Quantitative analysis of cultural trait development

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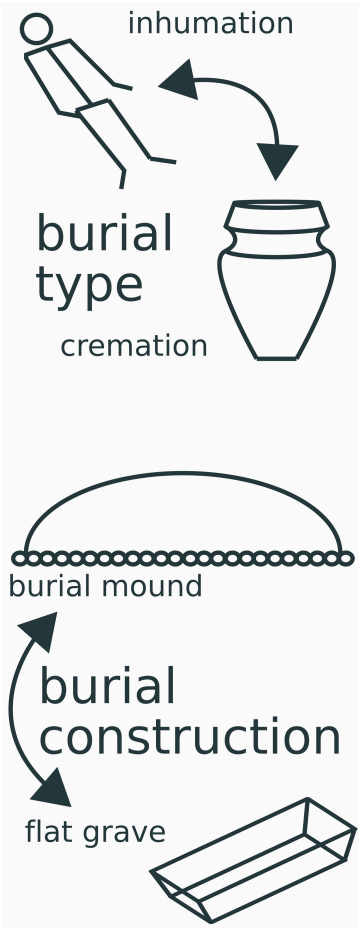
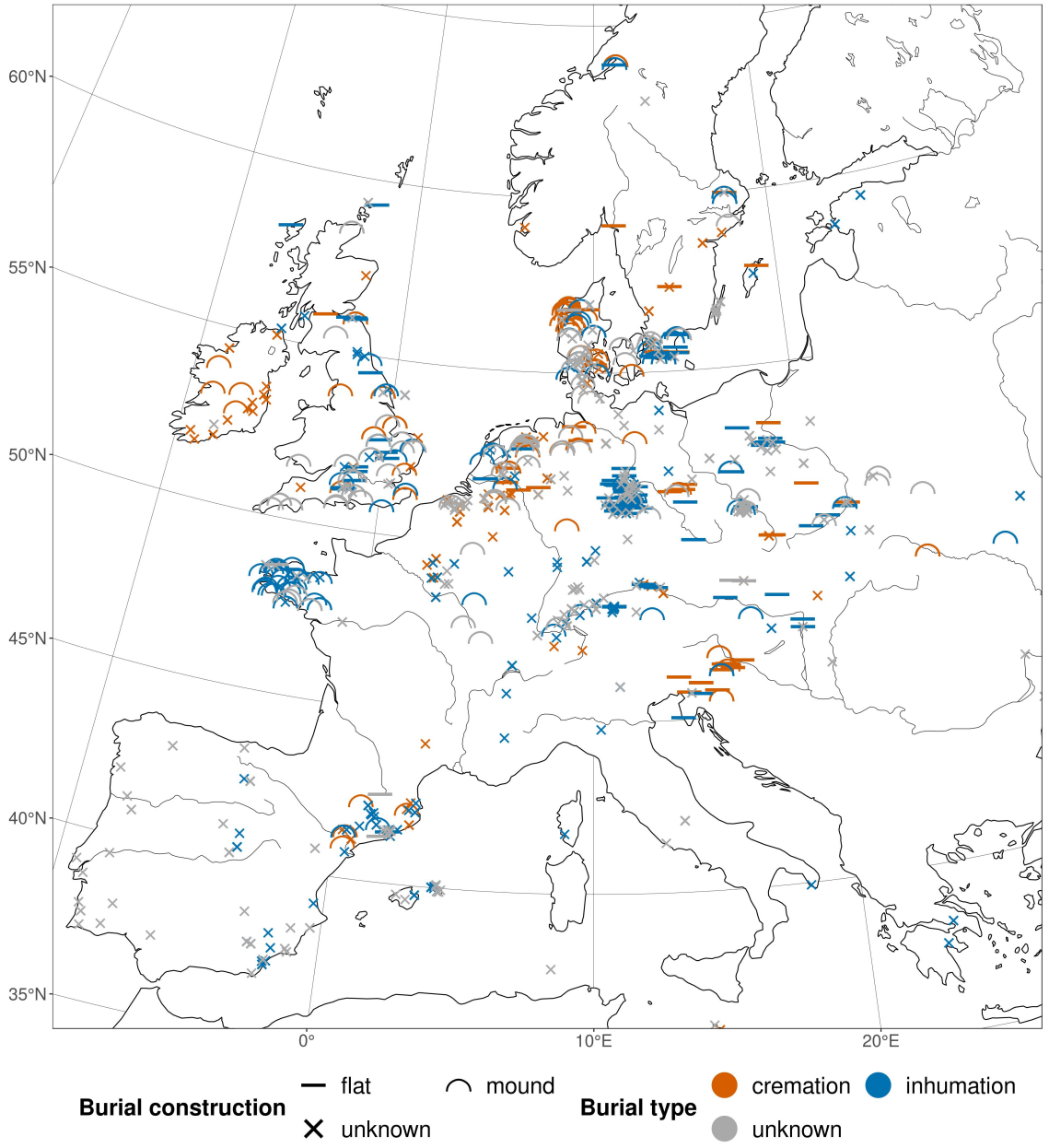
TOC

Introduction

Radiocarbon dates on graves





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

^{14}C dating is an important absolute dating method: One date equals a **fuzzy point in space and time with context information**

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

Dates on Graves through Time

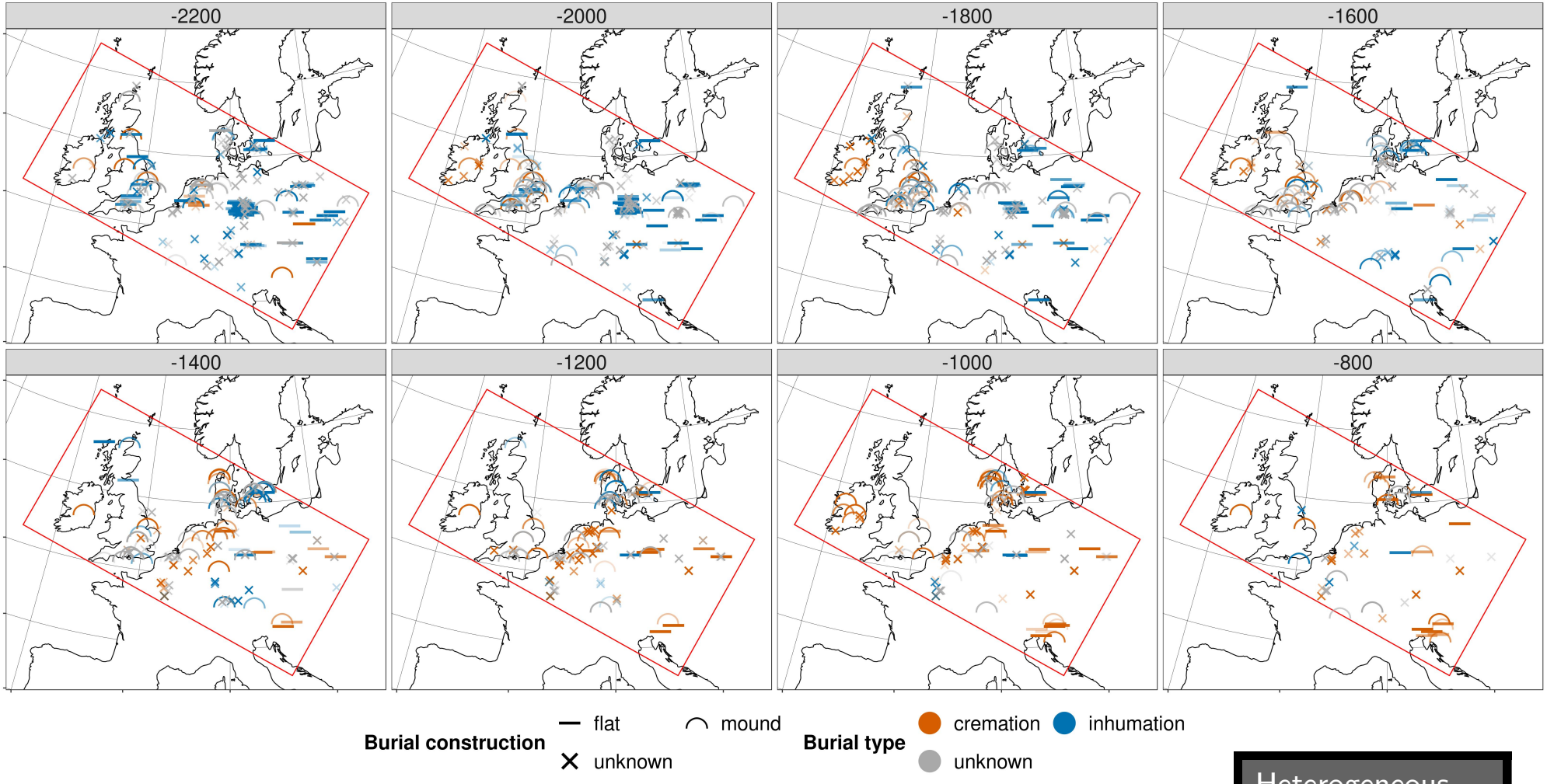


Figure 2: Plot matrix of radiocarbon dates on graves through time. 200 years time slices.

