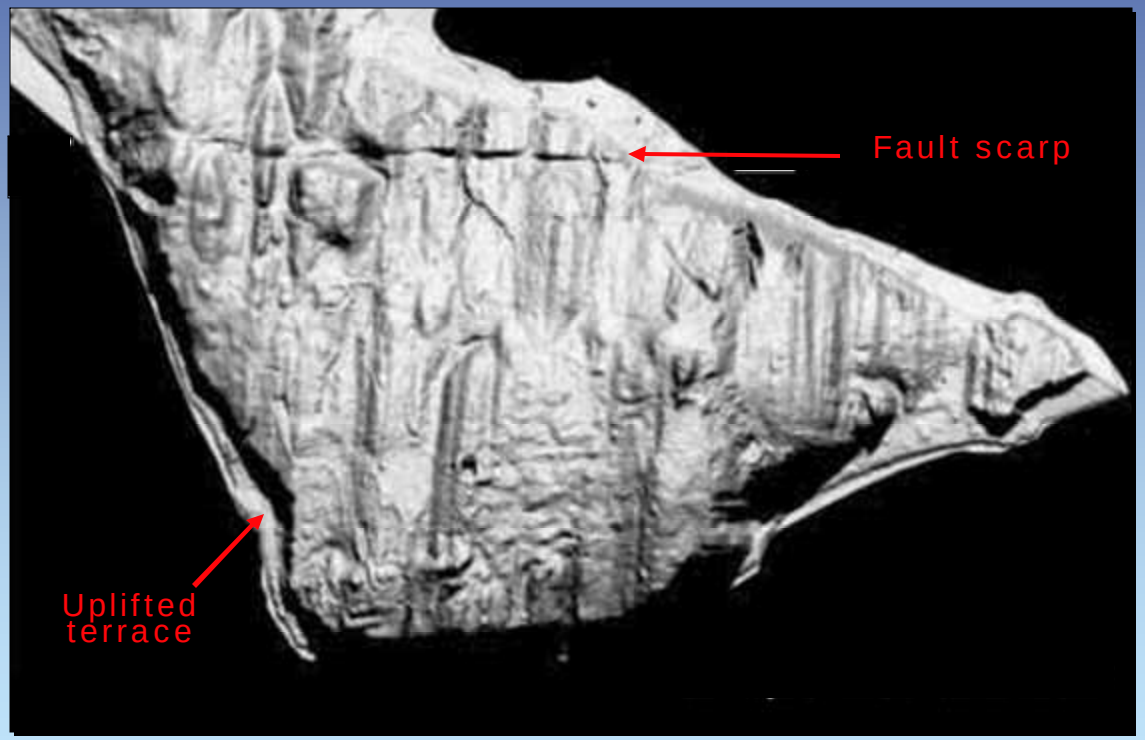
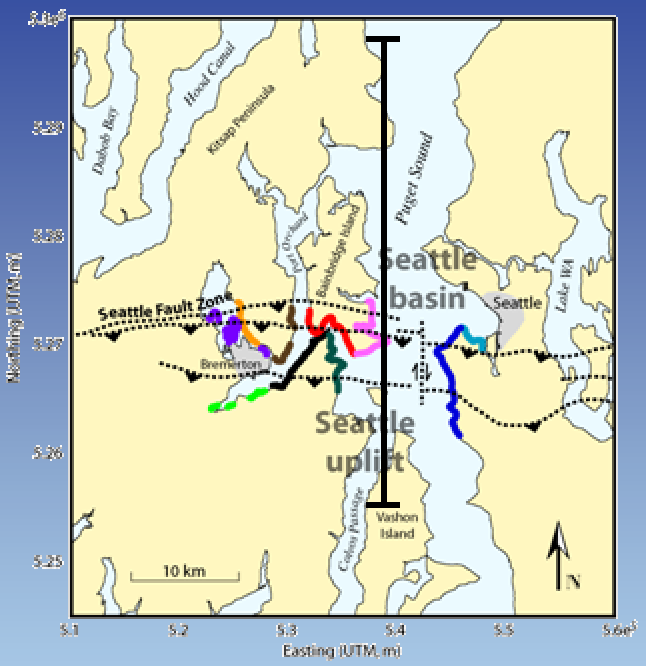
M_w = 7.2-7.4 estimated for A.D. 900 Seattle fault earthquake by modeling marine terrace uplift



