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Climate Change Based Prediction of Coastal Cliff Landslides Near San Francisco, California

Brian D. Collins
United States Geological Survey
Western Earth Surface Processes Team, Menlo Park, California

Climate Change, Natural Resources and Coastal Management Workshop
Concurrent Session C – Nearshore and Open Ocean

U.S. Department of the Interior
U.S. Geological Survey

Introduction

- Coastal bluffs/sea-cliffs
  - Susceptible to a number of forcing agents
  - Waves, rainfall
- Climate change effects
  - Sea level rise
  - Changes in wave climate
  - Variability of storms and precipitation
- This research
  - Process-based investigation of failure mechanisms
  - Empirical prediction of triggering event thresholds

Pacifica, California

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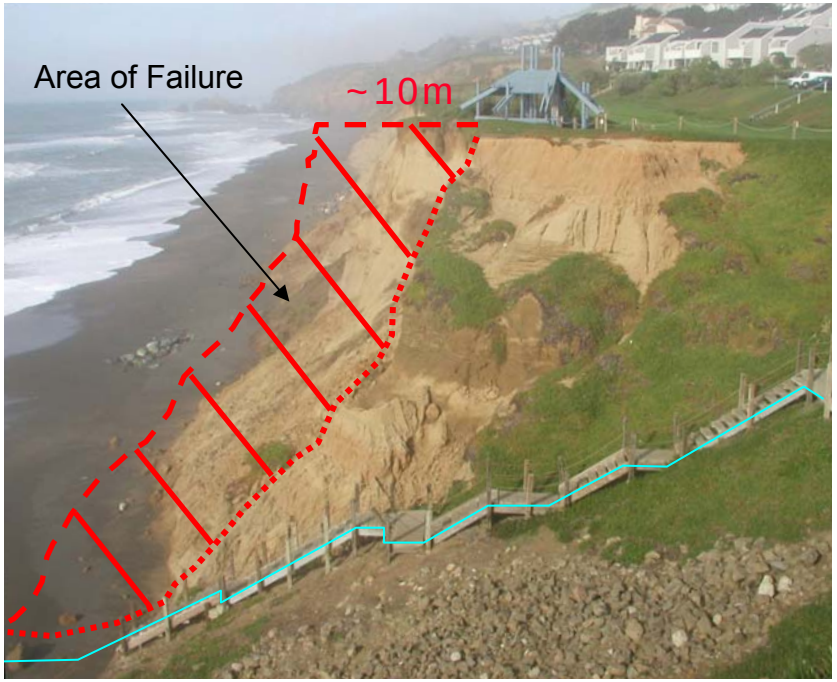
Coastal Cliff Landslides

December 22, 2002



January 30, 2003

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Goals and Methods

- Predict coastal cliff failures through development of intensity-duration thresholds
- Collection of temporally and spatially high-resolution landslide dataset
- Correlation with landslide process-based indicators
- Develop ability to forecast – predictions from expected weather (short-term) and climate (long-term)
- Planning for expected coastal response

