SPATIAL MODELLING

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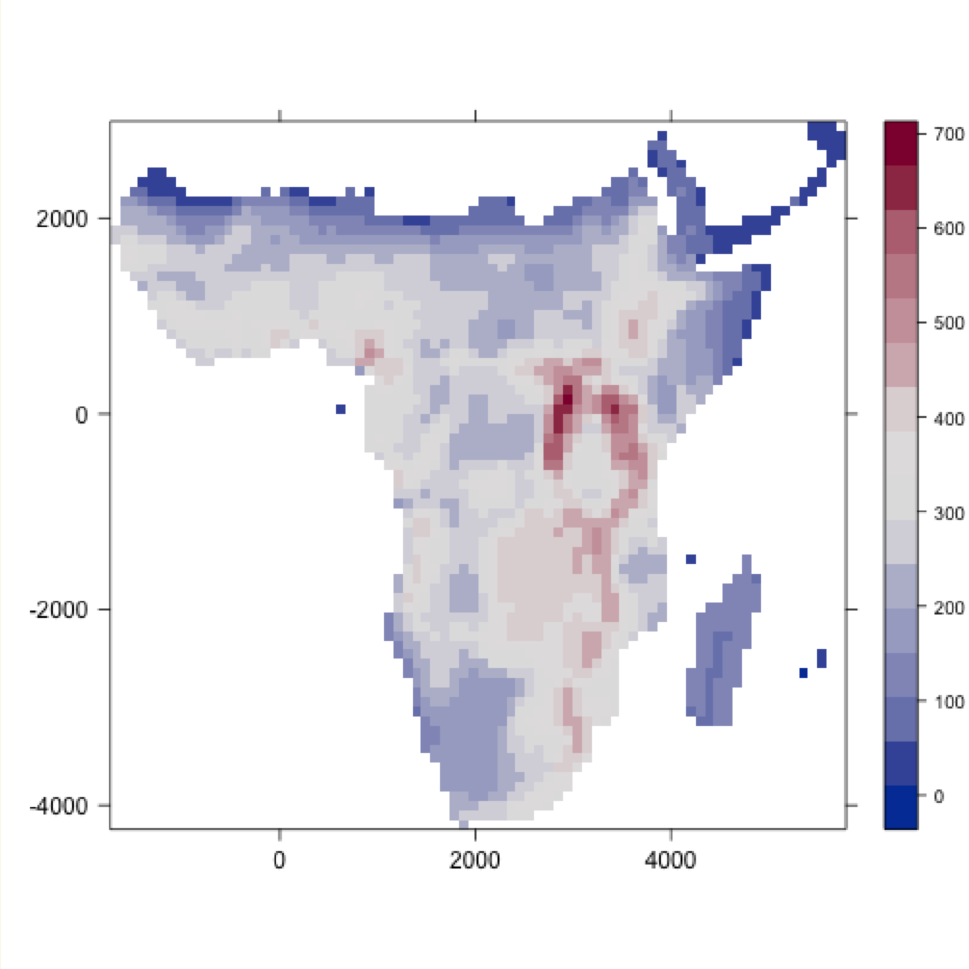
SPATIAL MODELLING TOOLS

- The examples presented here use R
- Another excellent program with a nice GUI interface:
    - Spatial Analysis in Macroecology
    - http://www.ecoevol.ufg.br/sam/

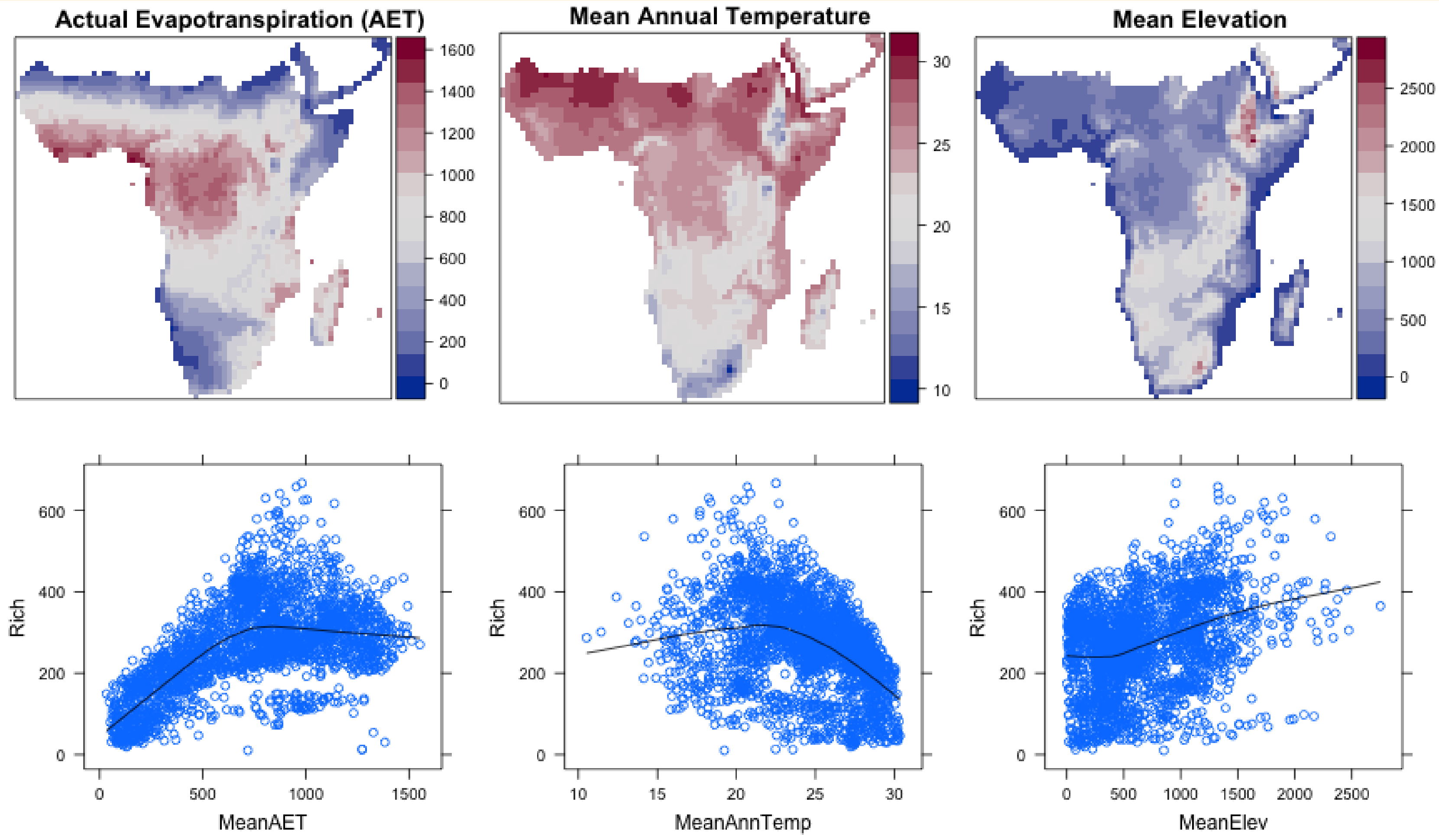
OVERVIEW

- Example data: Afrotropical bird diversity
- Naive models
- Describing spatial autocorrelation
- Accounting for spatial autocorrelation

