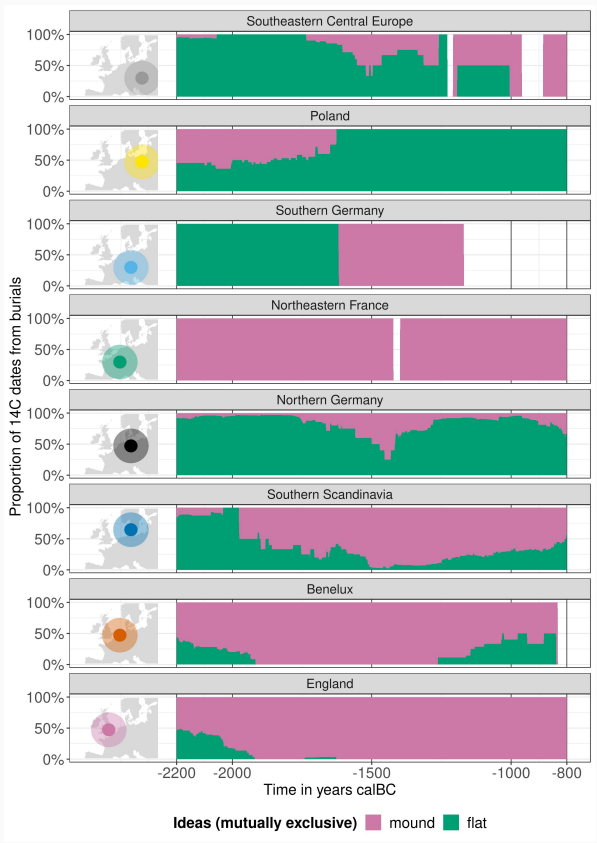


Figure 6: burial construction

Data structure transformation:
Time series of absolute appearances to **time series** of burial rite **proportions - burial rite proxy**

Cultural Distance

Squared Euclidian Distance (SED)

Question: How do the developments in these regions for **burial type** and **burial construction** relate to each other? Which regions behave alike?

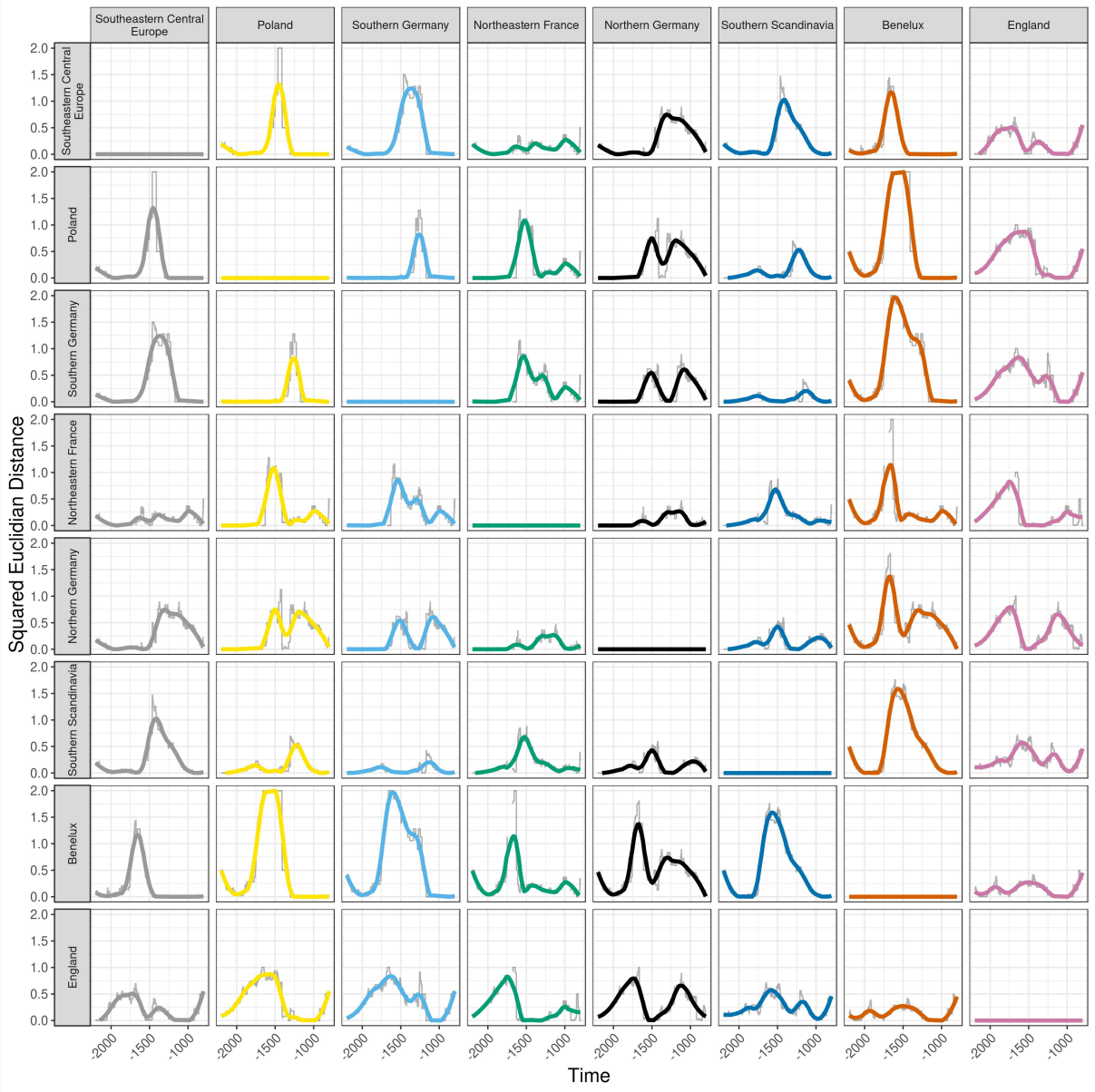
The **Squared Euclidian Distance** is a a simple **measure of between-group similarity** that can be applied to the **burial rite proxy** data.

$$d_{ij}^2 = \sum_{k=1}^{n} (p_{ik} - p_{jk})^2$$

- d_{ij}^2: Squared Euclidean Distance between two groups i and j
- k: Variant counter
- n: Total amount of variants in a population
- p_{ik}: Relative frequency of the k'th variant in population i
- p_{jk}: Relative frequency of the k'th variant in population j

Region-Region Distance Matrix

The **SED** can be calculated for every year of every one of the $8 * 8 = 64$ region relationships



Low distance at the start and end due to the **universal shift from inhumation to cremation** with rise of the **Urnfield culture**

The different **adoption rates** are visible as **peaks of cultural distance**

Figure 7: burial type: SED for each region relationship. Approximated with LOESS.

Parallel Developments?

