Joint Pursuit: Detecting Weak Joints Using TSD Measurements by Basis Pursuit

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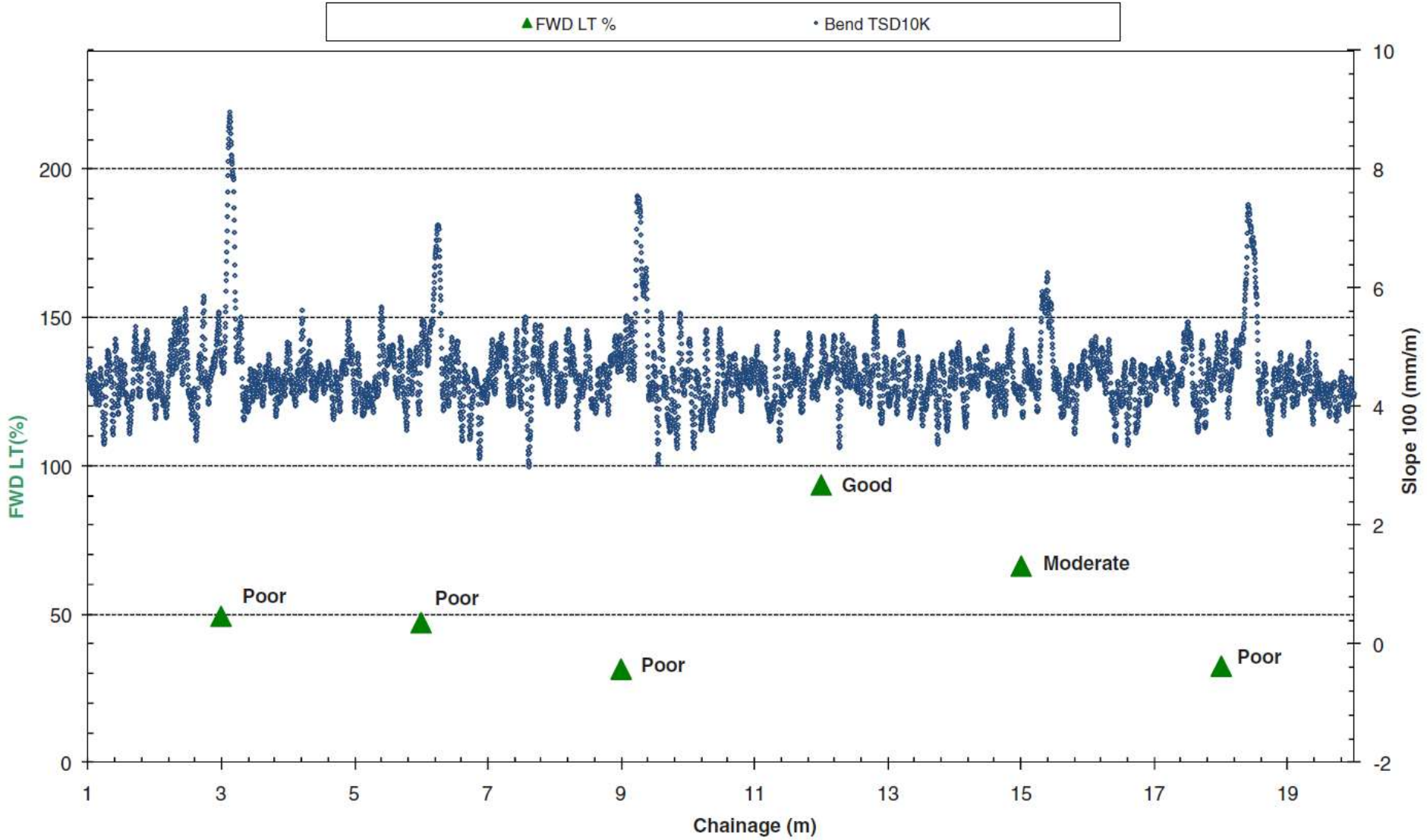
Outline

- Introduction
- Basis Pursuit
- Results
- Further Improvements

Introduction

- TSD has been extensively used for flexible pavement structural evaluation
- Rigid pavements have been harder to assess:
  - Low deflections are an issue relative to device accuracy
  - Joint evaluation requires higher data resolution (~ 1m)
- Limited research on joint evaluation:
  - SHRP2 R06(F)
  - United Kingdom
  - Wavelet analysis (Katicha et al. 2014,2016)

Introduction – Joints LTE



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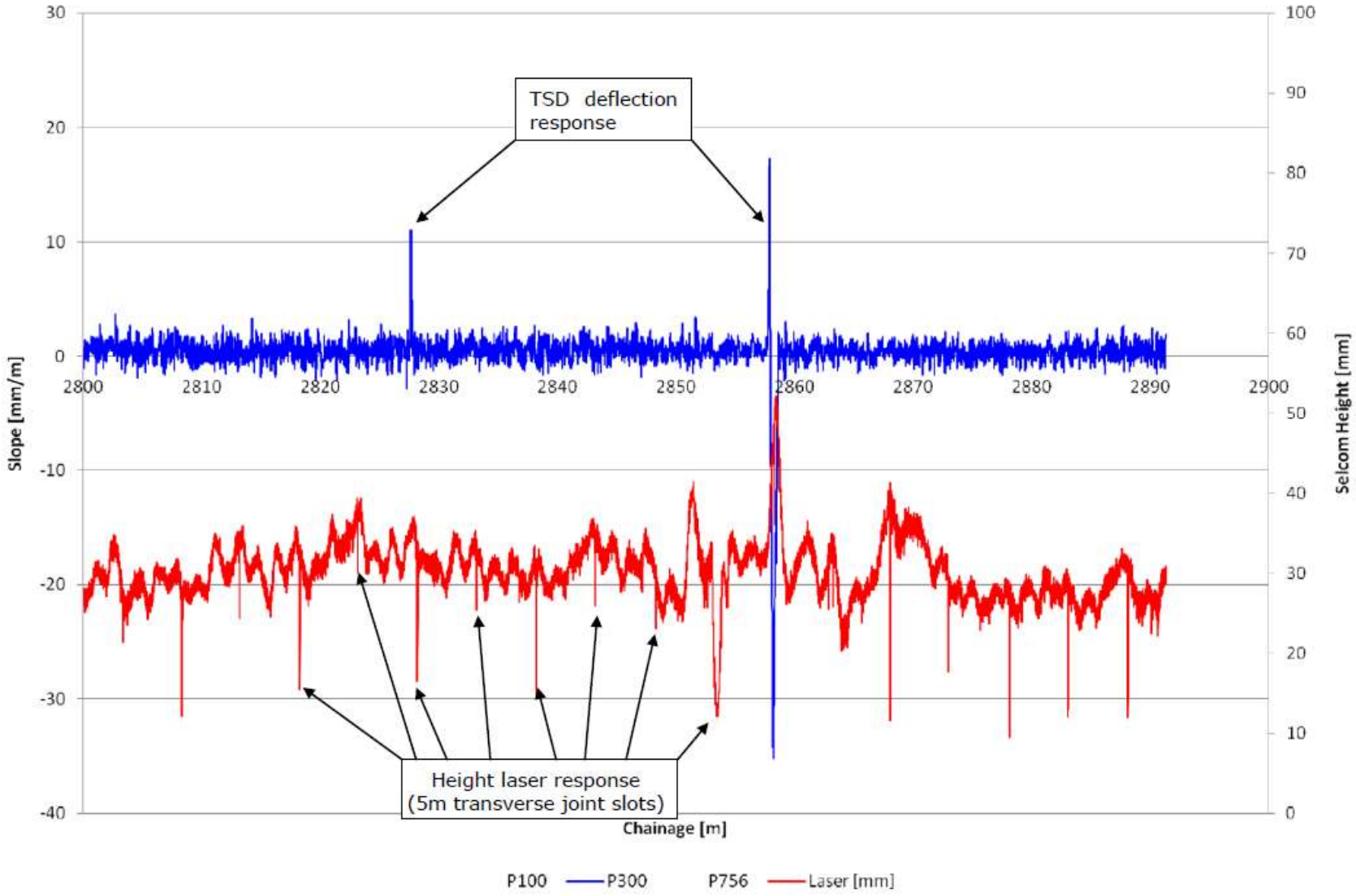
Introduction – Joints LTE