AFROTROPICAL BIRD SPECIES RICHNESS



EXPLANATORY VARIABLES



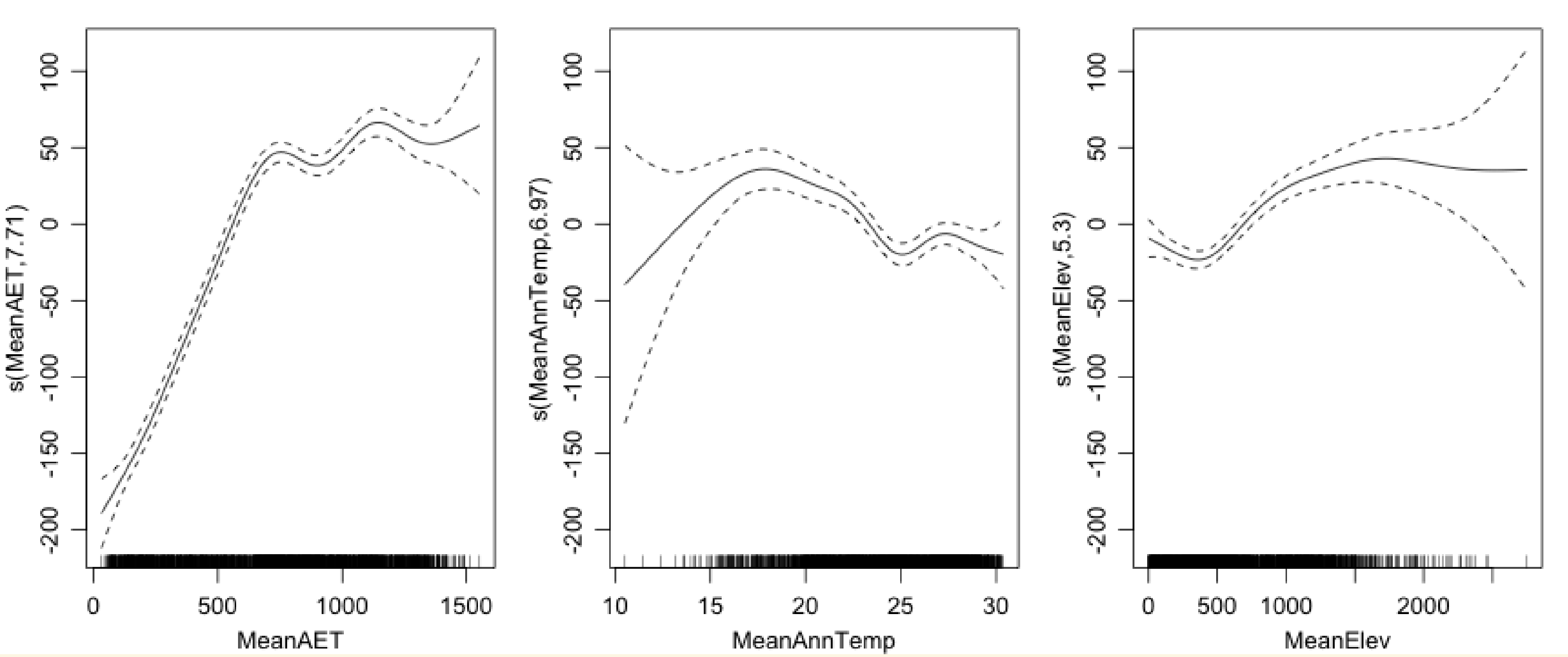
A SIMPLE LINEAR MODEL

Richness ~ AET + Temperature + Elevation

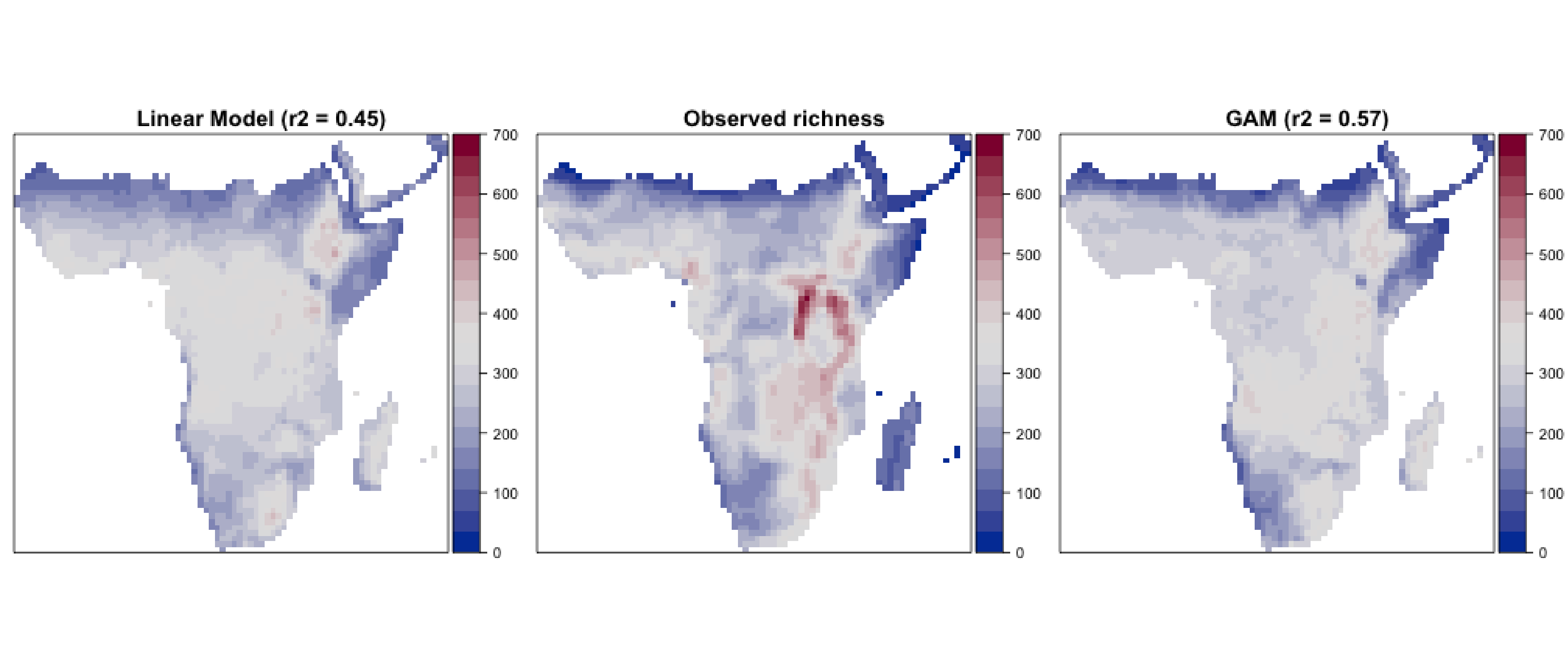
	Est	SE	t	p
(Intercept)	189.45	21.33	8.88	< 0.001
MeanAET	0.18	0.00	37.34	< 0.001
MeanAnnTemp	-4.18	0.72	-5.79	< 0.001
MeanElev	0.08	0.01	13.85	< 0.001

A SIMPLE GAM

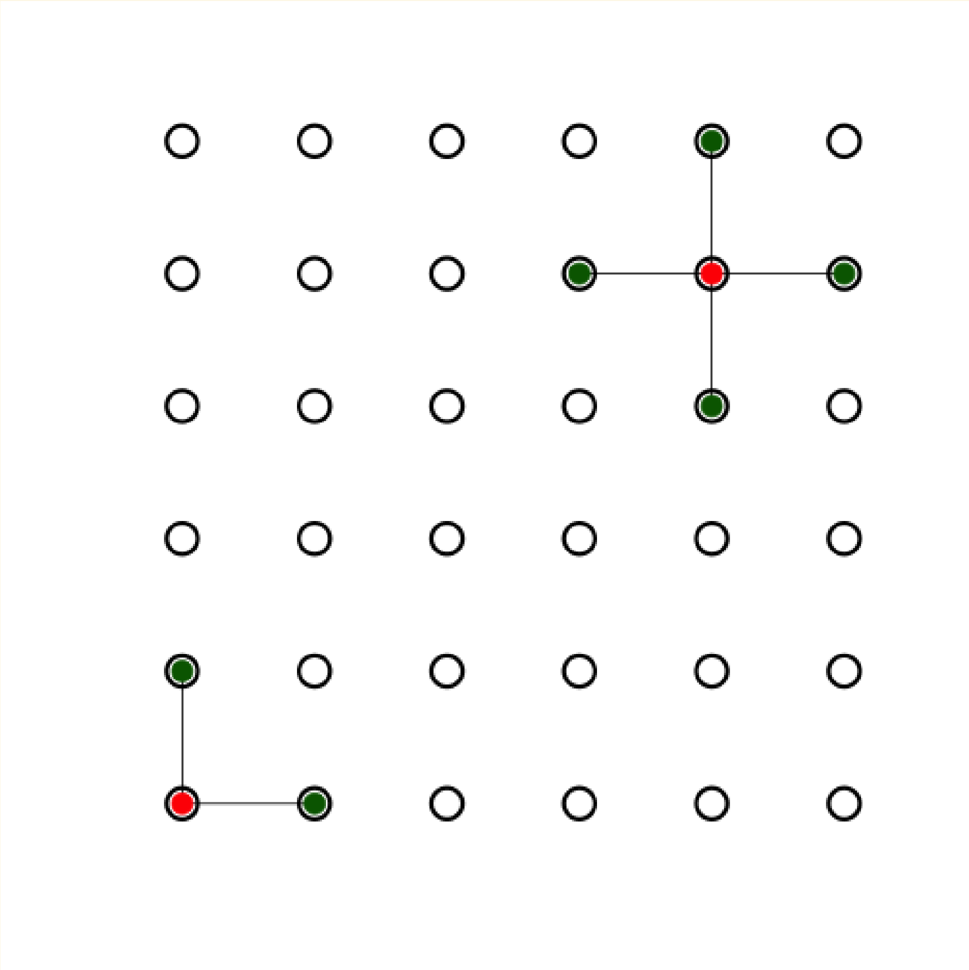
Richness ~ s(AET) +s(Temperature) + s(Elevation)



