

October 16, 2024

From:

Nathaniel Byars, Lonquist & Co. LLC

Julie Shemeta, MEQ Geo Inc.

**Re: Combined Monthly Surface Deformation Report – September 2024
Sulphur Mines Salt Dome, Louisiana**

Please find attached the combined monthly deformation report for Sulphur Mines dome which includes results from the precision tiltmeters and GNSS stations for the September monitoring period and the cumulative InSAR results as of month end.

Additional Notes:

- Due to an unsuccessful acquisition of the scheduled September 28, 2024 SNT satellite image, the report for the most recent September SNT dataset from September 16 has been included for this report

Status of a deformation alert plan. Additional time is still needed to create a deformation alert system with specific deformation readings from the tiltmeters, GNSS and InSAR monitoring efforts. A brief discussion on this topic is included in the attached tiltmeter/GNSS report. The deformation alert levels will include specific actions and updated reporting schedules as the alert levels progress in severity. In the meantime, while background ground motion values are established, any clearly anomalous deformation readings in any of the monitoring systems shall be promptly reported to the various stakeholders.

Sincerely,



Nathaniel Byars
Principal Engineer
Lonquist & Co. LLC



Julie Shemeta
MEQ Geo Inc.

Attachment List

- A. Tiltmeter/GNSS Data Report - September 2024
- B. SNT InSAR report - September 16, 2024
- C. TSX/PAZ InSAR report - September 24, 2024
- D. Vertical & East-West 2D InSAR report – September 24, 2024

ATTACHMENT A

Tiltmeter/GNSS Data Report - September 2024

October 16, 2024

Sergey Samsonov, PhD, InSAR Corporation
Nathaniel Byars, Lonquist & Co. LLC
Julie Shemeta, MEQ Geo Inc.

Re: Tiltmeter/GNSS Data Evaluation – September 2024, Sulphur Mines Salt Dome

The tiltmeter/GNSS network, which includes twenty tiltmeters and five GNSS stations, has been operational since June 1, 2024. It was installed and is currently being operated by Halliburton's Pinnacle Group. Please refer to Figure 1 for the map of the tiltmeter and GNSS stations and Table 1 for their coordinates.

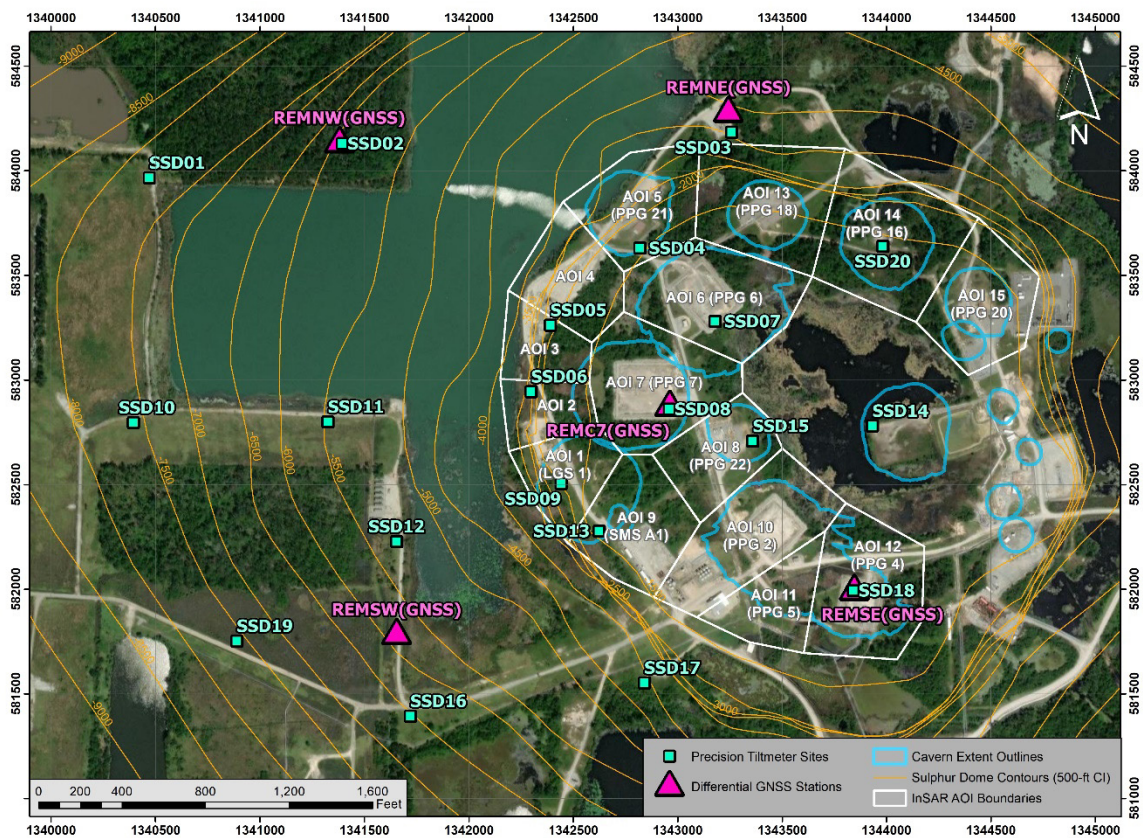


Figure 1. Map of the tiltmeter and GNSS network installed at Sulphur Mines dome. The cyan squares indicate the tiltmeter site locations. The GNSS stations are shown by pink triangles. The InSAR AOI boundaries are shown for reference. The surface projection of the various salt caverns is indicated by blue lines. The salt dome contours are in light orange. The backdrop is an aerial photograph of the Sulphur Mines salt dome.

Table 1. Location of GNSS and Tiltmeter Stations at Sulphur Mines Salt Dome (WGS 84)

Differential GNSS Stations		
Name	Latitude	Longitude
REMC7	30.253327	-93.414588
REMNE	30.257206	-93.413782
REMNW	30.256713	-93.419670
REMSE	30.250953	-93.411739
REMSW	30.250263	-93.418668
Off-dome Reference Station	30.257750	-93.426649

Precision Tiltmeter Sites		
Name	Latitude	Longitude
SSD01	30.256207	-93.422543
SSD02	30.256705	-93.419624
SSD03	30.256947	-93.413727
SSD04	30.255402	-93.415087
SSD05	30.254365	-93.416418
SSD06	30.253489	-93.416695
SSD07	30.254456	-93.413924
SSD08	30.253295	-93.414595
SSD09	30.252288	-93.416215
SSD10	30.252987	-93.422714
SSD11	30.253043	-93.419765
SSD12	30.251485	-93.418691
SSD13	30.251674	-93.415624
SSD14	30.253120	-93.411511
SSD15	30.252891	-93.413320
SSD16	30.249195	-93.418437
SSD17	30.249687	-93.414899
SSD18	30.250951	-93.411754
SSD19	30.250140	-93.421087
SSD20	30.255485	-93.411405

Introduction

This report describes tiltmeter and GNSS measurements from the Sulphur Mines Salt Dome collected in September 2024.

For each tiltmeter station, the report provides:

- Raw measurements of east and north tilt components at four-minute temporal resolution (measured in microradians), along with their linear trends
- Detrended east and north tilt components at four-minute temporal resolution
- Daily range of east and north tilt components
- Daily precipitation amount (measured in inches)
- Daily tilt direction distribution diagram, along with the direction to Cavern 7 and direction of the linear trend.

For each GNSS station, the report provides:

- Daily time series of east, north, and vertical deformation and their linear trends in the local reference frame.

For a more detailed description of the data visualization, please refer to the August 2024 report.

Summary of tiltmeter observations for September 2024

In September 2024, the tiltmeter network operated without interruption. During this time no signals related to processes in Cavern 7 were detected. The plots for each tiltmeter station are shown in Appendix 1 and described below.

The established tilt trends were disrupted by both precipitation events and mechanical activities near the sites. The rain events from September 4-6 affected the tilt response across the array to varying degrees. Not all sites were equally affected, possibly due to local site conditions or irregular precipitation patterns in the area. Significant tilt variations caused by precipitation require manual interpretation, which limits the development of automated monitoring techniques.

Large, short-duration tilt signals were linked to mechanical disturbances near the sites. These abrupt signals are considered outliers and are eliminated through filtering. Such a signal was observed at SSD14 on September 19-20th.

Additionally, small, somewhat random anomalies in the tiltmeter data were observed, not related to weather and likely linked to local, possibly shallow features in the near surface, such as movement in the cap rock.

Prolonged abnormal behavior was observed at SSD10 in September, with the tilt trend at this site changing several times. Currently, the site's behavior cannot be explained with certainty, but mechanical site disturbance and/or equipment failure are considered the most likely scenarios.

The established tilt trends reflect the current deformation processes, and an additional tilt due to failure at Cavern 7 will be superimposed on these established trends. Our objective is to learn how to accurately detect small but coherent signals at several sites. We are continuing to test various computational techniques for identifying such signals.

Presently, the tilt data are manually reviewed daily, using a 7-day rolling window, for any trend changes consistently observed at several tiltmeter sites over a period lasting at least a few days. With this approach, the September tiltmeter data shows no consistent pattern of ground movement that suggests deep-sourced deformation or any immediate concern with Cavern 7.

Summary of GNSS observations for September 2024

In September 2024, the GNSS network operated without interruption.

We have evaluated the full data history starting at the beginning of June 2024 for this report to improve measurement precision. The plots for each GNSS station are shown in Appendix 2.

The east, north, and vertical deformation time series at each GNSS site are used to compute the annual deformation rate in a local reference frame. These values are then shown on the rate vector map (Appendix 3). During September, daily measurements supported an established deformation trend, with a few of the GNSS sites recording horizontal motion directed approximately toward Cavern 7 and vertical motion indicating subsidence.

As previously described, the abnormally fast vertical motion at the NW GNSS station is related to field operations near the site in mid-July, and data from mid-July to the end of September appears to be stable.

Analysis Maps

Three maps have been created to visually summarize the results of the current analysis. These maps are shown below and are also provided in Appendix 3. Figure 2 is a rate vector map that portrays the direction and magnitude of the deformation rates that were identified for each tiltmeter and GNSS station by linear regression. Figure 3 portrays rose diagrams of the daily tilt direction frequency for each tiltmeter for the full data history

from June 2024 to present. Figure 4 portrays daily tilt direction frequency for the current monthly reporting period.

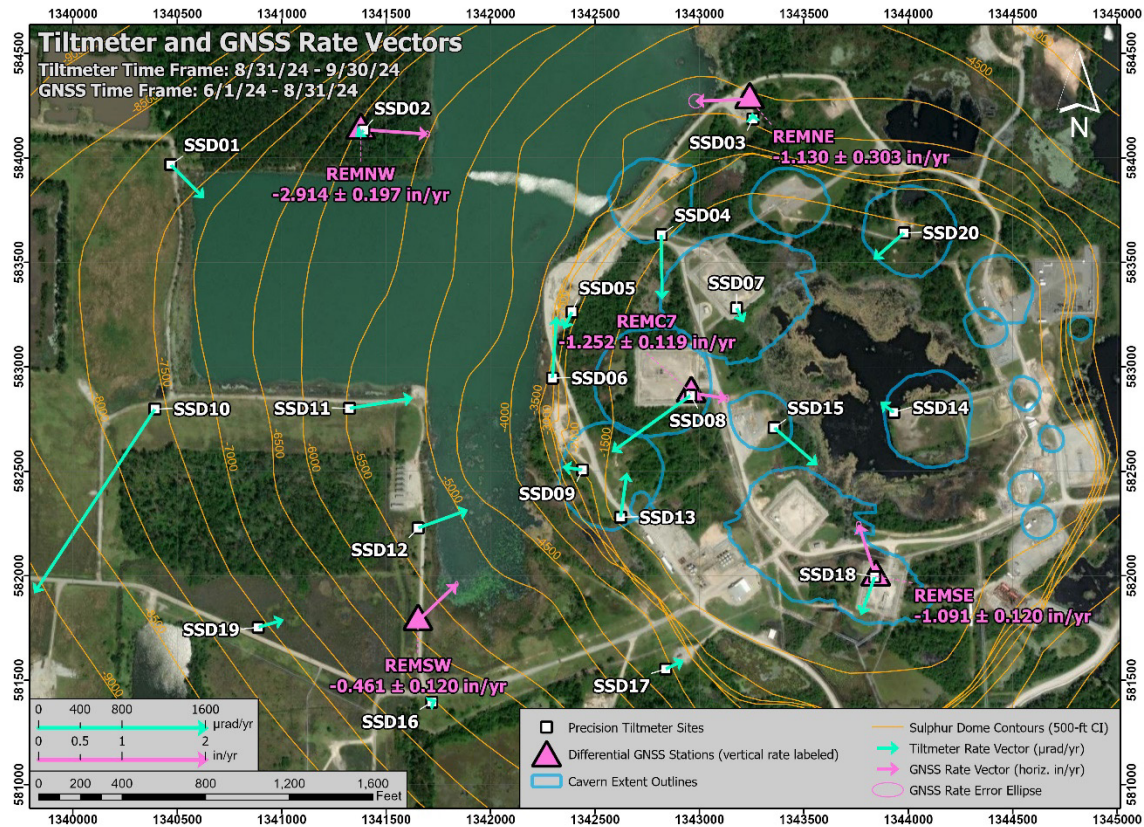


Figure 2. Map of deformation rate vectors for the tiltmeters and GNSS stations over their respective evaluated time frames. The tiltmeter vectors are shown in cyan and scaled according by their respective values in units of microradians per year. The GNSS vectors and their corresponding error ellipses (derived from east and north rate errors) are shown in pink representing inches of horizontal movement per year. The GNSS stations are additionally labeled with the vertical motion rate and corresponding error value.

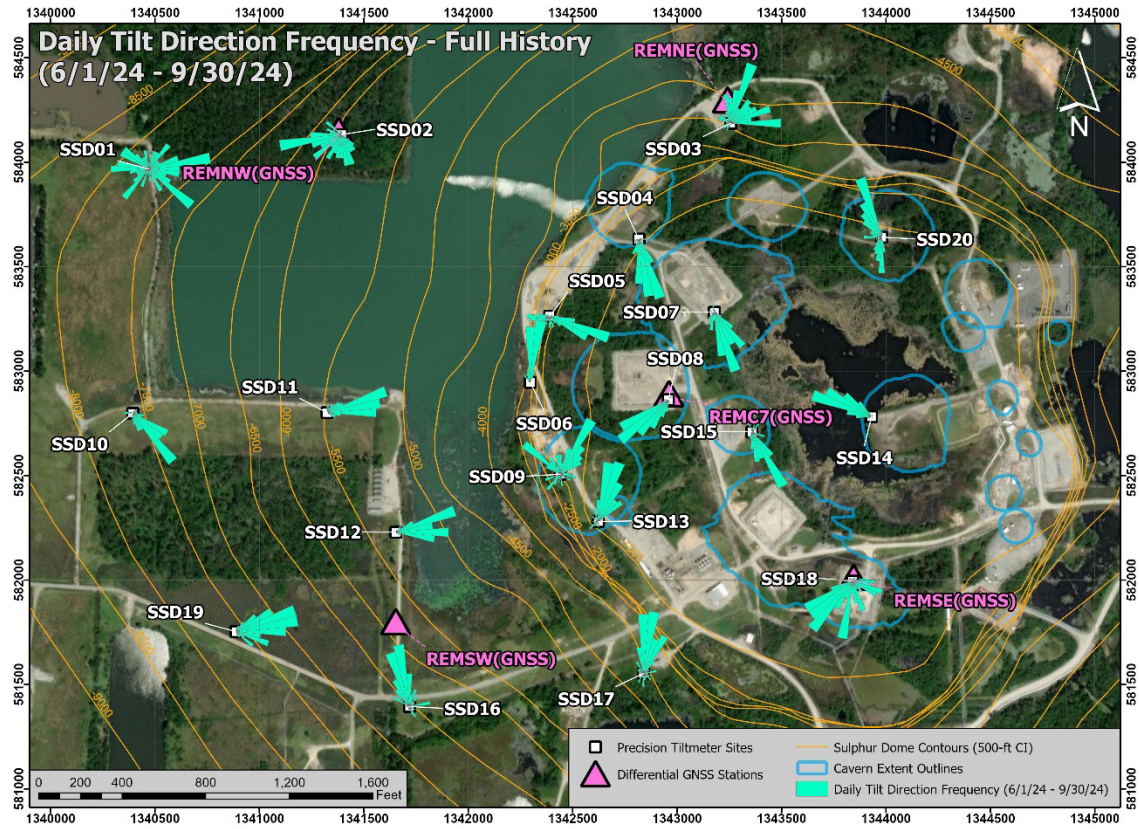


Figure 3. Map of daily tilt direction distribution for each tiltmeter for the full data history beginning in June 2024. Rose diagrams indicate the number of days that tilt was oriented along specific azimuths (bin size is 10°).

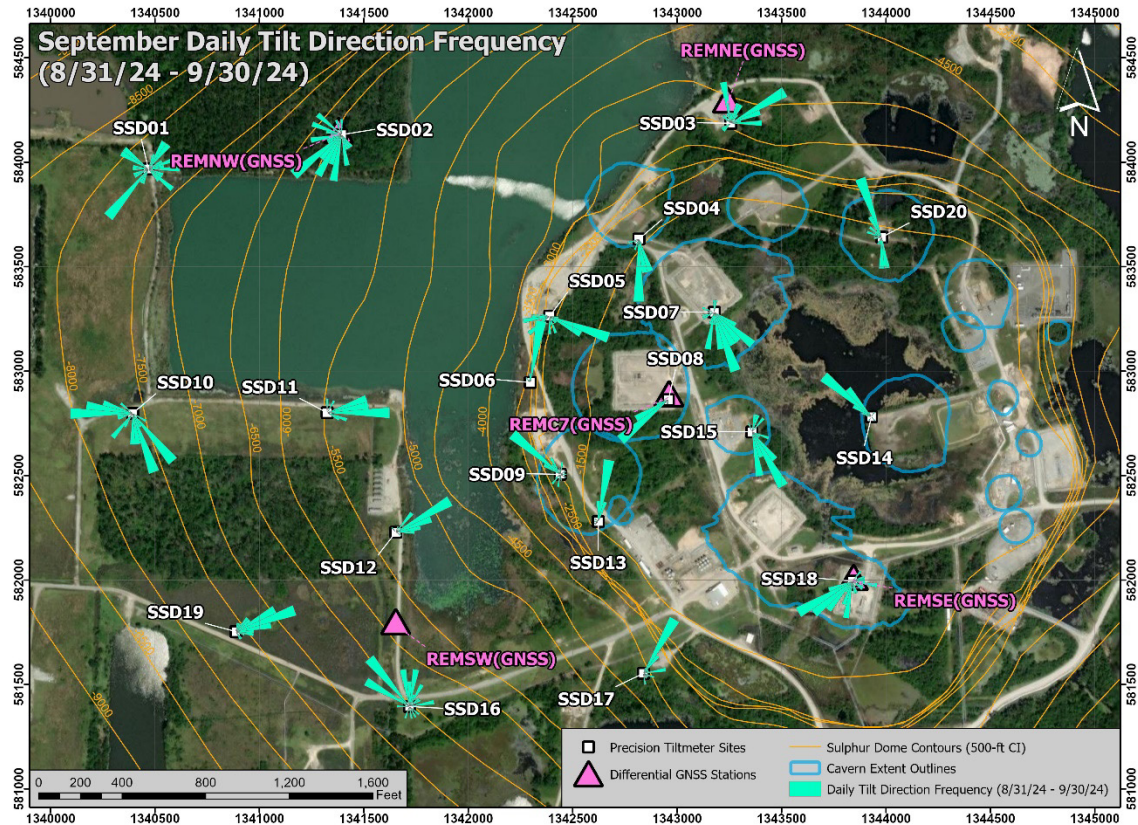


Figure 4. Map of daily tilt direction distribution for each tiltmeter for the current monthly reporting period. Rose diagrams indicate the number of days that tilt was oriented along specific azimuths (bin size is 10°).

Deformation Alert System

We continue working on developing a draft alert system that incorporates elements of both tiltmeter direction and magnitude. Over the past several months, we have observed that localized tilt changes are often linked to precipitation. The initial deformation alert "triggers" will likely take into account the consistency of tilt azimuth direction towards Cavern 7 or an area near to Cavern 7. These tilt changes must be observed across a large portion of the tiltmeter stations and persist for several days. Our Mogi modeling indicates that deep deformation associated with potential changes in volume at Cavern 7 (depth approximately 2500-3160 ft) is expected to impact the entire tiltmeter array. If the deformation moves upward from Cavern 7, we expect the corresponding tiltmeter response to narrow to the stations nearest the cavern and the tilt magnitude to increase.

In contrast, shallow deformation, such as movement in the cap rock, is likely to affect nearby tiltmeter sites only. It is unlikely that a short-term (hour-by-hour) alert system is

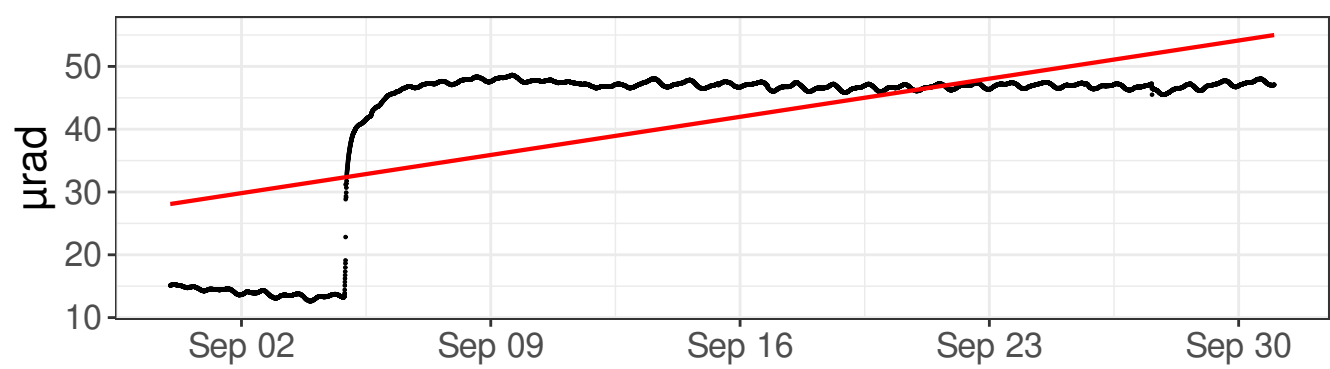
feasible for tiltmeter data. Our current plan is to establish a deformation alert that will trigger if a consistent pattern of tilt stations towards Cavern 7 is observed over a broad area for multiple days. The draft alert "levels" under consideration will also rely on supporting observations, such as Cavern 7 pressures, GNSS observations, InSAR trends, and microseismic activity.

APPENDIX 1

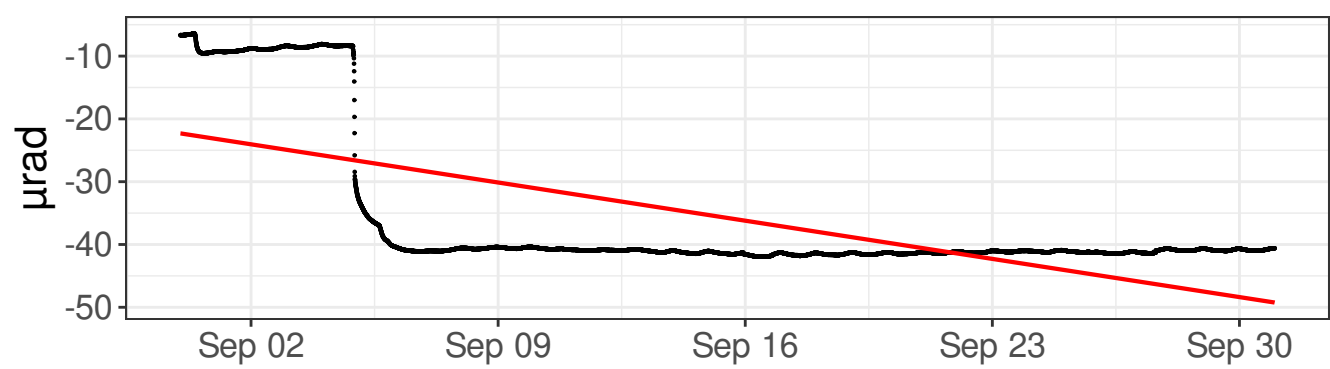
Tiltmeter Data Plots

SSD01, 08/31/2024 - 09/30/2024

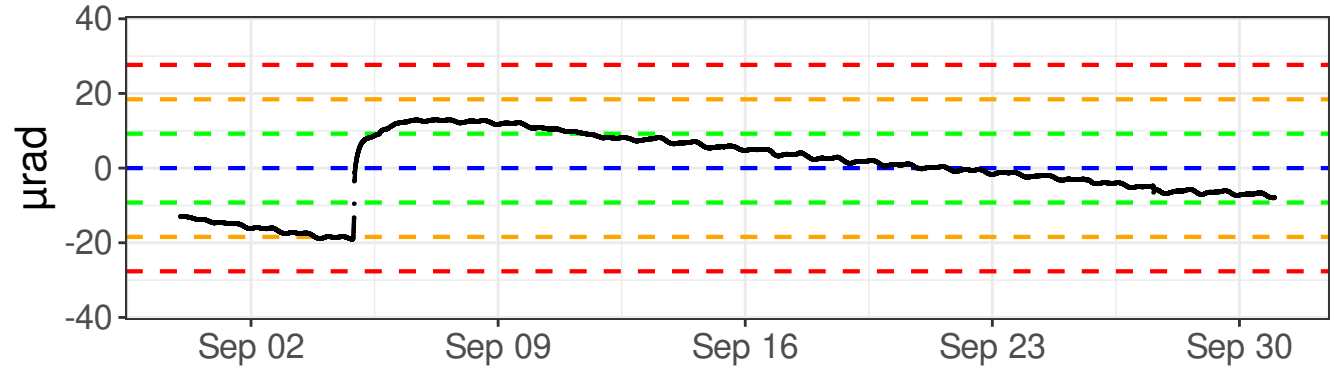
East tilt - raw values, Linear model R2 0.42



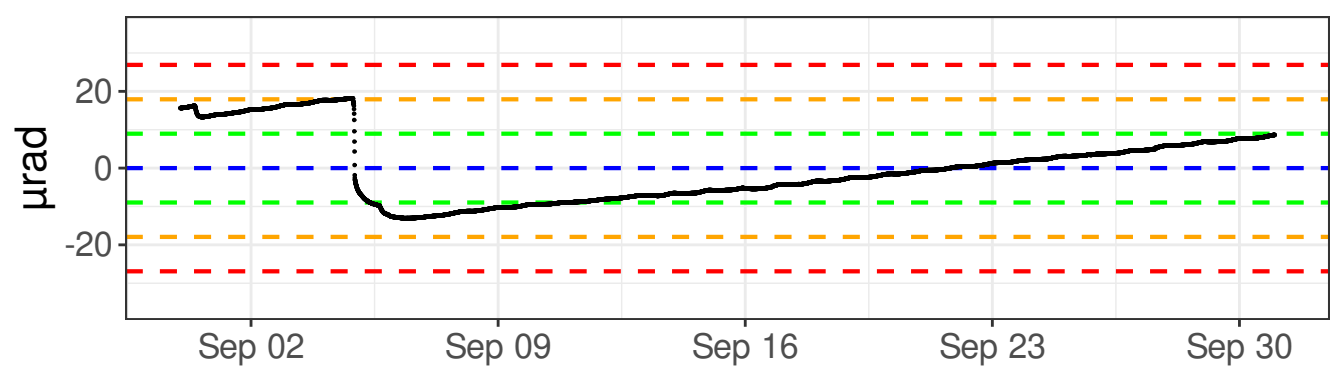
North tilt - raw values, Linear model R2 0.43



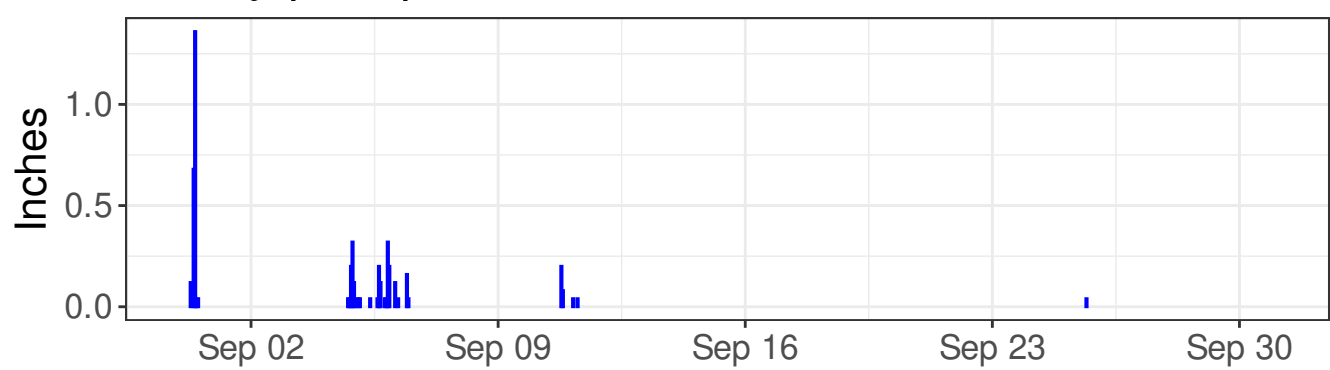
East tilt - detrended values



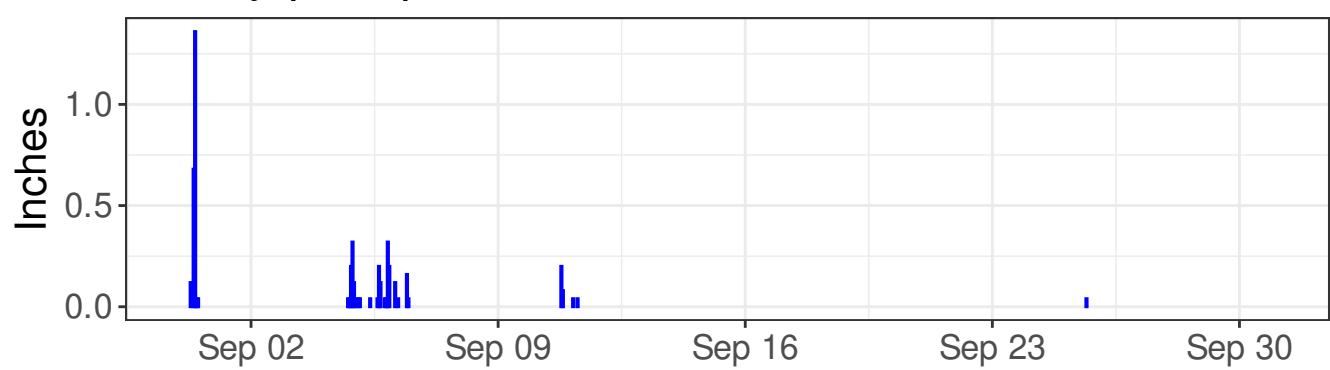
North tilt - detrended values



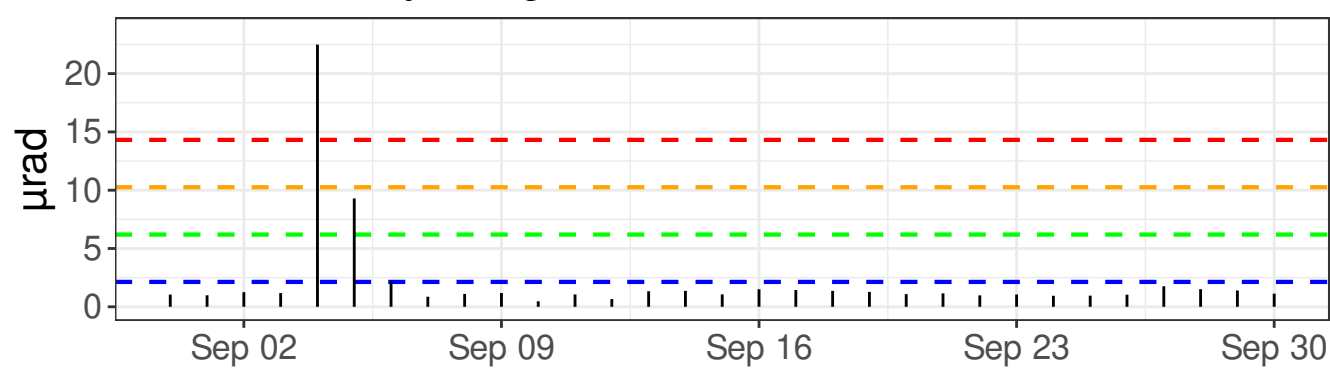
Hourly precipitation



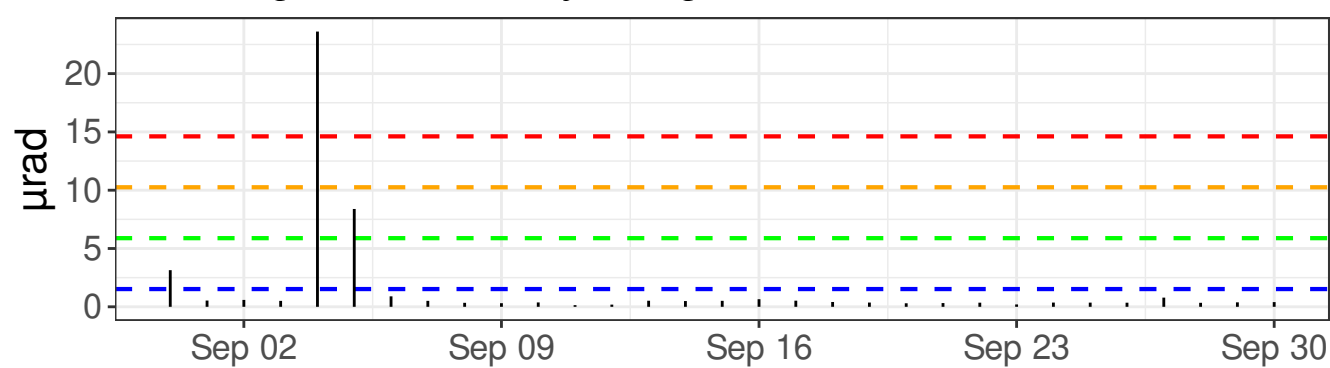
Hourly precipitation



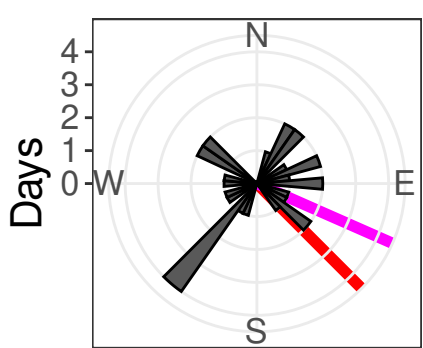
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $317.71 \pm 3.56 \mu\text{rad}/\text{year}$

North tilt rate: $-318.04 \pm 3.46 \mu\text{rad}/\text{year}$

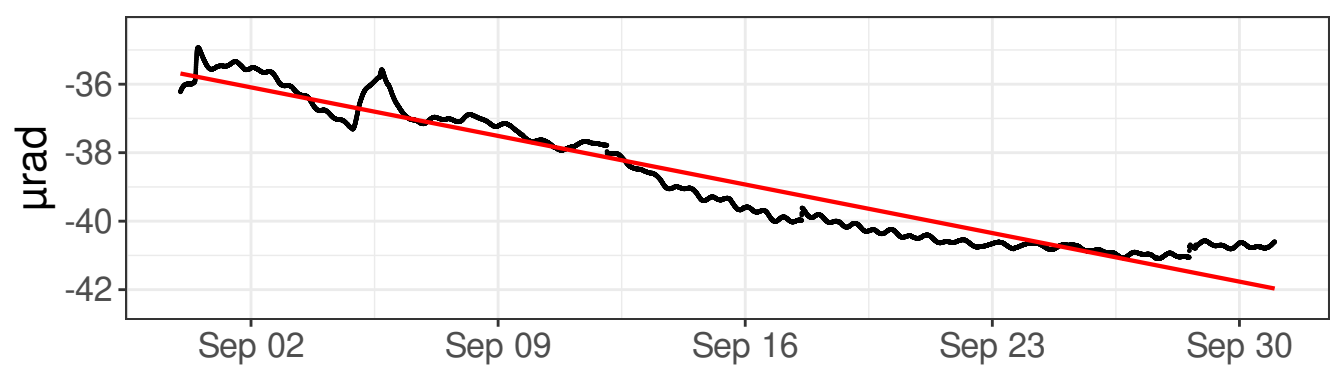
Azimuth to C7: 114 deg

Distance to C7: 2538 ft

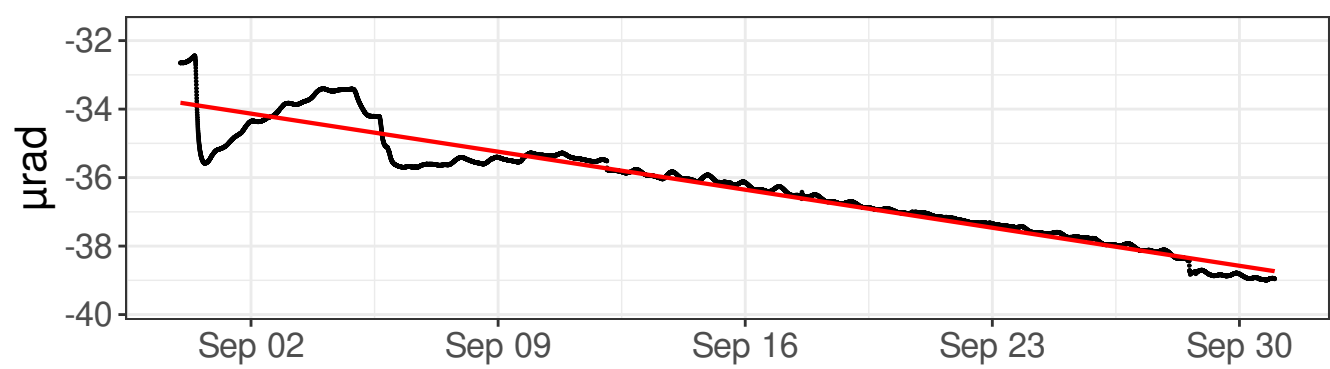
--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD02, 08/31/2024 - 09/30/2024

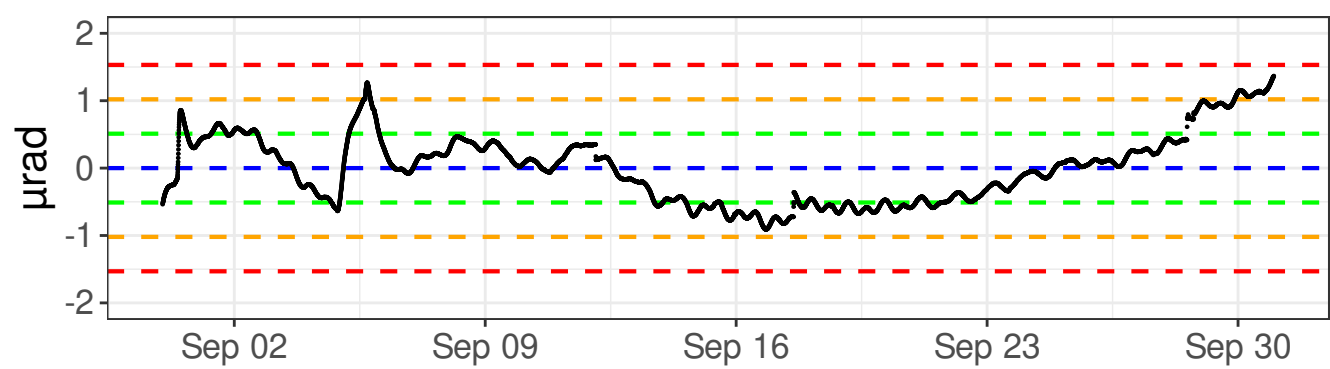
East tilt - raw values, Linear model R2 0.93



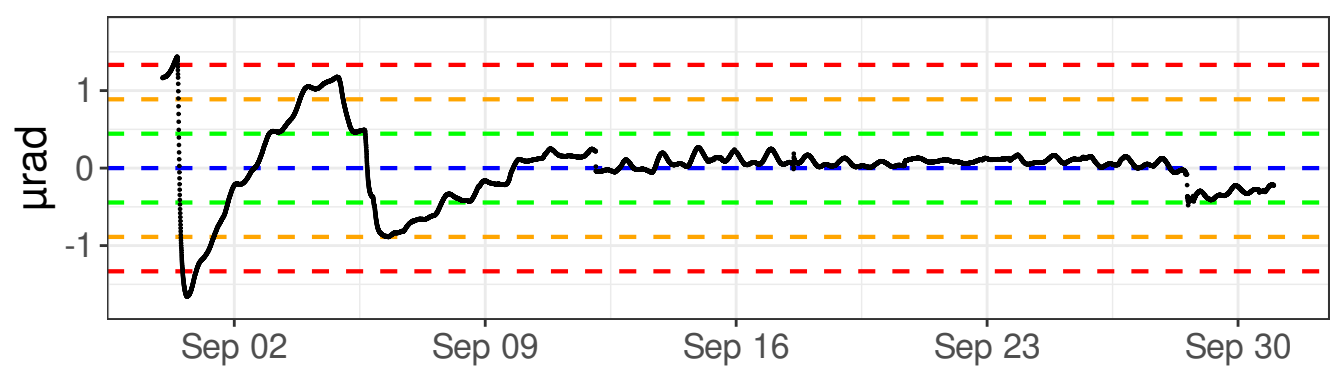
North tilt - raw values, Linear model R2 0.91



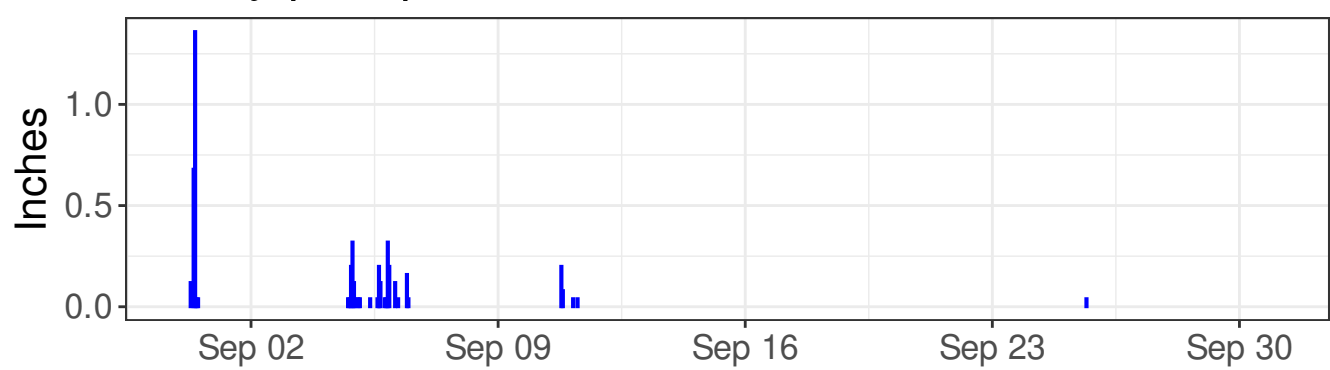
East tilt - detrended values



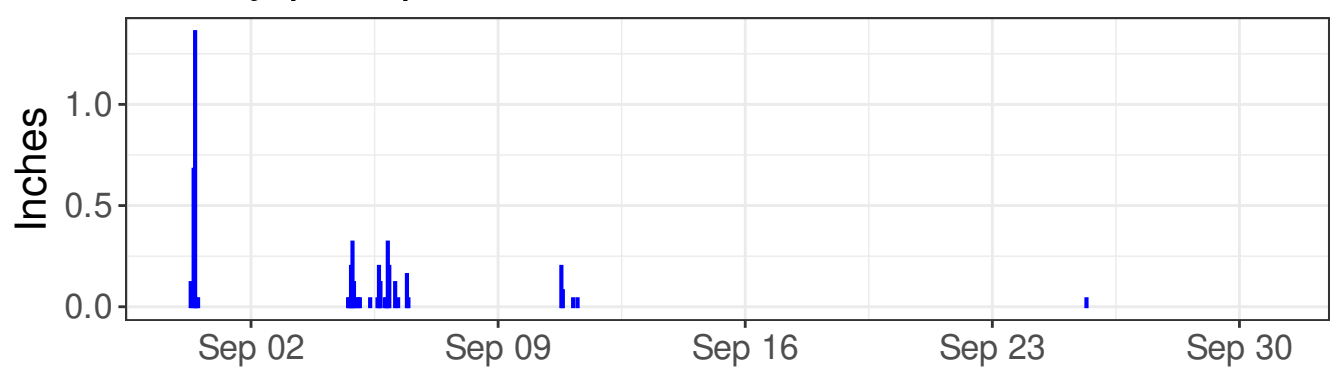
North tilt - detrended values



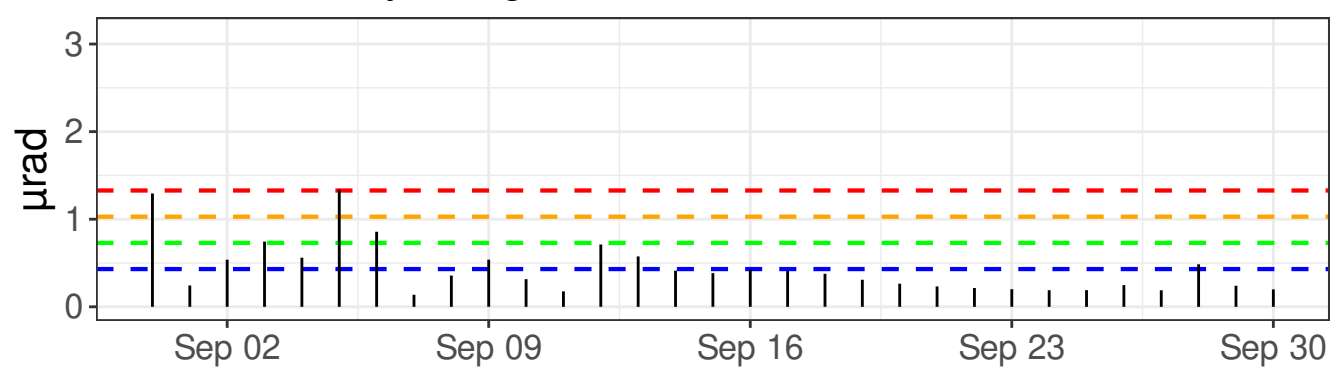
Hourly precipitation



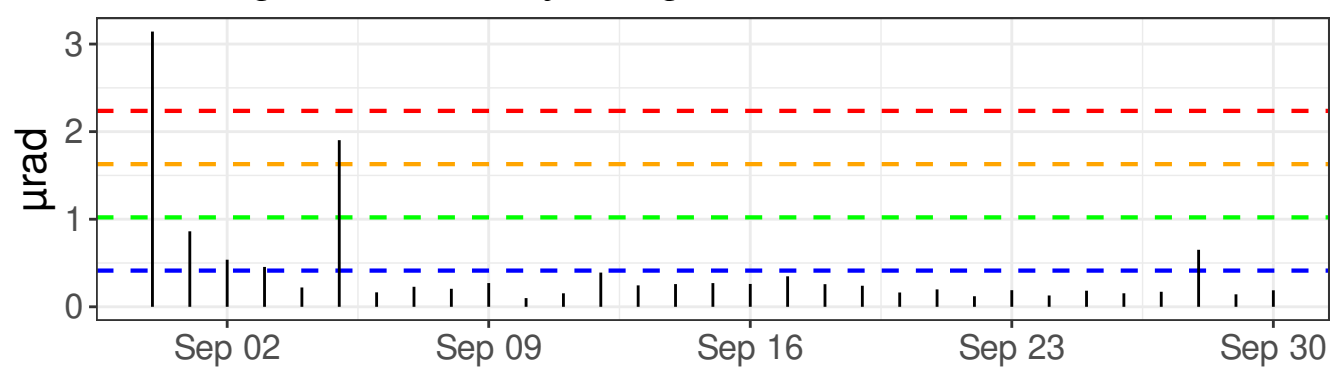
Hourly precipitation



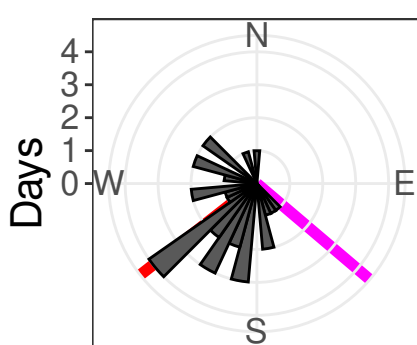
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $-74.15 \pm 0.20 \mu\text{rad}/\text{year}$

North tilt rate: $-58.08 \pm 0.17 \mu\text{rad}/\text{year}$

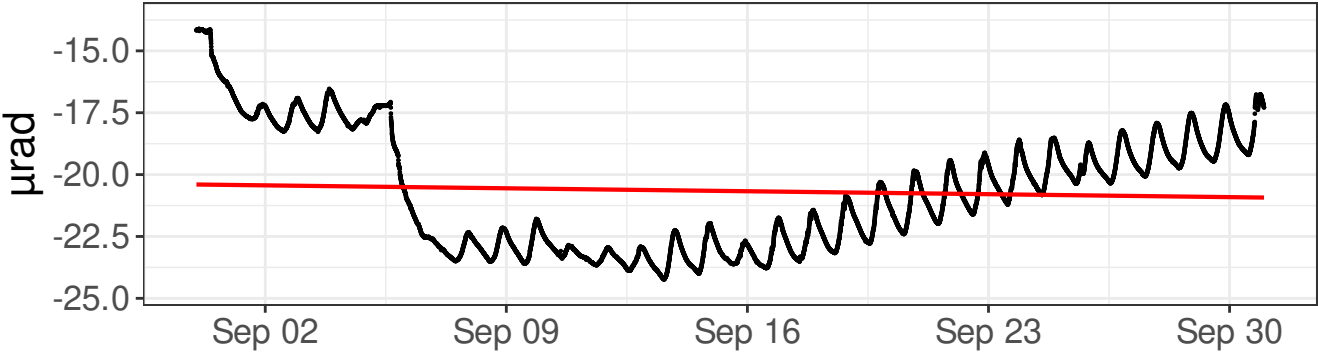
Azimuth to C7: 130 deg

Distance to C7: 1834 ft

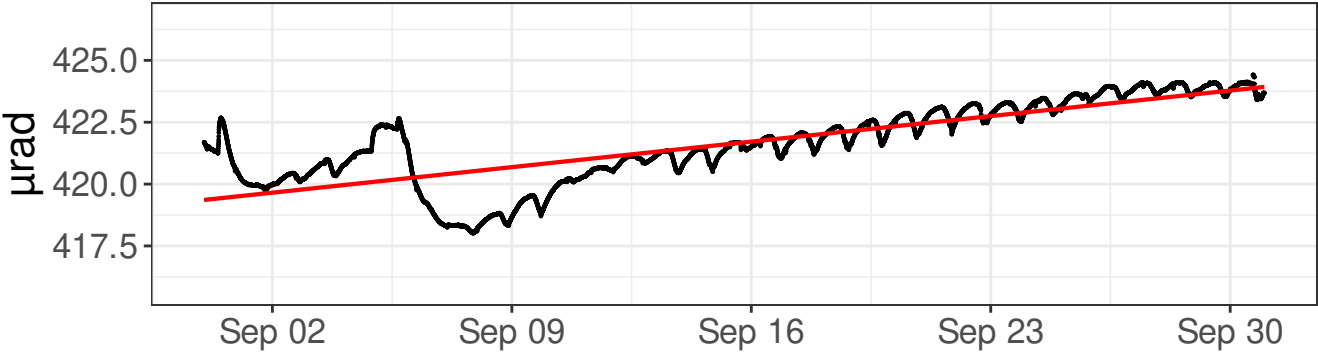
--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD03, 08/31/2024 - 09/30/2024

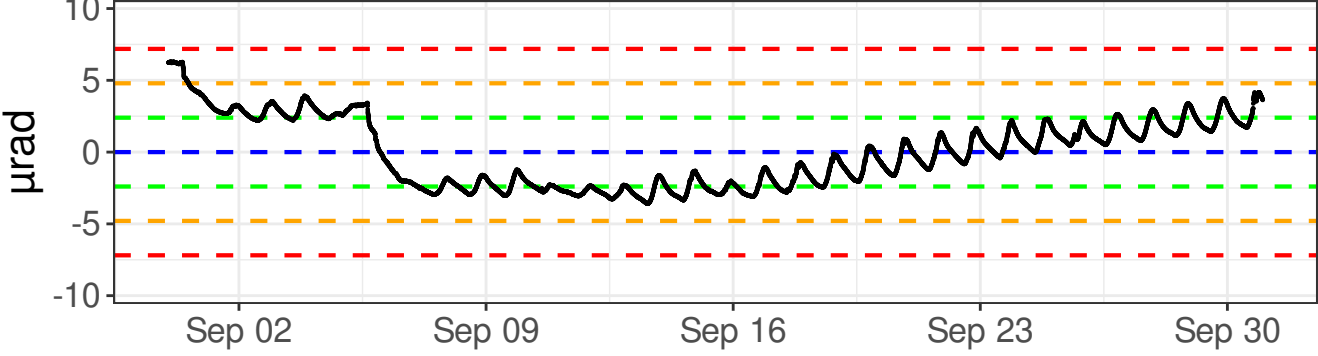
East tilt - raw values, Linear model R2 0.00



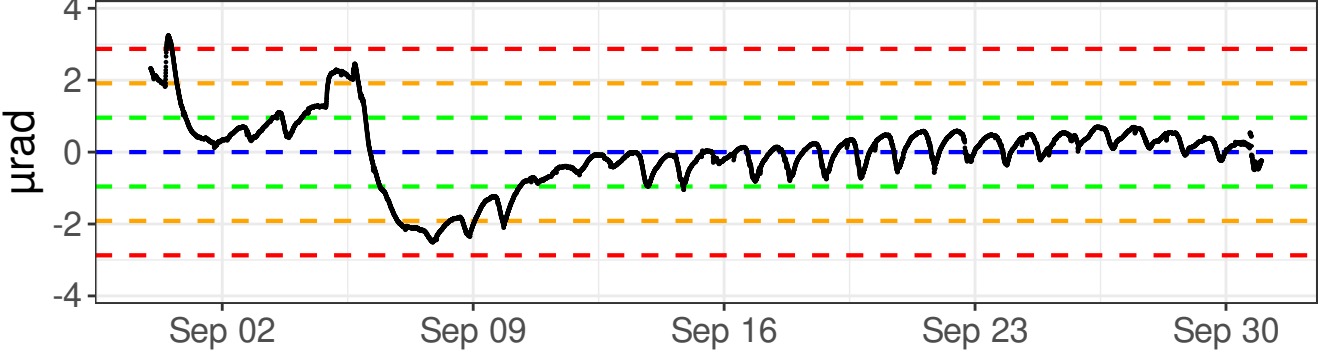
North tilt - raw values, Linear model R2 0.65



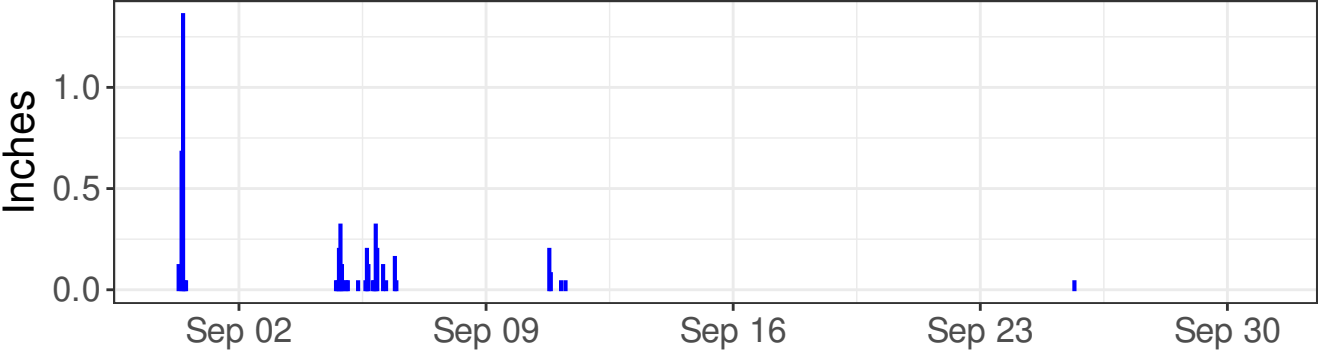
East tilt - detrended values



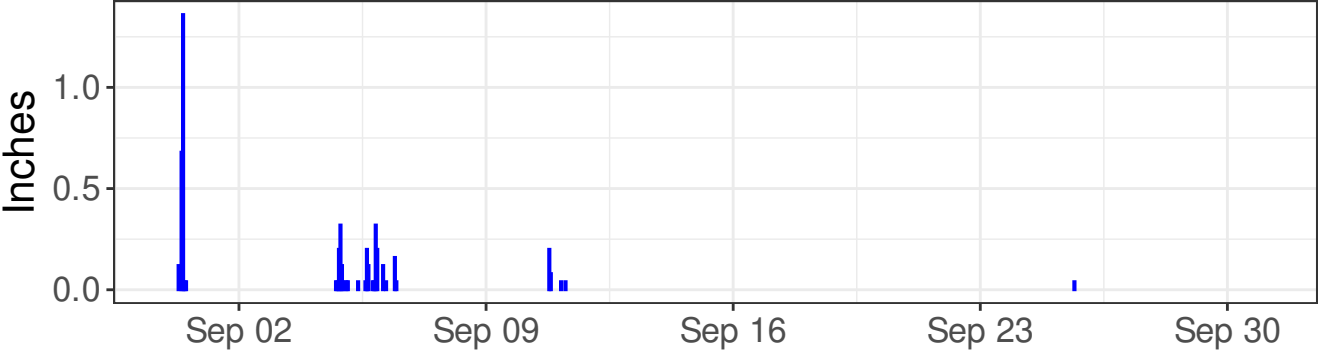
North tilt - detrended values



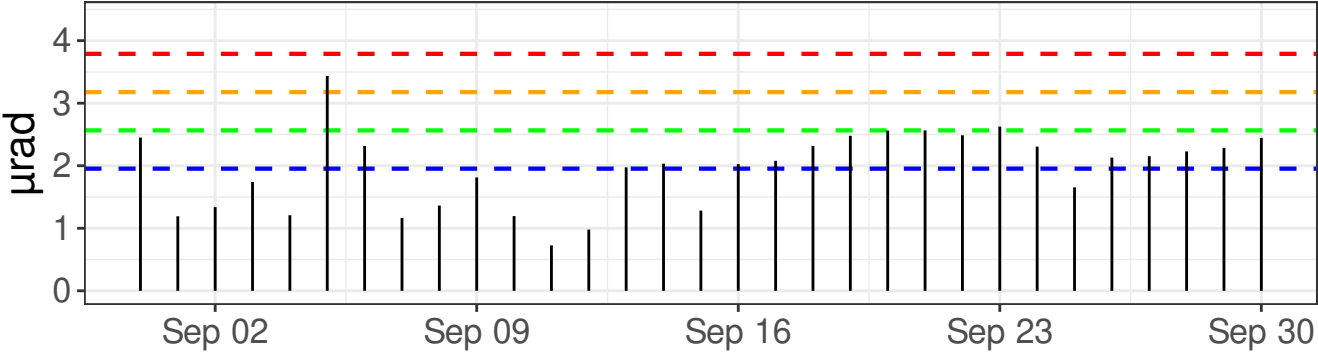
Hourly precipitation



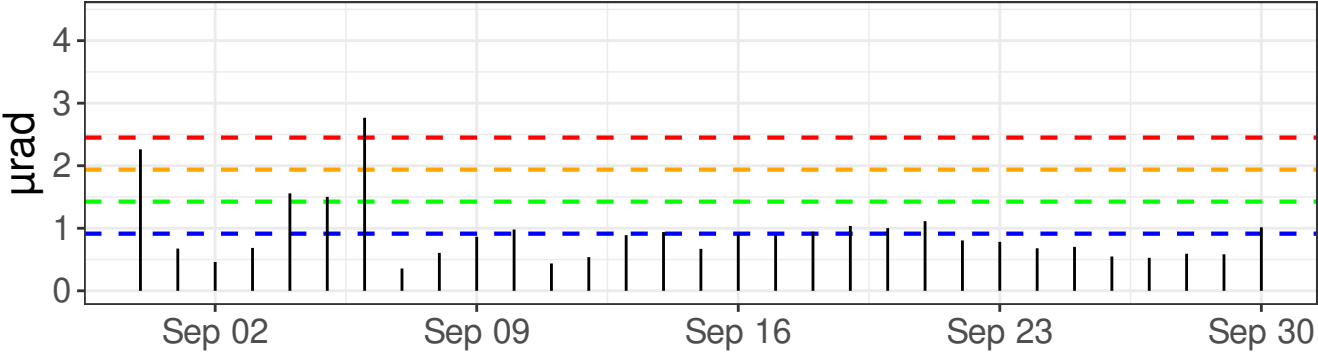
Hourly precipitation



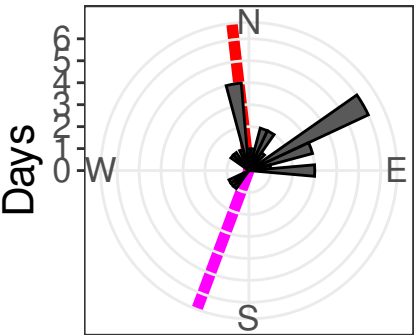
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $-6.22 \pm 0.93 \mu\text{rad}/\text{year}$

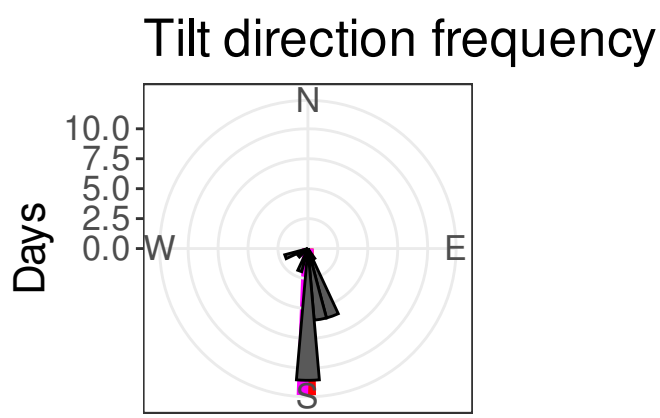
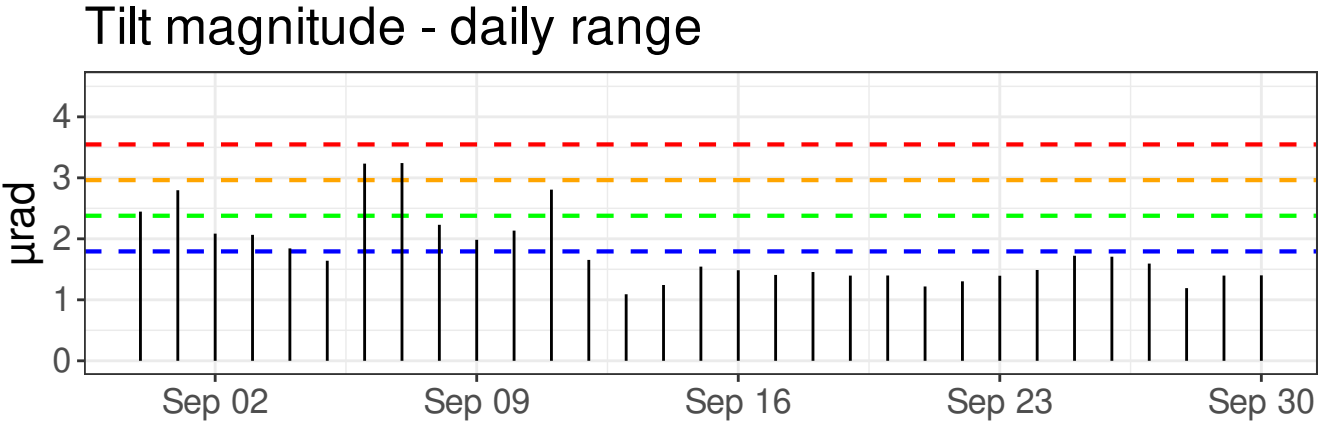
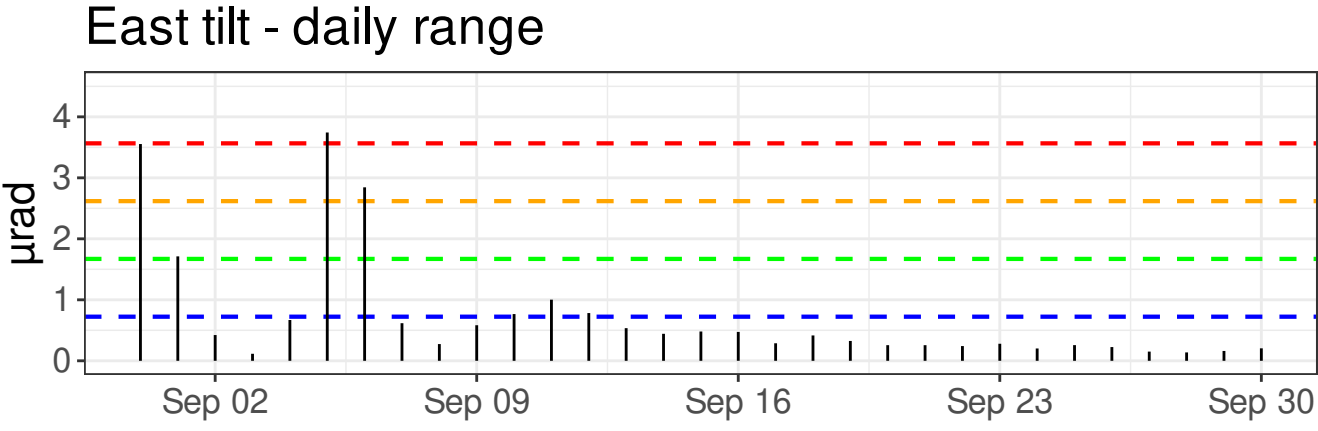
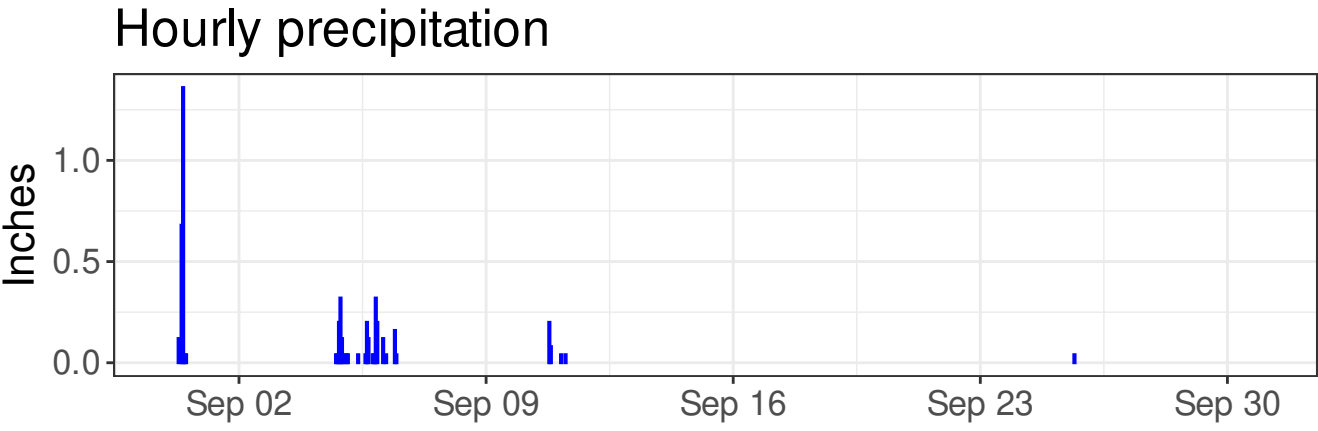
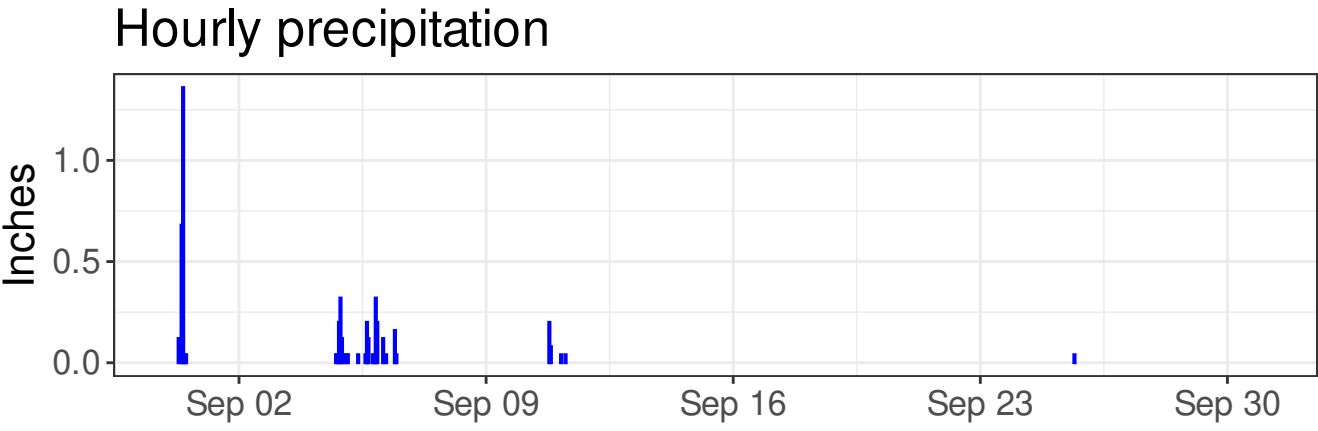
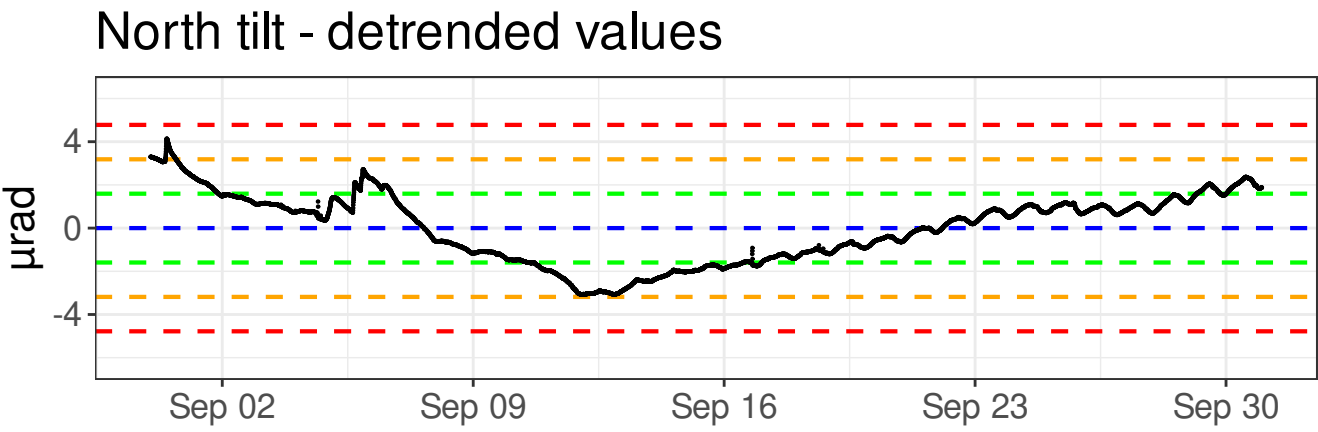
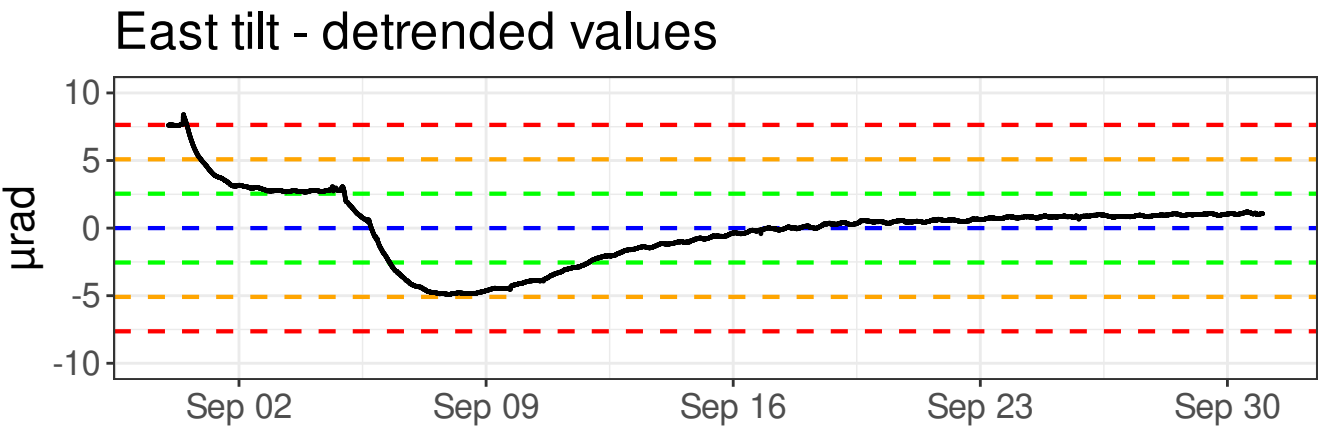
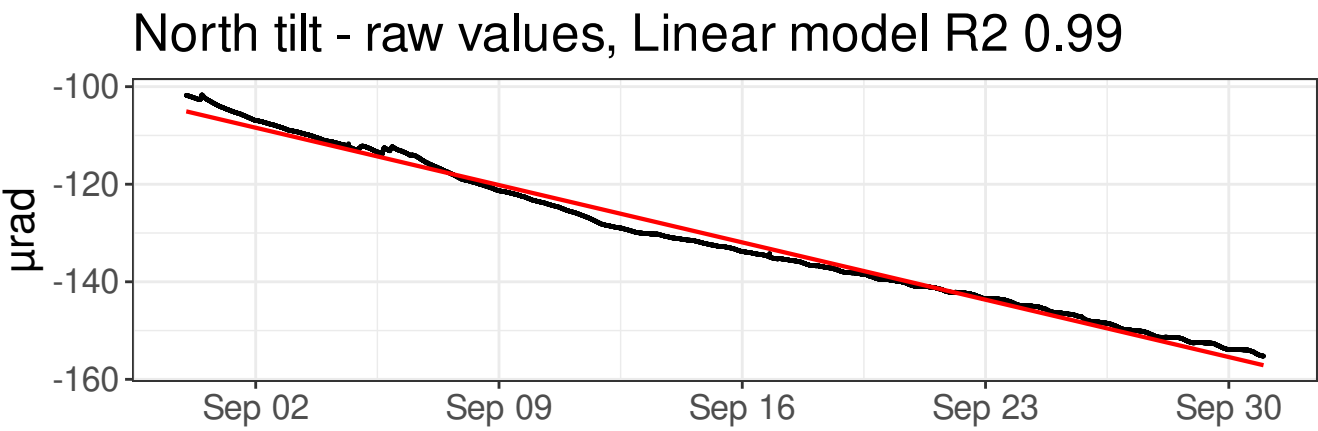
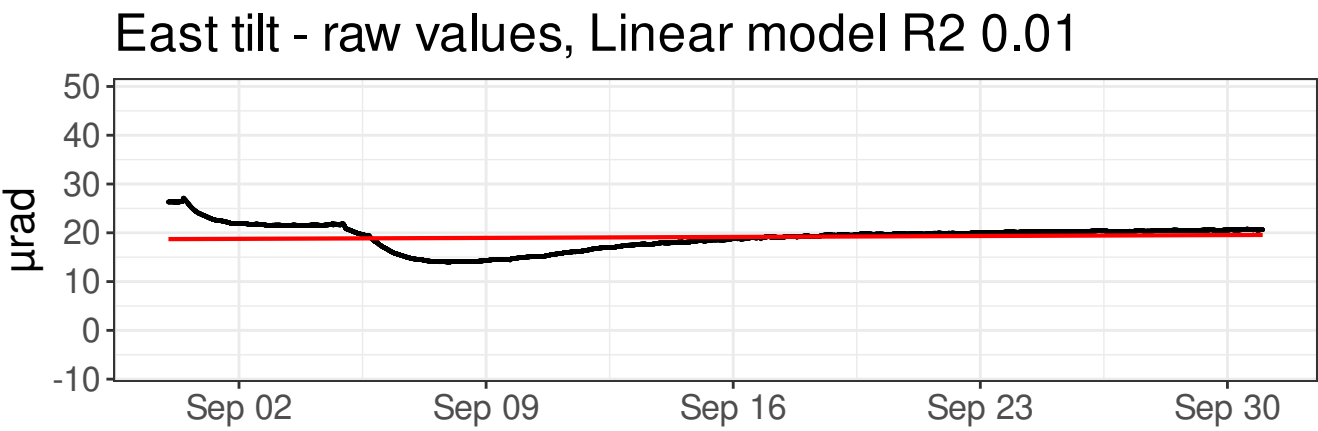
North tilt rate: $53.93 \pm 0.37 \mu\text{rad}/\text{year}$

Azimuth to C7: 201 deg

Distance to C7: 1326 ft

--- 0σ --- 1σ --- 2σ --- 3σ
— Linear model — Azimuth to C7

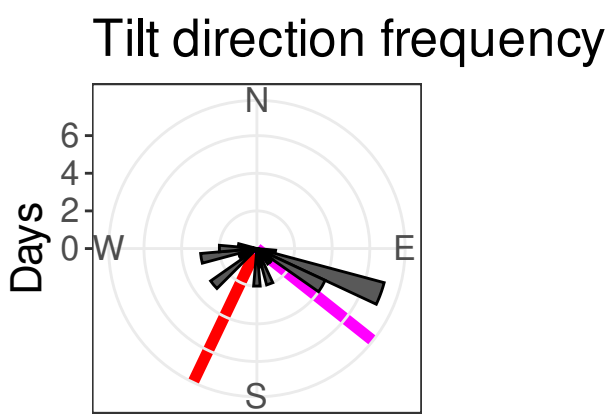
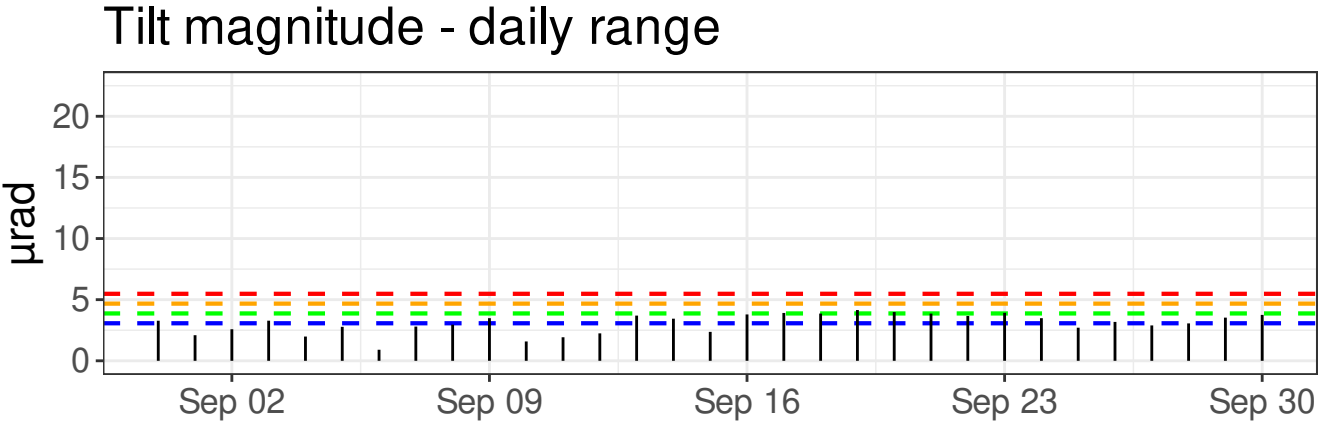
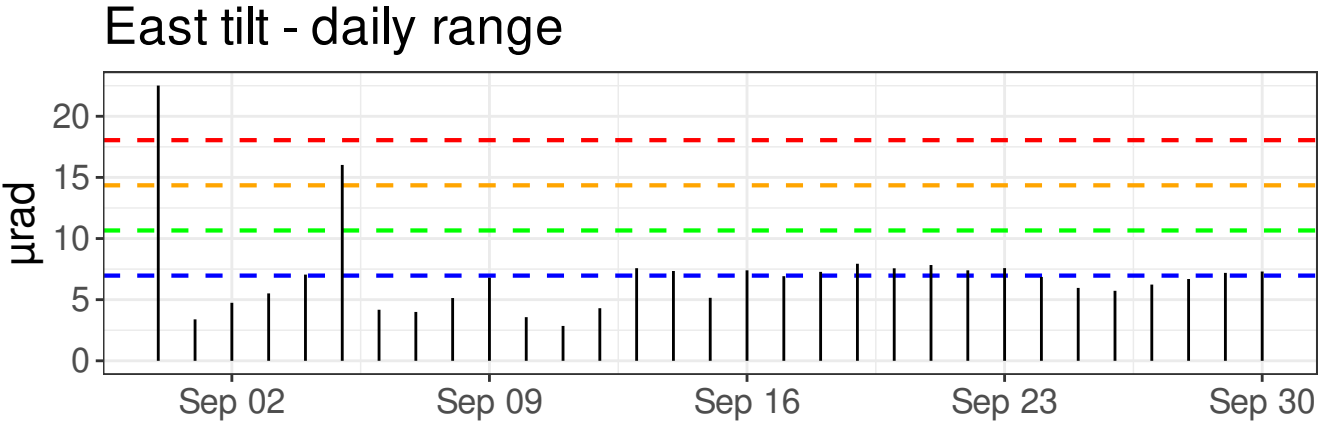
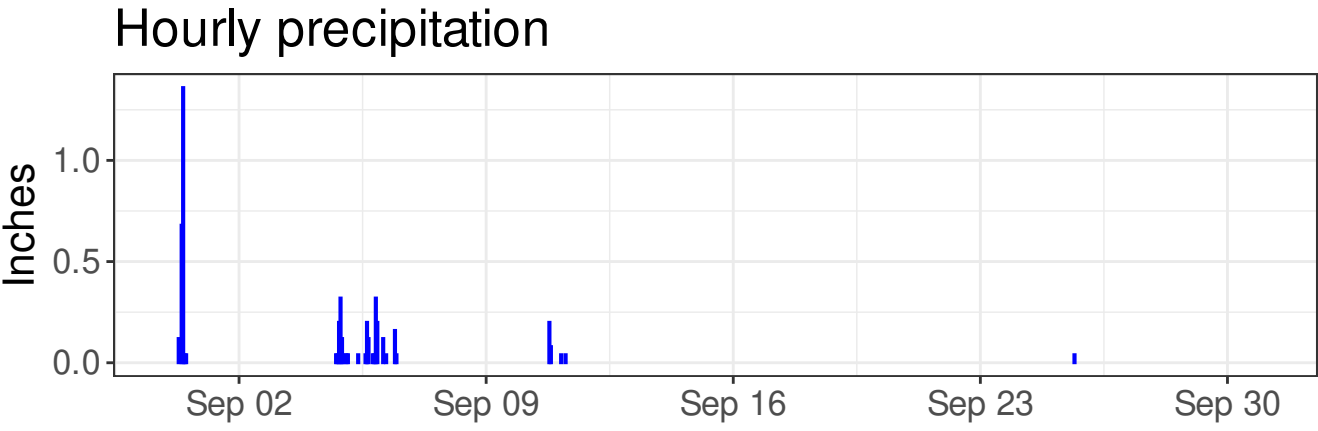
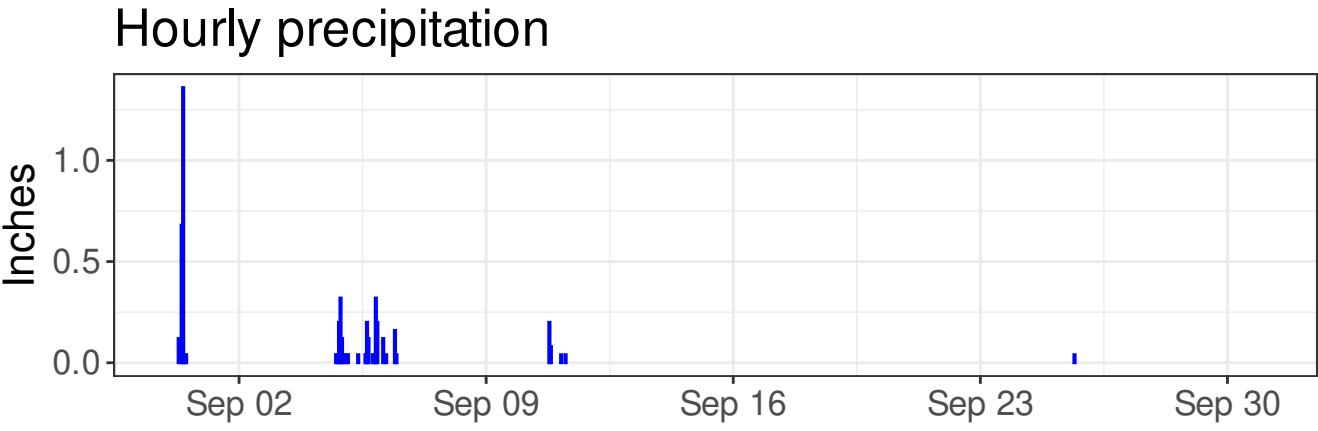
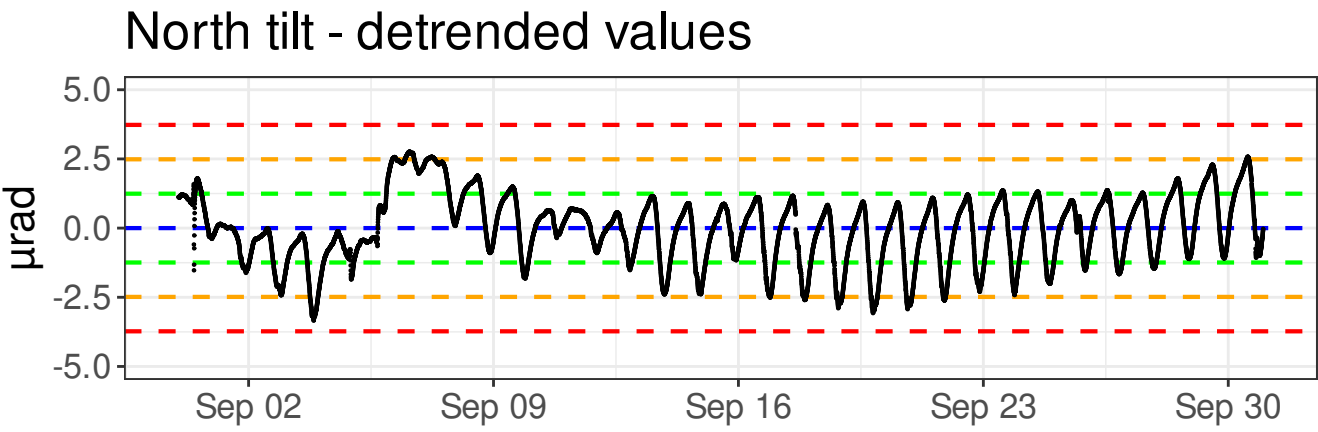
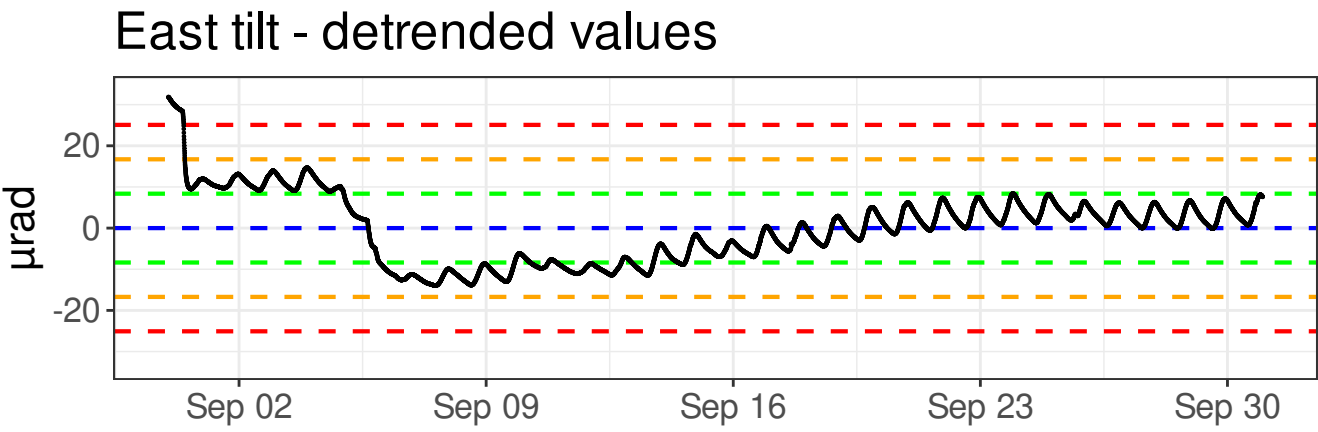
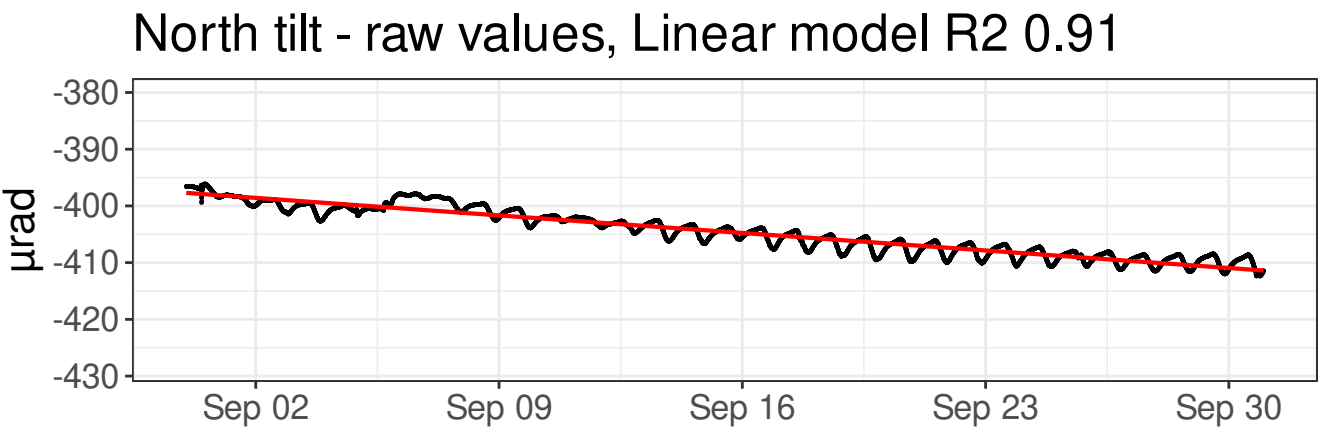
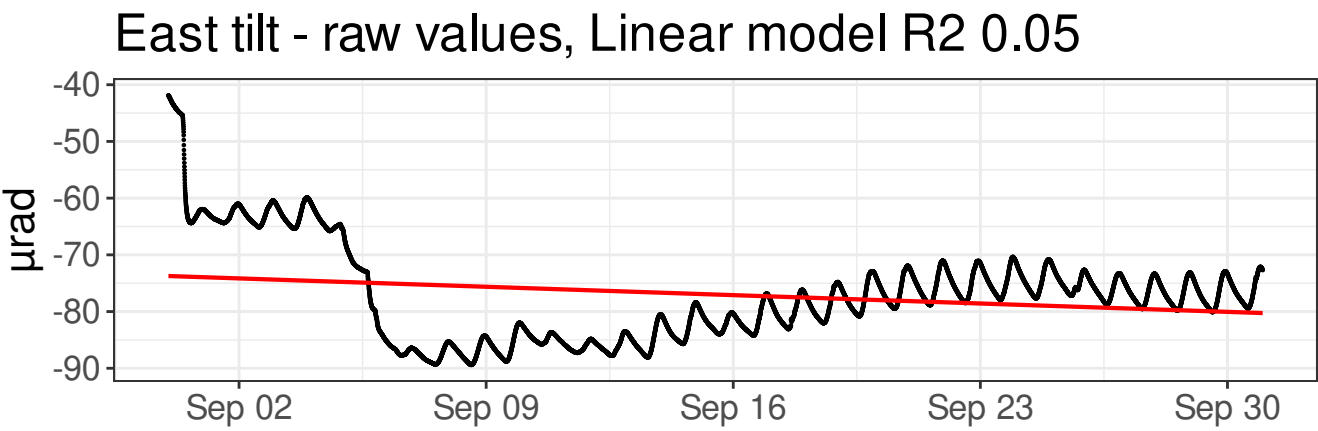
SSD04, 08/31/2024 - 09/30/2024



East tilt rate: 10.14 ± 0.98 $\mu\text{rad}/\text{year}$
North tilt rate: -614.51 ± 0.62 $\mu\text{rad}/\text{year}$
Azimuth to C7: 182 deg
Distance to C7: 688 ft

--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD05, 08/31/2024 - 09/30/2024

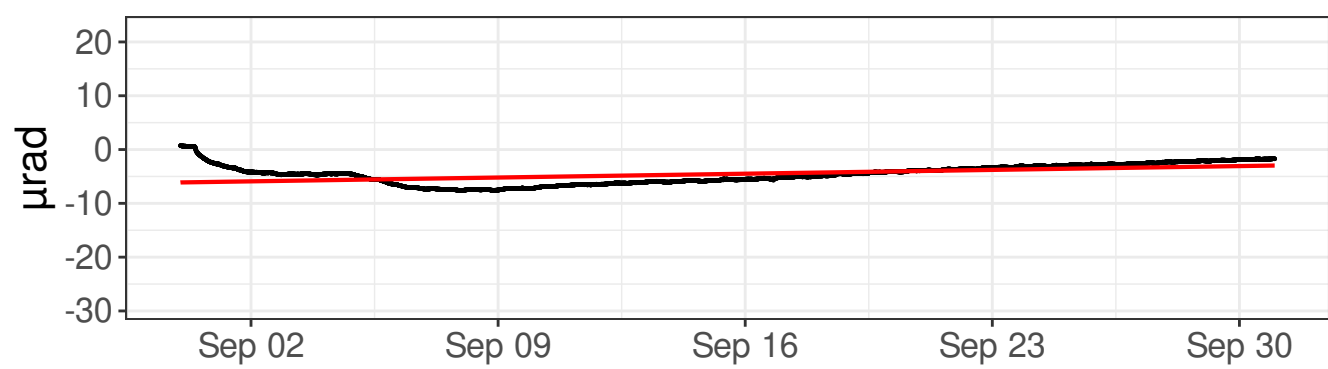


East tilt rate: $-77.11 \pm 3.23 \mu\text{rad}/\text{year}$
North tilt rate: $-161.65 \pm 0.48 \mu\text{rad}/\text{year}$
Azimuth to C7: 128 deg
Distance to C7: 512 ft

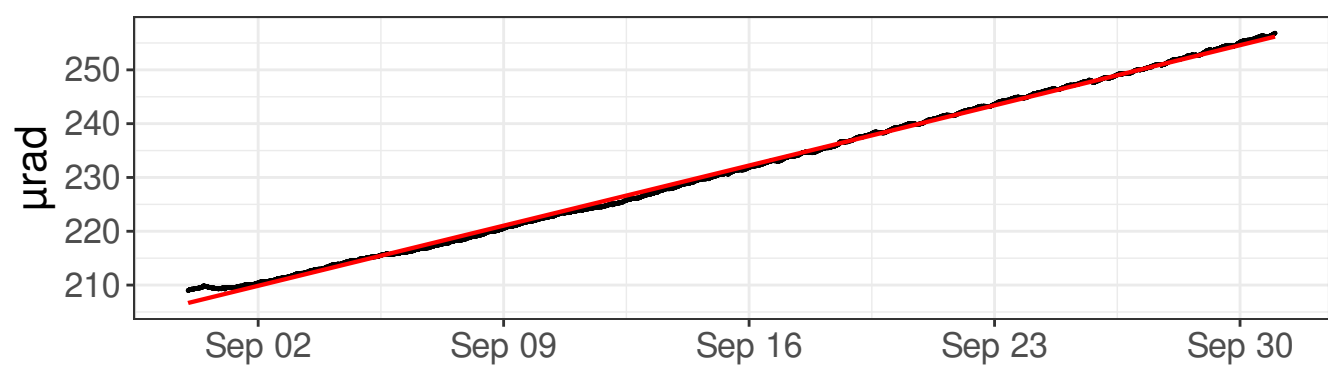
--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD06, 08/31/2024 - 09/30/2024

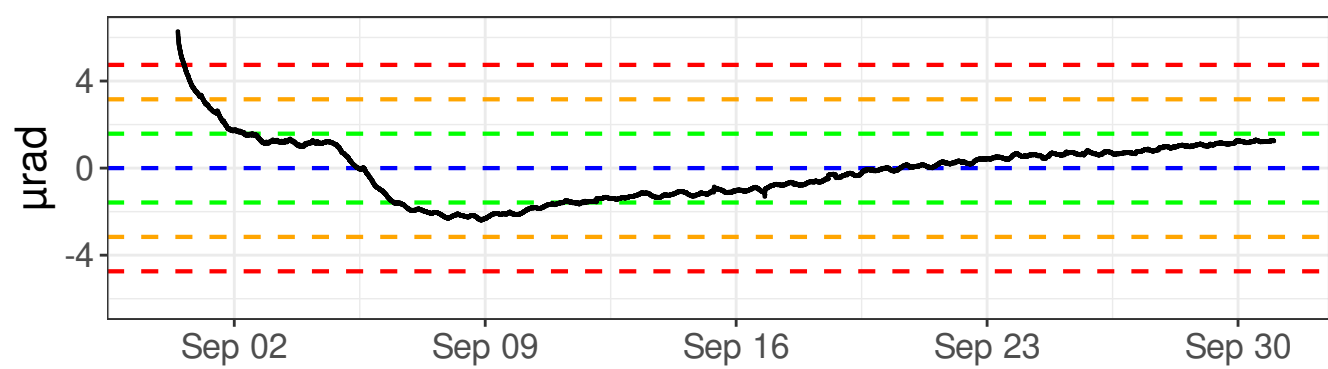
East tilt - raw values, Linear model R2 0.25



