RESSTE Workshop
Working on data from PREV'AIR with spacetime & R

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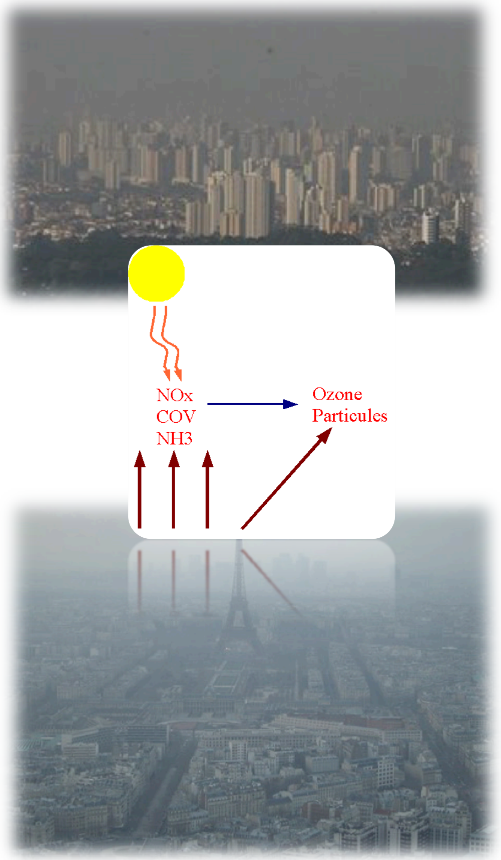
Montpellier Spatial Statistics METMA's workshop, the 12 th of June 2018

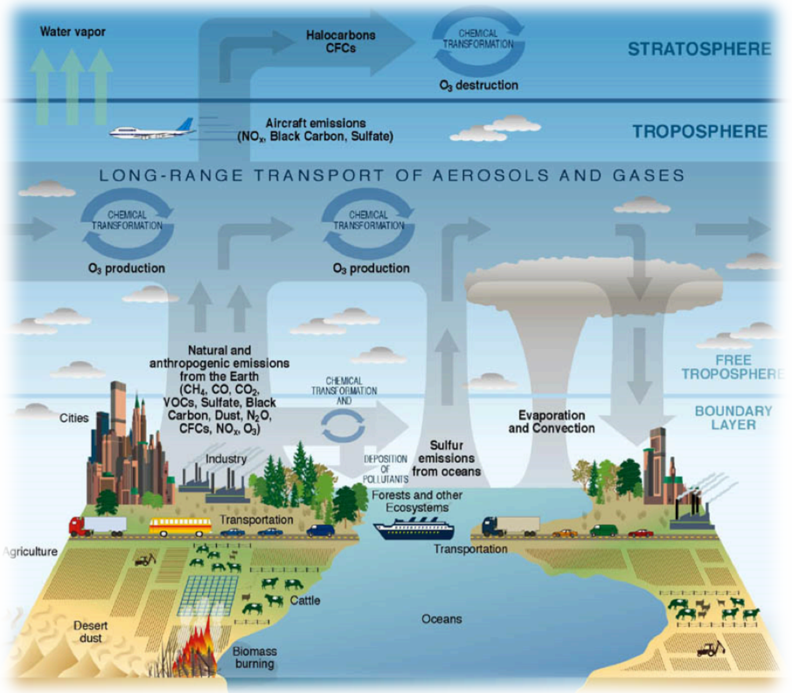
Predicting Air Pollutants

- **What:**
  - Pollutants levels with legal thresholds: O_3, NO_2 , PM_{10}, $PM_{2.5}$
  - Global / european / national scale
  - 3 days ahead

  Public warnings should not only depend on observations.
- **Where?**
  - Places with few or no observation
- **Why?**
  - **Air quality** management in case of polluted periods.
  - Sources of pollution

PREV’AIR: How does it work?

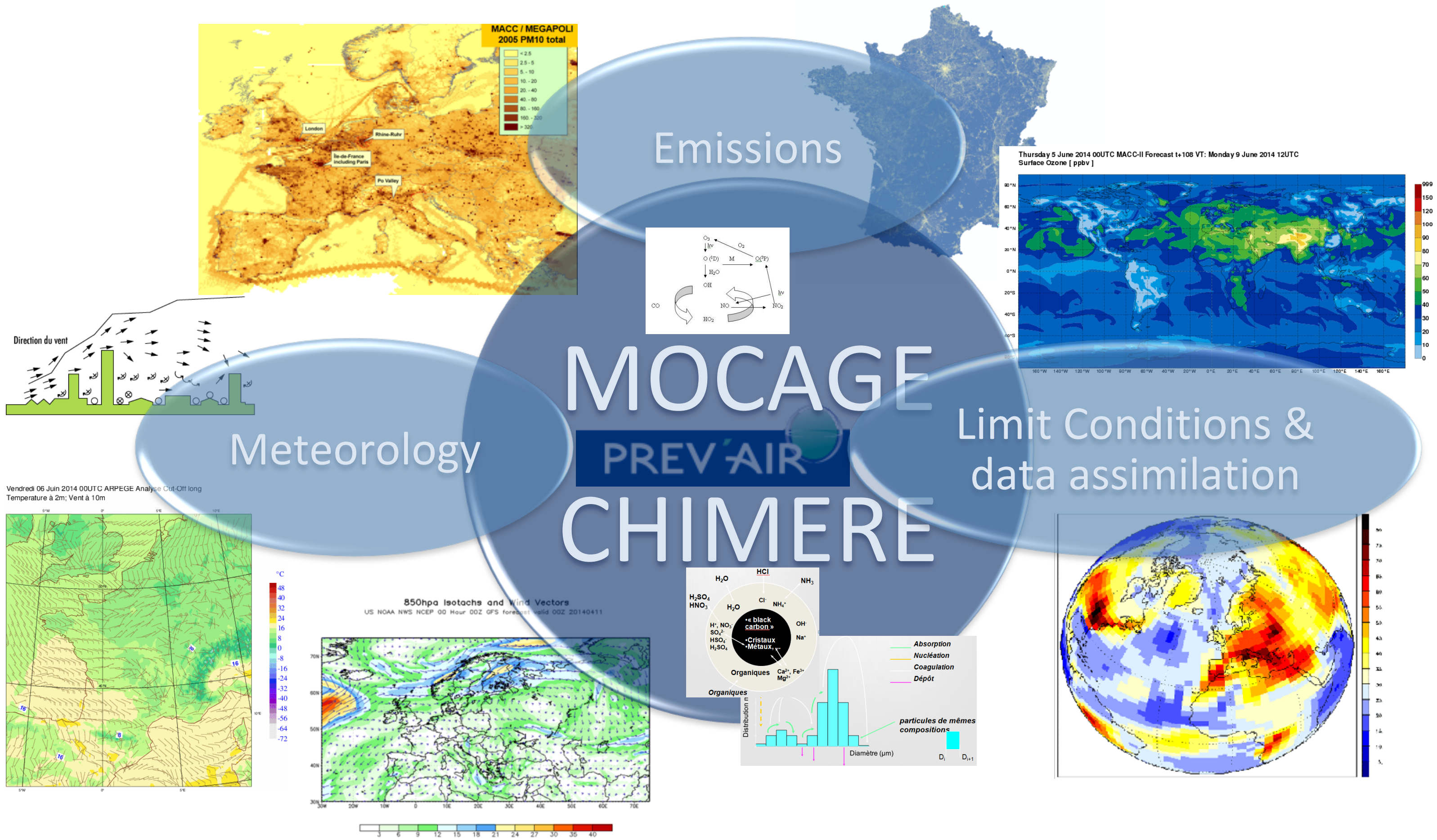




Water vapor
Halocarbons CFCs
CHEMICAL TRANSFORMATION
O_3 destruction
STRATOSPHERE
Aircraft emissions (NO_x, Black Carbon, Sulfate)
TROPOSPHERE
LONG-RANGE TRANSPORT OF AEROSOLS AND GASES
CHEMICAL TRANSFORMATION
O_3 production
CHEMICAL TRANSFORMATION
O_3 production
Natural and anthropogenic emissions from the Earth (CH_4, CO, CO_2, VOCs, Sulfate, Black Carbon, Dust, N_2O, CFCs, NO_x, O_3)
CHEMICAL TRANSFORMATION AND
DEPOSITION OF POLLUTANTS
Sulfur emissions from oceans
Evaporation and Convection
FREE TROPOSPHERE
BOUNDARY LAYER
Cities
Industry
Forests and other Ecosystems
Transportation
Transportation
Agriculture
Cattle
Oceans
Desert dust
Biomass burning

