Calculation Method for Large Seismic Hazard Models and the 2022 Revision of the New Zealand NSHM

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Te Tauira Matapae Pūmate Rū i Aotearoa
NSHM The New Zealand National Seismic Hazard Model
A GNS Science Led Research Programme

E mahi ana me
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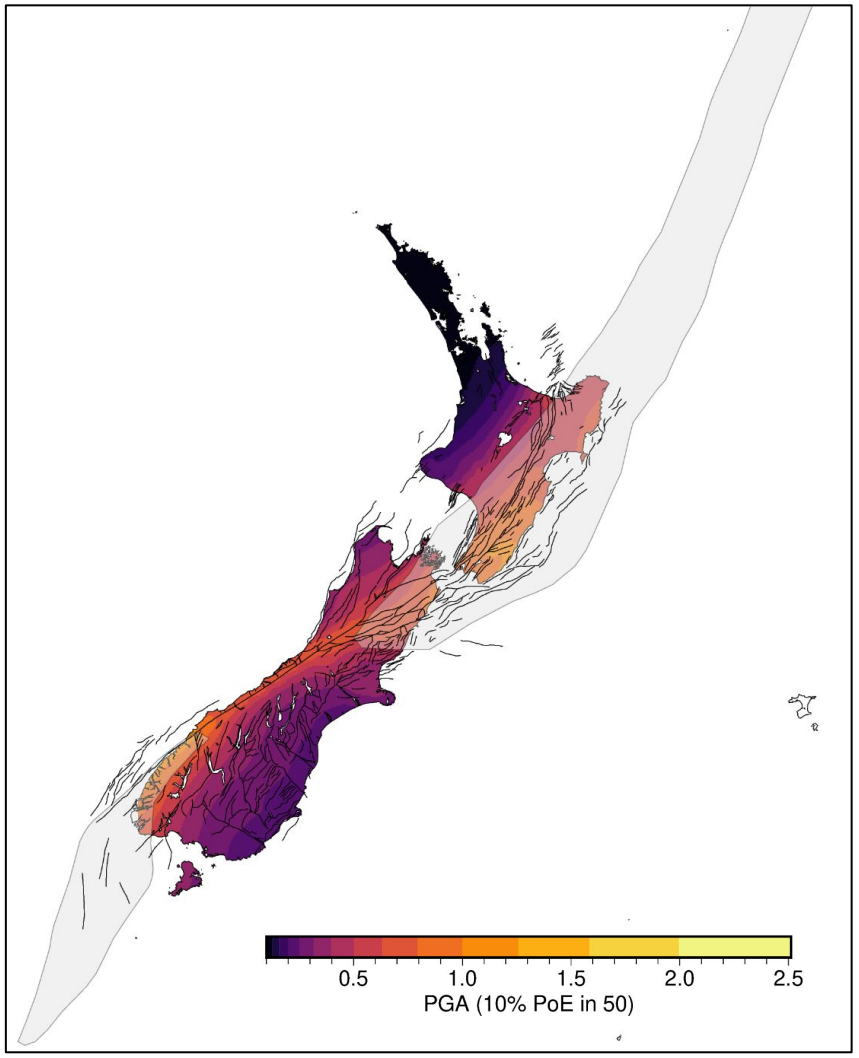
Outline / Summary

- **The NZ NSHM 2022 model is quite large for an NSHM and was initially not possible to calculate**
  - Capturing epistemic uncertainty was an important feature of NZ NSHM 2022
- **Our approach:**
  - decompose the logic tree into independent parts (component branches)
  - Store those realizations in a database (available in the cloud or on local disk)
  - *a posteriori* assemble realizations for all branches of logic tree and calculate aggregate statistics
- **Use of cloud computing and database technologies**
  - New portable DB format
- **Brief examples of application**

The New Zealand NSHM Revision 2022: Size of the Task



- 324 (SRM) x 3024 (GMCM) = 979,776 total branches
- 3774 sites (0.1 deg calculation grid)
- 16 spectral periods
- 18 site conditions (Vs30)

Initial tests using OQ v3.17 were hitting time and memory bounds. **We needed an alternate approach to calculating the hazard curves.**

Assuming we were able to calculate the model, we needed a way to easily and rapidly do so

Break the Problem Down . . .

