Handling spatio-temporal data in R

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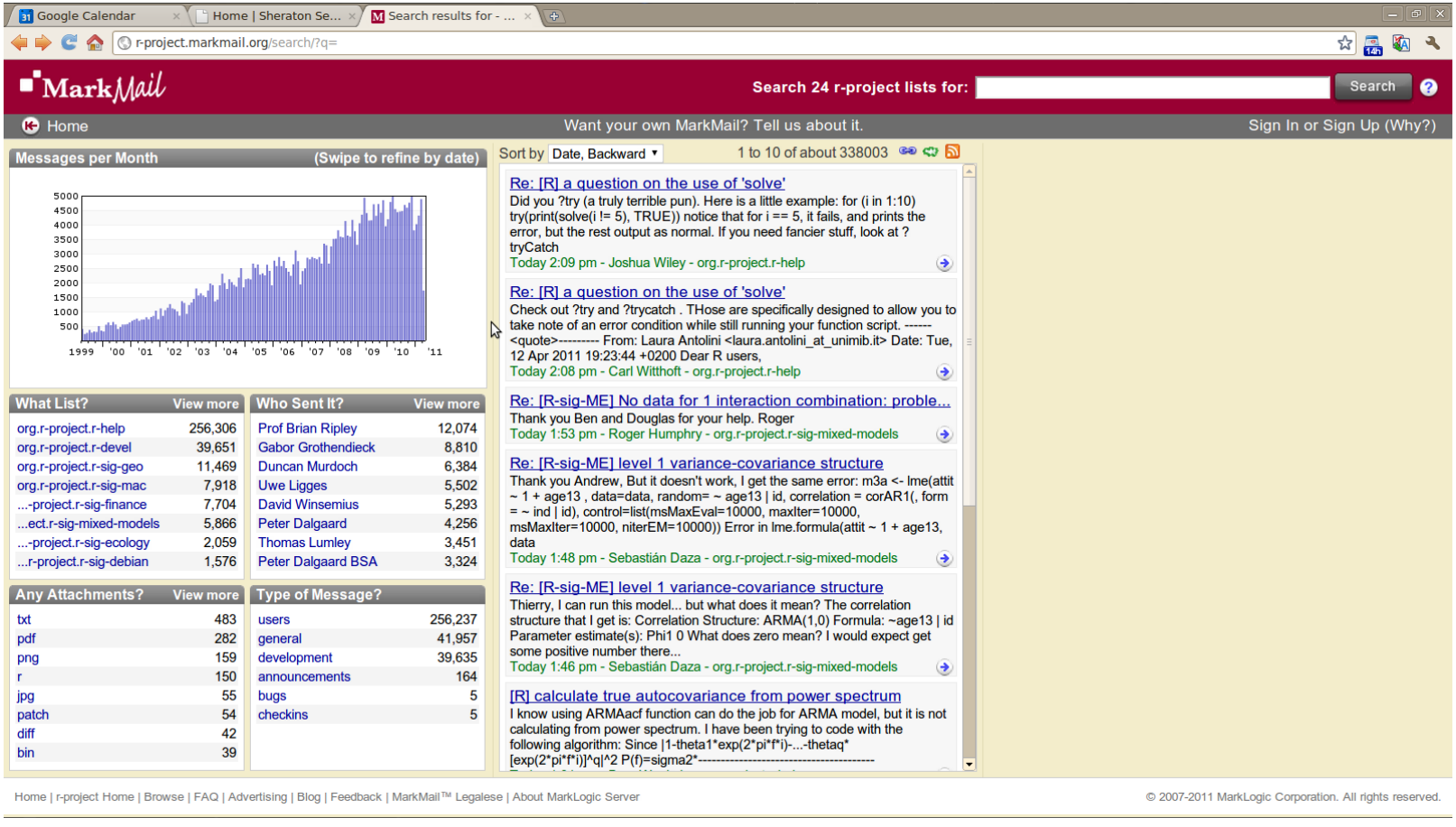
AAG Space-Time Symposium, Apr 13, 2011, Seattle, USA

*NHH Bergen; joint work with the r-sig-geo community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1 to 10 of about 338003
Re: [R] a question on the use of 'solve'
Did you ?try (a truly terrible pun). Here is a little example: for (i in 1:10) try(print(solve(i != 5), TRUE)) notice that for i == 5, it fails, and prints the error, but the rest output as normal. If you need fancier stuff, look at ? tryCatch
Today 2:09 pm - Joshua Wiley - org.r-project.r-help
Re: [R] a question on the use of 'solve'
Check out ?try and ?trycatch . THose are specifically designed to allow you to take note of an error condition while still running your function script. ------ <quote>--------- From: Laura Antolini <laura.antolini_at_unimib.it> Date: Tue, 12 Apr 2011 19:23:44 +0200 Dear R users,
Today 2:08 pm - Carl Witthoft - org.r-project.r-help
Re: [R-sig-ME] No data for 1 interaction combination: proble...
Thank you Ben and Douglas for your help. Roger
Today 1:53 pm - Roger Humphry - org.r-project.r-sig-mixed-models
Re: [R-sig-ME] level 1 variance-covariance structure
Thank you Andrew, But it doesn't work, I get the same error: m3a <- lme(attit ~ 1 + age13 , data=data, random= ~ age13 | id, correlation = corAR1(, form = ~ ind | id), control=list(msMaxEval=10000, maxIter=10000, msMaxIter=10000, niterEM=10000)) Error in lme.formula(attit ~ 1 + age13, data
Today 1:48 pm - Sebastián Daza - org.r-project.r-sig-mixed-models
Re: [R-sig-ME] level 1 variance-covariance structure
Thierry, I can run this model... but what does it mean? The correlation structure that I get is: Correlation Structure: ARMA(1,0) Formula: ~age13 | id Parameter estimate(s): Phi1 0 What does zero mean? I would expect get some positive number there...
Today 1:46 pm - Sebastián Daza - org.r-project.r-sig-mixed-models
[R] calculate true autocovariance from power spectrum
I know using ARMAacf function can do the job for ARMA model, but it is not calculating from power spectrum. I have been trying to code with the following algorithm: Since |1-theta1*exp(2*pi*f*i)-...-thetaq* [exp(2*pi*f*i)]^q|^2 P(f)=sigma2*----------
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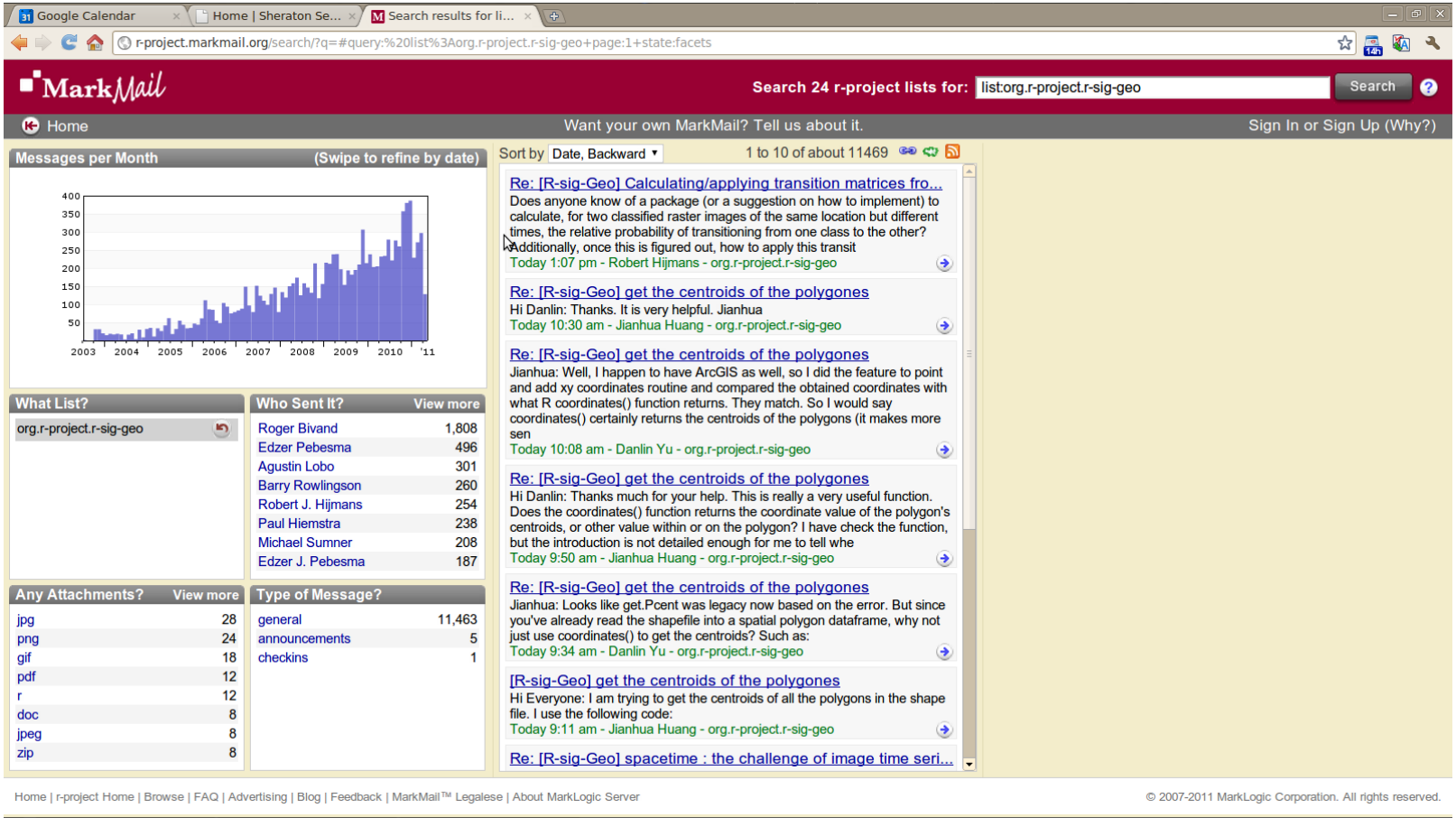
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Barry Rowlingson 260
Robert J. Hijmans 254
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Michael Sumner 208
Edzer J. Pebesma 187
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gif 18
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Type of Message?
general 11,463
announcements 5
checkins 1
Sort by Date, Backward
1 to 10 of about 11469
Re: [R-sig-Geo] Calculating/applying transition matrices fro...
Does anyone know of a package (or a suggestion on how to implement) to calculate, for two classified raster images of the same location but different times, the relative probability of transitioning from one class to the other? Additionally, once this is figured out, how to apply this transit
Today 1:07 pm - Robert Hijmans - org.r-project.r-sig-geo
Re: [R-sig-Geo] get the centroids of the polygones
Hi Danlin: Thanks. It is very helpful. Jianhua
Today 10:30 am - Jianhua Huang - org.r-project.r-sig-geo
Re: [R-sig-Geo] get the centroids of the polygones
Jianhua: Well, I happen to have ArcGIS as well, so I did the feature to point and add xy coordinates routine and compared the obtained coordinates with what R coordinates() function returns. They match. So I would say coordinates() certainly returns the centroids of the polygons (it makes more sen
Today 10:08 am - Danlin Yu - org.r-project.r-sig-geo
Re: [R-sig-Geo] get the centroids of the polygones
Hi Danlin: Thanks much for your help. This is really a very useful function. Does the coordinates() function returns the coordinate value of the polygon's centroids, or other value within or on the polygon? I have check the function, but the introduction is not detailed enough for me to tell whe
Today 9:50 am - Jianhua Huang - org.r-project.r-sig-geo
Re: [R-sig-Geo] get the centroids of the polygones
Jianhua: Looks like get.Pcent was legacy now based on the error. But since you've already read the shapefile into a spatial polygon dataframe, why not just use coordinates() to get the centroids? Such as:
Today 9:34 am - Danlin Yu - org.r-project.r-sig-geo
[R-sig-Geo] get the centroids of the polygones
Hi Everyone: I am trying to get the centroids of all the polygons in the shape file. I use the following code:
Today 9:11 am - Jianhua Huang - org.r-project.r-sig-geo
Re: [R-sig-Geo] spacetime : the challenge of image time seri...
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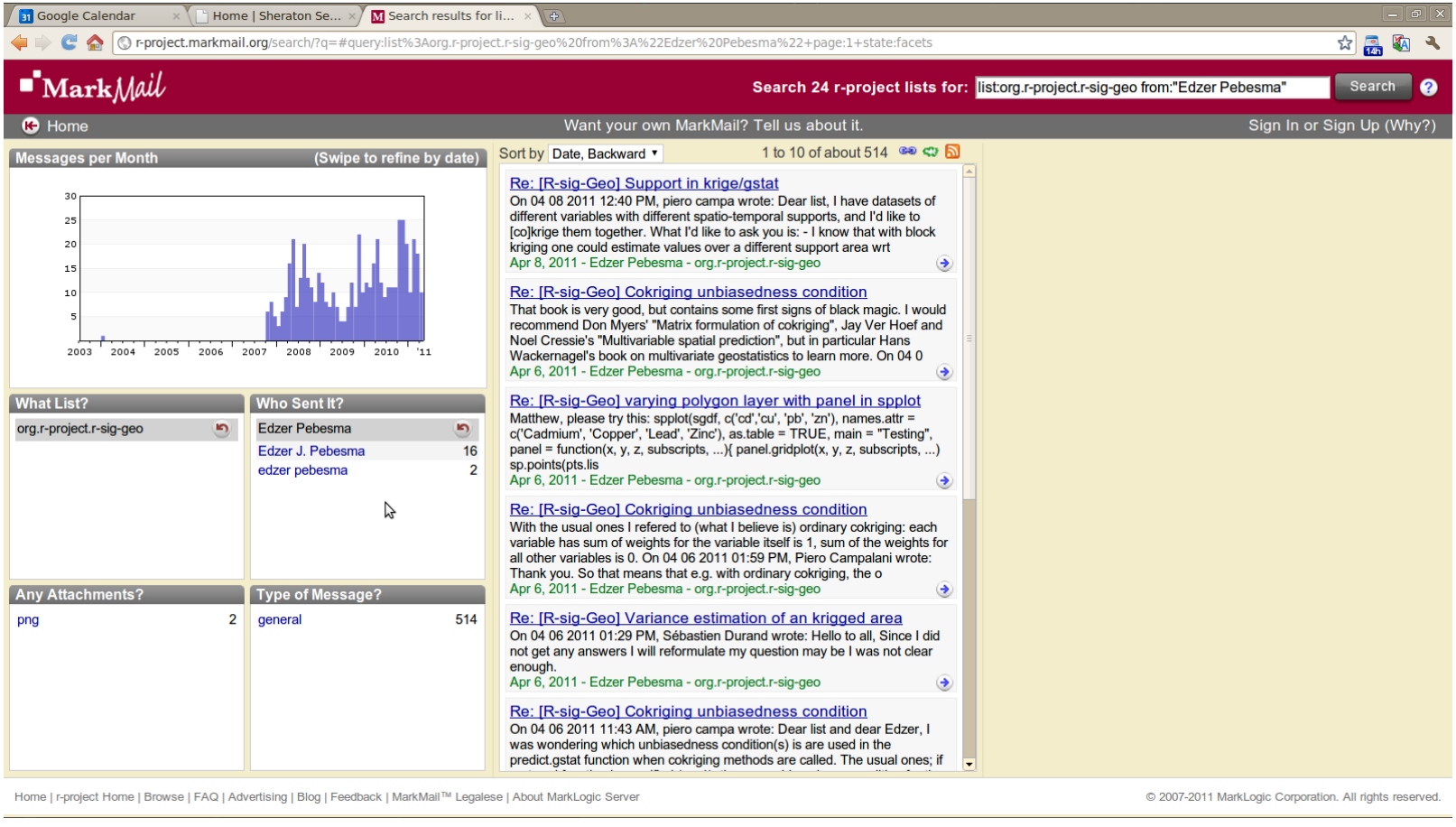
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Edzer J. Pebesma 16
edzer pebesma 2
Any Attachments?
png 2
Type of Message?
general 514
Sort by Date, Backward
1 to 10 of about 514
Re: [R-sig-Geo] Support in krige/gstat
On 04 08 2011 12:40 PM, piero campa wrote: Dear list, I have datasets of different variables with different spatio-temporal supports, and I'd like to [co]krige them together. What I'd like to ask you is: - I know that with block kriging one could estimate values over a different support area wrt
Apr 8, 2011 - Edzer Pebesma - org.r-project.r-sig-geo
Re: [R-sig-Geo] Cokriging unbiasedness condition
That book is very good, but contains some first signs of black magic. I would recommend Don Myers' "Matrix formulation of cokriging", Jay Ver Hoef and Noel Cressie's "Multivariable spatial prediction", but in particular Hans Wackernagel's book on multivariate geostatistics to learn more. On 04 0
Apr 6, 2011 - Edzer Pebesma - org.r-project.r-sig-geo
Re: [R-sig-Geo] varying polygon layer with panel in spplot
Matthew, please try this: spplot(sgdf, c('cd','cu', 'pb', 'zn'), names.attr = c('Cadmium', 'Copper', 'Lead', 'Zinc'), as.table = TRUE, main = "Testing", panel = function(x, y, z, subscripts, ...){ panel.gridplot(x, y, z, subscripts, ...) sp.points(pts.lis
Apr 6, 2011 - Edzer Pebesma - org.r-project.r-sig-geo
Re: [R-sig-Geo] Cokriging unbiasedness condition
With the usual ones I refered to (what I believe is) ordinary cokriging: each variable has sum of weights for the variable itself is 1, sum of the weights for all other variables is 0. On 04 06 2011 01:59 PM, Piero Campalani wrote: Thank you. So that means that e.g. with ordinary cokriging, the o
Apr 6, 2011 - Edzer Pebesma - org.r-project.r-sig-geo
Re: [R-sig-Geo] Variance estimation of an krigged area
On 04 06 2011 01:29 PM, Sébastien Durand wrote: Hello to all, Since I did not get any answers I will reformulate my question may be I was not clear enough.
Apr 6, 2011 - Edzer Pebesma - org.r-project.r-sig-geo
Re: [R-sig-Geo] Cokriging unbiasedness condition
On 04 06 2011 11:43 AM, piero campa wrote: Dear list and dear Edzer, I was wondering which unbiasedness condition(s) is are used in the predict.gstat function when cokriging methods are called. The usual ones; if
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Outline

