

Validating Nominal Bias Error Limits Using 4 years of WAAS Signal Quality Monitoring Data

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Introduction

- Nominal signal deformations lead to range biases.
- GNSS augmentation systems rely on assumptions about the magnitudes and stability of these bias errors to guarantee safe navigation for aviation users.
- These assumptions are often based on relatively limited or static observations.

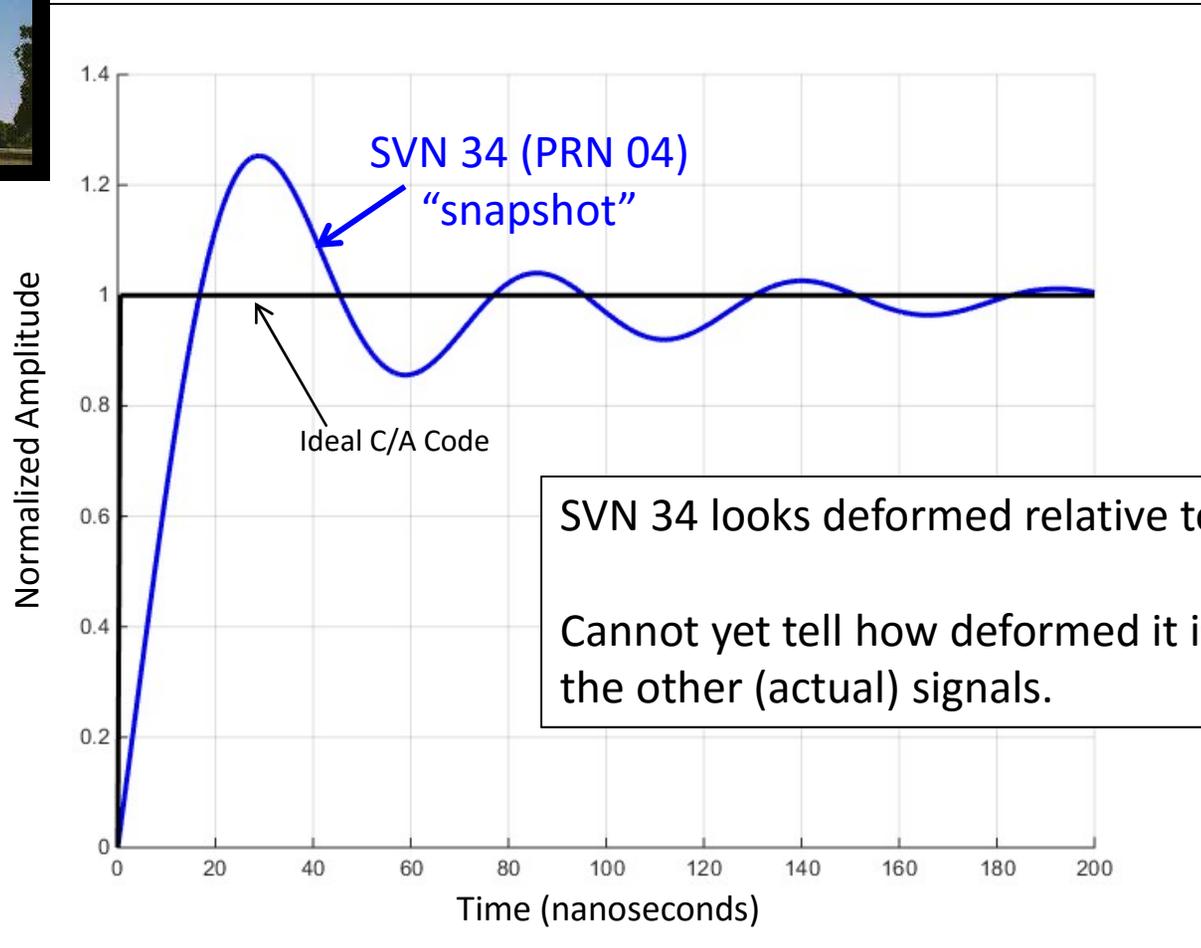
Objective

Validate current nominal range bias integrity assumptions for augmentation systems using data from the WAAS signal deformation monitor.

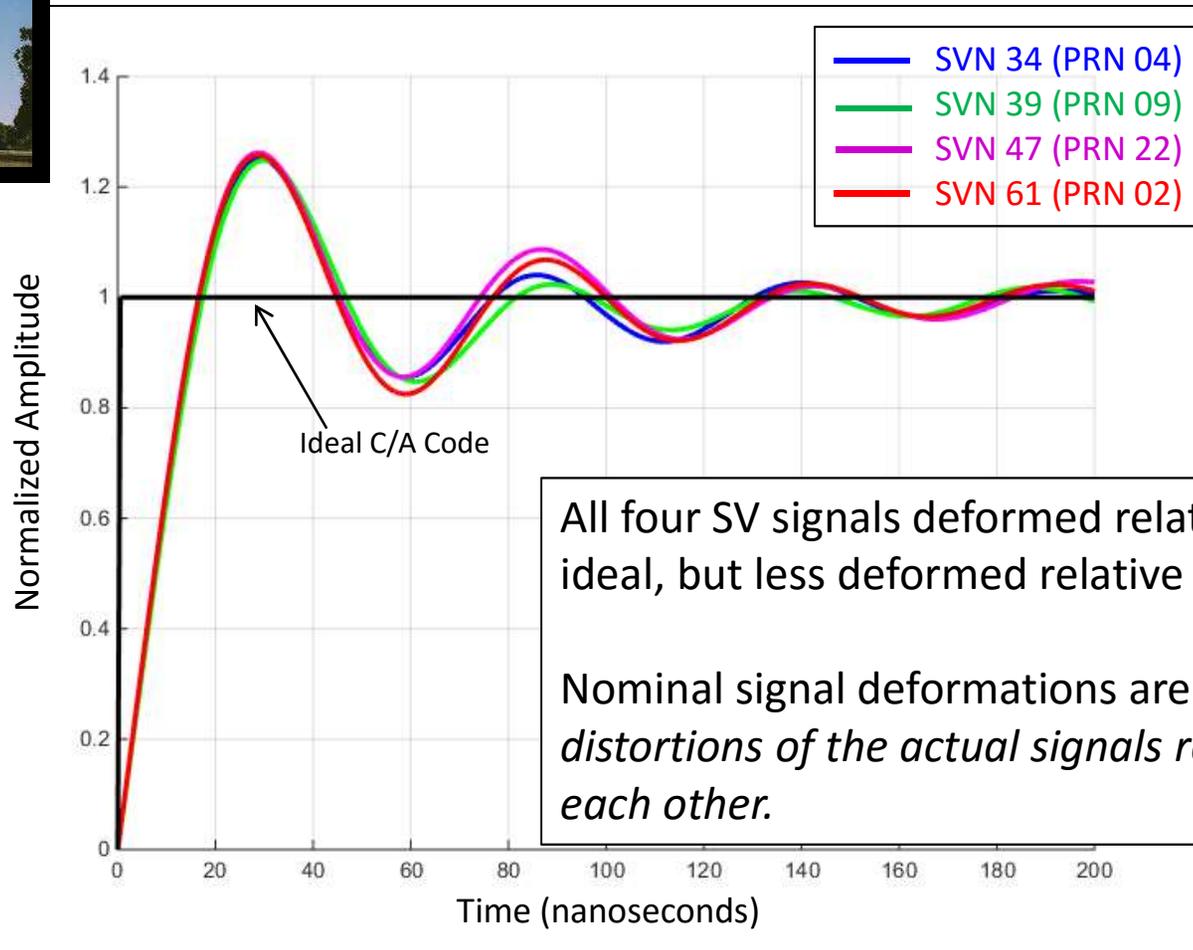
Outline

- What is Signal Deformation?
 - Dish Data (“snapshots”)
- How the WAAS Monitor Measures Signal Deformation
 - Correlator Data (continuous)
- How User Receivers Experience Signal Deformation
 - Range Errors and Integrity Assumptions
- Historical Trends and Statistics
 - Integrity Validation
- Conclusions

