Simulation Experiment Results

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Load in the results

```
library(knitr)
library(tidyverse)
library(latex2exp)

load("../data/synthetic-data.RData")
attach(synthetic.data.config)

estimates = readRDS("../data/sim_exp-estimate_extinction_results.RDS")
estimates = estimates %>% filter(!(method %in% c("SI-RM", "GB-RM")))
estimates = estimates %>% mutate(across(method, str_replace, 'SI-RM-corrected', 'SI-RM'))
estimates = estimates %>% mutate(method_cat = ifelse(method %in% c("SI-RM", "MINMI"), "Proposed", "Exis
head(estimates)
```

```
##   id error_factor method     lower     point    upper point_runtime
## 1  1          0.0    MLE        NA 12660.896       NA  1.907349e-05
## 2  1          0.0 BA-MLE        NA 12293.940       NA  1.682997e-03
## 3  1          0.0 SI-UGM 11262.804 12422.265 12681.61  3.777524e+00
## 4  2          0.5    MLE        NA  9871.056       NA  1.279831e-03
## 5  2          0.5 BA-MLE        NA  9364.609       NA  4.145861e-03
## 6  2          0.5 SI-UGM  7789.998  9518.421 10035.51  2.695084e+00
##   conf_int_runtime method_cat
## 1               NA   Existing
## 2               NA   Existing
## 3         3.777524   Existing
## 4               NA   Existing
## 5               NA   Existing
## 6         2.695084   Existing
```

```
# Point estimates
performance.point_estimates = estimates %>%
  filter(!is.na(point)) %>%
  group_by(error_factor, method, method_cat) %>%
  summarise(MSE_000 = mean((point - theta.true)^2)/1000,
            bias = mean(point)-theta.true,
            variance_000 = var(point)/1000,
            avg_runtime = mean(point_runtime))
```

```
## `summarise()` has grouped output by 'error_factor', 'method'. You can override
## using the `.groups` argument.
```

```
kable(performance.point_estimates)
```