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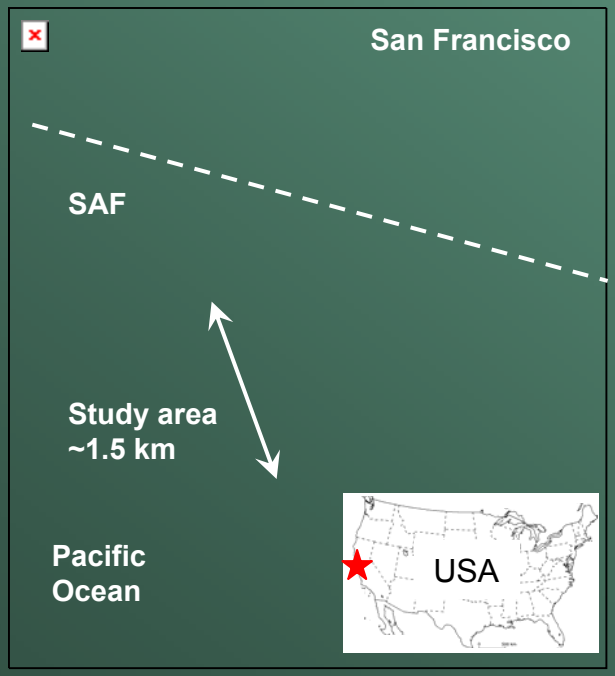
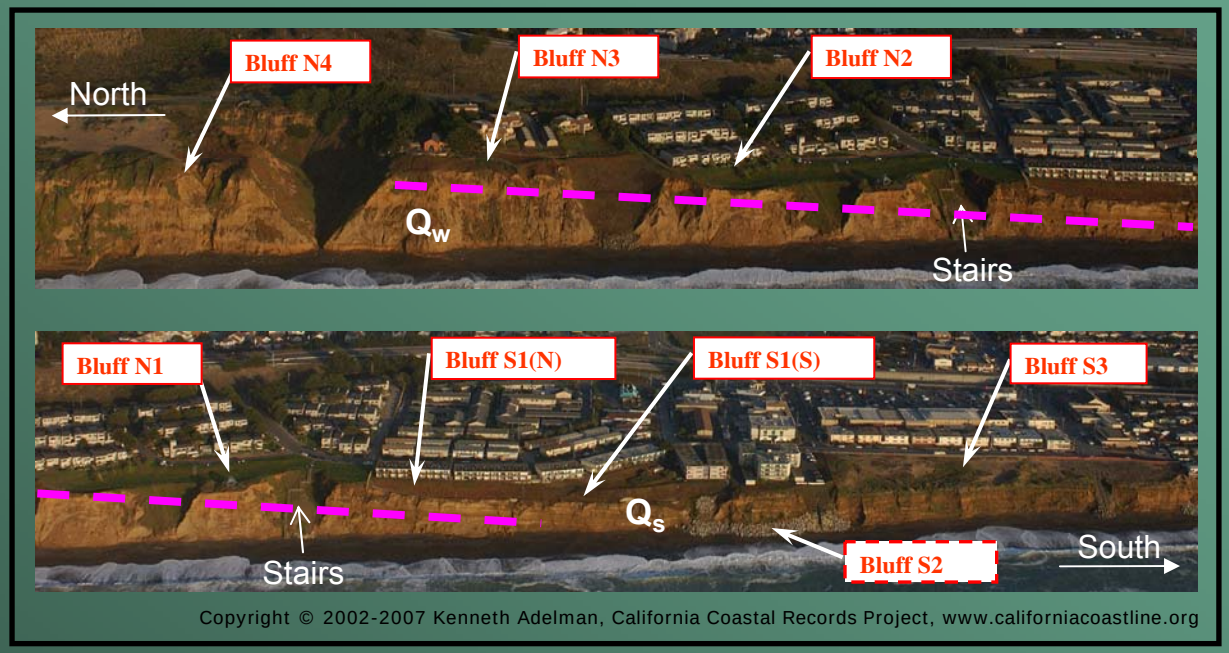
Study Area
(San Francisco, California)





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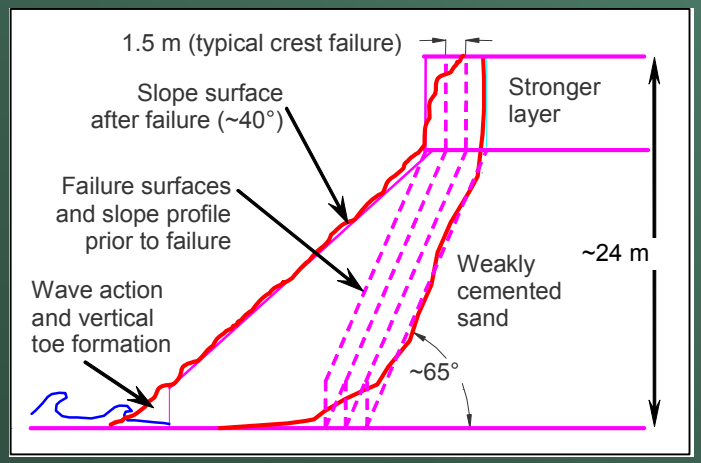
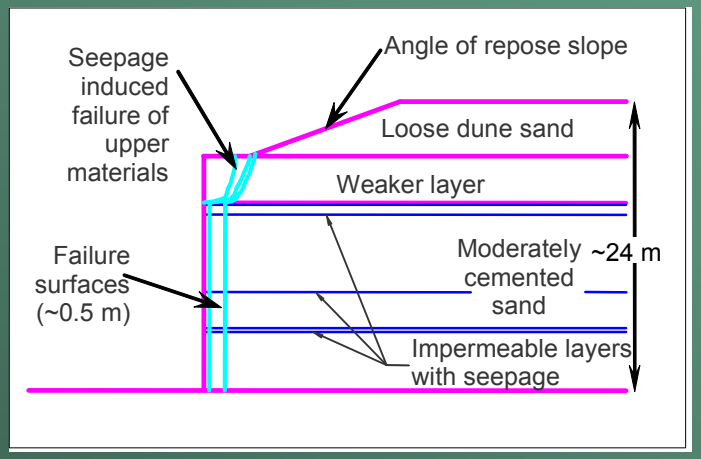
Failure Mechanisms of Weakly Lithified Sandstones