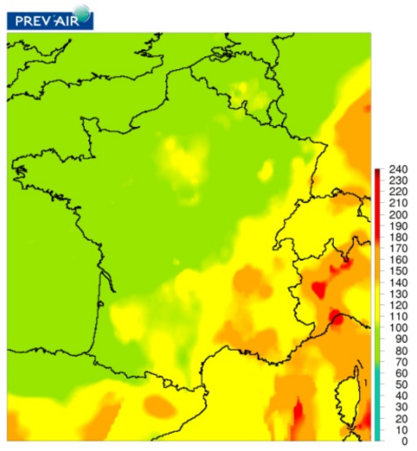
Mathematical models mimicking the dynamics of transport and chemical interactions of chemical pollutants within the troposphere

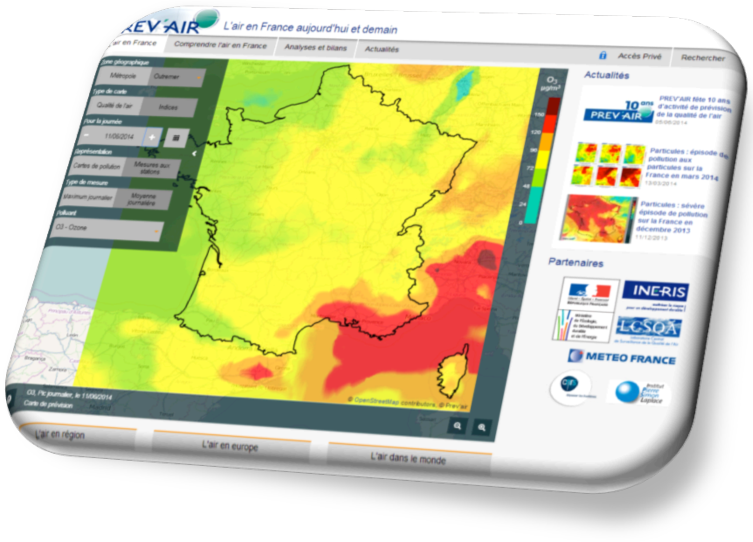
How does it work?

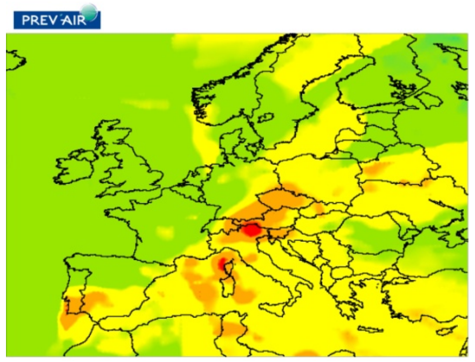


PREV'AIR website: see: www2.prevair.org

- Every morning, 8 o'clock
  - Daily values (max and mean) for :
    - yesterday, today, d+1, d+2
    - O_3, NO_2, Particles (PM_{10}, $PM_{2.5}$ & desert dust)

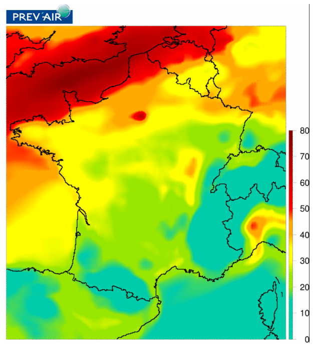






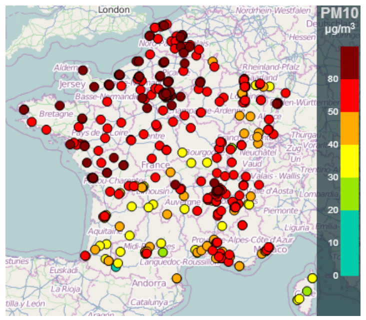
What is PREV'AIR used for?

- Statistical analyses



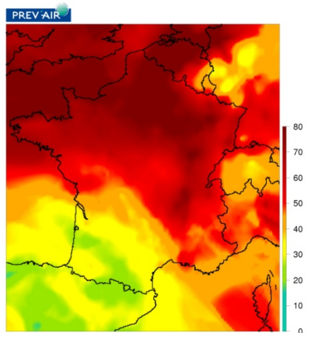
PM$_{10}$: raw Chimere
12 march 2014

+



PM$_{10}$: observations
12 march 2014

=



PM$_{10}$: corrected map
12 march 2014

- Many end-users :
  - nat/int. research projects,
  - air quality authorithies,
  - Medias…

Your data for the RESSTE workshop

- Repertories
  - A CHM repertory that contains data files (daily and hourly) from CHIMERE model for year 2014 (50 km resolution).
  - An OBS repertory containing hourly and daily data from the European database Airbase.

    One elementary file= (one pollutant, one time, all working locations)
  - A metadata file giving for each station its code, long/lat, etc…

- Focus on France… (for once!)

DATA.TABLE for building dataframes from the raw data

(One file per day per pollutant)

- 1.7 Go of data available from RENATER
- OBS &CHM : Many « rbind »'s, the dataframe gets bigger & bigger; merging large dataframes + need to work with missing data!
- data.table package with powerful « **rbindlist** ».

Some preliminary data cleaning has been made for you:

Let's start…

- data/OBS_hourly.Rdata: Dataframe of hourly records over 505 French stations (ID), long, lat, date, PM10, PM25, NO_2, O_3
- data/OBS_daily.Rdata : Dataframe of daily records over 505 French stations
- data/CHM.Rdata : 111x101 gridded values over France
- data/stations.Rdata : Station main covariates

SpaceTime = SP + XTS

Journal of Statistical Software

November 2012, Volume 51, Issue 7. *http://www.jstatsoft.org/*

spacetime: Spatio-Temporal Data in R

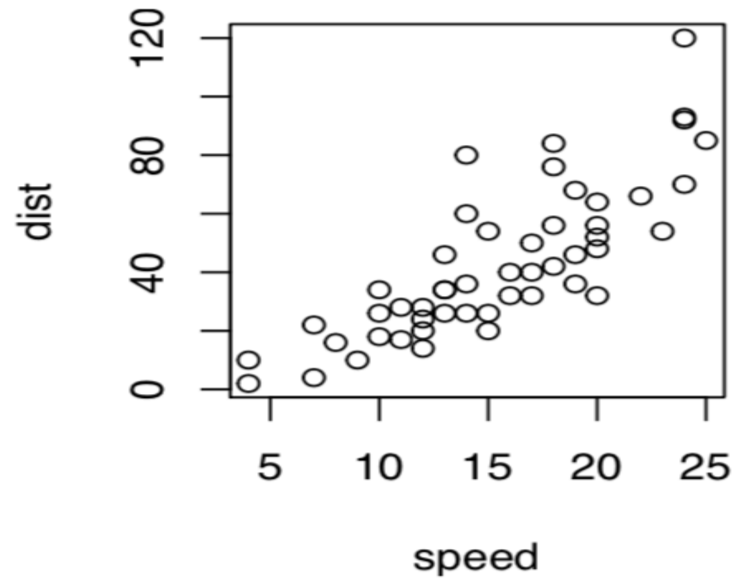
ifgi
Institute for Geoinformatics
University of Münster

