

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

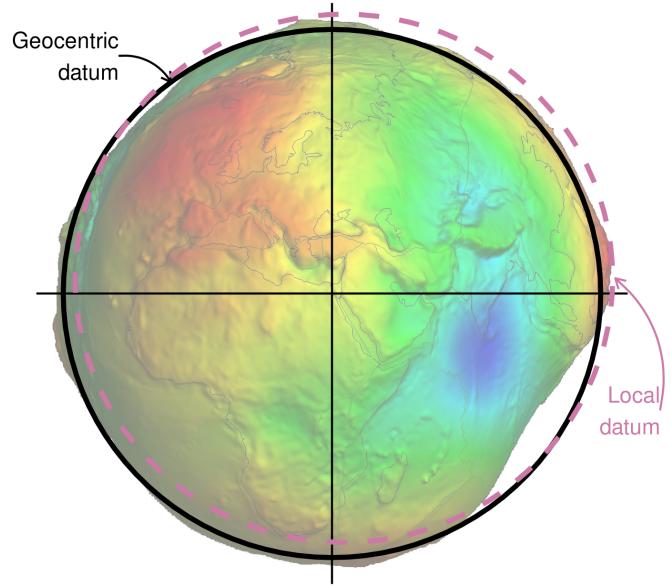
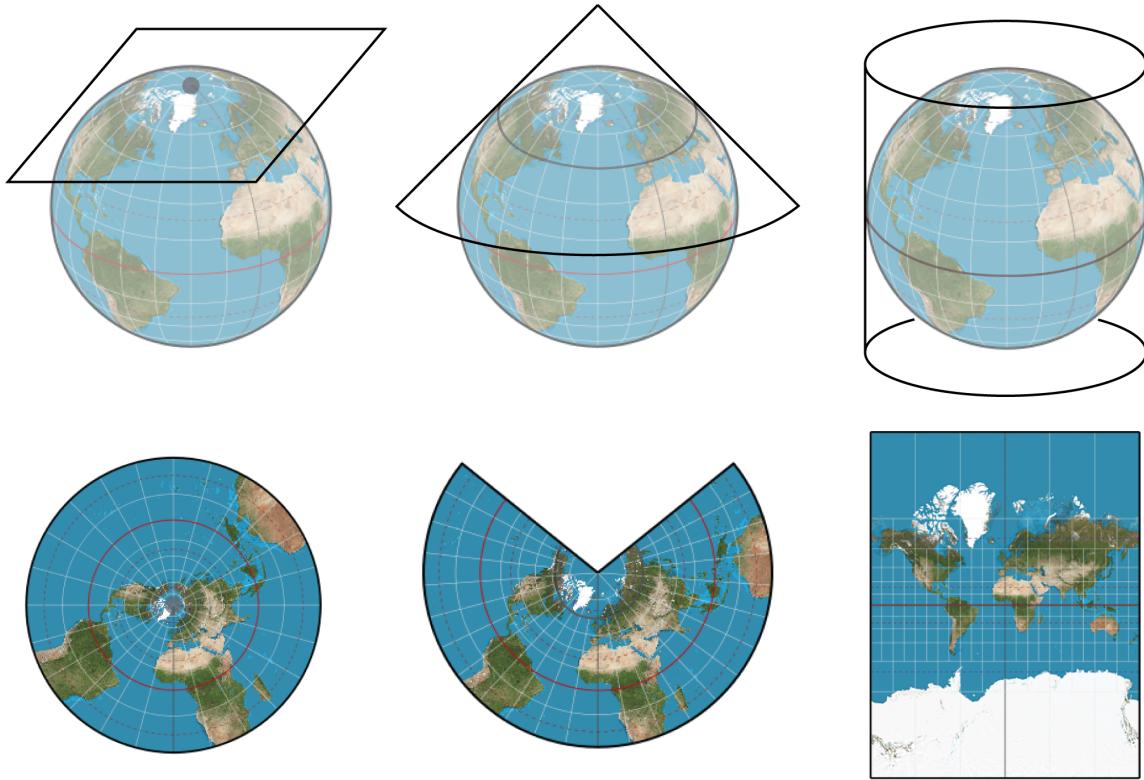


Figure 1: Geocentric and local geodetic datums shown on top of a geoid (in false color and the vertical exaggeration by 10,000 scale factor). From Lovelace, Nowosad, Muenchow: [Geocomputation with R](#)