This is ongoing work. For a documented overview of recent efforts, see: `www.opengeostatistics.org`

- Why R?
- R for spatial data analysis
- R for temporal data analysis
- Spatio-temporal data types, processes, models
- R infrastructure for spatio-temporal data analysis
- outlook

S/T mapping of PCB in North Sea sediment

E Pebesma, R N M Duin (2005) *Spatio-temporal mapping of sea floor sediment pollution in the North Sea.* In: Ph. Renard, and R. Froidevaux, eds. Proceedings GeoENV 2004 – Fifth European Conference on Geostatistics for Environmental Applications; Springer.

To reproduce the computations, tables and graphs in this paper, start R, then type

```
> library(gstat)
> demo(pcb)
```

R provides the combination of

having everything in one place:

- full control: from bit/bytes, to vectors, linear algebra, OOP

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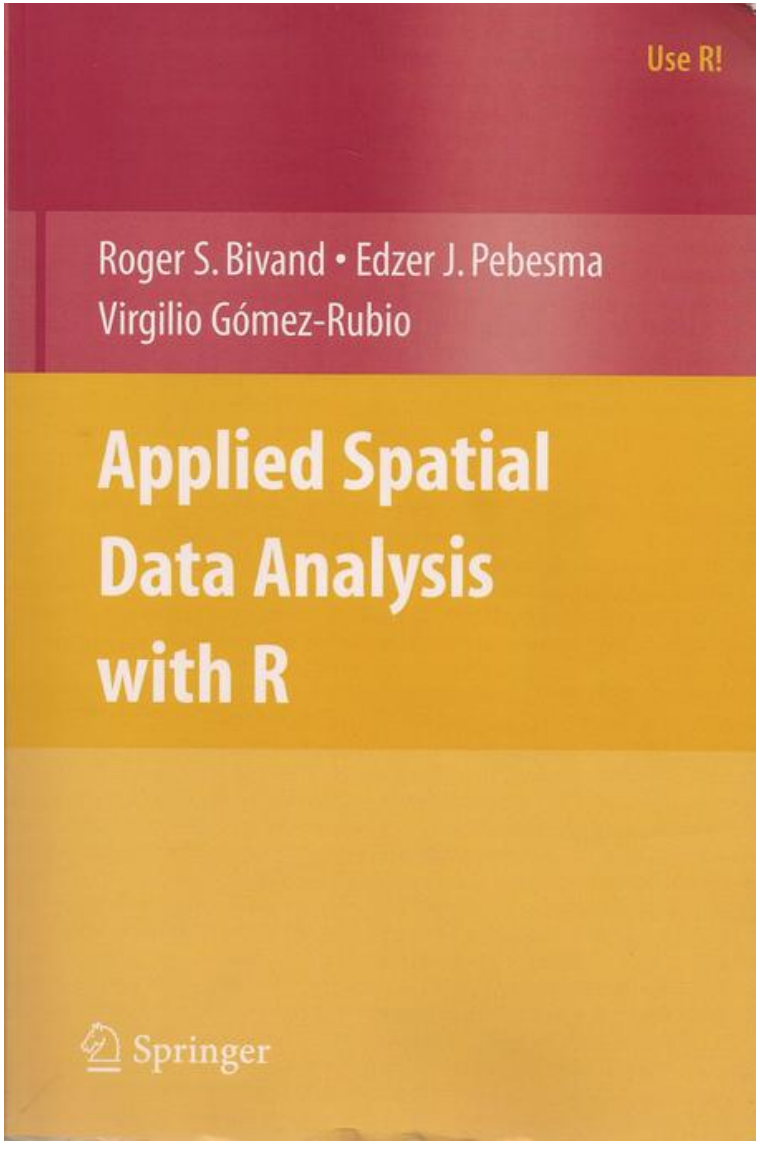
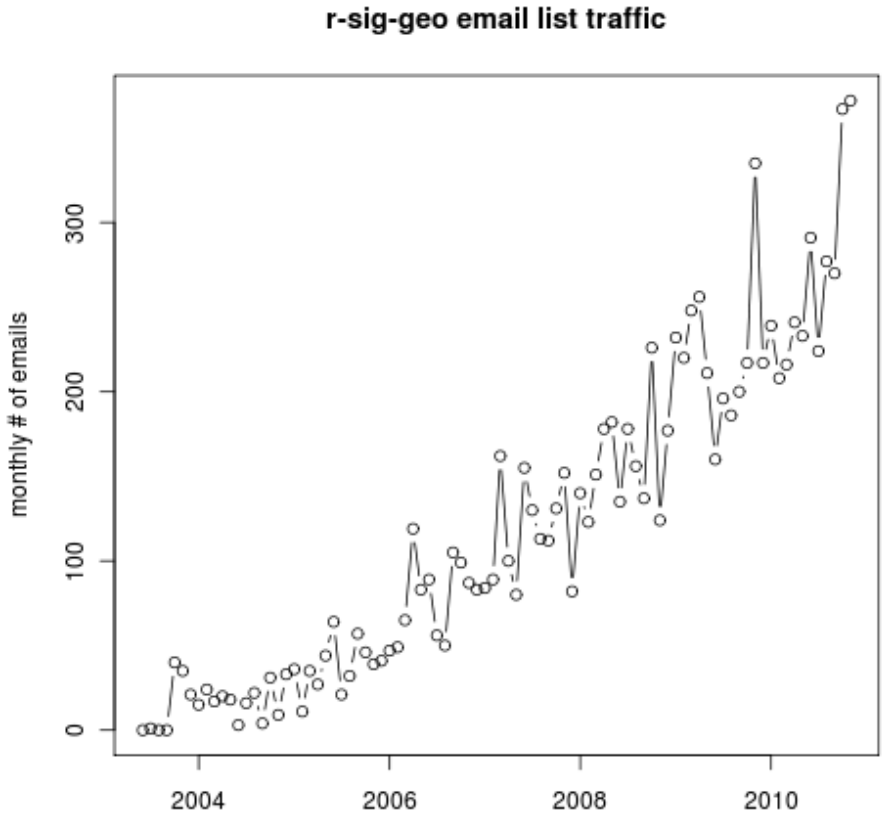
- 3000 maintained extension packages on CRAN for research dissemination
- reproducable research: Sweave
- (arguably:) lingua franca of statistical computation