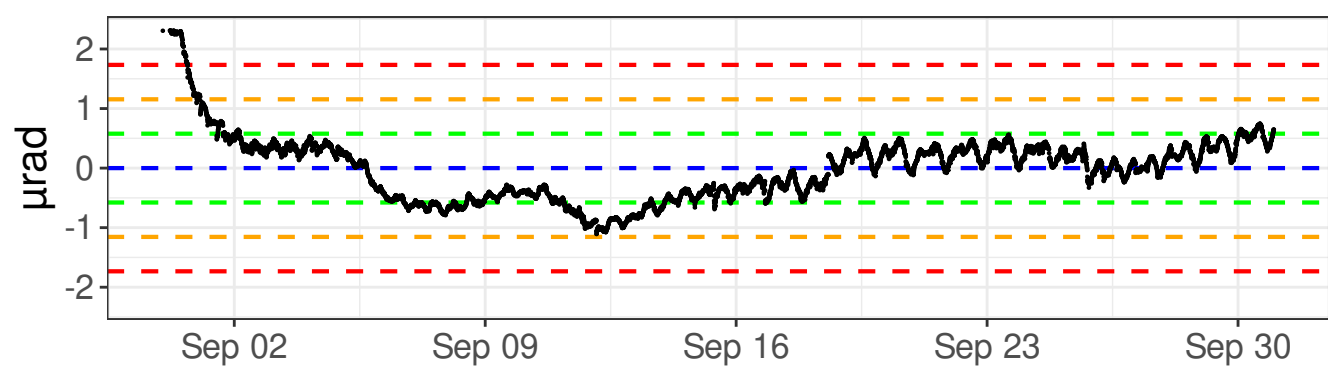
North tilt - raw values, Linear model R2 1.00



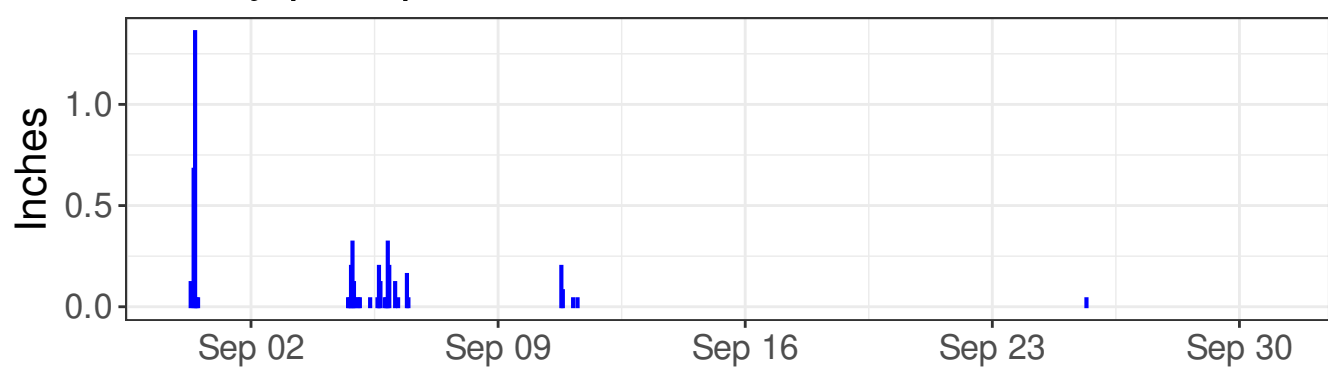
East tilt - detrended values



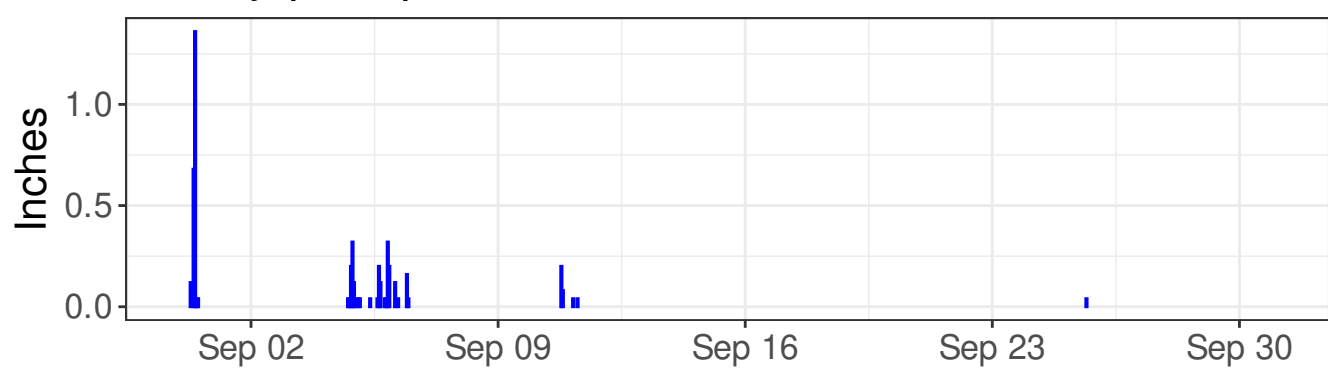
North tilt - detrended values



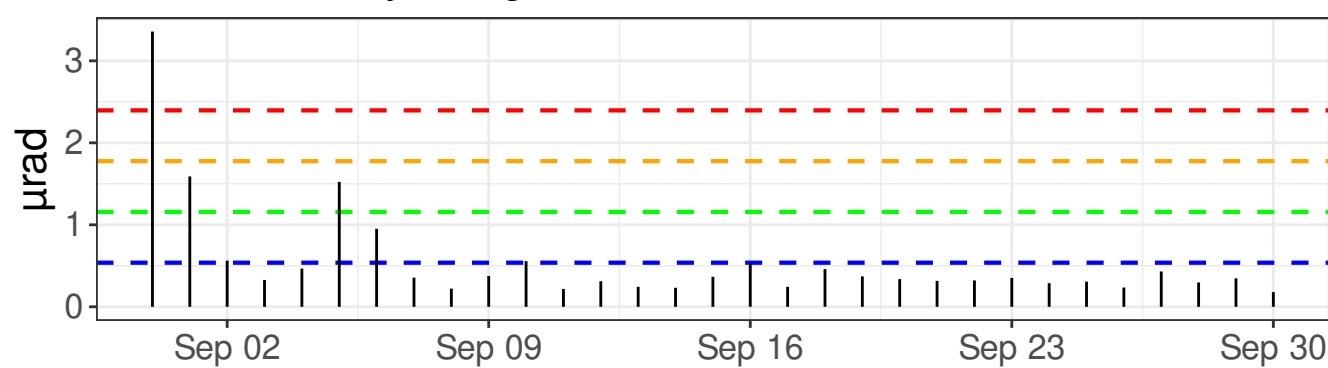
Hourly precipitation



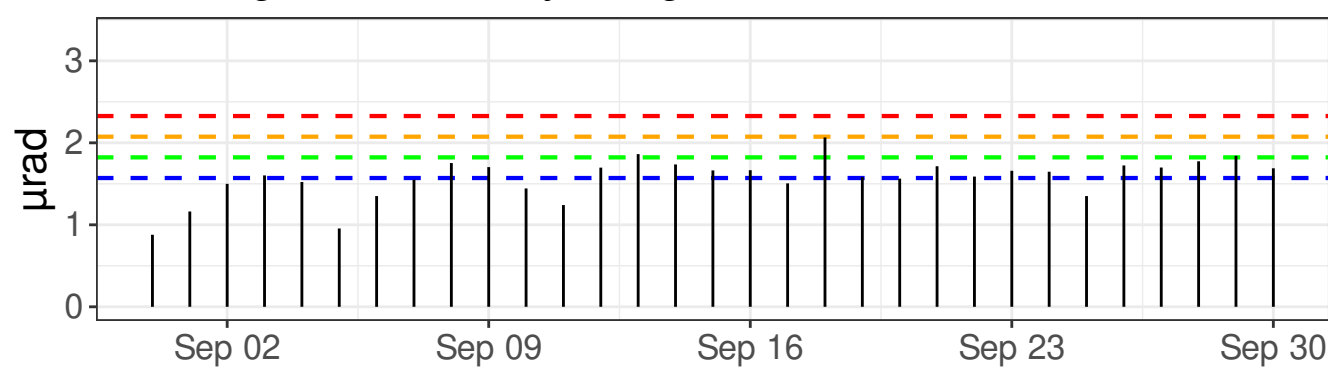
Hourly precipitation



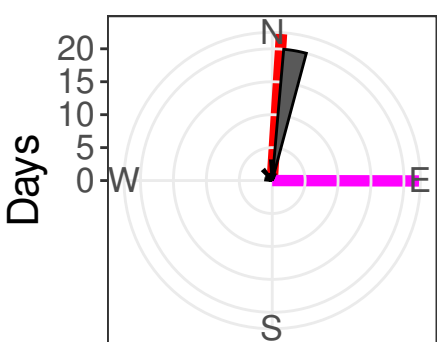
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $37.10 \pm 0.61 \mu\text{rad}/\text{year}$

North tilt rate: $584.60 \pm 0.22 \mu\text{rad}/\text{year}$

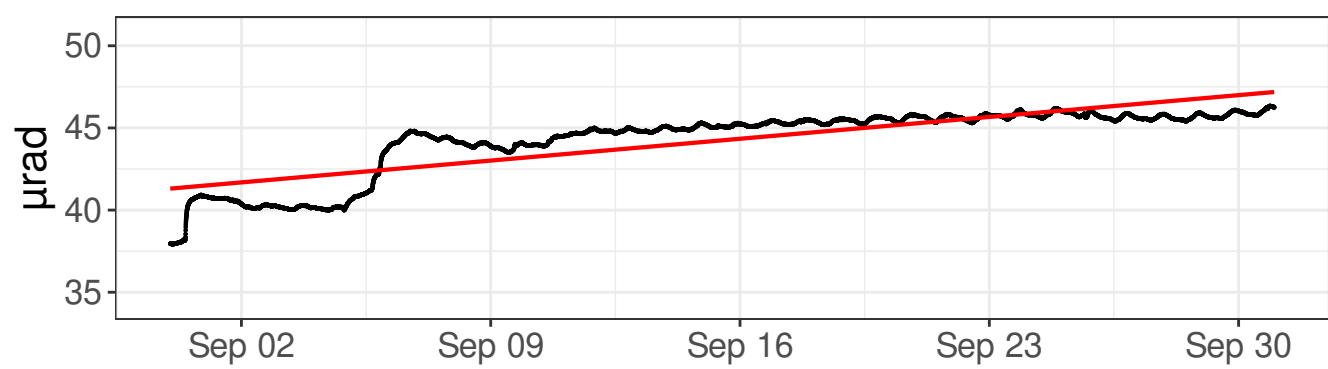
Azimuth to C7: 90 deg

Distance to C7: 494 ft

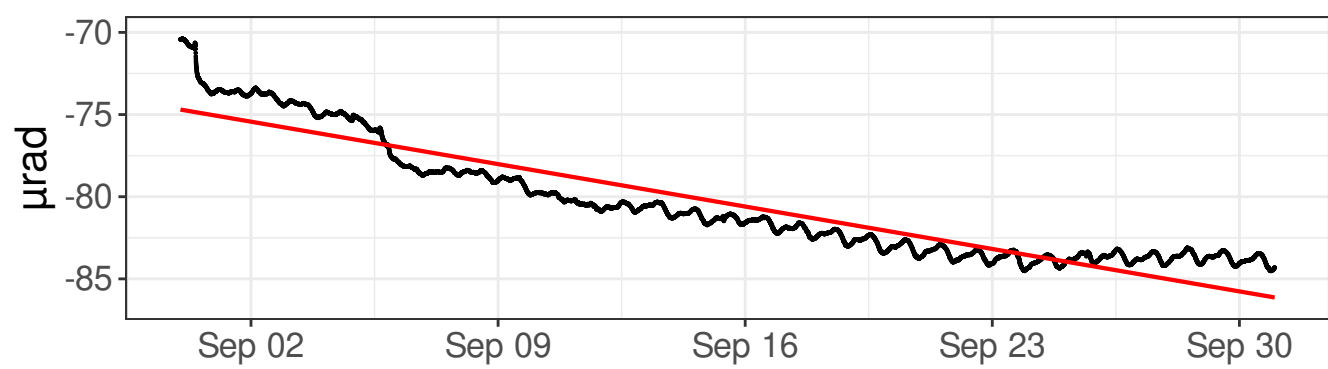
--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD07, 08/31/2024 - 09/30/2024

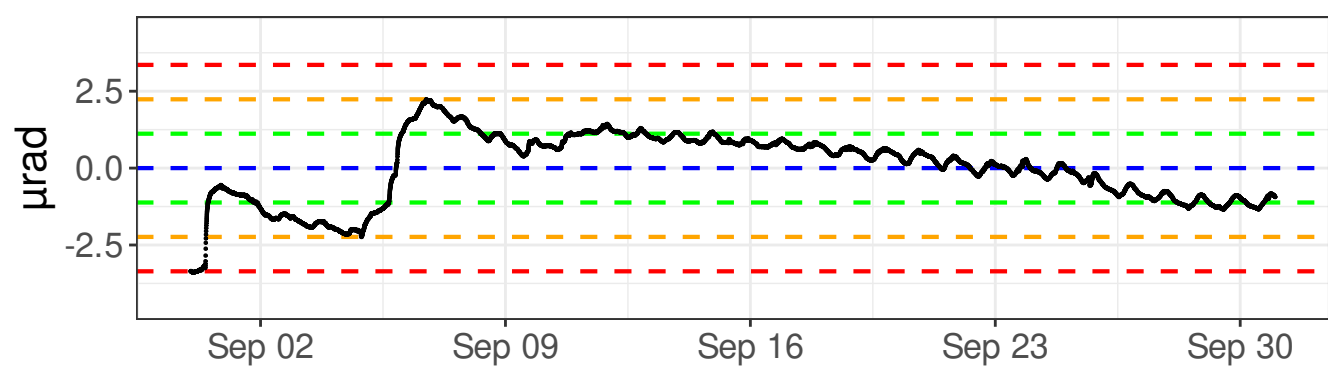
East tilt - raw values, Linear model R2 0.70



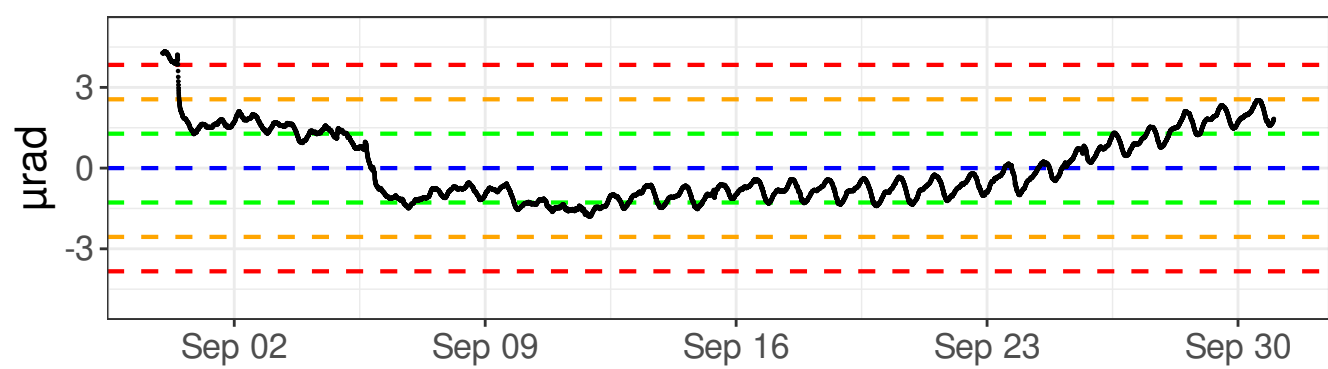
North tilt - raw values, Linear model R2 0.87



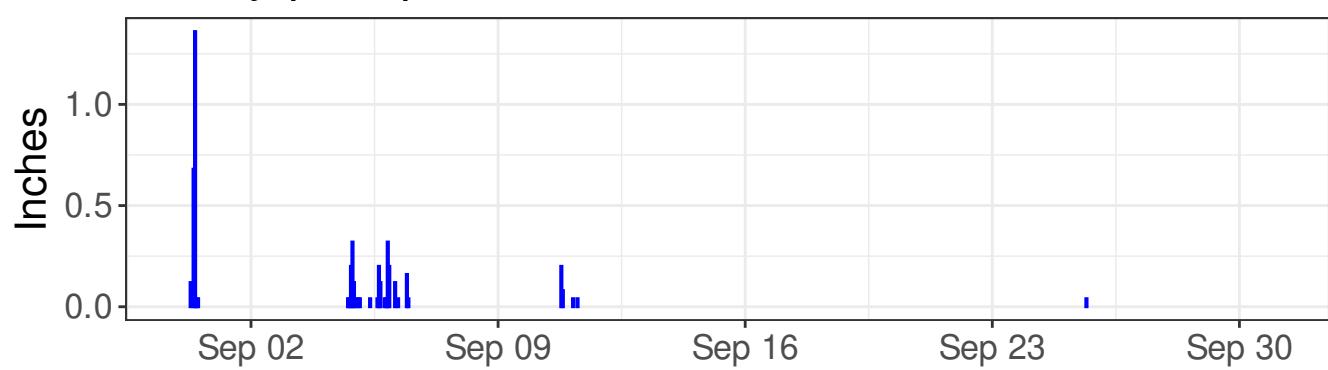
East tilt - detrended values



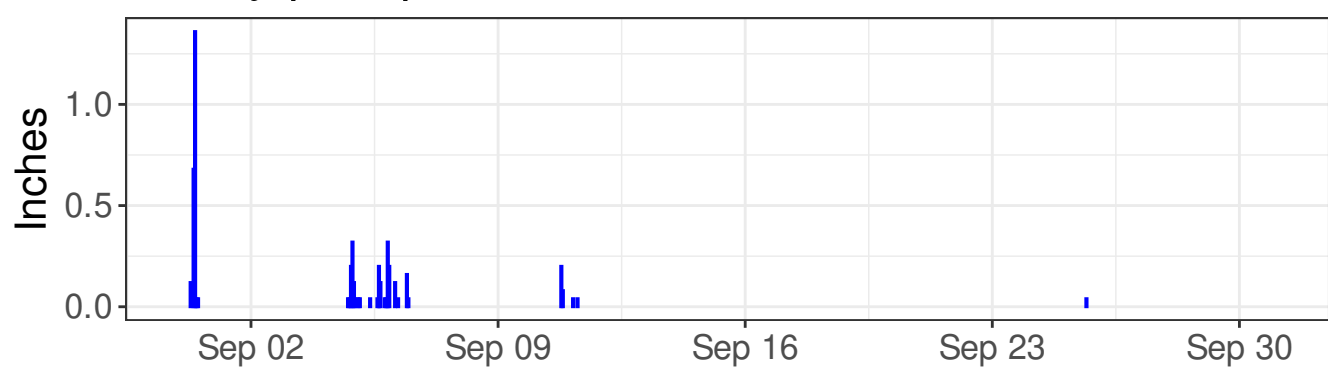
North tilt - detrended values



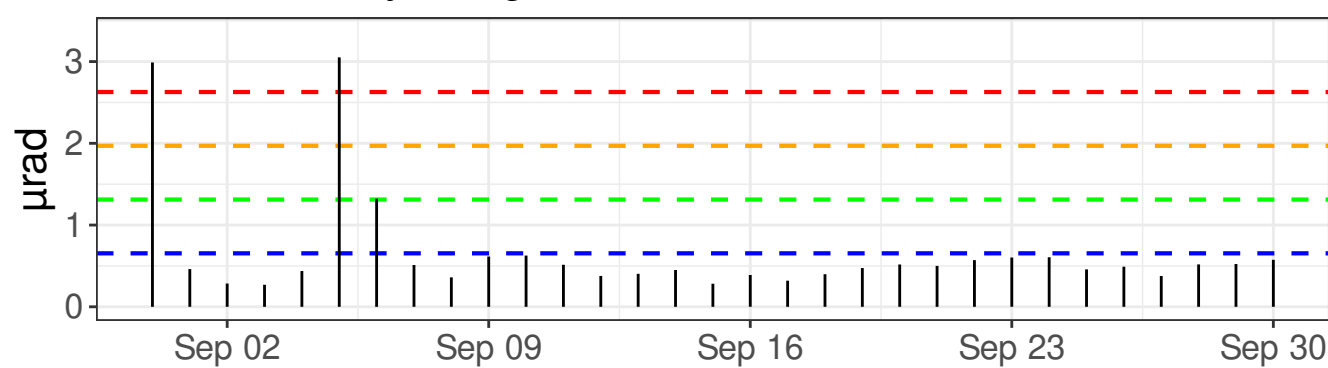
Hourly precipitation



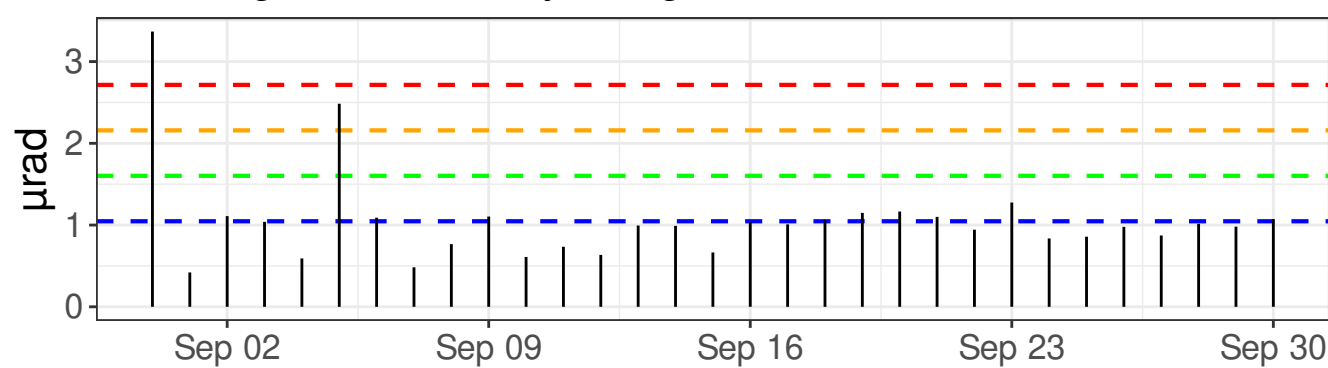
Hourly precipitation



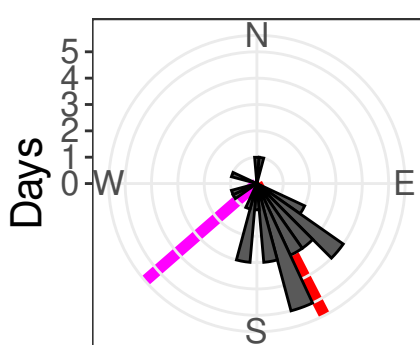
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $69.41 \pm 0.43 \mu\text{rad}/\text{year}$

North tilt rate: $-135.02 \pm 0.49 \mu\text{rad}/\text{year}$

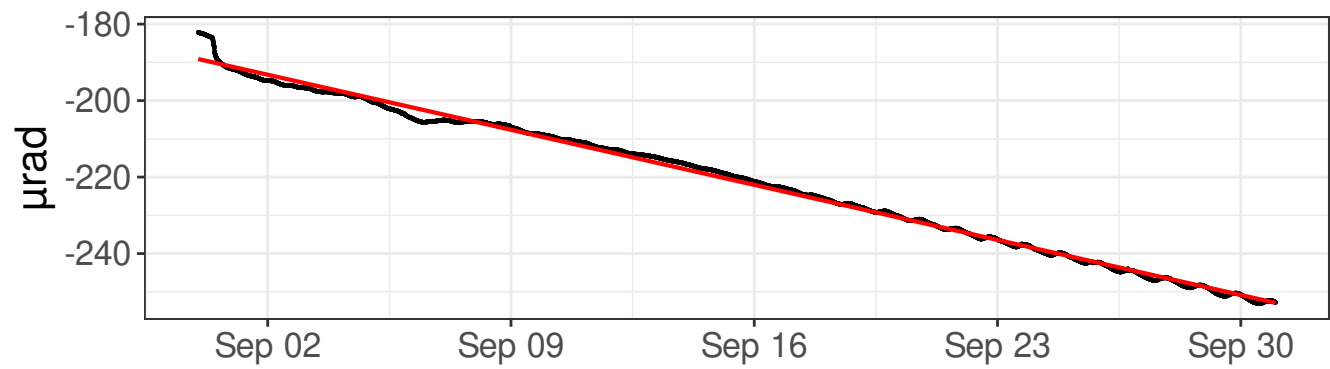
Azimuth to C7: 229 deg

Distance to C7: 513 ft

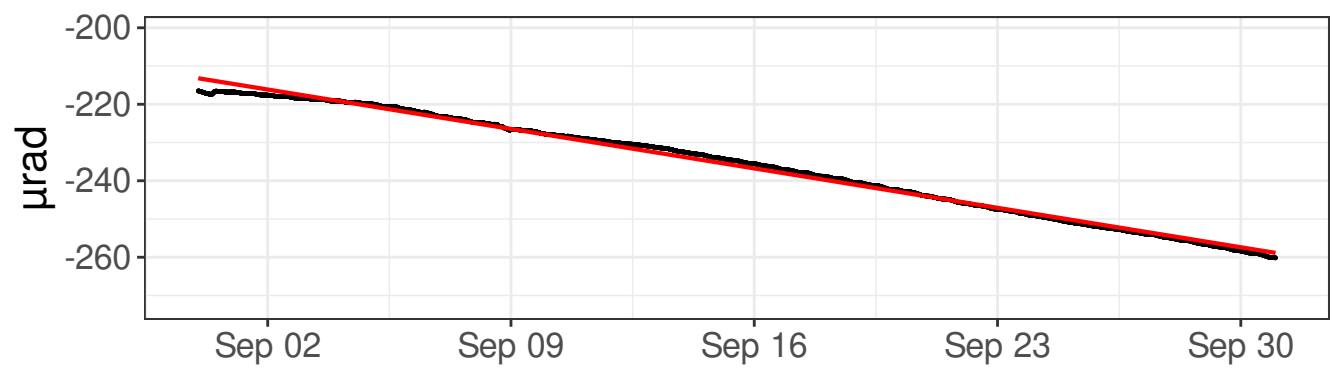
--- 0σ --- 1σ --- 2σ --- 3σ
— Linear model — Azimuth to C7

SSD08, 08/31/2024 - 09/30/2024

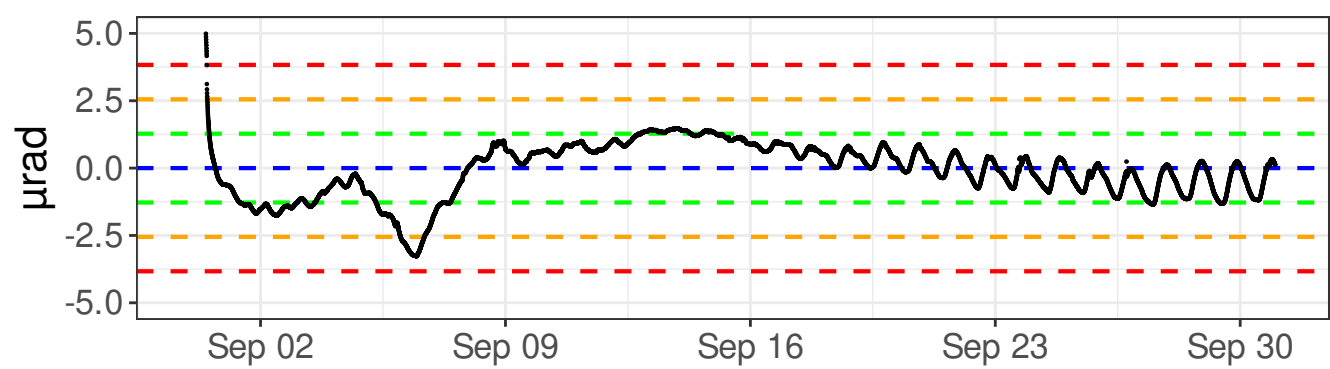
East tilt - raw values, Linear model R2 1.00



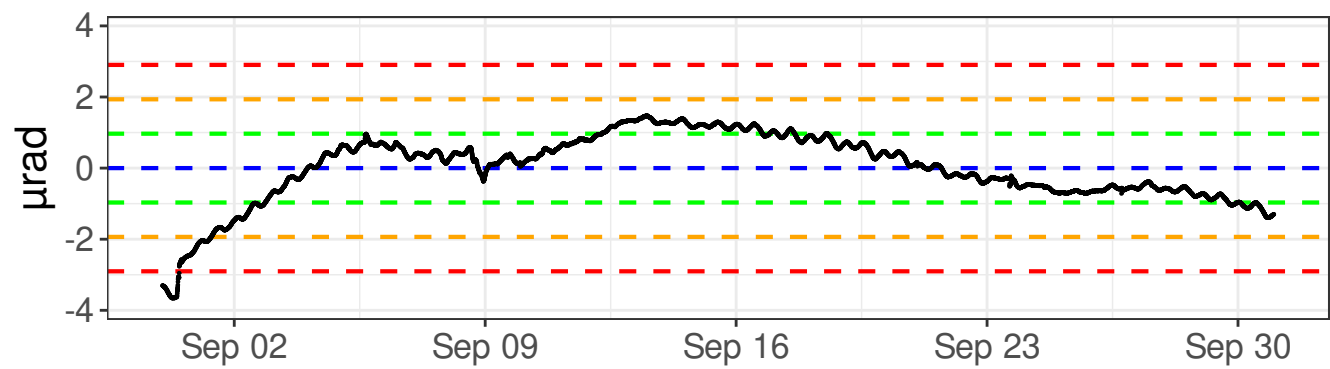
North tilt - raw values, Linear model R2 0.99



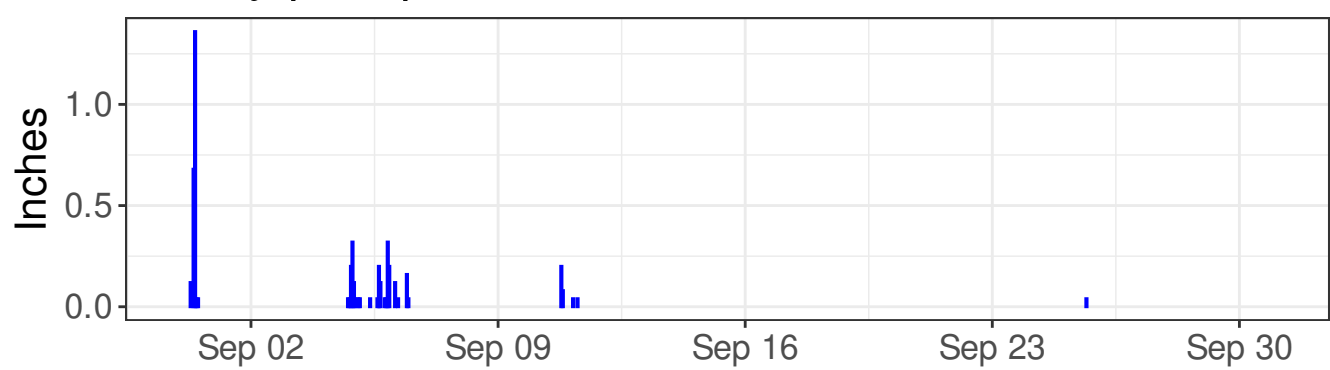
East tilt - detrended values



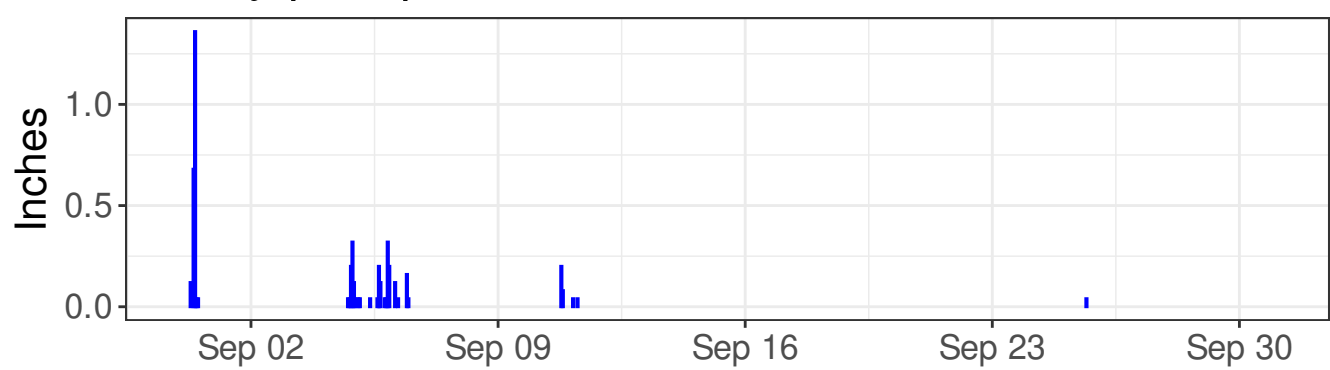
North tilt - detrended values



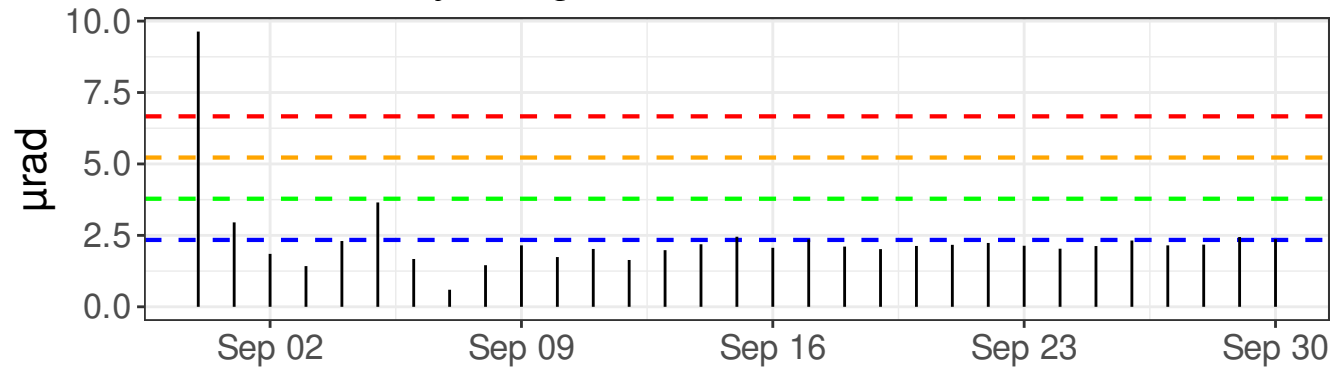
Hourly precipitation



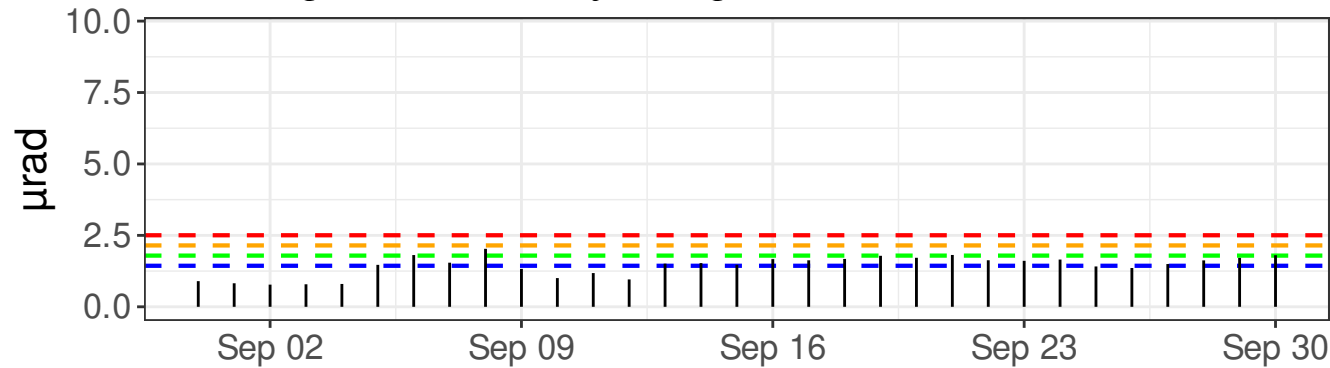
Hourly precipitation



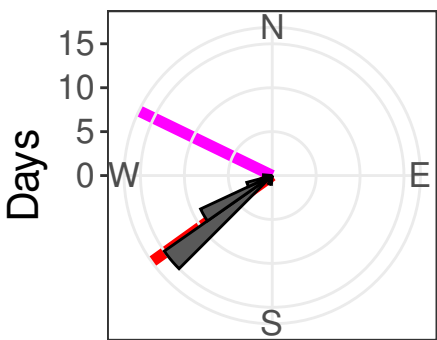
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: -752.83 ± 0.49 μrad/year

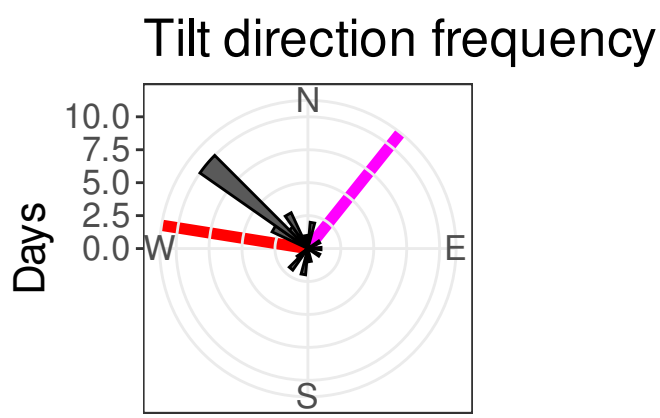
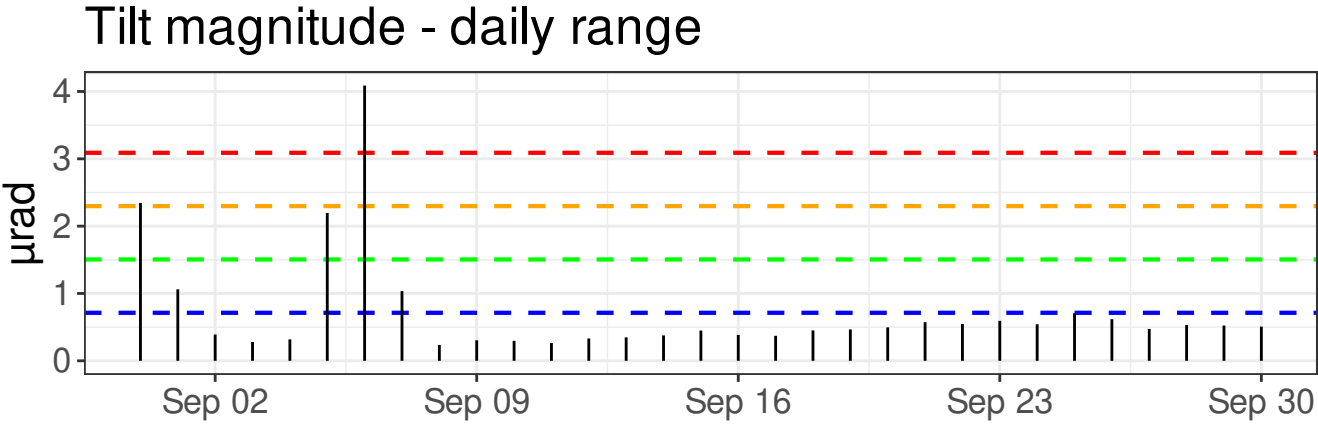
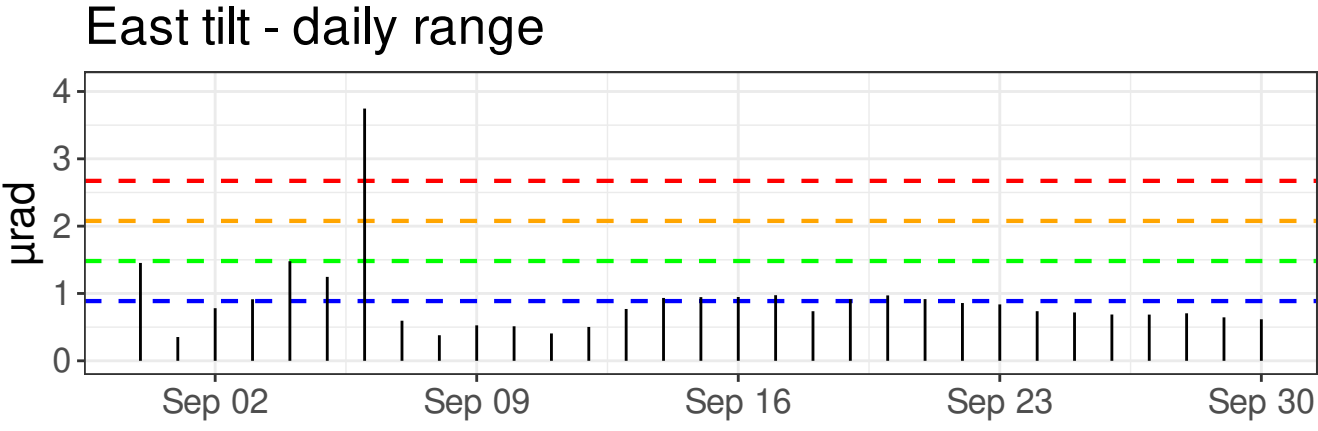
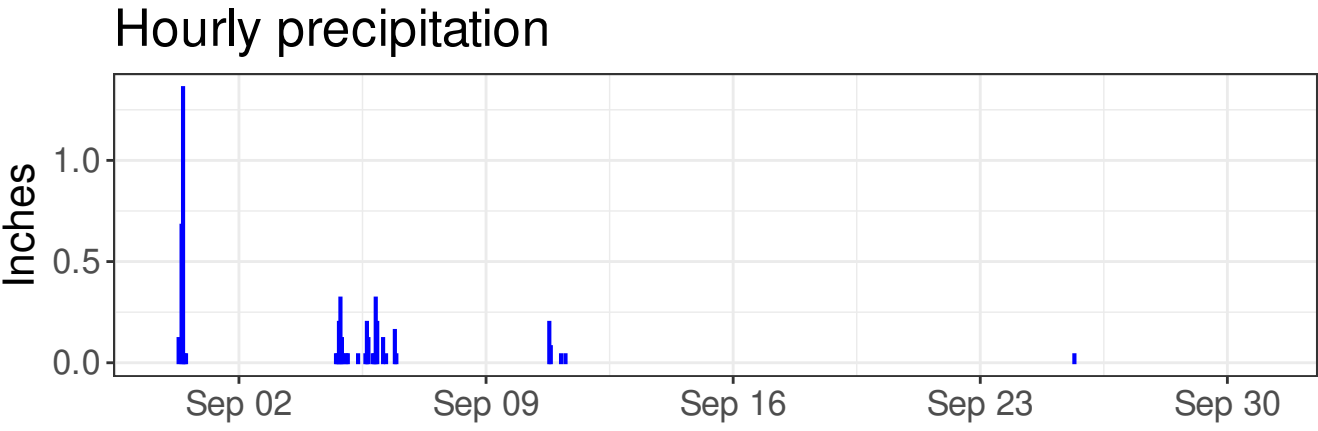
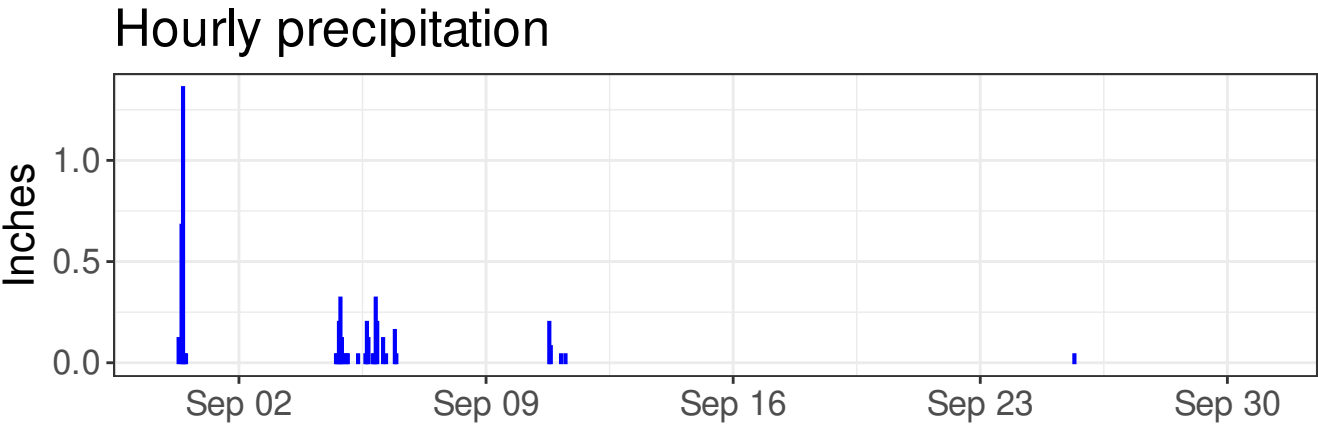
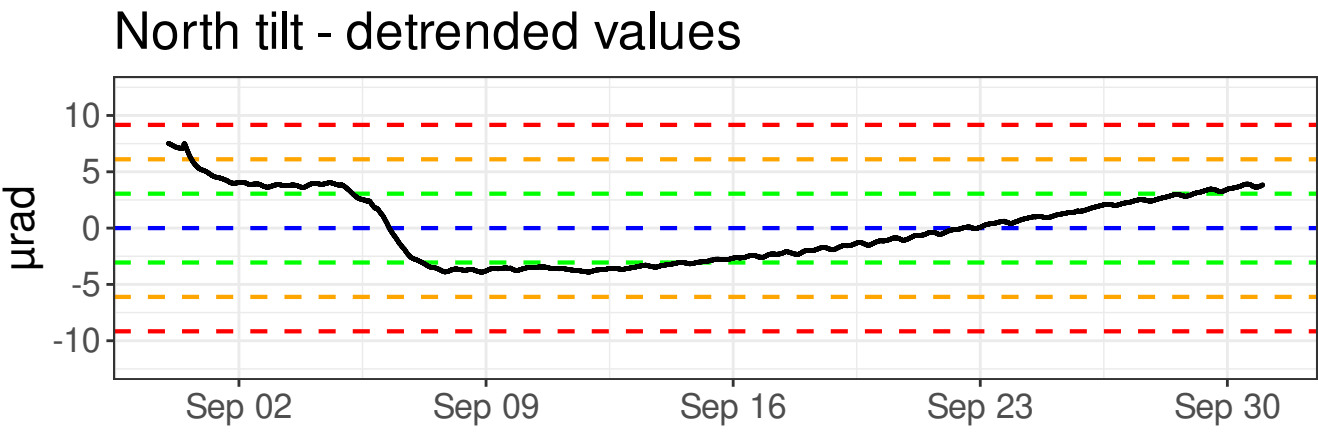
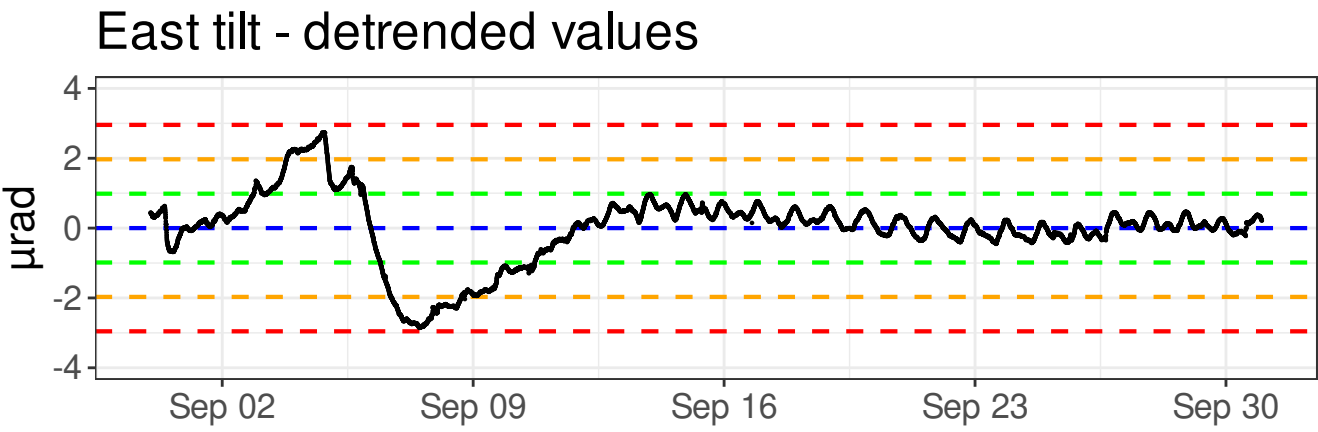
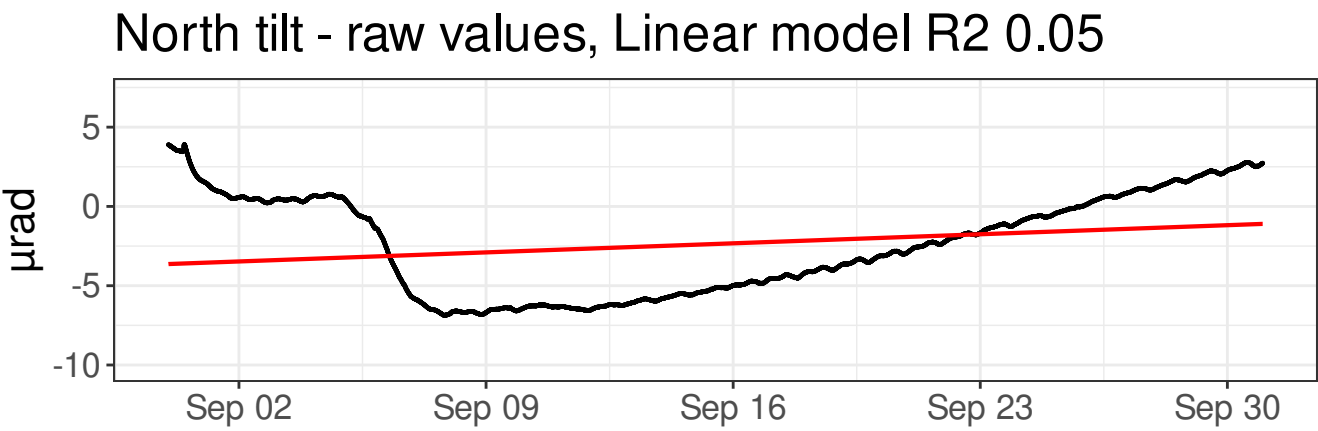
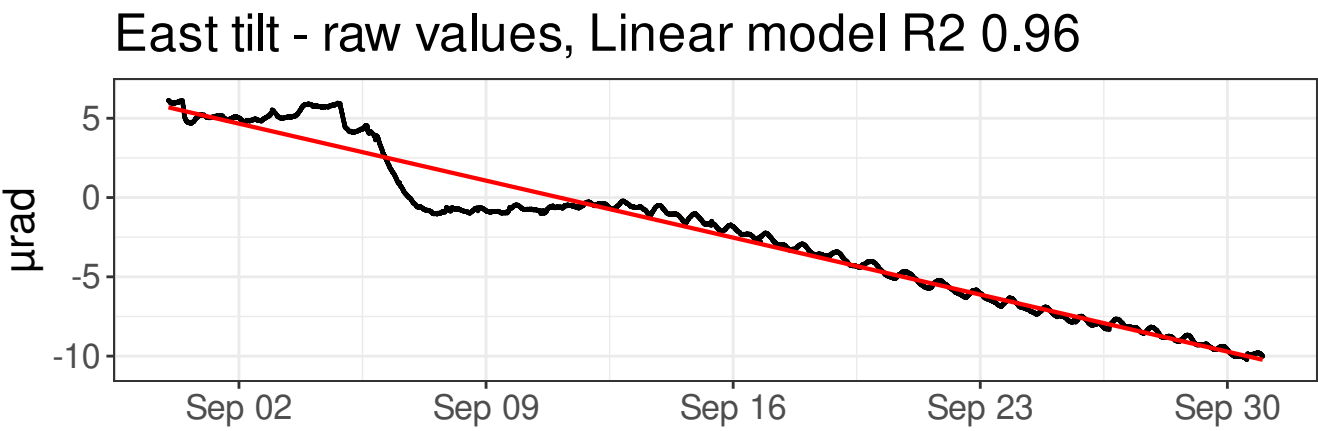
North tilt rate: -539.22 ± 0.37 μrad/year

Azimuth to C7: 296 deg

Distance to C7: 186 ft

--- 0σ --- 1σ --- 2σ --- 3σ
— Linear model — Azimuth to C7

SSD09, 08/31/2024 - 09/30/2024

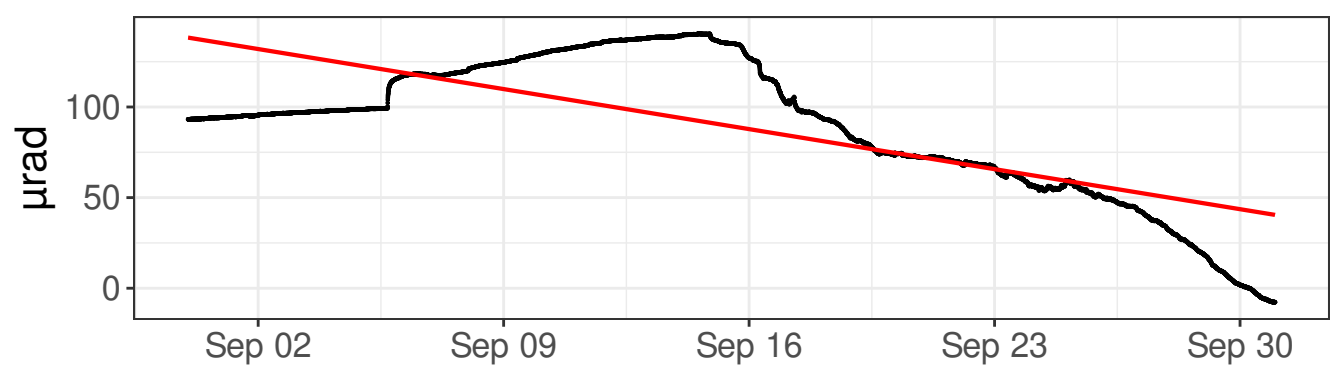


East tilt rate: $-187.92 \pm 0.38 \mu\text{rad}/\text{year}$
North tilt rate: $29.90 \pm 1.18 \mu\text{rad}/\text{year}$
Azimuth to C7: 39 deg
Distance to C7: 561 ft

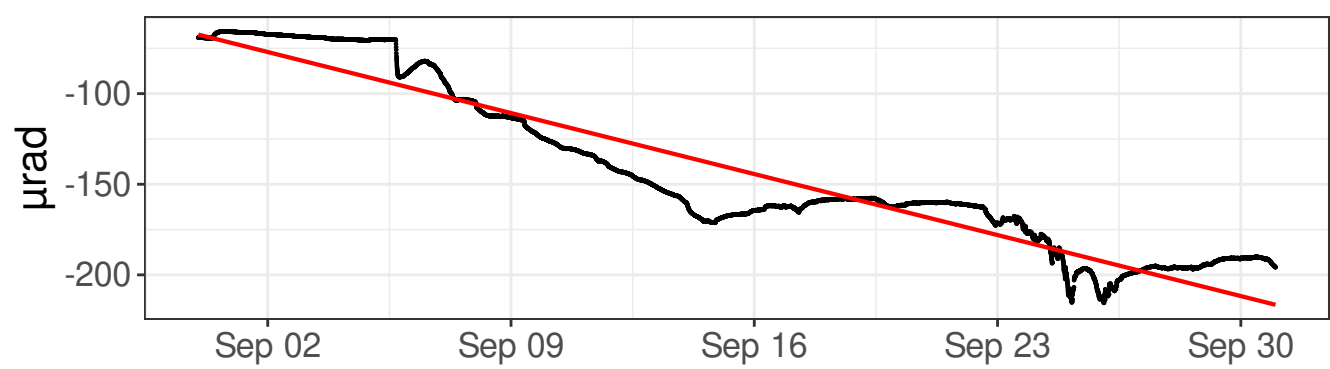
--- 0σ --- 1σ --- 2σ --- 3σ
— Linear model — Azimuth to C7

SSD10, 08/31/2024 - 09/30/2024

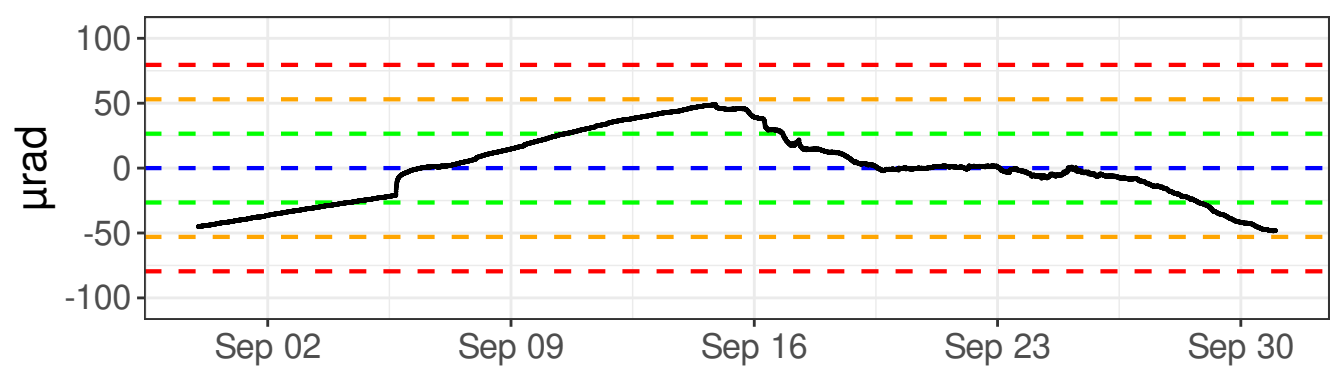
East tilt - raw values, Linear model R2 0.53



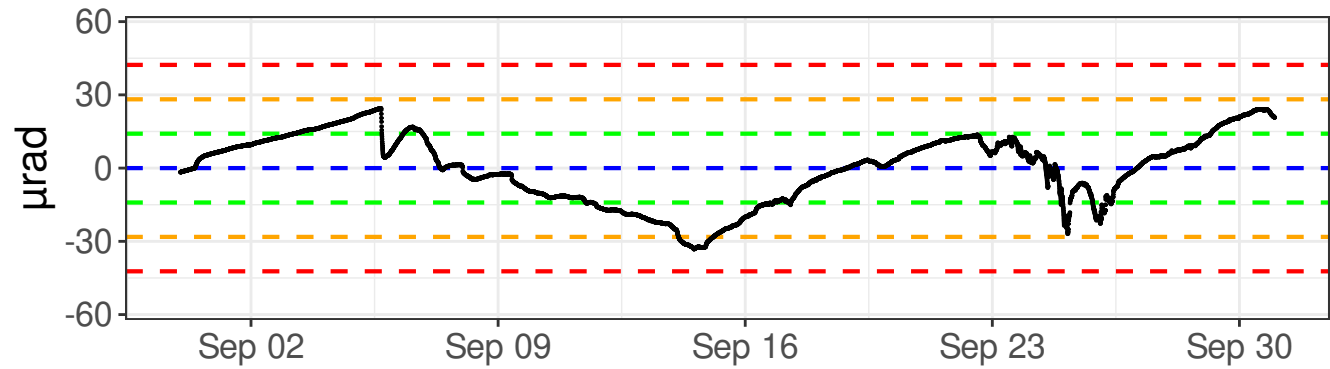
North tilt - raw values, Linear model R2 0.90



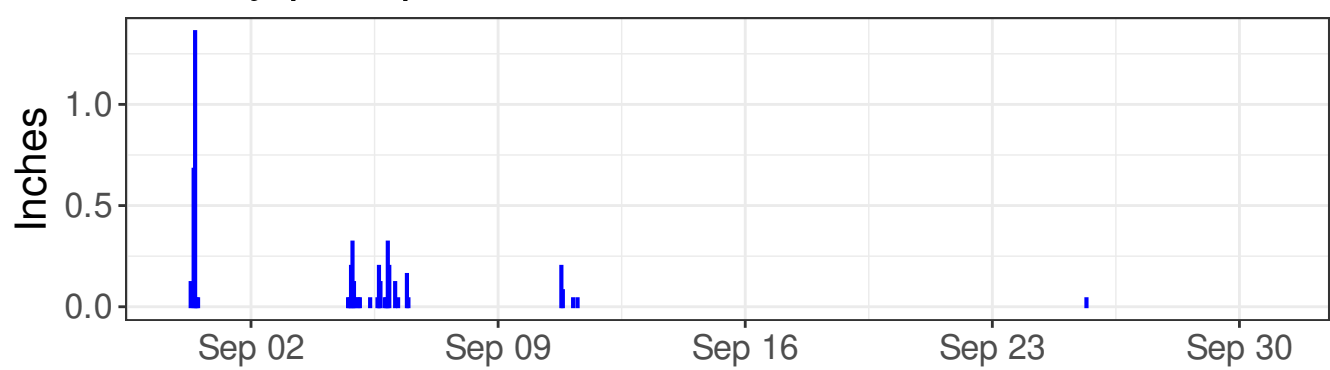
East tilt - detrended values



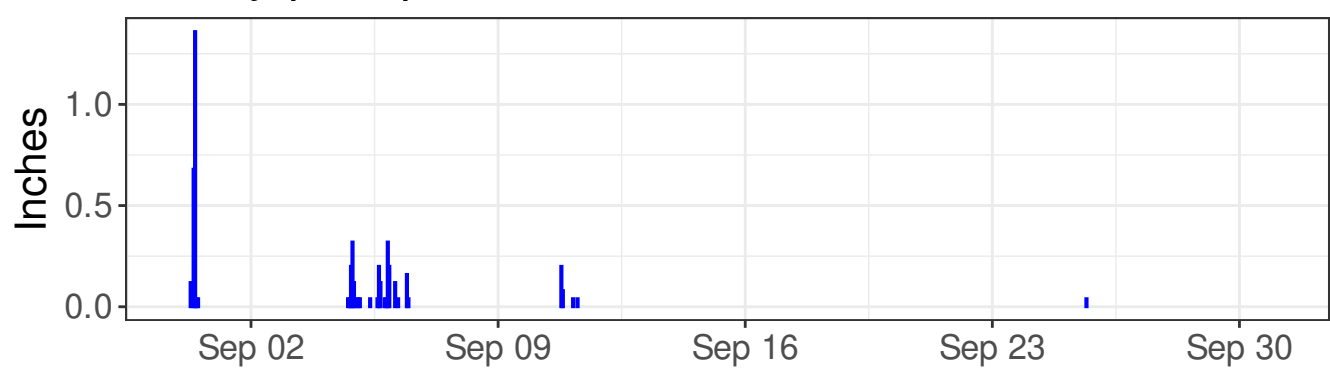
North tilt - detrended values



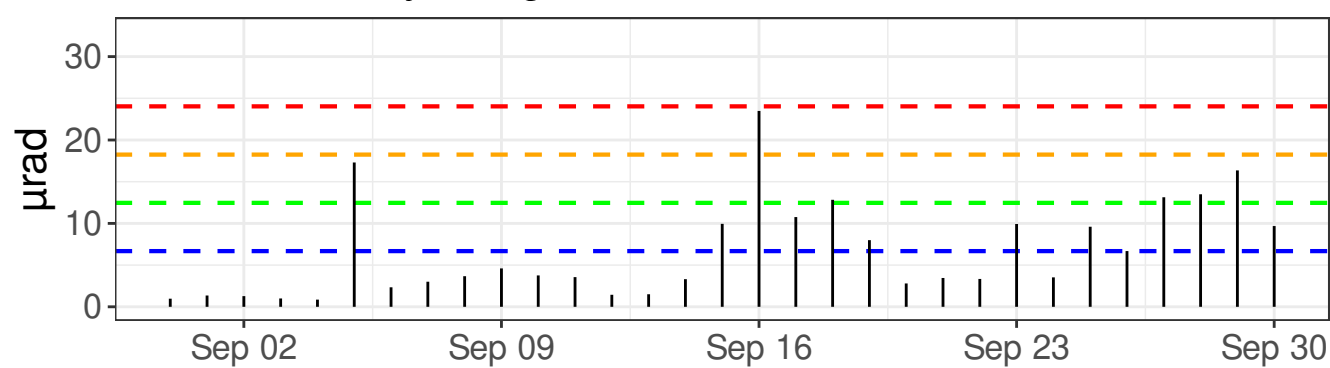
Hourly precipitation



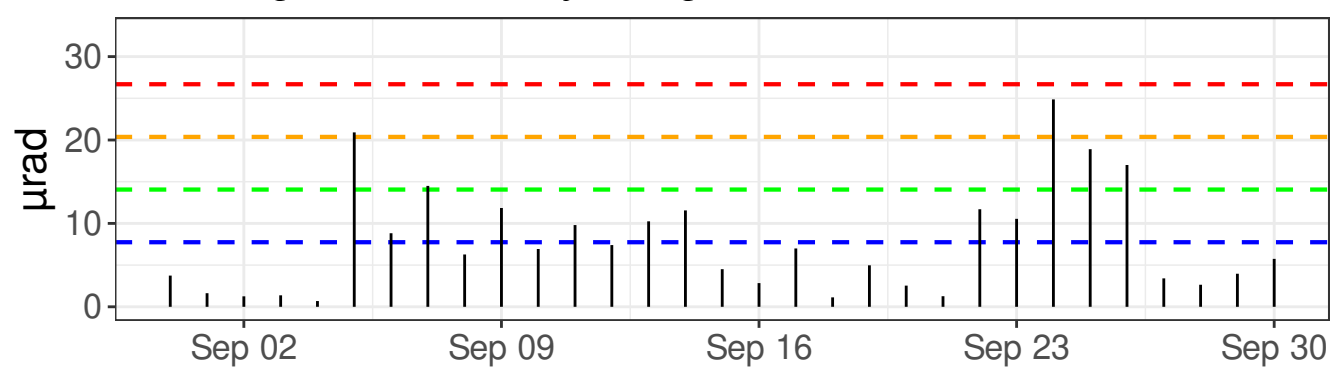
Hourly precipitation



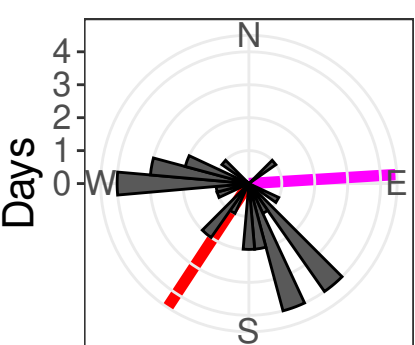
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $-1154.97 \pm 10.24 \mu\text{rad}/\text{year}$

North tilt rate: $-1760.16 \pm 5.44 \mu\text{rad}/\text{year}$

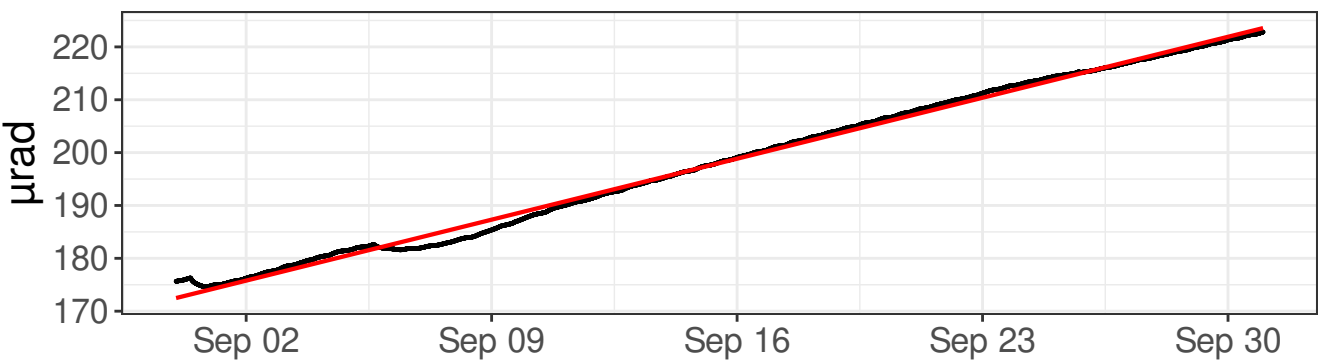
Azimuth to C7: 87 deg

Distance to C7: 2402 ft

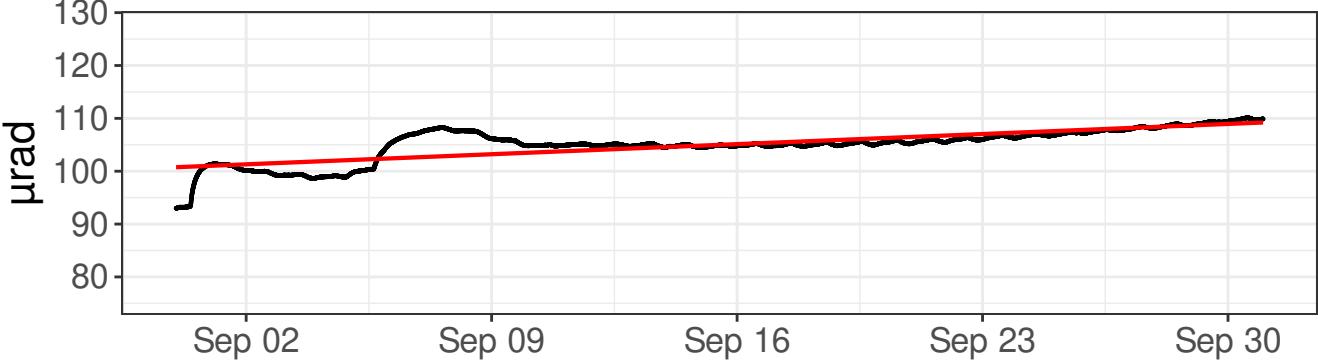
--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD11, 08/31/2024 - 09/30/2024

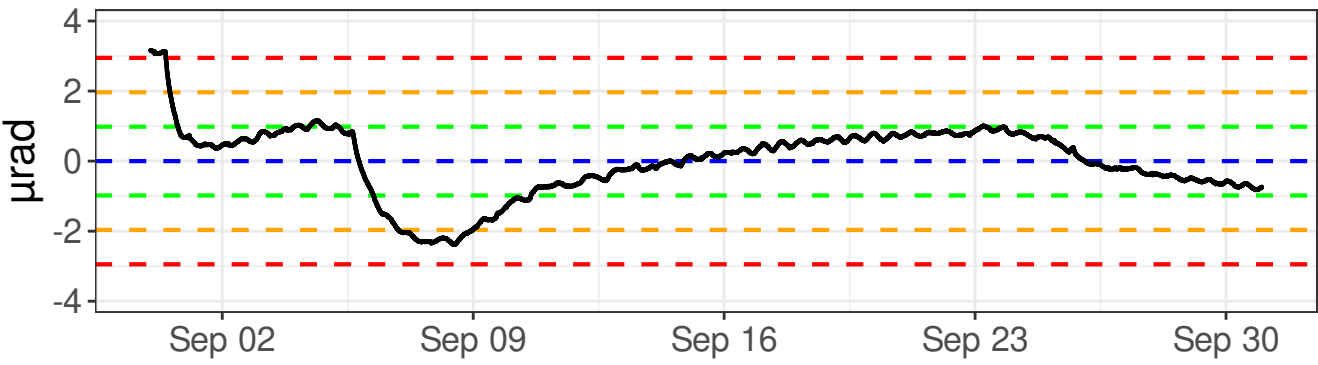
East tilt - raw values, Linear model R2 1.00



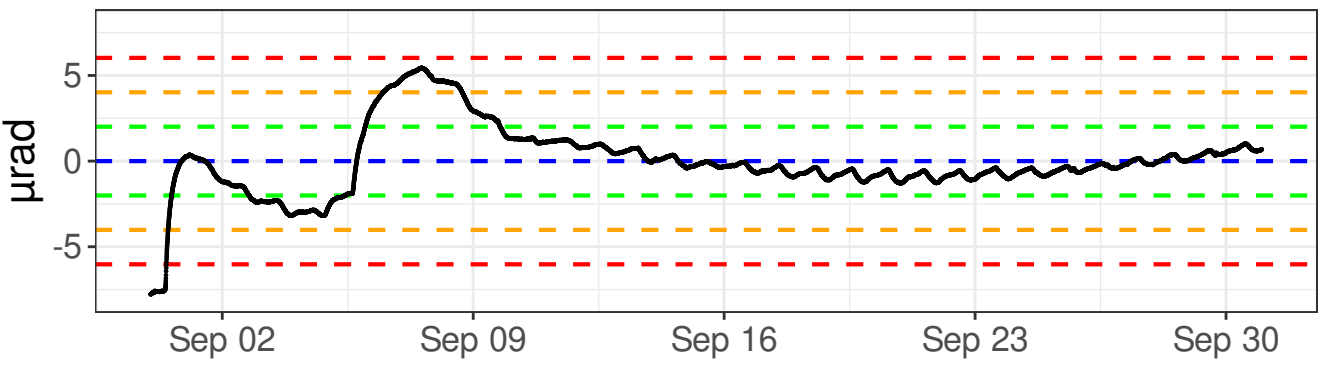
North tilt - raw values, Linear model R2 0.60



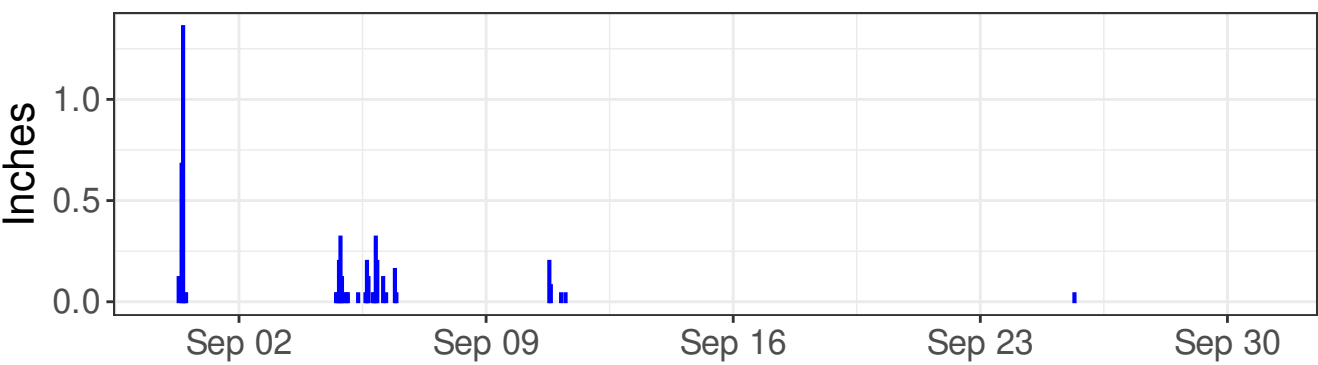
East tilt - detrended values



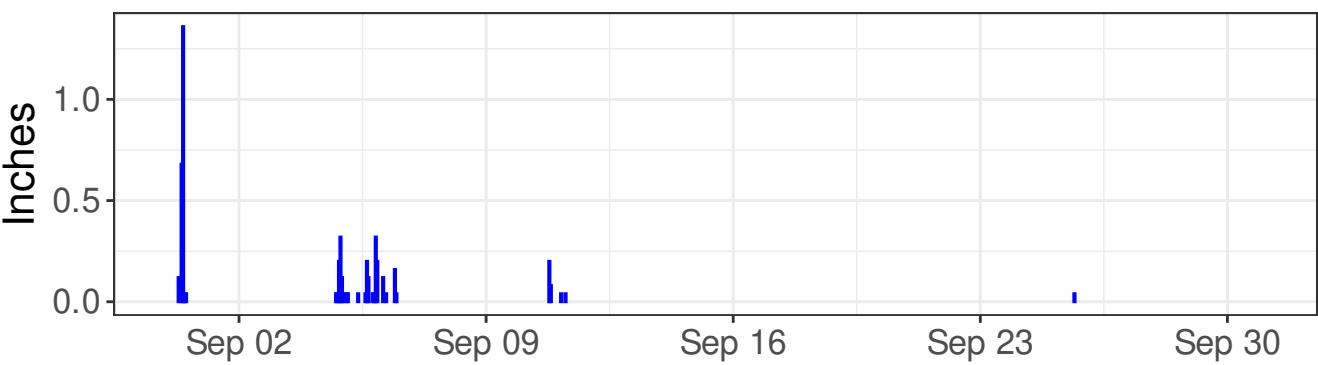
North tilt - detrended values



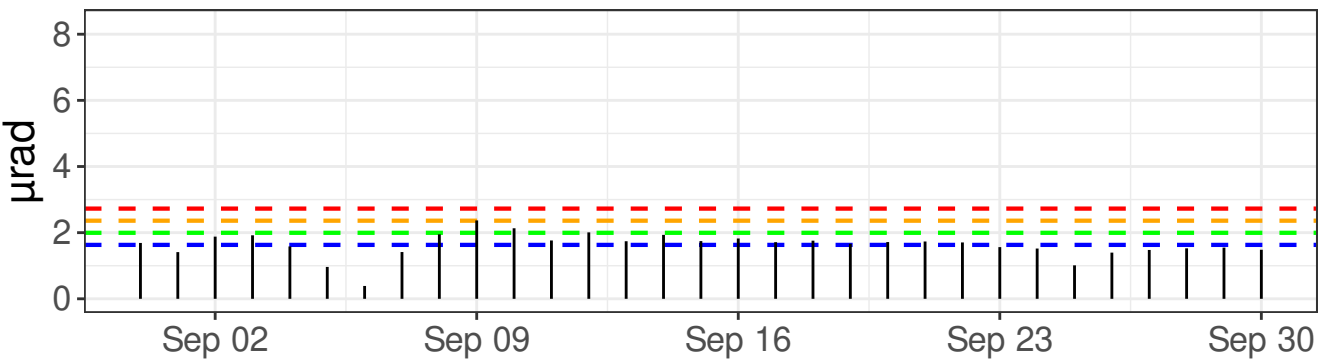
Hourly precipitation



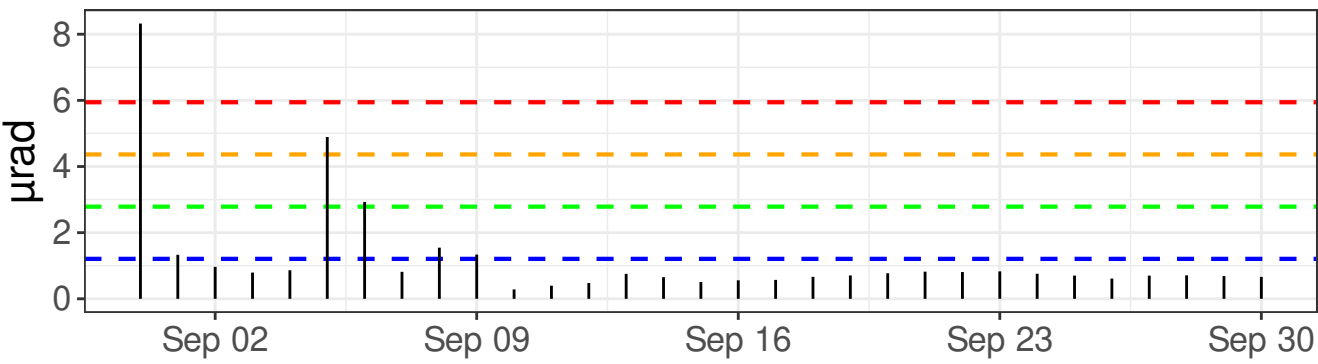
Hourly precipitation



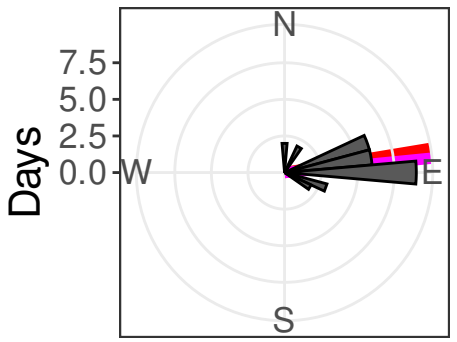
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $603.04 \pm 0.38 \mu\text{rad}/\text{year}$

North tilt rate: $99.92 \pm 0.78 \mu\text{rad}/\text{year}$

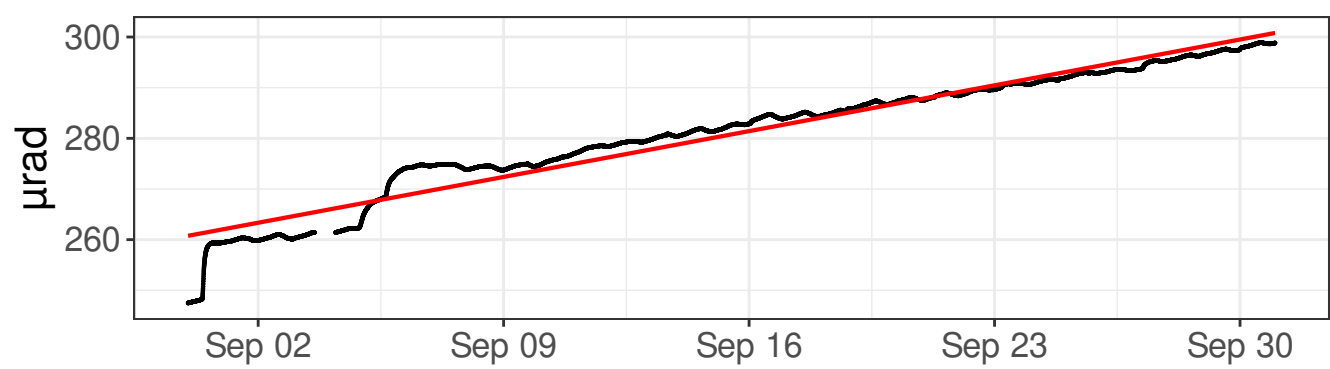
Azimuth to C7: 84 deg

Distance to C7: 1473 ft

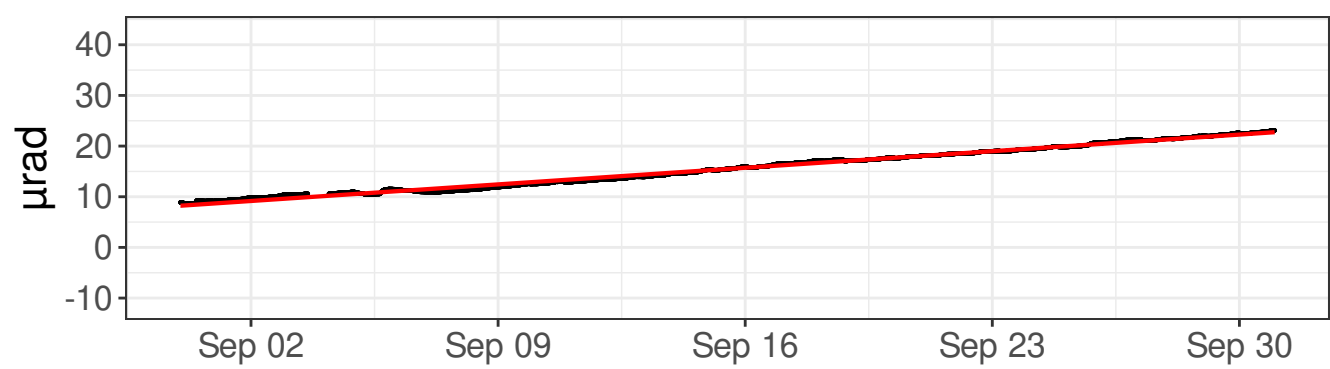
--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD12, 08/31/2024 - 09/30/2024

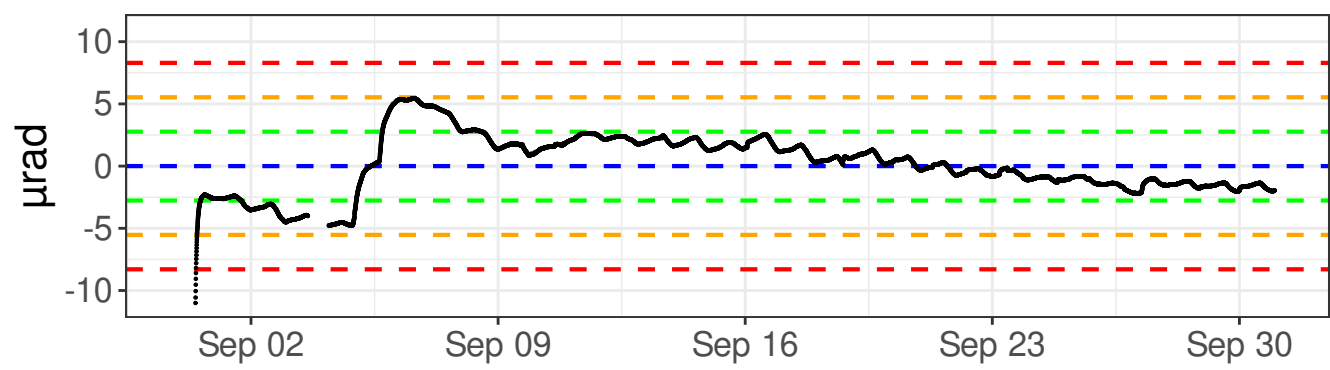
East tilt - raw values, Linear model R2 0.95



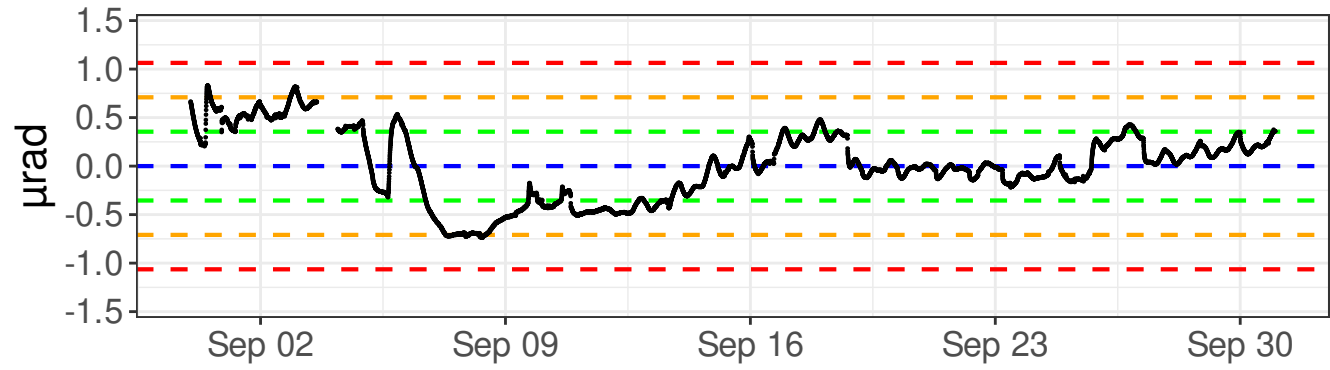
North tilt - raw values, Linear model R2 0.99



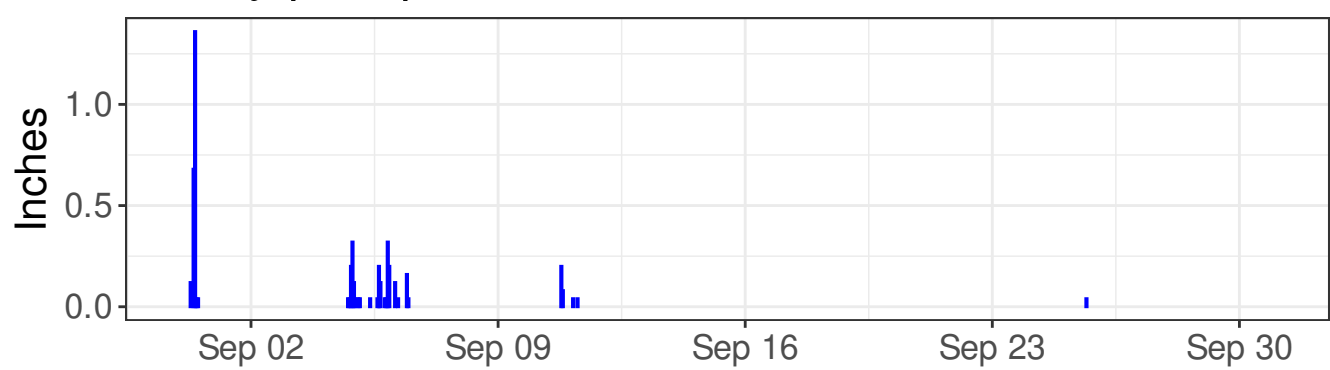
East tilt - detrended values



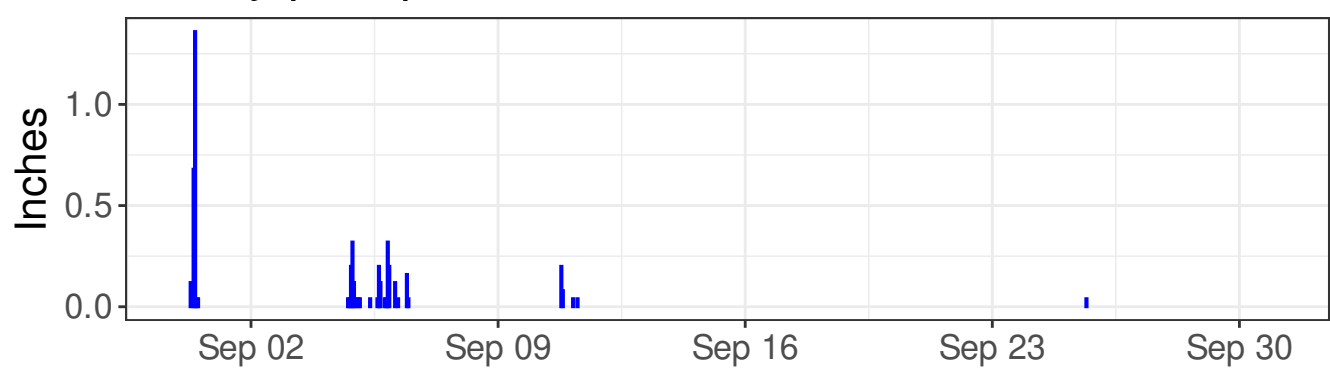
North tilt - detrended values



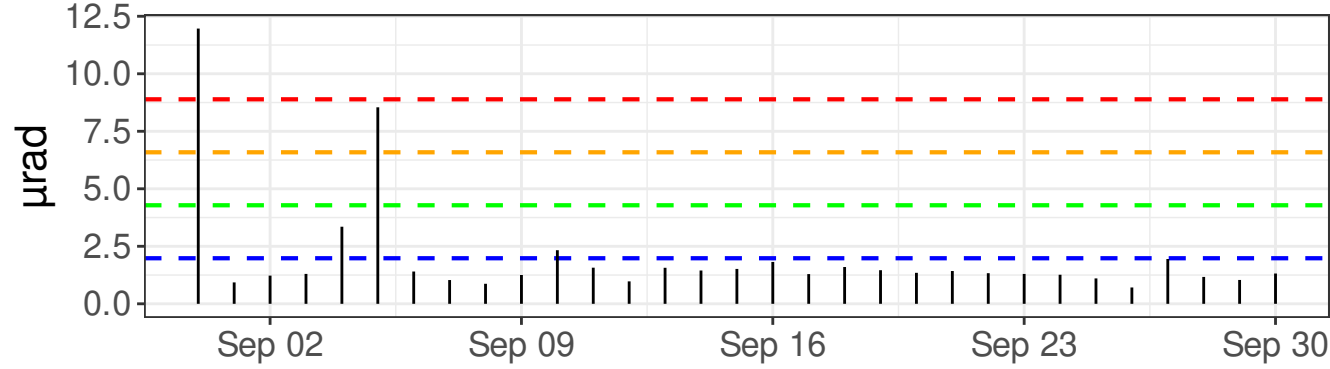
Hourly precipitation



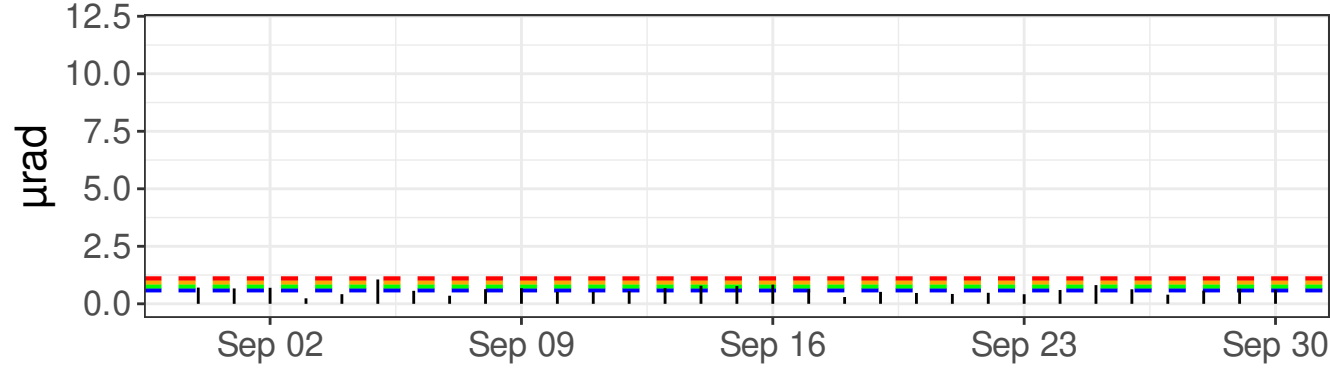
Hourly precipitation



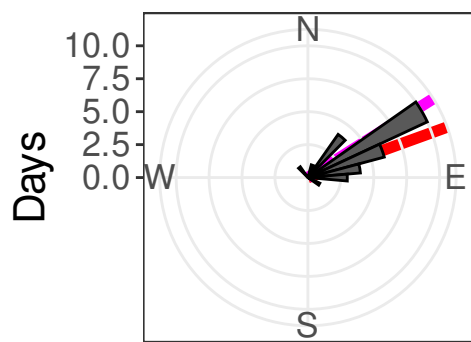
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $472.73 \pm 1.09 \mu\text{rad}/\text{year}$