Projections

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



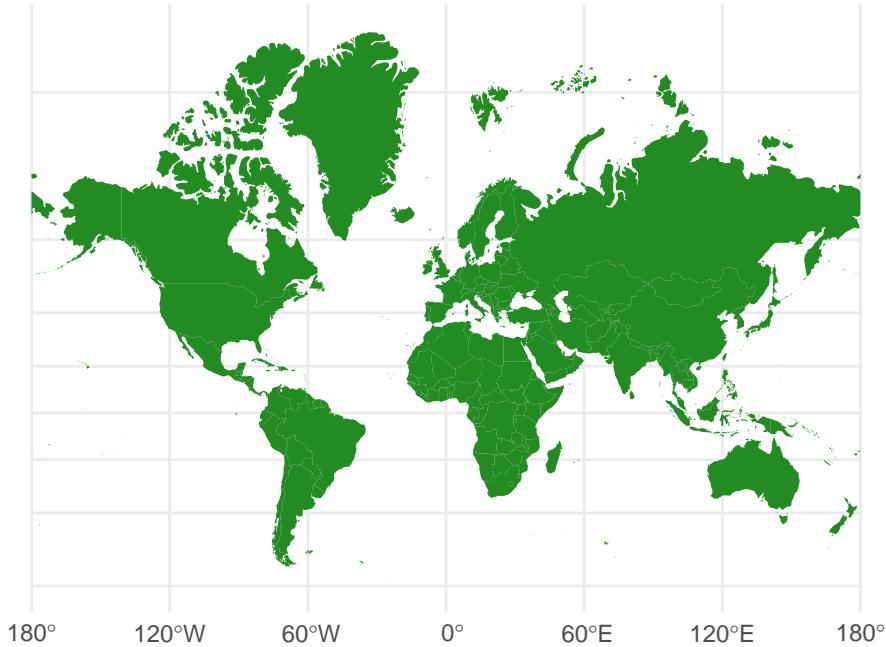


Figure 2: Mercator (1569)

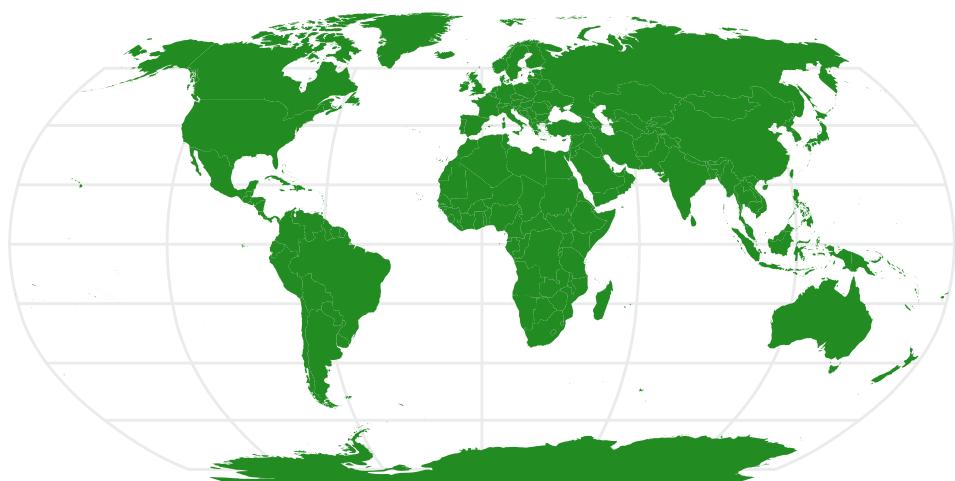


Figure 3: Robinson (1963)

