Analyses on Visual Inspection Data of Bridges + Project Progress

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Transports, Mobilité durable et Électrification des transports Québec Partenaire

Outline

Context

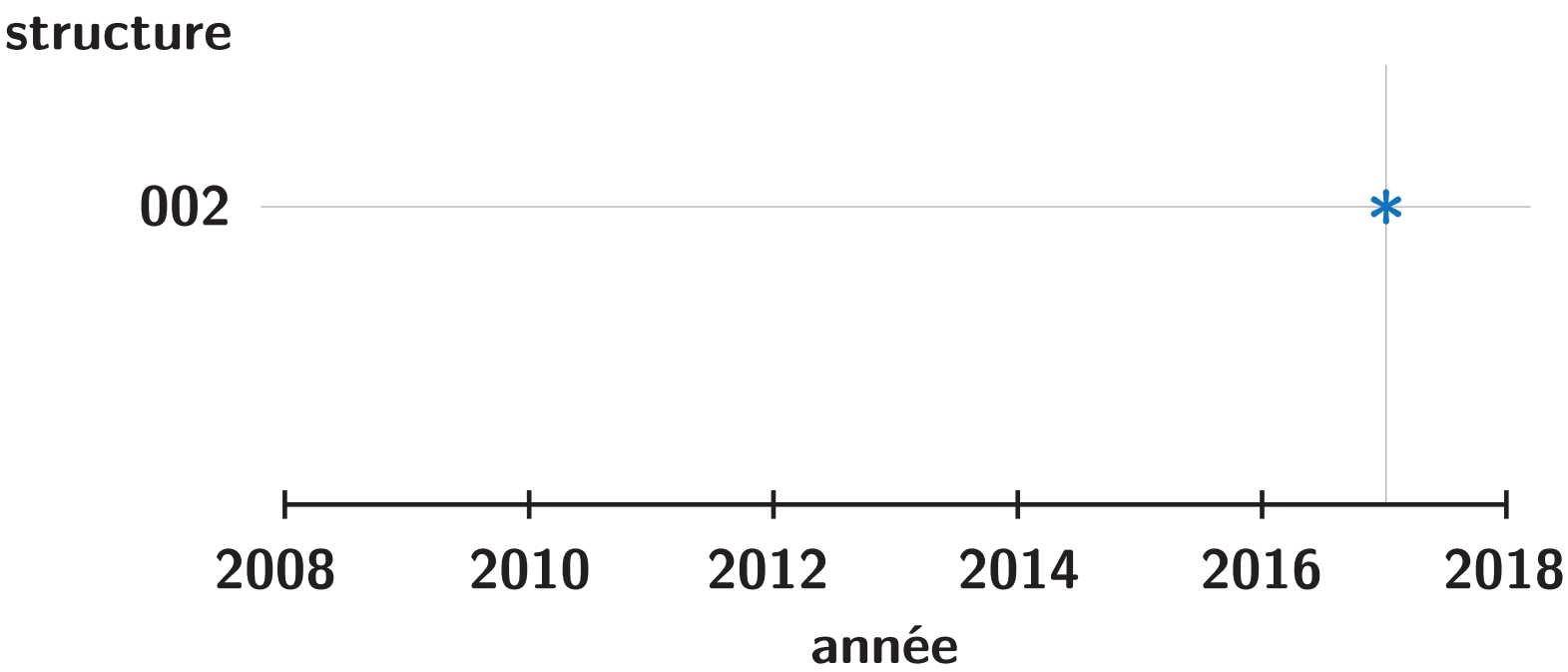
Deterioration Model

Model Verification

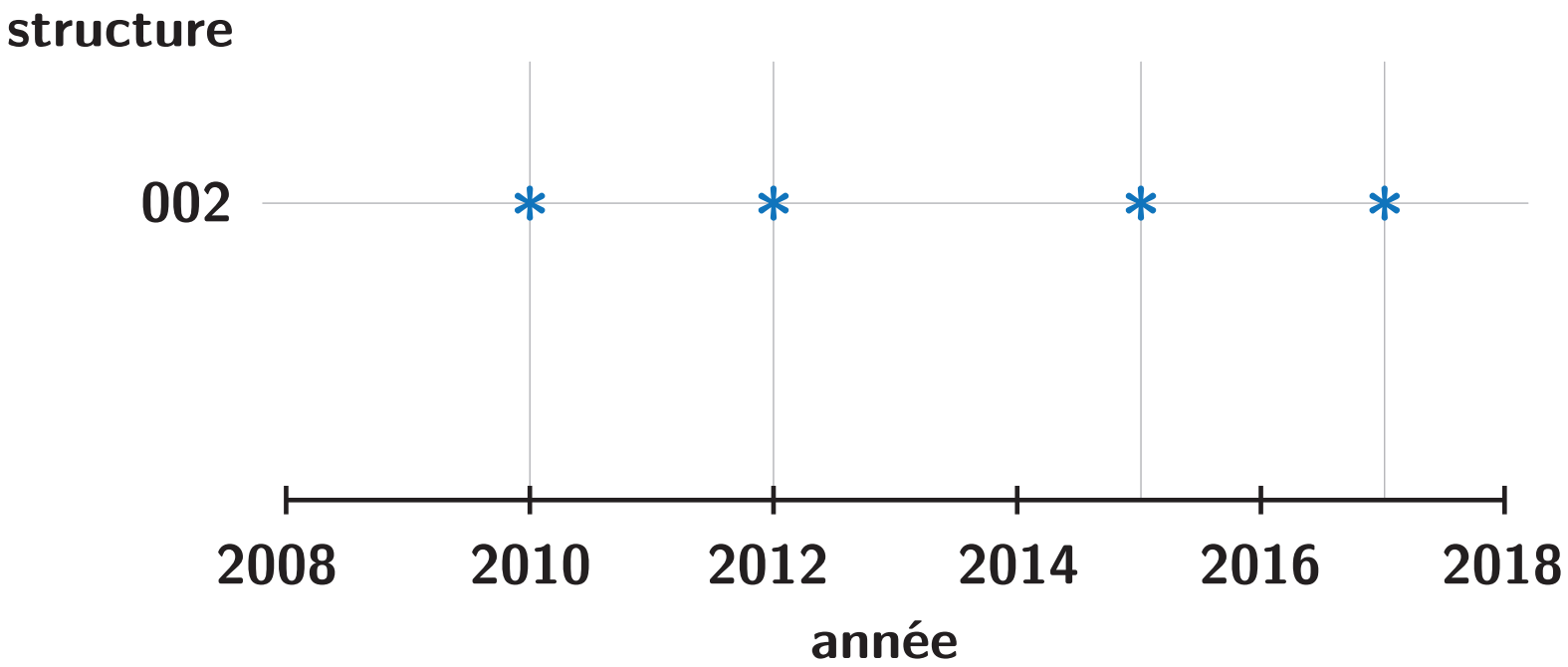
Real Data Analyses

Progress & Next Steps

Database of Visual Inspections



Database of Visual Inspections



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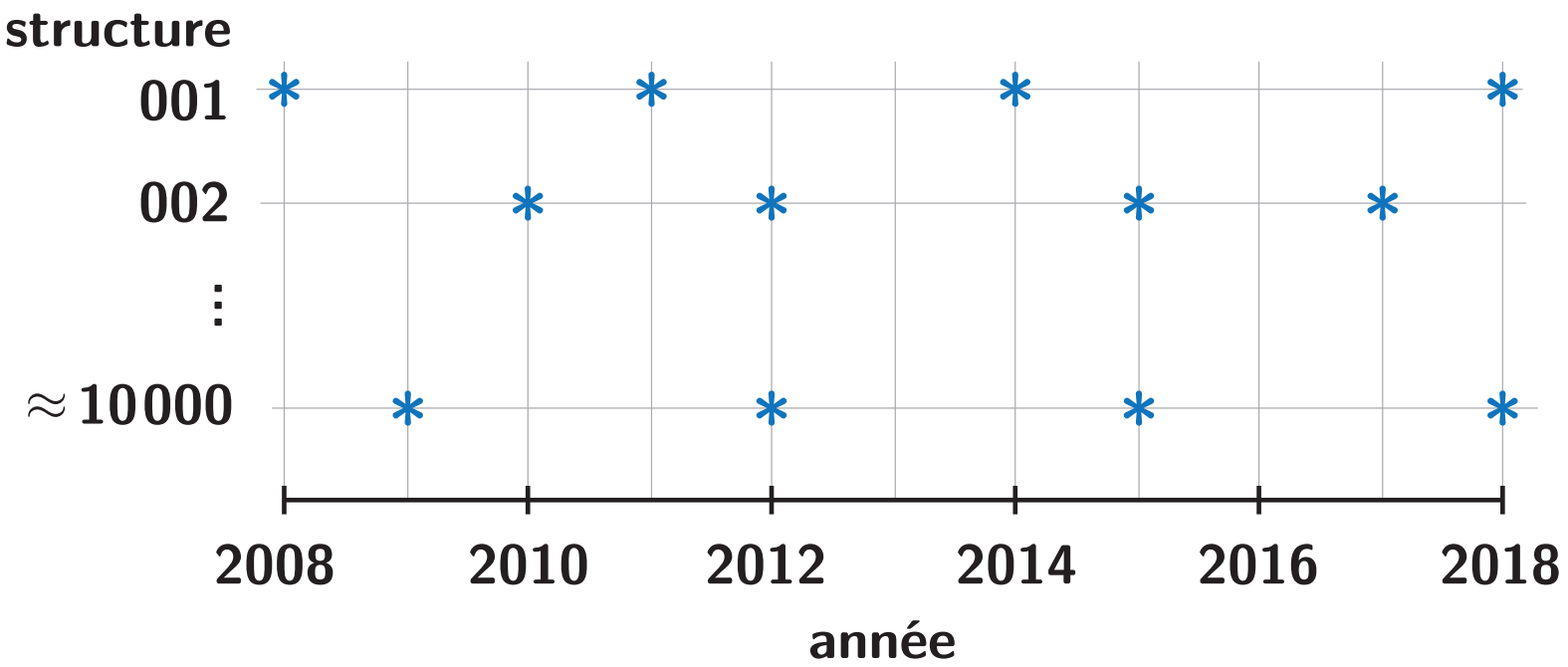
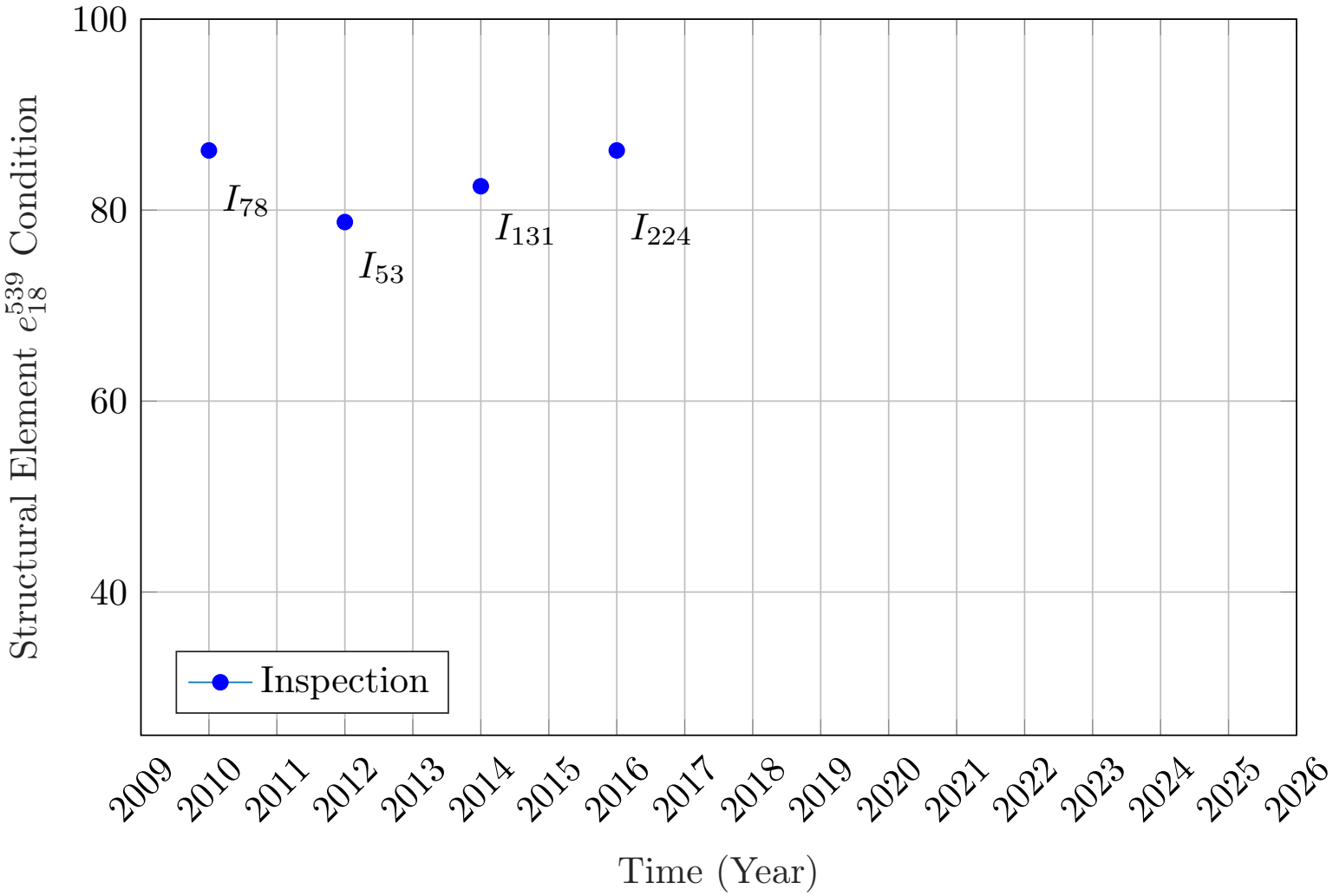