error_factor	method	method_cat	MSE_000	bias	variance_000	avg_runtime
0.0	BA-MLE	Existing	234.5607	-0.9379571	234.7946	0.0000219
0.0	GRIWM	Existing	1183.5359	-949.8850000	281.5360	2.3354816
0.0	GRIWM-corrected	Existing	246.1900	133.7070000	228.5410	13.8988053
0.0	MINMI	Proposed	247.4576	139.4092643	228.2509	0.0000110
0.0	MLE	Existing	438.6601	475.2971837	212.9656	0.0000173
0.0	SI-RM	Proposed	438.6601	475.2971837	212.9656	0.0310266
0.0	SI-UGM	Existing	248.9648	150.6138962	226.5068	4.7065676
0.0	STRAUSS	Existing	234.8453	-0.7152842	235.0799	0.0000186
0.5	BA-MLE	Existing	244.0353	-22.0990141	243.7908	0.0000253
0.5	GRIWM	Existing	1275.8894	-992.6550000	290.8162	2.3588714
0.5	GRIWM-corrected	Existing	244.7798	95.1730000	235.9578	13.8825358
0.5	MINMI	Proposed	250.5532	115.4530742	237.4612	0.0004929
0.5	MLE	Existing	428.0602	455.1437961	221.1254	0.0000192
0.5	SI-RM	Proposed	428.0602	455.1437961	221.1254	0.0096979
0.5	SI-UGM	Existing	250.7756	117.2579537	237.2634	2.3305912
0.5	STRAUSS	Existing	245.5802	-22.8493286	245.3034	0.0000224
1.0	BA-MLE	Existing	365.6242	-45.7554617	363.8946	0.0000216
1.0	GRIWM	Existing	1547.7470	-1060.0020000	424.5673	18.1072462
1.0	GRIWM-corrected	Existing	345.2420	34.4120000	344.4022	13.9009544
1.0	MINMI	Proposed	368.4990	100.8350222	358.6900	0.0005482
1.0	MLE	Existing	516.8878	432.6138460	330.0631	0.0000176
1.0	SI-RM	Proposed	516.8878	432.6138460	330.0631	0.0062744
1.0	SI-UGM	Existing	371.3002	115.2129004	358.3845	1.9374115
1.0	STRAUSS	Existing	366.4727	-50.5383309	364.2829	0.0000187
2.0	BA-MLE	Existing	542.9867	-233.5215118	488.9434	0.0000210
2.0	GRIWM	Existing	2506.9717	-1407.5250000	526.3714	2.3640996
2.0	GRIWM-corrected	Existing	504.9335	-278.4774775	427.8120	13.9421990
2.0	MINMI	Proposed	508.3236	20.6641924	508.4050	0.0005069
2.0	MLE	Existing	507.4514	253.7890364	443.4860	0.0000176
2.0	SI-RM	Proposed	507.4514	253.7890364	443.4860	0.0056648
2.0	SI-UGM	Existing	501.5358	65.3780494	497.7593	1.6800792
2.0	STRAUSS	Existing	553.8156	-247.9251968	492.8416	0.0000189
4.0	BA-MLE	Existing	1712.8705	-817.7749246	1045.1599	0.0000204
4.0	GRIWM	Existing	6714.4002	-2401.1470000	949.8431	2.3609959
4.0	GRIWM-corrected	Existing	2147.1454	-1173.6520000	770.4568	14.0341402
4.0	MINMI	Proposed	1171.7409	-178.1210176	1141.1550	0.0005369
4.0	MLE	Existing	1038.6355	-302.6427854	947.9908	0.0000176
4.0	SI-RM	Proposed	1038.6355	-302.6427854	947.9908	0.0058391
4.0	SI-UGM	Existing	1130.9207	-28.3481103	1131.2483	1.3896884
4.0	STRAUSS	Existing	1789.1141	-862.4420005	1046.3543	0.0000193

```
# Confidence Intervals
performance.conf_int_estimates = estimates %>%
  filter(!is.na(conf_int_runtime)) %>%
```

```
  mutate(width = upper - lower,
         contains_theta = ifelse(theta.true > lower & theta.true < upper, 1, 0)) %>%
  group_by(error_factor, method, method_cat) %>%
  summarise(Coverage = mean(contains_theta) * 100,
            `Average Width` = mean(width),
            `Average Runtime` = mean(conf_int_runtime)) %>%
  ungroup() %>%
  arrange(desc(Coverage), `Average Width`, `Average Runtime`)
```

```
## `summarise()` has grouped output by 'error_factor', 'method'. You can override
## using the `.groups` argument.
```

```
kable(performance.conf_int_estimates)
```

error_factor	method	method_cat	Coverage	Average Width	Average Runtime
0.0	SI-RM	Proposed	97.60000	2054.552	0.0310266
0.0	SI-UGM	Existing	97.30000	1961.144	4.7065676
0.5	SI-UGM	Existing	96.20000	2091.093	2.3305912
0.5	MINMI	Proposed	95.90000	2077.861	0.0012295
2.0	SI-UGM	Existing	94.90000	2964.298	1.6800792
4.0	SI-UGM	Existing	94.90000	4405.261	1.3896884
2.0	MINMI	Proposed	94.70000	2932.730	0.0014222
0.0	MINMI	Proposed	94.50000	1917.160	0.0000372
4.0	MINMI	Proposed	94.10000	4342.911	0.0015463
1.0	SI-UGM	Existing	93.70000	2351.533	1.9374115
1.0	MINMI	Proposed	93.60000	2329.949	0.0013297
4.0	SI-RM	Proposed	89.10000	3760.329	0.0058391
2.0	SI-RM	Proposed	83.70000	2500.858	0.0056648
2.0	GRIWM-corrected	Existing	80.58058	1949.667	13.9421990
0.5	SI-RM	Proposed	80.30000	2375.394	0.0096979
1.0	SI-RM	Proposed	79.40000	2459.189	0.0062744
4.0	GRIWM-corrected	Existing	69.90000	3647.415	14.0341402
1.0	GRIWM-corrected	Existing	69.50000	1047.995	13.9009544
0.5	GRIWM-corrected	Existing	49.90000	548.084	13.8825358
4.0	GRIWM	Existing	24.00000	4049.362	2.3609959
2.0	GRIWM	Existing	22.60000	2163.503	2.3640996
1.0	GRIWM	Existing	13.90000	1162.649	18.1072462
0.5	GRIWM	Existing	7.00000	608.326	2.3588714
0.0	GRIWM	Existing	0.00000	0.000	2.3354816
0.0	GRIWM-corrected	Existing	0.00000	0.000	13.8988053