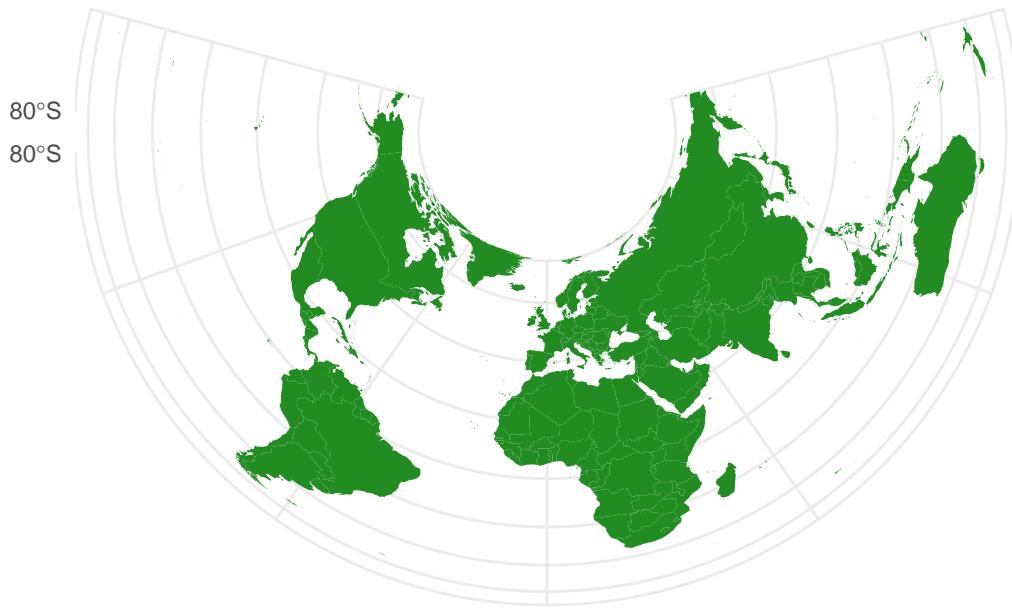


Figure 4: Albers (1805)

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:
 $N\ 49^{\circ}44.62543'$, $E\ 15^{\circ}20.31830'$
- 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!

