Considering space

Objectives

- Learn what is spatial data.
- Learn how spatial data is represented in R.
- Learn basic operations with vector data.
- Create basic maps.

What is Earth's shape?

- Spheroid
- Ellipsoid
- Geoid
- Potato

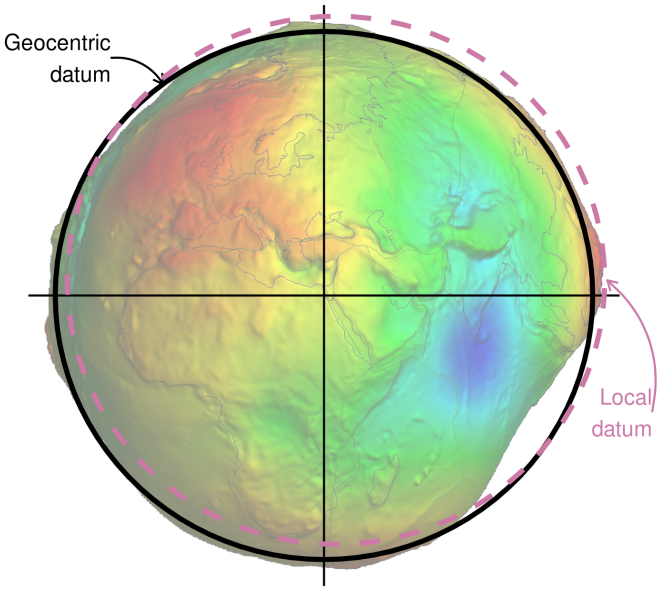
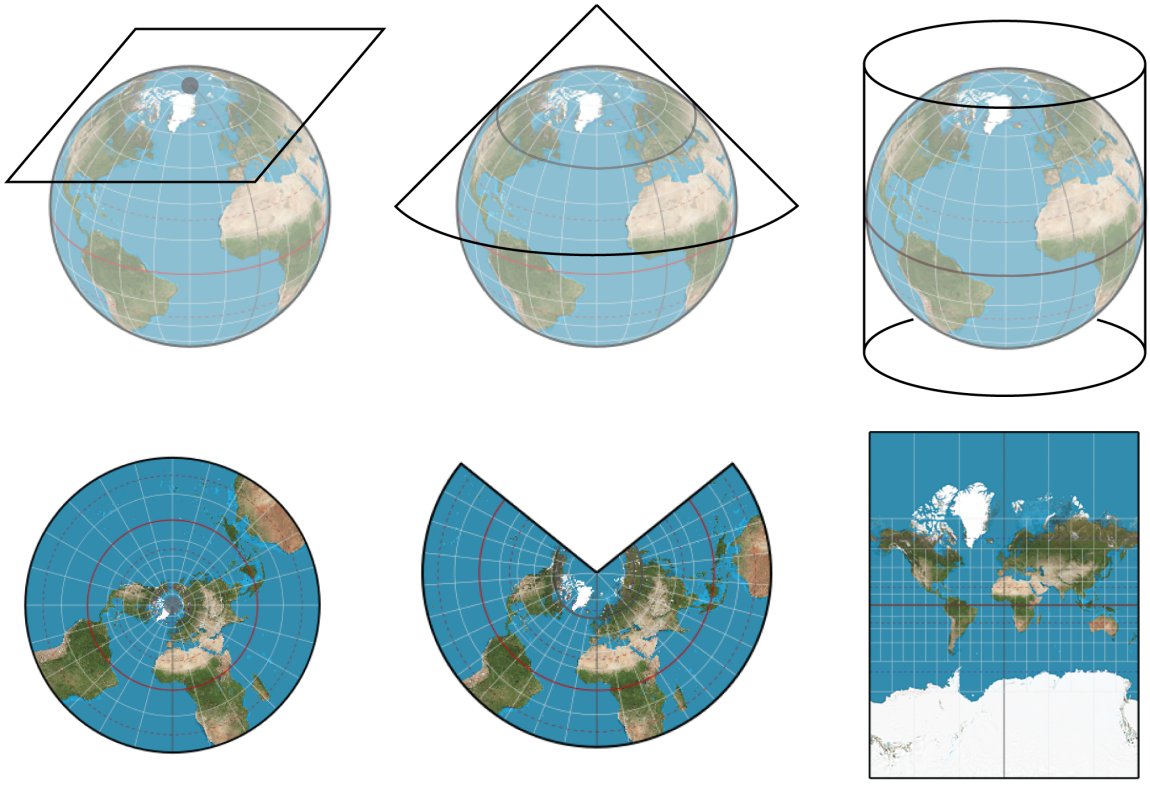


Figure 1: Geocentric and local geodetic datums shown on top of a geoid (in false color and the vertical exaggeration by 10,000 scale factor). From Lovelace, Nowosad, Muenchow: Geocomputation with R

Projections

How to transform a curved surface of an ellipsoid into a plane?



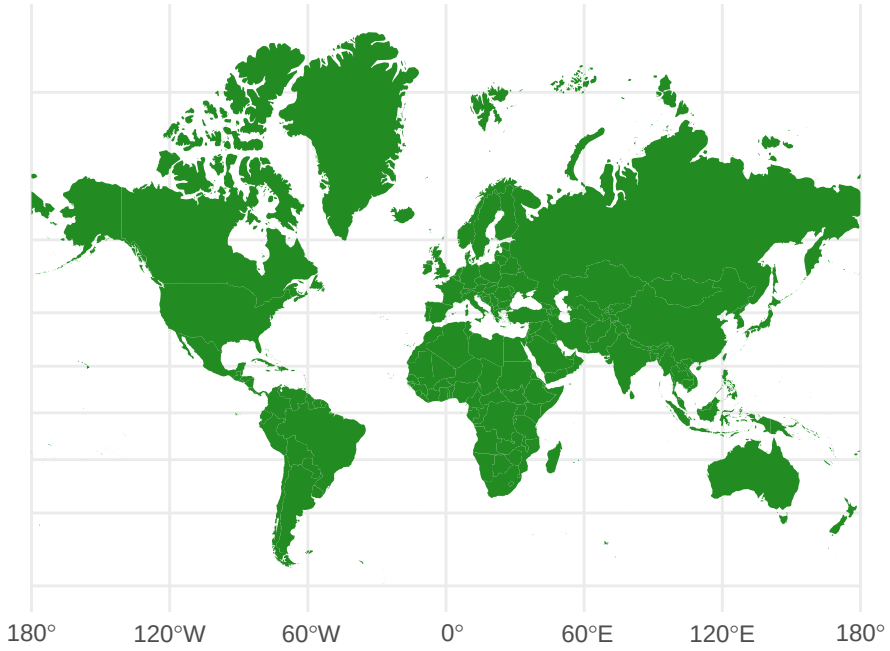


Figure 2: Mercator (1569)

