NZ-focmec (*version 1.0)*: Focal Mechanism Models of the New Zealand National Seismic Hazard Model 2022

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1. Introduction

The NZ-focmec consists of three model sets incorporated into the Distributed Seismicity Model of the New Zealand National Seismic Hazard Model 2022 (Gerstenberger et al., 2024). Each set corresponds to a distinct tectonic regime—shallow crust, subduction interface, and subduction slab.

This documentation describes the model file formats and Python scripts for extracting data from the models, either for use or for validation analyses. The data and methods applied to develop these models are explained in Thingbaijam *et al.* (2022) and Thingbaijam *et al.* (2024a; 2024b). Those details are not covered in this document.

The next section (i.e., Section 2) can be skipped if one is interested only in the Python scripts.

2. File Formats of the Models

Different file formats were used across the tectonic regimes, primarily reflecting differences in model structure. For example, shallow crustal events (hypocenter depth < 40 km) use neotectonic-zone–specific formats, interface events use location-specific formats, and intraslab events use depth-dependent formats. The following sections describe the file format used for each tectonic regime.

2.1. Shallow Crustal Events

The model files are located in the directory: *models/crust/*. There are two files. The first one is *nzfocmecmod.json*, which contains the focal mechanism model for shallow crustal events. The second file, *ntdomains_modified.json,* contains the revised neotectonic zones. The original zonation of neotectonic domains is from Seebeck *et al*. (2024).

Figure 2.1 illustrates the structure of the *nzfocmecmod.json* file. This JSON file is organized as a dictionary with each entry corresponding to a neotectonic domain identified by a unique key. Each domain contains two equally weighted cases (case 1 and case 2), included to account for rake uncertainty; in most domains, the two cases are identical (see Figure 2.2). The model is further classified by rupture length, and therefore by magnitude, using two length thresholds: '>15' for ruptures longer than 15 km and '>45' for those longer than 45 km. For each category, the distributions of strike, dip, and rake (in degrees), along with their associated probabilities, are provided.

A general approach to extract data from the model is as follows:

1. Get the neotectonic domain key (which is a string, not a number, e.g., '1a') based on the epicenter of the event, and
2. Extract the focal mechanism model for that domain number.

If the shallow crustal event is not located in any of the neotectonic domains, the model will not provide a focal mechanism. Note that depth dependence in the focal mechanism is yet to be incorporated.

In cases where only one focal mechanism must be associated with an event (e.g., the development of the Ground Motion database), one may consider the following. When case 1 is the same as case 2, it could be pragmatic to simply use the mean values (i.e., the focal mechanism with the largest probability. However, there could be a need to be creative where case 1 differs from case 2, for instance, constrained through a specific preference of either case 1 or case 2.

