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

L. Miller

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1900 Christmas Bird Count

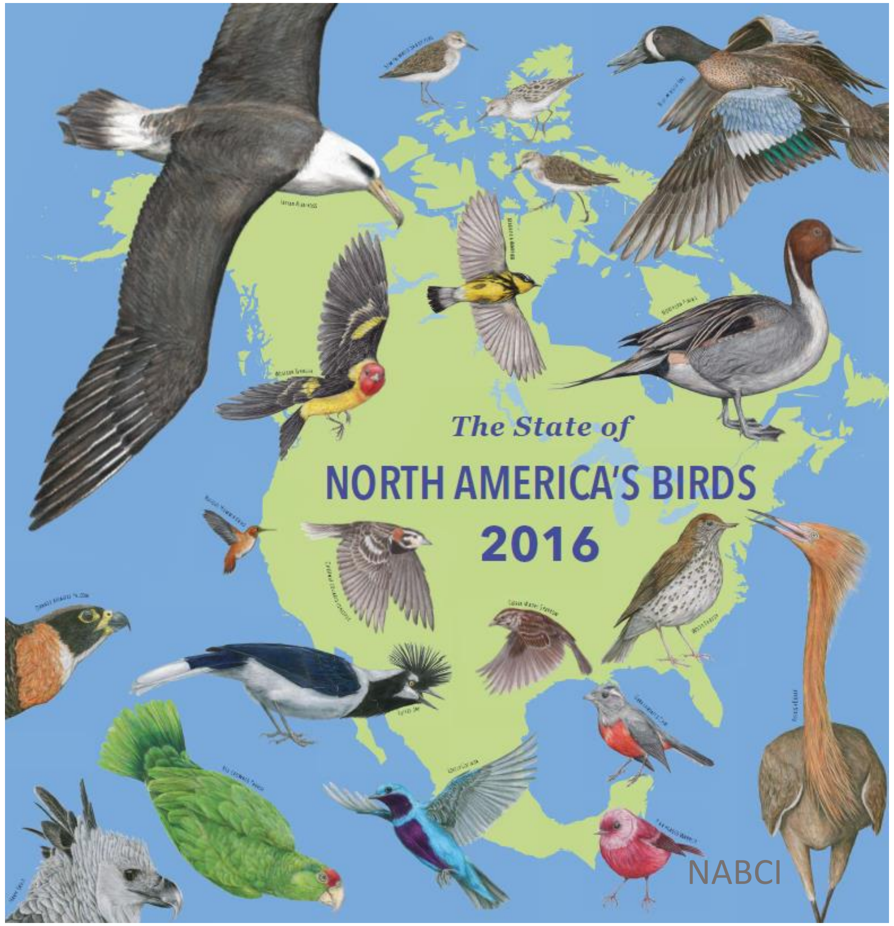
- 27 volunteers
- 25 count circles
- 18,500 birds counted
- 89 species recorded
- 2 Countries

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: Model Counts

1. Intercept per stratum

3. Log-linear year effect per stratum

6. Overdispersion

$$\log(\lambda_{i,j,t}) = S_i + \omega_j + \gamma_{i,t} + \beta_i(t - t^*) + \frac{B_i\left(\xi_{i,j,t}^{p_i} - 1\right)}{p_i} + \varepsilon_{i,j,t}$$

5. Circle random effect

4. Stratum by year residual

2. Effect effect per stratum

Soykan et al. 2016

Standard Approach: Abundance Index

Stratum by year residual

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

Area and occurrence scaling

Intercept per stratum

Linear year effect per stratum

Soykan et al. 2016

Standard Approach: Abundance 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: Emphasize Fine-Scaled Trends

Different Approach: Emphasize Fine-Scaled Trends

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

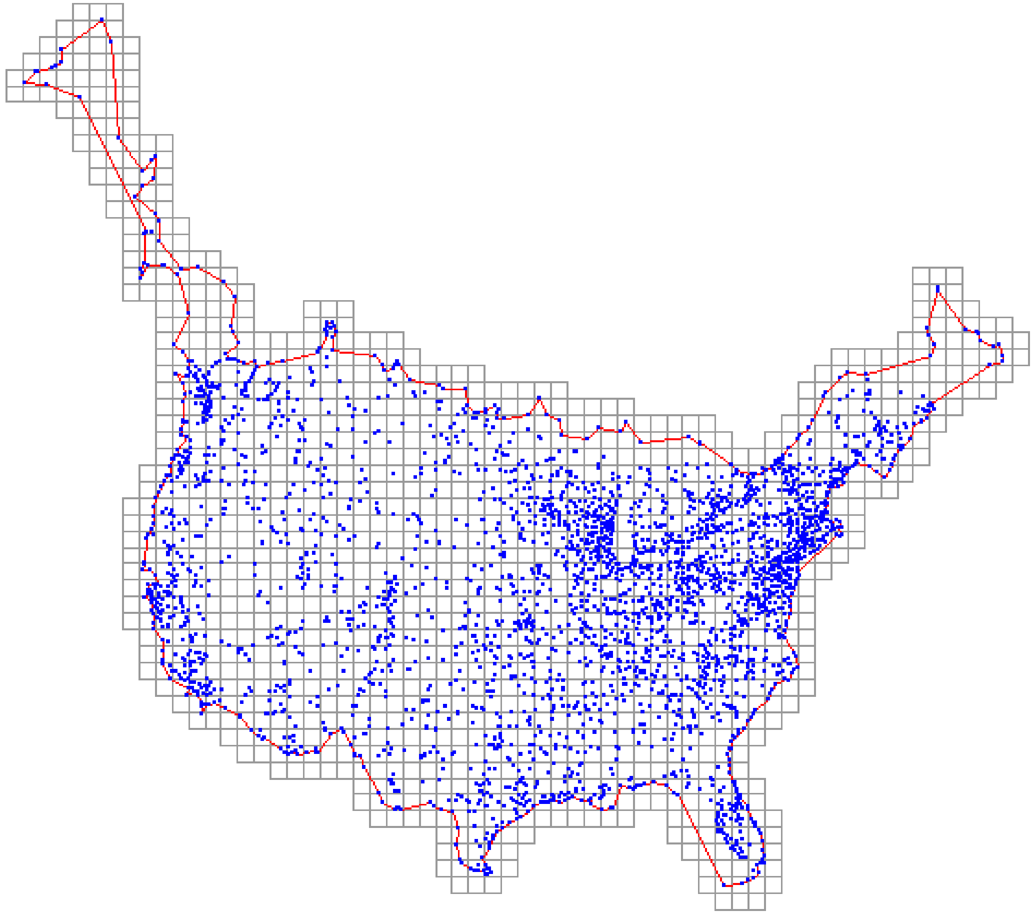
1. Global and CAR-random abundance index for reference year

