

Spatio-temporal Data Analysis and Visualization with R

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Topics

- 1** Introduction
- 2** Spatio-temporal data & tools
- 3** Spatio-temporal statistics
- 4** Spatio-temporal visualization
- 5** Case studies

1 Introduction

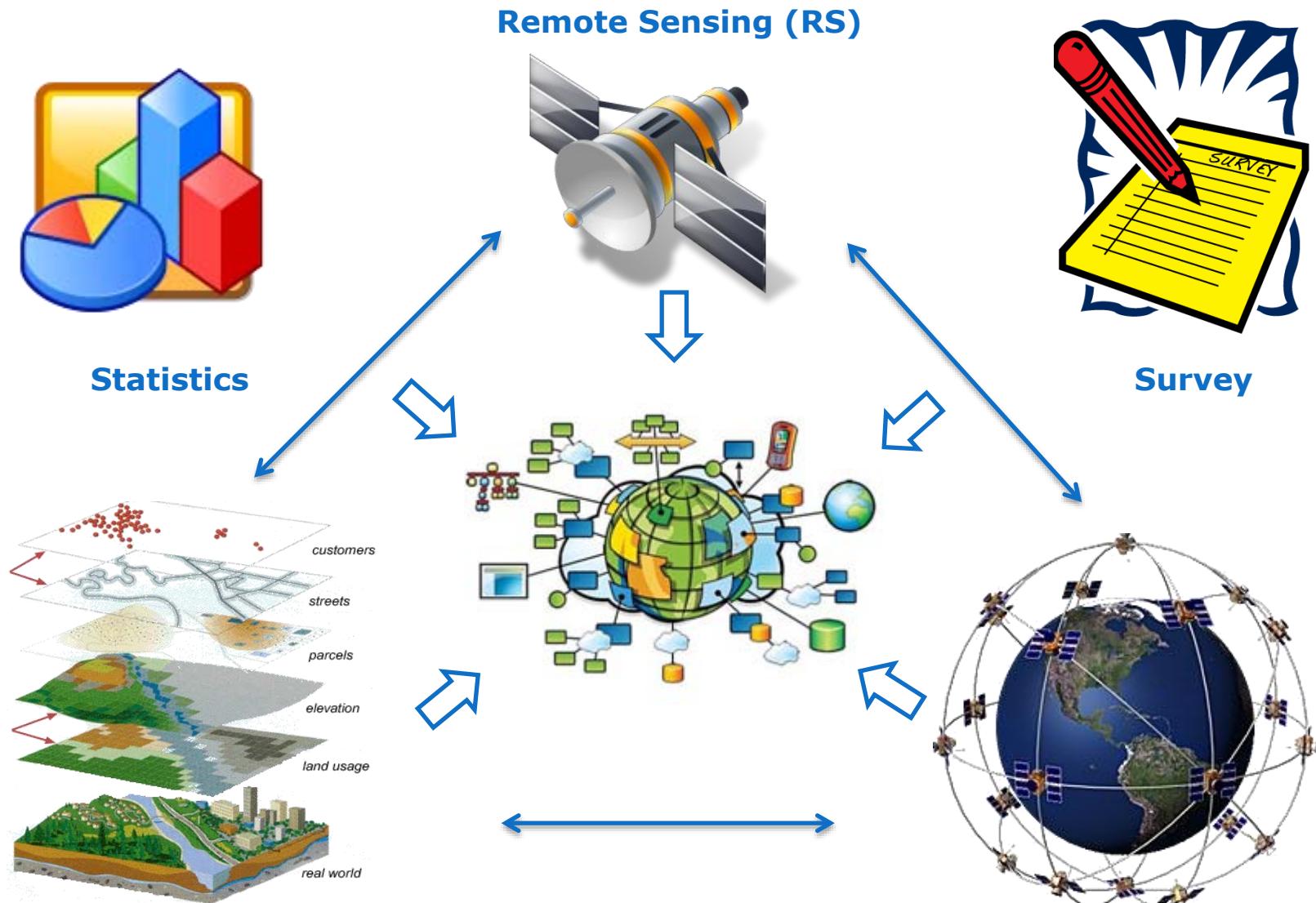


About Our World

- **Approximately 80%** of the informational needs of a local government policymaker is related to a geographical location. (*Robert E. Williams, 1987*)
- **Digital Earth** is the name given to a concept by former US vice president **Al Gore** in 1998, describing a virtual representation of the Earth that is georeferenced and connected to the world's digital knowledge archives.
- **Big Data Era**
- **Smart City**: a smart economy, mobility, environment, people, living, governance. (Caragliu et al. 2009)



Modeling and Manage Our World



Geographical Information System (GIS)

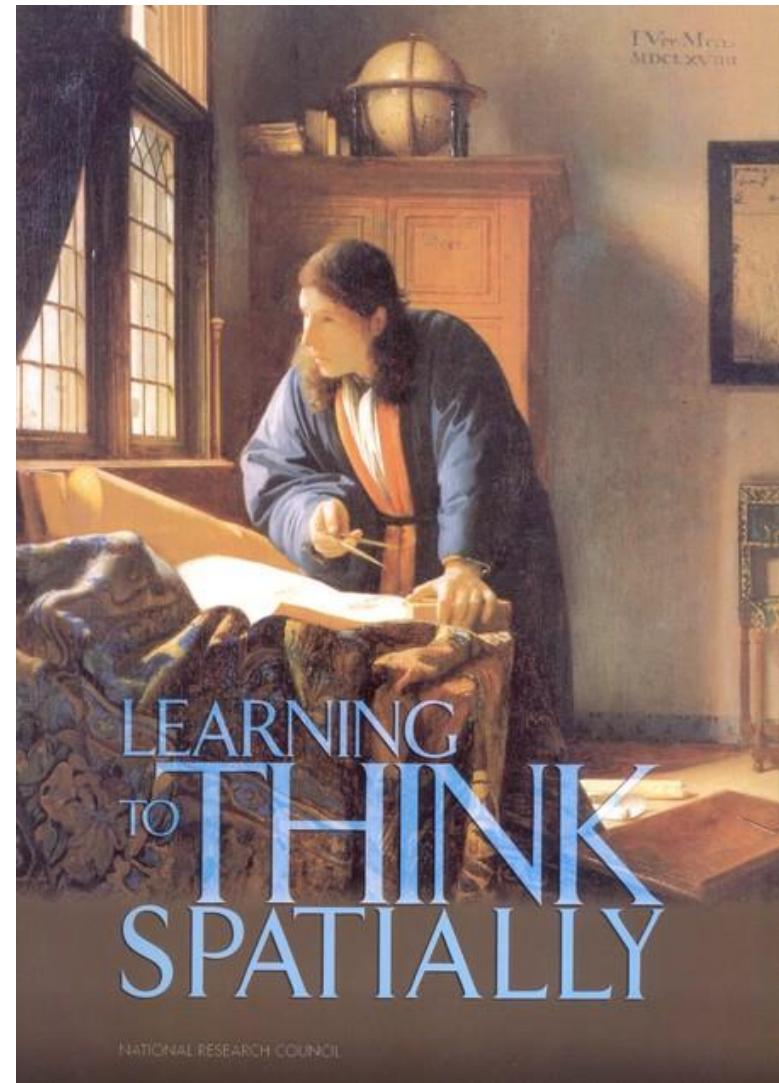
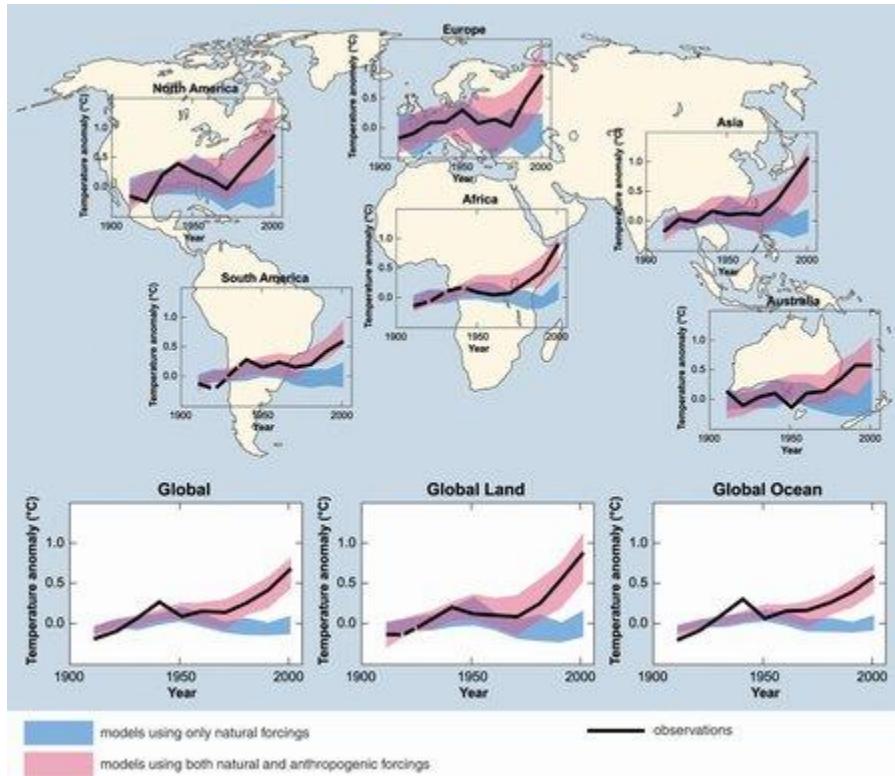
Global positioning System (GPS)

Thinking in Spatial-temporal

◆ Spatially

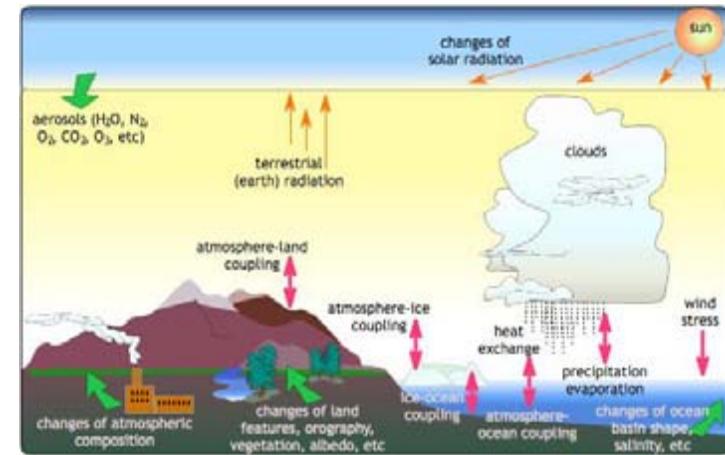
◆ Dynamically

◆ Interactively



Spatio-temporal modeling

- Description
- Separate model
 - Spatial analysis
 - Time series analysis
- Spatio-temporal model
 - **Statistical model**
 - Physical model for specific field
 - Statistical + physical model
- **Visualization**



Physical model



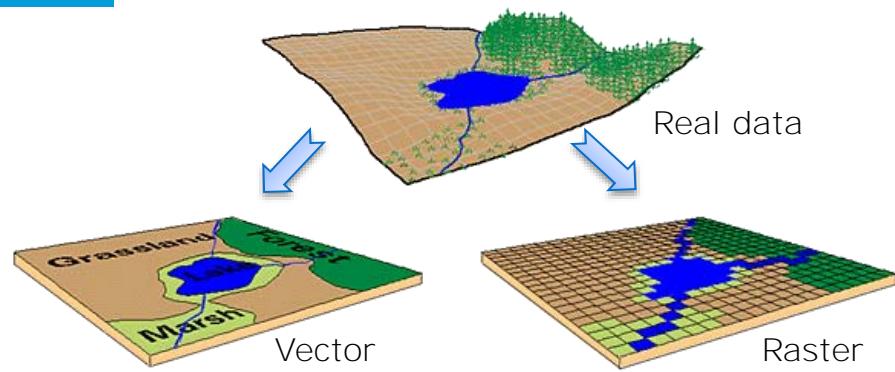
Statistics model

2 ST data & tools

Spatio-temporal Data

□ Spatial

- Vectorial: Point, Polyline, Polygon, Volume
- Raster
- Spatial Reference

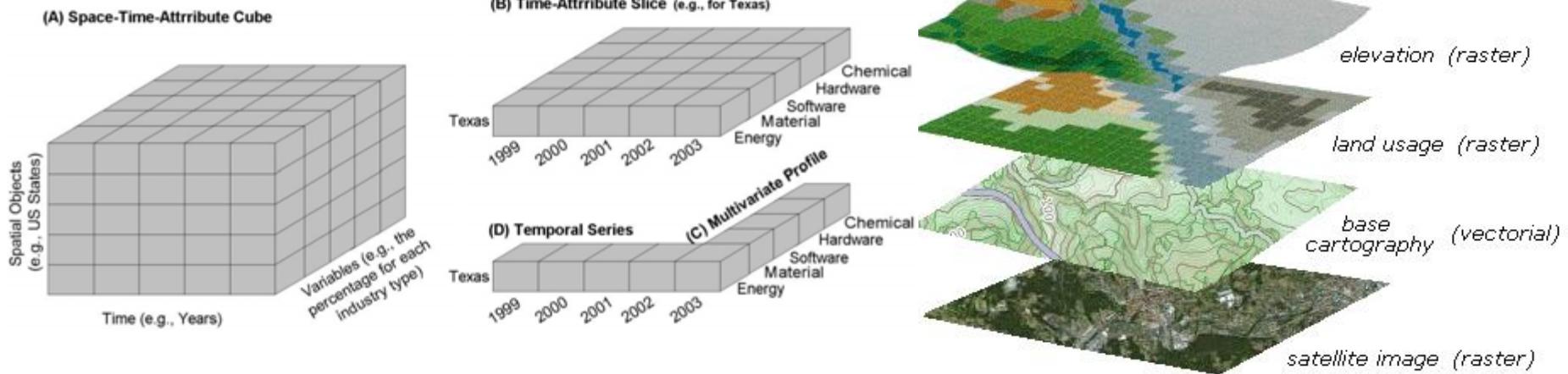


□ Temporal

- Date + Time

□ Attribute

- Data Frame



Get Spatio-temporal Data

- Basic geographic information
- Social statistical data
- Environmental monitoring data
- Scientific research data
- Remote sensing images
- Voluntary public data**

Free GIS Data

This website contains a categorised list of links to over 300 sites providing freely available geographic datasets.



