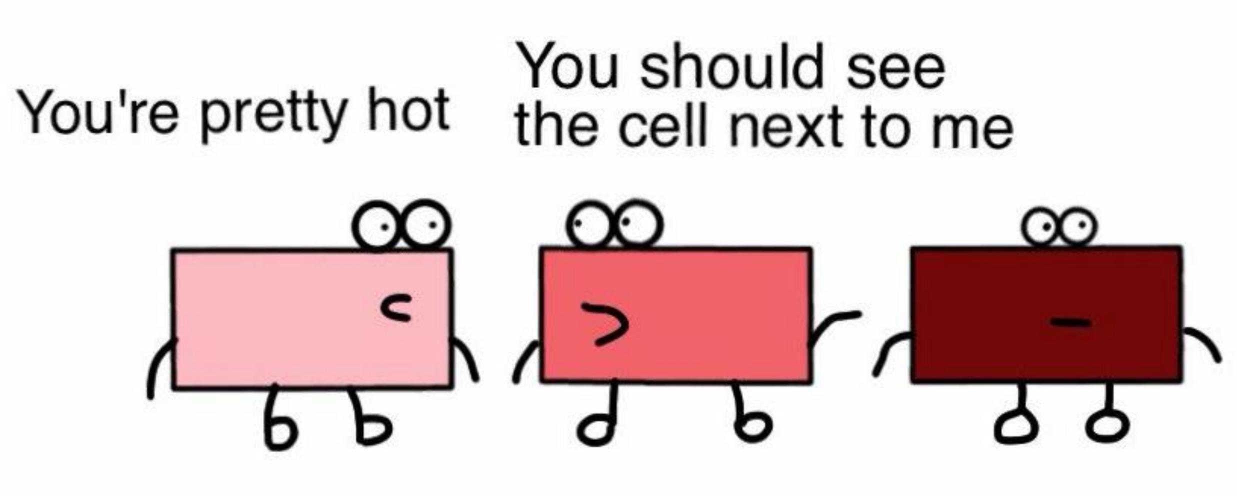


INSP/ESPM
Escuela de Salud Pública de México

Análisis espacial en R

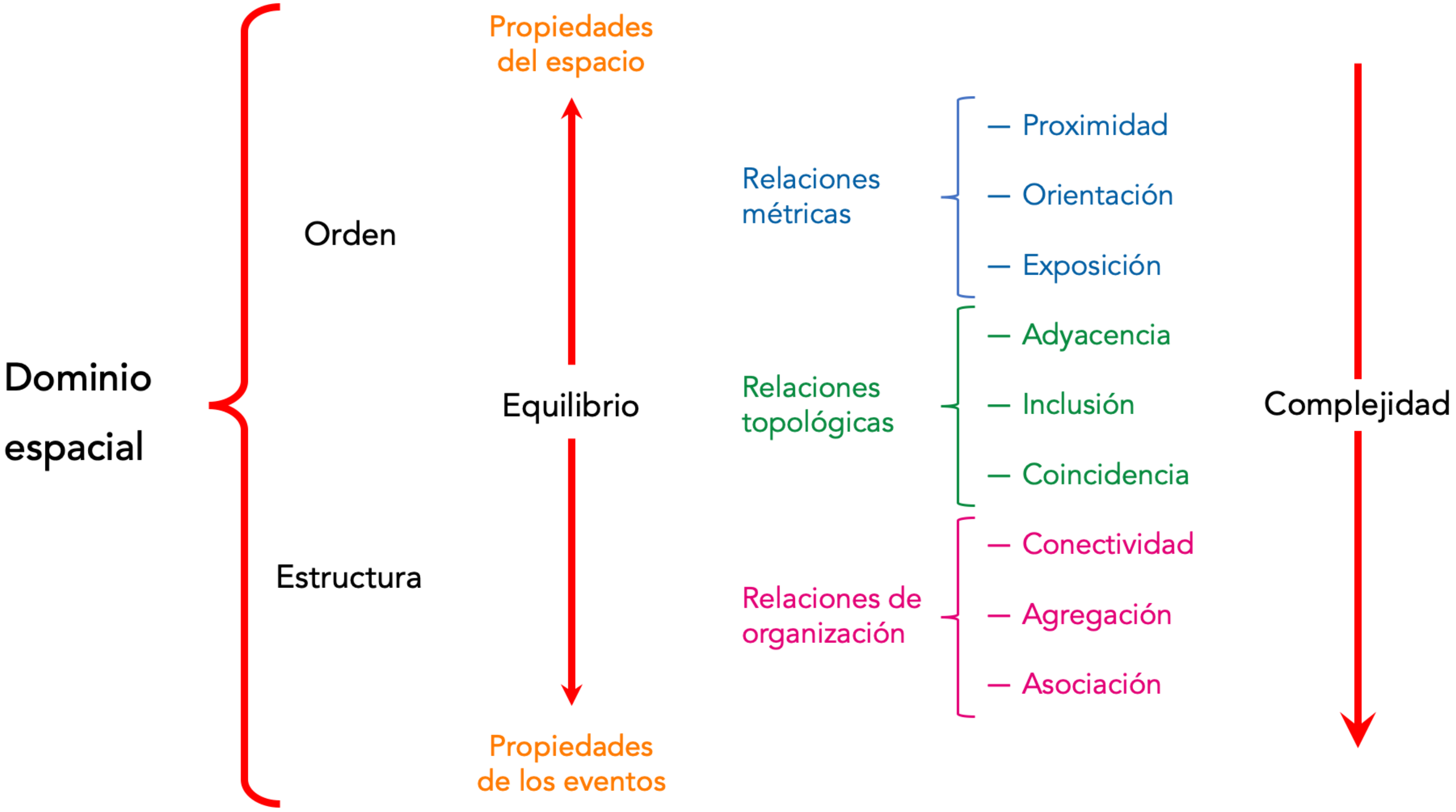
José Luis Texcalac Sangrador

Procesamiento y visualización de datos espaciales en R

Relaciones espaciales

- Son conceptos que surgen de la interacción entre el espacio y los eventos que en el ocurren.
- Se resumen en 9 tipos y tres grandes grupos.
  - Predominio de las propiedades del espacio
  - Equilibrio entre las propiedades del espacio y los eventos que en él ocurren.
  - Patrones espaciales definidos por las propiedades del espacio y los eventos que en él ocurren.