Example: Series of Inspections on Structural Element



Objectives

- Model the deterioration behaviour based on the data from network of bridges

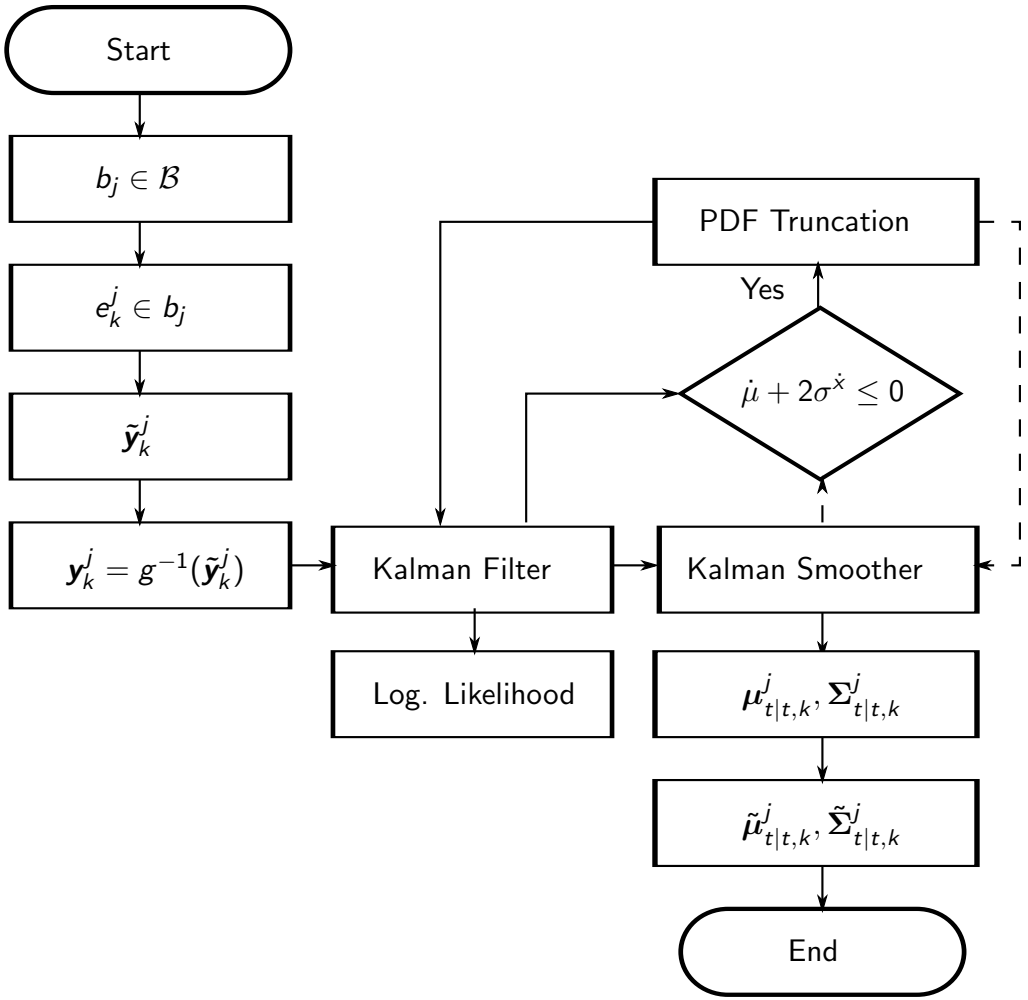
Plan de la section

Deterioration Model

2.1 Proposed Deterioration Model

2.2 Model Parameter Estimation

Deterioration Model Flowchart



Model Parameter Estimation

$$\mathcal{P} = \left\{ \underbrace{\sigma_v(I_1), \sigma_v(I_2), \cdots, \sigma_v(I_I)}_{\text{Inspector std.}}, \overbrace{\sigma_w}^{\text{Process error std.}}, \underbrace{n}_{\text{Transform. Param.}}, \overbrace{\dot{\mu}_0, \ddot{\mu}_0, \sigma_0^x, \sigma_0^{\dot{x}}, \sigma_0^{\ddot{x}}}^{\text{Initial state.}} \right\}$$

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$$\mathcal{P}^* = \arg\max_{\mathcal{P}} \quad \mathcal{L}(\mathcal{P}),$$

$$\text{subject to:} \qquad \text{(parameters feasible domain)}$$

Parameter Estimation Method

Optimization Algorithm:

Parameter Estimation Method

Optimization Algorithm: Newton-Raphson.

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Optimization Hierarchy & Hypotheses:

Parameter Estimation Method

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Optimize: $\mathcal{P}_0 = \{\sigma_W, \sigma_V, \sigma_0^x, p_1, p_2, p_3\} \subseteq \mathcal{P}$
For each time-series:

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Optimization Algorithm: Newton-Raphson.

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For each time-series:

$$\mu_0 = \frac{\sum_{t=1}^{3} y_t}{3},$$
$$\dot{\mu}_0 = 0,$$
$$\ddot{\mu}_0 = 0,$$

$$[\sigma_0^x]^2 = \max([\sigma_0^x]^2, [\sigma_v(I_i)]^2)$$
$$[\sigma_0^{\dot{x}}]^2 = p_1^2 * (100 - \tilde{\mu}_{1|T}) + p_2^2,$$
$$[\sigma_0^{\ddot{x}}]^2 = p_3^2$$

Parameter Estimation Method

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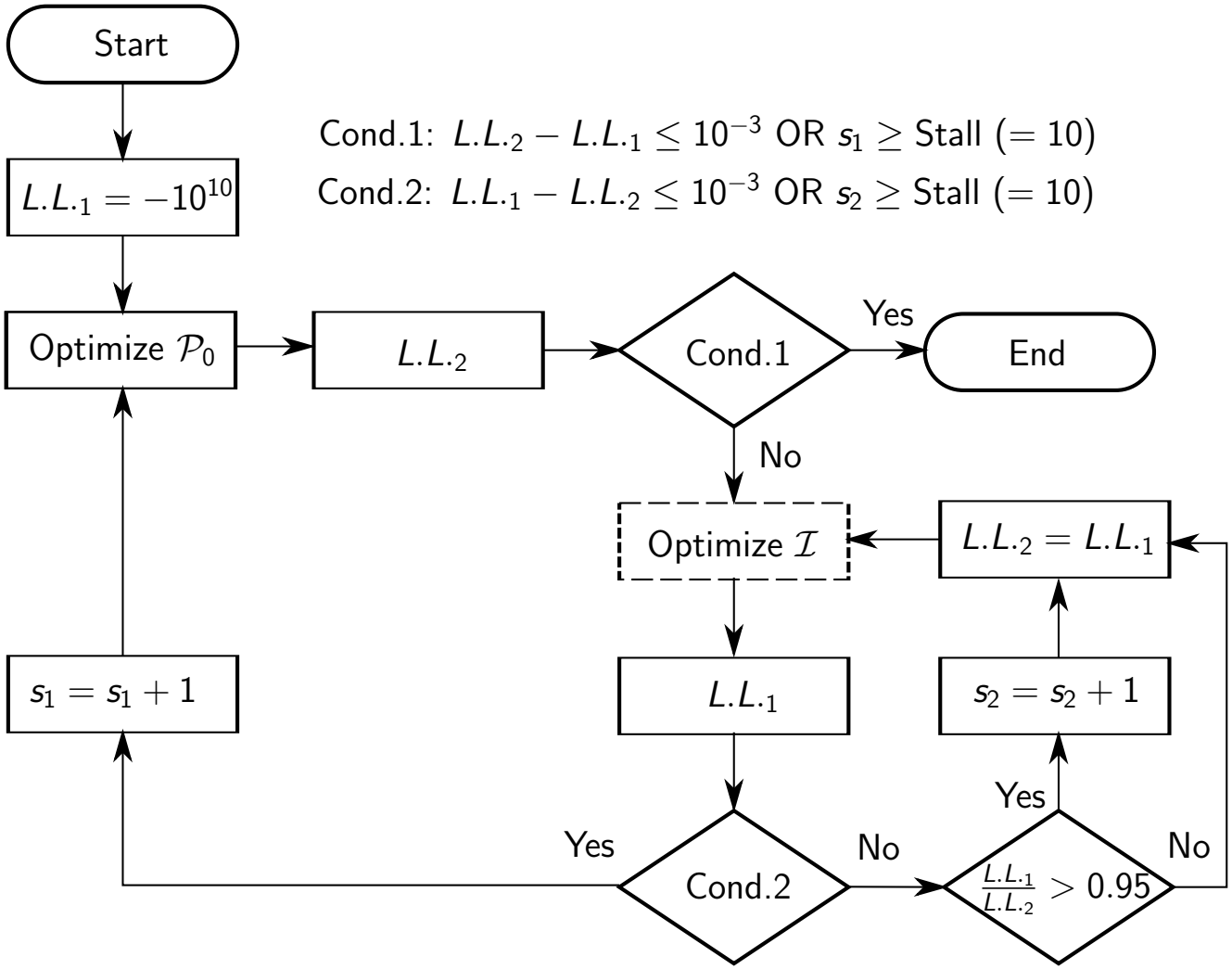
Initialize: $\sigma_v(I_i) = \sigma_V, \quad \forall \sigma_v(I_i) \in \mathcal{I}$
Optimize: $\mathcal{I} = \{\sigma_v(I_1), \sigma_v(I_2), \cdots, \sigma_v(I_I)\} \subset \mathcal{P}$

Optimization Framework



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- Number of observations less or equal to 2 observations.
- High noise in one of the observations: $\max(|\ y_t - y_{t-1}\ |) > 15$.
- Dominance of observations showing condition improvement: Number of $((y_t - y_{t-1}) > 5) \geq$ Number of $((y_t - y_{t-1}) \leq 5)$.

Plan de la section

Model Verification

3.1 Synthetic Data Characteristics

3.2 Verification Results

Quantitive Characteristics

Generating Synthetic Data

Method: Transition & Observation Models

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$$\underbrace{I_i \in [I_1, I_2, \ldots, I_{\mathrm{I}}] = \mathcal{I}}_{\text{inspectors}}$$

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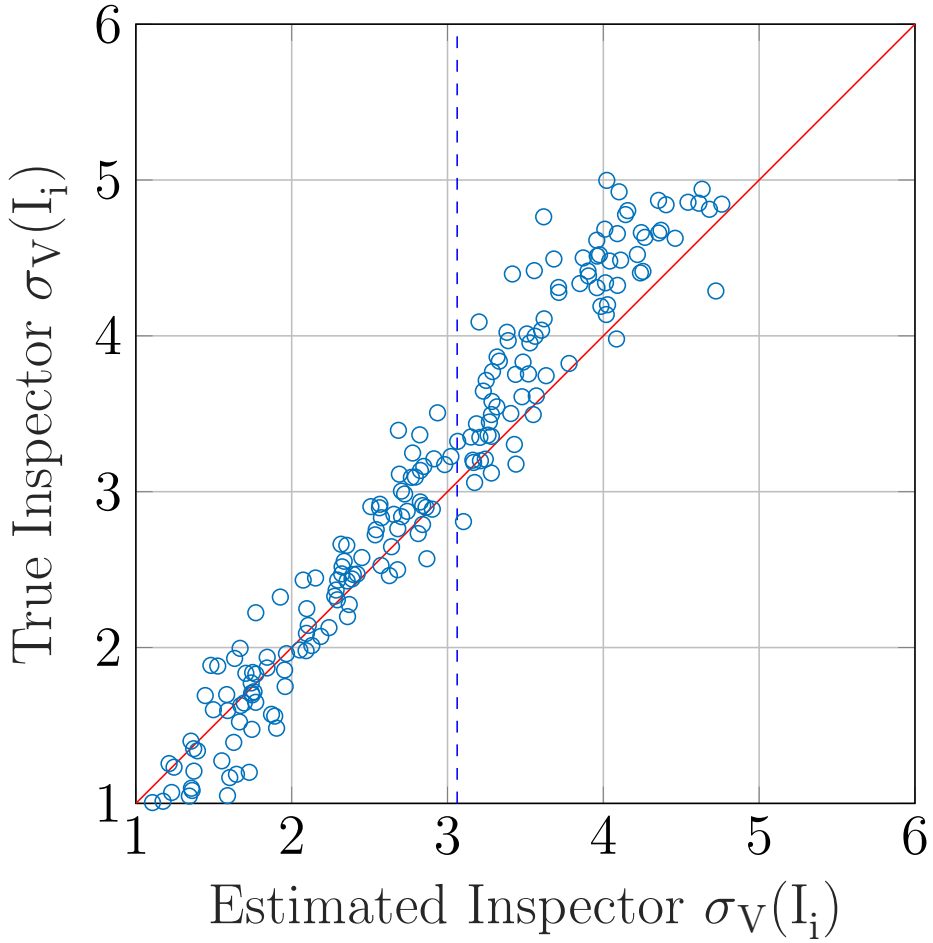
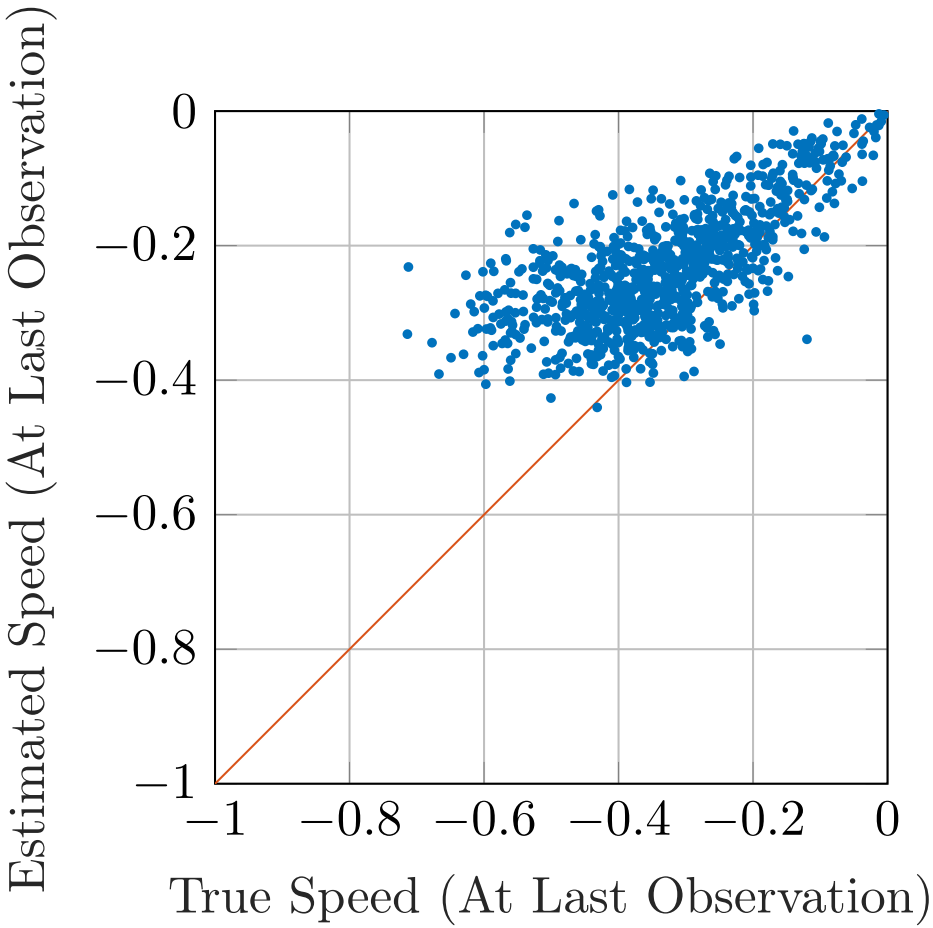
- Having a plateau curve: $x_T > 0.5 * x_1$
- Other conditions that ensures diversity in the starting conditions.