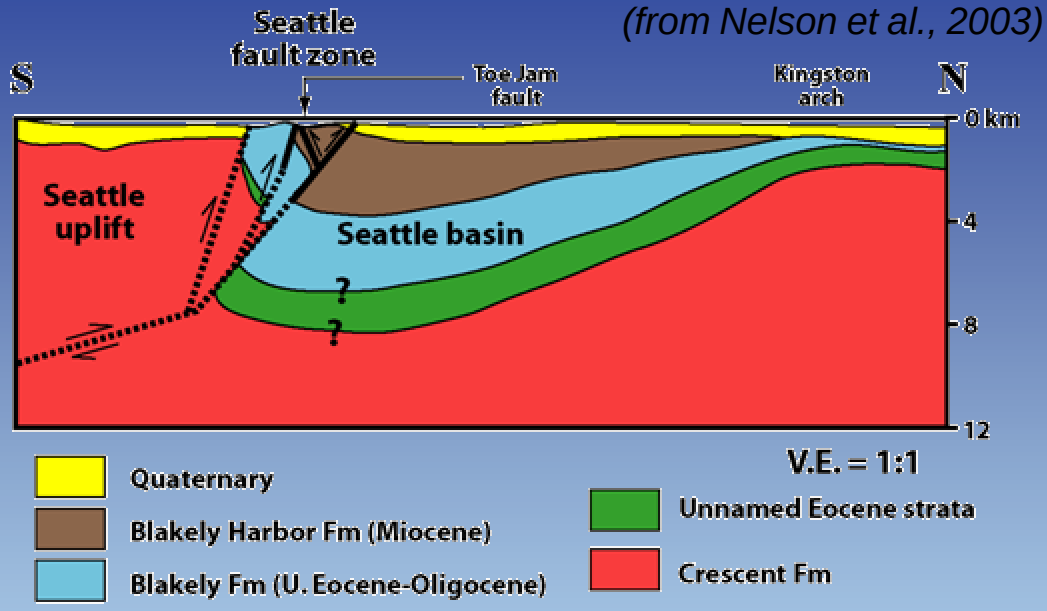
Jordan Muller
NASA Goddard Space Flight Center

USGS
PacNW Hazards Workshop
March 28-29, 2006

The Seattle Fault System At Depth

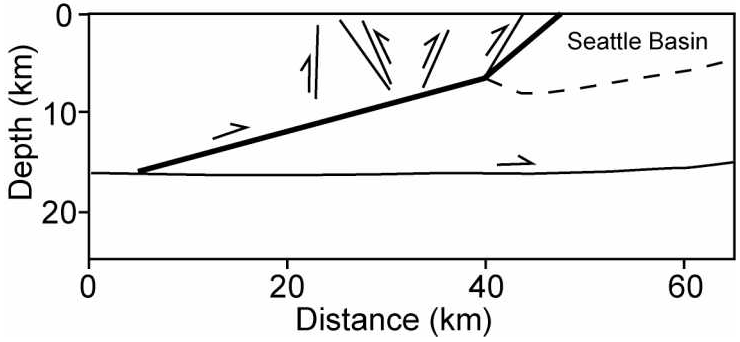


(from Nelson et al., 2003)