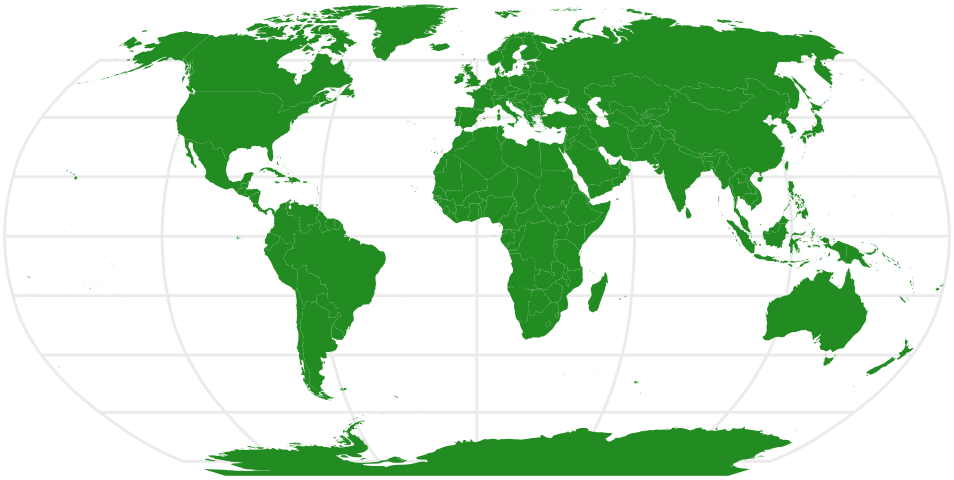


Figure 3: Robinson (1963)

Figure 4: Albers (1805)

Coordinate reference systems

- CRS defines how spatial data relate to the surface of the Earth.

Geographic

WGS 84

- EPSG: 4326
- latitude: N/S, 0 ° (equator) – 90 ° (poles)
- longitude: E/W, 0 ° (prime meridian) – 180° (*antimeridian*)
- in degrees, minutes:
  `N 49°44.62543', E 15°20.31830'`
- in decimal degrees:
  `49.7437572N, 15.3386383E`
- Package `parzer` helps to parse coordinates in weird formats.

Projected

- Many operations can be done only with projected coordinates!

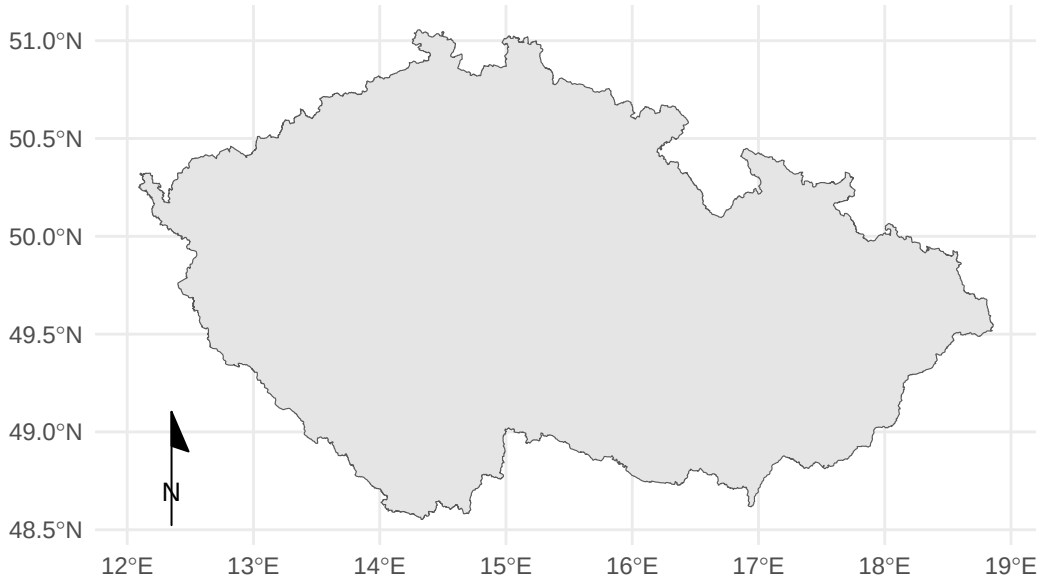
S-JTSK / Křovák East North

- EPSG: 5514
- Czech Republic and Slovakia
- in meters, in negative numbers:
  `-682473.3, -1089493`