Remotely Sensed Imagery



Voluntary provided data

Social Networking Services



Volunteer

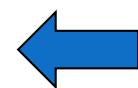


Grab data from Web

APIs



Hacker grabbing data



Computer Program

- Database
- Table
- JSON / GeoJSON
- POI



Manage and analysis of ST data

□ GIS software



GRASS GIS
The world's leading Free GIS software

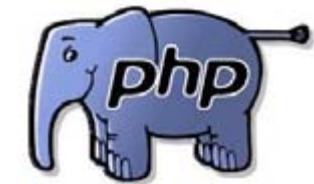


□ RS image processing tools



Tools for ST data analysis

□ Acquisition



□ Database



□ Analysis, data mining



□ Visualization

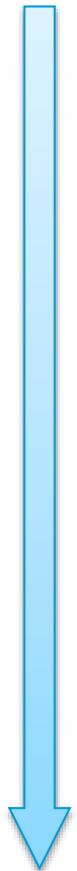


CartoCSS

3 Spatio-temporal statistics

Development of ST statistics

- classical statistics
- spatial statistics
 - Spatial target
 - Spatial autocorrelation , spatial heterogeneity
- Spatio-temporal statistics
 - Spatiotemporal observations
 - Spatial temporal autocorrelation;
 - Spatial temporal interaction *et al.*



Spatial statistics

□ Research contents

View of data model (Cressie 1993)

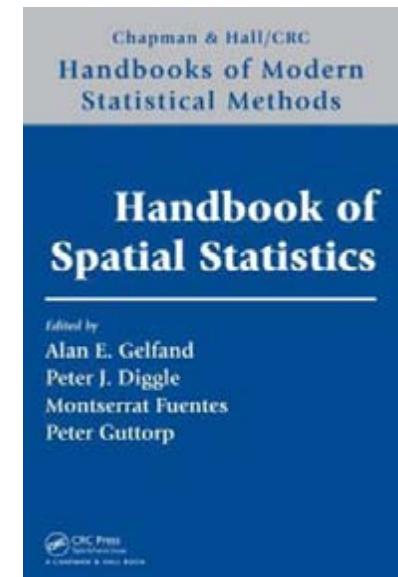
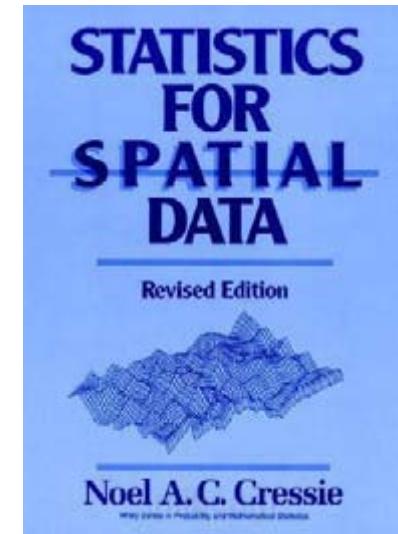
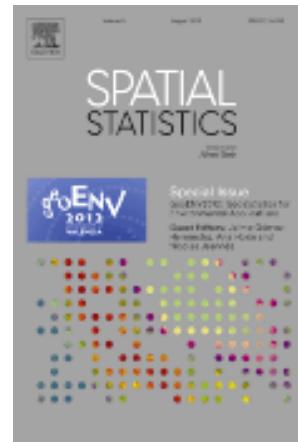
1. Point pattern
2. Lattice data
3. Geostatistical data

View of topics (Gelfand 2010)

1. Continuous spatial variation—including geostatistics , hierarchical model , non-stationary Gaussian random fields
2. Discrete spatial variation —spatial autocorrelation, disease mapping and spatial econometrics
3. Spatial point pattern—point pattern
4. Spatio-temporal process—ST model and assimilation
5. Addition topic—multivariate, change of support, aggregation and disaggregation

□ BOOKS

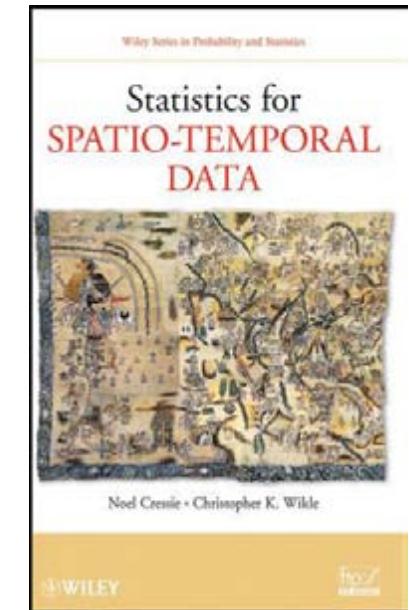
- Cressie, N. A. C. (1993). Statistics for spatial data. New York, Wiley.
- Gelfand, A. E. (2010). Handbook of spatial statistics. Boca Raton, CRC Press.



Spatio-temporal statistics

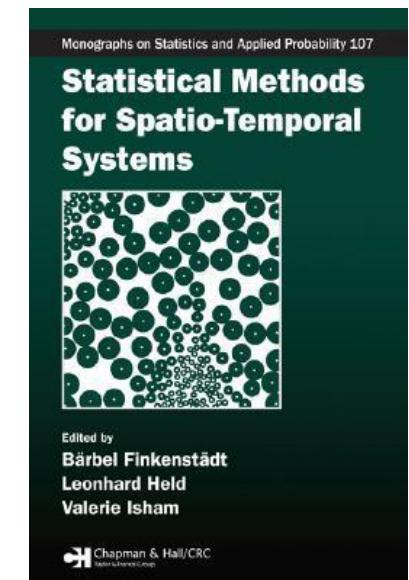
□ Research contents

- Based on spatial statistics and time series analysis
- Exploratory spatial data analysis (ESDA)
- Basic models
 - Spatio-temporal covariance model
 - Spatio-temporal kriging
 - Stochastic difference model
 - Spatial process with time series analysis
 - Spatio-temporal point pattern
- Hierarchical dynamic space-time model
-



□ BOOKS

- Cressie, N. A. C. and C. K. Wikle (2011). Statistics for spatio-temporal data. Hoboken, N.J., Wiley.
- Finkenstädt, B., L. Held, et al. (2007). Statistical methods for spatio-temporal systems. Boca Raton, FL, Chapman & Hall/CRC.



ST statistics application fields

- Earth system sciences
 - Climate, weather simulation and forecast
 - Geology, ocean, atmosphere, etc
- GIS, RS, and GPS (3S)
 - **GIS** : Collection, storage, management, analysis and visualize geographic information of time and spatial information
 - **RS** : Satellite and aerial remote sensing, Wireless sensor networks
 - **GPS** : position and tracking
- Global change and the ecological environment
- Environmental Health
- Socic-economic field
 - ST regression, STARMA *et al.*

ST statistics in R

□ Classified by task view

- TimeSeries

<http://cran.r-project.org/web/views/TimeSeries.html>

- Spatial

<http://cran.r-project.org/web/views/Spatial.html>

- Spatiotemporal

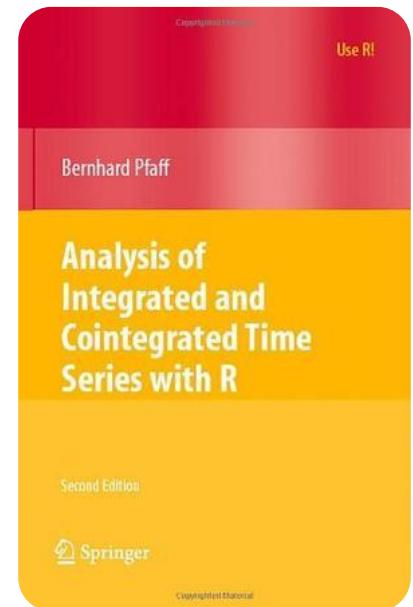
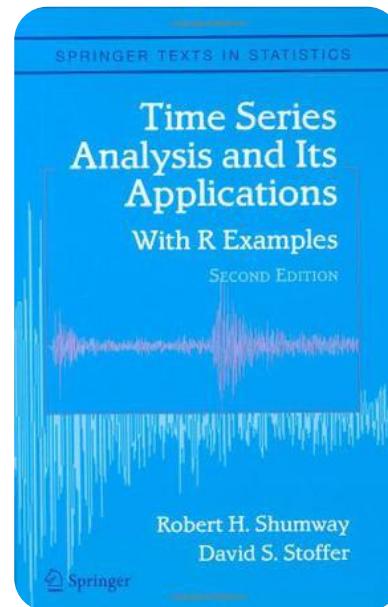
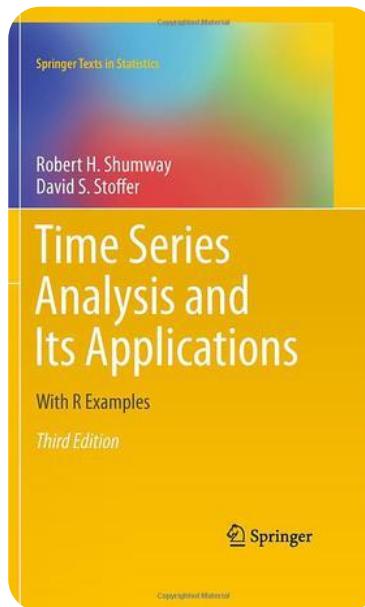
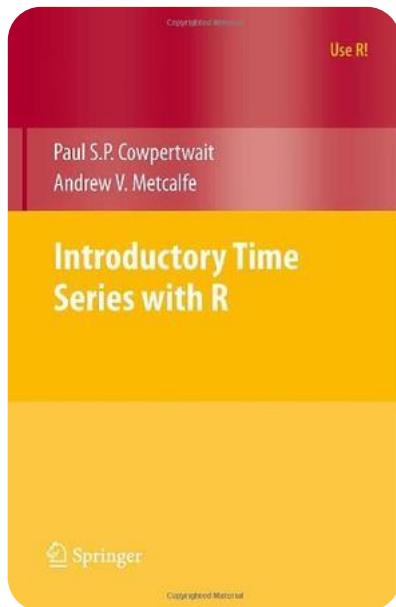
<http://cran.r-project.org/web/views/SpatioTemporal.html>

```
install.packages("ctv")
library("ctv")
install.views(" Spatial ")
update.views(" Spatial ")
```

3.1 Time series analysis

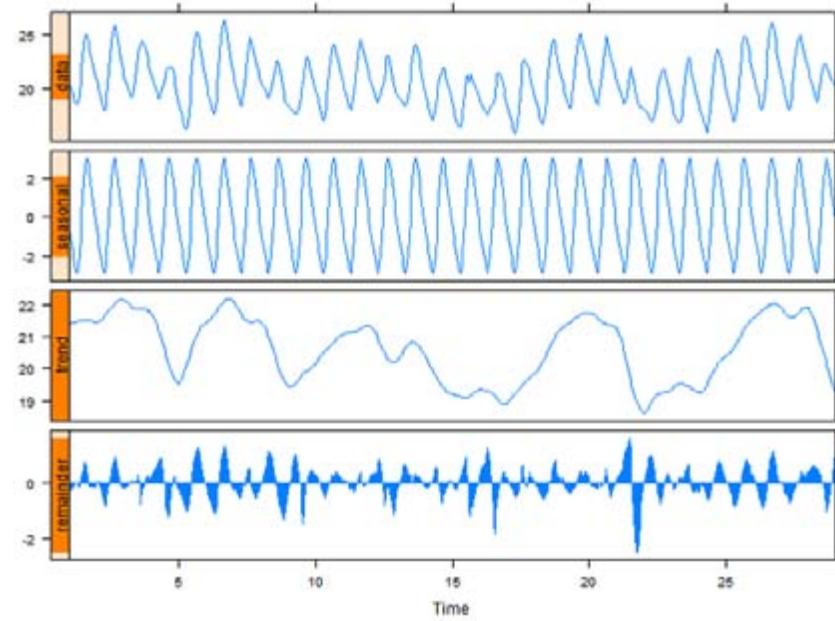
TimeSeries

- **Maintainer:** Rob J. Hyndman
- **Package stat. :** 179
- **Core package :** stat, forecast, tseries, xts, zoo
- **Application:** Econometrics and Finance



TimeSeries

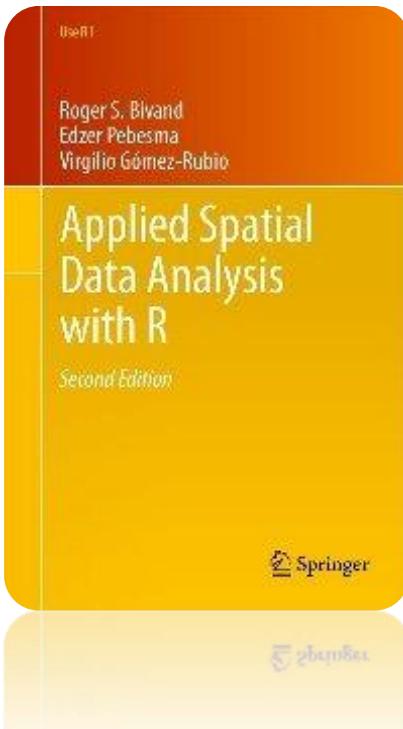
- Time and Dates structure **stat**
ts, POSIXct, POSIXlt
- Forecasting and Univariate Modeling
forecast & tseries
ets(); ar(); arima(); arma()
- Frequency analysis **wavelets**
spectrum()
- Decomposition and Filtering
stat
filter(); decompose(); stl()
- Multivariate / nonlinear Time Series Models
-



3.2 Spatial data analysis

Spatial – Spatial data analysis

- **Maintainer:** Roger Bivand
- **Package stat. :** 134
- **Core packages :** sp, geoR, gstat, maptools, raster, RandomFields, rgdal, spacetime, spdep, splancs
- **Mailing list :** R-SIG-Geo ; OSGeo



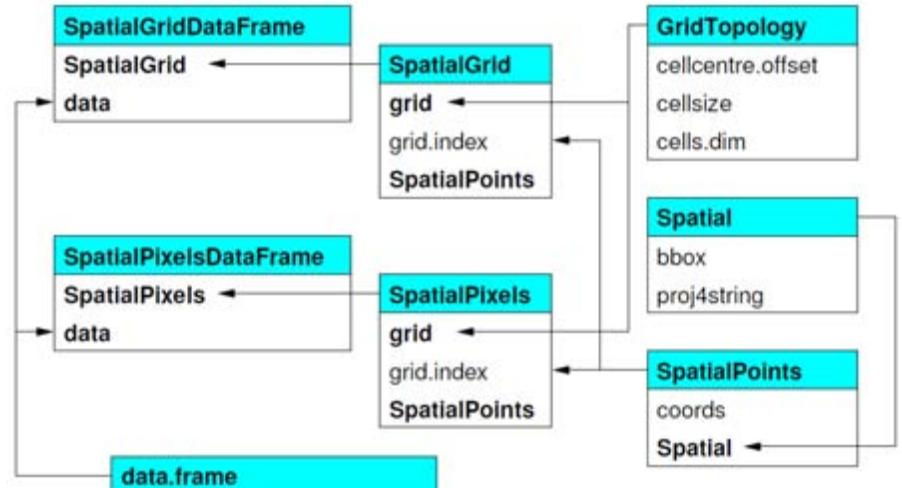
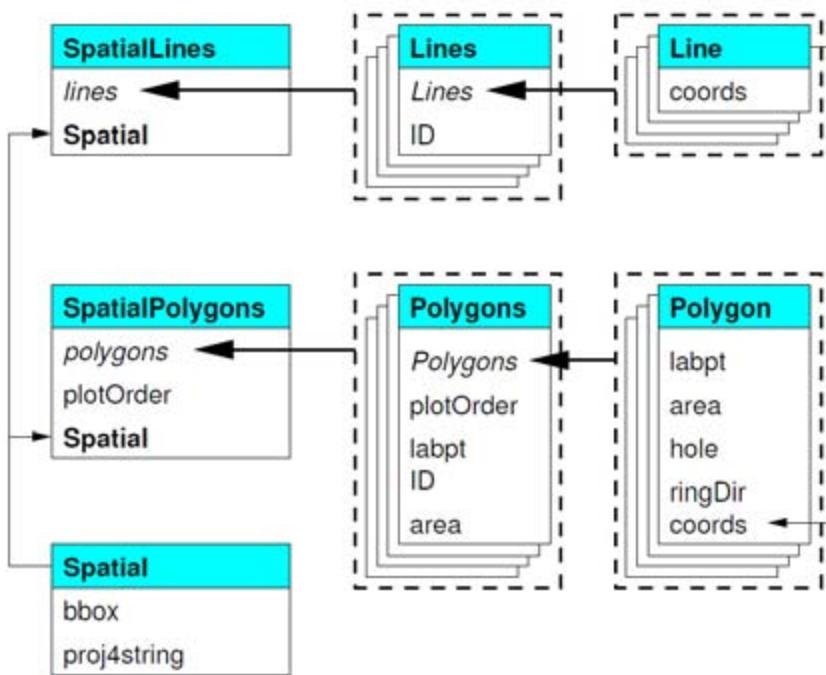
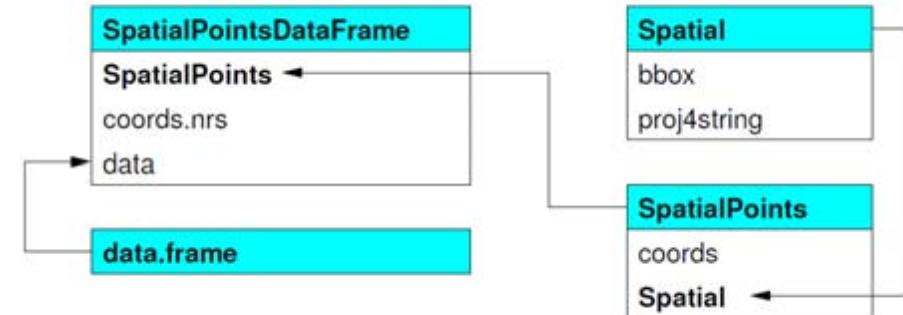
Overview of R spatial packages

