A flexible and efficient modeling strategy for trend analysis of North American Christmas Bird Counts

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Audubon

1900 Christmas Bird Count

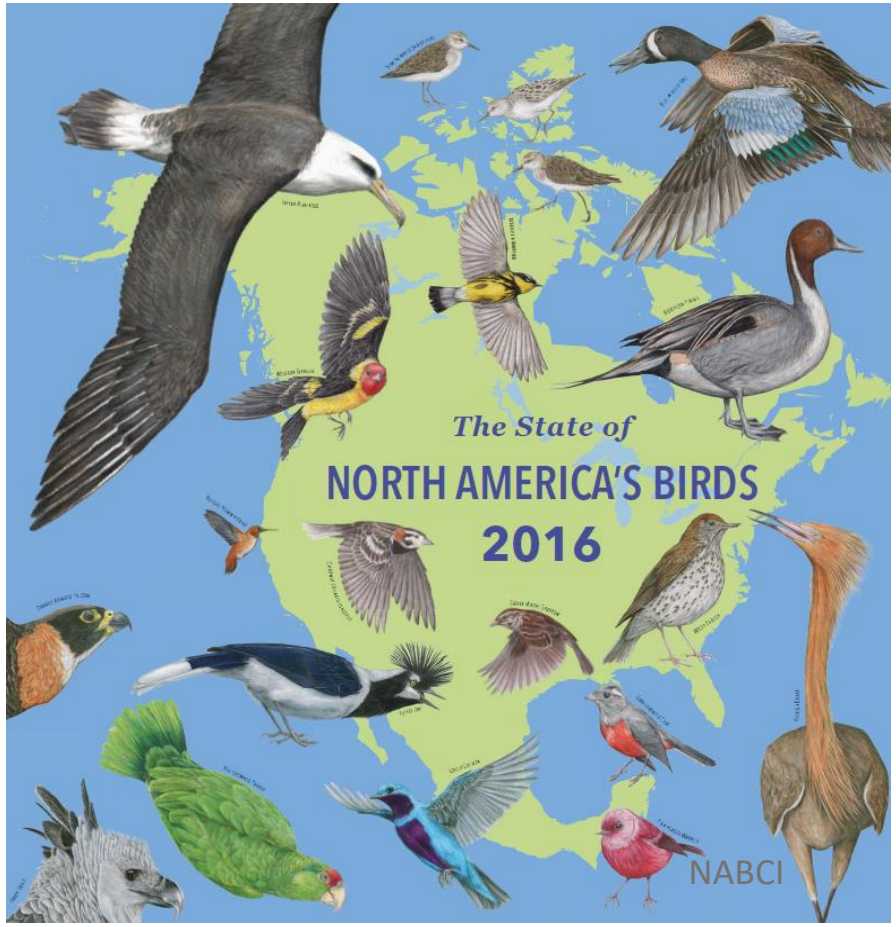
- 27 volunteers
- 25 count circles
- 18,500 birds counted
- 89 species recorded
- 2 Countries

2017 Christmas Bird Count

- 73,153 volunteers
- 2,536 count circles
- 56,139,812 birds counted
- 2,636 species recorded
- Across North and South America, Caribbean, Pacific Islands

CBC Trends and Conservation

- Count trends
- 1966-2017
- 550 species
- Partners in Flight
- North American Bird Conservation Initiative