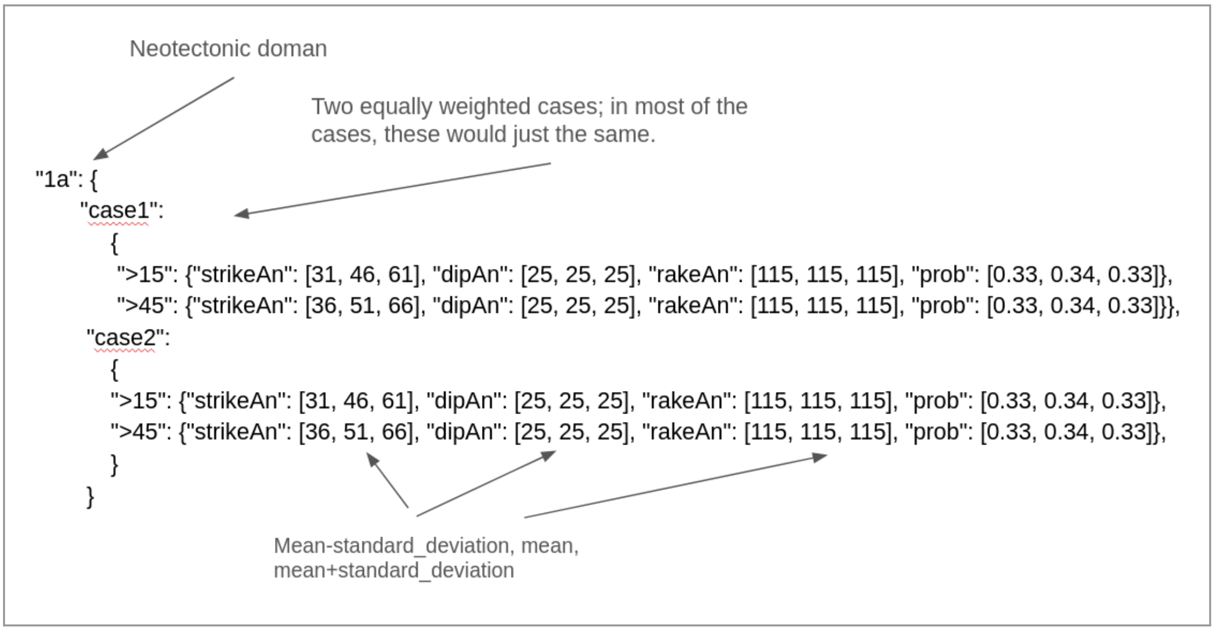

Figure 2.1. An example summarizing the JSON format used to store the formal mechanism model for the shallow crustal events.

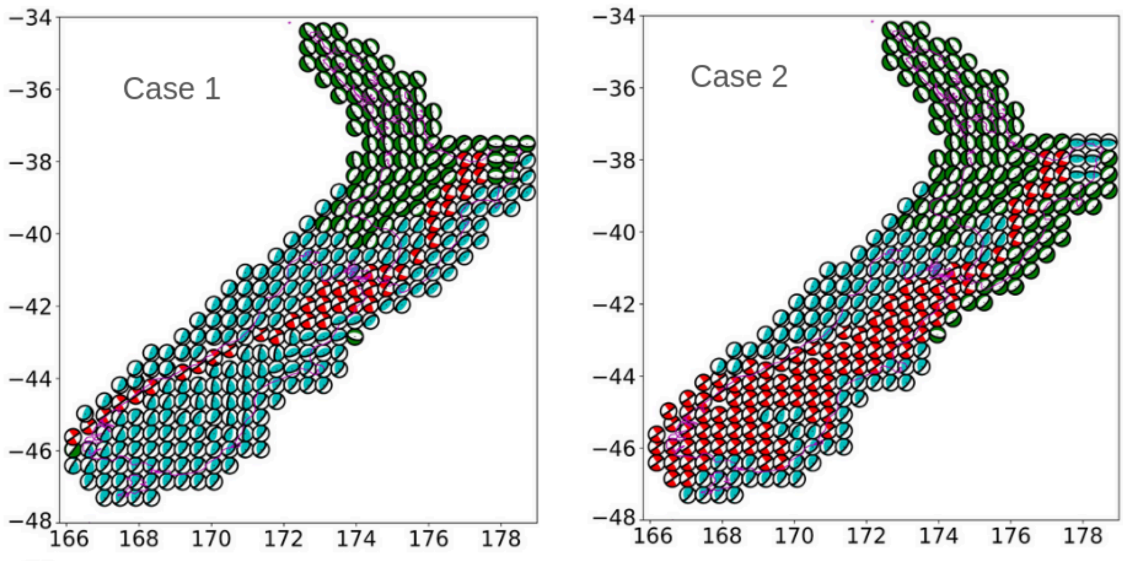

Figure 2.2. Two equally weighted cases for rake variability in the focal mechanism model for the shallow crustal events. Note that the strike and dip angles also vary with changes in the rake angles. This figure is taken from Thingbaijam *et al*. (2024a)

2.2. Subduction Interface Events

The focal mechanism model for the interface events is derived from published models describing the subduction geometry. The one for the Hikurangi subduction is that of Williams *et al.* (2013), and that for the Puysegur subduction was adapted from Slab2 (Hayes *et al*., 2018). The strike angle at a given epicenter is determined as aligned to the subducting trench, while the dip angle is estimated as the dip of the subducting plate at that location. The model is derived through spatial interpolations of these parameters and stored as Python Numpy binaries (or interpolators).

