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The IFoA Conference 2022

22–23 June – etc.venues, 133 Houndsditch, London



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Advancing Analytics with COVID-19

Louis Rossouw

Rob Kaner

COVID-19 Activities

During COVID-19

- R estimates
- COVID-19 models
- Understanding experience
- Uncertainty!

Learnings?

- Continuous
 - Sourcing data
 - Managing
 - Regular analysis
- Keeping track of it all
- Efficiency
- Handling uncertainty



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Estimating R

$$E(I_t) = R_t \sum_{s=1}^t I_{t-s} w_s$$

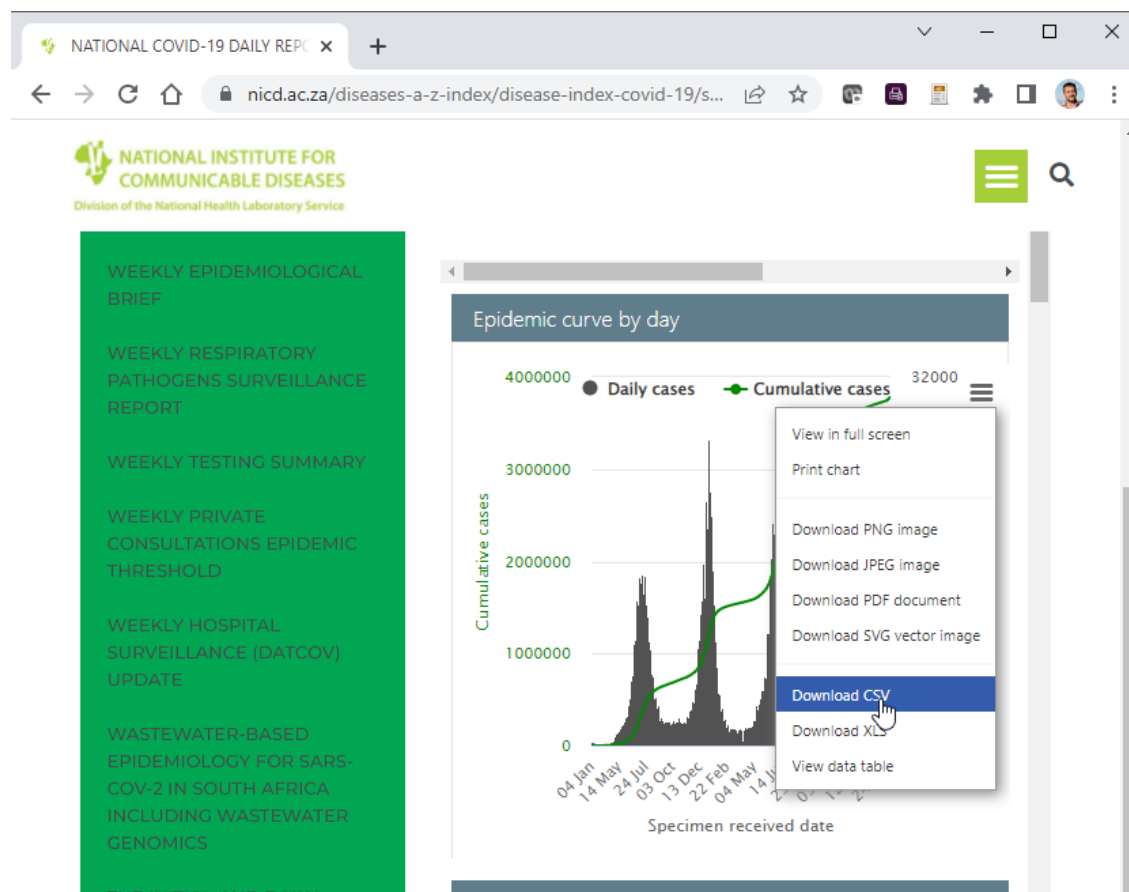
- I_t is infections on a day
- R_t is instantaneous reproduction number
- w_s is the generation interval (how infectious one is over time)
- Can use cases, admissions, deaths...

Cori, A. *et al.* (2013) 'A new framework and software to estimate time-varying reproduction numbers during epidemics', *American Journal of Epidemiology*, 178(9), pp. 1505–1512. doi:[10.1093/aje/kwt133](https://doi.org/10.1093/aje/kwt133).

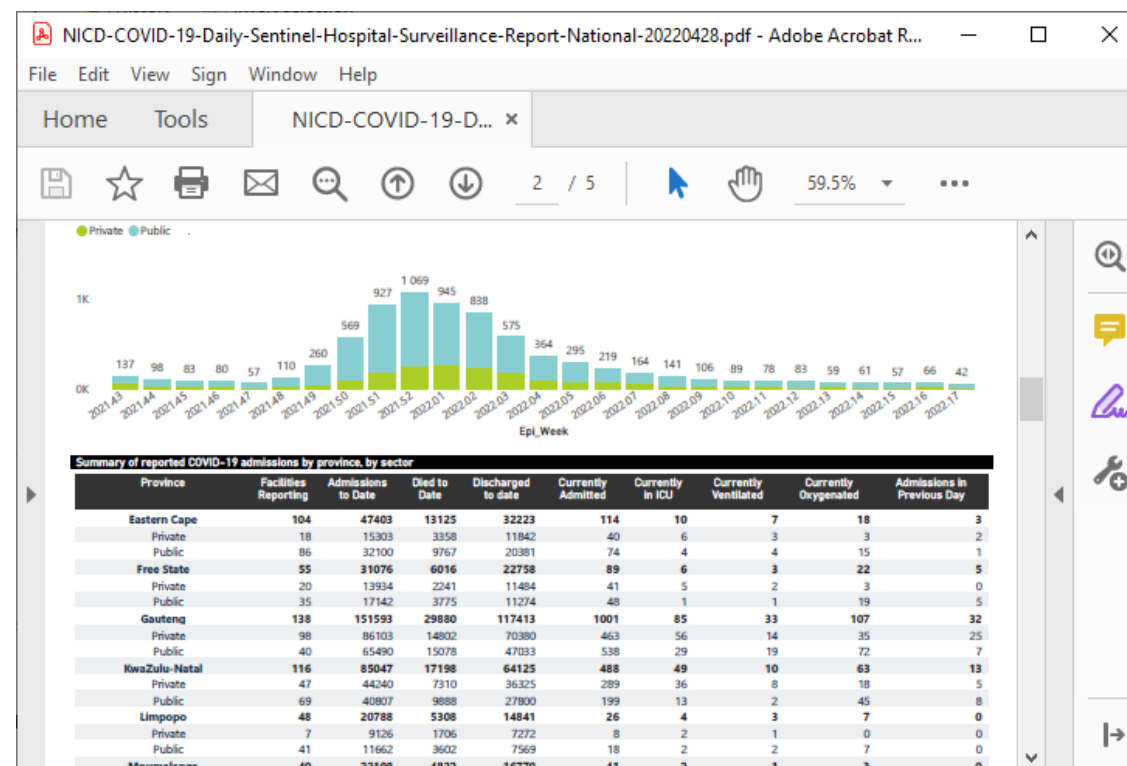


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Data sources – Dashboard and PDFs



National Institute for Communicable Diseases (2021) *National COVID-19 Daily Report*. Available at: <https://www.nicd.ac.za/diseases-a-z-index/covid-19/surveillance-reports/national-covid-19-daily-report/>.



National Institute for Communicable Diseases (2021) *Daily Hospital Surveillance (DATCOV) Report*. Available at: <https://www.nicd.ac.za/diseases-a-z-index/disease-index-covid-19/surveillance-reports/daily-hospital-surveillance-datcov-report/>.



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Open Data Sources

The screenshot shows the GitHub repository page for 'Coronavirus COVID-19 (2019-nCoV) Data Repository for South Africa'. The repository is public and has 53 contributors. The README.md file is displayed, containing the following information:

- DOI:** 10.5281/zenodo.3819126 (Zenodo) and 10.5334 (DSJournal)
- Description:** Coronavirus COVID-19 (2019-nCoV) Data Repository for South Africa created, maintained and hosted by Data Science for Social Impact research group, led by Dr. Vukosi Marivate, at the University of Pretoria.
- Disclaimer:** We have worked to keep the data as accurate as possible. We collate the COVID 19 reporting data from NICD and DoH. We only update that data once there is an official report or statement. For the other data, we work to keep the data as accurate as possible. If you find errors. Make a pull request.
- Contact:** If you use this repo for any research/development/innovation, please contact us (see contacts below)
- Blog posts:**
 - Why we built this and how we are working.
 - How this is a call to action across the African continent
 - A few weeks in, Data Science thoughts on COVID-19 in South Africa
- Interest:** If you are interested in the **Africa-wide effort**: Go to <https://github.com/dsfsi/covid19africa>
- Updates:** For information on daily updates on the repo, go to <https://twitter.com/vukosi/status/1239184086633242630?s=20>
- Licenses:** Code: MIT | Data: CC-BY-SA 4.0
- Data Available:** [/data]
- Note:** Please note that these reports are the daily reports as released by the National Department of Health or the NICD. The new cases reported are based on new positive test reports released. However, there may be significant lag from

The screenshot shows the GitHub repository page for 'M3IT / COVID-19_Data'. The repository is public and has 1 branch and 0 tags. The README.md file is displayed, containing the following information:

- Repository Name:** M3IT Data Update 2022-04-28 (610ebd3, 19 hours ago, 684 commits)
- Files:**
 - Data: Data Update 2022-04-28 (19 hours ago)
 - Images: Data Update 2021-04-10 (13 months ago)
 - .gitignore: Initial commit (2 years ago)
 - LICENSE.md: Update and rename LICENSE to LICENSE.md (2 years ago)
 - README.html: Typo fix in readme (6 months ago)
 - README.md: Data Update 2021-10-20 (6 months ago)
- README.md Content:**
 - COVID-19_Data**
 - COVID-19 Data for Australia**
 - Data summary**
 - Data provided currently covers:
 - Confirmed cases
 - Deaths
 - Tests
 - Positive Tests
 - Recovered

