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Methods and Examples to Quantify Uncertainty Associated with USGS Time-Series Water-Quality Data

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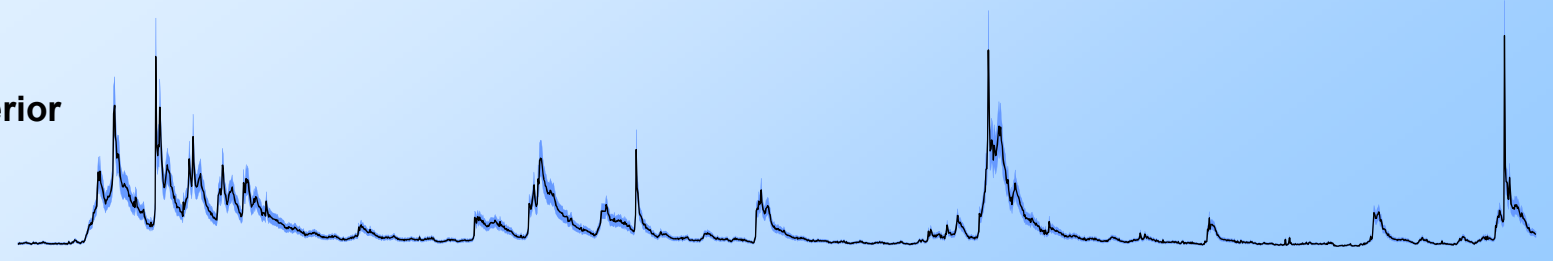
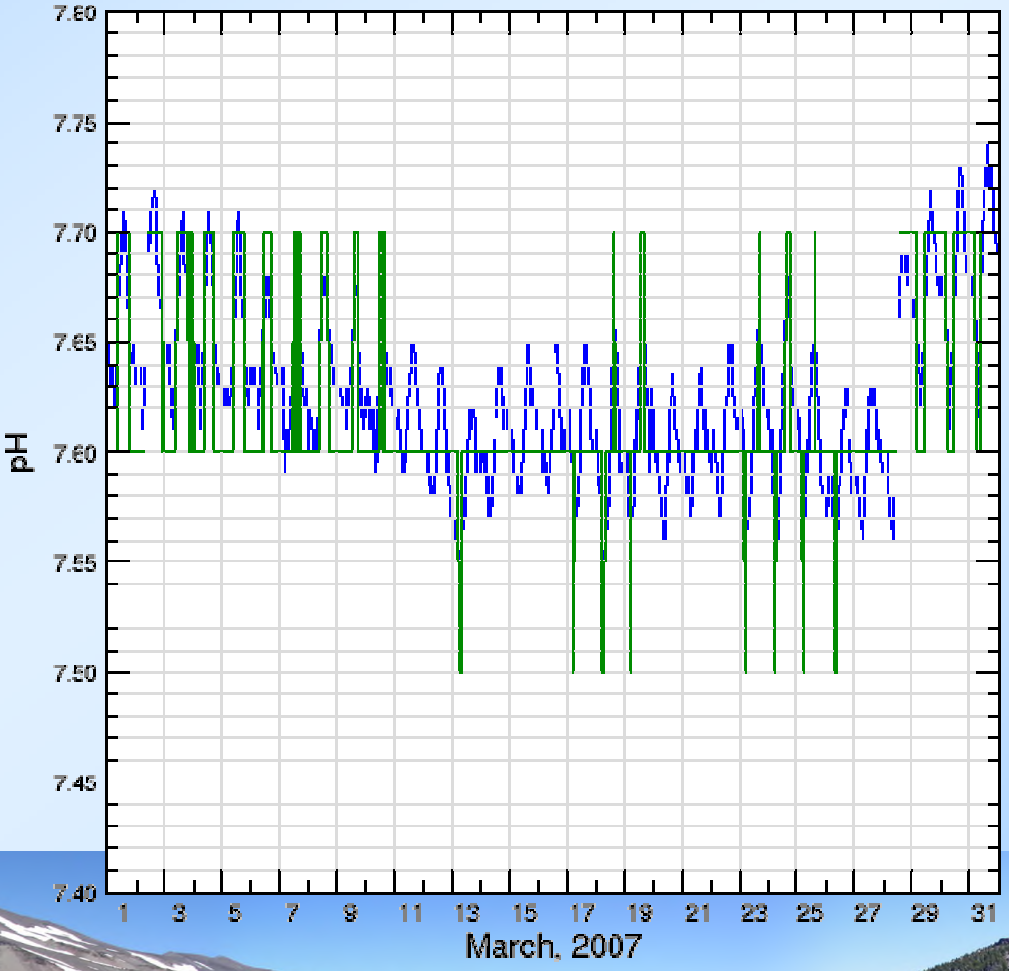


The Vision: Include Uncertainties with Data

Now:

- **Basic time-series graphs from USGS do *not* show uncertainties**
- **Data downloads are:**

  Date, Time, Time Zone, Value, Flag/Remark



Raw data

Rounded data

Rounding is a poor means of expressing uncertainty.

We can do BETTER!

data from USGS

USGS

The Vision: Include Uncertainties with Data

Now:

- **Basic time-series graphs from USGS do *not* show uncertainties**
- **Data downloads are:**

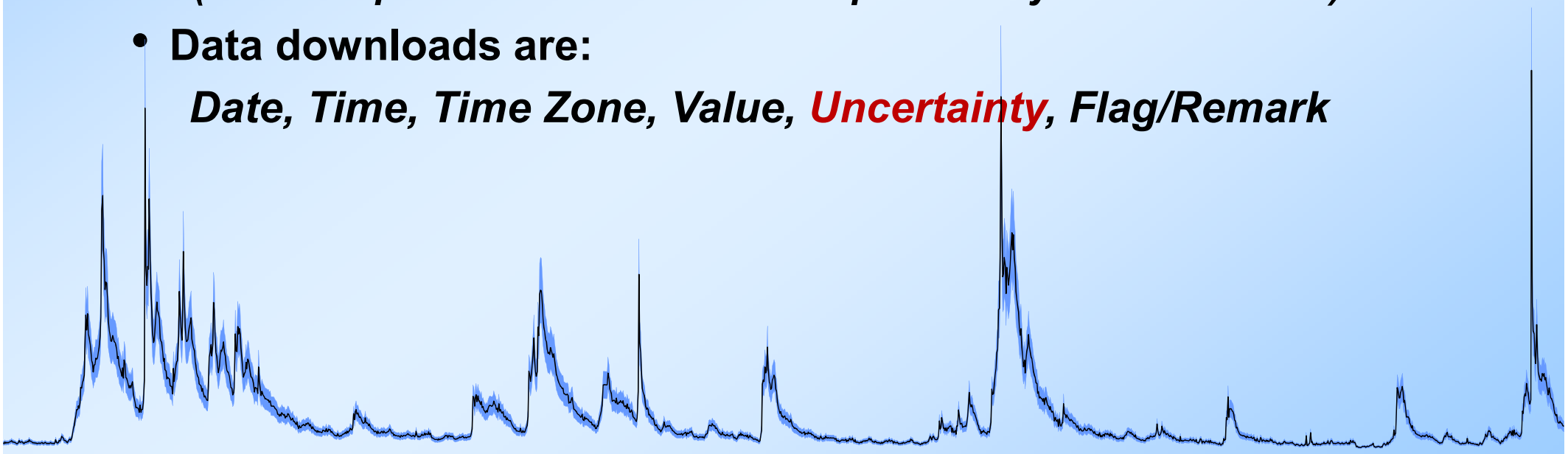
  Date, Time, Time Zone, Value, Flag/Remark

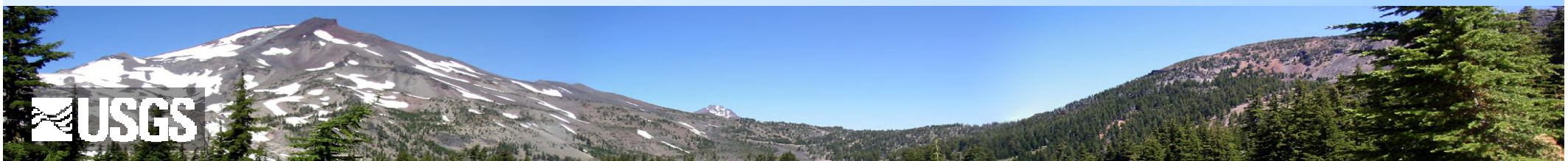
Future:

- **Time-series graphs from USGS show uncertainty bands**

  (with comparison to standards and probability of exceedance)
- **Data downloads are:**

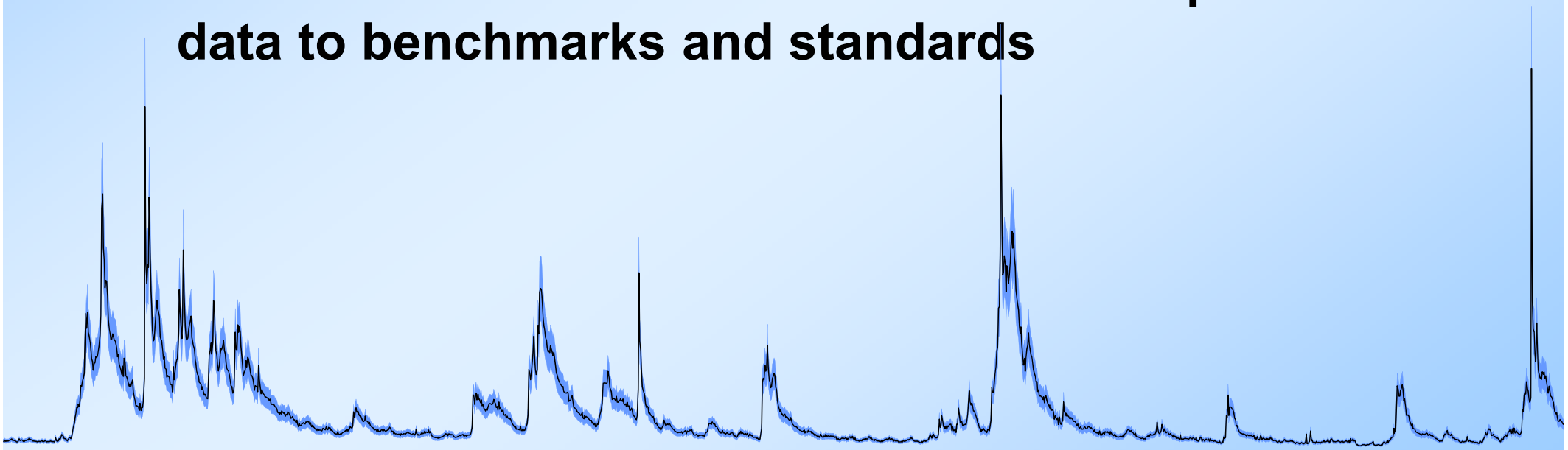
  Date, Time, Time Zone, Value, Uncertainty, Flag/Remark





Why Do We Care About Data Uncertainty?