Point Estimates

```
library(kableExtra)
```

```
## Warning: package 'kableExtra' was built under R version 4.2.2
```

```
##
## Attaching package: 'kableExtra'
```

```
## The following object is masked from 'package:dplyr':
##
##     group_rows
```

```
for (err in error_factors) {
  experiment.results.kbl = performance.point_estimates %>%
    filter(error_factor == err) %>%
    ungroup() %>%
    mutate(across(!c(method, avg_runtime, method_cat), round)) %>%
    mutate(avg_runtime=round(avg_runtime, digits=5)) %>%
    arrange(MSE_000) %>%
    select(-c(error_factor, method_cat)) %>%
    kable(booktabs=T, col.names = c("", "(000's years)", "(years)", "(000's years)", "(seconds)"), forma
    add_header_above(c("Method" = 1, "MSE" = 1, "Bias"=1, "Variance"=1, "Average Runtime"=1))
  writeLines(experiment.results.kbl, paste0("../figures/table-sim-exp-point-error", err, ".tex"))
  print(experiment.results.kbl)
}
```

Method	MSE	Bias	Variance	Average Runtime
	(000's years)	(years)	(000's years)	(seconds)
BA-MLE	235	-1	235	0.00002
STRAUSS	235	-1	235	0.00002
GRIWM-corrected	246	134	229	13.89881
MINMI	247	139	228	0.00001
SI-UGM	249	151	227	4.70657
MLE	439	475	213	0.00002
SI-RM	439	475	213	0.03103
GRIWM	1184	-950	282	2.33548

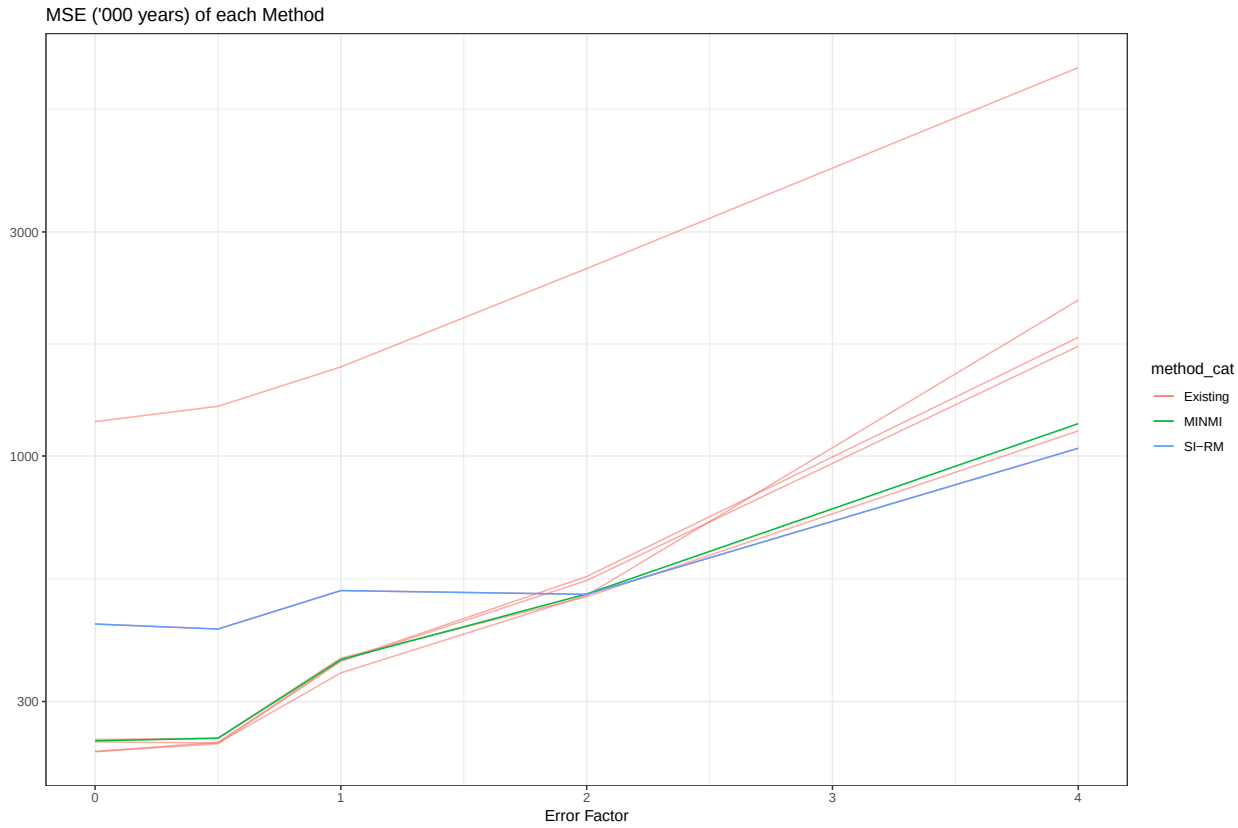
Method	MSE	Bias	Variance	Average Runtime
	(000's years)	(years)	(000's years)	(seconds)
BA-MLE	244	-22	244	0.00003
GRIWM-corrected	245	95	236	13.88254
STRAUSS	246	-23	245	0.00002
MINMI	251	115	237	0.00049
SI-UGM	251	117	237	2.33059
MLE	428	455	221	0.00002
SI-RM	428	455	221	0.00970
GRIWM	1276	-993	291	2.35887