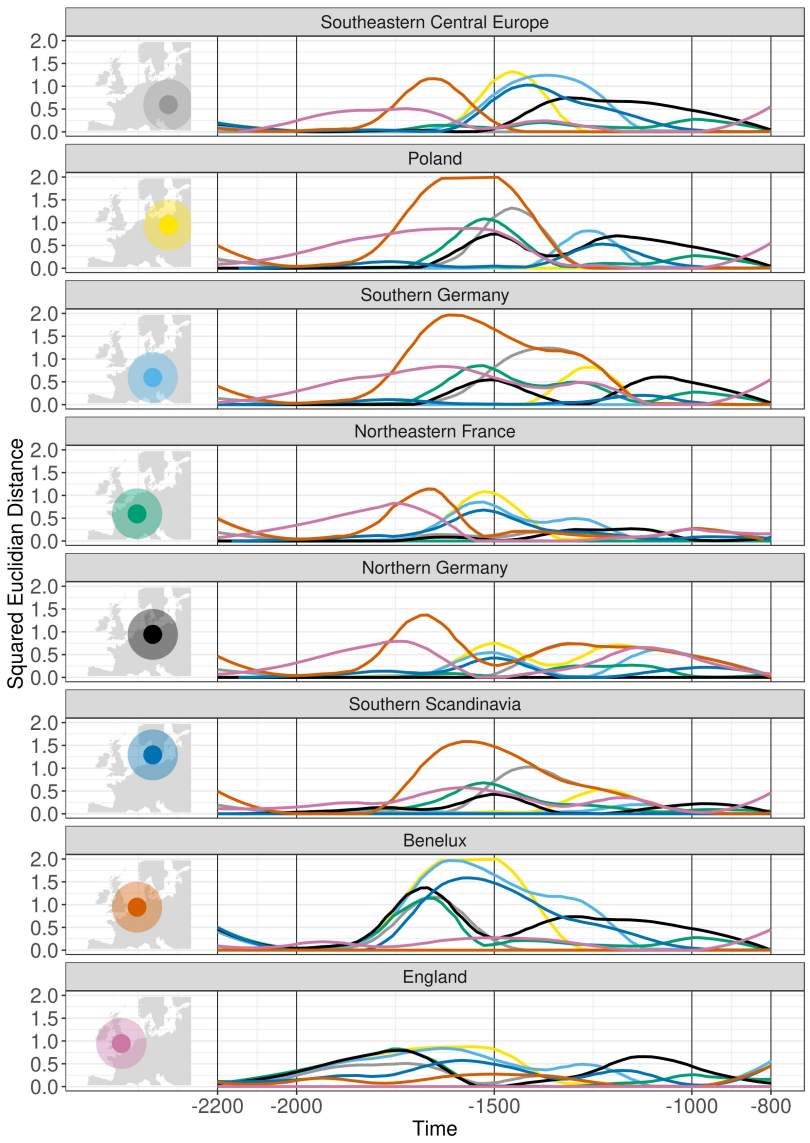


Figure 8: burial type Development of SED to all the others for each region.

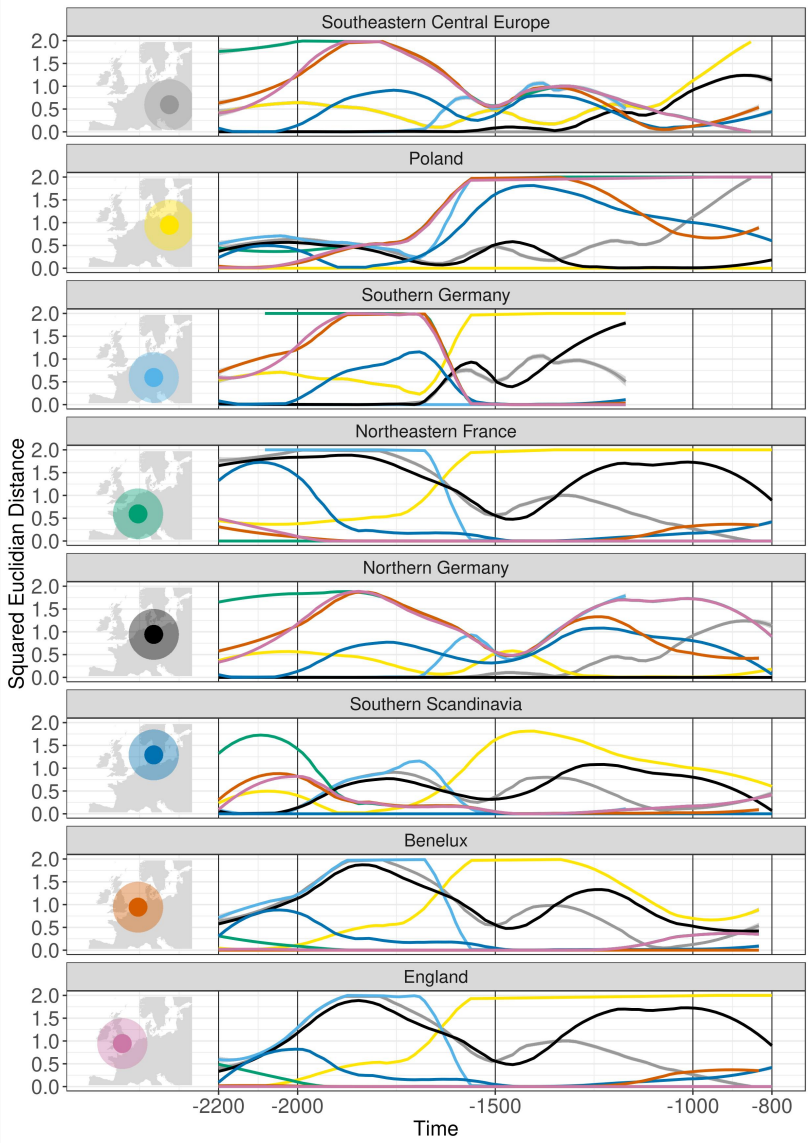
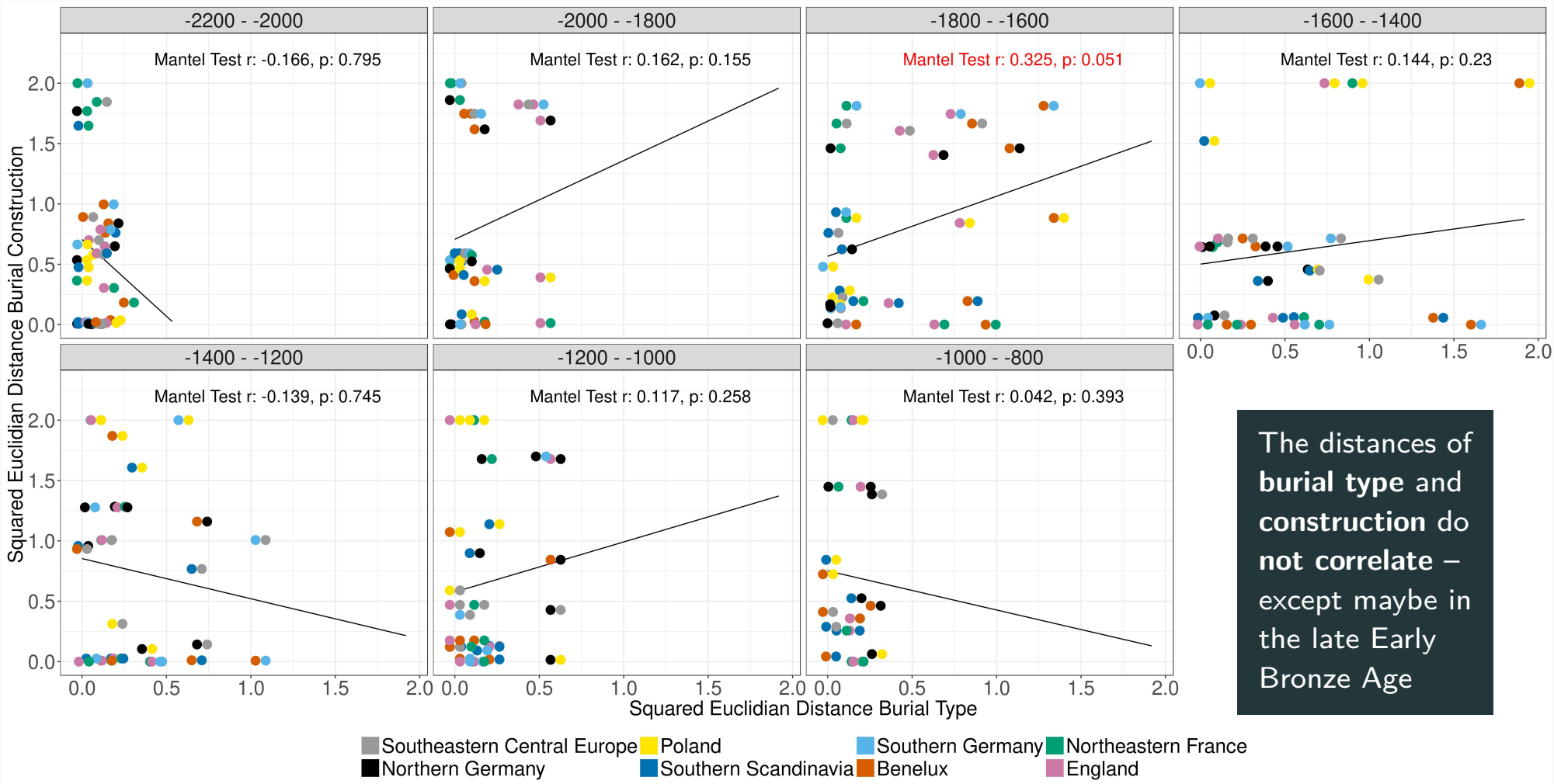