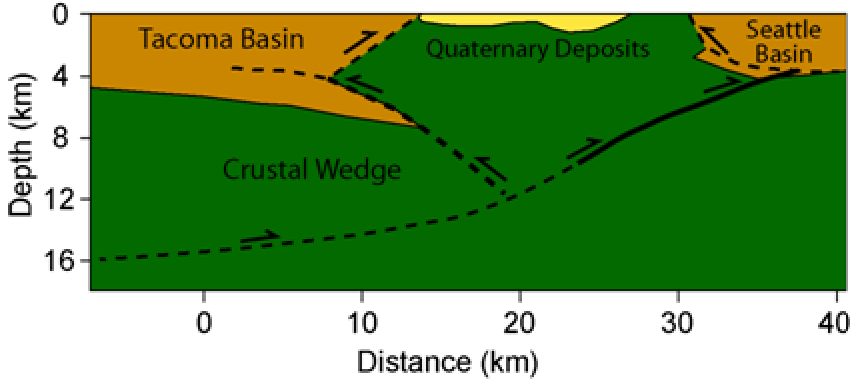


Alternative Fault Models Interpreted from Seismic Reflection and Refraction Data

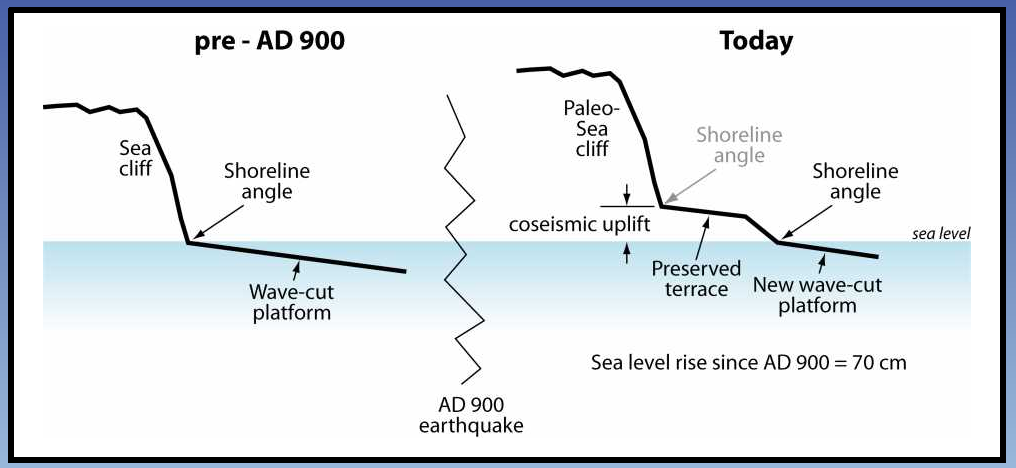
Johnson et al. 2004

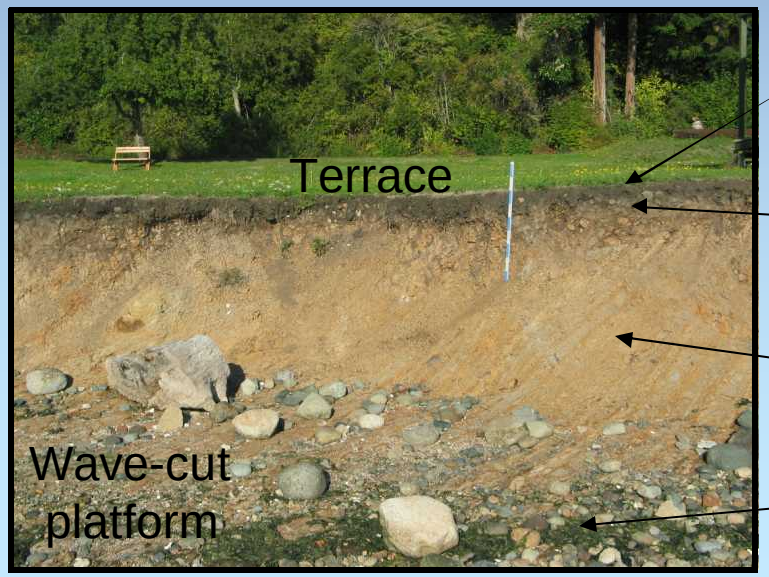


Brocher et al. 2004



Coseismic Shoreline Uplift





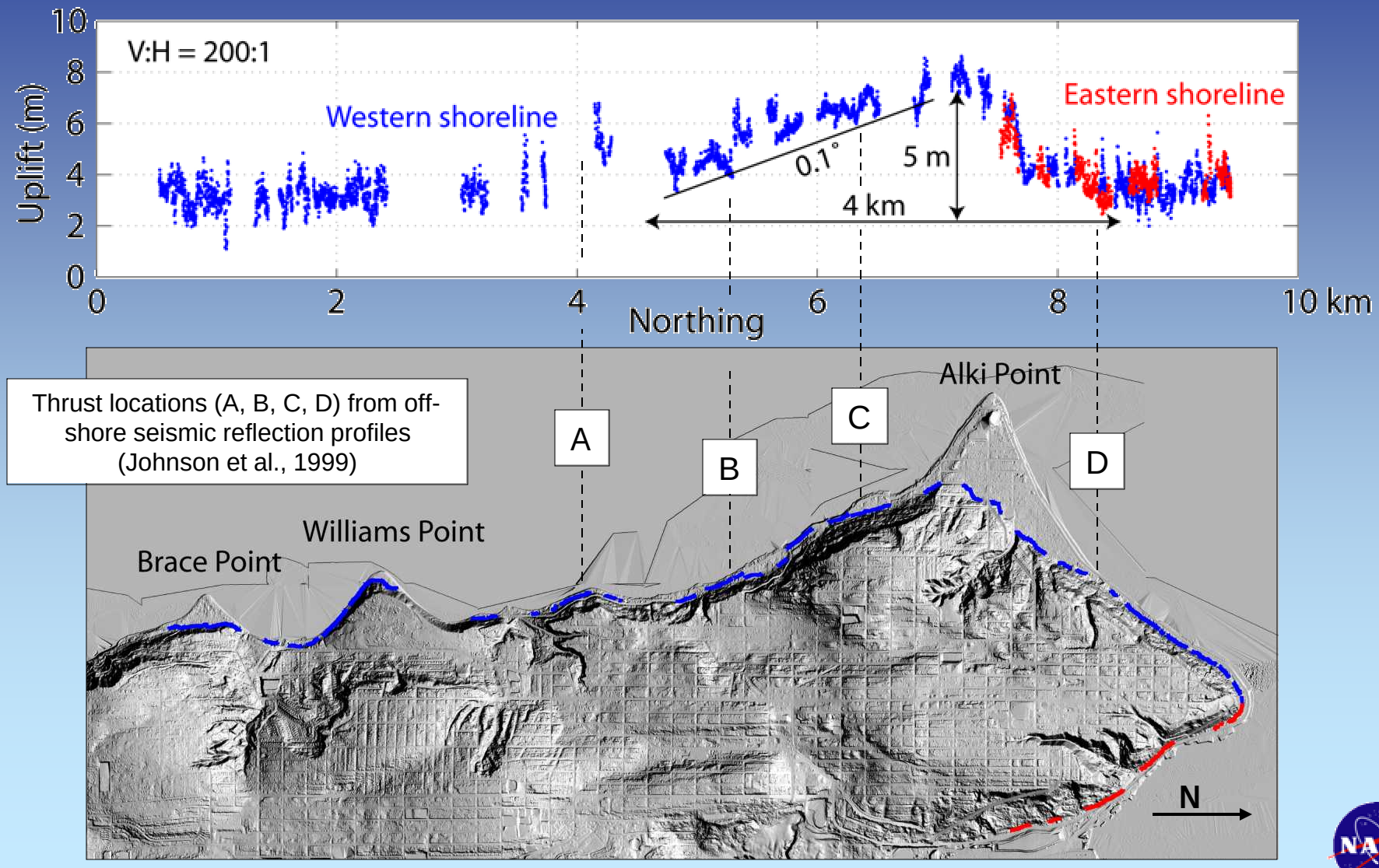
Modern soil

Cobble layer

Bedrock