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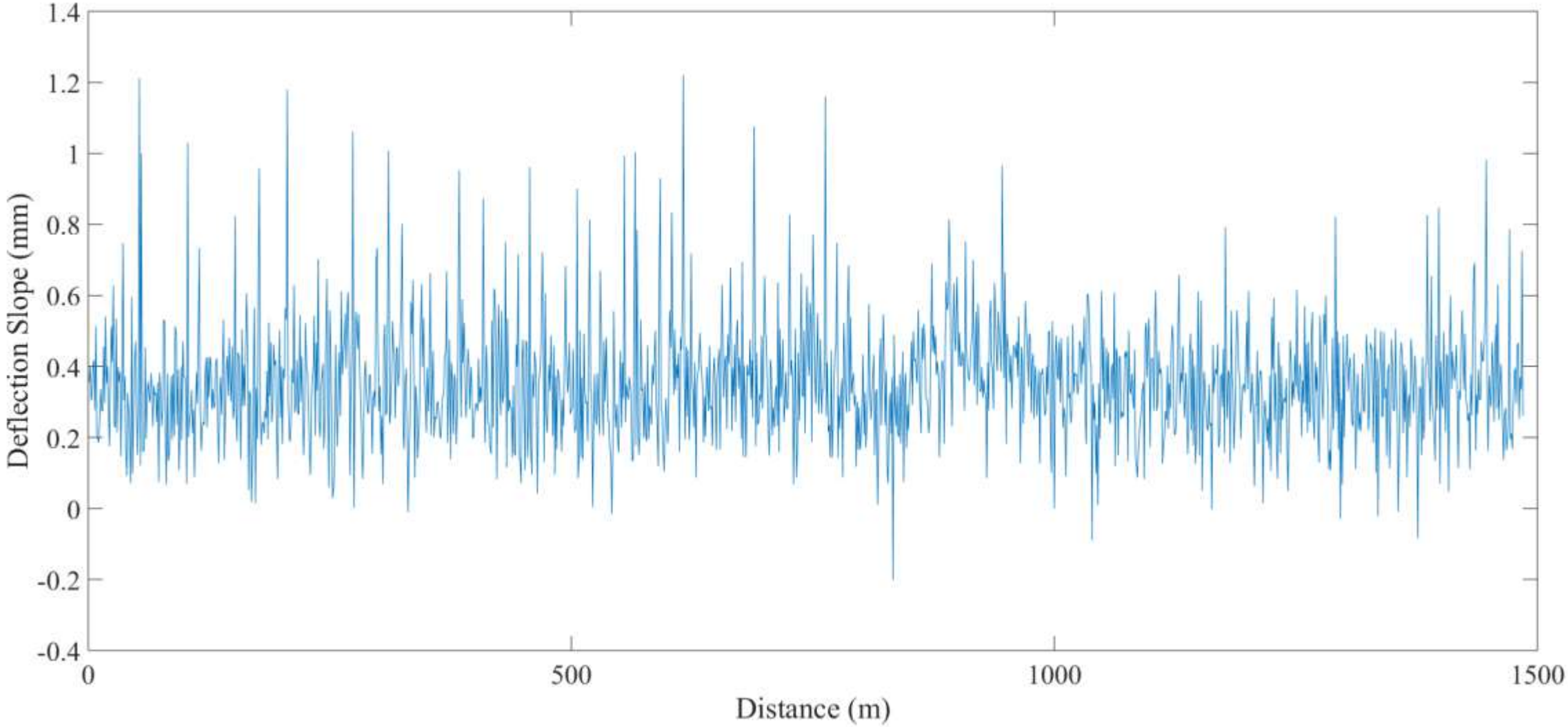
Introduction – Typical TSD Measurements



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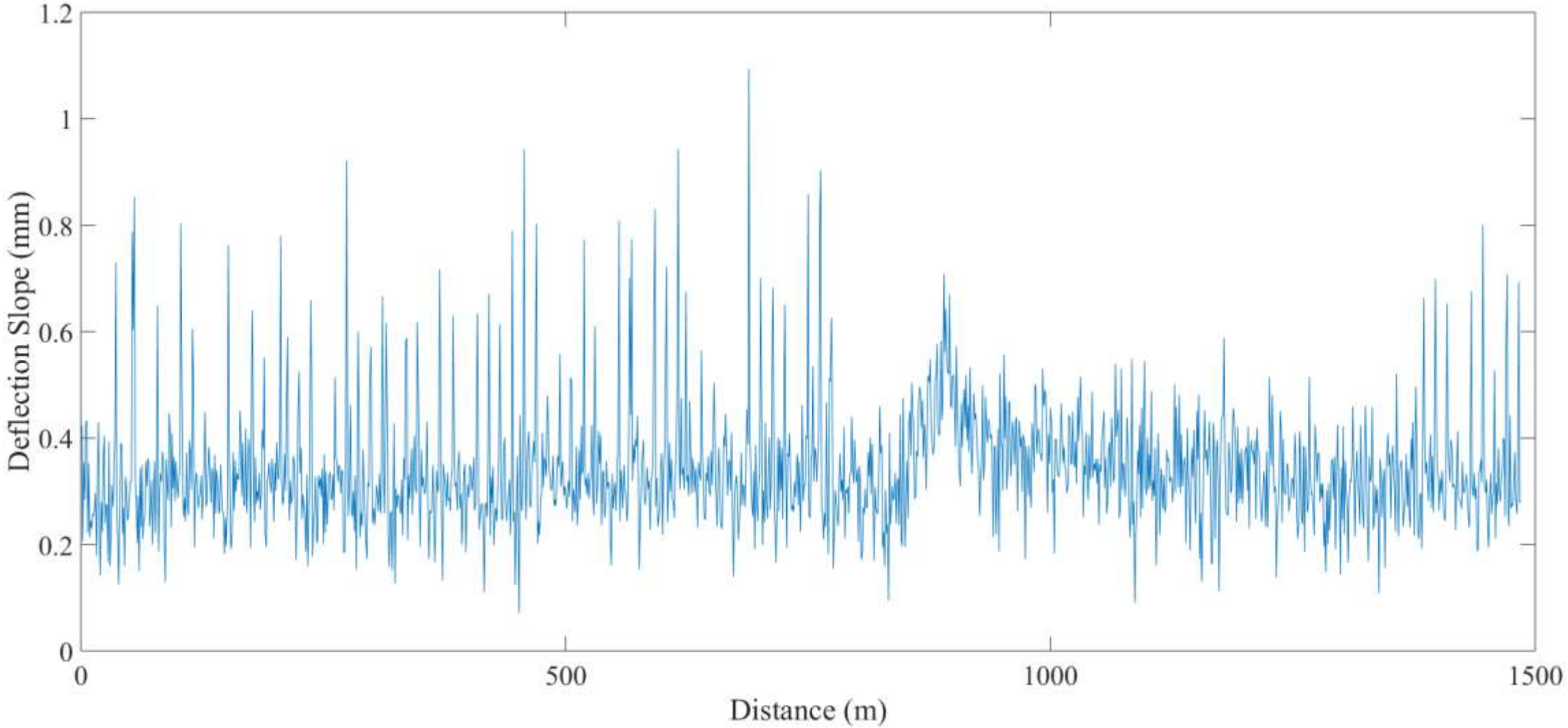
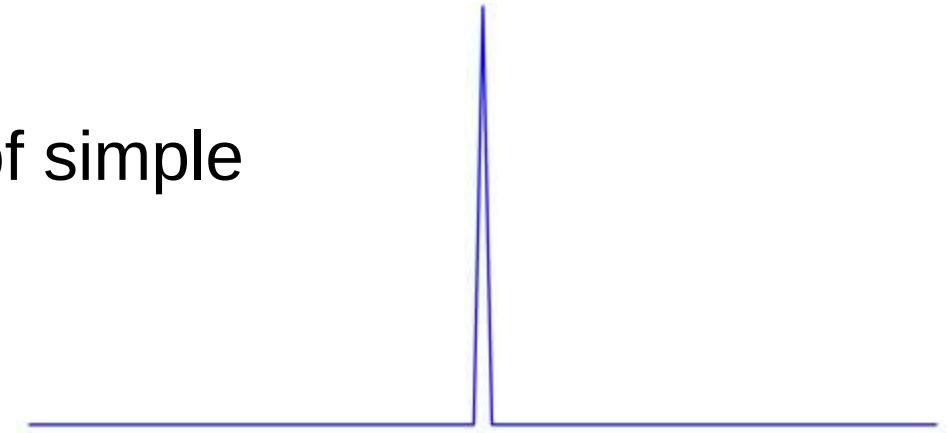
Introduction – Repeated Measurements