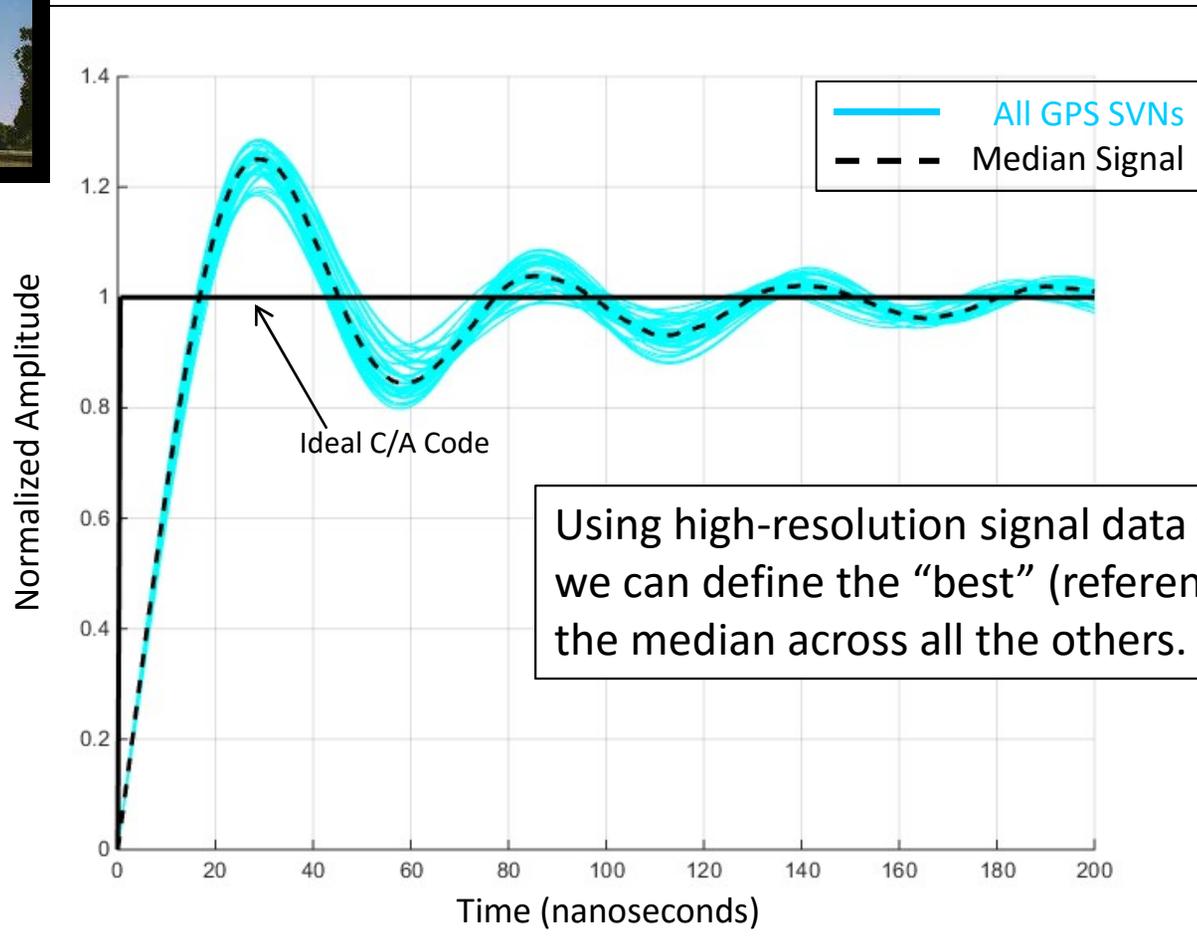
What is Signal Deformation?



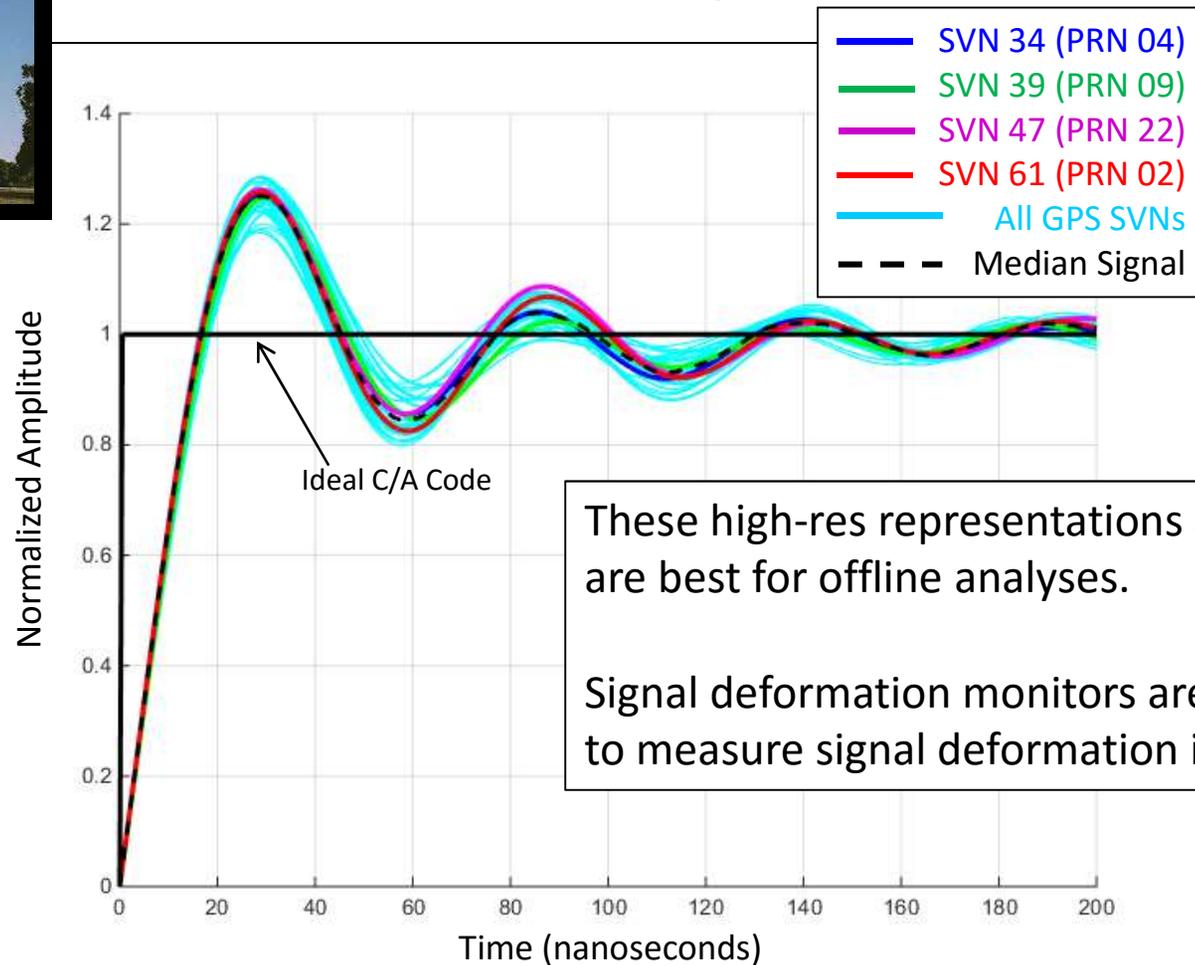
What is Signal Deformation?