The model files are located in the directory: *models/interface/*. They are *hik_focmec.npy* and *puy_focmec.npy*, respectively, for the Hikurangi and Puysegur subduction zones. These interpolators are not used directly, but the following constraints are applied.

For both subduction interfaces, the minimum and maximum dip angles are set to 10° and 45°, respectively. In the Puysegur subduction zone, the minimum and maximum strike angles are set to 0° and 40°, respectively. In contrast, for the Hikurangi subduction zone, the minimum and maximum strike angles are set to 240° and 260°, respectively. The rake angle is set to 90° for all cases, assuming pure reverse faulting type.

The model gives only one focal mechanism for one location. This will be revised in the near future to provide a probability distribution. The model files also contain the spatial bounds or polygons for each subduction zone. If the event is not located within either polygon, and hence, not in either subduction zone, the interpolators would not be applicable.

2.3. Intraslab Events

The model files are located in the directory: *models/slab/*. The file is slab-faulting2.json. The model is based on the regional moment tensor subcatalogs and is depth-dependent in each subduction zone. Spatial dependency has not been incorporated. Hence, the model does not need epicenter location. Figure 2.3 describes the JSON file.

Subduction tag

Mid depth

Strike, dip, rake, probability

```
{"hik":
    {"20": [[-144, 56.0, -85, 0.32], [229.0, 56.0, -85, 0.36], [242, 56.0, -85, 0.32]],
     "30": [[-143, 57.0, -84, 0.32], [230.0, 57.0, -84, 0.36], [243, 57.0, -84, 0.32]],
     "40": [[-141, 56.0, -89, 0.32], [231.0, 56.0, -89, 0.36], [243, 56.0, -89, 0.32]],
     "50": [[-138, 54.5, -76, 0.32], [235.5, 54.5, -76, 0.36], [248, 54.5, -76, 0.32]],
     "60": [[-140, 62.0, -78, 0.32], [239.0, 62.0, -78, 0.36], [258, 62.0, -78, 0.32]],
     "70": [[-145, 65.0, -123, 0.32], [236.0, 65.0, -123, 0.36], [257, 65.0, -123, 0.32]], ….
```

Figure 2.3. An example illustrating the JSON file format for the intraslab focal mechanism model.

3. Python Script

A Python module *nzfocmec.py* contains the relevant functions. The following examples illustrate the basic usage of these functions.

Example 3.1. Retrieve the distribution of the focal mechanism of a crustal event, given its epicenter.

```
# complete model
import nzfocmec as nzf
sdrp = nzf.get_focmec(170, -45, dep=None, Mw = 6, regime= 'crust', \
        preferred_model = 'all')
print(sdrp)

[[194, 45, 115, 0.33], [220, 45, 115, 0.34], [246, 45, 115, 0.33]]


# mean model, with preferred case of rake angle
import nzfocmec as nzf
sdrp = nzf.get_focmec(170, -45, dep=None, Mw = 7.2, regime= 'crust', \
        preferred_model = 'mean_case2')
print(sdrp[0])

[220, 45, 115, 1.0]
```

Example 3.2. Retrieve a preferred focal mechanism of an interface event, given its epicenter.

```
import nzfocmec as nzf
# Retrieve focmec distribution of interface event at a given epicenter
sdrp = nzf.get_focmec(lon=177, lat=-41, Mw = 7.5,
        regime= 'interface', preferred_model = 'mean_all')
print(sdrp[0])
[240.0, 10.0, 90, 1.0]
```

