28th Annual Road Profiler Users' Group Meeting

Warp and Curl of Arizona LTPP Jointed Concrete Pavement Test Sections

November 2, 2016

Steve Karamihas and Kevin Senn

Background

Authors:

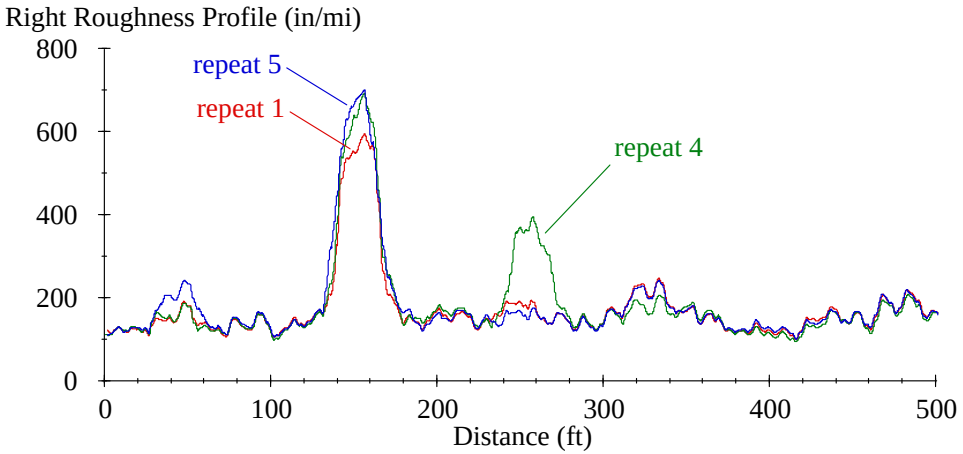
- Christopher R. Byrum,
  Julie M. Vandenbossche,
  Robert O. Rasmussen, George K. Chang,
  David K. Merritt

References:

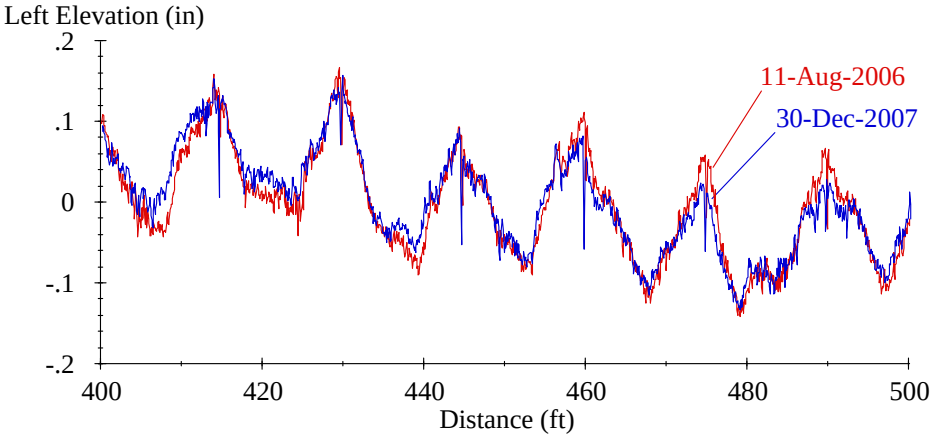
Merritt, D. K., et al., Evaluating the Effects of Concrete Pavement Curling and Warping on Ride Quality." *Report CDOT-2015-07* (2015) 76 p.

Karamihas, S. M. and K. Senn, "Curl and Warp Analysis of the LTPP SPS-2 Site in Arizona." *FHWA-HRT-12-068* (2012) 110 p.