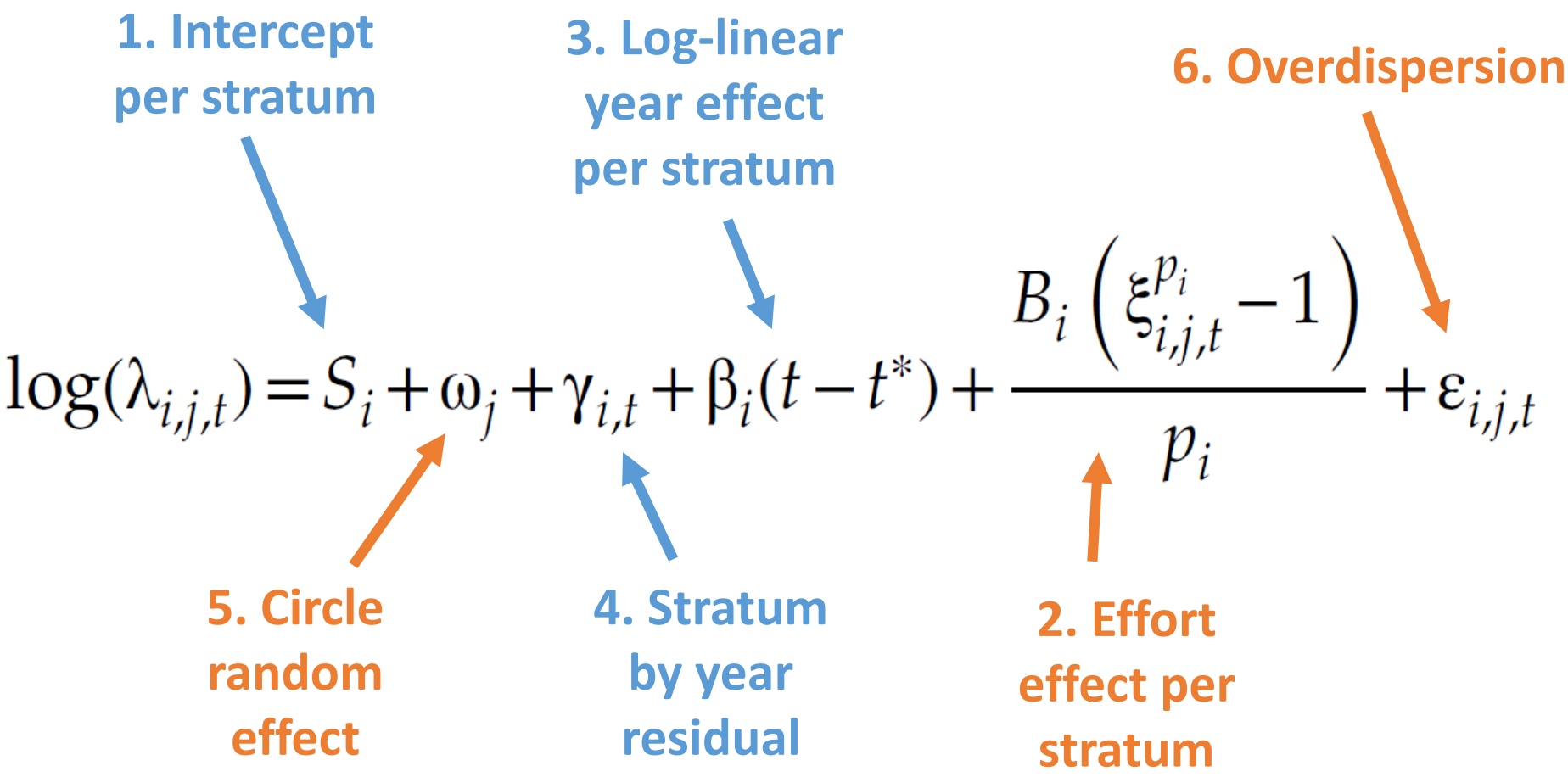
Standard Approach: Independent Strata

States and Provinces

Bird Conservation Regions

Analytical Strata and CBC Circles

Standard Approach: Stratum Index Model



Soykan et al. 2016

Standard Approach: Stratum Index

$$N_{i,t} = A_i z_i \exp(S_i + \beta_i (t - t^*) + \gamma_{i,t})$$

3. Stratum by year residual

4. Area and occurrence scaling

1. Intercept per stratum

2. Log-linear year effect per stratum

Soykan et al. 2016

Standard Approach: Stratum Index Trend

$$T_i = \left\{ \frac{N_{i,t_b}}{N_{i,t_a}} \right\}^{1/(t_b - t_a)}$$

Soykan et al. 2016

Different Approach: SVC Trend Model

1. Fine resolution
2. ICAR random intercepts
3. ICAR random slope for effort (SVC)
4. ICAR random slope for year (SVC)
5. Annual indices not a focus
6. R-INLA implementation

SVC strata

Different Approach: SVC Trend Model

$$\log(\mu_{i,t}) = \alpha_i + \epsilon_i \log(E_{i,k,t}) + \tau_i T_{i,k,t} + \kappa_k$$

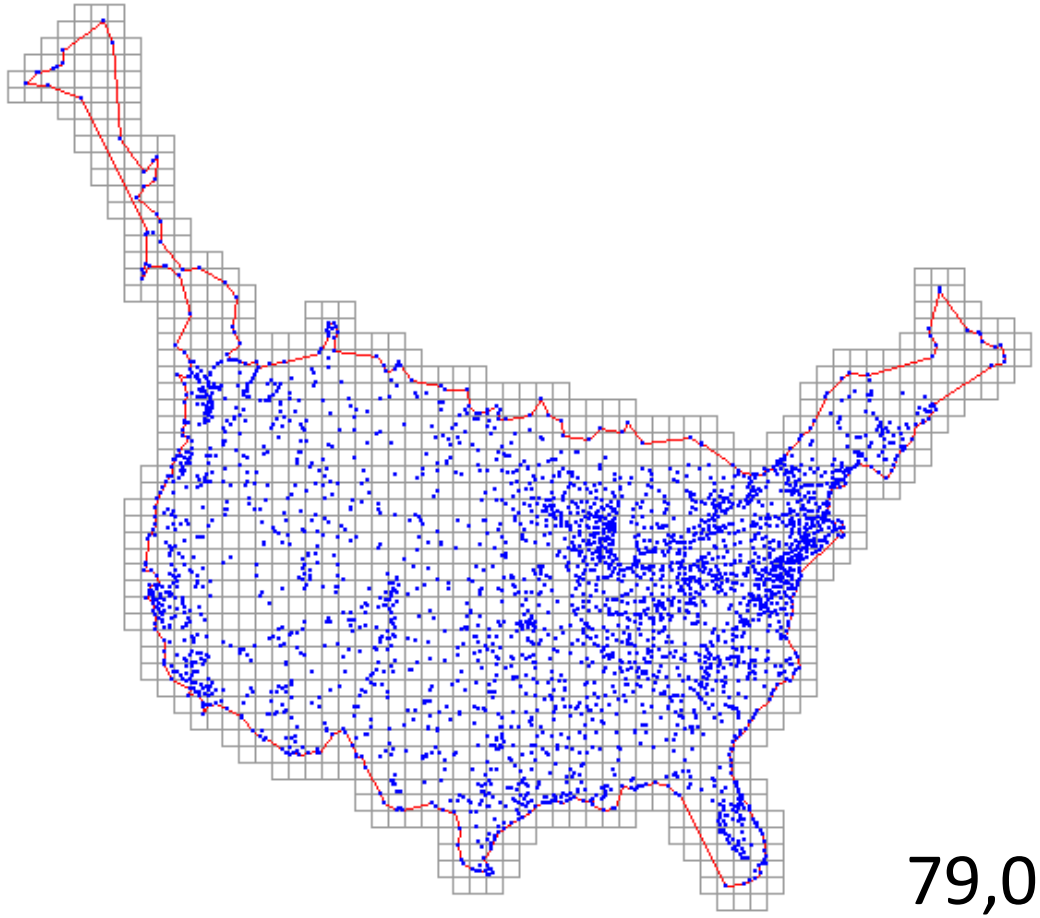
1. Global and CAR-random abundance index for reference year