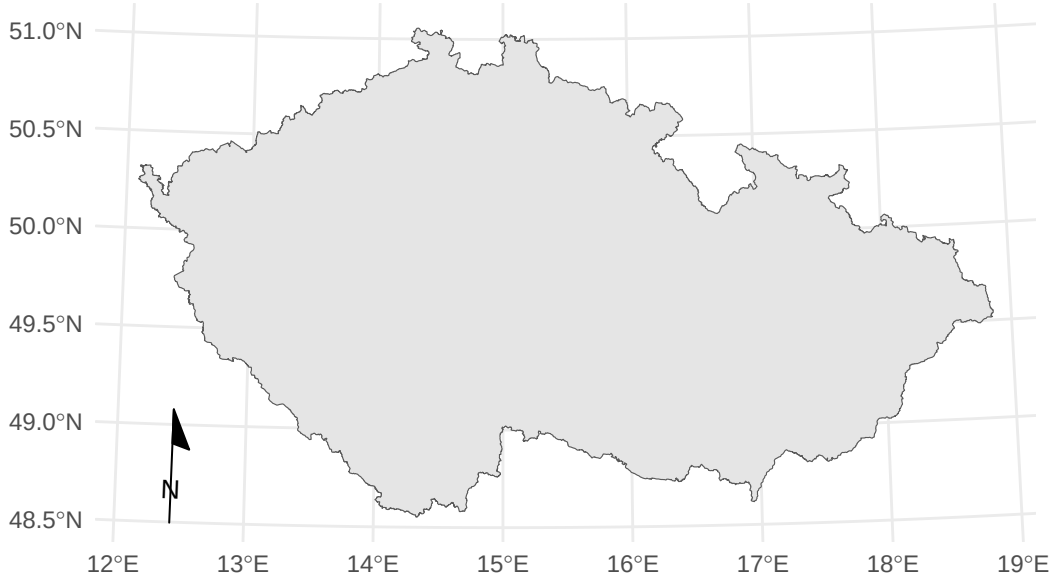
WGS 84 / UTM

- EPSG for zone 33N: 32633
- Czech Republic is in zone UTM 33N

Czech Republic in WGS 84



Czech Republic in WGS 84 / UTM



Czech Republic in S-JTSK / Krovak East North

Raster and vector data

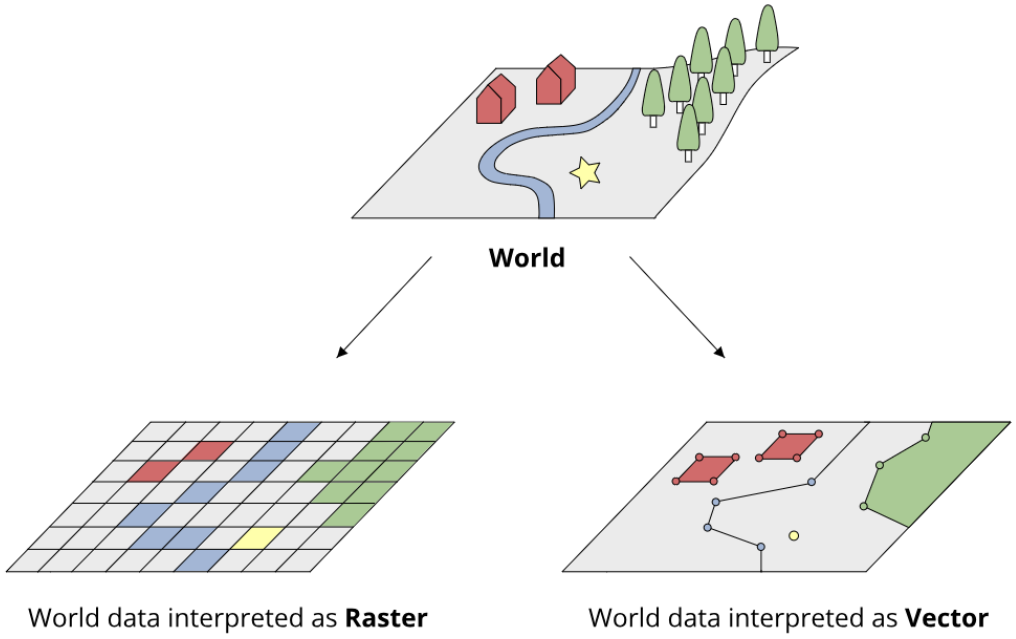
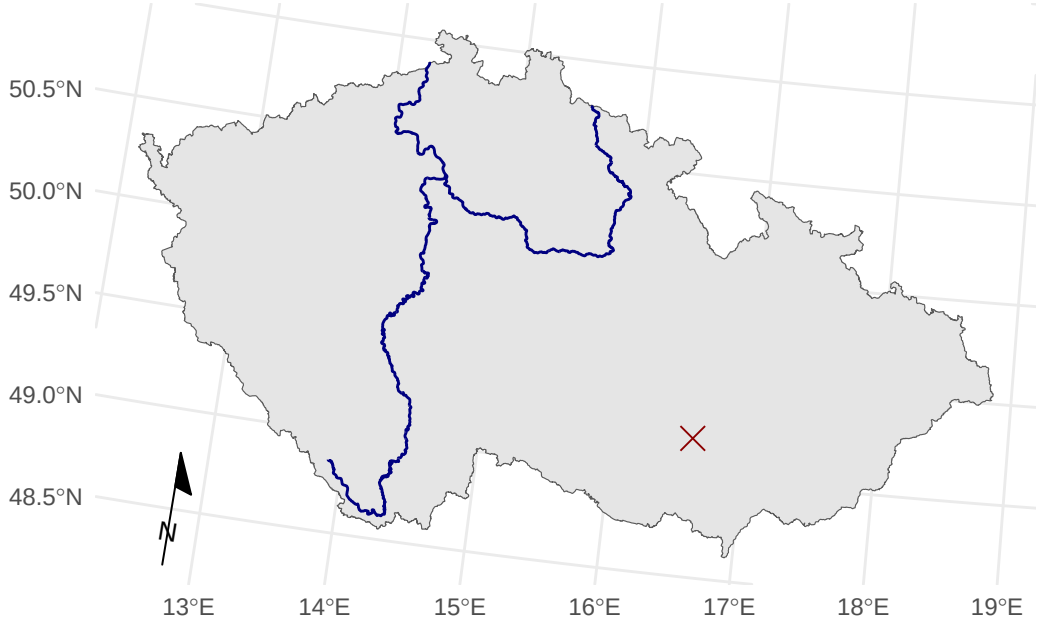