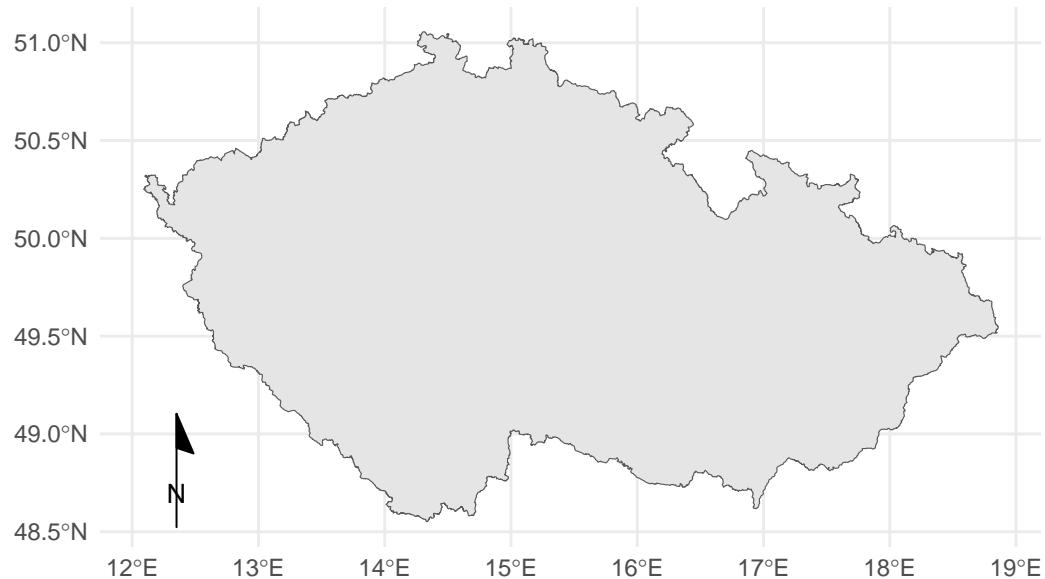
S-JTSK / Křovák East North

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

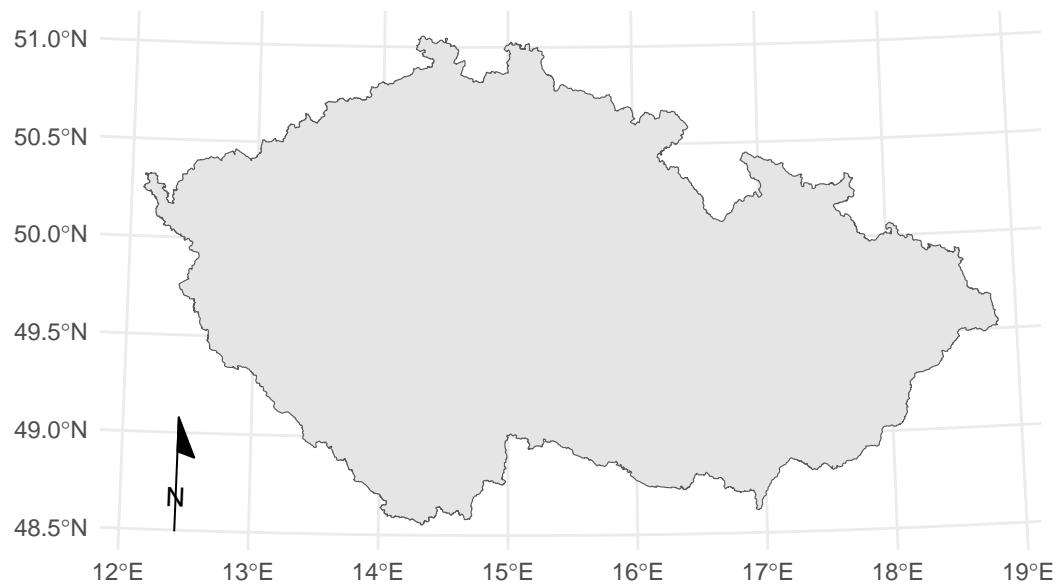
WGS 84 / UTM

- 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

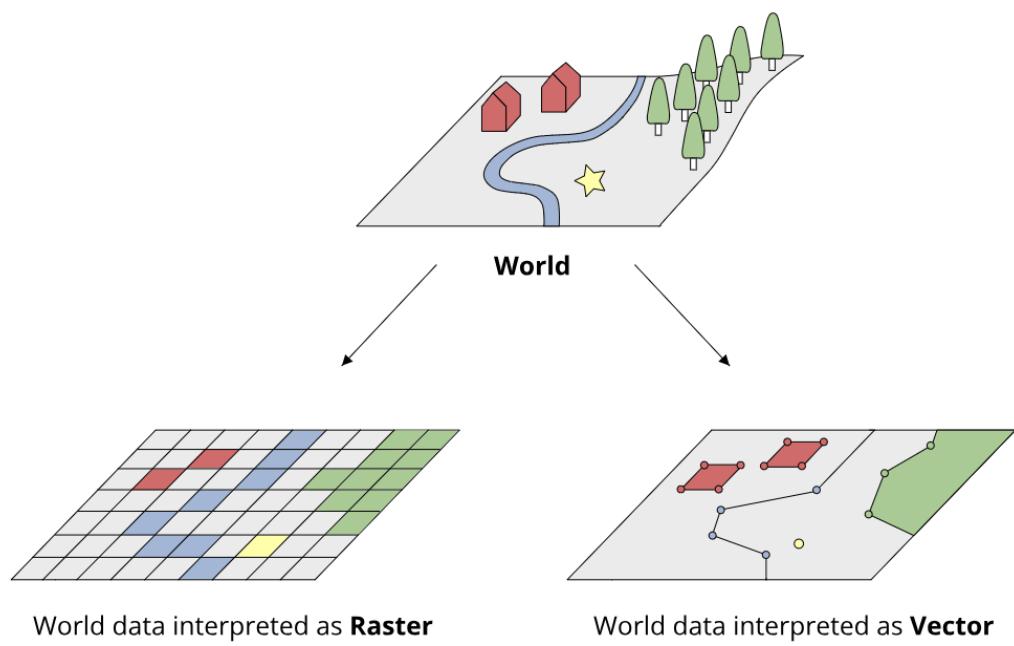


Figure 5: From <https://urstudio.sec.sg/wp-content/uploads/2022/03/featured-3.png>

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 predecessor, `raster`
- [stars package](#) – spatiotemporal arrays, raster and vector data cubes

