State of R in Hydrological Modelling

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Justification

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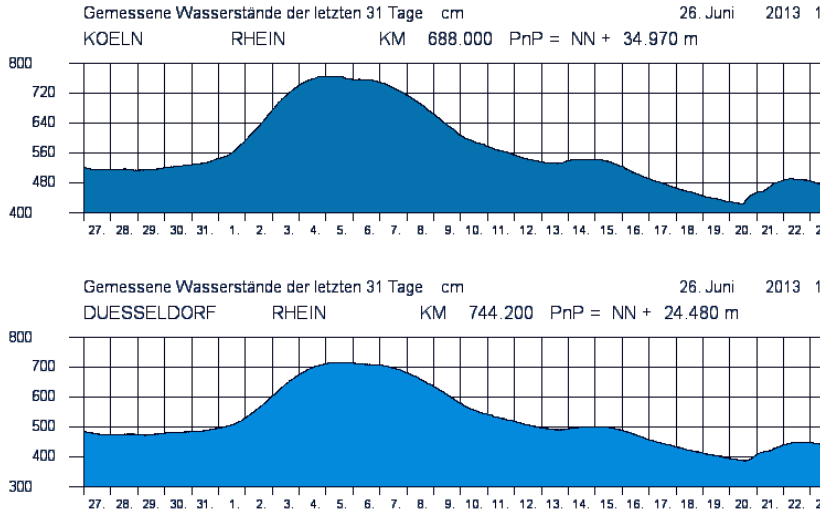
- Material flows to coastal waters: complex interaction
  - catchment boundaries,
  - human activities therein,
  - trade of materials.
- Trans-boundary processes
  - residence time,
  - transport and fate of WQ determinants
    - physical,
    - chemical,
    - microbiological.
- WQ status: global implications

Purpose

- Models for real-time flow prediction
  - improve decision making [Beven, 2012]
    - water resources planning
    - flood protection
    - mitigation of contamination



German Federal Institute of Hydrology - BfG. 26.06.2013 19:40

Purpose

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- model comparison in structure, calibration methods and simulation events is essential for choosing objectively the suitable model configuration in hydrological modelling

- a novel, versatile, and open source language is provided by the R Project for Statistical Computing
  [Ihaka and Gentleman, 1996, R Development Core Team, 2013]

Motivation

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- Several packages have been developed in R code for developing, implementing and evaluating different hydrological modelling tools and frameworks
- R language is an emerging environment where research and development are the primary purpose
- R is mostly being developed by its users, i.e. domain experts, not by programmers without hydrology knowledge (this implies commitment and long-term involvement, but also at times messy code)

Motivation

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- Comprehensive modelling framework
  - Uncertainty analysis
  - Identify primary physical controls
  - Coupling inland hydrological models with coastal
  - Regional, transboundary and global scales

Motivation

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- Open source data and software in R, for:
  - statistical analysis and graphics
  - suitable and reproducible modelling framework
  - basic data manipulation (import, export, selection, joining of tables)
  - spatial interpolation
  - calibration and simulation
  - uncertainty analysis
  - geospatial capabilities for querying, updating, sharing and visualization of data, methods and results
  - general tools as support in hydrological analysis

Useful functionality in R

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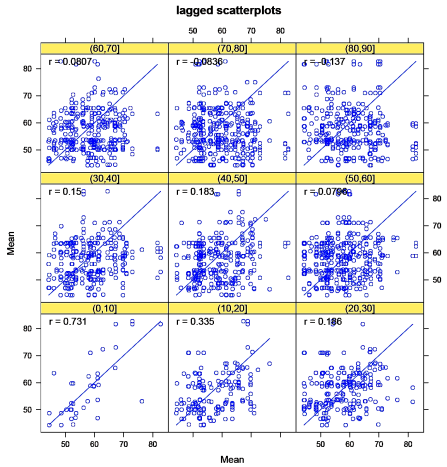
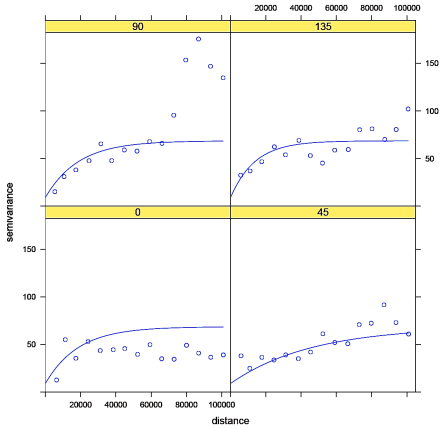
- R as statistical computing and graphics environment, provides a large amount of generic functionality useful in hydrological modelling:
  - MCMC outputs
  - print quality visualising
  - time series
  - spatial and spatio-temporal data
  - geostatistics, downscaling, upscaling,
  - aggregation and disaggregation