Figure 5: From https://urstudio.sec.sg/wp-content/uploads/2022/03/featured-3.png

Vector data

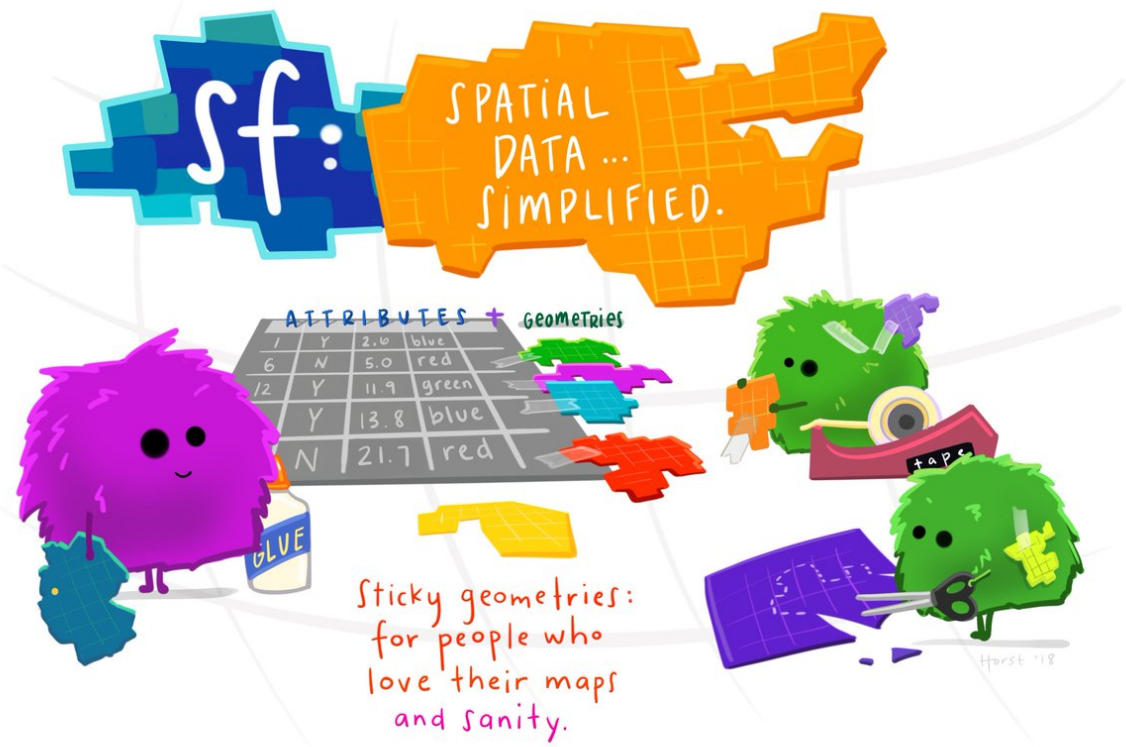


Points, lines, polygons...

Packages

`sf` package

- Vector data, *simple features*
- https://r-spatial.github.io/sf/
- Cheatsheet



Raster data

- `terra` package and its predeccessor, `raster`
- `stars` package – spatiotemporal arrays, raster and vector data cubes

Spatial statistics

- `spatstat` package

Making maps

- `ggplot2`
- `tmap` package – thematic maps
- `leaflet` package – interactive maps

Code along

Dataset

Towards New Demography Proxies and Regional Chronologies: Radiocarbon Dates from Archaeological Contexts Located in the Czech Republic Covering the Period Between 10,000 BC and AD 1250

Journal of open archaeology data

DATA PAPER

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JAN KOLÁŘ
*Author affiliations can be found in the back matter of this article

ubiquity press

ABSTRACT

The dataset described in this paper represents the largest and most comprehensive collection of radiocarbon dates from the Czech Republic to date. The dataset offers 1579 samples from 357 archaeological sites dating from the Early Mesolithic (10,000 BC) to AD 1250. Published in a simple spreadsheet format, it offers researchers a quick tool for further analyses.

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KEYWORDS:
radiocarbon dates; Czech Republic; database; Holocene; prehistory

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Tkáč, P., Kolář, J., 2021. Towards New Demography Proxies and Regional Chronologies: Radiocarbon Dates from Archaeological Contexts Located in the Czech Republic Covering the Period Between 10,000 BC and AD 1250. *Journal of Open Archaeology Data*, 9: 9, pp. 1–14. DOI: https://doi.org/10.5334/joad.85

- Dataset from *Journal of Open Archaeology Data* paper
- Article DOI: 10.5334/joad.85
- Data DOI: 10.5281/zenodo.5728242
- Table `LASOLES_14C_database.csv`

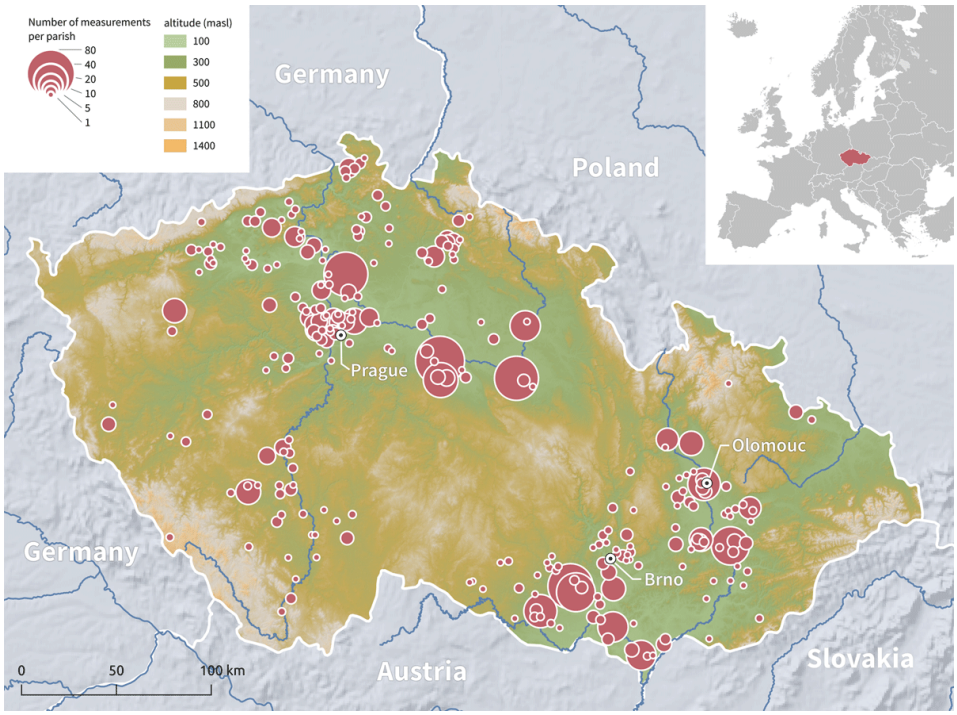


Figure 6: (Tkáč, Kolář 2021)