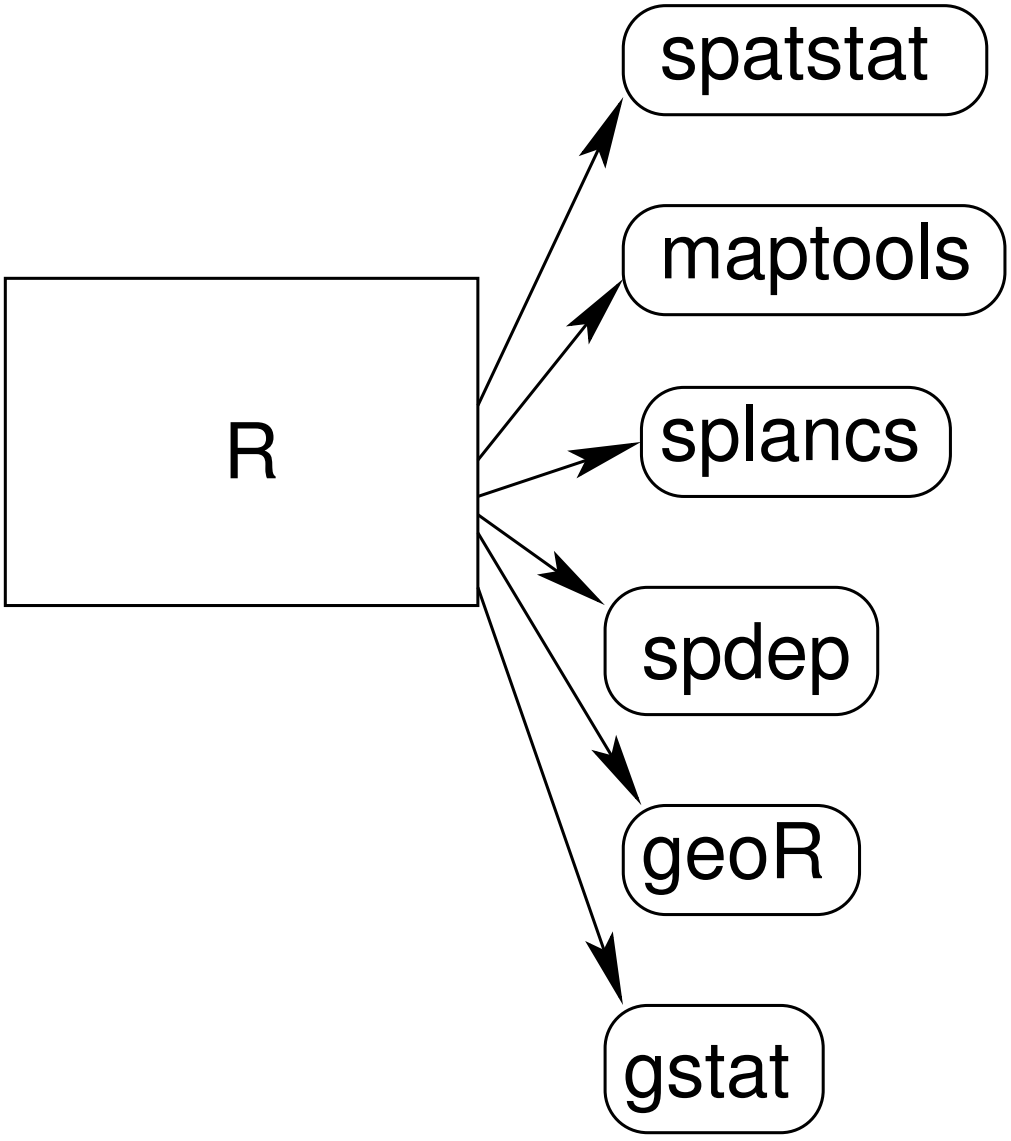
R spatial



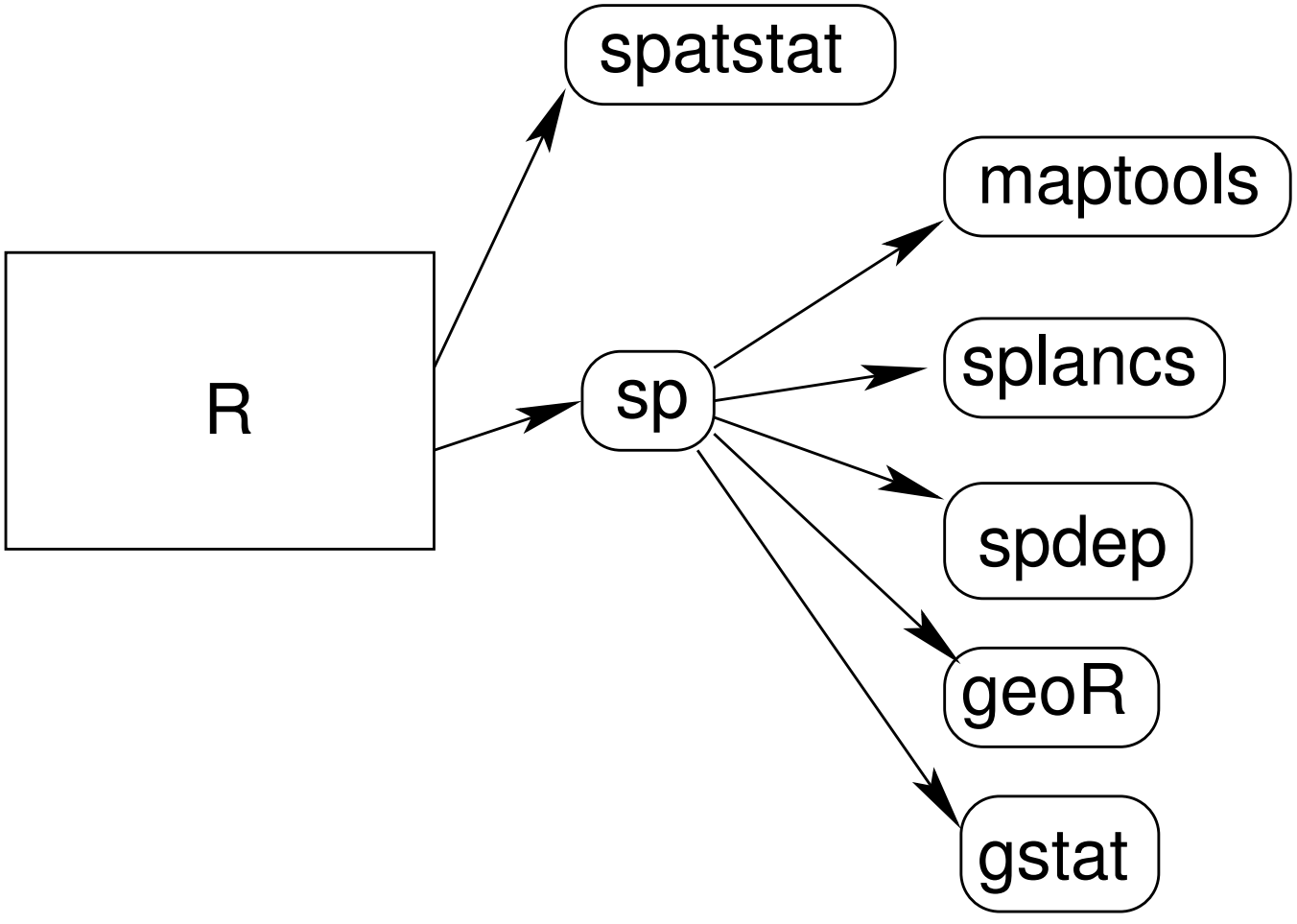


most active mailing list after r-help and r-devel!

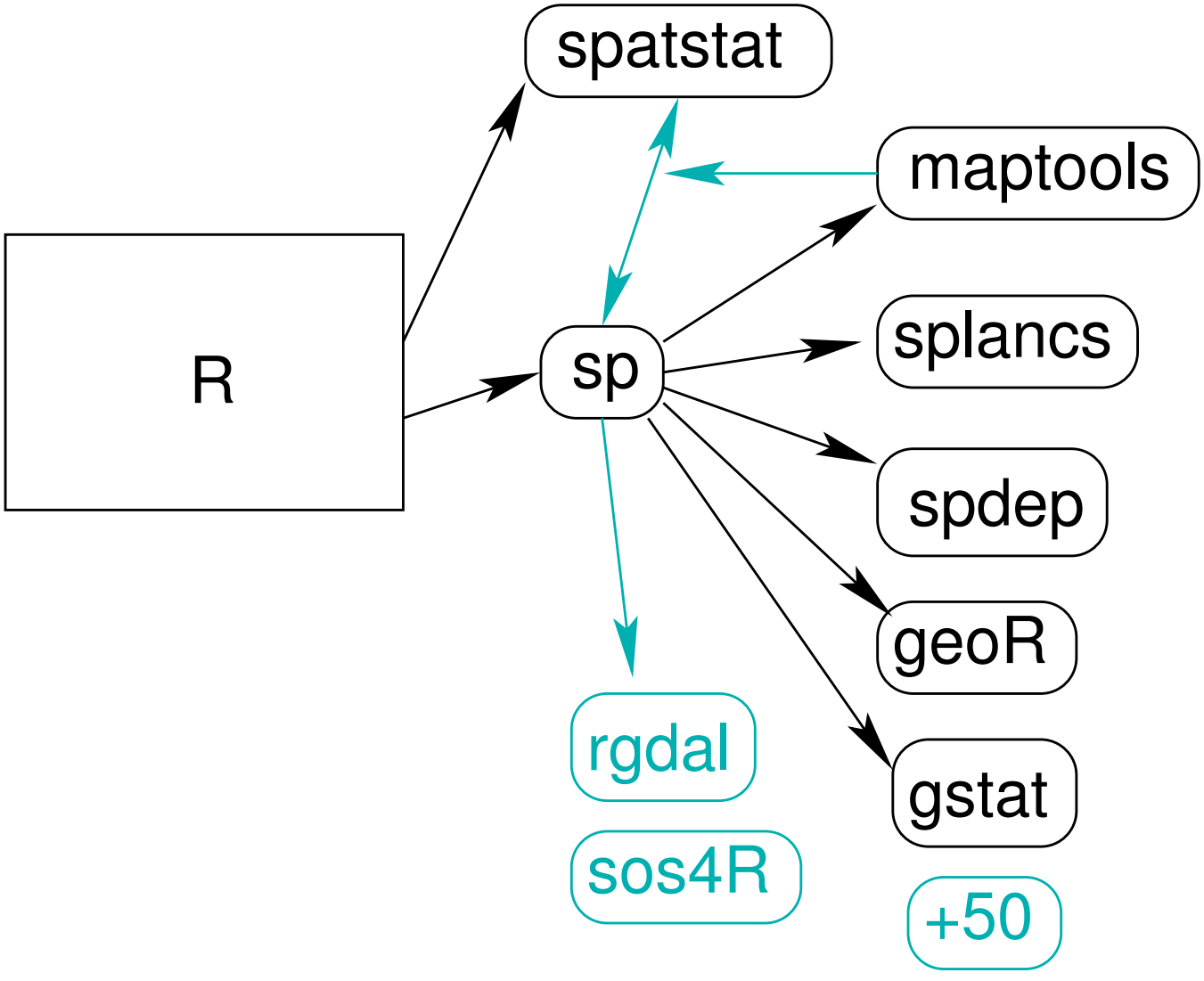
Before 2005



After 2005



2011: over 100 spatial packages on CRAN



Classes in sp

data type	class	attributes	contains
points	SpatialPoints	No	Spatial*
points	SpatialPointsDataFrame	data.frame	SpatialPoints*
pixels	SpatialPixels	No	SpatialPoints*
pixels	SpatialPixelsDataFrame	data.frame	SpatialPixels* SpatialPointsDataFrame**
full grid	SpatialGrid	No	SpatialPixels*
full grid	SpatialGridDataFrame	data.frame	SpatialGrid*
line	Line	No	
lines	Lines	No	Line list
lines	SpatialLines	No	Spatial*, Lines list
lines	SpatialLinesDataFrame	data.frame	SpatialLines*
rings	Polygon	No	Line*
rings	Polygons	No	Polygon list
rings	SpatialPolygons	No	Spatial*, Polygons list
rings	SpatialPolygonsDataFrame	data.frame	SpatialPolygons*