Measuring Signal Deformation: Dish Data (“Snapshots”)



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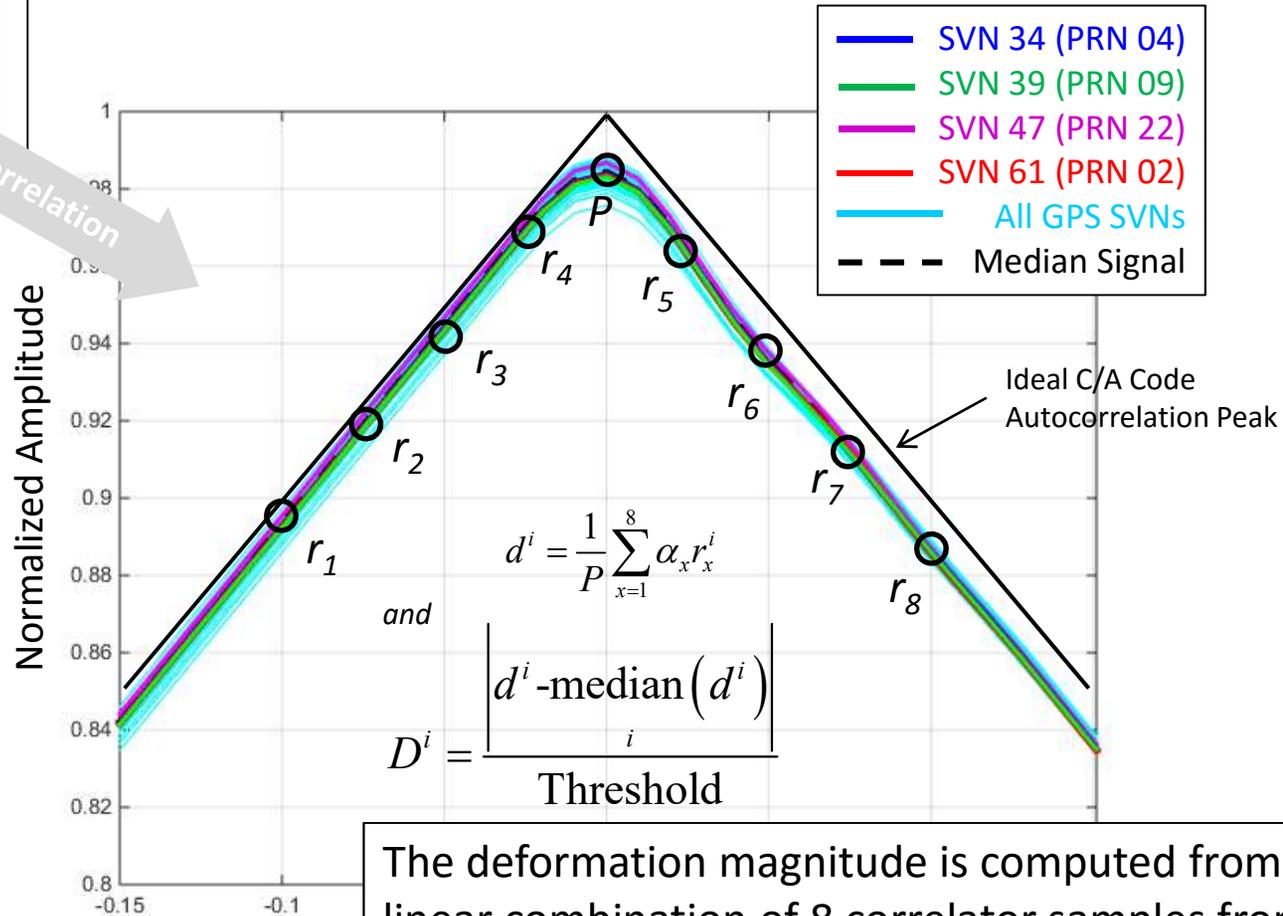
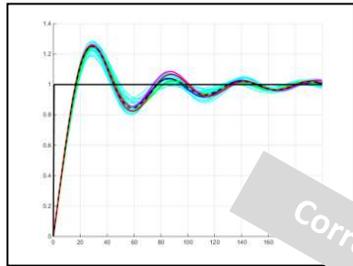


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Measuring Signal Deformations:

WAAS Monitor Receivers



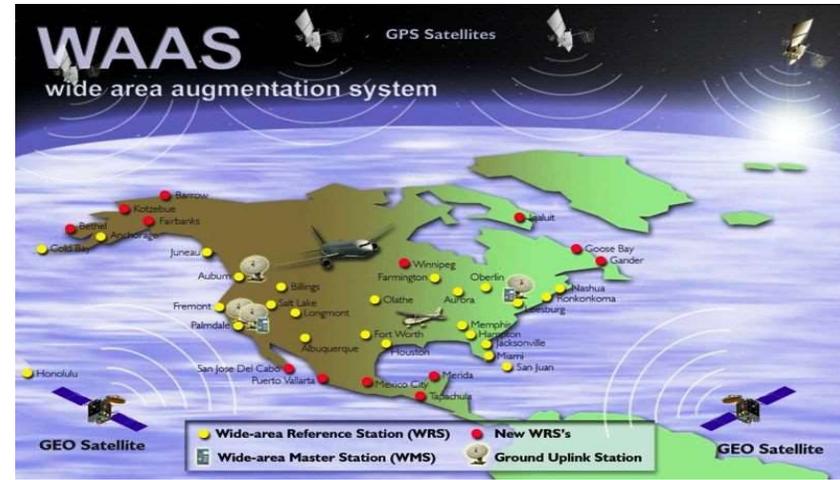
$$d^i = \frac{1}{P} \sum_{x=1}^8 \alpha_x r_x^i$$

and

$$D^i = \frac{|d^i - \text{median}(d^i)|}{\text{Threshold}}$$

The deformation magnitude is computed from a linear combination of 8 correlator samples from SV (referenced to median, normalized by a threshold).

Dish Data vs. WAAS Monitor Data



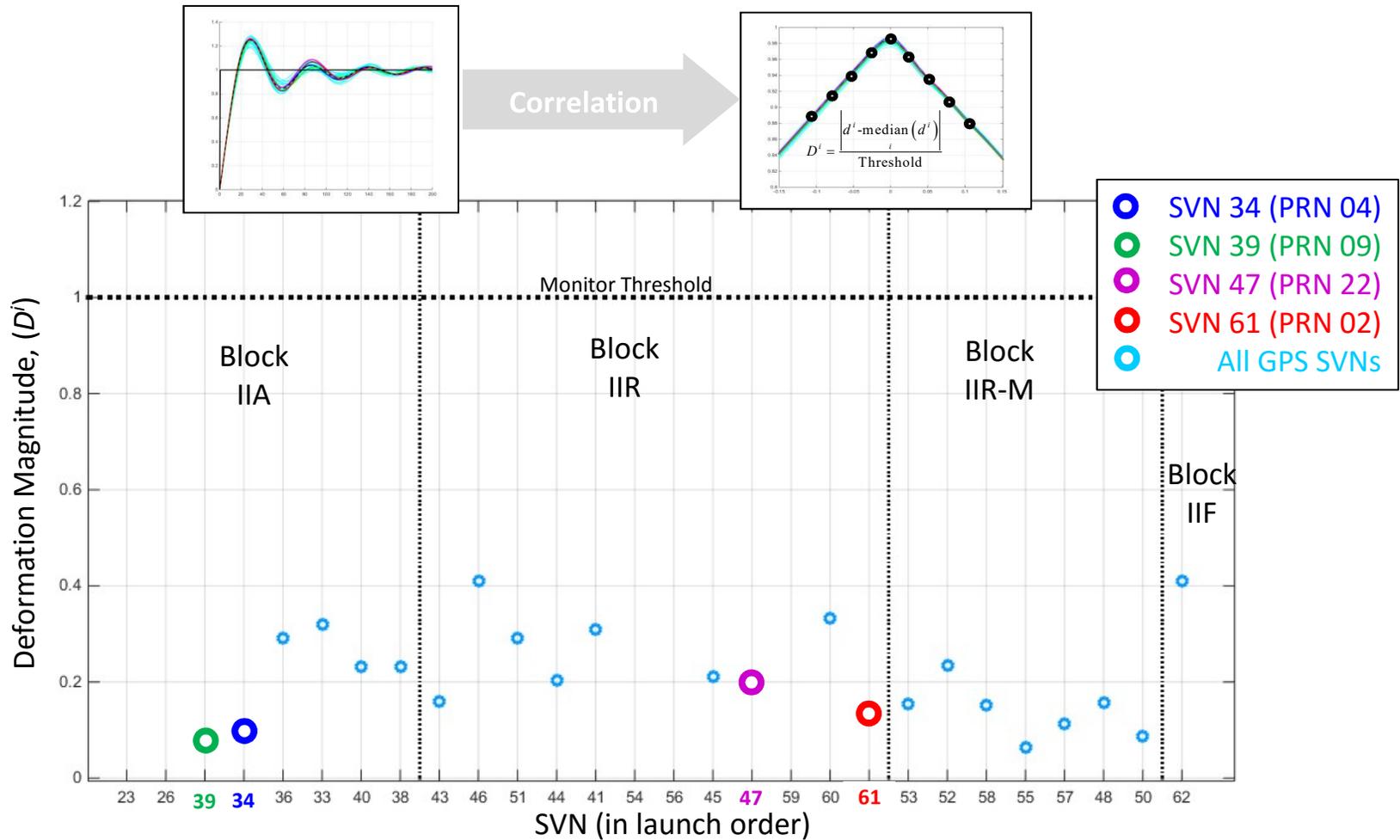
- High-gain Dish (“Snapshots”)