Break problem into smaller independent parts and calculate the solution in 2 stages

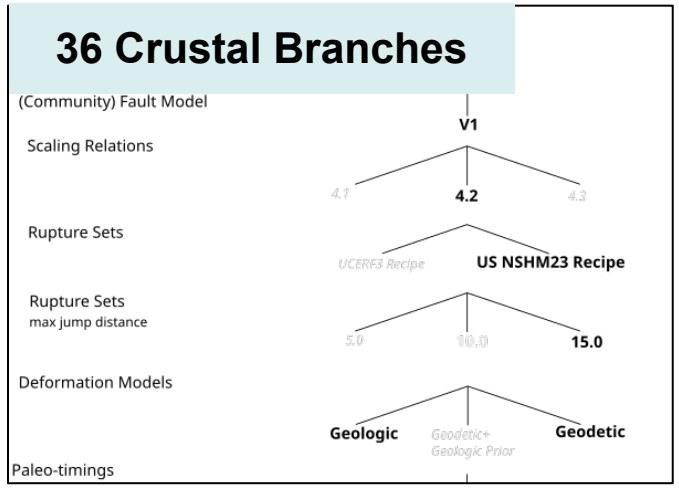
- Manageable sized parts
- Parallelization

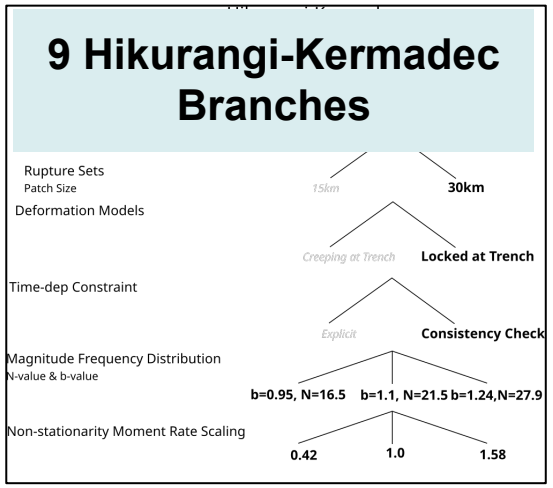
Stage 1:

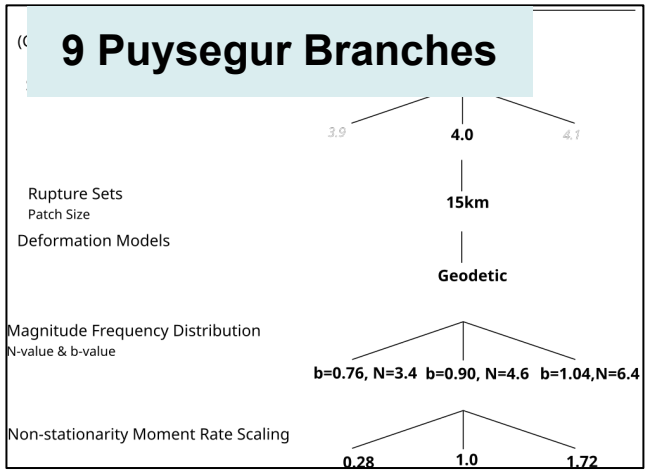
- Treat each branch of the SRM tree separately
  - 49 OpenQuake runs each producing 12 - 21 realisations
- Store independent realisations in cloud database (referenced by unique ID)

Stage 2:

- Calculate complete ~1M branch realizations as combinations of component realisations
- Calculate weighted mean, std, and quantiles from the full set of realisations