Weakly Cemented (UCS 5-30 kPa)



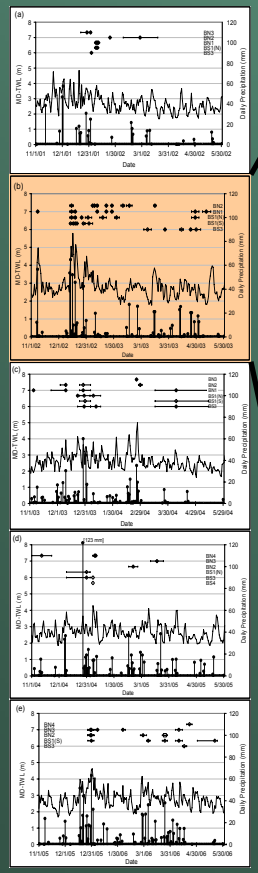
Strongly Cemented (UCS 100-400 kPa)

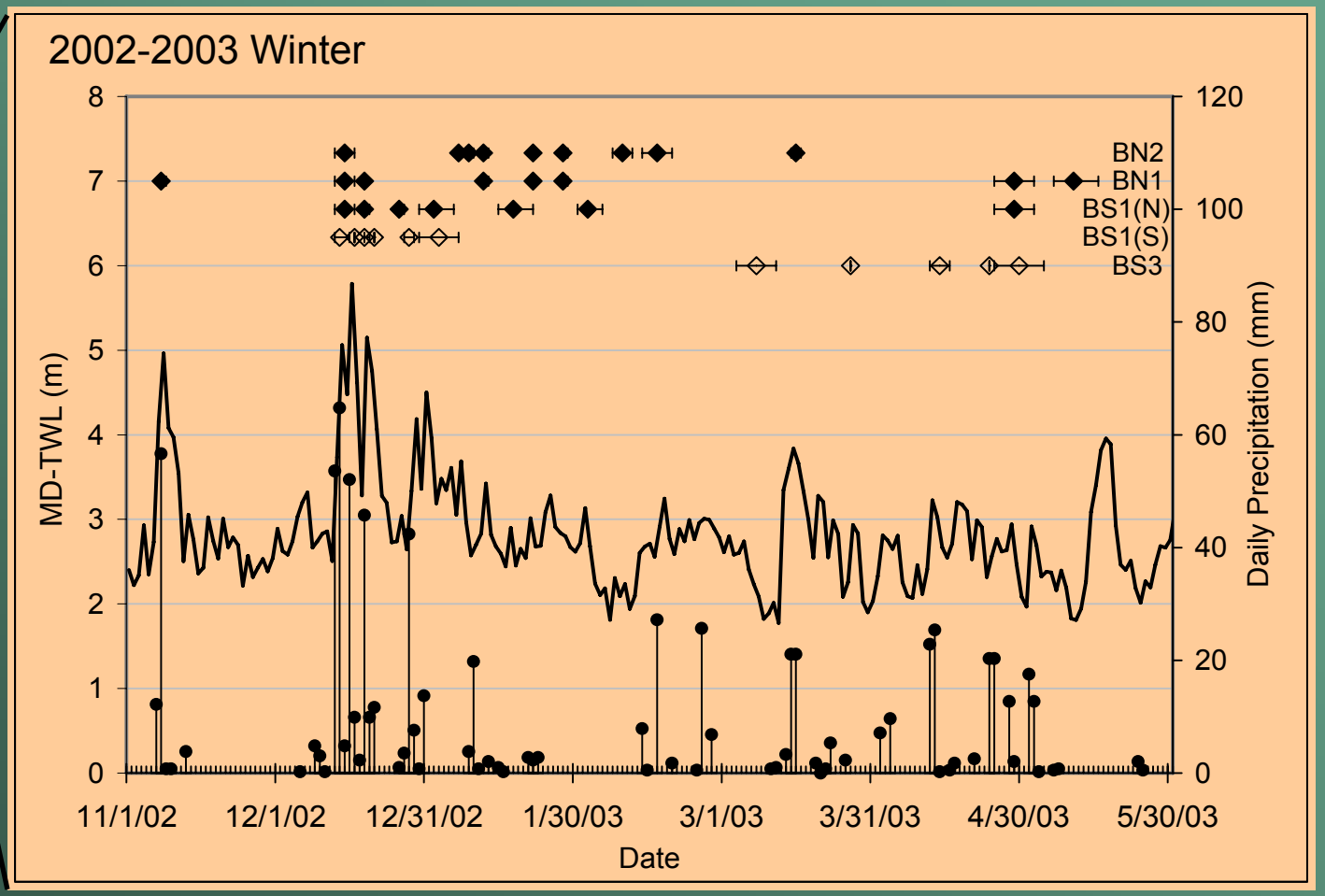


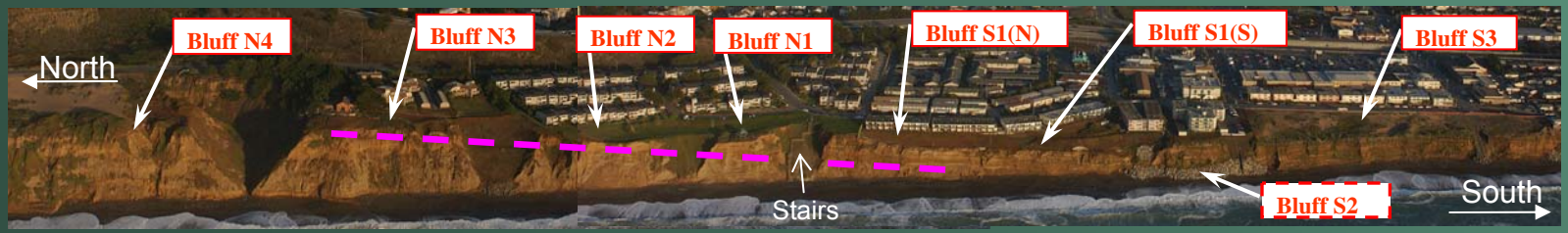
Collins, B.D. and Sitar, N., 2008, Processes of coastal bluff erosion in weakly lithified sands, Pacifica, California, USA, Geomorphology 97, pg.483-501.

BDC5

Data Collection – 2001-2006







BDC5 BCollins, 5/16/2007

Intensity - Duration Relationships

- **Wave Action: Mean Daily Total Water Level (MD-TWL)**
  - Average of the hourly wave run-up elevation
    - Measured local tide gauge height
    - Off-shore wave buoy data
  - TWL = $\eta + R_{2\%}$, where $R_{2\%} = 0.5H_s - 0.22$ (Ruggiero et al, 2001)
  - Cumulative sum of TWL difference from season average (duration index)

- **Precipitation: 48-hour Rainfall**
  - 48 hours gives indication of passing storms
  - Cannot take into account full delay of seepage
  - Cumulative sum of precipitation (duration index)