□ Core packages

| Purpose | Packages |
|------------------------|---|
| Data input / output | <code>rgdal</code> , <code>maptools</code> , <code>maps</code> <code>RArcInfo</code> , <code>spgrass6</code> , <code>GRASS</code> , <code>ncdf4</code> |
| Data clear and process | <code>sp</code> , <code>maptools</code> , <code>raster</code> |
| Spatial statistics | <code>Spatstat</code> , <code>gstat</code> , <code>geoR</code> , <code>spdep</code> , <code>splancs</code> |

Spatial data structure

- ✓ Point
- ✓ Polygon
- ✓ Polyline
- ✓ Spatial grid and pixel



Read/write spatial data

- **rgdal**: Bindings for the Geospatial Data Abstraction Library ([GDAL](#))
 - `rgdal`
 - `readGDAL()` / `writeGDAL()`
 - `readOGR()` / `writeOGR()`
- Other format
 - `maptools` , `shapefile` : shapefile formart
 - `ncdf`: NetCDF
 - `raster`: raster data
 - `RArcInfo` : *.e00

GIS interface

- **spgrass6**

Interface between GRASS 6+ geographical information system and R



- **RPyGeo**

ArcGIS Geoprocessing in R via Python



- **RSAGA**

SAGA Geoprocessing and Terrain Analysis in R



Point pattern analysis

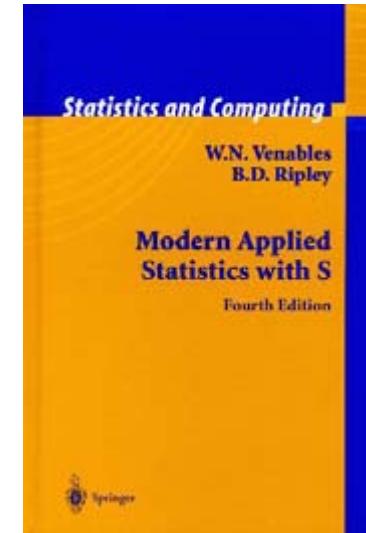
□ **Spatial**

Functions for Kriging and Point Pattern Analysis

□ **Spatstat**

Spatial Point Pattern analysis, model-fitting,
simulation, tests

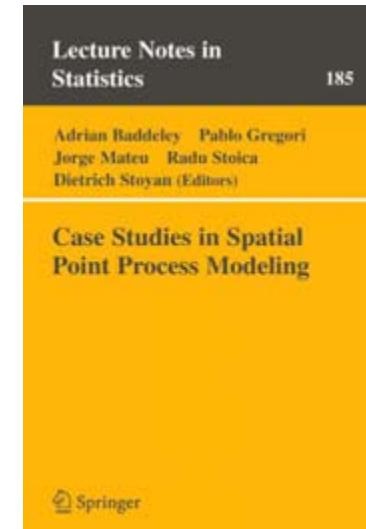
<http://www.spatstat.org/>



□ **splancs**

Spatial and Space-Time Point
Pattern Analysis

<http://www.maths.lancs.ac.uk/~rowlings/Splancs/>



Geostatistics

□ **gstat**

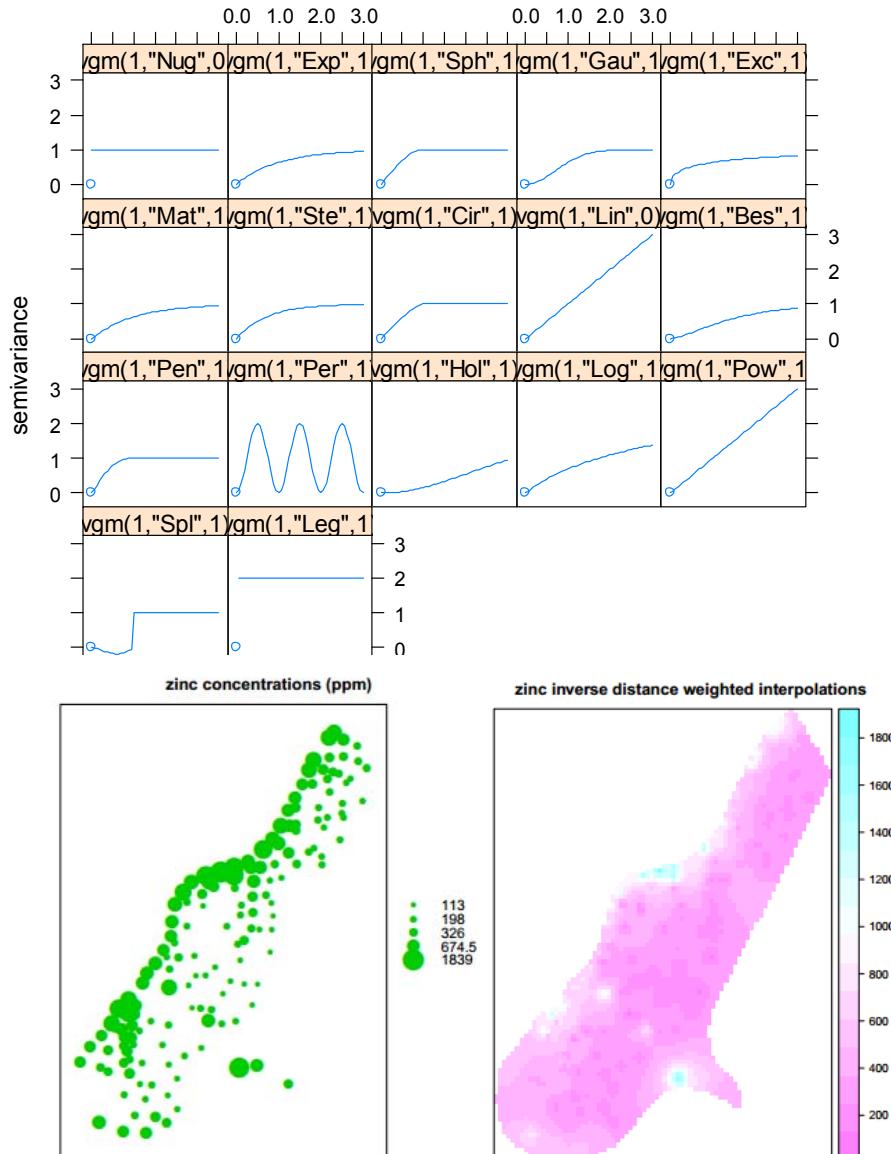
spatial and spatio-temporal
geostatistical modelling,
prediction and simulation

□ **geoR, geoRglm**

Model-based Geostatistics

□ **RandomField**

Simulation and analysis of
random field

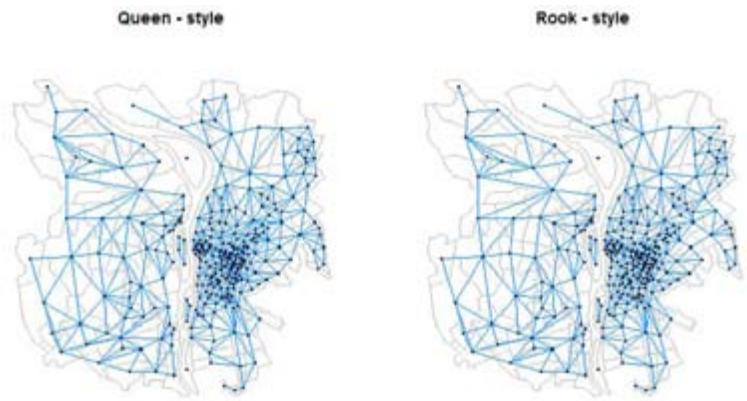


Spatial regression

□ **Spdep**

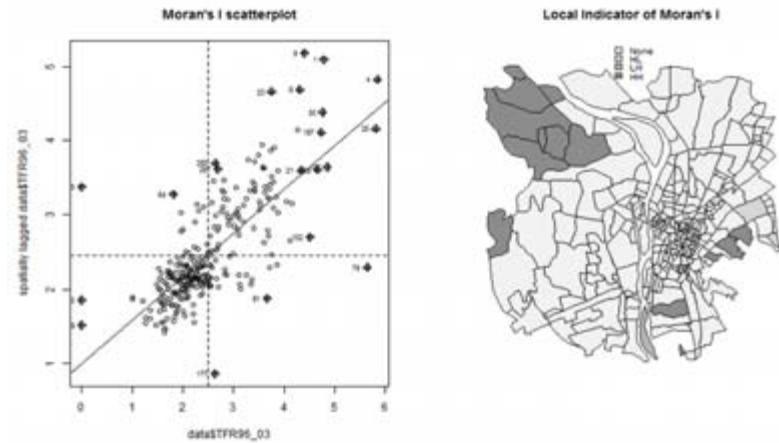
Spatial dependence: weighting schemes, statistics and models

1. Classical Resgression (CLR)
2. Simultaneous Autoregressive Models (SAR)
3. Conditional Autoregressive Models (CAR)
4. Spatial Lag Model (SLM)
5. Spatial error Model (SEM)



□ **nlme**

Linear and Nonlinear Mixed Effects Models



□ **spgwr**

Geographically weighted regression

3.3 Spatio-temporal data analysis

Spatiotemporal – data process and analysis

- **Maintainer:** Edzer Pebesma
- **Package stat. :** 46
- **Core package :** sp, xts, spacetime, stpp, surveillance, gstat, RandomFields, raster
- **Mailing list :** R-SIG-Geo ; OSGeo



Journal of Statistical Software

November 2012, Volume 51, Issue 7.

<http://www.jstatsoft.org/>

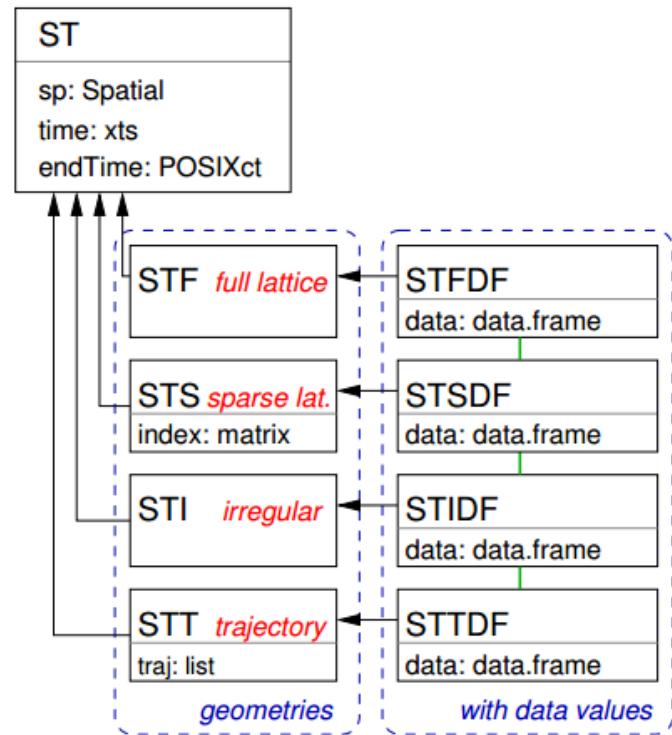
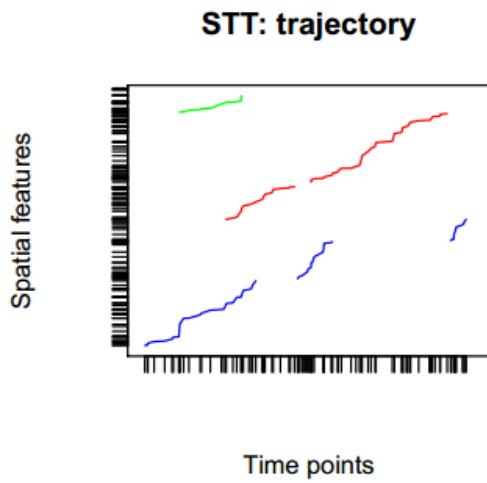
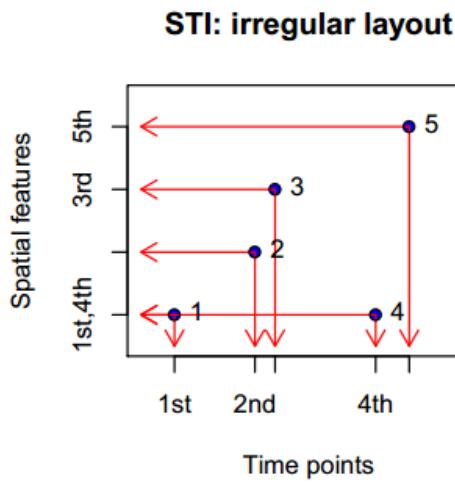
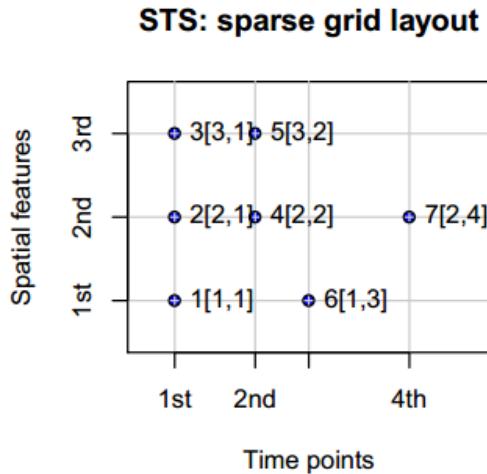
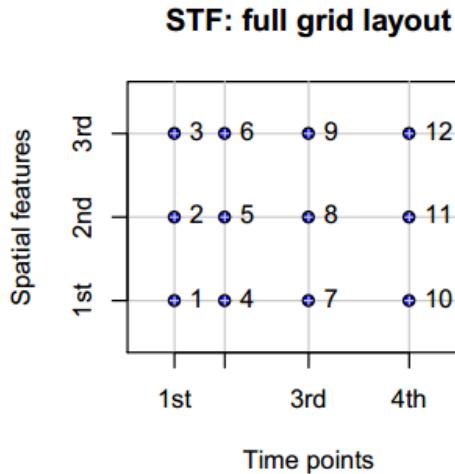
spacetime: Spatio-Temporal Data in R

Edzer Pebesma
University of Münster

Spatio-temporal data structure

- **data.frame**[longitude, latitude, time]
- time-wide table
- space-wide table
- Generic classes
 - spacetime : sp + xts
- Dedicated classes
 - Geostatistical data: SpatioTemporal {STdata}
 - Gridded/raster data: raster {rasters}
 - Lattice data: surveillance {sts}
 - Point patterns: stpp {stpp}
 - Trajectory data: adehabitatLT {ltraj}

spacetime data structure



Spatio-temporal data analysis

□ Geostatistics

`spacetime`, `SpatioTemporal`, `RandomFields`,
`spBayes`, `Stem`, `spcopula`, *et al.*