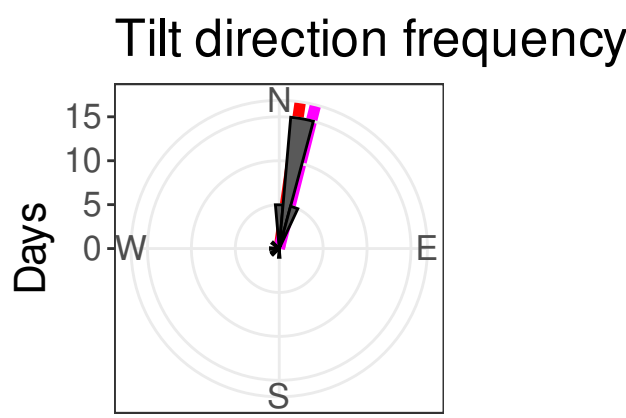
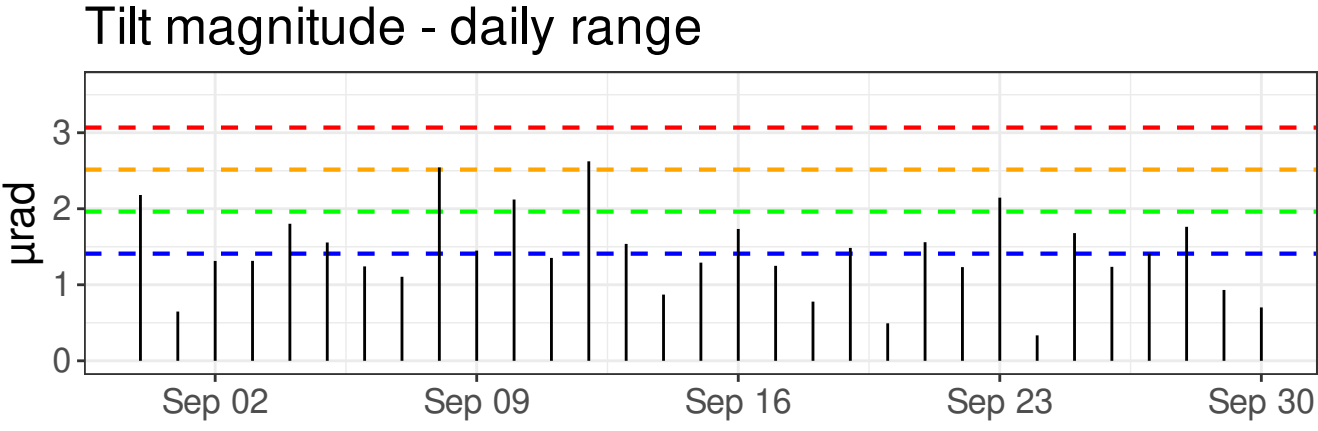
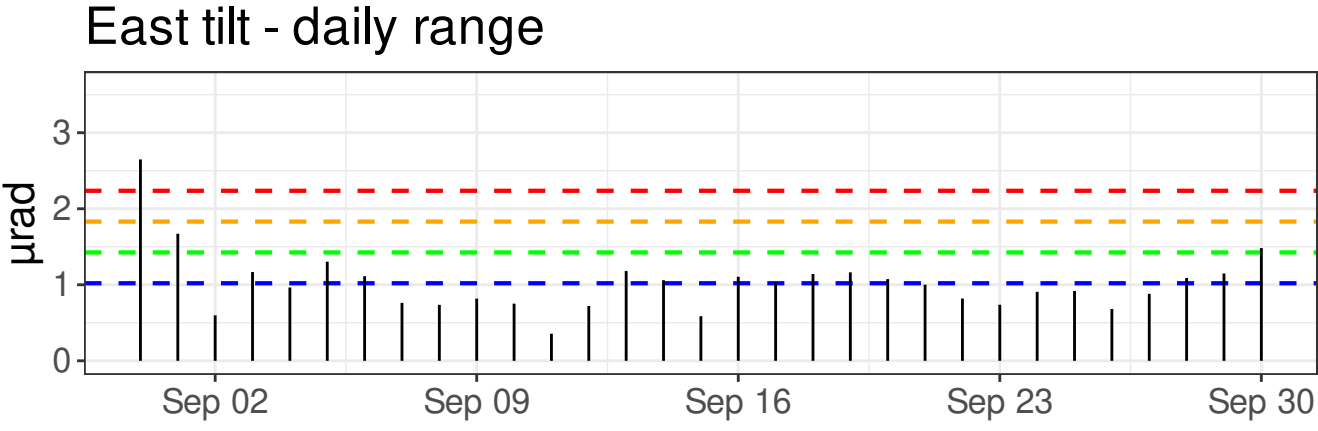
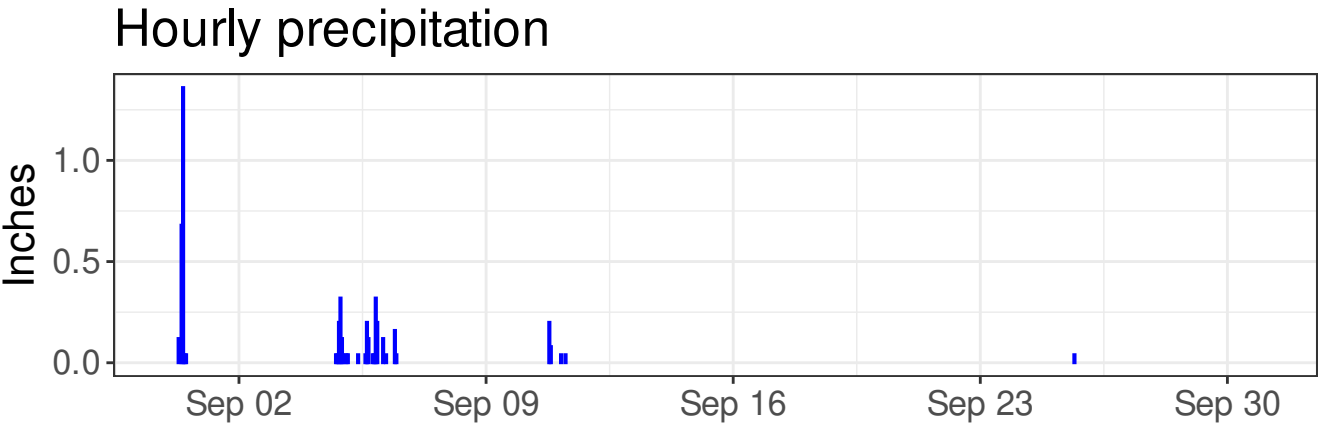
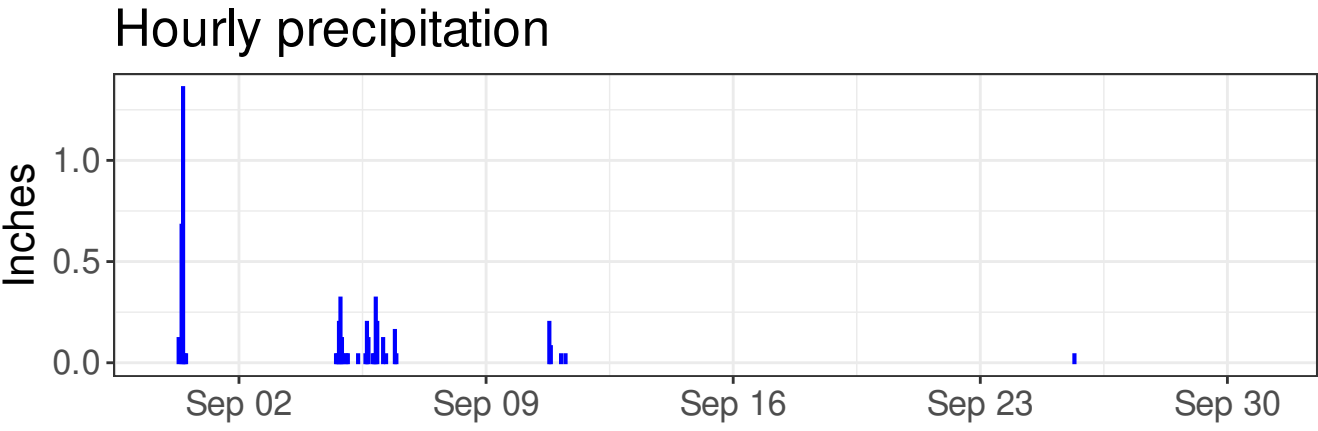
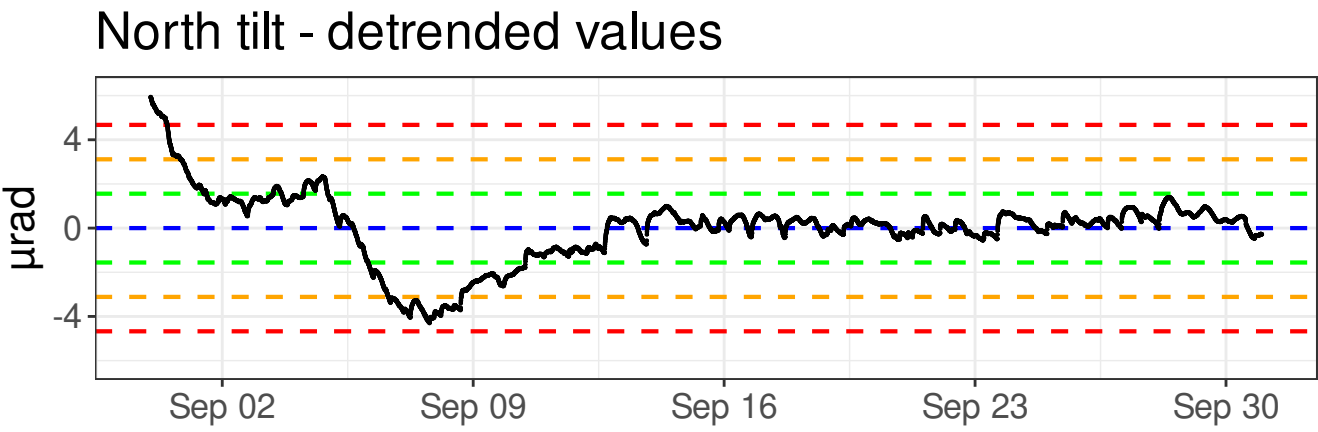
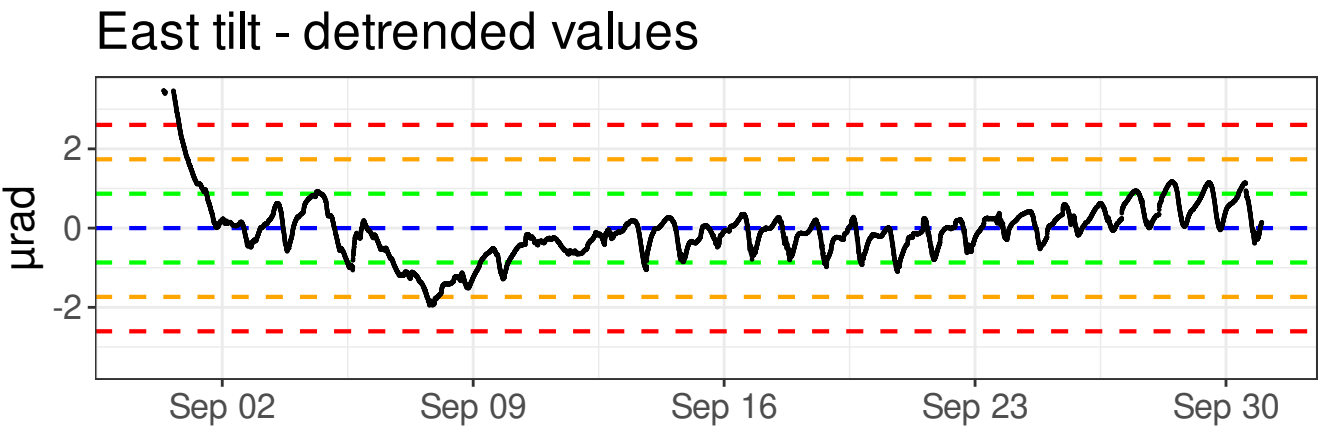
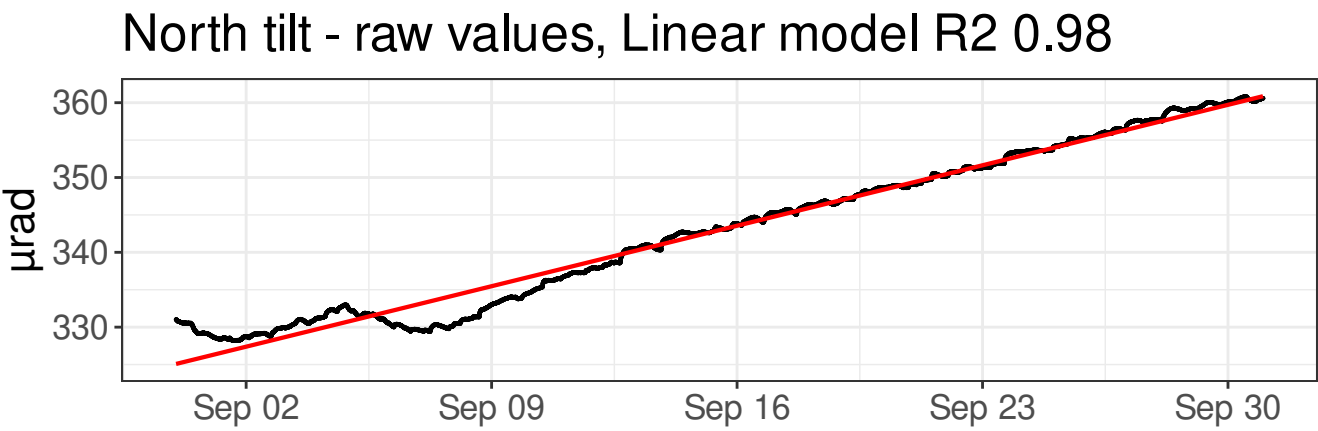
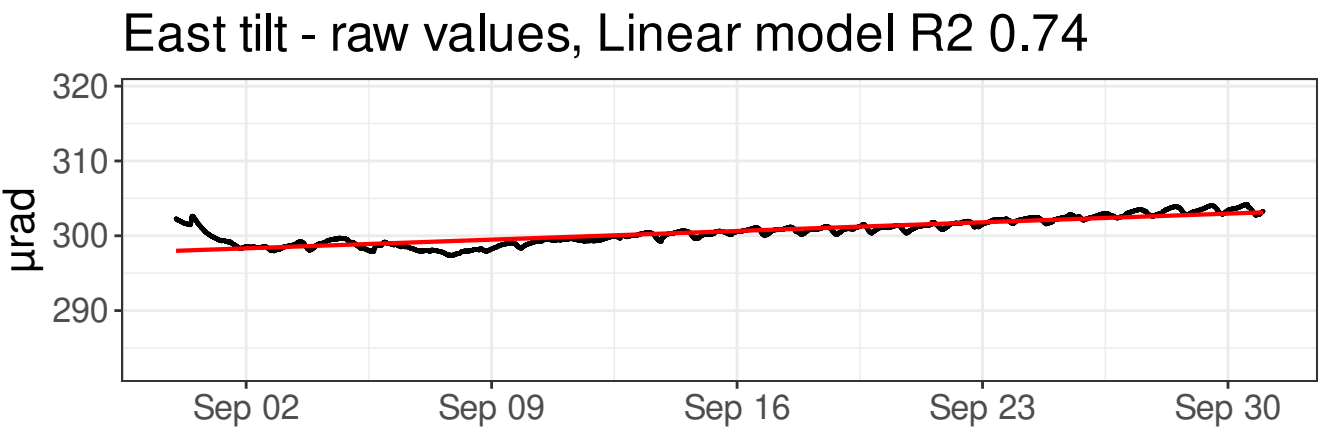
North tilt rate: $171.33 \pm 0.14 \mu\text{rad}/\text{year}$

Azimuth to C7: 58 deg

Distance to C7: 1344 ft

--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

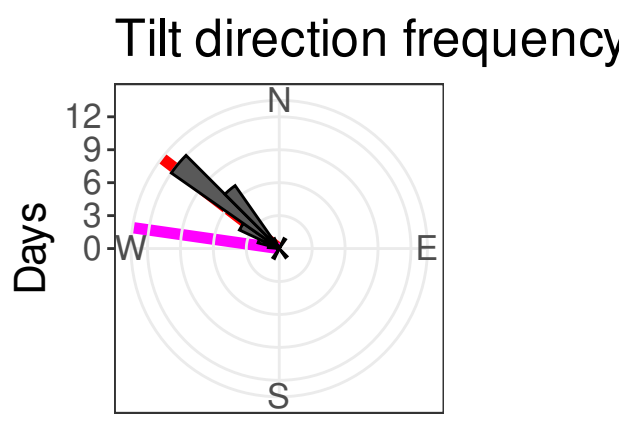
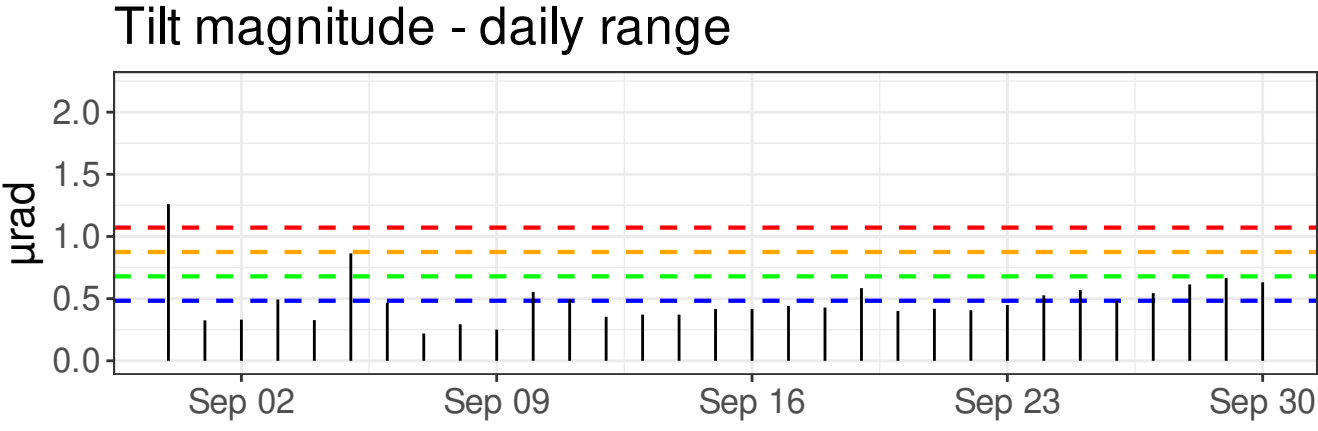
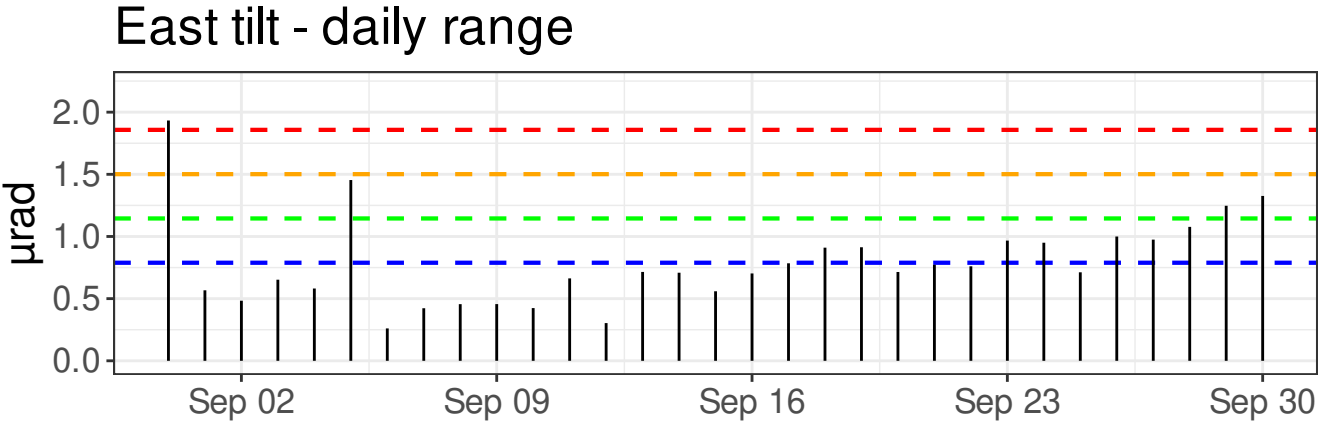
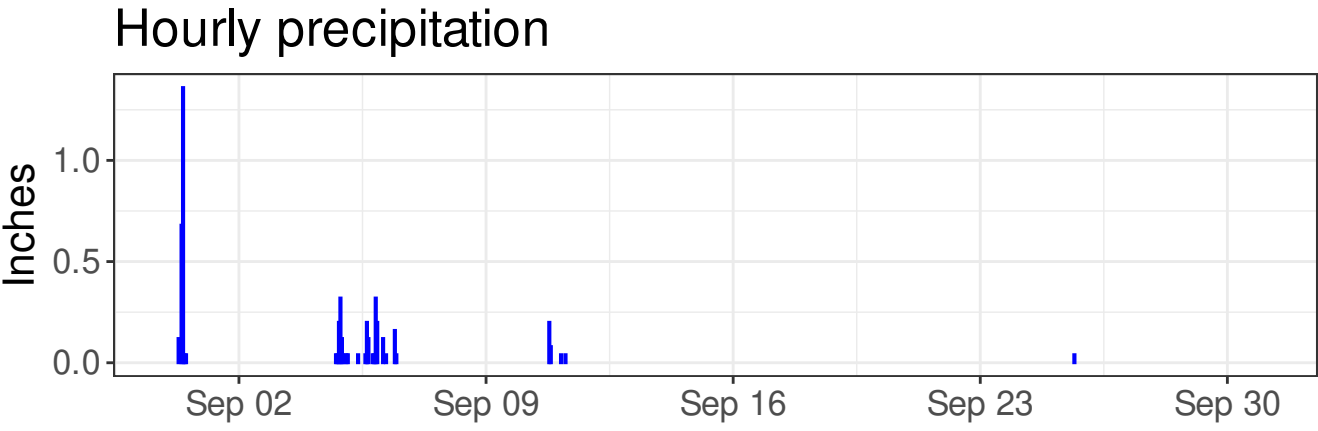
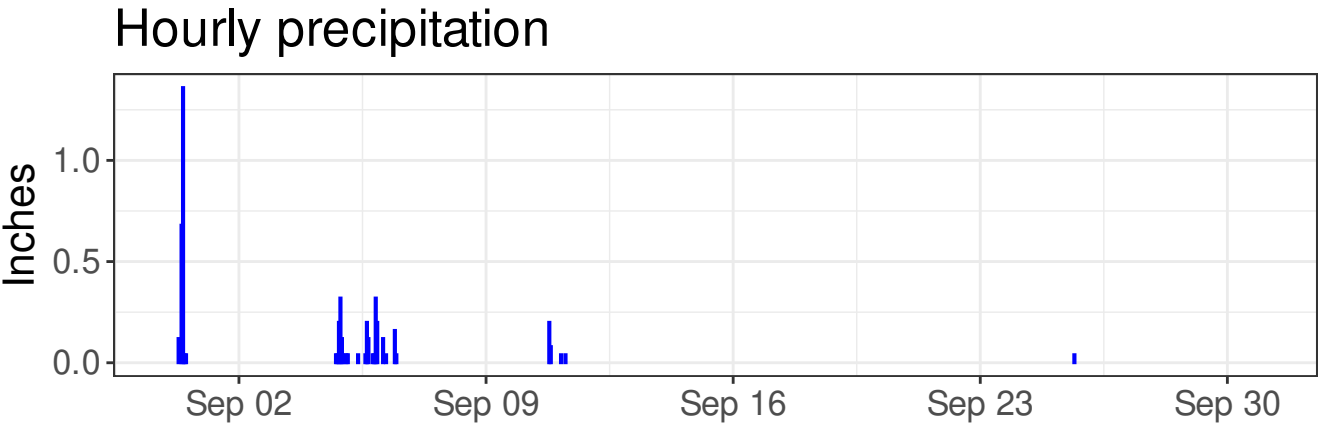
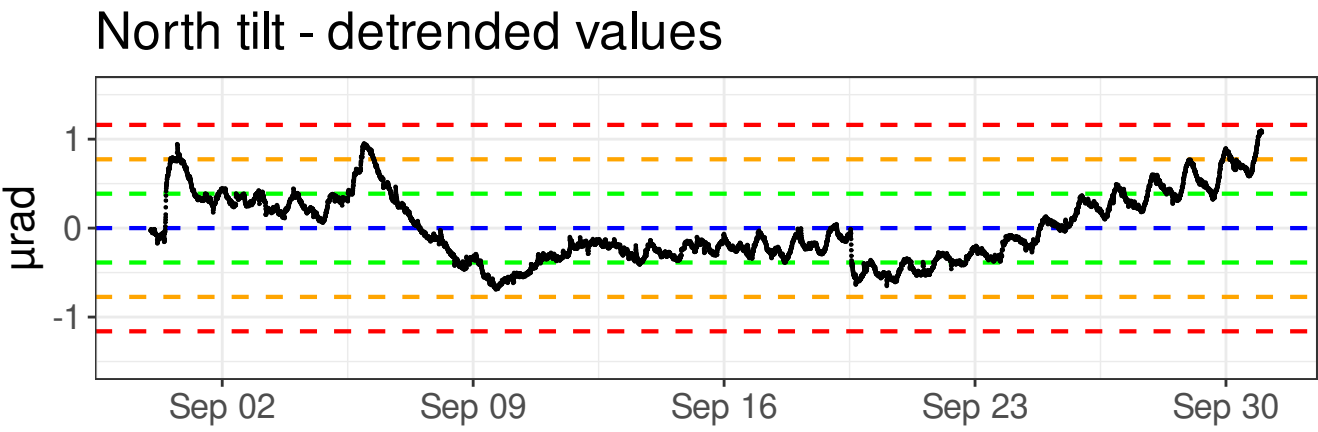
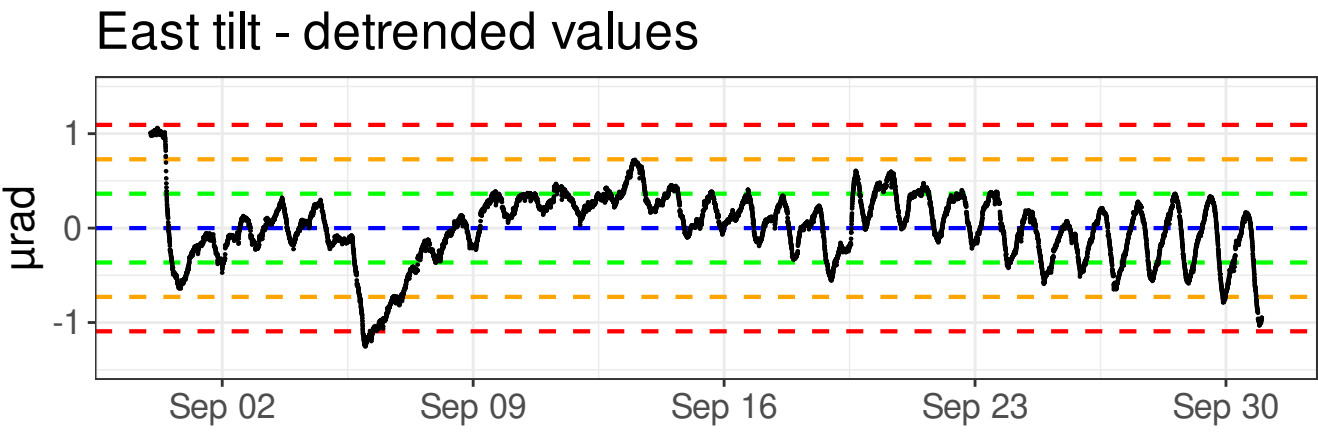
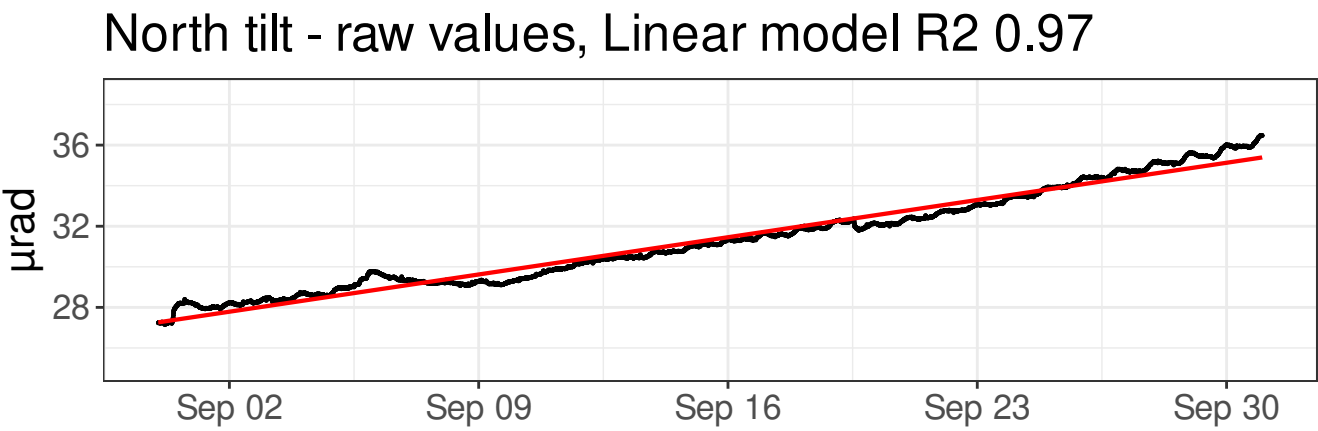
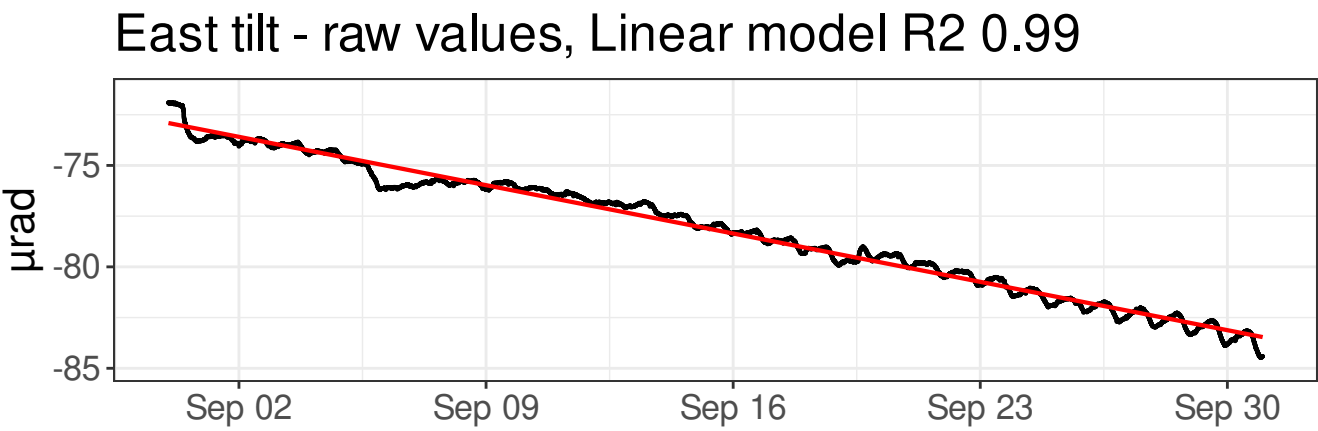
SSD13, 08/31/2024 - 09/30/2024



East tilt rate: $60.65 \pm 0.34 \mu\text{rad}/\text{year}$
North tilt rate: $422.55 \pm 0.60 \mu\text{rad}/\text{year}$
Azimuth to C7: 14 deg
Distance to C7: 686 ft

--- 0σ --- 1σ --- 2σ --- 3σ
— Linear model — Azimuth to C7

SSD14, 08/31/2024 - 09/30/2024

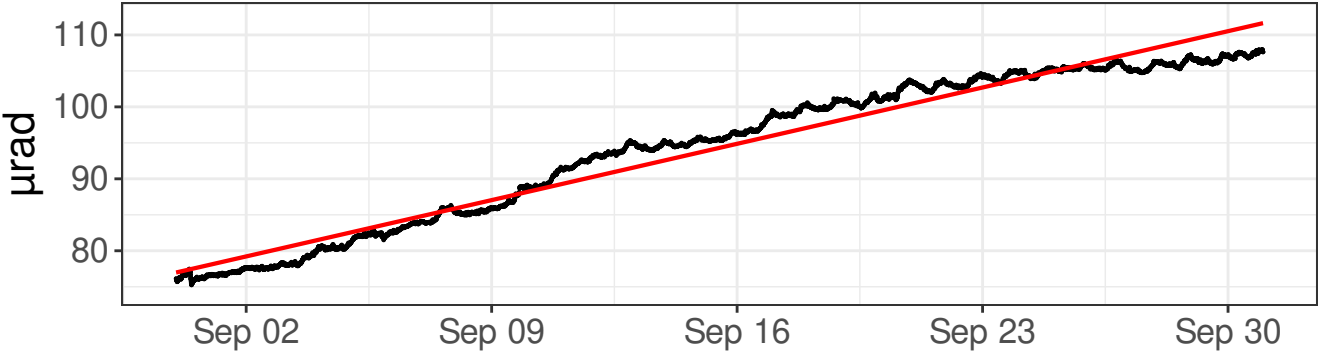


East tilt rate: $-124.58 \pm 0.14 \mu\text{rad}/\text{year}$
North tilt rate: $95.97 \pm 0.15 \mu\text{rad}/\text{year}$
Azimuth to C7: 278 deg
Distance to C7: 1151 ft

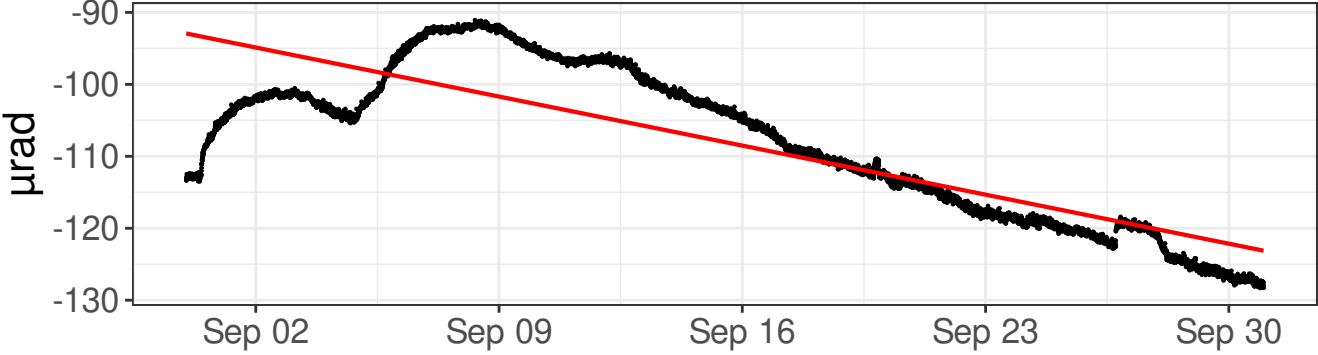
--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD15, 08/31/2024 - 09/30/2024

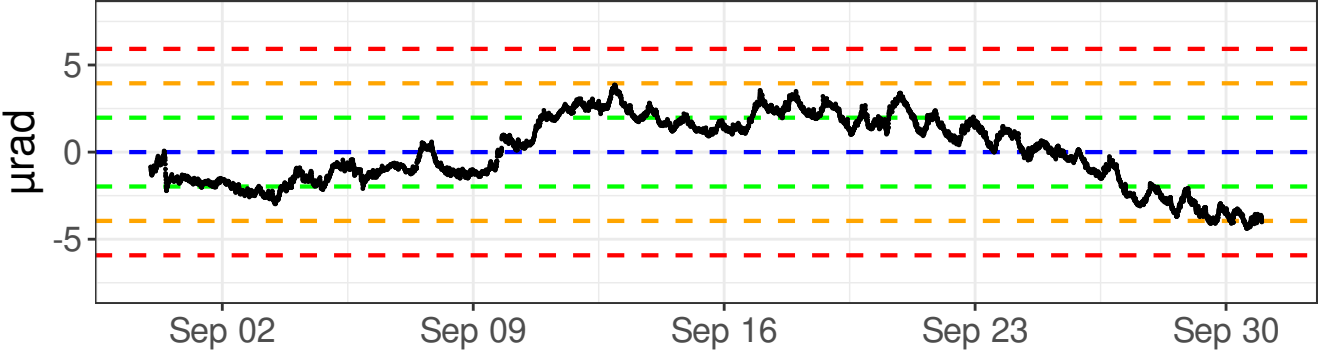
East tilt - raw values, Linear model R2 0.96



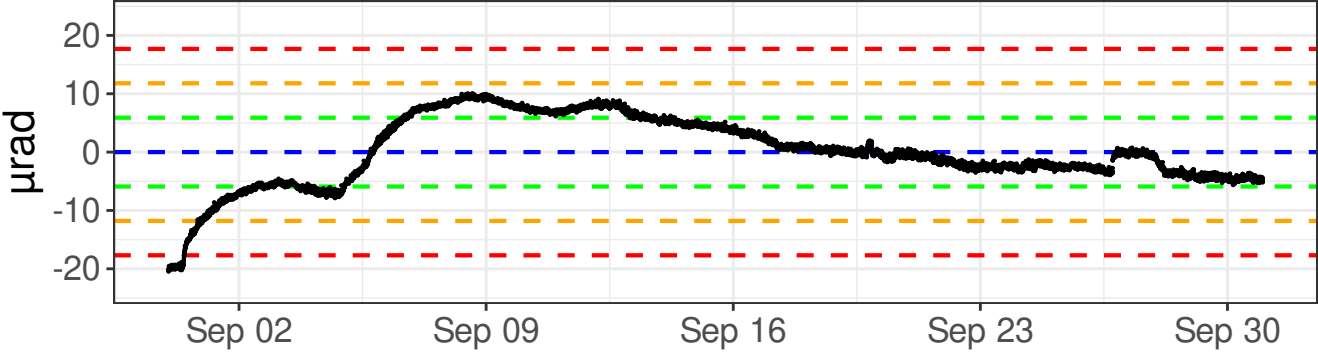
North tilt - raw values, Linear model R2 0.69



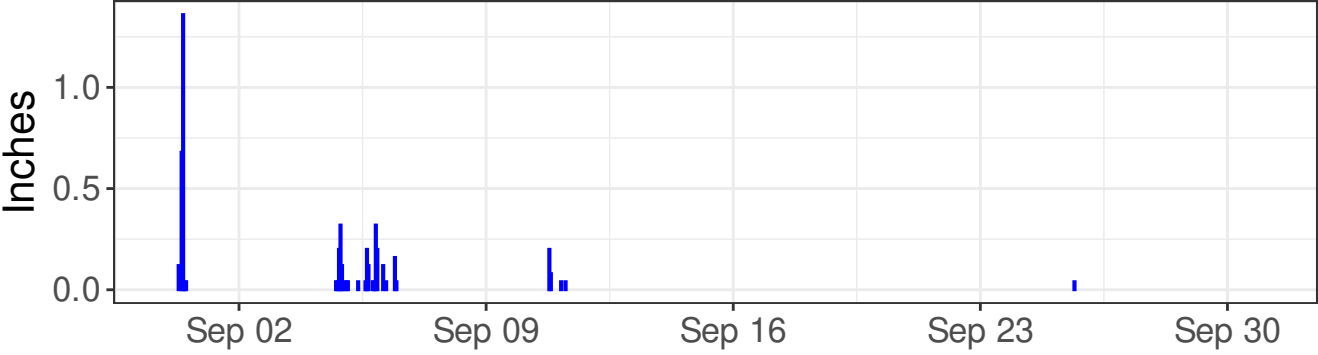
East tilt - detrended values



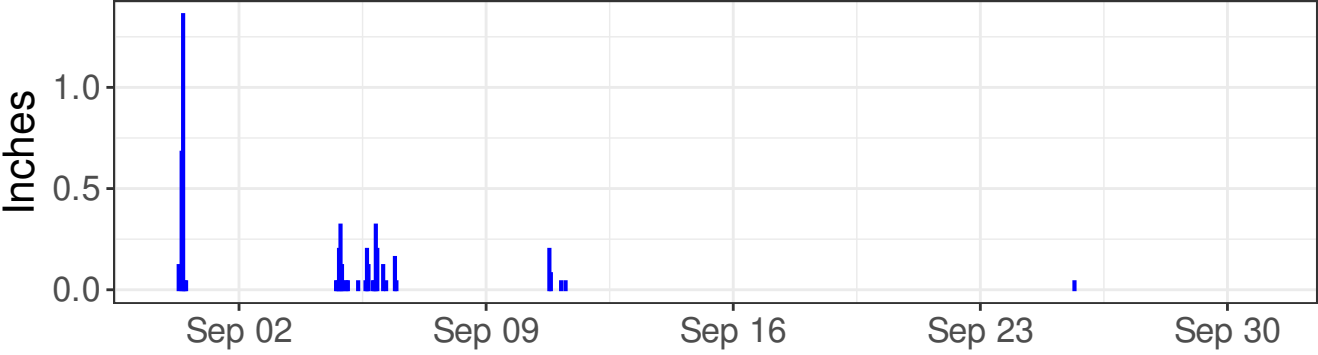
North tilt - detrended values



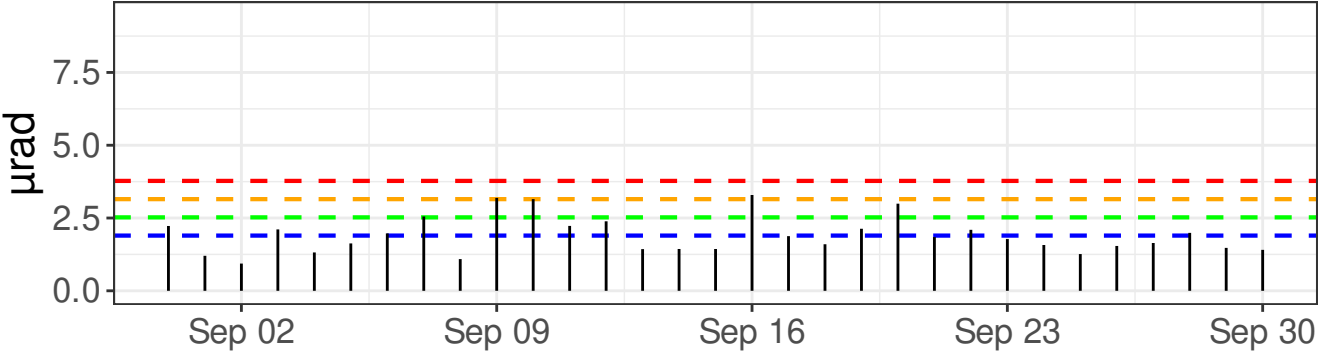
Hourly precipitation



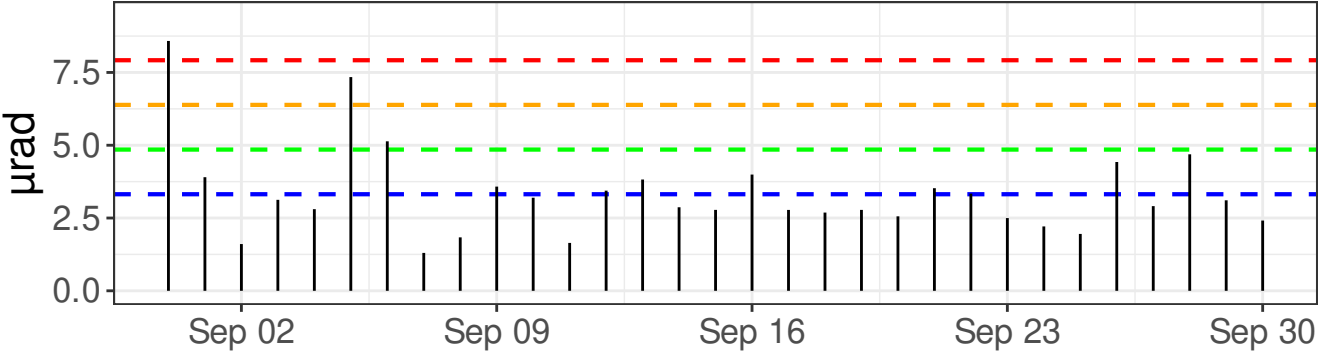
Hourly precipitation



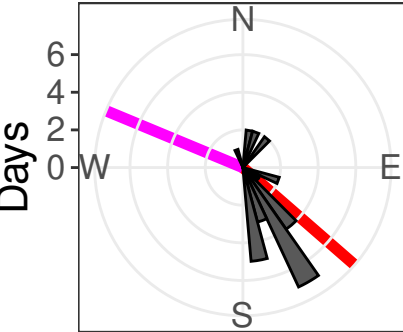
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $409.24 \pm 0.76 \mu\text{rad}/\text{year}$

North tilt rate: $-356.44 \pm 2.28 \mu\text{rad}/\text{year}$

Azimuth to C7: 293 deg

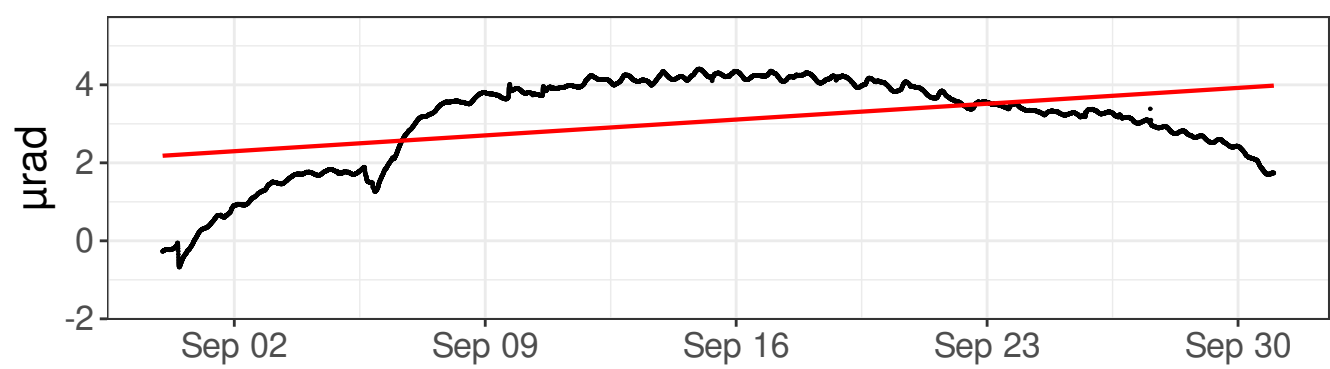
Distance to C7: 614 ft

--- 0 σ --- 1 σ --- 2 σ --- 3 σ

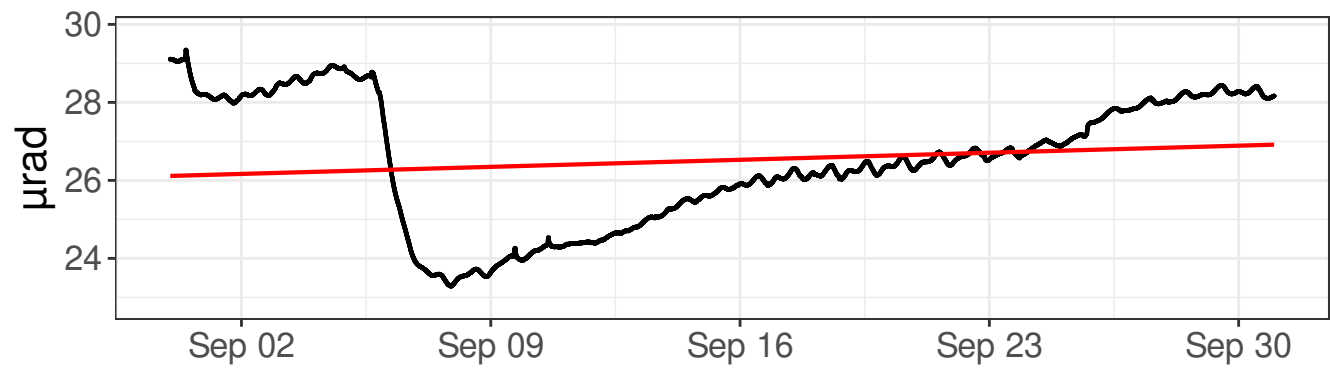
— Linear model — Azimuth to C7

SSD16, 08/31/2024 - 09/30/2024

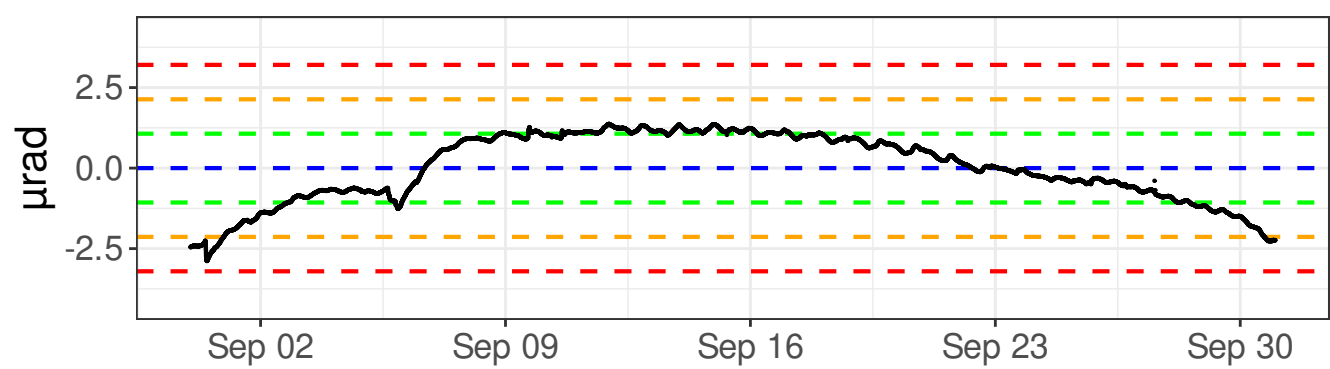
East tilt - raw values, Linear model R2 0.19



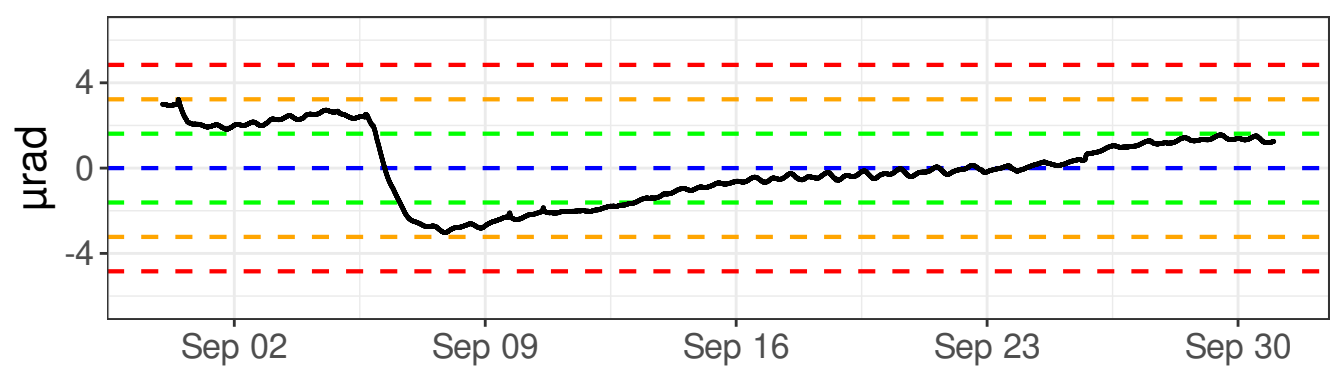
North tilt - raw values, Linear model R2 0.02



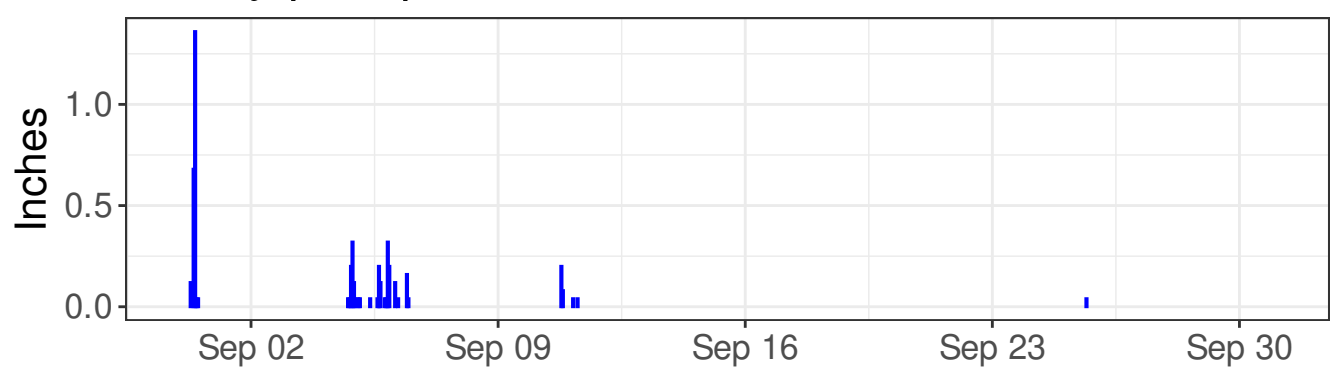
East tilt - detrended values



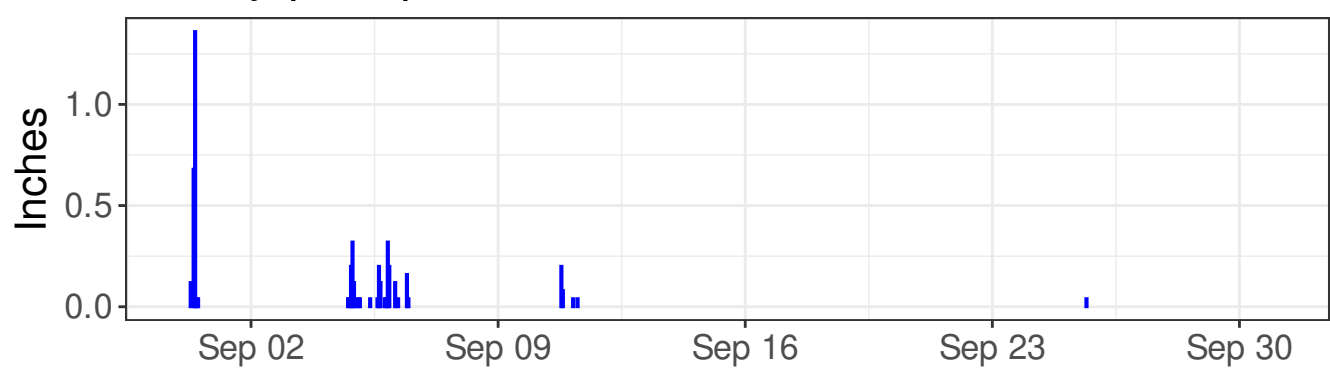
North tilt - detrended values



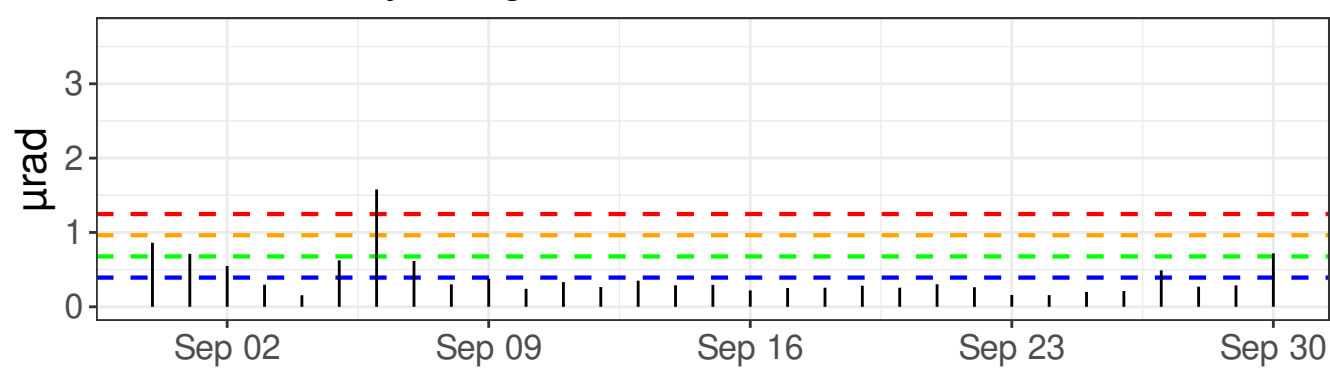
Hourly precipitation



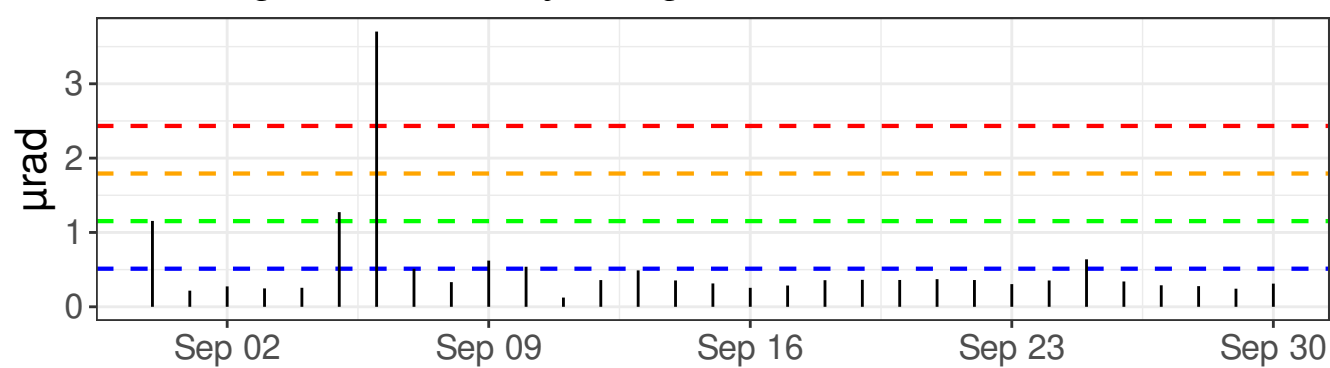
Hourly precipitation



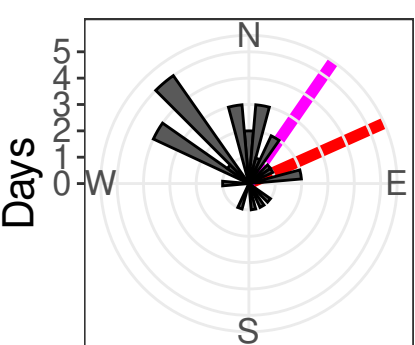
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $21.22 \pm 0.41 \mu\text{rad}/\text{year}$

North tilt rate: $9.47 \pm 0.62 \mu\text{rad}/\text{year}$

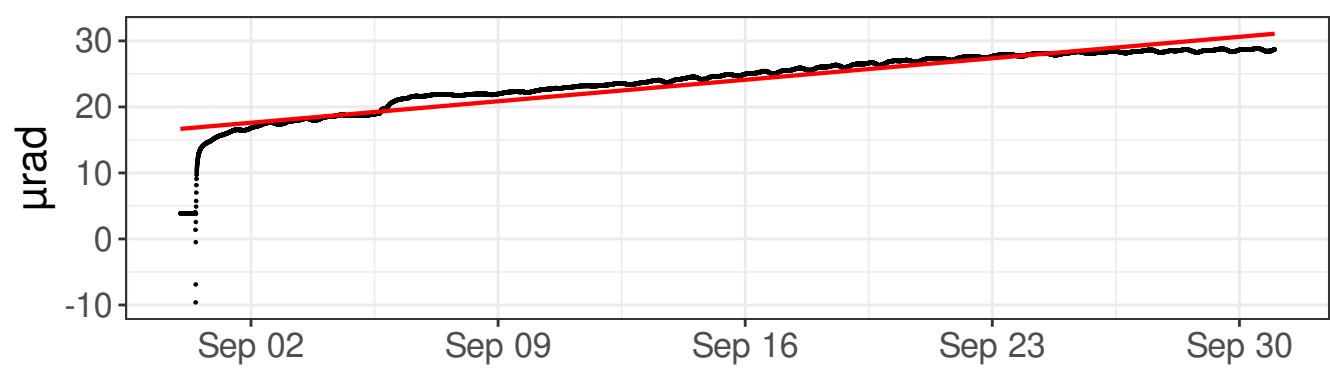
Azimuth to C7: 35 deg

Distance to C7: 1885 ft

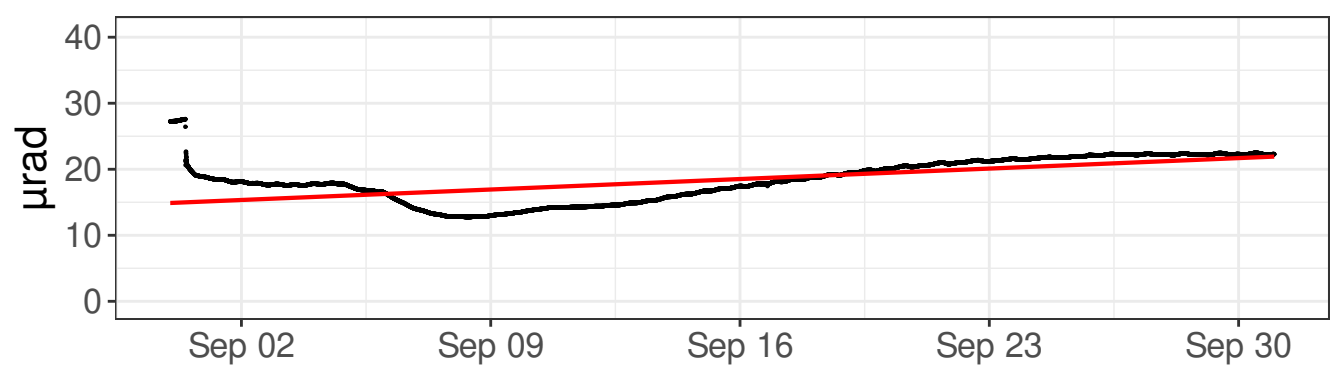
--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD17, 08/31/2024 - 09/30/2024

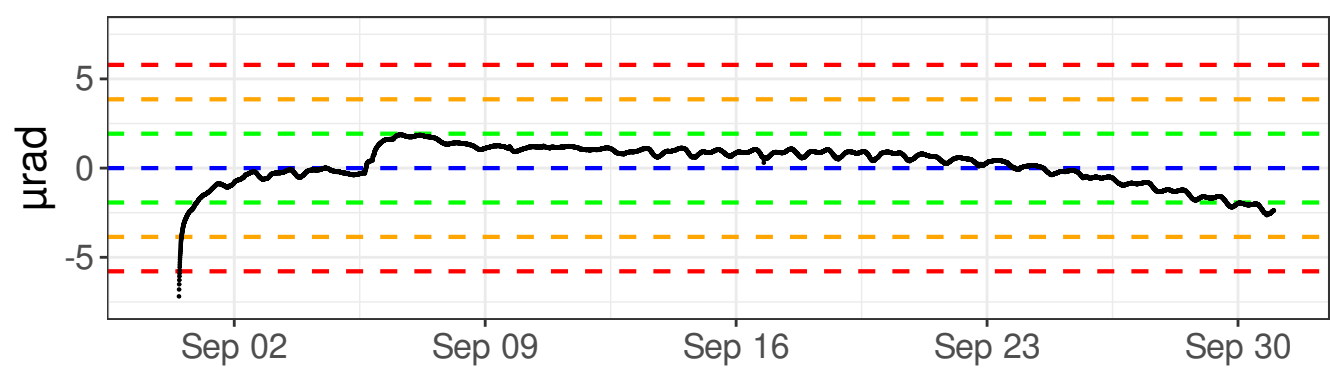
East tilt - raw values, Linear model R2 0.82



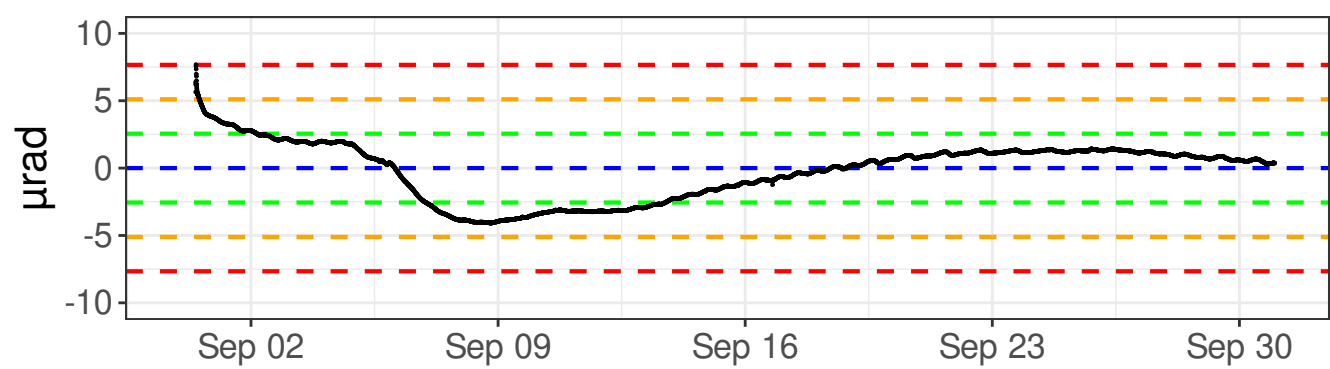
North tilt - raw values, Linear model R2 0.39



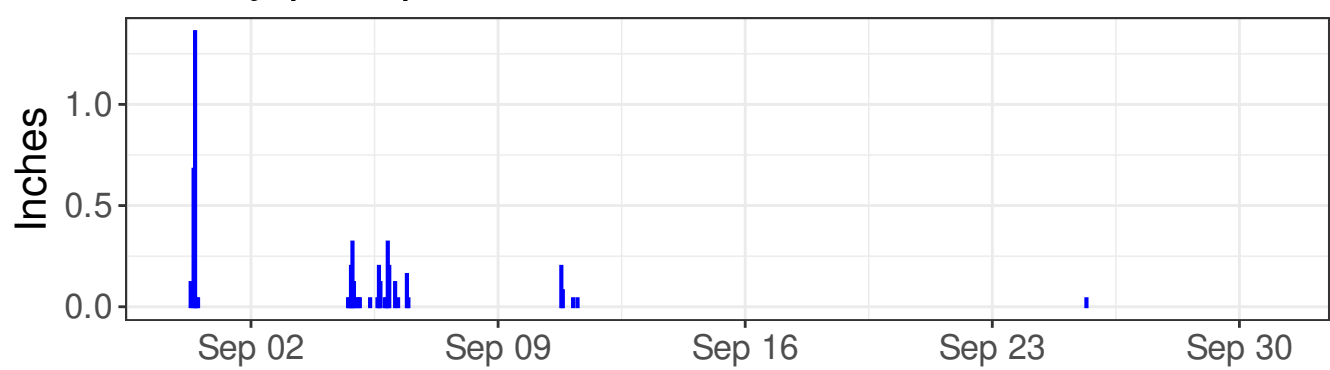
East tilt - detrended values



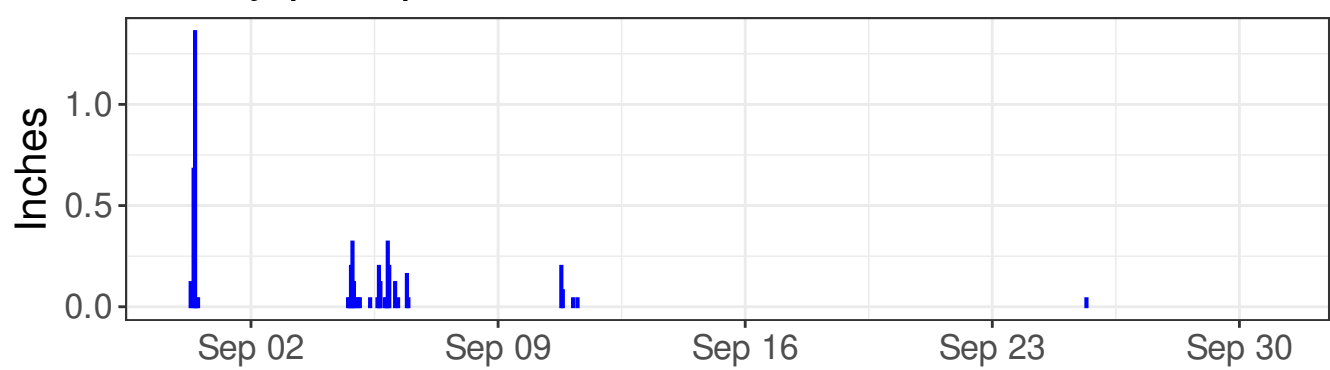
North tilt - detrended values



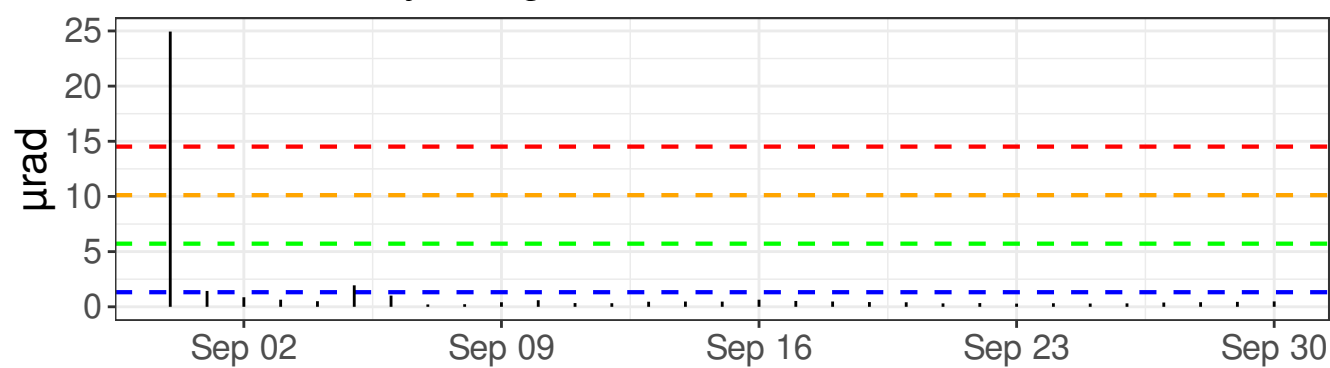
Hourly precipitation



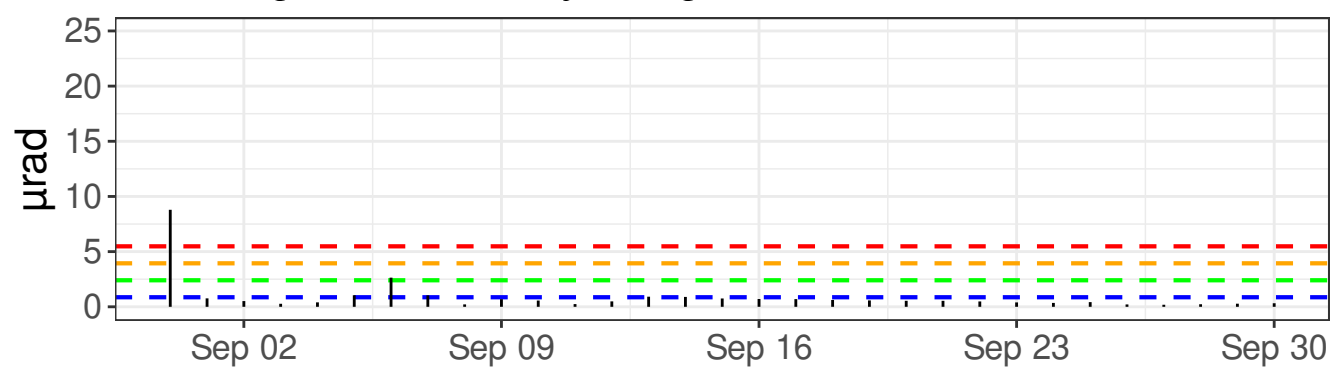
Hourly precipitation



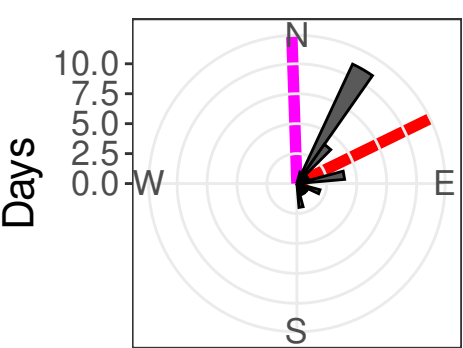
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $170.11 \pm 0.75 \mu\text{rad}/\text{year}$

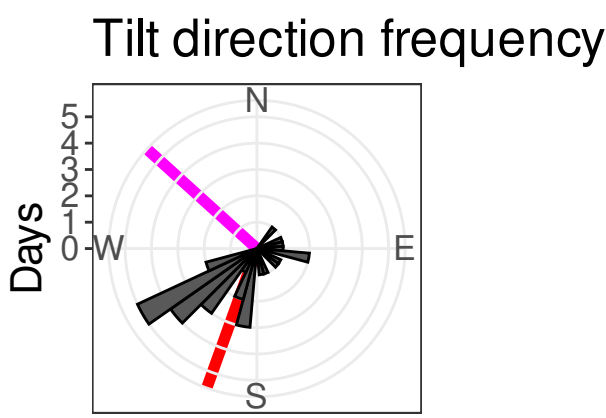
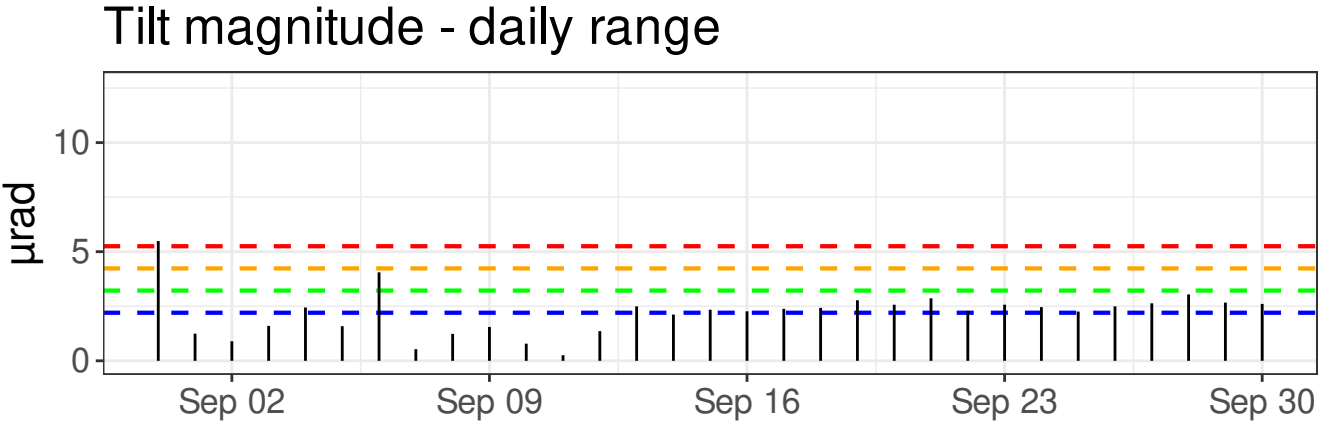
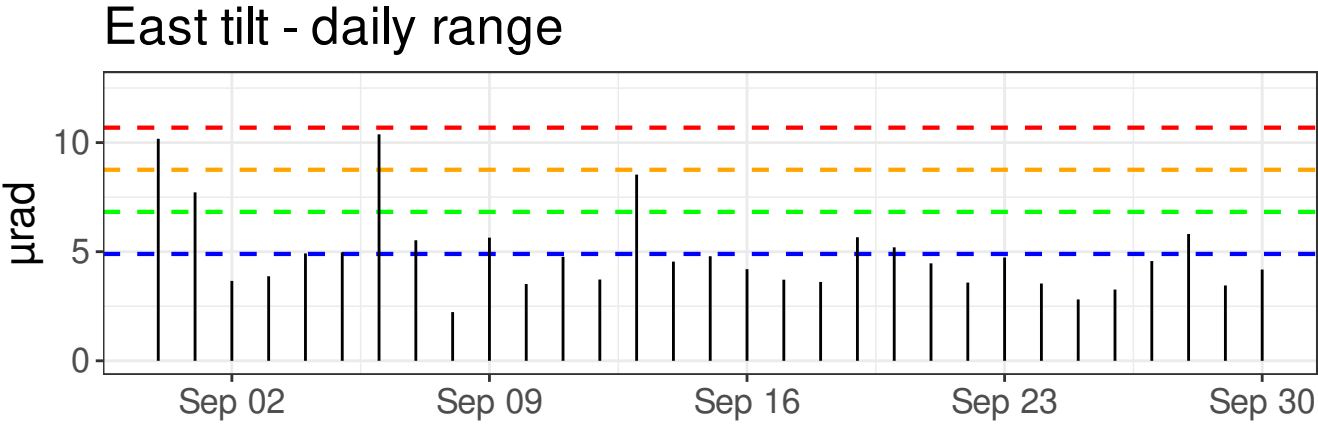
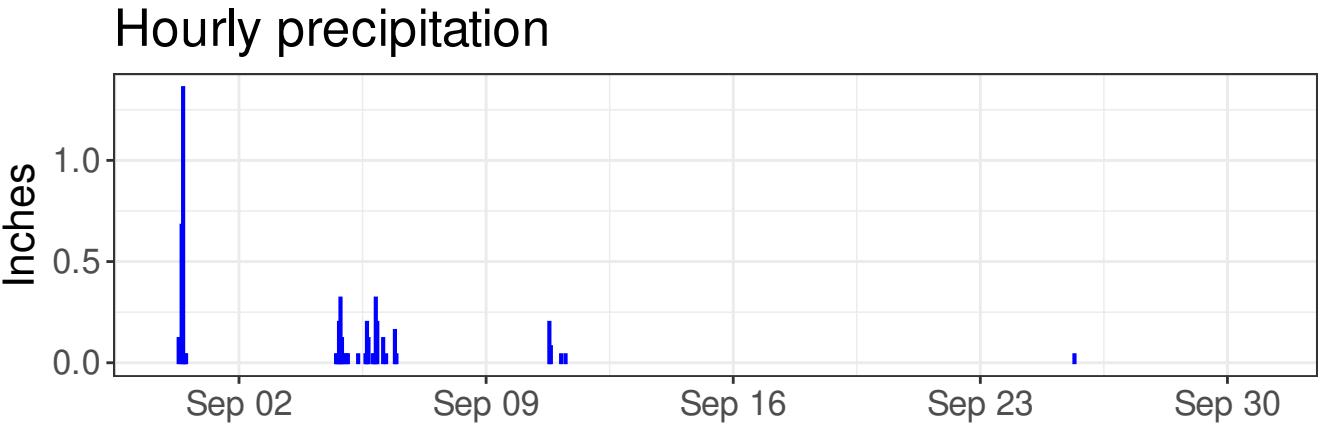
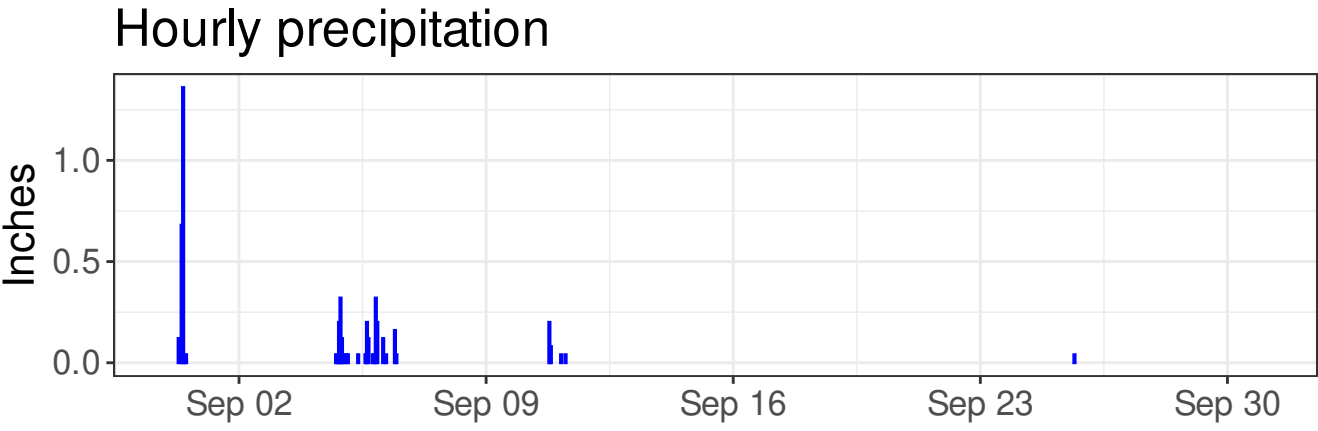
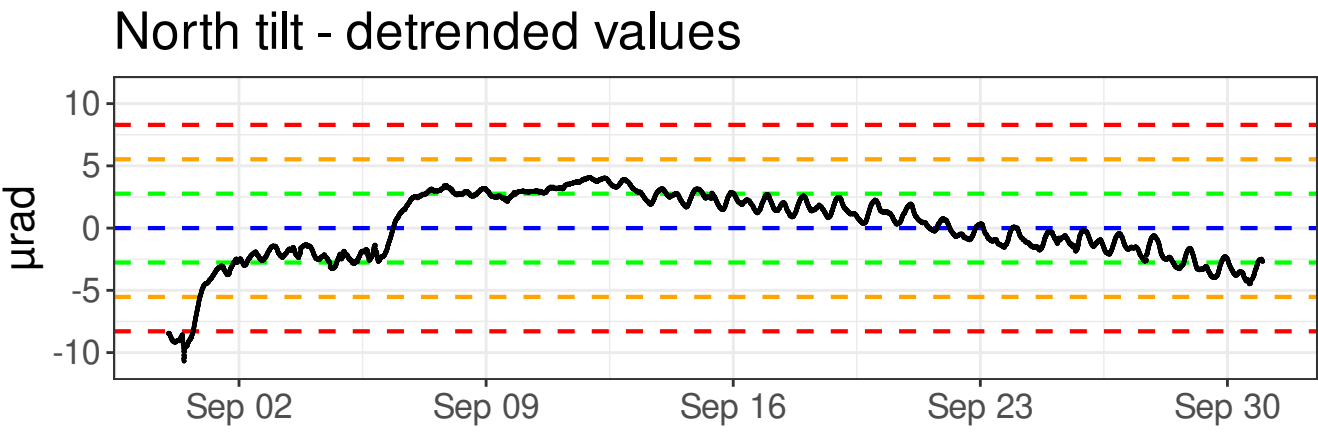
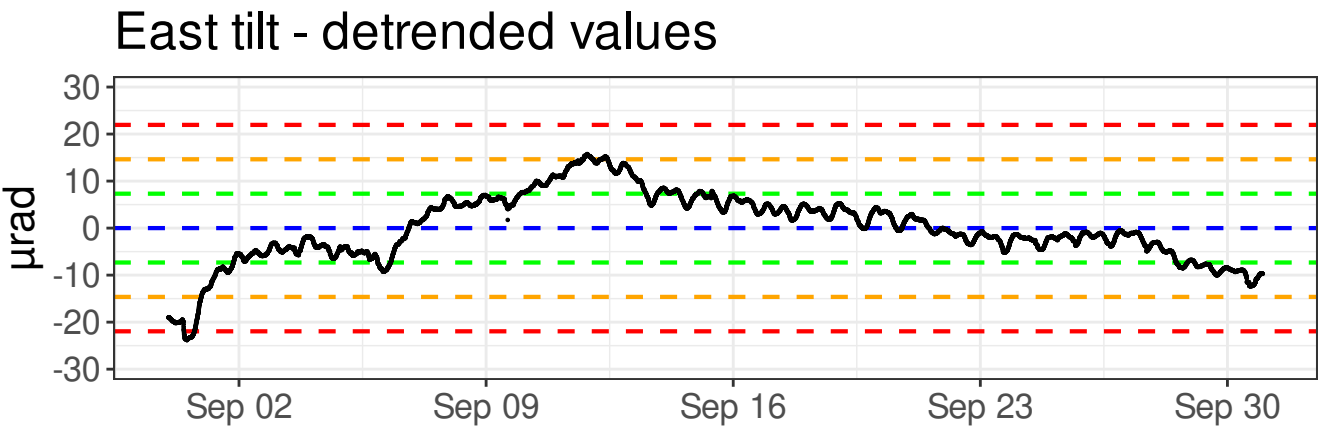
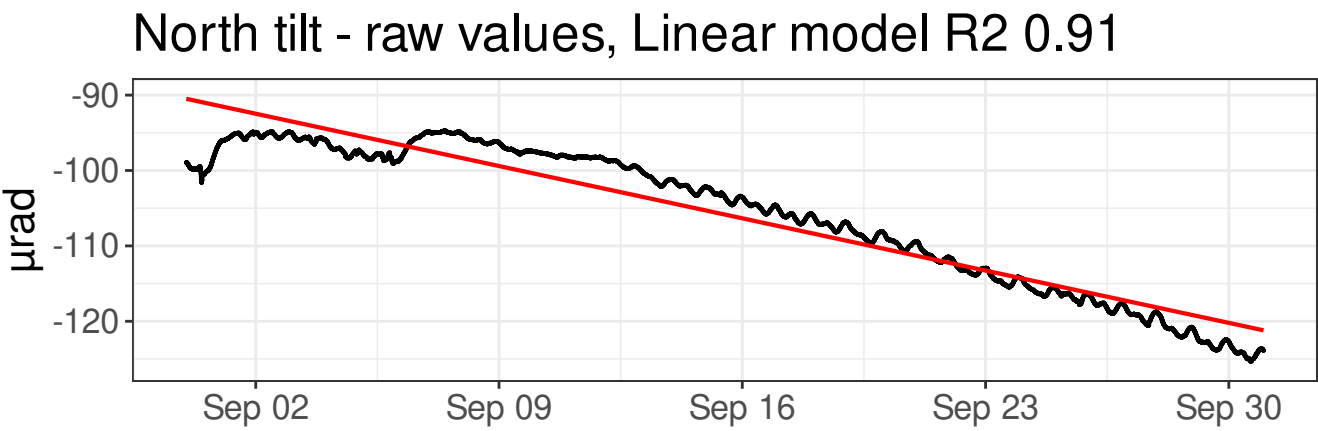
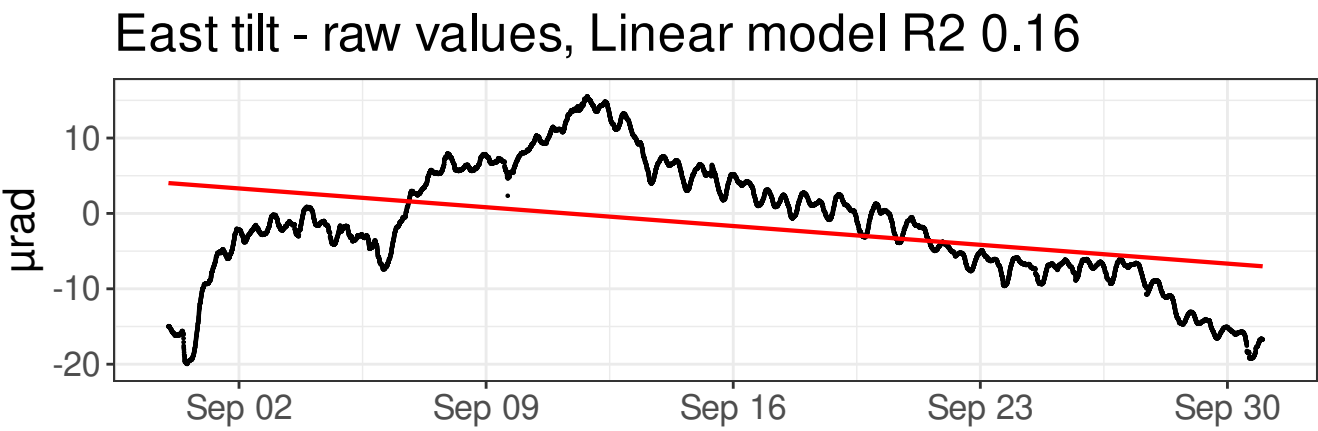
North tilt rate: $82.94 \pm 0.99 \mu\text{rad}/\text{year}$

Azimuth to C7: 358 deg

Distance to C7: 1392 ft

--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD18, 08/31/2024 - 09/30/2024

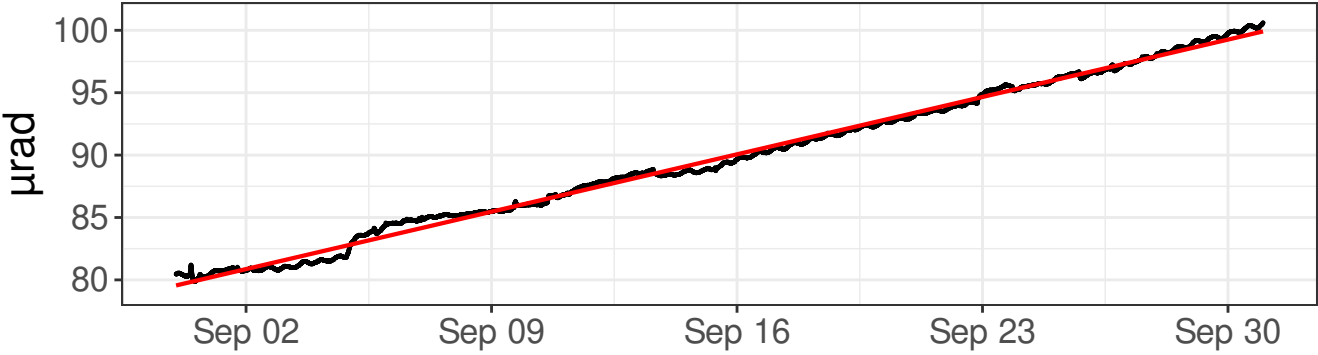


East tilt rate: $-130.35 \pm 2.83 \mu\text{rad}/\text{year}$
North tilt rate: $-362.61 \pm 1.07 \mu\text{rad}/\text{year}$
Azimuth to C7: 312 deg
Distance to C7: 1415 ft

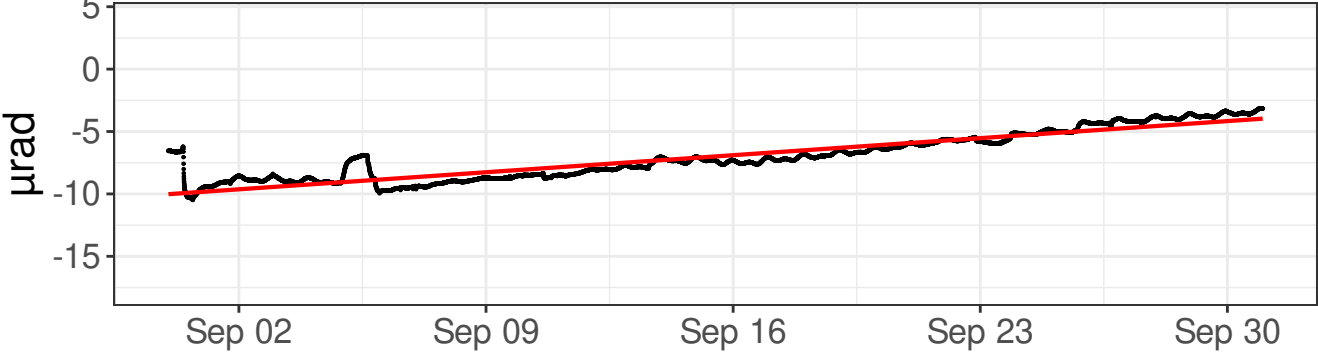
--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD19, 08/31/2024 - 09/30/2024

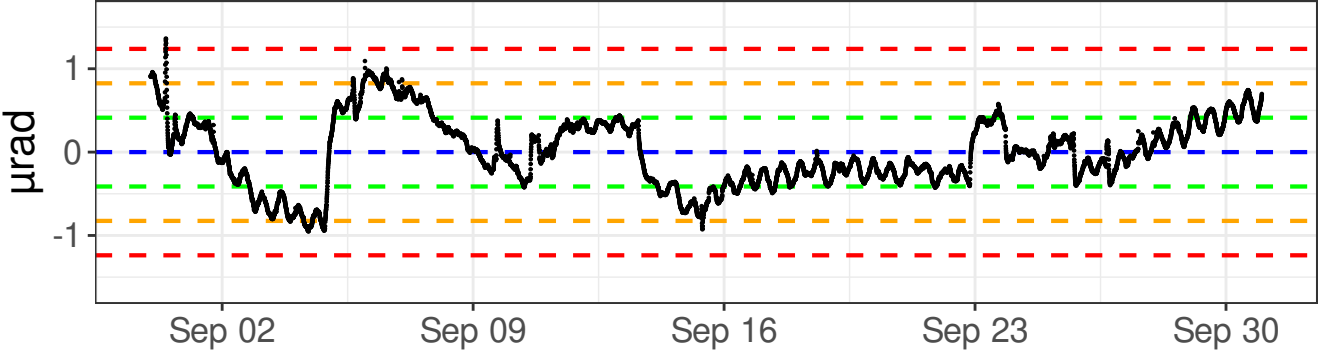
East tilt - raw values, Linear model R2 1.00



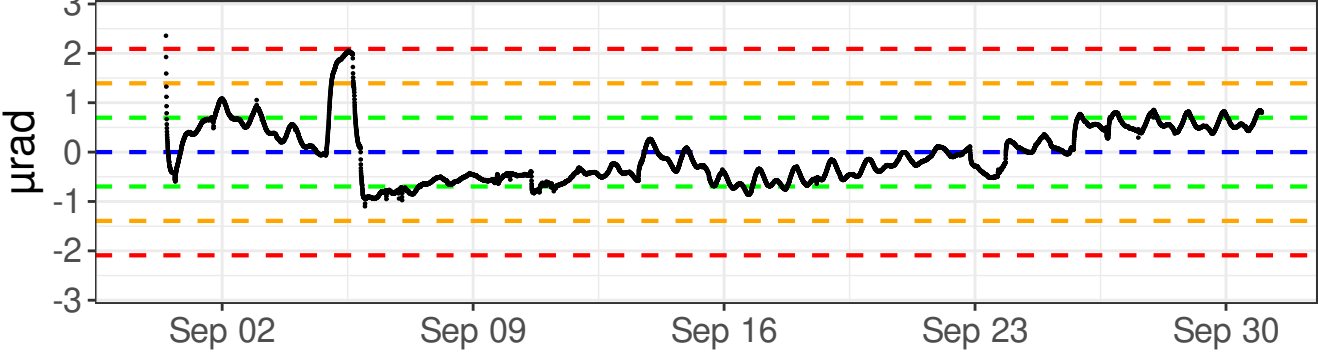
North tilt - raw values, Linear model R2 0.86



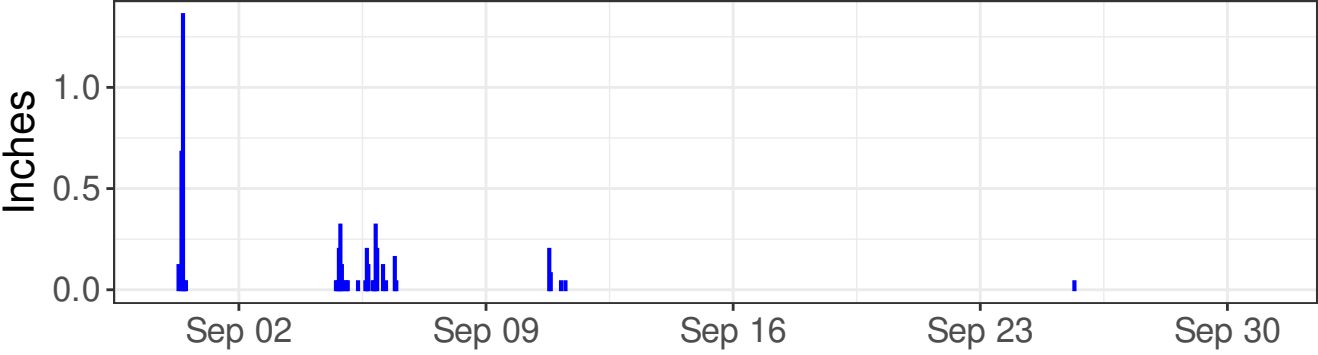
East tilt - detrended values



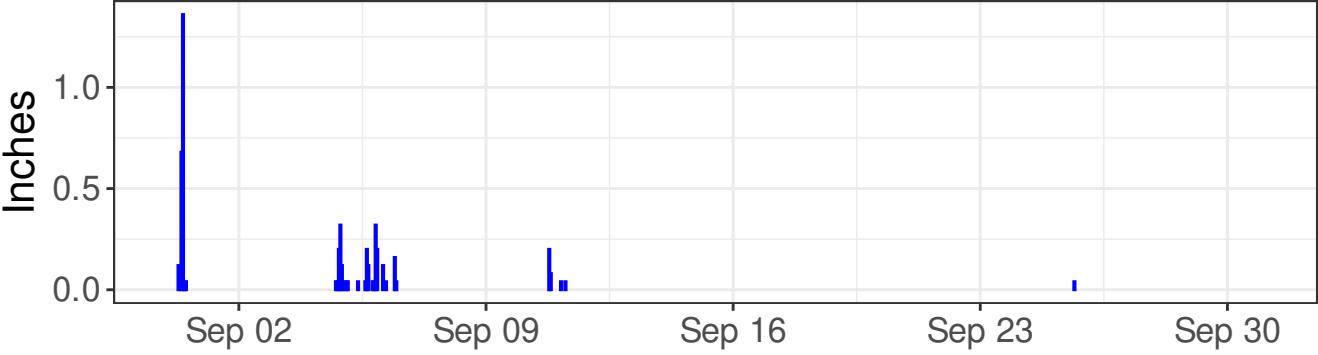
North tilt - detrended values



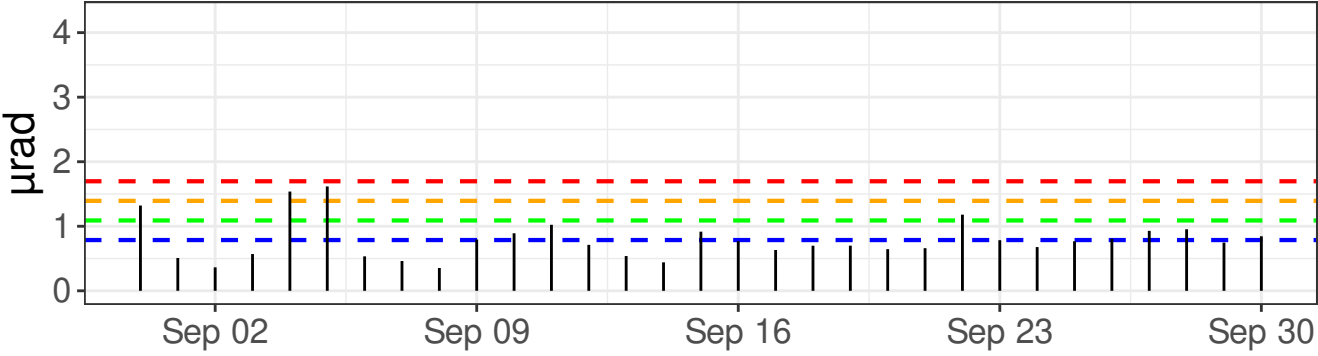
Hourly precipitation



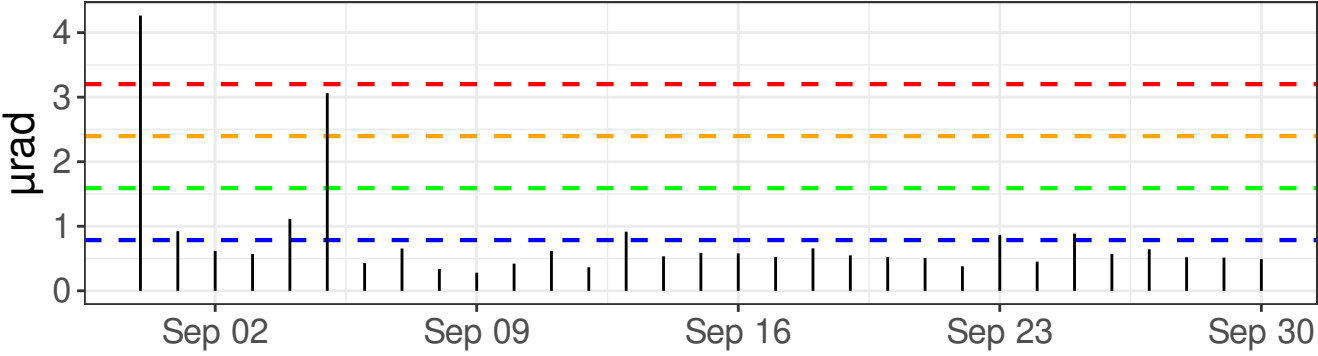
Hourly precipitation



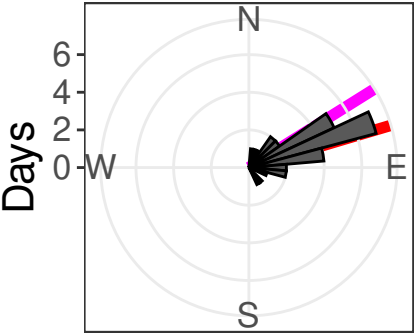
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $240.37 \pm 0.16 \mu\text{rad}/\text{year}$

North tilt rate: $71.45 \pm 0.27 \mu\text{rad}/\text{year}$

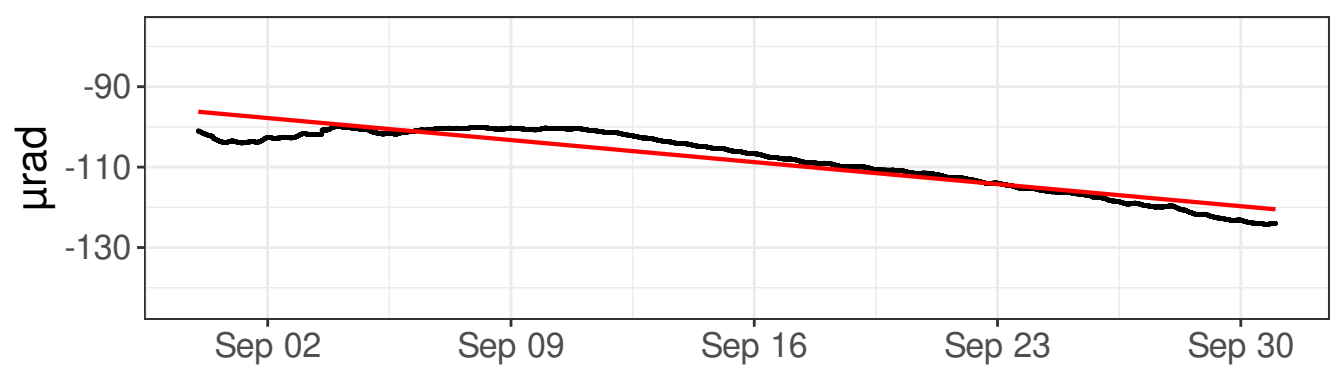
Azimuth to C7: 58 deg

Distance to C7: 2245 ft

--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

SSD20, 08/31/2024 - 09/30/2024

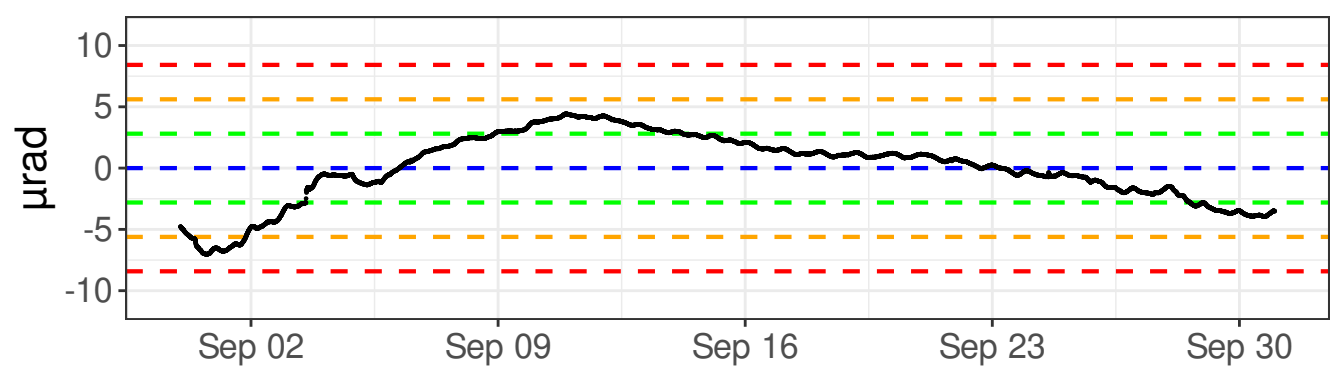
East tilt - raw values, Linear model R2 0.86