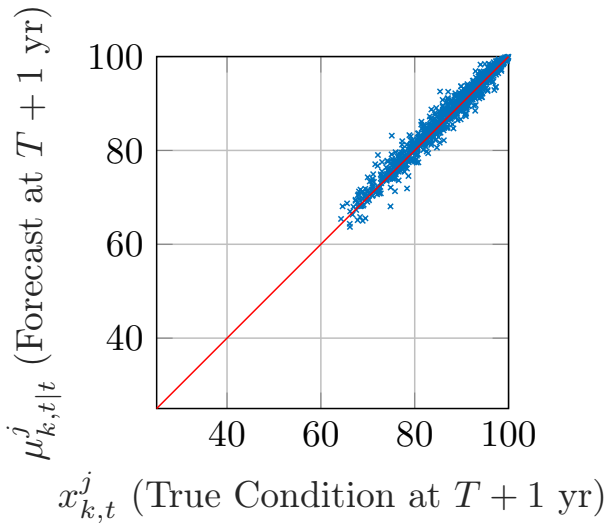
Estimating Inspectors Parameters



Predicting Speed - Scatter



Predicting Condition - Scatter



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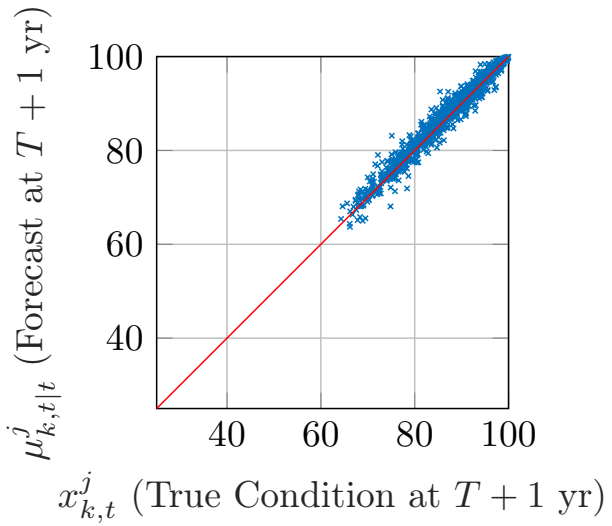

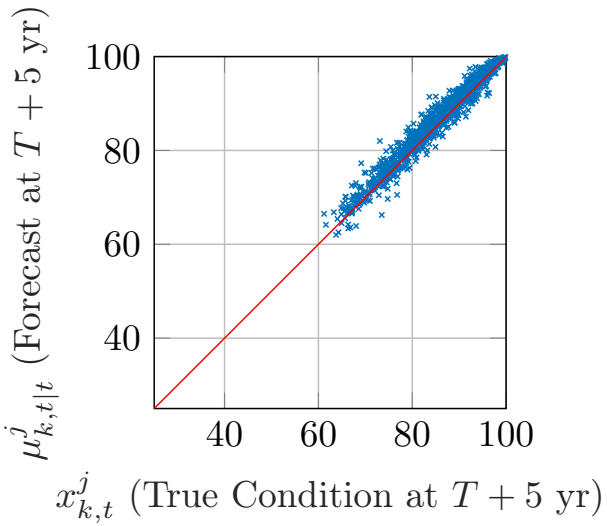

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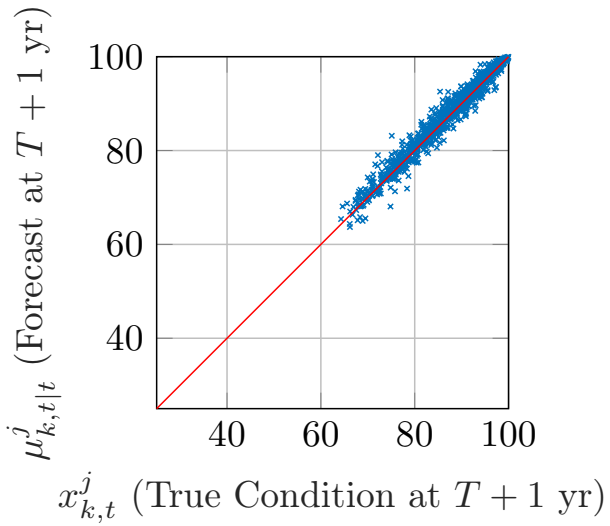

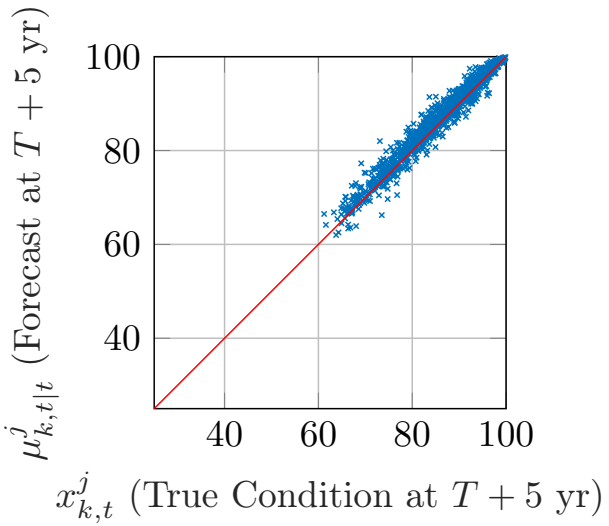

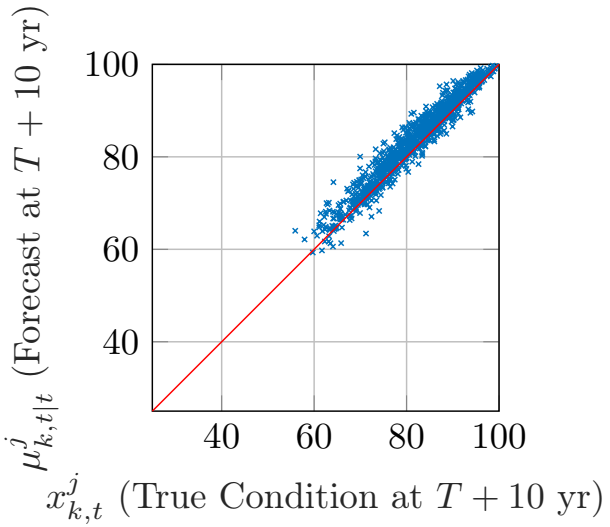

Plan de la section

Real Data Analyses

4.1 Validation with Real Data

4.2 Prediction - Real Data

Condition Validation

Condition Validation

- Database with inspections up to year 2017.

Condition Validation

- Database with inspections up to year 2017. $\rightarrow$ Training.

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- Database with inspections up to year 2019.

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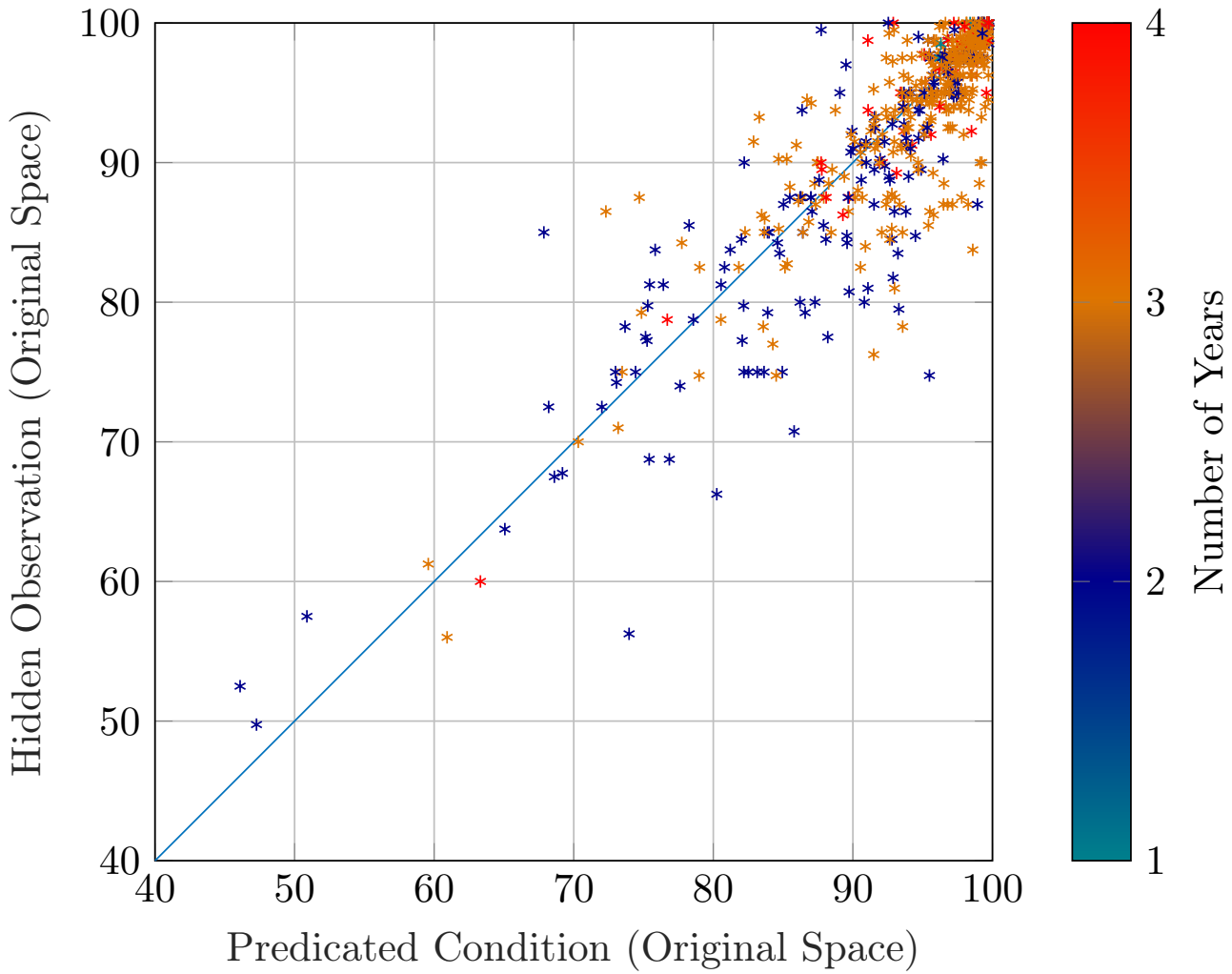
- Conditions:
- Inspections associated with new inspectors are Excluded.

Condition Validation

- Database with inspections up to year 2017. $\rightarrow$ Training.
- Database with inspections up to year 2019. $\rightarrow$ Validation.

- Conditions:
- Inspections associated with new inspectors are Excluded.
- The Training Conditions (Mentioned Earlier).