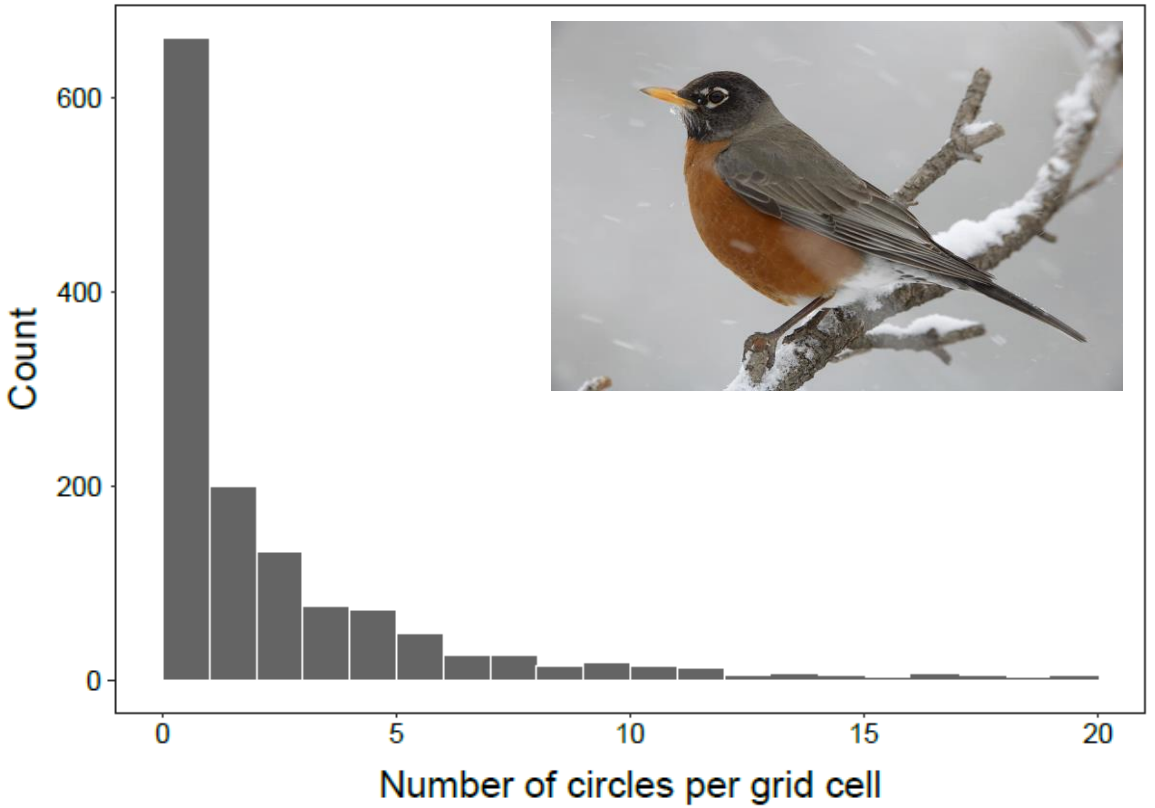
2. Global and CAR-random effort slope (SVC)

3. Global and CAR-random year slope (SVC)

4. Exchangeable random circle effect

Example: American Robin





79,038 records 3195 locations 52 years

Example: Computing with R-INLA

Model statement

```
formula <- count ~ 1 + f(grid_id1, model="besag", graph=g) + log_hrs +
  f(grid_id2, log_hrs, model="besag", graph=g) + std_yr + f(grid_id3, std_yr,
    model="besag", graph=g) + f(circle, model="iid")
```

Function call

```
result <- inla(formula, family="nbinomial", data=modeling_data,
  control.compute=list(cpo=T, config=T))
```