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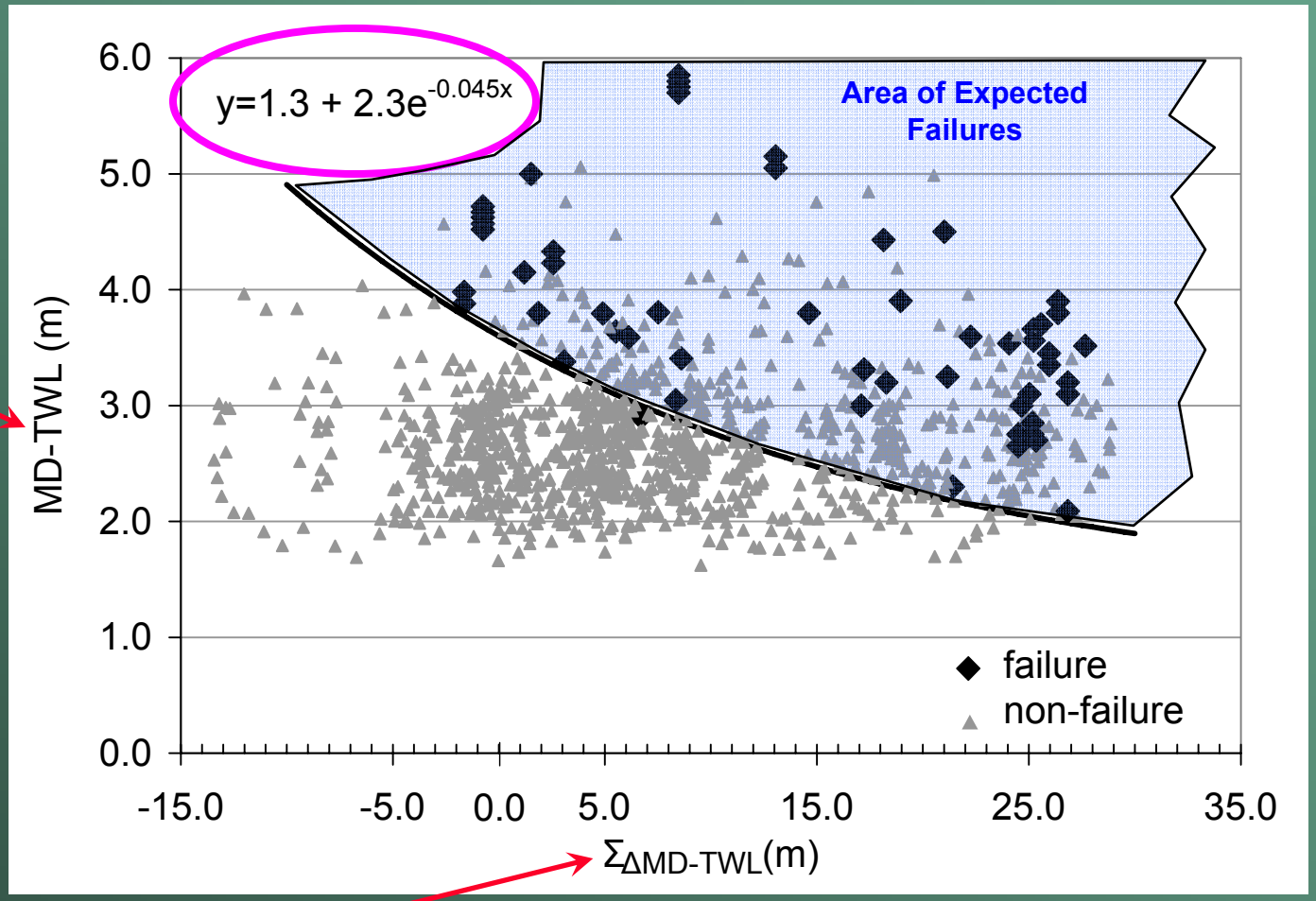
