# 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")
```

```
# Point estimates
performance.point_estimates = estimates %>%
  filter(!is.na(point)) %>%
  group_by(error_factor, method) %>%
  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'. You can override using the
## `.groups` argument.
```

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

| error_factor | method | MSE_000 | bias | variance_000 | avg_runtime |
|---|---|---|---|---|---|
| 0.0 | BA-MLE | 234.5607 | -0.9379571 | 234.7946 | 0.0000219 |
| 0.0 | GRIWM | 248.9280 | 145.5280000 | 227.9776 | 2.3971124 |
| 0.0 | MINMI | 247.4576 | 139.4092643 | 228.2509 | 0.0000109 |
| 0.0 | MLE | 438.6601 | 475.2971837 | 212.9656 | 0.0000173 |
| 0.0 | SI-UGM | 248.9648 | 150.6138962 | 226.5068 | 4.7065676 |
| 0.0 | STRAUSS | 234.8453 | -0.7152842 | 235.0799 | 0.0000196 |
| 0.5 | BA-MLE | 244.0353 | -22.0990141 | 243.7908 | 0.0000253 |
| 0.5 | GRIWM | 246.6816 | 107.0420000 | 235.4590 | 2.4313070 |
| 0.5 | MINMI | 250.6573 | 116.6643007 | 237.2840 | 0.0004708 |
| 0.5 | MLE | 428.0602 | 455.1437961 | 221.1254 | 0.0000192 |
| 0.5 | SI-UGM | 250.7756 | 117.2579537 | 237.2634 | 2.3305912 |
| 0.5 | STRAUSS | 245.5802 | -22.8493286 | 245.3034 | 0.0000251 |

| error_factor | method | MSE_000 | bias | variance_000 | avg_runtime |
|---|---|---|---|---|---|
| 1.0 | BA-MLE | 365.6242 | -45.7554617 | 363.8946 | 0.0000216 |
| 1.0 | GRIWM | 345.5350 | 46.5880000 | 343.7083 | 2.4390745 |
| 1.0 | MINMI | 373.1166 | 104.2616256 | 362.6088 | 0.0005133 |
| 1.0 | MLE | 516.8878 | 432.6138460 | 330.0631 | 0.0000176 |
| 1.0 | SI-UGM | 371.3002 | 115.2129004 | 358.3845 | 1.9374115 |
| 1.0 | STRAUSS | 366.4727 | -50.5383309 | 364.2829 | 0.0000206 |
| 2.0 | BA-MLE | 542.9867 | -233.5215118 | 488.9434 | 0.0000210 |
| 2.0 | GRIWM | 496.9831 | -265.7930000 | 426.7639 | 2.4381696 |
| 2.0 | MINMI | 508.2312 | 21.2383726 | 508.2884 | 0.0005367 |
| 2.0 | MLE | 507.4514 | 253.7890364 | 443.4860 | 0.0000176 |
| 2.0 | SI-UGM | 501.5358 | 65.3780494 | 497.7593 | 1.6800792 |
| 2.0 | STRAUSS | 553.8156 | -247.9251968 | 492.8416 | 0.0000199 |
| 4.0 | BA-MLE | 1712.8705 | -817.7749246 | 1045.1599 | 0.0000204 |
| 4.0 | GRIWM | 2112.6249 | -1159.8510000 | 768.1387 | 2.4349672 |
| 4.0 | MINMI | 1157.0951 | -174.3894207 | 1127.8112 | 0.0005682 |
| 4.0 | MLE | 1038.6355 | -302.6427854 | 947.9908 | 0.0000176 |
| 4.0 | SI-UGM | 1130.9207 | -28.3481103 | 1131.2483 | 1.3896884 |
| 4.0 | STRAUSS | 1789.1141 | -862.4420005 | 1046.3543 | 0.0000199 |

```
# 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) %>%
  summarise(Coverage = mean(contains_theta),
            `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'. You can override using the