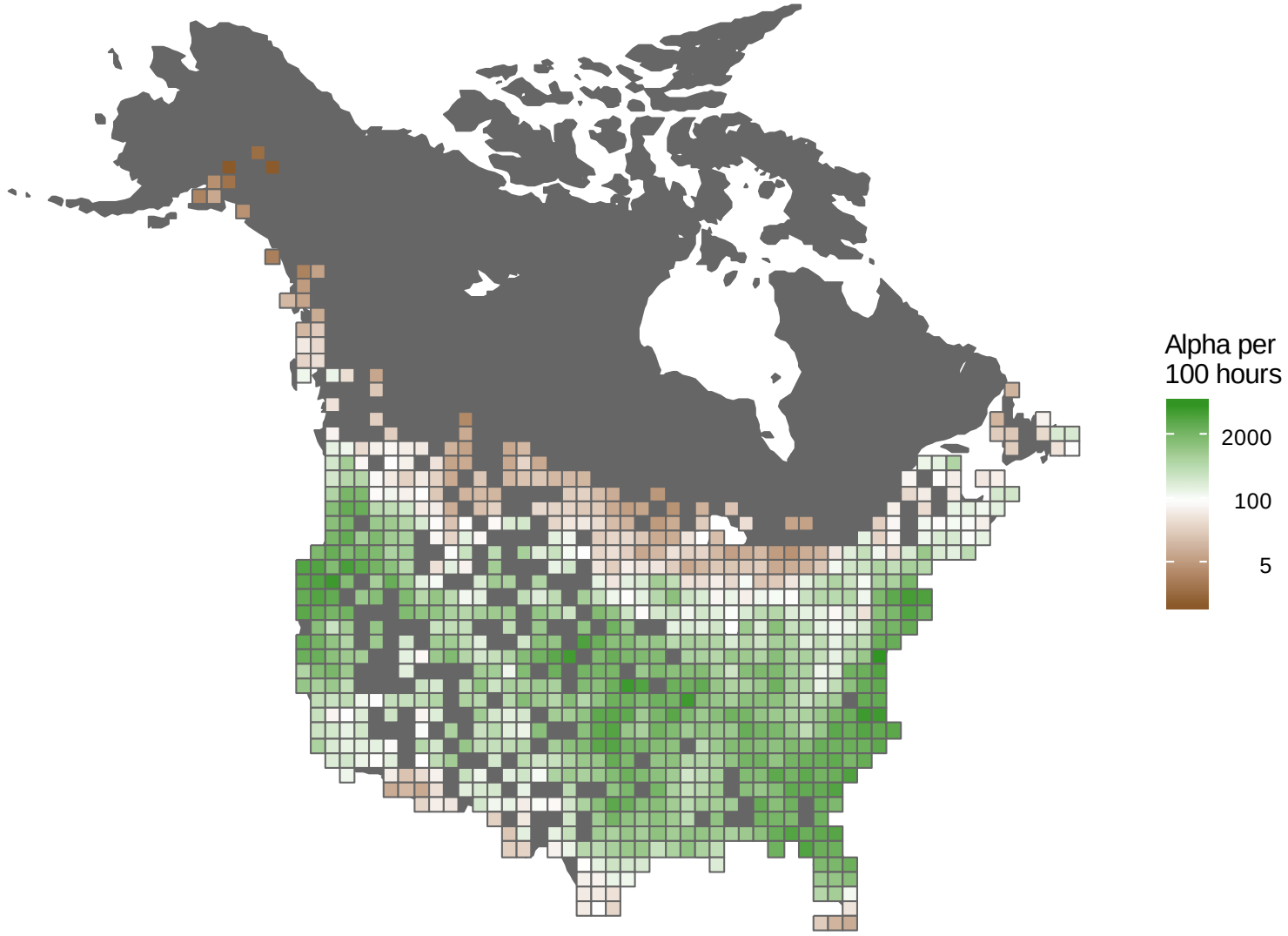
Example: Computing with R-INLA

Time used: 4.70 hr

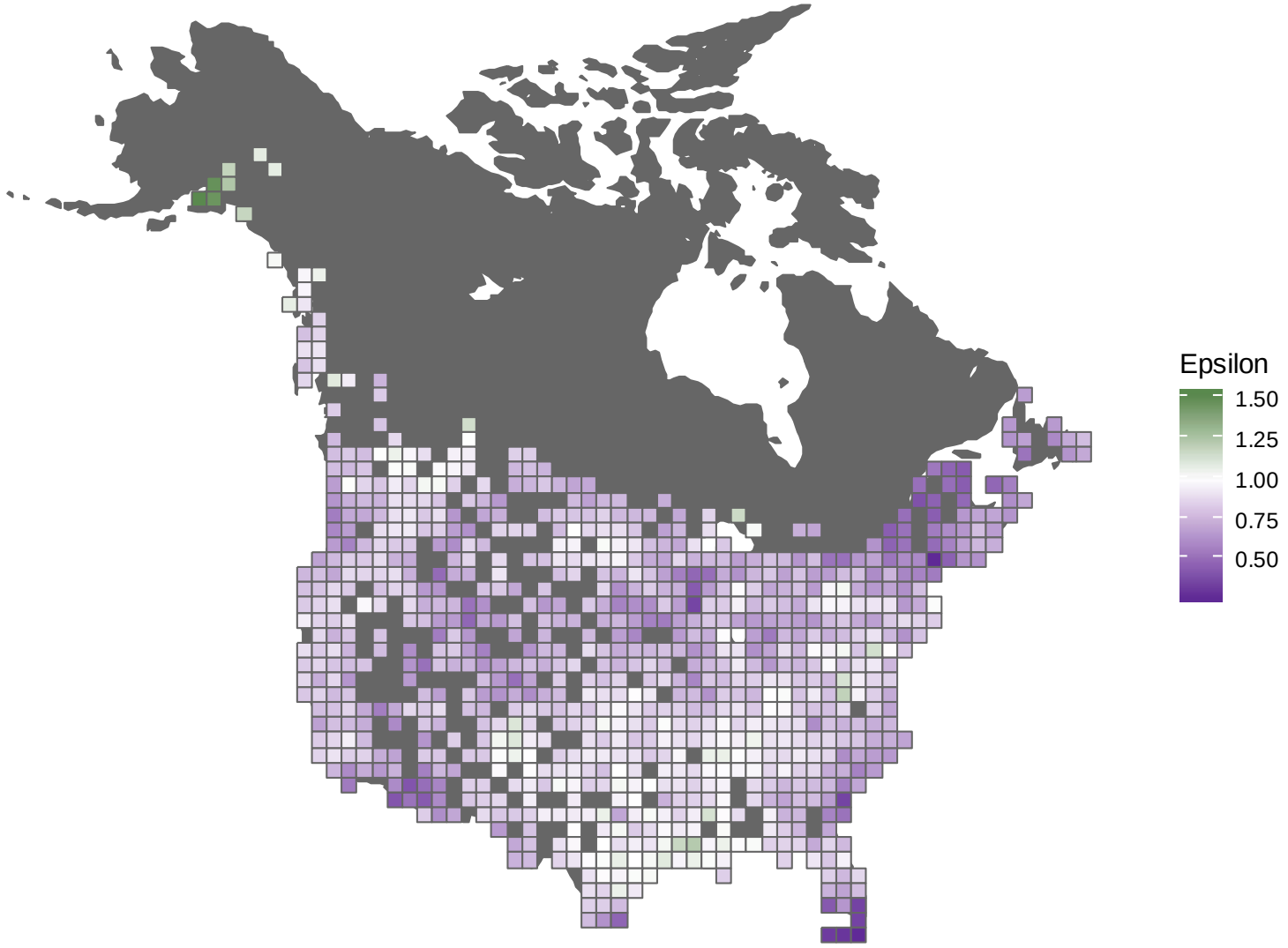
Fixed effect:	**0.025quant**	**0.5quant**	**0.975quant**
Global intercept	0.602	0.772	0.941
Global log_hrs effect	0.774	**0.815**	0.857
Global std_yr effect	0.022	**0.025**	0.027

Hyperparameter:	**0.025quant**	**0.5quant**	**0.975quant**
1/Overdispersion	0.444	**0.449**	0.453
Precision alpha CAR	0.673	**0.688**	0.703
Precision epsilon CAR	33.055	**33.691**	34.340
Precision tau CAR	678.391	**707.756**	738.433
Precision kappa iid	0.927	**0.969**	1.012