Spatial statistics

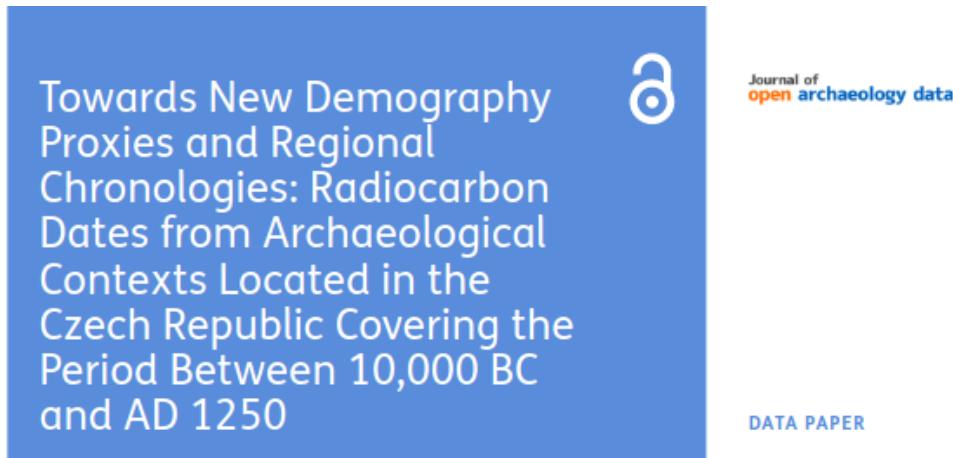
- [spatstat package](#)

Making maps

- `ggplot2`
- [tmap package](#) – thematic maps
- [leaflet package](#) – interactive maps

Code along

Dataset



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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](https://doi.org/10.5334/joad.85)
- Data DOI: [10.5281/zenodo.5728242](https://doi.org/10.5281/zenodo.5728242)
- Table [LASOLES_14C_database.csv](#)

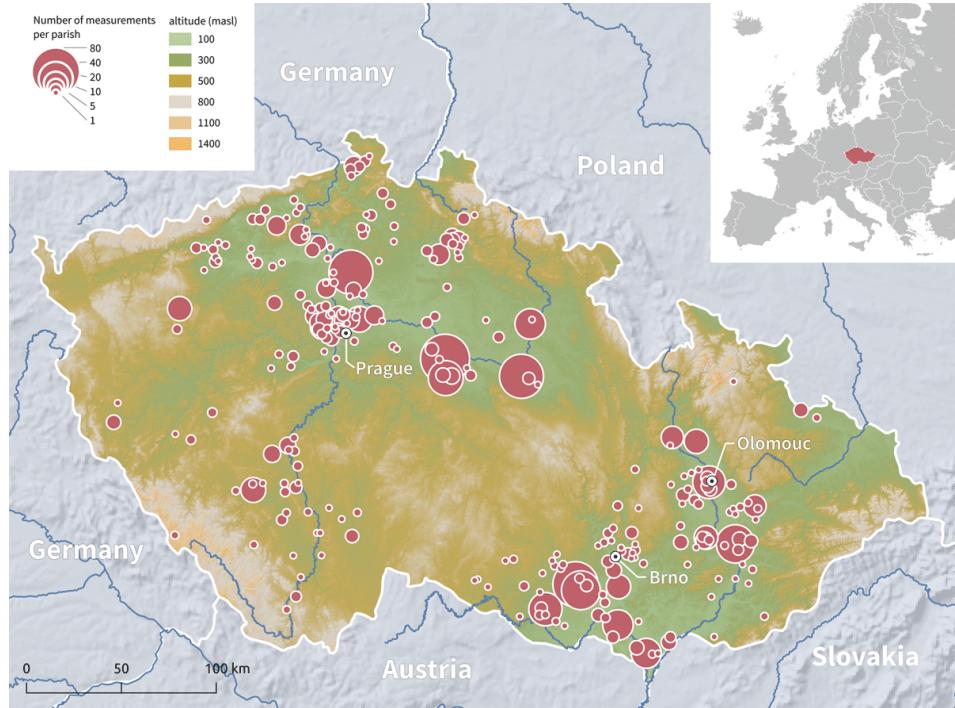


Figure 6: (Tkáč, Kolář 2021)

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"),
                           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)