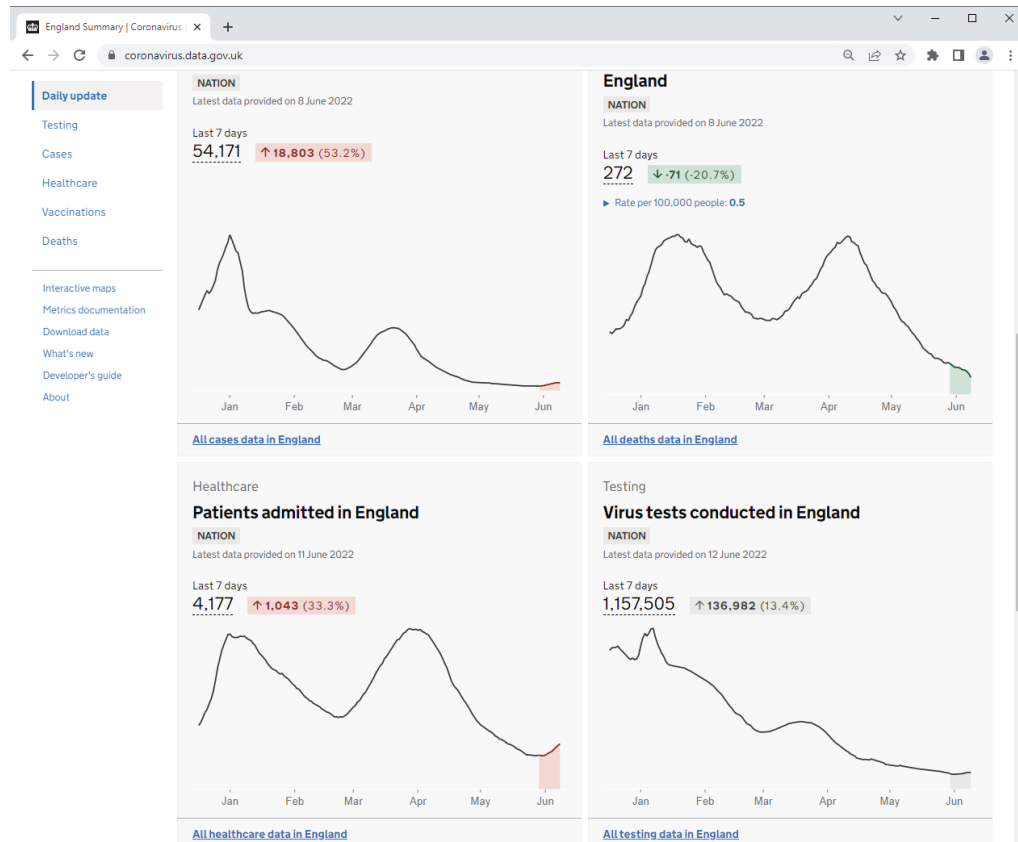
Marivate, V. *et al.* (2020) 'Coronavirus disease (COVID-19) case data - South Africa'. Zenodo. doi:[10.5281/ZENODO.3888499](https://doi.org/10.5281/ZENODO.3888499).

O'Brien, J. *et al.* (2021) *Coronavirus (COVID-19) in Australia, COVID-19-data-aus*. Available at: <https://www.covid19data.com.au> (Accessed: 29 December 2021).



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Data sources – Dashboard and APIs



UK Government summary dashboard for COVID-19 in England.
Available at: <https://coronavirus.data.gov.uk/>

Open Data API — v.1

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- [Version](#)
- [Software Development Kits \(SDK\)](#)
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 - [Timestamps](#)
- [Methods](#)
 - [HEAD](#)
 - [OPTIONS](#)
 - [Responses](#)
 - [GET](#)
 - [Responses](#)
- [Query parameters](#)
 - [filters](#)
 - [Multiple parameters](#)

<https://coronavirus.data.gov.uk/details/developers-guide/main-api>



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Open & Machine-Readable Data

Old Way

- Capture data
- Download
 - Spreadsheet
 - Report
 - PDF
 - Use export to Excel
- Fix data in Excel

New Way

- Already captured
- Read data
 - from API
 - Website
 - Database
- Use scripts to transform data



Chain Ladders



Rick McCharles

$$\ln(\theta^{t,d}) \approx \sum_i x'_i \beta'_i + \sum_j x''_j \beta''_j$$



$$x'_i = \begin{cases} 1, & i = t \\ 0, & i \neq t \end{cases}$$

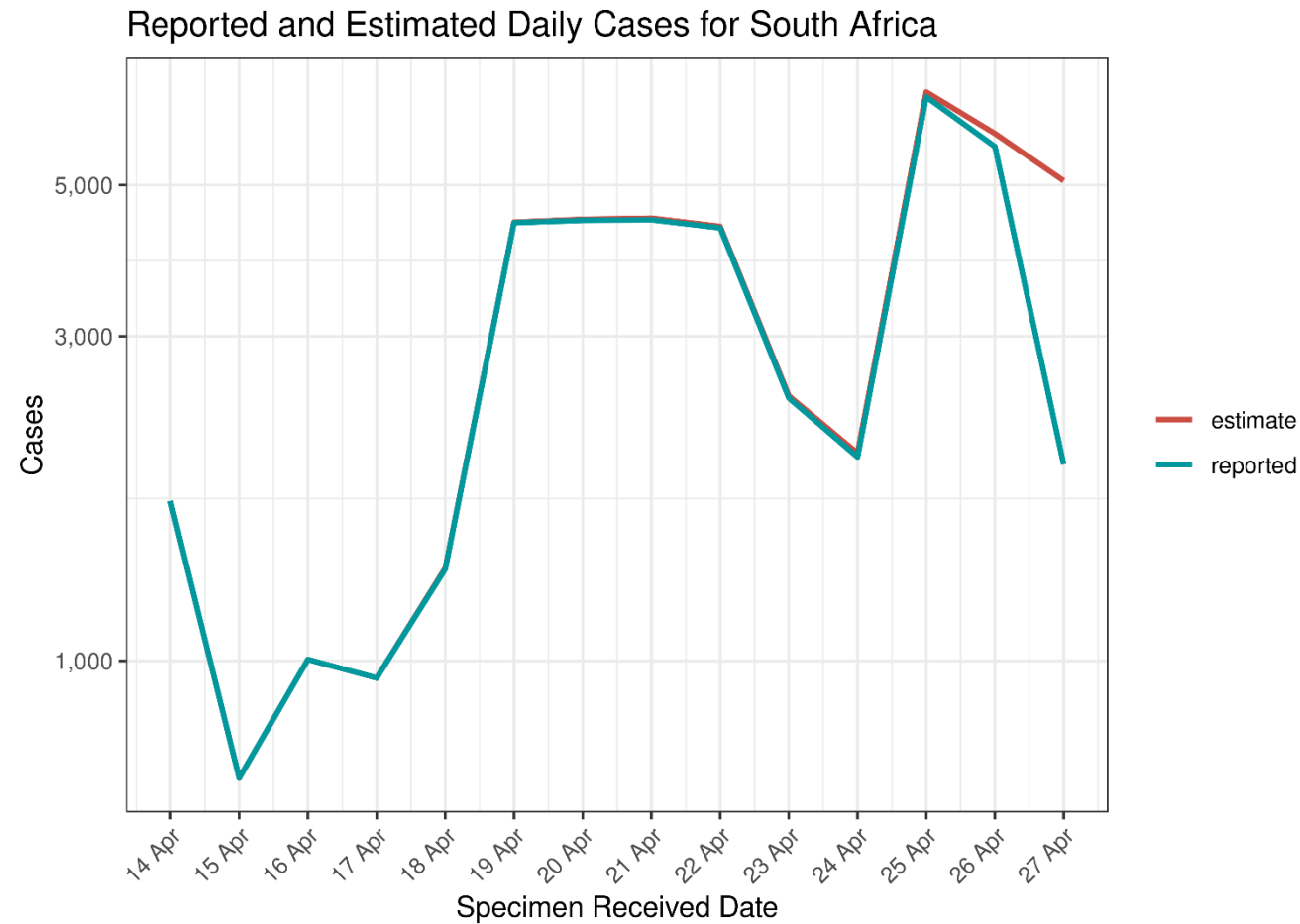
$$x''_j = \begin{cases} 1, & j = d \\ 0, & j \neq d \end{cases}$$

- That is a GLM!
- Allows automation
- (And other ML techniques)



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Allowance for late reported cases



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Estimating R with R



- R contains many packages
- All open source
- *ukcovid19*
 - Access UK COVID-19 data
- *EpiEstim*
 - Model R_t
 - Allowing for uncertainty

R Core Team (2019) *R: A language and environment for statistical computing*. manual. Vienna, Austria. Available at: <https://www.R-project.org/>.

Cori, A. (2013) *EpiEstim: A package to estimate time varying reproduction numbers from epidemic curves*. manual. Available at: <https://CRAN.R-project.org/package=EpiEstim>.



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Code Versioning (using git)

Code Changes

Remove zeroing negative LB	Louis Rossouw <lrossouw@genre. 3/30/22	e68e56e6
Remove negative excess deaths.	Louis Rossouw <lrossouw@genre. 3/14/22	7b849326
Extend run-off use_days.	Louis Rossouw <lrossouw@genre. 3/14/22	b2c2a3a4
Accept being out by 1 on counts deaths in CA (spreading deaths repo)	Louis Rossouw <lrossouw@genre. 3/9/22	4e0c9c33
Fix ZA excess deaths range for weekly excess.	Louis Rossouw <lrossouw@genre. 2/17/22	7df35861
Update packages.	Louis Rossouw <lrossouw@genre. 2/17/22	60897450
Remove maxima on plots.	Louis Rossouw <lrossouw@genre. 1/24/22	a074a905
Remove filtering of wide CIs	Louis Rossouw <lrossouw@genre. 1/24/22	23afed4d
Update UK IBNR	Louis Rossouw <lrossouw@genre. 1/9/22	15716e38
Save UK raw data.	Louis Rossouw <lrossouw@genre. 1/9/22	457743a0
Change the way r data files are saved for all countries.	Louis Rossouw <lrossouw@genre. 1/9/22	8a40539e
Change gap for world to 24h	Louis Rossouw <lrossouw@genre. 1/9/22	7671a4d8
Clear extra line	Louis Rossouw <lrossouw@genre. 1/9/22	123e3eae
Fix bug in update.R	Louis Rossouw <lrossouw@genre. 1/9/22	2f8c6649
Add logging of running_update	Louis Rossouw <lrossouw@genre. 1/9/22	a9f71153
Revamp update script to be clever.	Louis Rossouw <lrossouw@genre. 1/9/22	98a3edb7
Fix date on initial code for AU	Louis Rossouw <lrossouw@genre. 1/6/22	d9b5dac9
Allow for trends in ZA IBNR	Louis Rossouw <lrossouw@genre. 12/29/21	f2b05039
Rename _sa_ to _za_ and _au_	Louis Rossouw <lrossouw@genre. 12/29/21	25ddb293
Fix AU fig.cap labels	Louis Rossouw <lrossouw@genre. 12/29/21	e22ae7db
Fix AU state fig cap	Louis Rossouw <lrossouw@genre. 12/29/21	93dd5b1b
Add lib scales to scratch data history	Louis Rossouw <lrossouw@genre. 12/29/21	2bc62c4f
Drop rna library (what was it?)	Louis Rossouw <lrossouw@genre. 12/29/21	

Details of a specific change

estimating_r.au.Rmd	
352	@@ -352,11 +352,10 @@ Rt_data <-
353	data %>% inner_join(
354	unique_area_types_rcalc[i,],
355	by = c(
356	"report_date",
357	"area_type",
358	"country",
359	"state",
360	"district",
361	"population",
362	"type"
411	@@ -411,7 +410,7 @@ Rt_data <-
412	# count cases
413	c_data <- a_data %>% select(area_type, country, state, district, type, date, count)
414	c_data <- a_data %>% select(area_type, country, state, population, type, date, count)
415	c_Rt <- right_join(c_Rt, c_data, by = "date")
416	
417	
445	@@ -445,7 +444,7 @@ colnames(Rt_data) <- c(
446	"area_type",
447	"country",
448	"state",
449	"district",
450	"population",
451	"type",
452	"count"
453)
454	
455	
456	@@ -458,7 +457,7 @@ for (ci in c("50", "90", "95")) {
457	area_type = Rt_data\$area_type,
458	country = Rt_data\$country,
459	state = Rt_data\$state,
460	district = Rt_data\$district,
461	population = Rt_data\$population,
462	type = Rt_data\$type,
463	ci = rep(paste0(ci, "%"), nrow(Rt_data)),
464	Rt_mean = Rt_data\$Rt_mean,



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Code = Document

R Markdown (code + document)

Output

```
2814 ## Reproduction Number
2815 Below current (last weekly) effective reproduction number estimates are tabulated for South Africa and by
2816 province.
2817
2818 {r prep_table}
2819 # find the last estimates
2820 last_dates <- Rt_data %>%
2821   filter(!is.na(Rt_mean)) %>%
2822   group_by(area_type, country, province, district, type) %>%
2823   summarise(date = max(date), .groups = "drop")
2824
2825 # construct a table with nice fields names
2826 table <-
2827   inner_join(last_dates,
2828     Rt_data,
2829     by = c("area_type", "country", "province", "district", "type", "date")) %>%
2830   select(-count) %>%
2831   inner_join(
2832     inner_join(
2833       inner_join(
2834         last_dates,
2835         Rt_data,
2836         by = c("area_type", "country", "province", "district", "type", "date")
2837       ) %>%
2838       select(area_type, country, province, district, type, date_start, date_end),
2839       Rt_data %>% select(area_type, country, province, district, type, date, count),
2840       by = c("area_type", "country", "province", "district", "type")
```



5.1.11 Reproduction Number

Below current (last weekly) effective reproduction number estimates are tabulated for South Africa and by province.