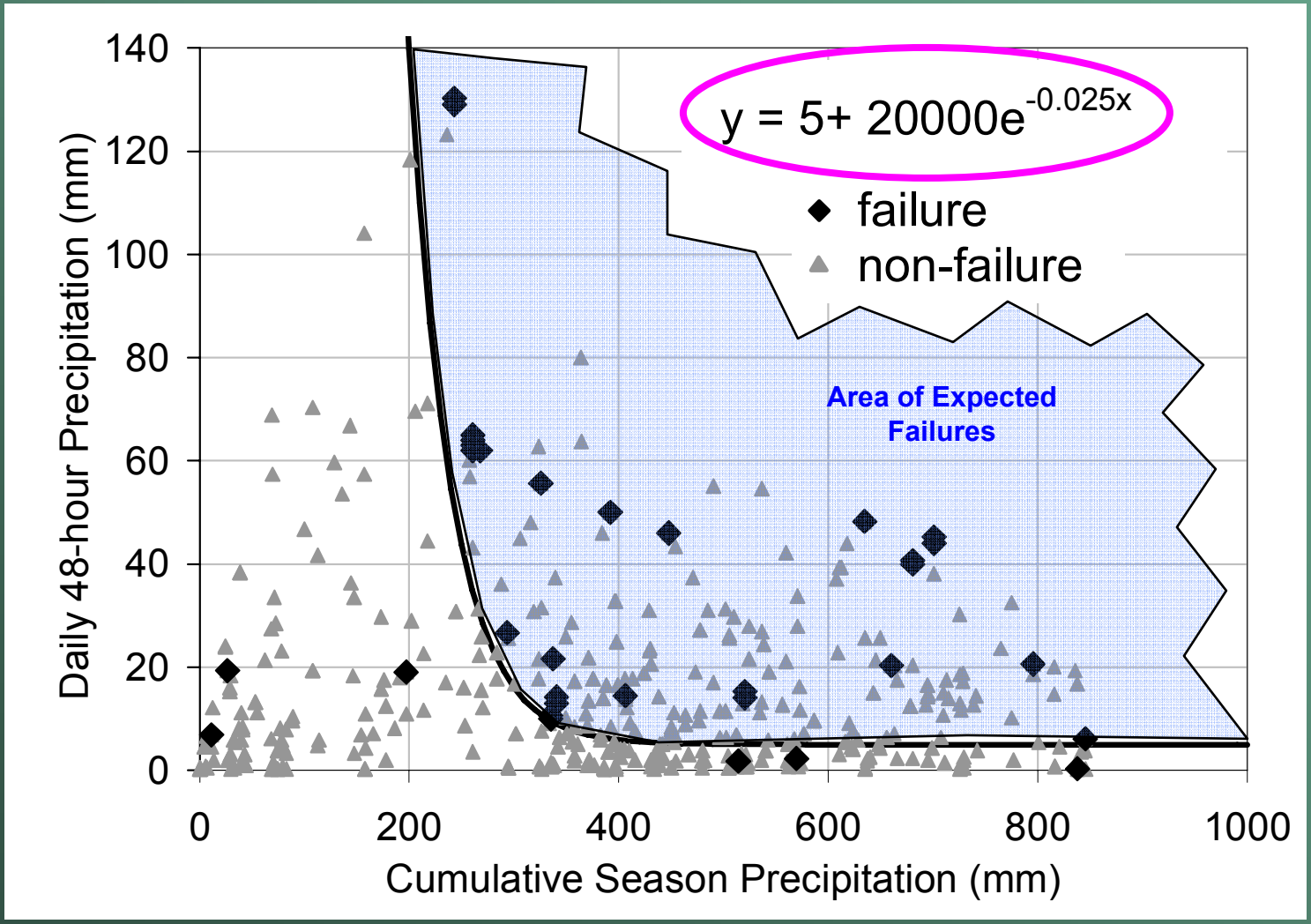
Correlation with Wave Action