Relaciones espaciales



Dominio espacial

Orden

Estructura

Propiedades del espacio

Equilibrio

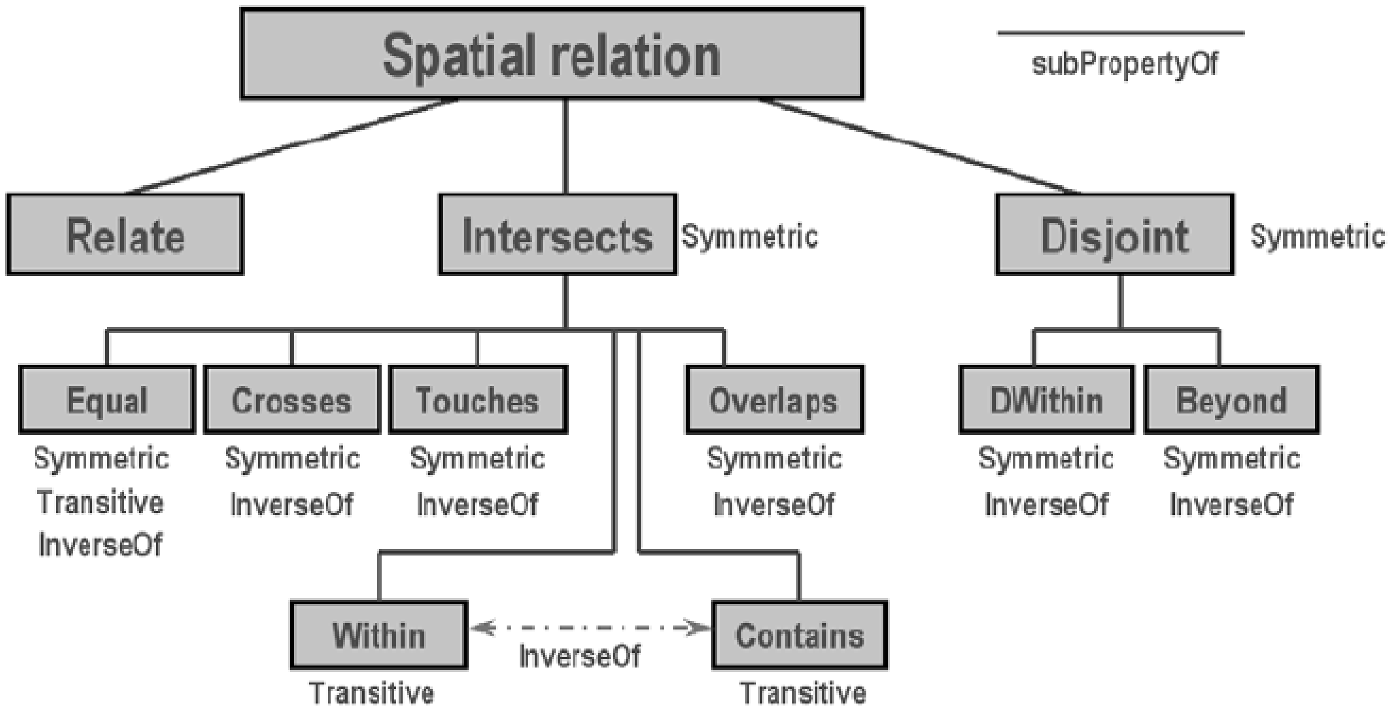
Propiedades de los eventos

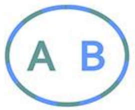
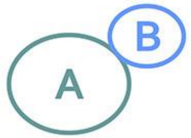
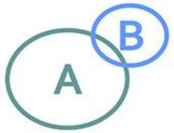
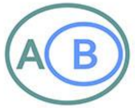
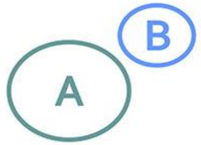
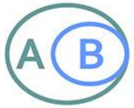
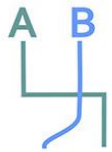
Relaciones métricas
- Proximidad
- Orientación
- Exposición

Relaciones topológicas
- Adyacencia
- Inclusión
- Coincidencia

Relaciones de organización
- Conectividad
- Agregación
- Asociación

Complejidad



Equals A is the same as B	
Touches A touches B	
Overlaps A and B have multiple points in common	
Contains A contains B	
Disjoint A shares nothing with B	
Covers A covers B (or vice versa)	
Crosses A and B have at least one point in common	

Spatial manipulation with sf: : CHEAT SHEET

The sf package provides a set of tools for working with geospatial vectors, i.e. points, lines, polygons, etc.

Geometric confirmation

st_contains(x, y, ...) Identifies if y is within x (i.e. point within polygon)

st_covered_by(x, y, ...) Identifies if x is completely within y (i.e. polygon completely within polygon)

st_covers(x, y, ...) Identifies if any point from x is outside of y (i.e. polygon outside polygon)

st_crosses(x, y, ...) Identifies if any geometry of x have commonalities with y

st_disjoint(x, y, ...) Identifies when geometries from x do not share space with y

st_equals(x, y, ...) Identifies if x and y share the same geometry

st_intersects(x, y, ...) Identifies if x and y geometry share any space

st_overlaps(x, y, ...) Identifies if geometries of x and y share space, are of the same dimension, but are not completely contained by each other

st_touches(x, y, ...) Identifies if geometries of x and y share a common point but their interiors do not intersect

st_within(x, y, ...) Identifies if x is in a specified distance to y

Geometric operations

st_boundary(x) Creates a polygon that encompasses the full extent of the geometry

st_buffer(x, dist, nQuadSegs) Creates a polygon covering all points of the geometry within a given distance

st_centroid(x, ..., of_largest_polygon) Creates a point at the geometric centre of the geometry

st_convex_hull(x) Creates geometry that represents the minimum convex geometry of x

st_line_merge(x) Creates linestring geometry from sewing multi linestring geometry together

st_node(x) Creates nodes on overlapping geometry where nodes do not exist

st_point_on_surface(x) Creates a point that is guarenteed to fall on the surface of the geometry

st_polygonize(x) Creates polygon geometry from linestring geometry

st_segmentize(x, dfMaxLength, ...) Creates linesting geometry from x based on a specified length

st_simplify(x, preserveTopology, dTolerance) Creates a simplified version of the geometry based on a specified tolerance

Geometry creation

st_triangulate(x, dTolerance, bOnlyEdges) Creates polygon geometry as triangles from point geometry

st_voronoi(x, envelope, dTolerance, bOnlyEdges) Creates polygon geometry covering the envelope of x, with x at the centre of the geometry

st_point(x, c(numeric vector), dim = "XYZ") Creating point geometry from numeric values