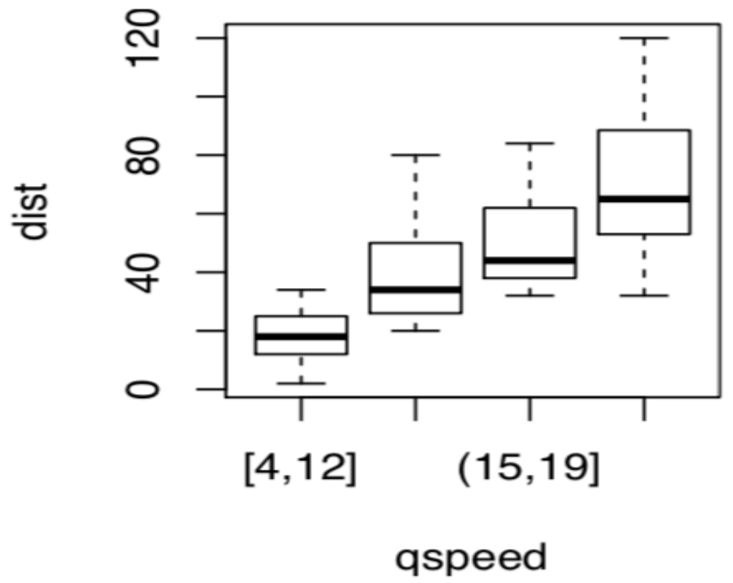
52north
exploring horizons

Edzer Pebesma

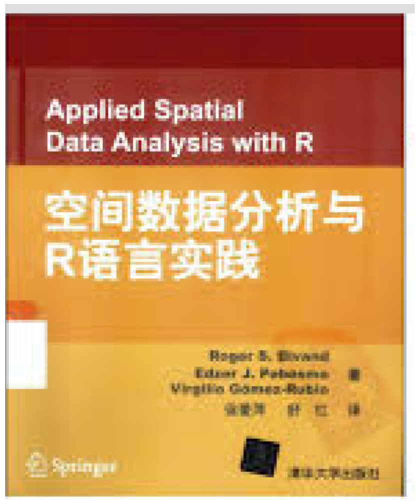
Why should we care about R class formats ?

```
cars$qspeed <- cut(cars$speed, breaks=quantile(cars$speed),
                   include.lowest=TRUE)
par(mfrow=c(1,2))
plot(dist ~ speed, data=cars)
plot(dist ~ qspeed, data=cars)
```





Spatial Formats (sp)