MODEL PREDICTIONS



NEIGHBOURHOODS

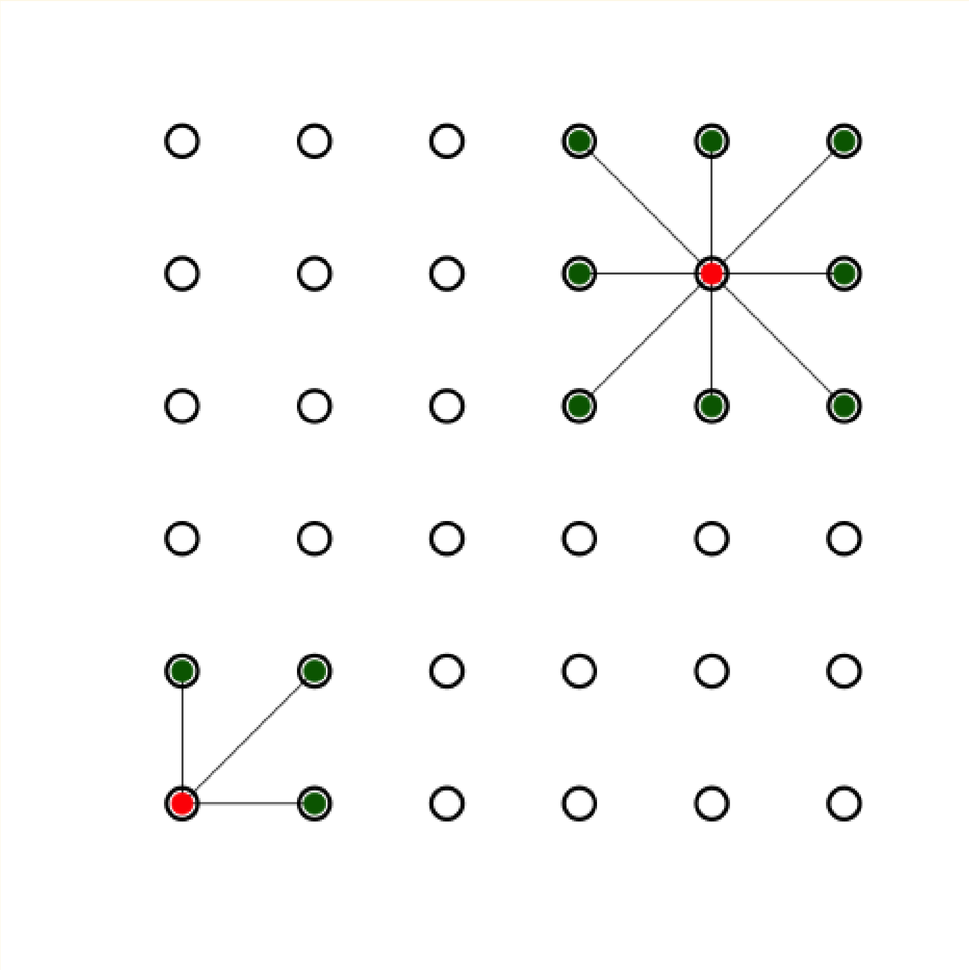


Rooks move

All cells within one step:

- vertically or
- horizontally

NEIGHBOURHOODS

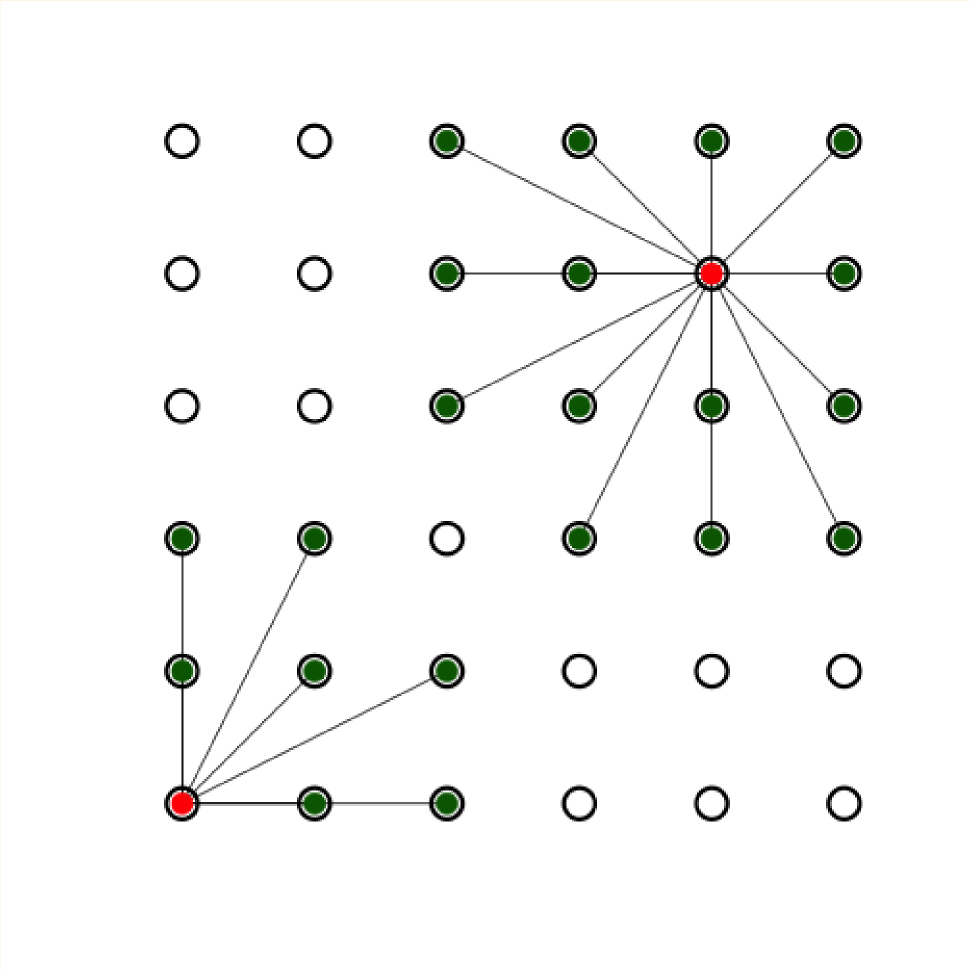


Queens move

All cells within one step:

- vertically,
- horizontally or
- diagonally

NEIGHBOURHOODS

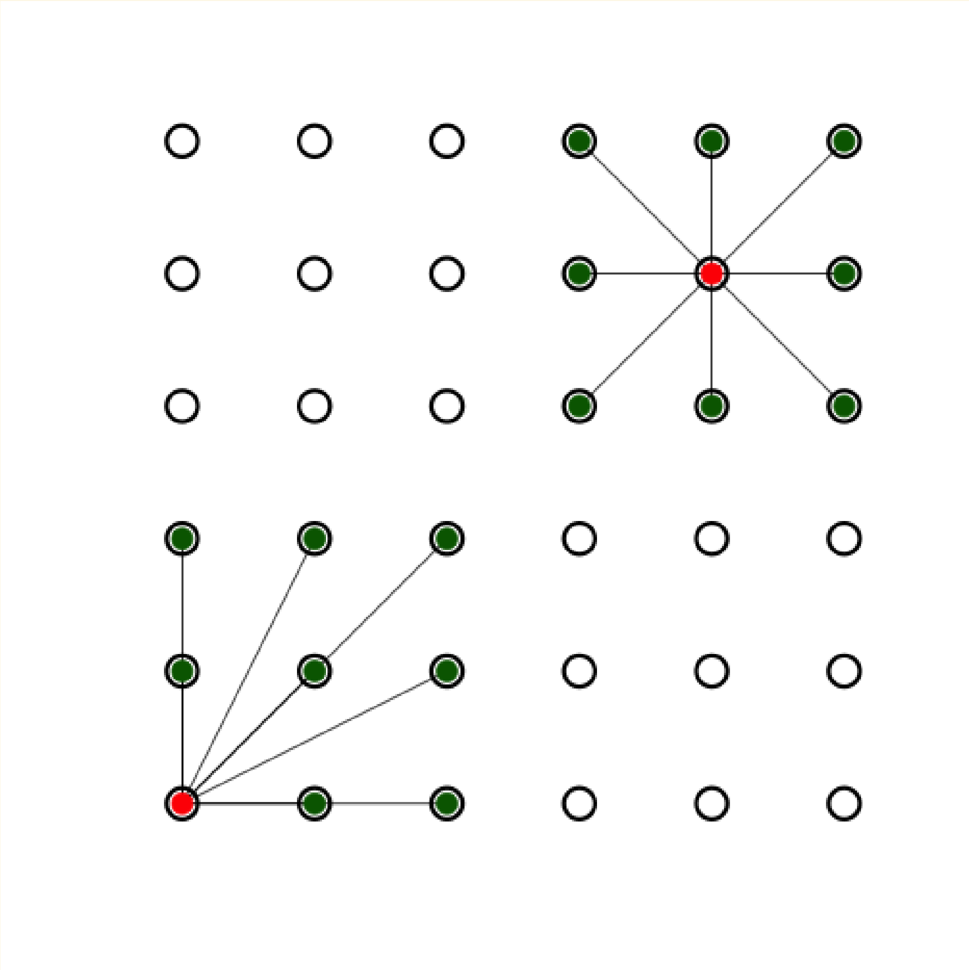


Distance based

All cells within:

- 2.4 units

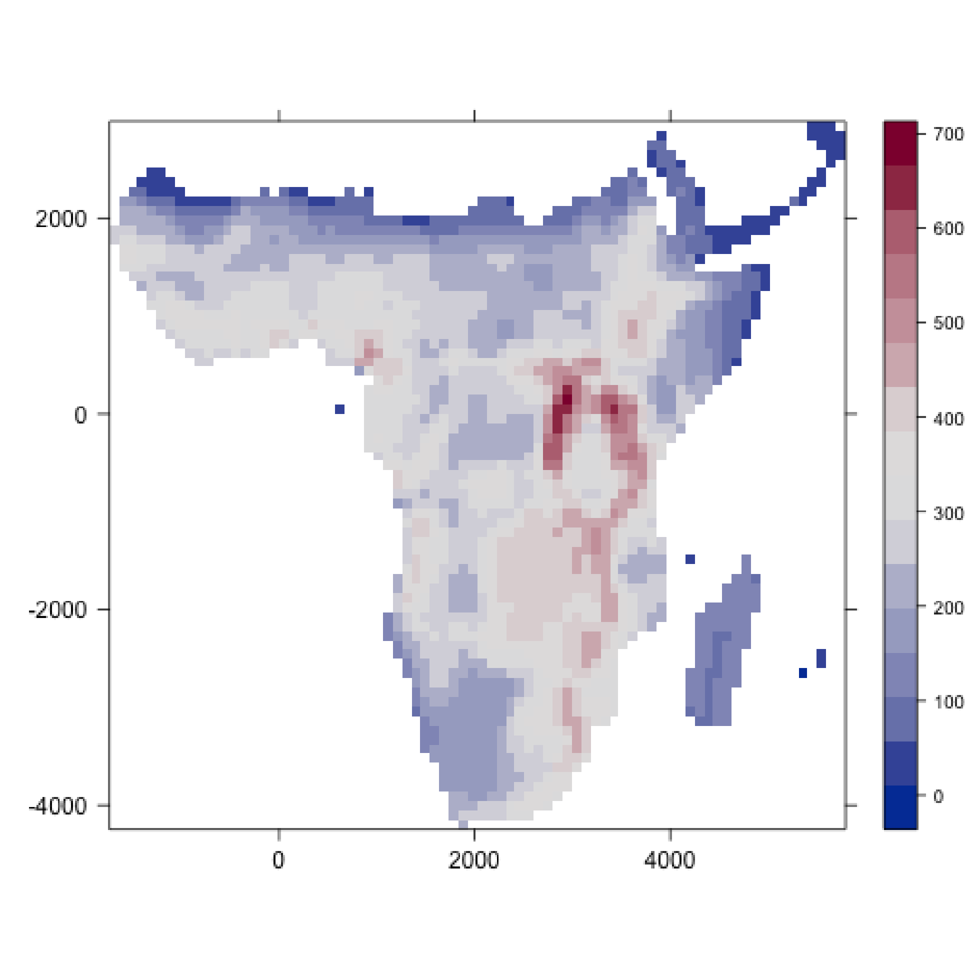
NEIGHBOURHOODS



***k* nearest**

The closest *k* cells

SPATIAL AUTOCORRELATION



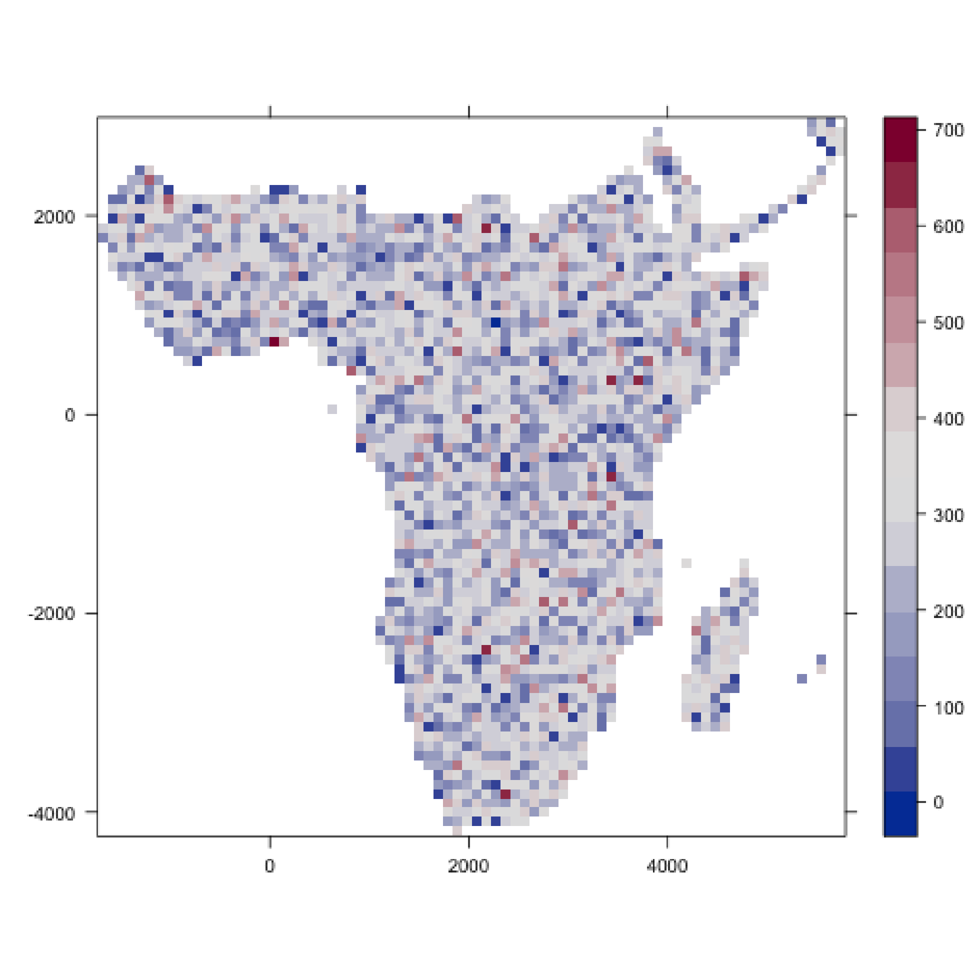
Global Moran's I

- I = 0.922
- p << 0.001

Global Geary's C

- C = 0.070
- p << 0.001

SPATIAL AUTOCORRELATION



Global Moran's I

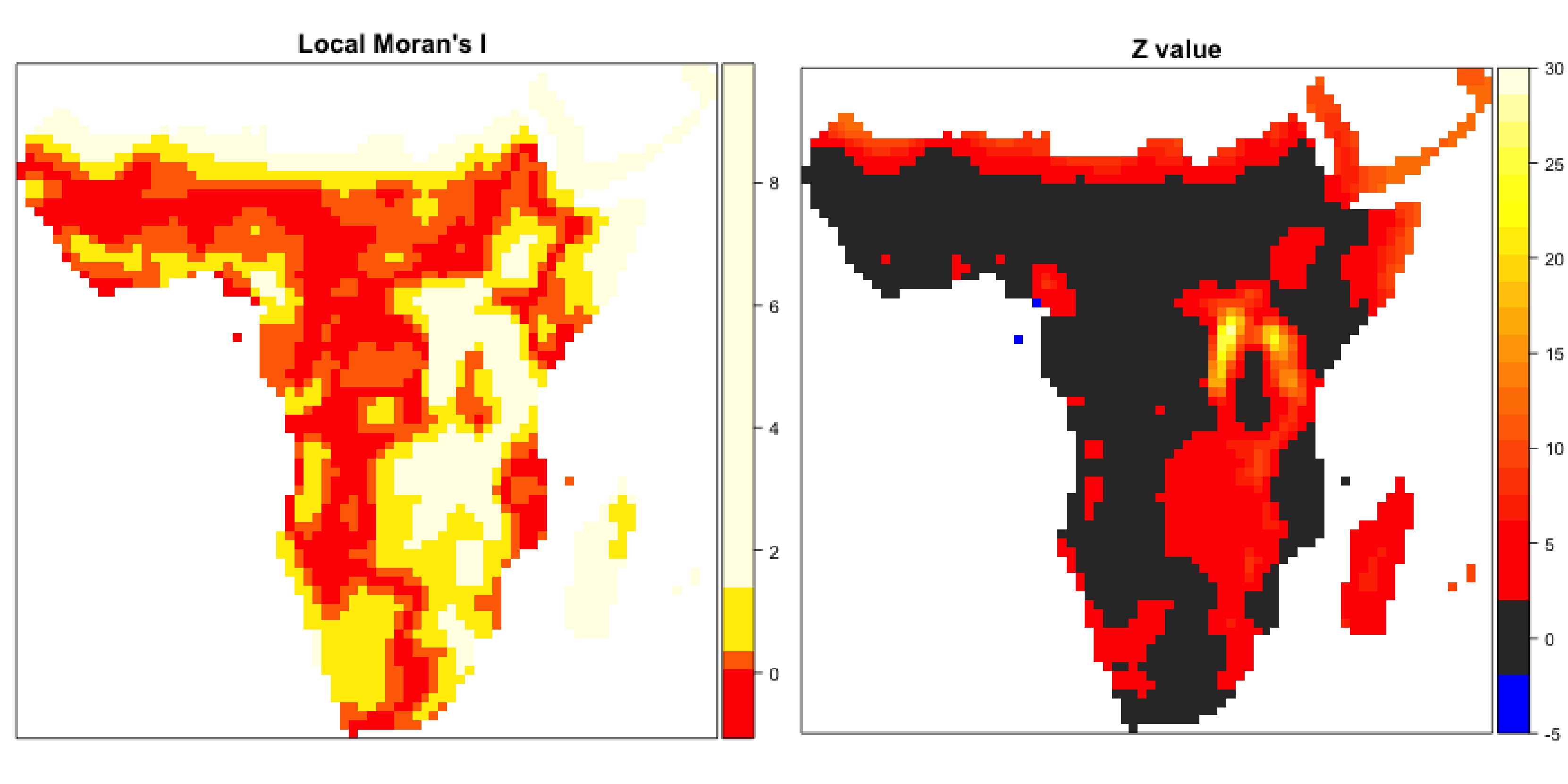
- I = 0.015
- p = 0.059

Global Geary's C

- C = 0.984
- p = 0.059

LOCAL AUTOCORRELATION

Local indicators of spatial autocorrelation (LISA)