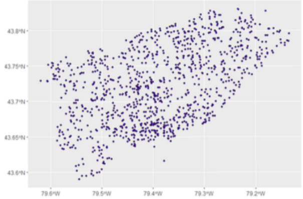
st_multipoint(x = matrix(numeric values in rows), dim = "XYZ") Creating multi point geometry from numeric values

st_linestring(x = matrix(numeric values in rows), dim = "XYZ") Creating linestring geometry from numeric values

st_multilinestring(x = list(numeric matricesin rows), dim = "XYZ") Creating multi linestring geometry from numeric values

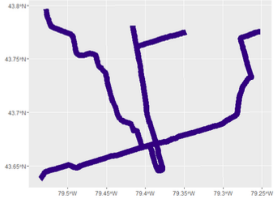
st_polygon(x = list(numeric matrices in rows), dim = "XYZ") Creating polygon geometry from numeric values

st_multipolygon(x = list(numeric matrices in rows), dim = "XYZ") Creating multi polygon geometry from numeric values



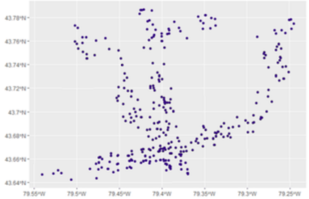
```
ggplot() +
  geom_sf(data = schools)
```

+



```
ggplot() +
  geom_sf(data = subway)
```

=>



```
ggplot() +
  geom_sf(data = st_intersection(schools, st_buffer(subway, 1000)))
```

This cheatsheet presents the sf package [Edzer Pebesma 2018] in version 0.6.3.   See https://github.com/r-spatial/sf for more details.

Spatial manipulation with sf: : CHEAT SHEET

The sf package provides a set of tools for working with geospatial vectors, i.e. points, lines, polygons, etc.

Geometry operations

st_contains(x, y, ...) Identifies if y is within x (i.e. point within polygon)

st_crop(x, y, ..., xmin, ymin, xmax, ymax) Creates geometry of x that intersects a specified rectangle

st_difference(x, y) Creates geometry from x that does not intersect with y

st_intersection(x, y) Creates geometry of the shared portion of x and y

st_sym_difference(x, y) Creates geometry representing portions of x and y that do not intersect

st_snap(x, y, tolerance) Snap nodes from geometry x to geometry y

st_union(x, y, ..., by_feature) Creates multiple geometries into a a single geometry, consisiting of all geometry elements

Geometric measurement

st_area(x) Calculate the surface area of a polygon geometry based on the current coordinate reference system

st_distance(x, y, ..., dist_fun, by_element, which) Calculates the 2D distance between x and y based on the current coordinate system

st_length(x) Calculates the 2D length of a geometry based on the current coordinate system

Misc operations

st_as_sf(x, ...) Create a sf object from a non-geospatial tabular data frame

st_cast(x, to, ...) Change x geometry to a different geometry type

st_coordinates(x, ...) Creates a matrix of coordinate values from x

st_crs(x, ...) Identifies the coordinate reference system of x

st_join(x, y, join, FUN, suffix, ...) Performs a spatial left or inner join between x and y

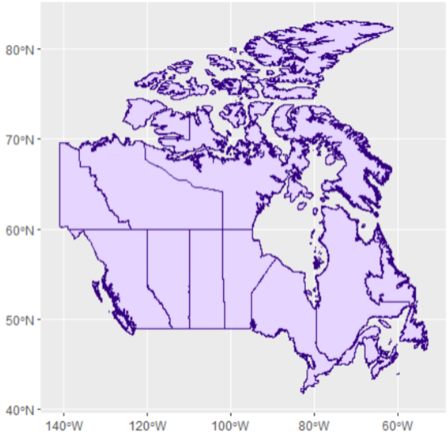
st_make_grid(x, cellsize, offset, n, crs, what) Creates rectangular grid geometry over the bounding box of x

st_nearest_feature(x, y) Creates an index of the closest feature between x and y

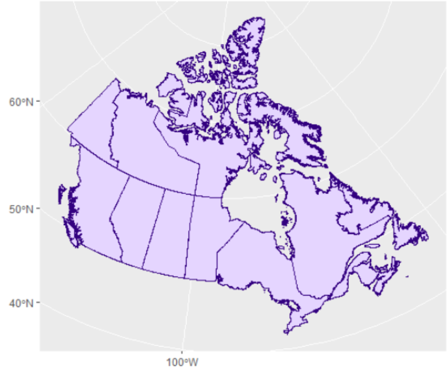
st_nearest_points(x, y, ...) Returns the closest point between x and y

st_read(dsn, layer, ...) Read file or database vector dataset as a sf object

st_transform(x, crs, ...) Convert coordinates of x to a different coordinate reference system



```
ggplot() +
  geom_sf(data = cdn) +
  coord_sf(crs = st_crs(4326))
```



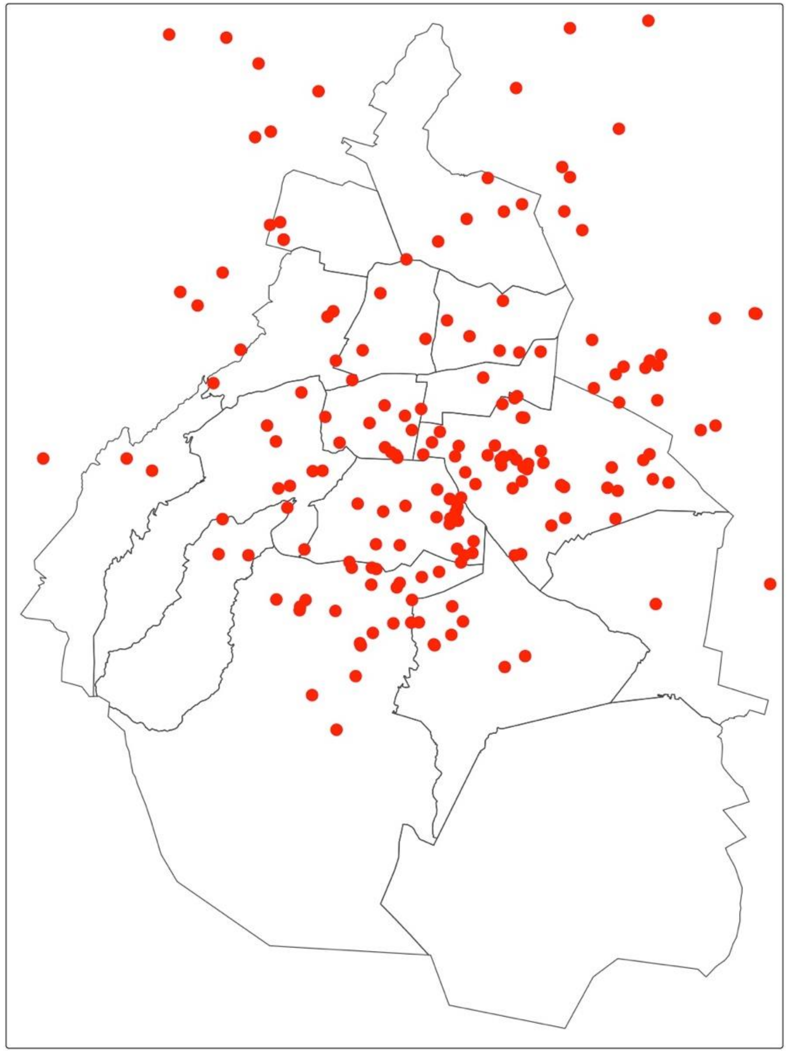
```
ggplot() +
  geom_sf(data = cdn) +
  coord_sf(crs = st_crs(3347))
```