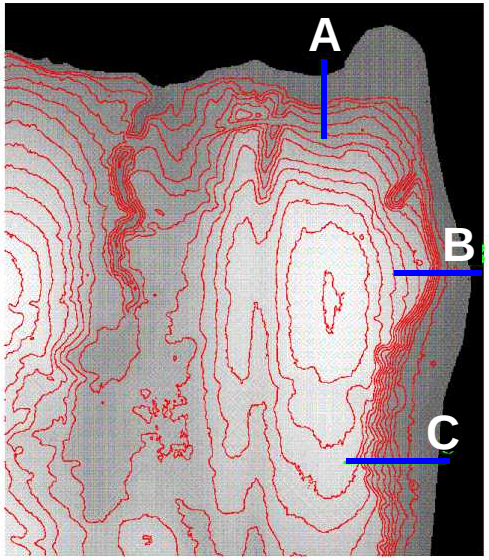
Modern beach

Mapping the Terrace Inner- Edge

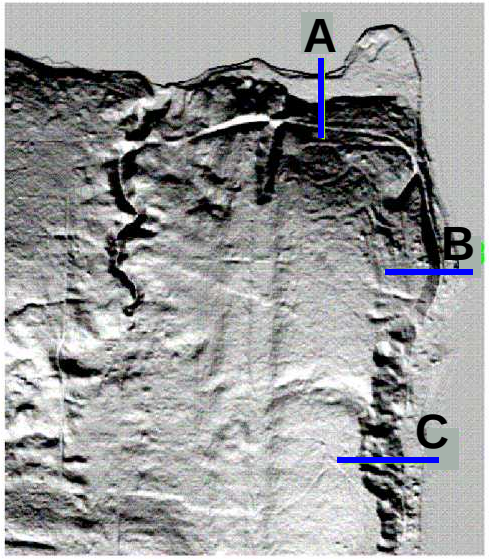


Identification of Preserved Shoreline Angles

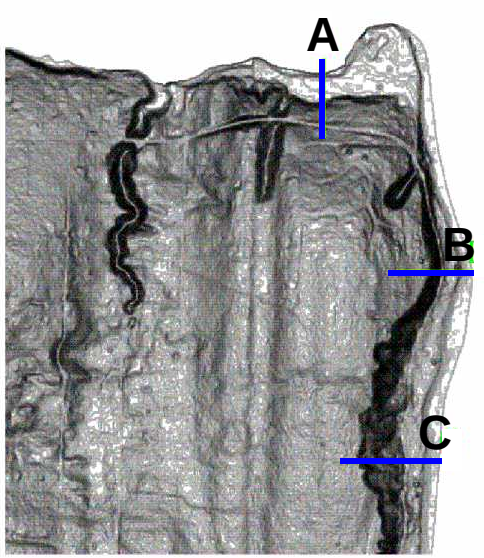
20 ft Contours on Gray-Scale

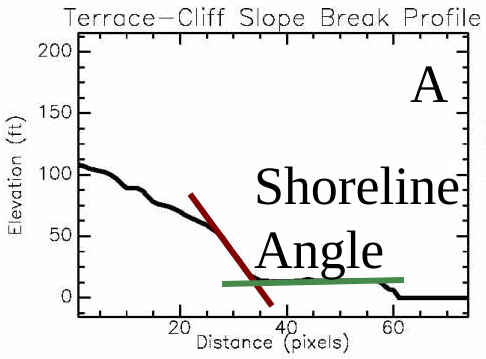


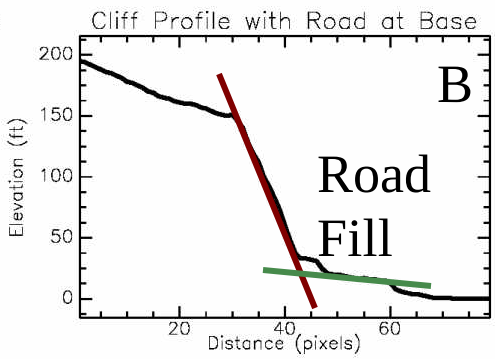
Shaded Relief (S illumination)