1. Need to quantify uncertainty in order to manage it
2. Need to communicate the accuracy of datasets
   → Improves acceptance and appropriateness of use
3. Would improve and extend the value and applicability of data
4. Would create a better framework for comparisons of data to benchmarks and standards



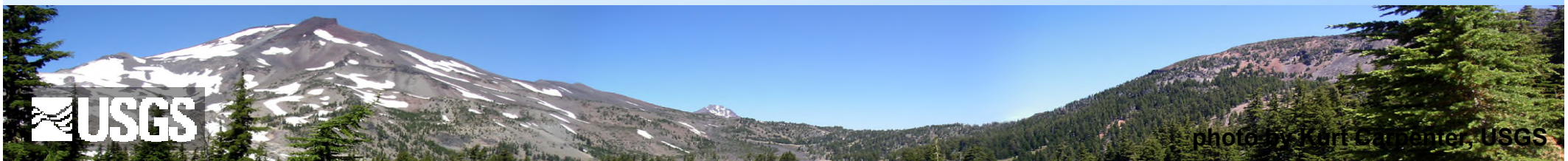


photo by Kurt Carpenter, USGS

Analysis Must Consider All Sources of Error

Measurement Error

- The difference between a measured value and a known reference or true value
- Composed of random and predictable components
  - Predictable components are repeatable and correctable
- Many sources of error
  - Avoidable Errors

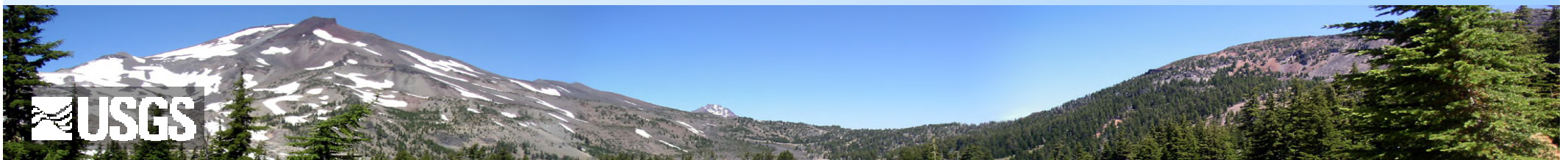
    User error, site-selection errors, site-installation errors
  - Unavoidable Errors (at some level)

    Signal noise/variability, site variability, interferences

    Probe fouling, probe failure, calibration drift

    Deviation from lab verification samples or other references

    Surrogate model error



Uncertainty is Derived from Error Analysis

Measurement Error

- The difference between a measured value and a known reference or true value
- Composed of random and predictable components
  - Predictable components are repeatable and correctable
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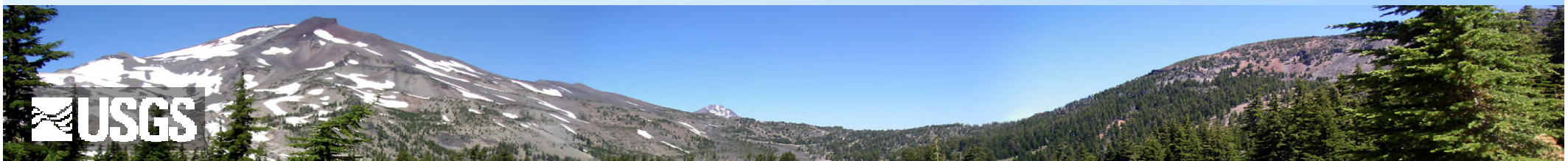
Uncertainty

- A description of the degree of accuracy of the final corrected data
  - Can be expressed in many ways, including statistical representations (std. dev.) or a simple half-width of a probable interval



Methods to Quantify Uncertainty

Rigorous statistical approach

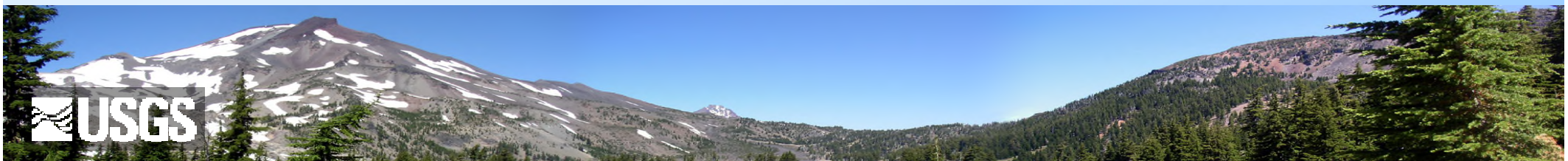
- The GUM— "Guide to the Expression of Uncertainty in Measurement" by the Joint Committee for Guides in Metrology
- Strict combination of variance approach w/ correlation coefficients and dependent cross terms

Root Mean Square Error approach

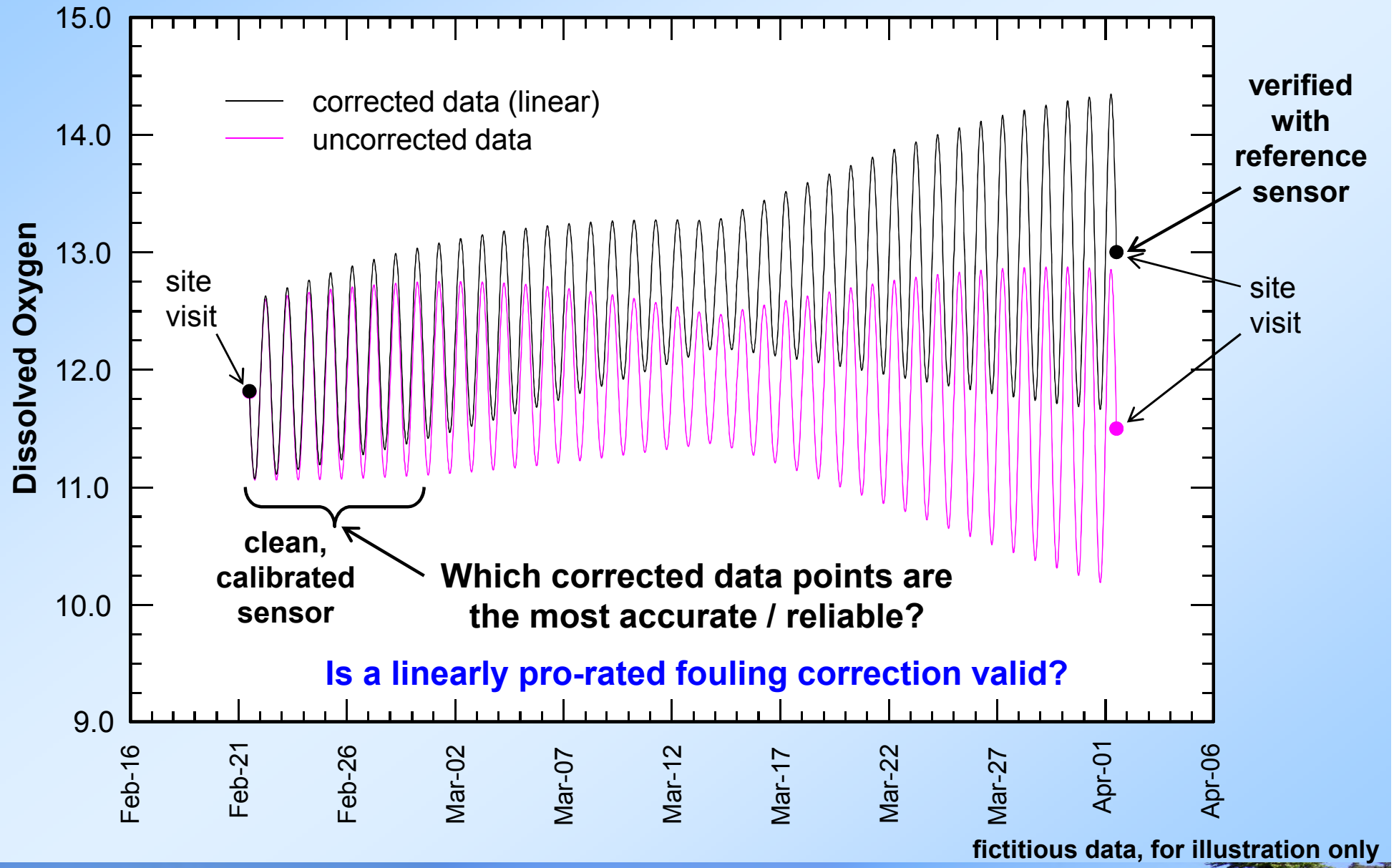
- Simpler method of accounting for all sources of error
- Estimates a most probable value of the cumulative error
- Assumes independence of error sources
  (note the lack of correlation coefficients and cross-terms)

$$E_P = \sqrt{E_1^2 + E_2^2 + \cdots + E_n^2} = \sqrt{\sum_i E_i^2}$$

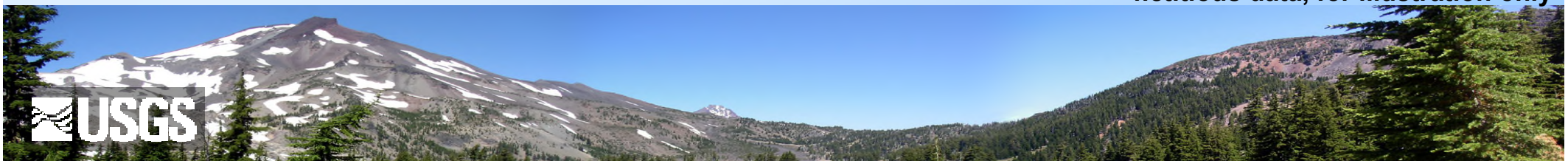
E_P is the combined probable error; E_i are the component errors



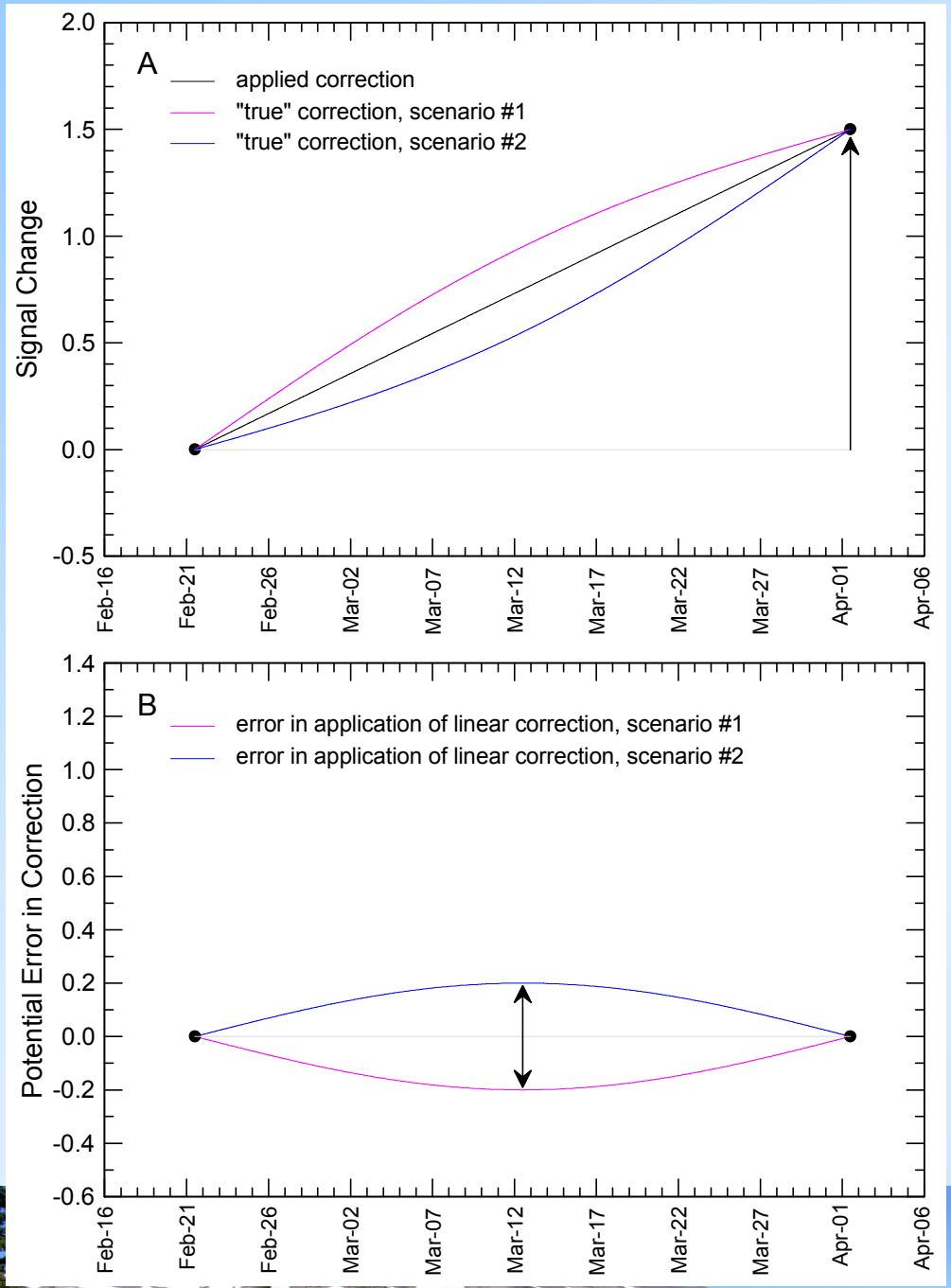
Focus on Assumptions of Fouling Corrections