R spatial - new developments

In sp: mix geometry types:

```
> PM10_Seattle = AirQualityUS[Seattle, "PM10"]
```

with `AirQualityUS` all stations and times of an air quality data base, `Seattle` a polygons or grid representation, and `PM10` an attribute.
Otherwise: spatial overlay, spatial aggregation

R spatial - new developments (2)

- rgeos: R interface to GEOS topology library (now on CRAN)
- raster: provides manipulation & map algebra on raster data, including those that do not fit in memory.
- Has R now become a GIS?

R temporal

- naive/implicit: vector, index represents time step
- various date/time base types: Date, DateTime, POSIXct, ...
- time series data objects: `ts`, `its`, `zoo`, `xts`
- none of them have explicit time *intervals* as reference
- `xts` allows ISO 8601 interval selection

```
> year = 1990:2000
> year

 [1] 1990 1991 1992 1993 1994 1995
 [7] 1996 1997 1998 1999 2000

> ts(1:20, frequency = 12, start = c(2010,
+     2))

     Jan Feb Mar Apr May Jun Jul
2010       1   2   3   4   5   6
2011  12  13  14  15  16  17  18
     Aug Sep Oct Nov Dec
2010   7   8   9  10  11
2011  19  20

> library(xts)
> x = xts(data.frame(sth = rnorm(4)),
+     Sys.time() + c(0, 1, 4,
+         10) * 3600)
> x["2011-04-13"]

                           sth
2011-04-13 22:27:15  1.4126865
2011-04-13 23:27:15 -0.3096746
```

Statistical analysis of spatio-temporal data

Questions to data often involve the words *where* and *when*, either implicitly (through covariates / predictors: under which circumstances) or explicitly (i.e., *there* [location] / *then* [time])
Statistical modelling proceeds, as usual, along the line of splitting variability in an understood and a random component (possibly: smooth + rough):

$$\text{observation} = \text{trend} + \text{residual}$$

where often the non-random trend relates copes with covariates, and the random residual with correlations in space and time.

What is there so far in R?

- space and time implicit, unreferenced (`lm`: lin.reg., `nlme`: mixed effects models)

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- in the end, you want maps to look like maps, and time series plots to look like time series plots.

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- space and time explicit, (partly) unreferenced (`RandomFields`, `stpp`, `spdep`)
- space and time explicit, both referenced (`surveillance`, `cshapes`, `gstat`)
- in the end, you want maps to look like maps, and time series plots to look like time series plots.
- referencing allows interoperability, prevents errors, and allows choosing sensible (warning against unsuitable) distance measures

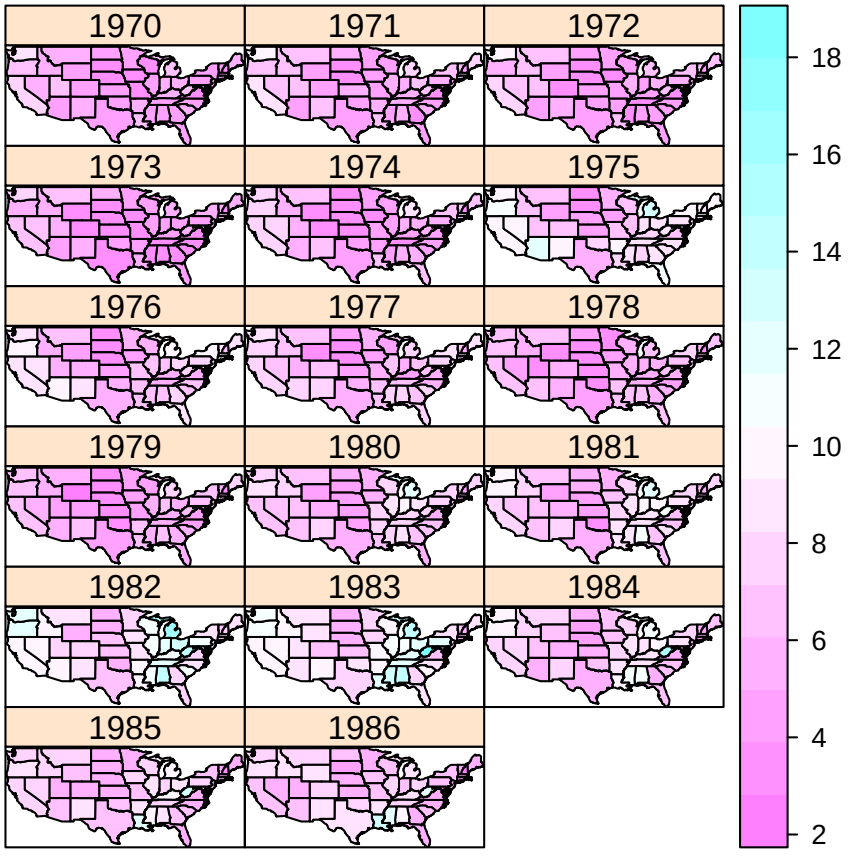
How do data come? panel data - long format

```
> data("Produc", package = "plm")
> Produc[1:5, ]

    state year     pcap     hwy
1 ALABAMA 1970 15032.67 7325.80
2 ALABAMA 1971 15501.94 7525.94
3 ALABAMA 1972 15972.41 7765.42
4 ALABAMA 1973 16406.26 7907.66
5 ALABAMA 1974 16762.67 8025.52
    water    util       pc   gsp
1 1655.68 6051.20 35793.80 28418
2 1721.02 6254.98 37299.91 29375
3 1764.75 6442.23 38670.30 31303
4 1742.41 6756.19 40084.01 33430
5 1734.85 7002.29 42057.31 33749
     emp unemp
1 1010.5   4.7
2 1021.9   5.2
3 1072.3   4.7
4 1135.5   3.9
5 1169.8   5.5
```

Panel data as ST structure

```
> library(maps)
> states.m = map("state", plot = FALSE,
+     fill = TRUE)
> IDs <- sapply(strsplit(states.m$names,
+     ":"), function(x) x[1])
> library(maptools)
> states = map2SpatialPolygons(states.m,
+     IDs = IDs)
> library(plm)
> data(Produc)
> yrs = 1970:1986
> time = xts(1:17, as.POSIXct(paste(yrs,
+     "-01-01", sep = "")))
> library(spacetime)
> Produc.st = STFDF(states[-8],
+     time, Produc[(order(Produc[2],
+         Produc[1])), ])
> stplot(Produc.st[, , "unemp"],
+     yrs)
```

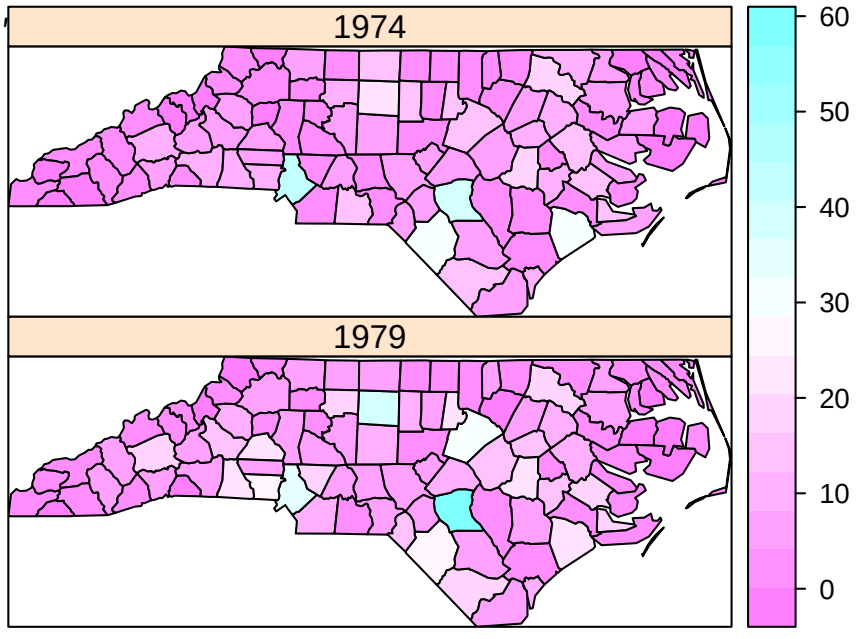


Time-wide format: NC Sudden infant death syndrome

Time-wide format: store time instances as columns in the attribute table.

```
> library(maptools)
> fname = system.file("shapes/sids.shp", package="maptools"
> nc = readShapePoly(fname,
+  proj4string=CRS("+proj=longlat +datum=NAD27"))
> as.data.frame(nc[1:5, c("SID74", "SID79")])

  SID74 SID79
0     1     0
1     0     3
2     5     6
3     1     2
4     9     3
```



This seems a typical way to do this in GIS (ArcGIS, TerraLib). Column (or raster) name, or meta-data, needs to encode the time, somehow.