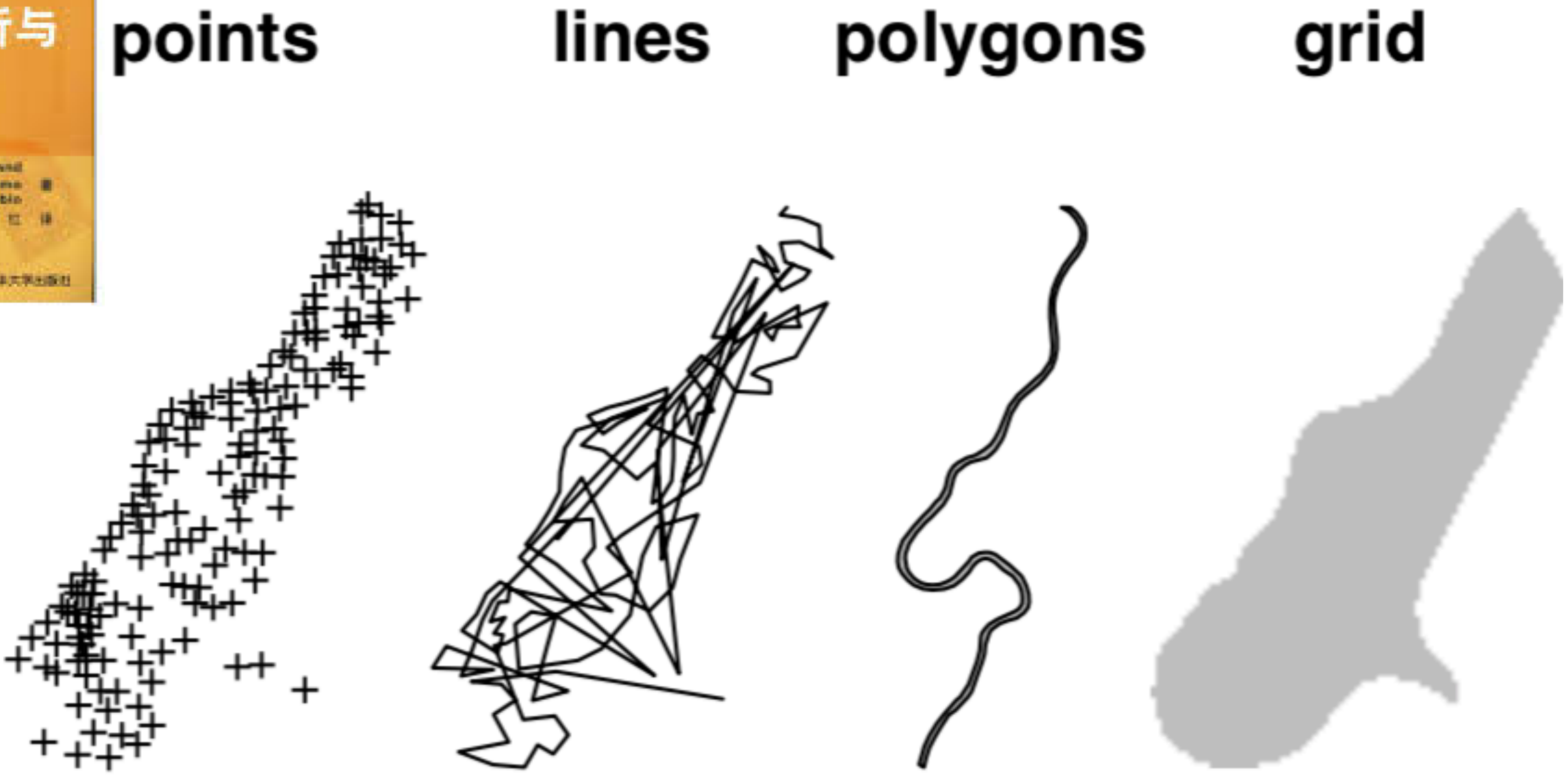

Applied Spatial Data Analysis with R

空间数据分析与R语言实践

Roger S. Bivand
Edzer J. Pebesma
Virgilio Gómez-Rubio 著
[illegible] 译

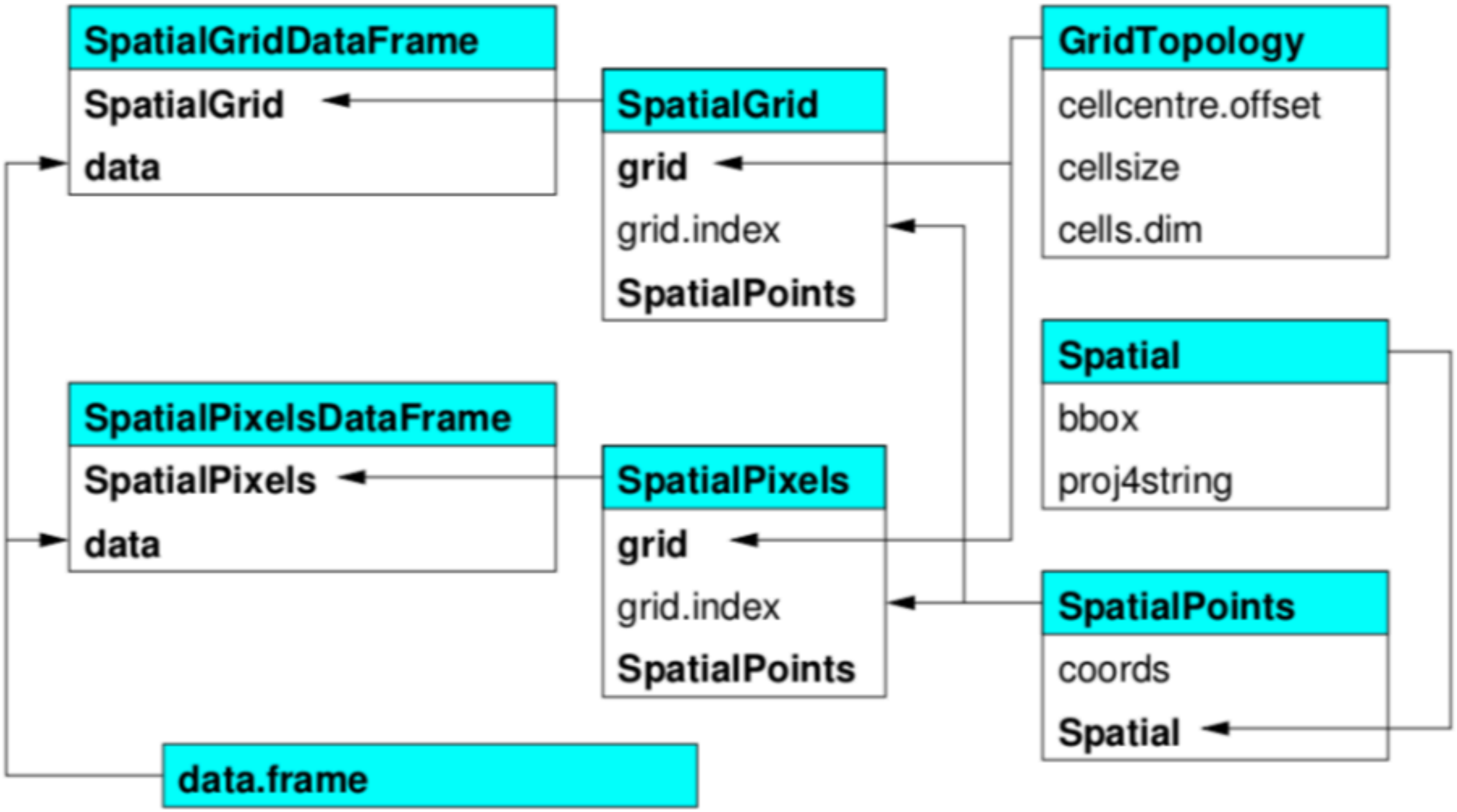
Springer

清华大学出版社



Spatial format: sp

```
library(sp)
coords <- SpatialPoints(OBS_jour[, c("long", "lat")])
summary(coords)
OBS_jour_sp <- SpatialPointsDataFrame(coords,
OBS_jour)
names(OBS_jour_sp)
is(OBS_jour_sp)
is(OBS_jour)
```


SpatialGridDataFrame
SpatialGrid
data
SpatialGrid
grid
grid.index
SpatialPoints
GridTopology
cellcentre.offset
cellsize
cells.dim
Spatial
bbox
proj4string
SpatialPixelsDataFrame
SpatialPixels
data
SpatialPixels
grid
grid.index
SpatialPoints
SpatialPoints
coords
Spatial
data.frame

E. Pebezma keeps on trucking…

- His 2016 package sf =sp+rgeos+rgdal
- See https://github.com/r-spatial/sf
- And for French people https://rgeomatic.hypotheses.org/1149

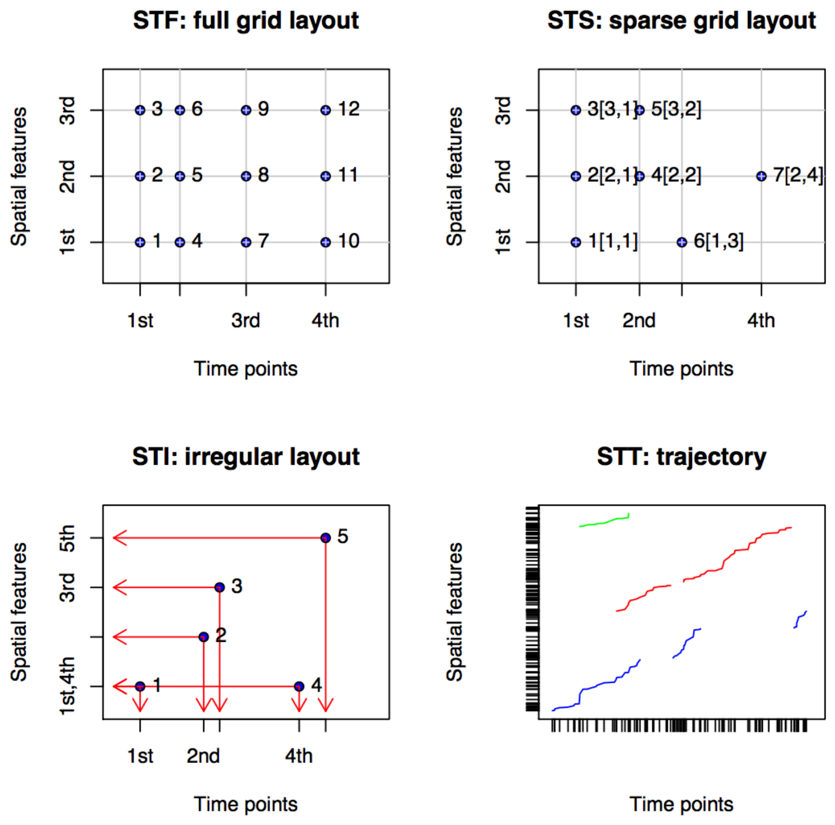
Time formats

- Class "POSIXct" represents the (signed) number of seconds since the beginning of 1970 (in the UTC time zone) as a numeric vector. Class "POSIXlt" is a named list of vectors representing sec, min, hour,day,month,year…