Figure 9: burial construction

Correlation of Burial Type and Burial Construction Distance



The distances of **burial type** and **construction** do **not correlate** – except maybe in the late Early Bronze Age

Figure 10: Correlation of **burial type** and **burial construction** mean SED in time slices of 200 years. Each double point represents one region-region relationship.

Cultural and Spatial Distance

Spatial Distance Classes

The definition of artificial regions as units of analysis makes distance measures difficult. **Ordinally scaled distance classes** are the only valid option here.

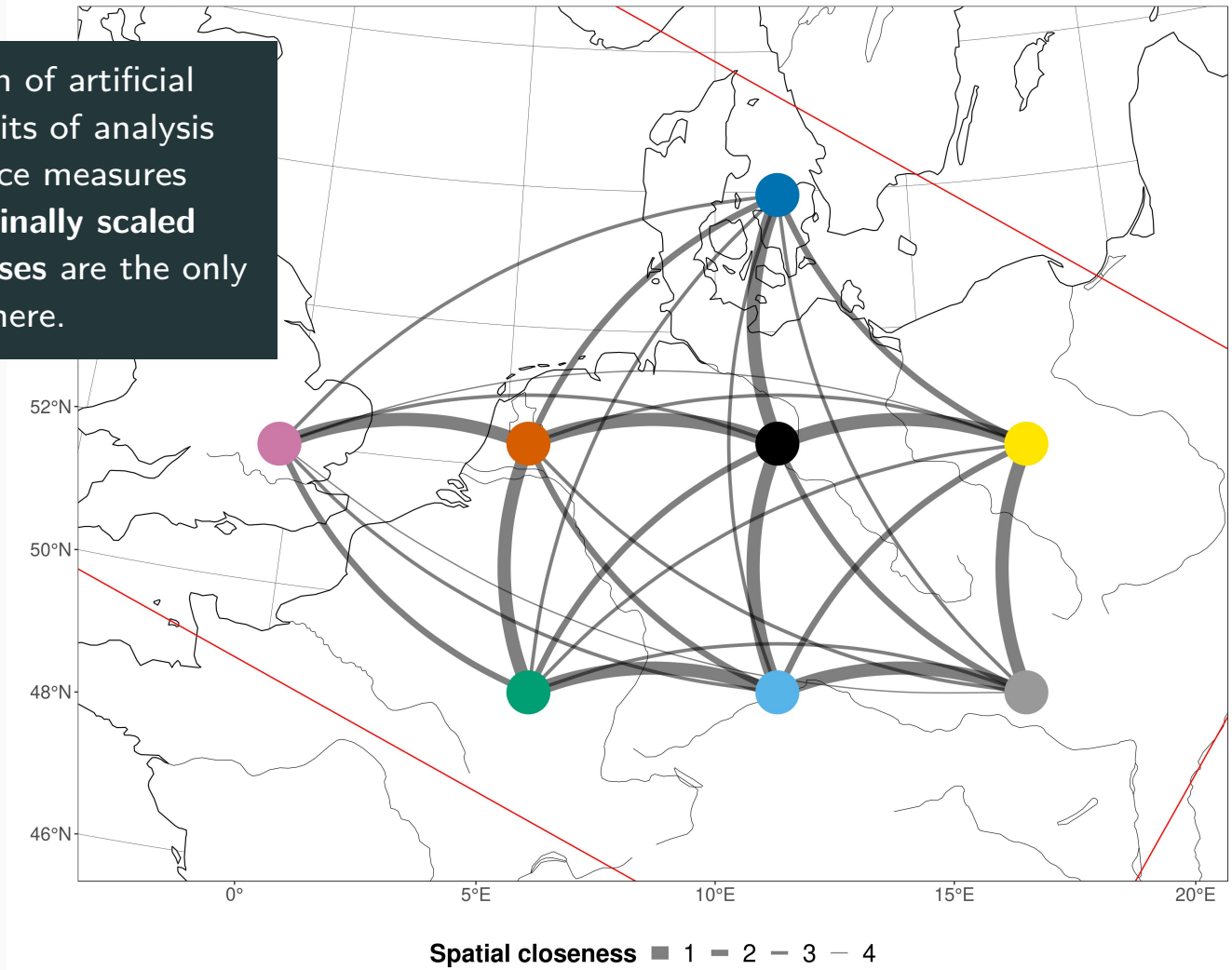
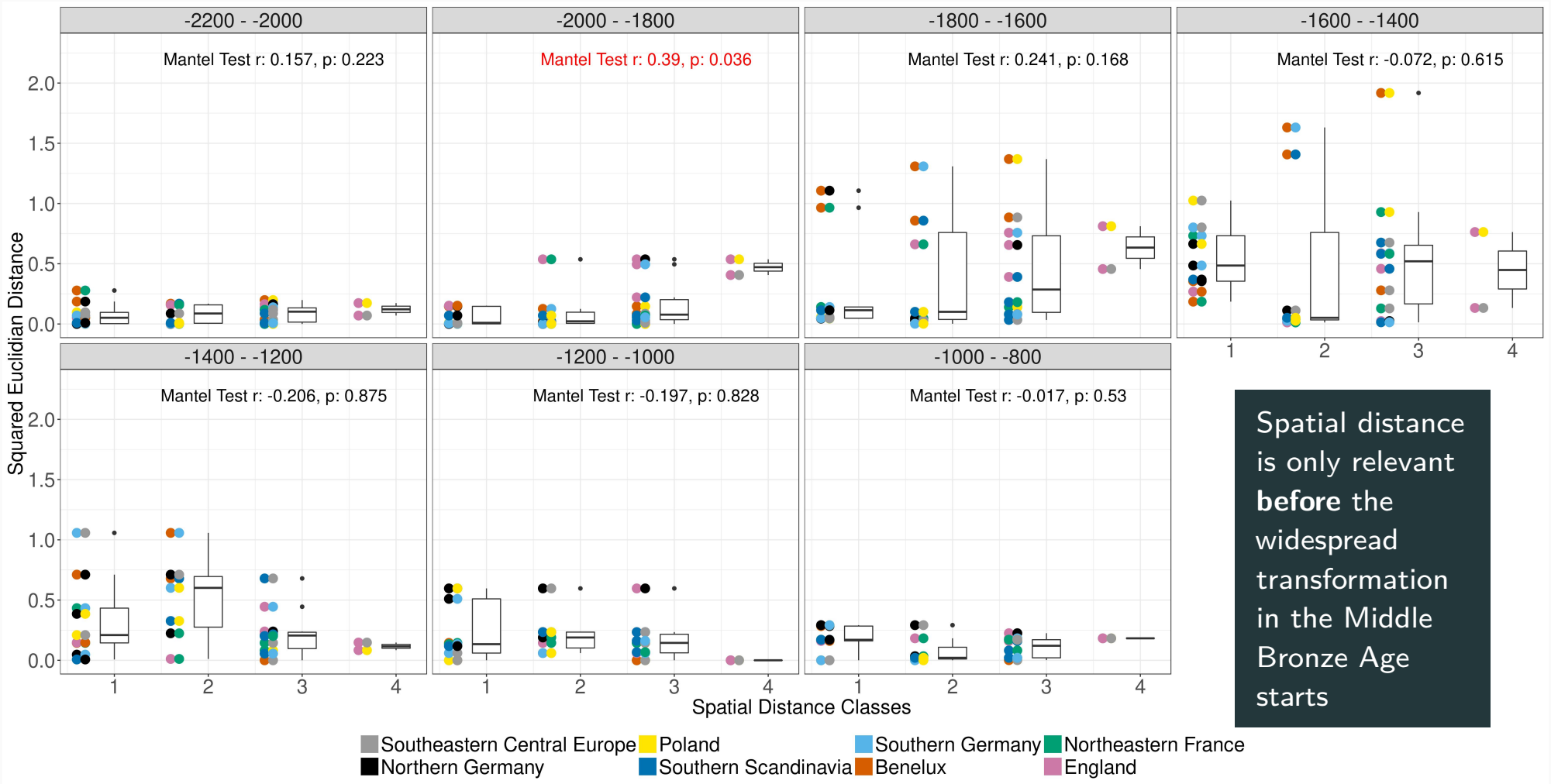