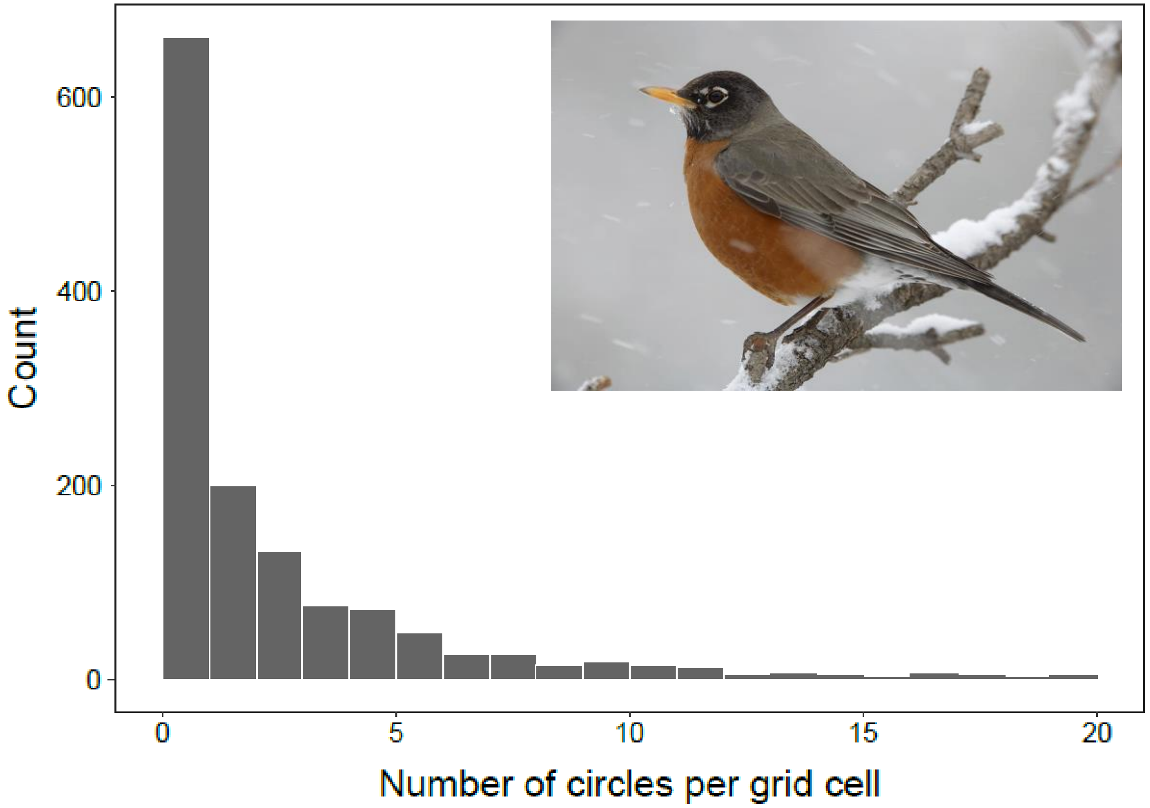
2. Global and CAR-random effort slope (SVC)