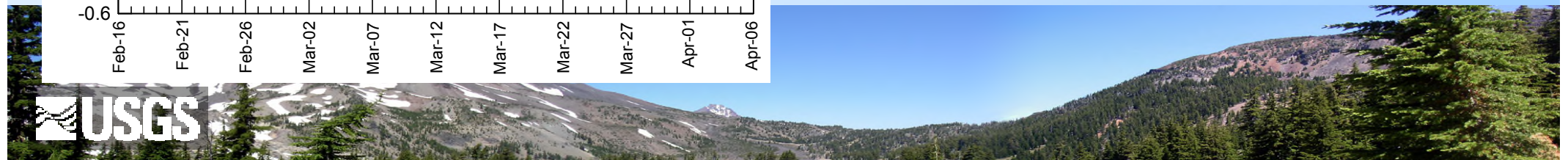
fictitious data, for illustration only



Potential Errors in Application of Corrections



- **Error only exists if the applied correction is different from the "true" correction**
- **Errors may arise from the assumed functional shape of a correction**



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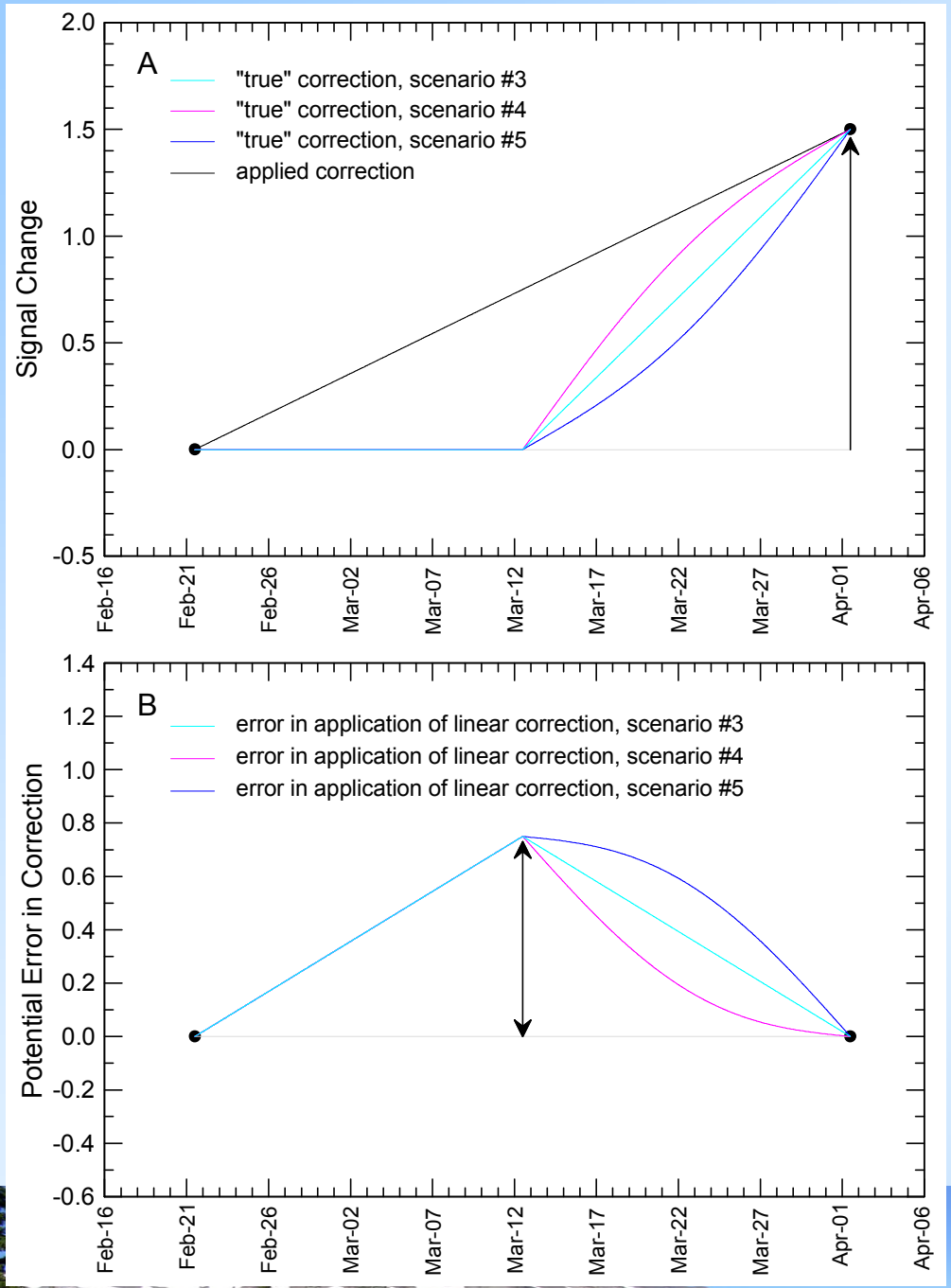
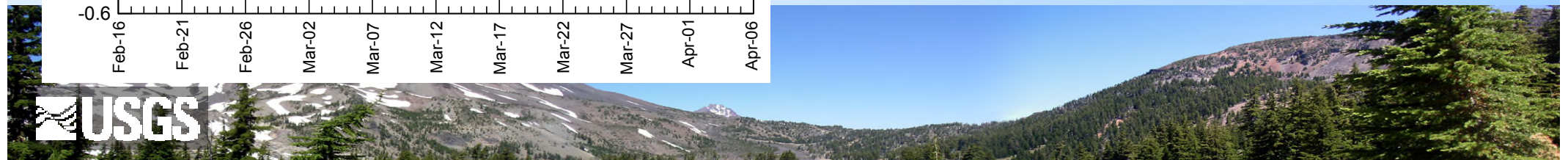


- **Error only exists if the applied correction is different from the "true" correction**
- **Errors may arise from the assumed functional shape of a correction**
- **Errors may arise from the assumed timing of a correction**



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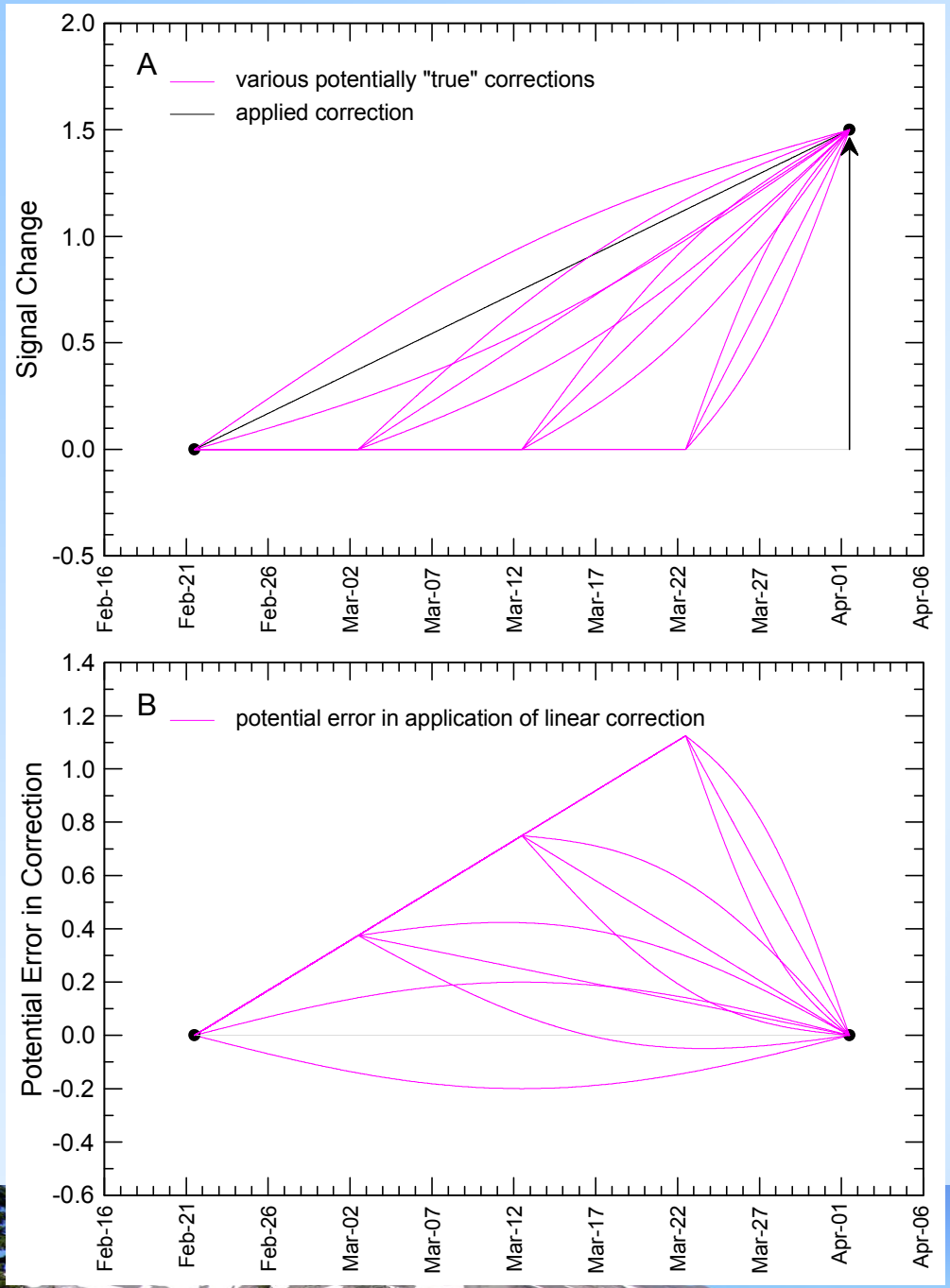
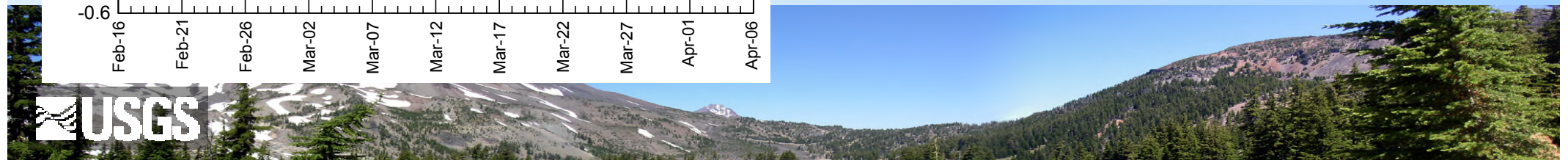