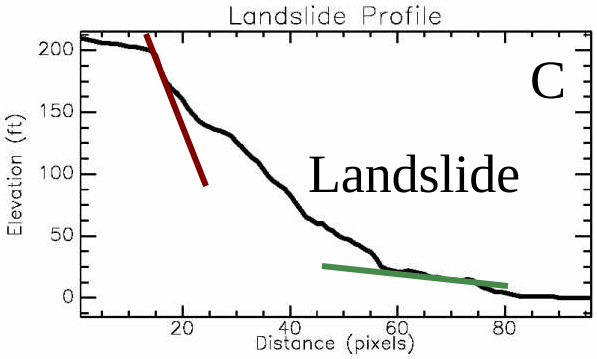


Slope Magnitude

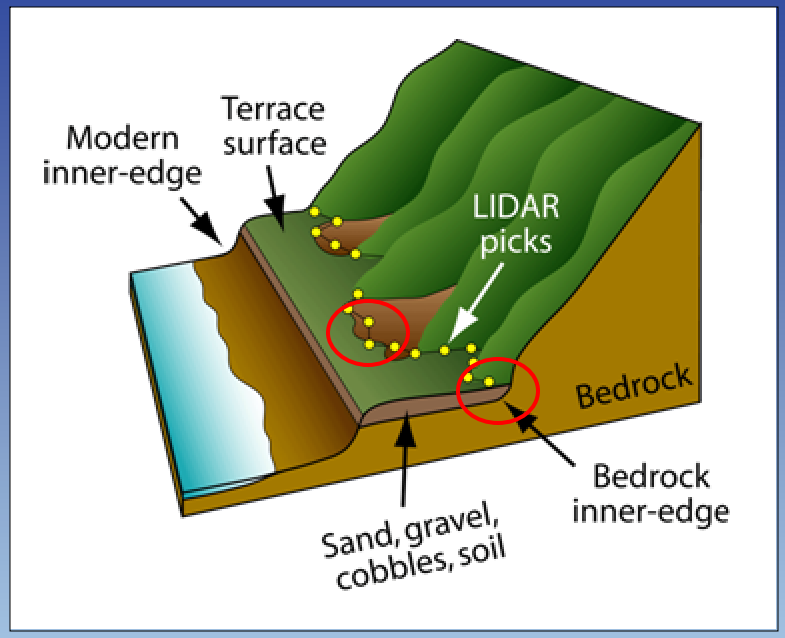


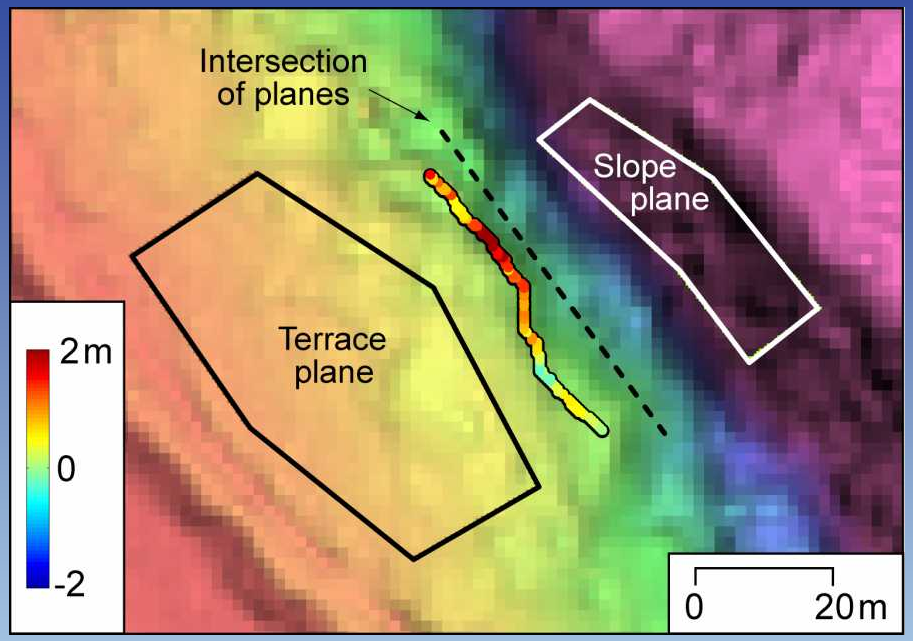






Error in LIDAR Terrace Elevations

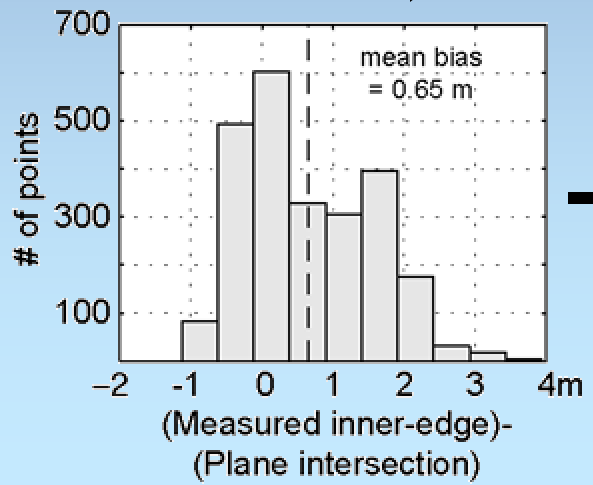


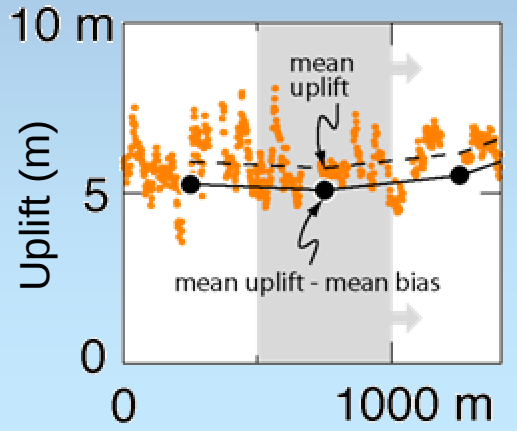


Analysis of 2439 measurements:

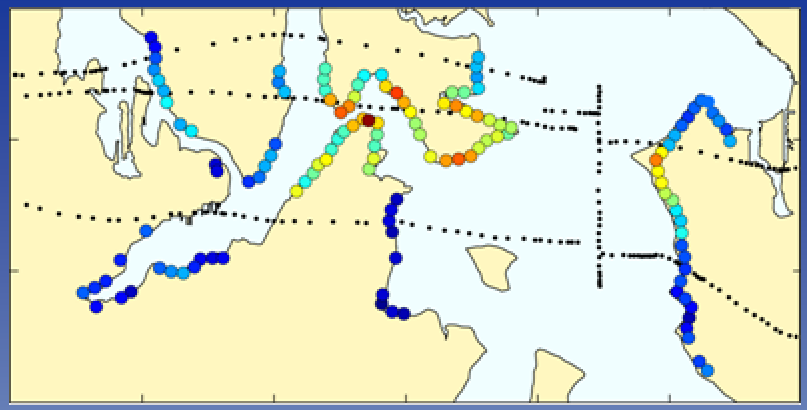
Mean bias = +65 cm

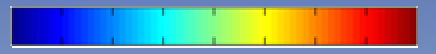
Std dev = 90 cm



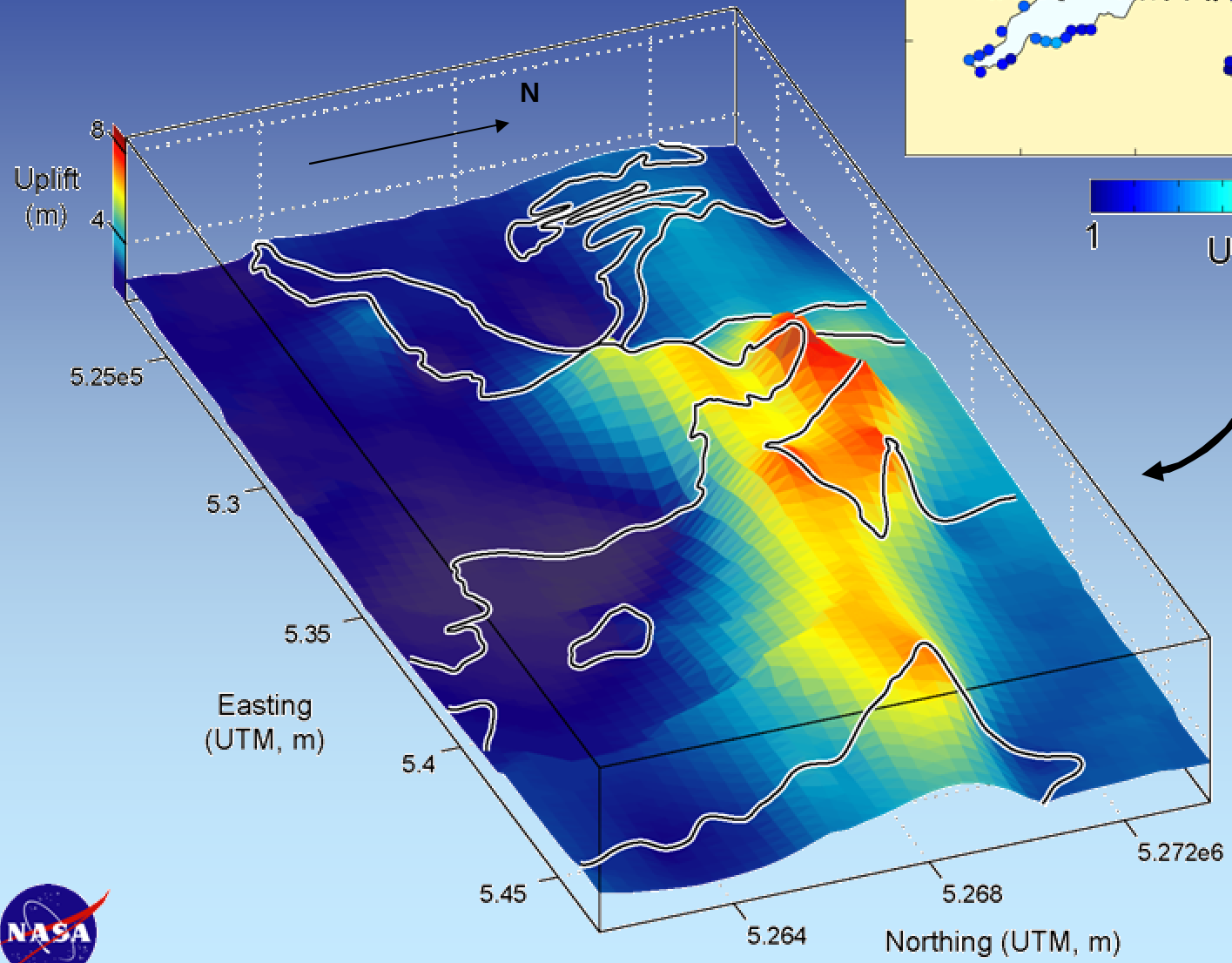


Anticline Shape

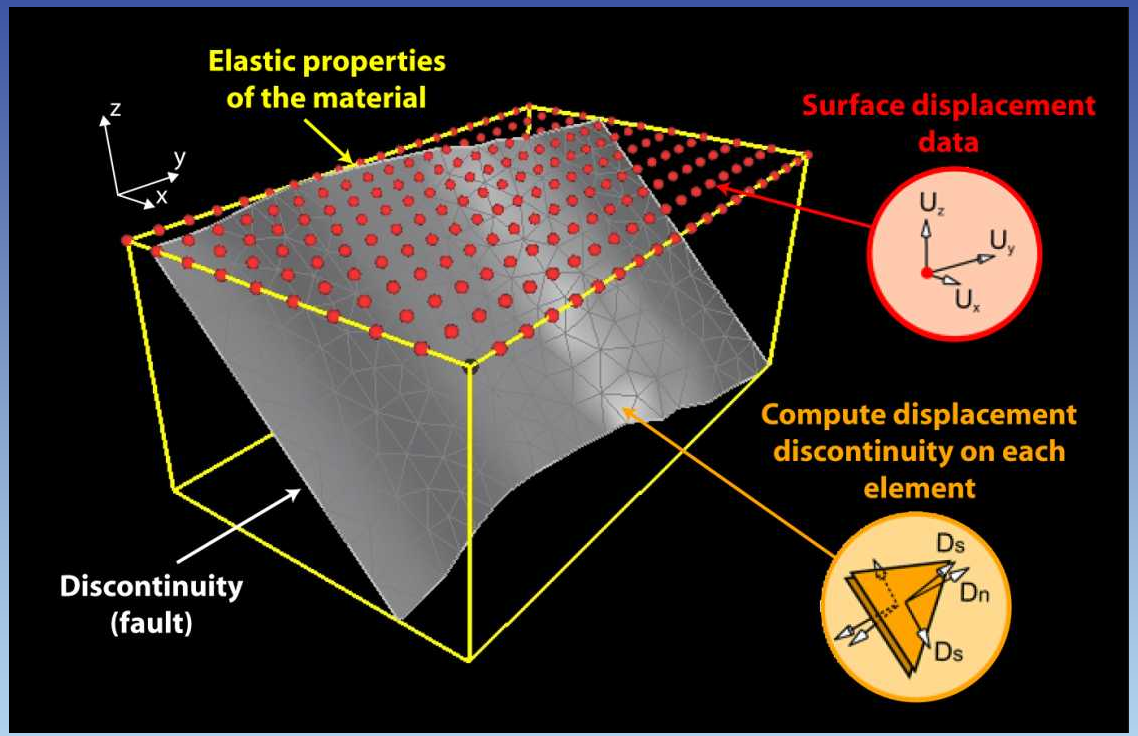




Kriging

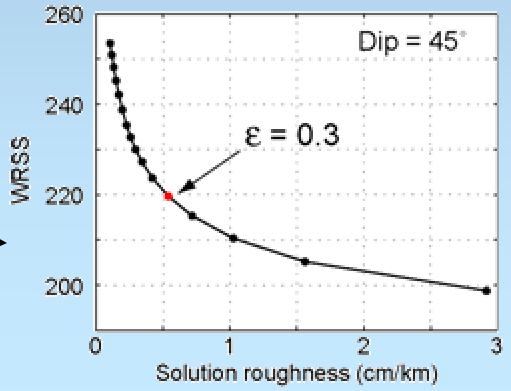


Slip Inversion with Angular Dislocations



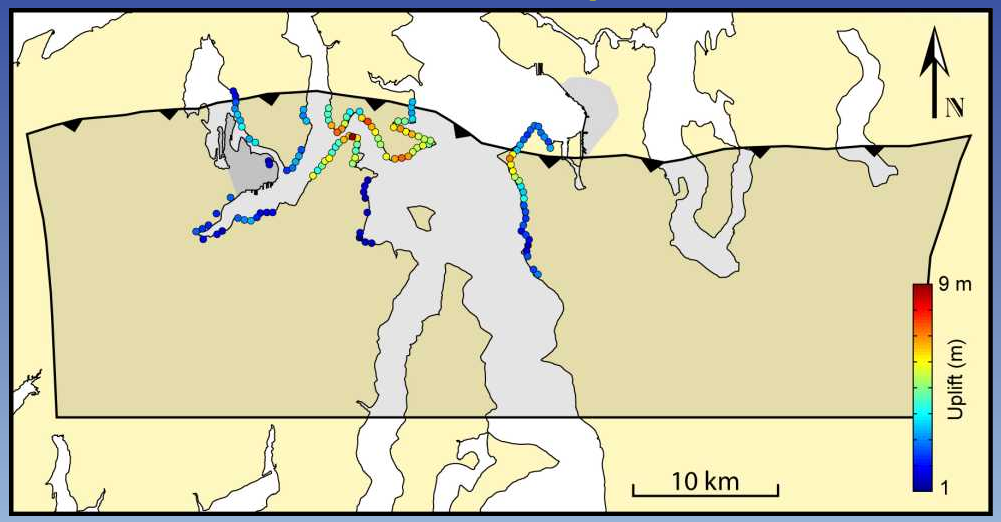
- **Given surface displacements, we solve for fault slip using a weighted damped least squares approach**
- **Minimizes data misfit and roughness of the slip distribution**
- ***Solution is implemented in Poly3Dinv (Maerten, et al., in press)***

