Malaria in Sierra Leone: A spatial-analysis on malaria mortality

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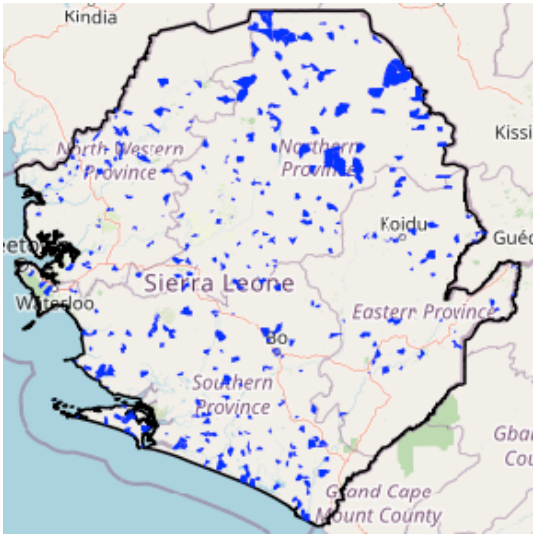
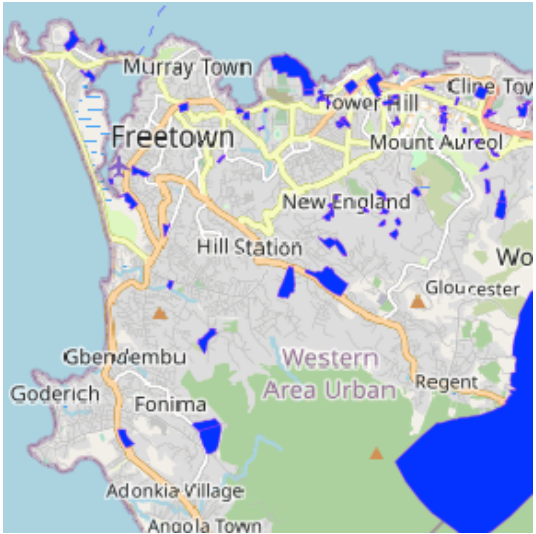
COMSA sampling units



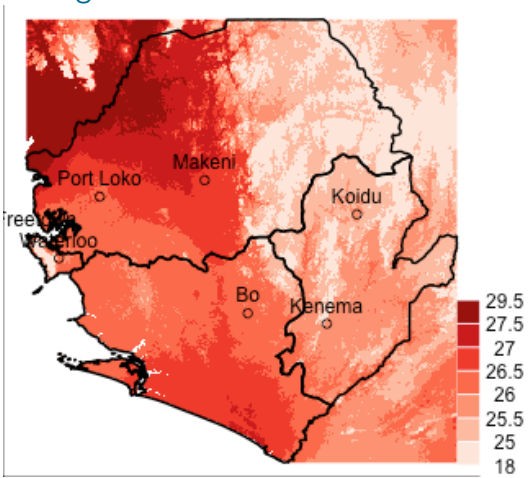


The Problem

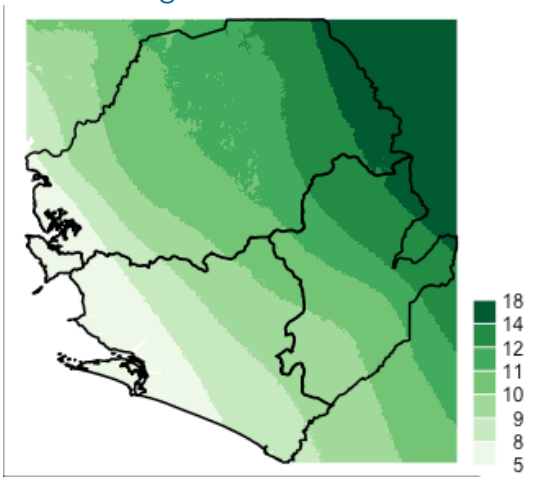
- we know malaria deaths in the sampling units
- can we infer risk at locations that aren't part of the sample?
- ... and quantify the effect of environmental risk factors?
- *Spatial Dependence* sampling units close together should be more similar than units far apart
- use nearby units to infer risk at unmeasured locations