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

4. Exchangeable random circle effect

Example: American Robin





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, waic=T, config=T),
  control.inla=list(int.strategy='eb'))
```

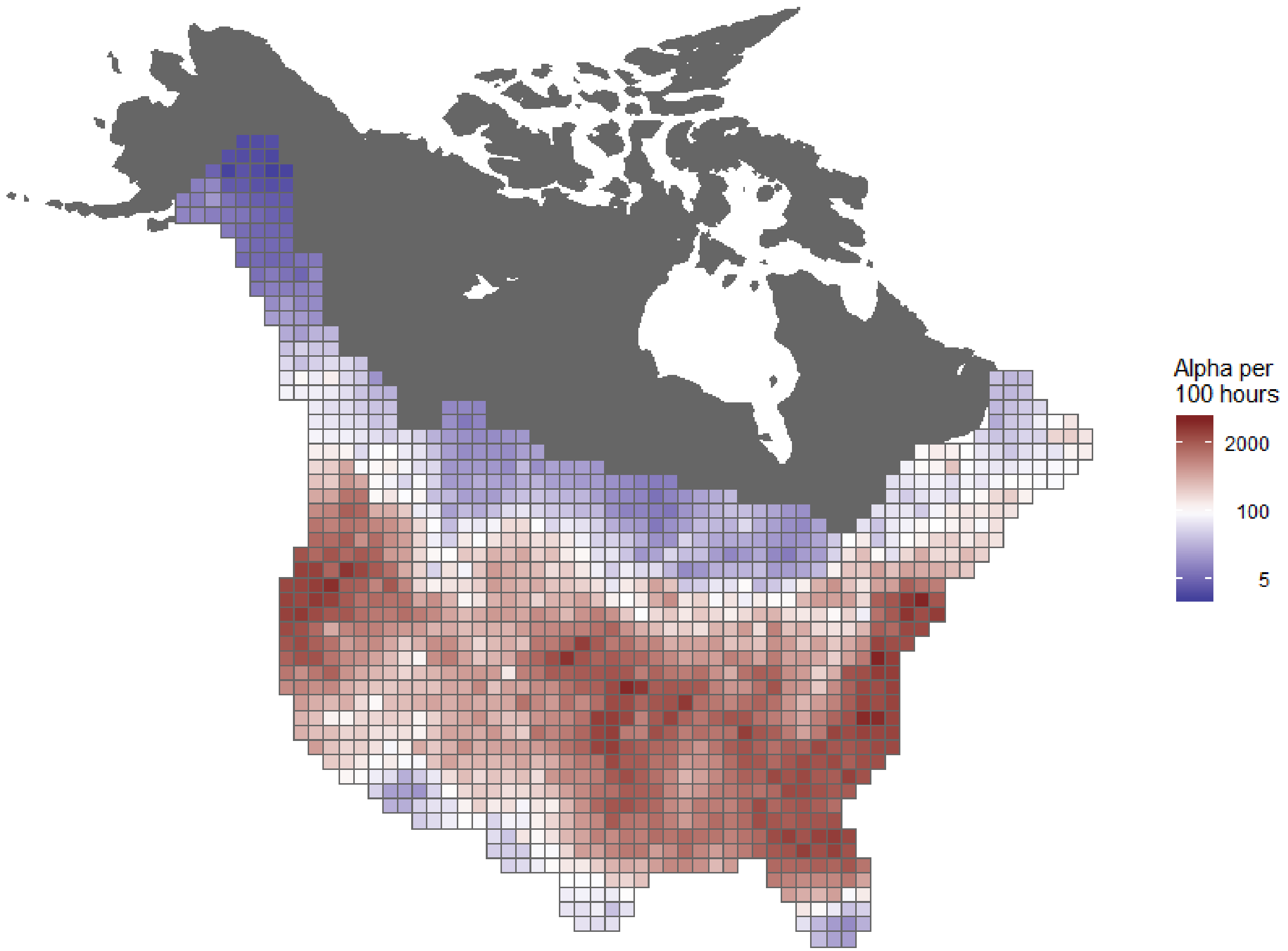