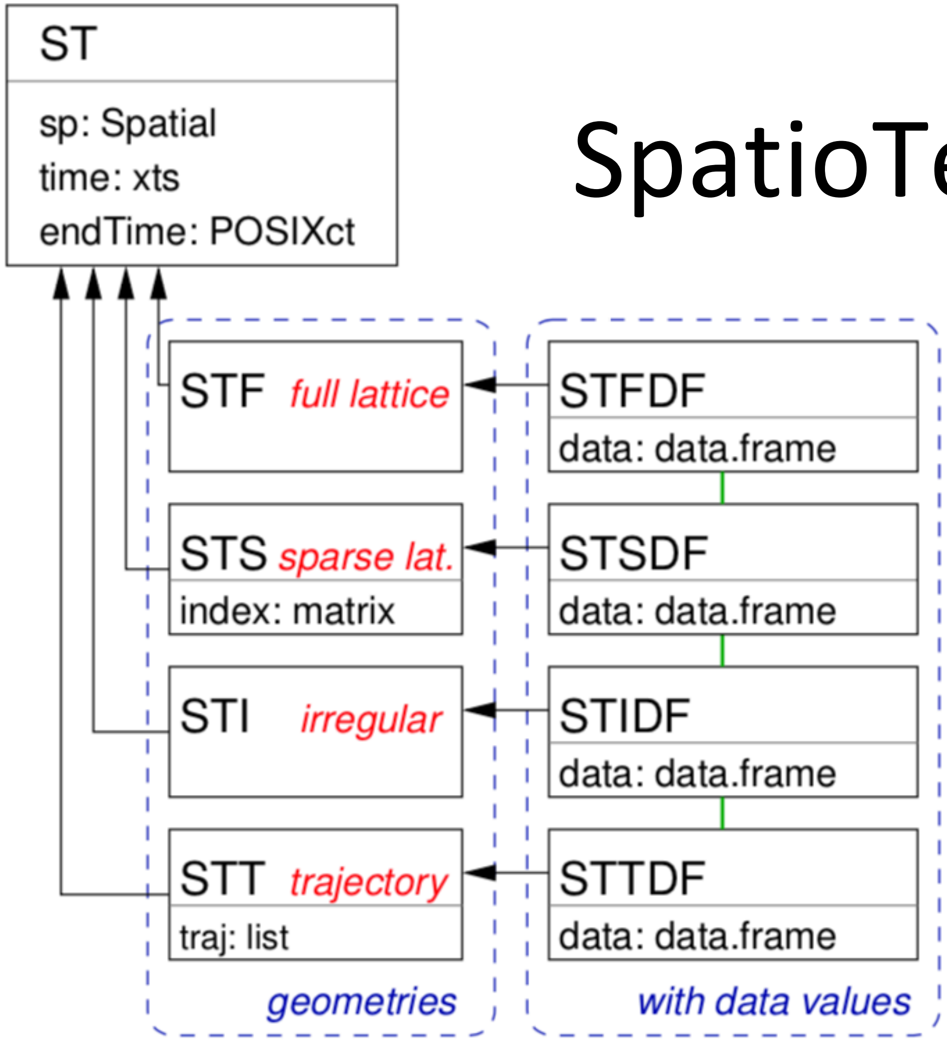
-
```
(z <- Sys.time())                  # the current date, as class "POSIXct"
 is(z)
 Sys.time() - 3600                  # an hour ago
 as.POSIXlt(Sys.time(), "GMT")     # the current time in GMT
```

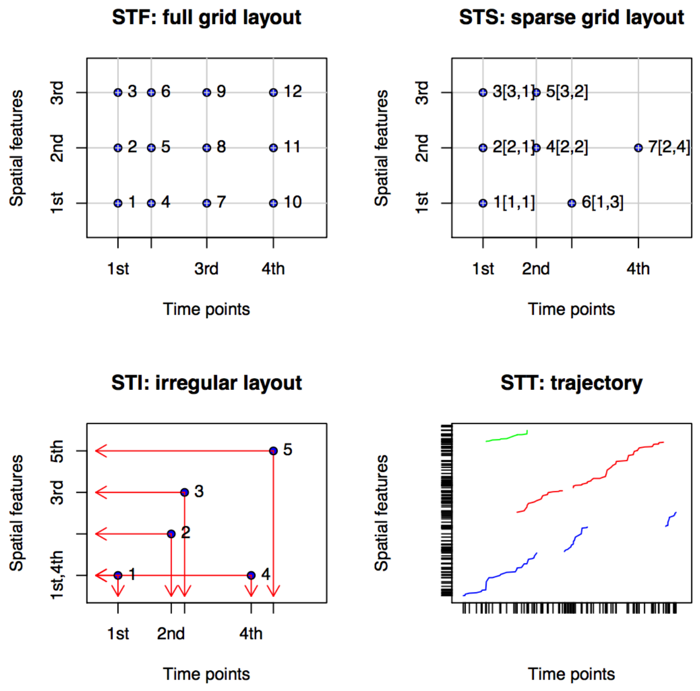
SpatioTemporal formats

- **Time-wide** format: row= location, columns=dates
- Space-wide format: row= date, columns=locations
- Long format: row= record, columns=location & date



SpatioTemporal formats





stConstruct(x, space, time, SpatialObj = NULL, TimeObj = NULL, crs = CRS(as.character(NA)), interval, endTime)

- X : object of class matrix or data.frame, holding the long, space-wide or time-wide table
- Space : in case x is a long table, character or integer holding the column index in x where the spatial coordinates are (if length(space)==2) or where the ID of the spatial location is (if (length(space)==1). If x is a space-wide table, a list with each (named) list element a set of columns that together form a variable
- Time : in case x is a long table, character or integer indicating the column in x with times;
- SpatialObj : object of class Spatial-class, containing the locations of a time-wide table, or the locations of a long table
- TimeObj: in case of space-wide table, object of class xts, containing the times for each of the columns in a list element of space
- Crs: object of class CRS-class; only used when coordinates are in x and no CRS can be taken from SpatialObj

stConstruct to build STIDF, STFDF & STSDF

```
STFDF_day <- stConstruct(OBS_jour,
space=c('long','lat'),
time='date’,
SpatialObj=SpatialPoints(OBS_jour[,c('long','lat')]))
#24 Mbytes
STFDF_day    <- as(STFDF_day, "STFDF") #6 Mbytes
```

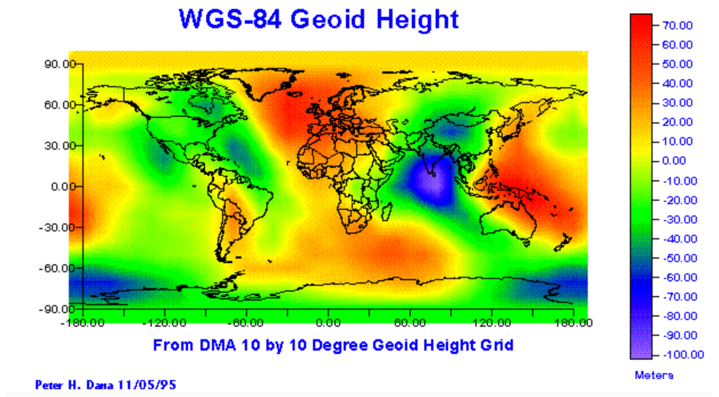
Coordinates Reference System

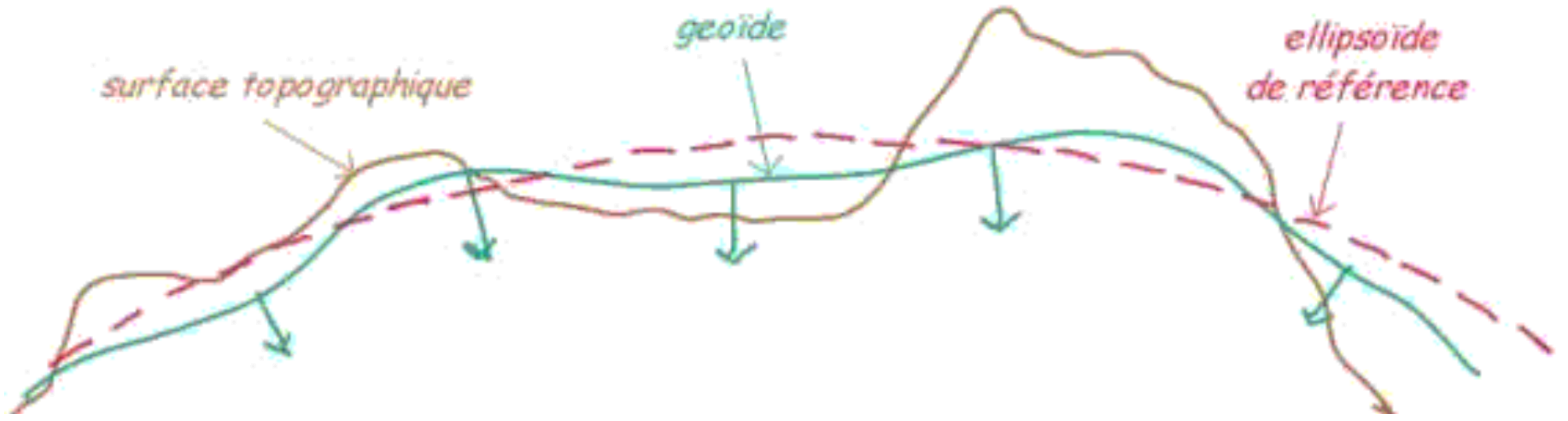
- proj4string(CHM_day)   <- "+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs"
- ???
- rgdal : geospatial abstract library