Method	MSE	Bias	Variance	Average Runtime
	(000's years)	(years)	(000's years)	(seconds)
GRIWM-corrected	345	34	344	13.90095
BA-MLE	366	-46	364	0.00002
STRAUSS	366	-51	364	0.00002
MINMI	368	101	359	0.00055
SI-UGM	371	115	358	1.93741
MLE	517	433	330	0.00002
SI-RM	517	433	330	0.00627
GRIWM	1548	-1060	425	18.10725

Method	MSE	Bias	Variance	Average Runtime
	(000's years)	(years)	(000's years)	(seconds)
SI-UGM	502	65	498	1.68008
GRIWM-corrected	505	-278	428	13.94220
MLE	507	254	443	0.00002
SI-RM	507	254	443	0.00566
MINMI	508	21	508	0.00051
BA-MLE	543	-234	489	0.00002
STRAUSS	554	-248	493	0.00002
GRIWM	2507	-1408	526	2.36410

Method	MSE	Bias	Variance	Average Runtime
	(000's years)	(years)	(000's years)	(seconds)
MLE	1039	-303	948	0.00002
SI-RM	1039	-303	948	0.00584
SI-UGM	1131	-28	1131	1.38969
MINMI	1172	-178	1141	0.00054
BA-MLE	1713	-818	1045	0.00002
STRAUSS	1789	-862	1046	0.00002
GRIWM-corrected	2147	-1174	770	14.03414
GRIWM	6714	-2401	950	2.36100

```
ggplot() +
  geom_line(data = filter(performance.point_estimates, method_cat == "Existing"),
            aes(x=error_factor, group=method, y=MSE_000, colour=method_cat), alpha=0.6) +
  geom_line(data = filter(performance.point_estimates, method_cat == "Proposed"),
            aes(x=error_factor, y=MSE_000, colour=method)) +
  theme_bw() +
  labs(x="Error Factor", y=NULL, title="MSE ('000 years) of each Method") +
  scale_y_continuous(trans='log10')
```