Example: Computing with R-INLA

Time used: 61.68 min

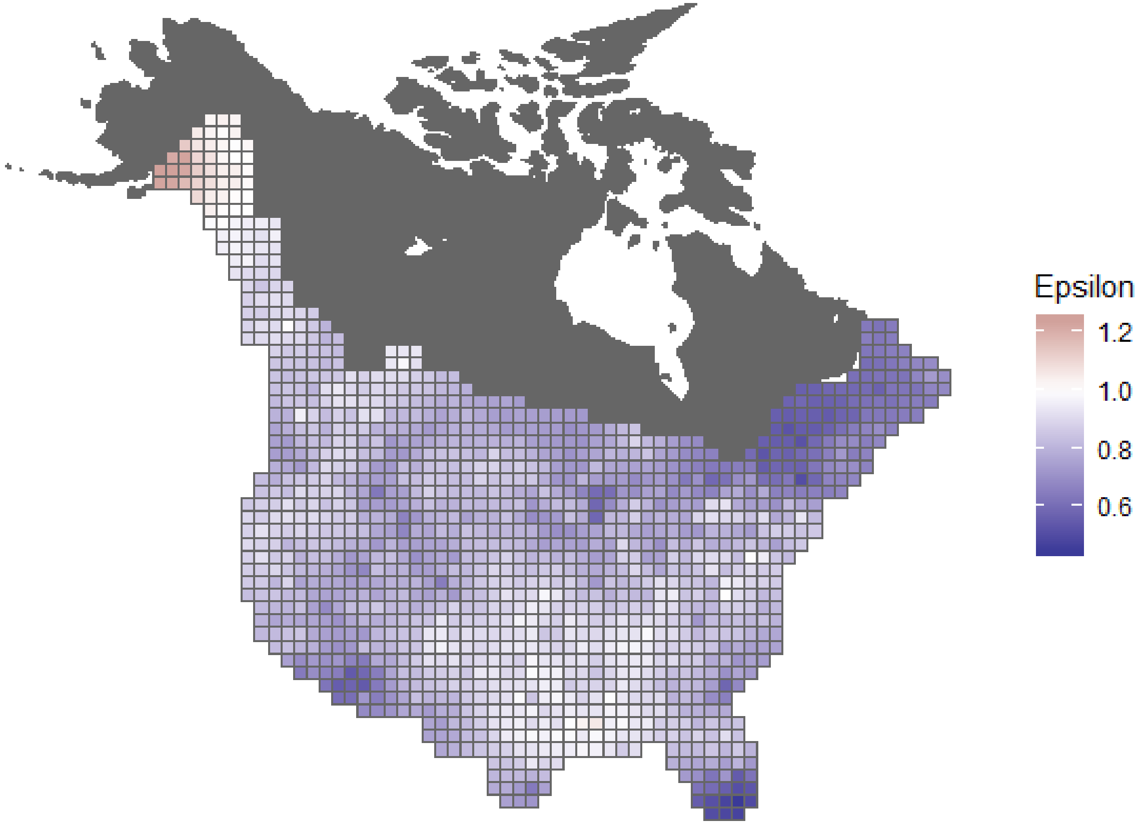
Fixed effect:	**0.025quant**	**0.5quant**	**0.975quant**
Global intercept	0.602	0.772	0.941
Global log_hrs effect	0.774	0.815	0.857
Global std_yr effect	0.022	0.025	0.027