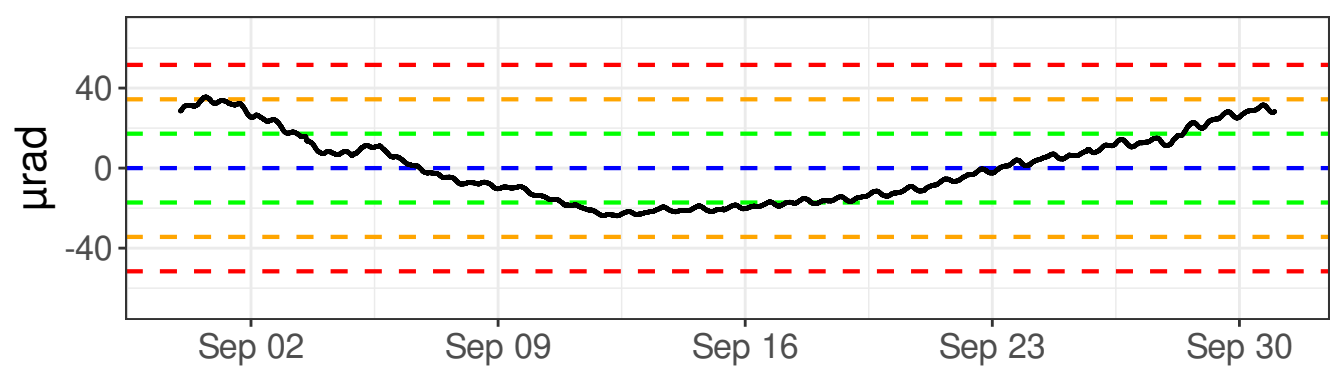
North tilt - raw values, Linear model R2 0.11



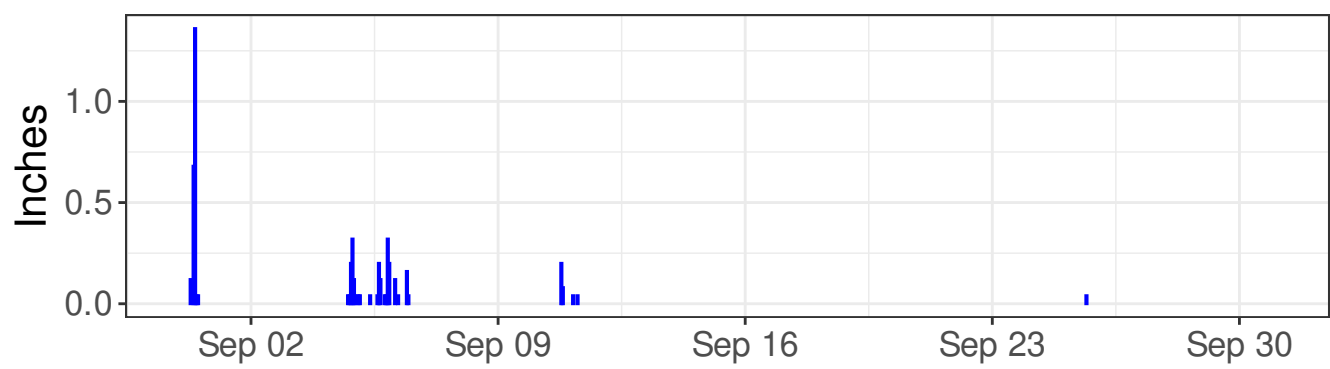
East tilt - detrended values



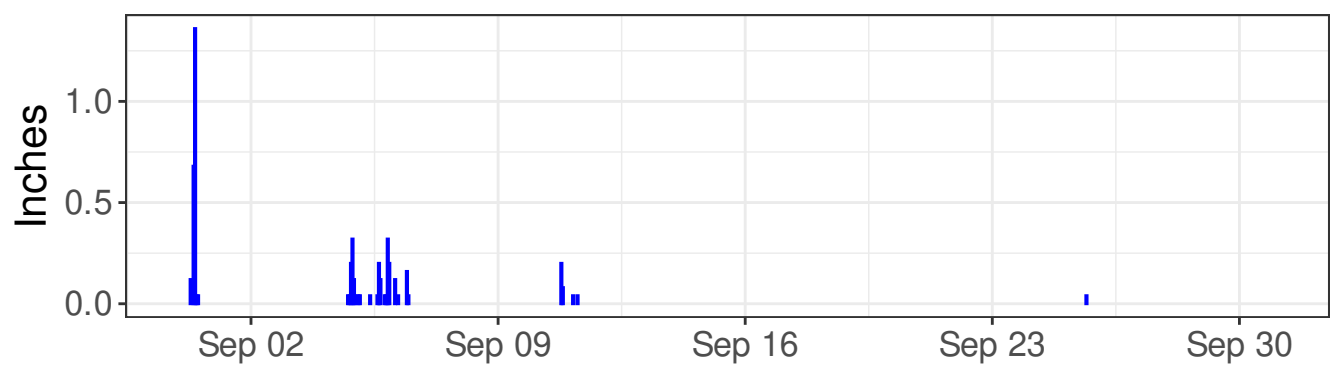
North tilt - detrended values



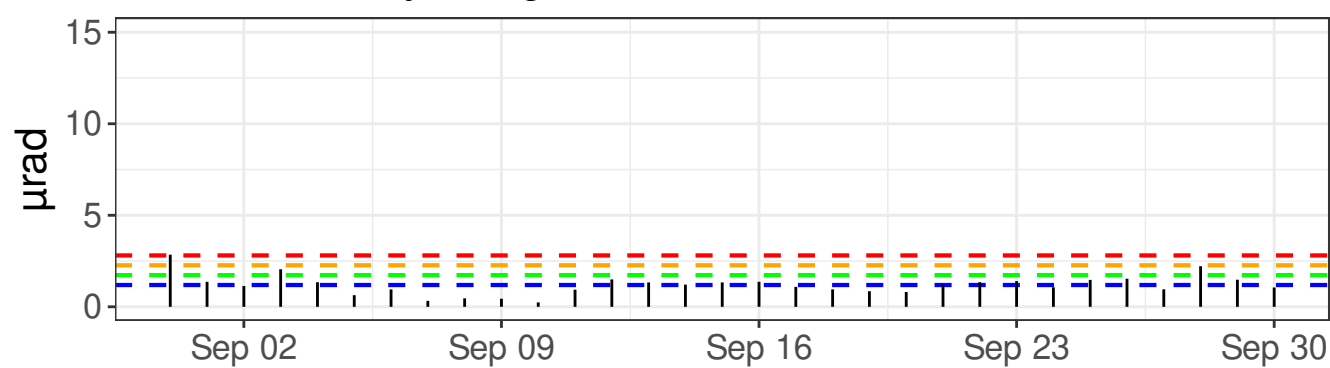
Hourly precipitation



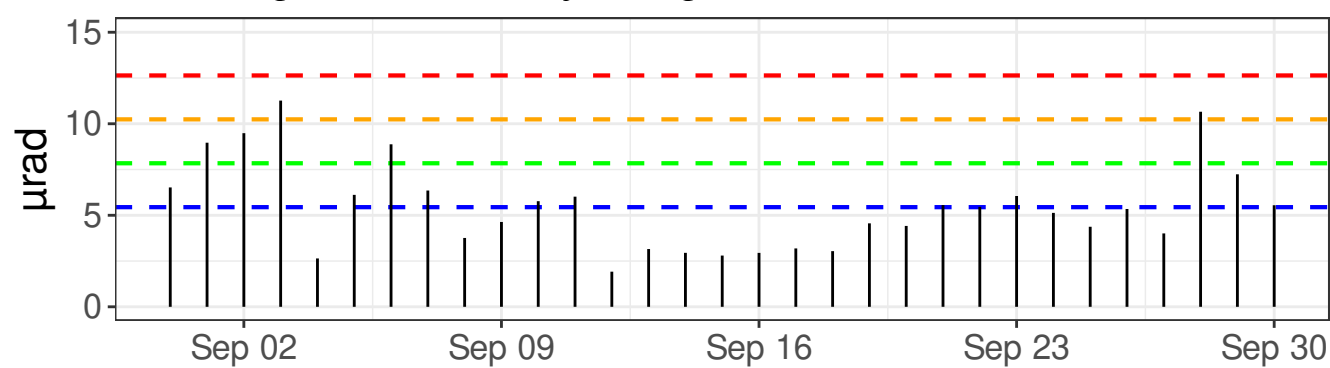
Hourly precipitation



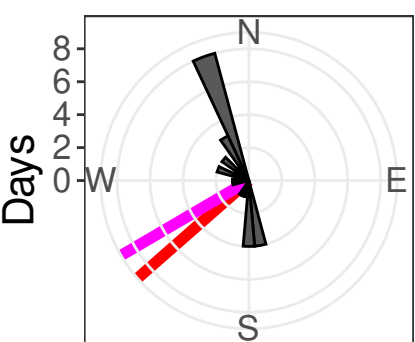
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: $-286.58 \pm 1.08 \mu\text{rad}/\text{year}$

North tilt rate: $-251.64 \pm 6.64 \mu\text{rad}/\text{year}$

Azimuth to C7: 240 deg

Distance to C7: 1378 ft

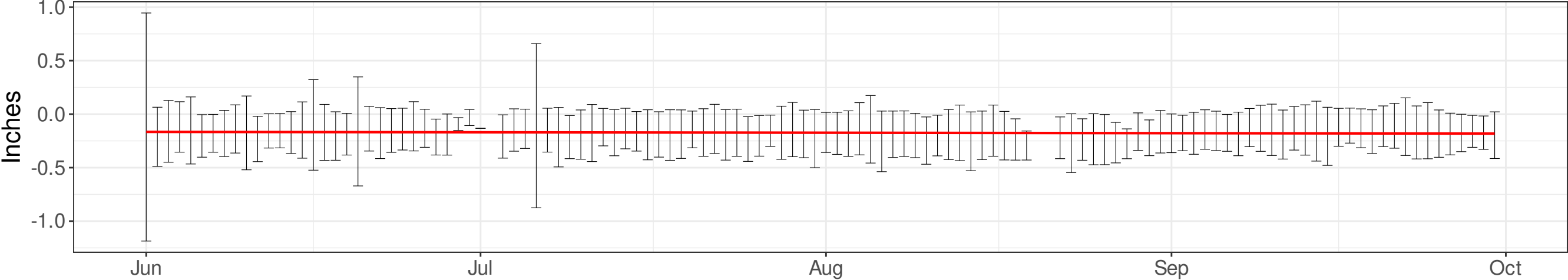
--- 0 σ --- 1 σ --- 2 σ --- 3 σ
— Linear model — Azimuth to C7

APPENDIX 2

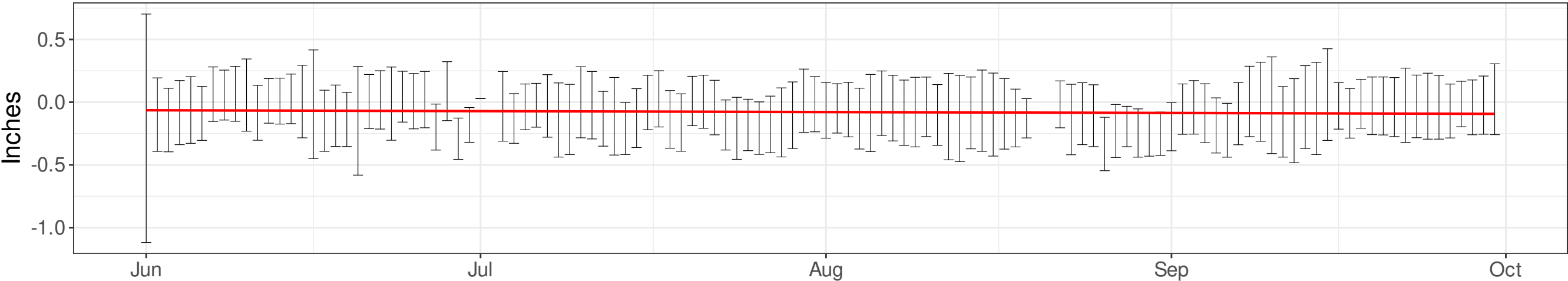
GNSS Data Plots

REMC7, 06/01/2024 - 09/30/2024

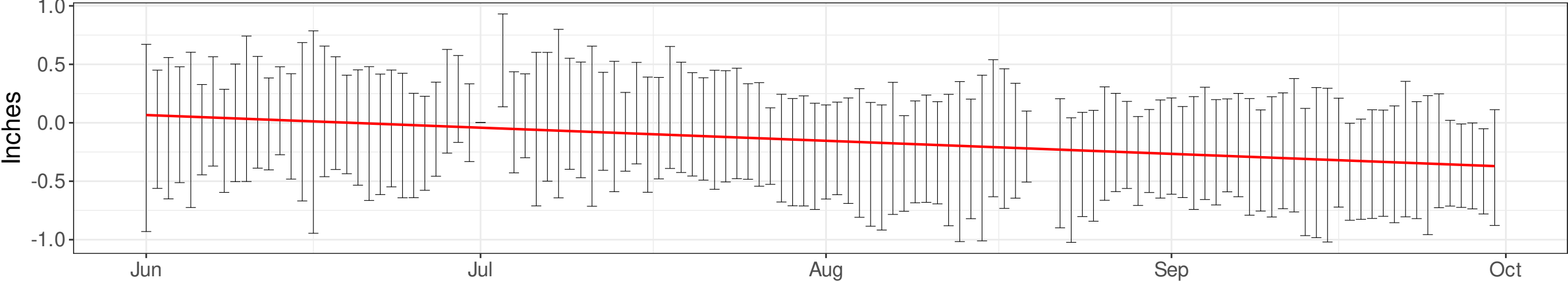
East displacement - daily values



North displacement - daily values



Vertical displacement - daily values



Local east rate: 0.427 ± 0.044 in/year, R2: 0.01

Local north rate: -0.064 ± 0.083 in/year, R2: 0.01

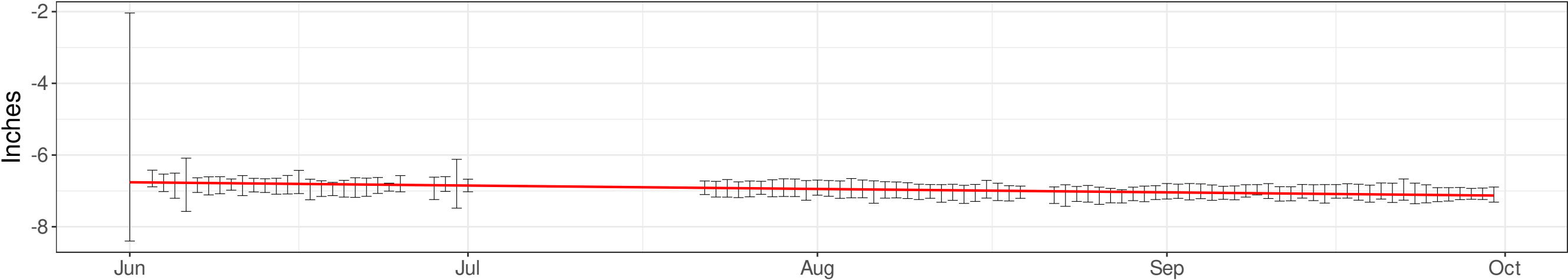
Local vertical rate: -1.252 ± 0.119 in/year, R2: 0.57

— Linear model

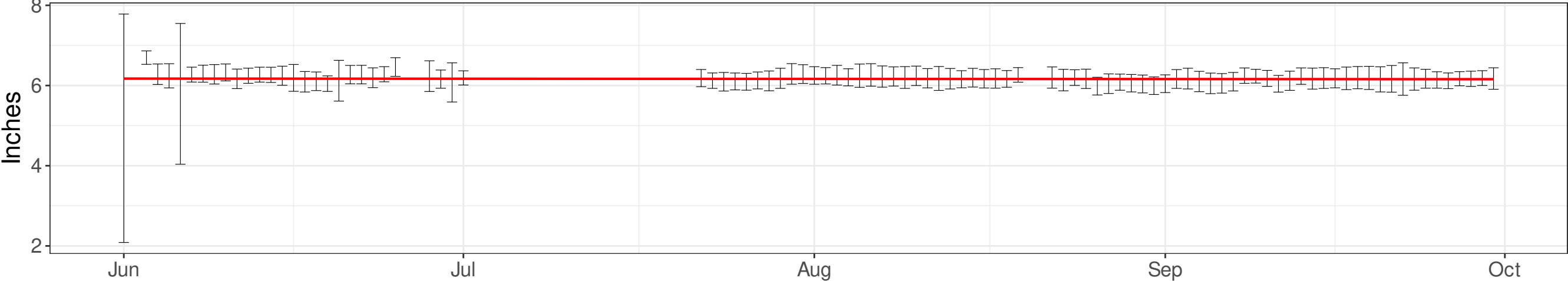
Local rate values have been calculated by removing the regional tectonic plate rates, estimated at site SAS4, from the raw data displayed in the charts.

REMNE, 06/01/2024 - 09/30/2024

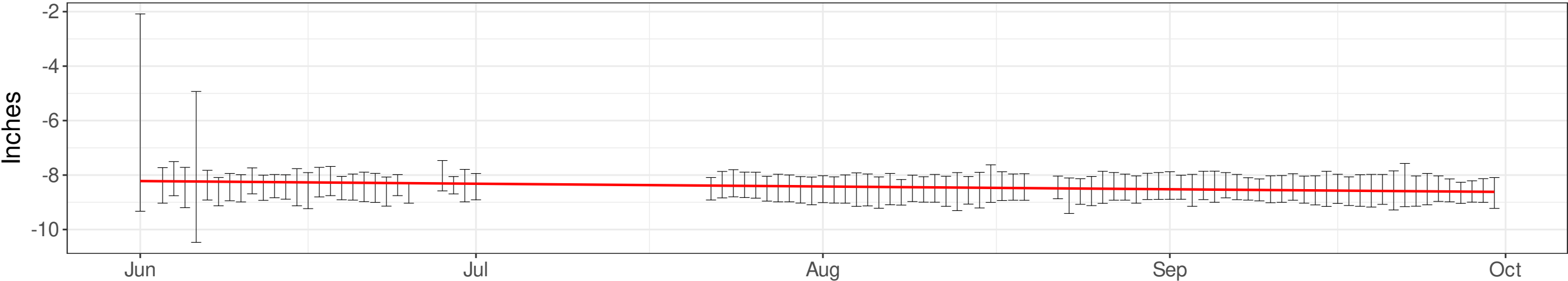
East displacement - daily values



North displacement - daily values



Vertical displacement - daily values



Local east rate: -0.643 ± 0.169 in/year, R2: 0.32

Local north rate: -0.022 ± 0.163 in/year, R2: 0.00

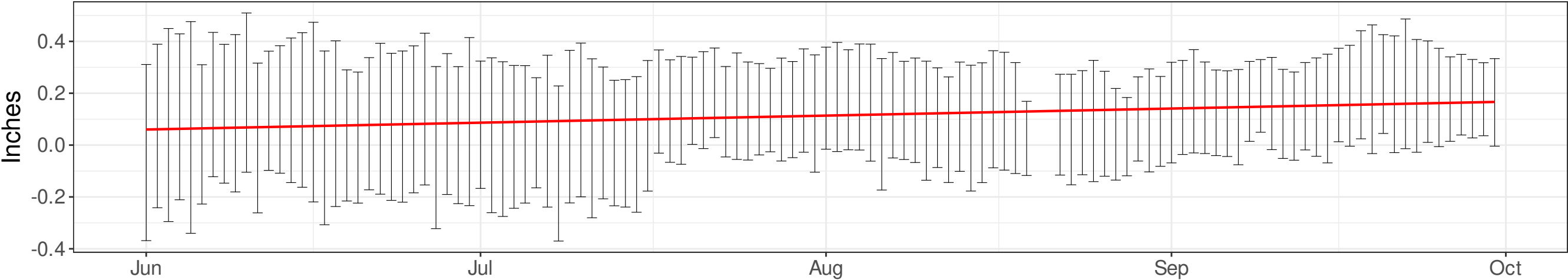
Local vertical rate: -1.130 ± 0.304 in/year, R2: 0.14

 ——— Linear model

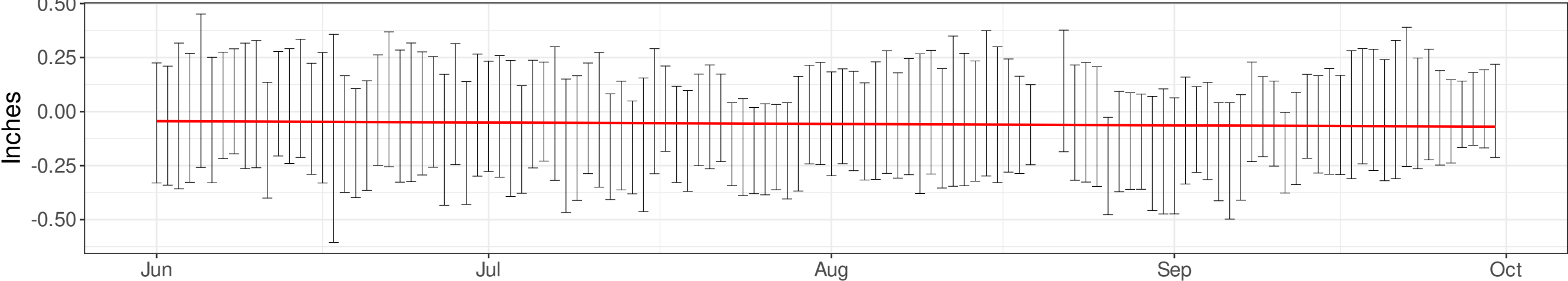
Local rate values have been calculated by removing the regional tectonic plate rates, estimated at site SAS4, from the raw data displayed in the charts.

REMNW, 06/01/2024 - 09/30/2024

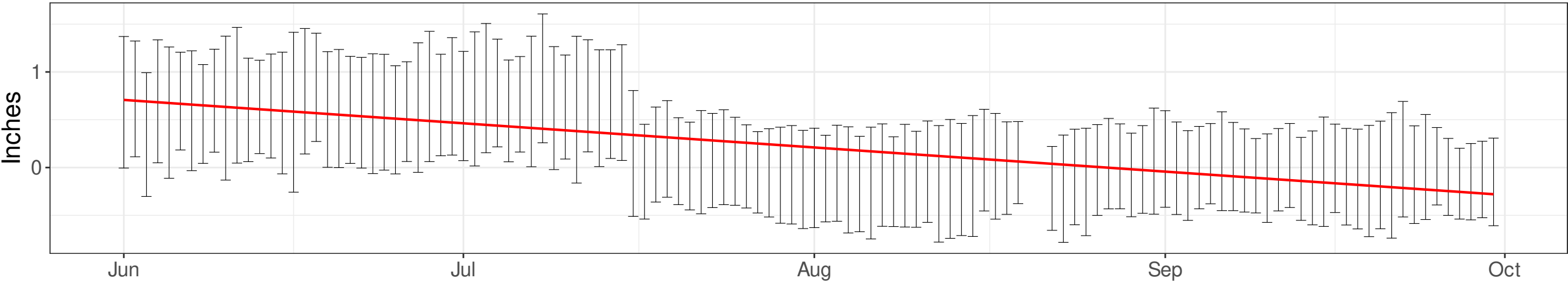
East displacement - daily values



North displacement - daily values



Vertical displacement - daily values



Local east rate: 0.798 ± 0.053 in/year, R2: 0.27

Local north rate: -0.054 ± 0.072 in/year, R2: 0.01

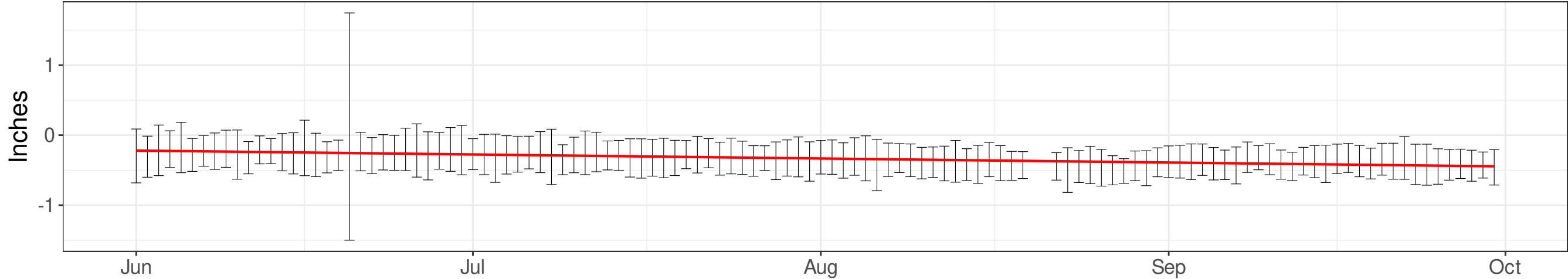
Local vertical rate: -2.915 ± 0.197 in/year, R2: 0.68

— Linear model

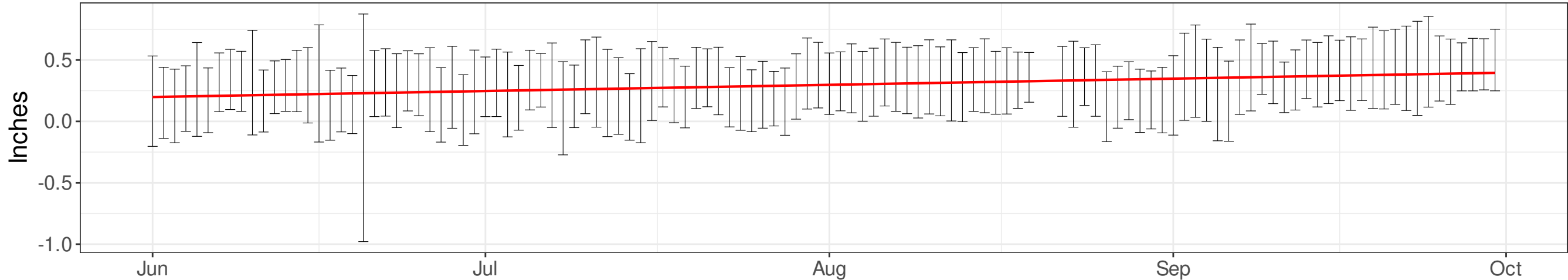
Local rate values have been calculated by removing the regional tectonic plate rates, estimated at site SAS4, from the raw data displayed in the charts.

REMSE, 06/01/2024 - 09/30/2024

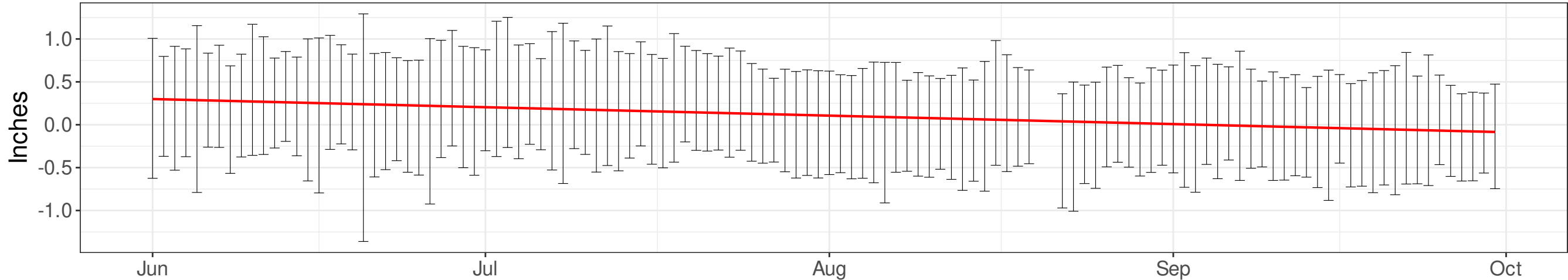
East displacement - daily values



North displacement - daily values



Vertical displacement - daily values



Local east rate: -0.204 ± 0.059 in/year, R2: 0.56

Local north rate: 0.618 ± 0.081 in/year, R2: 0.33

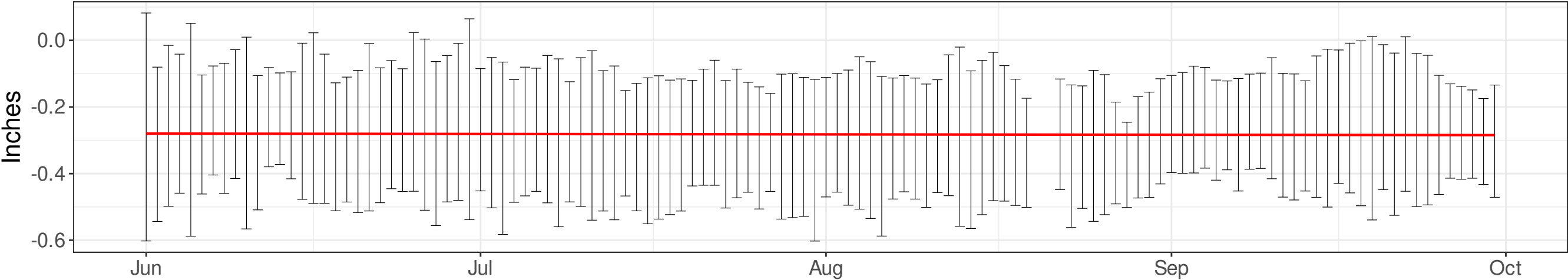
Local vertical rate: -1.091 ± 0.120 in/year, R2: 0.49

————— Linear model

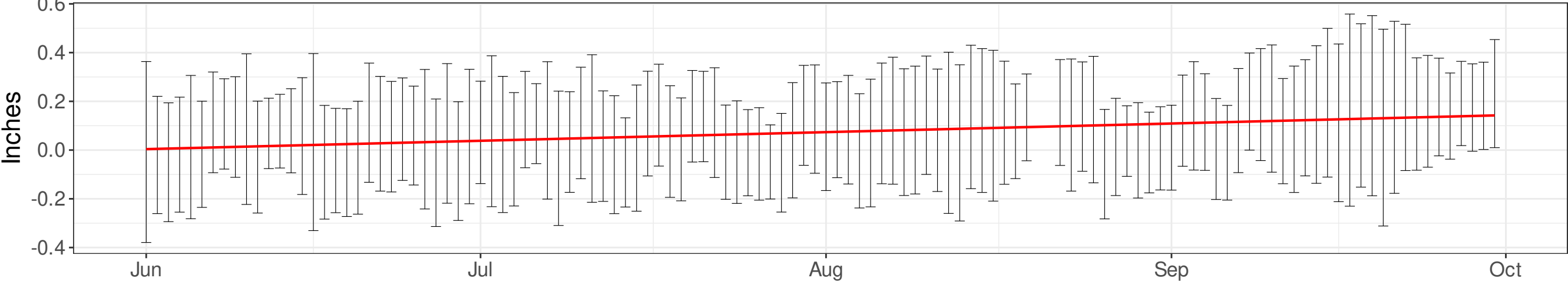
Local rate values have been calculated by removing the regional tectonic plate rates, estimated at site SAS4, from the raw data displayed in the charts.

REMSW, 06/01/2024 - 09/30/2024

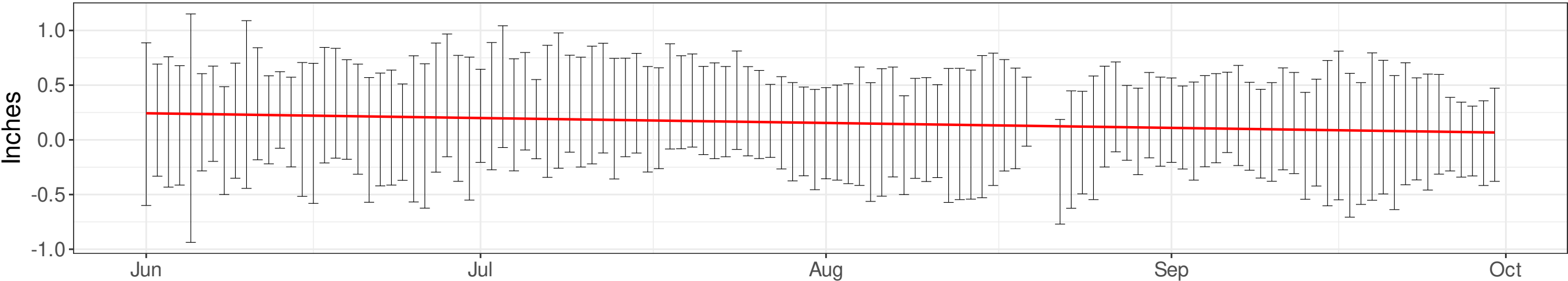
East displacement - daily values



North displacement - daily values



Vertical displacement - daily values



Local east rate: 0.462 ± 0.036 in/year, R2: 0.00

Local north rate: 0.441 ± 0.061 in/year, R2: 0.31

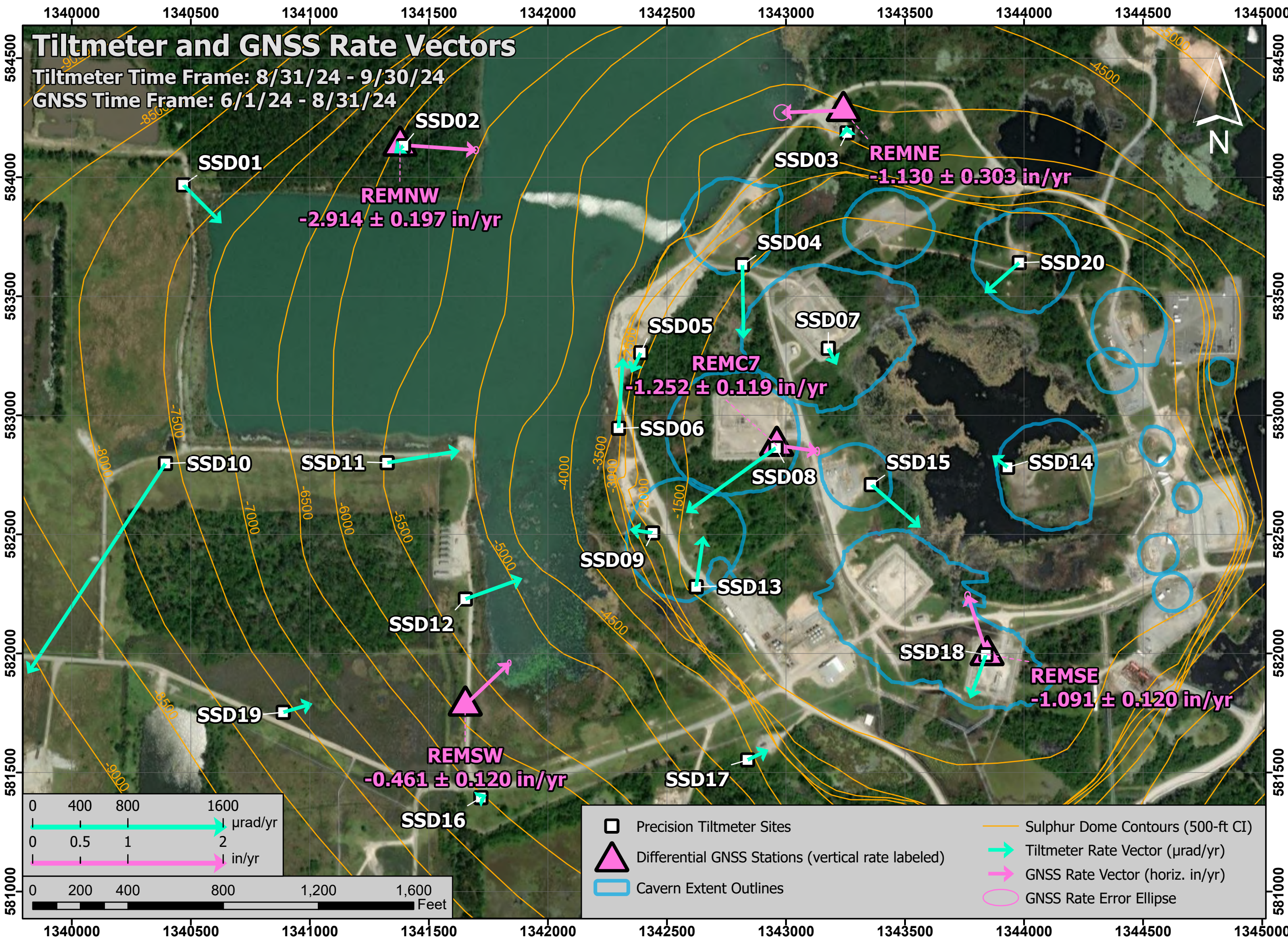
Local vertical rate: -0.462 ± 0.121 in/year, R2: 0.17

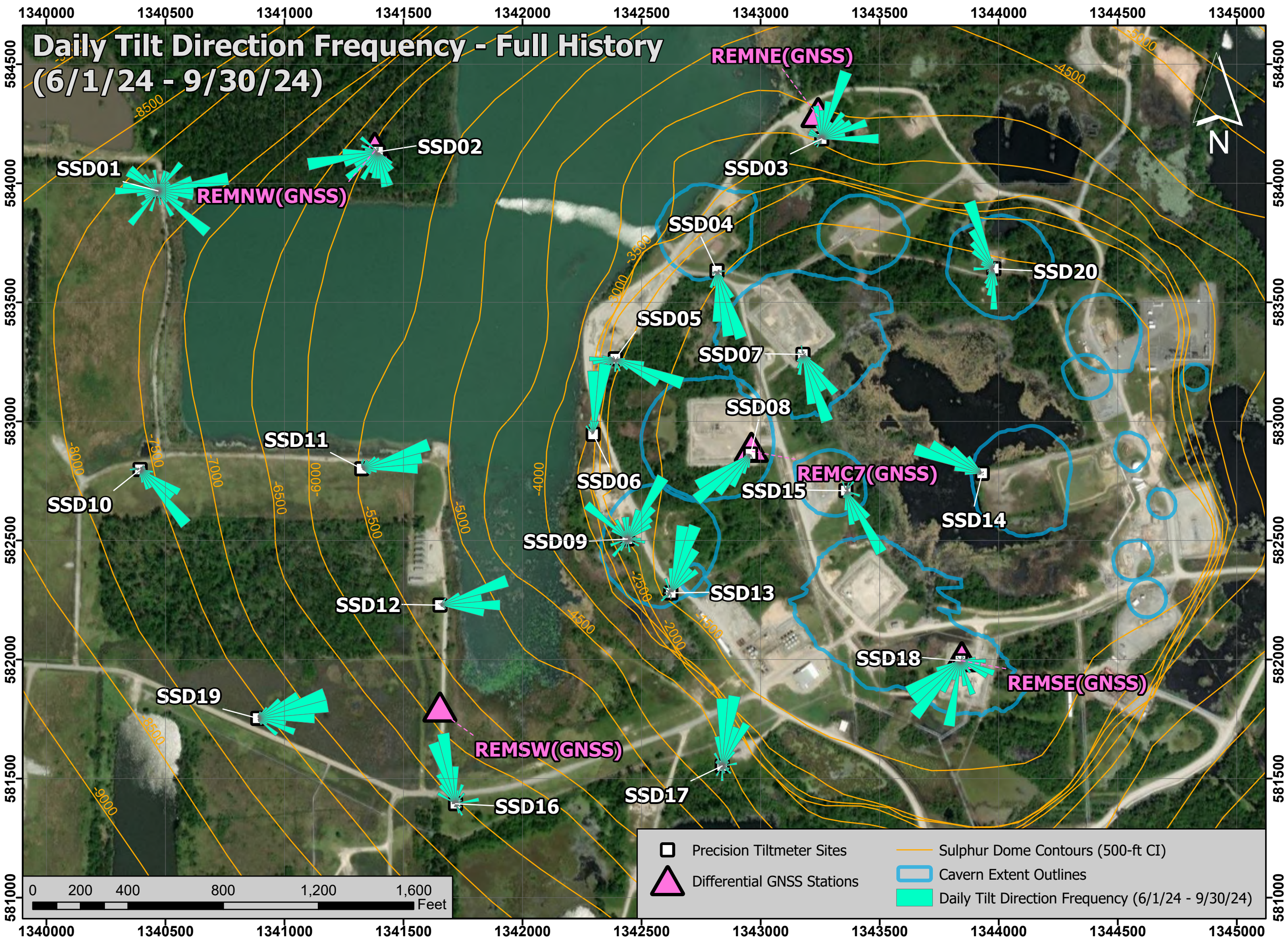
— Linear model

Local rate values have been calculated by removing the regional tectonic plate rates, estimated at site SAS4, from the raw data displayed in the charts.

APPENDIX 3

Analysis Maps







ATTACHMENT B

SNT InSAR report - September 16, 2024

SNT Satellite Update

Continuous InSAR Monitoring of
Ground Displacement At Westlake Caverns
and Western Dome Flank

Sulphur Mines Salt Dome

Prepared for:
Westlake Chemical

Prepared by:
Lonquist & Co., LLC
8591 United Plaza Blvd., Suite 280
Baton Rouge, LA 70809

Dataset
Satellite Source
Sentinel-1 (SNT)
Most Recent Image Date
Monday, September 16, 2024

Analysis Report Date:
September 20, 2024

Dataset Information

Satellite Source	Sentinel-1 (SNT)
Revisit Frequency	12 days
Most Recent Image Date	Monday, September 16, 2024
Dataset Image Count	209
Dataset Time Range	October 4, 2016 - September 16, 2024
Dataset Length	7.95 Years
Satellite Line-of-Sight (LOS)	43° West of Vertical (Viewing site from the West)

Analysis Methodology

Time Series Charts

Trend lines were calculated for the averaged displacement values within each AOI. Quadratic regression was used to determine Velocity and Acceleration of LOS displacement. Trends calculated for the AOI point groups are depicted for each AOI in the Time Series section of this report.

Contour Maps

A quadratic trend was also calculated for each individual measurement point across the analysis region. Trend values for each point were used to generate Velocity and Acceleration contour maps to depict the spatial distribution of the movement trends. Negative velocity values indicate subsidence or eastward movement. Negative acceleration values indicate increasing rates of subsidence, increasing eastward movement, or slowing westward movement and positive acceleration values indicate slowing rates of subsidence, slowing eastward movement, or increasing westward movement. Maps depicting the individual data points colored by these trend values are also included in the last section of the report.

Recent vs. Historical Data

The multi-year SNT dataset timeframe allows for Recent data to be evaluated separately from Historical data and for trends from the two timeframes to be compared. The change in the velocities and accelerations from the two timeframes are provided in the Time Series and Contour Map sections. Velocity values are calculated for the final date in either the Recent or Historical datasets.

Observations

To-date there have been no acute deviations from established subsidence trends in the areas investigated.

The comparison of Recent to Historical trends in the SNT data does imply a minor increase (≥ -0.10) in the negative velocity and/or negative acceleration of LOS displacement in 3 of the 15 AOI point groups. This suggests that marginal increases in subsidence rates may be occurring in these areas in recent years with the greatest velocity increases (in descending order) occurring in AOI 8 (PPG 22), AOI 10 (PPG2), and AOI 7 (PPG 7).

The mapped contours of the change in recent vs. historical subsidence velocity and acceleration mostly display minor fluctuations around 0, intermittently distributed within the AOIs. Some concentrations of negative rate change can be observed that generally support the observations in the above mentioned AOIs.



Date Signed: September 20, 2024
Austin, Texas

Nathaniel L. Byars, P.E.
Principal Engineer
Louisiana License No. 40697

InSAR Data Sources

InSAR Data

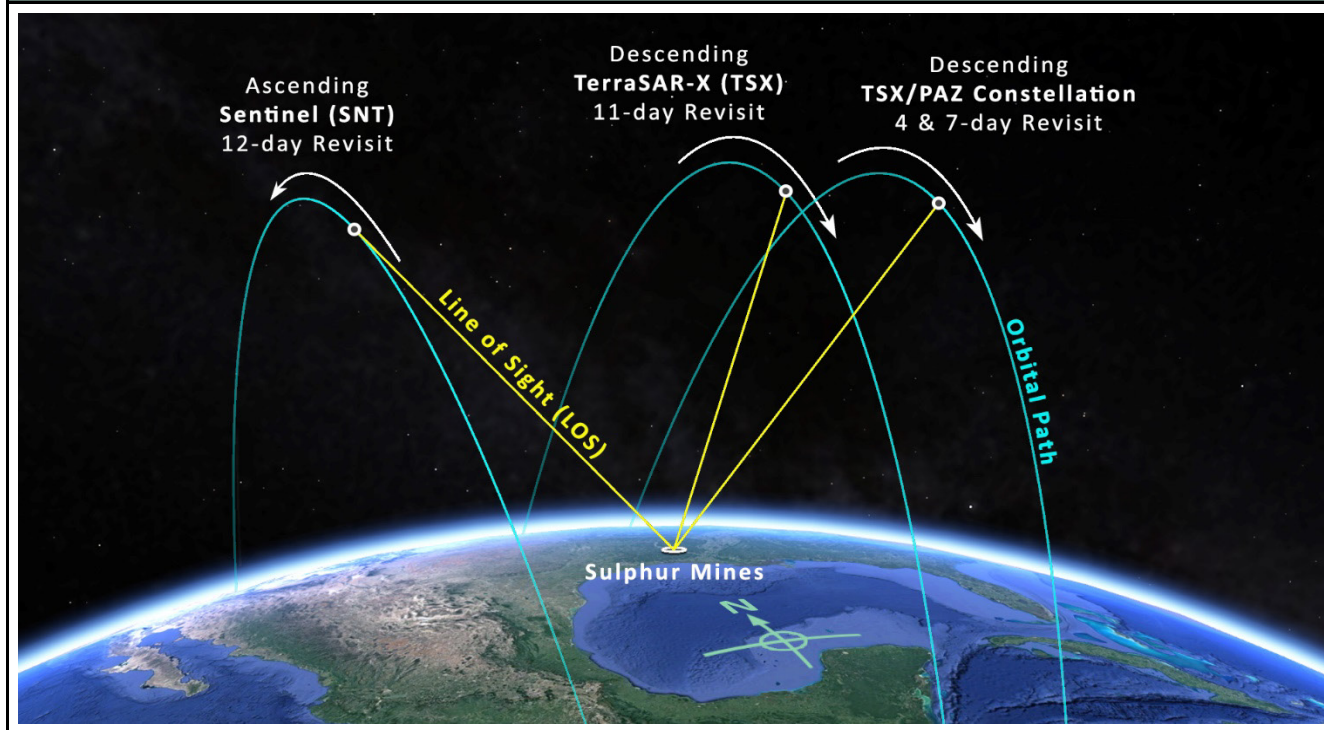
Interferometric Synthetic Aperture Radar (InSAR) is the most well established method to continually evaluate small, normally undetectable, ground movement over a large area. Radar imagery collected via satellites over successive orbital passes is used to identify and define measurement points on the ground. Objects or ground features providing a stable reflection of radar energy such as buildings, roads, and infrastructure produce the highest quality measurement points. InSAR analysis identifies the change in distance between the satellite and each measurement point over time relative to a stable reference point within the imaged area.

Satellite Sources

Two InSAR datasets are being used to evaluate subsidence over the Sulphur Mines Salt Dome. These datasets provide Line-of-Sight (LOS) displacement measurements from both ascending and descending orbits. An ascending orbit denotes the satellite's longitudinal course from south to north as it passes over the site, while a descending orbit denotes the satellite is moving from north to south.

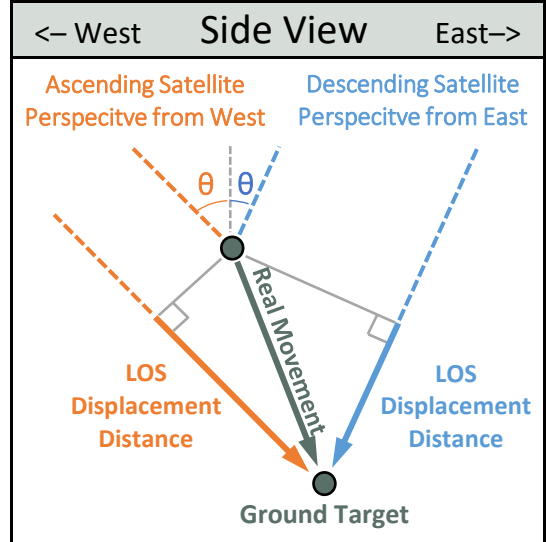
The first dataset comes from a low-resolution Sentinel-1 (SNT) satellite on an ascending orbit that captures data from the west of the site on a 12-day frequency. The second comes from a pair of high resolution satellites that share the same descending orbit and capture data from east of the site. These are a TSX satellite and the PAZ satellite (TSX/PAZ constellation), both with an 11-day revisit frequency. Their orbits are offset with the PAZ satellite passing over the site 4 days after the TSX satellite. Prior to May 2023, data was captured from a different high-resolution TerraSAR-X (TSX) satellite on a descending orbit that captured data from the east of the site on an 11-day frequency. The transition was made for the increased data frequency that resulted from a 4 and 7-day revisit period. The image below depicts the orbital paths of the satellites in relation to the Sulphur Mines Salt Dome.

Satellite Orbital Diagram



InSAR Line-of-Site (LOS) Data

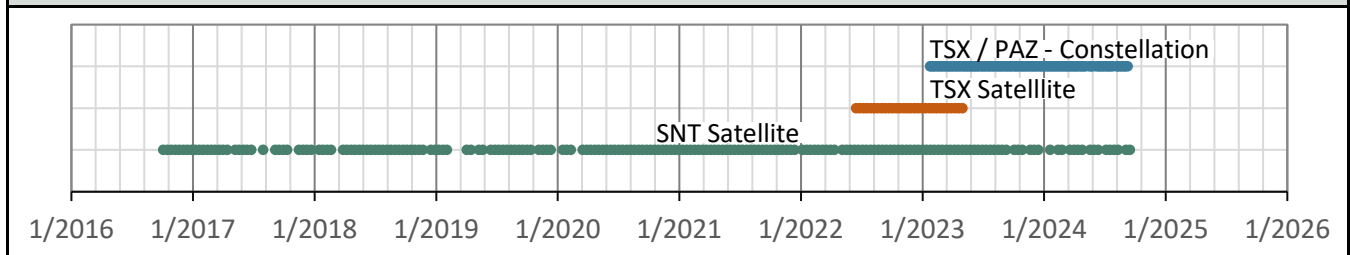
LOS displacement measurements refer to a change in distance between the satellite sensor and the ground target. Measurement positions on the west side of the Sulphur Dome are known to be experiencing some eastward movement toward the dome center due to the geometry of the subsidence basin. The InSAR satellites view the site from eastward and westward positions so LOS measurements are understood to convey a movement distance that is not purely vertical. The diagram to the right illustrates the geometric relationship between the theoretical Real movement of a ground target and LOS displacement measurements from two different satellite viewing directions.



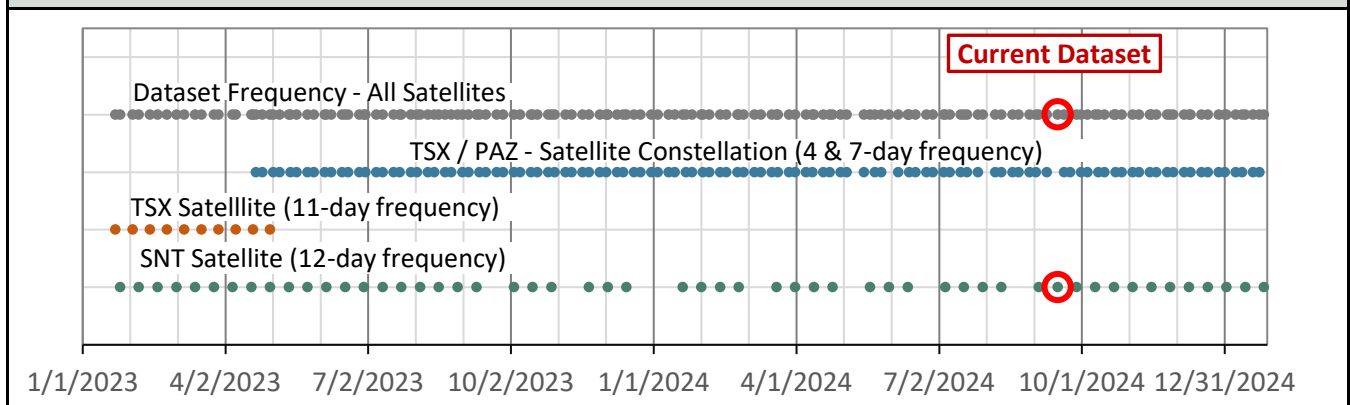
Satellite Properties & Image Frequency

Satellite and Data Properties	SNT	TSX	TSX/PAZ Constellation
Band (Wavelength)	C-band (2.20 in)	X-band (1.22 in)	X-band (1.22 in)
Track	T136	T29	T67 & T120
Pixel resolution	65 x 16 ft	3 x 3 ft	3 x 3 ft
Revisit frequency	12 days	11 days	4 & 7 days
Orbit (LOS Angle, θ)	Ascending (43°)	Descending (17°)	Descending (37°)
Data Start Date	10/4/2016	6/16/2022	1/24/2023
Measurement error range	± 0.20 in	± 0.03 in	± 0.03 in

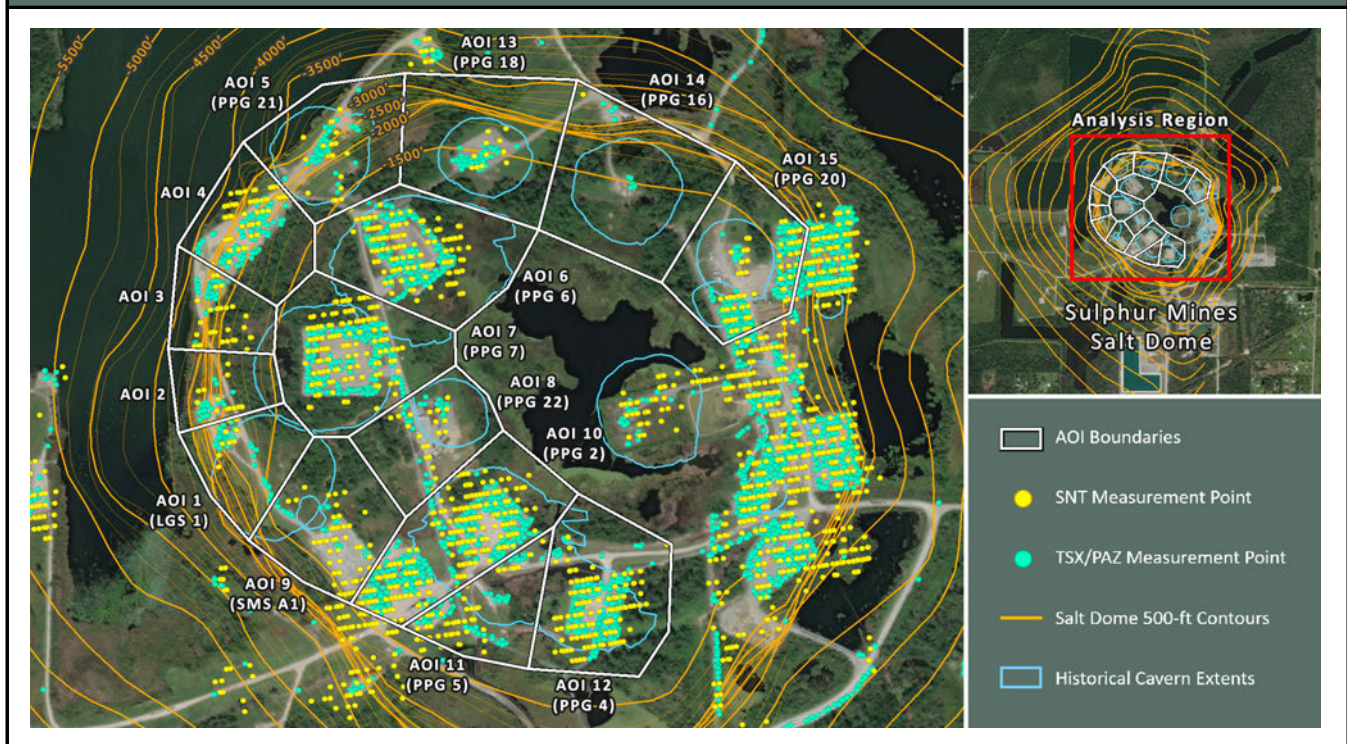
Dataset Measurement History



Dataset Update Frequency



AOI Boundaries & InSAR Measurement Points

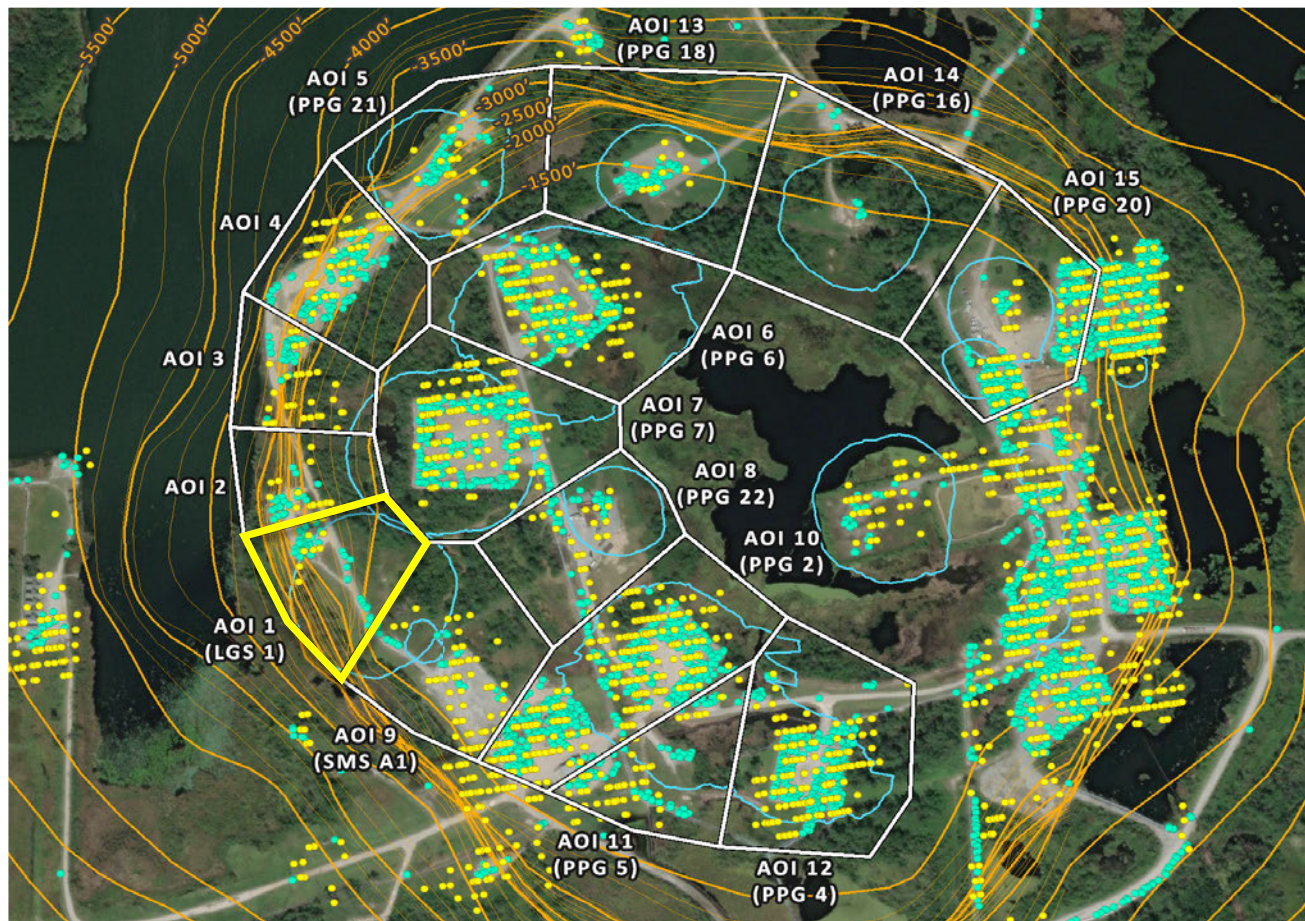


Subsidence Monitoring Areas of Interest (AOIs)

To visually convey and evaluate trend consistency for the displacement time series of each ground target, measurement points were grouped and their displacement values were averaged. The point groups are referred to as Areas of Interest (AOIs) in this analysis and their boundaries are depicted on the above map. The below table lists the trend values calculated in each AOI for the dataset evaluated in this report.

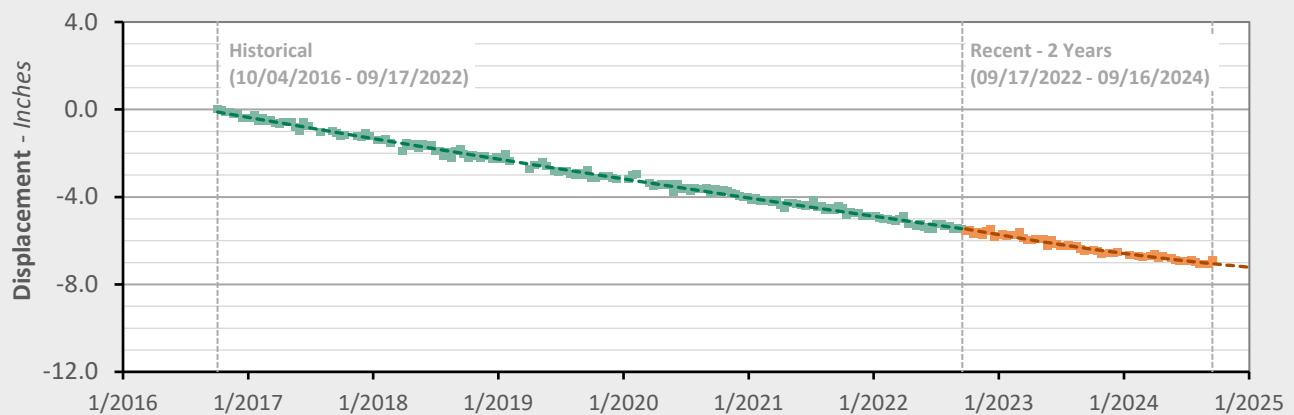
AOI Name	SNT (9/16/2024)	LOS Velocity (<i>in/yr</i>)			LOS Acceleration (<i>in/yr</i> ²)		
	Point Count	Historical	Recent	Change	Historical	Recent	Change
AOI 1 (LGS 1)	12	-0.80	-0.58	+0.22	+0.03	+0.23	+0.20
AOI 2	16	-0.79	-0.72	+0.07	+0.05	+0.16	+0.11
AOI 3	29	-0.66	-0.50	+0.17	+0.03	+0.19	+0.17
AOI 4	59	-0.77	-0.63	+0.13	+0.00	+0.06	+0.05
AOI 5 (PPG 21)	28	-0.66	-0.60	+0.06	+0.01	-0.05	-0.07
AOI 6 (PPG 6)	134	-0.87	-0.83	+0.03	+0.05	+0.03	-0.02
AOI 7 (PPG 7)	140	-0.99	-1.09	-0.10	+0.07	+0.00	-0.06
AOI 8 (PPG 22)	20	-1.05	-1.19	-0.14	+0.11	+0.05	-0.06
AOI 9 (SMS A1)	59	-0.86	-0.69	+0.17	+0.07	+0.17	+0.10
AOI 10 (PPG 2)	231	-0.90	-1.02	-0.12	+0.09	-0.01	-0.09
AOI 11 (PPG 5)	53	-0.89	-0.82	+0.07	+0.06	+0.09	+0.03
AOI 12 (PPG 4)	120	-0.73	-0.47	+0.27	+0.05	+0.21	+0.16
AOI 13 (PPG 18)	12	-0.61	-0.40	+0.21	+0.04	+0.21	+0.17
AOI 14 (PPG 16)	1	-0.20	+0.30	+0.50	+0.06	+0.76	+0.69
AOI 15 (PPG 20)	70	-0.29	-0.23	+0.06	+0.04	+0.04	-0.00

AOI 1 (LGS 1) - Location Map



AOI 1 (LGS 1) - Displacement Time Series

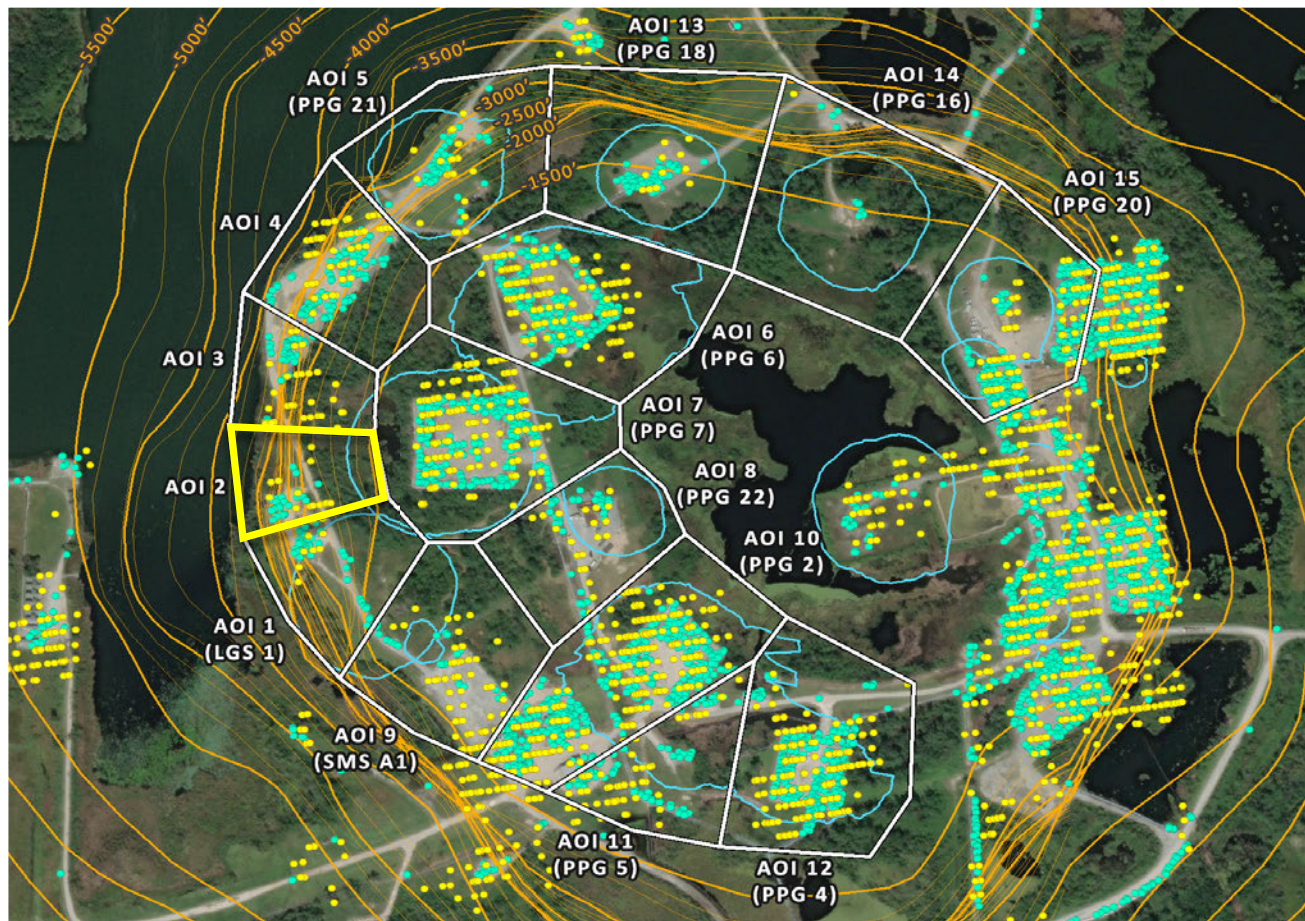
SNT (9/16/2024) Point Count: 12



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.80 in/yr	-0.58 in/yr	+0.22 in/yr
Acceleration:	+0.03 in/yr ²	+0.23 in/yr ²	+0.20 in/yr ²

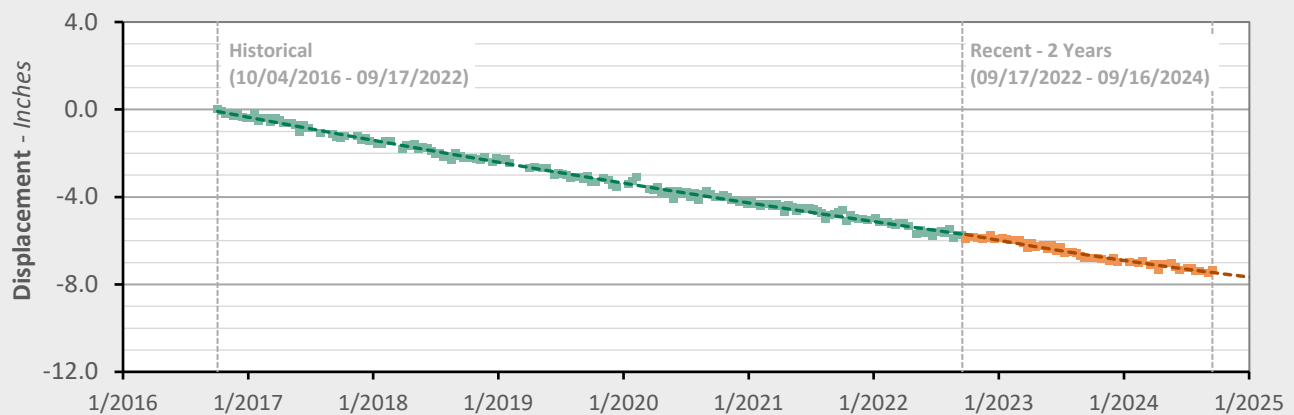
■ Historical LOS Displacement Measurement
 --- Historical Trend Line (Quadratic Regression)
 ■ Recent LOS Displacement Measurement
 --- Historical Trend Line (Quadratic Regression)

AOI 2 - Location Map



AOI 2 - Displacement Time Series

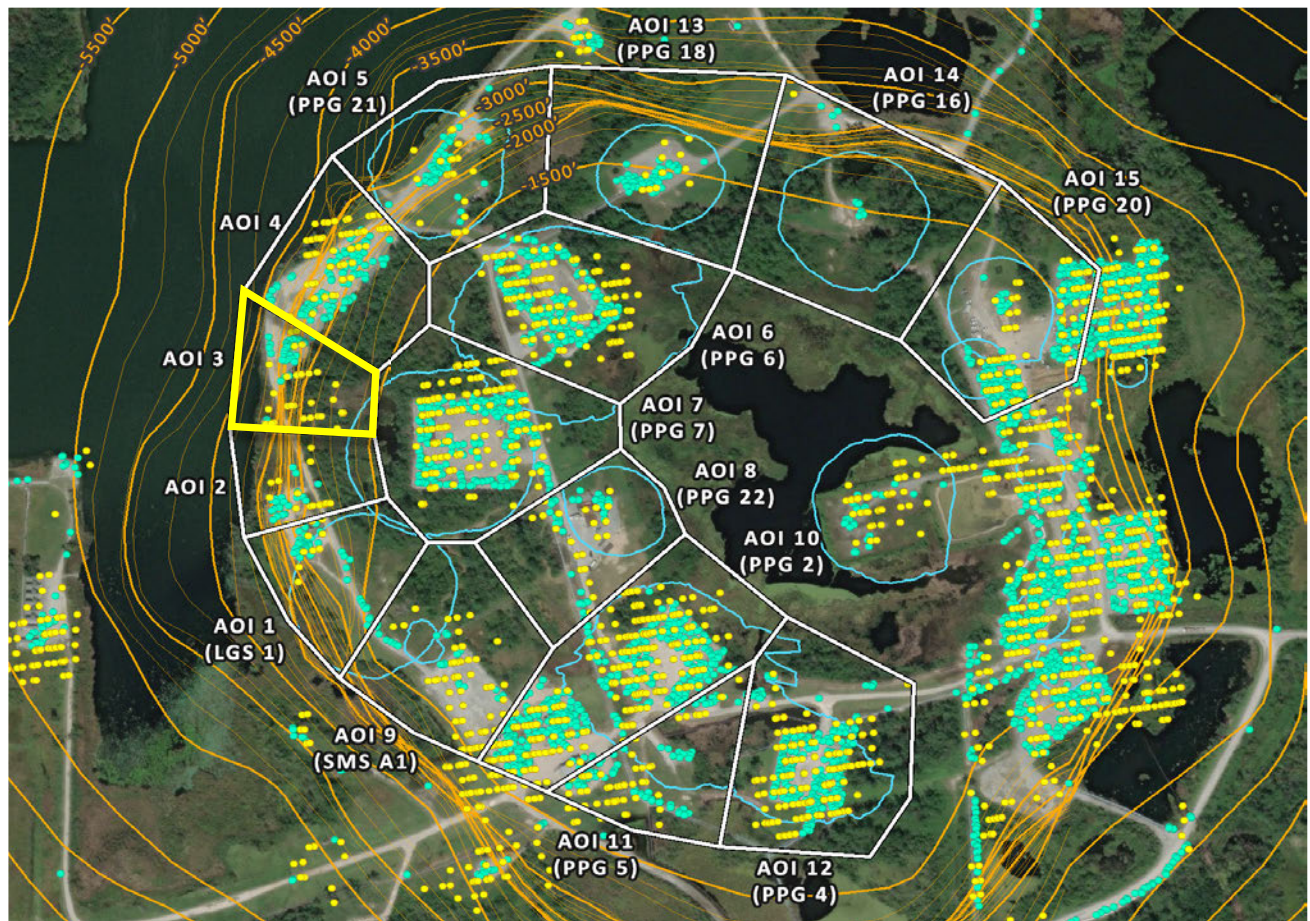
SNT (9/16/2024) Point Count: 16



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.79 in/yr	-0.72 in/yr	+0.07 in/yr
Acceleration:	+0.05 in/yr ²	+0.16 in/yr ²	+0.11 in/yr ²

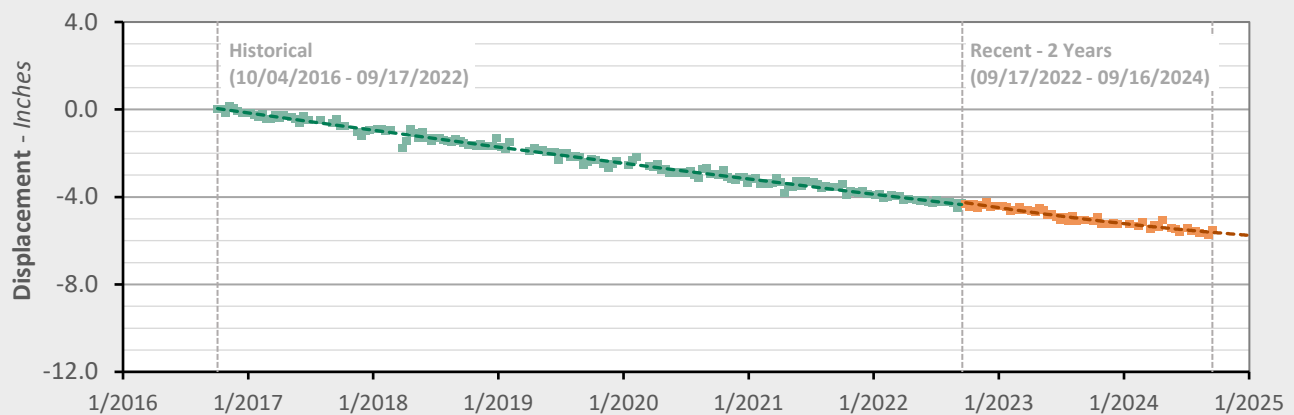
■ Historical LOS Displacement Measurement
 --- Historical Trend Line (Quadratic Regression)
 ■ Recent LOS Displacement Measurement
 --- Historical Trend Line (Quadratic Regression)

AOI 3 - Location Map



AOI 3 - Displacement Time Series

SNT (9/16/2024) Point Count: 29



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.66 in/yr	-0.50 in/yr	+0.17 in/yr
Acceleration:	+0.03 in/yr ²	+0.19 in/yr ²	+0.17 in/yr ²

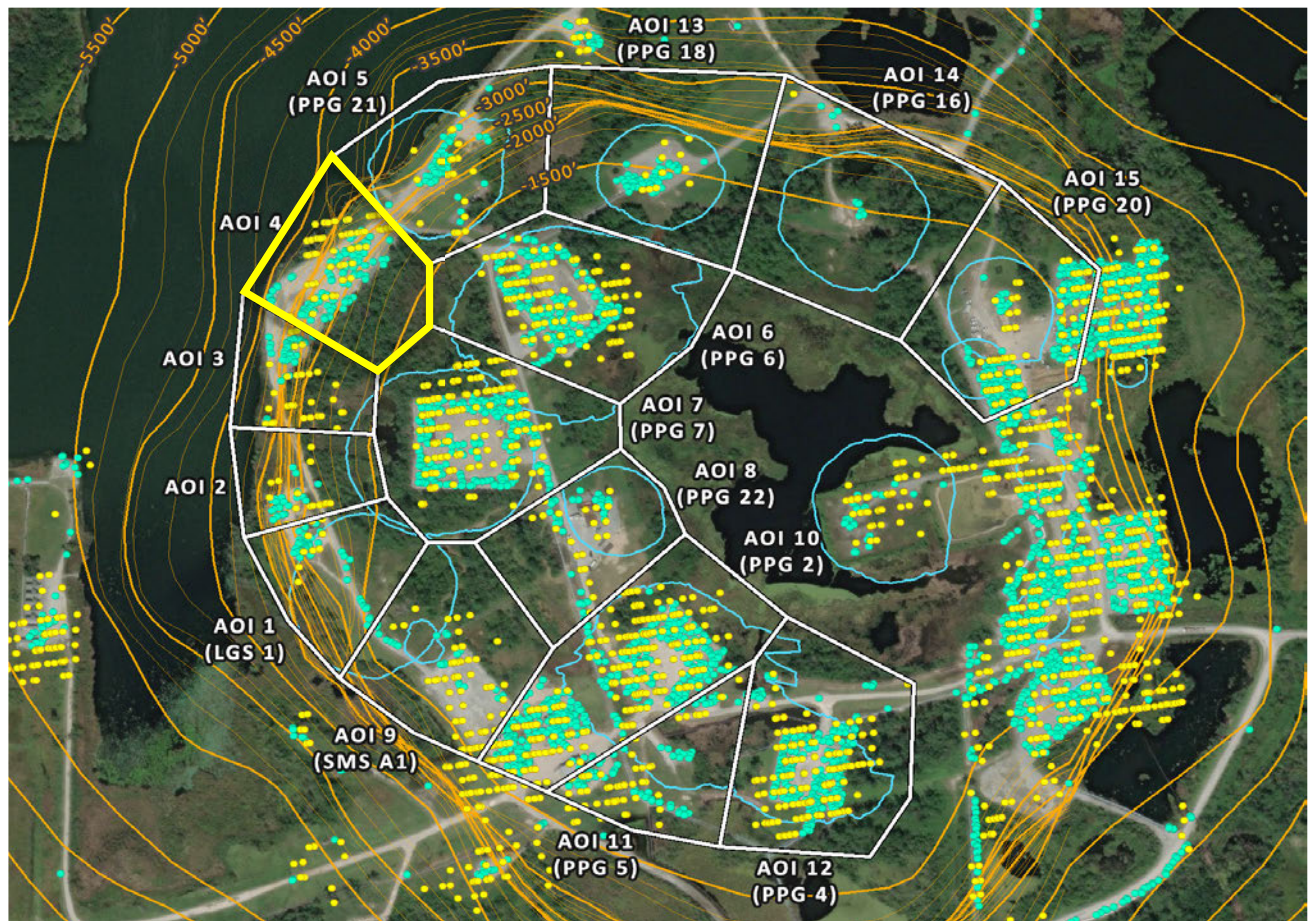
■ Historical LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

■ Recent LOS Displacement Measurement

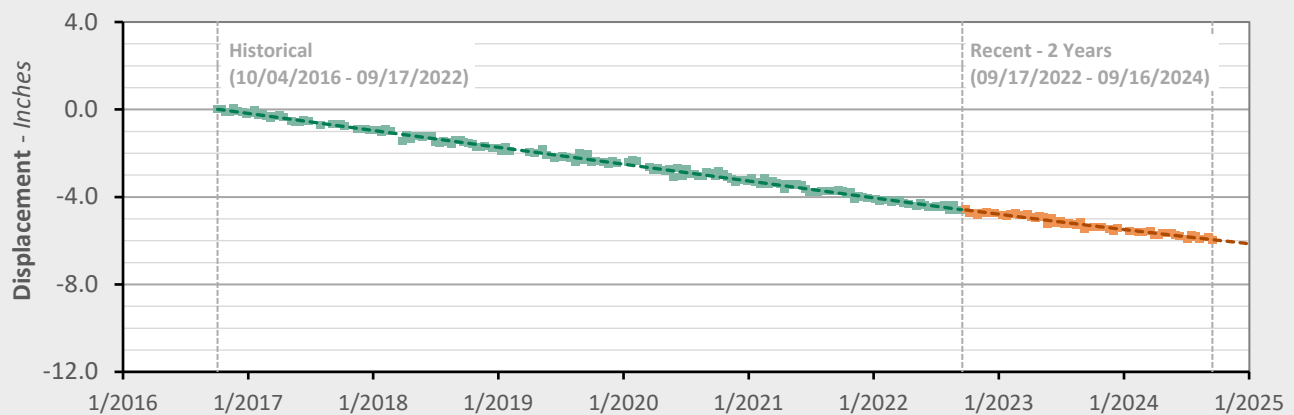
--- Historical Trend Line (Quadratic Regression)

AOI 4 - Location Map



AOI 4 - Displacement Time Series

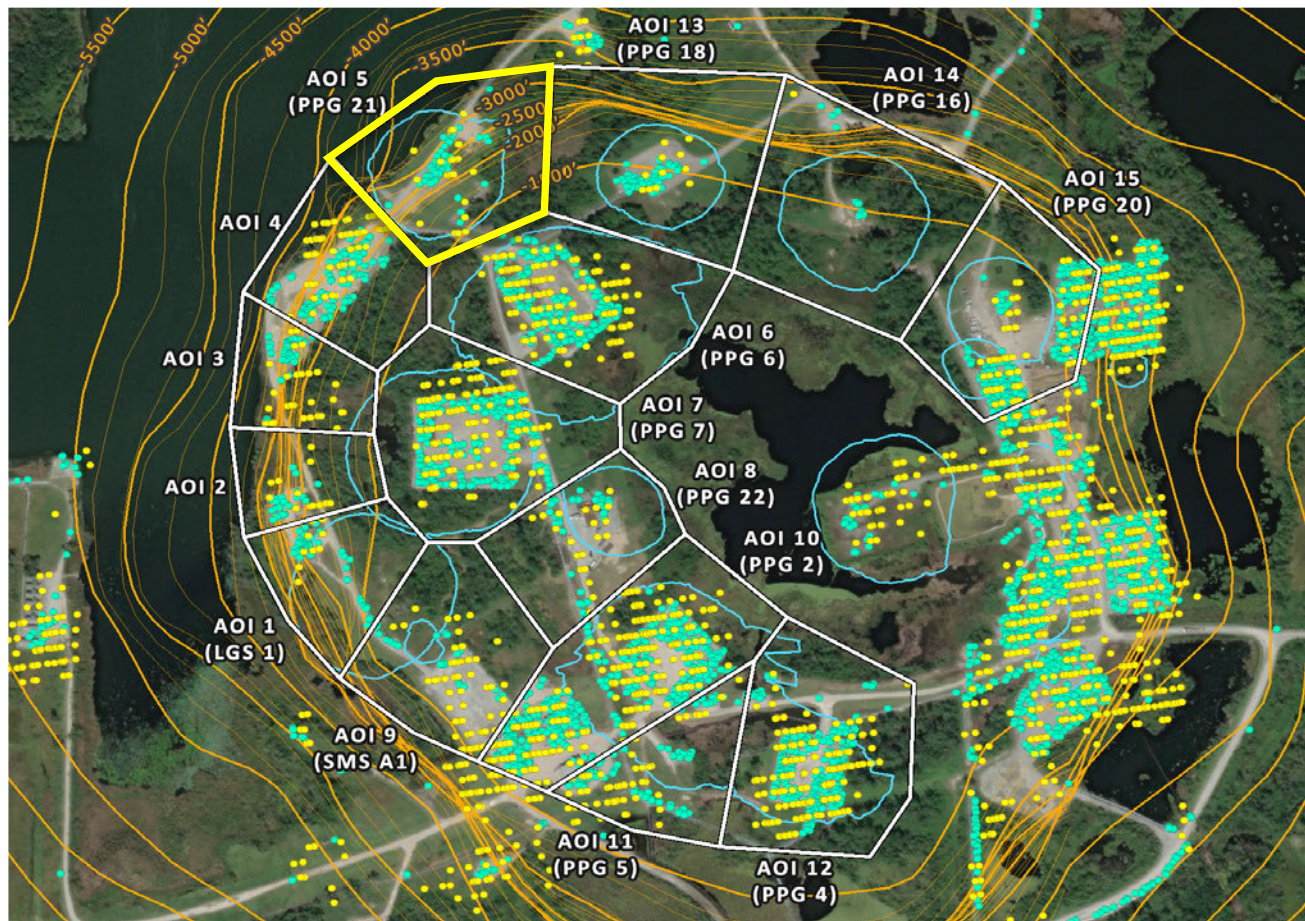
SNT (9/16/2024) Point Count: 59



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.77 in/yr	-0.63 in/yr	+0.13 in/yr
Acceleration:	+0.00 in/yr ²	+0.06 in/yr ²	+0.05 in/yr ²

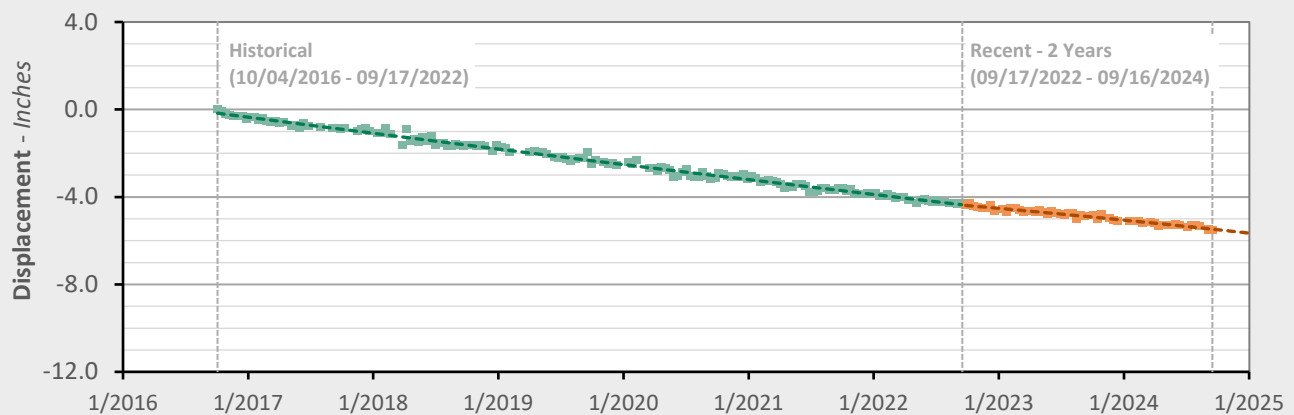
■ Historical LOS Displacement Measurement
 --- Historical Trend Line (Quadratic Regression)
 ■ Recent LOS Displacement Measurement
 --- Historical Trend Line (Quadratic Regression)

AOI 5 (PPG 21) - Location Map



AOI 5 (PPG 21) - Displacement Time Series

SNT (9/16/2024) Point Count: 28



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.66 in/yr	-0.60 in/yr	+0.06 in/yr
Acceleration:	+0.01 in/yr ²	-0.05 in/yr ²	-0.07 in/yr ²

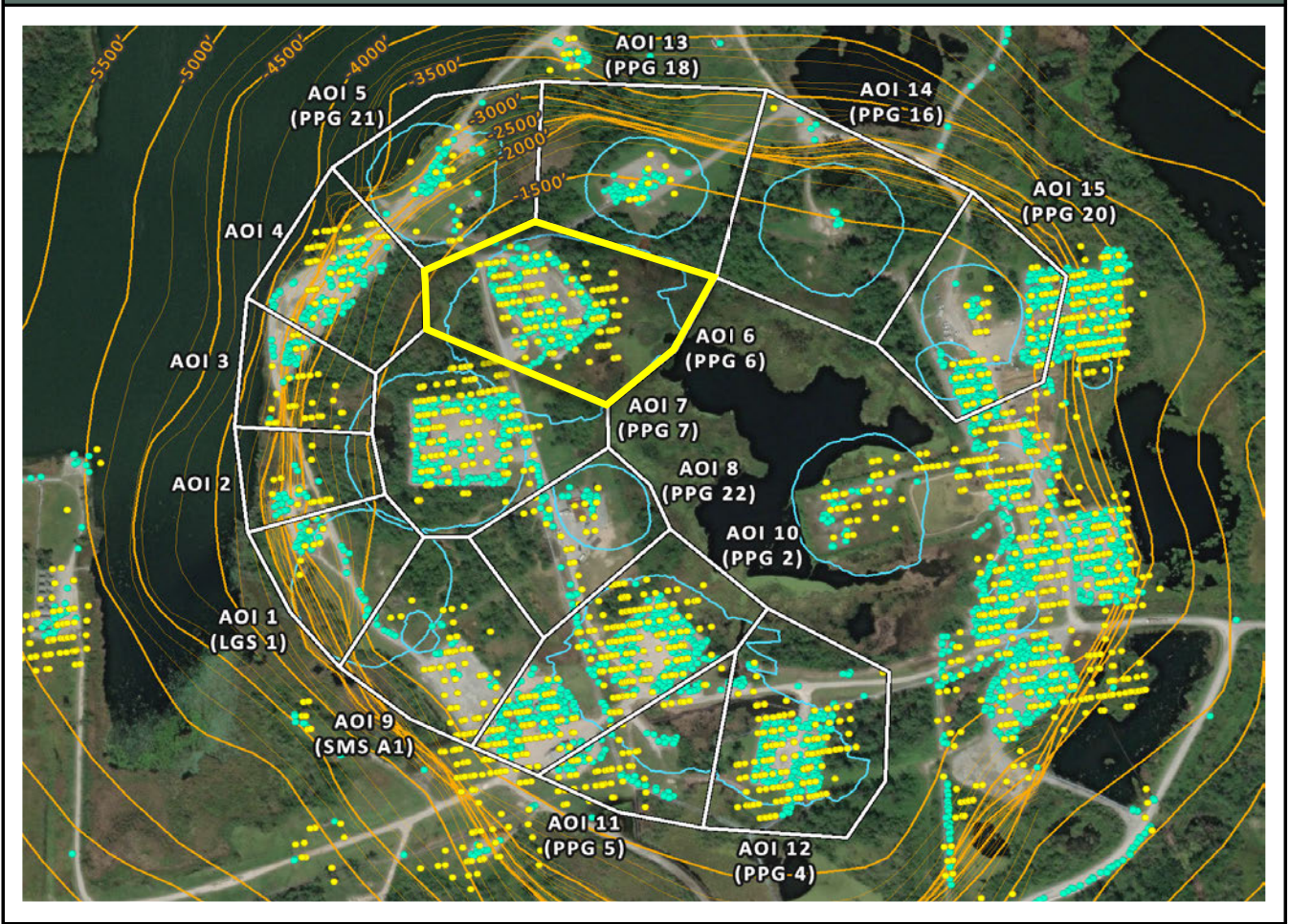
■ Historical LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

■ Recent LOS Displacement Measurement

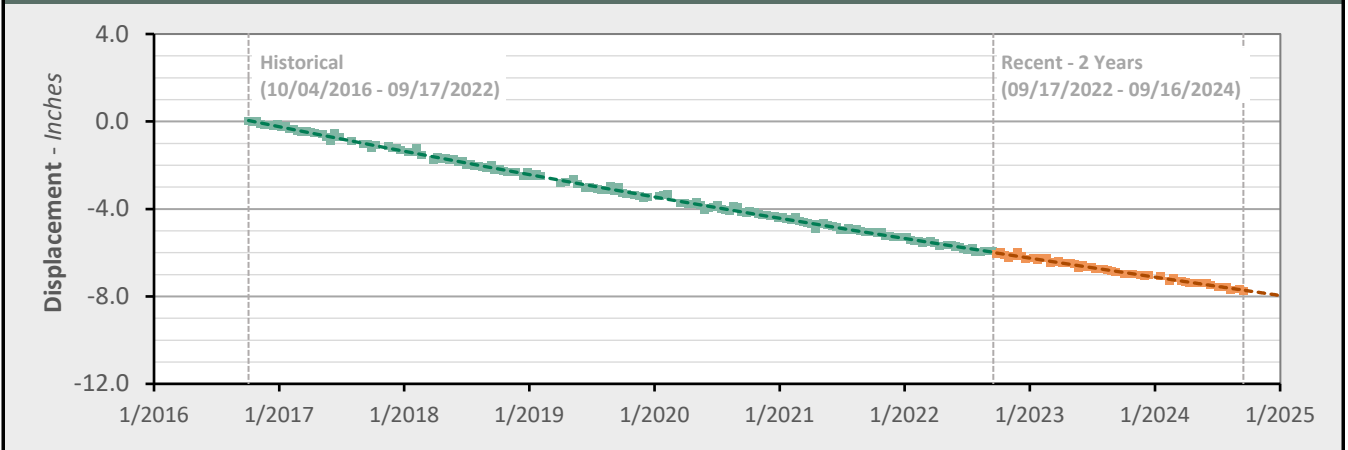
--- Historical Trend Line (Quadratic Regression)

AOI 6 (PPG 6) - Location Map

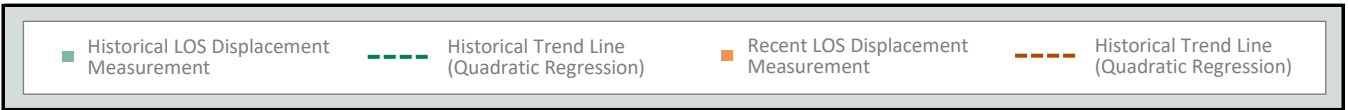


AOI 6 (PPG 6) - Displacement Time Series

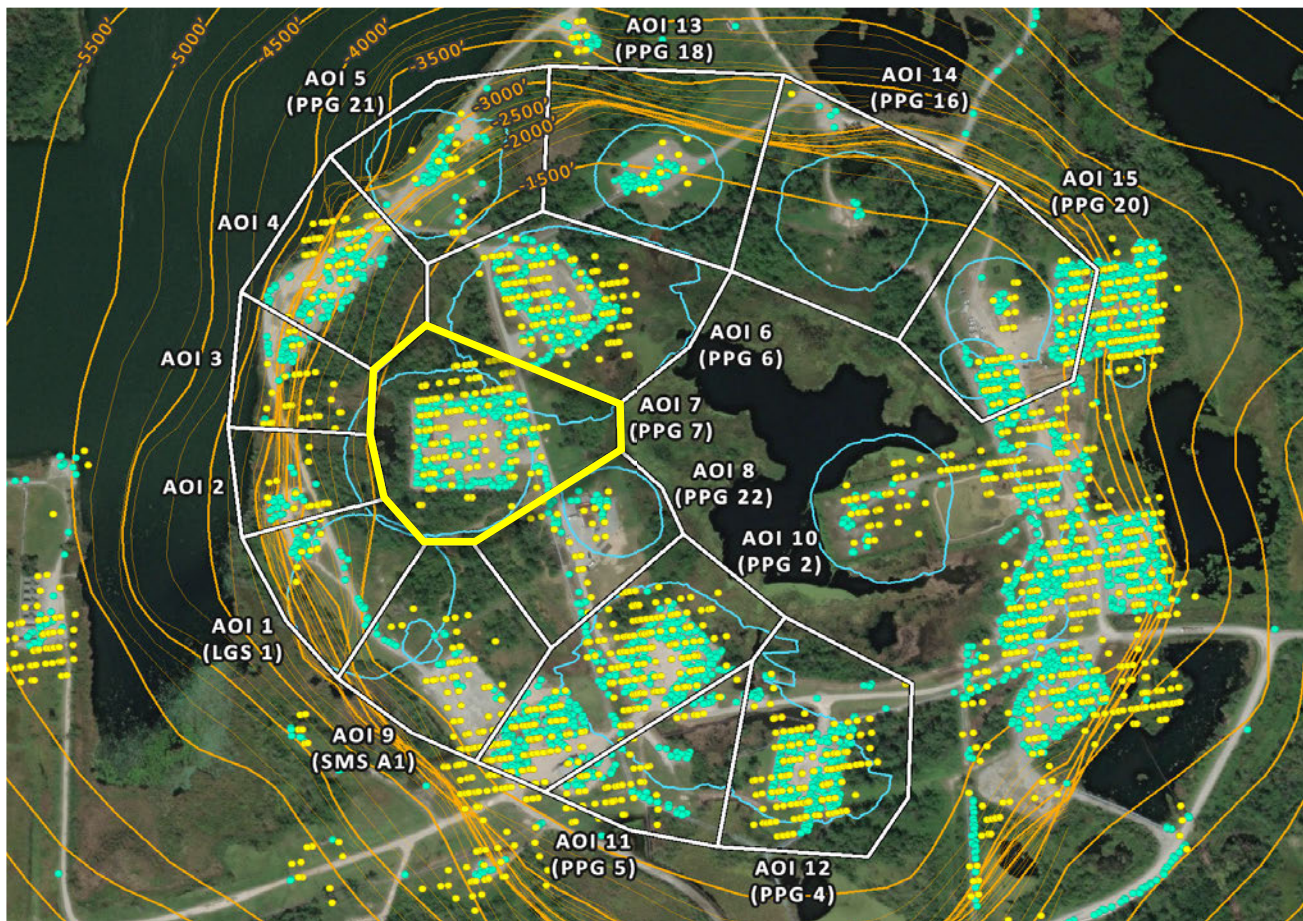
SNT (9/16/2024) Point Count: 134



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.87 in/yr	-0.83 in/yr	+0.03 in/yr
Acceleration:	+0.05 in/yr ²	+0.03 in/yr ²	-0.02 in/yr ²