Traditional Profile Analyses

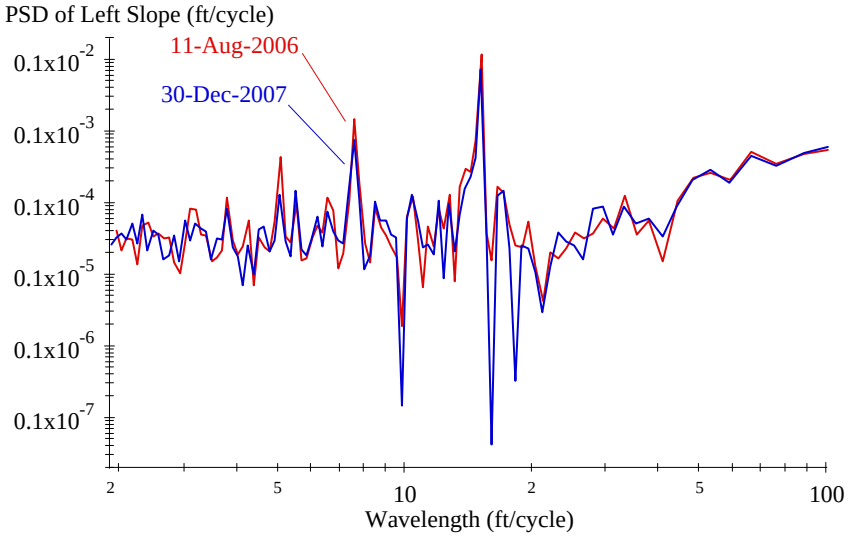


Roughness Profiles

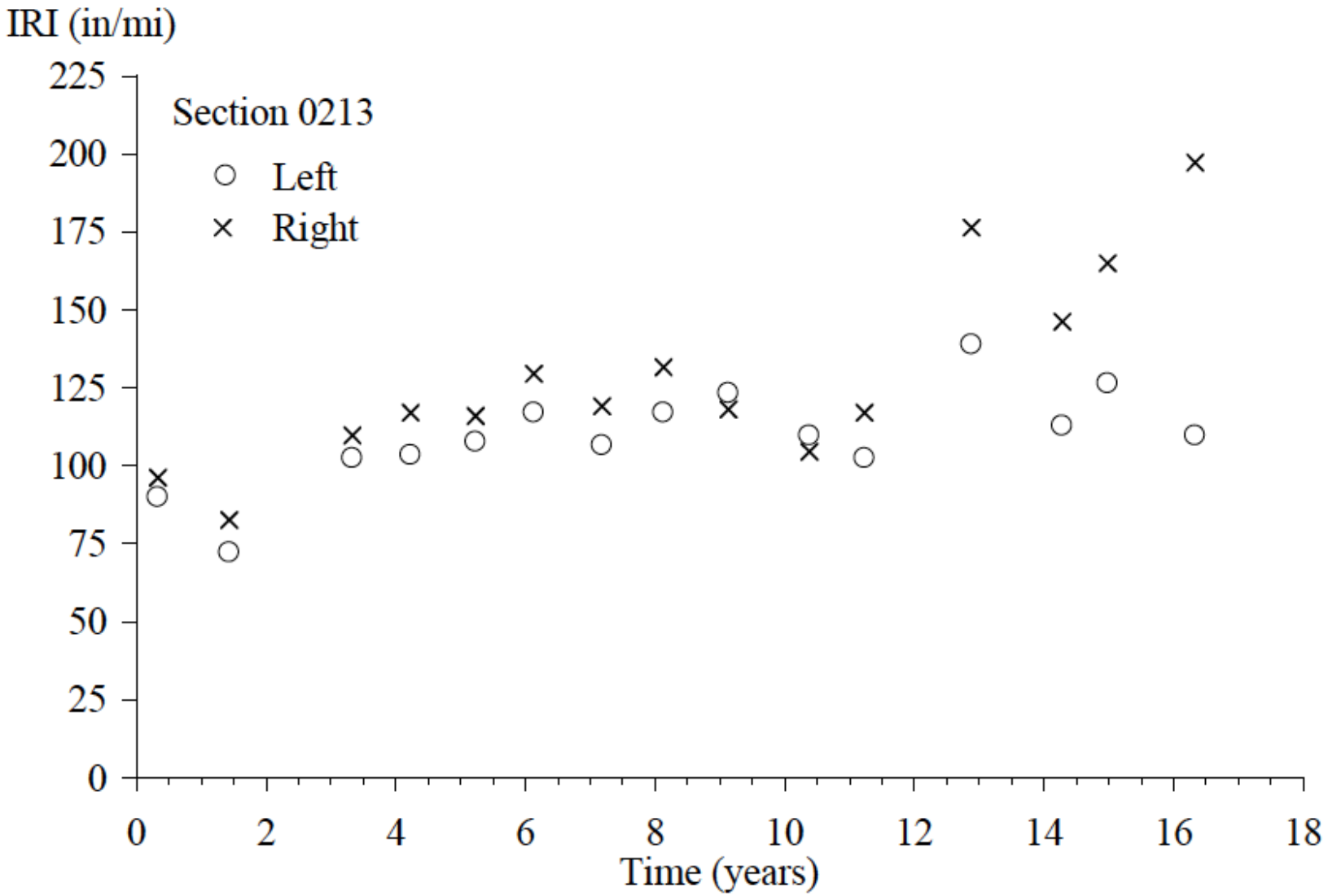


Filtered Profile Plots

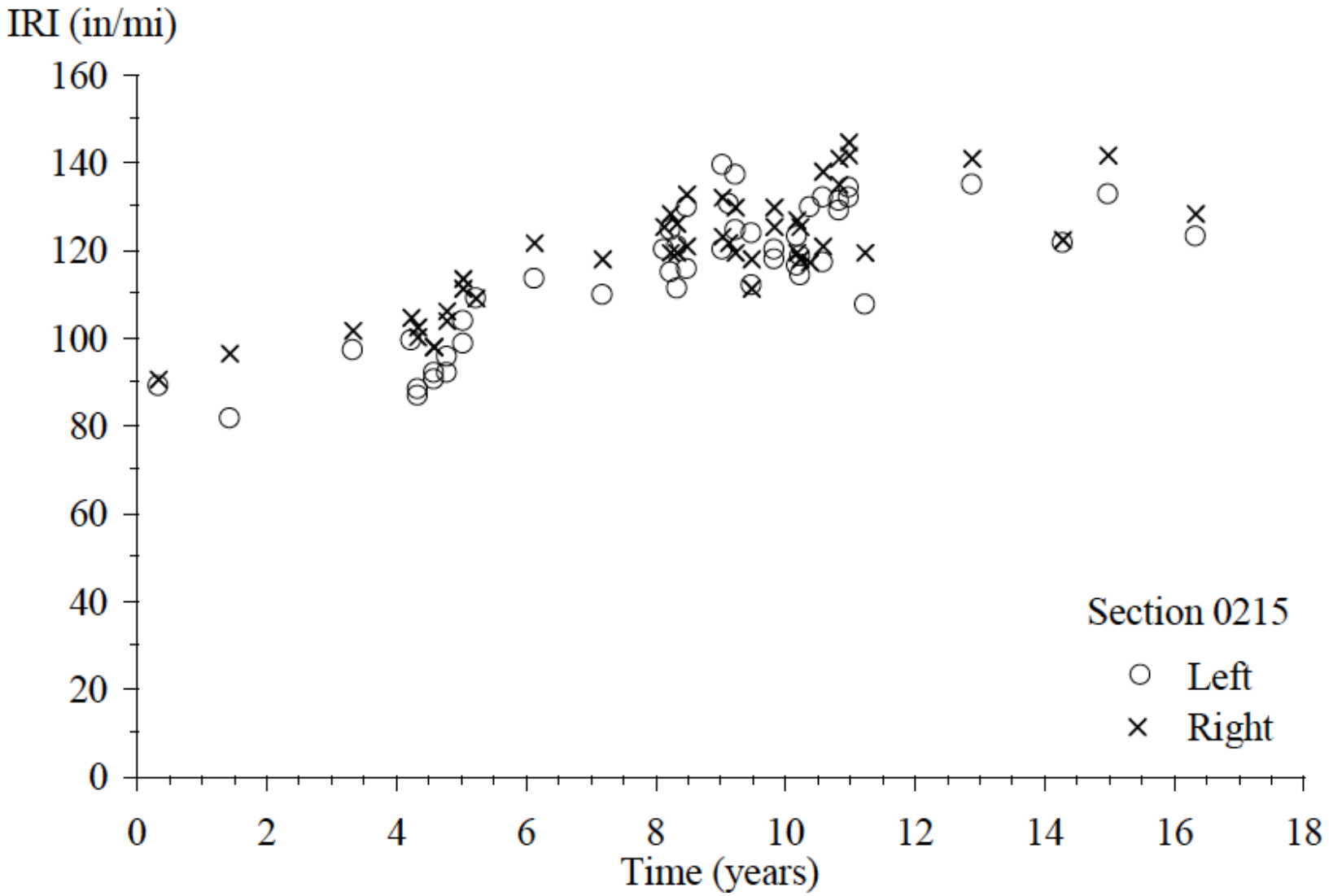
Spectral Analysis



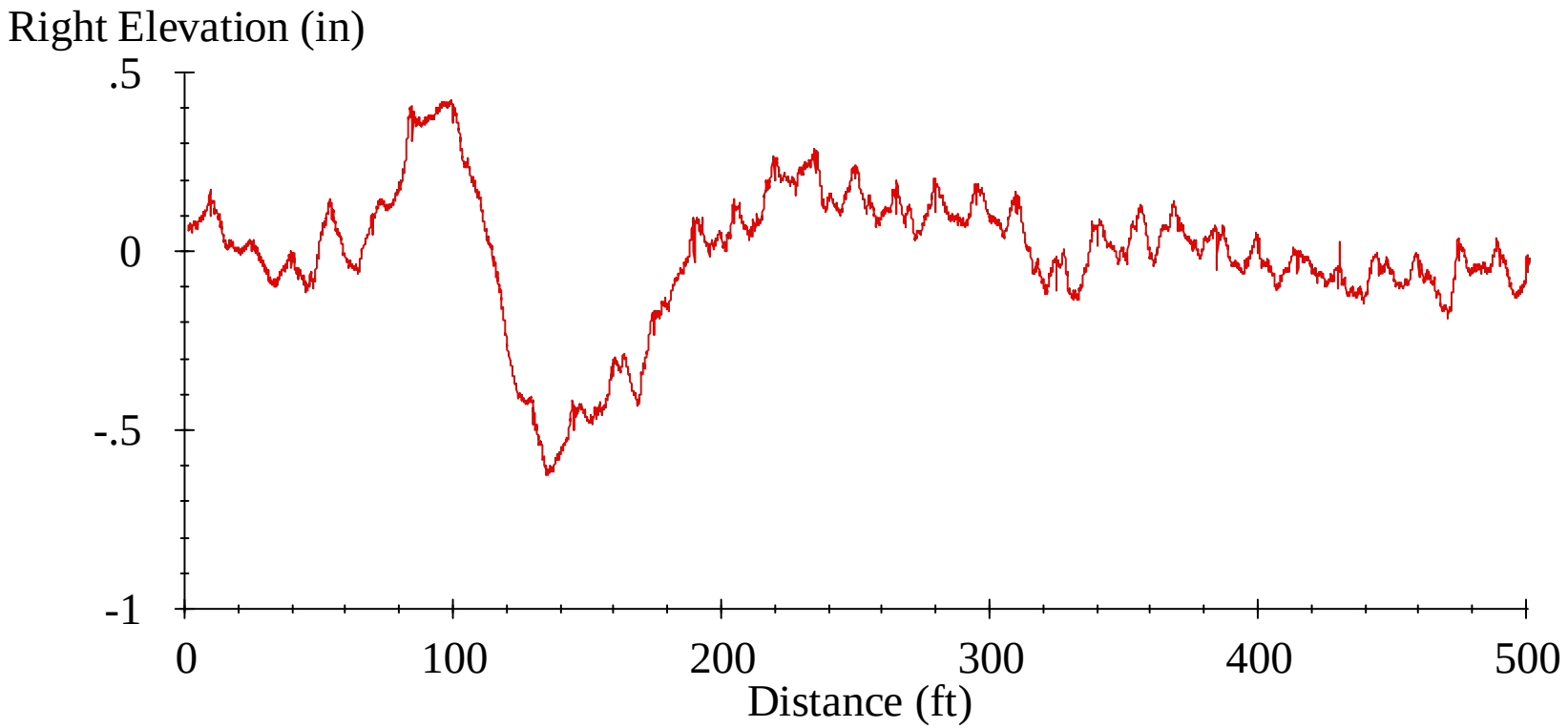
Roughness Progression, Section 040213



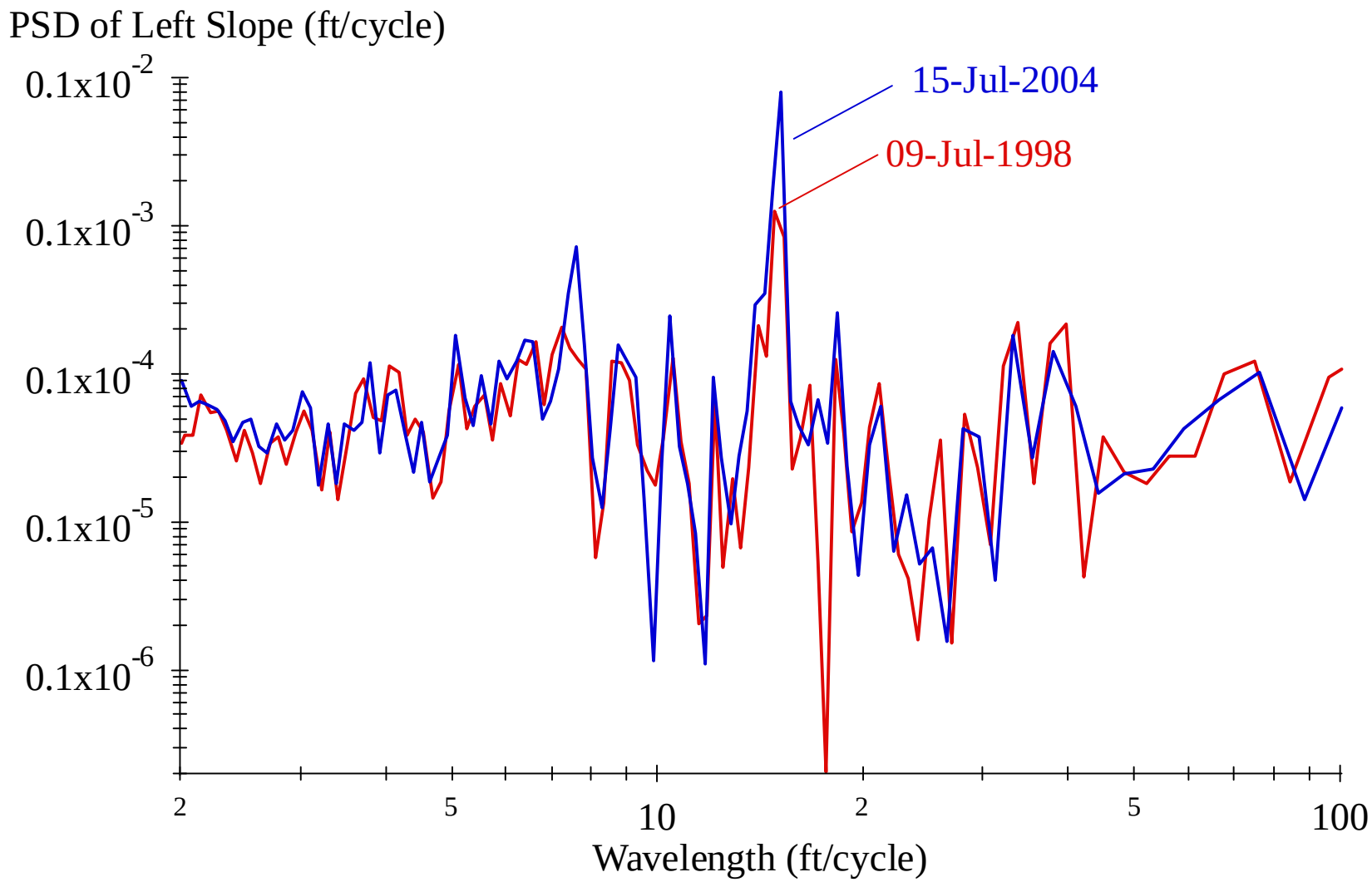
Roughness Progression, Section 040215



Elevation Profile, Section 040213



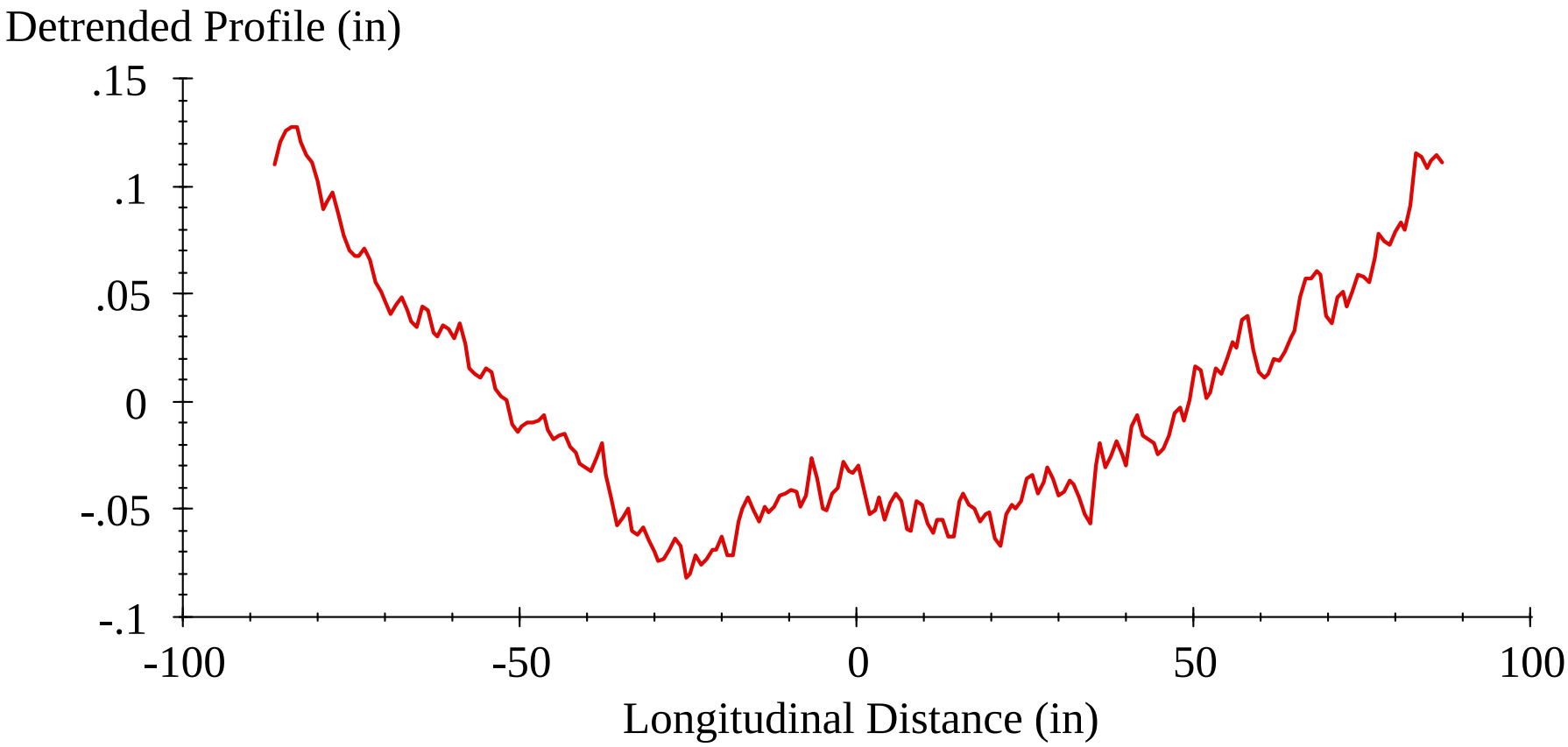
Spectral Density, Section 040215



Methods

- Perform slab-by-slab analysis
