What is needed for slope monitoring to inform loss models in meaningful terms?

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Monitoring technology

Monitoring has advanced to the point that small-scale changes can be detected.

Or is it small-scale differences between sensed scenes?

Some differences are interpreted to be vegetation growth.

Among the challenges associated with monitoring is interpreting the significance of detected changes.

"Significant" in what context?

Is vegetation growth "significant"?

What about change detected because of tilt of a tree?

Session Focus →
Nature and behavior of unstable slopes

This session calls upon landslide professionals to

use monitoring methods wisely and effectively

to better understand the nature and behavior of unstable slopes.

This is a narrow view

What really is needed is

better understanding of slope-system behavior, including the stable parts.

Exactly what is a "stable slope", anyway?

Why would a stable slope be of interest?

It depends on your perspective

From a geoscience perspective,
slope behavior would include
processes and intensities of
mass erosion, flux, and sediment accumulation.

Water movement, storm flow

Slope profile evolution

From a societal perspective,
slope behavior would include
Hazard characteristics
(amount, direction, and frequency of movement at a large number of points).

But only if the slope supported a
residence, grocery store, office building
hospital, fire station, police station
school, highway, buried utilities

Engineers care about loads for design

Slope Hazard, not slope hazard

Hazard has two levels of consideration

- "hazard" refers to processes which could cause damage or injury (think 'inventory map')
- "Hazard" refers to the probability that an event of damaging intensity will occur at a specific location
- "Uniform Hazard" refers to the intensity of an event at a specific location that corresponds to a designated exceedance probability

Hazard here at the
The Conference Center in Seattle:

- The earthquake Hazard here in Seattle is expressed as PGA = 0.592 g. This "intensity" has an annual exceedance probability of 4.04E-4 (2% in 50 yr)
- Where is the Seattle Fault trace?
- How much tectonic deformation is expected here with an annual frequency of 4.04E-4?
- What is the landslide Hazard at this site?

Slope Hazard, not slope hazard

Slope Hazard would be coupled with the Fragility of buildings, roads, utilities, and other facilities "at risk" of being damaged by slope processes.

The at-risk facilities could be those currently in place, or constructed in the future to standard designs.

Slope monitoring to be effective, therefore, also must include accurate documentation of damage that is caused by slope processes,

something that geologists may be well suited to observe, but perhaps not well suited to interpret.

Buildings, roads, and utilities are strain gauges, after all…

…what about undeveloped slopes?

What about earthquake damage?

Earthquake damage began to be documented systematically in the last century, which led to

a realization that damage was more severe on sites with certain characteristics, even though the ground motion and building age and construction details were comparable.

Post-earthquake surveys became more focused on details of ground motion, site characteristics, and building design and construction.

Earthquake damage was modeled, leading to modeled losses, which informed actuaries and enabled private insurance.

With insurance came funding for science and engineering studies to develop better loss models. Because a market existed for model output

Earthquake loss models

At one time, earthquake damage was considered to be uninsurable

Complex processes need loss models

- Lots of earthquakes have occurred, but not enough to use damage statistics as the basis for insurance premiums