Figure 11: Spatial distance network and definition of distance classes

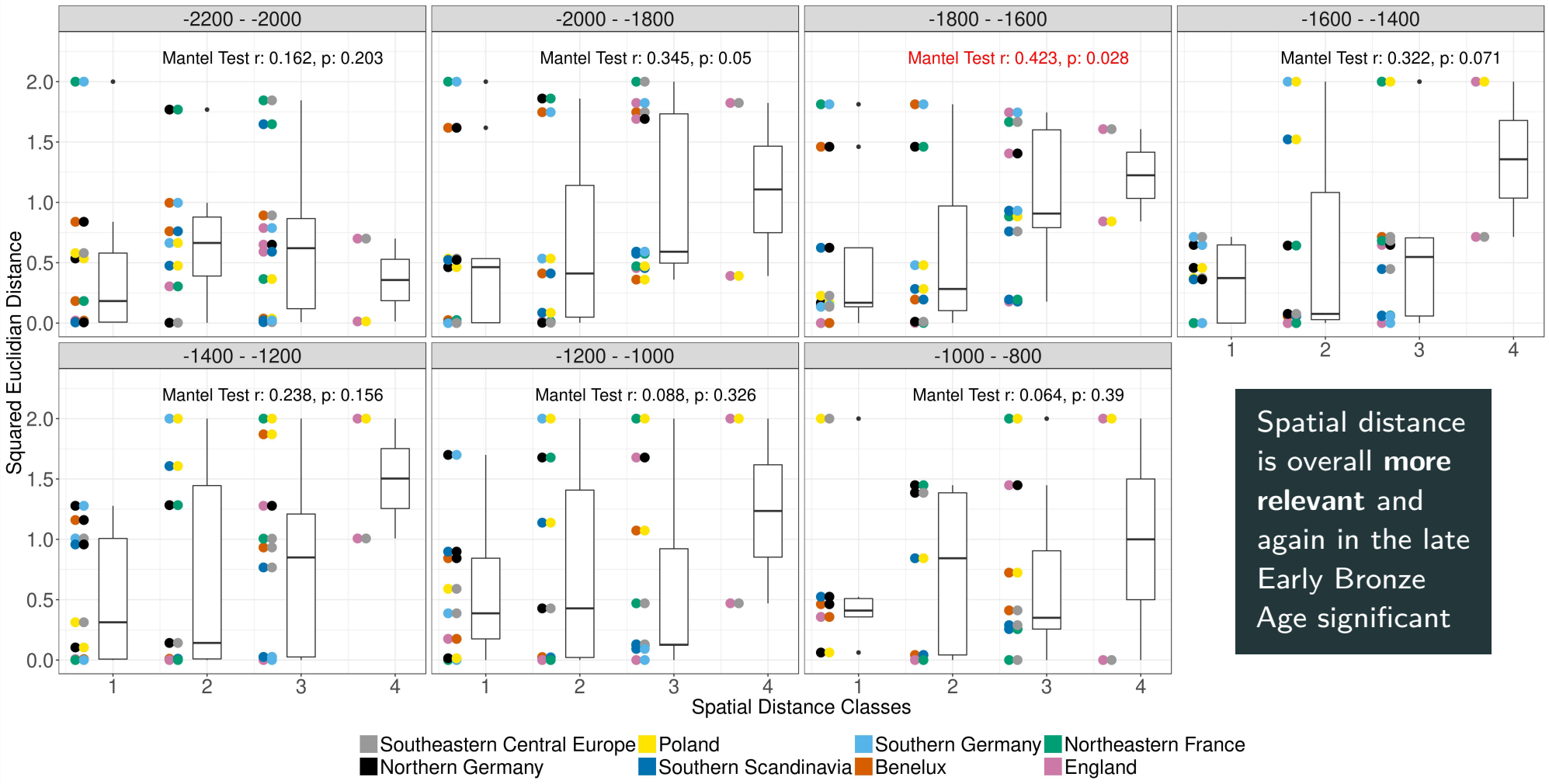
Correlation of Burial Type and Spatial Distance



Spatial distance is only relevant **before** the widespread transformation in the Middle Bronze Age starts

Figure 12: burial type: Correlation of mean SED and spatial distance in timeslices of 200 years.

Correlation of burial construction and spatial distance



Spatial distance is overall **more relevant** and again in the late Early Bronze Age significant

Figure 13: burial construction: Correlation of mean SED and spatial distance in timeslices of 200 years.

Simulation

Preliminary Considerations

Funeral rituals are **behaviour/ideas/cultural traits** and spread in space and time. They exist in **social space** and their spread depends on social relationships.