- Estimate curl at each slab with one value
- Aggregate the level of curl over each profile
- Estimate the influence of curl on the IRI
- Re-examine roughness progression

Isolated Slab Profile



Westergaard Equations

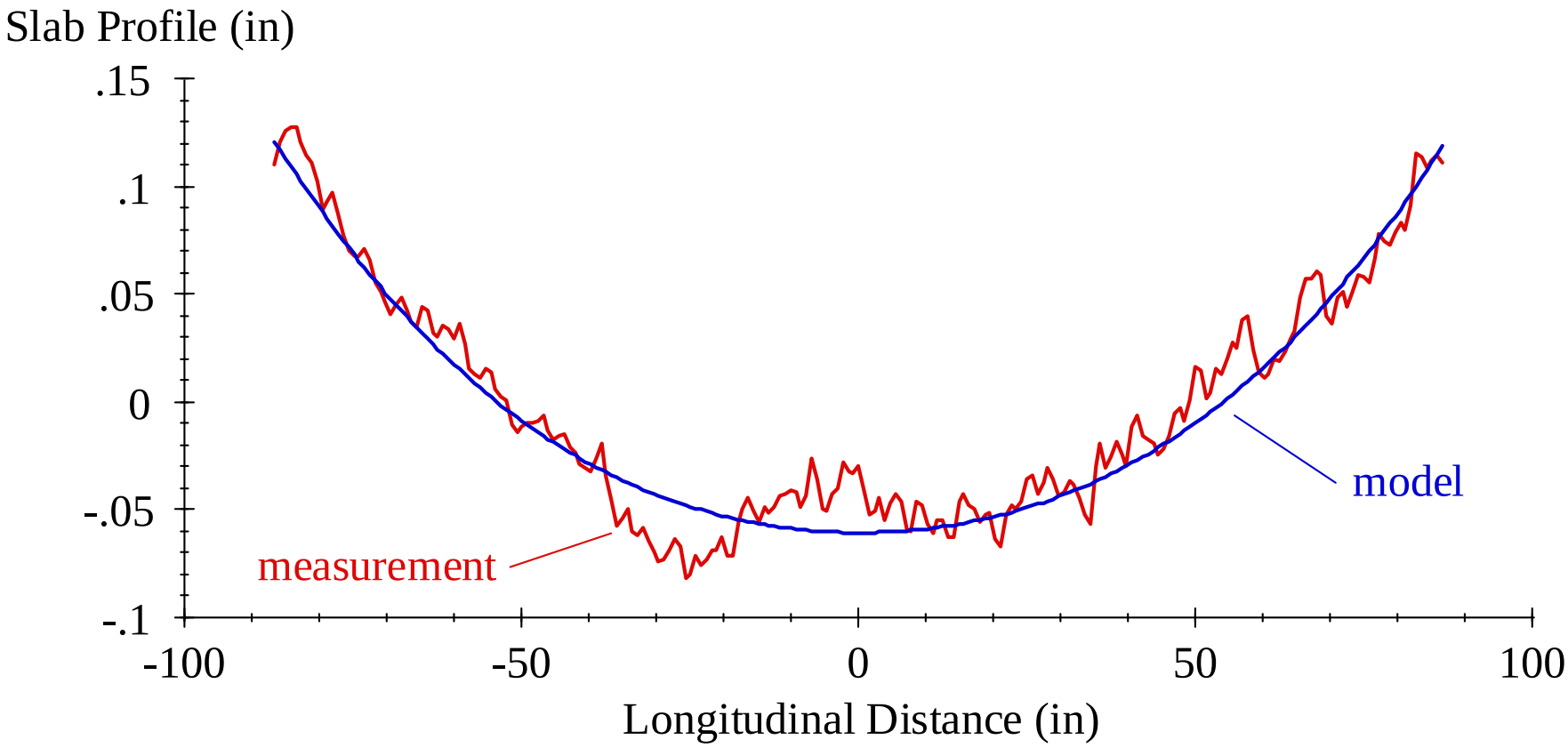
$$z = -z_0 \frac{2\cos\lambda\cosh\lambda}{\sin 2\lambda - \sinh 2\lambda}\left[(-\tan\lambda + \tanh\lambda)\cos\frac{x}{l\sqrt{2}}\cosh\frac{x}{l\sqrt{2}}\right.$$

$$\left. +(\tan\lambda + \tanh\lambda)\sin\frac{x}{l\sqrt{2}}\sinh\frac{x}{l\sqrt{2}}\right]$$