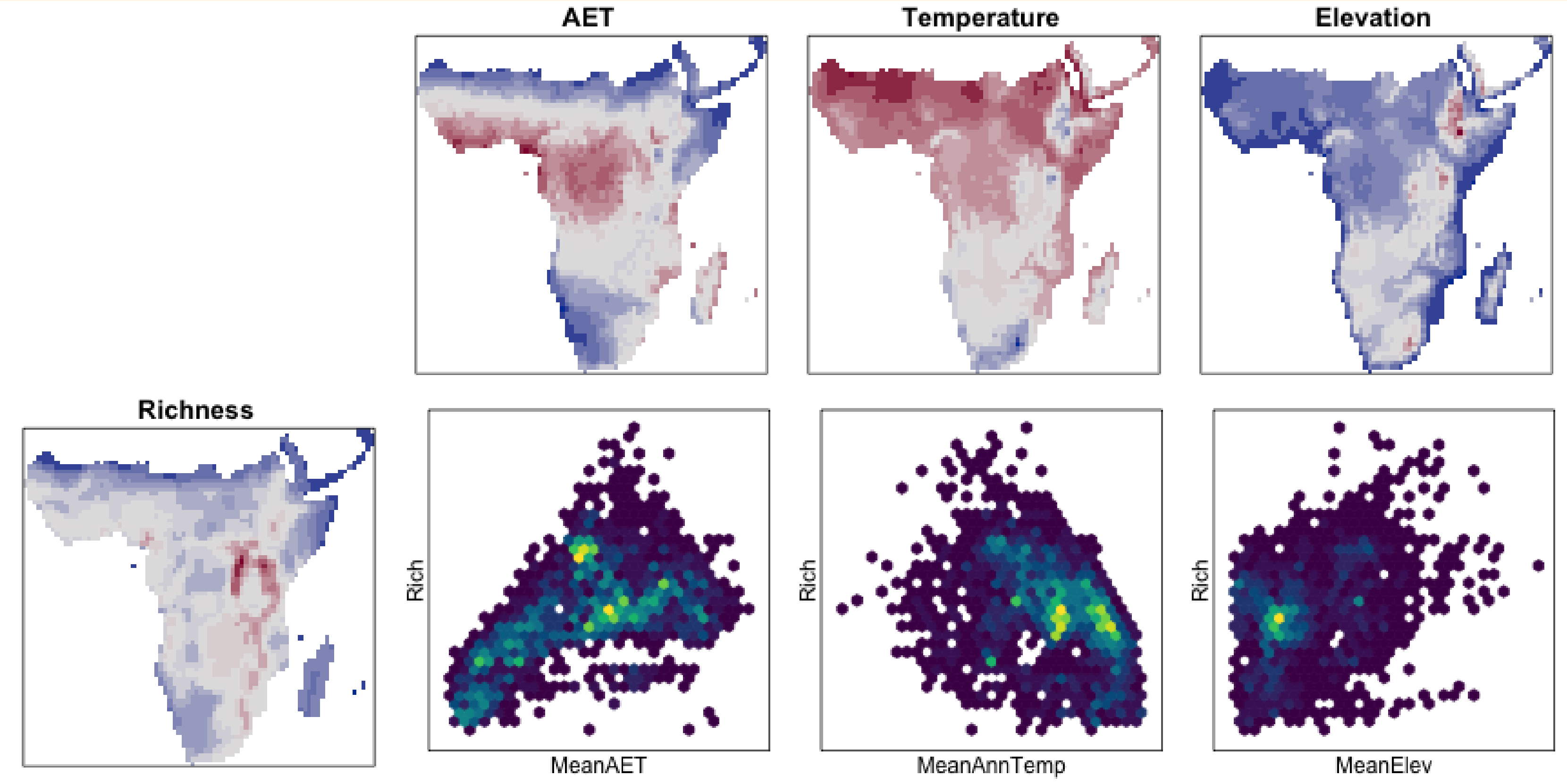
EFFECTS OF SPATIAL AUTOCORRELATION

- Data points **not independent**
- Degrees of freedom reduced:
  - **standard errors and significance testing affected**
- Not equally weighted :
  - **parameter estimation affected**

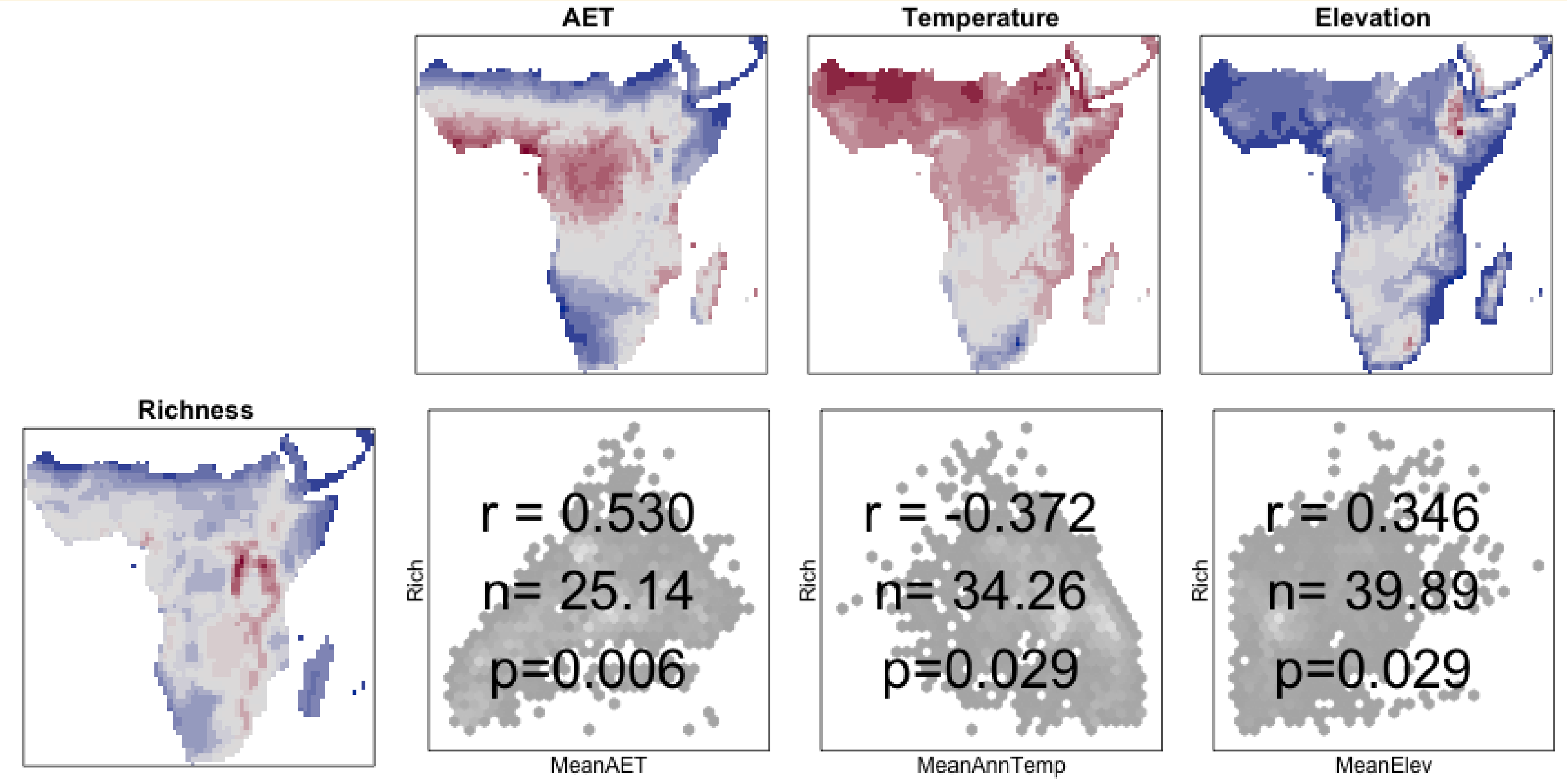
DEALING WITH SPATIAL AUTOCORRELATION

- Modify the degrees of freedom in significance testing
- Account for autocorrelation in models:
  - Simultaneous autoregressive models
  - Generalised least squares
  - Eigenvector filtering
  - Geographically weighted regression