- **A range of potential errors in the timing and functional shape of a correction begins to form a pattern**



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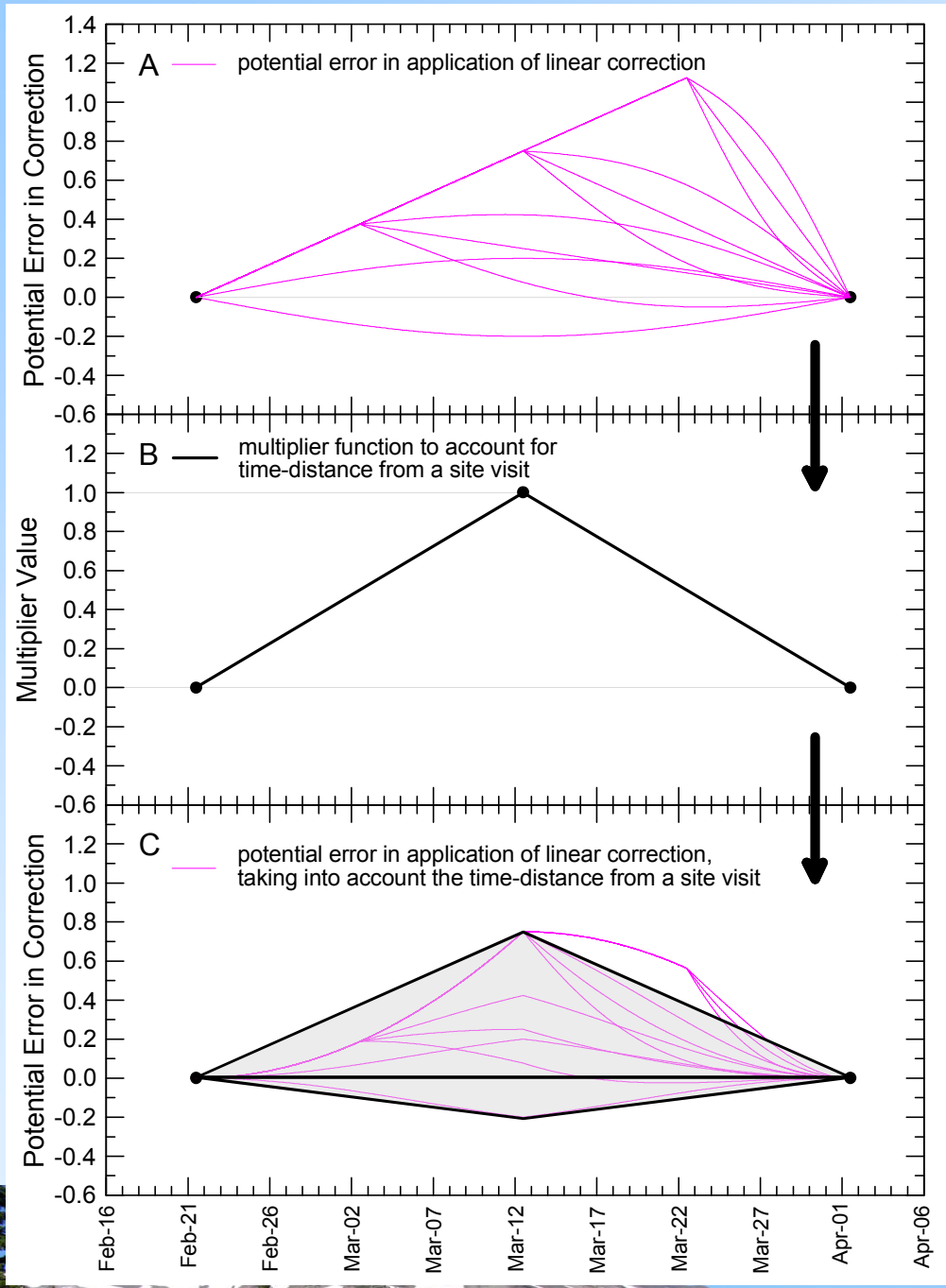
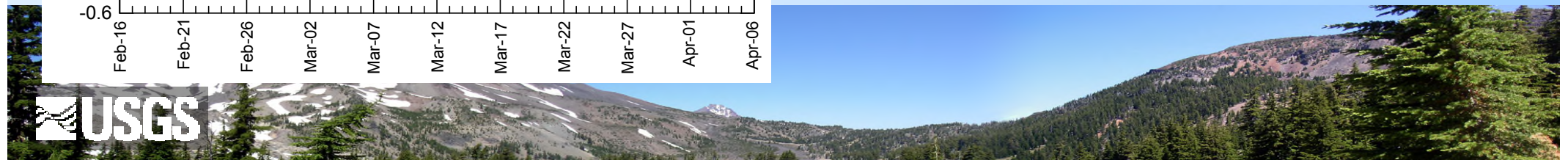


- **A range of potential errors in the timing and functional shape of a correction begins to form a pattern**
- **Applying a triangular filter represents the greater likelihood that:**
  1. **corrected data are more accurate if they are closer to a site visit, and**
  2. **the true correction is not as likely to be initiated right before the second site visit**



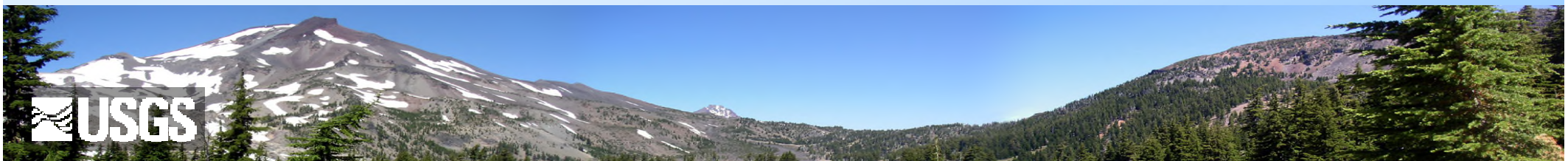
Assessment of Fouling Assumptions

Wiped vs Unwiped SC and DO sensors

- YSI EXO and 6-series sensors
- Fanno Creek near Portland, OR

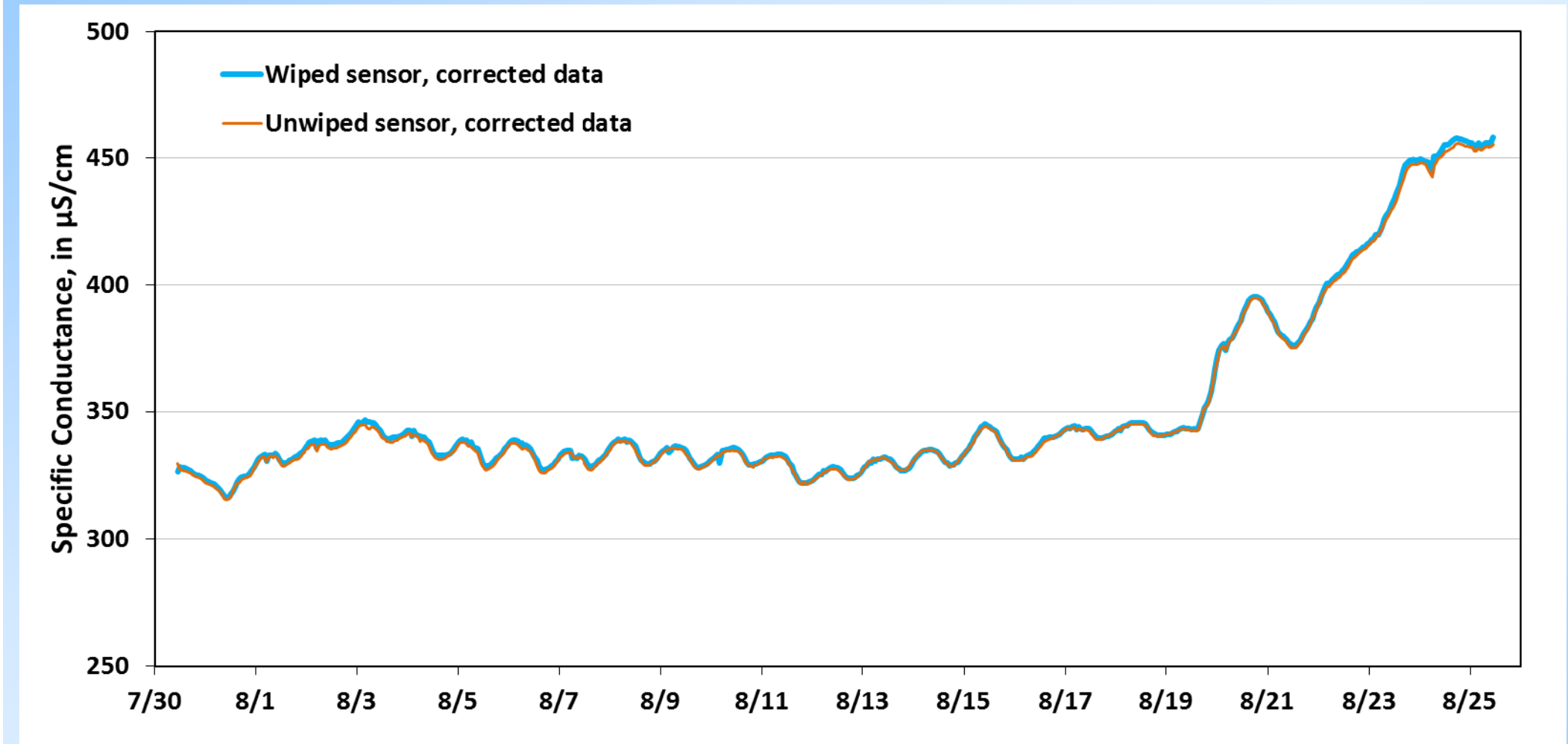
photo from USGS

sensor images from YSI;
not a product endorsement



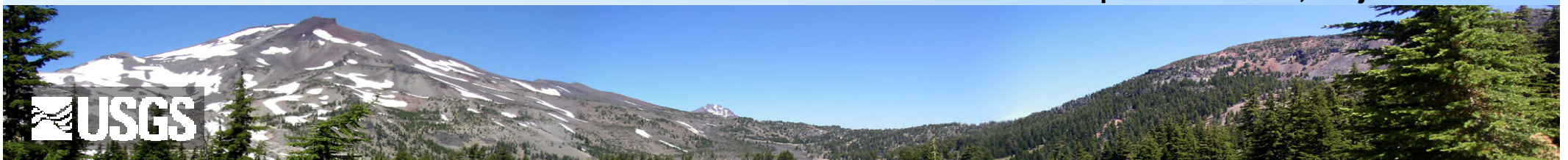
Wiped vs Unwiped SC Data

Fanno Creek at Durham Road (14206950)