Estimated Effective Reproduction Number for South Africa

	Type	Count (Per Day)	Week Ending	Reproduction Number [95% Confidence Interval]
South Africa	cases	4,789	2022-04-27	1.54 [1.42 - 1.69]
South Africa	hospital_admissions	216	2022-04-28	0.97 [0.86 - 1.09]

Estimated Effective Reproduction Number by Province

Province	Type	Count (Per Day)	Week Ending	Reproduction Number [95% Confidence Interval]
Eastern Cape	cases	167	2022-04-27	1.27 [1.17 - 1.39]
Eastern Cape	hospital_admissions	6	2022-04-28	1.09 [0.79 - 1.44]
Free State	cases	173	2022-04-27	1.93 [1.72 - 2.14]
Free State	hospital_admissions	9	2022-04-28	1.18 [0.90 - 1.50]
Gauteng	cases	2,346	2022-04-27	1.52 [1.41 - 1.64]
Gauteng	hospital_admissions	85	2022-04-28	0.74 [0.59 - 0.92]
KwaZulu-Natal	cases	1,102	2022-04-27	1.63 [1.47 - 1.81]
KwaZulu-Natal	hospital_admissions	58	2022-04-28	1.41 [1.24 - 1.61]
Limpopo	cases	55	2022-04-27	2.00 [1.70 - 2.32]
Limpopo	hospital_admissions	4	2022-04-28	1.32 [0.86 - 1.89]
Mpumalanga	cases	120	2022-04-27	1.63 [1.47 - 1.81]
Mpumalanga	hospital_admissions	7	2022-04-28	1.40 [1.03 - 1.84]
North West	cases	111	2022-04-27	1.74 [1.57 - 1.92]
North West	hospital_admissions	9	2022-04-28	0.70 [0.43 - 1.09]

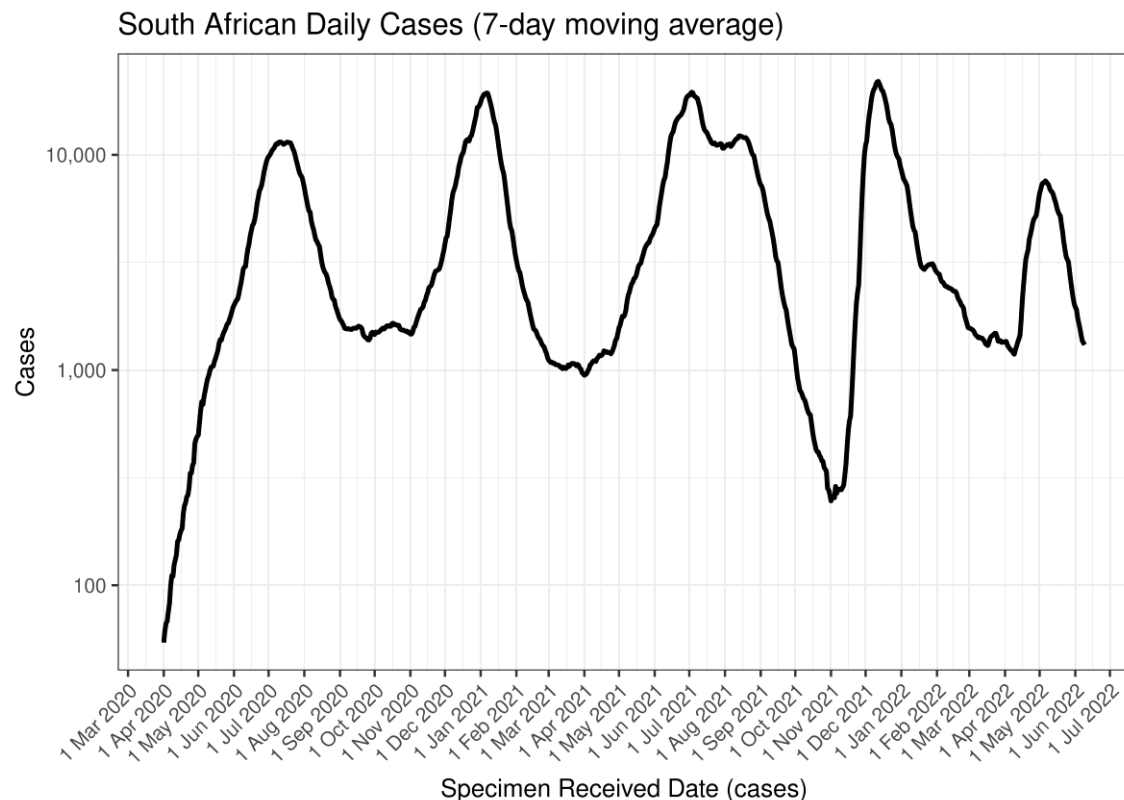
Other automation enablers

- Reproducible
 - Environment
 - Same data, same result
- Code contains all steps
 - No manual steps

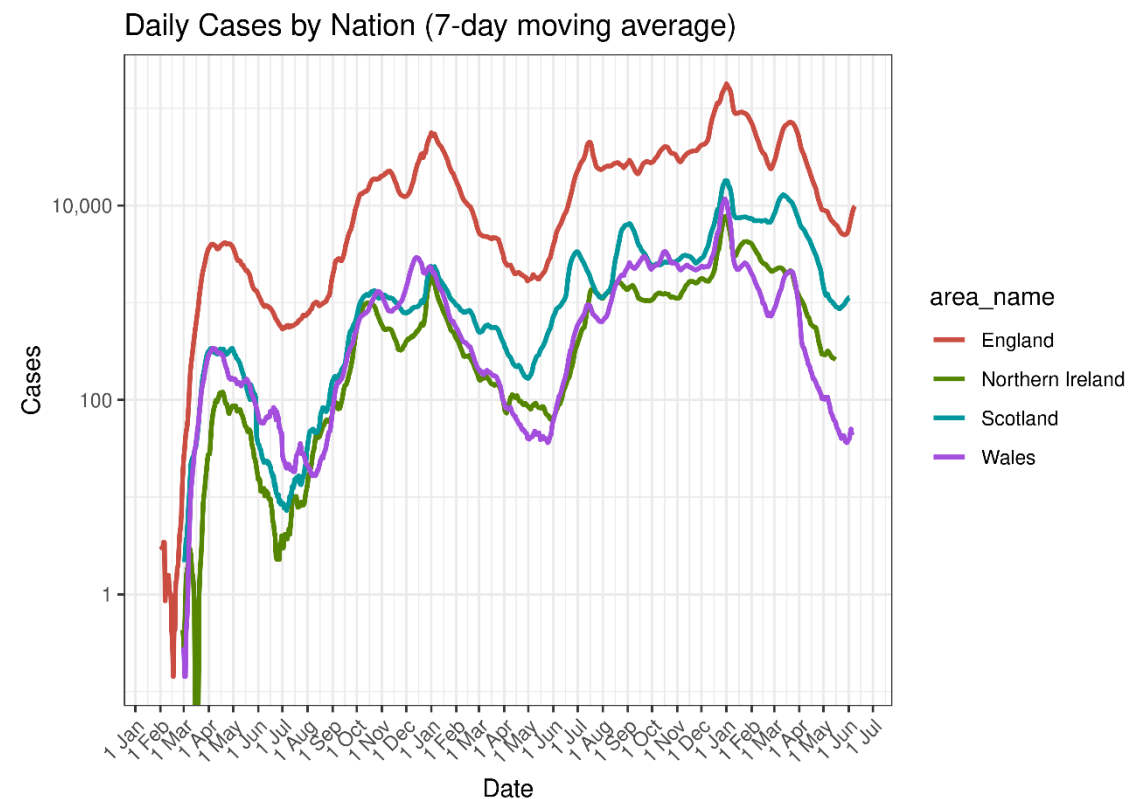


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Results – Cases



https://unsupervised.online/static/covid-19/estimating_r_za.html



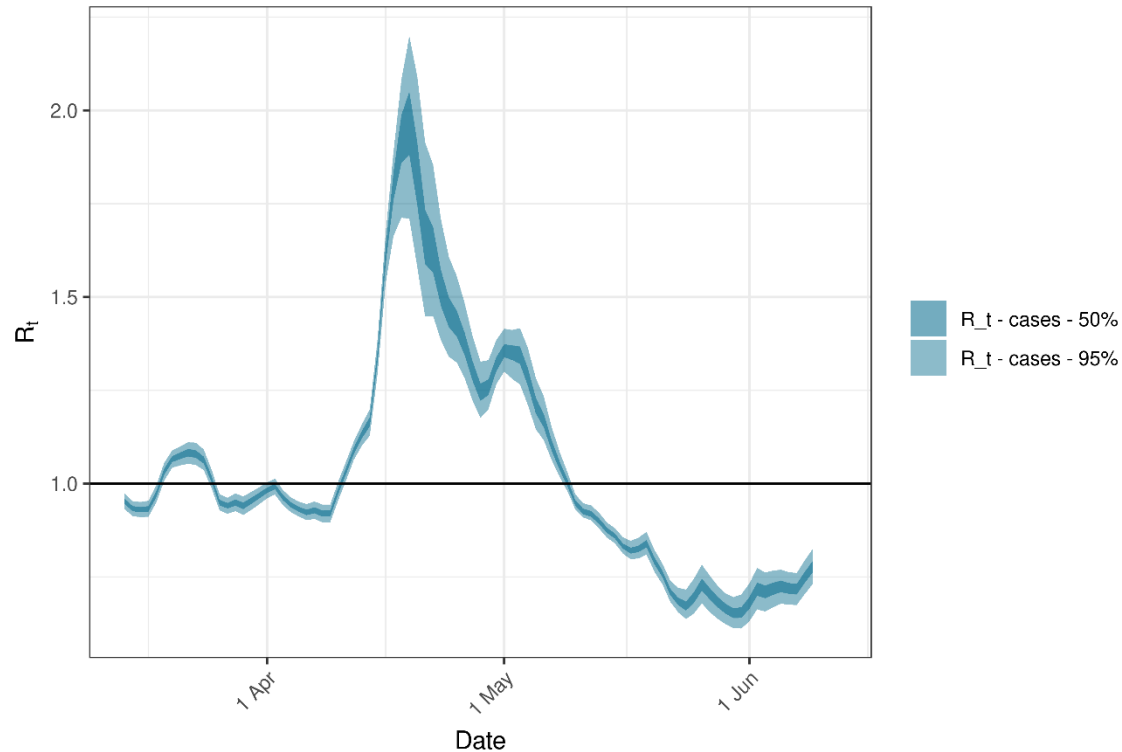
https://unsupervised.online/static/covid-19/estimating_r_uk.html



