# Simple Elastic Dislocation Models for Interseismic Deformation in Subduction Zones

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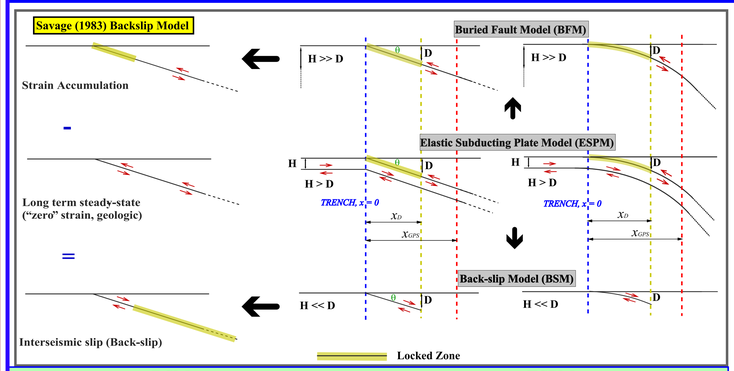
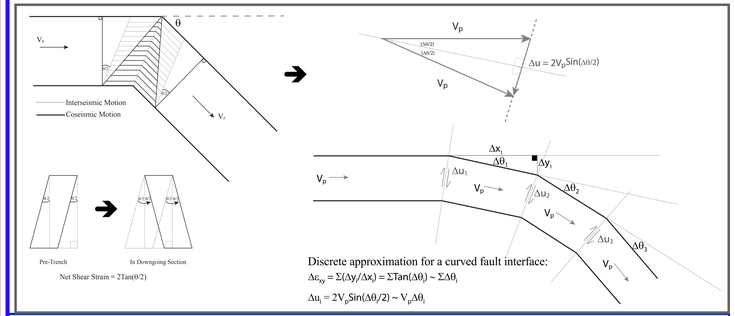
## I. Motivation

To understand the physical rationale behind the success of the backslip model for interpreting subduction zone geodetic data (Savage, 1983) by studying a kinematically more consistent model for subduction. Specifically, we want to know under what conditions the backslip model is a good approximation for predicting surface deformation on the over-riding plate.

## II. The Backslip Model (BSM) as a special case of the Elastic Subducting Plate Model (ESPM)



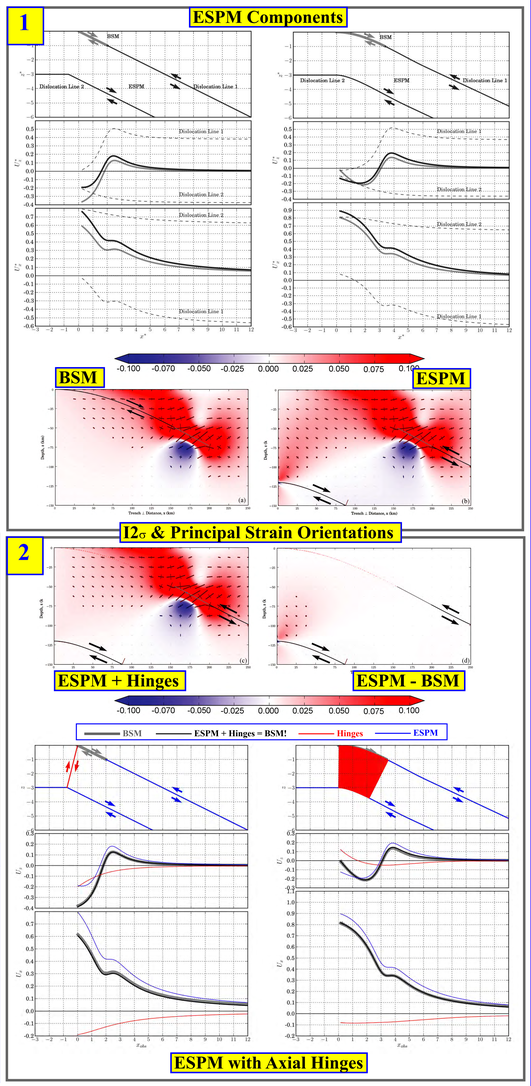

| BSM | vs. | ESPM |
|---|---|---|
| Uses artificial extensional slip along locked interface. | | Locked portion remains locked interseismically |
| Net long-term uplift of overriding plate w.r.t subducting plate. | | NO net uplift of over-riding plate w.r.t. subducting plate. |
| Surface displacement on the footwall is ~ ZERO w.r.t. the overriding plate, not the expected plate convergence velocity. | | Surface displacement on the footwall is equal to the expected plate convergence velocity of the oceanic plate. |
| | | REDUCES TO **BSM** FOR ZERO PLATE THICKNESS! |
| | | REDUCES TO **BFM** FOR LARGE PLATE THICKNESS! |



