3D geodynamic and geomorphic modelling of the Alaska/Aleutian Margin – STEEP and GeoPRISMS

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Photo: Eva Eckelmann, 2008
3D geomorphic and geodynamic modelling:

• Brings together geological and geophysical data and interpretations into an overarching framework

• Used to constrain ideas and make testable predictions

• We identify 3 topics which require modelling to address key SCD science questions

1. Evolution of deformation in space and time
   
   Thermal advection, surface processes, metamorphism, see Ben Hooks’ poster

2. Feedbacks between tectonic driven processes and surface processes
   
   Erosive response of large earthquakes, strain softening and erosion

3. Short term verses long term strain
   
   $T_{cr} \approx 10$ to $10^5$ years, covers the period between recoverable and permanent strain
Material strength evolution along the basal detachment:

3D macroscale models of SE Alaska identify:

Material strength evolution along the basal detachment

- Primary control on long term strain release
- Associated topographic development

Hooks (2009)
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Boundary conditions from macroscale model, incorporate sequentially the influence of:

- Erosion
- Regional observed topography
- Thermal evolution

See Ben Hooks’ Poster for details
With increasingly high resolution data, recent developments in modelling software and faster computers, we can expand upon existing models of the Alaska/Aleutian margin (as well as others).

Targets include:

- Rheological characteristics of the megathrust, constrained by geophysical data.
- Thermal evolution of the down going slab and overriding plate.
- Higher resolution geological, geophysical and topographic inputs to explore various system components.
Feedbacks between tectonic driven processes and surface processes

Chi-Chi Earthquake, $M_w$ 7.6, >20000 associated landslides
Enhanced mass wasting and sediment transport 5X background level
Returned to pre-earthquake levels in about 6 years.

Choshui River during Typhoon Mindulle, photo Jil Chian
Discharge – 6000 m$^3$/s, suspended sediment – 50 g/l
Strain softening

Rheology based on River Channel Fault, Otago, New Zealand

Focuses deformation $\rightarrow$ focuses erosion
Role of Alpine Glaciers

Extremely effective at eroding the landscape and transferring sediment

May have a significant role in the internal processes of mountain building

The Erosive Potential map of the Seward/Malaspina shows concentration of erosion and consequently rapid uplift within the narrow Seward Throat

Product of balance flux per unit width and the generalized surface slope
$T_{cr} - 10^{-10^5}$ years, Critical time period:

**Encompasses:**

Massive changes in normal and shear stresses due to ice sheet loading and unloading

Associated glacial:fluvial landscape development at very high observed rates

Mineralogical and thermal evolution of material strength in fault zones influencing linkages of fault zones

Strain accumulation periods of great subduction earthquakes
Tohoku:

One lesson is that incorporating geological studies of ancient earthquakes and tsunamis into risk assessments “is essential to compensate for the limitations in the current evaluation scheme”

But forecasts are generally based on studies covering the past several centuries—“not long enough for the cycle time for these big earthquakes,”
Challenges:

• Identification of characteristic geological/topographic signals in the landscape that can be used to identify locations of great earthquakes that have occurred outside the historic record.

• Linking kinematics of the permanent strain field to high-frequency topography using the evolving geomorphic theory of tectonic:surface coupling can provide constraints on timing and location of low-frequency, great earthquakes.