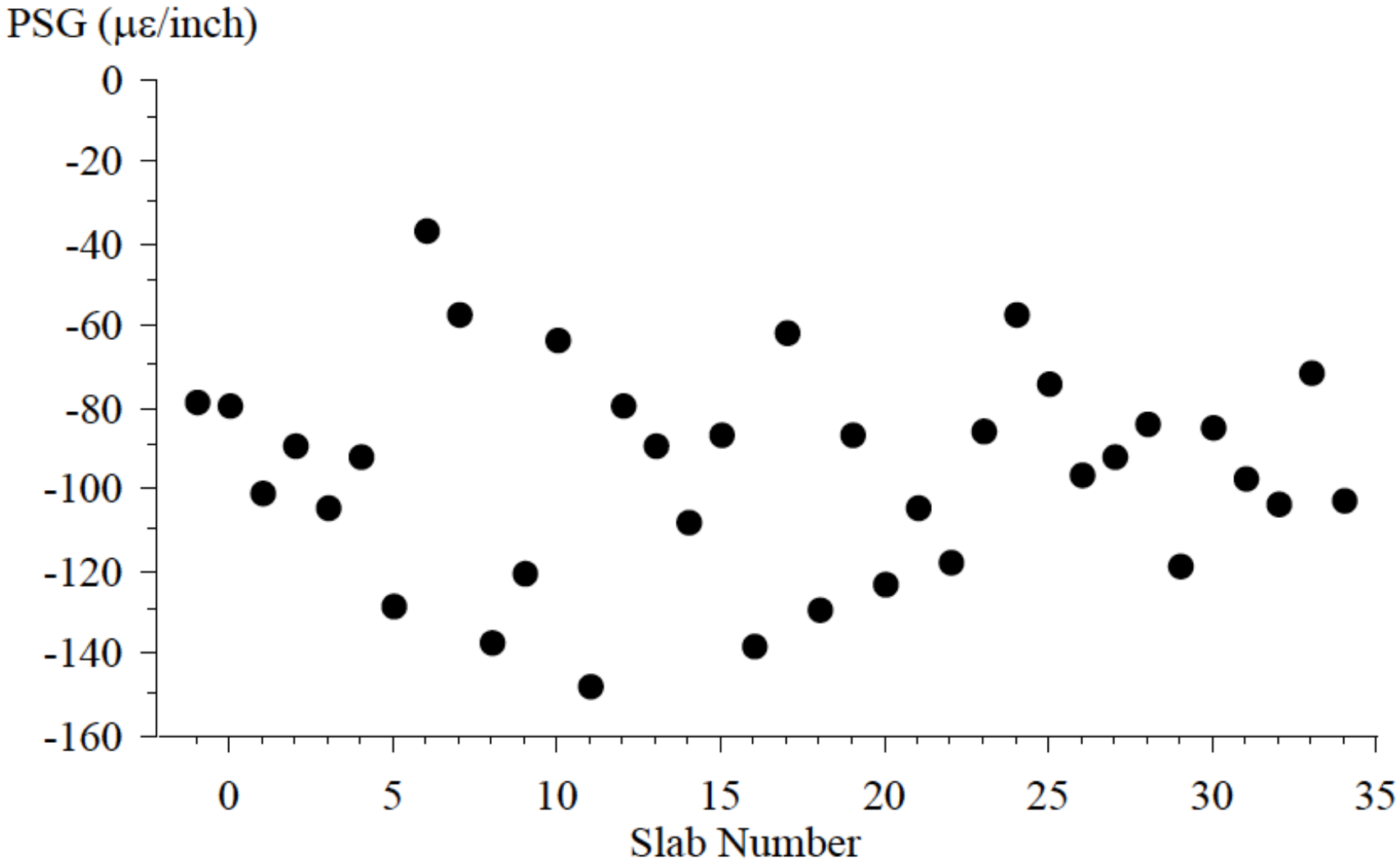
$$\lambda = \frac{b}{l\sqrt{8}} \qquad l = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}} \qquad z_0 = \frac{-(1+\mu)(\alpha\Delta T + \Delta\varepsilon_{sh})}{h}l^2$$