Reading the data

- Data is in CSV format, separated by semicolon (;)
- Columns `Latitude_WGS84` and `Longitude_WGS84`
- Coordinate reference system is WGS 84 (EPSG 4326)

```
lasoles <- read.csv("./data/LASOLES_14C_database.csv", sep = ";")
```

```
# A tibble: 4 x 5
  ID_Date  Latitude_WGS84 Longitude_WGS84 Site_category_ENG Contex_dating_AMCR
  <chr>             <dbl>           <dbl> <chr>             <chr>
1 CzArch_1           49.1            16.6 hillfort          br.st
2 CzArch_5           50.1            14.5 settlement        bronz
3 CzArch_6           49.8            17.0 settlement        ne.lin
```

```
4 CzArch_7           49.8            17.0 settlement        ne.lin
```

```
lasoles_wgs84 <- st_as_sf(lasoles, coords = c(x = "Longitude_WGS84", y = "Latitude_WGS84"), c
head(lasoles_wgs84, 4)
```

```
Simple feature collection with 4 features and 3 fields
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 14.52986 ymin: 49.05189 xmax: 16.95067 ymax: 50.05246
Geodetic CRS:  WGS 84
# A tibble: 4 x 4
  ID_Date  Site_category_ENG Contex_dating_AMCR            geometry
  <chr>    <chr>             <chr>                      <POINT [°]>
1 CzArch_1 hillfort          br.st              (16.62982 49.05189)
2 CzArch_5 settlement        bronz              (14.52986 50.05246)
3 CzArch_6 settlement        ne.lin             (16.95067 49.77669)
4 CzArch_7 settlement        ne.lin             (16.95067 49.77669)
```

Reprojecting CRS

Function `st_transform(x, crs)`

EPSG codes:

- WGS 84: `4326`
- S-JTSK East-North: `5514`
- UTM 33N: `32633`
- Find more at https://epsg.io/

```
lasoles_sjtsk <- st_transform(lasoles_wgs84,  crs = "EPSG:5514")
head(lasoles_sjtsk, 4)
```

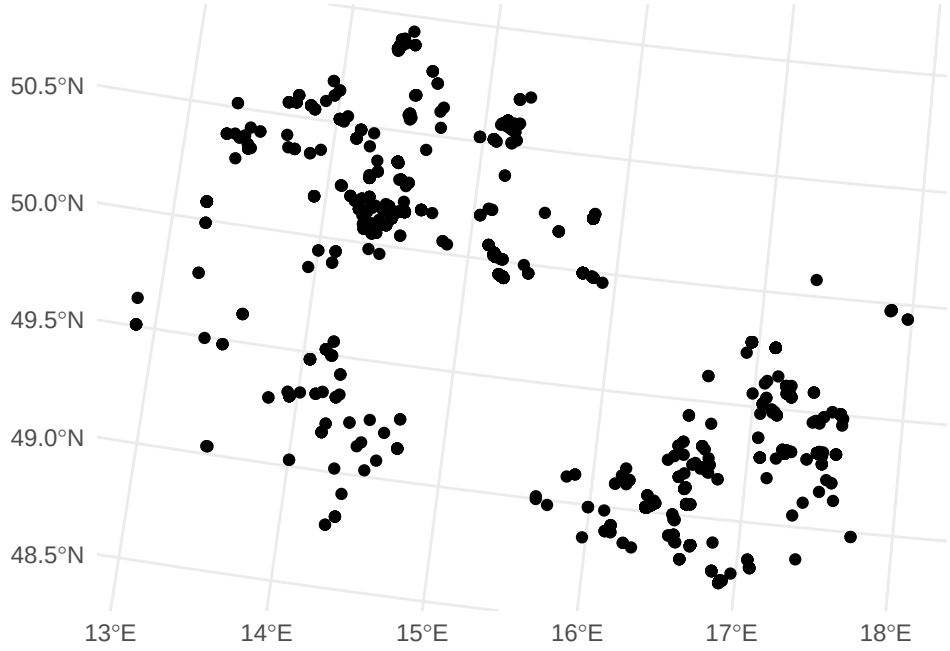
```
Simple feature collection with 4 features and 3 fields
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: -735634.8 ymin: -1176759 xmax: -566666.7 ymax: -1047924
Projected CRS: S-JTSK / Krovak East North
# A tibble: 4 x 4
  ID_Date  Site_category_ENG Contex_dating_AMCR              geometry
  <chr>    <chr>             <chr>                        <POINT [m]>
1 CzArch_1 hillfort          br.st              (-598287.7 -1176759)
```

```
2 CzArch_5 settlement        bronz              (-735634.8 -1047924)
3 CzArch_6 settlement        ne.lin             (-566666.7 -1099048)
4 CzArch_7 settlement        ne.lin             (-566666.7 -1099048)
```

Making maps

Geom `geom_sf()`

```
ggplot(lasoles_sjtsk) +
  geom_sf() +
  theme_minimal()
```



Some background data...