Condition Validation Scatter - Number of Years



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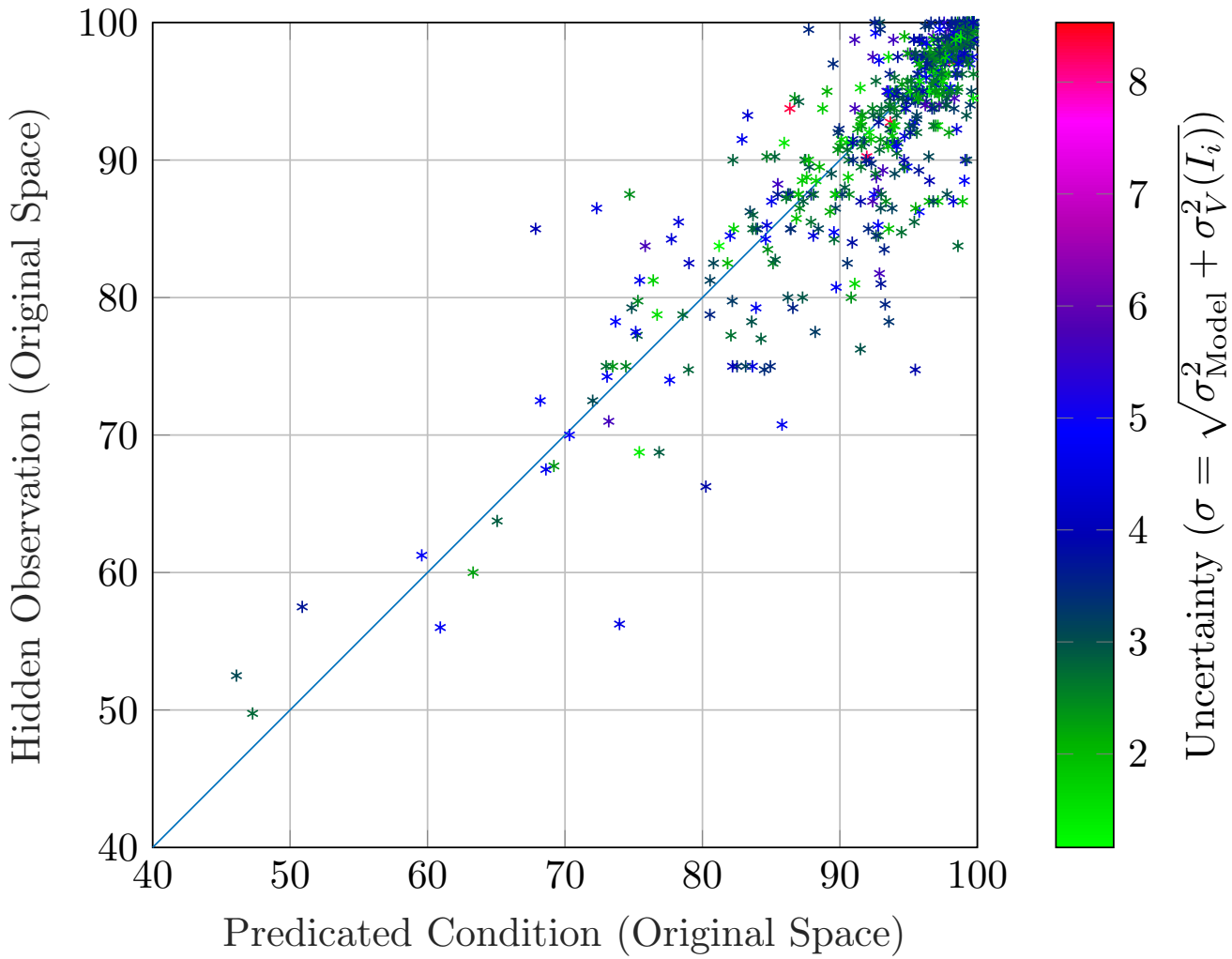
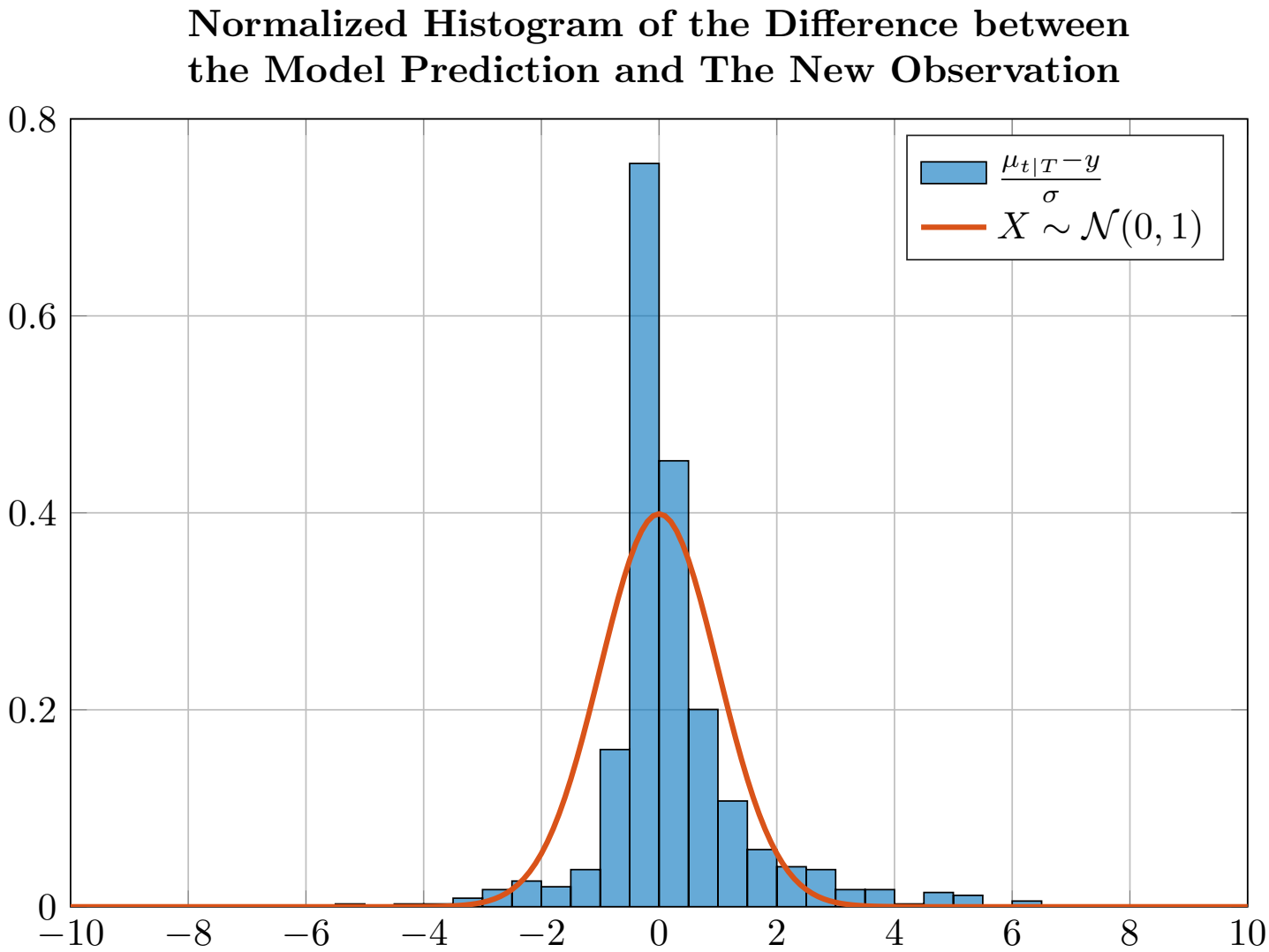
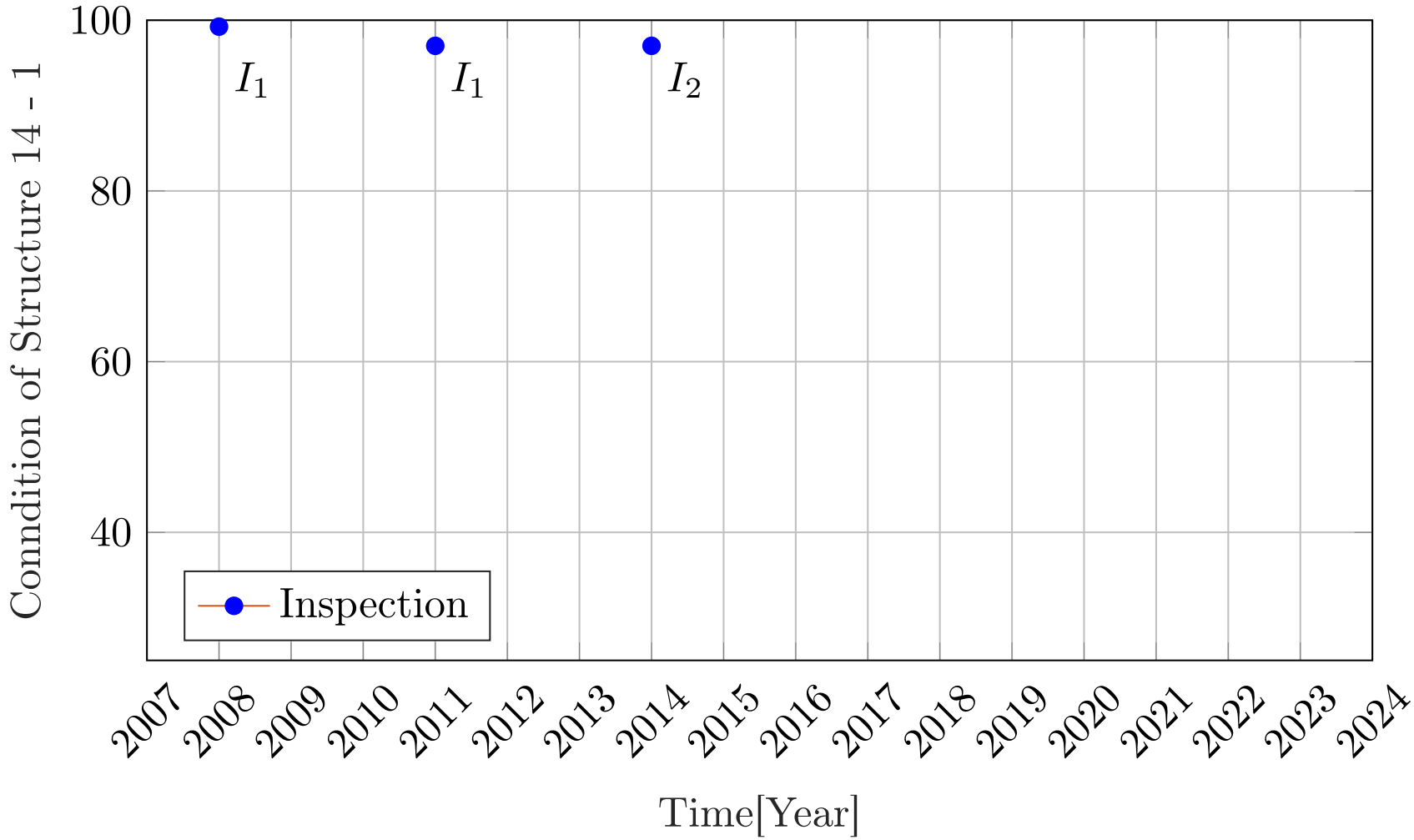



Normalized Histogram of the Difference between the Model Prediction and The New Observation
$\frac{\mu_{t|T}-y}{\sigma}$
$X \sim \mathcal{N}(0,1)$
0.8
0.6
0.4
0.2
0
−10
−8
−6
−4
−2
0
2
4
6
8
10

Low Variability Case



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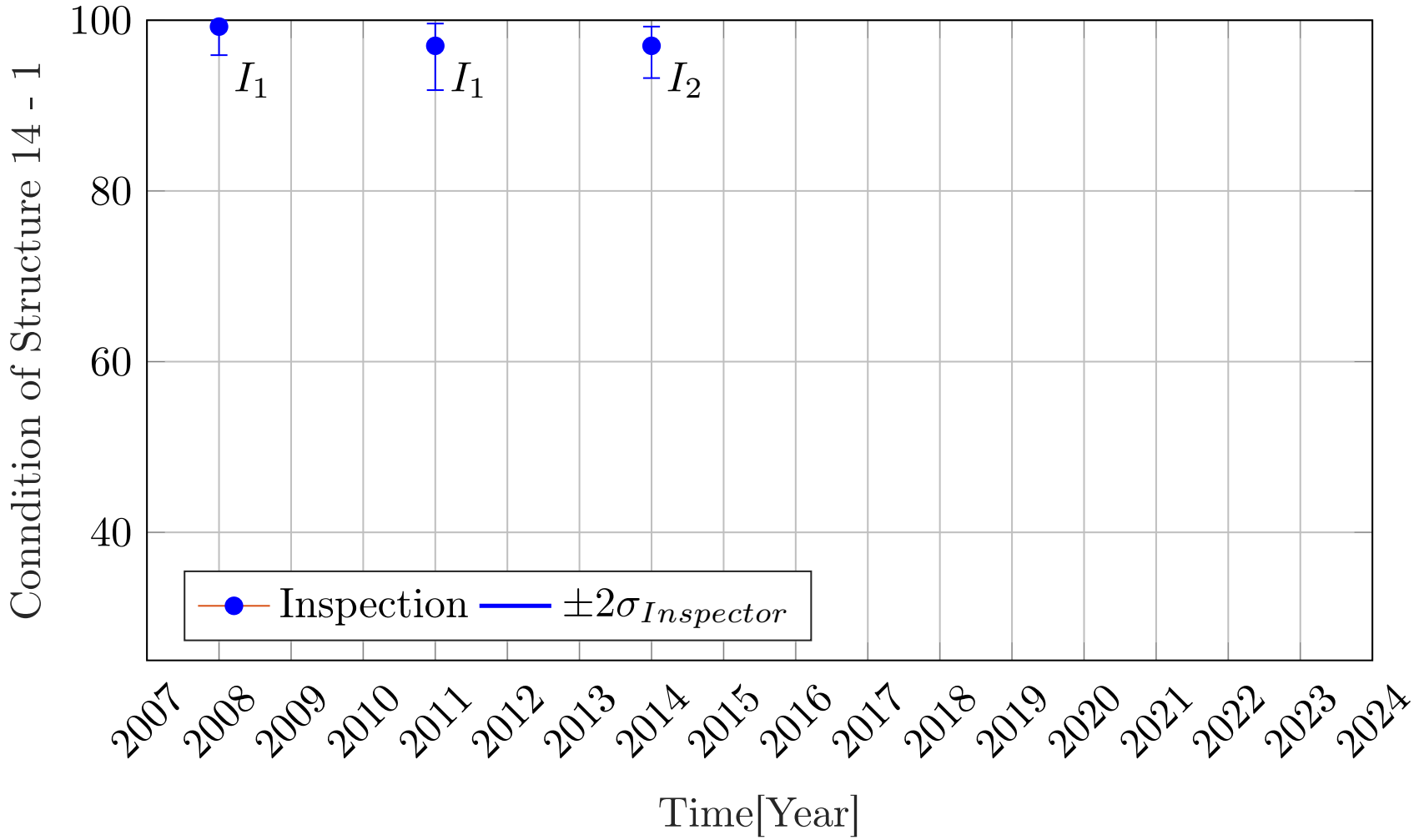