$$PSG = \frac{(\alpha\Delta T + \Delta\varepsilon_{sh})}{h}$$

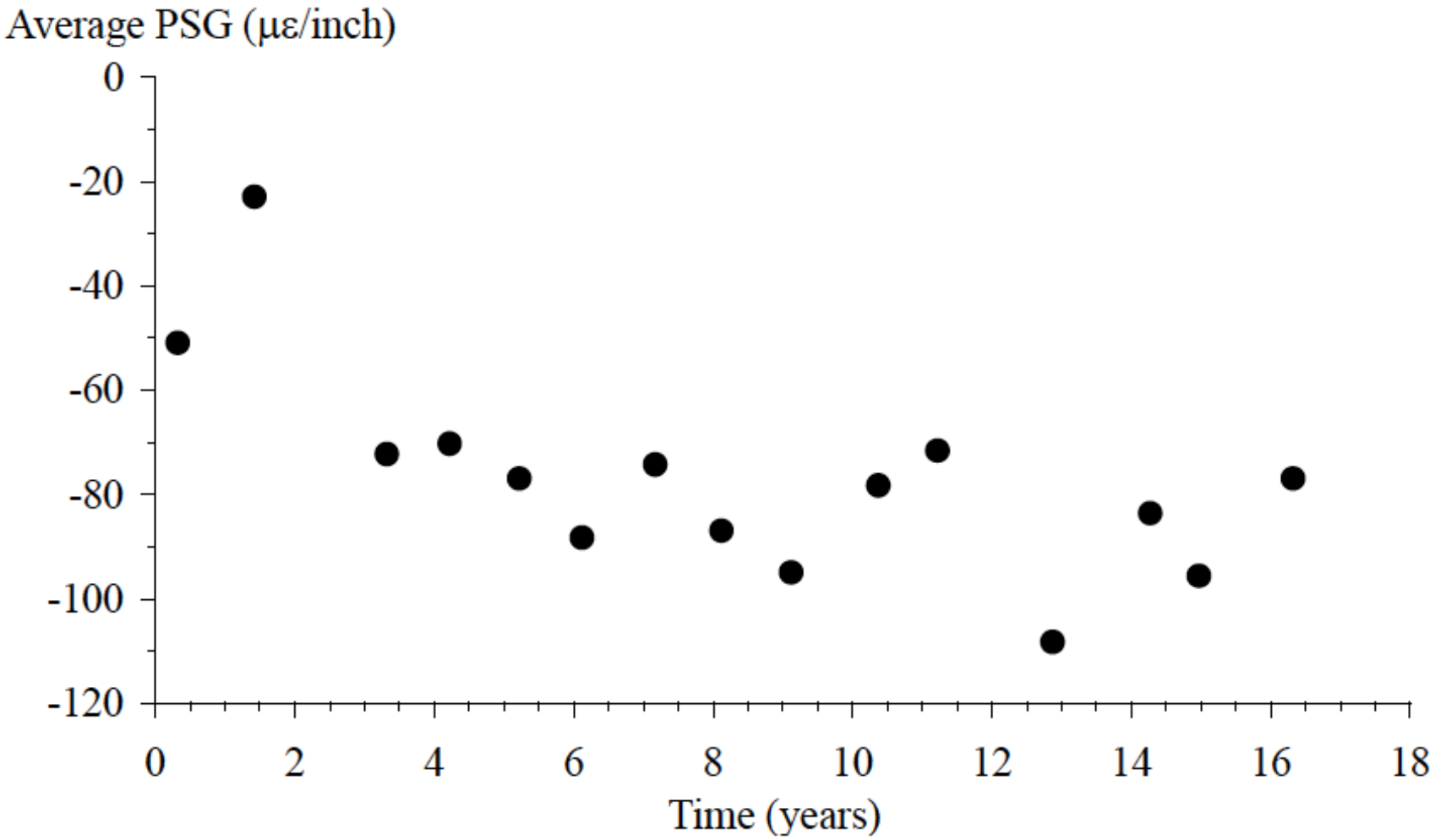
Sample Curve Fit



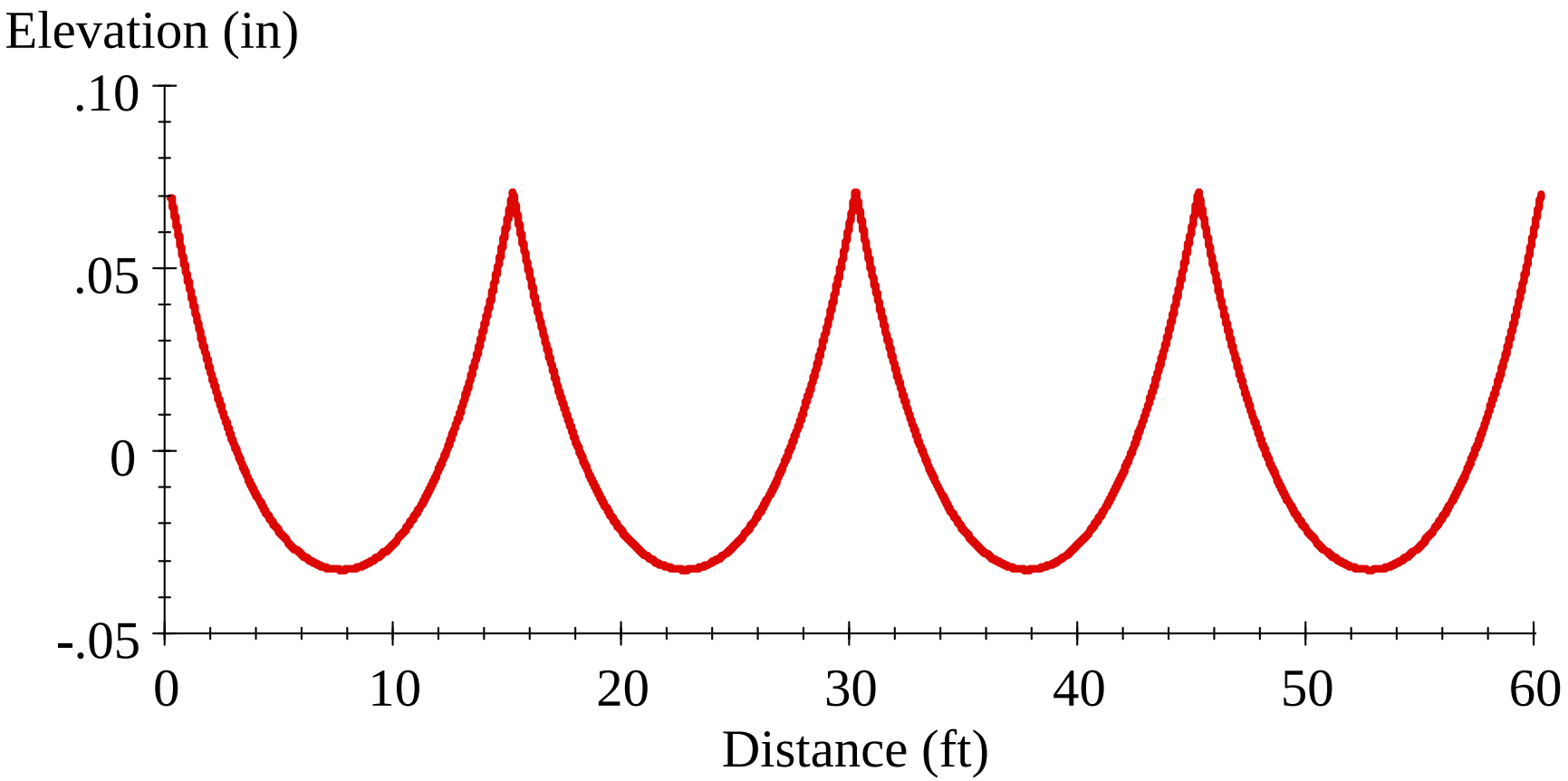
Slab by Slab Pseudo Gradient



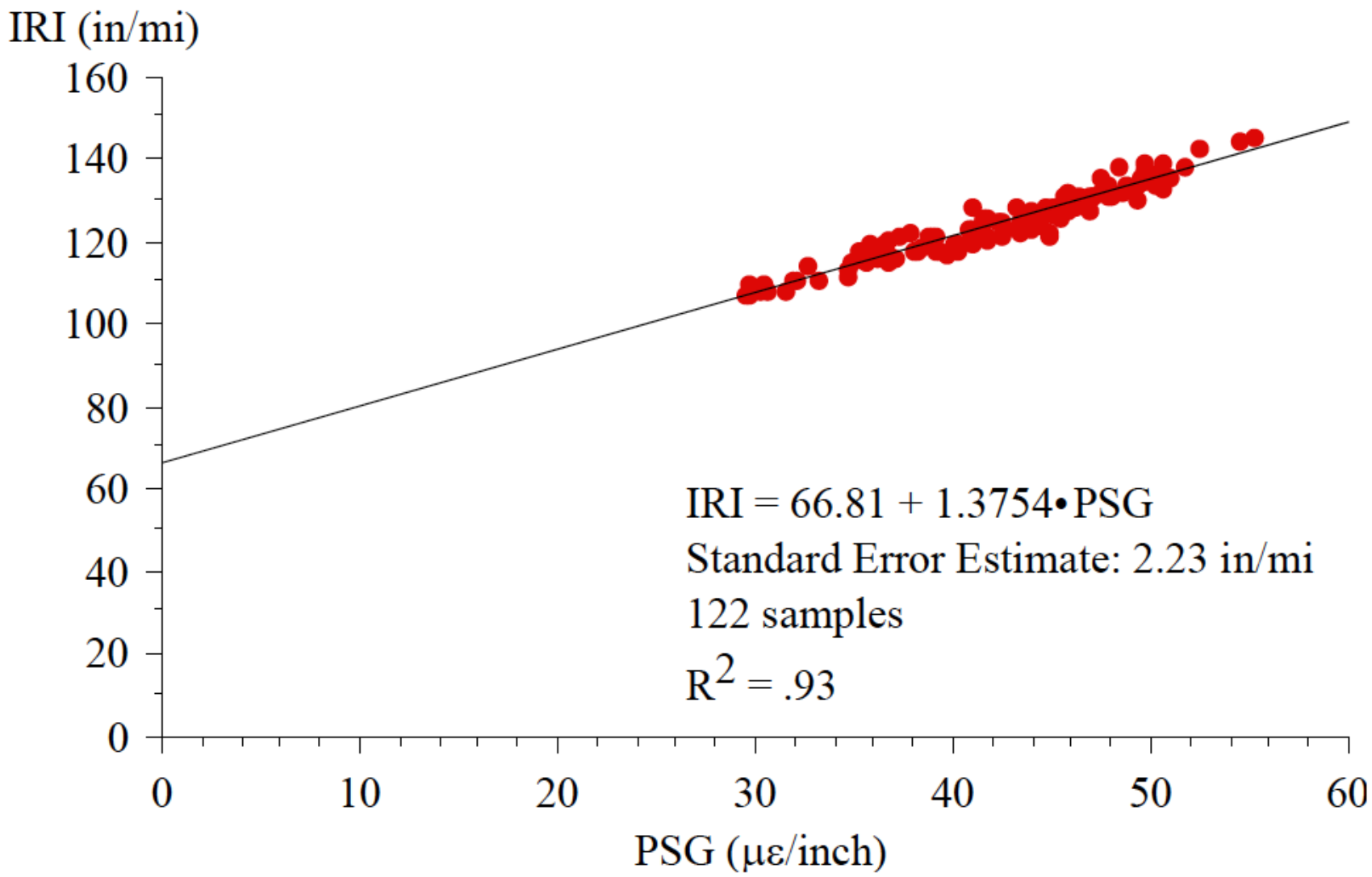
Average Pseudo Gradient over Time



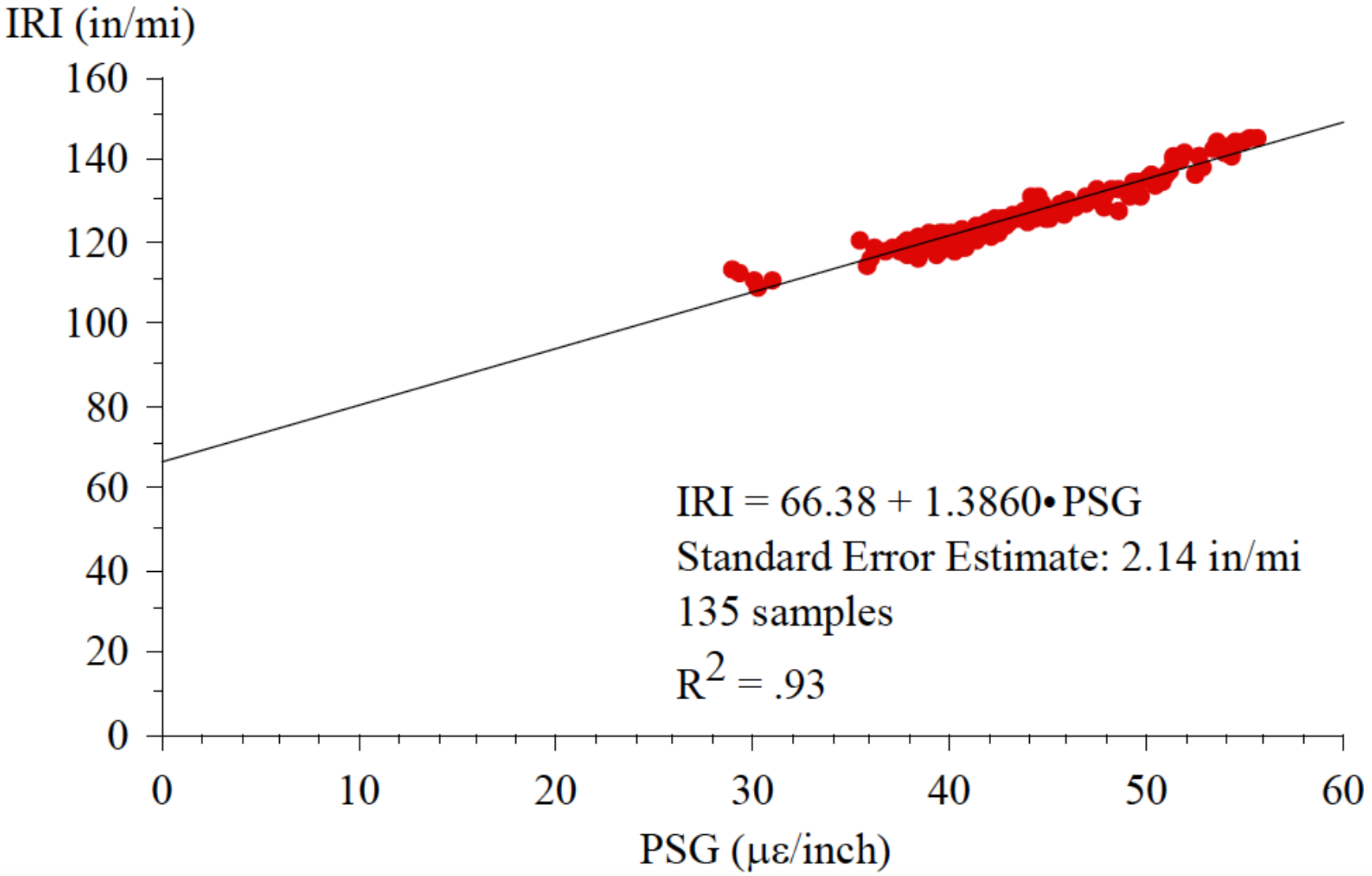
Idealized Profile



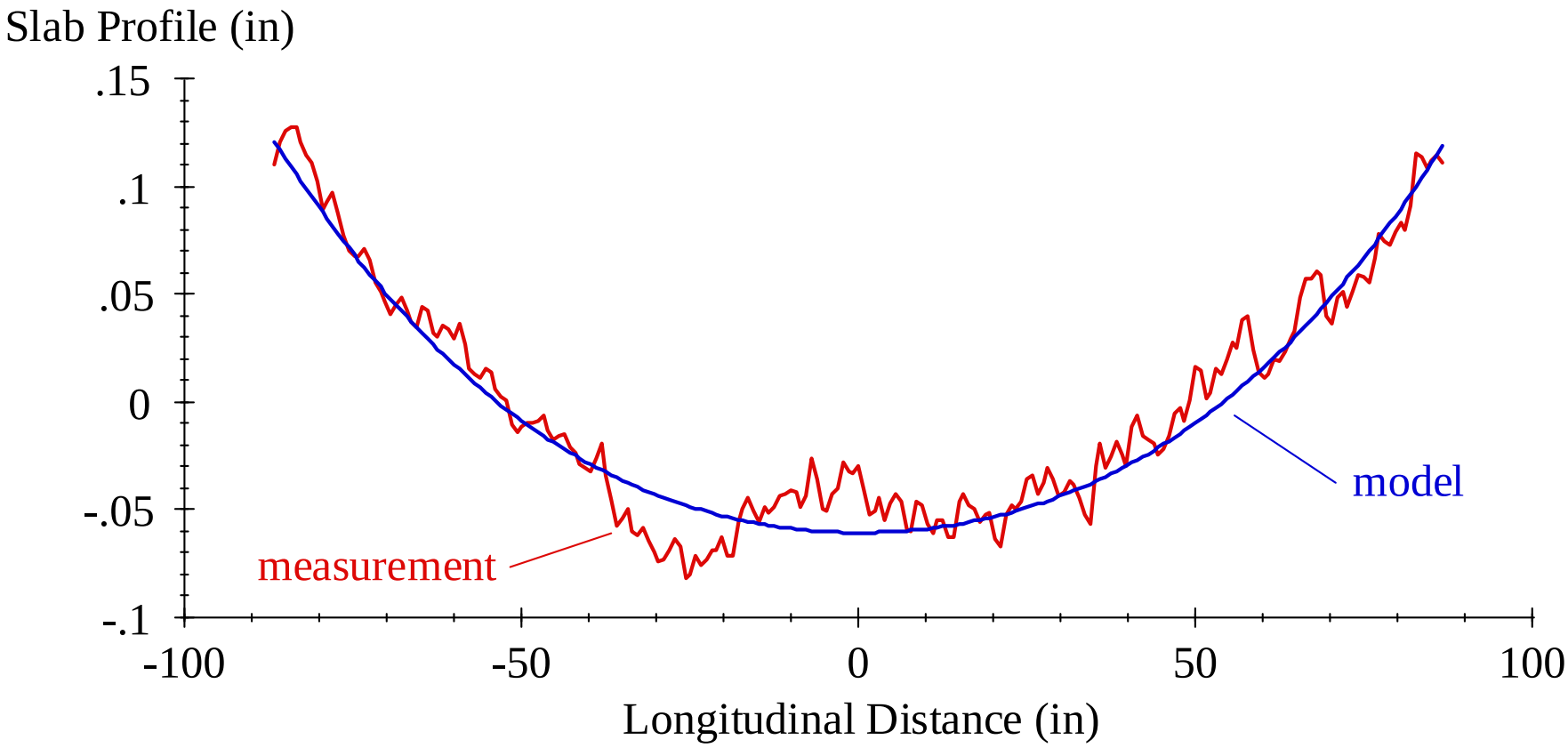
IRI versus PSG, LTPP Sections