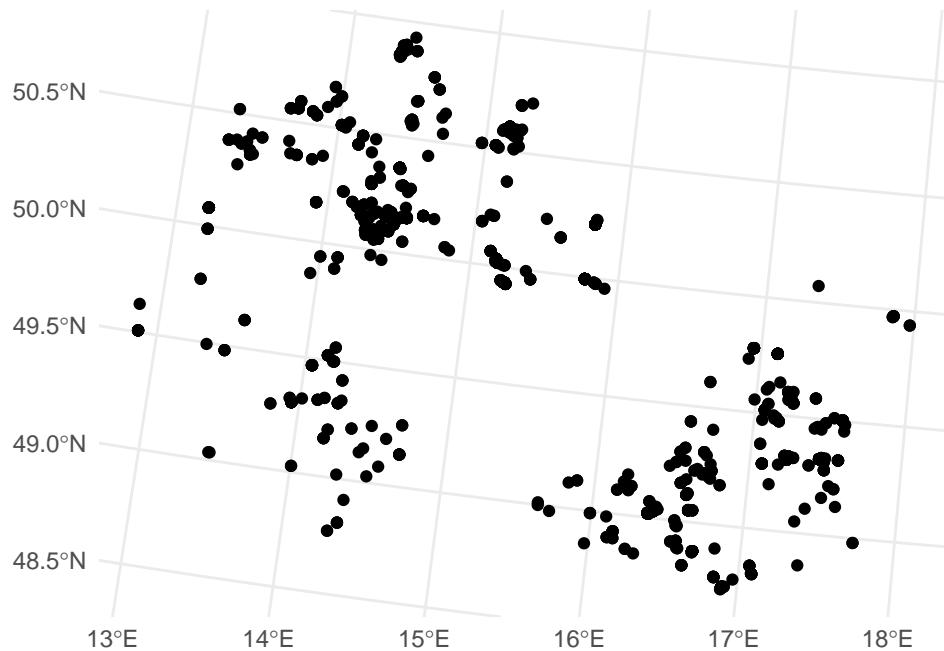
```

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...

```

```

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 -...

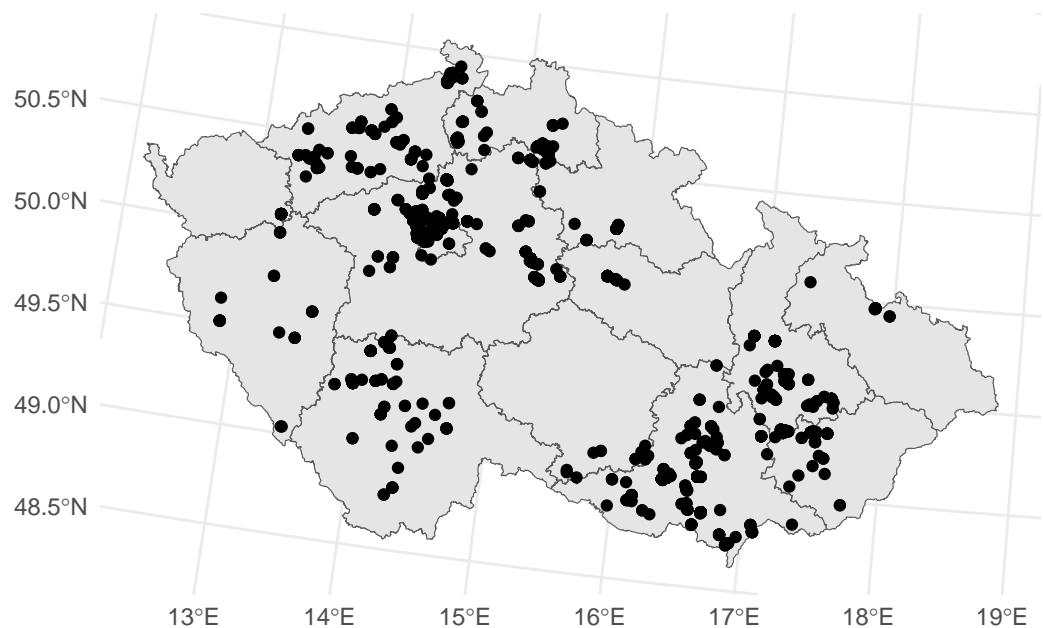
```