□ Spatio-temporal point pattern

`splancs`, `stpp`, `stppResid`, `stam`, `ptproc`

□ Lattice data analysis

`surveillance`, `plm`, `splm`, `sphet`, `nlme`

□ Trajectory data analysis

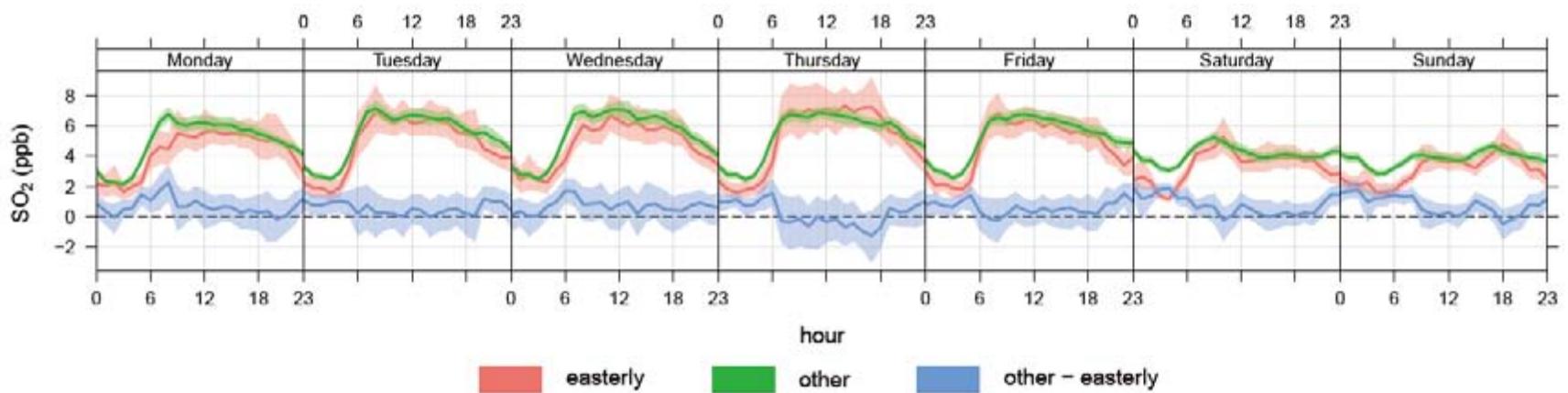
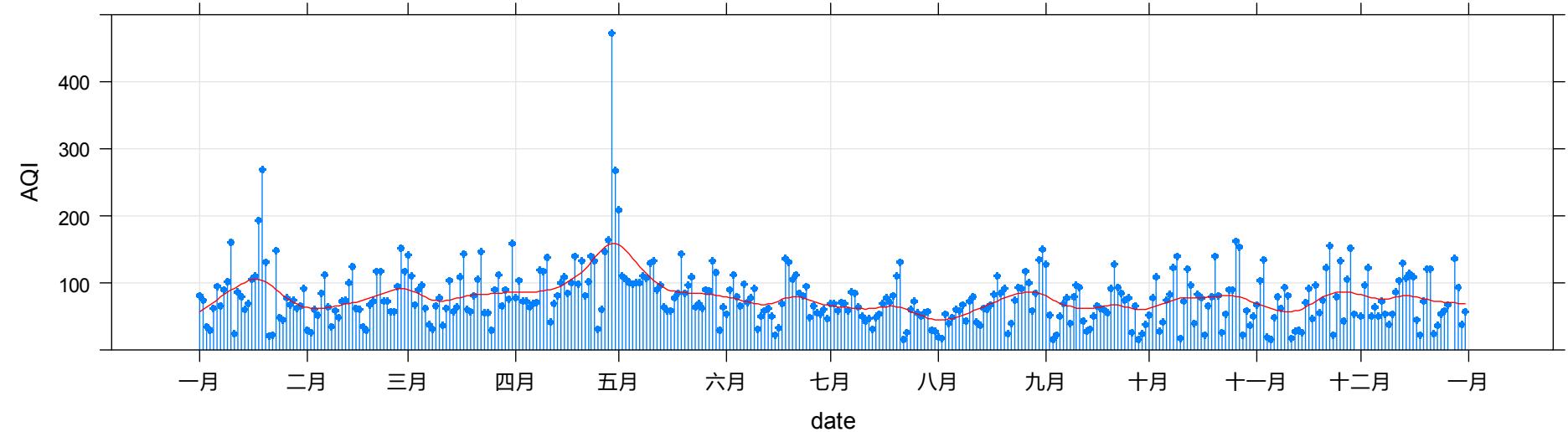
`adehabitatLT`, `trip`, `tripEstimation`, `diveMove`,
`move`, *et al.*