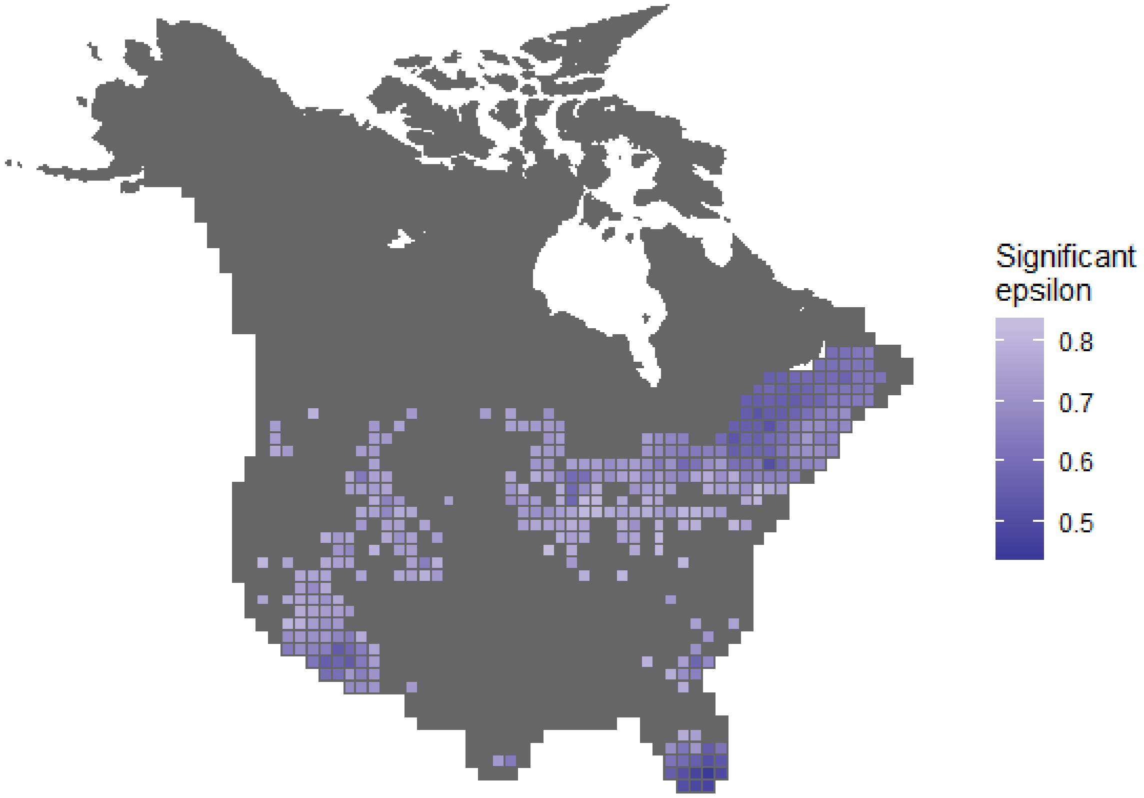
Hyperparameter:	**0.025quant**	**0.5quant**	**0.975quant**
1/Overdispersion	0.444	0.449	0.453
Precision alpha CAR	0.673	0.688	0.703
Precision epsilon CAR	33.055	33.691	34.340
Precision tau CAR	678.391	707.756	738.433