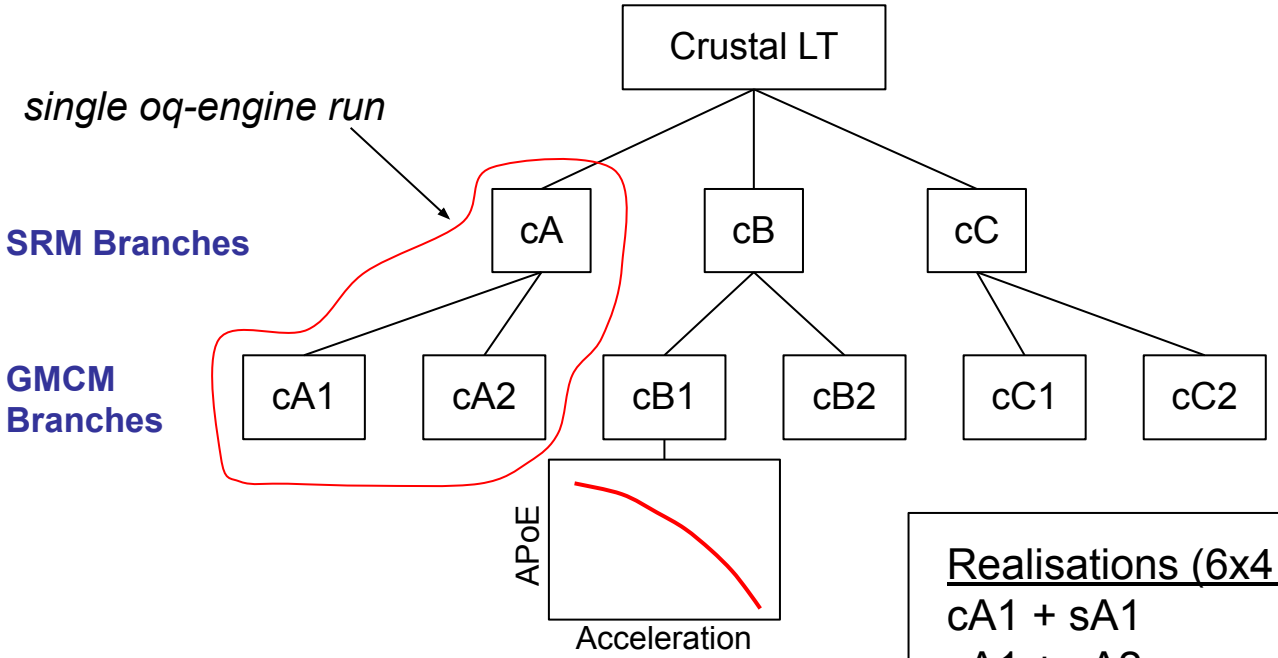


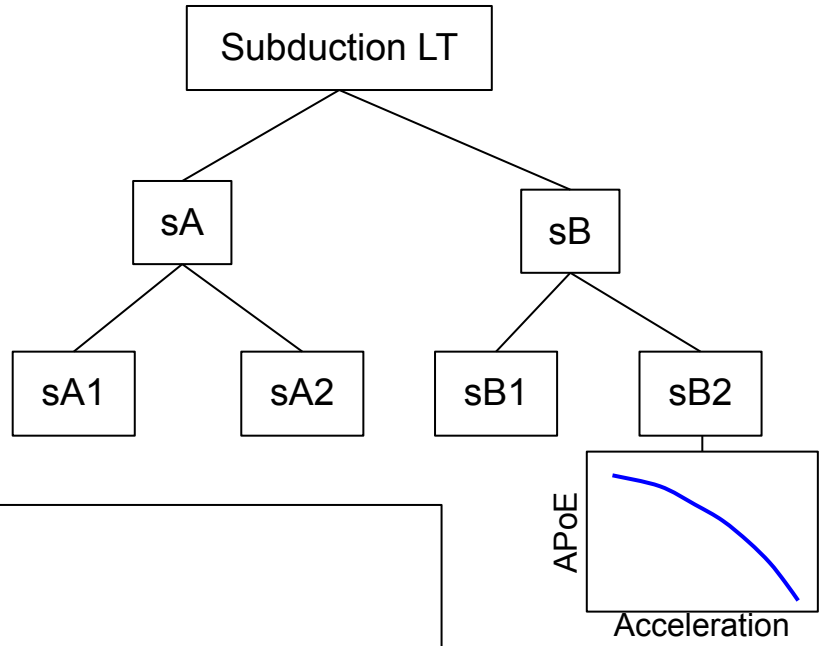


1 Intra-Slab Branch

<u>324</u> SRM Logic Tree Branches

Toy Example - 6 SRM branches, 4 GMCM branches





- 5 oq-engine runs
- 2 realisations per run
- 24 total combinations

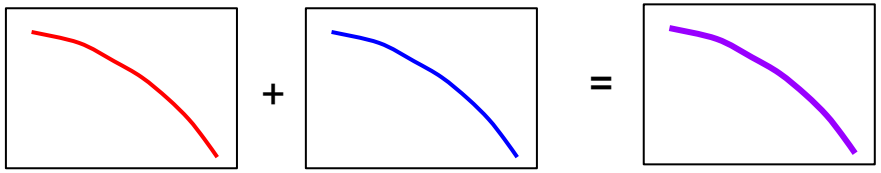
Realisations (6x4 = 24 total)