Space-wide format: Irish wind data

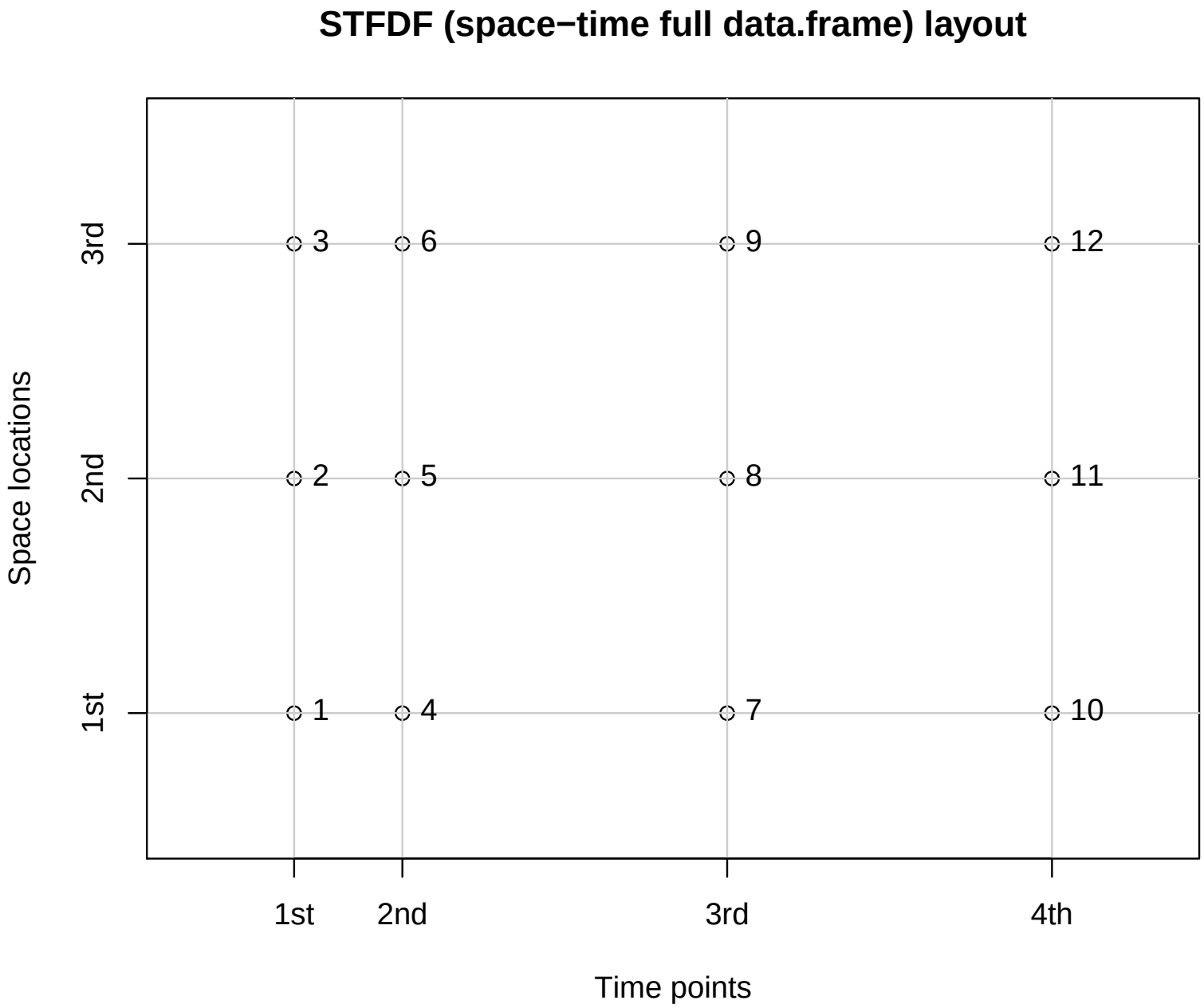
Space-wide format: store space instances as columns in the attribute table.

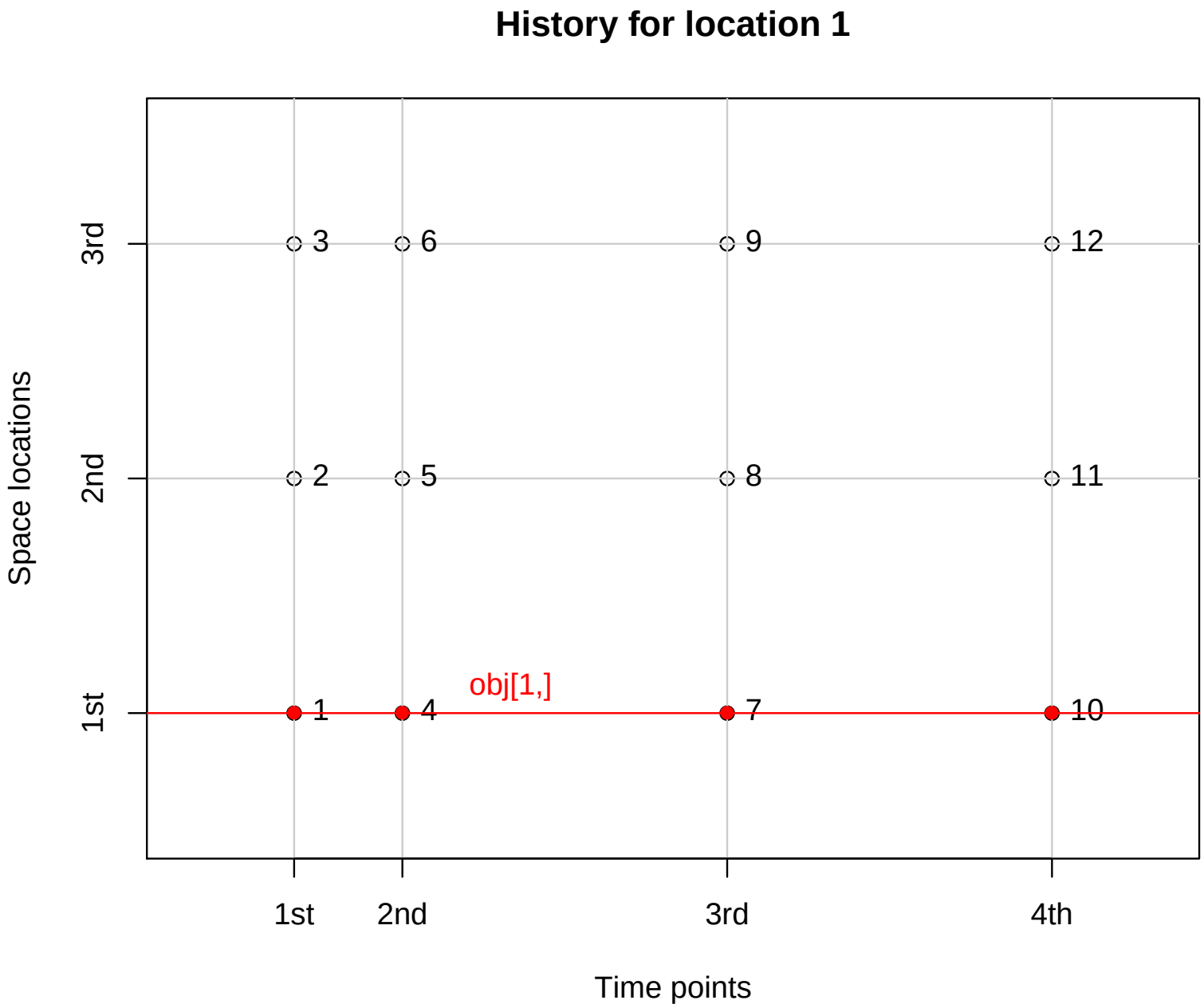
```
> library(gstat)
> data(wind)
> wind[1:10,]
```

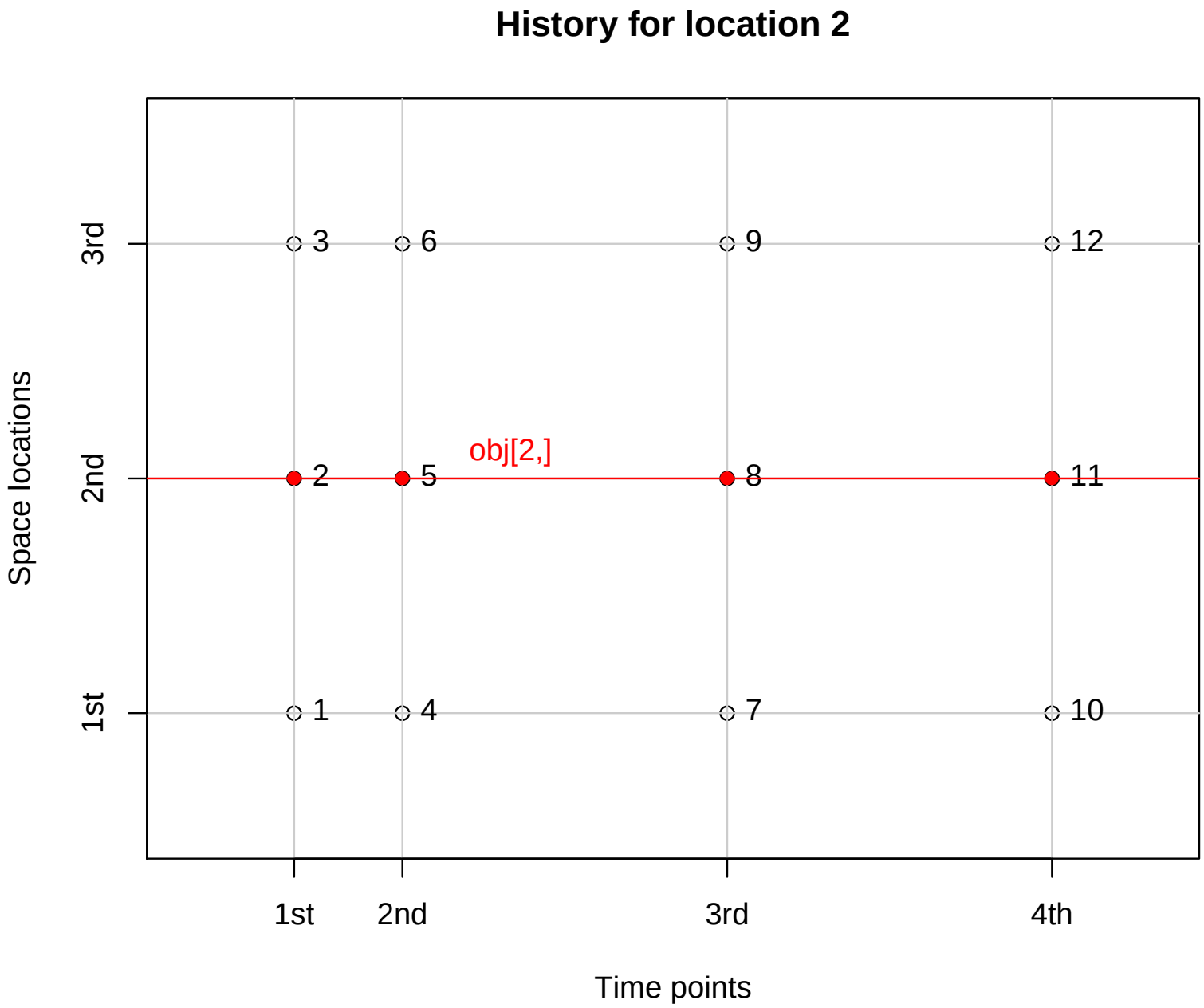
	year	month	day	RPT	VAL	ROS	KIL	SHA	BIR	DUB	CLA	MUL	CLO	BEL	MAL
1	61	1	1	15.04	14.96	13.17	9.29	13.96	9.87	13.67	10.25	10.83	12.58	18.50	15.04
2	61	1	2	14.71	16.88	10.83	6.50	12.62	7.67	11.50	10.04	9.79	9.67	17.54	13.83
3	61	1	3	18.50	16.88	12.33	10.13	11.17	6.17	11.25	8.04	8.50	7.67	12.75	12.71
4	61	1	4	10.58	6.63	11.75	4.58	4.54	2.88	8.63	1.79	5.83	5.88	5.46	10.88
5	61	1	5	13.33	13.25	11.42	6.17	10.71	8.21	11.92	6.54	10.92	10.34	12.92	11.83
6	61	1	6	13.21	8.12	9.96	6.67	5.37	4.50	10.67	4.42	7.17	7.50	8.12	13.17
7	61	1	7	13.50	14.29	9.50	4.96	12.29	8.33	9.17	9.29	7.58	7.96	13.96	13.79
8	61	1	8	10.96	9.75	7.62	5.91	9.62	7.29	14.29	7.62	9.25	10.46	16.62	16.46
9	61	1	9	12.58	10.83	10.00	4.75	10.37	6.79	8.04	10.13	7.79	9.08	13.04	15.37
10	61	1	10	13.37	11.12	19.50	8.33	9.71	6.54	11.42	7.79	8.54	9.00	8.58	11.83

