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

Rishabh Dutta[1], Sigurjón Jónsson[1], and Hannes Vasyura-Bathke[1,2]

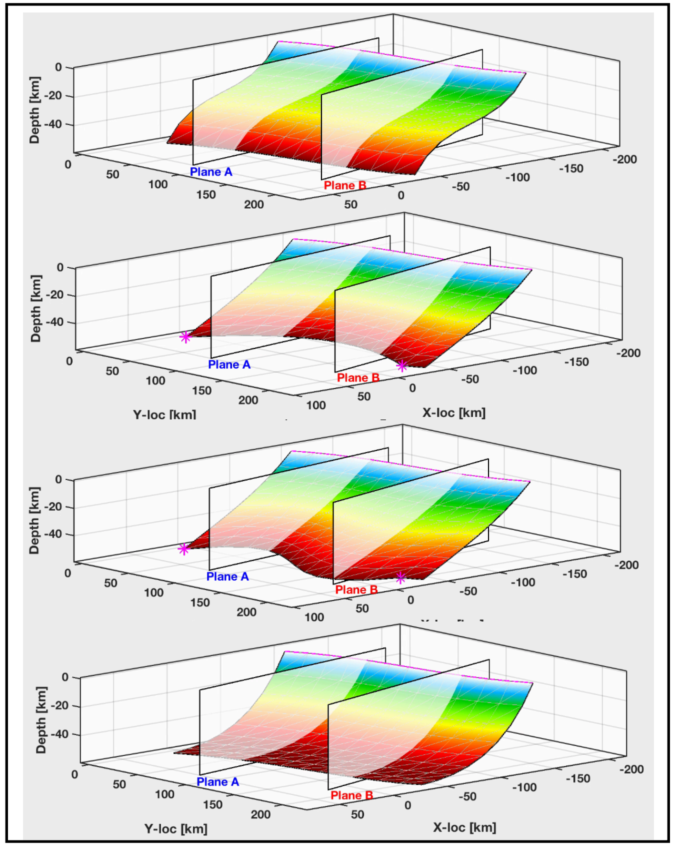
[1] King Abdullah University of Science and Technology (KAUST), Saudi Arabia
[2] University of Potsdam, Germany

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



 Email: rishabh.dutta@kaust.edu.sa

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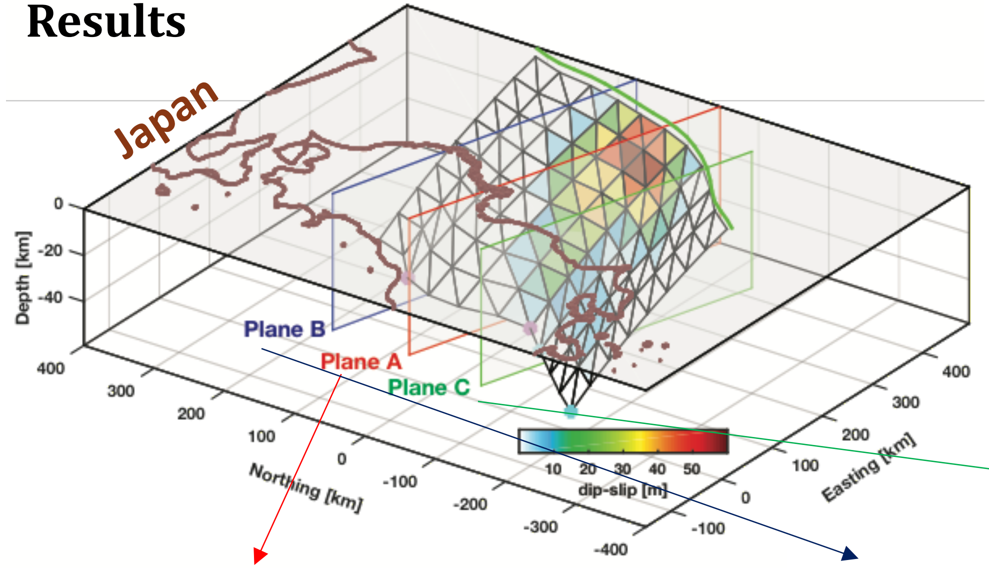
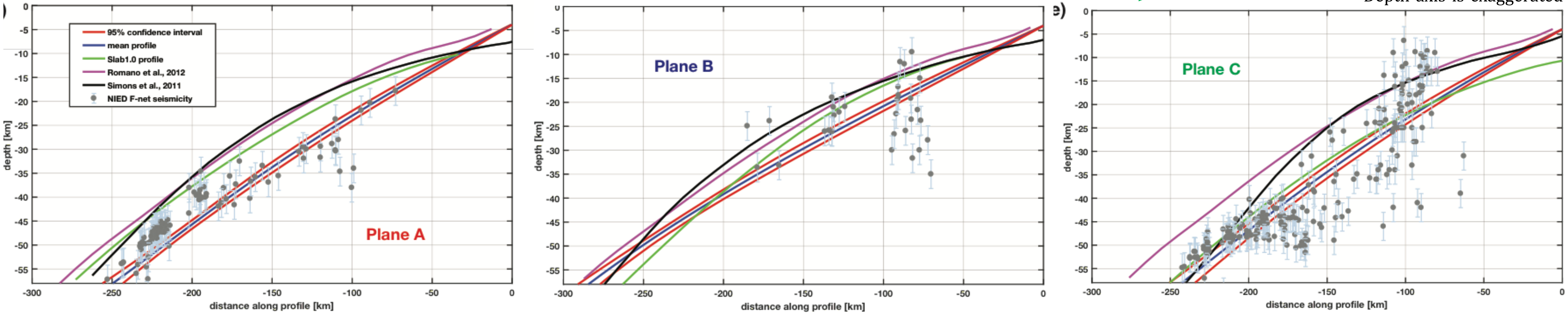
Methodology – see appendix