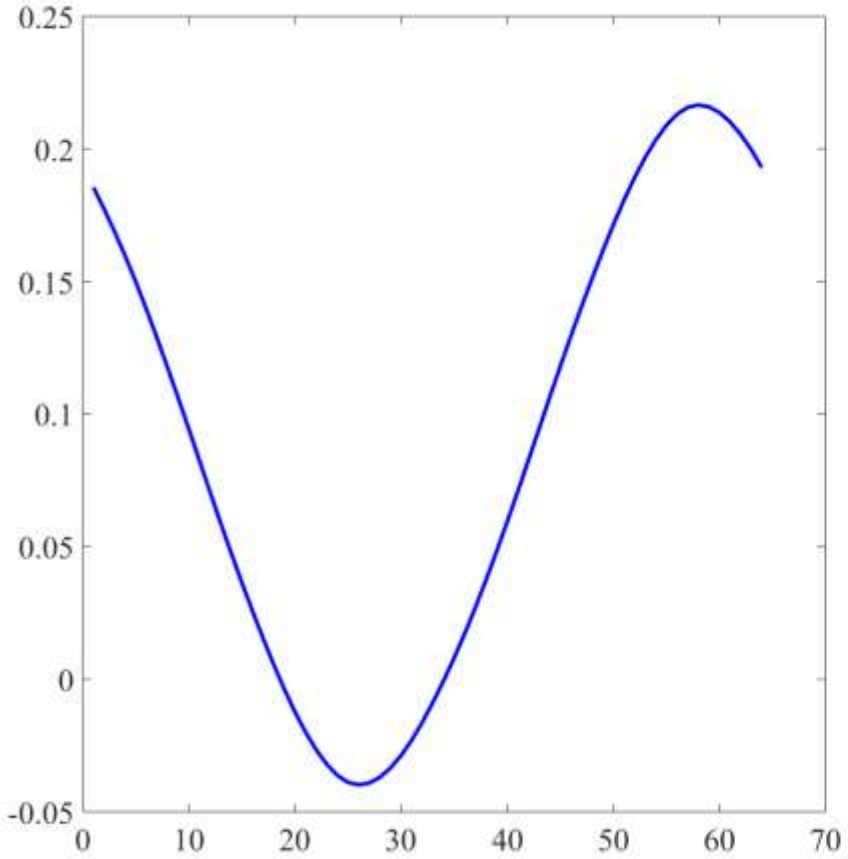
Basis Pursuit - Overview

- Help identify weak joints
  - Fast
  - Statistical balance between wrong identifications and missed identifications
  - Standard procedure (more science, less art)
- Key idea
  - Decompose TSD measurements into sum of simple features
  - Weak joints have specific geometric feature

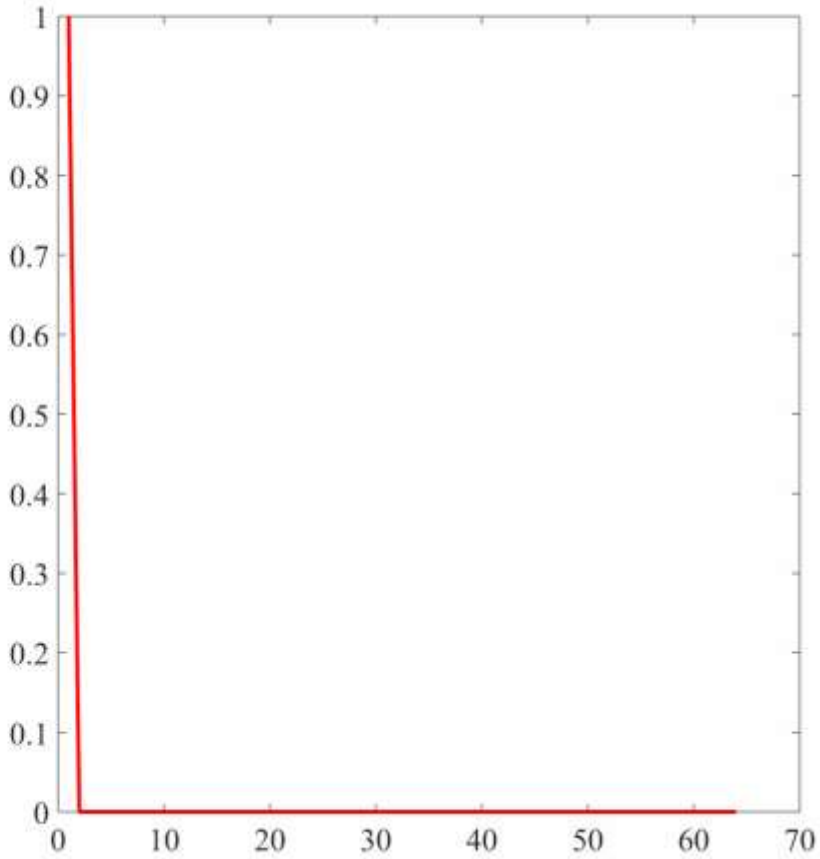


Basis Pursuit - Features

Wavelets



Joints

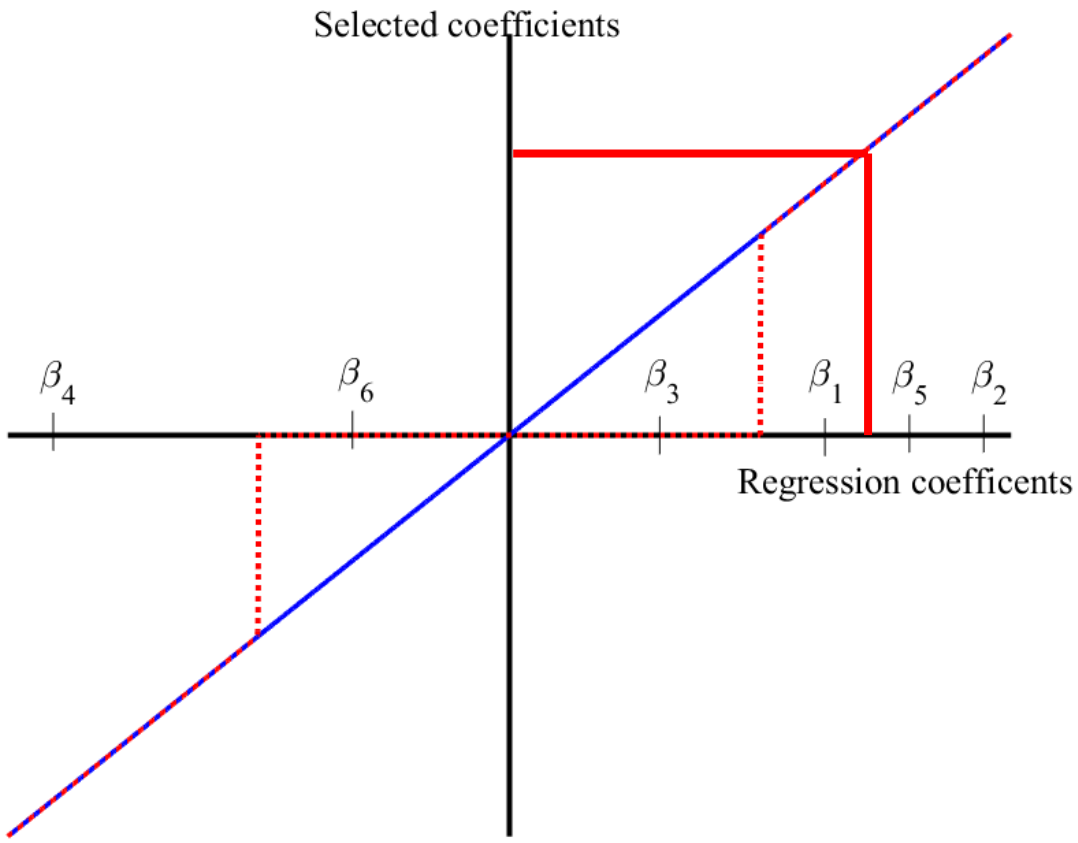


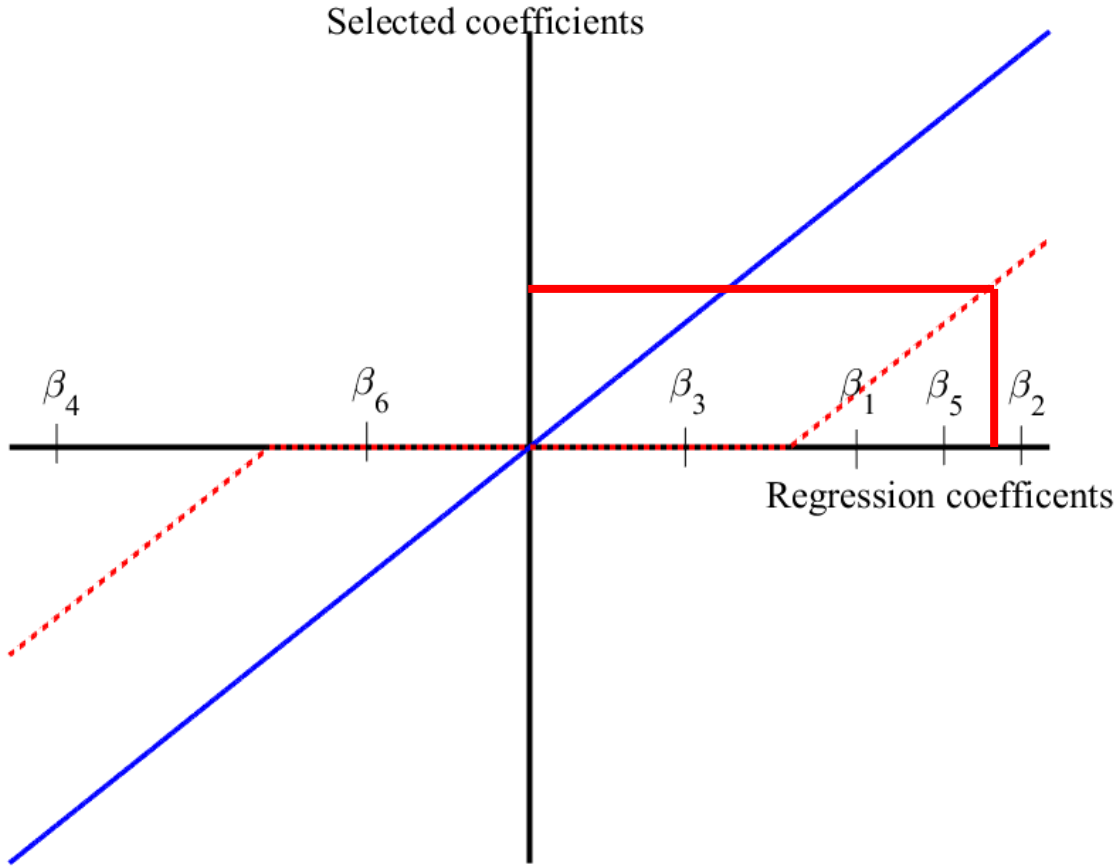
Basis Pursuit – Feature Selection

- How are features selected
  - Have twice as many features as measurements
- Best subset selection
  - Lowest number of features that works
  - Very hard (impossible) to solve
- Basis Pursuit selection
  - Lowest sum of absolute values of features coefficient
  - Very easy to solve (as easy as linear regression)