Heterogeneous **information density** in space and time

Artificial Macro-Regions

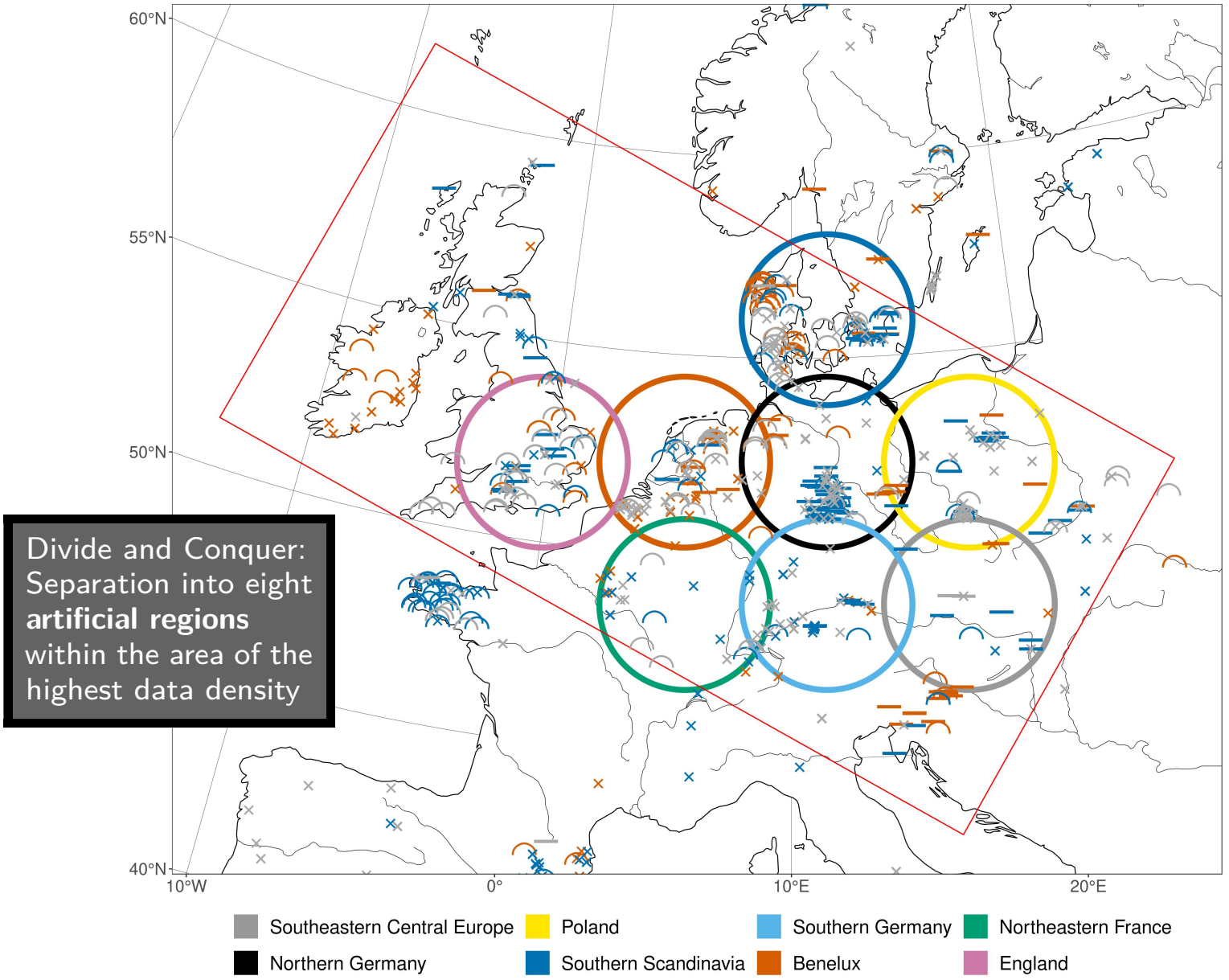


Figure 3: Artificial Regions: 400km distance, 240km radius, >= 70 dates.

Development – Absolute Numbers

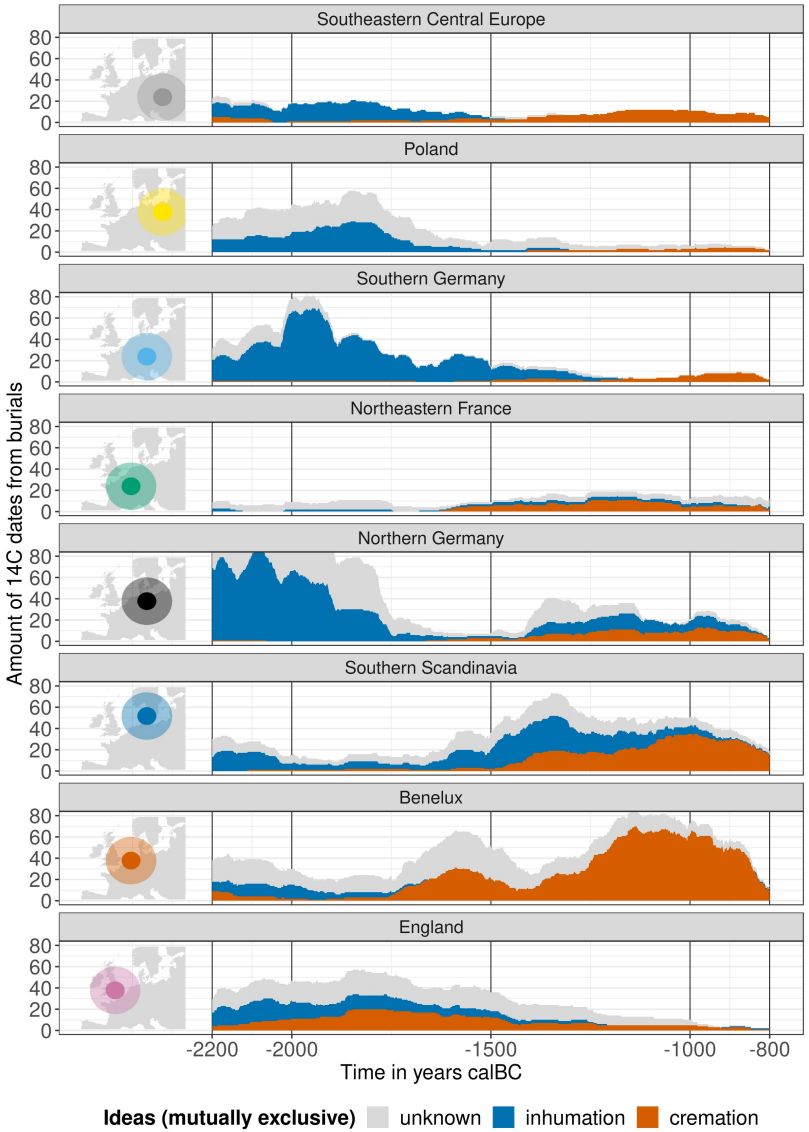


Figure 4: **burial type** development: Sum of ^{14}C dates whose 2σ range cover the respective year.

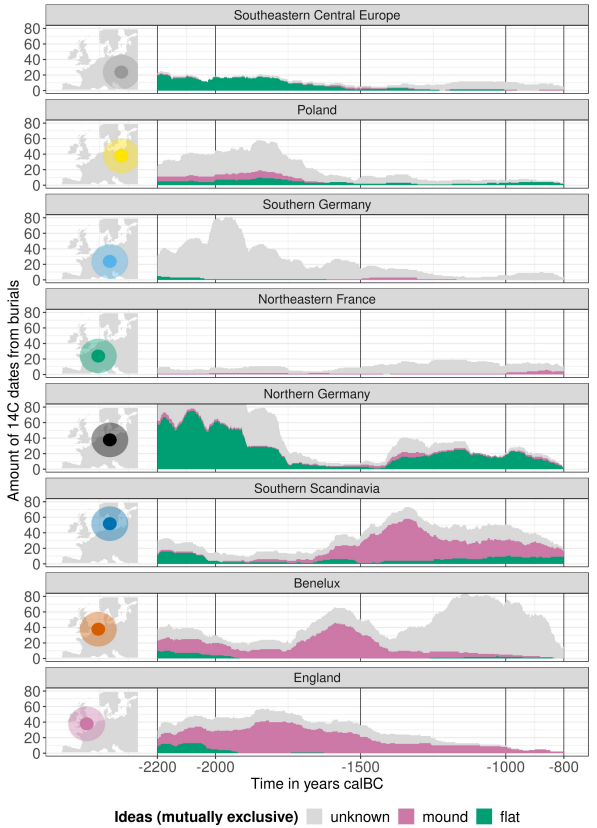


Figure 5: **burial construction**

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

Development – Proportions

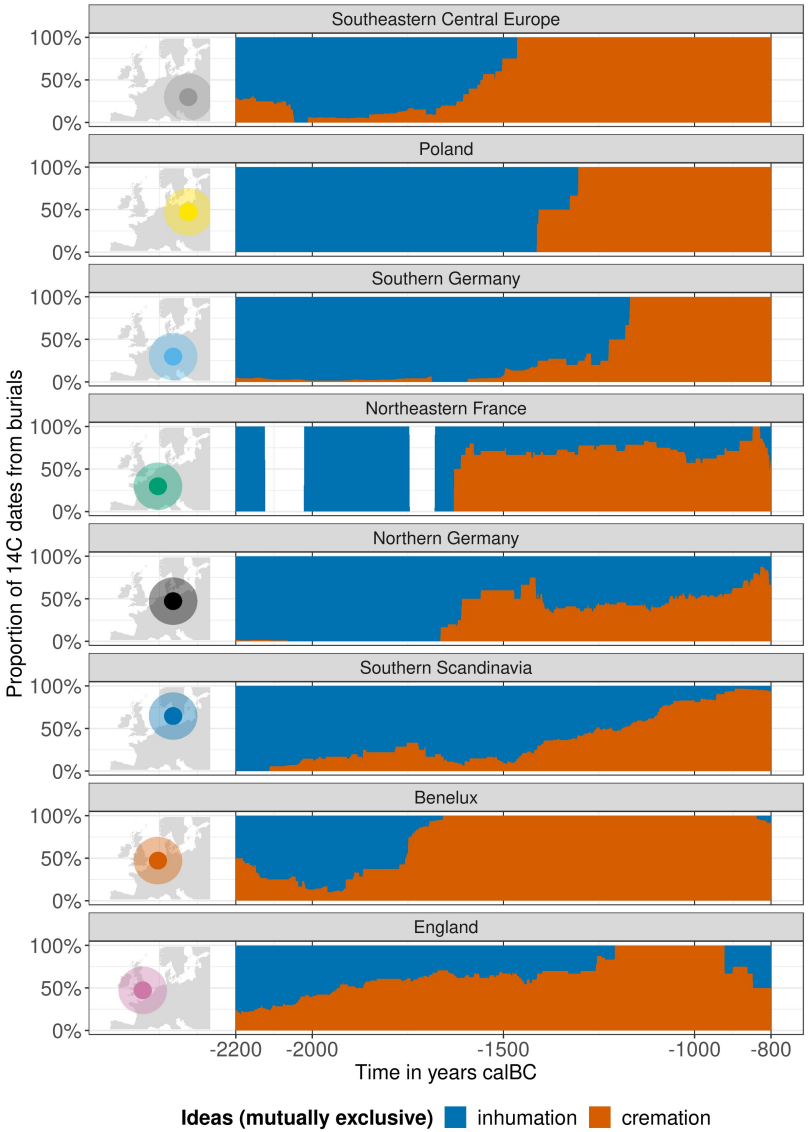


Figure 6: **burial type** development: Year wise proportions of dates. *unknown* is filtered out.