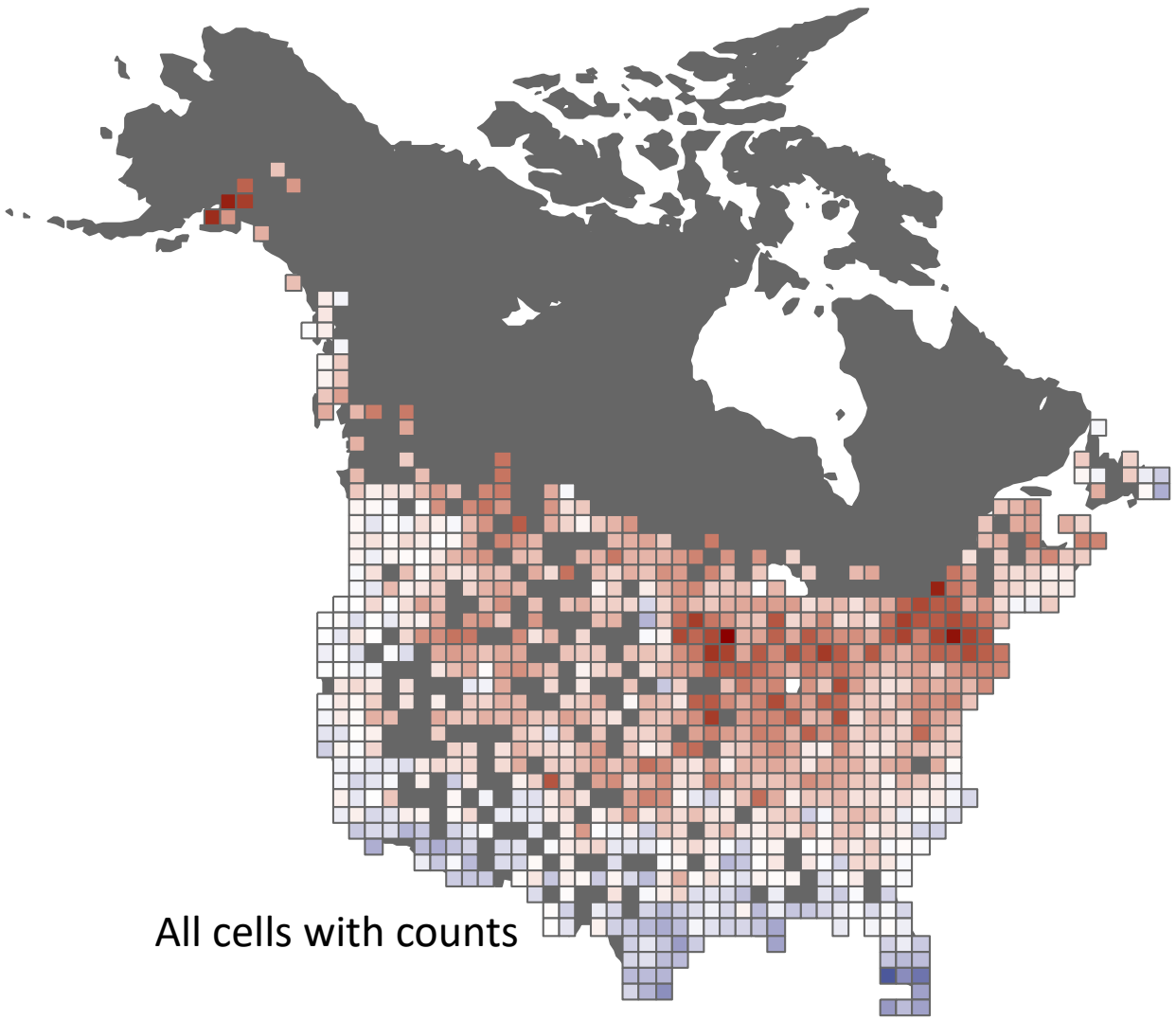
Alpha: 2017 Abundance Indices



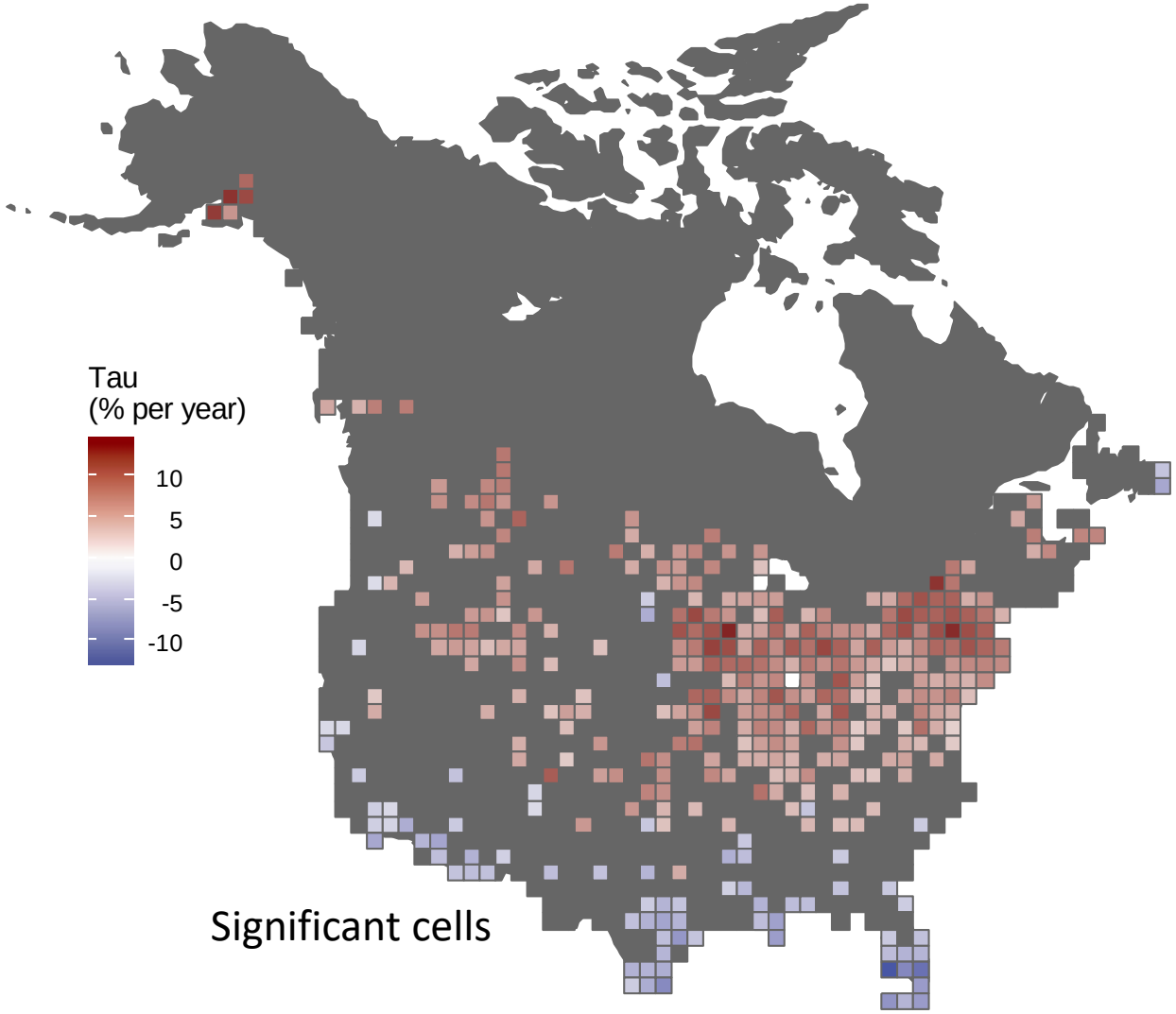