1. Projection projInfo(type=‘proj ’)
2. Datum projInfo(type=‘datum ’)
3. Ellipsoid projInfo(type=‘ellps ’)

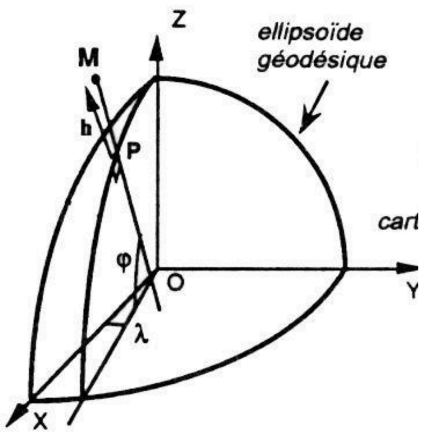
Datum

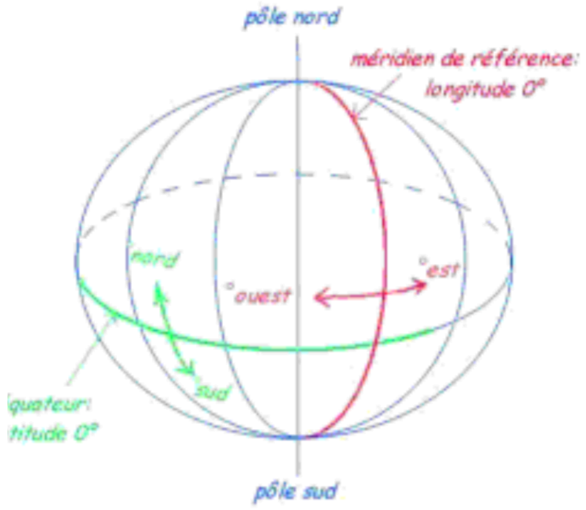
- Topological errestrial surface
- Reference Geoid
- Mathematical Ellipsoid

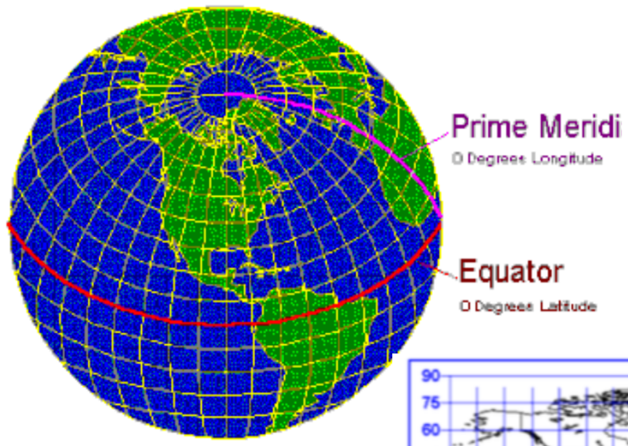


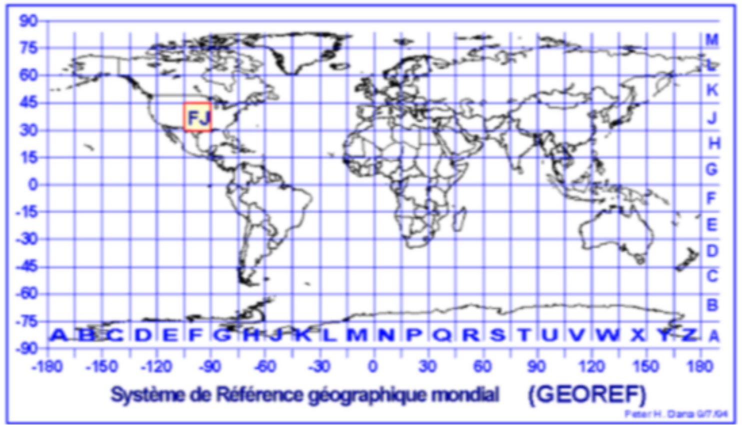


« Natural » polar coordinates latlong: unprojecting





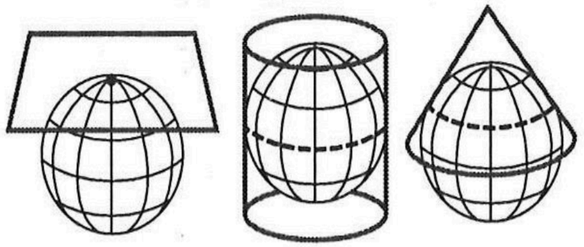




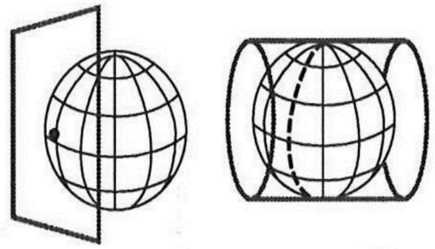
A (nautical) mile on the equateur
spans 1 mn in latitude

WGS84 (Google Earth)

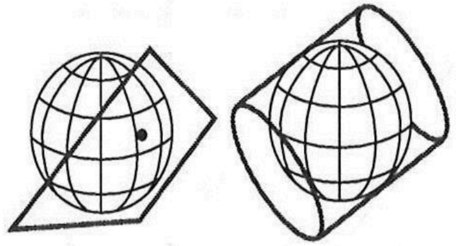
Projecting



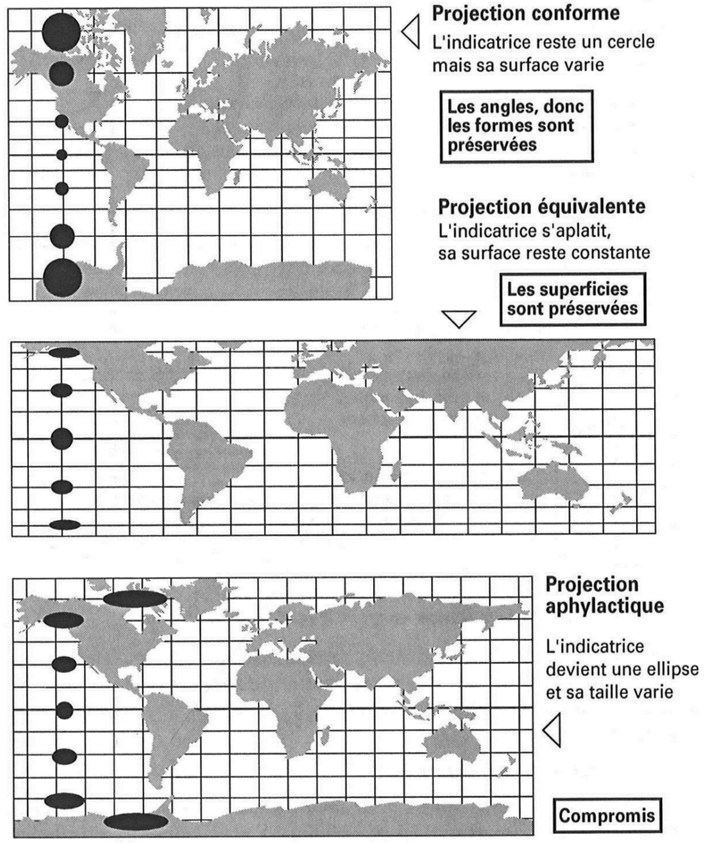
La projection est ***directe :***
la surface de projection est centrée
sur un pôle (projection azimutale),
sur l'équateur (projection cylindrique)
ou sur un parallèle (projection coniqu