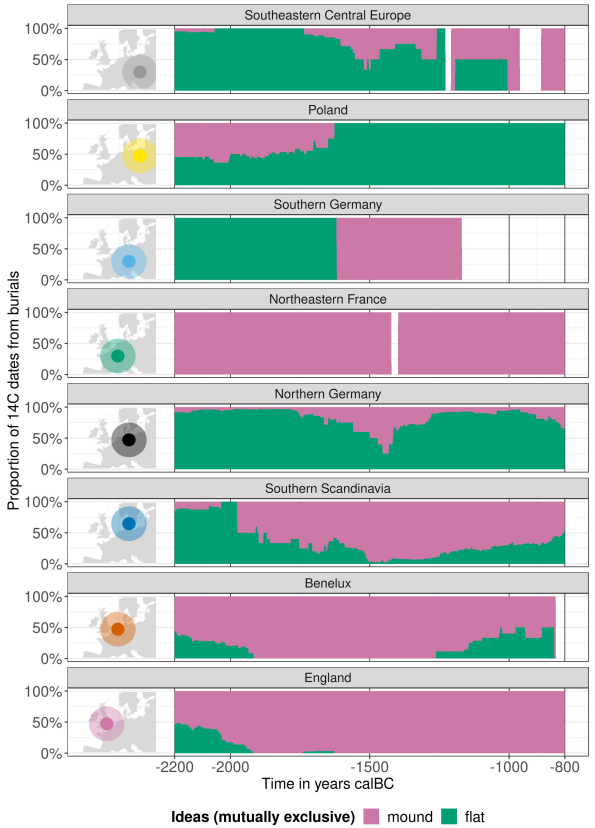


Figure 7: **burial construction**

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

Cultural Distance

Measuring cultural distance

How do the developments in these regions for **burial type** and **burial construction** relate to each other? Which regions behave alike? Can we measure spatial **interaction intensity**?

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

burial type: Low distance at the start and end due to the **universal shift from inhumation to cremation** (Urnfield culture)

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

burial construction: Heterogeneous distance development

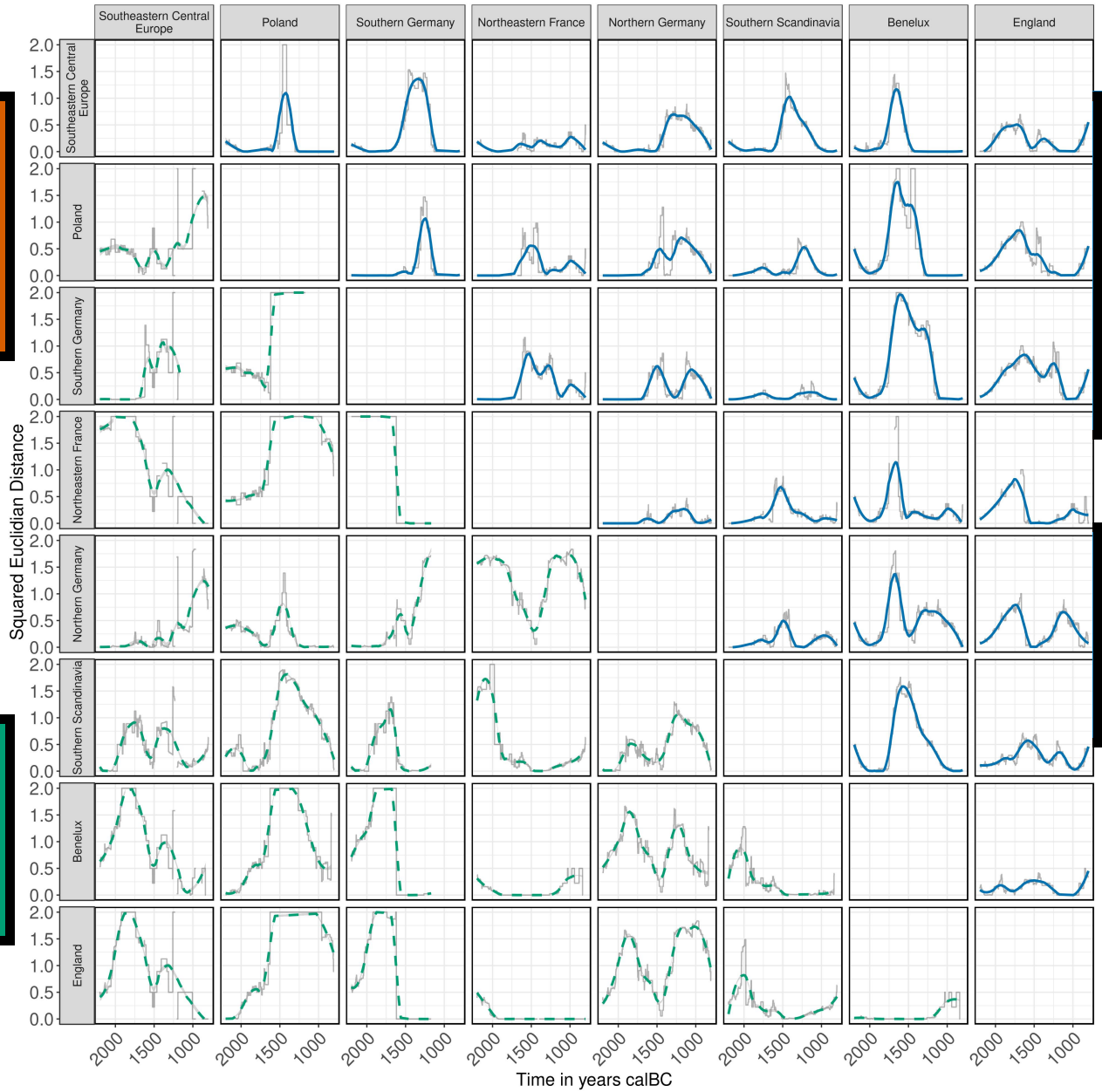


Figure 8: SED timeseries for each region relationship. Approximated with LOESS. **burial type** on top, **burial construction** in the bottom left corner.

Mean Region-Region Distance Matrix

Central European Cluster?

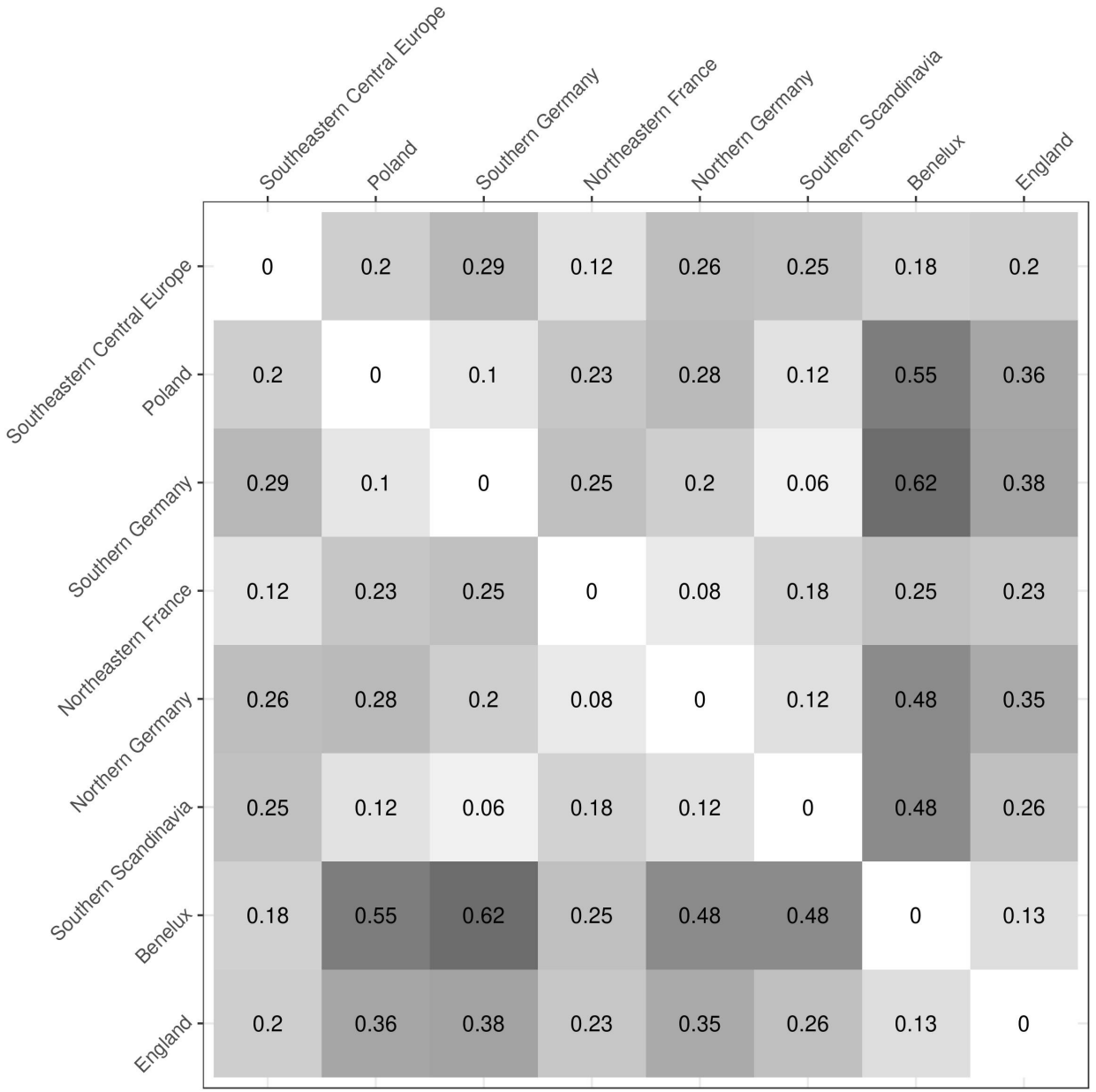
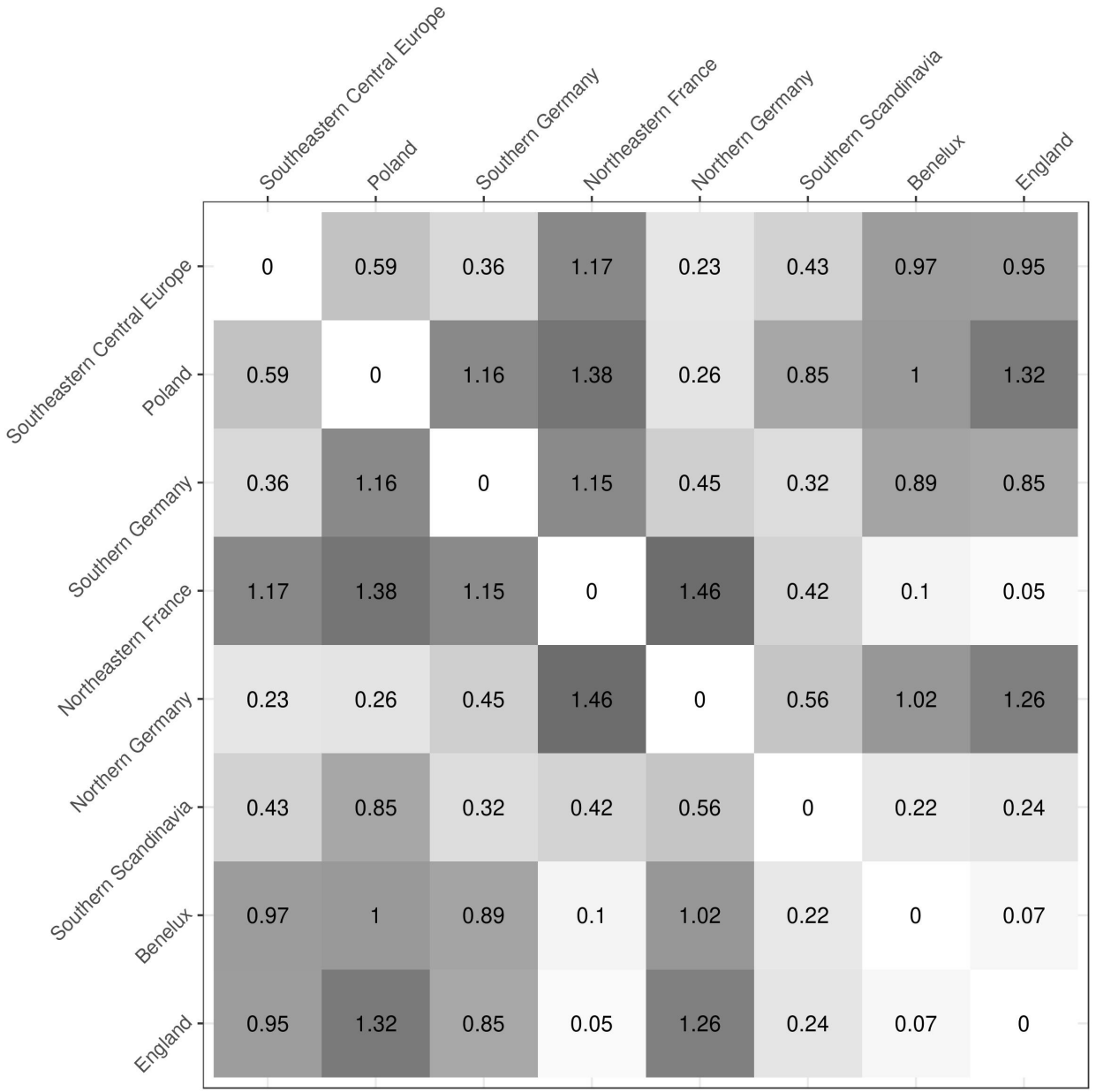