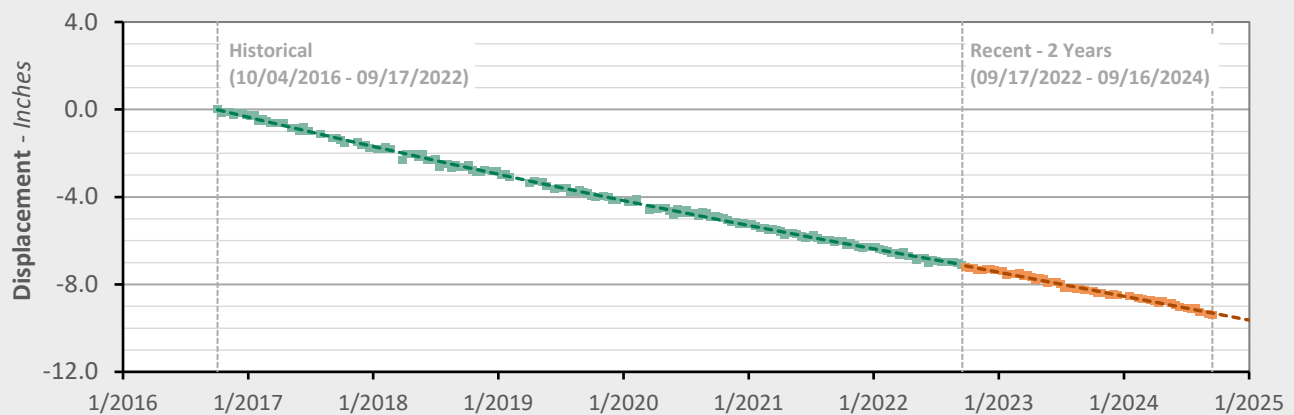


AOI 7 (PPG 7) - Location Map



AOI 7 (PPG 7) - Displacement Time Series

SNT (9/16/2024) Point Count: 140



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.99 in/yr	-1.09 in/yr	-0.10 in/yr
Acceleration:	+0.07 in/yr ²	+0.00 in/yr ²	-0.06 in/yr ²

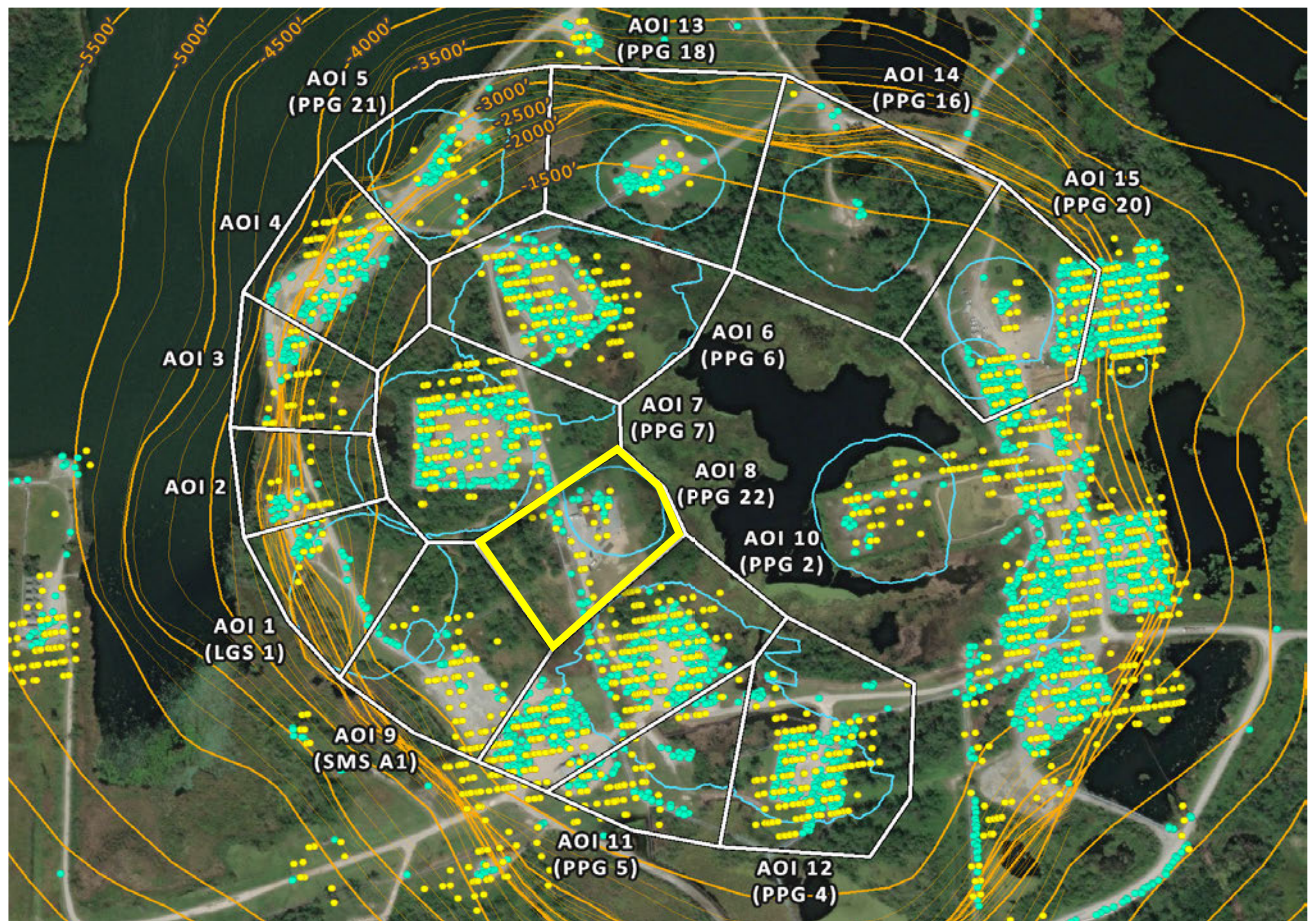
■ Historical LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

■ Recent LOS Displacement Measurement

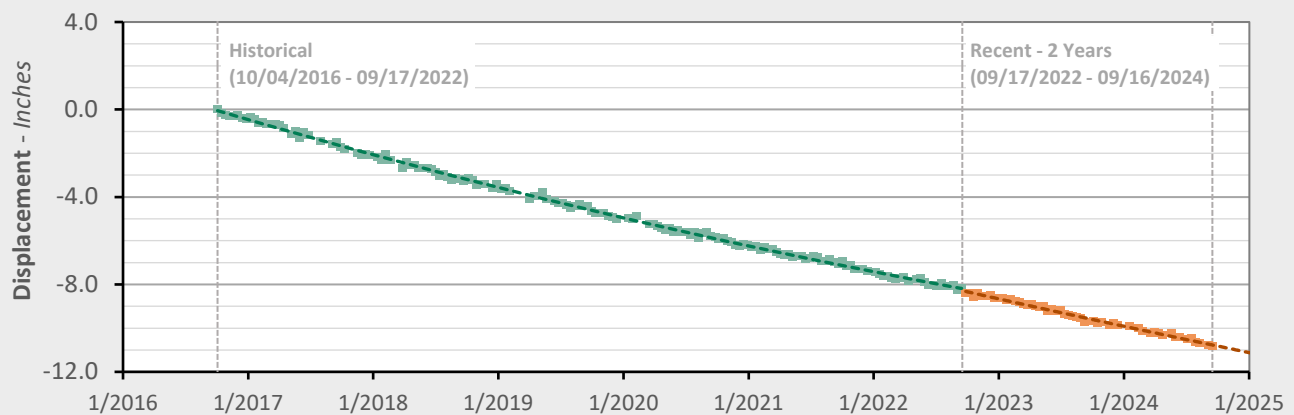
--- Historical Trend Line (Quadratic Regression)

AOI 8 (PPG 22) - Location Map



AOI 8 (PPG 22) - Displacement Time Series

SNT (9/16/2024) Point Count: 20



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-1.05 in/yr	-1.19 in/yr	-0.14 in/yr
Acceleration:	+0.11 in/yr ²	+0.05 in/yr ²	-0.06 in/yr ²

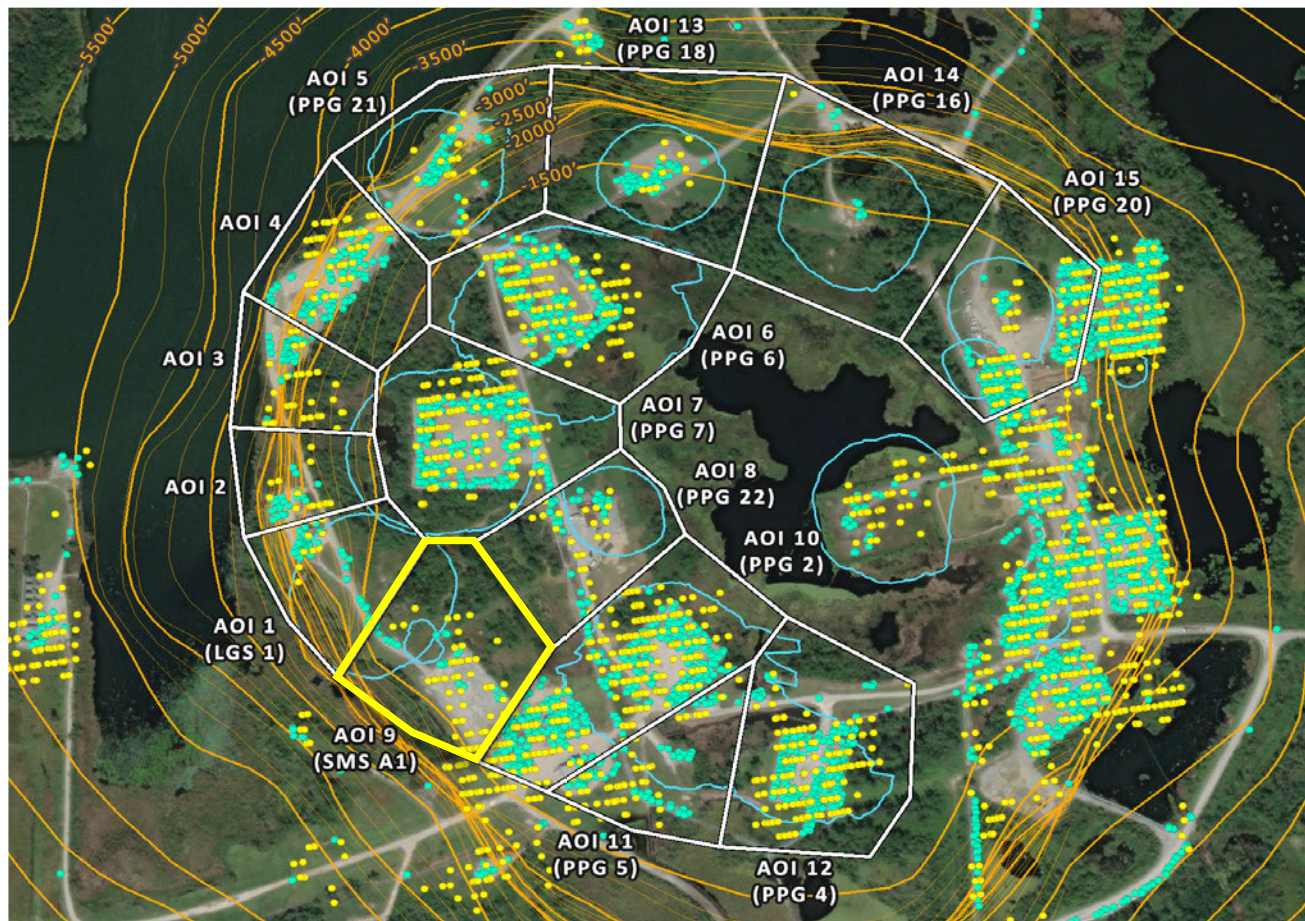
■ Historical LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

■ Recent LOS Displacement Measurement

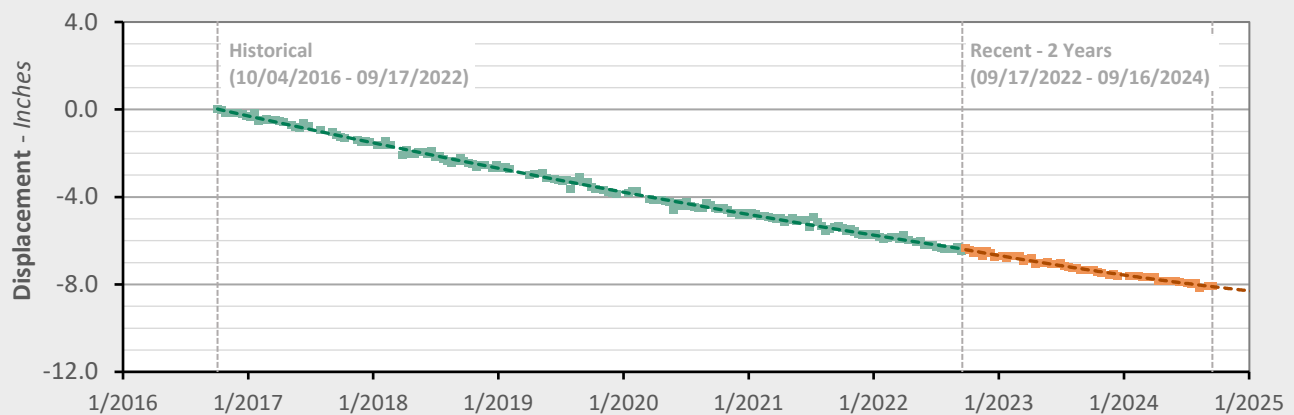
--- Historical Trend Line (Quadratic Regression)

AOI 9 (PPG A1) - Location Map



AOI 9 (SMS A1) - Displacement Time Series

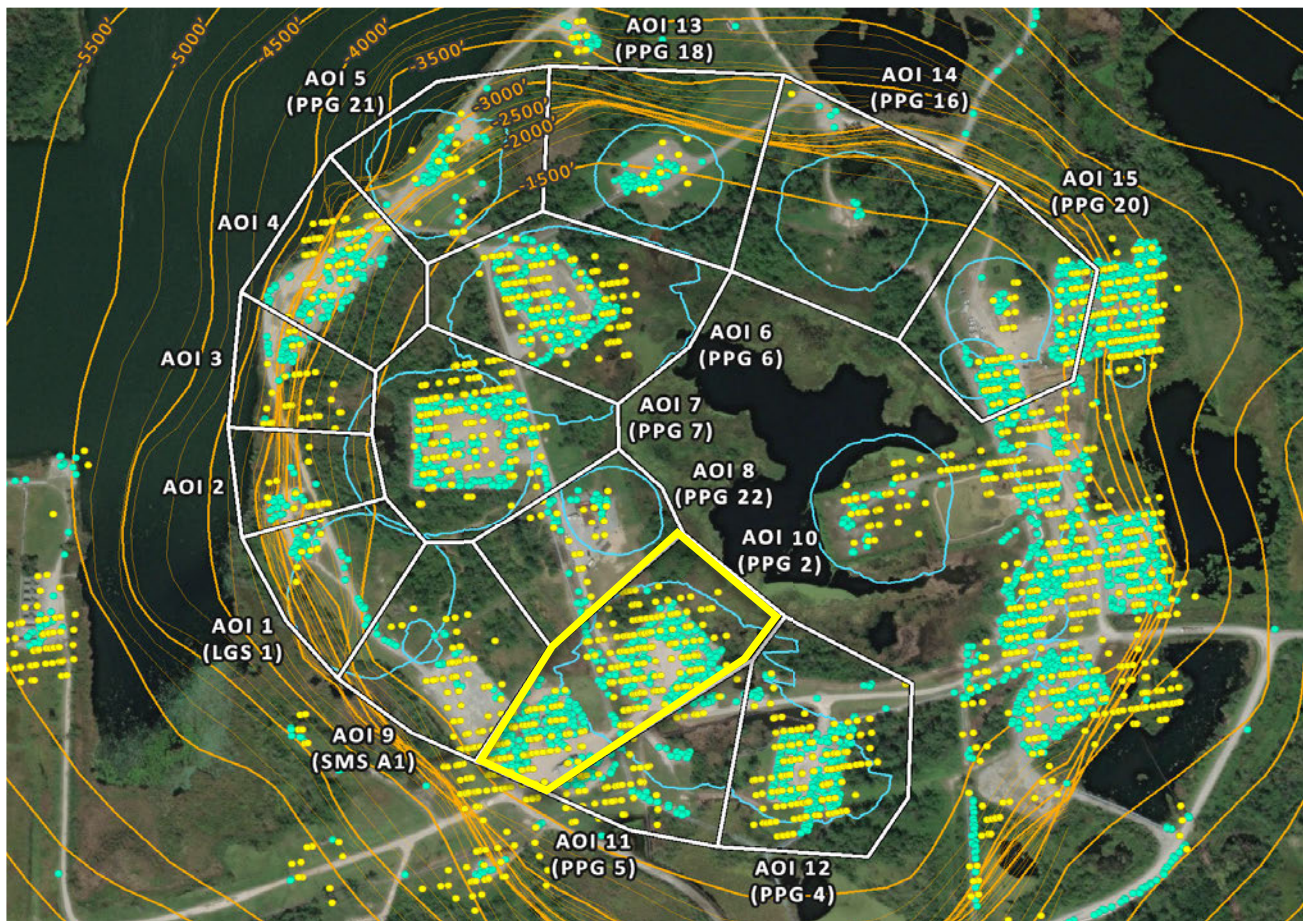
SNT (9/16/2024) Point Count: 59



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.86 in/yr	-0.69 in/yr	+0.17 in/yr
Acceleration:	+0.07 in/yr ²	+0.17 in/yr ²	+0.10 in/yr ²

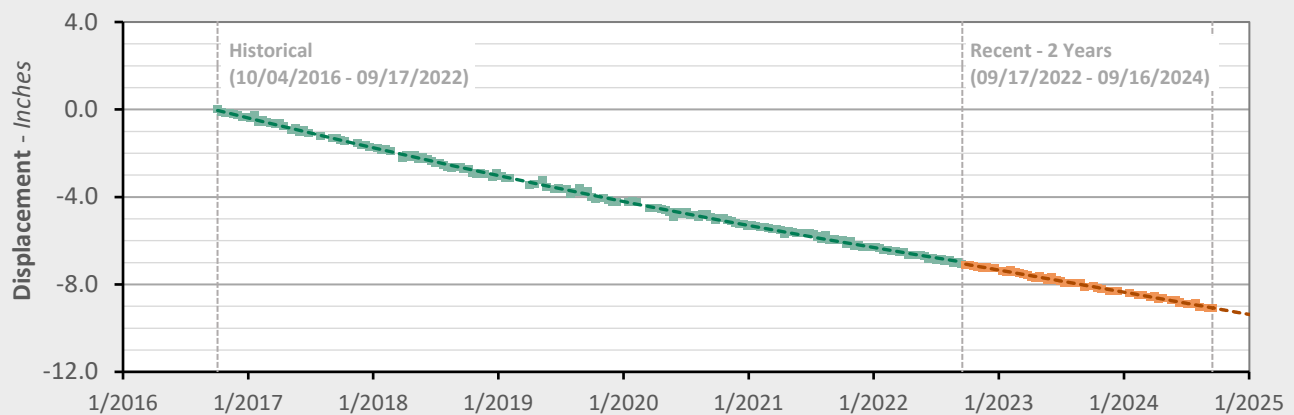
■ Historical LOS Displacement Measurement
 --- Historical Trend Line (Quadratic Regression)
 ■ Recent LOS Displacement Measurement
 --- Historical Trend Line (Quadratic Regression)

AOI 10 (PPG 2) - Location Map



AOI 10 (PPG 2) - Displacement Time Series

SNT (9/16/2024) Point Count: 231



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.90 in/yr	-1.02 in/yr	-0.12 in/yr
Acceleration:	+0.09 in/yr ²	-0.01 in/yr ²	-0.09 in/yr ²

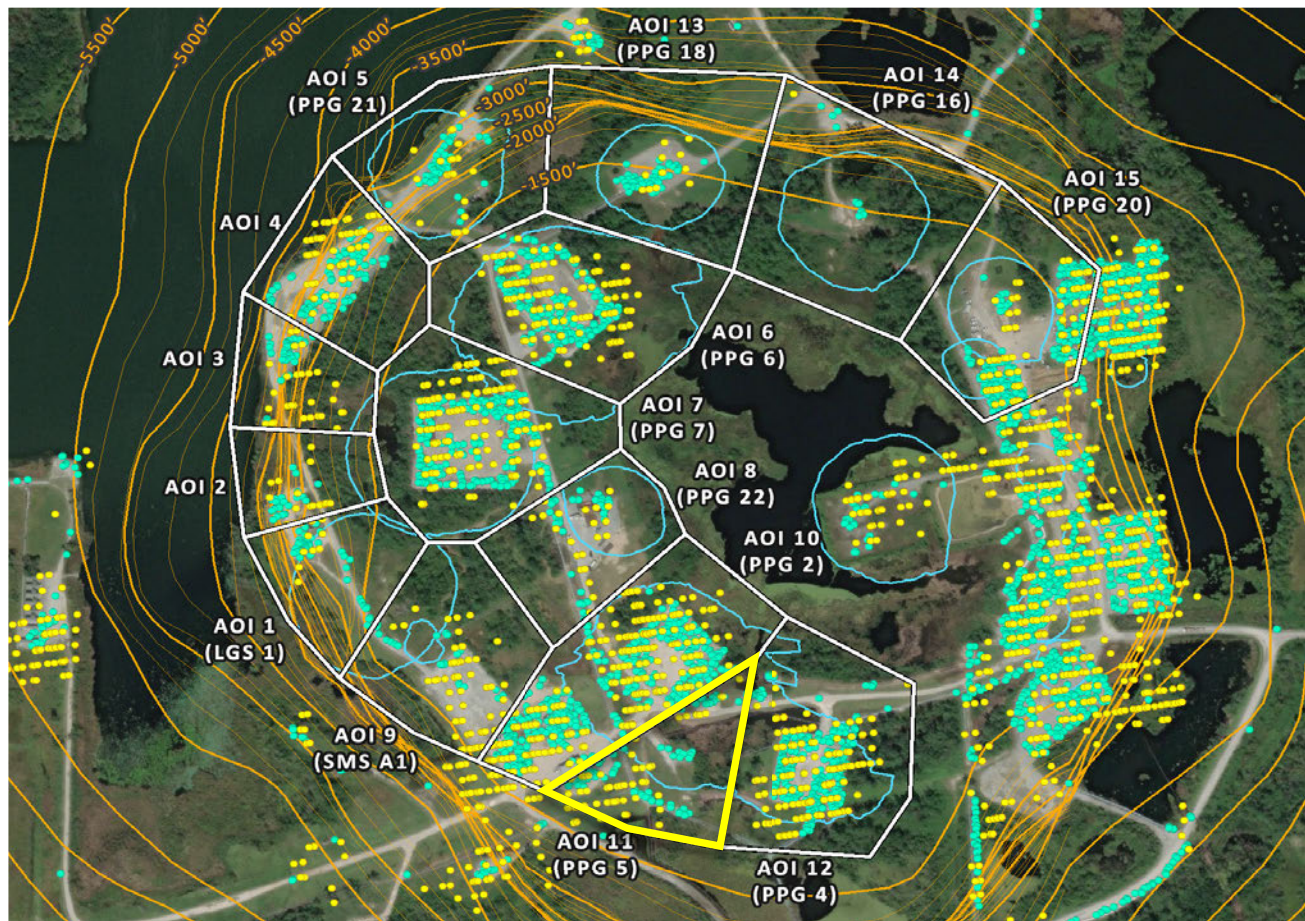
■ Historical LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

■ Recent LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

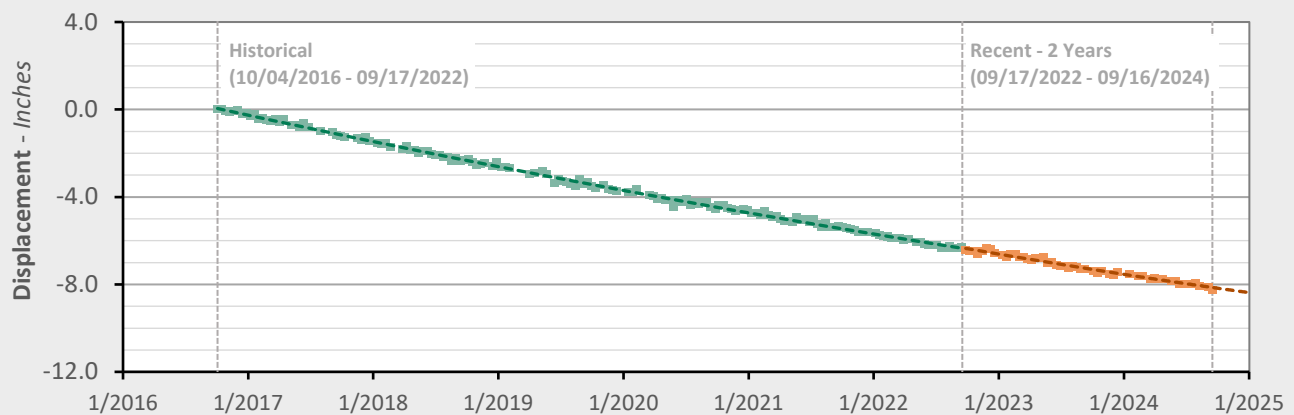
AOI 11 (PPG 5) - Location Map



AOI 11 (PPG 5) - Displacement Time Series

SNT (9/16/2024) Point Count:

53



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.89 in/yr	-0.82 in/yr	+0.07 in/yr
Acceleration:	+0.06 in/yr ²	+0.09 in/yr ²	+0.03 in/yr ²

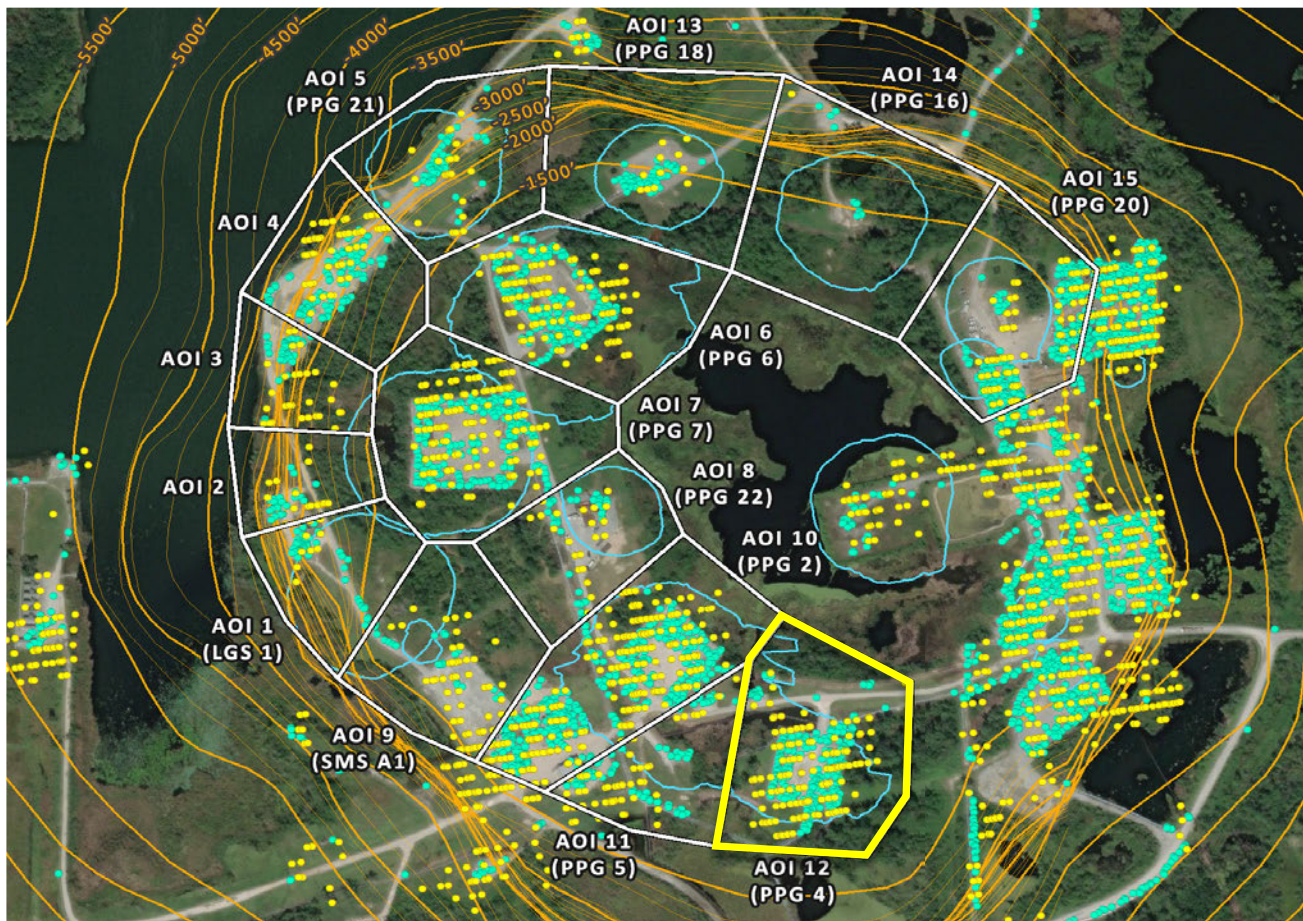
■ Historical LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

■ Recent LOS Displacement Measurement

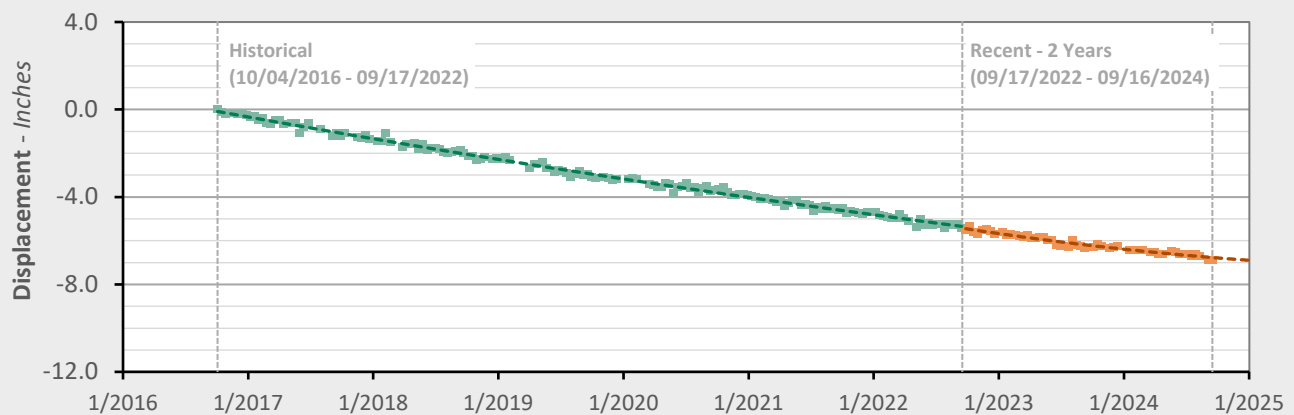
--- Historical Trend Line (Quadratic Regression)

AOI 12 (PPG 4) - Location Map



AOI 12 (PPG 4) - Displacement Time Series

SNT (9/16/2024) Point Count: 120



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.73 in/yr	-0.47 in/yr	+0.27 in/yr
Acceleration:	+0.05 in/yr ²	+0.21 in/yr ²	+0.16 in/yr ²

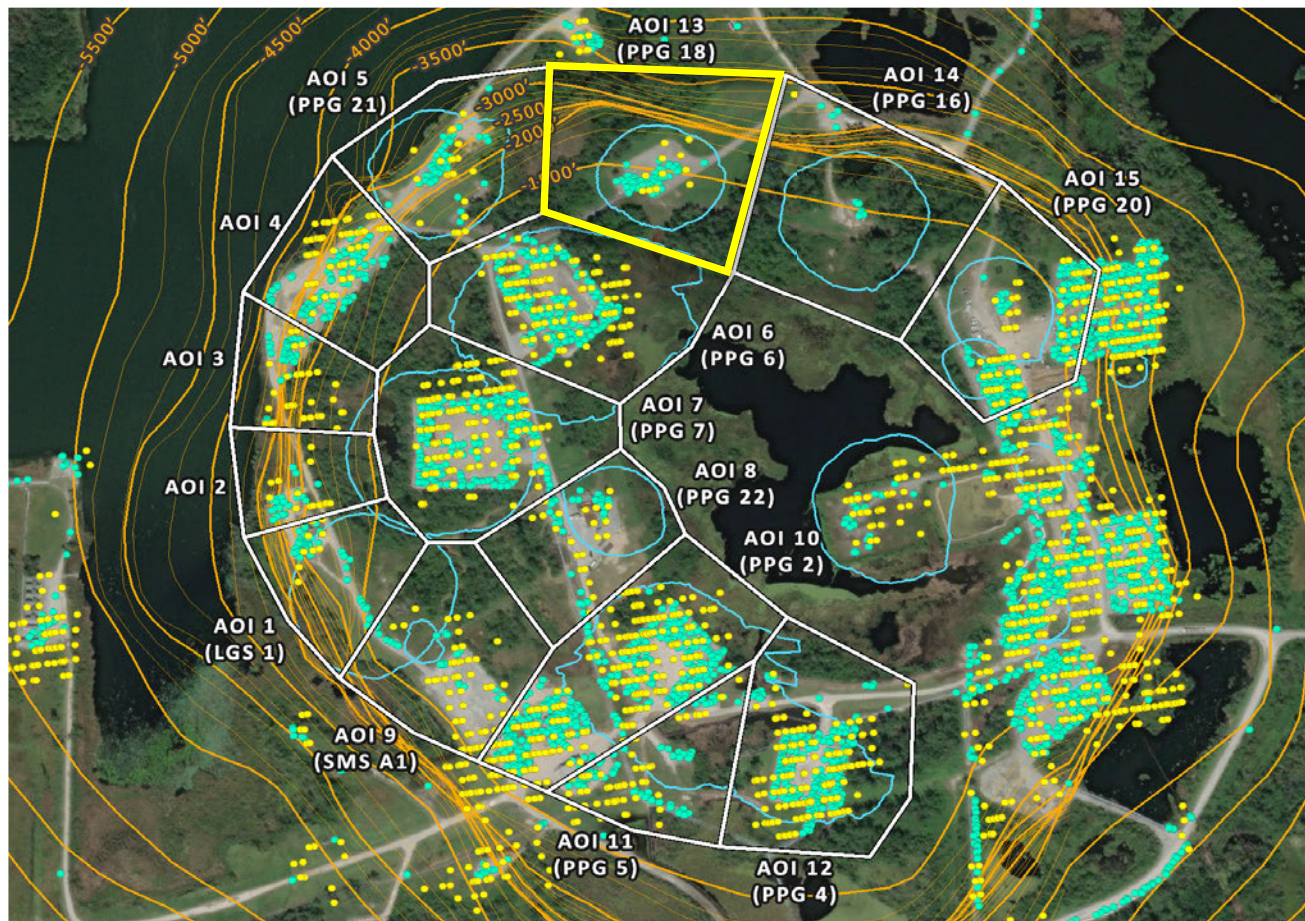
■ Historical LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

■ Recent LOS Displacement Measurement

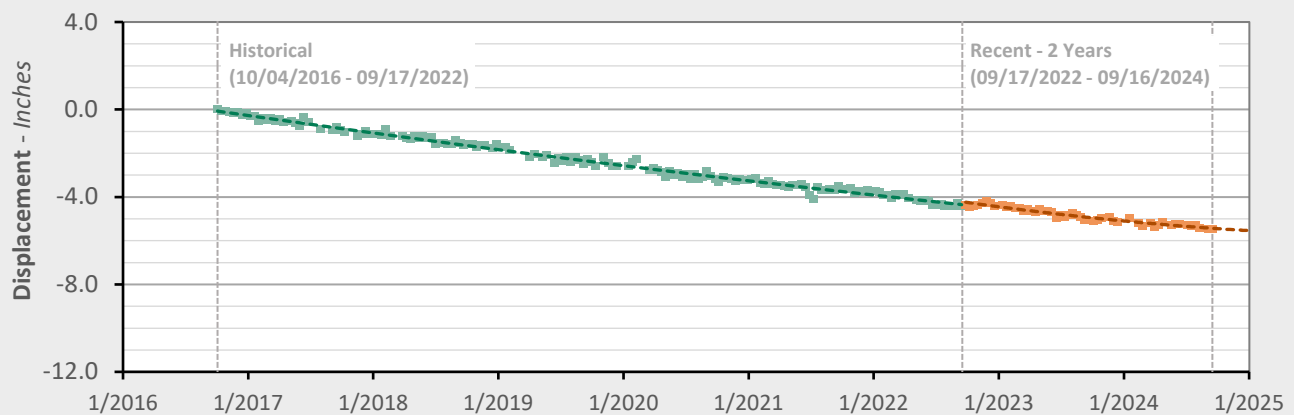
--- Historical Trend Line (Quadratic Regression)

AOI 13 (PPG 18) - Location Map



AOI 13 (PPG 18) - Displacement Time Series

SNT (9/16/2024) Point Count: 12



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.61 in/yr	-0.40 in/yr	+0.21 in/yr
Acceleration:	+0.04 in/yr ²	+0.21 in/yr ²	+0.17 in/yr ²

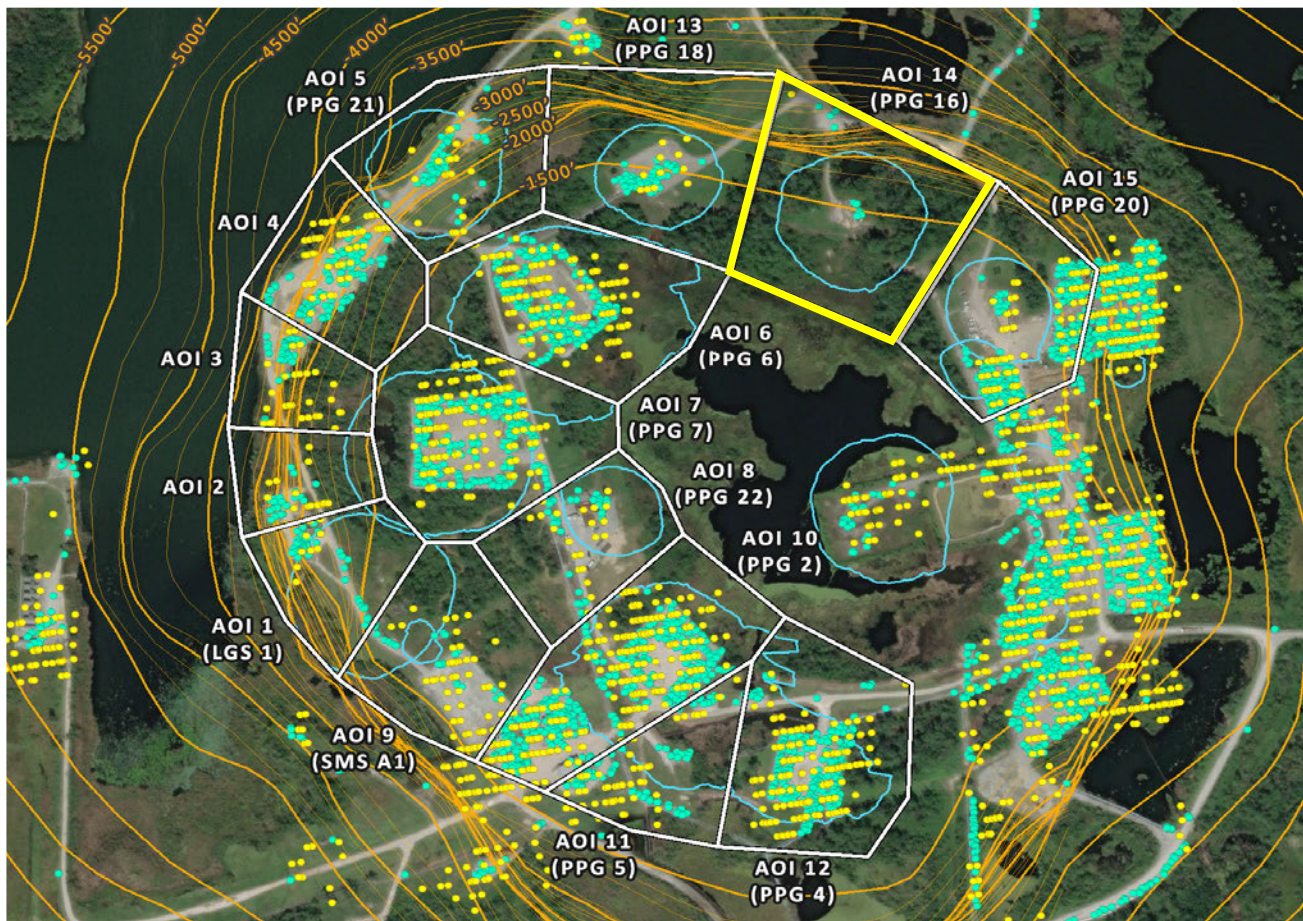
■ Historical LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

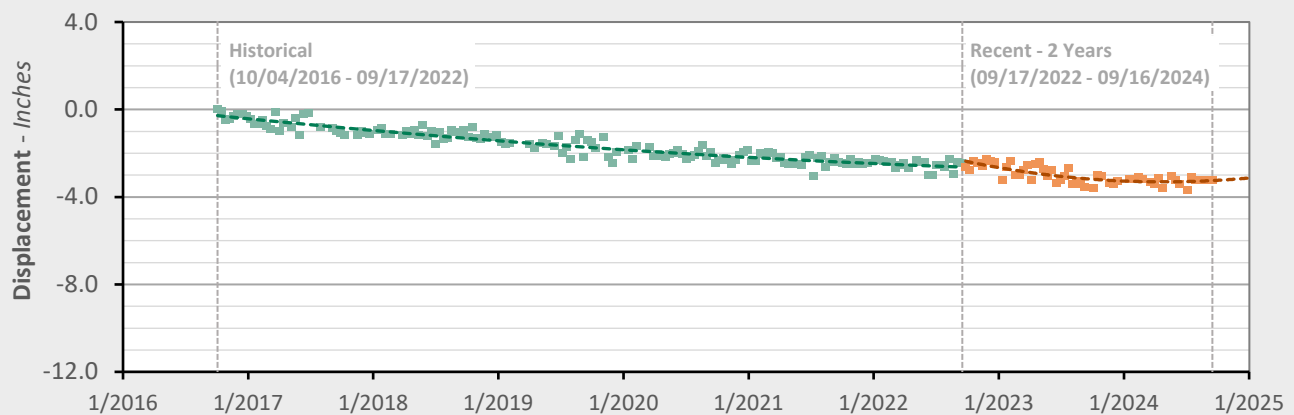
■ Recent LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

AOI 14 (PPG 16) - Location Map



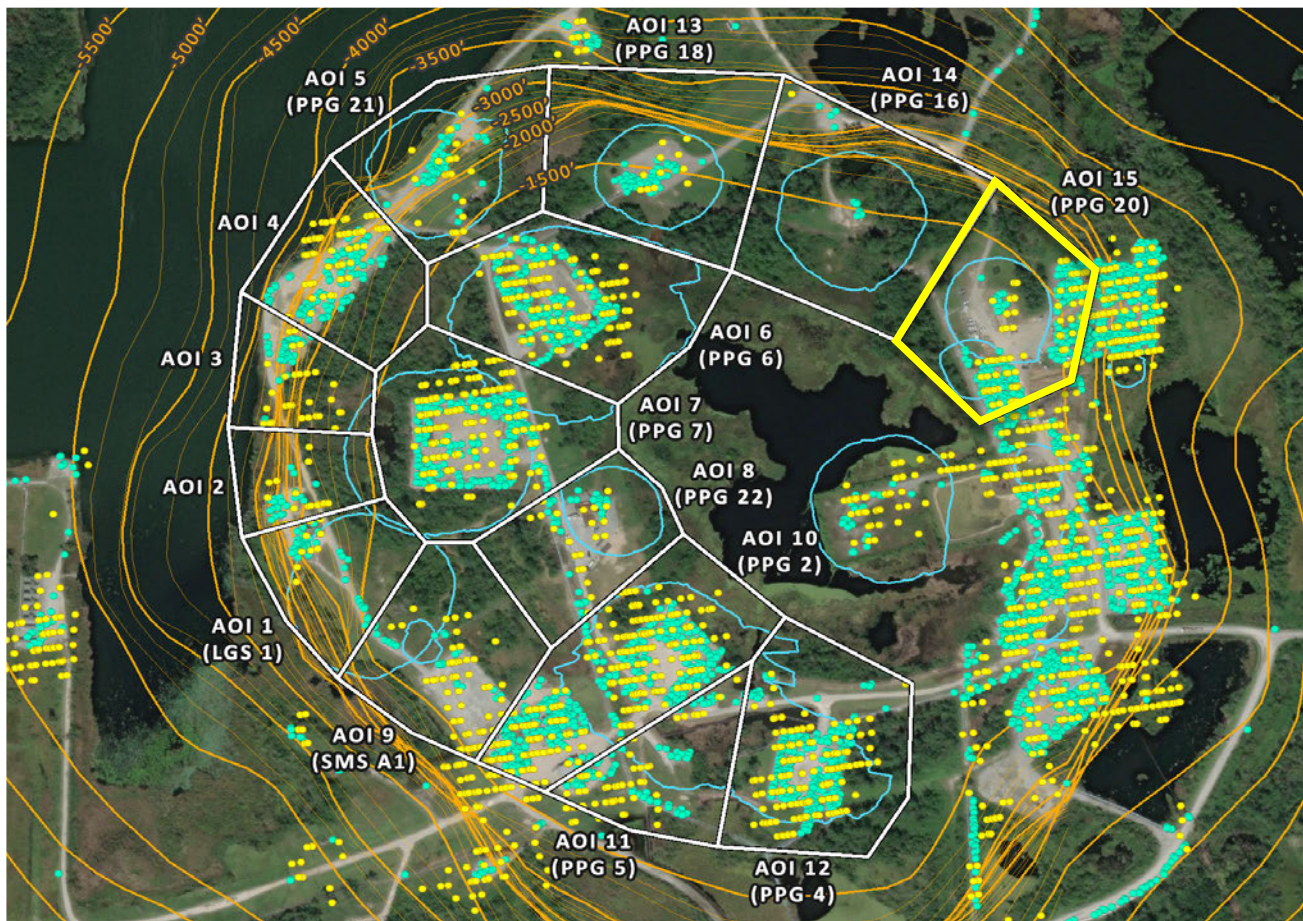
AOI 14 (PPG 16) - Displacement Time Series SNT (9/16/2024) Point Count: 1



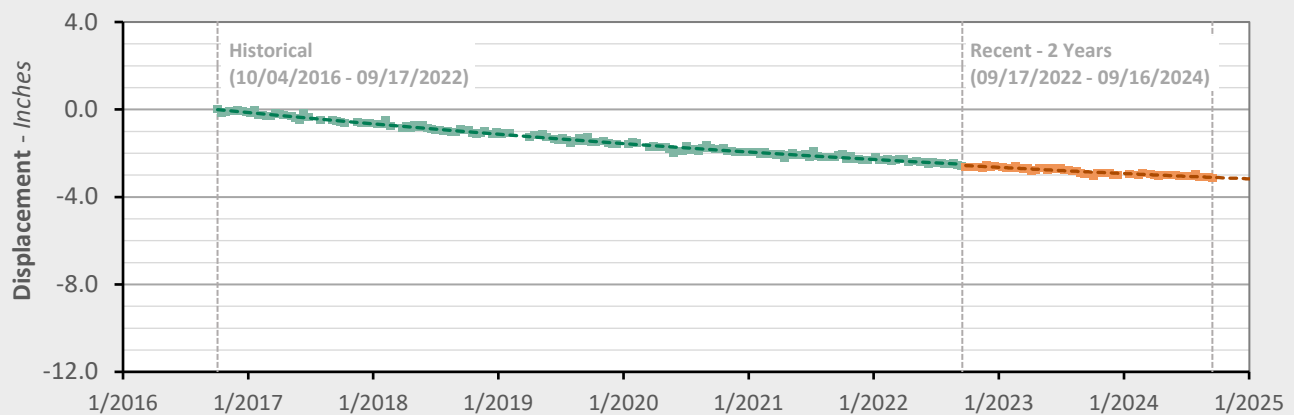
	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.20 in/yr	+0.30 in/yr	+0.50 in/yr
Acceleration:	+0.06 in/yr ²	+0.76 in/yr ²	+0.69 in/yr ²

■ Historical LOS Displacement Measurement
 --- Historical Trend Line (Quadratic Regression)
 ■ Recent LOS Displacement Measurement
 --- Historical Trend Line (Quadratic Regression)

AOI 15 (PPG 20) - Location Map



AOI 15 (PPG 20) - Displacement Time Series SNT (9/16/2024) Point Count: 70



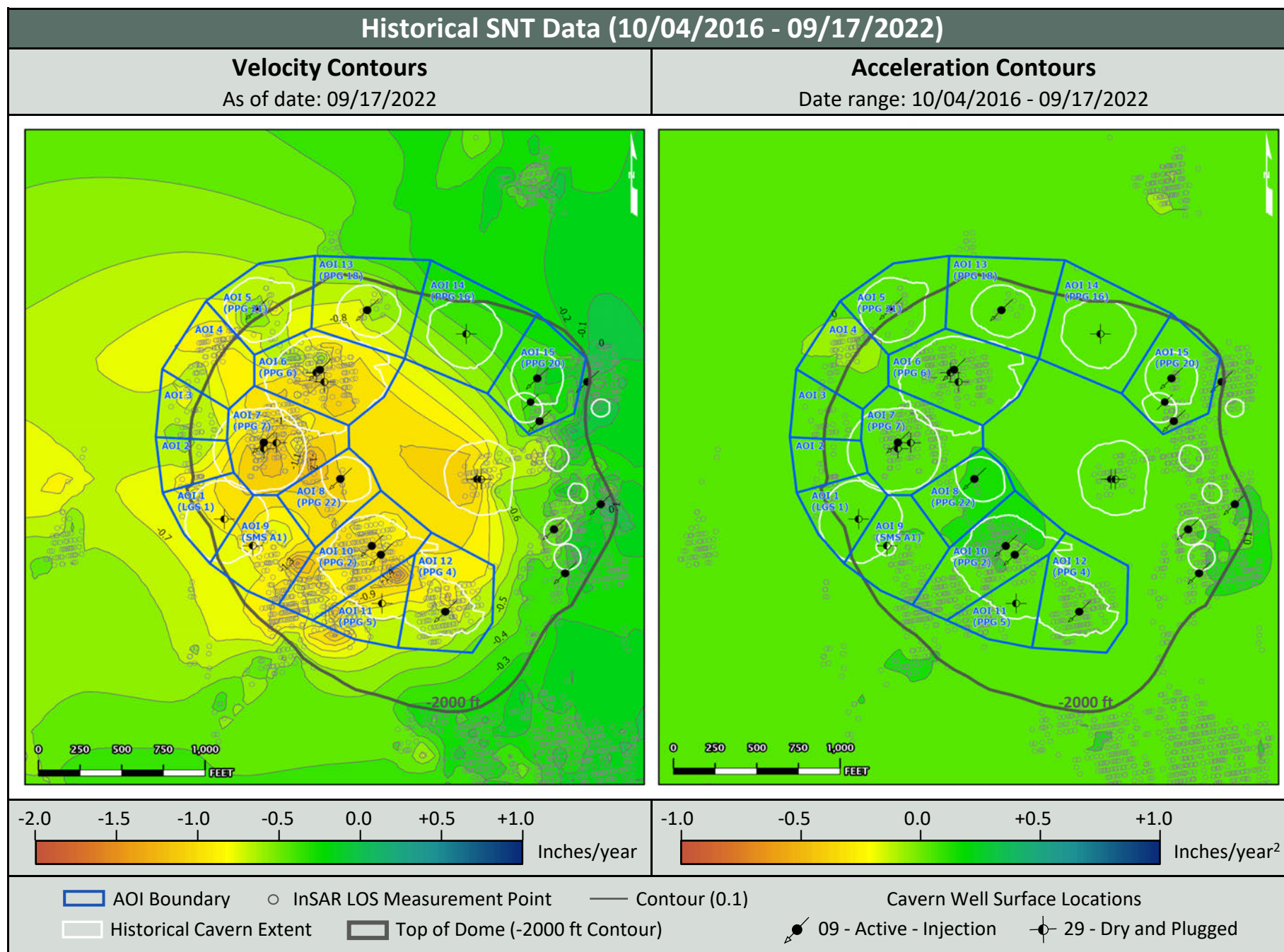
	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.29 in/yr	-0.23 in/yr	+0.06 in/yr
Acceleration:	+0.04 in/yr ²	+0.04 in/yr ²	-0.00 in/yr ²

■ Historical LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)

■ Recent LOS Displacement Measurement

--- Historical Trend Line (Quadratic Regression)



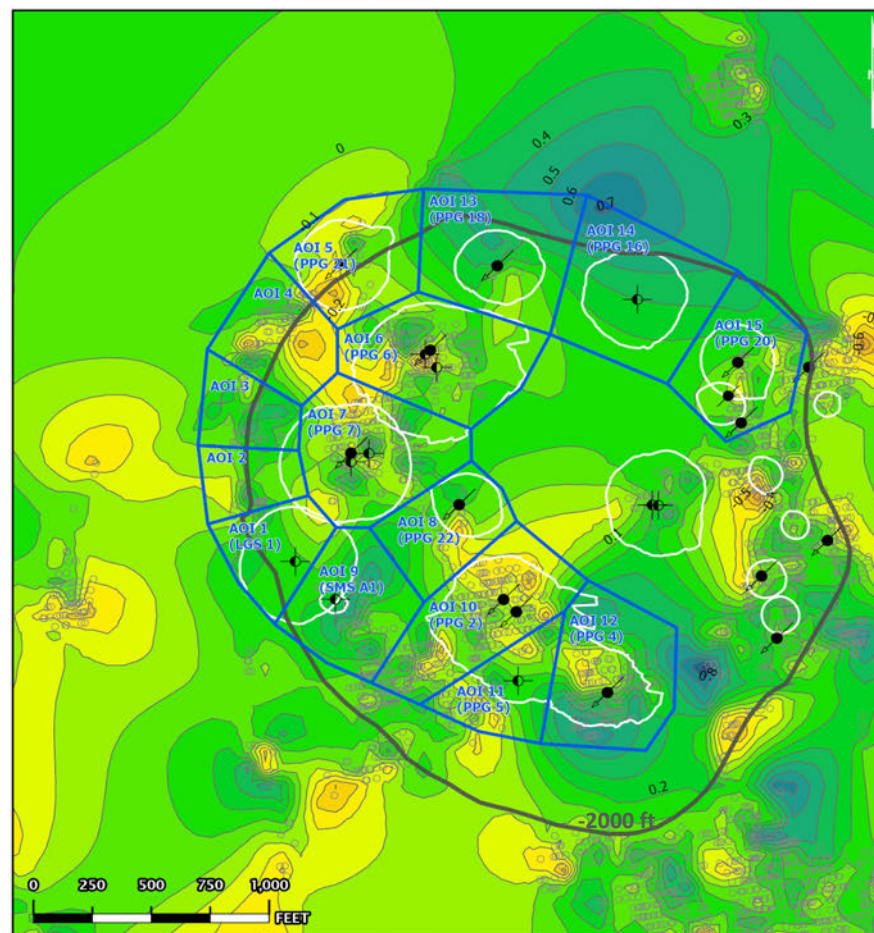
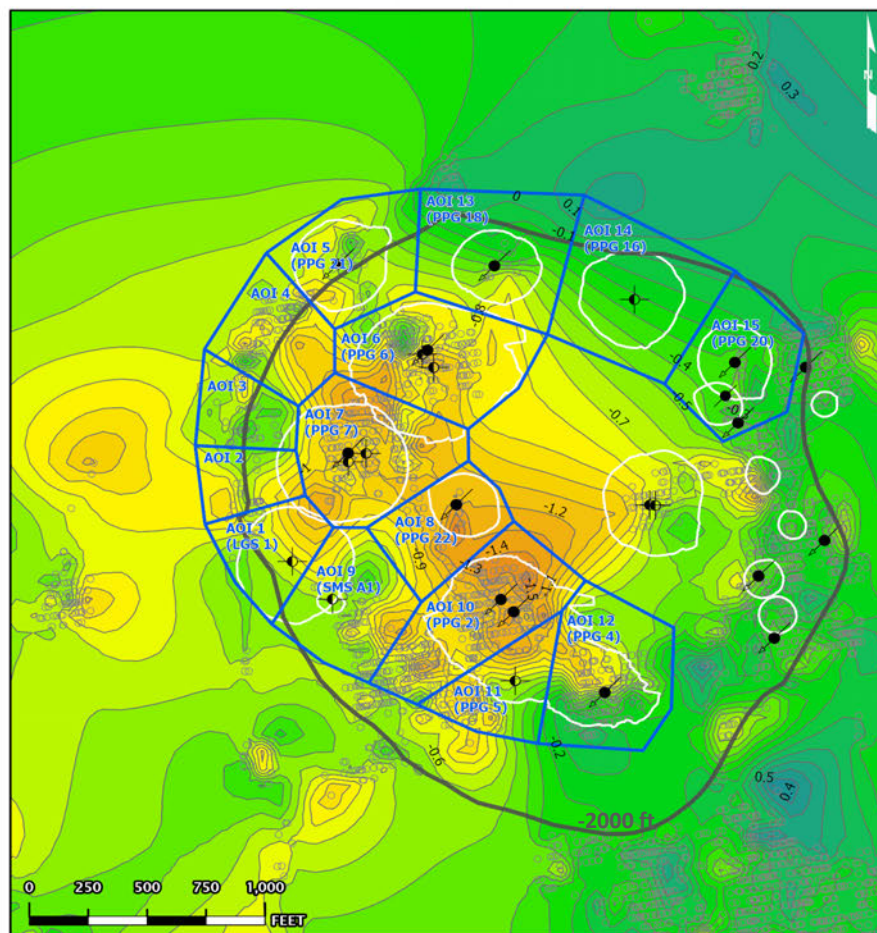
Recent SNT Data - 2 Years (09/17/2022 - 09/16/2024)

Velocity Contours

As of date: 09/16/2024

Acceleration Contours

Date range: 09/17/2022 - 09/16/2024

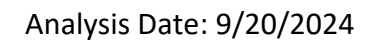


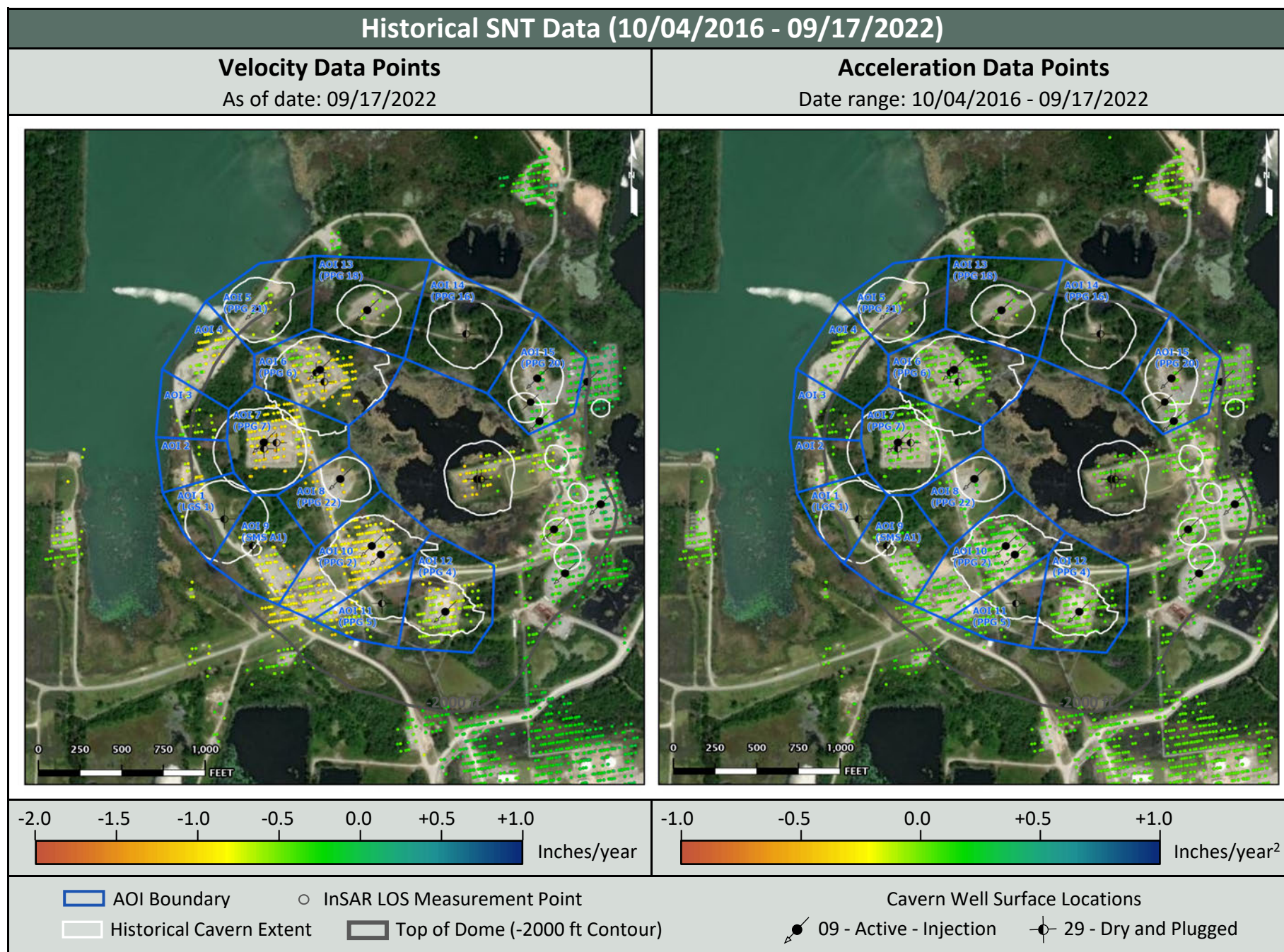
 AOI Boundary
 ○ InSAR LOS Measurement Point
 — Contour (0.1)

 Historical Cavern Extent
 Top of Dome (-2000 ft Contour)

Cavern Well Surface Locations

● 09 - Active - Injection
 ○ 29 - Dry and Plugged





Recent SNT Data - 2 Years (09/17/2022 - 09/16/2024)

Velocity Data Points

As of date: 09/16/2024

Acceleration Data Points

Date range: 09/17/2022 - 09/16/2024



AOI Boundary ○ InSAR LOS Measurement Point
 Historical Cavern Extent Top of Dome (-2000 ft Contour)

Cavern Well Surface Locations
 ● 09 - Active - Injection ● 29 - Dry and Plugged

Change from Historical to Recent SNT Data

Velocity Data Points

Historical Velocity subtracted from Recent Velocity



Acceleration Data Points

Historical Acceleration subtracted from Recent Acceleration



 AOI Boundary ○ InSAR LOS Measurement Point
 Historical Cavern Extent Top of Dome (-2000 ft Contour)

Cavern Well Surface Locations
 ● 09 - Active - Injection ● 29 - Dry and Plugged

ATTACHMENT C

TSX/PAZ InSAR report - September 24, 2024

TSX/PAZ Satellite Update

Continuous InSAR Monitoring of
Ground Displacement At Westlake
Caverns and Western Dome Flank

Sulphur Mines Salt Dome

Prepared for:
Westlake Chemical

Prepared by:
Lonquist & Co., LLC
8591 United Plaza Blvd.
Suite 280
Baton Rouge, LA 70809

Dataset
Satellite Source
TerraSAR-X - PAZ Constellation
Most Recent Image Date
Tuesday, September 24, 2024

Analysis Report Date:
September 27, 2024

Dataset Information

Satellite Source	TerraSAR-X - PAZ Constellation
Revisit Frequency	4 and 7 days
Most Recent Image Date	Tuesday, September 24, 2024
Dataset Image Count	107
Dataset Time Range	January 24, 2023 - September 24, 2024
Dataset Length	1.67 Years
Satellite Line-of-Sight (LOS)	37° East of Vertical (Viewing site from the East)

Analysis Methodology

Time Series Charts

Trend lines were calculated for the averaged displacement values within each AOI. Both a nonlinear (quadratic) and linear regression were applied to each AOI point group to identify rates of change in LOS displacement. These trends are displayed in the Time Series section of this report.

Contour Maps

A nonlinear (quadratic) and linear trend was also calculated for each individual measurement point across the analysis region. Nonlinear trend values for each point were used to generate Velocity and Acceleration contour maps to convey the spatial distribution of the calculated movement. The linear trend values for each point (which lack an acceleration component) were used to generate an additional Velocity contour map. Maps depicting the individual data points colored by these trend values are also included in the last section of the report.

Negative velocity values indicate subsidence or westward movement and positive velocity indicates uplift or eastward movement. Negative acceleration values indicate increasing rates of subsidence, increasing westward movement, or slowing eastward movement and positive acceleration values indicate slowing rates of subsidence, slowing westward movement, or increasing eastward movement.

Observations

To-date there have been no acute deviations from established subsidence trends in the areas investigated.

The timeframe of the dataset does not allow for comparison of recent to long-term LOS displacement rates. This dataset is primarily used to monitor for acute trend deviations and benefits from a higher measurement precision in individual readings than the SNT data.

Recent data has begun to indicate a negative acceleration of varying magnitudes across most of the AOI point groups evaluated. This is most evident in the trend acceleration values in the westernmost AOIs and in the mapped contours on the western side of AOI 2, AOI 3 and AOI 4. This suggests that marginal increases in subsidence rates may be occurring in this area of the dome. Seasonal effects are believed to contribute to fluctuations above and below the trend lines for each AOI and may play a significant role in the gradual changes that are being observed.



Date Signed: September 27, 2024
Austin, Texas

Nathaniel L. Byars, P.E.
Principal Engineer
Louisiana License No. 40697

InSAR Data Sources

InSAR Data

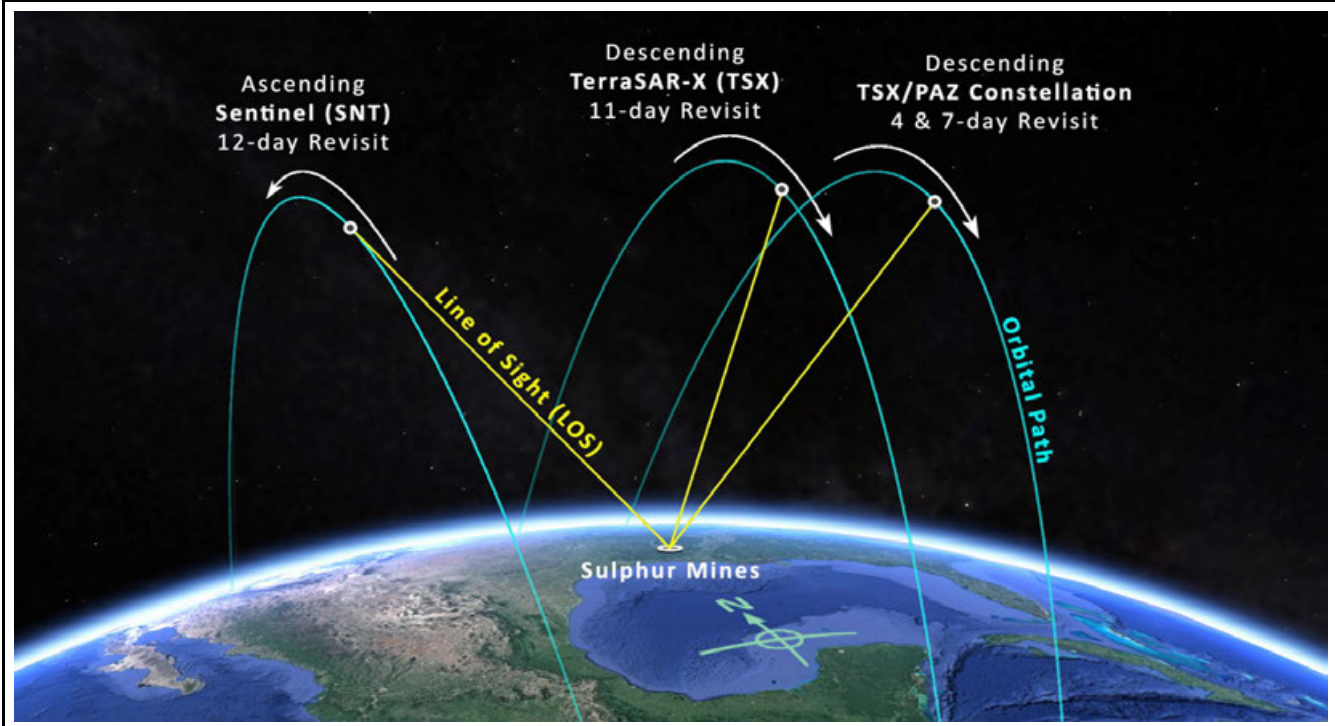
Interferometric Synthetic Aperture Radar (InSAR) is the most well established method to continually evaluate small, normally undetectable, ground movement over a large area. Radar imagery collected via satellites over successive orbital passes is used to identify and define measurement points on the ground. Objects or ground features providing a stable reflection of radar energy such as buildings, roads, and infrastructure produce the highest quality measurement points. InSAR analysis identifies the change in distance between the satellite and each measurement point over time relative to a stable reference point within the imaged area.

Satellite Sources

Two InSAR datasets are being used to evaluate subsidence over the Sulphur Mines Salt Dome. These datasets provide Line-of-Sight (LOS) displacement measurements from both ascending and descending orbits. An ascending orbit denotes the satellite's longitudinal course from south to north as it passes over the site, while a descending orbit denotes the satellite is moving from north to south.

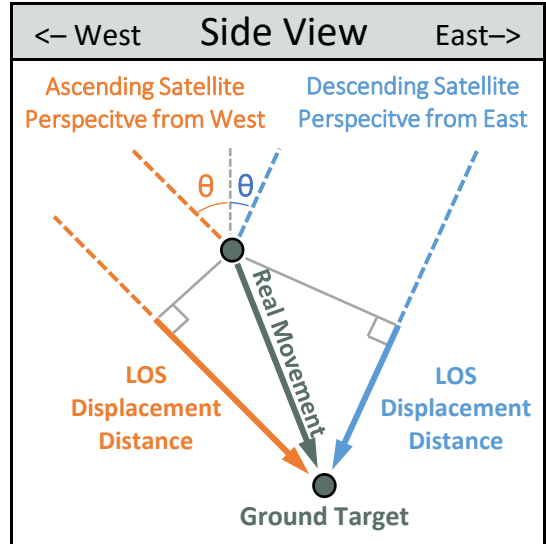
The first dataset comes from a low-resolution Sentinel-1 (SNT) satellite on an ascending orbit that captures data from the west of the site on a 12-day frequency. The second comes from a pair of high resolution satellites that share the same descending orbit and capture data from east of the site. These are a TSX satellite and the PAZ satellite (TSX/PAZ constellation), both with an 11-day revisit frequency. Their orbits are offset with the PAZ satellite passing over the site 4 days after the TSX satellite. Prior to May 2023, data was captured from a different high-resolution TerraSAR-X (TSX) satellite on a descending orbit that captured data from the east of the site on an 11-day frequency. The transition was made for the increased data frequency that resulted from a 4 and 7-day revisit period. The image below depicts the orbital paths of the satellites in relation to the Sulphur Mines Salt Dome.

Satellite Orbital Diagram

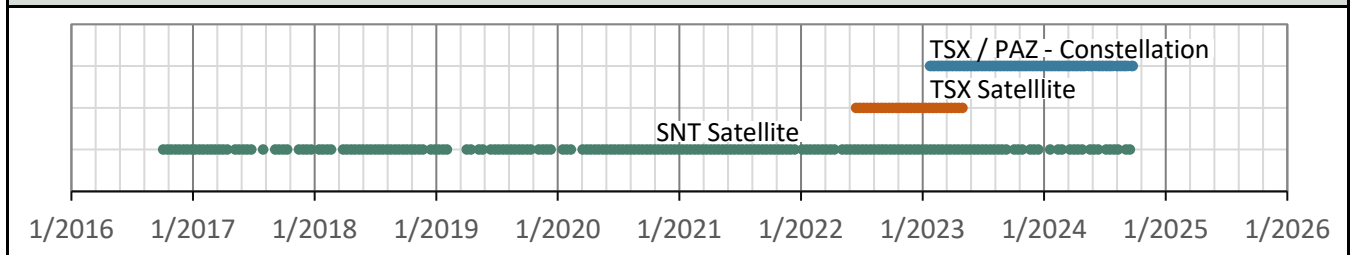
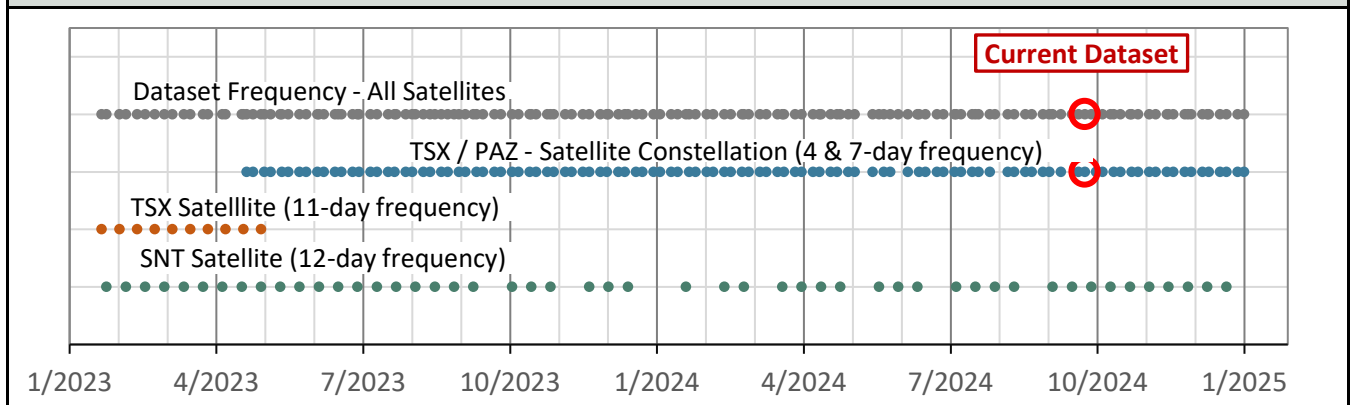


InSAR Line-of-Site (LOS) Data

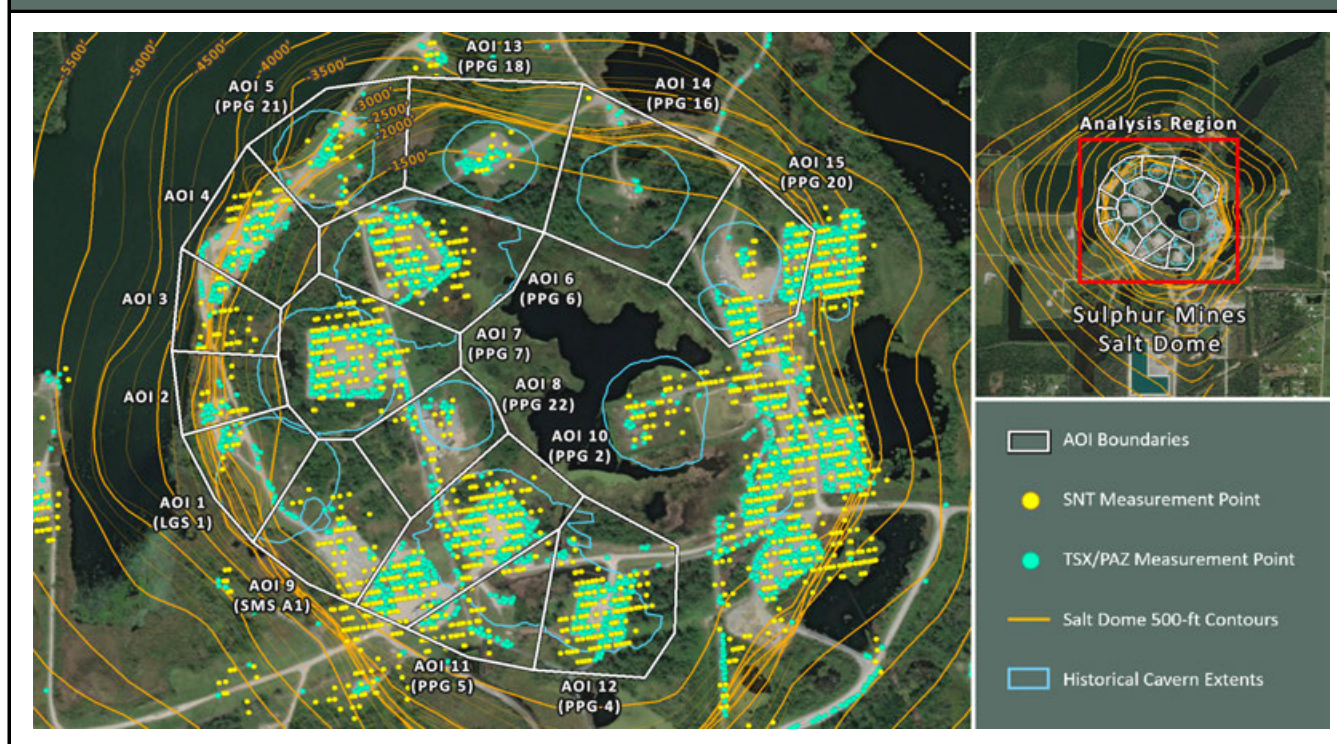
LOS displacement measurements refer to a change in distance between the satellite sensor and the ground target. Measurement positions on the west side of the Sulphur Dome are known to be experiencing some eastward movement toward the dome center due to the geometry of the subsidence basin. The InSAR satellites view the site from eastward and westward positions so LOS measurements are understood to convey a movement distance that is not purely vertical. The diagram to the right illustrates the geometric relationship between the theoretical Real movement of a ground target and LOS displacement measurements from two different satellite viewing directions.

**Satellite Properties & Image Frequency**

Satellite and Data Properties	SNT	TSX	TSX/PAZ Constellation
Band (Wavelength)	C-band (2.20 in)	X-band (1.22 in)	X-band (1.22 in)
Track	T136	T29	T67 & T120
Pixel resolution	65 x 16 ft	3 x 3 ft	3 x 3 ft
Revisit frequency	12 days	11 days	4 & 7 days
Orbit (LOS Angle, θ)	Ascending (43°)	Descending (17°)	Descending (37°)
Data Start Date	10/4/2016	6/16/2022	1/24/2023
Measurement error range	± 0.20 in	± 0.03 in	± 0.03 in

Dataset Measurement History**Dataset Update Frequency**

AOI Boundaries & InSAR Measurement Points

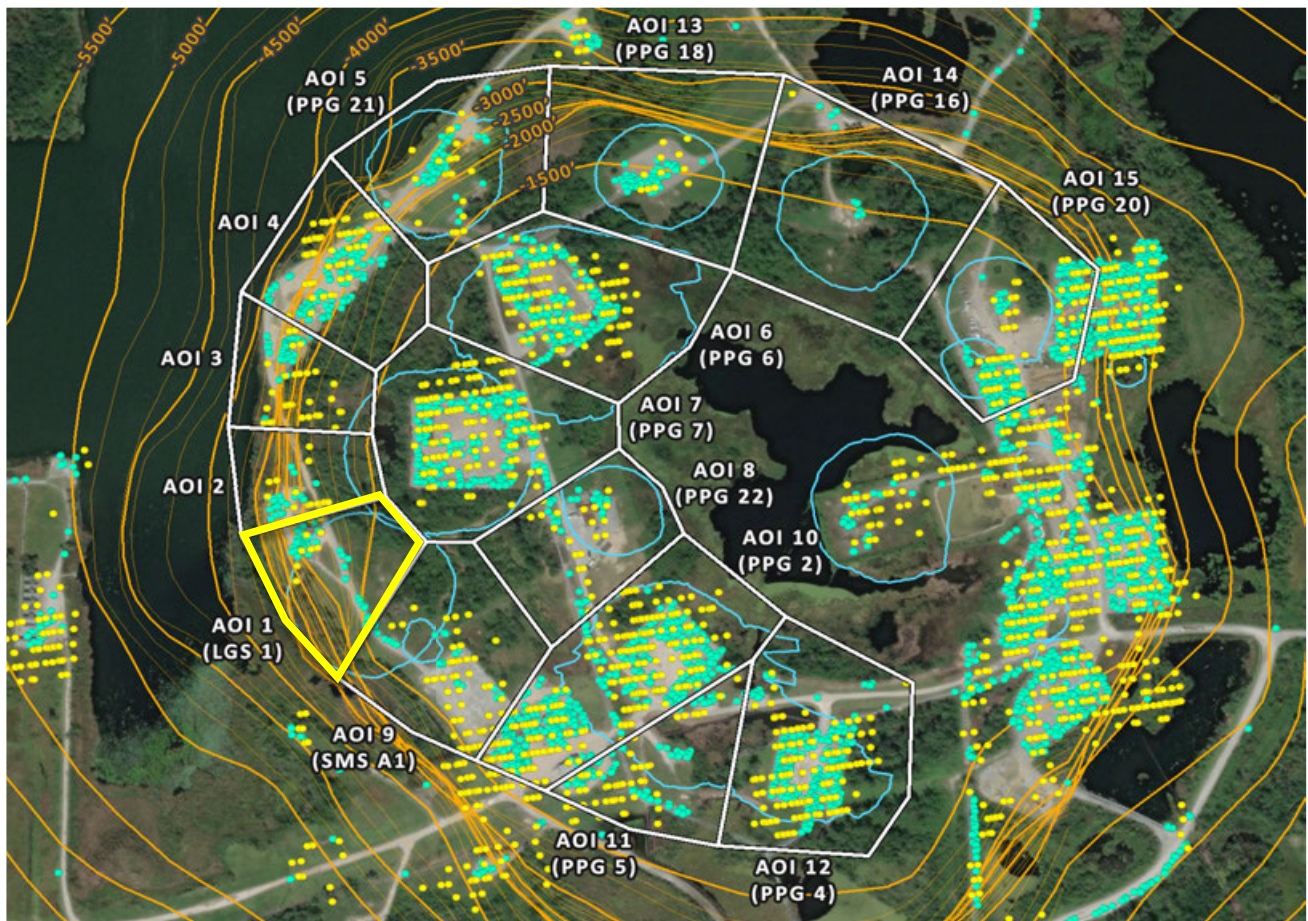


Subsidence Monitoring Areas of Interest (AOIs)

To visually convey and evaluate trend consistency for the displacement time series of each ground target, measurement points were grouped and their displacement values were averaged. The point groups are referred to as Areas of Interest (AOIs) in this analysis and their boundaries are depicted on the above map. The below table lists the trend values calculated in each AOI for the dataset evaluated in this report.

AOI Name	TSX/PAZ (9/24/2024)	LOS Velocity (in/yr)		LOS Acceleration (in/yr ²)	
	Point Count	Nonlinear	Linear	Nonlinear	Linear
AOI 1 (LGS 1)	42	-0.39	-0.08	-0.36	0.00
AOI 2	24	-0.50	-0.09	-0.49	0.00
AOI 3	40	-0.41	-0.05	-0.43	0.00
AOI 4	102	-0.31	-0.01	-0.36	0.00
AOI 5 (PPG 21)	47	-0.28	-0.19	-0.12	0.00
AOI 6 (PPG 6)	212	-0.70	-0.45	-0.31	0.00
AOI 7 (PPG 7)	216	-0.60	-0.32	-0.34	0.00
AOI 8 (PPG 22)	36	-0.79	-0.60	-0.22	0.00
AOI 9 (SMS A1)	23	-0.28	-0.26	-0.02	0.00
AOI 10 (PPG 2)	404	-0.79	-0.58	-0.25	0.00
AOI 11 (PPG 5)	85	-0.73	-0.49	-0.29	0.00
AOI 12 (PPG 4)	262	-1.07	-0.85	-0.26	0.00
AOI 13 (PPG 18)	52	-0.67	-0.46	-0.25	0.00
AOI 14 (PPG 16)	11	-0.53	-0.65	+0.14	0.00
AOI 15 (PPG 20)	224	-1.12	-0.98	-0.16	0.00

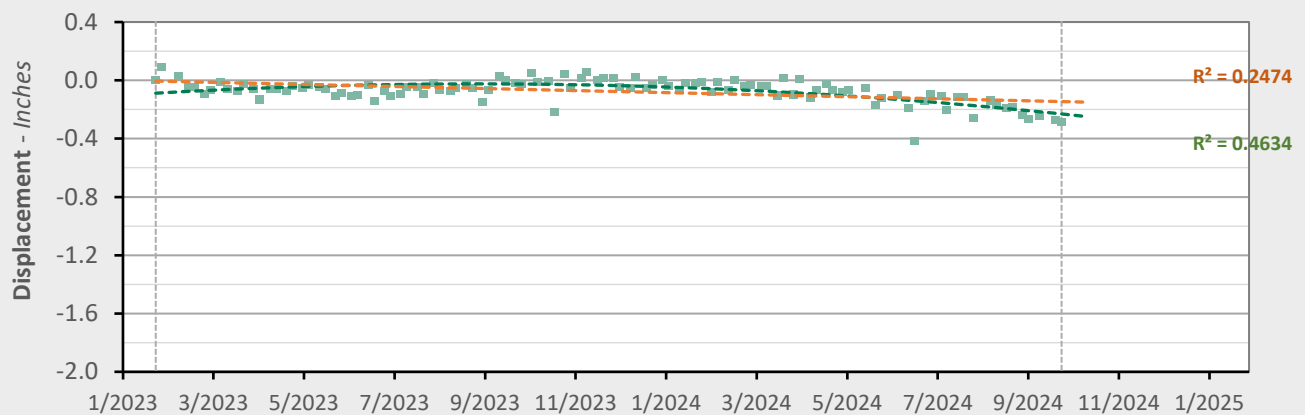
AOI 1 (LGS 1) - Location Map



AOI 1 (LGS 1) - Displacement Time Series

TSX/PAZ (9/24/2024) Point Count:

42



Nonlinear Trend

Linear Trend

Velocity: -0.39 in/yr

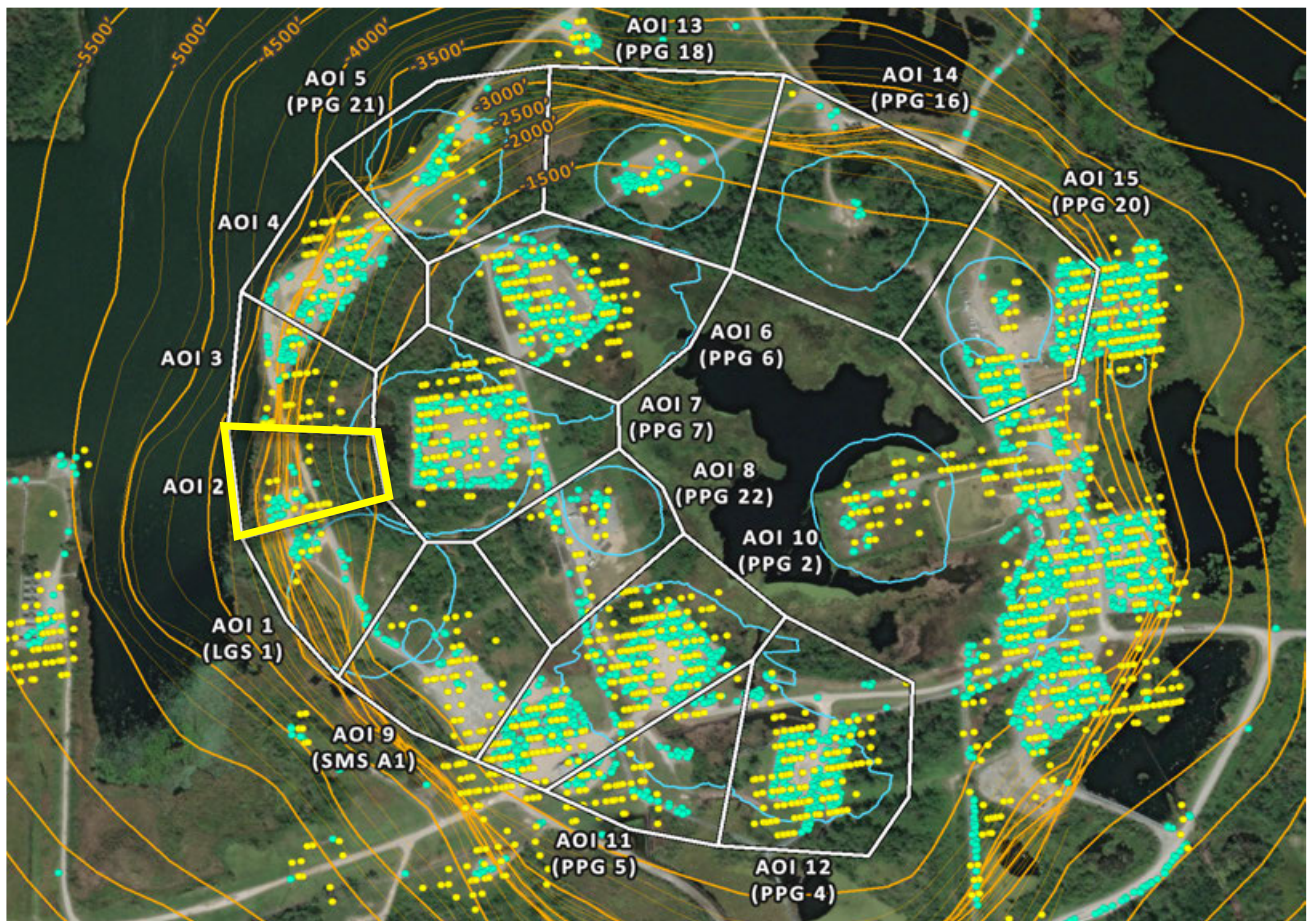
-0.08 in/yr

Acceleration: -0.36 in/yr²0.00 in/yr²

■ LOS Displacement Measurement

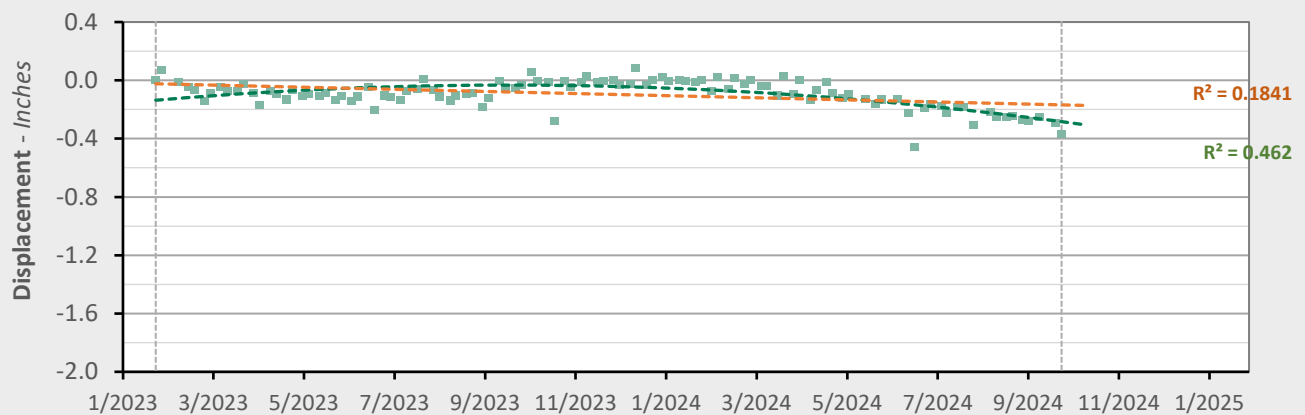
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 2 - Location Map



AOI 2 - Displacement Time Series

TSX/PAZ (9/24/2024) Point Count: 24



Nonlinear Trend

Linear Trend

Velocity: -0.50 in/yr

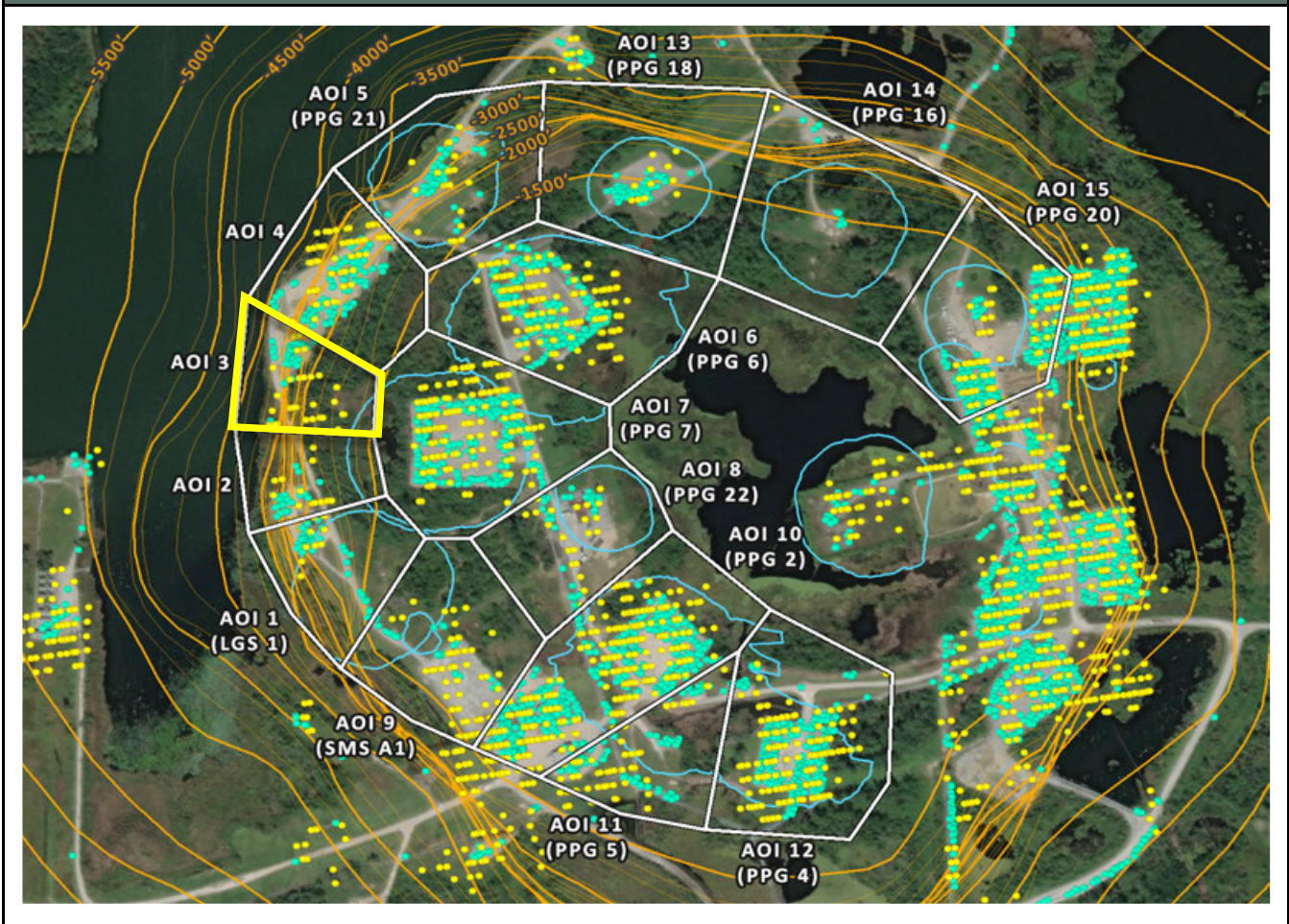
-0.09 in/yr

Acceleration: -0.49 in/yr²0.00 in/yr²

■ LOS Displacement Measurement

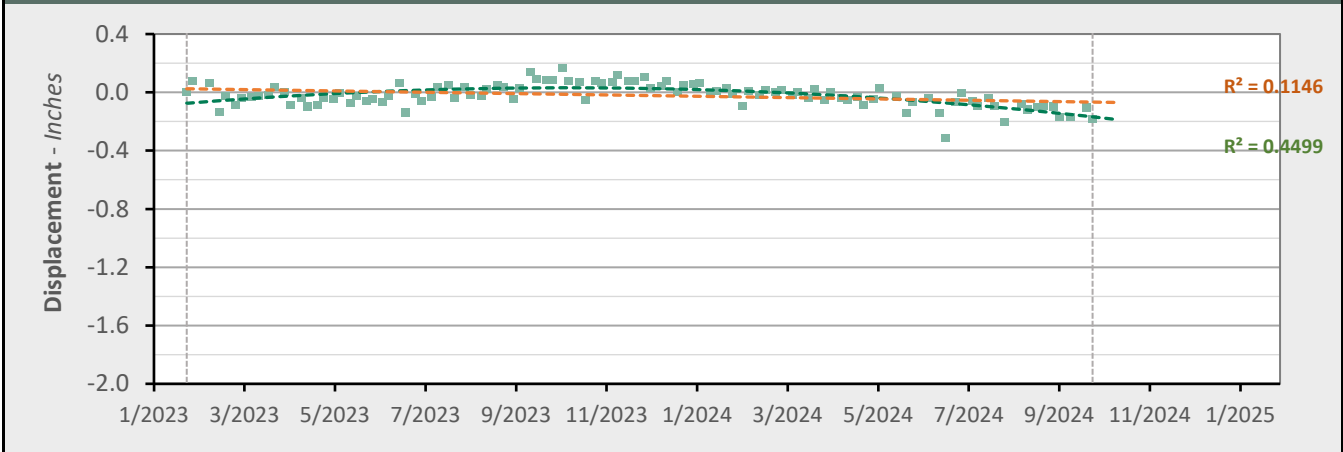
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 3 - Location Map