cA1 + sA1

cA1 + sA2

…

cB1 + sB2 =



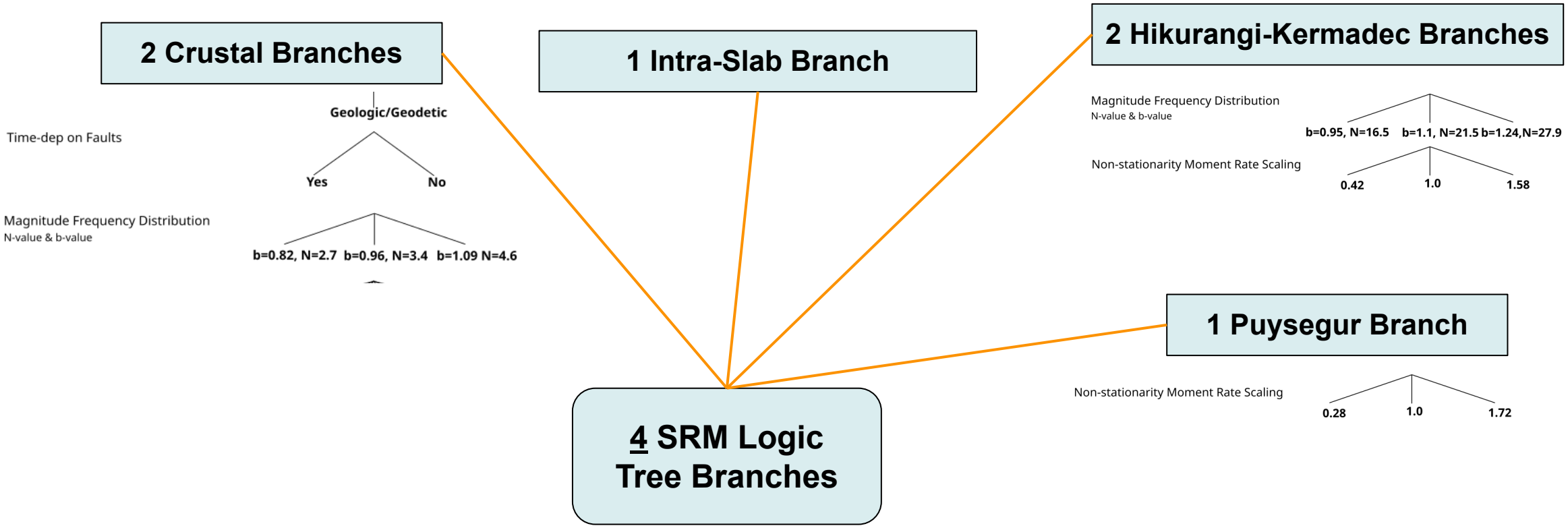
sum hazard curves in rate space

…

…

cC2 + sB2

Verification



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