Epsilon: Effort Effects



Tau: Year Effects

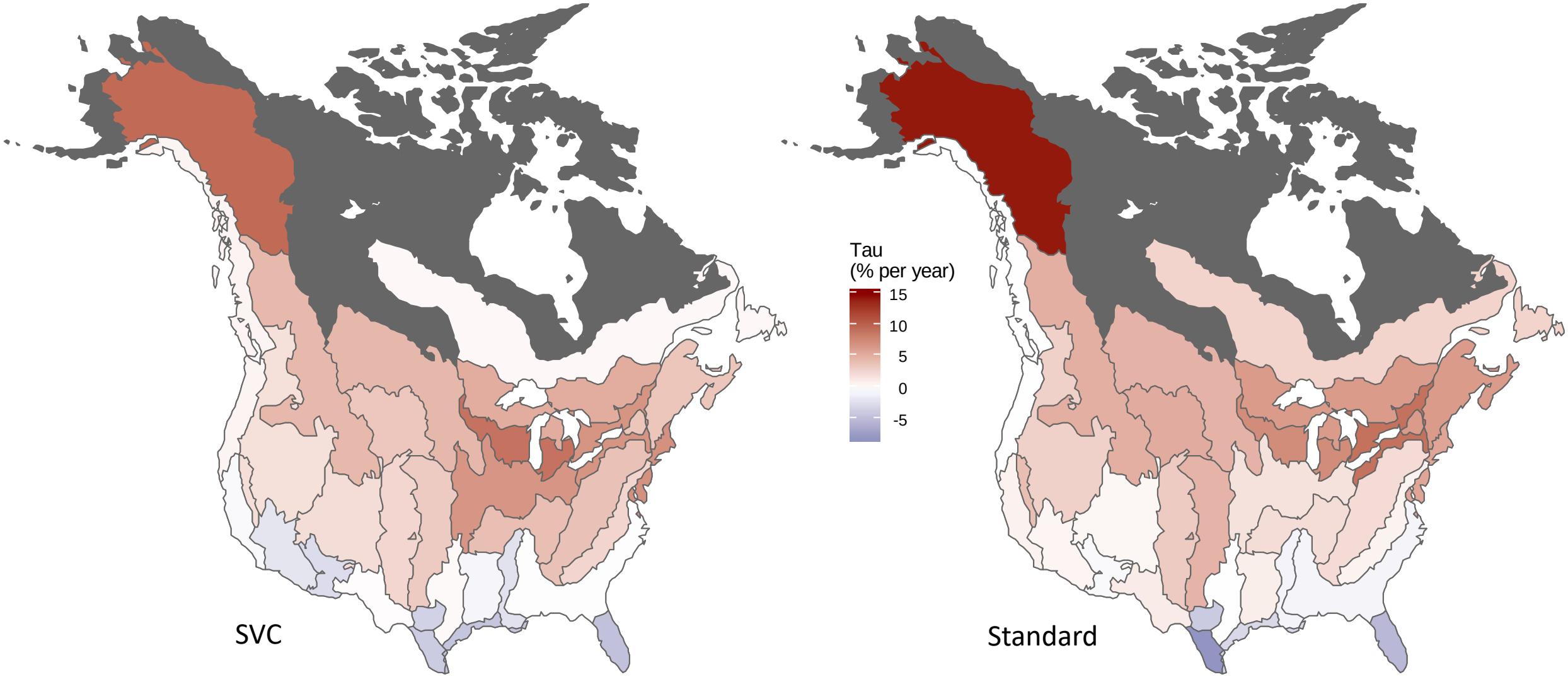


All cells with counts

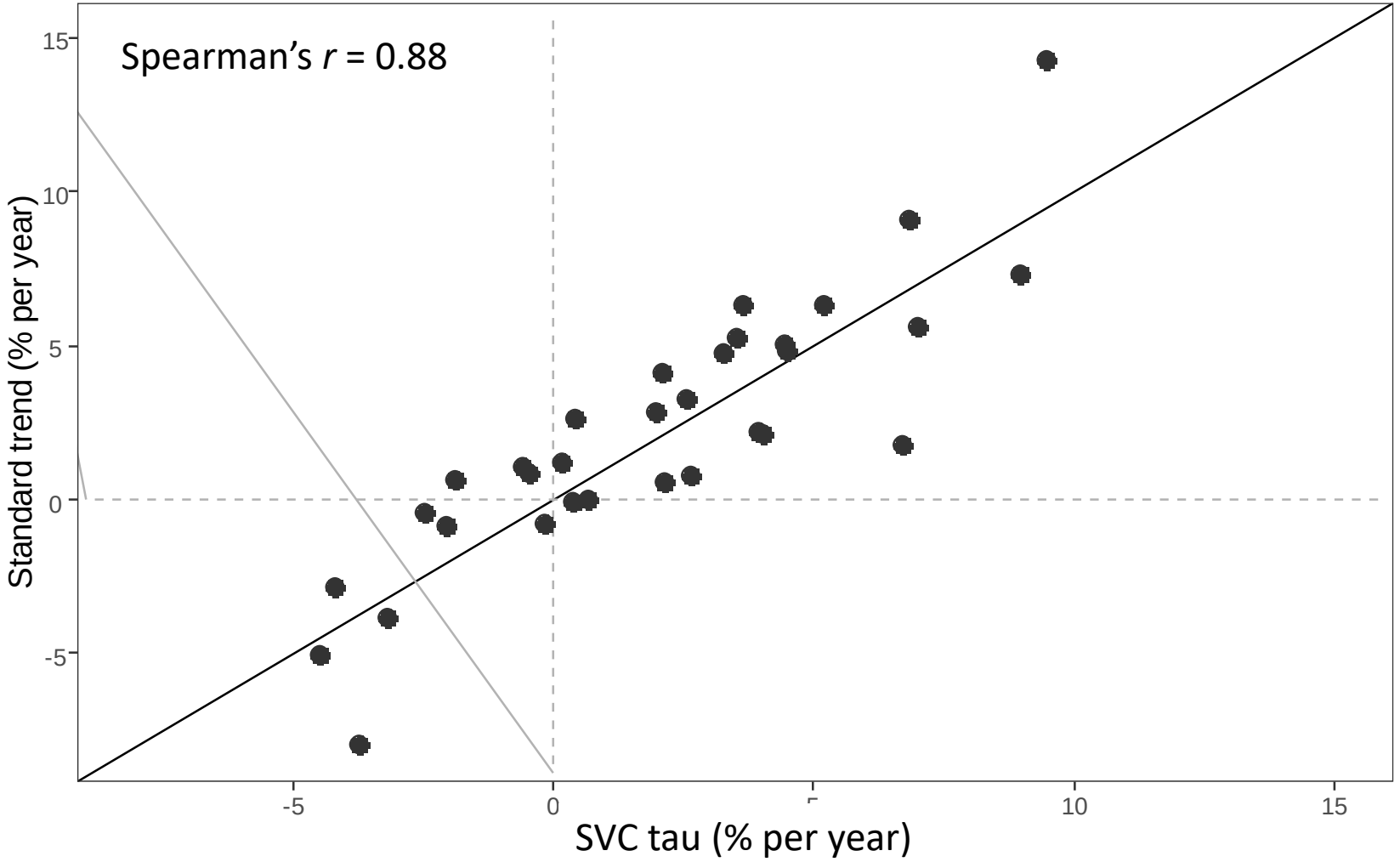