## `.groups` argument.
```

```
  # mutate(Coverage = scales::percent(Coverage, accuracy=0.1))
kable(performance.conf_int_estimates)
```

| error_factor | method | Coverage | Average Width | Average Runtime |
|---|---|---|---|---|
| 0.0 | SI-UGM | 0.973 | 1961.144 | 4.7065676 |
| 0.5 | SI-UGM | 0.962 | 2091.093 | 2.3305912 |
| 0.5 | MINMI | 0.959 | 2077.084 | 0.0012776 |
| 2.0 | SI-UGM | 0.949 | 2964.298 | 1.6800792 |
| 4.0 | SI-UGM | 0.949 | 4405.261 | 1.3896884 |
| 2.0 | MINMI | 0.947 | 2936.889 | 0.0013949 |
| 4.0 | MINMI | 0.947 | 4337.389 | 0.0014173 |
| 0.0 | MINMI | 0.945 | 1917.160 | 0.0000319 |
| 1.0 | SI-UGM | 0.937 | 2351.533 | 1.9374115 |
| 1.0 | MINMI | 0.933 | 2326.753 | 0.0012473 |
| 2.0 | GRIWM | 0.811 | 1947.517 | 2.4381696 |

| error_factor | method | Coverage | Average Width | Average Runtime |
|---|---|---|---|---|
| 4.0 | GRIWM | 0.707 | 3643.956 | 2.4349672 |
| 1.0 | GRIWM | 0.699 | 1046.012 | 2.4390745 |
| 0.5 | GRIWM | 0.507 | 547.268 | 2.4313070 |
| 0.0 | GRIWM | 0.000 | 0.000 | 2.3971124 |
| 0.0 | GB-RM | NA | NA | 0.0207461 |
| 4.0 | GB-RM | NA | NA | 0.0223523 |
| 1.0 | GB-RM | NA | NA | 0.0226802 |
| 2.0 | GB-RM | NA | NA | 0.0228241 |
| 0.5 | GB-RM | NA | NA | 0.0235220 |

**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) %>%
    mutate(across(!c(method, avg_runtime), round)) %>%
    mutate(avg_runtime=round(avg_runtime, digits=5)) %>%
    arrange(MSE_000) %>%
    ungroup() %>%
    select(-error_factor) %>%
    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 |
| MINMI | 247 | 139 | 228 | 0.00001 |