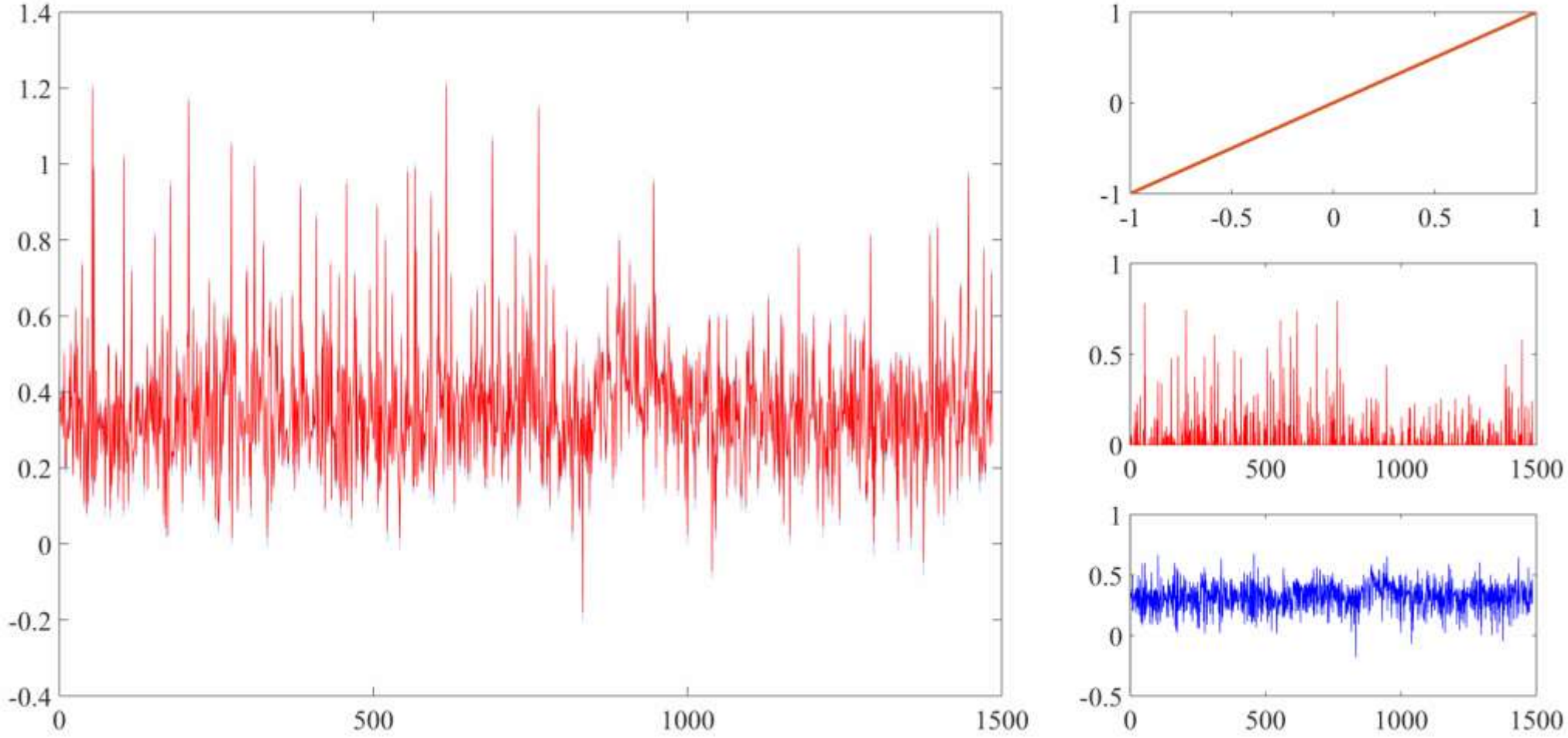
Basis Pursuit – Geometric Interpretation

- Fit feature to measurements by regression (*y* are the measurements and *x* are the features)