Trade-off curve suggests that ε = 0.3 balances data-fitting with smoothing



Inverted Slip and Modeled Uplift

Model set-up



Characteristics of slip solution:

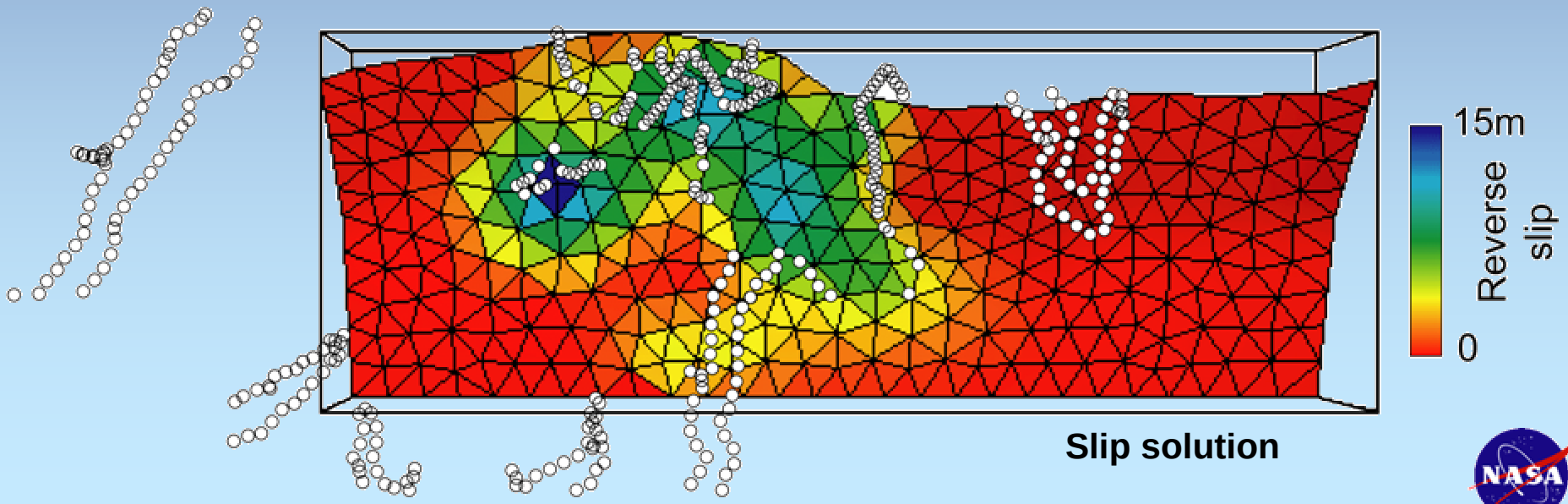
M_w = 7.27

Rupture area = 900 km^2

Rupture length = 30 km

Rupture width = 30 km

Rupture depth = 10 km



Slip solution

Model Comparison

Fault cross-section model	Fault area (km2)	# of elements	RMS error (m)	Roughness (cm/km2)	Mw
30 deg. dip	540	328	0.74	0.60	**7.33**
45 deg. dip	540	324	0.83	0.70	**7.27**
Johnson frontal fault	570	332	0.71	0.76	**7.30**
Johnson middle fault	530	309	1.72	1.85	**7.35**
Brocher fault	540	328	0.58	0.69	**7.41**
Preferred solution	1596	525	0.64	0.34	**7.27**

Regardless of differences in subsurface fault geometry…

A.D. 900 event approximately M_w = 7.2-7.4

Conclusions

1) **LIDAR mapping reveals fault scarps and regional deformation associated with the Seattle fault**

2) **A.D. 900 Seattle fault earthquake uplifted a marine terrace up to 8 m in a doubly-plunging anticline**

3) **Slip inversion modeling gives earthquake magnitude of M_w = 7.2-7.4**

4) **Larger magnitude is possible since terraces do not record uplift <1 m**

5) **Stress triggering between Seattle and Tacoma faults not a likely cause of coincident rupture**