Date in 2015

provisional data, subject to revision



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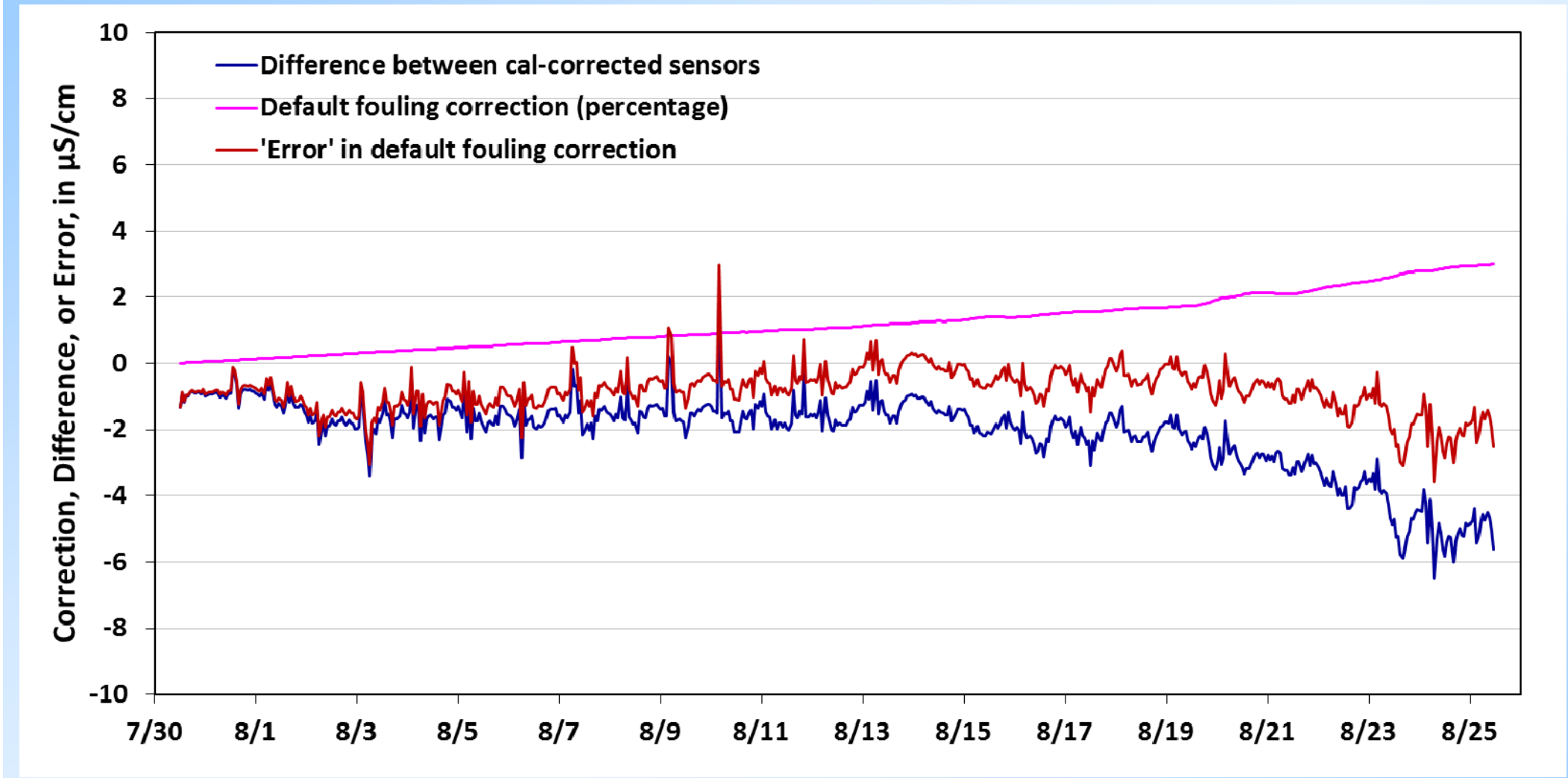

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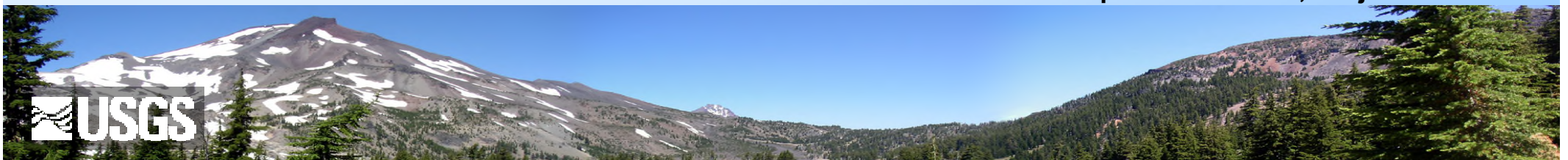
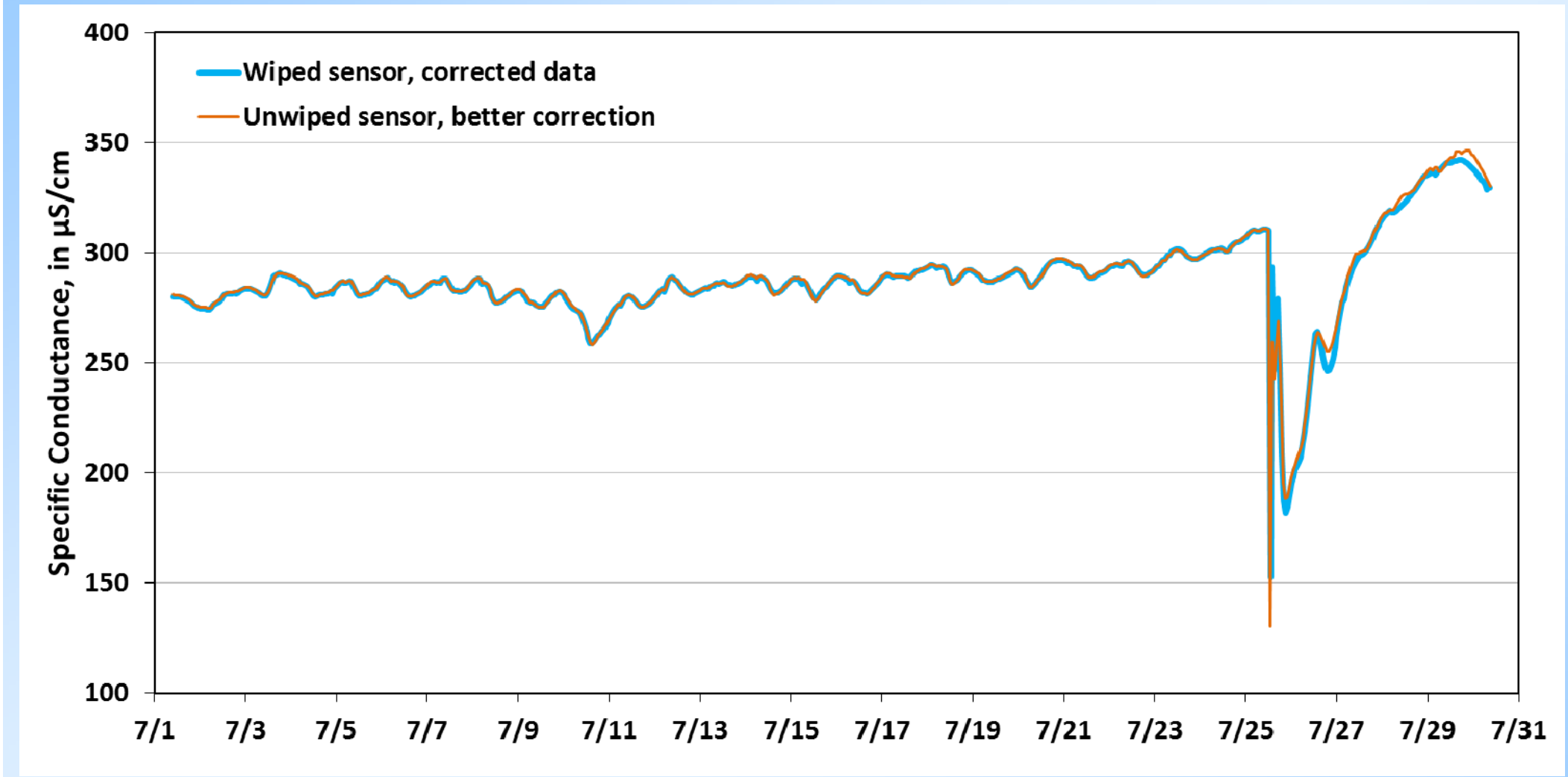
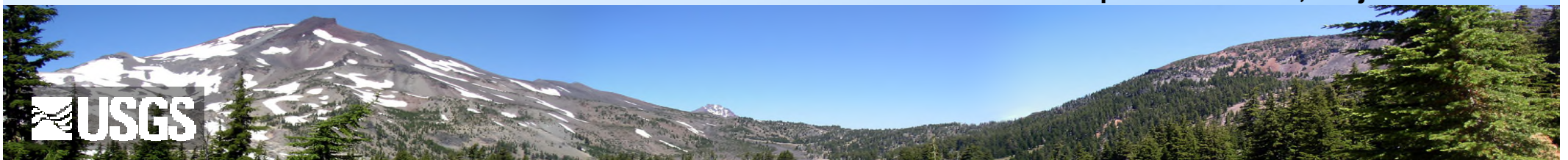