This cheatsheet presents the sf package [Edzer Pebesma 2018] in version 0.6.3. See https://github.com/r-spatial/sf for more details.

¿Qué folios están dentro de CDMX?

```r
tm_shape(cdmx) +
  tm_borders() +
  tm_shape(sitios) +
  tm_dots(fill = "red")
```

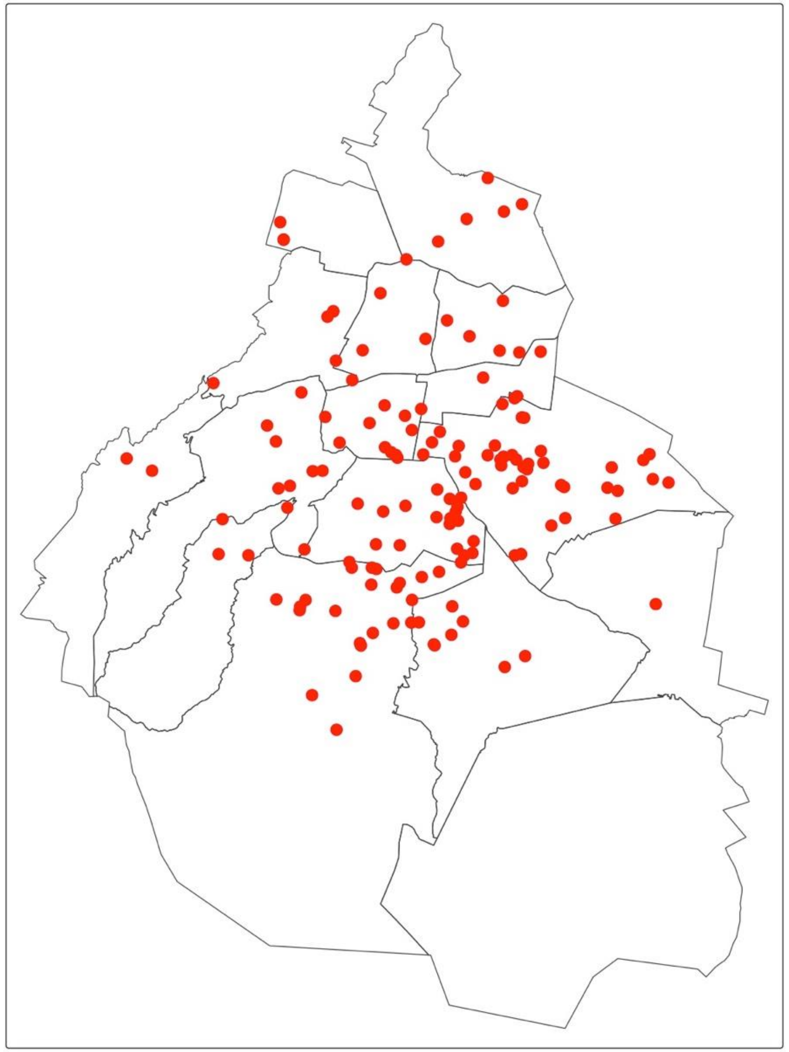
```r
sitios_cdmx <-
  st_filter(sitios, cdmx) %>%
  print()
```



¿Qué folios están dentro de CDMX?

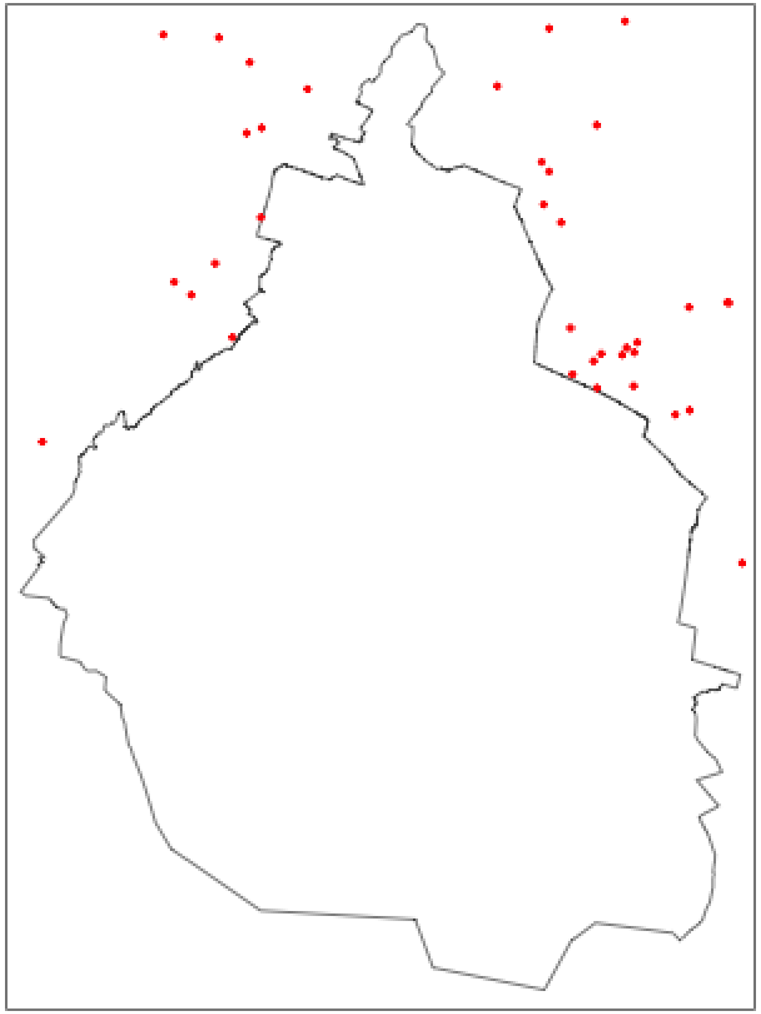
```
tm_shape(cdmx) +
  tm_borders() +
  tm_shape(sitios_cdmx) +
  tm_dots(fill = "red")
```

```
tm_shape(cdmx) +
  tm_borders() +
  tm_shape(st_filter(sitios, cdmx)) +
  tm_dots(fill = "red")
```