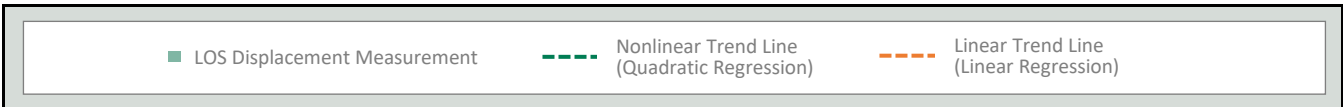


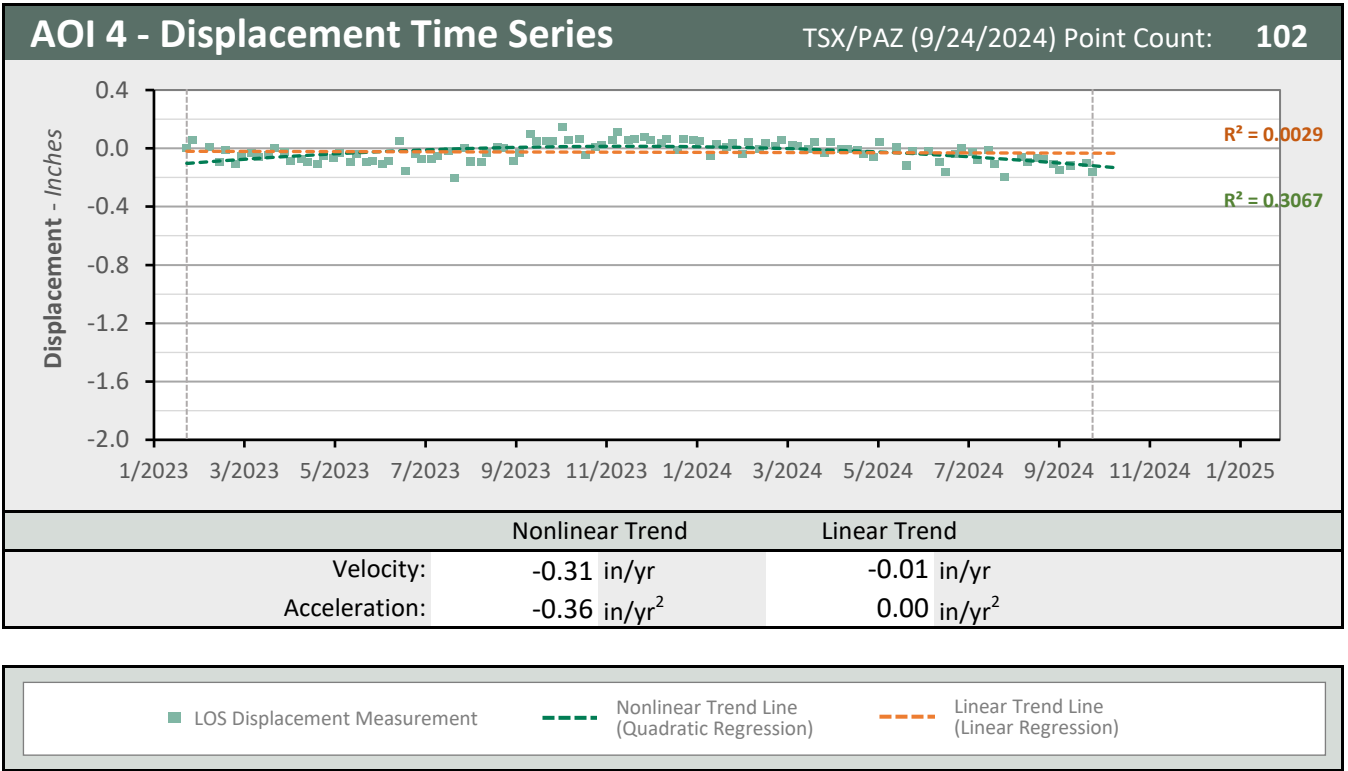
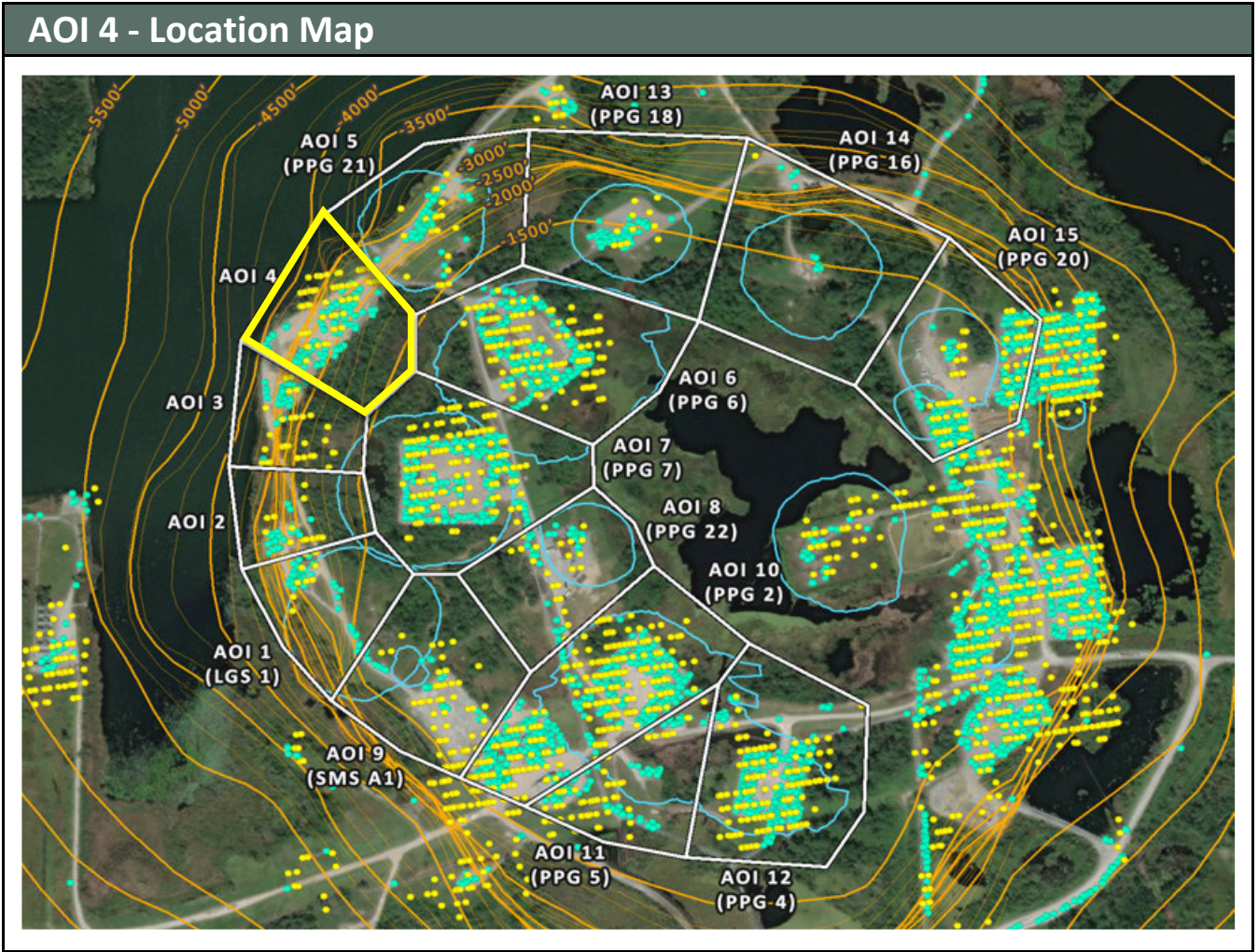
AOI 3 - Displacement Time Series

TSX/PAZ (9/24/2024) Point Count: 40

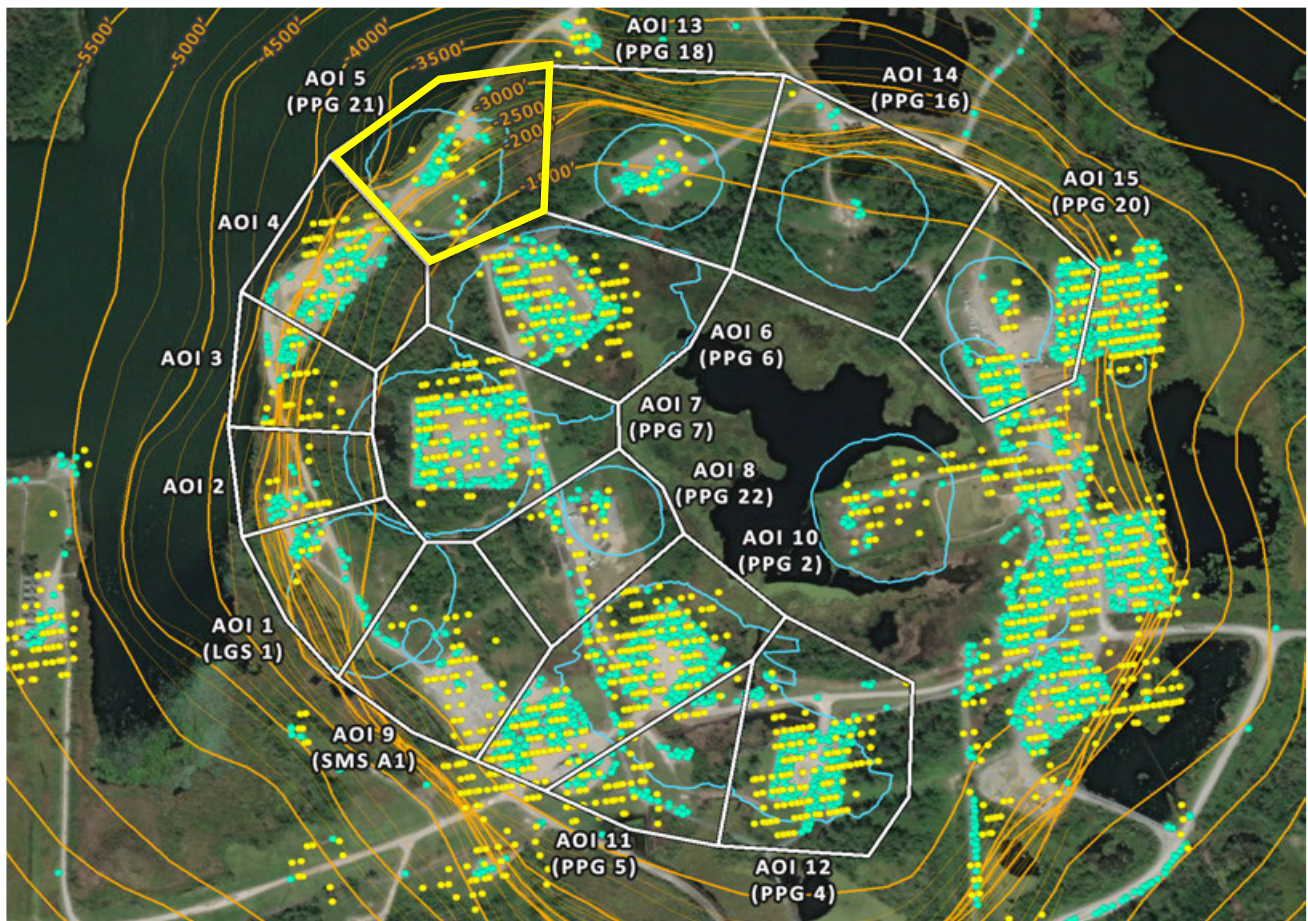


	Nonlinear Trend	Linear Trend
Velocity:	-0.41 in/yr	-0.05 in/yr
Acceleration:	-0.43 in/yr ²	0.00 in/yr ²





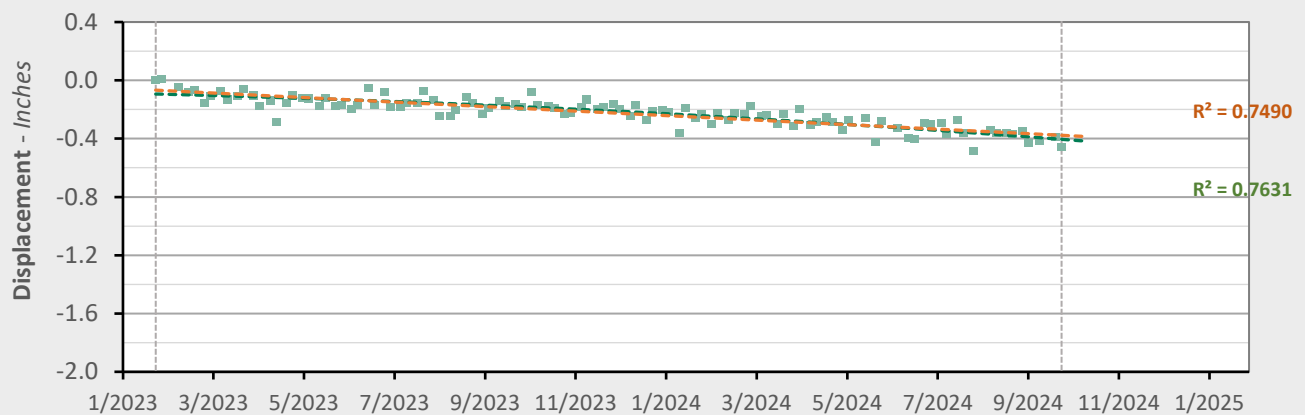
AOI 5 (PPG 21) - Location Map



AOI 5 (PPG 21) - Displacement Time Series

TSX/PAZ (9/24/2024) Point Count:

47



Nonlinear Trend

Linear Trend

Velocity: -0.28 in/yr

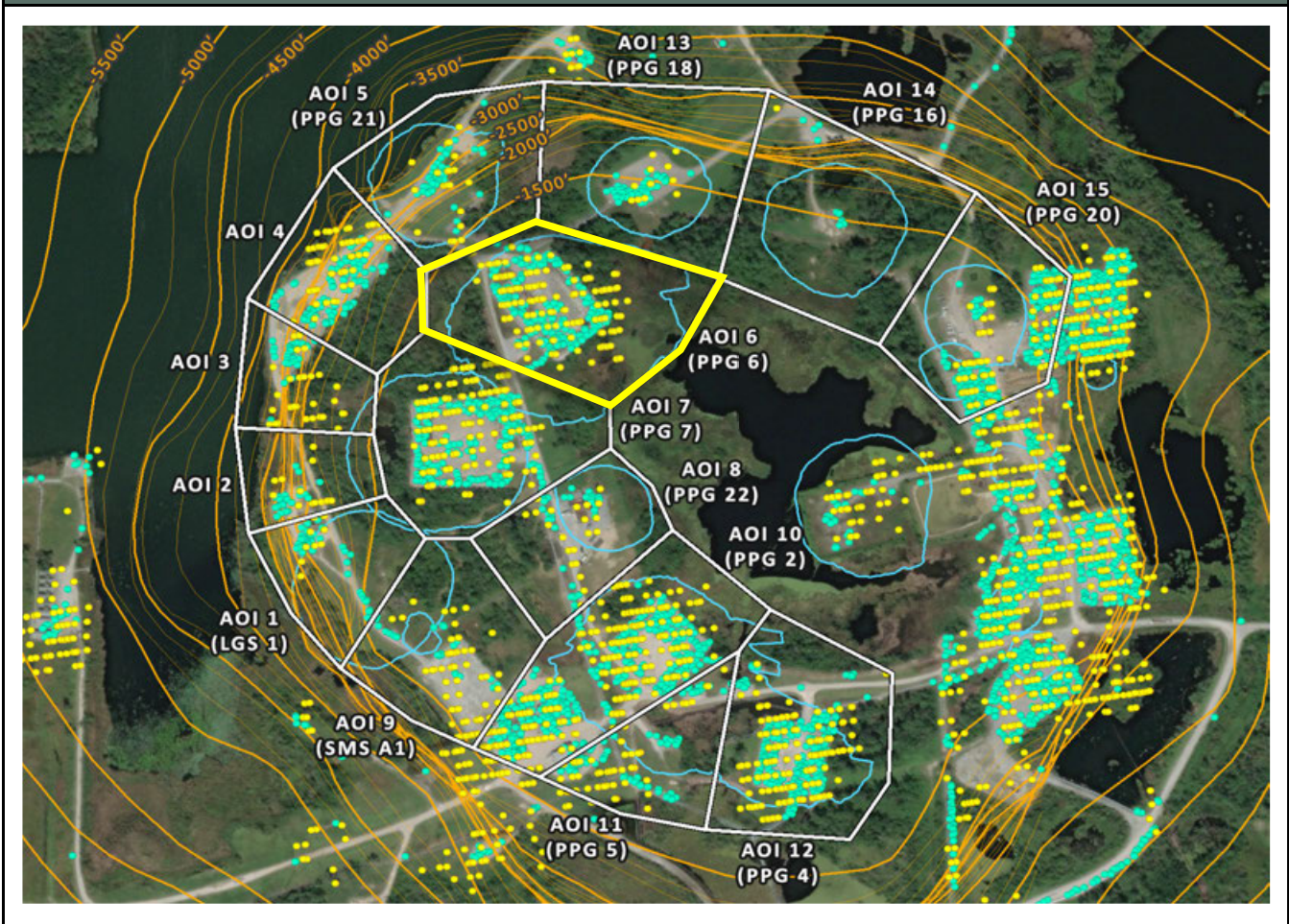
-0.19 in/yr

Acceleration: -0.12 in/yr²0.00 in/yr²

■ LOS Displacement Measurement

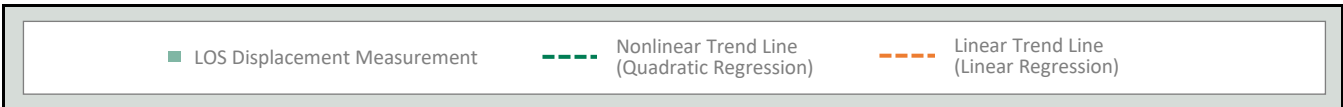
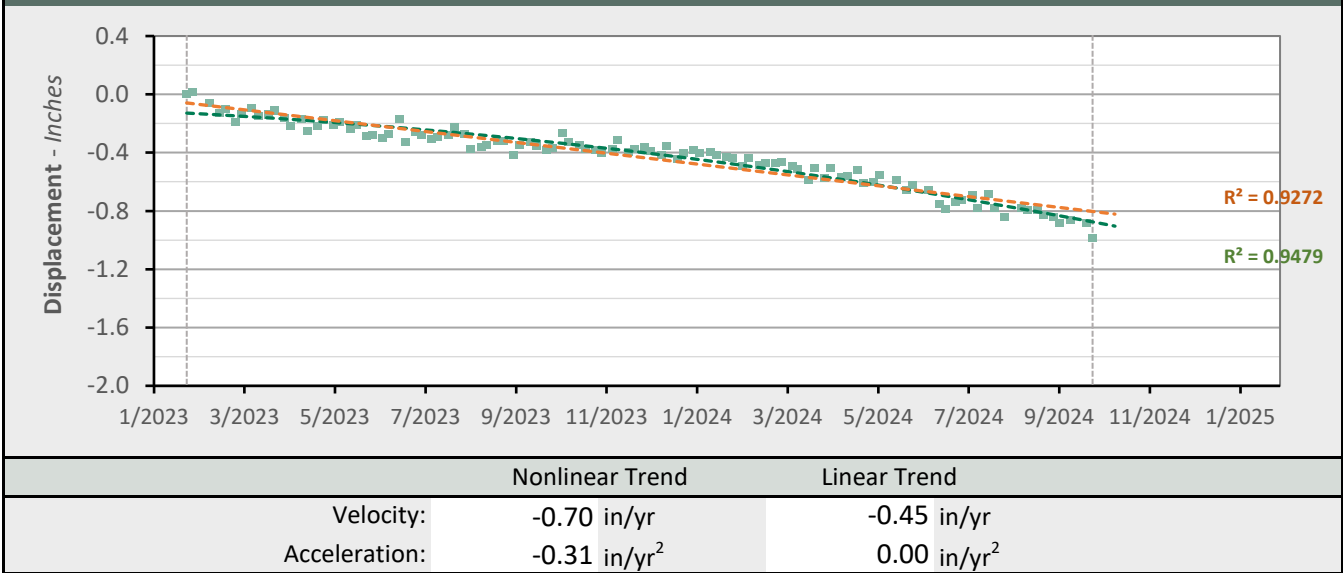
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 6 (PPG 6) - Location Map

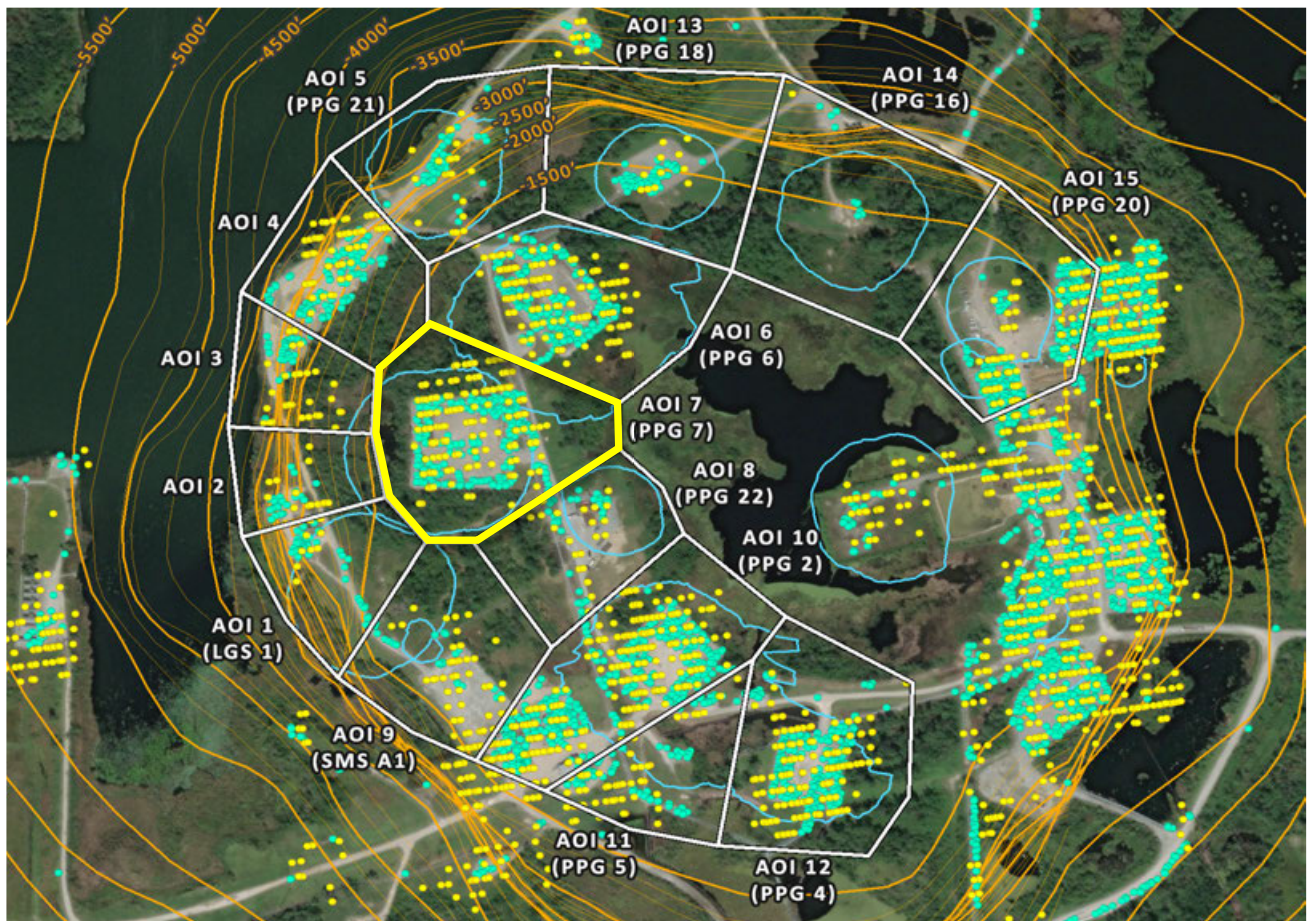


AOI 6 (PPG 6) - Displacement Time Series

TSX/PAZ (9/24/2024) Point Count: 212

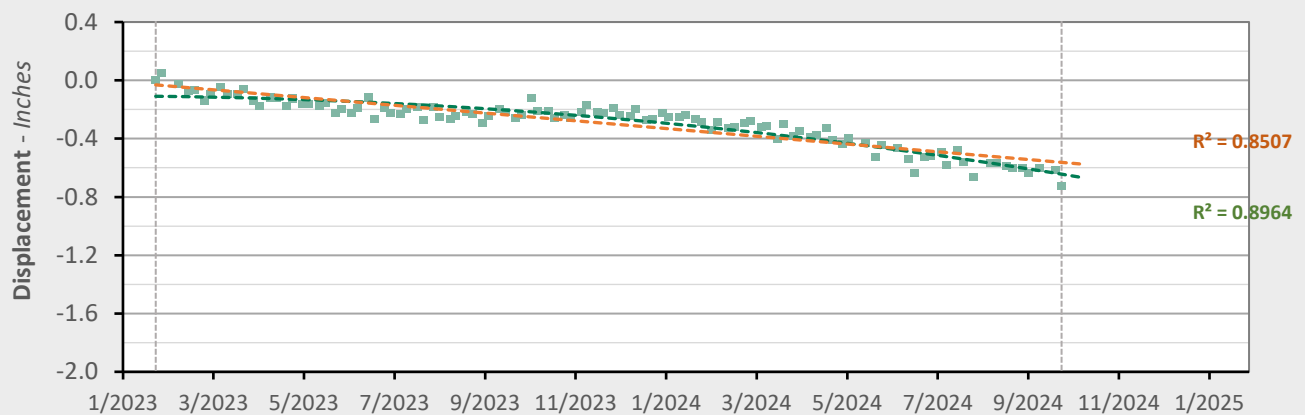


AOI 7 (PPG 7) - Location Map



AOI 7 (PPG 7) - Displacement Time Series

TSX/PAZ (9/24/2024) Point Count: 216



Nonlinear Trend

Linear Trend

Velocity: -0.60 in/yr

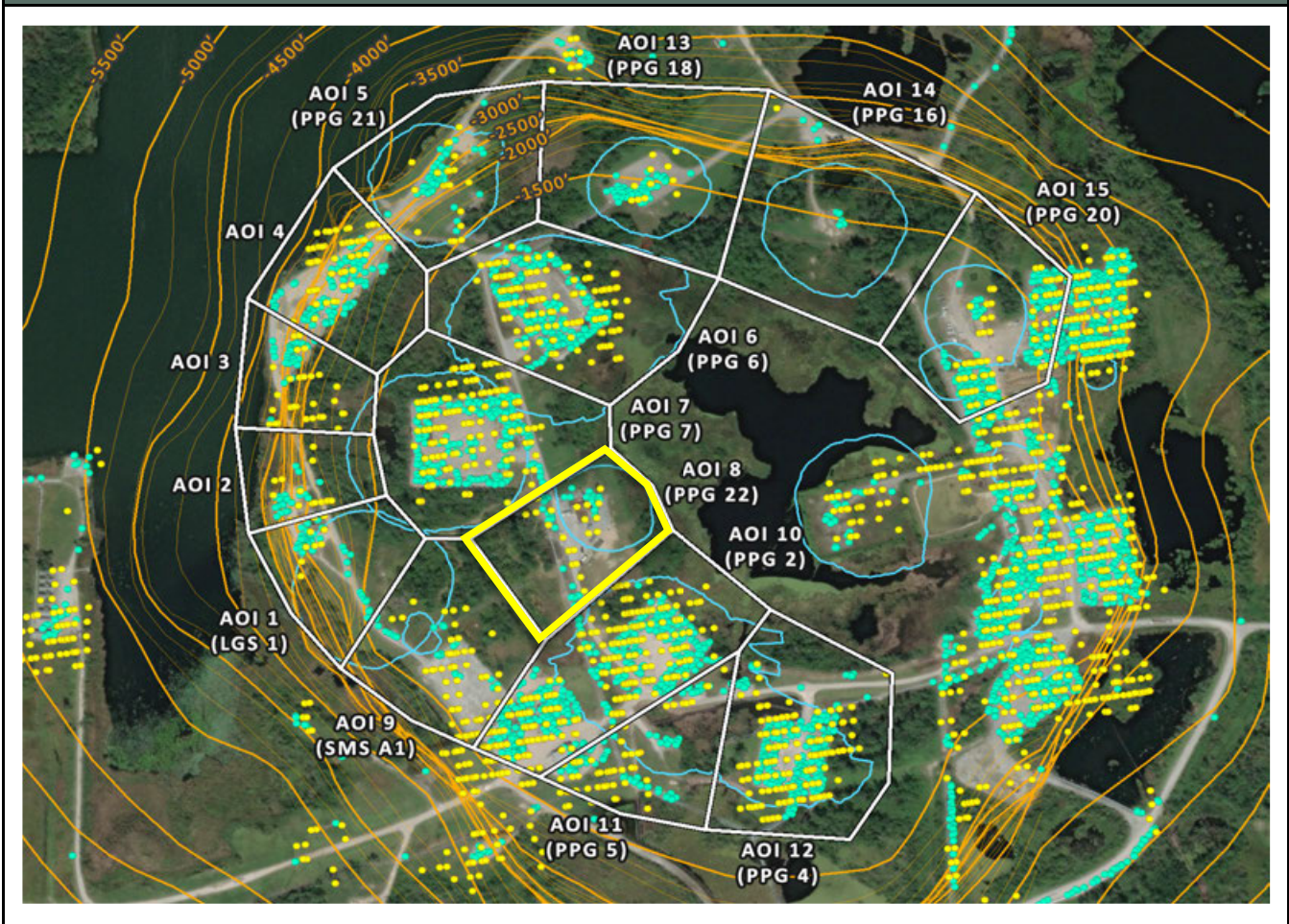
-0.32 in/yr

Acceleration: -0.34 in/yr²0.00 in/yr²

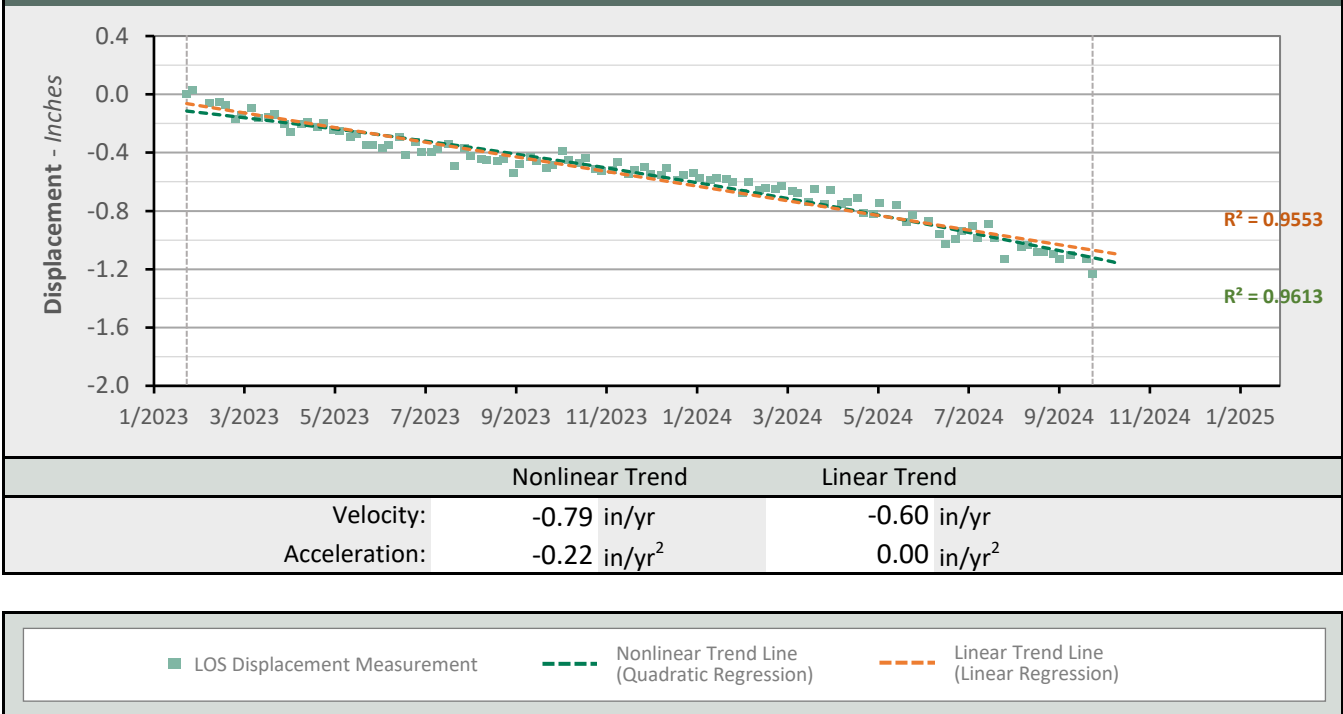
■ LOS Displacement Measurement

--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

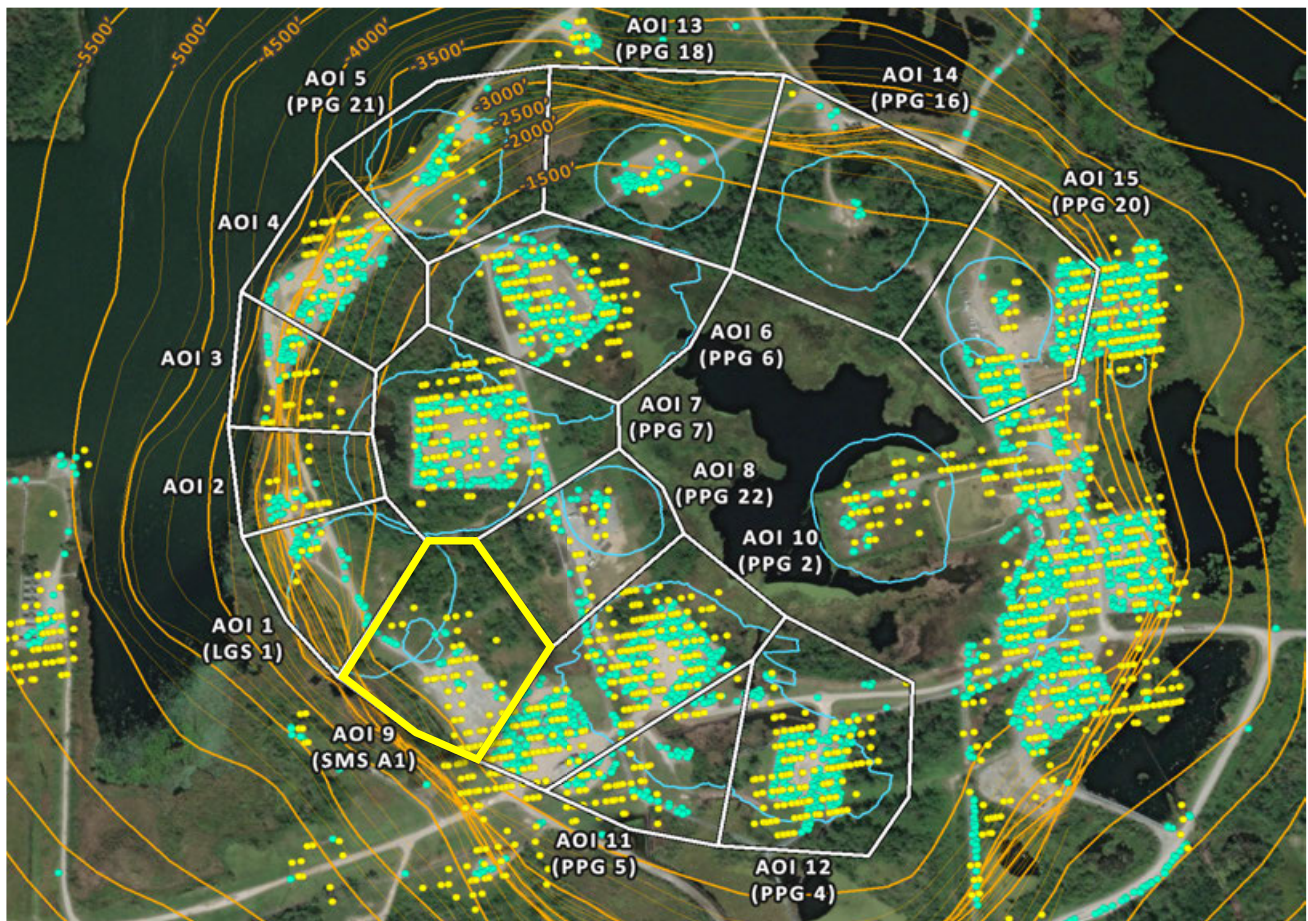
AOI 8 (PPG 22) - Location Map



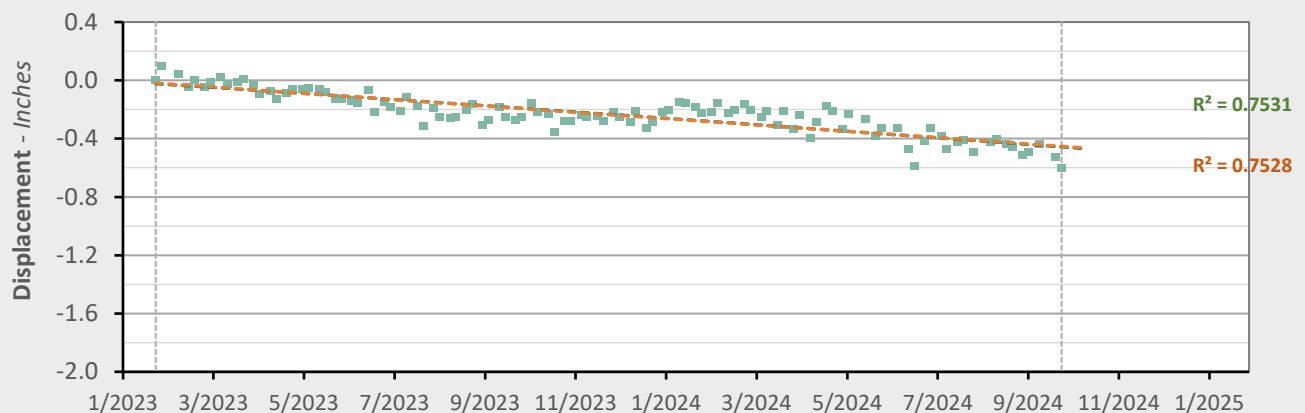
AOI 8 (PPG 22) - Displacement Time Series TSX/PAZ (9/24/2024) Point Count: 36



AOI 9 (PPG A1) - Location Map



AOI 9 (SMS A1) - Displacement Time Series TSX/PAZ (9/24/2024) Point Count: 23



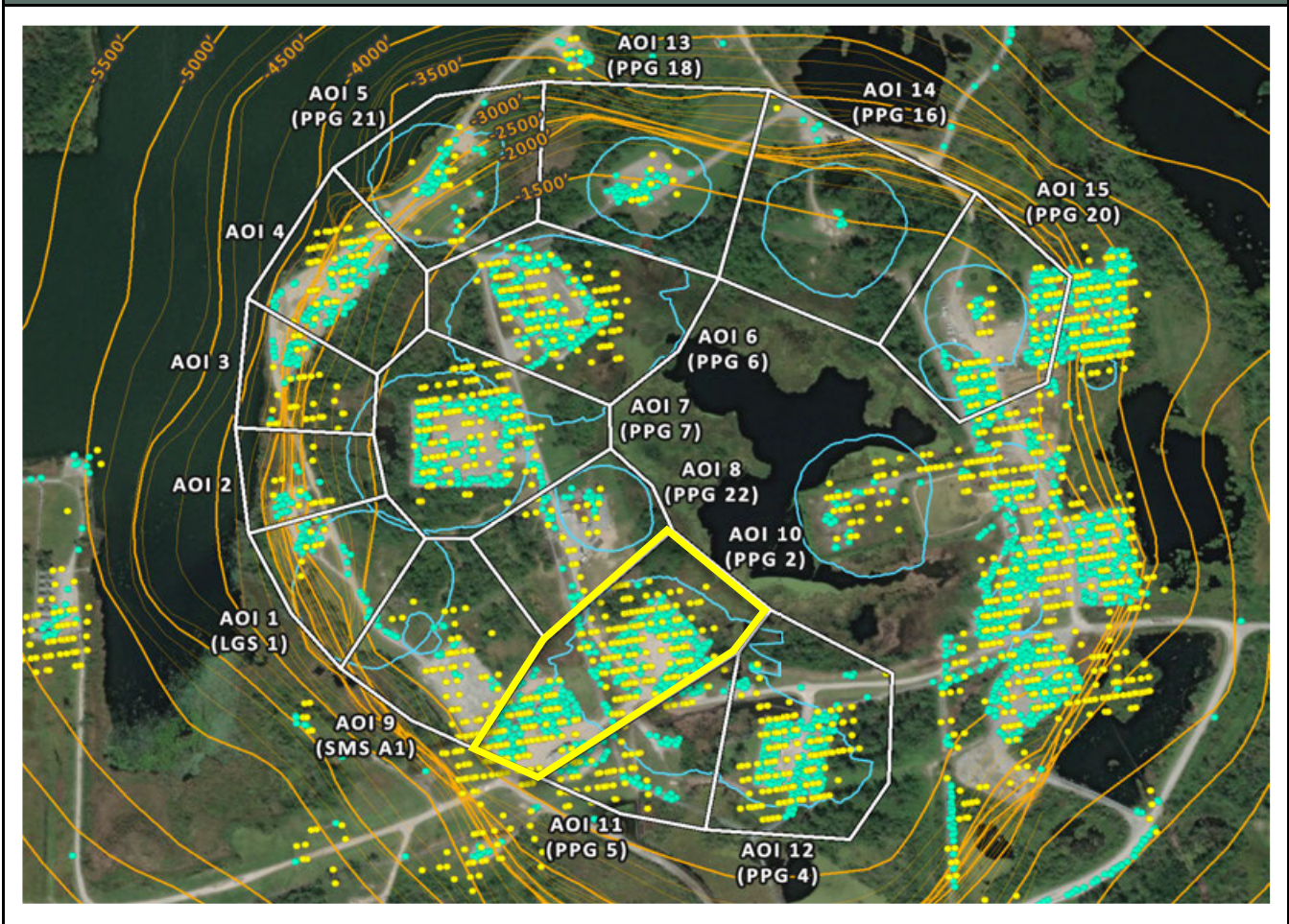
	Nonlinear Trend	Linear Trend
Velocity:	-0.28 in/yr	-0.26 in/yr
Acceleration:	-0.02 in/yr ²	0.00 in/yr ²

■ LOS Displacement Measurement

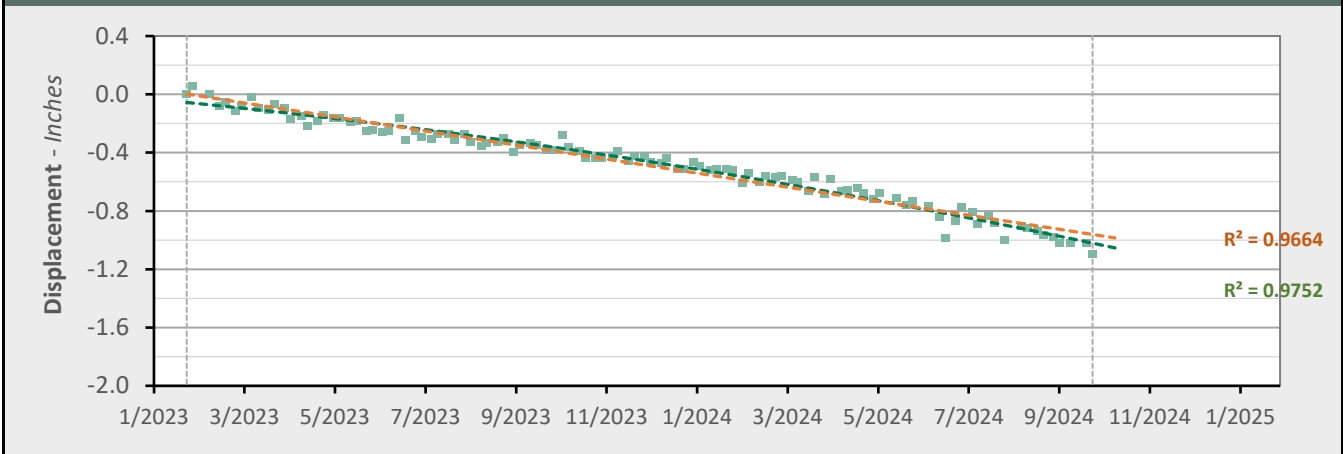
--- Nonlinear Trend Line
(Quadratic Regression)

--- Linear Trend Line
(Linear Regression)

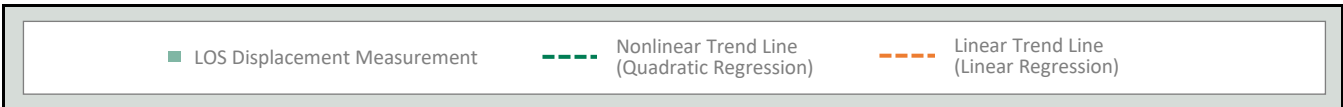
AOI 10 (PPG 2) - Location Map

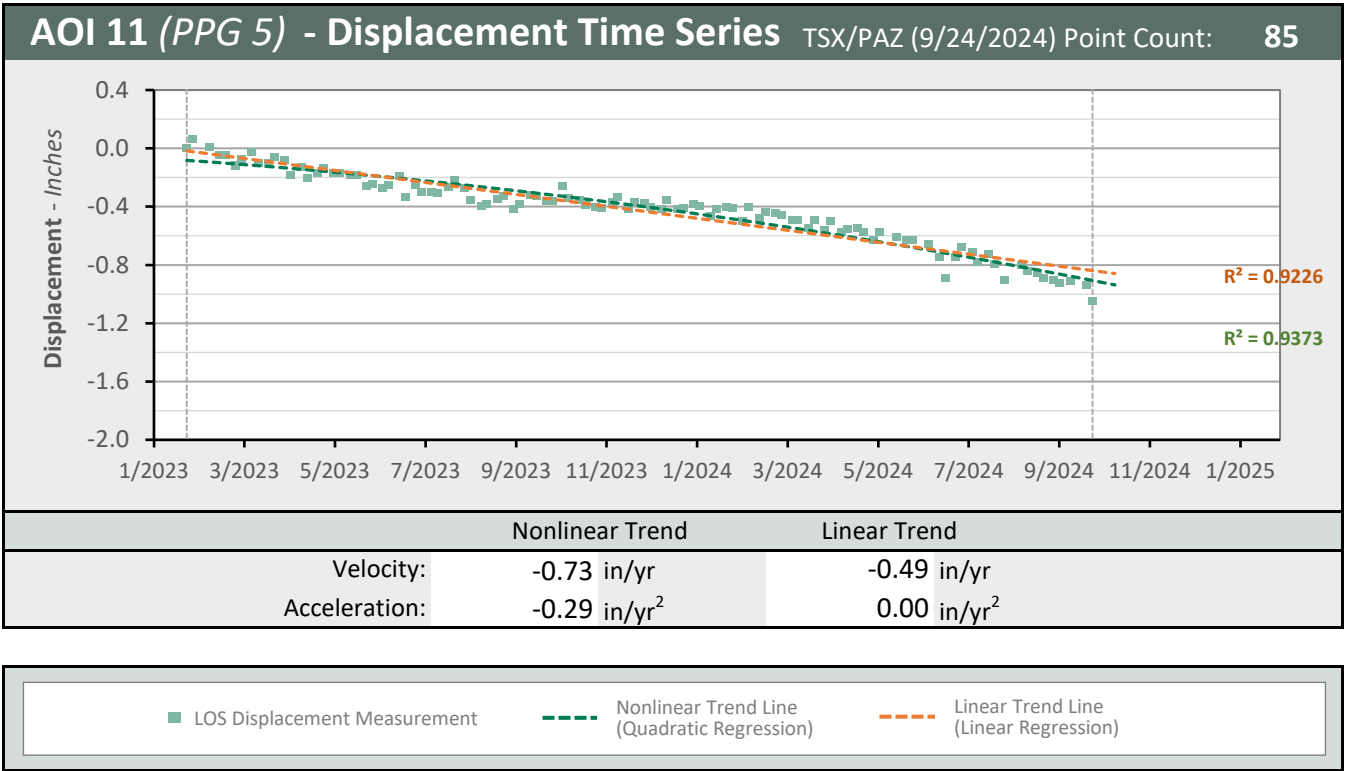
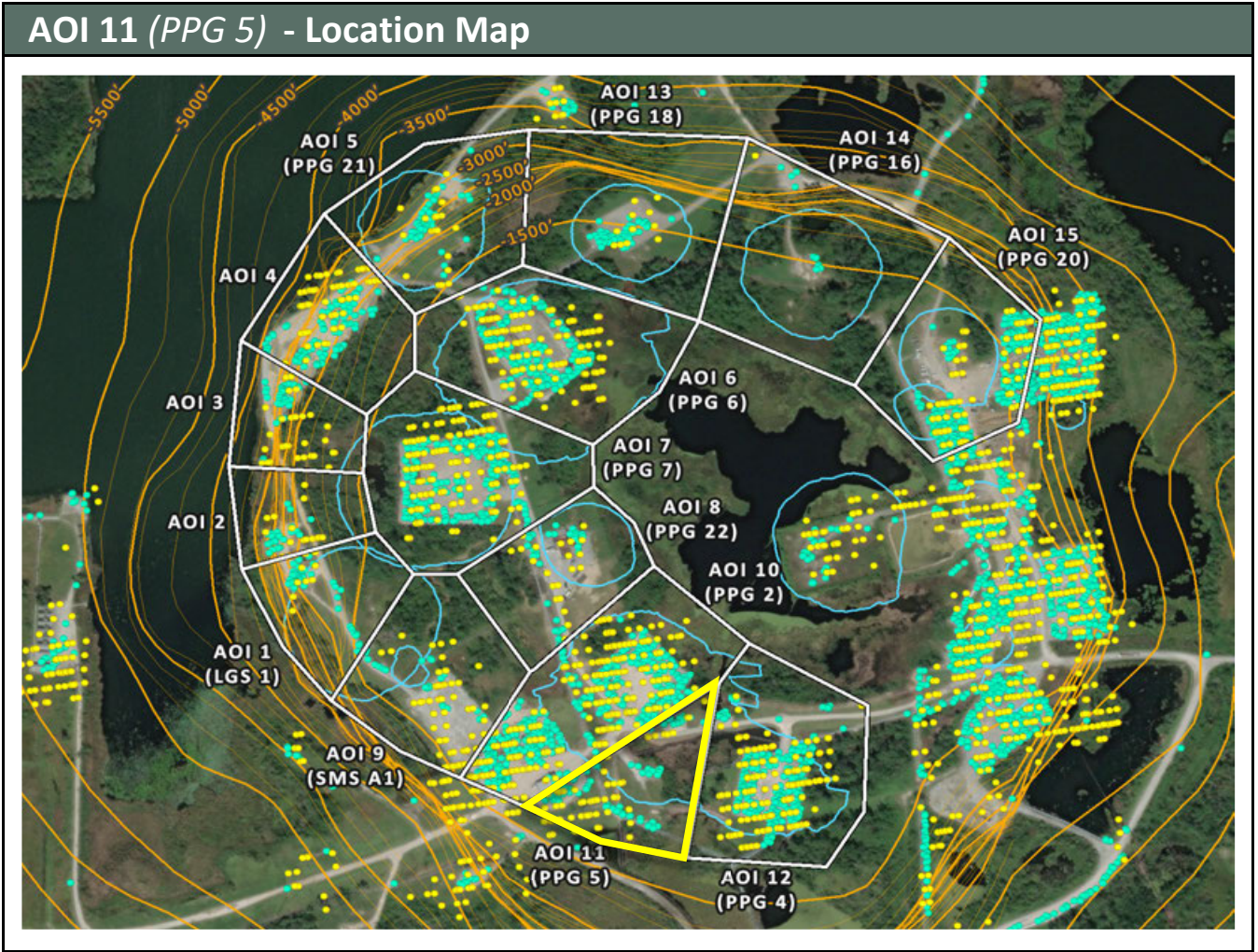


AOI 10 (PPG 2) - Displacement Time Series TSX/PAZ (9/24/2024) Point Count: 404

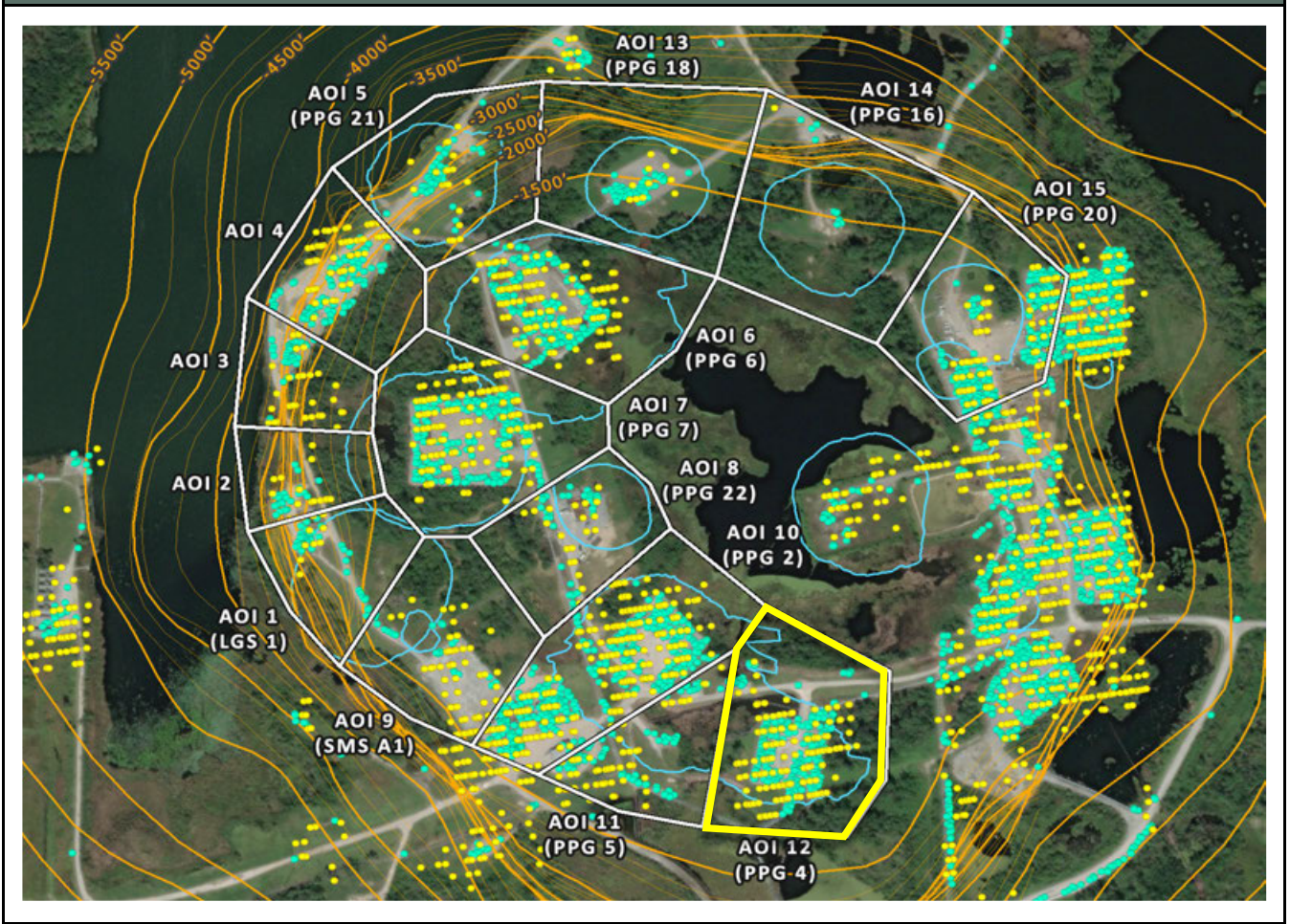


	Nonlinear Trend	Linear Trend
Velocity:	-0.79 in/yr	-0.58 in/yr
Acceleration:	-0.25 in/yr ²	0.00 in/yr ²

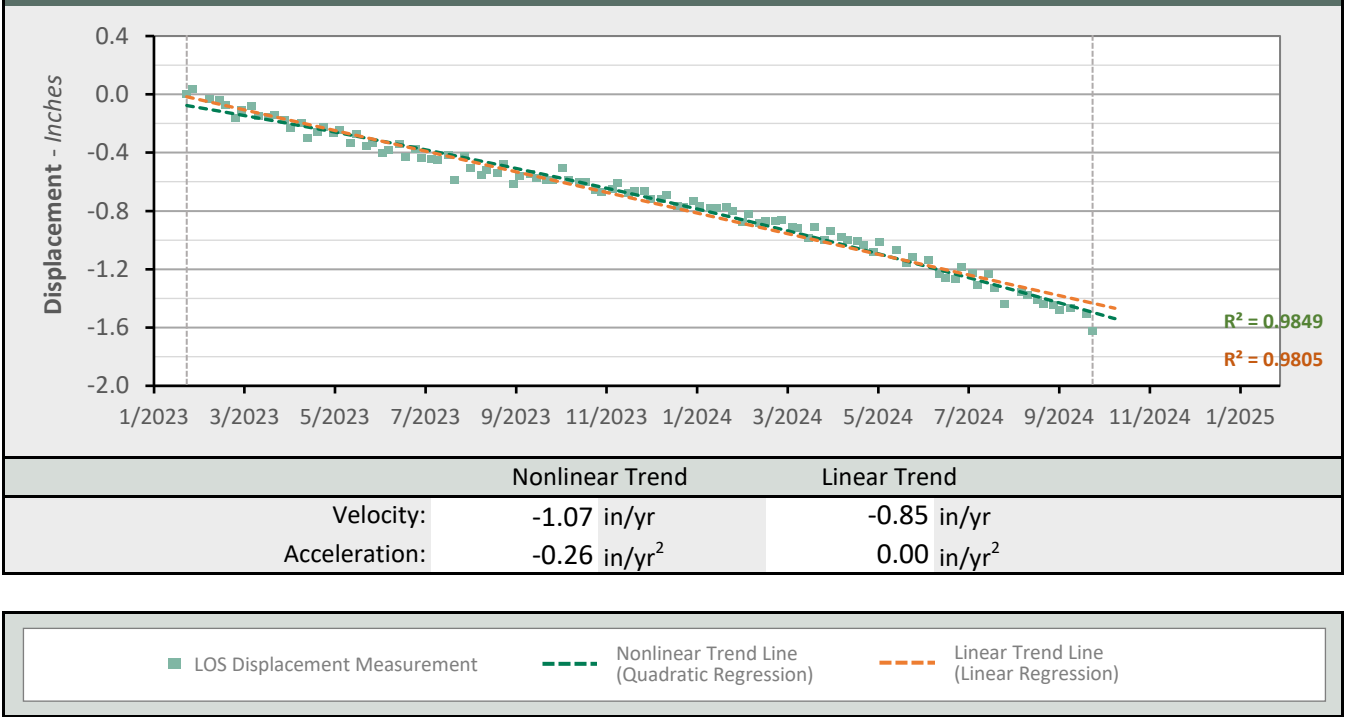




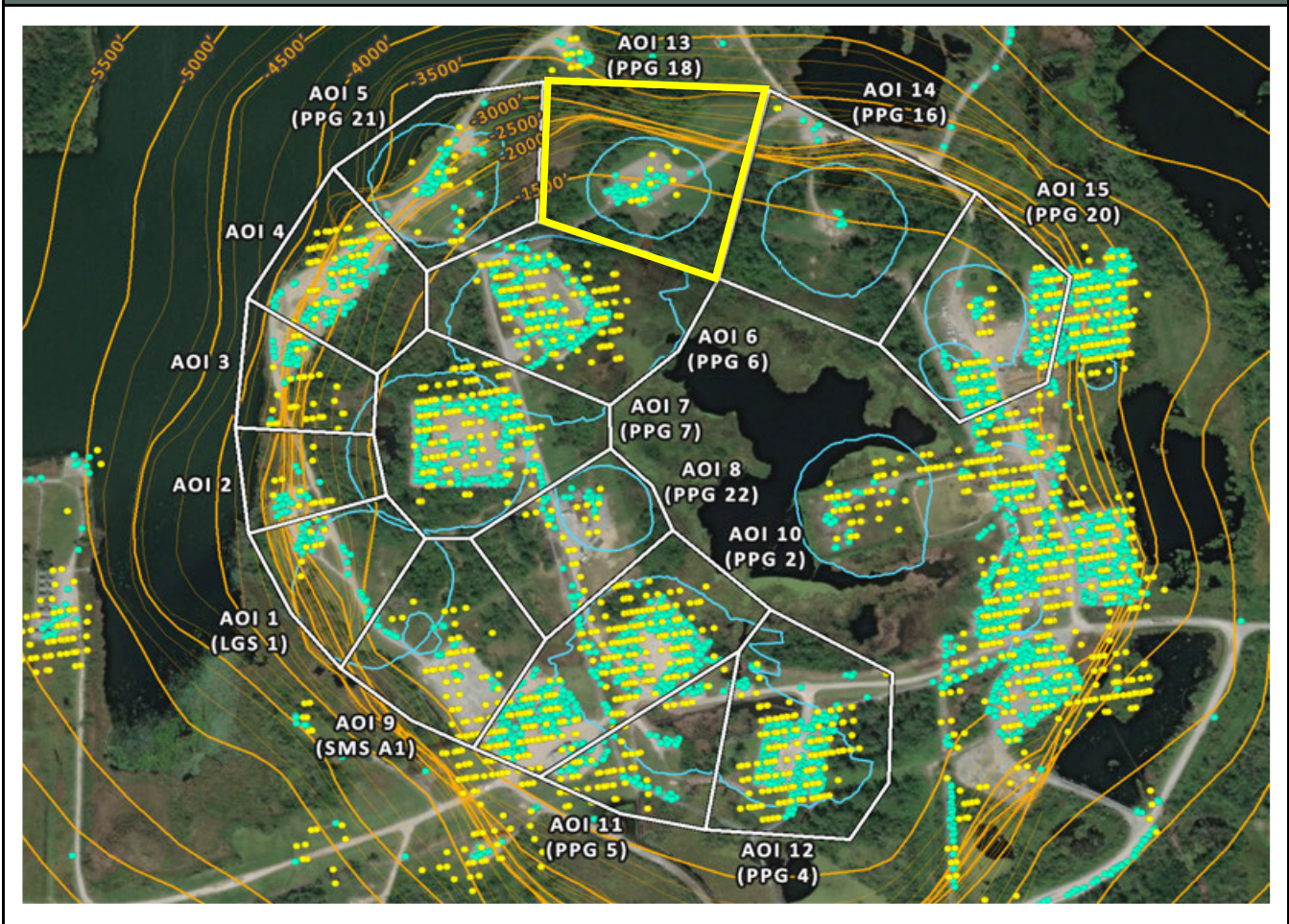
AOI 12 (PPG 4) - Location Map



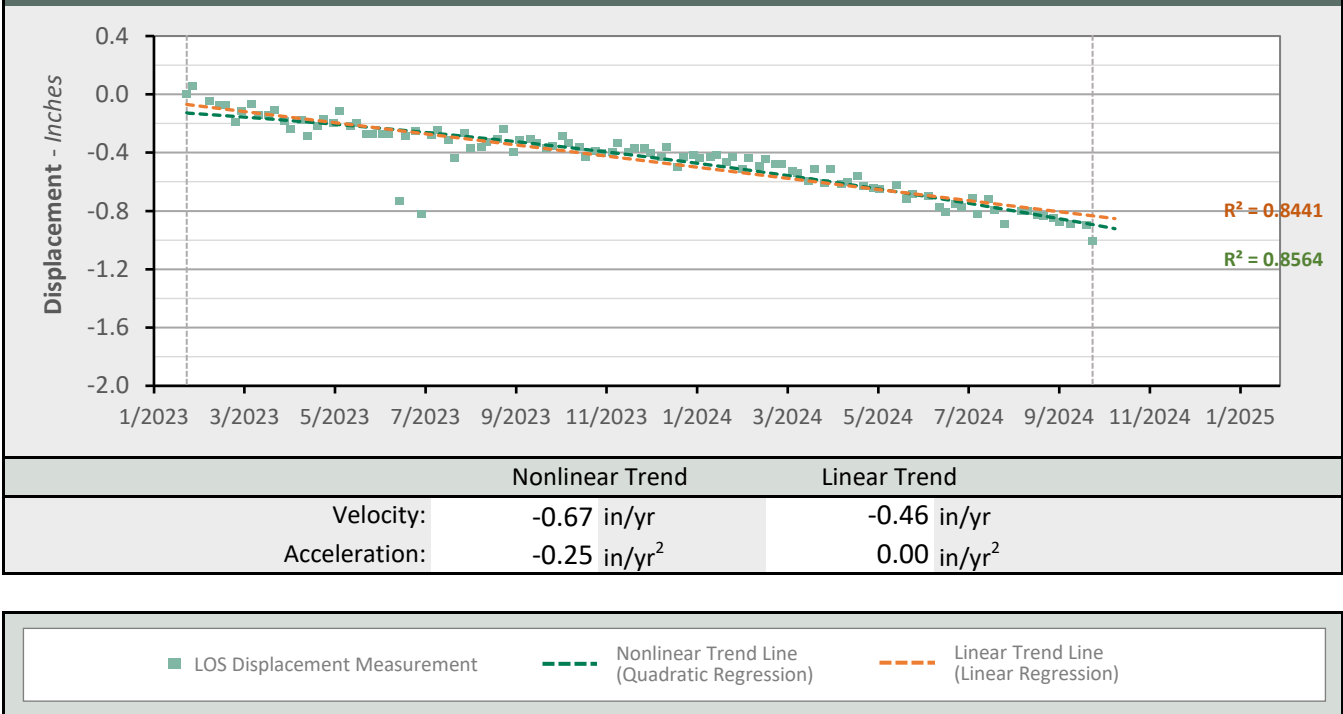
AOI 12 (PPG 4) - Displacement Time Series TSX/PAZ (9/24/2024) Point Count: 262



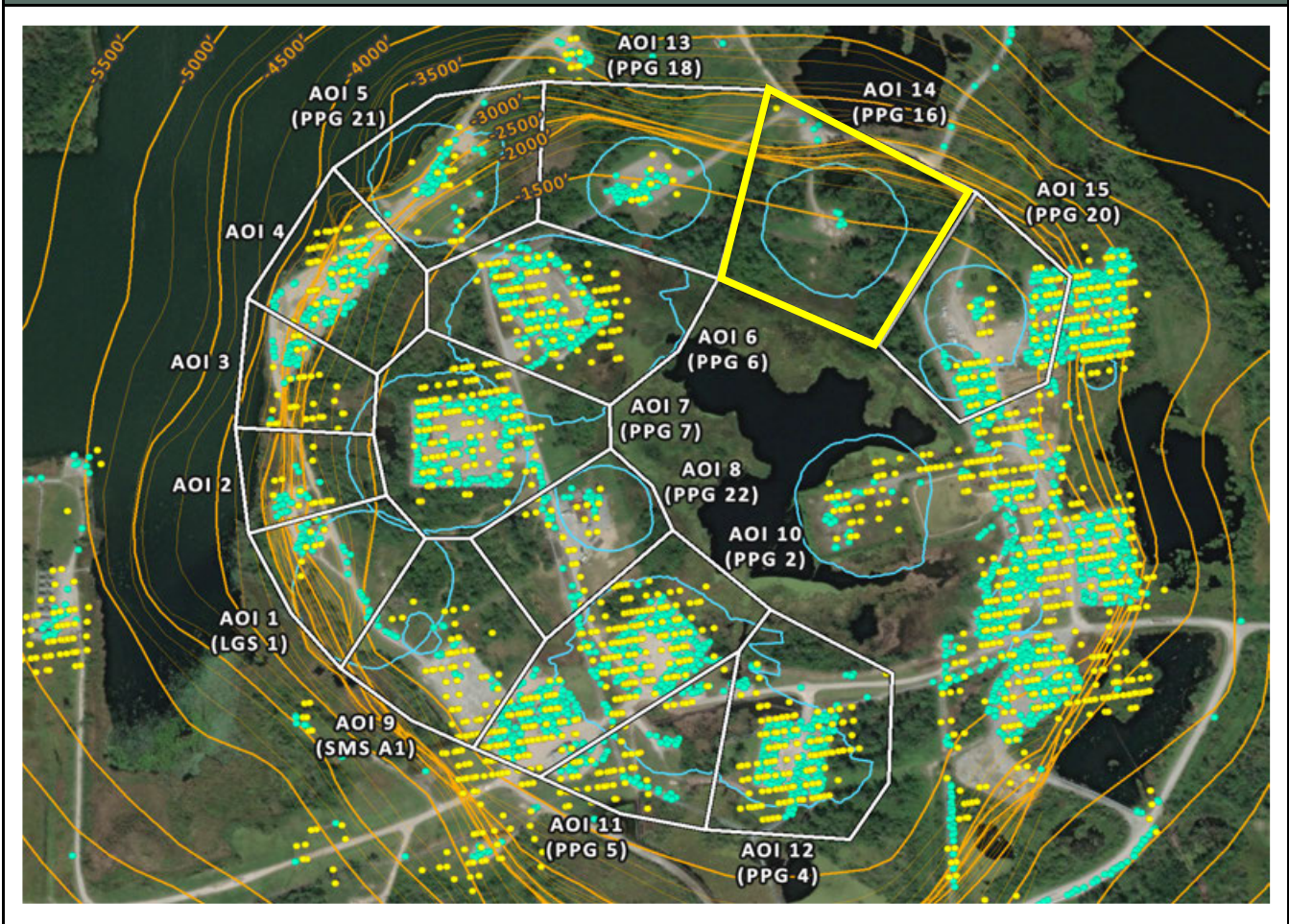
AOI 13 (PPG 18) - Location Map



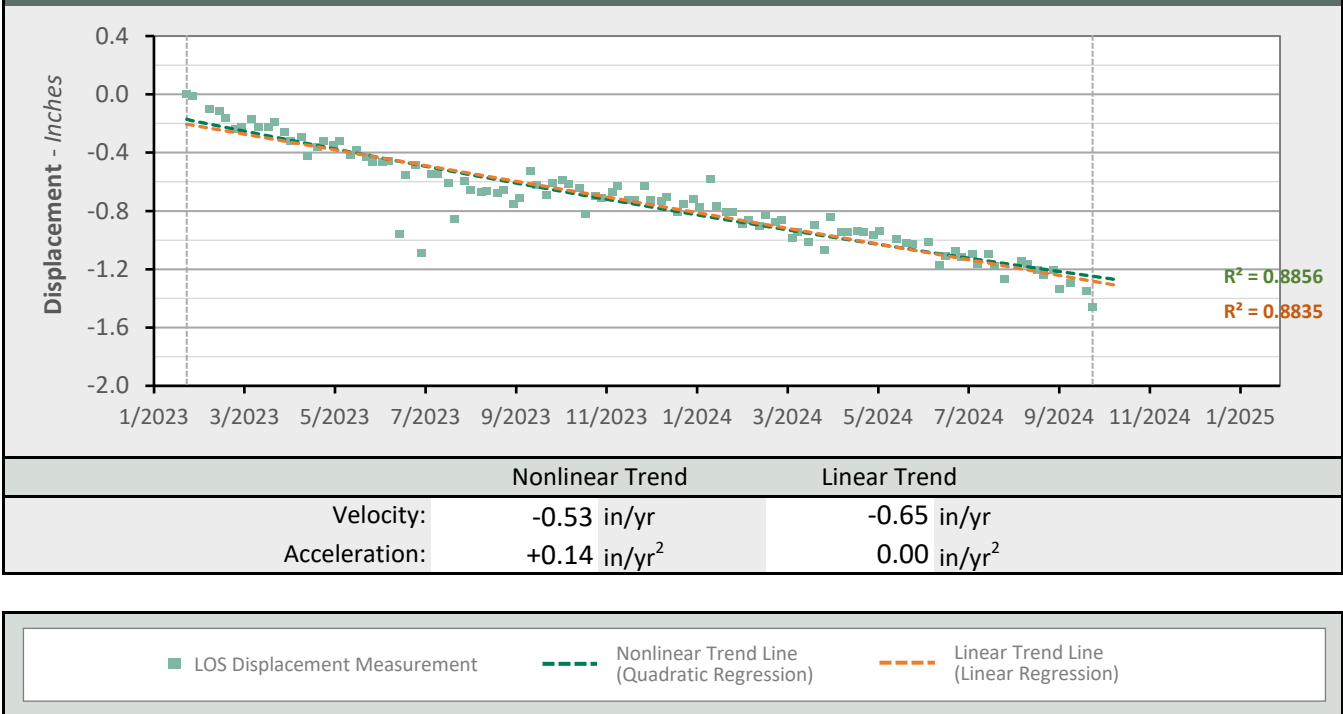
AOI 13 (PPG 18) - Displacement Time SeriesTSX/PAZ (9/24/2024) Point Count: 52



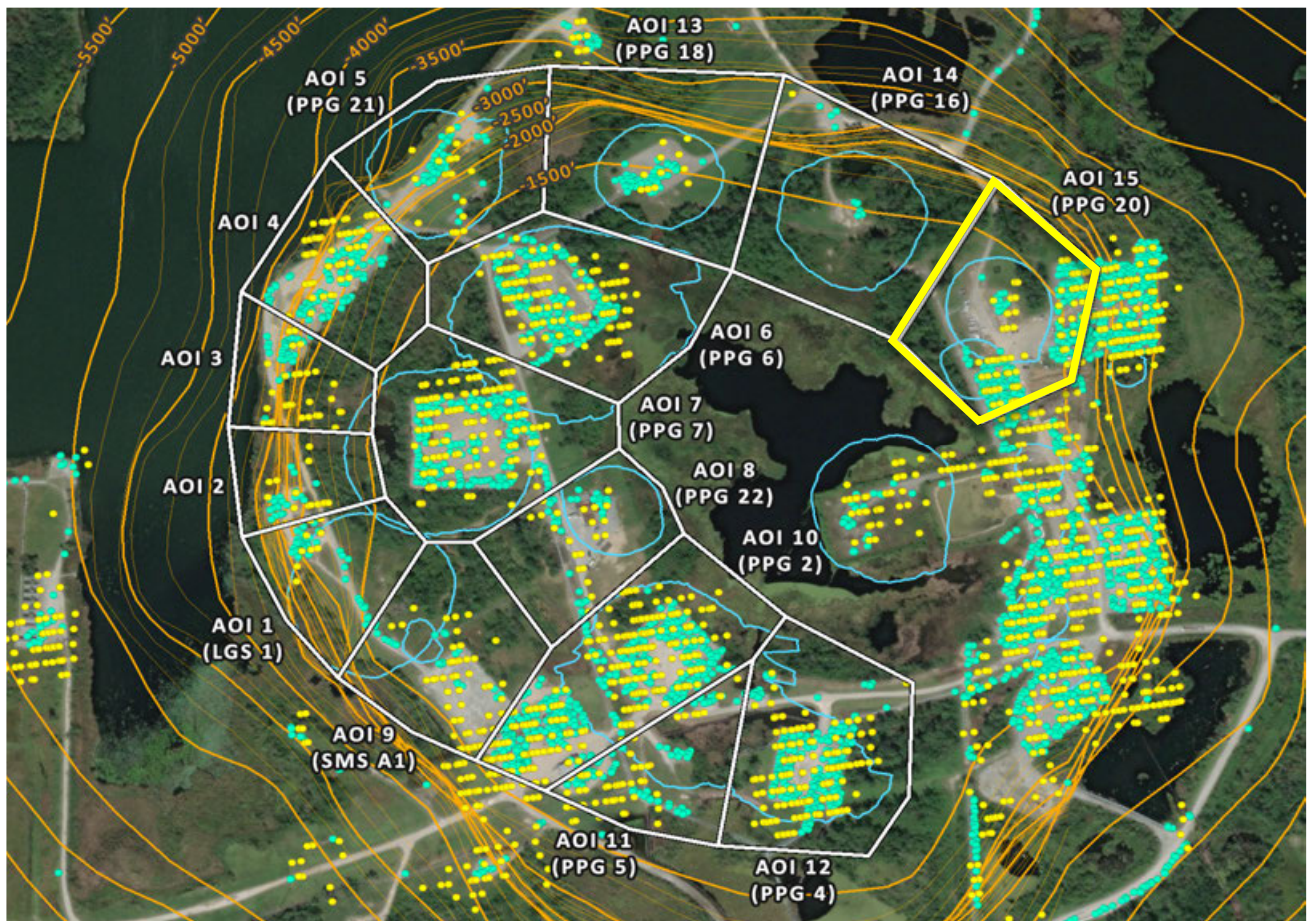
AOI 14 (PPG 16) - Location Map



AOI 14 (PPG 16) - Displacement Time SeriesTSX/PAZ (9/24/2024) Point Count: 11

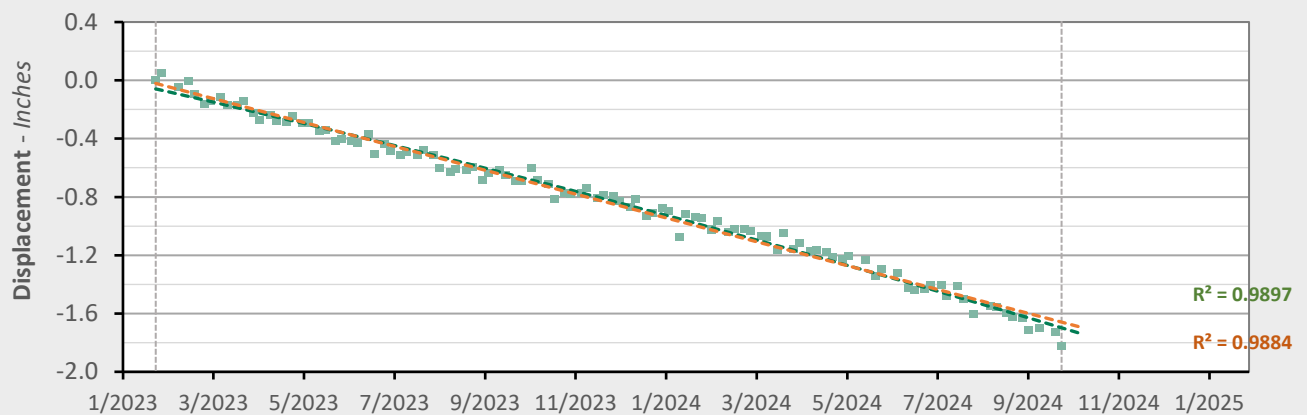


AOI 15 (PPG 20) - Location Map



AOI 15 (PPG 20) - Displacement Time Series

TSX/PAZ (9/24/2024) Point Count: 224



Nonlinear Trend

Linear Trend

Velocity: -1.12 in/yr

-0.98 in/yr

Acceleration: -0.16 in/yr²

0.00 in/yr²

■ LOS Displacement Measurement

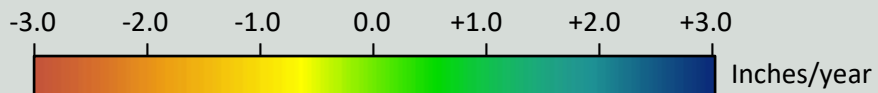
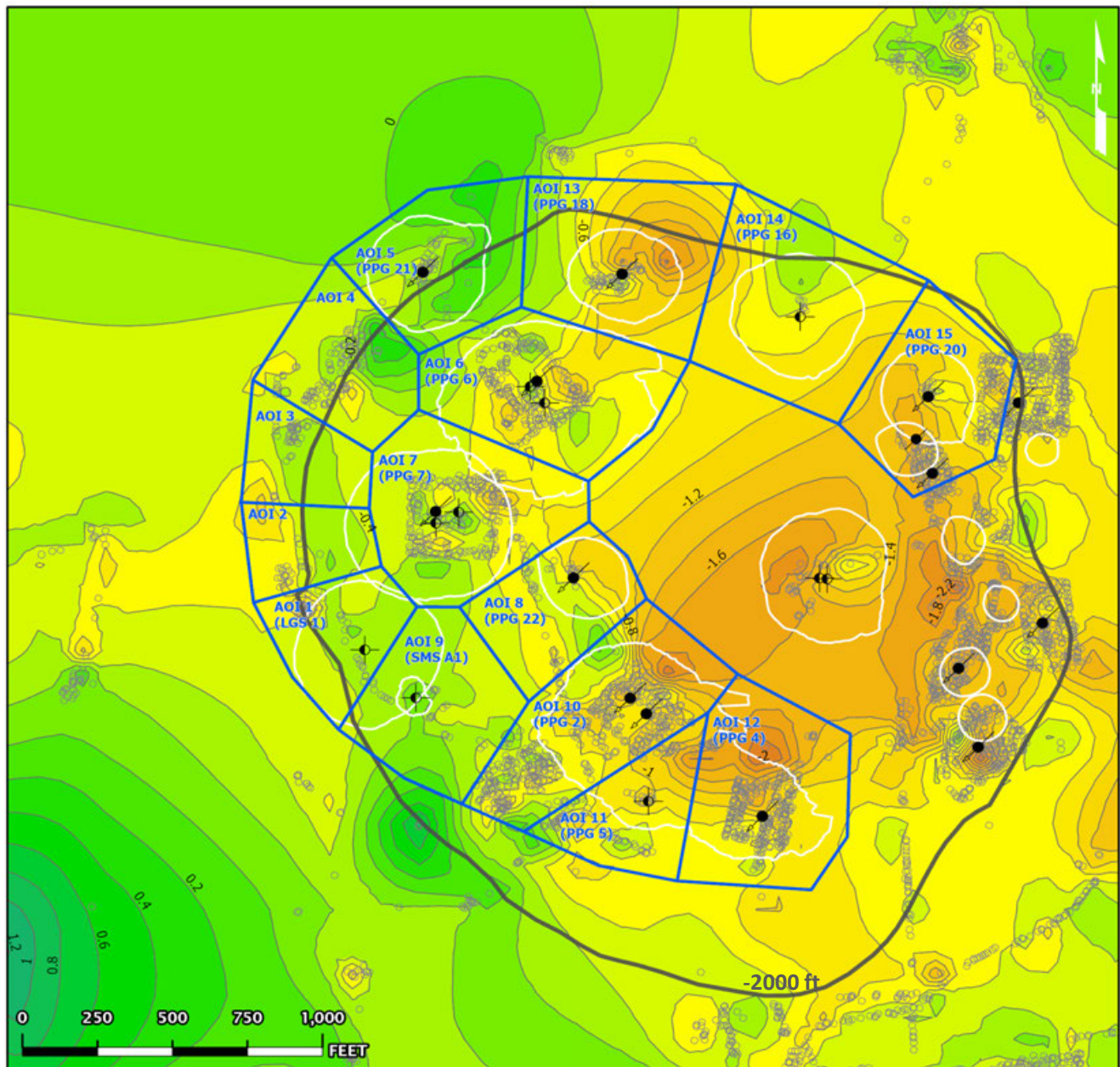
--- Nonlinear Trend Line
(Quadratic Regression)

--- Linear Trend Line
(Linear Regression)

TSX/PAZ Data (01/24/2023 - 09/24/2024)

Nonlinear Velocity Contours

As of date: 09/24/2024

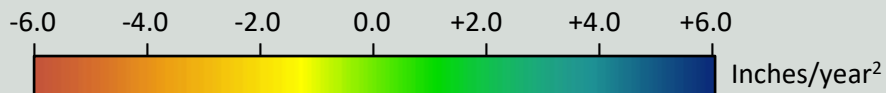
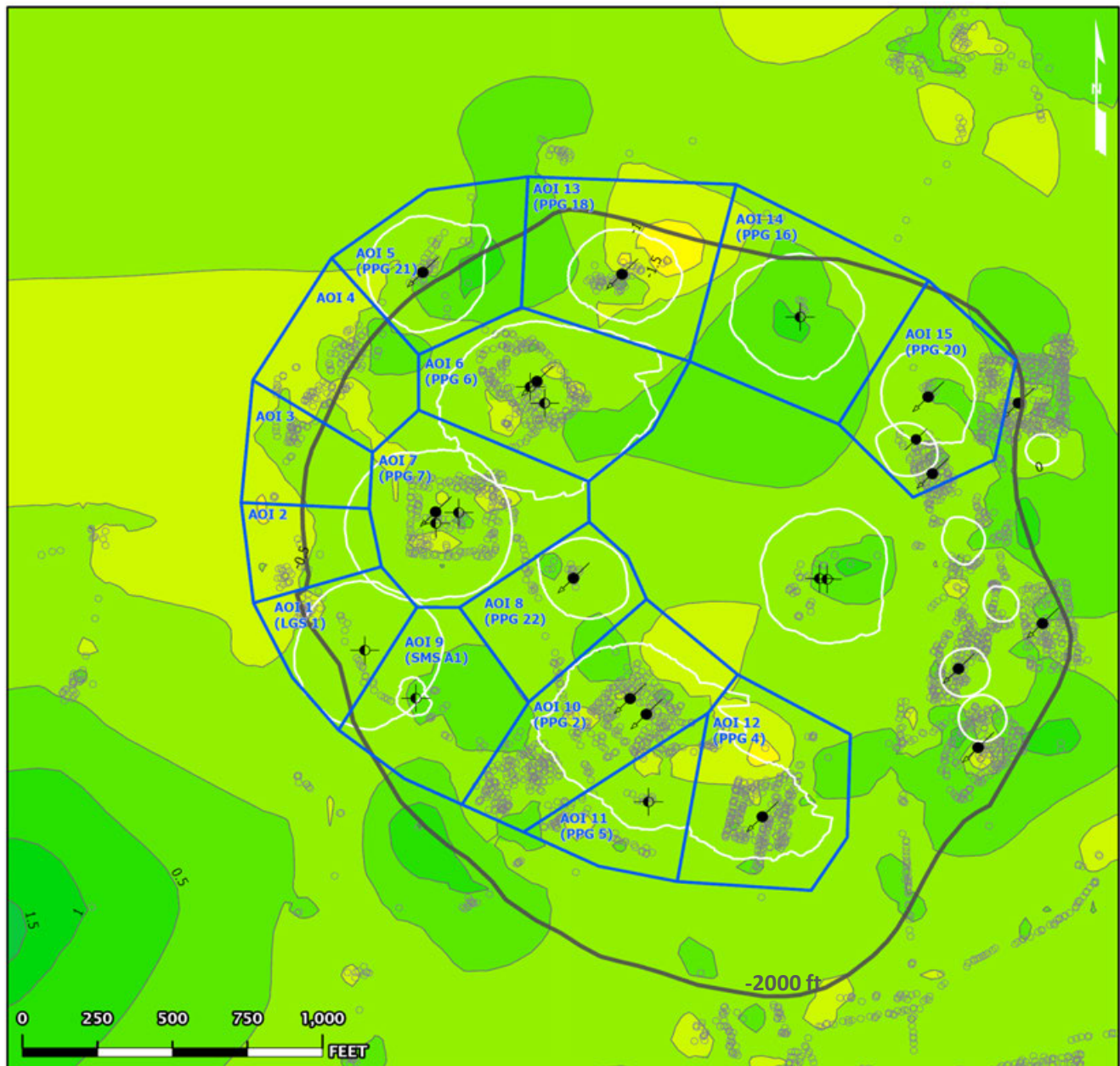


- Legend:
- AOI Boundary
 - Historical Cavern Extent
 - InSAR LOS Measurement Point
 - Top of Dome (-2000 ft Contour)
 - Contour (0.2)
 - Cavern Well Surface Locations
 - 09 - Active - Injection
 - 29 - Dry and Plugged

TSX/PAZ Data (01/24/2023 - 09/24/2024)

Nonlinear Acceleration Contours

Date range: 01/24/2023 - 09/24/2024



- AOI Boundary
- InSAR LOS Measurement Point
- Contour (0.5)
- Historical Cavern Extent
- Top of Dome (-2000 ft Contour)

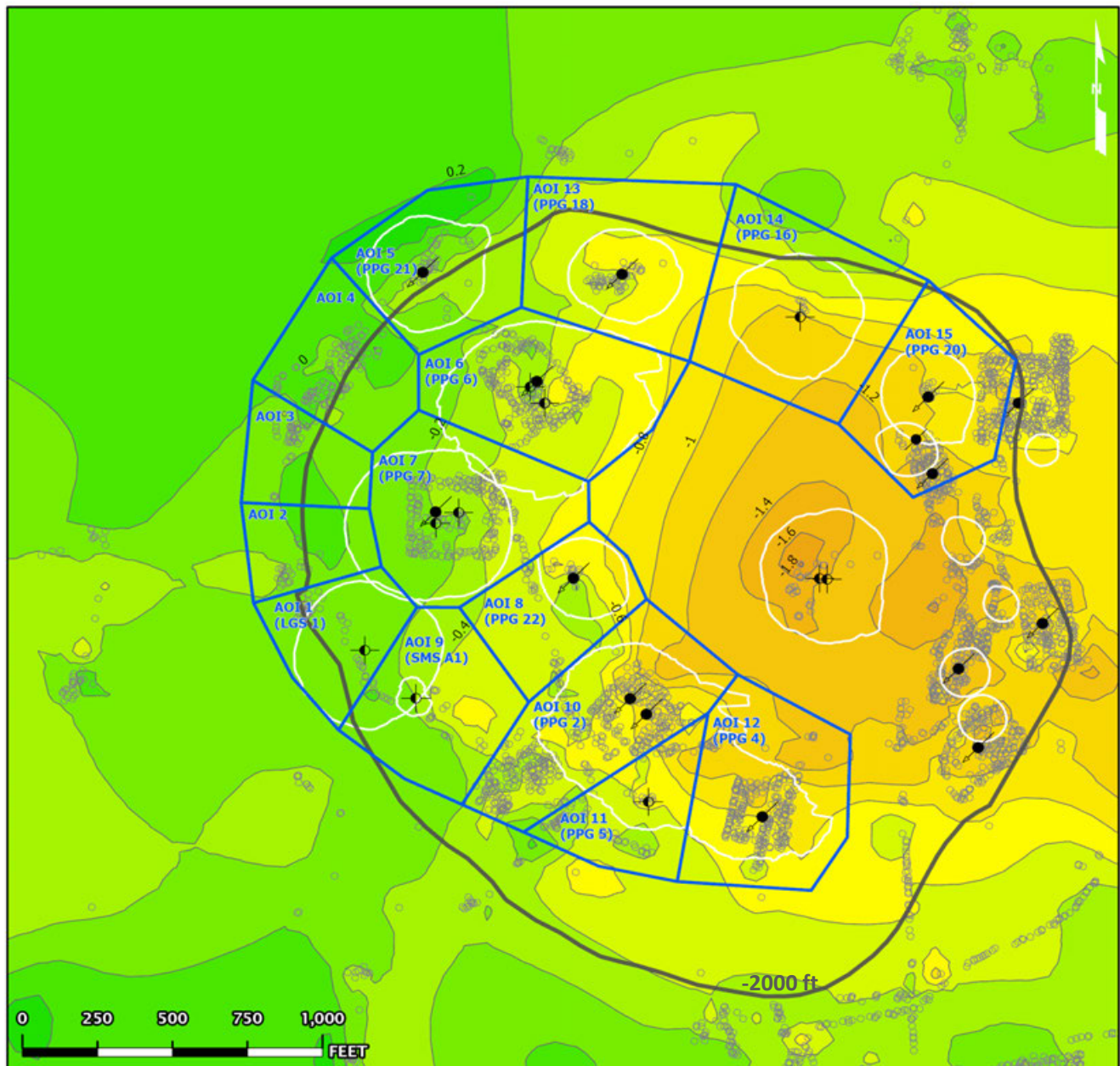
Cavern Well Surface Locations

- 09 - Active - Injection
- 29 - Dry and Plugged

TSX/PAZ Data (01/24/2023 - 09/24/2024)

Linear Velocity Contours

Date range: 01/24/2023 - 09/24/2024



- Legend:
- AOI Boundary
 - InSAR LOS Measurement Point
 - Contour (0.2)
 - Historical Cavern Extent
 - Top of Dome (-2000 ft Contour)
 - Cavern Well Surface Locations
 - 09 - Active - Injection
 - 29 - Dry and Plugged

TSX/PAZ Data (01/24/2023 - 09/24/2024)

Nonlinear Velocity Data Points

As of date: 09/24/2024

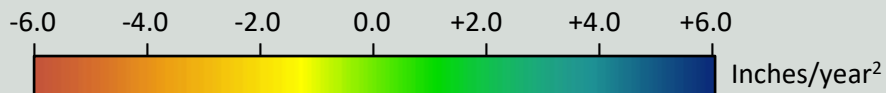


- AOI Boundary
- Historical Cavern Extent
- Top of Dome (-2000 ft Contour)
- InSAR LOS Measurement Point
- Cavern Well Surface Locations
- 09 - Active - Injection
- 29 - Dry and Plugged

TSX/PAZ Data (01/24/2023 - 09/24/2024)

Nonlinear Acceleration Data Points

Date range: 01/24/2023 - 09/24/2024



- AOI Boundary
 - InSAR LOS Measurement Point
 - Historical Cavern Extent
 - Top of Dome (-2000 ft Contour)
- Cavern Well Surface Locations
- 09 - Active - Injection
 - 29 - Dry and Plugged

TSX/PAZ Data (01/24/2023 - 09/24/2024)

Linear Velocity Data Points

Date range: 01/24/2023 - 09/24/2024



- AOI Boundary
- Historical Cavern Extent
- Top of Dome (-2000 ft Contour)
- InSAR LOS Measurement Point
- Cavern Well Surface Locations
- 09 - Active - Injection
- 29 - Dry and Plugged

ATTACHMENT D

Vertical & East-West 2D InSAR report - September 24, 2024

Vertical & E-W 2D Update

Continuous InSAR Monitoring of
Ground Displacement At Westlake
Caverns and Western Dome Flank

Sulphur Mines Salt Dome

Prepared for:
Westlake Chemical

Prepared by:
Lonquist & Co., LLC
8591 United Plaza Blvd.
Suite 280
Baton Rouge, LA 70809

Dataset
Satellite Source
Sentinel-1 & TerraSAR-X - PAZ Constellation
Most Recent Image Date
Tuesday, September 24, 2024

Analysis Report Date:
October 16, 2024

Dataset Information

Satellite Source	Sentinel-1 & TerraSAR-X - PAZ Constellation
Update Frequency	12 days
Most Recent Image Date	Tuesday, September 24, 2024
Dataset Image Count	137
Dataset Time Range	January 24, 2023 - September 24, 2024
Dataset Length	1.67 Years
Measurement Directions	Vertical and East-West

Analysis Methodology

Time Series Charts

Trend lines were calculated for the averaged vertical and east-west displacement values within each AOI. Both a nonlinear (quadratic) and linear regression were applied to each AOI point group to identify rates of change in LOS displacement. These trends are displayed in the Time Series section of this report.

Contour Maps

A nonlinear (quadratic) and linear trend was also calculated for each individual measurement point across the analysis region. Nonlinear trend values for each point were used to generate Velocity and Acceleration contour maps to convey the spatial distribution of the calculated movement. The linear trend values for each point (which lack an acceleration component) were used to generate an additional Velocity contour map. Maps depicting the individual data points colored by these trend values are included after the contour maps.

Rate Interpretation

For the vertical data, positive velocity values indicate uplift and negative velocity values indicate subsidence. Positive acceleration values indicate increasing rates of uplift or slowing rates of subsidence, while negative acceleration values indicate slowing rates of uplift or increasing rates of subsidence. For the east-west data, positive velocity values indicate eastward horizontal movement and negative velocity values indicate horizontal westward movement. Positive acceleration values indicate increasing rates of eastward movement or decreasing rates of westward movement, while negative acceleration values indicate increasing rates of westward movement or decreasing rates of eastward movement.

Observations

To-date there have been no acute deviations from established subsidence trends in the areas investigated.

The calculated vertical displacement values indicate that subsidence is occurring with near-linear trends in all AOIs where data is present. Minor positive acceleration (slowing subsidence) is present in all of the calculated nonlinear AOI trends.

The calculated east-west displacement values generally indicate horizontal movement toward the dome center with the greatest rates of eastward movement occurring in the western AOIs and the greatest rate of westward movement occurring in the easternmost AOI. All AOIs indicate varying amounts of negative acceleration (slower eastward or faster westward displacement) with the most pronounced values occurring in AOI 1 and AOI 3. This likely correlates to the minor increases in negative acceleration recently noted in the TSX/PAZ LOS dataset reports.



Date Signed: October 16, 2024
Austin, Texas

Nathaniel L. Byars, P.E.
Principal Engineer
Louisiana License No. 40697

InSAR Data Sources

InSAR Data

Interferometric Synthetic Aperture Radar (InSAR) is the most well established method to continually evaluate small, normally undetectable, ground movement over a large area. Radar imagery collected via satellites over successive orbital passes is used to identify and define measurement points on the ground. Objects or ground features providing a stable reflection of radar energy such as buildings, roads, and infrastructure produce the highest quality measurement points. InSAR analysis identifies the change in distance between the satellite and each measurement point over time relative to a stable reference point within the imaged area.

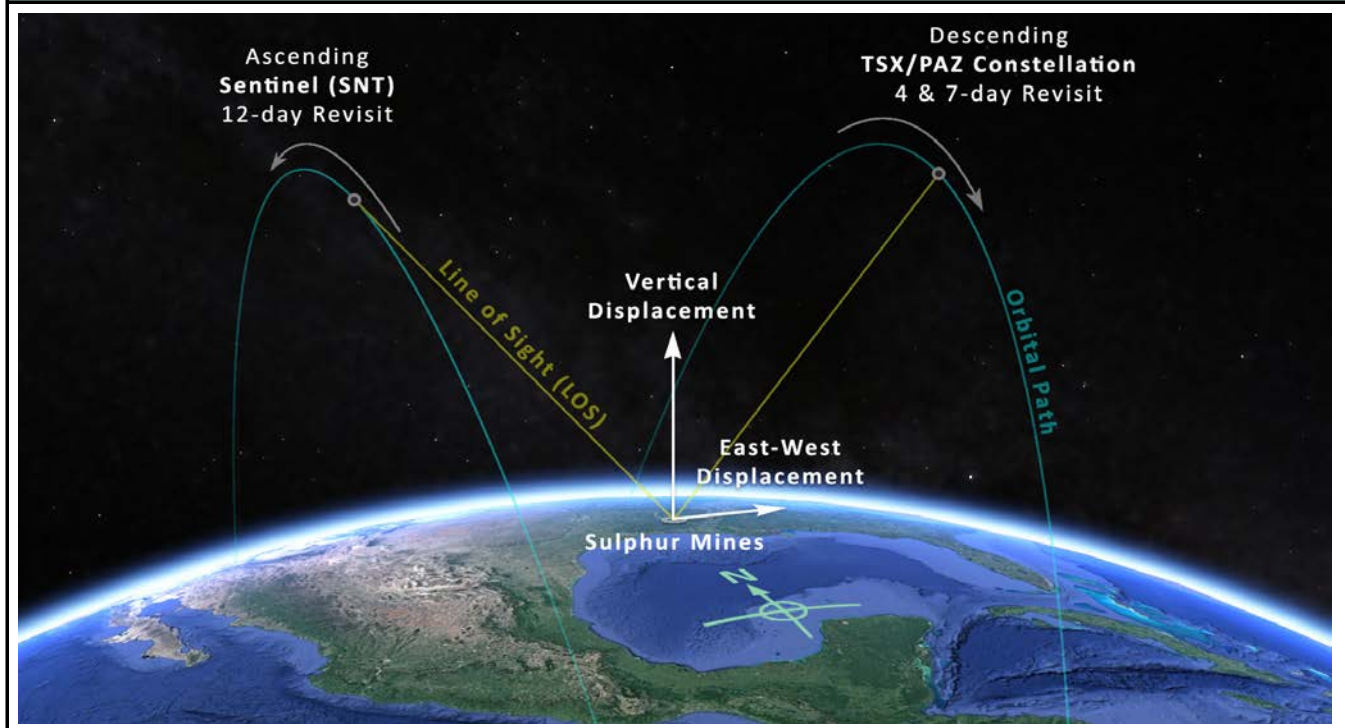
Satellite Sources

Two InSAR datasets are being used to evaluate subsidence over the Sulphur Mines Salt Dome. These datasets provide Line-of-Sight (LOS) displacement measurements from both ascending and descending orbits. An ascending orbit denotes the satellite's longitudinal course from south to north as it passes over the site, while a descending orbit denotes the satellite is moving from north to south.