The average water elevation on the beach from waves and tides.

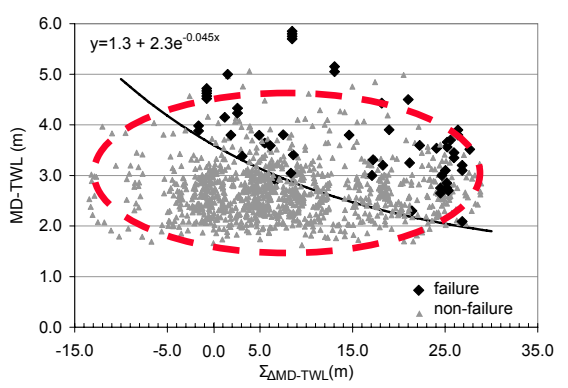


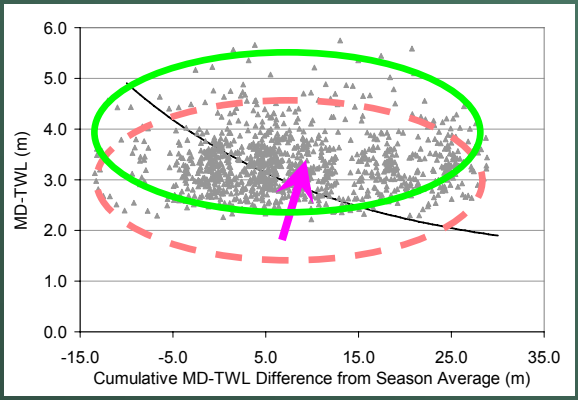
The cumulative sum of the difference in MD-TWL to the average of the MD-TWL for the entire season.

Correlation with Precipitation



Prediction of Future Response from Global Warming (Expected Sea Level Rise)





Prediction of failure events for a 5-year period in 100 years based only on sea level trend.

Sea level Trend* (m/100yr)	# points exceeding threshold	# days of predicted failure	% increase of failure	Global emissions scenario*
0	434	54	0	emissions decline
0.2	506	61	17	present rate
0.4	594	71	37	A2 average
0.6	675	81	56	A2 maximum
0.72	719	86	65	A1fi maximum

*Source: California Climate Change Center, derived from IPCC results.