Simulation concept:

- Ideas are **entities** with simple behaviour: **greedy expansion**
- Ideas life in a configurable, diachronic **population network**

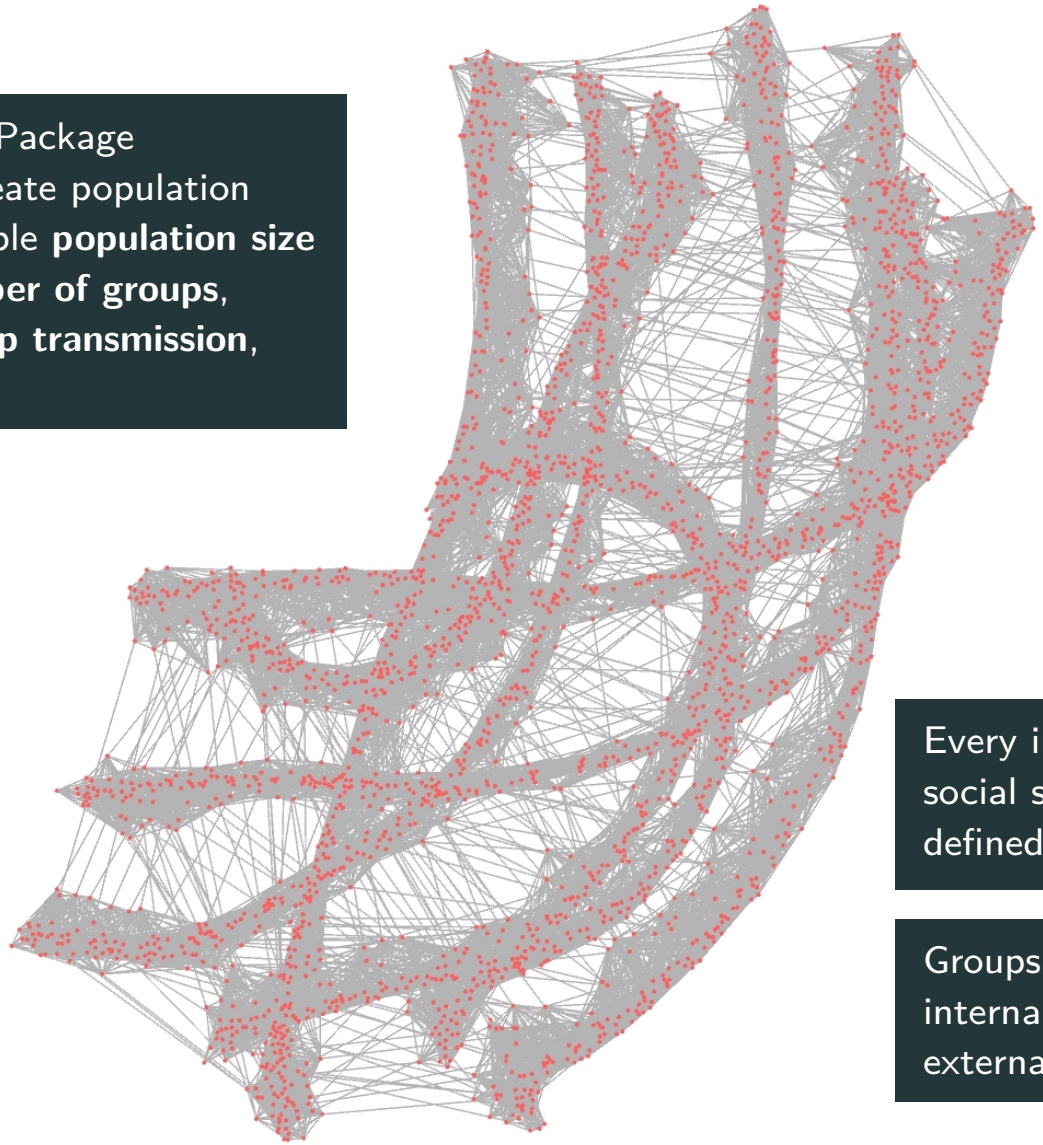
Funeral rituals are a special category of ideas: They have a relatively low interaction with the human-environment system and can be treated as **selectively neutral**. [Dunnell 1978]

The main mechanisms of diffusion of neutral variants are **innovation**, **drift** and **flow**. [Neiman 1995]

- **Drift:** Dominance of individual traits due to stochastic processes
- **Flow:** Information transfer and synchronization across group boundaries

Population Graph Creation

Implementation: R Package **popgenerator** to create population networks with variable **population size development**, **number of groups**, **degree of intergroup transmission**, etc.



Every individual's position in social space and time is defined by their connections

Groups have a high degree of internal and a low degree of external interaction

Figure 14: Example Population Graph. Arranged with the Fruchterman & Reingold algorithm.

Idea Expansion Simulation

```
...
// make random decision to convert or ignore a node based on the edge weight
  std::vector<std::pair<int, bool>> success_per_neighbor(neighbors.size());
  for (auto& i : all_neighbors_information) {
    // make decision
    // if the node is already occupied, it's more difficult
    // if more than one contact, then there's a convincing bonus
    std::pair<int, bool> success;
    if (std::get<3>(i)) {
      success = std::make_pair(
        std::get<0>(i),
        std::get<1>(i) * log2(std::get<2>(i) + 1) >= randunifrange(75, 100)
      );
    } else {
      success = std::make_pair(
        std::get<0>(i),
        std::get<1>(i) * log2(std::get<2>(i) + 1) >= randunifrange(0, 100)
      );
    }
    success_per_neighbor.push_back(success);
  }
...
```

Implementation: C++ CLI program **gluesless** to simulate idea expansion within the population network

Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation of spatial and cultural distance still plausible?