4 ST Data Visualization

Time series data visualization

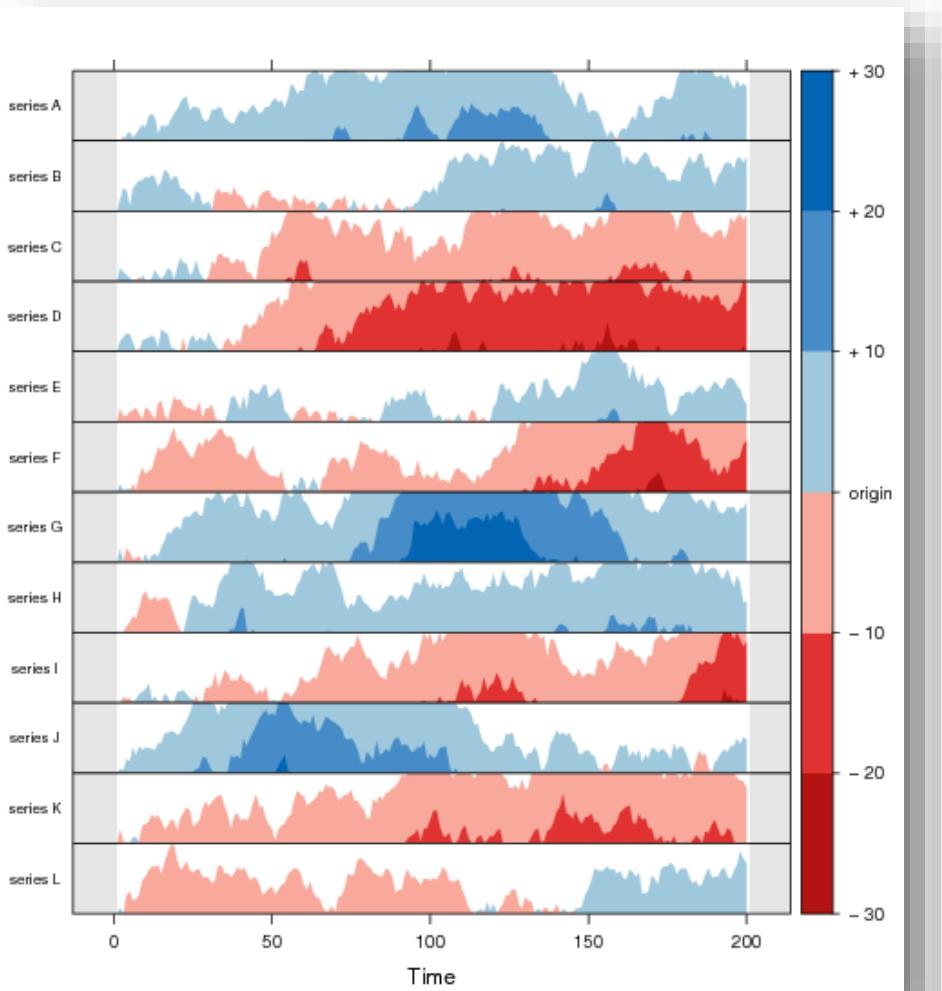
```
lattice {xyplot()}
```

2012 Daily AQI of Beijing

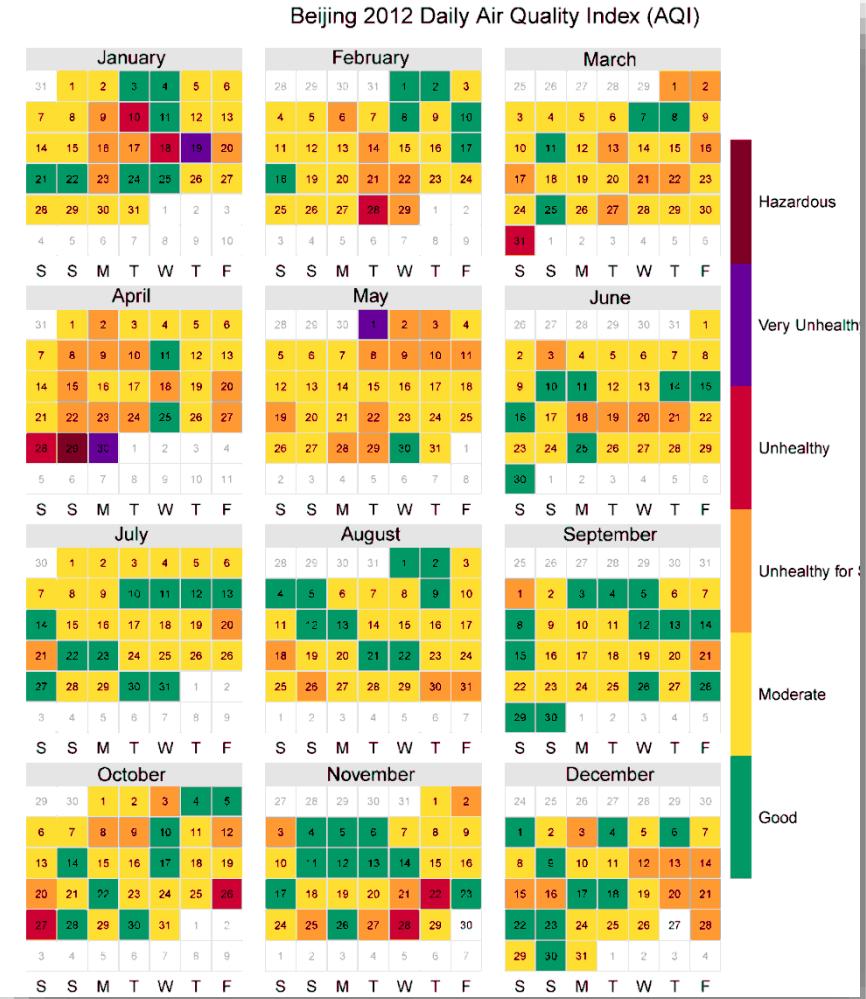


Time series data visualization

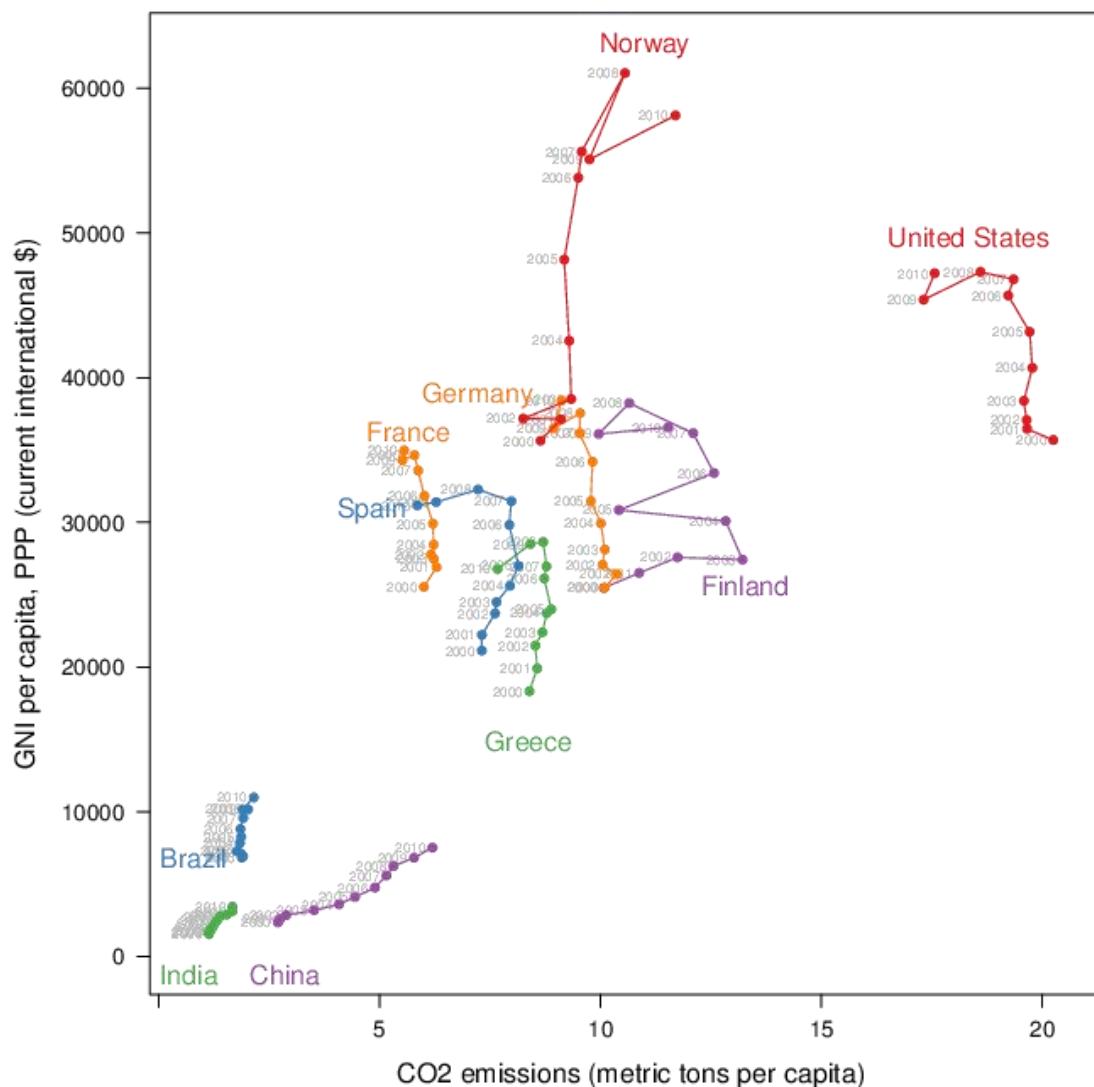
```
latticeExtra  
{horizonplot()}
```



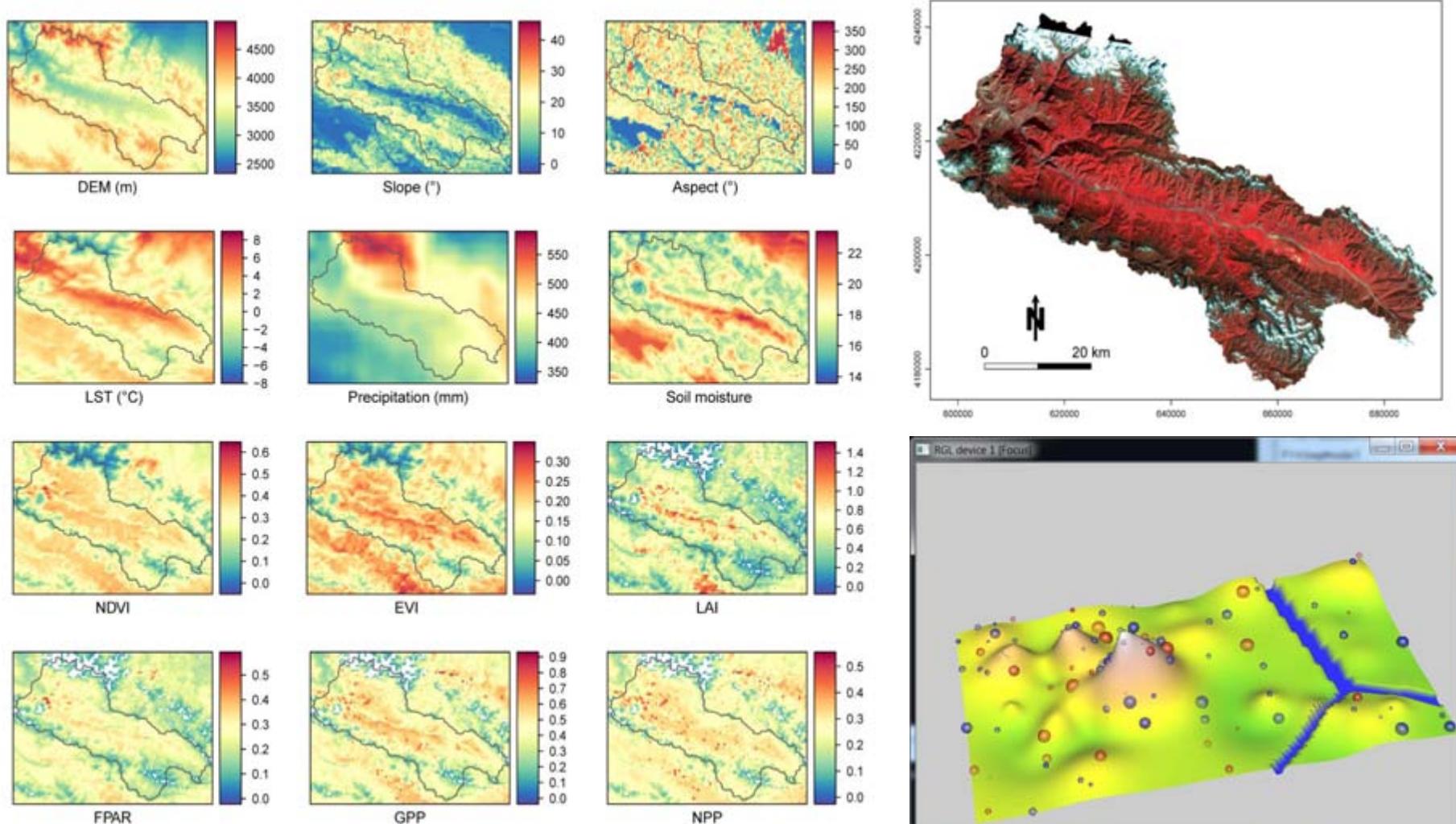
openair
{calendarPlot()}



Time series trajectory



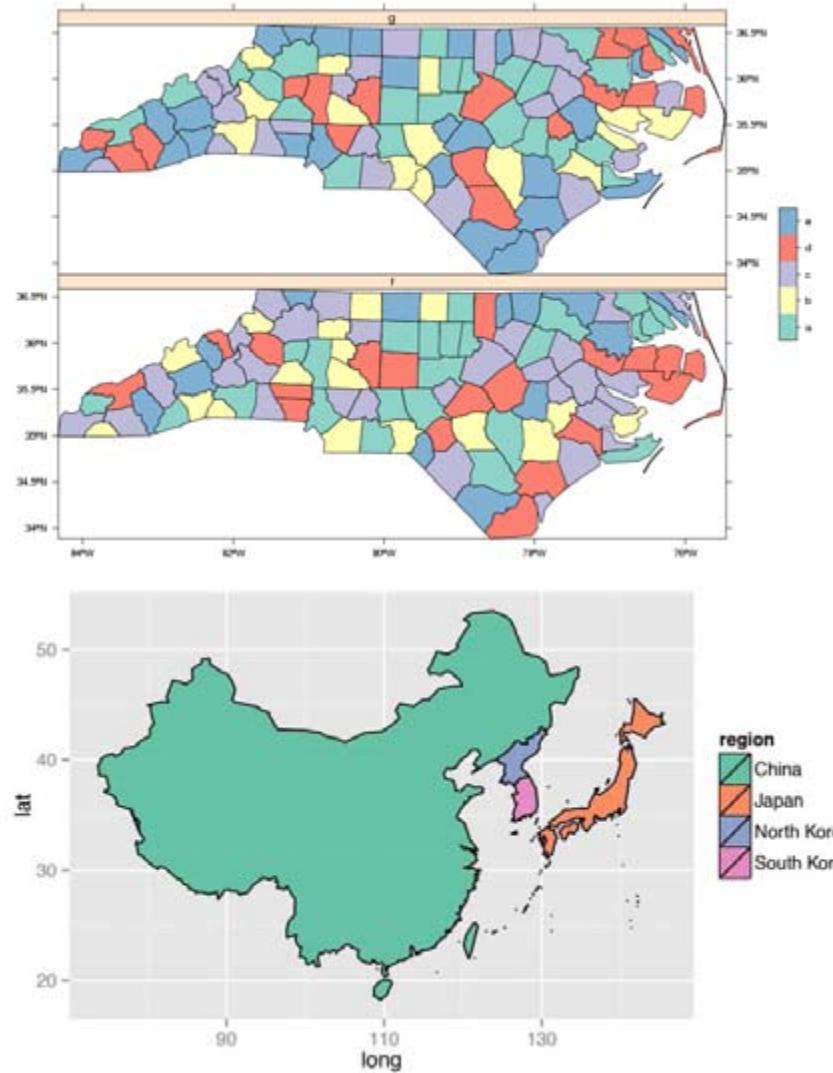
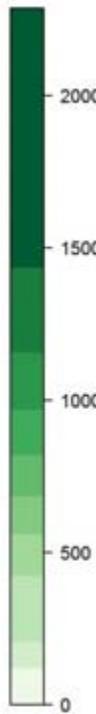
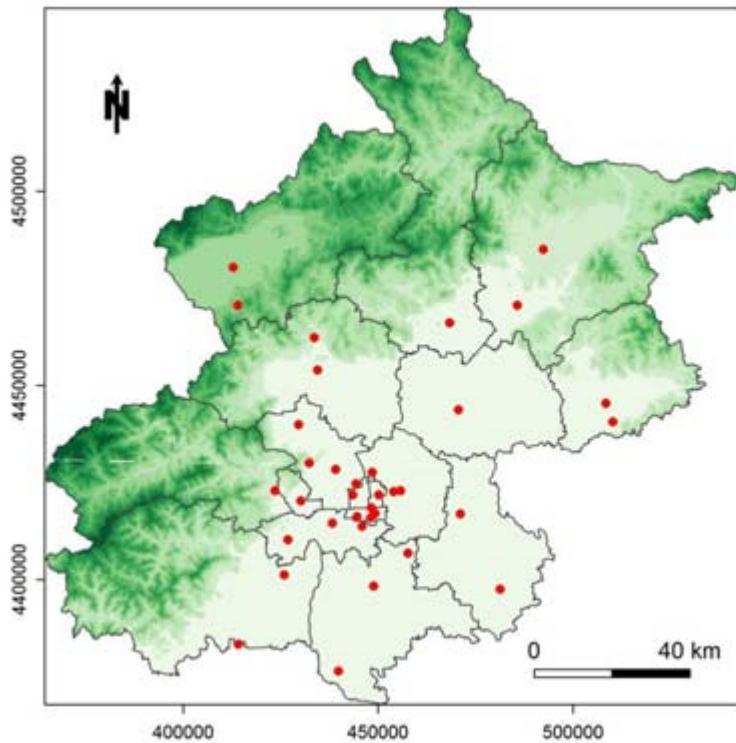
Raster data visualization



- `sp {spplot()}; raster {image()}`
- `lattice({levelplot(), contourplot(), wireframe() })`
- `rgl {surface3d}`

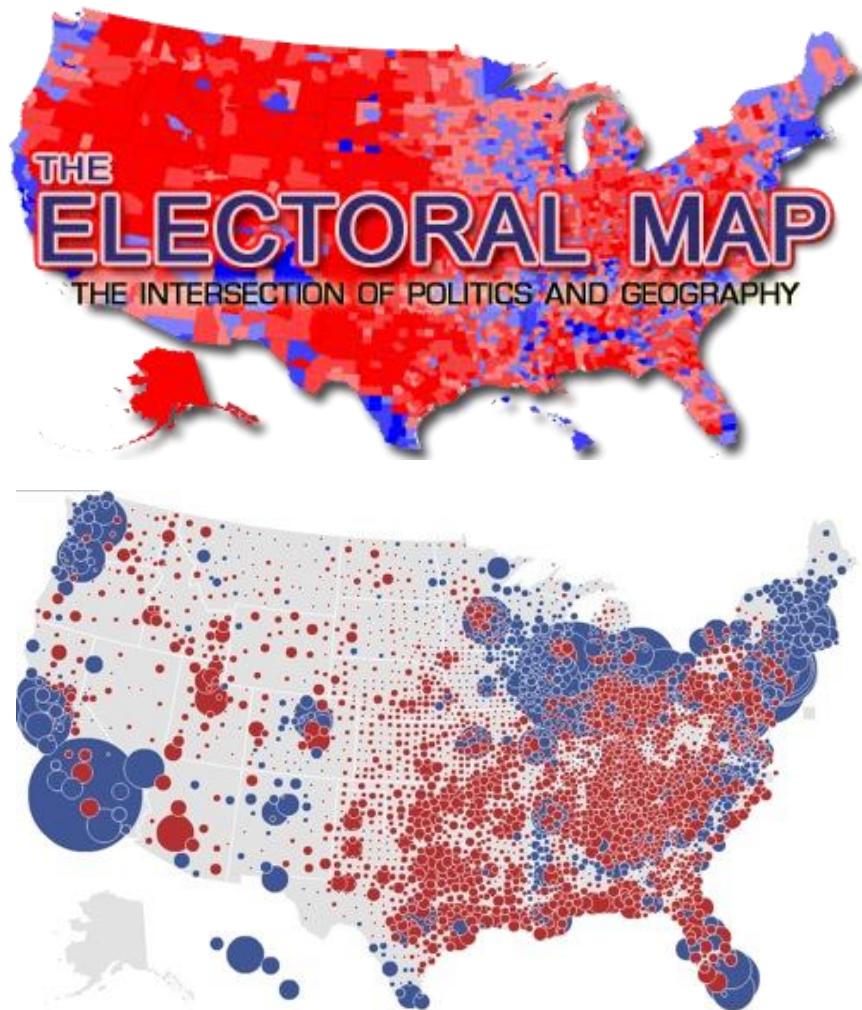
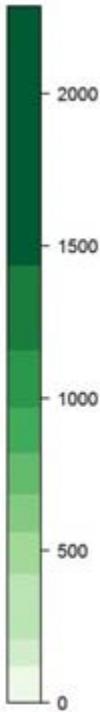
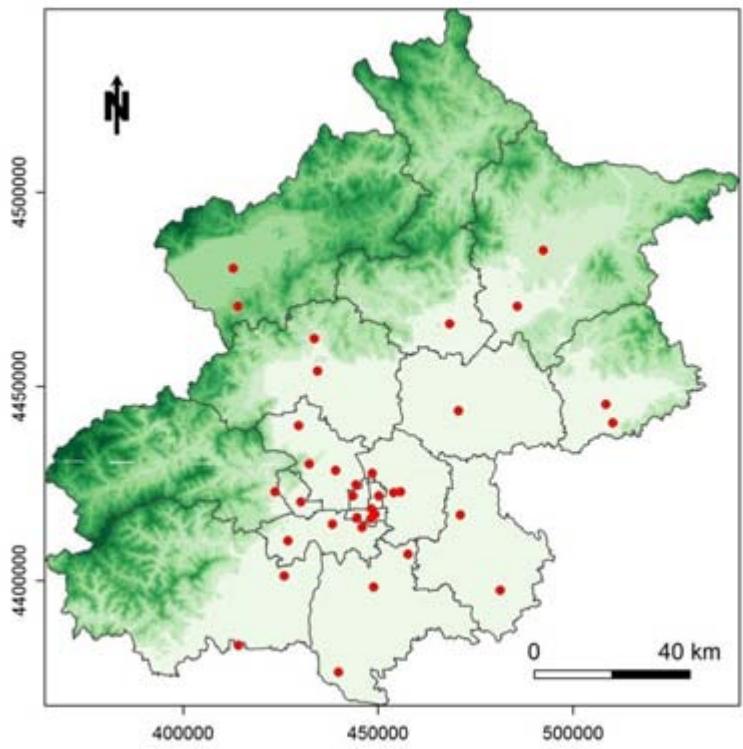
Vector data visualization

```
sp {spplot()}
lattice {xyplot()}
ggplot2 {geom_polygon}
```



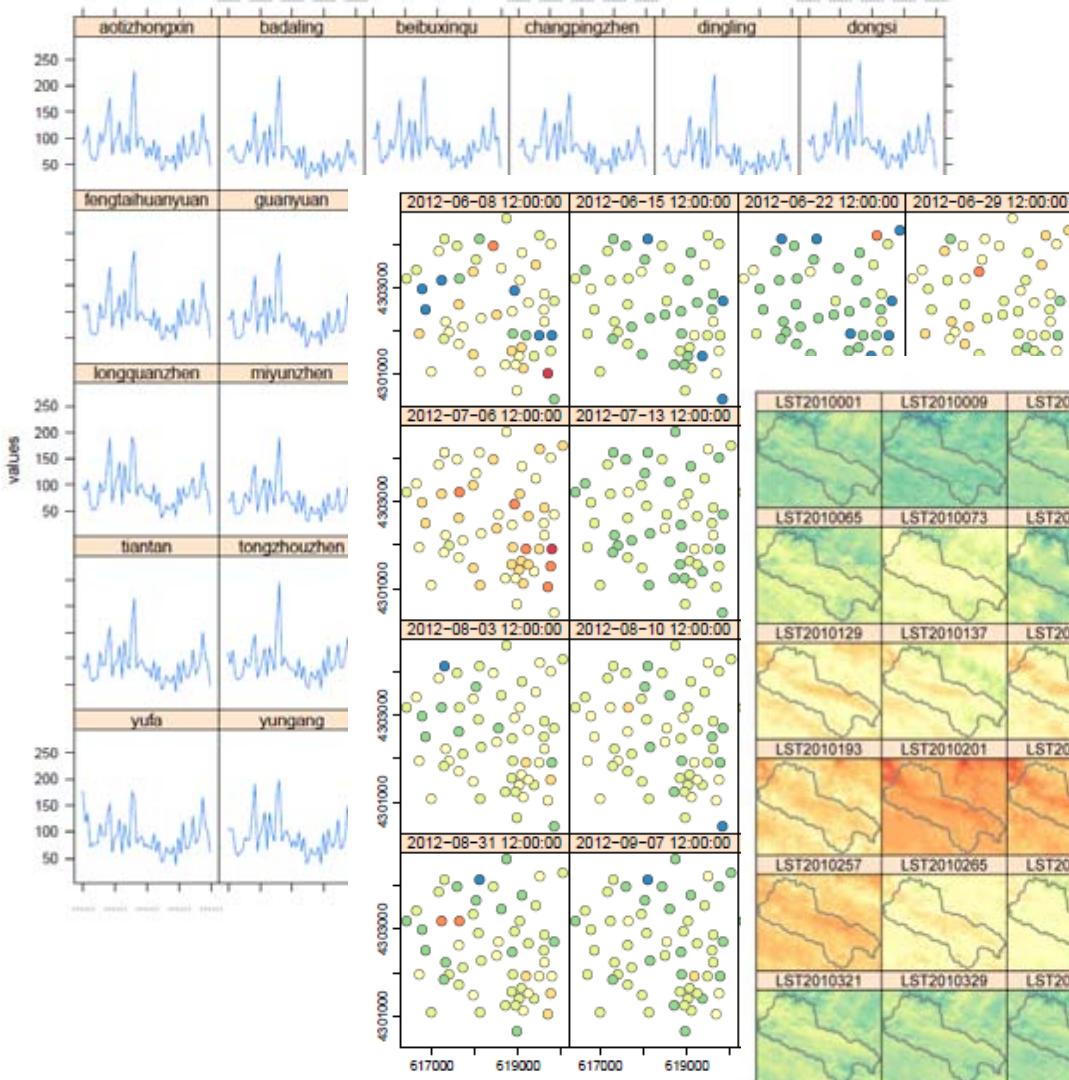
Vector data visualization

```
sp {spplot()}  
lattice {xyplot()}  
ggplot2 {geom_polygon}
```