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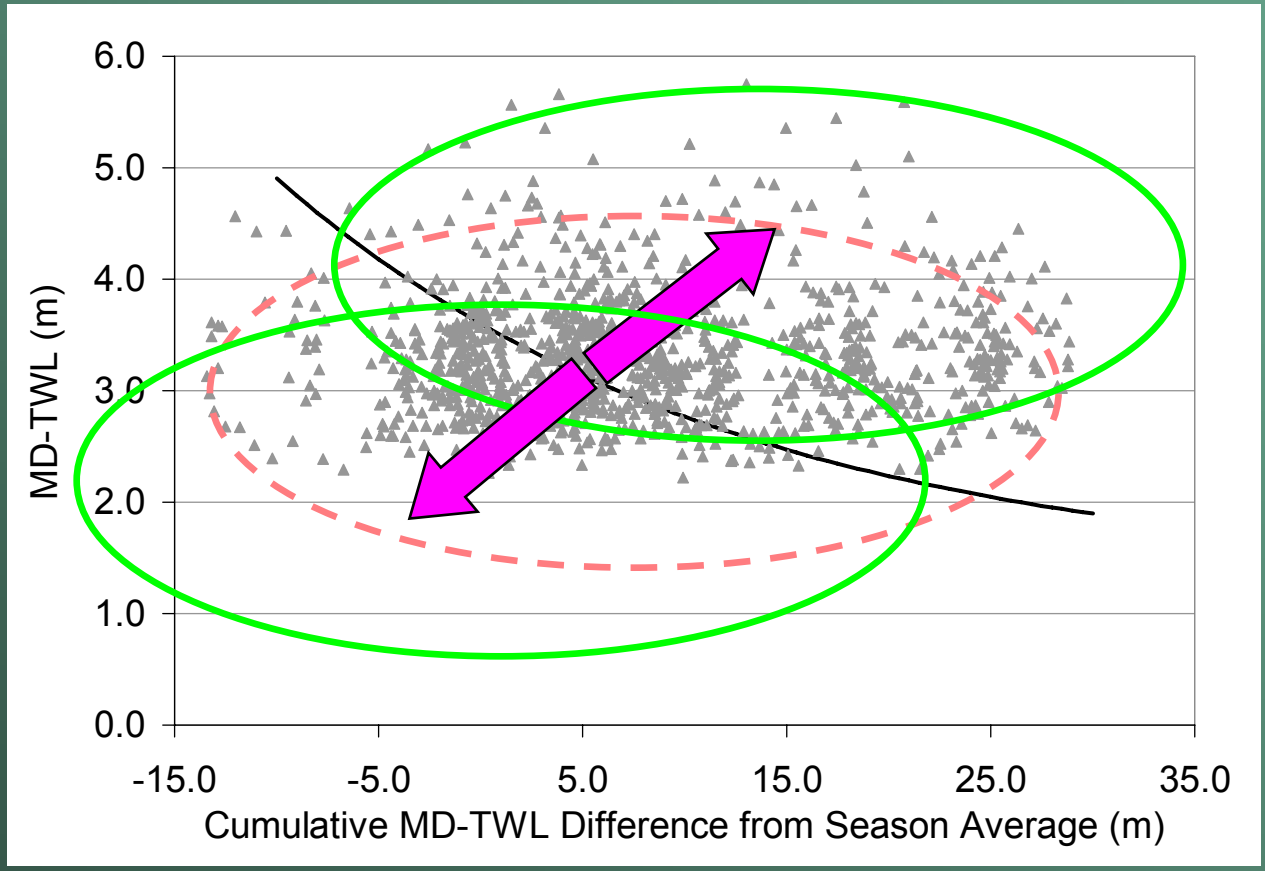
Prediction of Future Response from Global Warming (Potential Changes in Wave Action)



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Implications

- Pacifica, California – a site specific model
- But… weakest end member in California… a proxy for effects of climate change (canary in the coal mine)
- Important to continually monitor sites like this.
- Also important to establish new monitoring sites in other locations (more canaries)

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Conclusions

- Observations give new level of understanding to processes and insight to making predictions
- Empirical correlations show promise for defining conditions for failure
  - Newly developed wave-action thresholds.
- Ability to forecast landslide events from expected climate change is a new prospect for science and public awareness.
- Future direction I – incorporate effect of extreme sea-level events (predictions of increased North Pacific storm activity)
- Future direction II – extend methodology to other areas of the west coast

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Thank you.