Useful functionality in R

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- Higher level functionality:
  - cross platform
  - easy dissemination and new extension
  - reproducible research
  - support
    open mailing lists, forums, companies, books
  - open and active community

Data management and R

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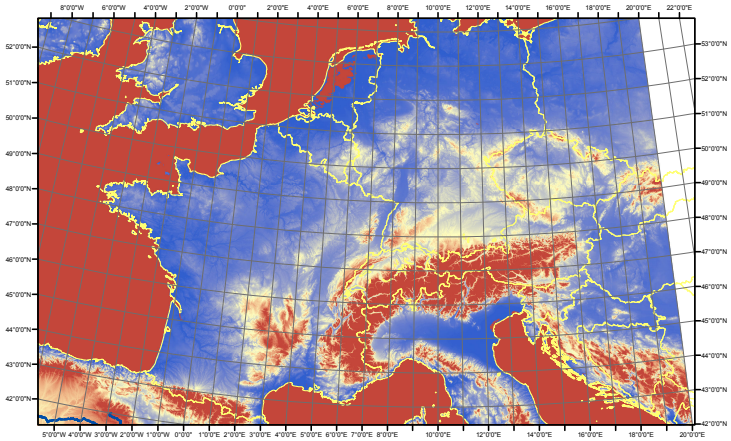
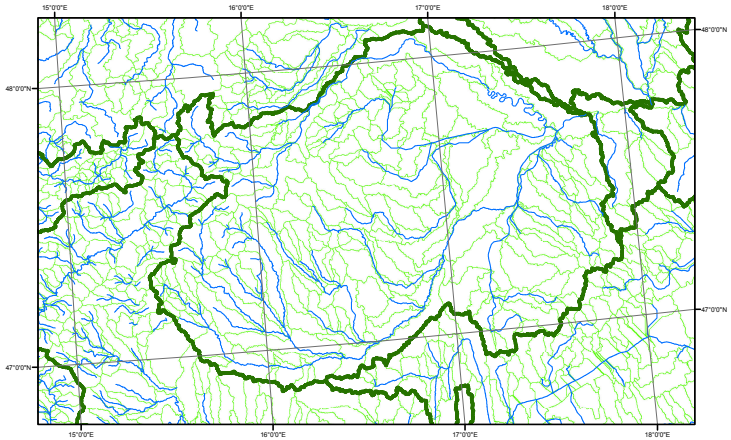
- reproducibility in research:
  - share a common data model
  - independence of modelling framework



- standardised open data for research:
  - ECRINS dataset
  - EOBS dataset
  - web services



Database access and manipulation

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- `foreign` package [R Core Team et al., 2013]
  - `read.dbf`: importing .dbf file $\longrightarrow$ R dataframe
- `sp` package [Pebesma and Bivand, 2012]
  - ESRI polygon shapefile $\longrightarrow$ `SpatialPolygons`
  - `SpatialPoints` & `SpatialLines`
- geospatial data abstraction library (GDAL) $\longrightarrow$ `rgdal` [Bivand et al., 2013]
  - multiple classes of `sp`
  - projection/transformation operations $\longrightarrow$ PROJ.4 library
  - ESRI Shapefiles and PGDBs .mdb files $\longrightarrow$ OGR library
- `igraph: network analysis and visualization (Csardi, 2013)`

Spatial and temporal analysis

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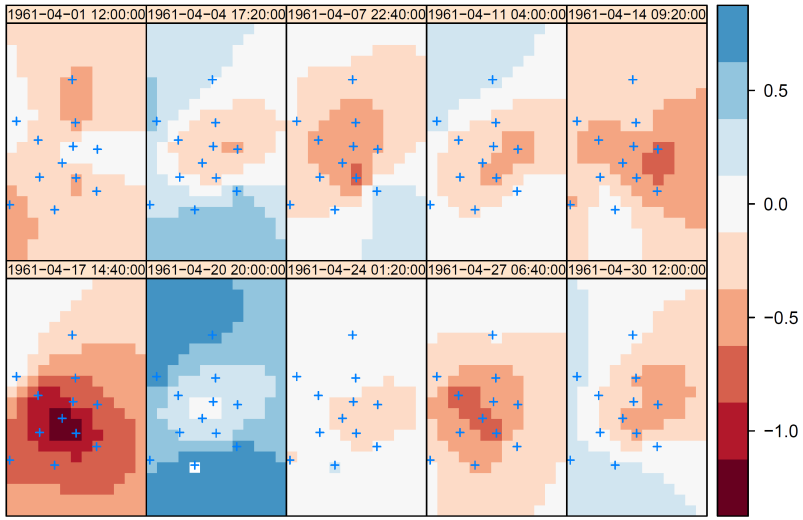
`spacetime` package