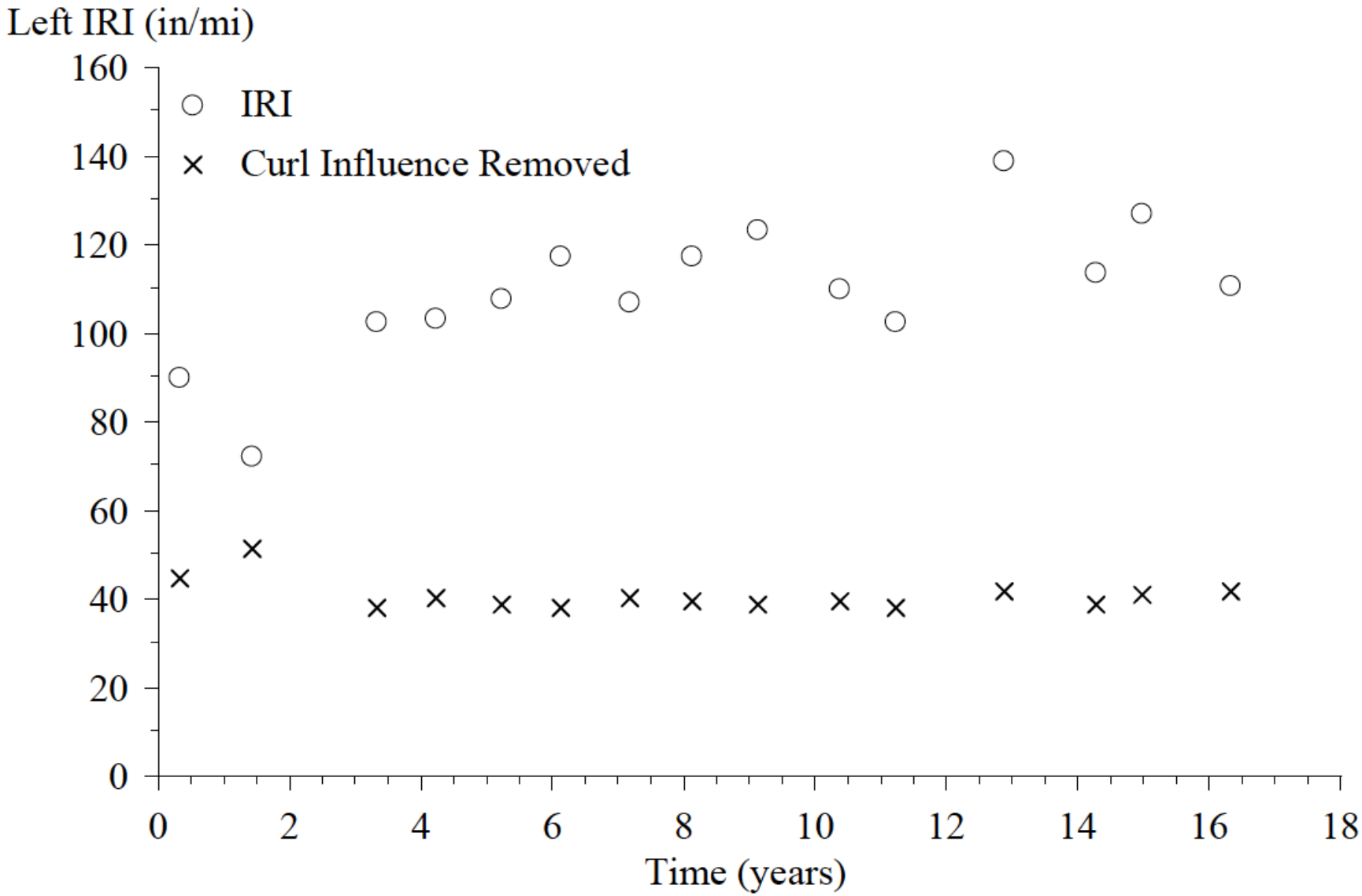
IRI versus PSG, FHWA Sections



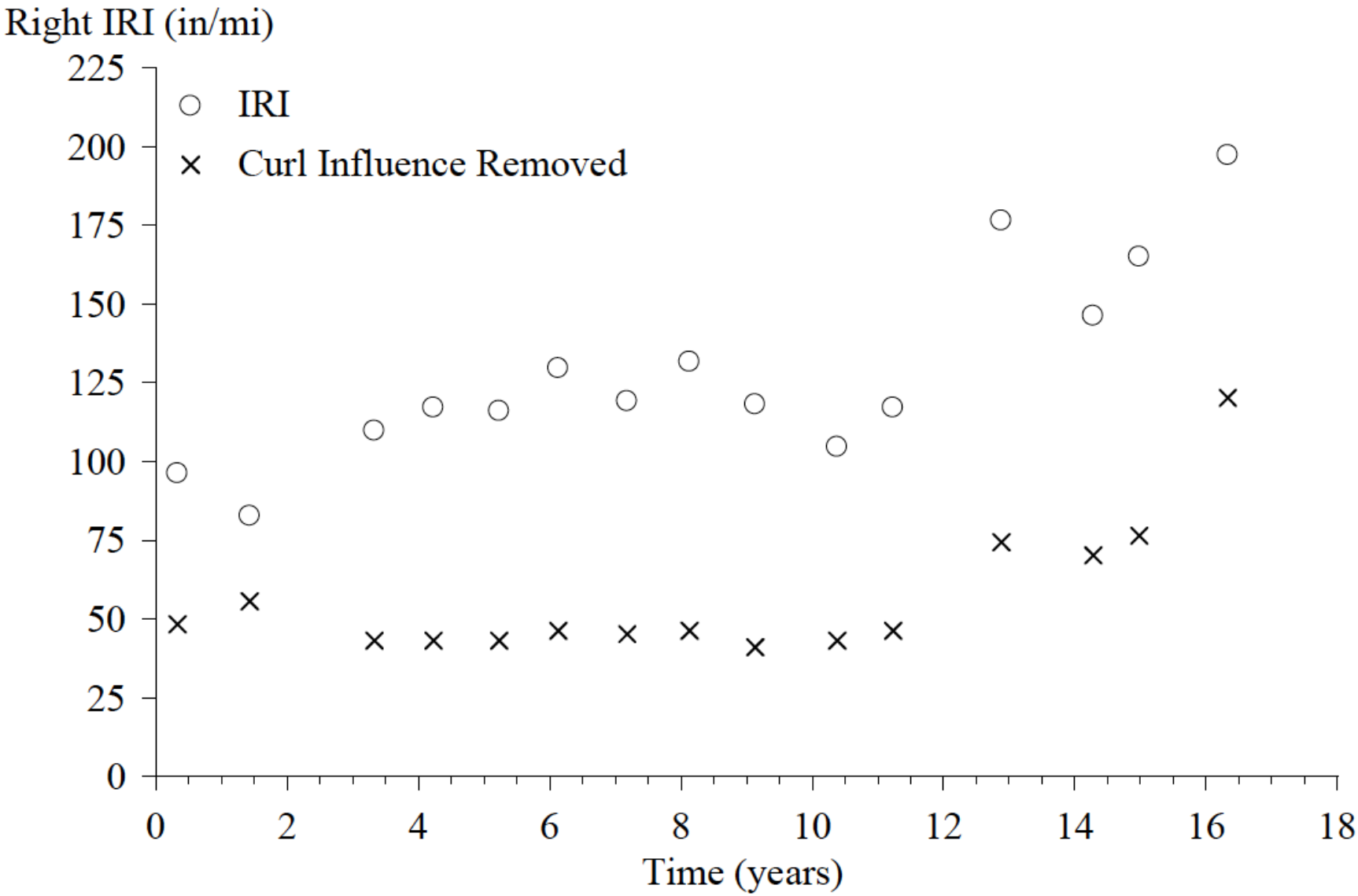
Sample Curve Fit



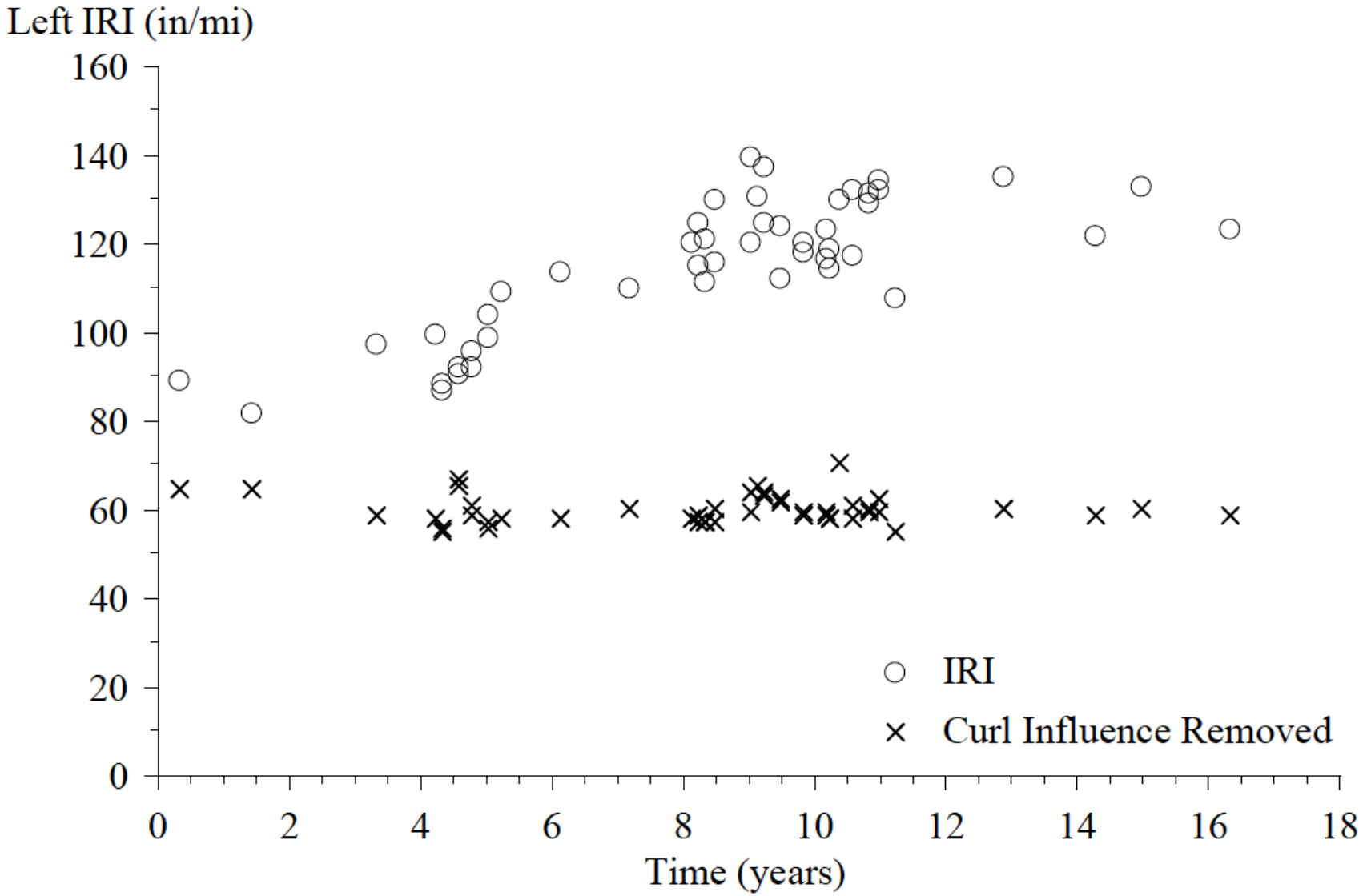
IRI versus PSG, Section 040213



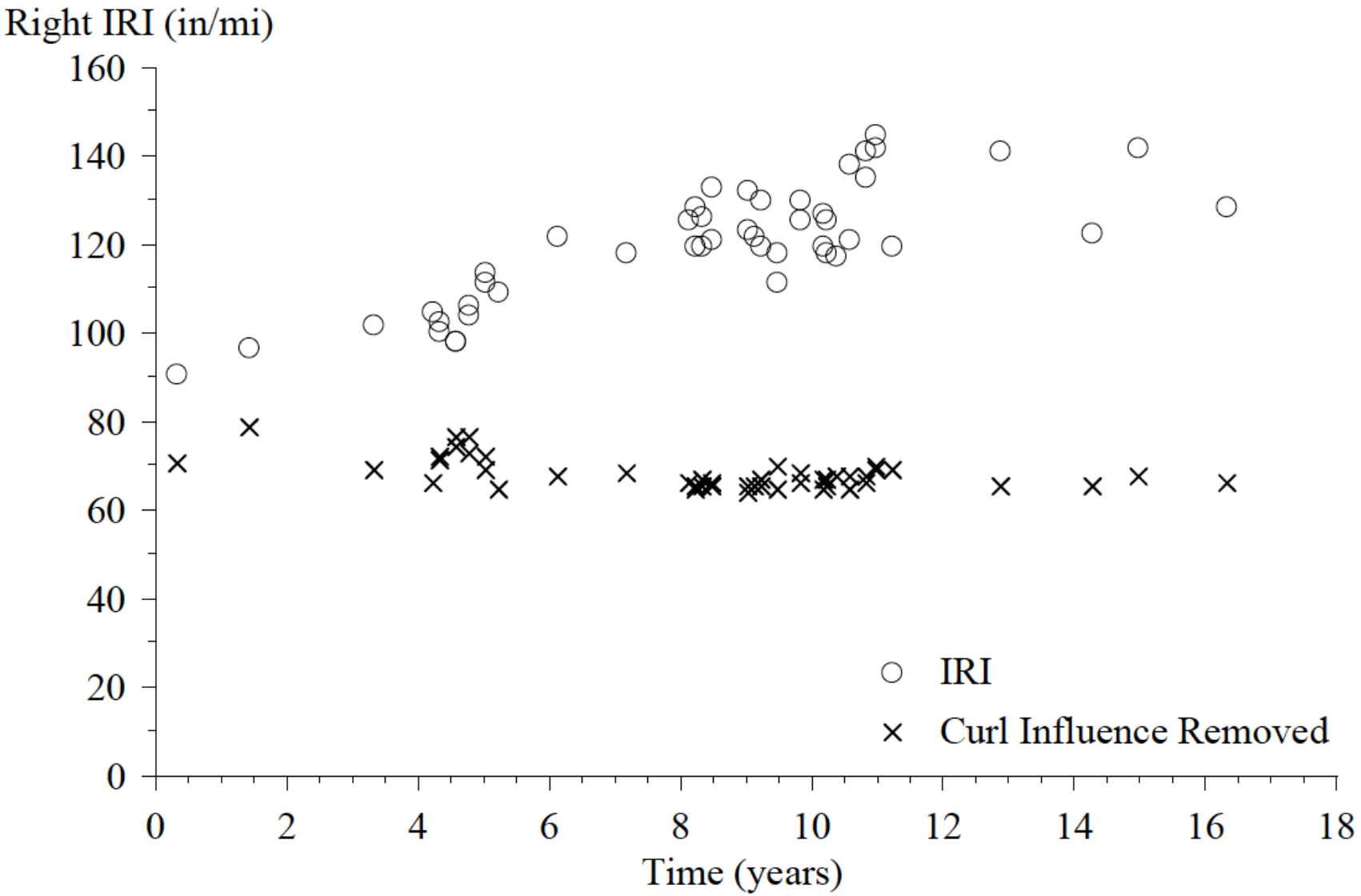
IRI versus PSG, Section 040215



IRI versus PSG, Section 040215



IRI versus PSG, Section 040215



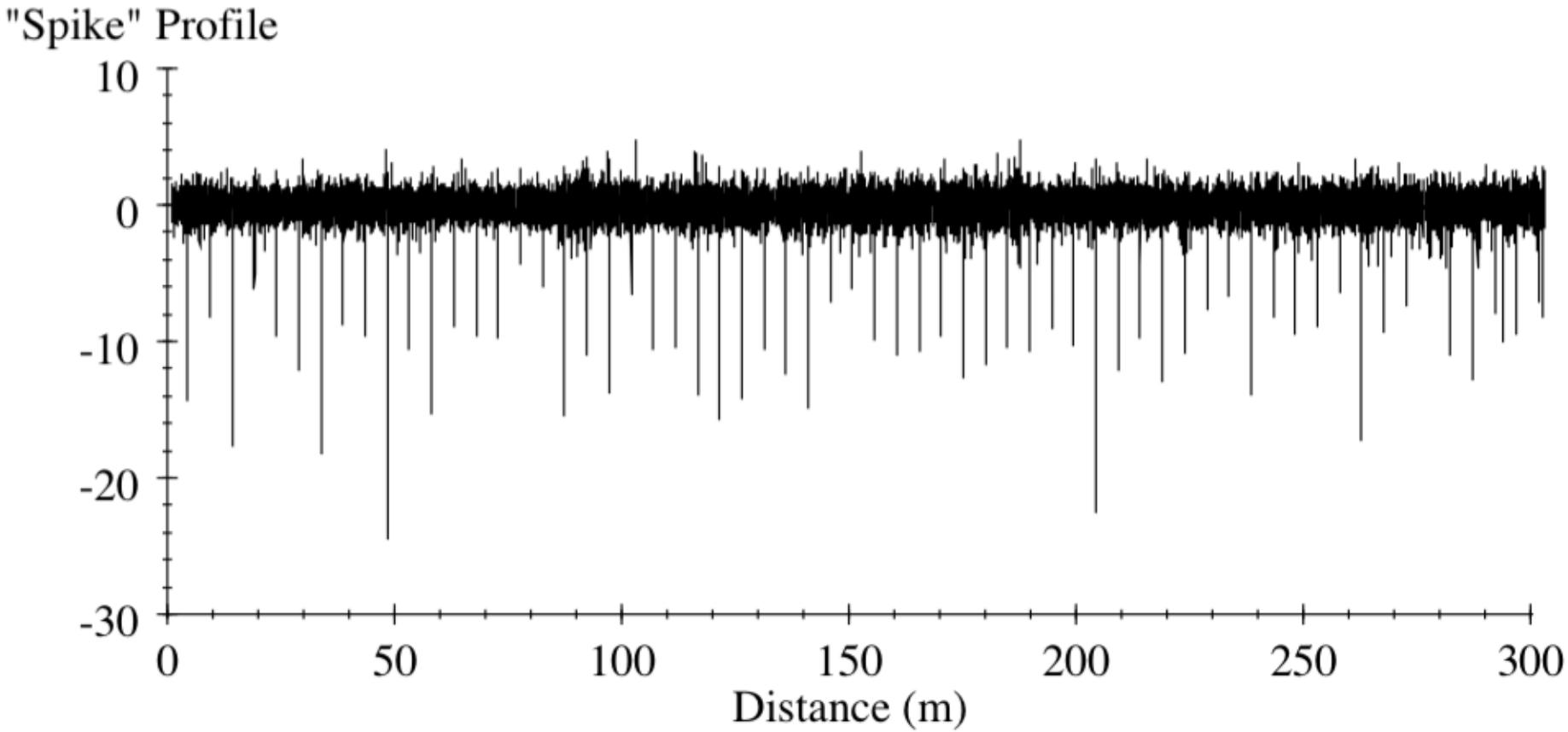
Remarks