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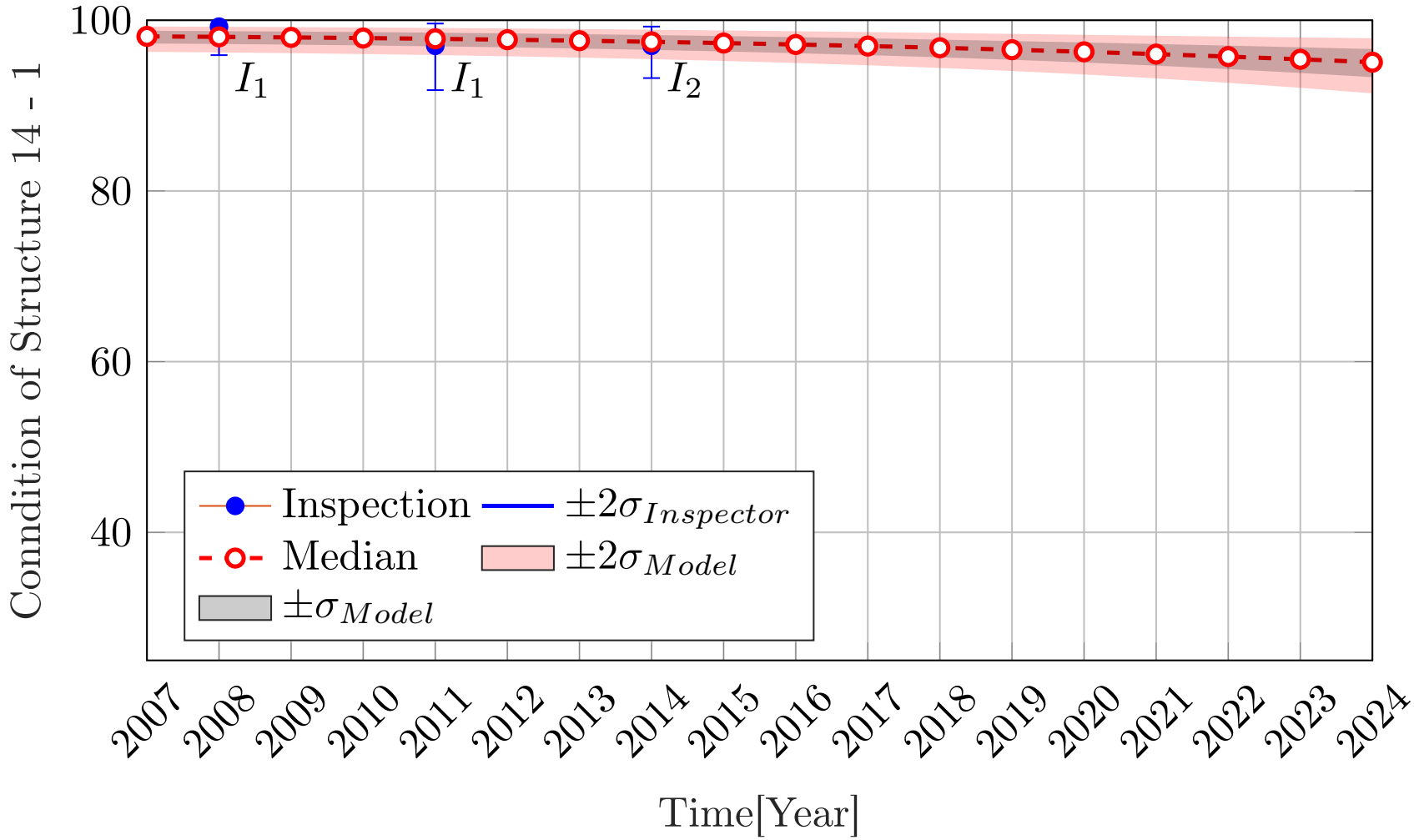

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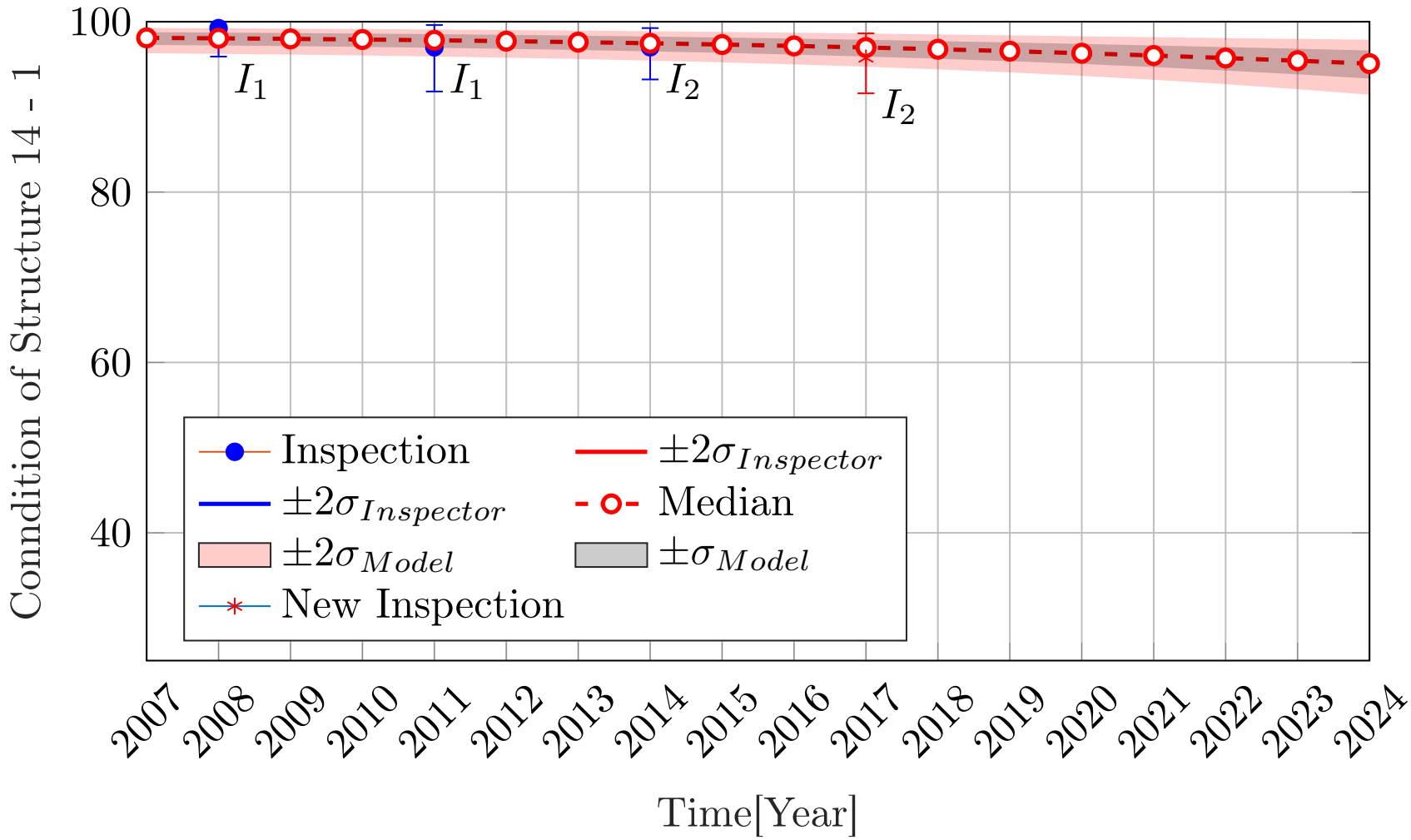
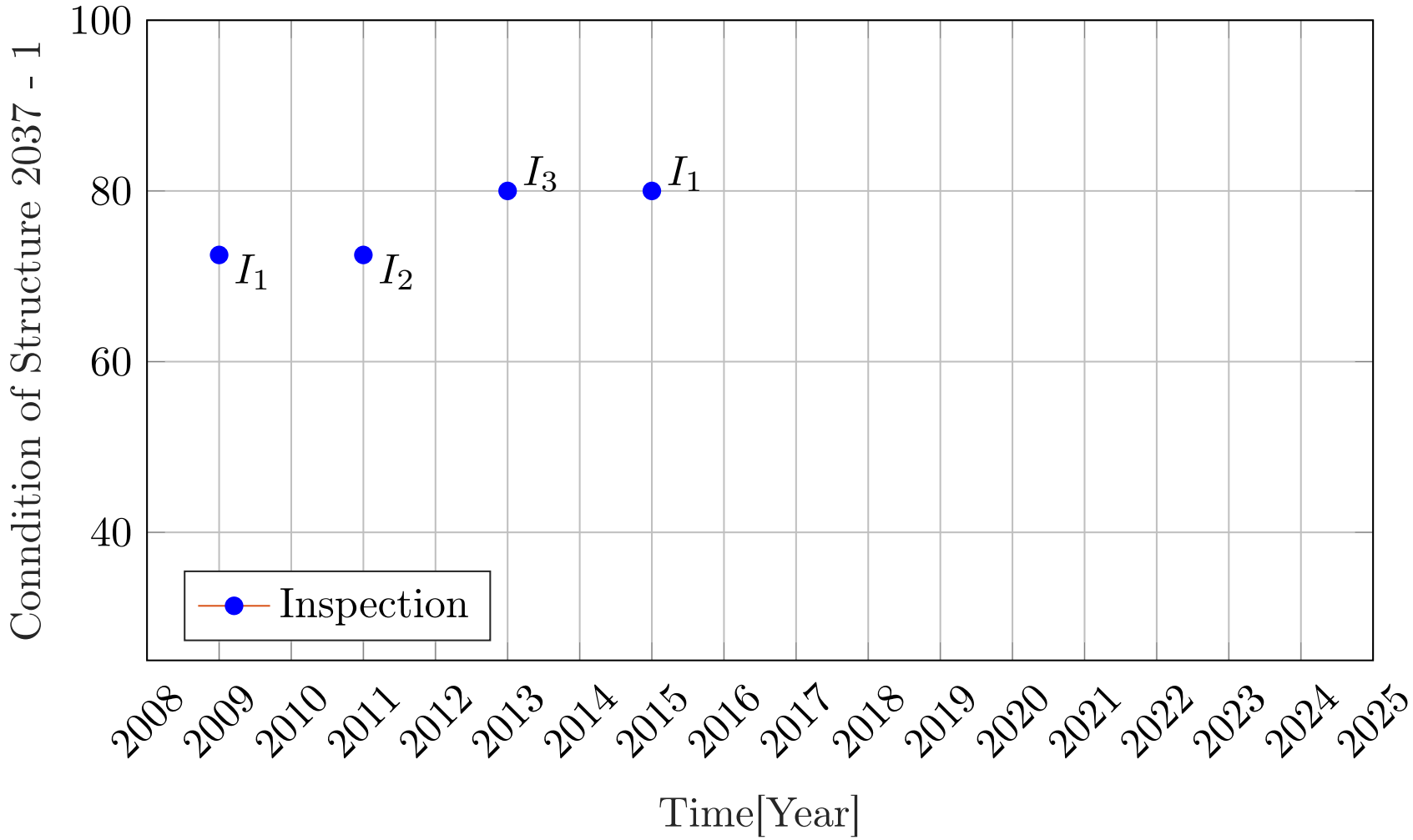