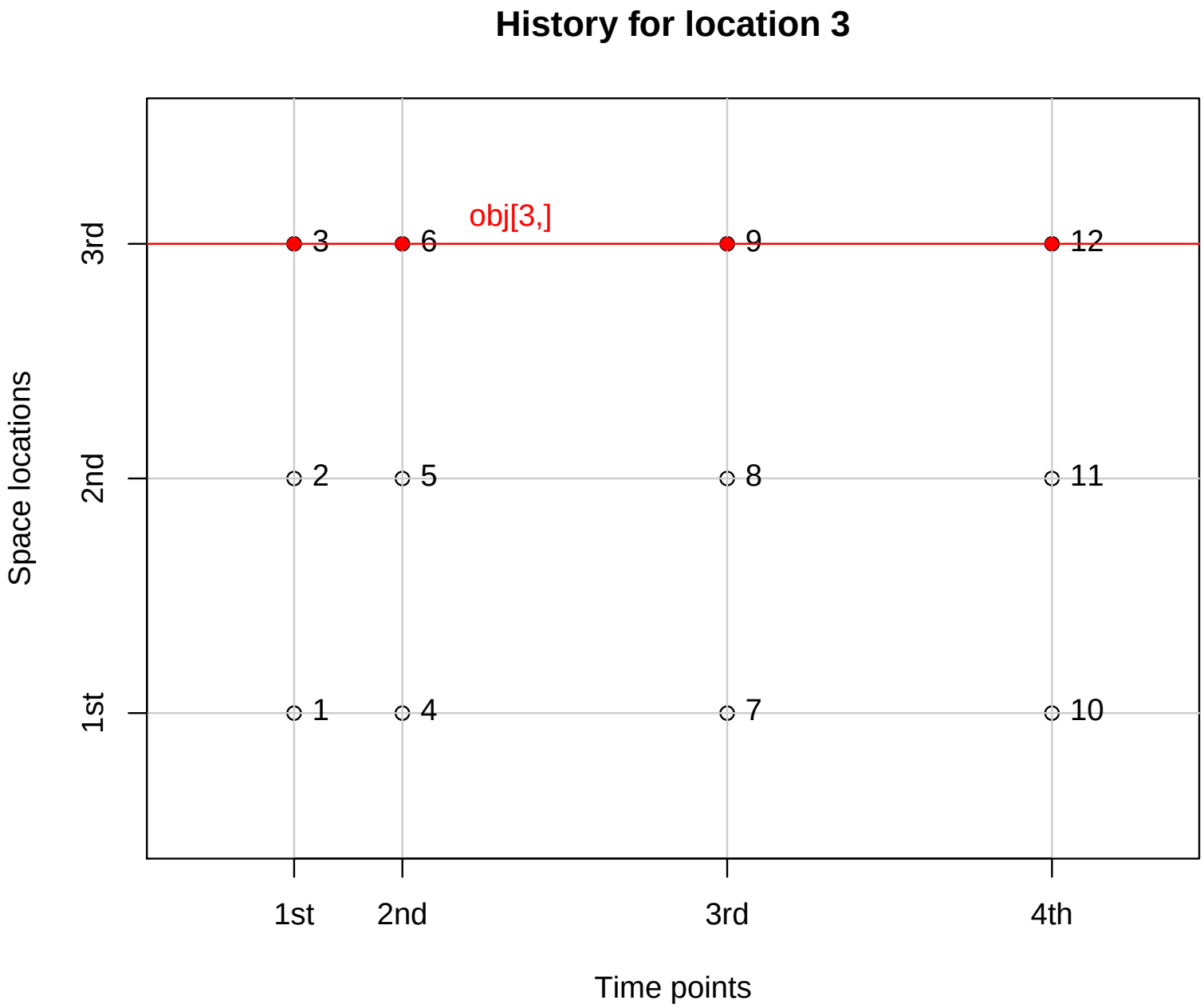
This seems a typical way to do for sensor readings, with few sensors.

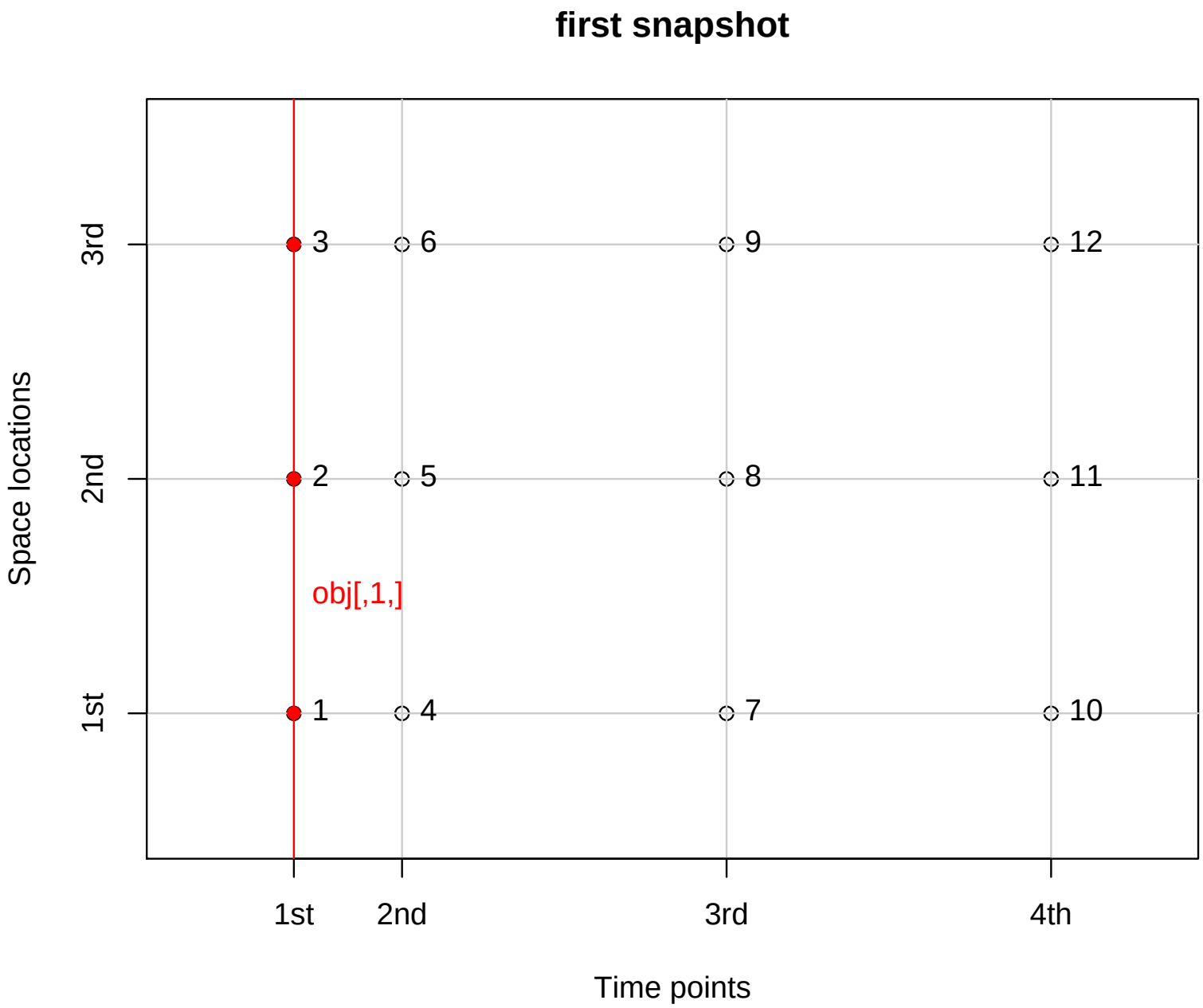
Column (or raster) name, or meta-data, needs to encode the location, somehow.

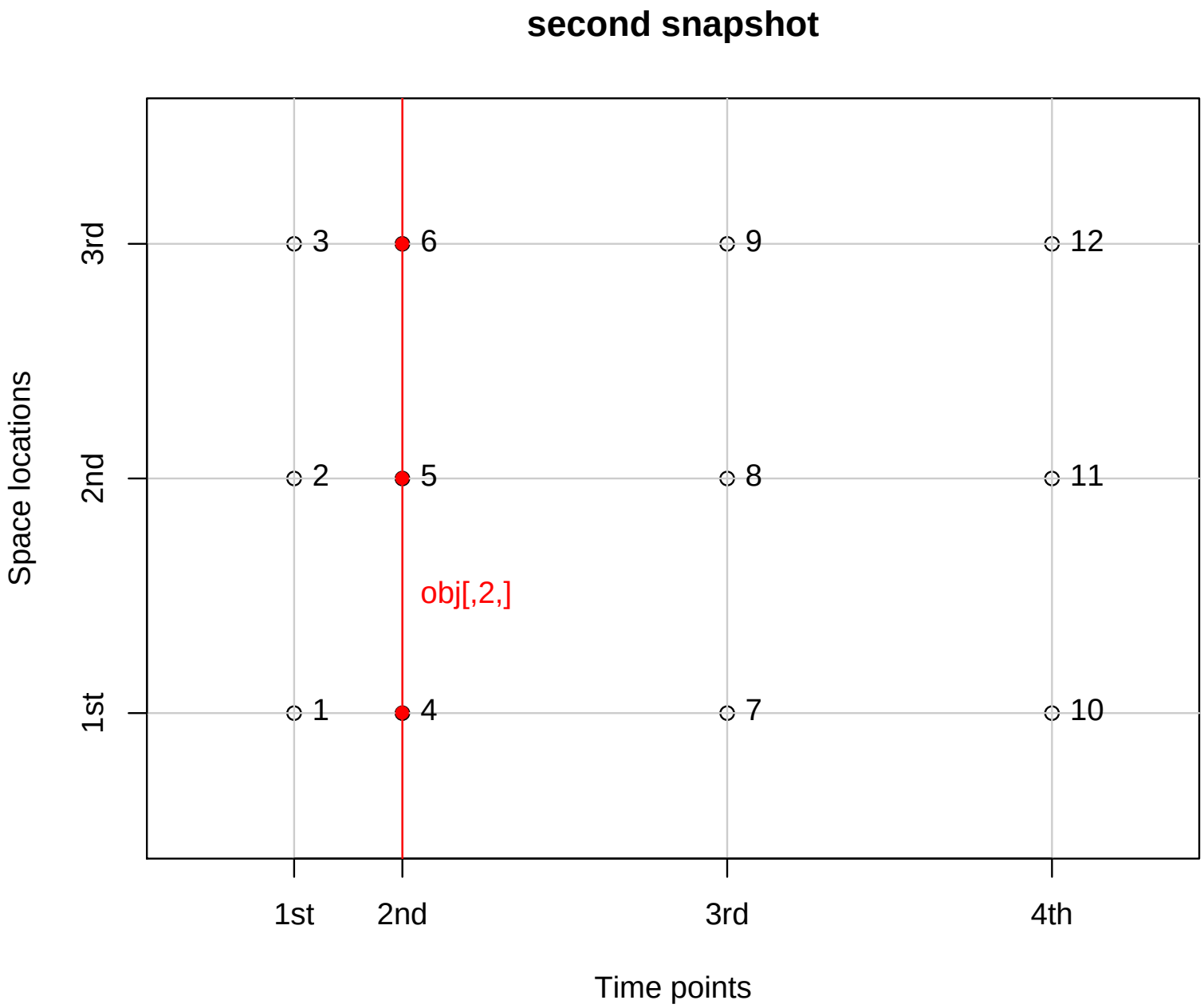

STFDF (space−time full data.frame) layout
Space locations
3rd
2nd
1st
3
6
9
12
2
5
8
11
1
4
7
10
1st
2nd
3rd
4th
Time points