Making maps

```

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

```



Geometry operations

Unions

```
st_union()
```

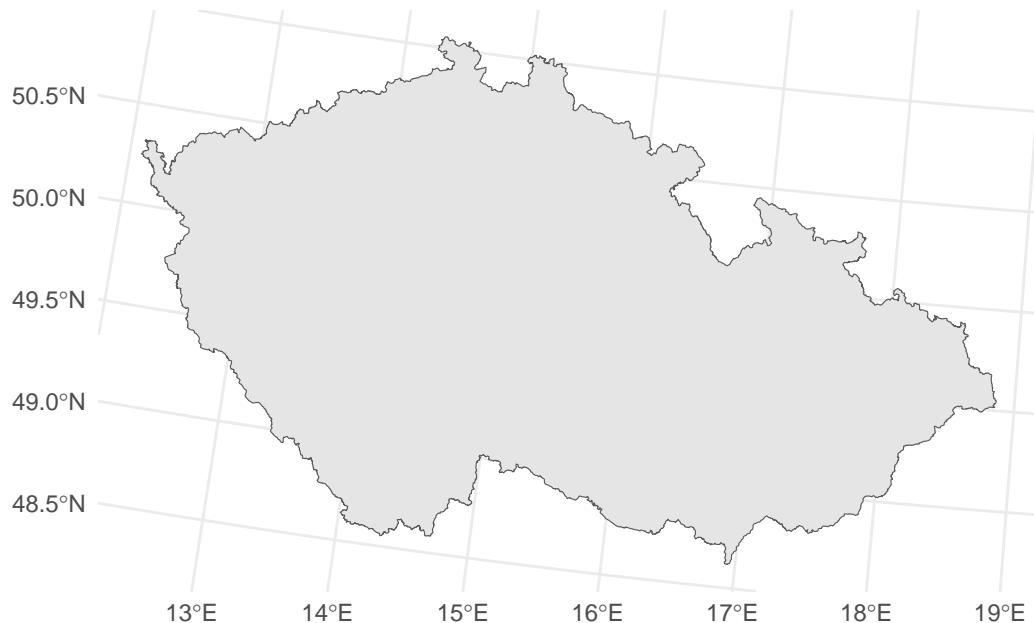
```
head(kraje, 2)
```

```
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_CZNUITS3      NAZ_CZNUITS3           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

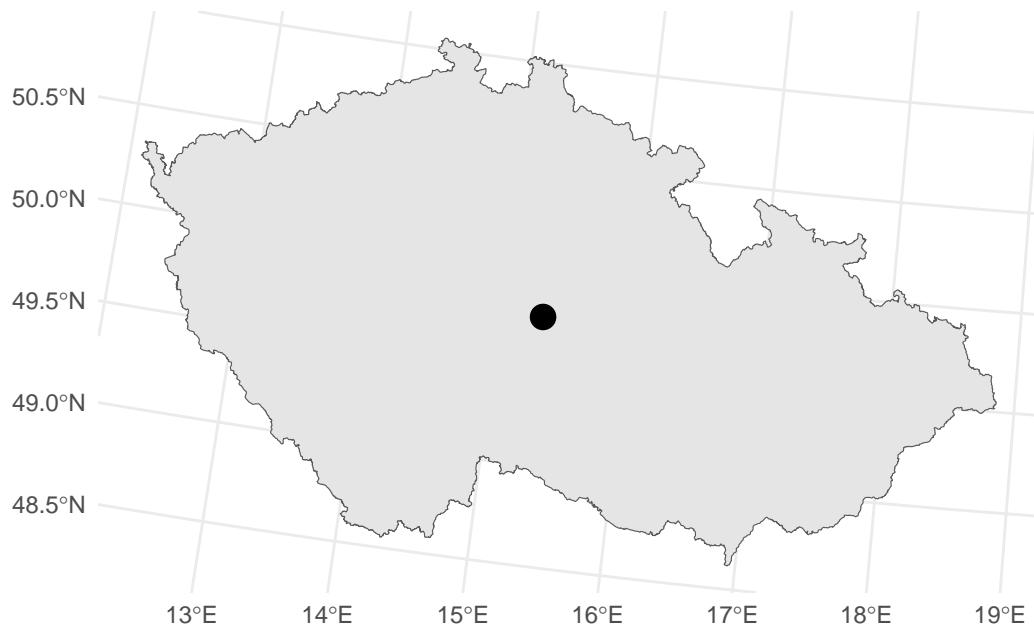
```
st_centroid()
```