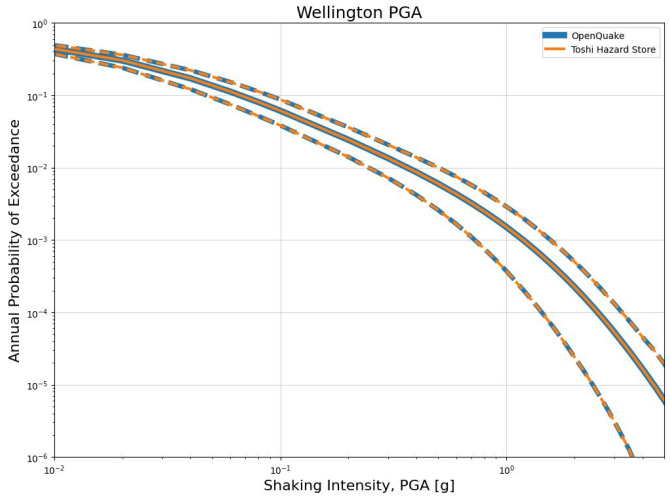
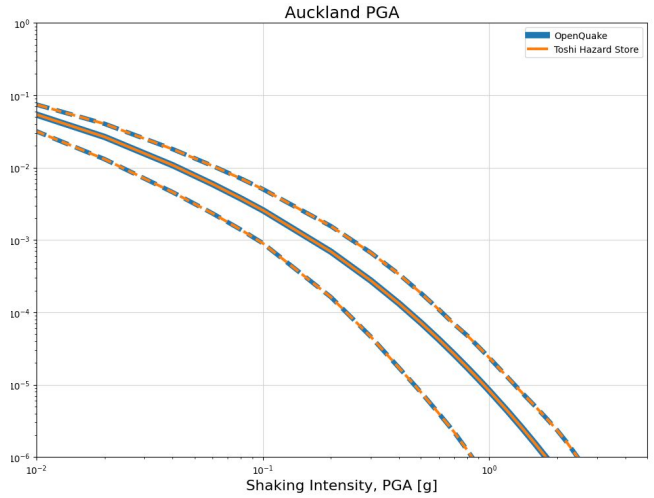
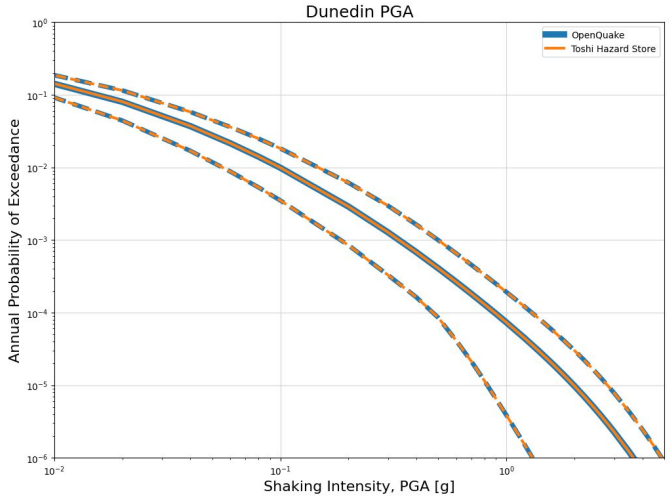
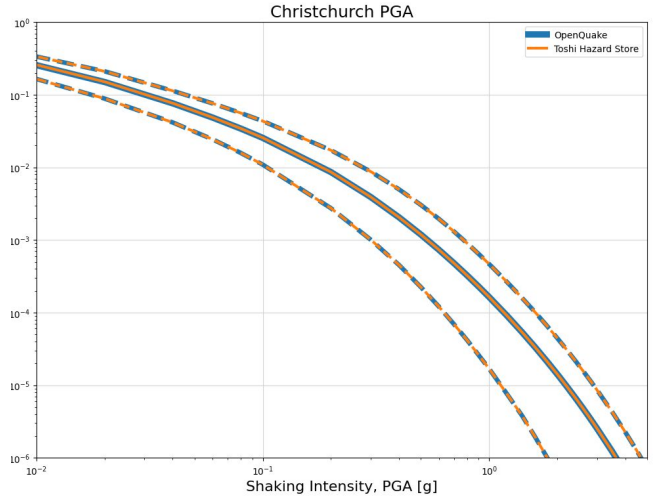
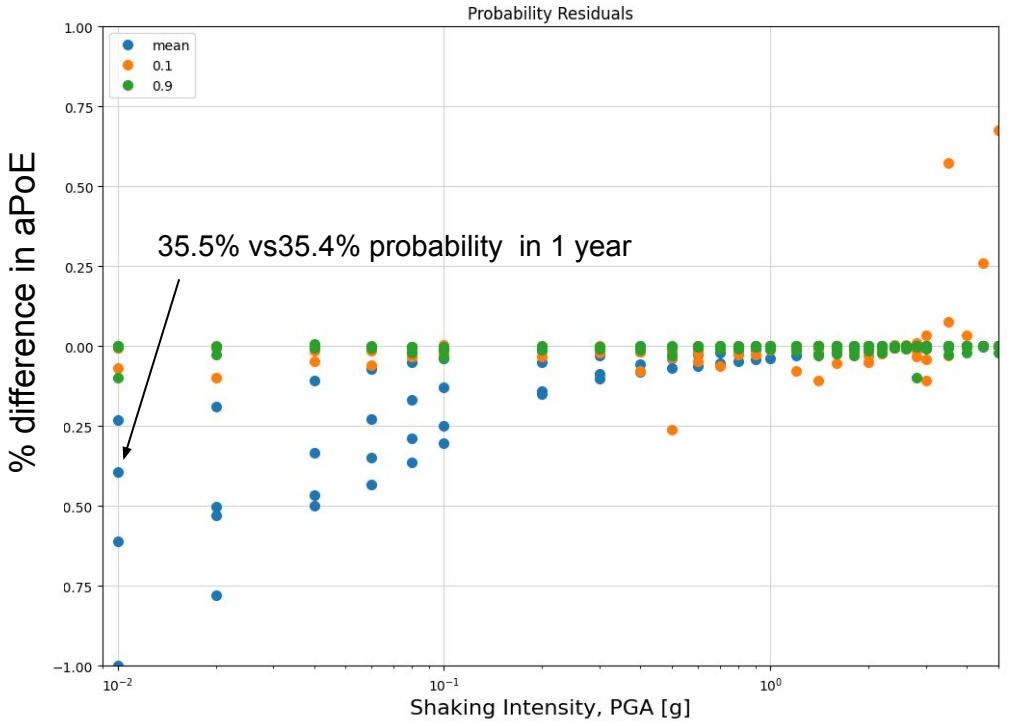