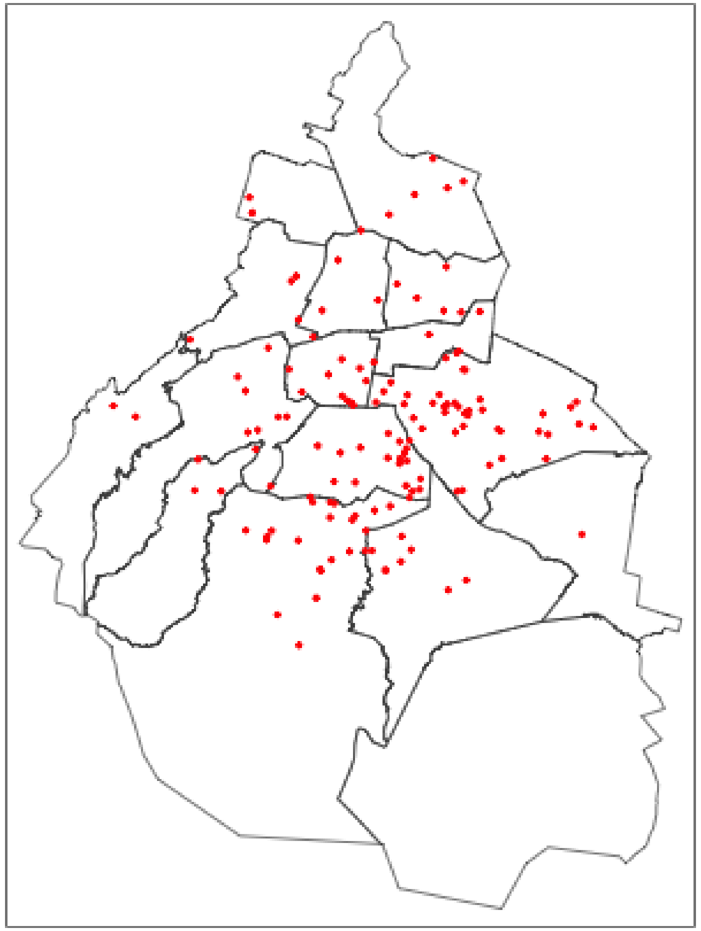


¿Qué folios están fuera de CDMX?

```
pts_cdmx <-
  st_filter(sitios, cdmx) %>%
  print()
```



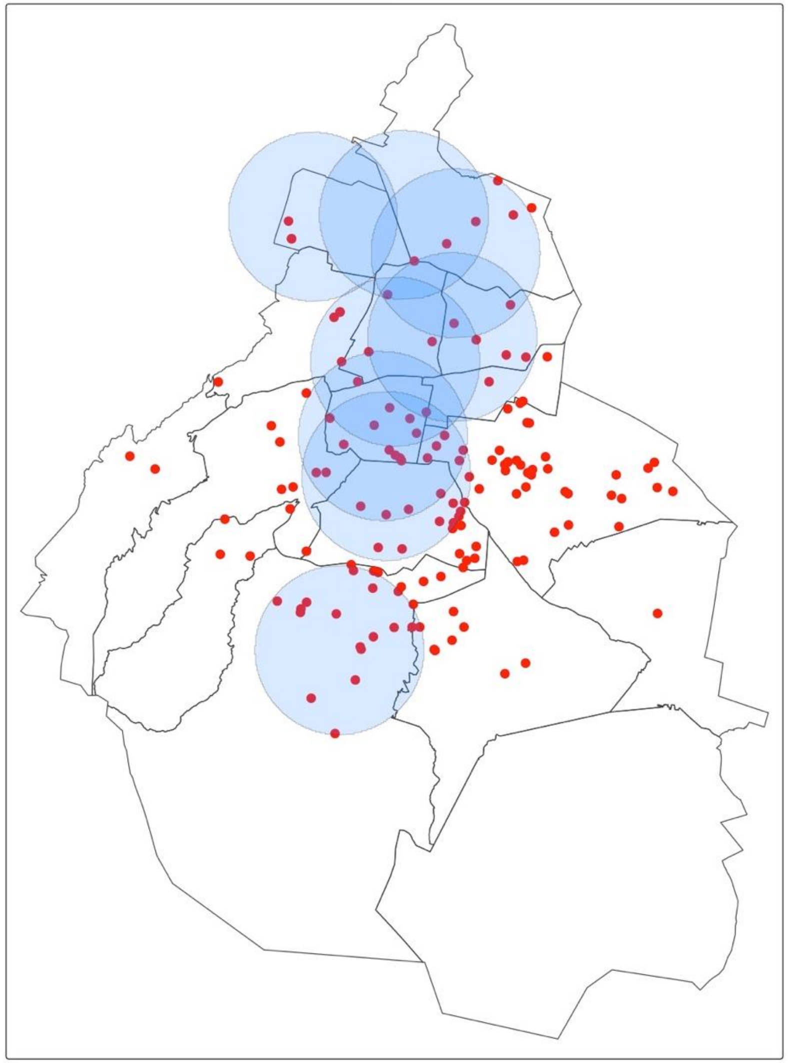
¿A qué alcaldía corresponde cada folio?



```
st_join(sitios, cdmx, join = st_within)
```