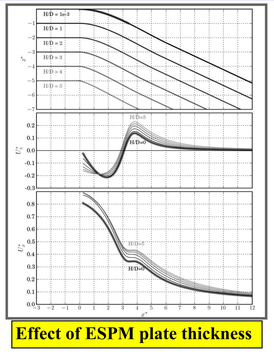

### ESPM experiences deformation in the subducting plate due to bending at the trench:

Due to a change in momentum associated with bending, the ESPM experiences compression in the overriding plate, adjacent to the trench (above, as well as Panels 1 & 2 to the right). In other words, material in the subducting plate undergoes simple shear as shown above as it passes through the "bend". This strain associated with bending is also shown in the bottom right color intensity plot which shows the second invariant of the strain tensor overlaid by the principal stress orientations within the elastic medium. The larger the dip (linear fault geometry) or curvature (curved geometry) at the trench, the larger this compression.

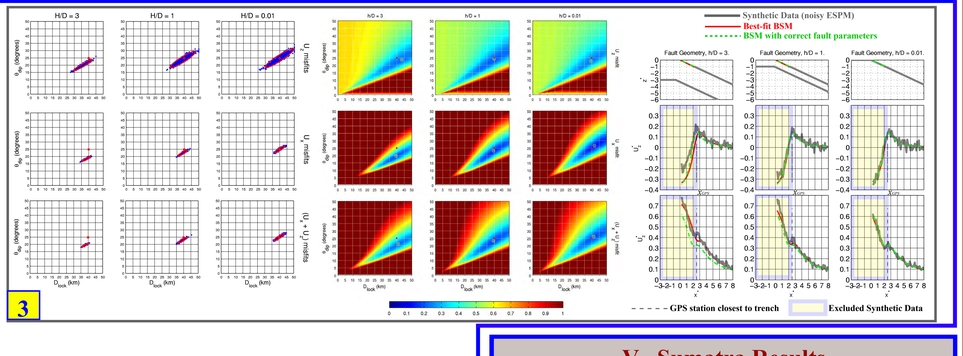
If the subducting plate is to not experience net strain, a process equivalent to slip along the axial plane (red lines, at right) of the hinge must occur, with a velocity, $\Delta u$, shown above. For a curved fault, this is distributed over a series of such planes (shown in red, at right). The slip computed above *EXACTLY* cancels the hinge shear strain, so that we recover the BSM from the ESPM for *ANY* plate thickness. So, IF THE STRAIN ASSOCIATED WITH BENDING IS RELEASED ONLY EPISODICALLY, OR AT DEPTH (> 100km), THEN ESPM & BSM DIFFER SIGNIFICANTLY UPTO A FEW LOCKING DEPTHS FROM THE TRENCH (top of Panel 1 & bottom of Panel 2).




## III. Synthetics: Comparison of BSM & ESPM predictions




Effect of ESPM plate thickness



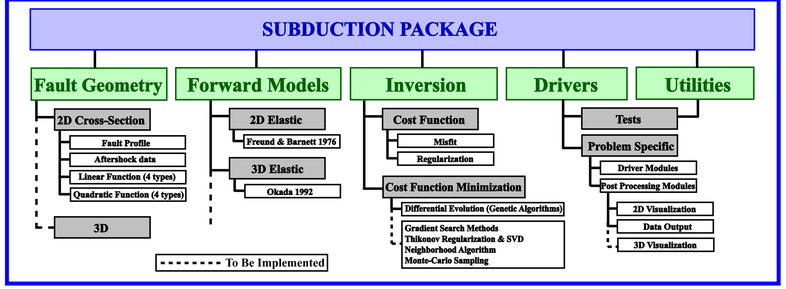

3

Monte-Carlo sampling of 10,000 minima of misfit between the BSM & synthetic data (noisy ESPM) assuming Gaussian distribution for noise are shown in the left plot of Panel 3. The misfit surface for one rendition of the synthetic data is shown in the middle plot of that panel. The right panel shows the fits for the best-fit BSM (red) from the middle plot, and the BSM with the same model parameters as the noise-free ESPM (green).