| GRIWM | 249 | 146 | 228 | 2.39711 |
| SI-UGM | 249 | 151 | 227 | 4.70657 |
| MLE | 439 | 475 | 213 | 0.00002 |

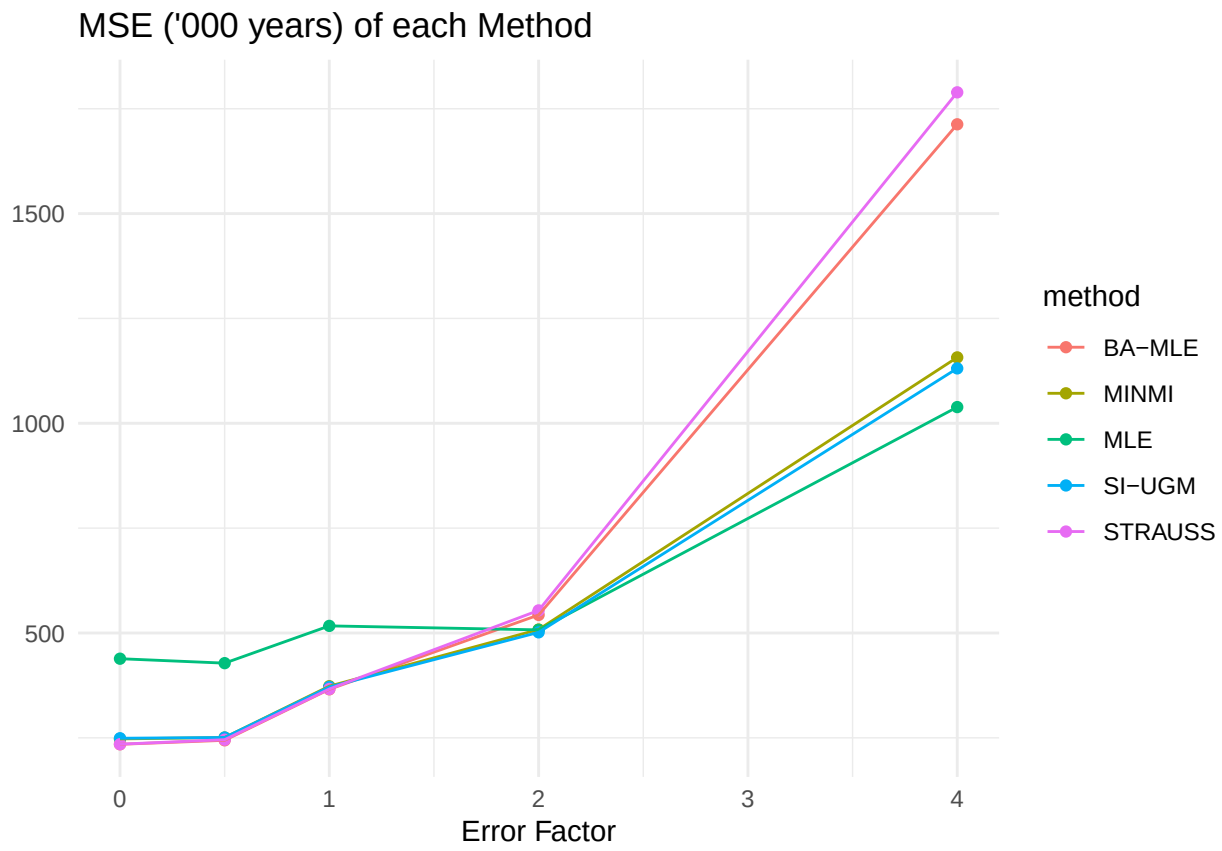
| Method | MSE | Bias | Variance | Average Runtime |
|---|---|---|---|---|
| | (000's years) | (years) | (000's years) | (seconds) |
| BA-MLE | 244 | -22 | 244 | 0.00003 |
| STRAUSS | 246 | -23 | 245 | 0.00003 |
| GRIWM | 247 | 107 | 235 | 2.43131 |
| MINMI | 251 | 117 | 237 | 0.00047 |
| SI-UGM | 251 | 117 | 237 | 2.33059 |
| MLE | 428 | 455 | 221 | 0.00002 |

| Method | MSE | Bias | Variance | Average Runtime |
|---|---|---|---|---|
| | (000's years) | (years) | (000's years) | (seconds) |
| GRIWM | 346 | 47 | 344 | 2.43907 |
| BA-MLE | 366 | -46 | 364 | 0.00002 |
| STRAUSS | 366 | -51 | 364 | 0.00002 |
| SI-UGM | 371 | 115 | 358 | 1.93741 |
| MINMI | 373 | 104 | 363 | 0.00051 |
| MLE | 517 | 433 | 330 | 0.00002 |

| Method | MSE | Bias | Variance | Average Runtime |
|---|---|---|---|---|
| | (000's years) | (years) | (000's years) | (seconds) |
| GRIWM | 497 | -266 | 427 | 2.43817 |
| SI-UGM | 502 | 65 | 498 | 1.68008 |
| MLE | 507 | 254 | 443 | 0.00002 |
| MINMI | 508 | 21 | 508 | 0.00054 |
| BA-MLE | 543 | -234 | 489 | 0.00002 |
| STRAUSS | 554 | -248 | 493 | 0.00002 |

| Method | MSE | Bias | Variance | Average Runtime |
|---|---|---|---|---|
| | (000's years) | (years) | (000's years) | (seconds) |
| MLE | 1039 | -303 | 948 | 0.00002 |
| SI-UGM | 1131 | -28 | 1131 | 1.38969 |
| MINMI | 1157 | -174 | 1128 | 0.00057 |
| BA-MLE | 1713 | -818 | 1045 | 0.00002 |