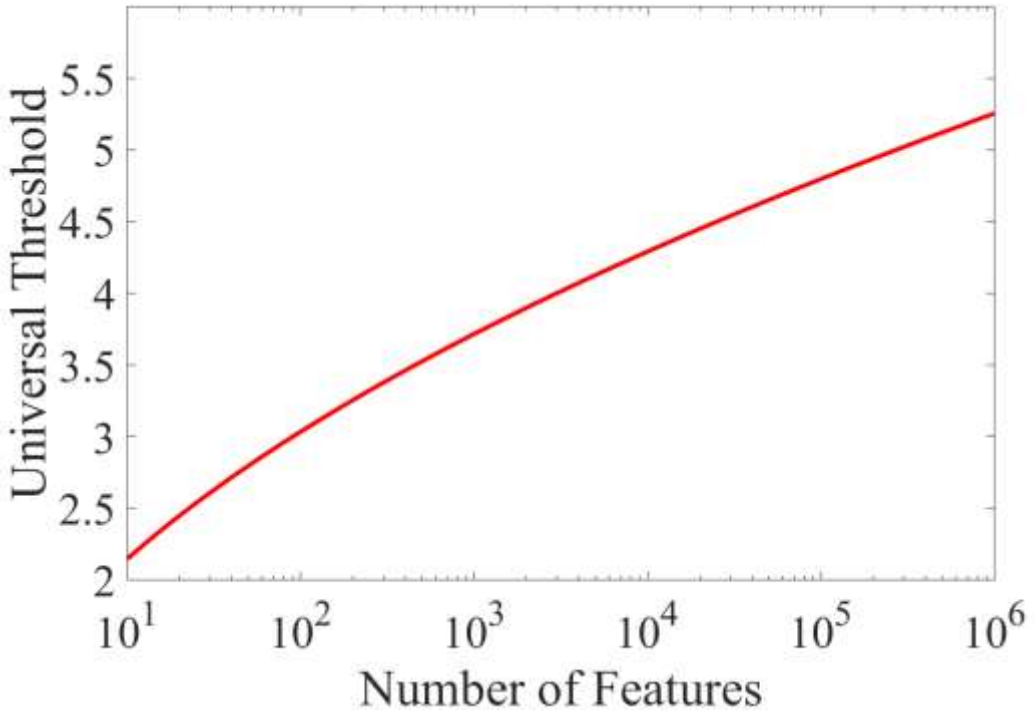


Results – Threshold Effect

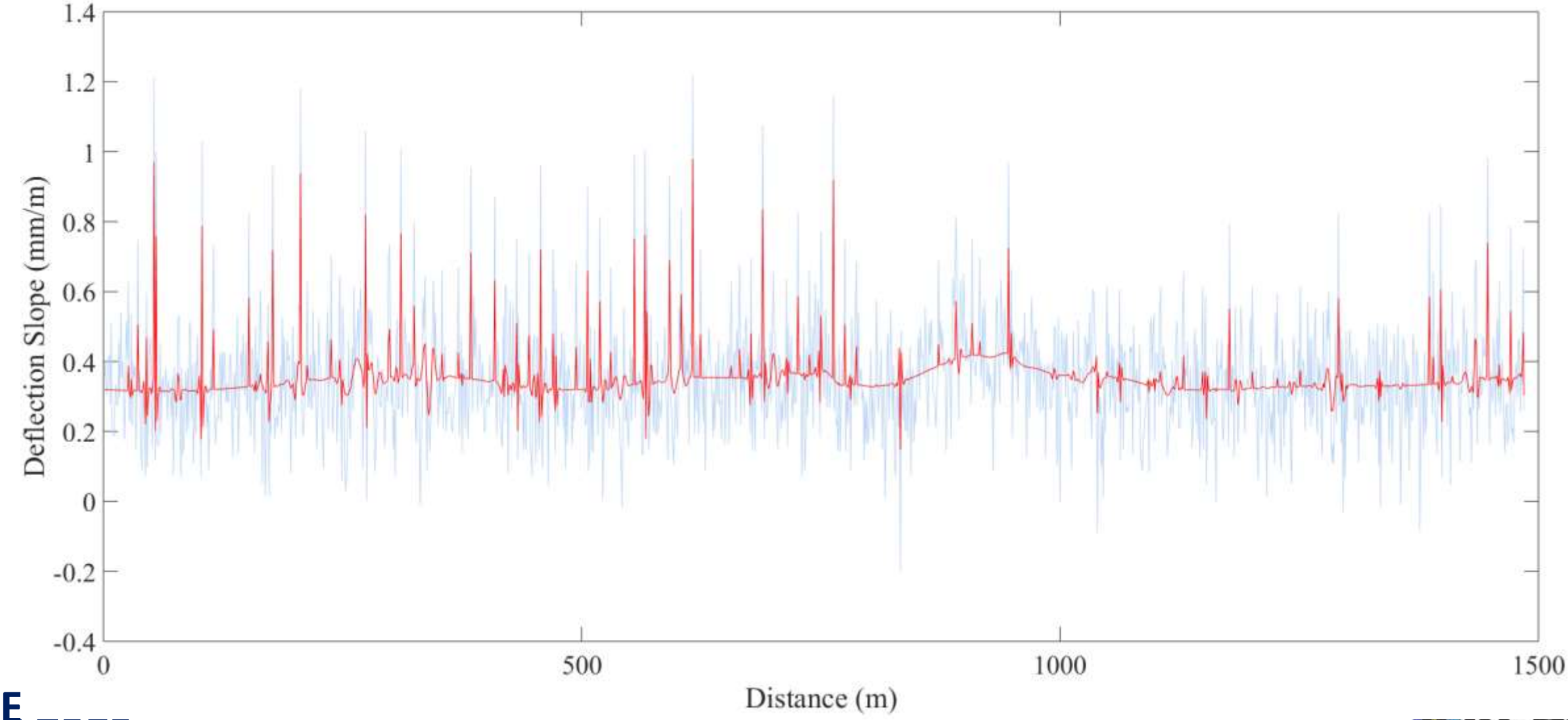


Results – Threshold Selection

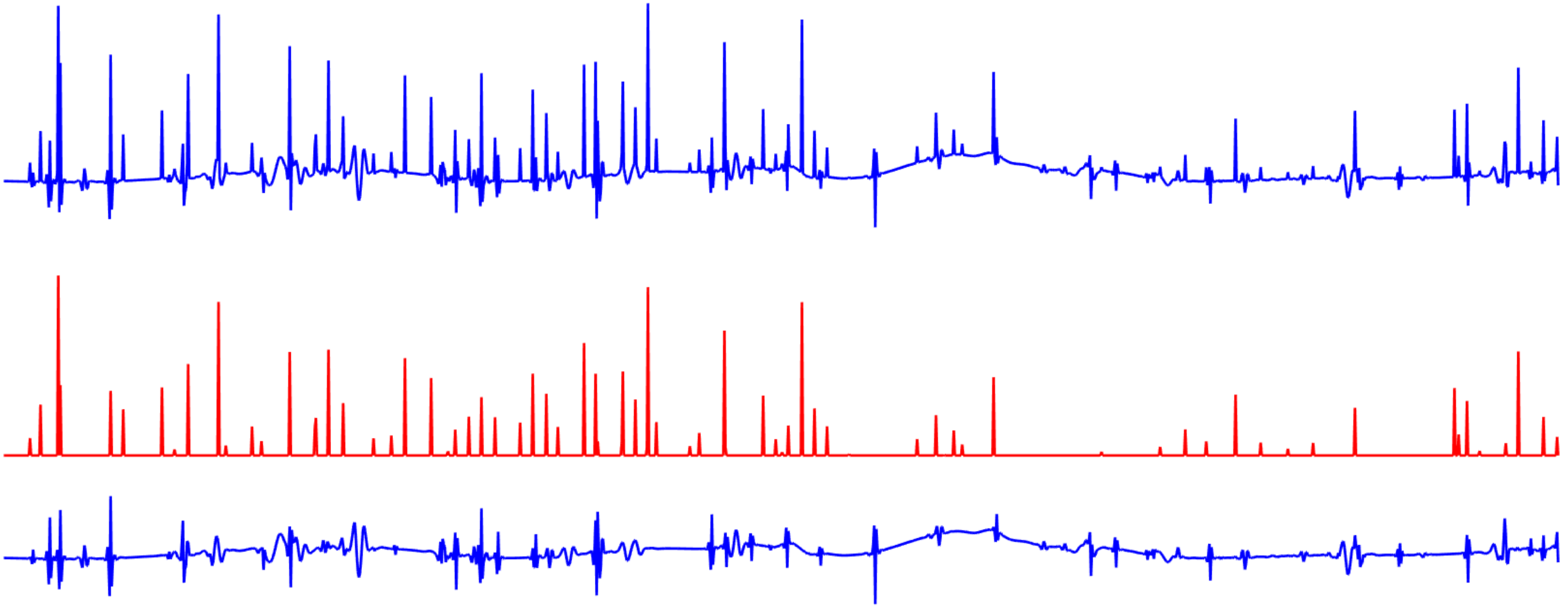
- Threshold
  - Need measurement accuracy of TSD σ
  - Upper limit T=$\sigma\sqrt{2log(n)}\approx 4\sigma$ (universal threshold)
  - Optimal: minimize Stein's Unbiased Risk Estimate (SURE)
    - Can go lower than 4σ depending on number of weak joints
    - Best fit