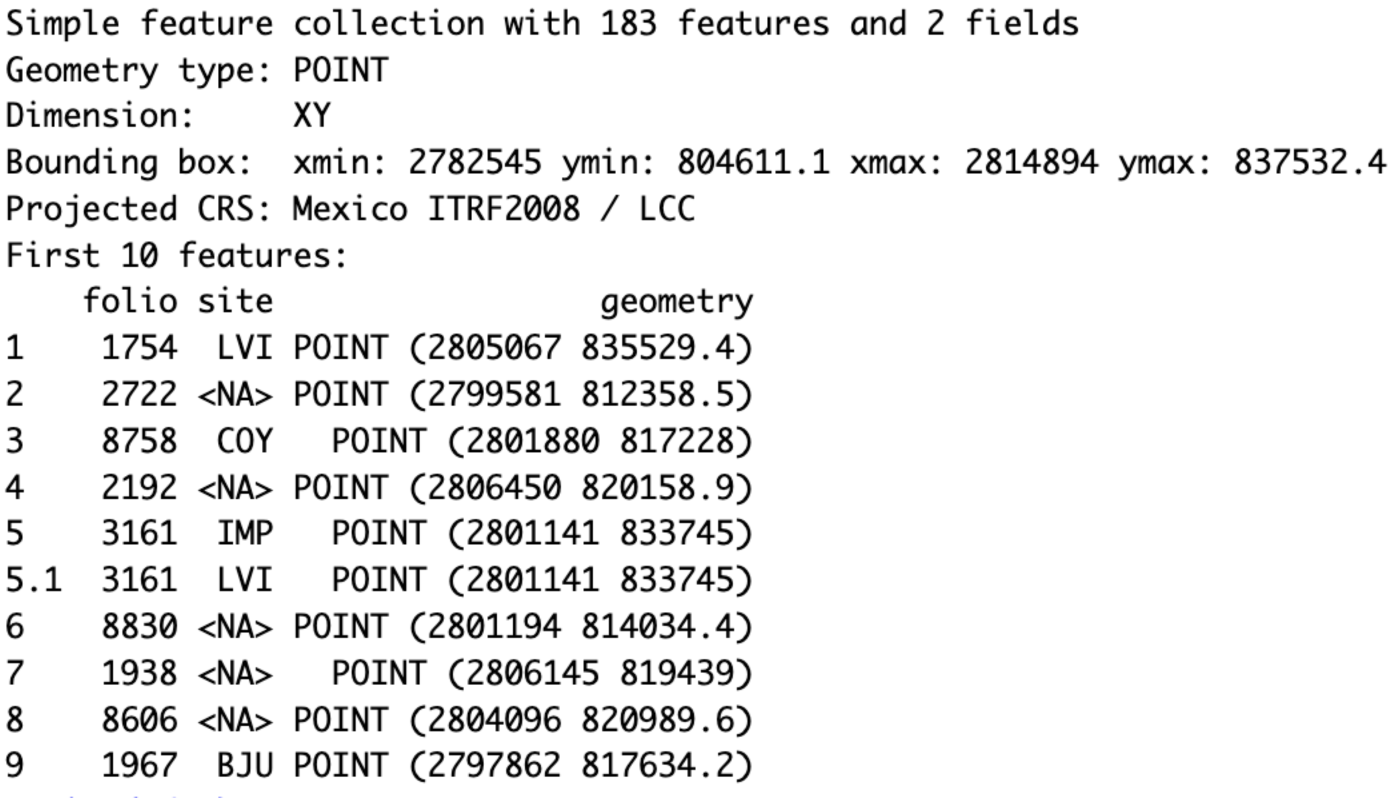
Área de influencia de un punto (buffer)

```
buf_monit <-
  st_buffer(monit, 5000, nQuadSegs = 30) %>%
  print()
```



¿En qué buffer o buffers cae cada folio?

```
st_join(sitios_cdmx,
         buf_monit)
```

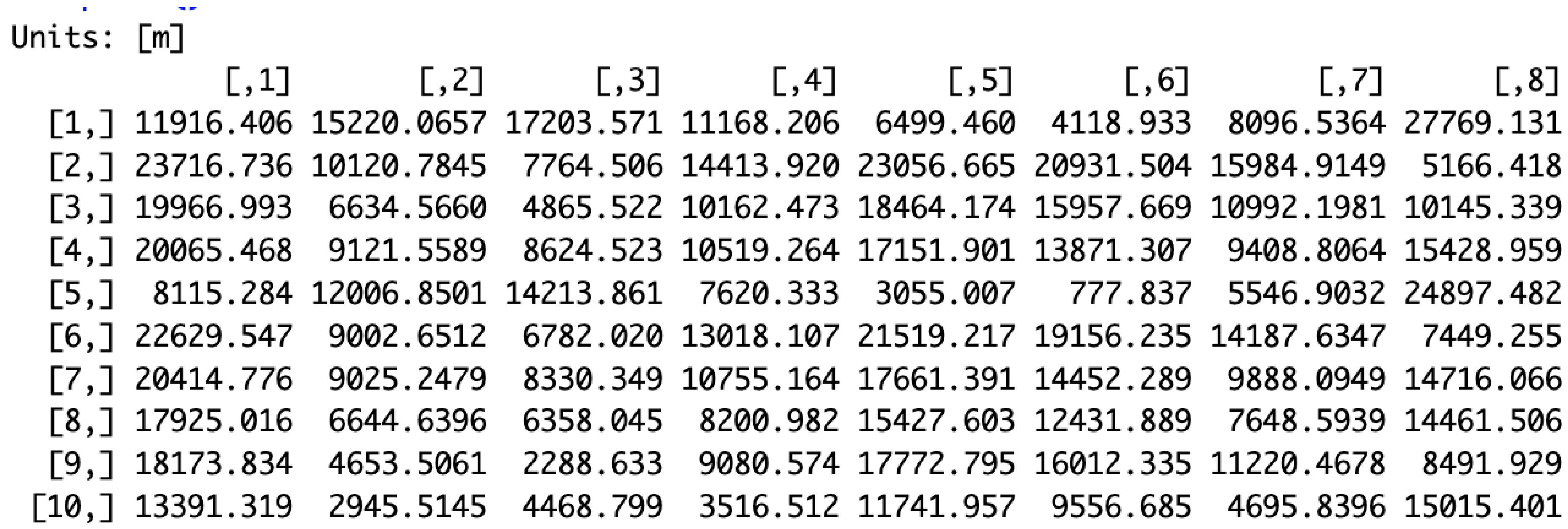


```
Simple feature collection with 183 features and 2 fields
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 2782545 ymin: 804611.1 xmax: 2814894 ymax: 837532.4
Projected CRS: Mexico ITRF2008 / LCC
First 10 features:
    folio site                  geometry
1    1754  LVI POINT (2805067 835529.4)
2    2722 <NA> POINT (2799581 812358.5)
3    8758  COY   POINT (2801880 817228)
4    2192 <NA> POINT (2806450 820158.9)
5    3161  IMP   POINT (2801141 833745)
5.1  3161  LVI   POINT (2801141 833745)
6    8830 <NA> POINT (2801194 814034.4)
7    1938 <NA>   POINT (2806145 819439)
8    8606 <NA> POINT (2804096 820989.6)
9    1967  BJU POINT (2797862 817634.2)
```

¿Cuál es la distancia entre folios y estaciones de monitoreo?

```
dist <-
  st_distance(sitios_cdmx, monit) %>%
  print()
```