Medium Variability Case



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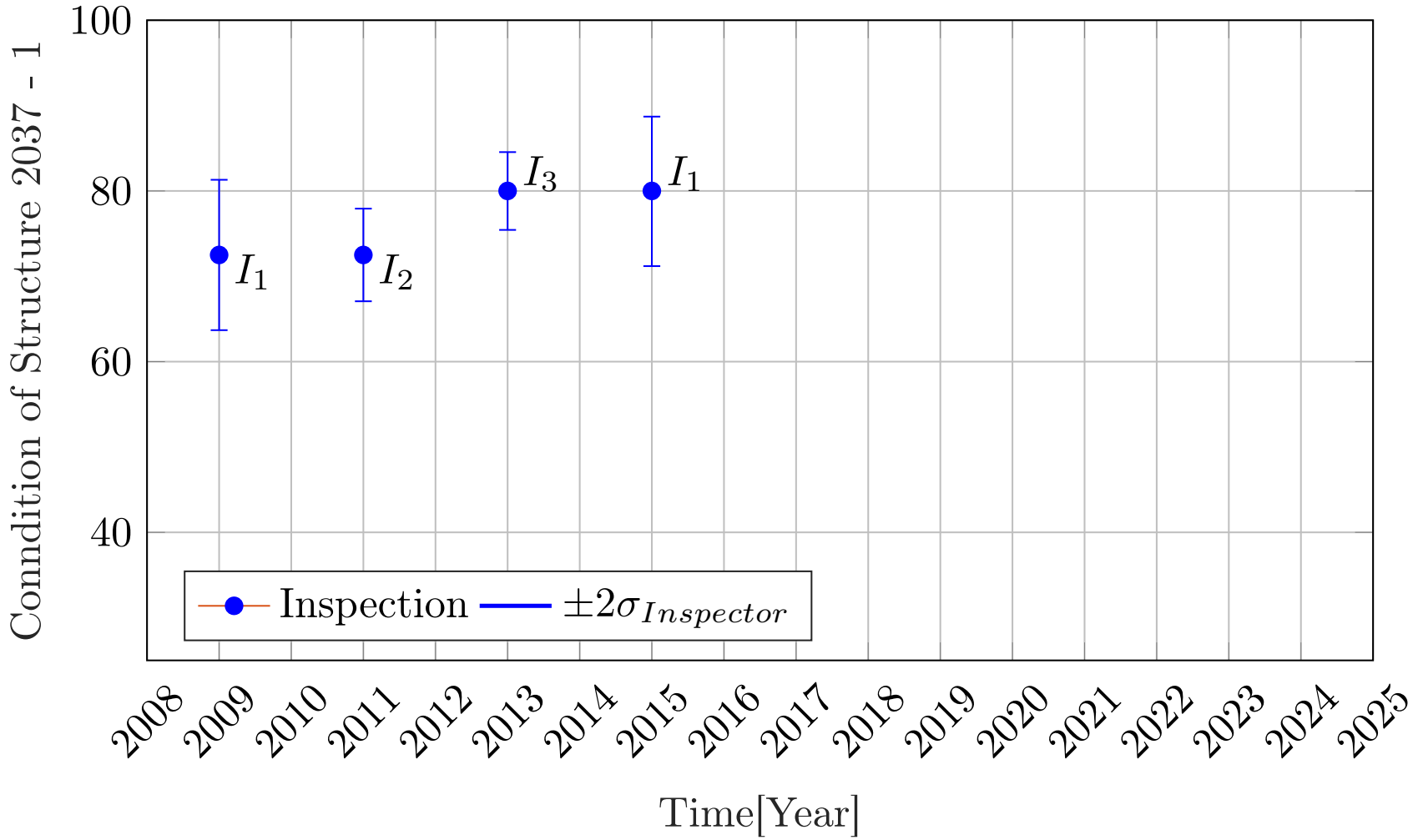

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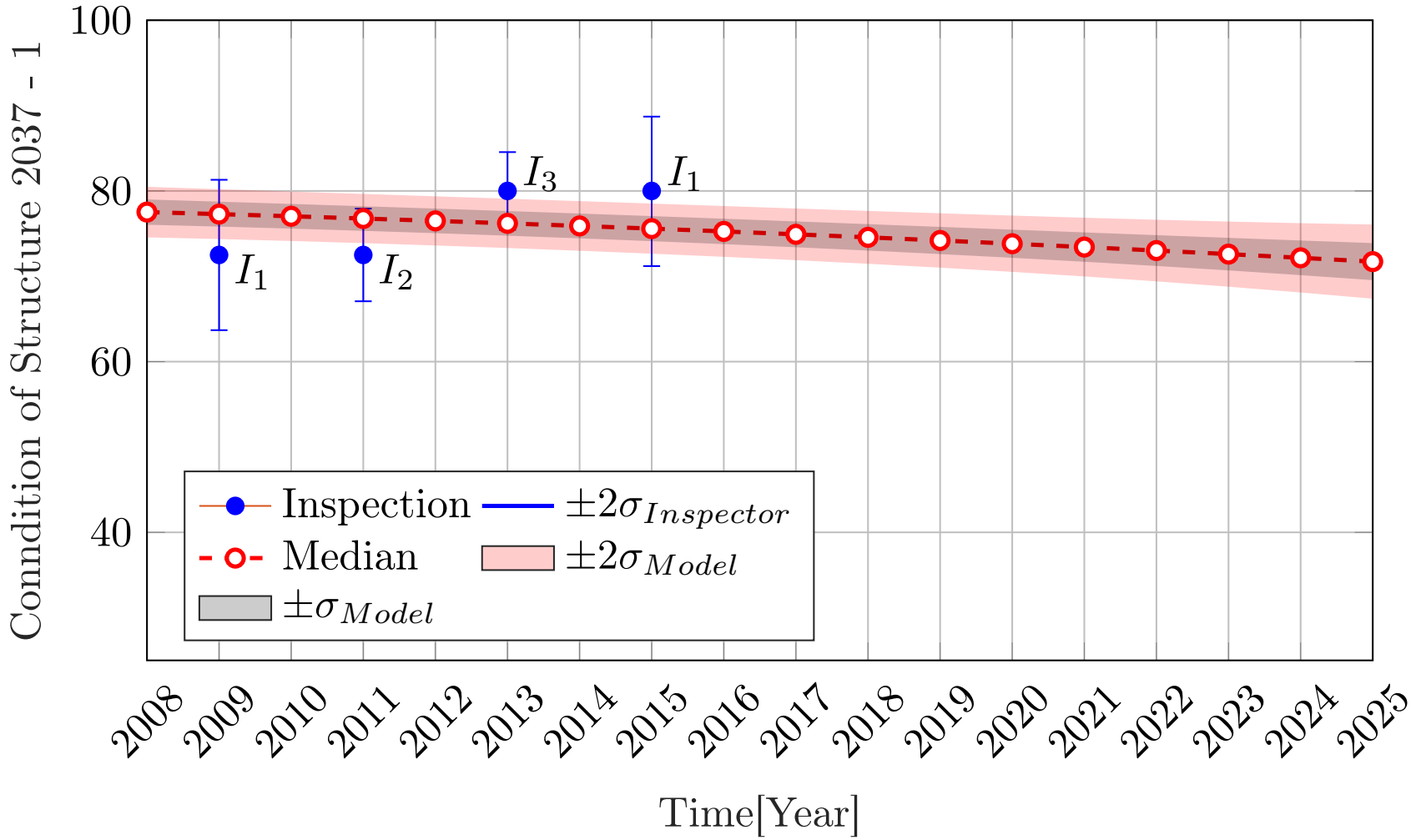

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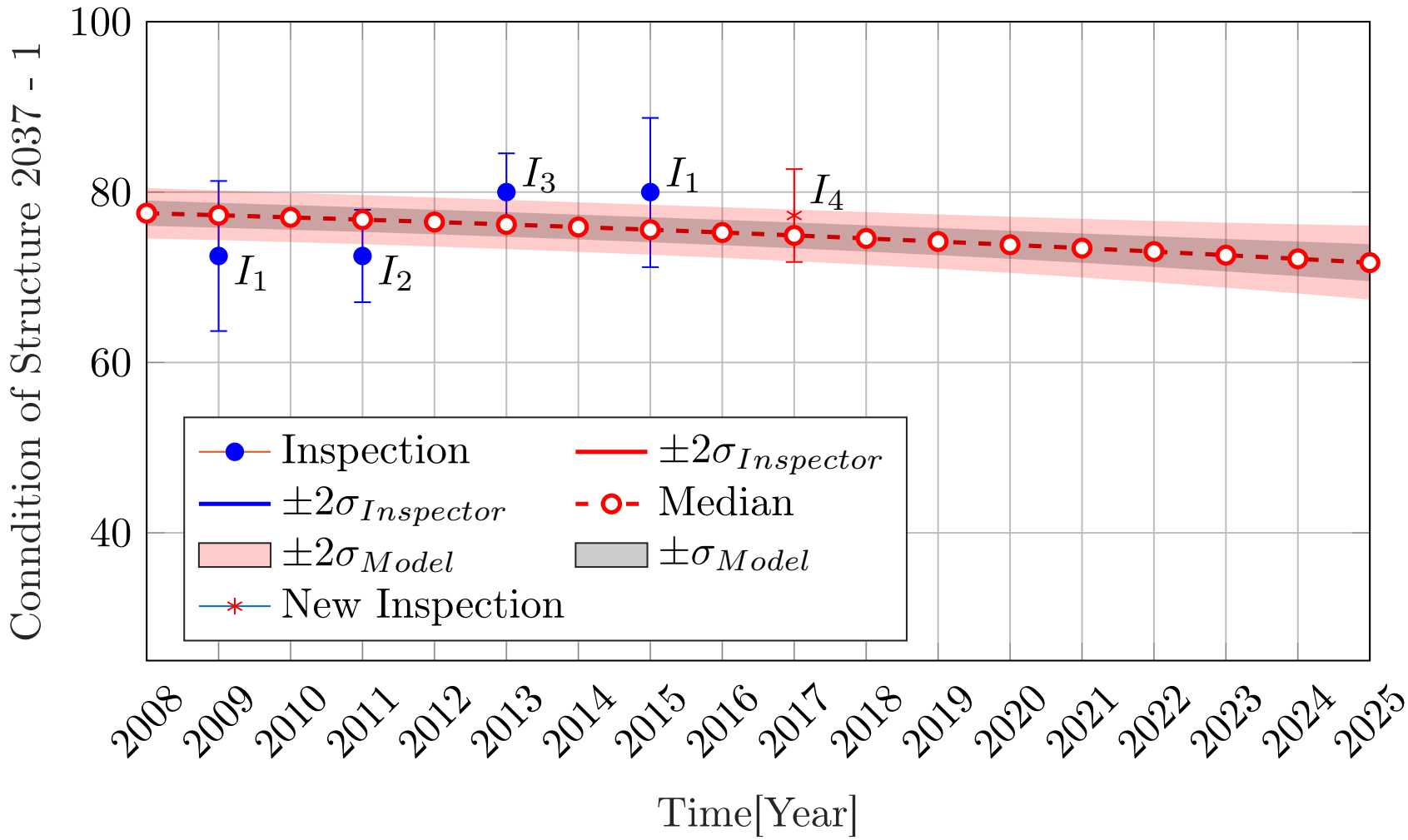
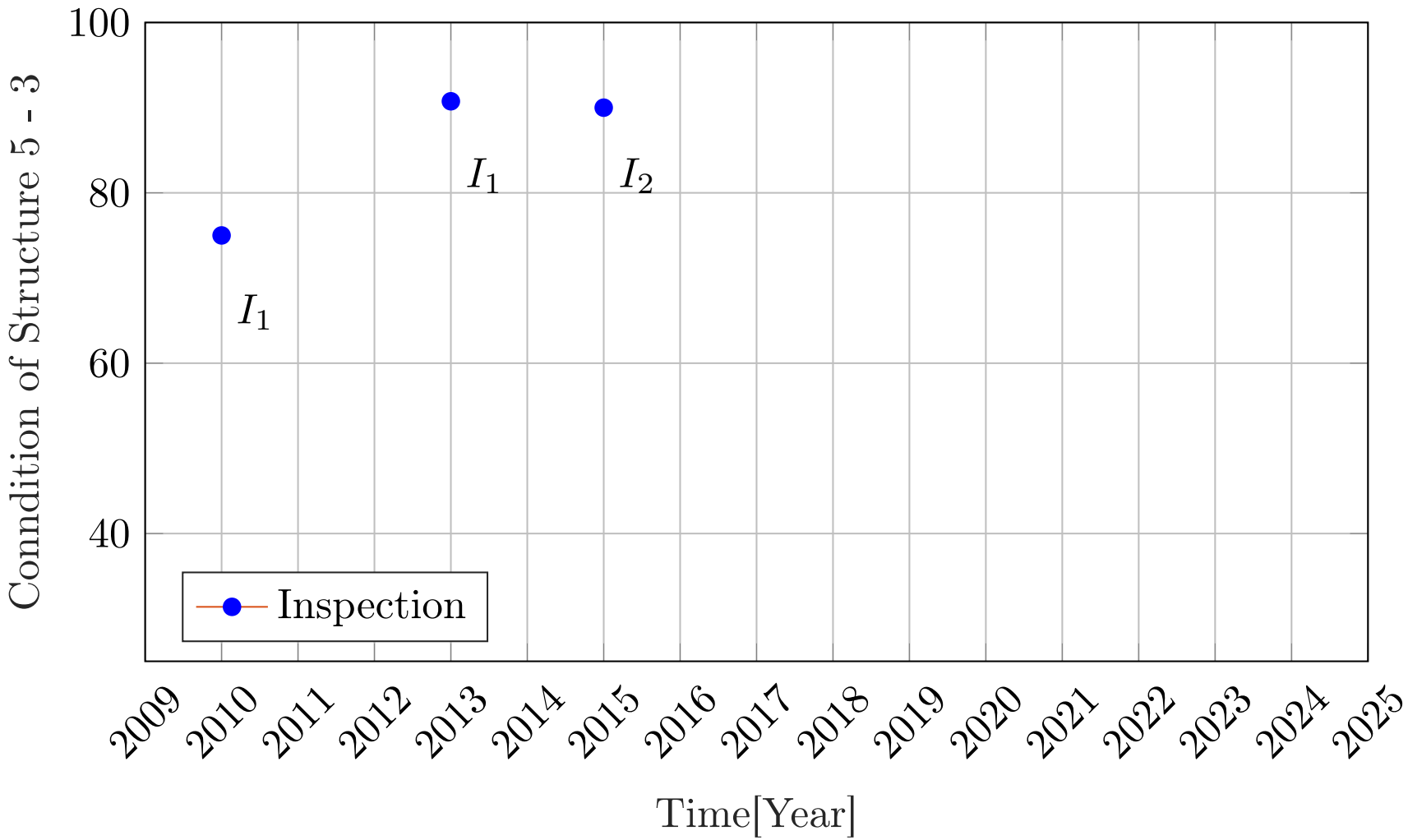