Figure 9: **burial type**: Mean SED for each region relationship. The lower, the closer.

Mean Region Distance Matrix



Northwestern European Cluster?

Figure 10: **burial construction**: Mean SED for each region relationship.

Parallel Developments of Burial Type and Burial Construction Distance?

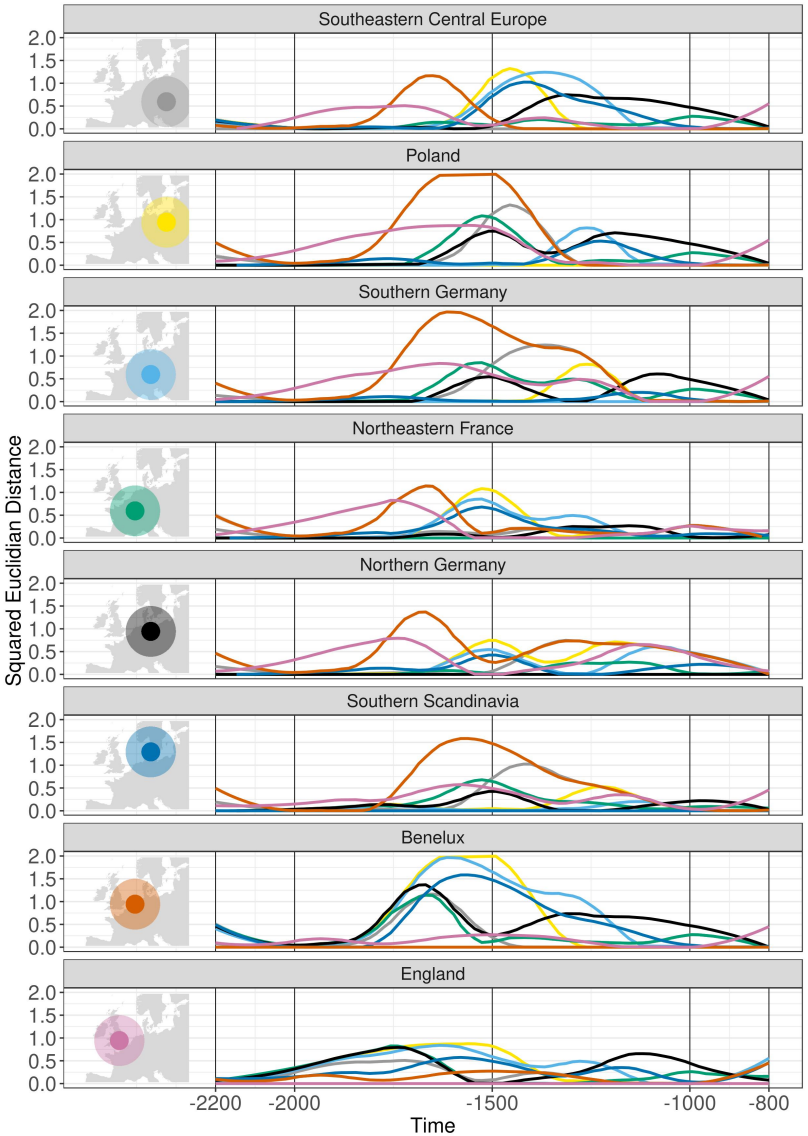


Figure 11: **burial type** Development of SED to all the others for each region.

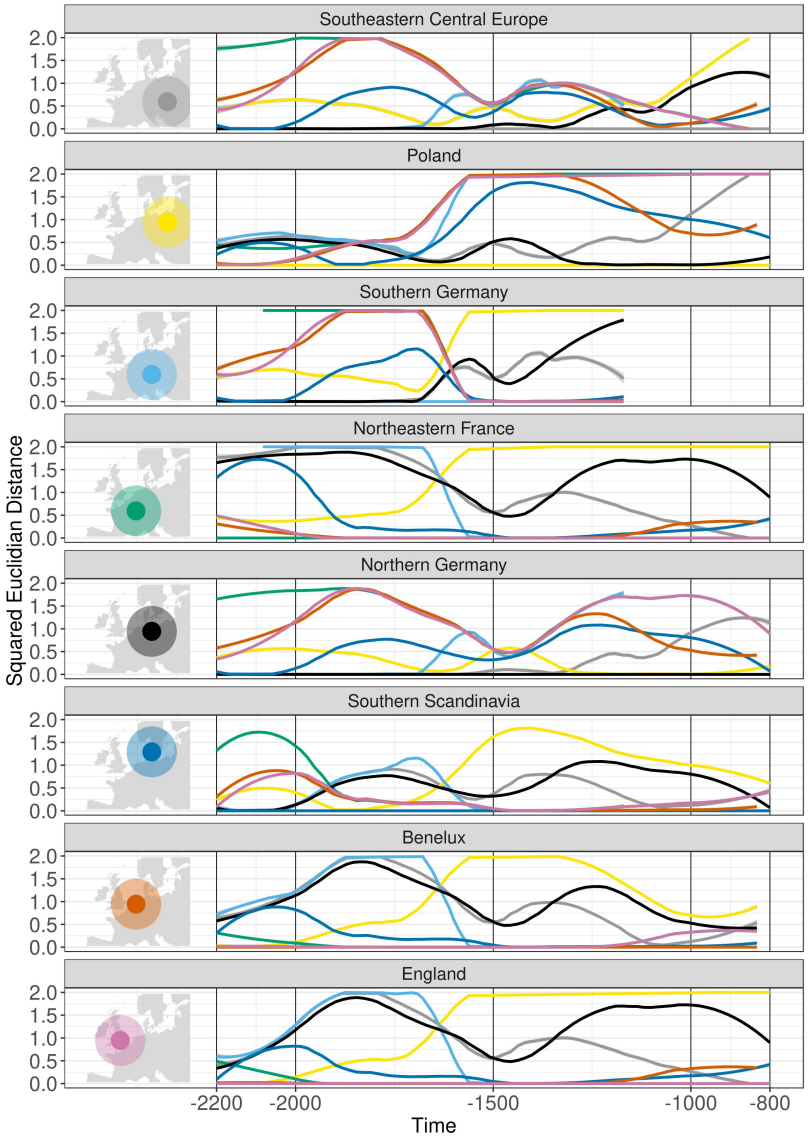
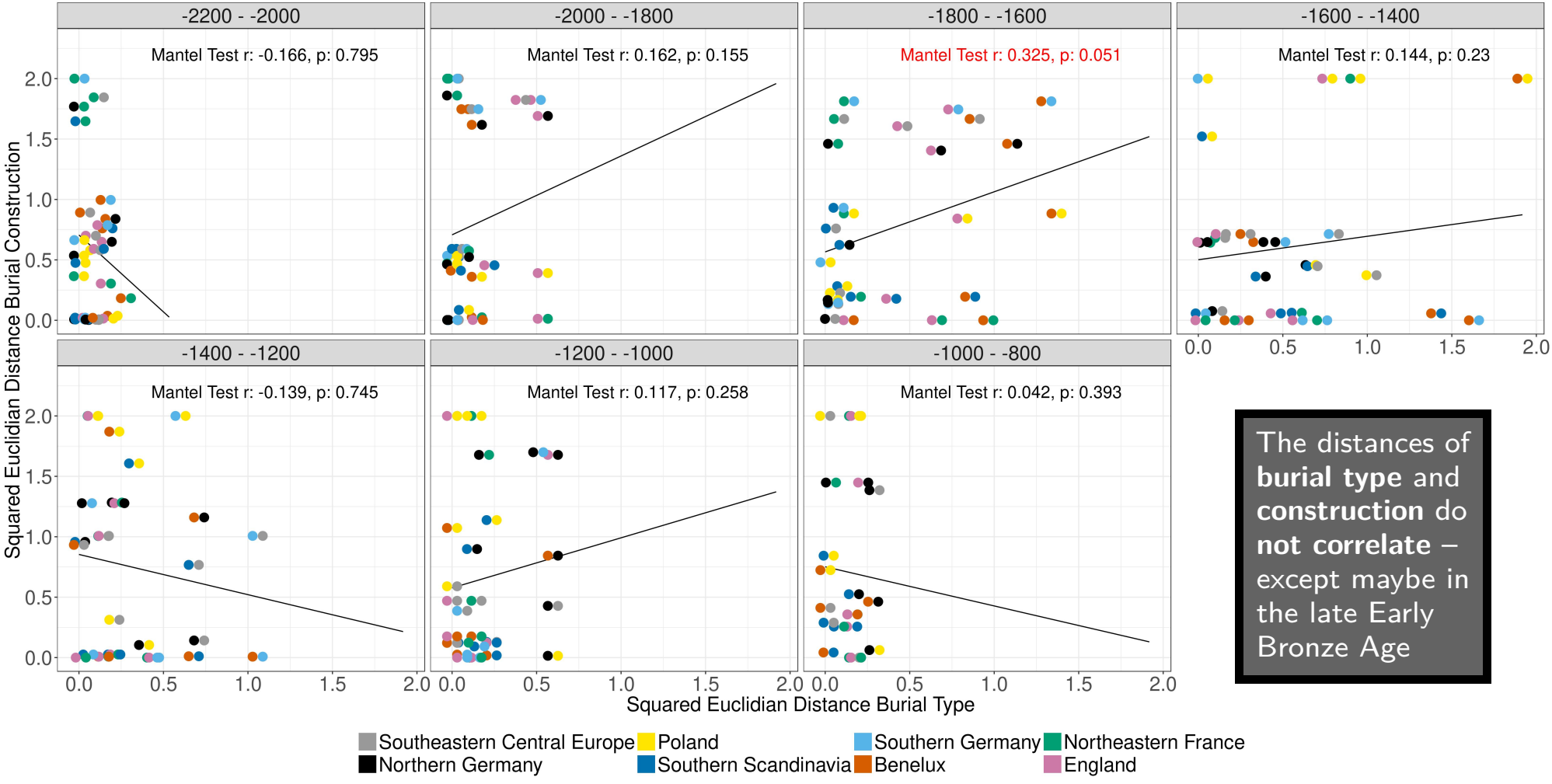