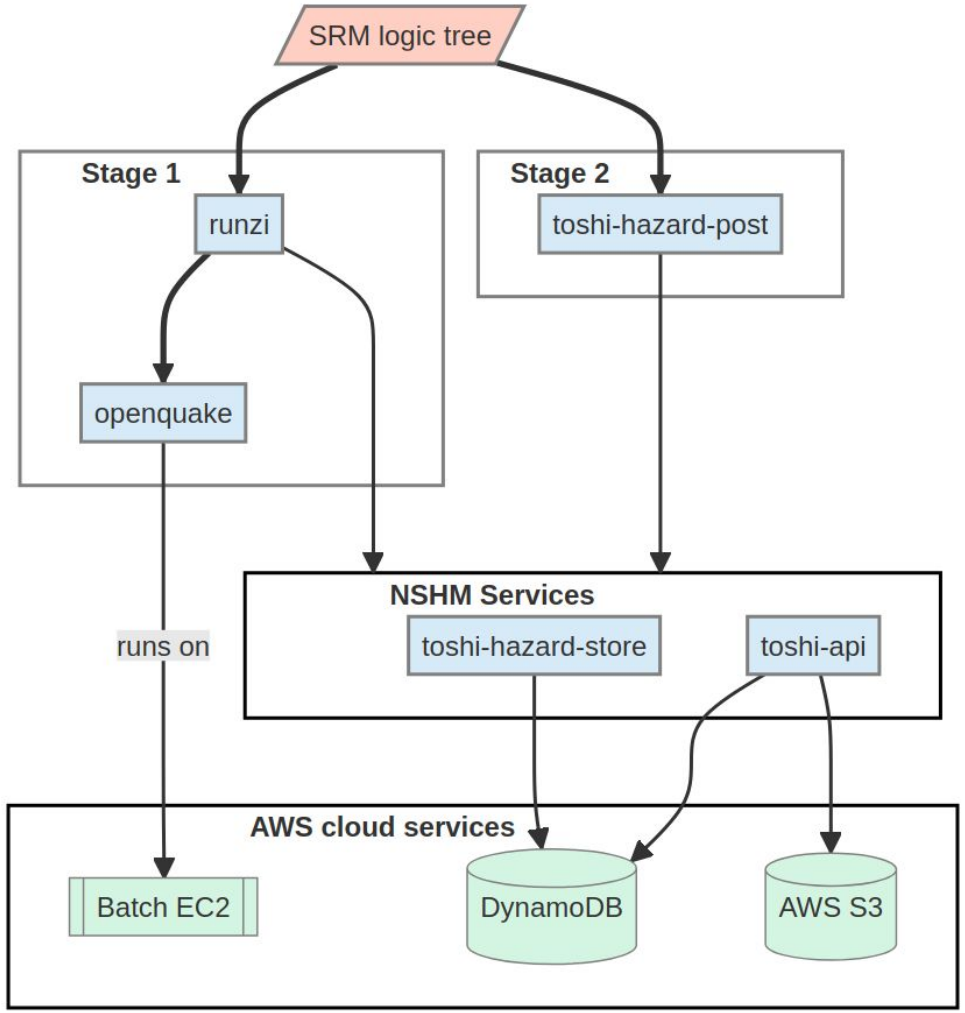






IT Stack and Deployment of Hazard Calc

- Allowed us to **parallel process hazard curves on modest compute nodes ... sometimes up to 750 concurrent jobs**, each between 1 to 24 hours duration.
- Recombination and calculation of aggregate statistics on workstation or parallel in cloud
  - **Embarrassingly parallel**
- Both stages of the process **easily parallelize and scale** across multiple dimensions of the model