Package `RCzechia` (Lacko, 2023) has spatial data for the Czech republic...

```
kraje <- RCzechia::kraje()
head(kraje, 4)
```

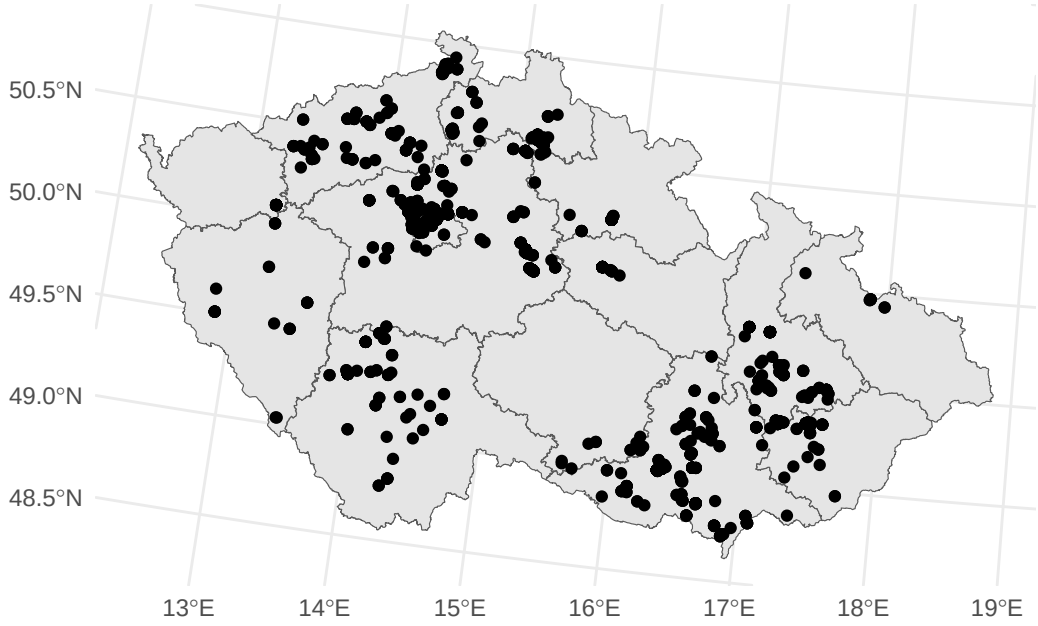
```
Simple feature collection with 4 features and 3 fields
Geometry type: GEOMETRY
Dimension:     XY
Bounding box:  xmin: 12.40056 ymin: 48.55189 xmax: 15.60422 ymax: 50.61901
Geodetic CRS:  WGS 84
  KOD_KRAJ KOD_CZNUTS3        NAZ_CZNUTS3                       geometry
1     3018       CZ010 Hlavní město Praha MULTIPOLYGON (((14.49806 50...
2     3026       CZ020   Středočeský kraj POLYGON ((15.16973 49.61046...
3     3034       CZ031     Jihočeský kraj MULTIPOLYGON (((15.4962 48....
4     3042       CZ032      Plzeňský kraj MULTIPOLYGON (((13.60536 49...
```

```r
kraje <- st_transform(kraje, crs = "EPSG:5514")
head(kraje, 4)
```

```
Simple feature collection with 4 features and 3 fields
Geometry type: GEOMETRY
Dimension:     XY
Bounding box:  xmin: -891822.3 ymin: -1211576 xmax: -665628.7 ymax: -989063.4
Projected CRS: S-JTSK / Krovak East North
  KOD_KRAJ KOD_CZNUTS3        NAZ_CZNUTS3                       geometry
1     3018       CZ010 Hlavní město Praha MULTIPOLYGON (((-736092 -10...
2     3026       CZ020   Středočeský kraj POLYGON ((-696420.7 -110267...
3     3034       CZ031     Jihočeský kraj MULTIPOLYGON (((-681445.6 -...
4     3042       CZ032      Plzeňský kraj MULTIPOLYGON (((-817386.4 -...
```

Making maps

```r
ggplot(lasoles_sjtsk) +
  geom_sf(data = kraje) +
  geom_sf() +
  theme_minimal()
```



Geometry operations

Unions

`st_union()`

```
head(kraje, 2)
```

```
Simple feature collection with 2 features and 3 fields
Geometry type: GEOMETRY
Dimension:     XY
Bounding box:  xmin: -816235.3 ymin: -1109600 xmax: -665628.7 ymax: -989063.4
Projected CRS: S-JTSK / Krovak East North
  KOD_KRAJ KOD_CZNUTS3        NAZ_CZNUTS3                       geometry
1     3018       CZ010 Hlavní město Praha MULTIPOLYGON (((-736092 -10...
2     3026       CZ020   Středočeský kraj POLYGON ((-696420.7 -110267...
```

```
republika <- st_union(kraje)
republika
```

```
Geometry set for 1 feature
Geometry type: POLYGON
Dimension:     XY
Bounding box:  xmin: -904576.9 ymin: -1227293 xmax: -431723.3 ymax: -935236.5
Projected CRS: S-JTSK / Krovak East North
```

```
republika %>%
  ggplot() +
   geom_sf() +
   theme_minimal()
```

Geometry operations

Centroids

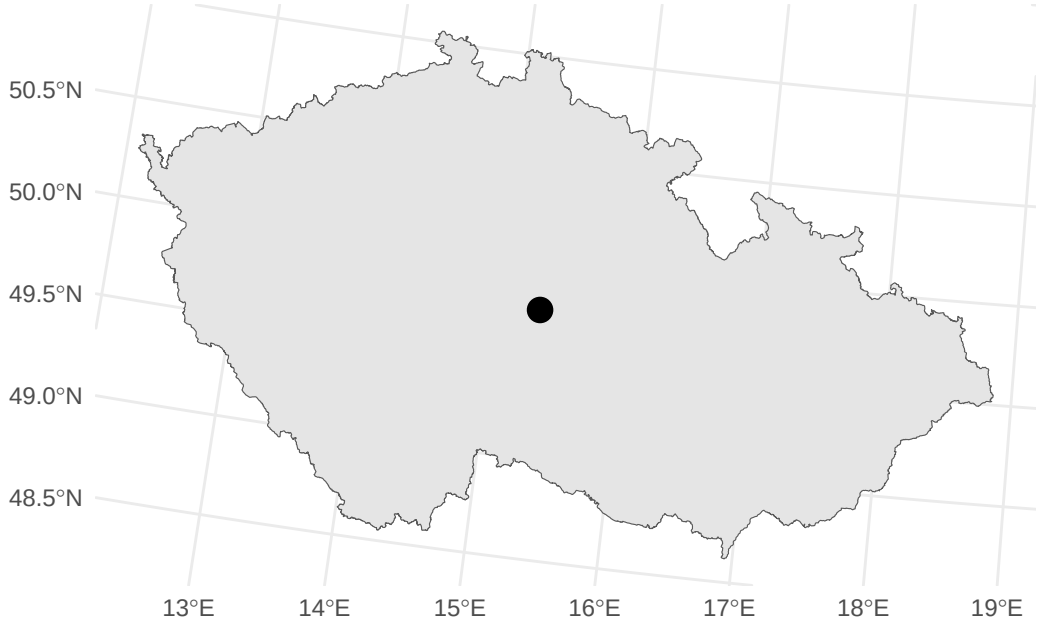
`st_centroid()`

```
stred <- st_centroid(republika)
stred
```

```
Geometry set for 1 feature
```

```
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: -682473.3 ymin: -1089493 xmax: -682473.3 ymax: -1089493
Projected CRS: S-JTSK / Krovak East North
```

```
ggplot() +
  geom_sf(data = republika) +
  geom_sf(data = stred, size = 4) +
  theme_minimal()
```