Spatio-temporal visualization

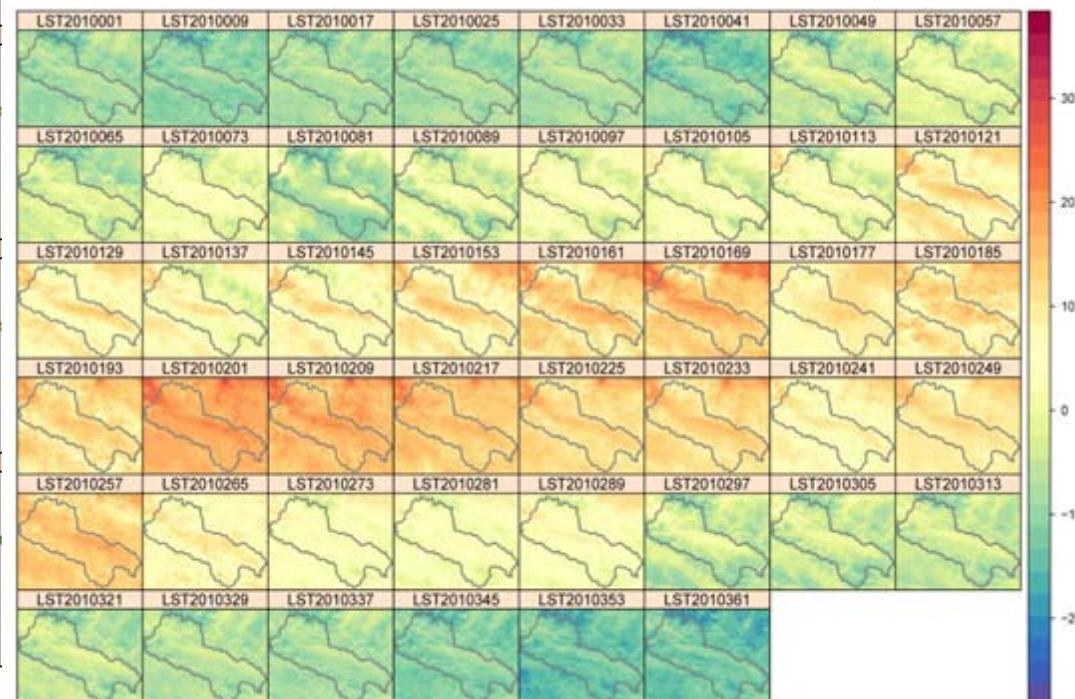
week mean



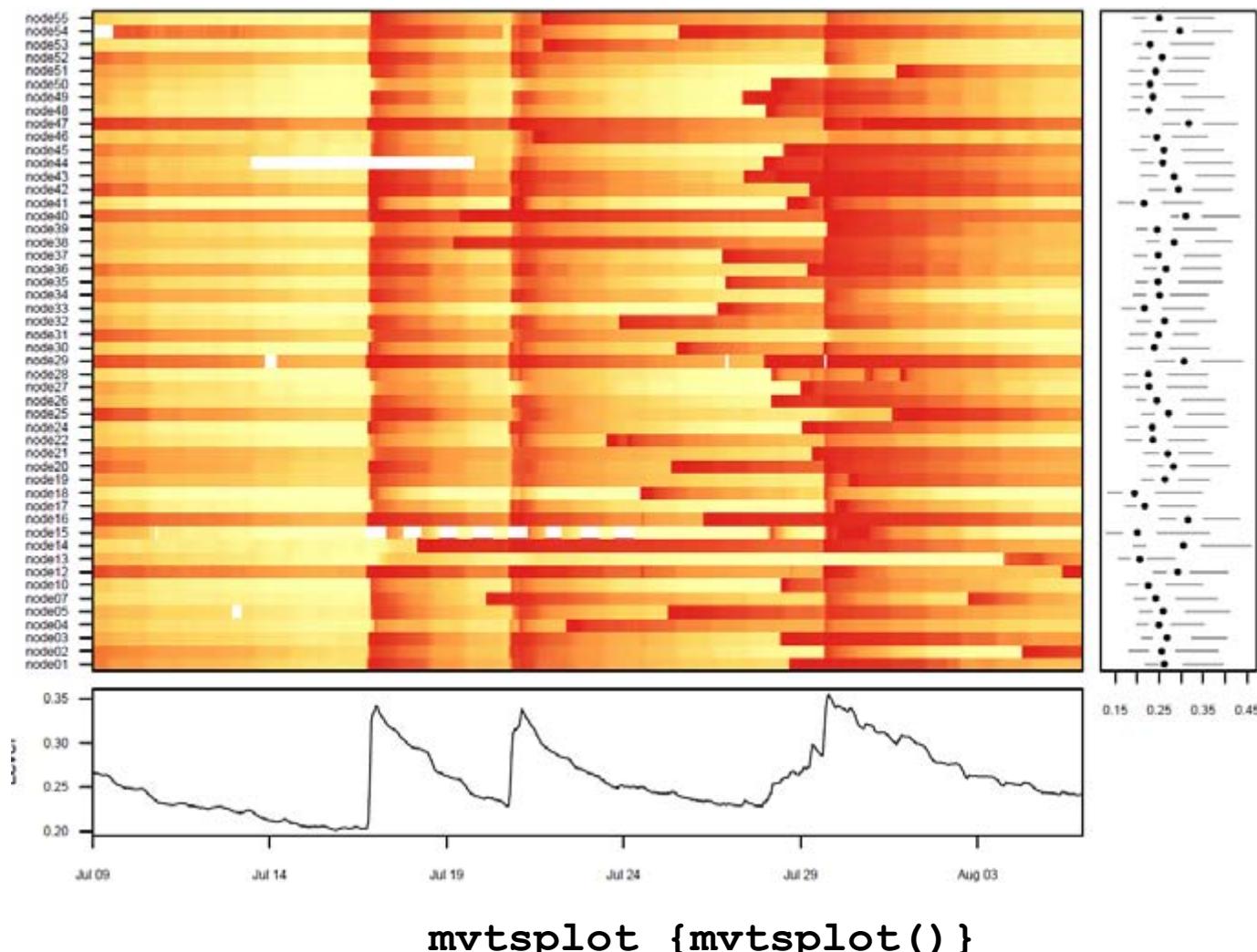
spacetime {stplot()}

MODE:

- = "tp"
- = "ts"
- = "xt"
- = "xy"



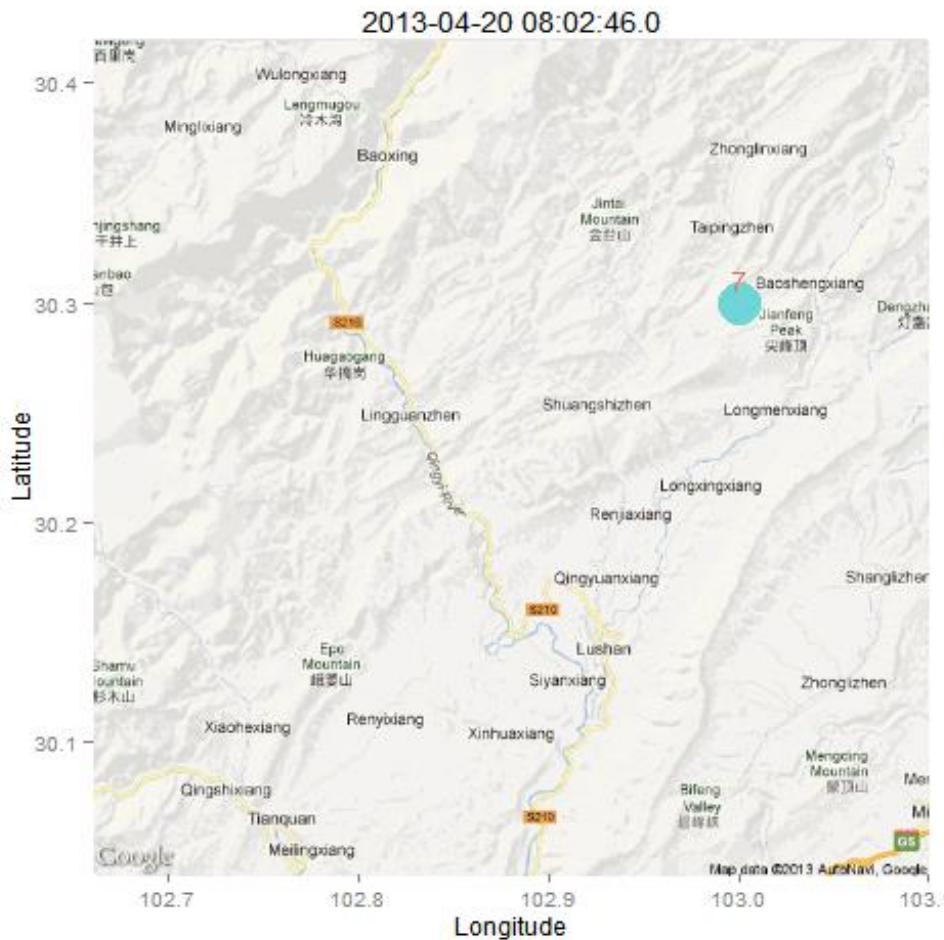
Spatio-temporal data visualization



Peng, R. (2008). "[A method for visualizing multivariate time series data](#)." Journal of Statistical Software 25(1): 1-17.

Spatio-temporal data visualization

animation



```
gridSVG  
{gridToSVG() }
```

<http://oscarperpinan.github.io/spacetim-vis/images/vLine.svg>

Web-based ST visualization

- Google Map or Earth : <https://maps.google.com/>
- Baidu Map : <http://developer.baidu.com/map/>
- LeafLet : <http://leafletjs.com/>
- OpenLayers : <http://openlayers.org/>
- OpenStreetMap : <http://www.openstreetmap.org/>
- ArcGIS online : <http://www.arcgis.com/home/>
- Cloudmate : <http://cloudmade.com/>
- Ploymaps : <http://polymaps.org/>
- Mapbox : <http://www.mapbox.com>
- Cartodb : <https://cartodb.com/>



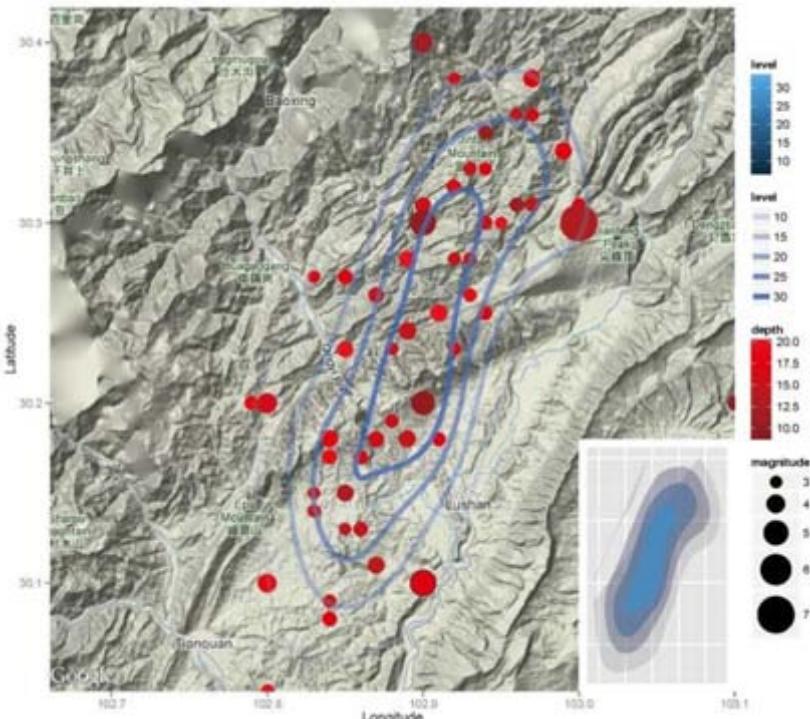
Google Map & R

□ ggmap

Kahle, D. and H. Wickham "ggmap: Spatial Visualization with ggplot2." The R Journal.

□ Data Sources

1. Google Maps
2. OpenStreetMap
3. Stamen Maps
4. CloudMade Maps

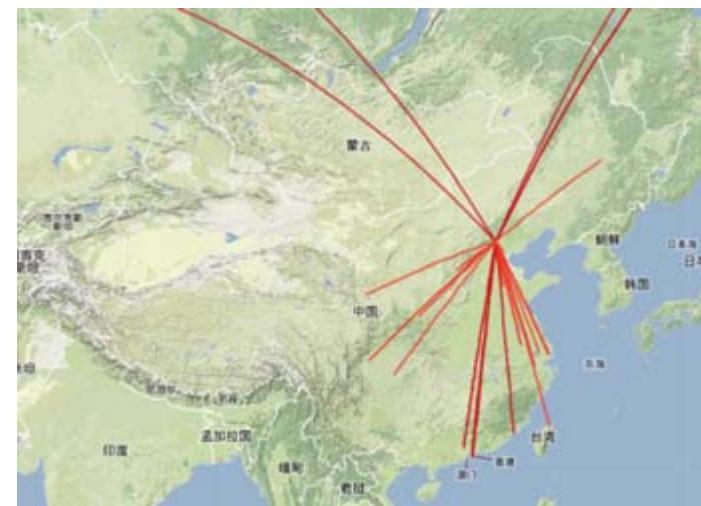
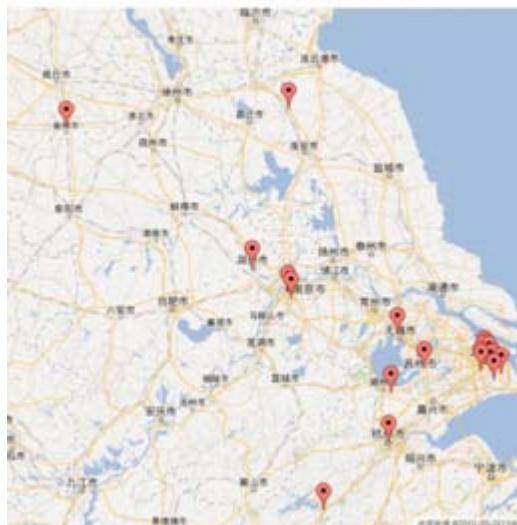


<http://jianghao.github.io/earthquake/spacetime/ppa.htm>

Google Map

□ plotGoogleMaps

- [Demo1](#)
- [Demo2](#)
- [Demo3](#)
- [Demo4](#)



Heatmap

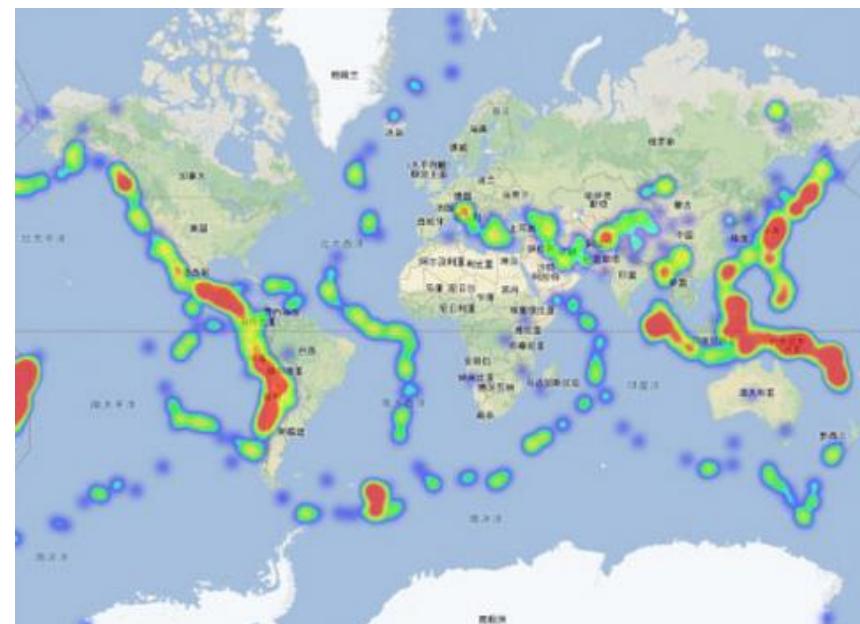
□ heatmap.js

[Demo1](#) (H7N9)

[Demo2](#) (Earthquake)

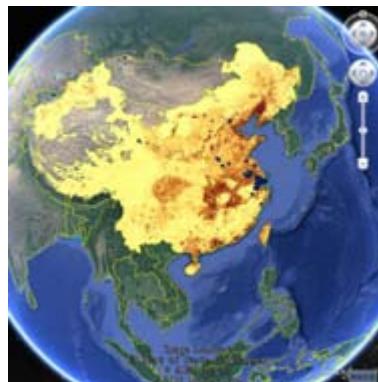
[Demo3](#) (land)

[Demo4](#) (hospital)



3D Spatial Visualization (GE)

- [Mapping the H7N9 avian flu outbreaks](#) (Nature, doi: 10.1038/nature.2013.12863)



Journal of Statistical Software

January 2015, Volume 63, Issue 5.