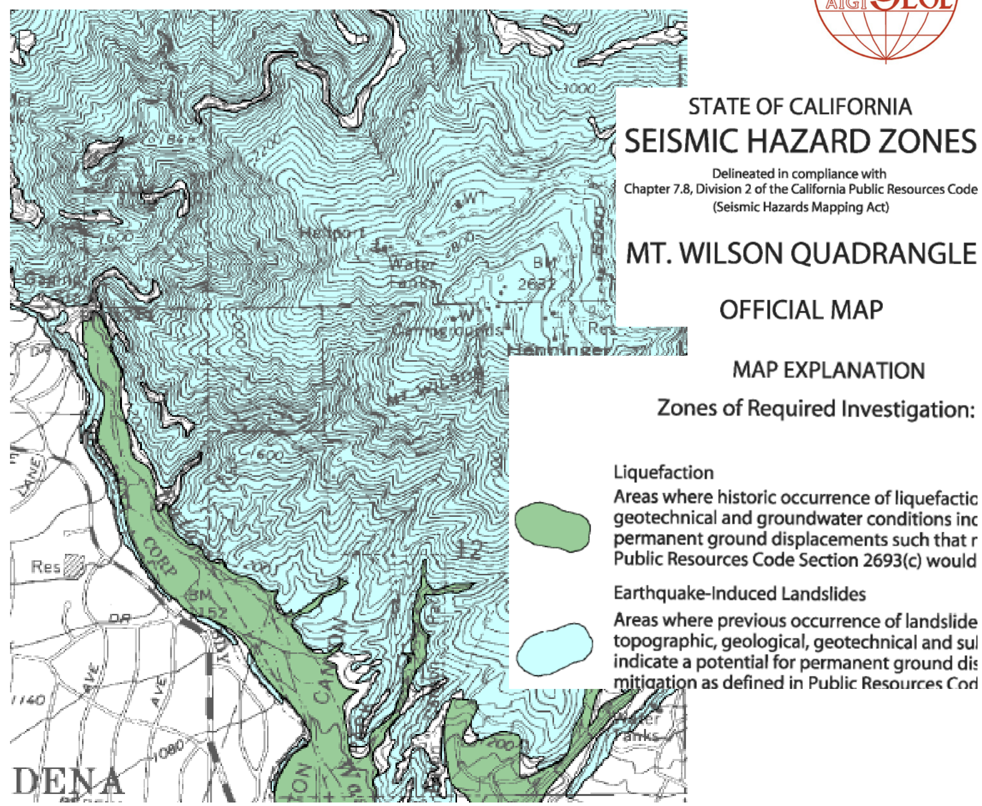
Damage and loss models

- Hazard → Ground motion value associated with annualized frequency (4.04E-04/yr)
- Reference site with local amplification
- Expected damage based on building type, age, number of stories, business function
- Value of building structure, contents, function
- Loss models consider replacement or repair cost; business interruption cost