- Breaking the calculation into stages and storing intermediate products provide benefits for experimentation
  - New logic tree configurations, easy sensitivity testing, sub-sampling to find minimum-viable logic trees, minimise calculation overheads, etc.



Parquet: a Portable Database

Initial model bilt using AWS DynamoDB cloud database

- Difficult to share
- Difficult for users to create their own database: requires cloud expertise and sophisticated IT stack

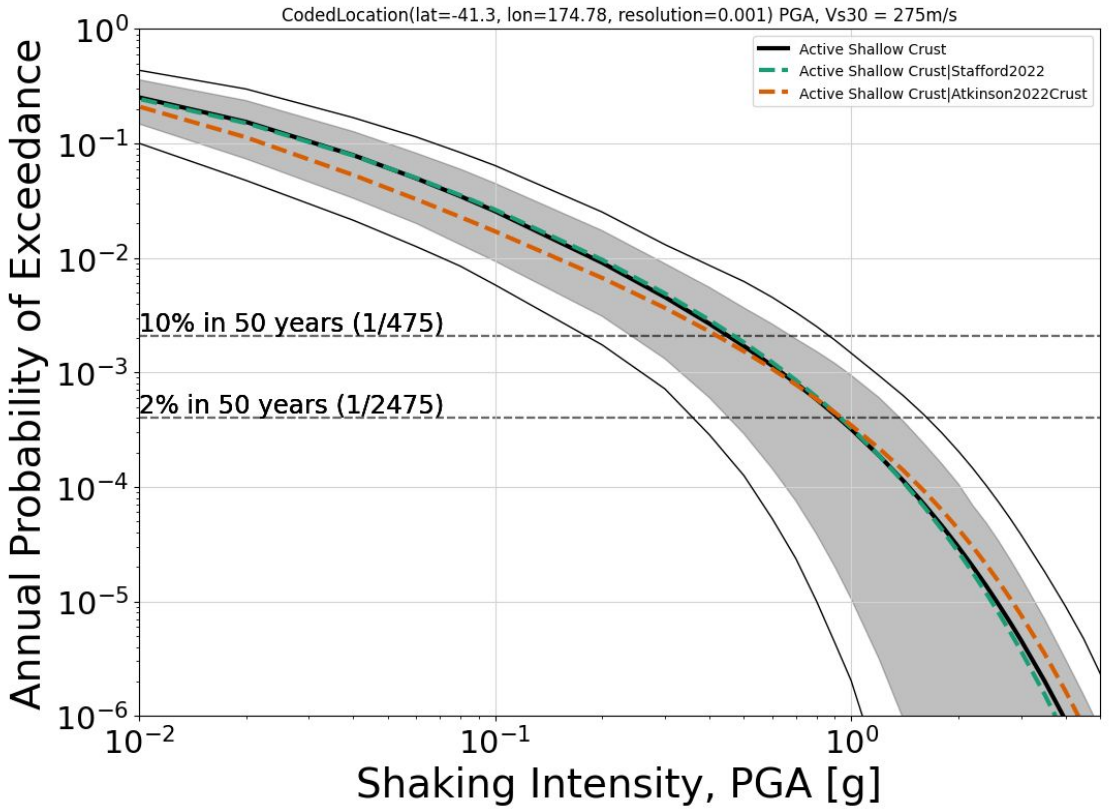
Moving to Parquet file format for component realizations