Precision kappa iid	0.927	0.969	1.012

Alpha: 2017 Abundance Indices

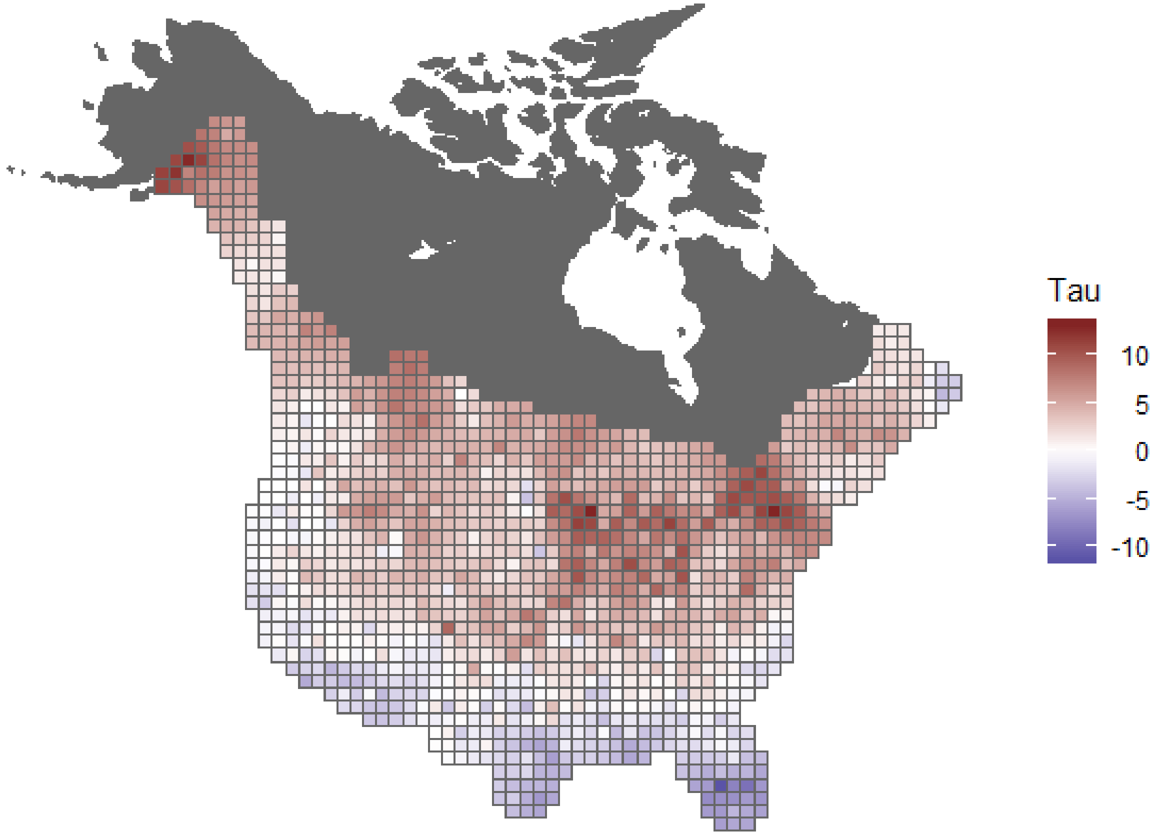


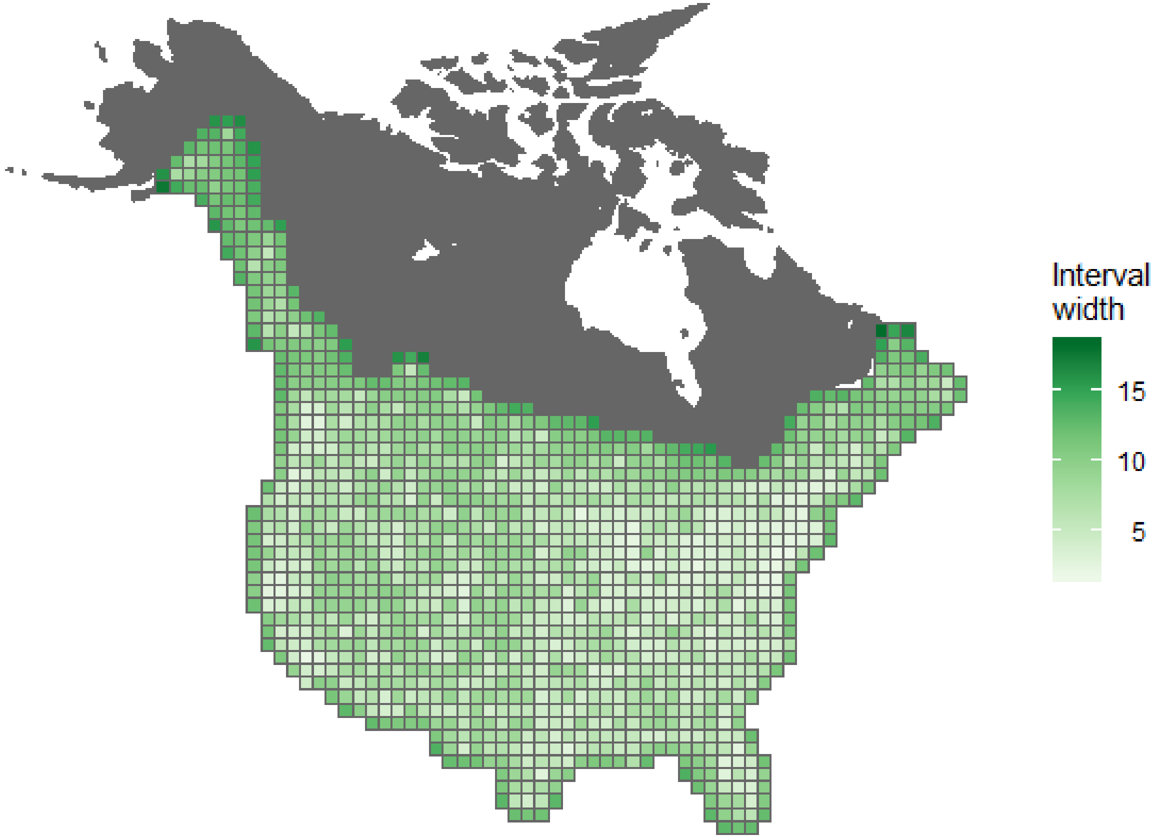
Epsilon: Effort Effects



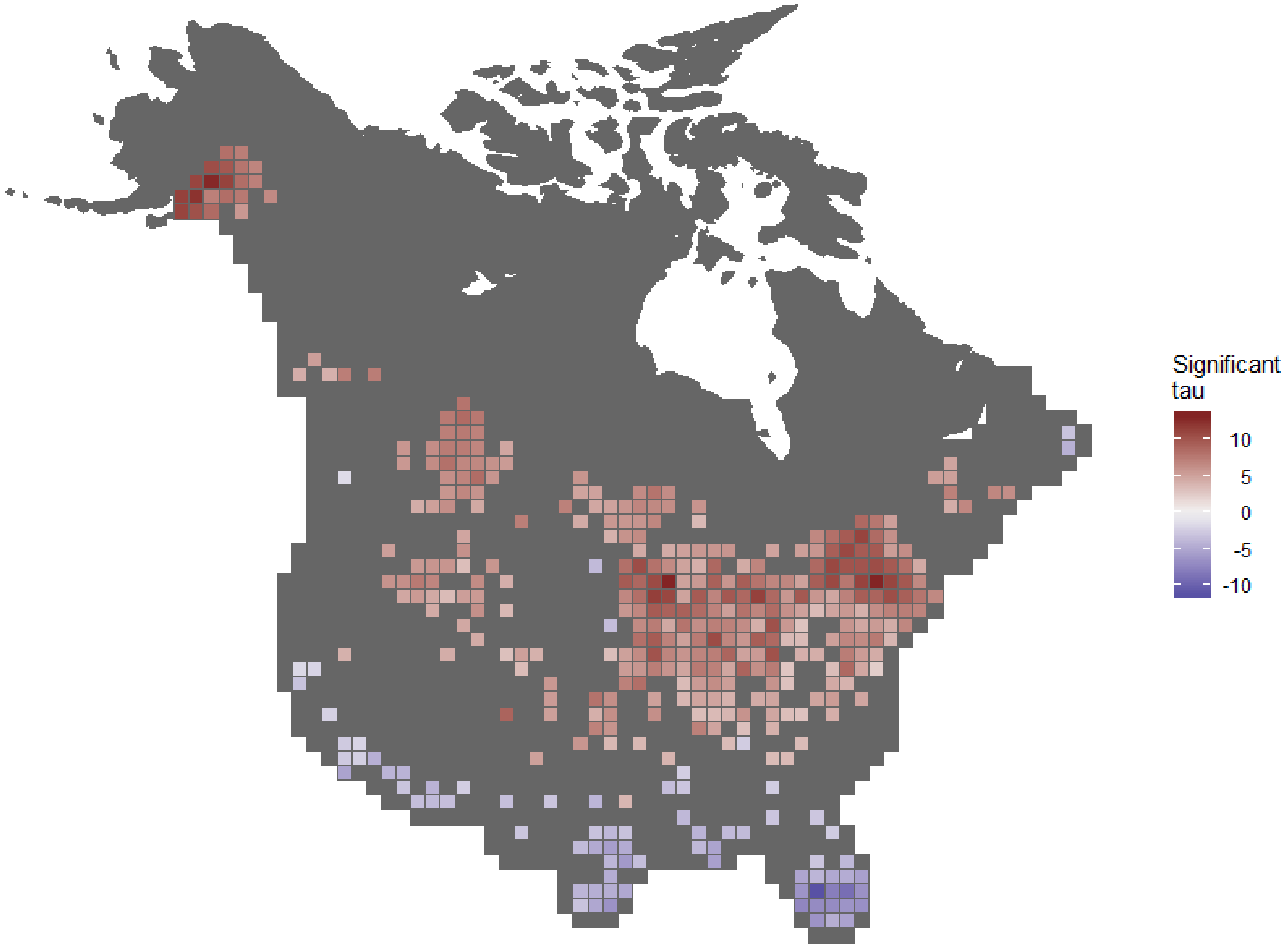


Tau: Year Effects

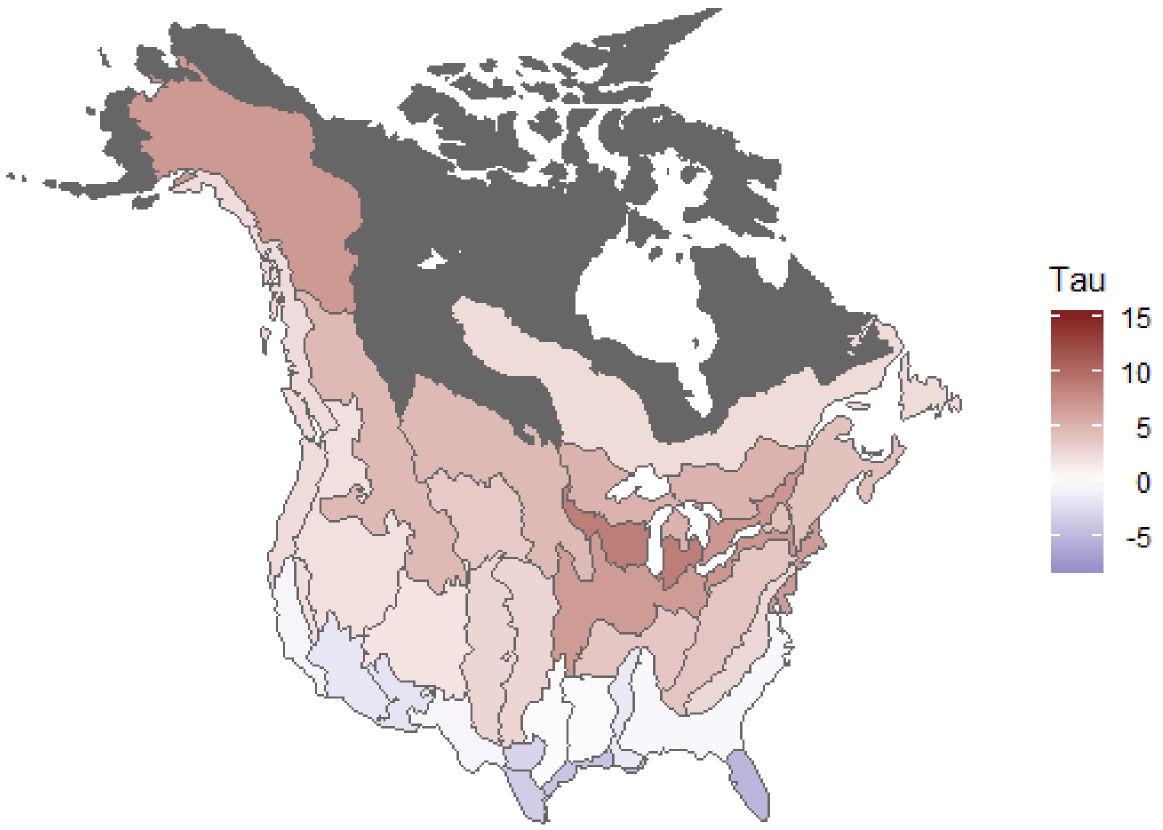