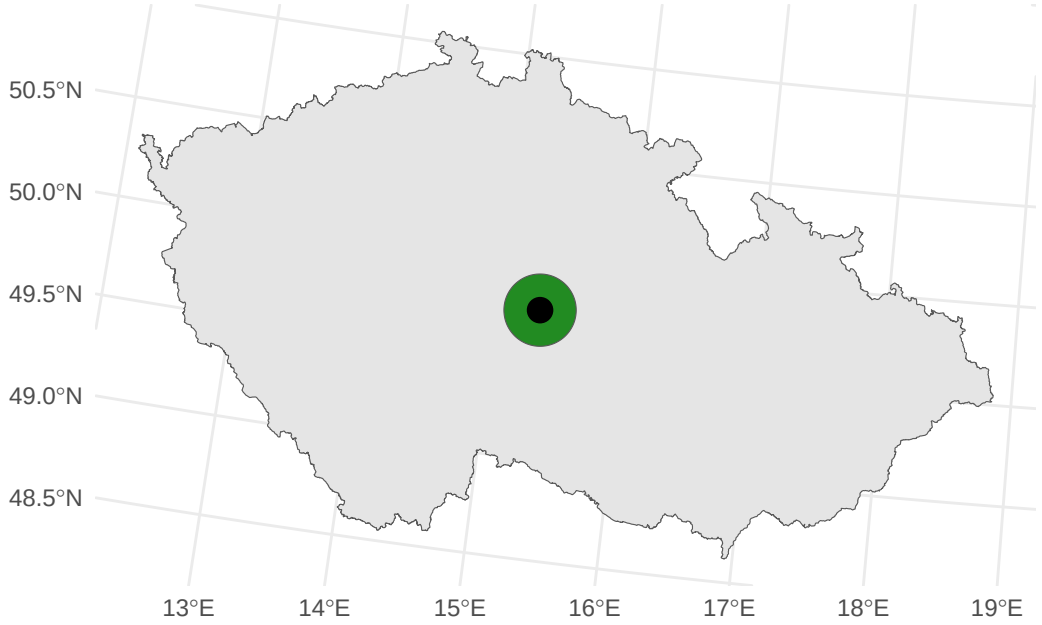
Buffers

`st_buffer()`

```
buffer <- st_buffer(stred, 20000)
buffer
```

```
Geometry set for 1 feature
Geometry type: POLYGON
Dimension:     XY
Bounding box:  xmin: -702473.3 ymin: -1109493 xmax: -662473.3 ymax: -1069493
Projected CRS: S-JTSK / Krovak East North
```

```
ggplot() +
  geom_sf(data = republika) +
  geom_sf(data = buffer, fill = "forestgreen") +
  geom_sf(data = stred, size = 4) +
  theme_minimal()
```



Spatial operations

Topological relations

Many types of raletionships, the most generic one is **intersection**:
`st_intersects(x, y)`

```
prunik <- st_intersects(kraje, stred)
prunik
```

```
Sparse geometry binary predicate list of length 14, where the predicate
was `intersects'
first 10 elements:
 1: (empty)
 2: (empty)
```

```
 3: (empty)
 4: (empty)
 5: (empty)
 6: (empty)
 7: (empty)
 8: (empty)
 9: (empty)
 10: 1
```

```
lengths(prunik)
```

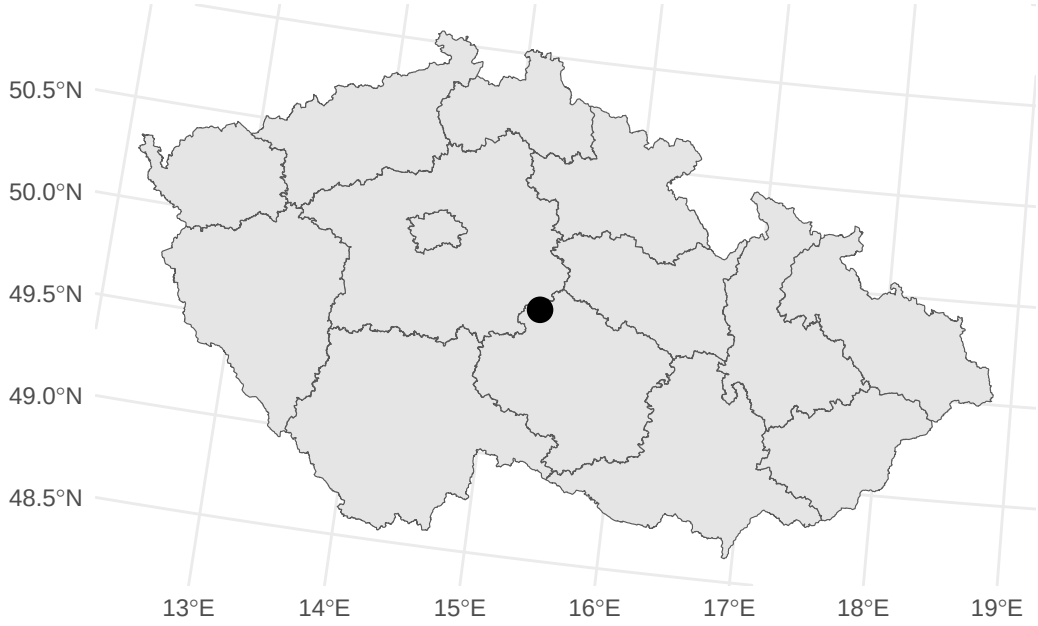
```
 [1] 0 0 0 0 0 0 0 0 0 1 0 0 0 0
```

```
lengths(prunik) > 0
```

```
 [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE  TRUE FALSE FALSE
[13] FALSE FALSE
```

```
kraje %>%
  dplyr::filter(lengths(prunik) > 0)
```

```
Simple feature collection with 1 feature and 3 fields
Geometry type: MULTIPOLYGON
Dimension:     XY
Bounding box:  xmin: -719989.4 ymin: -1181194 xmax: -607864.3 ymax: -1077931
Projected CRS: S-JTSK / Krovak East North
  KOD_KRAJ KOD_CZNUTS3   NAZ_CZNUTS3                       geometry
1     3107       CZ063 Kraj Vysočina MULTIPOLYGON (((-711377.1 -...
```