```
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()
```



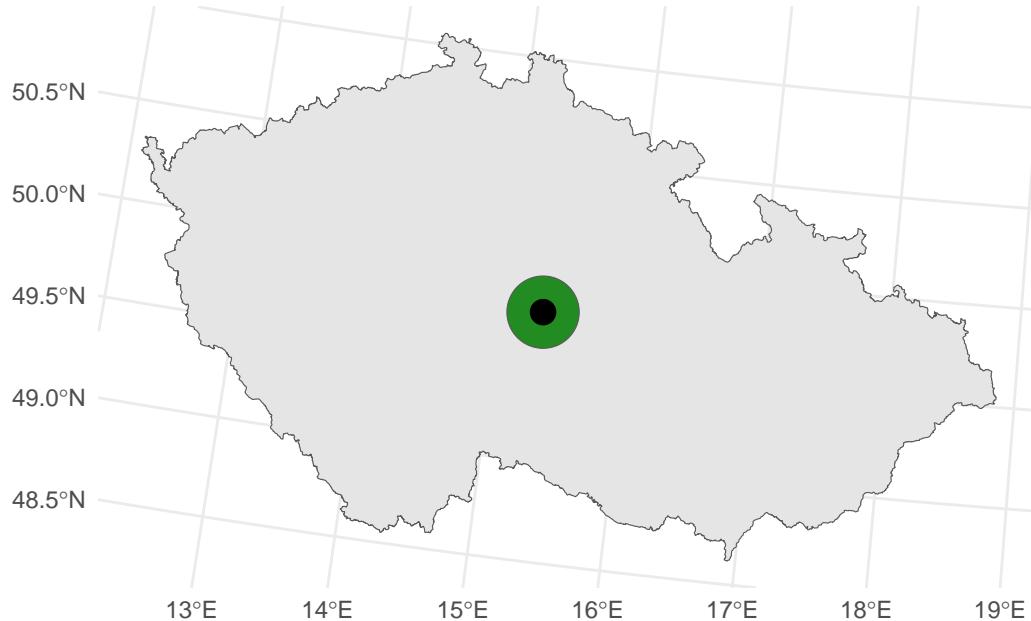
Buffers

```
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 relationships, 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)
```

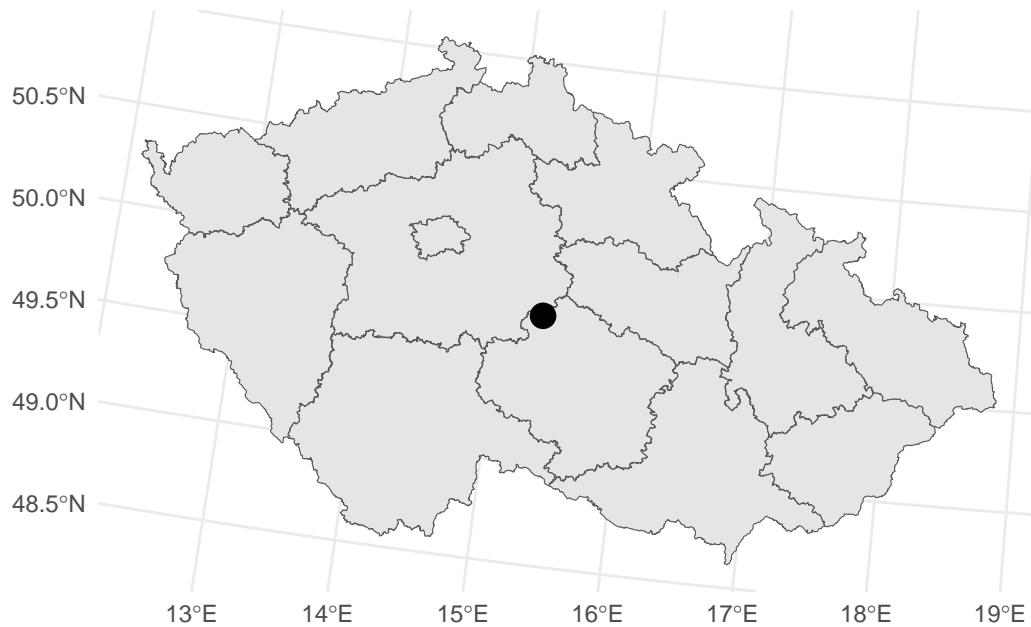
```
[1] 0 0 0 0 0 0 0 0 0 1 0 0 0 0
```

```
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

Modelling Human Behaviour in Landscapes

Basic Concepts and Modelling Elements

 Springer