- Best noise, multipath removal
- Full code sequences directly sampled
- One SV at a time, not real time
- Short datasets

- WAAS Monitor (130+ Receivers)

- Good noise, multipath removal
- Limited samples per code (correlation peak)
- All-in-view, real-time operation
- Long datasets

Measuring Signal Deformation: WAAS Monitor Metric “Snapshots” Using Dish Data

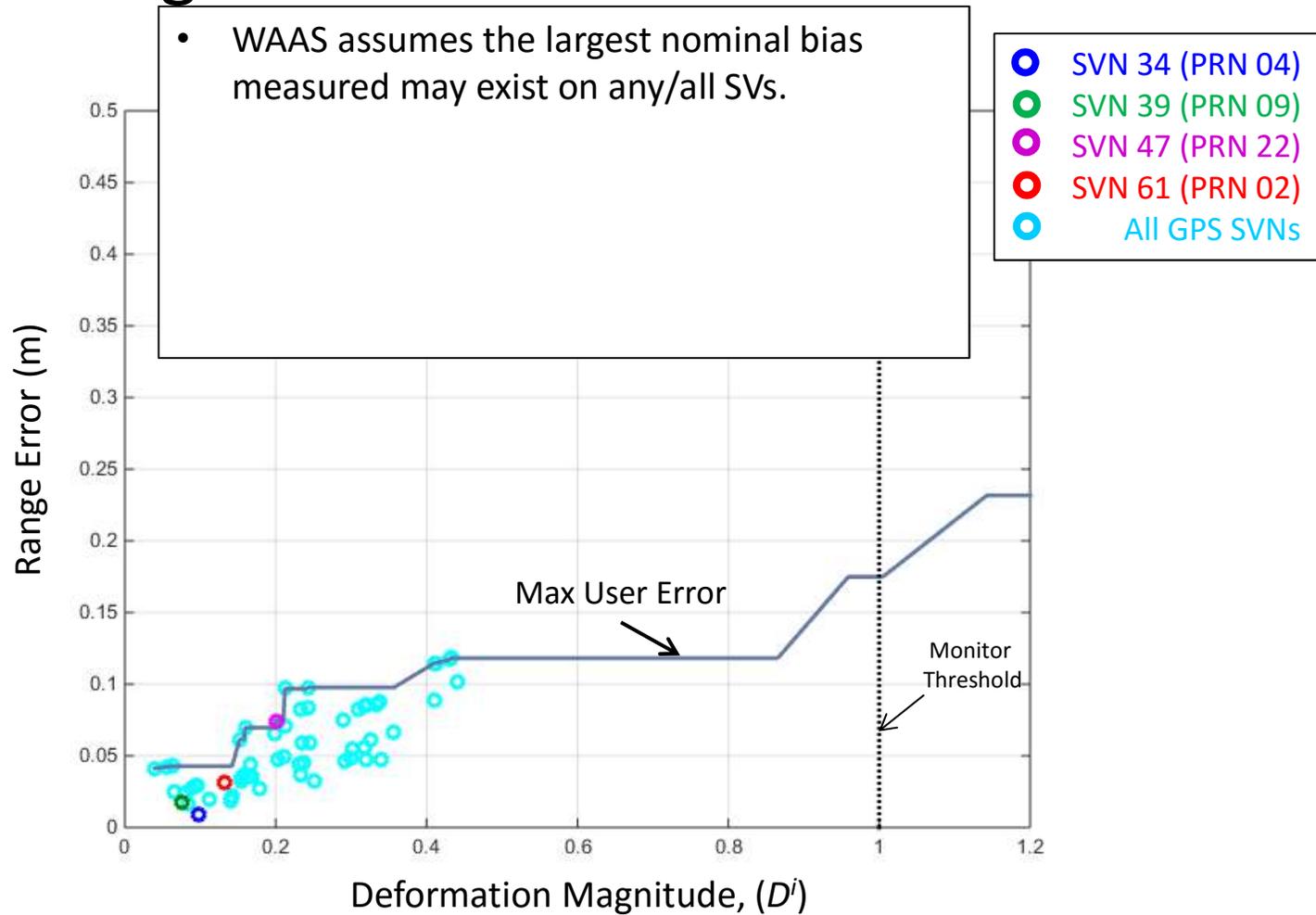


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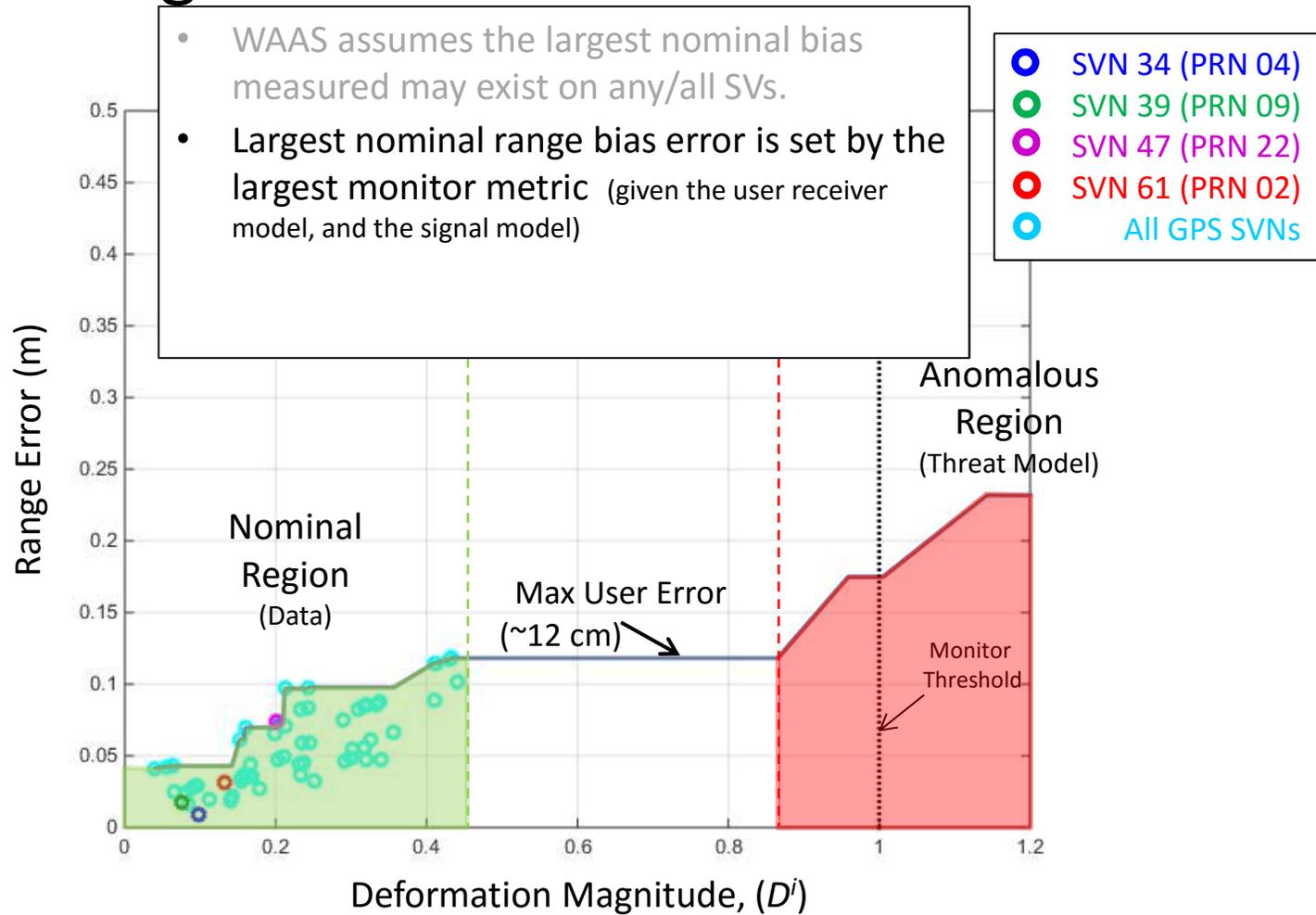
Signal Deformation Biases