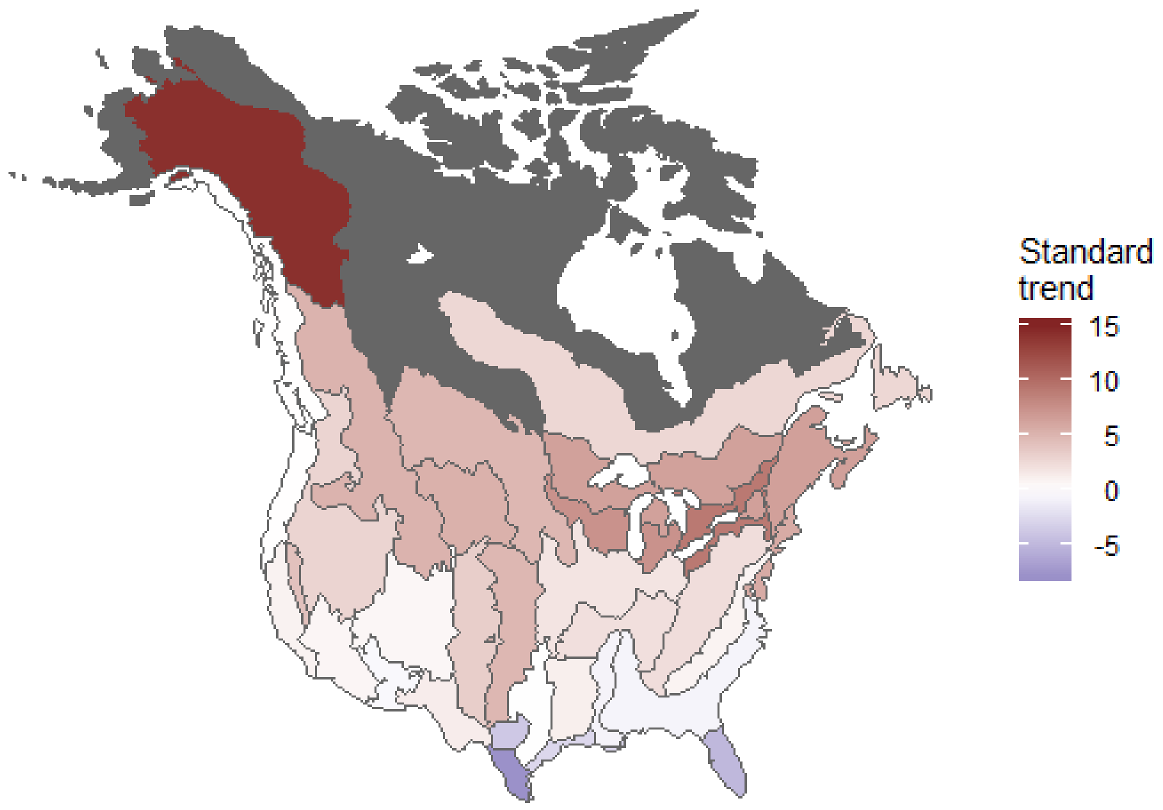


Tau: Significant Year Effects



Aggregation: Trend Estimates Compared





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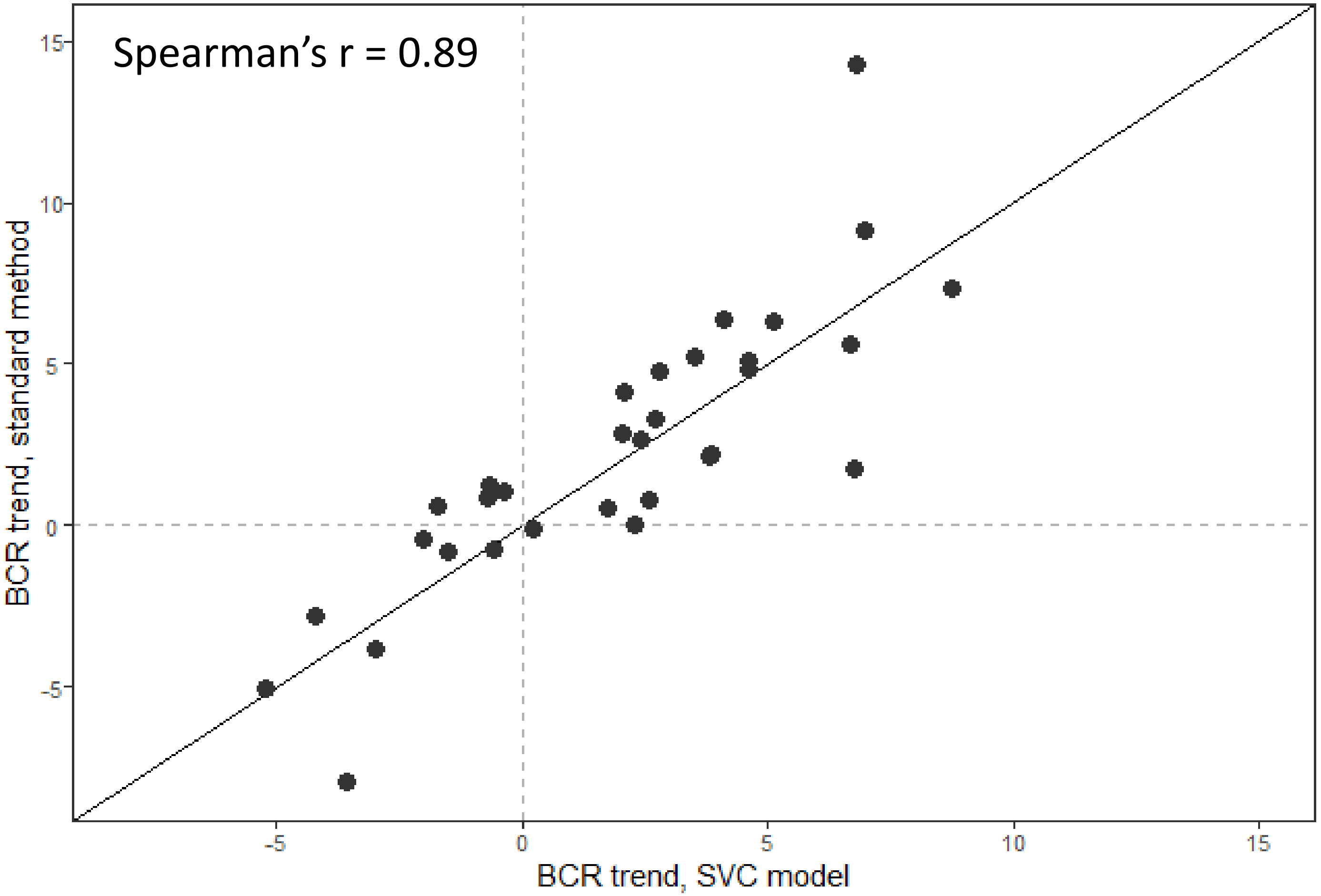
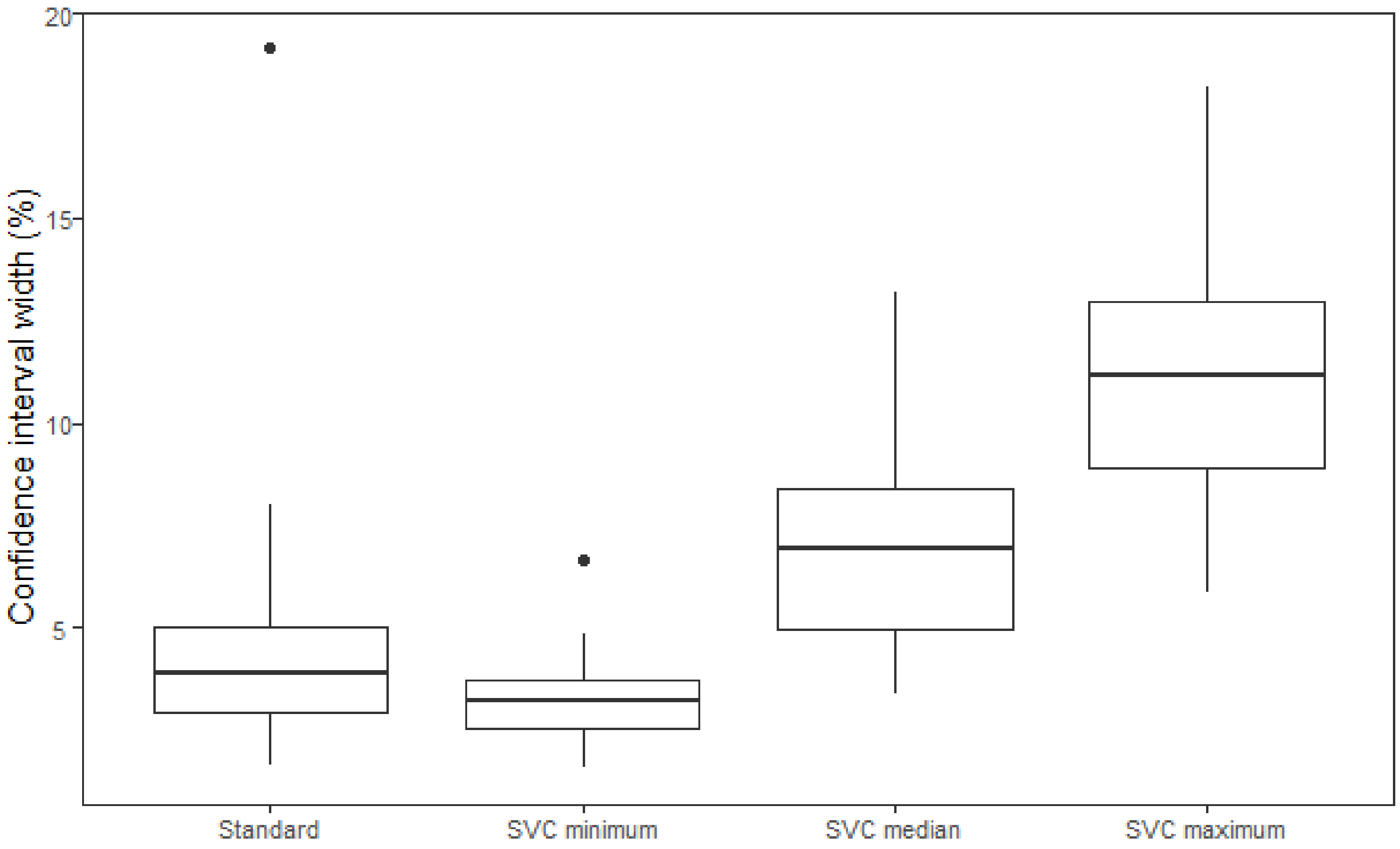