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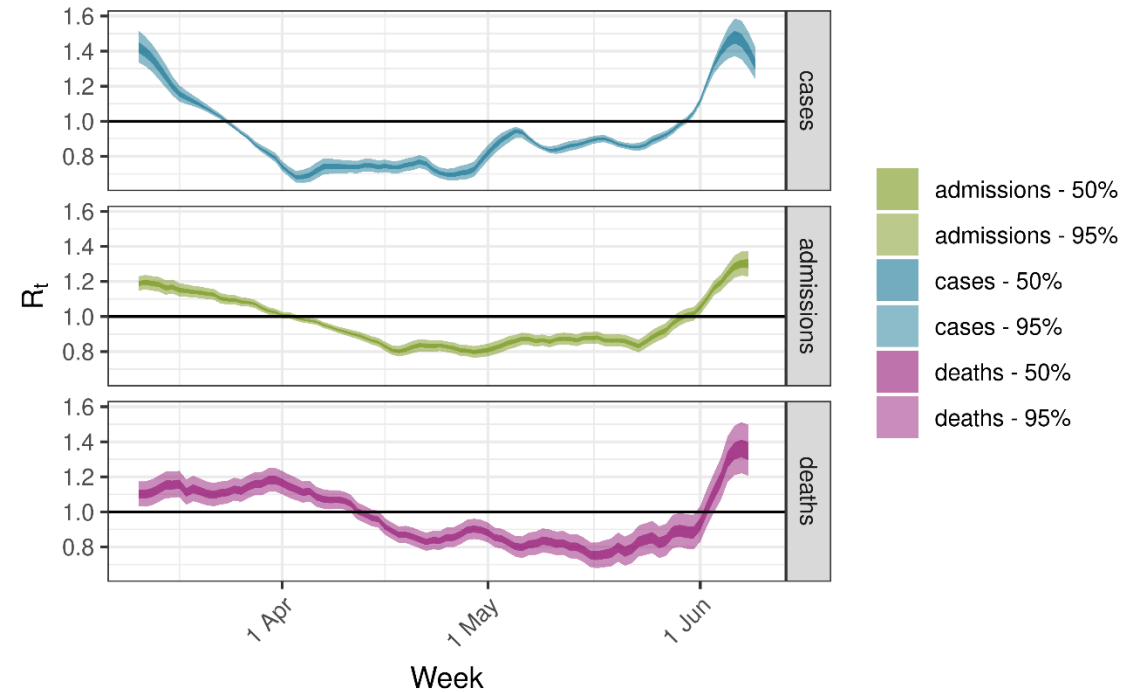
Reproduction number

Effective Reproduction Number (Cases) for South Africa



https://unsupervised.online/static/covid-19/estimating_r_za.html

Effective Reproduction Number for England



https://unsupervised.online/static/covid-19/estimating_r_uk.html



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South African Crude Ratios Per Wave

Wave	Case Admission Ratio	Case Fatality Ratio	Case Excess Deaths Ratio	Hospital Fatality Ratio	Death Reporting Ratio
Wave 1	10.2%	1.87%	7.01%	18.3%	26.7%
Wave 2 (Beta)	20.3%	4.40%	12.36%	21.7%	35.6%
Wave 3 (Delta)	13.4%	3.10%	8.36%	23.1%	37.0%
Wave 4 (Omicron)	9.8%	0.95%	4.45%	9.7%	21.4%
Wave 5 (BA.4/BA.5)	9.3%	0.72%	5.05%	7.7%	14.2%

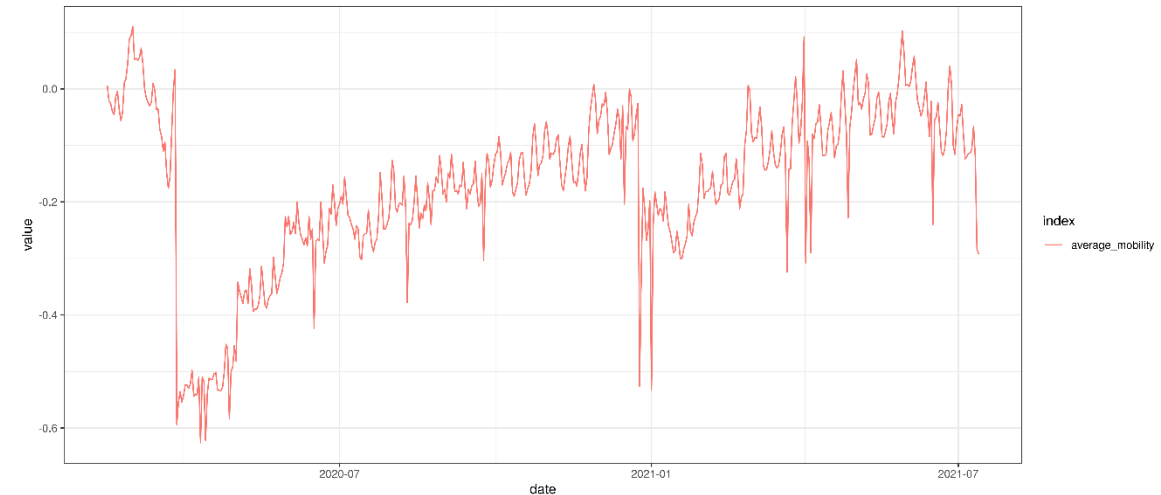
https://unsupervised.online/static/covid-19/estimating_r_za.html



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Modelling

- Bayesian Hierarchical Model to calibrate model parameters based on observed death data and prior assumptions
- Reproductive number is linked to mobility data as well as mask wearing laws
- Reproductive number generates infections
- Population weighted IFRs to model deaths from infections
- Single combined model for all provinces
- Allows for uncertainty
 - Prior assumptions
 - Updated posterior distributions
 - Projections allow for parameter uncertainty
- No allowance for vaccines.



Online model:

- South Africa by Province

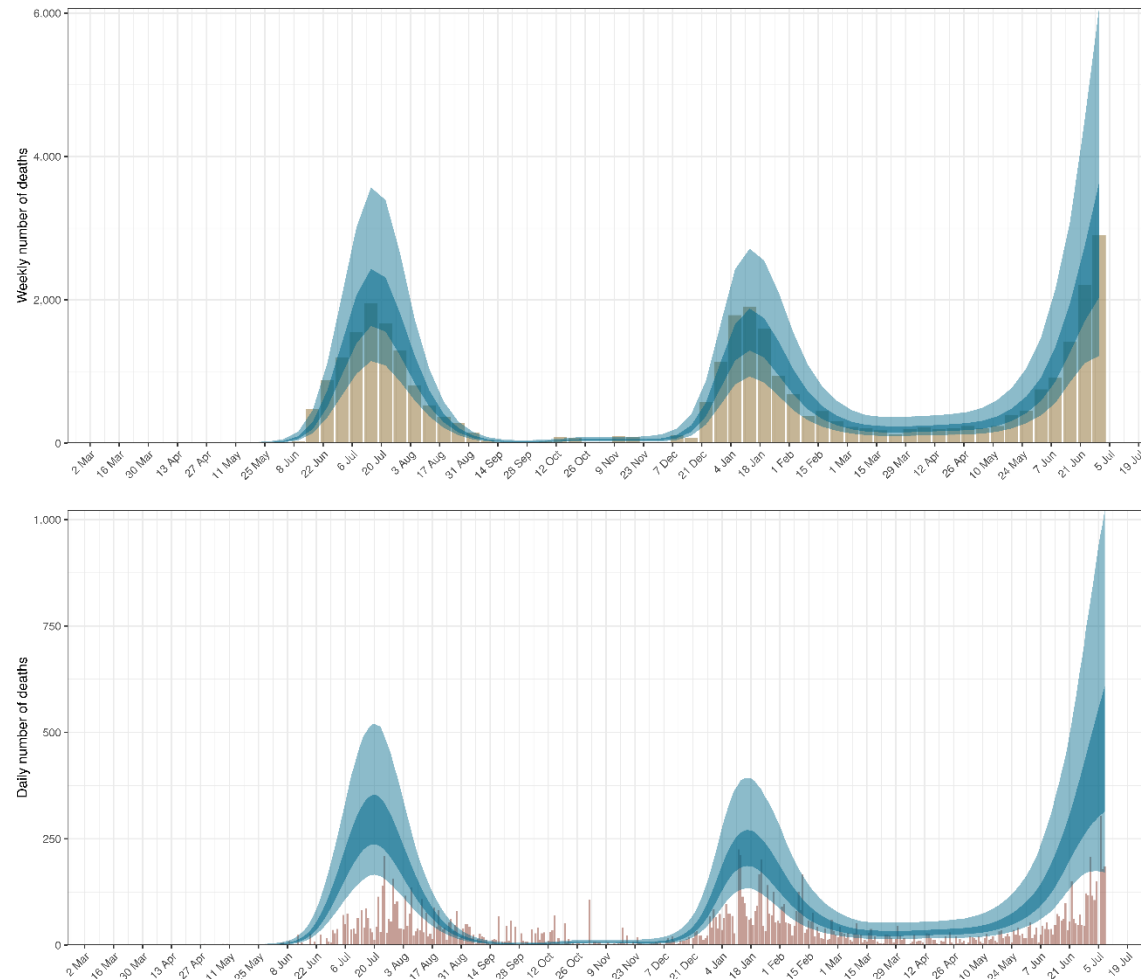


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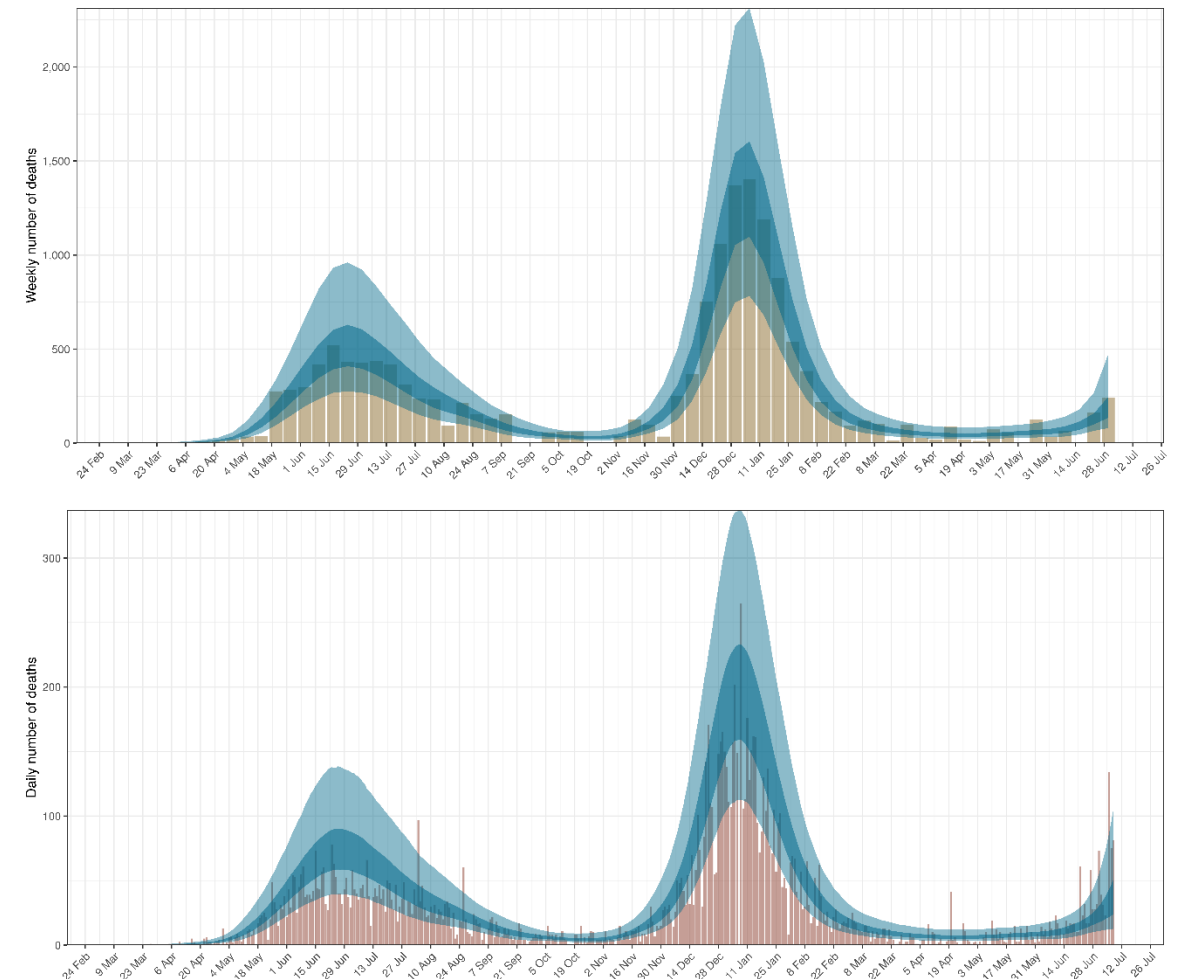
Calibration to Excess Deaths

Reported deaths shown for reference

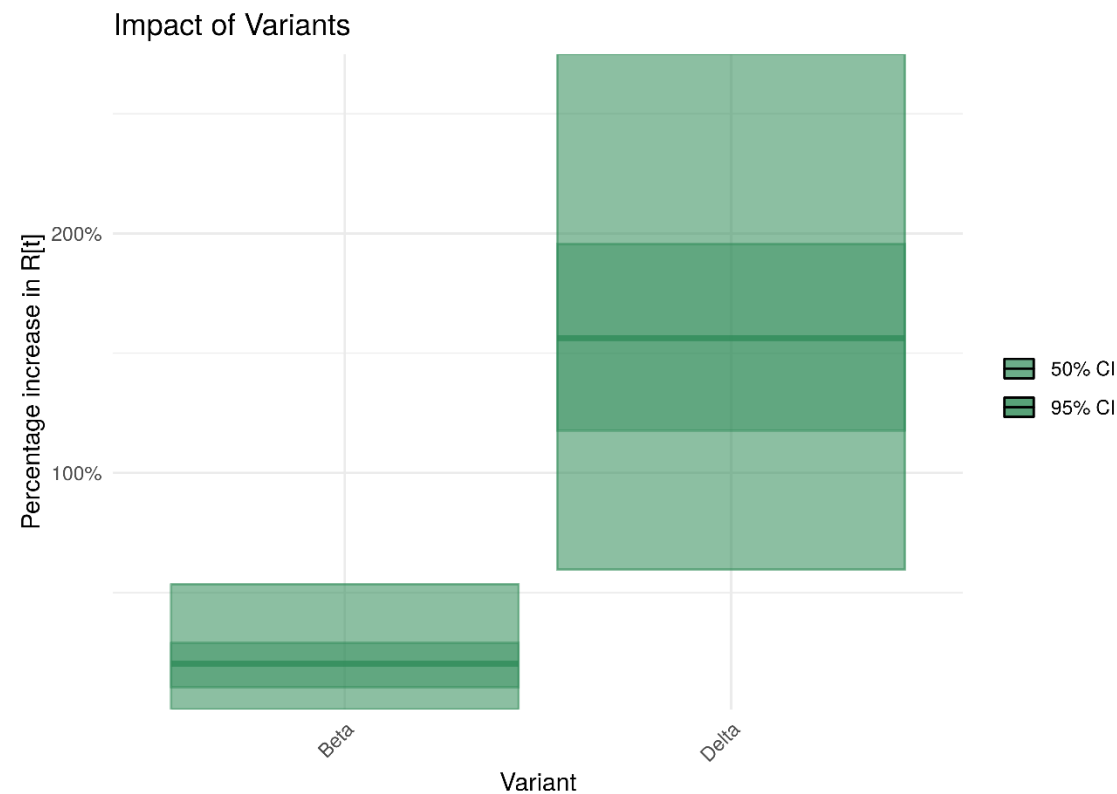
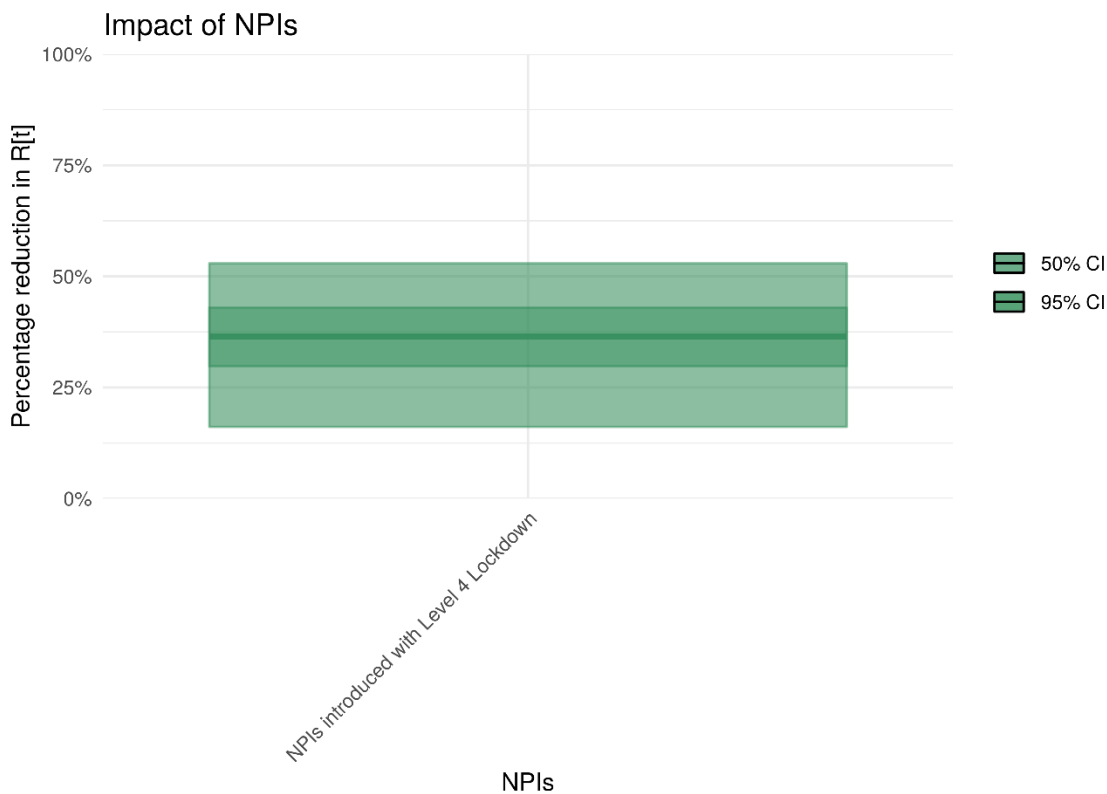
Gauteng



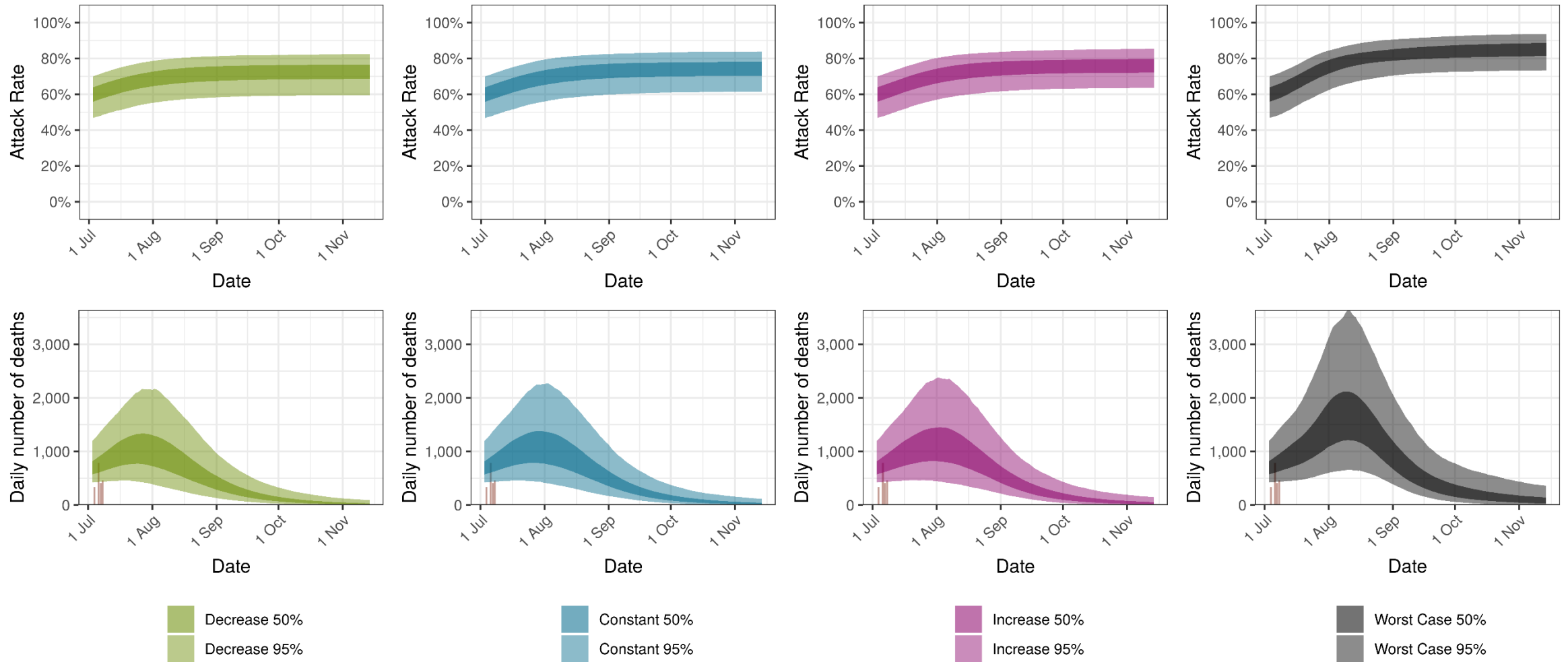
Western Cape



Parameters and uncertainty



Projections – South Africa



Predictions

“Nowcast” estimates as of 8 July 2021

Province	Attack Rate	Cumulative Deaths
South Africa	61.6% [48.6%-72.0%]	173 450 [155 890 – 192 740]

“Worst-case” predictions to December 2021

Scenario	Attack Rate	Cumulative Deaths
Worst Case	85.0% [73.6%-93.7%]	273 152 [221 026 – 355 246]
No Change	74.0% [61.6%-83.9%]	237 368 [198 504 – 293 123]



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Thinking past COVID-19?