| STRAUSS | 1789 | -862 | 1046 | 0.00002 |
| GRIWM | 2113 | -1160 | 768 | 2.43497 |

```
performance.point_estimates %>%
  filter(!(method %in% c("GRIWM", "GRIWM-corrected"))) %>%
  ggplot(aes(x=error_factor, y=MSE_000, colour=method)) +
  geom_point() +
  geom_line() +
  theme_minimal() +
  # guides(colour="none") +
  # annotate("text", x=4.18, y=c(1950, 1750, 1300, 1200, 1100), label=c("BA-MLE", "Strauss", "MINMI", "
  labs(x="Error Factor", y=NULL, title="MSE ('000 years) of each Method")
```




```
  #+  scale_y_continuous(trans='log10')
```

### Confidence Intervals

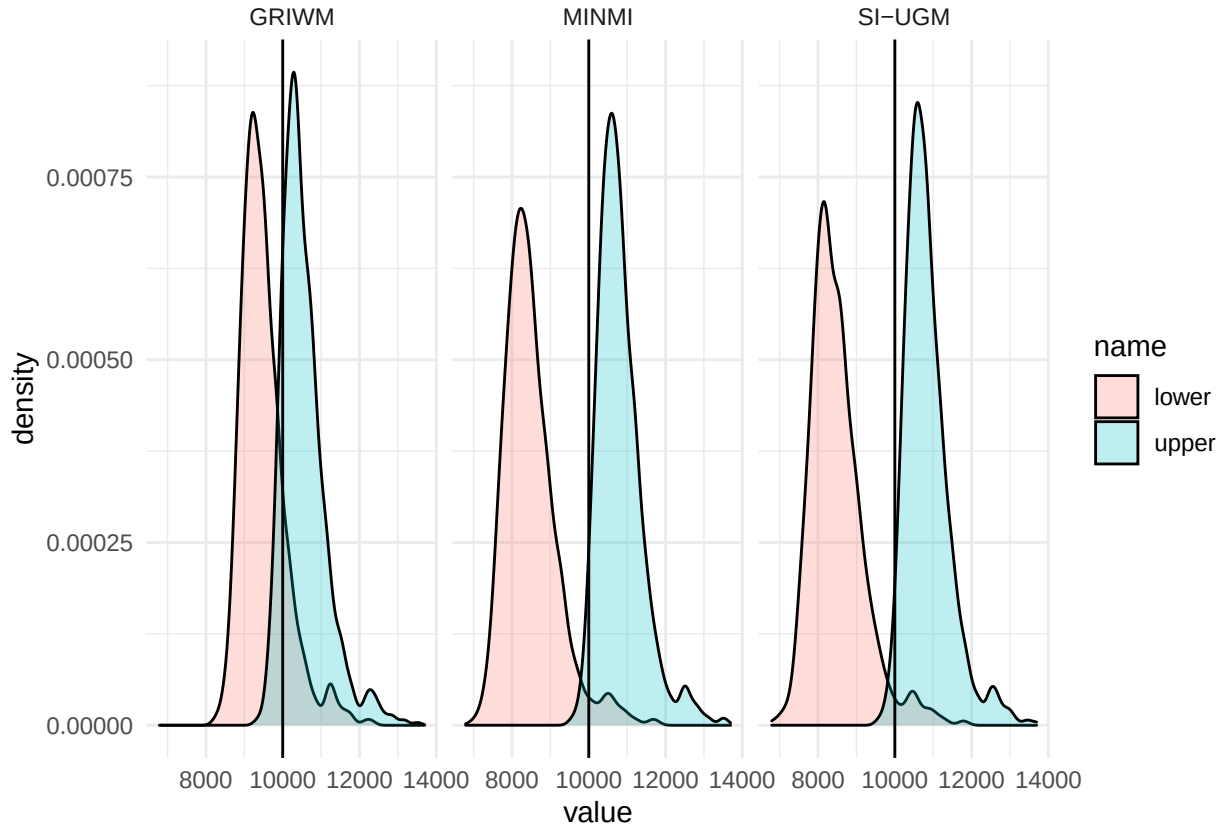
```
options(scipen=9)
for (metric in c("Coverage", "Average Width", "Average Runtime")) {
  experiment.results.kbl = performance.conf_int_estimates %>%
    select(c(method, error_factor, one_of(metric))) %>%
    pivot_wider(id_cols = method,
                names_from=error_factor,
                values_from=one_of(metric),
                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", d
    # 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(me
}
```

| | metric | | | | |
|---|---|---|---|---|---|
| Method | 0*$\sigma$ | 0.5*$\sigma$ | 1*$\sigma$ | 2*$\sigma$ | 4*$\sigma$ |
| SI-UGM | 0.973 | 0.962 | 0.949 | 0.949 | 0.937 |
| MINMI | 0.945 | 0.959 | 0.947 | 0.947 | 0.933 |
| GRIWM | 0.000 | 0.507 | 0.811 | 0.707 | 0.699 |
| GB-RM | NA | NA | NA | NA | NA |

| | metric | | | | |
|---|---|---|---|---|---|
| Method | 0*$\sigma$ | 0.5*$\sigma$ | 1*$\sigma$ | 2*$\sigma$ | 4*$\sigma$ |
| SI-UGM | 1961.144 | 2091.093 | 2964.298 | 4405.261 | 2351.533 |