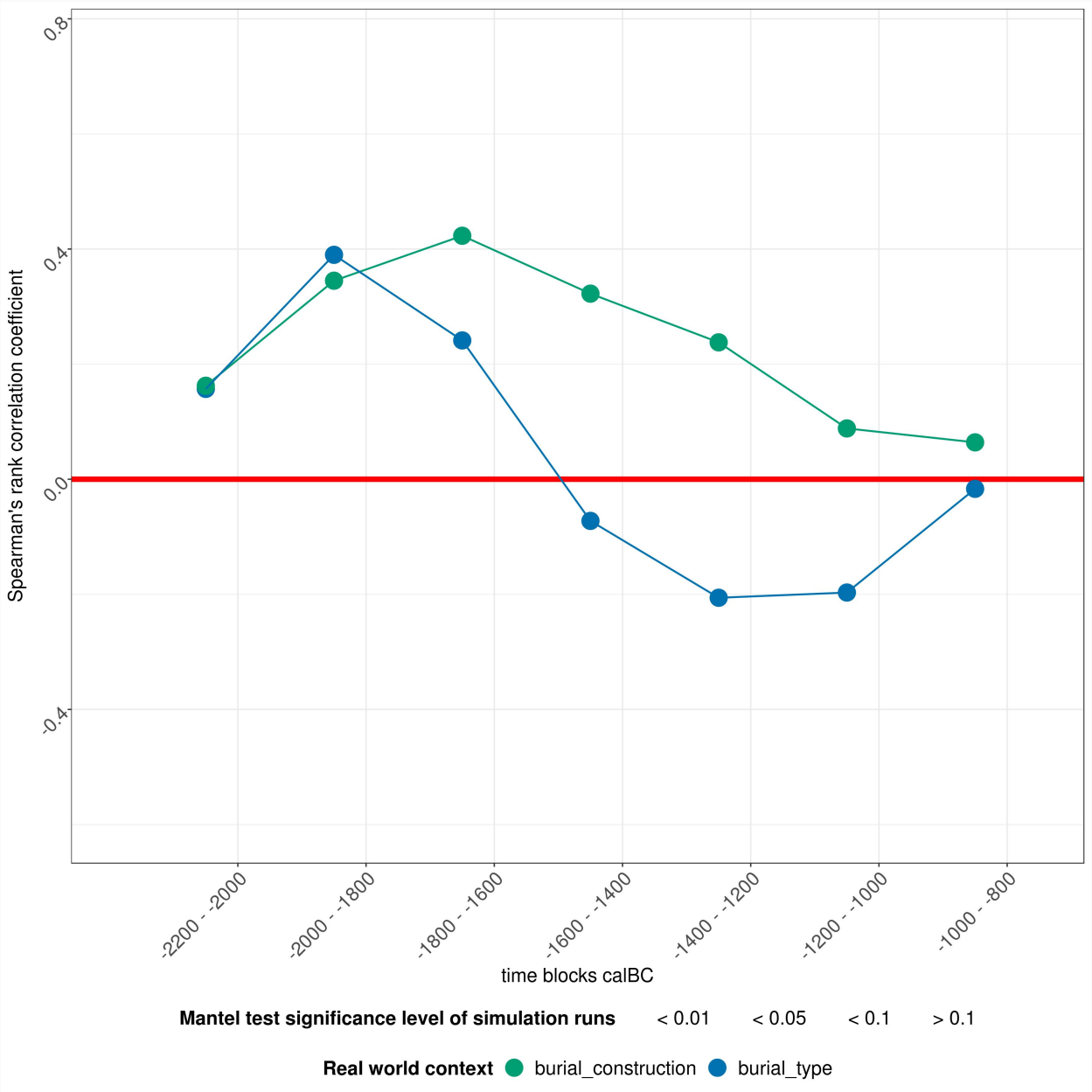


Figure 15: Correlation of cultural and spatial distance over time for **real world observations**.

Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation of spatial and cultural distance still plausible?

Simulation results in comparison with real world data

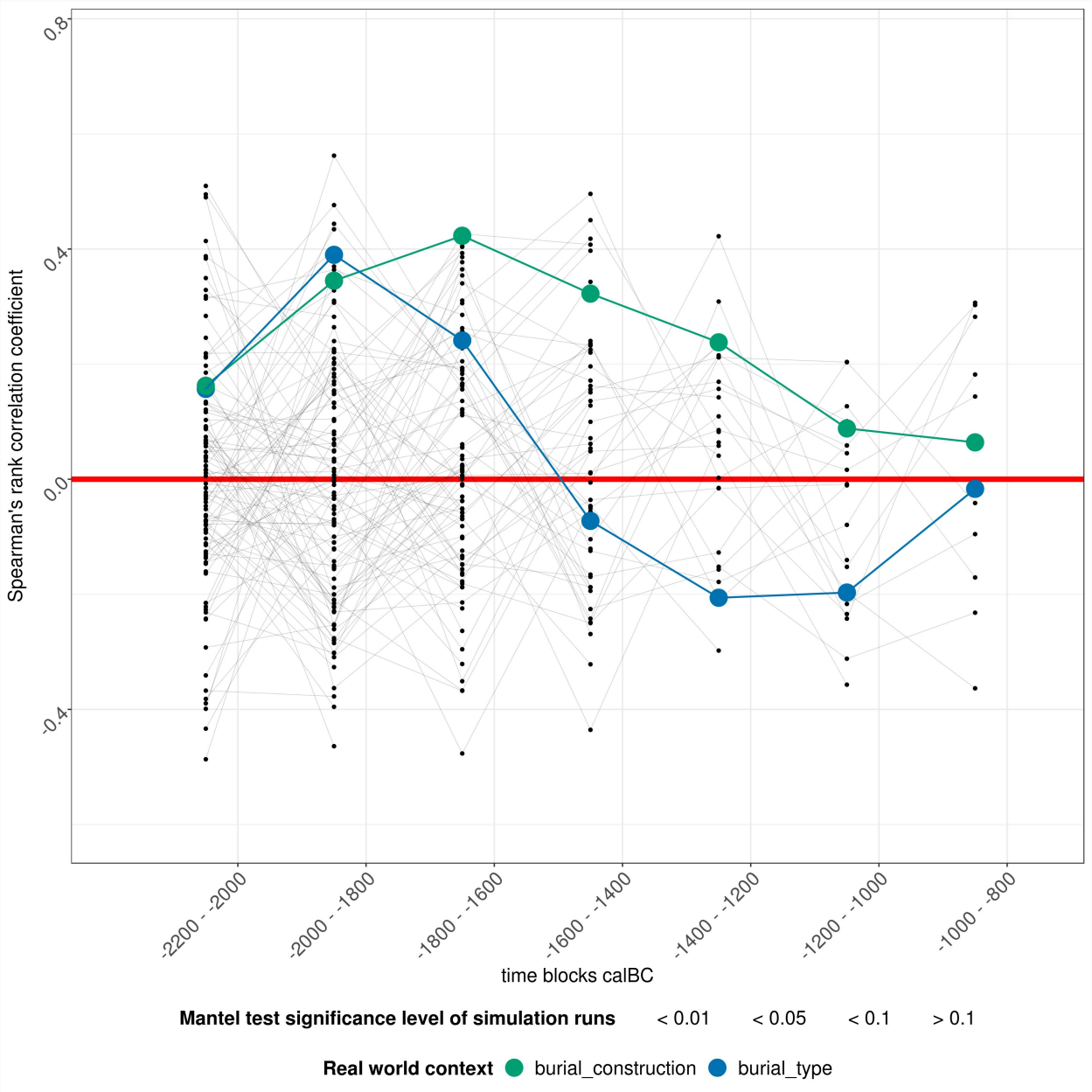


Figure 16: + Correlation development for **100 simulation runs** with **equal intergroup distance**.

Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation of spatial and cultural distance still plausible?

Simulation results in comparison with real world data

The real world correlation is mostly within the spectrum of equal intergroup distance simulations