Example 3.2. Retrieve a preferred focal mechanism of an intraslab event, given its epicenter and depth.

```
# mean model
import nzfocmec as nzf
sdrp = nzf.get_focmec(lon=177, lat=-41, dep=30, Mw = 6,
        regime= 'slab', preferred_model = 'mean_all')
print(sdrp)

[[230.0, 57.0, -84, 1.0]]

# distribution
import nzfocmec as nzf
sdrp = nzf.get_focmec(lon=177, lat=-41, dep=30, Mw = 6,
        regime= 'slab', preferred_model = 'all')
print(sdrp)
[[-143, 57.0, -84, 0.32], [230.0, 57.0, -84, 0.36], [243, 57.0, -84, 0.32]]
```

Example 3.3. Retrieve the distribution of the focal mechanism of an event, given its epicenter and tectonic regime, and compute Kagan's angle to compare with the observed focal mechanism.

TO DO…

References

Gerstenberger, M.C., Van Dissen, R., Rollins, C., DiCaprio, C., Thingbaijim, K.K., Bora, S., Chamberlain, C., Christophersen, A., Coffey, G.L., Ellis, S.M., and Iturrieta, P., 2024. The seismicity rate model for the 2022 Aotearoa New Zealand national seismic hazard model. *Bulletin of the Seismological Society of America*, *114*(1), pp.182-216.

Hayes, G.P., Moore, G.L., Portner, D.E., Hearne, M., Flamme, H., Furtney, M., and Smoczyk, G.M., 2014. Slab2, a comprehensive subduction zone geometry model. *Science*, *6410*(362), pp.58-61.

Seebeck, H., Van Dissen, R., Litchfield, N., Barnes, P.M., Nicol, A., Langridge, R., Barrell, D.J., Villamor, P., Ellis, S., Rattenbury, M., and Bannister, S., 2024. The New Zealand Community

Fault Model–version 1.0: An improved geological foundation for seismic hazard modelling. *New Zealand Journal of Geology and Geophysics*, *67*(2), pp.209-229.

Thingbaijam, K.K.S., Gerstenberger, M.C., Rollins, C., Rastin, S.J., Rhoades, D., Iturrieta, P., Van Dissen, R., and Christophersen, A. (2022). A Framework for a Distributed Seismicity Model: A case study from the New Zealand National Seismic Hazard Model 2022 [Poster], New Zealand Society for Earthquake Engineering, Annual Technical Conference, 9-11 April 2024, Wellington, New Zealand

Thingbaijam, K.K.S., Rattenbury, M.S., Van Dissen, R.J., Gerstenberger, M.C., Ristau, J., and Fitzenz, D.D. (2024a). Characterization of focal mechanisms for upper-crustal distributed seismicity in Aotearoa New Zealand. *Seismological Research Letters*, *95*(1), pp.150-158.

Thingbaijam, K.K.S., Gerstenberger, M.C., Rollins, C., Van Dissen, R.J., Rastin, S.J., Christophersen, A., Ristau, J., Williams, C.A., Fitzenz, D.D., and Pagani, M. (2024b). A seismogenic slab source model for Aotearoa New Zealand. *Bulletin of the Seismological Society of America*, *114*(1), pp.95-110

Williams, C.A., Eberhart-Phillips, D., Bannister, S., Barker, D.H., Henrys, S., Reyners, M,. and Sutherland, R., 2013. Revised interface geometry for the Hikurangi subduction zone, New Zealand. *Seismological Research Letters*, *84*(6), pp.1066-1073.

If you use the NZ-focmec for your study, please cite the following

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Thingbaijam, K.K.S., Rattenbury, M.S., Van Dissen, R.J., Gerstenberger, M.C., Ristau, J., and Fitzenz, D.D. (2024a). Characterization of focal mechanisms for upper-crustal distributed seismicity in Aotearoa New Zealand. *Seismological Research Letters*, *95*(1), pp.150-158.

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