El resultado es una matriz



```
Units: [m]
           [,1]       [,2]      [,3]      [,4]      [,5]      [,6]       [,7]      [,8]
 [1,] 11916.406 15220.0657 17203.571 11168.206  6499.460  4118.933  8096.5364 27769.131
 [2,] 23716.736 10120.7845  7764.506 14413.920 23056.665 20931.504 15984.9149  5166.418
 [3,] 19966.993  6634.5660  4865.522 10162.473 18464.174 15957.669 10992.1981 10145.339
 [4,] 20065.468  9121.5589  8624.523 10519.264 17151.901 13871.307  9408.8064 15428.959
 [5,]  8115.284 12006.8501 14213.861  7620.333  3055.007   777.837  5546.9032 24897.482
 [6,] 22629.547  9002.6512  6782.020 13018.107 21519.217 19156.235 14187.6347  7449.255
 [7,] 20414.776  9025.2479  8330.349 10755.164 17661.391 14452.289  9888.0949 14716.066
 [8,] 17925.016  6644.6396  6358.045  8200.982 15427.603 12431.889  7648.5939 14461.506
 [9,] 18173.834  4653.5061  2288.633  9080.574 17772.795 16012.335 11220.4678  8491.929
[10,] 13391.319  2945.5145  4468.799  3516.512 11741.957  9556.685  4695.8396 15015.401
```

¿Qué nos falta?

- Transformar a tibble

```r
dist <- as_tibble(dist)
```

- Nombres de columna

```r
names(dist) <- monit$site
```

- Recuperar el folio

```r
names(dist) <- monit$site
```

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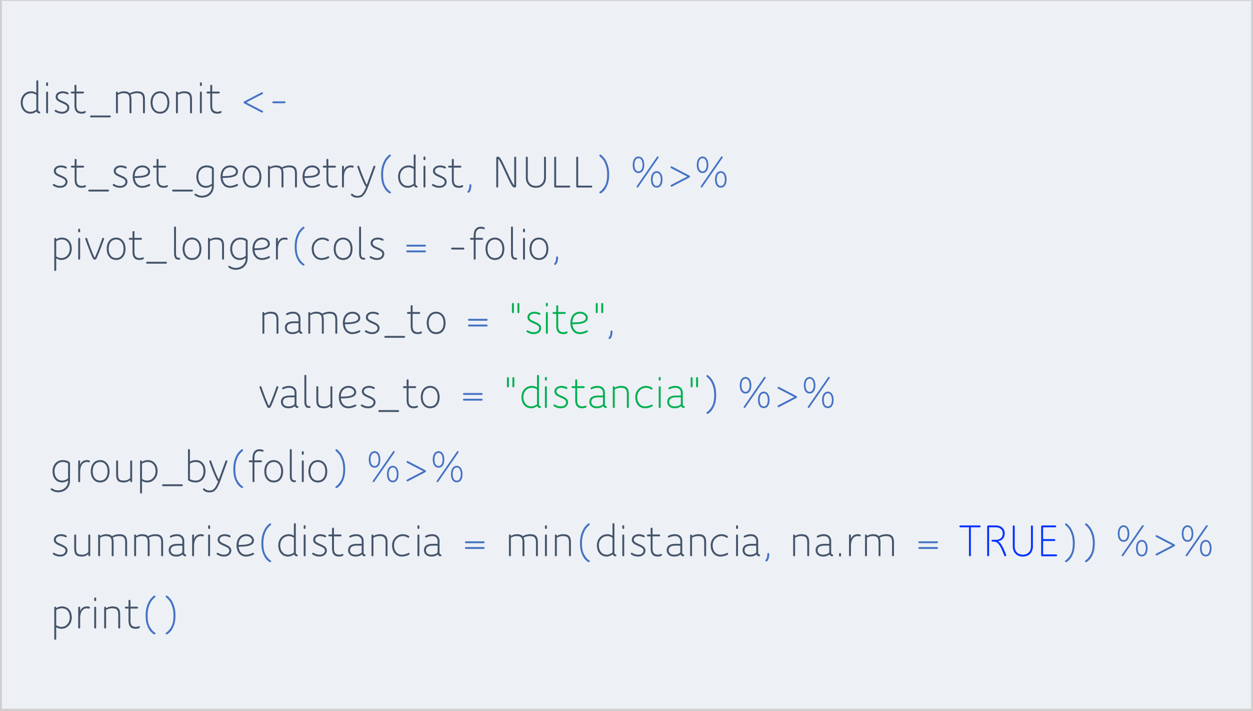
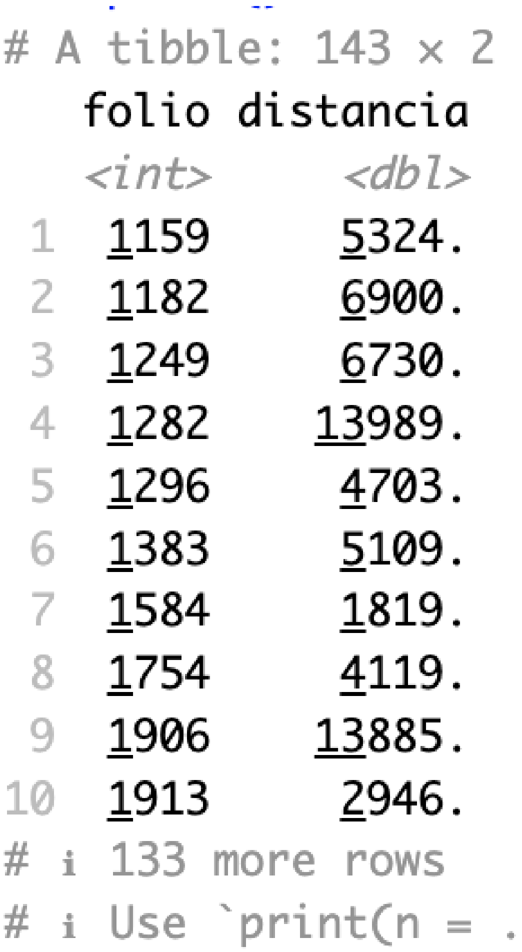
```
st_distance(pts_cdmx, monit) %>%
  as_tibble() %>%
  rename_all(list(~monit$site)) %>%
  bind_cols(pts_cdmx)
```

```
Simple feature collection with 143 features and 9 fields
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 2782545 ymin: 804611.1 xmax: 2814894 ymax: 837532.4
Projected CRS: Mexico ITRF2008 / LCC
First 10 features:
   folio       AZC       BJU       COY       HGM       IMP       LVI       MER       TPN                  geometry
1   1754 11916.406 15220.066 17203.571 11168.206  6499.460  4118.933  8096.536 27769.131 POINT (2805067 835529.4)
2   2722 23716.736 10120.784  7764.506 14413.920 23056.665 20931.504 15984.915  5166.418 POINT (2799581 812358.5)
3   8758 19966.993  6634.566  4865.522 10162.473 18464.174 15957.669 10992.198 10145.339   POINT (2801880 817228)
4   2192 20065.468  9121.559  8624.523 10519.264 17151.901 13871.307  9408.806 15428.959 POINT (2806450 820158.9)
5   3161  8115.284 12006.850 14213.861  7620.333  3055.007   777.837  5546.903 24897.482   POINT (2801141 833745)
6   8830 22629.547  9002.651  6782.020 13018.107 21519.217 19156.235 14187.635  7449.255 POINT (2801194 814034.4)
7   1938 20414.776  9025.248  8330.349 10755.164 17661.391 14452.289  9888.095 14716.066   POINT (2806145 819439)
8   8606 17925.016  6644.640  6358.045  8200.982 15427.603 12431.889  7648.594 14461.506 POINT (2804096 820989.6)
9   1967 18173.834  4653.506  2288.633  9080.574 17772.795 16012.335 11220.468  8491.929 POINT (2797862 817634.2)
10  1913 13391.319  2945.514  4468.799  3516.512 11741.957  9556.685  4695.840 15015.401 POINT (2800127 823754.8)
```