Figure 12: **burial construction**

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 13: 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.

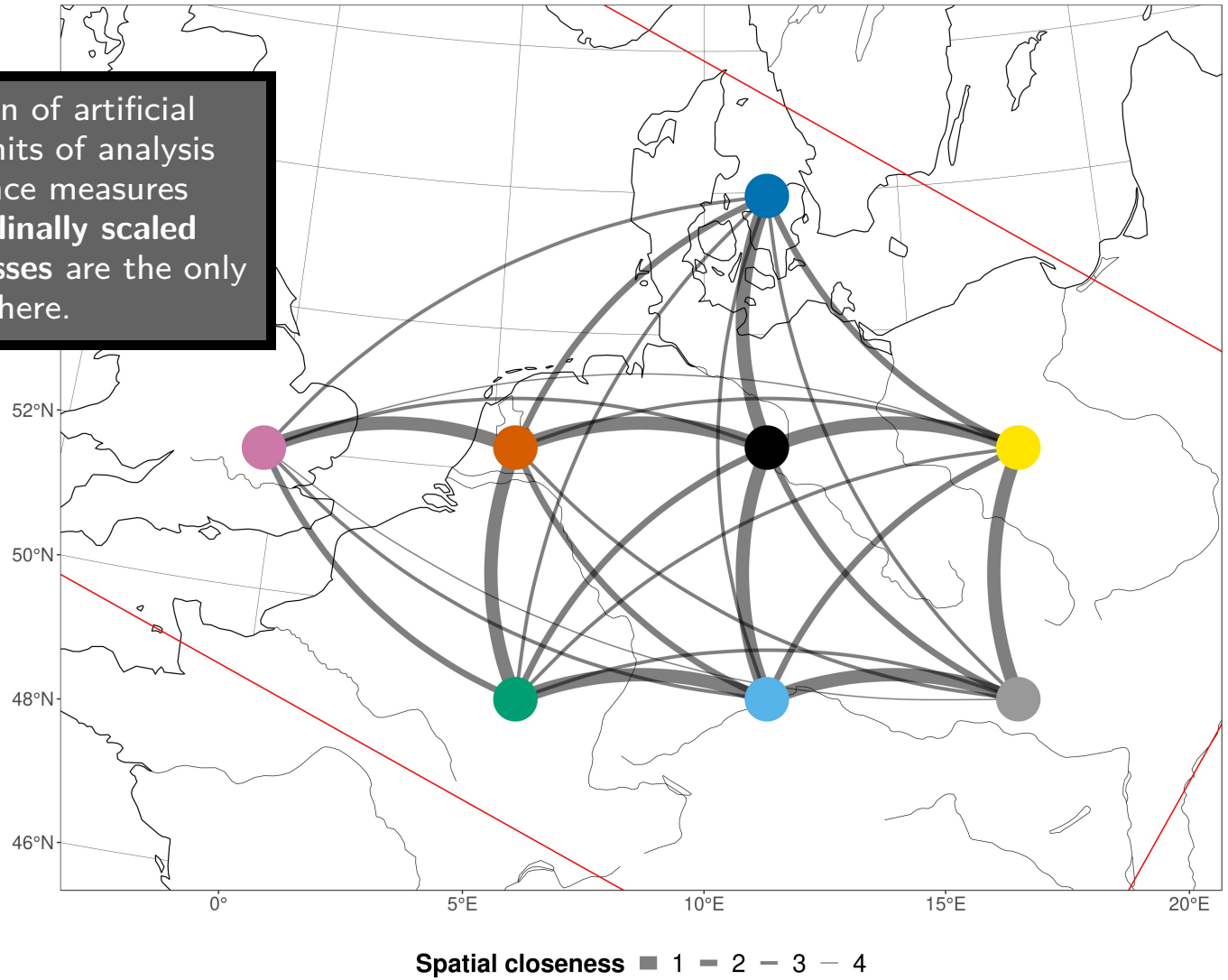
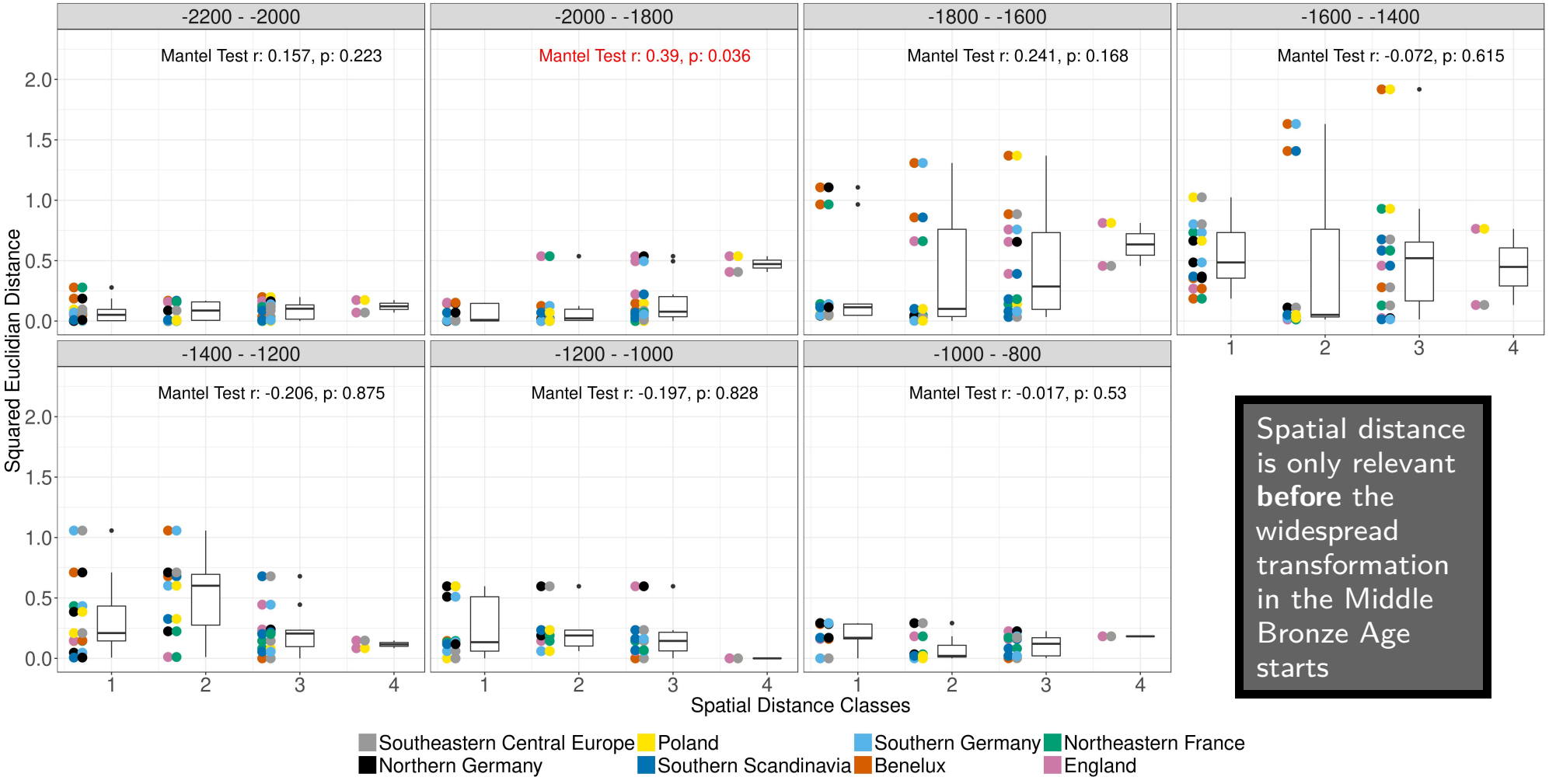