User Range Error vs. WAAS Monitor Metric



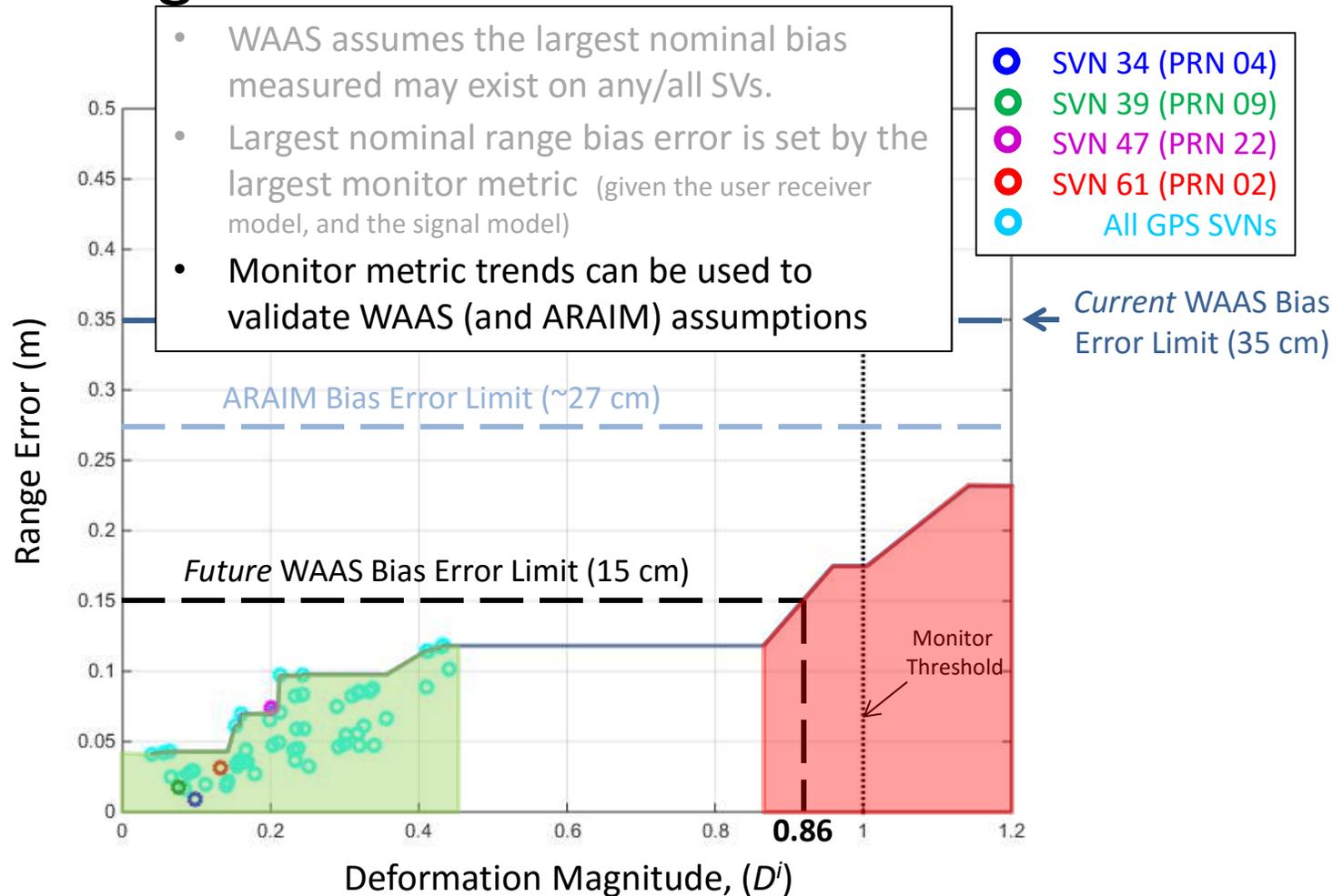
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Signal Deformation Biases