Temperature

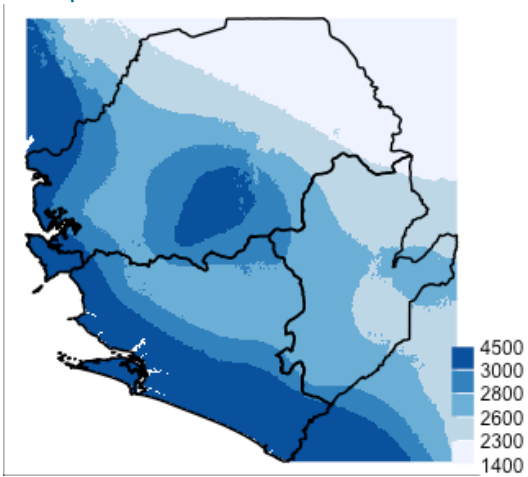
Average



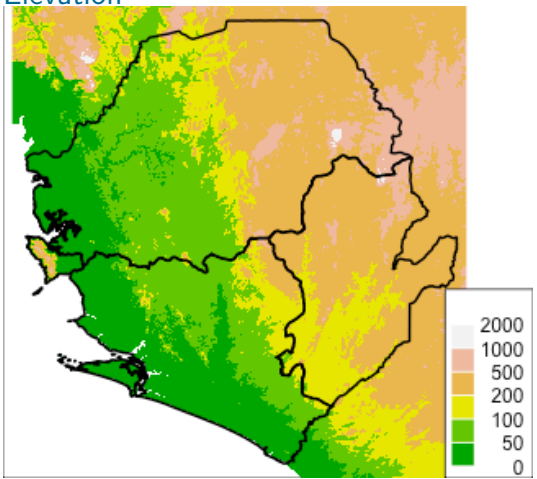
Diurnal Range



Precipitation



Elevation



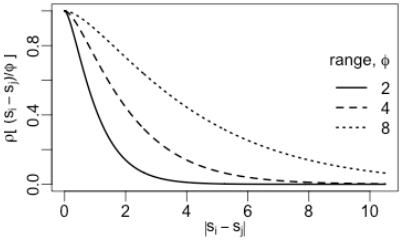
Generalized Linear Geostatistical Model

$$
\begin{aligned}
Y_{ij} &\sim \text{Poisson}(\theta_j \lambda_i P_{ij}) \\
\log(\lambda_i) &= X(s_i)\beta + U(s_i) + Z_i \\
U(\cdot) &\sim \text{Gaussian Random Field}(\phi, \sigma^2) \\
Z_i &\sim \text{N}(0, \tau^2)
\end{aligned}
$$

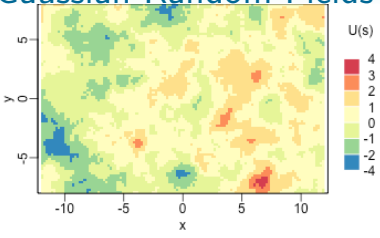
risk = age-sex + risk factors + other stuff

- sampling unit i, age-sex group j
- θ_j mortality rate
- λ_i relative risk
- P_{ij} population
- s_i location of unit i
- $X(s)$, β risk factors, effect sizes
- $U(s)$ *residual spatial variation*
  - stuff not explained by $X(s)$
- Z_i non-spatial variation
  - village-level risk factors

