rtop – an R package for interpolation along the stream network

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Motivation

- Increased interest in geostatistical methods for variables which has a support
- Examples:
  Regionalisation of runoff variables
  Health statistics
- Support can be spatial and/or temporal
- Methods includes integrals of variogram/covariance functions
- Several solutions to this problem, open source, versatile software still missing

Method

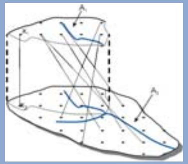
- Based on top-kriging method (Skøien et al, 2006) – for prediction of runoff characteristics at locations without observations
- Variogram values between observations and between observations and prediction locations found by integrating a point variogram over a large number of points in each of the catchments:

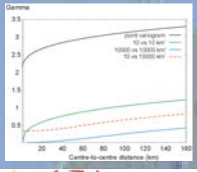
$$\gamma_{12} = 0.5 * Var(z(A_1) - z(A_2)) = \frac{1}{A_1 A_2} \int_{A_1}\int_{A_2} \gamma_p(|\mathbf{x}_1 - \mathbf{x}_2|) d\mathbf{x}_1 d\mathbf{x}_2 -$$

$$0.5 * \left[\frac{1}{A_1^2} \int_{A_1}\int_{A_1} \gamma_p(|\mathbf{x}_1 - \mathbf{x}_2|) d\mathbf{x}_1 d\mathbf{x}_2 + \frac{1}{A_2^2} \int_{A_2}\int_{A_2} \gamma_p(|\mathbf{x}_1 - \mathbf{x}_2|) d\mathbf{x}_1 d\mathbf{x}_2 \right]$$

- Variogram estimated as cloud variogram or 3-D binned variogram, with areas from each catchment of a pair on the 2nd and 3rd axis
- Variogram model found by back-calculation (fitting regularized variogram values to cloud or binned sample variogram)
- Prediction method able to take measurement uncertainty into account
- Kriging equations otherwise as normal

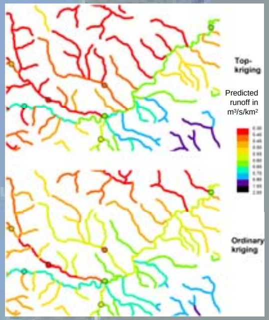
Semivariance found by regularization of a point variogram





Point variogram and semivariograms for different catchment size classes

Example from Skøien et al. (2006) – prediction of 100 year floods (HQ100)



Predictions from Top-kriging consistent with hydrological expectations

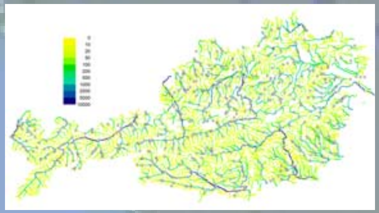
Predictions from Ordinary kriging not consistent with hydrological expectations

Implementation

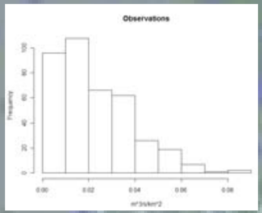
- Method implemented in statistical environment R (R Development Core Team, 2004)
- Taking advantage of existing methods for handling spatial objects (Bivand et al., 2008) and for creating graphical output
- All data and results stored in a single object – for simple interfacing
- Package created for simple interface with intamap-package (package under development for automatic interpolation through a web-service)
- Output similar to output from interpolation in gstat-package (Pebesma, 2004)
- Package will be submitted to CRAN, test versions available on request

Example: Predictions of annual mean

- Annual mean from 387 stations in Austria
- Catchments boundaries for all catchments
- Stationarity assumptions can be questioned

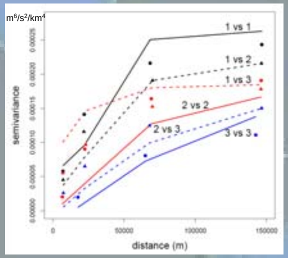


Upslope contributing area in km²

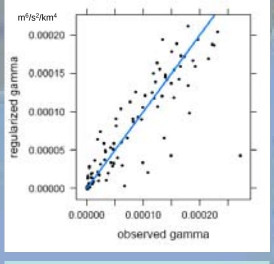


Histogram of observations (m³/s/km²)

Observed and fitted semivariogram values



Variograms and cross-variograms for different catchment size classes – observed as lines, regularized as dots and triangles



Scatter plot of observed and regularized semivariogram values

References

Gottschalk, L. 1993. Correlation and covariance of runoff. *Stochastic Hydrology and Hydraulics*, *7*, 85-101.

Pebesma, E. J. 2004. Multivariable geostatistics in S: the gstat package. *Computers & Geosciences*, *30*, 683-691.

R Development Core Team. 2004. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Skøien, J. O., R. Merz, and G. Blöschl. 2006. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, *10*, 277-287.

INTAMAP

- The INTAMAP project (www.intamap.org) will develop an interoperable framework for real time automatic mapping of critical environmental variables by extending spatial statistical methods and employing open, web-based, data exchange and visualisation tools
- Development case focuses on data from the data base of gamma radiation in Europe – EURDEP – but final software will also include real-time predictions of observations having a support

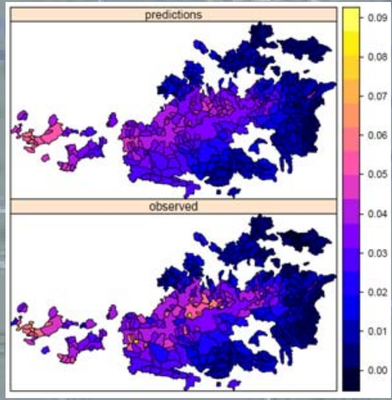
Usage

```
> library(rtop)
> # <read data> help functions exist
> rtopObj = createRtopObj(observations, predictionLocations, params)
> rtopObj = rtopFitVariogram(rtopObj)
> rtopObj = rtopKrige(rtopObj)
```

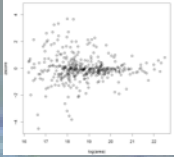
- Observations and predictionLocations are typically SpatialPointsDataFrame (easily created from shapefiles)
- Params includes different options, such as
  - cloud variogram / binned variogram (including parameters for how to make bins)
  - use of geostatistical distance or not
  - variogram model
  - maximum number of observations for local kriging
  - maximum limit for the size of weights for ill-conditioned kriging matrices
- Elements created in earlier analysis can be reused

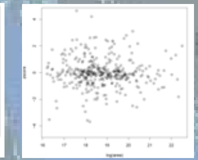
Results:

- Cross-validation gives correlation between observed and predicted around 0.9
- Result not significantly different from point kriging in this case!!
- But: kriging variance dependent on prediction area and zscore (residual/kriging standard deviation) not dependent on area (contrary to point kriging)



Difficult to predict some catchments with high values in central Austria (due to non-stationarity)





Figures show zscore ((obs-pred)/st.dev) for point kriging and top kriging.

Conclusions

- R-package for interpolation of observations with irregular support being developed
- Based on methods from Skøien et al. (2006)
- Planned improvements: more variogram models, more options for variogram fitting, improved graphical output for runoff variables
- Package will be submitted to CRAN (The Comprehensive R Network), test versions available on request

Acknowledgements

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