High Variability Case A



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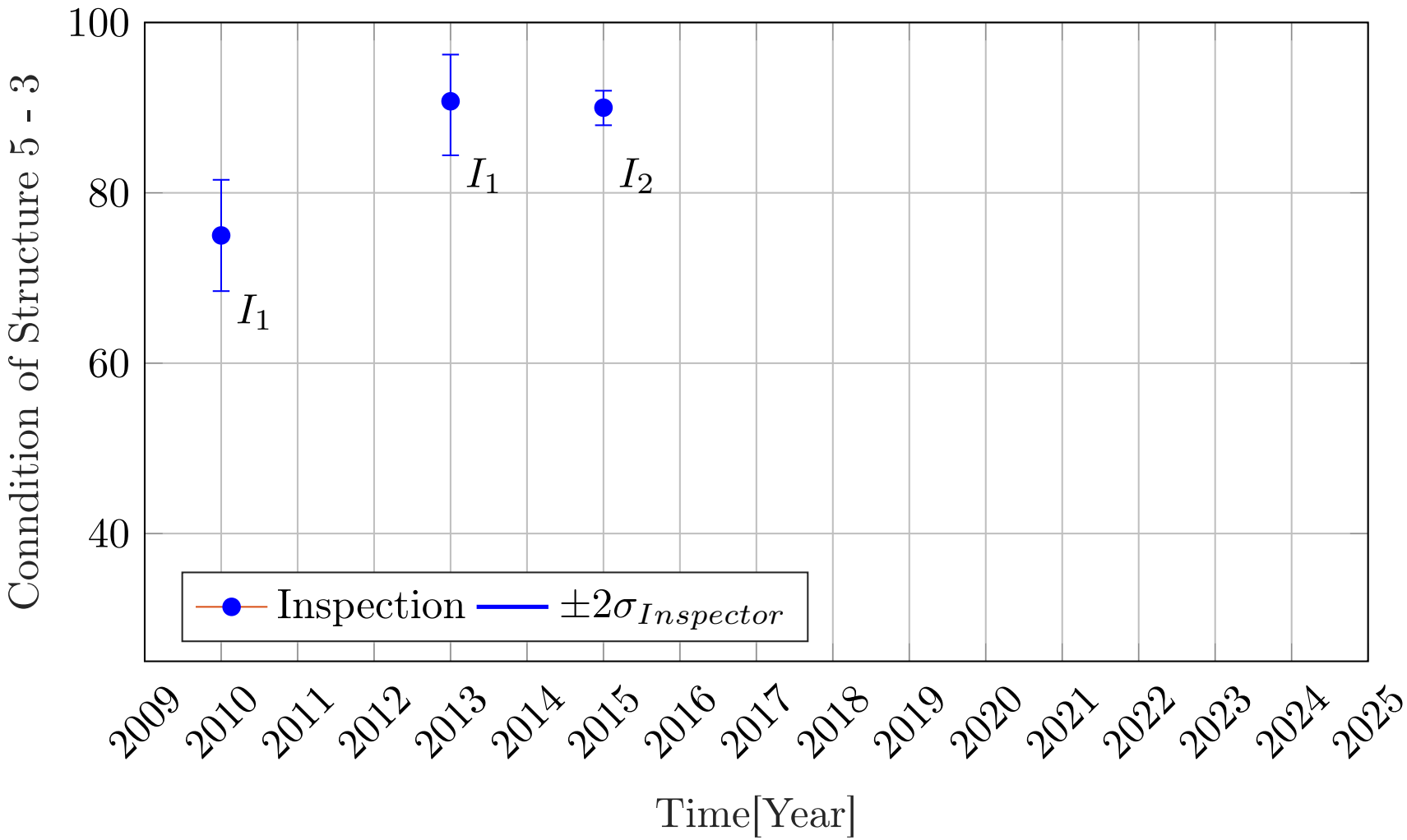

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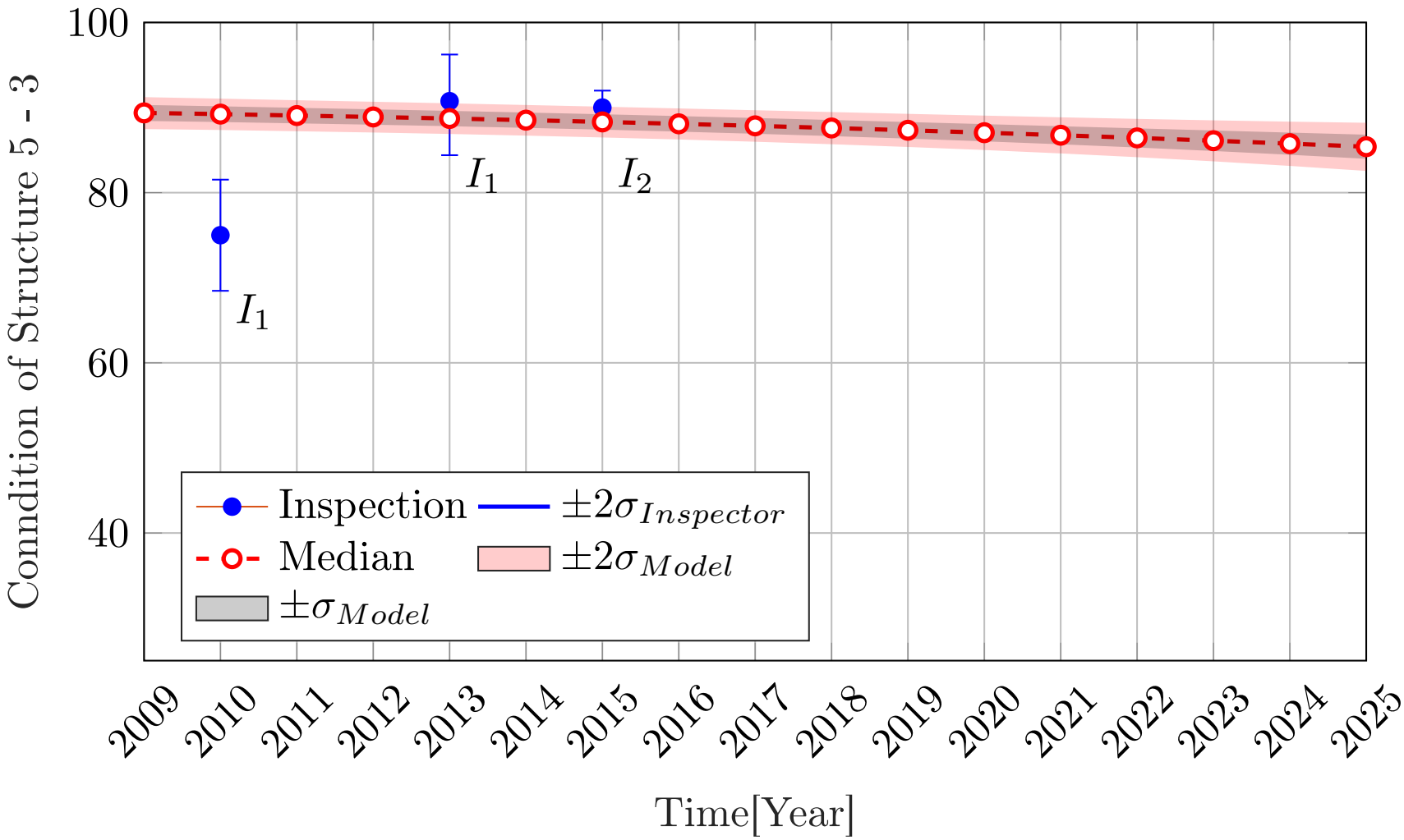

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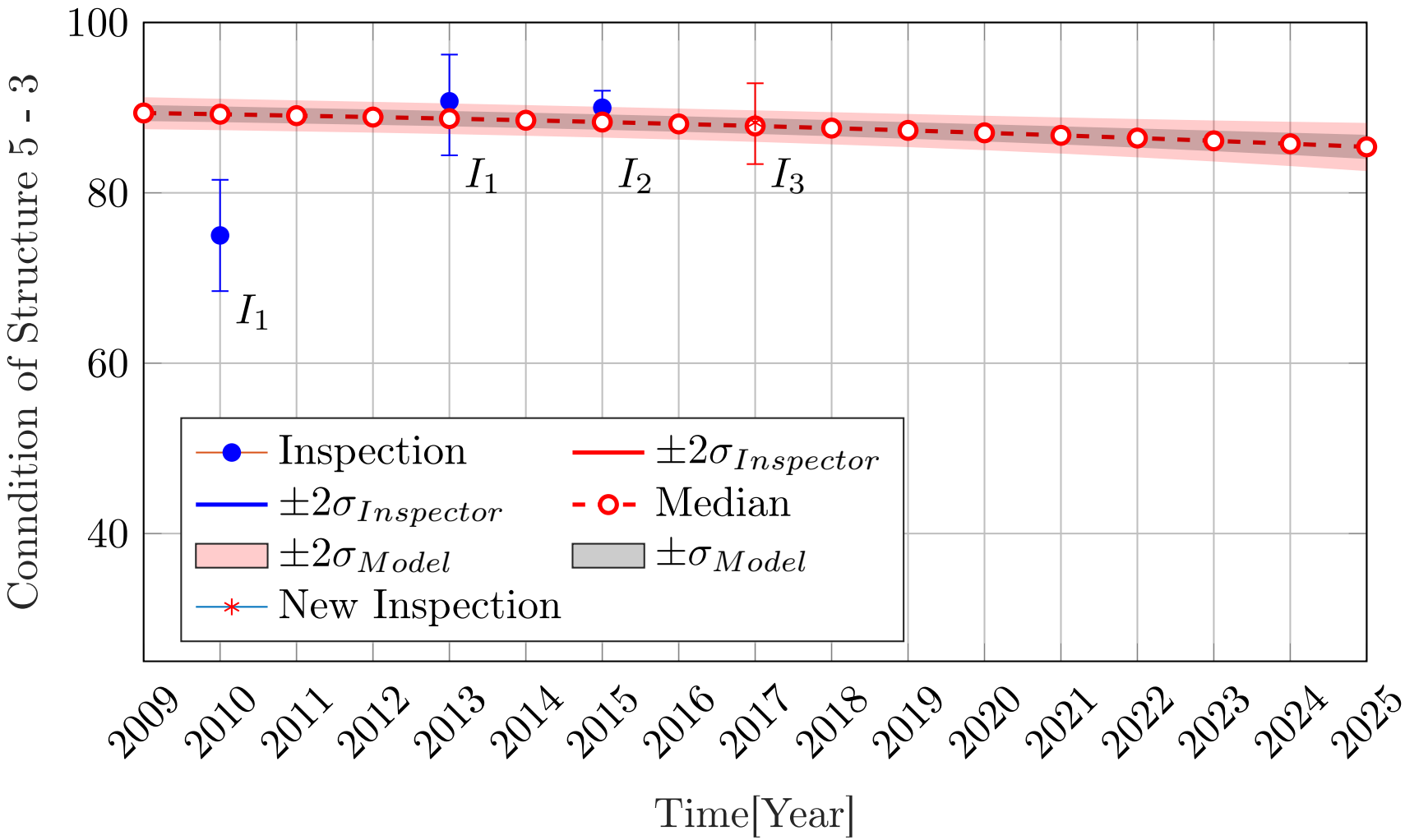
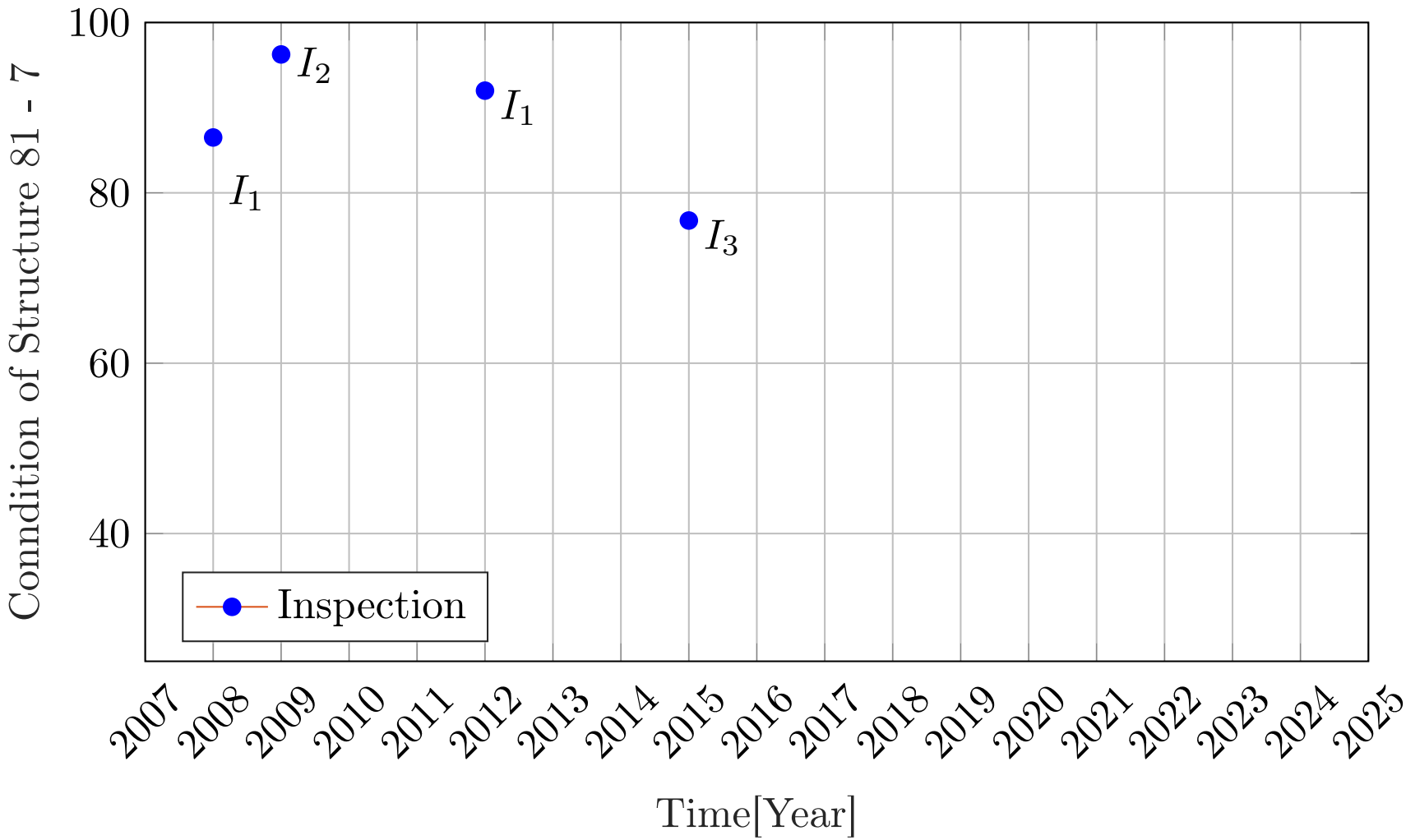