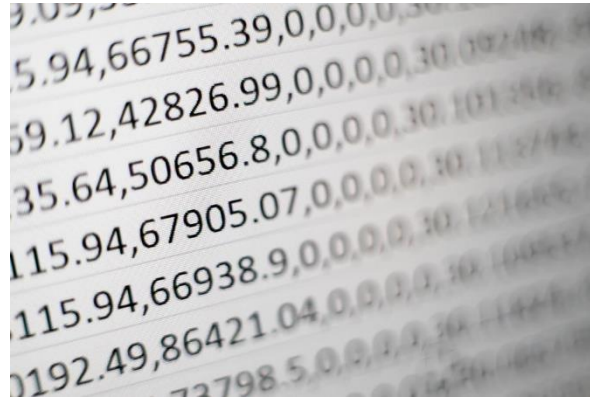
Actuaries need to handle uncertainty in many contexts

Prior Views

- Prior studies
- Judgement
- Population data
- Emerging risks



Data



Posterior

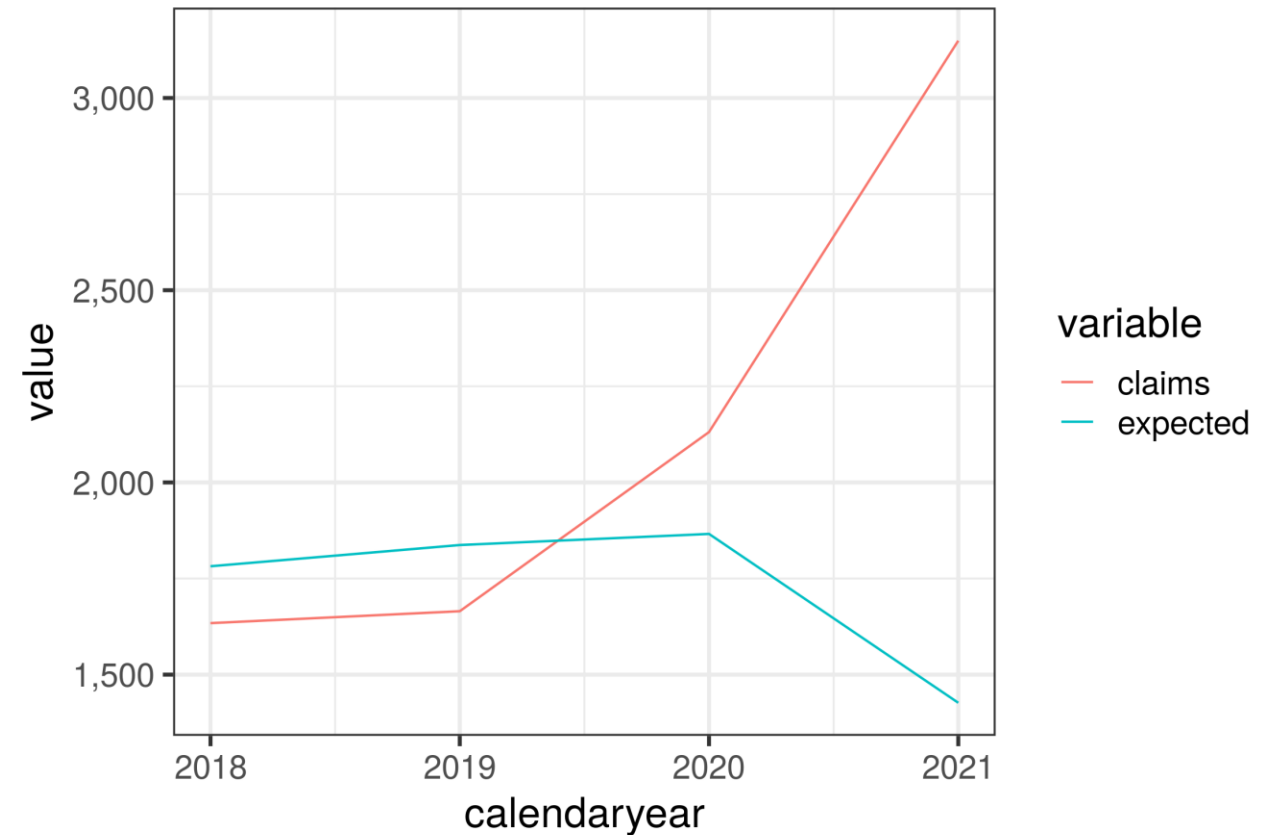
- Updated distributions
 - New mean
 - Updated uncertainty
- Reflecting combination
- Very complex models



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Insured Experience 2020-2021

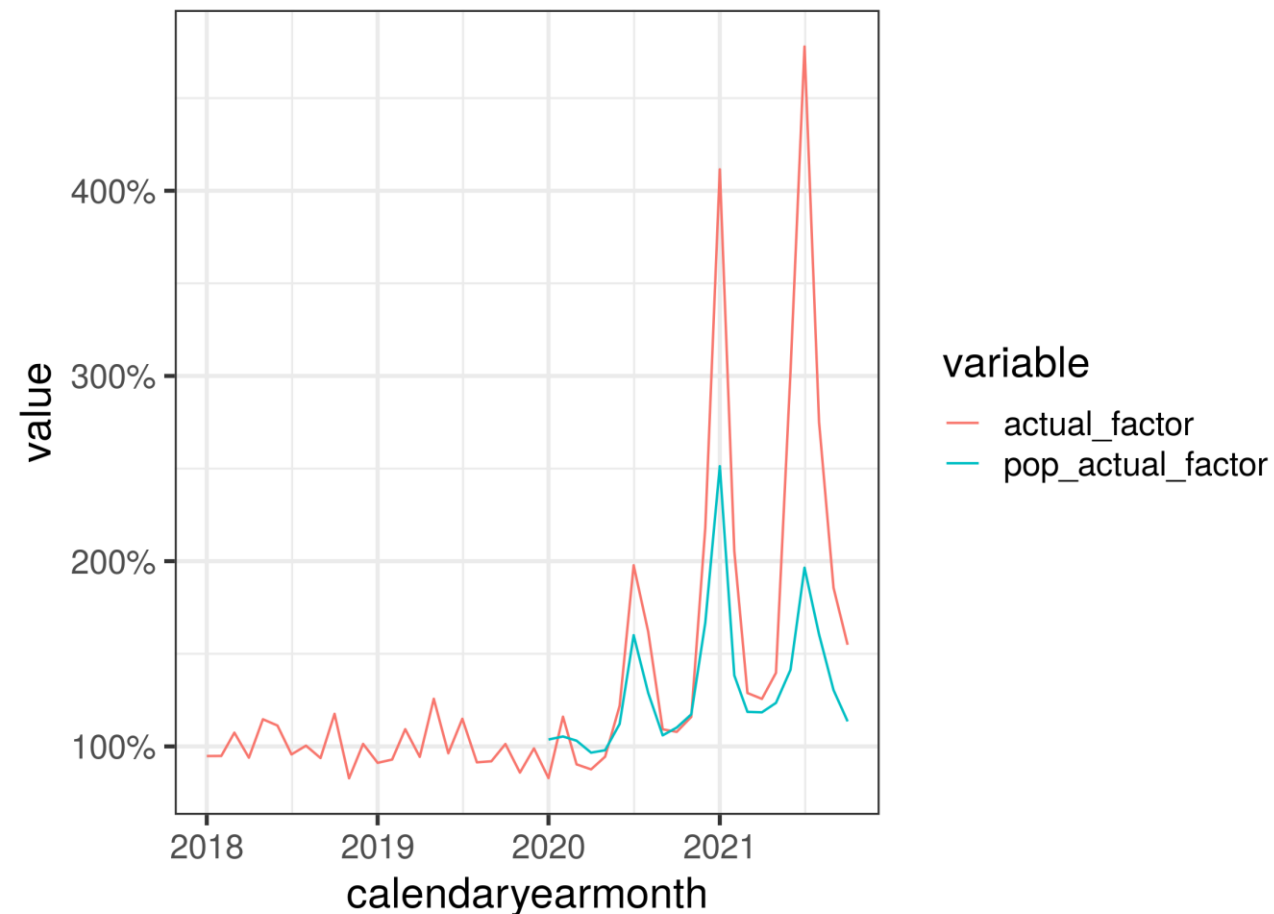
- Claims well over expected
- Understand patterns in experience
- Underlying experience?



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Step 1: Break-down exposure

- Monthly exposure and claims
- Insured experience worse?
- Median age in population <25
- Insured much older.