Writing/reading spatial data

`st_read()` – reads spatial data from the path (data source name, and layer name)
`st_write()` – writes an object to a specified path (DNS and layer name)

The functions detect what *driver* to use by the extension.

- For vector data, use OGC GeoPackage format (.gpkg)
- Do not use ESRI Shapefile (.shp) – it is old and has many limitations (see here for discussion)

```
st_write(republika, here::here("czrep.gpkg"))
```

```
Writing layer `czrep' to data source
  `<...>/czrep.gpkg' using driver `GPKG'
Writing 1 features with 1 fields and geometry type Polygon.
```

```
republika <- st_read(here::here("czrep.gpkg"))
```

```
Reading layer `czrep' from data source `<...>/czrep.gpkg' using driver `GPKG'
Simple feature collection with 1 feature and 1 field
```

```
Geometry type: POLYGON
Dimension:     XY
Bounding box:  xmin: -904576.9 ymin: -1227293 xmax: -431723.3 ymax: -935236.5
Projected CRS: S-JTSK / Krovak East North
```

Exercise

1. Find out how many *radiocarbon dated samples* are located within distance 15 km (or closer) from Brno.

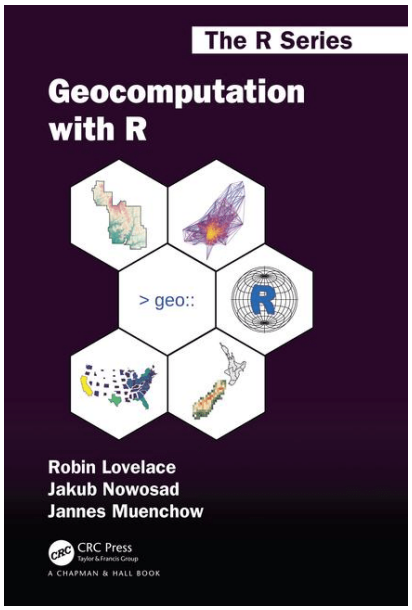
Brno is this point:

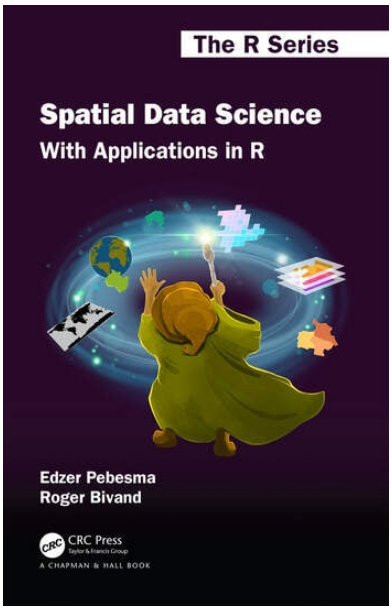
```
brno <- st_point(c(16.6078411, 49.2002211)) %>%
          st_geometry() %>%
          st_set_crs("EPSG:4326")
```

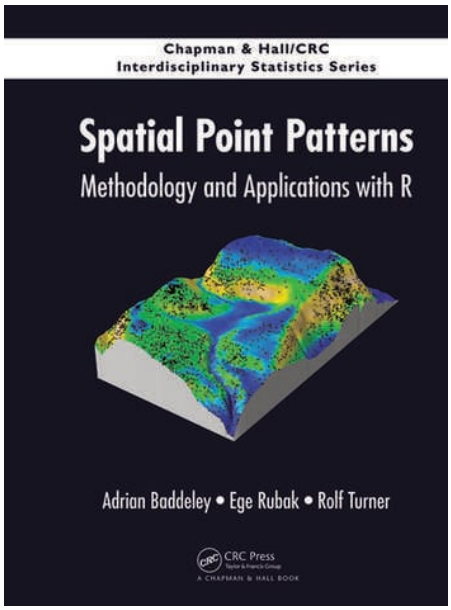
2. How many of these radiocarbon dates are from hillforts (`Site_category_ENG`)?
3. Create map of the Czech republic with a point showing Brno.
4. Create a map of all *radiocarbon dated samples* in *Jihomoravský kraj*.

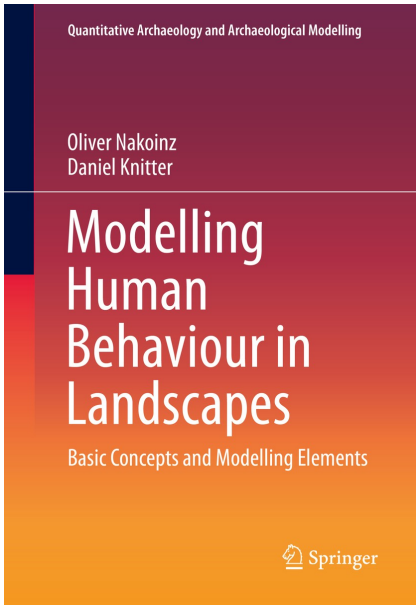
Where to learn more...

- CRAN Task View: Analysis of Spatial Data
- Books:








Quantitative Archaeology and Archaeological Modelling
Oliver Nakoinz
Daniel Knitter
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