DEGREES OF FREEDOM CORRECTION

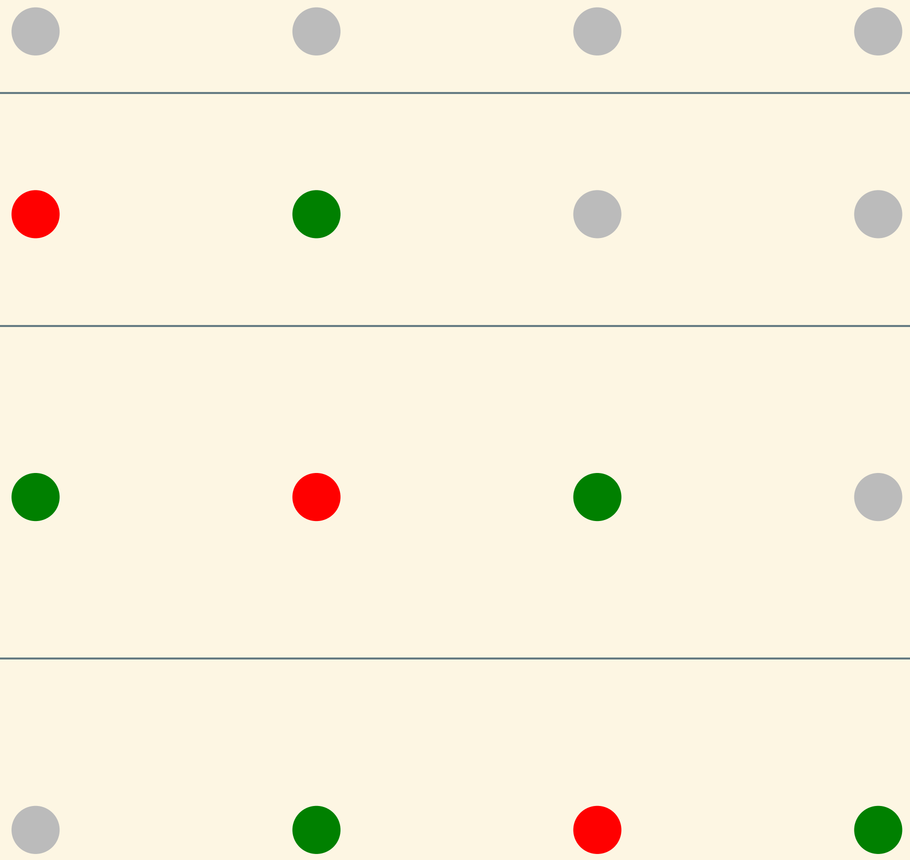


DEGREES OF FREEDOM CORRECTION



SPATIAL AUTOREGRESSION

Solve for b:



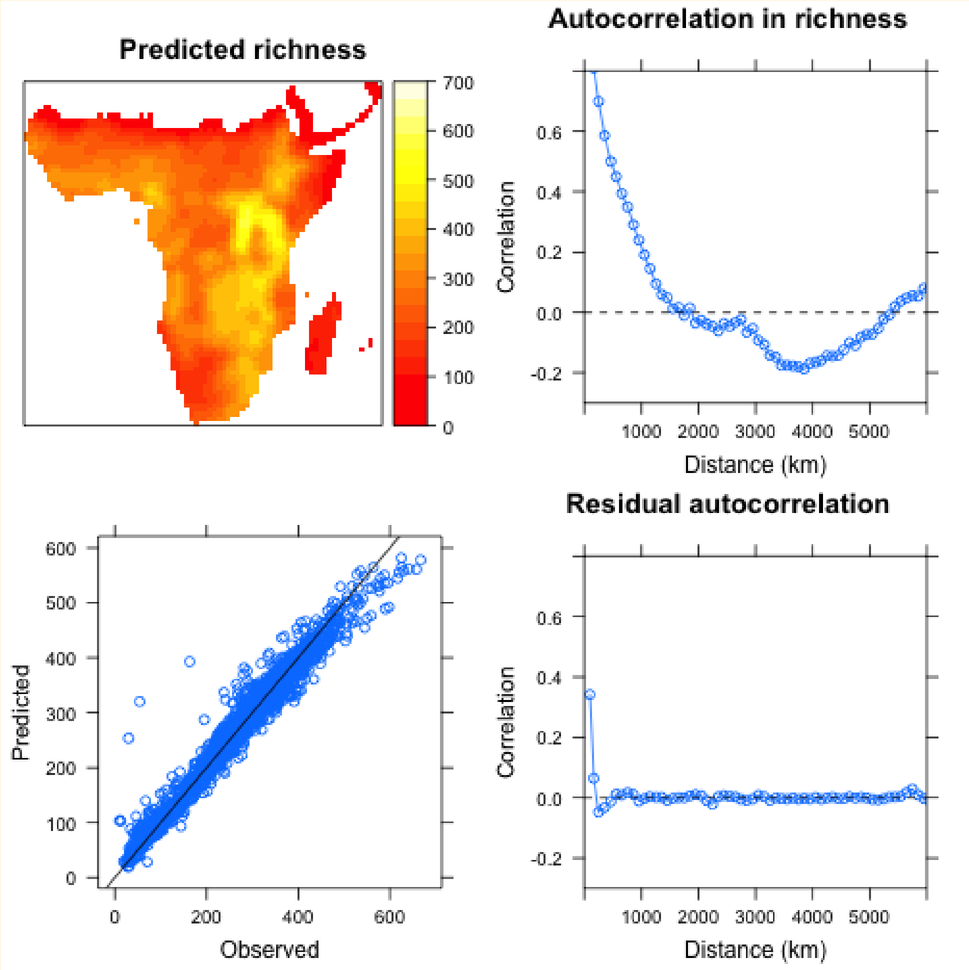
$bx_1 + \frac{1}{2}bx_2$

$\frac{1}{2}bx_1 + bx_2 + \frac{1}{2}bx_3$

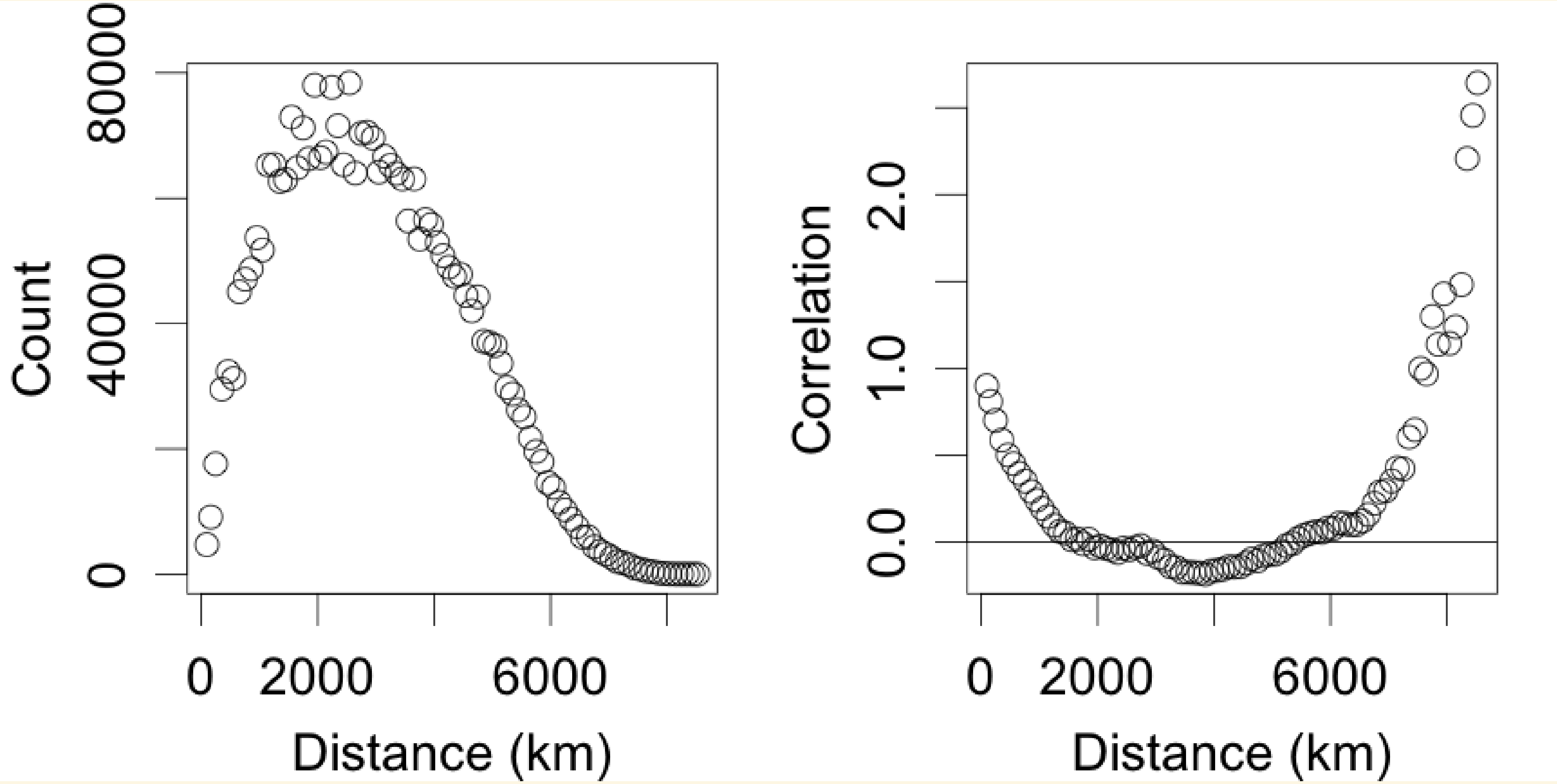
$\frac{1}{2}bx_2 + bx_3 + \frac{1}{2}bx_4$