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Step 2: Model

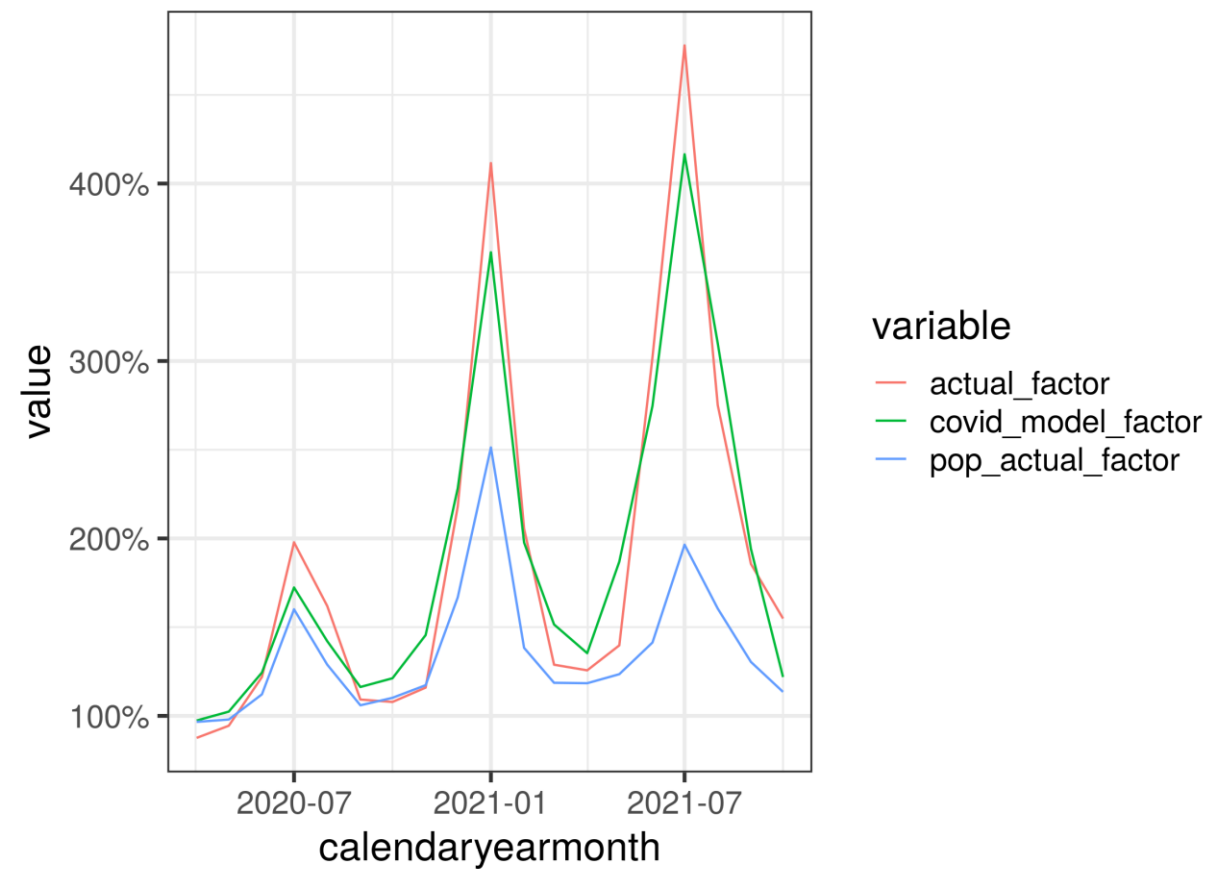
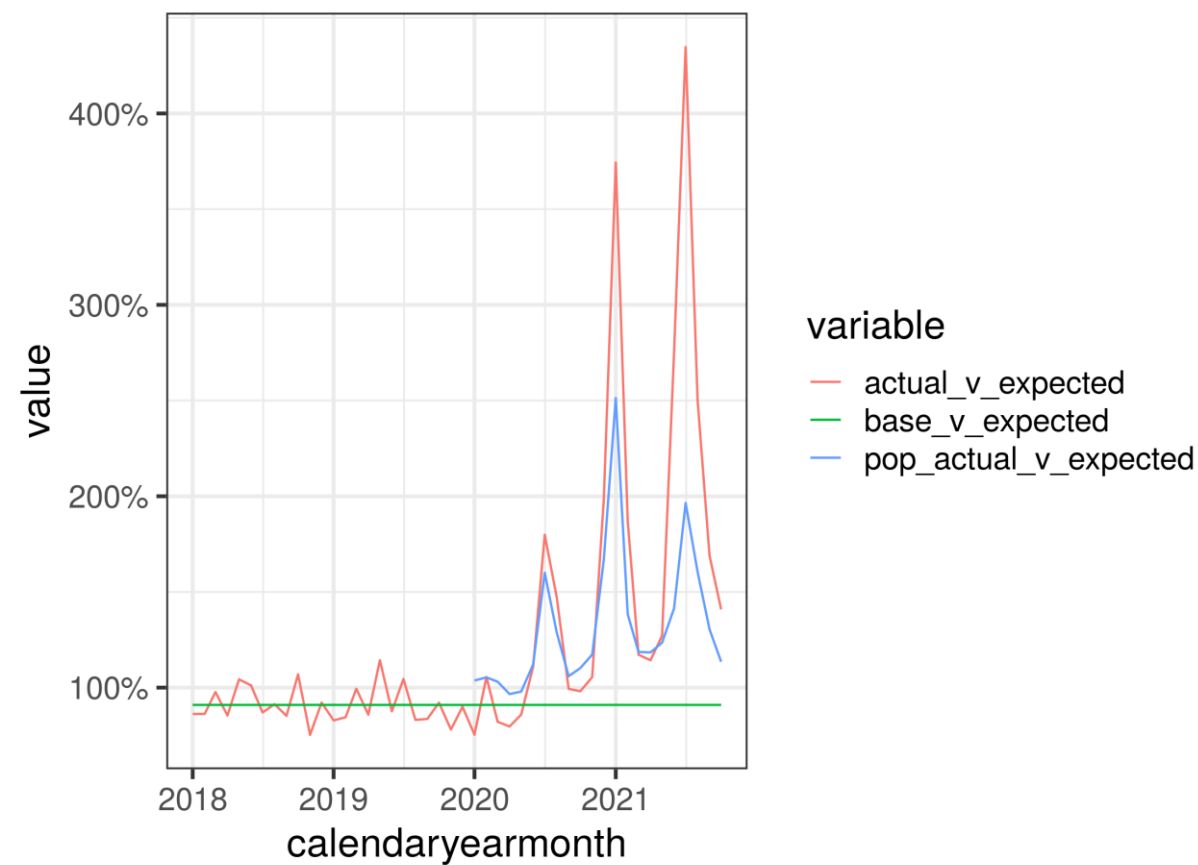
- Model structure

$$\log\left(\frac{actual}{expected}\right) \sim \sum_i x_i \beta_i + x^{covid} \sum_i x'_i \beta'_i$$

- x^{covid} is an indicator variable (0 before April 2020, otherwise 1)
- Additionally, the second term contains shape adjustments on a monthly basis
 - Allows approximate matching of experience by month
 - Allows contains terms for age, gender, face bands etc
- In theory we can separate out the underlying experience $\sum_i x_i \beta_i$ from the COVID-19 experience $x^{covid} \sum_i x'_i \beta'_i$
- Penalised regression to select variables.



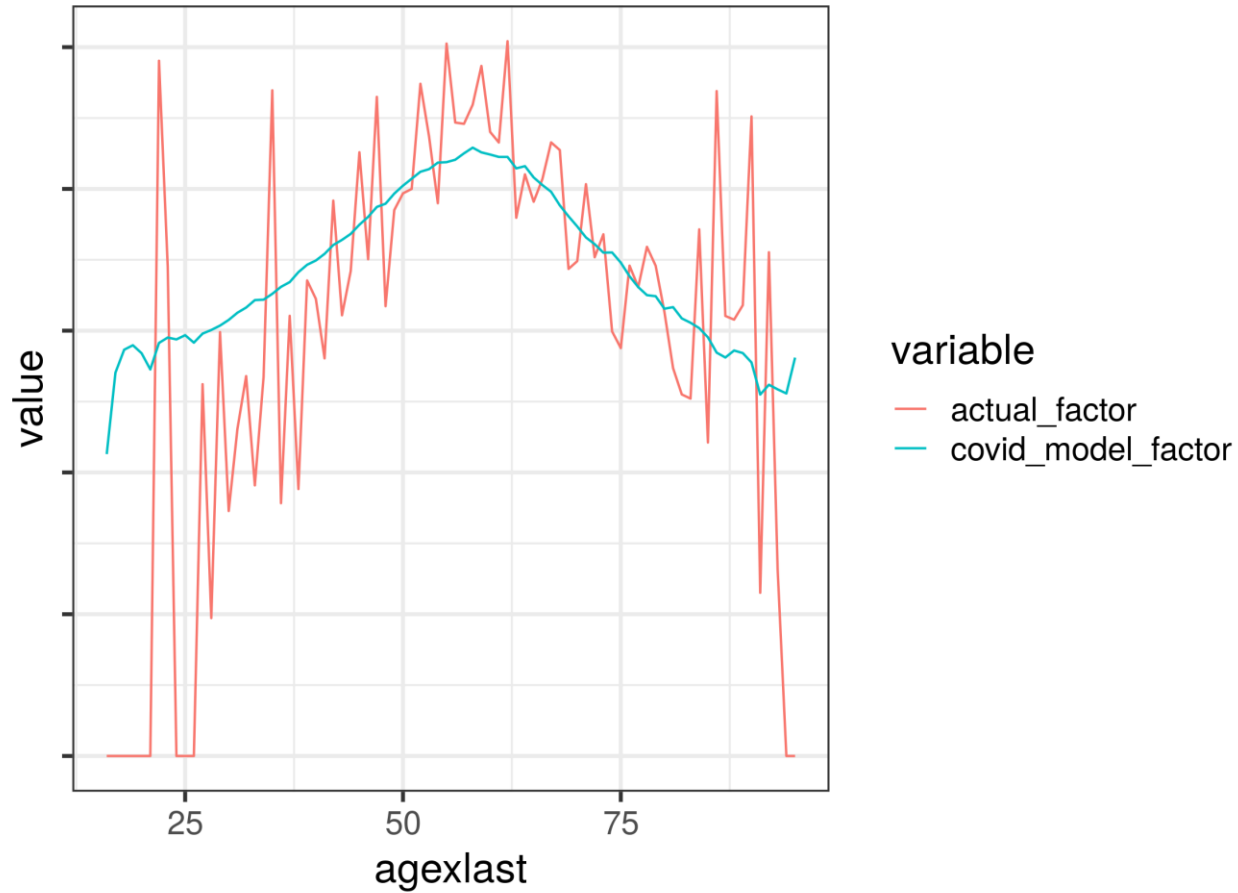
Updated Experience



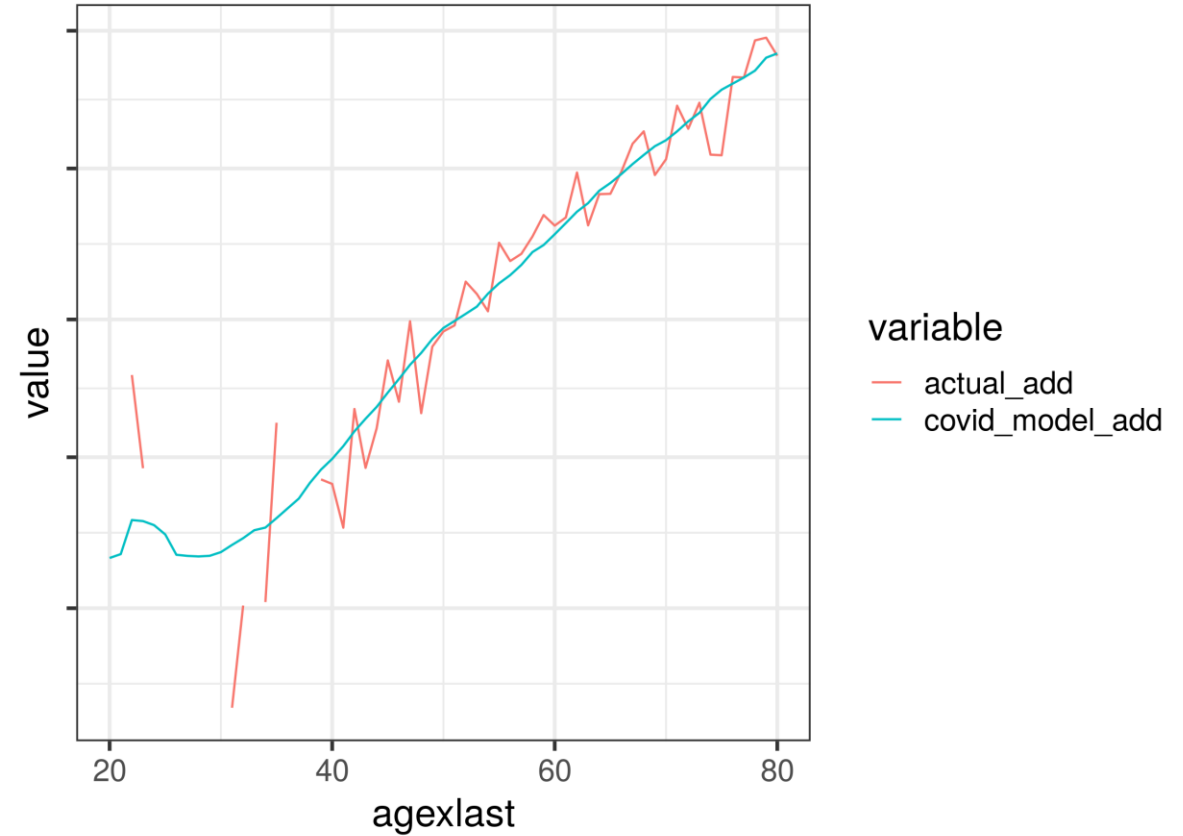
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By Ages