- These data provided a unique opportunity.
- Curl and warp accounted for a large share of the roughness on many of the sections.
- A roughness index is NOT an adequate surrogate for structural health.
- The methods presented here showed promise.
- The PSG-IRI relationship needed more study.

Follow-up

- Applying the method to SPS-2 sites in other regions.
- Seeking to generalize:
  - Joint finding.
  - The IRI-PGS correlation.
- Examining methods for estimating structural properties.

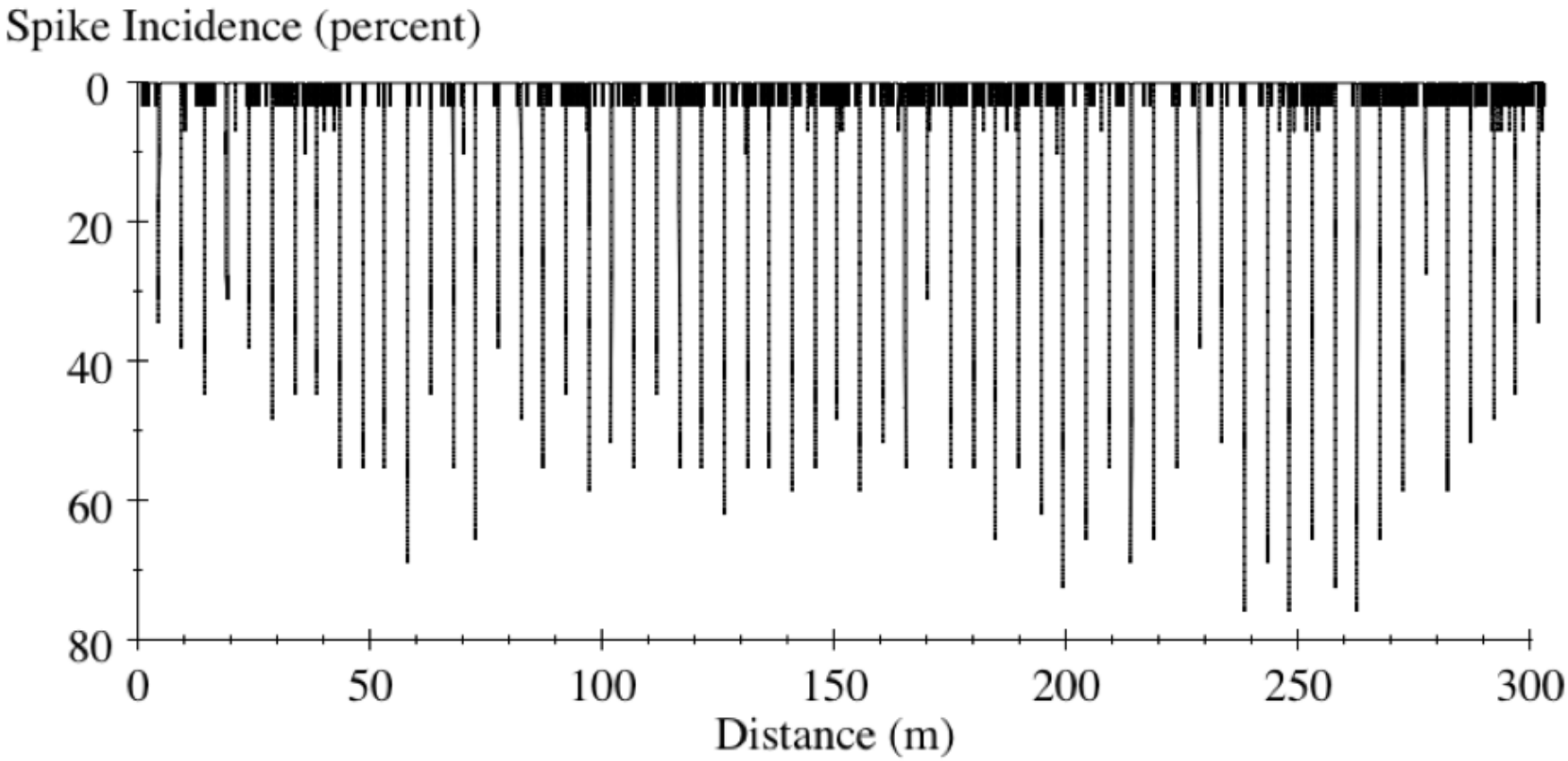
Joint Finding



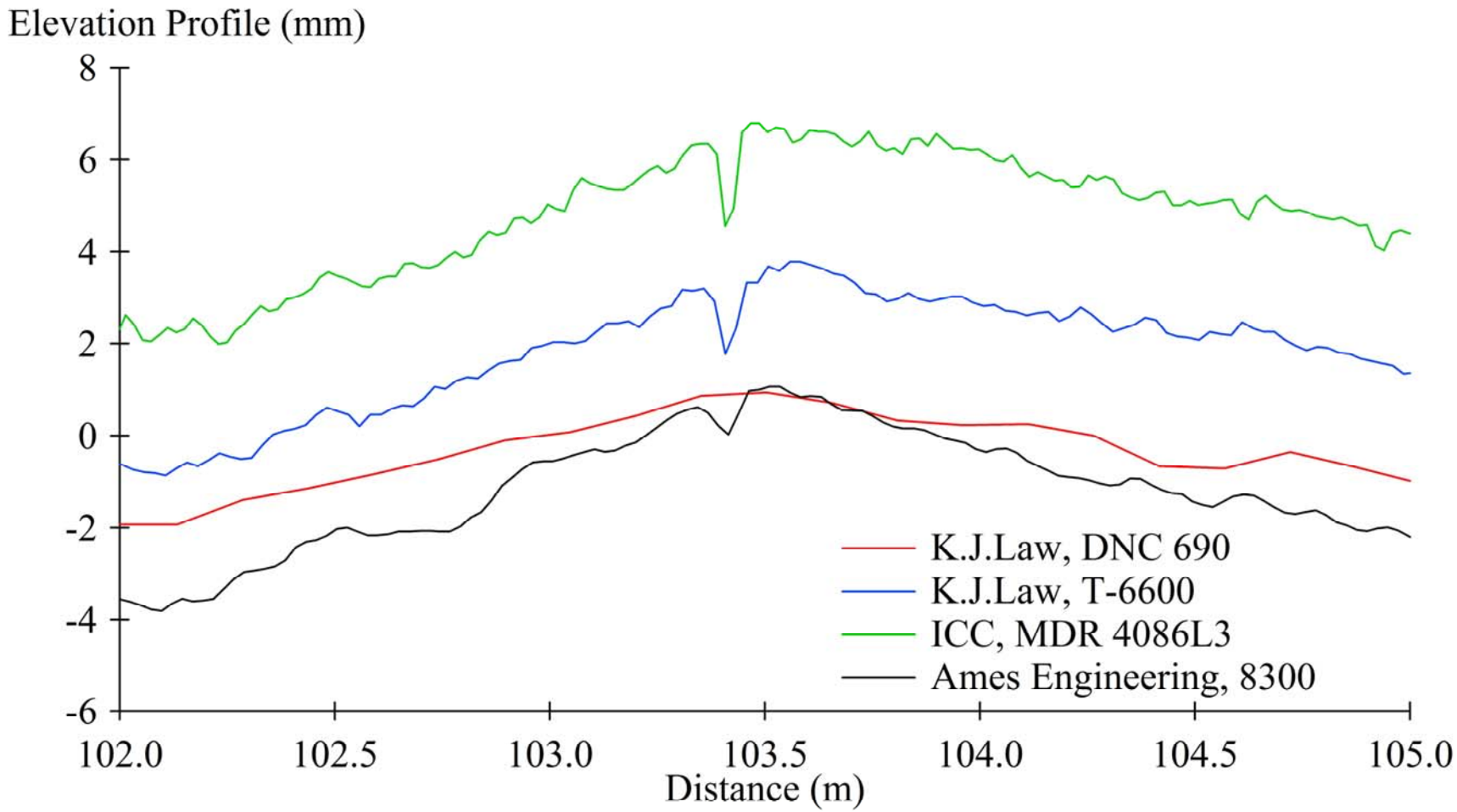
Joint Finding

- Search for impulses (e.g., spikes).
- Require left-right consistency.
- Enforce a joint spacing pattern.
- Search over multiple repeated passes.
- Search over multiple visits.

Joint Finding



Joint Finding



Thank you.