Example 2: Wiped vs Unwiped SC Data





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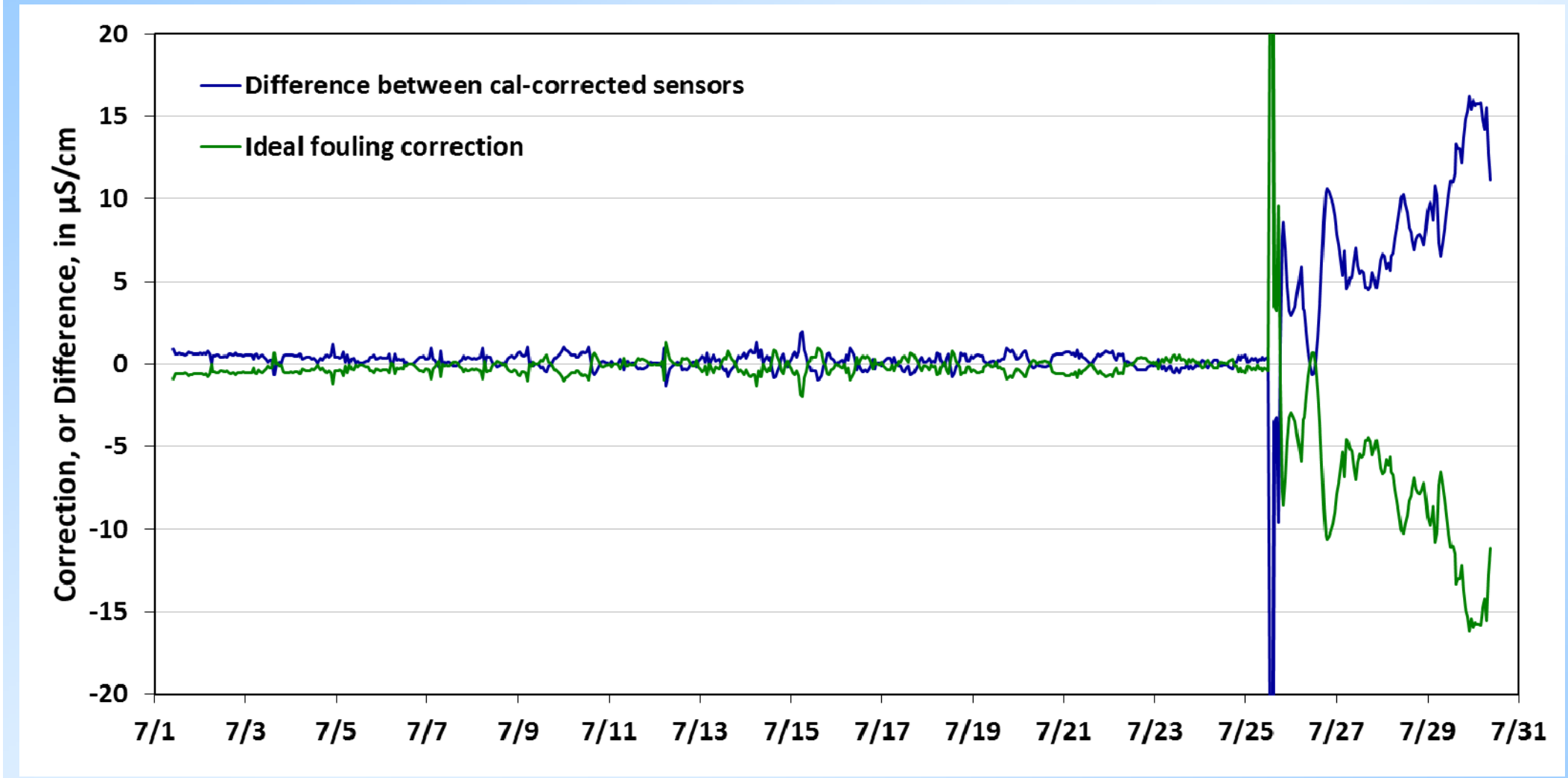

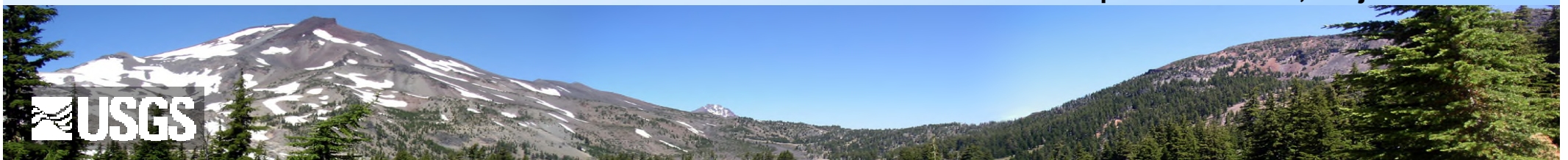

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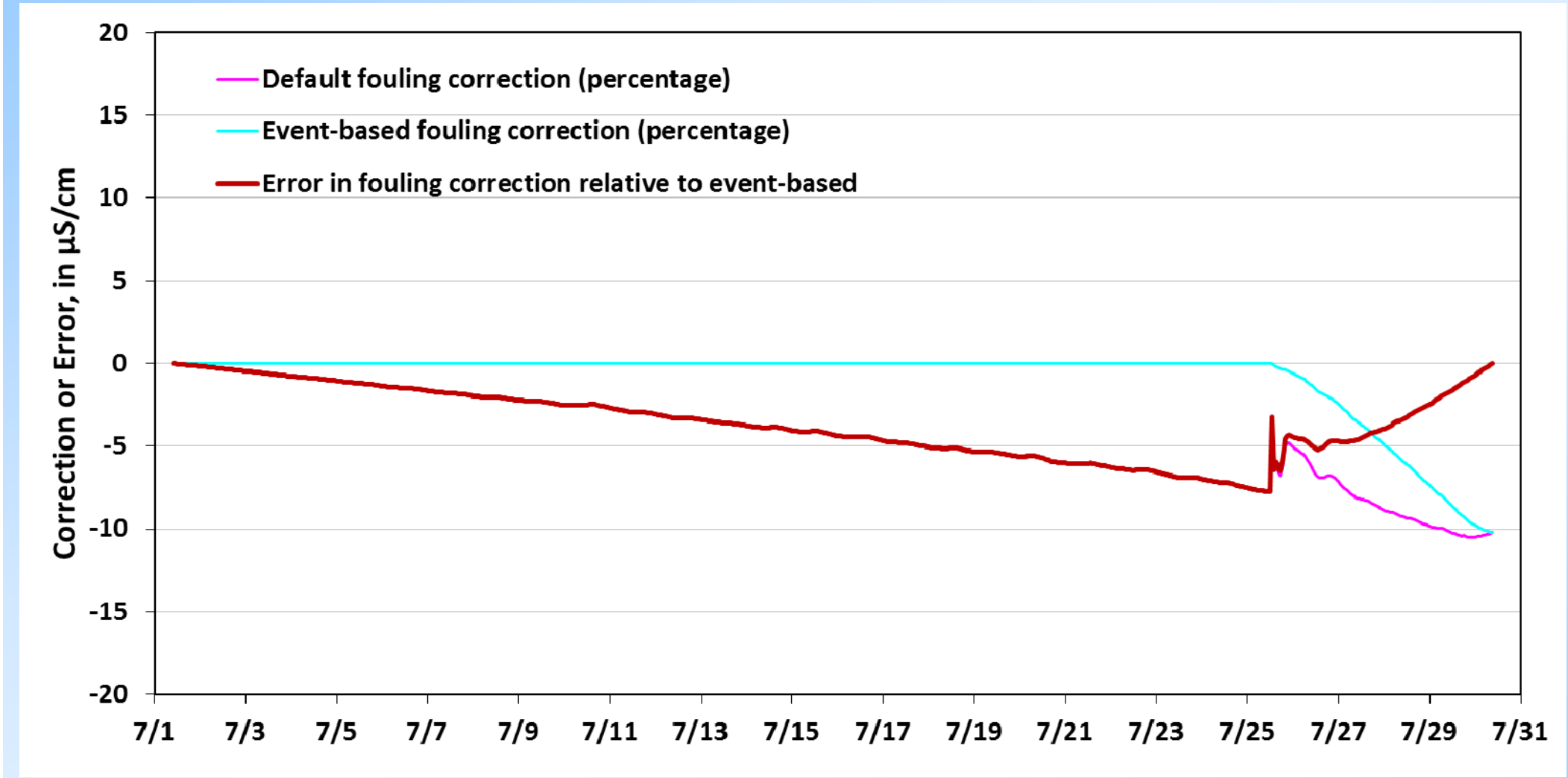

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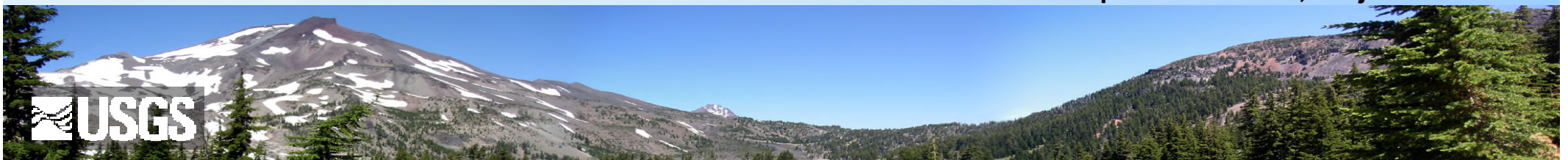

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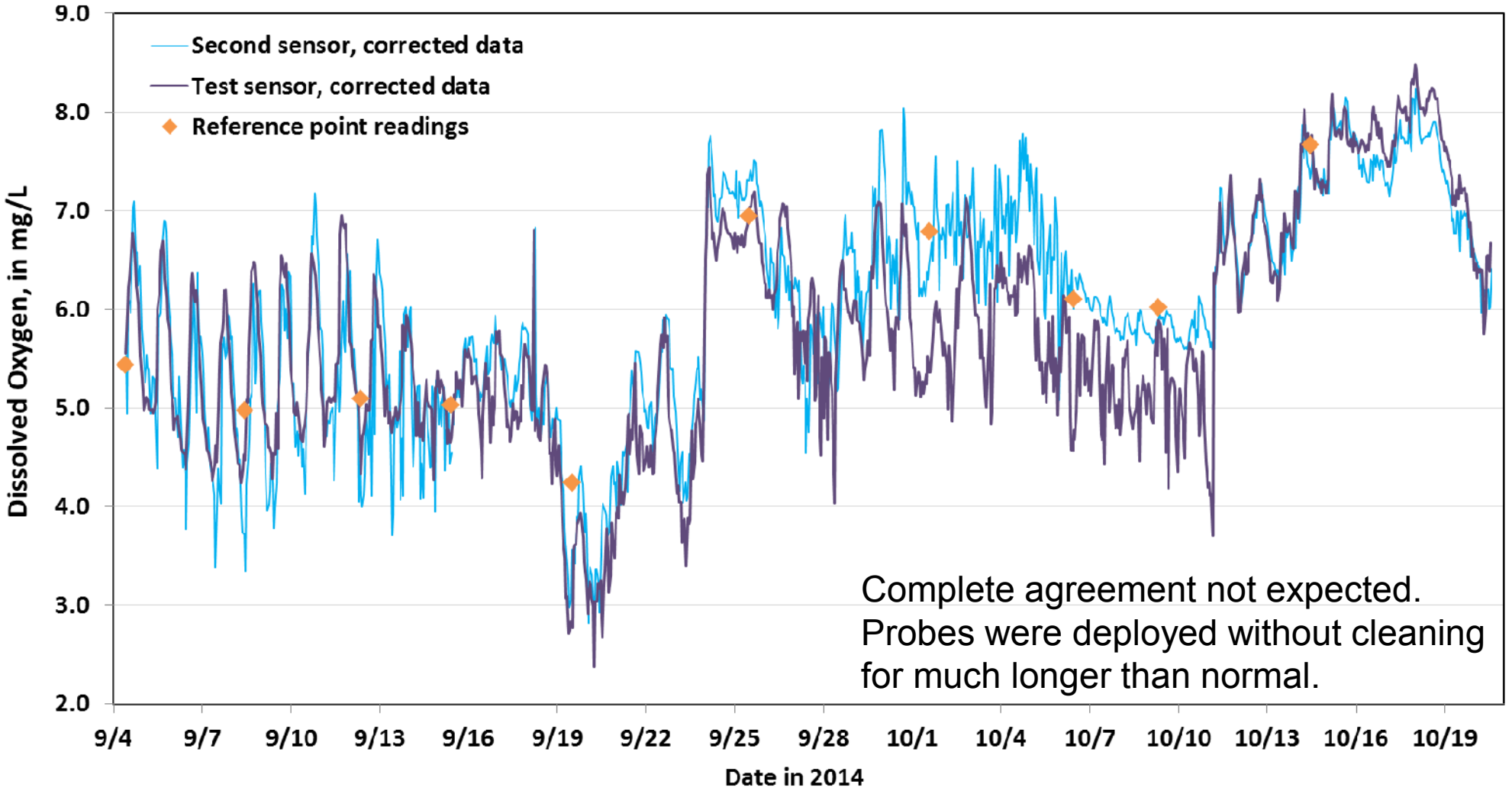

