# *Statistical software to identify spatiotemporal patterns and coherence over river networks*

SECURE project EP/M008347/1

November 2015 to April 2016

20th September 2016

# SECURE Annual Conference

## Project partners:

- John Douglass, Linda Pope (EA)
- Graeme Cameron, Mark Hallard (SEPA)
- Robert Willows (Honorary senior research fellow, UoG)
- Claire Miller, Marian Scott, Kelly Gallacher (UoG)

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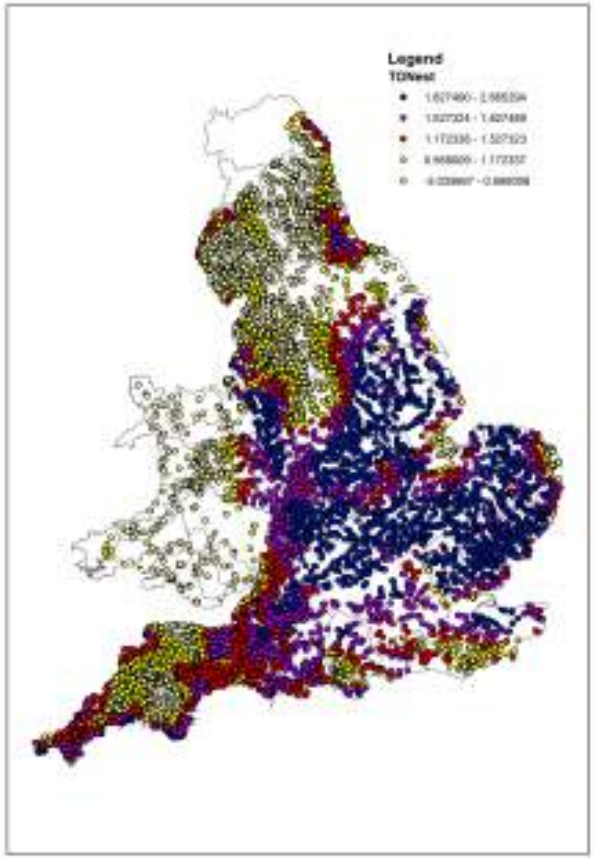
## Background:

Spatiotemporal Modelling of Nitrate and Phosphorus for River Catchments:

- Miller et al. (2014)
- Related work - O'Donnell, et al. (2014)



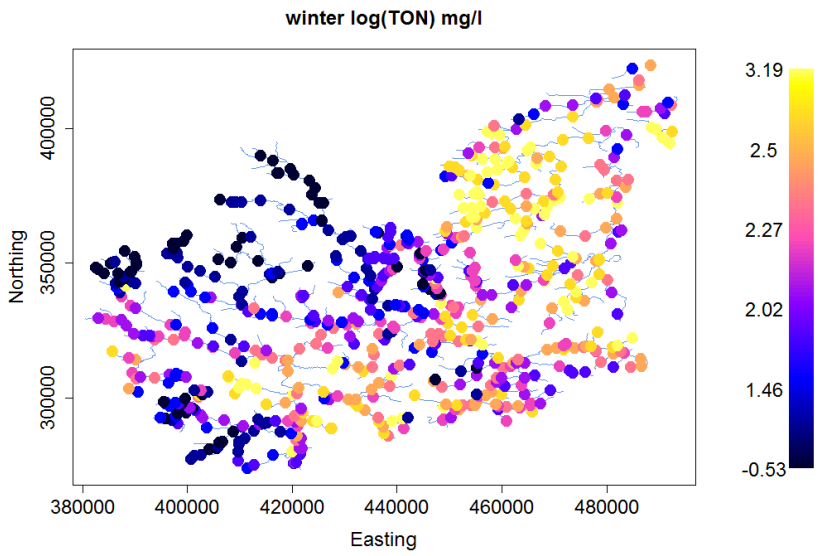

## Motivation:

- Water Framework Directive (EP 2000)
- Nitrates Directive (EP 1991)

## Background:

Using river network structure to improve estimation of common temporal patterns (Gallacher; 2016a):

- Are all of the monitoring points required?
- Can we identify common spatiotemporal patterns where future monitoring could be focussed?



## SECURE project

### Project aim

To develop novel statistical software tools, for use within environmental science partner communities, which enable identification of spatiotemporal and coherent patterns over river networks.

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## Objectives:

- identify statistical methodology from Gallacher (2016) of greatest relevance to the environmental science partners;
- develop R routines, interfaces (and associated tutorial documentation);
- demonstrate the utility and benefits to environmental science partners;
- demonstrate the integration of these routines within TIBCO Spotfire.

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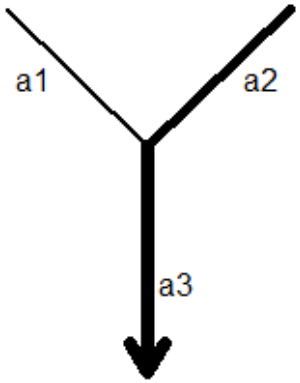
- **Tool A - Identifying common spatiotemporal patterns**
  - Identify dominant spatial pattern(s) that occur over time
  - Identify dominant temporal patterns across space
  - Adjust for spatial and/or temporal correlation if required to reveal 'hidden' features

- Tool B - Reducing the monitoring network
  - Investigate how predictions/uncertainty of predictions changes with network size.
  - Investigate how the choice of sampling scheme affects inferences.