				$\frac{1}{2}bx_3 + \frac{1}{2}bx_4$
x_1	x_1	x_3	x_4	

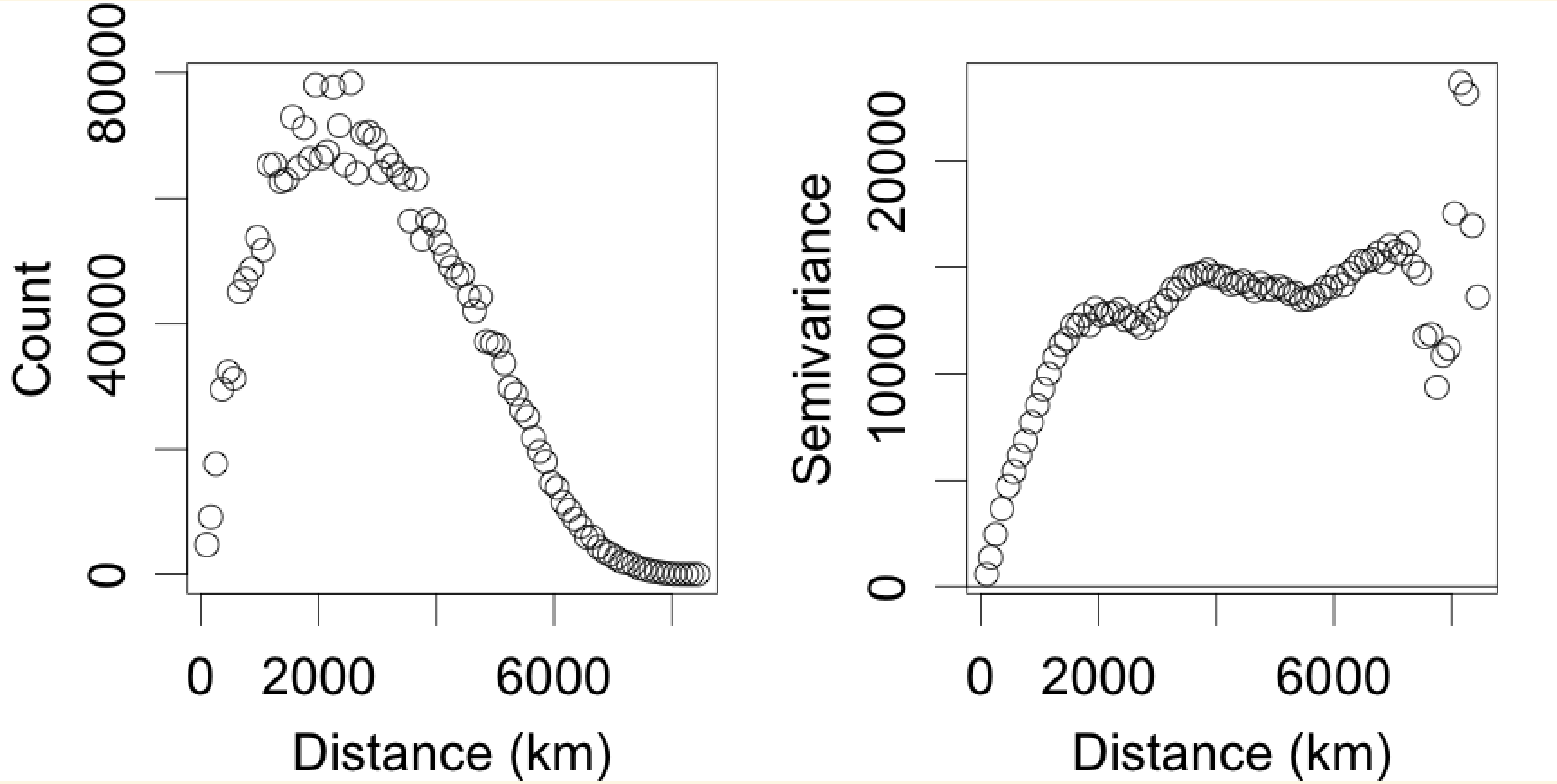
SPATIAL AUTOREGRESSSION



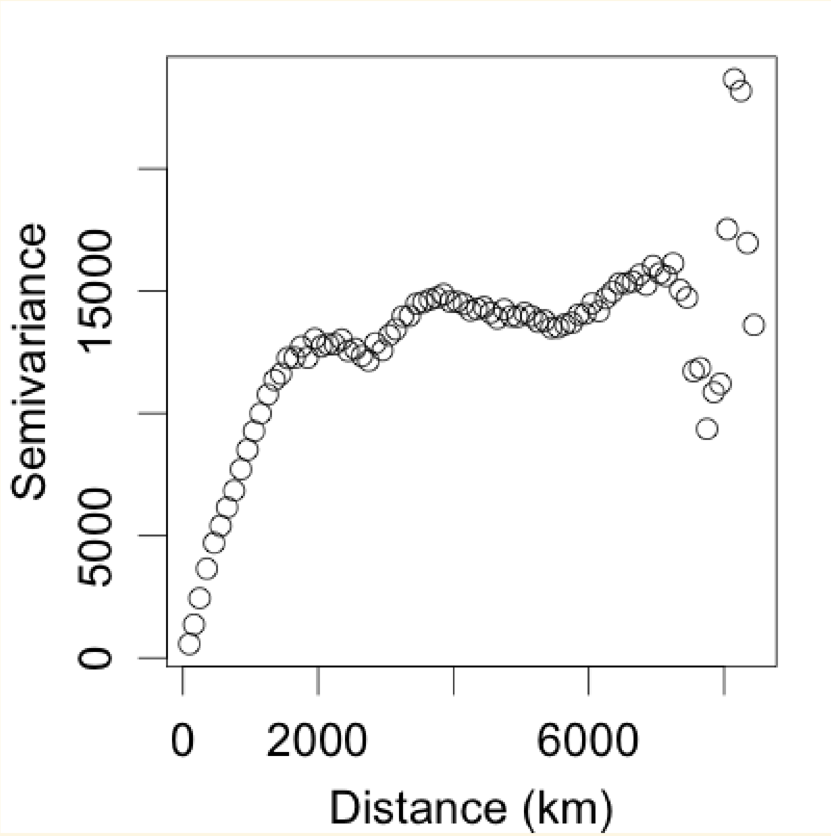
CORRELOGRAM



VARIOGRAM

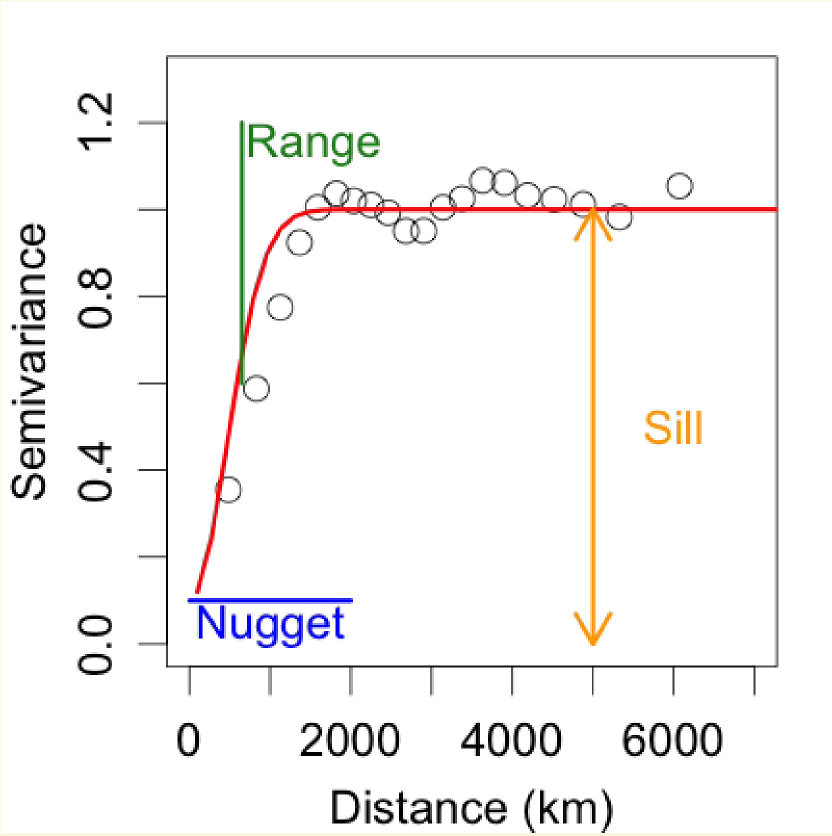

Count
0
400000
800000
0
2000
6000
Distance (km)
Semivariance
0
10000
20000
0
2000
6000
Distance (km)

GENERALISED LEAST SQUARES



- Model correlation as a function of **distance**
- Generate a correlation **matrix**

GENERALISED LEAST SQUARES



- Different shapes:
  - Exponential
  - Spherical
  - Linear
- Parameters

GENERALISED LEAST SQUARES

```
Generalized least squares fit by REML
  Model: Rich ~ MeanAETScaled + MeanAnnTempScaled + MeanElevScaled
  Data: figDat
       AIC      BIC    logLik
  24676.89 24705.97 -12333.44

Correlation Structure: Gaussian spatial correlation
 Formula: ~e_centre_behr + n_centre_behr
 Parameter estimate(s):
 range nugget
 650.0    0.1

Coefficients:
                      Value Std.Error   t-value p-value
(Intercept)       199.67323 16.755430 11.916927  0.0000
MeanAETScaled      17.65050  3.038337  5.809265  0.0000
MeanAnnTempScaled -27.53775  5.663121 -4.862645  0.0000
MeanElevScaled      3.59893  4.321932  0.832712  0.4051

 Correlation:
                  (Intr) MnAETS MnAnTS
MeanAETScaled     0.048
MeanAnnTempScaled 0.141  0.047
MeanElevScaled    0.156  0.079  0.936

Standardized residuals:
        Min          Q1         Med          Q3         Max
-2.35080108  0.09376345  0.73813223  1.30659392  4.48588628

Residual standard error: 97.85917
Degrees of freedom: 2484 total; 2480 residual
```

STATIONARITY AND ISOTROPY

Is the same process happening in:

- different locations (stationarity)?
- different directions (isotropy)?