Figure 14: Spatial distance network and definition of distance classes

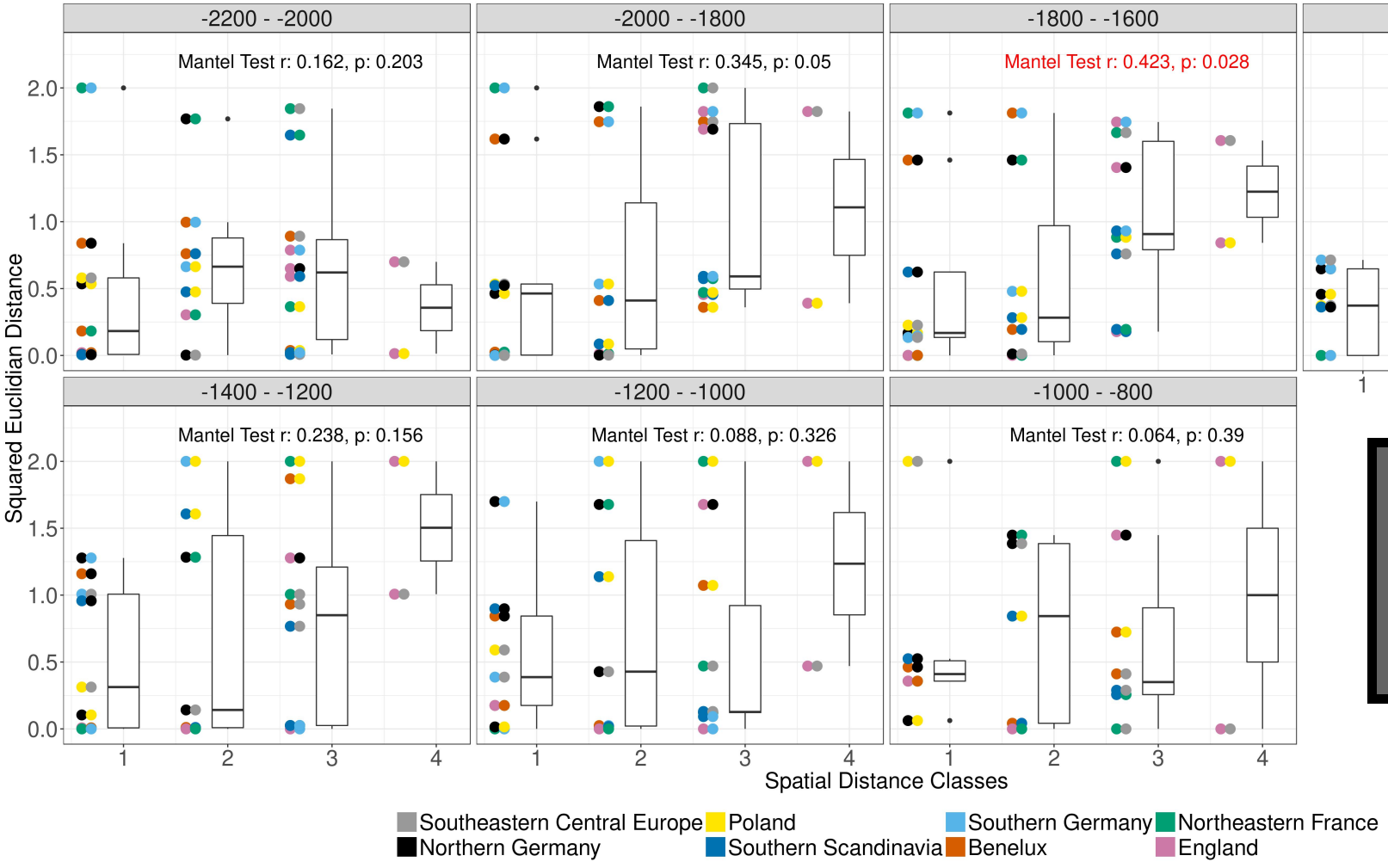
Correlation of Burial Type and Spatial Distance



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

Figure 15: **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 16: **burial construction**: Correlation of mean SED and spatial distance in timeslices of 200 years.

Distance Correlation Summary

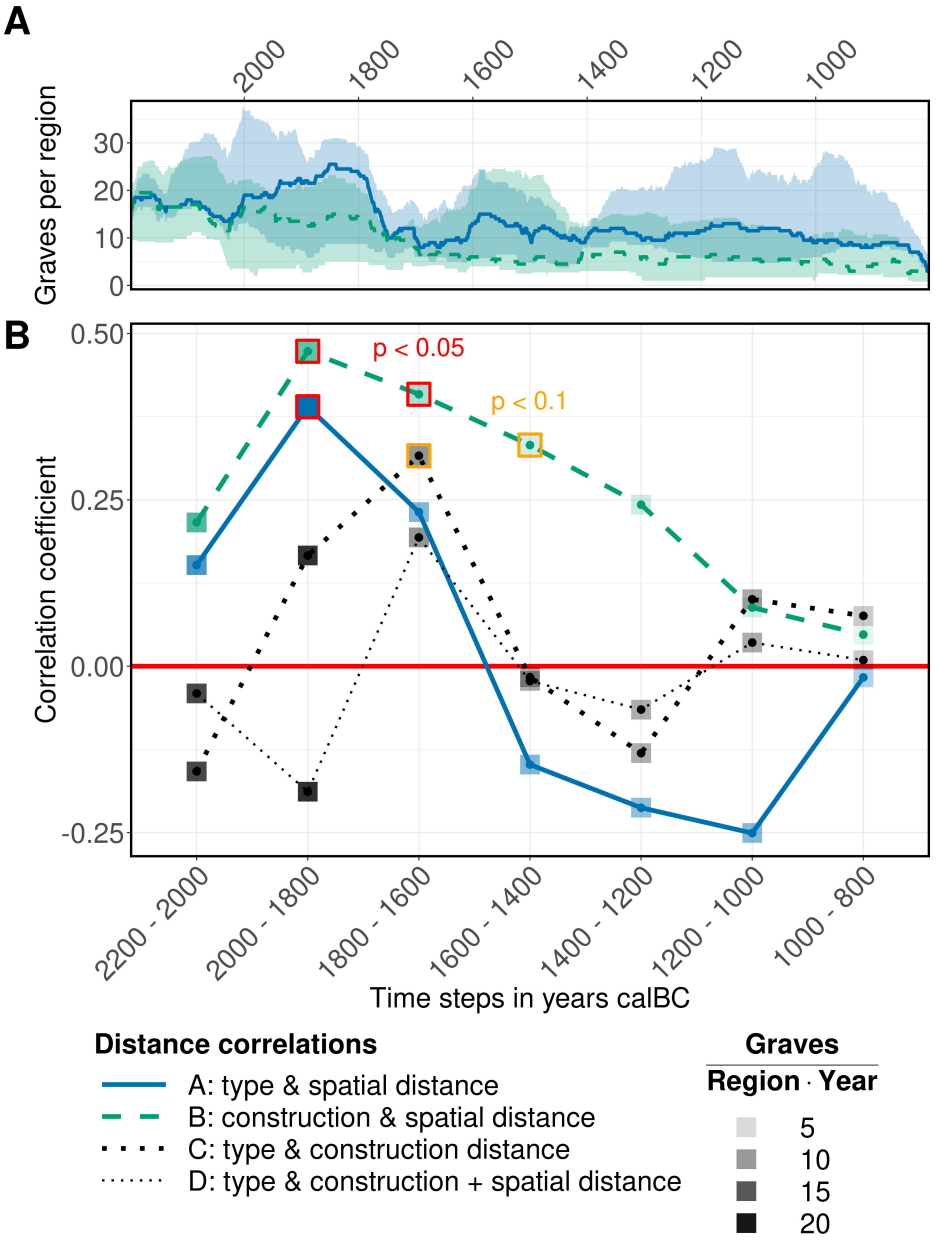
The complete distance network: Correlation of cultural and spatial distance

C&D: burial type & burial construction distance

No significant correlation

B: burial construction & spatial distance

Weak correlation in the EBA, no correlation in the LBA



A: burial type & spatial distance

Weak correlation in the EBA, negative correlation from the MBA

Figure 17: Time series of cultural and spatial distance correlation, 200 years time slots

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**.

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**.

The main mechanisms of diffusion of neutral variants are **innovation**, **drift** and **flow**.

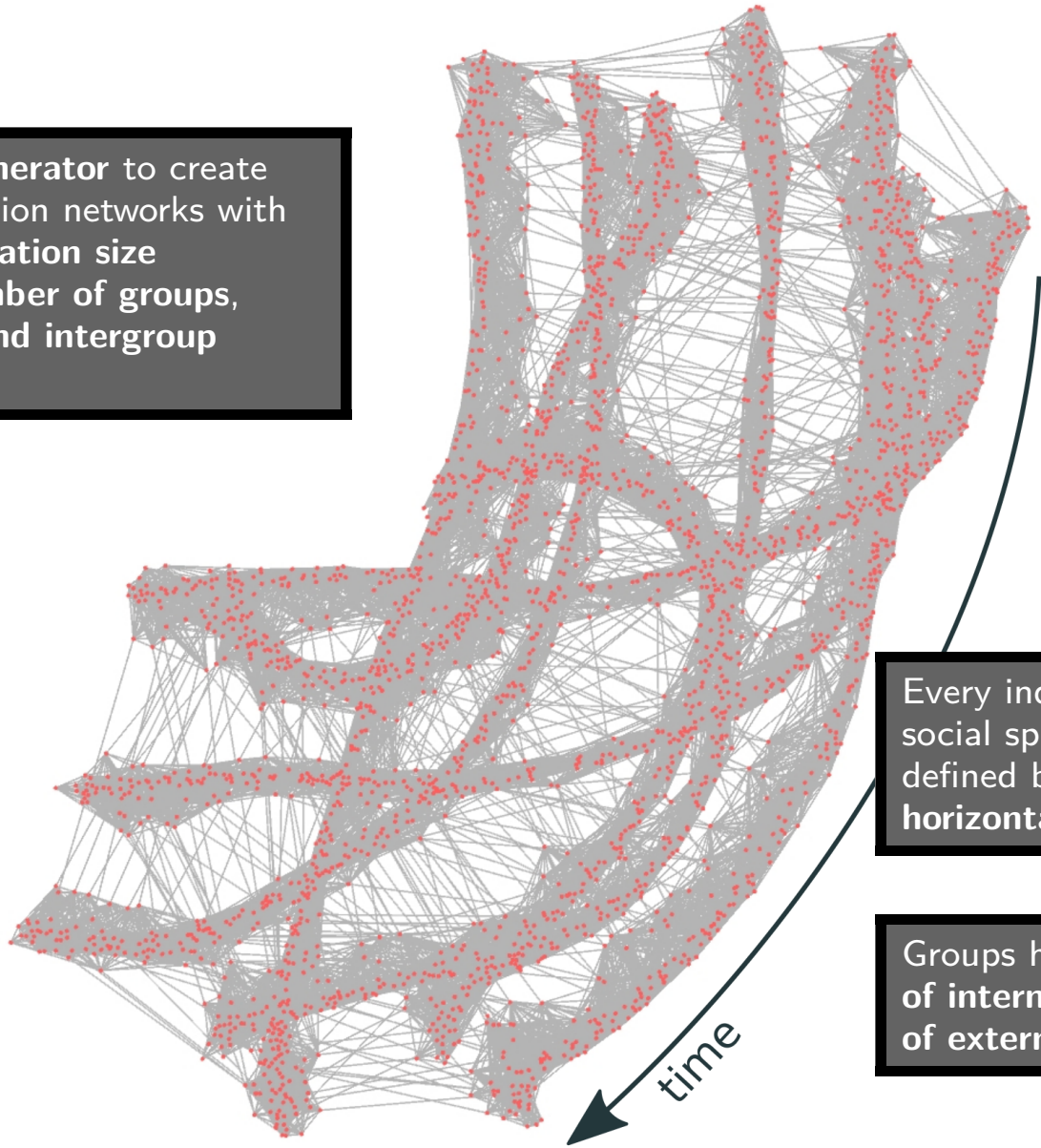
- **Drift:** Individual traits will dominate due to stochastic processes
- **Flow:** Information transfer causes synchronization across group boundaries

Simulation concept:

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

Population Graph Creation

R Package popgenerator to create undirected population networks with configurable **population size development**, **number of groups**, **degree of intra- and intergroup transmission**, etc.