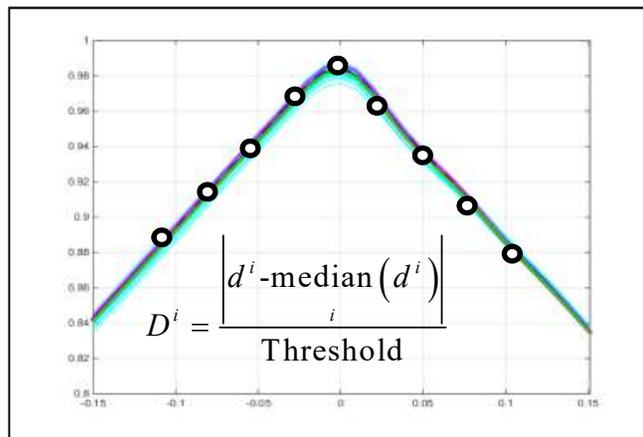
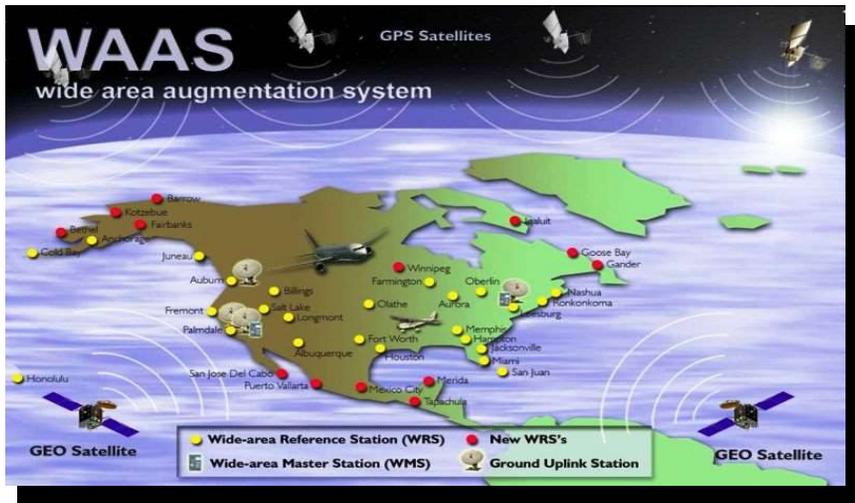
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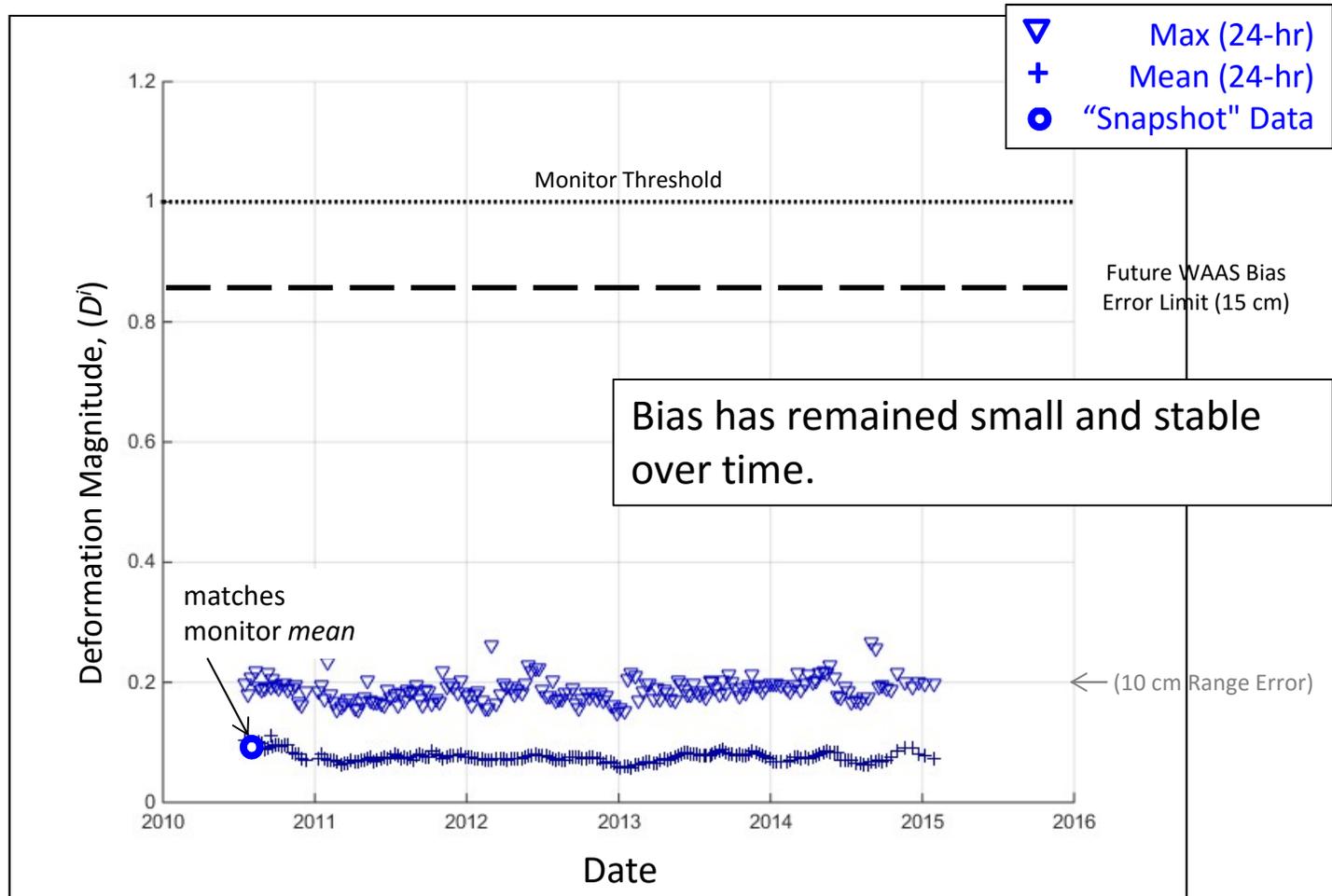
WAAS Monitor Data Collection



- Dates: Jul 2010-Feb 2015
 - Snapshot data (Aug 1, 2010)
- 130+ receivers averaged
- 1-Hz Monitor Data
- Trend statistics:
 - Mean (over 24-hour periods)
 - Max (over 24-hour periods)

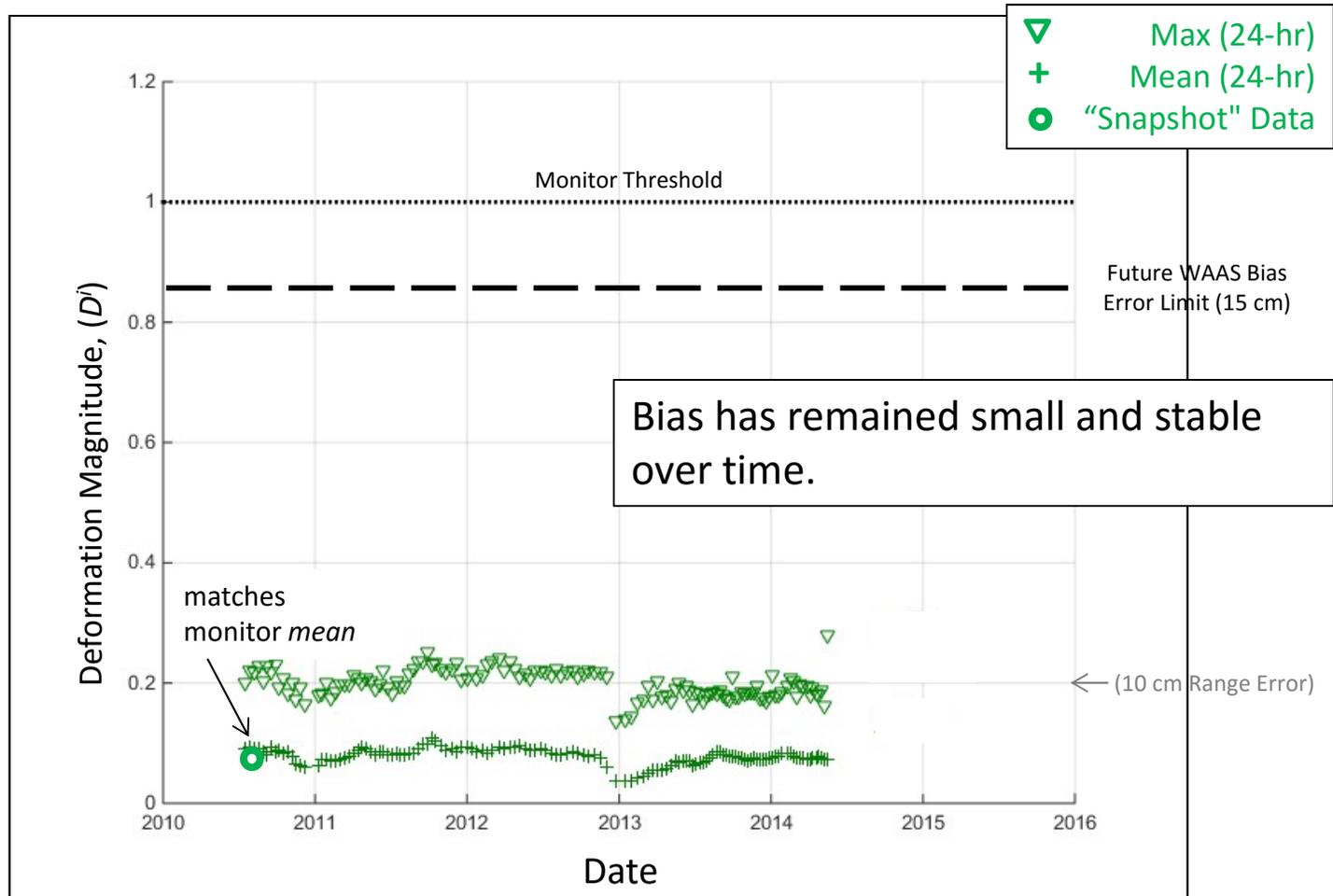
WAAS Monitor Historical Data

SVN 34 (PRN 04)