- Cloud (S3) or local storage
- Portable / sharable
- Easy to use
- Powered by PyArrow python library

Aggregate curves for dissemination to users still stored using DynamoDB

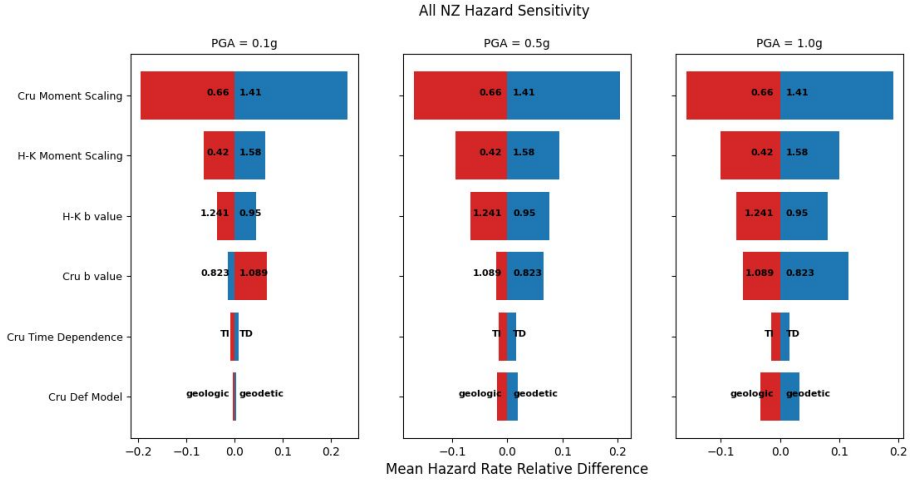
Component Re-Use Example: Sensitivity Testing

Every logic tree branch (both SRM And GMCM) has a unique identifier in the DB making it easy to select the components of interest.




```
args.srm_logic_tree = srm
args.gmcm_logic_tree = gmcm
args.hazard_model_id = trt
run_aggregation(args)

gsim_names = ['Stafford2022', 'Atkinson2022Crust']
for gsim_name in gsim_names:
    print(gsim_name)
    gmcm_1gsim = copy.deepcopy(gmcm)
    gmcm_1gsim.branch_sets[0].branches =
select_gmm(gmcm.branch_sets[0], gsim_name)
    args.gmcm_logic_tree = gmcm_1gsim
    args.hazard_model_id = f'{trt}|{gsim_name}'
    run_aggregation(args)
```



Summary

- **2 stage hazard calculation process allows for calculation of very large logic trees, circumventing software and hardware limitations**
- **Uses:**
  - Easy parallelization using modest computer hardware (e.g. cloud compute)
  - Full logic tree enumeration
  - Re-use of common components of model (e.g. sensitivity testing, logic tree re-weighting)
  - Sharing of common components of model
- **Move to new database technology makes it easier for others to:**
  - Use our model components
  - Build their own large hazard model

NB: Recent performance improvements in OpenQuake Engine (v3.20+) able to handle NZ NSHM 2022

DiCaprio, et. al., Calculation of National Seismic Hazard Models with Large Logic Trees: Application to the NZ NSHM 2022. Seismological Research Letters 2023 https://doi.org/10.1785/0220230226