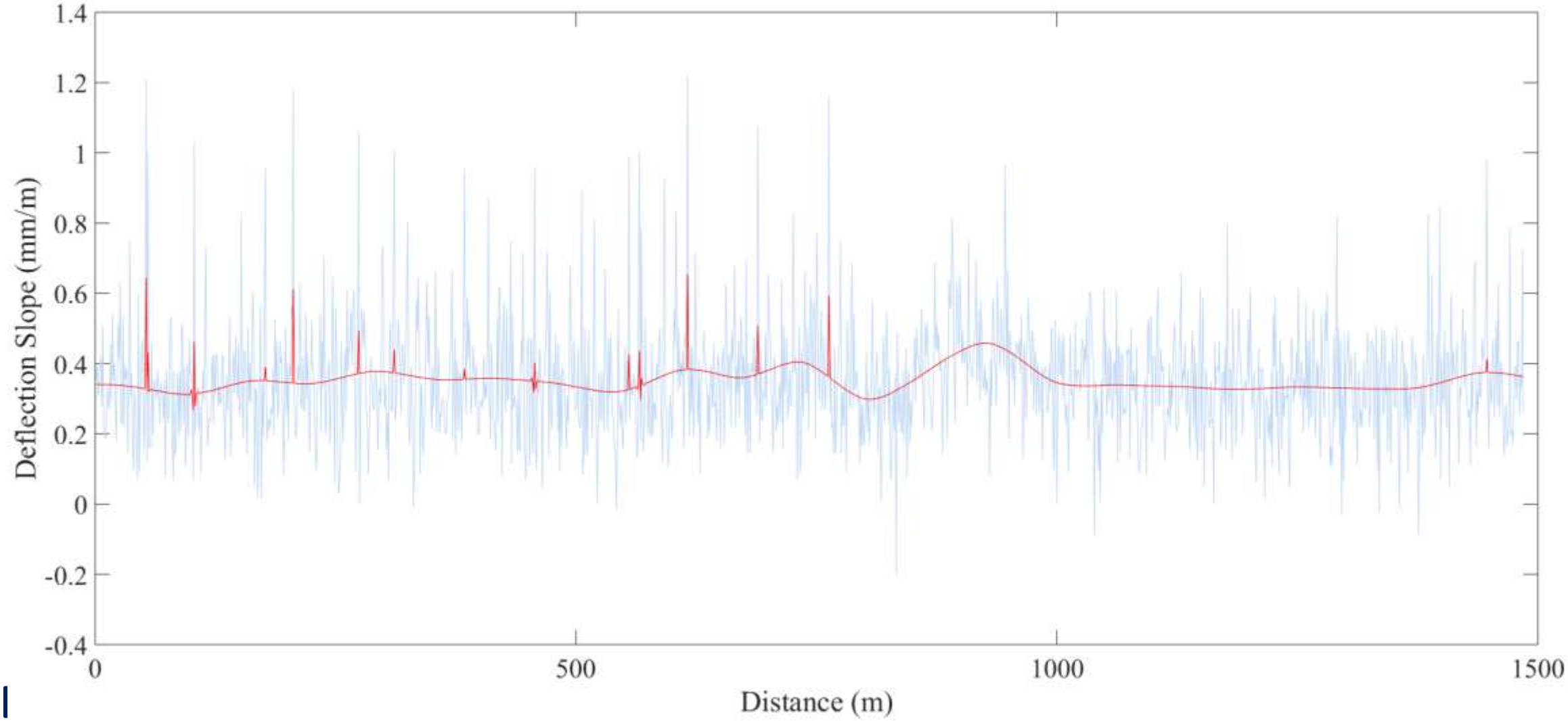
Results – Best Fit with SURE



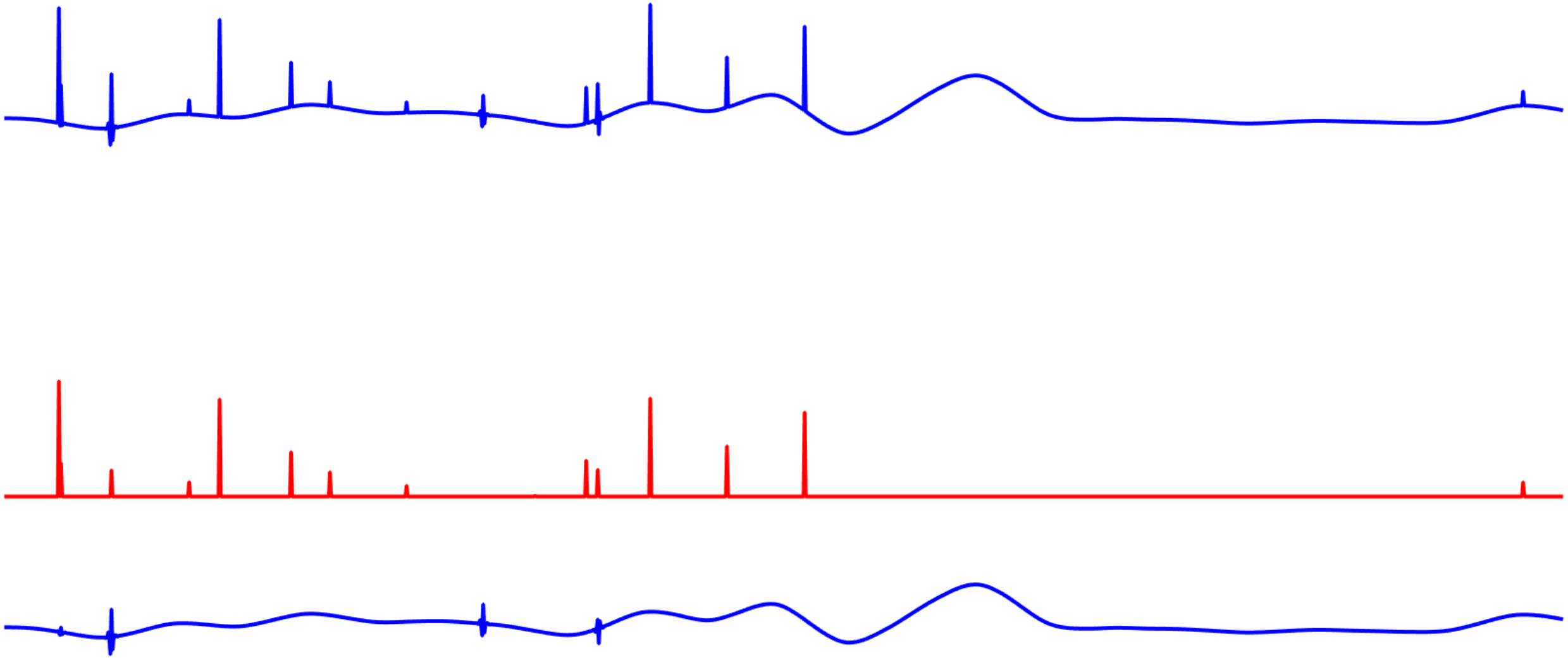
Results – Detected Joints



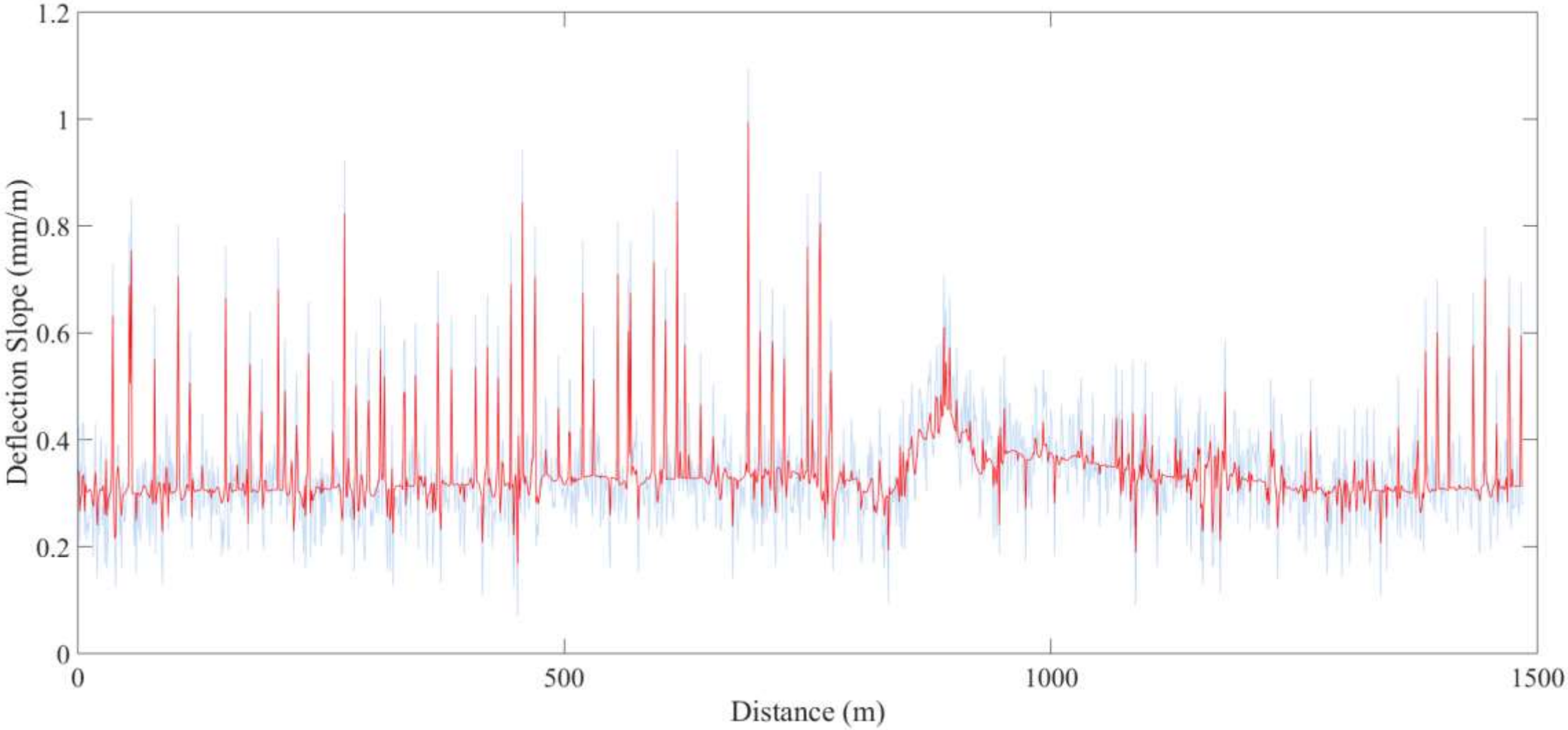
Results – Universal Threshold



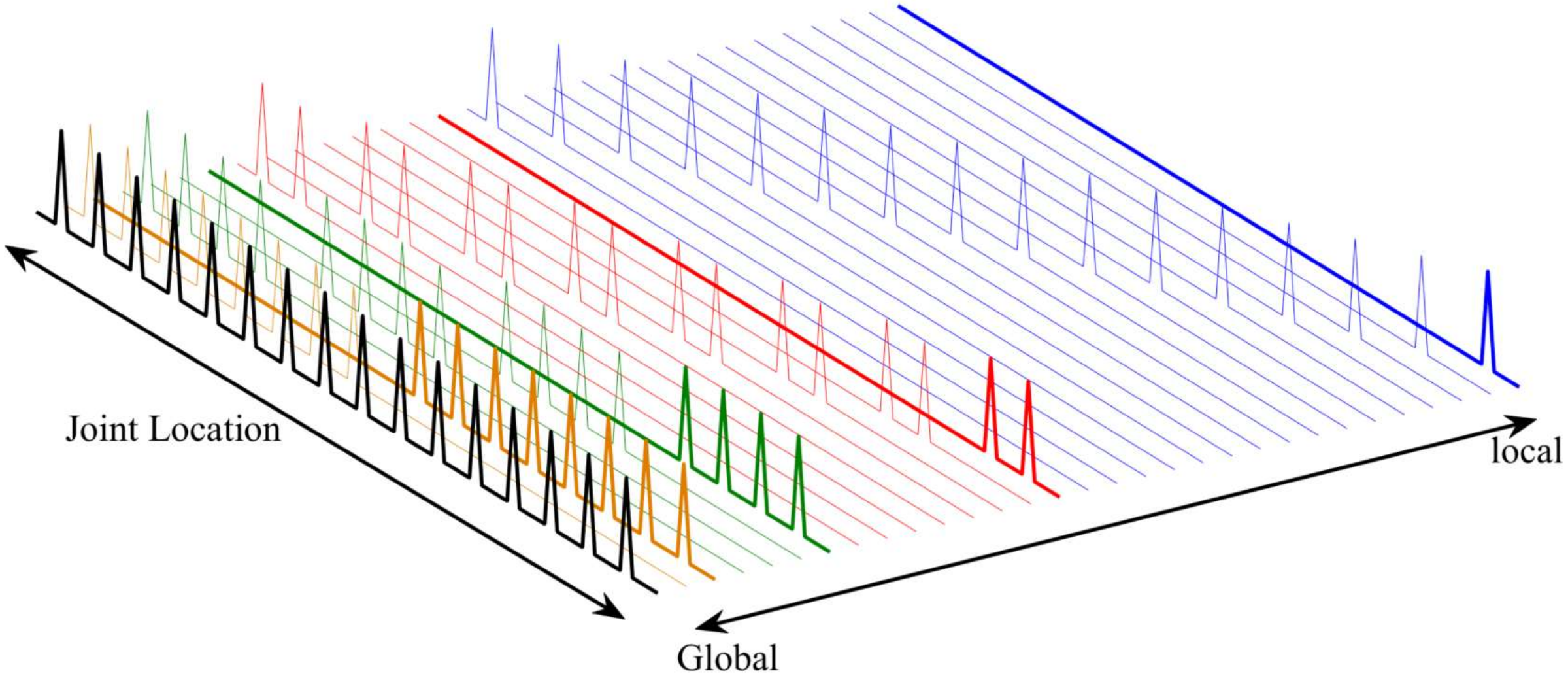
Results – Detected Joints



Results – Repeated Measurements



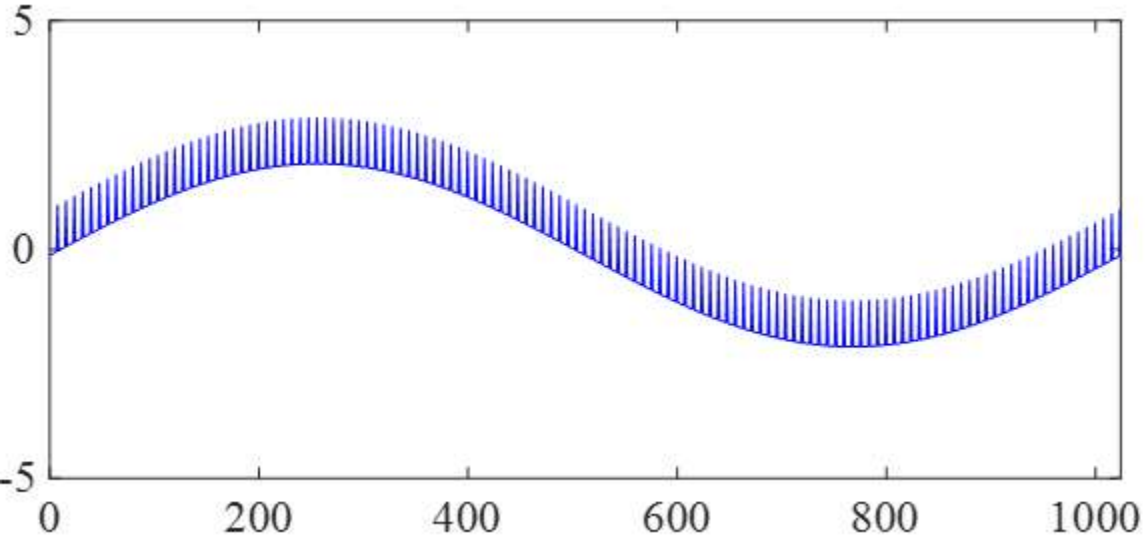