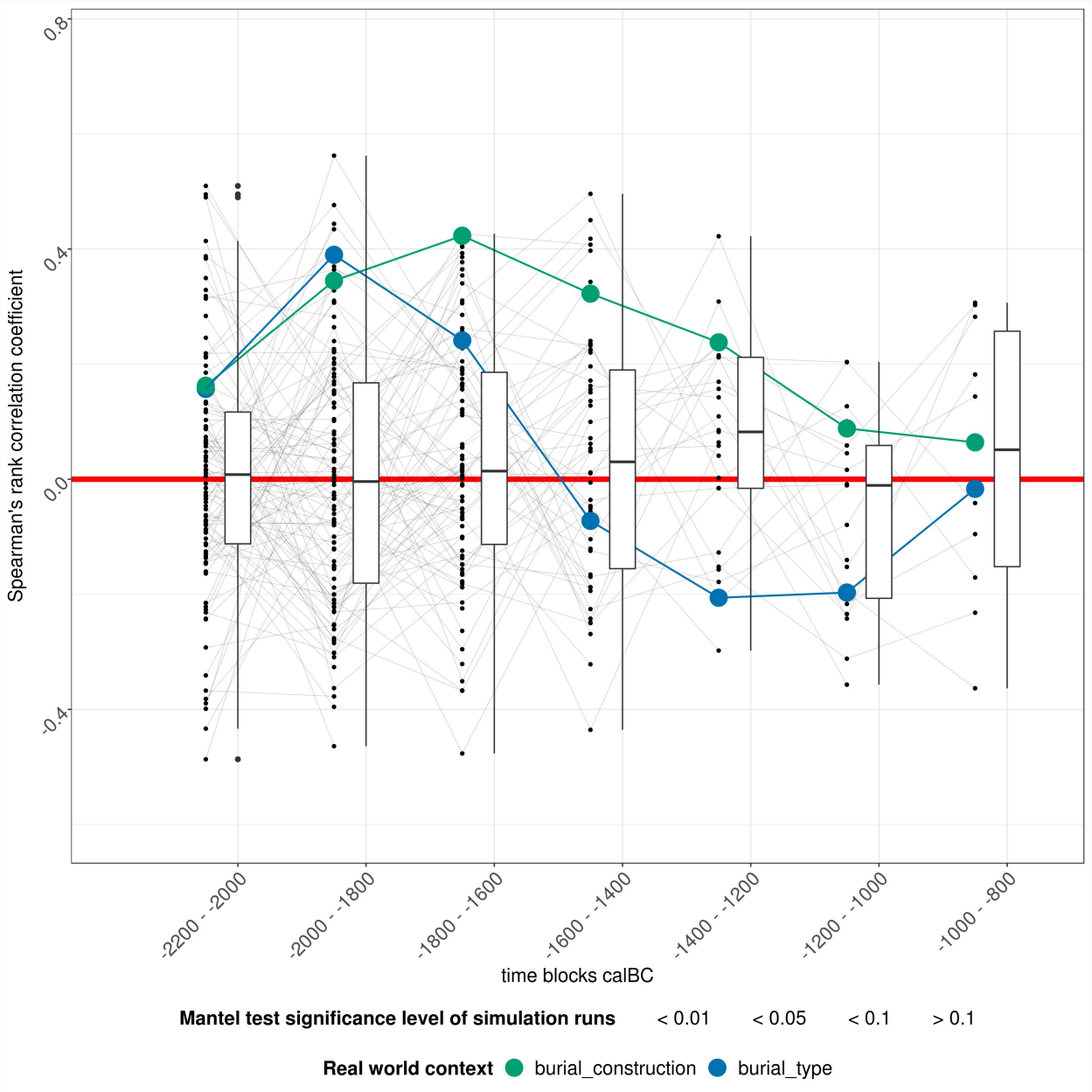


Figure 17: + Diagnostic **boxplots** for simulation runs.

Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation of spatial and cultural distance still plausible?

Simulation results in comparison with real world data

The real world correlation is mostly within the spectrum of equal intergroup distance simulations

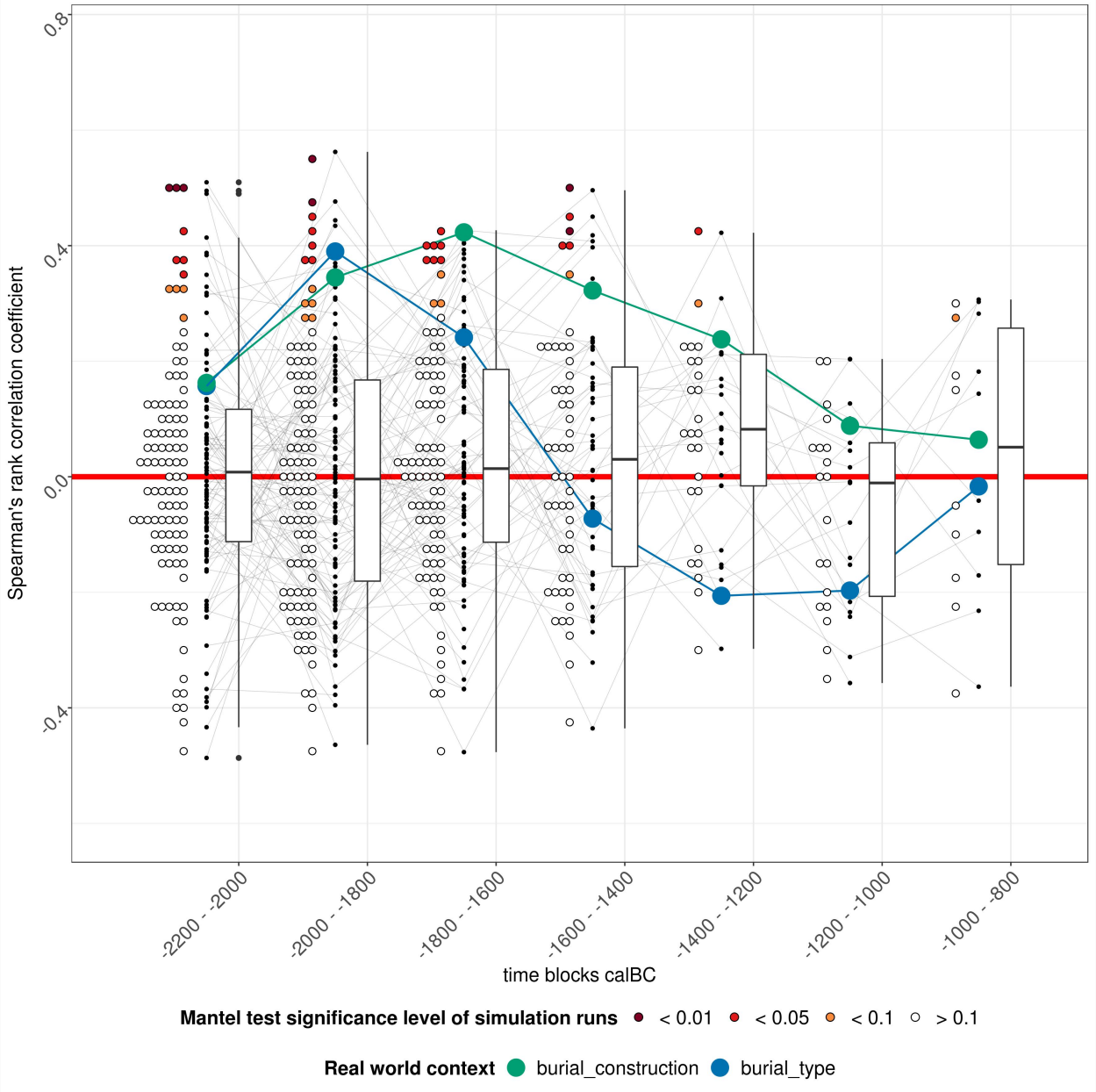


Figure 18: + Diagnostic **dotplots** indicating mantel test results.

Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation of spatial and cultural distance still plausible?