Confidence Intervals

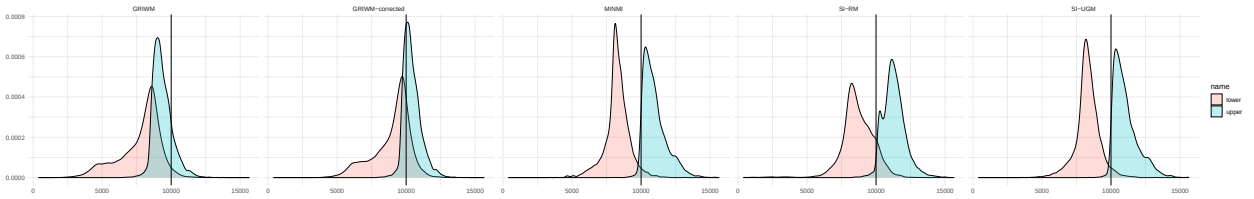
```
options(scipen=9)
for (metric in c("Coverage", "Average Width", "Average Runtime")) {
  experiment.results.kbl = performance.conf_int_estimates %>%
    select(c(method, error_factor, one_of(metric))) %>%
    pivot_wider(id_cols = method,
                names_from=error_factor,
                values_from=one_of(metric),
                names_prefix=paste(metric, "| error = sigma*")) %>%
    arrange(!!syms(paste(metric, "| error = sigma*0"))) %>%
    kable(booktabs=T, col.names = c("Method", paste0(c(0,0.5,1,2,4), r"{*$\sigma$}")), format="latex", 
    # kable_styling(full_width = F) %>%
    add_header_above(c(" " = 1, metric = 4))

  print(experiment.results.kbl)
  writeLines(experiment.results.kbl, paste0("../figures/table-sim-exp-conf-int-", str_replace(tolower(m
}
```

	metric				
Method	0*σ	0.5*σ	1*σ	2*σ	4*σ
SI-RM	97.6	80.3	83.70000	89.1	79.4
SI-UGM	97.3	96.2	94.90000	94.9	93.7
MINMI	94.5	95.9	94.70000	94.1	93.6
GRIWM-corrected	0.0	49.9	80.58058	69.9	69.5
GRIWM	0.0	7.0	22.60000	24.0	13.9

	metric				
Method	0*σ	0.5*σ	1*σ	2*σ	4*σ
SI-RM	2054.552	2375.394	2500.858	3760.329	2459.189
SI-UGM	1961.144	2091.093	2964.298	4405.261	2351.533
MINMI	1917.160	2077.861	2932.730	4342.911	2329.949
GRIWM-corrected	0.000	548.084	1949.667	3647.415	1047.995
GRIWM	0.000	608.326	2163.503	4049.362	1162.649

	metric				
Method	0*σ	0.5*σ	1*σ	2*σ	4*σ
SI-RM	0.0310266	0.0096979	0.0056648	0.0058391	0.0062744
SI-UGM	4.7065676	2.3305912	1.6800792	1.3896884	1.9374115
MINMI	0.0000372	0.0012295	0.0014222	0.0015463	0.0013297
GRIWM-corrected	13.8988053	13.8825358	13.9421990	14.0341402	13.9009544
GRIWM	2.3354816	2.3588714	2.3640996	2.3609959	18.1072462

```
estimates %>%
  filter(!is.na(lower)) %>%
  select(method, lower, upper) %>%
  pivot_longer(cols=c(lower, upper)) %>%
  filter(!is.na(value)) %>%
  ggplot(aes(x=value, fill=name)) +
  geom_density(alpha=0.25) +
  geom_vline(aes(xintercept=theta.true)) +
  facet_wrap(method ~ ., nrow=1) +
  theme_minimal() +
  labs(x=NULL, y=NULL)
```




```
estimates %>%
  filter(!is.na(lower) & error_factor == 1) %>%
  group_by(method_cat, method) %>%
  summarise(lower = mean(lower), upper=mean(upper)) %>%
  mutate(width=upper-lower) %>%
  mutate(method_cat_int = ifelse(method_cat == "Existing", 0, 1)) %>%
  ggplot(aes(y=reorder(method, method_cat_int), colour=method_cat)) +
```

```
  geom_errorbarh(aes(xmin=lower, xmax=upper)) +
  # geom_text(aes(y=method, x=(upper+lower)/2, label=round(width, 2)), vjust = -0.5) +
  guides(color = guide_legend(reverse=TRUE)) +
  labs(x=NULL, y="Years (BP)", title="Simulation Experiment Confidence Intervals", colour=NULL) +
  theme_bw()
```

```
## `summarise()` has grouped output by 'method_cat'. You can override using the
## `.groups` argument.
```