¿Cuál es la distancia entre cada folio y la estación más cercana?



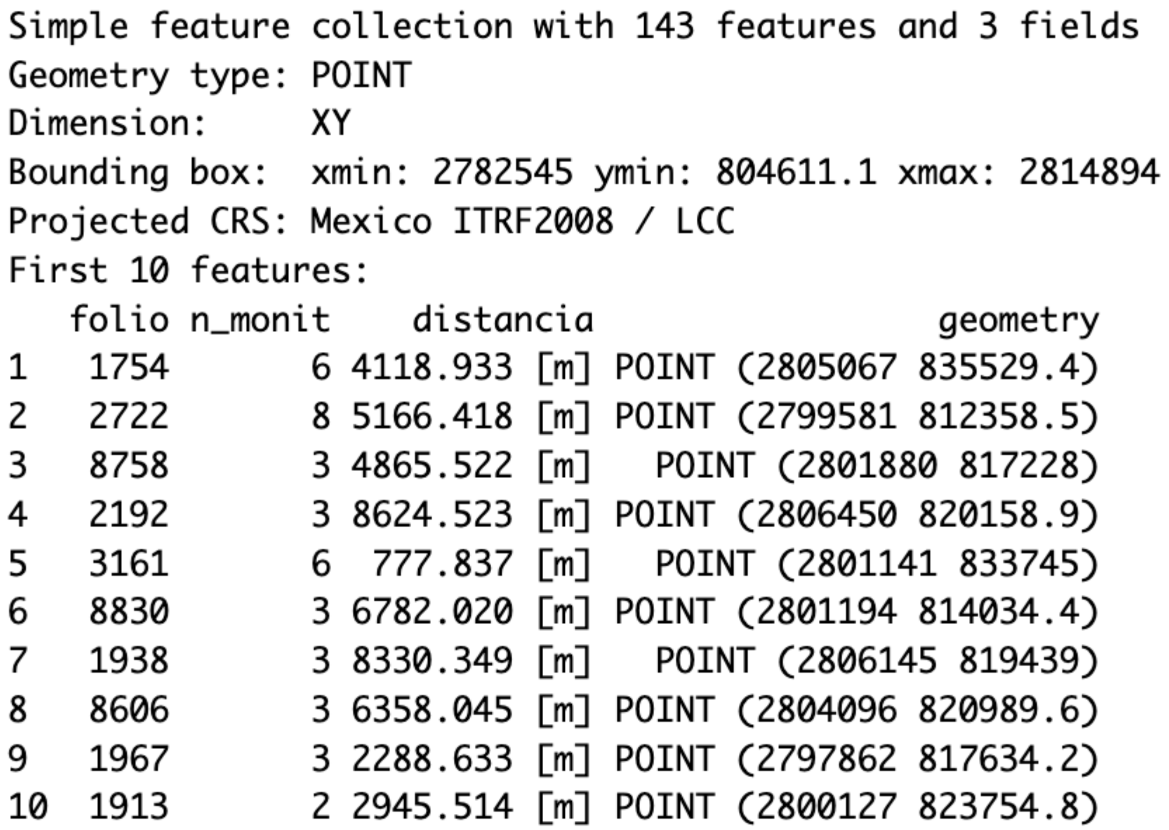
```
dist_monit <-
  st_set_geometry(dist, NULL) %>%
  pivot_longer(cols = -folio,
               names_to = "site",
               values_to = "distancia") %>%
  group_by(folio) %>%
  summarise(distancia = min(distancia, na.rm = TRUE)) %>%
  print()
```



```
# A tibble: 143 × 2
   folio distancia
   <int>     <dbl>
 1  1159     5324.
 2  1182     6900.
 3  1249     6730.
 4  1282    13989.
 5  1296     4703.
 6  1383     5109.
 7  1584     1819.
 8  1754     4119.
 9  1906    13885.
10  1913     2946.
# ℹ 133 more rows
# ℹ Use `print(n = .
```

¿Cuál es la distancia entre cada folio y la estación más cercana?

```
pts_cdmx %>%
  mutate(n_monit = st_nearest_feature(pts_cdmx, monit),
         distancia = st_distance(pts_cdmx, monit[n_monit, ],
                                 by_element = TRUE))
```



```
Simple feature collection with 143 features and 3 fields
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 2782545 ymin: 804611.1 xmax: 2814894
Projected CRS: Mexico ITRF2008 / LCC
First 10 features:
   folio n_monit    distancia                  geometry
1   1754       6 4118.933 [m] POINT (2805067 835529.4)
2   2722       8 5166.418 [m] POINT (2799581 812358.5)
3   8758       3 4865.522 [m]   POINT (2801880 817228)
4   2192       3 8624.523 [m] POINT (2806450 820158.9)
5   3161       6  777.837 [m]   POINT (2801141 833745)
6   8830       3 6782.020 [m] POINT (2801194 814034.4)
7   1938       3 8330.349 [m]   POINT (2806145 819439)
8   8606       3 6358.045 [m] POINT (2804096 820989.6)
9   1967       3 2288.633 [m] POINT (2797862 817634.2)
10  1913       2 2945.514 [m] POINT (2800127 823754.8)
```