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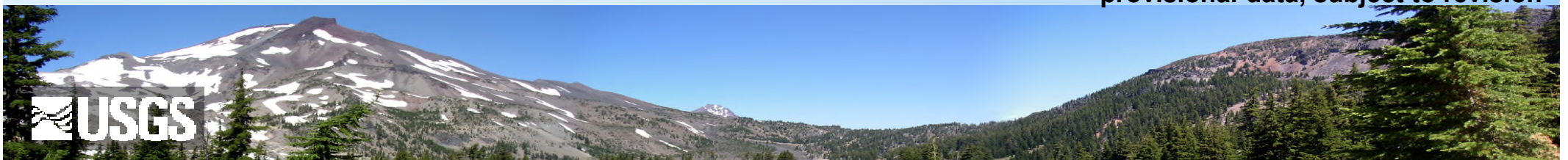

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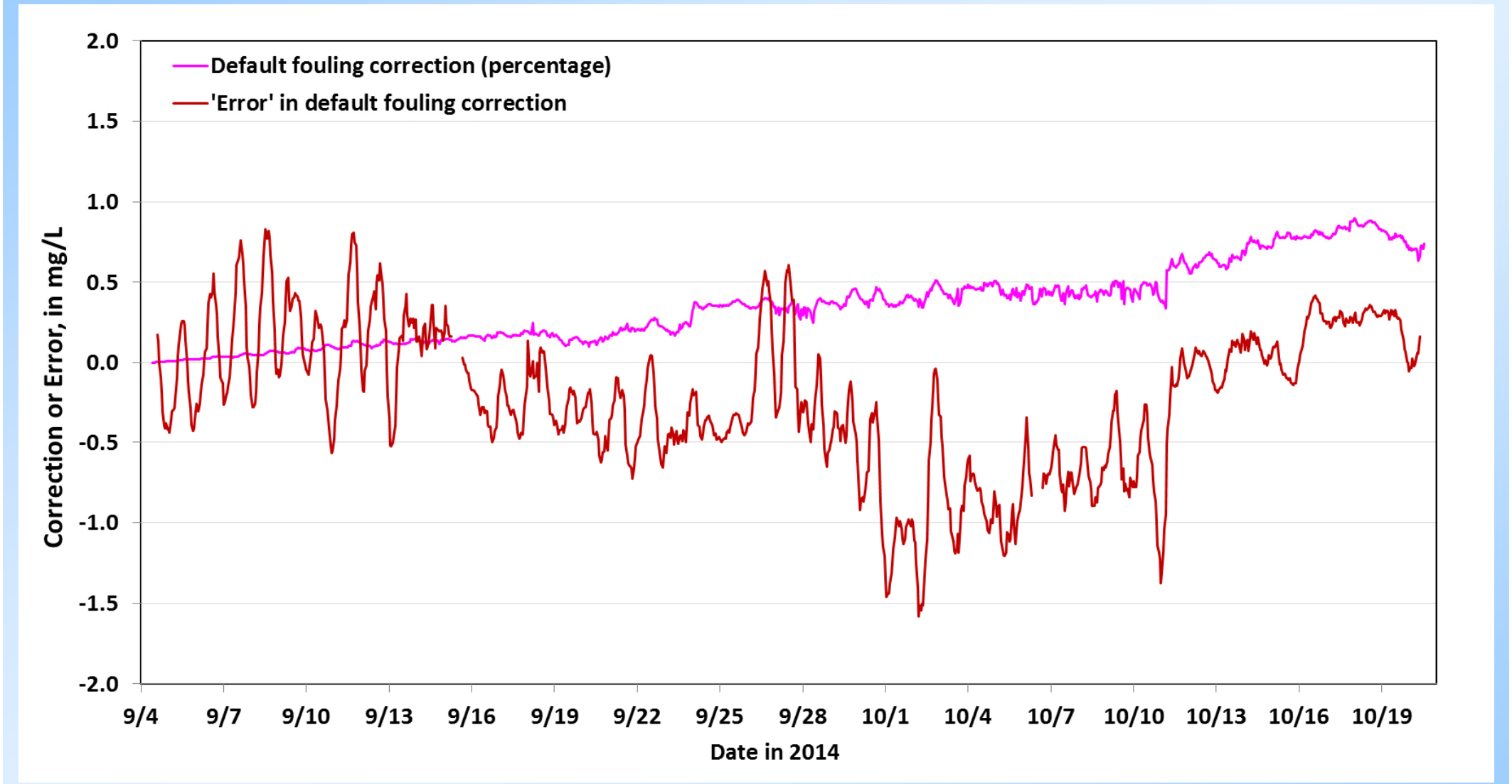

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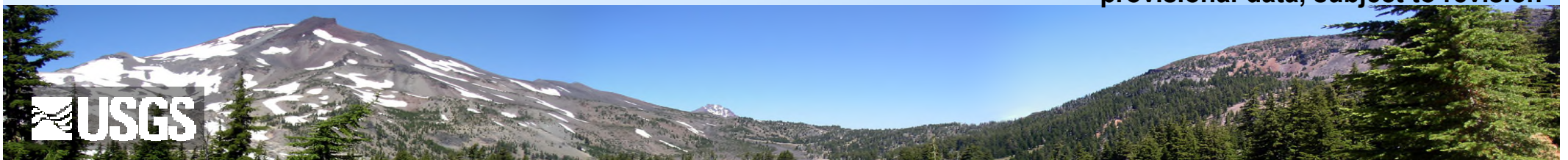

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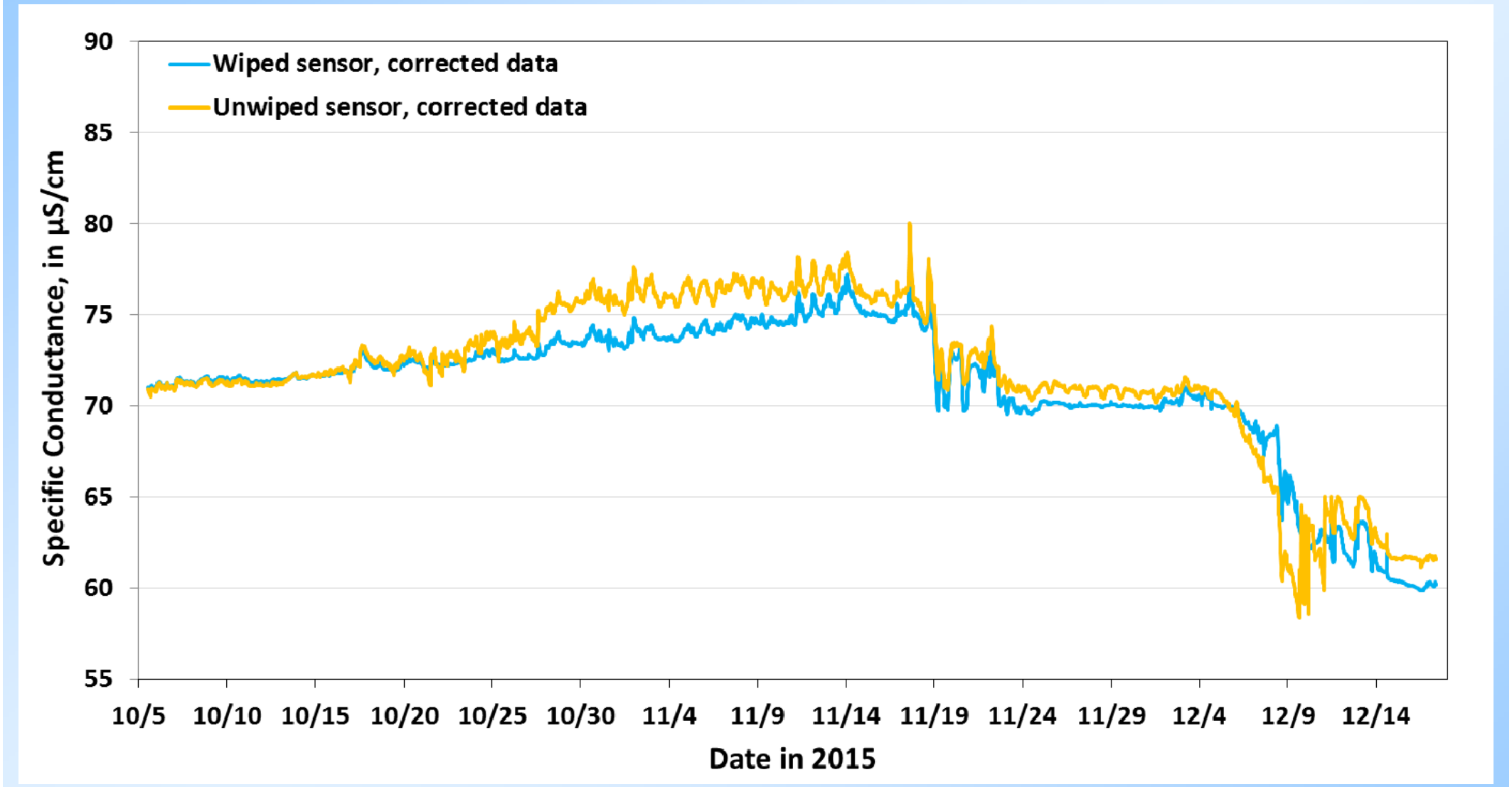

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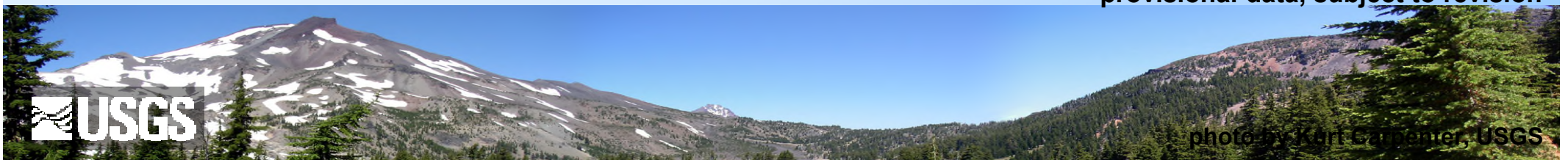