High Variability Case B



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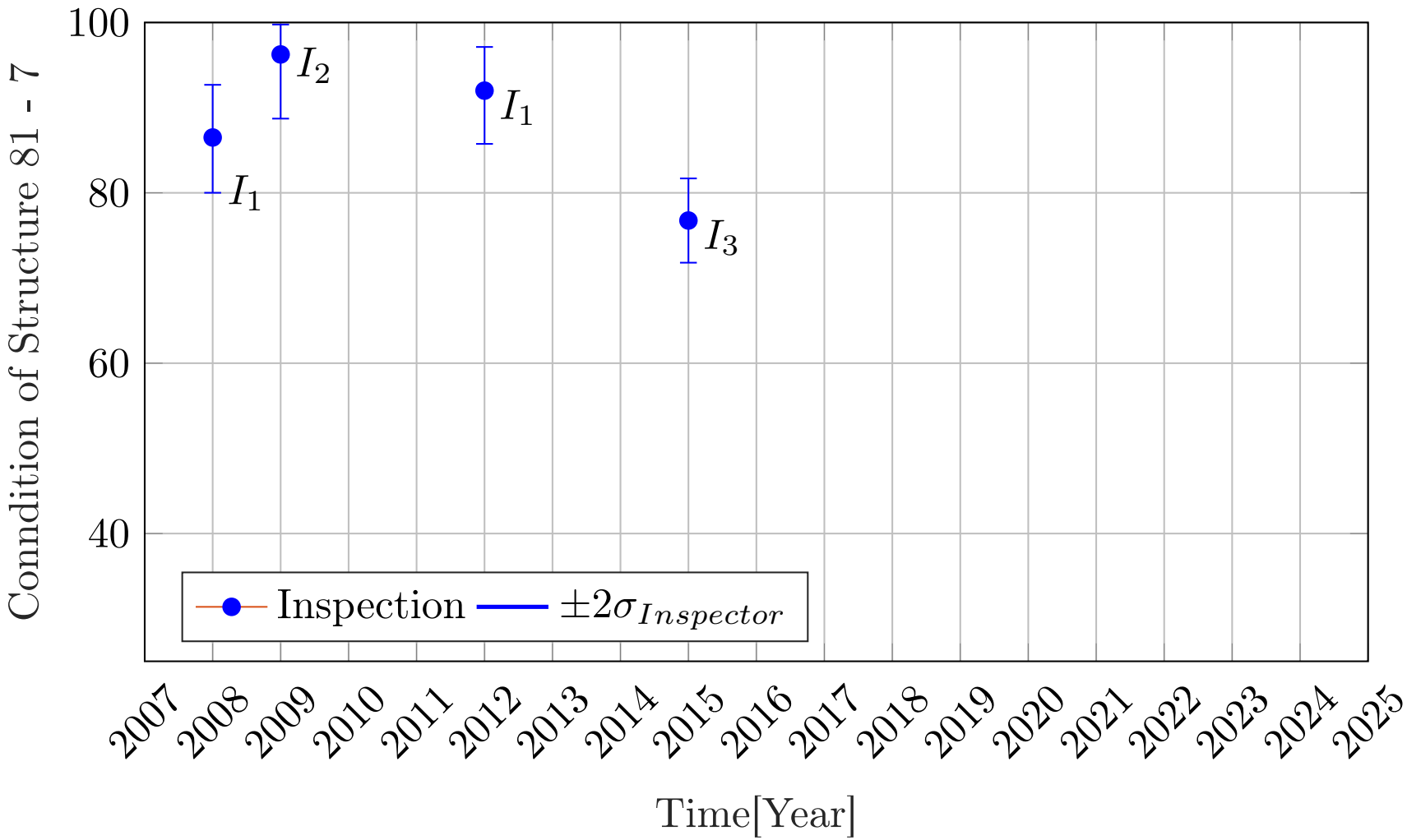

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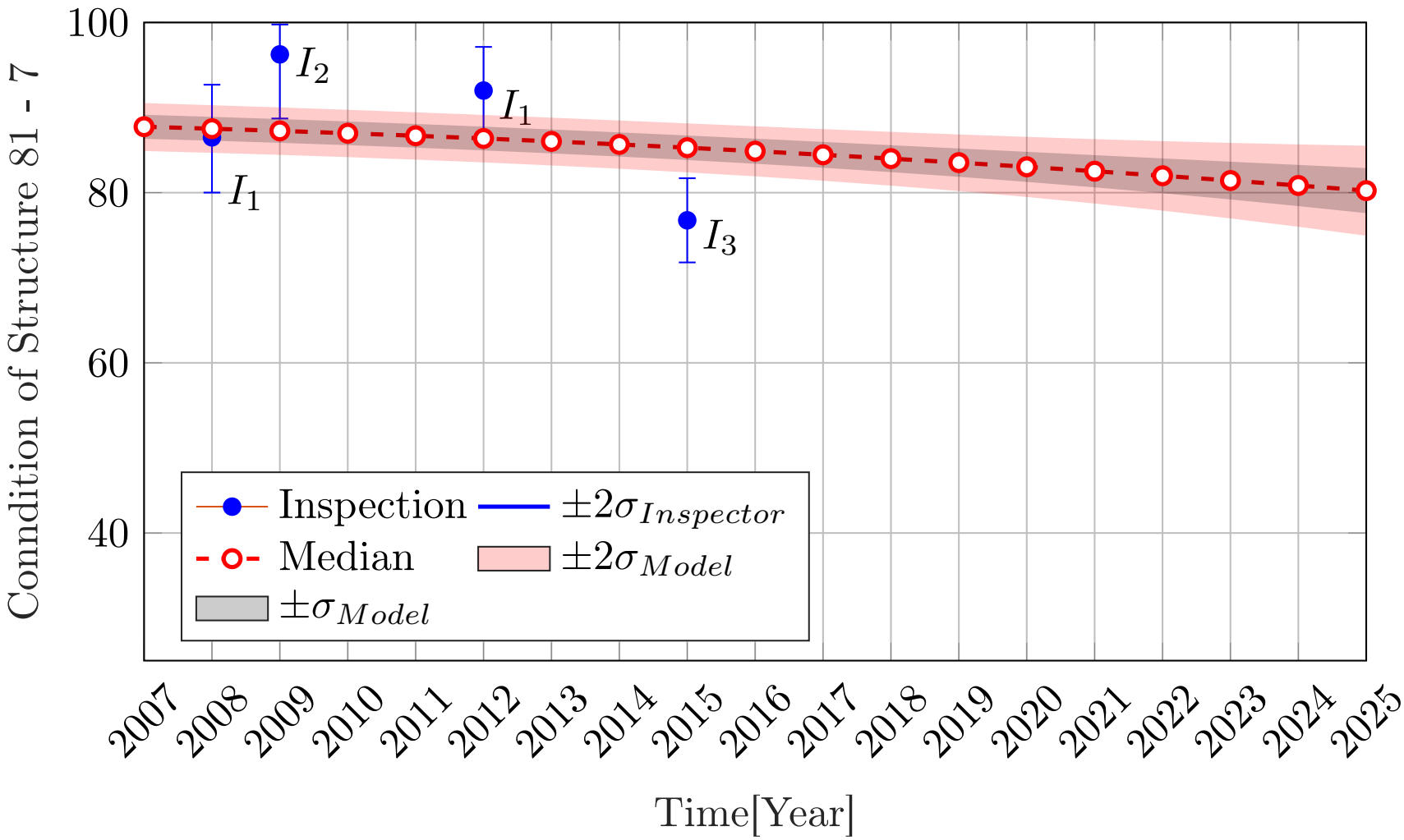

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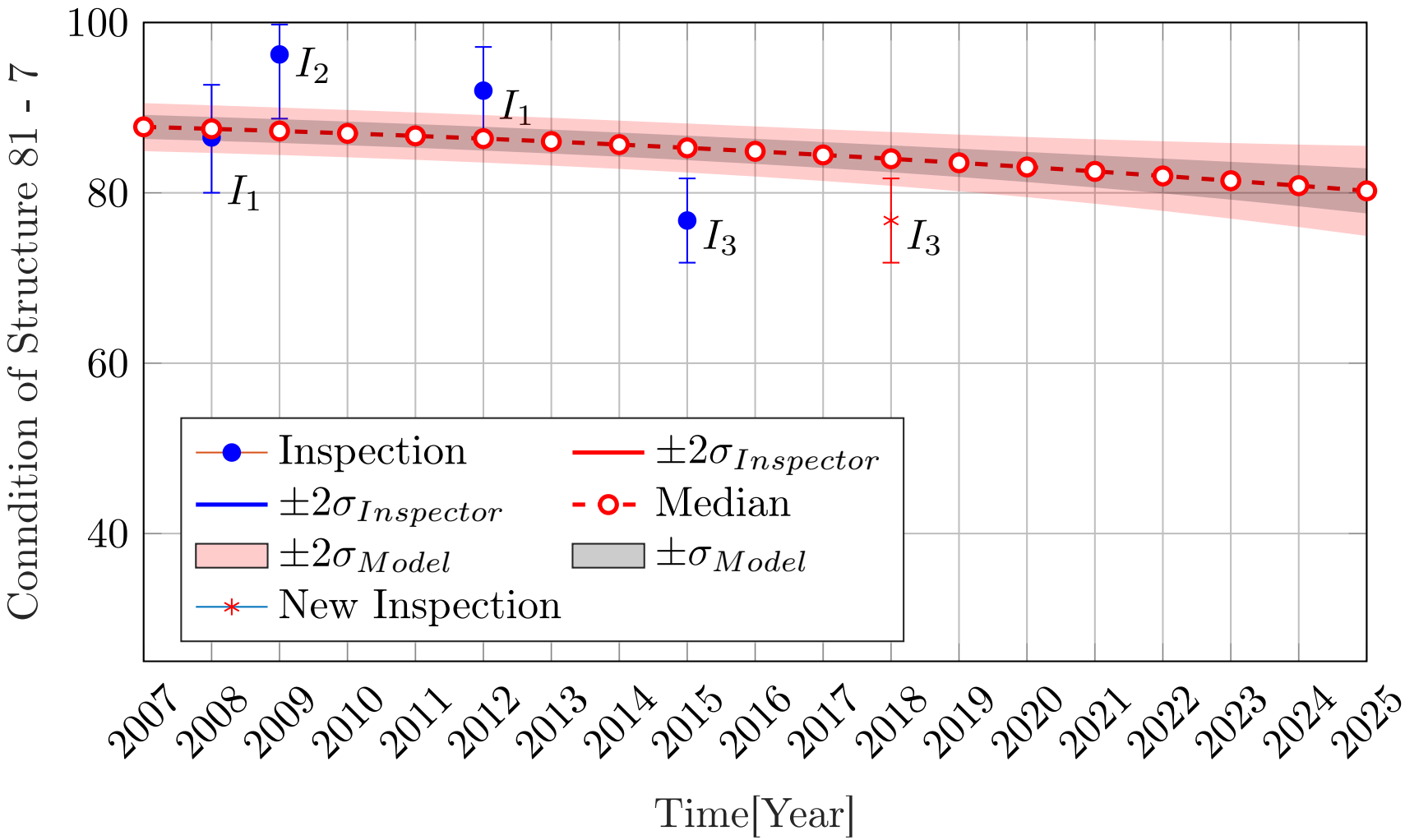

Plan de la section

Progress & Next Steps

5.1 Project Progress

5.2 Next Steps

Advancement Summary

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4. Validation with real data.

Next:

1. Examine the bounds for synthetic data.

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2. Improve the software.