The first dataset comes from a low-resolution Sentinel-1 (SNT) satellite on an ascending orbit that captures data from the west of the site on a 12-day frequency. The second comes from a pair of high resolution satellites that share the same descending orbit and capture data from east of the site. These are a TSX satellite and the PAZ satellite (TSX/PAZ constellation), both with an 11-day revisit frequency. Their orbits are offset with the PAZ satellite passing over the site 4 days after the TSX satellite.

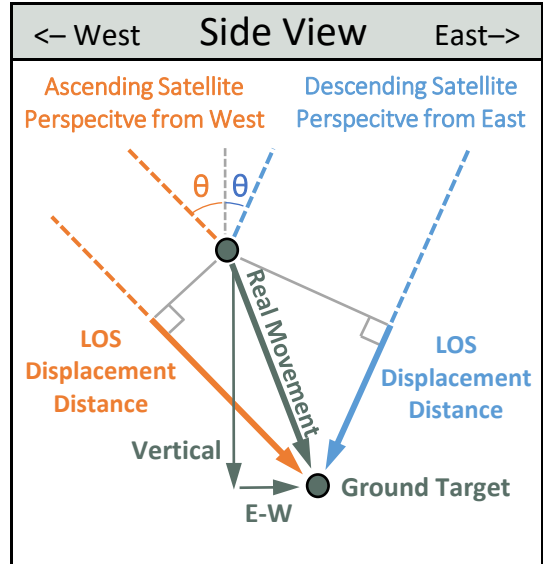
Each instance of data capture in either the SNT or TSX/PAZ constellation is used to generate 2D (two-dimensional) displacement values in the vertical and east-west directions for each measurement point within the 2D data grid. The image below depicts the orbital paths of the satellites in relation to the Sulphur Mines Salt Dome as well as the 2D components of the calculated displacement.

Satellite Orbital Diagram



InSAR 2D Vertical and East-West Data

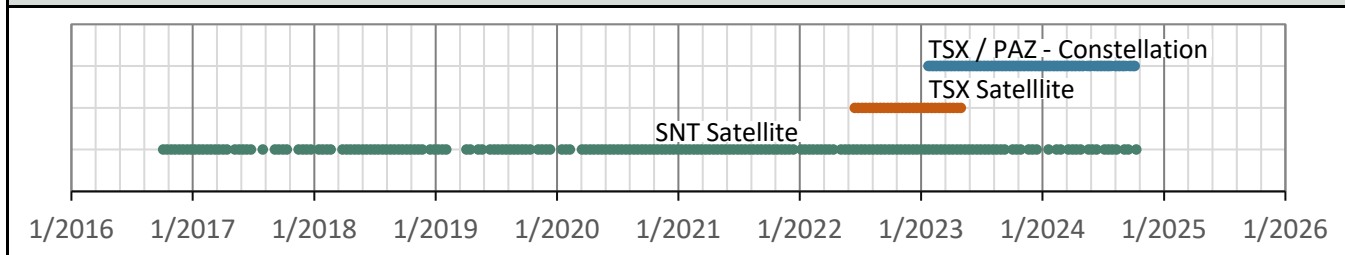
LOS (line-of-sight) displacement measurements, which refer to a change in distance between the satellite sensor and the ground target, are used to triangulate the real movement along the 2D plane defined by the satellite positions and the ground target. The diagram to the right illustrates the geometric relationship between the Real Movement of a ground target, the LOS displacement measurements from two different satellite viewing directions, and the resulting vertical and east-west components of calculated 2D displacement. Ground targets are not consistent between LOS datasets so these calculations are performed on averaged LOS data within 82-ft square cells. One 2D measurement point is generated within each cell where data from both LOS sources are present.



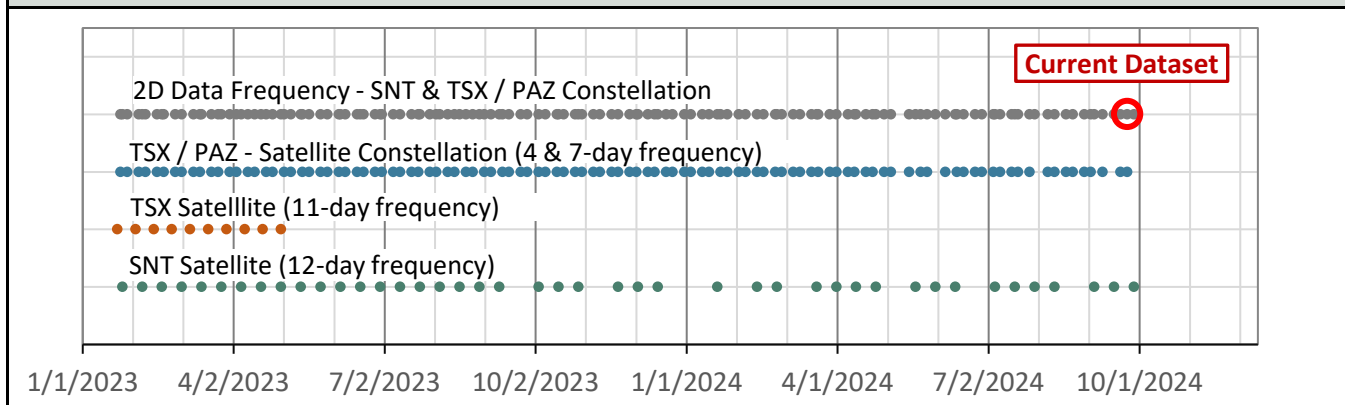
Satellite Properties & Image Frequency

Satellite and Data Properties	SNT	TSX/PAZ Constellation
Band (Wavelength)	C-band (2.20 in)	X-band (1.22 in)
Track	T136	T67 & T120
Pixel resolution	65 x 16 ft	3 x 3 ft
Revisit frequency	12 days	4 & 7 days
Orbit (LOS Angle, θ)	Ascending (43°)	Descending (37°)
Data Start Date	10/4/2016	1/24/2023
Measurement error range	± 0.20 in	± 0.03 in

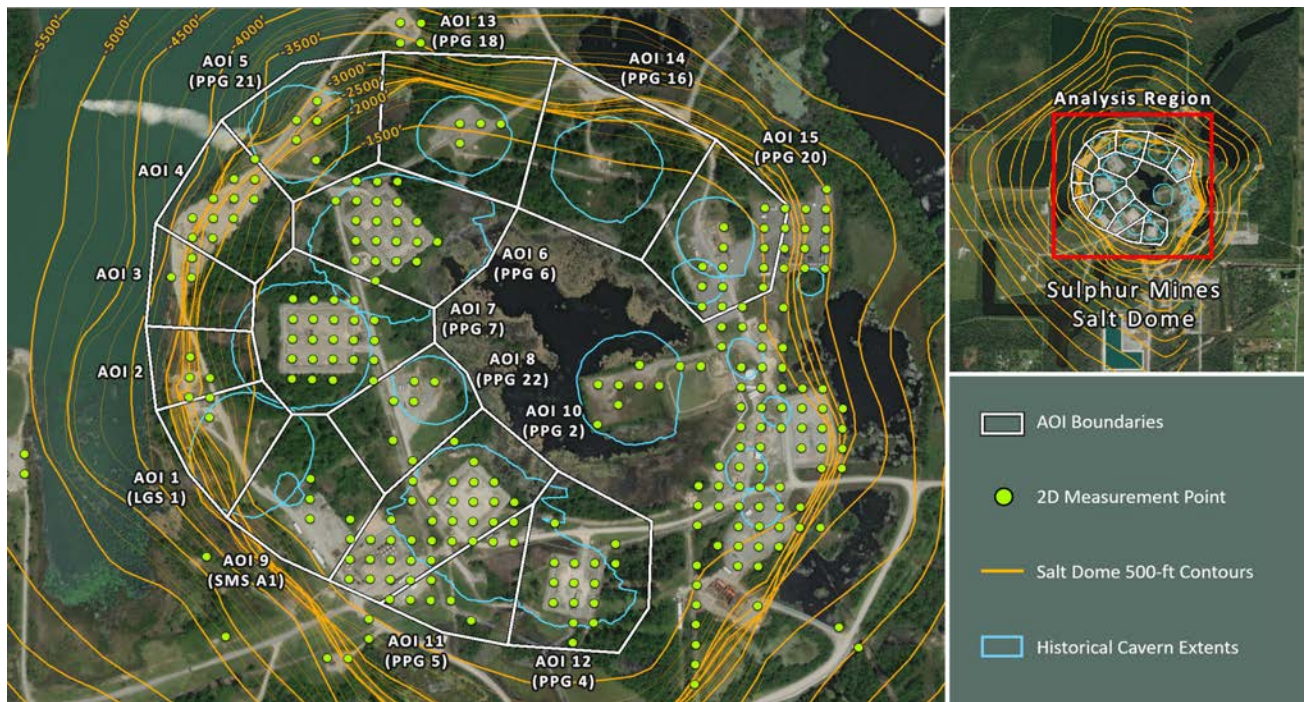
LOS Measurement History



2D Measurement Frequency



AOI Boundaries & 2D InSAR Measurement Points

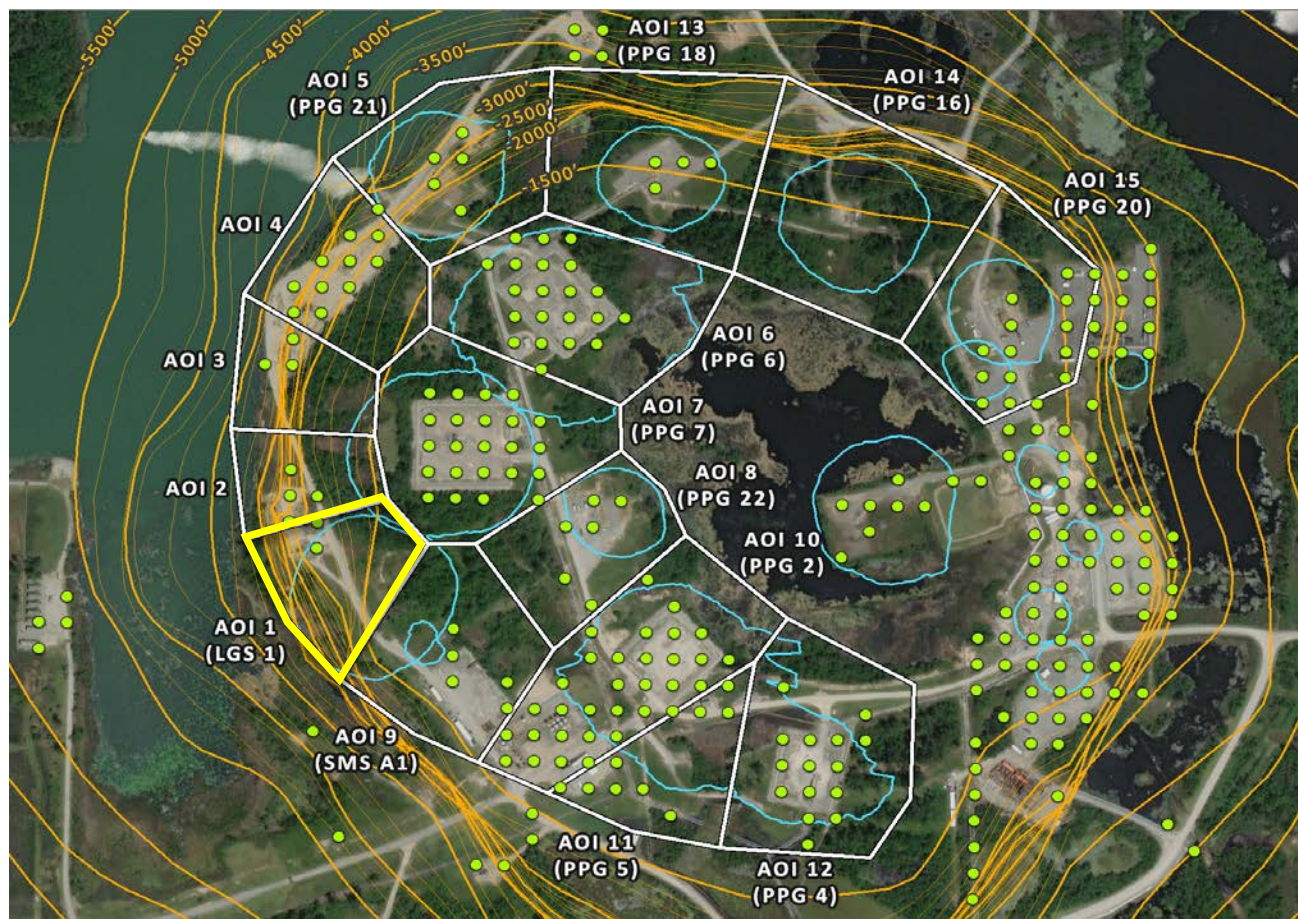


Subsidence Monitoring Areas of Interest (AOIs)

To visually convey and evaluate trend consistency for the Vertical displacement time series of each ground target, measurement points were grouped and their displacement values were averaged. The point groups are referred to as Areas of Interest (AOIs) in this analysis and their boundaries are depicted on the above map. The below table lists the Vertical trend values calculated in each AOI for the dataset evaluated in this report.

AOI Name	Vertical (9/24/2024)	Vertical Velocity (in/yr)		Vertical Acceleration (in/yr ²)	
	Point Count	Nonlinear	Linear	Nonlinear	Linear
AOI 1 (LGS 1)	2	-0.31	-0.70	+0.47	0.00
AOI 2	4	-0.41	-0.57	+0.20	0.00
AOI 3	3	-0.21	-0.62	+0.48	0.00
AOI 4	11	-0.28	-0.52	+0.28	0.00
AOI 5 (PPG 21)	5	-0.35	-0.54	+0.23	0.00
AOI 6 (PPG 6)	21	-0.83	-0.90	+0.09	0.00
AOI 7 (PPG 7)	23	-0.89	-0.98	+0.10	0.00
AOI 8 (PPG 22)	6	-1.08	-1.26	+0.21	0.00
AOI 9 (SMS A1)	5	-0.45	-0.95	+0.59	0.00
AOI 10 (PPG 2)	31	-0.96	-1.12	+0.20	0.00
AOI 11 (PPG 5)	10	-0.79	-0.96	+0.20	0.00
AOI 12 (PPG 4)	15	-0.95	-1.10	+0.18	0.00
AOI 13 (PPG 18)	3	-0.66	-0.78	+0.15	0.00
AOI 14 (PPG 16)	0	N/A	N/A	N/A	N/A
AOI 15 (PPG 20)	14	-0.75	-0.93	+0.21	0.00

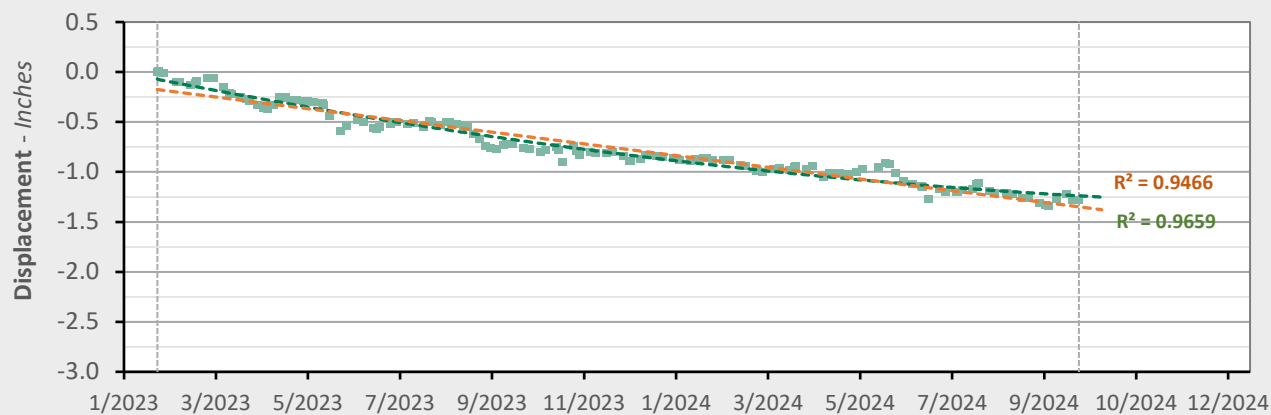
AOI 1 (LGS 1) - Location Map



AOI 1 (LGS 1) - Vertical Time Series

Vertical (9/24/2024) Point Count:

2



Nonlinear Trend

Linear Trend

Velocity: -0.31 in/yr

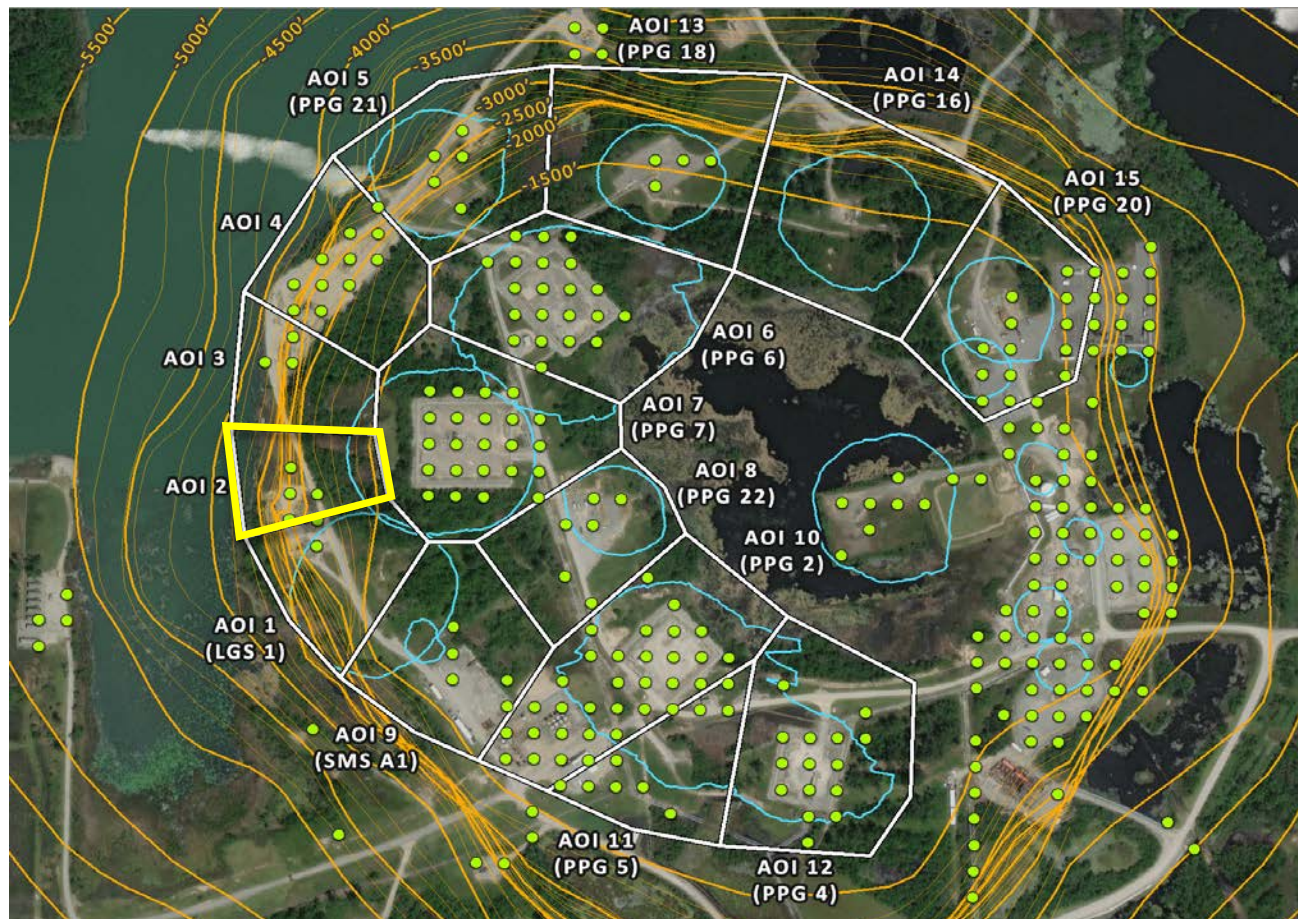
-0.70 in/yr

Acceleration: +0.47 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

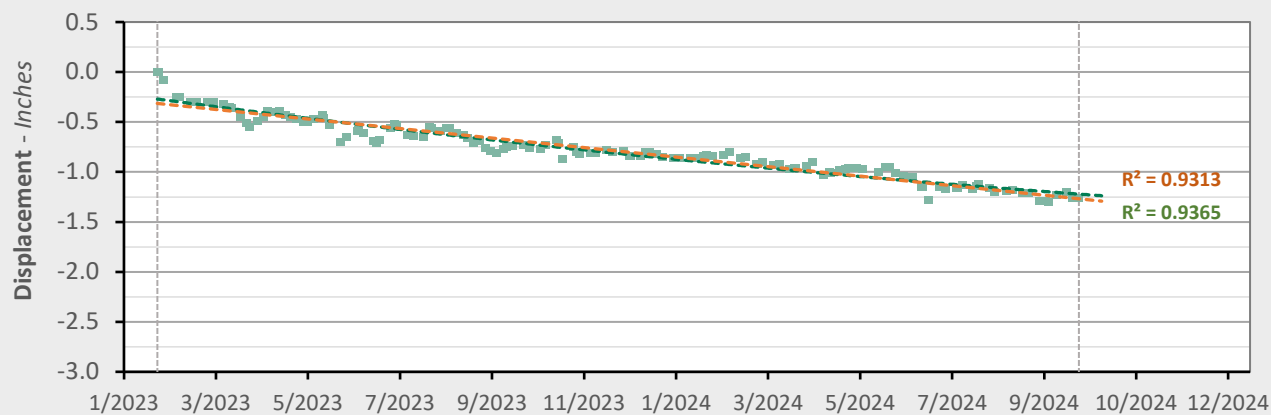
AOI 2 - Location Map



AOI 2 - Vertical Time Series

Vertical (9/24/2024) Point Count:

4



Nonlinear Trend

Linear Trend

Velocity: -0.41 in/yr

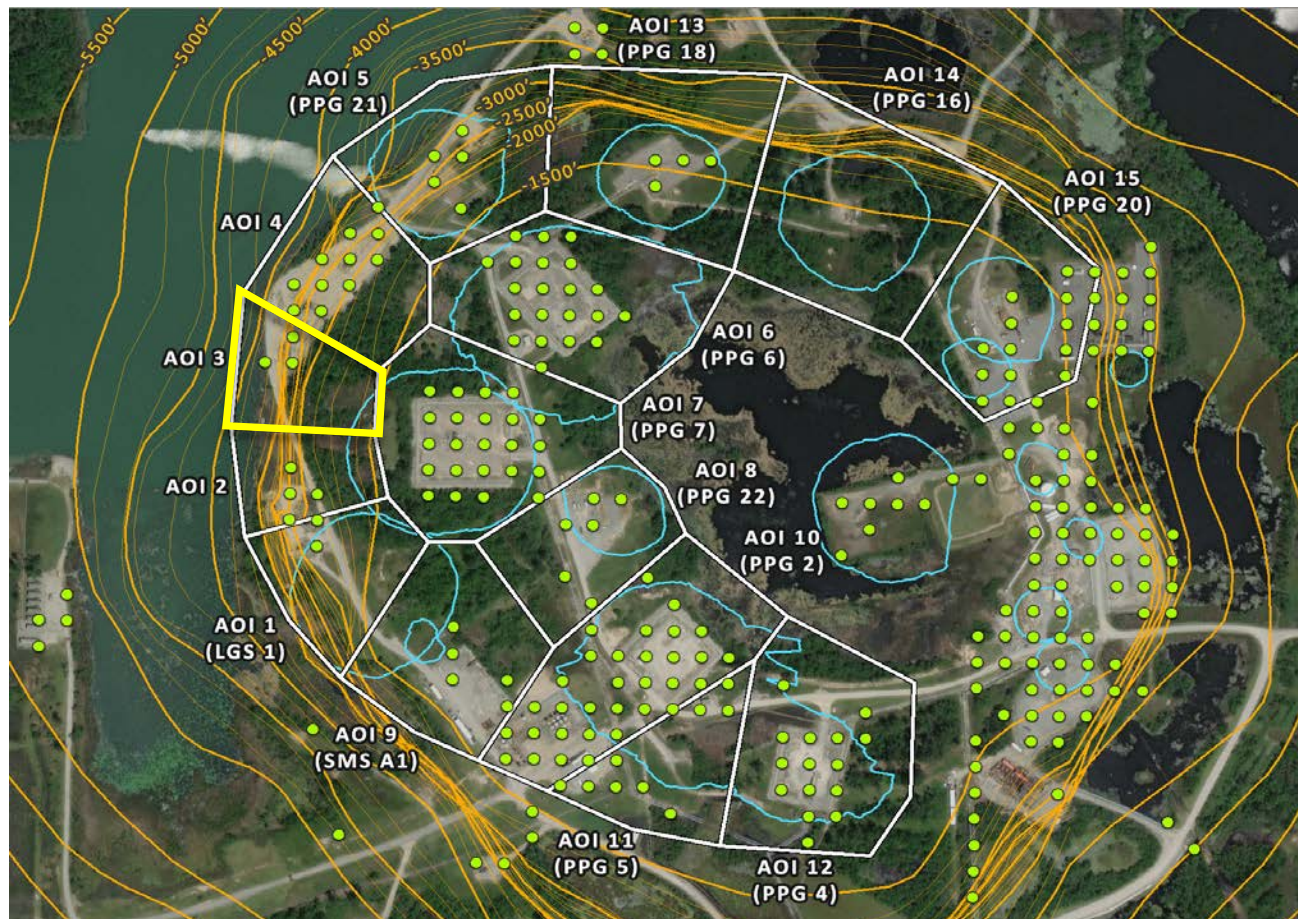
-0.57 in/yr

Acceleration: +0.20 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

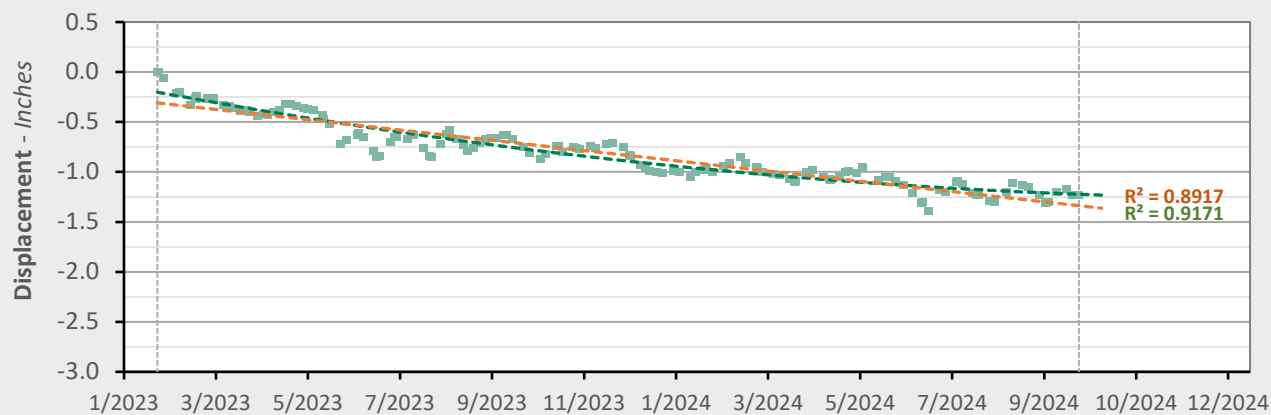
AOI 3 - Location Map



AOI 3 - Vertical Time Series

Vertical (9/24/2024) Point Count:

3



Nonlinear Trend

Linear Trend

Velocity: -0.21 in/yr

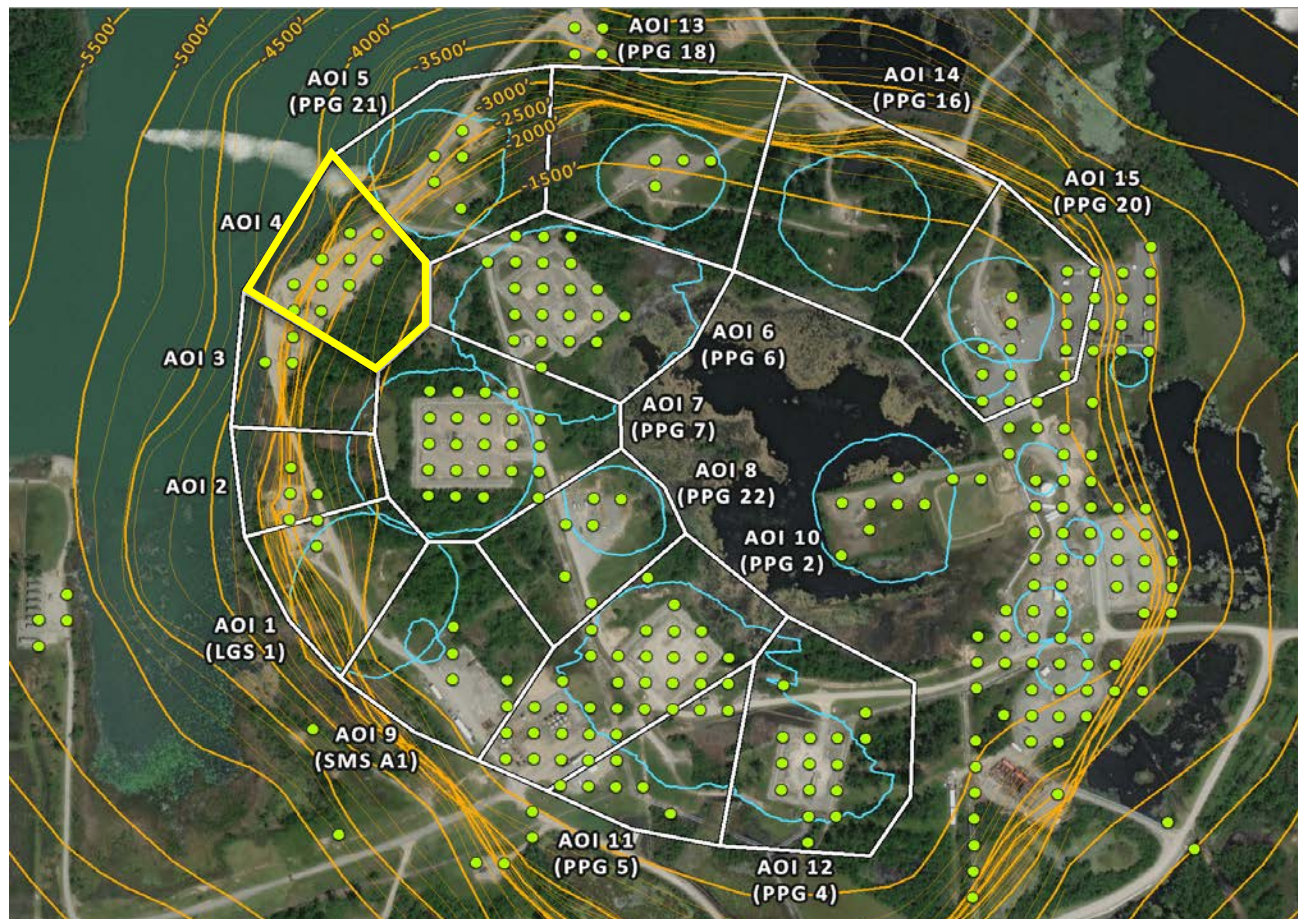
-0.62 in/yr

Acceleration: +0.48 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

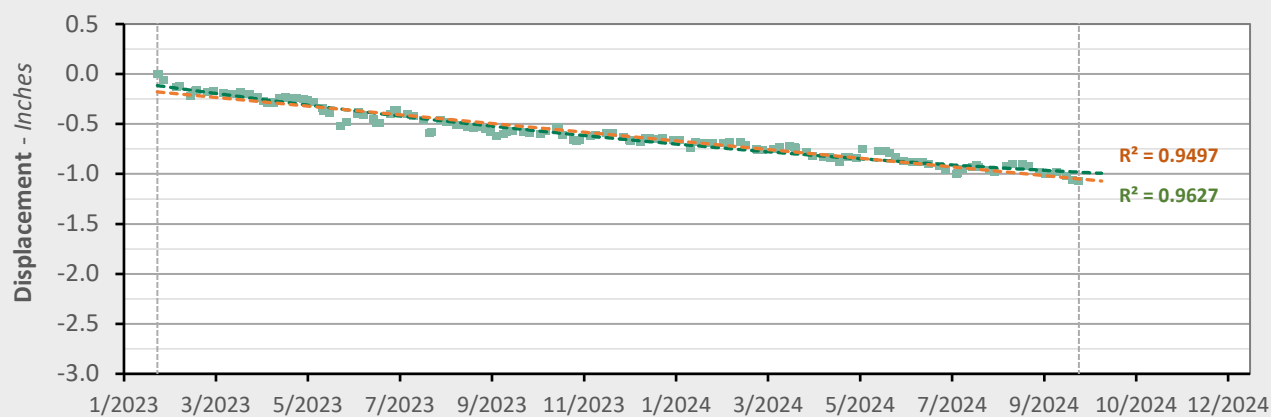
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 4 - Location Map



AOI 4 - Vertical Time Series

Vertical (9/24/2024) Point Count: 11



Nonlinear Trend

Linear Trend

Velocity: -0.28 in/yr

-0.52 in/yr

Acceleration: +0.28 in/yr²0.00 in/yr²

2D Displacement Measurement

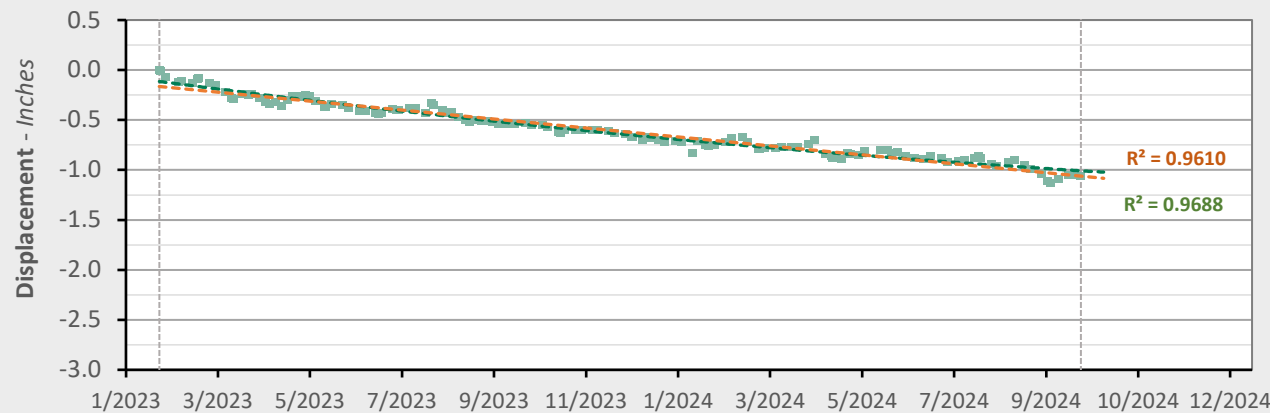
Nonlinear Trend Line
(Quadratic Regression)Linear Trend Line
(Linear Regression)

AOI 5 (PPG 21) - Location Map

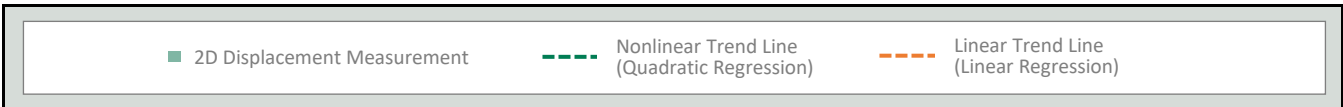


AOI 5 (PPG 21) - Vertical Time Series

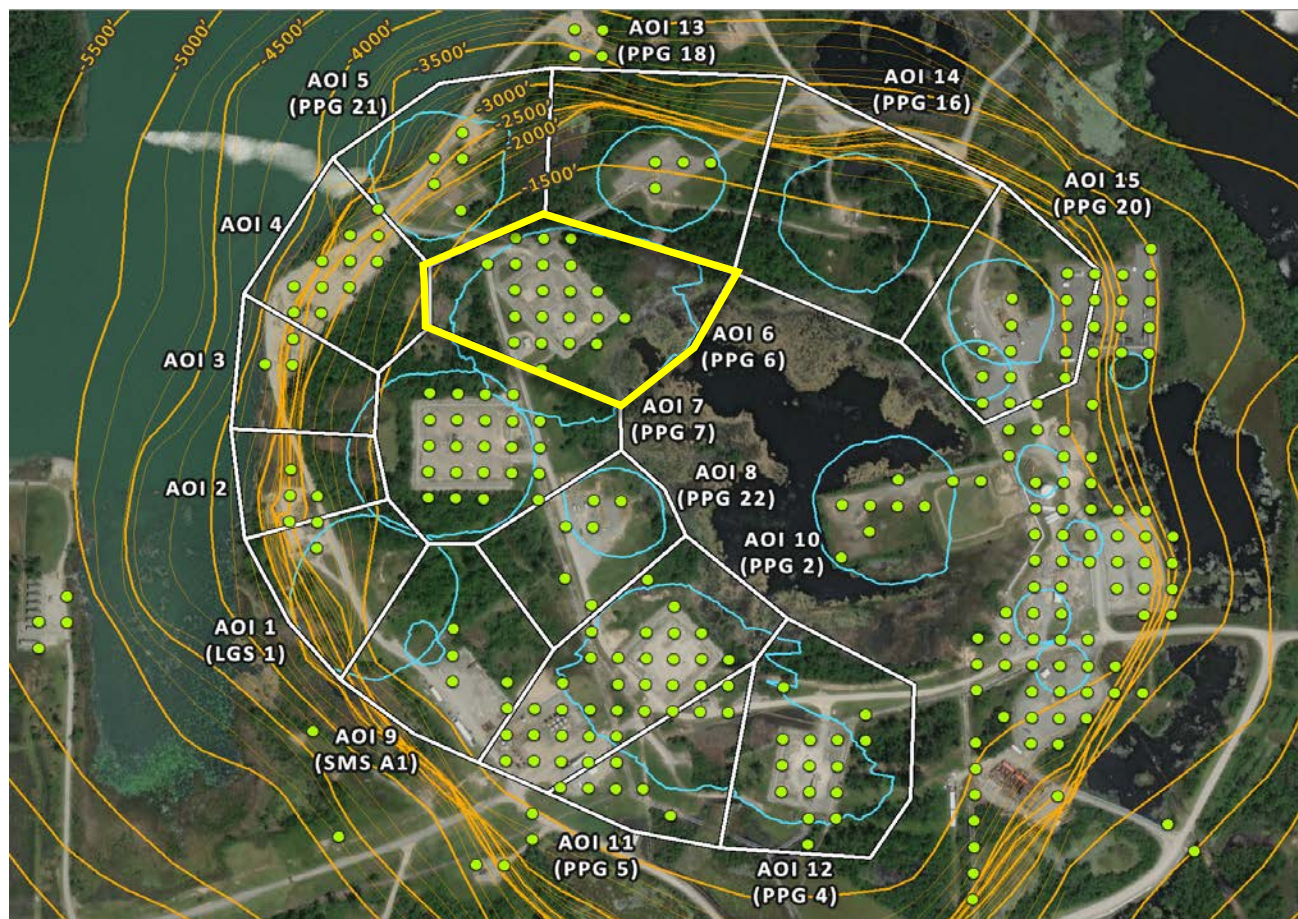
Vertical (9/24/2024) Point Count: 5



	Nonlinear Trend	Linear Trend
Velocity:	-0.35 in/yr	-0.54 in/yr
Acceleration:	+0.23 in/yr ²	0.00 in/yr ²

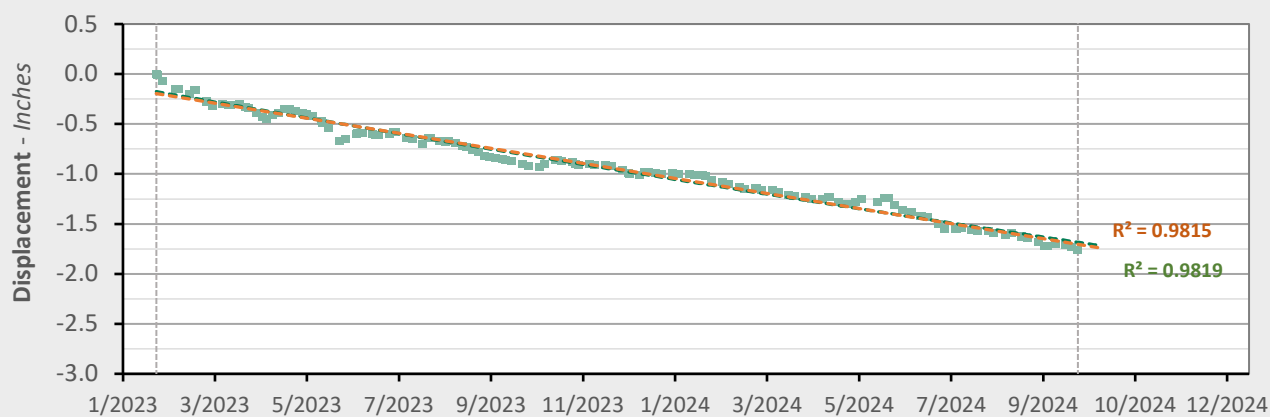


AOI 6 (PPG 6) - Location Map



AOI 6 (PPG 6) - Vertical Time Series

Vertical (9/24/2024) Point Count: 21



Nonlinear Trend

Linear Trend

Velocity: -0.83 in/yr

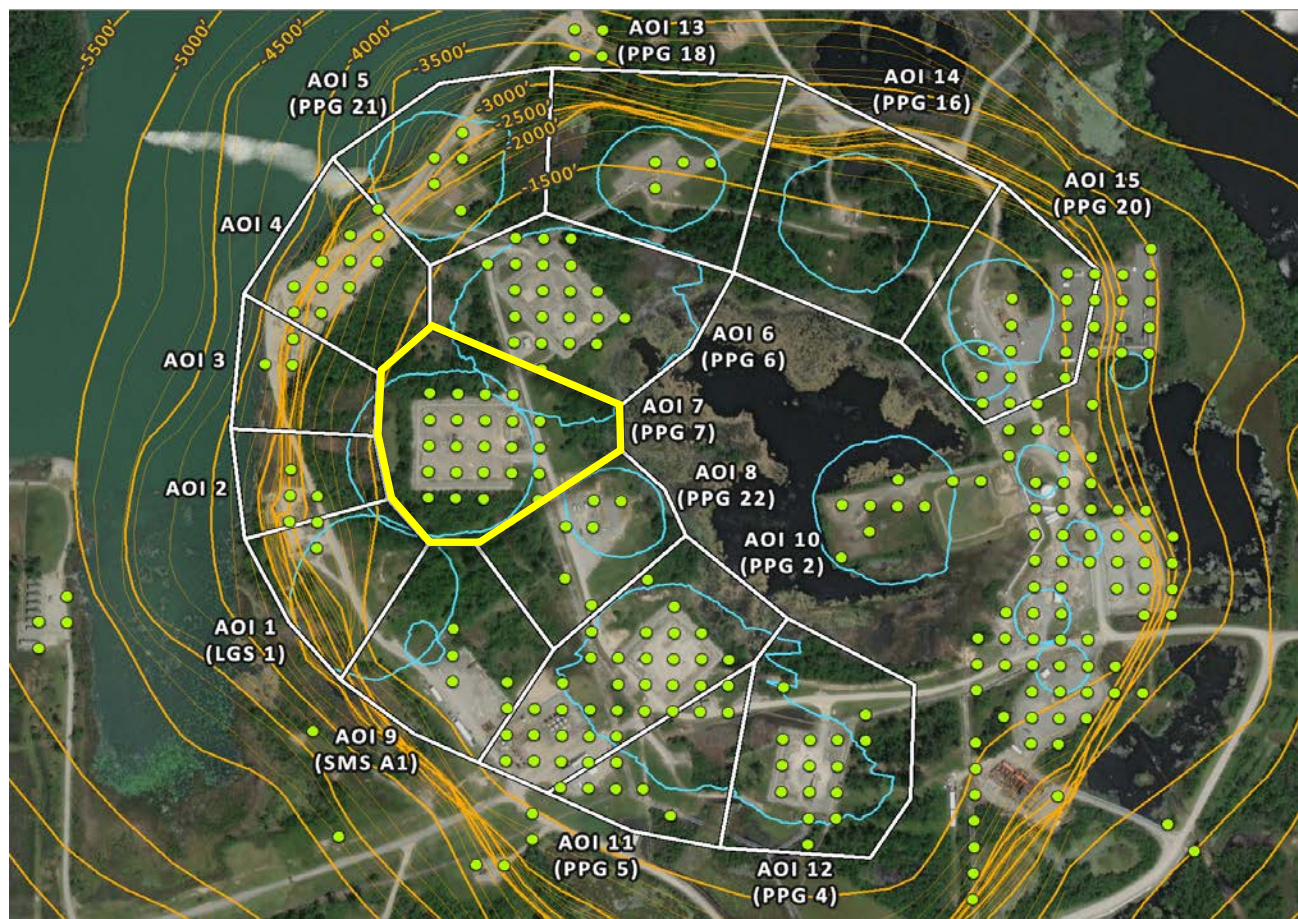
-0.90 in/yr

Acceleration: +0.09 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

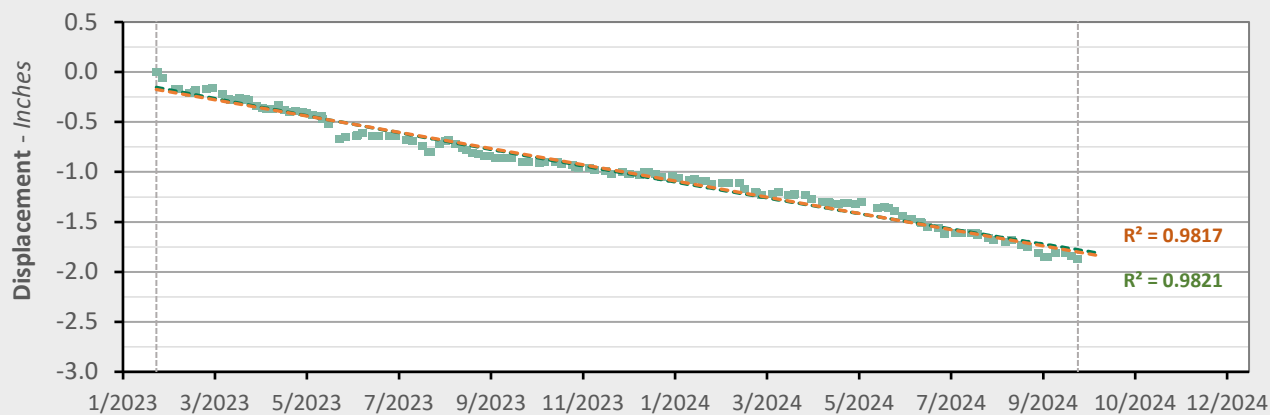
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 7 (PPG 7) - Location Map



AOI 7 (PPG 7) - Vertical Time Series

Vertical (9/24/2024) Point Count: 23



Nonlinear Trend

Linear Trend

Velocity: -0.89 in/yr

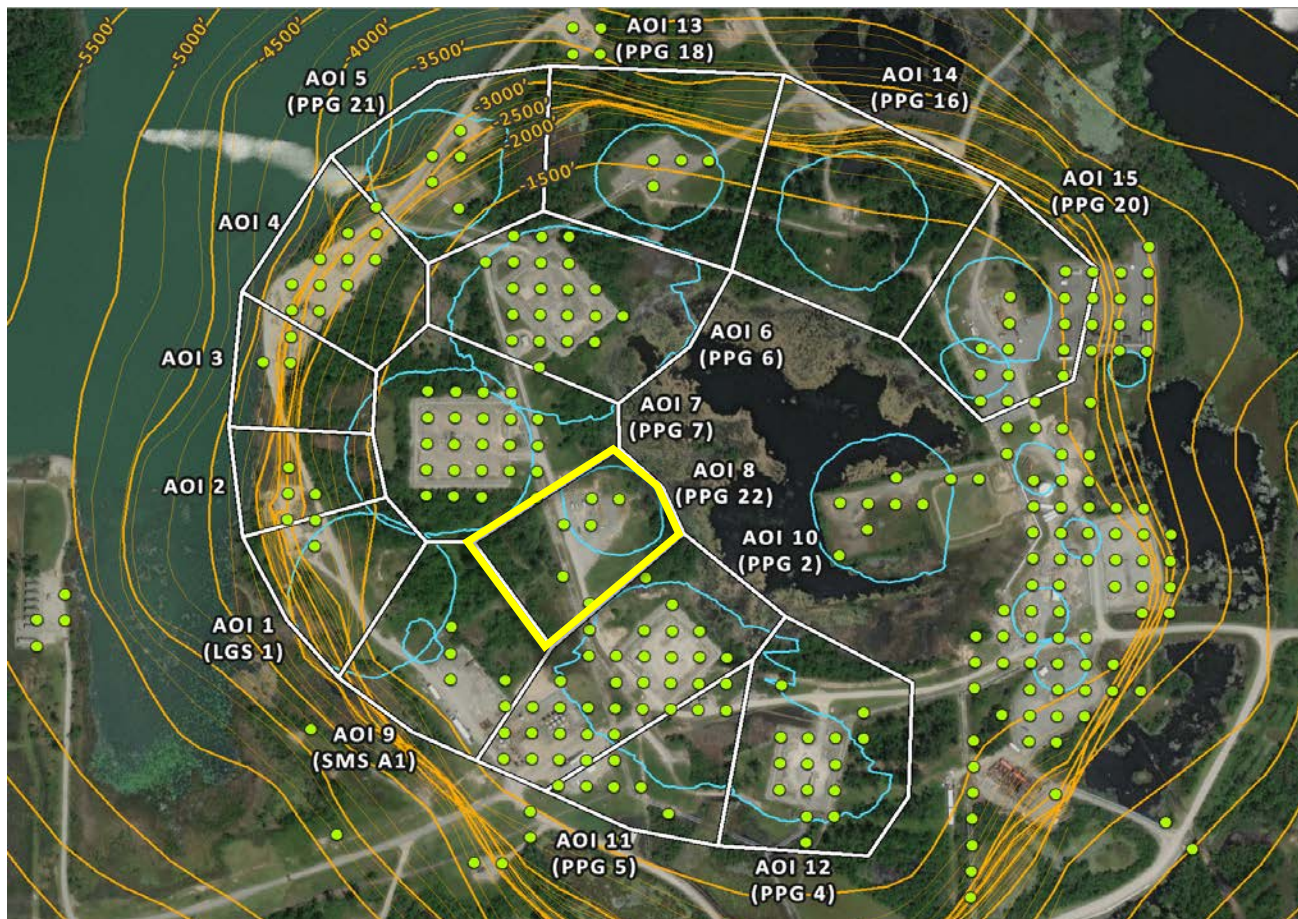
-0.98 in/yr

Acceleration: +0.10 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

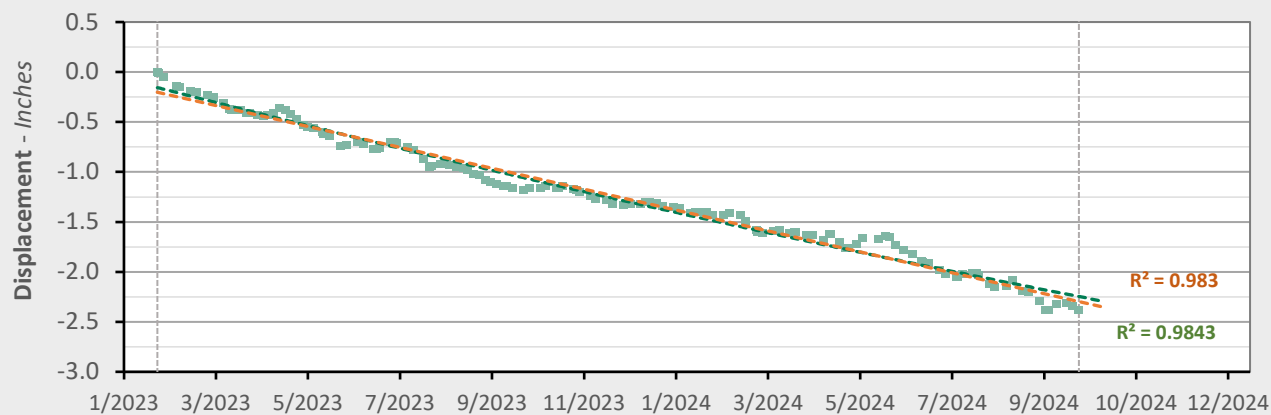
AOI 8 (PPG 22) - Location Map



AOI 8 (PPG 22) - Vertical Time Series

Vertical (9/24/2024) Point Count:

6



Nonlinear Trend

Linear Trend

Velocity: -1.08 in/yr

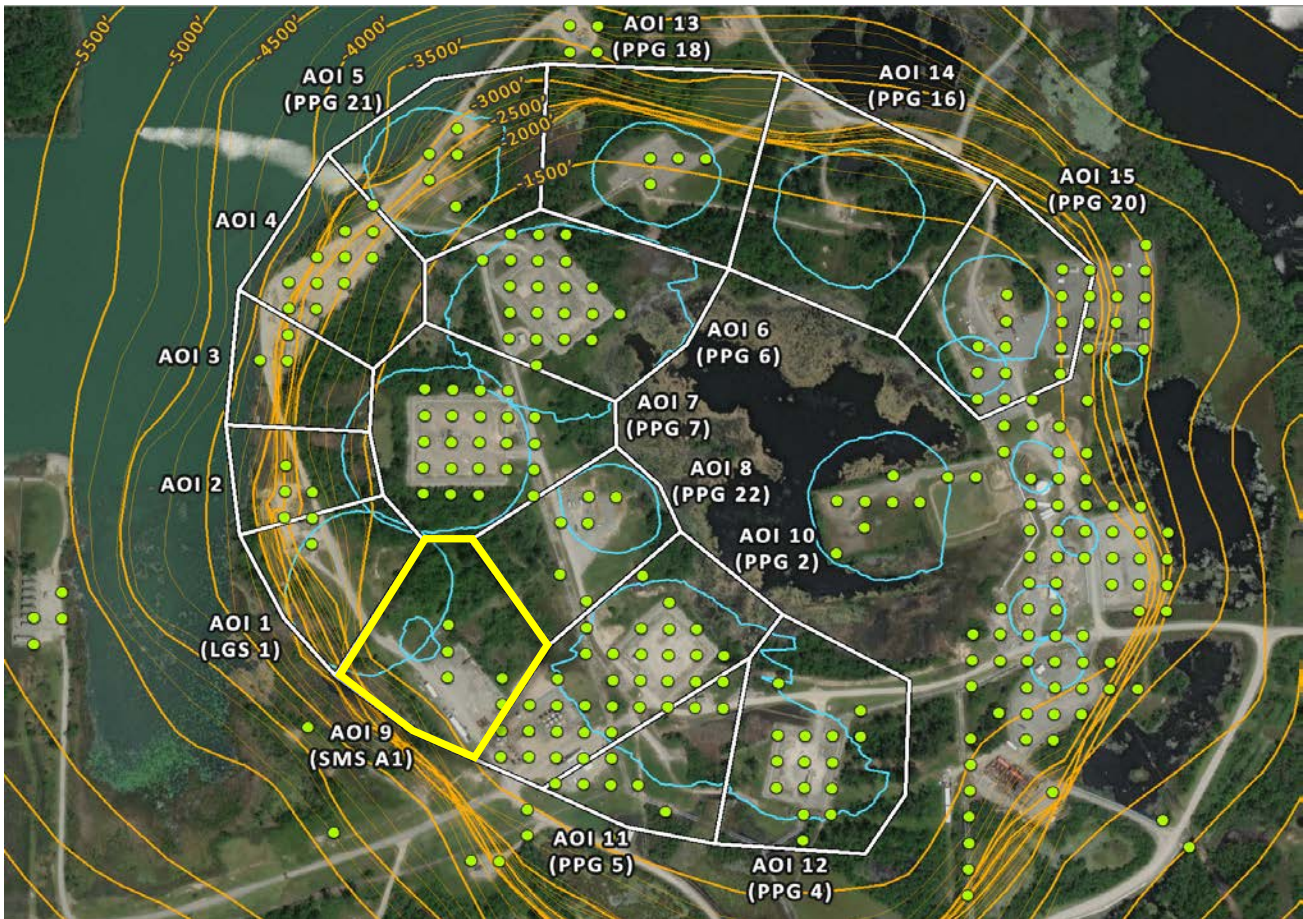
-1.26 in/yr

Acceleration: +0.21 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

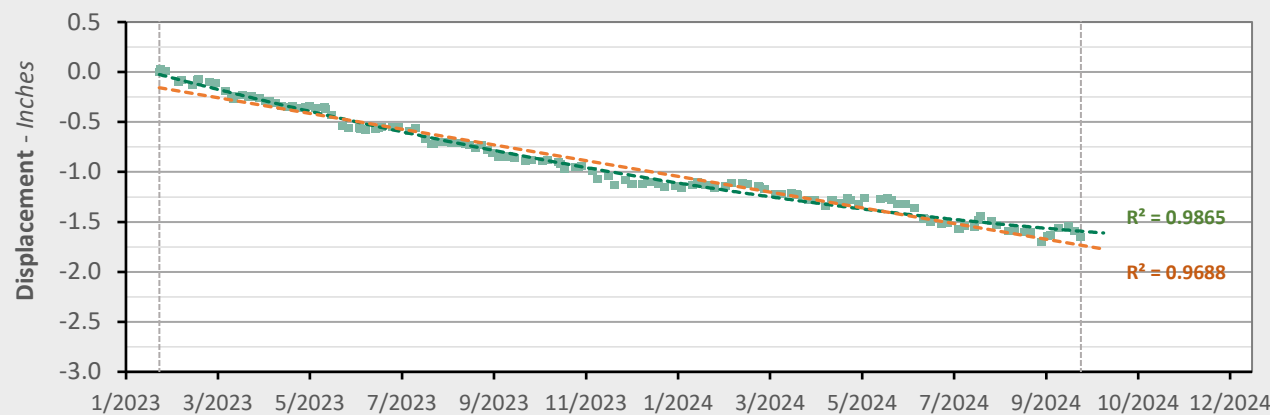
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 9 (PPG A1) - Location Map



AOI 9 (SMS A1) - Vertical Time Series

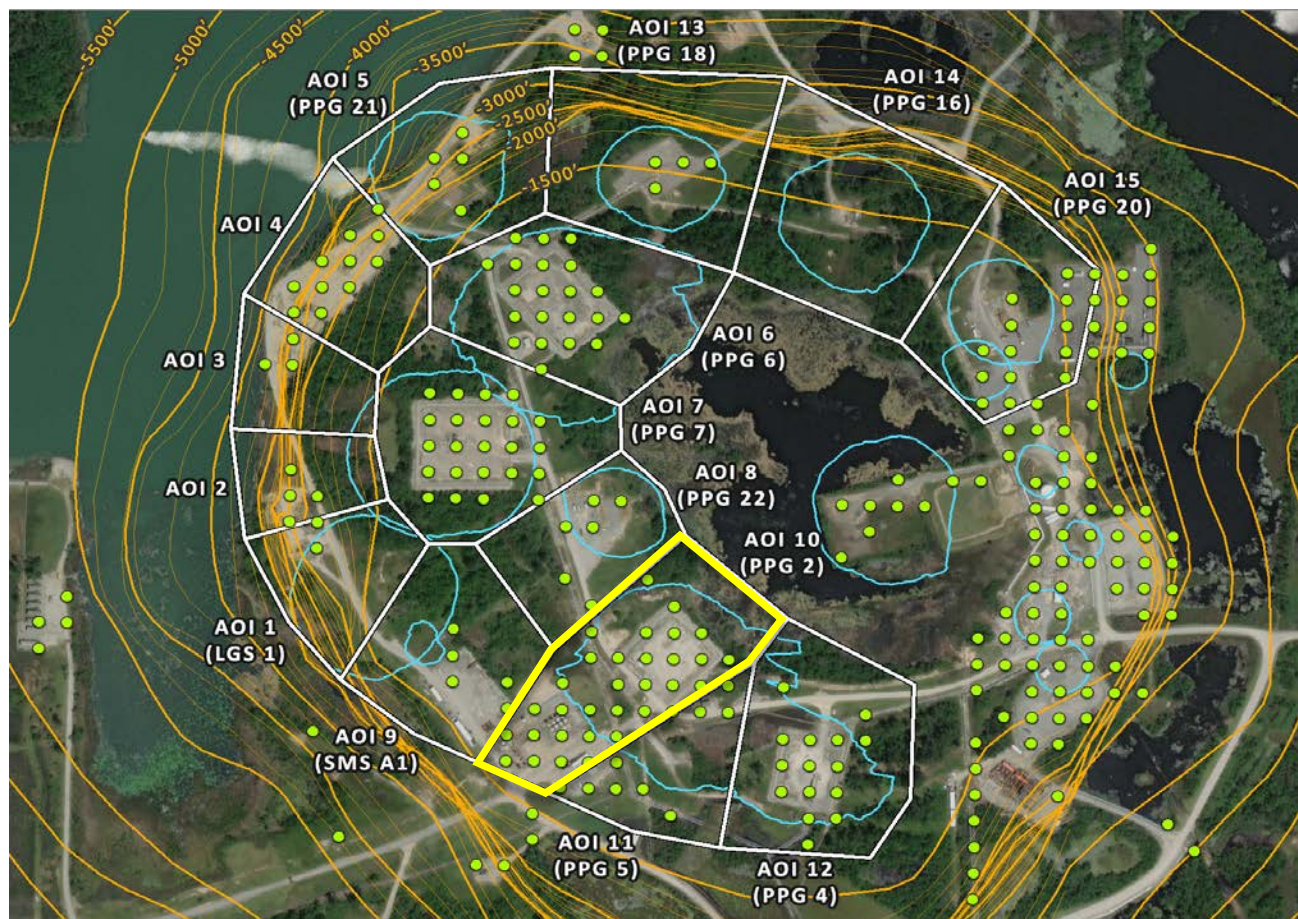
Vertical (9/24/2024) Point Count: 5



	Nonlinear Trend	Linear Trend
Velocity:	-0.45 in/yr	-0.95 in/yr
Acceleration:	+0.59 in/yr ²	0.00 in/yr ²

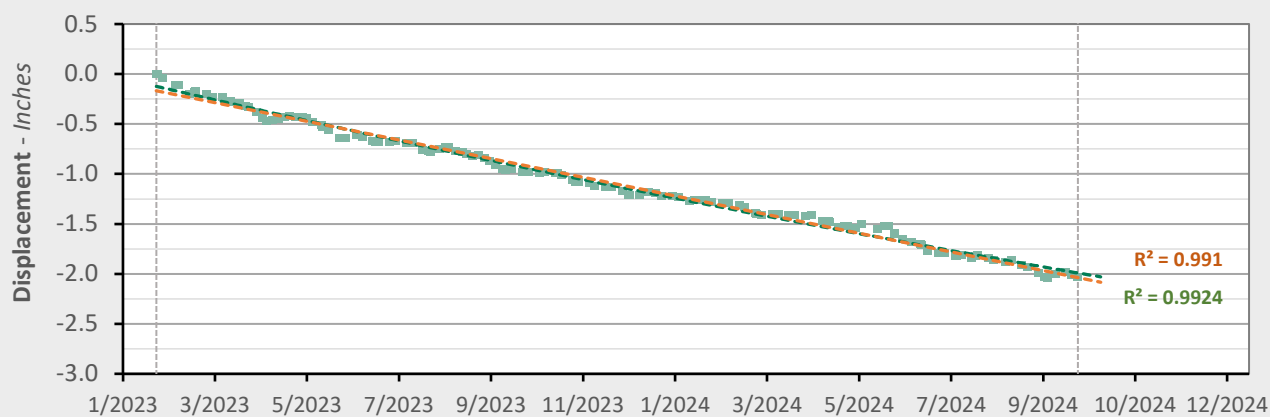
■ 2D Displacement Measurement - - - Nonlinear Trend Line (Quadratic Regression) - - - Linear Trend Line (Linear Regression)

AOI 10 (PPG 2) - Location Map



AOI 10 (PPG 2) - Vertical Time Series

Vertical (9/24/2024) Point Count: 31



Nonlinear Trend

Linear Trend

Velocity: -0.96 in/yr

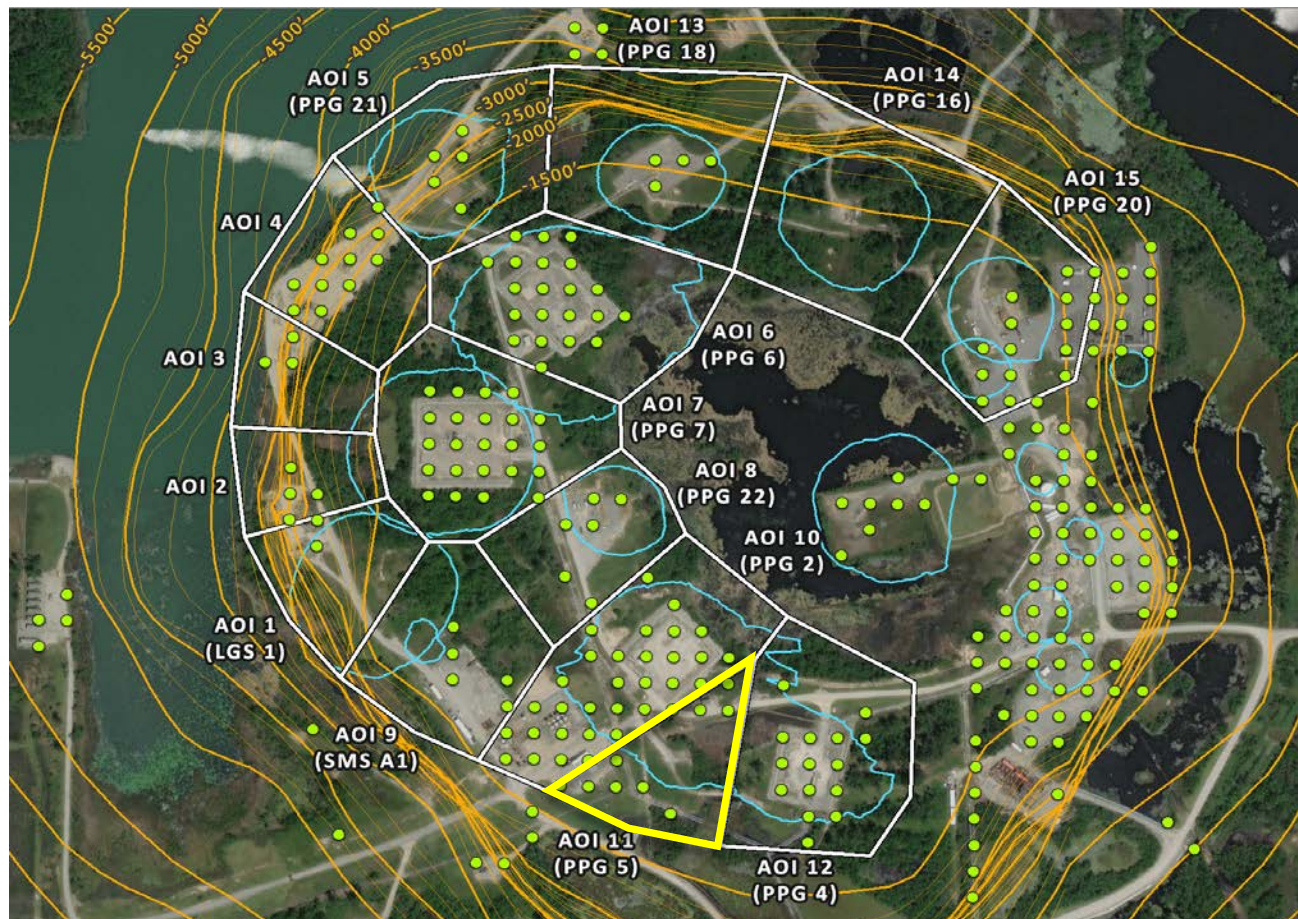
-1.12 in/yr

Acceleration: +0.20 in/yr²0.00 in/yr²

2D Displacement Measurement

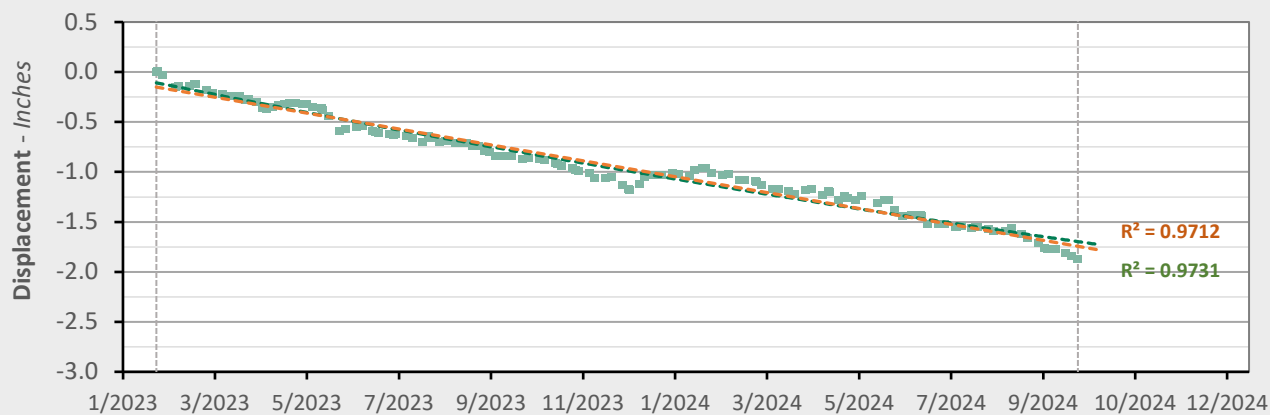
Nonlinear Trend Line
(Quadratic Regression)Linear Trend Line
(Linear Regression)

AOI 11 (PPG 5) - Location Map



AOI 11 (PPG 5) - Vertical Time Series

Vertical (9/24/2024) Point Count: 10



Nonlinear Trend

Linear Trend

Velocity: -0.79 in/yr

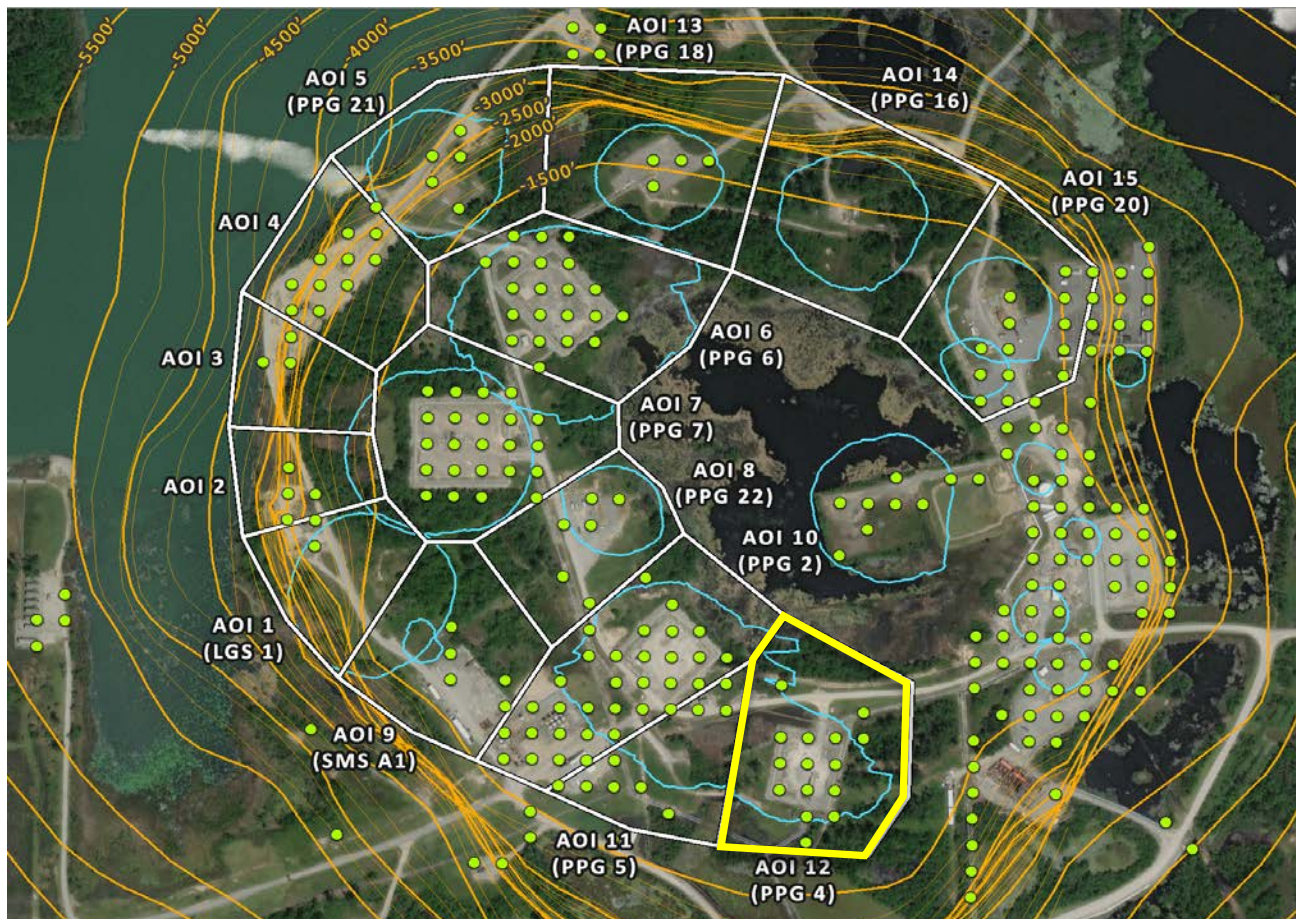
-0.96 in/yr

Acceleration: +0.20 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

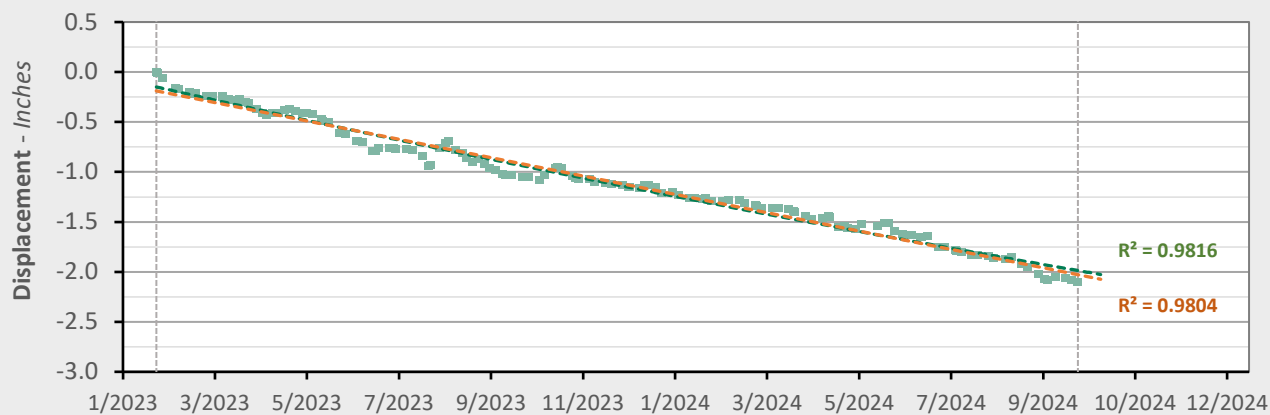
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 12 (PPG 4) - Location Map



AOI 12 (PPG 4) - Vertical Time Series

Vertical (9/24/2024) Point Count: 15



Nonlinear Trend

Linear Trend

Velocity: -0.95 in/yr

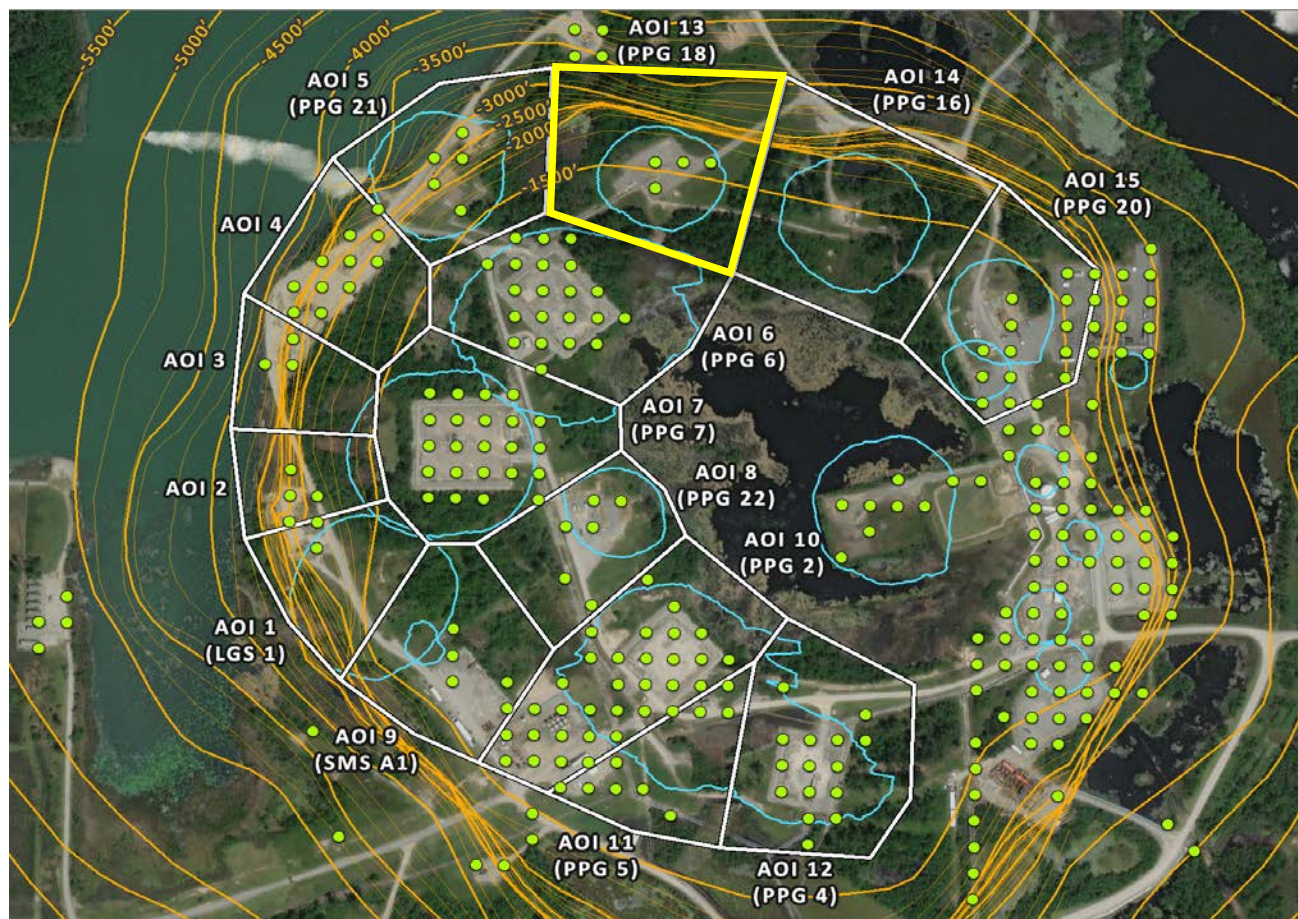
-1.10 in/yr

Acceleration: +0.18 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

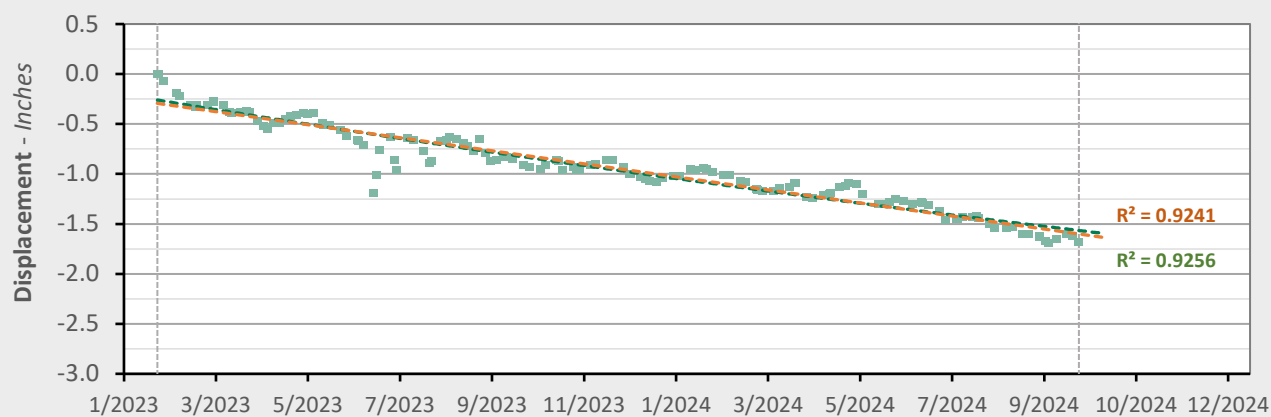
AOI 13 (PPG 18) - Location Map



AOI 13 (PPG 18) - Vertical Time Series

Vertical (9/24/2024) Point Count:

3



Nonlinear Trend

Linear Trend

Velocity: -0.66 in/yr

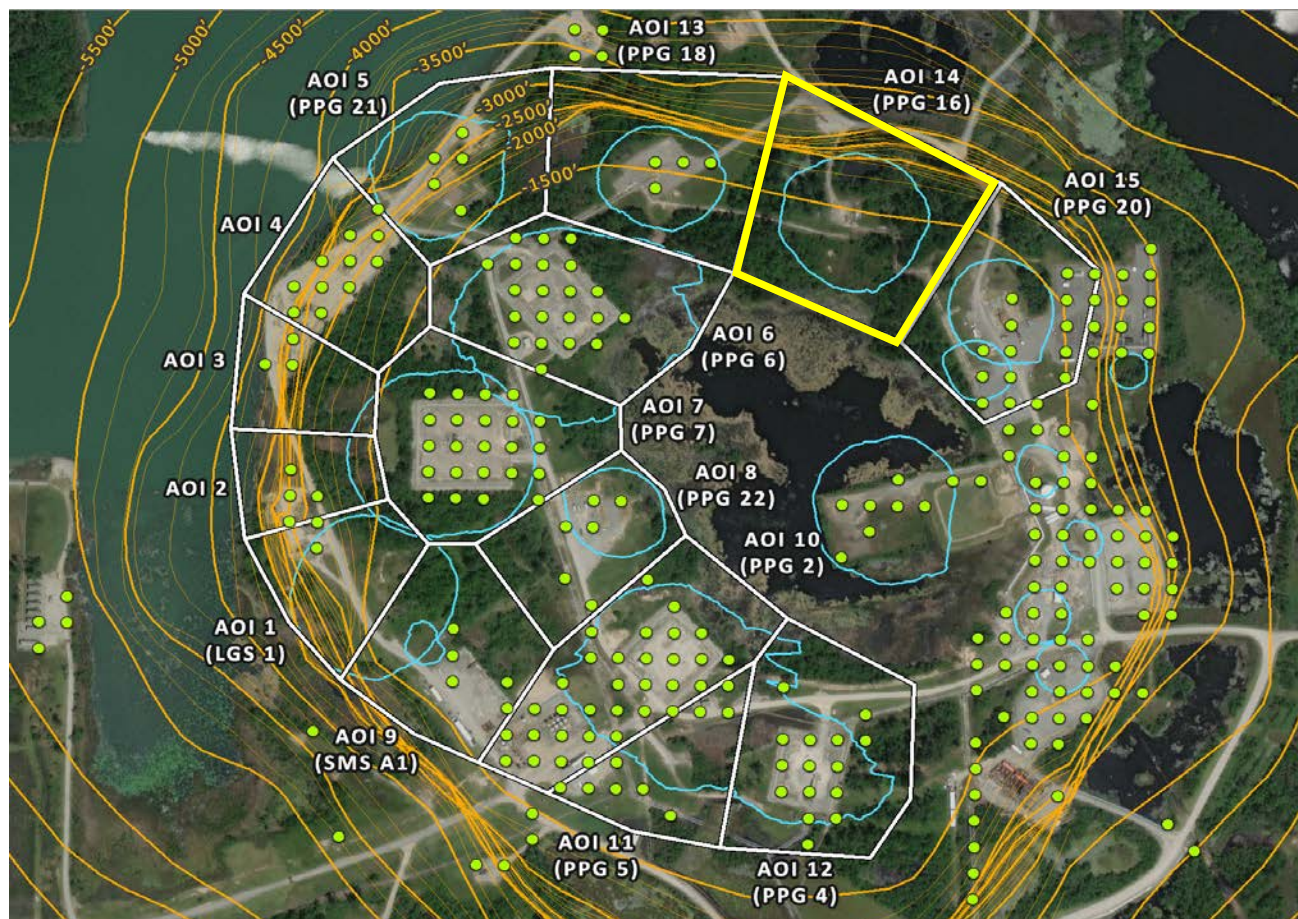
-0.78 in/yr

Acceleration: +0.15 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

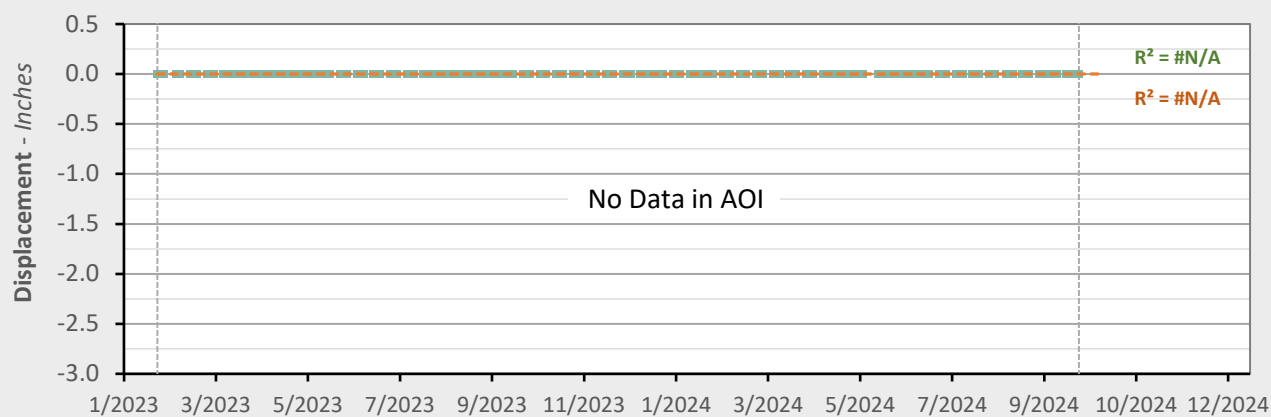
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 14 (PPG 16) - Location Map



AOI 14 (PPG 16) - Vertical Time Series

Vertical (9/24/2024) Point Count: 0



Nonlinear Trend

Linear Trend

Velocity: N/A
Acceleration: N/A

in/yr
in/yr²

N/A
N/A

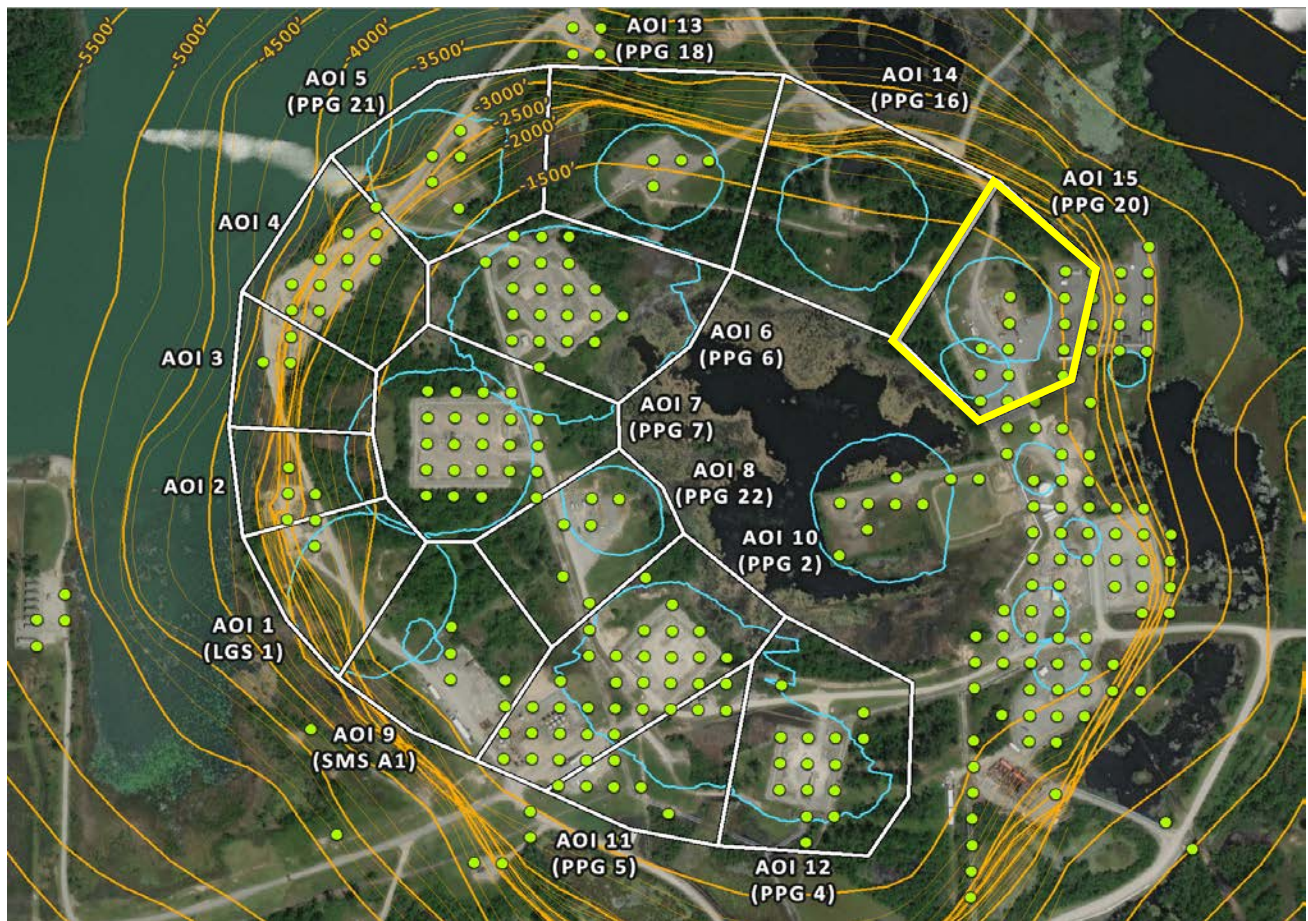
in/yr
in/yr²

2D Displacement Measurement

Nonlinear Trend Line
(Quadratic Regression)

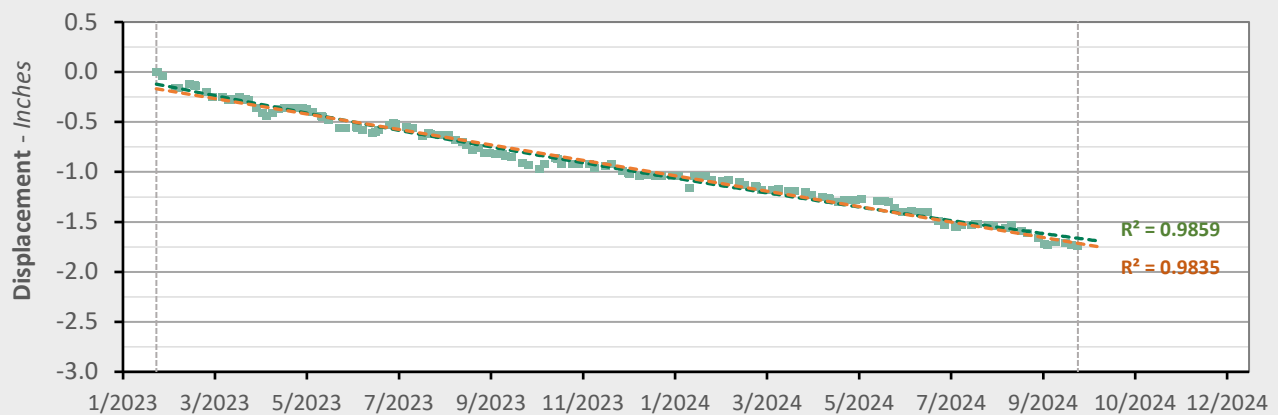
Linear Trend Line
(Linear Regression)

AOI 15 (PPG 20) - Location Map



AOI 15 (PPG 20) - Vertical Time Series

Vertical (9/24/2024) Point Count: 14



Nonlinear Trend

Linear Trend

Velocity: -0.75 in/yr

-0.93 in/yr

Acceleration: +0.21 in/yr²0.00 in/yr²

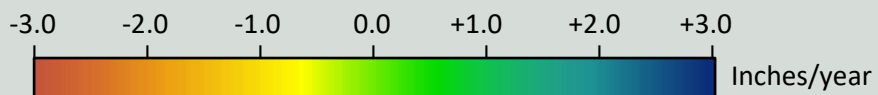
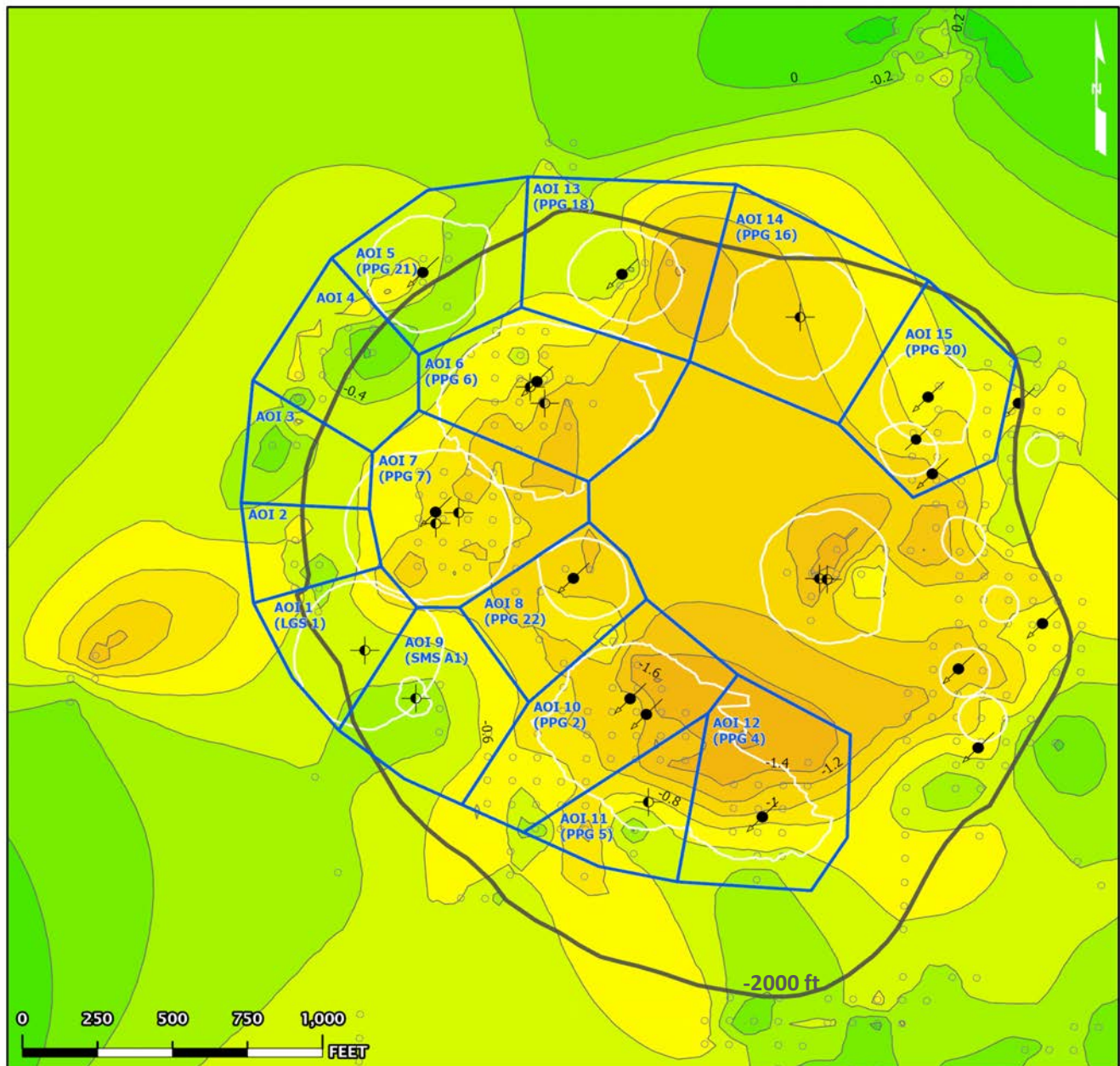
■ 2D Displacement Measurement

--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

Vertical Data (01/24/2023 - 09/24/2024)

Nonlinear Velocity Contours

As of date: 09/24/2024

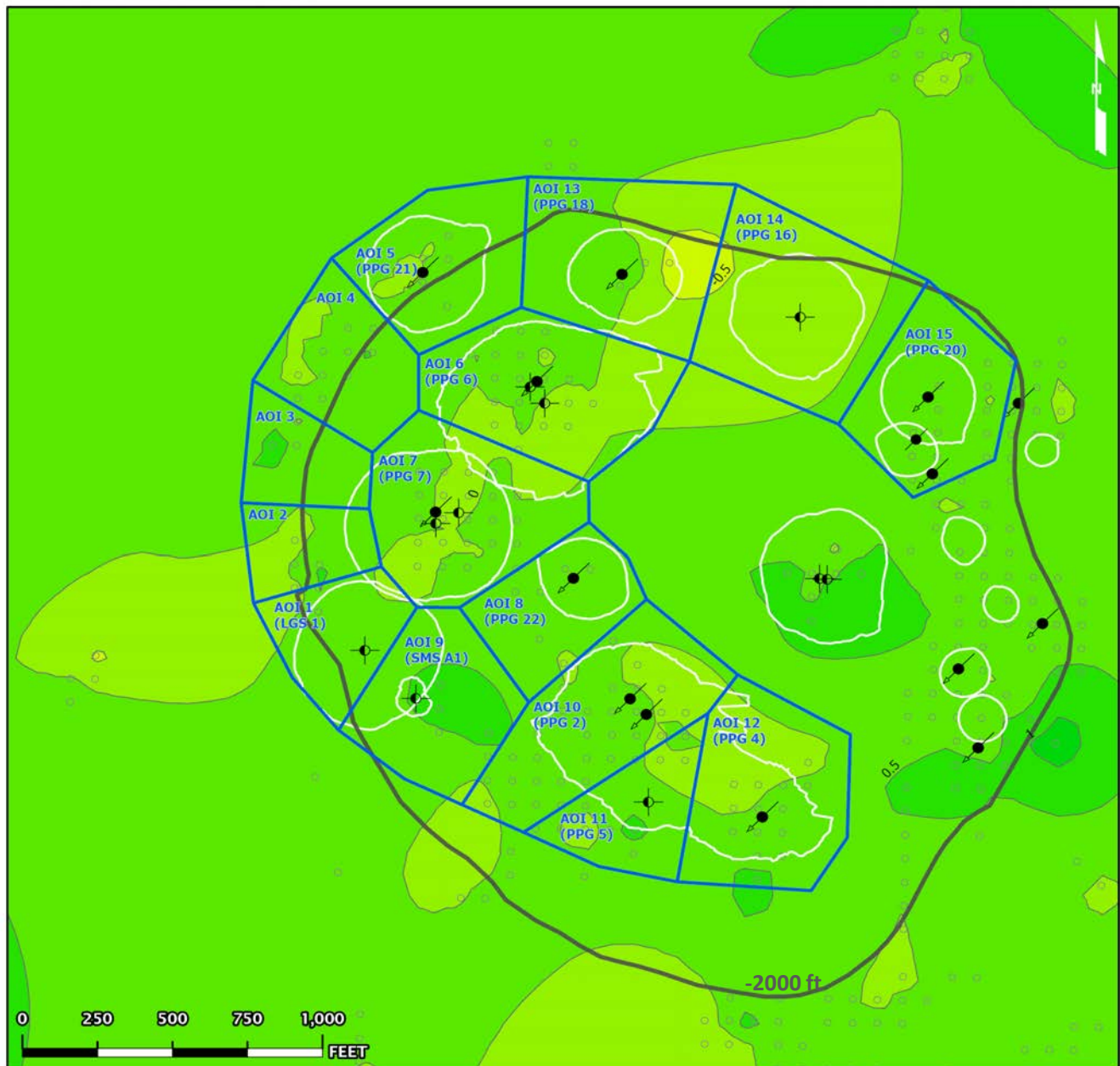


- Legend:
- AOI Boundary
 - InSAR LOS Measurement Point
 - Contour (0.2)
 - Historical Cavern Extent
 - Top of Dome (-2000 ft Contour)
 - Cavern Well Surface Locations
 - 09 - Active - Injection
 - 29 - Dry and Plugged

Vertical Data (01/24/2023 - 09/24/2024)

Nonlinear Acceleration Contours

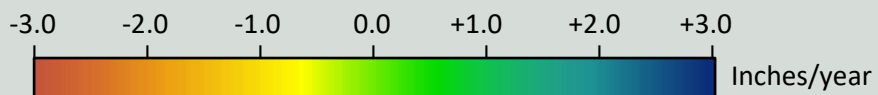
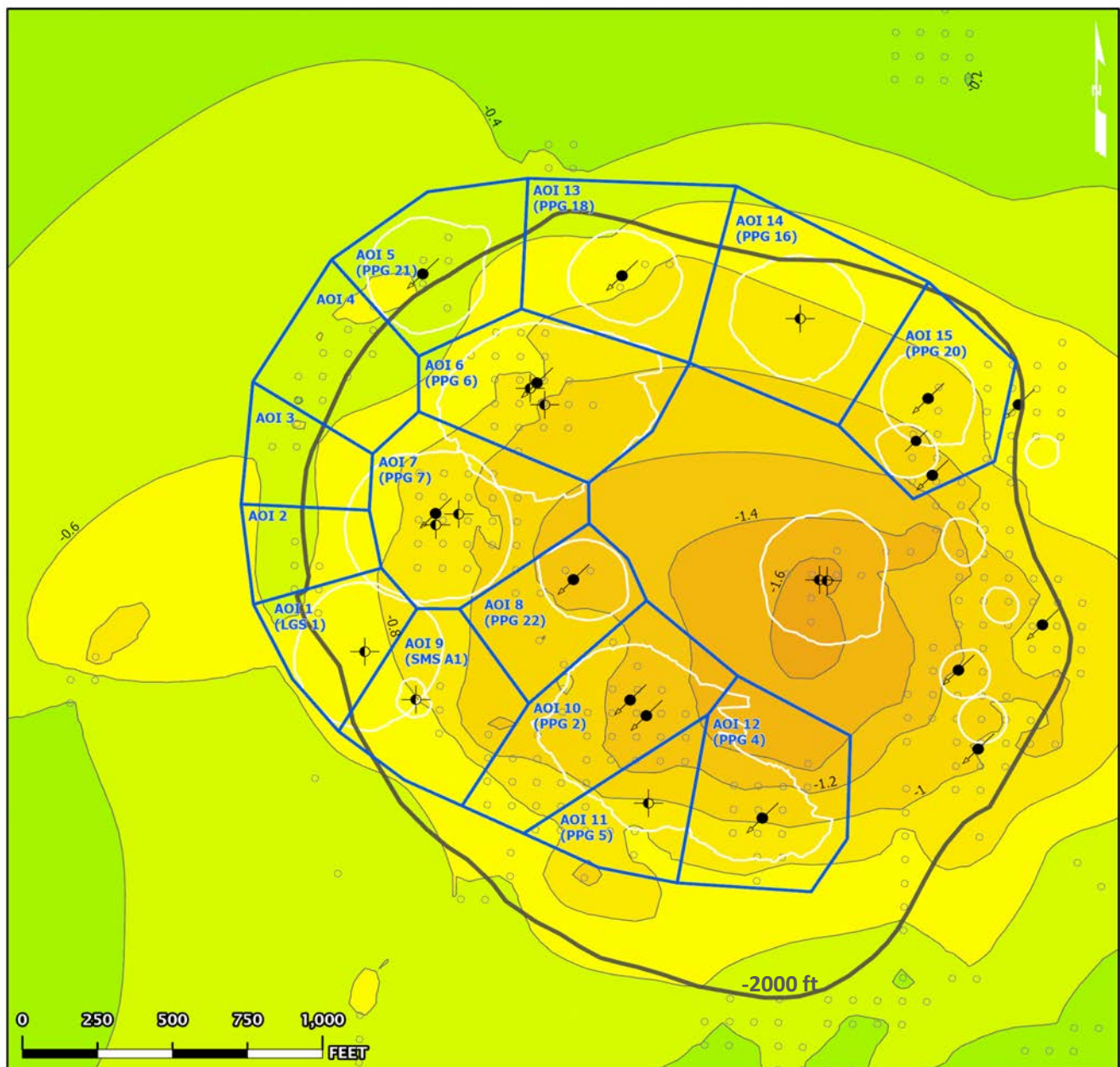
Date range: 01/24/2023 - 09/24/2024



Vertical Data (01/24/2023 - 09/24/2024)

Linear Velocity Contours

Date range: 01/24/2023 - 09/24/2024



- AOI Boundary
- InSAR LOS Measurement Point
- Contour (0.2)
- Historical Cavern Extent
- Top of Dome (-2000 ft Contour)

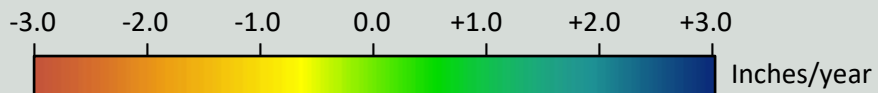
Cavern Well Surface Locations

- 09 - Active - Injection
- 29 - Dry and Plugged

Vertical Data (01/24/2023 - 09/24/2024)

Nonlinear Velocity Data Points

As of date: 09/24/2024

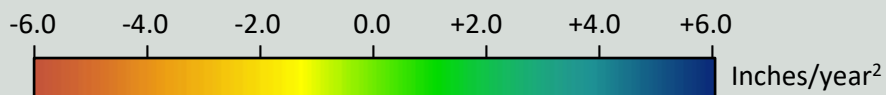


- AOI Boundary
- Historical Cavern Extent
- Top of Dome (-2000 ft Contour)
- InSAR LOS Measurement Point
- Cavern Well Surface Locations
- 09 - Active - Injection
- 29 - Dry and Plugged

Vertical Data (01/24/2023 - 09/24/2024)

Nonlinear Acceleration Data Points

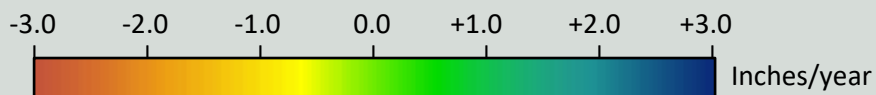
Date range: 01/24/2023 - 09/24/2024



Vertical Data (01/24/2023 - 09/24/2024)

Linear Velocity Data Points

Date range: 01/24/2023 - 09/24/2024



- AOI Boundary ○ InSAR LOS Measurement Point
Historical Cavern Extent Top of Dome (-2000 ft Contour)
Cavern Well Surface Locations
● 09 - Active - Injection ● 29 - Dry and Plugged

AOI Boundaries & 2D InSAR Measurement Points

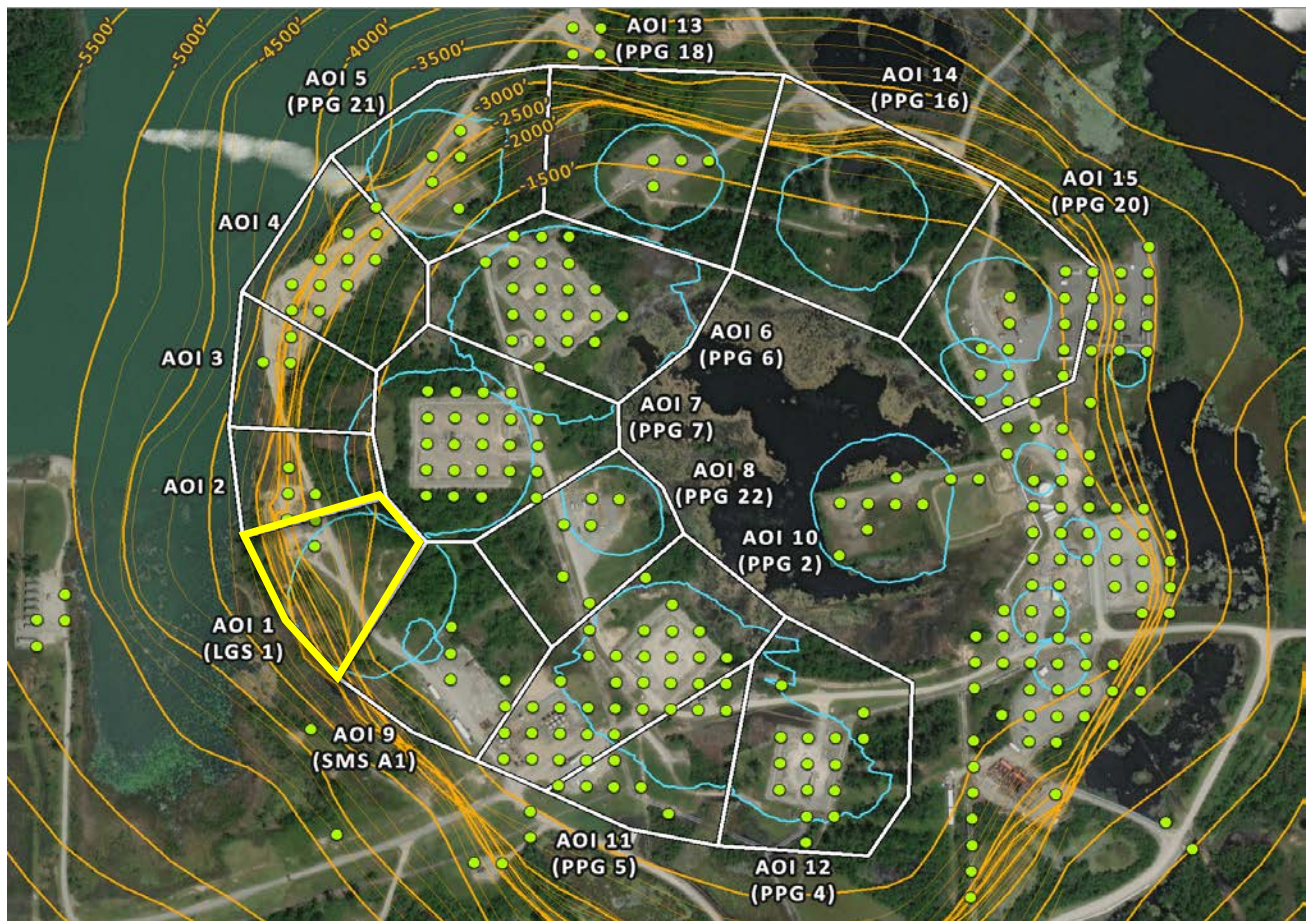


Subsidence Monitoring Areas of Interest (AOIs)

To visually convey and evaluate trend consistency for the East-West displacement time series of each ground target, measurement points were grouped and their displacement values were averaged. The point groups are referred to as Areas of Interest (AOIs) in this analysis and their boundaries are depicted on the above map. The below table lists the East-West trend values calculated in each AOI for the dataset evaluated in this report.