photo by Kurt Carpenter, USGS

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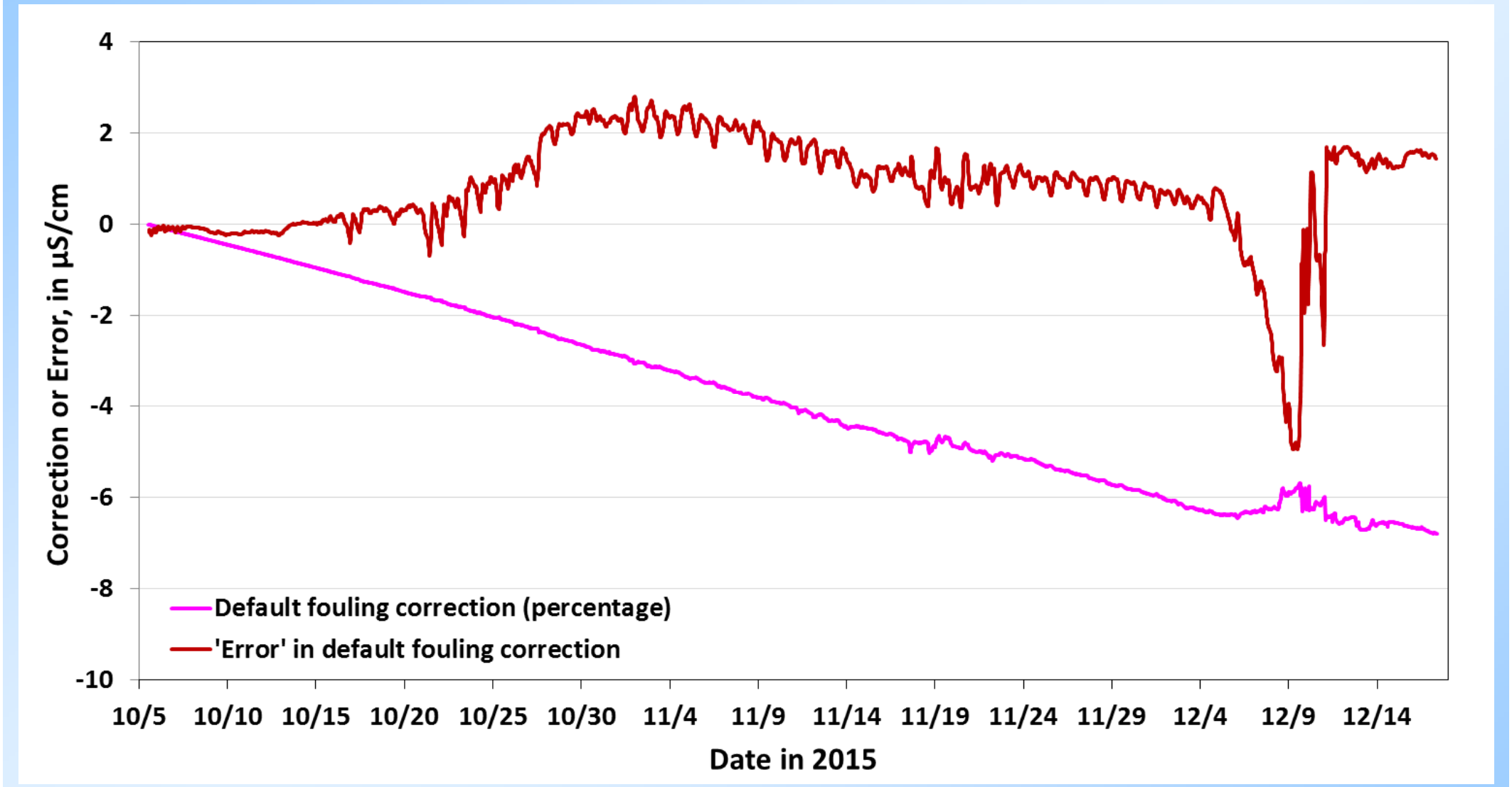

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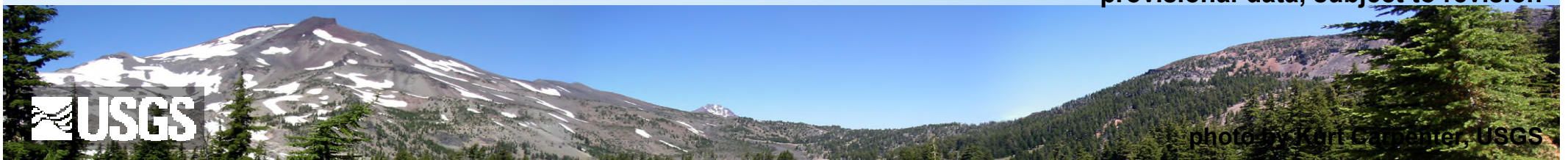

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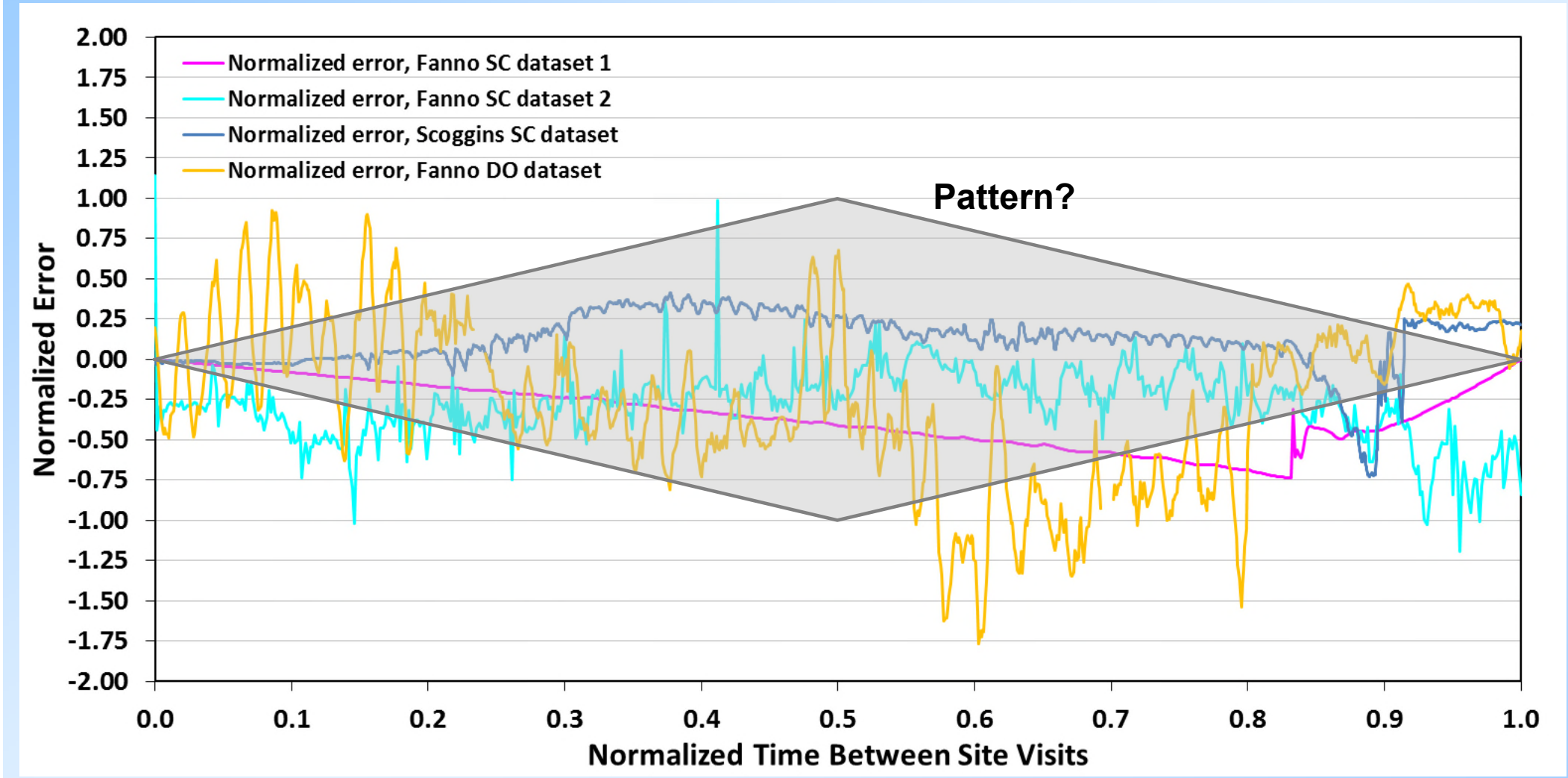
Errors Normalized to Maximum Fouling Correction



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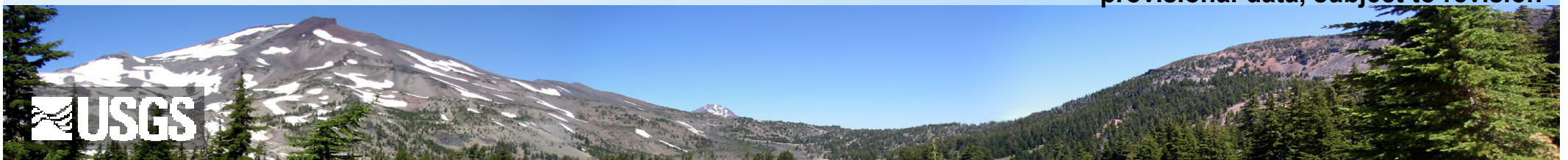


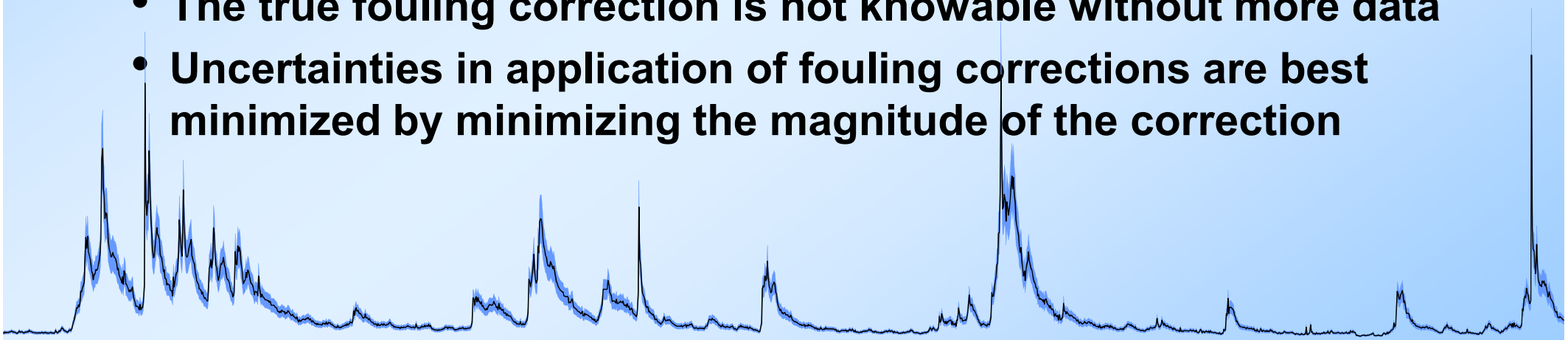
Take-Home Messages

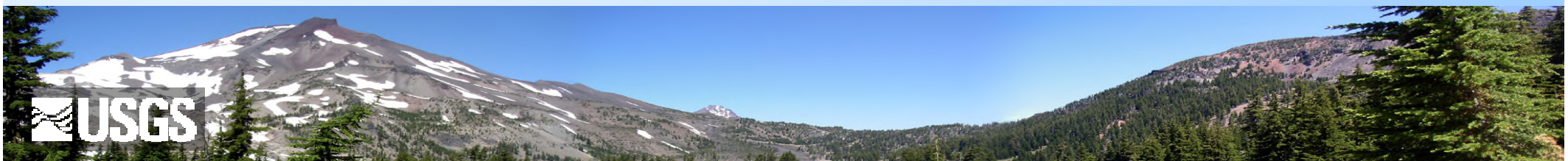
Methods/Guidelines under development:

- Rounding is not a valid method of expressing uncertainty
- Statistical approach needed to combine error estimates
- Avoid measurement errors, if possible
- Some errors unavoidable, and related to our assumptions

Fouling not always linear over time:

- Hydrologic events sometimes dictate initiation of fouling
- Linear pro-ration is a good first-cut assumption
- The true fouling correction is not knowable without more data
- Uncertainties in application of fouling corrections are best minimized by minimizing the magnitude of the correction





Contact, and Thanks

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Help and Insights from Data Uncertainty Team:

USGS:	Stacey Archfield, Zach Freed, Janice Fulford, David Holtschlag, Brian Pellerin, Pat Rasmussen, Susan Wherry
YSI / Xylem:	Rob Ellison
Aquatic Informatics:	Stu Hamilton, Brian Gouge