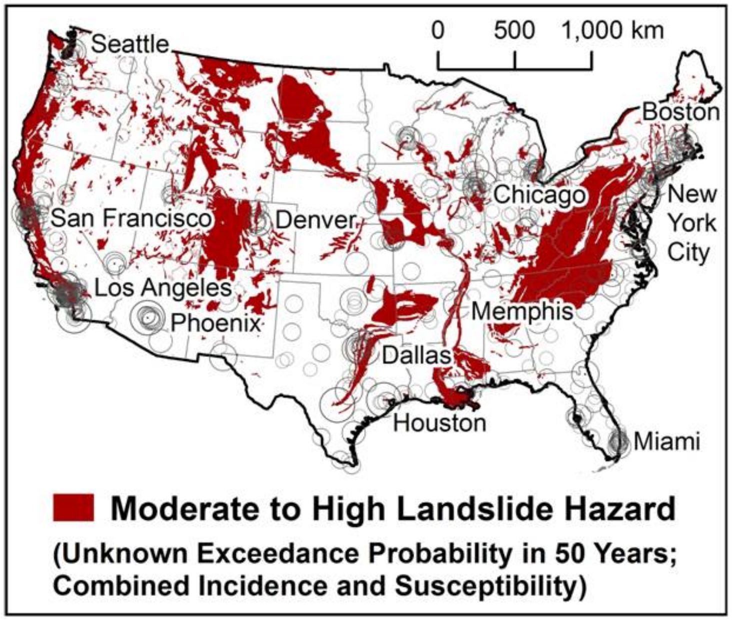
No landslide loss models

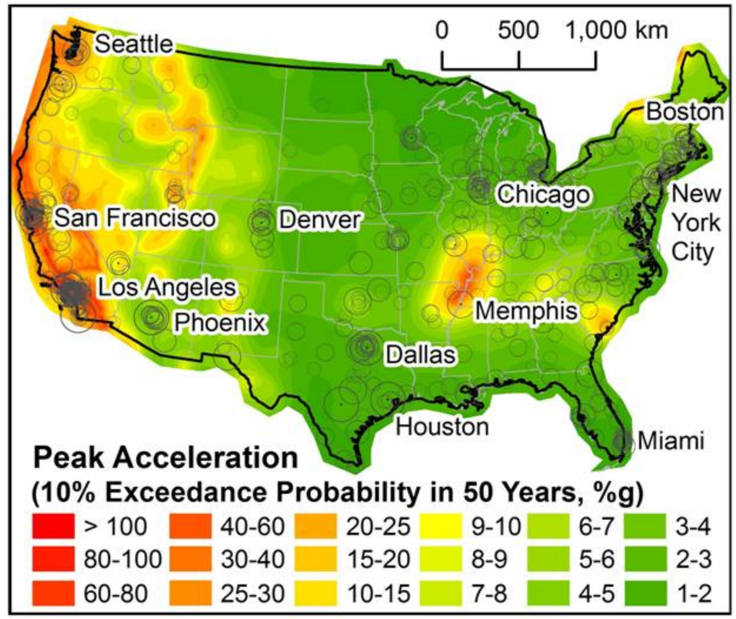
- No landslide loss models because
  - Geologists and engineers have not developed Hazard models that the insurance industry can use
  - Locations of landslide deposits may be useful for planning and zoning, but not for loss estimating
  - Landslide area doesn't cause damage; displacement causes damage, particularly differential displacement
- Without insurance products, no market exists for landslide-hazard-model output

"hazard" maps



Landslide and earthquake h Hazards in USA



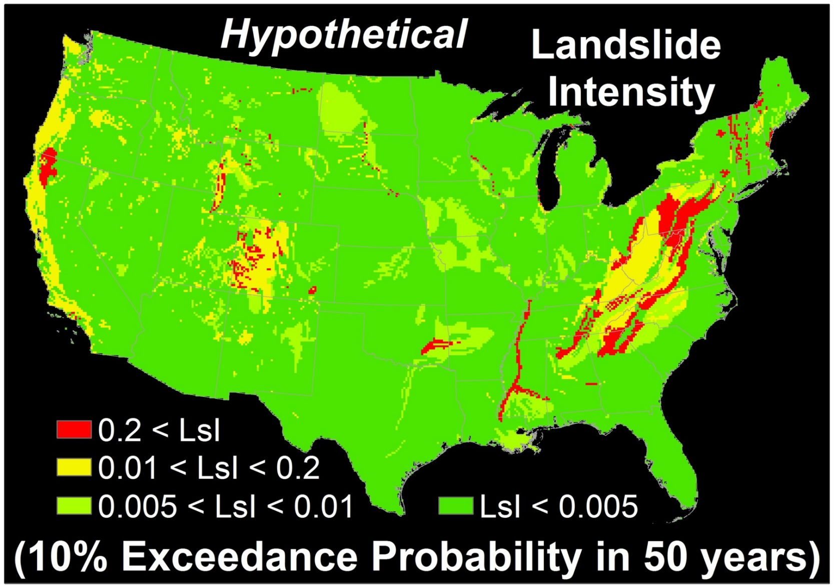


Hazard Factor	Landslide	Earthquake
Intensity	?	Peak acceleration values
Frequency	?	0.00211/year (475-yr average return period)

Detailed Landslide Hazard Maps

- First step toward serious landslide models = getting insurance industry interested
- Landslide Hazard maps are needed by insurance industry so that insuring landslides can be considered