- container for spatio-temporally referenced
- time series of points
- spatio-temporal fields
- catchment time series



[Pebesma, 2012]

Web services and interoperability

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- `RObsDat` by Reusser and Liersch (this Symposium)

- R provides generic interfaces to `curl` and `libxml`
- `RCurl` package [Lang, 2013a]
- `XML` package [Lang, 2013b]
  - access web services
  - `sos4R` [Nüst et al., 2011]
  - retrieve sensor data from an OGC sensor observation service
  - retrieve data in `waterML`.
- `Rserve` package $\longrightarrow$ web service interface [Urbanek, 2013]
- WPS4R [Hinz et al., 2013]: higher-level, generic OGC WPS interface

  52°North WPS

Hydrological Model Assessment and Development, hydromad

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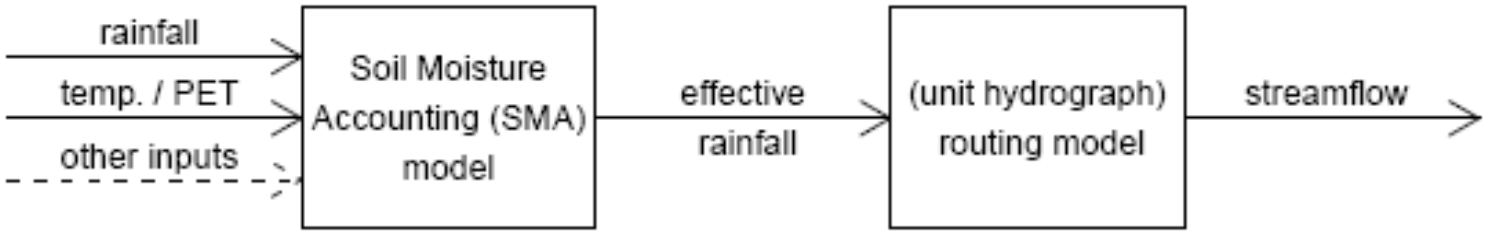
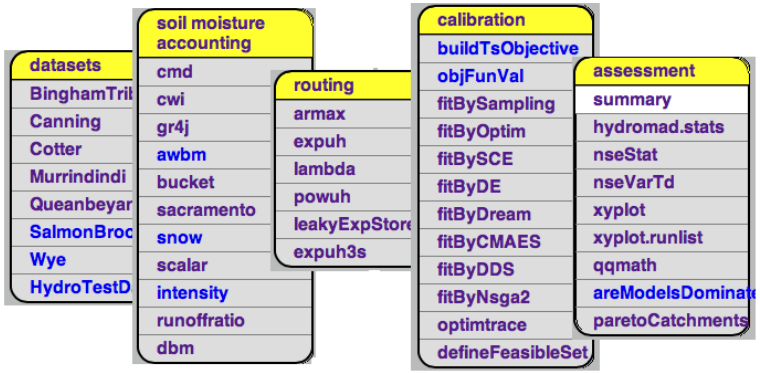
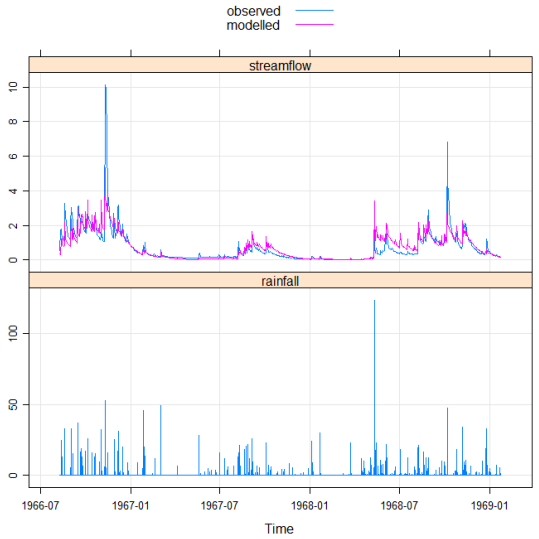
[Andrews et al., 2011]