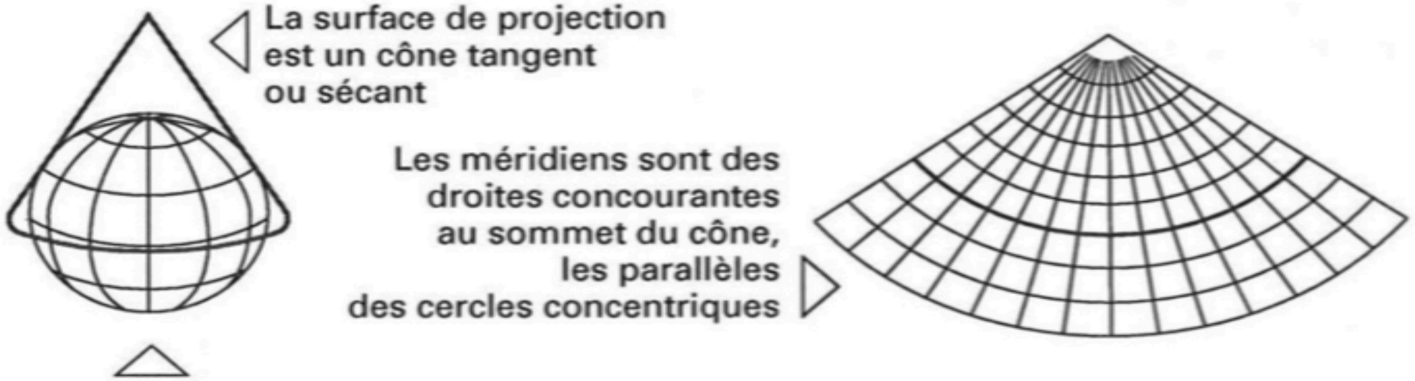


La projection est ***transverse :***
la surface de projection est centrée sur un
point de l'équateur (projection azimutale)
ou sur un méridien (projection cylindrique).

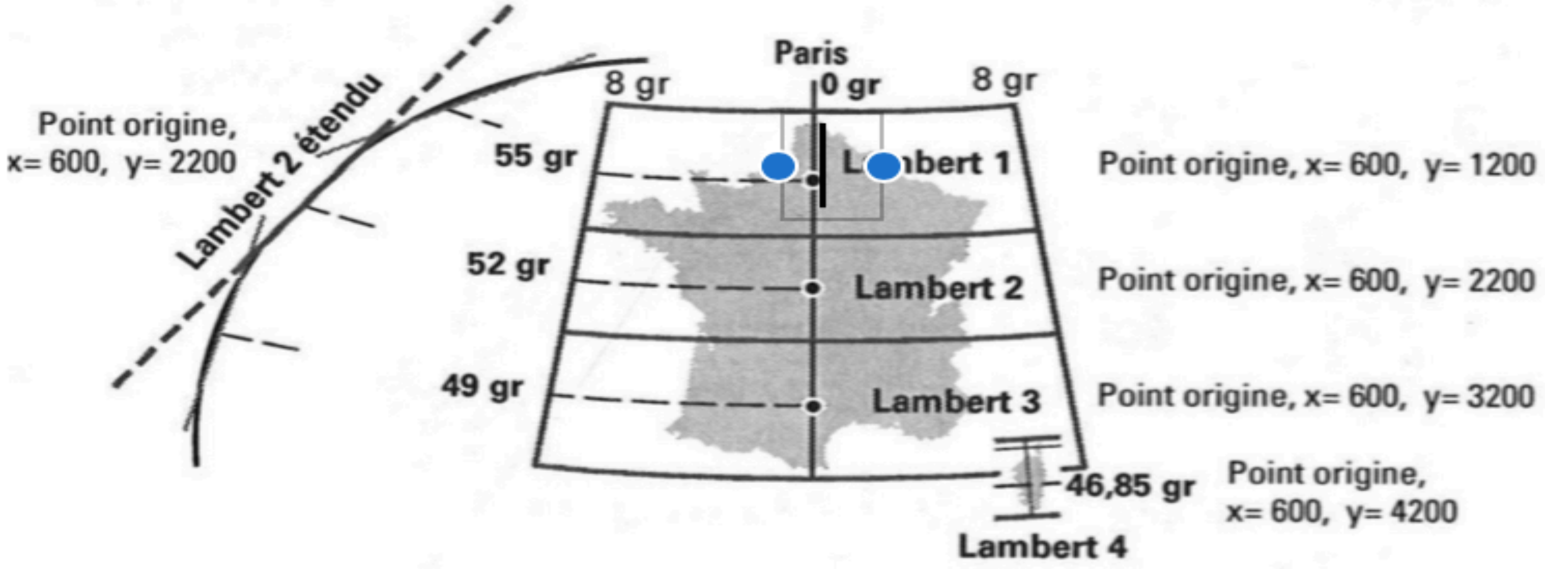


La projection est ***oblique :***
la surface de projection est centrée sur un
point quelconque de la sphère.


Projection conforme
L'indicatrice reste un cercle mais sa surface varie
Les angles, donc les formes sont préservées
Projection équivalente
L'indicatrice s'aplatit, sa surface reste constante
Les superficies sont préservées
Projection aphylactique
L'indicatrice devient une ellipse et sa taille varie
Compromis



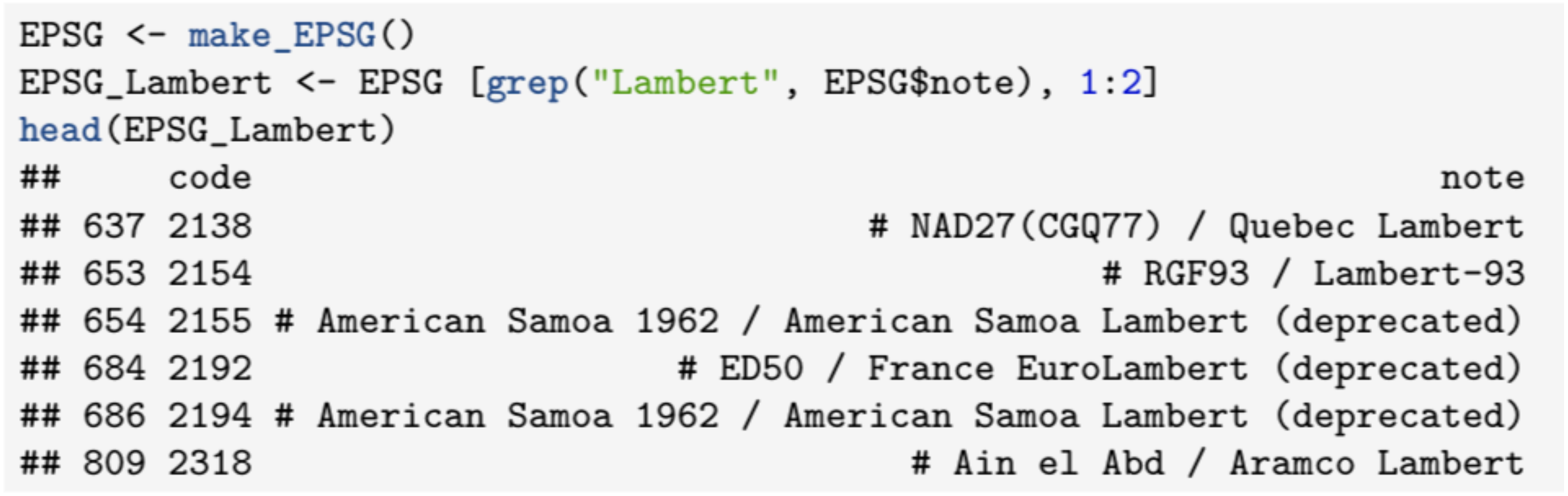
Le centre de projection est un parallèle (2 parallèles lorsque le cône est sécant)