| MINMI | 1917.160 | 2077.084 | 2936.889 | 4337.389 | 2326.753 |
| GRIWM | 0.000 | 547.268 | 1947.517 | 3643.956 | 1046.012 |
| GB-RM | NA | NA | NA | NA | NA |

| | metric | | | | |
|---|---|---|---|---|---|
| Method | 0*$\sigma$ | 0.5*$\sigma$ | 1*$\sigma$ | 2*$\sigma$ | 4*$\sigma$ |
| SI-UGM | 4.7065676 | 2.3305912 | 1.6800792 | 1.3896884 | 1.9374115 |
| MINMI | 0.0000319 | 0.0012776 | 0.0013949 | 0.0014173 | 0.0012473 |
| GRIWM | 2.3971124 | 2.4313070 | 2.4381696 | 2.4349672 | 2.4390745 |
| GB-RM | 0.0207461 | 0.0235220 | 0.0228241 | 0.0223523 | 0.0226802 |

```
estimates %>%
  filter(!is.na(lower)) %>%
  filter(error_factor==1) %>%
  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 ~ .) +
  theme_minimal() +
  labs()
```




```
metric="Coverage"
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")))
```

```
## # A tibble: 4 x 6
##   method `Coverage | error = sigma*0` Coverage | error~1 Cover~2 Cover~3 Cover~4
##   <chr>                         <dbl>              <dbl>   <dbl>   <dbl>   <dbl>
## 1 SI-UGM                        0.973              0.962   0.949   0.949   0.937
## 2 MINMI                         0.945              0.959   0.947   0.947   0.933
## 3 GRIWM                         0                  0.507   0.811   0.707   0.699
## 4 GB-RM                        NA                 NA      NA      NA      NA
## # ... with abbreviated variable names 1: `Coverage | error = sigma*0.5`,
## #   2: `Coverage | error = sigma*2`, 3: `Coverage | error = sigma*4`,
## #   4: `Coverage | error = sigma*1`
```