IHACRES CWI model with exponential unit hydrograph

`topmodel`, semi-distributed model

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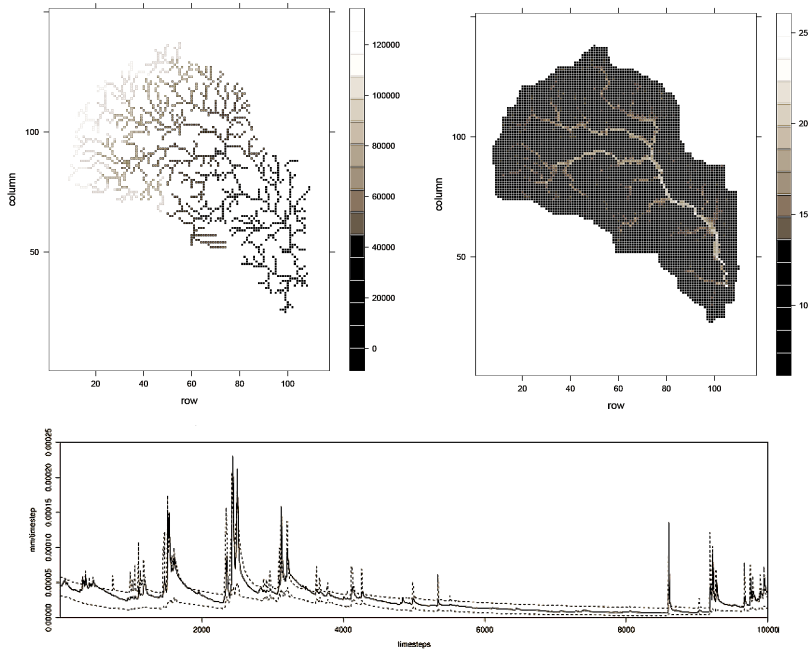
[Beven et al., 1995, Beven, 1997]

- 1995 Fortran version by Keith Beven
- R version by [Buytaert, 2012]
- new functionality developed as part of the `RHydro` package on R-Forge



Further hydrological functionality

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- there are nearly 5000 packages on CRAN
- several additional packages published at CRAN in the area of hydrology
  - `HydroMe` package
  - `hydroTSM` package
  - hydroGOF
  - hydroPSO
  - EcoHydRology
  - wasim
  - seacarb
  - StreamMetabolism
  - oce
  - nsRFA
  - boussinesq
  - rtop

`http://cran.r-project.org/web/views/Environmetrics.html`

Current contribution

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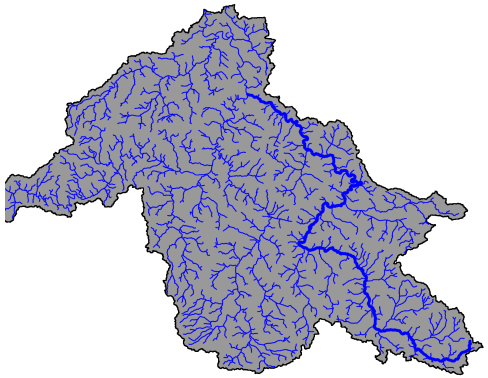
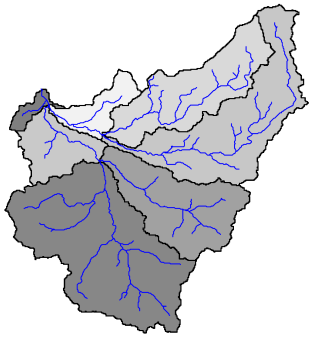
`watersheds` package

- spatial analysis for watersheds aggregation
- spatial drainage networks analysis
- based on `sp` and `rgeos` packages (Pebesma & Bivand, 2005-2012)





Looking forward:

- Modelling framework for real-time flow prediction
  - flood assessment
  - mitigation of contamination

Conclusions

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- we present an introduction to the state-of-art of hydrological modelling as is developed in the open source software R.
- this constitutes a starting point for research because it grants a suitable programming platform where standardised tests and comparisons of models is possible, searching for reproducibility of methods and results as is often required in the context of science and research.

Thank you!

Questions?

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