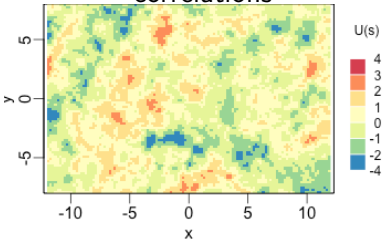
Gaussian Random Fields



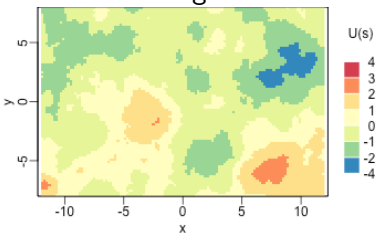
correlations



range.4



range.2



range.8

- $U(s)$: value of the GRF at location s
- Correlation is a function of distance

$$\text{cor}[U(s+h), U(s)] = \sigma^2 \rho(h/\phi)$$

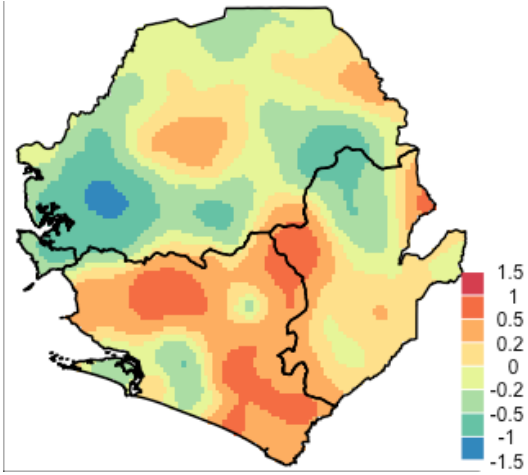
- A range parameter ϕ controls how quickly correlation falls
- big range $\Rightarrow$ slow decay $\Rightarrow$ smooth surface

Fitting the model

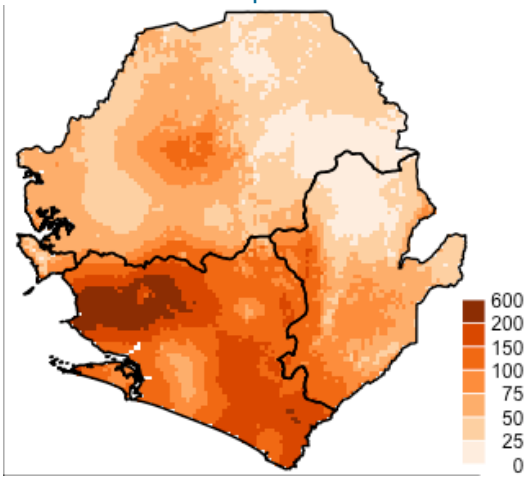
- Bayesian inference
- exponential prior distributions on σ, τ, $1/\phi$
- Sparse approximation to spatial variance matrix
- `geostatsp` package in `R`

Results

Residual variation

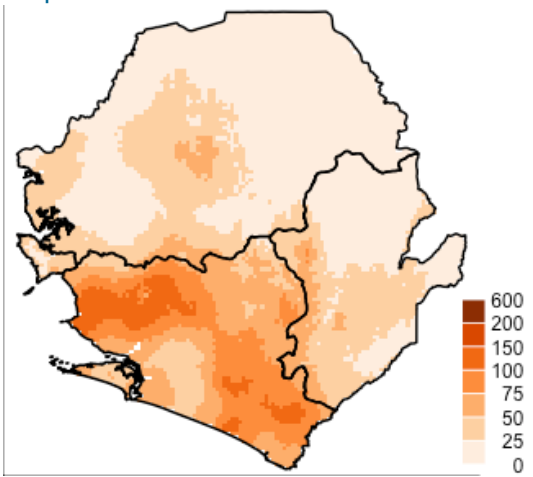


Standardized Rate per 100k

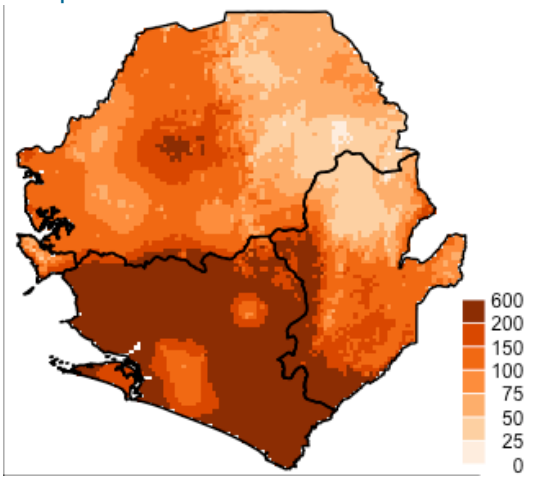


Standardized rate

2.5pct



97.5pct



Parameters

	0.5quant	0.025quant	0.975quant
urban	-0.27	-0.51	-0.03
temperature	-0.55	-1.08	0.01
diurnalRange	0.07	-0.16	0.29
elevation, 100m	-0.59	-0.99	-0.17
rain	0.09	-0.55	0.70
range	64km	38km	115km
sd	0.57	0.43	0.80
sd areaid	0.53	0.44	0.64

Conclusions

- More malaria mortality in the south
- Considerable residual spatial variation
  - Unobserved covariates
  - Mosquito species
- Elevation, urban important. temperature?
  - spatial models + causality = grain of salt
- Add other risk factors?
  - socio-economic? vegetation?
- Take your malaria pills!

References I