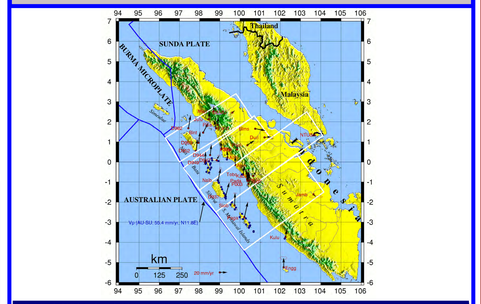
The BSM Locking Depth and Fault Dip are positively correlated, when fitting synthetic data which results from a similarly shaped misfit minimum surface.

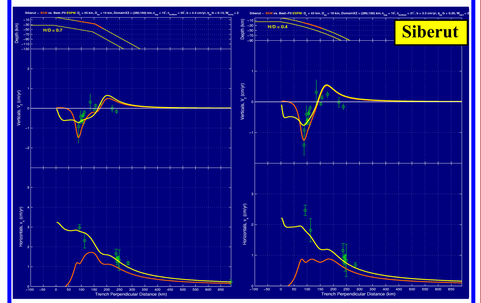
The BSM tends to underestimate fault dip (to compensate for the increase in surface displacements closer to the trench.

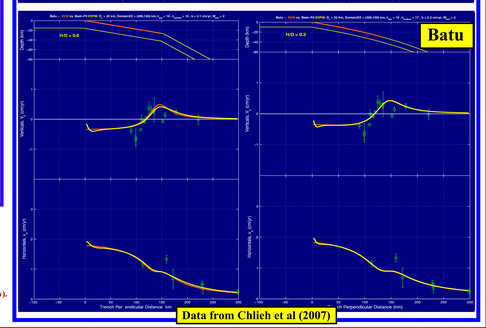
## IV. Inversion Software Developed (PYTHON package)




## V. Sumatra Results




Data from Chlieh et al (2007)

## VI. Conclusions & Future work

Sieh et al. (1999) & Zhao and Takemoto (2000) suggested models similar to ESPM but did not analyze the effects of plate thickness on deformation in the elastic Earth. We show that the ESPM provides a more intuitive rationale for both the BSM and the BFM. ESPM may provide an "elastic" plate thickness appropriate for interseismic time-scales.

Plate thickness by locking depth ratios, *H/D*, for the best-fitting ESPM for *ALL* Sumatra cross-sections are ≤ 1. The BSM does an equally good job of fitting currently available geodetic data in Sumatra.

Our results are consistent with more detailed inversions (e.g., Chlieh et al., 2006):
Siberut: $D_{lock}$ ~35-45 km, $x_D$ ~ 160-180 km, Coupling ~ 70-80%, Aseismic to a depth of ~15-20 km
Batu: $D_{lock}$ ~ 25-35 km, $x_D$ ~ 130-150 km, Coupling ~ 40-50%, No updip aseismic section.

As can be seen at the right, models are highly sensitive to assumed fault geometry. Difficult to fit *BOTH* verticals & horizontals at the same time (elastic structure & geometry may both be important).

GPS data from Japan is being re-processed by MS to check if plate thickness is better resolved for Tohoku or Nankai.

Savage J.C. 1983. A dislocation model of strain accumulation and release at a subduction zone, J. geophys. Res., 142, 4984–4996.

Sieh, K., S. Ward, D. Natawidjaja and B. Suwargadi, 1999, Crustal deformation at the Sumatran subduction zone revealed by coral rings, Geophysical Research Letters 26, 3141-3144.

Zhao, S and S. Takemoto, 2000, Deformation and stress change associated with plate Interaction at subduction zones: a kinematic modelling, Geophys. J. Int., 142, 300-318.

Chlieh, M., J.-P. Avouac, K. Sieh, Natawidjaja, D. H., and J. Galetzka, 2007, Heterogeneous coupling on the Sumatra megathrust constrained from geodetic and paleogeodetic measurements, J. Geophys. Res. (in review).

Kanda, R. V. S., and M. Simons, 2007, Simple elastic dislocation models for interseismic deformation in subduction zones, (in preparation).