Simulation results in comparison with real world data

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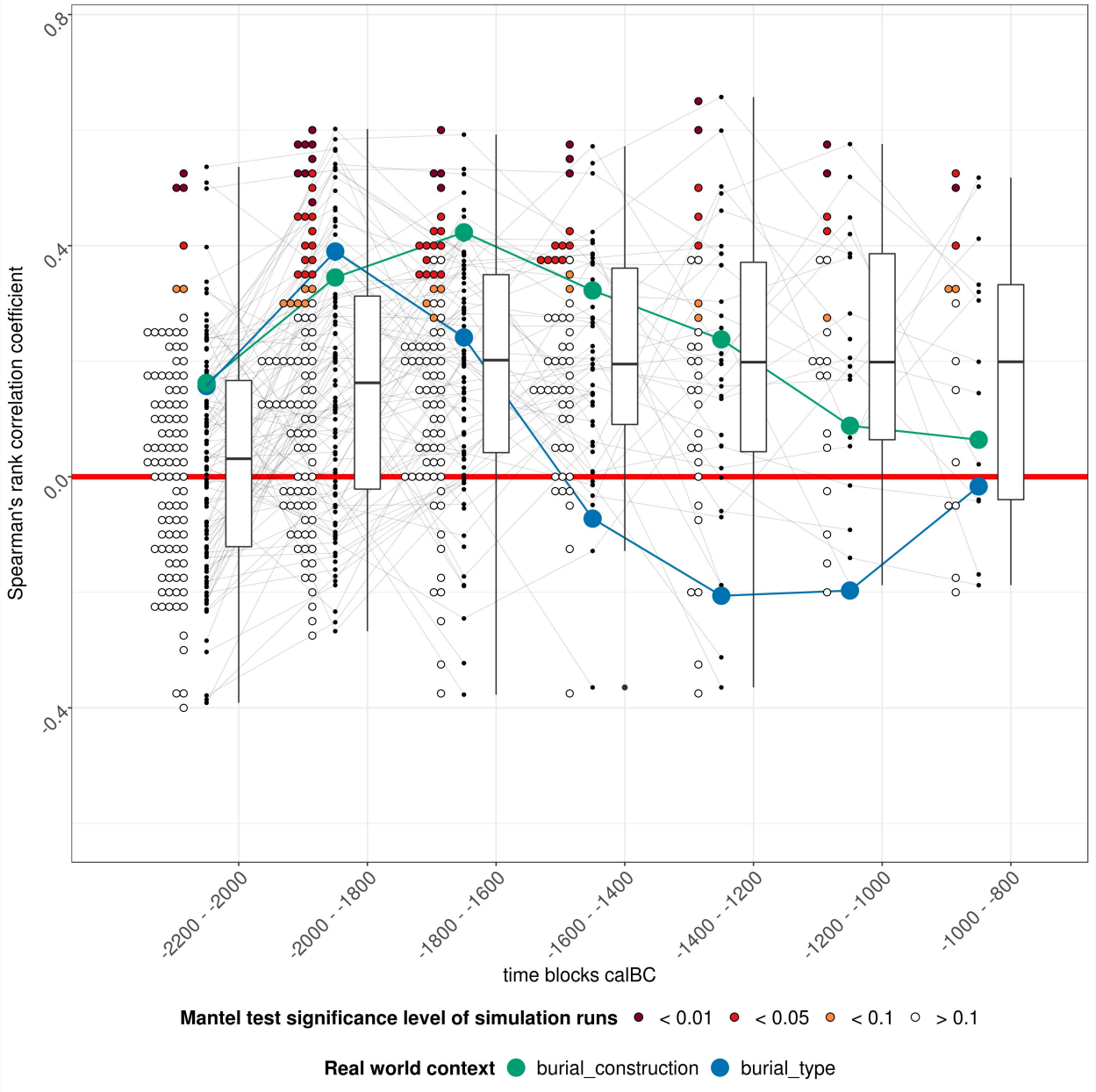


Spatial intergroup distance in the population graph increases correlation

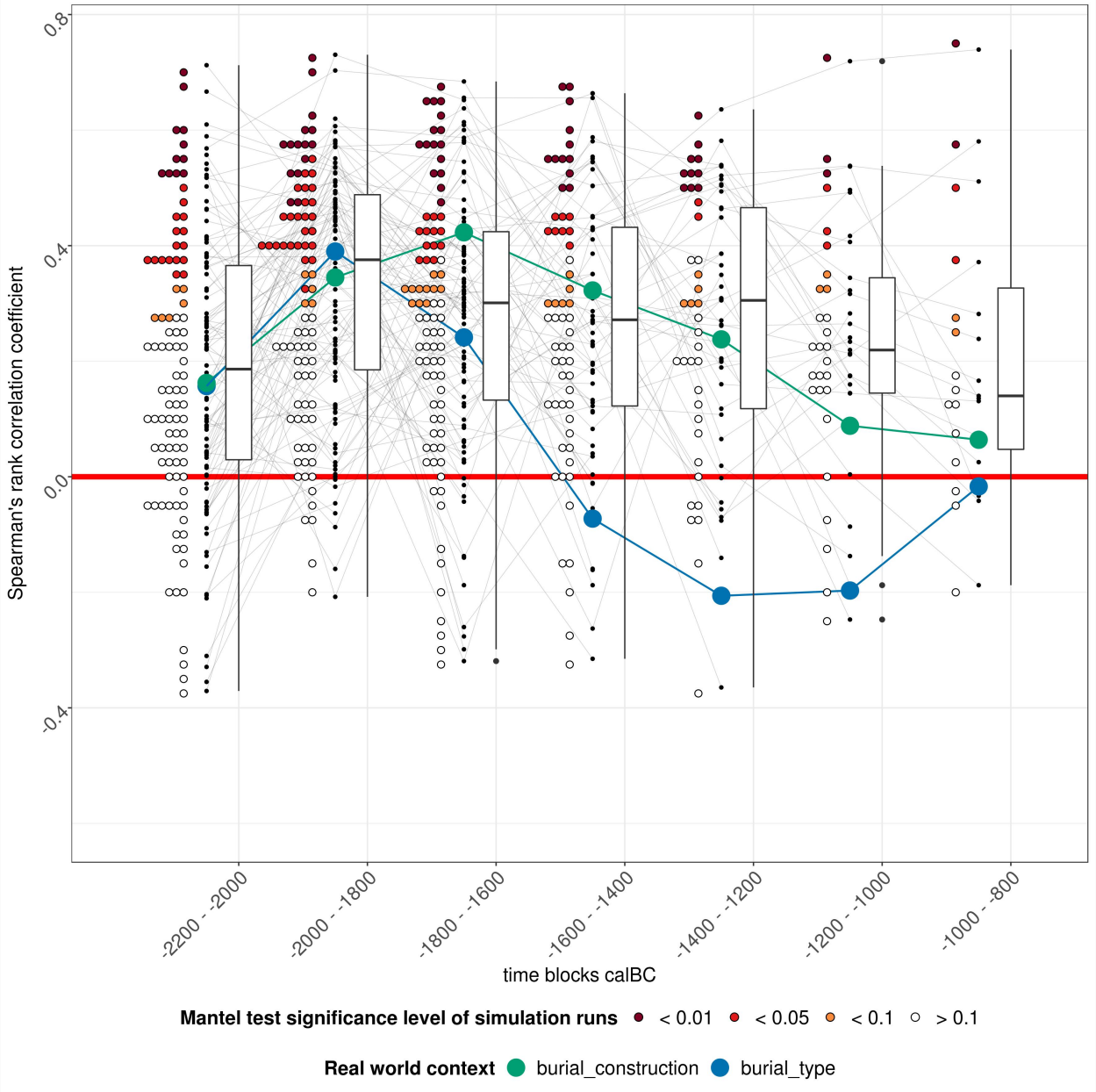
Figure 19: Same plot, but simulations now with low **spatial intergroup distance**.

Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation of spatial and cultural distance still plausible?

Simulation results in comparison with real world data

The real world correlation is mostly within the spectrum of equal intergroup distance simulations



Spatial intergroup distance in the population graph increases correlation

Generally more interaction increases correlation

Compared to simulation results the expansion of cremation behaves highly atypical if we assume spatial correlation

Figure 20: Same plot, but simulations now with **high** spatial intergroup distance.

Conclusion

Observations and Hypotheses

- The diffusion of the cremation funeral tradition and traditions of flat vs. mound graves are mostly **independent**, except for a short period in the late Early Bronze Age.
- Both contexts are to a certain degree correlated to **spatial distance** in the Early Bronze Age, but become **increasingly unpredictable** in the Middle Bronze Age.
- Both contexts can both be explained by **neutral variant drift and flow** on a large scale. Local innovation might not have been necessary.
- **Sociocultural complexity** in the Bronze Age is generally **increasing**. Still the **homogeneity & heterogeneity** of certain cultural traits **vary greatly**.