Aggregation: Trend Precision Compared



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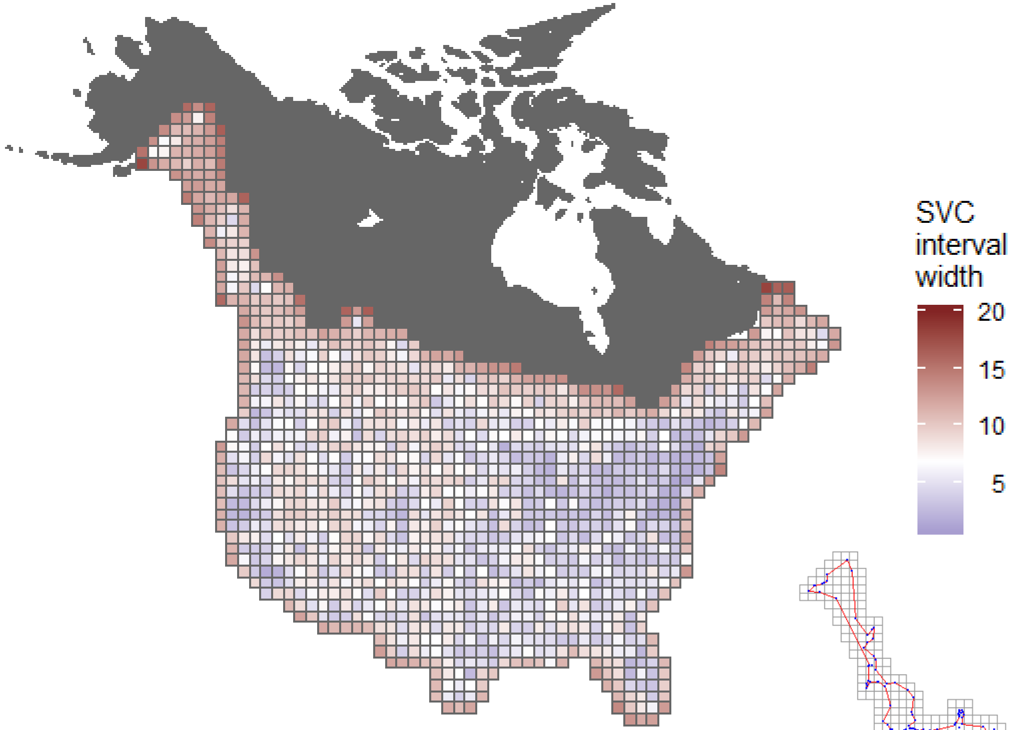

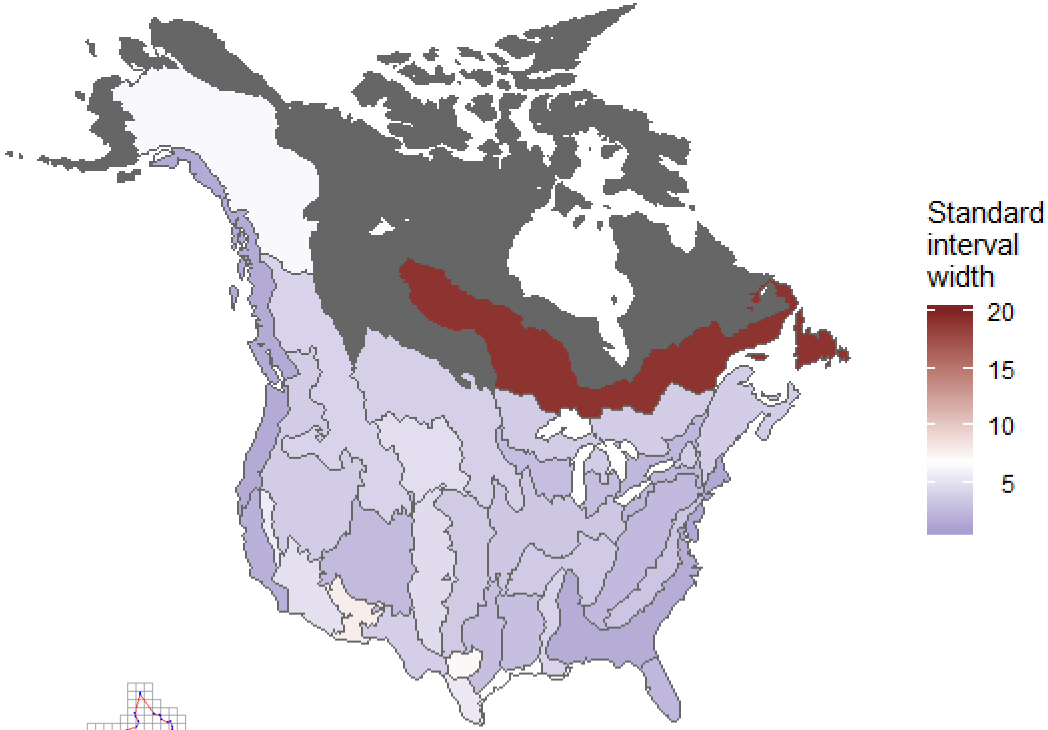

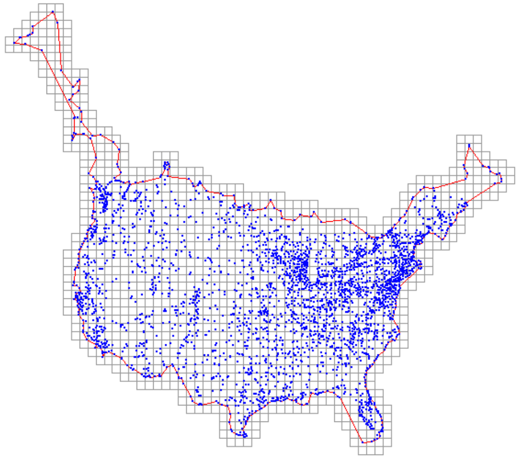

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