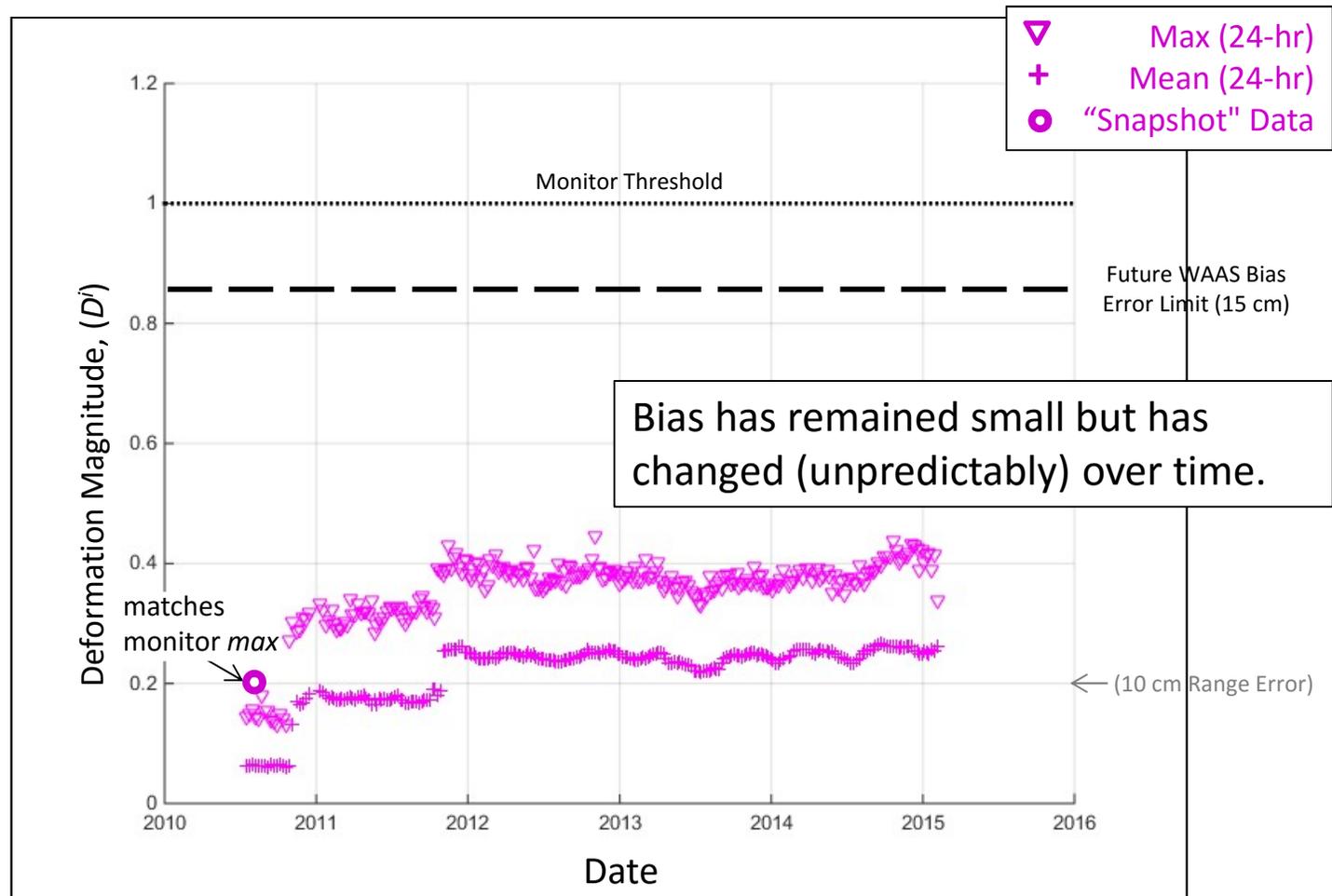
WAAS Monitor Historical Data

SVN 39 (PRN 09)



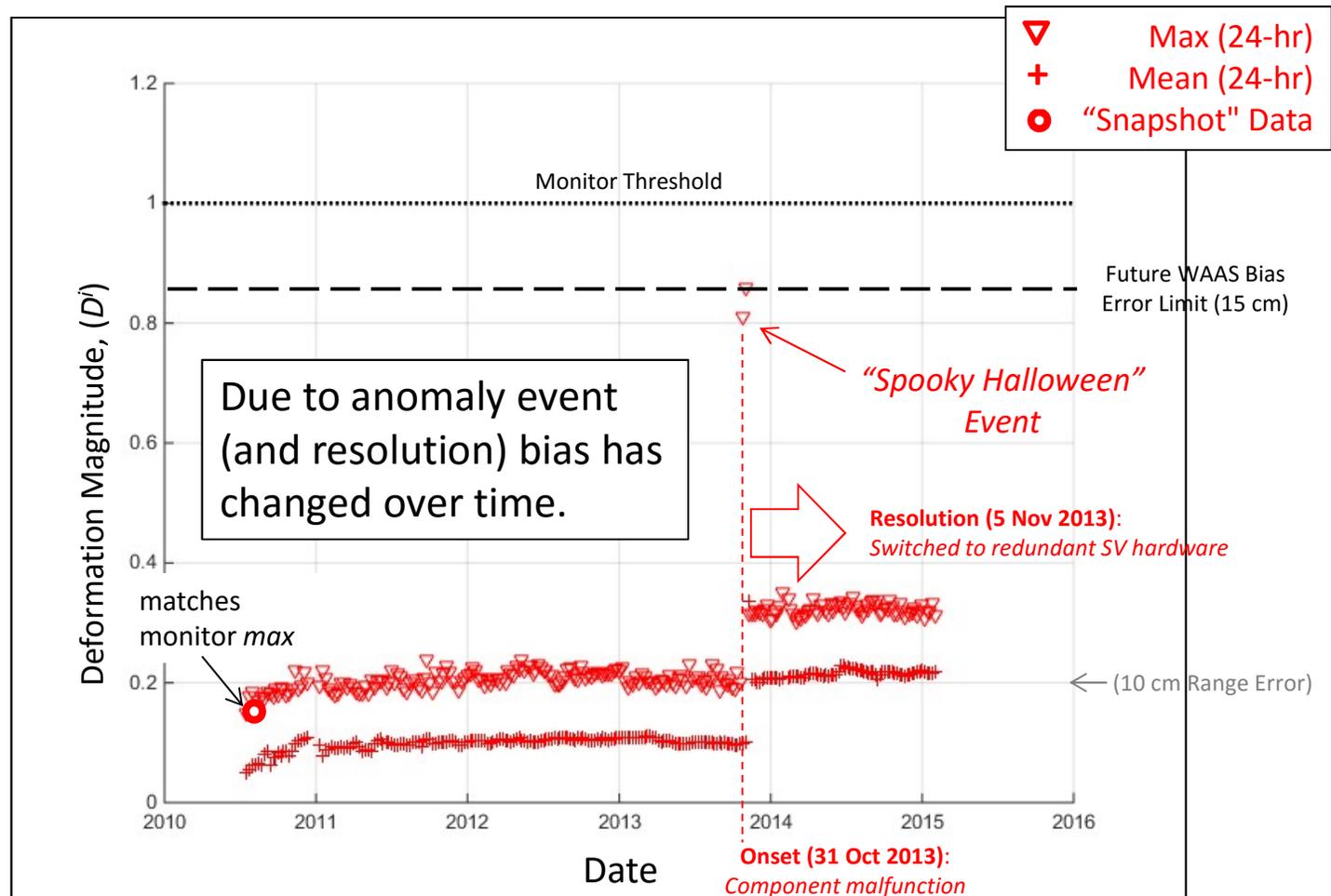
WAAS Monitor Historical Data

SVN 47 (PRN 22)