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

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

Figure 18: Example Population Graph. Arranged with the Fruchterman & Reingold algorithm.

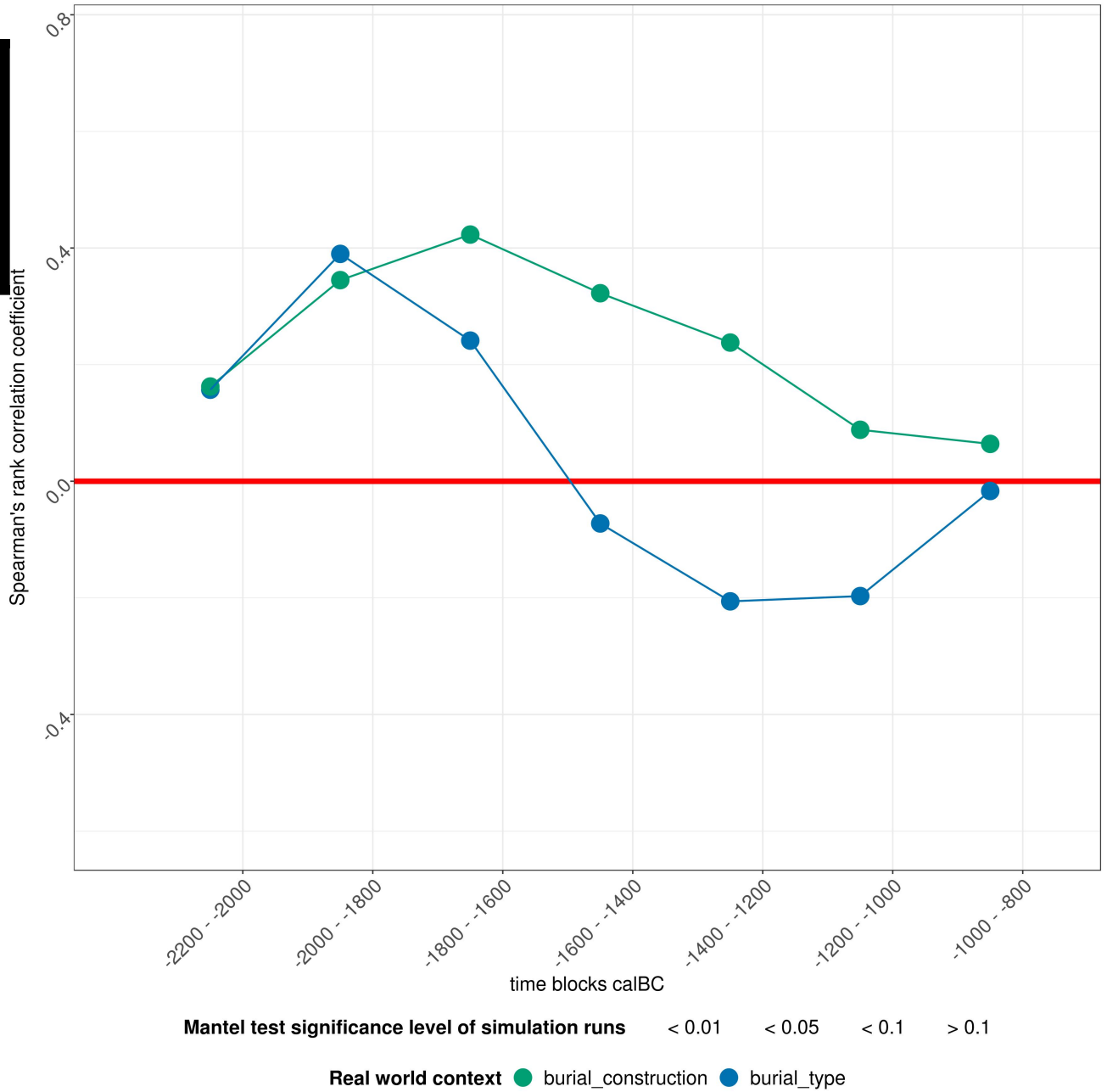
Idea Expansion Simulation

```
...
// 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);
  }
...
```

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

Simulation Application: Correlation of Spatial and Cultural Distance

Can correlation of spatial and cultural distance **be ruled out?**



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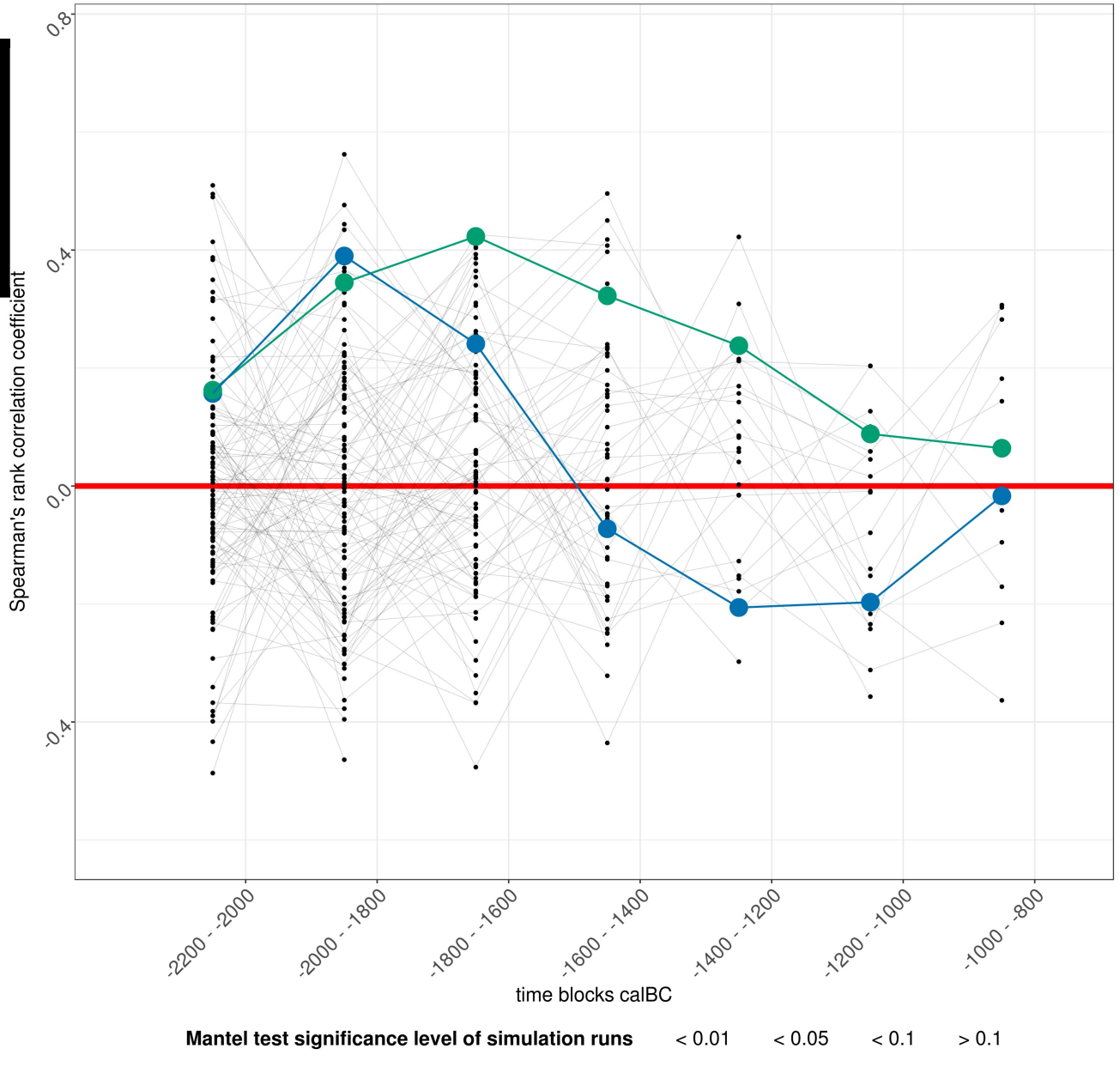