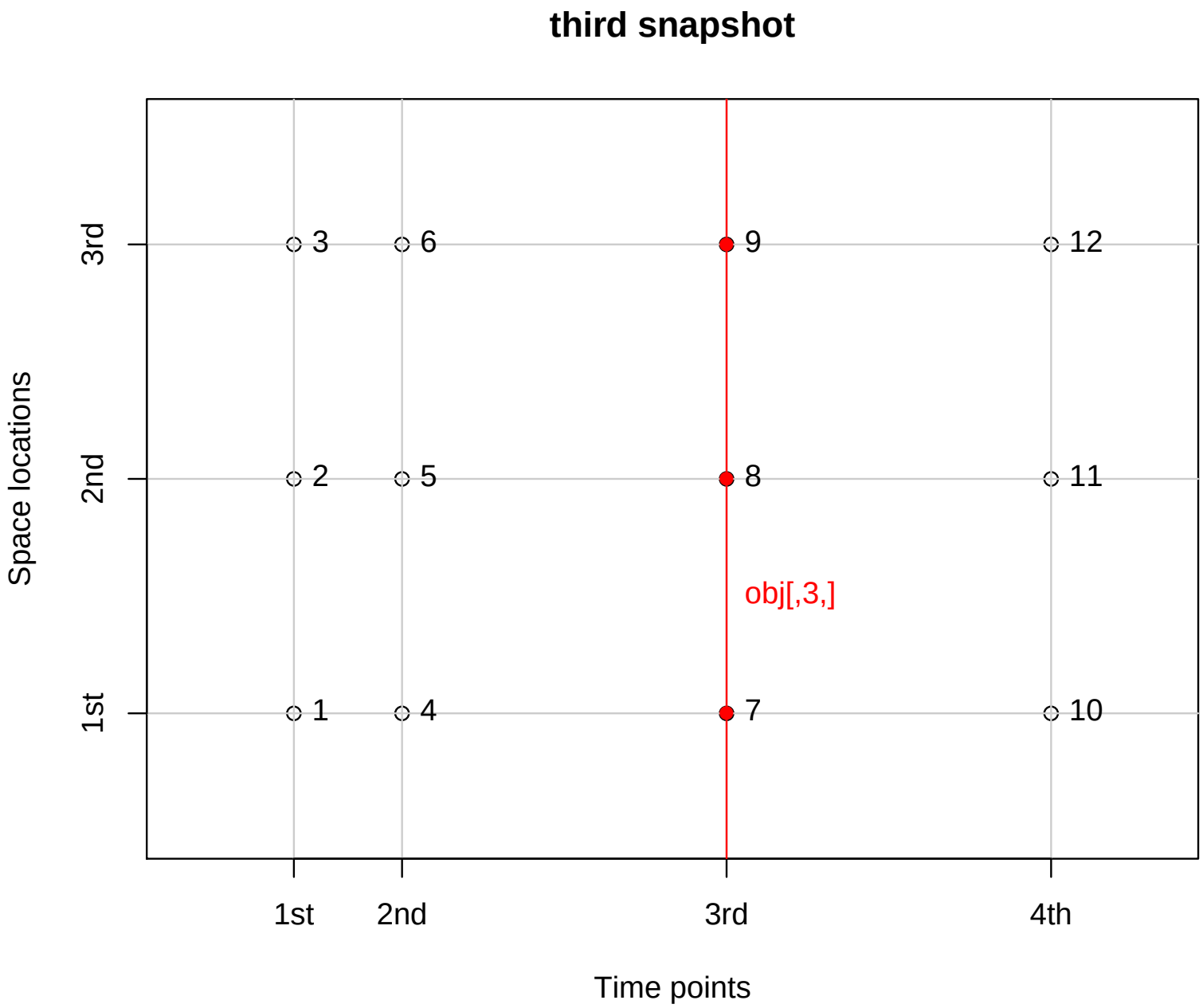

History for location 1
Space locations
3rd
2nd
1st
3
6
9
12
2
5
8
11
1
4
7
10
obj[1,]
1st
2nd
3rd
4th
Time points

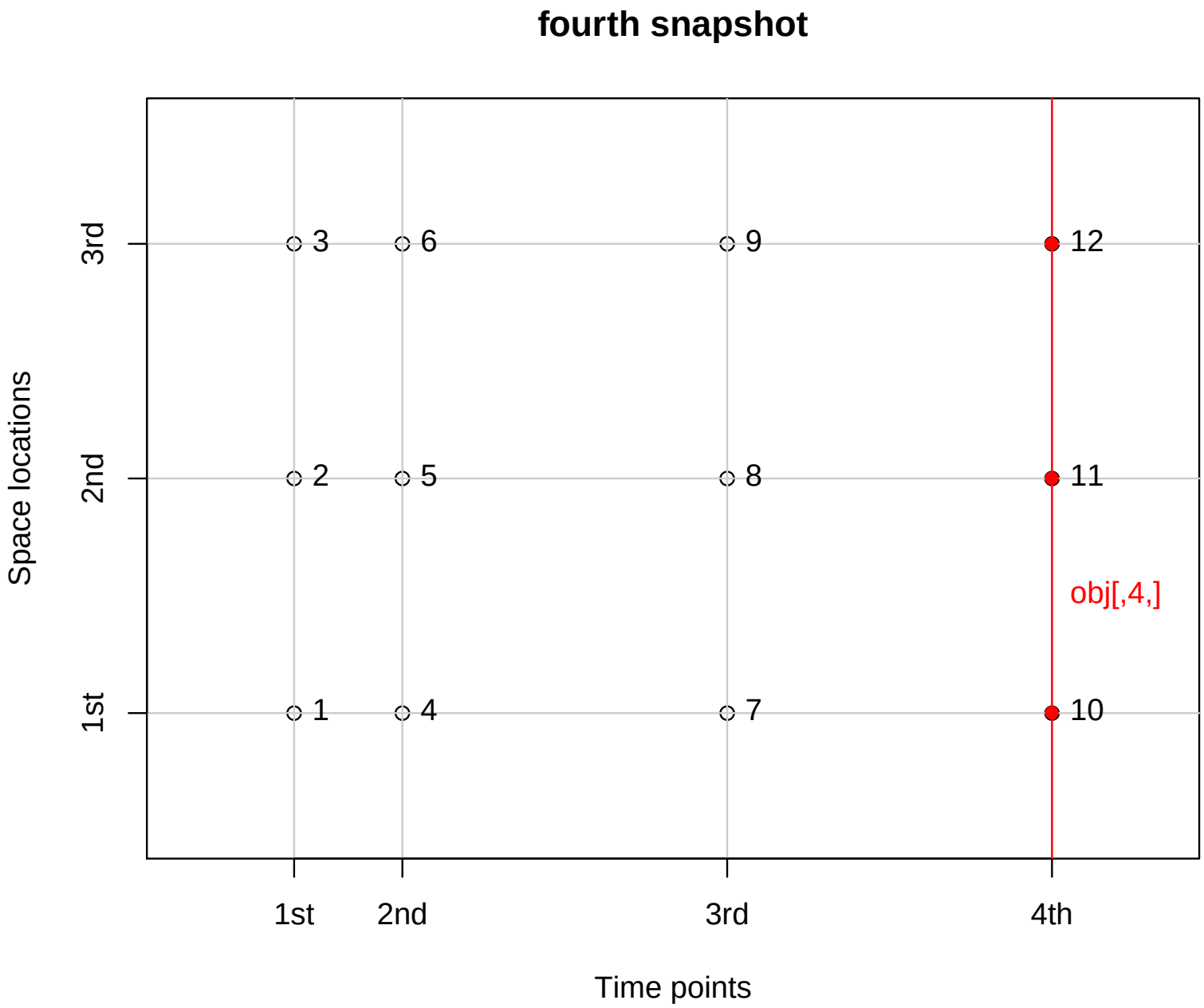

History for location 2
Space locations
3rd
2nd
1st
3
6
9
12
obj[2,]
2
5
8
11
1
4
7
10
1st
2nd
3rd
4th
Time points

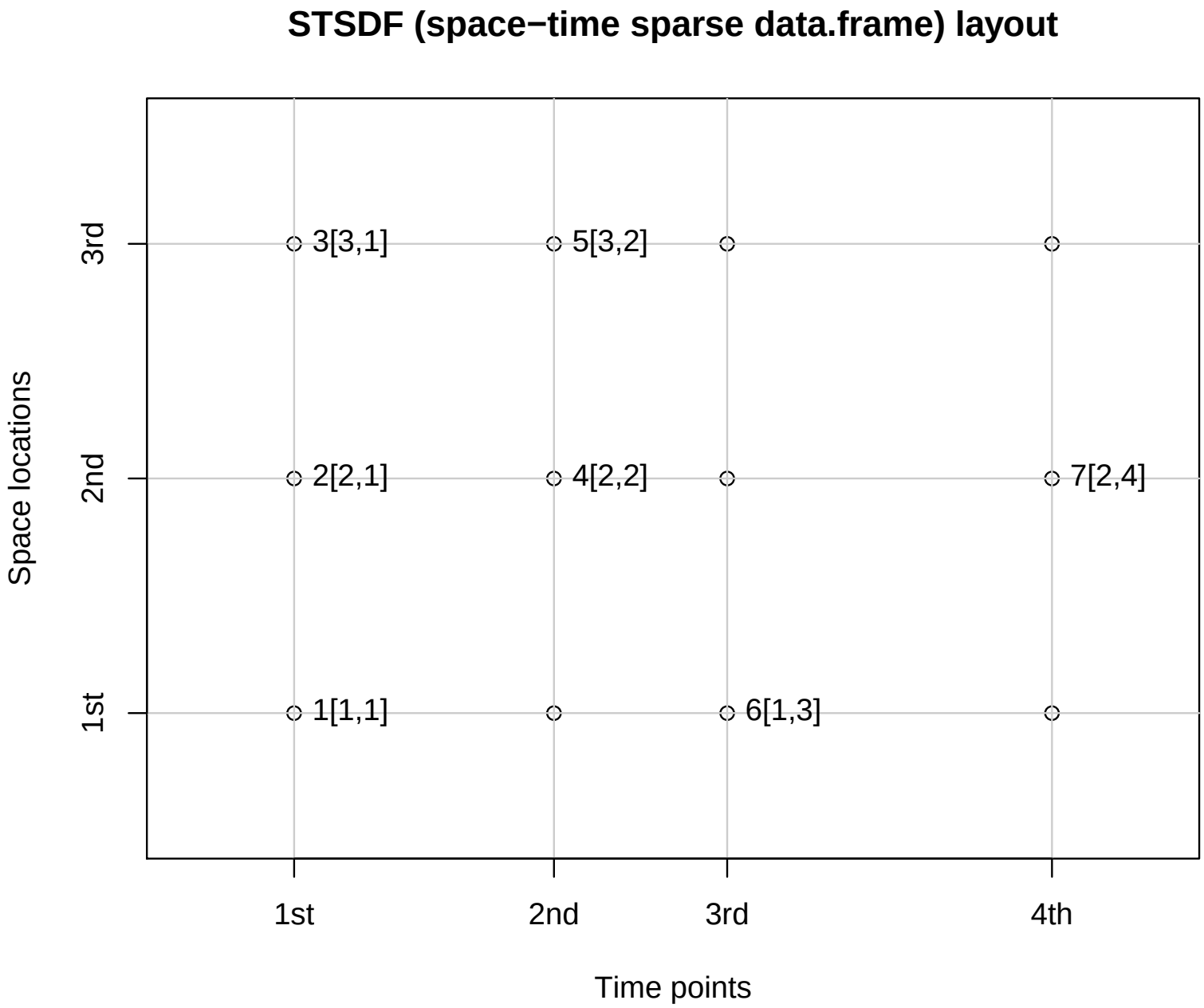

History for location 3
obj[3,]
3
6
9
12
2
5
8
11
1
4
7
10
3rd
2nd
1st
Space locations
1st
2nd
3rd
4th
Time points