Excess Mortality (Factor)



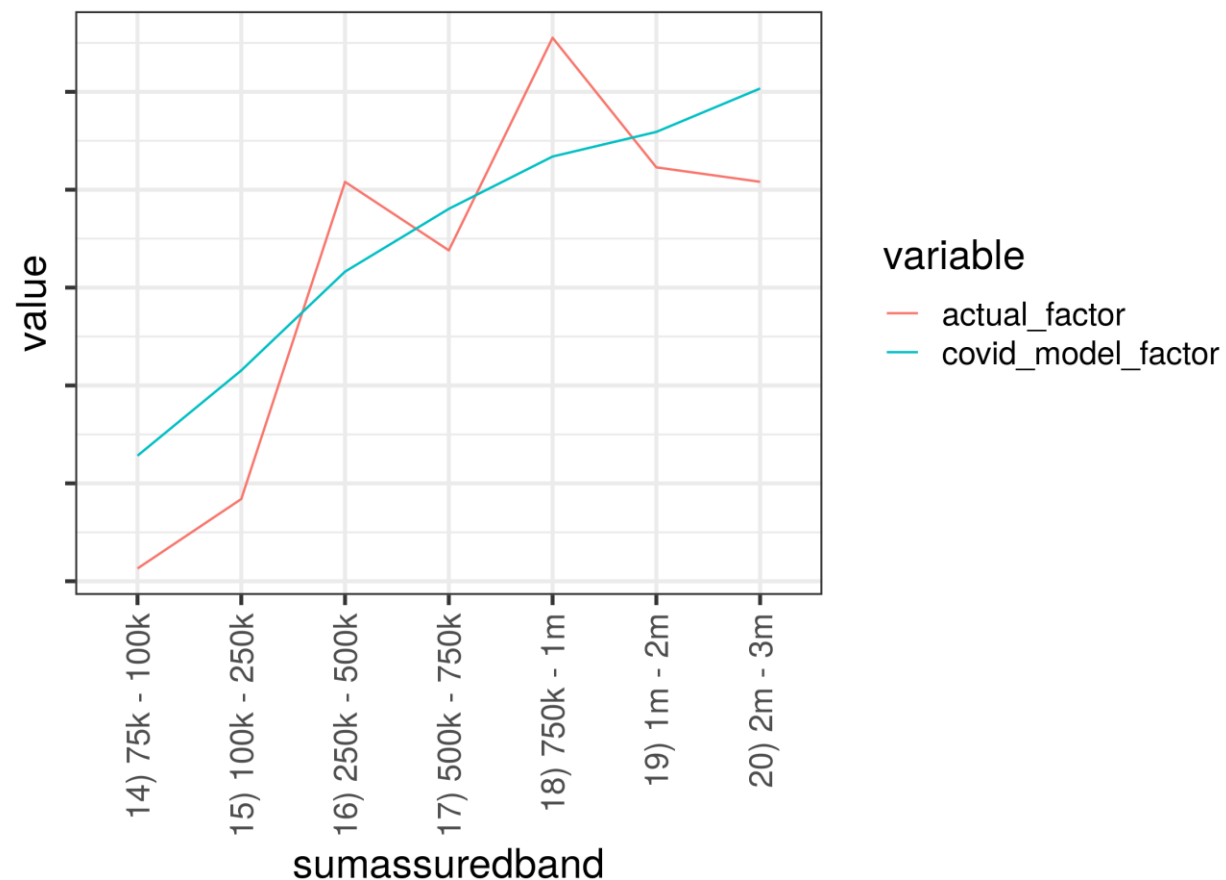
Excess Mortality (Additional)



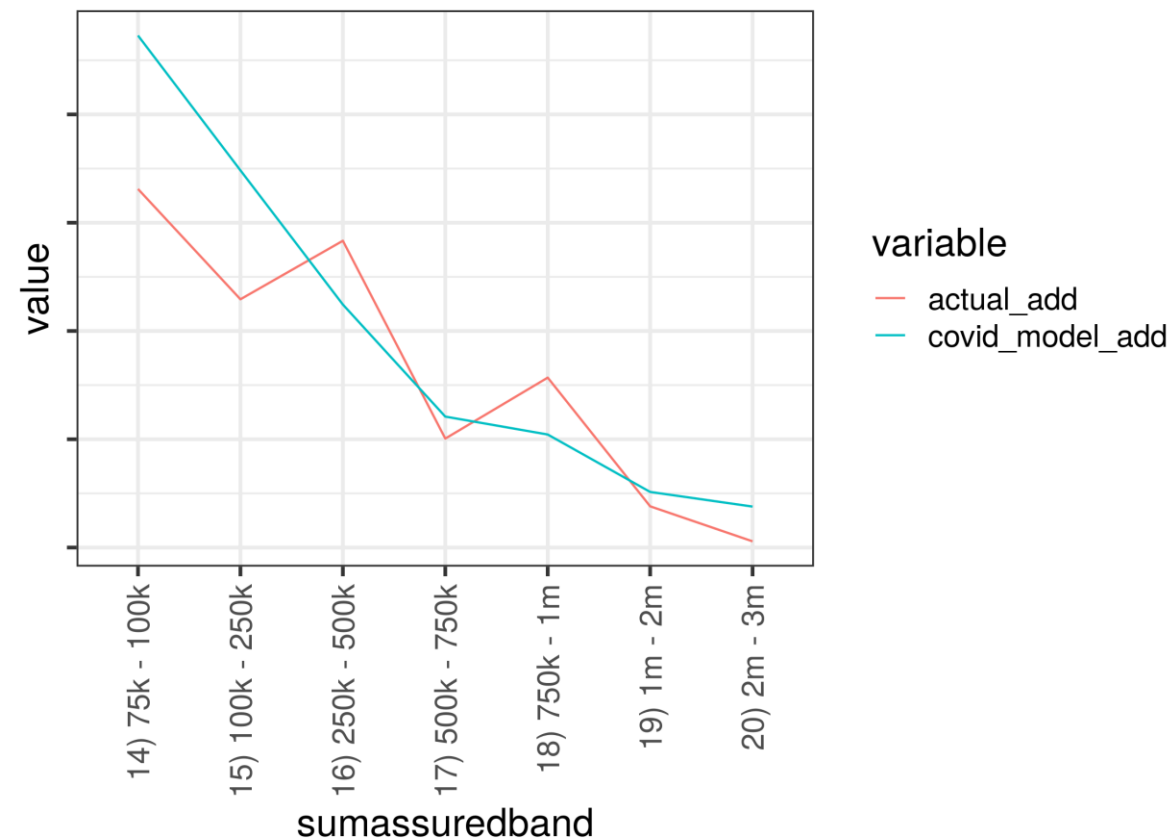
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Sum Assured Bands

Excess Mortality (Factor)



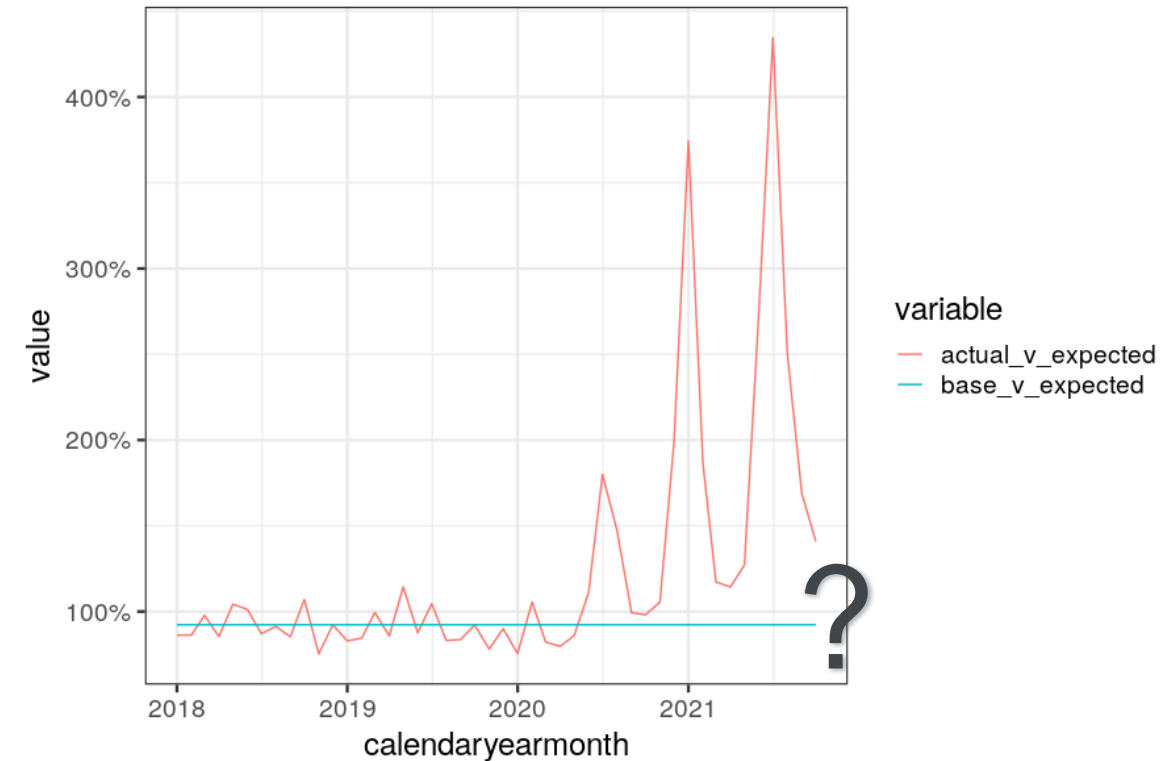
Excess Mortality (Additional)



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Problem Solved?

- A bridge too far?
- Some “post-COVID” experience would be useful
- Extreme example
- Helps understand underlying patterns
- Informed decision making
 - Requiring judgement
 - Allowance for outlook
- Monitoring.



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Advancing Analytics with COVID-19

- “Standing on the shoulders of giants”
 - Open data
 - Open packages
 - Collaboration gets things done
- Code tracking
- Automation is key
- Uncertainty
 - Parameter
 - Systemic
- Parameter uncertainty
- Judgement required



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Questions

Comments

Expressions of individual views by members of the Institute and Faculty of Actuaries and its staff are encouraged.

The views expressed in this presentation are those of the presenter.



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Thank You

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