Multiresolution – Weak Joints Grouping

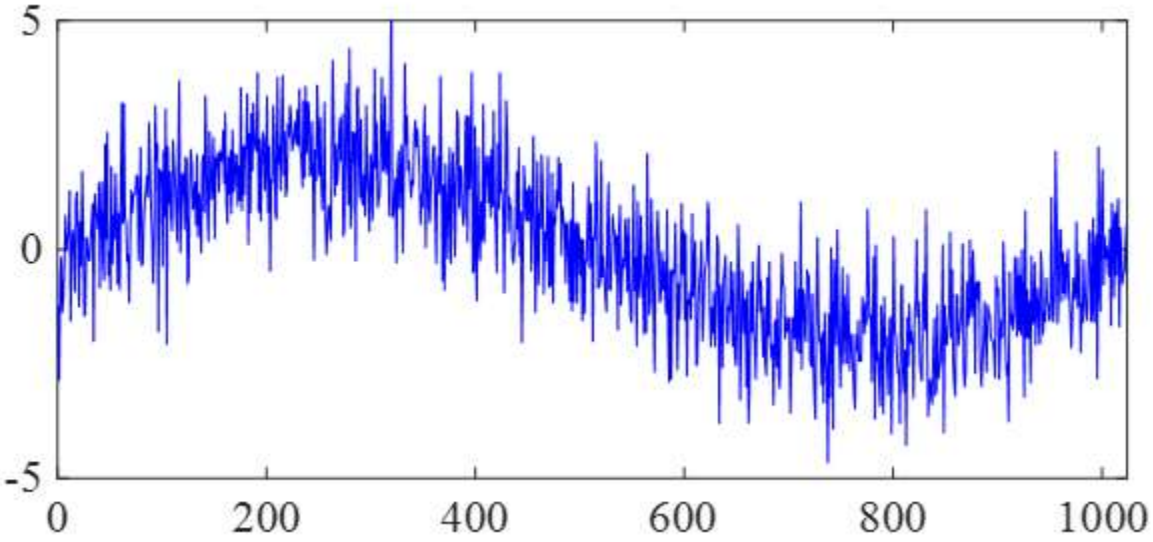


Multiresolution – Benefits

- Why?
- Detection depends on the number of weak joints in the group
  - $\sigma\sqrt{2log(n)} \approx 4\sigma$ order of detection limit for individual joints
  - If we have k joints in a group
    - $\sigma\sqrt{\frac{2log(n)}{k}}$