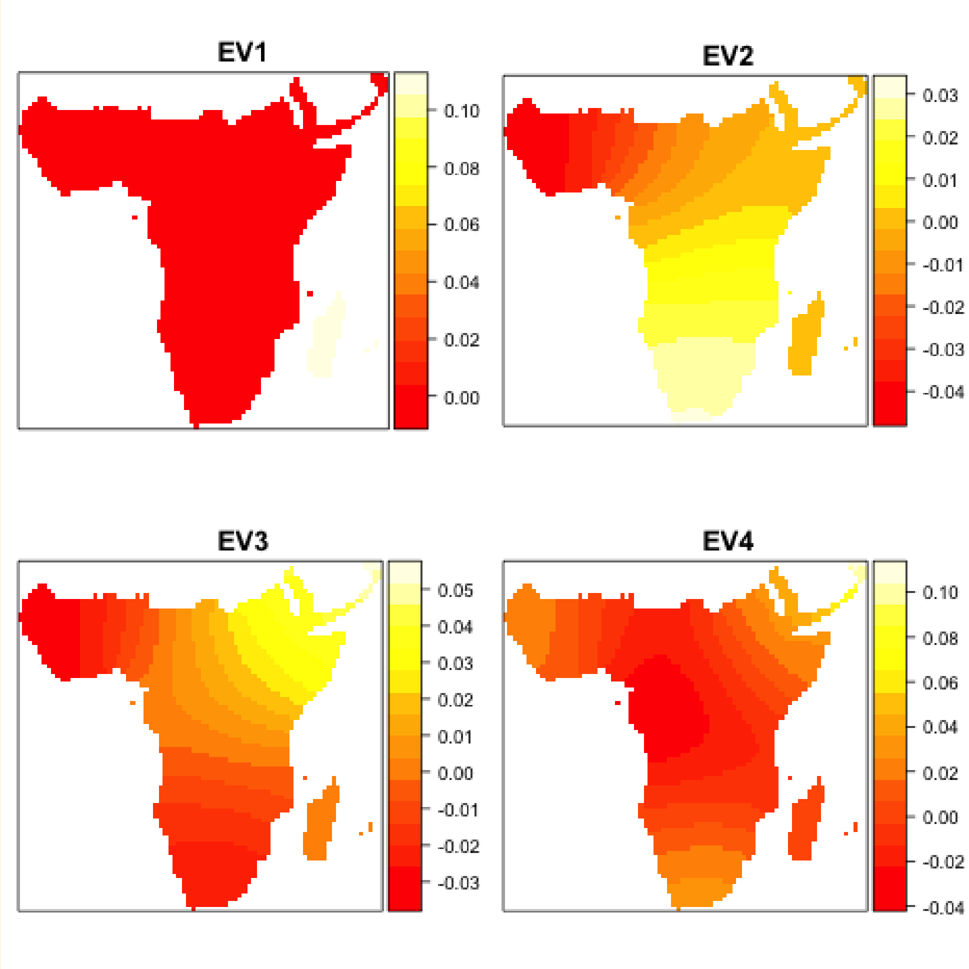
Is the problem in:

- the spatial structure of autocorrelation?
- differences in the actual relationship?

EIGENVECTOR FILTERING

- Take the **eigendecomposition** of a spatial weights model
- Use the **eigenvectors** as variables in the model
- Use a selection process to identify and include only important eigenvectors

EIGENVECTOR FILTERING



EIGENVECTOR FILTERING

lm(Rich ~ MeanAET + MeanAnnTemp + MeanElev

	Est	SE	t	p
(Intercept)	189.45	21.33	8.88	< 0.001
MeanAET	0.18	0.00	37.34	< 0.001
MeanAnnTemp	-4.18	0.72	-5.79	< 0.001
MeanElev	0.08	0.01	13.85	< 0.001

EIGENVECTOR FILTERING

lm(Rich ~ MeanAET + MeanAnnTemp + MeanElev + Re(spEV1) + Re(spEV2) + Re(spEV3) + Re(spEV4)

	Est	SE	t	p
(Intercept)	80.23	33.00	2.43	1.5e-02
MeanAET	0.18	0.01	31.43	< 0.001
MeanAnnTemp	0.10	1.14	0.09	9.3e-01
MeanElev	0.08	0.01	12.70	< 0.001
Re(spEV1)	-1617.63	77.64	-20.83	< 0.001
Re(spEV2)	963.97	129.21	7.46	< 0.001
Re(spEV3)	-813.56	95.87	-8.49	< 0.001
Re(spEV4)	-150.38	100.28	-1.50	1.3e-01

EIGENVECTOR FILTERING

lm(Rich ~ MeanAET + MeanAnnTemp + MeanElev + Re(spEV1) + Re(spEV2) + Re(spEV3)

	Est	SE	t	p
(Intercept)	58.39	29.62	1.97	4.9e-02
MeanAET	0.19	0.00	43.68	< 0.001
MeanAnnTemp	0.75	1.06	0.71	4.8e-01
MeanElev	0.08	0.01	13.78	< 0.001
Re(spEV1)	-1610.75	77.53	-20.78	< 0.001
Re(spEV2)	1031.60	121.11	8.52	< 0.001
Re(spEV3)	-848.19	93.07	-9.11	< 0.001

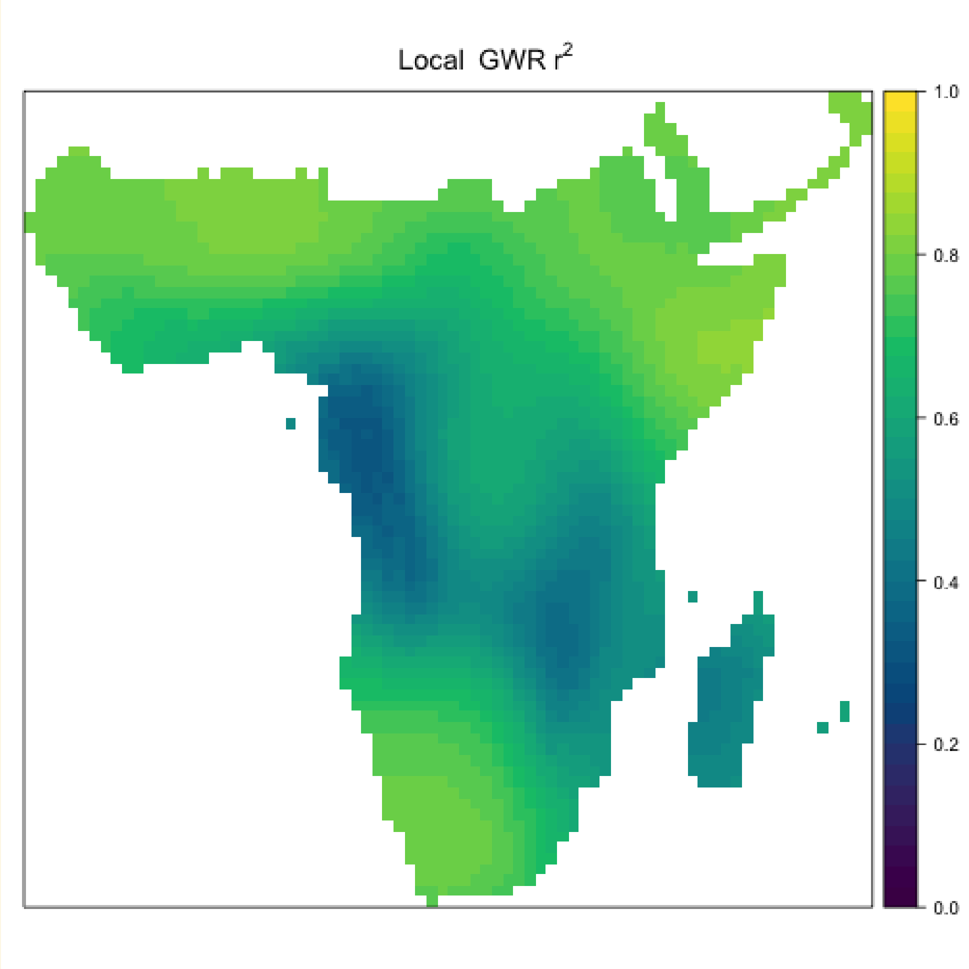
GEOGRAPHICALLY WEIGHTED REGRESSION

Fit a model for **every cell**:

- Define a local **region size** and a **weighting function**
- Fit a weighted regression for each cell using the weights
- Look at how coefficients **vary in space**
- Possibly serious statistical issues!

GEOGRAPHICALLY WEIGHTED REGRESSION

GEOGRAPHICALLY WEIGHTED REGRESSION



PROBLEMS

- Profusion of packages: sf, sp, spdep, mgcv, ncf, gstat, nlme, spgwr
- Different data structures
- Sometimes poor documentation
- Speed of calculation (= size of dataset)
- Memory hungry
- Too many options