<http://www.jstatsoft.org/>

plotKML: Scientific Visualization of
Spatio-Temporal Data

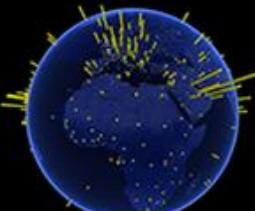
Tomislav Hengl
ISRIC – World
Soil Information

Pierre Roudier
Landcare Research

Dylan Beaudette
USDA-NRCS, Soil
Science Division

Edzer Pebesma
University of
Münster

thematicmapping.org

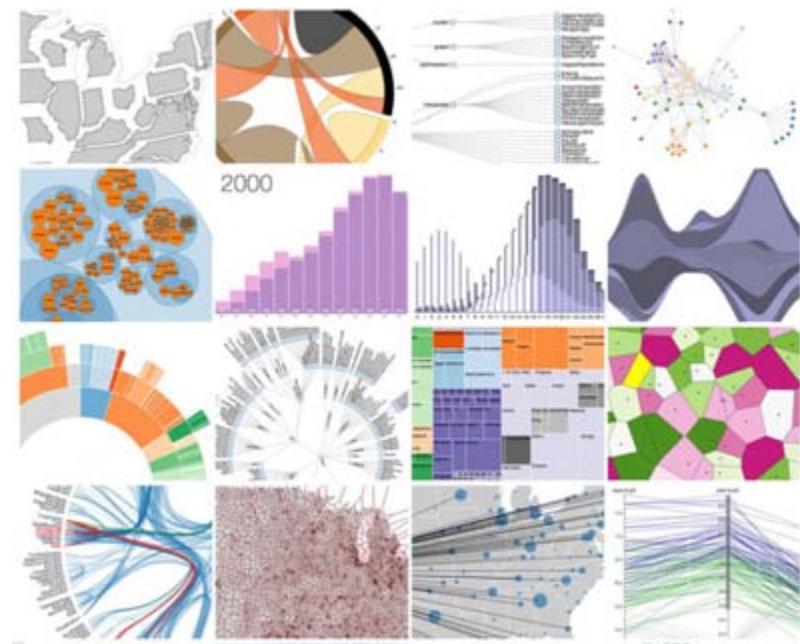


Thematic Mapping API

Create KML based thematic
maps
with a few lines of
JavaScript

Other Web-based Visualization tools

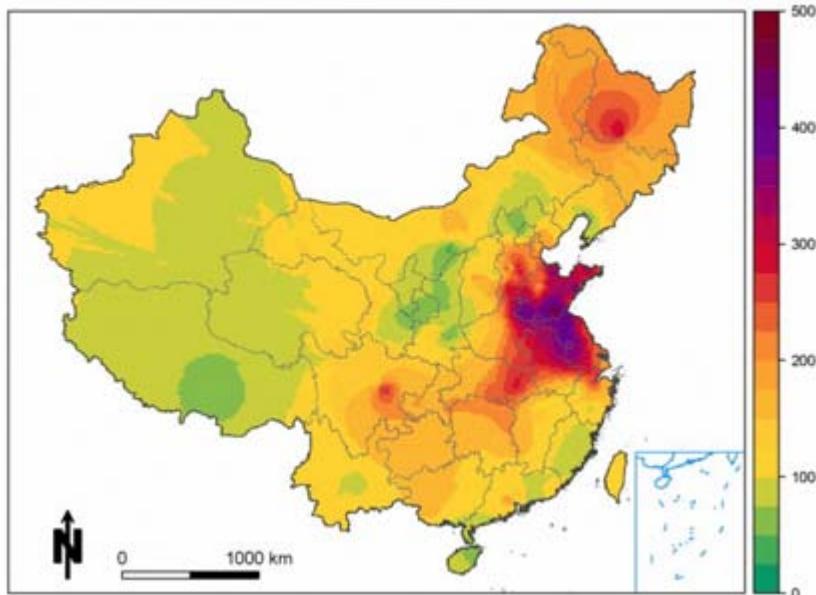
- [googleVis](#) , [rchart](#), [recharts](#)
- **d3js**: <http://d3js.org>
- **Processing** (Java and Javascript)



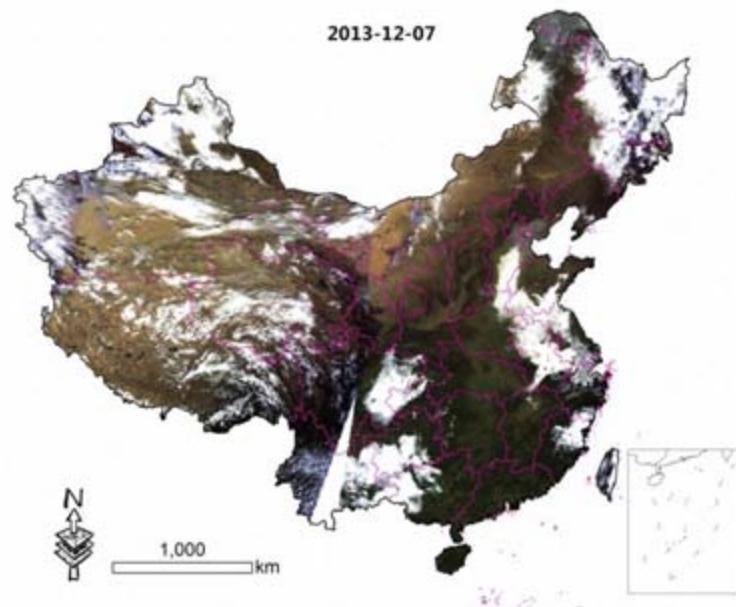
5 Case Studies

Environment

2013-12-04T12



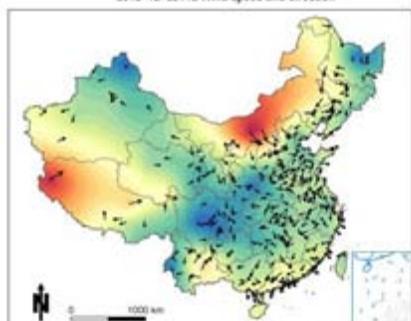
2013-12-07



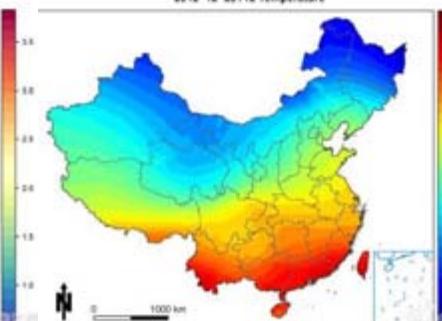
中国区域MODIS 影像合成——2013年12月4日



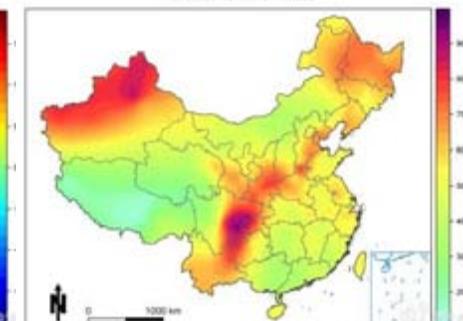
2012-12-25T12 Wind speed and direction



2012-12-25T12 Temperature

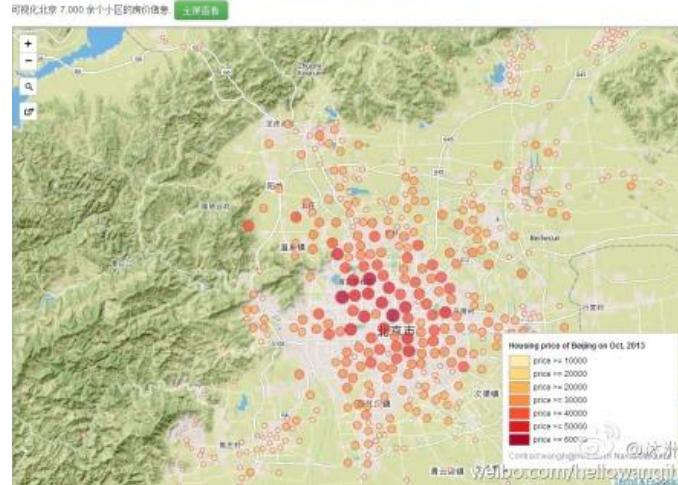


2012-12-25T12 humidity



National housing price

北京房价信息可视化



上海房价信息可视化



SouFun 房

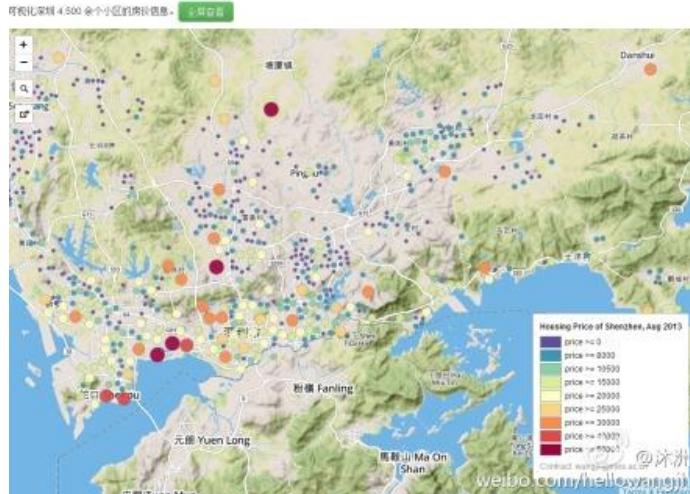
房价网
www.fangjia.com

安居客

58 同城
58.com

ganji 赶集
赶集网 哪都有

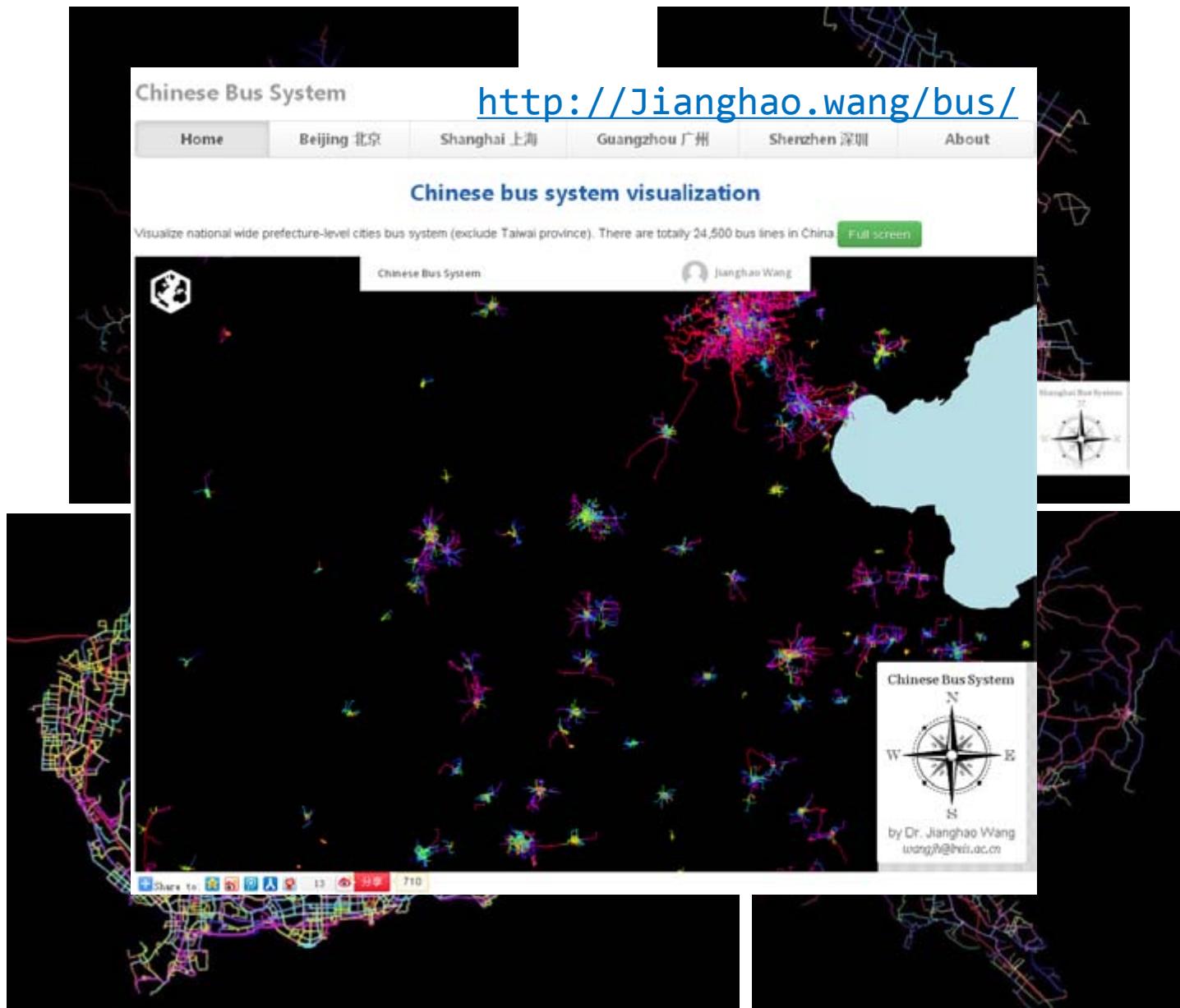
深圳房价信息可视化



广州房价信息可视化



National Bus System



Earthquake

四川雅安地震信息



预案 地震时间序列 地震动画展示 Google Earth三维 (街景) Google Earth三维 (3D) 点模式分析

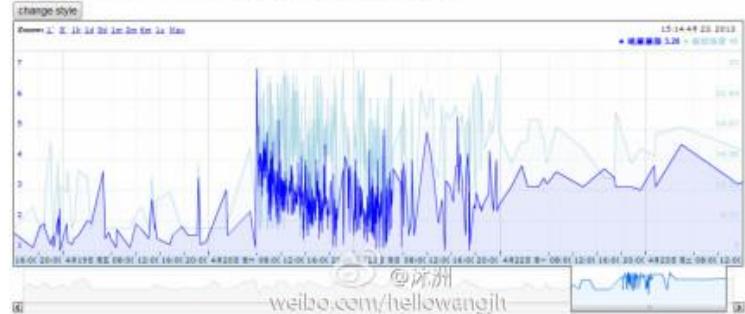
四川区域2013年4月所有地震三维显示



预案 地震时间序列 地震动画展示 Google Earth三维 (街景) Google Earth三维 (3D) 点模式分析

四川地区2013年4月以来地震时间序列分析

查看中国地震台网中心四川地震(震级介于9~100级, 震源介于26~34度). 自2013年4月1日来发生的地震, 共计10550条记录(带震源机制或在线查看表格). 其中绝大部分为震级低于3.0的小地震. 将这些地震按发生时间从早到晚排列在下面, 其中深蓝色表示地震的震源, 浅蓝色表示地震的震源深度, 可以帮助您查询任一次地震的详细信息. 需要说明的是, 下面中密集发生地震的时间即是四川雅安地震爆发的时间.