Significant cells

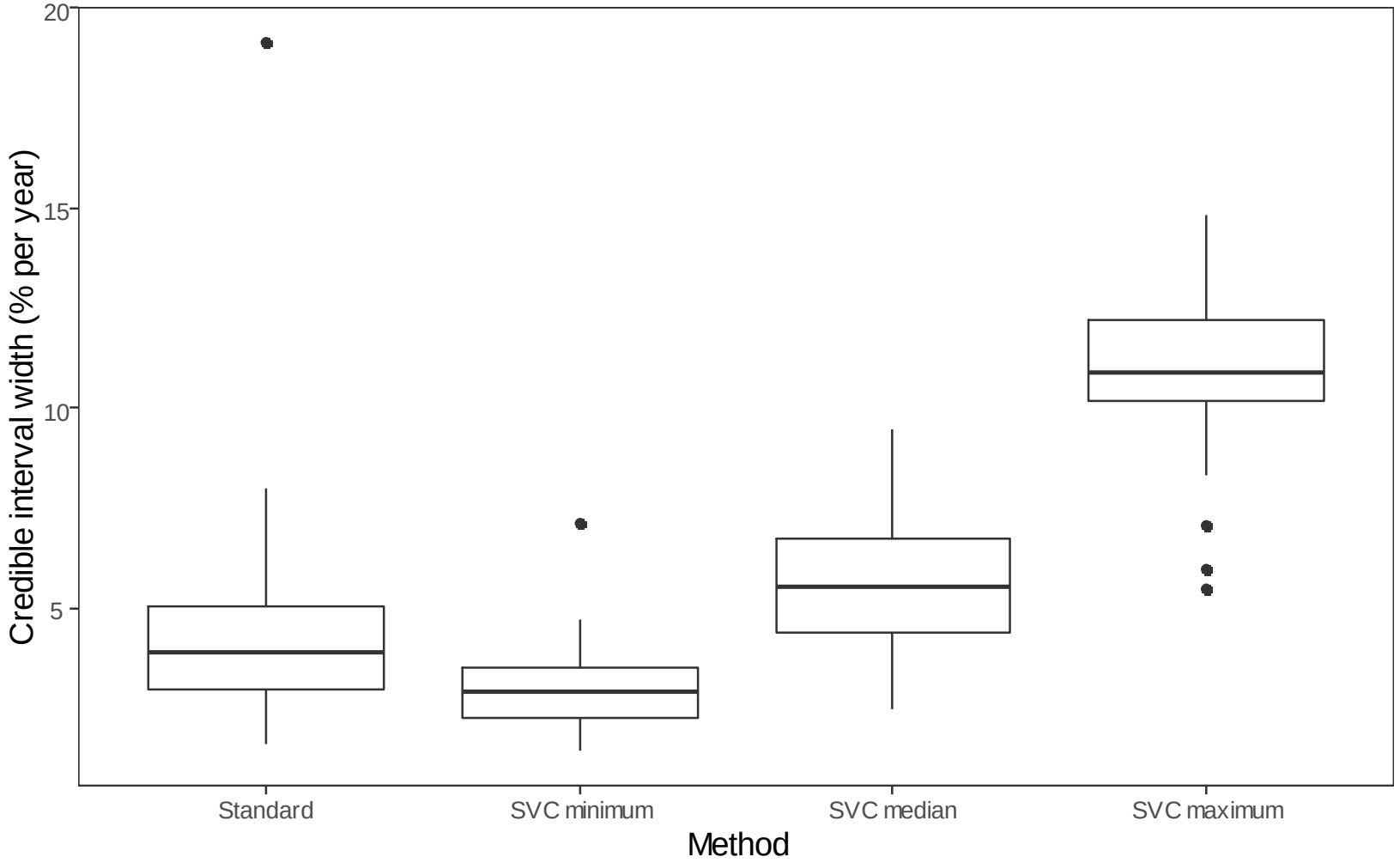
Aggregation: BCR Trend Estimates Compared