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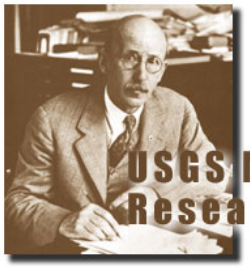

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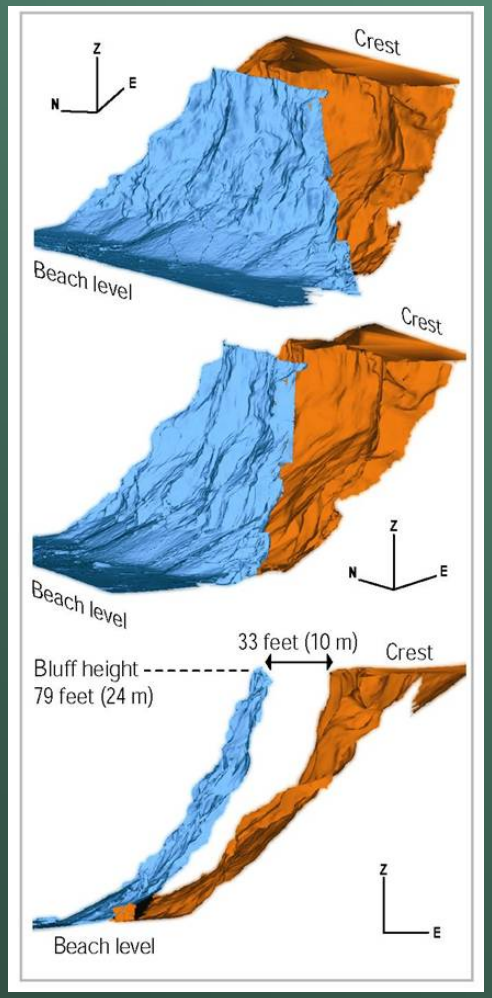
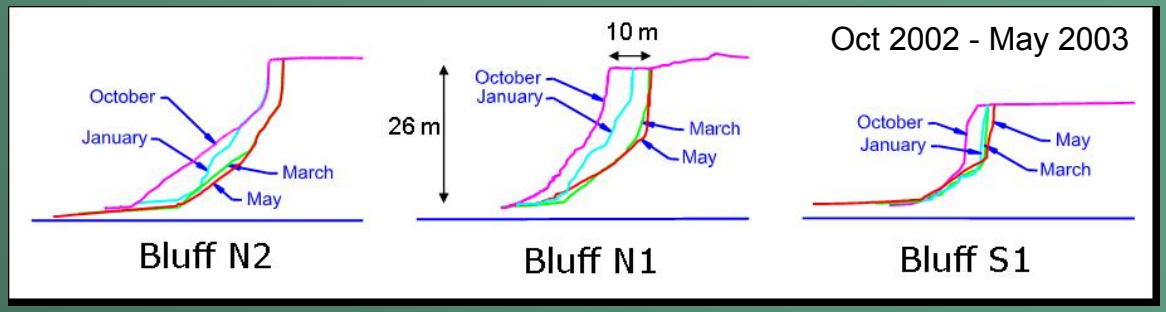
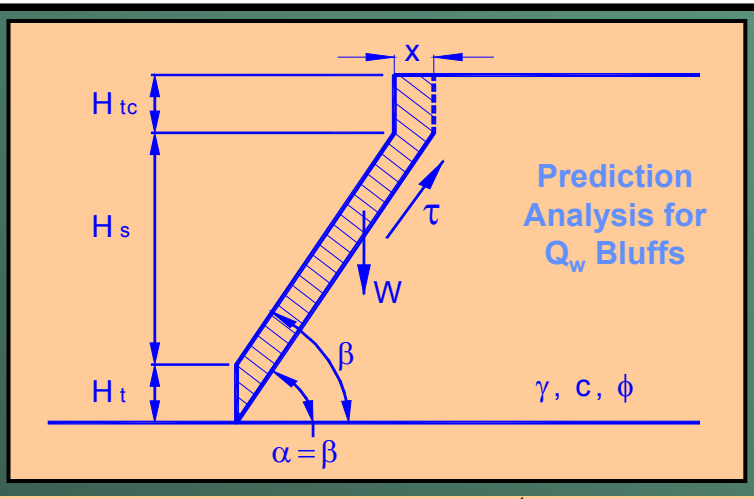
Analysis and prediction of coastal bluff erosion

Pacifica, San Mateo County, California



Bluff N1 (Oct 2002-May 2003)





$$c = \frac{\gamma}{2\tan\beta(H_s+H_t)}\left(H^2-(H_s+H_{tc})^2\right)\cdot\left(\sin^2\beta-\sin\beta\cos\beta\tan\phi\right)$$