## Statistical Approach:




- Statistical method used is principal components analysis;
- Spatial weights reflect flow direction and strength of relationship between upstream sites and downstream sites, (Peterson et. al 2010);
- Temporal correlation can also be incorporated to improve inference.

## Snapshot of stpca results -:

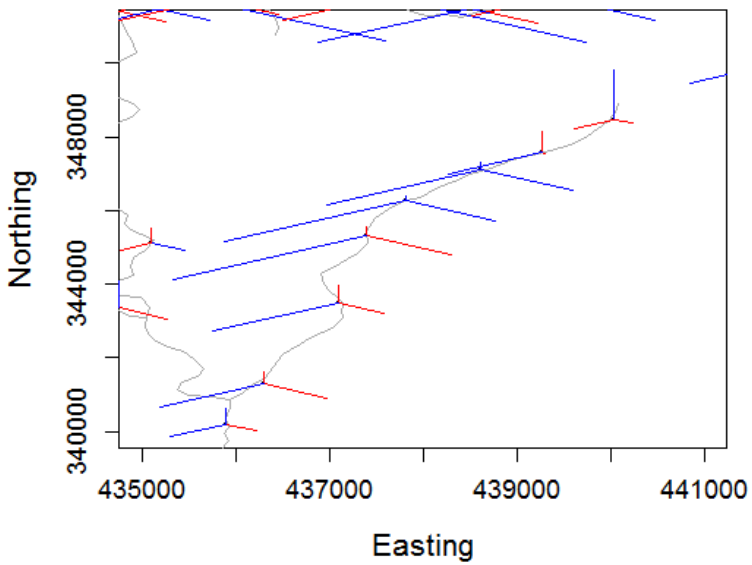



Figure : Standard PCA

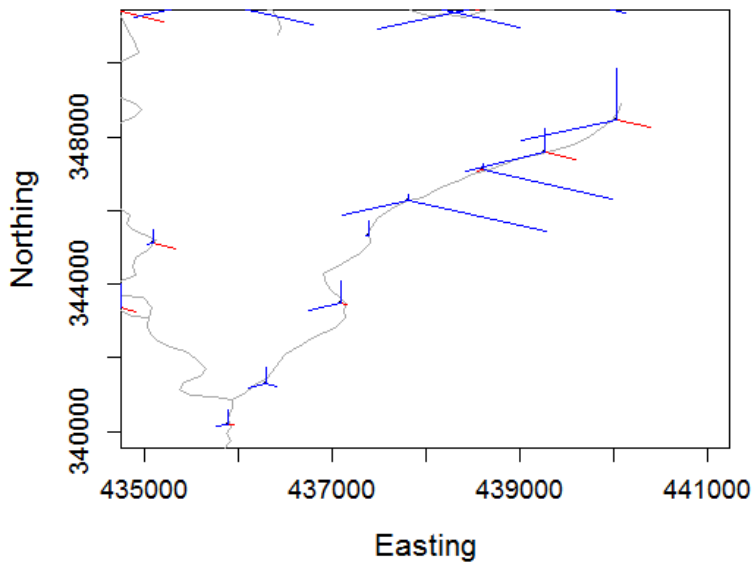



Figure : Flow-weighted PCA

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## Environmental science community engagement:

- Secondment at SEPA
- Workshops at EA and SEPA

## Project outputs:

- An R package: **stpca** with demo data and full tutorial documentation `http://dx.doi.org/10.5525/gla.researchdata.277`
- A tool within TIBCO spotfire for SEPA
- Publication: Flow directed PCA for monioring networks (under revision for Environmetrics)

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## Conclusions:

- Exploratory tools to provide fresh intelligence and new insights into water quality monitoring of river networks.
- Tutorial documents are available, based on demo river network data.
- Functions can be applied to different data formats and adapted for user needs.

**Future directions:** Further collaborative projects to ensure results are interpreted/used effectively.

European Parliament (1991). Council directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC). Off J Eur Communities 1991b:L375/1.

European Parliament (2000). Directive 2000/60/EC of the European parliament and of the council of 23 October 2000 establishing a framework for community action in the field of water policy. Off J Eur Communities 2000:L327/1.

Gallacher (2016). Using river network structure to improve estimation of common temporal patterns. PhD thesis, University of Glasgow

Miller, C., Magdalina, A., Willows, R., Bowman, A., Scott, E., Lee, D., Burgess, C., Pope, L., Pannullo, F., and Haggarty, R. (2014) Spatiotemporal statistical modelling of long-term change in river nutrient concentrations in England & Wales. Science of the Total Environment, 466-7, pp. 914-923.(doi:10.1016/j.scitotenv.2013.07.113).

O'Donnell D, Rushworth A, Bowman AW, Scott EM, Hallard M. (2014) Flexible regression models over river networks. J R Stat Soc Ser C Appl Stat Jan; 63(1): 47–63.

Peterson, E. E. and J. M. Ver Hoef (2014). Stars: An arcgis toolset used to calculate the spatial information needed to fit spatial statistical models to stream network data. J Stat Softw 56 (2), 1-17.