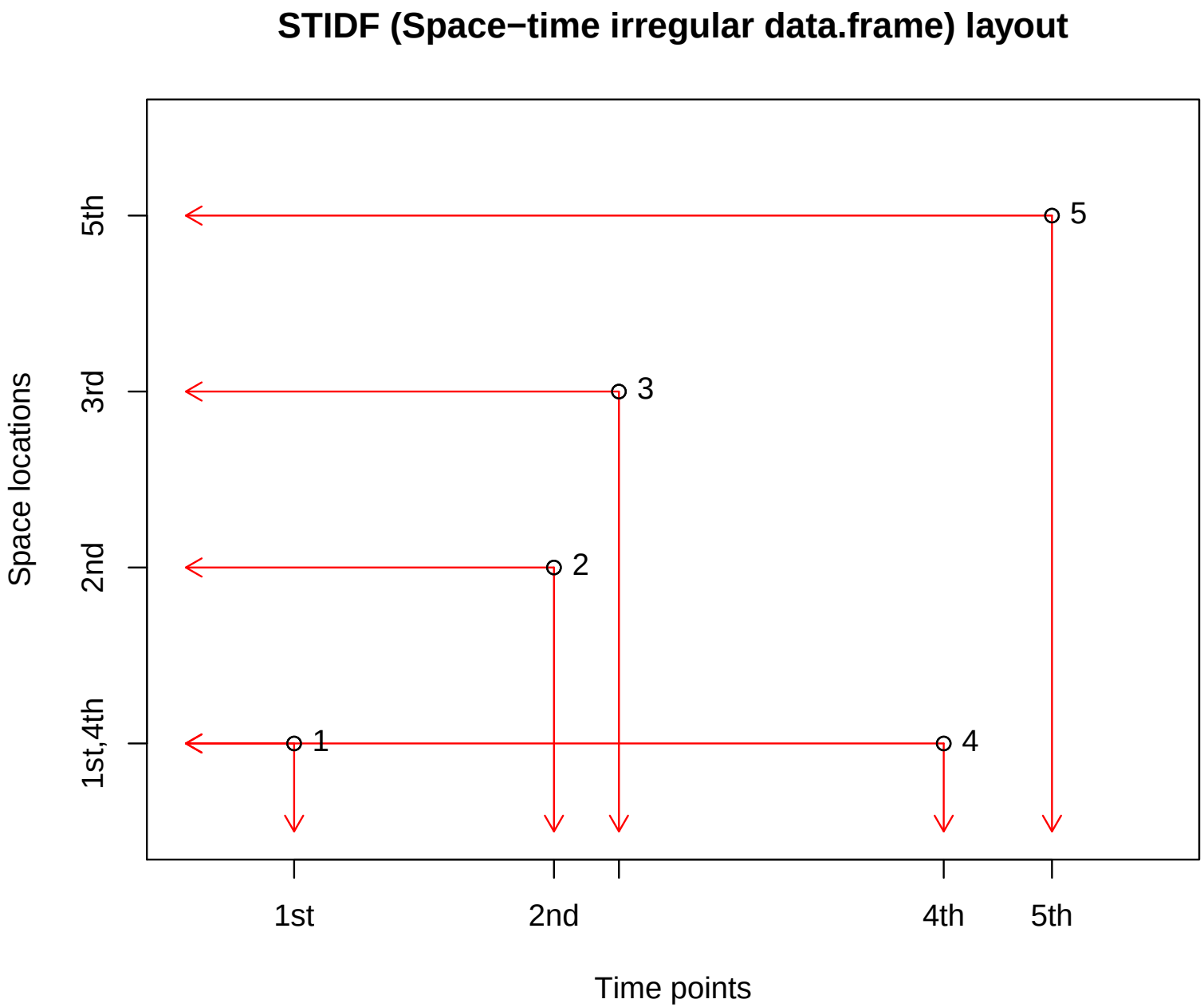

first snapshot
Space locations
3rd
2nd
1st
3
6
9
12
2
5
8
11
obj[,1,]
1
4
7
10
1st
2nd
3rd
4th
Time points


second snapshot
Space locations
3rd
2nd
1st
3
6
9
12
2
5
8
11
obj[,2,]
1
4
7
10
1st
2nd
3rd
4th
Time points


third snapshot
Space locations
3rd
2nd
1st
3
6
9
12
2
5
8
11
obj[,3,]
1
4
7
10
1st
2nd
3rd
4th
Time points


fourth snapshot
Space locations
3rd
2nd
1st
3
6
9
12
2
5
8
11
1
4
7
10
obj[,4,]
1st
2nd
3rd
4th
Time points


STSDF (space−time sparse data.frame) layout
Space locations
3rd
2nd
1st
3[3,1]
5[3,2]
2[2,1]
4[2,2]
7[2,4]
1[1,1]
6[1,3]
1st
2nd
3rd
4th
Time points



spatial

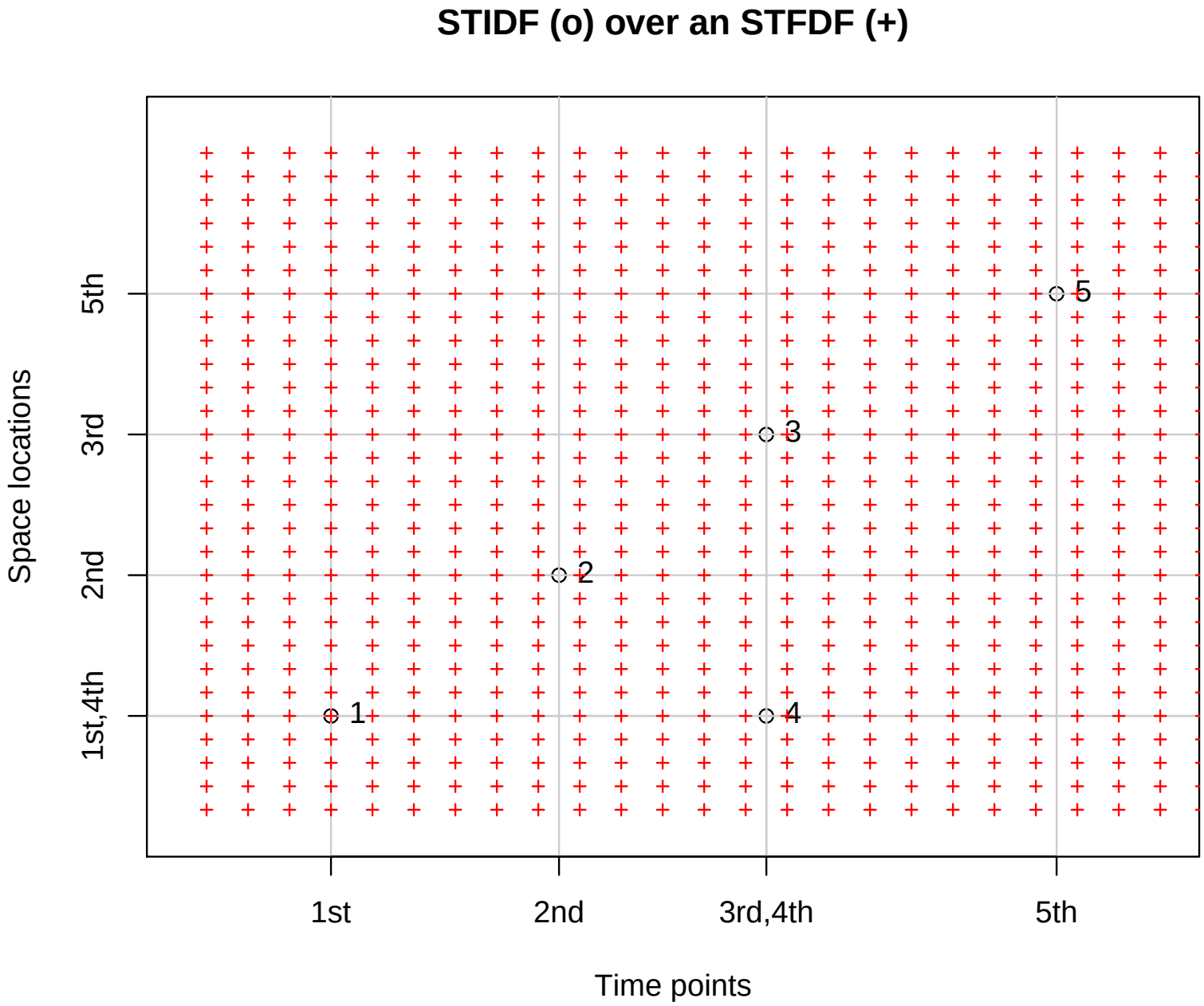
location 1 is duplicated, and will appear twice.

Classes in package spacetime

data type	class	attributes	contains
(virtual)	`ST`	No	`Spatial, xts`
full grid	`STF`	No	`ST`
partial grid	`STS`	No	`ST`
sparse grid	`STI`	No	`ST`
full grid	`STFDF`	data.frame	`STF, data.frame`
partial grid	`STSDF`	data.frame	`STP, data.frame`
sparse grid	`STIDF`	data.frame	`STS, data.frame`
trajectories	`STIDFtraj`	data.frame*	`STSDF`

* columns `id` and `burst` reserved for ID (car) and burst (car trip) [see class `ltraj` in package adehabitat].

Methods: coercion, selection (`obj[space,time,attr]`), summary, plot, ...


STIDF (o) over an STFDF (+)
Space locations
1st,4th
2nd
3rd
5th
1
2
3
4
5
1st
2nd
3rd,4th
5th
Time points

Typical operations

- reduce to space-only or time-only
- visualize: cartoon, 3D, animated/dynamic slicing
- analyze in one domain, borrowing strenght from the other (e.g. RS time series, classify pixel time series using neighbouring pixel time series)
- correct for mis-alignment: interpolate, aggregate, disaggregate, redistribute
- smooth (interpolate, density estimation, fit model)
- combine two data sets (overlay/cross), e.g. find the aggregated exposure over a trajectory through a dynamic air quality field

cshapes: changing country shapes

- Package cshapes provides a data base with country shapes, and their change
- data come as a `SpatialPolygonsDataFrame`, with start time and end time for each shape
- conversion to STIDF is done ignoring end time, assuming (i) end of the time series is known, and (ii) no overlapping intervals

```
> library(cshapes)
> cs = cshp()
> class(cs)

[1] "SpatialPolygonsDataFrame"
attr(,"package")
[1] "sp"

> cshp.2002 = cshp(date=as.Date("2002-6-30"), useGW=TRUE)
> t = strptime(paste(cs$COWSYEAR,cs$COWSMONTH,cs$COWSDAY,
+  sep="-"), "%Y-%m-%d")
> tt = as.POSIXct(t)
> st = STIDF(geometry(cs), tt,
+  as.data.frame(cs))
> pt = SpatialPoints(cbind(7, 52),
+  CRS(proj4string(cs)))
> as.data.frame(st[pt,])[c("CNTRY_NAME", "time")]

                CNTRY_NAME
1 Germany Federal Republic
2                  Germany
        time
1 1955-05-05
2 1990-10-03
```

Spatial and/or temporal support

- for spatial nor temporal data, the support (physical size) of measurements is explicitly available

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- implicit assumptions for spatial spatial: point = 0, grid cell is grid cell size; line / polygon idem;

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- for spatial nor temporal data, the support (physical size) of measurements is explicitly available
- implicit assumptions for spatial spatial: point = 0, grid cell is grid cell size; line / polygon idem;
- implicit assumption for time: length of time step, or explicit (e.g. in Open/High/Low/Close).

Conclusions

- We take a pragmatic approach: what do data analists do?
- R (program, packages, mailing lists) provides a rich ecosystem for analyzing data, but also for studying how people analyze data
- spatio-temporal data analysis of all kinds is abundant in R, convergence based on common classes and methods started – please participate and help shape the things to come!
- extending aggregation, disaggregation, and smoothing methods is high priority; then: massive data volumes, graphs for evolution; no s/t prisms, but look what ecologists do
- need to express how proximity, similarity, correlation etc extent to s/t (e.g. asymmetries, as opposed to 3D/4D)
- we see time as an extension of the geometry, not of the attributes (NetCDF vs. shapefile)
- we're building a rich tool set that deals with many aspects of *the scale problem*, in space and time.