CRS: A word of warning

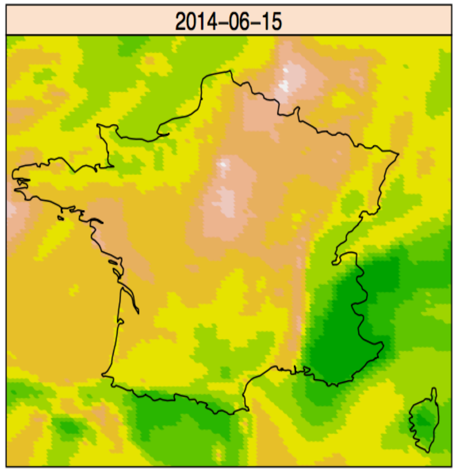
In R , 2 ways to define the projection system:

- either write it directly the projection formula in the proj4string slot (forget it! Weird tag expression)
- or use EPSG code, for instance WGS84 = 4326 (google) ou 2154 (Lambert-93) see http://spatialreference.org + library gdal



```
EPSG <- make_EPSG()
EPSG_Lambert <- EPSG [grep("Lambert", EPSG$note), 1:2]
head(EPSG_Lambert)
##     code                                                note
## 637 2138                          # NAD27(CGQ77) / Quebec Lambert
## 653 2154                                  # RGF93 / Lambert-93
## 654 2155 # American Samoa 1962 / American Samoa Lambert (deprecated)
## 684 2192                    # ED50 / France EuroLambert (deprecated)
## 686 2194 # American Samoa 1962 / American Samoa Lambert (deprecated)
## 809 2318                             # Ain el Abd / Aramco Lambert
```

European Petroleum Survey Group codes

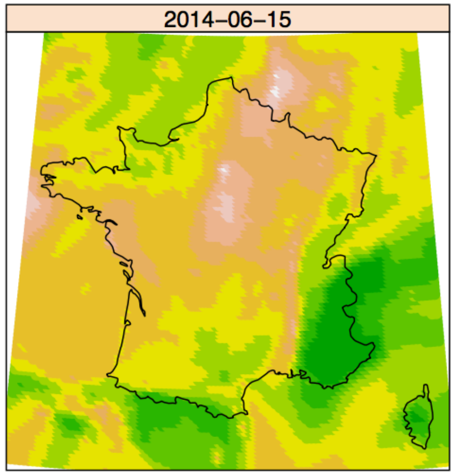


All-in-one encoding using « weird » tags

- epsg:4326 (Google unprojected)
- epsg:4269 (most US federal agencies)
- epsg:2154 (French Lambert 93)

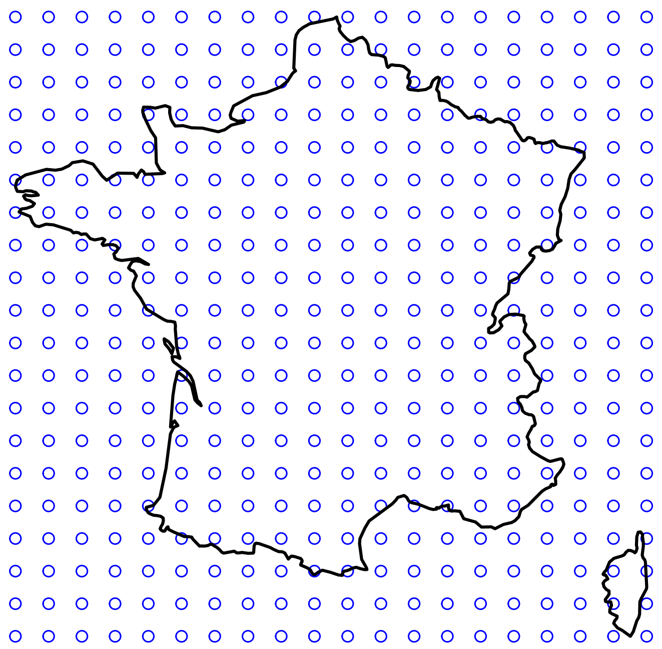
- To retrieve CRS: proj4string(xsp)
- To assign CRS: proj4string(xsp)=CRS('+init=epsg:2154')
- To **transform** coordinates: new=spTransform(old,CRS('+init=epsg:2154'))

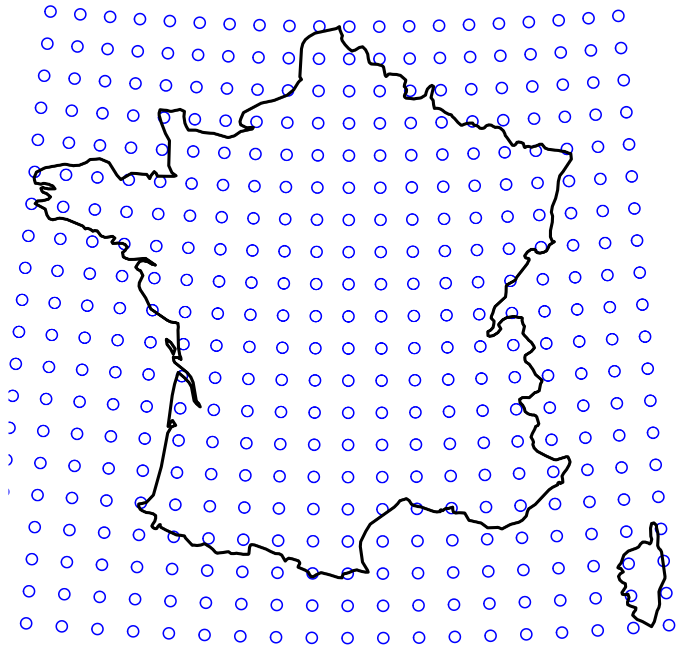
(i.e. Retro-projection)



```
bbox(france)
##          min       max
## x -4.790282  9.562218
## y 41.364927 51.091109
france_Lambert93 <- spTransform(france, CRS("+init=epsg:2154"))
bbox(france_Lambert93)
##          min     max
## x  124535.3 1242296
## y 6049526.6 7110717
```

Retro-project!





***spacetime**: Spatio-Temporal Data in R*

E Pebezma J Stat Softw. Nov. 2012, 51(7).

method	what it does
`stConstruct`	Creates STFDF or STIDF objects from single or multiple tables
`[[`, `$`, `$<-`	Select or replace data values
`[`	Select spatial and/or temporal subsets, and/or data variables
`as`	coerce to other spatio-temporal objects, `xts`, `Spatial`, `matrix`, or `data.frame`
`stplot`	create spatio-temporal plots, see Section 5
`over`	overlay: retrieve index or data values of one object at the locations and times of another
`aggregate`	aggregate data values over particular spatial, temporal, or spatio-temporal domains

Table 1: Methods for spatio-temporal data in package **spacetime**.

Plotting ST objects

- Ordinary base plots using plot, image, etc.
- Lattice (treillis) plots using spplot
- ggplot2 for nice graphs of time series

- New capabilities of stplot
  1. multi-panel plots
  2. space-time plots (Hovmöller diagrams)
  3. Animated plots
  4. Time series plots

Practical: Do it yourself

- Find the AirBase stations located in Paris (av des champs Elisées) , in Lyon (St Just) , in Rennes (les Halles)
- Make a daily time series plot of PM10 & NO2 for these 3 locations for year 2014
- Compare your series to the time series of the nearest Chimere pixel