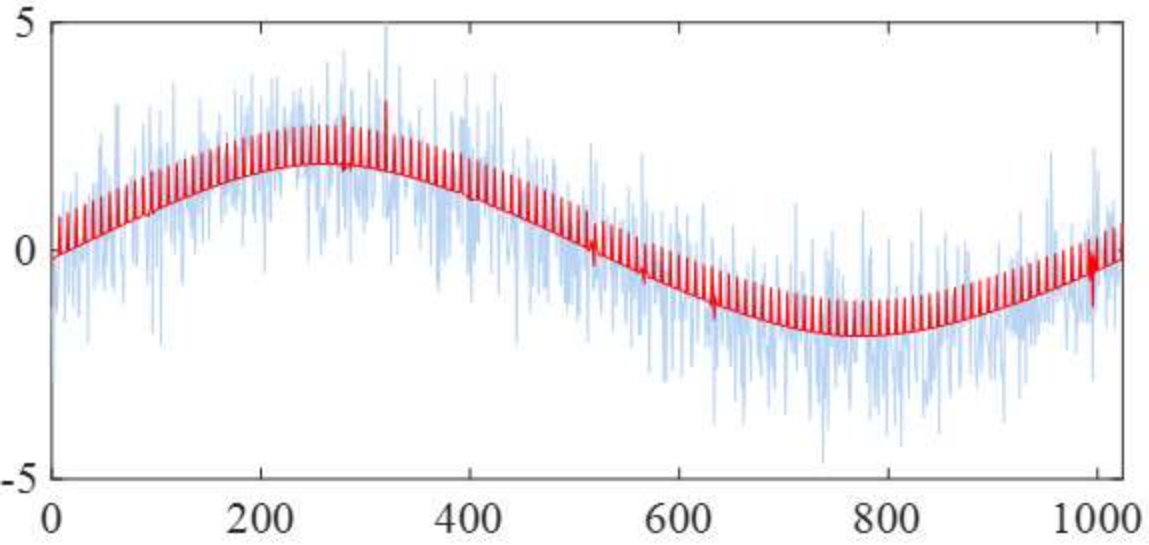
Multiresolution – Example



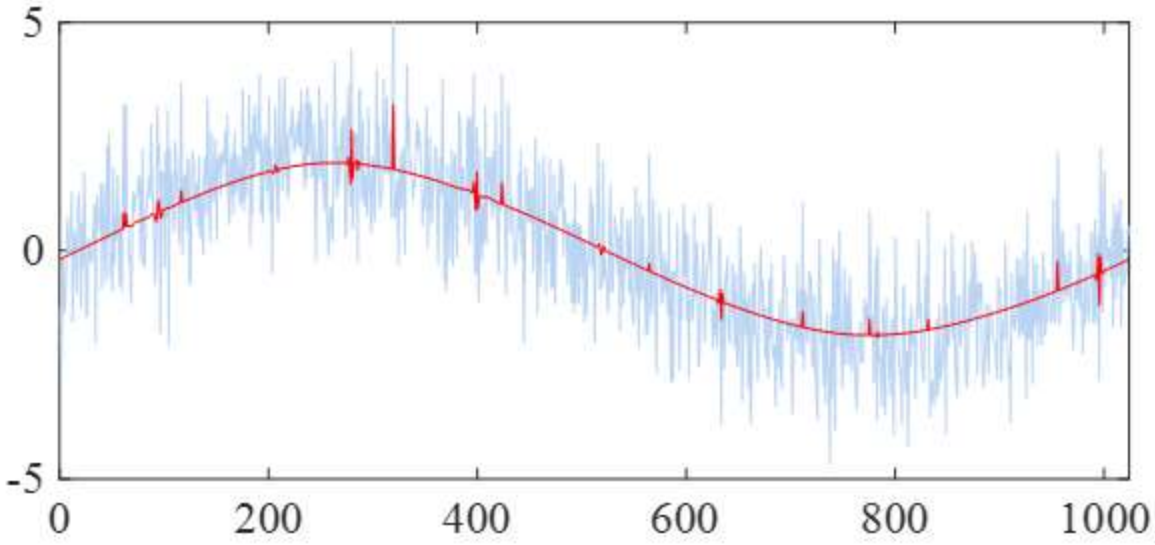


Multiresolution – Example Solution

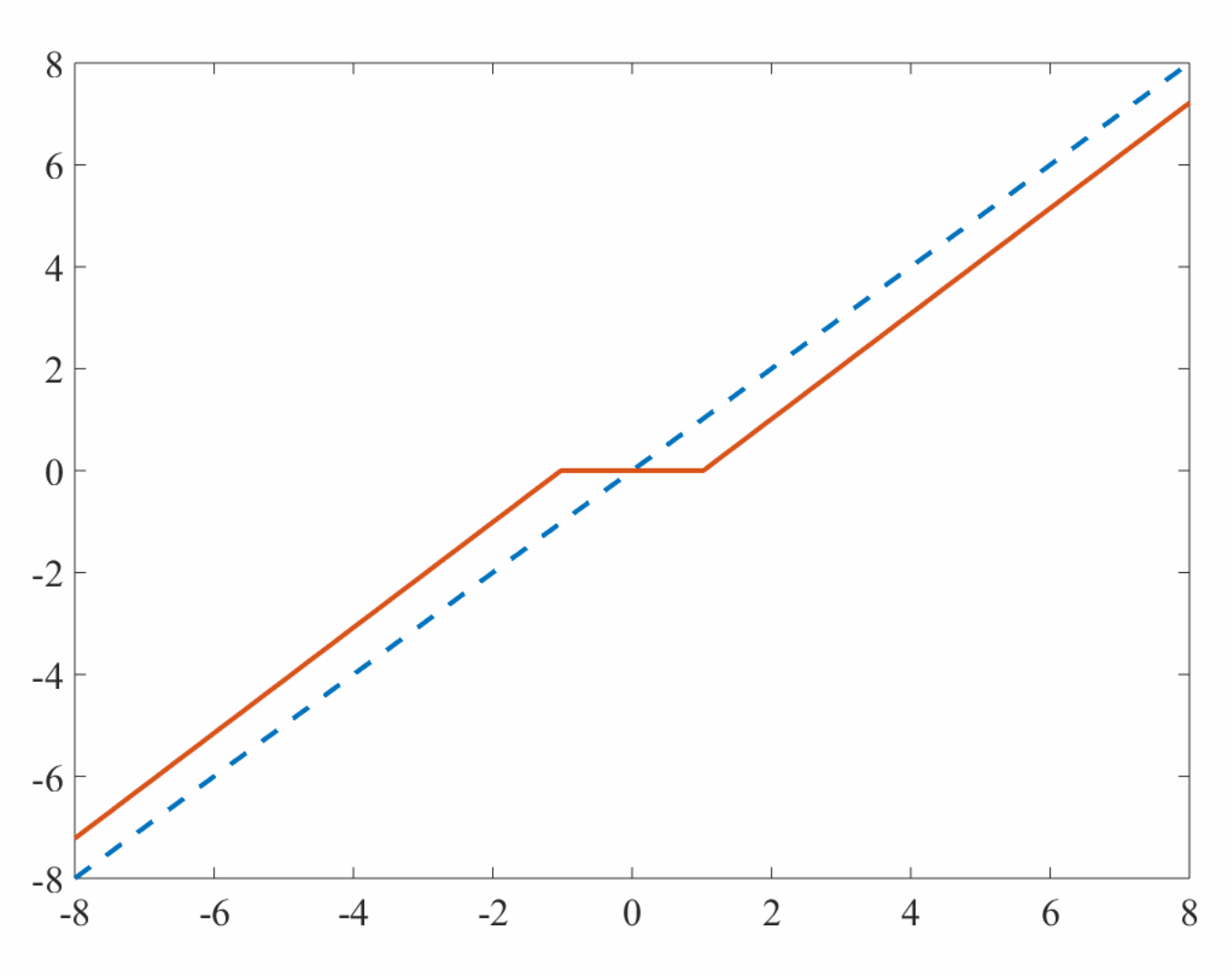
Multiresolution



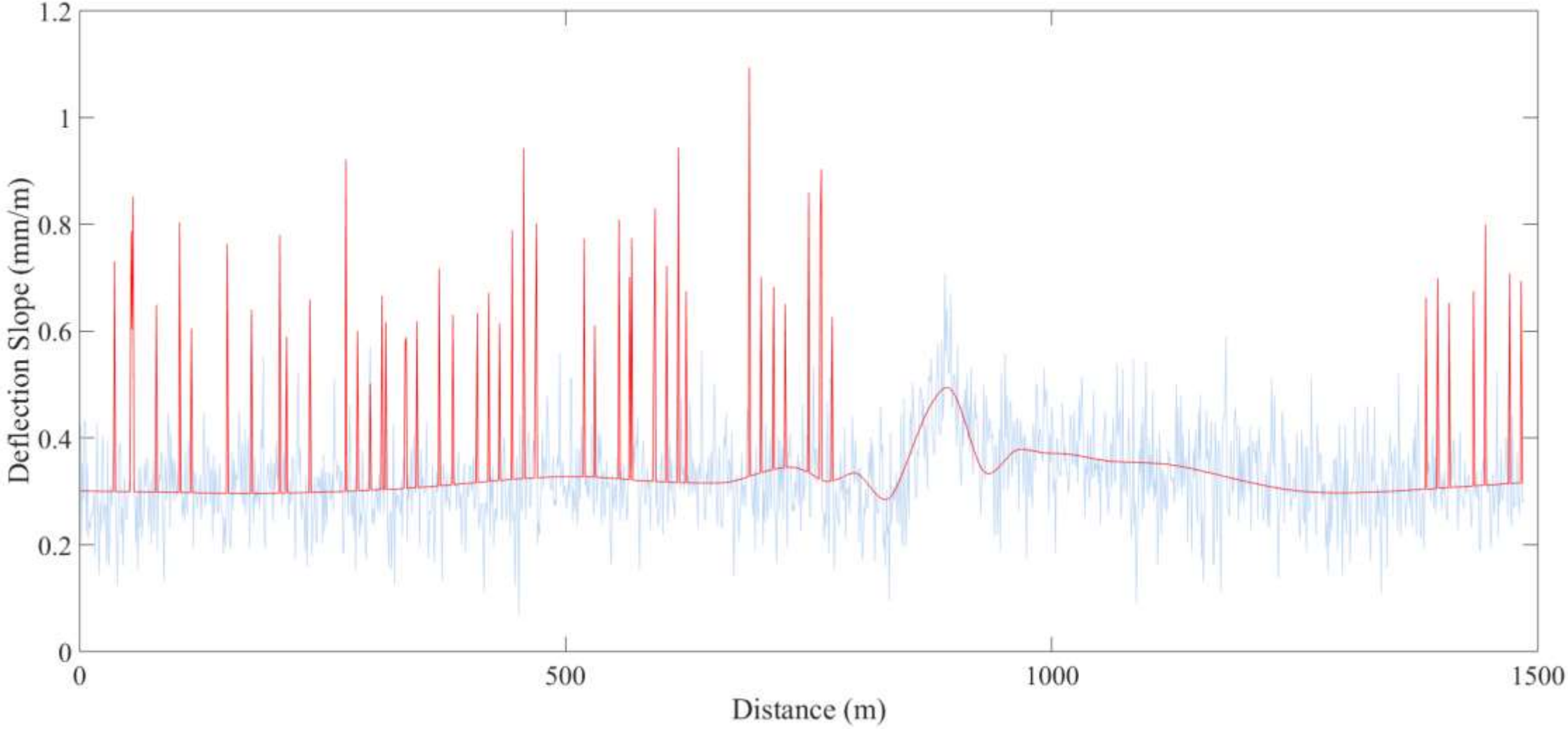
No multiresolution



SparseNet



SparseNet – Universal Threshold



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