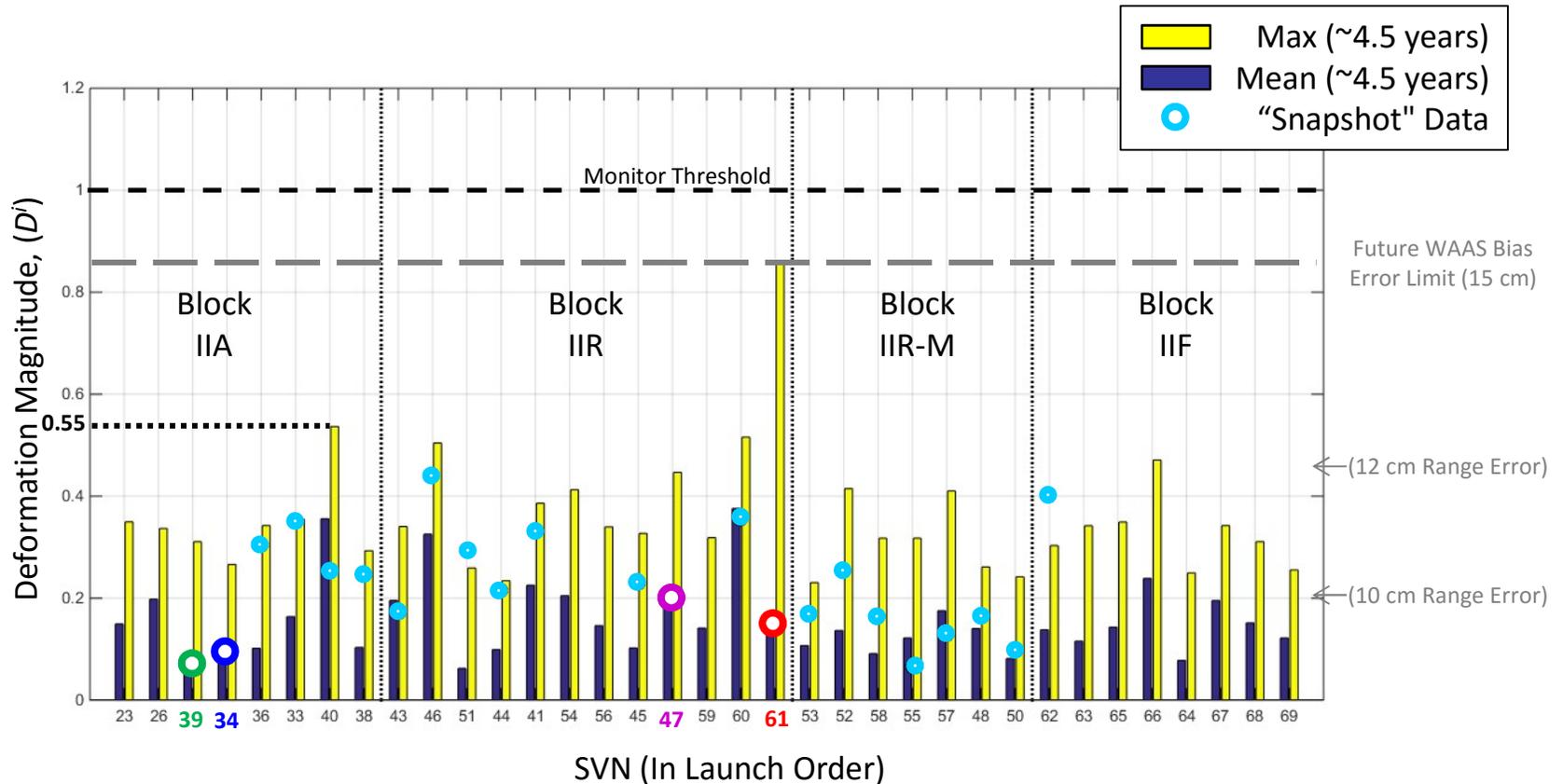
WAAS Monitor Historical Data

SVN 61 (PRN 02)



WAAS Monitor Metric Historical Data

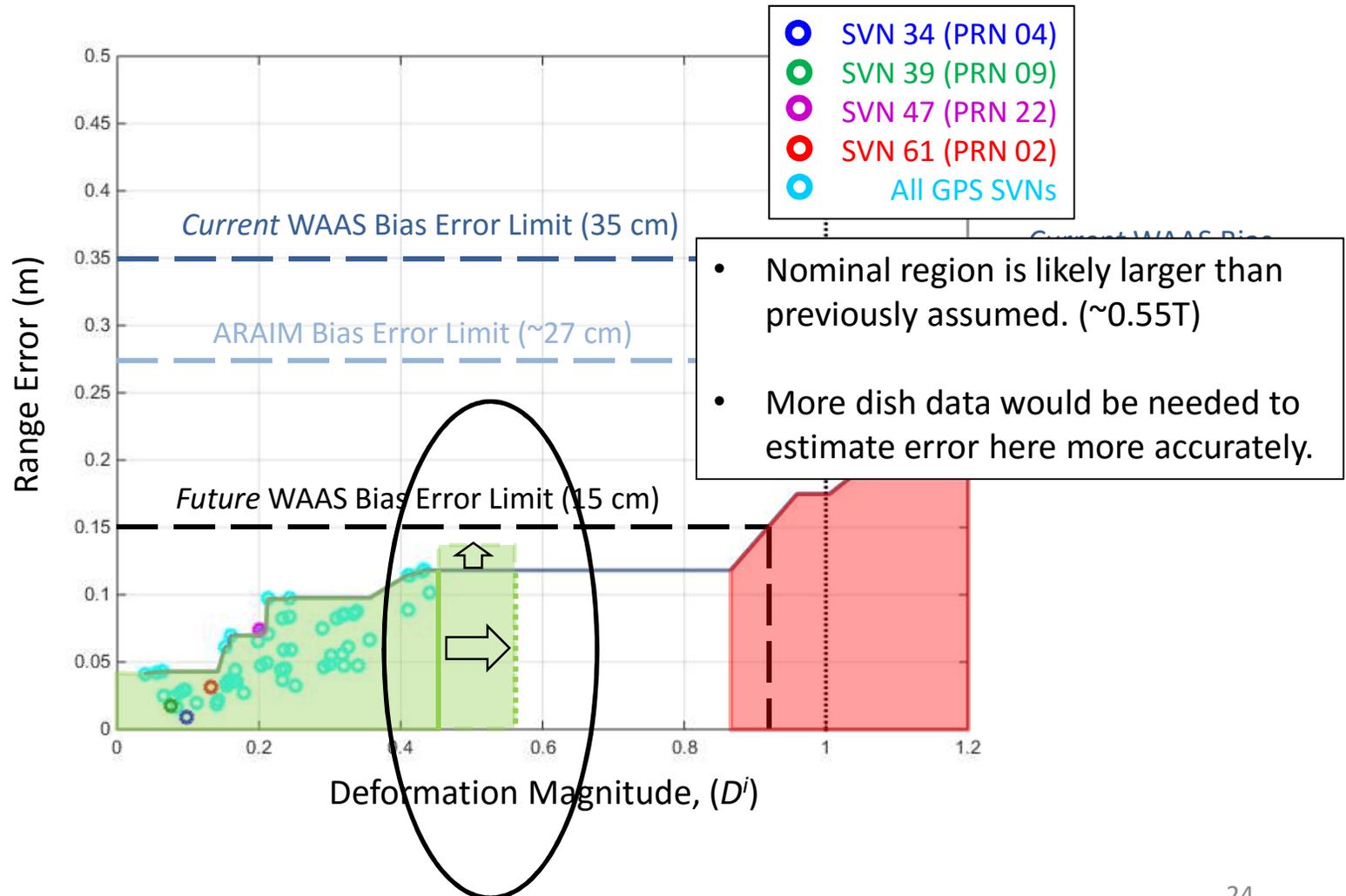
Summary Statistics



- Dish data "snapshots" are generally between the Mean and Max values of the WAAS monitor data.
- Largest nominal monitor metric measured is 0.55 (SVN 40).

Signal Deformation Biases

User Range Error vs. WAAS Monitor Metric



Summary and Conclusions

- 4.5 Years of WAAS Signal Monitoring data was collected and analyzed
 - Signal Deformation Monitor
 - Code-Carrier Coherence Monitor (See paper)
- The dish data collected (August of 2010) agrees with the WAAS monitor data
- The biases are relatively stable, however, unpredictable changes can occur
 - Faults or anomalies (e.g., SVNs 47 and 61)
 - SV hardware changes (e.g., SVN 61)
- The max nominal deformation is likely 55-60% of monitor threshold
- Augmentation error limits are valid, but largest signal deformation error may be very close to the 15 cm limit for future (dual-frequency) WAAS users.
 - Dish data needed to verify this