Aggregation: BCR Trend Estimates Compared



Aggregation: BCR Trend Precision Compared



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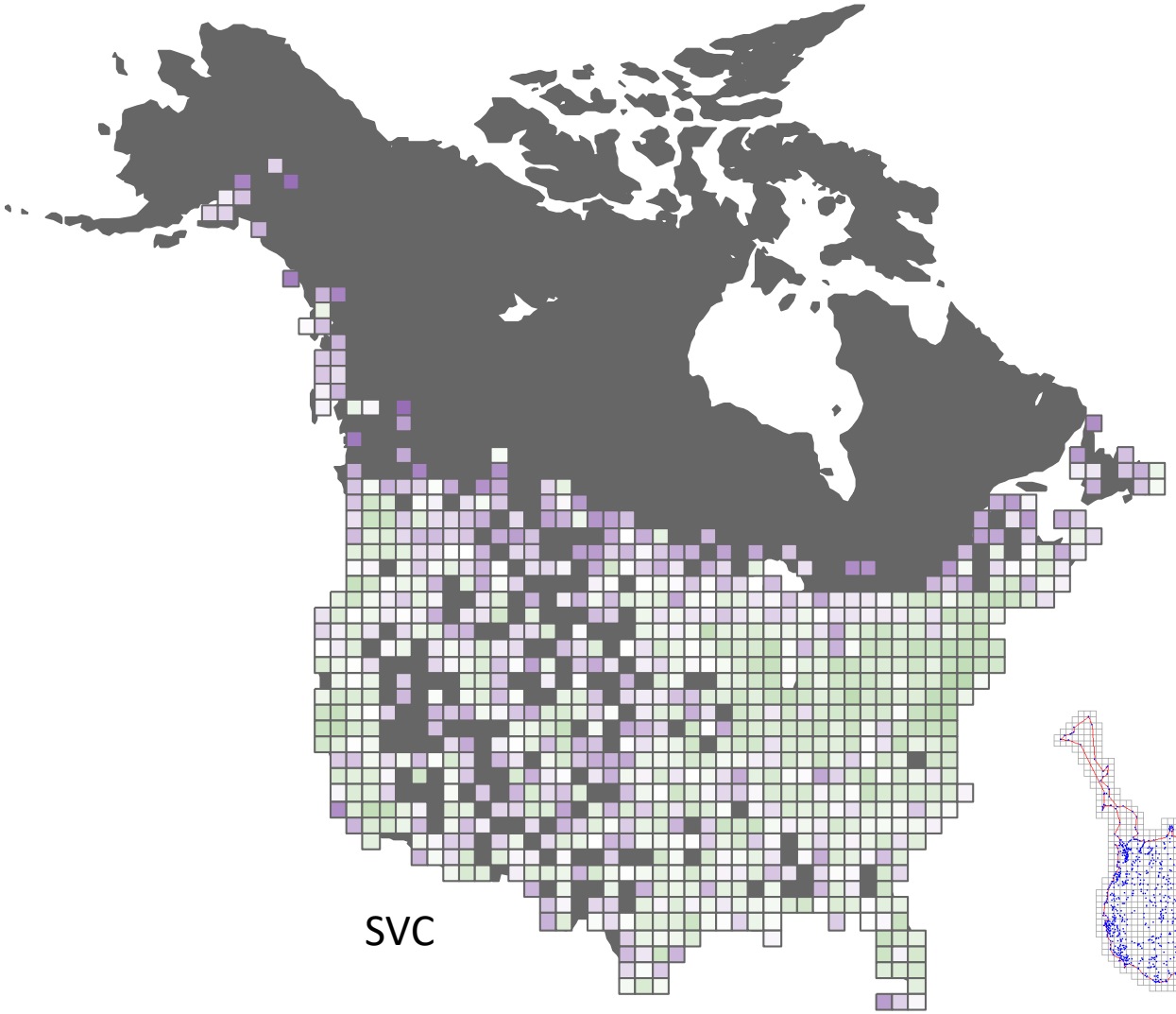

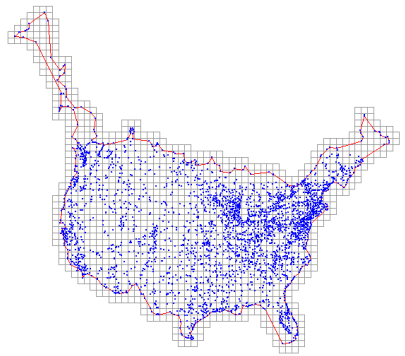

SVC interval width (% per year)

20
15
10
5

Take Aways: SVC Trend Model with R-INLA

1. Fine resolution results are possible when modeling spatial structure.
2. With spatially-structured random slopes (SVC), trends are part of model and they vary spatially.
3. Spatially-explicit estimates of trend uncertainty become possible.
4. Aggregate trends (BCR) are similar in magnitude and precision.
5. Cell by year term is possible for creating annual indices.
6. With R-INLA, code is clean and analysis is fast.