Simultaneous Bayesian Estimation of Complex Non-planar Earthquake Fault Geometry and Spatially-variable Slip from Geodetic Data

Motivation:

• Faults in nature are complex and often include an en echelon segments or are curved or warped at different spatial scales

• However, they are usually modeled as one or more planar fault segments, leading to slip singularities and unphysical gaps between fault segments

• Better spatial resolution of InSAR/GPS data can help in resolving

Key implementation:

• Estimate non-planar fault geometry parameterized using a set of polynomials

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**Methodology**  – see appendix

**Results**

- Non-planar fault geometry estimated simultaneously with slip distribution for the 2011 $M_w 9.1$ Tohoku-Oki megathrust earthquake from GPS data
- We use earthquake locations (NIED F-net) as a prior in the estimation
- We find significant along-strike variation in fault dip
- Fault dip varies from $7^\circ$ to $22^\circ$ with depth
- Maximum slip of $\sim 60$ m estimated – comparable to previous studies
- Uncertainties of the geometrical and slip parameters and the trade-off between them are estimated

Estimated non-planar fault geometry with its 95% confidence interval at Planes A, B and C compared with Slab1.0 and previous studies

Depth axis is exaggerated
Conclusions

• Along-strike and down-dip variations in fault-dip can be estimated from geodetic data

• In the case of the Tohoku-Oki earthquake, we find a fault geometry that is mostly in agreement with the slab interface model, but differs from several previous studies

• The resulting fault geometry shows both significant along-strike and down-dip variations in fault dip

• The maximum slip was found to be about ~60 m and the down-dip variations in dip 7° to 22° with depth

Resources

• Python codes for SMC sampling: Github repository (https://github.com/rishabhduetta/SMC-python)
Methodology

Fault model parameters = Geometrical parameters + Slip parameters

Slip values superposed on Triangular dislocation elements (both dip-slip and strike-slip components)

Polynomial parameters – $S_1$, $D_1$, $D_2$, ...

Bayesian inference:

- Model parameters relate stochastically to the data (InSAR/GNSS)
- A priori information about model parameters (slip smoothness prior + geometrical prior)
- Modelling and data errors used
- Obtain uncertainties and trade-offs of the estimated model parameters