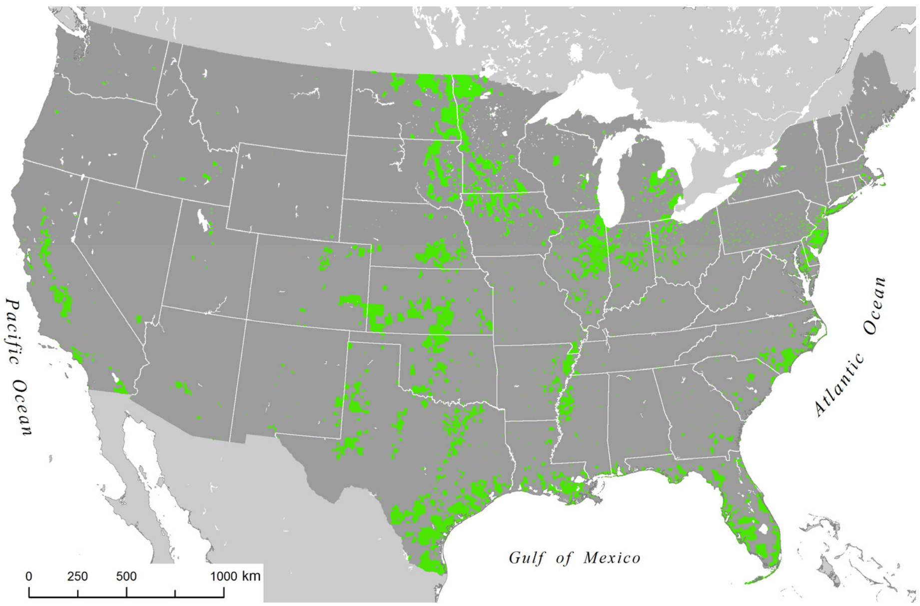
- Back in 2008…
- Hypothetical Landslide Intensity (indexed to earthquake ground motion with AF = 0.0021)



Insurance Industry Could

- Back in 2008…
- Use modeling results to set premiums
- Include landslide coverage in all-risk policy for areas with essentially zero risk
- Issue limited number of landslide policies in areas with 1-in-100 chance (AF = 0.01)
- Issue no landslide policies in areas with more than 1-in-100 chance without effective landslide mitigation measures

- By 2012…
Godt et al. developed a zip code-based map of nil hazard from landslides in the U.S.

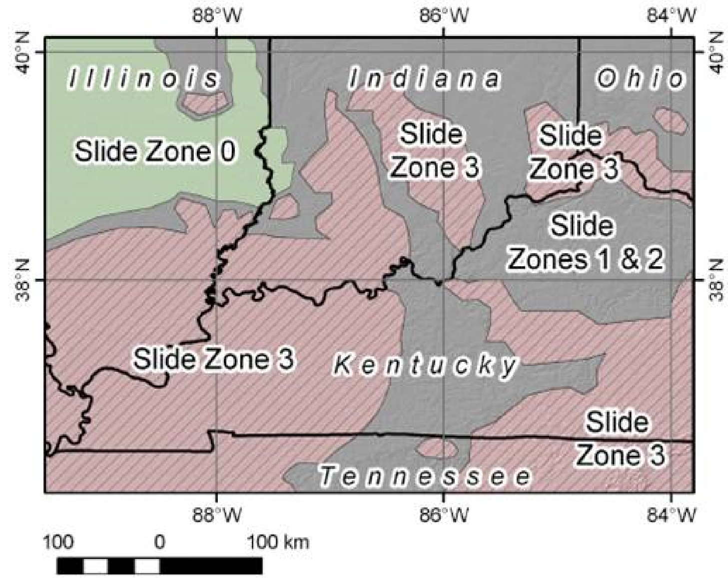


Probabilistic Landslide Intensity

- Back in 2008…
- Estimate distribution of landslide-triggering processes (earthquake magnitude and distance, rainfall intensity and duration)
- Define landslide intensity
- Characterize landslide intensity on a site with *standard conditions* caused by triggering processes (earthquake, rainfall)
- Define site susceptibility to landsliding

(inspired by Perkins, 1997)

- By 2010… Keaton and Roth developed a conceptual hazard map based on geology, relief, earthquake, and rainfall modeled after early seismic hazard zones (0, 1, 2, and 3)



Session Focus →
Nature and behavior of ~~unstable~~ slopes

Maybe this session should call upon landslide professionals to

use monitoring methods wisely and effectively

to better understand the nature and behavior of unstable slopes, and also provide context for stable slopes.

The narrow view could be broadened

Pick a few "stable slopes" and document how stable they really are

in addition to monitoring unstable slopes

This is a business case for mapping low-hazard areas with the same degree of detail as high-hazard areas

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