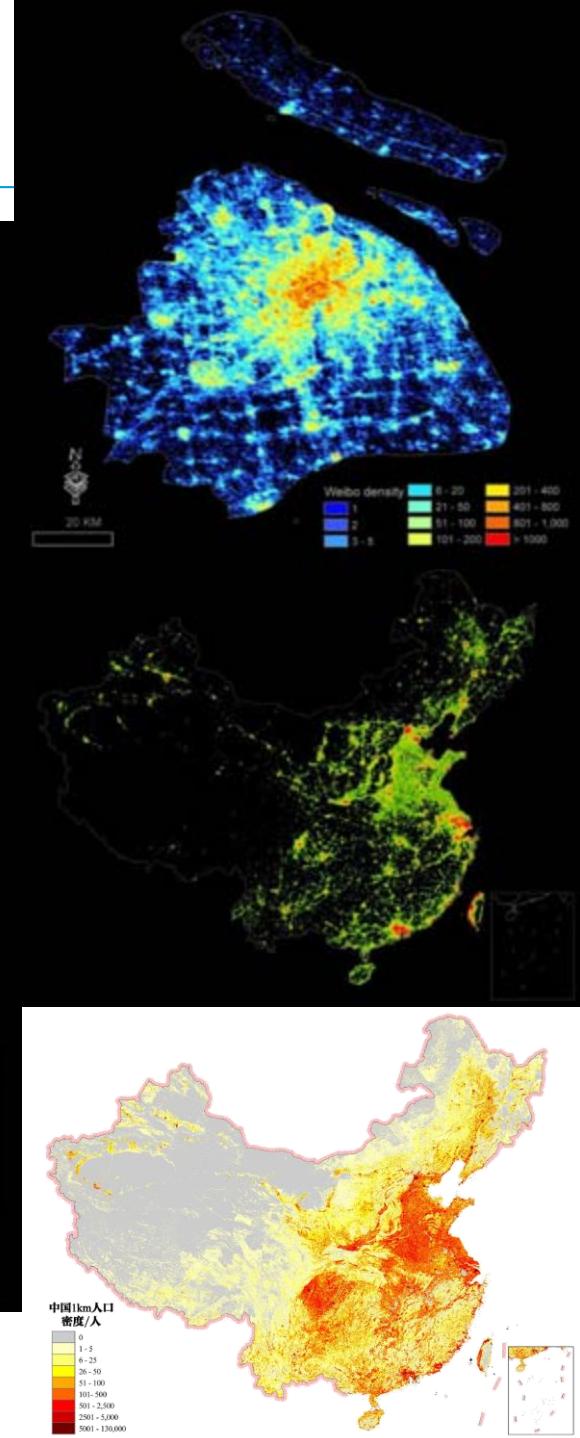
<http://jianghao.wang/earthquake/>

POI data

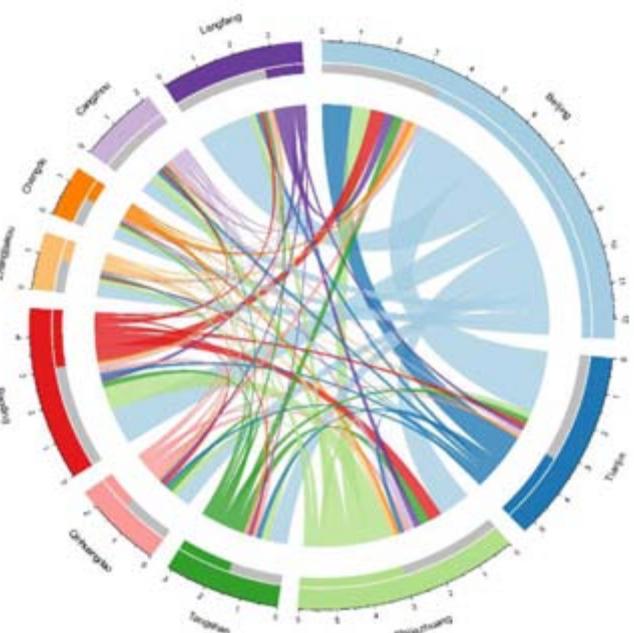
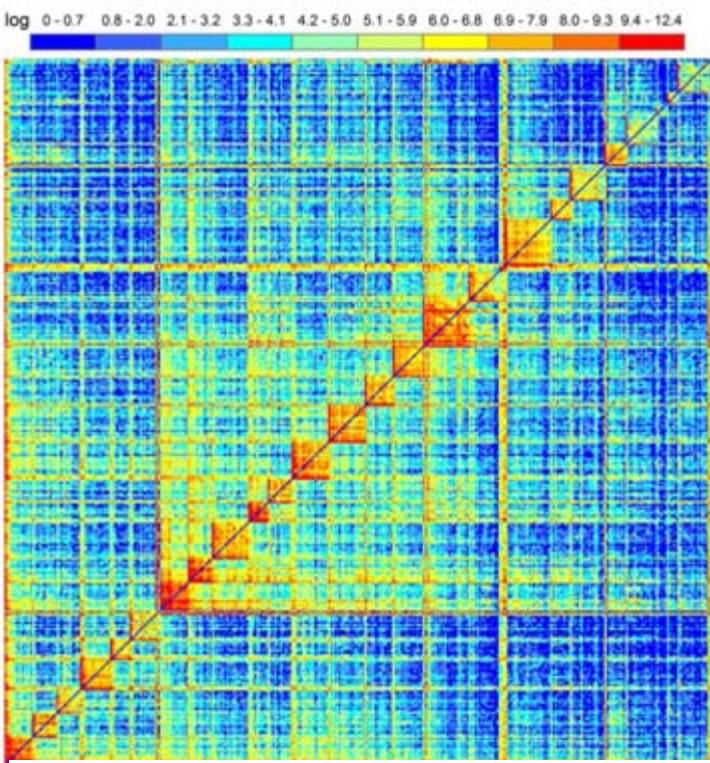
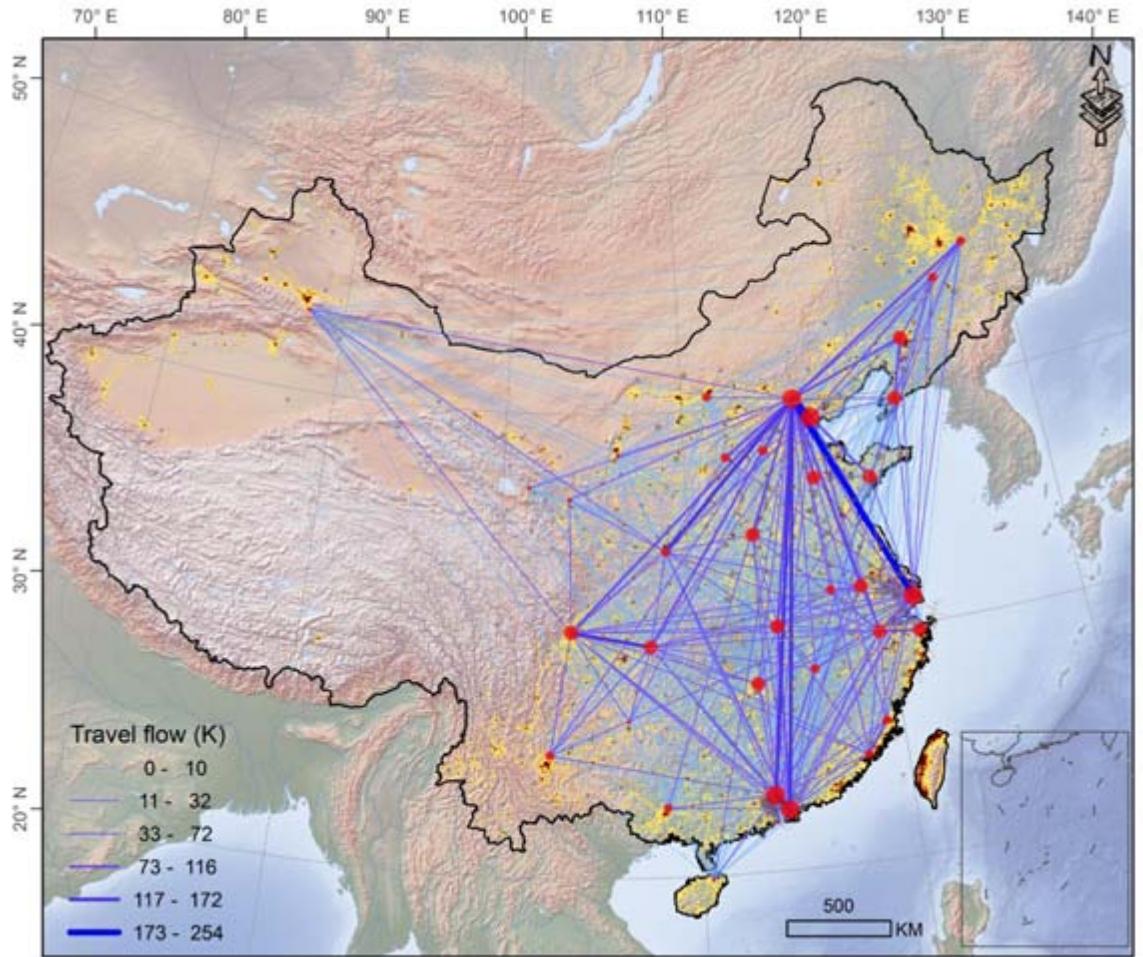


Web-based Map; Sina Weibo; Dianping.com

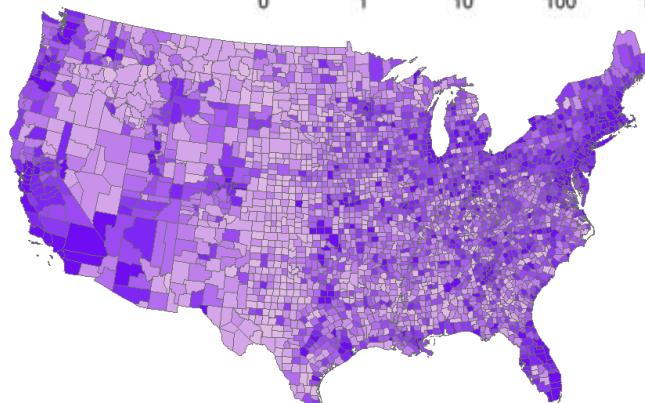
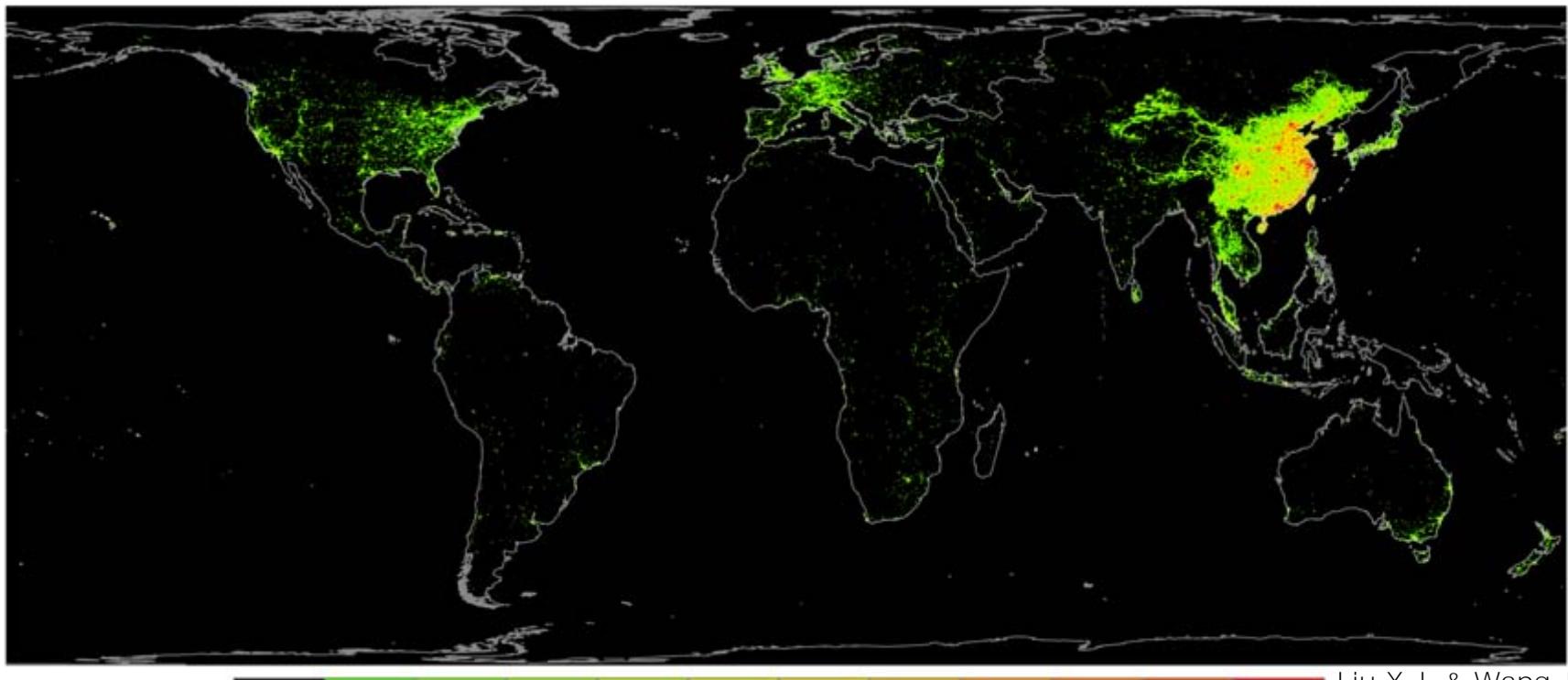
Social Media



Human Mobility

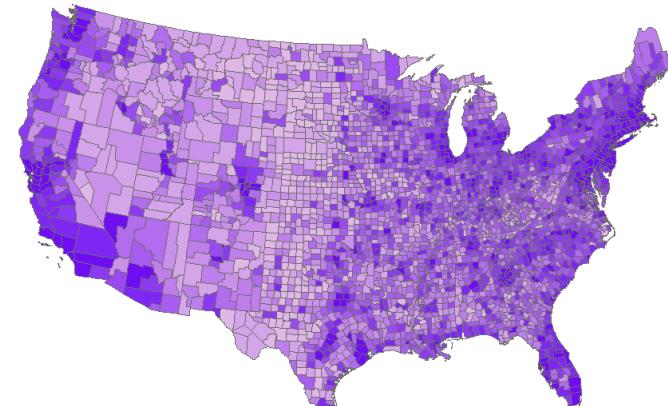


Where are the Chinese?



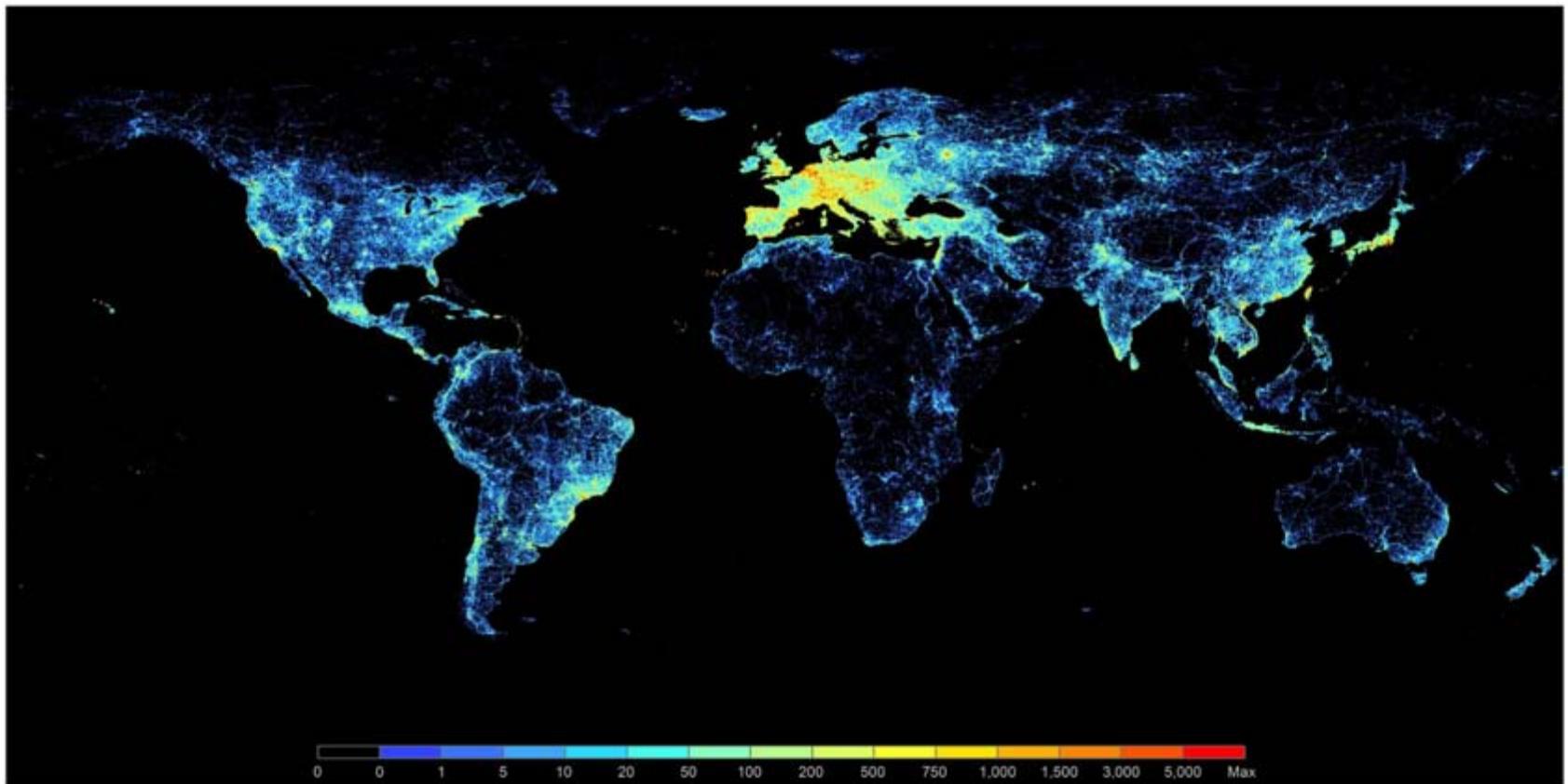
Chinese American

(Pew Research, based on 2010 Census)



(Estimated based on geotagged Weibo)

Mapping world geotagged photos



Data from Flickr and Panoramio

Wang J.H. 2015

Summary

- Spatio-temporal information plays an important part in social environment phenomenon analysis and representation.
- Spatio-temporal data is commonly ***complicated and big data***. Special tools (e.g. R) are needed in processing and analyzing spatio-temporal information.
- The main applications
 - Obtain spatial temporal data
 - Represent the spatio-temporal information;
 - Analysis social environment phenomenon: thinking in spatial and dynamic;
 - Making an **interactive** and **attractive** web apps;
 - In scientific research

Thanks !

Q & A



王江浩CAS

<http://jianghao.wang>