Results



- Non-planar fault geometry estimated simultaneously with slip distribution for the 2011 M_W9.1 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° to 22° with depth
- Maximum slip of ~60 m estimated – comparable to previous studies
- uncertainties of the geometrical and slip parameters and the trade-off between them are estimated

Depth axis is exaggerated



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

Email: rishabh.dutta@kaust.edu.sa

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^{o} to 22^{o} with depth

Resources

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

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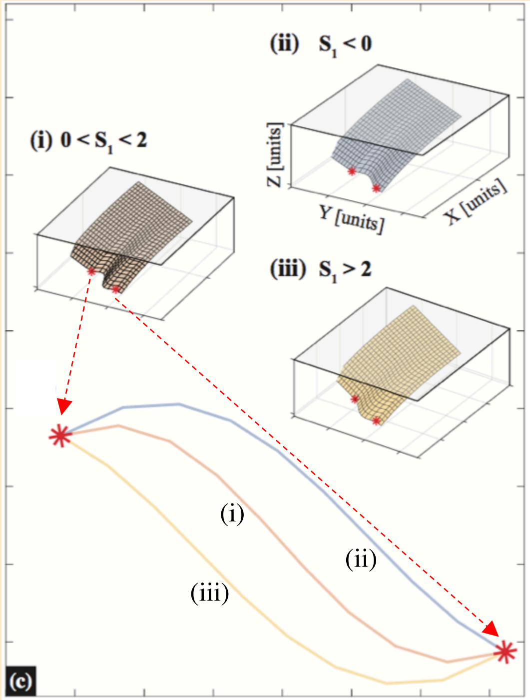
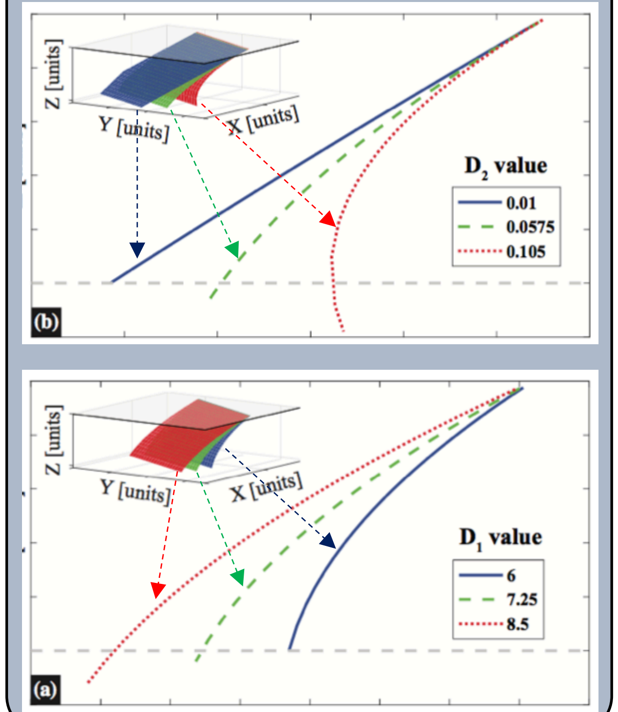
Methodology

Fault model parameters = **Geometrical parameters** + **Slip parameters**

Along-strike variations



down-dip variations



Polynomial parameters – S_1, D_1, D_2, …

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

Forward model – triangular dislocation placed within isotropic elastic half-space

Bayesian sampling – Sequential Monte Carlo technique

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

Email: rishabh.dutta@kaust.edu.sa

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