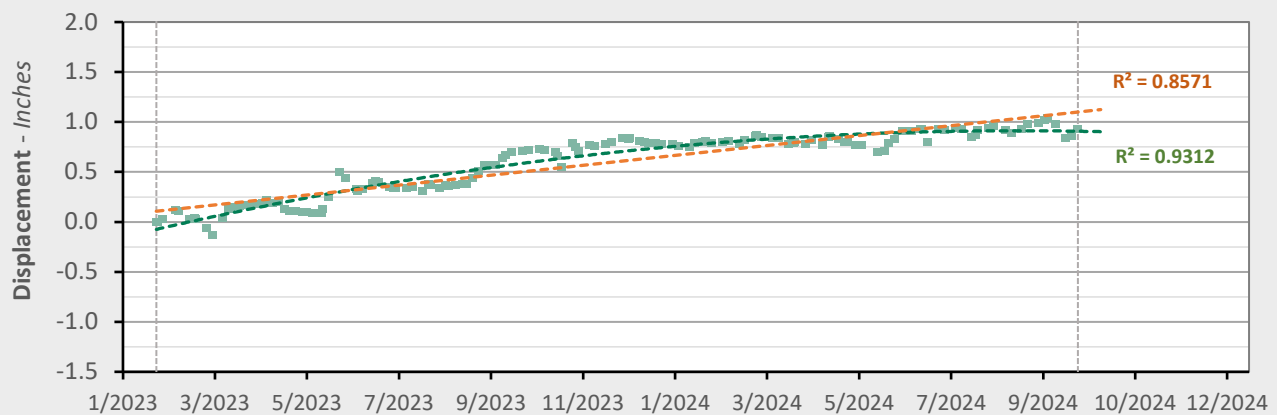
AOI Name	East-West (9/24/2024)	East-West Velocity (in/yr)		East-West Acceleration (in/yr ²)	
	Point Count	Nonlinear	Linear	Nonlinear	Linear
AOI 1 (LGS 1)	2	-0.09	+0.60	-0.81	0.00
AOI 2	4	+0.01	+0.58	-0.68	0.00
AOI 3	3	-0.09	+0.53	-0.74	0.00
AOI 4	11	+0.13	+0.46	-0.39	0.00
AOI 5 (PPG 21)	5	+0.19	+0.20	-0.01	0.00
AOI 6 (PPG 6)	21	+0.14	+0.33	-0.23	0.00
AOI 7 (PPG 7)	23	+0.37	+0.59	-0.26	0.00
AOI 8 (PPG 22)	6	+0.15	+0.51	-0.42	0.00
AOI 9 (SMS A1)	5	+0.16	+0.43	-0.32	0.00
AOI 10 (PPG 2)	31	+0.20	+0.35	-0.18	0.00
AOI 11 (PPG 5)	10	+0.07	+0.32	-0.30	0.00
AOI 12 (PPG 4)	15	-0.38	-0.19	-0.22	0.00
AOI 13 (PPG 18)	3	-0.57	-0.03	-0.65	0.00
AOI 14 (PPG 16)	0	N/A	N/A	N/A	N/A
AOI 15 (PPG 20)	14	-0.67	-0.56	-0.12	0.00

AOI 1 (LGS 1) - Location Map



AOI 1 (LGS 1) - East-West Time Series

E-W (9/24/2024) Point Count: 2



Nonlinear Trend

Linear Trend

Velocity: -0.09 in/yr

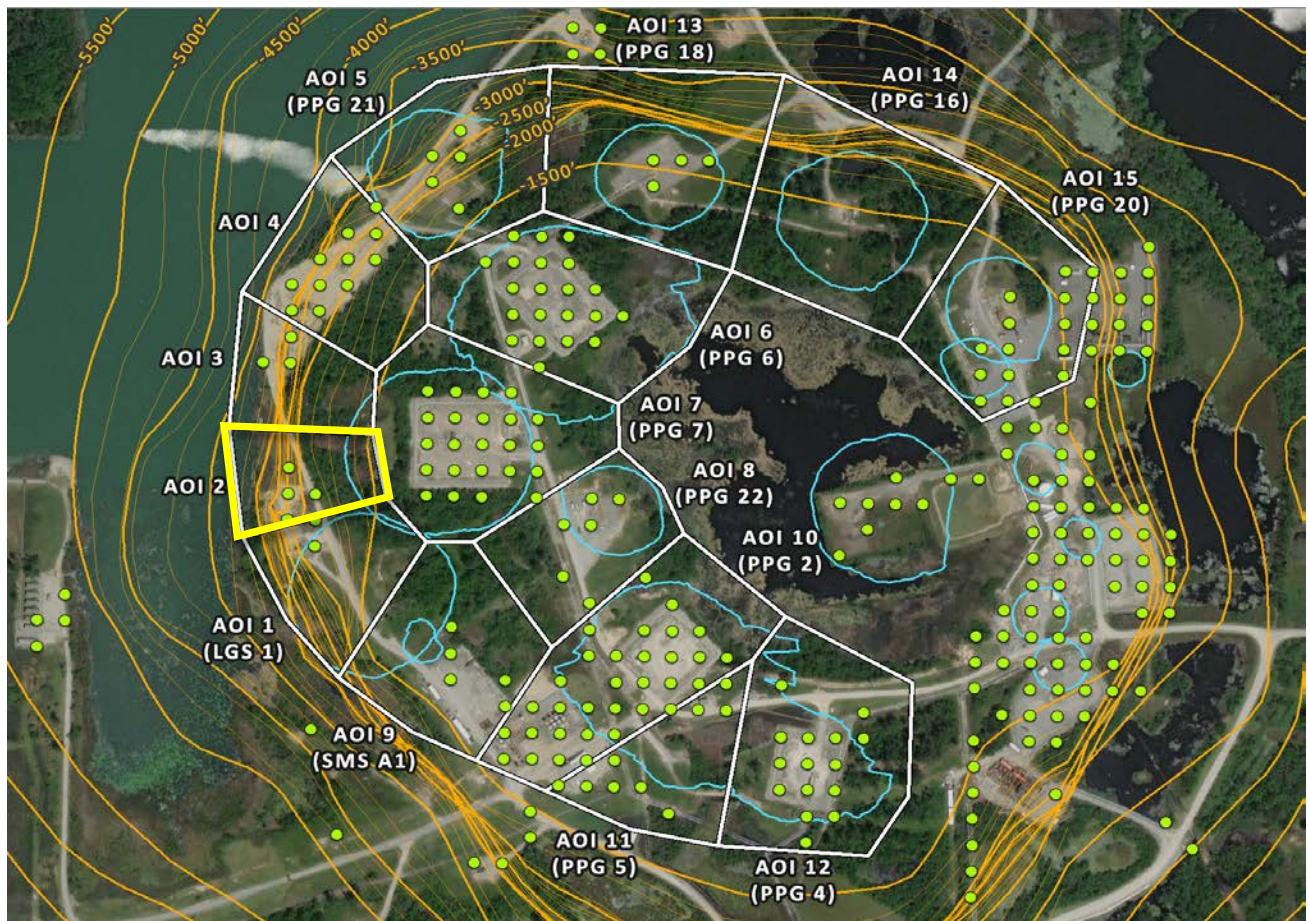
+0.60 in/yr

Acceleration: -0.81 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

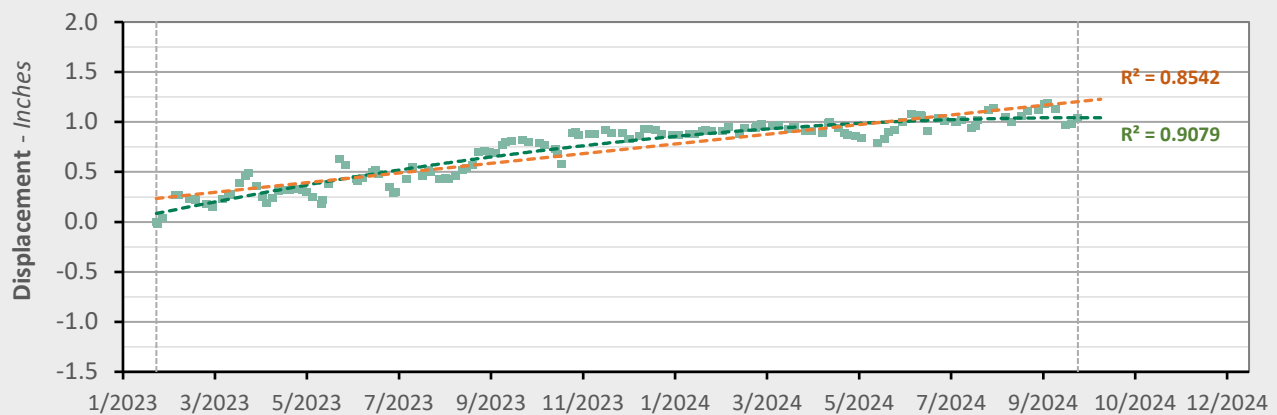
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 2 - Location Map



AOI 2 - East-West Time Series

E-W (9/24/2024) Point Count: 4



Nonlinear Trend

Linear Trend

Velocity: +0.01 in/yr

+0.58 in/yr

Acceleration: -0.68 in/yr²0.00 in/yr²

■ 2D Displacement Measurement

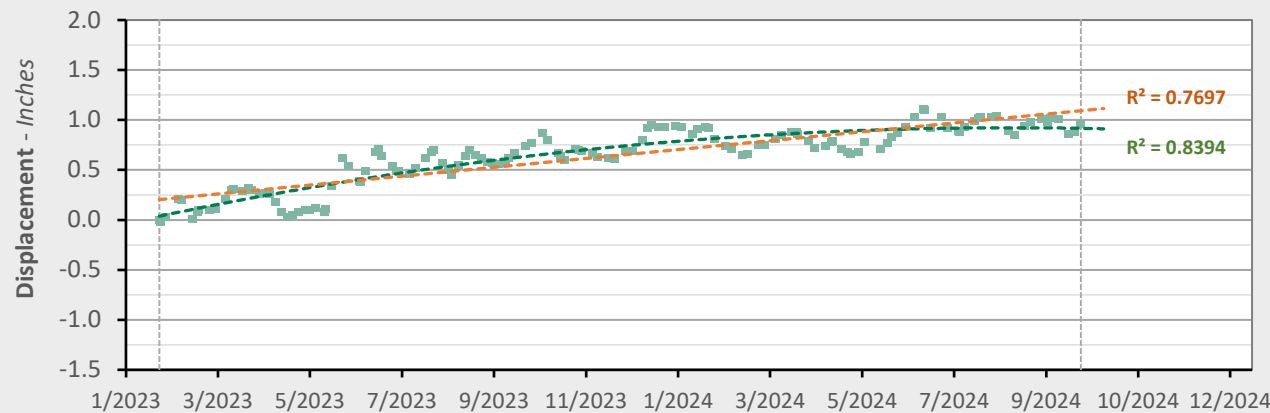
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 3 - Location Map



AOI 3 - East-West Time Series

E-W (9/24/2024) Point Count: 3



Nonlinear Trend

Linear Trend

Velocity: -0.09 in/yr

+0.53 in/yr

Acceleration: -0.74 in/yr²

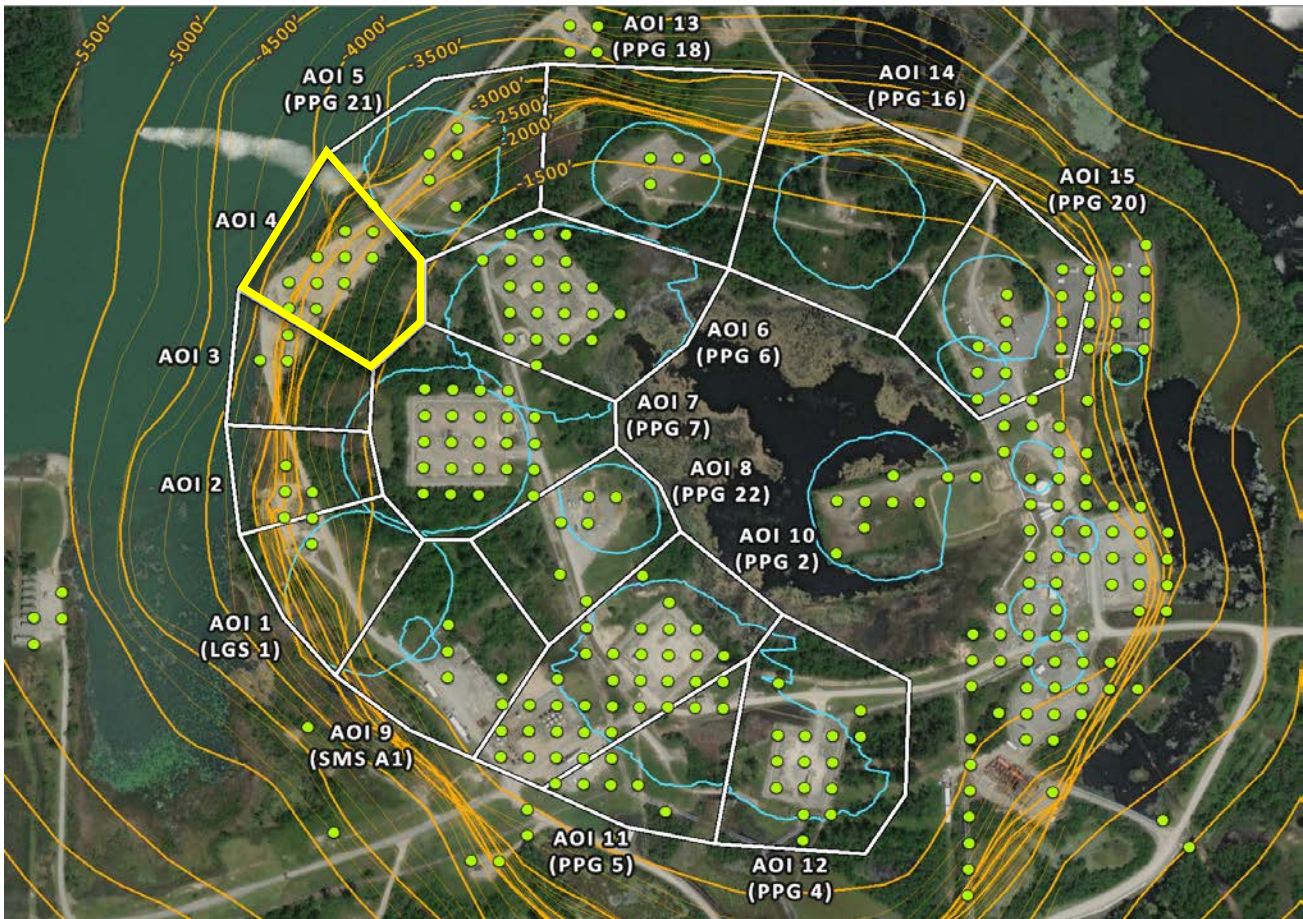
0.00 in/yr²

2D Displacement Measurement

Nonlinear Trend Line
(Quadratic Regression)

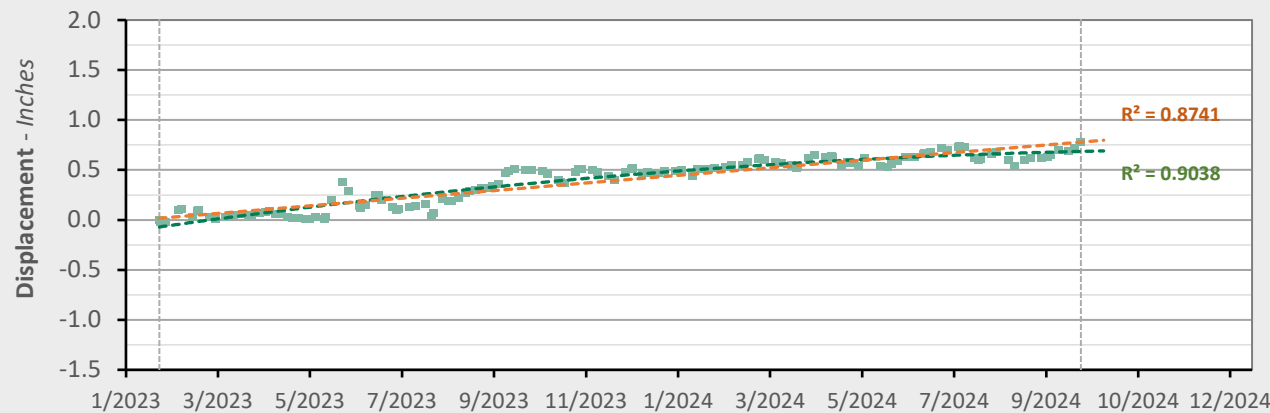
Linear Trend Line
(Linear Regression)

AOI 4 - Location Map



AOI 4 - East-West Time Series

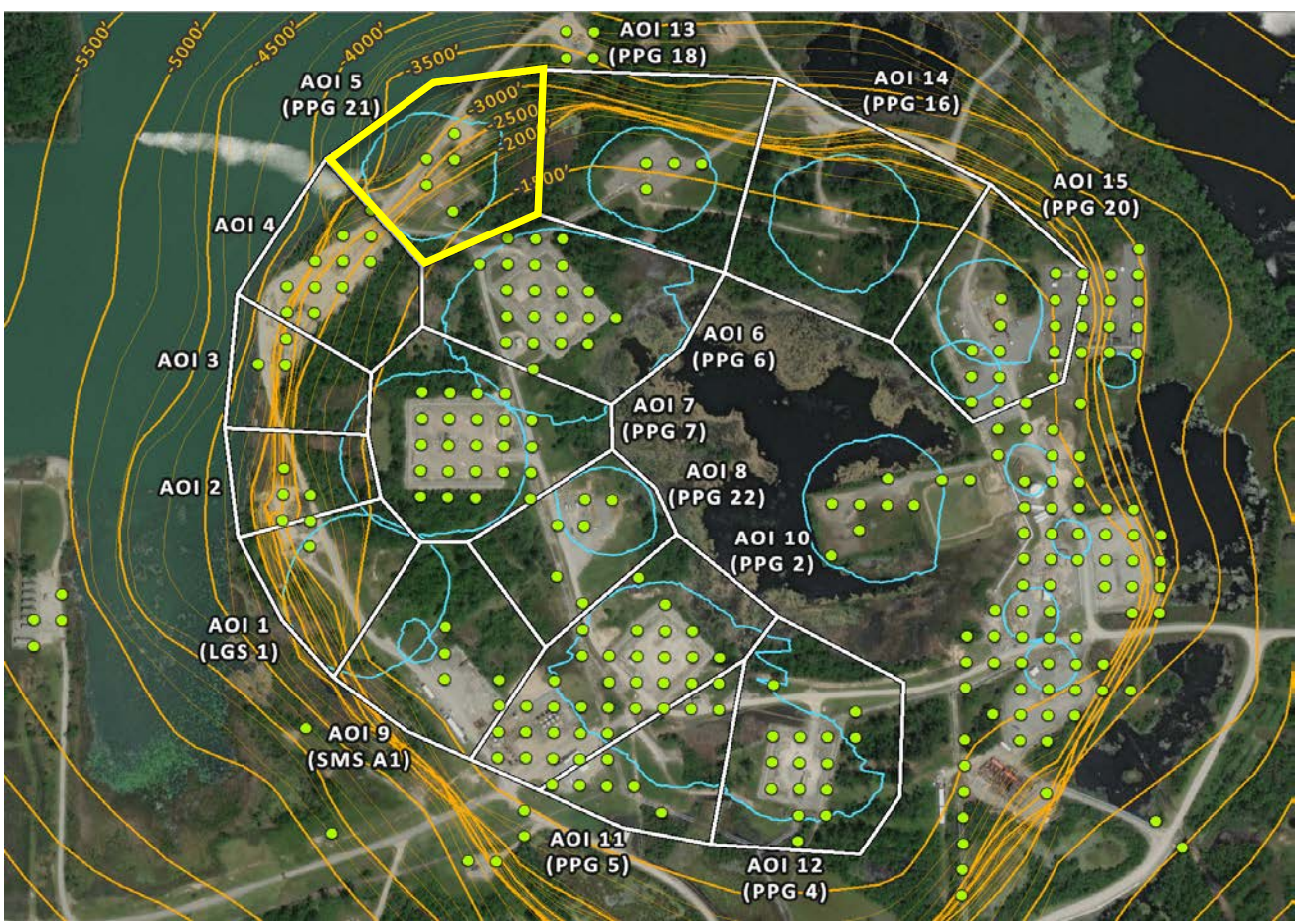
E-W (9/24/2024) Point Count: 11



	Nonlinear Trend	Linear Trend
Velocity:	+0.13 in/yr	+0.46 in/yr
Acceleration:	-0.39 in/yr ²	0.00 in/yr ²

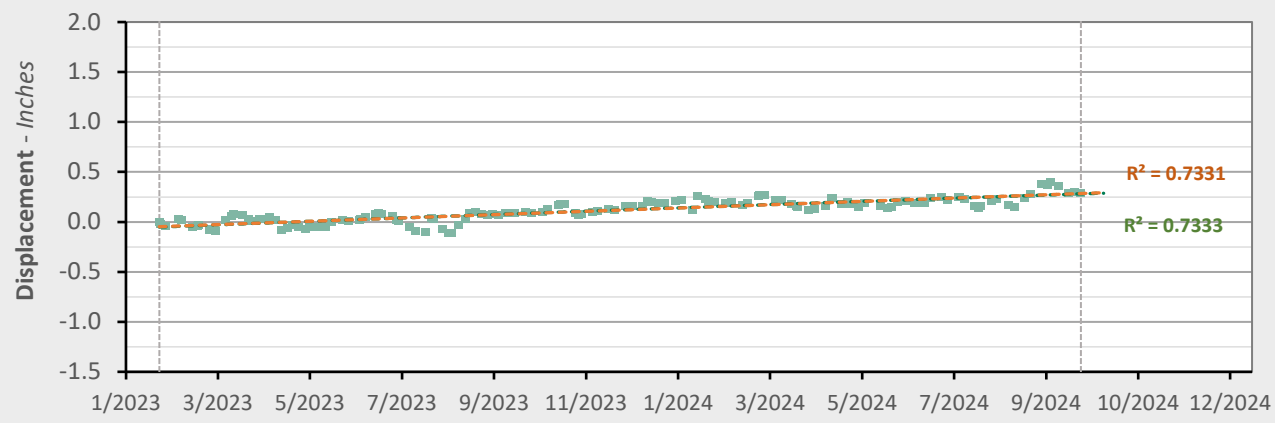
■ 2D Displacement Measurement - - - Nonlinear Trend Line (Quadratic Regression) - - - Linear Trend Line (Linear Regression)

AOI 5 (PPG 21) - Location Map



AOI 5 (PPG 21) - East-West Time Series

E-W (9/24/2024) Point Count: 5



	Nonlinear Trend	Linear Trend
Velocity:	+0.19 in/yr	+0.20 in/yr
Acceleration:	-0.01 in/yr ²	0.00 in/yr ²

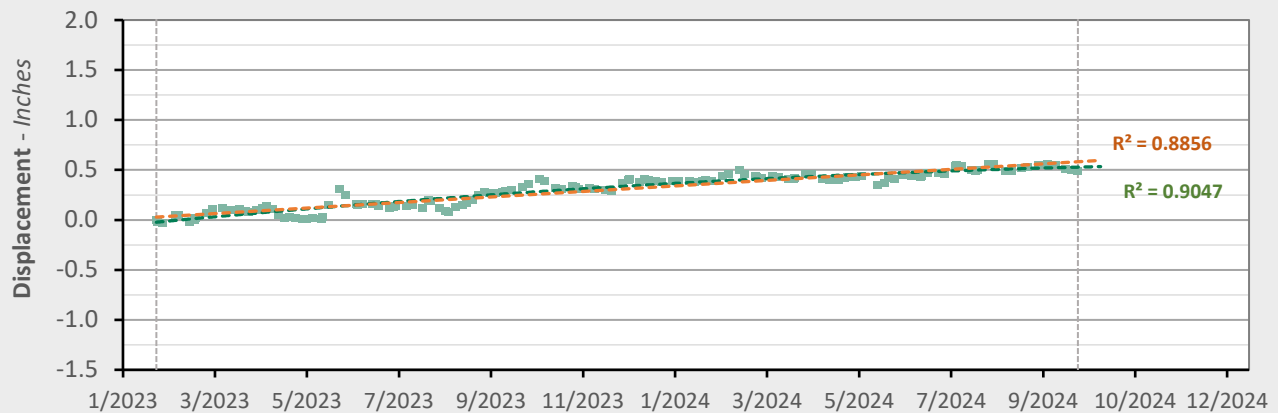
■ 2D Displacement Measurement - - - Nonlinear Trend Line (Quadratic Regression) - - - Linear Trend Line (Linear Regression)

AOI 6 (PPG 6) - Location Map



AOI 6 (PPG 6) - East-West Time Series

E-W (9/24/2024) Point Count: 21



Nonlinear Trend

Linear Trend

Velocity: +0.14 in/yr

+0.33 in/yr

Acceleration: -0.23 in/yr²

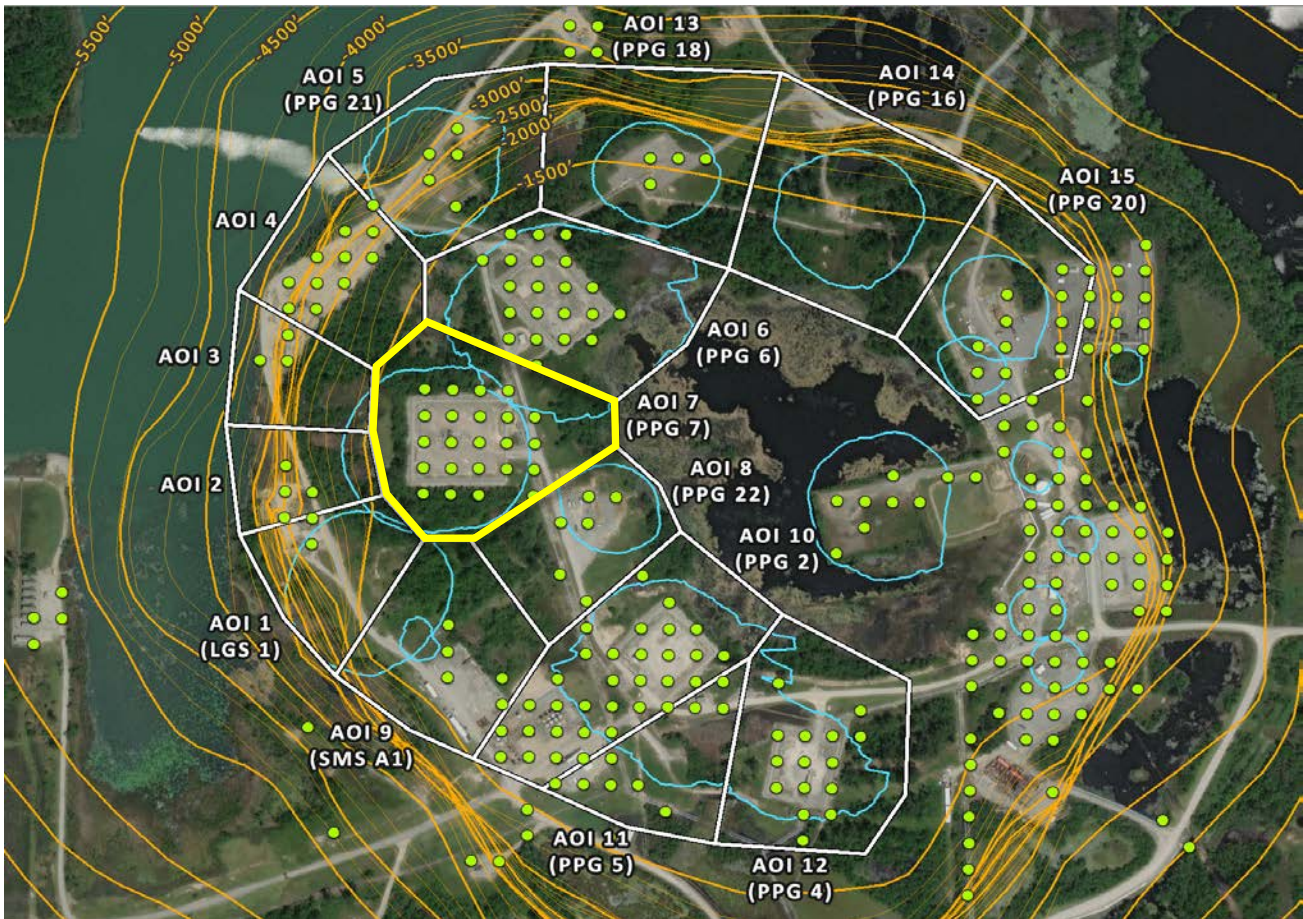
0.00 in/yr²

■ 2D Displacement Measurement

--- Nonlinear Trend Line
(Quadratic Regression)

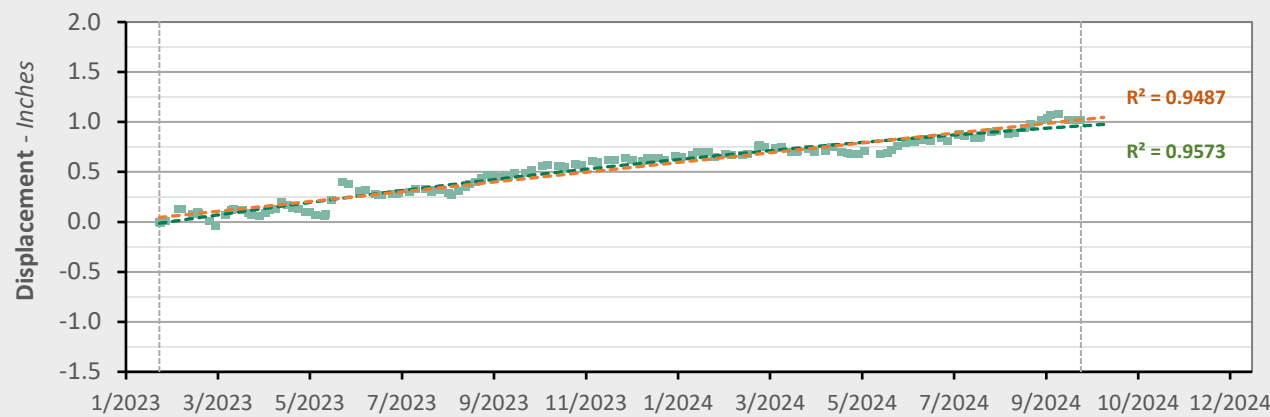
--- Linear Trend Line
(Linear Regression)

AOI 7 (PPG 7) - Location Map



AOI 7 (PPG 7) - East-West Time Series

E-W (9/24/2024) Point Count: 23

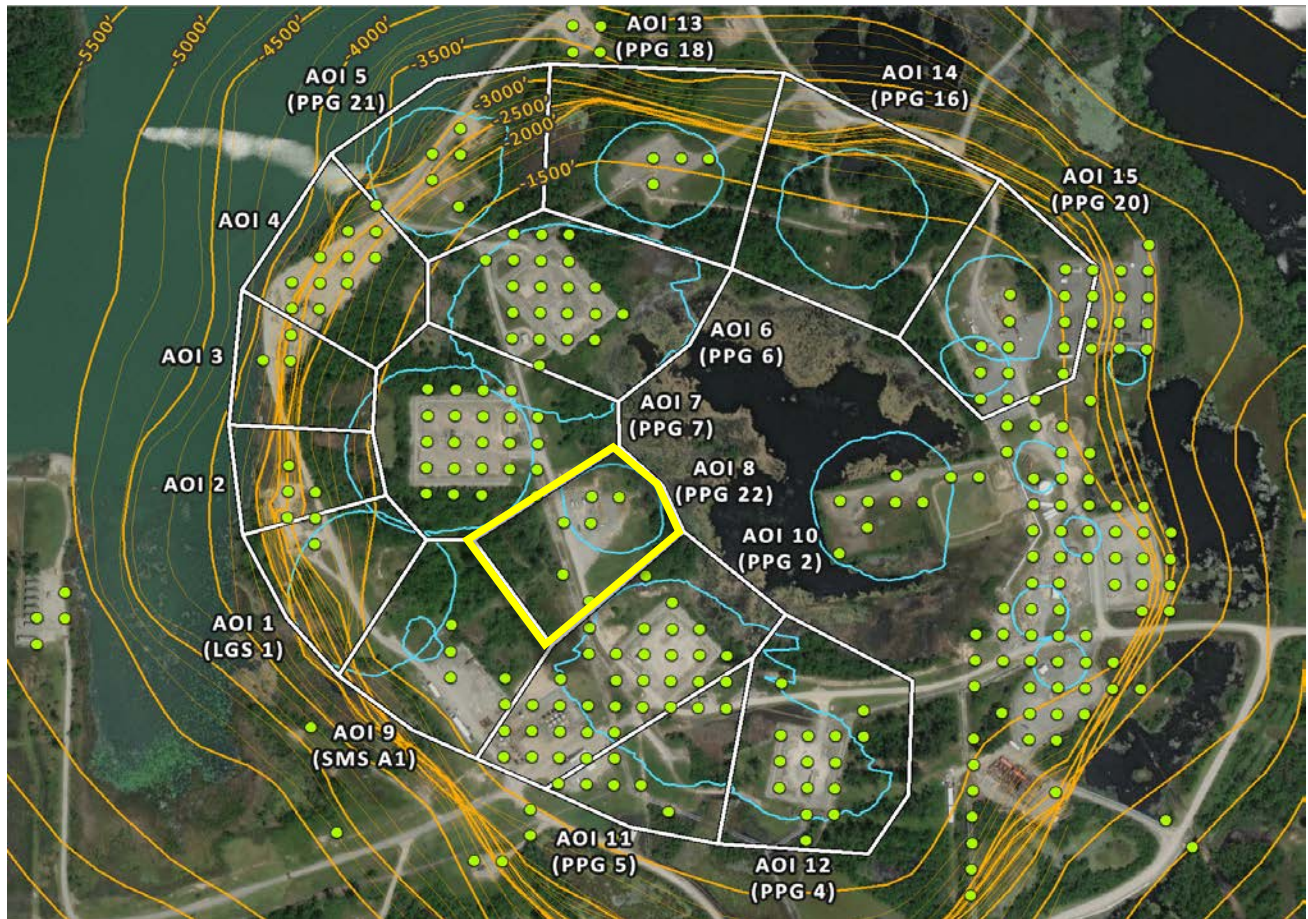


2D Displacement Measurement

Nonlinear Trend Line
(Quadratic Regression)

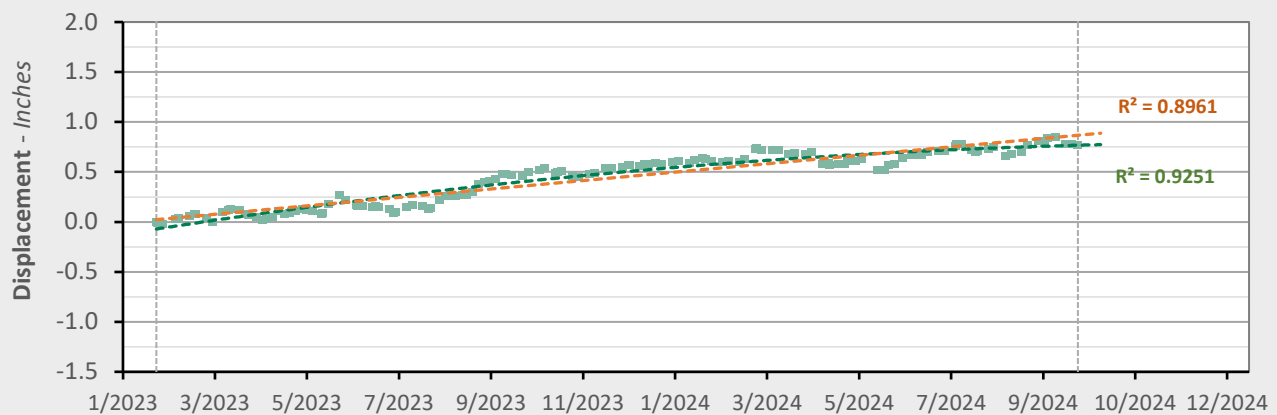
Linear Trend Line
(Linear Regression)

AOI 8 (PPG 22) - Location Map



AOI 8 (PPG 22) - East-West Time Series

E-W (9/24/2024) Point Count: 6

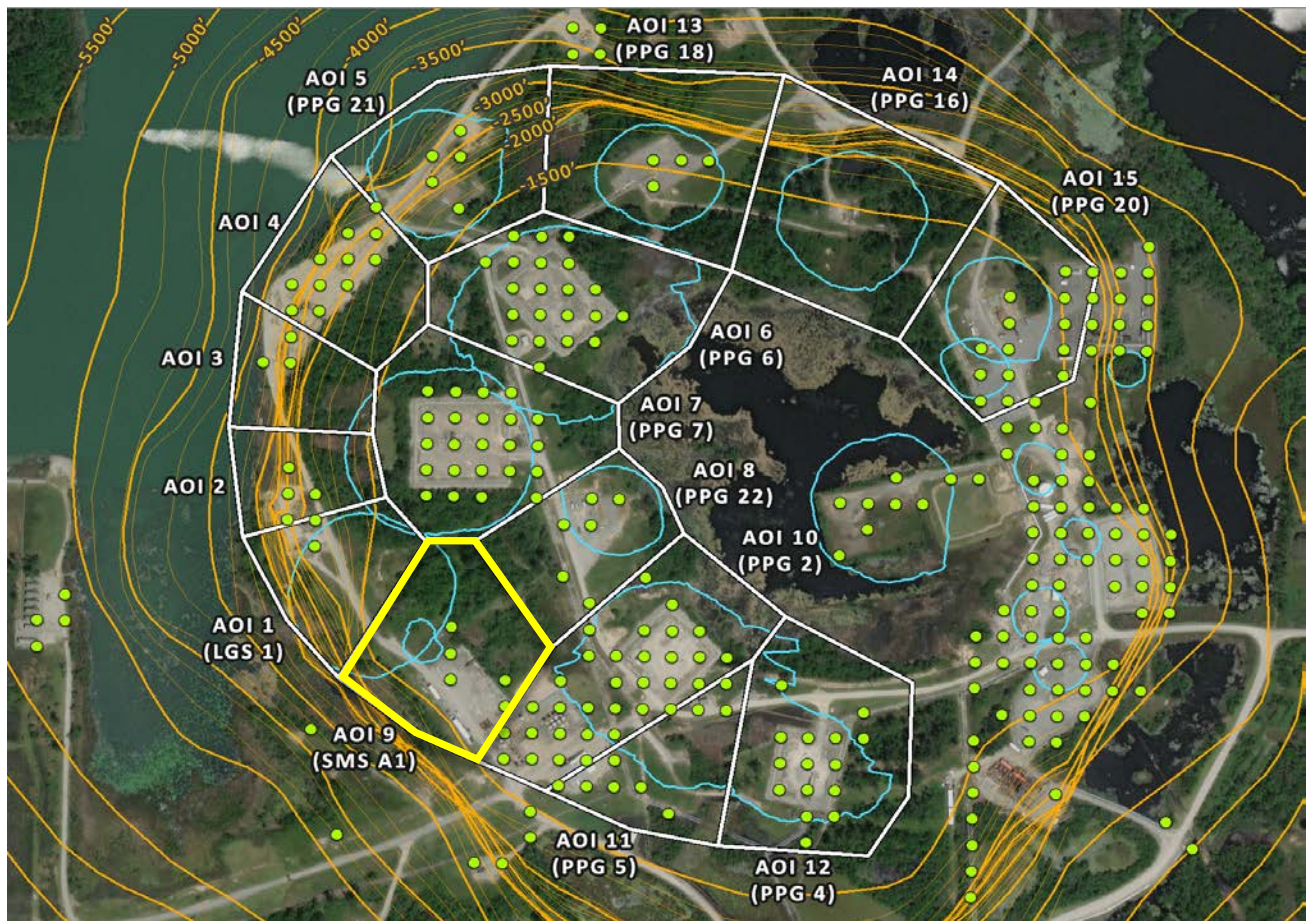


	Nonlinear Trend	Linear Trend
Velocity:	+0.15 in/yr	+0.51 in/yr
Acceleration:	-0.42 in/yr ²	0.00 in/yr ²

■ 2D Displacement Measurement

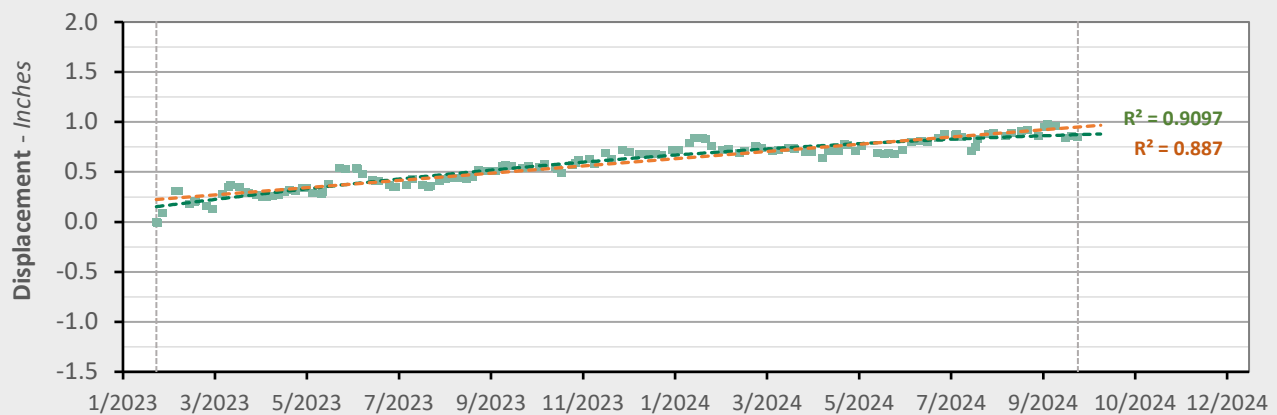
--- Nonlinear Trend Line
(Quadratic Regression)--- Linear Trend Line
(Linear Regression)

AOI 9 (PPG A1) - Location Map



AOI 9 (SMS A1) - East-West Time Series

E-W (9/24/2024) Point Count: 5



Nonlinear Trend

Linear Trend

Velocity: +0.16 in/yr

+0.43 in/yr

Acceleration: -0.32 in/yr²

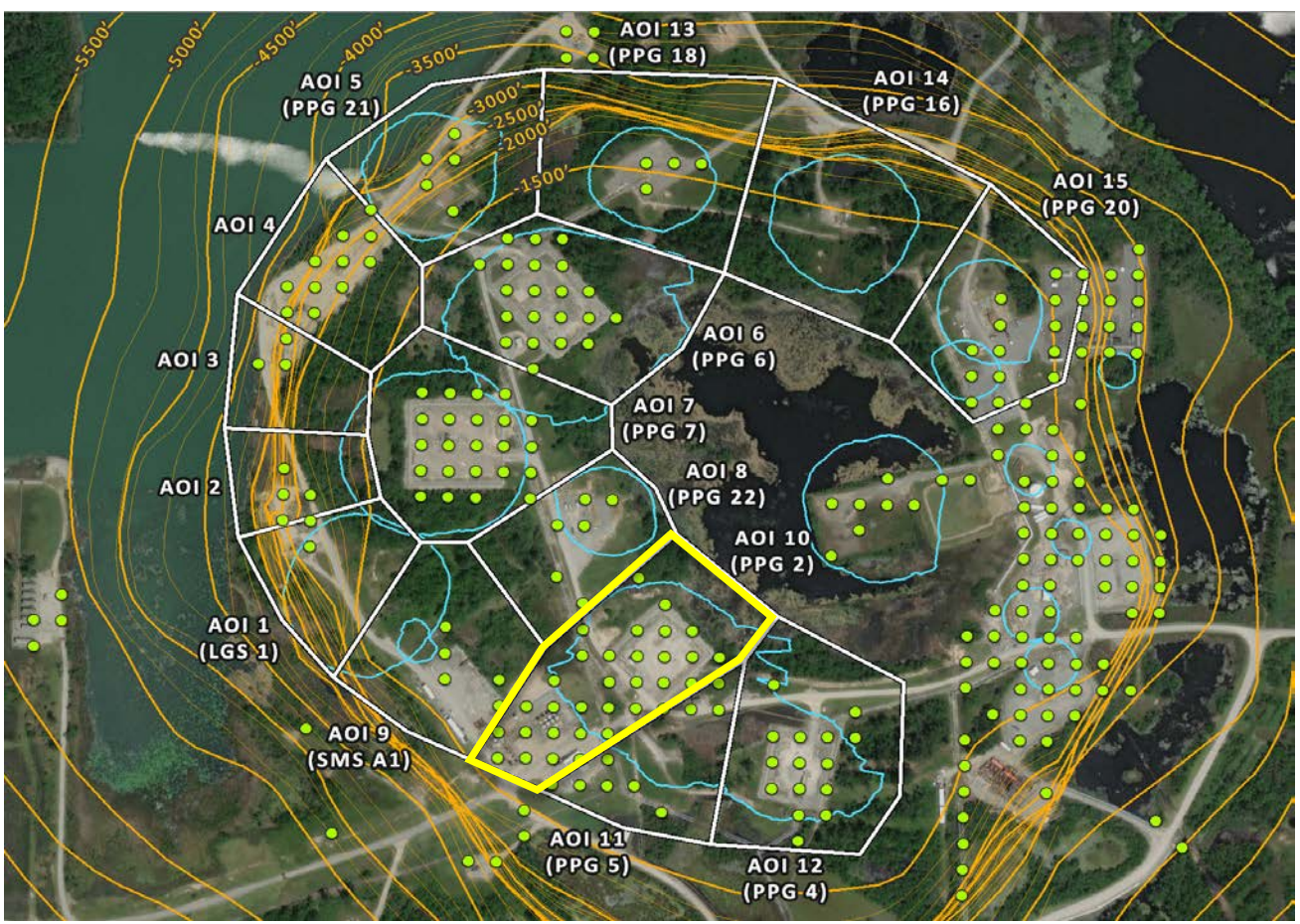
0.00 in/yr²

■ 2D Displacement Measurement

--- Nonlinear Trend Line
(Quadratic Regression)

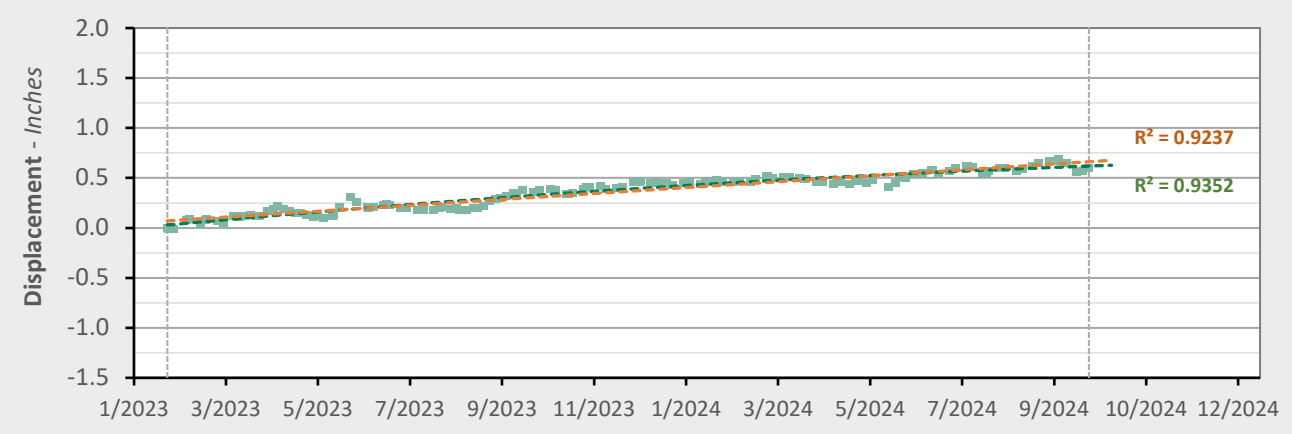
--- Linear Trend Line
(Linear Regression)

AOI 10 (PPG 2) - Location Map

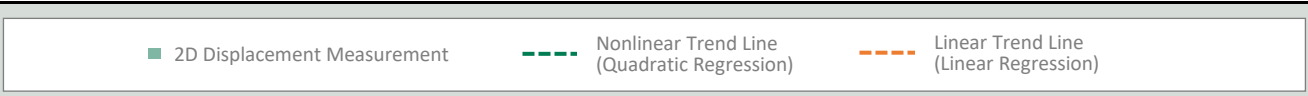


AOI 10 (PPG 2) - East-West Time Series

E-W (9/24/2024) Point Count: 31



	Nonlinear Trend	Linear Trend
Velocity:	+0.20 in/yr	+0.35 in/yr
Acceleration:	-0.18 in/yr ²	0.00 in/yr ²

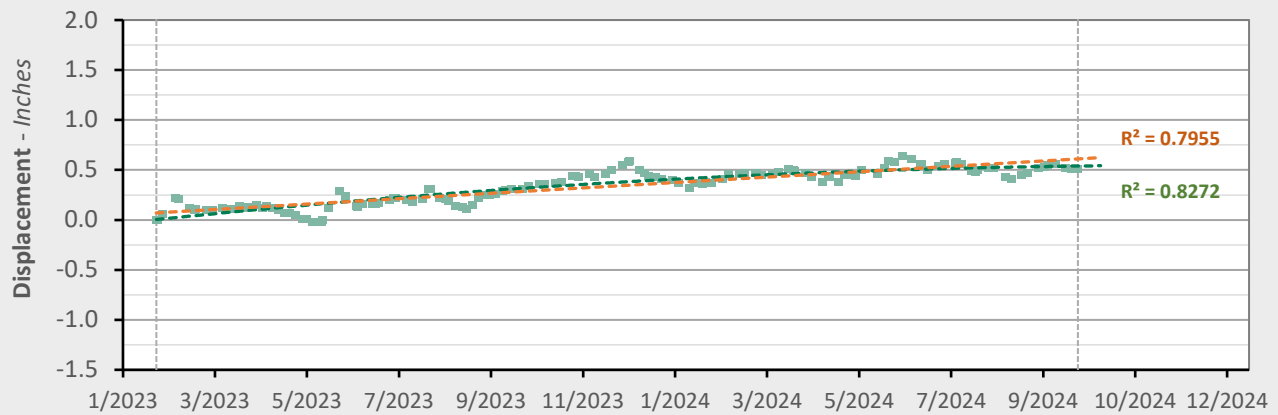


AOI 11 (PPG 5) - Location Map



AOI 11 (PPG 5) - East-West Time Series

E-W (9/24/2024) Point Count: 10



Nonlinear Trend

Linear Trend

Velocity: +0.07 in/yr

+0.32 in/yr

Acceleration: -0.30 in/yr²

0.00 in/yr²

■ 2D Displacement Measurement

--- Nonlinear Trend Line
(Quadratic Regression)

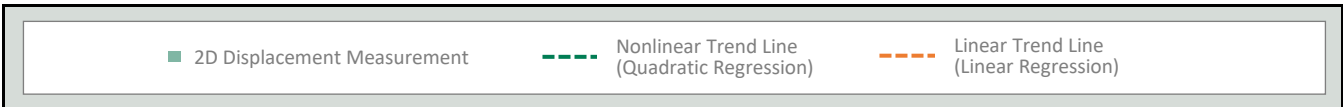
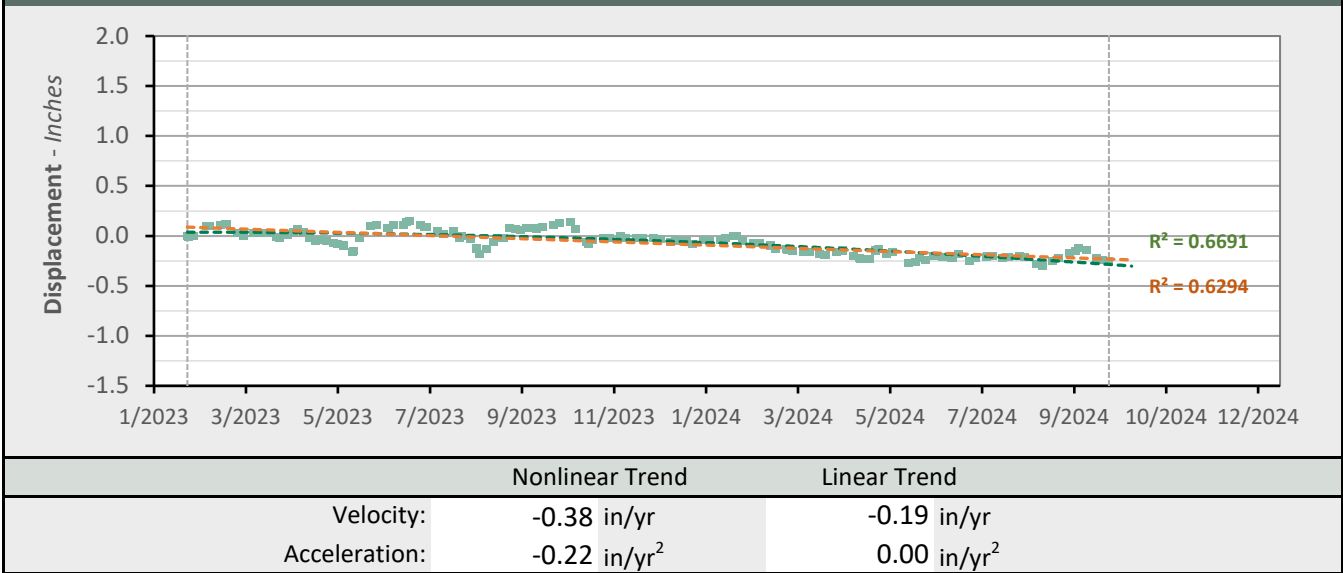
--- Linear Trend Line
(Linear Regression)

AOI 12 (PPG 4) - Location Map

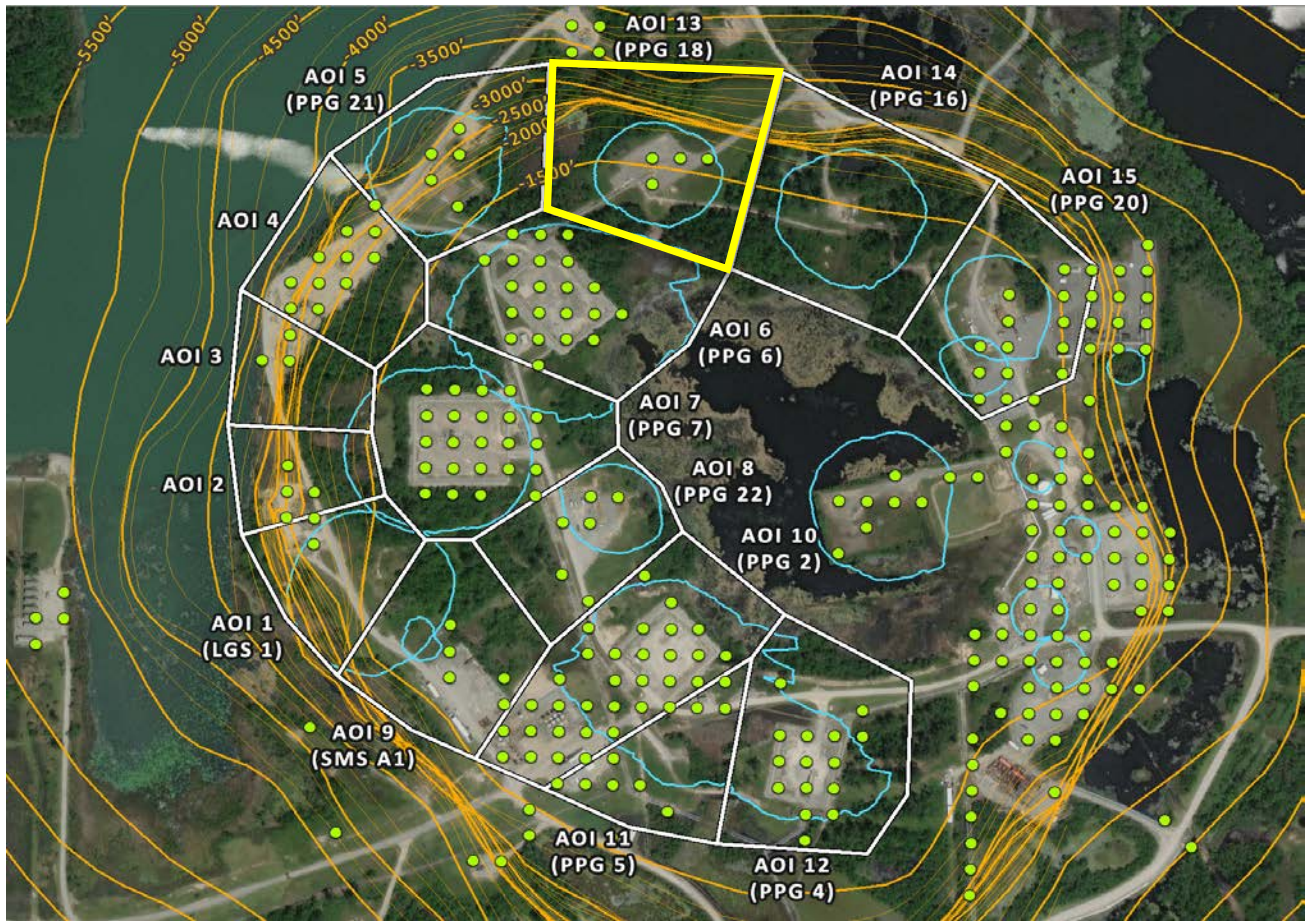


AOI 12 (PPG 4) - East-West Time Series

E-W (9/24/2024) Point Count: 15

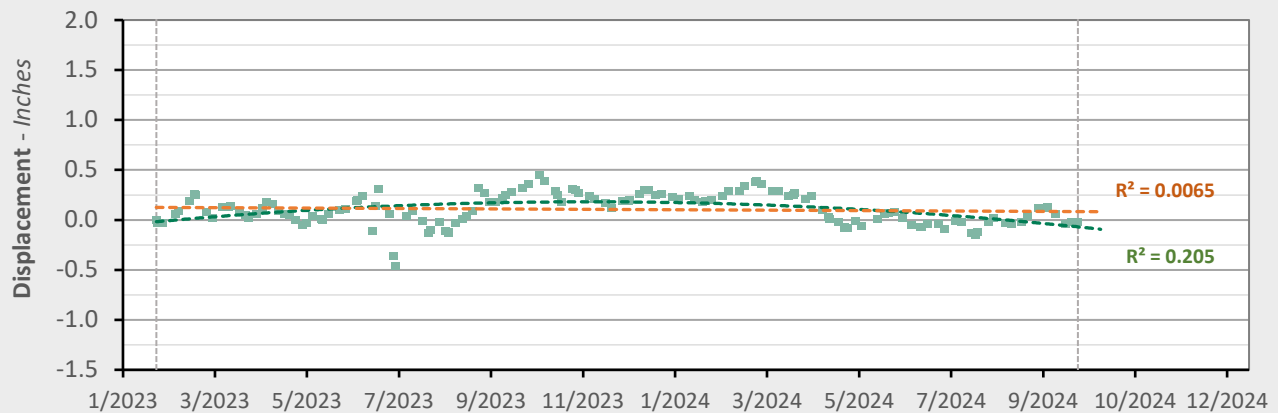


AOI 13 (PPG 18) - Location Map



AOI 13 (PPG 18) - East-West Time Series

E-W (9/24/2024) Point Count: 3



Nonlinear Trend

Linear Trend

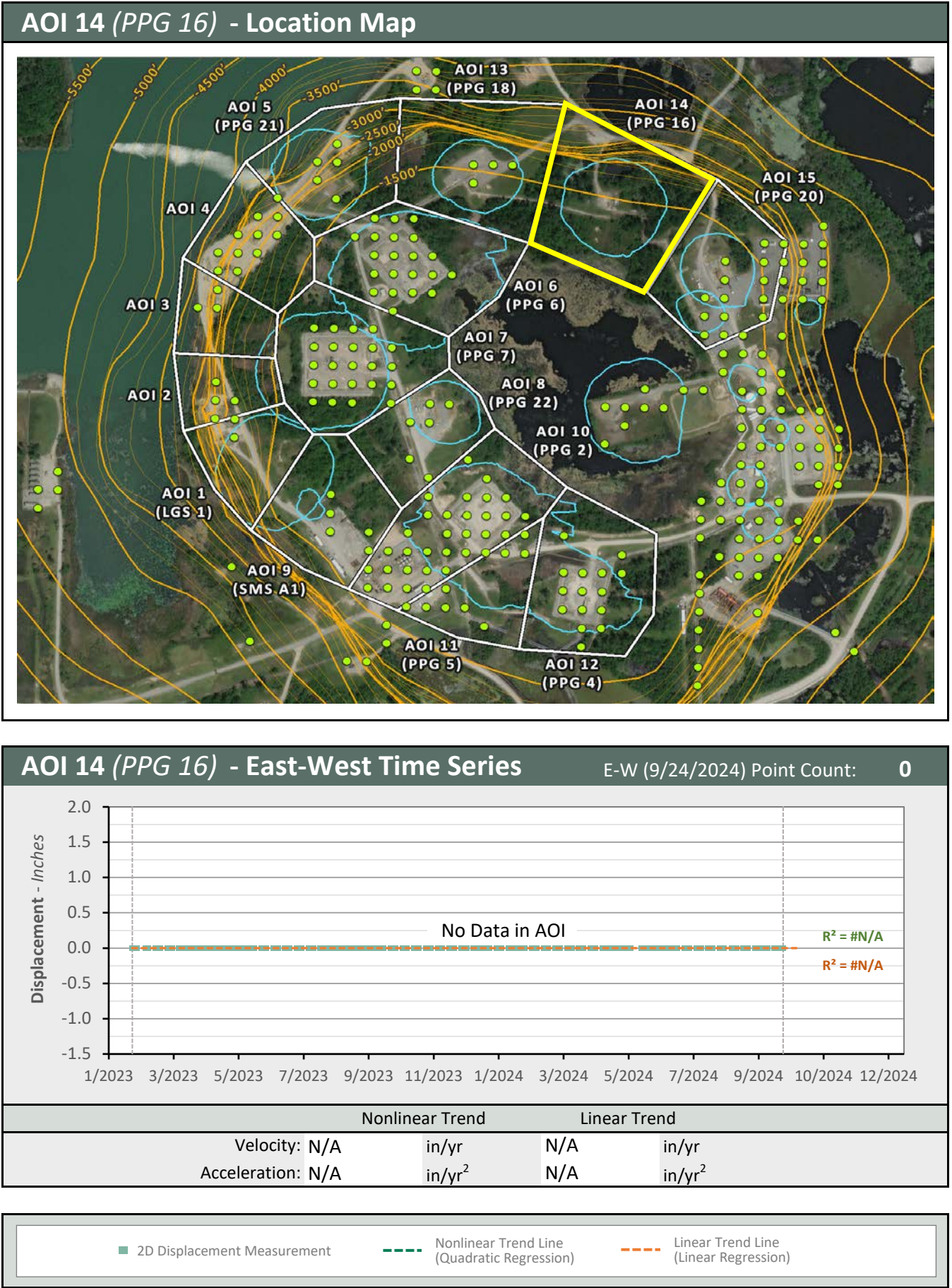
Velocity: -0.57 in/yr
Acceleration: -0.65 in/yr²

-0.03 in/yr
0.00 in/yr²

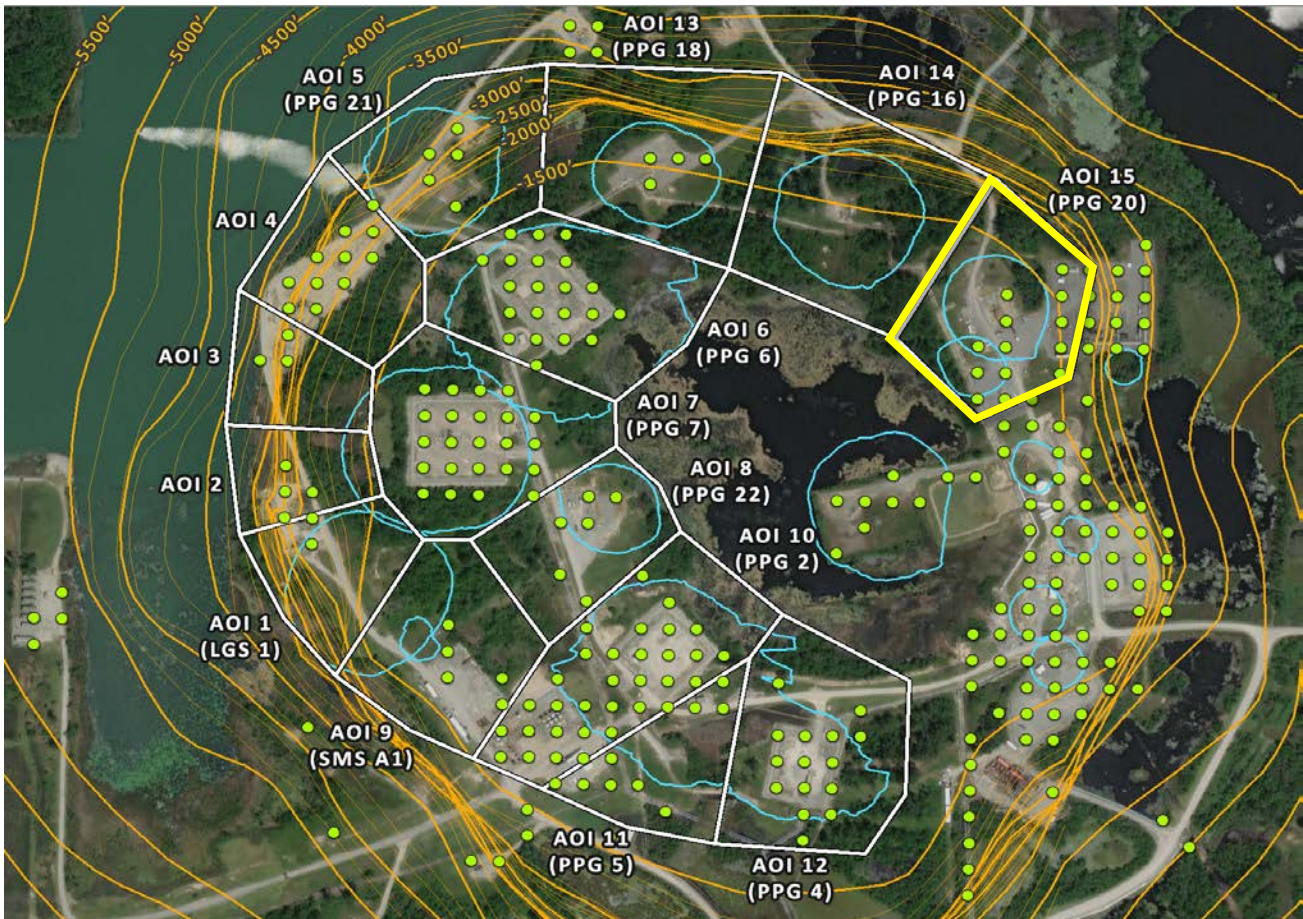
■ 2D Displacement Measurement

--- Nonlinear Trend Line
(Quadratic Regression)

--- Linear Trend Line
(Linear Regression)

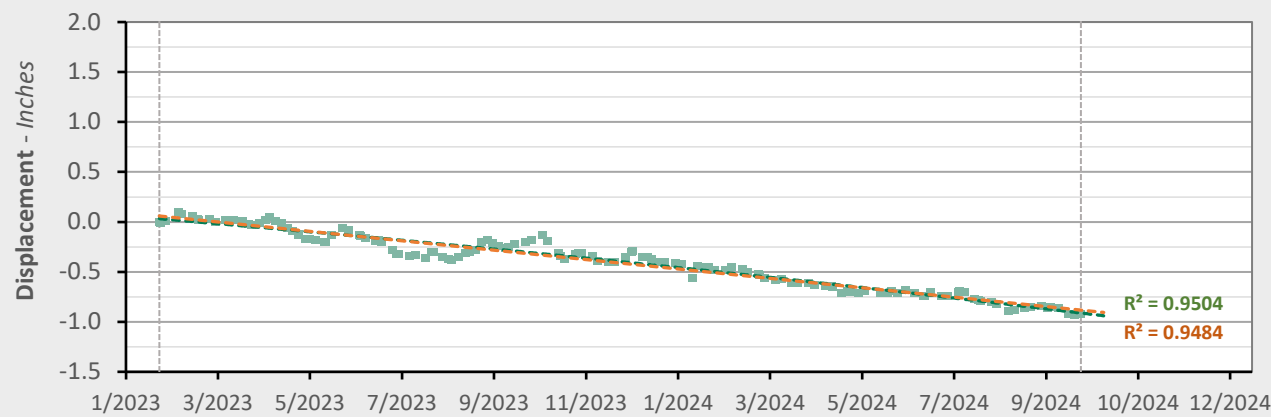


AOI 15 (PPG 20) - Location Map



AOI 15 (PPG 20) - East-West Time Series

E-W (9/24/2024) Point Count: 14



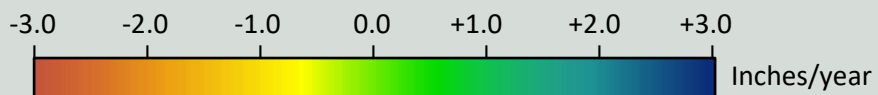
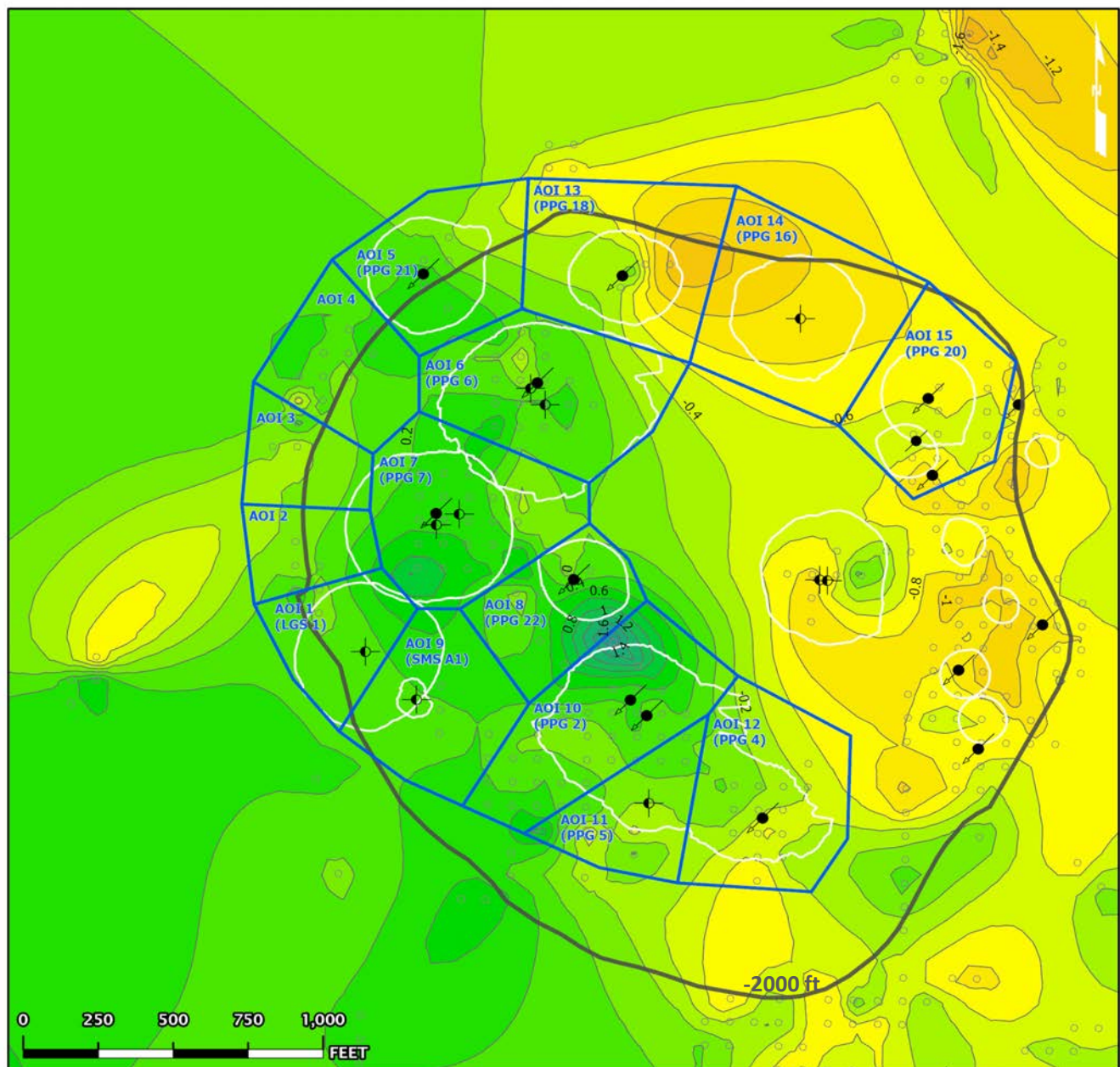
	Nonlinear Trend	Linear Trend
Velocity:	-0.67 in/yr	-0.56 in/yr
Acceleration:	-0.12 in/yr ²	0.00 in/yr ²

■ 2D Displacement Measurement - - - Nonlinear Trend Line (Quadratic Regression) - - - Linear Trend Line (Linear Regression)

East-West Data (01/24/2023 - 09/24/2024)

Nonlinear Velocity Contours

As of date: 09/24/2024



- AOI Boundary
- InSAR LOS Measurement Point
- Contour (0.2)
- Historical Cavern Extent
- Top of Dome (-2000 ft Contour)

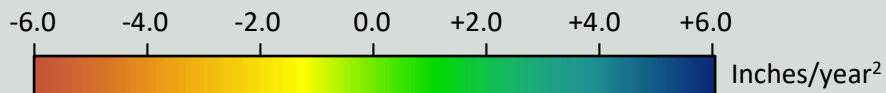
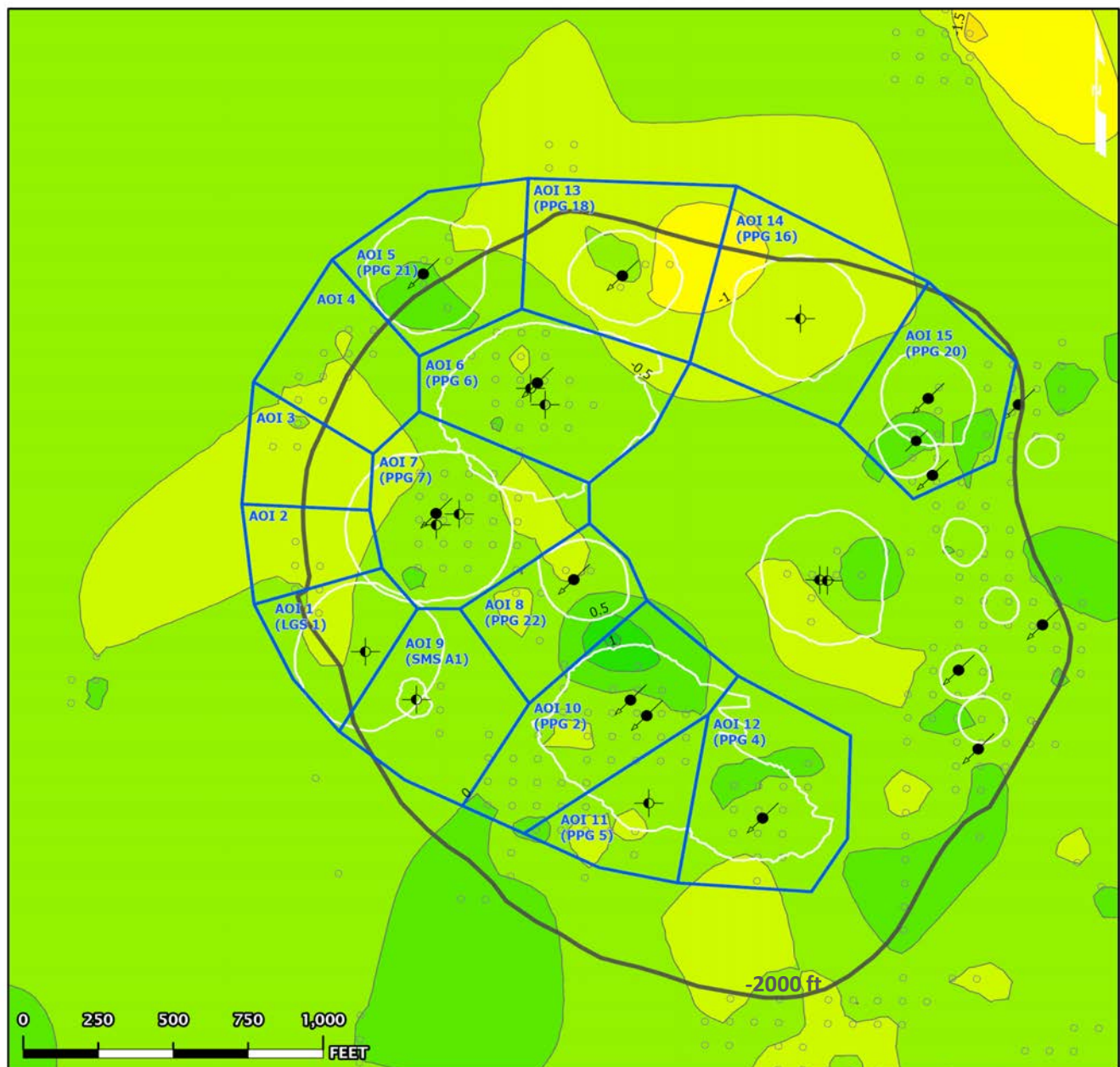
Cavern Well Surface Locations

- 09 - Active - Injection
- 29 - Dry and Plugged

East-West Data (01/24/2023 - 09/24/2024)

Nonlinear Acceleration Contours

Date range: 01/24/2023 - 09/24/2024

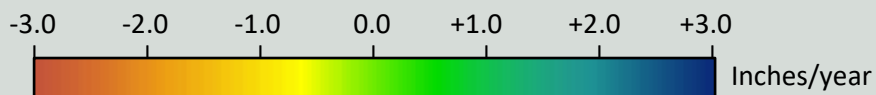
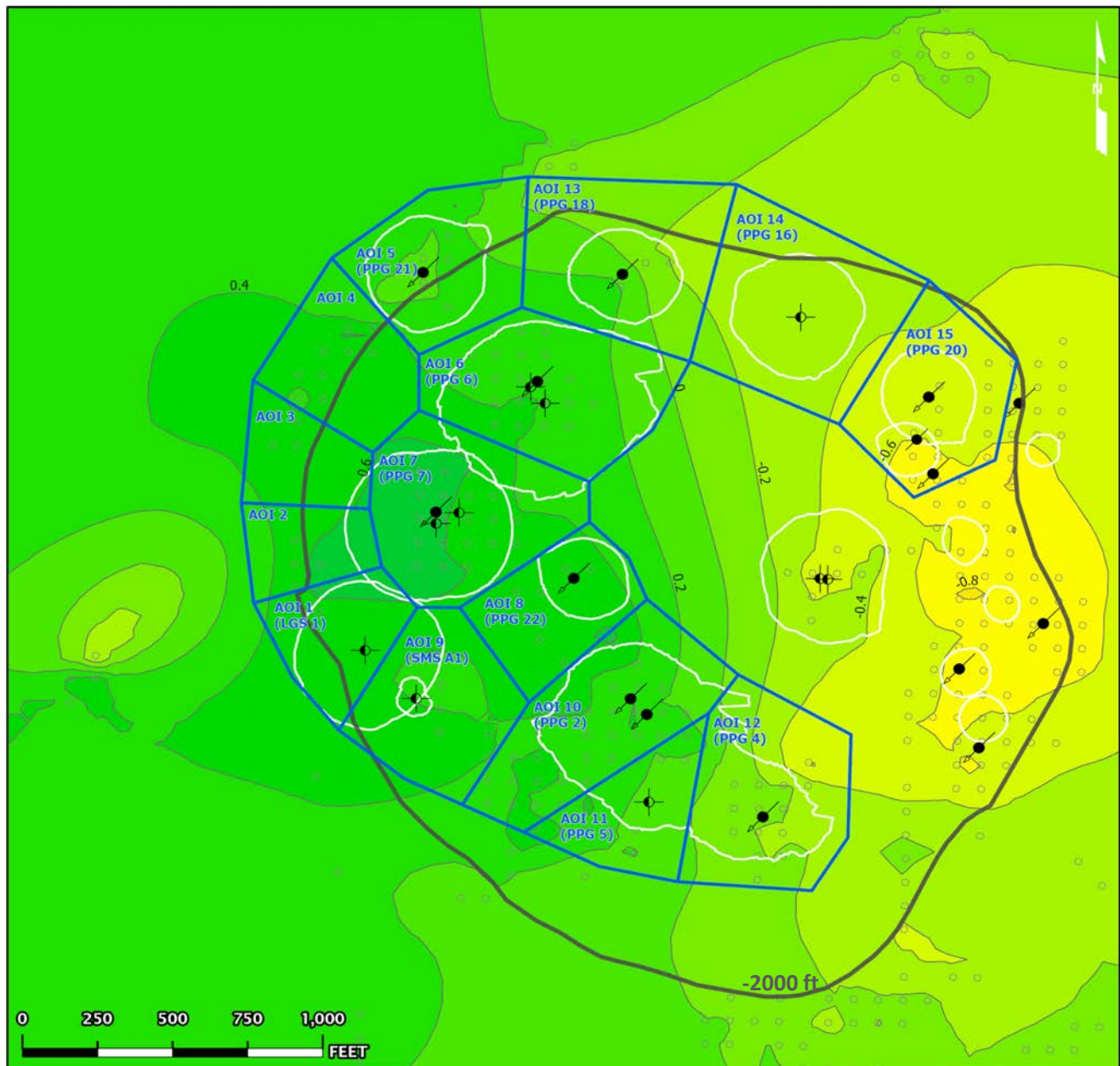


- Legend:
- AOI Boundary
 - InSAR LOS Measurement Point
 - Contour (0.5)
 - Historical Cavern Extent
 - Top of Dome (-2000 ft Contour)
- Cavern Well Surface Locations
- 09 - Active - Injection
 - 29 - Dry and Plugged

East-West Data (01/24/2023 - 09/24/2024)

Linear Velocity Contours

Date range: 01/24/2023 - 09/24/2024



- AOI Boundary
- Historical Cavern Extent
- Top of Dome (-2000 ft Contour)
- InSAR LOS Measurement Point
- Contour (0.2)

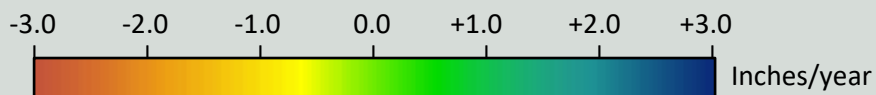
Cavern Well Surface Locations

- 09 - Active - Injection
- 29 - Dry and Plugged

East-West Data (01/24/2023 - 09/24/2024)

Nonlinear Velocity Data Points

As of date: 09/24/2024

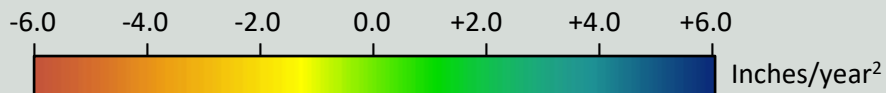


- Legend:
- AOI Boundary
 - Historical Cavern Extent
 - InSAR LOS Measurement Point
 - Top of Dome (-2000 ft Contour)
 - Cavern Well Surface Locations
 - 09 - Active - Injection
 - 29 - Dry and Plugged

East-West Data (01/24/2023 - 09/24/2024)

Nonlinear Acceleration Data Points

Date range: 01/24/2023 - 09/24/2024

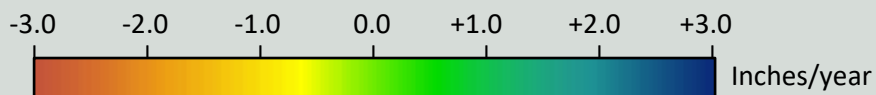


- AOI Boundary ○ InSAR LOS Measurement Point
- Historical Cavern Extent Top of Dome (-2000 ft Contour)
- Cavern Well Surface Locations
- 09 - Active - Injection ● 29 - Dry and Plugged

East-West Data (01/24/2023 - 09/24/2024)

Linear Velocity Data Points

Date range: 01/24/2023 - 09/24/2024



- Legend:
- AOI Boundary
 - Historical Cavern Extent
 - Top of Dome (-2000 ft Contour)
 - InSAR LOS Measurement Point
 - Cavern Well Surface Locations
 - 09 - Active - Injection
 - 29 - Dry and Plugged