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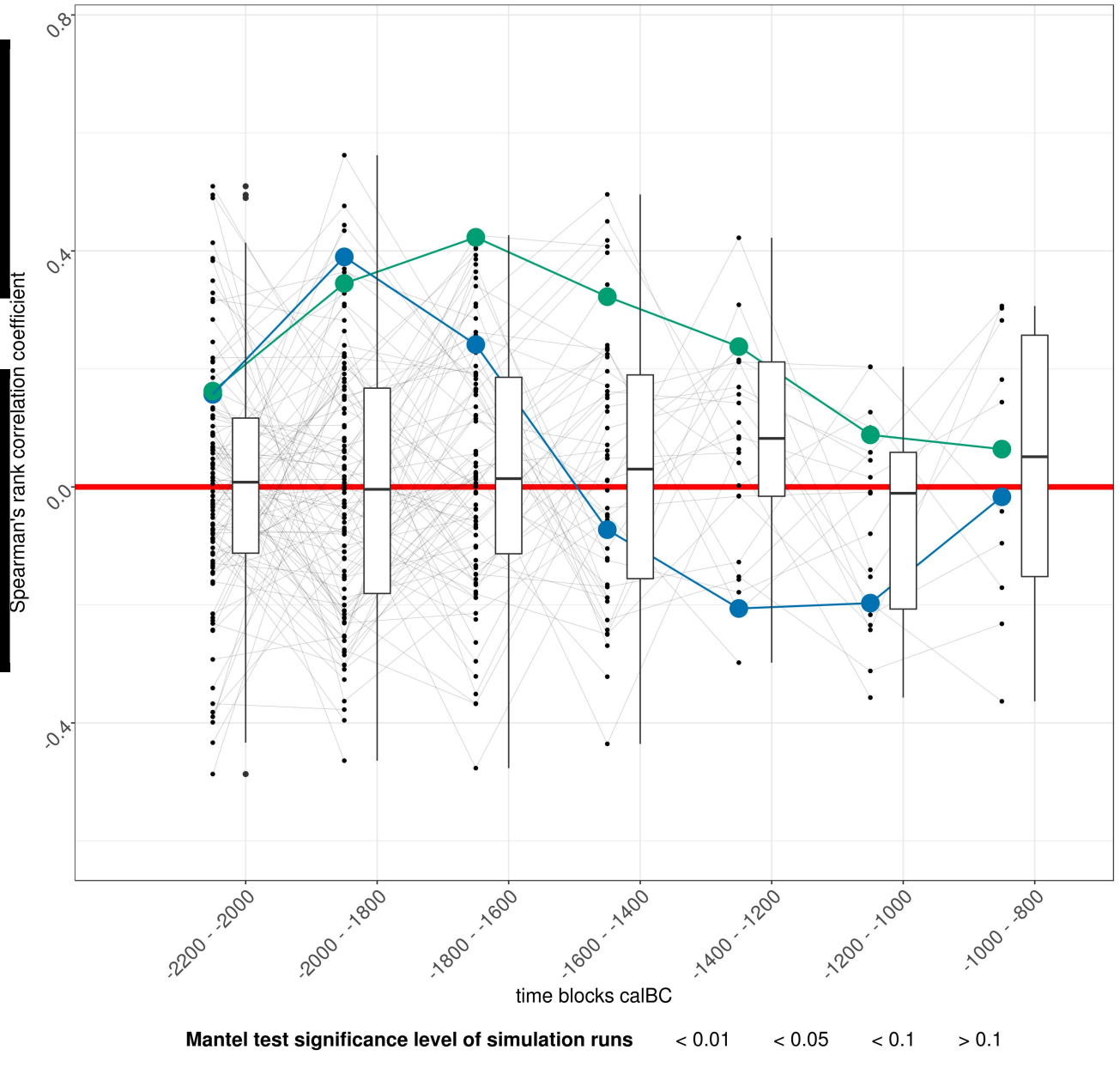
Equal intergroup distance: Unlikely development in the Early Bronze Age



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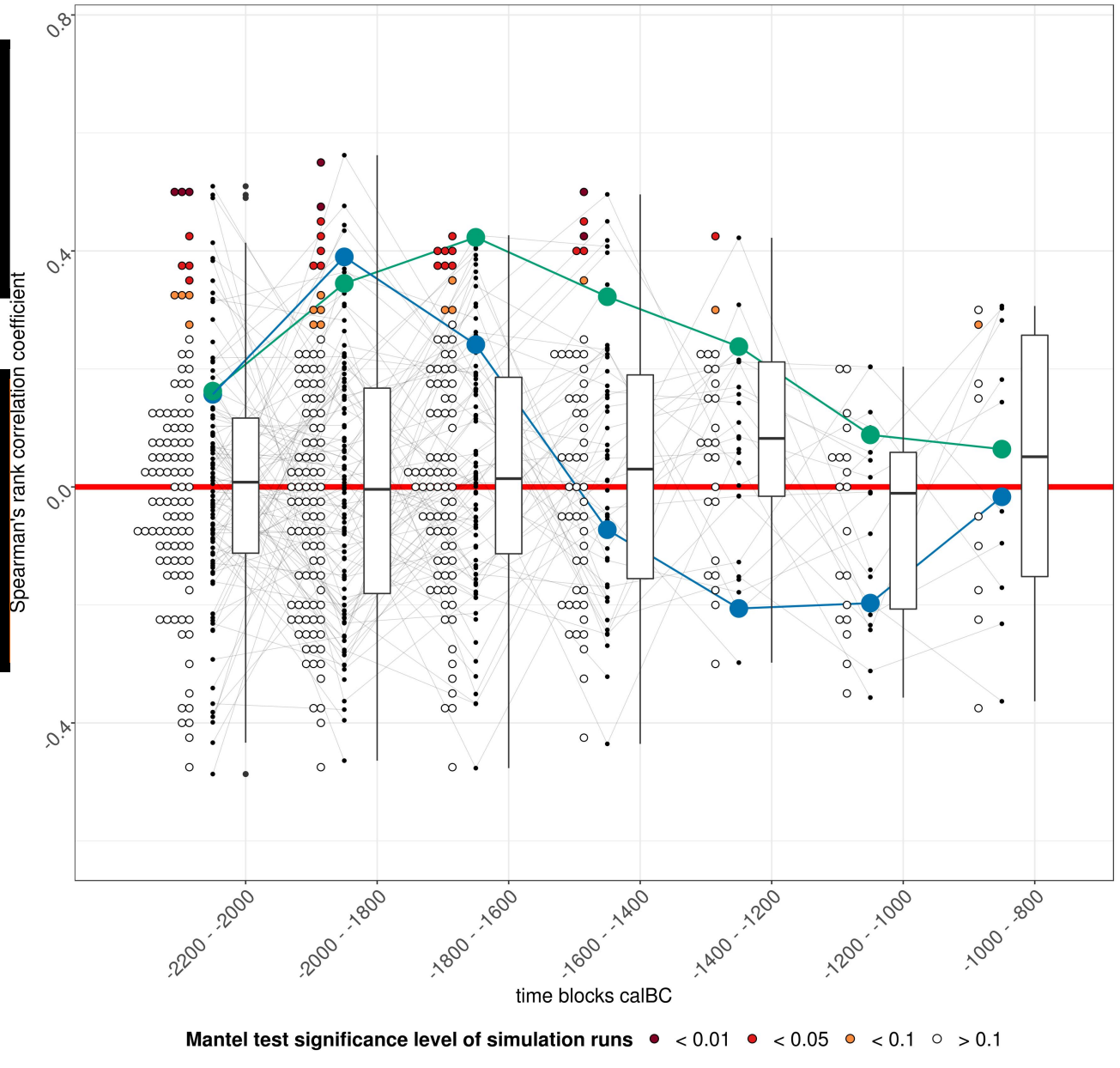

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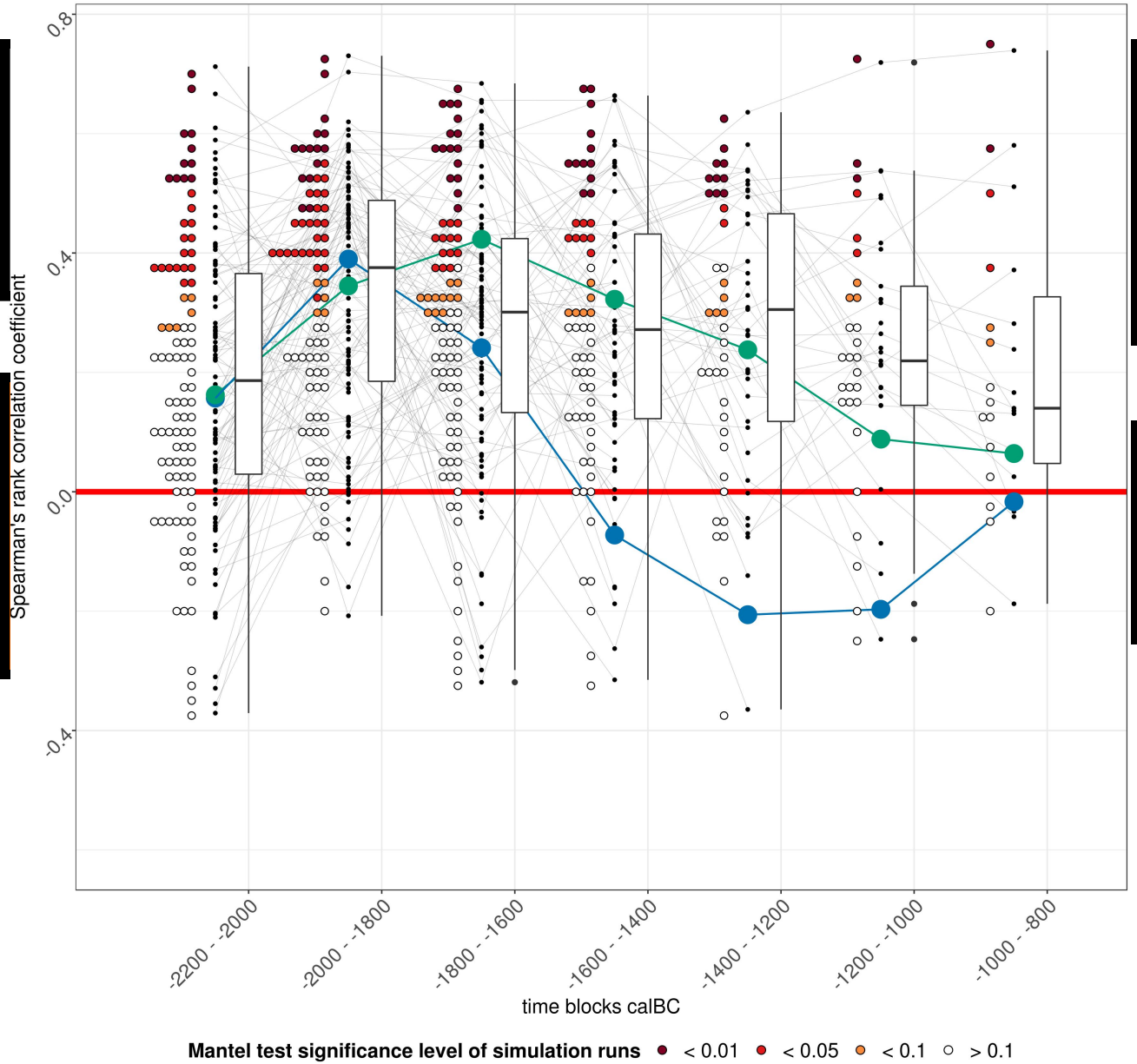

Spatial intergroup distance: Unlikely development in the Late Bronze Age

burial type behaves **highly atypical** if we assume spatial correlation

Conclusion

Observations and Hypotheses

- The **main trends** in the distribution of burial rites in Bronze Age Europe **can be detected** in **bulk radiocarbon data**
- The diffusion of the **cremation funeral tradition** and **traditions of flat vs. mound graves** are **mostly independent**
- Both processes are **mostly independent** of **spatial distance**, except for some time periods in the Early Bronze Age
- **Big phenomena** like the ones initiated by **Tumulus culture** and **Urnfield culture** do not spread in simple diffusion processes
- **Other interaction networks** could yield better predictions: Elite Networks, Religious superstructures, ...

Clemens Schmid